WMO Barcelona Dust Regional Center: SDS Forecast Products

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Outline

WMO SDS-WAS

History and Objectives

- Impacts on health, transport, industry, climatology, ...
- SDS-WAS WMO program (2004-2007)
- Sand and Dust Storm Warning Advisory and Assessment System
- Improvement of Sand and Dust Storm Observation and Forecast
- Difusion of knowledge and products
- Regional Centers: Beijin (Asia 2008), Barcelona (NAMEE 2010), Barbados (America 2016-2017), GCC (Saudi Arabia, 2022)

WORLD METEOROLOGICAL ORGANIZATION

GAW

WMO Barcelona Dust Regional Center

- Barcelona Dust Regional Center (2010)
- WMO Regional Specialized Meteorological Center on Atmospheric Sand and Dust Forecast, (RSMC-ASDF 2014)
- AEMET & BSC (Barcelona Supercomputing Center)

Marenostrum 4: BSC

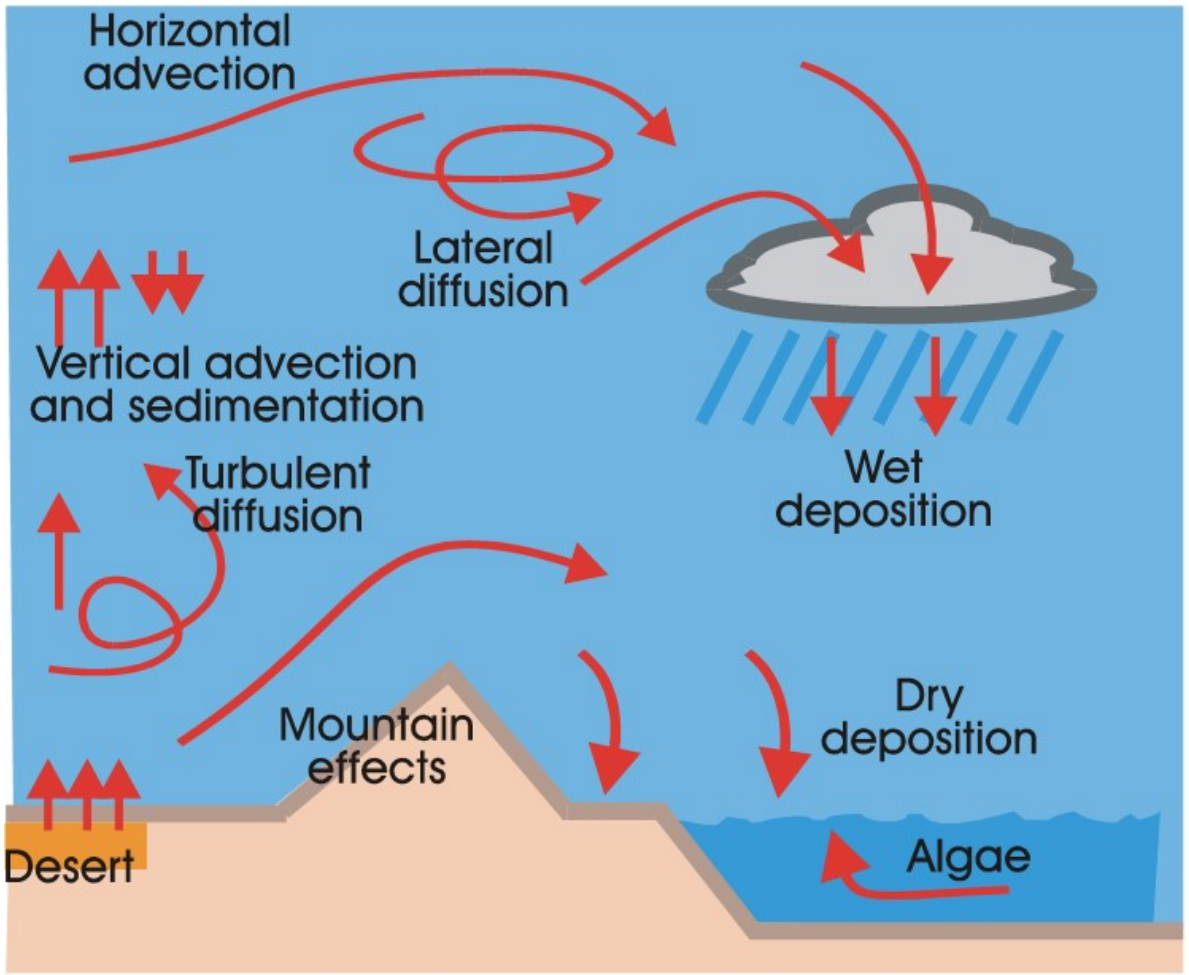
Cirrus-Atos: AEMET

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

AEMet
Agencia Estatal de Meteorología

Outline

Dust Cycle



Source: Barcelona Dust Forecast Center

- Emission
- Vertical movement
- Transport
- Wet & Dry Deposition

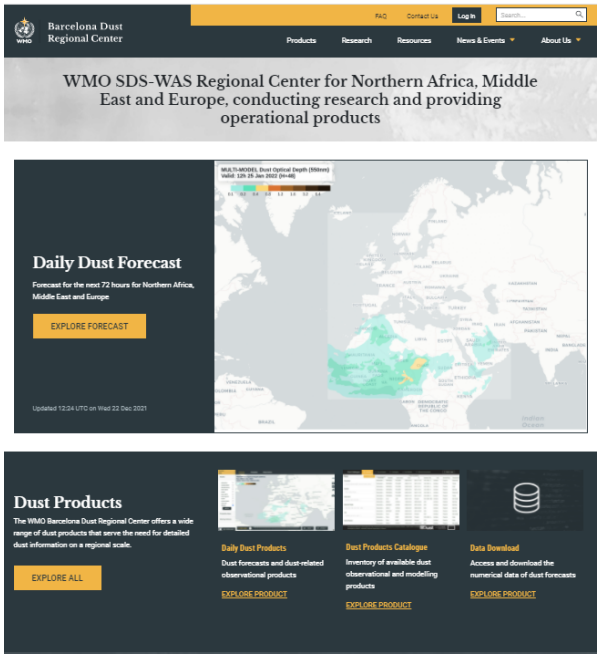
Operational model: MONARCH (https://dust.aemet.es)

Multiscale Online Nonhydrostatic AtmospheRe CHemistry

- Daily forecast: 12 UTC run, 72 h forecast, 3 h step
- Resolution: 0.1° x 0.1°
- Domain: Northern Africa, Middle East and Europe

