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., Meeeziane M., Petiot V., Pelletier S.
CNRM/Météo-France, Toulouse, France

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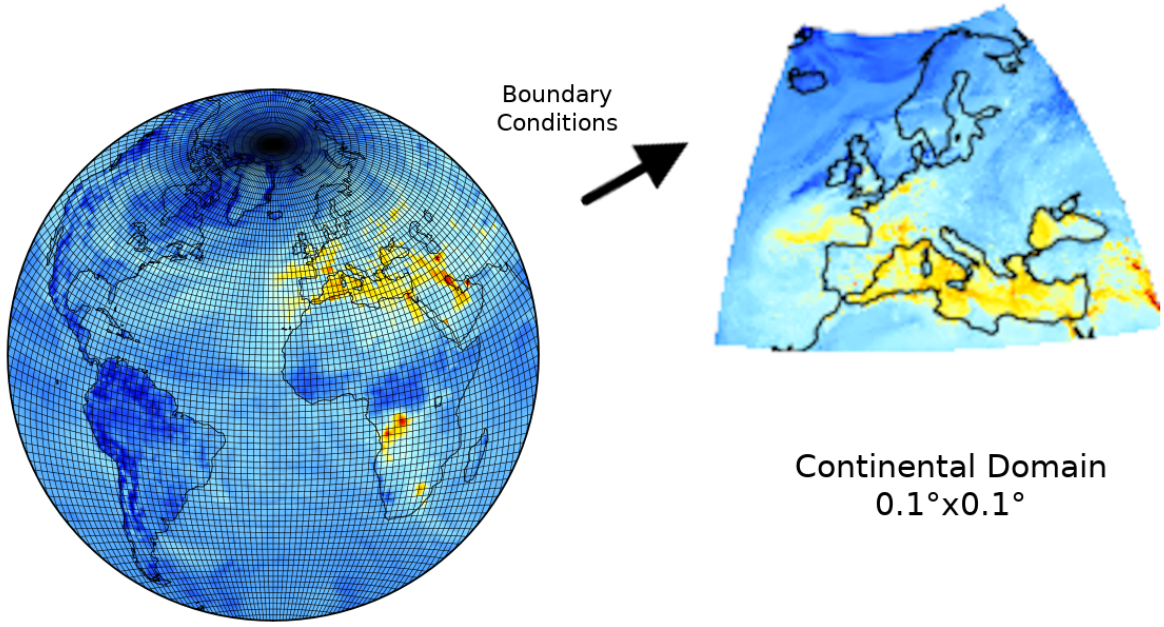
The MOCAGE model : general features

- **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**

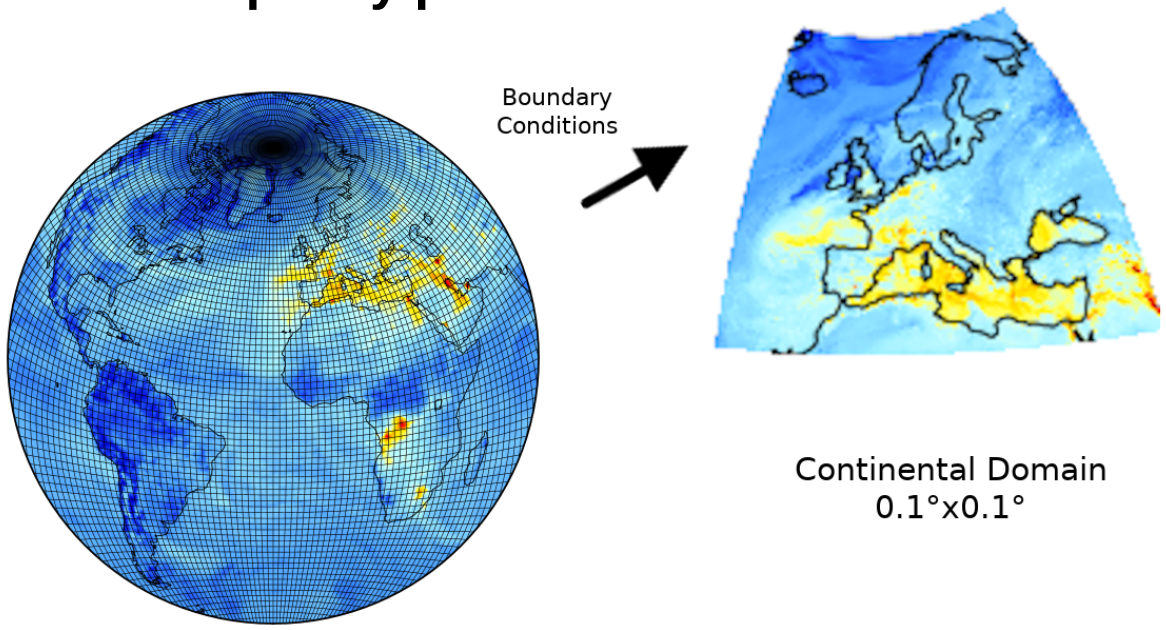


Global Domain
1°x1°

Continental Domain
0.1°x0.1°

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**



Global Domain
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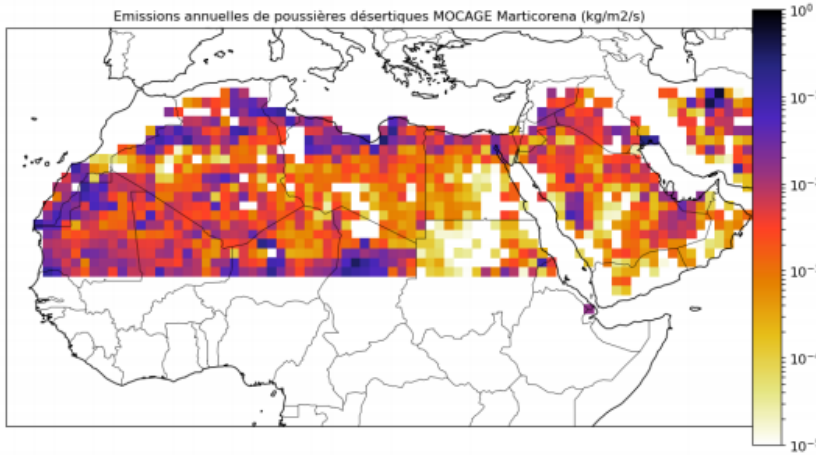
Continental Domain
0.1°x0.1°

