BARCELONA DUST REGIONAL CENTER (RSMC-ASDF): ACTIVITY REPORT 2024

BDGC-2025-003

TECHNICAL REPORT

BDFC-2025-003

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Series: Barcelona Dust Forecast Center (BDFC) Technical Report

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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 2024 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.

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

In 2024 MONARCH was upgraded from the version v2.1.0 to the version v2.7.2. This last version does not introduce significant changes in the model or in the model configuration with respect to the previous version (v2.1.0), but mostly contains bug-fixes.

The main novelty of this version is the output of vertical layers of dust concentration that are now displayed on daily basis in the BDRC website.

The impaction collection efficiency factor within the aerosols dry deposition was corrected by factor of 1/G, where G is the gravitational constant, which was missing in the original parametrization described by Zhang et al. (2001). This leads to lower impaction collection efficiency and higher dust concentrations, all other aspects being unchanged.

Dust wet scavenging, specifically below stratiform clouds, was strongly suppressing dust concentrations over sea surfaces and in the lowermost layers. The addition of a threshold controlling the amount of wet scavenging in presence of very light precipitations was added to mitigate this effect.

Furthermore, 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 2024 two updates to fix bugs and updated products were release on July and December.
Link to the user guide: https://dust03.bsc.es/products/overview/user-guide/@@download

2. Model integration

The MONARCH model is executed daily at 12 UTC with 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.

