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

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Sophie Pelletier

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

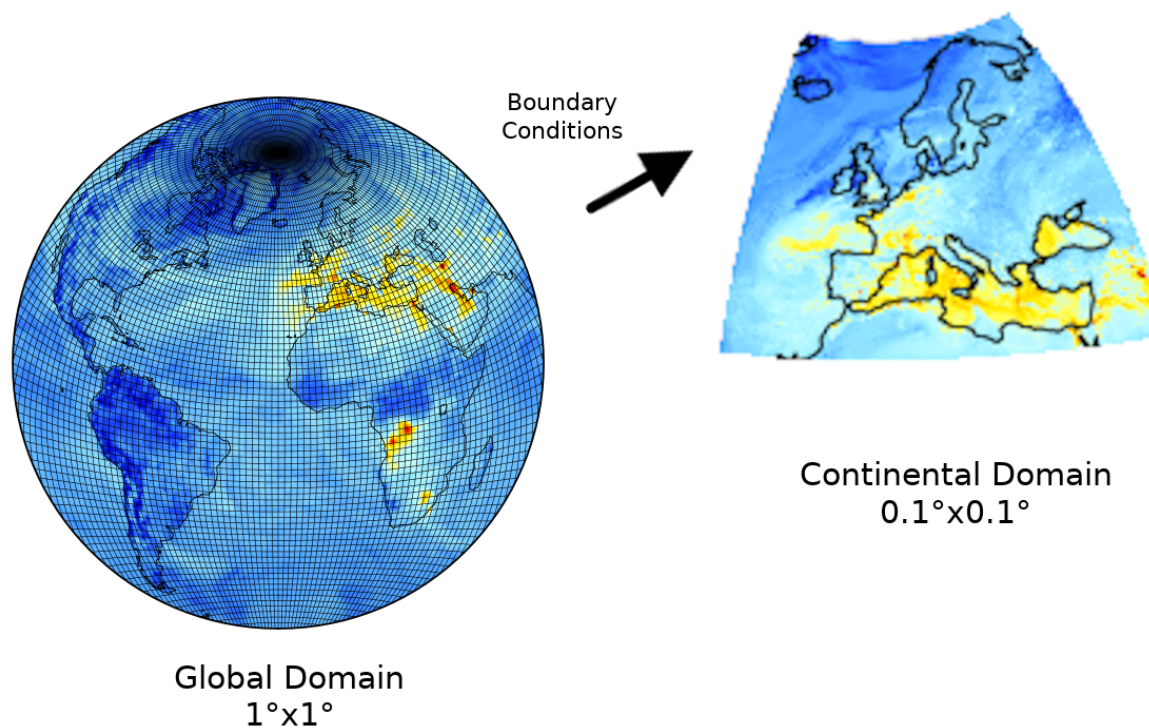
Guth. J, Josse B., Bacles M., Guidard. V, Perrot A., Pannekoucke O., Joly M.,
Meeziane M., Petiot V., Pelletier S.
CNRM/Météo-France, Toulouse, France

18.10.2022

Technical Working Group Meeting, Monterrey California

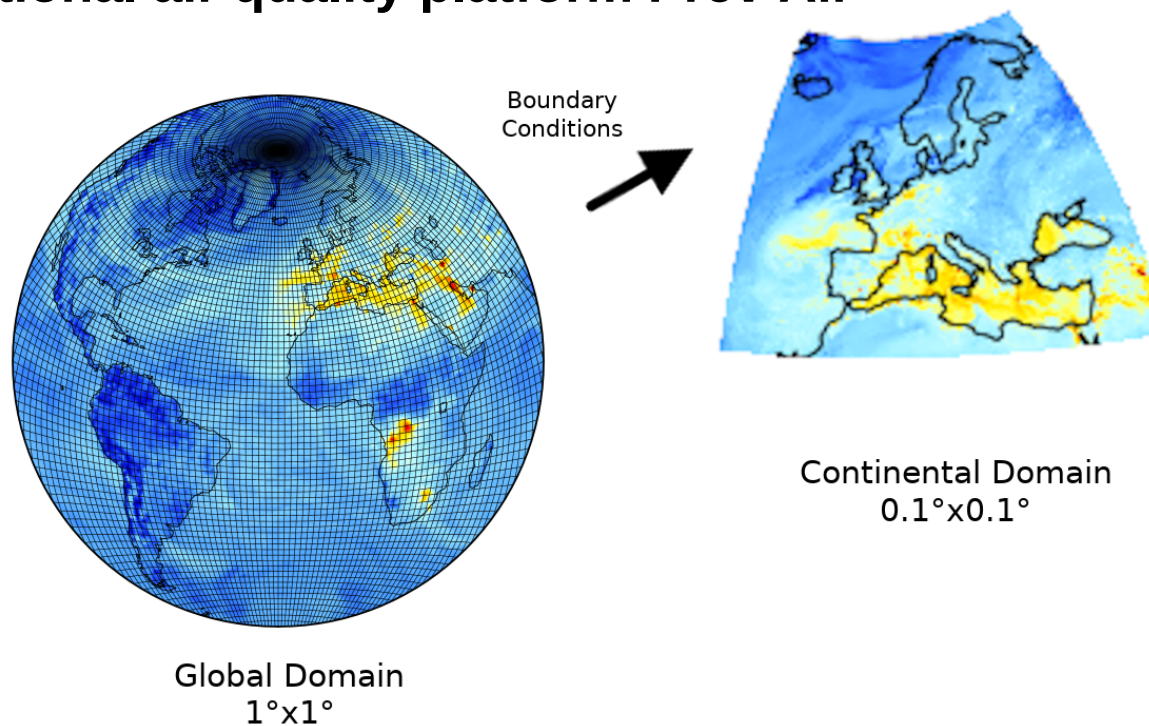
The MOCAGE model : general features

- Off-line Chemistry Transport Model
- Semi-lagrangian transport scheme with convection and diffusion
- RACM + REPROBUS chemical scheme, DD, SS, POC, BC, SIA, SOA
- 47 σ -hybrid vertical levels from surface up to 5 hPa



The MOCAGE model : general features

- **Global domain is used for :**
 - **ICAP** → Connection with this community in order to improve our model
 - **Participation to forecast of the WMO Dust Regional Center at BSC**
 - <https://dust.aemet.es/products/daily-dust-products>
 - **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**