Developpement of a new dust emission scheme

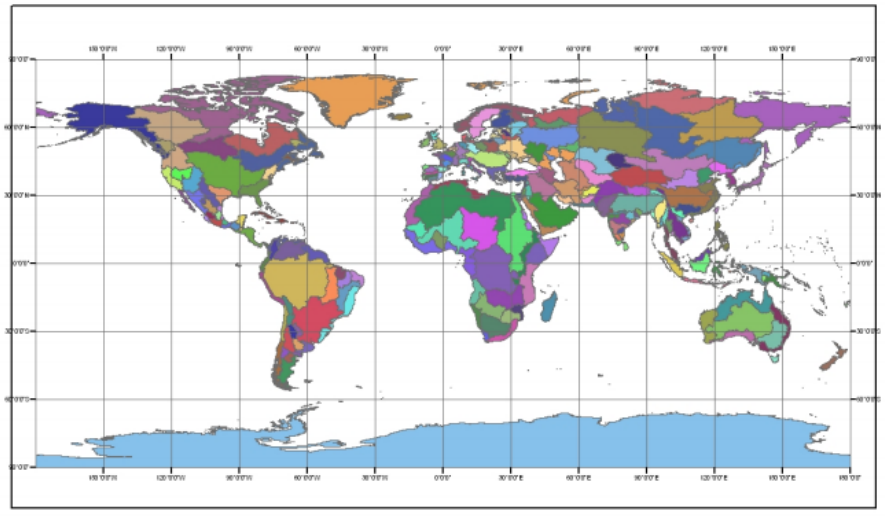
New dust emission scheme

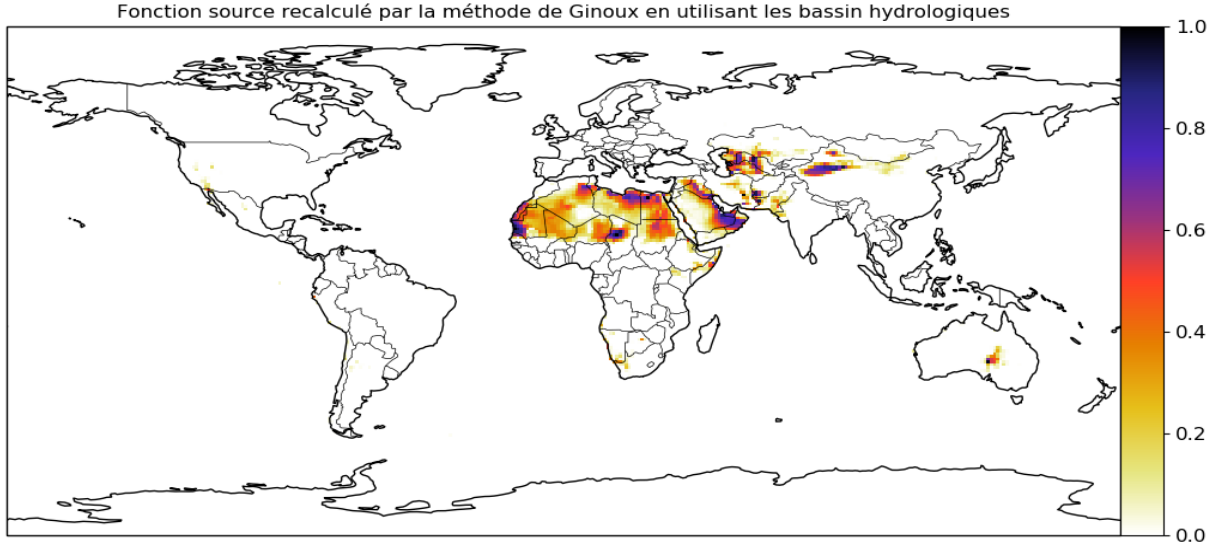
Historical Marticorena parameterisation VS Ginoux (2001)

- **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 calulated this source map based on hydrological basin and elevation data**



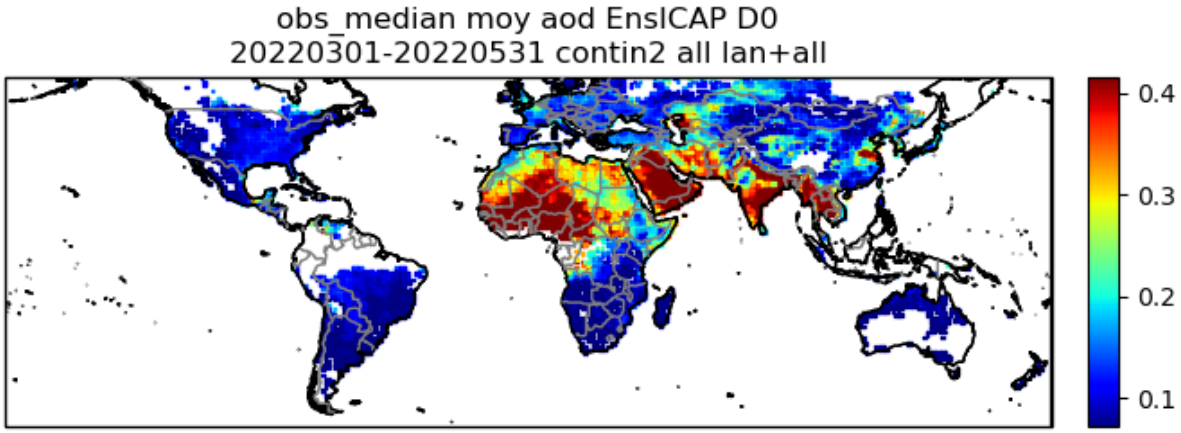
$$S = \left(\frac{z_{max} - z_i}{z_{max} - z_{min}} \right)^5$$



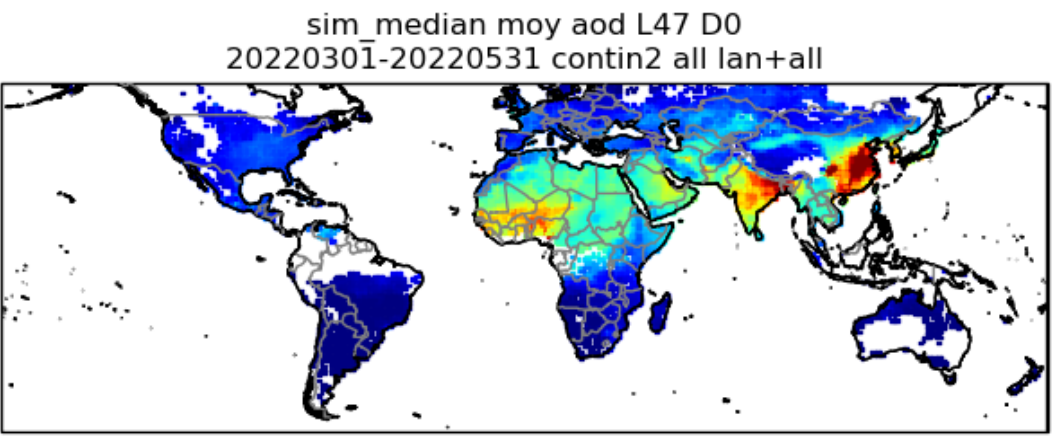


New dust emission scheme

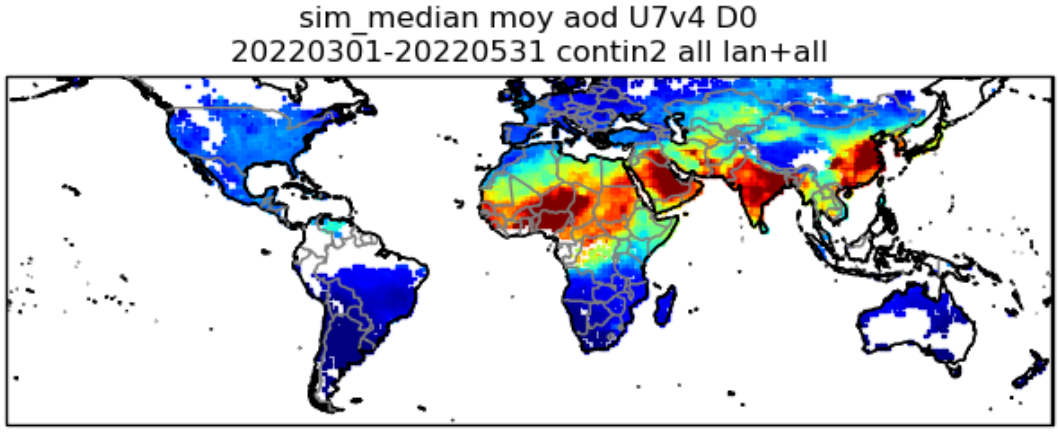
- **AOD comparison vs ICAP Ensemble considered as a reference (MAM 2022)**
- **Better results with Ginoux emission scheme (right)**



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



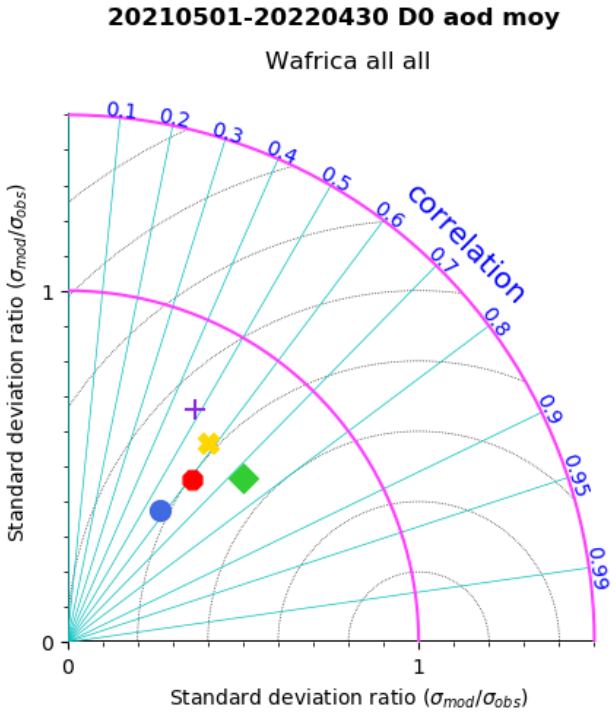
8294 processed stations over 8314
min: 0.03, avg: 0.17, max: 0.57

