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Modeling the dust cycle at BSC

From R&D to operational forecast

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What

Environmental modelling and forecasting

Why

Our strength ...

- ... research ...
- ... operations ...
- ... services ...
- ... high resolution ...



***MareNostrum
supercomputer***

How

Develop a capability to model air quality processes from urban to global and the impacts on weather, health and ecosystems

Implement climate prediction system for subseasonal-to-decadal climate prediction

Develop user-oriented services that favour both technology transfer and adaptation

Use cutting-edge HPC and Big Data technologies for the efficiency and user-friendliness of Earth system models

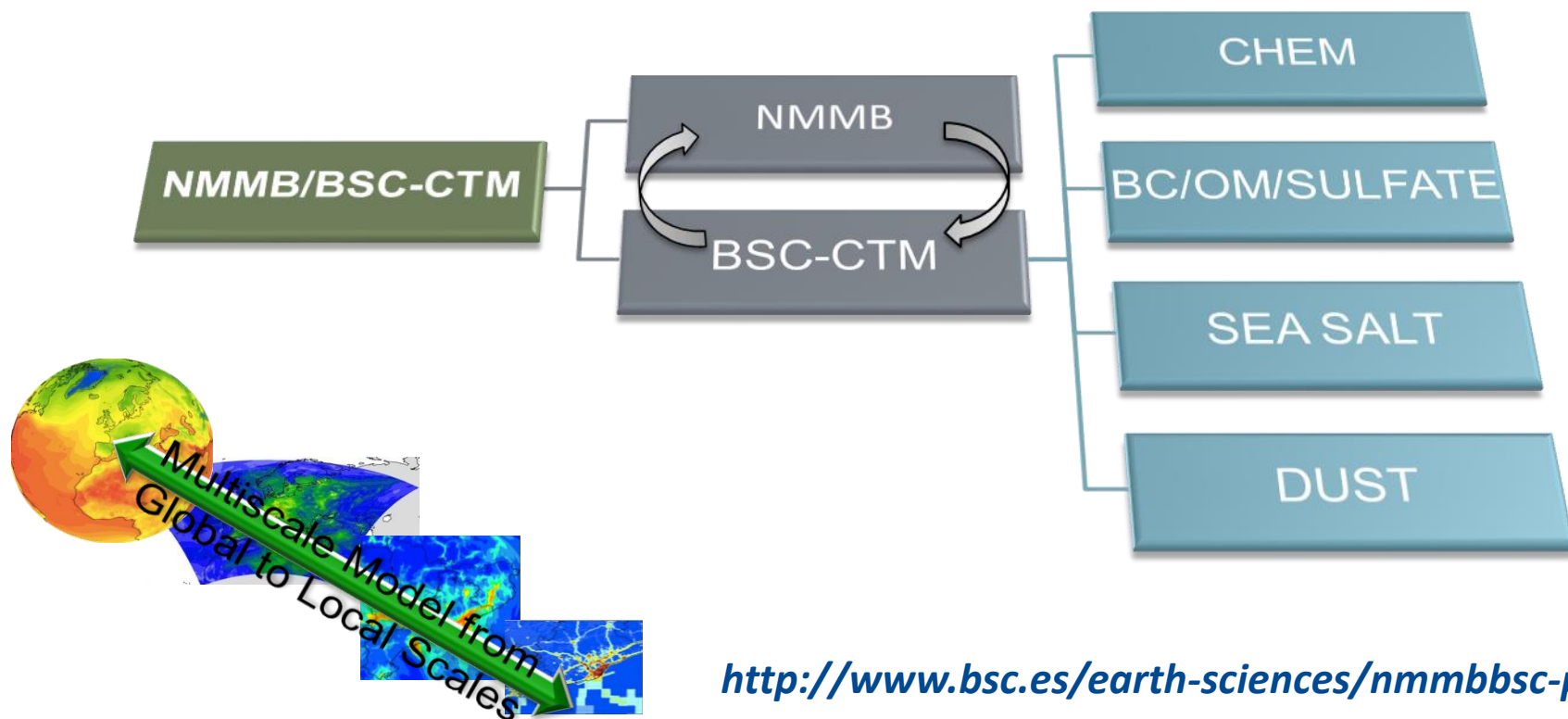
Earth system
services

Climate
prediction

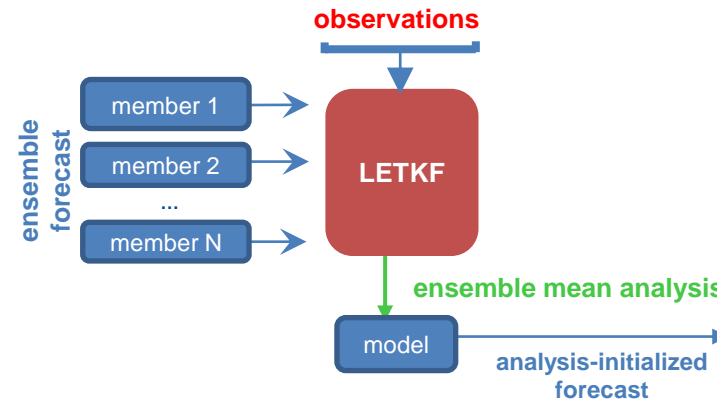
Atmospheric
composition

Computational
Earth sciences

- 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



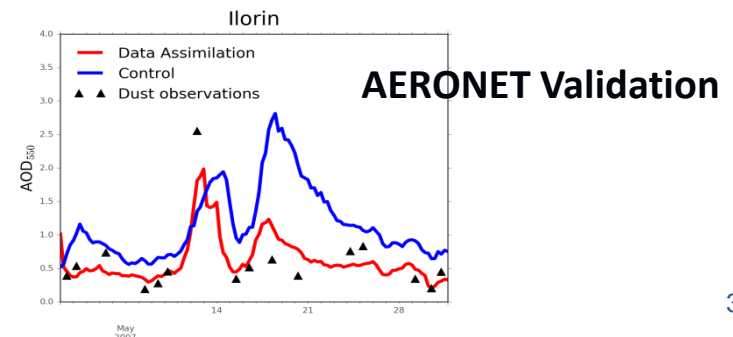
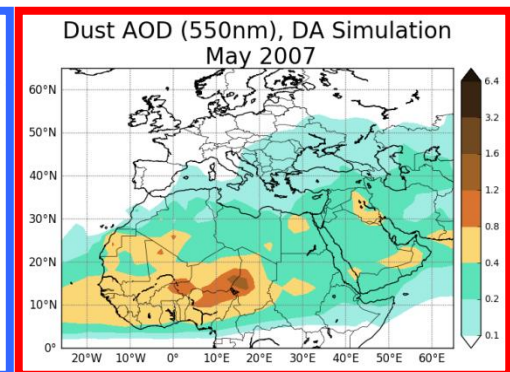
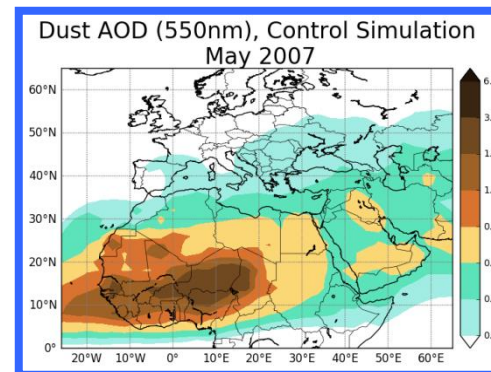
NMMB/BSC-CTM coupled with a Local Ensemble Transform Kalman Filter (**LETKF**) for the assimilation of aerosol optical depth observations



