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

Jonathan Guth, Vincent Guidard, Mathieu Joly, Joaquim Arteta, Mickaël Bacles, François Besson, Olivier Coopmann, Béatrice Josse

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# 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.

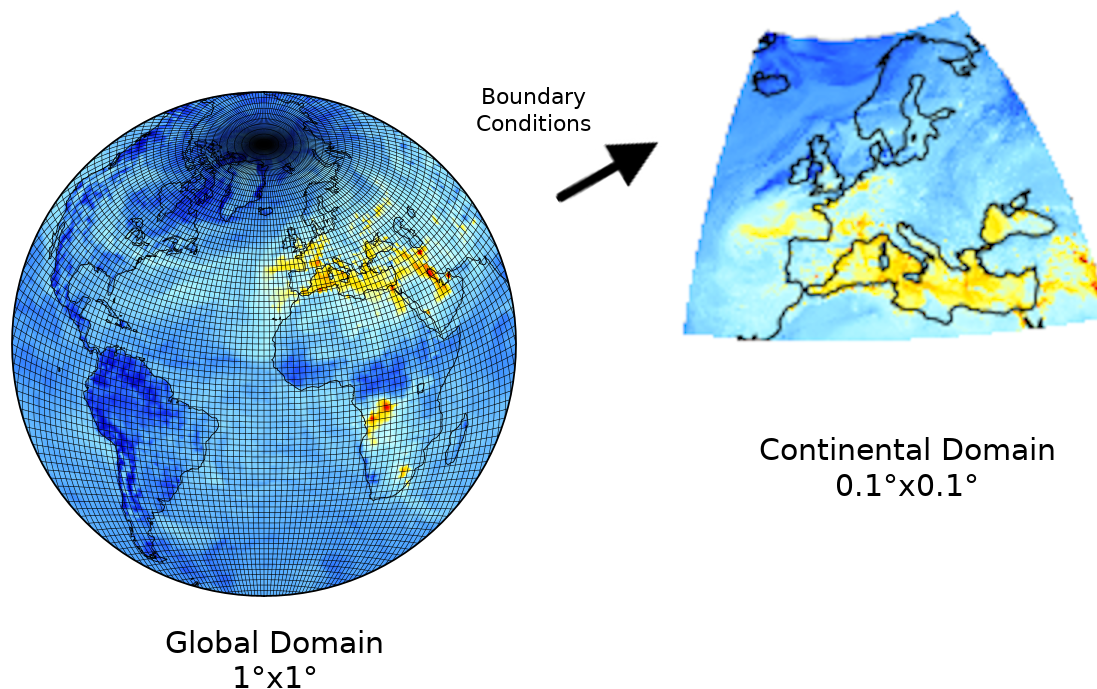
8<sup>th</sup> November 2023

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# MOCAGE operational configuration

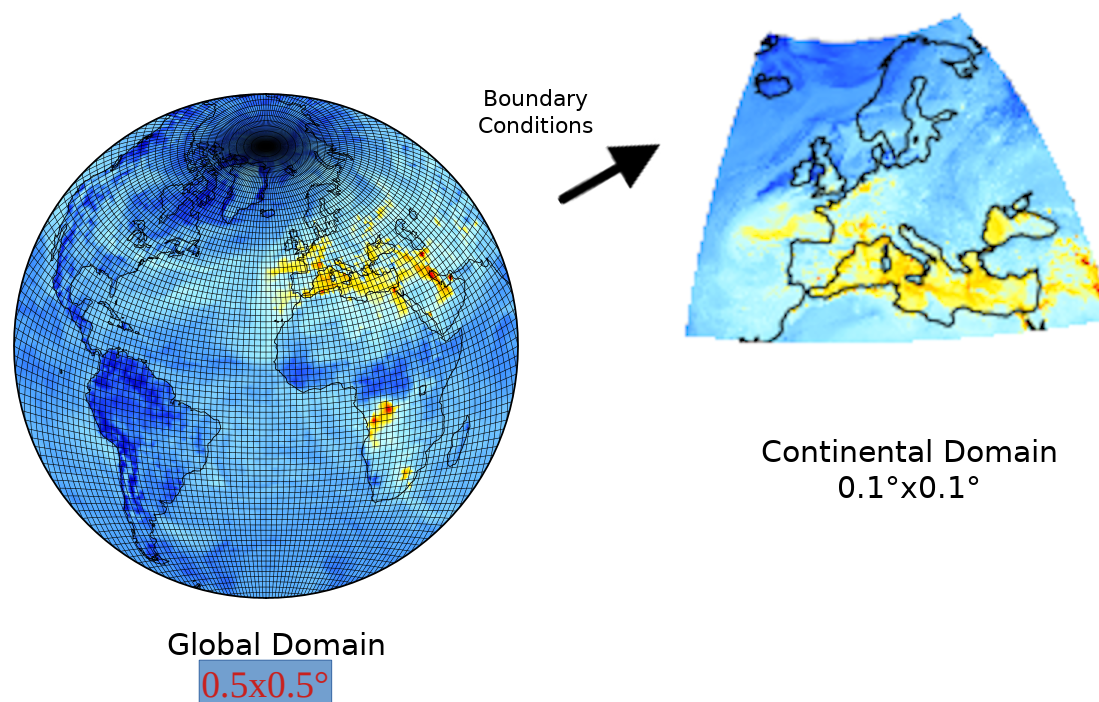
## Off-line chemistry transport model

- 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  $\sigma$ -hybrid vertical levels from surface to 5hPa



## 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  $\sigma$ -hybrid vertical levels from surface to 0.01 hPa



## 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)

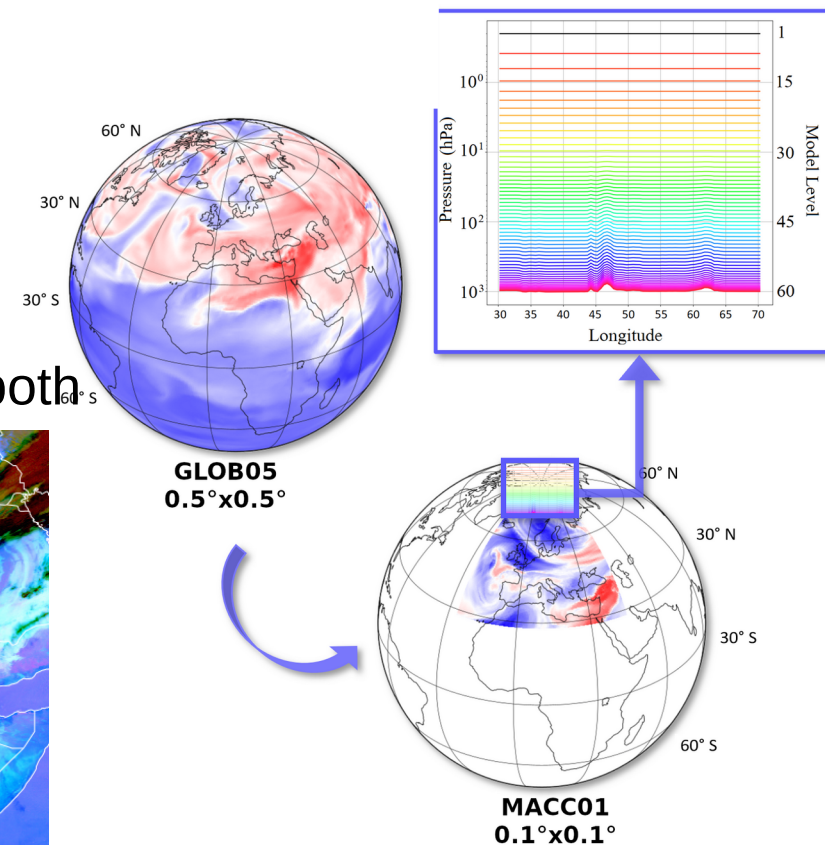
## European domain is used for:

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

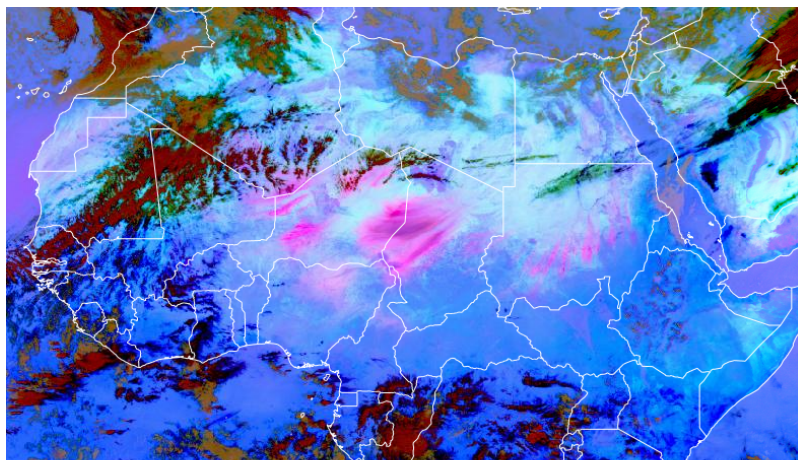
# New 0.5x0.5° and 60 levels version (no DA)