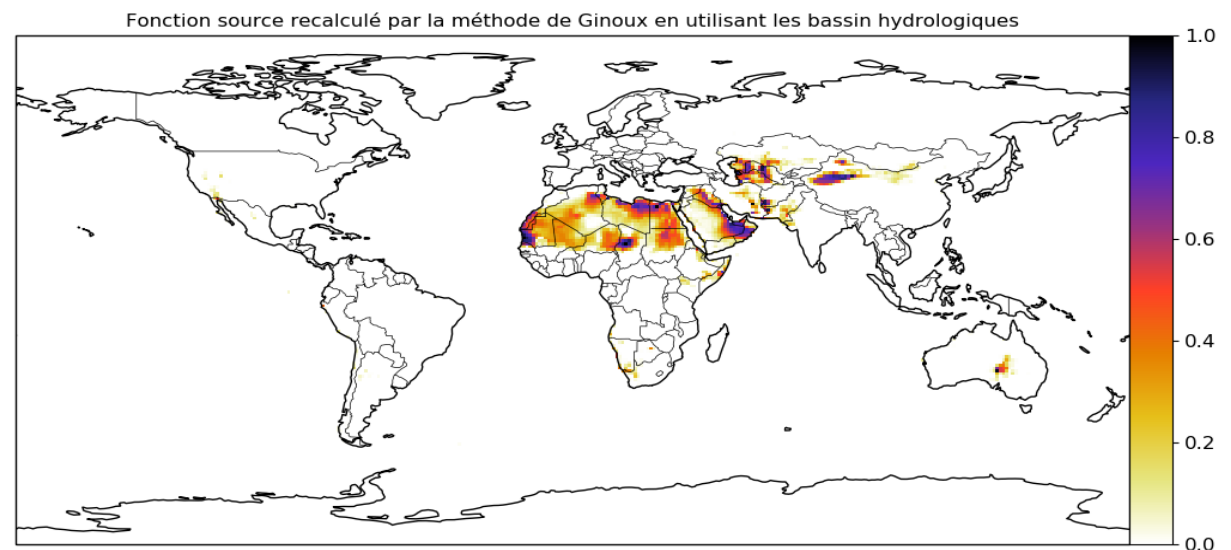
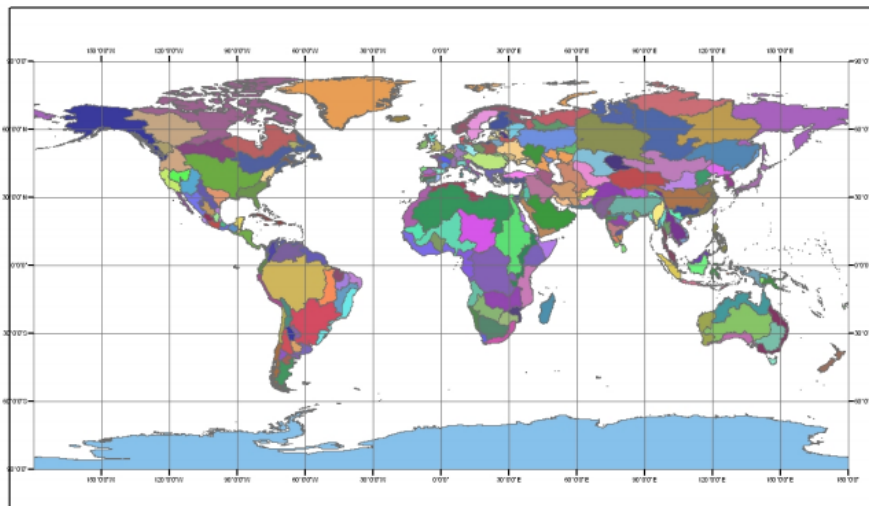
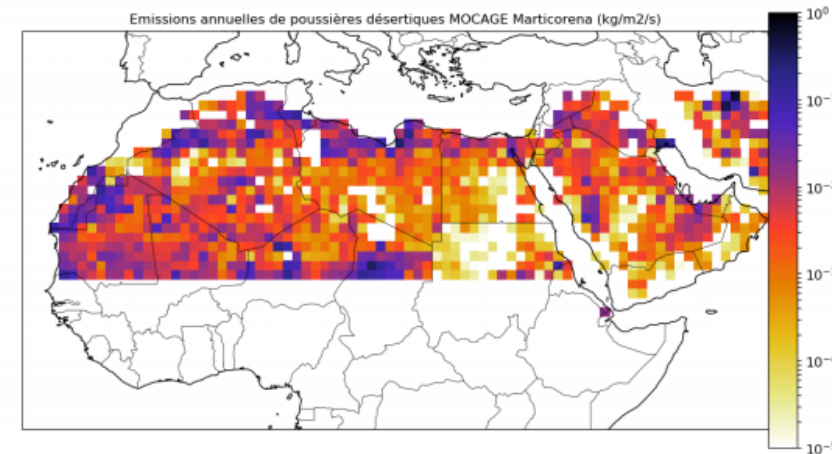
Developpement of a new dust emission scheme

New dust emission scheme

Historical Marticorena parameterisation VS Ginoux (2001)

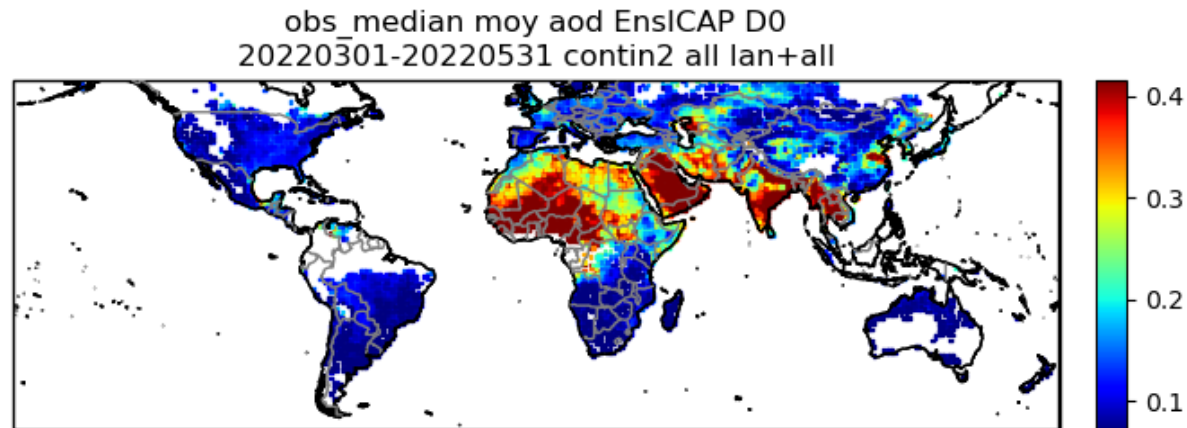
- Marticorena et Bergametti (1995) : efficient but limited by the geographical extension of original soil data
- Ginoux (2001) emissions are based on a map of potential sources representing accumulation of sediment in geographical depression.
- We calculated this source map based on hydrological basin and elevation data

$$S = \left(\frac{z_{max} - z_i}{z_{max} - z_{min}} \right)^5$$



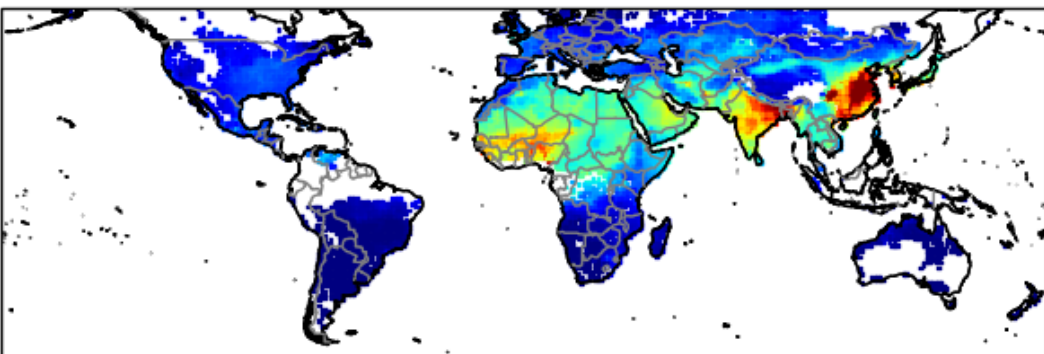
New dust emission scheme

- AOD comparison vs ICAP Ensemble considered as a reference (MAM 2022)
- Better results with Ginoux emission scheme (right)



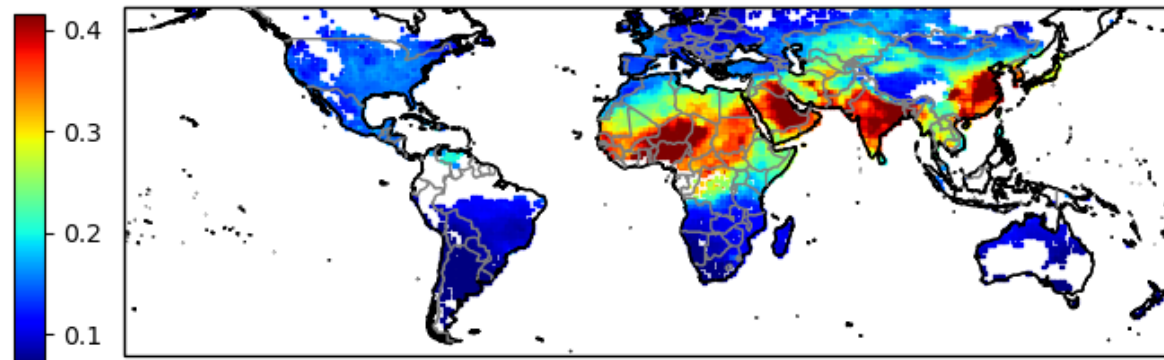
8294 processed stations over 8314
min: 0.05, avg: 0.22, max: 1.25