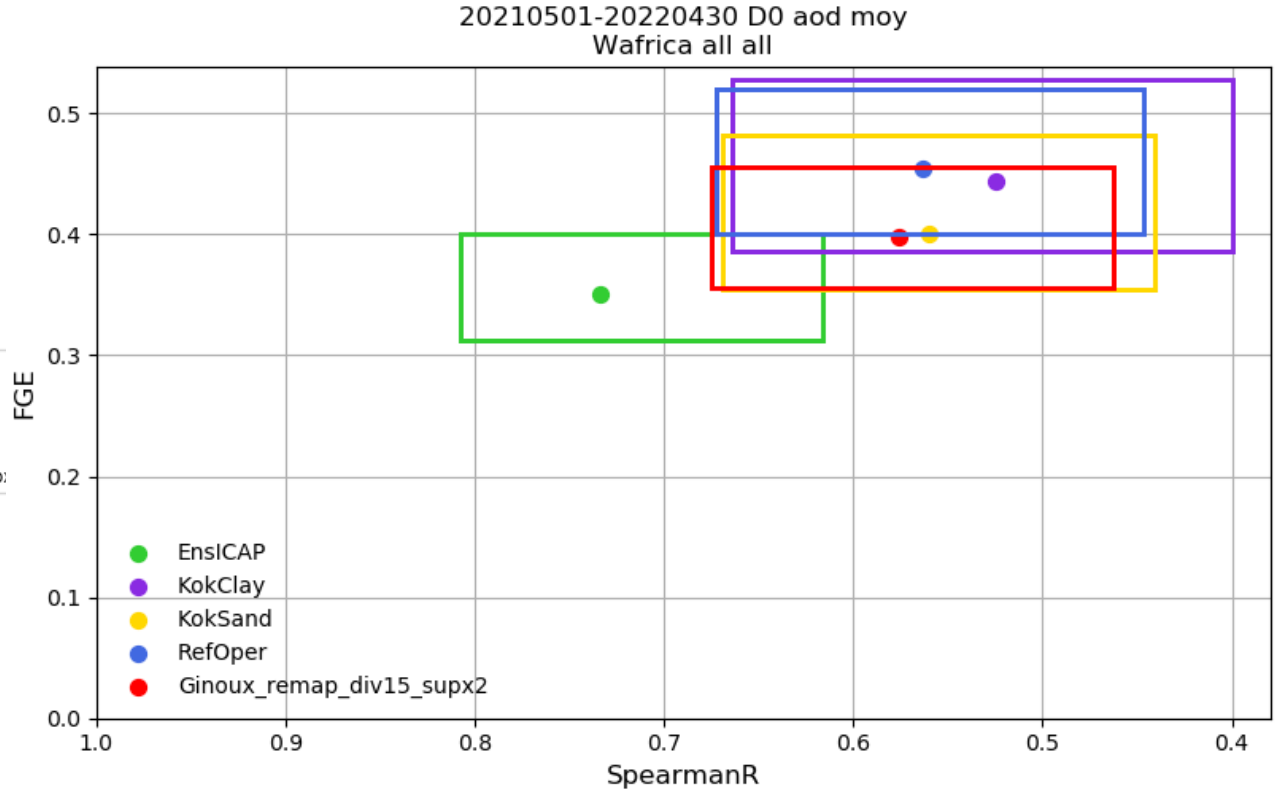


8294 processed stations over 8314
min: 0.04, avg: 0.21, max: 0.76

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**



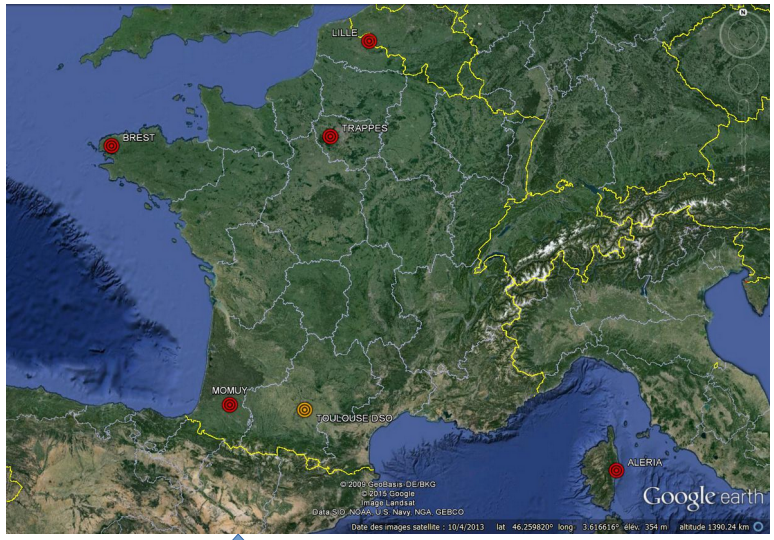


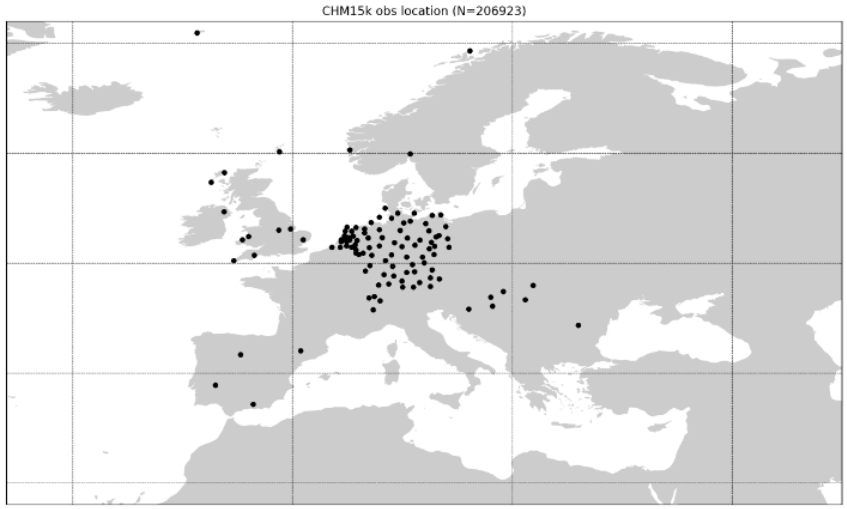
Data assimilation in operationnal MOCAGE chain

Data assimilation is now operationnal !

Description of the next operationnal 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-MPL)**
  - **E-profile telemeters (CHM15K at 1064nm)**





Data assimilation is now operationnal !

