BARCELONA DUST FORECAST CENTER: ACTIVITY REPORT 2023

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TECHNICAL REPORT

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http://dust.aemet.es/about-us/technical-reports

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Summary

This report summarizes new technical information about the operational model, products availability, products dissemination and capacity building activities carried out in 2021 by the Barcelona Dust Regional Center. Besides, information about the number of users who accessed the Regional Center website is also provided.

Contents

1. Introduction

The operational activities are carried out by the **Barcelona Dust Forecast Center** (BDFC) that was created in February 2014 by the **State Meteorological Agency** of Spain (AEMET) and the **Barcelona Supercomputing Center** (BSC) to fulfil the commitment acquired with **World Meteorological Organization** (WMO) to host the first Regional Specialized Meteorological Center with activity specialization on Atmospheric Sand and Dust Forecast (RSMC-ASDF). The Center operationally generates and distributes dust predictions for Northern Africa (north of equator), Middle East and Europe.

As described in its Activity Report 2014 (Terradellas et al., 2015), the BDFC daily releases regional forecast fields using the **MONARCH** model, previously named NMMB/BSC-Dust, (Pérez et al., 2011; Haustein et al., 2012; Jorba et al., 2012; Spada et al., 2013; Badia et al., 2017; Di Tomaso et al., 2017) over a domain covering Northern Africa, Middle East and Europe (25°W - 65°E, 0° - 65°N, Figure 1). BDFC predictions include dust load, dust surface concentration, dust optical depth (DOD) at 550 nm, dust surface extinction at 550 nm and 3-hour accumulated dry and wet deposition from the starting time (12 UTC) up to a lead time of 72 hours. Monthly averages of dust surface concentration and dust load are computed for long-term monitoring.

In June 2023 a new upgrade of the model was released. The main new features were:

- Aerosol-radiation interaction allowed with dynamic coupling of dust-radiation
- Introduction of spheroid particles.
- SNES tool in the workflow.

The most significant change implemented in the workflow was the replacement of the old postprocessing and diagnostic tools with a single one called SNES which provides almost all the operations needed to postprocess and generate diagnostics from the MONARCH outputs in a single parallelized tool.

You can find the technical report of 2023 here: https://dust.aemet.es/resources/upgrading-the-monarch-operational-forecast-v2-1-0

An upgrade version of the MONARCH model is in operation since December 2020.
Some of the new features are:

- Implementation of a new high-resolution mapping of dust sources based on high-resolution MODIS Collection (Ginoux et al., 2012) within the model.
- In addition to the standard emission scheme in MONARCH based on a variation of Marticorena and Bergametti (1995), six additional emission schemes are now available in the model: the GOCART scheme from Ginoux et al. (2001), four schemes that represent dust emission through saltation bombardment and aggregate disintegration (Shao, 2001; Shao, 2004; Shao et al., 2011, Kok et al., 2014) and one scheme represents aerodynamic dust entrainment (Klose et al., 2014).

Furthermore, a completely new version of the Regional Center website was released on the

20th January 2022. This website gather all the information and products developed by the WMO Barcelona Dust Regional Center (BDRC) which manages and coordinates the research activities and operations of WMO related to sand and dust storms in the region of Northern Africa, Middle East and Europe. The forecast products of our operational model MONARCH can be found in this new website here: https://dust.aemet.es/products/daily-dust-products

New updates to the website are scheduled to be released regularly to add more products and capabilities and to fix bugs and improve the user experience. During 2022 two updates to fix bugs and updated products were release on 26th May and 12th December.
Link to the user guide: https://dust03.bsc.es/products/overview/user-guide/@@download

2. Model integration

The MONARCH model is daily executed at a horizontal resolution of 0.1° longitude per 0.1° latitude with 40 σ-vertical layers over the domain of interest in HPC infrastructures. The primary run is executed at the BSC MareNostrum IV supercomputer using dedicated resources (288 cores). A backup integration is daily performed with the same configuration at Cirrus, the AEMET supercomputing facility.

