Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

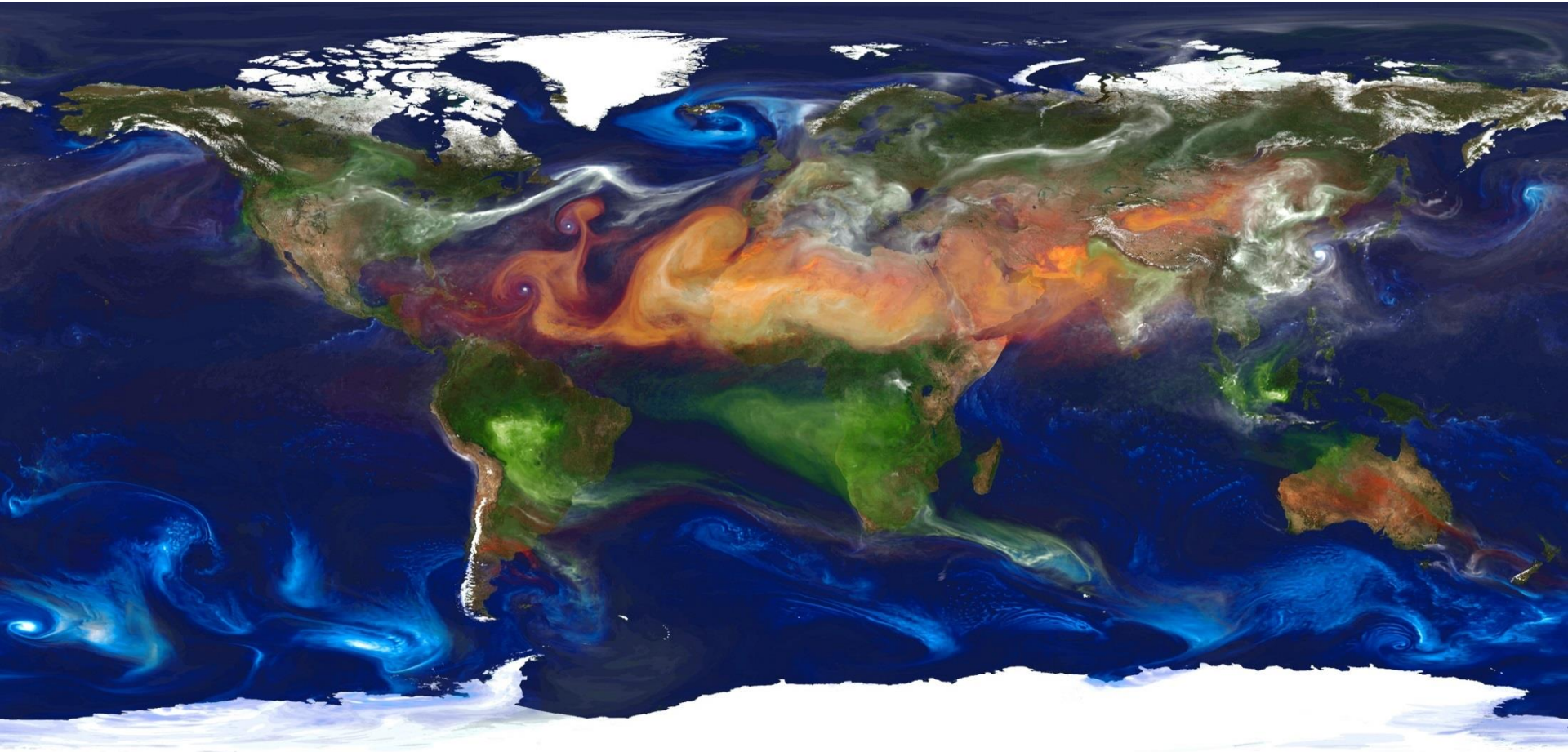
Modelling and forecasting Sand and Dust Storms

Sara Basart (sara.basart@bsc.es)

Earth Sciences Department,
Barcelona Supercomputing Center (BSC)

inDust User Workshop on Air Quality, 11th March 2019, Rome, Italy

Dust cycle and its extension

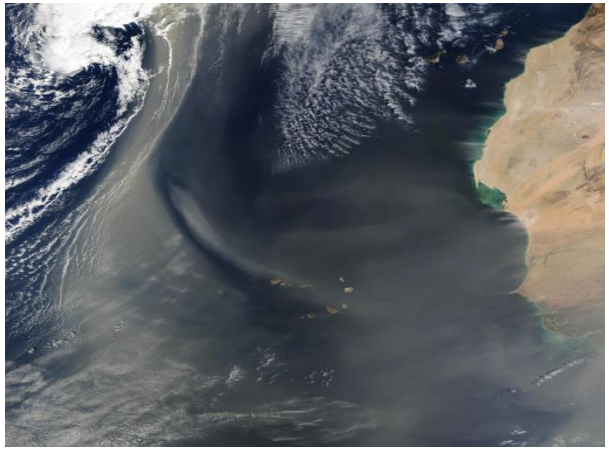


Organic Carbon + Elemental carbon
Dust
Sulfate
Sea salt

NASA | GEOS-5 Aerosols

Dust cycle and associated processes

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

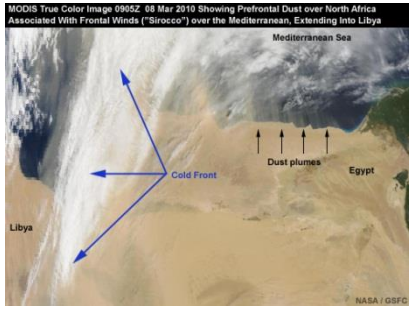


MODIS True color Western Africa – Altantic Ocean

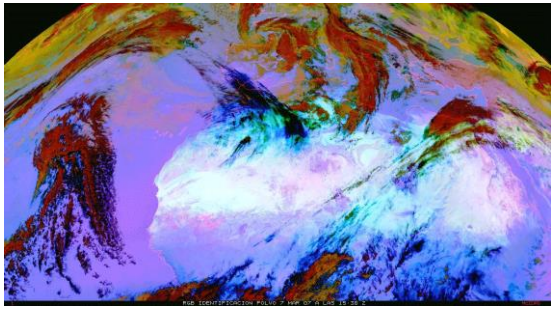
Dust transport is a global phenomenon. However, **dust emission** is a threshold phenomenon, sporadic and spatially heterogeneous, that is locally controlled on small spatial and temporal scales.

Dust cycle and associated processes

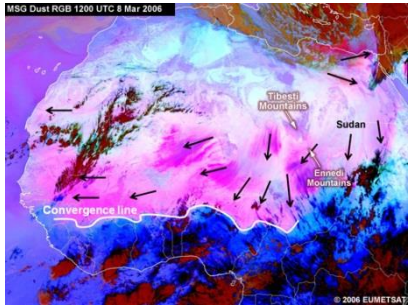
Synoptic dust storms (large scale weather systems)