sim_median moy aod L47 D0
20220301-20220531 contin2 all lan+all



8294 processed stations over 8314
min: 0.03, avg: 0.17, max: 0.57

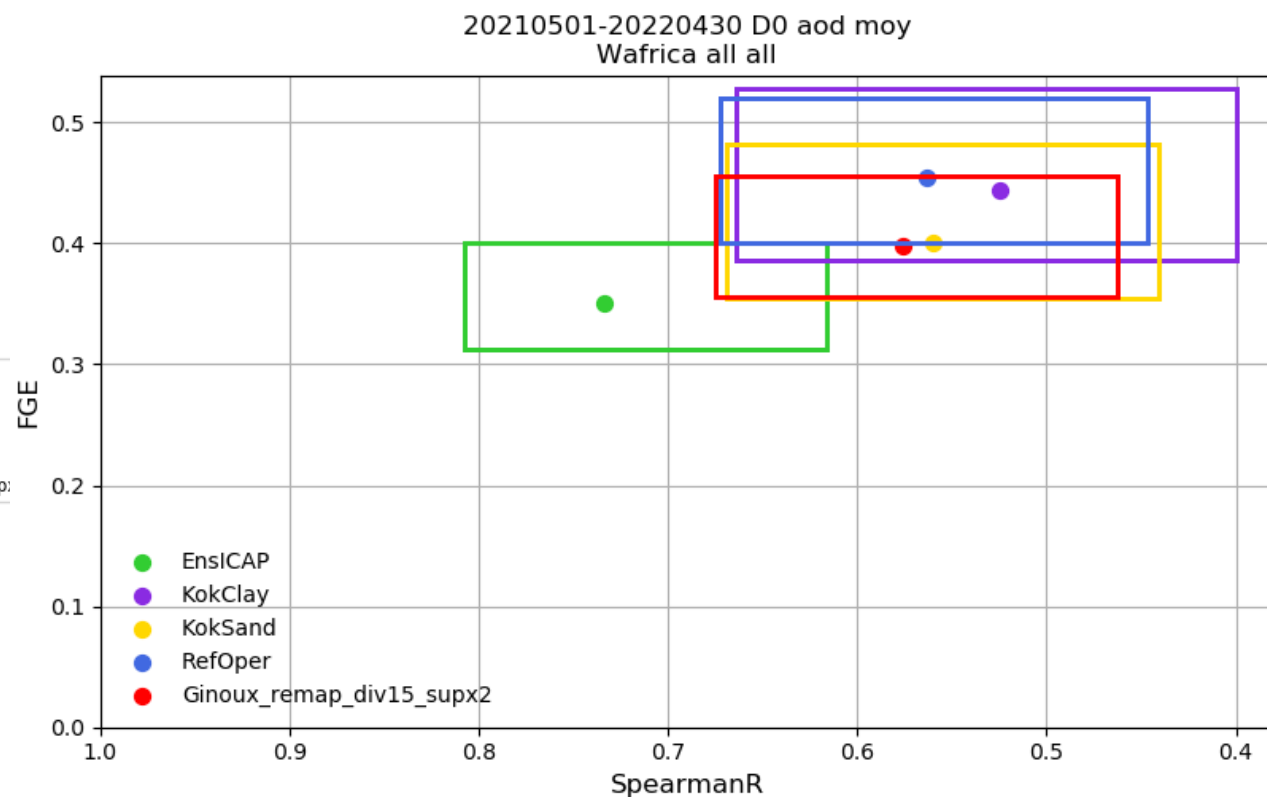
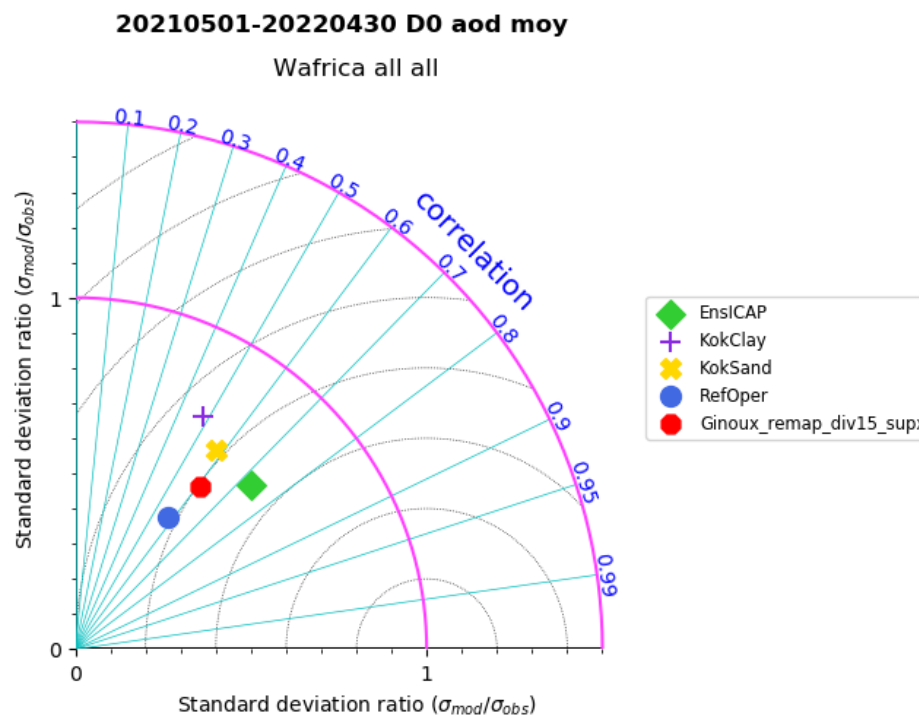
sim_median moy aod U7v4 D0
20220301-20220531 contin2 all lan+all



8294 processed stations over 8314
min: 0.04, avg: 0.21, max: 0.76

New dust emission scheme

- Comparison to AERONET AOD (May 2021 - April 2022) on a big Saharan domain
- EnsICAP (green) is the ICAP ensemble and is a goal
- Ginoux in red has better results than previous schemes

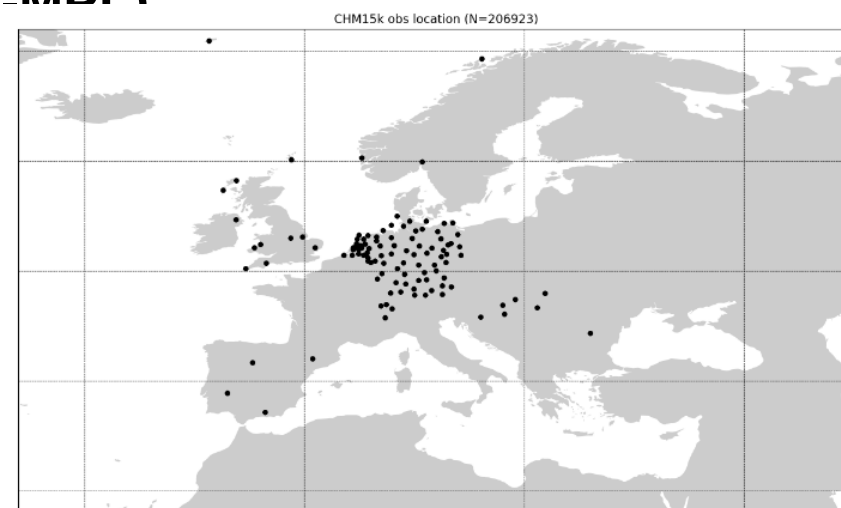
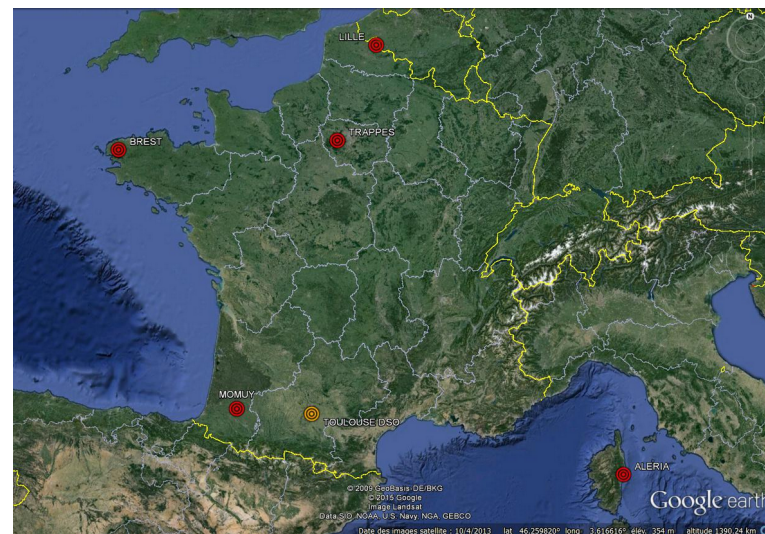


Data assimilation in operational MOCAGE chain

Data assimilation is now operational !

Description of the next operational system soon to be used

- 3D-var algorithm using 1h windows
- Global domain assimilates :
 - MODIS AOD
 - VIIRS AOD
 - TROPOMI SO2 for volcanic event
- Regional domain assimilates :
 - MODIS AOD
 - 6 Lidars from Météo-France network (Mini-MDI \
 - E-profile telemeters (CHM15K at 1064nm)



Data assimilation is now operational !

