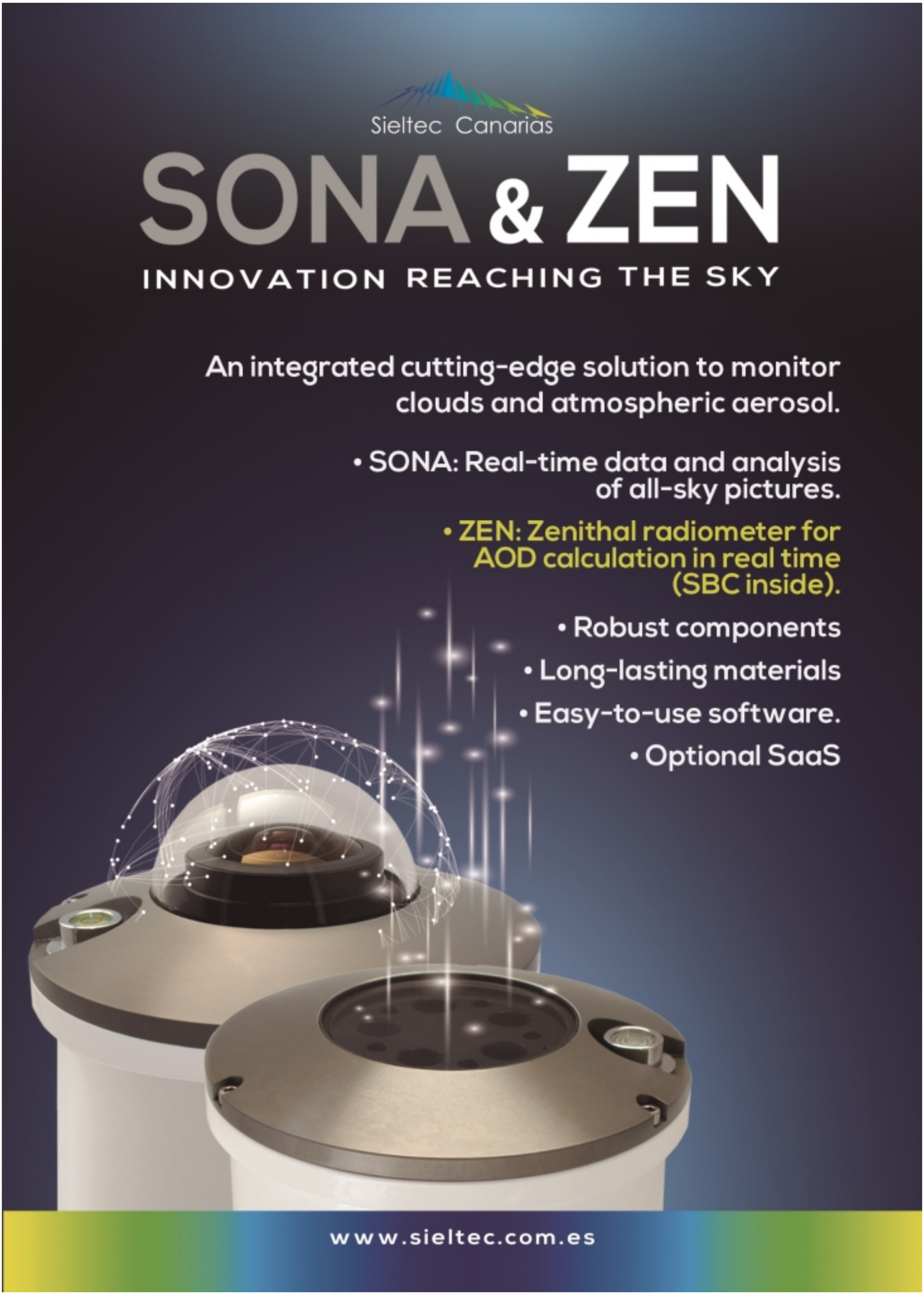
DUSTWORKSHOP9

Tenerife, 22-24 May 2018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PLENARY LECTURES

Analysis of the controlling factors of dust and climate variability

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Mineral dust is interacting with most components of the Earth's system affecting climate from different processes. Indeed, dust particles interact with short- and longwave radiation modifyin the Earth's energy budget. They provide long-range transport of nutrients for the land and ocean biosphere affecting CO2 exchanges. They provide surfaces for heterogeneous reactions affecting ozone chemistry, an important greenhouse gas. Dust deposition is darkening snow, which will increase snowmelt and decrease surface albedo. Ideally, climate models would include these diverse interactions consistently. But these climate models should first simulate satisfactorily dust emission, transport and deposition, and their variability.

Based on published studies, transport models seem to represent quite well trends and variability of dust at global and regional scales, while this is not the case for climate models. To understand the underlying causes, we examined seven CMIP5 models, which have included interactive dust emission against satellite derived dust optical depth. We found that mulit-model mean largely captures global spatial pattern and zonal mean of DOD for present-day climatology. But interannual variations of DOD are neither captured by most of models nor by multi-model mean, as models do not capture the observed connections between DOD and local controlling factors such as surface wind speed, bareness, and precipitation.

The implementation of a dust module within a dynamic land model of the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) climate model is used to better represent dust interannual and decadal variability. We performed a set of simuations to evaluate the contribution of surface winds, soil moisture, vegetation and landuse changes to long-term variability of dust. The analysis of these simulations will be presented by contrasting the similarities and differences between regions.

Keywords: dust, climate, modelling, emission

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Applications of dust research in solar energy technologies

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In the operation and maintenance as well as the yield calculations of solar plants, dust-related issues play an increasing role. Here we give an overview on the most prominent topics with a focus on soiling in concentrating solar power (CSP) plants.

The accumulation of dust and dirt on the optical surfaces of solar power plant components is called soiling and reduces the plant's efficiency. The operators of solar power plants find a compromise between minimizing cleaning costs and maximizing solar energy output and therefore knowledge about site-specific soiling rates is important. Historic knowledge on soiling can lead to better yield analysis calculations, improved plant site selection and optimized solar field layouts. The availability of present and future soiling rates can help to optimize cleaning schedules potentially increasing the profit of a CSP project by up to 2.6 %.

Soiling related issues are not yet standard in solar resource assessment measurement campaigns. Therefore, methods to estimate the soiling rate from weather parameters which are usually measured during the resource assessment phase could significantly improve the state of the art. We developed a soiling model which predicts the soiling rate from ground measured weather parameters such as particle concentration, wind velocity and relative humidity. The model is based on atmospheric dust transport equations that have been adapted to solar fields. It was tested at two measurement sites in Spain and the Moroccan desert.

A further dust related issue is the extinction of light on its way from the mirror (heliostat) to the receiver on top of the solar tower. Especially in the lower boundary layer high aerosol loads can be present and the vertical and horizontal aerosol particle distribution in this layer is therefore of interest. Because heliostats can be located up to several kilometers away from the receiver, atmospheric extinction can cause significant losses in the solar plant output. Degradation of materials exposed to the environment can irreversibly reduce the performance of components of a solar power plant. The erosive action of particles hitting the components with high speeds as found in sand storms can result in a significant increase in electricity generation costs.

Atmospheric dust also increases the circumsolar radiation, i.e. the solar radiation received from the angular region close to the sun disc. Circumsolar radiation is only partially used by concentrating collectors and has to be considered for performance evaluation of CSP plants. No information on circumsolar radiation is available for many sites that are currently of interest for CSP projects.

Dust information is thus of great use in current solar energy research topics.

Keywords: solar energy, CSP, photovoltaics, soiling, extinction, abrasion, sunshape.

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The ageing of African mineral dust during transport

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.Mineral dust emitted by wind erosion of arid and semi-arid areas is one of the largest player in the mass and radiation budget of the global atmosphere and the ocean, affecting the Earth's climate in many ways. Mineral dust scatters and absorbs radiation across the electromagnetic spectrum, affects warm and ice clouds, and, by deposition, participates to the marine biogeochemical activity. Fundamentally, these effects depend on the chemical composition and size distribution of the mineral dust during its atmospheric lifetime, when various chemical and physical processes intervene to modify them at different time scales from the properties mineral dust had at emission.

In this presentation I will discuss the body of field observations and numerical modelling, as well as new laboratory experiments, of the chemical and physical ageing of African mineral dust. I will focus on the consequences of ageing on the optical properties and its possible effect on radiation. Africa is the largest source of mineral dust worldwide, and contributes to the transport of aerosols across the Atlantic towards the Americas and across the Mediterranean to Europe and the Middle East. Open questions and the needs for future research will be highlighted.

Keywords: mineral dust, Africa, ageing, transport, observations.

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Atmospheric iron as nutrients: emission, processes, deposition and impacts

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Millions of tons of aerosol particles are transported to remote ocean each year. These particles, once deposited, provide the ecosystems, particularly those iron-limited ones, with an external source of iron. This, in turn, stimulates primary production (a plant's ability to produce complex organic compounds from water, carbon dioxide, and simple nutrients) and enhances carbon uptake and thus indirectly affects the climate.

This talk will outline the key factors that affect the biogeochemical implications of atmospheric nutrients, including emissions, atmospheric transformation, and Fe-microorganism interaction.

Emissions: Mineral dust is the dominant emission sources of iron to the global ocean, with anthropogenic sources contributing no more than a few percent of total Fe. However, Fe solubility (soluble to total Fe) in the dust may be orders of magnitude lower than some anthropogenic Fe sources such as shipping and biomass burning. Therefore, soluble Fe emissions from anthropogenic sources is likely to be significant. However, our knowledge of the soluble Fe emission flux remains poor, primarily due to a lack of systematic experimental measurements of Fe solubility from different sources.

Atmospheric processes: Modelling and laboratory studies suggested that atmospheric processes, in particular the acid processes, can cause the solubilisation of insoluble Fe in aerosols. This is recently confirmed in a field observation. Recent measurement and modelling studies indicated that organics can also contribute to the solubilisation of Fe in natural and anthropogenic aerosols. However, major uncertainties remain in global models to simulate the secondary production of soluble Fe.

Impacts: There is growing evidence that atmospheric Fe deposition affects ocean biogeochemistry, both from laboratory and field observations. However, there is little, if any, direct field evidence on the significant impact of atmospheric Fe deposition on oceanic primary production. In addition, to model the impact of Fe deposition on ocean carbon storage and climate, we need to improve our understanding of the complex processes involved in Fe biogeochemistry in the surface ocean, for example, deposition, bioavailability, biological uptake and processing, and recycling.

In summary, major progress has been made in Fe biogeochemistry but much uncertainty remains in global models regarding soluble Fe flux to the oceans, particularly in the Fe-limited Southern Ocean, and the impact of Fe deposition on primary production and the climate.

Keywords: iron; biogeochemical cycle; climate; aerosol.

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Radiative Forcing and Response to Anthropogenic Dust Aerosols

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Human activities like cultivation and animal husbandry increase soil erosion, creating sources of dust aerosols. These anthropogenic sources can be identified using land-use atlases, although the anthropogenic fraction is uncertain where dust was emitted prior to human activity. An additional challenge is to determine systematic differences in the soil condition between natural and anthropogenic sources. We increase the threshold wind speed for emission in regions of complex topography and extensive vegetation; the latter, inferred from satellite retrievals of leaf-area index, introduces a seasonal variation to the threshold. We use a global Earth System Model with prognostic dust aerosols to calculate dust emission, concentration and forcing for both natural and anthropogenic sources. We estimate the associated radiative forcing, and the uncertainty that arises from regional variations in soil composition.

Keywords: anthropogenic dust, emission threshold, dust composition, radiative forcing.

Acknowledgements
This work is supported by the NASA Modeling, Analysis and Prediction Program.

ORAL PRESENTATIONS

SOURCES AND TRANSPORT OF DUST

Characterizing the transport of African mineral dust to South America and the Amazon Basin using long-term PM measurements at Cayenne, French Guiana, and the MERRA-2 model.

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Various studies suggest that there is a substantial transport of dust from Africa to South America during boreal winter and spring. This assessment is largely based on satellite and modeling efforts. However, there is little data that could be used to place this assessment on a quantitative basis. Previous studies suggest that high concentrations of particulate matter with an aerodynamic diameter of 10 um or less (e.g., PM10) in Cayenne, French Guiana, are largely attributable to incursions of African dust and that PM10 could thus be used as a proxy for dust. Here we present the results of one year of mineral dust filter measurements made at Cayenne concurrently with PM10 measurements carried out by the French national air quality program. We show that PM10 concentrations greater than about 15 µg m-3 are entirely attributable to mineral dust. On this basis we subtract the background and convert the long-term record of Cayenne PM10 data from 2002 - 2017 into a daily record of estimated dust mass concentrations, PM10-Dust. We compare our monthly-averaged Cayenne dust record to the MERRA-2 monthly mean surface dust concentration (DUSMASS) record for Cayenne and find excellent agreement both from the standpoint of the timing of the seasonal cycle and the concentrations measured during the dusty months. In most years, MERRA correctly identifies the peak month in our PM10-Dust record. Peak concentrations are frequently close to that measured, usually within 25%.

To address the issue of transport to the greater Amazon Basin, we compare our daily PM10-Dust measurements at Cayenne with those made in aerosol studies in 2014 and 2015 at the Amazon Tall Tower Observatory (ATTO) located 1000 km southwest of Cayenne, near Manaus, Brazil. We find that in some cases we can make a direct match between peaks in PM concentrations at these two sites after allowing for an appropriate transport time of a couple days. In some of these events the shape of the dust peaks observed at ATTO are quite similar to those observed at Cayenne suggesting that the dusty air mass remained as a relatively coherent body. However, the concentrations during these events at ATTO were greatly reduced from those measured at Cayenne, to about a quarter of the original concentrations. Also many major events observed at Cayenne never reach ATTO as a recognizable event.

We also compare the monthly mean MERRA-2 dust surface concentration at Cayenne to those at ATTO over the period 2002 – 2017. MERRA shows systematic transport to ATTO over the record although there is great year-to-year variability compared to Cayenne and quantities are reduced to about a third or more in the mean.

In the future the pairing of systematic measurements at Cayenne with those at ATTO will enable us to better quantify transport to the Amazon and to better characterize changes to the aerosol properties as the air masses travel deep into the Amazon Basin.

Atmospheric controls on the interannual variability of dust concentration and dust transport pathways

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Dust emitted over the North African deserts is transported towards the adjacent Oceans and Europe. Thereby, the actual dust transport pathway and atmospheric dust loading are determined predominantly by emission flux and atmospheric transport capacity (i.e. wind). Both dust source activity respective dust emission flux and atmospheric circulation in concert depict the interannual variability by superposing each other resulting into a net variability. This interannual net variability is illustrated by means of temporally varying atmospheric dust concentrations as observed by ground-based and space-borne measurement.

Whereas observations reflect the current atmospheric concentration at ground level, its distribution throughout the vertical column, or the vertical integral, numerical modelling studies allow for examining the atmospheric processes resulting into the observed situation. Recent work published on the atmospheric controls fostering the variability in dust export towards the Mediterranean and Europe [Schepanski et al., 2016] and the tropical northern Atlantic [Schepanski et al., 2017] for summer 2013 highlight the relevance of superimposing major atmospheric circulation regimes such as the strength of the trade winds (Harmattan), the Saharan heat low, the position of the intertropical discontinuity (ITD), and the strength of the West African Monsoon circulation. Here, we aim for extending these studies in order to investigate the variability in atmospheric circulation fostering long-term variability in atmospheric dust loading over northern Africa, the adjacent Seas, and Europe. We used the global atmosphere-aerosol model ECHAM-HAM to simulate 39 years of atmospheric circulation and aerosol concentrations including mineral dust. The model output is examined regarding the variability in predominant atmospheric circulation patterns and associated dust concentrations over northern Africa, the northern Atlantic, the Mediterranean Sea and Europe.

Results from this study illustrate the atmospheric controls on the interannual variability in the atmospheric dust burden at climatological time scales (39-years). Ultimately, the outcome contributes to the understanding of the interplay between atmosphere and potential dust sources (soil characteristics). Lessons learned from this long-term study point towards applications for investigating future dust scenarios in a changing climate.

Keywords: dust sources, dust transport, atmospheric circulation, interannual variability, atmosphere-aerosol model

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Saharan Air Layer profiling at the Canary Islands using MPL and radiosondes

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The aerosol vertical distribution is known to impact profoundly on the Earth's radiative budget and climate. Since mineral dust is one of the major contributors to total aerosol loading, representing about 75% of the global aerosols injected in the atmosphere, the vertical characterization of the Saharan Air Layer (SAL) is considered relevant in climate studies, playing an important role on the climate of Northern Africa and tropical/subtropical Atlantic region, and playing also an important role as ice nucleus, affecting the properties of clouds and their impact on climate.

There are few references in the literature to long-term vertical characterization of the SAL. In this sense, systematic ground-based measurements of the SAL vertical distribution are required to validate satellite products. These studies should ideally include a vertical thermodynamic characterization of the SAL in the lower troposphere.

Eight years (2007-2014) of vertical atmospheric extinction profiles from a Micropulse Lidar (MPL) and meteorological parameters from radiosondes at Tenerife (Canary Islands, Spain) have been analyzed in this study to characterize the SAL at this subtropical site. Canary Islands are characterized by large scale subsidence processes, and its location near the most important mineral dust sources makes this site suitable to study both clean conditions and the vertical structure of the SAL. We have defined four different atmospheric scenarios that characterize the aerosol climatology by means of AErosol RObotic Network (AERONET) aerosol optical depth (AOD) and Angström exponent (AE) data extracted at two stations in Tenerife (Santa Cruz coastal station -SCO- and Izaña high mountain station -IZO-). These two stations are representative of two different atmospheric layers. SCO (52 m a.s.l.) is inside the well-mixed marine boundary layer (MBL), typically affected by marine aerosols and sporadically by mineral dust. IZO is mostly representative of clean free troposphere (FT) conditions, though it is also sporadically affected by mineral dust, mainly in summertime. We have classified the atmospheric scenarios into a clean scenario (CS), with no impact of mineral dust in both stations (67% of the overall conditions, mainly from November to March), and other three dust scenarios affecting the FT (S2), the MBL (S3), or both (S1). The S1 scenario, typical of summer months in the Canary Islands, implies 19% of the overall conditions. The other two scenarios (S2 and S3) together only encompass 14% of the time-period.

Information from atmospheric soundings, launched at a nearby station (Güímar, Tenerife), has been used to restrict the information of the four different scenarios to those cases in which the planetary boundary layer (PBL) presents a double temperature inversion structure, and therefore two atmospheric layers appear below the 750 hPa level: the MBL and the trade wind layer (TWL) in case of clean conditions, in addition to another layer with dust influence otherwise. We have followed the criterion presented in Carrillo et al. (2015) to identify these different atmospheric layers, based on temperature and water vapor mixing ratio gradients.

Our results have revealed that, in case of clean conditions, the PBL is relatively well-mixed and significantly clean conditions are observed in the free troposphere ($\alpha \leq 0.018$ km^{-1}). There is a readily visible inversion layer, the MBI, associated with low extinction values, which seems to separate MBL and TWL within the PBL. When dust is observed in the FT and MBL (scenario S1), an important increase in extinction values ($\alpha = 0.08$ km^{-1}) was found at all levels, with a PBL affected by dust and values twofold those found in clean conditions ($\alpha \leq 0.035$ km^{-1}). The subtropical FT is also affected by the CBL. The vertical structure of the SAL appears to be decoupled from the layer aloft, with a peak in extinction at around 2.8 km. Under the SAL influence, PBL reach altitudes normally characterized by clean FT conditions and Saharan air masses are more humid than clean FT at the same levels, with a peak in relative humidity (RH) of about 47% at 5.6 km. SAL's top is located at 6.4-6.6 km. It is noteworthy the decrease in the 0°C level in S1 scenario, in comparison to the clean scenario, indicating the presence of colder air at higher levels under the presence of SAL. In case of scenario S2, in which dust is not present in the MBL, lower values of aerosol extinction were found at surface in contrast to S1, but higher than in typically clean conditions, suggesting the presence of some residual dust by gravitational settlement or downward entrainment of mineral dust in lower layers. Extremely clean conditions were observed within the TWL and TWI layers, suggesting these two layers observed in the vertical are decoupled. In scenario S2, the SAL seems to have a similar extension than in the scenario S1 but lower aerosol loads in the peak. RH maximum is located at similar altitude and a similar decrease in 0°C level than in S1 was found. Finally, in scenario S3, normally observed in winter time, in which dust is only present at lower levels, below IZO's height, we have found similar two-decoupled layers in the vertical but compressed in the first 2 km height, where clean FT conditions were found (from 2.5 km on). This is a dry layer (RH up to 21%) with extinction coefficients ($\alpha \approx 0.095$ km^{-1} near the dust peak at 1.4 km) more than twice values at surface than those found in CS.

Our results suggest an enhancement in the TWI as a result of the SAL effect, a reinforcement in the trade wind regime as well as a possible effect of the SAL on heterogeneous ice nucleation through a higher occurrence of modestly super-cooled mid-level altostratus clouds near its top (5 - 7 km).

Keywords: Saharan Air Layer, Micropulse Lidar, radiosondes, atmospheric aerosol extinction.

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Modelling Namibian dust emission in the framework of AEROCLO-sA

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The southwestern coast of southern Africa is one of the driest regions in the world. It is not surprising that the arid to hyperarid conditions there lead to a very low expanse in vegetation cover and to a huge amount of barren sediments that are prone to wind erosion. In fact, a number of studies have already proven the importance of southern African dust sources for the atmospheric dust load from both, large scale features like salt pans as well as small geomorphologic features like ephemeral river basins along the coastline.

Adjoined to the AEROCLO-sA campaign, the EUFAR funded project ALLDUST-SA (Alluvial Dust Sources – a Sub-Basin Analysis) took place in Namibia in August and September 2017, which focused on the precise localization of dust sources in Namibia using LIDAR measurements.
The study consists of two parts: The first part makes use of different LIDAR systems operating onboard the SAFIRE F20 aircraft during the campaign and at ground-based sites in Namibia, as well as satellite dust and AOD products. We will present first results on the spatio-temporal variability of active dust sources and the vertical distribution of dust in the atmospheric column.
In the second part, we will show how the gained knowledge on the localization and characteristic of dust sources in Namibia can be implemented in dust-emission-models: As a first attempt, an offline dust emission model is used to reproduce the activity of Namibian dust sources by determining and including surface characteristics that are responsible for the variability in dust emission. Like this, the study provides a first step towards a better representation of southern African dust sources in dust emission models and for a better estimation of the total atmospheric aerosol load in the region.

Keywords: dust sources, dust modelling, remote sensing, southern Africa.

Analyses of temporal and spatial variations in sand and dust storm events in East Asia from 2007 to 2016

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Sand and dust storms (SDSs) are natural events that can have disastrous effects on both the environment and human activities (Sun et al. 2001; Zhou and Wang 2002; Tam et al. 2012). SDS events in East Asia mainly occur in the spring and may cause a decrease in visibility to less than 10 km, or even occasionally to less than 0.1 km. The concentrations of particles with diameters less than 10 μm increase significantly, which affects the air quality and can cause respiratory symptoms in humans (Zhang et al., 1998; Kim et al., 2001; Che et al., 2006). We analyzed the frequency and intensity of sand and dust storms (SDSs) in East Asia from 2007 to 2016 using observational data from ground stations, numerical modeling, and vegetation indices obtained from both satellite and reanalysis data. The relationships of SDSs with surface conditions and the synoptic circulation pattern were also analyzed.

The spring SDS events recorded by the CMA from 2007 to 2016 showed decreasing trends in both number and intensity, with 2011 as a clear boundary year. There were five to eight spring SDS events in each of the four years before 2011, but only one or two in each of the six years after 2011. In the same time period, the total number of SDS events decreased from at least ten each year before 2011 to less than ten times per year after 2011, with some exceptions. The SDS events in spring 2007 were the strongest and SDS events occurred most frequently in spring 2010 (15 events). The lowest number of SDS events occurred in spring 2013 (6 events) and their intensity was the weakest.

The distribution of the mean surface dust concentration in spring varied greatly in different regions during 2007 to 2016, particularly in the source areas regions for dust. Most of East Asia was affected by SDSs and the mean surface dust concentration in these regions decreased each year. The decreasing trend of the surface dust concentration was greater in the areas with a high mean surface dust concentration. The overall average annual variation of the surface dust concentration in four dust source regions were −33.24 μg/m3 (−11.75%) per year. The decrease was greatest in central Inner Mongolia, where the mean surface dust concentration decreased on average by 45.05 μg/m3 (16.25%).

Based on the NDVI, the vegetation coverage improved and spring dust emissions were suppressed in and around the dust source regions during 2007 to 2016. The mean temperature at 2 m height and at 0-0.1 m depth level in the MDIA showed an increasing trend and the amount of precipitation also increased over time. The VSMC at 0-0.1 m depth level in most parts of MDIA increased each year. These conditions are favorable for plant growth, which may reduce the intensity and frequency of SDSs. Artificial afforestation has also played an important part in the improvement of vegetation coverage. Although the condition of vegetation coverage because better and better on the edge of deserts, little were changed in the desert interiors. That's because the measures to prevent and control desertification are unable to change the condition of vegetation coverage in the interior of deserts, including the Gobi Desert.

The strong winds that blow up sand and dust particles are usually accompanied by an influx of cold air from high latitudes. The north wind components showed a decreasing trend, resulting in a decrease in the number of SDSs, while the observed decrease in the west wind component was not conducive to the long distance transmission of SDSs to the east. The MSLP gradient between the high pressure area in northwest Asia and in East Asia decreasing showed an annual decrease over the decade, which resulted in a decrease in wind velocity in the main source area for dust. The decreased intensity of the polar vortex, which affects the frequency and intensity of the influx of cold air into East Asia, was closely related to the decrease in the intensity and frequency of SDSs. As the decrease of wind speed could influence the SDSs both on the edge of deserts and in the desert interiors, it played a key role in the decadal decrease of SDSs.

Keywords: Sand and dust storms, Surface conditions, NDVI, Climate change.

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Causes and control measures of dust sandstorms in the adjacent Steppe region between China and Mongolia

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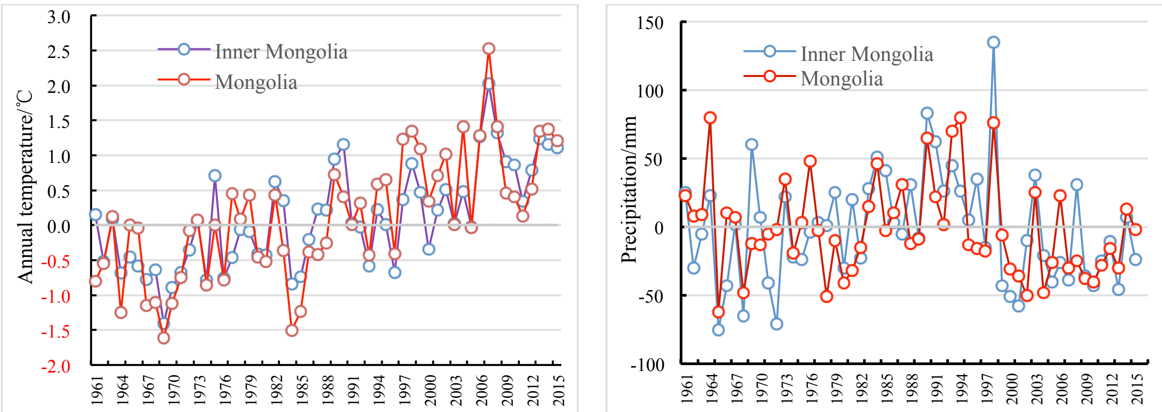
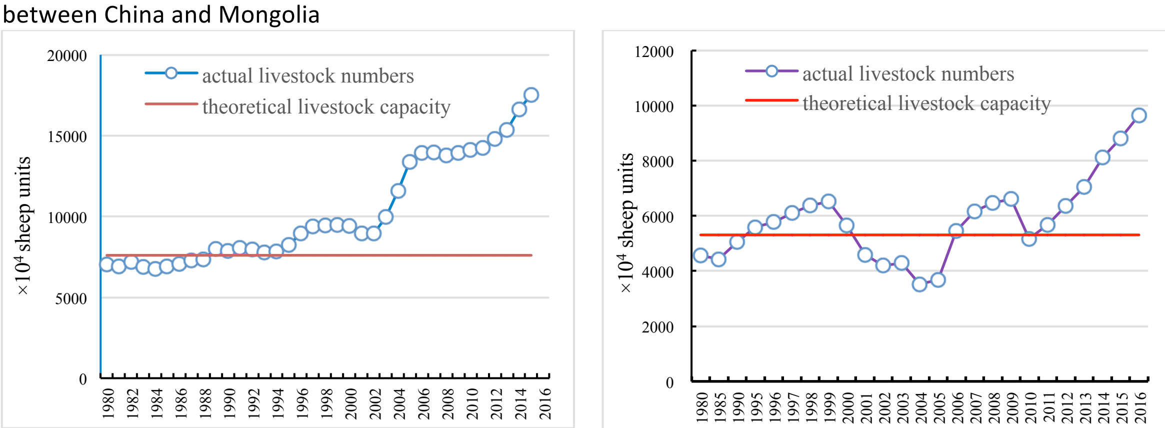
Abstract: The adjacent Steppe region between China and Mongolia is located in the hinterland of Mongolia plateau and the eastern part of Eurasian Steppe, which is one of the most significant ecological barriers in North China and plays a crucial role in maintaining regional ecological security, biodiversity, grassland animal husbandry etc.. Special regional environment factors such as dry and windy climate, low vegetation coverage, large ground surface exposure and strong soil erosion have caused extremely fragile ecological environment. Since 1960s, strongly affected by climate change (Graph. 1) and over grazing (Graph. 2), the regional eco-environmental degradation has been very serious and it has become the most important sources of dust sandstorms in Northeast Asia region.

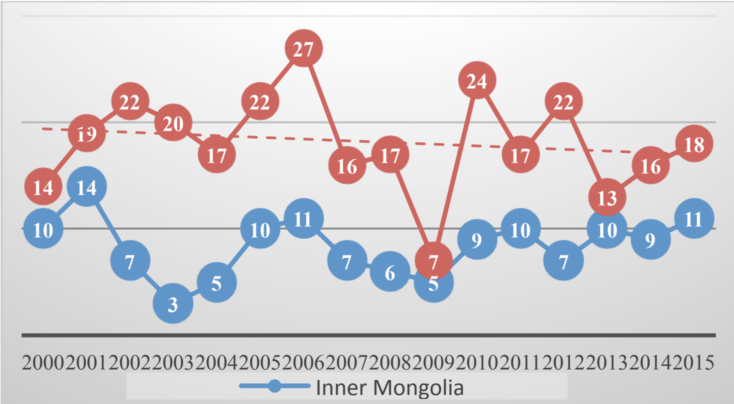


Graph.1 Variation tendency of Annual temperature and precipitation anomalies in the adjacent steppe between China and Mongolia



Graph.2 Variation tendency of Livestock numbers of Inner Mongolia(L) and Mongolia(R) in the adjacent steppe between China and Mongolia

By 2015, the degraded grassland areas in Mongolia and Inner Mongolia (China) of the adjacent Steppe have accounted for 72.0% and 74.7% of the local land area, respectively. The severe dust sandstorm (Graph. 3) caused by grassland desertification poses a serious threat to the ecological safety of the local and Northeast Asian regions.



Graph.3 The frequency of severe DSS in different source areas in the adjacent steppe between China and Mongolia

Our study showed that the most effective technical measure for controlling grassland desertification and sandstorm is to establish a joint protection mechanism between China and Mongolia, and jointly implement strict spatial control measures. First, strict protection system should be established for nature reserves, important wetlands and other biodiversity enriched areas, where the exploitation and utilization are strictly prohibited. Second, 30% of vegetation coverage should be considered as the threshold of ecological conservation in the large area of arid grassland. Among which, the part with vegetation coverage >30% should be scientifically caculated the ecological carrying capacity according to the prediction based on precipitation and grassland productivity and then implement protection and utilization, while the part with vegetation coverage of 10%-30% should apply the fencing and grazing management to restore grassland vegetation. Third, the serious desertification grassland or sand with vegetation cover of less than 10% should be established sand barrier protection system, that is to plant suitable sand shrubs such as *Caragana microphylla*, *Artemisia halodendron* etc. at the density of 25000-30000 shurbs per hm^2, and reseeded herbs such as *Agropyron desertorum* etc. at the density of 25-30 kg per hm^2, and then establish composite artificial vegetation in the sandy land to restore degraded grassland ecosystems. It has been proved that these restoration and management measures have achieved significant ecological and economic benefits in the northern grassland of China.

Key words: Dust sandstorms; the causes and control measures; arid grassland; the adjacent region between China and Mongolia

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Observational Analyses of Multi-Scale Interactions Among Baroclinic Waves, Complex Terrain, and Moist Convection Recirculating Saharan Dust to Spain

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This case study of dust transport from the Sahara represents an example of an extraordinarily strong circulation regime over the region from the western Atlantic Ocean to western Europe as well as western Africa. Data from a large number of air quality stations (261), METAR observations at 39 airports and records from meteorological networks were used. Information from dispersion models, satellite observations, synoptic charts and back-trajectory analysis, supported the interpretation. During the event, 89% of the monitoring stations exceeded the daily PM10 limit value. The highest daily averaged PM10 concentration across Spain ranged from 378 to 18 μg m^{-3}, following a hyperbolic decay with increasing latitude. This represents one of the strongest observed episodes in terms of ground-level aerosol concentration in the southern Iberian Peninsula (IP) which also impacted most of Europe in subsequent days.

Dust mobilized in the lee of the Atlas by moist convective downdrafts, propagated along the leeslope and was then recirculated from the region just to the lee of the Atlas Mountains back to southwestern Europe as a result of very strong cyclonic development in conjunction with embedded moist convection. Rossby wave breaking followed by baroclinic instability occur during this 4-day period. The signal of this impending dynamical activity is first evident on 8 October 2008 over the North Atlantic Ocean as a massive tropospheric ridge begins to tilt positively in response to a deep polar jet at and above 330K with numerous embedded wind and Isentropic Potential Vorticity (IPV) maxima along its northern flank. The first of two key jet streaks propagating around the breaking Atlantic ridge arrives over Spain very early on 8 October. This first streak is short-lived on the 330K isentropic surface as a very fast mover as it exits before 06 UTC 8 October and is closely followed by a second stronger and longer-lived streak which establishes an early equatorward pressure gradient at low-levels between France and Spain consistent with north-northeasterly flow. The second streak arrives less than 6 hours later over the downstream side of the planetary wave break manifested as a positively-tilted ridge and thinning trough. The trajectory of the streak is such that the left exit region of the jet with the leading edge of a strong IPV maximum and its cross-stream shear zone is established over the IP and the Atlas Mountains of northwestern Africa by 06 UTC October 8. By 12 UTC 8 October the left exit region 330K IPV value exceeding 1 IPV unit and upward vertical motion arrive over central and western Spain, the western Mediterranean Sea, and extreme northwestern Africa. Two zones of upward vertical motion are established near 30^{o}N latitude during the next 6-hour period period. One lower-midtropospheric ascent plume develops equatorward of the leeslope of the Atlas Mountains. A second weaker upper tropospheric plume is slightly poleward at this time between southern Spain and the upslope of the Atlas. This second plume is easily attributable to an indirect, secondary ageostrophic circulation across the jet exit region. The lower and stronger plume is consistent with both surface heating over the leeslope and a southerly confluent low-level return branch circulation into the Atlas. By 00 UTC 9 October the potential instability is established as cold air with the jet left exit region, ascent, dry air advection down the Atlas Mountains, and low-level moisture from the Mediterranean phase which is followed by the development of moist convection. The Mediterranean moisture arrives as a result of the northeasterly low-level flow accompanying the first earlier jet streak and the mid-level dry air arrives accompanying the second jet's cross-Atlas flow. Isentropes become erect by 00 UTC 9 October in response as moist convection develops and strengthens both zones of upward motion producing a low-level haboob

zone on the lee of the Atlas due to high pressure caused by moist cold downdrafts and negatively buoyant outflow from the convection. North-northeasterly low-level flow develops, intensifies in response to the leeside pressure gradient, and is forced by the Atlas to propagate southwestwards along the lee slope establishing a rapidly expanding anticyclonic low-level mass, momentum perturbation. This strong anticyclonic equatorward surge of mass/wind is a locus of increased turbulent kinetic energy that ablates surface dust.

During the course of 9 October, cold air advection with the upper jet streak and upward motion in the jet left exit region act to turn a straight jet into a curved jet and cyclonic vortex which becomes cutoff from the flow and drifts slowly southwestwards off the northwestern African Coast. The cooling aloft turns straight flow into cyclonic flow as the column thickness becomes lower, heights fall, and winds back in the vertical. By 00 UTC 10 October several features develop as the newly-formed upper vortex/IPV center and surface cyclone expand in scale to surround the mesoscale convective outflow which responded earlier to cold convective downdrafts on the leeside of the Atlas. The cyclonic flow wraps around the residual and weakening convective northeasterly outflow creating a deep southerly flow southeast of the surface cyclone and east of the Atlas. Simultaneously low-level easterly flow accelerates through the Straits of Gibraltar over the eastern Mediterranean in response to the strengthening pressure gradient force directed southwestwards between the newly formed low and residual high pressure over France left over from the first jet streak. This easterly flow becomes extreme as it exceeds 25 m s^{-1}. After 06 UTC 10 October the southerly flow east of both the Atlas and the dead zone of cold air outflow accompanying the mesoscale high creates a well-organized southerly mid and low-level jet that propagates from northwestern Africa poleward towards Spain. During the remainder of the period between 12 UTC 10 and 00 UTC 11 October the low-level vortex retrogresses off the African coast as it transports south-southwesterly momentum towards Spain and with it growing descending flow which arrives as a strong surge of southwesterly momentum, increasing pressure, dry, and dust laden air over southern Spain by 00 UTC 11 October from a tropopause fold rich in ozone. The dust imagery supports the trend of the dust plume over more than 24 hours which emanated southwestwards from the convective downdrafts followed by being stretched by the deformation zone created by this new south-southwesterly jet. The dust plume now takes on a structure like a typical scalar tracer representing the shear established between the new south-southwesterly low-level jet and former northeasterly flow accompanying the convective downdrafts. This creates a linear pattern in the dust oriented south to north in proximity to the low-level cold front wrapping around the surface cyclone. As the southerly jet moves into Spain the dust and any stratospheric constituents sinking Earthward in the tropopause fold move into Spain with it along the rear flank of the cold front and just west of newly developing convection downstream of the cold front. Hence, the dust on the leeside of the Atlas Mountains accompanying the mesoscale downdraft-induced high pressure area is effectively recycled by the south-southwesterly low-level/mid-level jets and advected polewards towards Spain arriving along the southern Spanish Coast by 00 UTC 11 October. A second plume of dust forms on the leeside of the Hoggar Mountains in Algeria as a new round of convection develops and both plumes merge into Spain.

Keywords: Jetstream, Convection, Haboob, Turbulence, Acceleration.

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The voyage of detrital calcites from the Sahara-desert to the bottom of the Dead Sea

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The Sahara-Arabia desert belt has provided during the past few million-years enormous amounts of fine particles to the continents and oceans. These particles termed as "desert dust" comprise surface cover soils (e.g. the loess deposits and mountain soils such as Terra Rossa) in the circum Mediterranean areas, soils that are instrumental in human agriculture development. While observations clearly spot the areas of origin of modern desert dust, e.g. dry morphological depressions in the Sahara or Arabia deserts, the sources, modes and routes of past transport (e.g., during the late Quaternary) of desert dust to the continents (e.g. Levant area) are not well known. The constituents of desert dust are mainly detrital grains of quartz and calcite. While, quartz is abundant in the deserts the source of the "detrital calcites" is not known and revealing its sources and depositional environment would provide important information on past hydro-climate conditions in the deserts. Here, we use Nd-Sr isotope compositions of detrital calcites in modern settled dust, loess deposits and the fine detritus comprising the late Quaternary lacustrine formations at the Dead Sea Basin to trace the origin and processes of formation, transport and fate of the detrital calcites. Detrital calcites from modern and ancient dust archives show unique $^{87}Sr/^{86}Sr$ ~ 0.7081, and eNd values that lie in the range of ~ -10 to -15. The very negative eNd values indicate that the calcites were deposited in lakes that derived their waters from the mid-Proterozoic shields during times of enhanced precipitation in the Sahara deserts (e.g. during past interglacials or African Wet Periods). The detrital calcites (along with the quartz grains) were blown to the east Mediterranean- Levant mainly during the glacial periods forming there the loess and Terra Rossa surface cover. The dissolution of the calcites provided calcium and bicarbonate to the Dead Sea where it was redeposited as primary aragonite.

Keywords: Dead Sea, Desert dust, detrital calcites, Nd-Sr isotopes, paleoclimate.

Spatial and Temporal Analysis of Sand And Dust Storms (SDS) Between the Years 2003 and 2016 in the Middle East

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Mineral dust particles, aerosols suspended in the atmosphere, play a key role in the atmospheric radiation budget and hydrological cycle through their radiative and microphysics effects. Moreover, mineral dust aerosols influence the climate system in multiple ways. The most important sources of dust aerosols are located in the Northern Hemisphere, primarily over the Sahara in North Africa, the Middle East, Central and South Asia respectively. The objective of this study to carry out intensity and frequency analysis of sand and dust storm in the Middle East for the period 2003-2016. To identify aerosol episodes, the method, at which Gkikas et al (2009) investigated the aerosol events based on their frequency and intensity in the Mediterranean Basin by using AOD (Aerosol Optical Depth) data from MODIS, is applied. The AOD and AE parameters can be used to differentiate between coarse and fine particles of aerosols. To investigate average annual and monthly AOD and AE for the period 2003-2016, AOD and AE data of MODIS Aqua is obtained from Giovanni website. Spatial and temporal analyses of the Middle East (extending from 20° to 38° North and 36° to 64° East) between the years 2003 and 2016 are performed with five sub-regions: Southeastern Turkey, Northern part of Syria-Iraq, marshlands at the north of Persian Gulf, Ahwaz-Iran, Ilam-Iran. The correlations of daily AOD values between the regions are also analyzed. Moreover, the relation between strong aerosol events and precipitation over Southeastern Turkey and Euphrates-Tigris Basin is also examined. The results point out that there is no significant correlation between strong aerosol events and precipitation over those regions. In summary, for the last years (2013-2016), annual mean AOD and the number of SDS are comparably lower than the other periods while the values are the highest between 2008 and 2012.

Keywords: AOD, dust, Middle East, trend

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Characterizing Dust Storms Over the Persian Gulf and Oman Sea Using CALIPSO Recordings

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The considerable situation of the Persian Gulf and the Oman Sea have been led climatologist to focus on them. They are surronded with the major sources of dust which are on the dust belt. Hence, their atmosphere are under influence of dust outbreak of intense sources [1]. The most significant dust sources on the dust belt which influence on the Persian Gulf and the Oman Sea as an attractive region include the Tigris-Euphrates Basin, Arabian Peninsula, Afghanistan and Pakistan Basin, Thar desert in Indian subcontinent and also Sistan Basin in Iran [1, 2]. Accordingly, the best way to obtain information about the activities of such sources is monitoring dust event over the open waters in south of Iran Plateau. The Persian Gulf is also under impression of Syrian and Iraqi sources due to the strong northwesterly windswhich known as “Shamal winds” [3]. A wave of high pressure by funneling through the Persian Gulf between Saudi Arabia and Iran causes Shamal winds with perilous weather conditions [4]. In addition, the Arabian Peninsula and its surrounding deserts as the main dust sources in the Middle East can impress on the Persian Gulf and the Oman Sea [5, 6]. The Iranian Plateau with arid center as another effective source is also substantial. Dust storms activity over a low lying basin with dried lakes known as Sistan Basin at the border of Iran, Afghanistan and Pakistan as a most impressive region have interesting affect on the Oman Sea. This arid region extremely is under influence of the strong insistent northerly winds which commonly famed as the “wind of 120 days” or locally as Levar [7–10]. This potent winds fall out during mid-May to mid-September which motivate dust storms over Sistan Basin in late spring, throughout summer and early autumn [7,11]. On the other hand, some main arid regions in western and southernmost western Afghanistan, Balochistan Basin in Pakistan and a large areas of Pakistan and the western region of north Indian Subcontinent [1] also contribute to dust outbreaks over the Oman and Arabian Seas. Accordingly, the Persian Gulf and the Oman Sea are striking regions in climatology studies. The Sistan region in southeast Iran is another one of the strongest dust source regions in Southwest Asia. The powerful Levar winds in summer uplift large quantities of dust from the Hamoun Basin in this region and transport toward the Oman Sea. Since there have not been any studies in a long period of time over the Persian Gulf and the Oman Sea, the present study focuses on characterizing dust storms over the interest region and aims to survey monthly variations by using CALIPSO recording during June 2006 to December 2015. For this purpose, associated columnar averaged particulate depolarization ratio (PDR), column integrated attenuated backscatter (IAB), column aerosol optical depth (AOD), column integrated particulate color ratio (CR) at 532 nm, column angstrom exponent (AE) as well surface wind speed (SWS) have been retrived from the CALIPSO level 2 data products. Moreover, ground-based (Zabol station) meteorological data are applied to present profound role of Sistan Basin and associated surface wind in the aerosol loading over the Oman and Arabian Sea. Finally, aerosol loding over studied zone is analyzed and dicussed by synoptic meteorological reanalysis (ECMWF) in this work.

Keywords: Aerosol, Atmospheric optics, Backscattering, Lidar, Dust.

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Consideration of wildfires as a source of airborne mineral dust

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Wildfires, like biomass burning, are a very common phenomenon in semi-arid regions nearly all over the world. Investigations of smoke plumes originating from such wildfires found significant fractions of mineral dust and crust-related minerals within these plumes (e.g., Nisantzi et al., 2014; Schlosser et al., 2017) – raised by strong turbulent winds related to the fire. Since wildfires are not considered as a source of mineral dust in aerosol models so far, a better understanding of the processes, which drive fire-related dust emission, is required.

Therefore, high resolved Large-Eddy Simulations (LES) with the All Scale Atmospheric Model (ASAM) were performed to investigate the impacts of wildfires on the near-surface wind pattern. The analysis of fire-related wind pattern is crucial since the emission of mineral dust is a threshold problem, which means that an efficient mobilization of mineral dust particles requires wind velocities above a certain threshold. The influence of different fire properties (intensity, size, and shape) and different atmospheric wind regimes on the dust emission potential is investigated.

The wind fields derived from the LES fire simulations were coupled with an offline dust emission model (Tegen et al., 2002) to calculate the emission fluxes in dependency on the fire properties and the ambient atmospheric conditions. The gained results can be used to estimate typical values of the emitted amount of mineral dust during wildfires, which can be applied for the development of a parameterization of fire-driven dust emission. With that, an estimation of the importance of the process on a continental scale in relation to other types of mineral dust emissions is possible.

Keywords: wildfires, mineral dust, emission, LES modelling, ASAM.

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Observational analysis of dust-convection interaction over the Sahara and its transport to the Iberian Peninsula

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The African dust outbreak of September 2007 represents a complex process of convective organization leading to downstream dust transport to the Iberian Peninsula (IP). Dust RGB imagery supports two convectively-driven large mesoscale haboobs that develop first at ~07UTC 4 September to the southwest of the Adrar des Iforas Mountains in northern Mali and a second approximately 12 hours later on the western slopes of the Hoggar Mountains in southern Algeria. Both convective outflow zones eventually merge after 00UTC 5 September over central Algeria and then the dust from this merger is transported northwestwards to the southern coast of the Iberian Peninsula and arrives in the late morning of 6 September. The dust plume does not displace further to the north during 6 and 7 September but instead it contracts in the meridional direction while it elongates zonally as it is being accumulated over the southern Iberian Peninsula. That led to spatially-limited, very high AOD levels (and small AE) that peaked on 6 September in Spain and on 7 September in Portugal while the impact was moderate at the ground.

The analysis lends by itself to two main components: (1) How was the environment organized for the convection that ablated the dust and (2) how was the dust transferred to the IP.
Concerning (1), the circulation in the Sahara-Sahel region during the first days of September shares the typical features of the summer Western African Monsoon in situations where the Saharan Heat Low (SHL) is located west of the Hoggar: the Tropical Easterly Jet (TEJ) at upper-levels; the midtropospheric African Easterly Jet (AEJ) with a wave structure and widespread mesoscale convective activity mostly between 5^0 and 15^0 N; and low-level convergence of moist southerly monsoon flows and drier and hotter northeasterly (Harmattan) flows at the ITCZ located in a northern location. Additional relevant features are located at more poleward latitudes: the Subtropical Jet (STJ) above 200 hPa that is far equatorward and more intense than its climatological mean; and a deep upstream wave in the Polar Front Jet (PFJ) associated with a pronounced ridge over the northern Atlantic that is displaced towards western Europe and eventually will reinforce a separate polar front which is propagating southeastwards towards the north Lybian coast. The STJ is moving across northern Africa with a streak of momentum exiting the region over and well northeast of the Hoggar Mountains, in a location very far equatorward than its climatological mean. There is also a weak but well-defined trough in the STJ west of this streak's entrance region, which strengthens on 00UTC 4 September and it is located just west of the Hoggar. Equatorwards, the TEJ has a very long streak of momentum located mostly equatorward of 15^0 N over western Africa and at higher latitudes over the eastern part of North Africa. Hence most of the Hoggar is near the right entrance region of the STJ streak, ahead of its trough, and poleward of the exit region of the TEJ which is trending towards more curved flow in time. Critical to the organization of the convective systems over the mountain ranges are two fundamental divergence and convergence generation processes at upper and lower levels. Aloft, moist convective outflow in the right exit region of the TEJ and dry convective outflow in the right entrance region of the STJ are juxtaposed with dual low-level mountain plains solenoidal circulations along the slopes of the mountains. The low-level thermally direct circulations phase with divergence between the upper-level jets and moist inflow from the AEJ's monsoonal flows to create lift and deep potential instability as warm dry Saharan air overruns the cooler moist monsoonal air. This moist convection above the Adrar des Iforas and Hoggar drives cool and high momentum downslope flows that ablate dust and transport the dust northwestwards as low-level jets towards the SHL. Significant precipitation accompanying this convection is also supported in NASA TRMM imagery.

Concerning (2), between 5 and 6 September an offshore isentropic potential vorticity maximum strengthens within the broader STJ over the northeastern Atlantic Ocean northwest of the Iberian Peninsula and Africa, and propagates southeast to the northwestern African coast. This reinforces poleward and westward dust-laden airflow in the lower and middle troposphere. Convective heating is the driving mechanism for upslope wind flow over the southern slope of the Atlas and uplifting along the isentropic surface between 310 and 330 K, which transports dust to the southern coast of Spain. Calipso lidar imagery indicates that this dust exceeds 5 km in elevation after moving northwestwards from the Atlas Mountains. This is consistent with balloon sounding and ground-based lidar profiles in the area, as well as with back-trajectories calculated at different heights in the troposphere, during 5 -7 September. The sloping isentropic surface along which the dust is transported is not unlike the Saharan Air Layer that typically transports dust to the Atlantic. Deep convective overturning and the formation of a col or saddle in the pressure field between northern Africa and the southern Iberian Peninsula during the second half of 6 September prevents further poleward displacement of the African dust.

Keywords: Jetstream, Ageostrophy, Convection, Haboob, Dust transport.

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DUST IMPACTS

Environmental Destruction and Economic Outcomes: Evidence from Dust Storms

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Dust storms have been shown to cause damage to both health and economic activity in particular cases and systematic effects on child mortality. However, they can have a range of impacts on both health and economic outcomes. In this paper, I study these effects in West Africa, one of the poorest regions of the world. To measure dust exposure, I use MERRA-2 Reanalysis of Aerosol Optical Depth (AOD). Since local AOD could respond to various factors, I predict local AOD using AOD observed over the Bodélé depression prior to the observation period. I extend an analysis of macroeconomic outcomes with data from Living Standards Measurement Surveys across the region. Outcomes of interest include the effect of dust storms on agriculture, health, labor supply, and asset destruction. I find evidence that agricultural yields are substantially negatively impacted, and that individuals substitute labor hours away from agriculture and into other activities. Assets held by both households and firms are also found to lose value more quickly during times of high dust storm activity.

Keywords: MERRA-2, Health, Economics

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Impacts of ambient dust on air quality and solar energy production in a desert environment

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Particulate matter levels in large urban environments of the Middle East are affected by both anthropogenic and natural sources including frequent dust events which result in considerably enhanced particulate matter concentrations. In this work we used WRF-Chem, a regional meteorology-chemistry model coupled with an advanced aerosol module, to simulate the impact of aerosols over the Arabian Peninsula during a summer and winter time period as well as during a major spring-time dust storm. Field measurements of ambient PM_{10} and $PM_{2.5}$ concentrations were also used from the air quality monitoring station located at the Qatar Science & Technology Park in Doha, Qatar (operated by the Qatar Environment and Energy Research Institute). The scope of this work is twofold: 1) quantify the effect of severe dust events on air quality, radiation and regional climate, and, 2) assess the impact of deposited dust on solar energy production. For this study, a mobile air quality monitoring station was positioned for a period of one year next to a solar PV (photovoltaics) test facility and a solar radiation station in the desert environment of Doha, Qatar.

In spring 2015 a massive sandstorm passed over the Arabian Peninsula crossing the state of Qatar on the evening of the 1st of April, 2015 and lasted through much of the day on the 2nd followed by two dust events, of lower intensity, over the next few days. The leading edge of the storm passed over Doha around 9:30 p.m. on April 1st reducing visibility and sharply increasing ground level PM concentrations as shown in Fig. 1.