## Next operational version configuration:

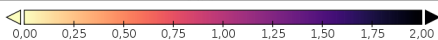
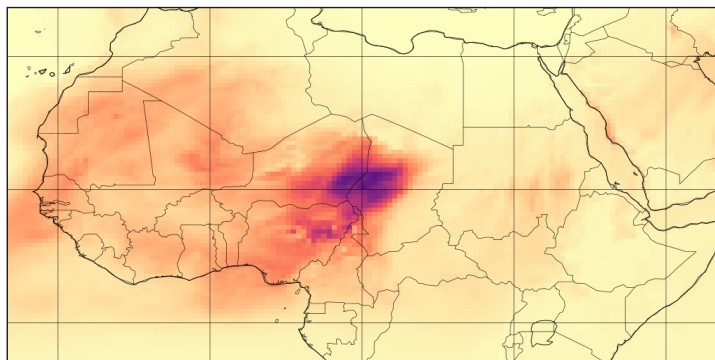
- Global domain at 0.5°x0.5° associated to a 0.1°x0.1° regional domain
- 60 vertical levels up to 0.01 hPa
- The general behaviour of aerosols is very similar in both versions



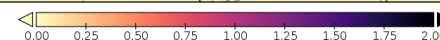
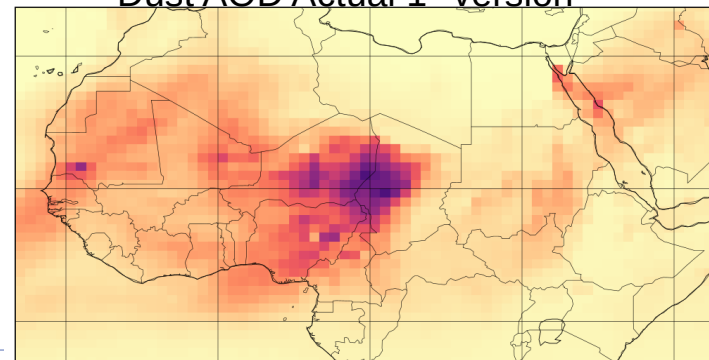
14/02/2023 12UTC  
Seviri RGB Dust



Dust AOD New 0.5° version



Dust AOD Actual 1° version



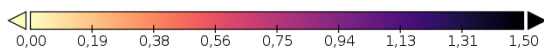
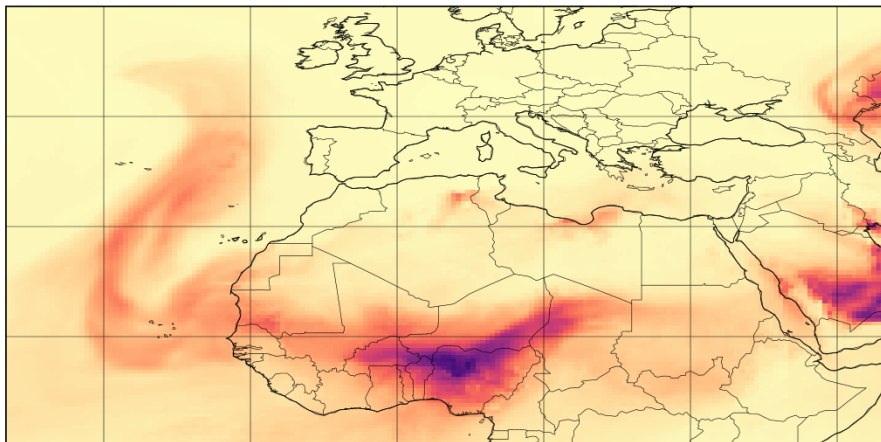
# New 0.5x0.5° and 60 levels version (no DA)

New 0.5° version

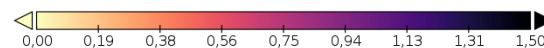
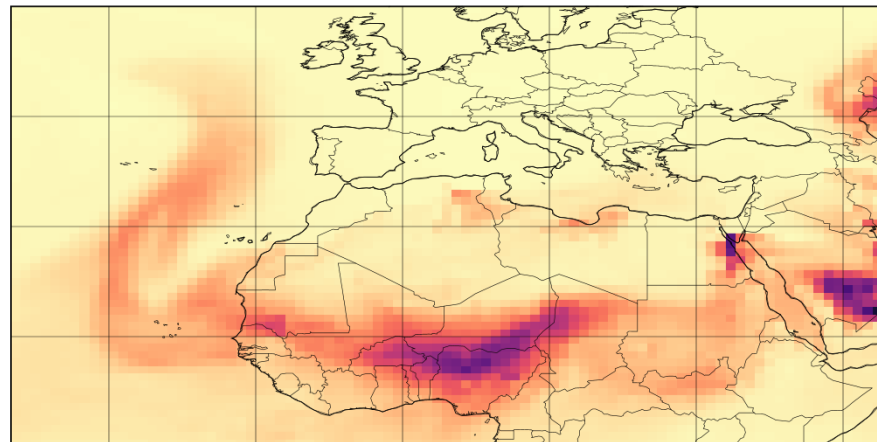
02/04/2023 12UTC