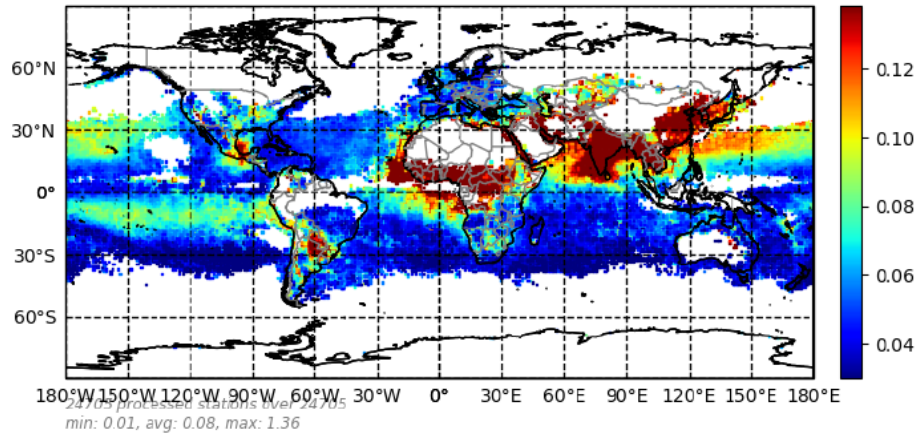
Description of the next operational system soon to be used

Exemple of L2 MODIS and VIIRS AOD assimilation

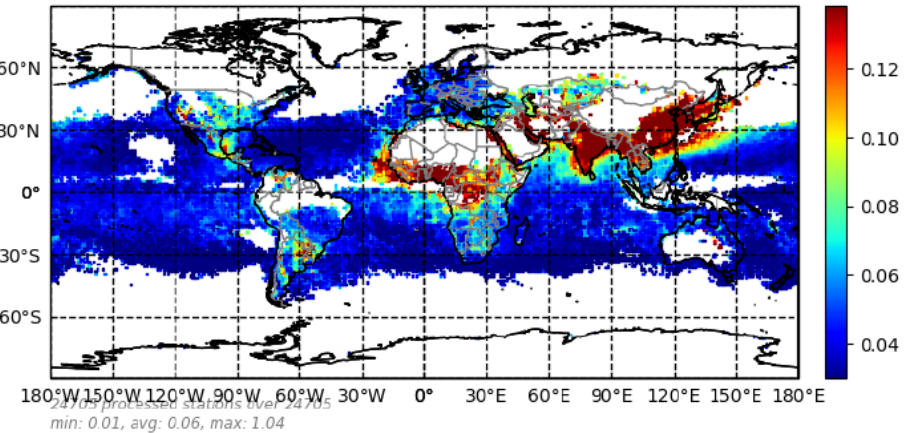
5 month from January to May 2022 – scores vs MODIS L3 data

24h forecast AOD RMSE

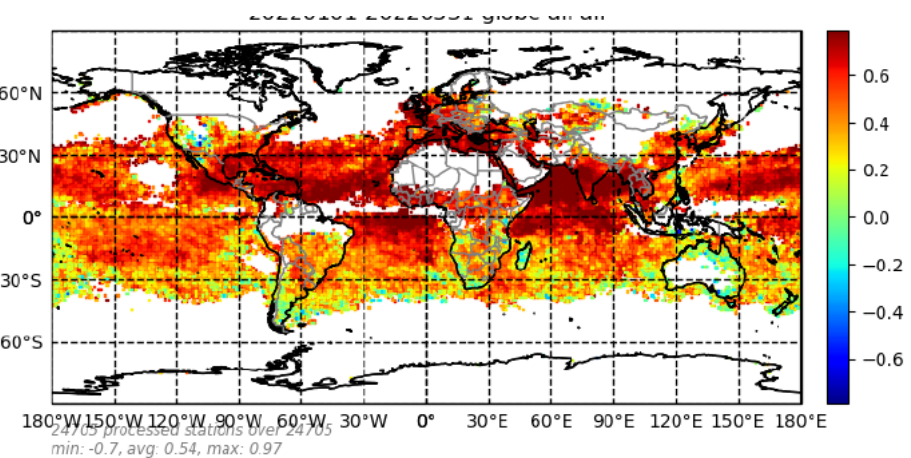
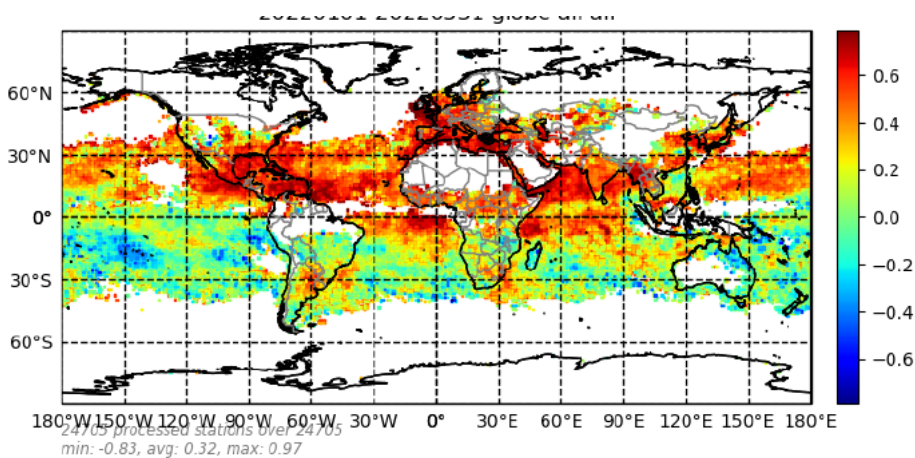
Without assimilation



With assimilation



24h forecast AOD Correlation

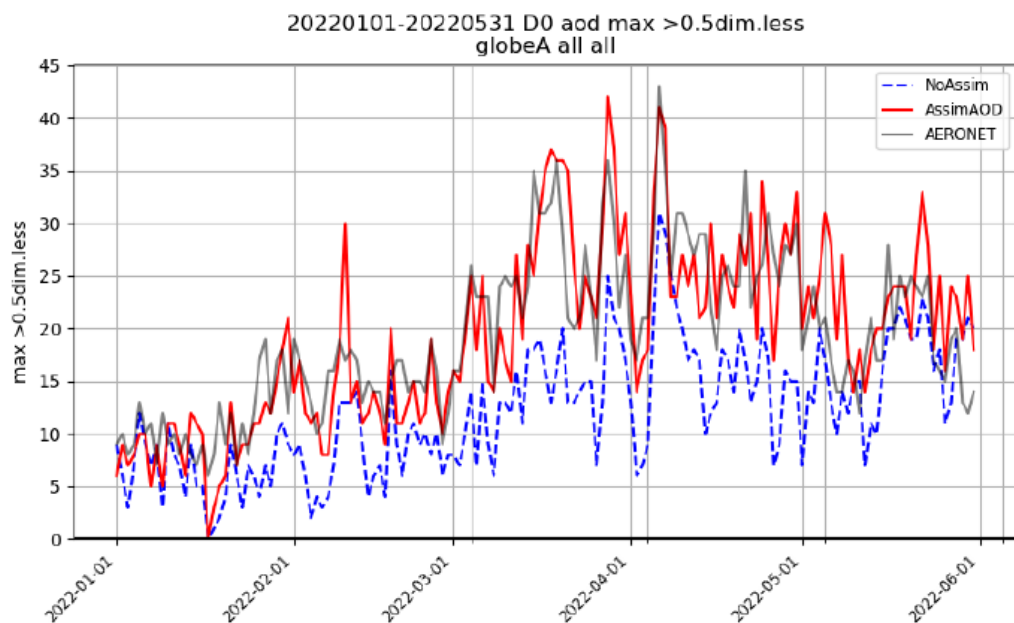


Data assimilation is now operational !