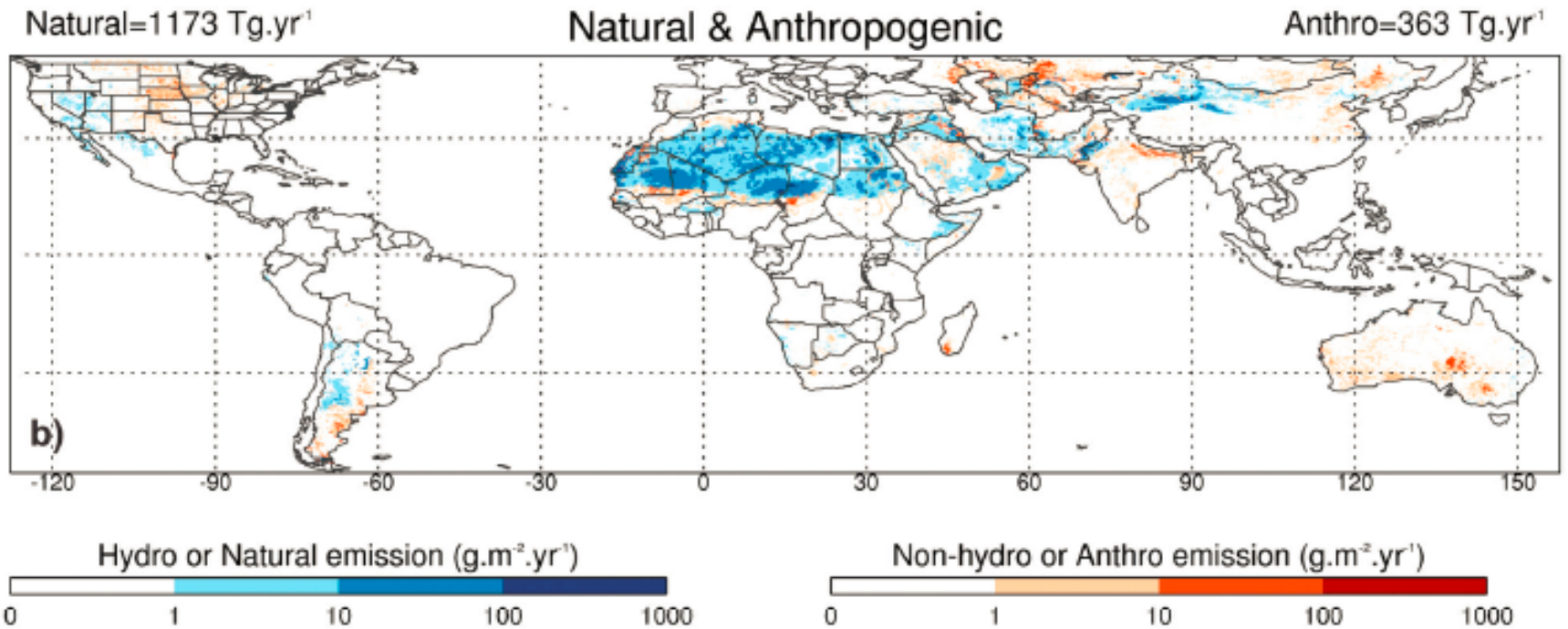
Parameters

- **Dust Surface Concentration** [μg/m3]
- Extinction [M/m]
- Dust Load [g/m2]
- **Dust Optical Depth (Dust AOD)** [–]
- Dry Deposition [mg/m2]
- Wet Deposition [mg/m2]

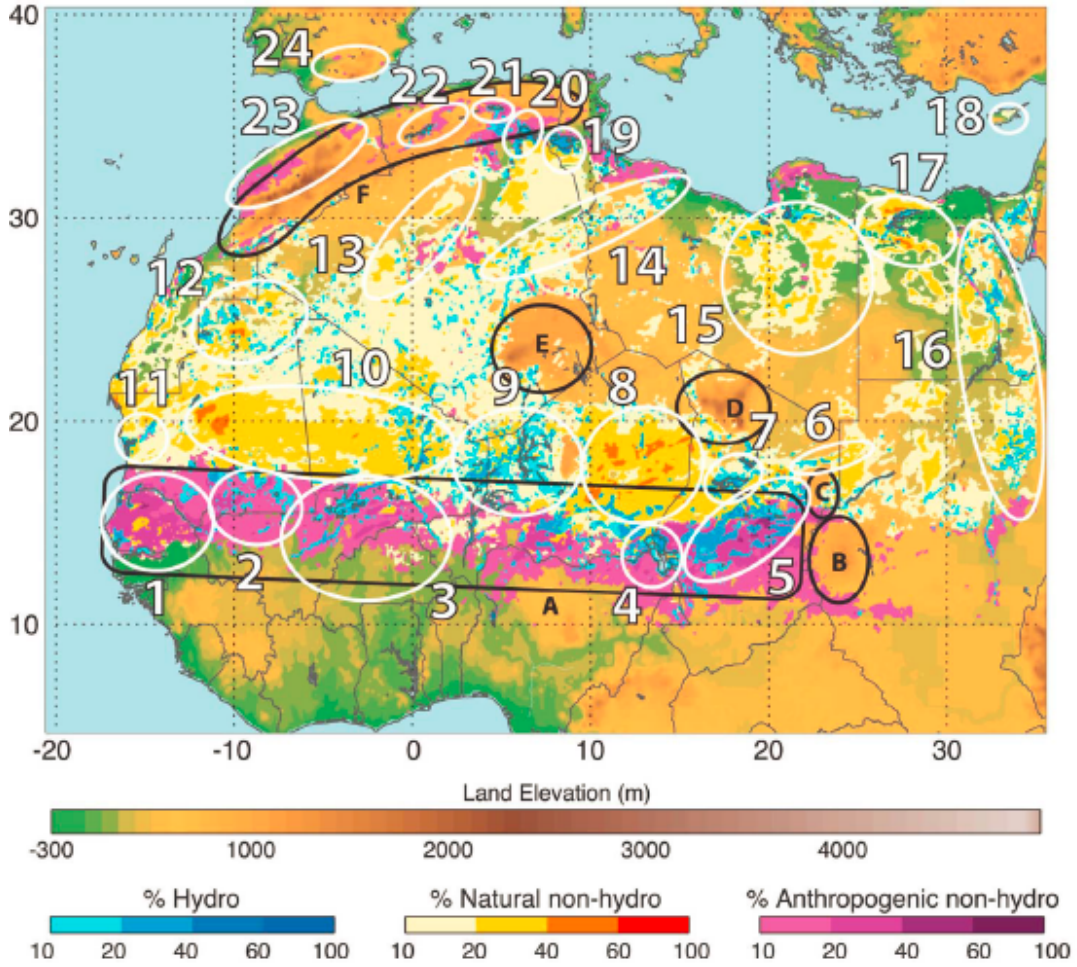


Operational model: Current Configuration (Technical Report)

- Meteorological driver: NMMB Nonhydrostatyc Multiscale Model on the B-grid (NCEP)
- Dust source map from Ginoux et al. (2012)
- Emission scheme from Ginoux et al. (2001)
- 40 layers extending up to approximately 15 km in the vertical.
- Meteorological boundary conditions: NCEP/GFS 0.1° x 0.1°



Exemple: Northern Africa Dust Sources (Anthropogenic & Natural)



