CAMAERA

OFFLINE INVERSION OF DUST EMISSIONS

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PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Coordinated by HYGEOS

TASK 1.1: DUST EMISSION INVERSIONS

Rationale

- Spatial and temporal simulation of mineral dust in the model can be better estimated with the use of satellite aerosol optical depth observations
- Better the spatial and temporal estimates, better the assessment of the impact of the dust

Why in CAMAERA?

- Top-down emission inversions typically depends on the numerical modelling system: **target optimal dust emissions in IFS**

T1.1 Outcome:

- Dust emission dataset that can be use as baseline for online dust inversions (WP2)
- Provides useful information for new dust scheme developments (WP5)

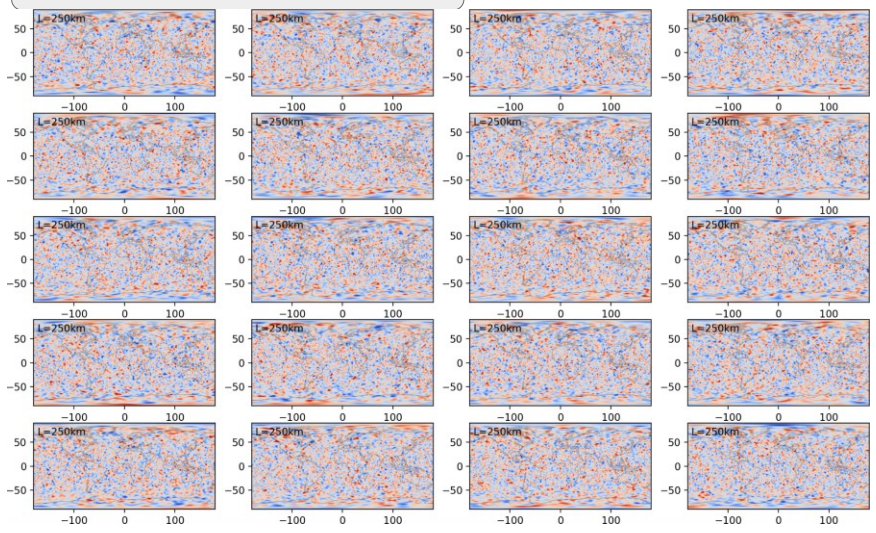
How?

- **Data assimilation** of satellite dust optical depth to estimate dust emissions
- Modified workflow of the **Local Ensemble Transform Kalman Filter** used at the Barcelona Supercomputing Center
- Scale factors for the prior **emissions** (3 days temporal resolution, gridpoint spatial resolution)

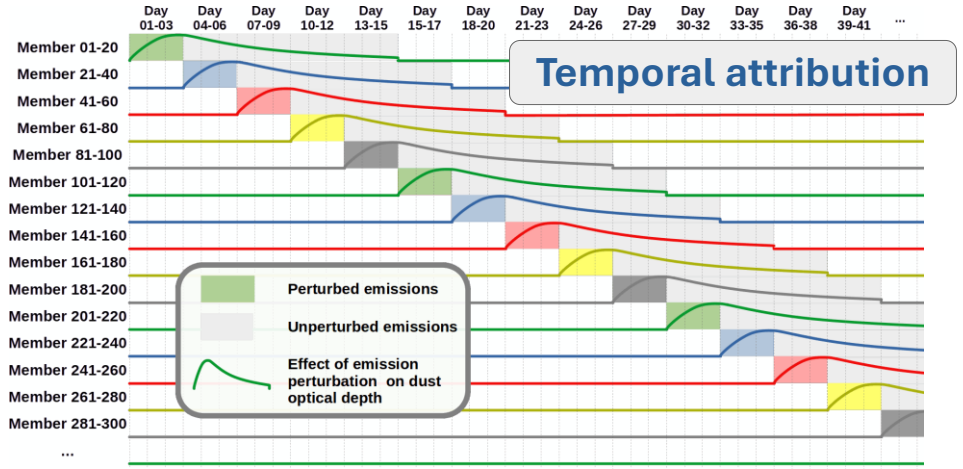
METHOD: MODIFIED ENSEMBLE AND WORKFLOW OF LETKF

Spatial perturbations

ENS inputs



Temporal attribution



Assimilated DOD

VIIRS SNPP Deep Blue

IFS-COMPO Ensemble

20 members with perturbed emissions at the time

100 *active* members

LETKF (smoother)

Control: dust emission

- 3 days temporal resolution
- Model horizontal resolution

Observations: Dust AOD or AOD 550nm

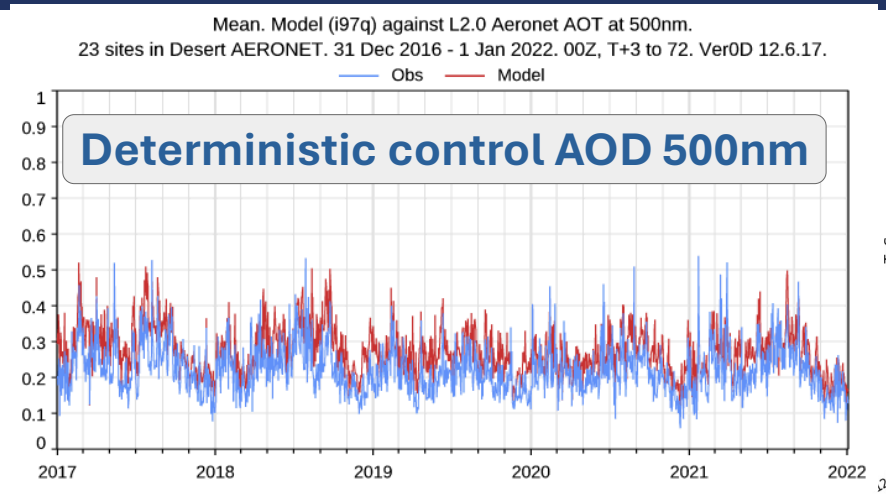
Analysis emissions (correction factors)

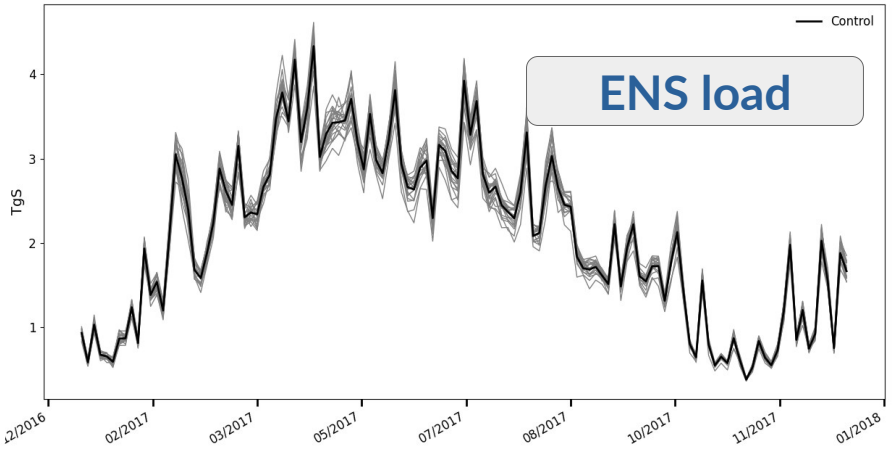
IFS

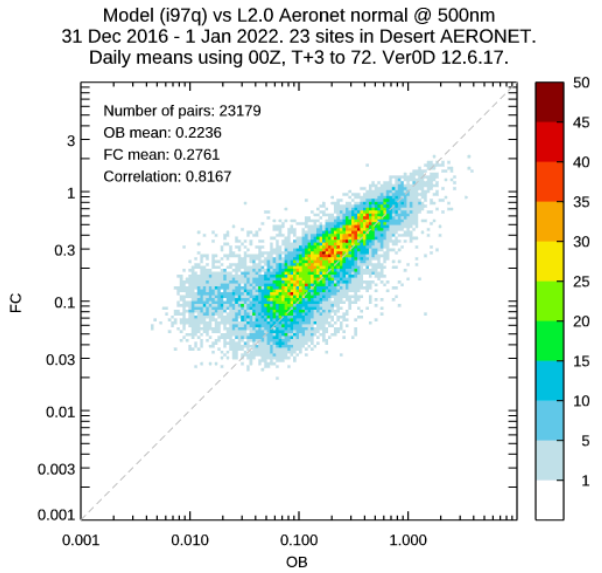
Analysis driven AOD, Dust AOD, PM, etc.

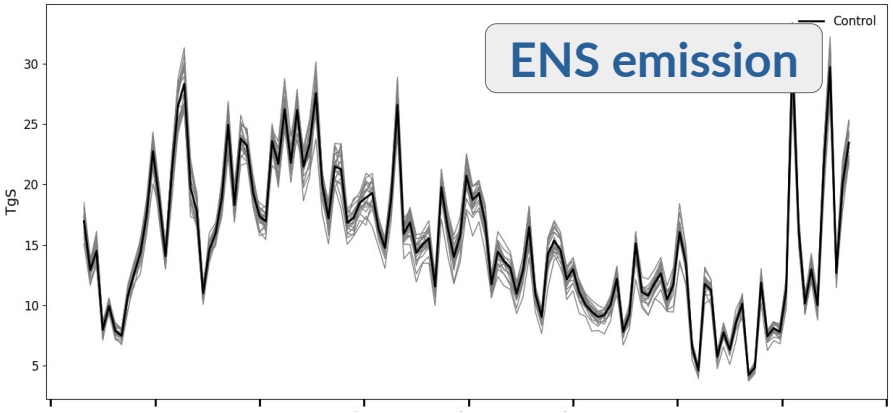
CONTROL RUN AND ENSEMBLE

- 1 control and 20 perturbed members,
- 15 days forecasts, cycling every three days, no data assimilation,
- Meteorology nudged to ERA-5 during the forecast,
- Perturbation of dust emissions applied in the first three days,
- TL511 L137 resolution,
- Aerosol only IFS-COMPO pre cycle 50R1 version, no chemistry configuration,
- Processed from 31/12/2016 to 1/1/2022.



