Barcelona Supercomputing Center
Centro Nacional de Supercomputación

AXA Research Fund

Introduction to desert dust

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Training School and Workshop on Dust Aerosol Detection and Monitoring, 9-17 November 2021

Outlook

Session 1. Introduction to desert dust

- *Atmospheric aerosols*
- *Desert dust and its cycle*
- *Types of sand and dust storms*
- *Dust global climatology*

Session 2. Evaluating models

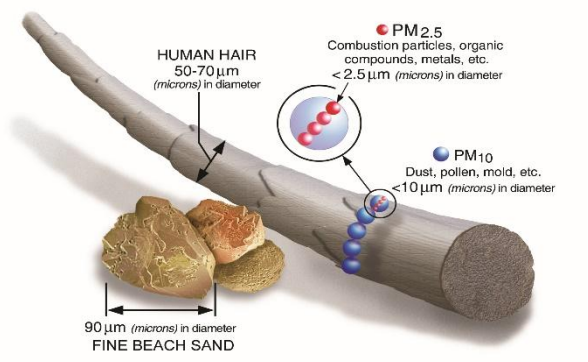
- *Dust forecasting models*
- *Model evaluation:*
  - *NRT verification vs. long-term assessment*
  - *Dust-filtered satellite products*

Atmospheric aerosols

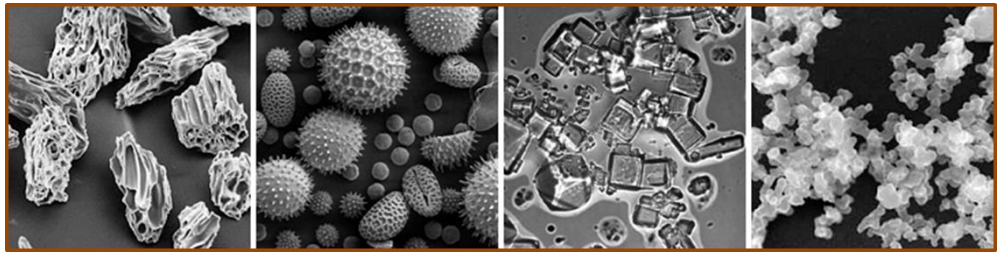
Atmospheric aerosols are suspensions of liquid, solid, or mixed particles with highly variable chemical composition and size distribution. **Aerosol** particles are either emitted directly to the **atmosphere** (primary **aerosols**) or produced in the **atmosphere** from precursor gases (secondary **aerosols**).

The present considerable differences in:

- Size range (1nm to 100µm)
- Chemical composition
- Sources of emission



Extracted from EPA website



PENDING

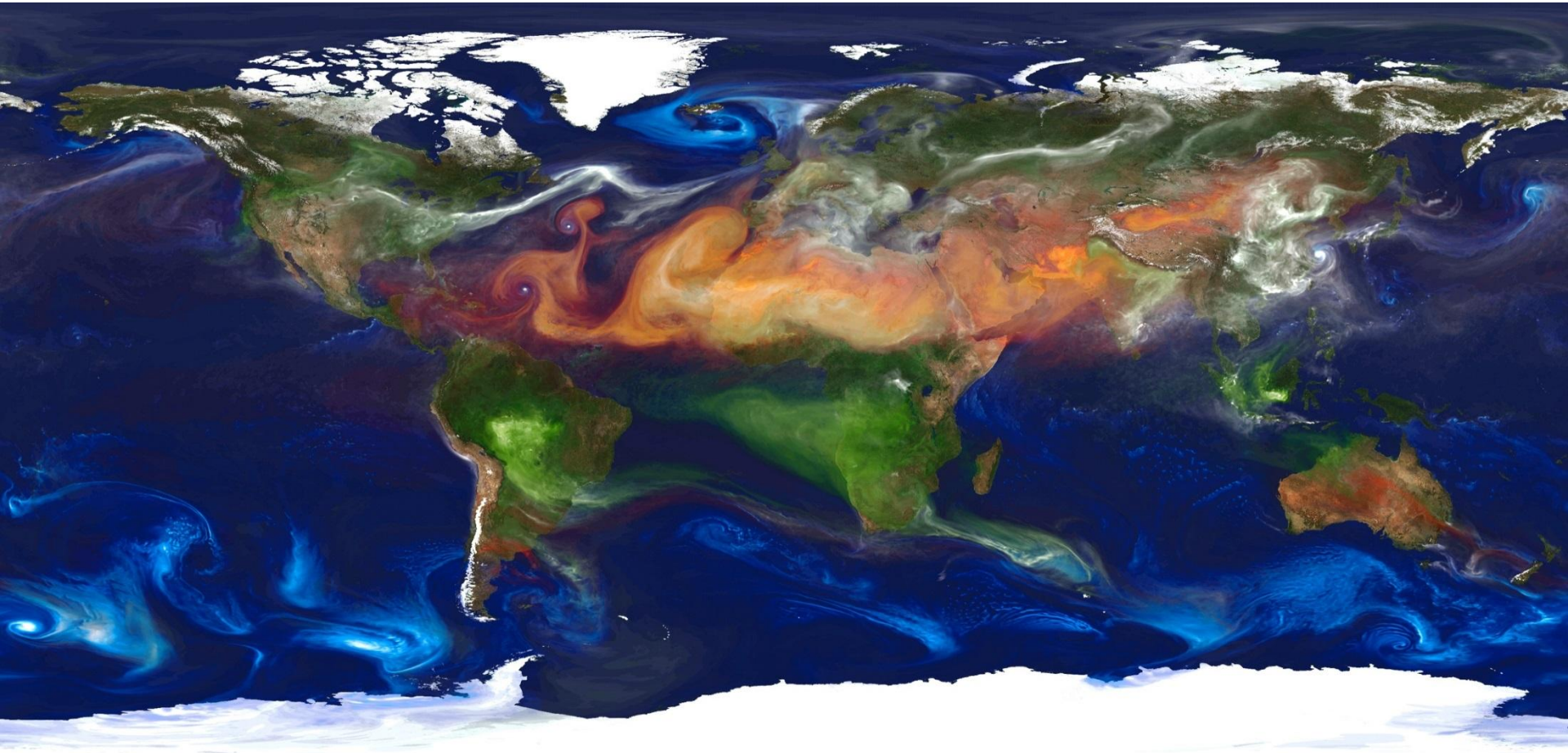
Atmospheric aerosols

mass vs optical properties

Aerosol's extension

NASA | GEOS-5 Aerosols
https://www.youtube.com/watch?v=oRsY_UviBPE

Aerosol's extension



Organic Carbon + Elemental carbon

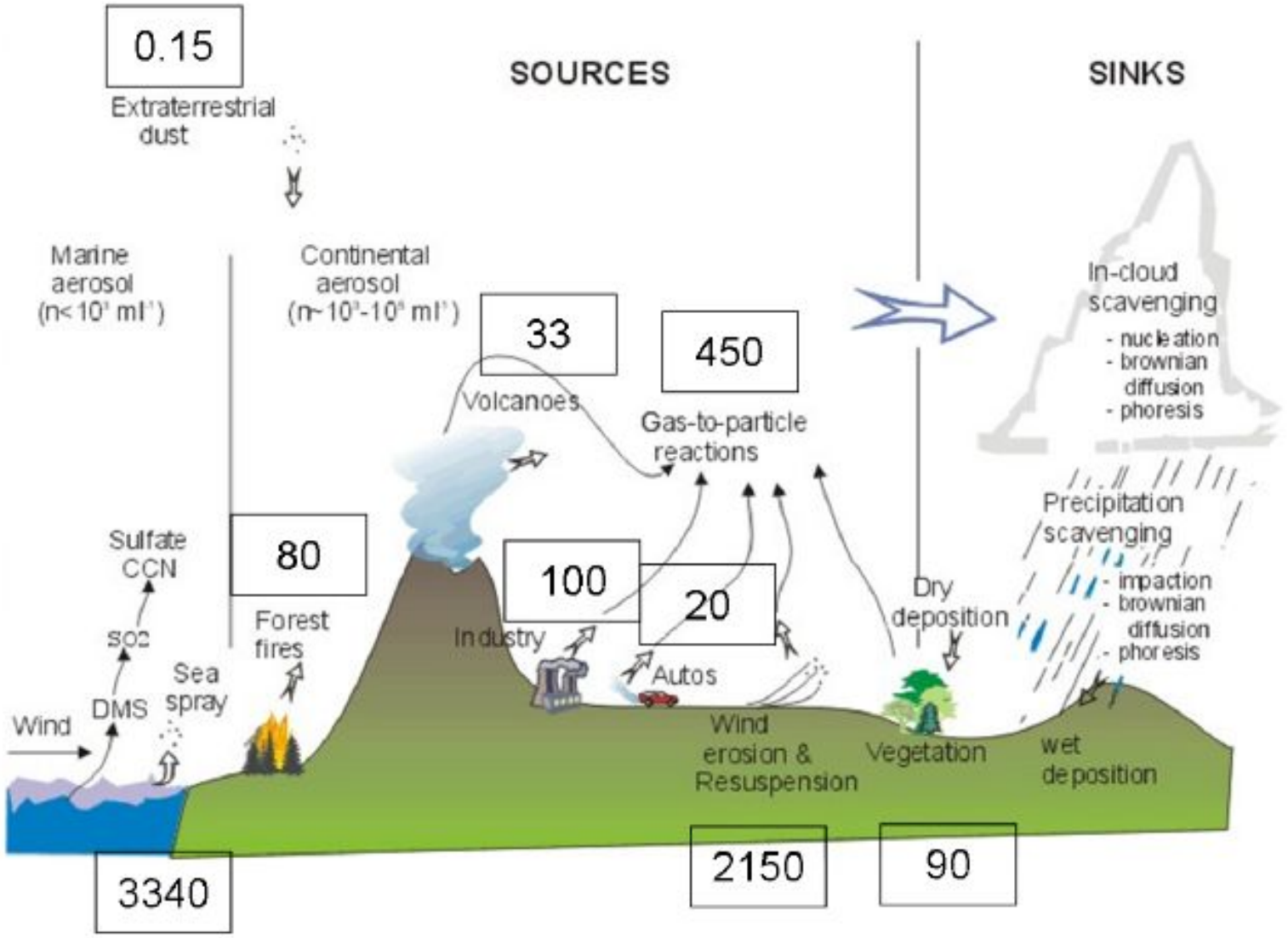
Dust

Sulfate

Sea salt

NASA | GEOS-5 Aerosols

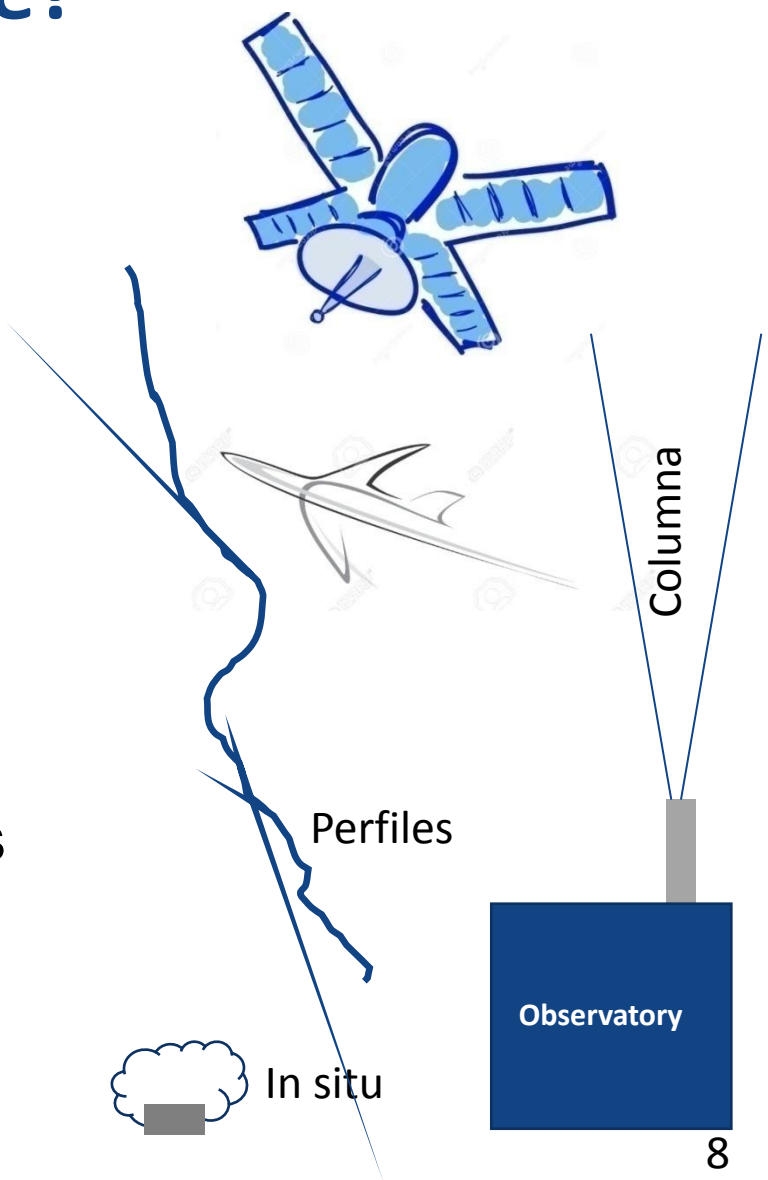
Atmospheric aerosols



IPCC

How we can characterize the state of the atmosphere?