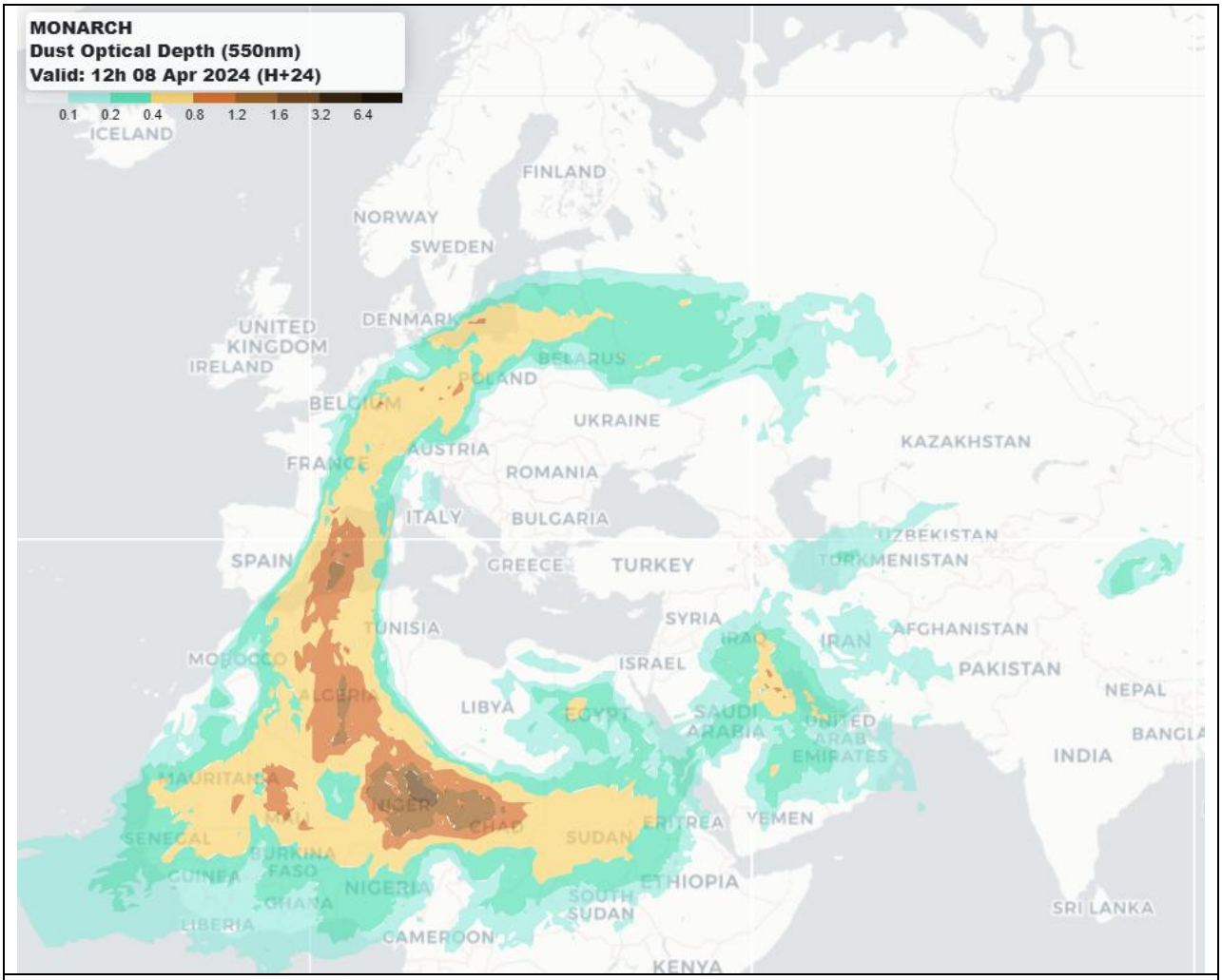

Figure 1: MONARCH forecast of dust optical depth at 550 nm valid for 8 April 2024 at 12 UTC (H+24)

The numerical outputs are stored

The model numerical outputs are stored, both in netcdf and in WMO FM 92 GRIB Edition 2 formats. For GRIB files, version 13.0.0 of the code tables is used:

- Code and flag tables v. 13.0.0
- Local tables v. 1.0.0 (see Table 1). These tables have been built by the Barcelona Dust Regional Center to complement the WMO Master Tables in order to enable encoding/decoding dust-related products.

Number	Parameter	Units
248	Dust surface extinction at 550 nm	Mm
249	Dust load	$g.m^{-2}$
250	3-hour accumulated dust dry deposition	$\mu g.m^{-2}$
251	3-hour accumulated dust wet deposition	$\mu g.m^{-2}$
252	Dust surface concentration	$\mu g.m^{-3}$
253	Dust optical depth at 550 nm	–

Table 1. Code Table 4.2 - Parameter number by product discipline and parameter category. Product discipline 0 - Meteorological products, parameter category 13: aerosols

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 2.

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.

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	-0.12	0.15	0.43	1.77	22261
Mediterranean	-0.09	0.14	0.68	1.46	31722
Middle East	-0.12	0.18	0.59	0.93	7441
Northern Africa	-0.06	0.27	0.61	0.90	11899
TOTAL	**-0.10**	**0.18**	**0.66**	**1.41**	**74295**

Table 2: Annual evaluation scores for the forecasts released by the BDFC in 2024 mean bias (MBE), Root Mean Square Error (RMSE), correlation coefficient (r), Fractional Gross Error (FGE) and the number of observations considered for verification (Ndata).

Furthermore, as in 2023, we used the dust filtering method based on the Spectral Deconvolution Algorithm (SDA; O'Neill et al., 2003), which provides AERONET products with coarse and fine AOD fractions (AOD_{coarse} and AOD_{fine}). 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).

For the statistics of the NAMEE region the correlation is the same (0.74) for both models' setups but we observe a decrease in the mean bias from -0.02 to 0.01 with the model upgrade, an increase in RMSE from 0.11 to 0.13 but a decrease in both MFE and MFB. In each subregion the MFE and MFB are always reduced, and the correlations increase slightly. In North Africa the MB increases to 0.05 but the correlation increases and the MFB decreases. Lower fractional errors indicate a better capability of the model to predict both low and high values of DODcoarse.

As in the previous year, we have included in 2024, the comparison of MONARCH with the PM10 and PM2.5 dust-filtered observations in Spain (22 stations) 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.

In the new upgrade and in terms of annual statistics, the correlations increase for both PM10 and PM2.5 concentrations from 0.51 to 0.53 and from 0.18 to 0.19 respectively. The mean and fractional biases, RMSE and fractional errors are also all decreased with the new upgrade since the underpredictions we had noticed in the previous operational setup are now slightly reduced.