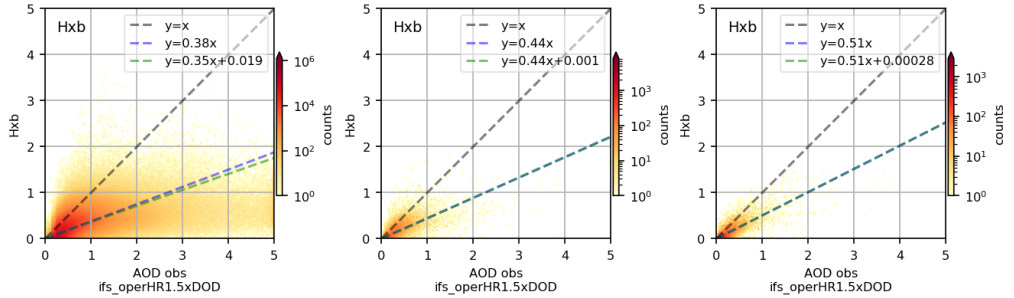




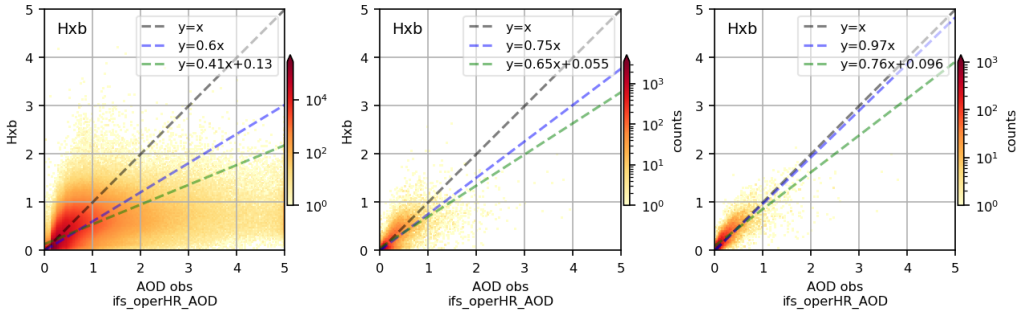


CONTROL VS OBS

Model DOD



Model AOD



VIIRS

AERONET (ang<0.3, all stations)

AERONET (all points, selected stations)

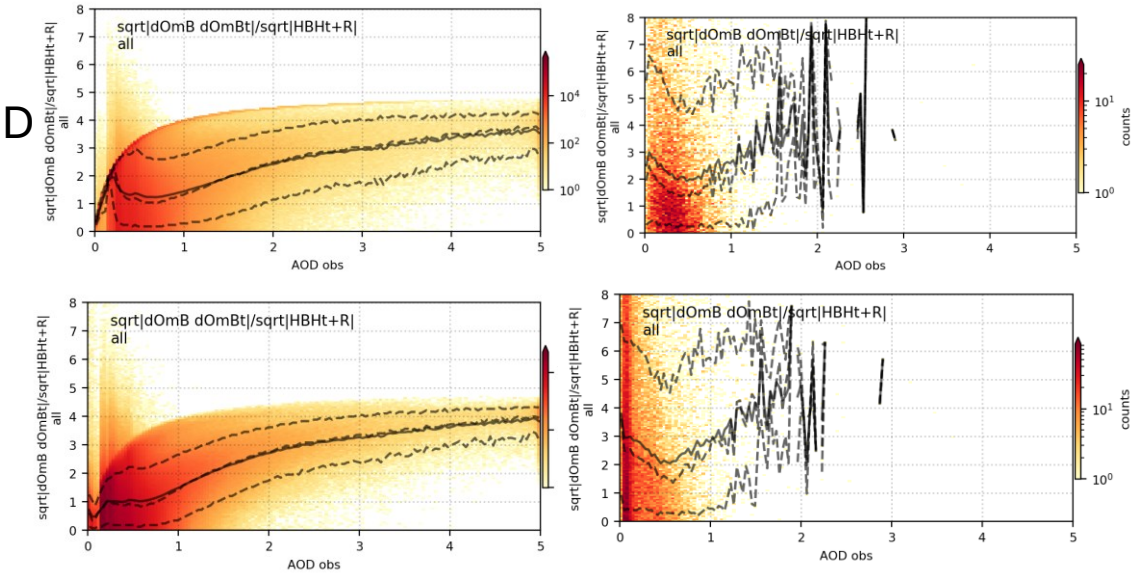
DA experiments:
EXP1: AOD
EXP2: 1.5xDOD

Analysis AOD experiments:
EXP1: AOD (daily)
EXP2: 1.5xDOD (daily)
***EXP3*: MONTH (monthly averaged scaling)**

Diagnostic on innovation:
(ideally) $\mathrm{sqrt}[\ d^o_b\ (d^o_b)^T\ /\ (\ HBH^T+R\ )\ ]\sim 1$

1.5xDOD

AOD

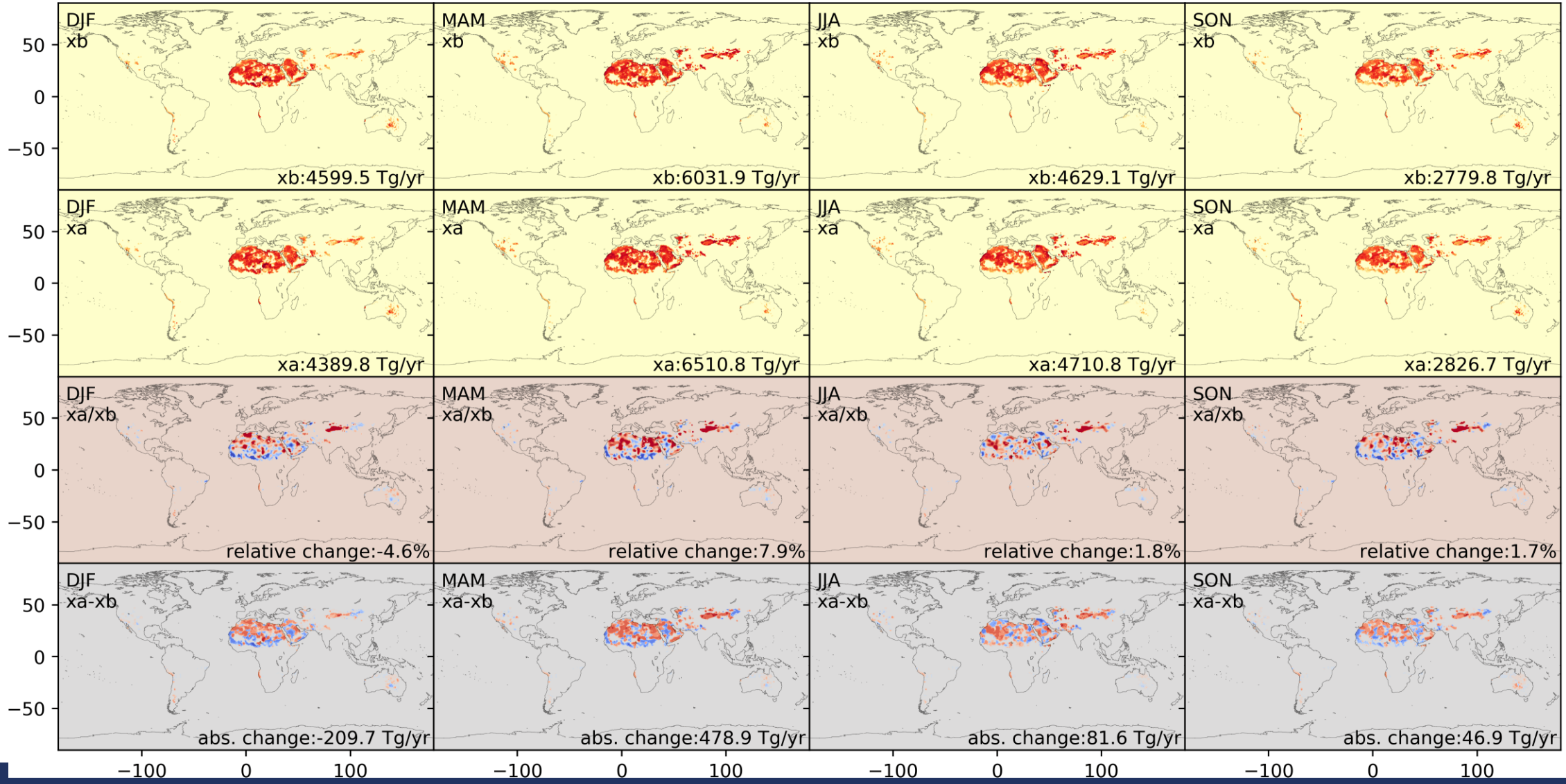


VIIRS

AERONET (ang<0.3, all stations)

B inflation of 2.5

RESULTS: EMISSION CHANGES (EXAMPLE: AOD, B INFL2.5)