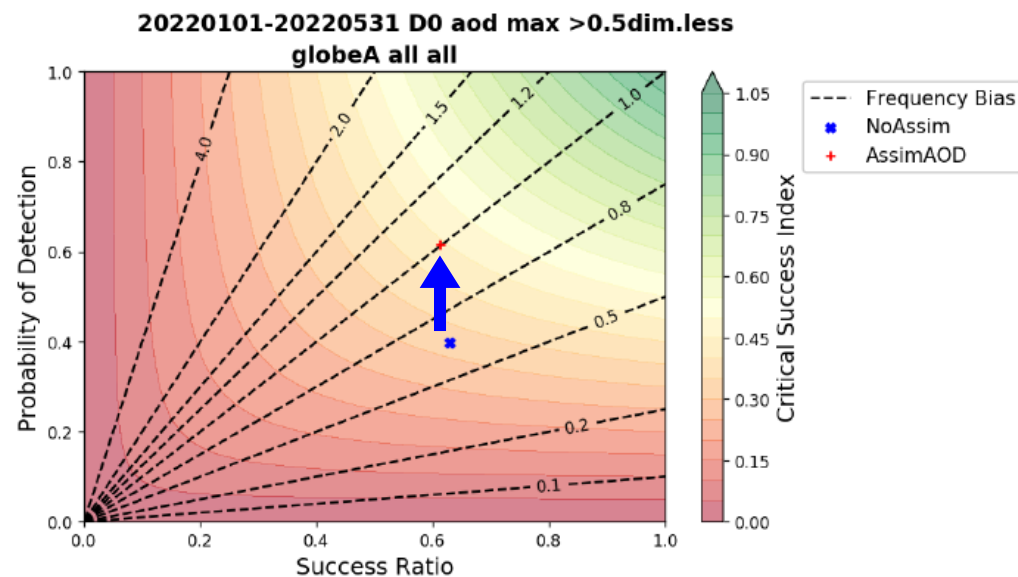
Description of the next operational system soon to be used

- **Exemple of L2 MODIS and VIIRS AOD assimilation**
5 month from January to May 2022 – scores vs AERONET data

Threshold exceedance number (AOD > 0.5)



Detection scores

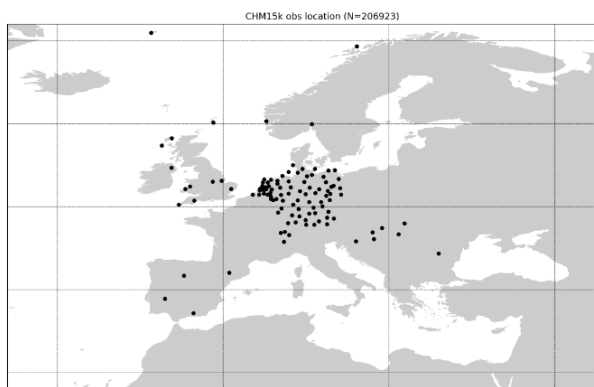


Data assimilation is now operational !

Description of the next operational system soon to be used

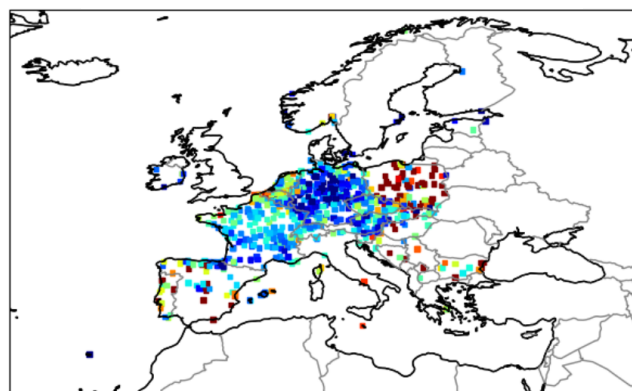
Exemple assimilation of telemeters data

3 months from March to May 2022 – scores vs AERONET data



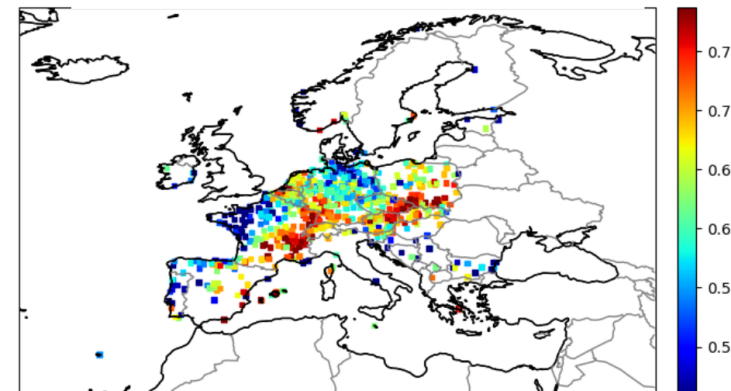
Telemeters locations

RMSE – PM10 – OPER



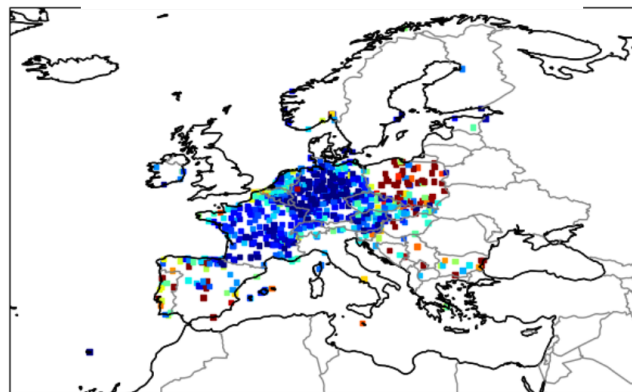
779 processed stations over 789
min: 4.57, avg: 11.74, max: 63.54

Correlation – PM10 – OPER



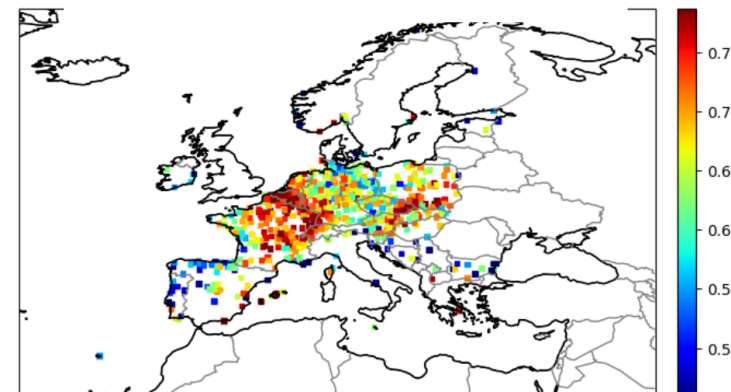
779 processed stations over 789
min: 0.13, avg: 0.63, max: 0.88

RMSE – PM10 – DBLE



779 processed stations over 789
min: 4.18, avg: 10.41, max: 63.2

Correlation – PM10 – DBLE



779 processed stations over 789
min: 0.14, avg: 0.67, max: 0.89

Data assimilation is now operational !

Description of the next operational system soon to be used

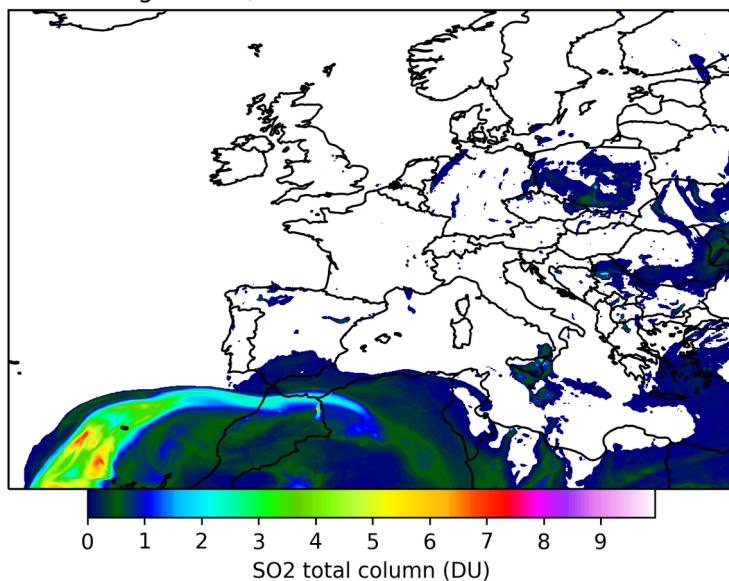
- **Exemple assimilation of TROPOMI SO2 data**