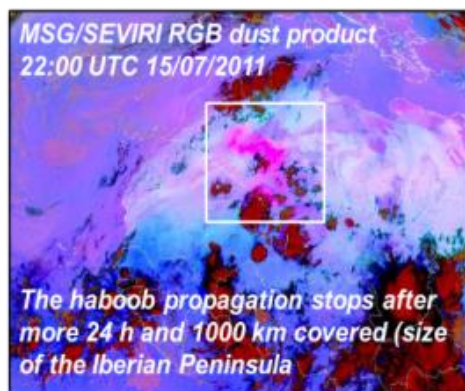
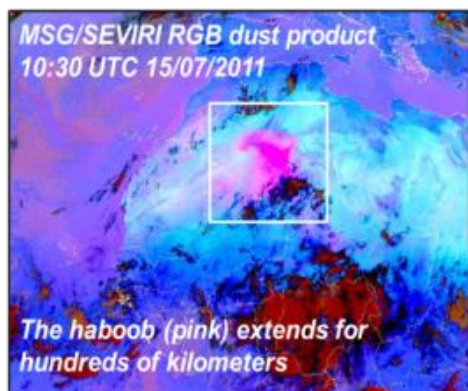
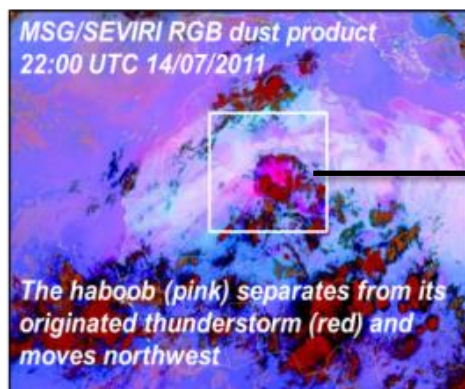
Mineral dust application

The ensemble forecast is based on uncertainties in the dust emission scheme

- vertical flux,
- size distribution at emission
- threshold on friction velocity



Mineral dust: haboobs (with explicit convection)



MODEL CONFIGURATION

Study domain: 6°W-10°E to 15°N-31°N

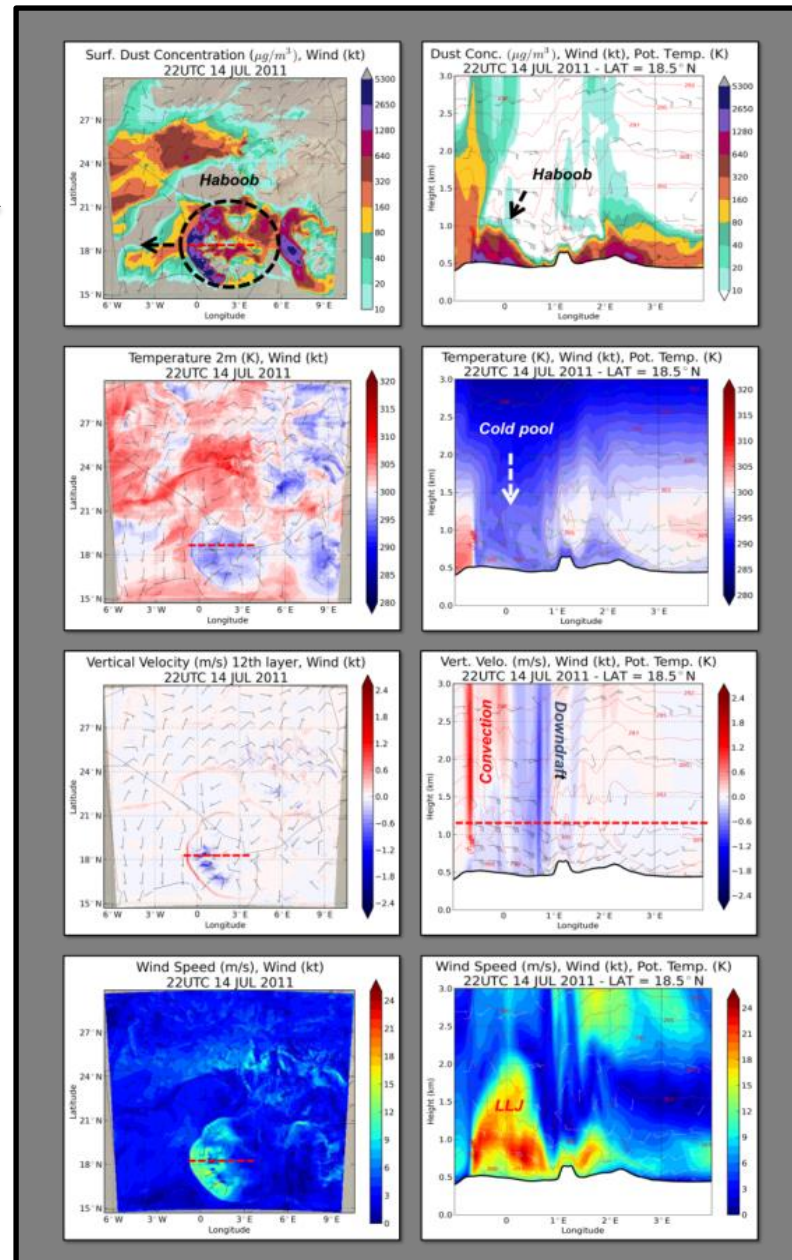
Study period: from 14 to 15 July 2011

Horizontal resolution: 0.03°x0.03° (about 3 km)

Vertical resolution: 60σ-layers (12-15σ-layers in the first 1000 m)

Cold start (No data assimilation)

(Vendrell et al., Aeolian Res., in preparation)



Daily dust operational forecast (global and regional domains)

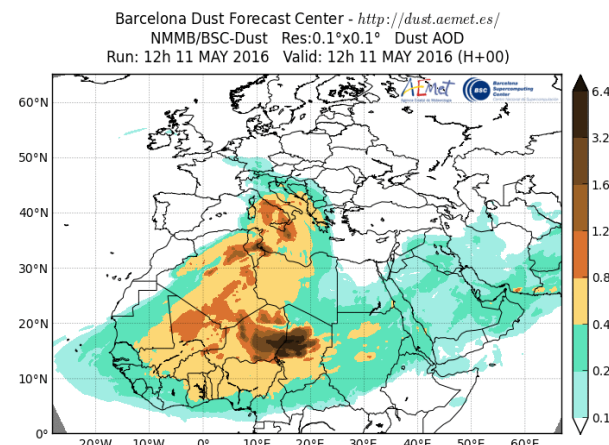
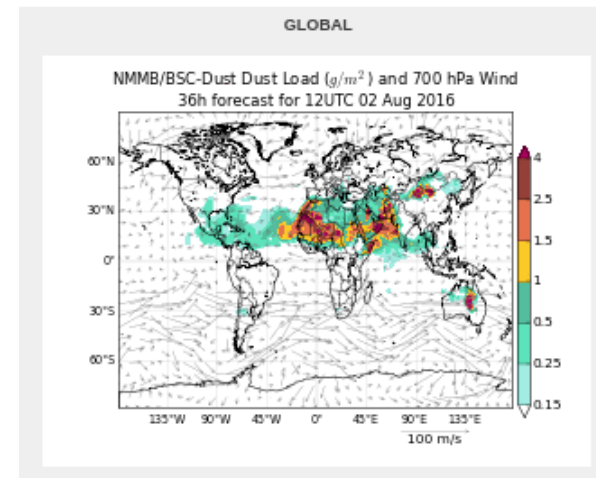
<http://www.bsc.es/earth-sciences/mineral-dust/nmmbbsc-dust-forecast>

✓ Contribution to the **ICAP** multi-model ensemble
(global) <http://icap.atmos.und.edu>

WMO Dust Centers

**SDS-WAS. North Africa, Middle East and Europe
Regional Center.** <http://sds-was.aemet.es>
started in 2010 – **Research**

Barcelona Dust Forecast Center.
First specialized WMO Center for mineral dust prediction.
<http://dust.aemet.es> started in 2014 – **Operational**



SDS-WAS NAMEE: Dust Forecasts



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FORECAST AND PRODUCTS

- Data exchange
- Joint visualization
- Common forecast evaluation
- Generation of multi-model products
- Calculation of monthly evaluation metrics
- New sources of data for model evaluation
- Sharing model output data files
- Time-averaged products

SDS-WAS NAMEE: Dust Forecasts



Dust prediction models provide 72 hours (at 3-hourly basis) of dust forecast (AOD at 550nm and surface concentration) covering the NAMEE region.