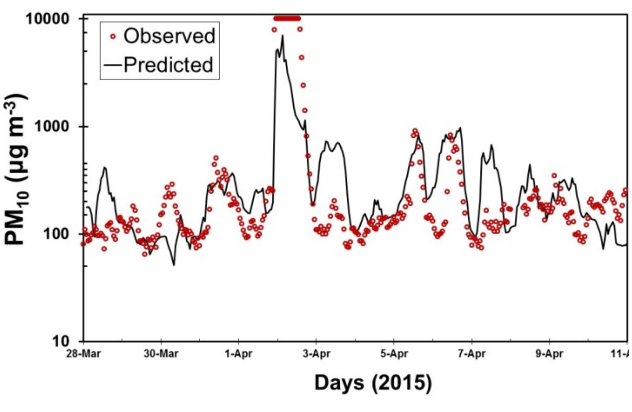

Figure 1: Hourly concentrations of predicted and observed PM_{10} at the QEERI air quality monitoring station in Doha, Qatar during a major dust storm in April 2015.

The tail-end of the system passed over Doha around 2:30 p.m. on the 2nd of April leaving strong winds in its wake. The sandstorm was associated with a low pressure system, with strong winds and counter clockwise circulation around the low that gained momentum over southern Iraq (link to QEERI MeteoSat station video loop provided here: https://www.youtube.com/watch?v=0RKJrlXy5Fg&feature=youtu.be). As the storm front reached the station, a sharp increase in wind speed from 1.3 - 10 m/s was recorded. At its peak, PM_{10} concentrations were greater than 2.1 g/m^3. To further study the characteristics and impacts of this episode, WRF-Chem was applied over the greater Middle Eastern Area in a domain of 3-D grids on a two-way nesting configuration with a high grid resolution over Qatar (2 km × 2 km) for a period of three weeks. An advanced dust scheme (Fountoukis et al., 2016) implemented within WRF-Chem was able to successfully predict the onset and intensity of the storm as well as the two smaller dust events observed during the first week of April 2015 (https://youtu.be/RUrw_v7WK0E). The modelled aerosol optical depth and the direct radiative effect of aerosols during this dust outbreak will be discussed.

The effect of deposition of atmospheric dust onto photovoltaic modules is investigated using both field measurements and modelling throughout a period of a year. Energy yield, solar irradiance, ambient particulate matter concentrations, and meteorological data were monitored continuously during a 12-month period at a solar test facility in the arid environment of Qatar. Dust concentration alone, is a weak predictor of PV soiling and performance, even for particles larger than 10 µm. Instead, a strong non-linear correlation between aerosol mass, RH and PV losses was observed (Fig. 2a). Since only a fraction of the ambient PM_{10} concentration will normally be deposited onto the PV panels which also depends on the relative humid at the time, we assume that this fraction follows a behaviour that resembles a step function, and thus using a modified sigmoid function we estimate this fraction and the resulting deposited aerosol mass (x-axis in Fig. 2a).

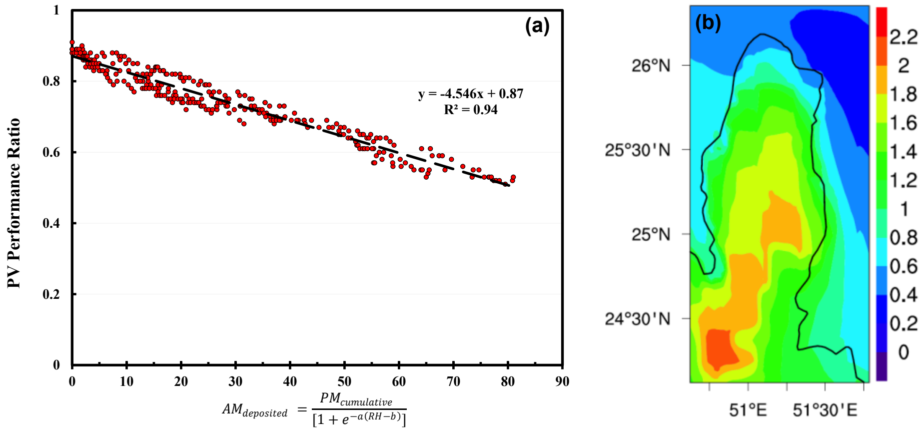

Fig. 2: a) PV performance ratio as a function of deposited aerosol mass during the period 1 May 2015 – 1 May 2016 at a solar test facility in Doha, Qatar. b) Monthly average spatial distribution of dust gravitational settling (in µg m^{-2} s^{-1}) as predicted by WRF-Chem at the ground level during a winter period in Qatar.

WRF-Chem was employed to simulate the emissions and transport of dust particles in the surrounding environment (Fig. 2b). The advantage of using such a model for this study is that most of the complexities of the deposition process are grouped together in a single parameter: the particle deposition velocity. The model predicts an average deposition velocity ranging between 1.1 cm s^{-1} and 3.3 cm s^{-1} during summer and 1.6 cm s^{-1} and 3.7 cm s^{-1} in winter for the different size ranges of coarse dust particles (Fountoukis et al., 2018). A numerical weather prediction model coupled with an explicit treatment of aerosols could be a beneficial tool for comprehensive PV soiling predictive capabilities on an urban-to-regional scale. Results from the predicted geographical distribution of dust settling suggests that floating PV modules could benefit from significantly lower dust deposition.

Keywords: AOD, PV soiling, solar radiation, PM, aerosol size distribution, deposition rate.

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Impact of African dust on air quality of Spain 2001-2016. Is it only dust that matters?

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We present here results of the occurrence of African dust over Spain in the last two decades, its impact on PM_{10} and $PM_{2.5}$ levels, as well as a summary of major health effects deduced from cross studies using different air quality parameters. We will discuss what are the major patterns of dust outbreaks that may have relevant health effects, as well as the forecasting system that we implemented in Spain to alert air quality networks and most sensible population.

Different regions of Spain are influenced by dust outbreaks with varying frequency and intensity depending on the distance to the north of Africa. During extreme episodes this impact may result in exceeding the PM_{10} standards for human protection. Since January 2001 we report to the Ministry of Agriculture, Fishing, Food and Environment of Spain on the occurrence of these dust outbreaks over Spain. This includes forecasting and post-event evaluation of the impact of each episode on PM_{10} and $PM_{2.5}$ ambient levels. Furthermore we monitor levels of PM_{10}, $PM_{2.5}$ and PM_1 as well as their chemical speciation, and concentrations of ultrafine particles and black carbon (UFP and BC) at 3 monitoring sites in and around Barcelona (NE Spain): urban background (Barcelona), regional background (Montseny) and continental background (Montsec).

Using a statistical method to quantify the African dust contributions to daily PM_{10}, $PM_{2.5}$ and PM_1 levels (Escudero et al 2007, subsequently modified in EC 2011), we evaluate the 2001-2016 time series of PM_{10} and $PM_{2.5}$ concentrations of 25 remote air quality monitoring sites covering the whole Spanish territory to determine the mass contributions to daily and annual ambient PM_x. Furthermore, we analyse also the 2009-2016 PM_{10}, $PM_{2.5}$ and PM_1 levels and chemical speciation time series from the 3 monitoring sites from NE Spain to evaluate the influence on the PM_x composition and the impact of dust outbreaks on both mineral and non-dust-related PM components. Finally we review prior results and discuss the direct and indirect heath impact of African dust episodes.

The annual mean African dust contribution to ambient PM_{10} levels ranged from 1 to 8 $\mu g/m^3$ (from the NW region to the Canary Islands). Levels of $PM_{2.5}$ and PM_1 were also highly affected due to fine dust particles but also, as already described by Pandolfi et al (2014), by the increase of the anthropogenic PM load. The latter is attributed to i) the decrease of the height of the planetary boundary layer; ii) interaction of dust with gaseous pollutants favouring secondary PM formation; iii) co-transport of anthropogenic pollution with dust in air masses travelling over N Africa and crossing the Mediterranean. The results from the chemical speciation support that levels of Se, As, SO_4^{2-} and other anthropogenic components might reach the maxima during dust episodes when compared with the other atmospheric transport scenarios and atmospheric stagnation episodes affecting Barcelona.
Results indicate that, in addition to the marked increase of mineral dust, dust outbreaks favour the accumulation of locally emitted anthropogenic elements/species. Accordingly, it is not only mineral dust that matters for air quality during African dust episodes. Thus, when analysing health effects of PM during

dust outbreaks it is convenient to evaluate the effects for the coarse and fine fractions and also for the mineral and anthropogenic loads of PMx.

Keywords: African dust PM contributions, health impact, secondary PM formation, boundary layer height, anthropogenic pollution transport

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PM2.5 characteristics in and around Jeddah city, Saudi Arabia

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The Arabian Peninsula is one part of the dust belt around the globe, the other two parts being the Gobi and the Sharan deserts. The massive dust storms originating from the empty-quarter desert are important source of dust and particulate matter of various sizes. Along with natural PM anthropogenic activities are on the rise in the region prompting concerns over air pollution. Jeddah is the second largest city in Saudi Arabia with a population of around 4 million. It hosts various industries and is a major gate to the country with a very busy airport and the largest sea port in the region.
Until recently pollution data on the city was scarce. In recent years people took interest in observing air pollution in its various forms. Air pollution, especially particulate matter is of great concern due to sever health hazards it presents. We have conducted an extensive PM2.5 sampling campaign at three locations in and around the city. During the twelve months period starting June 2014 through May 2015 samples were collected every other day bringing the number of samples collected at each location to about 180 samples and a grand total of about 545 samples. Sampling was conducted using three low volume partisol-plus sequential air samplers deployed at the three locations. Samples were analyzed for PM2.5 mass concentrations, elements, water soluble inorganic ions, black carbon, and UV absorbing organic matter.
A summary of the analytical data observed from all measurements will be presented Spatial and temporal variations of concentrations will be shown. Differences in concentrations between suburban and urban areas will be discussed. Comparison with data in other countries and possible sources of pollutants will be discussed.

Keywords: PM2.5, air pollution, Jeddah city, black carbon.

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The Association between Dust Storms and Daily Non-Accidental Mortality in the United States, 1993–2005

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Background: The impact of dust storms on human health has been studied in the context of Asian, Saharan, Arabian, and Australian storms, but there has been no recent population-level epidemiological research on the dust storms in North America. The relevance of dust storms to public health is likely to increase as extreme weather events are predicted to become more frequent with anticipated changes in climate through the 21st century.
Objectives: We examined the association between dust storms and county-level non-accidental mortality in the United States from 1993 through 2005.
Methods: Dust storm incidence data, including date and approximate location, are taken from the U.S. National Weather Service storm database. County-level mortality data for the years 1993–2005 were acquired from the National Center for Health Statistics. Distributed lag conditional logistic regression models under a time-stratified case-crossover design were used to study the relationship between dust storms and daily mortality counts over the whole United States and in Arizona and California specifically. End points included total non-accidental mortality and three mortality subgroups (cardiovascular, respiratory, and other non-accidental).
Results: We estimated that for the United States as a whole, total non-accidental mortality increased by 7.4% (95% CI: 1.6, 13.5; p = 0.011) and 6.7% (95% CI: 1.1, 12.6; p = 0.018) at 2- and 3-day lags, respectively, and by an average of 2.7% (95% CI: 0.4, 5.1; p = 0.023) over lags 0–5 compared with referent days. Significant associations with non-accidental mortality were estimated for California (lag 2 and 0–5 day) and Arizona (lag 3), for cardiovascular mortality in the United States (lag 2) and Arizona (lag 3), and for other non-accidental mortality in California (lags 1–3 and 0–5).

Conclusions: Dust storms are associated with increases in lagged non-accidental and cardiovascular mortality.

Keywords: Dust Storm, Mortality, Conditional Logistic.

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Modelling the short-term health effects of desert dust in epidemiogical studies

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In epidemiological studies to assess the short-term health effects of desert dust the most important distinction concerns the statistical modelling of the dust exposure metric. This has usually been considered in three different ways:

a) Dust as an exposure binary variable. Most of the studies conducted in Asia and some of the first ones carried out in Europe compared the occurrence of health outcomes (daily cause-specific mortality or hospital admissions) on days with desert dust episodes versus days without (Hashizume et al., 2010; de Longueville et al., 2013; Zhang et al., 2016). In general, these studies consistently found excess risks on days with desert dust, especially for cardiovascular mortality and respiratory morbidity. Despite intuitive in their design, these studies might suffer from two major drawbacks. First, they are prone to residual confounding due to the poor adjustment for seasonality or meteorological covariates, because dust days tend to occur on specific seasons and under peculiar atmospheric conditions, which might themselves cause excess mortality risks. Some of the published studies documented how such confounding factors were controlled for in the statistical models, but others failed to do so. Second, and most importantly, these studies cannot provide any information on the dose-response relationship between desert dust exposure and human health, as all dust intrusions are treated in the same way, with no attempt to quantify the dust load at the ground level and the consequent population exposure.

b) Dust as an effect modifier of the health effects of particulate matter (PM). Near all the studies belonging to this group have been conducted in Southern Europe (Karanasiou et al., 2012; de Longueville et al., 2013; Zhang et al., 2016). These considered total daily PM concentrations as the main exposure variable and evaluated whether the PM-health relationship differed between dust and no-dust days, i.e. considered the dust indicator variable as an effect modifier of the PM-health association. The hypothesis underlying this approach is that not only PM from anthropogenic sources is related to adverse health effects, but also PM originating from natural sources, especially desert dust advection from arid regions. Most of the studies found consistent evidence of similar PM-health relationships on days with and without desert dust intrusions, supporting the conclusion that PM from natural sources cannot be considered harmless. The main limitation of this approach is that total PM is a mixture of natural and anthropogenic sources, even within the dust days, therefore it is impossible to attribute the health effects to one or the other source simply by classifying days according to the presence of a dust advection episode. Some of the studies circumvented this problem by estimating separate effects for the fine and the coarse fractions of PM, providing consistent evidence of larger effects of the coarse PM on dust days, and larger effects of fine PM on non-dust days.

c) Independent effects of dust and anthropogenic sources of PM. Very few studies have applied the methodology for desert dust quantification and were able to attribute daily PM exposures at the population level separating desert and anthropogenic sources (Kashima et al., 2012; Pérez et al., 2012; Stafoggia et al., 2016). Interestingly, these studies showed that such exposures were minimally correlated to each other, and could be jointly analysed as risk factors for human health. This approach presents several advantages: first, it enables to estimate independent effects of the two sources of PM, as both exposures are modelled at the same time; second, since the two exposures are quantitative measures of PM concentrations, they are suitable to estimate concentration-response functions between PM and multiple health outcomes (such as cause-specific mortality and morbidity), easily applicable in health impact assessment studies; third, the method described in the previous section easily allows to describe the differential contribution of desert and non-desert sources on the different PM fractions, providing further evidence of the relative contributions of the different sources on the fine and coarse fractions of PM, and their effects on human health.

We will illustrate the use and interpretation of these three exposure metrics for desert dust to assess its short-term effects on daily mortality due to all natural causes (*International Classification of Diseases*, 9th or 10th Revision–ICD-9/ICD-10 codes: 1–799/A00–R99), using data from two of the cities participating in the MED-PARTICLES project (Stafoggia et al., 2016): Barcelona (Spain) and Rome (Italy), between 2005 and 2010.

The correct understanding of the way to model dust exposure in environmental epidemiology studies would help to develop appropriate measures to decrease the exposure levels to the population during dust events and also to reduce local emissions of pollutants that can be accumulated during dust episodes.

Keywords: Health effects, particulate matter, dust sources.

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Assessing desert dust contribution to regional PM10 and PM2.5 levels: a one-year study over Portugal

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Desert dust outbreaks affect air quality in many regions around the world. This study intends to estimate the importance of African dust contribution to the PM10 and PM2.5 concentrations observed in rural regional background sites in Portugal during a one-year period (2016). Desert dust contribution is evaluated by two different approaches: (i) a measurement-based approach using the monthly moving 40th percentile (P40), and (ii) a model-based approach using WRF-CHIMERE simulations. The P40 is the official method (EC, 2011) adopted by the European Commission, and by the Portuguese Environment Agency, for evaluating the occurrence of African dust outbreaks and quantifying their contributions. This method corresponds to the statistical approach of Escudero et al. (2007), based on the variability of PM concentrations at rural background sites. The WRF-CHIMERE modelling system was applied for the year in analysis, considering three nested domains with horizontal resolutions of 27x27 km^2 (over North Africa and Europe), 9x9 km^2 and 3x3 km^2 (over Portugal). Regarding model vertical resolution, 24 levels were used, which extend from the surface up to 200 hPa.

Desert dust episodes were quite frequent during 2016, affecting atmospheric aerosols in the planetary boundary layer over Portugal. Their intensity was variable, with at least two events (in February and October) contributing to exceedances of the PM10 daily limit value defined in the European Air Quality Directive (Directive 2008/50/EC). African dust contributions obtained with the P40 methodology are higher than the ones simulated by WRF-CHIMERE. Contributions to PM10 and PM2.5 concentrations range from 0 to 90 µg m^{-3} and from 0 to 30 µg m^{-3}, respectively, in most regions and days. Caution must be employed when using the P40 method to quantify dust contributions to particulate matter levels when forest fires occur simultaneously to long-range transport of desert dust, as in August 2016.

The application of these methodologies allows to determine with sufficient certainty the natural contributions from desert dust outbreaks to particulate matter levels in ambient air, and therefore to subtract those natural contributions when assessing compliance with air quality limit values, as foreseen in the Air Quality Directive.

Keywords: desert dust, particulate matter, Portugal, air quality, CHIMERE, monthly moving 40th percentile.

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Influence of African dust events of different intensity on atmospheric pollutants and mortality in Madrid, Spain

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This study aims to evaluate the impact of long-range transport of African dust (AFR) events of different intensity, on levels of particulate matter, gaseous pollutants, vertical structure of the atmosphere and daily mortality in the Madrid metropolitan area. During the period 2011-2015, a robust procedure based on the daily interpretation of air mass back trajectories and meteorological products (Escudero et al., 2007) was used to identify all the AFR days with impact in the regional-background levels of PM_{10} that occurred in the central region of Spain. This procedure, created ad hoc, allows quantifying the AFR contribution on the PM_{10} daily records. The higher the AFR contribution, the more intense the event. Hence, a database of identified events with impact in the Madrid urban area classified by its intensity was created and analyzed. Then, the variability of levels of atmospheric pollutants at urban-traffic and urban-background monitoring sites of the Madrid air quality network, was correlated with the occurrence of AFR events of variable intensity. Next, the vertical structure of the atmosphere over Madrid was characterized by means of radiosondes launched at the Madrid airport (40.47ºN, 3.56ºW, 611 m asl) and LIDAR products obtained at the multiwavelength Raman LIDAR station installed at CIEMAT site (40.45ºN, 3.73ºW, 663 m asl). Especial attention was paid to the mixing layer, defined as the lower part of the atmosphere through which air pollutants can be effectively dispersed. The mixing layer height at midday (MLH) was calculated by means of the "simple parcel method" by using the vertical profiles of pressure and temperature from radiosondes. With the aim to characterize atmospheric dispersion capability, wind speed mean values from surface to MLH and daily mean surface solar radiation levels were also computed. The basic LIDAR products are vertical profiles of intensive aerosol optical properties which are related to aerosols mass concentration. These vertical profiles allow detecting aloft dust-rich layers and the study of the temporal evolution of the mixing layer using aerosols as tracers. The correlation between the mixing layer evolution and the AFR events is also established.

Finally, the association between all-cause mortality and daily measurements of air quality parameters was investigated using a case-crossover design that compares exposure at case days (i.e. death) with exposure at days without deceases (control days). Daily mortality by all-external causes (International Classification of Disease - ICD9: 001-799, ICD10 A00-R99) was obtained from the Spanish Statistical Institute. For the period 2011–2014 a total of 104,148 deaths were considered, corresponding to an average of around 71 deaths per day. Data were analyzed using conditional Poisson regression models as in Pandolfi et al., (2014). The short term effects were examined at different lags, up to 4 days. The strongest effects were observed at lag 1 and are reported below.

The main results obtained can be summarized as follows, mean PM_{10} levels at the urban and the urban background stations site increased by 86% and 126%, respectively, during AFR days with respect to the rest of the days (non-AFR days). High, moderate and low AFR days were defined on the basis of the dust contribution to PM_{10}. Our results showed that the levels of $PM_{2.5}$, NO_2, NO and CO significantly increased with stronger AFR events at Madrid urban and urban background monitoring stations. The Kruskal-Wallis non-parametric test determined that there were statistically significant differences in all the cases between the medians for a 95% confidence level.

Regarding the mixing layer analysis, the MLH significantly decreased with increasing intensities of the AFR days. Mean reductions of 22% and 16% of MLH were observed from high to low and from high to medium AFR days, respectively. Besides, solar radiation at surface and wind speed across the mixing layer, also decreased progressively from low to medium to high AFR days. Hence, these results suggest that the presence of high amounts of dust over Madrid reduced the MLH as well as the atmospheric dispersion due to the formation of upper thermal inversions at the bottom of the warm dust layer. Thus, the increase of the levels of NO_x and CO in Madrid during high and moderate AFR days could be attributed to their progressive accumulation of emissions from local sources such as road traffic in the reduced distribution atmospheric volume (Salvador et al., 2015).

Finally, statistically significant associations of PM_{10} with all-cause daily mortality were observed for AFR and non-AFR days. However, the percentage increase in risk of mortality (%IRR) for an interquartile range increase in the PM_{10} exposure was higher for AFR (2.2%) than for non-AFR days (1.6%). Similar values of %IRR were obtained for $PM_{2.5}$ in both cases (1.2-1.3%). These results are in good agreement with a similar study carried out for the Madrid area during the period 2003-2005 (Tobías et al., 2011). Moreover, we have found evidence of stronger adverse health effects of PM_{10} during AFR days of increasing intensity. It can be concluded that ambient air in Madrid is more toxic during moderate and intense AFR days, due to the contribution of mineral dust but also to the accumulation of PM_{10} emissions from local sources. Furthermore, AFR episodes increased the concentrations of other atmospheric pollutants that may potentially affect human health and the environment. Future investigations are required to fully characterize these results, since the exacerbation of these long-range transport events predicted in some changing climate scenarios will impact on exceedances of air quality standards and human health.

Keywords: PM_{10}, African dust events, mixing layer, atmospheric dispersion, health effect.

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Linking mineral dust aerosols in Barbados and Houston to North African sources using elemental composition

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North Africa is the world's largest source of Aeolian dust, emitting an estimated 170-1,600 Tg/year of mineral material to the atmosphere, 50-70% of the total global aerosol burden. Once airborne, trade winds carry large quantities of this dust over thousands of kilometers across the Atlantic Ocean in large-scale meteorological systems to the Caribbean Basin and southern United States where it plays an important role in the biogeochemistry of soils and waters. Of particular interest to us is that long-range transported African dust occasionally increases ambient fine particulate matter ($PM_{2.5}$) concentrations in cities such as Houston Texas above air quality standards designed to protect public health and the environment.

We are developing methods to quantitatively distinguish between long-range transported aerosols from the Sahara-Sahel region versus locally-emitted $PM_{2.5}$ in industrialized areas such as Houston that have myriad local sources. Such a methodology is vitally important because it can enable the exclusion of "exceptional events" such as African dust intrusion into urban areas that impact local air quality but are beyond regulatory control. We would also like to be able to identify major North African dust source areas to develop a better understanding of source-receptor relationships and to anticipate how these might change with climate. However, the tracing of dust aerosols to specific source terrains based on composition characteristics is difficult. North African soil composition cannot be employed for this purpose because of (1) soil diversity, (2) fractionation of different mineral components during emission, and (3) mixing of dust from different locations during long-range transport.

Thus, in order to identify and quantify African dust influence on air quality especially in urban environments in the United States, it is imperative to characterize the dust transported across the North Atlantic but before it enters the United States mainland and mixes with local sources at receptor locations. Consequently, we have comprehensively characterized dusts' elemental composition in Barbados, which an ideal location for monitoring African dust transport because it lies in the main transport belt to the western Atlantic and the continental United States. Barbados is also the most easterly of the Windward Islands and as such it enables us to obtain aerosol samples that are not normally affected by western hemisphere sources.

We recently reported concentrations of 50 elements for daily bulk dust aerosol samples collected in Barbados during July to September 2013 and 2014 when the entire Caribbean basin is frequently impacted by large-scale incursions of dust-laden air masses (Bozlaker et al. 2018). Major and trace elements in $PM_{2.5}$ were quantified using inductively coupled plasma – mass spectrometry (ICP-MS) during the summer – the season of maximum dust transport. This is one of the first comprehensive measurements of Barbados dust elemental composition over a wide range of concentrations. We then us this African dust profile to accurately estimating its contributions to ambient $PM_{2.5}$ in Houston using the chemical mass balance model.

In **Figure 1**, we show three-component Ca-Al-Fe relationships in various hypothesized African source regions along with medium to long-range transported African dust to look for possible links to sources and the variations in dust compositions between source and receptors normalized so that the average upper continental crust appears at the centroid. As depicted, dust originating from Western Sahara and Morocco typically contain higher Ca, grouping near the Ca-apex, compared to the majority of measurements at Hoggar Massif, Bodélé depression, Chad Basin, Niger, and Sahel regions. This is also consistent with the well-established seasonal variability of dust activity in North Africa which is centered in the Sahara during the summer months in contrast to winter and spring where the most persistent activity is located in the lower latitudes including the Sahel (Bozlaker et al. 2018).

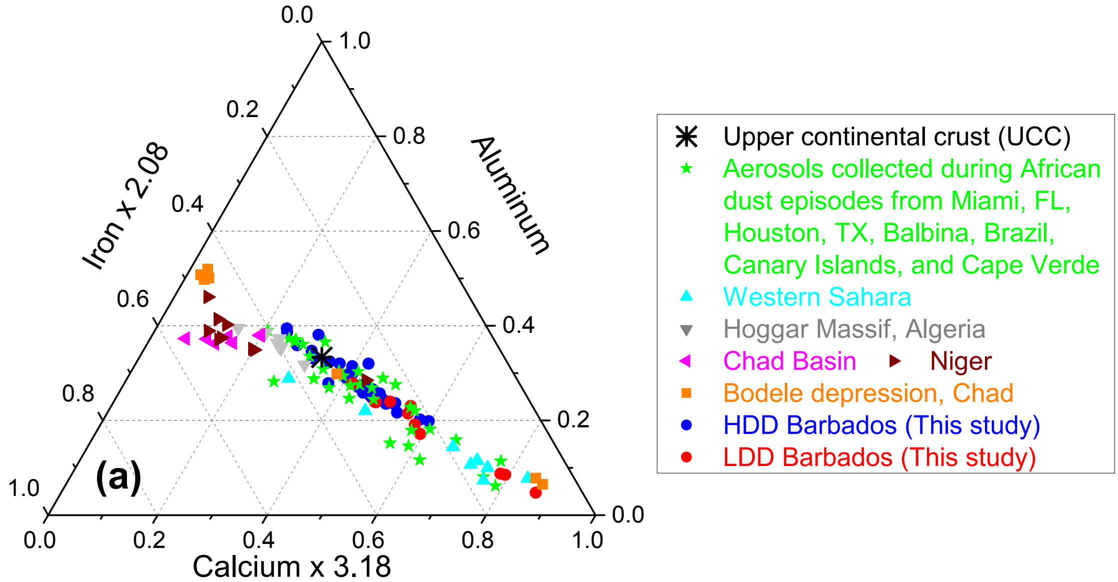

Figure 1. Ca-Al-Fe ternary diagrams showing African dust signatures in Barbados and other medium to long-range transported African dust from Miami, FL, Houston, TX, Balbina, Brazil, Canary Islands, Cape Verde along with dust from source regions in North Africa are also included.

Ca, Al, and Fe variations in Barbados, Cape Verde, Canary Islands, Miami, Houston, and Balbina aligned linearly between the Ca-apex (representing Western Sahara) and other North African source regions. This suggests that dust largely results from a mixing of soil uplifted from a combination of these source regions and that the relative contributions can change from event-to-event. Low dust days Barbados aerosols (red circles) are distinguished from high dust days samples (blue circles) by a composition that moves toward the Ca-apex symptomatic of its higher Ca/Al and Ca/Fe ratios. In any case, all Barbados samples, both during and between dust peaks, fell along a straight line connecting the Ca-apex, the UCC centroid, and other source regions signifying that all summertime Caribbean dust was dominated by a mixture of particles originating from different Sahara-Sahel regions (Bozlaker et al. 2018).

The presentation will conclude with a discussion on how we isolated, differentiated and quantified relative African dust contributions during an intense outbreak beginning on August 17 and ending on August 25, 2014 in Southeast Texas. Approximately 35% of apportioned $PM_{2.5}$ mass during the 9-day outbreak in Houston and Galveston was attributed to African dust.

Keywords: African dust, long-range transport, Barbados, Houston, elemental composition

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A through analysis of a severe dust storm in the Arabian Peninsula using WRF-Chem, satellite imagery, and ground observations: impact on air quality in the United Arab Emirates

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A strong dust event occurred in the Arabian Peninsula from the 31 March to 3 April 2015. The event affected the United Arab Emirates (UAE) on 2 April 2015. Simulation of the dust event was carried out using the Weather Research Forecasting model coupled with the Chemistry module (WRF-Chem). Outputs of the model were assessed against the Aerosol Optical Depth (AOD) from the new 1 km Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm for MODIS Terra/Aqua, ground-measurements of Particulate Matter (PM_{10}) from monitoring stations in the UAE, and meteorological data. The synoptic of the dust event was analyzed with data from the Modern Era Retrospective-Analysis for Research and Applications (MERRA) and from an upper-air radiosonde. In addition, origin of the dust event was carried out using HYSPLIT back trajectory analysis simulated on hourly basis. Modeled temperature, relative humidity and wind speed favorably agreed with ground observations of meteorological parameters at six monitoring stations in the UAE. On 2 and 3 April 2015, measurements and WRF-Chem simulations over the UAE showed northwest wind speed blowing within the range of 11-14 m s^{-1}. Average air temperature decreased from 33 to 26 ºC over all the UAE. At local level, comparisons between modeled and estimated AOD and PM_{10} concentrations from one monitoring station in the UAE showed a bias of about 7% and 25%, respectively during the peak time of the dust event on 2 April 2015.
The above dust event affected air quality conditions in the UAE resulting in high concentration of Particulate Matter (PM_{10}) above the national limit levels. Analysis of air quality data during the dust event showed that Air Quality Index (AQI) values over the UAE reached severe levels on 2 April 2015 lasting for few hours. However, due to the transitory nature of the dust event, AQIs returned to moderate-good levels starting from 3 April 2015.

Keywords: Dust event; Arabian Peninsula; WRF-Chem model; Air Quality; PM_{10} concentrations

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DUST COMPOSITION AND PROPERTIES

Coarse mode dust size distributions and optical properties from aircraft measurements during AER-D over the Tropical Eastern Atlantic

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Mineral dust is an important component of the climate system, impacting the radiation balance, cloud properties, biogeochemical cycles, regional circulation and precipitation, as well as having negative effects on aviation, solar energy generation and human health. These processes are all impacted by dust size distribution. Changes in size distribution during dust transport are poorly understood and poorly represented in climate models, particularly coarser dust particles.

Here we present in-situ airborne observations of dust in the Saharan Air Layer (SAL) during the beginning of its trans-Atlantic transport pathway, from the AER-D fieldwork in August 2015, within the peak season of North African dust export.

Size distributions spanning 0.1 to 100 µm are presented to fully characterize the coarse and giant modes of dust. Dust events were estimated to have undergone 17 hours' to 4.6 days' transport, all being initially uplifted by convective systems with associated haboobs. Within the SAL, we find particles sized over 20 µm diameter in 100% of cases, including up to 5 km altitude, and over 40 µm in 50% of cases, with a mean effective diameter of 4.0 µm and a mean volume median diameter of 6 µm. Larger particles were detected than can be explained by sedimentation theory alone. (Ryder et al., 2018, in prep.)

AER-D observations show a weaker coarse mode and lower total volume concentrations compared to observations close to dust sources, accounted for by the greater transport times in AER-D. Compilation of multi-campaign observations suggests that dust size distributions stabilize after around 1.5 days' transport. Single scattering albedos (SSAs) at 550 nm representing the AER-D full size distribution were 0.91-0.98 (mean 0.95), mean mass extinction coefficient was 0.34 m2g-1. Variability in SSA was mainly controlled by variability in dust composition (determined by a derived refractive index), rather than dust size, in contrast to observations over the Sahara.
We contrast size-resolved to optical properties from AER-D to those measured close to dust sources during Fennec, (Ryder et al., 2013), and find that only representing particles up to 10 µm omits 4% of extinction for AER-D and 38% for Fennec. For absorption, this size cut-off results in 13% and 72% of absorption being omitted for AER-D and Fennec respectively, which will lead to errors in radiative effects and atmospheric heating rates, and potentially atmospheric circulation.

This work shows that during transport in the SAL coarse dust particles are present to a lesser extent than over the Sahara, but still have a significant contribution to optical properties and are transported further than predicted by settling velocity theory, thus presenting a challenge for models to represent the coarse mode and its impacts accurately.

Keywords: SAL, aircraft, size, optical properties, transport

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Rapid changes in mineralogy and mixing state of transported Saharan dust measured by on-line single-particle mass spectrometry.

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The mineralogy of dust particles originating from the African continent influences climate and marine ecosystems in the North Atlantic due to its effect on radiation, clouds properties and biogeochemical cycling. Single-particle mineralogy is particularly important in many processes but is difficult to predict because of large temporal and spatial variability in composition and number concentration and the lack of in-situ measurements of dust properties during emission, transport and deposition (Scanza 2015). This lack of measurements is in part due to the remoteness of potential source areas (PSA) and transport pathways, but also because of the lack of an efficient method to report the mineralogy of single particles with a time resolution relevant to atmospheric processes.

In this work we present in-situ measurements of mineralogy and mixing state of transported dust at Praia, Cabo Verde during the ICE-D project, August 2015. Using a novel technique that differentiates mineralogy using on-line single-particle mass spectrometry (Marsden 2018), we express the clay matrix of the fine dust fraction (0.5-2.5µm) as an illite/kaolinite particle number ratio (IK ratio) which is reported in ambient data at a 1 hour time resolution over a 15 day period (Fig.1). In addition, the internal mixing of silicate dust particles with organic, in-organic and biological substances is described.

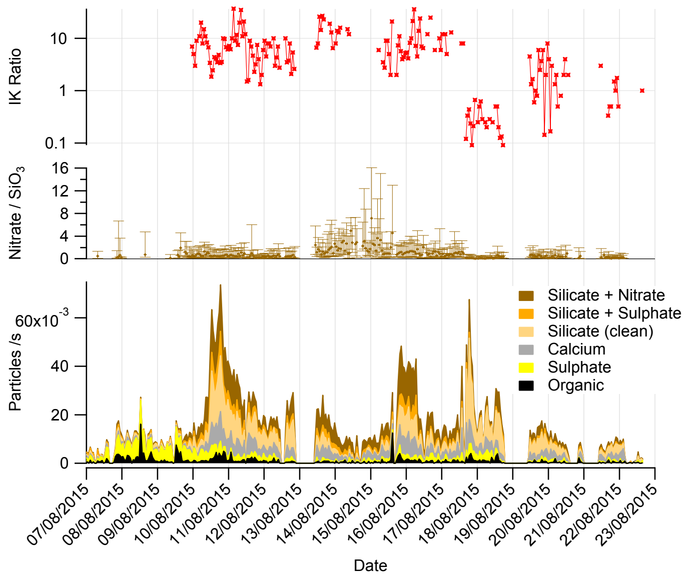

Figure 1. Time-series of silicate particle number concentrations, internal mixing with nitrate, and single-particle mineralogy (IK ratio) measured at Cabo Verde, August 2015.

The IK ratio was found to change by an order of magnitude between distinct dust events, indicating a sudden shift in source and transport pathways from the Northern Sahara to the Sahel region, which is supported by back-trajectory analysis and satellite imagery. This work shows the potential for detecting regional changes in dust sources and inferring physiochemical properties of particles from on-line measurement with high temporal resolution.

Keywords: Mineralogy, mixing-state, single-particle mass spectrometry.

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Dust concentration and composition measurement using different passive and active dust samplers in a dust transport region (Tenerife): Results from Single-particle characterization

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Abstract

Mineral dust aerosol particles affect the Earth's radiative budget through their interaction with solar and terrestrial radiation. Mineral dust aerosol particles also play an important role in biogeochemical cycles by providing important and limiting nutrients. They are the single largest component of long-range transported global atmospheric aerosol budget, contributing about one third of the total natural aerosol mass annually. Deposition measurement data of mineral dusts are useful to validate numerical simulation models and to improve our understanding of deposition processes. However, the scarcity and the limited representatively of the deposition measurement data pose a major challenge to assess dust deposition at regional and global scales (WMO, 2011). Consequently, data from observations are most important to support the modelling of deposition fluxes of mineral dust particles.

Mineral dust is dominated by particles in the supermicron range and consists to a great extent of particles larger than 10µm. Therefore, assessment of its properties can't rely on standard PM_{10} instrumentation. Frequently, deposition or other passive measurement techniques are used to sample mineral dust from the atmosphere. However, there exists a multitude of different collection instruments with different, usually not well-characterized sampling efficiencies, so the resulting data might be considerably biased with respect to their size representatively.

In this study, individual particle analysis by automated scanning electron microscopy (SEM) coupled with energy-dispersive X-ray (EDX) was used to characterize different, commonly used samplers (Big Spring Number Eight, Modified Wilson and Cooke, funnel, bucket and flat-plate geometries) with respect to their size-resolved deposition flux. Samples were therefore collected on pure carbon adhesive substrate inside the different passive samplers. In addition, computational fluid dynamics modeling was used in parallel to achieve deposition velocities from a theoretical point of view.

The samplers were operated in a mineral dust transport region (Izaña, Tenerife) in July – August 2017. During this campaign, a wide variation of aerosol concentrations and wind speeds was encountered, allowing for an accordingly wide value range of deposition flux /sampling efficiency estimates.
First results of the analysis show that there is a considerable differences in concentration measurements among different samplers (of an order of magnitude in concentration between different sampler types). Generally, the **Modified Wilson** and **Cook** (MWAC) sampler obtains considerably higher concentrations when compared to other passive samplers. In particular, it shows higher at coarser particle sizes. It is observed that the deposition mass size distribution peaks between 4 and 10µm. The maximum concentration measured is about 12.2µg/m^3. These results obviously provide evidence of positive

correlation between wind speed and efficiency of samplers for trapping particles (Mendez et al., 2016). In addition, the study showed that there is high temporal variation in dust concentration between dust event days and non dust event days.

From the chemical and mineralogical analysis point of view, unsurprisingly silicates are the dominant component of mineral dust particles. In addition to the silicates, the quartz particles contribute to the composition in significant amount. The quartz and the silicate composition increase with the particle size across the size distribution. The higher abundance of quartz towards larger particle sizes could be indicating its resistance towards mechanical breakdown when compared to other components in the composition. Iron-rich particles (like hematite) are found in small amounts particularly for particles less than 5µm. In the size distribution, the ratio of Fe to quartz shows a decrease with increasing particle size. Clearly, there is strong dependence of the chemical compostion on the particle size. Moreover, the temporal variation of the major compounds is considerable. For example, in the case of silicates, quartz, and Fe, the variation is more than an order of magnitude.

Key words: Mineral dust particles, SEM-EDX, single particle analysis, particle size distribution

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High variability of dust composition in the Saharan Air Layer

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Dust is a mixing of tens of minerals, each presenting specific physicochemical properties that influence differently on dust impacts on the Earth system. The varied composition of dust modulates its role as ice nuclei (e.g. feldspars), its ability to absorb UV radiation (hematite and goethite), neutralize acids (carbonates) or its efficiency in ecosystems fertilization (Fe- and P- bearing minerals). Even of the increased interest on dust research, many studies on the identification of sources, on emissions, continental mobilization, export and transatlantic transport of North African dust are still based on bulk dust. This is, in part, due to the lack of automatic techniques to perform long-term measurements of mineralogy and of elemental composition of dust. Based at Izaña Observatory (Tenerife), we performed 1-hour resolution measurements for studying the variability of the composition of the dust exported to the North Atlantic. We studied periods of up to ~1 week of continuous impact of the Saharan Air Layer (SAL) at Izaña. In the dusty SAL we found that the ratios of some elements (e.g. Ca, Mg or K, among others) to Al (soil tracer) varied up to a factor of 2 in a few (7 to 10) hours. The geographical location of the sources was identified by using backtrajectories based - Median Ratios At Receptor (MRAR) plots and satellite based MODIS and MSG – SEVIRI observations. Along 1-week of continuous dust presence at Izaña (50 – 200 µg/m^3), the identified sources resulted in 7 concatenated impacts, which were traced by the variability in the ratios of the different elements to Al. We studied the meteorological scenarios associated with the impact of the identified sources and found that the variability in the large-scale meteorology plays an important role in the activation of the meteorological processes (even of small scale) prompting dust emissions and export within the SAL. The impact of different dust sources along a SAL episode makes dust composition and its physicochemical characteristics change, which is a new more complex vision compared to the simplistic approach of evaluating bulk-dust The results highlight the importance of viewing dust as a cocktail of minerals, and not as a single (unique composition) particle.

Keywords: dust composition, North Africa, sources, large-scale meteorology, NAFDI.

Acknowledgements
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PollyNET: A network of continuously running multiwavelength polarization/Raman lidars for dust extinction, mass, CCN and INP profiling

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PollyNET was recently described by Baars et al. (2016) and consists of 10 continuously running smart Polly (***PO***rtaba***L***e ***L***idar s***Y***stem) lidars (Engelmann et al., 2016) operated in six European countries from Finland over Germany and Poland to Portugal, and, with focus on dust observations, from Portugal over Crete and Cyprus to Israel (Haifa). One Polly is measuring Asian dust in South Korea. A mobile containerized system participates in regular transects of the ice breaker Polarstern from northern Germany to Punta Arenas (Chile) and Cape Town (South Africa) and thus regularly measures dust outbreaks from the Sahara and the Patagonian desert almost during each spring and autumn season. PollyNET is part of EARLINET (European Aerosol Research Lidar Network) and thus part of the EU-ACTRIS-2 (Aerosols, Clouds, and Trace gases Research InfraStructure) project. Actual measurements can be found at http://polly.tropos.de/.

Presently, we build four new Polly instruments for permanent dust profiling at Mindelo (Cabo Verde), Limassol (Cyprus), Dushanbe (Tajikistan), and at Tel Aviv University (Israel, this Polly will replace the Haifa Polly). Together with the stations at the Evora University (Portugal) and Finokalia (Crete, this Polly of the National Observatory of Athens will be moved to an island close to Greece mainland), there will be a robust network of advanced lidars for Saharan dust, Middle East dust, and Central Asian dust monitoring. Furthermore, the Finnish Meteorological Institute (FMI) will run the FMI Polly for one year in the United Arab Emirates (spring 2018 to spring 2019).

The integration of multiwavelength, Raman, and polarization lidar techniques in *one* Polly instrument permits the retrieval and separation of height profiles of the basic aerosol components (mineral dust, maritime aerosol, anthropogenic particles). Furthermore, it was recently shown that even fine dust (particles with diameter < 1 µm) and coarse dust can be distinguished in terms of light extinction and mass concentration (Mamouri and Ansmann, 2017). The method also allows us to estimate height profiles of cloud condensation nucleus (CCN) and ice-nucleating particle (INP) concentrations (Mamouri and Ansmann, 2016).

The new technique was tested and applied in recent international field campaigns in the Caribbean (SALTRACE, June-July 2013/2014, Weinzierl et al., 2017), aboard the research vessel Meteor cruising across the tropical Atlantic (April/May 2013, Ansmann et al., 2017), and in the Eastern Mediterranean (Cyprus-Crete region, CyCARE, 2016-2018, and A-LIFE, April 2017, ERC starting grant project, Weinzierl, University of Vienna). During the SALTRACE and CyCARE/A-LIFE campaigns the lidar observations could be combined and compared with in situ dust/aerosol measurements aboard the DLR Falcon aircraft.

We will demonstrate the potential of the Polly instruments with focus on vertical profiling of dust extinction coefficient and mass concentration (separately for fine dust and coarse dust), and cloud-relevant CCN and INP concentrations, based on the observation taken during these recent field activities. We also want to use the opportunity to discuss how these PollyNET data products can be used for in-depth model validation, and, in the framework of a tentative future pilot study, even for assimilation into dust forecast models.

Keywords: aerosol, dust, optical properties, CCN, INP, lidar, network.

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Desert Dust Identification and Characterization by lidar

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In the last 30 years, lidar observations of atmospheric desert dust particles have given a better insight into the 4D distribution dust and its optical properties, investigating on a global scale previously hidden features: the vertical layers and associated properties. Lidar dust observations revealed a complex vertical distribution of mineral particles, with dust particles reaching altitudes up to 10 km in multi-layer structures, and with dust particles often mixed with aerosol of different types and modified during transport from the source region. In addition, lidar measurements collected worldwide highlight the high variability of dust optical and microphysical properties.
Measurements collected by aerosol Raman lidars like the ones of EARLINET, the European Aerosol Research Lidar Network, show the high variability not only in altitude range and quantities related to desert dust presence, but even in terms of their intensive optical properties.
Intensive properties, those that depend only on the type of dust, like Angstrom exponent, lidar ratio and linear particle depolarization ratio, are highly variable even for each site and for each event, in particular in the vertical profile. These quantities can be used for a reliable aerosol typing allowing in an almost automatic way the identification of altitude ranges affected by the presence of the different aerosol particles, and in particular of desert dust.
In particular, the particle linear depolarization ratio has been demonstrated as the most significant parameter for the identification of aspherical particles like desert dust in the vertical profile.

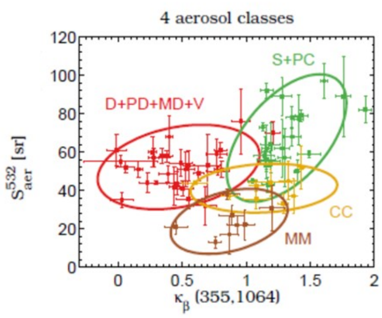

Figure 1: classification of aerosol types on the base of lidar ratio @ 532 nm measurement (S532) and backscatter related Angstrom exponent ò 355/1064 nm (kb). The EARLINET measurements collected during specific measurement campaigns are grouped in 4 aerosol classes: marine (MM = mixed marine); clean continental (CC), absorbing particles (S=Smoke and PC = polluted continental) and aspherical particles (Dust, PD = pollute dudts ; MD = mixed dust with marine mainly) and Volcanic).

CALIOP, the Cloud-Aerosol LIdar with Orthogonal Polarization, the first lidar in space for aerosol and cloud measurement at global coverage has been providing detailed description of desert dust distribution thanks to its depolarization capability.
Nowadays the availability of desert dust observation at global scale from the space and of advanced high quality measurements from the ground offers new possibilities for the advancement in many fields related to desert dust. Recently lidar profiles have been used for assessing dust model performances. On the other hand, the combination of lidar measurements with other remote sensing observations can provide a better insight of the desert dust properties.
At the conference, the main advantages and limitations of lidar measurements for desert dust identification and characterization, and new and promising advancement in this field will be presented.

Keywords: desert dust, lidar, aerosol type, intensive properties.

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The A-LIFE field experiment in the Eastern Mediterranean – Overview and early results

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In spring 2017, the A-LIFE aircraft field experiment (Absorbing aerosol layers in a changing climate: aging, lifetime and dynamics**;** www.a-life.at) was conducted in the Eastern Mediterranean. The overall aim of the ERC-funded A-LIFE project is to investigate the properties of absorbing aerosols (in particular mineral dust – black carbon mixtures) during their atmospheric lifetime to gather a new data set on key parameters of mixtures of absorbing aerosols and their distribution throughout the tropospheric column and to study potential links between the presence of absorbing particles, aerosol layer lifetime and particle removal.

For A-LIFE, the German Aerospace Center (DLR) research aircraft Falcon was equipped with an extensive in-situ aerosol payload, a wind lidar and meteorological sensors. Between 3 and 29 April 2017, the Falcon was based in Cyprus and carried out measurements of the entire atmospheric column from the ground up to 12 km in the Mediterranean. Altogether, 22 research flights (~80 flight hours) were conducted and several outbreaks of Saharan, Arabian and Middle East dust, as well as pollution, biomass burning, and dust-impacted clouds were studied. During a number of flights, coordinated observations including overflights of the ground-based sites in Cyprus (Limassol, Paphos, Agia Marina), Crete (Finokalia), and over Austria (Vienna, Sonnblick Observatory) were performed. The A-LIFE campaign was carried out in close coordination with the 18-month field observations conducted in the framework of the *Cyprus Clouds, Aerosol, and Rain Experiment* (CyCARE; October 2016 – March 2018) organized by the Leibniz Institute for Tropospheric Research (TROPOS) in Leipzig, and with the PreTECT initiative of the University of Athens.

Highlights during the A-LIFE field experiment include a sequence of six flights between 19 and 22 April 2017 which studied a Saharan dust outbreak and dust-impacted clouds between Malta, Crete and Cyprus while the dust outbreak moved eastwards across the Mediterranean. The event was also captured by the ground-based in-situ instrumentation and the lidars. Another highlight is a sequence of four flights between 26 and 29 April 2017 which investigated Arabian/Middle East dust at altitudes below 4 km and Saharan dust aloft. In most cases, a strong vertical layering of different aerosol types was observed. An unexpected observation during the measurements in the Eastern Mediterranean region was that the dust very frequently extended up to altitudes above 9-11 km. In addition, the fine mode scattering properties in Arabian dust mixtures which also contained a significant black carbon contribution did not show the typical dust signature, but rather showed a wavelength-dependency of the scattering coefficient.

In our presentation, we will give an overview of the A-LIFE study, show early results covering profiles of dust microphysical and optical properties, and discuss similarities and differences between Saharan and Arabian/Middle East dust. We will also compare the A-LIFE observations with results from other dust field experiments (SAMUM, SALTRACE) over Africa, Cape Verde and in the Caribbean

Original balloon observations of large Saharan dust particles in the free troposphere over the western Mediterranean Sea

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We have developed a balloon-borne optical particle counter/sizer named LOAC (Light Optical Aerosol Counter/sizer; Renard et al., 2016a and b). Tests and validation of LOAC measurements have been performed to qualify the instrument, including comparisons with concurrent aircraft and tethered balloon measurements, and remote sensing measurements including an AERONET sun-photometer, and both a ground-based and the space-borne CALIOP lidar systems. In the framework of the Chemistry and Aerosol Mediterranean Experiment (ChArMEx) field campaigns, boundary-layer pressurized balloons (BLBPs) drifting at a given float altitude (Doerenbecher et al., 2016) as well as sounding balloons were launched during desert dust episodes over the western Mediterranean basin, allowing us to perform original quasi-Lagrangian monitoring and vertical profiling of desert dust aerosols over the sea, with the objective of documenting the particle size distribution of desert dust particles during their long-range transport, and especially the coarse size fraction.

During ChArMEx, 10 LOAC flights were successfully performed under a BLPB, during 4 Saharan moderate dust transport events (AOD <0.4), sometimes with two balloons concurrently drifting at different ceiling altitudes. Dual scattering angle measurements by LOAC confirmed turbid layers were due to mineral dust. Most balloons were launched from Minorca Isl., Spain. The respective ceiling altitudes ranged between 2.0 and 3.3 km a.s.l. and the longest flight exceeded 700 km and lasted more than 25 h. LOAC data from BLBPs could generally be fitted by a 3-mode log-normal distribution at roughly 0.2, 4 and 30 µm in modal diameter. Unexpectedly, no significant evolution of the particle size distribution was observed during the flights. Shorter integration time during sounding balloon flights limits the sensitivity to large particles but their presence was confirmed in dust layers, and large dust particles were also occasionally observed during routine LOAC soundings at Aire-sur-l'Adour in southwestern France. The persistence of such a 'giant' 30-µm mode after several days of transport and its apparent stability, in contradiction to calculations of particle sedimentation velocity, is a challenge for atmospheric dust transport models. The LOAC measurements provided an indirect evidence of the presence of charged particles, and we speculate that electrical forces might counteract gravitational settling of the coarse particles. Details of this study can be found in Renard et al. (2018).

We finally illustrate that desert dust transport across the north tropical Atlantic or Pacific Ocean offer the opportunity to reproduce such an experiment during more intense desert dust episodes with much longer drifting balloon trajectories.

Keywords: Saharan dust, particle size distribution, Mediterranean, balloon measurements, long-range transport.

Acknowledgements

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Assessing eRSTdust performance in detecting dust on SEVIRI data by means of EARLINET measurements

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Nowadays, dust/sand storms play a significant role on many aspects of human activities. In particular, dust has a considerable impact on climate, and represents a potential hazard to human health and infrastructures. One must take into account the persistence of airborne dust that varies from hours to days, depending on intensity of phenomenon and on dynamics of transport. Therefore, it is very important to develop a monitoring system capable of assessing the temporal and spatial distribution of dust/sand storms. Since decades, satellite remote sensing techniques are used to detect, monitor and characterize dust clouds from space, thanks to several platforms orbiting around Earth, offering several advantages (e.g. synoptic view; continuity of observations). The $e\mathrm{RST}_{\mathrm{DUST}}$ algorithm (Marchese et al., 2017a) is an advanced multi-temporal method which exploits SEVIRI (Spinning Enhanced Visible and Infrared Imager) data to automatically identify and track dust outbreaks from space. This algorithm, by using three local variation indexes in combination (based on signals measured in the visible and thermal infrared SEVIRI channels), is capable of detecting dust under different observational conditions, and over different background surfaces (land/sea), without requiring any ancillary information.