- Satellite measurements
- Ground based remote sensing
- Near surface characterization
- Measurement campaigns
  - *Development of new methods*
- Climate and forecasting models



Dust cycle and associated processes

pending

Dust emission

ingredients soil eroded, surface winds

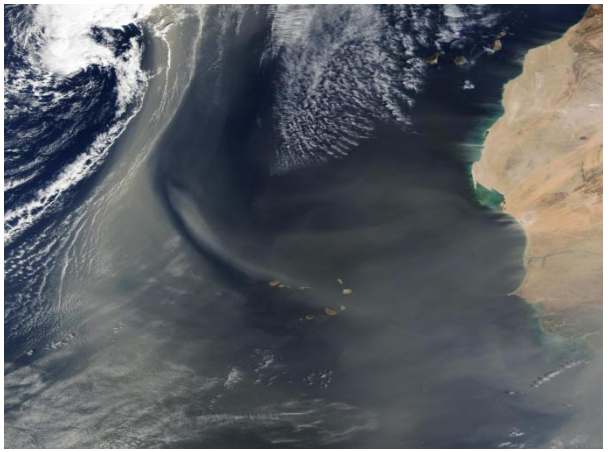
transport - meteorological conditions pending

to add a calipso vertical cross section

Dust cycle and associated processes

Dust **transport** is a global phenomenon. However, **dust emission** is a threshold phenomenon, sporadic and spatially heterogeneous, that is locally controlled on small spatial and temporal scales.

MODIS true colour composite image for March 2005 depicting a dust storm initiated at the Bodélé Depression (Chad Basin)

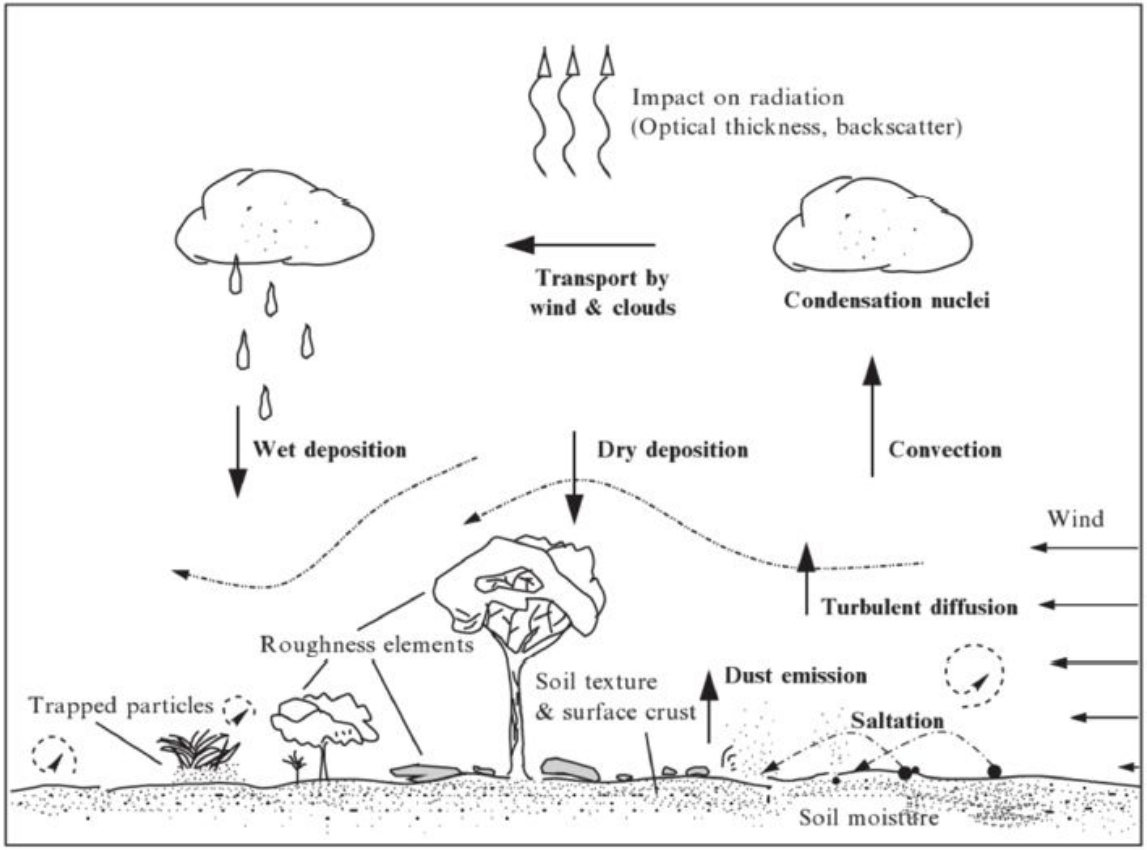


MODIS True color Western Africa – Altantic Ocean

Dust emission, transport and deposition are sensitive to **surface wind speed** and precipitation, among other factors.

Dust cycle and associated processes

The atmospheric dust cycle and involves a variety of processes:



Extracted from Shao (2008)

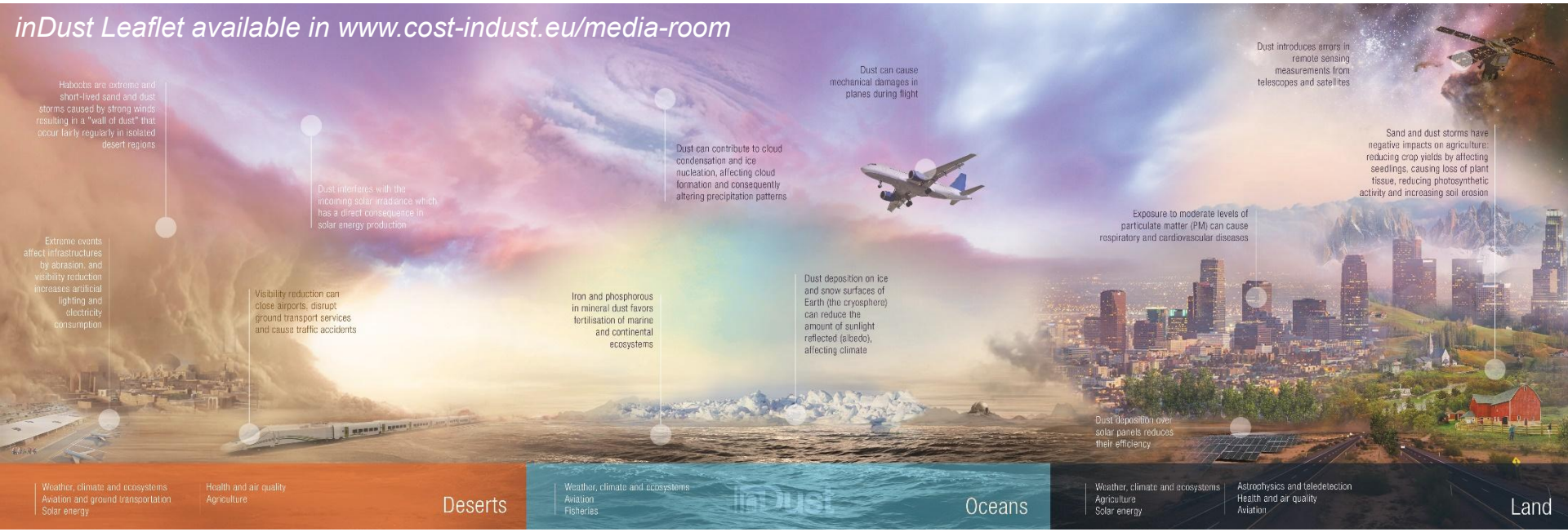
- Dust emission from dry unvegetable surfaces (dust sources)
- Mid- and long-range transport
- Sedimentation, wet and dry deposition

Dust cycle and associated processes

pending

check inDust video Earth

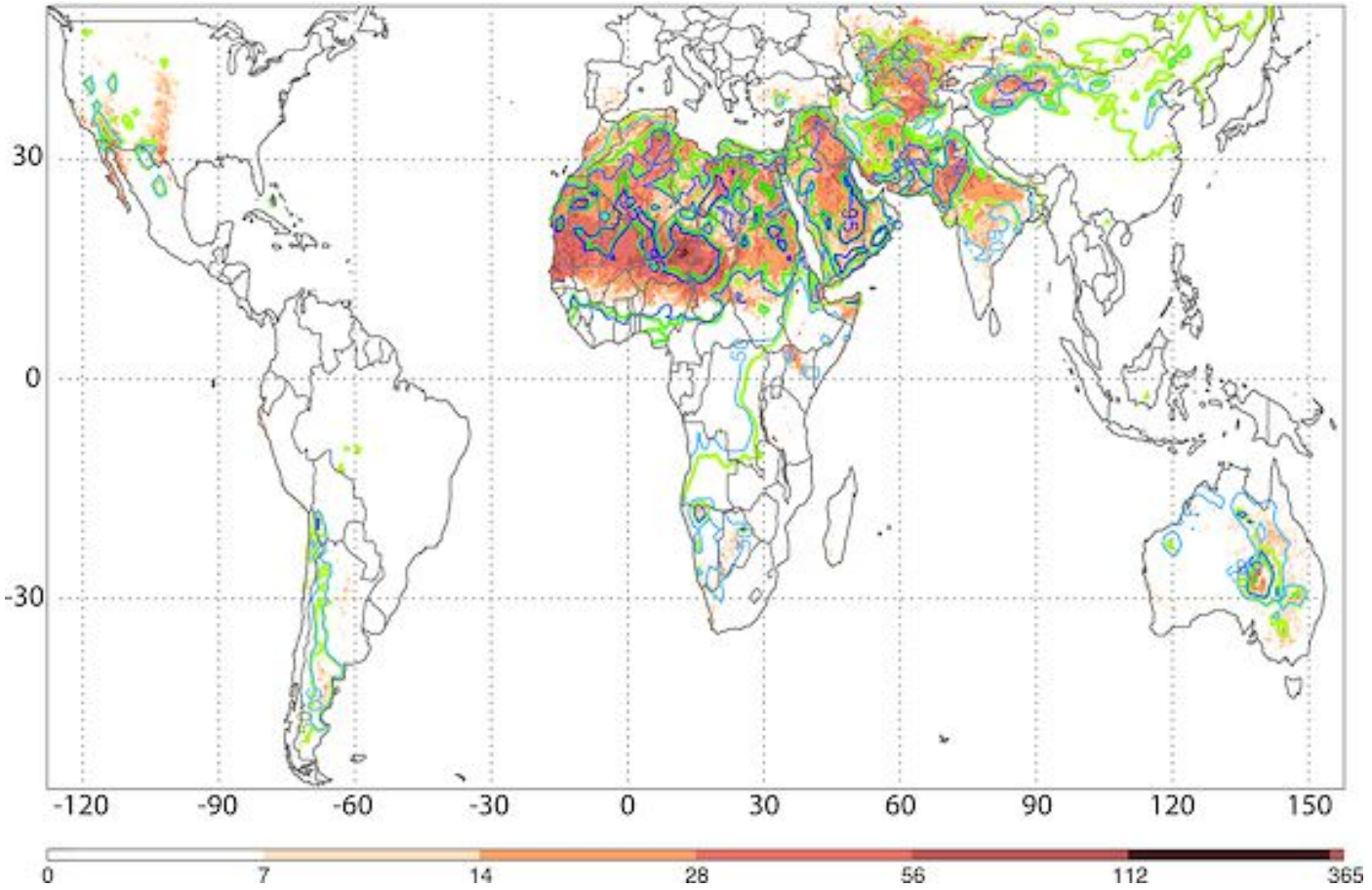
Dust impacts



inDust dissemination materials www.cost-indust.eu/media-room

Desert sources

Dust global distribution



Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products by Ginoux et al. (2012)

Desert sources: Soil types

Main landscapes of the North Africa (Photos from Callot et al. 2000) :

A) Central part of Saharan Atlas. In the background, mountains, and in front, an overgrazed plain;

B) Northern part of Saharan Atlas. Esparto grass steppe degraded by a strong anthropic action. The sandy soil disappears, denuding the sandstone substratum;

C) The Great Hamada south-west of El-Abiodh-Sidi-Cheikh;