Actual 1° Version

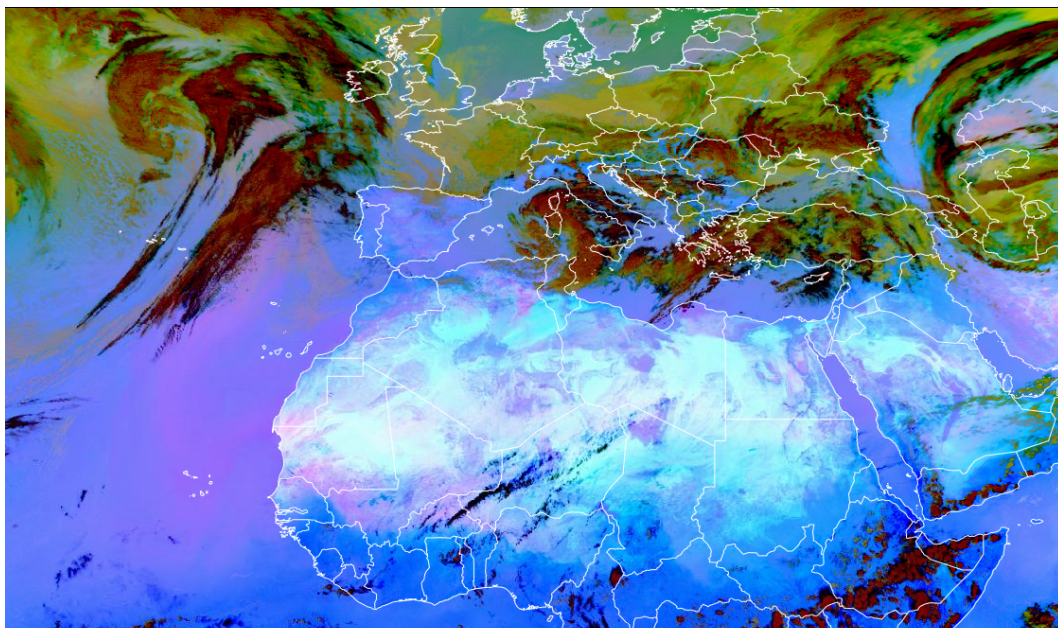
Desert Dust AOD  
0.5° resolution



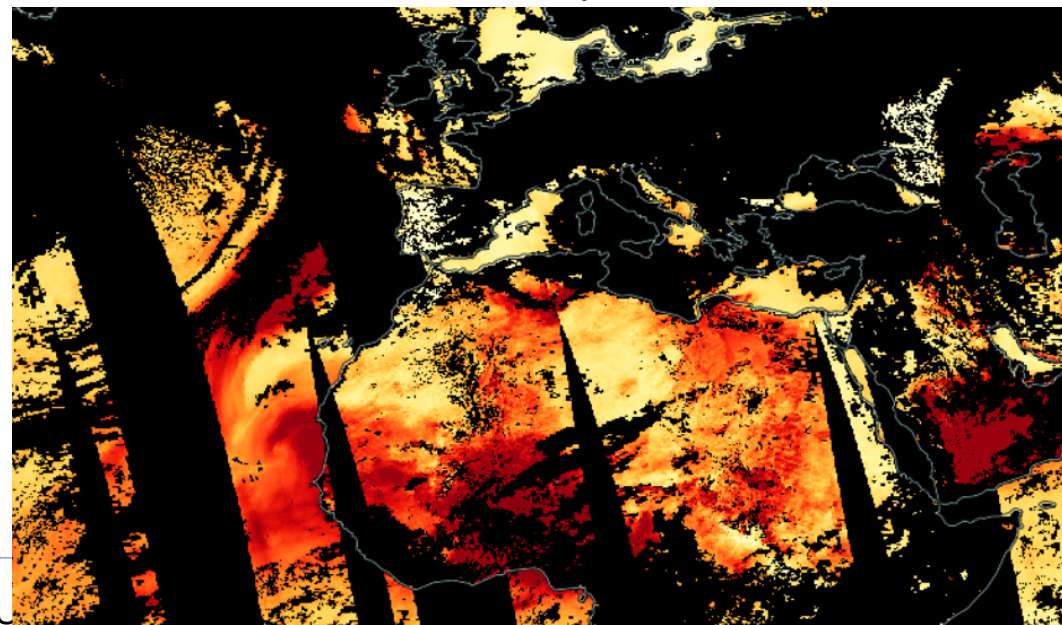
Desert Dust AOD  
1° resolution



Seviri Dust RGB



Aqua MODIS AOD





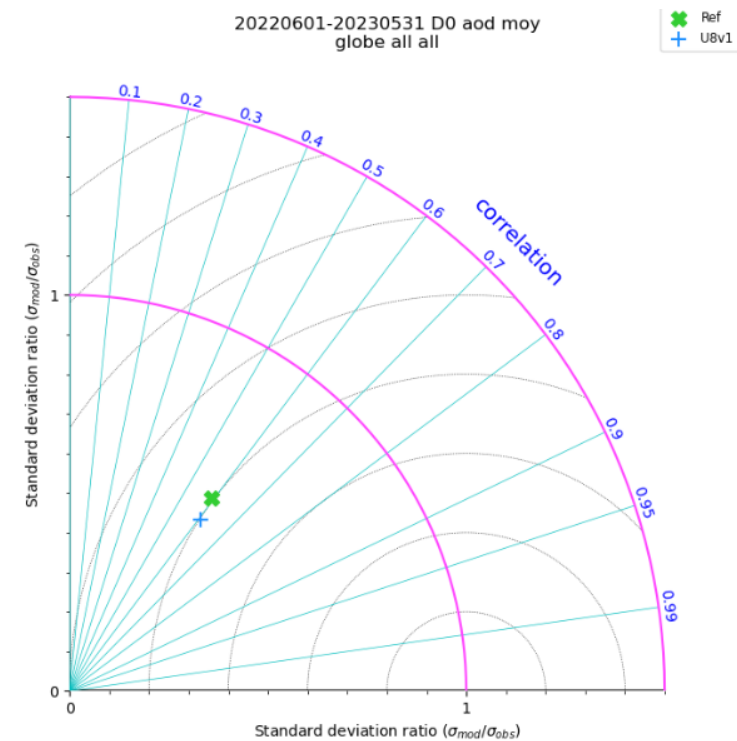
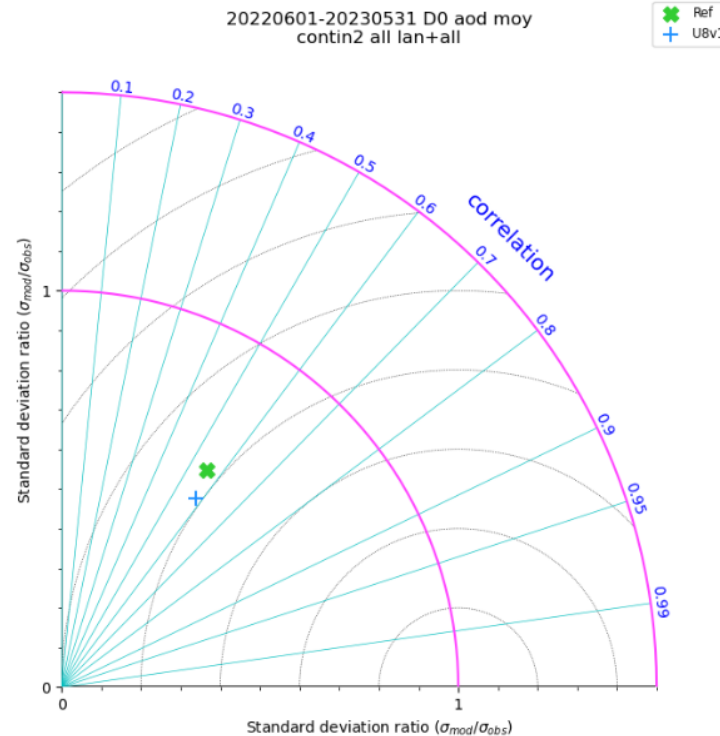
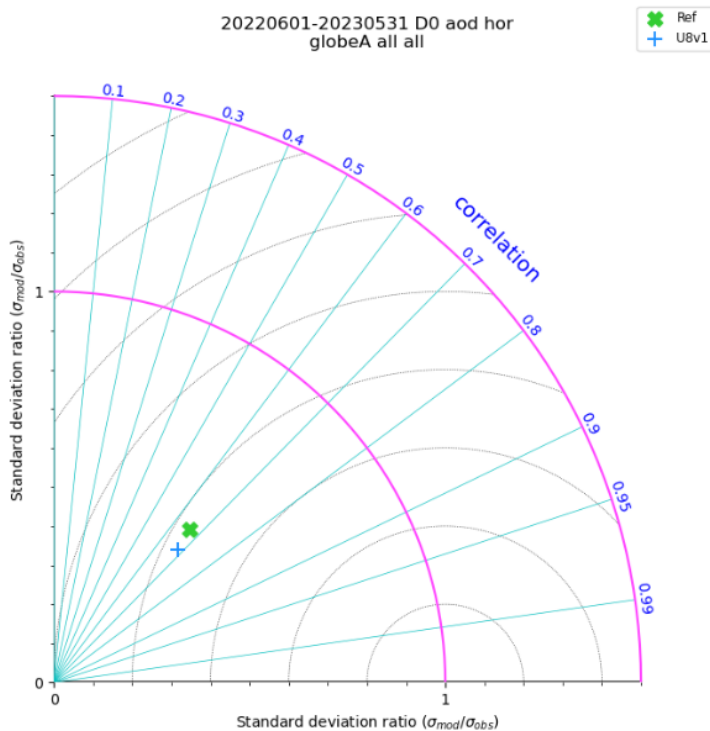
# New 0.5x0.5° and 60 levels version (no DA)

## 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)

## 3D-var algorithm using 1h windows:

- Global domain assimilation:
  - ▶ MODIS AOD
  - ▶ VIIRS AOD
  - ▶ TROPOMI SO<sub>2</sub> for volcanic events
  
- Regional domain assimilation:
  - ▶ MODIS AOD
  - ▶ 6 Lidars from Météo-France network (Mini-MPL)
  - ▶ E-profile telemeters (CHM15K at 1064nm)

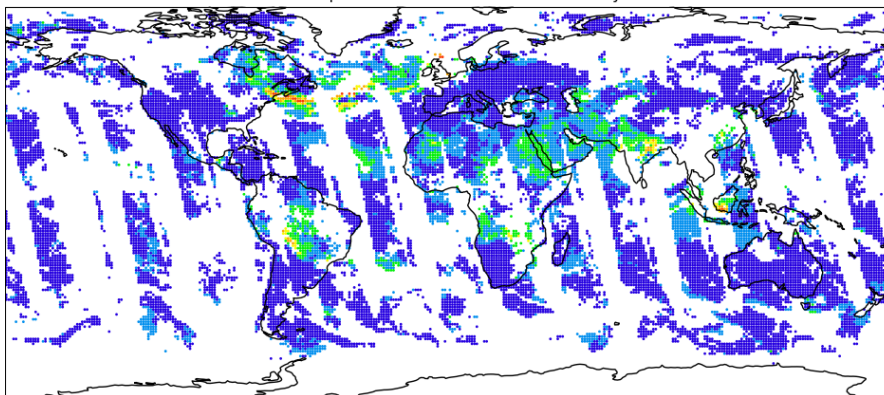
## 3D-var algorithm using 1h windows:

- Global domain assimilation:
  - ▶ MODIS AOD
  - ▶ VIIRS AOD
  - ▶ TROPOMI SO<sub>2</sub> for volcanic events
  - ▶ **Added monitoring of IASI SO<sub>2</sub> Cris O<sub>3</sub> 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 SO<sub>2</sub> data**