The European Aerosol Research Lidar Network (EARLINET; Pappalardo et al., 2014) provides high quality profiling aerosol measurements in Europe. The network consists, nowadays, of 32 active stations and its geographical extent covers most of the European countries. The network has long experience in validating satellite products (e.g., Papagiannopoulos et al., 2016), as well as in dust monitoring (e.g., Mona et al., 2014). Here, the $e\mathrm{RST}_{\mathrm{DUST}}$ algorithm is validated using EARLINET ground-truth measurements.
During May 2008, big dust loads originating from the Saharan desert covered a large part of European continent (i.e. from south to central/north Europe). In this study, we assess the $e\mathrm{RST}_{\mathrm{DUST}}$ performance based on EARLINET observations. As an example, Figure 1 shows the $e\mathrm{RST}_{\mathrm{DUST}}$ map of May 20, 2008 at 12:00 UTC, where the two colours indicate regions characterized by a high (orange pixels) and low (yellow pixels) probability of dust presence in atmosphere. The dust plume extends from the south dispersing over the Mediterranean region, with an eastward motion affecting the Balkans Peninsula. The EARLINET stations, providing measurements for the day of interest, are grouped into red and green dots. Specifically, red dots indicate the dust presence whereas green dots refer to the opposite. The ground-based observations corroborate the $e\mathrm{RST}_{\mathrm{DUST}}$ detections. This study will exploit EARLINET's data record and other aerosol products (i.e., geometrical properties, intensive properties); in the workshop, more exhaustive results will be presented and discussed.

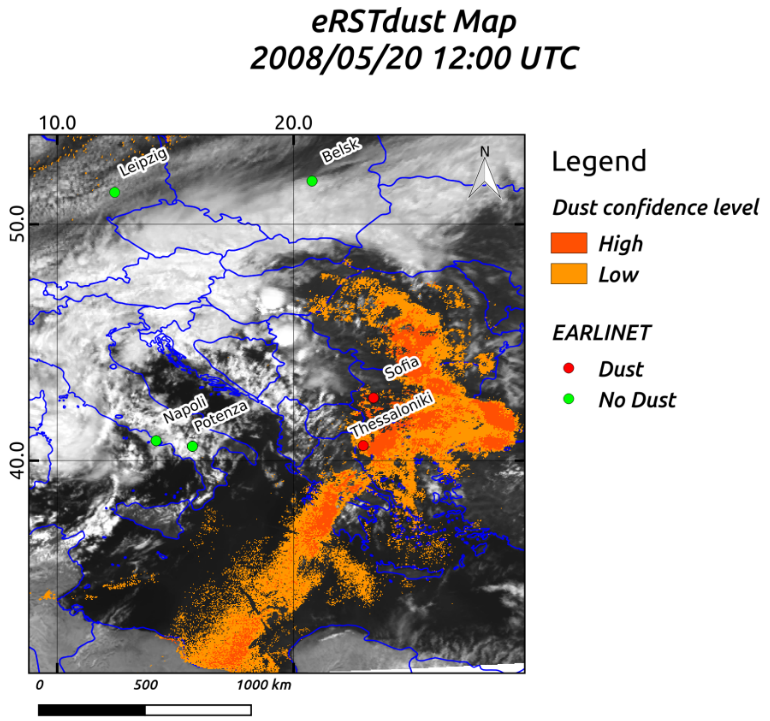

Figure 2: The eRST dust map on 20 May 2008. The map is color-coded according to the dust confidence level. Orange indicates higher probability while yellow lower. The EARLINET stations measuring during that day are also overlayed. The existence of dust over the stations is confirmed when dots are red.

Keywords: SEVIRI, RST, EARLINET, validation, remote sensing.

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Vertical particle size distributions of winter Subarctic dust storms

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Icelandic deserts are located both in the arctic and subarctic areas. Total extent of the deserted areas is about 44,000 km^2 which makes Iceland the largest Arctic as well as European desert. This represents that > 40% of Iceland is poorly vegetated and with high erosion rates, not including the 11% extent of the glaciers. These areas used to be, however, vegetated while forests covered at least 25% of the country about 800 years ago. Woodlands were reduced due to medieval agricultural methods to almost total elimination about 100 years ago. Cold climate and massive erosion caused a collapse turning vegetated ecosystem into desert. Today Iceland experiences >130 dust event days annually affecting the area of > 500,000 km^2. Dust events frequently occur in the winter and during sub-zero temperatures.

We focused on the winter dust events when snow covered majority of the country and performed six LOAC (Light Optical Aerosol Counter) flights under meteorological balloons in Iceland in 2013-2016. LOAC is an optical aerosol counter that uses a new optical design to retrieve the size concentrations in 19 size classes between 0.2 and 100 µm and to provide an estimate of the main nature of aerosols. Vertical profile of aerosol size distribution showed the presence of volcanic dust particles up to altitudes of 8 km for three flights. The MODIS satellite images confirmed a dust plume present above the southern coast from the deposits of September 2015 glacial outburst flood (jökulhlaup). These deposits had been actively suspended in November and December 2015. The ground PM10 mass concentration measurements in Reykjavik showed elevated PM measurements over 100 µgm^{-3}, confirming the particle presence 250 km far from the source.

The number concentration exceeded 200 particles cm^{-3} at altitude of 1 km and 60 particles cm^{-3} at altitude of 5 km, which is at least 5 times higher than during background conditions. The particles were < 3 µm in size at >1 km altitude while largest particles, up to 20 µm, were detected close to the ground. Such high number concentrations in several km height were captured by LOAC only during Saharan dust plume with larger particles (around 5 µm). The aircraft measurements of winter dust storm in 2007 detected only 30-50 particles per cm3 in altitude 1900 m. Our results show that fine volcanic glacially reworked dust can reach high altitudes relatively close to the dust source and reside in terms of days under the stratospheric polar vortex conditions. The remaining question is the further transport of these high altitude particles outside Iceland.

Keywords: volcanic dust, Snow-Dust Storm, high latitude

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Characterization of Falling Sand and Dust at El Paso, Texas, USA: Preliminary Results

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El Paso, Texas is the largest city in the USA portion of the Chihuahuan Desert, contiguous to Ciudad Juarez, Mexico (forming a single metropolitan area) and surrounded by some of the principal dust source regions in North America (Prospero et al., 2002). Perhaps one of the dustiest cities in North America, El Paso averages approximately 15 dust and sand weather events per year, occurring primarily during the dry, windy season (November- May) and associated with cold fronts and regional gradient winds (Novlan et al., 2007). These events originate primarily from playas and alluvial deposits in the desert, especially immediately southwest (upwind) of the city (Baddock et al., 2011). Dust and sand weather in the Chihuahuan Desert (blowing dust/sand, dry haze, dust/sand storm) is associated with hazardous particulate matter concentrations (Rivera Rivera et al., 2010), causes road accidents and transportation disruptions (Li et al., 2018), has acute effects on human respiratory health (Grineski et al., 2011), and provides a mechanism for tiny organisms to disperse on the wind to new habitats (Rivas et al., 2018). In this study, we monitor and characterize dry deposition of particles falling during dust and sand events in El Paso over a four-year period (2012- 2016), including a period of extreme drought.

To collect falling aeolian sediment, we deployed marble dust collectors (MDCO) (Sow et al., 2006) on the roof of the Biological Sciences building at the University of Texas, El Paso (UTEP), 21m above ground level, located in the west-central part of the metropolitan area. These sediment traps were only emplaced when sand/dust weather without precipitation was forecasted by the USA National Weather Service El Paso office: the MDCOs were deployed hours prior to the predicted onset of the events, and removed after the events had concluded. Sediment was collected from the MDCOs following the protocols of Reheis and Kihl (1995). Samples were weighed and analysed for particle size by laser diffractometry, for mineralogy by X-ray diffraction (XRD), and for major element composition by ICP-OES. Hourly TEOM-based $PM_{2.5}$ and PM_{10} data for each event were provided from a Texas Commission on Environmental Quality (TCEQ) continuous air monitoring station (CAMS- 12) located 217m ESE of the sampling site. HYSPLIT (Stein et al., 2015) back trajectories were calculated at time of peak PM_{10} concentration for each event.

A total of 55 dust events were sampled at UTEP over the four-year period. Total annual (measured during sampled events from October through the following September) deposition varied from 99.4 $g/m^2/yr$ in 2014- 2015 to 169.4 $g/m^2/yr$ in 2012- 2013: the average annual deposition rate over the period was 119 $g/m^2/yr$. The volumetric mean grain size of the sediments ranged from 99.0 µm in 2013- 2014 to 155.7 µm in 2014- 2015. The fraction of total falling aeolian sediment as PM_{10} ranged from 6.2% in 2014- 2015 to 11.3% in 2013- 2014. The fraction of total falling aeolian sediment as $PM_{2.5}$ ranged from 2.0% in 2014- 2015 to 4.1% in 2013- 2014. The $PM_{2.5}/PM_{10}$ ratio for all events for sediment falling in the dust traps was 0.37, while the $PM_{2.5}/PM_{10}$ ratio over the periods of sampling for the TCEQ TEOM monitor's data was 0.24. The maximum hourly PM10 recorded at the TCEQ site was 1955.2 $\mu g/m^3$ and the maximum hourly PM2.5 was 288 $\mu g/m^3$, both of which occurred on February 20, 2013. XRD results showed quartz was the dominant mineral in all analyzed samples; plagioclase, calcite, alkali feldspar, gypsum, muscovite, and clay minerals were also identified in various events. Elemental analyses indicated the falling sediment overall had ≈70% silica and ≈10% alumina content, with minor amounts of calcium, potassium, iron, sodium, and magnesium, and traces of phosphorus, titanium, manganese, barium, strontium, zirconium, and other elements, changing slightly between events and years. HYSPLIT trajectory results indicated airflows primarily from the southwest, with some events originating from the north and east, and consistent with paths crossing known hotspots of wind-erodible sediments.

The reported quantities of falling dust and sand reported represent amounts less than total seasonal and annual dust/sand-weather deposition at the site, since events occurring concomitant with precipitation were not sampled, and considering that a certain amount of aeolian sediment is still transported and falls outside of strong wind events. On the other hand, the MDCO samplers were located atop a multistory building where dust concentrations and winds would be higher than at ground level. It must also be noted that since the collection site was inside an urban area, some material consisted of fugitive dust entrained from anthropogenic sources and activities rather than true advected desert dust. The reported deposition rates are amongst the highest reported in North America, though lower than those reported from cities in the global dust belt stretching across Africa, the Middle East, and Asia. The deposition rate was highest following the extreme regional drought year of 2012, indicating the effect of land cover change and sediment availability on dust emission in the Chihuahuan Desert. Although much dust and up to hazardous concentrations of PM_{10} and $PM_{2.5}$ are carried by the wind to El Paso, the mean grain size was fine to very fine sand, suggesting the events are better characterized as “sand storms” than “dust storms.” The higher $PM_{2.5}/PM_{10}$ ratios measured in dry-deposited sediments compared to air quality monitor data is likely due to differences in sampling and measurement methodologies. The mineralogy and chemistry of the falling dust and sand is consistent with the broad composition of regional soils and surface sediments, somewhat more calcareous than global desert dusts in general, and with the occasional presence of less common dust-transported minerals such as gypsum, reflecting the unique nature of some Chihuahuan Desert aeolian hotspots.

These results provide an initial assessment of the rates and physical and chemical composition of dust deposition in El Paso, providing context and comparison to similar measurements made in other dusty desert cities and ecosystems in North America and the global dust belt.

Keywords: Chihuahuan Desert, dry deposition, blowing dust, blowing sand, dustfall.

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Size-resolved and bulk chemical composition of Saharan dust over the Atlantic Ocean

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The northern Atlantic Ocean experiences regular and frequent deposition of Saharan dust. The dust contains high amounts of mineral nutrient that is required for the bioproductivity of the ocean biota. To better assess the key nutrients transported by Saharan dust, a detailed chemical composition of the mineral dust especially at the different size fractions is important. At the Cape Verde Atmospheric Observatory (CVAO) situated in the northeastern tropical Atlantic, both long term and short term field experiments have been conducted to investigate the size distribution of the chemical components of Saharan dust. Here we present observations of long term and size resolved chemical characterisation of Saharan dust performed at the CVAO over a period of 7 years from 2007 to 2013.

Dust samples were collected using PM10 high volume DIGITEL DHA-80 sampler for bulk analysis and using a 5-stage Berner impactor for size-resolved measurements. Sampling was done in a 72 h period or in a 24 h period during field campaigns lasting about 4 weeks. The filters were analyzed for inorganic ions, soluble and non-soluble trace metals as well as for the organic and elemental carbon (OC/EC) content.
Our observations show that continental and Saharan dust air masses strongly influence the particulate matter in this region for about 45% of the year with varying concentrations (10 -930 $\mu g/m^3$) and clear seasonality. Higher dust concentrations were observed during the winter months. Mineral dust was found in both fine and coarse mode with the coarse mode dominating the dust mass. In addition to the dust minerals, EC and non-sea salt sulfate often showed elevated concentrations during dust episodes. Strong seasonal trends were observed for ammonia and non-sea salt sulfate with peaks observed in the spring and summer, respectively.

Trace metal concentrations showed strong variability of over 3 orders of magnitude especially for metals such as Fe (0.06 -31 µg/m³), Ca (0.03- 21 µg/m³), Ti (0.01-2 µg/m³). During dust events most anthropogenic trace metals (Zn, Pb, Cu, Ni, V) were partitioned in the coarse mode while during non-dust events, they were often found in the fine mode. Iron solubility was found to be pH dependent with higher iron solubility observed at lower pH's of up to 5% at pH 1 and between 0.1 to 0.5 % at pH 5.4. In deionized water, soluble iron was mainly observed in the fine mode aerosol particles. Days of high iron solubility were correlated with days of low Saharan dust content and vise versa.

Keywords: Saharan dust, chemical composition, trace metals, size-distribution.

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DUST, RADIATION AND CLOUDS

Role of mineral dust in cloud formation: modelling aspects

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The ice nucleation process (IN) is generally not well represented in the atmospheric/climate models. Recent findings indicate that mineral dust is the aerosol having probably the most important role in formation of mixed-phase and cold clouds. In the presence of dust, such clouds form at warmer temperature and thus strongly influence the atmospheric thermodynamics. Many studies have identified mineral dust particles as very efficient ice nuclei, which glaciate supercooled cloud water in the process of heterogeneous ice nucleation even in regions distant from desert sources where only a small number of dust particles, a few in a litre, are sufficient to trigger the cloud glaciation process at temperatures lower than -20^{0}C (DeMott et al., 2015). Particle residues in ice crystals of high clouds sampled by aircraft measurements clearly indicate that dust particles dominate over other ice nuclei such as soot and biological particles (Cziczo et al., 2013). In the nucleation process dust chemical aging plays a minor role.

Following the interest of research, numerical weather prediction and climate modelling communities to better represent clouds in atmospheric models, and consequently improve cloud-aerosol interaction and radiative forcing, a new generation of parameterization schemes of ice nucleation induced by dust has been recently developed (Niemand et al., 2012; Tobo et al., 2013; Atkinson et al., 2013; DeMott et al., 2015). Dust models since typically driven by the atmospheric models thus become an ideal tool to introduce such parameterizations and make dust as an active tracer.

In this study, we will present results of a coupled regional real-time forecasting system composed of the atmospheric NMME model and the DREAM dust model (Nickovic et al., 2016), which for the first time predicts the concentration of dust-caused ice nuclei concentration n_N as an online model variable. n_N is the input parameter which is typically used as a constant or as a climatic value in cloud microphysics schemes in current atmospheric models. The calculation of the number of ice nuclei is based on atmospheric parameters (temperature and relative humidity) and on dust concentration. The immersion ice nucleation parameterization (DeMott et al., 2015) has been implemented for the temperature interval (-36°C; -5°C), and the deposition ice nucleation parameterization Steinke et al. (2015) for the temperature interval (-55°C; -36°C).

We have been thoroughly validated model simulations against available remote sensing observations using the CNR-IMAA Potenza lidar and cloud radar observations to explore the model capability to represent vertical features of the cloud and aerosol vertical profiles (Madonna et al., 2011). We also utilized the MSG-SEVIRI and MODIS satellite data to examine the accuracy of the simulated horizontal distribution of cold clouds. In addition, data from two field measurement campaigns (INUIT project at Jungfraujoch during January/February 2017 and the PRE-TECT campaign April 2017) has been used to extensively validate simulations of n_N.

Keywords: mineral dust, cold clouds, ice nucleation

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The effect of atmospheric weathering on` the ice nucleating ability of K-feldspar and quartz

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The formation of ice in supercooled water droplets in our atmosphere plays a central role in regulating important cloud properties such as cloud radiative properties and the generation of precipitation. While this process only becomes kinetically favourable at temperatures below -33C for cloud sized droplets (Herbert et al., 2015), certain particles, known as ice nucleating particles can catalyse the freezing process at much high temperatures (Murray et al., 2012). Globally, a component of mineral dusts, K-feldspar, has been shown to be an important source of Ice Nucleating Particles (INPs) around the world (Atkinson et al., 2013). While it is known that reactions of feldspar with acids modify its surface properties, the extent to which atmospheric processing of feldspars by common environmental acids (a process known as "weathering") affects its ice nucleating abilities is largely unknown. Similarly, quartz has also been shown to be an effective INP (Harrison et al., 2016) and may compete with K-feldspar under certain circumstances such as when mineral dust is transported over a large distance and exposed to persistent atmospheric weathering, as quartz is expected to be less affected to weathering due to its relative chemical inertness. Given that large burden of mineral dusts in our atmosphere, understanding how this weathering process affects its ice nucleating abilities is of first order importance to improving our current knowledge of how mineral dusts contribute to the total INP loading around the globe (Vergara-Temprado et al., 2017). In this study we show the effects of chemical weathering by sulphuric acid on the ice-nucleating activity of K-feldspar and Quartz. We further show the effects of different concentrations of acid and different time dependences with regards to the mixing of solution and acid. Some first results are shown below in figures 1 and 2.

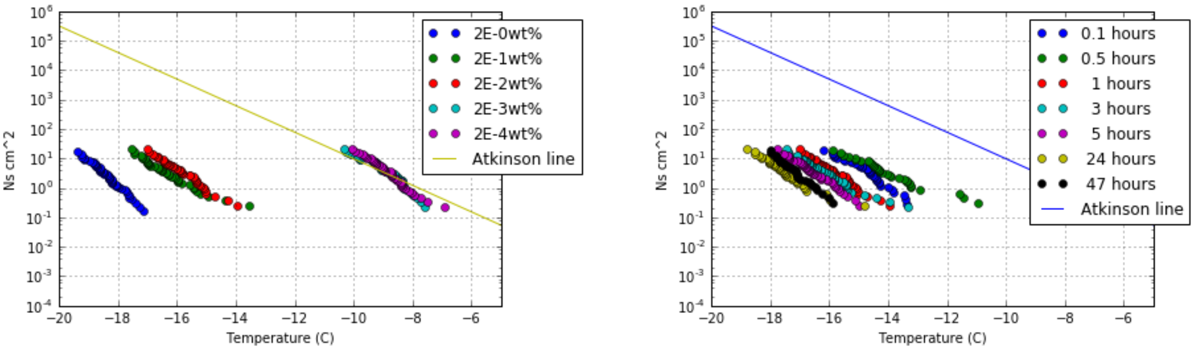

Figure 3: a) The ice-nucleating ability of K-feldspar when mixed with sulphuric acid for 1 hour at different concentrations. b) The ice-nucleating ability of K-feldspar at 2E-2wt% mixed for different lengths of time.

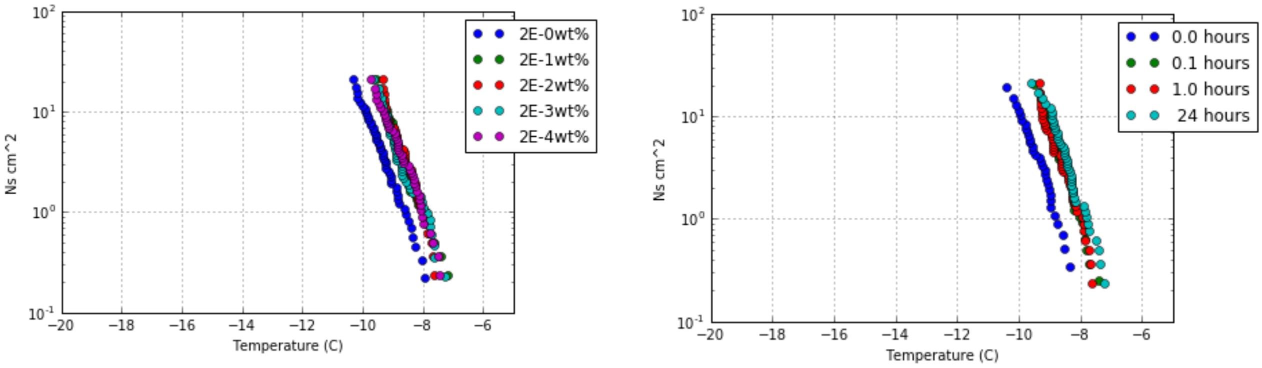

Figure 4a) The ice-nucleating ability of chalcedony when mixed with sulphuric acid for 1 hour at different concentrations. b) The ice-nucleating ability of chalcedony at 2E-2wt% mixed for different lengths of time.

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Uncertainty of ice nucleating particle number to source distribution, size distribution, and mixing state of K-feldspar

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The effect of aerosol particles on ice nucleation and, in turn, the formation of ice and mixed phase clouds is recognized as a significant source of uncertainty in climate prediction. Dust minerals are efficient ice nucleating particles (INPs), affecting the formation of mixed-phase and ice clouds. Most global modeling studies of dust acting as INPs assume uniform dust composition, whereas relatively few have taken dust mineralogy into consideration, for which INPs have been calculated based on the assumption that the mineral fractions measured in wet-sieved soil samples directly determine the mineral fractions of the emitted aerosols. An improved sectional dust module was implemented in NASA GISS Earth System ModelE, (Perlwitz et al. 2015), which distinguishes eight different mineral species and accretions between iron oxides and the other minerals, while considering soil aggregation to account for wet sieving, partial fragmentation at emission (Kok, 2011) in the saltation range of dust emission (< 20 µm particle diameter) as well as emission of large dust particles, based on empirical data (20-50 µm) (Kandler et al. 2009). The model is utilized to calculate the INP concentration from potassium(K)-feldspar for immersion freezing, using two formulations of an active size parameterization, one for external mixing and the other one for internal mixing of K-feldspar with other dust minerals (Atkinson et al., 2013). We test the sensitivity of the calculated INP concentration to the source distribution and the mass fraction size distribution (ModelE versus simpler assumption) of the emitted dust minerals, both for the external and internal mixing case of K-feldspar. The calculations are done for various fixed activation temperatures, in the range where immersion freezing of K-feldspar occurs. We find that the relatively largest contribution to the total INP number comes from the size range 2-4 µm diameter, except for the case of external mixing at the coldest activation temperature for the ModelE size distribution, where a shift of the maximum INP to a smaller size is calculated. Even though the total INP number is reduced when accounting for the various aspects that make the size distribution of emitted dust minerals physically more realistic in ModelE, a relatively larger INP number fraction relative to the total INP number is found for sizes greater than 4 µm. Different source distributions lead to larger regional differences, for instance exceeding 50% over some Southern Ocean regions. The ModelE size distribution reduces the globally averaged INP concentration by a factor of 2 to 3, and up to a factor of 5 regionally, compared to the simpler approach. The calculated INP concentrations are similar between external and internal mixing except for the coldest activation temperature. Our results suggest that differences in assumptions for dust modeling such as the source distribution and size distribution of the ice nucleating mineral fractions may strongly influence the calculated INP number. Since the uncertainty and bias due to different assumptions varies strongly regionally, it cannot be compensated by simply tuning the calculated total INP number in the parameterizations. Extending measurements of INP concentrations up to a size of at least 10 µm diameter will help to better evalute and constrain INP

activation calculated with models. Since our study is concerned with the sensitivity of calculated INP to fundamental assumptions on the properties of the simulated minerals that are efficient INP, but not with specifics of applied INP parameterizations, we hypothesize that our main results will also hold for other INP parameterizations than the one used in our study.

Keywords: dust aerosols, mineralogy, size distribution, K-feldspar, ice nucleating particles

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Global scale variability of the mineral dust shortwave and longwave refractive index from laboratory chamber experiments

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Mineral dust is one of the most abundant aerosol species in the atmosphere and strongly contributes to the global and regional direct radiative effect. Still large uncertainties persist on the magnitude and overall sign of the dust direct effect, where indeed one of the main unknowns is how much mineral dust scatters and absorbs light in the shortwave (SW) and longwave (LW) spectral ranges. Aerosol scattering and absorption are represented by the real (n) and the imaginary parts (k) of the complex refractive index (m=n-ik).

In this study we present a new dataset of SW (0.37 to 0.95 µm) and LW (2-16 µm) complex refractive indices for mineral dust aerosols obtained from in situ measurements in the 4.2 m^3 CESAM simulation chamber at LISA (Laboratoire Interuniversitaire des Systemes Atmospheriques) in Créteil, France. Investigated dust aerosol samples were issued from major desert sources worldwide, including the African Sahara and Sahel, Eastern Asia, the Middle East, Southern Africa, Australia, and the Americas, with differing mineralogies (clays, quartz, calcite, and iron oxides content). Results from the present study provide a regional mapping of the SW and LW optical properties by dust and show that the imaginary part of the refractive index largely varies for the different source areas due to the change in the particle composition. In the LW k varies between ~0.001 and 0.92 due to changes in the clays, quartz, and calcite content in dust. In the SW range k varies in the range 0.003-0.020 at 0.37 µm and 0.001-0.003 at 0.95 µm in relation to changes of the iron dust content. The results of this study indicate for dust a lower imaginary refractive index compared to past literature, which suggests that dust is less absorbing than previously thought. In the SW range, indeed, our range of variability for k is well bracketed by already published literature estimates.

For both the SW and the LW range our results suggests that regional–dependent values of the dust refractive index should be used in models. A linear relationship between the magnitude of k at 7.0, 9.2, and 11.4 µm and the mass concentration of calcite and quartz absorbing at these wavelengths, and between k and the iron content at 0.37 to 0.95 µm was found. Predictive rules could be thus established to estimate the SW and LW refractive index of dust in specific bands based on an assumed or predicted mineralogical composition. This is the first attempt to provide parameterizations of the regional–dependent dust optical properties to include in climate models.

Keywords: mineral dust, direct radiative effect, complex refractive index, mineralogy, laboratory simulation.

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DUST AND THE OCEAN

Lithogenic and Biogenic Fluxes from Sediment Trap Samples Collected at 150 m Depth in the Canary Basin

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Saharan desert dust is the major source of lithogenic input on the Canary Basin. When a Saharan dust event occurs, physicochemical changes follow during particle settling through the water column. Particles act as ballast of organic matter and it produces a measurable variety of aggregates. Studies reporting lithogenic and biogenic fluxes in the mixing layer using drifting sediment traps are scarce in spite of the environmental importance of the ocean mixed layer for biological processes. Here, we studied the biogenic and lithogenic fluxes in relation to Saharan dust events in the Canary Island waters.

Samples were collected at 150 m depth using a PPS3/3-24 S time-series sediment trap of 0.125 m^2 sampling area at 12 h frequency, discriminating between day and night samples. After recovery, samples were sieved thought Nucleopore® GF/C filters and particle quantification and textural analysis were measured using image processing with ImageJ program. This treatment allowed to quantify the whole particles size range, their shapes and to estimate the particle volume. All samples were analyzed and photographed with a Leika® MZ6 stereomicroscope, equipped with a photographic camera and non-polarized natural light at an image resolution of 5.0 megapixels.

The Saharan dust event studied here was observed from 3rd March to 13th April 2011 using the Barcelona Supercomputing Center data (https://dust.aemet.es/forecast). The event was generated in the Western Sahara and North of Mauritania. Dust flux varied between 2 and 16 mg m^{-2} d^{-1}. A marked reduction of finer particles was found at 150 m depth and the lithogenic flux was 0.83 ± 0.6 mg m^{-2} d^{-1}. The higher concentration of Saharan dust flux input at the surface was followed by the lithogenic flux at 150 m three days later. This delay allowed the assessment of their settling rate of 50 m d^{-1}. A relative increase of iron mineral particles (hematite and goethite) was detected in the mixed layer in a previous study (Jaramillo et al., 2016), suggesting a longer permanence of iron in the water column despite the large density of these mineral particles (4000-5000 kg·m^{-3}) in relation to silicates and carbonates (2600-2700 kg·m^{-3}). The main biogenic fluxes were composed of foraminifera (calcite), gastropods (aragonite), and transparent exopolymeric (gelatinous) particles. The mean foraminiferal flux was 2 mg m^{-2} d^{-1}. Similar delay of Saharan dust and biogenic fluxes were observed, but the biogenic flux was two orders of magnitude higher than the lithogenic flux. Both lithogenic and biogenic fluxes were compared with carbon gravitational flux (POC flux), finding the best correlation between lithogenic and POC fluxes. These relationships suggest that biogenic and lithogenic fluxes driven by Saharan dust flux should be taken into account for future models of the ocean carbon pump.

Keywords: lithogenic fluxes, biogenic fluxes, foraminifera, Saharan Dust, Canary Islands

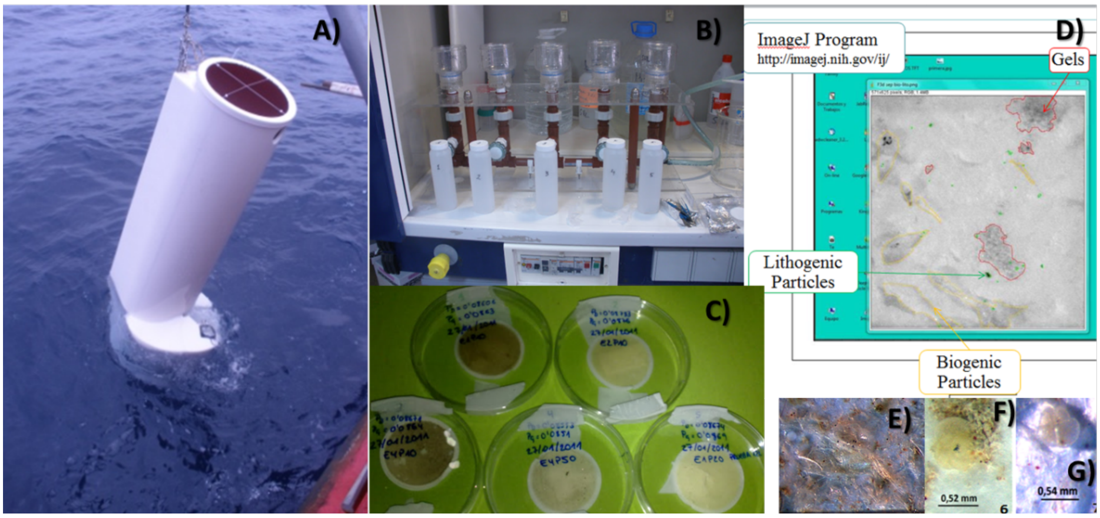

Figure 1. A) PPS3/3-24 S time-series sediment trap recovery. B) Collected bottles samples before filtering. C) Example of filters showing samples of different dust events. Observe the differences in the amount of matter among events. D) Example of the output image obtained with ImageJ Program for the identification and measurement of lithogenic and biogenic particles. E) Chitin masses. F and G) Planktonic foraminifers of the genus *Globorotalia*.

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ProcEss studies at the Air-sEa Interface after dust deposition in the MEditerranean sea (PEAcEtIME project)

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The PEACETIME project investigates the fundamental physical, chemical and biological processes and their interactions at the air-sea interface in this Mediterranean environment, and in particular the effect of a Saharan dust deposition event. The purpose of this project is to provide understanding to assess how these processes impact, and will impact, the functioning of the pelagic ecosystem and the feedback to the atmosphere, today and in the future. Indeed, the Mediterranean Sea which is considered as a hot spot for biodiversity but also for climate change and anthropogenic pressure is an ideal natural laboratory to study these processes.

In the frame of the PEACETIME project (http://peacetime-project.org/), an oceanographic cruise onboard the R/V 'Pourquoi Pas?' took place in the Western/Central Mediterranean Sea May 10–June 11, 2017. The purpose of this expedition was to study the processes induced by atmospheric deposition, in particular Saharan dust, occurring at the air-sea interface in the Mediterranean Sea, a region of the world where atmospheric input plays a key role as a nutrient source for the marine biosphere.

Combining in situ observations in the atmosphere and ocean with process studies in the water column as well as Climate Reactors incubation experiments, we characterized the chemical, biological and physical properties of the atmosphere, the marine surface micro-layer, and the deeper layers of the Mediterranean.

Experimental simulation of dust deposition were performed in climate reactors reproducing different water temperatures and pCO2 conditions so that scientists could assess the atmospheric impacts in both present and future climate conditions.

Moreover, the PEACETIME strategy included an “in-situ, real-time” approach: catching a real event of atmospheric deposition in Mediterranean waters, and documenting the ensemble of interactions induced on the surface ocean ecosystem. A fine-tuned team of people (on and off-board) worked together to examine quasi-real time dust transport forecasts and satellite observations, adjust the cruise track, and position the ship in an area where deposition events were forecasted. This unique coordinated effort succeeded, and the scientists were able to sample and measure the “real-time” effects of a dust deposition event on the marine surface waters.

PEACETIME yields insights into the composition/solubility of dust deposition in Mediterranean and the impact of atmospheric deposition on the cycle of chemical elements (nutrients, metals), on the biogeochemical functioning of the pelagic ecosystem and on the retroaction to the atmosphere. A first set of results concerning physical, chemical, and biological measurements before and after “in-situ” real dust deposition on both in the atmospheric boundary layer and marine surface waters, and the climate reactor experiments will be presented to highlight the major findings so far.

Keywords: dust deposition, air-sea exchange, composition, solubility, dust impact.

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Global transport of airborne microbes over the tropical and subtropical oceans.

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Airborne particles comprise not only mineral dust but also a significant fraction of microbes and biogenic particles. Surveys of microbial diversity conducted in the last decades across all kinds of marine and terrestrial ecosystems have uncovered a striking diversity of microbial life. Yet, the abundance and composition of airborne microbial assemblages have received little attention as compared to terrestrial and marine environments. The few studies available focus mostly on continental or coastal air masses, while the organisms suspended in the atmosphere over the open oceans, which cover most of the Earth's surface, remain unexplored. This study presents the first global survey of airborne microbes conducted over the Atlantic, Indian and Pacific Oceans during the Malaspina Circumnavigation Expedition. Thousands of taxonomically different microbes were found, uncovering a large diversity of airborne microbes comparable to that of terrestrial and marine environments. Our results show a large contribution of marine organisms to the total found in the global atmosphere, but also that terrestrial contributions make a large fraction of the airborne microorganisms found at remote marine locations. We estimate that atmospheric circulation may transfer microbes as fast as thousands of kilometers per day, sufficient to allow for intercontinental transport of microbes.

Keywords: airborne microbes, aerobiology, microbial abundance, microbial diversity.

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Sources and composition of water-soluble trace elements in aerosols over the South Atlantic, Arctic and Equatorial Pacific oceans

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Atmospheric deposition of trace elements and nutrients are crucial determinants of ocean biogeochemistry, providing a direct supply of essential macro- and micronutrients to surface seawaters. However, very few direct measurements exist to quantify aerosol trace element and nutrient input to remote oceanic regions. To address this we collected 42 high volume aerosol samples on recent cruises in the South Atlantic (GEOTRACES section GA08 November 2015), the Arctic (GEOTRACES section GN05 September 2016), and the Equatorial Pacific (SFB cruise M138 June 2017). We will present the results from leaching experiments conducted with these samples, which were designed to simulate the release of trace elements and nutrients into seawater following deposition into the surface ocean. Aerosol filters were leached in ultrapure water for a duration of 1 h and the leachates were analysed via ICP-MS (Element XR) for trace element determination and nutrient analyser (QuAAtro AutoAnalyser) for macronutrient analysis. Analysed trace elements included Al, Cd, Co, Cu, Fe, Pb, Mg, Mn, Ni, Th, Sn, Ti, U and Zn, and macronutrients included phosphorous, nitrate+nitrite and ammonia. These data represent some of the first observations of aerosol trace metal and nutrient inputs into these remote, under sampled, yet biogeochemically critical oceanographic systems.

Keywords: Aerosols, nutrients, trace elements, ocean productivity, GEOTRACES.

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Elemental atmospheric deposition fluxes from insoluble particles deposition samples collected in the western Mediterranean region

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In order to constrain regional models of the mineral dust atmospheric cycle and especially the dust mass budget, a network of automatic samplers (CARAGA) has been installed throughout the western Mediterranean basin to monitor the dust deposition(Laurent et al., 2015). Weekly samples of the insoluble fraction of total atmospheric deposition were collected during several years on cellulose ester filters concurrently at 5 sites including 4 on western Mediterranean islands (Frioul and Corsica, France, Mallorca, Spain, and Lampedusa, Italy), and 1 in the southern French Alps (Le Casset) (Vincent et al., 2016). An ignition and weighing protocol was applied to determine the mineral dust mass. . However, there is little data on trace metal deposition in the literature since their deposition measurement is difficult to perform. This study aimed at deriving elemental deposition fluxes in addition to the total dust flux from the CARAGA atmospheric deposition samples. The elemental chemical analysis of CARAGA filter samples was based on an acid digestion and an elemental analysis by inductively coupled plasma atomic emission spectroscopy (ICP-AES) and mass spectrometry (MS) in a clean room. The sampling and analytical protocols were tested to determine the elemental composition for mineral dust tracers (Al, Ca, K, Mg, and Ti), nutrients (P and Fe), and trace metals (Cd, Co, Cr, Cu, Mn, Ni, V and Zn) from simulated wet deposition of dust analogues and traffic soot. The relative mass loss by dissolution in wet deposition was lower than 1% for Al and Fe, and reached 13% for P due to its larger solubility in water. For trace metals, this loss represented less than 3% of the total mass concentration, except for Zn, Cu and Mn for which it could reach 10%, especially in traffic soot. Thus, tests allowed us to conclude that the CARAGA insoluble deposition samples could be used to estimate contents of nutrients and trace metalsin the limits of dissolution losses. More details can be found in Fu et al. (2017). Chemical characterization of CARAGA deposition samples corresponding to the most intense dust deposition events recorded between 2011 and 2013 has been performed and showed elemental mass ratios consistent with the ones found in the literature for Saharan dust. It means that CARAGA samples could be used to estimate elemental mass fluxes from dust deposition, except for Cd due to its too low concentrations, and Cu and Zn due to their high anthropogenic origin on the Lampedusa and Frioul islands. Thus, our data provide a first characterisation of trace metals composition in deposited dust in the Mediterranean (Fu et al., 2017). The whole CARAGA samples collected in 2013 and 2014 was also used to estimate annual mass fluxes of traces metals in Corsica, Mallorca, Lampedusa and Medenine. A statistical analysis of these data enabled us to discriminate the contribution of anthropogenic or dust origin of trace metals atmospheric fluxes at these sites.

Keywords: atmospheric deposition, Saharan dust, Mediterranean Sea, trace metals, mass fluxes. 9th Internatıonal Workshop on Sand/Duststorms and Assocıated Dustfall 22-24 May 2018 Tenerife, Spain

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Importance of direct deposition measurements and impact of aerosols in coastal waters of the NW Mediterranean

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Marine phytoplankton and bacteria need to take up dissolved substances to grow. Most surface ocean water shows limiting conditions for one or more of these elements during, at least, part of the seasonal cycle. This is especially relevant in oligotrophic areas such as the Mediterranean where such elements in seawater are naturally scarce. Aerosols contain these elements in different proportions and can alleviate the nutrient limiting conditions of the upper ocean sea water microbes. The conditions under which this alleviation happens, what are the chemical elements involved and the organisms responding to the aerosols is still far from being solved. We have measured direct bulk atmospheric deposition at two northwestern Mediterranean coastal locations with a different degree of anthropogenic influence. In Barcelona, we have collected samples for 4.5 years, while in a Blanes, 70 km north of Barcelona, samples were collected for 3 years. Deposition was collected in polyethylene bottles left exposed in 3 m high towers for one week during the warm season and two weeks during the cold season. The bottles were left with 500 ml of sterile artificial seawater to simulate chemical reactions of aerosols falling at sea. At the end of the exposure time, samples were taken for inorganic nutrients (nitrate, nitrite, ammonium, phosphate and silicate) and for total organic carbon (TOC). Nitrate and nitrite showed clear seasonal patterns although with opposite trends. Nitrate peaked in the warm season and nitrite in the cold. TOC also showed slight increases in the summer, while silicate deposition was slightly larger in spring. Other nutrients showed little or no seasonality. Deposition was close to double in Barcelona with respect to Blanes pointing to a large anthropogenic component. When data are compared with air quality measurements no tight relationships are evident. The nitrate increase in summer must be related to nitrogen gases reacting with seawater salts. For several months we have collected deposition in milliQ water in addition to deposition in seawater in order to discern the role of salts in seawater in this process, but results show no clear trends. We have also sampled the nutrient concentrations in coastal seawater in order to estimate the potential impact of nutrients derived from atmospheric deposition in the local budgets. Calculations based on direct deposition measurements show substantial differences with respect to calculations based on air quality measurements and estimates of particle settling velocities, pointing to the need for direct deposition measurements for impact studies. We will also use results from impact experiments on heterotrophic bacteria, which seem to be most susceptible to aerosol amendment, and phytoplankton to explain microorganism community dynamics in the northwestern Mediterranean coastal ocean.

Keywords: deposition, nutrients, microorganisms, seasonality, nitrate, bacteria

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DUST AT DIFFERENT SCALES

Considering subgridcale wind variability in large-scale dust models – are we there yet?

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Large-scale dust transport models cannot resolve all the atmospheric processes that are relevant for atmospheric dust distributions at the appropriate scales. Dust emissions non-linearly depend on surface wind friction velocities that can be highly variable at small spatial scales; vertical mixing of dust is influenced by boundary layer turbulence and convective transport; and removal of atmospheric dust particles is influenced by cloud processes and precipitation events that also strongly variable at different scales.
It is a well-known but still major problem that small-scale wind systems responsible for dust emissions cannot be resolved and thus may lead to erroneous dust emission patterns in large scale models (e.g. Tegen et al., 2013). A possible solution is the application of subgridscale parameterizations as for example surface wind speed corrections via probability density functions that can be either constant or depend on convection and turbulence (e.g., Cakmur et al., 2004). In recent years simulations of different wind systems responsible for dust emissions are being regarded more specifically. At subgrid-scale, models have e.g. particular problems in reproducing high wind speeds originating from wet convective processes such as density currents and haboobs. Parameterizations of such specific processes are being developed (e.g. Pantillon et al. 2016) but are difficult to validate. Direct simulation of these processes require model grid resolutions of less than few kilometres such that wet convection events do not need to be parameterized. Another emerging issue is the modeling of dust at high latitude sources, where convection plays a lesser role but a mismatch of the distribution of simulated small-scale strong katabatic winds and surface features determining the erodible surface fraction will lead to insufficiencies in modeled dust emission.
While parameterization of subgridscale atmospheric processes in dust emission models is advancing, some major problems remain. The use of multi-scale models such as the new ICON (ICOSahedric Non-hydrostatic) atmospheric model (developed jointly by the German Weather Service and the Max Planck Institute for Meteorology (Zängl et al., 2015)) that operates on global, regional and LES scales and has two-way nesting capability for multiple nests will allow to focus on dust source regions and at the same time allow computing large scale dust transport. In addition to briefly review the status of subgridscale dust emission parameterizations we will show first results of dust simulations by the ICON model coupled to the MUSCAT dust transport model.

Keywords: Mineral dust, emission, modelling, model scale.

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Short-term variations of the Saharan Air Layer atmospheric properties over the North Atlantic driven by NAFDI: Summer 2017 case analysis

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Summer 2017 was characterized by frequent and intense intrusions of the Saharan Air Layer (SAL) over the subtropical North Atlantic. Successive heat waves with high mineral dust content took place affecting the entire population of the Canary Islands. The shape of these heat waves resembled atmospheric pulses characteristic of Rossby waves. The pulsating incursions of the SAL on the subtropical North Atlantic in summer not only produce drastic changes in the content of mineral dust and in temperature affecting both the free troposphere (FT) and the Marine Boundary Layer (MBL), but also affect other atmospheric parameters. The SAL intrusions affect the water vapor content with a significant humidification of the FT, and the concentration of reactive gases such as ozone, with a drastic decrease, and the carbon monoxide, registering a slight increase as the air mass spends more time on the African continent. Rodríguez et al. (2015) showed that the interannual variations of dust transport over the subtropical North Atlantic were modulated by the North African Dipole Intensity (NAFDI), while Cuevas et al. (2017) showed that the variations induced by NAFDI in dust transport to the North Atlantic and the Mediterranean occurred on an intra-seasonal scale, and were driven by the impact of Rossby waves on the lower troposphere over North Africa. They also showed the physical connection between the variations of the NAFDI index and the longitudinal displacements of the Saharan Heat Low (SHL), and therefore indirectly with the atmospheric processes associated with the activation of dust sources over the Sahara. The objective of this work is to study the short term (day-to day) variations of Saharan Air Layer (SAL) intrusions over the Subtropical North Atlantic by analysing dust-related parameters (aerosol optical depth, PM10 and vertical aerosol backscattering), surface ozone, and carbon monoxide recorded at the Izaña Global Atmospheric Watch observatory (Tenerife, the Canary Islands, Spain), meteorological data from several weather stations at Tenerife, meteorological vertical profiles from radiosondes at Güimar station (Tenerife), the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis and Flextra/ECMWF backward-trajectories during June-September 2017 period. This information is crossed with daily NAFDI and SHL indexes time series. The results show that very fast day-to-day changes in NAFDI modulate SHL index changes and, in turn, changes of atmospheric properties within the SAL.

Keywords: Saharan Air Layer, NAFDI, SHL, Rossby waves, meteorology, aerosol optical depth, PM10, radiosonde profiles, aerosol vertical backscattering, ozone, carbon monoxide, ECMWF reanalysis.

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How can dust measurements constrain the representation of the dust cycle in Earth System Models?

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As of today there is no consistent framework using observations to constrain the dust cycle in atmospheric models either at the regional or at the global scale. As pointed out by Huneuus et al. (2011), the main processes/characteristics that need to be represented to simulate dust (emissions, size distribution, vertical distribution, wet and dry deposition and optical properties) need to be all individually assessed to have a reasonable representation of the atmospheric dust cycle.

The aim of this presentation is to present the strategy developed within the H2020 CRESCENDO (Coordinated Research in Earth Systems and Climate: Experiments, kNowledge, Dissemination and Outreach) project, to evaluate strengths and weaknesses of all seven European Earth System Models. This strategy is not restricted to ESM but can be applied to regional models. Particular emphasis is put upon the choice of the measurements to which the models will be compared and explain why they constitute a good set to illustrate model behaviour.

To develop the strategy for this inter-comparison we choose three very different regions of the world:

- The Sahara-Sahel together with the tropical and sub-tropical Atlantic since the largest portion of airborne dust is over this region,
- Asia and the downwind North Pacific regions, as Asian sources constitute an important input of natural aerosols in the northern hemisphere,
- North America since it presents a good test-case for the interactions between dust sources and vegetation.

Measurements that will be discussed in relation to this work are:

- MODIS optical depth,
- MISR aerosol optical depth,
- AERONET optical depth and coarse mode optical depth,
- CALIOP extinction,
- Total deposition measurements (compilation by Albani et al., 2014 & http://dustironclimate.lsce.ipsl.fr/),
- Dust size distribution,
- Transect of total deposition and surface concentrations over the Sahel from 2006 to present,
- Dust refractive indices inferred from both short-wave and long-wave measurements,

- Satellite-derived products of dust (only!) optical depth,
- PM10 concentrations during strong dust evens.

We will discuss the scientific basis for why any 2D or 3D field derived from the median of an ensemble of models is more representative of the observations than the one from any single model.

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CATS Lidar Observations of Dust and Applications for Data Assimilation in the NASA GEOS-5 AGCM

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From February 2015 to October 2017, the NASA Cloud-Aerosol Transport System (CATS) [Yorks et al. 2015] backscatter lidar operated on the International Space Station (ISS) as a technology demonstration for future Earth Science Missions, providing vertical measurements of cloud and aerosols properties while operating in two different science modes. Mode 1 (February – March 2015) measured total attenuated backscatter and depolarization ratio at both 532 and 1064 nm from two different fields of view and Mode 2 (March 2015 – October 2017) measured total attenuated backscatter and depolarization ratio at 1064 nm from a single field of view.
Using measurements of depolarization ratio, CATS can discriminate dust from other aerosol types, yielding high quality measurements of dust vertical profiles between +/- 51°N. Here, we present final (Version 3) CATS data products resulting from improved algorithms used to discriminate clouds from aerosols, and subsequently identify cloud and aerosol type. Using Version 3 CATS data products, we present observations of dust events from around the world and characterize predominant transport pathways using almost 3 years of CATS data.

Owing to its location on the ISS, a cornerstone technology demonstration of CATS was the capability to acquire, process, and disseminate near-real time (NRT) data within 6 hours of observation time. CATS delivery of NRT data products within 6 hours of CATS relates to several applications, including providing notification of hazardous events for air traffic control and air quality advisories, field campaign flight planning, as well as for constraining cloud and aerosol distributions in via data assimilation in aerosol transport models. Recent developments in aerosol data assimilation techniques have permitted the assimilation of aerosol optical thickness (AOT), a 2-dimensional column integrated quantity that is reflective of the simulated aerosol loading in aerosol transport models [Nowottnick et al. 2015]. While this capability has greatly improved simulated AOT forecasts, the vertical position, a key control on aerosol transport, is often not impacted when 2-D AOT is assimilated. Here, we also present efforts to assimilate CATS observations of dust events into the NASA Goddard Earth Observing System version 5 (GEOS-5) atmospheric general circulation model and assimilation system using a 1-D Variational (1-D VAR) approach, demonstrating the utility of CATS for future Earth Science Missions.

Keywords: CATS, lidar, assimilation

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Revisiting the observed correlation between weekly averaged Indian monsoon precipitation and Arabian Sea aerosol optical depth

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Dust influences the Indian summer monsoon on seasonal time scales by perturbing atmospheric radiation. On weekly time scales, aerosol optical depth retrieved by satellite over the Arabian Sea is correlated with Indian monsoon precipitation. This has been interpreted to show the effect of dust radiative heating on Indian rainfall on synoptic (few-day) time scales. However, this correlation is reproduced by Earth System Model simulations, where dust is present but its radiative effect is omitted. Analysis of daily variability suggests that the correlation results from the effect of precipitation on dust through the associated cyclonic circulation. Boundary layer winds that deliver moisture to India are responsible for dust outbreaks in source regions far upwind, including the Arabian Peninsula. This suggests that synoptic variations in monsoon precipitation over India enhance dust emission and transport to the Arabian Sea. The effect of dust radiative heating upon synoptic monsoon variations remains to be determined.

Keywords: mineral dust aerosols, synoptic scale monsoon variations, Indian summer monsoon

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Constraining soil dust emissions from natural and anthropogenic sources

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The contribution of anthropogenic sources to the global soil dust load has been under debate over more than two decades with estimates ranging from 10 – 50% (e.g. *Tegen and Fung*, 1995; *Sokolik and Toon*, 1996; *Tegen et al.*, 2004; *Mahowald et al.*, 2004). Reasons for this large uncertainty include (1) deficits in the representation of small-scale anthropogenic dust sources (cropland and pasture); (2) a lack of data available to constrain the global dust load; (3) deficits in the model representation of parameters affecting dust emissions as well as of the dust emission process itself. In light of these issues, *Ginoux et al.* (2010, 2012) utilized MODIS Deep Blue 2 satellite data to estimate the frequency of occurrence (FoO) of dust optical depth (DOD) > 0.2 globally at a high resolution (0.1° × 0.1°). The identified areas were interpreted as dust sources and were attributed to source type using a land use data set (Klein Goldewijk, 2001). For the identified source regions, dust emission rates were estimated based on a simple expression from *Ginoux et al.* (2001) and a uniform threshold wind speed below which no dust is emitted. This threshold was set to be higher for anthropogenic sources than for natural sources: a heuristic representation of elements that inhibit wind erosion in cultivated environments, including higher soil moisture and more extensive vegetation shielding the soil from wind forces. Combining the so obtained dust emission rates with the calculated FoO (used as a "preferential source" scaling factor), *Ginoux et al.* estimated that 25% of global dust emissions originate from anthropogenic sources.

Here we aim to further constrain dust emissions from natural and anthropogenic sources. For this purpose, we make use of the recent advances by *Ginoux et al.*, and combine the advantages of direct source identification and attribution with the benefits of using a state-of-the-art integrated numerical modeling system containing a fully-coupled online dust component. These benefits include: (1) a physics-based threshold friction velocity for saltation varying in time and space; (2) a satellite-based representation of aerodynamic roughness length, an important parameter for sediment flux estimates; (3) a physics-based dust emission parameterization; and (3) a 4D dust concentration field allowing for in-depth model evaluation.