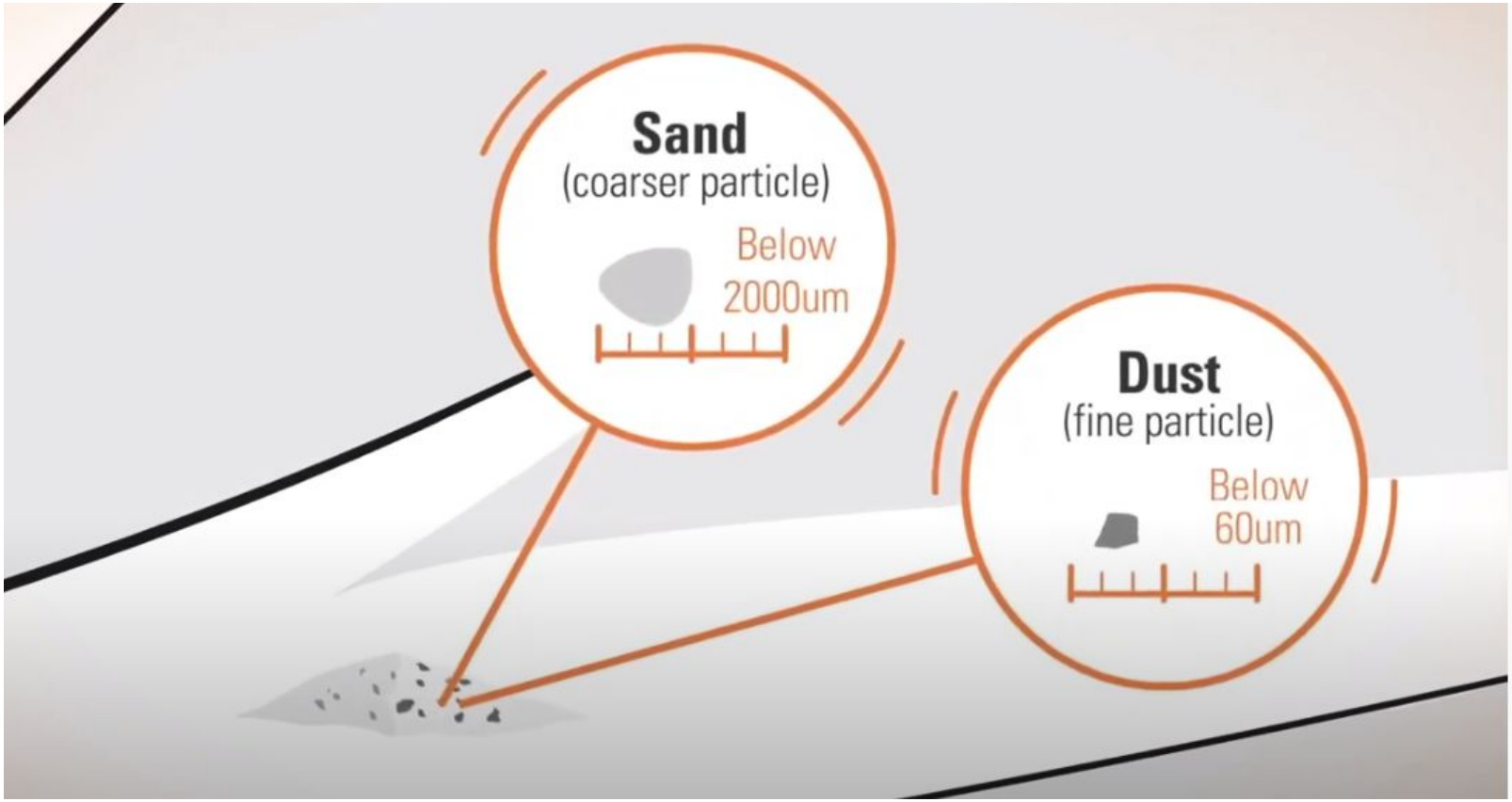
D) Daïa in the Mechfar, at Hassi Cheikh well;

E) North-east of the Great Western Erg: coarse sand interdune corridor with deflation cauldron and palaeolake deposits;

F) North-east of the Great Western Erg: great coarse sand dome dunes, covered by fine sand active dunes.

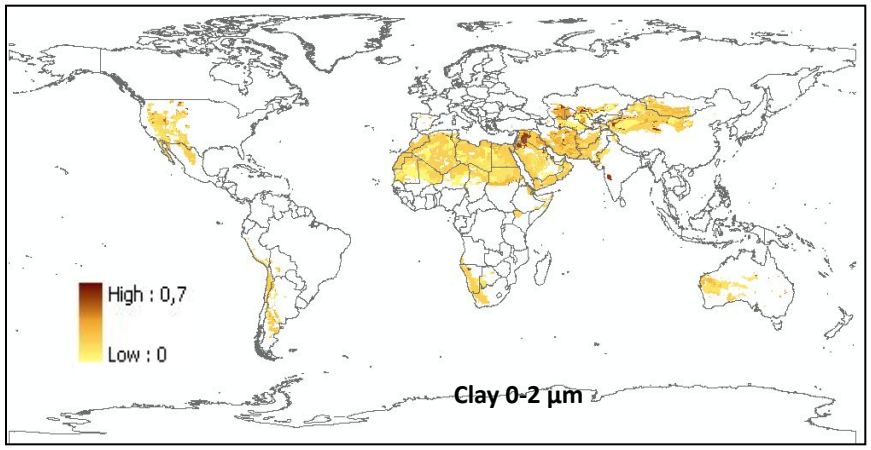
Desert sources: Size

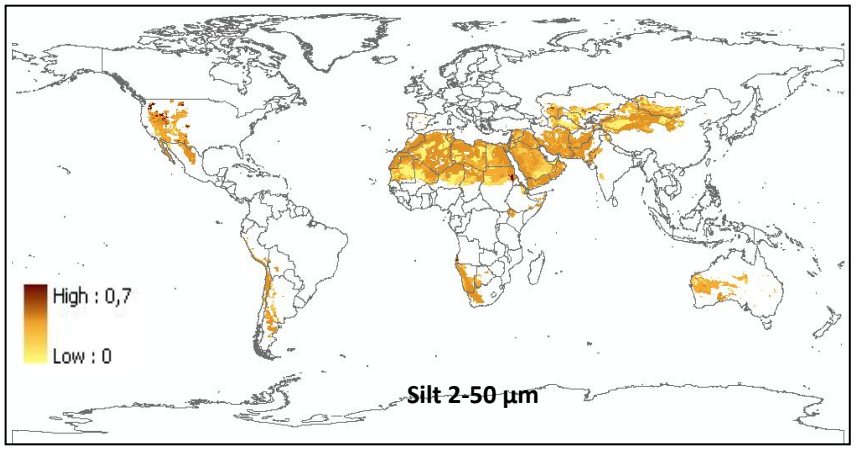
Definition of sand and dust

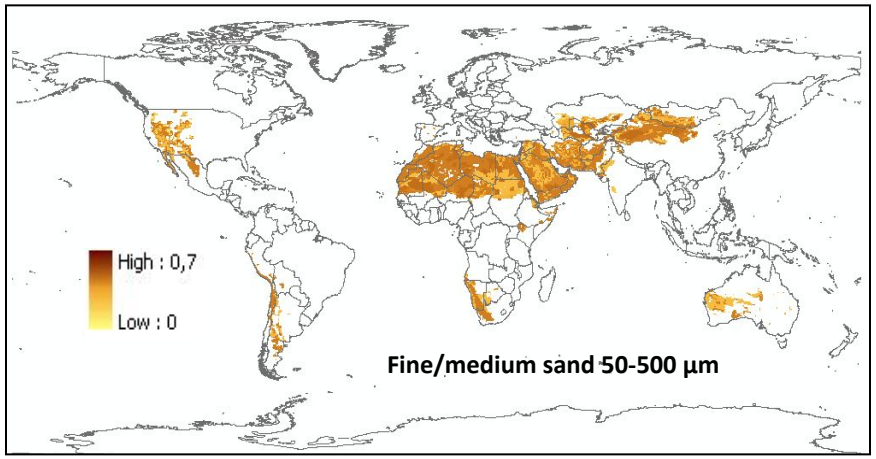


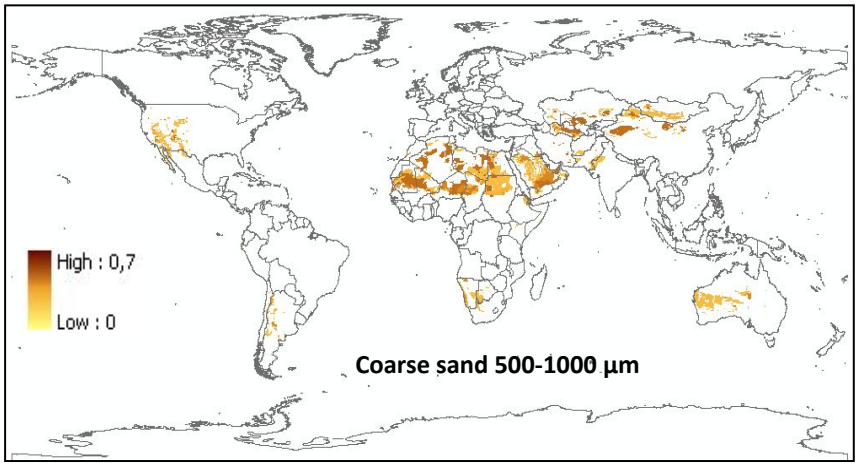
add reference to indust video

Desert sources: Size - Global distribution









Four top soil texture classes according STASGO-FAO 1km database are converted to 4 parent soil size categories following Tegen et al. [2002].

Desert sources:
Dust chemical composition - Mineralogy

pending

IMAGE FROM MODIS AND image on mineralogy (inDust video)

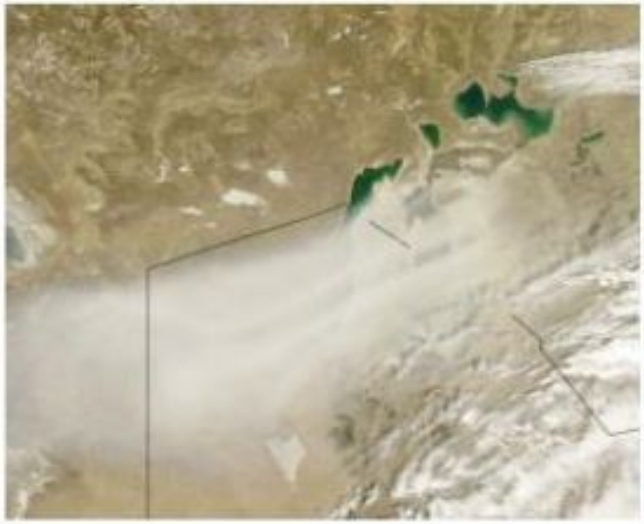
It is a natural phenomena?

La **emisión y resuspensión de polvo** debida a actividades humanas son consideradas fuentes antropogénica

Cattle herds, Chad

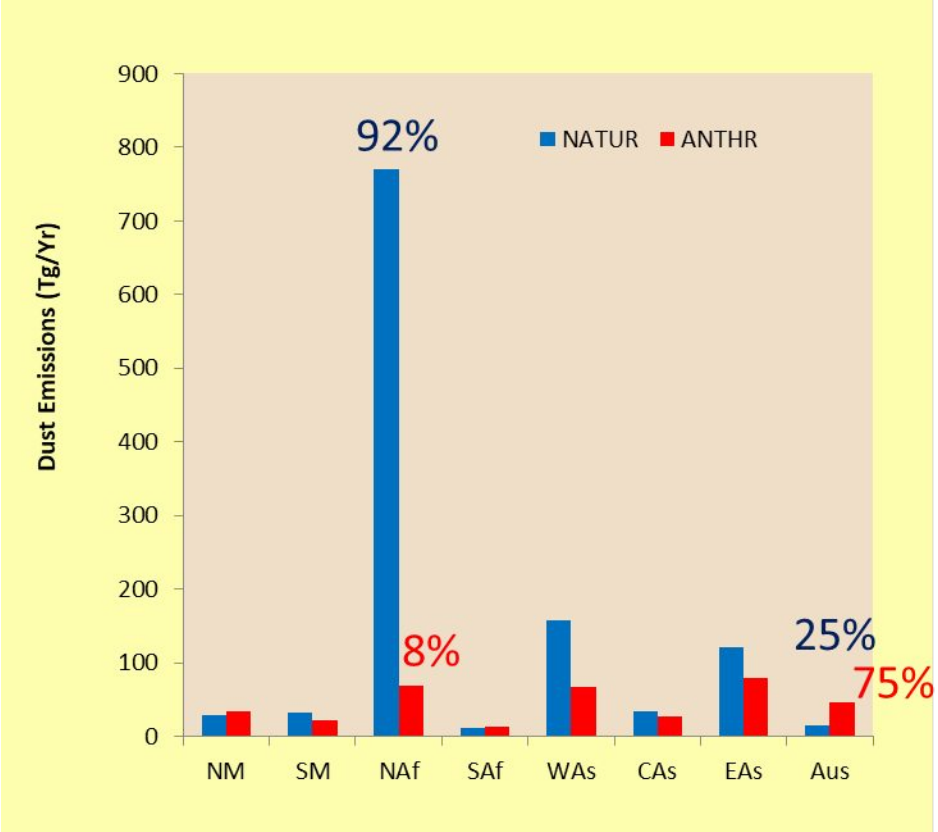
Mining, Ohio valley

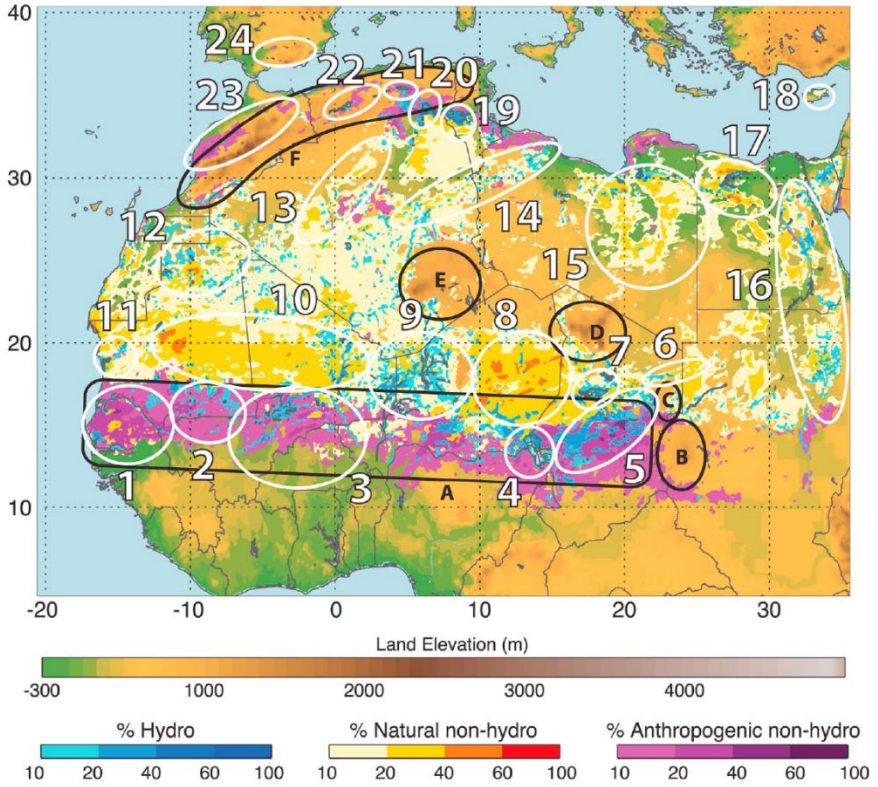
Dust from dry sea bed, Aral sea (Uzbekistan)