LMD



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LSCE



MODEL	RUN TIME	DOMAIN	DATA ASSIMILATION
BSC-DREAM8b v2.0	12	Regional	No
CHIMERE	00	Regional	No
LMDzT-INCA	00	Global	No
CAMS-ECMWF	00	Global	MODIS AOD
DREAM8-NMME	00	Regional	CAMS analysis
NMMB/BSC-Dust	12	Regional	No
MetUM	00	Global	MODIS AOD
GEOS-5	00	Global	MODIS reflectances
NGAC	00	Global	No
EMA REG CM4	12	Regional	No
DREAMABOL	12	Regional	No
NOA WRF-CHEM	12	Regional	No
FMI-SILAM	12	Global	No

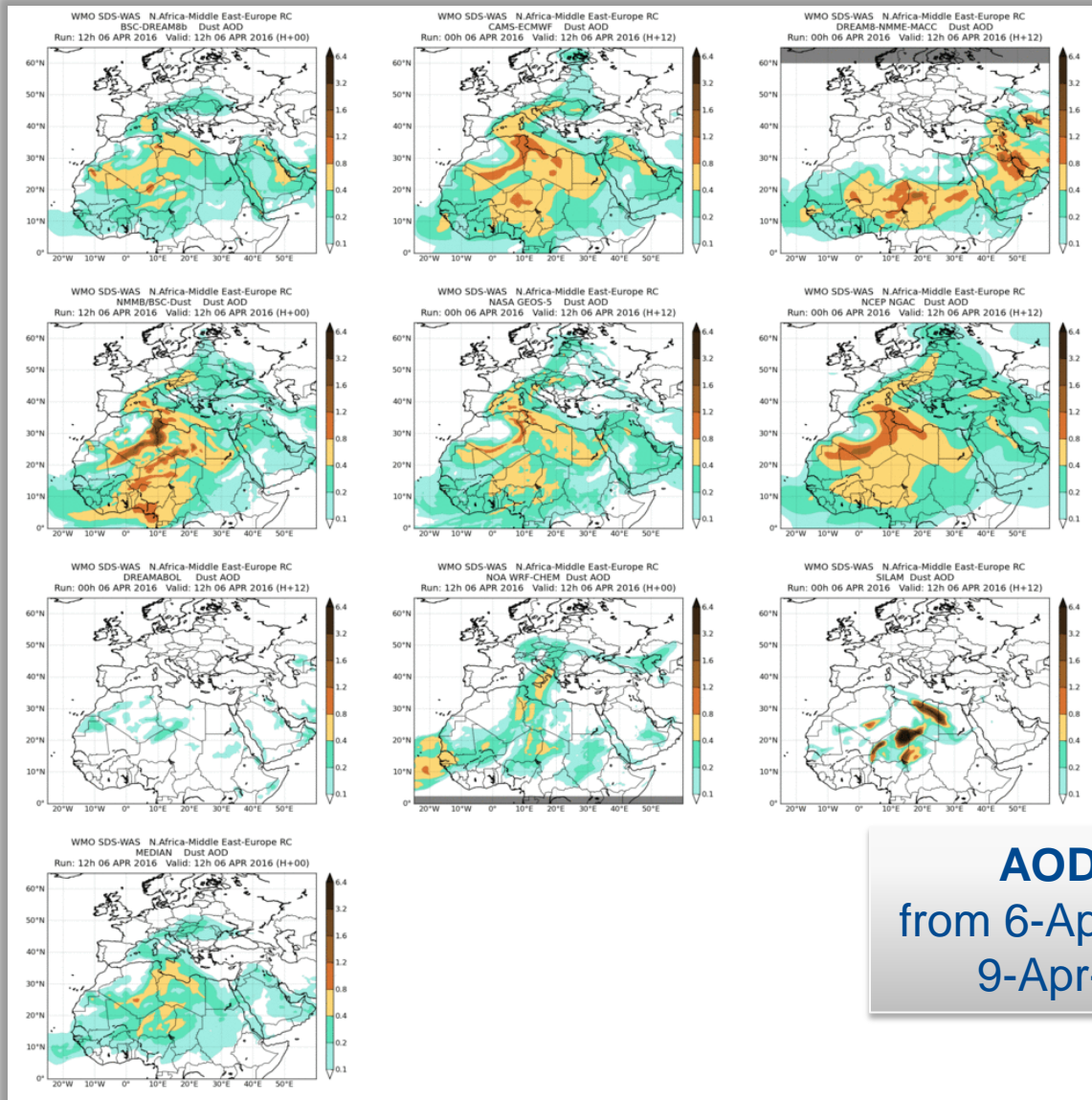
SDS-WAS NAMEE: Joint visualization



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AOD at 550nm
from 6-Apr-2016 12:00 to
9-Apr-2016 00:00

SDS-WAS NAMEE: Multi-model



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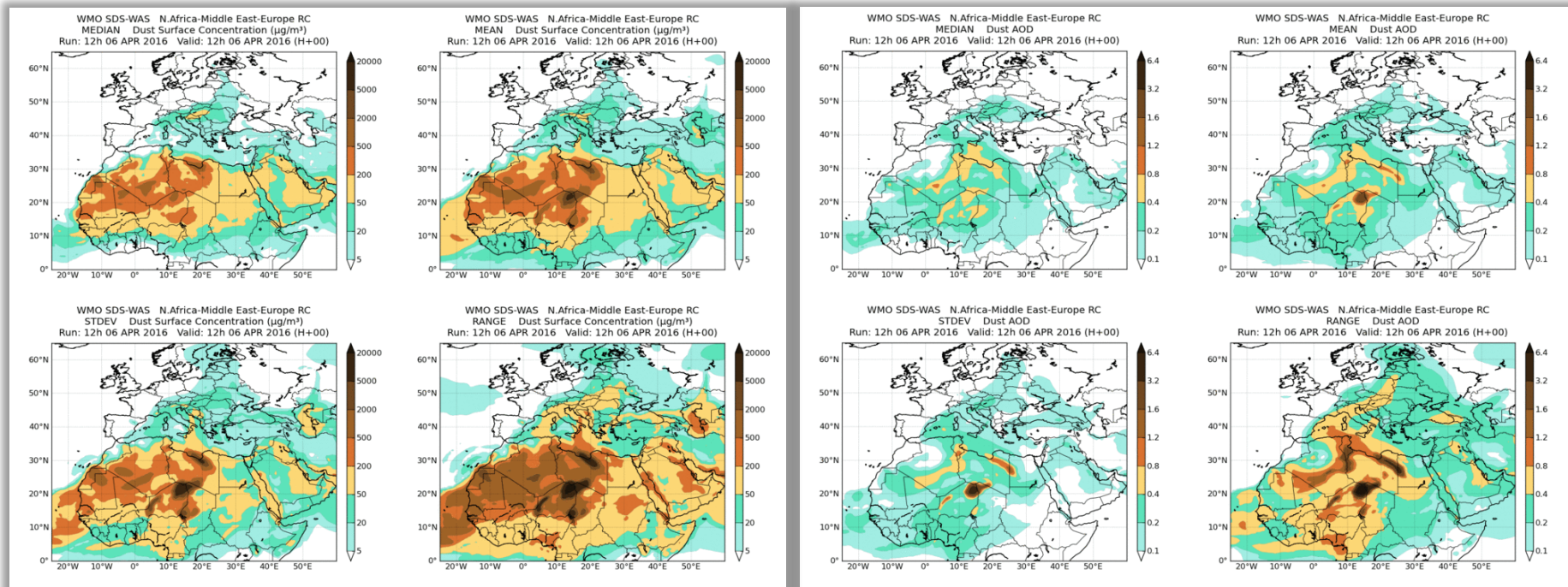