Pre-frontal winds

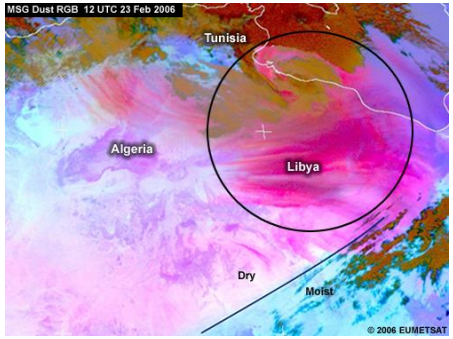


Post-frontal winds

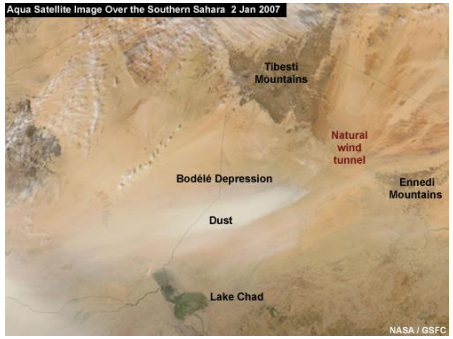


Large-scale trade winds

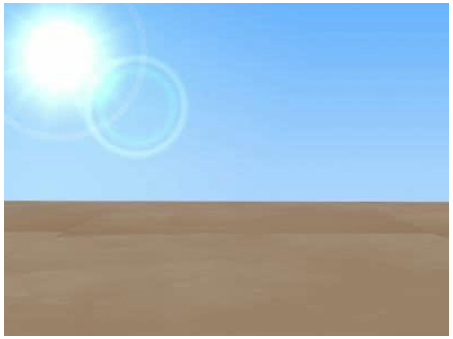
Mesoscale dust storms



Downslope winds



Gap flow

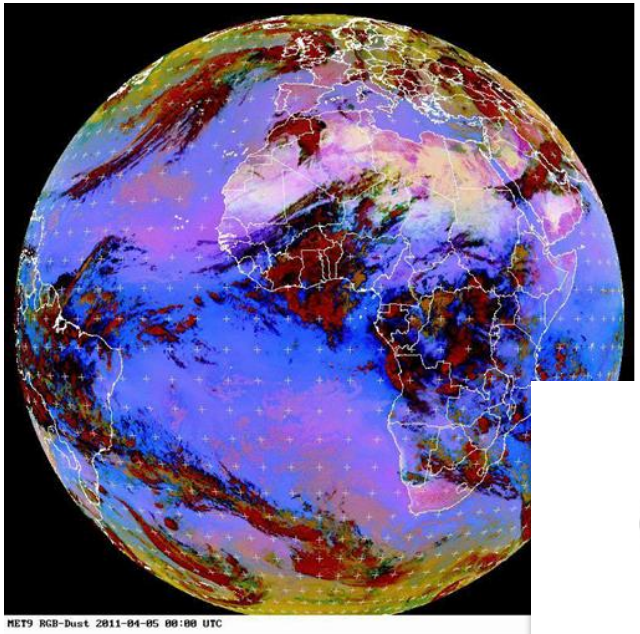


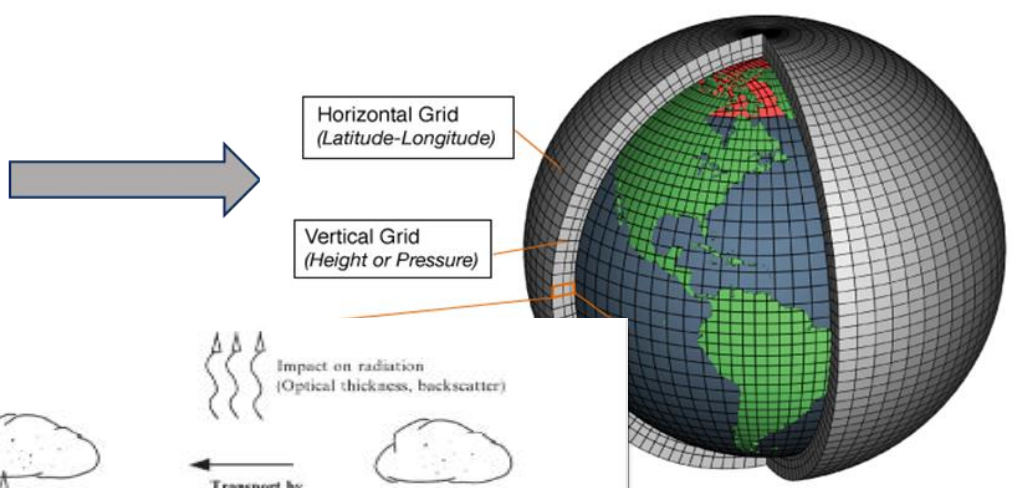
Dust devils

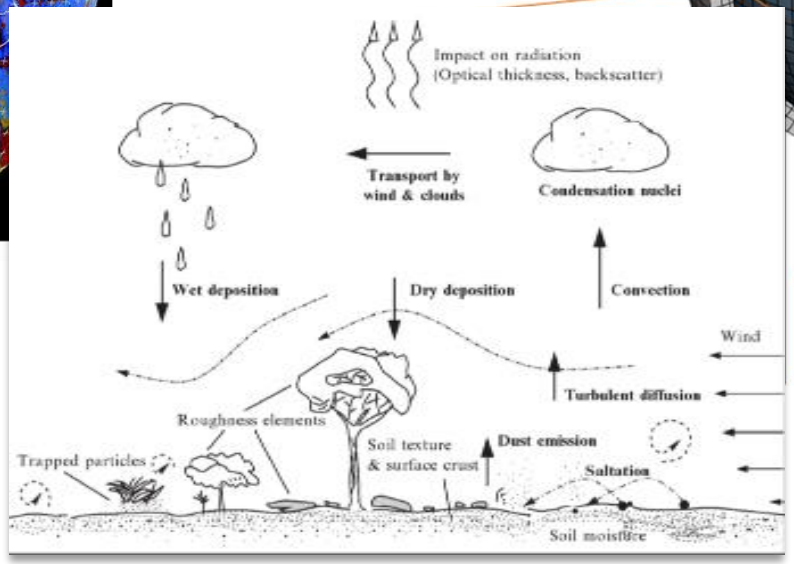
Haboobs

Dust forecasting models

Dust models are a **mathematical representation** of atmospheric dust cycle.







Dust forecasting models

Dust forecasting models do **not** take account dust **resuspension**

Kathmandu, Nepal, March 2017

Earth Sciences Department at BSC

Environmental modelling and forecasting, with a particular focus on weather, climate and air quality

Modeling **air quality** and **Sand and Dust Storms** Processes from urban to Global and the impacts on weather, health and ecosystems

Research and Forecasts

Climate predictions system from subseasonal-to-decadal forecasts

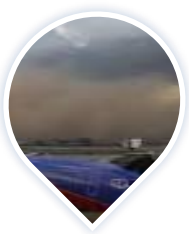
AXA Research Fund

Service Users Sectors


Infrastructures


Solar Energy

Urban development


Transport


Wind Energy


Agriculture


Insurance

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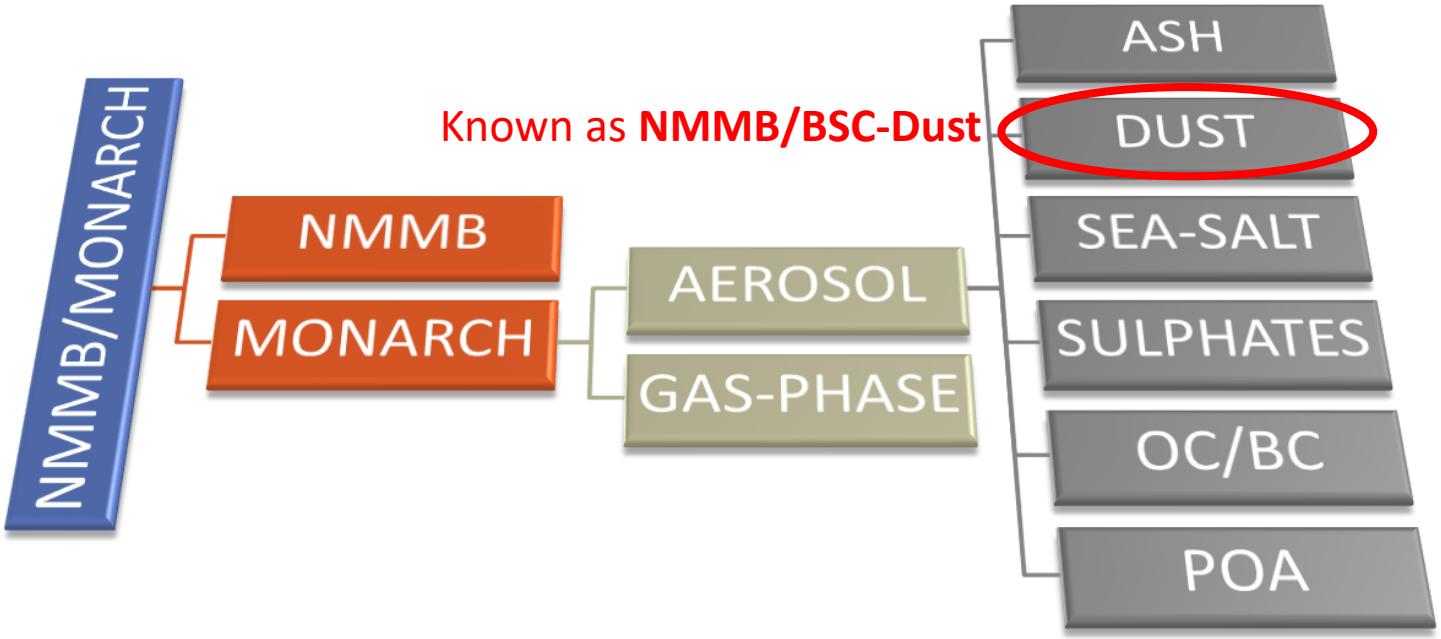
www.bsc.es/ess/

NMMB-MONARCH: Atmospheric Composition and Air Quality

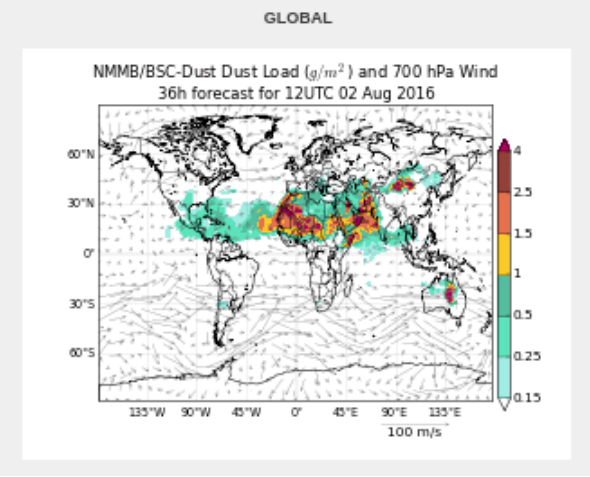
- The main system is build on the **meteorological driver NMMB**
- ***Multiscale***: global to regional scales allowed (nesting capabilities)
- ***Nonhydrostatic*** dynamical core: single digit kilometre resolution allowed
- Fully ***on-line*** coupling: weather-chemistry feedback processes allowed
- Enhancement with a ***data assimilation*** system