Kathmandu, Nepal, March 2017

Natural and anthropogenic dust sources





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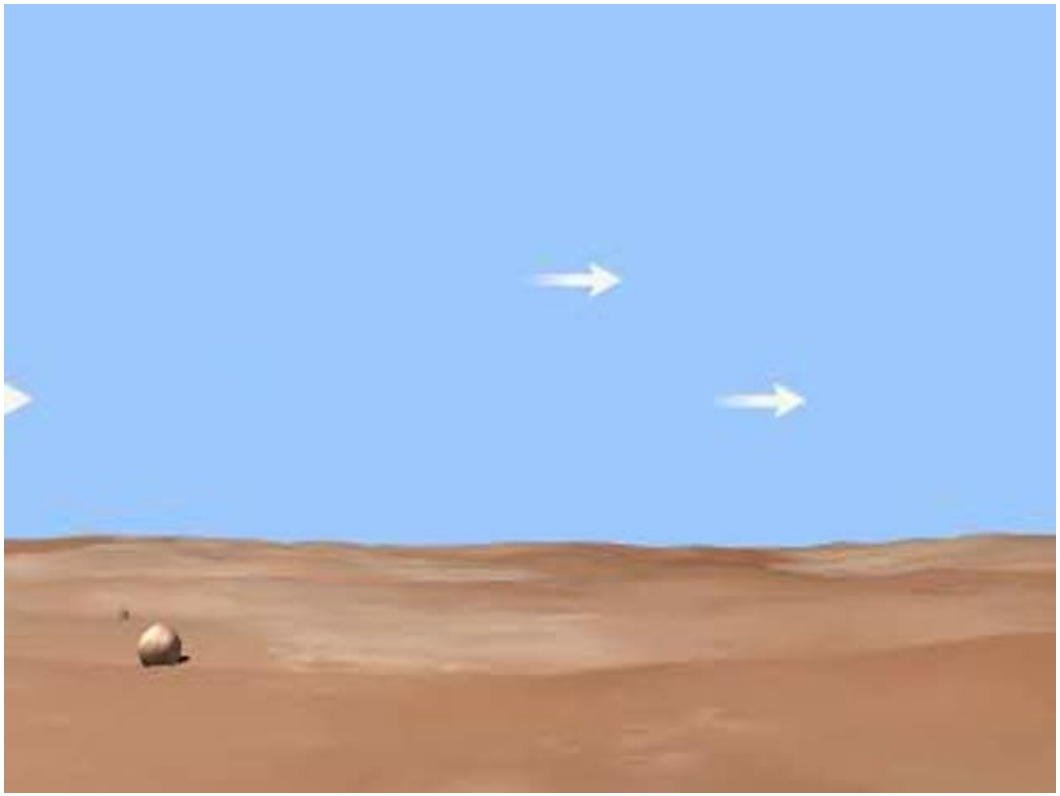
(Ginoux et al., RoG, 2012)

Dust emission mechanisms

- Complex physical process involving entrainment of soil particles by the surface winds.



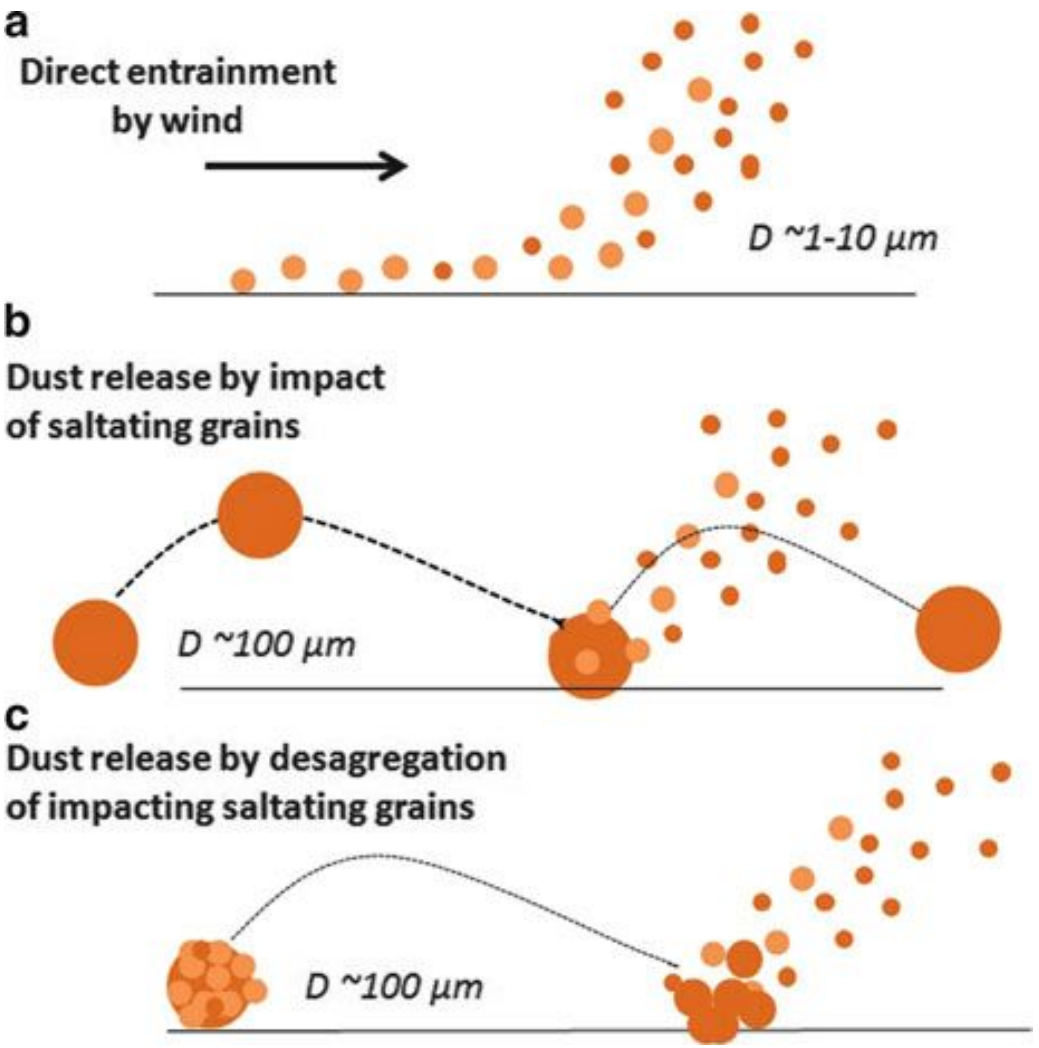
- Creep or rolling motion of the largest particles (> 500 um)

- Saltation or horizontal motion of large soil grains (sand) (50-500um)

- Suspension of dust (after sandblasting or saltation bombardment) (0.1-50 um)

Movie from the COMET program at http://meted.ucar.edu/ of the University Corporation for Atmospheric Research (UCAR)

Dust emission mechanisms



Emitted dust mass

&

Size distribution

Dust emission mechanisms

The emission threshold depends on the type and status of the land

Dry session

Wet session → Flooded soil

Crusted soil

Snow

Dust emission mechanisms

The emission threshold depends on the type and status of the land

Urmia Lake, Iran
NASA MODIS

Types of sand and dust storms

Synoptic storms (large scale weather systems)

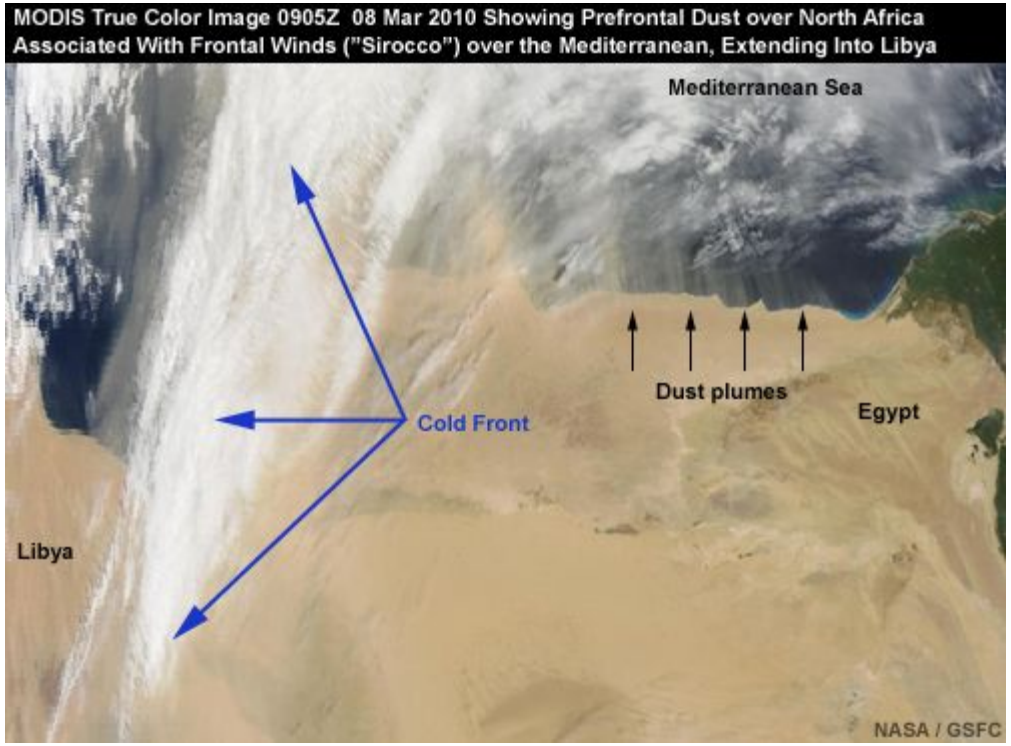
- Prefrontal winds
- Postprontal winds
- Large-scale Trade winds
- …

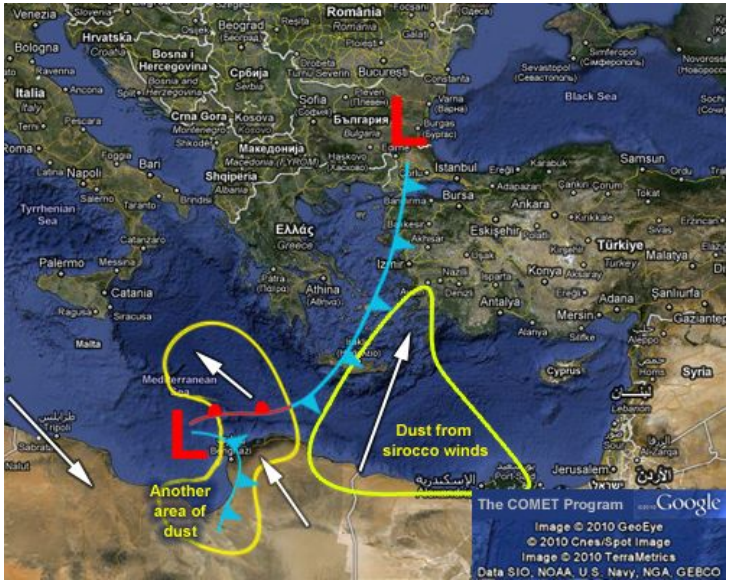
Mesoscale storms

- Downslope winds
- Gap flow
- Convection (dust devils and Haboobs)
- Inversion downburst storms
- …

