Météo-France update : evolution of the MOCAGE model and research results

Guth J., Guidard V., Joly M., Arteta J., Bacles M., Besson F., Coopmann O., Jeoffrion M., Josse B.

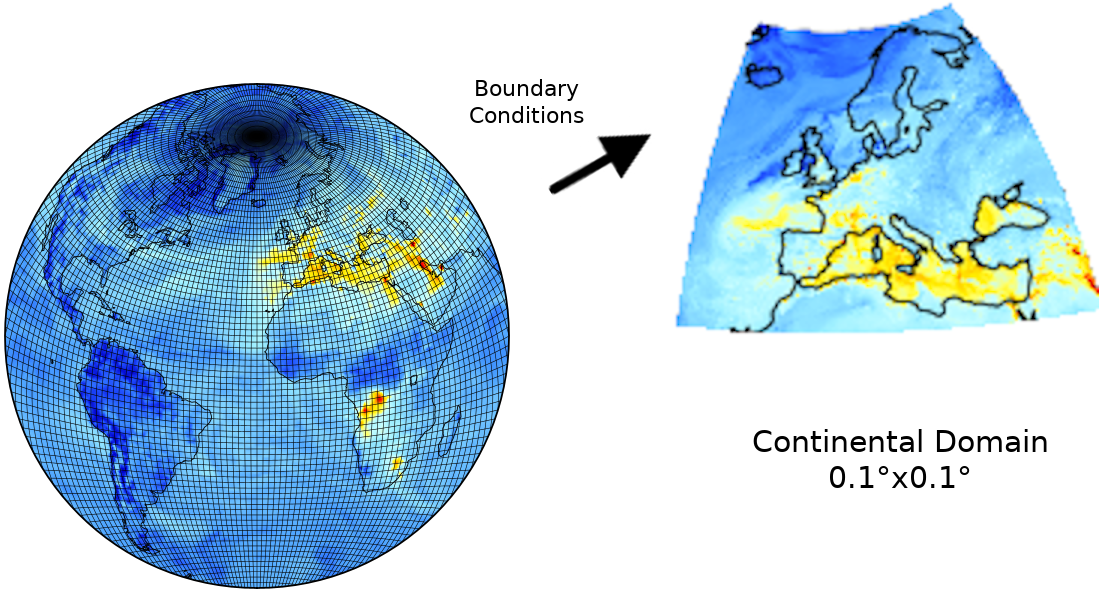
8th November 2023

MOCAGE operational configuration

The MOCAGE model : general features

Off-line chemistry transport model

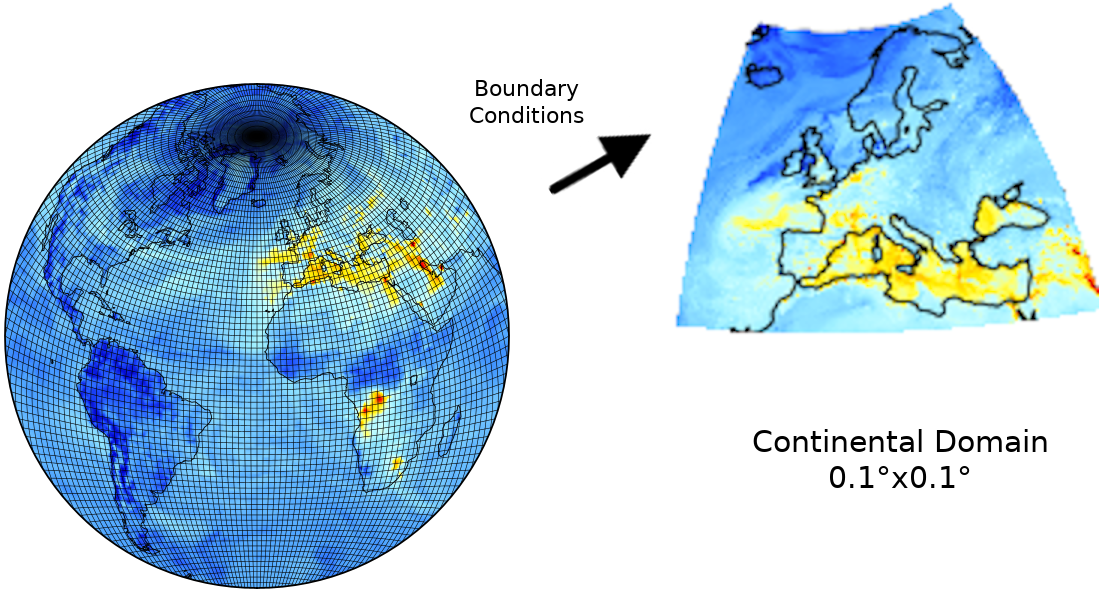
- Semi-Lagrangian advection scheme with convection and diffusion parametrization
- RACM+REPROBUS chemical scheme, Desert Dust, Sea Salt, Primary Organic Carbon, Black Carbon, SIA, SOA
- 47 σ-hybrid vertical levels from surface to 5hPa



The MOCAGE model : general features

Off-line chemistry transport model

- Semi-Lagrangian advection scheme with convection and diffusion parametrization
- RACM+REPROBUS chemical scheme, Desert Dust, Sea Salt, Primary Organic Carbon, Black Carbon, SIA, SOA
- 60 σ-hybrid vertical levels from surface to 0.01 hPa



The MOCAGE model : general features

Global domain is used for:

- ICAP → Connection with this community, help to improve our model
- Participation to forecast of the WMO Dust Regional Center (Northern Africa-Middle East-Europe)
- UV Index forecast for French territory (ozone column)

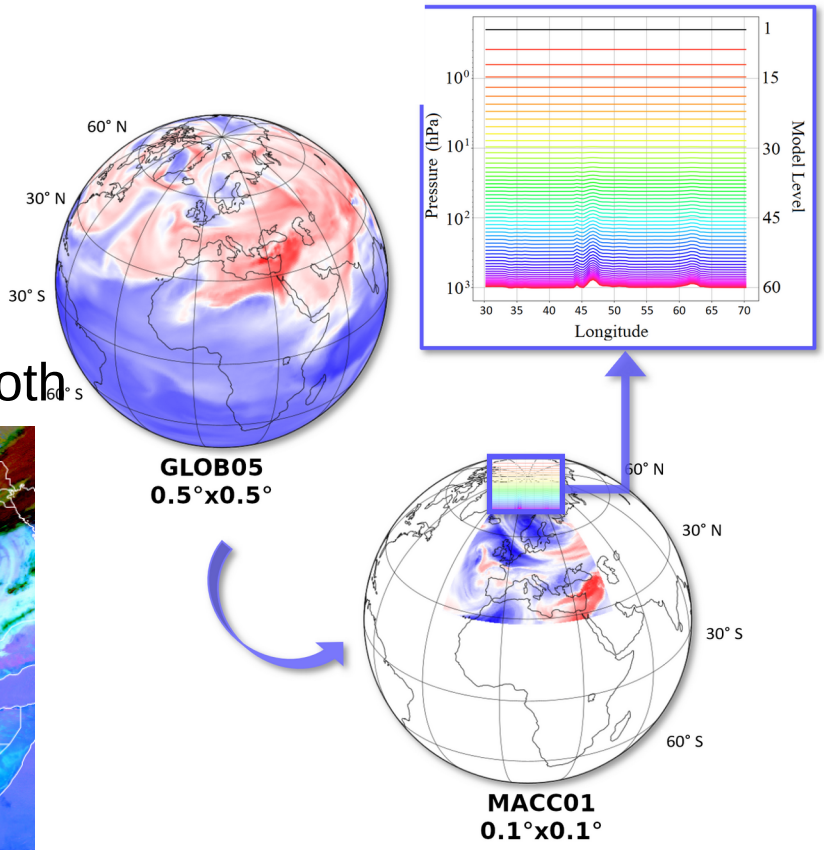
European domain is used for:

- CAMS-atmosphere regional air quality ensemble forecast
- French national air quality platform Prev'Air

New 0.5x0.5° and 60 levels version (no DA)

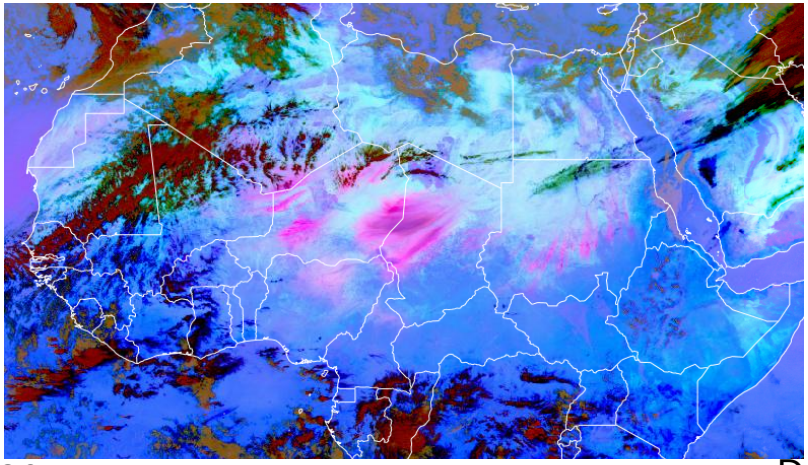
Next operational version configuration:

- Global domain at 0.5°x0.5° associated to a 0.1°x0.1° regional domain
- 60 vertical levels up to 0.01 hPa
- The general behaviour of aerosols is very similar in both versions