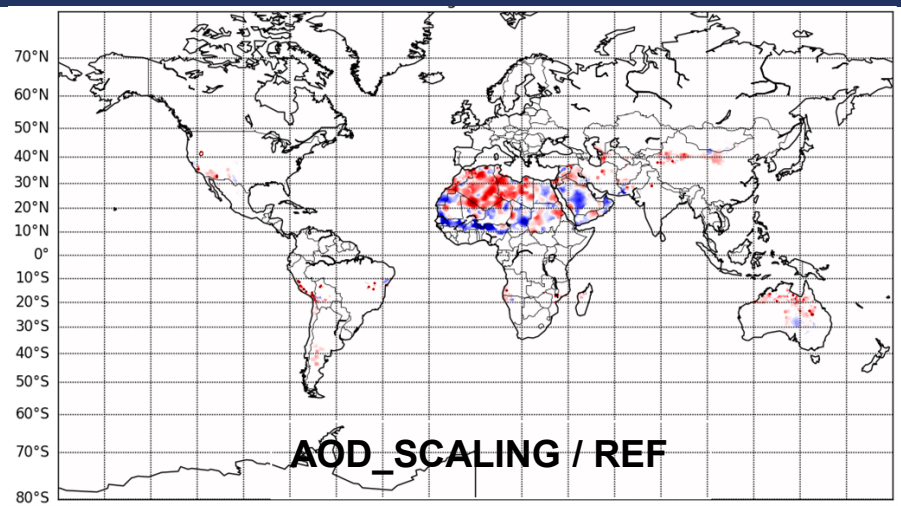
RESULTS: DUST EMISSION MAPS

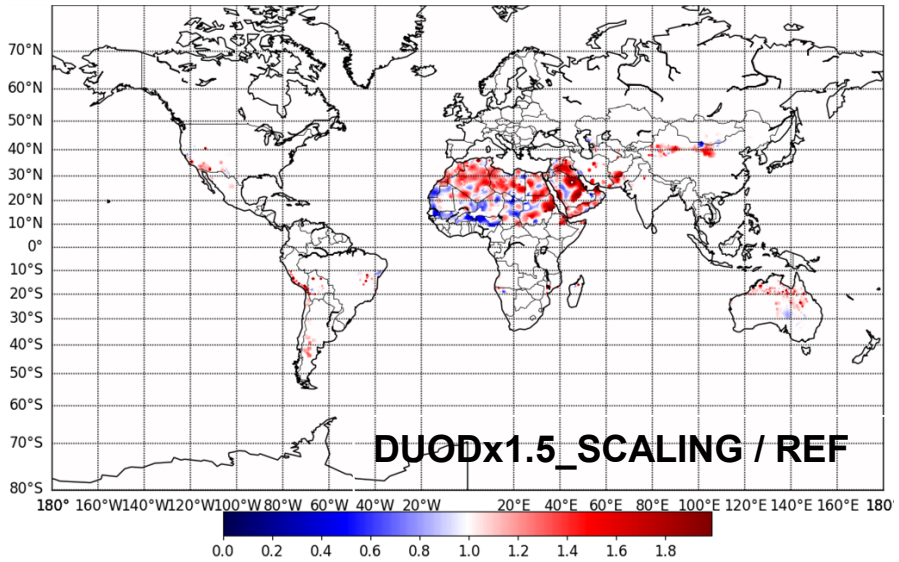
January 2017 mean

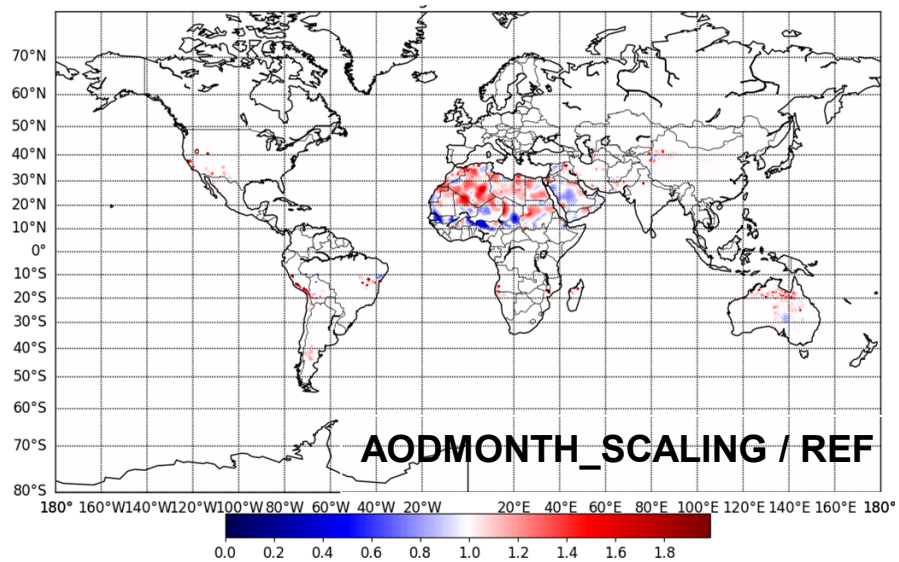
Regional decrease/increase of dust emissions of up to 40%

Some agreements (lower emissions over Sahel)

Some disagreement (Arabic Peninsula)







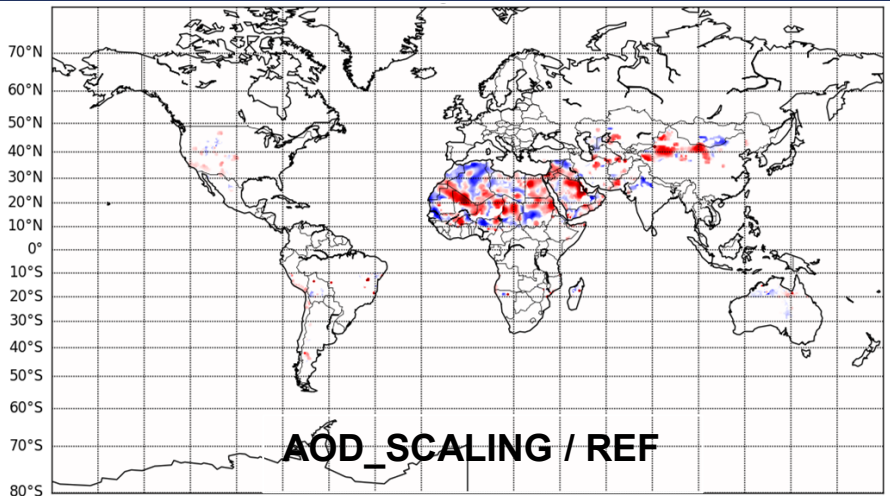
RESULTS: DUST EMISSION MAPS

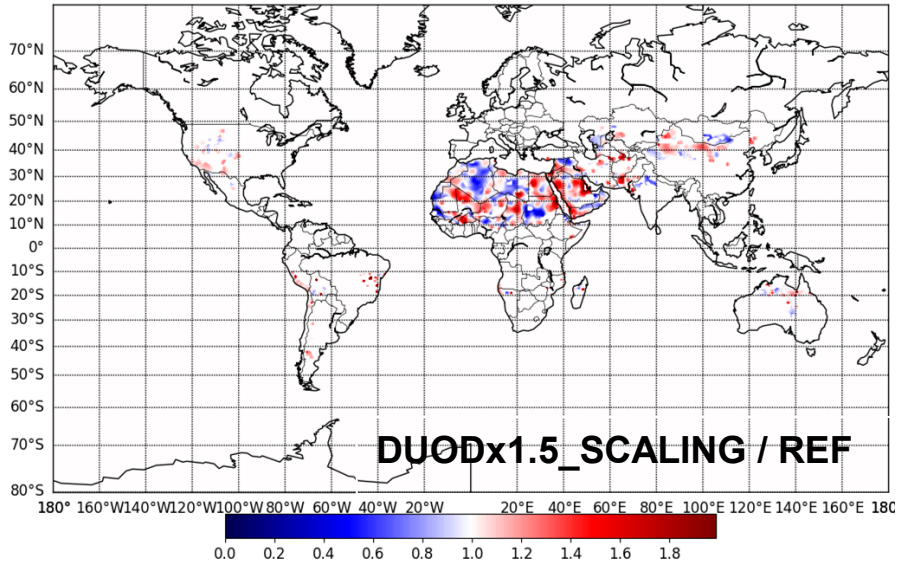
May 2017 mean

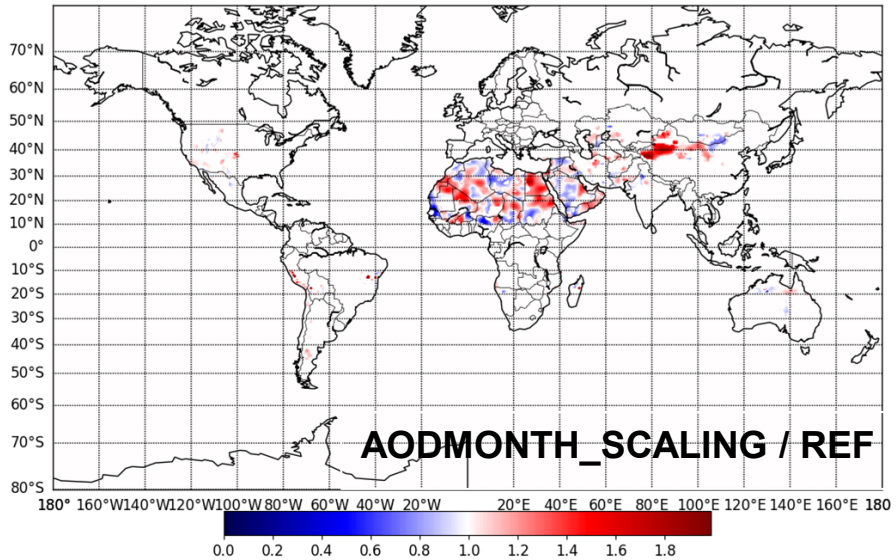
Regional decrease/increase of dust emissions of up to 40%

Some agreements (lower emissions over Sahel)

Some disagreement (Arabic Peninsula)