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Surface concentration

DOD at 550nm



from 6-Apr-2016 12:00 to 9-Apr-2016 00:00

Model outputs are bi-linearly interpolated to a common $0.5^\circ \times 0.5^\circ$ grid mesh. Then, different multi-model products are generated:

CENTRALITY: median - mean

SPREAD: standard deviation – range of variation

Terradellas et al. “SDS-WAS multi-model ensemble” presentation at 16:45

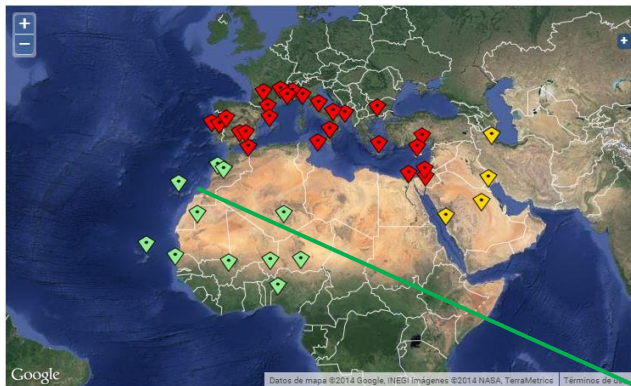
SDS-WAS NAMEE: NRT AERONET



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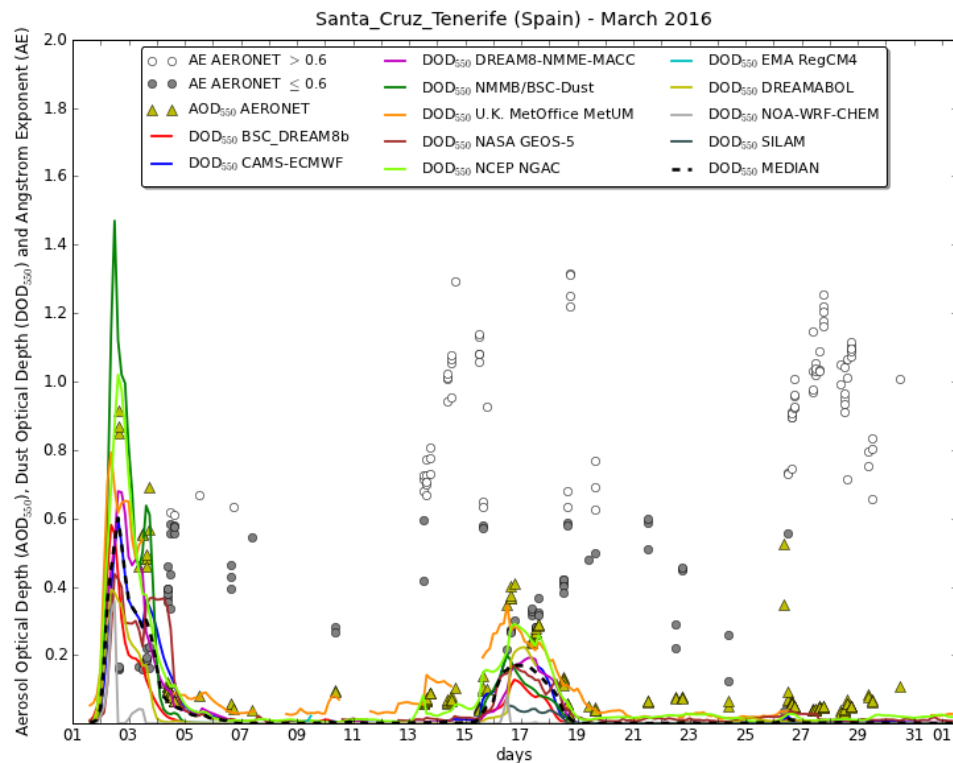
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A set of evaluation metrics are selected: **Bias**, **RMSE**, **correlation coefficient** and **FGE**

Calculations evaluation metrics are done for:

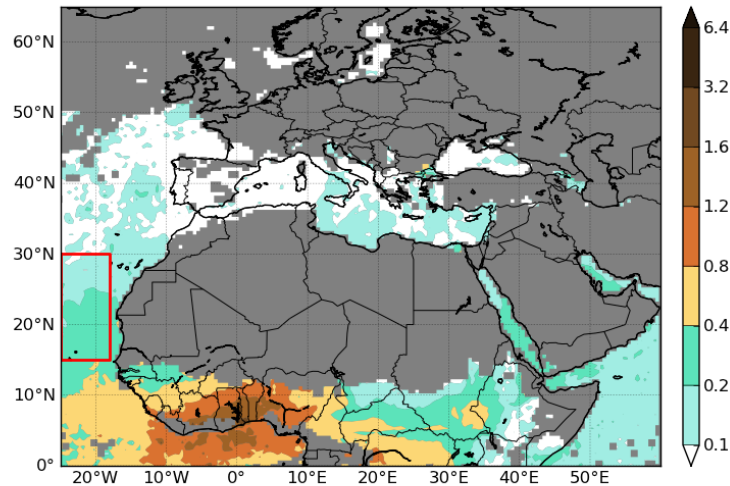
- **monthly/seasonal/annual**
- **sites and regions**



SDS-WAS NAMEE: MODIS

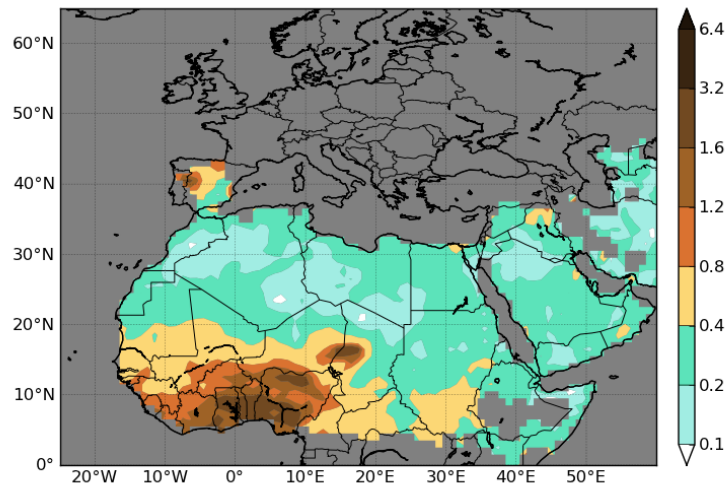


WMO SDS-WAS N.Africa-Middle East-Europe RC
MODIS AOD₅₅₀ - DEC 2015 - FEB 2016



	BIAS	ROOT MEAN SQUARE ERROR	CORRELATION COEFFICIENT	FRACTIONAL GROSS ERROR	NUMBER OF CASES
BSC_DREAM8b	-0.24	0.43	0.63	1.07	207012
NMMB/BSC-Dust	-0.10	0.29	0.78	0.98	201353
NCEP NGAC	-0.12	0.32	0.68	0.71	207012
EMA RegCM4	0.11	0.54	0.29	0.94	39231
DREAMABOL	-0.21	0.44	0.36	0.96	198954
NOA-WRF-CHEM	-0.19	0.41	0.46	1.04	198463

WMO SDS-WAS N.Africa-Middle East-Europe RC
MODIS DEEPBLUE AOD₅₅₀ - DEC 2015 - FEB 2016



	BIAS	ROOT MEAN SQUARE ERROR	CORRELATION COEFFICIENT	FRACTIONAL GROSS ERROR	NUMBER OF CASES
BSC_DREAM8b	-0.23	0.44	0.45	0.89	51308
NMMB/BSC-Dust	-0.11	0.34	0.78	1.03	47494
NCEP NGAC	-0.14	0.34	0.69	0.66	48659
EMA RegCM4	0.17	0.59	0.35	0.82	12050
DREAMABOL	-0.25	0.46	0.41	0.91	48036
NOA-WRF-CHEM	-0.22	0.43	0.48	1.03	51220