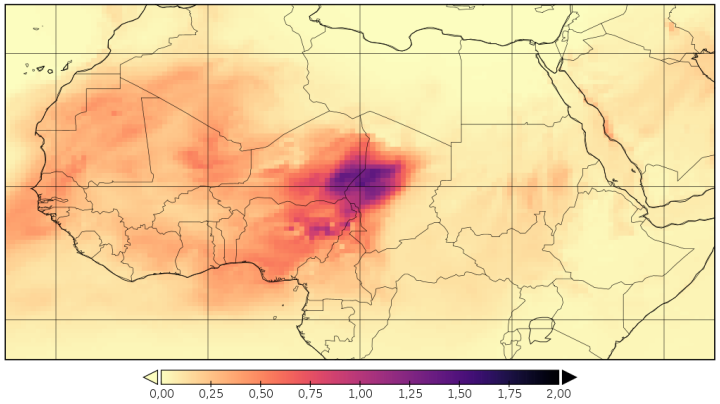


14/02/2023 12UTC

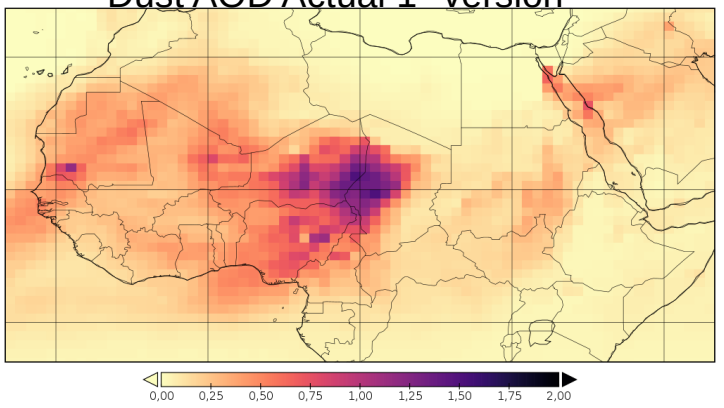
Seviri RGB Dust



Dust AOD New 0.5° version



Dust AOD Actual 1° version



New 0.5x0.5° and 60 levels version (no DA)

New 0.5° version

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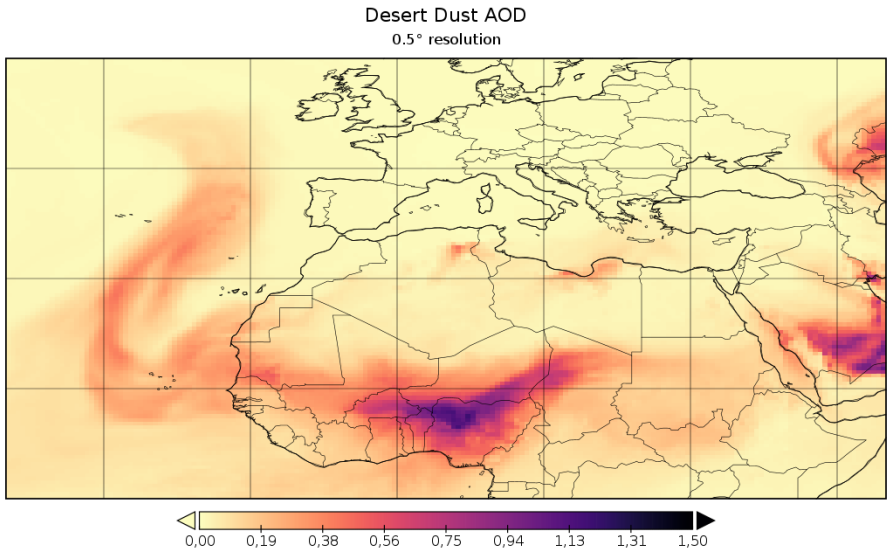
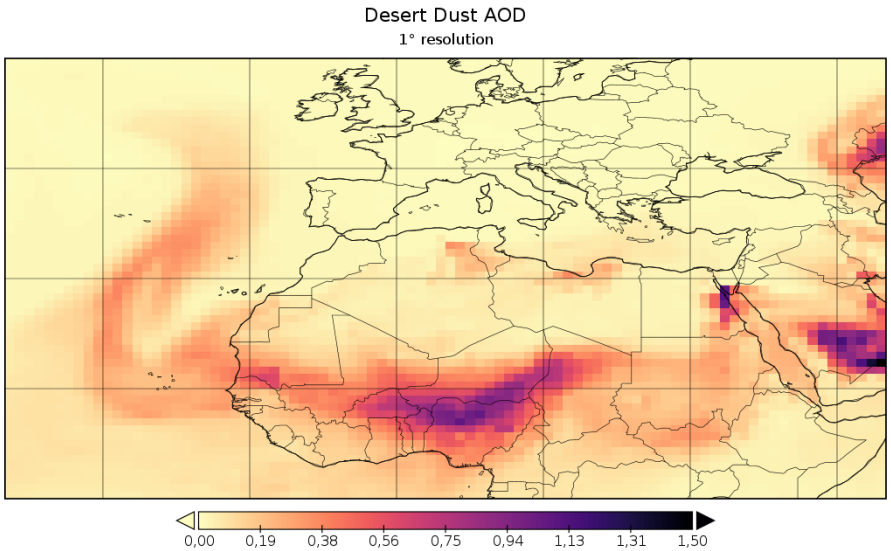
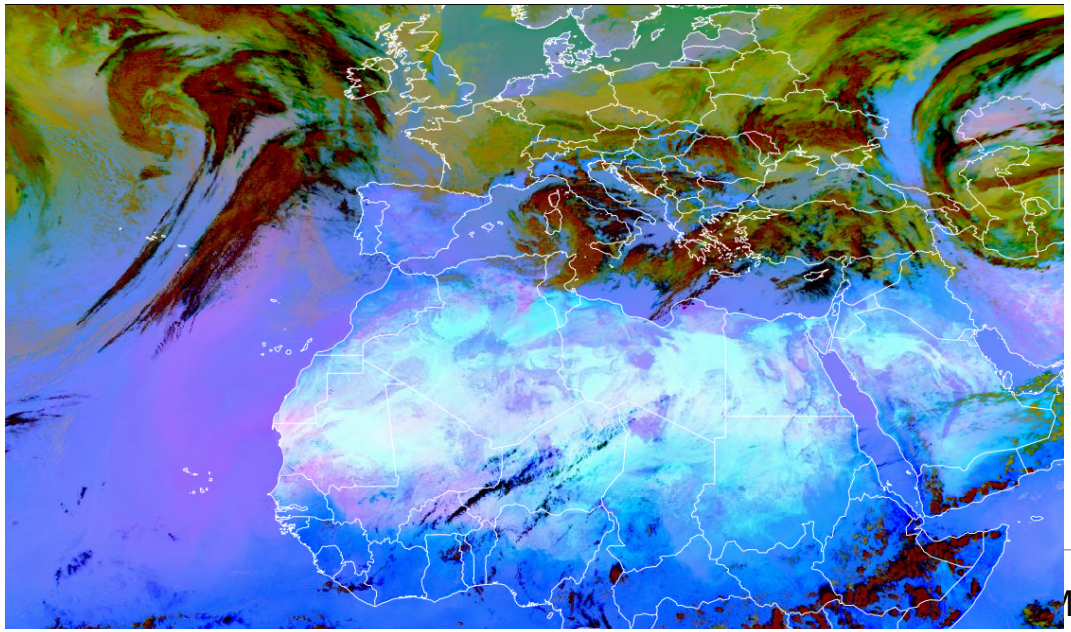
Actual 1° Version