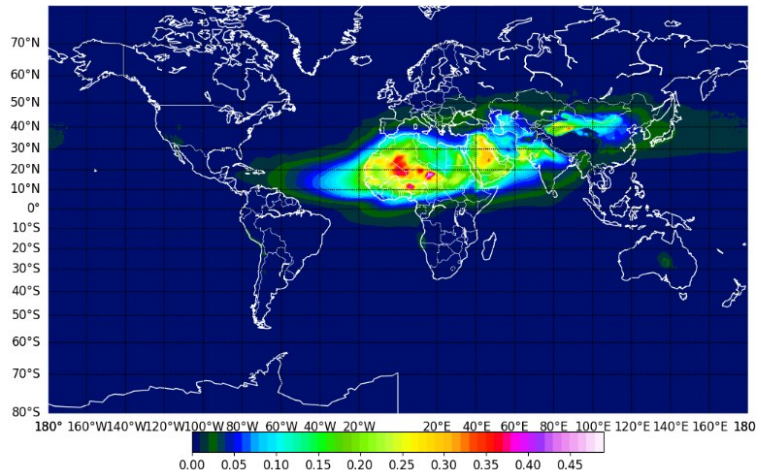






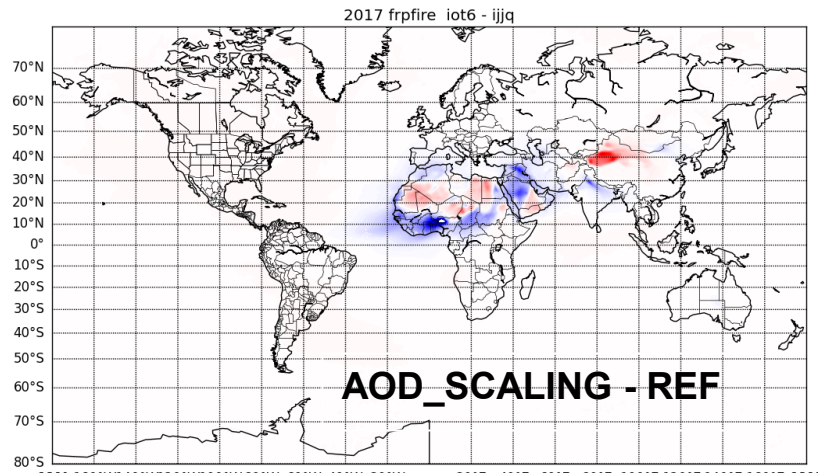
RESULTS: DOD MAPS WITH DAILY CORRECTION FACTORS

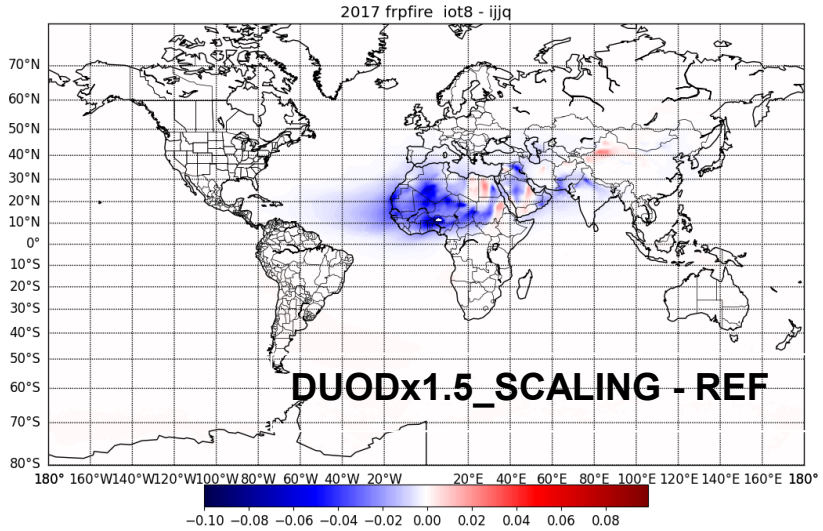
Averaged AOD

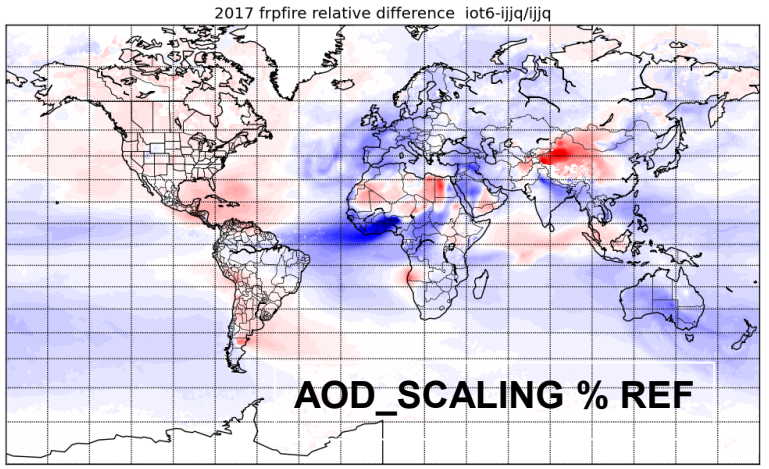


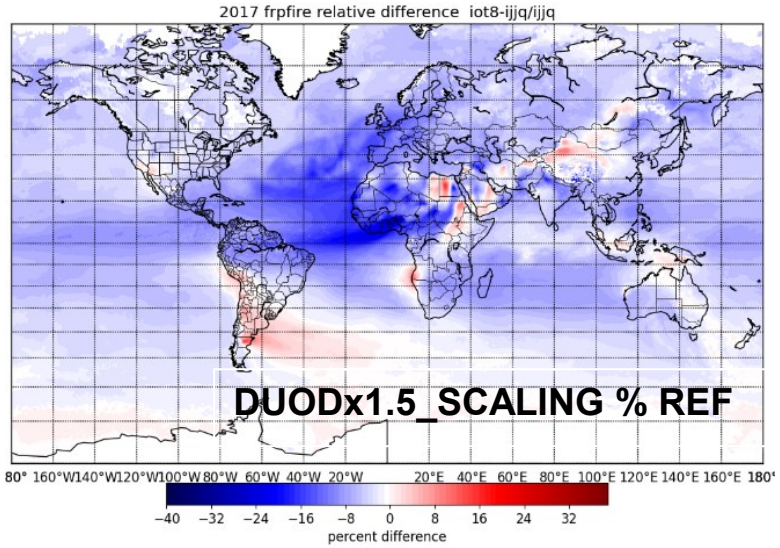
AOD in agreement with emission scaling

Max relative changes of ~10% in dusty regions



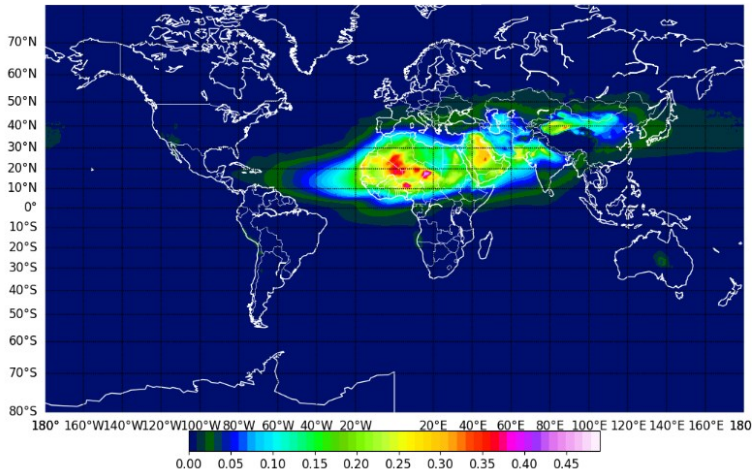


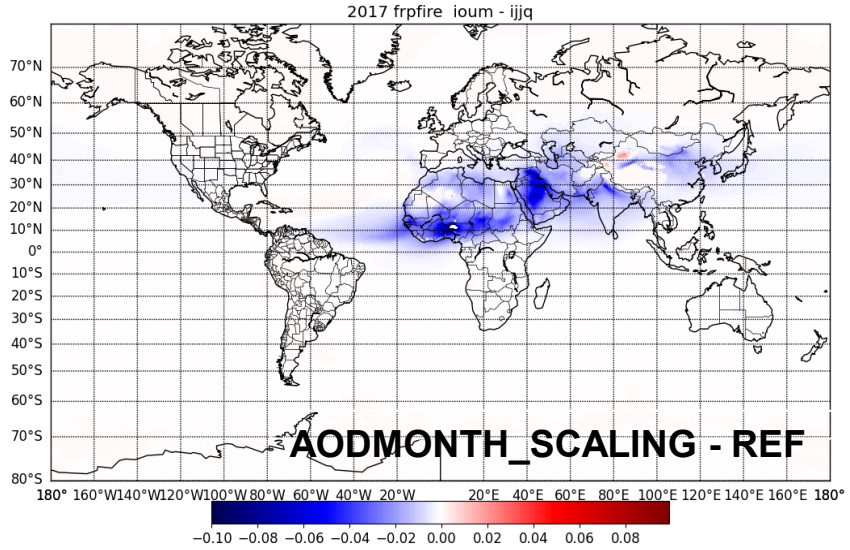


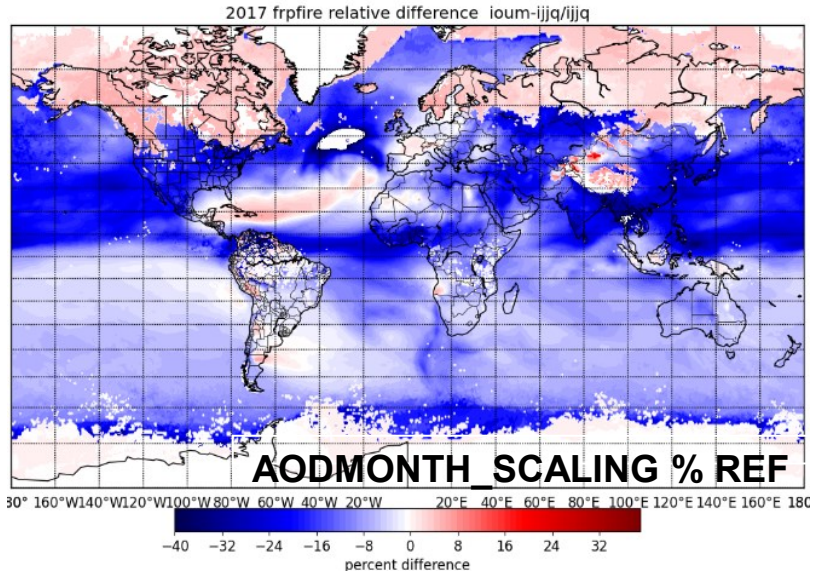


RESULTS: AERONET AND USE IN FORECASTS

Averaged AOD

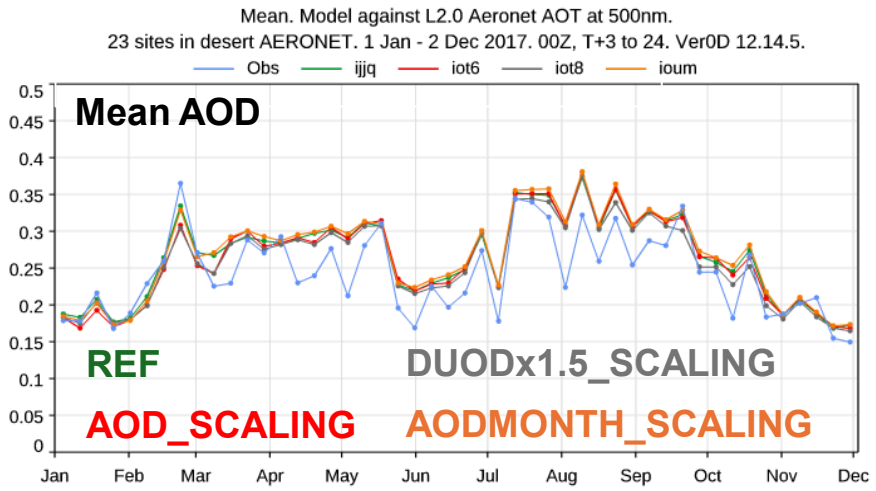


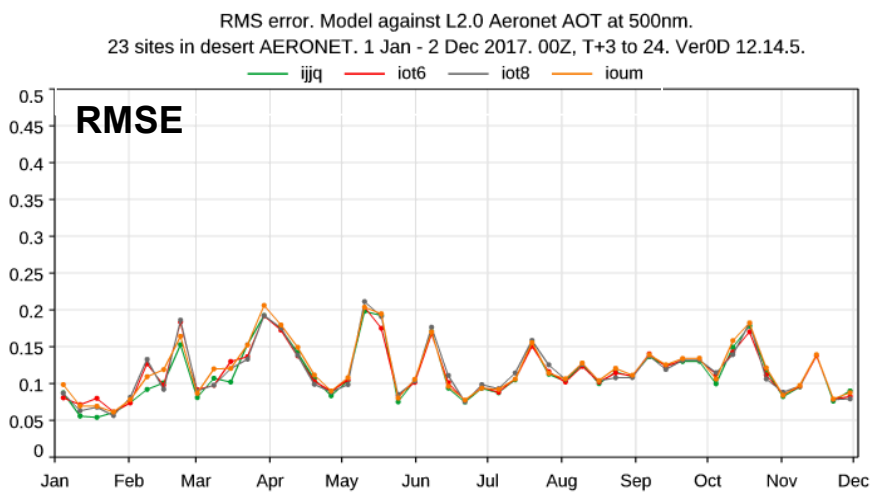




Very low impact on the aggregated time series

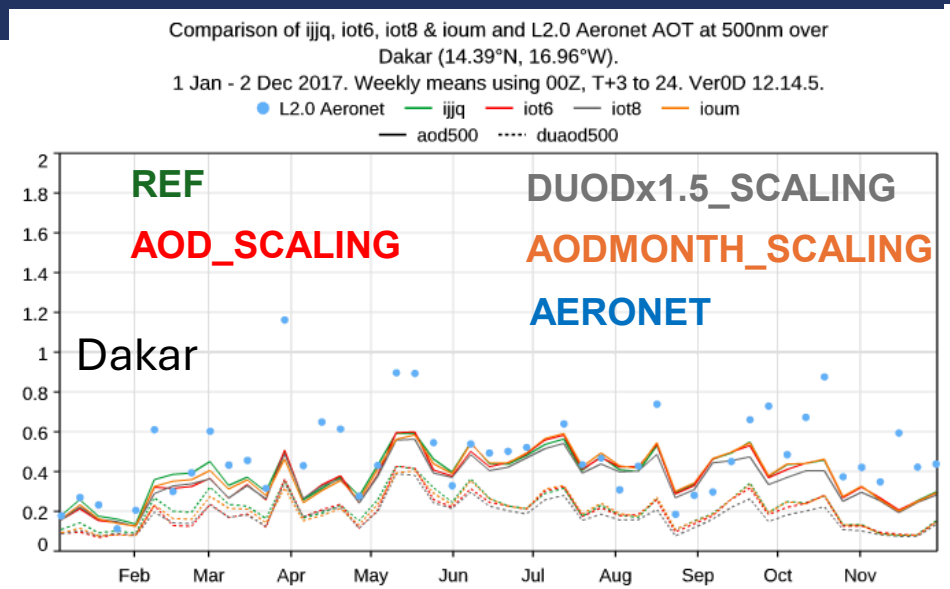
AODMONTH scaling not improving forecast on the aggregated time series