Both model runs use initial meteorological conditions (at 12UTC) from the U. S. National Centers for Environmental Prediction (NCEP) global analysis at a 0.5° latitude x 0.5° longitude horizontal resolution and 6-hourly boundary meteorological conditions from the NCEP Global Forecast System at the same resolution.

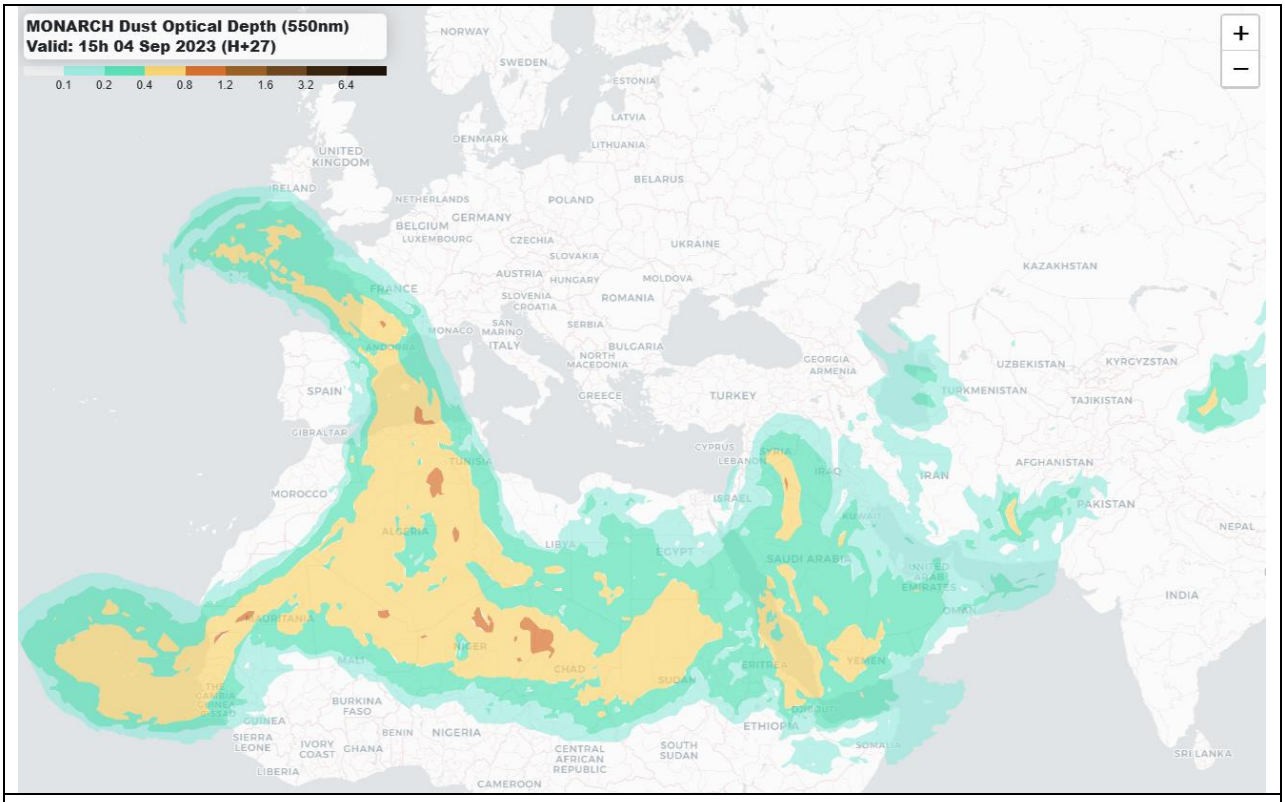

Figure 1: 12-hour forecast of dust optical depth at 550 nm valid for 4 Sep 2023 at 15 UTC