## Example of a daily satellite AOD usage (20230928):

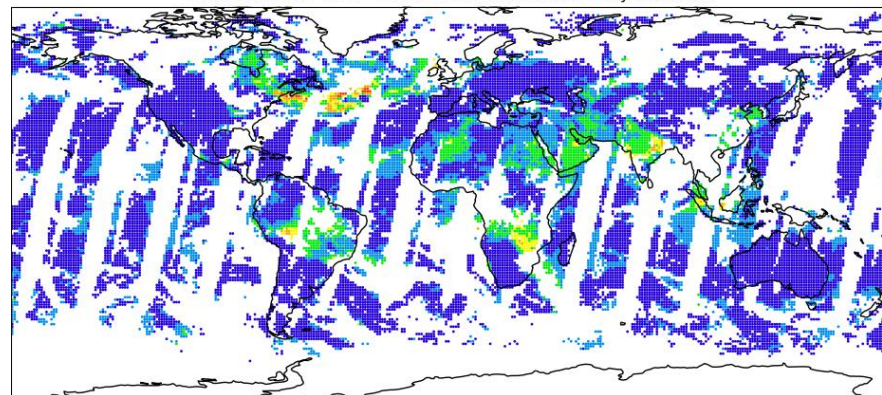
### MODIS - Aqua

MODIS Satellite Aqua - 3023108 Obs used values - Day 20230928



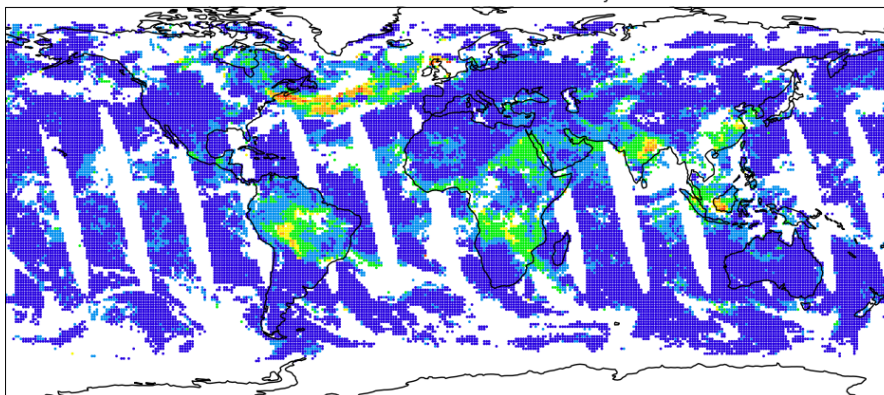
### MODIS - Terra

MODIS Satellite Terra - 3023268 Obs used values - Day 20230928



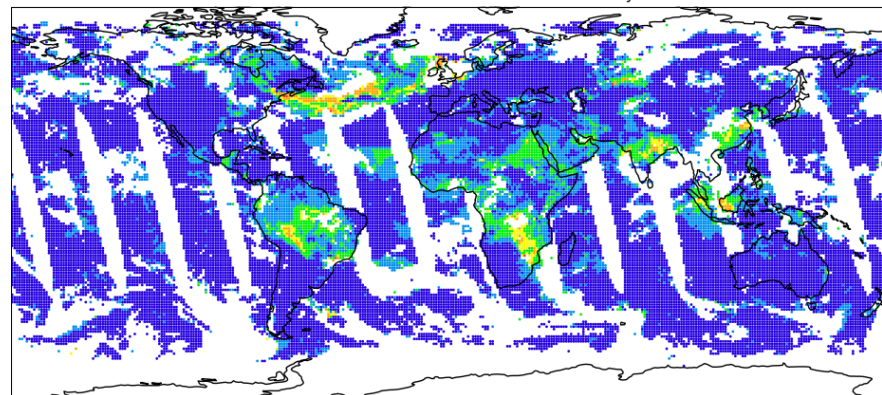
### VIIRS - S-NPP

VIIRS Satellite NPP - 6825216 Obs used values - Day 20230928



### VIIRS - NOAA-20

VIIRS Satellite NOAA20 - 6826367 Obs used values - Day 20230928

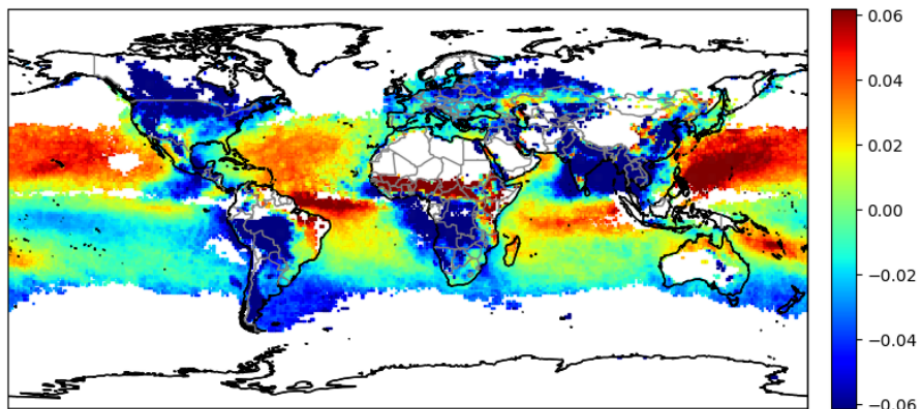


## Impact of satellite AOD assimilation:

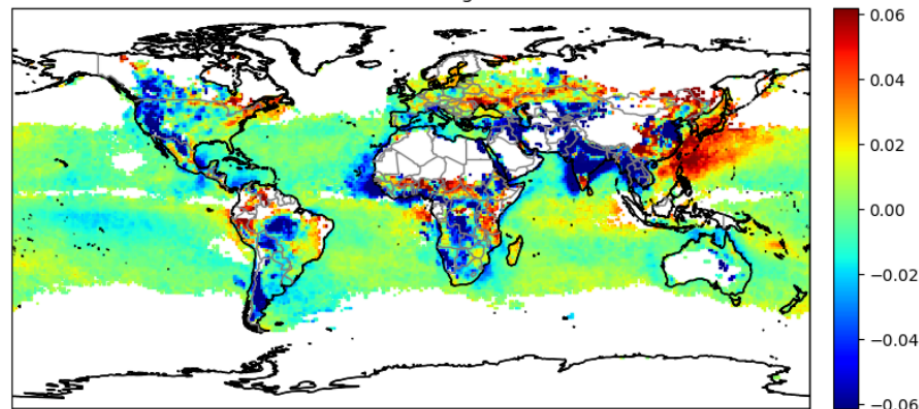
- Scores over a 1 year period June 2022 to May 2023 wrt MODIS Daily L3

Bias of AOD forecasts at 24h forecast range

with DA



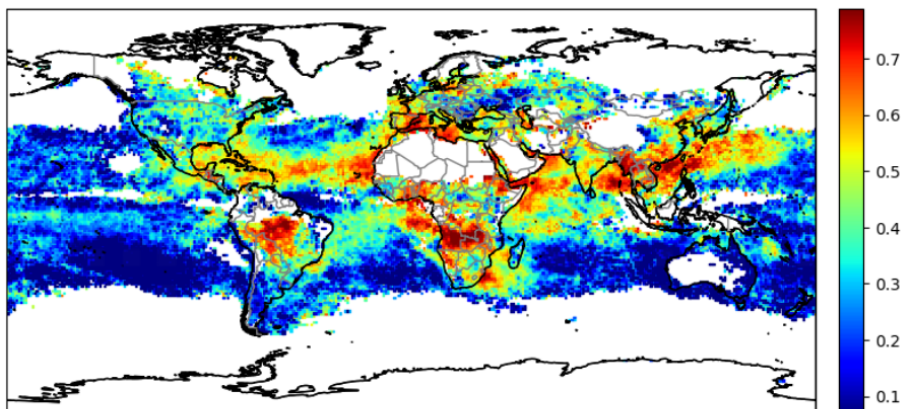
27775 processed stations over 27821  
min: -3.32, avg: -0.01, max: 0.29



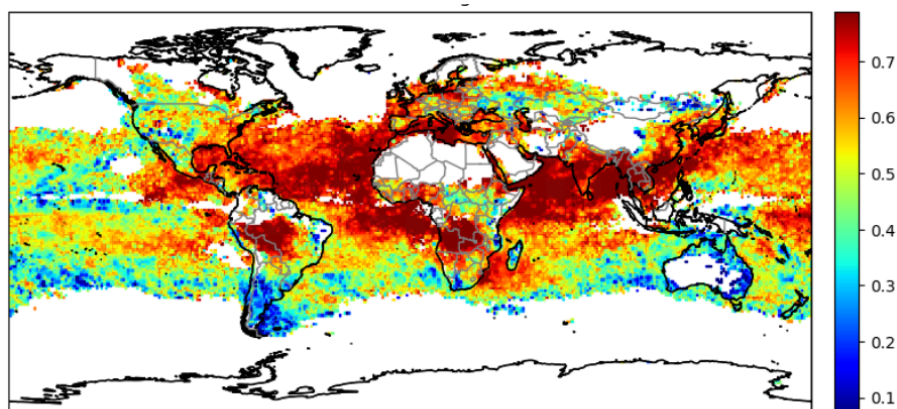
27775 processed stations over 27821  
min: -3.32, avg: -0.0, max: 0.24