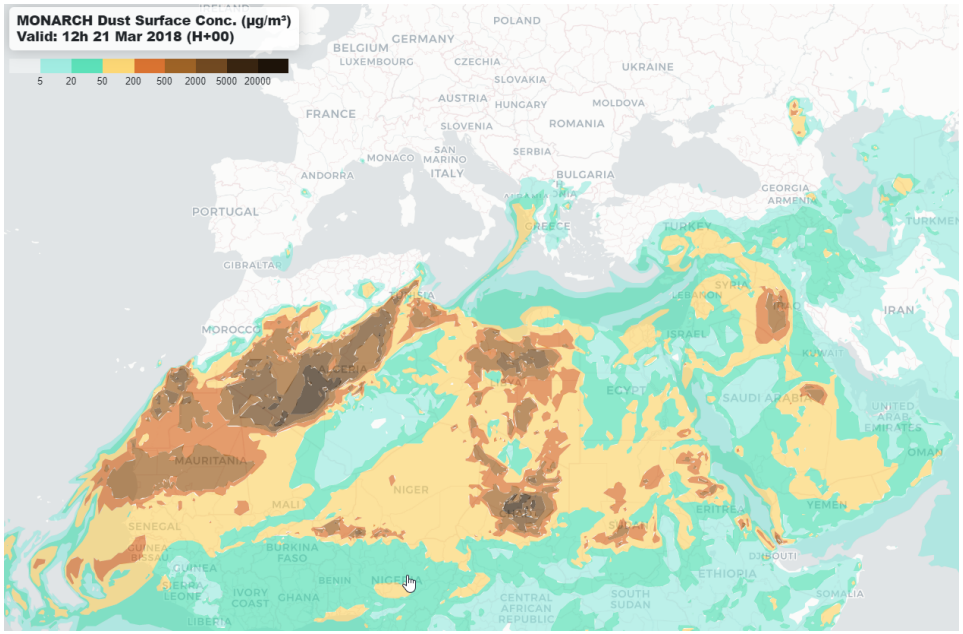
Source: Paul Ginoux et.Al, 2012

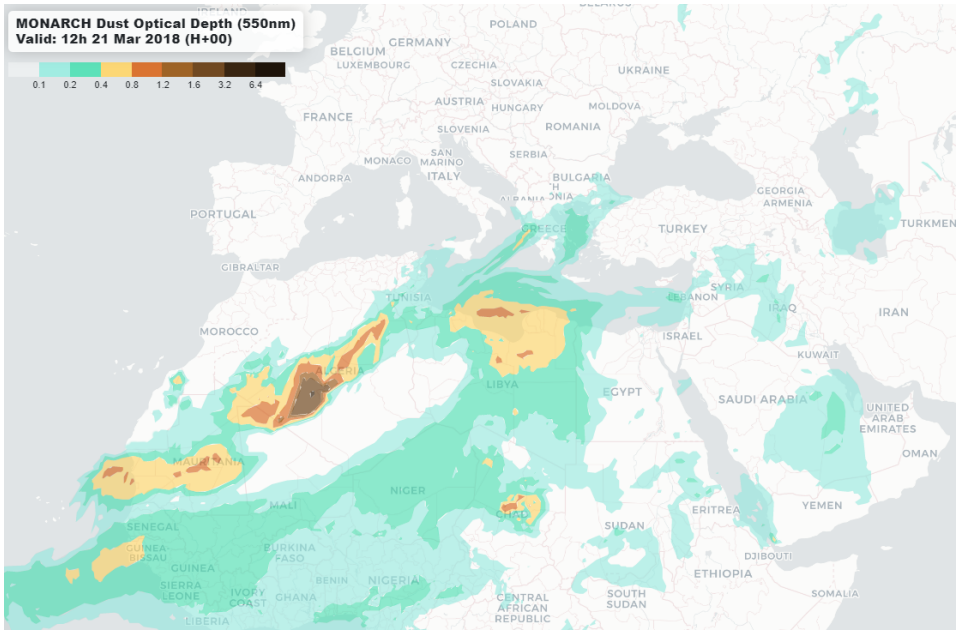
Data: MODIS Deep Blue Level 2

...
19, Chott el Jerïd
20, Chott Melrhir
21, Chott el Hodma
22, Chott ech Chergui
23, Morocco coastal plains
24, Andalusia
A, the Sahel
B, the Ouaddaï Highlands
C, Ennedi
D, Tibesti
E, Ahaggar
F, Atlas Mountains

Dust source map (resolution: 0.1°)
→ **MONARCH**

Dust AOD & SFC Dust Concentration

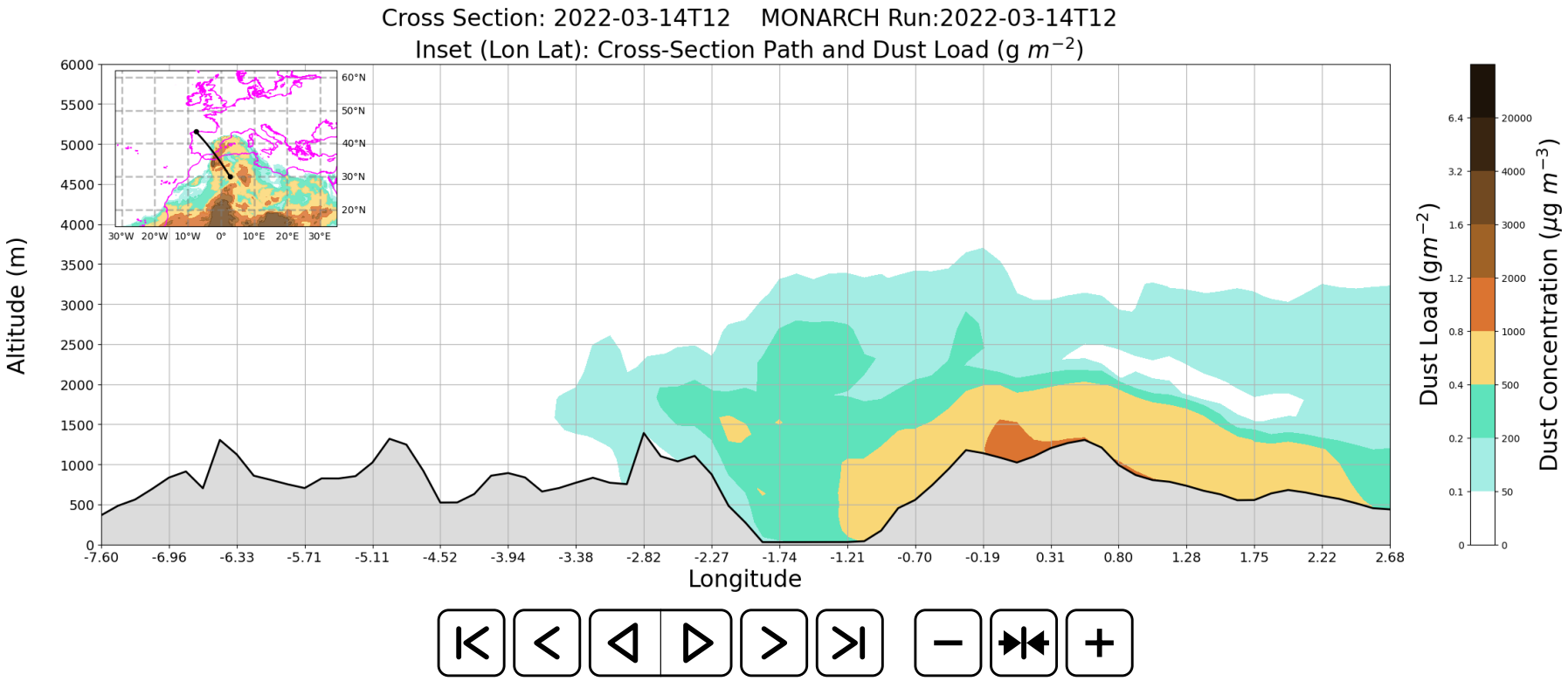




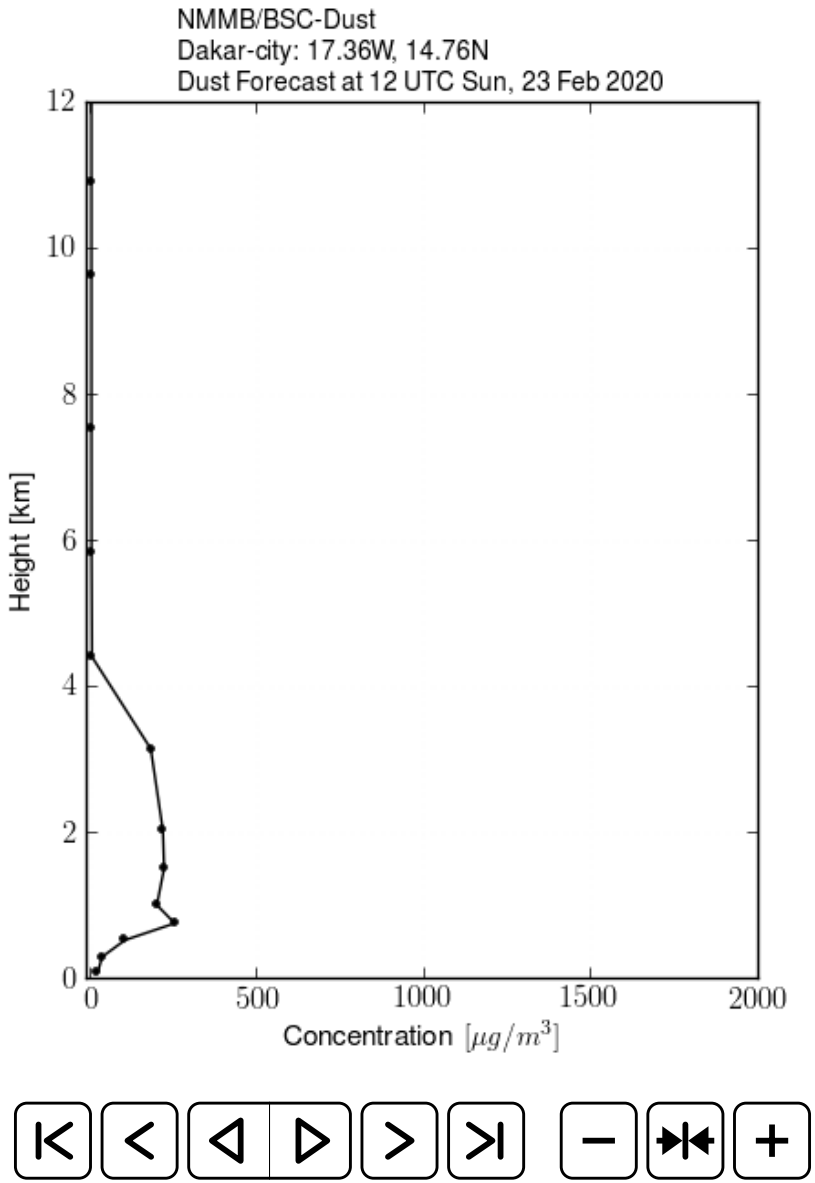
- Impacts at SFC
- Air Quality stations → PM10
- Vertical levels of dust concentration (ongoing)