3.Model evaluation

The BDFC conducts regular evaluation of the predicted DOD. In the Near-Real-Time (NRT) evaluation, forecasts of DOD at 550 nm with lead times from 0 to 24 hours are compared with total aerosol optical depth (AOD) provided by the **AErosol RObotic NETwork** (AERONET); Holben et al., 1998; Dubovik and King, 2000) for 40 selected dust-prone stations (Figure 2). Then, evaluation scores are computed on a monthly, seasonal and annual basis by site and considering particular regions (i.e. Sahara/Sahel, Mediterranean and Middle East). To minimize the sources of error, it is intended to restrict the comparison to situations in which mineral dust is the dominant aerosol type. Threshold discrimination is made by discarding observations with an Ångström exponent 440-870 nm higher than 0.6. However, other particles are always present in the atmosphere (anthropogenic aerosol, products from biomass burning, etc.) and therefore a negative bias can be expected. The annual evaluation scores for 2020re summarized in Table 1.

From 2019 the AERONET Version 3 (V3) algorithm is operational. In Version 2 (V2) of the AERONET database, the near real-time AOD was semi-automatically quality controlled utilizing mainly cloud screening methodology, while additional AOD data contaminated by clouds or affected by instrument anomalies were removed manually before attaining quality assured status (Level 2.0). The large growth in the number of AERONET sites over the past 25 years resulted in significant burden to manually quality control millions of measurements in a consistent manner. The AERONET Version 3 (V3) algorithm provides fully automatic cloud screening and instrument anomaly quality controls. All of these new algorithm updates apply to near real-time data as well as post-field deployment processed data, and AERONET reprocessed the database in 2018. A full algorithm redevelopment provided the opportunity to improve data inputs and corrections such as unique filter specific temperature characterizations for all visible and near-infrared wavelengths, updated gaseous and water vapor absorption coefficients, and ancillary data sets.

For the comparison, modeled DOD and DODcoarse fields are bilinearly interpolated over the AERONET stations. Because AERONET data are acquired at 15-min intervals, all AERONET measurements within ±90 min of the 3-hourly instantaneous model outputs have been extracted and averaged to perform a model comparison. All AERONET stations that are available for the year 2021 and are included in the North Africa, Mediterranean and Middle East (NAMEE) domain are used in the evaluation.

During 2022 a review of the evaluation system and an update of the AERONET station database was done, complementing the redefinition of the regions performed in 2021. In 2023 a revision and update of the AERONET stations data base used for the evaluation has led to an increase of the number of Total Cases available and a more significant scores.

These statistics can be found on the webpage here:

https://dust.aemet.es/products/daily-dust-products?tab=evaluation&section=statistics

Region	MBE	RMSE	r	FGE	Total Cases
Europe	-0.13	0.16	0.30	1.70	6490
Mediterranean	-0.09	0.14	0.64	1.23	9520
Middle East	-0.09	0.20	0.58	0.73	2015
Northern Africa	-0.00	0.25	0.61	0.73	3666
TOTAL	**-0.08**	**0.17**	**0.64**	**1.23**	**26535**

Table 1: Annual evaluation scores for the forecasts released by the BDFC in 2023 mean bias (MBE), Root Mean Square Error (RMSE), correlation coefficient (r), Fractional Gross Error (FGE) and the number of observations considered for verification (Ndata).

In 2023 we have started using a dust filtering method based on the Spectral Deconvolution Algorithm (SDA, also known as O'Neill; O'Neill et al., 2003) AERONET products that provide AODcoarse and AODfine fractions. AODcoarse observations are fundamentally associated with maritime/oceanic aerosols and desert dust. Since sea-salt is related to low AOD (< 0.03; Dubovik et al., 2002) and mainly affects coastal stations, high AODcoarse values are mostly related to mineral dust (i.e. DODcoarse).