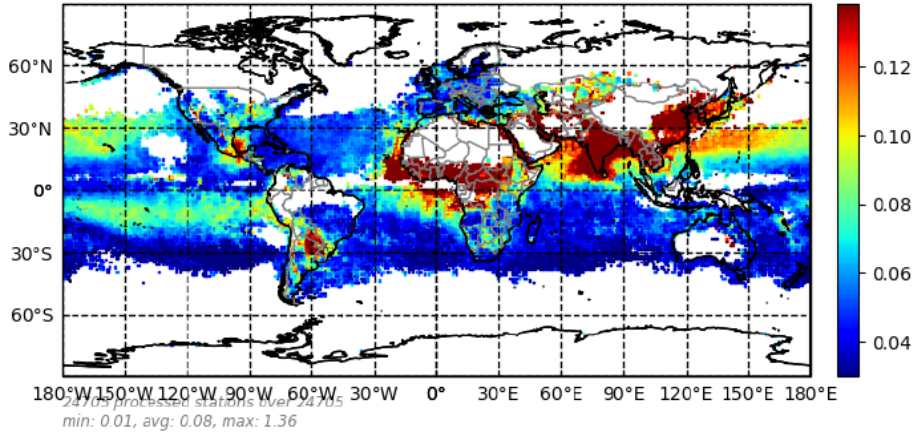
Description of the next operationnal system soon to be used

- **Exemple of L2 MODIS and VIIRS AOD assimilation**

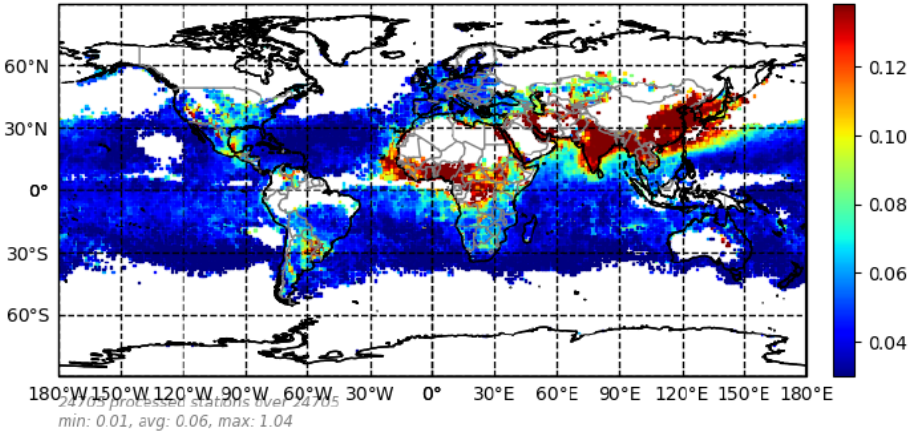
  5 month from January to May 2022 – scores vs MODIS L3 data

24h forecast AOD RMSE

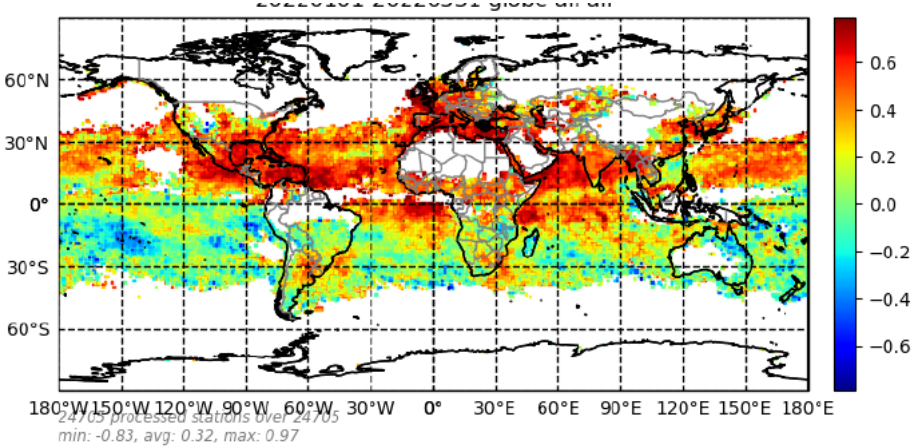
Without assimilation

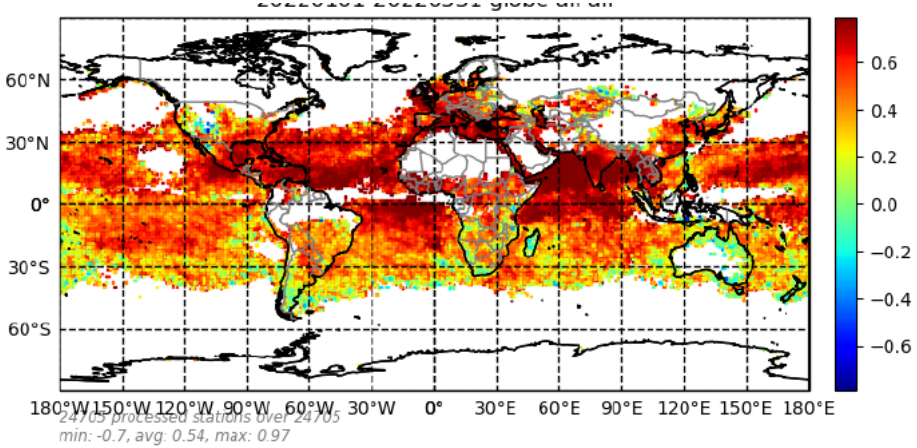


With assimilation



24h forecast AOD Correlation



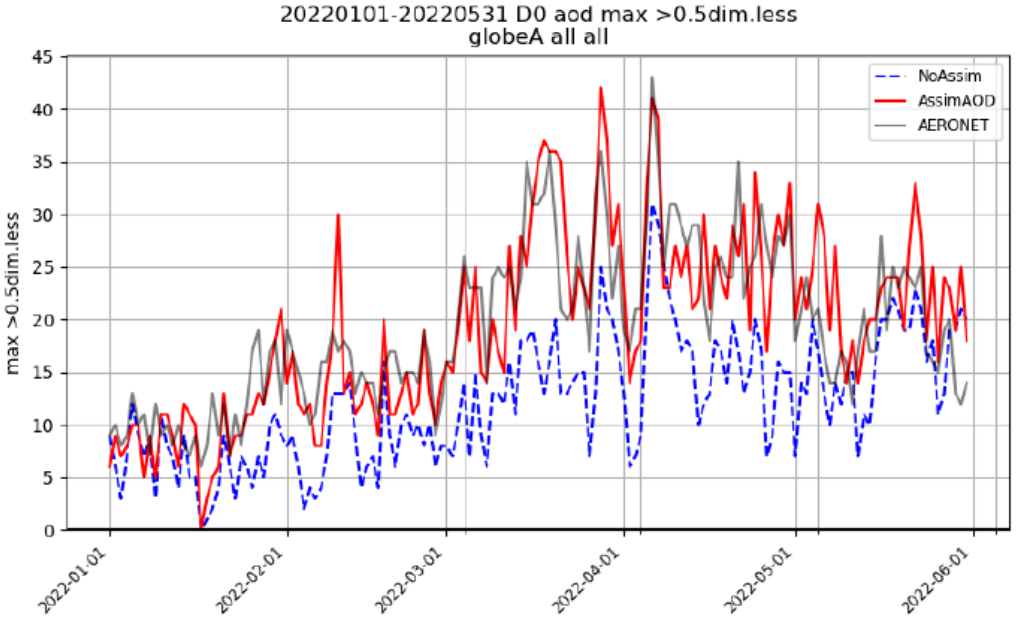


Data assimilation is now operationnal !