SDS-WAS NAMEE: Model evaluation



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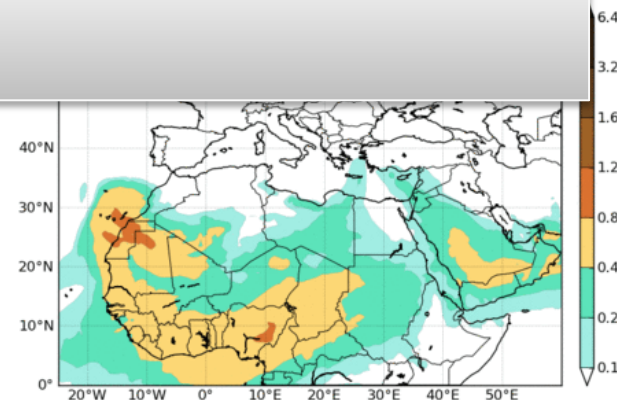


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7 March 2015

New observational datasets for model evaluation in Northern Africa



MET10 RGB-Dust 2015-03-07 23:00 UTC

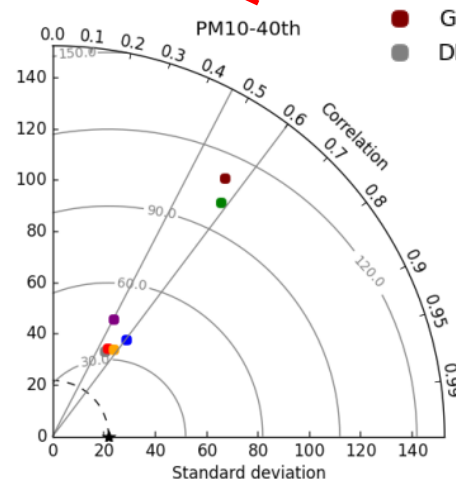
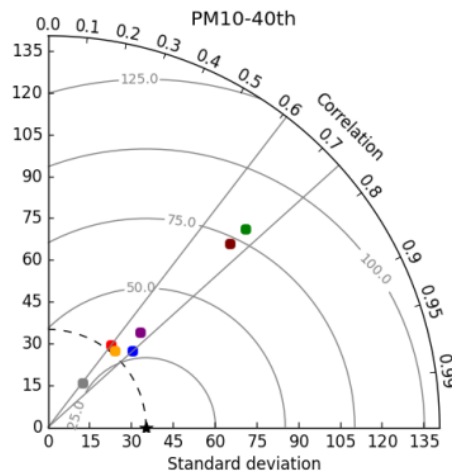
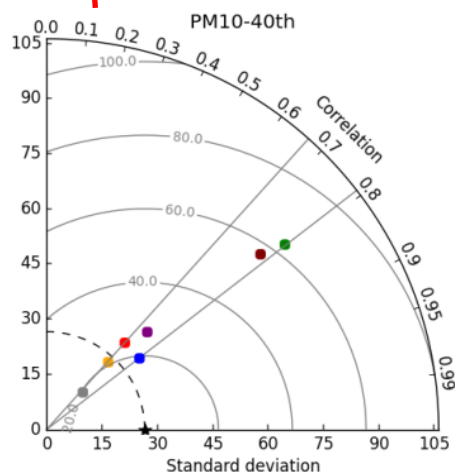


<http://sds-was.aemet.es/>

AQ networks: Canary Islands 2013-2014



Not all PM10 is dust: Local sources
Dust filter: Moving 40th percentile of 30 days, 15 days before and 15 days after (Escudero et al. 2007).

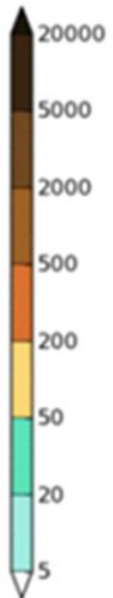
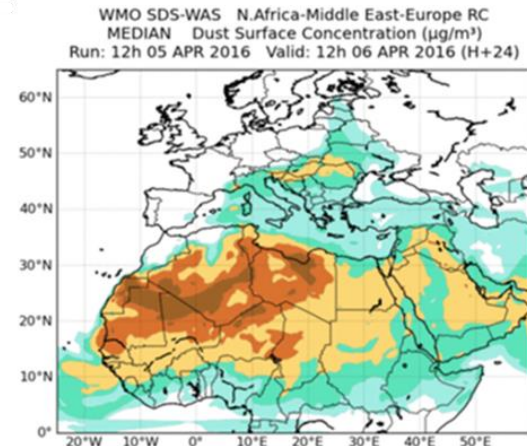
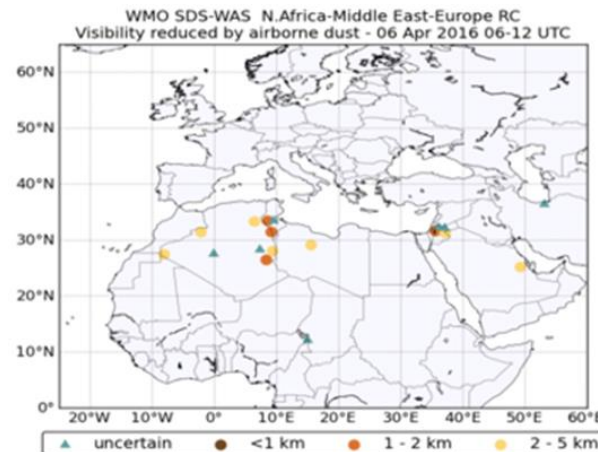
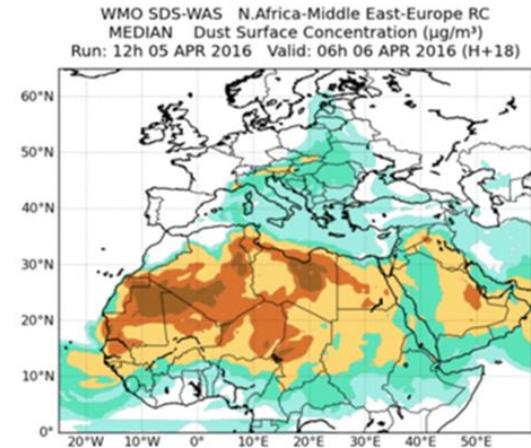
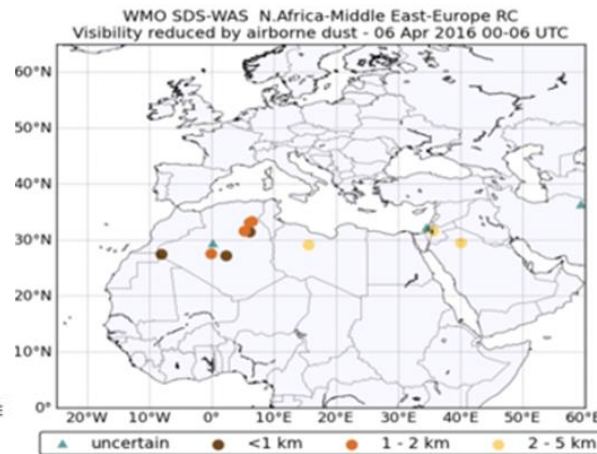
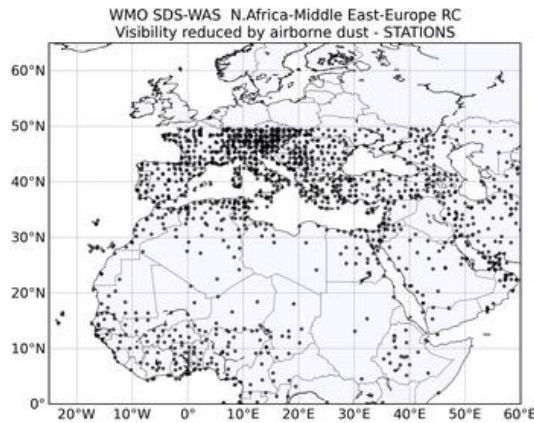