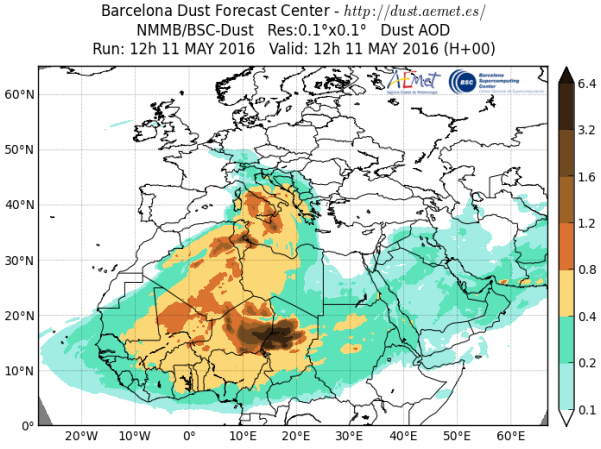
Known as **NMMB/BSC-Dust**

Mineral Dust Services

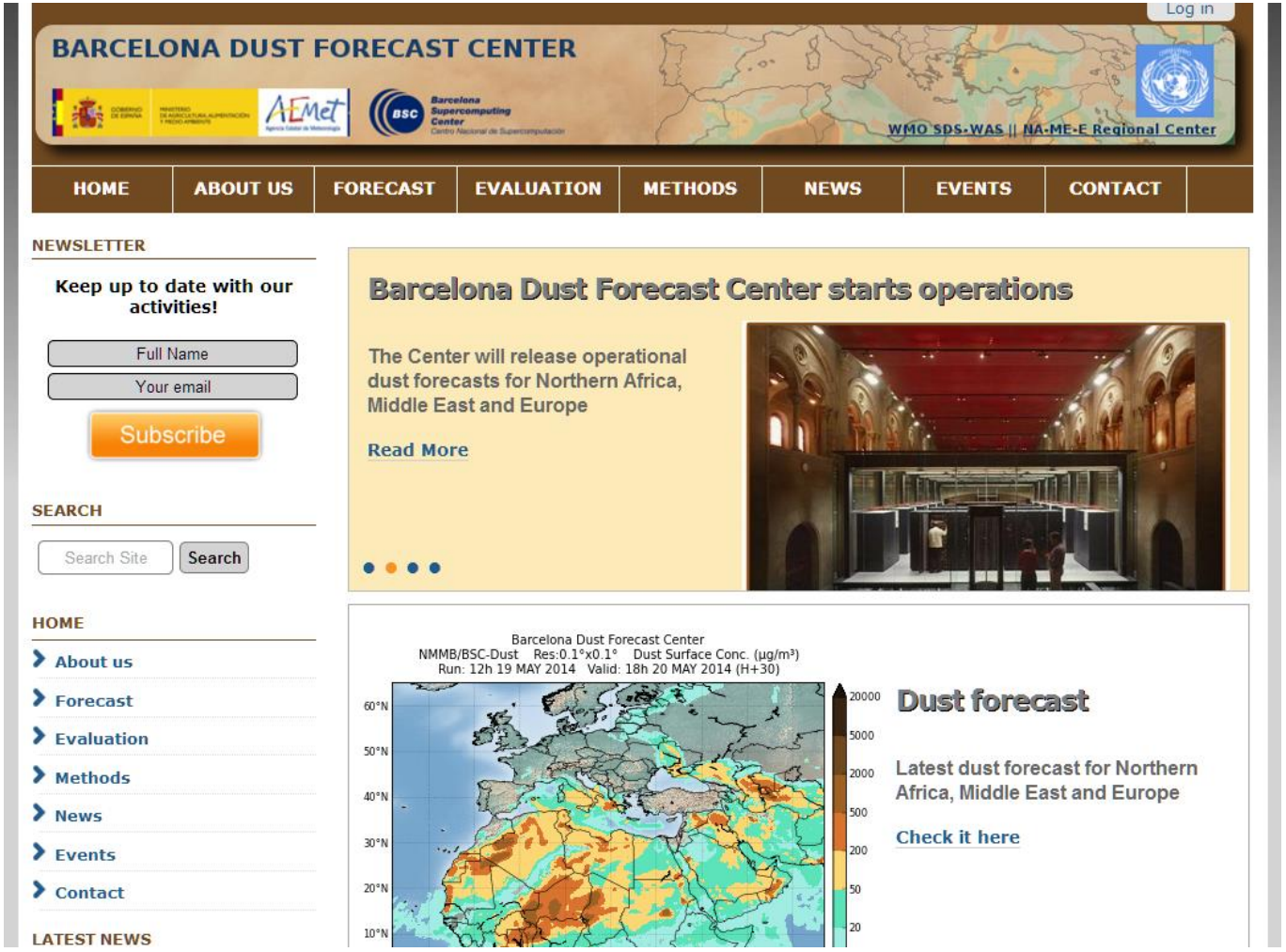
- **BSC dust operational forecast** (global and regional domains)
  - Contribution to the SDS-WAS (regional) and ICAP (global) multi-model ensembles



- **WMO Dust Regional Centers**
  - **Barcelona Dust Forecast Center.** First specialized WMO Center for mineral dust prediction. Started in 2014 - Operational
    - http://dust.aemet.es
    - *@Dust_Barcelona*
  - **SDS-WAS Regional Center**. Sand and Dust Storm Warning Advisory and Assessment System. Started in 2010 – Research
    - *http://sds-was.aemet.es*



Barcelona Dust Forecasting Center



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AEMet
Agencia Estatal de Meteorología

World Meteorological Organization

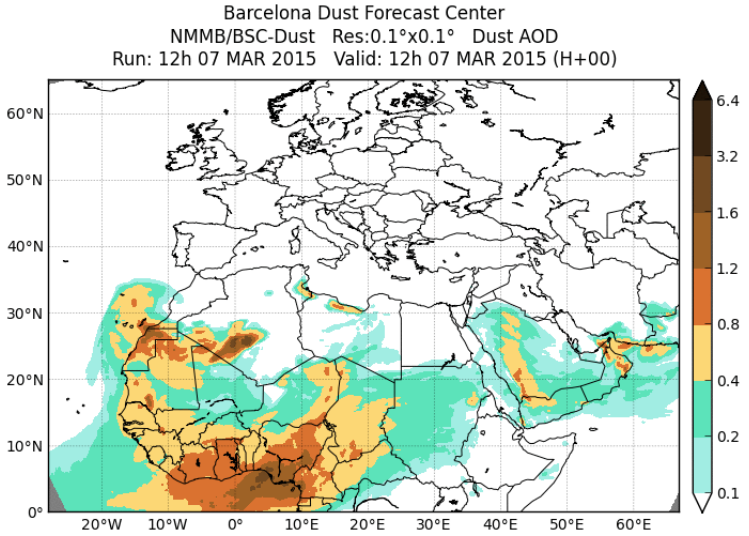
@Dust_Barcelona

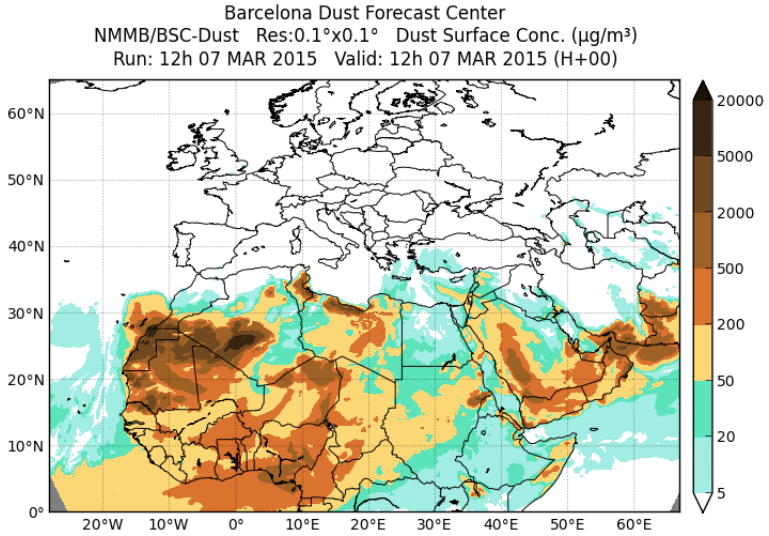
http://dust.aemet.es/

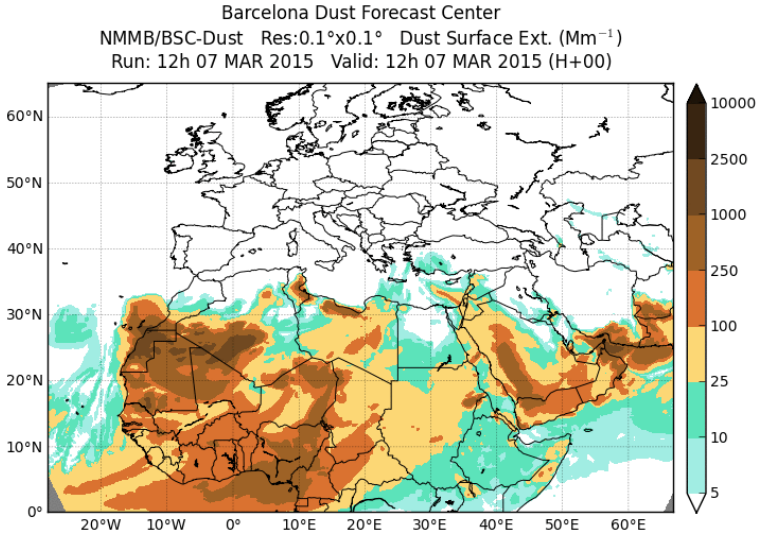
Barcelona Dust Forecasting Center

72-hours forecasts of:

- *Dust Optical Depth at 550nm*
- *Dust Dry and Wet Deposition*
- *Dust Load*
- *Dust Surface Concentration*
- *Dust Surface Extinction at 550nm*





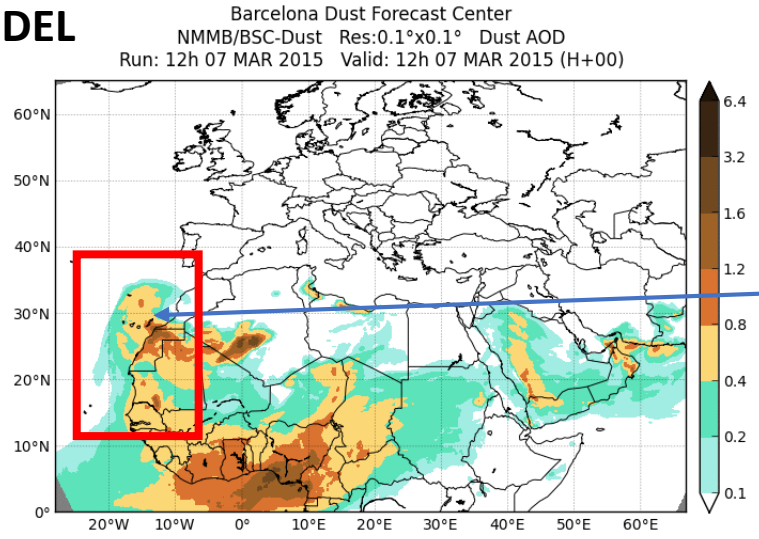


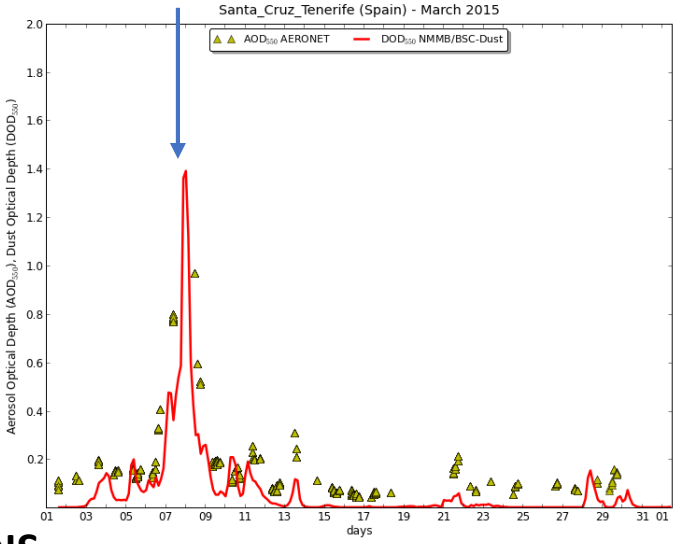
@Dust_Barcelona

http://dust.aemet.es/

Barcelona Dust Forecasting Center

MODEL

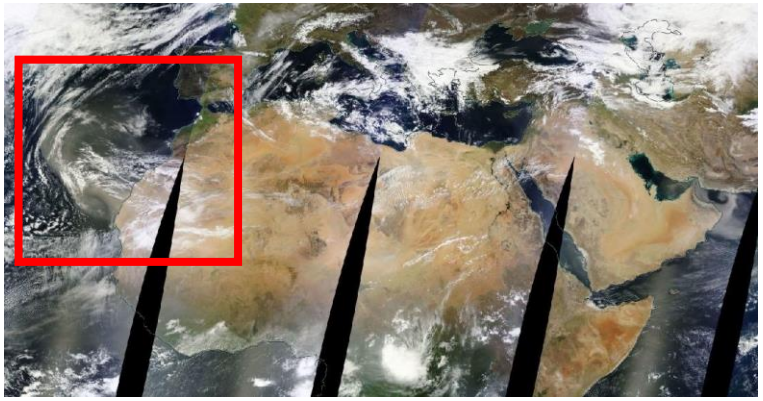




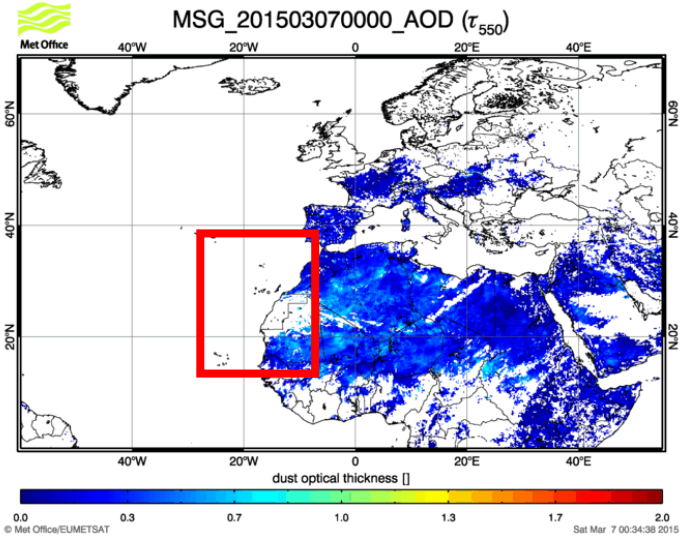
Model

AERONET Obs.

