USER GUIDE

MAY 2022

VERSION 2.0

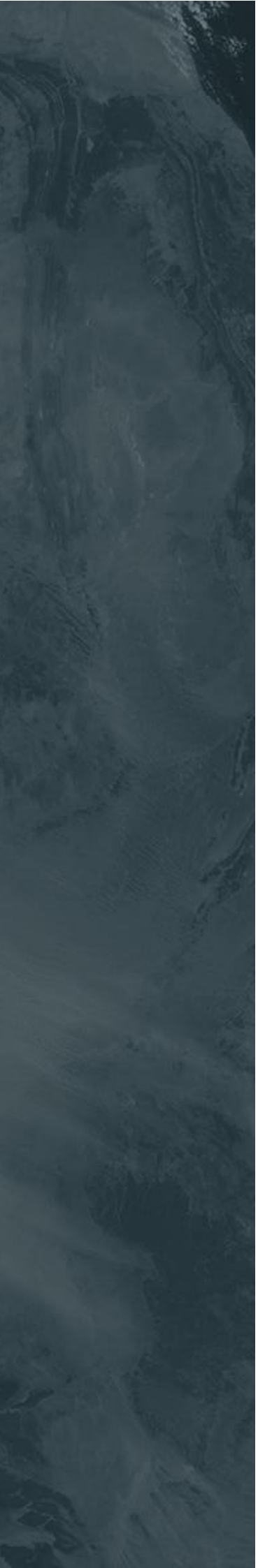
Barcelona Dust Regional Center

WMO SDS-WAS Regional Center for Northern Africa, Middle East and Europe, conducting research and providing operational products

AEMet Agencia Estatal de Meteorología

BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación

WORLD METEOROLOGICAL ORGANIZATION



ABOUT

The **WMO Barcelona Dust Regional Center** coordinates the research activities and operations of the World Meteorological Organization Sand and Dust Storms Warning Advisory and Assessment System (**WMO SDS-WAS**) in **Northern Africa, the Middle East, and Europe**.

The main objective of **the Center** is to enhance the ability of the countries to deliver timely and high-quality sand and dust storm forecasts, observations and knowledge to the users. Providing access to such information is fundamental to support the development of early warning systems and mitigation plans. Additionally, it responds to the growing interest of stakeholders from different sectors, enforcing the international partnership between research, operational services and user communities.

This **User Guide** explains how to access and explore the available dust products through **the Center's** website and describes the key features that allow users to customize their experience and the analysis of the provided information.

DOCUMENT VERSIONS

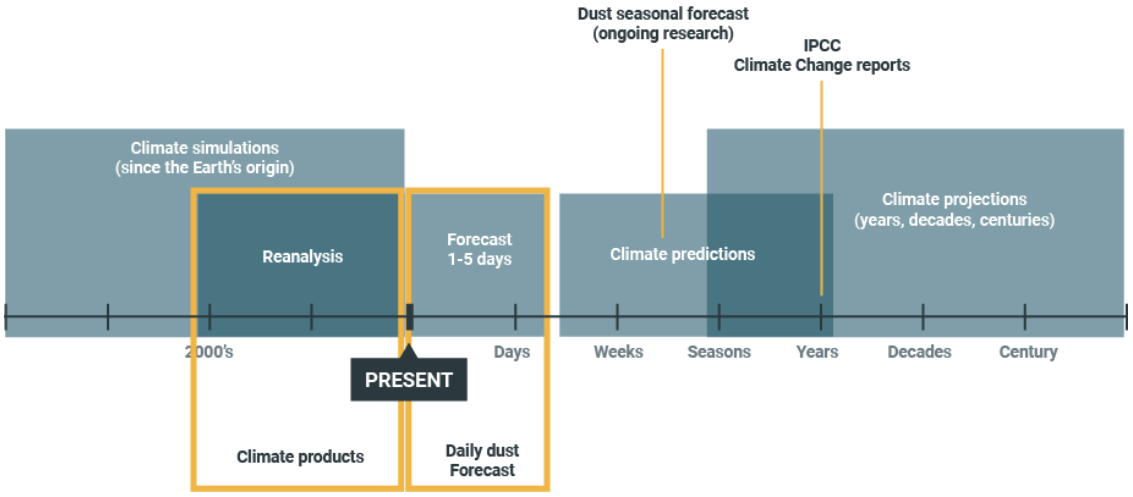
Version number	Date of publish	Version description
1.0	20/01/2022	Includes descriptions for: daily dust products, dust catalogue, numerical data download service and citation.
2.0	26/05/2022	Includes updates on the following products: Models, Warning Advisory System, Observations.

CONTENTS

1 From research to products

Numerical modelling is one of the most important sources of dust information. Models of dust emission, transport and deposition are used as a tool to complement dust observations and to deepen our understanding of the aspects that control the distribution of dust particles and the impacts they provoke. While global models of the dust cycle are used to investigate dust at large scales and its long-term changes, regional dust models are an ideal tool to study in detail the processes that influence dust distribution, as well as individual dust events.

The dust research can be associated with and conducted considering different time scales. Therefore, dust model simulations can result in either short-term forecasts for up to 5 days ahead, seasonal forecasts for several weeks ahead or dust projections that consider future scenarios about the concentration of desert dust and are important for climate research. Additionally, the historical record of information on desert dust can be completed with climate simulations and reanalysis datasets.

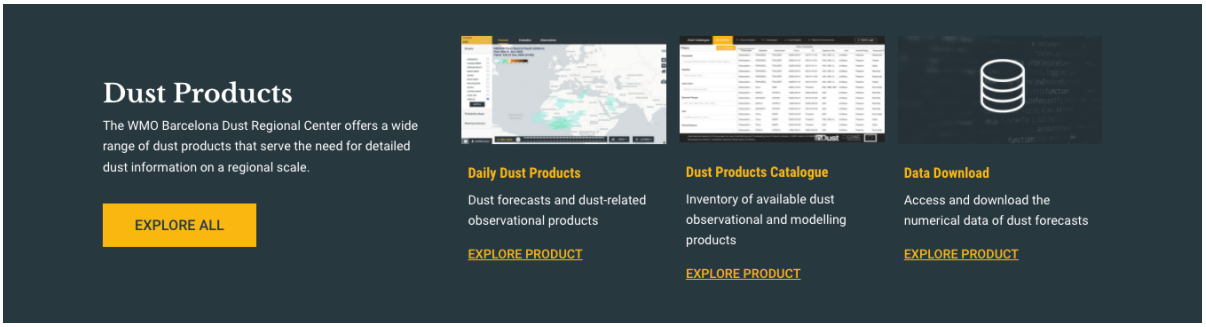


At the moment, the dust products available through the **WMO Barcelona Dust Regional Center** are mainly short-term dust forecasts which are useful to support the development of early warning systems.