A key aspect to calculate the anthropogenic fraction of dust emission is the threshold wind speed or friction velocity that must be exceeded for sediment emission. Global models have generally neglected the effect of roughness upon wind erosion because it depends on local environmental parameters that are not known globally. Environmental contrasts between natural and cultivated regions are large and a physically based representation of the threshold is needed that accounts for these differences. Our approach is to assume that the roughness is controlled predominately by variables that are related to satellite retrievals with high spatial resolution, namely, a static aerodynamic roughness length for arid regions along with a time varying contribution to roughness related to seasonal variations of vegetation.
We conduct and thoroughly evaluate global model simulations for one year using NMMB-MONARCH, the Multiscale Online Nonhydrostatic AtmospheRe CHemistry model (*Pérez et al.*, 2011; *Badia et al.*; 2017) using multiple combinations of source, emission, and drag partition parameters. Based on these simulations, we quantify the present-day relative contributions of natural and anthropogenic sources to global dust emission and deposition together with their uncertainties. We discuss the challenges of constraining the anthropogenic fraction of dust, anticipating that it heavily depends on variables that are

poorly constrained at global scale. In addition, we use the simulation to identify model deficits which we are going to address in the future.

Keywords: dust emission, anthropogenic dust sources, drag partition, global modeling, NMMB-MONARCH

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DUST FORECAST AND SERVICES SDSWAS & INDUST NETWORK

Sand and dust storms as a complex interdisciplinary problem

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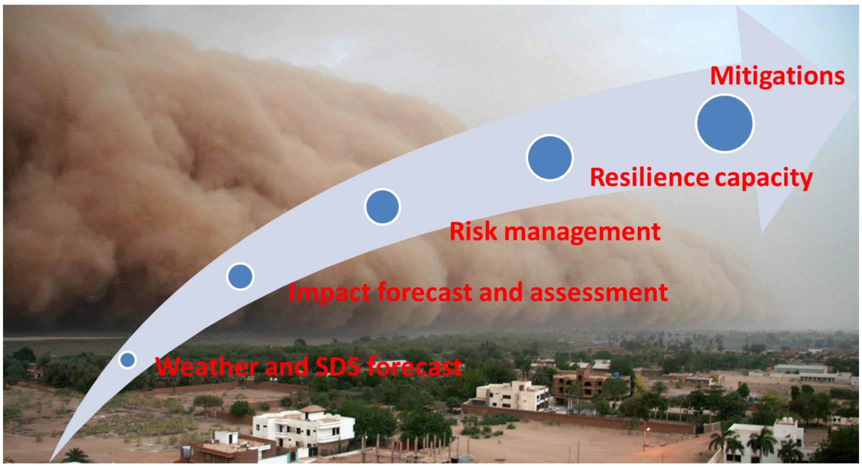
Sand and dust storms pose a major challenge to sustainable development in arid and semi-arid regions of the planet. They occur when strong or very turbulent winds blow over dry, unvegetated soils and lift loose particles from the Earth's surface to the atmosphere. The main drivers for the increase of sand and dust storms, specifically in arid and semi-arid areas, are the drastic changes in annual rainfall, temperature and droughts as the results of climate change as well as unsustainable land management and water use.
The challenge of sand and dust storms is one where science has a clear and essential role in supporting policies for sustainable development. It is very important to enhance national, regional and international cooperation and partnerships to observe, predict, mitigate and cope with the adverse effects of sand and dust storms, and seek support from UN agencies to meet the relevant Sustainable Development Goals (SDGs).

Over the last decades, the social interest in and the eagerness of the research community to enhance the understanding of the physical processes associated with the dust cycle, to predict future events and to prevent their undesired impacts has increased rapidly. The World Meteorological Organization (WMO) was one of the first United Nations (UN) Agencies, that started addressing the problem of Sand and Dust Storms (SDS), their observations, assessments and forecasting since 2004 in response to the intention of 40 WMO member countries.

In 2007, the 15th World Meteorological Congress highlighted the importance of the SDS problem and endorsed launching of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS, see: http://www.wmo.int/sdswas). More than 20 organizations currently provide daily global or regional dust forecasts in different geographic regions. The WMO SDS-WAS (WMO, 2015), which is a global federation of partners organized around regional nodes, integrates research and user communities (e.g., health, aeronautical, and agricultural users). Presently there are three Regional Nodes: the Northern Africa-Middle East-Europe Node (with its Center hosted by Spain), the Asian Node (with its Center hosted by China) and the Pan-American Node (hosted by Barbados and the USA) with their global coordination by the SDS-WAS Steering Committee. In February 2014, WMO established the Barcelona Dust Forecast Center, which operationally generates and distributes forecasts for North Africa, Middle East and Europe. In May 2017, WMO approved the second operational center for Asia, hosted by China.
Two resolutions from the United Nations General Assembly (A/RES/71/219 in 2015 and A/RES/70/195 in 2016) have recognized the importance of the SDS problem and called on United Nations entities to promote a coordinated approach to combatting sand and dust storms globally for assistance from the United Nations system.

In response to A/RES/71/219, the United Nations Environment (UNEP), the World Meteorological Organization and the United Nations Convention to Combat Desertification (UNCCD) conducted together a "Global Assessment of Sand and Dust Storms" (UNEP, WMO, UNCCD, 2016). The assessment report, which was recognized in UN General Assembly resolution A/RES/70/195, sets out proposals for consolidated and coordinated technical and policy options for responding to sand and dust storms. These recommendations include an integrated policy framework to guide further action to mitigate sand and dust storms. The priority in the short to medium-term is to reinforce protective strategies to reduce negative impacts of sand and dust storms on human health, infrastructure and operations (see the figure below). Monitoring, prediction, and early warning are critical for mobilizing emergency responses and further efforts are recommended towards extending the WMO SDS-WAS involving also other UN Agencies. In the longer term, emphasis should be on preventing new dust sources through integrated strategies that promote sustainable land and water management, including cropland, rangelands, deserts, and urban areas.



Keywords: sand and dust storm observations and forecast; early warning and assessment system; impact based predictions; vulnerability, resilience and mitigations.

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SDS-WAS: ensemble prediction of airborne dust

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The WMO SDS-WAS Regional Center for Northern Africa, Middle East and Europe has established a protocol to routinely exchange products from dust forecast NWP models as the basis for model inter-comparison and forecast evaluation. Currently, 12 modeling groups provide daily forecasts of dust surface concentration (DSC) and dust optical depth (DOD) at 550 nm for a reference area intended to cover the main dust source areas in the region. The action involves forecasts up to 72 h with a 3-hour frequency (Terradellas et al., 2016).
Currently poor-man multi-model Ensemble Prediction system (EPS) products are daily generated after bi-linearly interpolating all forecasts to a common grid mesh of 0.5 x 0.5 degrees. Centrality products (median and mean) are aimed at improving the forecasting skill of the single-model approach and spread products (standard deviation and range of variation) bound predictability indicating whether forecast fields are consistent within the models, in which case there is greater confidence in the forecast.

Evaluation scores are routinely computed using aerosol optical depth retrievals provided by the AERONET network for 45 dust-prone stations. In a pilot study, forecasts of DSC have been compared with PM10 measurements performed by the Air Quality Control and Monitoring Network of the Canary Islands (Spain) (García-Castrillo and Terradellas, 2017).
In this study, a one-month period has been selected to perform a deeper verification of the 12 members poor-man multi-model EPS in order to evaluate its consistency and reliability before tackling the design and implementation of more significant social impact probabilistic forecast products, such as DSC and DOD probabilities about relevant thresholds, EPSgrams on localities and so on. First, the ordinary deterministic verification of the different 12 models or members, as well as their median, has been carried out. Then, verification has been undertaken from a probabilistic point of view. The study has been performed using the HARMONIE monitor deterministic and the HARP (Hirlam Aladin R-based package) probabilistic verification packages. A further step is the calibration of the DSC and DOC PFDs. Preliminary probabilistic verification results show that calibration is totally necessary for DSC due to is incositent and overdispersive, whereas it is expected to improve reliability on for DOD forecasts, which are quite consistent yet. We have considered different parametric and nonparametric calibration methods and Quantile Regression Forest (QRF) (Meinshausen, 2006) appears to be the best candidate for operational implementation.

Keywords: ensemble prediction system, airborne dust, forecast verification, EPS calibration

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Dust assimilation activities at the Barcelona Supercomputing Center

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An accurate quantification of dust's spatial and temporal distribution is crucial to correctly characterize the effect that dust has on the earth's energy balance, and to improve the skill in forecasting not only its concentrations in the atmosphere and on the surface, but also the weather (Pérez et al., 2006; Chaboureau et al., 2011). High accuracy in the characterization of dust can be best achieved by optimally combining observations and model simulations, through data assimilation. Data assimilation has in fact impacted significantly the forecast and monitoring of aerosols (and dust; Benedetti et al., 2009; Niu et al., 2008; Wang and Niu, 2013), and is operational in some of the main aerosol forecasting centres (Sessions et al., 2015). The majority of the aerosol forecasts rely on the assimilation of aerosol optical depth (AOD) retrieved from observations in the visible part of the spectrum (e.g., MODIS Dark Target observations), and pertaining to all aerosol species.

We report here on data assimilation simulations specifically targeting dust aerosols, which are performed with the Multiscale Online Nonhydrostatic AtmospheRe CHemistry model (NMMB-MONARCH; Pérez et al., 2011) coupled to an ensemble-based technique known as local ensemble transform Kalman filter (LETKF; Hunt et al., 2007; Miyoshi and Yamane, 2007). Ensemble-based techniques use flow-dependent model error amplitudes and structures which evolve during forecast. They are therefore able to capture better instabilities in the background flow compared to techniques requiring precalculated, and constant in time, model error structures.

More specifically, our ensemble forecast is designed considering model uncertainties with respect to surface winds, soil humidity, and vertical flux distribution at sources. That is, we make an imperfect model scenario assumption, and run each ensemble member with a different perturbation of uncertain model parameters in the dust emission scheme (Di Tomaso et al., 2017).

We will show here results from the assimilation with such a scheme of observations particularly relevant for dust applications, like MODIS Deep Blue and IASI dust AOD, where the evaluation of the simulations, and comparisons among the different analyses, is performed through data assimilation internal diagnostics, and through the agreement with independent AERONET observations. We will discuss in particular the settings for the representation of model and observation uncertainty, which are key factors in the estimation of the dust analysis.

Keywords: dust data assimilation, dust observations, observation uncertainty, model uncertainty.

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The Impacts of Asian dust on numerical weather forecasts

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Mineral dust aerosols affect the earth weather/climate systems due to their physiochemical characteristics. Such characteristics are determined by the dust-source regions. Asian dust breaks out late winter to spring in the northern hemisphere. It is known to include the larger particle size and the less absorbing light than the dust originated from the other regions (Jeong and Sokolik, 2007). In this study, we will investigate how characteristics of mineral dust aerosols affects numerical weather forecasts during Asian dust periods.

In order to calculate aerosol optical properties used in the numerical weather forecast models, Korean Integrated Model (KIM, Hong et al., in preparation), aerosol climatology was built. Aerosol optical properties were calculated based on Mie theory,by utilizingaerosol size and compositions collected from observation data and mass mixing ratio of 9 mode aerosols of Monitoring Atmospheric Composition and Climate (MACC) reanalysis data (http://www.ecmwf.int).Aerosol climatology and aerosol radiative forcing were evaluated with surface and satellite data and the previous studies. We verified weather forecast using statistics, radiosonde, precipitation, and surface observations during Asian dust events.We also discussed the roles of Asian dust on the weather forecast in East Asia region.

Keywords: 1, Asian Dust 2, aerosol climatology 3, aerosol optical properties 4, numerical weather predictions

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iNdust: international network to encourage the use of monitoring and forecasting dust products

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Sand and Dust Storms (SDS) are extreme meteorological phenomena that generate significant amounts of airborne mineral dust particles. SDS play a significant role in different aspects of weather, climate and atmospheric chemistry while they represent a serious hazard for life, health, property, environment and economy. Understanding, managing and mitigating the risks and effects of SDS requires fundamental and cross-disciplinary knowledge.

Over the last few years, numerical prediction and observational products from ground- and satellite platforms have become prominent at several research and operational weather centres as a result of growing interest from diverse stakeholders, such as solar energy plant managers, health professionals, aviation and policy makers. Current attempts to transfer tailored products to end-users are not coordinated, and the same technological and social obstacles are tackled individually by all different groups. The usage of data is therefore slow and expensive.

The EU-funded COST Action InDust has an overall objective to establish a network involving research institutions, service providers and potential end users on airborne dust information. Airborne dust transport has multi- and trans-disciplinary effects at local, regional and global scales; InDust involves a multidisciplinary group of international experts on aerosol measurements, regional aerosol modelling, stakeholders and social scientists. Moreover, InDust searches to coordinate and harmonise the process of transferring dust observation and prediction data to users as well as to assist the diverse socio-economic sectors affected by the presence of high concentrations of airborne mineral dust.

Cooperation with institutions from near-neighbouring and international partner countries in Northern Africa and the Middle East will be essential and of mutual benefit, because dust concentrations are markedly higher while the adverse effects more severe near the sources than far downwind. Moreover, the participation of South African, American and importantly Asian partners brings the possibility of extending the application of the developed products, protocols and tools well beyond the European borders, including areas like Asian regions where dust particles play a significant role in the air quality and meteorological processes.

Keywords: services, networking, applied science, users, models, observations.

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DUST FORECAST AND SERVICES UNCDD-DESERTIFICATION

The NASA Micro Pulse Lidar Network (MPLNET): near real time lidar observations across the global dust belt

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The global dust belt is a vast region roughly considered to extend across Northern Africa to the Middle East, over Southern Asia to China. Large amounts of dust are transported seasonally outside the belt, extending the influence of this region to places such as the Caribbean and Europe, as well as open ocean over the Atlantic and Pacific. Observational data are essential for dust research, operational forecasting, and air quality monitoring. Remote sensing observations are a vital component of the overall observational strategy due to the expense and time required to provide in-situ data over such a large region. Satellite observations using both passive imagery and active lidar profiling, coupled with advances in dust modeling, have led to the ability to more accurately forecast dust plumes and their impact on the Earth system. Lidar observations remain the primary method to determine dust vertical distributions, especially relative to cloud heights and the atmospheric boundary layer. Space-based lidar missions such as CALIPSO and CATS have provided valuable data, and the upcoming launch of EarthCare will continue such data records. However, space lidars have limited lifetimes and their orbits provide snapshots of dust vertical distribution globally, not continuous profiles at a given location. Thus, they cannot provide diurnal information or examination of finer scale processes, especially those in the boundary layer where their signals are weakest. A successful lidar observation strategy should rely on ground based lidar networks as well as space-based lidar assets. Lidar networks such as EARLINET, AD-NET, and MPLNET are now fully mature projects running for nearly 20 years. Each has developed high level of standards, data quality, and long-term observational databases. All three provide observations within the dust belt. In 2008, the WMO GAW Aerosol Lidar Observation Network (GALION) was created as a network of lidar networks with the goal to provide a coordinated framework of communication, best practices, calibration and processing standards, data definition, and eventually coordinated data distribution. Working together in the GALION framework, these networks can provide bridging capability between successive space missions, in addition they have the capability to provide continuous, near real time lidar data for diurnal studies. Finally, there are many network sites with advanced lidar systems capable of providing more accurate products and microphysical retrievals not possible from space. Since its beginning in 2000, MPLNET has deployed 24 sites within the dust belt and areas heavily impacted by dust transport. There are currently 8 active long-term MPLNET sites in the dust belt and three more in planning stages. MPLNET sites provide this coverage from Miami to Taiwan, spanning all SDS-WAS regions. Here we present an MPLNET observation strategy to provide continuous, near real time, standardized lidar products that span the global dust belt. The MPLNET strategy has been designed to leverage GALION, complementing the more dense network coverage provided regionally by EARLINET and AD-NET as well as their suite of more advanced lidar systems.

Keywords: MPLNET, lidar, dust, networks.

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Saharan dust in Central Europe: Results from a combined Ceilometer/Lidar network

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Triggered by the eruptions of Eyjafjallajökull/Iceland in spring 2010, European Meteorological and Hydrological Services started to establish a European network for aerosol profiling based on lidars and ceilometers. Current ceilometers, e.g. the Vaisala CL51 and the Lufft CHM15K Nimbus, allow for the detection of aerosol layers in the atmosphere up to the tropopause region (Wiegner *et al.*, 2014). Based on experience gained during the European COST action EG-CLIMET (ES0702) another two European consortia established in 2013 and continued the work on harmonizing national ceilometer networks in Europe with respect to routine operations, data exchange and data formats (E-PROFILE, see reference below) and harmonized aerosol profile retrievals (TO-PROF, COST ES1303). Several members of EARLINET, the European Aerosol Research Lidar Network actively supported this development.
Such combined networks of ceilometers and advanced lidar systems have already shown their value for providing the four-dimensional aerosol distribution over larger areas (Pappalardo *et al*. 2014). Moreover, measured backscatter profiles from the network are routinely used to validate modeled aerosol distributions from the COPERNICUS Atmospheric Monitoring Service (CAMS).

The Deutscher Wetterdienst (DWD) contributes to the European ceilometer/lidar network with its currently 121 CHM15K Nimbus instruments (as of February 2018), which are all connected to the Internet. DWD operates furthermore a multi-wavelength Raman Lidar (Polly^{XT}) at the Hohenpeissenberg Meteorological Observatory and a UV-backscatter lidar with a depolarization channel, the latter being currently installed at Karlsruhe/Southwest Germany. Another Raman lidar instrument (RAMSES = **R**aman lidar for **a**tmospheric **m**oisture **se**n**s**ing) at DWD's meteo-rological observatory at Lindenberg near Berlin is dedicated to retrieve water vapor profiles but can also be used for retrieving aerosol parameters in case of emergency, e.g. a volcanic ash event.
Computation of the attenuated backscatter from ceilometer backscatter data requires calibration of such instruments (see e.g. Wiegner and Geiß, 2012; O'Connor *et al.,* 2004). Two calibration approaches for the CHM15K and both the Vaisala instruments CL31 and CL51, thus covering the majority of instruments in Europe, were jointly developed within TO-PROF mainly by DWD, MeteoSwiss, and the University of Reading/UK. During the development process it turned out that also firmware issues need to be analyzed and taken into account (see Kotthaus *et al*., 2016).
All DWD instruments, except for RAMSES, provide freely available quick looks of the attenuated backscatter coefficient which can be accessed (on a global scale) through the „ceilomap" web site hosted by DWD. A

selection of different instruments in Europe is already calibrated and processed within E-PROFILE by a single retrieval algorithm. The related quick looks of again the attenuated backscatter coefficient are provided through the E-PROFILE web presence (see references below).

We present case studies of Saharan dust episodes and biomass burning plumes from North-American wild fires which were tracked and analyzed in recent years. Furthermore, a frequency distribution of recent dust events over Germany (starting in August 2013) has been established, which is mainly based on the calibrated ceilometer and lidar observations.

Keywords: ceilometer and lidar networks, aerosol profiling, long-range transport, Saharan dust.

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COST ES1303 – TO-PROF: http://www.toprof.imaa.cnr.it/
DWD's ceilomap: www.dwd.de/ceilomap

E-PFOFILE:
http://eumetnet.eu/activities/observations-programme/current-activities/e-profile/
http://eumetnet.eu/activities/observations-programme/current-activities/e-profile/alc-network
New web presence under construction: http://e-profile.org

Dust Products of the Korean New-Generation Geostationary Meteorological Satellite Geo-KOMPSAT-2A

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Korea Meteorological Administration (KMA) has developed second geostationary meteorological satellite, Geo-KOMPSAT-2A (GK-2A) since 2013. It is scheduled for a launch in November 2018. GK-2A will have a new generation of geostationary imager named Advanced Meteorological Imager (AMI) like sensors equiped on Himawari-8/9 and GOES-16 satellites. GK-2A/AMI will provide huge observational data through 16 channels with high spatio-temporal resolutions to observe the Earth's weather, climate and environment.

Korean Peninsula has been affected by Asian dust events during winter season as well as spring season, therefore it is needed to monitor continuouly when to occur and then where to go. In order to implement these applications, KMA has developed algorithms which can retrieve dust products such as aerosol type, optical depth and effective radius from GK-2A/AMI data in cooperation with the Korea Electronics and Telecommunications Research Institute (ETRI) and domestic academia. We are now in the initial validation stage of the products to evaluate their performances and utilizations for satellite data users.

This presentation will give an overview of the development and preliminary results of GK-2A's dust products.

Keywords: GK-2A, AMI, dust

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DUST FORECAST AND SERVICES

Aerosol profiles from GRASP code using ceilometer and sunphotometer measurements

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The properties of aerosol particles and their vertical distribution play a crucial role in the climatic change field due to the aerosol radiative forcing. The vertical aerosol profiles, usually obtained by lidar systems, combined with sun/sky photometer measurements improve the retrieved properties of the aerosol profiles (Lopatin et al., 2013; Benavent-Oltra et al., 2017). However, lidar systems are generally expensive and require supervision, so these devices are only available in few stations. Ceilometers are a cheaper alternative to multiwavelength lidars, they were originally designed for studying cloud heights but recent ceilometer models are able to detect aerosol layers at altitudes of up to 10 km. Ceilometers only measure at one wavelength and are less accurate than classic lidars, but they are more operational than multiwavelength lidar systems and they also can work continuously and unattended. In addition, the number of available ceilometers in the world allows a better monitoring and understanding of the vertical transport of the aerosol. These issues motivate the present work, which principal objective is to retrieve vertical aerosol properties using ceilometer measurements in combination with sun/sky photometer records.

A new method is presented on this work, it consists in the use of aerosol optical depth (AOD) and sky radiances, both at 440, 675, 870 and 1020 nm, from AERONET (AErosol RObotic NETwork) sun/sky photometer in combination with ceilometer range corrected signal (RCS) profiles in the GRASP code (General Retrieval of Aerosol and Surface Properties; Dubovik et al., 2014). This new method, described in detail by Román et al (2018), has been applied to a ceilometer and sun/sky photometer located on the rooftop of the "Andalusian Institute for Earth System Research" (IISTA-CEAMA) building at Granada, Spain (37.1638º N; 3.6051º W; 680 m a.s.l.). These instruments were the CHM-15k ceilometer (*Lufft manufacturer*), which belongs to the Iberian CEilometer NETwork (ICENET; Cazorla et al., 2017) and the sun/sky CE-318 photometer which belongs to AERONET. GRASP code provides the column and vertical profiles of aerosol properties, as volume concentration (VC) and size distribution.

Two VC profiles obtained by the mentioned method have been compared with airborne in-situ measurements acquired during two flights over Granada (Spain) within the framework of ChArMEx/ADRIMED (Chemistry-Aerosol Mediterranean Experiment/Aerosol Direct Radiative Impact on the regional climate in the MEDiterranean region; Mallet et al., 2014) 2013 campaign. The retrieved aerosol VC profiles agree well with the airborne measurements, showing a mean bias error (MBE) and a mean absolute bias error (MABE) of 0.3 $\mu m^3/cm^3$ (12%) and 5.8 $\mu m^3/cm^3$ (25%), respectively. The differences between retrieved VC and airborne in-situ measurements are within the uncertainty of GRASP retrievals.

Moreover, the retrieved VC values at 2500 m a.s.l. in the Granada vertical have been compared against in-situ measurements obtained at the same altitude in a near mountain station in the during the SLOPE I campaign (Sierra Nevada Lidar AerOsol Profiling Experiment) developed in summer 2016. The correlation between the VC retrieved by GRASP and the measured in the mountain station with the in-situ measurements is high (r=0.91), but GRASP overestimates these measurements, being the MBE and MABE equal to 23% and 43%.
In general, the obtained results indicate that the combination of sun/sky photometer and ceilometer measurements in GRASP provides reliable products if the uncertainties are considered. Hence, the application of this method to networks related with this kind of measurements could provide an interesting product for the aerosol monitoring and even for assimilation to some models.

Keywords: GRASP, ceilometer, aerosol profiling, sun/sky photometer, lidar, AERONET.

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Spectral and synoptic analysis of a rare case of haboob in Tehran

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Poor land surface vegetation and soil moisture, low precipitation, high surface temperature and considerable wind speeds at low levels are suitable for the dust genesis and mobilization. On 2 Jun, 2014, a dust storm occurred in Tehran, which lasted less than 2 hours, caused severe damages to properties and involved loss of human life. It can be regarded as a case of haboob that was unprecedented in the last 50 years. This paper describes the behavior of this storm by assessing the mesoscale and micro scale patterns, as well as meteorological parameters such as temperature, humidity, pressure, dew point, wind field, and visibility in the study area leaded to the occurrence of dust. In this study, these cold and strong downdrafts along with the cold front activity during the maximum temperature over central hot desert and Tehran province, on the surface and near surface layers, have been strengthened and intensified the wind velocity and prevent a possible precipitation in the region, thereby causing a strong haboob in Tehran province. This typically occurs at high wind speed, temperature drop, rise in dew point temperature and pressure, resulting reduction of visibility. In synoptic analysis, low-pressure system stretching from the southeast of Iran to the northwest of Iran and Iraq was the dominant feature, despite the presence of a weak high-pressure in the center of Iran. At 850 hPa, the geopotential height contours crossed the isotherms strongly in the north and northwest of Iran and resulting solenoids indicated the existence of an active front in this region. At 500 hPa, a ridge of high geopotential height was stretched across the country towards the north from Saudi Arabia. At the same time, deep trough was established in the west of Iran, Turkey and Iraq. The dust storm is also analyzed, tracked and nowcast by satellite imagery. The RGB satellite images of the METEOSAT on 2 Jun, reveals the movement of cloud mass to north and central of Iran. More ever, the dust enhancement technique was applied in four steps as follow: remove bad pixels, remove cloudy pixels, use MNDVI (modified normalized difference vegetation index), reflectance and BT, and finally dust categorization considering its thickness from satellite data with the time resolution of 30 minutes that is an innovation aspect in this article. The time series, area-averaged of aerosol optical depth (AOD) of the MODIS obtained from Giovanni website, which shows a considerable amount of AOD concentration on 2 Jun. 2014. The PM10 and PM2.5 concentration related to I.R of Iran department of environment (DOE) air quality stations can be considered as a suitable measure of the concentration of natural mobilized dust particles. The increase of PM10 and PM2.5 values is in coincidence with visibility reduction as well.

Key words: Haboob, Meteorological Patterns, Satellite Images, Aerosol Optical Depth

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Atmospheric and surface properties during the record-breaking dust event of September 2015 in Middle East and East Mediterranean

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We analyze and discuss the atmospheric and surface properties that led to the development of a severe dust event on September 2015 extending over the entire Middle East and eastern Mediterranean. The record-breaking dust concentrations that were recorded during this specific episode make it a unique event lying at the borders of our remote sensing and modeling capabilities. A synergistic hindcast analysis with high resolution RAMS simulations together with passive (MSG-SEVIRI, MODIS) and active (CALIPSO/CALIOP) satellite and ground based EARLINET lidar observations reveals the main processes that defined the generation and transport of the dust clouds. The event was mainly driven by convective activity along the Syria-Iraq-Iran-Turkey borders which resulted in the generation of very intense haboob systems propagating westwards towards Cyprus and southwards towards Egypt and Saudi Arabia. Surface properties also played an important role. First, the topographic flow barriers at the island of Cyprus and the associated turbulence assisted the downward mixing of dust from the elevated layers towards the surface and increased dramatically the surface concentrations. Second, the changes in landuse and landcover due to war increased the efficiency of dust sources at these areas. Updating the surface conditions in the model based on MODIS NDVI partially explained the severity of the duststorm. In general, the major processes during this event have been identified. However, the exact amounts and transport of dust are neither accurately resolved by the model (implying the need for higher resolution simulations and/or improved model physics) nor fully retrieved by satellites due to signal attenuation by the dense dust layers. Undergoing research involves the extension of the NDVI-based landuse characterization for the greater Middle East and Arabian Peninsula in order to provide a dynamically evolving dust source map for future dust studies at these areas.

Keywords: haboob, RAMS, CALIPSO, EARLINET, NDVI

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ABSTRACTS

SOURCES AND TRANSPORT OF DUST

Assessing the response of a TEOM dichotomous FDMS and BETA monitors to aerosol dust in the Saharan Air Layer

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Desert dust is a major atmospheric aerosol that influence on climate, air quality and other environmental fields. Because of the lack of automatic techniques for performing continuous online dust measurements, PM_{10} and $PM_{2.5}$ are regularly used to assess the impact of dust events. The monitoring of PM_{10} and $PM_{2.5}$ has spread along the last two decades. These measurements are mostly performed in urban areas, where PM_x composition is often dominated by combustion derived compounds. Some studies have shown that the physical properties (volatility, hydrophilicity, or particle size, among other) of some major compounds may influence on the response of the PM_x monitors. For this reason, monitor for measuring PM_{10} and $PM_{2.5}$ have been subject to standardization within the European Union, the USA and in other parts of the Globe. In this study we assess, as part of the QA/QC protocol, the response of two automatic PM_x monitors to the presence of dust in the Saharan Air Layer. The location of the Izaña mountain observatory (~2400 m.a.s.l. in Tenerife, Canary Islands) offers the possibility to study fresh desert dust because during summer time the station is within the Saharan Air Layer – the warm, dry and dusty airstream that expands from North Africa to the Americas at subtropical and tropical latitudes. Studies dealing with the concentration and chemical composition of particulate matter have been carried out in the last thirty years, based on aerosol collection on filter, gravimetric determination and off line chemical analysis [1]. Recently, two continuous monitors, a TEOM dichotomous 1405 to measured $PM_{2.5}$ and $PM_{2.5\text{-}10}$ and a BETA 5014i to measure PM_{10}, have been incorporated to the Izaña - aerosol observation program. We assess the response of these instruments to the gravimetric standard method EN-14907.

Keywords: dust, Saharan Air Layer, gravimetric method, TEOM, BETA.

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Vertically resolved observations of African dust outbreaks by lidar and radiative forcing estimations at Madrid, Spain

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Mineral dust constitutes around 40% of aerosol mass yearly emitted into the troposphere (Andreae 1995). In particular, the Mediterranean basin is usually affected by African dust outbreaks from the Sahara desert, which is the largest dust source worldwide (Prospero, Ginoux et al. 2002, Salvador, Almeida et al. 2016). Currently, the number of studies which tackle this phenomenon has been increased for several reasons, mainly due to climate change. Mineral dust exerts an influence on atmospheric radiative budget by scattering and absorption of the incoming solar and outgoing infrared radiation, and by acting as cloud condensation nuclei (IPCC 2013). Likewise the high variability of mineral dust concentration in the atmosphere in both spatial and temporal dimensions leads to a large uncertainty in aerosol radiative forcing estimates. Furthermore, the frequency and intensity of African dust outbreaks have been suggested to be linked to climate change (World Meteorological Organization 2011).

In this work we report on 46 African dust events registered by the CIEMAT-Madrid lidar station throughout the period 2011-2014. This station is member of the EARLINET (European Aerosol Research LIdar NETwork) and consequently performs lidar measurements within its framework. The parameters of the African dust layers that have been studied through the vertical column are the plume base and top, the centre of mass and the AOD (Aerosol Optical Depth). In addition, this study has been carried out considering the intensity of the African dust outbreaks, quantified at ground level. Finally, we have estimated the aerosol radiative forcing during these events by means of the GAME model. This model uses as input the vertically-resolved extinction profiles provided by the lidar instrument and other aerosol optical properties obtained by a sun photometer (integrated in AERONET network) closely located to the CIEMAT-Madrid lidar station. The main concern is to evaluate such radiative forcing at longwave radiation because mineral dust is known to have a non-negligible effect in this radiative spectrum. Our current estimates vary from almost 0.75 to 10.51 Wm^{-2} for 7 cases where lidar and sunphotometer observations were coincident (less than 2.5h of difference). No LW radiative forcing dependency on the intensity of the events has been found, nevertheless the number of cases is not statistically significant. Further research is ongoing.

Keywords: mineral dust, lidar, radiative forcing

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Dust outbreaks during SLOPE-2 aircraft campaign

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The main objective of SLOPE-2 (Sierra Nevada Lidar AerOsol Profiling Experiment - 2) summer field campaign is the validation of atmospheric aerosol microphysical profiles retrieved from lidar using in-situ measurements. To this end, one mountain station equipped with in-situ instrumentation were set up on the north-west slope of Sierra Nevada (SNS). The station in Granada (UGR) provides in-situ but also remote sensing measurements with lidar and ceilometer.

Three research flights were carried out over the city of Granada between 21 and 24 June 2017. The aircraft was equipped with in-situ instrumentation similar to the instrumentation deployed at the stations. Two dust outbreaks were observed in the in-situ stations, one before Flight 1 and a second one between Flight 2 and Flight 3. The entrance of the second dust event was observed during Flight 2. The aircraft performed two ascending vertical spiral profiles per flight over UGR station with lower altitude level of ~1000 m asl and top altitude level up to 4750 m asl (depending on the location of the highest aerosol layer). During Flight 2, a decoupled dust layer enters and was observed between 3 and 4.5 km. In addition, ceilometer profiles from the Iberian CEilometer NETwork, ICENET, (Cazorla et al., 2017) over the city of Granada show that the aerosol layer reaches about 4000 m agl during most of the flight periods.

GRASP code (General Retrieval of Aerosol and Surface Properties; Dubovik et al., 2014) was used with aerosol optical depth (AOD) and sky radiance data from AERONET (AErosol RObotic NETwork) sun/sky photometer in combination with lidar (Benavent-Oltra et al, 2017) or ceilometer (Román et al, 2018) data. These retrievals show an overestimation of scattering profiles in most cases, but the shape of the profiles is in agreement with aircraft observations. The discrepancy on the dust plume during Flight 2 is within the error of the retrieval but, due to time difference, the dust layer appears lower with lidar/ceilometer. Absorption differences are within the error of the retrieval for two of the three flights.

Keywords: aerosol profiling, aircraft, GRASP, lidar, ceilometer.

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Investigating local contributions during a natural dust episode in Turkey

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Anatolian peninsula as an open exposure region to mostly Middle East and North African deserts, is nearly located amidst of the 'dusty belt'. By this means, natural dust advection in the region is occasionally occurs as sand and dust storms. Furthermore, this impact triggers continental dust mobility from local arid regions. In this study, natural dust storm driven continental dust mobility in April 18, 2012 was analysed for Turkey via satellite observations, dust transport model outputs and air quality measurements.
Synoptic maps dated 17 and 18 April, 2012 indicates that low pressure centre over Italy was moved through Greece and settled to the north-western of Turkey. This cyclonic movement was generated north-westerly winds and led to the transport of particulate matter from Libya and Egypt to Turkey, through Eastern Mediterranean and Cyprus. Furthermore, plotted Dark Target & Deep Blue Combined, Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua, 1º×1º data clearly depicts significant aerosol optical depth (AOD) loads (> 0.9) over Libya, Egypt, Iraq, and northern Black Sea in aforementioned days. Considering air quality measurements in Central Anatolia for 18 April, PM_{10} daily mean values reveal extremely high results as 164, 217 and 427 $\mu g/m^3$ for Burdur, Konya and Ankara respectively. Ankara, where the peak value observed province, is located in the neighbourhood of the most arid regions in Central Anatolia as Konya-Karaman Basin and Tuz Lake. In order to determine whether there was a local dust contribution from these areas, firstly a 3-day back trajectory analysis has run via The Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT). It has observed that all of the three back trajectories arrives to Ankara in different altitudes reveals the same pattern over Anatolia that moves through arid regions. Where 10 and 1500 m above ground level (magl) trajectories overpasses Algeria and Libya, 3000 magl trajectories arise from Libya and Egypt.
Two versions (V1 and V2) of BSC-DREAM8b model was run in the sequel of these preliminary analyses. For both versions two types of dust mask was implemented as including source regions up to 35º and 42º latitudes (V1_35º, V1_42º, V2_35º, and V2_42º). Modelled dust-AOD values for V2 shows better agreement with MODIS total AOD values in remote sources over North Africa. However, apart from V1_42º (0.4) the rest three types of the model are bearing resemblance in low dust-AOD values (~0.15) over Turkey. Contrary to V2, significant difference between V1_35º and V1_42º values indicate contribution of arid regions in Central Anatolia to total aerosol load. Another comparison was made between PM_{10} measurements and corresponding modelled surface dust concentration outputs for Ankara and Konya. Once again V1_42º shows better consistency with measured values but all models fail on low peaks. In consideration of all these results, it is possible to emphasize that there are significant local dust sources in Central Anatolia affecting air quality. Moreover, for better predictions including local and remote sources, high resolution topographic analyses are strongly needed.

Keywords: desert dust, continental dust, BSC-DREAM8b, PM_{10}, AOD.

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Spatial and Temporal Distribution of Storms in the Deserts of Central Asia and Kazakhstan

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Due to the vast and diverse desert types across Central Asia and Kazakhstan, dust storms vary by frequency, duration, and intensity. The spatial distribution of dust storms in Central Asia and Kazakhstan is varied during the periods 1936–1960, 1936–1980, 1980–2000, and since 2000. During the period 1936–1960, the number of dust storms in Central Asia was high (great) compared with the following decades with the average number of dust-storm events being 10–20 days/year. Based on measurements, 24% of weather stations (WS) registered dust storms of vary high frequency with >40 days of dust storms/year. Dust storms were registered with a frequency >40 days/year only at three storm sources in the Central Karakum Desert (Erbent WS), the Southern Pre-Balkhash deserts (Saryesikatyrau Desert), and the Aralkum desert (dried bottom of the Aral Sea).

The Karakum Desert is the largest source of dust storms in the area. The desert is an enlarged source of frequent outbreaks of dust storms with >30 days of dust storms/year, which appear as a "dust belt" stretched from west to east over the southern deserts, Northern Caspian sands, deserts around the Aral Sea basin, and Southern Pre-Balkhash deserts. The "dust belt" of high frequency of dust storms extended from the Northern Caspian sands in the west, with the maximum number of days at Kurguzul WS being 81/year. Furthermore, the source persisted throughout the Central Karakum Desert (Erbent WS, 56 days/year, Repetek WS, 62 days/year), and Bokhordok WS, 48 days/year). The northern part of the Aral Sea was the only significant area to generate dust storms. The number of dust-storm events at Aral Sea WS almost doubled. In previous decades it was <40 days, whereas during 1980–2000 the average number of dust events increased to 64 days/year. This active source area of frequent dust storms was associated with the desiccation of the Aral Sea, and the source area extended to the south due to the dried bottom of the sea.

Keywords: dust storms, deserts, Aral Sea, Central Asia, Kazakhstan.

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Modelling dust emission from European cropland land

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Dust emission from anthropogenically disturbed soil such as arable land is a considerable contribution to the natural aerosol burden in Europe. Modelling studies estimate the global fraction of dust emitted from these soils to up to 60%. For Europe, the amount of dust emitted from agricultural land is estimated to more than 50%. Wind erosion from agricultural lands is of importance for several reasons: The loss of fertile topsoil ultimately reduces the bio-productivity and biodiversity. Furthermore, airborne dust reduces the air quality fostering negative impacts on human well-being. Soil particles dispersed through the atmosphere may act as a transport medium for pathogens and thus contribute to its spreading.

The susceptibility of agricultural land to wind erosion is strongly controlled by vegetation, in particular crop cultivation. In between harvest and sowing, bare and possibly ploughed land is in particular prone to wind erosion.

In order to fully assess the contribution of mineral dust from human-induced dust sources such as agricultural land, we apply the meso-scale dust-atmosphere model system COSMO-MUSCAT. In a first step, the dust emission module is revised in order to represent agricultural lands as temporary dust source. The soil type data set is updated now using the European Soil Database. Results from wind tunnel experiments will be used to update prescribed soil erodibilities. As dust emission from arable land is strongly controlled by vegetation, we apply the non-linear approach developed by Okin et al. (2008) accounting for a decreasing dust emission flux for increasing vegetation cover. The actual vegetation cover is taken from the 10-daily PROBA-V satellite product FCOVER. Simulations performed using the improved COSMO-MUSCAT model are validated against measurements from two field campaigns carried out in spring and early summer 2017 in eastern Germany (Brandenburg).

Ultimately, outcomes from this study contribute to the current level of knowledge on mineral dust emitted from human-induced dust sources in a non-desert environment. The results further allow for an assessment on the role of dust emitted from an agrarian landscape for air quality and human well-being.

Keywords: human-induced dust source, agriculture, meso-scale modelling

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Wind Erosion Measurements and Spatial Variations in Different Land Use in Central Anatolia, Turkey

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Wind erosion is the most significant process responsible for land degradation in arid regions. Especially conventional agricultural system increase wind erosion risks and enlarge the size of wind erosion-susceptible lands. Many models developed for modeling water erosion at regional scale have been tested in different ecological regions and very successful estimates have been made. However, the physical and/or mathematical models developed for wind erosion measurements did not exceed estimates in the parcel scale. The main reason for this is that wind erosion mechanism is quite complex. For this reason, direct measurement methods for determining the size of wind erosion seem to be the most accurate way to estimate sediment transport at the regional scale. The present study was conducted for spatial modeling of Aeolian sediment transport over different land use (fallow, cultivated land, natural pasture and artificial pasture) between April and July with the most frequent erosive wind cases. Temporal variations in sediment transport were also determined; sediment transport rate was mapped with geo-statistical methods. Experiments were conducted over these areas of Altınova Agricultural Enterprise of the General Directorate of Agricultural Enterprises. Altınova Agricultural Enterprise is located in the Central Anatolia. Total land resource of the enterprise is about 31157 ha. Long-term annual average precipitation is 315 mm and the average temperature is 11 ^{o}C (evaporation is almost 1000 mm). The enterprise has been exposed to severe wind erosion. Since 1960, windbreaks have been established in the region. Wind-blown sediment transport and spatial-temporal variations have not been searched in detail in the region. For this reason, sediment measurements for different areas are being made since 2014. In this study, we only analyzed measurements for years 2016 and 2017. In 2016, Sediment flow rates were measured with sediment traps placed over grid system at 25 locations over the cultivated land, 16 locations over the fallow land and 25 locations over the fallow land protected by windbreaks. Measurements were thus performed at 66 locations. Climate data were supplied from the meteorological station located within the enterprise. Throughout the research period, totally 6 wind erosion cases were recorded. For each case, climate parameters such as case duration, mean wind velocity, mean wind direction, mean temperature and soil moisture content were correlated with sediment transport rate. Sediment flux rate varied between 0,033-0,283 kg m^{-1}. In 2017, sediment traps were placed over a grid system at 25 locations for both natural and artificial pastures. 3 wind erosion cases were recorded for this period. Case season and herbage cover mostly affected dust transport over the pastures.
Keywords: Wind Erosion, Sediment Trap, Windbreak, Dust Transport, Erosion.

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Observation and Characterization of Transported Saharan Dust and Biomass Burning Aerosols over the United Kingdom during ex-hurricane Ophelia

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On 15th and 16th October 2017 large amounts of Saharan dust were transported to the UK. At the same time, wildfires in Portugal produced biomass burning aerosols which were also transported towards the UK. The South-westerly flow that transported both aerosols was associated with the passage of ex-hurricane Ophelia along the west coast of Ireland This event attracted the attention of the UK national press for the orange/yellow skies and red sun that it caused, and also because a number of flights were grounded due to pilots and passengers reporting a smell of smoke [BBC, 2017; Hecimovic, 2017].

In this presentation we will use observations made using the Met Office Raman lidar and sunphotometer network [Marenco et al. (2016), Adam et al. (2017)], with additional data from UK AERONET and SKYNET sun-photometers, to characterise the aerosol plumes over the UK during this unusual event. Night-time and daytime Raman lidar observations will be used to classify the aerosols as dust and biomass burning [Gross et al (2015)], and show that the combined dust / biomass burning aerosol optical depth exceeded 1.5 at 355nm (lidar observations) and 2.8 at 500nm (sun-photometer observations). Observed aerosol optical depths will be compared with those from the Met Office and ECMWF-CAMS operational forecasts for dust, and an additional offline forecast for biomass burning aerosol. Back trajectories from the Met Office Numerical Atmospheric-dispersion Modelling Environment (NAME) will also be used to identify the source of the aerosols and estimate transport times.

The exceptionality of this event for the United Kingdom can be understood by noting that the mean aerosol optical depth for the period 2005-2017 from the longest running UK AERONET site (Chilbolton) is 0.16 (std. 0.13) (version 3, level 1.5), and the recorded AOD exceeded 1.5 on only two occasions.

We will present the UK Raman lidar / sun-photometer network for volcanic ash detection, illustrate the unusually swift transport of dusty air from the West African coast and Southwest Europe to the UK, report the detailed observations of the optical properties of the dust and biomass burning aerosols, and estimate their radiative forcing.

Keywords: Raman lidar, Sun-photometer, Optical properties, dust, smoke, long-range transport

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Relationship between dust emission amount and soil moisture content

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Dust emission amount depends on many surface land and meteorological parameters. The amounts greatly vary depending dust models. Many studies have been made to estimate the amount of dust emission using a top-down approach (data-assimilation and inversion), but it is also important to improve the prediction accuracy of the dust emission amount of the model itself. In East Asia, soil moisture content is one of the most important parameters which determine dust emission amount. We have continued to develop a global aerosol model named MASINGAR (Model of Aerosol Species IN the Global atmospheRE). The MASINGAR is a component of Meteorological Research Institute Earth System Model (MRI-ESM) and used for dust prediction (Japan Meteorological Agency; http://www.jma.go.jp/en/kosafcst/index.html), aerosol reanalysis (JRAero; Meteorological Research Institute (MRI); http://www.mri-jma.go.jp/Dep/ap/ap_1_en.html) and climate research (CMIP; MRI). The MASINGAR is coupled with a general circulation model and a land surface model (HAL) via a coupler and can make use of several land parameters of the models. It was hard to validate model grid size soil moisture content (volumetric soil water content) for a long time due to the difficulty of observation. These days, we can obtain soil moisture observation data from satellites. In this study, we compare soil moisture content from the MASINGAR (MRI-ESM) against satellite data (GCOM-W) between 2013 and 2015. The results show that the soil moisture content of the MASINGAR at Gobi Desert is relatively smaller than that of satellite data almost through the year. The underestimation trend is consistent with an excessive trend of dust concentration by the model at East Asia. It is suggested that incorporating soil water observation data by satellite into the model will improve the dust emission amount of the model.

Keywords: Dust emission, Soil moisture content, satellite data, Dust model.

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The effect of vegetation coverage on sand transport and erosion characteristics in Hunshandake sandy land, China

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Abstract: Vegetation generally plays the role of inhibiting wind erosion and protecting the surface by blocking the direct action of wind on the surface soil material, dispersing near surface air volume and retaining part of the eroded material, etc. The vegetation has a significant anti wind effect. With the increase of coverage, the wind protection gradually increases, and the total amount of sand gradually decreases with the increase of coverage. Undisturbed soil wind erosion under different vegetation coverage in the Hunshandake Sandy Land was study by the wind tunnel experiment, in order to understand the wind sand flow structure within the 0~20 cm air layer and to reveal the distributed height of cumulative percentage of sand is up to 100%. The result shows that: (1) The sand flux gradually decreases with the increase of vegetation coverage, and 80% of the sand transport volume was distributed under the height of 10cm. (2) With the same wind speed, with the increase of vegetation coverage, the corresponding distribution was reduced when the cumulative sand transport amount is 100%. (3) When the wind speed were 10m/s and 13m/s, the vegetation coverage with 40% and 30% were in the accumulation stage, and the vegetation coverage with 20% and 10% were in the wind erosion state. (4) The change trend of the cumulative percentage of sand concentration with the increase of height is in accordance with the exponential function. At the same wind speed, the corresponding distribution height decreases with the increase of vegetation coverage when the cumulative percentage of sand is up to 100%. This study can provide theoretical support for rational utilization of grassland and effective recovery of sandy land. This study can provide theoretical support for rational utilization of grassland and effective recovery of sandy land.coast.

Keywords: wind tunnel test, sand flow structure, vegetation coverage, erosion characteristic, recovery of sandy land.

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Relationships between sand and dust storms in East Asia with surface conditions and climate change

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Precipitation, soil moisture, low air temperature, surface soil conditions as well as human activities are the important factors that determine the vegetation coverage and then influence Sand and Dust Storms (SDSs) events indirectly (Liu et al., 2004; Lee et al., 2011;Wang et al., 2018). Furthermore, the distribution and frequency of SDSs are strongly related to the near-surface wind which is supposed to be linked with large-scale atmospheric circulations such as polar vortex, cold air activity, surface pressure field, and so on (Qian et al., 2002; Zhao et al., 2004; Yang et al., 2007).We make a comprehensive study of the reduction of the distribution and frequency of SDSs in East Asia in recent years, by using both ground observation data and dust mode results in order to get better spatial and temporal resolution and accuracy. We carried out a detailed analysis of the distribution and frequency of SDSs in East Asia during 2007 to 2016. The relationship between the variation in climatic factors (such as temperature, air pressure, wind, polar vortex, and so on) and the occurrence of SDSs were compared to determine the main controls on the interannual variation in SDSs.

We analyzed the frequency of spring SDSs events from 2007 to 2016 based on data from 673 standard ground stations in China. The statistical analyses demonstrated that the number and intensity of SDS events recorded in spring during 2007 to 2016 showed a decreasing trend. The total number of spring SDSs decreased from at least ten events per year before 2011 to less than ten events per year after 2011. The average number of Blowing Sand or Dust (BSD) events in spring during 2007 to 2016 was 4.9, with four or five BSD events in more than half of these years. The number of SDS events showed decreasing trend, meanwhile, that of the BSD events show an increasing trend, indicating the intensity SDSs became weaker. The mean surface dust concentration of the main dust influence area (MDIA) in spring from 2007 to 2016 was 102.66 $\mu g/m^3$ and the mean surface dust concentration of the MDIA decreased by 9.9 g/m3 (9.64%) per year. The overall average annual variation of the surface dust concentration in the dust source regions was −33.24 $\mu g/m^3$ (−11.75%) per year.

The annual mean variation of the Normalized Difference Vegetation Index (NDVI) in most of East Asia was positive, indicating that vegetation coverage has improved and dust emissions have been suppressed in the source areas. Areas with a higher mean NDVI may show greater improvements in vegetation coverage. The variation in the temperatures near and below the ground surface and the amount of precipitation and soil moisture all favored an improvement in vegetation coverage, which reduced the intensity and frequency of

SDSs. The mean spring 2 m temperature in the MDIA varied from −10 to 15 ℃ from 2007 to 2016 and soil temperature at 0-0.1 m depth were slightly higher. Several degrees of warming both the temperature at 2 m height and the soil temperature at 0-0.1 m depth favor the growth of most plants, which can reduce the incidence of SDSs. Furthermore, the annual mean variation in the daily precipitation in the MDIA was 0.018 mm/day per year (1.527%), indicating that precipitation exhibited an increasing trend, improving the coverage of vegetation.

The strong winds accompanying the influx of cold air from high latitudes showed a decreasing trend, leading to a decrease in the number of SDSs and playing a key role in the decadal decrease of SDSs. The mean meridional wind components in MDIA were mostly positive, with a dominant west wind. The annual mean variation in the meridional wind component in MDIA was −0.020 m/s per year, indicating a decrease in the west wind component, which does not favor the long distance transport of SDSs to the east. The reduction in the north wind component was accompanied by an increase in the southerly component, indicating that the influx of cold air from the north has decreased and the warm air following the south wind has increased. This favored an increase in temperature. Therefore the reduction in the meridional wind components indirectly decreased the frequency and intensity of SDSs by increasing the temperature of the near-surface layer, which improved the vegetation coverage and surface conditions in the dust source areas. The decrease in the intensity of the polar vortex during study period was also closely related to the decrease in the intensity and frequency of SDSs.

Keywords: Sand and dust storms, Surface conditions, NDVI, Climate change.

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Long-term aerosol optical depth (1941-2017) at the Izaña Observatory

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In this work, we present a long-term data series of aerosol optical depth (AOD) at 500 nm from 1941 to 2017 (77 years) at the subtropical high-mountain Izaña Observatory (IZO) located in Tenerife (The Canary Islands, Spain). AOD measurements were performed with Precision Filter Radiometer (PFR) from 2003 and 2017, and before that (1941-2001) AOD was estimated from neuronal networks (ANNs). This analysis is limited to cloud-free conditions (oktas = 0) and for July month, when significant Saharan mineral dust burden is observed at IZO (García et al., 2016).

The AOD time-series has been compared with long-term meteorological records identifying Saharan dust events at IZO. The number of days with AOD≥0.20 has been compared with the number of days in which the meteorological observes reported presence of suspended dust (05-06 SYNOP codes, WMO, 1998) at IZO every July. On the other hand, we have analysed the relation between the AOD monthly medians and the monthly percentage of time the wind is blowing from each one of the four quadrants. Both analysis provide consistent results. We found that the number of days with 05-06 SYNOP codes time series agrees with the number of days with AOD≥0.20 time series (R = 0.88) and that there is a high correlation between AOD monthly medians and the percentage of time the wind blows in the second quadrant (R =0.87). Therefore, we conclude that the reconstructed AOD time series captures well the AOD variations and dust-laden Saharan air mass outbreaks on both short-term and long-term timescales and, thus, it is suitable to be used in climate analysis.