- AOD [–] → total amount of dust in the atmosphere
- Optical properties → Satellite AOD, AERONET

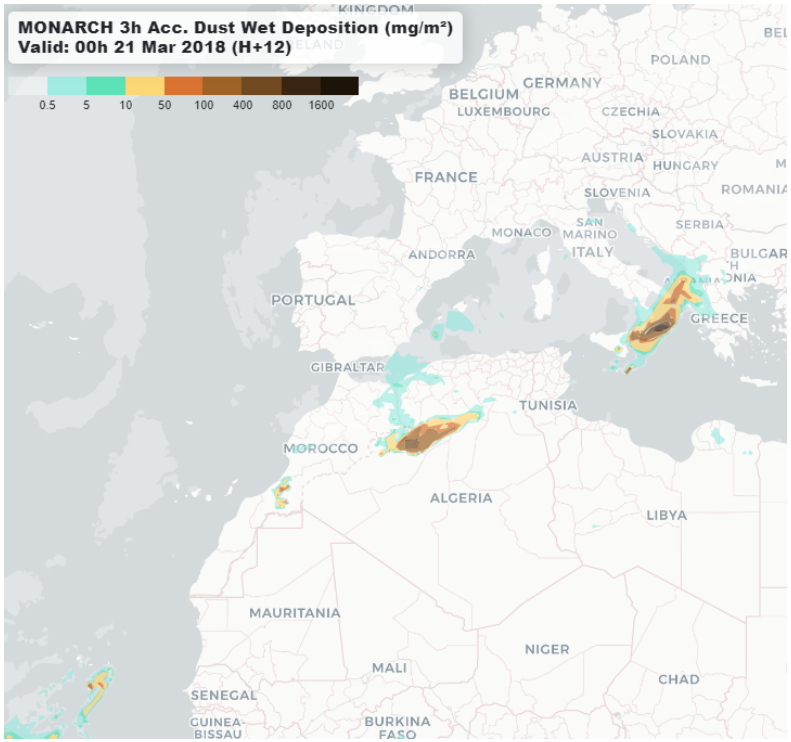
Dust Vertical Distribution: Cross Section (ongoing!)

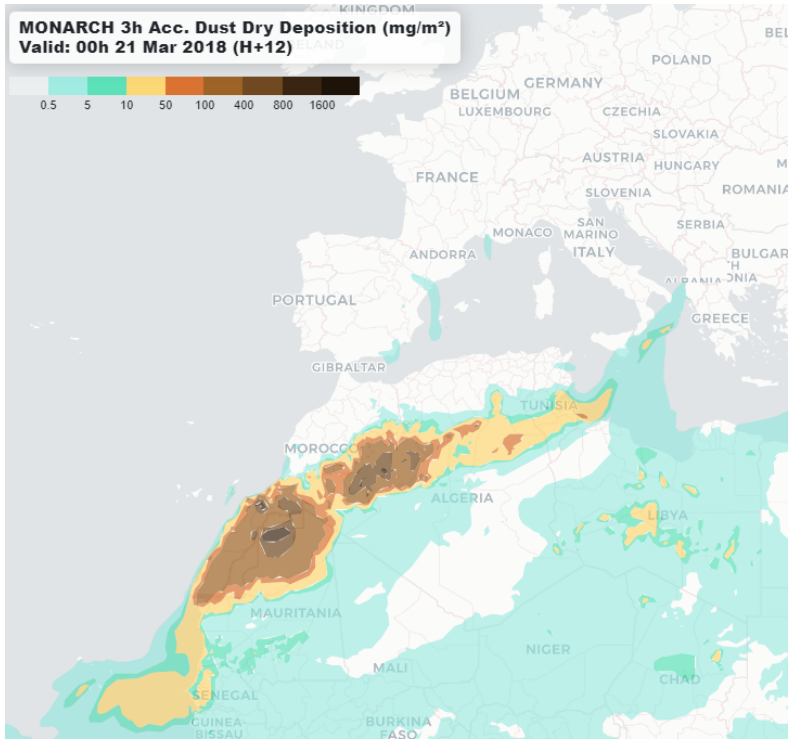


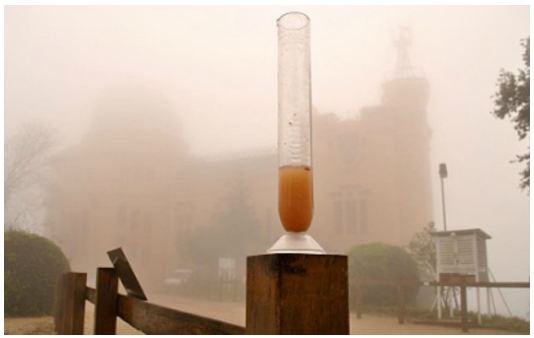
Dust Vertical Distribution: Vertical profile, Dakar (ongoing!)



Wet (rain) & Dry (gravitational force) Deposition







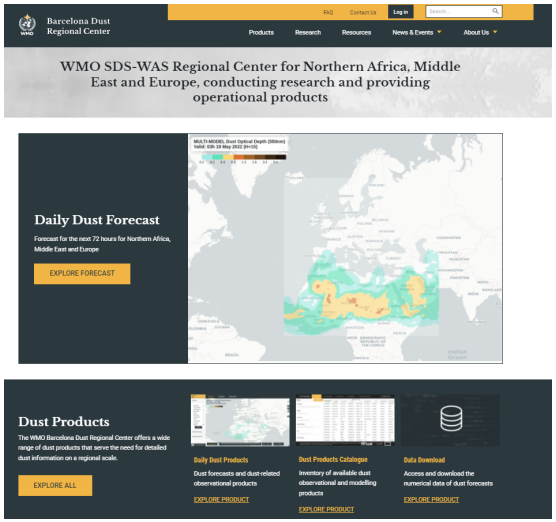
Source: Alfons Puertas. Observatori Fabra

Outline

Multimodel products (Link: Technical report multimodel)