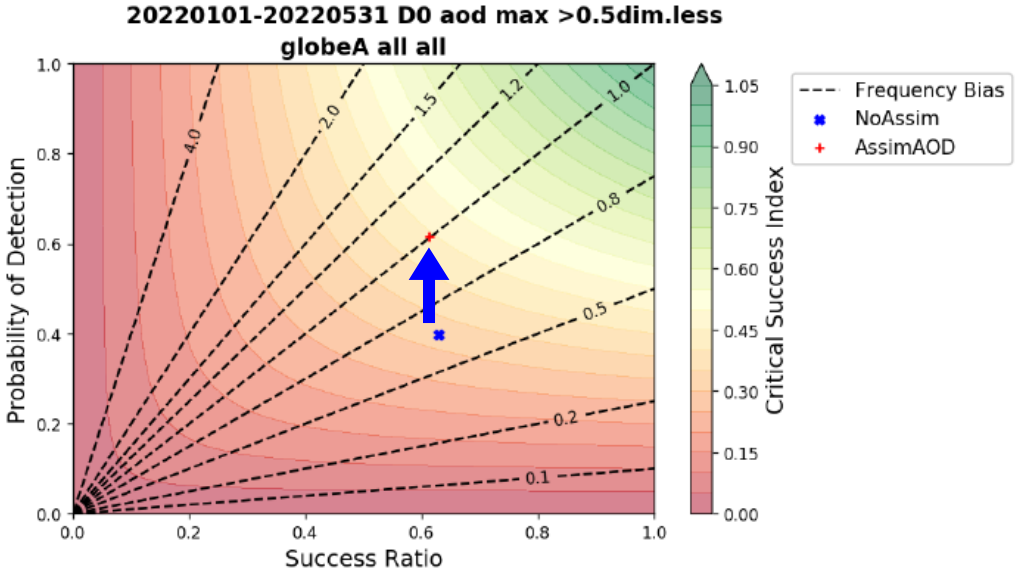
Description of the next operationnal system soon to be used

- **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

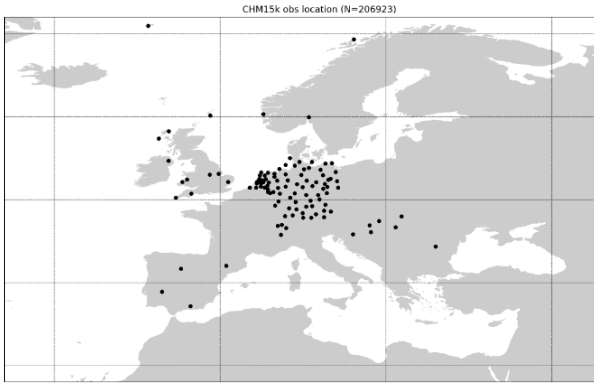


Data assimilation is now operationnal !

Description of the next operationnal system soon to be used

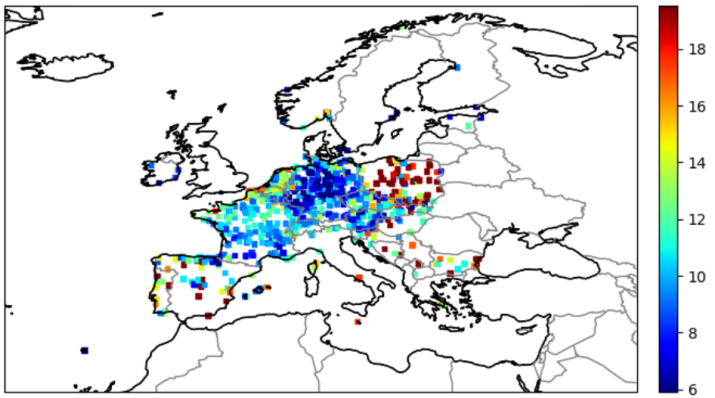
- **Exemple assimilation of telemeters data**

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



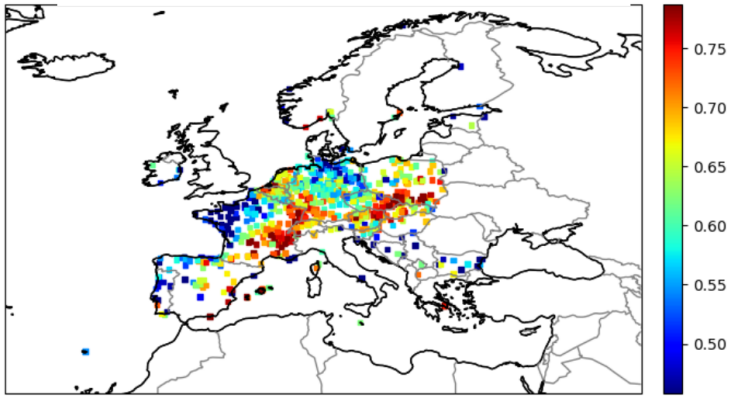
Telemeters locations

RMSE – PM10 – OPER



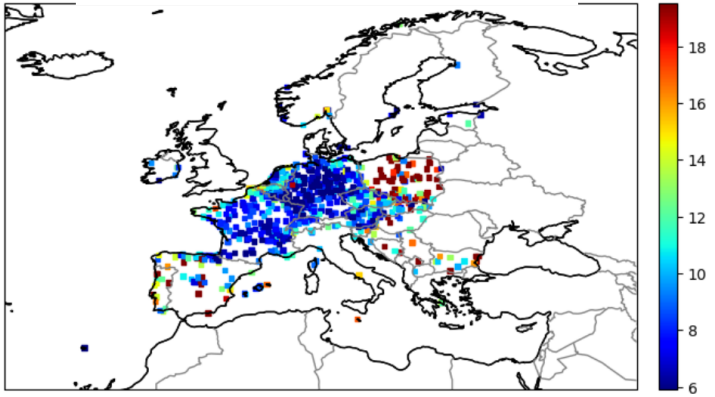
779 processed stations over 789
min: 4.57, avg: 11.74, max: 63.54

Correlation – PM10 – OPER



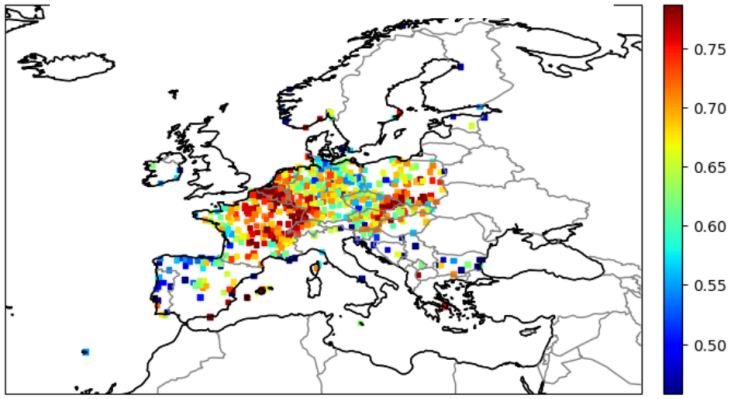
779 processed stations over 789
min: 0.13, avg: 0.63, max: 0.88

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 operationnal !

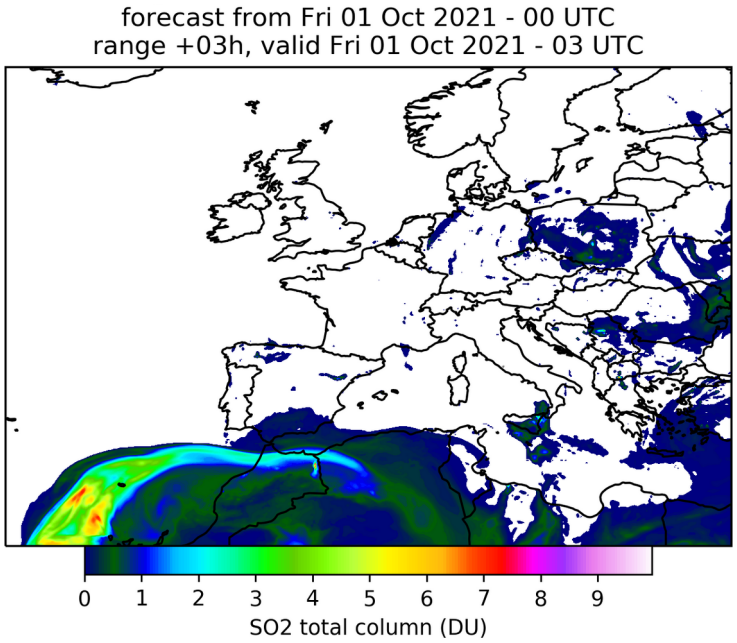
Description of the next operationnal system soon to be used