La Palma eruption from September to December 2021

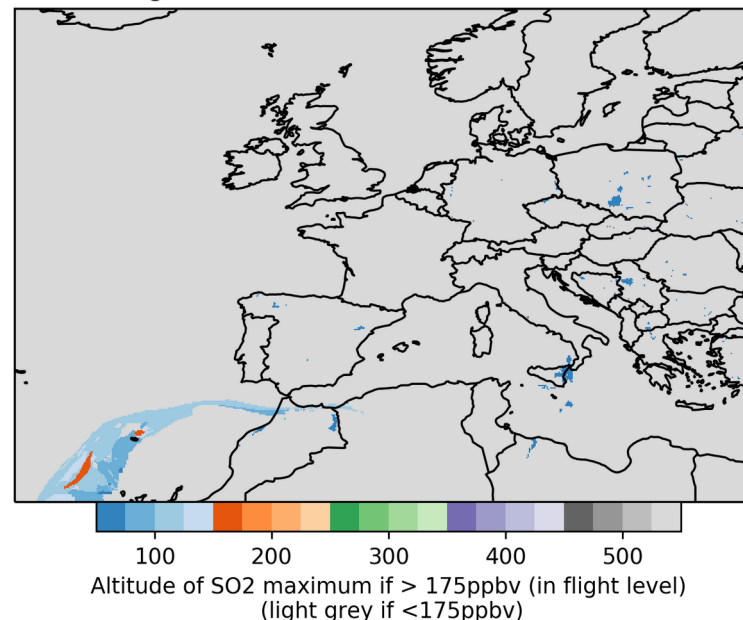
- **Volcanic SO2 for the VAAC operational needs:**

Assimilation of TROPOMI data in order to correct the atmospheric state for volcanic eruption (correction only between 3 and 10 kms)

forecast from Fri 01 Oct 2021 - 00 UTC
range +03h, valid Fri 01 Oct 2021 - 03 UTC



forecast from Fri 01 Oct 2021 - 00 UTC
range +03h, valid Fri 01 Oct 2021 - 03 UTC

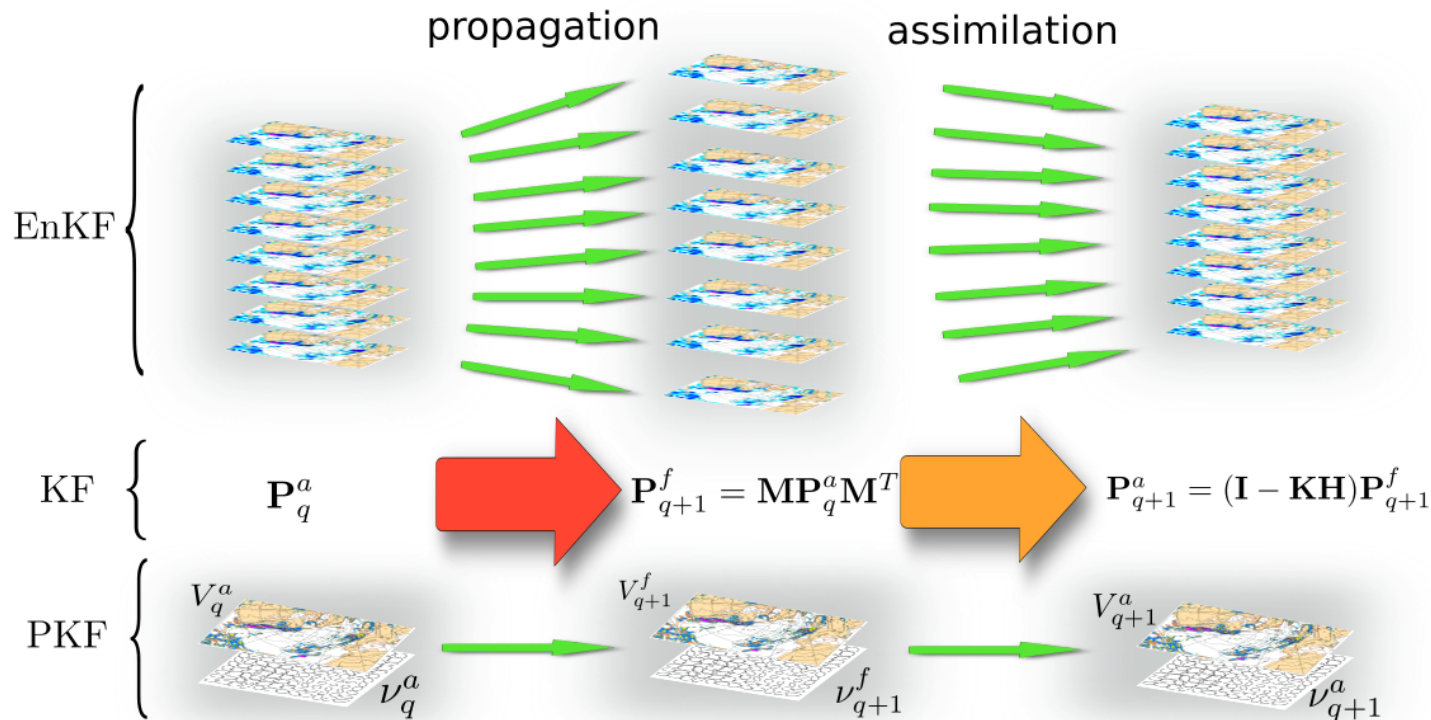


Parametric Kalman filter exploratory data assimilation

Data assimilation a look into the PKF

PKF, an approximation of the KF

- The Parametric Kalman Filter (PKF) is an approximation of the Kalman Filter where the error covariance matrices are approximated by a covariance model fitted with a set of parameters.

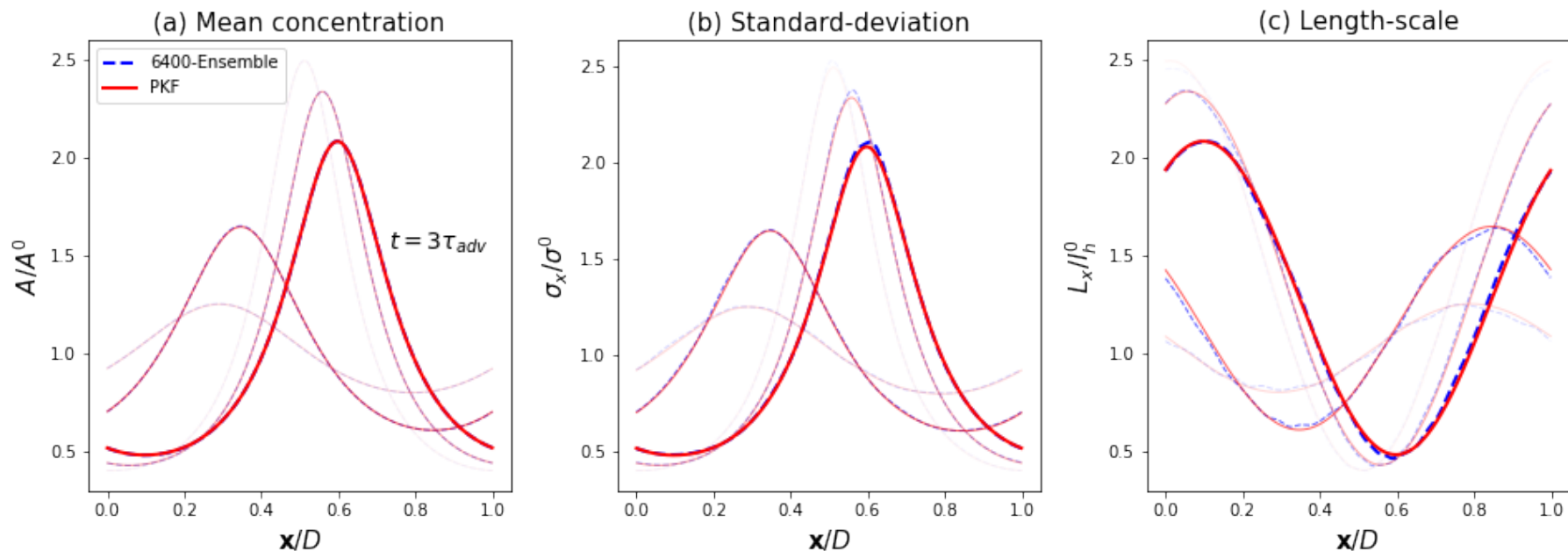


- Applying the PKF approach for CTMs is attractive because the parametric dynamics is known for the transport equations (Cohn, 1993; Pannekoucke et al., 2018),

Illustration for an univariate 1D transport problem

- Numerical experiment : PKF and EnKF comparison for a univariate conservative advection by an heterogeneous wind :