Correlation of AOD forecasts at 24h forecast range

with DA



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

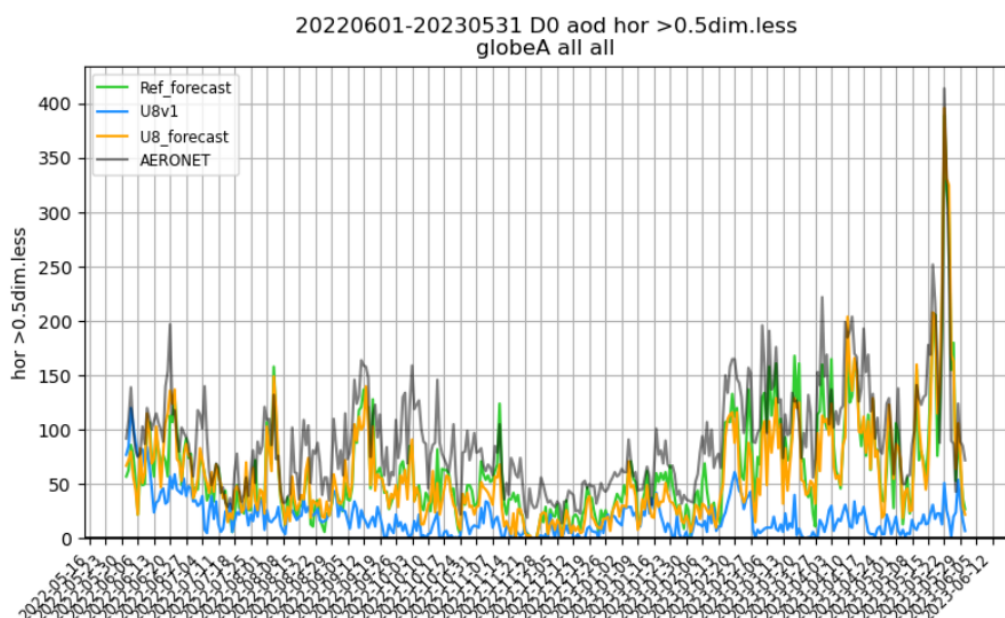


27775 processed stations over 27821  
min: -0.27, avg: 0.58, max: 0.94

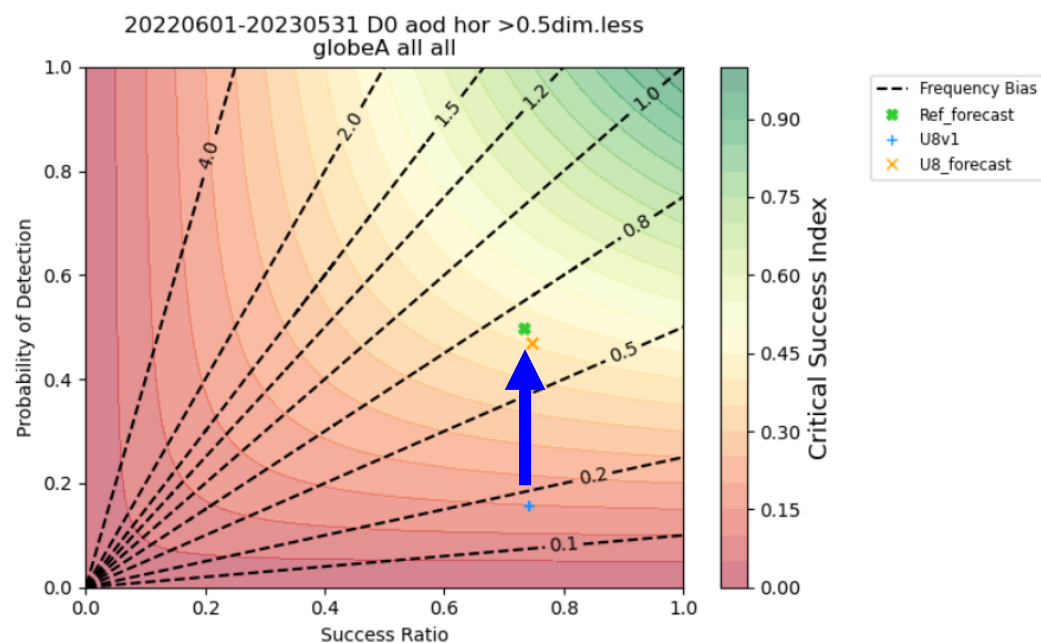
## Impact of satellite AOD assimilation on 24h forecasts:

- 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)