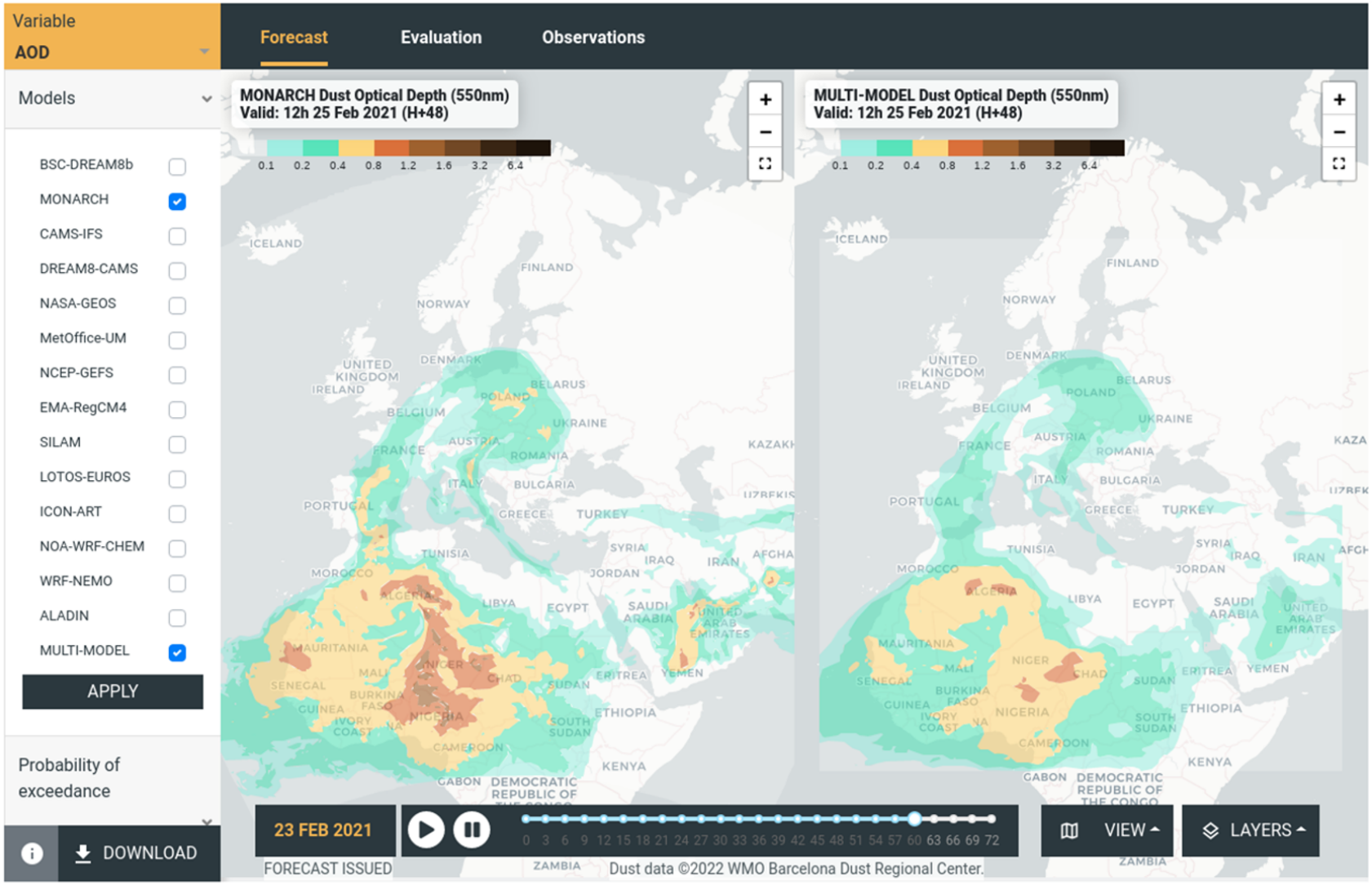
Model	Institution	Domain	Data Assimilation
BSC-DREAM8b_c2 (End 2022)	BSC-CNS	Regional	NO
CAMS-ECMWF	ECMWF	Global	MODIS-AOD
DREAM8-NMME-CAMS	SEEVCCC	Regional	ECMWF dust-analysis
NMMB/MONARCH	BSC-CNS	Regional	NO
MetUM	Met Office	Global	MODIS/Aqua
GEOS-5	NASA	Global	MODIS
GEFS	NCEP	Global	NO
EMA REG CM4	EMA	Regional	NO
NOA-WRF-CHEM	NOA	Regional	NO
WRF-NEMO	NOA	Regional	NO
SILAM	FMI	Global	NO
LOTOS-EUROS	TNO	Regional	NO
ALADIN-DUST	ONM-Algeria ALADIN Consortium	Regional	NO
ICON-ART	DWD	Regional/Global	NO
ZAMG-WRF-CHEM	ZAMG	Regional	NO
MOCAGE	MétéoFrance	Global	MODIS and VIIRS

- 15 models
- Median → Multimodel!
- Probability maps, Warning System
- Evaluation: AERONET & MODIS

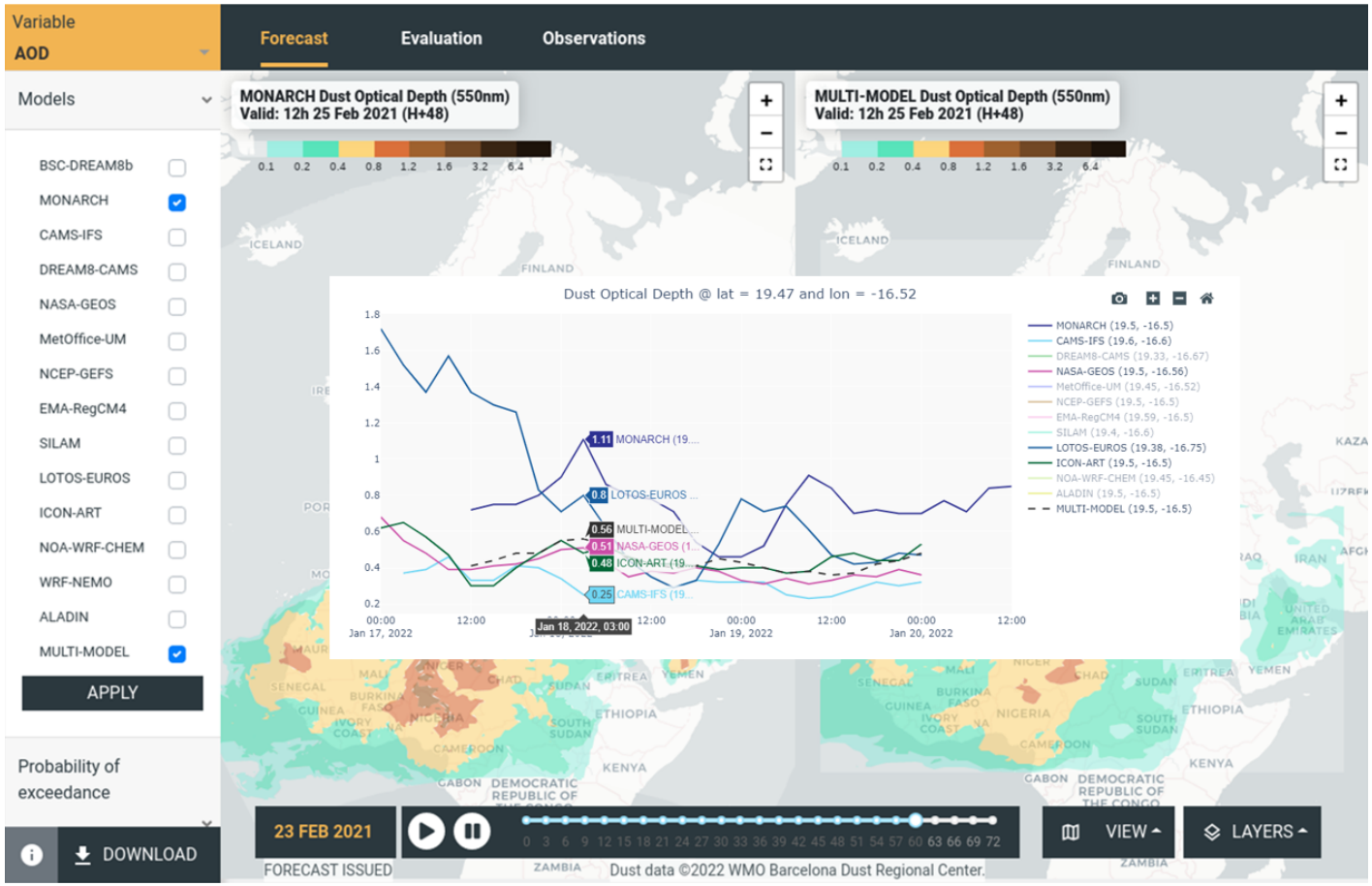


Model Intercomparaison

Dust Optical Depth (AOD) & Surface Concentration



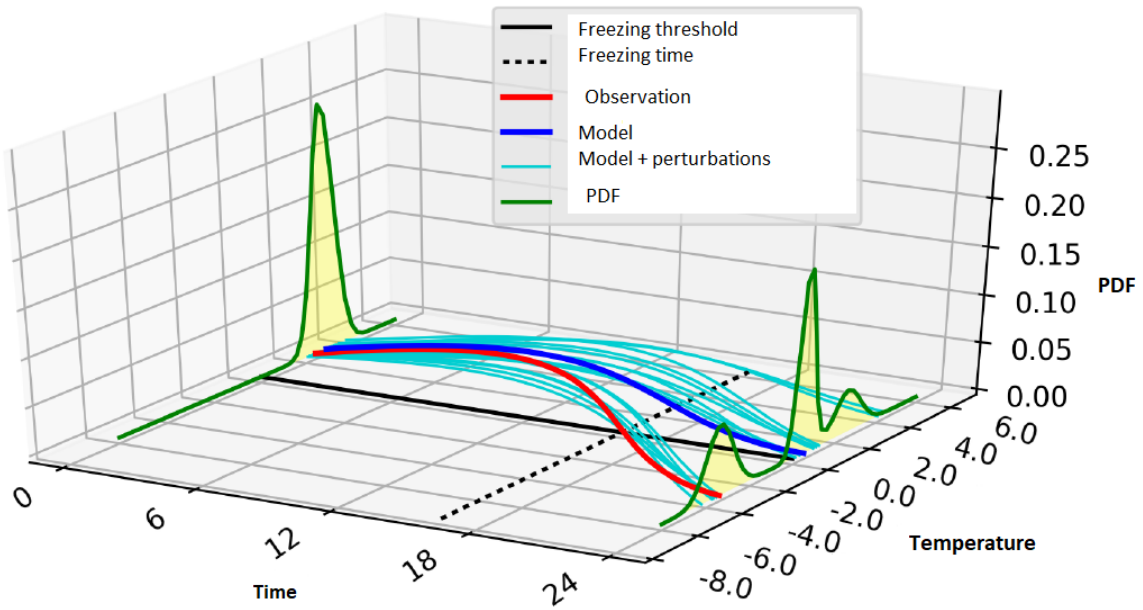
Summay SDS forecast products (II)