In addition, we constructed a contingency table to evaluate the two forecasts based on the percentages of times they exceed or not the daily threshold of PM10 equal to 50 μgm-3 for

several stations. Overall, the comparison with CSIC-IDAEA observations shows that the upgraded version of the model presents improved skills scores in all the validation metrics and an increase for the hit rate, which remains, however, relatively low (less than 50%). The difficulties to match the absolute values of dust PMs concentration during the peaks suggests that some further scientific investigation is needed before considering such product for public dissemination.

Detail information about the evaluation technics and results can be found here: https://dust.aemet.es/resources/upgrading-the-monarch-operational-forecast-v2-7-2

Providentia tool

An important new feature of this report compared to previous one (https://dust.aemet.es/resources/upgrading-the-monarch-operational-forecast-v2-1-0) is that a new model evaluation tool developed at the Barcelona Supercomputing Center has been employed: Providentia.

Providentia is designed to allow on-the-fly and offline analysis of numerical simulations, with respect to processed observational data. The Providentia workflow consists of i) interpolation of model fields at the location and time of observations ii) computation of statistics and plots. Once step i) is performed, Providentia allows multiple types of filters to be applied to the collocated observational and modelled time series. Then, temporal and spatial averaging can be applied to the filtered time series. Standard evaluation metrics (like those in Table 2.1) can be further computed using different aggregation strategies. For this study we used the so-called flattened computations, which consist in using all data points over the time record, across all selected stations.

Hence, the reported statistics represent the skills of the reanalysis in predicting local and 3-hourly measurements for the ensemble of selected sites. This evaluation method was also introduced as a new protocol for validation purposes in the latest reanalysis report (https://dust.aemet.es/resources/dust-regional-reanalysis-update-extension-to-2017) .

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.

- **EUMETCast**

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

- **WMO Global Telecommunications System (GTS)**

Model GRIB files are sent via FTP to AEMET, which uploads them to the GTS system. The headers of the GTS bulletins are as follows:

PZBcnn **LEMM** dd**1200**, where:

- c=**A** denotes a 0-hour forecast, c=**B** a 3-hour forecast, ..., c=**Y** a 72-hour forecast
- nn=**01** denotes dust surface concentration, nn=**02** dust optical depth, nn=**03** dust dry deposition, nn=**04** dust wet deposition and nn=**05** dust load.
- dd indicates the day

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 BDRC 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.