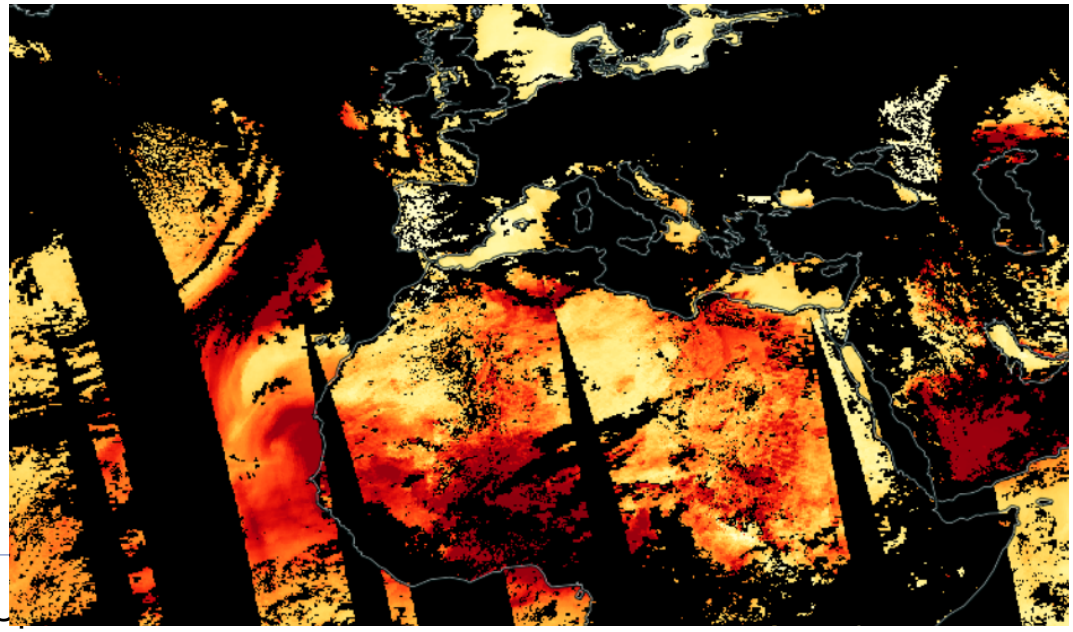




Seviri Dust RGB



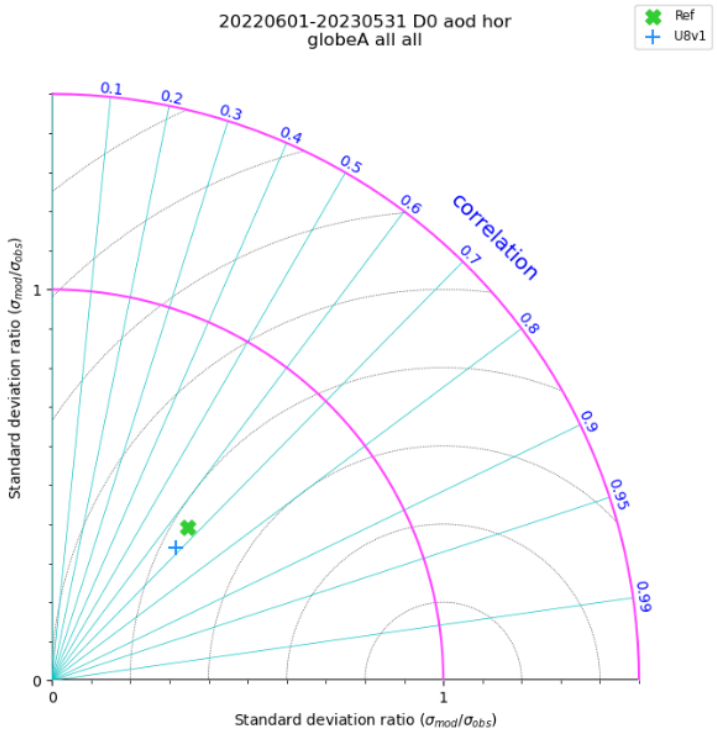
Aqua MODIS AOD

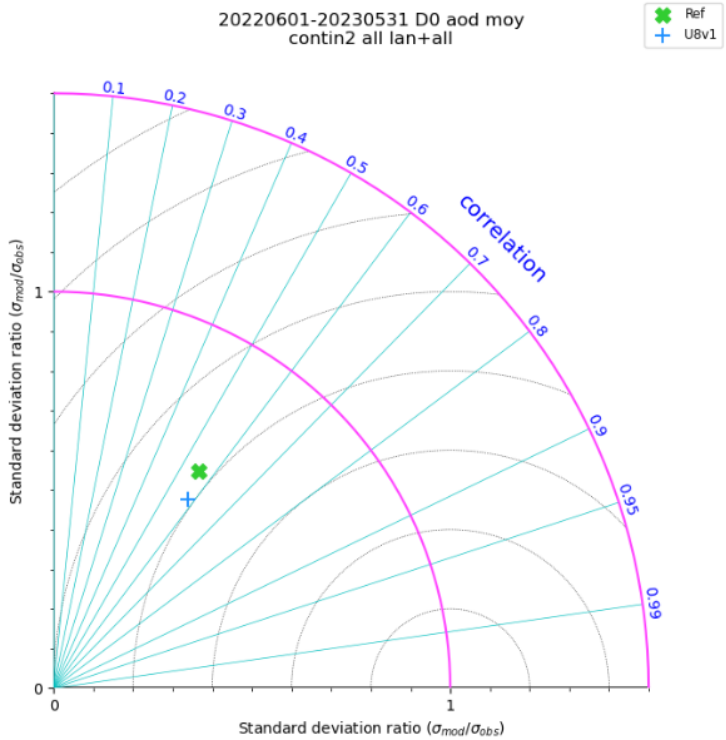


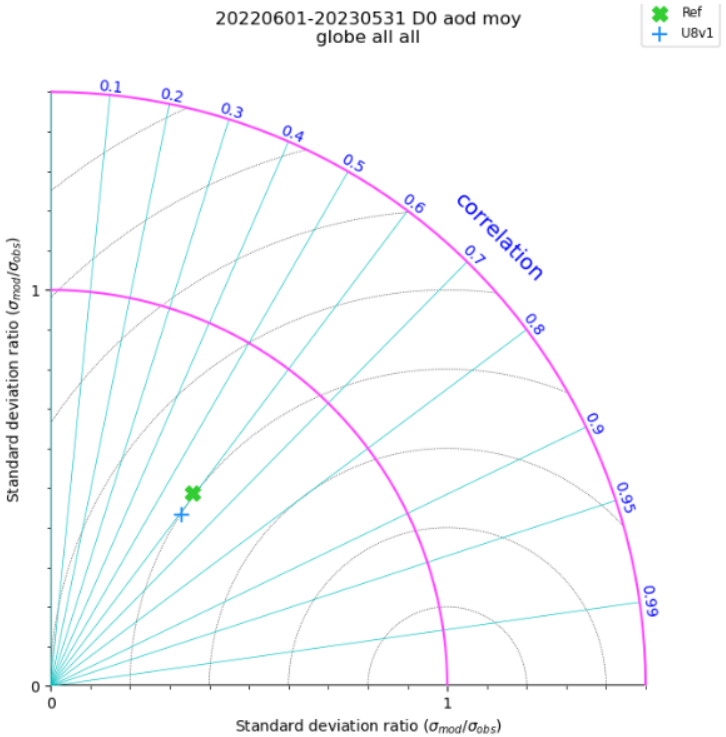
New 0.5x0.5° and 60 levels version (no DA)

Validation during a 1 year period (June 2022 – May 2023):

AERONET MODIS-DB MODIS-LO







- Similar behaviour between new 0.5° version (Blue) and historic version at 1° (green)

Data assimilation system

3D-var algorithm using 1h windows:

- Global domain assimilation:
  - MODIS AOD
  - VIIRS AOD
  - TROPOMI SO2 for volcanic events

- Regional domain assimilation:
  - MODIS AOD
  - 6 Lidars from Météo-France network (Mini-MPL)
  - E-profile telemeters (CHM15K at 1064nm)

Data assimilation system

3D-var algorithm using 1h windows:

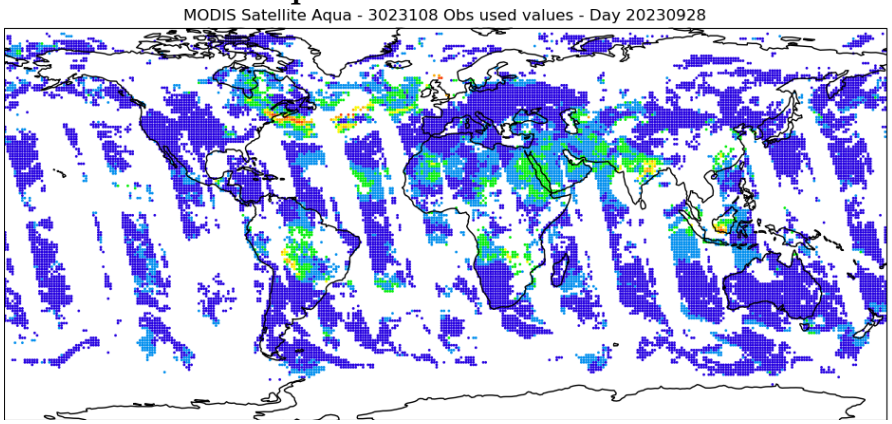
- Global domain assimilation:
  - MODIS AOD
  - VIIRS AOD
  - TROPOMI SO2 for volcanic events
  - Added monitoring of IASI SO2 Cris O3 data

- Regional domain assimilation:
  - MODIS AOD
  - 6 Lidars from Météo-France network (Mini-MPL)
  - E-profile ceilometers (CHM15K at 1064nm)
  - More E-profile ceilometers (CL31 and CL51)
  - Added monitoring of IASI SO2 data

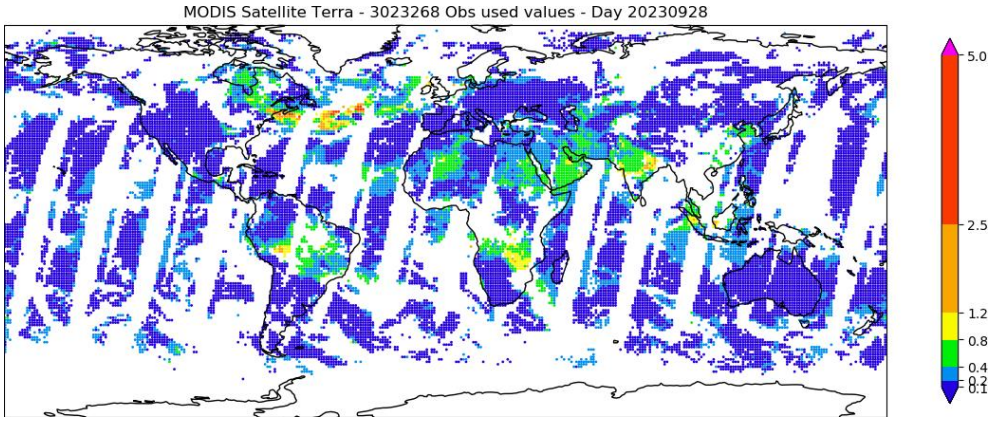
Global aod data assimilation

Example of a daily satellite AOD usage (20230928):