Keywords: aerosol optical depth, artificial neural networks, Saharan mineral dust, time series
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Soil Information System, Turkey

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The Ministry of Forestry and Water Affairs carried out below activities grouped as the "Soil Information System Project" in order to provide a basis to the data themes handled for the "Watershed Monitoring and Evaluation Project" that is developed under the coordination of the General Directorate of Combating Desertification and Erosion subject to the responsibility of the Ministry;

1. Concerned representatives of public and private sectors, universities and research institutes in Forestry and Agriculture sectors were gathered together at workshops, seminars and meetings on "National soil database, soil mapping, and survey studies" to determine the needs, challenges and goals.
2. The database structure of the "National Soil Database" was drafted subsequent to the encounters with representatives from Forestry and Agriculture sectors, and the "Soil Database" was set up in 2013, hosted by the Information Technologies Department of the Ministry of Forestry and Water Affairs. Three major project activities were conducted to further improve the database;
   - **a)** ***Digitisation Project of Soil Maps and Survey Reports***: Soil maps, survey reports and analysis reports of previous afforestation, erosion control, rehabilitation, rangeland etc. projects in the archives of the former General Directorate of Afforestation and Erosion Control and the General Directorate of Forestry were digitised and uploaded to the database.
   - **b)** ***AraziMOBIL: Field Data Collection System via Mobile Devices***: In order to ensure accurate, timely and low-cost data collection measuring up to standards of the soil database directly from field, the web-based "AraziMOBIL" software was developed compatible with Android, iOS and Windows operating systems for use on smart phones, tablets, and other such mobile devices.
   - **c)** ***Laboratory Data Management System:*** A web-based laboratory data management system that allows multiple user access to view, search, and modify data was developed for the pilot location, Eskişehir Forest, Soil and Ecology Research Institute, in order to accelerate soil analysis procedures, and to ensure transparency and credibility.
3. ***Soil Portal***: A web-based soil portal that provides to users soil maps and survey reports archived in a standardised manner in the soil database, produces thematic maps, and facilitates various inquiries and analyses, was developed under the coordination of the General Directorate of ÇEM.

Keywords: Soil Information System, Geographical Information Systems, Mobile GIS, Soil Portal

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February 2017 extreme Saharan dust storm in the Iberian Peninsula

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This article presents an extreme Saharan dust event registered from 20 to 23 February 2017 over the entire Iberian Peninsula (IP). In particular at: Barcelona (41.38ºN, 2.17ºE), Burjassot (39.51ºN, 0.42ºW), Cabo da Roca (38.78ºN, 9.50ºW), Évora (38.57ºN, 7.91ºW), Granada (37.16ºN, 3.61ºW) and Madrid (40.45ºN, 3.72ºW). We report on aerosol optical properties observed under this extreme dust outbreak through remote sensing techniques (active and passive). For that, EARLINET (European Aerosol Research LIdar NETwork) lidar (Light Detection and Ranging) (Pappalardo et al., 2014) and AERONET (AErosol RObotic NETwork) (Holben et al., 1998) sun-photometer Cimel CE 318 measurements were utilized in this study. Furthermore, an estimation of vertical distribution of mineral dust is accomplished by two dust transport models: the BSC-DREAM8b and the NMMB/BSC-Dust (Pérez et al., 2006; Pérez et al., 2011) and subsequently compared against results obtained from remote sensing observations.

In general, large aerosol optical depth (AOD) and really small Angstrom exponent (AE) in the range 440/870 nm are identified by the Cimel CE 318 at each station when mineral dust was present. Several stations reached an AOD of 2 at 675 nm and maximum values were registered at Évora were the value of 2.5 was overpassed. Likewise during the most intense period AE was close to 0 at every station. With regard to vertically-resolved aerosol optical properties, particle backscatter coefficients reached values up to $1.5 \cdot 10^{-5}$ m^{-1} sr^{-1} at 355 nm at most of EARLINET stations, which is to our knowledge an unprecedented phenomenon to be reported at the Iberian Peninsula scale in terms of intensity and affected area. Because of that, a detailed analysis of aerosol optical properties observed during this event and an evaluation of the dust transport models to forecast the African dust outbreak is fulfilled. The thorough knowledge of these phenomena is important and necessary given the different implications they have on climate, air traffic security or health, especially when it comes to extreme events as the one described in this work.

Keywords: mineral dust, lidar, sun-photometer, dust transport models

Acknowledgements

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Saharan dust outbreaks over Sardinia Island: PM10 concentration and its relation with synoptic condition

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Dust events over Italy have usually origin in the Sahara and Sahel regions that represent the dust sources nearest to Italy. In those regions, the dust-lifting activity occurs in remarkable way. The greatest amount of dust is transported across the Atlantic Ocean and southward (Barkan et al., 2004), but it has been estimated that 80-120 Tg of dust per year are also transported across the Mediterranean towards Europe (Collaud Coen et al., 2003; Dulac et al., 1996).

In Sardinia, dust events are more frequent in the May-November period, but they can also take place in the December-April period.

This work aims to describe dust outbreaks in Sardinia, to identify the main meteorological scenarios that originate the transport of dust towards the central and western Mediterranean Basin, and to assess the influence of Saharan dust on the level of PM10 observed at the air-quality monitoring network of the Regional Environmental Protection Agency of Sardinia (ARPAS).

The study was carried out during 2014. A total of five events that occurred during the year (two in spring and three in autumn) were analyzed.

The evaluation of the geographical dispersion of Saharan dust was performed by using MODIS satellite data and Meteosat imagery combined with SKIRON (Nickovic et al., 2001) forecasting model. SKIRON is a version of the ETA/NCEP weather forecasting model developed at the University of Athens with a forecast horizon of 5 days.

The origin and the back-trajectory plot of the dust carried by winds towards Italy were inferred by the NOAA HYSPLIT model (Hybrid Single Particle Lagrangian Integrated Trajectory Model (Rolph, 2014; Draxler et al., 2014)).

The daily PM10 concentration values registered by the ARPAS air-quality stations were analyzed through the application of the methodology for the estimation of natural dust contributions on daily PM10 concentrations described in the European Air Quality Directive (2008/50/EC, EC, 2011).

The results showed that all the event analyzed were characterized by a low-pressure system over the Iberian Peninsula that extended towards Morocco and by the associated high-pressure system over the North-East Africa (Algeria, Tunisia and Libya) and Sicily. This synoptic structure (low pressure over North-Western Africa) forced the dusty air masses towards the Mediterranean basin, favoring the transport of African air masses towards the Sardinia Island. The arrival of air masses from Africa caused the daily mean air temperature to rise whereas relative humidity values decreased. The origin of air masses loaded with dust from North Africa was confirmed by satellite imagery and 3-days air mass backward trajectories calculated by the NOAA HYSPLIT model. The analysis of the PM10 daily pattern registered at northern and southern Sardinia sites showed an increase of concentrations during the dust events.

Keywords: Air quality, PM10, Sahara dust, Satellite imagery, Sardinia.

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Characterization of Saharan dust episodes over central Italy

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Saharan dust episodes can be observed over the Mediterranean region several times a year, affecting PM10 concentrations. In particular, the Italian peninsula can be affected by Saharan dust outbreaks, which can contribute to the exceedance of the PM10 limit value. For this reason, it is mandatory to identify the quantitative amount of relevant mineral dust events. Several methods and techniques have been proposed to identify and quantify the amount of mineral dust to PM10 concentration, using both experimental techniques and numerical models. Numerical models can simulate the dynamic of long-range transport of mineral dust and the consequent deposition, while the measurement of the concentrations of soil dust elements can be used to quantify the effective amount of Saharan dust in PM10 samples. During the summer of 2014, the University of Florence and INFN carried out a specific field campaign, in the framework of PATOS project [1], allowing the assessment of the mineral dust contribute to PM10 concentrations. In particular, the concentrations of all the main soil dust elements were measured by the PIXE technique. This campaign included daily measurements, on alternate days, for the whole period and hourly measurements for two weeks. The PM samplings were performed in two sites: one along the Tuscany coast (Livorno-La Pira) and the second at a hinterland site (Pistoia-Montale).

The characterization of the main Saharan dust outbreaks affecting the Tuscany Region during the same period, has been conducted using the SPARTA model chain [2], developed by the LaMMA Consortium, as designated by the Tuscany Regional Government. SPARTA is based on the meteorological model WRF-ARW and on the chemical model CAMx, using CHIMERE boundary conditions. This modelling system is able to provide a threedimensional description of the dynamic evolution of the dust episode. In such a way, it is possible to recognize, in a more efficient way with respect to using the back-trajectories or satellite images, the episodes involving the lower part of the atmosphere, near the soil, contributing to the increase of PM10 concentration.

The joined use of a numerical model and in-situ measurements provides a complete characterization of the Saharan dust outbreaks, which includes both the meteorological and dynamical aspects as well as the quantification of the impact on PM10 at the ground level. The comparison between simulations and measurements, during the studied period, reveals a good agreement, properly detecting all the high concentration episodes, both on hourly and daily bases.

Keywords: Saharan dust, numerical model, elemental composition, PIXE.

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Northern African sources of mineral dust from measurements at the Izaña GAW Observatory

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The Canary Islands are located in the path of the mineral dust export from North Africa across the Atlantic Ocean in the Saharan Air Layer. In particular, dust events with concentrations above 10µg/m^3 are frequently recorded at high altitude in the island of Tenerife in the months of July, August, and September every year [1]. Since 1987, summer campaigns are carried out at the Izaña GAW Observatory (IZO), located at 2370 m.a.s.l. in the free troposphere (see [2] for an overview of recent activities carried out at IZO). Aerosol samples are collected in quartz filters for later chemical analysis, which allows us to determine the main elements of the mineral dust's composition.

Previous studies have highlighted the relationship between the chemical composition of the mineral dust samples and the northern African source areas (see [3] and references therein). For instance, Scheuvens *et al*. found that the ratio (Ca+Mg)/Fe obtained from atmospheric concentration data show a North-South gradient across North Africa [3]. In this work we examine the feasibility of using the data on the chemical composition from the samples collected at IZO to discriminate different northern African source areas of mineral dust. To carry out this task we use trajectory statistical methods, which combine data from chemical composition and back trajectories (see e.g. [4]). In the present case, these methods allow us to obtain maps of source areas' markers, such as the above-mentioned (Ca+Mg)/Fe ratio. We compare the results obtained with different trajectory statistical methods, such as the Concentration Weighted Trajectories (CWT) [4] and the Median Concentration at Receptor (MCAR) [5], and also check the effect of using back trajectories obtained with different models and parameters.

Keywords: dust sources, Saharan Air Layer, trajectory statistical methods.

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Climatology of dust aerosols transportation over the Atlantic Ocean toward Caribbean area

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The Caribbean region is regularly flown over by desert dust air masses (Saharan Air Layer) come from Saharan and sub-Saharan area. For four islands of the West Indies arc: Puerto Rico, Guadeloupe, Martinique and Barbados; we assessed the origin of polluting particles and their impact on air quality, by performing a statistical and climatological study of desert dust events. We therefore based on the air quality measurement networks, the international AEronet RObotic NETwork (AERONET) photometric measurements installed on each of these islands. And finally, this study builds on sounding data produced locally.
The first step in our work was to define and describe an "desert dust episode" in the tropical region. Thus, we studied the relationship of correlation between Aerosols Optical Depth (AOD), Angstrom Exponent (AE, characterizing the particle size) and Particulate Matter 10 microns or less in diameter (PM_{10} data). On the other hand, the radiative properties (Single Scattering Albedo, refractive indexes) have been used to highlight sea salt contribution (coarse particle just as dust particle) that significantly influences PM_{10} measurement due to the geographical context of Caribbean islands. Our investigations led us to propose a daily PM10 threshold at 35 µg m^{-3} that mainly associated with desert dust phenomenon. This latter is more suited for the Lesser Antilles compared to the European PM10 threshold related to desert dust events: 50 µg m^{-3}.
As a result, a climatological study of dusty events in the Caribbean during the last decade (2006-2016) is carried out. Four dust seasons were identified: the high dust season (May to August), the low dust season (November to February, and two intermediate periods (March to April, September to October). We then examine dust exportation from African coasts toward the Lesser Antilles (Puerto Rico, Guadeloupe Martinique and Barbados) by mean of back-trajectories [Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model] displaying atmospheric circulation day-to-day over the Atlantic Ocean.
This analysis enabled us to better understand the seasonal cycle of desert dust transportation, specific to each island (Puerto Rico, Guadeloupe, Martinique, Barbados); while most of the previous studies treats average data including the whole Caribbean zone. It emerges that islands are not affected by dust events similarly, i.e. by intensity of events and its includes some variation in dust periods.
Lastly, we describe the vertical structure of the tropical zone atmosphere in situation of “desert dust events” and "Non-desert dust event" to observe the thermodynamic effects of mineral aerosols on the Caribbean atmospheric layer. This analysis allowed us to consider desert dust aerosols effects on the thermodynamic parameters (Temperature and humidity) during the dry-season (November to April) named “câreme” and the wet season (May to October) named “hivernage”.

Keywords: Aerosol Optical Depth (AOD), Angstrom Exponent (AE), AERONET, Particulate Matter 10 microns or less in diameter (PM_{10}), back-trajectories (HYSPLIT), Desert Dusty Day, dust events, dust seasons, climatology.

Acknowledgements

Measurements at Guadeloupe, Martinique, Puerto Rico are carried out with support from Gwad'air, Madinin'air and Air Now (air quality networks) respectively. We thank Mr Joseph Prospero for dust concentrations data from Barbados. The authors gratefully acknowledge the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model and/or READY website (http://www.ready.noaa.gov) used in this study. The authors also gratefully acknowledge the NASA AERONET program for data used in this study. Using the ArcInfo/ArcView GIS program (version QGIS-2.18.14: http://www.qgis.org/fr/site/) to illustrate back-trajectories. We also thank Wyoming University for provided sounding data.

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DUST IMPACTS

Dust emission and air quality modeling using a new high-resolution dust source function in WRF-Chem over the Middle East and North Africa (MENA)

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Despite improvement in model physics, and development in computational capability, calculating dust emission from the first principles remains a challenge. Application of orographic and statistical source functions significantly improves the results. Although several source functions exist which work well in coarse-scale (~1 degree) modeling, high-resolution source function is necessary to represent the highly heterogeneous nature of dust sources in finer scale.

In this study, we implement a newly developed high-resolution (~500 m) source function in the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) to address two important aspects of dust modeling over the Middle East and North Africa. In the first part, we simulate dust emission and associated optical properties over the entire dust belt (Middle East and North Africa) using 10 km grid spacing, and evaluate against AERONET and MODIS observations. In the second part, as an example to illustrate the use of high-resolution source function in air quality modeling, we simulate the emission and transport of dust originating from Tigris-Euphrates basin at high resolution (~4 km), which is one of the most important dust source regions in the Middle East.

Results show that in most cases the new source function in WRF-Chem helps to represent well fine-scale dust sources as evaluated in terms of simulated aerosol optical depth (AOD). The dust originating from the Tigris-Euphrates basin by strong Shamal winds is spread over a wide region, especially in the summer season, producing particulate matter (PM10) concentrations exceeding the limit on air quality standard in some of the highly populated, down-wind cities of the Arabian Peninsula. This is consistent with the available observations of the deposition of radionuclides from depleted uranium weapons, used during the Gulf War in 1991 in Kuwait and Southern Iraq, found all over the Arabian Gulf coast.

Our results demonstrate the benefits of using the high-resolution source function for regional-scale dust dispersion simulations over MENA. In addition to air quality, our results have important policy implications on pollutant dispersion over the region suggesting that integrated and coordinated management of Tigris-Euphrates basin is necessary to maintain the air quality standards in the downwind region.

Keywords: WRF-Chem, Dust Emission, Air Quality, Dust Source Function, Erodibility, MENA

Urban fugitive dust in Asian dust aerosols

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The contribution to global dust emission of desertification through human activities is uncertain: estimates vary from 50% (Tegen et al., 1996; Mahowald et al., 2004) to less than 10% (Tegen et al., 2004) to insignificant values (Ginoux et al., 2001; Prospero et al., 2002). A 43-year estimate of Asian dust emissions reveals that meteorology and climate have a greater influence on Asian dust emissions and associated Asian SDS occurrences than does desertification (Figure 7.19 of IPCC WG1 AR4, 2007; Zhang et al., 2003). Asian dust mainly originates from 10 source areas (Zhang et al., 2003), the combined dust produced in Mongolia, the deserts in western China and the high dust emission areas in northern China, amounts to ~70% of the total Asian dust production. These three areas can be considered as the major sources for Asian dust aerosol. Dust aerosol observed in the SDS affected areas are not only from the transport of the Asian SDS from their sources mentioned above, but also included those called the urban fugitive dust. Dust aerosol dominates the aerosol mass over Asian continental regions with relatively higher concentrations especially in urban South Asia and China (IPCC WG1 AR5, 2013; Zhang et al., 2012), in which there are substantial fractions can be considered as urban fugitive dust. These urban fugitive dust may impact to heavy aerosol pollution episodes through heterogeneous phase chemical reaction to increase more secondary organic aerosol (SOA), sulfate and nitrate. Of course, the formation of heavy pollution also has the contribution of the interaction between aerosol and boundary layer (PBL). The relative contributions of heterogeneous reaction and interaction with PBL meteorology are discussed here. It is also the interesting direction of future dust aerosol research.

Keywords: Urban fugitive dust, SDS, Asian dust, Heterogeneous phase chemical reaction, PBL

Dust inducing occupational auto-immune diseases

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Occupational exposure is a factor closely related to few immune system diseases.
An association between occupational exposures of inhaled dust, and auto-immunity, was postulated as early XXe century. Genetic factors exist and affect the development of systemic autoimmune disease in certain individuals. But occupational factors could also play a substantial role.
The objective was to explore the potential association between dust and airborne hairdresser's exposure inducing autoimmune diseases, more specially Systemic Lupus Erythematous (SLE).
The study investigated the relationship of occupational dust inhalation exposure in hairdressing salons, and onset of SLE.. Cases were defined as, those who reported having SLE, with clinical and biological confirmation.
Cases were more likely to have been exposed to Hairdressing Dust Inhalation Exposure (HDIE), than other people without the disease. Onset of SLE appears in a close temporal relationship with HDIE. The development of symptoms of fatigue, myalgia, arthralgia, dysesthesias of the hands and feet and skin problems, appeared to be linked to HDIE. Moreover increase positive autoantibodies have been observed, followed by a decrease, after cessation of HDIE. These biomarkers were dependant of HDIE.
SLE may be caused by a large number of chemically unrelated agents under circumstances of exposure, which were prolonged and frequent. Agents implicated in triggering or accelerating SLE were mercury, iodine, vinyl chloride, and crystalline silica, possibly included in hairdressing products. But, it is difficult to infer correctly the exact agent, because hairdressing products are made of many chemicals and mixtures.
It is important to underline that dust itself has adjuvant effects.
In conclusion, mechanism and epidemiology linking HDIE to development of SLE, are not well known. But these findings support the hypothesis that HDIE is frequently associated with SLE.

Keywords: occupational diseases, airborne, lupus.

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Oral and lung bioaccessibility of dust particles under the influence of forest fires ashes (Tentúgal - Portugal)

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Forest fires have been an even more frequent phenomenon in Portugal and, particularly in 2017, the forest fires were of extreme severity, devastating huge forest and urban areas and causing a dramatic number of deaths and high economic losses. These scenarios are likely to become increasingly frequent and severe in future, not only due to climate changes (IPCC, 2013), but also due to rural depopulation, land abandonment and afforestation with fire-prone species.

Wildland fire emissions are physically and chemically complex and worsen air quality. The ashes are mainly composed by oxides and hydroxides of base cations (e.g. Ca, Mg and K, but also Si and P), and characterized by high alkalinity (Khanna et al., 1994). However, ashes also contain significant amounts of trace metal(loid)s that could induce toxicity in soil solution and water resources (Pitman, 2006), and, therefore, exert harmful effects on the health of local populations and animals. Fires can substantially affect a wider range of physical and biogeochemical properties of soils, and contribute to the release and re-deposition of metal(loid)s on the soil surface (Campos et al., 2016). Due to its low weigh, ashes are often rapidly (re)distributed and removed from burnt sites by wind and water (Pereira et al., 2013), and easily deposited in inhabitant areas. Thus, the settled dust of these areas is a complex mixture of “decomposing” and different sized particles from a wide range of geological, biological and anthropogenic weathering resulting processes, including the ashes inputs. The small size particle of these last ones facilitates their resuspension, which the increase the human exposure through ingestion and inhalation to them. Thereby, the assessment of metal exposure via ingestion and inhalation of these dust particles is needed. For an accurate assess it is required the measurement of metal(loid) bioavailability using in vivo assays, but due to ethical issues, the time consuming, cost-prohibitive, and complex nature of these in vivo assays, the bioaccessibility of metal(loid)s is usually predicted by various in vitro methods. The bioaccessibility is defined as the fraction that is soluble in the target compartment, i.e., the gastrointestinal tract for oral bioaccessibility (Oomen et al., 2002; Ruby et al., 1996) and the lungs for pulmonary bioaccessibility (Pelfrêne and Douay, 2017).

In this study, dust samples were collected in sidewalks and roadsides, using small brushes and shovels, in an area affected by forest fires located near Tentúgal city (Coimbra district, center of Portugal). In addition, soil samples (surface and subsurface horizons) were collected in the burned areas. Samples were dried at 40 ºC, and then separated into two different size fractions (<250 µm and <10µm) using a stainless steel sieve due to the different ‘environmental’ behaviour of the particles. The fraction smaller than 250 µm has been reported as the one that easily adheres to human hands, which is particular important for children who do not have the same perception for handwashing as an adult (EPA, 2000). On the other hand, the fraction <10 µm is considered as a health-relevant fraction for inhalation exposure (Boisa et al., 2014). Several heavy metals were analysed by ICP-MS, as well as the pH (by 1_{solid}:5_{water} solution) and the organic matter (by loss on ignition). For determination of lung bioaccessibility the artificial lysosomal fluid (ALF) was used as the leaching solution (Pelfrêne et al., 2017), and for oral bioaccessibility the unified bioaccessible method (UBM) method was used.

The goals of this study were to 1) identify which trace elements were present in ash and burned soil samples; 2) assess the heavy metals bioaccessibility via ingestion and inhalation of dust particles; 3) examine the influence of the pH and OM on the total and bioaccessible concentrations of heavy metals.

The results showed that dust and soil samples exhibited neutral pH values, ranging between 6.7 and 7.4, while the percentage of OM was very variable, ranging from 2 to 36%. It was particularly evident that average concentrations of heavy metals in the <10 µm particle size fraction were significantly greater (2311, 135 and 456 mg kg^{-1} for Ni, Cu and Zn, respectively) than the average concentrations in the <250 µm fraction (11, 39 and 145 mg kg^{-1} for Ni, Cu and Zn, respectively).
Oral bioaccessibility of Ni, Cu and Zn was measured in the <250 µm size fraction, while the lung bioaccessibility was measured in <10 µm size fraction (results expressed as a percentage of the total concentrations). The results showed that the average percentage of oral bioaccessibility is higher than lung bioaccessibility for these metals (38 and 31% for Ni, 38 and 27% for Cu and 66 and 56% for Pb in the gastric and lung phases, respectively). Moreover, the results showed high variability on the bioaccessible data between sites sampled, which means that metal release could be influenced by the heterogeneous composition and the specific surface area of dust particles.

Keywords: heavy metals, fires, ash, lung bioaccessibility, oral bioaccessibility.

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The project PerduS – Improving the forecast and observations of Saharan dust induced reductions on photovoltaic power production in Germany

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Already today Photovoltaic power production contributes with about 7.2% to the total electricity production in Germany. This needs to be constantly increased to achieve Germany's goal to produce 80% of the total electricity supply using renewable energy. The obvious dependency of PV power production on atmospheric conditions, induce a high demand on an accurate weather forecast to insure grid stability also in the future. A driving risk factor in forecasting PV power production in Germany, are Saharan dust clouds transported to Europe. The joint project PerduS which is a collaboration between the German weather service (DWD), the Karlsruhe Institute for Technology (KIT) and Meteocontrol, has its focus on the improvement of weather forecasts during such Saharan dust events. The online coupled NWP model ICON and the ART modules for the treatment of Aerosol and Reactive Trace gases form the base of the project PerduS. To achieve the project goals and to examine in detail, how strong the effect of Saharan dust on PV production is, accurate and extensively measurements of the Saharan dust in the atmosphere and of the ground reaching solar radiation is needed.

An important part of the project is to utilize the ground based measurement network of the DWD to observe dust clouds transported from the Saharan region to Germany. With a newly developed retrieval algorithm we estimate the an effective aerosol optical depth (AOD) and aerosol size from ground based broadband measurements. In the NWP evaluation studies the measurements and retrieval results are used to evaluate the predicted Saharan dust AOD from the ICON-ART model. Further we want to close the circle of radiation measurements, the retrieval and the forecast results. Therefore the algorithm will be used under cloudless conditions as a radiative transfer model to calculate the solar radiation at the surface for the predicted atmospheric conditions. In our contribution to the workshop we show the potential of the retrieval algorithm to estimate the effective AOD from broadband measurements. Further we present results and analyses of several Saharan dust events which occurred since the start of the project.

Keywords: remote sensing observations, dust and radiation, dust forecast, solar energy production

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Radiative impact of an extreme dust and wildfire episode on the performance of the photovoltaic plant at the University of Valencia, Spain

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In recent years, the progressive depletion of fossil fuels has strongly boosted the generation of energy from sustainable and non-polluting sources. In fact, renewable energies, such as wind or solar photovoltaic, are called to significantly contribute to the energy mix in the coming years (Gaetani,et al., 2014). However, renewable energies are based on local resources that are strongly conditioned to their natural availability. Therefore, in order to improve the grid integration of the renewable energies we need to increase knowledge and forecast of atmospheric variables, as well as the impact they have on renewable energy generation (Chan et al., 2014; Perry and Troccoli, 2015). The aim of this work is empirically evaluate the impact produced by an unusually extreme dust and wildfire episode on the photovoltaic plant owned by the University of Valencia. The plant is located in the Burjassot Campus where the aerosol-radiation and photovoltaic power are routinely measured. The dust event was noticed on 26-28 June 2012 and increased the aerosol optical depth (AOD) up to 1. It was followed on 29June-1July by an intense smoke plume due to the combination of two wildfire sources close to the station that cause an extreme AOD peak of 8 (Gómez-Amo et al., 2017).

These high AOD caused a great reduction of the solar irradiance reached the photovoltaic panels and consequently of the power generated by the plant. This reduction is calculated with respect to a reference day with 15- minutes temporal resolution. We took June 24 since a daily averaged AOD of 0.14, much lower than the observed on the dust and wildfire days.

In terms of power reduction, we obtain instantaneous values up to 10 and 70 kW due to dust and smoke, respectively. The instantaneous power losses have been integrated throughout the day to obtain the total daily energy losses. Thus, we obtain a daily energy reduction of 71 and 289 kWh for dust and smoke days that represent the 10 and 45 % with respect to the total energy generated on the reference day. The significant differences in the daily energy reduction between the dust and smoke are extremely dependent on the AOD of each considered day. In order to avoid this dependency on the aerosol load and to evaluate the efficiency of each aerosol type (dust and smoke) to reduce the power generated by the solar plant, the power reduction per unit of AOD at 500 nm at instantaneous and daily level have been obtained. In this case, no significant differences between dust and smoke are observed in the 15-minute evolution throughout the day. For both aerosol types, the maximum value of the instantaneous power reduction is 20kW per unit of AOD. This result in a daily power reduction of 90 and 111 kWh per unit of AOD for dust and smoke aerosols, respectively. These results confirm that extreme aerosol events may drastically reduce the power generated by a photovoltaic plant. This reduction is mainly modulated by the aerosol load and shows little dependency on the aerosol type. This results show the importance of considering aerosols in the photovoltaic power forecast, especially during extreme episodes.

Keywords: dust, wildfire, radiative impact, energy generation, photovoltaic plant.

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Source Apportionment of PM2.5 and PM10 aerosol by Mass Balance, in an urban atmosphere during two contrasting seasons

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PM2.5 and PM10 aerosols were collected at an urban site in Porto, Portugal, during one year, within the framework of AIRUSE LIFE+ project, and analysed for total mass, water-soluble ions, elements, carbonated, elemental and organic carbon, and levoglucosan.

The sources and processes responsible for the aerosol loading were estimated based on a previously developed Ionic and Mass Balance (IMB) methodology (Cardoso et al., 2018), adapted to the available database. The chemical composition was used for the source apportionment of the aerosol, which was performed for the total sampling period and for discriminated summer and winter seasons.

Edge lines and average crust composition were applied to estimate the amounts of insoluble and water-soluble soil material. Using this information and the ionic balance between cations and anions, contributions from sea salt and secondary products involving the reaction of acidic precursors with ammonium, sea salt and soil, were discriminated. Non-exhaust road vehicles emissions were calculated from excess calcium and iron. Bibliographic information, edge lines, carbon, levoglucosan and excess potassium were employed to evaluate biomass burning emissions and to discriminate between primary fossil fuel and secondary carbonaceous matter.

Ten sources / formation processes were found and accounted for, covering, on average, 80-90% of the measured total mass concentration. Water was added to water soluble and hygroscopic source components with basis on thermodynamic and bibliographic information, bringing the PM coverage to approximately 100%.

During summer, soil and road dust were important contributors to the aerosol mass, principally for PM10. Approximately one third of dust loading seems to suffer reaction with acidic compounds in the urban atmosphere. Also, during summer, half of sea salt suffers the attack of acidic gases. In this season, 20-30% of aerosol mass results from secondary formation of carbonaceous matter.

In winter, biomass burning is the largest individual aerosol source, contributing with 30-35% of the aerosol loading. In the PM10 fraction, sea salt is the second most frequent aerosol source, in this season, followed by primary carbonaceous material from the burning of fossil fuel. This primary carbonaceous component is the second contributor to PM2.5 during winter, followed by secondary carbonaceous matter.

The source apportionment contributions calculated with IMB compared well with the results of Positive Matrix Factorization (PMF) applied to the same data set (Amato et al., 2016), demonstrating the feasibility and interest of this methodology that permits the obtaining of information on sources and formation processes, being complementary to other methods such as PMF.

Keywords: Urban Aerosol, Urban Dust, Source Apportionment, Ionic and Mass Balance.

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Dust and Air Quality Modelling for the Caribbean

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Every year significant quantities of dust travel from the Saharan region to the Caribbean and beyond. During high dust transport episodes, concentrations of Saharan Dust in the Caribbean often exceed United States Environmental Protection Agency (EPA) and World Health Organisation (WHO) standards for particulate matter of 2.5 microns or less (PM 2.5) and 10 microns or less (PM10). Exceeding these standards, in particular the PM 2.5 standard, can have serious implications for human health, national health services providers and national productivity across the region. However, the majority of territories in the Caribbean do not have operational air quality monitoring programmes and several do not have or enforce air quality standards for PM2.5 and PM10. For the past two years, the Caribbean Institute for Meteorology and Hydrology (CIMH) has been providing dust and air quality forecasts for the Caribbean using the Advanced Weather Research and Forecasting (WRF) model coupled with Chemistry (WRF-Chem) and is currently testing the Dust Regional Atmospheric Model (BSC-DREAM).

The WRF-Chem model is used as a coupled: (i) weather /dispersion model to simulate the release and transport of constituents; and (ii) weather/dispersion/air quality model with full interaction of chemical species to predict PM2.5, PM10 and ozone (O3). The BSC-DREAM system will be used to forecast dust transport from primarily the African continent across the Atlantic into the Caribbean, Central America and South America regions. The model results will be compared to satellite observations and validated by in situ dust, PM2.5 and PM10 measurements at various locations in the region including Ragged Point, Barbados (world's oldest dust record since 1965), Martinique, Guadeloupe, French Guiana and Puerto Rico. The CIMH WRF-Chem accurately predicted the April 1-4, 2017 Eastern Caribbean dust episode and its persistence seven (7) days in advance. The model's dust forecasts were also instrumental in the University of Leeds summer field experiment to study long range transported desert dust and marine ice nucleating particles at Ragged Point, Barbados.

Future work will include prediction of ultraviolet (UV) radiation as well as examining dust radiative forcing and effects on atmospheric precipitation and dynamics. Currently plans are underway to develop and implement air quality and health early warning systems for the Caribbean. CIMH is one of the lead institutions of the Caribbean Aerosol-Health Network (CAHN) and hosts the Pan-American Regional Centre for the World Meteorological Organization Sand and Dust Storm Warning Advisory and Assessment System (WMO SDS-WAS).

Keywords: dust modelling, WRF-Chem, Caribbean, particulate matter, SDS-WAS

Dust emissions from vehicle brake wear: the ECO-BRAKE project

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Due to the strict regulation of vehicle exhaust emissions in the last two decades, road traffic emissions are nowadays about half composed by non-exhaust particles (including mineral dust) from brake wear and road dust resuspension. The brake wear emissions are poorly understood due to the large variety of chemical composition of brake pads, emission rates and a standardized method for their measurement. The ECO-BRAKE project aims at estimating emission rates for total PM and its components (including dust) from conventional and innovative brake pads, including Semi-metallic, low metallic, non-asbesto organic (NAO) and with different types of binder. Several bench tests were performed in a brake dynamometer simulating the emission rates in the AK Master driving cycle. Particle number and mass size distribution were monitored by means of ELPI+ (Dekati), OPS and Nanoscan (TSI). Dust components mass size distribution and emission rates were obtained by means of DLPI (Dekati) sampler and subsequent ICP-AES and ICP-MS analysis of particles collected oon aluminium foils. Other monitored parameters were absorption, CO, CO2 and total particle number.

Keywords: dynamometer, disc, iron, emission factor, metals.

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Development of a nose/mouth filter against the Harmattan dust: An experimental set-up for testing the Harmattan nose/mouth filter

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Abstract:
The concentration of suspended dust aerosols during the Harmattan period in most parts of West Africa is very high. The impact of this polluted atmosphere on the people has aroused the interest of researchers in the phenomenon. Many studies have been initiated including the need for various respiratory filters to be designed to serve as air filter for breathing. This study is focused on the design of a test rig for assessing the performance of the nose/mouth Harmattan dust aerosol filters we have designed. Four concepts were generated using brainstorming method and random online survey of existing test rig set-ups. The four concepts were generated and evaluated based on design criteria such as adaptability, ability to mimic respiration, ease of parameter measurement, cost, size, ease of fabrication and complexity. The Weighting and Digital Logic method of concept selection was used to select a concept which allows suction to be directly downwards and a manikin for holding the filter firmly. The concept selected was designed and the detailed drawings of the various parts prepared using AutoCAD following which the parts were fabricated. The components were assembled and the final product evaluated and tested. A sample filter was fixed to a manikin and an air flow rate of 5×10^{-4} m^3/s with Harmattan dust mass loading of 72.7 g was passed through the system for a period of 30 minutes. The pressure drop observed across the filter was recorded to be equal to 32.4 Pa. The efficiency of the filter was 45% with a quality factor of 18×10^{-3} Pa^{-1}.

Key words: Harmattan dust, particle penetration, pressure drop, filter quality factor, filter efficiency, nose/mouth air filter.

Dust concentration and water soluble speciation at the Caribbean region under the influence of long-range transported African dust

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An increase in PM_{10} concentrations that could exceeds the exposure limit of 50 µg/m³ 24-hour mean established by the World Health Organization (WHO) have been observed during African dust (AD) incursions at the Caribbean region. Every year, during the summer month's long–range transported African dust (LRTAD) particles reach the Caribbean region. In order to have a better understanding of the impacts of AD incursions to climate and public health, aerosols samples were collected in the presence and absence of AD incursions during the summer of 2017. Aerosol samples were collected on Whatman 41 grade filters using a Hi-Volume (Hi-Vol) sampler for total suspended particles (TSP) at two sampling stations in Puerto Rico. The first station (marine site) is located at Cabezas de San Juan (CSJ) nature reserve in Fajardo, and the second station (urban site) at the Facundo Bueso (FB) building at the University of Puerto Rico-Rio Piedras campus. A ¼ of the aerosol sample filter was extracted in ultra pure water and then combusted at 500 ºC overnight from which the water-soluble ions (e.g., Na^+, NH_4^+, Ca^{+2}, Cl^-, SO_4^{-2}) and the concentration of dust particles were determined. Saharan Air Layer (SAL) imagery and the results from the air mass backward trajectories calculated with the NOAA Hybrid Single Particle and Lagrangian Integrated Trajectory Model (HYSPLIT) were used to monitor and confirm the presence of air masses coming from North Africa. Preliminary results demonstrated that the average dust concentrations at the marine station (CSJ) during AD incursions were about 6 µg/m^3. AD concentrations observed at CSJ reached values up to 15 µg/m^3 during AD incursions. LRTAD concentrations for the urban station, and ionic speciation results for the marine and urban sites will be presented at the conference.
Keywords: African dust concentration, aerosol water-soluble ions, mineral aerosol

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African dust impact on aerosol concentrations at two heights (2250 and 650 m asl) in SE Spain

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The simultaneous aerosol sampling at two heights in southern Spain may provide valuable information on the vertical structure of the dust transport from North Africa to the Iberian Peninsula. It also allows the characterization of the ambient air at two sites with distinct anthropogenic influence. This work presents the results obtained from the first field campaign of the FRESA project (Impact of dust-laden African air masses and of stratospheric air masses in the Iberian Peninsula. Role of the Atlas Mountains), performed in the period July-November 2017 at El Albergue Universitario in Sierra Nevada (2550 m a.s.l.) and the city of Granada (650 m a.s.l.). The two sites were instrumented with a low-volume sampler with PM10 inlet for daily sampling and mass and chemical composition characterization, a high-volume sampler for total suspended particles (TSP) for weekly sampling and radionuclide activity determination, and with a GRIMM 365 optical particle counter that provides continuously the aerosol size distribution.

In Sierra Nevada, daily PM10 concentrations ranged from 0 to 104 µg m^{-3} depending mainly on the origin and features of the air masses that reach this high-elevation site. Levels overpassed 50 µg m^{-3} during 5 days and were lower than 20 µg m^{-3} for 90 days over a total of 124 sampling days. The impact of dust-laden African airflows at this site is particularly intense as dust is transported in most of the cases within well-defined low mid-tropospheric layers. The associated episodic concentrations exceeded 40 µg m^{-3}. In turn, clean subsiding airflows associated to the polar jet strongly reduced concentrations.
In Granada, daily PM10 concentrations are moderately high with values generally between 20 and 40 µg m^{-3} before the first snows fall over Sierra Nevada. Levels were over 50 µg m^{-3} on 2 days and below 20 µg m^{-3} on 32 days over a total of 103 sampling days. The highest concentrations do not reach the peaks found at Sierra Nevada. The impact of anthropogenic aerosols of local origin, which are accumulated during high-stability conditions, and also of regional origin (both from the Mediterranean and from the SW Iberian Peninsula) is significant. The contribution of African dust outbreaks superimposes to background ambient air concentrations and in some events the increase is observed one day after the African dust impacts over Sierra Nevada. After the first snowfall of the year in Sierra Nevada, there's a change in wind regime, PM10 levels drop and only accumulation periods or African dust events are able to increase concentrations at levels similar to those detected before.
The diurnal pattern of PM10 and particle number concentrations (both of the fine and the coarse fractions) at Granada presents the two typical peaks in the morning and evening; there's one peak at 16 Local Time - LT in Sierra Nevada. Particle concentrations are smaller in the colder period than in the warmer one, primarily due to the much higher concentrations in the coarse fraction (> 1 µm) in summertime. However, the fine fraction (submicronic) presents a stronger morning peak (centered about 10 LT) in the colder period and also concentrations are slightly higher at about 20-21 LT.

Trajectories (calculated 96-hour backward in time starting at 00, 06, 12 and 18 UTC with HYSPLIT using ERA-Interim data of 0.5 degree resolution) show that air flows are quite often decoupled at the two altitudes. Dust-laden African flows reached Sierra Nevada on 33 days; of these, dust was advected poleward over the Atlas near the Algerian-Moroccan border on 19 days and on the remaining 14 it followed a pathway over the Atlantic close to the Moroccan coast. However, only on 3 days large-scale flows of African origin reached Granada. In turn, airflows reaching Granada passed previously over the western Mediterranean Sea on 32 days while only on 3 days Mediterranean flows reached Sierra Nevada. Moreover, the total residence time over North Africa of the air parcels reaching Sierra Nevada amounts 9474 hours, and during the corresponding days the total residence time over the Mediterranean of the parcels reaching Granada is 10,055 hours. In contrast, the residence time of the air masses arriving to Granada after residing over Africa is only of 56 hours. This implies that during African dust outbreaks the air masses reaching the study area at the lowest levels do not have African origin but have resided over the Mediterranean, and it is in accordance with Cabello et al. (2017) for Málaga and Orza et al. (submitted) for the whole Spanish Mediterranean. Chemical analysis of the PM10 samples (in progress) will provide the first direct experimental evidence of this fact.

The identification of episodes was done by analysing the fine and coarse fractions registered with the Grimm OPCs at the two sites and by the aerosol optical depth (AOD) and Angström exponent (AE) from the AERONET station of IISTA-CEAMA in Granada, in combination with back-trajectories. The low availability of satellite information (Dust RGB product and MODIS aerosol properties) is a major limitation at the study area.

A number of distinct episodes can be identified: strong African dust impact at Sierra Nevada while Granada is heavily polluted by anthropogenic aerosols (1 August 2017); strong African dust impact at Sierra Nevada which is observed the following day in Granada (15-16 August 2017); African dust outbreaks impacting simultaneously both sites (e.g., 25 November 2017); episode of accumulation of pollutants at Granada whilst very low concentrations are registered at Sierra Nevada (19-24 November 2017); impact of remote fires at both sites (27 July and 9 September 2017) and fair air quality at both sites (e.g., 16 September 2017).
Differences in the onset and duration of the African dust episodes are found between the two sites as well as between the surface and the columnar measurements.

Keywords: African dust, dust transport, air quality

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Air quality in La Paz metropolitan area

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We present here results of the chemical characterisation of PM_{10} during a year period at two sites in the metropolitan area of La Paz, a populated city located in the Andes at an altitude of 3,200-4,000 m a.s.l. Results demonstrated a high correlation between the two sites, despite the different altitude. PMF model permitted to identify 7 sources impacting PM_{10} concentrations with a higher contribution of mineral dust and traffic related sources.

La Paz Metropolitan area, which is formed by La Paz, El Alto and Viacha, with a population of 2.3 million, is the highest major metropolis in the world. Atmospheric research in this area has a great interest given its peculiarities with two major population centres located at high altitude. La Paz, set in a canyon created by the Choqueyapu River, is the highest capital city in the world, at an elevation of roughly 3,650 m a.s.l. El Alto, one of Bolivia's fastest-growing urban centres with a population of around 1,000,000 inhabitants, is spread over a broad area to the west of the canyon, on the Altiplano highlands with an average elevation of 4,150 m a.s.l. Atmospheric pollution in La Paz Metropolitan area is mainly related to the increase of road traffic emissions (more than 1.5 million vehicles registered in 2012). The high altitude may undoubtedly influence the combustion processes affecting the composition of the vehicle exhausts. The main objective of this campaign is to identify the sources affecting air quality in the Metropolitan area of La Paz and El Alto.

The study was conducted at two monitoring sites: 1) Pipiripi, a urban background site located in La Paz, at 3600 m a.s.l., and 2) Aeropuerto background site, located in the Airport in El Alto at 4,000 m a.s.l. PM_{10} sampling was performed simultaneously at the two sites for a year period, from April 2016 to April 2017, with high-volume samplers (MCV 30 m3/h) using 150mm quartz fibre filters (Pallflex), with a frequency of one 24h filter every three days. Concentrations of inorganic and organic components (more than 150 components) were determined by different techniques at the laboratories of LCME, LGGE and IDAEA. The concentration database was used for a PMF analysis.

Average annual PM_{10} concentrations were 34 $\mu g/m^3$ at Aeropuerto-El Alto and 30 $\mu g/m^3$ at Pipiripi-La Paz. There is a high correlation between daily concentrations of PM_{10} registered at Pipiripi and Aeropuerto (R^2=0.81). Results evidenced the high contribution of dust to PM_{10} at both sites (36% at Pipiripi and 45% at Aeropuerto). The organic matter (OM) accounts for 28% of PM_{10} at Pipiripi and 22% at Aeropuerto. PMF permitted to identify 7 different sources to PM_{10}. PMF corroborated the importance of dust contribution, related to soil wind and vehicle resuspension, in the area. Biomass combustion has a low contribution at the two study sites. Two sources of fuel combustion are identified with inverse contribution at the two sites showing different vehicle patterns or unlike industrial or domestic emission sources.

Air pollution is an emerging environmental problem in La Paz Metropolitan area. Dust resuspension and traffic emissions are the major contributors to PM in the area. An external contribution of biomass combustion cannot be discarded. This information is useful to provide data for exposure studies, to help plan abatement measures and provide the baseline for future studies. Further research on the evaluation of the health impact of atmospheric pollutants at this altitude is needed.

Keywords: source contribution, dust resuspension, soil wind resuspension, road dust resuspension.

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The influence of Saharan dust intrusions on atmospheric metal concentrations at a Mediterranean urban site

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Between February 2015 and February 2017, PM_1 and PM_{10} daily samples were collected three times a week at a traffic site in the urban center of Elche (southeatern Spain). Samples were subsequently analyzed by Energy Dispersive X-Ray Fluorescence (ED-XRF) in order to determine the concentrations of major and trace metals.

Average levels were calculated for days under the influence of Saharan intrusions and non-event days. The results obtained for the PM_{10} fraction are shown in Fig. 1. Similar outcomes were obtained for PM_1, although the relative increases in metal concentrations during Saharan outbreaks relative to non-event days were lower. The transport of mineral dust from the Sahara Desert had an outstanding impact on Ti concentrations at the sampling site (the relative increase was higher than 400%). Other crustal elements such as K, Fe and Mn also showed significant increases (> 150%). The substantial increment in V levels could be due to its presence in soil dust or to the transport of anthropogenic pollutants by Saharan dust plumes.

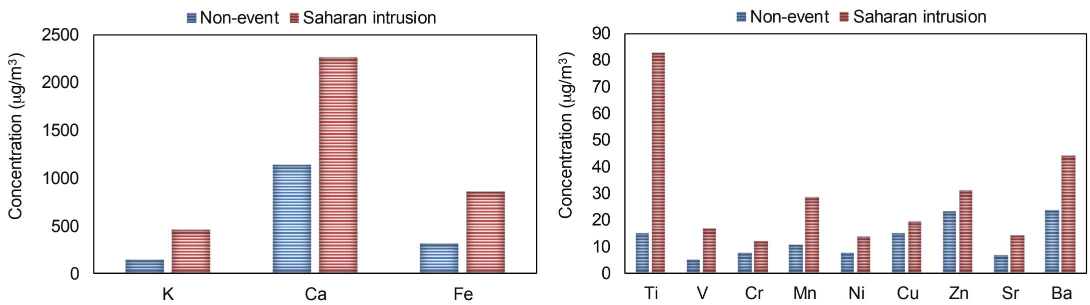

Fig. 1. Average concentrations of metals associated to PM_{10} for Saharan dust outbreaks and non-event days.

The concentrations of other metals originating from earth crust erosion, namely Ca, Sr and Ba, approximately doubled during Saharan outbreaks. This increase, although significant, was lower than that observed for Ti or K. These results are consistent with the reduction in the Ca/Ti ratio during African episodes that has been observed at a regional background site located at Mt. Aitana, approximately 55 km northeast from Elche (Galindo et al., 2017). Zn and Cu, which are mainly emitted from tyre and break wear (Pant and Harrison, 2013), showed small increases compared with the other elements analyzed in this work.

Enrichment factors (EFs) are commonly to estimate the relative contribution of soil dust to metal concentrations in the air (Padoan et al., 2016). The EFs of elements in aerosols are calculated as:

$$EF_x = (X/R)_{sample}/(X/R)_{crust}$$

Where X represents the element considered and R is a reference element for crustal material. Therefore, $(X/R)_{sample}$ is the concentration ratio between both elements in the aerosol sample and $(X/R)_{crust}$ is the average concentration ratio in the upper continental crust. In the present study, Ti was used as a reference element to calculate EFs in PM_1 and PM_{10} (Fig. 2, Galindo et al., 2017).

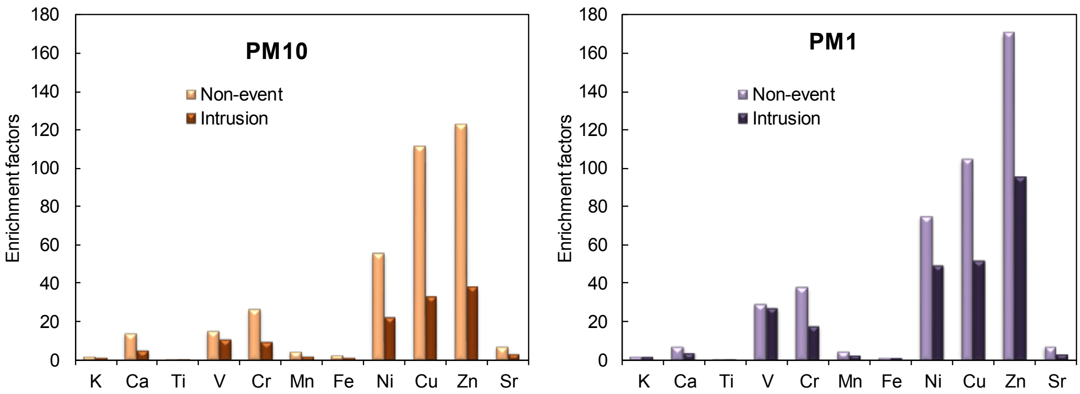

Fig. 2. Enrichment factors of metals on Saharan and non-event days.

EF values for K, Mn, Fe and Sr were lower than 10 during both intrusion and non-event days, indicating that these elements are mainly of crustal origin. In contrast, Ni, Cu and Zn presented EFs considerably higher than 10, in particular during non-event periods, clearly pointing to anthropogenic emissions. Regarding Ca, V and Cr, these elements seem to be associated with both human activities and natural sources. The contribution from anthropogenic sources to the levels of trace metals were in general higher for PM_1 than for PM_{10}, except for typically crustal elements. EFs calculated for the PM_{10} fraction in the present study were considerably larger than those reported for Mt. Aitana (Galindo et al., 2017), especially for Cu, Zn Cr and, to a lesser extent, Ni. This result confirms the important contribution of local anthropogenic emissions to the levels of these elements in urban areas.

Keywords: PM_1, PM_{10}, metals, mineral dust, enrichment factors.

Acknowledgements
We thank the Elche City Hall for allowing access to their facilities and the Elche Traffic Office for supplying data. This work was partially supported by the I+D+I National Plan of the Spanish Government under the CGL2012-39623-C02-2 (PRISMA) project and by the Generalitat Valenciana under the GV/2017/199 (FAME) project.

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Changes in elemental mass-size distributions due to Saharan dust outbreaks

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The Saharan Outbreaks (SO) impacts are common and frequent in the European Mediterranean regions. It has been observed that SO cause an increase in environmental levels of airborne particles. In urban and suburban areas is sometimes masked by the contributions of particulate matter from anthropogenic sources. This is particularly significant to study the effect of the air African masses over the elemental mass-size distribution of some characteristic metallic elements.
The objective of this work is to evaluate the variation of atmospheric concentrations of metallic elements when the SO impacts over a point located at a Mediterranean regional background site. The effect of the event can be easily quantified, due to the low levels of suspended particles for the typical weather conditions in the area.

In order to measure the aerosol elemental mass-size distributions during SO impacts and to compare them with those on a "normal day" (ND), a Dekati cascade small-deposit area low-pressure impactor (SDI) was used. This sampler classifies airborne particles, from 30 nm up to 10 µm, into 12 size-fraction small deposit area stages.
Particulate matter samples were collected during 48 h period for a) SO and b) an average normal (non SO) day (ND). The impactor samples were chemically analysed by Proton-Induced X-ray Emission (PIXE). The raw chemical concentration-size data (mass per stage and per m3) was processed with an inversion procedure (code MICRON) to generate smooth modal mass-size distributions for more than 20 elements: Na, Mg, Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Cu, Zn, As, Br, Ba, Pb, Ni, Rb, Sr y Zr.

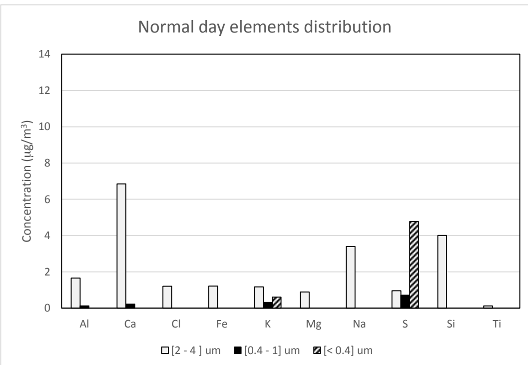

Figure 1a

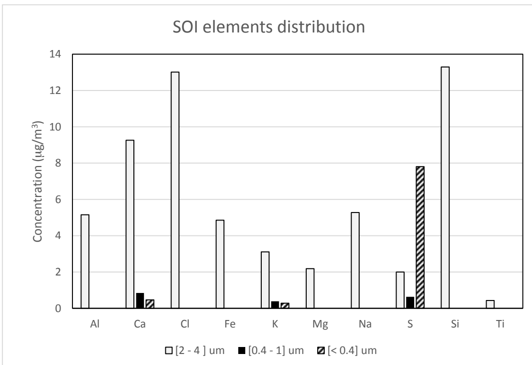

Figure 1b

Fig. 1. Comparison of concentrations between normal days and days affected by SOI's.