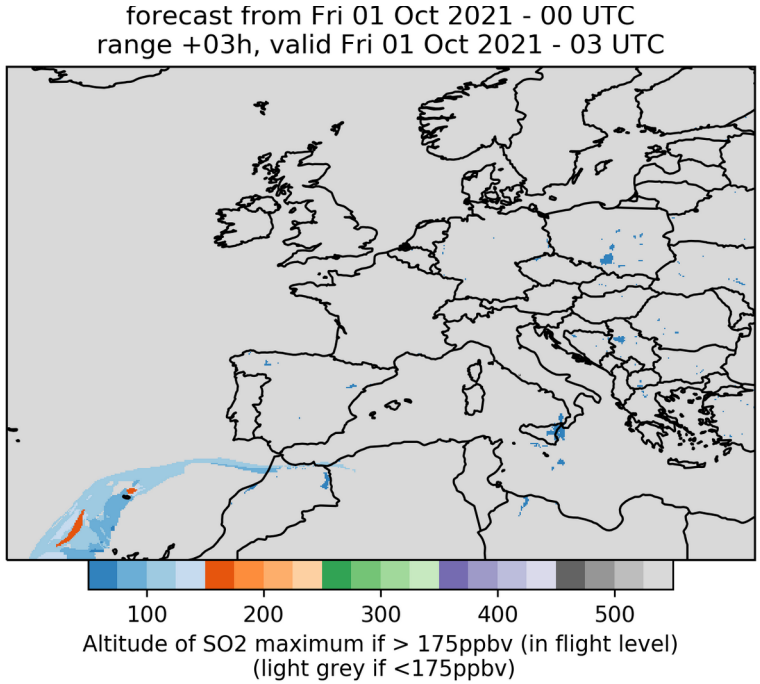
- **Exemple assimilation of TROPOMI SO2 data**

  La Palma eruption from September to December 2021

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

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



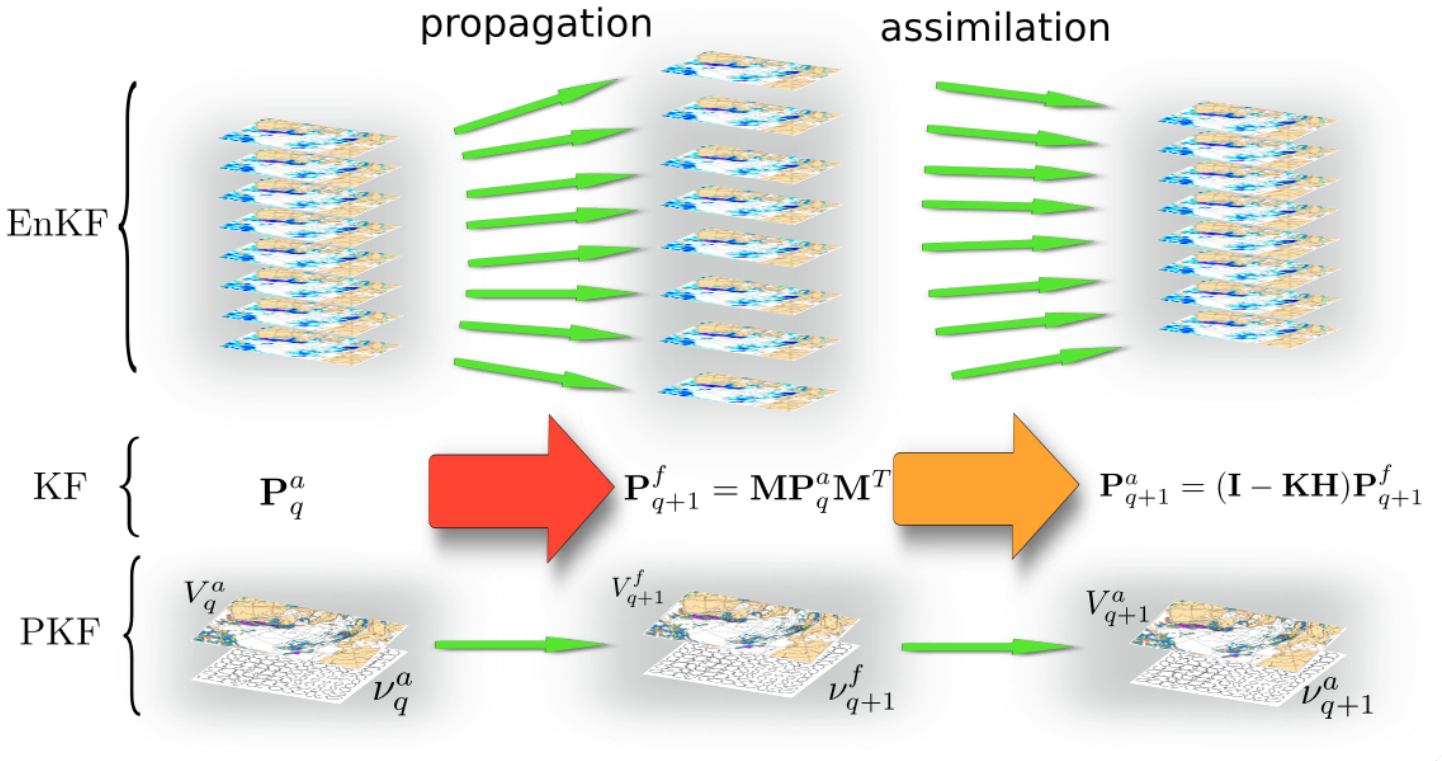


Parametric Kalman filter exploratory data assimilation

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.**

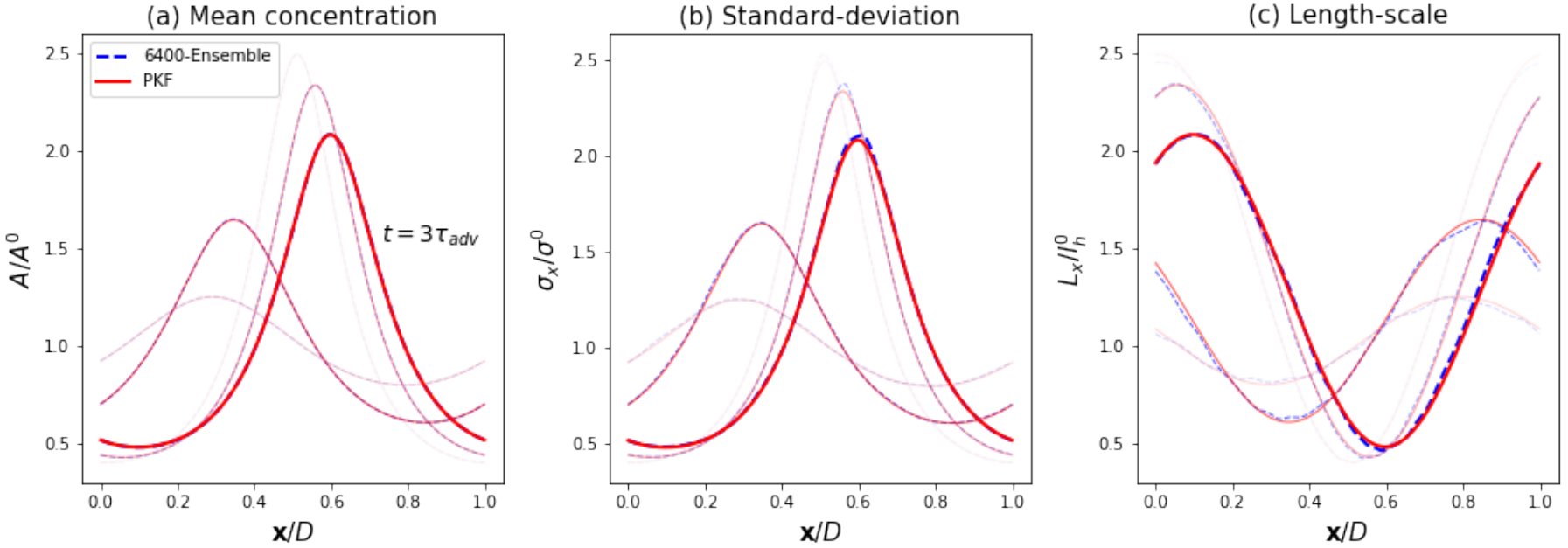


- **Applying the PKF approach for CTMs is attractive because the parametric dynamics is known for the transport equations (Cohn, 1993; Pannekoucke et al., 2018),**