Types of sand and dust storms

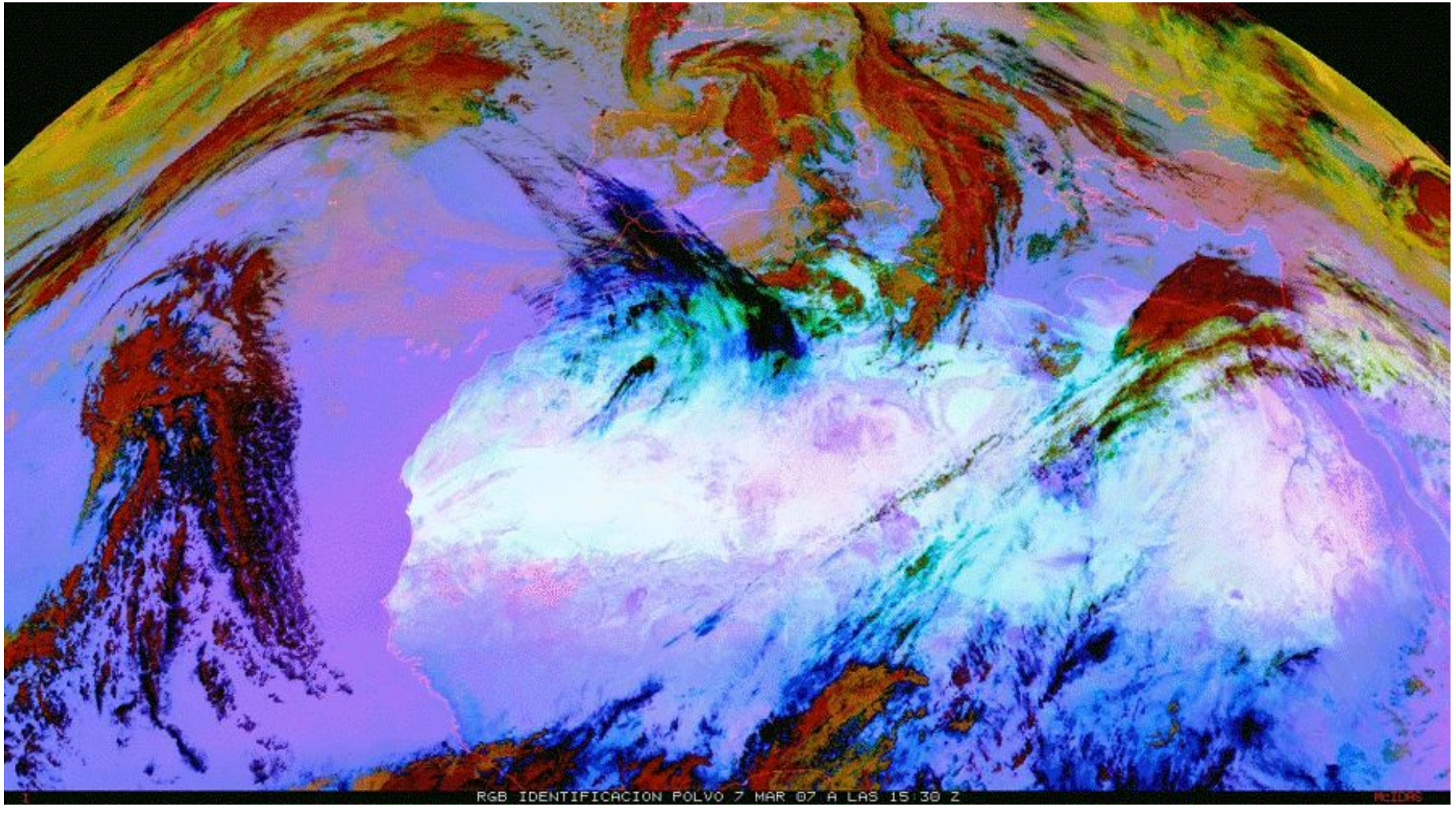
Synoptic dust storms: Pre-frontal





Types of sand and dust storms

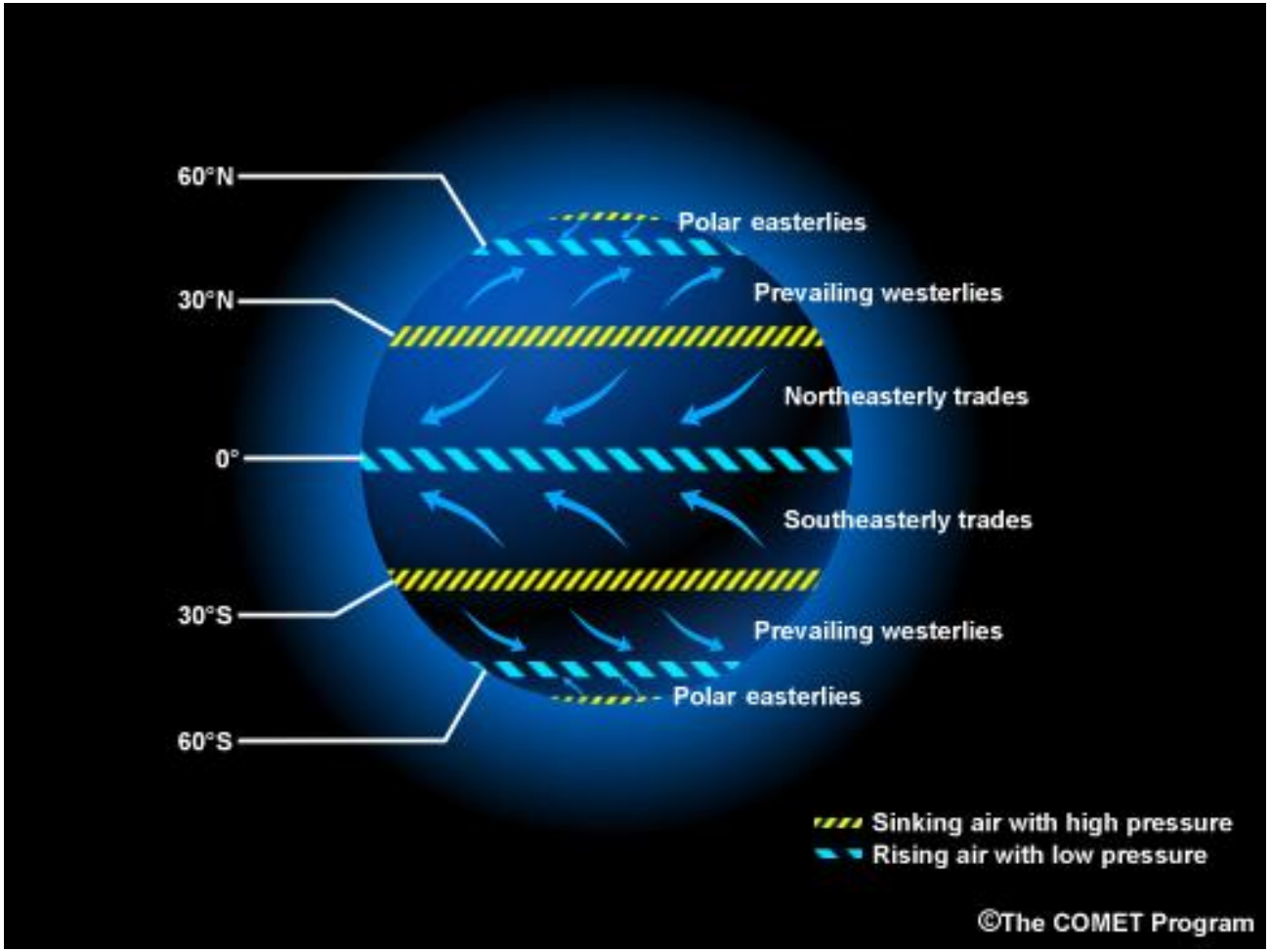
Synoptic dust storms: Post-frontal



animation is not working!