Element Mass-size Distribution

Results show that during Normal Day (ND) crustal/marine elements, like Na, Mg, Si, Al, Cl, Fe, Ti, Ca, Mn, Sr (Figure 1) had mainly a unimodal coarse size distribution with geometric mean aerodynamic diameter (GMAD) of about 3 µm and atmospheric concentrations above 1µg/m^3. The highest concentrations were obtained for Ca, Si and Na. A second group of elements, associated with anthropogenic origin, were also present in the fine size range but only S and K with significant concentrations. S exhibits trimodal mass-size distribution which peaks at about 3.0 µm, 0.7 µm, and 0.2 µm GMADs, respectively with relative high concentration in the accumulation mode (4.8 mg/m^3). K presents smaller concentration and also exhibits trimodal distribution which peaks (1.1 mg/m^3) at about 3.5mm.

Mode mass concentration increased in general throughout SOI, depending on element and mode. Mostly Crustal/Marine elements increased coarse mode concentration by a factor between 2 and 3. Particularly, Fe and Ti, specific indicators of Saharan events, raised their coarse mode concentration in a factor of 4 during SOI. The element with the highest relative increment in the coarse mode was Cl, from 1.2 ng/m^3 up to 9.3 ng/m^3, a factor of 8. Probably due to the trajectory of the African air mass approaching the Spanish coast from the Mediterranean Sea.

It can be seen from Figures 2 that there were different types of distribution profiles. The first group is formed by Crustal/Marine origin elements and it is characterised by a unimodal size distribution, coarse mode, with elevated concentration levels.

Crustal elements, figure 2b, do not basically change the distribution profile during SO, showing also a main coarse mode with greater concentration.

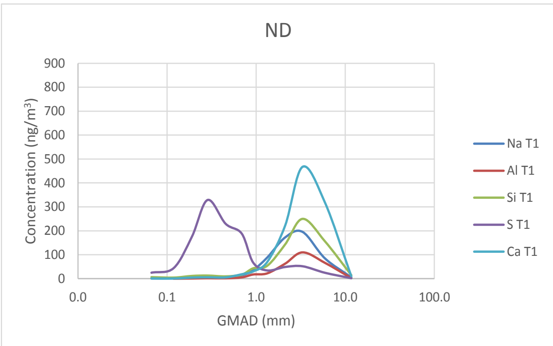

Figura 2a

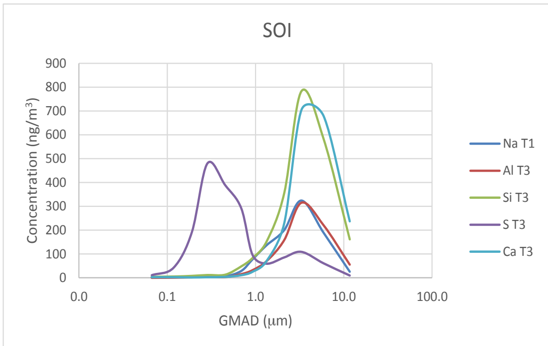

Figure 2b

Fig. 2. Mass-size distributions for different elements during "Normal days" and with SOI's.

S has a special behavior, as shown in Figure 2. The distribution, both ND and SOI profile is trimodal, with GMAD equivalent in both cases. It noted an increase in concentration of magnitude approximately constant in the entire range of sizes. It could be interpreted as that the mechanism of generation of compounds of sulfur in the air is the same for ND and SOI.

Keywords: mass-size distribution, metals, mineral dust,

Acknowledgements
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African dust and biomass combustion impact on mortality in Spain

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Mineral aerosols may greatly increase the ambient levels of PM_{10} (particulate matter lower than 10 µm) recorded in monitoring sites in southern Europe by means of long-range transport episodes of desert dust. The main goal of this work was to examine the effect of African dust events on daily mortality in different Spanish regions. It should be noted that African dust episodes and wildfires happened simultaneously in most of the Spanish regions, because both types of events occurred mainly in summer, on days with high temperatures and under the same synoptic meteorological situations (Díaz et al., 2017). Since PM_{10} emissions from biomass combustion during wildfires can be highly significant, we also estimated the impact on daily mortality during days with biomass advections in the same regions, with the aim to differentiate between the respective effects of both types of natural events.

For determination of days with African dust (AFR) and biomass (BIO) advections, we used information supplied by the Spanish Ministry of Agriculture and Fisheries, Food & Environment (MAPAMA), which divides Spain into 9 main areas: North; North-east; North-west; Centre; South-west; South-east; Levant; Balearic Isles; and Canary Islands. In each of these regions, a representative province was selected on the basis of the availability and quality of the air pollution and mortality data. A time series analysis was performed to analyse the relationship between daily mortality and PM_{10} levels in the period 2004-2009, using Poisson regression and stratifying the analysis by the presence or absence of AFR and/or BIO. The independent variable was daily mean PM_{10} concentrations measured in $\mu g/m^3$. As control variables, we used the mean daily concentrations of SO_2, NO_2 and O_3, obtained from the same site as those corresponding to PM_{10}. We also controlled for the effect of the maximum daily temperature in heat waves. Maximum (Tmax) and minimum daily temperature (Tmin) data for each provincial capital were provided by the State Meteorological Agency (Agencia Estatal de Meteorología/AEMET). The dependent variable was daily mortality due to all causes except accidents: "natural-cause" (International Classification of Diseases 10^{th} Revision (ICD-10: A00-R99) for the period 2004–2009 in Spanish towns of over 10,000 inhabitants, grouped by provincial capitals and by geographical location into the 9 main areas.

The frequency of AFR during the period of study ranged from 9.6% (North-west) to 30.1% (South-east). The frequency of BIO was lower than AFR. It ranged from 0% (Canary Islands) to 8.5% (North-west). The simultaneous development of BIO and AFR accounted for 13% to 100% of all BIO, depending on the region. In all regions, the concentration of PM_{10} increased statistically significantly when AFR happened. The statistical analysis with Poisson regression was performed on the data sets corresponding to the representative province of each region (Díaz et al., 2017). The impact on daily mortality for PM_{10} was higher during AFR than on days without African dust contributions in the North-west, Centre and South-west regions (Table Ia). The results obtained also indicated that daily mean PM_{10} concentrations were significantly higher on BIO than on days without biomass advections at most of these regions (Linares et al., 2018). Furthermore, PM_{10} was associated with higher daily mortality on BIO during the whole year in regions where wildfires were most frequent (the North-west, Centre, South-east and South-west regions) but not in the remaining provinces (Table Ib). When those BIO on which there were also African dust contributions were excluded from the analysis, the association between PM_{10} and daily mortality remained for the Centre and South-west regions, but with a lower effect (Table Ib).

Table I. Relative risks (RR) for PM_{10} concentrations that proved statically significant in the Poisson regression models fitted for each provincial capital in the respective regions considered, for the whole year. RR is calculated for PM_{10} increases of 10 μg/m^3. AR (Attributable Risk)

Table Ia	AFR days		Non-AFR days	
Region	RR (95% CI)	AR(%) (95% CI)	RR (95% CI)	AR(%) (95% CI)
North	-	-	1.006 (1.000-1.012)	0.63 (0.004-1.22)
North-east	-	-	-	-
North-west	1.05 (1.024-1.077)	5 (2.36-7.71)	-	-
Centre	1.007 (0.999-1.015)	0.67 (−0.12 to 1.46)	-	-
South-east	1.006 (1.000-1.012)	0.58 (0.00-1.18)	1.010 (1.002-1.018)	1.00 (0.21-1.79)
South-west	1.009 (1.004-1.015)	0.94 (0.35-1.53)	1.007 (1.003-1.011)	0.70 (0.31-1.09)
East	-	-	-	-
Canary Islands	-	-	-	-
Balearic Islands	-	-	-	-

Table Ib	BIO days		BIO days but without AFR days	
Region	RR (95% CI)	AR (%) (95% CI)	RR (95% CI)	AR (%) (95% CI)
North	-	-	-	-
North-east	-	-	-	-
North-west	1.079 (1.024-1.138)	7.93 (2.36-13.81)	-	-
Centre	1.038 (1.014-1.062)	3.76 (1.36-6.22)	1.034 (0.999-1.070)	3.41 (-0.08-7.02)
South-east	-	-	-	-
South-west	1.045 (1.030-1.059)	4.46 (2.99-5.94)	1.027 (1.000-1.054)	2.67 (0.02-5.39)
East	-	-	-	-
Canary Islands	-	-	-	-
Balearic Islands	-	-	-	-

It can be concluded that adverse effects on health (increases in daily mortality) of mineral dust and PM_{10} emissions from biomass burning are independent and additive in many Spanish regions and comes in addition to the harmful environmental effects (local pollution, high temperatures,…) that already exists in major cities. While many studies have considered the effect on health of African dust previously, the analysis conducted here broken down by region and city, makes it especially relevant in the research background, indicating that mineral dust may be a risk factor for daily mortality and that it may increase when wildfires take place at the same time.

Keywords: PM_{10}, African dust events, daily mortality, wildfires.

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Saharan Dust and Pediatric Asthma in the Eastern Caribbean

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Fine particulate matter (PM), is detrimental to human health, and the PM10 concentration in the Caribbean consistently exceeds the World Health Organization (WHO) guidelines during Saharan dust events. Trans-oceanic transport of Saharan dust may be contributing directly to the high incidence of asthma in the Caribbean, as small inhalable PM ≤10 µm can easily enter the lungs and exacerbate asthma. Asthma is a major cause of morbidity in the Caribbean (Monteil et al, 2008) and for unknown reasons the Caribbean has the highest rate of pediatric asthma cases in the world (Howitt, 2000). There is a suggestion that the increasing rate of asthmatic attacks correspond to an increase in the amount of Saharan dust reaching the islands (McCarthy et al, 2001). Cadelis et al (2014; Guadeloupe) showed for the first time that particles $PM_{2.5}$ & $PM_{2.5\text{-}10}$ contained in Saharan dust increased pediatric asthmatic emergency room visits. The objectives of this study are to determine if Saharan dust events result in an increase in the number of asthmatic episodes in the pediatric population of the Eastern Caribbean islands, if there is variation in the dust mineralogy, and if there is a correlation between mineralogy and asthma incidence. This the first study undertaking a multi-island analysis in the Caribbean of Saharan dust and pediatric asthma as well as any potential mineralogical contribution to asthma risk.

This study examines asthma treatment data for Dominica, St. Lucia, St. Vincent and Grenada. The data for Dominica and St. Vincent were collected for the period January 2015 to June 2017. Ethics approval was time consuming and data for the same period will be collected for St. Lucia and Grenada in February 2018. Final data collection for all the islands will be obtained for the period July 2017 to December 2018 at the end of the year. Saharan dust days will be determined by analysis of satellite MODIS data for each of the islands. Studies have shown a reasonable correlation between surface in situ measurements and satellite analysis (Hu 2009). In addition, daily in situ PM 2.5 & 10 values will be recorded daily in St. Lucia and dust samples collected. The samples will be characterized chemically and minerologically using scanning electron microscopy (SEM) and x-ray diffraction (XRD) analysis. Preliminary analysis for this abstract utilized data retrieved from the NASA affiliated AERONET sites on Guadeloupe (96.4 kilometers North of Dominica) and Barbados (190 kilometers to the East of St. Vincent).

Preliminary analysis of the asthma patient data from two of the four islands, Dominica (n= 1317) and St. Vincent (n=1620) showed more males were affected than females (54% males to 46% females) from January 2014 to June 2017. This is in keeping with previous studies in the region by Cadellis et al (2014) (males 60% vs females 40%) and Gyan et al (2005) (males 61% and females 39%). The major Saharan dust events occurred during the summer months for both islands extending from May to September, but there was also an unusual dust event in January to March of 2016 which was not seen in 2015 or in 2017. No obvious visible correlation between the major summer dust events are observed in either of the islands during 2015 and 2016, but there was a quantitative temporal correlation to the dust event of 2016.

There are several factors that need to be considered in the apparent lack of correlation during the summer when the major dust events occur, including climatic variables, pollen levels, and summer vacation from school; students may leave the urban region where the data was collected, and are treated in rural communities. Another contributing factor may be related to the annual variability in the source and

distribution of Saharan dust and mineralogy; something that this study aims to try to identify using samples collected from the islands over the upcoming year.

In any event, direct correlation of near-ground dust density and pediatric asthma incidence is complex. Other cultural or seasonal factors may amplify Saharan dust effects. If the character of Saharan dust days continues to change in the Caribbean, these amplification factors may prove to be important influences on morbidity in the pediatric population.

Keywords: Saharan Dust, dust, asthma, pediatric asthma.

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Cumulative and intense exposure to Saharan dust days and respiratory emergency hospital admissions in the Canary Islands

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Background
The proximity of the Canary Islands to the Northwestern Coast of Morocco (100km) and the regional atmospheric circulation result in an ideal scenario for the transport of African dust from Sahara and Sahel regions towards Canary Islands ("Saharan dust intrusions"). Therefore, this issue is of relevance for their citizens due to the intensity and frequency of these events, that involves their exposure to natural dust and its interaction with local pollutants. These intrusions can last for one or more days (episodes), reaching occasionally daily average levels higher than 600 µg/m^3 of PM_{10} and 250 of $PM_{2.5.}$

Aims
The aim of this study was to analyze in detail the short-term association between days with Saharan dust intrusions (Saharan dust days, SDD) and emergency hospital admissions for respiratory diseases in the cities of Las Palmas de Gran Canaria (LPGC) and Santa Cruz de Tenerife (SCTF) during the period 2001 to 2005
Methods
An ecological study of longitudinal time series (from 2001 to 2005) was performed and generalized additive models were adjusted, controlling for potential confounding variables. The effect of concurrent SDD and their intensity [SDDs with low levels of PM10 (<50µ/m^3), medium (50-150) and high (> 150)], as well as polynomial distributed lag models [PDLM]) were assessed.
Results
561 SDDs (31% of total days) were identified in LPGC, 25 of them were “heavy SDDs” and 591 (32%) in SCTF, with 38 “heavy SDDs”. A SDD associated with a risk of 22.6% (95% CI 10.4, 36.0) and 29.9% (6.6, 58.4) of being hospitalized by all respiratory and chronic obstructive pulmonary disease (COPD) admissions respectively in SCTF during the concurrent and the 5 consecutive days. During “heavy SDDs” the risk increase was 29,1%(6,3-56,8) and 83,4%(32,2-154,3) respectively and 53,7%(3,8-127,7) in LPGC for COPD.
Conclusions
We found a short-term impact of SDD on emergency hospital admissions for respiratory diseases in both cities that spread over several successive days and that are higher during SDDs with high PM10 levels (>150 µ/m^3). The SDDs and their episodes, should not be considered a natural phenomenon benign to health. Anthropogenic pollution must be thoroughly controlled in these urban areas, seasonally exposed to these episodes. Health information and education measures (collective and individual) as well as management and planning of health services must be implemented to deal with these episodes.

Keywords: Saharan dust, hospital admissions, respiratory diseases, particulate matter, time-series, generalized additive model, African air intrusions

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Real-world efficiency of commercial face masks to reduce personal PM exposure

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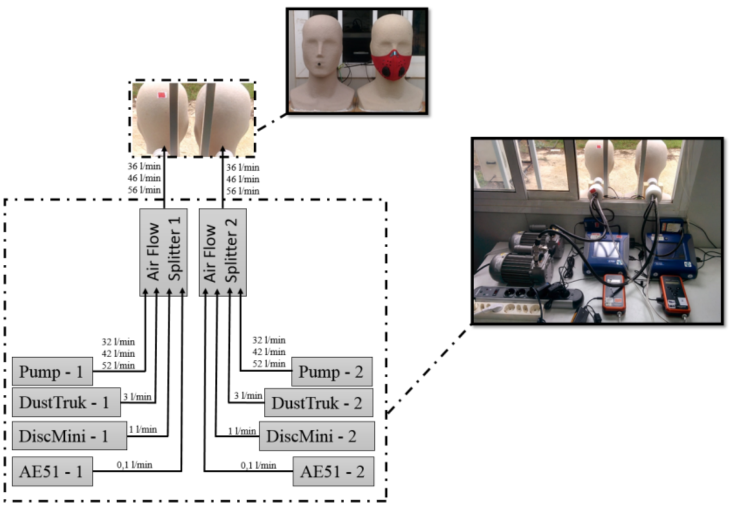
The high concentrations of dust and other atmospheric particulate (PM) pollutants in cities induce people to consider protecting themselves through the use of face masks, mostly for those who commute walking or by bicycle. However, very little is known details regarding the actual efficiency of the face masks to reduce exposure to ambient air PM are until today limited. In this study we evaluated the efficiency of nine commercial face masks (EU market) on real-world (urban background) exposure to PM2.5, ultrafine particles (UFP), black carbon (BC) and lung deposited surface area (LDSA). Face masks were tested using 2 dummy heads (1 with face mask, 1 without), both equipped with an inlet tube and an air flow splitter for the simultaneous monitoring of PM2.5 (DustTrack), BC (AE-51 mini-aethalometer), UFP and LDSA (Discmini TESTO). Efficiencies were tested at three different minute-ventilation rates in order to cover a comprehensive range of breathing scenarios. Duplicate instruments were inter-compared several times during the study and also run simultaneously and in proximity to other instrumentation (CPC, MAAP and GRIMM) of the official monitoring site of Palau Reial in Barcelona (Spain).
Results showed a mean facemasks efficiency for $PM_{2.5}$ in a range of 51-97% with a median value equal to 65%. For others metrics (UFP, LDSA and BC) efficiencies were lower, showing median values below 30% in a range of 5-65 %.



Keywords: dust, UFP, BC, exposure reduction, commuting.

Impact of long-range transport of dust on in-situ measurements of particulate matter and ozone – case study: Austria

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Mineral dust from desert area is an important source of natural aerosol. Under weather conditions, dust particles can be lifted in the atmosphere and can be transported over long distances due to atmospheric circulation. In the lower atmosphere, large mineral aerosol particles can strongly influence the concentrations of atmospheric trace gases (including ozone) and of particulate matter (PM). The aerosols are removed from the atmosphere through settling and dry and wet deposition. For in-situ measurements, the level of PM is a result of both dust from long-range transport and PM from local sources. If PM from local sources can be estimated, the difference of PM concentration can be attributed to transported aerosols.

The purpose of this analysis is to determine the correlations between the long-range transport of mineral dust over Austria and in-situ measurements of PM10, PM2.5 and ozone, using selected dust transport events recorded over Central Europe in the period May - June 2017.

The study has been performed for Illmitz, Austria (47°46'N, 16°48'E), an EMEP regional background site for reactive gases and aerosols, which provides daily mean concentrations for PM10 and PM2.5 and maximum daily ozone measurements.

Two cases of long-range transport of mineral dust over Austria were identified in the analyzed period using measurements from AERONET stations from and close to Austria: Vienna-BOKU, Vienna-UNIVIE, Munich, Leipzig. From these measurements, the aerosols optical properties (aerosol optical depth AOD, Angstrom exponent AE, single-scattering albedo) and aerosol size distributions have been retrieved. When the measurements were not available, the properties have been retrieved from MODIS satellite data. One can estimate the surface PM2.5 mass concentration from the AOD and profile of temperature and humidity using multiple linear regression, with the assumptions that the boundary layer is well mixed and there is no significant aerosol aloft in regions dominated by small particles (AOD > 0.15).

The regression coefficients were computed for four consecutive days, starting one day before the dust event occurs, using the measured daily averaged values for PM2.5, AOD at 500 nm, and the temperature and relative humidity profile. The meteorological fields are taken from ECMWF's ERA-Interim reanalysis, with a spatial resolution of 0.5º x 0.5º, 61 vertical levels from the surface to 150 hPa, and a time resolution of 3 h. Hourly averaged PM2.5 concentrations have been computed using these regression coefficients and the hourly averaged AOD at 500 nm retrieved from AERONET, when the dust events occurred. A good correlation was obtained between concentrations of PM2.5 measured in-situ and PM2.5 estimated from AOD measurements. An increase of ozone concentrations over 130 $\mu g/m^3$ was observed at the in-situ station during both dust cases selected. The correlation between dust concentration and ozone concentration is, however, smaller.

Starting from the aerosol concentrations measured at Illmitz, split for each time interval according to the concentrations of PM2.5 modelled, the source-receptor sensitivity was computed using the Lagrangian transport model FLEXPART, run in backward mode for a transport time of five days for.several receptor heights, ground level and 1500 m (850 hPa level), 3000 m (700 hPa level) and 5500 m (500 hPa level). The source-receptor sensitivity shows the likely source of the aerosol is the Sahara desert.

We obtained a correlation coefficient between PM2.5 derived from AERONET and ozone concentrations measured at Illmitz of 0.71 for the first case and 0.75 for the second case. The correlation coefficient between the Angstrom exponent (AE) and ozone concentration was 0.15; as the AE depends on the aerosol size, it is not possible to establish a relation between aerosol size and ozone concentration.

In conclusion, the surface ozone and PM concentrations in Austria are strongly influenced not only by local, anthropogenic aerosols but also by long-range transported aerosols and ozone: air pollution is a global problem, requiring global solutions.

Keywords: Dust, ozone, particulate matter, aerosol optical depth, Lagrangian transport model.

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We thank the PI investigators and their staff for establishing and maintaining the four AERONET sites used in this investigation.

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DUST COMPOSITION AND PROPERTIES

Mineral dust in fine and coarse particles in Beijing during APHH-China campaigns

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APHH-China (Atmospheric Pollution and Human Health in a Chinese Megacity) is a major international collaborative research programme to examine the emissions, processes and health effects of air pollution in a developing megacity in China. The overall aim of APHH-China is to better understand the sources, atmospheric transformation and health impacts of air pollutants in the Beijing megacity and to improve the capability of forecasting air quality and developing cost-effective mitigation measures. APHH-China had two major field campaigns in Beijing, one in Nov-Dec 2016 and one in May-June 2017.

During these APHH-China campaigns, we collected daily fine ($PM_{2.5}$) and coarse ($PM_{2.5-10}$) samples on the PTFE filters using the Partisol 2025 Dichotomous Sequential Air Sampler. The samples were analysed by X-ray Fluorescence spectroscopy (XRF) for crustal elements and Inductively Coupled Plasma – Mass Spectrometer (ICP-MS) for trace metals. An online Horiba XRF was also deployed during the campaigns, providing hourly resolution data on major and trace elements in $PM_{2.5}$. In addition, we collected hourly $PM_{2.5}$ and $PM_{2.5-10}$ samples with streaker samplers, which were analysed by Proton-Induced X-ray Emission (PIEX) for major and trace elements.

The mean daily concentration of fine and coarse at the urban site of Beijing was 92±66 µg/m^3 and 37±28 µg/m^3 during the winter campaign. The average concentrations of Ti, Fe, Si and Al in the fine particles were 40, 680, 910 and 531 ng/m^3, respectively. Estimated concentration of soil dust ranged from 1.3 to 13.2 µg/m^3, which contributed an average of 64% to $PM_{2.5}$ mass, while the contribution of trace metals in the fine particles was 0.7%. Ratios of the crustal elements between coarse and fine particles was 1.9, 2.6, 3.5 and 2.3 for Ti, Al, Si and Ca. The contribution of mineral dust to coarse fraction was up to 39%. Polar plots suggest that the most likely source of soil dust was from the local emissions. Crustal elemental concentration peak at daytime in the diurnal pattern, which indicates that dust emission is associated with anthropogenic activities.

Further sample and data analyses are ongoing to provide a quantitative source apportionment of soil dust to fine and coarse particles in Beijing.

Keywords: $PM_{2.5}$; aerosol; crustal elements; trace metals

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Atmospheric transport of mineral dust associated with anthropogenic elements in marine aerosol over the Indian Ocean

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In the Indian subcontinent, release of anthropogenic substances into the atmosphere has been rapidly increasing due to rapid population growth and urbanization, and air pollution in the region has become seriously worse. A large amount of mineral dust and anthropogenic substances is expected to be transported and deposited from the continental region to the coastal area of the Indian subcontinent and the open Indian Ocean, where would impact biogeochemical cycles of the trace metals in the marine environment. However, observations of chemical composition in atmospheric aerosols are scarce in the Indian Ocean. In particular, few studies reported trace metal elements in the atmospheric aerosols over the southern Indian Ocean.

In this study, a shipboard observation of atmospheric aerosols over the North and South Indian Oceans was conducted during the R/V Hakuho Maru reseach cruise (Nov. 2009 – Jan. 2010), which covered almost entire Indian Ocean including near Antarctic region (70°S).

Generally, elemental concentrations of both natural and anthropogenic origins were several times higher in the North Indian Ocean than those in the South Indian Ocean. Average concentrations of Al and Zn over the Arabian Sea, where ~ 500 km away from the Indian continent, were 670 ± 240 and 28 ± 11 ng m^{-3}, respectively. On the other hand, they were 58 ± 43 and 0.2 ± 0.1 ng m^{-3} in the South Indian Ocean, respectively. Not only anthropogenic Zn, but also natural crustal Al was high over the Arabic Sea, suggesting that both natural mineral and anthropogenic aerosols were outflowing from the Indian subcontinent to the northern Indian Ocean. The low concentrations observed in the South Indian Ocean were similar to those observed in the central North Pacific Ocean, which are considered as background concentrations (Uematsu et al., 1983). This clearly reflects the isolation of northern and southern hemispheres by ITCZ and the hemispherical difference in the strengths of natural and anthropogenic aerosol emissions.

Keywords: Indian Ocean, mineral dust, anthropogenic elements, marine aerosol, transport.

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Sr-Nd isotope composition of Saharan dust observed in the North Atlantic free troposphere

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In this work, we present a preliminary characterization of Sr-Nd isotopes in TSP (total suspended particles) in the Izaña Atmospheric Observatory (IZO, Canary Island). The main interest of the study is to determinate the Sr-Nd isotopic composition of TSP under the influence of North African dust outbreak, in order to characterise the source of Saharan dust. The strategic location of IZO (2400 m a.s.l., North Atlantic free troposphere) allows to obtain the pristine isotopic source of the North African aerosol without the interference of other natural or anthropogenic sources. Sr-Nd isotopic characterization of atmospheric aerosols has been considered as a key methodology in the determination of source area (e.g. Abouchami et al. 2013; Pourmand et al. 2014, Bozlaker et al. 2017).
A total of 19 samples were collected on quartz fibre filters with high volume samplers (40 m^3 h-1) MCV in summer 2015 at IZO. In order to avoid the influence of local breeze, the sampling has been performed during the night, between 22:00 - 06:00h GMT.
Major and trace elements were analysed by ICP-OES and ICP-MS respectively (CIQSO, University of Huelva). Secondary inorganic compounds (SO_4^{2-}, NO_3^- and NH_4^+) and Cl were determined by Ion Chromatography. SUNSET instrument was used for the analysis of organic and black carbon. Analysis of NIST 1663b were analysed simultaneously in the same run than the filters in order to assess the quality control of ICP analysis. Accuracy and precision were better than 5-10% for most analysed elements.
Sr and Nd isotopes have been analysed in 4 representative samples (7th, 11th and 12th August and 3rd October 2015). The samples were prepared before to Sr and Nd purification using ion extraction chromatography. The samples were analysed into a Thermo Neptune MC-ICP-MS (SGIKER, Basque Country University). The accuracy and reproducibility of the method is verified by periodic determinations under the same conditions of the certified reference material NBS 987 (^{87}Sr/^{86}Sr ratio) and JNdi-1 (^{143}Nd/1^{44}Nd ratio).
The study of air mass origin, using satellite image (Worldview NASA; https://worldview.earthdata.nasa.gov/) and back-trajectories of HYSPLIT dispersion model (https://ready.arl.noaa.gov), shows as South of Morocco (7th August 2015) and Mauritania (11th-12th August and 3rd October 2015) are the origins of main analysed samples (Fig. 1).
In order to know the geochemical anomalies of saharan dust, elemental compositions were normalized to Upper Continental Crust (UCC) values (Rudnick & Gao, 2003). Major elements (Al, Mg, Fe, Ca, Na and K) display enrichments (<x10) compared to UCC. Moreover, trace elements show high concentration (>x10) mainly in Zn, Ge, As, Cd, Sn, Sb, Bi and U. Rare Earth Elements are enriched 5 times compared with UCC. These enrichments have been related with geochemical anomalous sources and not with fractionation process by atmospheric transport.

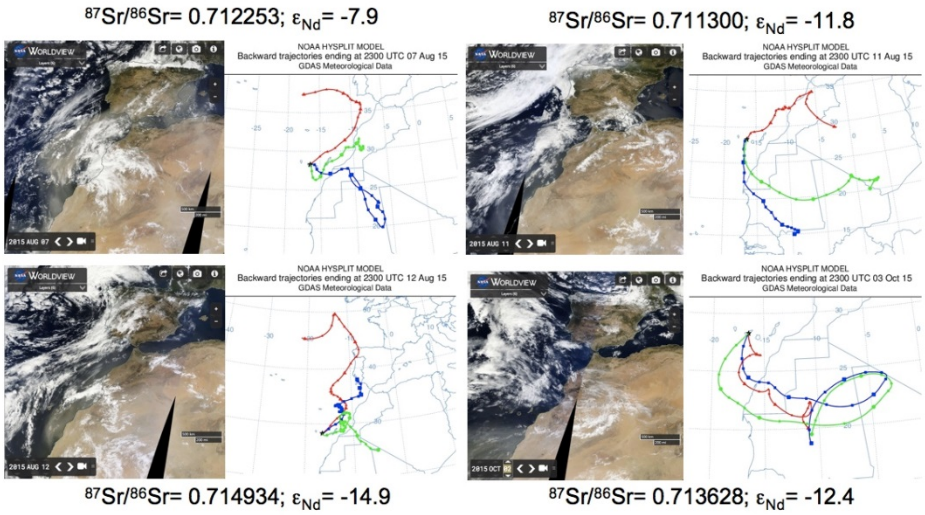

Figure 1. Satellite image (Worldview NASA) and back-trajectories (HYSPLIT ARL-NOAA) of Saharan dust analysed for Sr-Nd isotopes. 7th, 11th and 12th August and 3rd October 2015.

We compared e_{Nd} vs $^{87}Sr/^{86}Sr$ of several soil sources and TSP during North African dust outbreak in IZO (this study) and Doñana (SW Spain). Saharan dust of IZO is characterized by a lineal array ($-7.9 \leq e_{Nd} \leq -14.9$; $0.711300 \leq {}^{87}Sr/^{86}Sr \leq 0.714934$). Other linear arrays have been distinguished in Doñana. However, in this case Sr-Nd isotopic composition of Saharan dust can be mixed with local soils (see trajectory II).

Keywords: Sr-Nd isotopes, Geochemistry, North African dust outbreak, Izaña, Doñana.

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Changes of optical and microphysical Saharan dust properties caused by long-range transport over the Atlantic Ocean

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Mineral dust aerosol can be a major driver of aerosol climatology in regions distant from the sources. This study addresses the change of columnar aerosol properties when mineral dust arrives to the Caribbean Basin after transport from Africa over the Atlantic Ocean.

We use data from NASA Aerosol Robotic Network (AERONET) sites in five Caribbean and two West African locations to characterize changes in the following aerosol properties: aerosol optical depth (AOD), Ångström exponent (AE), vertical particle size distribution (VPSD), single scattering albedo (SSA), asymmetry factor, and refractive indices. The datasets include the AERONET products from the sun/sky photometer CE-318 (*Cimel Electronique*) in the following sites

- West Africa:
  - Cape Verde (16.71ºN, 22.93ºW)
  - Dakar (14.38ºN, 16.95ºW)
- Caribbean Basin:
  - Barbados and Barbadods_SALTRACE (13.15ºN, 59.62ºW)
  - La Parguera (17.97ºN, 67.03ºW)
  - Guadeloup (16.22ºN, 61.53ºW)
  - Ragged Point (13.15ºN, 59.42ºW)
  - Cape San Juan (18.38ºN, 65.62ºW)

The first step of this study is to carry out a first global climatology over a long-term period (1996-2014) with more than 5000 daily values. The seasonal cycles of AOD (at 440 nm) and AE in the two areas are similar between May and September being the maximum AOD (0.6 and 0.3 in Africa and the Caribbean Basin, respectively) and the minimum AE (about 0.2 in both areas) in June. The VPSD shows the dominant presence of coarse particles throughout the year in both areas, with maximum values during the summer months when dust transport is at a maximum.

The air mass connections between West African and Caribbean sites have been investigated by means of air mass back trajectories calculated by HYSPLIT model (Stein et al., 2015). Over the period 1996-2014 we identify 3174 connection days, on average, 167 connection days per year. Among these, 1162 pairs of data present aerosol data in Caribbean sites with corresponding aerosol observations in Western Africa sites ~5-7 days before. Of these 1162 days, 484 satisfy the criteria to be characterized as mineral dust outbreaks (AOD ≥ 0.2 and AE < 0.6) at the West African and Caribbean sites (484 cases, 15% of the total connection days). When aerosol inversion products are analysed, only 71 days satisfied these criteria.

Based on these days, we observe the following changes in aerosol-related properties in transiting the Atlantic: AOD at 440 nm decreases about 0.16 (~-30%); the shape of VPSD shows no changes; SSA, refractive indices, and asymmetry factor remain unchanged; non-spherical particles are the predominant in both areas; the analysis of the total effective radius shows larger aerosol particles in the West African sites.

Therefore, intensive radiative properties do not change significantly in spite of the long range transport. All the results obtained in this study (Velasco-Merino et al., 2017) can be considered in the developing of better model projections of dust transport and to better understand the role of dust in the Climate Change.

Keywords: Saharan dust, aerosol optical and microphysical properties, AERONET, long transport, Caribbean Sea.

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Optical single particle sizing of desert dust aerosol: Effect of refractive index and shape variability and application to A-LIFE data

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Optical particle counters (OPCs) measure the intensity of laser light scattered by individual particles into the detector of the instrument. OPCs have specific laser wavelength and measurement geometry (e.g., location of the detector). The size of each particle is inverted from the measured instrument-specific differential scattering cross section σ_{opc}. The inversion is based on the pre-calculated σ_{opc} as function of size.

The instrument-specific σ_{opc} depends on particle size only and can be easily calculated with the Mie theory if an aerosol consists of spherical particles of a single known refractive index. In case of desert dust aerosol, however, particles have irregular shapes and the refractive index varies from particle to particle (Kandler et al, 2009) which introduces a variability of σ_{opc} for fixed particle sizes. In addition, σ_{opc} also depends on the orientation of the non-spherical particle during the scattering event. The variability of σ_{opc} for fixed particle size is usually not accounted for during the inversion of OPC data which can lead to a reduced precision of inverted desert dust size distributions.

In this contribution, we investigate the dust-related variability of σ_{opc} measured in the forward scattering channel of the Cloud, Aerosol, and Precipitation Spectrometer (CAPS) manufactured by Droplet Measurement Technologies, Boulder (USA) as well as the effect on particle sizing. This OPC operates at a wavelength of 658 nm and measures light scattered into the angular range from 4.2° to 13.2° off the incident light direction. As a first step, we model the distribution of σ_{opc} for a wide range of particle sizes using a Discrete Dipole Approximation code (Yurkin and Hoekstra, 2011). We use six irregular dust-like shapes as introduced by Gasteiger et al. (2011) assuming that they have a random orientation during their transit through the laser beam of the instrument. The refractive index variability is considered in these simulations by applying the size-dependent refractive index distribution measured by Kandler et al. (2011) for Saharan dust samples. The standard deviations of the modelled σ_{opc} for fixed particle sizes are on the order of 20%-40% with some size dependence.

As a next step, we apply the modelled σ_{opc} distributions to measurements of the CAPS instrument collected on board the DLR research aircraft Falcon during the A-LIFE campaign (http://a-life.at) which was performed in April 2017 in the Eastern Mediterranean. CAPS measurements in a long-range transported Saharan dust plume and in a younger Arabian dust plume are investigated. Our inversion methodology is based on a Bayesian approach using Markov Chain Monte Carlo similar to the one proposed by Walser et al. (2017). First preliminary inversions are performed where the measured σ_{opc} are grouped into 24 bins and non-parameterized size distributions with smoothness constraints are obtained. We compare the inverted size distributions to size distributions obtained using the Mie theory with the average refractive index of the distribution by Kandler et al. (2011). It is found that the measured data is much better reproduced, i.e. the deviations between the measured number of particles in the σ_{opc} bins and the numbers modelled for the retrieved size distributions are significantly reduced, if the presented σ_{opc} distribution is considered. This indicates that this σ_{opc} distribution is more realistic than σ_{opc} calculated for spherical particles with a single refractive index. In addition, the obtained size distributions are smoother and the effective particle size is about 10% smaller compared to results obtained assuming spherical particles.

Investigations using other refractive index distributions (e.g. specific for Arabian dust), improvements of the inversions approach considering other sources of uncertainty, and investigations for additional instruments are planned.

Keywords: in-situ measurements, size distribution, optical particle counters, non-spherical shapes, refractive index distribution.

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Strategic positioning of the ERATOSTHENES Research Centre for dust-related field studies in the center of the African-Asian dust belt

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The deserts in northern Africa and in the Middle East are major dust sources and have a strong impact on air quality and aerosol conditions in the Eastern Mediterranean/Middle East (EMME) region. Emissions from arid (non-desert) and semi-arid regions and from areas with strong agricultural activities contribute as well. For a proper consideration of mineral dust in climate, dust outbreak, and air quality modeling, vertical profiling of dust with the potential to distinguish between fine and coarse dust as well as to separate dust from marine and anthropogenic aerosol contributions is required (Solomos et al. 2017). Fine and coarse dust particles influence the Earth's radiation budget, cloud processes, and environmental conditions in different ways. 20–40% of the dust optical depth is caused by fine dust according to Aerosol Robotic Network (AERONET) sun/sky photometer observations. Coarse dust particles are favorable cloud condensation nuclei and ice-nucleating particles, whereas fine dust particles can significantly affect air quality and may sometimes dominate PM1.0 (particles with diameters < 1.0 μm) levels in the EMME region.

Cyprus, in the center of the African-Asian dust belt, can be regarded as an ideal natural laboratory for advanced and comprehensive field studies of dust and aerosol pollution and the complex aerosol impact on weather, climate, clouds, and precipitation formation. The island is almost continuously influenced by Middle East and Saharan dust outbreaks. Modern atmospheric and environmental research (dealing with process understanding and improvement of forecasts) is based on a close link between atmospheric modeling and state- of-the-art observations (for model validation and data assimilation, Binietoglou et al. 2015). However, a super site equipped with state-of-the-art remote sensing technique for continuous aerosol, cloud, and precipitation profiling does not exist in the entire EMME region, a key region of climate change and strongly increasing urbanization and associated pollution levels.

The ERATOSTHENES Research Centre (ERC) of the Cyprus University of Technology (CUT) with the vision to become a Centre of Excellence for Earth Surveillance and Space- Based Monitoring of the Environment (in the framework of phase 2 of the EXCELSIOR H2020 Teaming Project) wants to close this important gap on climate and environmental research. In close collaboration with the German Leibniz Institute for Tropospheric Research (TROPOS), we plan to build up a remote sensing ACTRIS (EARLINET/AERONET/ Cloudnet) supersite equipped with an advanced aerosol lidar, cloud radar, wind Doppler lidar, microwave radiometer, disdrometer and a radiative flux measurement unit. The ERATOSTHENES Research Centre is already a member of the European Aerosol Research Lidar Network (EARLINET) and of the worldwide Aerosol Robotic Network (AERONET). To demonstrate the usefulness of a remote sensing supersite at Cyprus, the Leipzig Aerosol and Cloud Remote Observation System (LACROS, a mobile Cloudnet station) was deployed at Limassol, Cyprus in October 2016, within a pioneering pilot study, and continuouslyperformed measurements until the end of March 2018. In this way two rain seasons (November to March) were covered and 17 months of dust profiles were collected in the framework of CyCARE (Cyprus – Clouds Aerosol and pRecipitation Experiment). In our presentation we will show case studies of dust layering up to the tropopause and cloud formation (mixed-phase altocumulus and cirrus clouds) embedded in aerosol layers composed of dust and anthropogenic pollution (urban haze, biomass burning smoke etc.). These examples and the 17-month campaign clearly corroborates that an atmospheric monitoring super site is highly demanded in this important region of the world.

The EXCELSIOR project is a team effort between CUT (acting as the coordinator), the German Aerospace Centre (DLR), the Institute for Astronomy and Astrophysics Space Applications and Remote Sensing of the National Observatory of Athens (NOA), the TROPOS and the Cyprus' Department of Electronic Communications of the Ministry of Transport, Communications and Works (DEC-MTCW). These institutions will work together to improve the network structures significantly, so that Cyprus will become a cornerstone of the European atmospheric networking infrastructure organized in the framework of ACTRIS (Aerosols, Clouds, and Trace Gases Research InfraStructure).

Keywords: dust, profiling, remote sensing, Middle East dust, Saharan dust

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Heavy metals in atmospheric deposition in Málaga (SE Spain) and the influence of African dust intrusions

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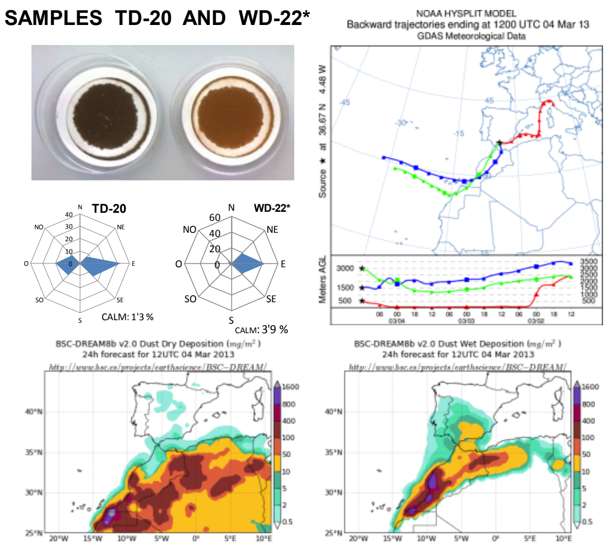
This study reports information on deposition samples collected weekly at a coastal sampling site (Málaga, SE Spain) as part of a research project focused on the impact of atmospheric deposition on the Alborán Sea (W-Mediterranean). This semi-enclosed basin is a transitional area between the Atlantic Ocean and the Mediterranean. Moreover, due to its geographical location the area is frequently affected by intrusions of air masses loaded with high concentrations of atmospheric particulate matter. Major and trace metal analysis of filters and filtrates were aiming at finding the dissolved and non-dissolved fractions of the deposited material. The origin of the air masses reaching the study region was interpreted based on back-trajectories and principal component analysis was performed to find out the groups of elements with similar behaviour. Deposition fluxes at this site were marked by meteorological conditions and the external influence of other sources on a regional scale and the frequency and magnitude of African dust intrusions.

Keywords: Atmospheric deposition, major and trace metals, African dust intrusions, Mediterranean Sea

Mineral dust plays an important role in the optical, physical and chemical processes within the atmosphere while dust deposition adds exogenous mineral and organic material to land and ocean surfaces, having a significant impact on ecosystems and biogeochemical cycles (Jickells et al., 2005). Metals contained in atmospheric particles can reach the Earth's topsoil surface, the continental surface waters as well as the surface of the ocean via dry and wet deposition processes, and eventually become absorbed by biota. Different studies (i.e. Guerzoni et al., 1999; Guieu et al, 2002; Sandroni and Migon, 2002) have found atmospheric transport to be the main form of pollutants transportation from the continent to the sea. The Alborán Sea (Western Mediterranean area) is a semi-enclosed basin in the transitional area between the Atlantic Ocean and the Mediterranean Sea. Regarding the atmospheric input, it is a very interesting case study because the atmospheric chemistry is dominated by the influences of both natural (mainly from the Sahara) and human activity due to the relative proximity of land-based sources, densely populated shores and high ship traffic area.

This study reports information of deposition samples collected at a coastal sampling site at the NW-Alboran Sea, in the city of Málaga (36° 43′ 40″ N; 4° 28′ 8″ W). This Mediterranean city is surrounded by mountains, which causes a special wind regime. Prevailing wind directions are from the NW, generally bringing dry air, and from the SE, bringing maritime, humid air. Due to its geographical proximity to the African continent, our study area is frequently affected by intrusions of air masses loaded with high concentrations of atmospheric particulate matter. Samples of bulk deposition (wet + dry) (TD) were collected on a weekly basis using a standard rain collection gadget. Using the bulk deposition collector, dry deposition samples were collected during dry periods (dry deposition samples, DD). The wet-only deposition was concurrently measured with a standard automatic rain collector (wet deposition samples, WD). The samples were filtered to separate the dissolved and the suspended fractions and filtrates and filters were analyzed by ICP-MS for selected heavy metals (Al, Cd, Cr, Cu, Fe, Ni, Mn, Pb, V and Zn) to evaluate their presence under different meteorological scenarios.

Average daily heavy metal flux deposition rates for the dissolved and suspended fractions were calculated and the contribution of the soluble fraction in deposition fluxes were usually greater for all the metals except for Al, Fe and Pb. Maximum values in soluble and insoluble forms were mainly recorded in the WD samples. Wet deposition rates were much more significant than the dry deposition rates on a daily basis. However, the relative contribution of dry and wet deposition for the supply of elements from the atmosphere was, to some extent, depending on the precipitation regime in the area. Some meteorological factors like wind speed, wind direction as well as relative humidity can also determine the chemical composition of the atmospheric deposition of heavy metals in this coastal area of the Mediterranean.



In order to investigate the influence of African dust intrusions on the amount and chemical composition of bulk, dry and wet atmospheric deposition, we compared mean values between the different samples sorted depending on the presence or not of African dust outbreaks. The identification of African events during the sampling period was confirmed by means of back trajectory analysis (at 500 m, 1500 m, 3000 m a.g.l.) using the HYSPLIT model and BSC-Dream8b dust images. The figures, where some examples are depicted, clearly show that during the sampling period the origin of these events was mainly from the North and West Sahara. The results of the present study show that the monitoring of atmospheric deposition at this coastal site gives useful information on the potential significance of atmospheric inputs of the dissolved and non-dissolved fractions of major and trace metals to this area.

Acknowledgements
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Mineralogical characterization of the insoluble fraction of the atmospheric deposition at a coastal Mediterranean station

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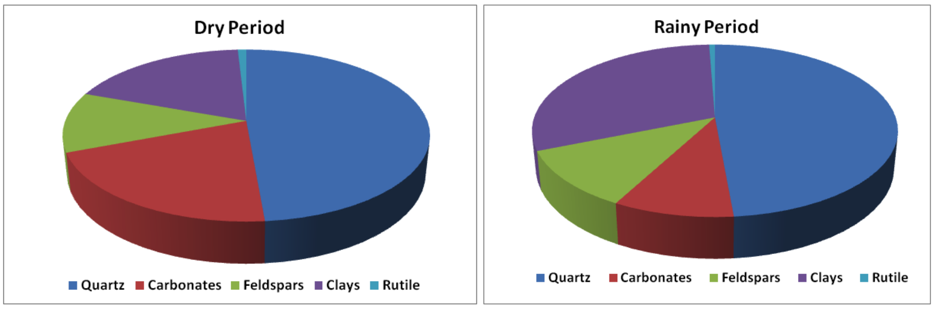
The aim of this study is to characterize by X-ray powder diffraction the insoluble mineral fraction of atmospheric deposition samples collected at a sampling station located in Málaga (SE Spain), to determine their mineralogical composition and to study the influence of African dust episodes. Concerning the mineralogical composition of the samples taken, it was possible to detect the presence of quartz, albite, muscovite, kaolinite and clinochlore in all the samples analyzed, and the presence of dolomite, rutile, calcite and palygorskite in 93.9% 75.8%, 51.5% and 18.2% of them, respectively. Furthermore, samples taken under rainy conditions showed a remarkable increase in their clay content. Instead, the content in carbonates decreased considerably under similar rainy conditions. Various complementary tools such as modeled back trajectories, satellite and true color SeaWiFS images have been used to document and characterize the dust events during which several samples were collected. In particular, we were able to relate the content of palygorskite and rutile in the samples taken at Málaga with the presence of air masses of African over the sampling point.

Keywords: Atmospheric deposition, mineralogical composition, X-Ray diffraction

Windblown transport and deposition of dust is widely recognized as an important physical and chemical concern to climate, human health and ecosystems. The importance of mineral dust as a source of trace elements and nutrients to the open ocean has stimulated research into its production, transport, deposition and subsequent dissolution in surface waters (i.e. Guerzoni et al., 1997; Jickells, et al., 2005; Baker, 2007). Mineral dust consists of irregular particles, often aggregates of different composition and sizes varying from tenths of nanometers to hundreds of microns. The size distribution evolves rapidly according to time after emission. As the particles move away from source regions, the desert dust properties may change. Therefore dust particles studies at different monitoring sites are of peculiar importance to know about processes affecting levels and compositions of mineral aerosols. Being the characterization of crystalline materials by X-ray powder diffraction a powerful technique based on the intensity and position of the peaks, we have chosen it to identify the insoluble mineral fraction of the atmospheric particulate matter deposited in the samples collected.
The Sahara desert represents one of the main sources of mineral aerosols and it is considered to be the dominant dust source for the Mediterranean Basin. The aeolian transport of desert aerosol is also responsible for the episodes of "red snow" or "red rain" described in various parts of Europe (Ávila et al., 1997). Our sampling site is located in the city of Málaga, on the southeastern coast of the Iberian Peninsula. Due to its proximity to the African continent, the province of Málaga is a place of great interest to study the atmospheric deposition. Every year, frequent dust outbreaks are observed, transporting variable amounts of mineral dust aerosols across the region and beyond.
A total of 33 atmospheric deposition samples from February till October 2013 were taken on the top of a building at the University of Málaga in an open area with no nearby buildings to interfere with air circulation. The atmospheric particulate matter deposited at surface-level was collected using a standard rain collection device. The samples were filtered and the insoluble fraction of the atmospheric particulate matter collected on each filter was weighed after drying. Mineralogical composition of the samples was

determined by X-ray powder diffraction using CuKα1 radiation (1.5406 Å) in a PANalytical diffractometer X'Pert PRO MPD. The mineral phases were identified by comparing their X-ray powder diffraction patterns with those stored in the Powder Diffraction File 2, 2004 database. Once the phases were identified, they were quantified by using the Rietveld method (Rietveld, 1969). It was possible to identify and quantified a total of 9 crystalline phases such as quartz, calcite, dolomite, albite, muscovite, kaolinite, clinoclore, palygorskite and rutile. It is important to underline that only the crystalline fraction of the samples was identified and quantified.
From the data provided by the Spanish Meteorological Agency (AEMET), two meteorological situations took place during the sampling: one period with regular rainfall between February and April 2013, and another period with very weak or nonexistent rainfall, from May to October 2013. In order to facilitate this study, several phases were pooled in mineral families so that three main groups were established: 1) Group of carbonates with calcite and dolomite, 2) Group of feldspar with albite and, 3) Group of clays with muscovite, kaolinite, clinochlore and palygorskite. The average mineralogical composition of these families is shown in the Figure. It was noted a remarkable increase in the clay content of the samples taken under rainy conditions in Malaga, likely to be caused by the dragging of this type of particles by the rainwater.



With the assistance of complementary tools such as BSC-Dream, NAAPS and HYSPLIT and the analysis of satellite images from the NASA SeaWIFS project we have been able to relate the presence of palygorskite and rutile in several samples analyzed coinciding with the presence of African air masses over the area of study.

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Mineralogical and geochemical characterization of Saharan dust sources based on an approach combining field measurements and remote sensing data

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Mineral dust is an active component of the climate system. Dust can absorb and/or scatter solar and terrestrial radiations and may act as condensation or ice nuclei in the atmosphere. Eolian mineral particles therefore have an impact on the radiative balance of the earth surface-atmosphere system and on the hydrological cycle. Dust play an additional role as a fertilizer by supplying iron and phosphorous, among other micronutrients, to oceanic and terrestrial ecosystems, potentially boosting the biological productivity in some regions. Besides, mineral dust has also an impact on air quality. The optical and hygroscopic properties of the dust, as well as its biogeochemical and health impact, depend on its mineralogical and chemical composition as well as on its grain size. The Sahara/Sahel is by far the most important dust source region in the world. It is estimated that several hundreds of Tg of Saharan dust is injected in the atmosphere every year, most of which in the direction of the Northeastern Atlantic Tropical Ocean (Yu et al. 2015). Considering the vastness of the Saharan desert and the intermittency of dust emissions, however, Saharan dust geochemical composition is poorly constrained. The main objective of this work is to improve our knowledge of the mineralogical and geochemical composition of the Saharan dust sources, particularly those responsible for long-range transport over the Atlantic Ocean (*see joint presentation by Aloys Bory et al.*).

This study combines remote sensing data and field measurements. First, we use the Infrared Difference Dust Index (IDDI) satellite product to identify the geographical location of Saharan dust sources (Legrand et al. 2001). This satellite product takes advantage of Meteosat Infrared imagery and is based on the impact of aerosols on thermic infrared radiance. The difference of brightness temperature is calculated using a reference value given by the maximal brightness temperature during a period of 15 days centred on the day of interest. Indeed, ground brightness temperature can be up to 15 to 20°C lower with dust than without. A database of 24 years of IDDI images (1982-2006) is available for this study. This time series enables us to establish a new mapping of dust emission in the Sahara/Sahel region and its temporal variability throughout the year. IDDI monthly means will be discussed in the light of other available satellite products such as TOMS/OMI (Prospero 2002) or BMDI/DSA (Schepanski et al. 2007).