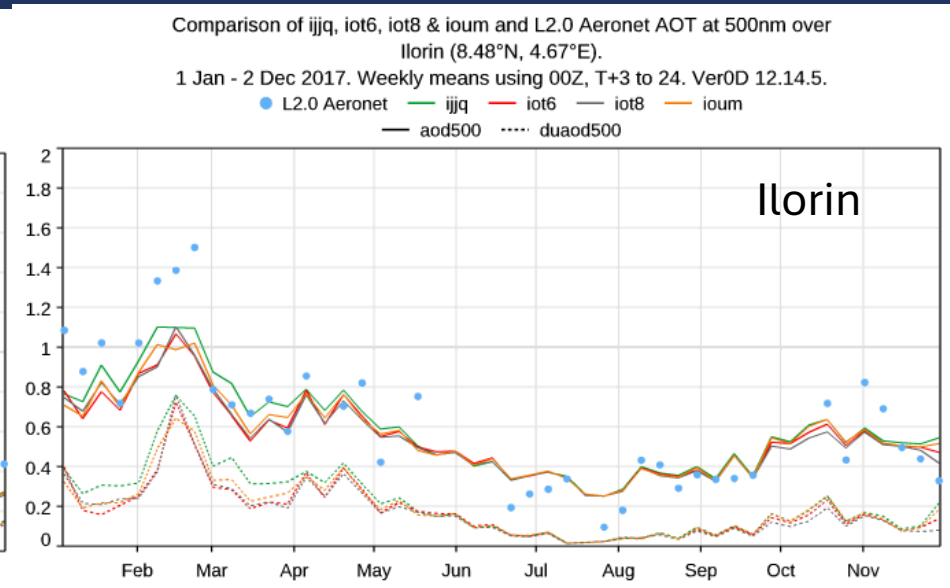


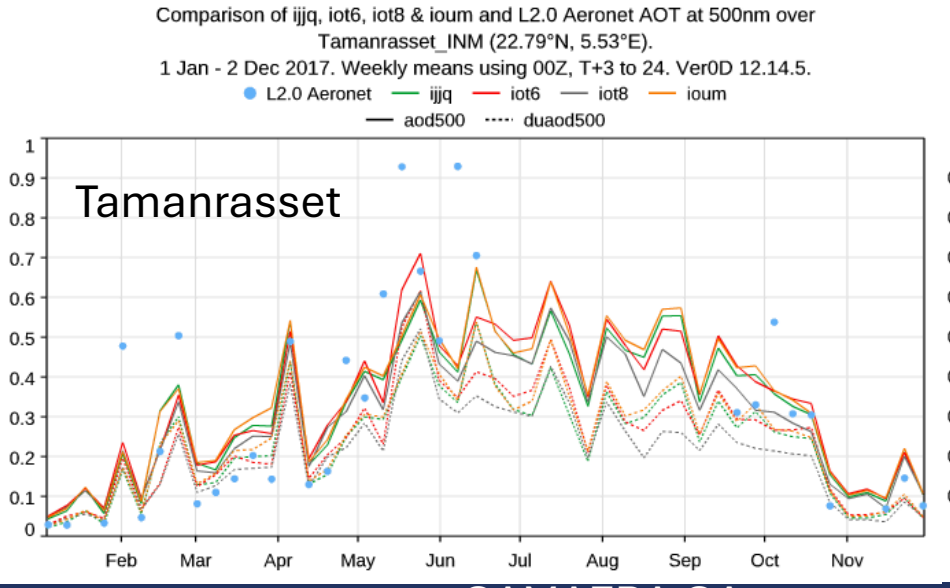


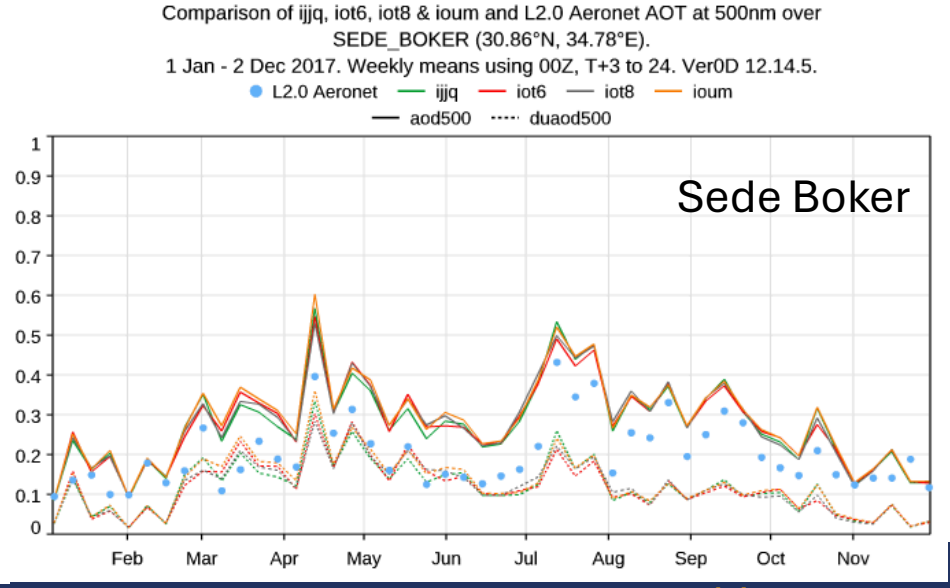
RESULTS: AERONET AND USE IN FORECASTS

Larger impact on individual station plots





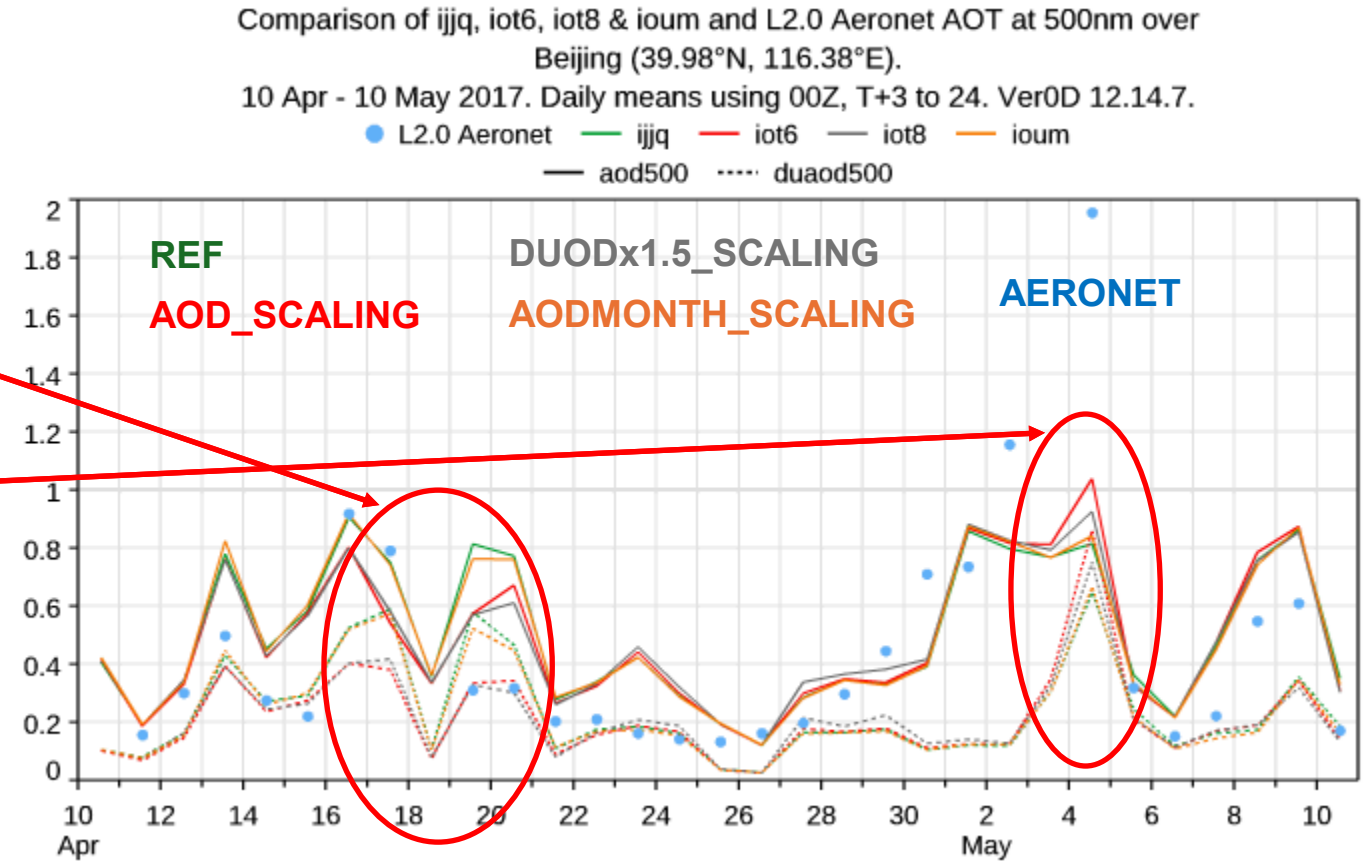




RESULTS: AERONET AND USE IN FORECASTS

Zoom on North China dust storms in April/May 2017

- The use of the scaling factors brought a decrease in simulated dust OD on 16-21 April => Desert dust from Inner Mongolia?
- The use of the scaling factors brought an increase in simulated dust OD on 3-5 May => Desert dust from Taklimakan/Gobi