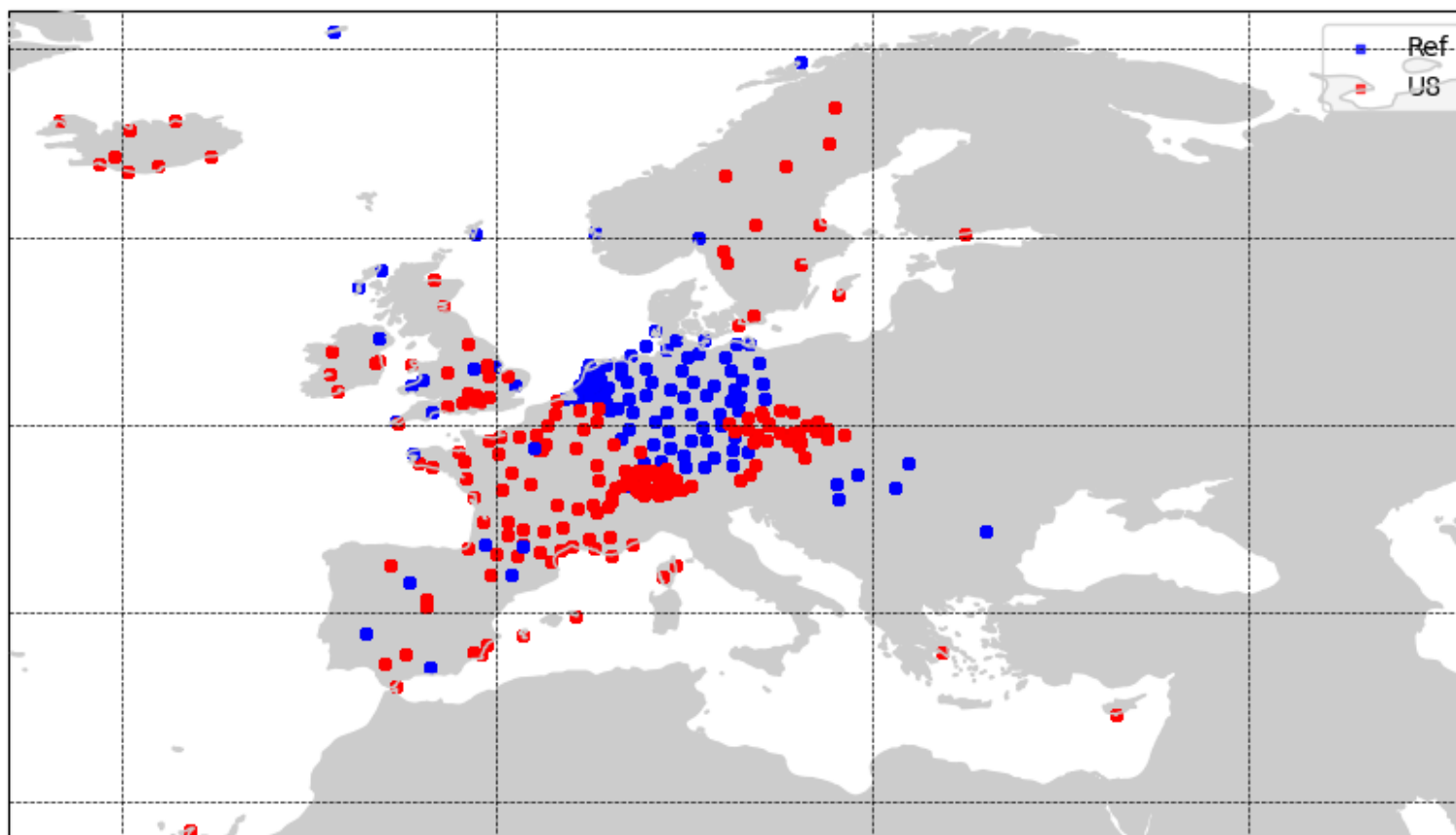
**Blue** : No assimilation

**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.

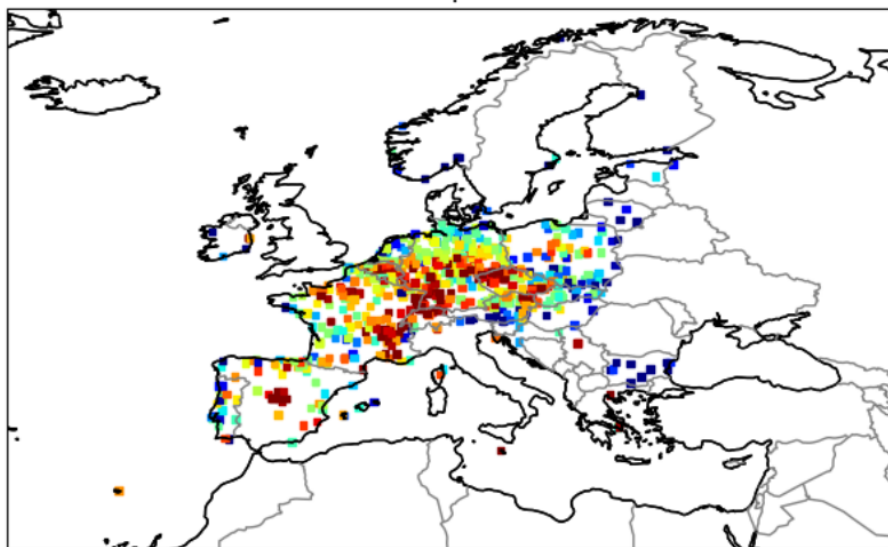


## Added value of supplementary ceilometers data to the assimilation system:

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

Correlation – PM10 at surface – all e-profile

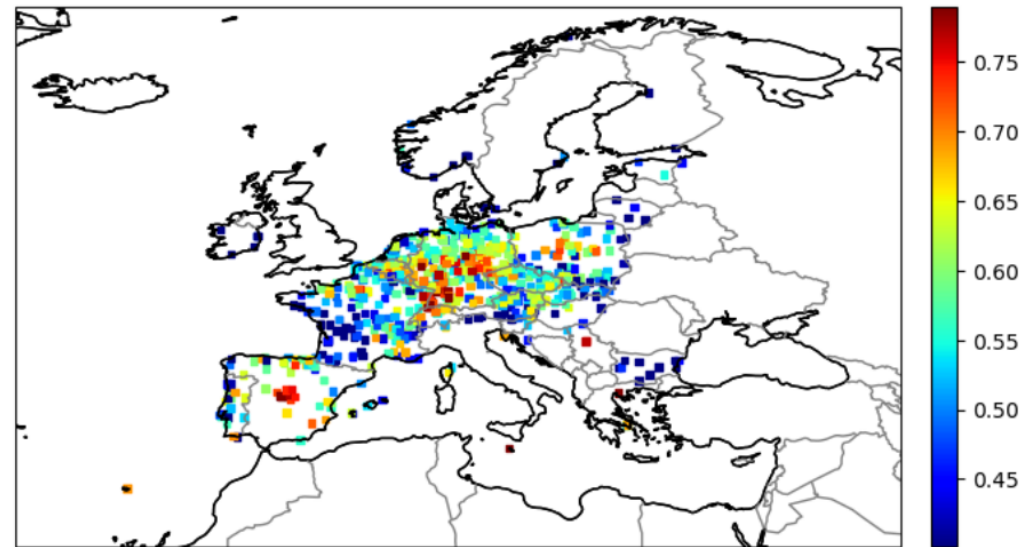
PearsonR moy pm10 assim\_eprofile D0  
20230101-20230531 europe2 1-2-3-4-5-6-7 all+bac



748 processed stations over 759  
min: 0.02, avg: 0.63, max: 0.92

Correlation – PM10 at surface – only miniMPL+CHM15K

PearsonR moy pm10 OPER D0  
20230101-20230531 europe2 1-2-3-4-5-6-7 all+bac



748 processed stations over 759  
min: 0.02, avg: 0.56, max: 0.88

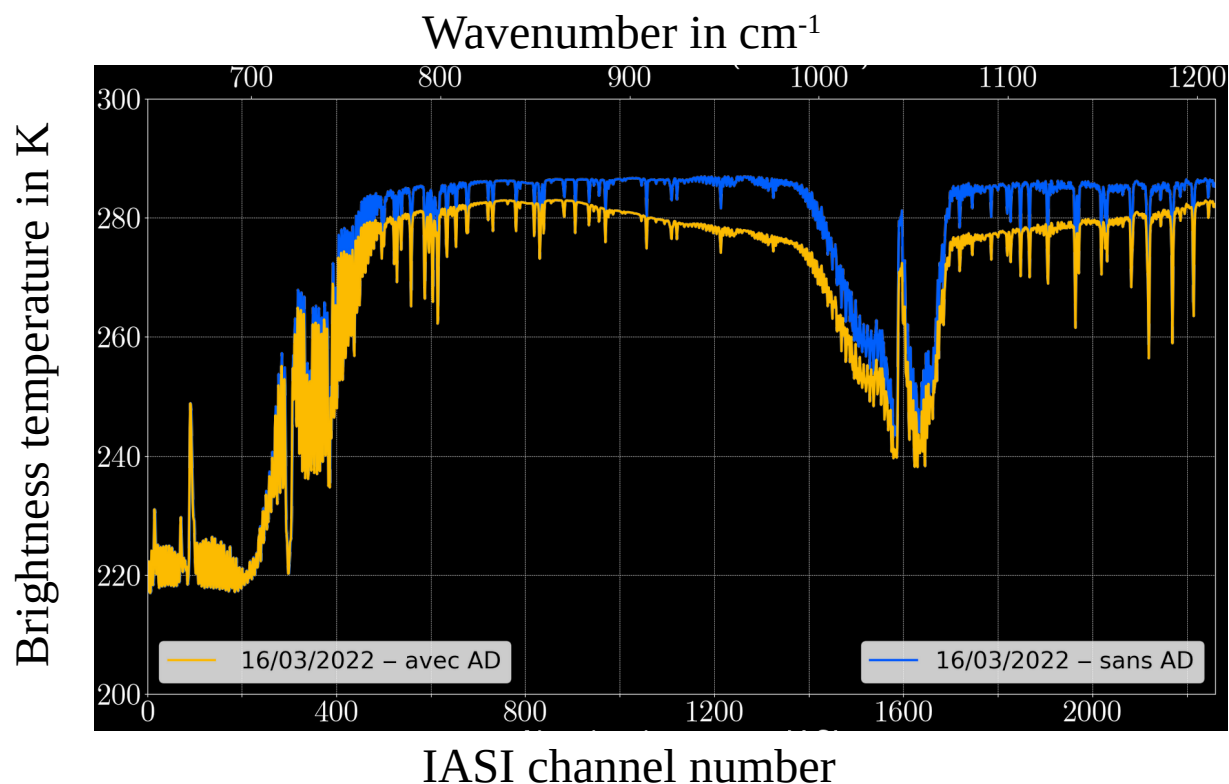


## Let's have a look into research studies

## 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

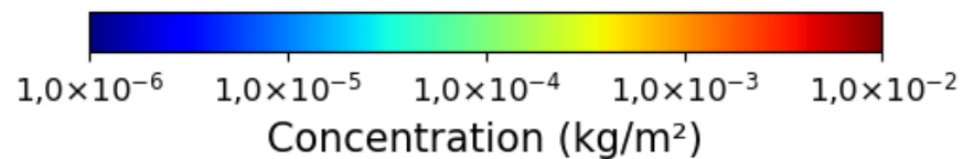
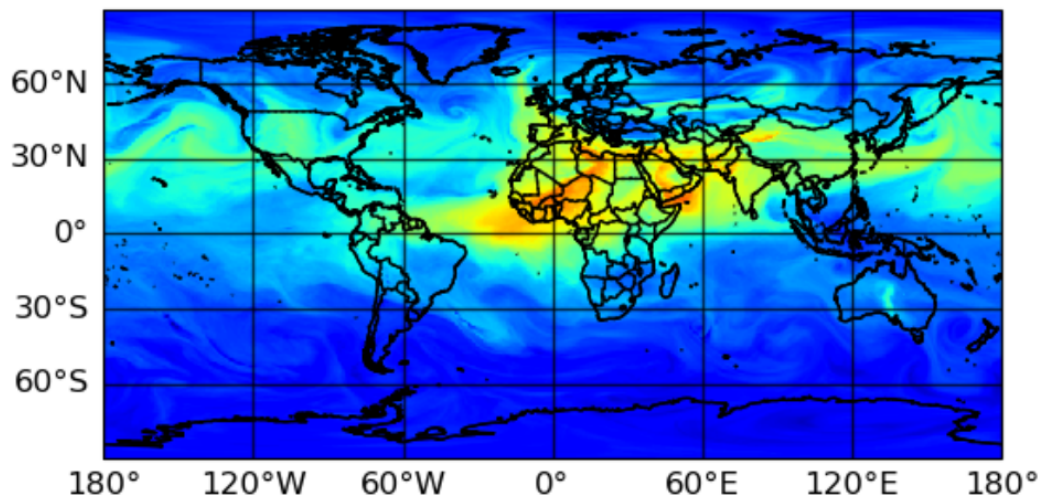
- With Desert Dust —
- Without Desert Dust —



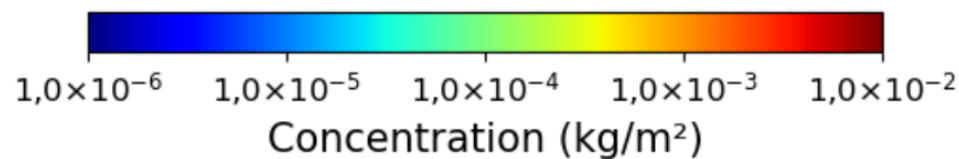
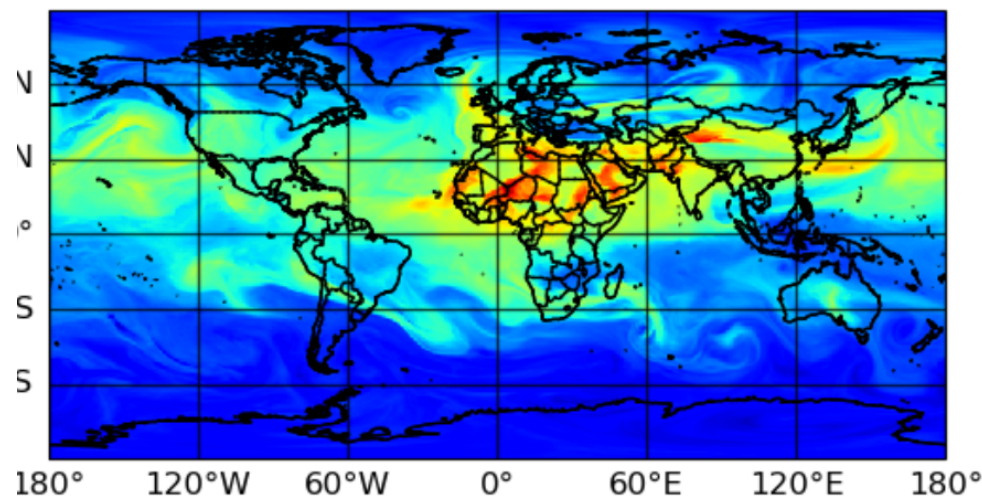
## Impact of desert dust in RTTOV simulation of IASI spectrum