Illustration for an univariate 1D transport problem

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

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

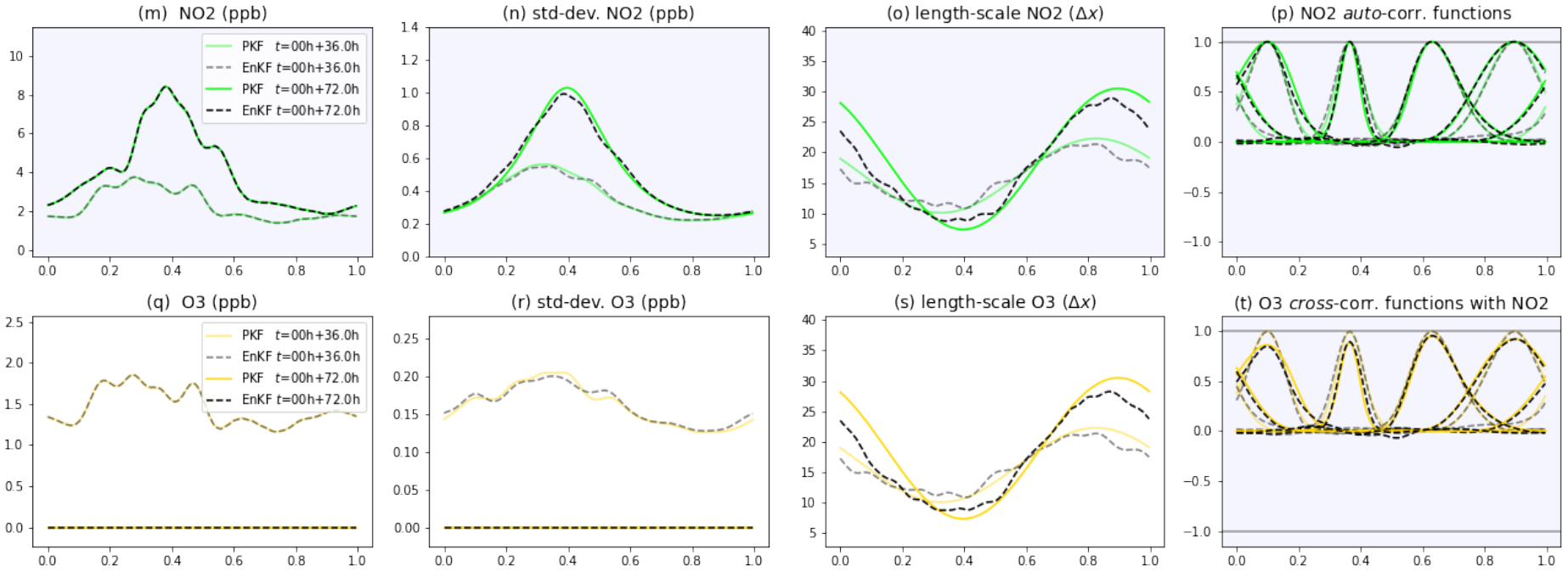


→ **The PKF reproduces the results of a large EnKF at a low numerical cost**

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

- **GRS is a 6 simplified species chemical scheme**

Mean **Std** **Anisotropy** **Auto and cross-cor.**



(Perrot et al . 2022)

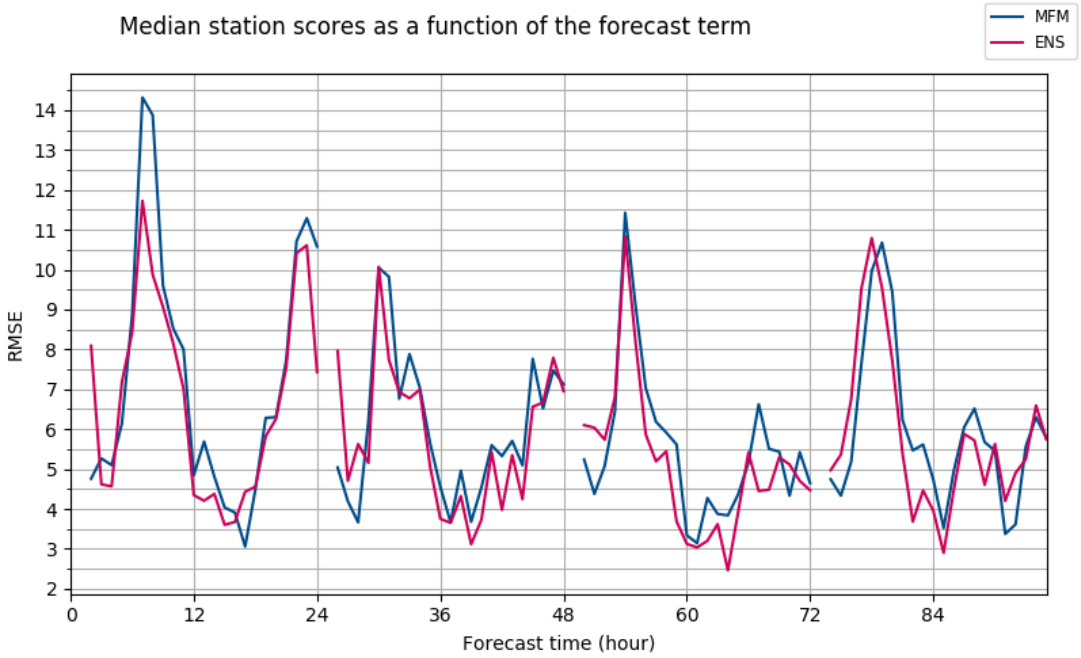
Evaltools : a new extension designed for simulation ensembles