2 Dust products

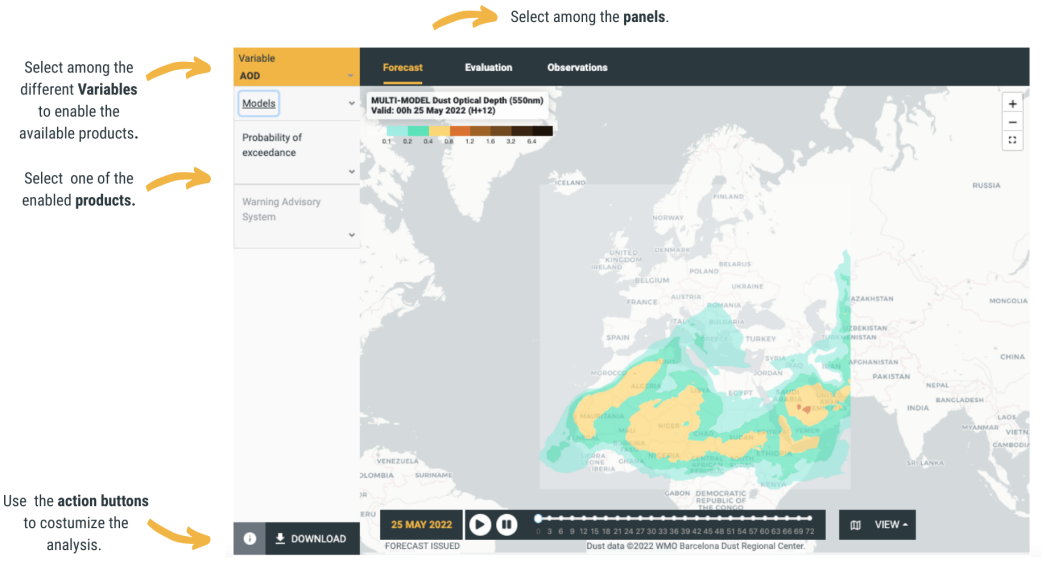
The **WMO Barcelona Dust Regional Center** coordinates a network of collaborators (researchers, data providers and user communities) in **Northern Africa, the Middle East and Europe** and provides access to available dust products via the Center's official webpage (https://dust.aemet.es/). The products are available for visualization and analysis on the fly through the interactive dashboard, as well as for download through the numerical data download service (THREDDS).

On the Products page, users can select whether they want to explore the Daily Dust Products for short-term issued forecasts, the Dust Products Catalogue for a detailed inventory of dust observational products and models or the Data download system for numerical data.



2.1 Daily Dust Products

This section includes daily dust forecasts, their comparison with observations, and dust-related observations. The products are displayed in an **interactive dashboard** that consists of three panels: i) **Forecast**, ii) **Evaluation** and iii) **Observations**. Users need to select one of the panels from the top menu and a variable from the side menu to see the products that are available for visualization.



Dashboard action buttons

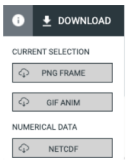
The dashboard includes several **action buttons** to customize and facilitate the analysis of the products. Users can change the base map (**VIEW** button), add extra layers of information (**LAYERS** button), change the spatial zoom of the displayed map, click on a specific location to obtain more detailed information about this point, access useful documents and download images, animations and numerical data (**DOWNLOAD** button).

Access to **information** and documents (User Guide)

Zoom **in**

Zoom **out**

Full screen mode



Download the currently displayed data in **image, animation or numerical** format

Change the base map displayed, selecting among **Light, Open Street, Terrain or ESRI** map

2.1.1 Exploring the forecast

The **"Forecast"** panel contains a map displaying the daily dust forecast, according to the variable and product parameters selected by the users on the left sidebar.

Forecast variables

The full definition of the **variables**, as well as the enabled products for each one, can be found in the following table:

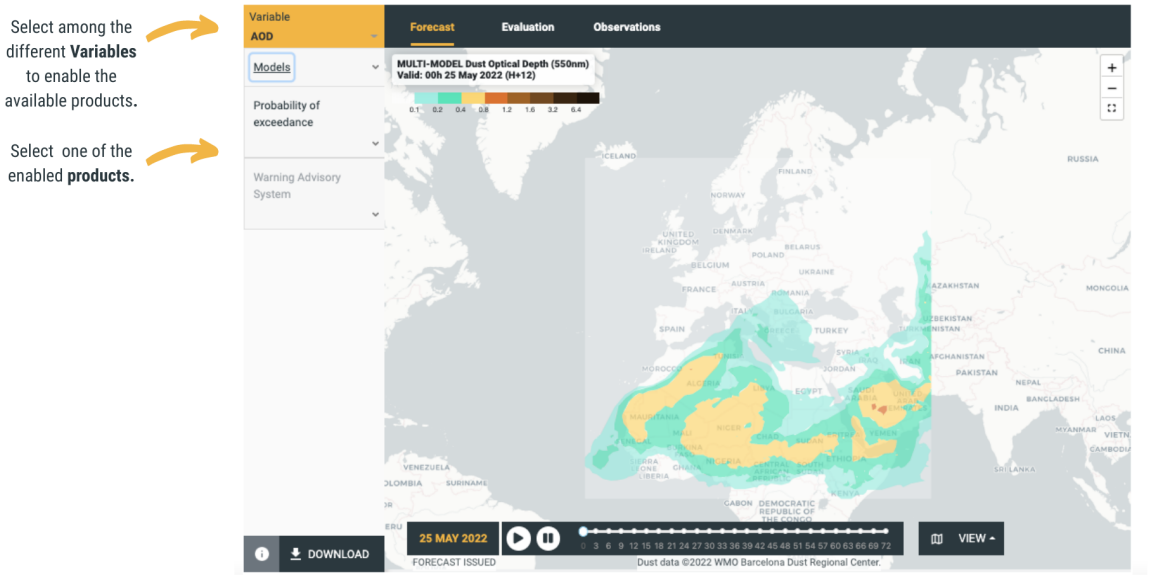
Variable name	Description	Units	Full name	Enabled products
AOD	Effective depth of the dust-aerosol column from the viewpoint of radiation propagation. It corresponds to the integrated extinction coefficient over a vertical column.	Dimensionless	Dust aerosol optical depth at 550 nm	Models, Probability of exceedance
Concentration	Mass concentration of dust particles in the atmosphere. By default, the dust concentration at surface level is shown.	$\mu g/m^3$	Dust surface concentration	Models, Probability of exceedance, Warning Advisory System
Dry deposition	Accumulated dry dust deposition over the previous 3 hours. Dry deposition processes consider the removal of dust (and sand) by sedimentation and turbulent diffusion.	mg/m^2	Dust dry deposition	Models (only available for MONARCH)
Wet deposition	Accumulated wet dust deposition over the previous 3 hours. Wet deposition processes consider the removal of dust (and sand) by in-cloud and below-cloud scavenging.	mg/m^2	Dust wet deposition	Models (only available for MONARCH)
Load	Accumulated mass concentration of dust (and sand) in the vertical column of the atmosphere.	g/m^2	Dust load	Models (only available for MONARCH)
Extinction	The sum of scattering and absorption of solar and infrared radiation by dust (and sand) at surface level. It is associated with visibility.	Mm^{-1}	Dust surface extinction at 550 nm	Models (only available for MONARCH)

Based on the **"Variable"** selection (in the upper-left corner), the available dust products for the selected variable are enabled. These may include:

- Models *(intercomparison)*: Access to 72h dust forecasts of individual models and the MULTI-MODEL result (median of all individual models). This product (MULTI-MODEL and all individual models) is available for the variables: **AOD**, and **Concentration**. In the case of the MONARCH model, the product is available for the following variables: **AOD**, **Concentration, Dry deposition, Wet deposition, Load,** and **Extinction.**

- Probability of exceedance: Percentage of models that predict the exceedance of a given threshold for a particular variable. This product is available only for the variables: **AOD**, and **Concentration.**

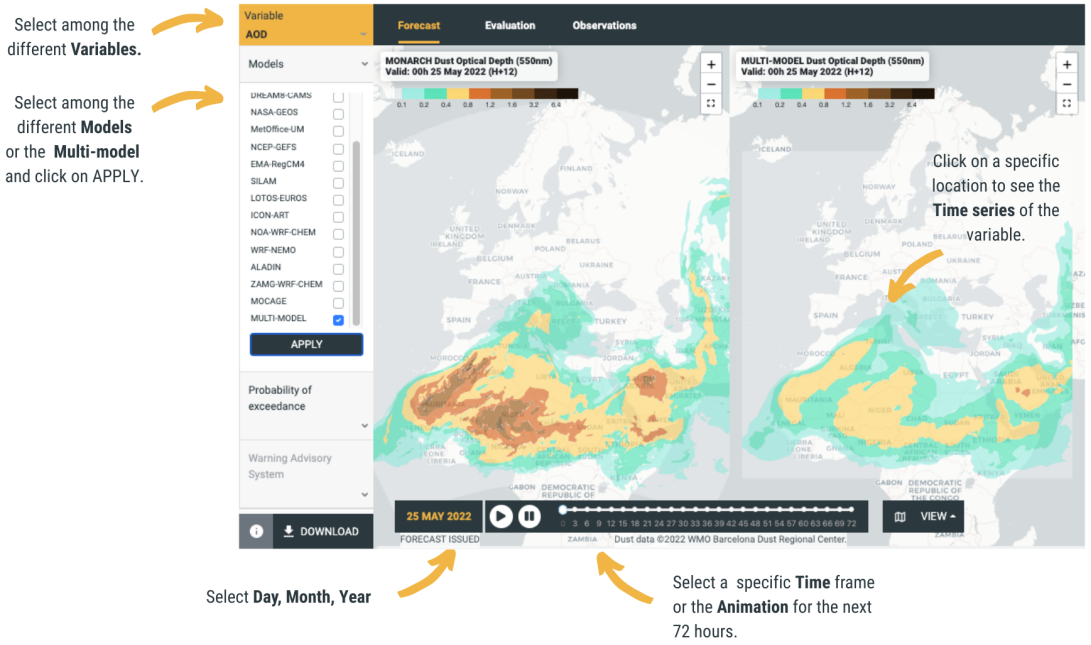
- Warning Advisory System: Information about the warning levels of dust and sand concentration (from Normal to Extremely High) for the next 2 days at province level for particular countries. This product is available only for the variable: **Concentration.**



Product: Models

This menu includes all the **individual models** that contribute to the daily dust forecasts provided by the Center. The individual models are used to produce the **MULTI-MODEL** forecast, which is the median of all the available dust forecasts for a particular day, after bi-linear interpolation to a common grid mesh of 0.5º x 0.5º. At present, the **MULTI-MODEL** forecast is calculated only for **Concentration** and **AOD.** In general, the **MULTI-MODEL** forecast shows better verification scores than any of the contributing models in most regions and time periods, and is therefore considered a valuable tool to issue trust-worthy predictions of mineral dust in the domain served by the Center.

Based on their selection of models, users can analyze and compare forecasts from various models simultaneously. Lead times range from 0 to 72 h, and predictions are available for every 3 hours.