OBSERVACIONS

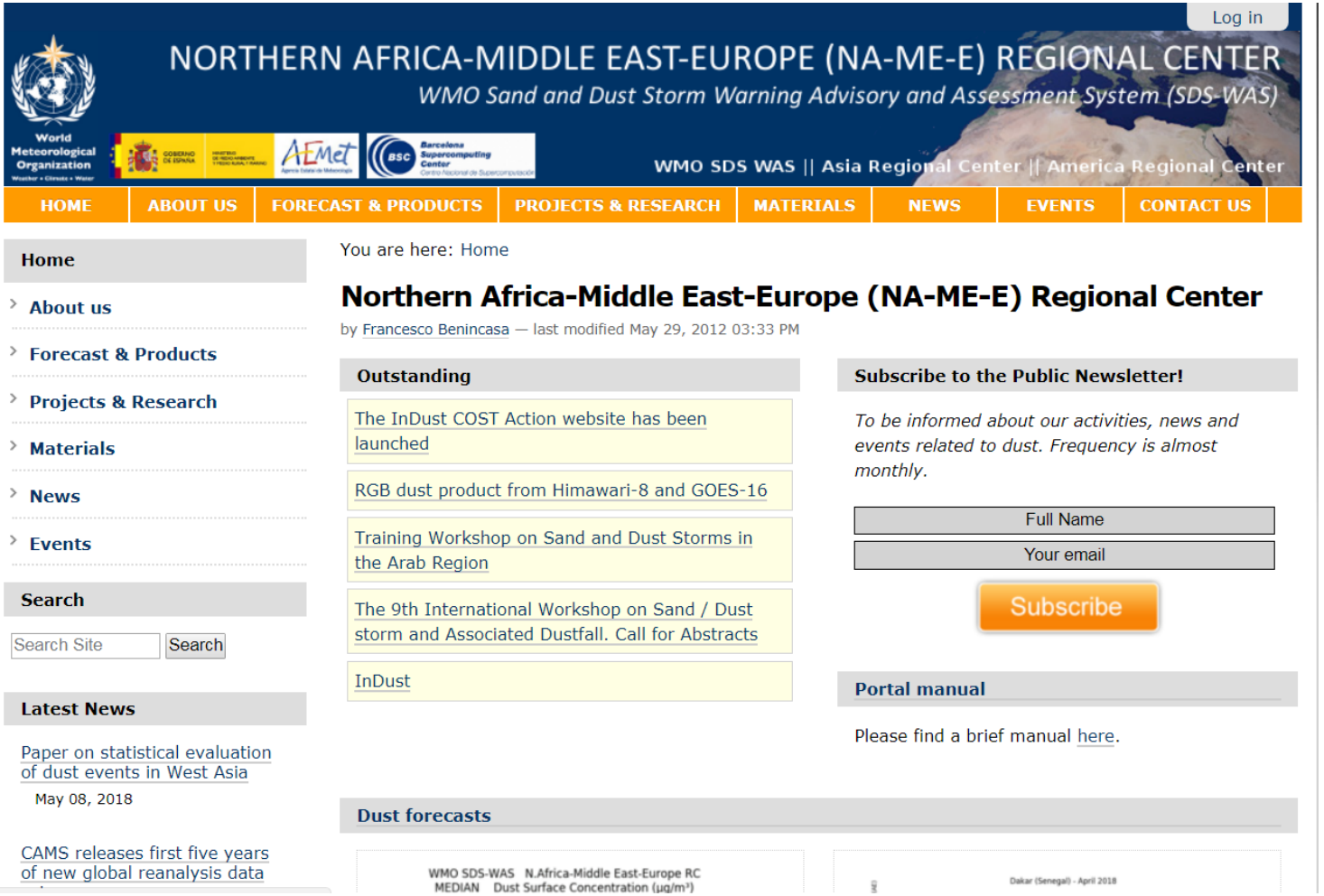


MODIS composite 8th March from EOSDIS World Viewer



SDS-WAS and the NAMEE Regional Center

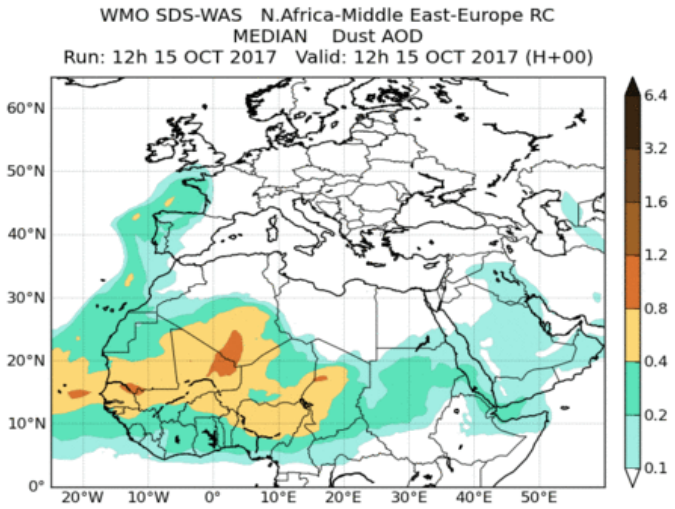
http://sds-was.aemet.es/



SDS-WAS NAMEE: Modelling

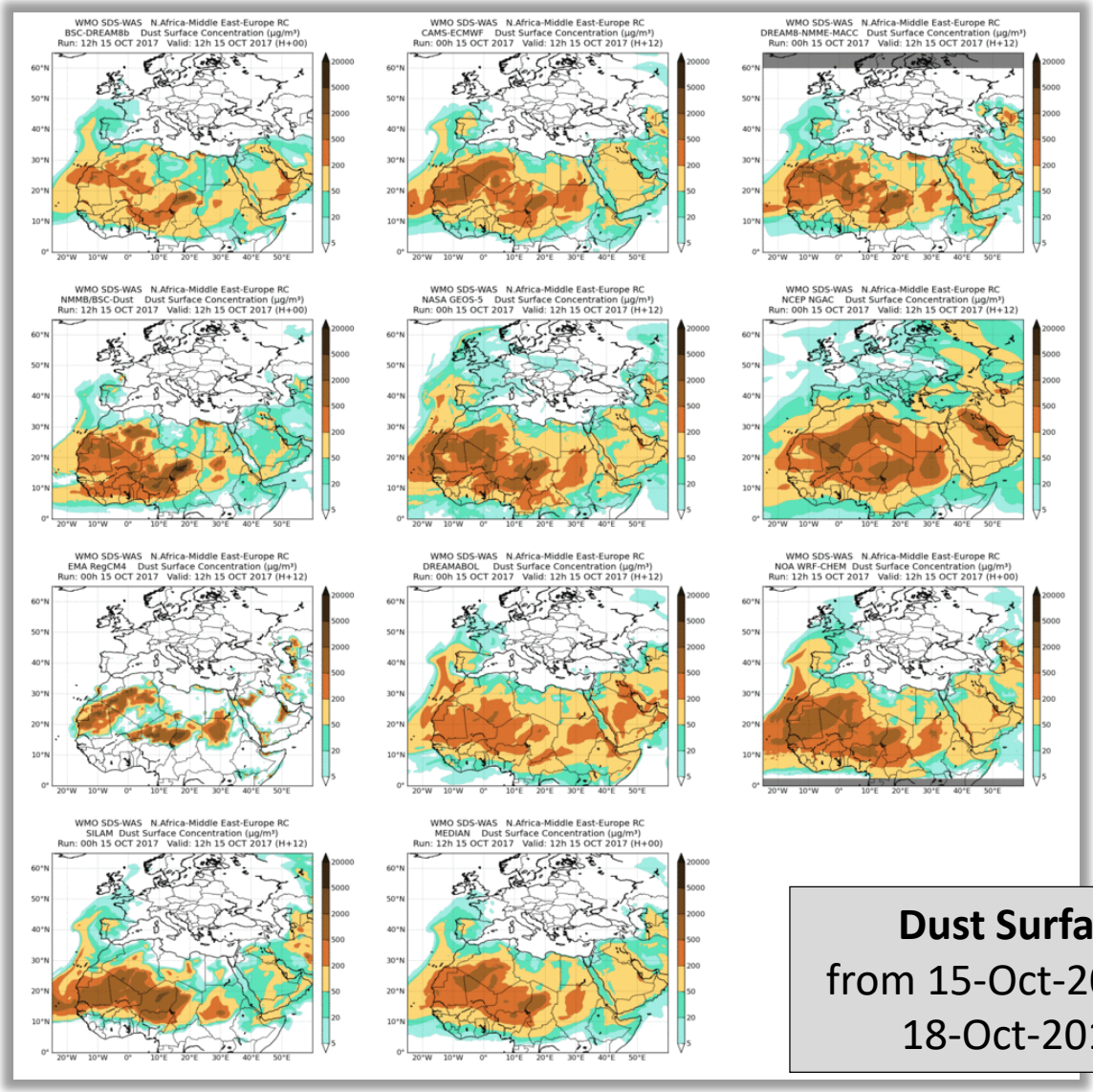
Products: surface concentration and DOD maps, the SDS-WAS multi-model product