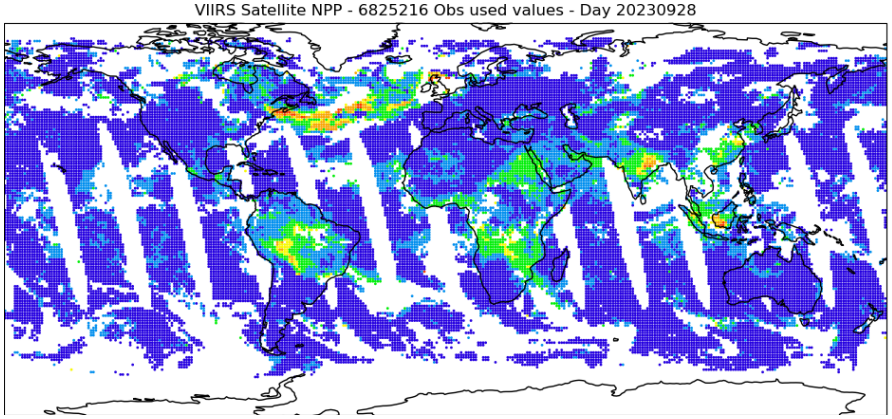
MODIS - Aqua



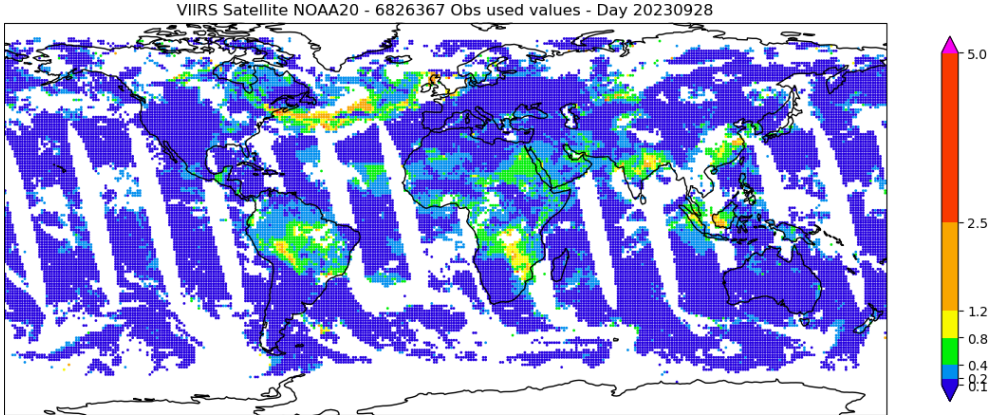
MODIS – Terra



VIIRS – S-NPP



VIIRS – NOAA-20

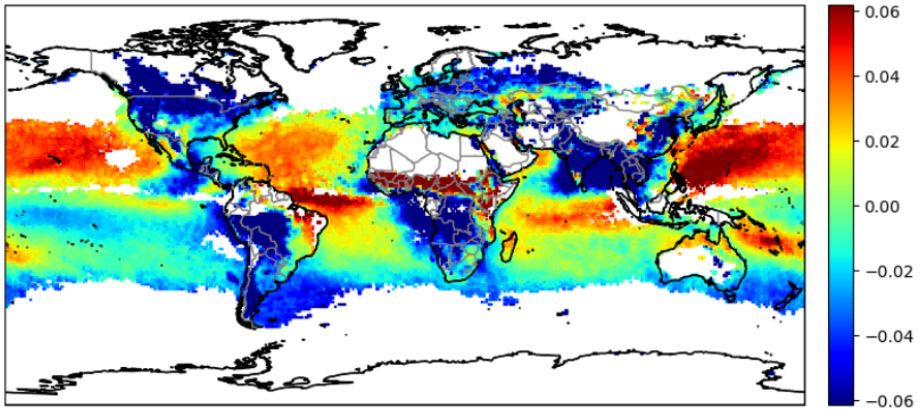


Global aod data assimilation

Impact of satellite AOD assimilation:

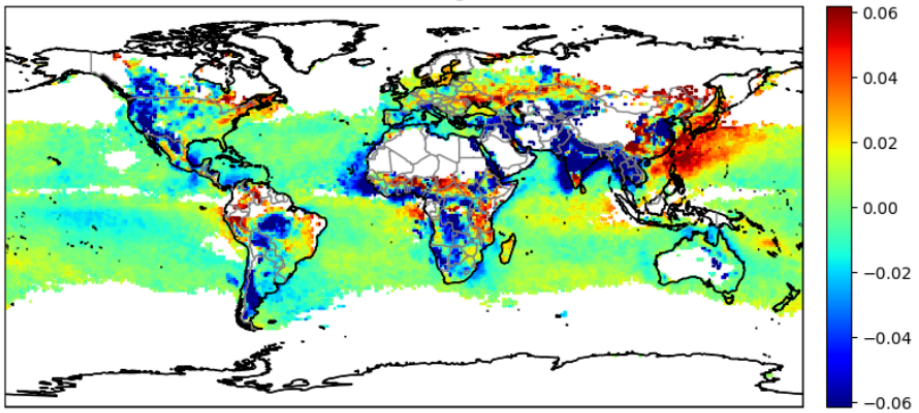
- Scores over a 1 year period June 2022 to May 2023 wrt MODIS Daily L3

Bias of AOD forecasts at 24h forecast range



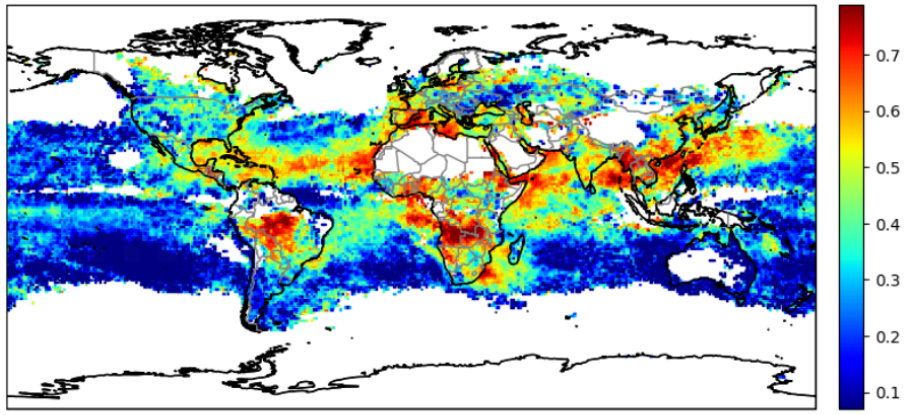
27775 processed stations over 27821
min: -3.32, avg: -0.01, max: 0.29

with DA



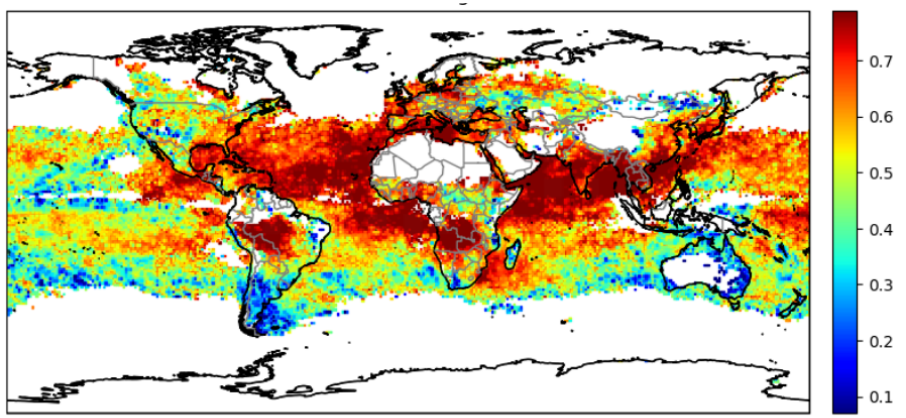
27775 processed stations over 27821
min: -3.32, avg: -0.0, max: 0.24

Correlation of AOD forecasts at 24h forecast range



27775 processed stations over 27821
min: -0.44, avg: 0.35, max: 0.9

with DA



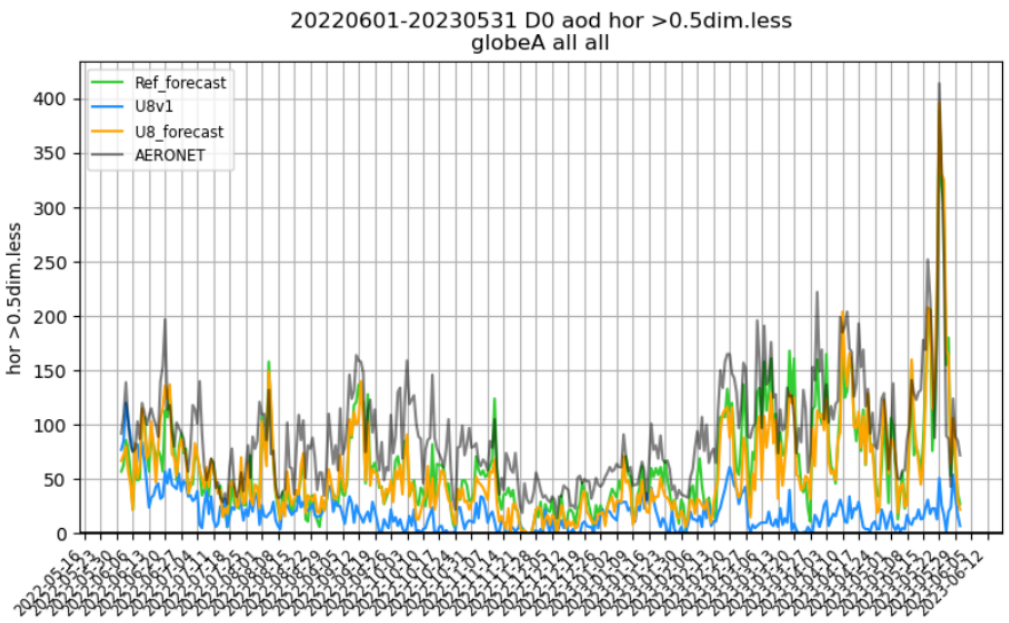
27775 processed stations over 27821
min: -0.27, avg: 0.58, max: 0.94