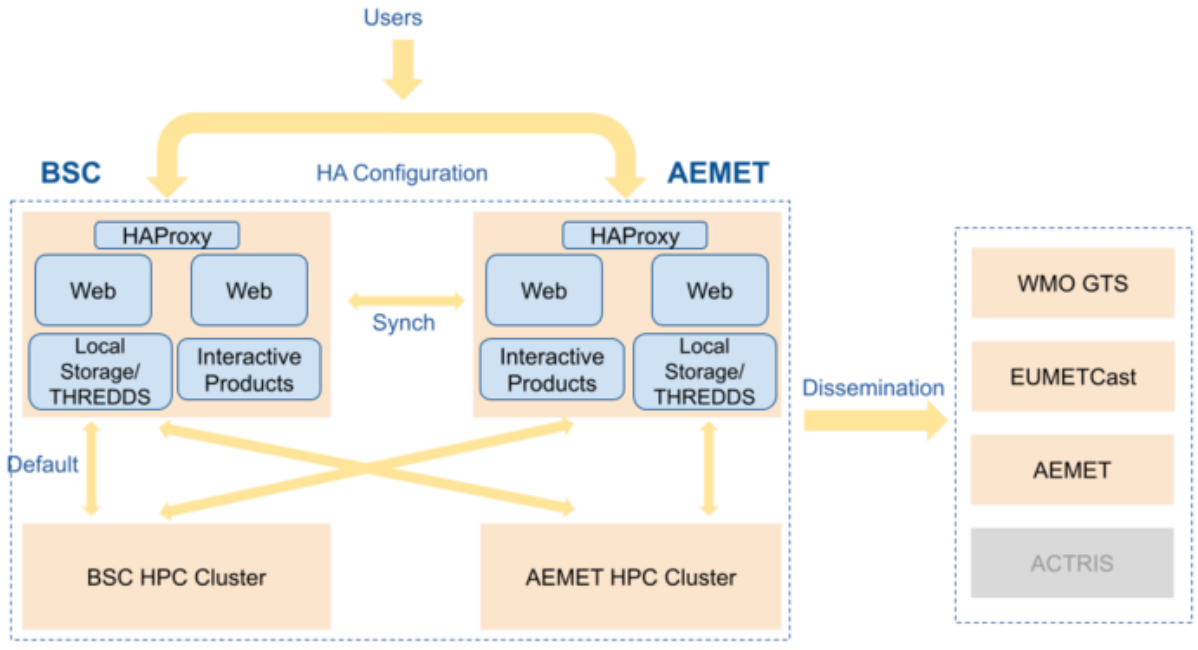

Figure 2: Configuration of the BDRC systems

6. Capacity building

All the training and webinar activities organized or with participation of the Barcelona Dust Regional Center during 2024 can be found on our website (https://dust.aemet.es/resources) Most of them include recordings and presentations which can be downloaded.

These training activities have been carried out within the framework of initiatives such as WMO CREWS or in collaboration with the GCC countries SDSWAS Regional Center in Jeddah.

The center also participated in the Conference of the Parties (COP16) of the United Nations Convention to Combat Desertification (UNCCD).

List of activities carried out in 2024:

Workshops and training schools	
Atelier SDS-WAS Afrique CREWS: Chad	https://dust.aemet.es/news-events/events/atelier-sds-was-afrique-crews-chad
The first International conference on Sand and Dust Storms, Riyadh, Saudi Arabia	https://dust.aemet.es/news-events/events/the-first-international-conference-on-sand-and-dust-storms-riyadh-saudi-arabia
Conference of the Parties (COP16) of the United Nations Convention to Combat Desertification (UNCCD)	Conference of the Parties (COP16) of the United Nations Convention to Combat Desertification (UNCCD)

Barcelona Dust Regional Center webinars	
Special Webinar for the International Day of Combating Sand and Dust Storms	https://dust.aemet.es/news-events/events/2nd-webinar-for-the-international-day-of-combating-sand-and-dust-storms
Webinar for the Dust Doctoral Network	https://dust.aemet.es/news-events/events/webinar-for-the-dust-doctoral-network
17 PhD positions on dust offered across Europe by the MSCA Dust Doctoral Network	https://dust.aemet.es/news-events/events/europe-webinar-for-the-dust-doctoral-network

7. Staff

Ernest Werner, Technical Director

Emanuele Emile, Lead Scientist

Gerardo García-Castrillo, Scientific Support

Carlos Pérez García-Pando, Scientific Advisor

África Barreto, Scientific Advisor

Francesco Benincasa, Lead Developer

Elliot Rose, Web Developer

Marina Conde, Web Developer

Diana Urquiza, Product Designer

Kelsey Bailey, 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 3) show the number of sessions and page views.

Season	Sessions	Page views
Dec 2023 – Feb 2024	24.000	61.000
Mar 2024 – May 2024	46.000	101.000
Jun 2024 – Aug 2024	37.000	74.000
Sep 2024 – Nov 2024	26.000	58.000

Table 3: Quarterly overview of web access during 2024

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
Dec 2023 – Nov 2024	134.000	294.000

Table 4: Evolution of annual web access (*, ** Google analytics new version)

The seven top countries ranked by number of visitors in 2024 are Spain, Germany, United States, Poland, and with similar values, France, United Kingdom and Portugal.

The number of sessions and page views increased significantly in 2024 with two picks in March (fig.1) and April due to dust outbreaks that affected Europe. It is interesting to note that access from mobile devices is about 40%, which highlighting the importance of the mobile version of the website.

The BDRC X account (@Dust_Barcelona) is an effective tool to disseminating our forecast products and other activities carried out by the BDRC. During 2024, and since the latest management changes, the number of followers has remained stable at around 4,000.