Operational
SDS-WAS Ensemble



12 Global – Regional models from ~ 100 to 10 km

SDS-WAS NAMEE: Joint Visualization

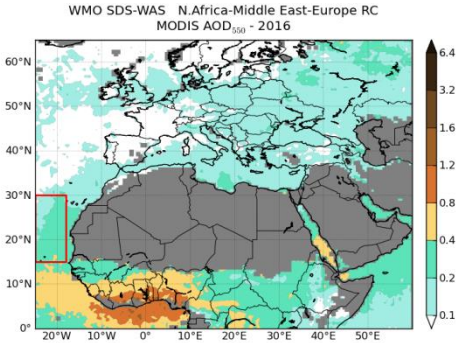


Dust Surface Conc.
from 15-Oct-2017 12:00 to
18-Oct-2017 00:00

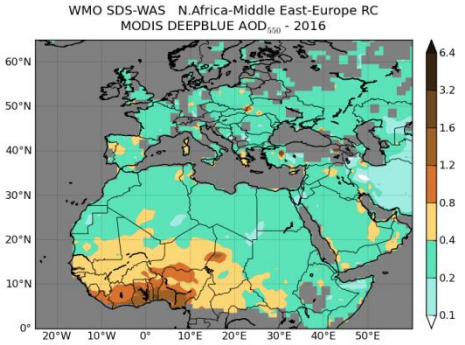
SDS-WAS NAMEE: DOD Model Evaluation

- **Evaluation with AERONET data**
  - Graphical NRT Evaluation by site
  - Evaluation scores monthly/seasonal/annual and sites

- **Evaluation with MODIS data onto the Atlantic**
  - Evaluation scores monthly/seasonal/annual



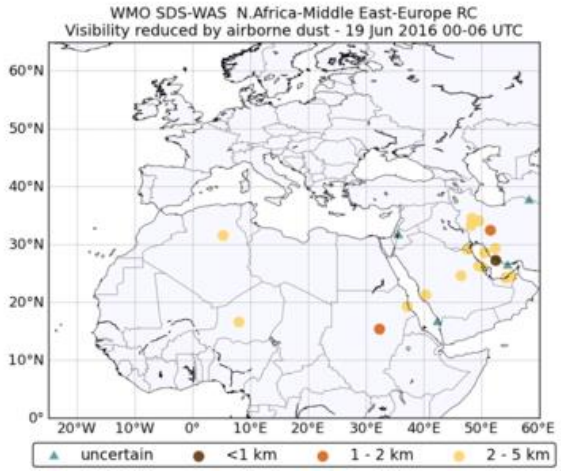
- **Evaluation of dust models with MODIS Deep Blue retrievals**
  - Evaluation scores monthly/seasonal/annual

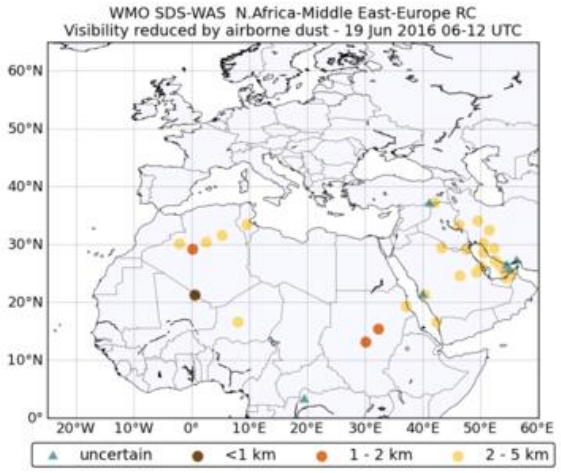


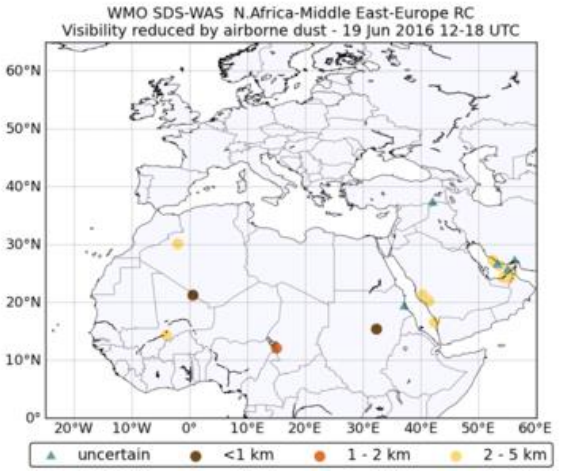
http://sds-was.aemet.es/forecast-products/forecast-evaluation

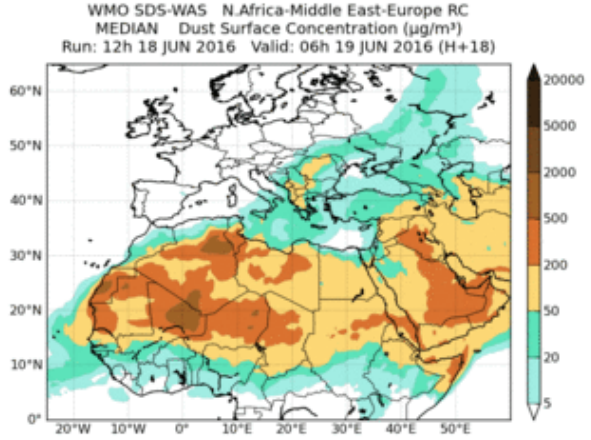
SDS-WAS NAMEE: Visibility vs Surf. Conc.

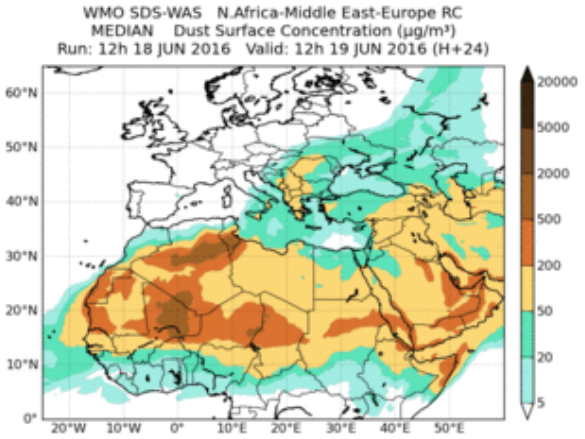
NRT visibility evaluation: 19th june 2016