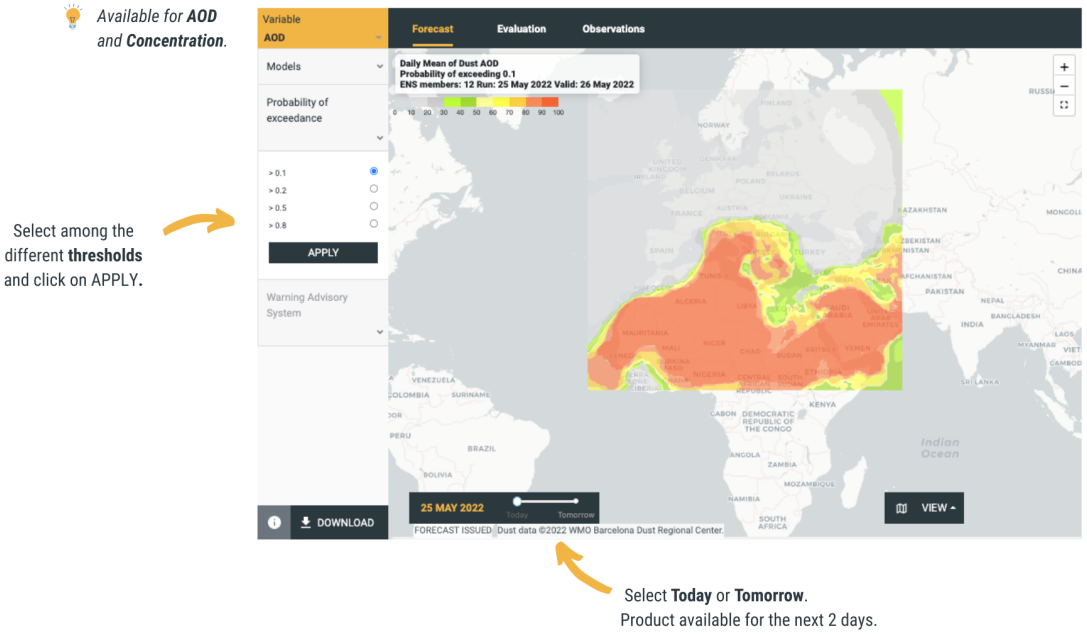


After clicking on a specific location on the map, the time series of the selected variable is plotted.

More information on the participating models and the generation of the MULTI-MODEL forecast can be found in Terradellas et al. (2020), while more details about MONARCH, the reference model of the Center, is available in Basart et al. (2020). Moreover, detailed information about the individual models that contribute to the Center, their technical features and the contact details of the modelling groups can also be found in the Dust Products Catalogue and here.

Product: Probability of exceedance

Users can consult the **"Probability of exceedance"** to check the percentage of models that predict the exceedance of a given threshold based on the daily mean value of **Concentration** and **AOD**. It is calculated taking into account all the individual models that contribute to the Center and is generated for the following 2 days with spatial resolution of 0.5ºx0.5º.



This product is particularly useful for air quality stakeholders and for planning and managing any activity that can be affected due to the presence of airborne dust. More information about this product can be found in Werner et al. (2020).

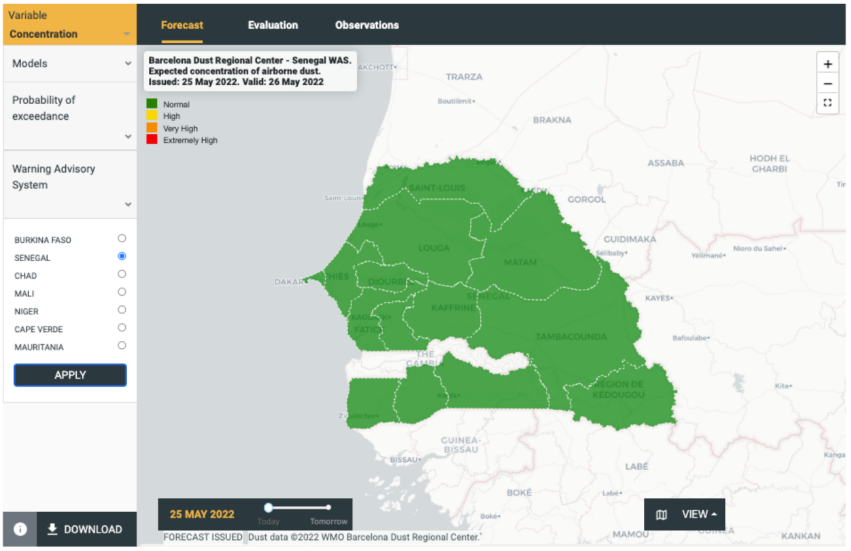
Product: Warning Advisory System

Users can consult the color-coded maps of the **"Warning Advisory System"** product for categorical (qualitative) information about the warning levels of sand and dust concentration (from Normal to Extremely High) for the next 2 days for some of the most vulnerable countries in the Sahel region.

The warning levels are based on the **MULTI-MODEL Concentration** forecast and are established for each region according to the highest concentration value expected for the day, at any model grid-point within the province. The warning advisory thresholds have been set based on a percentile-based approach using the daily maximum concentration of the historical **MULTI-MODEL** time series.

This product has been developed under the Climate Risk and Early Warning Systems (CREWS) initiative.

*Available only for **Concentration**.*



Select a **country** and click on APPLY.

Currently available for 7 countries.

Select **Today** or **Tomorrow**.
Product available for the next 2 days.

This product could be taken into account to help the planification of any activity that is potentially affected by airborne dust, or the activation of services and procedures aimed at the mitigation of damages caused in vulnerable sectors. More information about this product can be found in Terradellas et al. (2018).