In addition and to improve the evaluation, we have included in 2023 the comparison of MONARCH with the PM10 and PM2.5 dust-filtered observations provided by the CSIC-IDAEA and available through the Spanish government website: (https://www.miteco.es/es/calidad-y-evaluacion-ambiental/temas/atmosfera-ycalidad-del-aire/calidad-del-aire/evaluacion-datos/fuentes-naturales/default.aspx). In this case 3-hourly outputs of our model are averaged on daily basis for the comparisons with the CSIC-IDAEA dataset.

Both new methods are used to compare the performance of the last upgrade with the previous one. The conclusion with the AERONET data is that the upgraded MONARCH led to a reduction of the overestimations of dust in most cases. Furthermore, the comparison with CSIC-IDAEA PM observations shows how the upgraded version of the model presents some improved skills scores, i.e. annual correlation coefficient increases and RMSE decreases.

Detail information about the evaluation technics and results can be found here: https://dust.aemet.es/resources/upgrading-the-monarch-operational-forecast-v2-1-0

4. Product dissemination

Operational forecasts are made available 12 hours after the starting forecast time on the Center's web portal, on the WMO **Global Telecommunications System** (GTS) and on **EUMETCast**, which is a dissemination system based on commercial telecommunication geostationary satellites that uses digital video broadcast standards. It is managed by EUMETSAT.

4.1. Dissemination of dust forecasts in numerical form

Since 8 November 2018 the dust forecast released by the Barcelona Dust Forecast Center is available through EUMETCast in numerical form. The daily dust prediction is delivered in netCDF format.

The filename convention is the following:

<DATETIME>_3H_SDSWAS_NMMB-BSC-v2_EUMETCAST.nc where <DATETIME> = model run in YYYYMMDDHH UTC. Example: 2018110412_3H_SDSWAS_NMMB-BSC-v2_EUMETCAST.nc

The datafiles are distributed as follows:

EUMETCast Europe:
Channel: EUMETSAT Data Channel 12
Multicast address: 224.223.222.35
PID: 301

EUMETCast Africa:
Channel: A1C-TPC-6
Multicast address: 224.223.225.4
PID: 100

5.High availability of products

In previous years the system had been operating over 98% of the time. However, a plan was designed to reduce disruptions and ensure higher availability of products. The plan is based on adding redundancy and eliminating single points of failure. Its main elements are:

- Duplication of the Center's webserver at AEMET headquarters (Madrid, Spain).
- Duplication of the model run on the Cirrus (ATOS) cluster, also at AEMET headquarters

The system architecture is represented in Figure 3. The AEMET Domain Name System (DNS) by default directs the web requests to the main BDFC server. However, in case of connection failure, it transfers the request to the secondary server. The two web servers are daily synchronize at 1 UTC, after receiving the forecast files.

Regarding the model forecasts, both runs are done in a totally independent way. Then, once each integration is completed, output files are loaded into both servers.