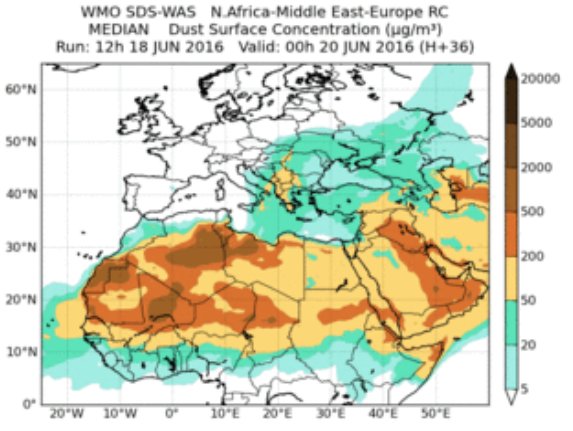






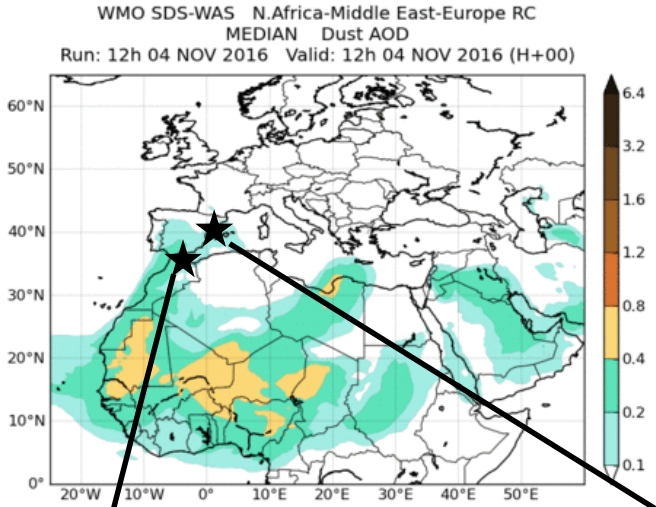




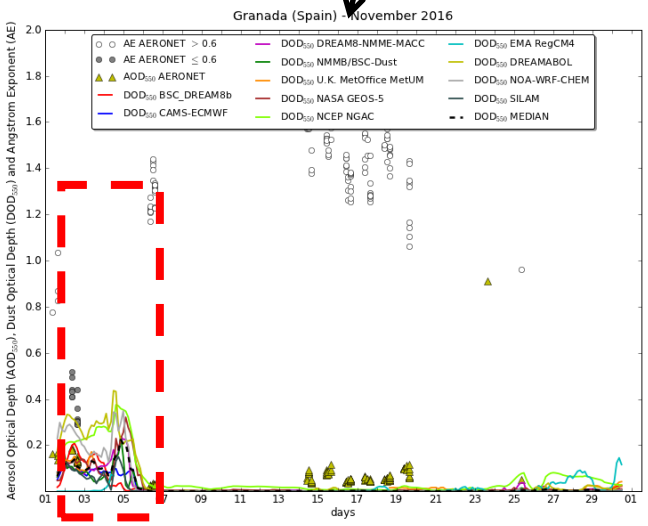


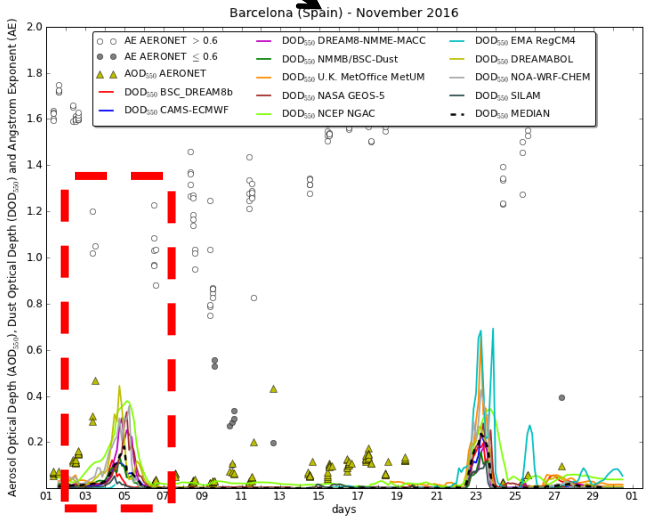
SDS-WAS NAMEE: Dust Profiles Evaluation

W. Mediterranean dust event: 2 - 5 November 2016



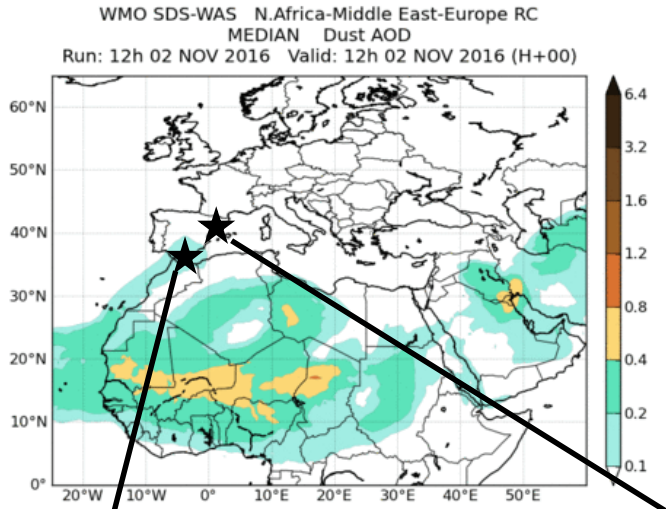
AERONET

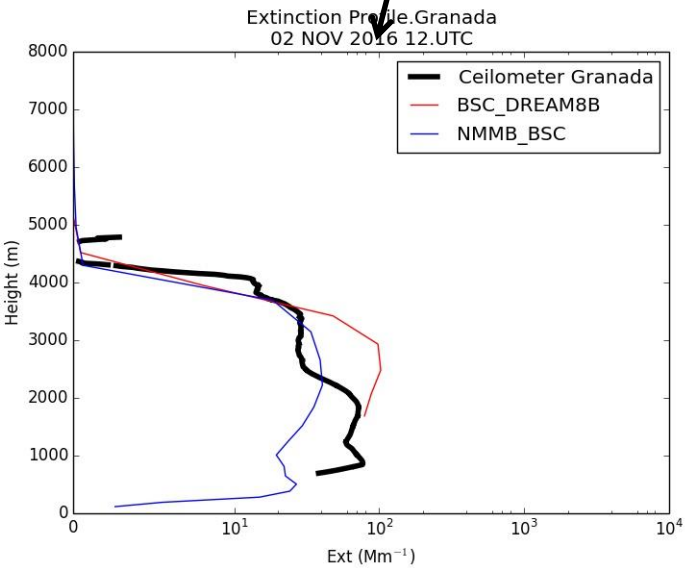


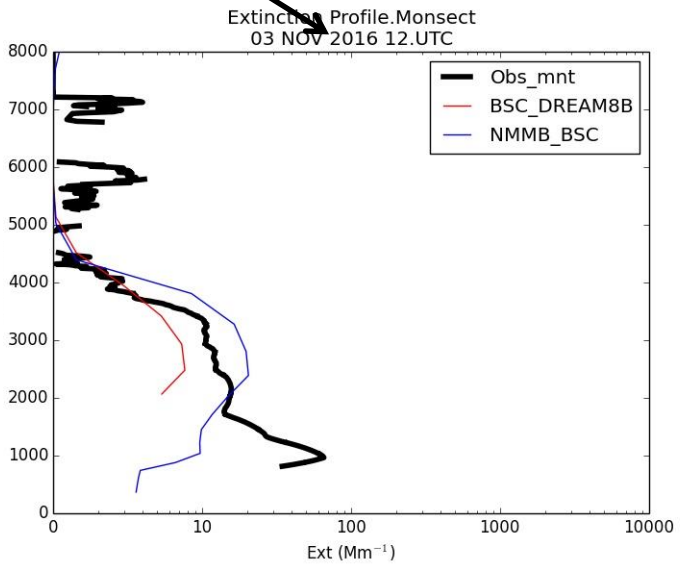


SDS-WAS NAMEE: Dust Profiles Evaluation

Atlantic dust event: 2 - 5 November 2016

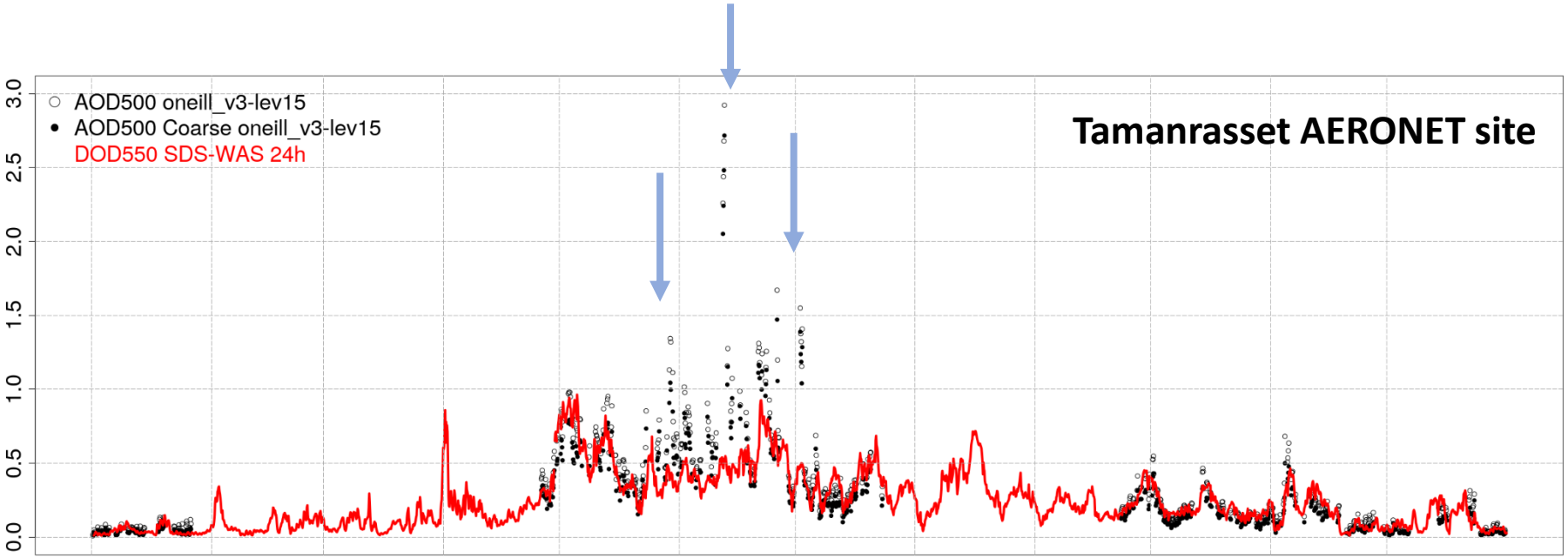






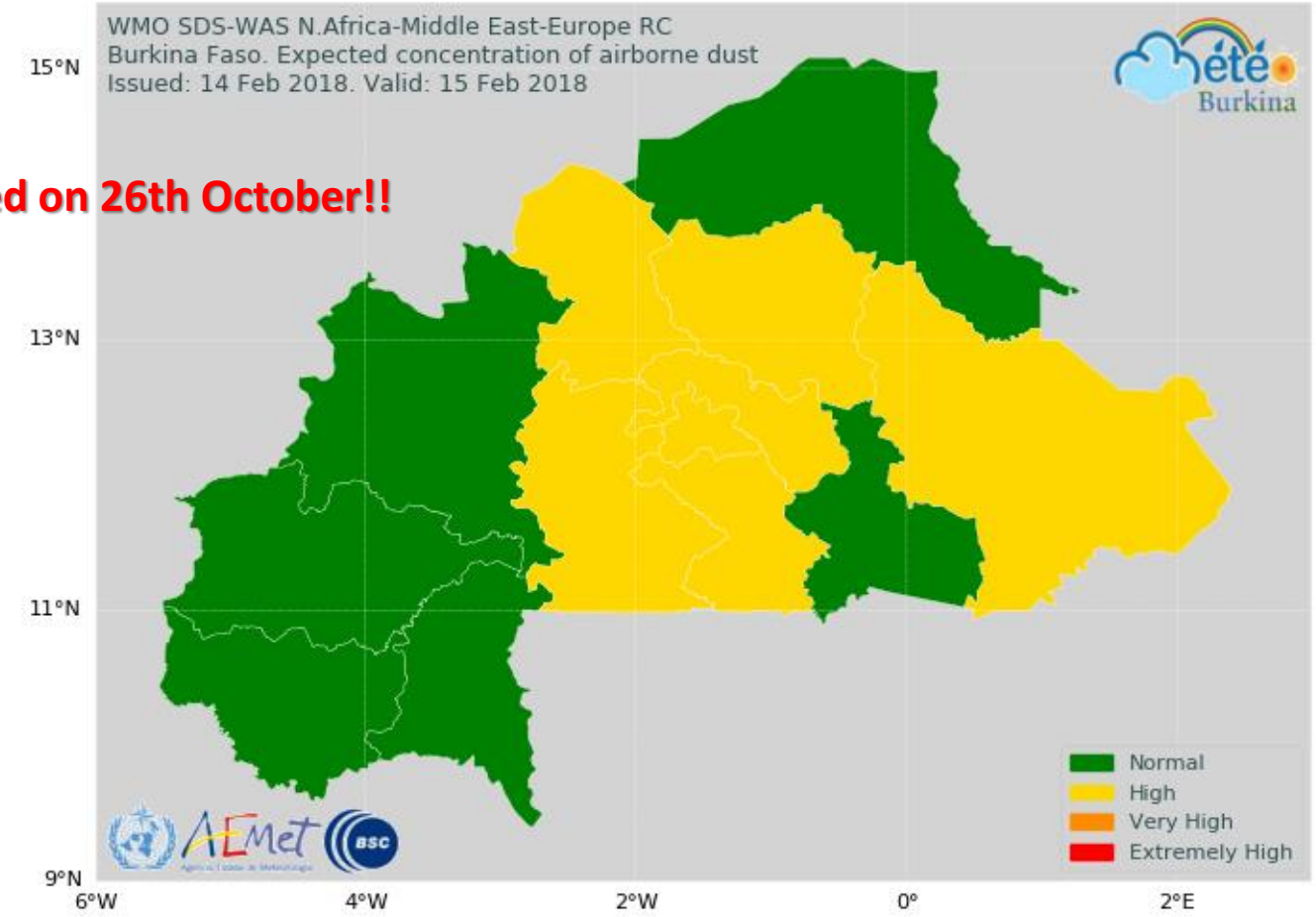
SDS-WAS NAMEE: DOD Model Evaluation

- **Evaluation results**
  - The current state-of-the art operational dust models are not able to reproduce smaller scale SDS → High-resolution simulations



SDS-WAS NAMEE:
Early Warning System for Burkina Faso

Launched on 26th October!!