- ★ Reference
- CAMS
- Median
- NGAC
- NMMB/BSC-Dust
- BSC-DREAM8b
- GEOS-5
- DREAM8-NMME

SDS-WAS NAMEE: Model evaluation



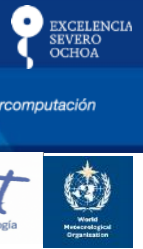
NRT visibility evaluation: 6th April 2016 0-12UTC



SDS-WAS NAMEE: Model evaluation



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Ceilometer

Santa Cruz de Tenerife and Granada (Spain)

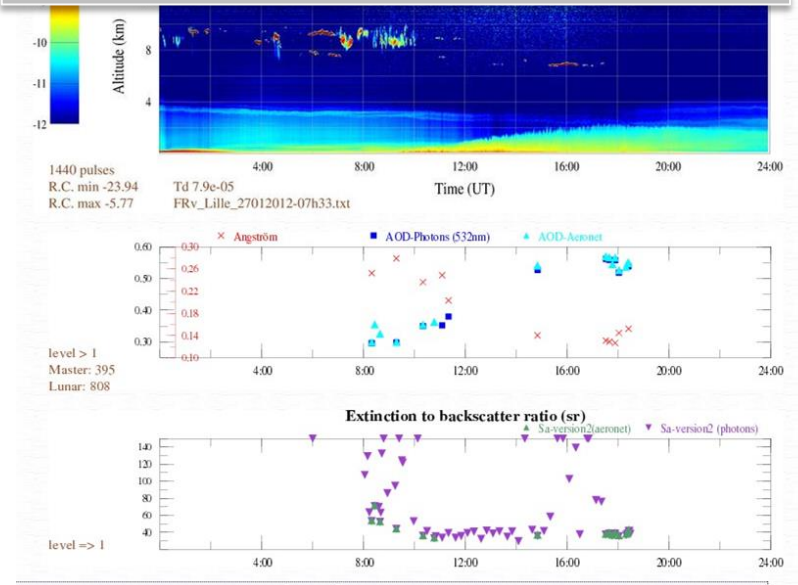
- + High density of stations
- Qualitative products



Lidar

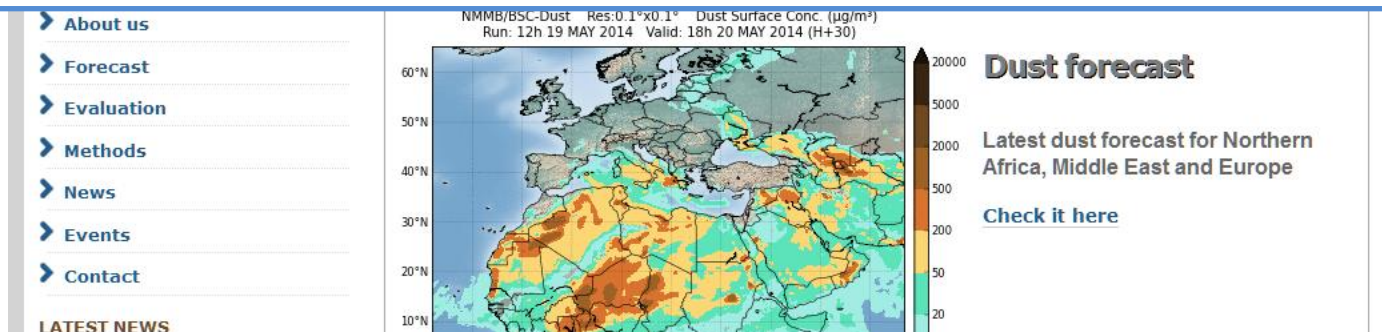
M'Bour (Senegal)

- Low number of stations
- + Quantitative products





*In 2014, the First Specialized Center for Mineral Dust
Prediction of WMO is created
NMMB/BSC-Dust selected to provide operational forecasts
for NAMEE region*



<http://dust.aemet.es/>

[@Dust_Barcelona](#)

BDFC: Dust Forecasts products



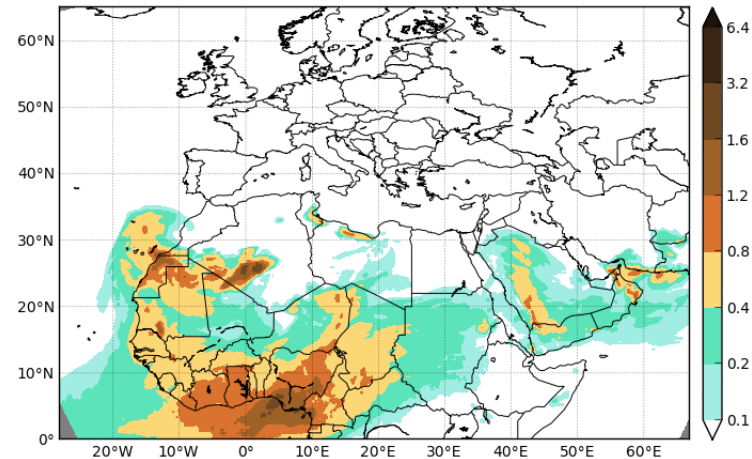
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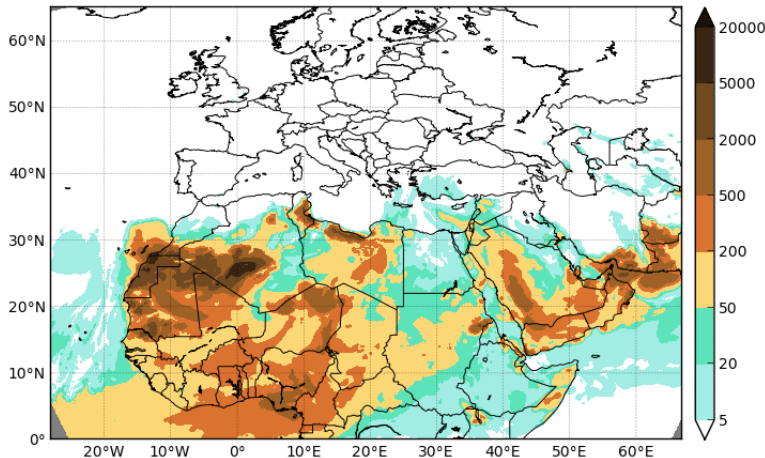


Barcelona Dust Forecast Center
NMMB/BSC-Dust Res:0.1°x0.1° Dust AOD
Run: 12h 07 MAR 2015 Valid: 12h 07 MAR 2015 (H+00)

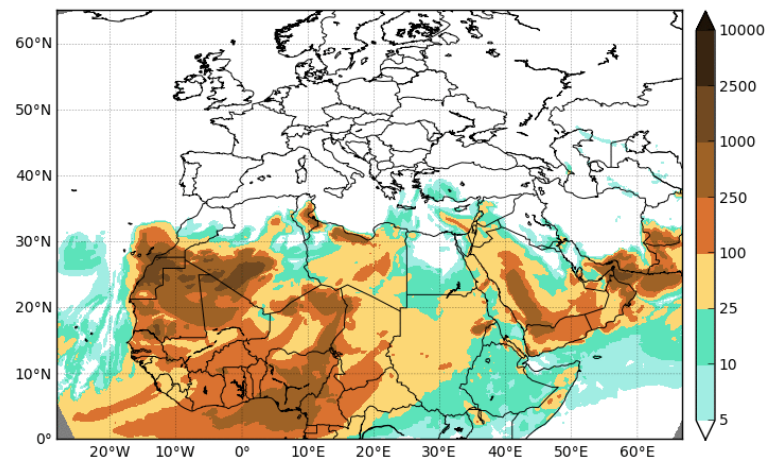


Dust Optical Depth at 550nm
Dust Dry Deposition
Dust Load
Dust Surface Concentration
Dust Surface Extinction at 550nm
Dust Wet Deposition