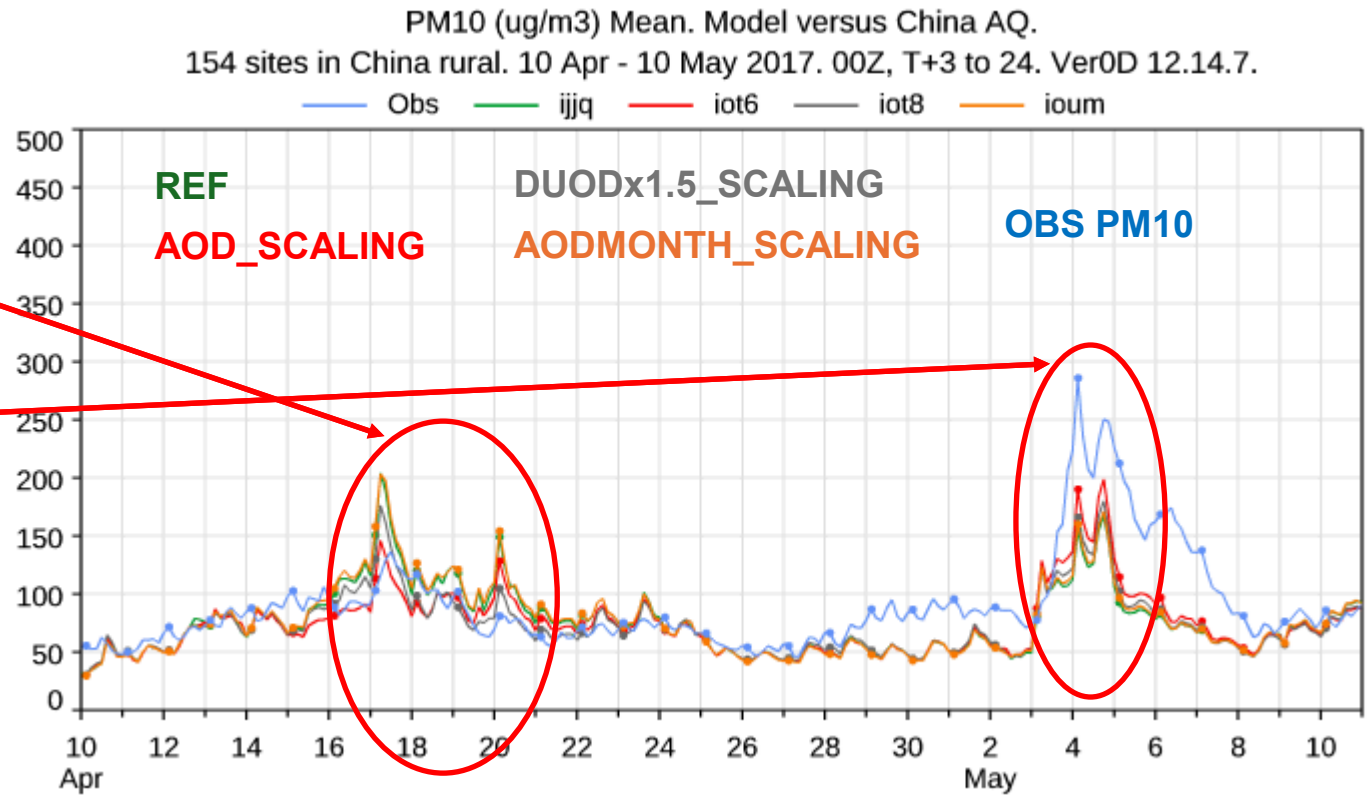


AOD BEIJING

RESULTS: PM10 AND USE IN FORECASTS

Zoom on North China dust storms in April/May 2017

- The use of the scaling factors brought a decrease in simulated dust OD on 16-21 April => Desert dust from Inner Mongolia?
- The use of the scaling factors brought an increase in simulated dust OD on 3-5 May => Desert dust from Taklimakan/Gobi

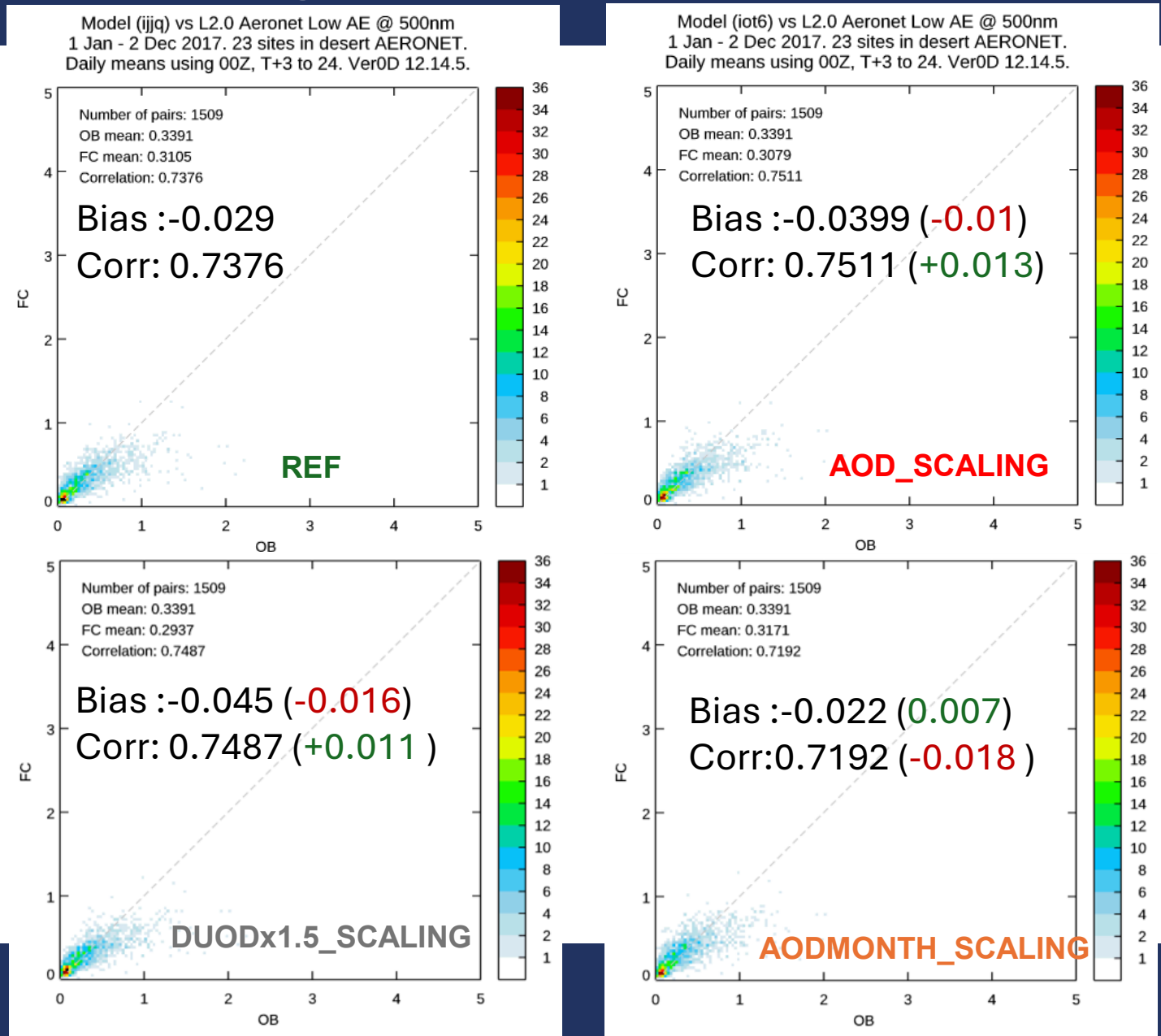


PM10 BEIJING

RESULTS: AERONET AND USE IN FORECASTS

Density scatter plot of obs/simulated AOD at 500nm, with an AE threshols on observations => only dusty observations