The mineralogical and geochemical characterization of Saharan dust is based on a time series of dust samples collected at Mbour in Senegal (80 km south of Dakar) since 2006 on the premises of the Institut de la Recherche et du Développement (IRD) ecological center (Skonieczny et al., 2013). Total dust deposition has been collected using a PVC Capyr-type reversed pyramid-shaped passive collector installed at about 12 m above ground on a sampling tower facing the Atlantic Ocean. We will present results from a selection of samples collected during major Saharan dust outbreaks originating from various sectors of West Africa.

These samples are currently being characterized mineralogically (clay mineral assemblages) and geochemically (major and trace elements, including REE, as well as Sr and Nd isotopes). The observed mineralogical and geochemical differences observed at Mbour will be tracked as precisely as possible to the likely sources, on the basis of back trajectories computed with the HYSPLIT model and the IDDI source map. This study should enable us to provide a preliminary combined optical-field characterization of the mineralogical and chemical signatures of several important sources in West Africa.

Keywords: mineral dust, Sahara, Sahel, source regions, remote sensing, clay mineralogy, geochemistry, Sr and Nd isotopes.

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Contrasting range in Saharan dust chemical composition during and outside major outbreaks on the Senegalese margin

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Considering the vastness of Sahara-Sahel region and the numerous dust emission areas within contrasting geological contexts, Saharan dust composition is expected to be mineralogically and geochemically diverse. The large number of sources, whose contributions are both quantitatively and temporally variable, and are often mixed during dust outbreaks at changing spatial scales, makes it particularly challenging to satisfactorily appreciate the compositional variability of Saharan dust though. In order to improve our understanding of Saharan dust compositional diversity, we launched a continuous sampling of dust deposition at Mbour (~80 km south of Dakar) on the Senegalese margin in 2006, as part of the African Multidisciplinary Monsoon Analysis (AMMA) framework. The sampling site, located under the major corridor for Saharan dust transport, is ideally situated for monitoring mineral dust as they reach the North-eastern Tropical Atlantic and dust deposits have been collected for more than a decade at a weekly (or better) resolution. The building of this long time series has two main objectives: first, to document the temporal change in mineralogical and chemical composition of Saharan dust transported towards the Tropical Atlantic, and second, to typify the mineralogical and geochemical signature of the major dust sources "feeding" the tropical Atlantic and identified with the help of back-trajectories, dust transport models and satellite data (*see joint presentation by Meryll Le Quilleuc et al.*). Mass fluxes, grain-size, clay mineralogy measurements spanning the first few years of this unique time series, as well as a few discrete Sr and Nd isotope measurements across major Saharan outbreaks, have revealed significant compositional variations associated with seasonal shift in transport patterns, demonstrating contributions from various sources within distinct geological provinces [Skonieczny et al., JGR 116, 2011; EPSL 364, 2013]. Here we will present major and trace elements data covering several seasonal cycles of dust deposition at Mbour. These elemental time series reveal significant variability in the dust chemical composition on the Senegalese margin. Major changes are observed at seasonal pace but also on much shorter time scales across Saharan dust outbreaks. The observed compositional range at Mbour often matches and sometimes even exceeds the entire span reported in the literature for West African source regions [Scheuvens et al., 2013]. Remarkably, the elemental composition of mineral dust collected during large Saharan outbreaks, however, is much less varied, suggesting a more modest compositional diversity between the sources involved during major outbreaks and/or intense mixing before dust events reach the African coast. In any case, these results suggest that major compositional evolution during transport across the Atlantic may not be needed to reconcile Saharan dust signatures on both sides of the ocean, and that the chemical signature of long range Saharan dust may be acquired early in the dust cycle in the regions of emission as recently hypothesized by Bozlaker et al. [JGR 123, 2018].

Keywords: deposited mineral dust, elemental composition (major and trace elements), West African margin, Sahara-Sahel, North-eastern Tropical Atlantic

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Global modelling simulation of aerosol dust: budget assessment and sensitivity of their direct radiative forcing to mixing state assumptions

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Aerosol particles affect directly the climate by scattering and absorbing solar and planetary radiation. In addition, some aerosol species as mineral dust, black carbon (BC), and brown carbon (BrC) heat the atmosphere absorbing the solar radiation. The local warming may increase the atmospheric stability, leading to a decrease in cloud cover through the so called semi-direct effect.
Aerosol direct radiative effect (DRE) estimation depends critically on many assumptions about the aerosol size, shape, optical properties calculation. One of the most uncertainty in the calculation of aerosol optical depth (AOD) and single scattering albedo (SSA) is the assumption of the aerosol mixing state. In this study dust mass will be simulated with GEOS-Chem jointly to BC and BrC. Dust emission is parameterized with the DEAD scheme. Dust emission is distributed in four dimensional bins following Kok et al. (2017). BC and BrC are treated as in Wang et al. (2014, 2018). The aim of the work is to study the sensitivity of dust AOD to the several mixing state assumptions and aerosol shape through the comparison with AERONET stations. Moreover, the sensitivity of dust DRE to mixing state assumptions and aerosol shape will be investigated.

Keywords: mixing state assumption, direct radiative forcing

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Typical and unusual structures of the dust layer off the Western African coast

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The Saharan Air Layer over the Eastern Atlantic is usually found at altitudes between 1–2 km and 5–6 km (Tsamalis et al, 2013). A table in Huneeus et al (2011) suggests that most current mineral dust models represent particle size bins up to 10 µm in size, with a few models extending this to 20-25 µm. On the other hand, Kok et al (2017) suggest that models may underestimate the size of airborne dust particles, and as a consequence, they could overestimate their global cooling effect.
In this presentation we shall show experimental evidence that the vertical structure of the Saharan Air Layer may differ significantly from the usual one, and that a significant presence of giant particles needs to be accounted for. These results may have an impact on the estimate of dust radiative forcing.
In August 2015, the AER-D campaign was held, making use of the FAAM BAe-146 atmospheric research aircraft, with base in Cape Verde. Remote sensing with lidar revealed two types of vertical distribution: a typical Saharan Air Layer structure, and an atypical profile with a very intense dust loading at around 1 km altitude during a dust outbreak. In situ measurements revealed a broad size distribution, from 0.1 to 100 um (diameter), and a consistent presence of giant particles: the number and size of particles were enhanced further during the dust outbreak. Giant particles were also encountered in the marine boundary layer.
The aim of this presentation is to discuss the campaign objectives, the first results, the observations during the intense outbreak that was sampled, and the nature of giant particles in the marine boundary layer.

Keywords: dust layer, Eastern Atlantic, vertical structure, particle size.

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DUST, RADIATION AND CLOUDS
DUST AND THE OCEAN

The effect of advection and physical processes on dust transport and deposition in North African coast and over the Atlantic Ocean

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Saharan dust represent more than 50% of the total desert dust aerosols emitted around the globe. The advection of desert aerosols by air masses flux from West Africa to the Atlantic ocean can be enriched the ocean surface in nutrients through the atmospheric deposition. It has been shown that dust deposition is clearly seasonal and in opposite phase between the eastern and the western Tropical Atlantic. This seasonality is driven by the advection and the physical processes redistributing aerosols in the atmosphere over continental area and by other processes involved in the atmosphere-land-sea interactions. Here, we used the LMD General Circulation Model in a West Africa regional configuration to investigate the processes at work in the fate of dust. We quantify the atmospheric dust aerosols dry and wet deposition respectively in winter and boreal summer for the year 2006. In these estimates, we use simulations with aerosols scavenged by convection or convective features and large-scale precipitations. In the region between 35°W-18°W (longitude) and 0°N-25°N (latitude), we find that 2694 $\mu g.m^{-2}.mth^{-1}$ are deposited by dry processes and 157 $\mu g.m^{-2}.mth^{-1}$ are washout in the atmosphere, representing respectively 95% and 5% of the total dust deposition in January. In July, the wet deposition increases up to 58% (1719 $\mu g.m^{-2}.mth^{-1}$) while dry deposition reaches only 42% (1261 $\mu g.m^{-2}.mth^{-1}$). These deposition are related to the physical processes dominated by the sedimentation near the emissions sources, the turbulence in the marine boundary layer in winter and the large-scale rainout in summer over the Atlantic Ocean.

Keywords: desert dust aerosols, deposition, scanvenging, processes, seasons.

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Influence of nonlinear oscillations on the sedimentation of a gas suspension partially filling a closed tube

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The main working bodies in many technological processes are various inhomogeneous media with droplets or solid particles. Investigations of wave processes in such media are one of the important problems of dynamics and thermophysics of multiphase systems [1]. Technologies created on the basis of the wave principle can be used for cleaning gases, including high-temperature (furnace, smoke) and radioactive from solid fine-dispersed inclusions; sedimentation of gas suspension, fogs, including toxic, chemically active in limited quantities; catching water vapor and other liquids in heat-engineering structures, in particular, in cooling towers. For the development of such technologies, the study of coagulation and sedimentation of gas suspension under the action of a wave acoustic field is of great importance [2-3]. Coagulation and sedimentation of gas suspension in acoustic fields in tubes under various oscillation modes near resonances were considered in experimental studies [4-15]. In [4-6] coagulation and sedimentation of droplets of machine oil and tobacco smoke (1-10 µm), drops of oleic acid (1-10 µm) and smoke particles obtained from the combustion of an incense stick (0.3 µm) under the oscillations in the shock-wave formation mode in closed tubes. In [7-15], coagulation and sedimentation of droplets obtained from liquid di-ethyl-hexyl-sebacate (0.8 µm) were investigated in shock-free wave and shock-wave modes and in the mode of transition to shock waves. It is shown that when shock waves are applied to the gas suspension, coagulation ends after a few seconds, but even a low-intensity wave field causes accelerated coagulation.

In the present work, the influence of nonlinear oscillations on the sedimentation of a polydisperse gas suspension partially filling a closed tube is experimentally investigated. Tobacco smoke was used as the polydisperse gas suspension. The piston, located at the bottom of the closed quartz tube, created sinusoidal vibrations by means of a vibrostend in the mode of transition to the shock waves near the first fundamental frequency. Several cases of filling tube with a gas suspension are considered: by quarter, half, three quarters and full. The gas suspension in the absence of vibrations is in equilibrium for a long time. When the vibrations are excited, as soon as the oscillations of the piston reach the first fundamental frequency, the gas suspension begins to sediment rapidly, the movement of the gas suspension in the form of vortices can be seen. There is a nonmonotonic dependence of the sedimentation time of the gas suspension on the degree of filling of the tube. This is due to the formation of secondary streaming in the closed tube in resonance in the form of two toroidal vortices in the upper and lower halves of the tube. The fastest sedimentation of the gas suspension occurs in a tube filled in half, an ejection into the upper part of the tube is practically not observed, since the process occurs in the contact zone of the vortices. Somewhat more slowly, sedimentation takes place in a tube filled with a gas suspension part by a quarter and by a three-fourths. There is emission of gas suspension in the upper of the tube is again observed. At the same time, when the tube is filled on three-fourths on the gas suspension is affected by the vortex in the partially empty top part of the tube. In a fully filled tube, both vortices act on the process of sedimentation of the gas suspension, despite this time the deposition increases several times.

Keywords: gas suspension, coagulation and sedimentation, oscillations, experiment.

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Immersion Freezing Activity of Natural Desert Dust and its Relationship to their Mineralogical Composition

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Soil dust from arid and semi-arid regions is by mass one of the most abundant aerosol types in the atmosphere with global emission rates of about 1600 Tg per year (Andreae et al., 2009). Therefore, soil dust plays an important role for the atmospheric radiative transfer and also for the formation of clouds. In both laboratory and field studies, soil dusts were found to be very efficient ice nucleating particles (INP) in mixed-phase clouds (e.g. Kamphus et al., 2010, Hoose and Möhler, 2012, Ullrich et al., 2017). However, laboratory studies also indicate that the variability in the ice nucleation ability for different natural soil dust samples might be induced by their broad spectrum of mineralogical compositions (Steinke et al., 2016). Feldspar is only a minor component in natural soil dust, but was found to be very ice-active (Atkinson et al., 2013, Harrison et al., 2015) and therefore was suggested to dominate the ice nucleation ability of natural soil dust aerosol.

With a combination of comprehensive ice nucleation experiments and the analysis of the mineralogical composition of 10 different natural soil dust samples from Africa, we try to clarify whether and how much feldspar and other minerals affect the IN ability of natural dust aerosol. For the IN experiments we performed AIDA cloud chamber experiments in the mixed-phase cloud temperature regime. The mineralogical composition was determined by combined XRF and XRD analysis, single particle mass spectrometry and SEM.
This contribution will show the results from AIDA cloud chamber experiments during the INUIT09 campaign in July 2017 complemented by droplet freezing results for the same soil dust samples. The results will be interpreted with respect to the sample mineralogical composition and the impact on cloud and weather modeling.

Keywords: immersion freezing, desert dust, INP, mineralogy, AIDA.

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Ice-nucleating particle concentrations in transported desert dust in the western Atlantic

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Ice-nucleating particles (INPs) can influence the temperature at which ice formation occurs in mixed-phase clouds. This in turn impacts global processes such as the hydrological cycle and radiative feedbacks. Desert dust is thought to be one of the most important INP types around the globe (Vergara-Temprado *et al.*, 2017), but there are very few measurements of INP concentrations in desert dust plumes far from their sources. K-Feldspar is known to be an efficient INP and a common component of desert dust (Atkinson *et al.*, 2013; Augustin-Bauditz *et al.,* 2014), and modelling suggests it is an important INP type around the globe even in regions remote from sources (Vergara-Temprado *et al.*, 2017). However, K-feldspar weathers under natural conditions so it is plausible that the ice-nucleating ability of this mineral may change with time when exposed to atmospheric conditions, which is not accounted for in models at present. Here we make measurements of desert dust which has been transported across the Atlantic at the Ragged Point atmospheric observatory in Barbados. This site was chosen as it is the first land mass that many dust plumes encounter after crossing the Atlantic, making it an ideal location to investigate the role of transport and aging on INP efficiency. Filters were used to collect aerosol samples over the course of six weeks. In conjunction with this, aerosol size distributions and local meteorological data were recorded as well as a cascade impactor being deployed to size segregate the aerosol. Using our mobile laboratory, the IcePod, we processed and analysed filters on-site for the INP concentrations, thereby minimising the impact of storage and transport. Concentrations of INP ranged from around 10^{-2} L^{-1} at around –17 °C to 10 L^{-1} at –27 °C. These concentrations were generally lower than at a mid-latitude site in the UK where we used the same techniques and also much lower than our model predicts. In addition, the INP were mostly insensitive to heat treatment, suggesting they were most likely mineral in origin and that INP from terrestrial biogenic or marine biogenic sources were a minor component of the INP population at concentrations greater than around10^{-2} L^{-1}. Scanning Electron Microscope (SEM) work revealed the aerosol was mainly desert dust along with large amounts of sea salt. This contrasts strongly with results from Europe where there is often a strong biogenic INP component and the INP concentrations are correspondingly much higher. Furthermore, INP concentrations were much lower in Barbados than observed in Cape Verde (Price *et al.*, 2018), which is qualitatively consistent with the decreasing concentration of desert dust across the Atlantic. However, the INP concentrations below −15 °C were lower than model predictions. This is consistent with there being a physical or chemical process that is removing INP on transport through the atmosphere.

Keywords: ice-nucleating particles, ice nuclei, dust ageing, field measurements, mineralogy.

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African dust as a cloud condensation nuclei in the Caribbean

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African dust can travel huge distances, crossing the Atlantic Ocean and reaching the Caribbean. Dust particles can play an important role in cloud formation and be deposited to the ecosystems as wet deposition in cloud and rainwater. To improve our understanding of the role of long-range transported African dust (LRTAD) in cloud formation processes and as a source of nutrients in a tropical montane cloud forest (TMCF) in Puerto Rico, we had field campaigns measuring dust physical and chemical properties in summers of 2013, 2014 and 2015, as part of the *Luquillo Critical Zone Observatory* (LCZO). Measurements were performed at the TMCF of Pico del Este (PE, 1051 masl) and at the nature reserve of Cabezas de San Juan (CSJ, 60 masl), that serves as a control station. In both stations, we monitored meteorological parameters (e.g., temperature, wind speed, wind direction). At CSJ, we measured light absorption and scattering at three wavelengths (467, 528 and 652 nm). At PE we measured cloud microphysical properties (i.e., droplet number, diameter and liquid water content) and collected cloud and rainwater for chemical analyses. Soluble ions, insoluble trace metals, pH, conductivity, total and dissolved organic carbon and nitrogen were measured for cloud and rainwater. Results show that in high dust periods the scattering and absorption coefficients are higher on average (19.1 and 1.8 Mm^{-1}, respectively) than for low dust concentration periods (2.5 and 0.8 Mm^{-1}, respectively). Cloud water conductivity for low and high dust periods was 47.7 vs 81.1 μS/cm, respectively, and for rainwater was 12.8 μS/cm vs 15.0 μS/cm. pH showed differences no larger than 11% for both 2013 and 2014 periods. Also, increases in the overall ion concentration were seen in high dust samples as well as an increase in droplet number and a decrease in droplet diameter. Detailed results will be presented at the meeting.

Keywords: African dust, indirect effect, tropical montane cloud forest, nutrient budget, water budget.

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The Aerosols, Radiation and Clouds in southern Africa (AEROCLO-sA) field campaign in Namibia: overview of objectives, first research highlights and way forward

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The AEROCLO-sA project (Aerosol, Radiation and CLOuds in southern Africa) investigates the role of aerosols on the regional climate of southern Africa. This is a unique environment where natural and anthropogenic aerosols encounter a semi-permanent and extended stratocumulus cloud deck.

The project aims to improve our understanding of aerosol-cloud-radiation interactions over coastal southern Africa in various landscapes and under various meteorological conditions to investigate the dynamical, chemical and radiative processes involved in their life cycle.

AEROCLO-sA is based on a field campaign conducted in August/September 2017 over Namibia. An aircraft equipped with active and passive remote sensors as well as aerosol in situ probes performed a total of 30 research flight hours over northern Namibia. The focus laid on terrigenous aerosol emission over land as well as biomass burning aerosol plumes which were advected from Angola, and their subsequent transport over the marine clouds over the Atlantic Ocean. Concomitantly, an instrumented mobile station was implemented at the Namibian coast in order to measure boundary layer aerosols at the ocean-atmosphere interface using a state-of-the-art suite of in situ aerosol probes as well as balloon-borne dynamics and thermodynamics observations of the lower troposphere.

This presentation presents an overview of the AEROCLO-sA field campaign as well as first highlights from the airborne and surface-based observations.

We expect these observations to significantly contribute to improving the representation of aerosol-cloud-radiation interactions over the region in climate models. They also will be instrumental in promoting capacity building in Namibia and will support policies towards a more sustainable development for the region.

Keywords: southern Africa, mineral dust, biomass burning, Etosha Pan, observations.

Acknowledgements

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A model for absorption of solar radiation by mineral dust within liquid cloud drops.

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Models of light scattering and absorption that consider the effect of insoluble inclusions present within liquid cloud droplets may assume the inclusion occupies random locations within the droplet. In certain cases, external forces can lead to certain orientations or alignments that are strongly preferred. Within this modeling study, we consider one such case in which an insoluble mineral dust inclusion (ρ = 2.6 g/cm^3) is placed within a liquid water drop (ρ = 1.0 g/cm^3). Such an instance mimics mineral dust aerosols being incorporated within cloud drops in Earth's atmosphere. Model results suggest super-micron mineral dust settles to the bottom of cloud droplets. However, Brownian motion largely randomizes the position of sub-micron mineral dust within the droplet. The inherent organization of the particles that result has important consequences for light absorption by mineral dust when present within a cloud drop. Modeled results suggest light absorption efficiency may be enhanced by as much as 4–6 fold for an isolated droplet experiencing direct solar illumination at solar zenith angles of < 20°. For such an isolated droplet, the absorption efficiency enhancement falls rapidly with increasing solar zenith angle indicating a strong angle of incidence dependence. We also consider the more common case of droplets that contain dust inclusions deep within optically dense clouds. Absorption efficiency enhancements for these locales follow a dramatically different pattern compared to the optically isolated droplet due to the presence of diffuse rather than direct solar irradiation. In such cases, light absorption efficiency is decreased through including super-micron dust within water droplets. The study has important implications for modeling the absorption of sunlight by mineral dust aerosol within liquid water clouds – particularly near cloud tops of tropical cyclones that develop off the African coast during boreal summer. The angle of incidence dependence also reveals that experimental measurement of light absorption for cases in which particle alignment occurs may not always accurately reflect atmospheric absorption of sunlight. Therefore, care must be taken to extrapolate measurement data to climate models.

Keywords: mineral dust, light absorption, clouds

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Influence of Saharan dust events on optical absorption parameters at a remote site

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Site and methods

Measurements of particulate matter (PM) and optical aerosol parameters were performed during three years (2014-2016) at a monitoring station located on top of the peak Aitana (38° 39´N; 0° 16´W; 1558 m a.s.l). The sampling point is located on the southeast of the Iberian Peninsula, very close to the Mediterranean coast (~16 km).

An Aethalometer (model AE31), was used to obtain the absorption coefficient (σ_{ap}) at seven wavelengths (370, 470, 520, 590, 660, 880 and 950 nm). To obtain the "real" aerosol absorption coefficient from the aerosol attenuation coefficient, the corrections using the procedure developed by Weingartner et al. (2003) were applied. From the different spectral absorption behavior the Aerosol Angstrom Exponent (AAE) was quantified. A spectrometer GRIMM (190) was used to measure PM concentrations. PM daily values were corrected by comparing with PM concentrations obtained by the gravimetric technique. Several meteorological parameters (temperature, relative humidity, wind velocity and direction and precipitation) were obtained from a weather station located at the monitoring station.

The identification of Saharan dust events (SDEs) in the study area was carried out by consulting the CALIMA governmental database (http://www.calima.ws). The methodology of the percentile 40 (P40) described in details in Escudero et al., 2007, was the procedure applied in this work to obtain the contribution (% Dust) of SDEs to PM_{10} mass concentrations.

Results

PM levels and monthly SDE frequencies

Fig. 1 shows PM_{10} monthly mean values averaged over the three years of study (11.3 mg·m^{-3} - global mean value), the monthly percentage of days affected by SDEs as well as the mineral dust (MD) load in PM_{10} obtained by the P40 method. The temporal evolution PM_{10} concentrations after subtraction of the MD load is also presented.

In general, the greater frequency of SDEs during warm months contributes (among other factors) to the higher summer PM_{10} concentrations. Nevertheless, as can be seen in Fig. 1, both the percentage of days under the influence of SDEs and the MD load during late autumn and winter in the study period were comparable to those recorded during warm months. In fact, the highest contribution of MD to PM_{10} levels was reached in December and February, so it can be stated that the contribution of Saharan mineral dust to PM_{10} average concentrations during those months was noteworthy. The average seasonal contribution of MD to PM_{10} mass concentrations was: winter (27%), summer (34%), spring (31%) and autumn (40%). This implies that during the sampling period, approximately one-third of the measured PM_{10} concentration was made up of MD from North Africa. The temporal evolution described by the blue line in Fig. 1 (PM_{10}-Dust load) was comparable to

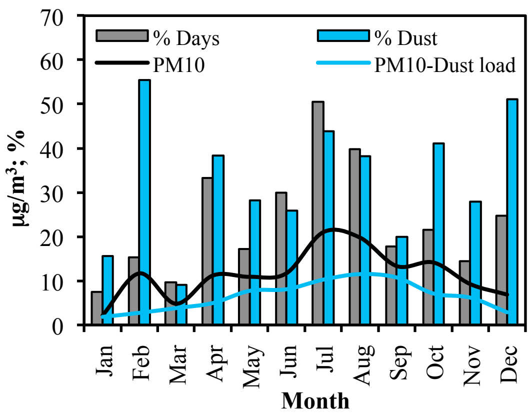

Figure 1.- Average monthly variations of PM_{10} concentrations (black line), PM_{10} levels after subtraction of the dust contribution (blue line), monthly percentages of days affected by SDEs (grey bars) and monthly percentage contribution of MD to

that of PM_{10}, indicating a similar seasonal variation of the percentage of mineral dust in PM_{10} during the study period. Even though SDEs contributed to increase PM_{10} concentrations, the increment was similar in all seasons and therefore did not significantly affect the seasonal variability of PM_{10}.

Influence of SDEs on σ_{ap} and AAE values

In order to assess the influence of MD on optical parameters, SDEs identified during the study period were divided into 4 categories (L_i / i = 1, 2, 3, 4) depending on its intensity (Table 1). This classification was performed according to the MD load estimated by the P40 method. Table 1 also shows the total number of days under the influence of Saharan events in each season, as well as the average value of AAE and σ_{ap} (λ=520 nm). Average values for non-event days (L_0) are also presented.

Table 1: AAE and σ_{ap} mean values and standard deviations (SD) as a function of the dust load during SDEs. The number of days under the influence of African episodes in each season is also shown.

Level	Dust load (mg/m^3)	N (Days) (Wi/Sp/Su/Au)	AAE (SD)	σ_{ap} (SD) (Mm^{-1})
L_0 (Non-SDE)	0	712	1.167 (0.232)	1.90 (1.39)
L_1	0-15	105 (19/35/30/21)	1.209 (0.161)	2.80 (1.08)
L_2	15-30	69 (2/13/40/14)	1.247 (0.181)	3.02 (1.21)
L_3	30-60	48 (3/13/19/13)	1.278 (0.166)	3.28 (1.12)
L_4	>60	17 (3/3/6/5)	1.514 (0.230)	4.63 (1.56)

(Wi: Winter; Sp: Spring; Su: Summer; Au: Autumn)

If the average AAE value for non-event days is taken as reference, almost linear increments lower than 10% were observed as the MD load increased. This increase was highest (~30%) for SDEs of category L_4. Regarding σ_{ap}, percentage increases with respect to the reference value were higher than those observed for AAE. An outstanding increase was also obtained under L_4 conditions. Similar results were found at a site in the center of the Iberian Peninsula (Fernández et al., 2017) taking the contribution of Saharan dust to PM concentrations as a criterion to classify SDEs. The highest daily values for both AAE (1.920) and σ_{ap} (8.40 Mm^{-1}) were registered during high intensity events (L_4). Likewise, AAE hourly values higher than 2.700 were recorded during SDEs of category L_4.

Keywords: Absorption Coefficient; Absorption Angstrom Exponent; Particulate Matter; Mountain Site; Saharan Dust Events.

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XMed-Dry – A Cross-Mediterranean Dry Deposition Measurement Network: first results

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Dry deposition is one of the two major pathways for aerosol particles to be removed from the atmosphere and be transferred into another compartment. Depending on the precipitation pattern and thus, locality, it can dominate then total aerosol flux. Still, measurements of dry deposition with sub-weekly time resolution are rare, as usually the mass collected during this period is too low.

For XMed-Dry, a set of seven new dry deposition-only collectors were installed at different locations across the Mediterranean and Atlantic coasts (Huelva, Barcelona, Spain; Île-Rousse, France; Gozo Island, Malta; Lecce, Italy; Athens, Greece; Nicosia, Cyprus) to capture spatial and temporal variability. Sampling was performed on a 3-times-per-week schedule. Particles deposited on a 25 mm pure carbon adhesive protected from wet deposition by a shelter and an active closing mechanism during rain. The carbon adhesive was subject to electron microscopy with energy-dispersive X-ray analysis to obtain size, shape and elemental composition of single particles. Several hundred to several thousand particles were analyzed for each sample.

First results show that deposition consists of a highly variable mixture of sea-salt, sulfate, mineral dust, metal oxides and biological material, depending on location, season and meteorological situation. Moreover, different state of ageing of sea-salt was detected by the single particle analysis. Statistical back-trajectory analyses allowed for the discrimination of potential source regions for different compounds. The latter showed that particles of similar chemical composition, but different size can have different origin, e.g., in Gozo large (d>4µm) iron-rich particles (possibly fly-ashes) have probably SE European origin, whereas small iron-rich ones originate from the Saharan desert. For the same receptor location, S-rich sea-salt particles were transported in the boundary layer over Italy and SW Europe, while the more pristine ones were produced locally or coming from the Atlantic Ocean.

In this paper, we will additionally compare dust deposition patterns across Europe during spring and autumn based on six weeks periods for five selected stations.

Keywords: Dry deposition, SEM-EDX, single particle analysis, aerosol composition.

Trace metals and nutrients fluxes and solubility during the Mediterranean PEACETIME cruise

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The atmospheric inputs to the Mediterranean Sea, in particular dust deposition, play a significant role in marine nutrient cycles during the summer period of surface water stratification. The PEACETIME cruise aimed at studying the physical, chemical and biological processes and their interactions at the air-sea interface in this Mediterranean environment, and in particular the effect of a Saharan dust deposition event. During the PEACETIME oceanographic cruise in May-June 2017, two rains were collected and analysed, including a targeted wet deposition during a Saharan dust event. The results show a first rain with a high anthropogenic influence and a second associated to a Saharan dust event. About 40 aerosol filter sets were also sampled during the cruise, containing filters dedicated to measurements of major elements, trace metals, organic and black carbon, and inorganic salts concentrations. Filters were also used for solubility measurements (quick leaching GEOTRACES protocol). The chemical composition of filters emphasize a large variability of particles along the cruise route, showing the influence of various anthropogenic and natural sources. The atmospheric deposition fluxes of nutrients (DIN, DIP and DFe) and trace metals (Cd, Co, Cr, Cu, Mn, Ni, V and Zn) associated to wet and dry deposition are estimated from rainwater and aerosol filters composition, respectively. Zn, Mn, Cu, Ni and V are much more abundant than other trace metals in the two rainwater samples, with higher concentrations in the anthropogenic rain than in the dusty rain for Zn, Ni and Cu.

Keywords: PEACETIME, Saharan dust, deposition, trace metals, solubility.

Acknowledgements

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The Role of Sand Storms and Dust Deposition in Stimulating Harmful Algal Blooms in the Arabian Gulf and the Sea of Oman

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Harmful algal blooms (HABs) are a frequently occurring phenomena in the waters of the Arabian Gulf, the sea of Oman and the Arabian sea. HABs that originate in the Arabian and Omani seas usually find their way to the Arabian gulf through the strait of Hormuz seriously affecting the marine ecosystem in the Arabian gulf. Major HABs episodes occurred in 2008-2009, 2012, and 2014 that significantly affected the marine ecosystem leading to major fish mortalities, damage to coral reefs and suspension of some desalinization plants operations affecting the major cities water supply. The key environmental factors that lead to the HABs outbreak are not quite fully understood, however. This study investigates the hypothesis that HABs outbreak in the area are strongly correlated to the occurring sand storms and dust depositions into the nearby water bodies. Deposited sand in the water bodies brings large amounts of nutrients into the water surface stimulating the growth of phytoplankton blooms. Satellite images from the Moderate Resolution Imaging Spectroradiometer (MODIS) of estimated phytoplankton concentrations and aerosol optical depth (AOD) over the area show strong positive correlation between these two variables. MODIS data show that in particular, the summer outbreaks of HABs are usually preceded by massive dust storms and increased AOD from the nearby deserts of Saudi Arabia, Oman and United Arab Emirates. It can be concluded that atmospheric transport of dust aerosols in the area affects oceanic conditions, water quality, and marine life in diverse ways. One of these is the dust deposition on open water bodies leading to the potential growth of bacteria and nutrients transported by dust particles in turn leading to massive harmful algal blooms in the shallow waters of the Arabian Gulf and the Sea of Oman.

Keywords: Arabian Gulf, Sea of Oman, Dust deposition, Harmful Algal Blooms, MODIS

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Extraordinary lightning episode during 12th and 13th of August 2015 in Canary region, was it the effect of dust aerosols?

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The number of lighting registered in the REDRA (Red de Detección de Rayos de AEMET, Meteorological State Agency's Lightning Detection Network) during the 12th and 13th of August 2015 in an area that covered between 27.5 and 29.5 latitude North and between 13.0 and 18.5 longitude West (the Canary Islands Region), was extraordinary huge, 4339 and 1446 respectively. Stands out this unusual number of lighting, at least in the registers of the last 12 years (2006-2017), as one of the most important events and also the only one with more than 1000 lightning's registered not only in August, but also in the whole summer period. Information about this particular intensification of the electrical activity was looked up in the bibliography, in as much as the models did not expect such activity. Though the background conditions were not extremely "convective/unstable" (deduced from the soundings data), it was characterized by a deep moist layer extended from mid-levels (700 hPa) until higher levels. Perhaps this last feature could explain why the precipitation forecast was major as in reality was registered.

The key of these discrepancies between forecast and observation could be found in the remainder of aerosol dust coming from Africa, that was also recirculating around the archipelago during some days, not only that but also with new inputs, mostly in mid and high levels, being that at coastal level the effect of this phenomena was not observed.

Analysing the lightning data in more detail, we found that the major lightning activity took place exactly during the night of 12th and the following early morning of 13th and mostly in the Anaga-Agaete canal. Also comparing the MSG-satellite images RGB and IR10.8 (plus lightning's), we can see that the zone of lightning activity coincided with the dust tongue (RGB image) and LIDAR registers in Santa Cruz de Tenerife Observatory (IARC-AEMET).

Although a deeper study is required, we found in the bibliography some studies that support this possible explanation. Nevertheless, most of them agree with the fact that aerosols, both natural and anthropogenic, itself does not play the principal role in the electrification of clouds, but prevailing meteorological conditions are necessary. For lack of sufficient quantitative observations, the relative contributions of the hypothesized aerosol effect could not be determined, but in a convective scenario, increased aerosol load seems to enhance the clouds lightning activity (Williams et al., 2002; Sassen et al., 2003; Proestakis et al., 2016).

Keywords: Lightning activity, aerosol, dust, MSG-satellite image, LIDAR.

Aknowlegment:
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UV Aerosol Optical Depth in the European Brewer Network

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Networks operating in near-real time over large areas are key to characterize aerosols, because this atmospheric component features high temporal and spatial variabilities [1]. Furthermore, the optical properties of aerosols in the UV are quite different from those in the visible – producing, for example, higher aerosol optical depths (AOD) – and not yet well known [2], which makes measurements in this wavelength range of high scientific interest. In particular, these measurements are of special importance in the case of mineral dust, which is responsible of a large contribution to the AOD at worldwide level. The European Brewer Network (EUBREWNET) [3] is devoted to measurements in the UV range, and is currently comprised by close to 50 instruments, most of them in Europe, although Brewer spectrophotometers operating farther away, e.g. at South America and Australia, have also joined the network. EUBREWNET's data server (http://rbcce.aemet.es/eubrewnet) is operated by the Regional Brewer Calibration Center for Europe (Tenerife, Spain), and currently provides ozone and UV radiation data. In this work we present results of a near-real time UV AOD product which will be publicly available soon, providing data in a wavelength range in which only a few instruments operate. Building upon previous works on Brewer AOD, this AOD product has been designed to use data from standard ozone measurements and calibrations which are already available at EUBREWNET's data server [4]. To check the stability of this Brewer AOD product, we have compared it over a period of 2 years at selected sites with the data from Cimel sun photometers, as provided by AERONET [5]. Our Brewer data are further compared to the AOD retrieved by the UVPFR instrument developed at the Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center (Davos, Switzerland), which also operates in the UV wavelength range [6]. Our results highlight the value of the coordinated, quality-assured, and harmonised data provided by EUBREWNET in comparison to independent measurements.

Keywords: aerosol optical depth, UV.

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A long time-series of atmospheric fluxes of trace metals and nutrients to the eastern subtropical North Atlantic Ocean.

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Atmospheric inputs of soluble trace elements and nutrients to the ocean are a key component in marine biogeochemical cycles (Jickells and Moore, 2015). Aerosol inputs to the Canary Basin are among the highest in the world, due to the region's proximity to the Sahara and Sahel desert regions of Africa. However, to date there have been few long-term aerosol studies in the Canary Basin (Gelado-Caballero et al., 2012; Rodriguez et al., 2015), and limited data available from sporadic oceanographic research cruises which have crossed the region, generally as part of larger transects of the Atlantic Ocean (Baker and Jickells, 2017).
This study forms part of a long-term aerosol monitoring programme started in 1996 in Gran Canaria, Spain. We present a 16-year record of total suspended particle (TSP) sampling and a 14-year record of wet and dry deposition measurements. Aerosol samples have been collected at three stations on the island (Taliarte (TL) at sea level; Tafira (TF), at 269 m altitude; and Pico de la Gorra (PG), at 1930 m altitude) representing a valuable contribution to the understanding of deposition of these soluble components in the region. The geometric mean TSP concentrations were 21.3 and 32.8 μg m^{-3} (75.2 and 76.7 μg m^{-3} standard deviations) for PG and TF stations, respectively. Dry and wet deposition fluxes at the TF station were: 29.1 and 17.0 mg $m^{-2}d^{-1}$ (26.7 and 43.8 mg $m^{-2}d^{-1}$ standard deviations), respectively (WD values are for days with rainfall only). The wet deposition flux was approximately 7 % of the total flux in the studied period.
The data presented in this work show a good correlation between dust concentrations in Pico de la Gorra and the North Atlantic Oscillation (NAO) index in winter. The interannual variability of the observed events is related to the NAO index although some discrepancies are observed due to the location and altitude of the sampling stations and the effect of the marine boundary layer (MBL) on the Islands.

Although many authors have found differences in the mineralogical and chemical composition of African dust related to the lithology of the source regions (e.g. Caquineau et al., 2002), our results suggest that a homogenization of African aerosols appears to occur with respect to the total metal content of the aerosol particles. Some recognizable signatures were found in samples originating from the Sahel (SH), western and central Sahara (WCS) and northern Sahara (NS) due to characteristic variations in the content of Ti, Mg and Ca, respectively, but no in the content of Fe was detected. The Fe/Al ratio was 0.57±0.15 (n=266) in the total particulate samples analysed from the days with African dust.
The solubility of trace metals (Fe, Al, Mn, Co and Cu) and ions (Ca, sulphate, nitrate and phosphate) has also been estimated from the analysis of a long-time series of 109 samples collected over a 3-year period (2008, 2009 and 2011). Solubility is primarily a function of aerosol origin, with higher solubility values corresponding to aerosols with more anthropogenic influence. Moreover, flux estimates for aerosol-derived soluble metals reveal that phosphate is highly

depleted relative to Fe and N when compared to Redfield ratios. Therefore, aerosol deposition may be an important source of nutrients and trace metals (Fe, Co, Mn and Al) to the NE subtropical Atlantic Ocean.

Keywords: Aerosol, Dust, Deposition fluxes, Nutrients, Trace metal solubility.

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Correlating the occurrence of marine low clouds to overlying Saharan dust layers in trade wind regions using airborne lidar measurements

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Every year an estimated amount of 200 to 1000 Tg Saharan mineral dust is transported over the North Atlantic Ocean within an elevated atmospheric layer – the so-called Saharan air layer (Huneeus et al., 2011). During the westward transport dust particles influence the Earths Energy budget in two different ways. On the one hand, they directly interact with solar and terrestrial radiation via scattering and absorption. On the other hand, dust particles act as cloud condensation nuclei and therefore modify droplet number concentration and cloud lifetime. Low-level clouds in North Atlantic trade wind regions are thus affected by both mechanisms. The dust radiative effect modifies atmospheric stability, reduces sea surface temperature and hence affects cloud development, whereas cloud lifetime and precipitation formation is manipulated by dust deposition into the cloud layer. For a better understanding of the role Saharan dust is playing on North Atlantic low-clouds, high resolution measurements are crucial. Although active spaceborne remote sensing techniques provide long-term observations, they lack in observing cloud and aerosol variability on small temporal scales. In contrast, airborne remote sensing measurements allow spatially and temporally high resolved observations of both cloud and aerosol properties. In the course of the NARVAL-II field campaign (Next-generation Aircraft Remote-Sensing for Validation Studies-II) in August 2016 over North Atlantic trade wind regions, measurements with the advanced DLR lidar system WALES (Wirth et al., 2009) onboard the German research aircraft HALO were conducted. To study the influence of Saharan dust on low cloud macrophysical properties, i.e. cloud fraction, cloud top height, cloud length, cloud gap length, research flights were designed to cross sharp aerosol gradients from mineral dust free to mineral dust laden regions. WALES makes major parts of the needed data for dust and cloud characterization available, as it employs high spectral resolution lidar technique (HSRL) to directly measure simultaneous profiles of particle backscatter, depolarization and extinction. We use WALES measurements to identify and characterize observed Saharan dust layers (Groß et al., 2013) and investigate the atmospheric structure with additional information of dropsondes. In a next step, we investigate the impact of elevated Saharan dust layers on subjacent marine low clouds by studying changes in cloud fraction, cloud top height and cloud length and linking cloud macrophysical properties to the occurrence and optical properties of the overlying dust layer.

In our presentation, we will give an overview on the conducted measurements during NARVAL-II. Furthermore, we will investigate the impact of elevated Saharan dust layers on macrophysical properties of subjacent marine low clouds using an aerosol and cloud detection scheme. We will discuss changes in cloud fraction and cloud top height from dust-laden to dust-free regions and relate them to properties of the overlying dust layer.

Keywords: Saharan air layer, marine low cloud occurrence, NARVAL-II field campaign, polarization sensitive airborne high spectral resolution lidar.

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The key role of submicron sulfate particles for the cloud condensation nuclei properties of the Saharan Air Layer dust aerosol

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Annually, the Saharan Air Layer (SAL), formed by the westbound outflow of warm and dry air masses from North Africa, transports considerable amounts of dust aerosol across the Atlantic Ocean as far as into the Caribbean Sea and the Americas. Supplying the affected areas with additional cloud condensation nuclei (CCN), this aerosol influences the formation and properties of clouds, thereby indirectly impacting on climate.

However, so far there has been a lack of comprehensive investigations of the CCN properties of the SAL aerosol, complicating the assessment of these impacts. During the Saharan Aerosol Long-Range Transport and Aerosol-Cloud Interaction Experiment (SALTRACE) in summer 2013, the SAL was therefore thoroughly probed with an extensive airborne in situ instrumentation at both ends of its transatlantic journey. The measurements covered the full vertical extent of the layer, on average ranging from about 1 to 6 km a.s.l. at the Northwest African coast and from about 2 to 4.5 km a.s.l. in the Caribbean. Besides the concentration of CCN at a water vapor supersaturation of 0.2%, the acquired data set includes information on particle number size distribution (NSD), size-resolved particle composition and volatility (at temperatures above 250°C).

Based on these data, we show that the SAL carries large numbers of hygroscopic non-dust particles that constitute an essential part of its CCN. We find that at 0.2% supersaturation particles act as CCN down to diameters of about 80 nm, which is close to the position of the particle NSD maximum. In this size range, that contributes the lion’s share to CCN number, the particulate matter is dominated by non-refractory material, primarily identified as ammonium sulfate (AS). This finding of the compositional analysis is corroborated by a high, near-AS particle hygroscopicity ($\bar{\kappa} \approx 0.5$) inferred from the combination of CCN and NSD measurements. The actual mineral dust in the “dust layer” is the dominant component only for particle diameters larger about 500 nm. Whereas these coarse dust particles control particulate surface and volume/mass, their contribution to CCN number is subordinate (only around 10%).

We further show that the features of the SAL aerosol, i.e. size-dependent particle composition and CCN properties, are likewise observed at the Northwest African coast and in the Caribbean, meaning that they remain approximately preserved during transatlantic transport. Accordingly, these features are characteristic for the initial dust aerosol in Northern Africa. Finally, we suggest that a significant fraction of

the AS found in this aerosol is ascribable to anthropogenic sources, shedding new light on the human influence on SAL-induced climate effects.

Keywords: North African dust aerosol, Saharan Air Layer, airborne field experiment, ammonium sulfate, cloud condensation nuclei

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A deep time perspective on the mineralogy of Earth's dust.

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In the past five years research conducted upon aerosol has revealed important mineralogical controls on ice nucleation in mixed phase clouds. Ice nucleation increases the albedo, and shortens the lifetime, of clouds. Since the mineralogy available at the Earth's surface has not been constant in time or space, we may ask how important these changes might be to Earth's hydrosphere. Our approach is to focus upon the most important mineral for ice nucleation: potassium feldspar (Kfs). We show that Kfs availability through time is linked to the production of granites in the continental crust over >3 billion years. Secondary controls on availability such as vegetation or ice cover or removal are probably more important to the atmosphere on far shorter timescales. Today's Kfs availability is controlled by the clay barrier prevalent over much of the Earth, which we term the normal regime. We identify a subset of major bolide strikes in the past 600 million years that hold the potential to have caused dramatic upsurges in Kfs availability, by covering large portions of the Earth in ejecta blankets rich in Kfs. These events, and others of similar size yet without appreciable Kfs, are good targets for multidisciplinary research asking: "how important is Kfs availability to the atmosphere within the Earth system?"

Keywords: Ice nucleation, potassium feldspar, granite production, bolide strike, ejecta blanket mineralogy.

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DUST AT DIFFERENT SCALES
DUST FORECAST AND SERVICES

Dust detection over the United Arab Emirates using SEVIRI satellite data: time-series comparison with surface observations

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Data from the geostationary satellite sensor SEVIRI (Spinning Enhanced Visible and Infrared Imager) have been processed to estimate the dust signature from the brightness temperature signal emitted from the atmosphere. The dust detection algorithm provided by EUMETSAT and developed by MétéoFrance, has been tuned to operate over the Arabian Peninsula. The high emissivity detected from specific infrared bands, has been mitigated using customized threshold temperature levels, which discriminated the brightness temperatures from surface temperatures.
14 years of SEVIRI data (2004-2017) has been processed to detect spatially distributed dust episodes over the United Arab Emirates (UAE) at a resolution of 3 km. Time-series of hourly duration of dust have been compared with surface observations of hourly duration of dust episodes and visibility obtained from NOAA (National Oceanic and Atmospheric Administration). The comparison has been carried out at the main airports sites in the UAE where surface observation were issued. To find possible relation between dust events and Air Quality, Aerosols Optical Depth (AOD) observations, from 2014 to 2017, were also processed from the Moderate Resolution Imaging Spectroradiometer - MODIS Terra and AQUA at a resolution of 10 km. Therefore, time-series of AOD have been compared with the trend of dust episodes to find possible matches over specific times. Results showed that the satellite data were able to detect most of the dust events as reported from semi-empirical surface observations from NOAA. Additionally, temporal AOD intensities were somewhat consistent with the trend followed by hourly duration of dust detected from satellite data. The dust detection algorithm revealed to be a reliable tool to monitor dust and highlighted the possibility to use satellite data to detect and tracking dust over the UAE with the possibility to rise alerts when necessary.

Keywords: Dust event; Arabian Peninsula; SEVIRI; Remote Sensing; AOD.

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North African regional climate sensitivity to mineral dust optical properties

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Wind-blown dust influences the climate conditions of vast regions of the world through interaction with both short- and long-wave radiation. The large spatiotemporal variability, in load and composition, and the persistent uncertainties in optical properties of mineral dust, constitute a challenge for the characterization of its effects.
This work analyses a set of regional climate simulations with the NMMB-MONARCH model over North Africa, the Middle East and Europe, designed to derive the influence of variations on mineral dust single scattering albedo, aerosols' load, and spatiotemporal variability, through variations of commonly used climatologies; as well as the effect of the online coupling of mineral dust with radiation. When NMMB-MONARCH accounts for full dust-climate feedbacks, there is a reduction on mineral dust emission compared to a radiation-blind-to-aerosol simulation, leading to a decrease of seasonal mean Dust Optical Depth at 550 nm by -18% to -23%, which is in agreement with previously reported feedbacks. The aerosol-radiation interaction significantly changes seasonal mean temperature and precipitation over areas characterized by large mineral dust loads, i.e. North Africa, but also over the Mediterranean, especially during the warm season. Absorptive/scattering properties constitute the leading factor of the climate response. Low/high single scattering albedos imply opposite modelled responses of the all-sky radiative anomaly at TOA (positive/negative), seasonal mean temperature (increase/decrease) and West African Monsoon development (increased/reduced precipitation). The obtained results are consistent with recently published sensitivity experiments using a fully coupled global model. We will also discuss radiative impacts at sub-daily scales.

Keywords: regional climate, dust-radiation interaction, aerosols' scattering, mineral dust climate impacts

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Application and analysis of D*-parameter algorithm using Himawari-8 data

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The satellite observation is helpful for the Asian dust detection and its continuous monitoring on the synoptic scale. The physical and chemical properties of dust aerosol affect the radiation over the wide range of wavelength. The various methods have been developed using these radiative properties. Among them, the method using IR has the advantage to detect over areas with high albedo surfaces and at night (Ackerman, 1997). The National Meteorological Satellite Center (NMSC) currently has operated the Aerosol Index (AI) algorithm using two channels of the COMS, which based on Brightness Temperature Difference (BTD: 10.8㎛-12㎛) and Brightness Threshold Value (BTV). BTV was adopted to mitigate false detection generated by the $BTD_{10.8㎛-12㎛}$. Because this two channel method has limitation that surface emissivity depending on the surface type affect the $BTD_{10.8㎛-12㎛}$ values, we applied D*-parameter to Himawari-8 data because Himawari-8 data which has 16 channels and high resolution can be available. D*-parameter is the approach to separate dust from cirrus clouds (Hansell et al., 2007) and is based on the spectral variability of dust emissivity at 8.6㎛, 11㎛ and 12㎛ wavelengths. The wavelengths of 8.6㎛, 10.4㎛ and 12.3㎛were selected as similar channels with MODIS (8.6㎛, 11㎛, 12㎛). D*-parameter showed similar results with AI. Although the movement and distribution of Asian dust were well detected at daytime, false detection occurred over the source region in the morning and at dawn in spring and autumn due to the effect of surface emissivity. In order to improve the problem, we used characteristic of $BTD_{8.6-10.4㎛}$which can be enable to distinguish desert (De Paepe and Dewitte, 2009) and dust. Then we performed BTD analysis for weather phenomenon to find threshold value for the dust. The low clouds, clear sky, desert had lower values and dust, upper clouds had high values than -0.5 of $BTD_{8.6-10.4㎛}$. As a result, D*-parameter showed that the false detection over the source region was mitigated by comparing with ground observation data and CALIPSO data. It is important to analyze long term cases statistically. Therefore, more study case will be proceeded. We will apply D*-parameter to GEO-KOMPSAT 2A (GK-2A) which is planned for launch in late 2018.

Keywords: D*-parameter, Himawari-8, $BTD_{8.6-10.4㎛}$

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The sensitivity of SEVIRI Desert Dust RGB imagery to infrared dust optical properties

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The appearance of atmospheric mineral dust in MSG-SEVIRI 'Desert Dust' RGB imagery is highly sensitive to the infrared optical properties of the dust, governed by the mineral refractive indices, particle size, and particle shape. It is also highly sensitive to the background surface and meteorological conditions, in particular the surface thermal emissivity and the atmospheric water vapour content.

In order to investigate the sensitivity of the colour of the imagery to assumed dust properties, simulations of mineral dust in the SEVIRI imagery have been performed using the COSMO-MUSCAT (COSMO: COnsortium for Small-scale MOdelling; MUSCAT: MUltiScale Chemistry Aerosol Transport Model) dust transport model and the Radiative Transfer for TOVS (RTTOV) program.

Here we introduce the technique and present comparisons with SEVIRI measurements and retrievals over North Africa. Using the assumption that dust particles are spherical or spheroidal, wavelength- and size-dependent dust extinction values are calculated for a number of different dust IR refractive index databases.

It is found that there is a high degree of variability in the colour response to dust when simulated using various dust refractive index databases, and that spherical particles do not appear to be sufficient to describe fully the resultant colour of the dust in the IR imagery.
It is also found that the IR imagery is most sensitive to intermediately-sized particles (radii between 0.9 and 2.6 microns): larger particles have too small a contrast in extinction between wavelength channels to have much ability to perturb the resultant colour in the SEVIRI dust imagery.

Keywords: SEVIRI imagery, dust infrared optical properties, COSMO-MUSCAT, RTTOV.

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Satellite observation of dust through Meteosat index products

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Satellites contribute essentially to the observation of synoptic and mesoscale dust floating in the atmosphere. These valuable data provide models with initial conditions and with a verification basis. In addition, imagery by itself is used to generate warnings for the next days, as a source usually more reliable than models, even if not so easy to project into the future. Now, some satellite products are consolidated as optimal for subjective monitoring dust in large areas of hundreds of km. One of them is called “dust RGB”, an excellent eye aid to picture the distribution and progress of dust in the atmosphere. However, it seldom helps to interpret radiances in terms of amount, height and even less for particle size. Alternatively, products based on infrared and solar information are proposed for an objective measurement of dust.

Keywords: satellite, meteosat, rgb, dust, aerosol, infrared, solar.

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Aerosol characterization using Calitoo hand-held sunphotometer at the District 22 of Tehran

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This work presents the first integrated atmospheric column aerosols measurements in Tehran, Iran. One year (November 2016- November 2017) of measurements are analyzed. They were conducted under clear sky conditions at the Atmospheric Science and Meteorological Research Center (ASMERC) site in the district 22 of Tehran, Iran (35.75ºN, 51.17ºE, 1309m a.s.l.). The Calitoo hand-held sunphotometer used in this study measures Aerosol Optical Depth Thickness (AOT) at three wavelengths (465 nm, 540 nm and 619 nm). The AOT variability observed during the study period is highly dependent on the height of the atmospheric mixing layer that is affected not only by micro-scale circulations, but also by mesoscale circulations, such as mountain breeze and urban heat islands, as well as synoptic patterns leading to dust intrusions. Observations of AOT>0.4 at 540 nm during the months of November and December are related to meteorological conditions such as temperature inversion and the domination of Siberian anticyclone over the region that play an important role leading to urban air pollution episodes. The other cases in the cold season with high recorded AOT are linked to airborne winter Shamal dust events normally originating from cold post-frontal systems over southwestern Iran. AOT>0.4 at 540 nm are in good agreement with visibility reduction observations as well as PM concentration. Moreover, comparison between in-situ AOD and daily MODIS Level 3 Collection 6 of combined Deep Blue and Dark Target Terra data, as well as output from numerical dust prediction models provided by WMO SDS-WAS Northern Africa, the Middle East and Europe Regional Node have been applied.
The local characterization of mineral dust using Calitoo sunphotometer can be considered as a precious tool leading to better understanding of direct radiative forcing by atmospheric aerosols, as well as the potential influence of aerosols on air quality and human health.