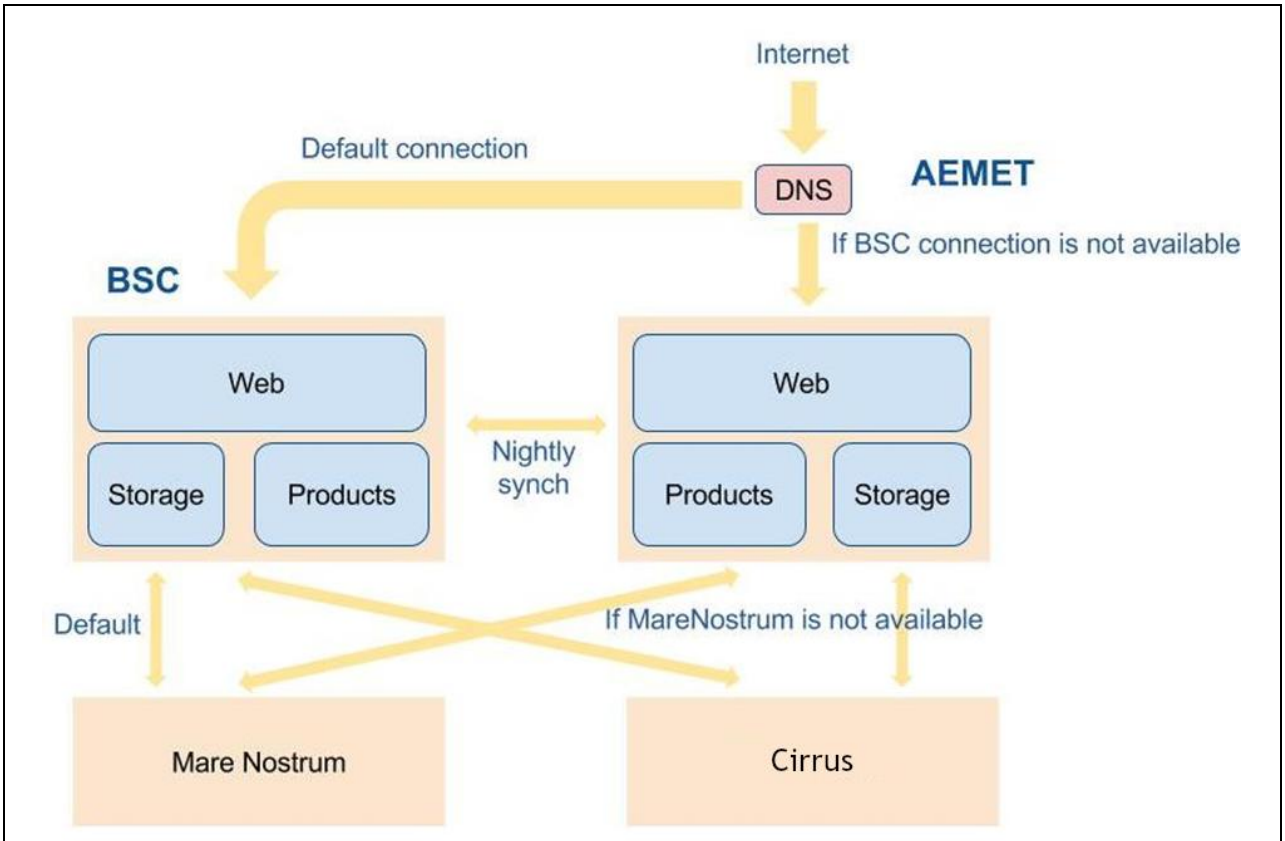

Figure 2: Configuration of the BDFC systems

6. Capacity building

Most of the training activities organise or with participation of the Barcelona Dust Regional Center during 2023 have been online. All of them, can be found on our website (https://dust.aemet.es/resources) and most of them include recording and presentation which can be downloaded.

These training activities have been carried out within the framework of initiatives such as MAC-CLIMA (Interreg) and WMO CREWS. The inDust webinars series has been taken over by the Barcelona Dust Regional Center. Collaboration with EUMETSAT has continued with new editions of the online dust training school. These new editions also included Python Notebooks with basic and advanced scripts to work both models and observation datasets.

List of training activities carried out in 2023:

Workshops and training schools	
CREWS/SWFP – Eastern Africa- Training Workshop on Severe Weather and Impact-based Forecast and Warning	https://dust.aemet.es/news-events/events/copy_of_crews-swfp-2013-west-and-central-africa-training-workshop-on-severe-weather-and-impact-based-forecasting-and-warning-services
Atelier EUMETSAT: Manipulation et traitement des données satellitaires + accent sur les poussières désertiques (face-to-face)	https://dust.aemet.es/news-events/events/manipulation-et-traitement-des-donnees-satellitaires-accent-sur-les-poussieres-desertiques
CREWS/SWFP – West and Central Africa-Training Workshop on Severe Weather and Impact-based Forecasting and Warning Services	https://dust.aemet.es/news-events/events/crews-swfp-2013-west-and-central-africa-training-workshop-on-severe-weather-and-impact-based-forecasting-and-warning-services
Webinar on Air Quality Monitoring in Africa	https://dust.aemet.es/news-events/events/crews-swfp-2013-west-and-central-africa-training-workshop-on-severe-weather-and-impact-based-forecasting-and-warning-services
Joint Training School and workshop on dust aerosol detection and monitoring	https://dust.aemet.es/news-events/events/joint-training-school-and-workshop-on-dust-aerosol-detection-and-monitoring
MAC-CLIMA Workshop on SDS-WAS West Africa: Cabo Verde	https://dust.aemet.es/news-events/events/mac-clima-workshop-on-sds-was-west-africa-cabo-verde