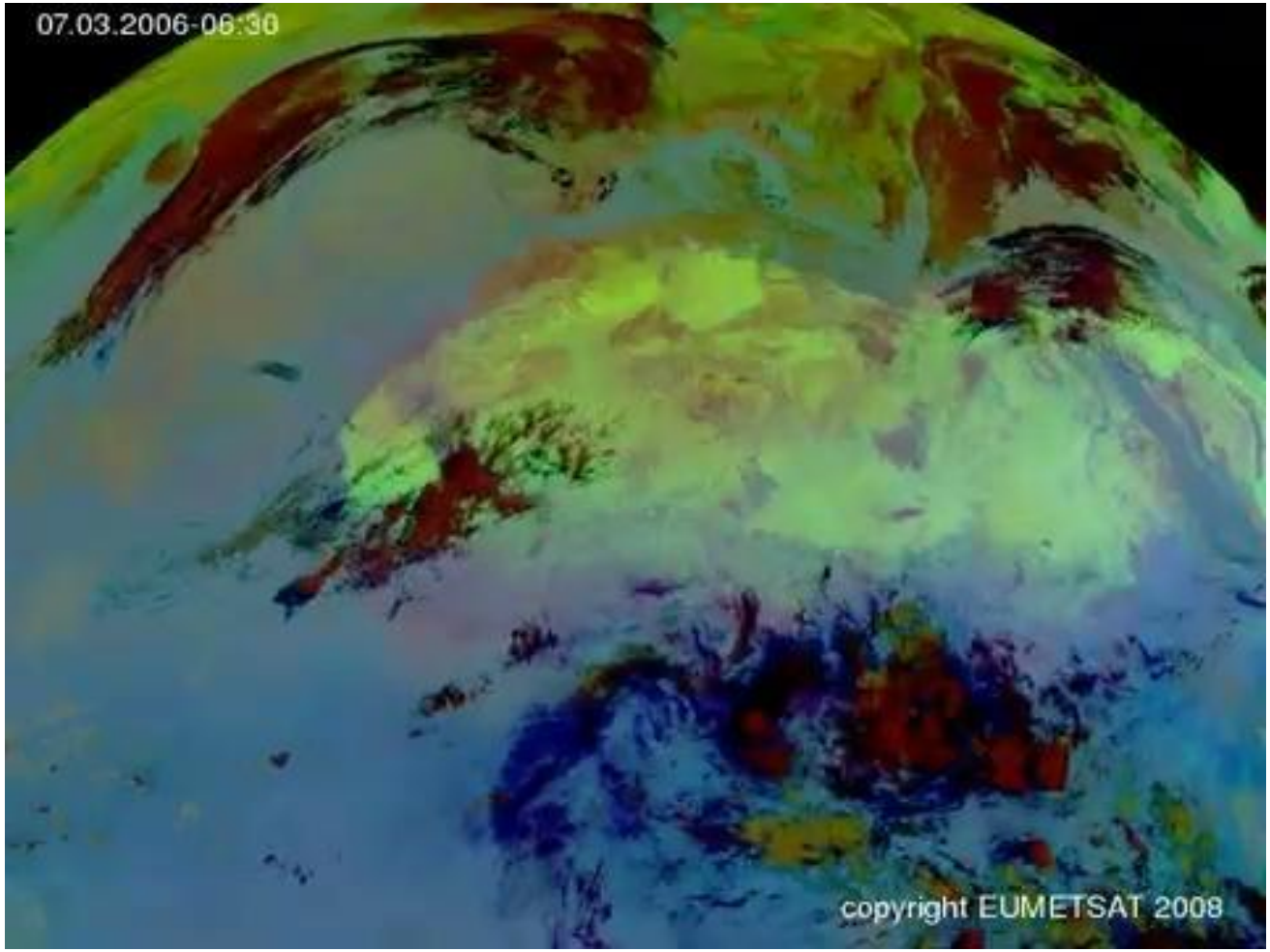
Types of sand and dust storms

Synoptic dust storms: Large-scale trade winds



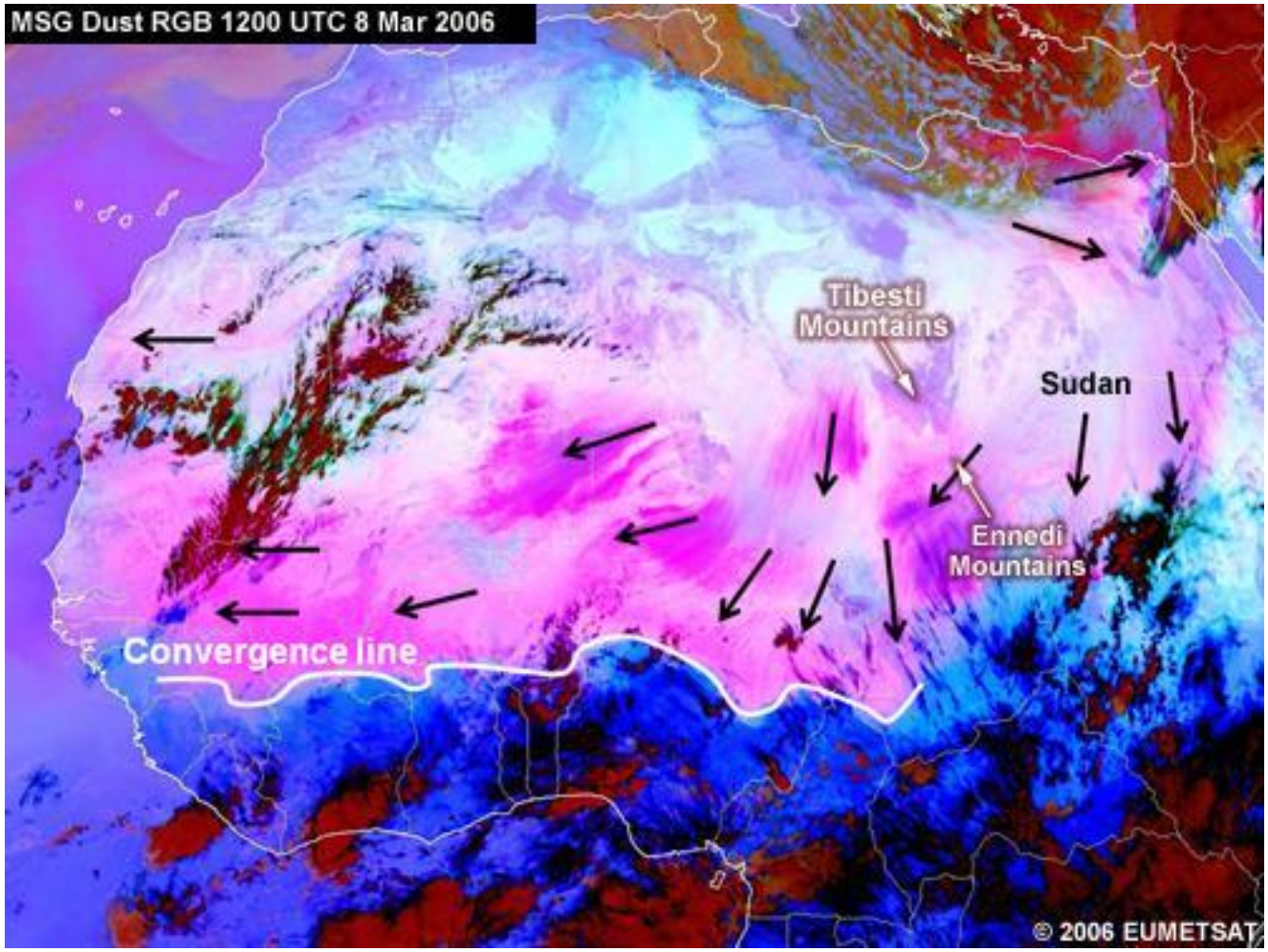
Types of sand and dust storms

Synoptic dust storms: Large-scale trade winds



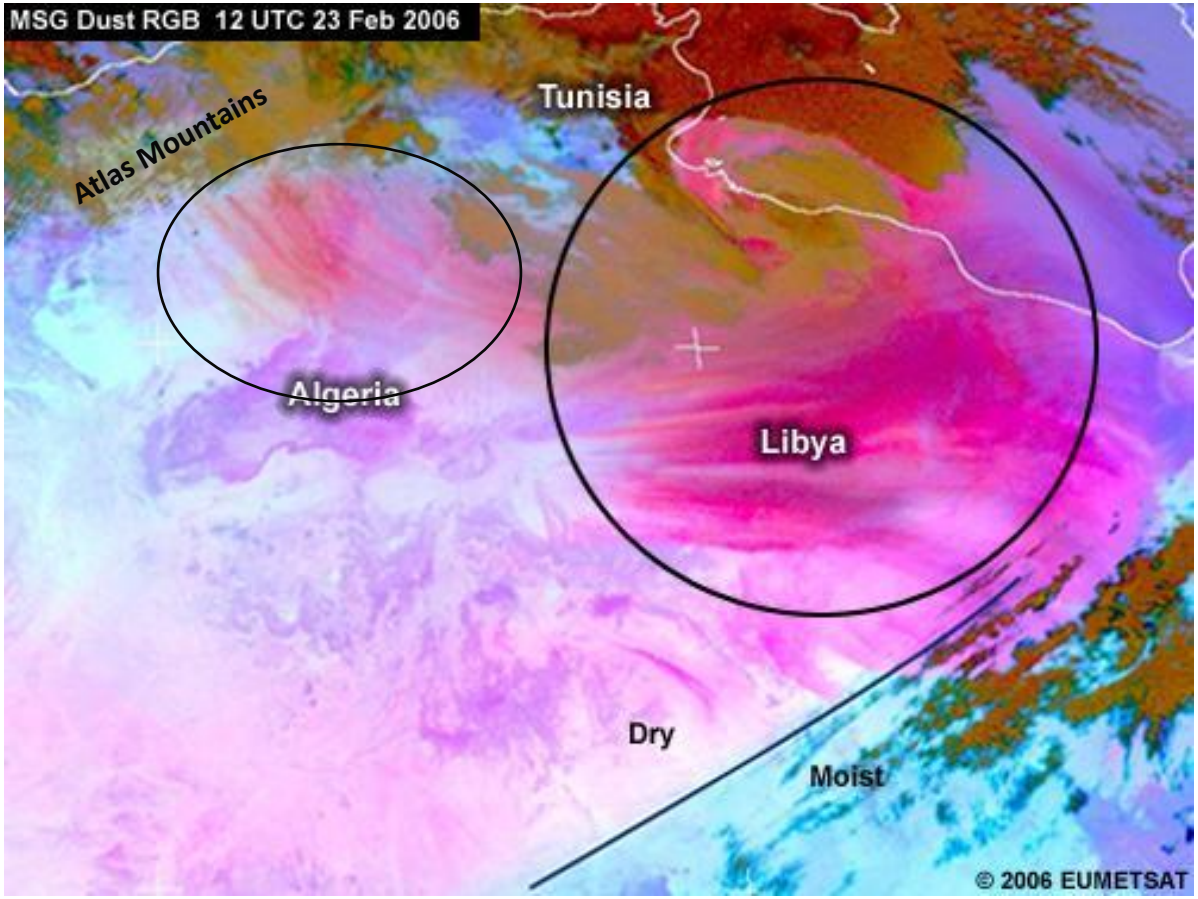
Types of sand and dust storms

Synoptic dust storms: Large-scale trade winds



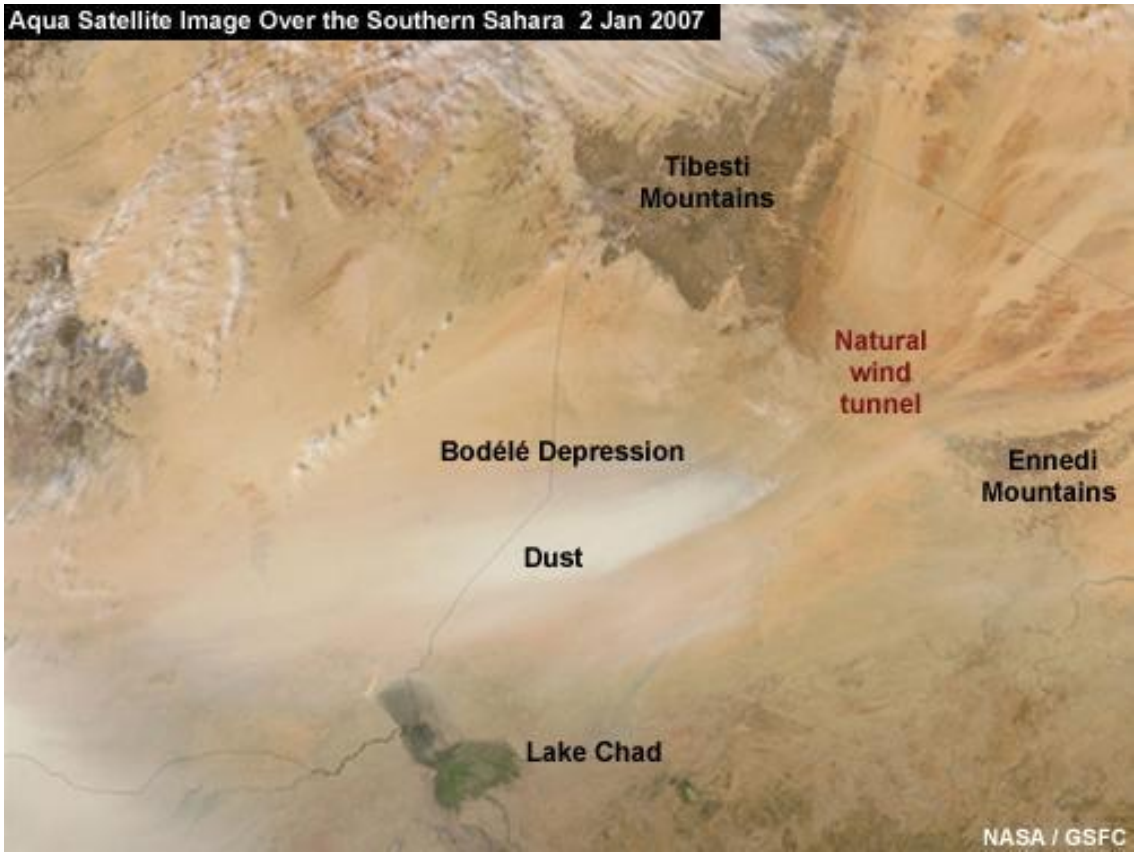
Types of sand and dust storms

Mesoscale dust storms: Downslope winds



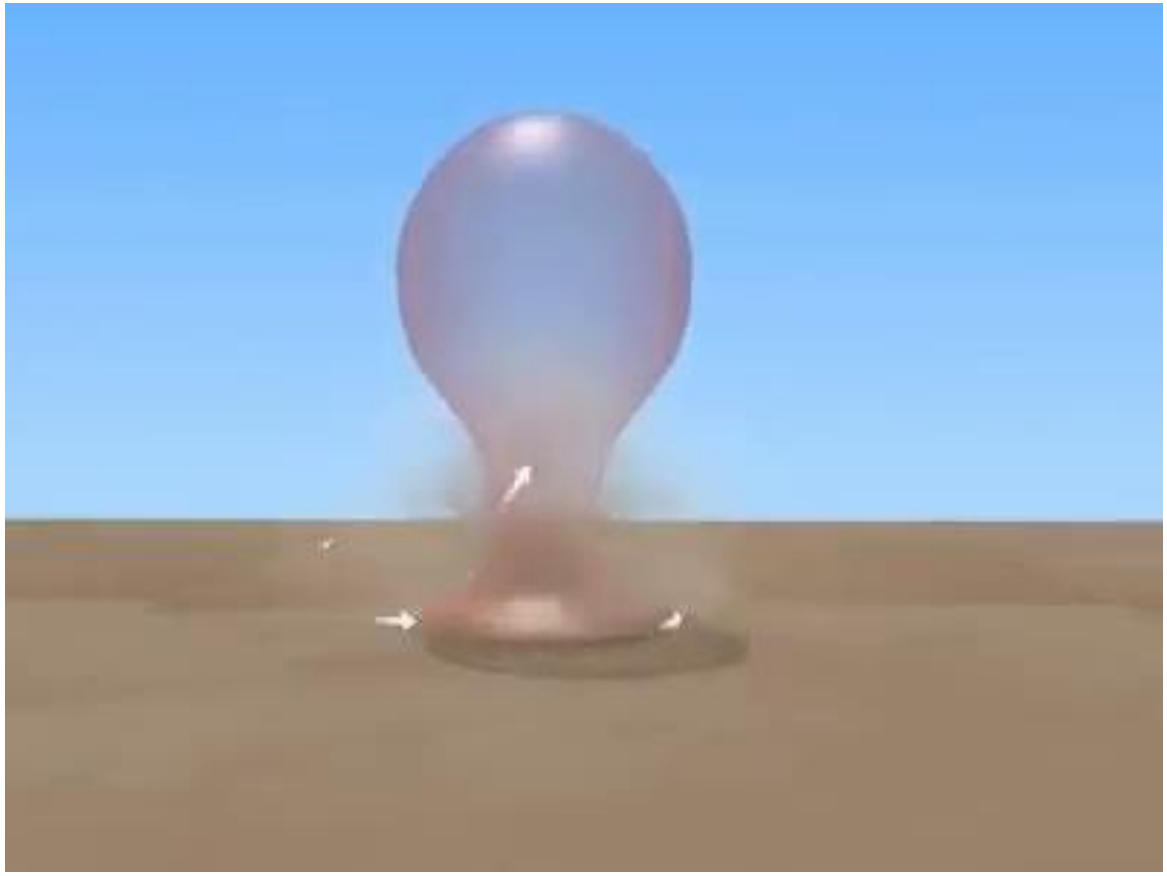
Types of sand and dust storms

Mesoscale dust storms: Gap flow



Types of sand and dust storms

Mesoscale dust storms: Dust devils (convection)



Movie from the COMET program at http://meted.ucar.edu/ of the University Corporation for Atmospheric Research (UCAR)

Types of sand and dust storms

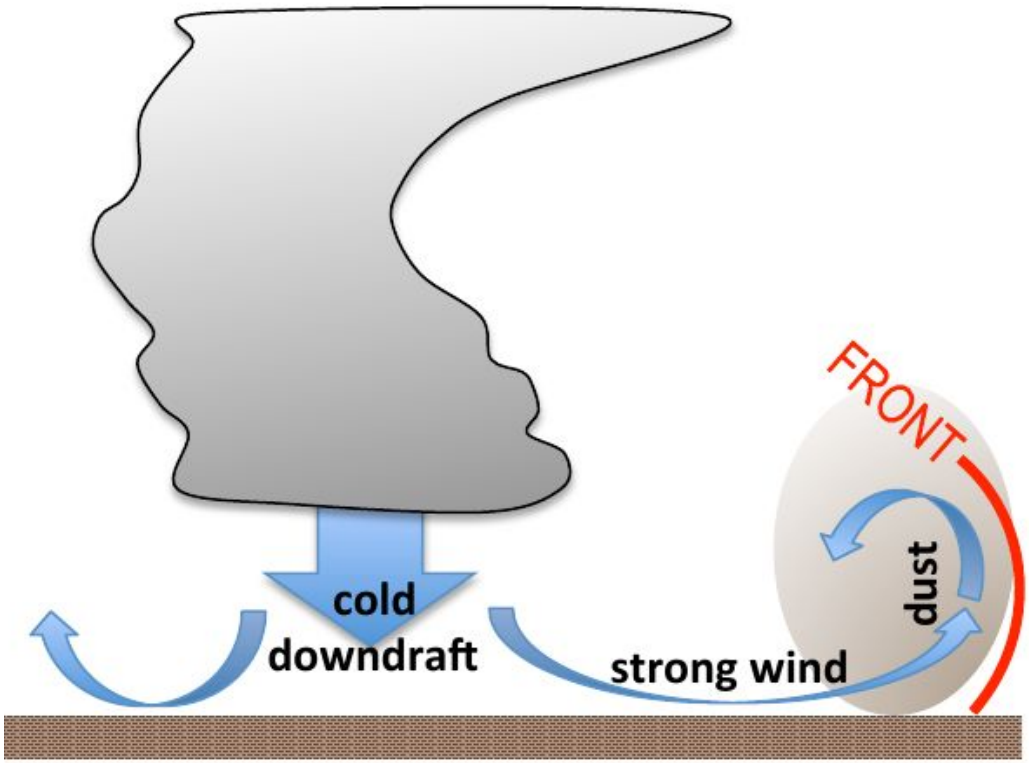
Mesoscale dust storms: Haboobs

Movie from the COMET program at http://meted.ucar.edu/ of the University Corporation for Atmospheric Research (UCAR)