Barcelona Dust Forecast Center
NMMB/BSC-Dust Res:0.1°x0.1° Dust Surface Conc. ($\mu\text{g}/\text{m}^3$)
Run: 12h 07 MAR 2015 Valid: 12h 07 MAR 2015 (H+00)



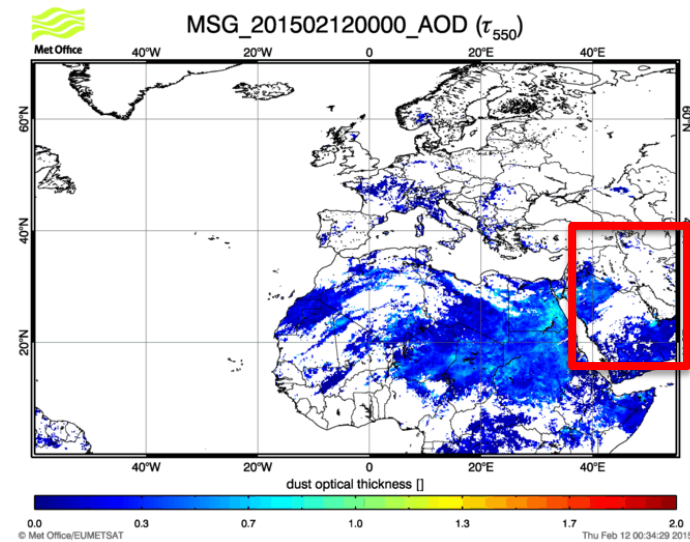
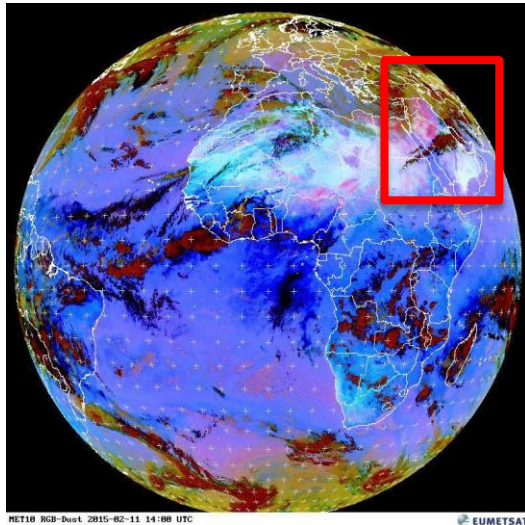
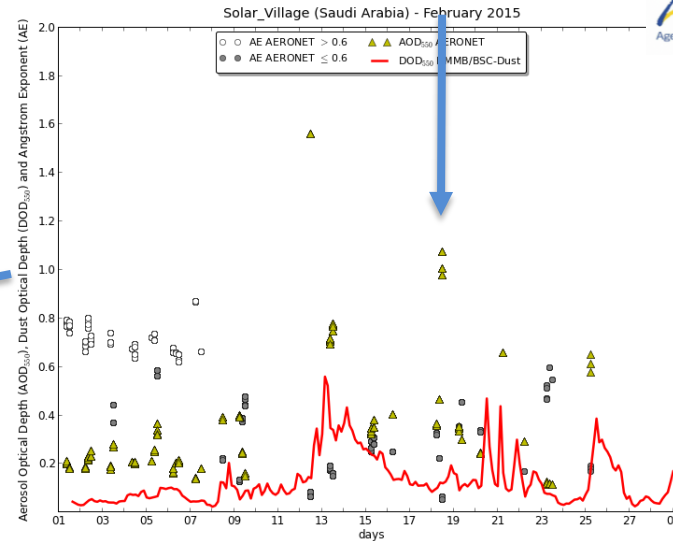
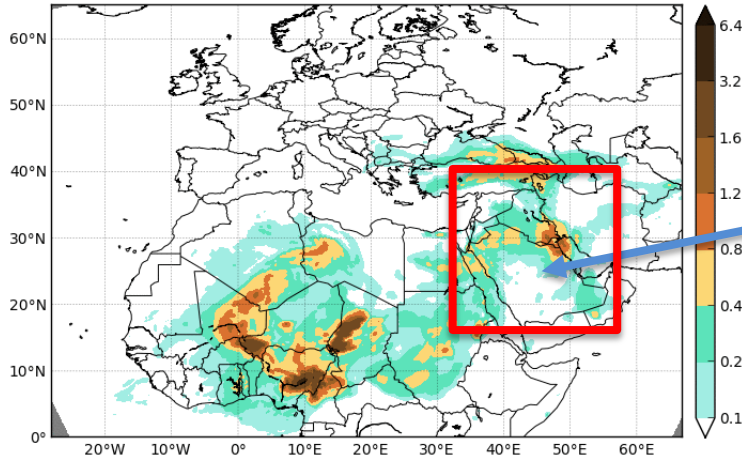
Barcelona Dust Forecast Center
NMMB/BSC-Dust Res:0.1°x0.1° Dust Surface Ext. (Mm^{-1})
Run: 12h 07 MAR 2015 Valid: 12h 07 MAR 2015 (H+00)



<http://dust.aemet.es/>
@Dust_Barcelona

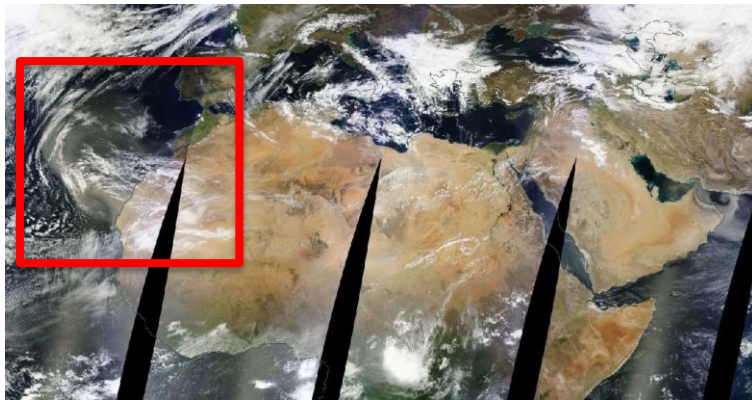
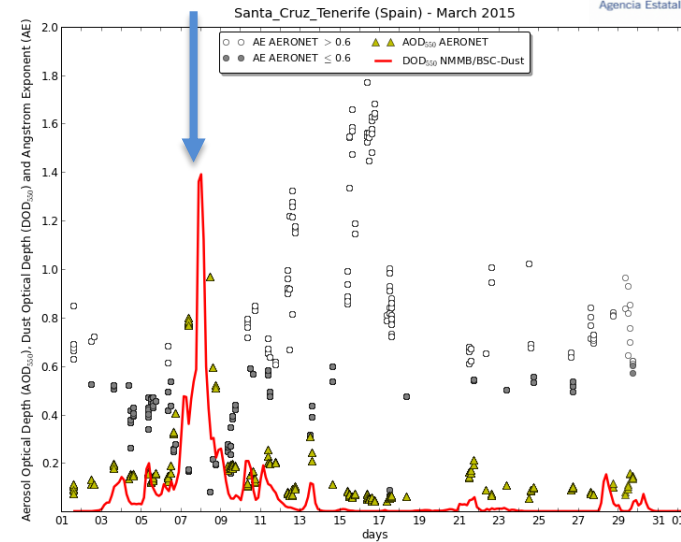
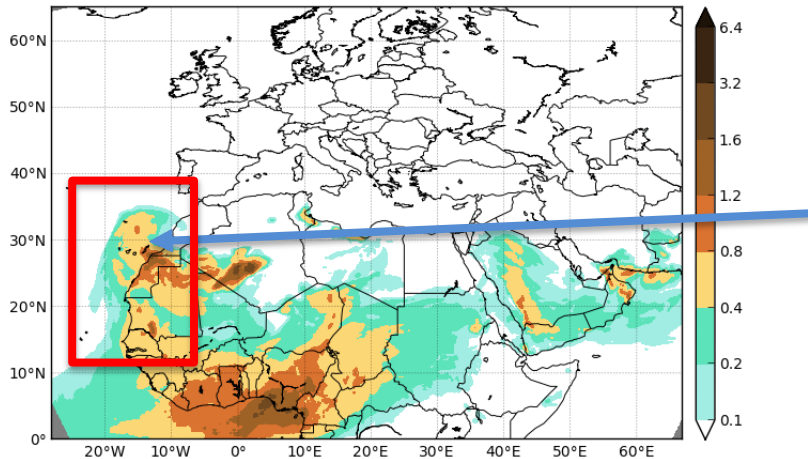
BDFC: Dust event Middle East Feb 2015