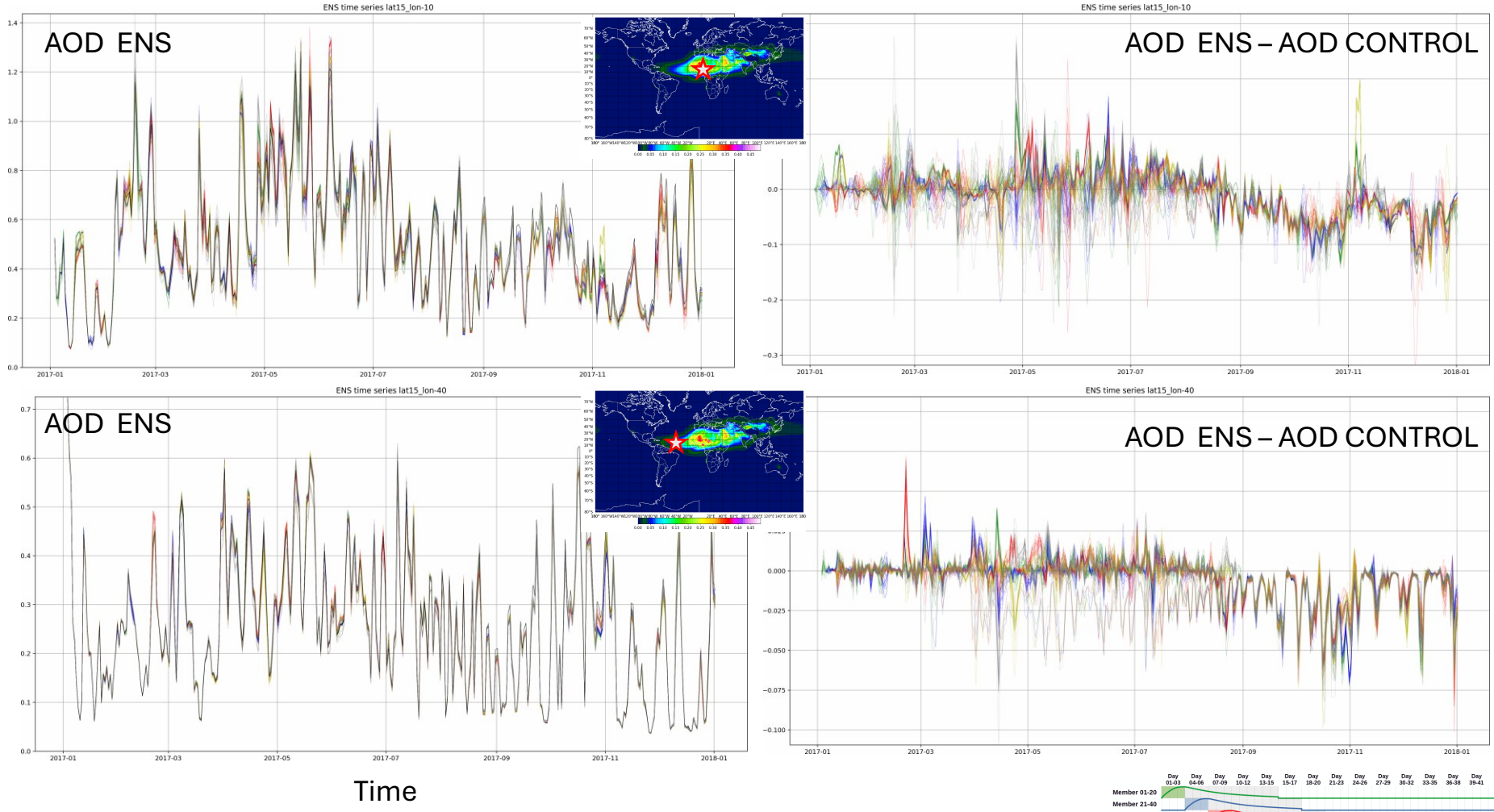
Small improvement in correlation with AOD_SCALING and DUODx1.5_SCALING, degradation with AODMONTH_SCALING



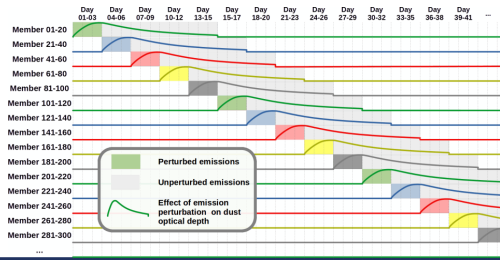
TWO POSSIBLE REASONS OF SMALL IMPACT IN AOD TIMESERIES

Small impact of emission in AOD time series for the ENS1 experiment.

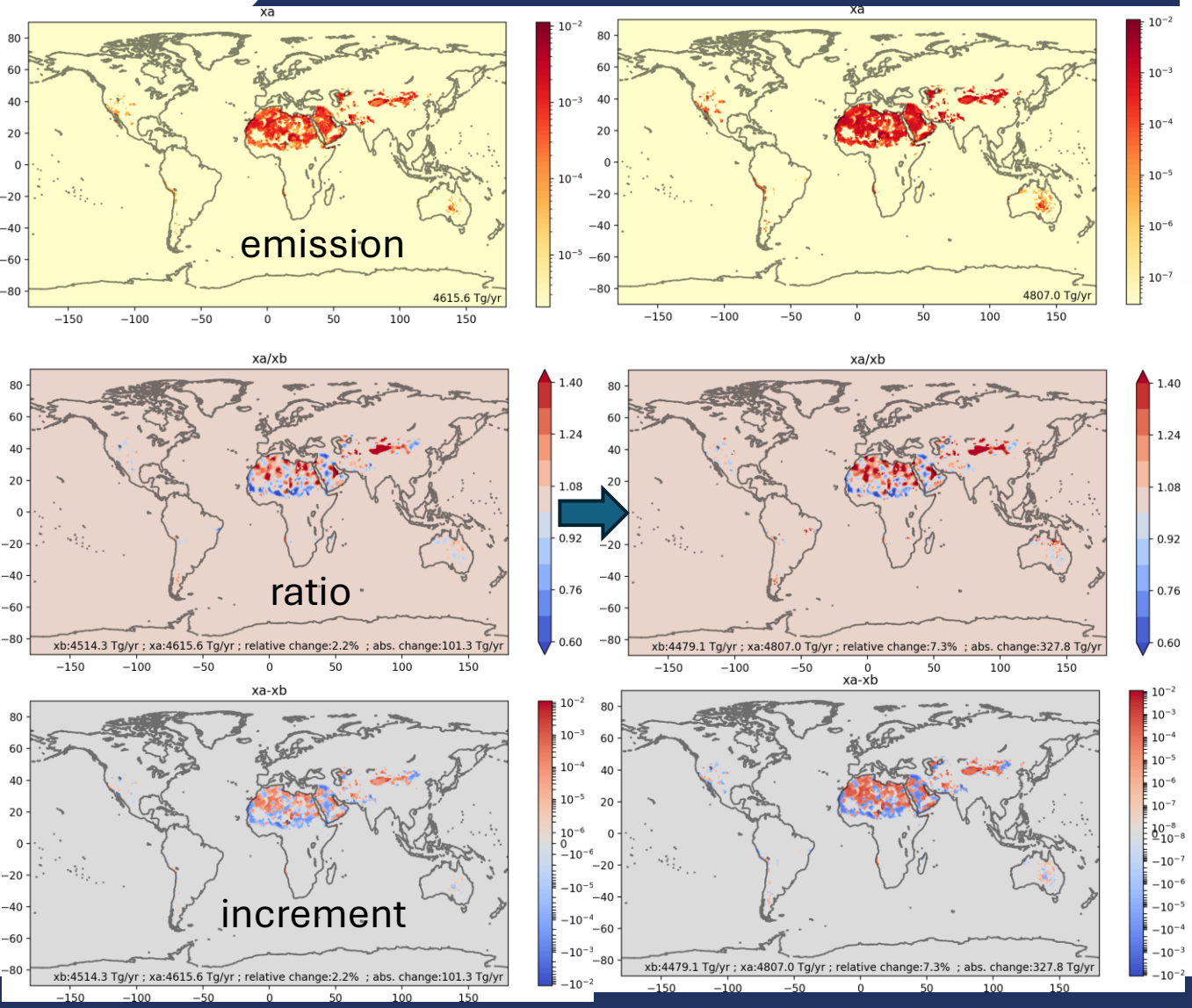
- The validation time series are spatial averages of weekly averages of AOD simulations at AERONET sites.
  - Scales of 250km of perturbation cannot resolve inter-weekly variations
  - **New ENS3 should help**
- Control run is somehow not aligned with ENS from ~September (at least 2017)
  - Probably an unwanted technical issue
  - **Estimate control with ENS mean**