Barcelona Dust Regional Center webinars	
Climate Change, Dust Storms, and Social Vulnerabilities in the United States	https://dust.aemet.es/news-events/events/climate-change-dust-storms-and-social-vulnerabilities-in-the-united-states
Identifying new sources of dust emissions from high latitudes	https://dust.aemet.es/news-events/events/high-latitude-dust
Modeling of dust-radiation interaction within the NASA GISS ModelE2.1.	https://dust.aemet.es/news-events/events/modeling-of-dust-radiation-interaction-within-the-nasa-giss-modele2-1
Why the Complex Refractive Indices of Mineral Dust Matter	https://dust.aemet.es/news-events/events/why-the-complex-refractive-indices-of-mineral-dust-matter-by-gregory-l-schuster
Long-Term Monitoring in Africa: from AMMA to INDAAF	https://dust.aemet.es/news-events/events/long-term-monitoring-in-africa
Dust research at TROPOS	https://dust.aemet.es/news-events/events/dust-research-at-tropos
The ASKOS experiment at Cabo Verde	https://dust.aemet.es/news-events/events/the-askos-experiment-at-cabo-verde

7. Staff

Ernest Werner, Technical Director

Emanuele Emile, Lead Scientist

Gerardo García-Castrillo, Scientific Support

Carlos Pérez García-Panda, Emilio Cuevas and África Barreto, Scientific Advisors

Francesco Benincasa, Lead Developer

Elliot Rose, Web Developer

Marina Conde, Web Developer

Diana Urquiza, Product Designer

Julieta Rosenbluth, Product Designer

More information about the staff on this link: https://dust.aemet.es/about-us/who-we-are

8. User

The BDFC conducts regular monitoring of website access. The results (Table 2) show the number of sessions and page views.

Season	Sessions	Page views
Dec 2022 – Feb 2023	23.000	42.000
Mar 2023 – May 2023	24.000	42.000
Jun 2023 – Aug 2023	28.000	59.000
Sep 2023 – Nov 2023	23.000	49.000

Table 2: Quarterly overview of web access during 2023.

Year	Sessions	Page views
Dec 2014 – Nov 2015	31.578	62.443
Dec 2015 – Nov 2016	55.270	98.378
Dec 2016 – Nov 2017	79.173	146.954
Dec 2017 – Nov 2018	84.676	147.579
Dec 2018 – Nov 2019*	76.451	131.708
Dec 2019 – Nov 2020	98.954	163.846
Dec 2020 – Nov 2021	109.456	188.688
Dec 2021 – Nov 2022	150.799	299.190
Dec 2022 – Nov 2023**	98.000	192.000

Table 3: Evolution of annual web access (*, ** Google analytics new version)

The top countries ranked by number of visitors in 2023 are Spain, France, Cyprus and Germany and with similar values, United States, United Kingdom and Portugal.

The number of sessions and page views decreased significantly in 2023 due to the major dust outbreaks that affected Europe in 2022 and 2021 but viewer numbers surpassed those of 2020.

The BDFC Twitter account (@Dust_Barcelona) is a very effective way to disseminate our forecast products and other activities that the BDRC carries out. During 2023 after becoming X, the number of followers increased in 100, exceeded the 4000 followers at the end of the 2023.