Global aod data assimilation

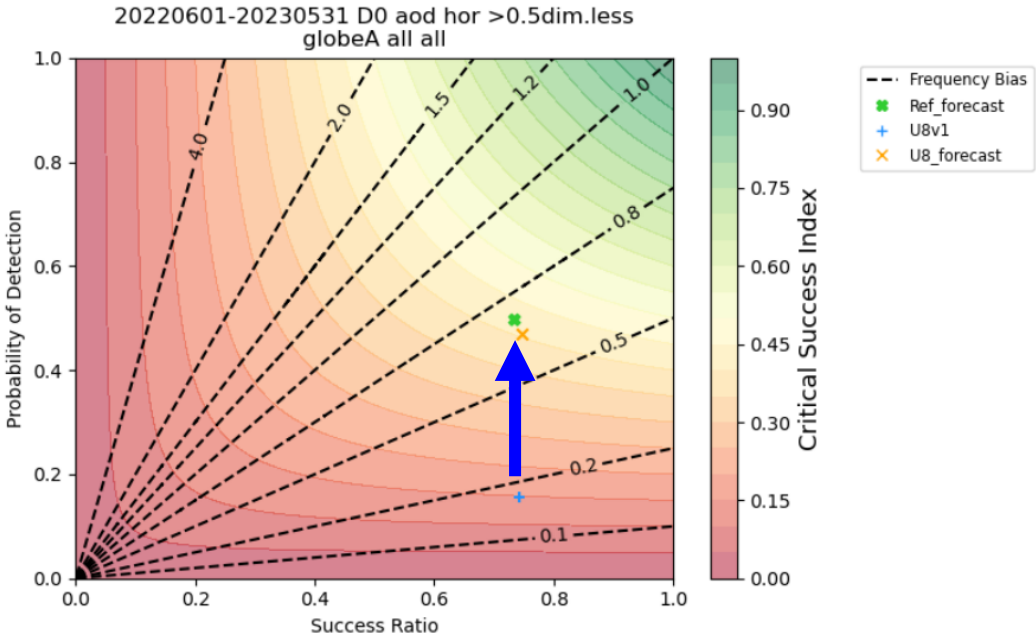
Impact of satellite AOD assimilation on 24h forecasts:

- Scores over a 1 year period June 2022 to May 2023 wrt AERONET data

Threshold exceedance number (AOD > 0.5)



Detection scores

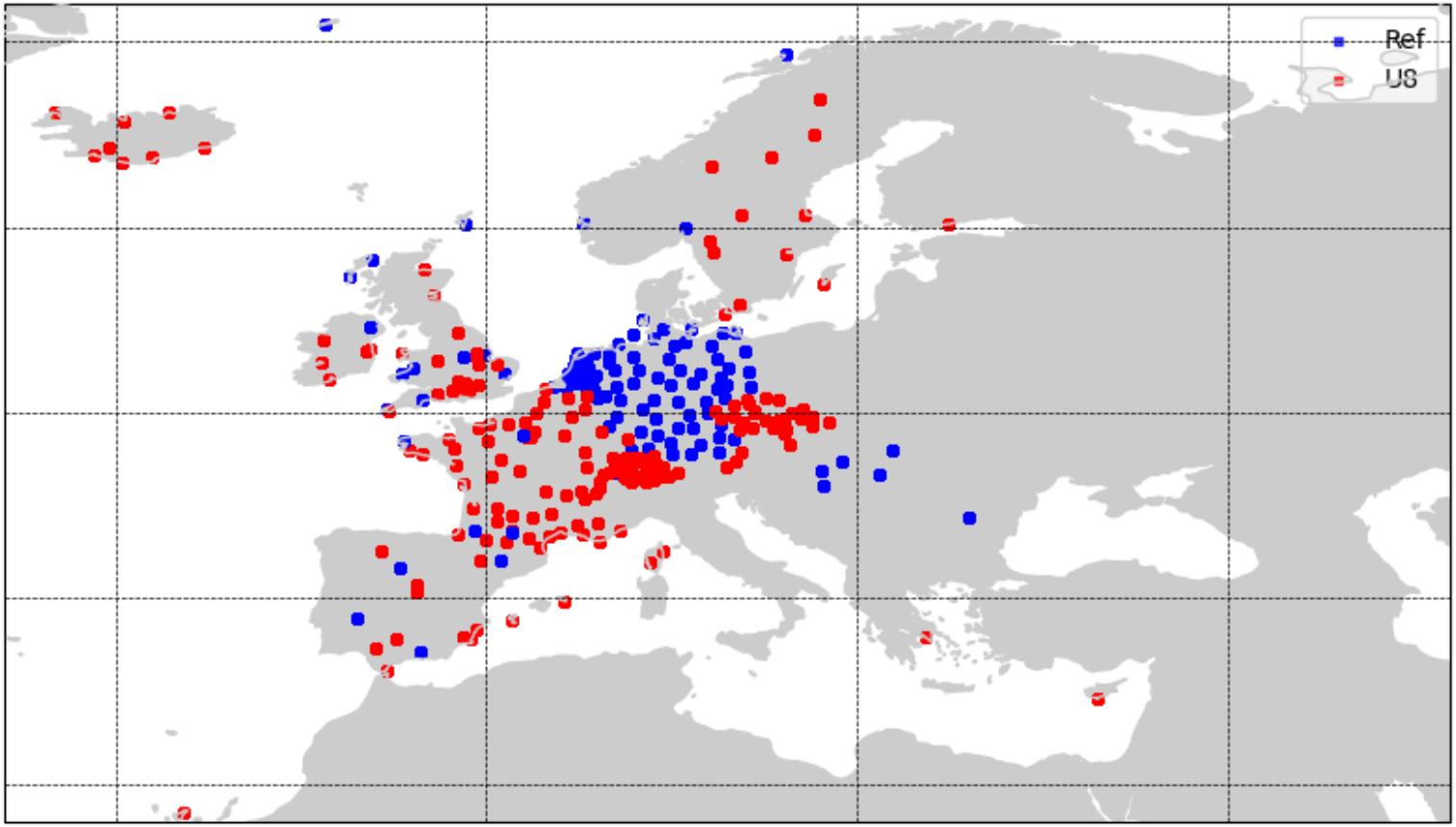


Grey : AERONET (validation)
Blue : No assimilation
Orange : Satellite AOD assimilation

New 0.5x0.5° and 60 levels version

Added value of supplementary ceilometers data to the assimilation system:

- Currently assimilated (blue): CHM15K (ceilometers) and miniMPL (lidars).
- To be added in November 2023 (red) CL31 and CL51 ceilometers.

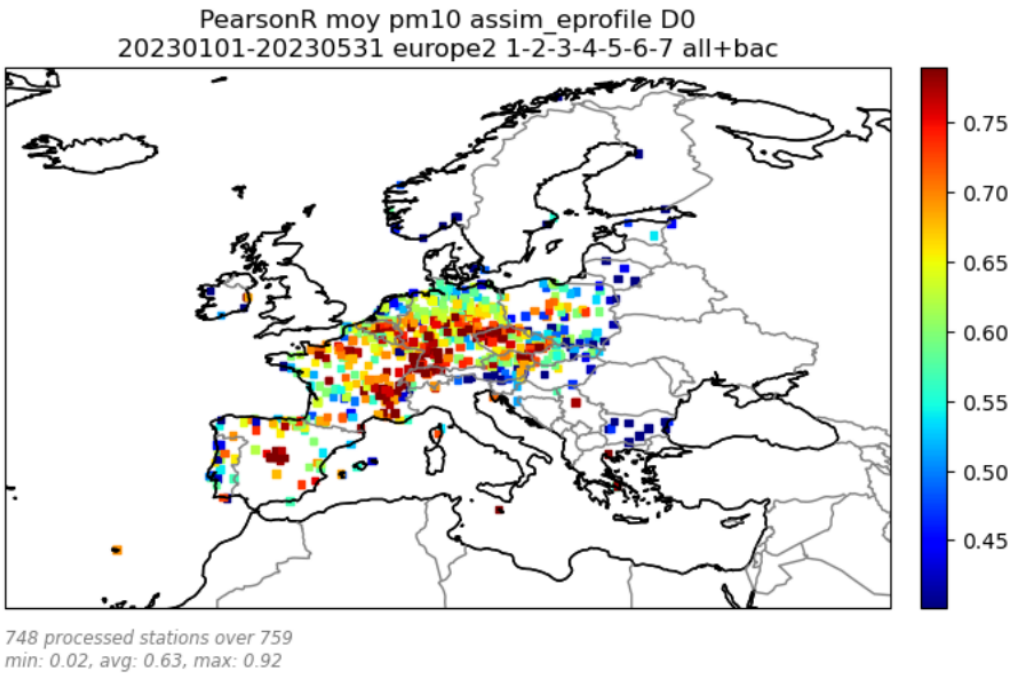


New 0.5x0.5° and 60 levels version

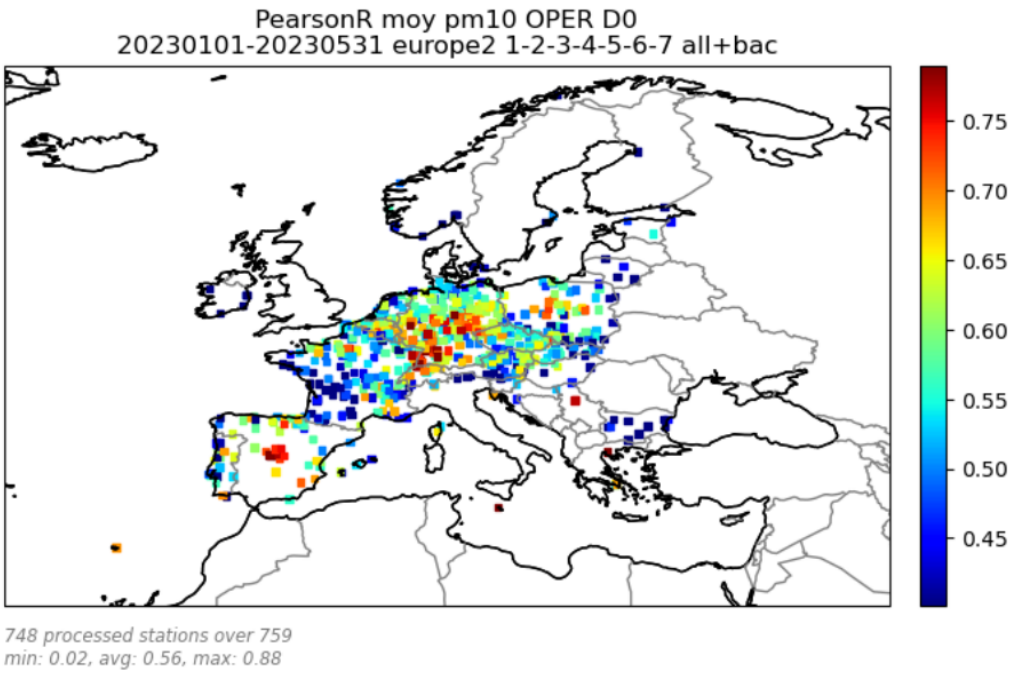
Added value of supplementary ceilometers data to the assimilation system:

- Scores over a 5 month period (Jan-May 2023) – Impact on PM10 at surface against EEA observations

Correlation – PM10 at surface – all e-profile



Correlation – PM10 at surface – only miniMPL+CHM15K



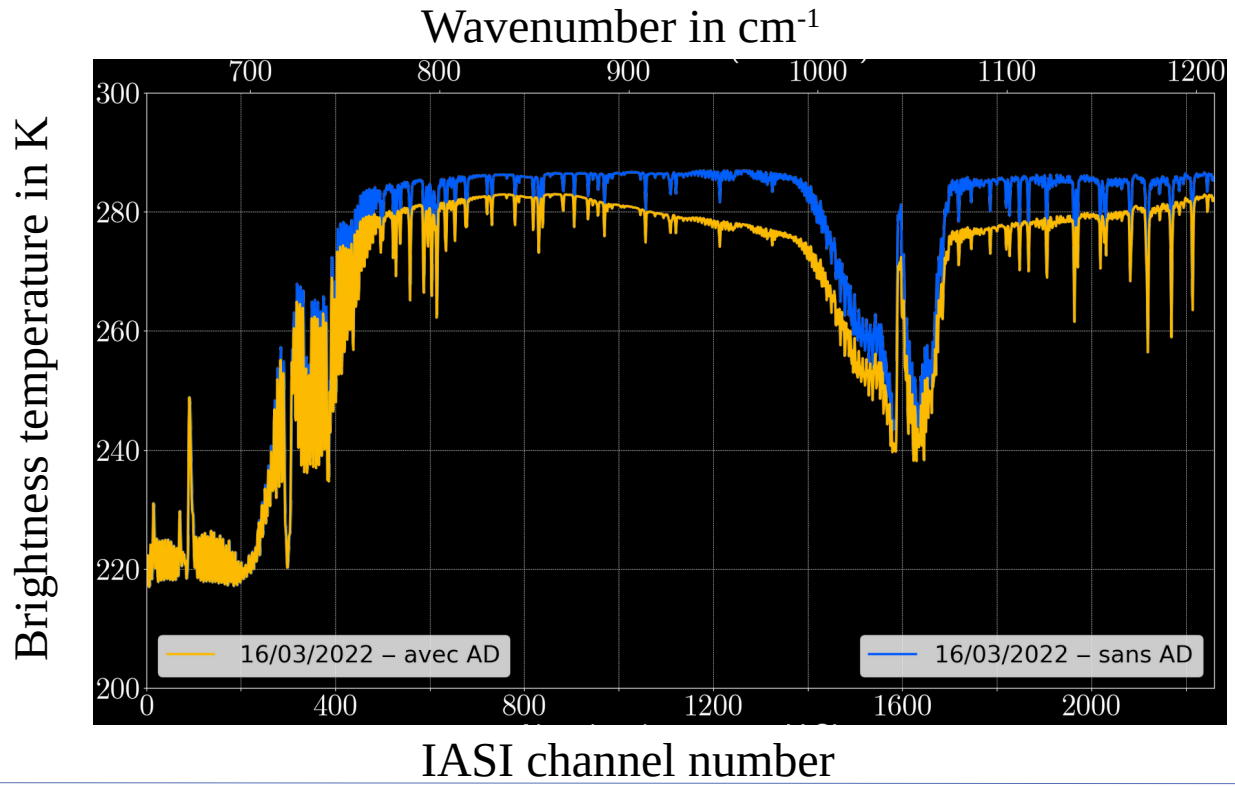
Let’s have a look into research studies

Direct assimilation of IASI radiances for desert dust

Impact of desert dust in RTTOV simulation of IASI spectrum

- Preparatory studies:
  - M. El Aabaribaoune's PhD (2022)
  - Master 1 internship by A. Marchand and L. Guichard (2023)
- Using RTTOV 12.3 with CAMS aerosol representation
- Conversion from MOCAGE 6 bins to CAMS 3 bins for desert dusts

- With Desert Dust
- Without Desert Dust

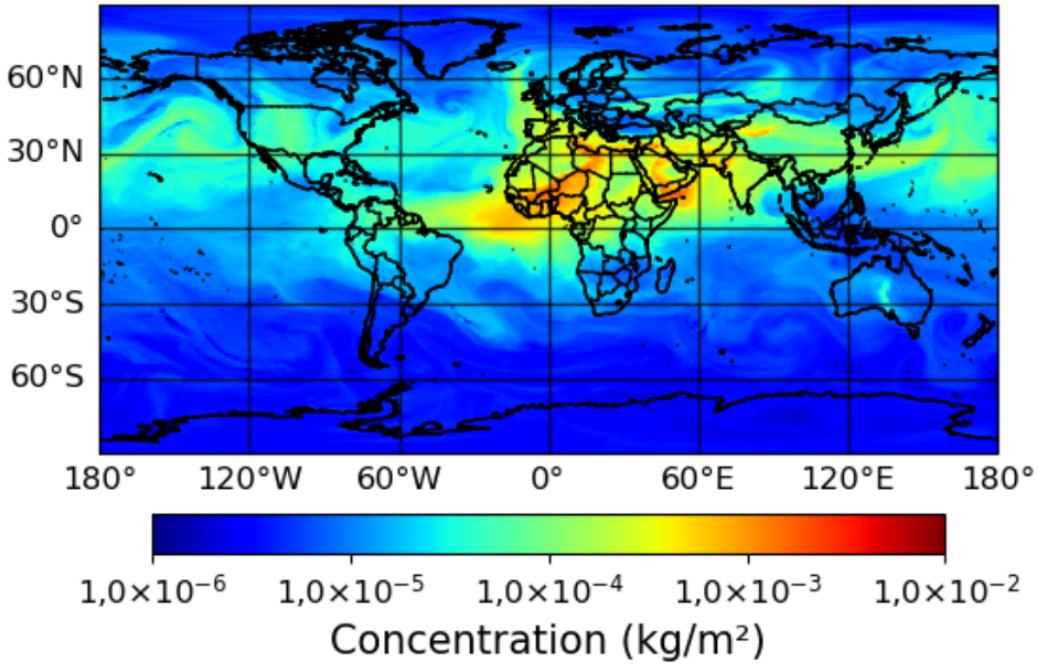


Direct assimilation of IASI radiances for desert dust

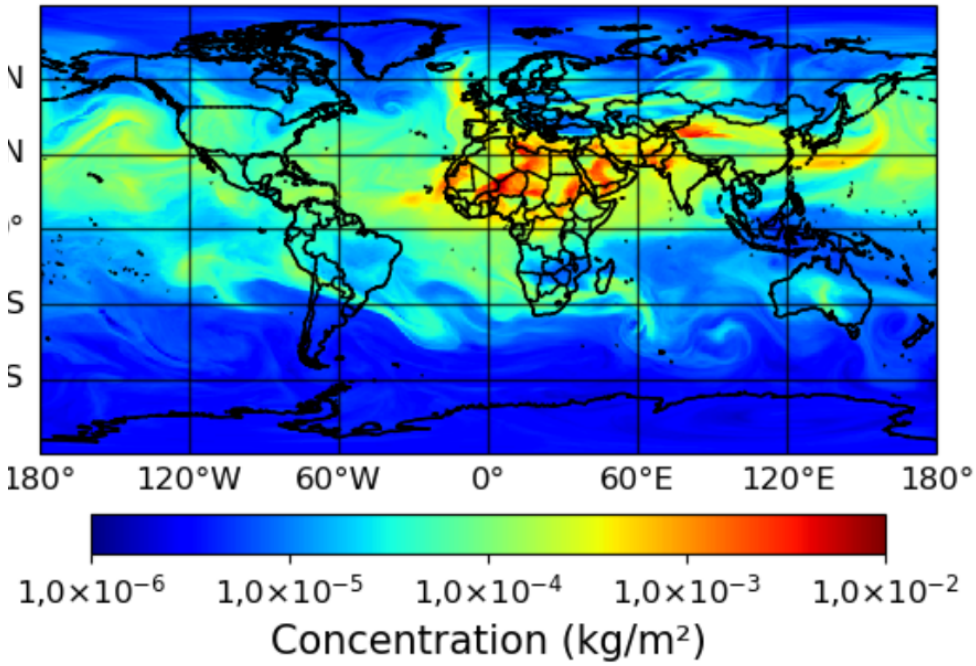
Impact of desert dust in RTTOV simulation of IASI spectrum

- Desert dust outbreak from Sahara to Europe
- ~300 IASI channels assimilated (ozone + desert dusts)
- Good impact but still work to do on vertical distribution and bias correction