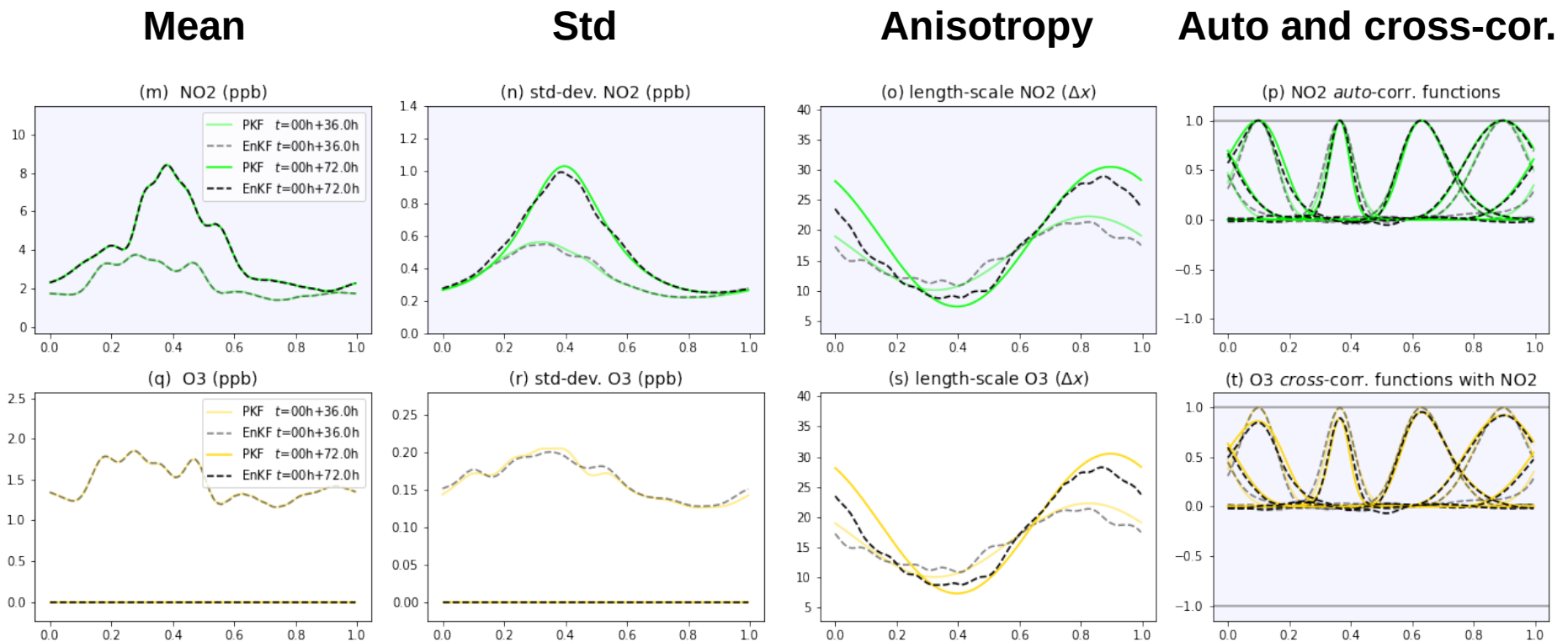
$$\partial_t \mathcal{X} + \partial_x (u \mathcal{X}) = 0$$



→ The PKF reproduces the results of a large EnKF at a low numerical cost

Multivariate forecast for GRS CTM (1D) : focus on NO2 and O3

- GRS is a 6 simplified species chemical scheme



(Perrot et al . 2022)

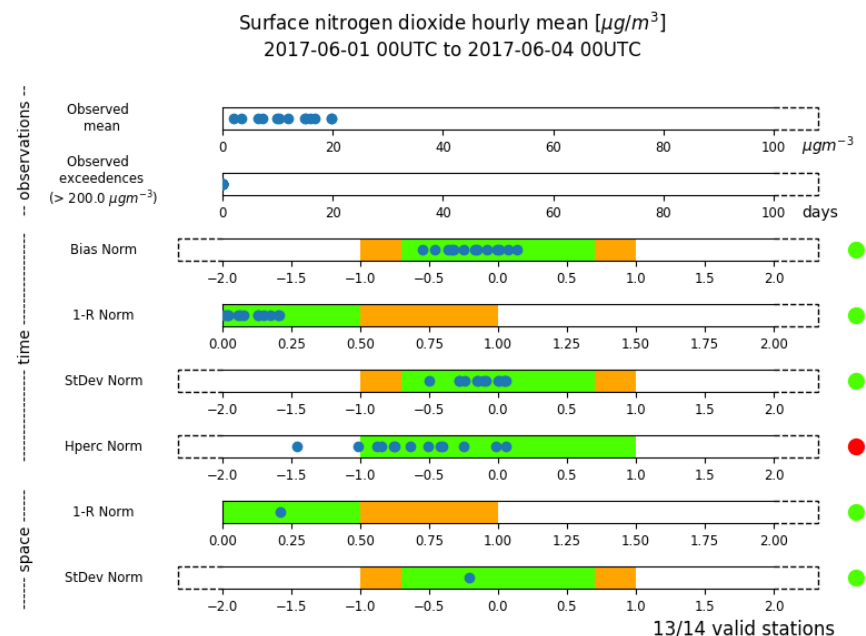
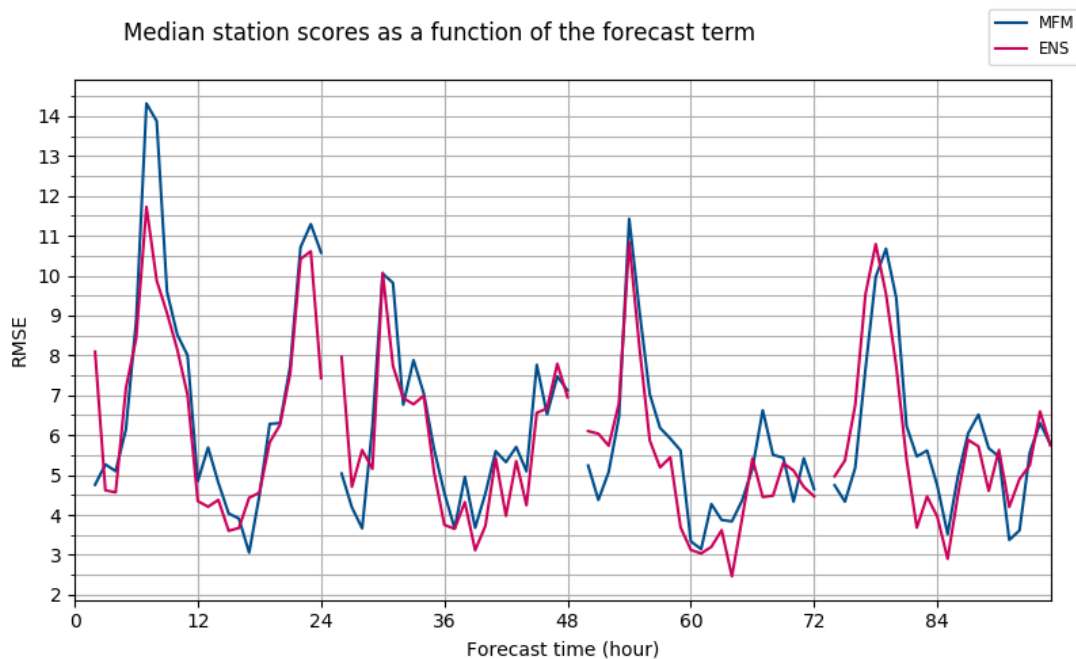
Evaltools : a new extension designed for simulation ensembles

Ensemble forecasting comparison tool

- Evaltools is a python package used for model evaluation developed inside Copernicus Atmosphere Monitoring Service (CAMS) projects