- 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

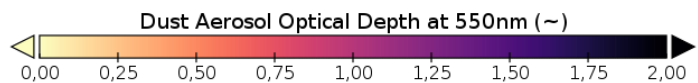
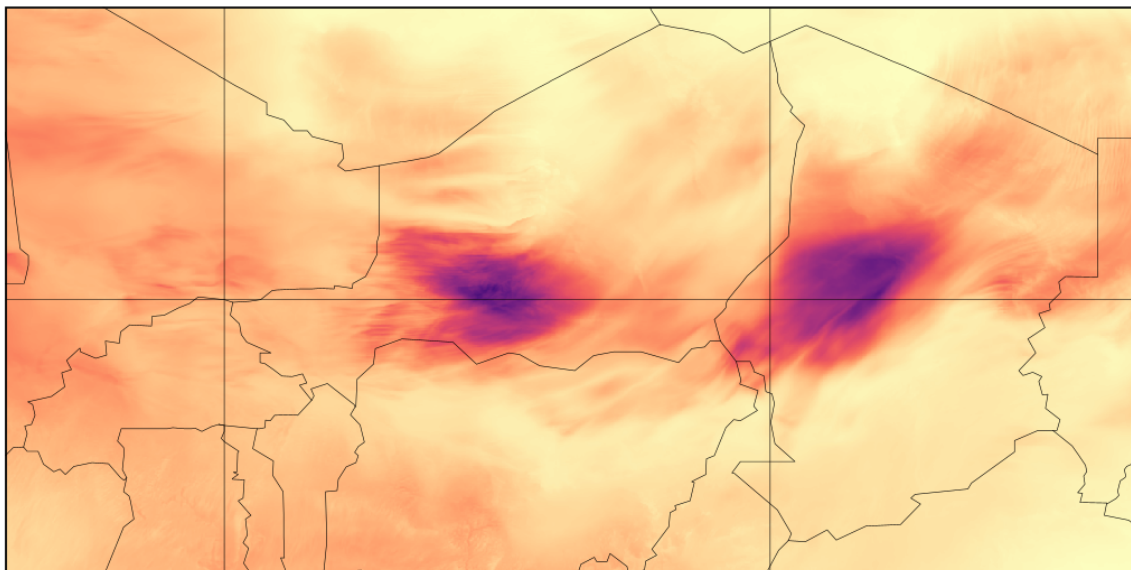


## Dust modelling with the AROME NWP model

- 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 microphysical processes.

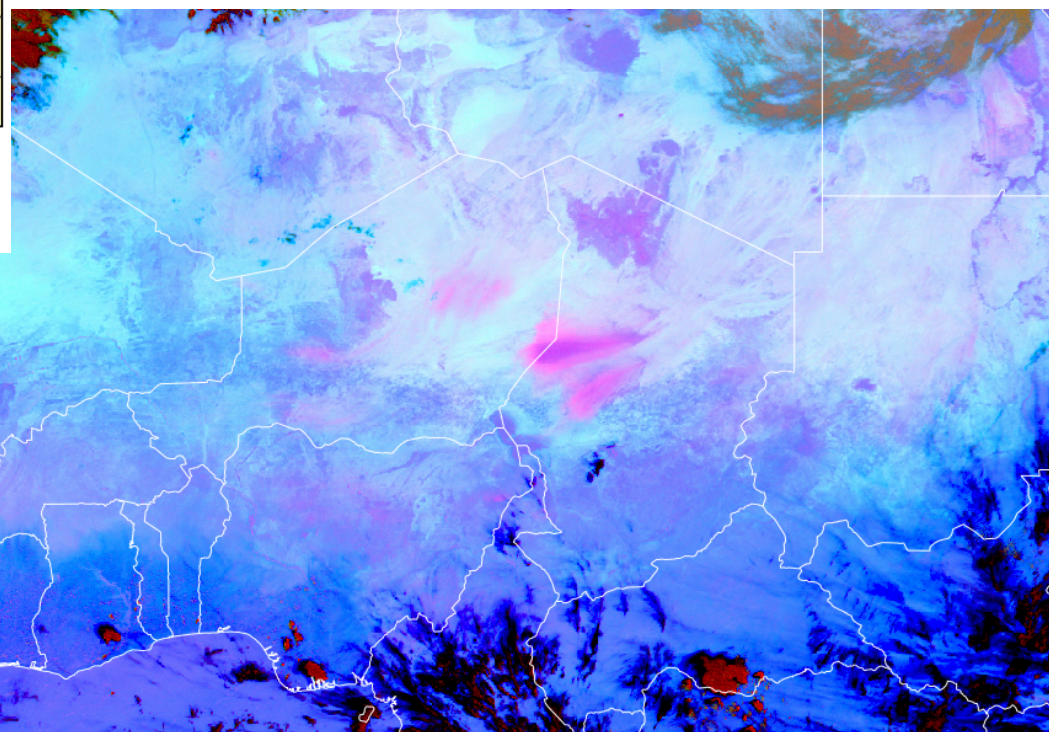
## Forecast over Sahel region: 24 February 2022