2.1.2 Exploring the evaluation

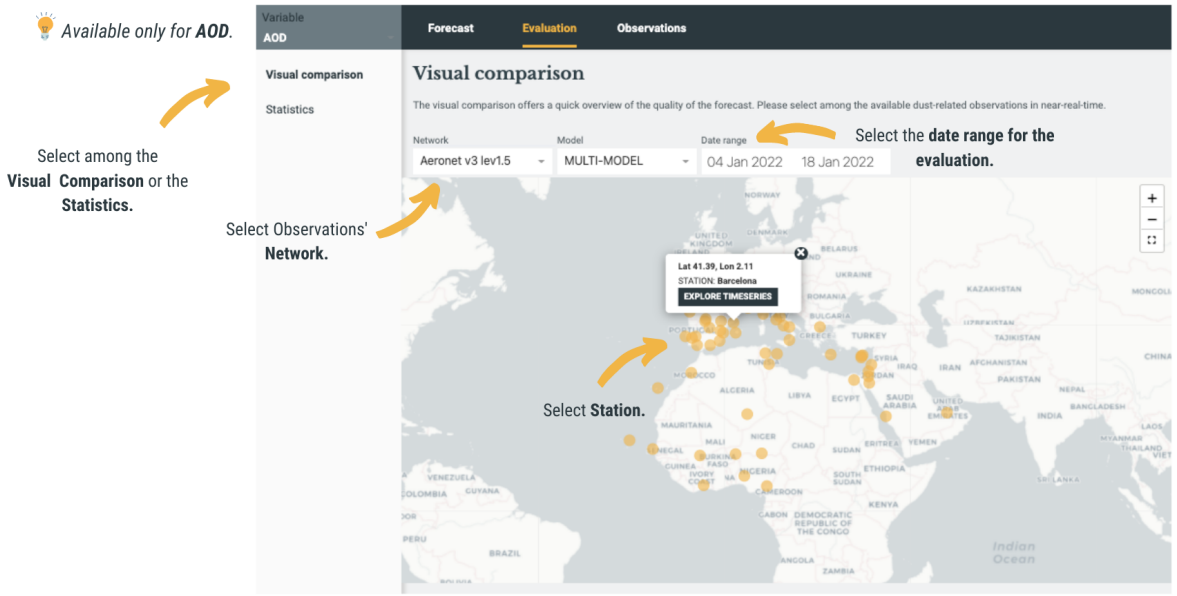
The **"Evaluation"** panel presents the comparison of the dust forecasts against dust-filtered observations. Here, the forecasts are compared to:

- AERONET AOD photometric measurements; The global-international AERONET network provides AOD at different wavelengths. In this comparison the direct-sun cloud-screened (Level 1.5) AOD is used. A dust filter that corresponds to **Ångström Exponent at 440-870 nm lower than 0.6**, is applied to the AOD observations prior to the comparison (Basart et al., 2017).
- NASA-MODIS/Aqua (Collection 6.1) AOD product; MODIS Deep Blue AOD retrieval is available over areas not easily covered by other observational data sets, e.g. very bright reflective surfaces such as deserts, and is therefore particularly relevant for dust applications.

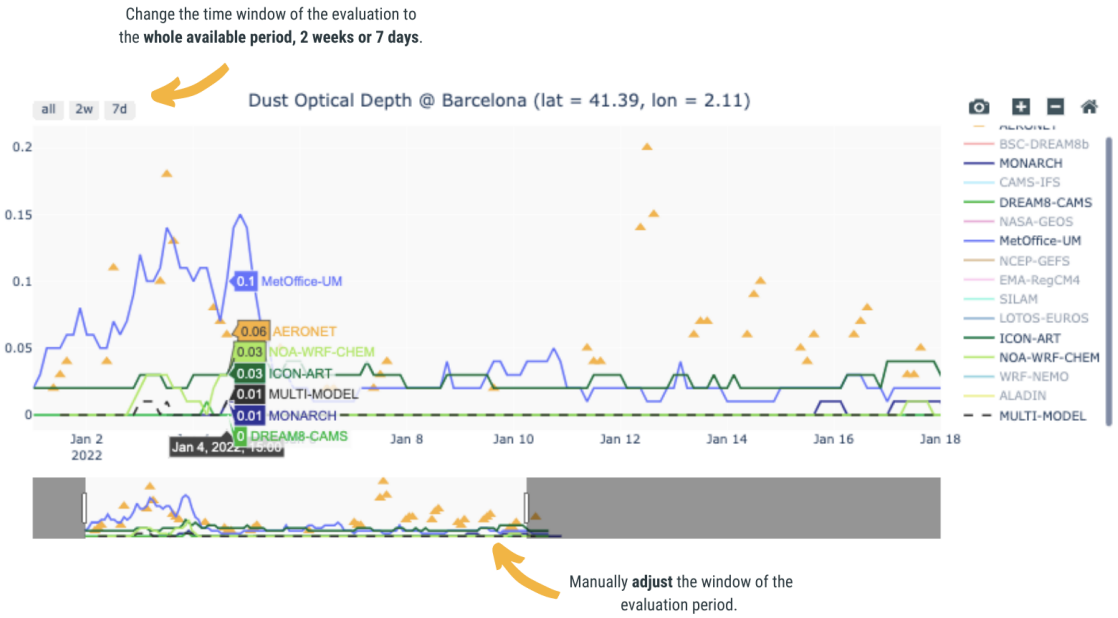
The time period of the comparison, as well as the forecasts to be compared can be defined by the users. The evaluation results are presented in the form of **visual comparison** and **statistics** (skill scores).

Visual comparison: AERONET

The visual comparison of dust AOD (MULTI-MODEL and individual models) against dust-filtered AOD observations is available for AERONET stations located in Northern Africa, the Middle East and Southern Europe for the selected date range selected. The comparison is made on a 3hourly basis.