https://sds-was.aemet.es/forecast-products/burkina-faso-warning-advisory-system

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AEMet Agencia Estatal de Meteorología
World Meteorological Organization

Studies on Air Quality

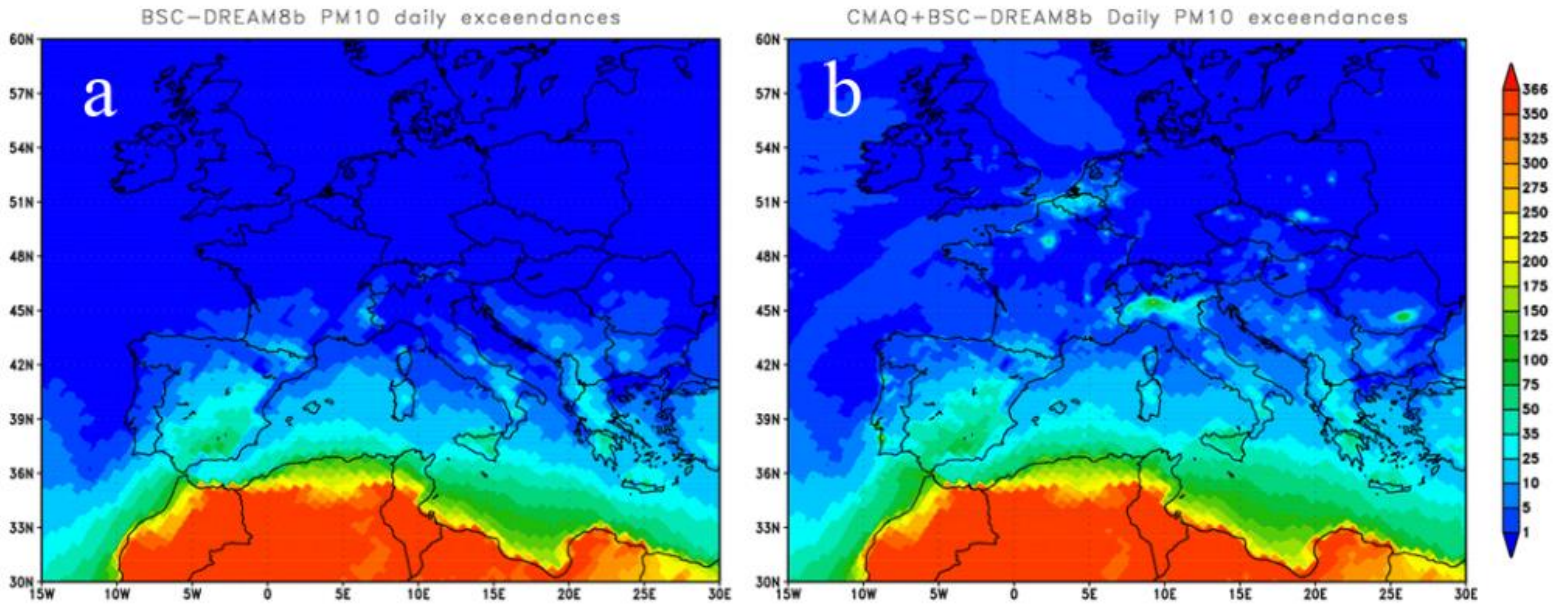
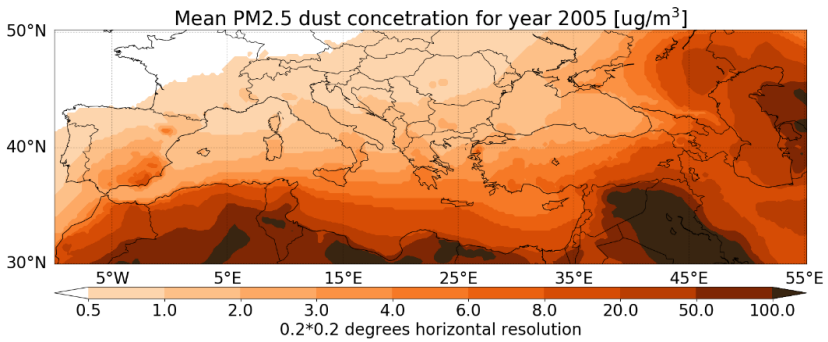


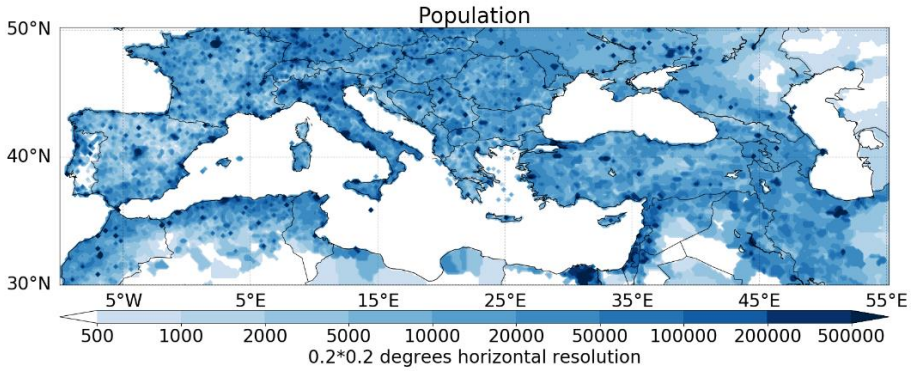
Fig. 11. Number of the days exceeding the EU PM_{10} daily limit value ($>50\,\mu g\,m^{-3}$) for **(a)** BSC-DREAM8b and **(b)** BSC-DREAM8b + CMAQ derived aerosol. Correction factors are applied to sulphate, nitrate, ammonium and EC + OC in CMAQ model outputs.

Extracted from Basart et al. (2012, ACP)

Pilot studies on health impact

NMME-DREAM model simulations





CRF functions

- $\Delta Mort = y0 * (1 - e^{-\beta \Delta X}) * Population$

where ΔMort is the change in annual mortality due to a pollutant, y0 the baseline mortality rate (BMR) for a given population, β the concentration–response function (CRF), ΔX the change in concentration of a given pollutant X relative to clean conditions

- Concentration response function describes increased risk of a population to certain diseases when exposed to a particular pollutant
- The CRFs used in this study (Krewski et al. (2009), Lelieveld et al. (2013)) based on American Cancer Society (ACS) Cancer Prevention Study II (CPS-II). CRFs used may not be representative for all regions

Courtesy of Luka Ilić and Slobodan Ničković

Pilot studies on health impact

Cardio Pulmonary Diseases Mortality with dust

Country (Europe)	CPD mortality (in thousands) in year 2005
Turkey	36
Russian Federation	14
Azerbaijan	12
Italy	7
Ukraine	6
Spain	6
Romania	3
Armenia	2
Germany	2
Bulgaria	2
Greece	2

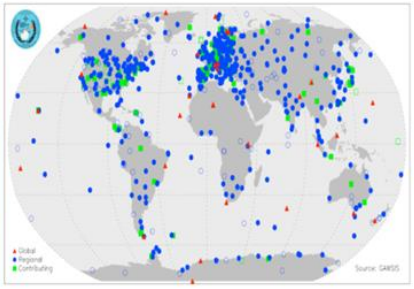
Courtesy of Luka Ilić and Slobodan Ničković

DustClim

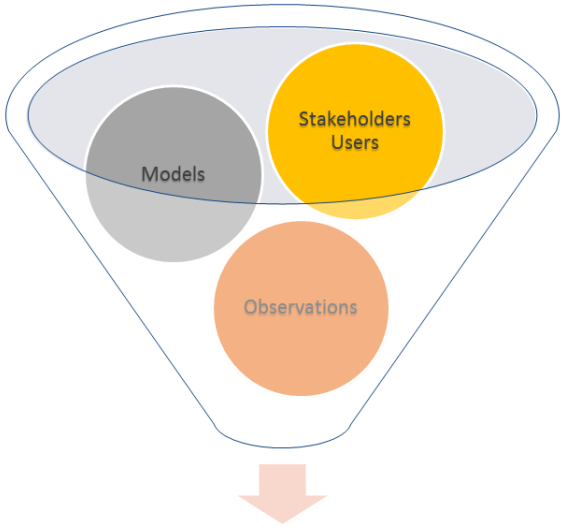
ERA4CS European Research Area for Climate Services

Dust Storms Assessment for the development of user-oriented **Clim**ate Services in Northern Africa, Middle East and Europe

- SDS is a serious hazard for life, health, environment and economy
- Lack of dust observations (past trends and current conditions)



GOAL: Develop **dust-related services** to specific socio-economic sectors based on an advanced **dust reanalysis** for the NAMEE region