Epaisseur optique à 550nm  
24-02-2022 14TU



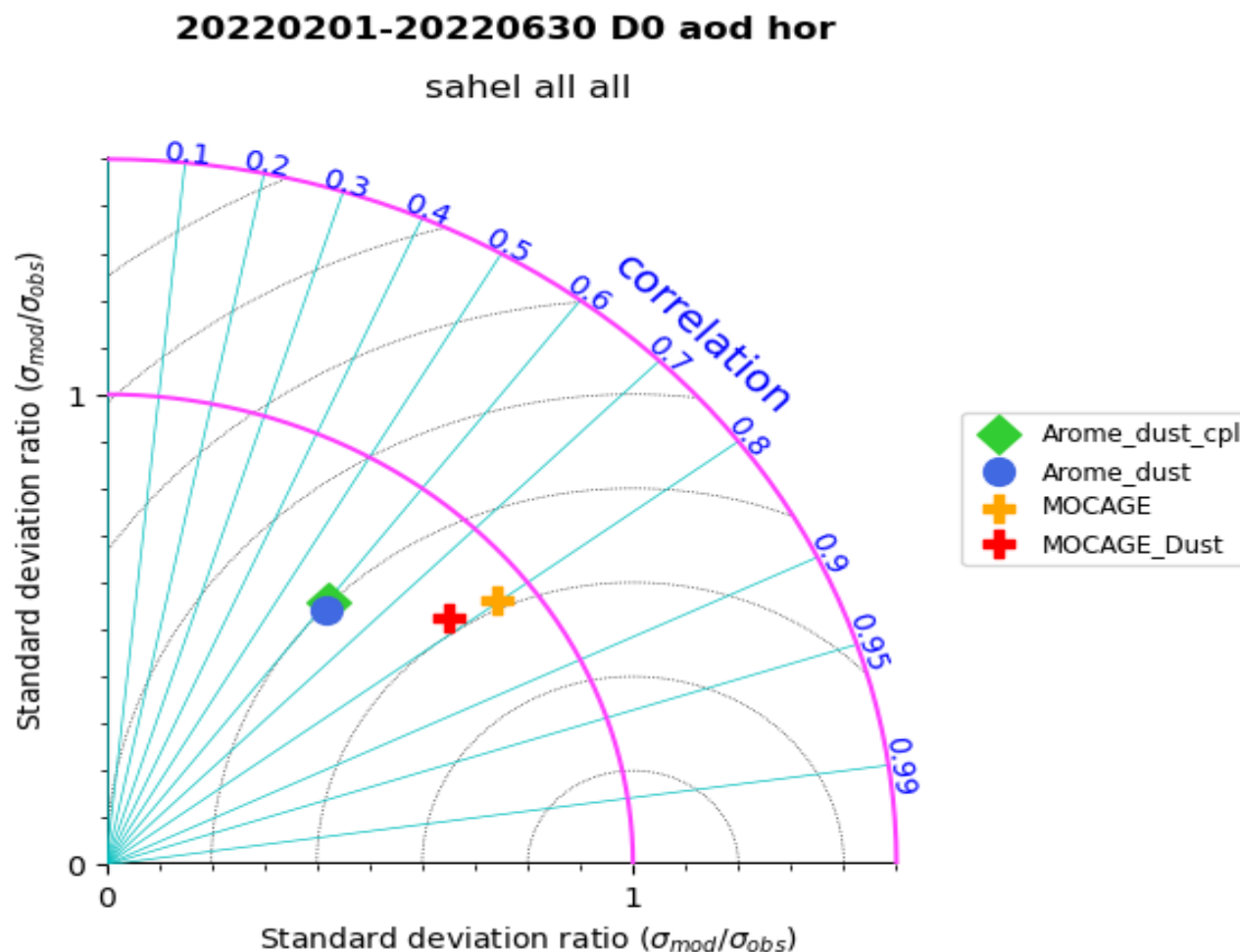
AROME-Dust AOD, 2.5 km resolution

MSG Seviri RGB Dust



## Comparison with AERONET data on Sahel domain

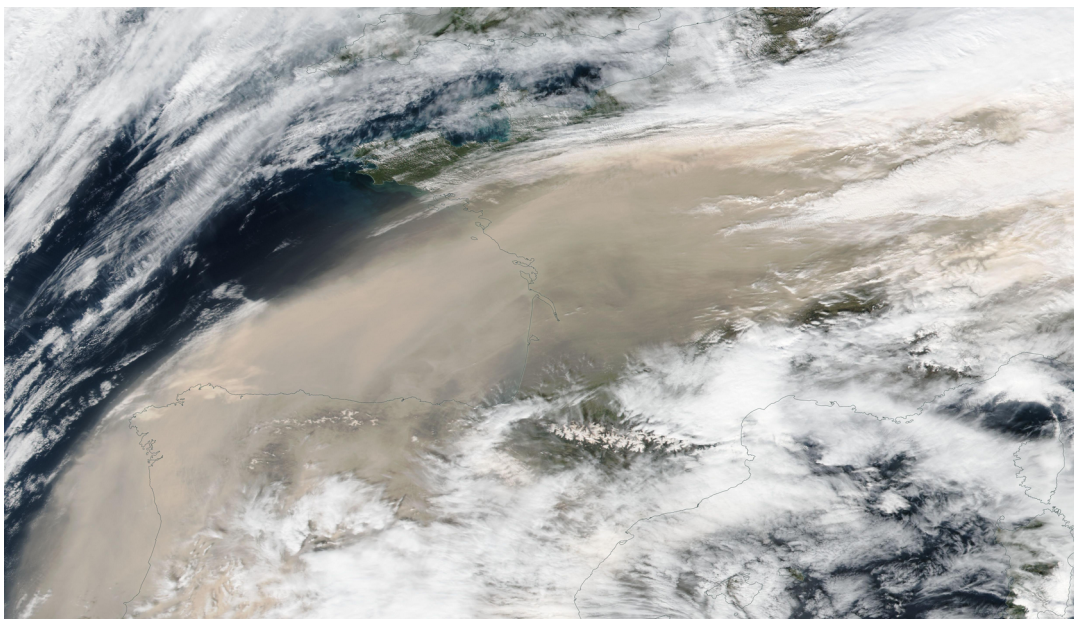
- 5 months between February and June 2022



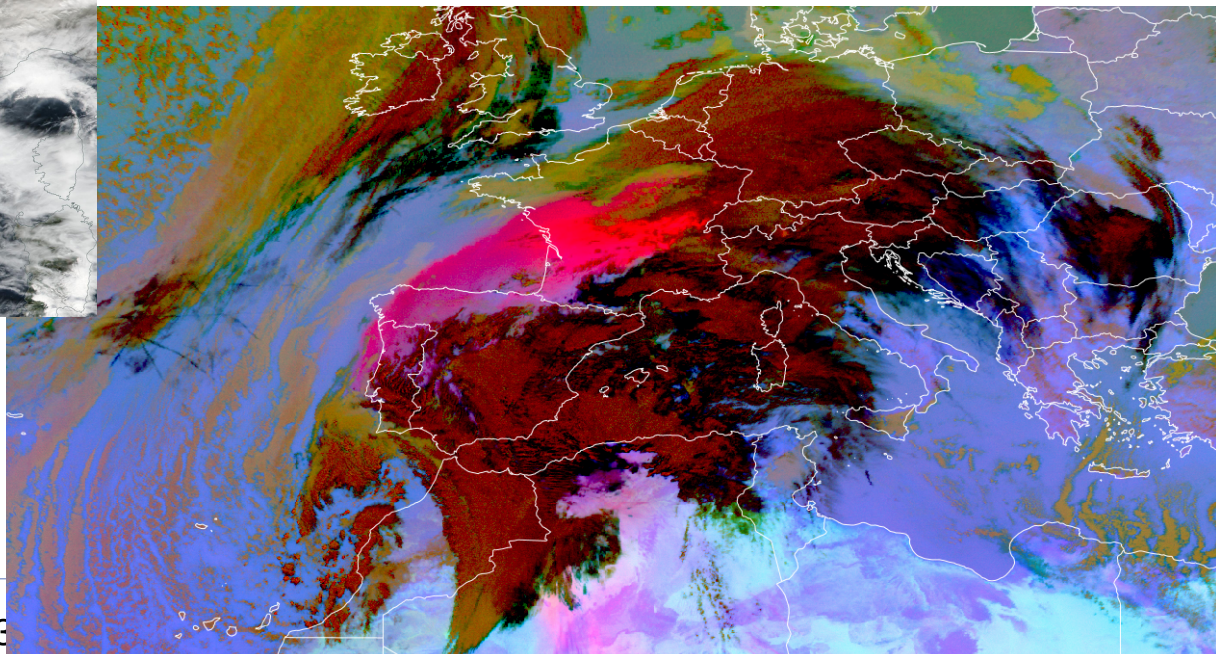
## Dust outbreak over France: impact on temperature

- 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



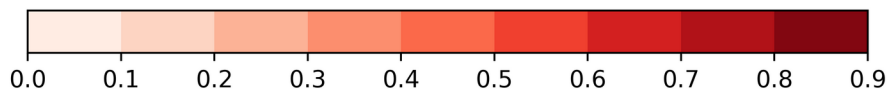
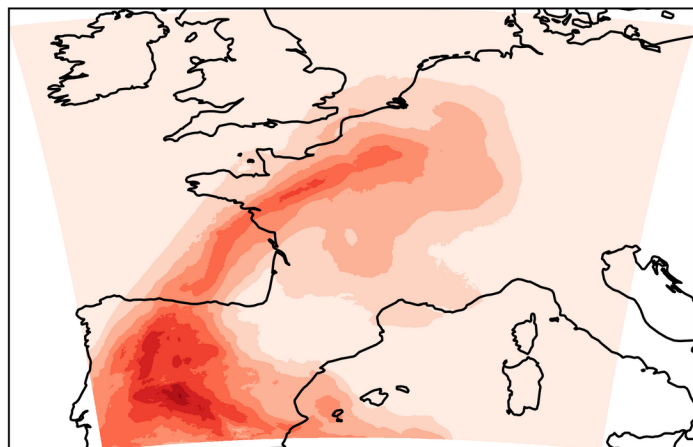
Seviri Dust 15/03/2022 09 UTC



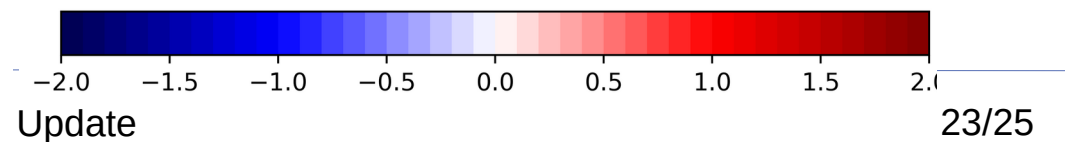
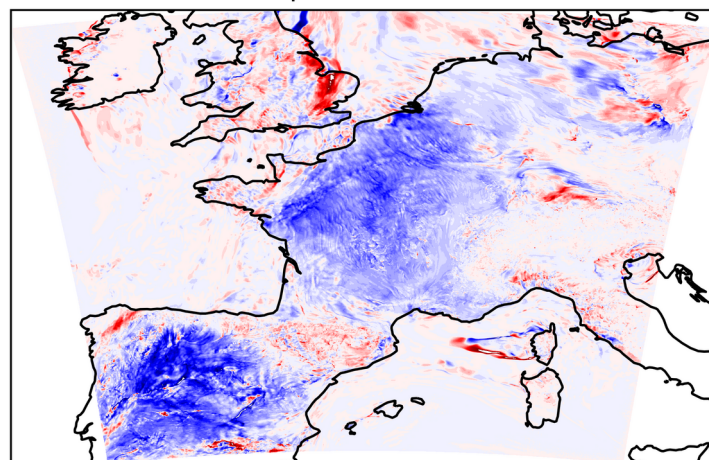
## Dust outbreak over France: impact on temperature

- 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





## 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

## 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.