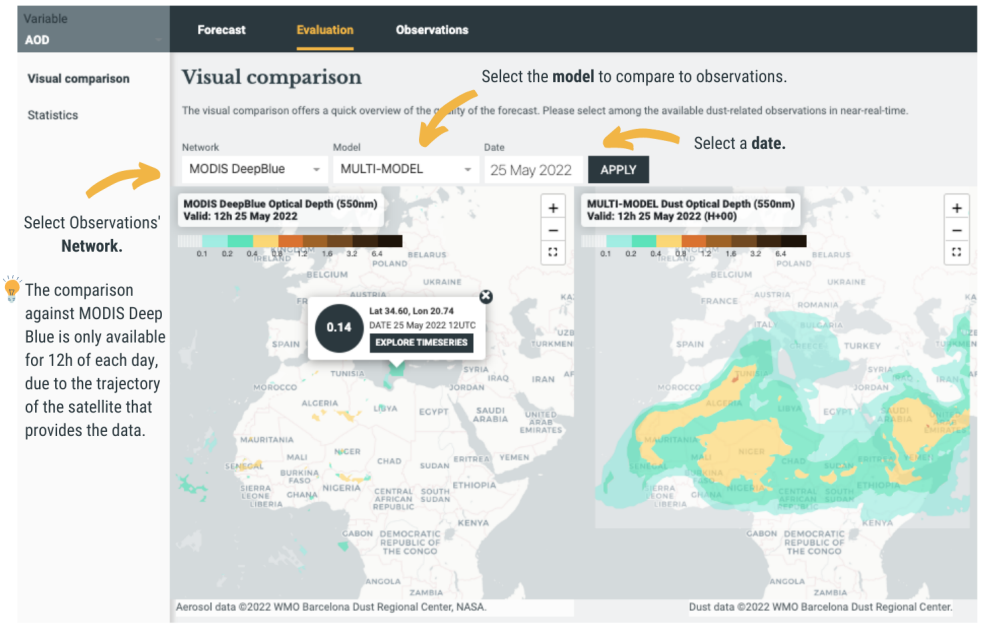


After selecting a specific AERONET station on the map, the comparison between the dust AOD forecasts and observations is plotted as time-series.



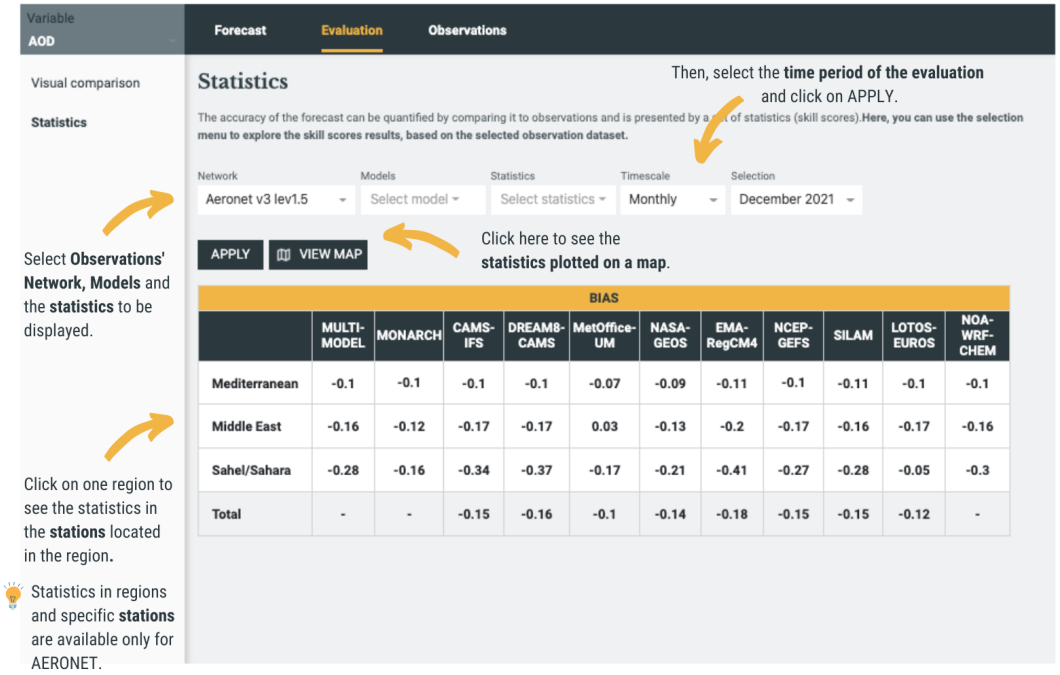
Visual comparison: MODIS

The visual comparison of the dust AOD forecast (MULTI-MODEL and individual models) against MODIS/Aqua AOD Deep Blue products is available in the form of maps plotted side-by-side for a particular day (at 12UTC), and also in the form of time series upon click to a specific location on the map.



Statistics

The corresponding skill scores of the evaluation against AERONET and MODIS observations are available for the whole domain. In the case of the AERONET network, they are also available per region (Northern Africa, the Middle East and the Mediterranean) and stations. They can be displayed in a list or map format, according to the user´s selection. The metrics used to quantify the mean departure between modelled and observed quantities are the mean bias error (BIAS), the root mean square error (RMSE), the correlation coefficient (CORR), the fractional gross error (FGE) and the number of total cases (TOTAL CASES). Their definition is given in Terradellas et al. (2020).



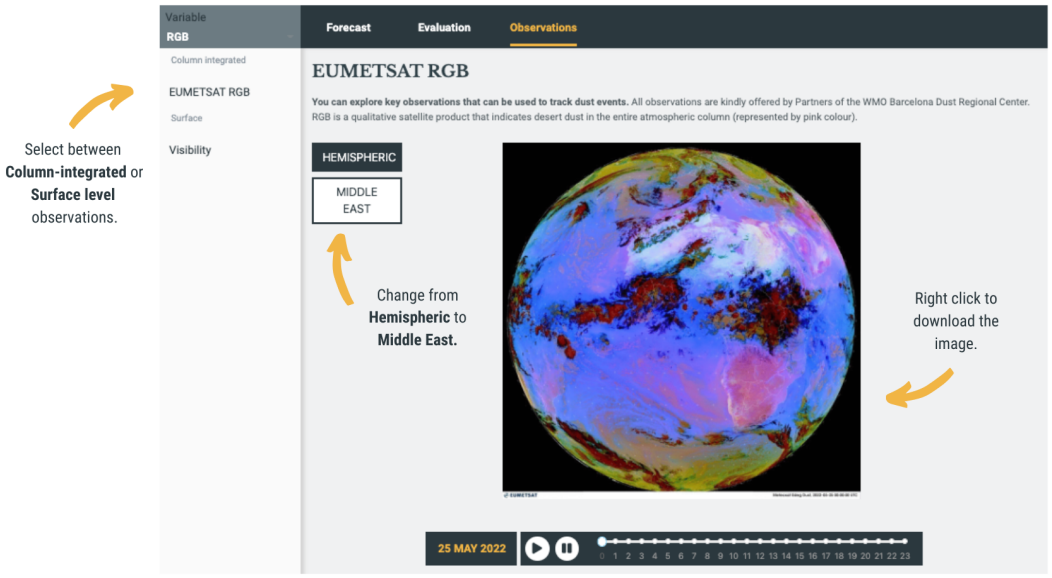
2.1.3 Exploring the observations

The **"Observations"** panel offers a visualization of key observations that can be used to track sand and dust storms. The datasets presented here are different from those used for model evaluation (see 2.1.2 Exploring the evaluation). All observations are kindly offered by Partners of the WMO Barcelona Dust Regional Center.