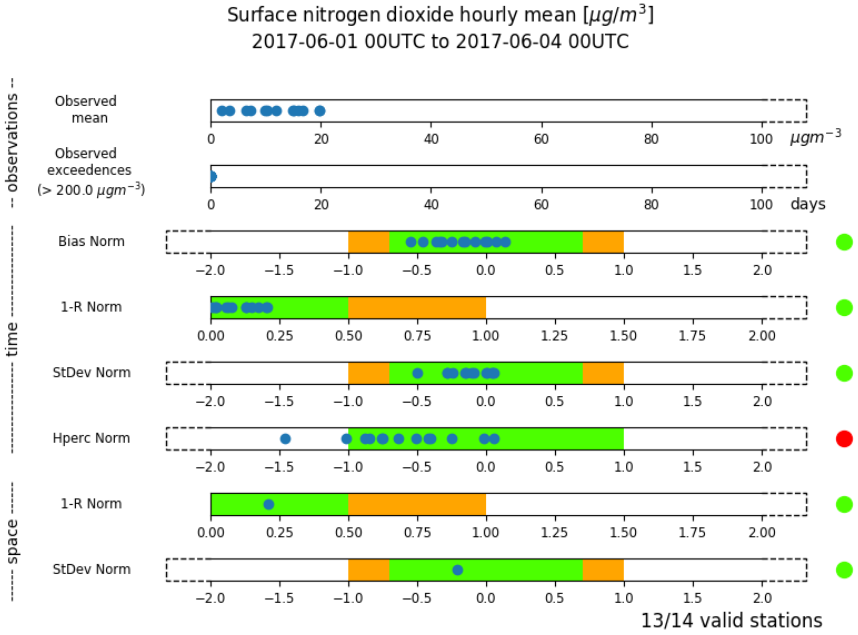
Ensemble forecasting comparison tool

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

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

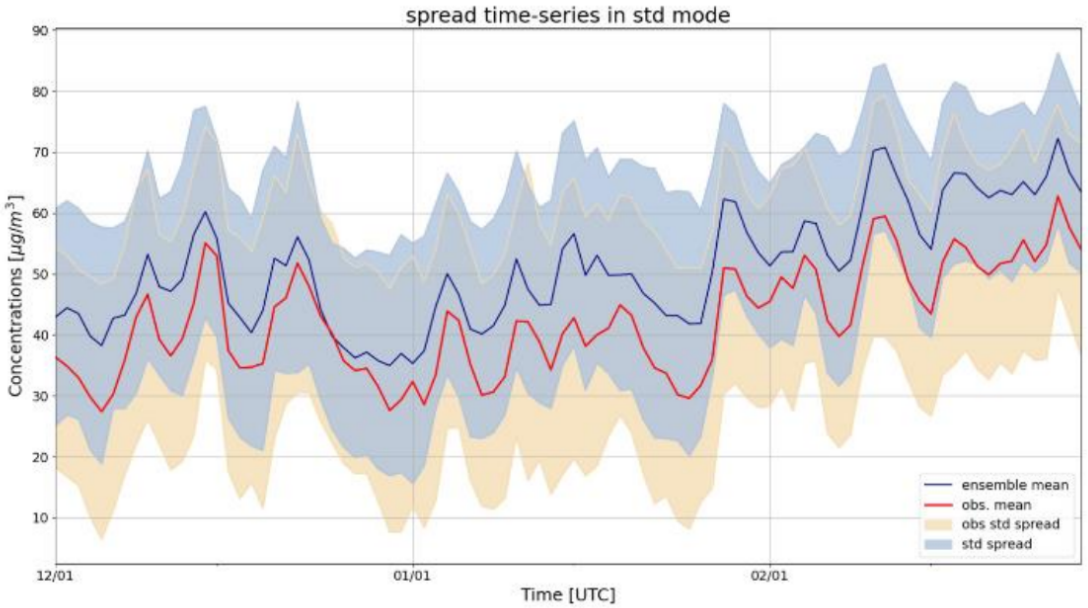
- **It is designed to assess surface atmosphere composition prediction models regarding to in-situ observations. This package provides different tools to compute model scores and plot them.**

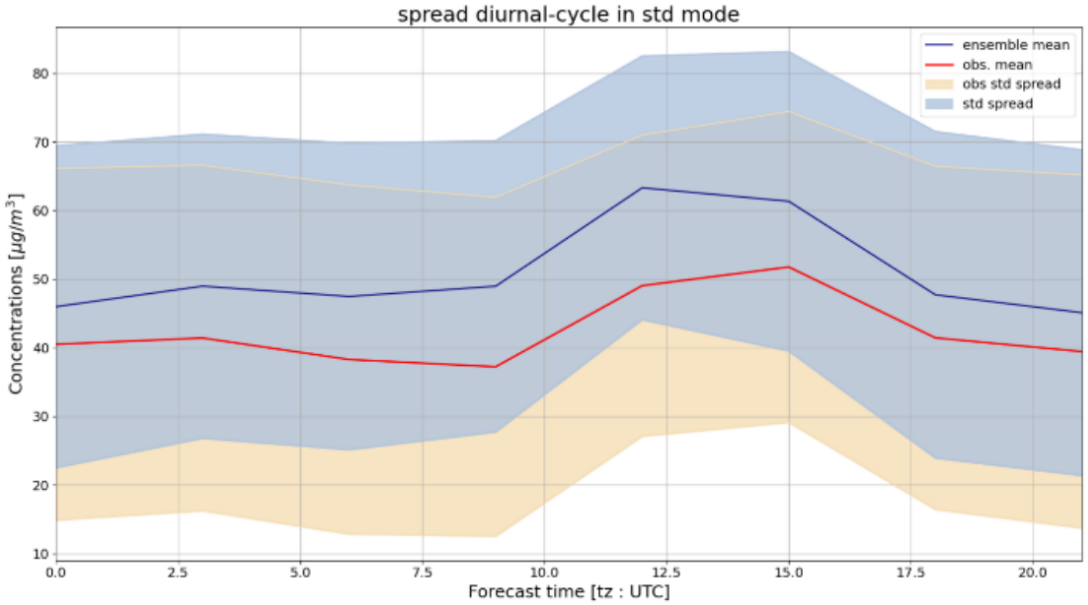




Ensemble forecasting comparison tool

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





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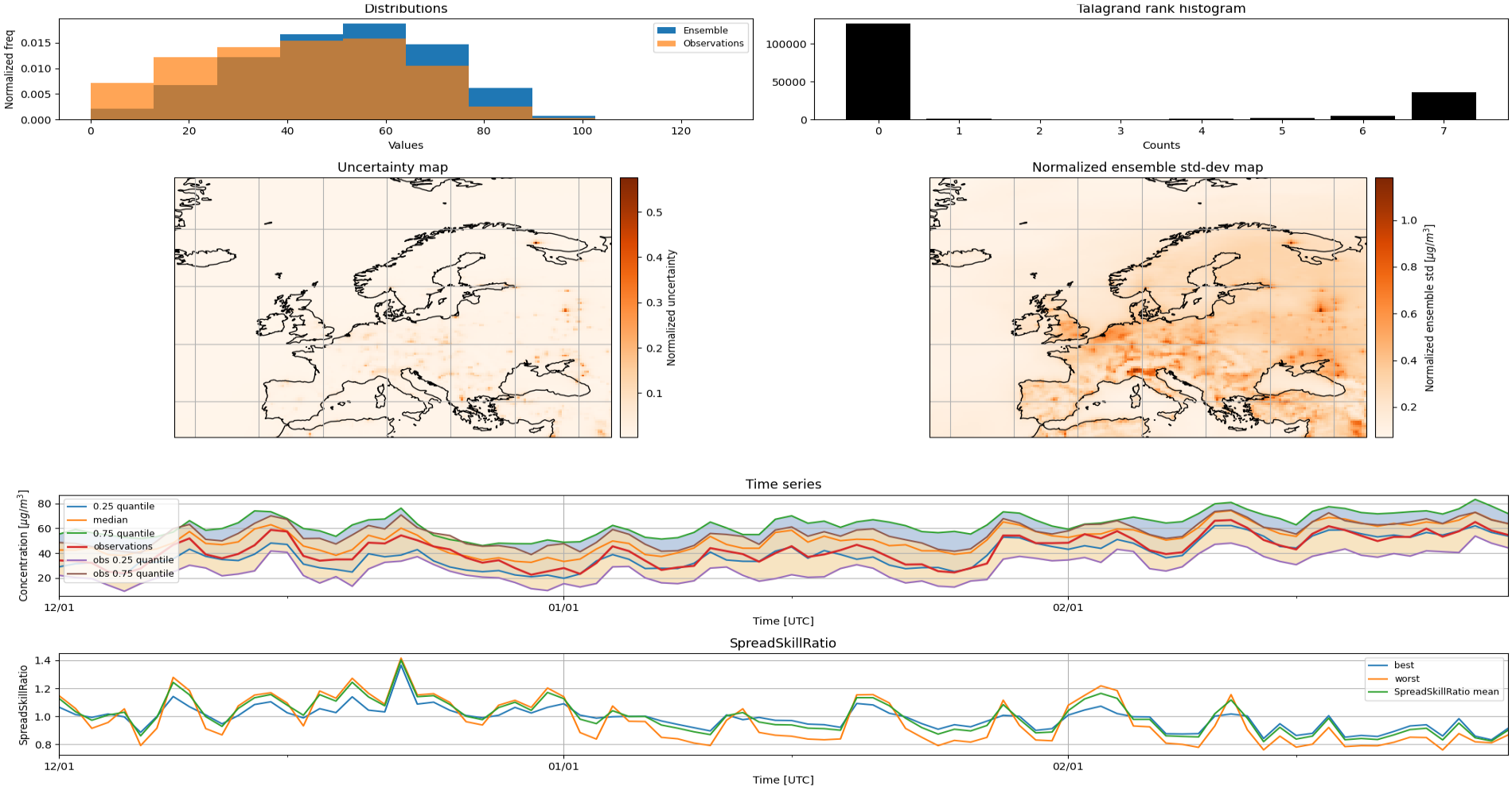

Conclusions

- **The forecasts are improved by the new dust emission scheme developped in MOCAGE**

- **The operationnal implementation of the MOCAGE model now has data assimilation capabilities that helps improving the forecasts**

- **Theoritical 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°x1° grid to a 0.5x0.5°
  - Expansion of the vertical level from 47 levels (~5hPa) to 60 (~0.1hPa)

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 y ear with an internship

Thank you for your attention !