DD total column – no assim



DD total column – IASI assim

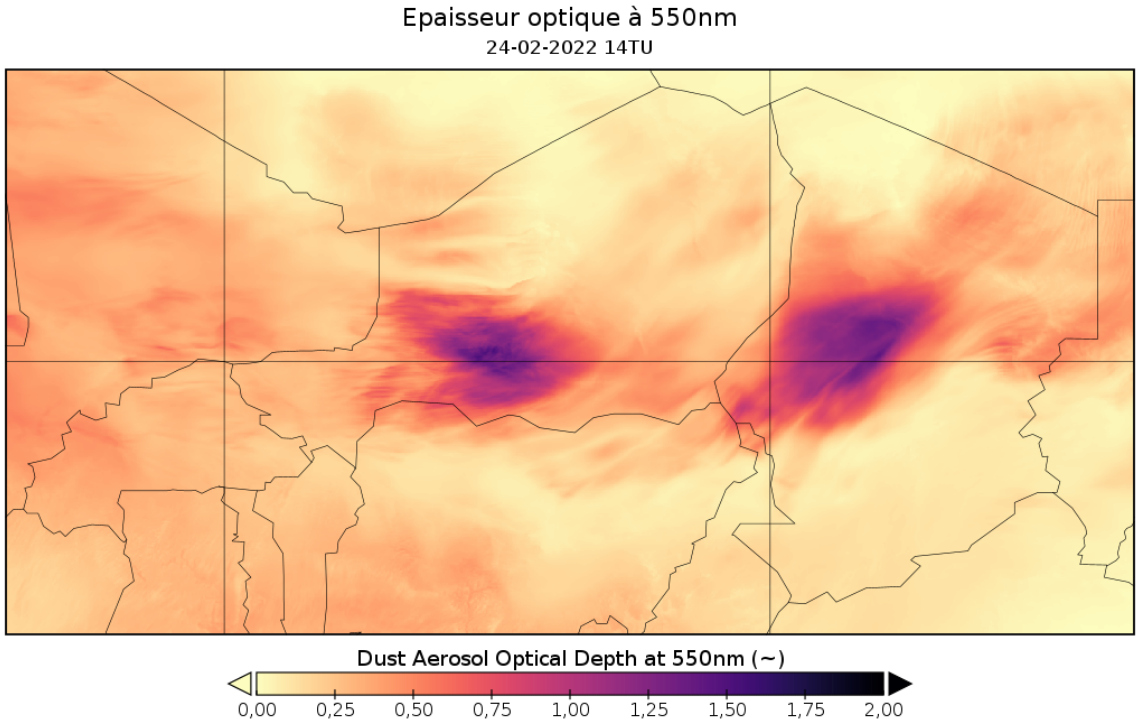


Dust modelling with the AROME NWP model

- AROME is a non-hydrostatic limited area NWP model used at Météo-France since 2008
- AROME has been built using ALADIN dynamical core while most of the physical parametrization came from the MESO-NH community LES model.
- The dust model of AROME is a legacy of the ALDAIN-Dust initiative
  - Emissions are computed within the SURFEX surface model, based on the DEAD model (Mokhtari and al., 2012)
  - Desert dust are managed using a 3 moment log-normal representation inherited from MESO-NH-C (Chemistry)
  - Dust are taken into account in radiation scheme, but not in mycrophysical processes.