Product: EUMETSAT RGB

This product is an RGB (Red, Green, Blue) composite based on three infrared channels of the EUMETSAT SEVIRI, which provides images every 15-minutes. This RGB combination is designed to monitor the evolution of dust storms during both day and night (the presence of dust is associated with pink/magenta colour).

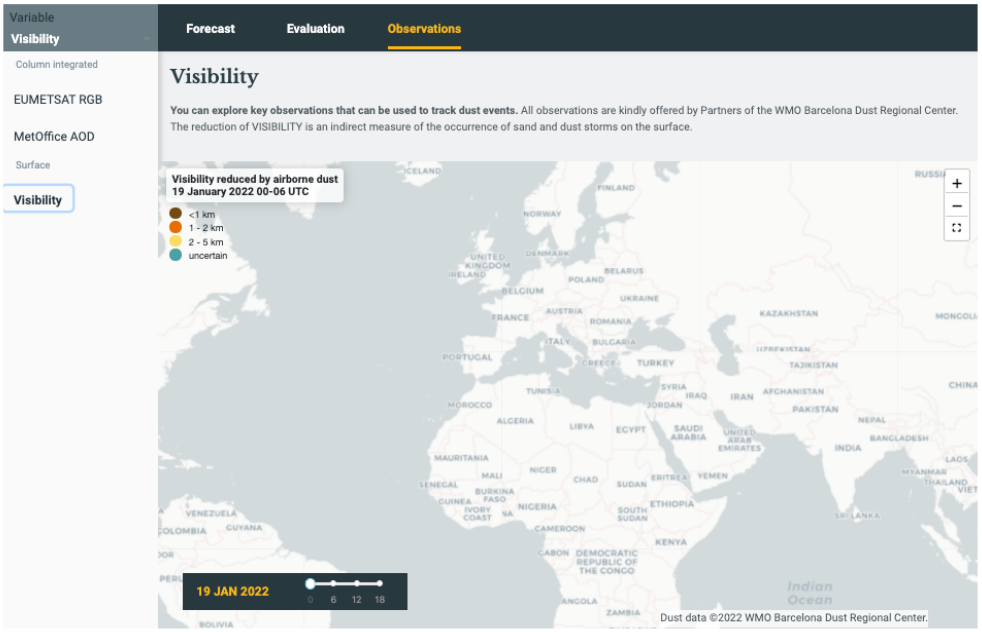
This product is kindly offered by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).



Product: Visibility

Visibility can be used as an indirect measure of the presence of airborne sand and dust at surface level. This product shows cases of 6-hourly visibility reduction less than 5 km associated with airborne sand or dust reported in METAR (METeorological Aerodrome Reports) and SYNOP (surface synoptic observations) bulletins.

This product is kindly offered by the AEMET meteorological database.

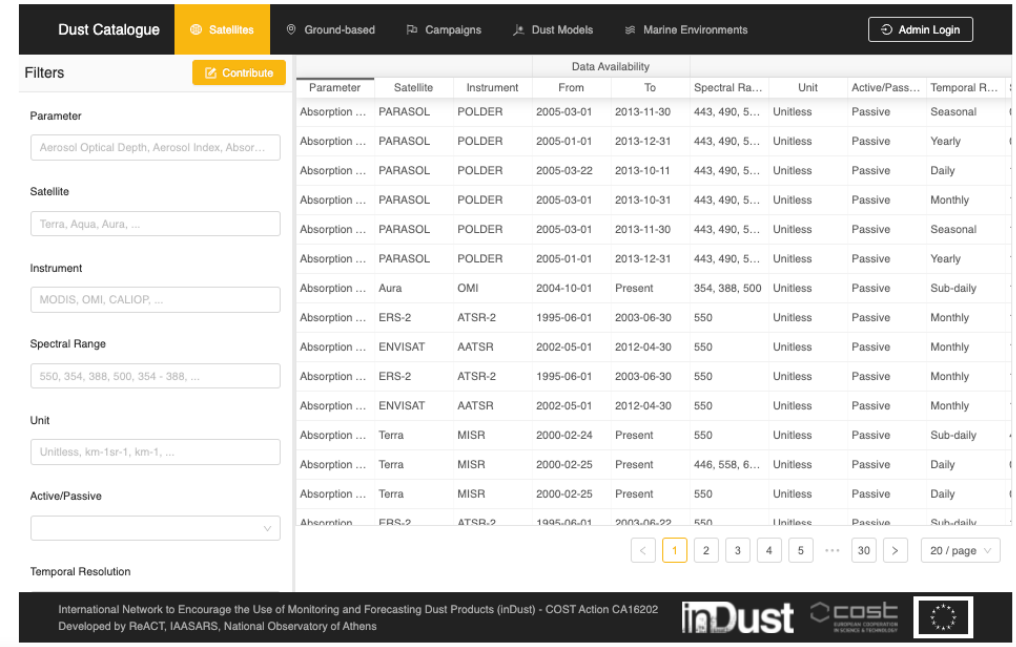


2.2 Dust Products Catalogue

A detailed inventory of the available dust observational and modelling products is compiled in the **"Dust Products Catalogue"**, developed in the framework of the COST Action inDust.

Users can find centralized dust information from different sources (satellites, ground-based networks, experimental campaigns, marine ecosystems and models), as well as the contact details of the person/group in charge of each source. A wide range of filtering options based on parameters, type of measurement/instruments, and region among others, is available to facilitate the search.

The database was developed by the National Observatory of Athens (NOA) and it is hosted by the WMO Barcelona Dust Regional Center.