Keywords: Calitoo hand-held sunphotometer, Atmospheric aerosols, Aerosol Optical Thickness.

Validation of AERONET and ESR/SKYNET size distributions with airborne insitu measurements in dust conditions

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The Sunphotometer Airborne Validation Experiment (SAVEX-D) experiment took place in August 2015 in the Cape Verde archipelago, clustering with the ICE-D (Ice in Clouds Experiment – Dust) campaign led by the Met Office and the Universities of Leeds and Manchester. The SAVEX-D team included researchers from the University of Valencia (Spain), University of Reading (UK), National Research Council (Italy) and Met Office (UK).

The main objective of the SAVEX-D campaign was the validation of AERONET and ESR/SKYNET ground based sunphotometer retrievals of columnar aerosol properties such as volume size-distribution, single scattering albedo, refractive index and phase function. This validation was to be achieved with direct comparison with aircraft in-situ measurements (including size-distributions and filter samples) supplemented by radiative closure using the lidar and both short and longwave radiometers onboard the aircraft. Previous comparative studies between the AERONET (Holben et al., 1998) and ESR/SKYNET (Campanelli et al., 2012) networks products have shown that important discrepancies in retrieved aerosol properties can arise, that are very important for climatological studies, aerosol model verification and satellite retrieval validations.

Two Cimel CE318 - AERONET and Prede POM01 - ESR/SKYNET sunphotometers were deployed in Praia (Cape Verde) for the duration of the campaign, alongside ground-based insitu
aerosol observations. The location of the campaign was ideal due to its situation in the path of mineral dust aerosols originating from the Sahara and being transported westwards in the Saharan Air Layer. The FAAM Bae-146 aircraft participated in the experiment, carrying in-situ instruments for the determination of the aerosol properties in the atmospheric column. Main instruments onboard the aircraft were nephelometers (scattering coefficient), PSAP (absorption coefficient), PCASP and CDP (size distributions), LIDAR (aerosol backscattering below the aircraft level), SWS (spectral sky radiance) and filters (chemical composition). Thermodynamic structure was also measured with dropsondes and the net fluxes of short and long wave radiation were obtained with broadband radiometers. Stacked runs and profiles were performed during the experiments, in order to characterise the vertical distribution of aerosols.

Two flights on 16th and 25th August 2015 were successfully performed under mostly cloud free conditions. The average aerosol optical depth during the experiments time was 0.4 - 0.6, guaranteeing good conditions for aerosol inversions. As a result, AERONET level 2 retrievals (based on CIMEL CE318 data) are available for Praia and Cape Verde sites during the experiments flight time. Similarly, ESR/SKYNET retrievals (based on PREDE POM01 data) performed with different algorithm versions, were possible.

For the validation of the sunphotometer retrievals, airborne in situ size distributions were used at several straight runs over the sunphotometer area with three different instruments (PCASP, CDP, 2DS). The average distributions were vertically integrated by combining the straight runs distributions and the airborne LIDAR and nephelometer profiles. Results show that ground based AERONET and SKYNET are fairly consistent in the interval 0.2 – 2.0 µm in comparison to the reference in situ distribution, although the differences increase in the extremes of the distributions. For coarse particles, the AERONET distributions underestimate the reference in situ distributions. Different versions of the ESR/SKYNET produce different results, but in general the agreement in the coarse mode of the distributions is good, mainly when non-spherical versions are used.

Keywords: AERONET, SKYNET, size distribution, campaign

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Using dust deposition measurements to constrain dust emissions in WRF-Chem model over the Arabian Peninsula

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The dust emissions are difficult to measure and they are not well constrained in the models. They are usually tuned to reproduce the observed aerosol optical depth that, with some caveats, reflects the dust mass retained in the atmosphere. However, dust in the atmosphere is a residual of emission and deposition processes. Here, to constrain dust mass balance over the Arabian Peninsula we have combined two years (2015-2016) of dust deposition observations, using passive dust samplers, aerosol optical depth measurements using CIMEL Robotic and hand-held sun-photometers, and aerosol vertical distribution retrievals using a micro-pulse lidar. These observations are employed to constrain the WRF-Chem simulations and to test the recent MERRA-2 reanalysis. WRF-Chem is configured with GOCART 5-bin dust scheme and uses meteorological and aerosol initial and boundary conditions calculated using MERRA-2 reanalysis.

The comparison of 2 years of WRF-Chem simulations with initial and boundary conditions calculated using MERRA-2 reanalysis meteorological and aerosol fields, with MERRA-2 reanalysis shows a high correlation in dust emission and aerosol optical depth (AOD) but WRF-Chem slightly overestimates AOD and emissions especially in summer time. Both WRF-Chem and MERRA2 underestimate observed dust deposition. The analysis of dust size distributions in the deposited samples, reveals that most of the deposited mass is contributed by particles larger than 10 microns. These sizes are not represented in the model dust scheme. However, the calculated amount of deposited PM10 in samples compares well with the model predictions.

Keywords: dust emission, dust mass balance, AOD, dust sampler, merra2 reanalysis, gocart

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Aerosol vertical properties retrieved by GRASP code during SLOPE I and II campaigns

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The southern Iberian Peninsula is an important area for the study of the desert dust properties due to the frequent intrusion of African desert air masses, especially during summer (Lyamani et al., 2006; Valenzuela et al., 2012). The SLOPE I and II campaigns (Sierra Nevada Lidar AerOsol Profiling Experiment) were developed in Granada (Spain) in 2016 and 2017 during summer. One of the objectives of these campaigns was the validation of the aerosol properties profiles retrieved by remote sensing using high-altitude and air-borne in-situ measurements.

In this study, we used the GRASP code (Generalized Retrieval of Atmosphere and Surface Properties) (Lopatin et. al., 2013), which combines vertical profiles and column-integrated aerosol properties retrieved with lidar and sun/sky photometer systems, respectively. The multiwavelength Raman lidar MULHACEN is used for obtaining vertical profiles of the atmospheric aerosol properties at 355, 532 and 1064 nm. The sun/sky photometer provides the AOD (Aerosol Optical Depth) and sky radiance at 440, 670, 870 and 1020 nm. These instruments were operated at the Andalusian Institute for Earth System Research (UGR, IISTACEAMA) at Granada. GRASP allows independently retrieving aerosol optical and microphysical properties (e.g. refractive index, volume concentration, extinction, backscatter, absorption and scattering coefficients) for two distinct aerosol modes, namely fine and coarse modes.

Once the aerosol vertical properties by GRASP code were retrieved, we compared the values obtained at 2500 m a.s.l. with the measurements of the in-situ instrumentation operated at the Sierra Nevada station (SNS, 2500 m a.s.l.) (Román et al., 2018). SNS is located about 20 km away (horizontally) from IISTA-CEAMA and it is a high altitude station located on the northwestern slope of Sierra Nevada mountain range. SNS provides 24-hour aerosol in-situ measurements of microphysical and optical aerosol properties. SNS was equipped with an integrating nephelometer (model 3563 from TSI Inc.) and an aethalometer (model AE33 from Magee Scientific) that provide the scattering and absorption coefficients, respectively. Furthermore, we calculated the in-situ aerosol volume concentration combining the measurements of a scanning mobility particle sizer (model 3938 from TSI Inc.) and an aerodynamic particle sizer (model 3321 from TSI Inc.) measurements.

In this study we check remote sensing retrievals against in-situ measurements of scattering coefficient, single-scattering albedo and volume concentration. The linear fit reveals an overestimation of volume concentration from GRASP retrievals. In the case of scattering coefficients at 532 nm and the volume concentration, the correlation coefficient, R^2, between GRASP and in-situ measurement are greater than 0.80. However, for single-scattering albedo the correlation coefficient is low, ~0.5, likely as a result of the discrepancies between GRASP and in-situ measurements in terms of absorption coefficient related to the horizontal distance between the vertical column analyzed and the location of SNS.

Keywords: GRASP, SLOPE, aerosol properties.

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SUNPHOTOMETER COMBINATION AGAINST SUNPHOTOMETER MEASUREMENTS AT VARIOUS HEIGHTS

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Aerosols are a key piece in the Earth climatic system, constituting up until now the climatic element with the highest uncertainty in the radiative balance. The most extended and advanced instrumentation used to obtain the aerosol vertical distribution is the atmospheric LiDAR (Light Detection And Ranging). However this instrumentation is complex, it requires a large amount of economic resources and constant supervision. Ceilometers are a simplified version of the atmospheric LiDARs, but they are significantly cheaper and they can work unattended.

Aerosol extinction profiles at Granada (Spain) have been obtained combining ceilometer and sun/sky measurements in the $GRASP_{pac}$ method (Román et al., 2018). In order to see the goodness of these retrieved profiles, three photometers at different altitudes have been used. The aerosol optical depth (AOD) at different height layers have been calculated with these photometers and it has been compared against the integrated retrieved extinction at the same layers.

The Granada station is equipped with, among other instruments, a ceilometer (CHM-15k; Lufft manufacturer) since 2012, and a sun/sky photometer (CE318; Cimel Electronique) since 2004 which belongs to AERONET (Holben et al., 1998). In addition to Granada station, two AERONET stations, managed also by GFAT (Atmospheric Physic Group of Granada University), are included in this work due to their high altitude and their proximity to Granada station. These stations are Cerro_Poyos (CP; 1830 m a.s.l.), and Albergue_UGR (AU; 2501 m a.s.l.), both at Sierra-Nevada Mountain Range. Sun/sky photometer data at CP is available since 2011, while for AU the first measurements were recorded in spring 2016. The photometers at AU and CP are usually operative only in spring and summer due to snowfall in autumn and winter. Thus five different layers have been analysed: CP-TOA (Top of the Atmosphere), AU-TOA, GR-CP, GR-AU and CP-AU.

Aerosol optical depth (AOD) and sky radiances both at 440, 675, 870 and 1020 nm measured by sun/sky photometers at the three stations have been obtained from AERONET (version 2 level 1.5). These data and ceilometer range corrected signal averages have been used, for each almucantar sequence available from sun/sky photometer, as input in GRASP (Generalized Retrieval of Aerosol and Surface Properties) code (Duvobik et al., 2014) in order to obtain an aerosol profile following the $GRASP_{pac}$ method. As a result 7387 extinction profiles have been obtained at Granada from 2012 to 2017. The minimum height is 250 m a.g.l. for all retrieved profiles since the ceilometer shows frequently very noisy signal below this height due to the overlap correction. Any changes in the profile are not taken into account from 250 m a.g.l. (overlap reference level) to the ground. The extinction cannot be directlycompared against AOD obtained from photometer, thus, the retrieved aerosol extinction has been integrated for the different mentioned layers, which are marked by the height of the AERONET stations. The layers which have not their top in the TOA are not directly comparable with AERONET AOD values, the AOD at these layers have been calculated as the differences on AOD between two photometers.

The obtained AOD (from $GRASP_{pac}$ and from photometers at different altitudes) correlates good, the most of r^2 values above 0.62, presenting a higher correlation for the longer wavelengths, which could be due to the vertical information is also obtained by the long wavelength of the ceilometer profile used in the retrieval. The best correlation appears for the CP-TOA layer ($r^2 \geq 0.92$), which range of AOD values is high, while lowest correlation is showed by the shortest layers: GR-CP and CP-AU. Analysing the differences in the AOD retrieved by both sources, $GRASP_{pac}$ overestimates the AOD obtained by AERONET in the lower layers, and correspondingly underestimates the AOD in higher ones. The lower layer overestimation could be explained by the assumption of the non-varying overlap region in the ceilometer profiles, caused by a higher aerosol concentration in the overlap reference level than in the ground level.

Classifying the data in different values of AOD it can be clearly seen how as higher the AOD is, higher are the differences between the $GRASP_{pac}$ and AERONET values, and also a higher standard deviation is found.

On the other hand attending to the type of particles measured, it can be appreciated how the $GRASP_{pac}$ values fit worse with the photometer values for the events with a larger size particles and better for the smaller ones. This can be partially explained by the fact that the events corresponding to lower Angstrom Exponent 440-870 values are usually associated to high AOD values.

Furthermore an analysis of the AOD values corresponding to the Solar Zenith Angle (SZA) when they were taken also was made. It was found no significant correlation among the SZA and the differences among both AOD time series in any layer or wavelength.

Despite the different classifications made in this study, the overestimation of $GRASP_{pac}$ AOD values in the lower layers (and in all the wavelengths) persists, pointing out as the most plausible explanation for this bias should be the overlap assumption in the lower range of the ceilometer profile.

Keywords: Ceilometer, Aerosol Extinction, Aerosol Optical Depth, GRASP, aerosol profiles.

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Triple-wavelength dust depolarization-ratio observations: From Morocco to Barbados and the US (SAMUM/SALTRACE results)

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The transport of Saharan dust from the source regions in North Africa towards the far field of the long-range transport in the Caribbean and North America was studied in a series of field experiments, ranging from the Saharan Mineral Dust experiment (SAMUM-1) in Morocco (Heintzenberg, 2009) to SAMUM-2 at Cabo Verde (Ansmann et al., 2011), and to the Saharan Aerosol Long-range Transport and Aerosol-Cloud-Interaction Experiment SALTRACE at Barbados (Weinzierl et al., 2017).

Multiwavelength lidar measurements were performed in the framework of these campaigns and delivered vertical profiles of the dust optical properties. The measured linear depolarization ratios provide information about the shape of the particles, and therefore possible aging effects can be studied and mineral dust can be separated from biomass-burning smoke and maritime aerosols. Using the depolarization ratio at several wavelengths (355, 532, and 1064 nm) provides additional information about the dust size distribution by separating the dust fine and coarse mode contributions (Mamouri and Ansmann, 2014, 2017) and the removal of large dust particles (diameters > 5 µm).

Triple-wavelength polarization lidar measurements in Saharan dust layers were performed at Barbados (13°N, 59°W), 5000–8000 km west of the Sahara during SALTRACE in 2013 and 2014 (Haarig et al., 2017). On average, the particle linear depolarization ratios for aged Saharan dust were found to be 0.25±0.03 at 355 nm, 0.28±0.02 at 532 nm, and 0.23±0.02 at 1064 nm after approximately one week of transport over the tropical Atlantic.

The SALTRACE results are set into the context of previous depolarization-ratio studies performed during SAMUM-1 and SAMUM-2 (Freudenthaler et al, 2009, Groß et al., 2011). Only minor changes in the dust depolarization characteristics were observed on the way from the Saharan dust sources towards the Caribbean. Possible aging affects seem not to change the shape of the dust particles significantly. The decrease in the particle linear depolarization ratio at 1064 nm (between Morocco and Barbados) points to a loss of large supermicron dust particles.

A unique case of long-range transported dust over more than 12 000 km is presented. Saharan dust plumes crossing Barbados were measured with an airborne triple-wavelength polarization lidar over Missouri in the midwestern United States 7 days later (Burton et al., 2015). Similar dust optical properties and depolarization features were observed over both sites indicating almost unchanged dust properties within this one week of travel from the Caribbean to the United States. From these observations, it can be concluded that the dust optical properties within the Saharan air layer remain widely unchanged during long-range transport across the Atlantic.

Keywords: Saharan Air Layer, Long-range transport, Lidar, Depolarization ratio.

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Evaluation of the Transport of Atmospheric Sahara Dust on Natal-RN through the LIDAR Technique of Depolarization

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The objective of this work is describe some results of the Natal LIDAR system (DUSTER), an integrating station of The Latin America Lidar Network (LALINET), aimed to detect and evaluate the transcontinental transport of Sahara dust (SD) to the Brazilian territory during the aerosol MOnitoring campaign Long-range Transportation OVer Natal I (MOLOTOV I) which occurred from December 2016 to February 2017. The city of Natal is located in northeastern Brazil and is one of the continental points closest to the African continent, a important fact to observe the entry of SD in the South American continent. The DUSTER system allows the detection of signals at wavelengths of 355 nm, 532 nm (parallel), 532 nm (perpendicular) and 1064 nm. To detect and characterize SD aerosols and other particles in the atmosphere, DUSTER uses the ability of suspended aerosol particles to change the polarization state of light. The data retrieved by DUSTER allow calculate fundamental parameters in the characterization of atmospheric aerosols such as linear volume depolarization ratio (δ^v) and particle linear depolarization ratio (δ^p). Campaign data showed that on a few days the value of δ^p varied between 0.09 and 0.33 at a transport altitude within the range of 1-3.3 km above sea level indicating in some cases probably a mixture of SD with other types of aerosols such as marine particles, anthropogenic pollution or biomass burning smoke. The data obtained with DUSTER have allowed verify the seasonality of this transport, the altitudes of detected particles and study its optical properties.

Keywords: Sahara Dust, LIDAR, Depolarization, LALINET, Transcontinental Transport

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Airborne particle and ground-based Ceilometer measurements of Saharan dust over Germany – case studies to prepare volcanic ash measurements

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Keywords: volcanic ash, mineral dust, aircraft measurements, Ceilometer network

The Deutscher Wetterdienst (DWD) is responsible for the detection of volcanic ash contaminations within the German airspace by national rules and the regulations of the International Civil Aviation Organization (ICAO).
For this task DWD has implemented several procedures including ground-based Ceilometer and airborne particle measurements, in order to determine atmospheric ash concentrations and their spatial extension (Weber et al., 2012; Wiegner et al., 2014).

The aircraft measurements are used for verification of the volcanic ash model forecasts as well as for comparison with data from the DWD ceilometer network. Final goal of these collaborative efforts is an improved and distinguished designation of the flight restriction zones in case of an intense volcanic ash plume over Germany (Schumann et al., 2011).

To guarantee the operational readiness of airborne measuring systems, which has permanently to be adopted by following latest scientific and technical improvements, DWD performs flights on a regular basis. During these measurement flights technical and organizational steps/iterations are practiced and optimized under realistic conditions.
Airborne volcanic ash concentrations are determined by optical particle counters which measure the particle size distribution. For data evaluation it is crucial to consider that the scattering properties of volcanic ash particles strongly differ from a typical European background aerosol. Because of the lack of intense volcanic ash plumes over Central Europe Saharan dust events were chosen as a realistic test scenario. Saharan dust and volcanic ash are both dominated by larger and irregular shaped mineral particles having comparable optical properties.
Furthermore, the operational procedures in case of a desert dust event over Germany are basically similar to those of the volcanic ash case. DWD uses the ICON-ART model (Rieger et al., 2015) to predict the occurrence of Saharan Dusts over Germany with a lead time of 4 days.

On April 3rd 2014 and on December 17th 2015 measurement flights during Saharan dust events over Germany were performed. Airborne aerosol particle measurements and corresponding ground-based Ceilometer observations of the two mineral dust cases over Southern and Northwestern Germany will be presented.

The flight over Northwestern Germany was conducted with two aircrafts performing measurements. This campaign was successfully operated even under challenging winterly conditions. The focus of this test flight was the intercomparison of two different airborne volcanic ash measuring systems. The Hochschule

Düsseldorf operated a Diamond Twin Star DA42 and the company enviscope performed measurements onboard a Partenavia P68B. In the area between the German-Dutch border and Mönchengladbach (Germany) both aircrafts successfully measured Saharan dust during coordinated horizontal flights at heights between 500m and 3000m.

The experiment showed that DWD may rely on high-quality aircraft based aerosol particle measurements, even under challenging conditions.
The results of this campaign will be presented and will demonstrate that Saharan Dust events are well suited to act as test scenario for the evaluation of airborne volcanic ash measurements.

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Validation of Calitoo hand-held sun photometer for aerosol characterization under background and dust conditions

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Ground-based aerosol optical depth (AOD) measurements are very important for dust aerosol characterization as well as satellite and modelling validation. However, limited measurements are available in vast remote areas, most of them important sources of mineral dust, such as the Sahara desert. In this sense, hand-held photometers are suitable for experimental campaigns in those remote areas providing valuable dust measurements. A NOAA J-309 type of hand-held photometer [1] was previously evaluated achieving good results under clean and dust conditions in Tamanrasset, Algeria [2]. In this work, we firstly present the calibration of three Calitoo hand-held sun photometers that measures AOD at three wavelengths: 465 nm, 540 nm and 619 nm. Then we analyse their performance in two stations, Santa Cruz de Tenerife and Izaña (Tenerife, Canary Islands) during a summer campaign from 28 July to 7 October 2016. These stations are, respectively, representative of marine and free troposphere atmospheric conditions although in summer are regularly affected by mineral dust transported within the Saharan Air Layer. Therefore, Calitoo sun photometers were measuring AOD under different aerosol type and load conditions. Coincident AERONET v2 AOD data from Cimel Electronique 318N sun photometers [3] have been used to empirically estimate the quality and limitations of Calitoo performance. General results show a coefficient of determination R^2 around 0.99 and absolute differences ranging from ±0.01 for lower AOD. However, under dust conditions, Calitoo AOD is systematically slightly lower than AERONET AOD (absolute differences ranging from 0.00 to -0.02, with higher differences for higher AOD), probably related to the field of view (FOV): 1.3º for Cimel and 3.5º for Calitoo. These differences are, any way within the instrument uncertainty. In general, Calitoo hand-held sun photometers have shown a very good performance as well as their potential for providing good quality dust measurements in sites where no other total column aerosol information is available. Although these hand-held photometers cannot be used for long-term monitoring given their relatively large uncertainty and possible little stability, they are undoubtedly very useful for dust monitoring and dust nowcasting if they are used in airports and other meteorological observatories located in remote regions as part of synoptic observations disseminated through the World Meteorological Organization GTS/WIS telecommunication system.

Keywords: hand-held sun photometer, aerosol optical depth, mineral dust.

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This work has been developed within the framework of the activities of the World Meteorological Organization (WMO) Commission for Instruments and Methods of Observations (CIMO) Testbed for Aerosols and Water Vapor Remote Sensing Instruments at Izaña Observatory. AERONET sun photometers used in this work have been calibrated within the AERONET Europe TNA, supported by the European Community-Research Infrastructure Action under the Horizon 2020 research and innovation program, ACTRIS-2 grant agreement No. 654109. We would like to thank the observers of the Izaña Observatory (Conchy Bayo, Rubén del Campo, Virgilio Carreño, Cándida Hernández and Fernando de Ory) for their support providing daily Calitoo measurements.

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Dust aerosol optical depth (DOD) monitoring with a ZEN-R52 radiometer: An upgraded version of ZEN-R41 prototype

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In the present work we show the first results of the ZEN-R52 radiometer, an improved and upgraded version of the ZEN-R41 prototype (Almansa et al., 2017). The new ZEN-R52 zenith looking narrow band radiometer has been specifically designed to monitor dust aerosols and atmospheric water vapor with a high degree of autonomy and robustness. This instrument, jointly developed by Sieltec Canarias S.L. Company and the Izaña Atmospheric Research Center (IARC) State Meteorological Agency of Spain (AEMET) has been conceived to expand dust aerosol monitoring from ground based instrumentation in desert areas. Compared to ZEN-R41, the ZEN-R52 device has a reduced field of view, an increased signal to noise ratio, better stray light rejection and an additional channel (940 nm)for precipitable water vapor (PWV) retrieval as remarkable differences. DOD and PWV are inferred from the ZEN-R52 downwelling Zenith Sky Radiances (ZSR) measurements using a look up table (LUT) methodology.

The results of the ZEN-R41 prototype and the new ZEN-R52 radiometer been compared with a collocated Aerosol Robotic Network (AERONET) Cimel CE-318standard instrument at Izaña Observatory, a Global Atmospheric Watch (GAW) high mountain station located in Tenerife (Canary Islands, Spain) which is strategically located within the Saharan Air Layer when it intrudes into the subtropical North Atlantic, mainly in summer. . The results show an improved performance of the ZEN-R52 compared with ZEN-R41, showing more accurate DOD results. In addition, PWV is compared with AERONET data concluding that ZSR measurements are sensible to variations in the the column water content, providing fair good estimations of PWV.

Keywords: remote sensing, dust aerosol optical depth, precipitable water vapor, radiometer, dust, look-up table.

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Lidar signal analysis using AOD at two heights

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The classical Fernald-Klett (Fernald, 1984; Klett, 1985) inversion of a single-wavelength elastic lidar is usually performed using aerosol optical depth (AOD) measured with a collocated sun photometer. In this way it is possible to retrieve aerosol backscattering and extinction vertical profiles. However, this method is based in the assumption that there are no vertical variations in the ratio between the backscattering and the extinction coefficients. This is a strong restriction, since this ratio can vary significantly due to changes in the type of aerosol that may be at different heights. This is precisely the sort of situation we can find over the Canary Islands. The lower troposphere in contact with the sea surface, namely the marine boundary layer (MBL) characterized by the presence of marine aerosols, is capped by a temperature inversions driven by the subsiding air from the upper troposphere associated with the descent branch of the Hadley cell. Above the MBL is found the free troposphere with very low humidity and very low aerosols content. The Canary Islands are periodically affected, mainly in summer time, by the Saharan Air Layer (SAL) intrusions impacting from about 0.5 to 5-6 km height, with a maximum dust concentration at about 3 km a.s.l. SAL intrusions modify significantly the aerosol composition in both the MBL and in the FT.

In the present work, the classical analysis of the lidar has been compared with a two-layer approach using AOD data from two photometers located at two heights, at Santa Cruz Observatory (sea level) and Izaña Observatory (2373 m.a.s.l.) on the island of Tenerife (Cuevas et al. 2017). The results of the new methodology, with two lidar ratios, corresponding to the MBL and FT, show significant differences in the aerosol backscattering and extinction vertical profiles compared with the classical method, being more consistent with vertical distributions of meteorological parameters provided by radiosondes, and more in agreement with the realistic two-layer structure, typical of the subtropical lower troposphere.
Keywords: lidar, inversion, two layers.

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Dust Products of the Korean New-Generation Geostationary Meteorological Satellite Geo-KOMPSAT-2A

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Korea Meteorological Administration (KMA) has developed second geostationary meteorological satellite, Geo-KOMPSAT-2A (GK-2A) since 2013. It is scheduled for a launch in November 2018. GK-2A will have a new generation of geostationary imager named Advanced Meteorological Imager (AMI) like sensors equiped on Himawari-8/9 and GOES-16 satellites. GK-2A/AMI will provide huge observational data through 16 channels with high spatio-temporal resolutions to observe the Earth's weather, climate and environment.

Korean Peninsula has been affected by Asian dust events during winter season as well as spring season, therefore it is needed to monitor continuouly when to occur and then where to go. In order to implement these applications, KMA has developed algorithms which can retrieve dust products such as aerosol type, optical depth and effective radius from GK-2A/AMI data in cooperation with the Korea Electronics and Telecommunications Research Institute (ETRI) and domestic academia. We are now in the initial validation stage of the products to evaluate their performances and utilizations for satellite data users.

This presentation will give an overview of the development and preliminary results of GK-2A's dust products.

Keywords: GK-2A, AMI, dust

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Composition of Aerosol Optical Depth Products from Multi-Satellites in East Asia

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Atmospheric aerosols play an important and dynamic role in climate and atmospheric chemistry (Andreae, M. O. and P. J. Crutzen., 1997). Aerosol loading is measured in the units of Aerosol Optical Depth (AOD) routinely retrieved by many geostationary and low-earth orbit satellites such as Communication, Ocean and Meteorological Satellite (COMS), Terra, Aqua, Suomi-National Polar-orbiting Partnership (Suomi-NPP) and so on. AOD is widely used in aerosol and air quality characterization as well as aerosol-climate effect assessment. The differences in satellite-based retrieval algorithms, spatio-temporal resolutions, sampling, radiometric calibration, and cloud-screening schemes have led to significant differences among AOD products retrieved from diverse sensors. A composition of AOD datasets retrievals from multi-satellites is therefore desirable, which utilizes the strengths of the individual products, and improves the accuracy when compared with the ground-based AOD data e.g., AERONET (Gautam, R., 2016; Xue, Y., 2012).

In order to make more accurate and complete dataset of AOD over the East Asia region, we make composite AOD products based on dataset from Meteorological Imager (MI) and Geostationary Ocean Color Imager (GOCI) equiped on COMS, Moderate Resolution Imaging Spectroradiometer (MODIS) aboard Terra and Aqua, and Visible Infrared Imaging Radiometer Suite (VIIRS) aboard Suomi-NPP. We use Cumulative Distribution Function (CDF) approach to estimate error statistics of each satellite data from the AERONET data for 4 selected areas in East Asia (Reichle, R. H. and R. D. Koster., 2004). And, in order to apply the AERONET point-specific error, coefficents of each satellite are calculated by the Inverse Distance Weight (IDW) method.

In this paper, we will present temporal and regional characterisitics of the above satellite-based AODs and results of the composite AOD in East Asia region.

Keywords: AOD, satellite, AERONET, composition

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On the Predictability of Asian Dust Days over the Northern China Using ADAM2 Model

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The Asian Dust Aerosol Model 2 (ADAM2) is operating as Asian dust forecast model by Korea Meteorological Administration. ADAM2 is optimized in East Asia region and also can reflect seasonal variability of Asian dust by adapting seasonality of threshold wind speed, threshold relative humidity, and reduction factor. In first half of 2017, the tendency of overestimation of Asian dust over the northern China is found in ADAM2. Verification of Asian dust days over northern China in ADAM2 is required to improve model forecast ability. PM_{10} and $PM_{2.5}$ observation data by Ministry of Environment Protection (MEP) of China are also used to set standard concentration for discrimination of Asian dust event over northern China. Upper 5 % values of PM_{10}-$PM_{2.5}$ in observation and simulation, 160 μg m^{-3} and 130 μg m^{-3}, are designated as criteria of dust event respectively. Asian dust days of ADAM2 defined by satisfying dust criteria at least one hour in a day are evaluated by using accuracy indices. Hit rate (HR), Critical success index (CSI), Probability of detection (POD), and False-alarm ratio (FAR) are used to evaluate Asian dust event of ADAM2. HR depicts high scores over the northern China except Taklamakan desert area. High values of POD are detected in Manchuria and low scores appeared in Taklamakan and east China plain. In particular east china plain case, because east china plain area is main anthropogenic aerosol source region, PM_{10}-$PM_{2.5}$ surpasses the criteria of dust event in absence of Asian dust event. FAR of Manchuria is relatively high compared to other areas due to surface wind difference between ADAM2 simulations and GTS observations. By evaluating ADAM2 with observation, we anticipate to contribute improvement of the performance of ADAM2.

Keywords: Asian dust, Forecast verification, ADAM2, China

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Improvement of Dust Emission Reduction Factor of ADAM2 Model using MODIS NDVI

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The Asian Dust Aerosol Model 2 (ADAM2) is an operational model for forecasting the evolution of Asian dust in Korea Meteorological Administration. ADAM2 is an Eulerian dust transport model that includes physical processes such as three-dimensional advection, diffusion, dry and wet deposition as well as dust emission from the source regions. Monthly thresholds for meteorological conditions of surface wind speed, relative humidity, precipitation, and ground temperature determine the dust outbreak, depending on the soil types (i.e., gobi, sand, loess, and mixed soils) in the ADAM2. Dust emission flux under satisfactory conditions is proportional to the fourth power of the friction velocity with the reduction factor determined by the Normalized Difference Vegetation Index (NDVI) obtained from the Spot4/vegetation data over the source region (Park et al. 2010). The current operational ADAM2 model contains monthly reduction factors which were made with the Spot4 NDVI for five years (May 2007 to April 2012). In this study we made the monthly reduction factors using MODIS NDVI for ten years (January 2007 to December 2016) to reflect the latest vegetation effect over the Asian dust source region. Furthermore, we developed the update system of the reduction factor by composing the MODIS NDVI data on every last 30 days. To examine the impact of the modification of reduction factor, experiments were performed between the current (CTL) and new version (EXP) during the period from March to May of 2017. The simulations were verified with ground-based PM_{10} and $PM_{2.5}$ observation data by Ministry of Environment Protection (MEP) of China. Results suggest that the latest NDVI data contribute positively to the forecasting Asian dust.

Keywords: Asian Dust, ADAM2, Dust Emission, Reduction Factor, NDVI, China

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Combined use of MSG images and other data for local dust sources identification over southwestern parts of Iran

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Abstract: Sand and dust storms have significant impacts on the atmospheric system of earth and are considered as important players in the climate system. Satellite Remote sensing technology is considered as an effective way in sand and dust detection, nearcasting and the identification of dust sources in comparison with traditional ground-based observations that are restricted by many factors, e.g. insufficient number of observing instruments and stations, time consuming, and high survey costs. Detection of these highly variable aerosol events is challenging because of: episodic features, short lifetimes, multiple-scales, and strong interactions with local surface and meteorological conditions. Sand and dust phenomena have been a recurrent problem in Iran, especially in the west and southwest regions in recent years. In this study by using MSG dust products and numerical weather prediction, the behavior of the wind field, soil moisture and friction velocity is evaluated for the local dust genesis over west and southwestern parts of Iran. Moreover, Google Earth software and HYSPLIT model are applied for the identification of coordinates of new dust sources created over the region as a result of land coverage variation and climate change.
Keywords: Dust Source, MSG Image, Wind Direction and Velocity, Dust Storm, EUMETSAT.

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Global early warning system of airborne hazards in the frame of EUNADICS-AV project

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To warrant and maintain the safety of flight crews and passengers, the aviation and its complex infrastructure requires the availability of real-time monitoring of airborne hazards. This study reports on a global multi-hazard monitoring and early warning system (EWS). The implementation of this EWS takes place in the frame of EUNADICS-AV project (European Natural Airborne Disaster Information and Coordination System for Aviation; http://www.eunadics.eu). The main objective of this project is to close the gap in data availability, enabling all stakeholders in the aviation system to obtain fast, coherent, and consistent information. For this task, improved near real-time retrievals from satellite and ground-based platforms (maximum delay of a few hours), are used in order to detect and send notification of sandstorms, dust clouds, but also emissions from volcanic eruptions (ash and SO2) and aerosols produced from forest fires and radioactive plumes. This system is designed to trigger model forecasts aiming to demonstrate the added-value of integrating observed aerosols/radionuclide data for selected case crises affecting European air space.

Keywords: airborne hazard, early warning system, global monitoring, remote sensing, ground-based instruments.

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Development of an Operational Dust Forecast System for the Arabian Peninsula

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The Arabian Peninsula is the second largest dust source in the world only after the Sahara Desert (Tegen and Fung, 1994; Ginoux et al., 2001; Prospero et al., 2002; Tanaka and Chiba, 2006; De Longueville et al., 2010). Every year dust storms affect various parts of the Arabian Peninsula with destructive effects in air quality and human health. In Saudi Arabia, dust storms are considered to be one of the most severe environmental problems (Pease et al., 1998; Alharbi, 2009; Badarinath et al., 2010). Immediate impacts of dust storms include: (a) reduction of visibility, (b) degradation of air quality, (c) increase in respiratory illness in people and livestock, (d) reduction of solar radiation and the efficiency of solar devices, (e) reduction of soil fertility, (f) damage to telecommunication and mechanical systems, (g) widespread dust deposition, and (h) damage to buildings, vehicles, and trees. Dust aerosols also play an important role in radiation budget by scattering and absorbing solar and terrestrial radiation and interacting with clouds, thereby impacting weather and climate at local and regional scales.

The General Authority for Meteorology and Environmental Protection (GAMEP) in Saudi Arabia in collaboration with the National Center for Atmospheric Research (NCAR) has developed a high resolution dust prediction system with the goal of providing improved early warning forecasts in an effort to reduce the risk of these dangerous conditions. The dust prediction system is based on the Weather Research and Forecasting – Chemistry (WRF-Chem) modeling system (Zhang et al., 2015). WRF-Chem is a fully coupled chemistry – forecast system based on the WRF model (Grell et al., 2005). WRF-Chem has been successfully used for a variety of research and applications for the prediction of weather, climate, air quality, dispersion of pollutants, and the prediction of dust.

The dust forecast system has been integrated into the operational WRF-data assimilation forecast system at PME. The model has been evaluated for several significant dust storm events. The evaluation of the case studies have demonstrated that WRF-Chem model is capable of simulating dust storms events in the region. The system will be useful for providing dust forecast guidance for GAMEP operational forecasting activities. This presentation will provide an overview of the dust forecast system and summarize the ongoing dust forecast research and development in Saudi Arabia.

Keywords: Regional Dust Model, Arabian Peninsula, WRF-Chem, High Resolution forecast
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Detection AND Forecast of Dust Events over Egypt

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Egypt suffer from air pollution from long-range transport of desert dust . desert dust are one of the natural hazards , Dust storms increase impact on urban areas and farms as well as affecting ground and air traffic. They cause damage to human health. Historical dust events measured by air quality and satellite observations are analyzed based on their characteristics in data sets of regular meteorology, satellite based aerosol optical depth (AOD), and air quality measurements. There are database for more than 30 monitoring sites for measuring pm10 and meteorological data represented north, middle and upper Egypt .Here we present a an automated system to identify dust storms sources and forecast its trajectories for all monitoring sites .The system consists of :

1-Air mass back trajectories database at levels 500,1000,2000,3000,4000 m using hysplit model, back trajectories (from 2011 to 2015) are extremely useful. When many back trajectories (over months to years) are analyzed in specific ways they begin to show the geographic origin most associated with elevated concentrations. Often, it is useful to use cluster analysis on back trajectories to group similar air mass origins together. Database for monitoring sites will be connected with back trajectories database. Analysis of back trajectories data by using data mining define the most sources of dust for each monitoring site.

2-Several satellite sensors are used in this study coupled with Aerosol Robotic Network (AERONET) ground measurement data. We used MODIS and Ozone Monitoring instrument (OMI) data to find the aerosol optical depth(AOD)(from 2011-2015),and the Multi-angle Imaging Spectro Radiometer (MISR) to examine the microphysical properties of the atmospheric aerosols. These measurements calculated for dust sources to create database for AOD and meteorological data from GFS model for All sources which defined by air masses back trajectories analysis.

By analyzing dust sources data base using data mining we can define Average of AOD for different dust sources ,if the dust source is active hysplit will calculate the air masses forward trajectories and dispersion of dust from this source to different monitoring sites ,also use data mining to define the concentrations levels for pm10 for each monitoring site.

The accuracy of this approach was tested by observed pm10 data for each monitoring site , and dust storms events which occurred in 2011-2015 and which are classified by the Earth Observatory as dust storm images (http://earthobservatory.nasa.gov/NaturalHazards/)

Assimilation of MODIS collection 6.1 dust AOD in the Met Office global model

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The Met Office provides operational dust forecasts from its global numerical weather prediction model (MetUM) since July 2011. Assimilation of the Moderate Resolution Imaging Spectro-radiometer (MODIS) Level 2 aerosol optical depth (AOD at 550 nm) from the Aqua satellite was introduced operationally in the Met Office four-dimensional variational data assimilation (4DVAR) system in April 2013 (Brooks et al, in prep). Data quality checks and filters are applied in-house to the MODIS AOD in order to better represent the dust aerosol (see Table1). Initially, the dust AOD observations were included from MODIS Deep Blue collection 5.1 land retrievals only. Since then, we have updated the MODIS dust selection criteria and included AOD retrievals over ocean incrementally with observations from latest MODIS releases (Pradhan, 2015; 2017).

The NASA-LANCE released a new version – Collection 6.1 (C6.1) – in late October 2017 for all MODIS Level-1 and higher-level Level-2 and Level-3 atmosphere products (NASA, 2017). The MODIS C6.1 dataset is expected to address a number of issues in the C6.0 Level-1B data, which had negative impact to varying degrees in downstream MODIS Atmosphere Level-2 products.

In this presentation, we a) demonstrate the performance of MODIS C6.1 AOD retrievals against C6.0 using AERONET ground observations, and b) assess the MetUM global dust forecast skill with the new C6.1 MODIS AOD assimilation from both Aqua and Terra platforms. Initial analysis for August 2013 and 2015 test period shows an overall improvement to AOD retrievals from both Aqua and Terra in C6.1 (Figure a).

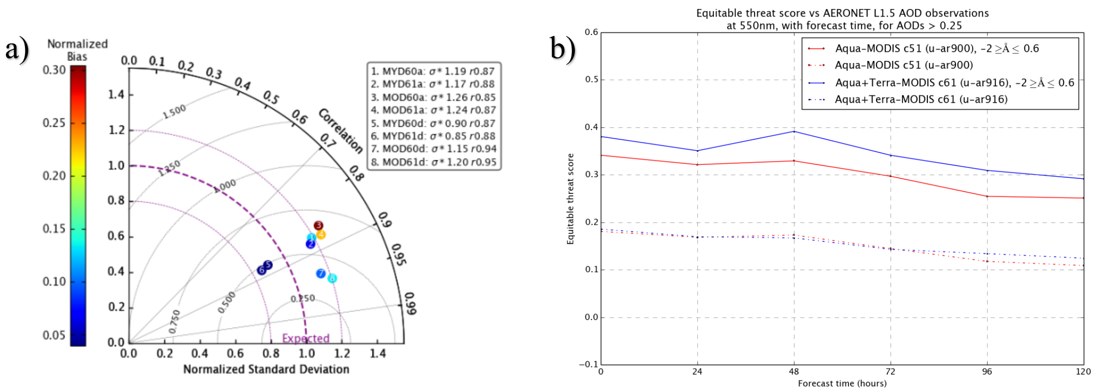

Figure 5. (a) Taylor diagram showing statistical match-up summary of MODIS (total and dust) AOD retrievals against AERONET version-3 Level-1.5 data (closer to Expected is better). (b) MetUM dust prediction equitable threat scores (ETS, higher is better) at different forecast time steps with MODIS C5.1 and C6.1 AOD assimilation – solid lines for dust AOD and dotted lines for total AOD.

Further, the AERONET match-up scores from Terra dust AOD cases display better statistics compared to total AOD cases.

Table 1: Filters applied on MODIS Deep Blue and Dark Target total AOD to better represent dust aerosol (Bellouin et al, 2007; Jones and Christopher, 2011; Muller et al, 2011)

Fine mode fraction	$f \leq 0.4$
Angstrom exponent	$\alpha \leq 0.6$
Effective radius	$r_e > 1\ \mu m$
Single scattering albedo at 470 nm	$0.878 < w_0^{470} < 0.995$
Aerosol optical depth at 550 nm	$\tau_{obs}^{550} \geq 0.1\ OR\ (\tau_{model}^{550} \geq 0.1\ AND\ \tau_{obs}^{550} < 0.1)$

Assimilation of MODIS C6.1 AOD observations from Aqua and Terra for the short trial period improves the global dust forecast skills for moderate to high dust loadings (dust AOD >= 0.2) at all forecast time steps (Figure 5b) and shows neutral impact on the overall global NWP forecasts.

Keywords: Aerosol, MODIS, MetUM.

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TOWARDS CONTINUOUS EVALUATION OF DUST PROFILES IN THE WMO SDS-WAS

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Aerosols alter the radiative energy budget of the Earth and atmosphere system by scattering and absorbing atmospheric radiation. The impacts on regional and global climate depend on the optical properties of the aerosols and their vertical distribution in the atmosphere [1]. The vertical distribution of absorbing aerosols (such as mineral dust) is especially important as they modify the vertical profile of radiative heating in the atmosphere. This changes the stability of the atmosphere, thereby influencing convective and turbulent motions and clouds. The vertical distribution of aerosol also influences the radiative effect at the top of the atmosphere, especially when aerosols have strong absorption of shortwave radiation. The free troposphere contribution to aerosol optical depth (AOD) and the altitude of lofted layers are provided thanks to the vertical profiling capability of the lidar/ceilomenter technique. One of the most important activities of the World Meteorological Organization's Sand and Dust Storm Warning Advisory and Assessment System - Northern Africa-Middle East-Europe Regional Center (WMO SDS-WAS NAMME RC, http://sds-was.aemet.es) is the dust model verification and evaluation, which is deemed an indispensable service to the users and an invaluable tool to assess model skills. Currently, the Center collects daily dust forecasts from models run by different partners (BSC, ECMWF, NASA, NCEP, SEEVCCC, EMA, CNR-ISAC, NOA, FMI, TNO and UK Met Office). Multi-model ensembles have also been set-up in an effort to provide added-value aerosol products to the users. Currently, a lidar located in Dakar (Senegal) and three ceilometers in Santa Cruz de Tenerife (Canary Islands, Spain), Granada (Spain) and Montsec (Spain) provide near-real-time (NRT) vertical extinction profiles of aerosols, which are compared with those simulated by models. The present contribution presents the results on the implementation of a NRT model evaluation of airborne dust profiles in the SDS-WAS RC.

Keywords: model evaluation, ceilometers, lidars, profiles, operational

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Information of Space Spatial Technology in the environmental education (Case study: Tehran, Iran)

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Environmental education is one of the important environmental issues and the acquisition of knowledge and technologies related to it today's contemporary requirements. Today, the use of environmentally-friendly technologies for a quiet life, with no intellectual concern, is a requirement of humanity. Information technology has changed dramatic changes in various areas of information management and information such as environmental debate can be noted. The purpose of this research is to discuss geographic knowledge in the environment, including the use of remote sensing, geographic information system (GIS), and the use of unmanned aerial vehicles in the surrounding environment. Using this kind of technology in the environment, we can talk about maintaining, storing, organizing and accessing data types and information for optimizing the environment. The application of information technology involves the use of RS, GIS and UAV in the design and implementation of an environmental information system and the identification of green spaces in the city of Tehran in the direction of urban polluted areas and provides suitable solutions for reducing urban pollution. Measurement is to obtain information from surface and sea levels using images taken upwards, using parts of the electromagnetic spectrum that are spun or reflected from the surface of the earth. The purpose of this research is to identify the thermal islands of the city of Tehran and the suburbs that have been created due to the expansion of urbanization in and around it. The classification is based on the geomorphology using Sensei Land Sets. The results show that most of the urban hot spots are below and without vegetation and under the influence of excessive heat of vehicles and traffic in the city. And the lowest level of surface heating is related to upland heights with vegetation and more soil moisture and is affected by high rainfall. Areas with low vegetation and bare soil indicate a high temperature. Most of areas had surface temperature of 42.9 to 46.2 degrees Celsius. The lowest areas with surface temperatures have been between 36.5 and 39.5 degrees Celsius. The results show that the urban thermal islands in Tehran are related to different factors. This difference is primarily due to the condition of land cover in the region, which indicates the close relationship between the land cover and the surface temperature. Also, distribution of vegetation and green space in different regions of Tehran using normal vegetation index (NDVI) was studied using remote sensing data. In urban traffic, most of the area is affected by the urban thermal islets related to Shahid Modarres Highway. Low pollution areas have the lowest urban heat islands (R2 = 0.59) and regions with higher pollution with the highest thermal islets (R2 = 0.72).

Keywords: Space Spatial Technology, Environmental, vegetation index, land surface temperature and pollution

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Validation of radiation parameters from NWP models over Spain

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Introduction.

Forecast of radiation parameters from Numerical Weather Prediction (NWP) models has become an important instrument to improve the predictability and flexibility of concentrated solar power (CSP) plants. Forecasting direct solar irradiance is a very difficult task due to the high variability of atmospheric components (such as gases, aerosols and clouds), the very complex nature of NWP models and the extremely large underlying systems for the data capture required to initialize these models. Nevertheless, several papers have shown that radiation forecast parameters can be used operationally (Schroedter-Homscheidt et al, 2016, among others). Following this idea, the objective of our study is to verify the accuracy of the forecasted radiation parameters to allow a fully predictable energy dispatch.

In this work two models have been verified for almost three years of measurements, from February 2015 to November 2017, against observations from stations of the AEMET radiation network, selected attending to the quality and completeness of the data. The models used are the Harmonie-Arome (Hirlam Aladin Regional/Meso-scale Operational NWP In Europe)-(Applications of Research to Operations at Mesoscale) limited area model and the Integrated Forecast System (IFS) global model, developed by the European Centre for Medium-Range Weather Forecasts (ECMWF). Verification scores for direct horizontal irradiance (DHI), direct normal irradiance (DNI) and global horizontal irradiance (GHI) from the deterministic models over the selected stations will be shown. In addition, preliminary results from the recently developed gamma Short Range Ensemble Prediction System (gSREPS) probabilistic model will be presented as well. In this abstract, as an example, we show results for the DHI over the Badajoz station.

Model outputs present different characteristics that have to be taken into account for the verification. For this work, the most significant difference is that Harmonie-Arome model provides outputs every hour while IFS model does it every 3 h. Therefore, in order to make data comparable, the 1 h Harmonie-Arome outputs have been accumulated to 3 hours.

A quality assessment study of the measurements have been performed in order to eliminate erroneous data based on the work of Geiger et al., 2002.

Results.

Seasonal correlation coefficients of the models against observations for the 3 h accumulation data ranged from 0,82 (winter 2016) to 0,97 (summer 2016) for IFS and from 0,76 (winter 2016) to 0,95 (summer 2016) for Harmonie-Arome. Figure 1a and 1b show the scatter plots of the DHI predicted by the IFS and Harmonie-Arome models, respectively, against observations. In general, IFS shows slightly better results than Harmonie-Arome. In addition, the data has been stratified according to the hour of the day and the season of the year to explore those dependencies. Furthermore, it has been accumulated for several periods of time (3, 6, 12 and 24 hours) as well. CSP plants are specially interested in daily accumulated values. As expected, the validation shows decreasing errors with increasing accumulation time, see Figure 1c where the rRMSE varies from around 38% for the 3 h accumulated period to about 25% for the 24 h accumulated period.

Case studies.

In Figure 2 heatmaps for the 24 h accumulated DHI observations (Figure 2a) and model errors (Figures 2b and 2c) for the period under study are presented. These plots allow to get an overall idea of the results for the whole period, giving the possibility discard observation errors and detect special interesting cases at a rapid glance. Based on these figures some special days have been selected where the errors are higher than the average. For example, during 21-25 February 2017 an intrusion of Saharan dust occurred over the Iberian Peninsula. During these days both IFS and Harmonie-Arome models failed because they do not assimilate aerosol observations and therefore they are not able to predict such intrusions. This issue will be analyzed in detail in the extended work during the conference.

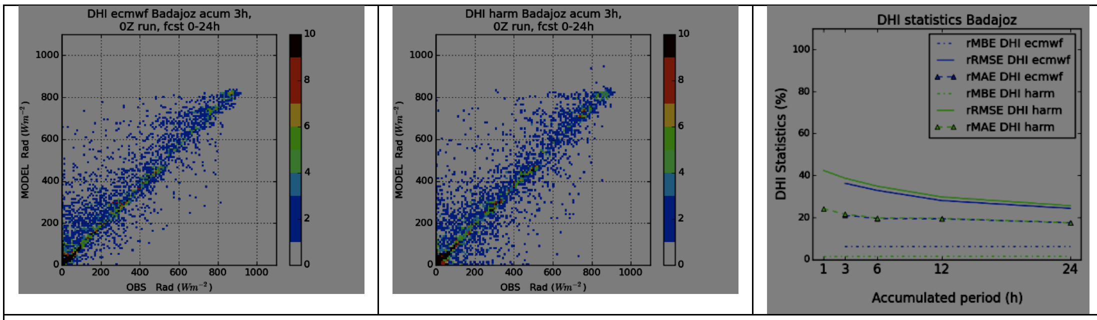

Figure 1. Scatter plots of the 3 h accumulated DHI measurements (X axis) against the values predicted by the IFS (a) and Harmonie-Arome (b) models (Y axis). (c) the rRMSE, rMAE and rMBE are shown for various accumulation times.

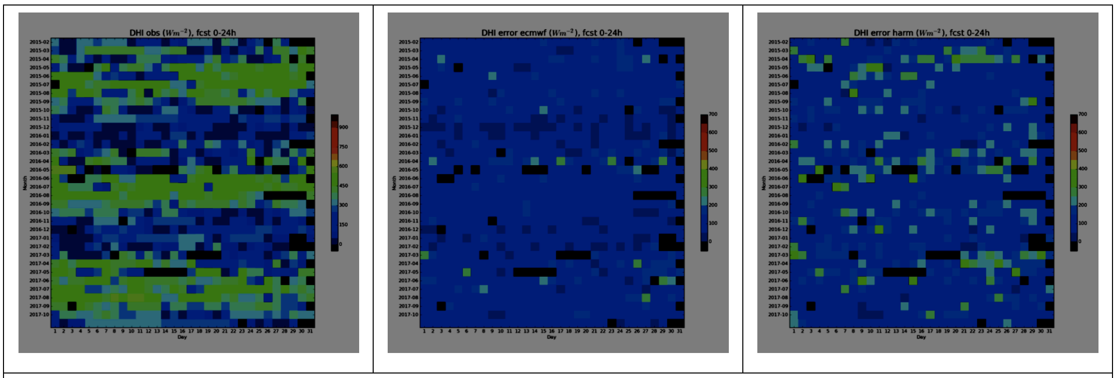

Figure 2. Heatmap of the 24 h accumulated DHI, the X axis presents each day of the months shown in the Y axis. (a) presents the measurements while (b) and (c) present the errors of the DHI predicted by the IFS and Harmonie-Arome models, respectively. Black squares indicate that no data were available.

Keywords: Direct solar radiation, Numerical Weather Prediction models, Concentrated Solar Power plants.

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