- One-point comparison of models and median of multi-model

Ensemble Prediction System (EPS)

- Chaotic system → limited predictability
- Sensitivity to initial conditions
- Uncertainties: emission schemes, physics, parametrizations,....
- Median → Reference
- Best verification but... best prediction?



Source: Física del caos en la predicción meteorológica, Carlos Santos et al.

Ensemble Prediction System (EPS)

Parameters available

- Dust Surface concentration
- Dust Aerosol Optical Depth (AOD)
- 48 h forecast (soon 72 h!)
- Resolution: 0.5° x 0.5°

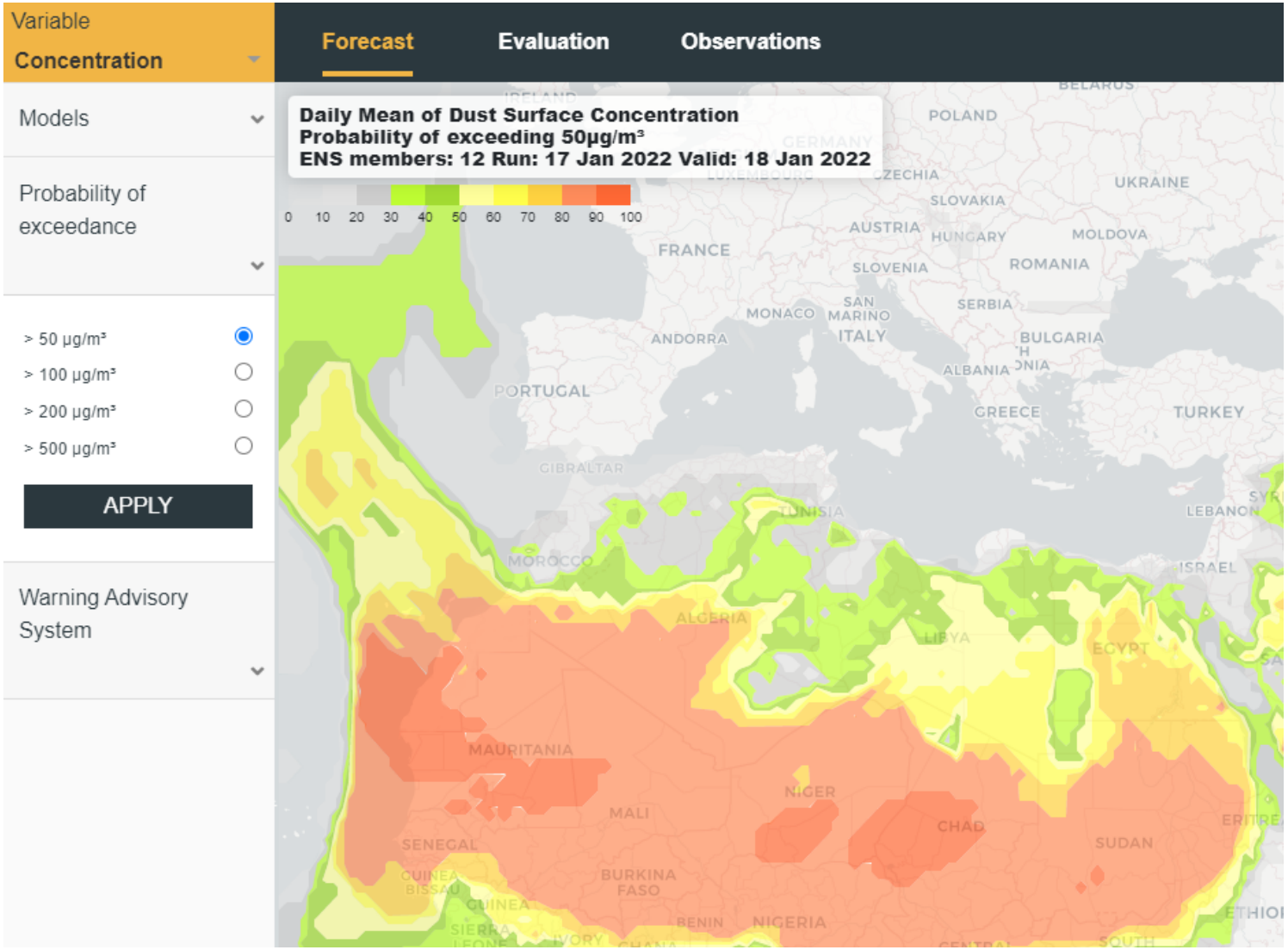
Goals

- Ensemble forecasts are built with the models available in the BDRC (member of the ensemble) $\rightarrow$ **Poor man's ensemble**
- Condense all forecasts into a simpler product
- Objective probability of the weather situation

Probability Maps

- These maps indicate the probability of a certain event
- This probability can help users in their decision making

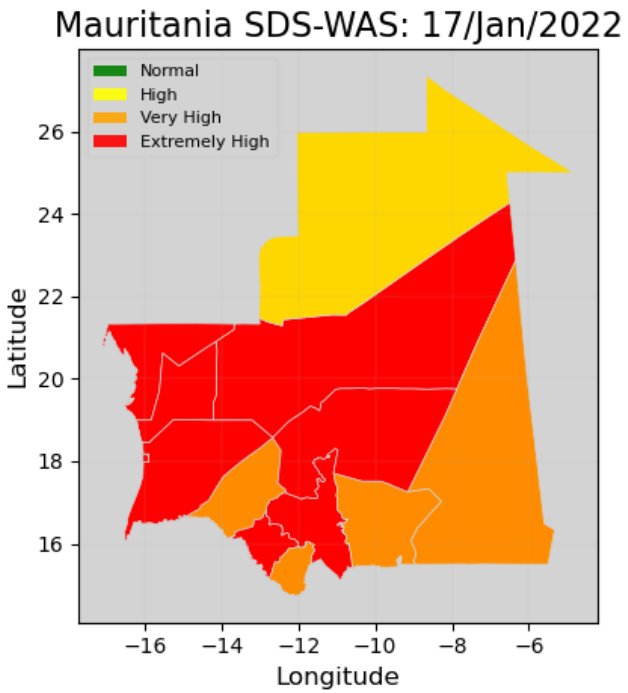
Probability Maps



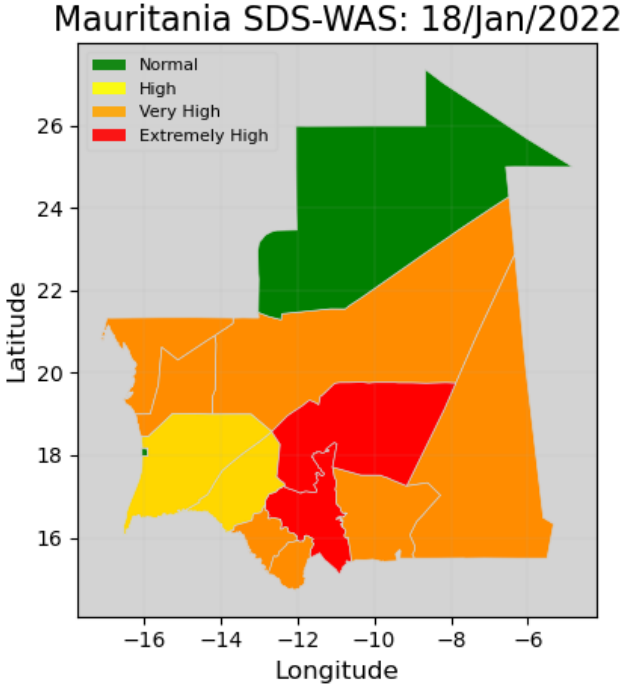
Outline

WAS: Exemple Mauritania

today



tomorrow



- Warning for Today and Tomorrow
- One color for each province
- Green: Normal Dust SFC Concentration
  Yellow: High
  Orange: Very High
  Red: Extremely High