3 Numerical Data Download Service

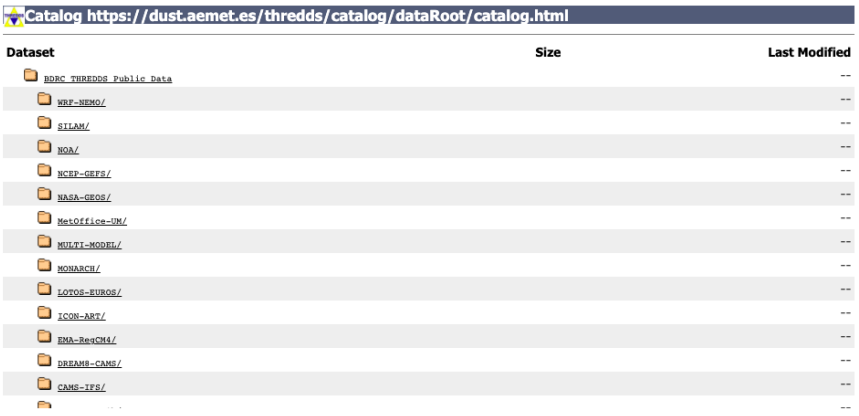
The WMO Barcelona Dust Regional Center provides easy access to the numerical data of the products available in the website through a THREDDS Data Server (TDS). TDS is a web server that provides metadata and data access for scientific datasets, using remote data access protocols. THREDDS is developed and supported by Unidata, a division of the University Corporation for Atmospheric Research (UCAR), and is sponsored by the National Science Foundation. The download can be completed using a variety of services (OPeNDAP, HTTPServer, NetcdfSubset).

In order to access and download the numerical data of the daily dust forecasts, registration is needed. User access can be requested via email. Two types of access to the daily dust forecasts are implemented:

- **Public**, providing access to numerical predictions issued more than 2 days ago.
- **Restricted**, providing access to all the numerical predictions available for re-distribution, including those issued less than 2 days ago. Access is normally limited to National Meteorological and Hydrological Services and other institutions contributing actively to the WMO Barcelona Dust Regional Center and the SDS-WAS programme. Public administrations, research and educational institutions are eligible to access these services in support of specific activities. Applications will be evaluated and answered within 30 days of the date of the petition.

Once registration is completed, users can access the archive of the numerical data of the daily dust forecasts, according to the type of access that has been granted to them (Public or Restricted).

The repository is divided into two folders (BDRC THREDDS Public Data and BDRC THREDDS Restricted Data). These are divided into various subfolders; one for every model that provides data to the Center.



Each of the models´ folders contain the published dust daily forecasts ordered per year and month. After selecting a specific month, users can access the list of files that can be downloaded. When users select a specific file, the available download links appear.


Initial TDS Installation

THREDDS Data Server

Catalog https://dust.aemet.es/thredds/catalog/dataRoot/MULTI-MODEL/2021/12/catalog.html

Dataset: 12/20211231_3H_MEDIAN.nc

- *Data size:* 3.772 Mbytes
- *Data type:* GRID
- *ID:* publicDatasetScan/MULTI-MODEL/2021/12/20211231_3H_MEDIAN.nc

Access:

1. **OPENDAP:** /thredds/dodsC/dataRoot/MULTI-MODEL/2021/12/20211231_3H_MEDIAN.nc
2. **HTTPServer:** /thredds/fileServer/dataRoot/MULTI-MODEL/2021/12/20211231_3H_MEDIAN.nc
3. **NetcdfSubset:** /thredds/ncss/dataRoot/MULTI-MODEL/2021/12/20211231_3H_MEDIAN.nc

Dates:

- 2022-01-01T01:35:12.054Z **(modified)**

Viewers:

- NetCDF-Java ToolsUI (webstart)
- Integrated Data Viewer (IDV) (webstart)

Alternatively, the download of files can be done through the command line, by using the following commands:

Download a file

```
wget --user="USER" --password="PASSWORD"
"https://dust.aemet.es/thredds/fileServer/dataRoot/MODEL/YEAR/MONTH/FILE"
```

working example:

```
wget --user="publicUser" --password="TestPublicUser"
"https://dust.aemet.es/thredds/fileServer/dataRoot/SILAM/2020/12/2020123100
_SILAM.nc"
```

Subsetting time, latitude, longitude and variable

```
wget --user="USER" --password="PASSWORD"
"https://dust.aemet.es/thredds/ncss/dataRoot/MODEL/FILE.nc?var=OD550_DUST&v
ar=SCONC_DUST&north=NORTH&west=WEST&east=EAST&south=SOUTH&horizStride=1&tim
e_start=TIME_START&time_end=TIME_END&timeStride=1&addLatLon=true&accept=net
cdf4"
```

working example:

```
wget --user="publicUser" --password="TestPublicUser" -O
20201231_3H_MEDIAN_test.nc
"https://dust.aemet.es/thredds/ncss/dataRoot/MULTI-MODEL/20201231_3H_MEDIAN
.nc?var=OD550_DUST&var=SCONC_DUST&north=50.0000&west=-20.0000&east=50.0000&
south=0.0000&horizStride=1&time_start=2020-12-31T12%3A00%3A00Z&time_end=202
1-01-01T12%3A00%3A00Z&timeStride=1&addLatLon=true&accept=netcdf4"
```

4 How to cite

The WMO Barcelona Dust Regional Center must be acknowledged as the source of information in any materials (graphs, articles, papers, written scientific works, etc.) derived from the numerical data, visualizations or products available in the Center's official webpage.

A citation example is shown below, which should be adapted accordingly:

> "Dust data and/or images were provided by the WMO Barcelona Dust Regional Center and the partners of the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) for Northern Africa, the Middle East and Europe."

In addition, it is strongly recommended to include the reference article per model(s) in the bibliography. A more detailed explanation of how to appropriately acknowledge the Center can be found in the Data Policy.

User support (contact)

Users can get in touch with the WMO Barcelona Dust Regional Center for additional information through the Contact page.

Additionally, for issues concerning the models that contribute to the Center, users can consult the contact details of the modeling groups.

To stay informed about the latest activity of the Center, users can subscribe to the newsletter.