Types of sand and dust storms

Mesoscale dust storms: Haboobs

Intensive cold downbursts from convective cells produced high velocity surface wind, creating cold front which was lifting, mixing and pushing dust

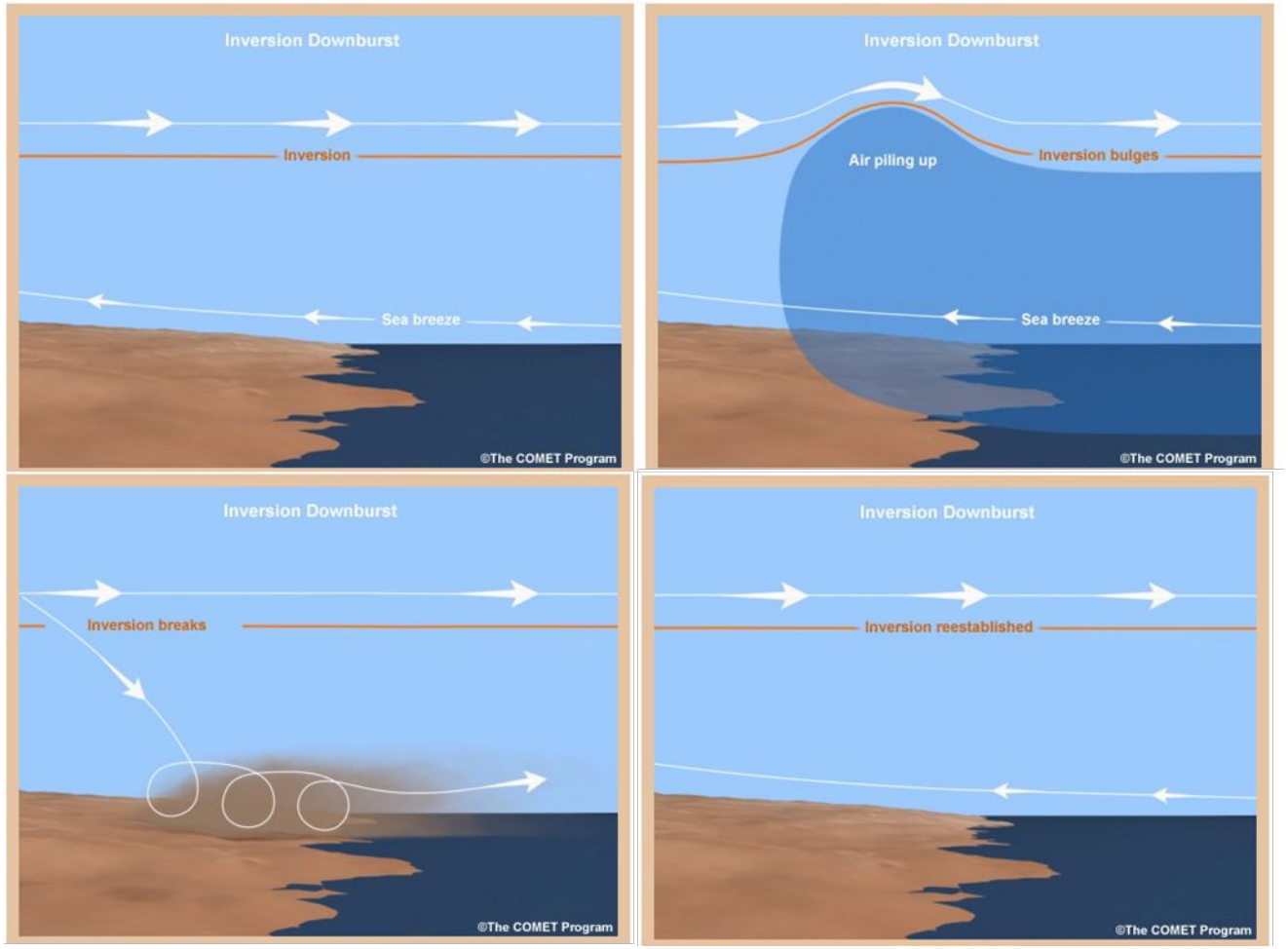


Expected: high wind speed, drop in temperature, rise in humidity, rise in pressure, reduction of visibility.

(Vukovic et al., in preparation)

Types of sand and dust storms

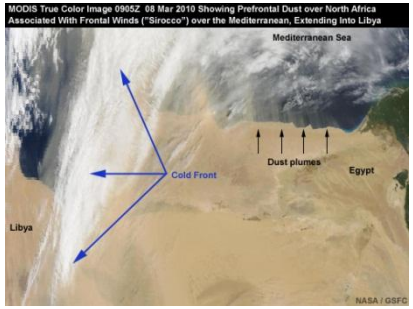
Mesoscale dust storms: Inversion downbursts



Movie from the COMET program at http://meted.ucar.edu/ of the University Corporation for Atmospheric Research (UCAR)

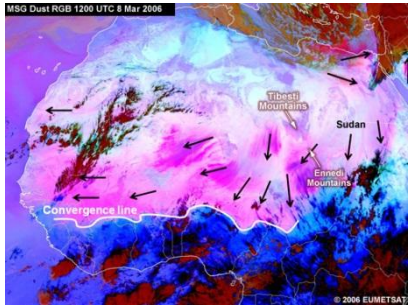
Types of sand and dust storms

Synoptic dust storms (large scale weather systems)



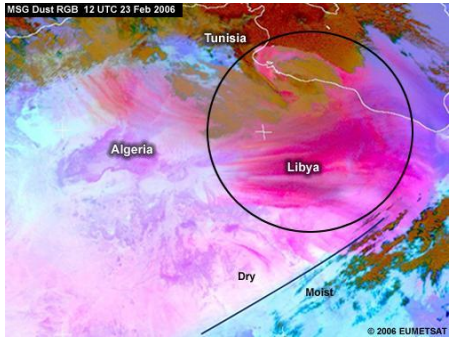
Pre-frontal winds

Post-frontal winds

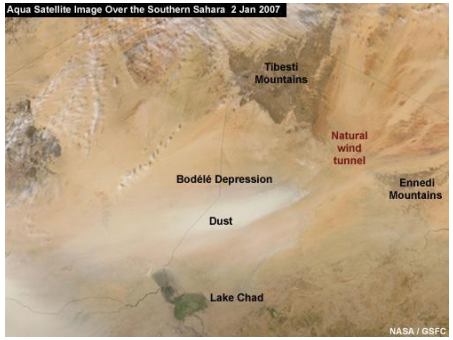


Large-scale trade winds

Mesoscale dust storms



Downslope winds

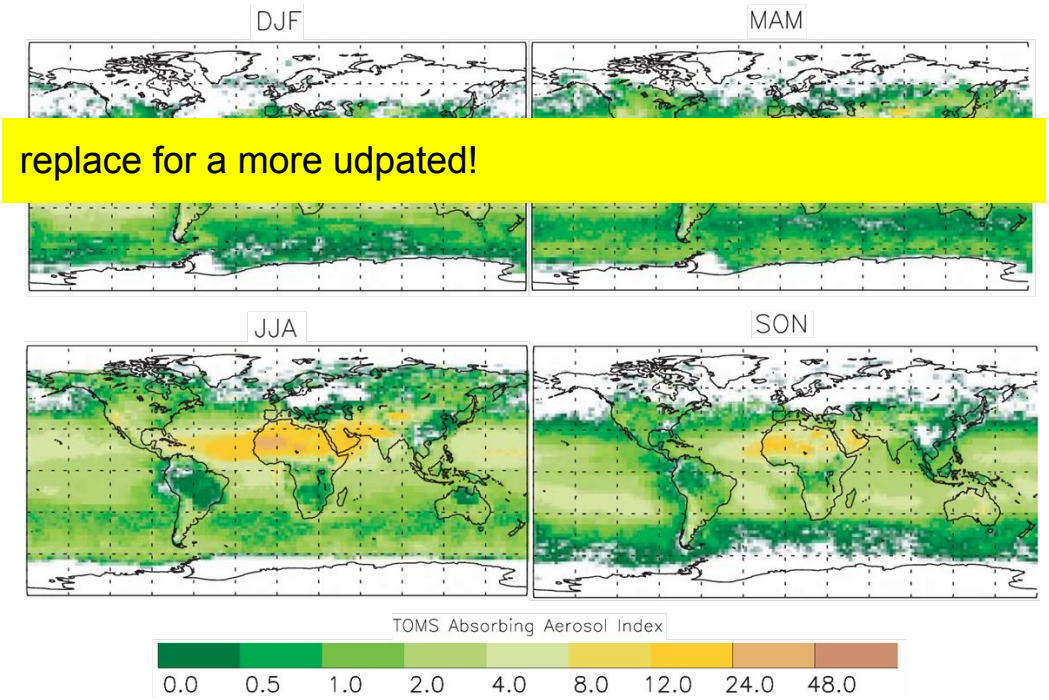


Gap flow

Dust devils

Haboobs

Interannual, decadal and long-term trends



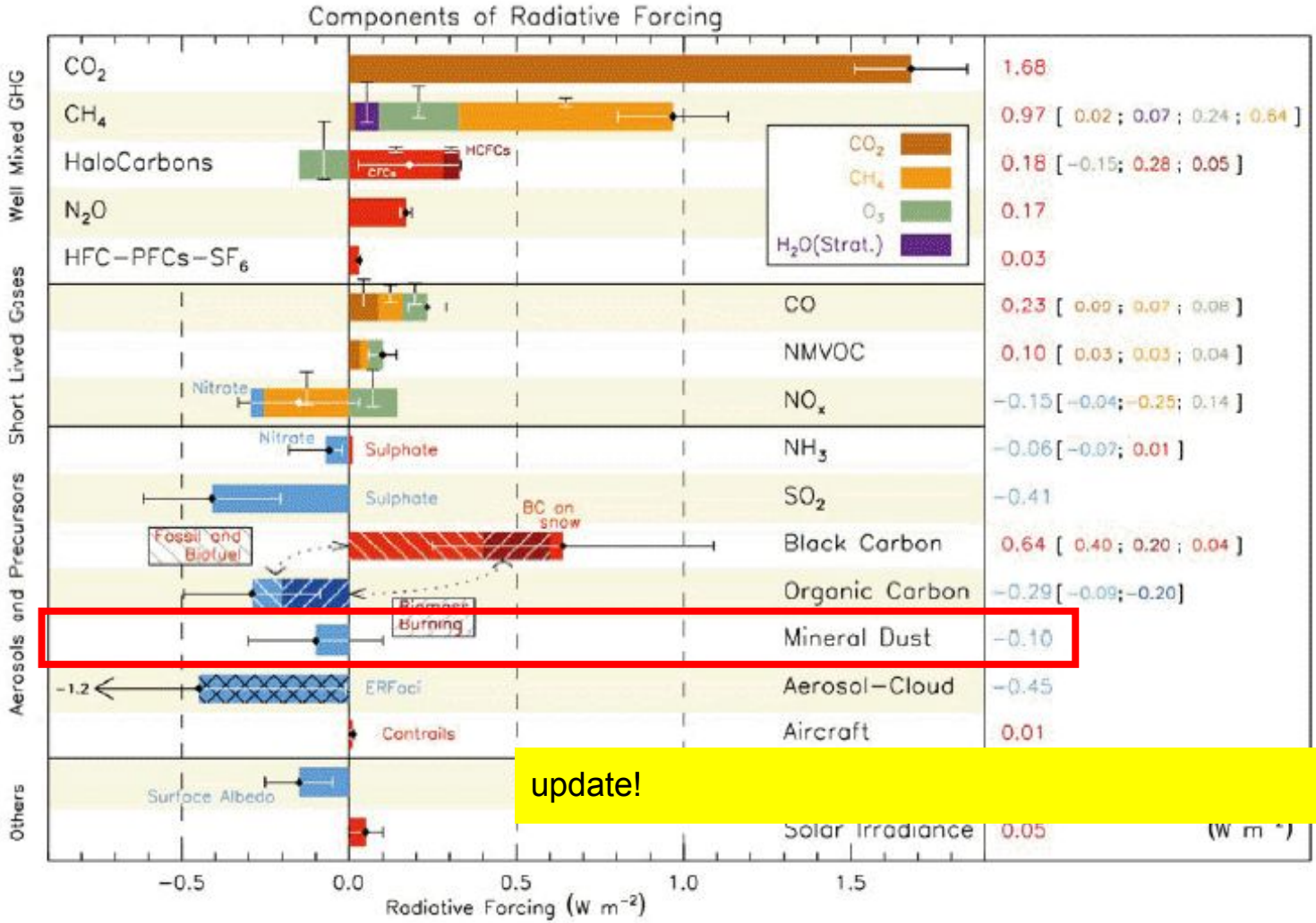
replace for a more udpated!

- **Seasonal** dust distribution changes well characterized. Follows seasonal changing weather regimes (mainly) and vegetation changes (in semi-arid areas)

- **Interannual/decadal** changes are controlled by climate and surface modification (land use, desertification). Decadal changes are not well captures by models

Figure extracted from Tegen al. (2002)

How dust interact with the climate?