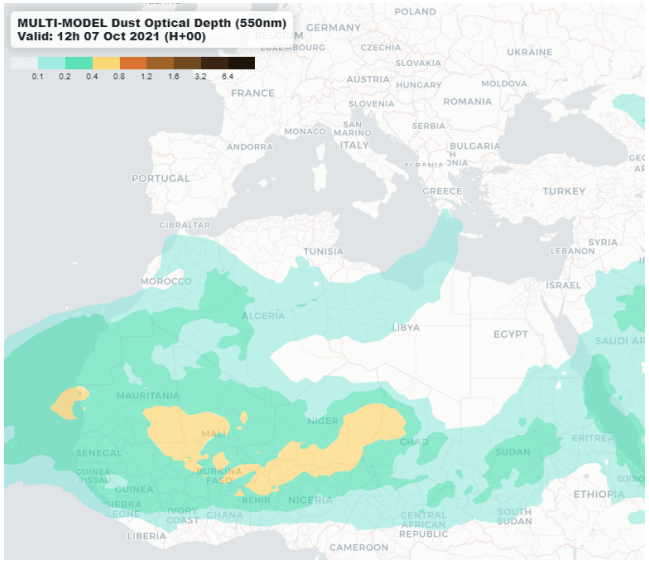
- A third day soon!!

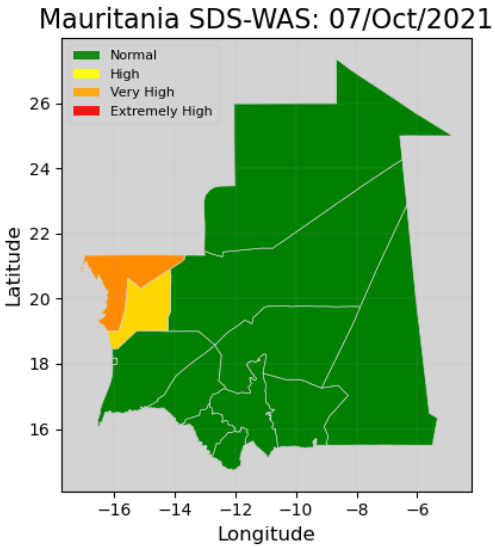
WAS warning thresholds: Exemple Mauritania [μg/m3]

Perc	Adrar	Assaba	Brakna	'Dakhlet-Nouadhibou	Gorgol	Guidimakha	'Hodh El Chargi	'Hodh El Gharbi	Inchiri	Nouakchott	Tagant	Trarza	Tris-Zemmour
50% median	472	358	492	544	393	241	371	312	550	291	339	620	576
80% yellow	742	579	770	760	584	366	571	504	800	507	581	944	952
90% orange	921	727	966	893	700	436	707	651	938	661	766	1160	1189
97.5% red	1213	970	1256	1126	947	612	982	892	1206	890	1048	1406	1575

- Time series of the multimodel median (5 years)
- **Daily maximum** value of Dust Surface Concentration
- Considered all the grid points in each province
- Threshold [μg/m3] based on the percentiles
- Compare median forecast with the thresholds to assign a color

WAS: Exemple Mauritania





Perc	Adrar	Assaba	Brakna	'Dakhlet-Nouadhibou	Gorgol	Guidimakha	'Hodh El Chargi	'Hodh El Gharbi	Inchiri	Nouakchott	Tagant	Trarza	Tris-Zemmour
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97.5% red	1213	970	1256	1126	947	612	982	892	1206	890	1048	1406	1575

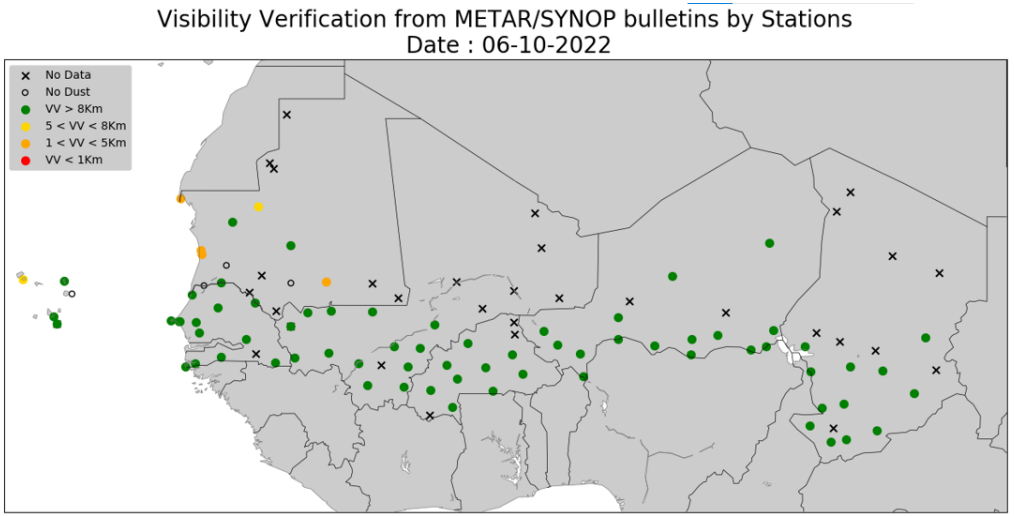
- Comparison of the median forecast with the thresholds calculated with the time series
- No probability!
- **Assess surface dust concentration forecast**

WAS Evaluation Exemple: Cabo Verde

Data and methodology

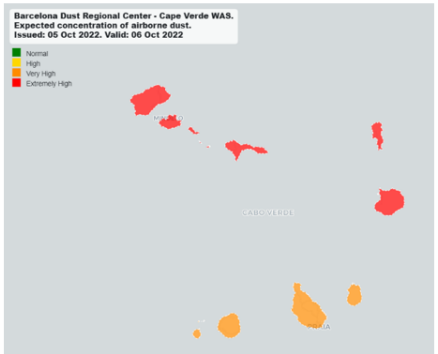
- Visibility, present weather and relative humidity SYNOP & METAR
- Data filtering:
  - Relative humidity < 70 %
  - Daily mean visibility < 8000 m
  - Daily Minimum Visibility
- Time Series Visibility $\rightarrow$ Thresholds: yellow, orange, red
- Evaluation: Comparison of visibility warnings with WAS warnings for each province/region

WAS Evaluation Exemple: Cabo Verde

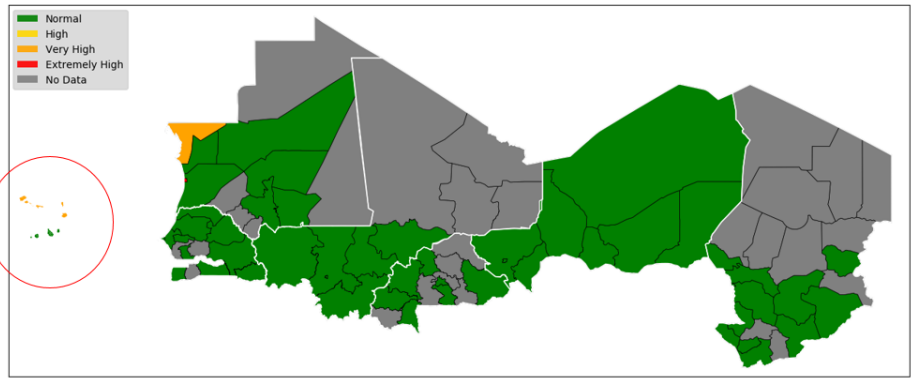


Filter **METAR** & **SYNOP:**

- **RH < 70 %**
- **Present Weather (Dust)**
- **VIS daily mean < 8000 m**



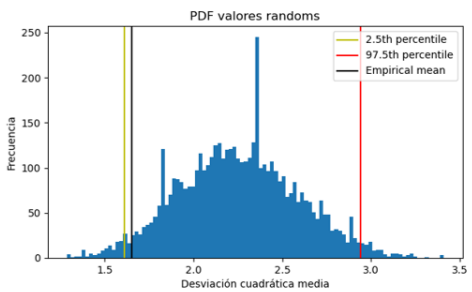
Warning from Models



Warning from Observations

Warning Advisory System: Persistence Comparison

Bootstrapping Praia CapeVerde



False Alarms

OB\MO	green	gold	orange	red
green	0.0	30.61	16.33	0.0
gold	2.04	2.04	0.0	0.0
orange	8.16	12.24	16.33	4.08
red	2.04	0.0	0.0	6.12