Barcelona Dust Forecast Center
NMMB/BSC-Dust Res:0.1°x0.1° Dust AOD
Run: 12h 12 FEB 2015 Valid: 12h 12 FEB 2015 (H+00)

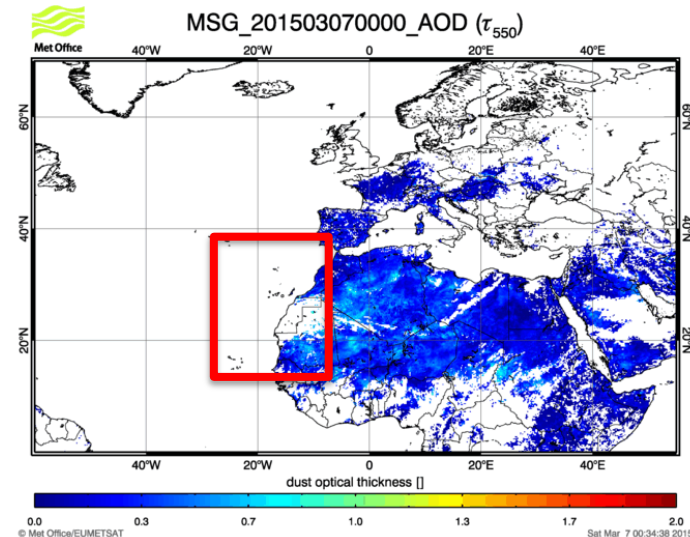


BDFC: Dust event Canary Islands Mar 2015

Barcelona Dust Forecast Center
NMMB/BSC-Dust Res:0.1°x0.1° Dust AOD
Run: 12h 07 MAR 2015 Valid: 12h 07 MAR 2015 (H+00)

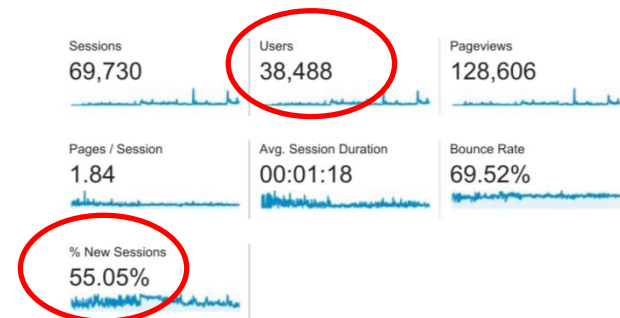
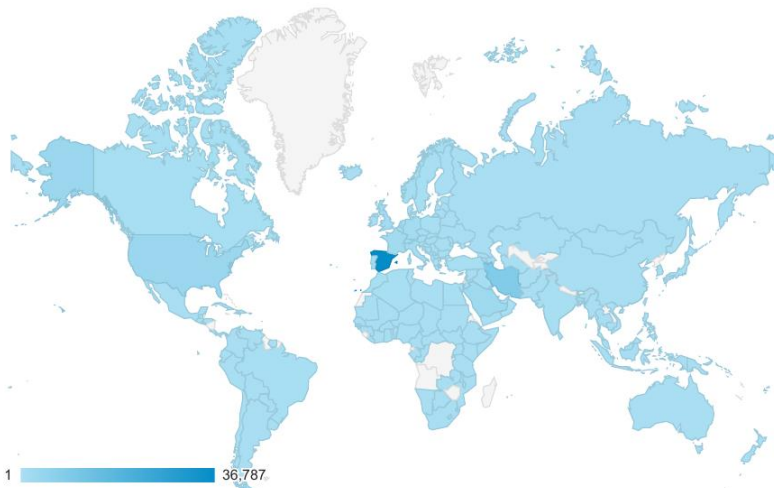
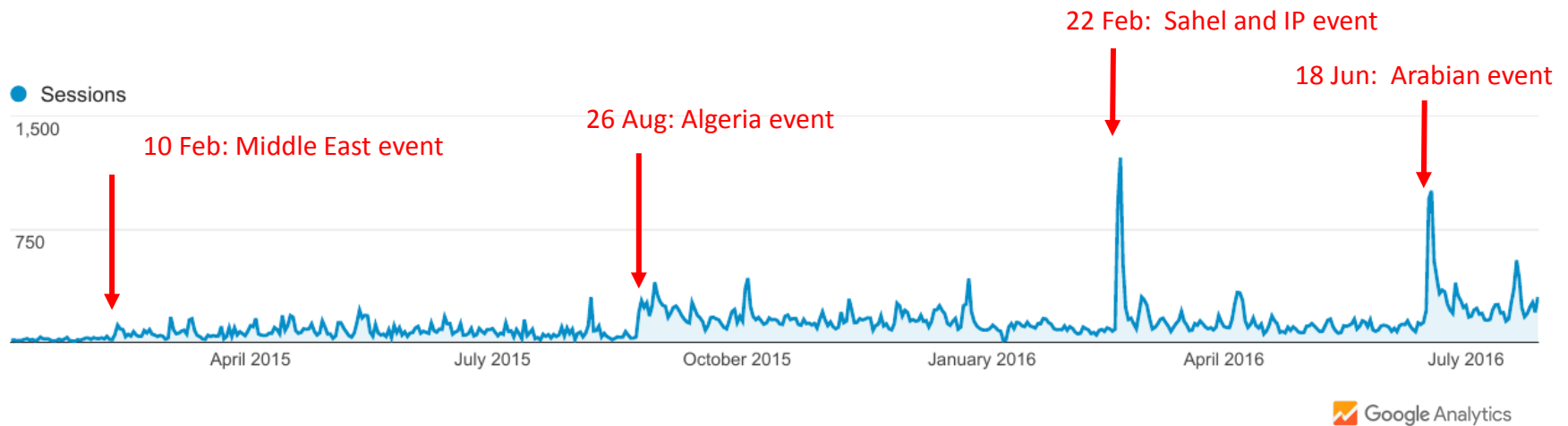


MODIS composite 8th March
from EOSDIS World Viewer



<http://dust.aemet.es/>
@Dust_Barcelona

Website visits: 1 January 2015 – 28 July 2016



Ongoing **NMMB/BSC-Dust** model developments to improve the quality of daily dust forecast includes:

- Data assimilation of satellite aerosol products for mineral dust analysis
- Exploration of the advantages of the high-resolution simulations (> 4km spatial horizontal resolution) → Haboobs and complex terrains

Ongoing activities of the **WMO Dust Centers** includes:

- **Model evaluation** including data from satellites, and lidar, Sun-photometer and in-situ networks, both for gaseous and aerosol species, covering multiple time-scales.
- Increased education and awareness to promote the information and forecasts that are publically and freely available
- Establishment of appropriate communication channels for the dissemination of interpreted dust forecasts at a frequency that enables preparedness (i.e. through weather news networks, text message alerts)



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