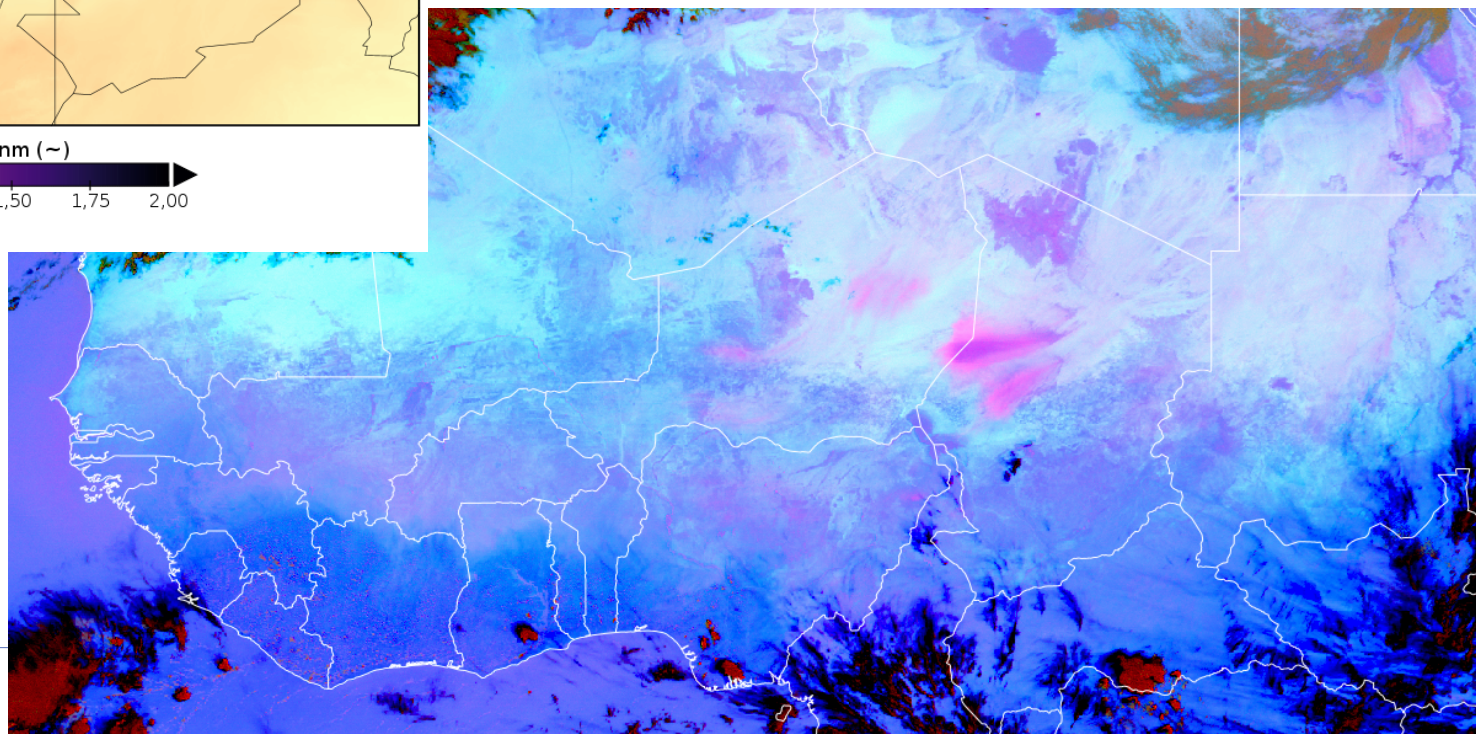
First step of in-line aerosol modelling

Forecast over Sahel region: 24 February 2022



AROME-Dust AOD, 2.5 km resolution

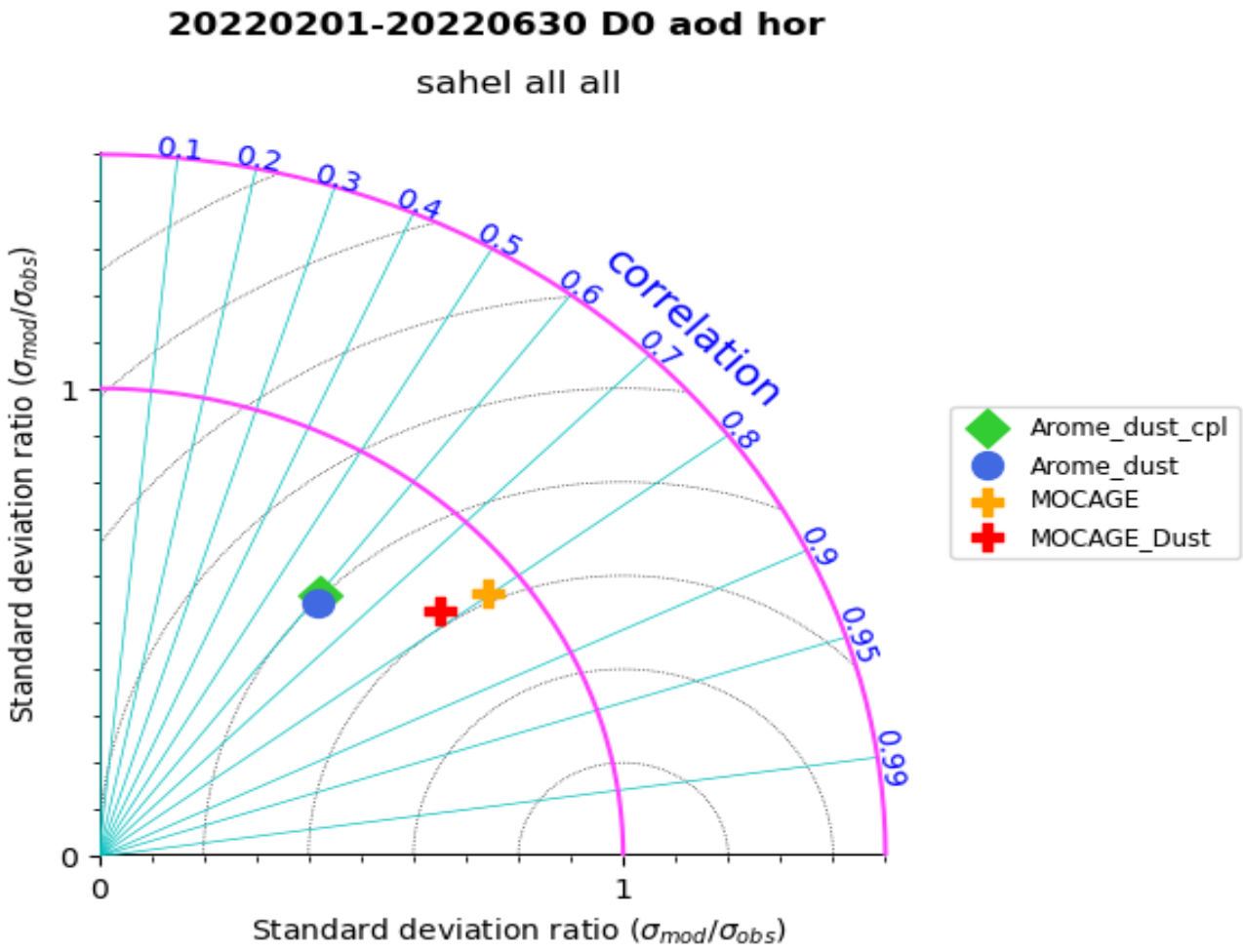
MSG Seviri RGB Dust



First step of in-line aerosol modelling

Comparison with AERONET data on Sahel domain

- 5 months between February and June 2022

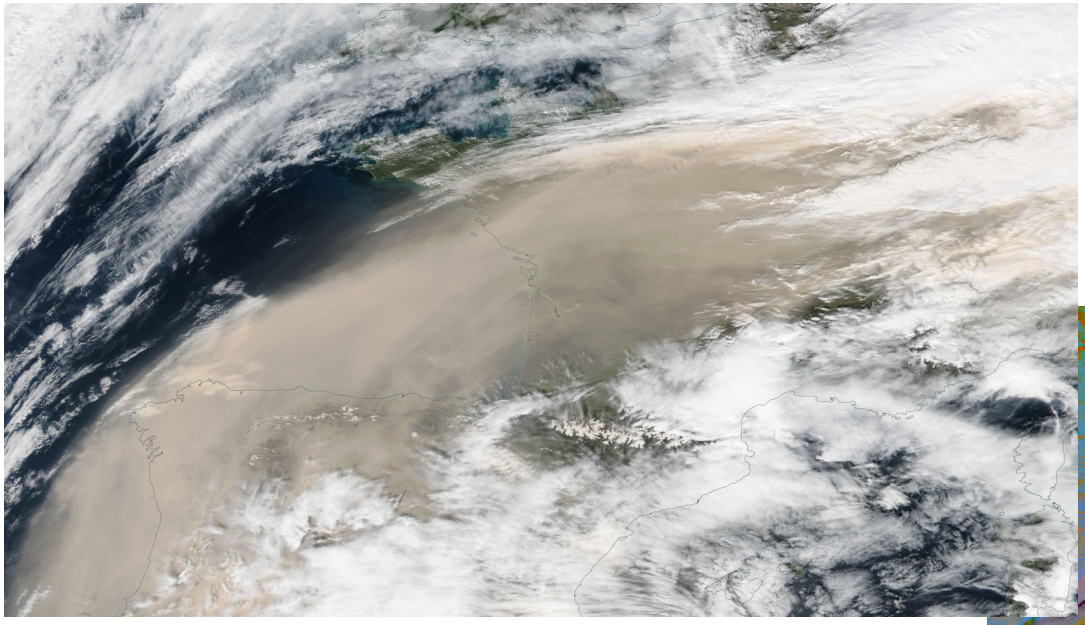


First step of in-line aerosol modelling

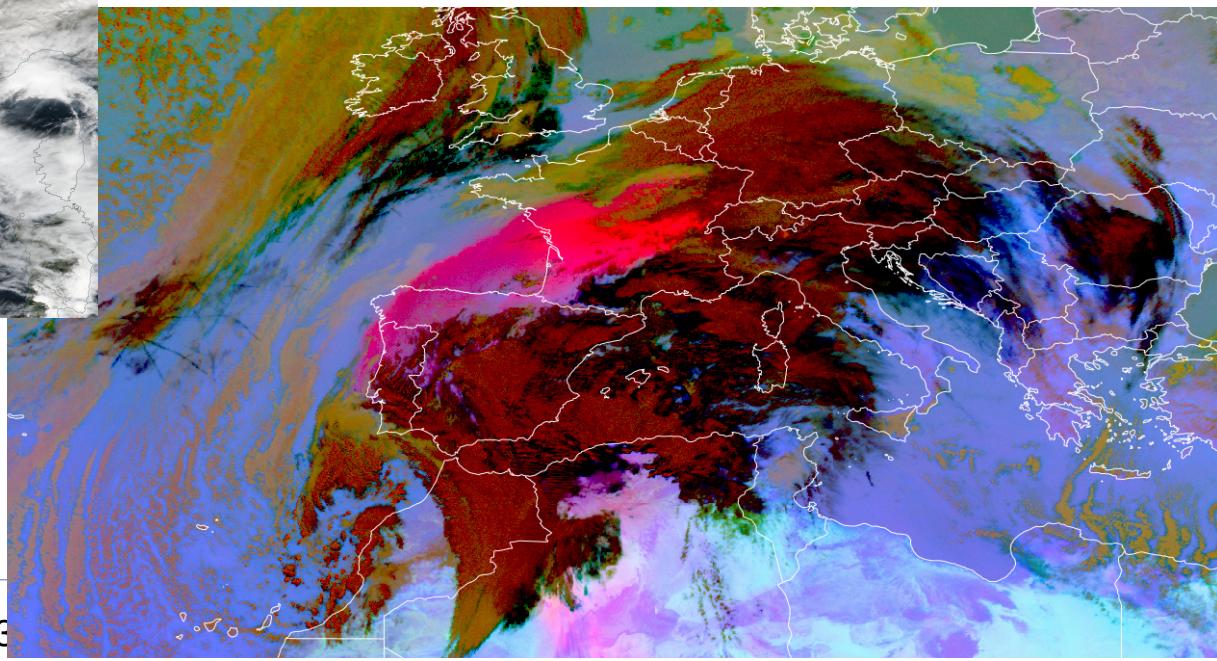
Dust outbreak over France: impact on temperature

- In March 2023 there was a dust outbreak over Europe that had a significant impact on temperature forecast but also on photovoltaic power generation.

Terra natural colour 15/03/2022 12 UTC



Seviri Dust 15/03/2022 09 UTC

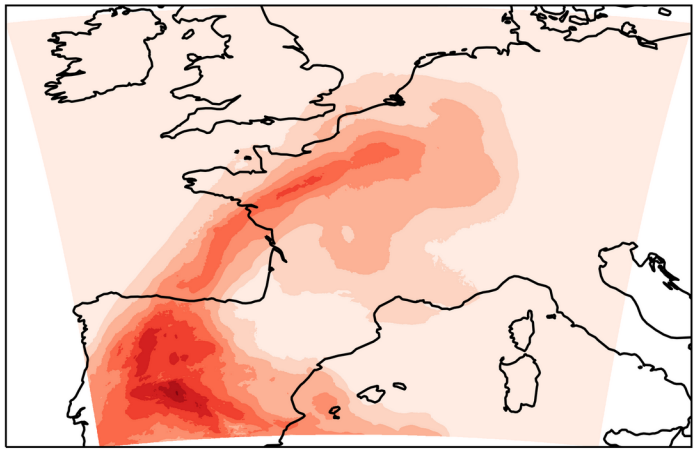


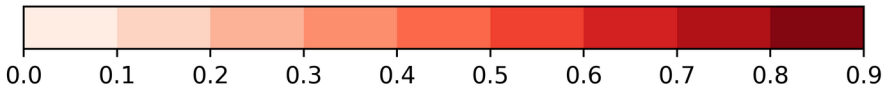
First step of in-line aerosol modelling

Dust outbreak over France: impact on temperature

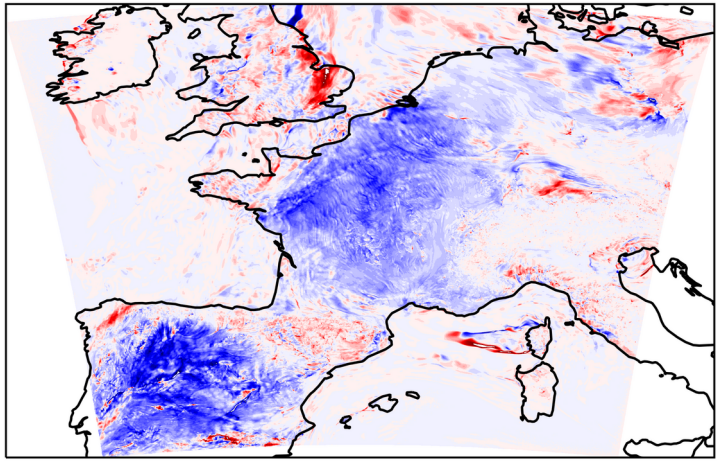
- AROME-Dust with dust lateral boundary conditions from MOCAGE
  - Usual AROME domain over France at 1.3 km resolution
- Impact on surface temperature around 1° over Spain and France
  - Reduction of the bias wrt to 2m temperature observations (not shown)
  - Still ~1° bias due to the formation of cirrus clouds
    - Need to work on aerosol-cloud interactions

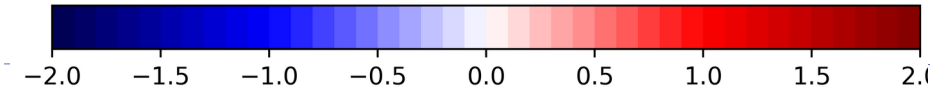
AOD 14TU





Temperature 14TU





Update

Conclusions & Perspectives

Next version of the MOCAGE model.

- New operational version of MOCAGE at 0.5° global resolution will be in production at the end of November
  - Results show finer representation of aerosol clouds, but without changing large scale behaviour
  - Technical issues mean that the data at 0.5° won’t be available immediately
  - New paradigm for us to monitor new types of observations to prepare future assimilation

Conclusions & Perspectives

New activities

- First attempt of assimilating IASI data for dust aerosols
  - First tests shows promising results but need more investigations
- We are initiating a move to in-line modelling activities:
  - AROME-Dust for now only is able to represent desert dust aerosols
    - Take into account radiation interaction, but has no aerosol-cloud interactions
    - Plans to go into production in 2024
  - An internal project is underway to create a library that will allow the use of chemistry and aerosols physical implementation and parametrization through Météo-France's model
    - ACCALMIE: Coordinated Approach for Chemistry and Aerosols in CNRM, Inline and offlinE Models
    - Will allow the use of MOCAGE's legacy in terms of chemistry and aerosols into AROME and ARPEGE NWP models.

      The other way around, the advance in terms of data assimilation within NWP models will be very helpful.