Miss

Hits

Counts :	347
Counts OBS without green:	26
Counts without green-green :	49
Empirical mean:	1.65
Bootstrap replicates mean:	2.25
The confidence interval 95%:	[1.61 2.94]
p-Value =	3.36 %
Thresholds Visibility(m) :	3200 7000 9999

Hits :	24.49 %
Misses :	12.24 %
False Alarm :	46.94 %
Overforecasting :	51.02 %
Underforecasting :	24.49 %

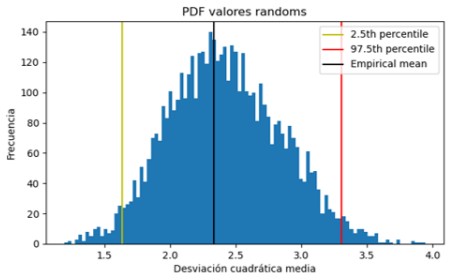
WAS Evaluation 2021

Total days:	347
Days with dust event:	26
Days with warning observed or predicted:	49

- Contingency table
- Define Index for evaluation
- No Green-Green days
- Bootstrapping
- Comparison with Persistence

Persistence Evaluation 2021

PERSISTENCIA Bootstrapping Praia CapeVerde



OB\MO	green	gold	orange	red
green	0.0	5.56	19.44	2.78
gold	2.78	0.0	2.78	0.0
orange	22.22	0.0	30.56	2.78
red	2.78	0.0	2.78	5.56

Counts :	335
Counts OBS without green:	26
Counts without green-green :	36
Empirical mean:	2.33
Bootstrap replicates mean:	2.42
The confidence interval 95%:	[1.64 3.31]
p-Value =	44.26 %
Thresholds Visibility(m) :	3200 7000 9999

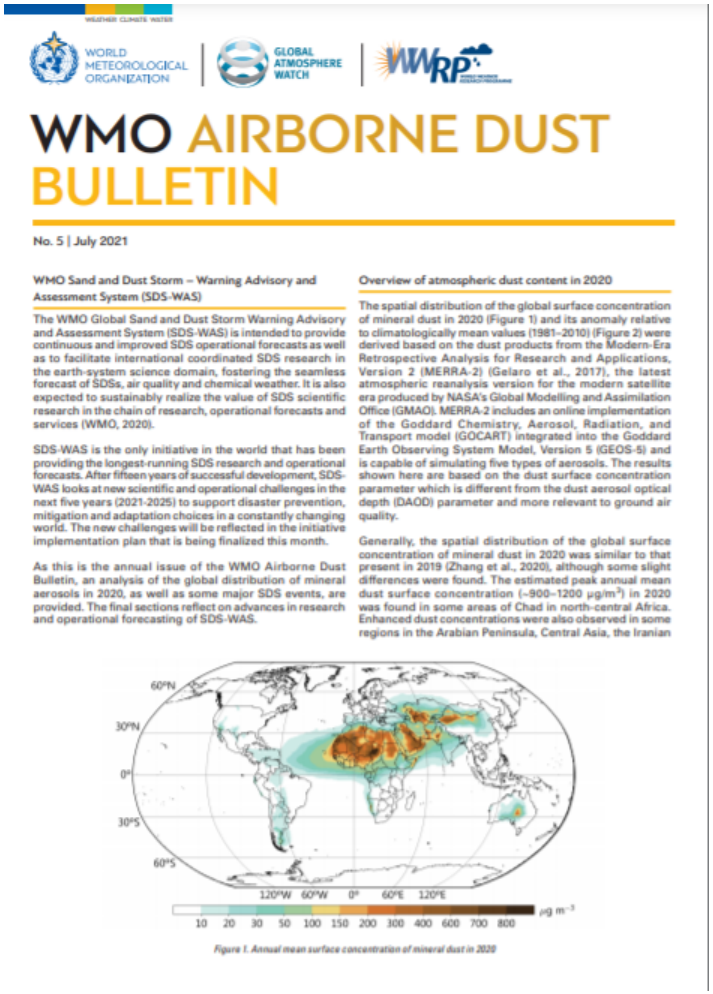
Hits :	36.11 %
Misses :	27.78 %
False Alarm :	27.78 %
Overforecasting :	33.33 %
Underforecasting :	30.56 %

Warning Advisory System: Evaluation

Conclusions

- Not enough SYNOP & METAR stations
- Qualitative evaluation $\rightarrow$ lack of PM data
- Visibility good proxy for regions near the dust sources
- Not so good for regions relatively far away
- Dust homogeneous regions $\rightarrow$ instead of Administrative divisions
- Better than Persistence $\rightarrow$ WAS forecasts better when a situation starts or ends
- Objective evaluation $\rightarrow$ WAS updates

WMO Annual Airborne Dust Bulletin



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WMO AIRBORNE DUST BULLETIN

No. 5 | July 2021

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

The WMO Global Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) is intended to provide continuous and improved SDS operational forecasts as well as to facilitate international coordinated SDS research in the earth-system science domain, fostering the seamless forecast of SDSs, air quality and chemical weather. It is also expected to sustainably realize the value of SDS scientific research in the chain of research, operational forecasts and services (WMO, 2020).

SDS-WAS is the only initiative in the world that has been providing the longest-running SDS research and operational forecasts. After fifteen years of successful development, SDS-WAS looks at new scientific and operational challenges in the next five years (2021-2025) to support disaster prevention, mitigation and adaptation choices in a constantly changing world. The new challenges will be reflected in the initiative implementation plan that is being finalized this month.

As this is the annual issue of the WMO Airborne Dust Bulletin, an analysis of the global distribution of mineral aerosols in 2020, as well as some major SDS events, are provided. The final sections reflect on advances in research and operational forecasting of SDS-WAS.

Overview of atmospheric dust content in 2020

The spatial distribution of the global surface concentration of mineral dust in 2020 (Figure 1) and its anomaly relative to climatologically mean values (1981–2010) (Figure 2) were derived based on the dust products from the Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) (Gelaro et al., 2017), the latest atmospheric reanalysis version for the modern satellite era produced by NASA's Global Modelling and Assimilation Office (GMAO). MERRA-2 includes an online implementation of the Goddard Chemistry, Aerosol, Radiation, and Transport model (GOCART) integrated into the Goddard Earth Observing System Model, Version 5 (GEOS-5) and is capable of simulating five types of aerosols. The results shown here are based on the dust surface concentration parameter which is different from the dust aerosol optical depth (DAOD) parameter and more relevant to ground air quality.

Generally, the spatial distribution of the global surface concentration of mineral dust in 2020 was similar to that present in 2019 (Zhang et al., 2020), although some slight differences were found. The estimated peak annual mean dust surface concentration (~900–1200 μg/m³) in 2020 was found in some areas of Chad in north-central Africa. Enhanced dust concentrations were also observed in some regions in the Arabian Peninsula, Central Asia, the Iranian

Figure 1. Annual mean surface concentration of mineral dust in 2020

The work presented here is possible thanks to the collaboration of the active members of the **WMO SDS-WAS** and in particular the partners of the regional node NAMEE.

My thanks to the colleagues of **BSC** and **AEMET**.

Thanks also to the associated researchers from **NASA** (i.e. AERONET, MODIS), **EUMETSAT** as well as the **inDust** and **DustClim** networks.

Thank you for your attention!