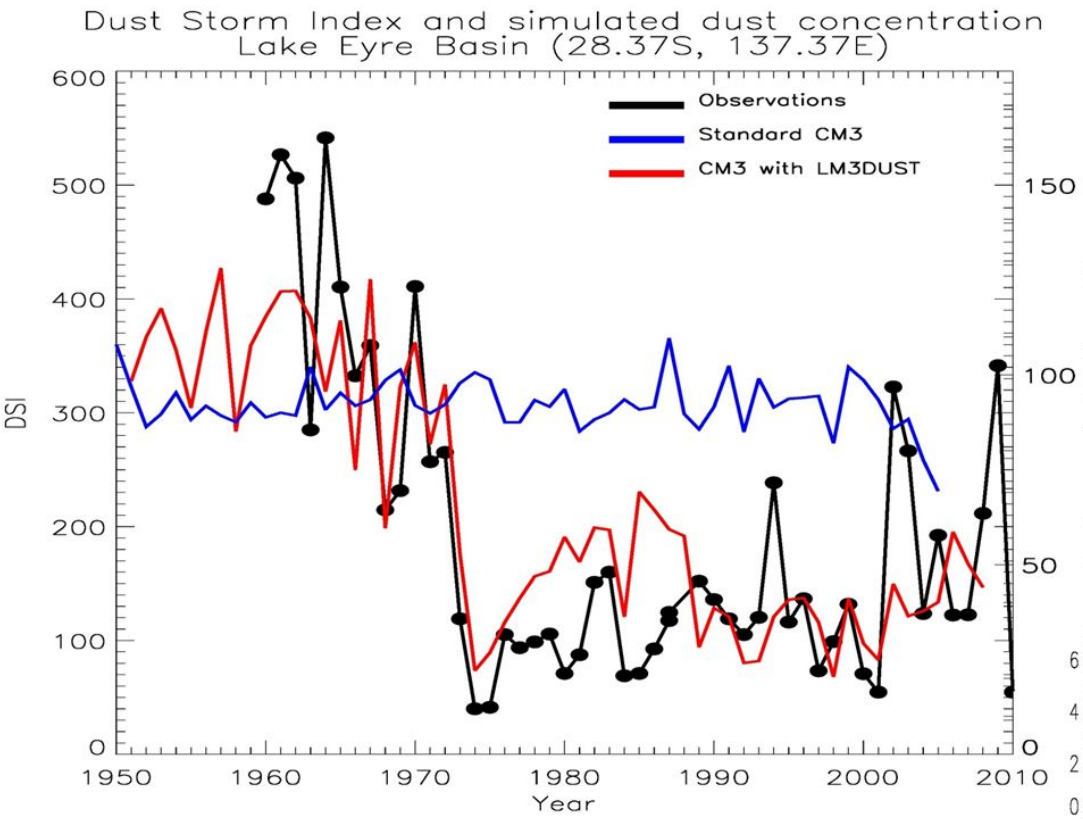


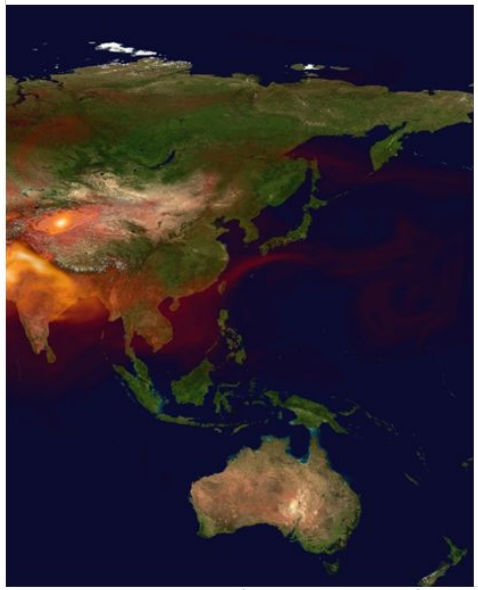
update!

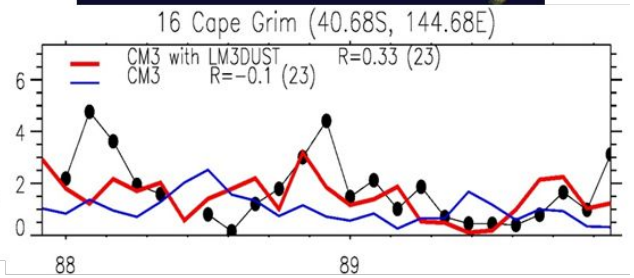
(IPCC, 2013)

How dust interact with the climate?

Connecting dust emission
to dynamic vegetation model and land use change







Following heavy precipitation in early 70s, surface dust concentration dropped by a factor 3 in agreement with Dust Storm Index.

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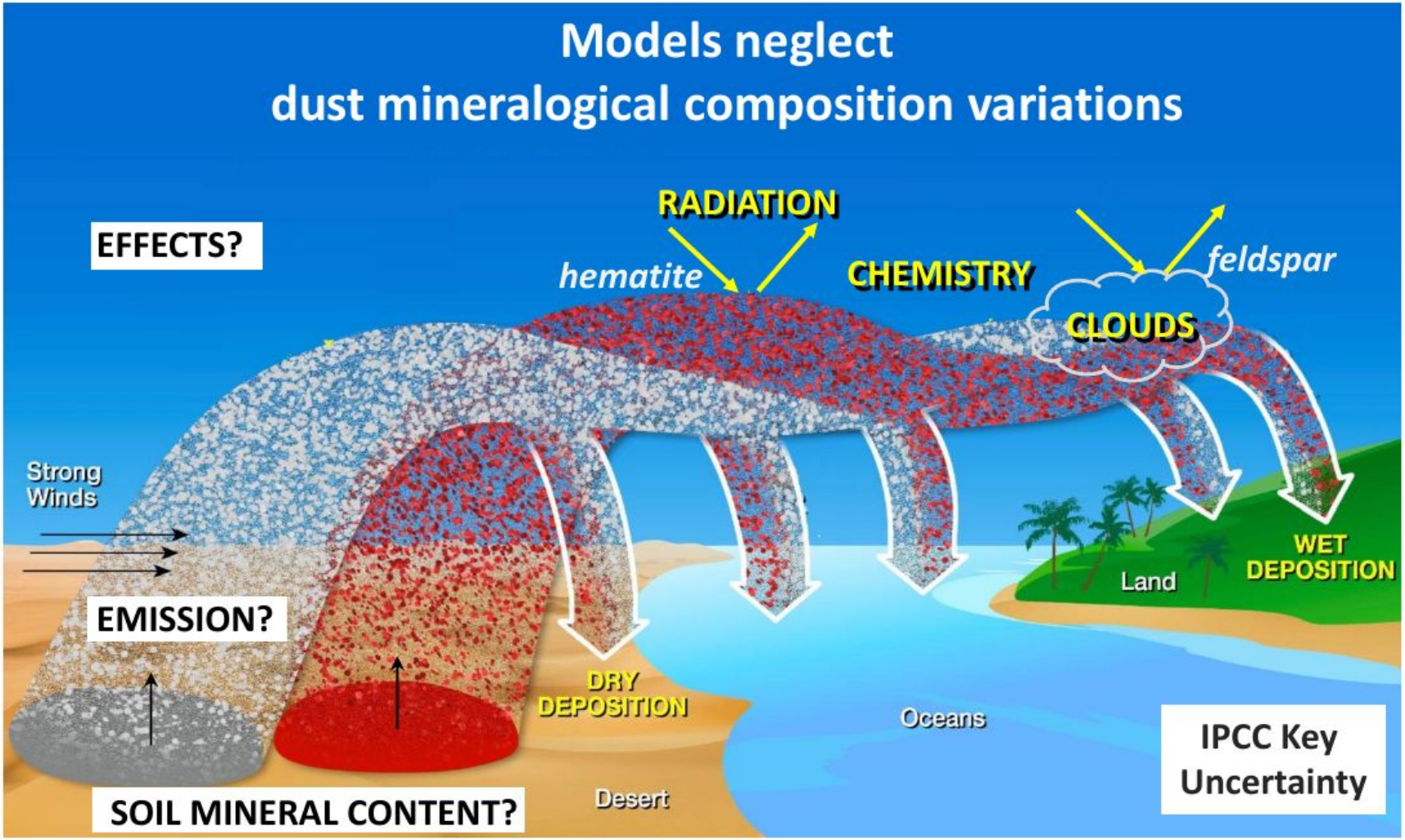
Courtesy Paul Ginoux, NOAA

How dust interact with the climate?



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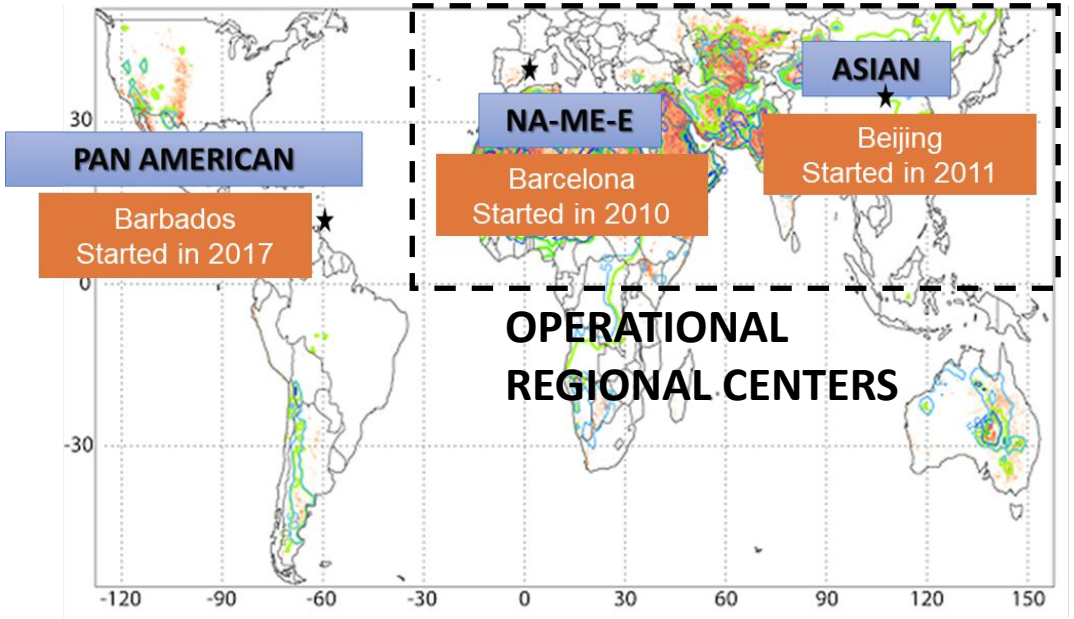
Courtesy Carlos Pérez García-Pando, BSC

WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)

Objectives:

- Identify and improve products to monitor and predict dust by working with research and operational organizations, as well as with users.
- Facilitate user access to information.
- Strengthen the capacity of countries to use the observations, analysis and predictions provided by the WMO SDS-WAS.

Regional Nodes and Centers

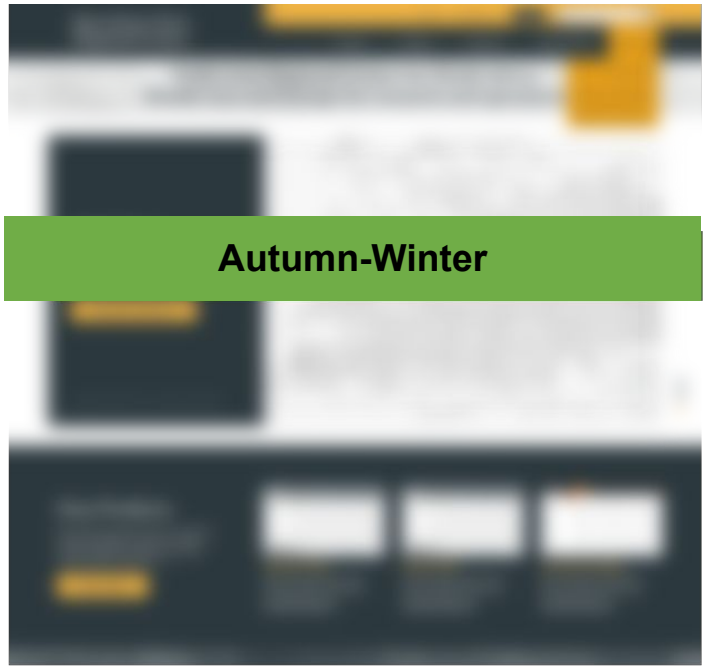


WMO Barcelona Dust Regional Center

The **WMO Barcelona Dust Regional Center** is coordinating and active in the ongoing research projects that search to produce **dust services**. Our activities are taking as a reference by the U pending ion of dust **impacts**.

Barcelona Dust Forecast Center
Operations
http://dust.aemet.es

SDS-WAS
R&D and operations
http://sds-was.aemet.es



http://dust.aemet.es
@Dust_Barcelona

The work presented here it is possible thanks to the support of collaboration of the active members of the WMO SDS-WAS NAMEE Regional Node and associated researchers from NASA (i.e. AERONET, MODIS) as well as the inDust networks.

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Centro Nacional de Supercomputación
AEMet Agencia Estatal de Meteorología
World Meteorological Organization
Weather · Climate · Water

Thank you

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