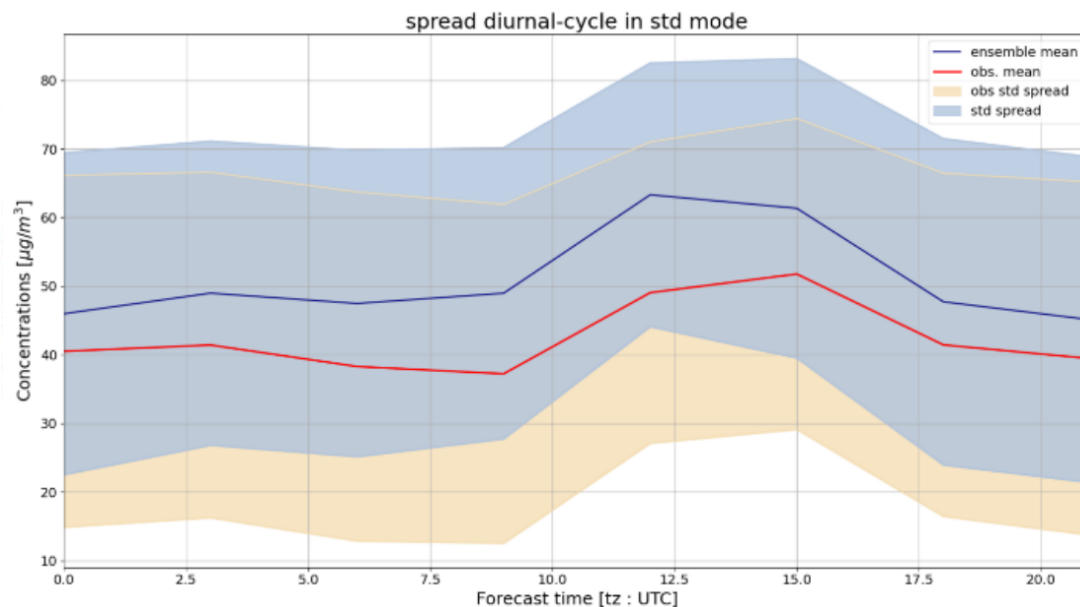
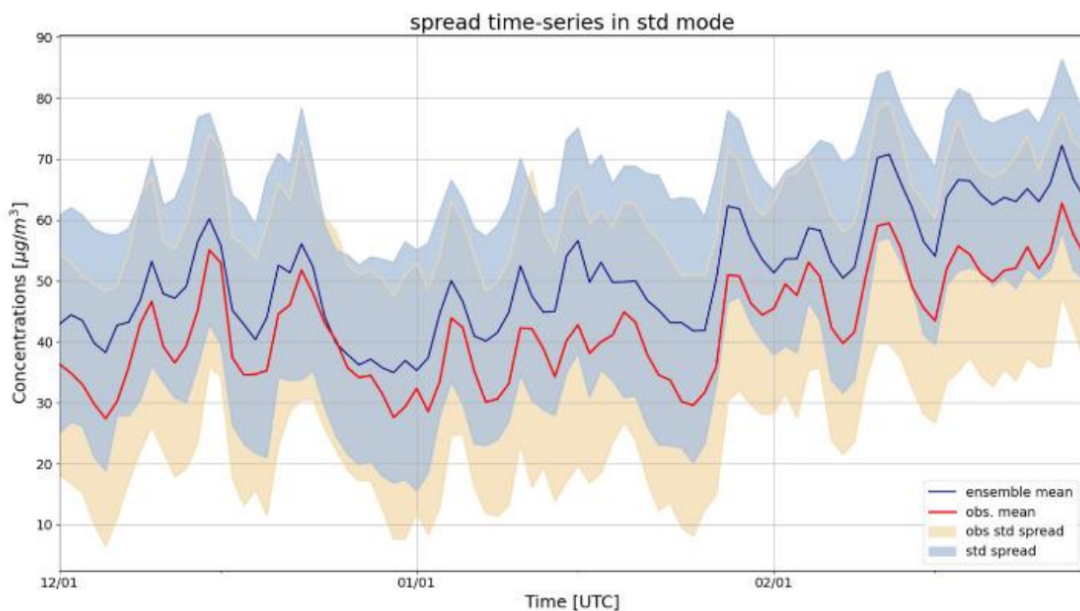
<https://opensource.umr-cnrm.fr/projects/evaltools>

- It is designed to assess surface atmosphere composition prediction models regarding to in-situ observations. This package provides different tools to compute model scores and plot them.



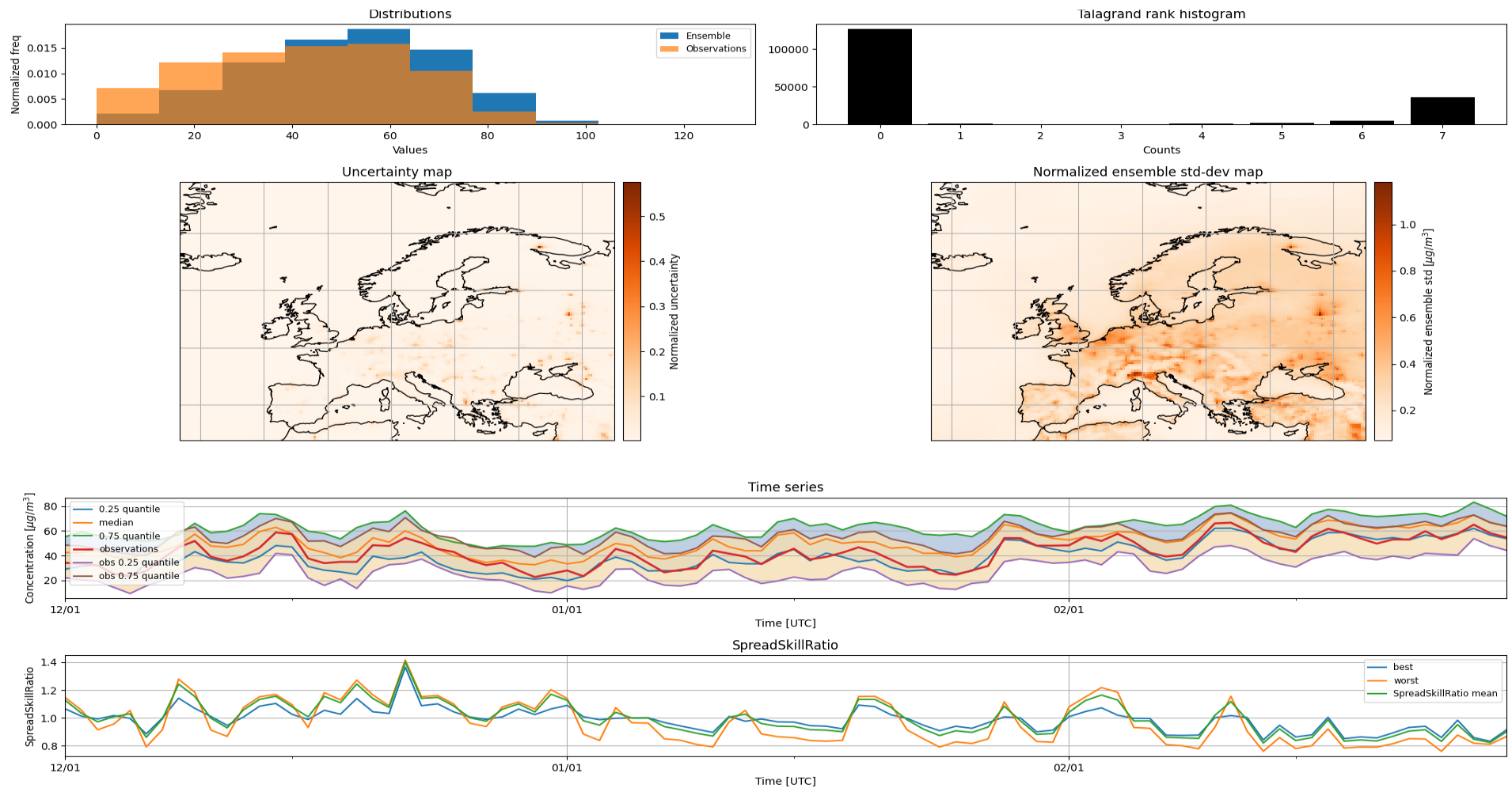
Ensemble forecasting comparison tool

- A new extension has been recently developed in order to be able to treat simulation ensembles :
 - Ensemble scores vs observations
 - Ensemble diagnostics



Ensemble forecasting comparison tool

- A new extension has been recently developed in order to be able to treat ensemble :
 - Ensemble scores vs observations
 - Ensemble diagnostics



Conclusions

- **The forecasts are improved by the new dust emission scheme developed in MOCAGE**
- **The operational implementation of the MOCAGE model now has data assimilation capabilities that helps improving the forecasts**
- **Theoretical work in data assimilation field are done in order to preparer the next generation of data assimilation algorithms which can be as precise as an ensemble Kalman-Filter as being less expensive.**
- **Evaltools and the new extension has new ensemble simulations capabilities**

Futur Work

Direct modelling :

- For next year, plan for an evolution of the grid :
 - Evolution from a $1^{\circ}\times 1^{\circ}$ grid to a $0.5\times 0.5^{\circ}$
 - Expansion of the vertical level from 47 levels ($\sim 5\text{hPa}$) to 60 ($\sim 0.1\text{hPa}$)

Data assimilation :

- Work on the inclusion of more telemeters on european domain
- PhD of Mohammad El Aabaribaoun started a work of the use of IASI radiances to constrain dust aerosol :
 - Continuation of a work started for ozone
 - Use of RTTOV as observation operator
 - Work will go on next year with an internship



Thank you for your attention !