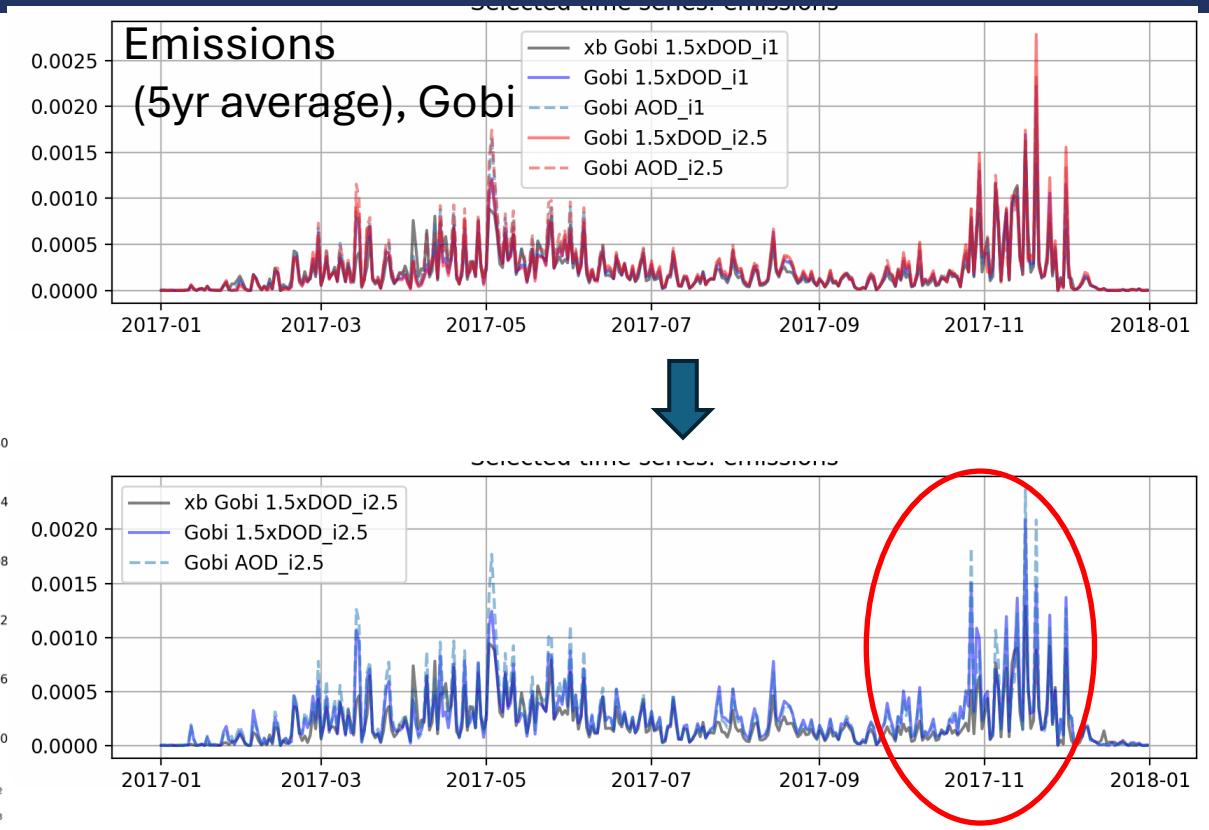


Timeseries colours are grouped by emission perturbation time:



UPGRADE: CONTROL AND ENS MEAN CONSISTENCY





Better consistency in the LETKF

Larger increments in total emissions (2.2% -> 7.4%)

Not strong qualitative impact in emission time series

ONGOING WORK: NEW ENSEMBLE

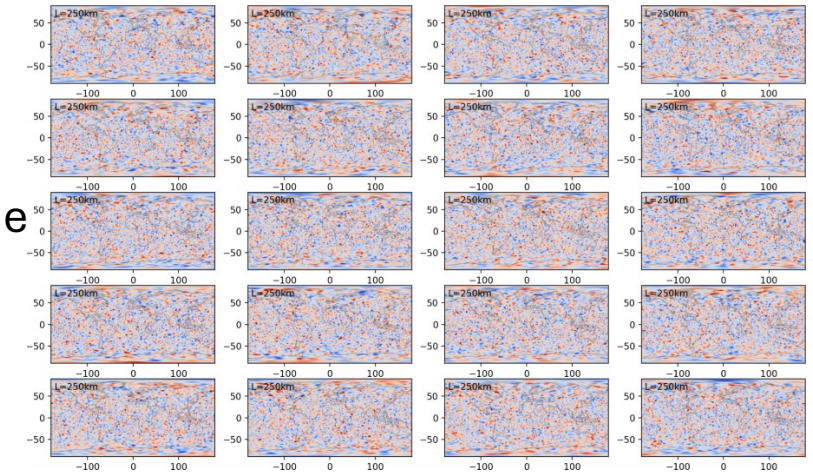
(2017-2021)

(preliminar: only 2017)

L:250km

Standard dust emission scheme

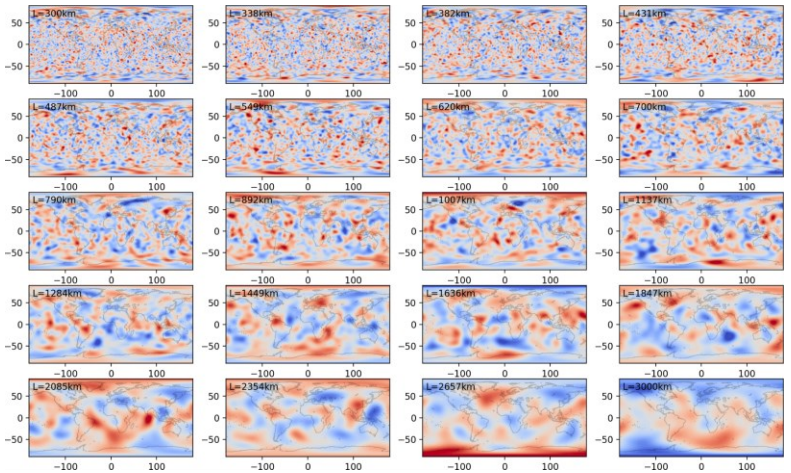
Fc: 4514 Tg/yr
An: 4615 Tg/yr
(+2.2%)

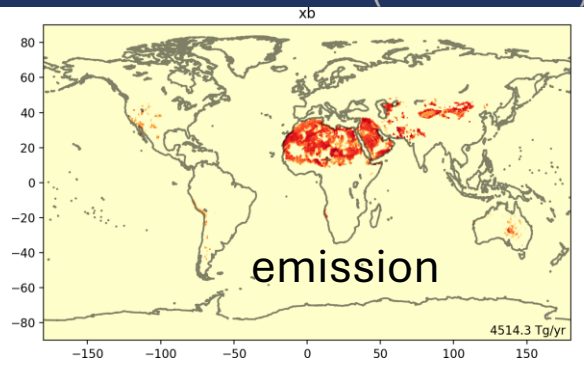


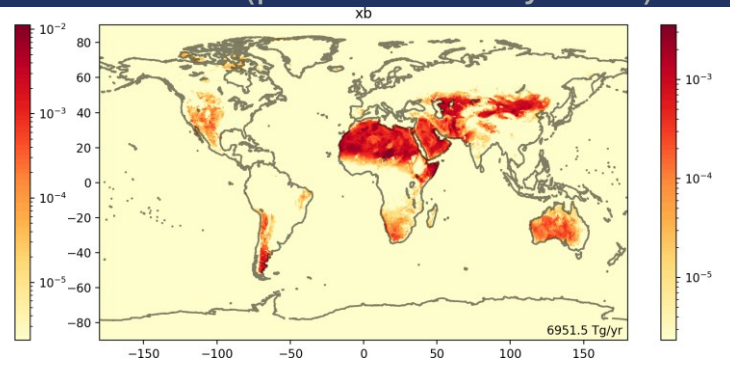
L: 300 to 3000 km

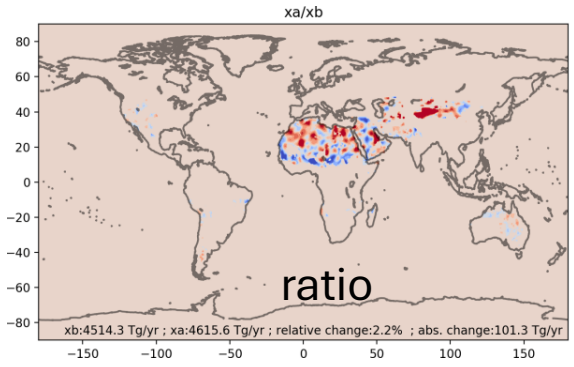
New dust scheme (Deliv 5.1)

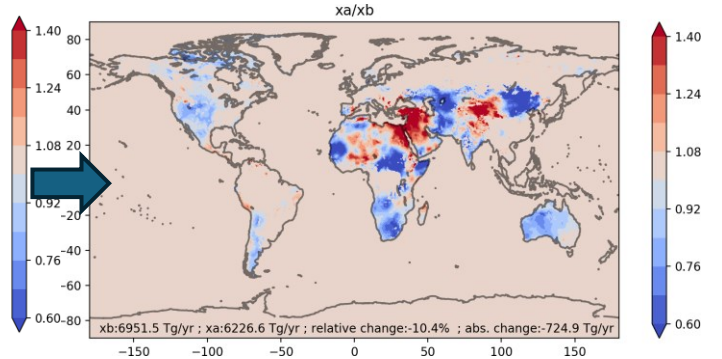
Fc: 6951 Tg/yr
An: 6229 Tg/yr
(-10.4%)

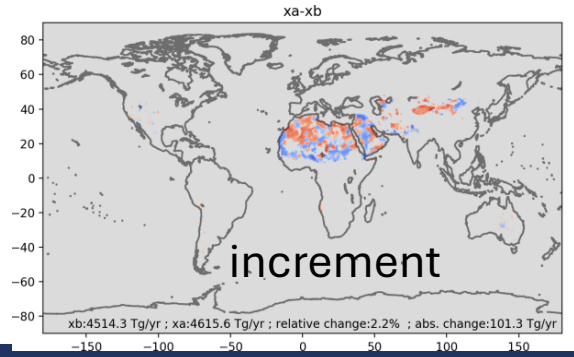


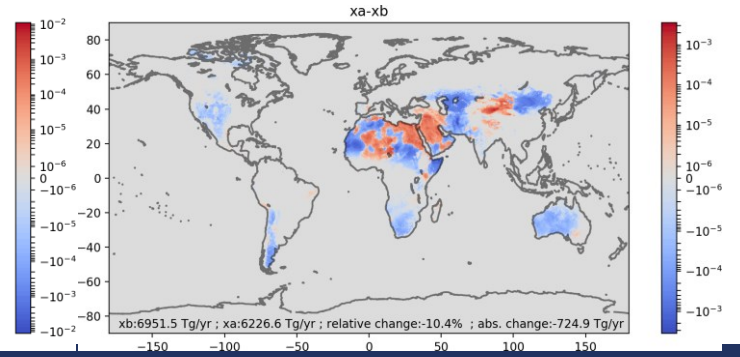












SUMMARY, CONCLUSIONS, FUTURE WORK

- Offline dust emission inversion has been implemented and tested for IFS-COMPO
  - Detected issues and biases in the forecasts: DOD -> AOD in the OO
  - Ensemble shows expected spread, control shows good skills

- Emission corrections shows a spatial correction with reatively small seasonal variations
- Improvements with respect to weekly AERONET AODs are very small in the aggregated scale
  - Increments are smoothed during transport -> Testing new ensemble with larger correlation length
  - Small improvement in correlation coefficient and disaggregated comparisons (by station)
  - Monthly scaling experiment does not show better skills

Next steps:

- New sets of IFS-COMPO simulations are being produced, with new perturbation set and dust emission scheme
- Inconsistency between the mean state and the control run in the DA code has been detected and the impact has been mitigated
- Latest developments will provide a better constrain of IFS-COMPO dust emissions.

Thank you!