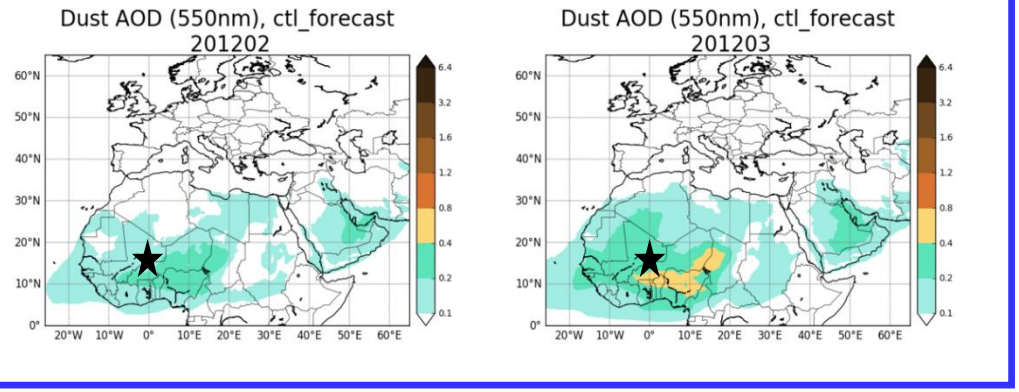


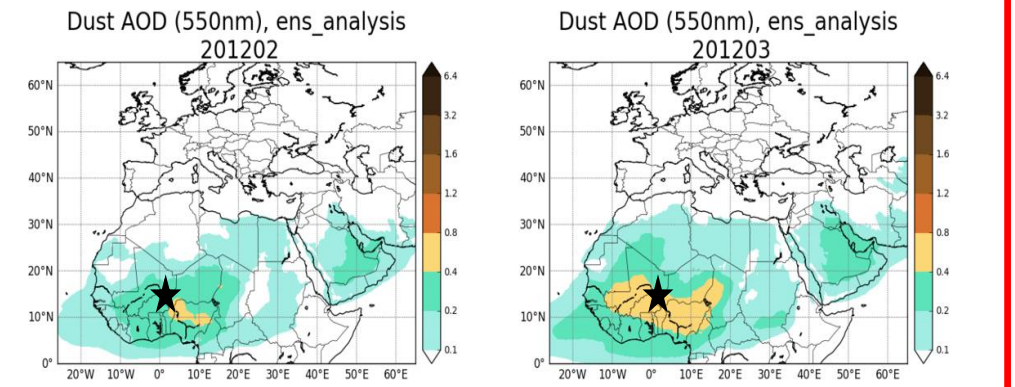
Dust-related Climate Services

BSC AEMet Agencia Estatal de Meteorología cnrs

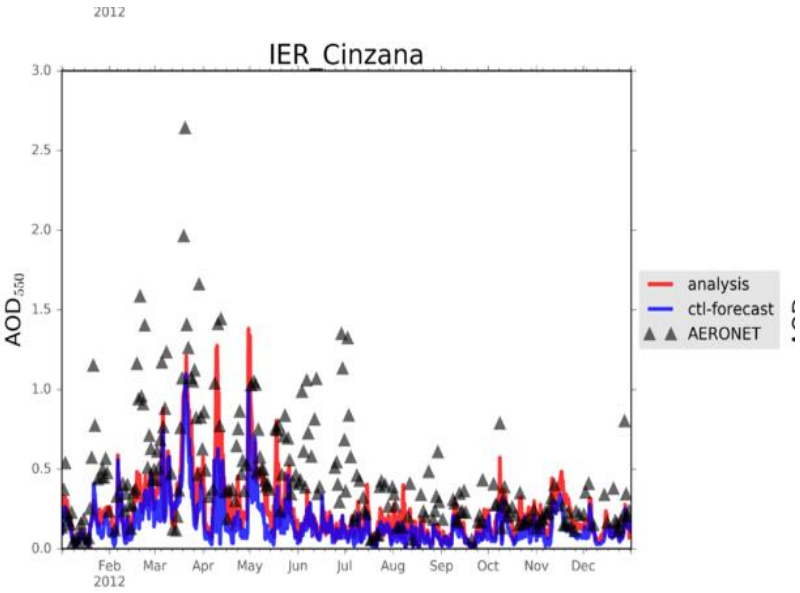
DustClim

ERA4CS European Research Area for Climate Services



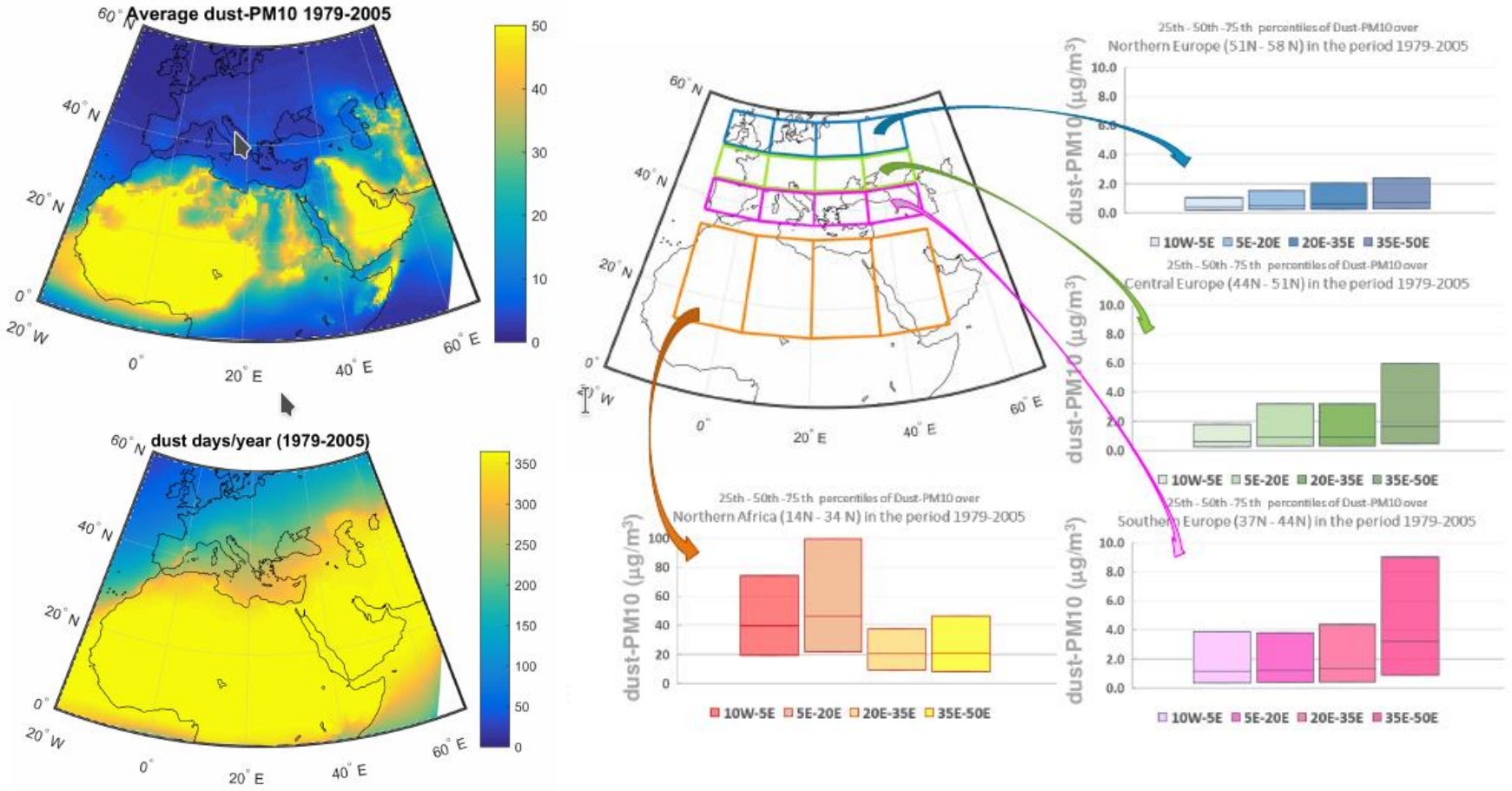


Assimilating MODIS DOD Land product (Courtesy P. Ginoux, NOAA)



(Courtesy E. Di Tomaso, BSC)

AIR QUALITY: Design of AQ Early warning systems – First tests based on NMMB-MONARCH simulations



Number of days that exceed the EU limit of PM10 (i.e 50 µg/m3)

(Courtesy F. Barnaba, CNR-ISAC)

Summary

Dust Models

- ✓ To complement dust-related observations, filling the temporal and spatial gaps of the measurements.
- ✓ To help us to understand the dust processes and their interaction with climate, weather ecosystems and help.
- ✓ To predict the impact of dust on surface level concentrations used as **SHORT-TERM FORECASTING TOOLS** (3-5 days ahead)

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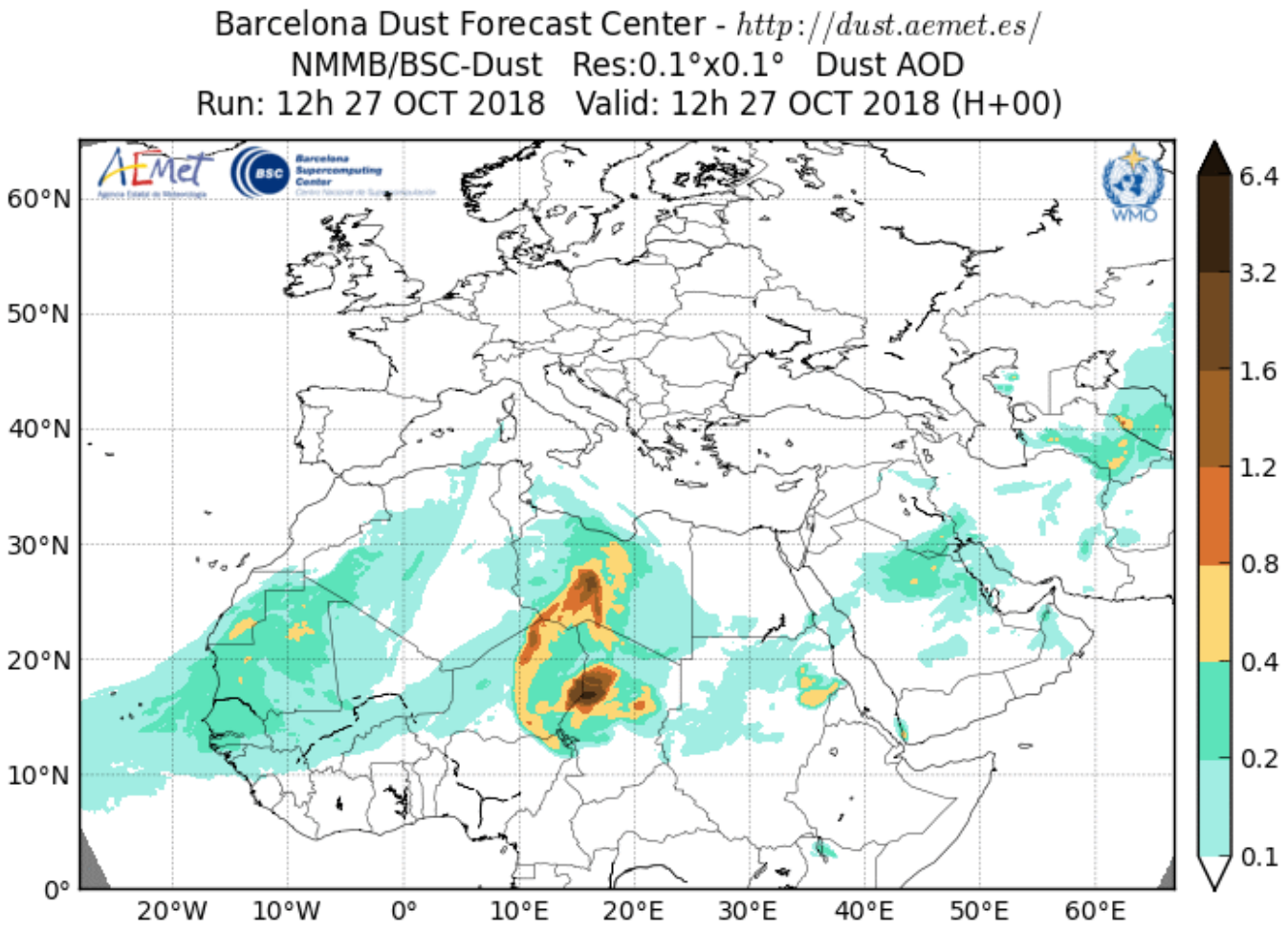

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