climate change initiative

→ CLIMATE MODELLING USER GROUP

CMUG PHASE 3 – Cross-ECV Climate Science Study: Cloud and Aerosol Analysis Study

cmug cci

Institutes: BSC, ECMWF, (DLR for a potential follow up study)

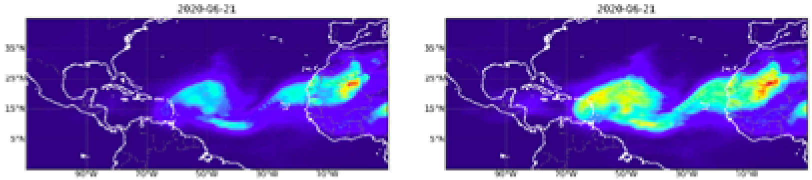
Leads: Angela Benedetti, Kirsti Salonen, Jeronimo Escribano, (Axel Lauer)

WP5.5 Cloud and Aerosol Analysis Study

Aerosol ECVs : Aerosol Optical Depth (Dust AOD, FM AOD, AOD)
Cloud ECVs : Cloud Optical Depth (Cloud Top Height, Cloud Fraction, Ice Water Path, Liquid Water Path)

WP5.5.1 Dust aerosol analysis with the BSC system

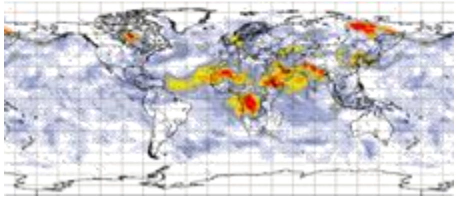
Jeronimo Escribano (**BSC**)



Constrain global **dust** aerosol simulations from the BSC MONARCH model with CCI data to produce dust analyses during the extraordinary event of June 2020.
→ Explore pixel-level uncertainties, Coarse AOD vs DOD, Comparison with DOMOS results.

WP5.5.2 Cloud/Aerosol analysis with the ECMWF system.

Angela Benedetti and Kirsti Salonen (**ECMWF**)



Joint assimilation of **aerosol** and **cloud** ECVs in the ECMWF IFS during June 2020 and September 2021 with the IFS 4DVar scheme in CAMS configuration.
→ Impact of COD and AOD level 2 data on the 4D-Var analysis

OWP5.5 Cloud and Aerosol Analysis Validation Study:

Evaluation using the ESMValTool and internal tools at BSC/ECMWF
Soil Moisture, Water Vapour ECVs.
A. Benedetti and K. Salonen (ECMWF), Axel Lauer (**DLR**), J. Escribano (BSC)

WP5.5.1
Dust aerosol analysis with the BSC system

Jerónimo Escribano

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

"Godzilla" dust event and data visual inspection

Dust plume from the Sahara towards the Caribbean, June 2020.

Benefits of assimilation dust optical depth dust forecasts

SLSTR – SU v1.14 for assimilation
Aerosol optical depth (AOD)
Dust aerosol optical depth (DOD)
Coarse AOD

- Linear model of uncertainties
- Pixel-wise uncertainties provided in the retrievals

AERONET 500nm for verification

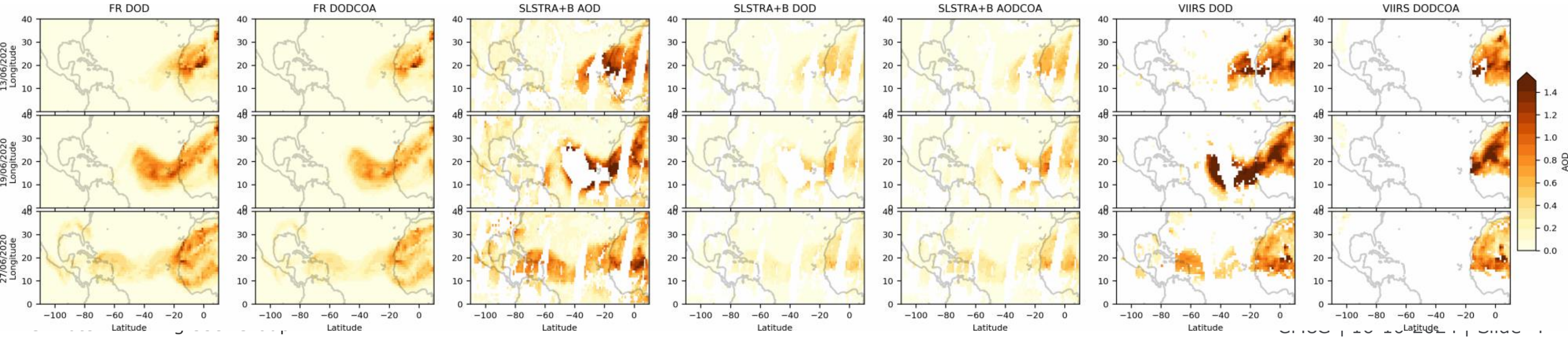
- Direct sun, Angstrom exponent <0.3
- Coarse AOD from SDA.

BSC's Multiscale Online Nonhydrostatic AtmospheRe CHemistry (MONARCH) model:

- Global, 1 x 1.4 configuration a, GOCART dust emission scheme (as in Klose et al., 2021)

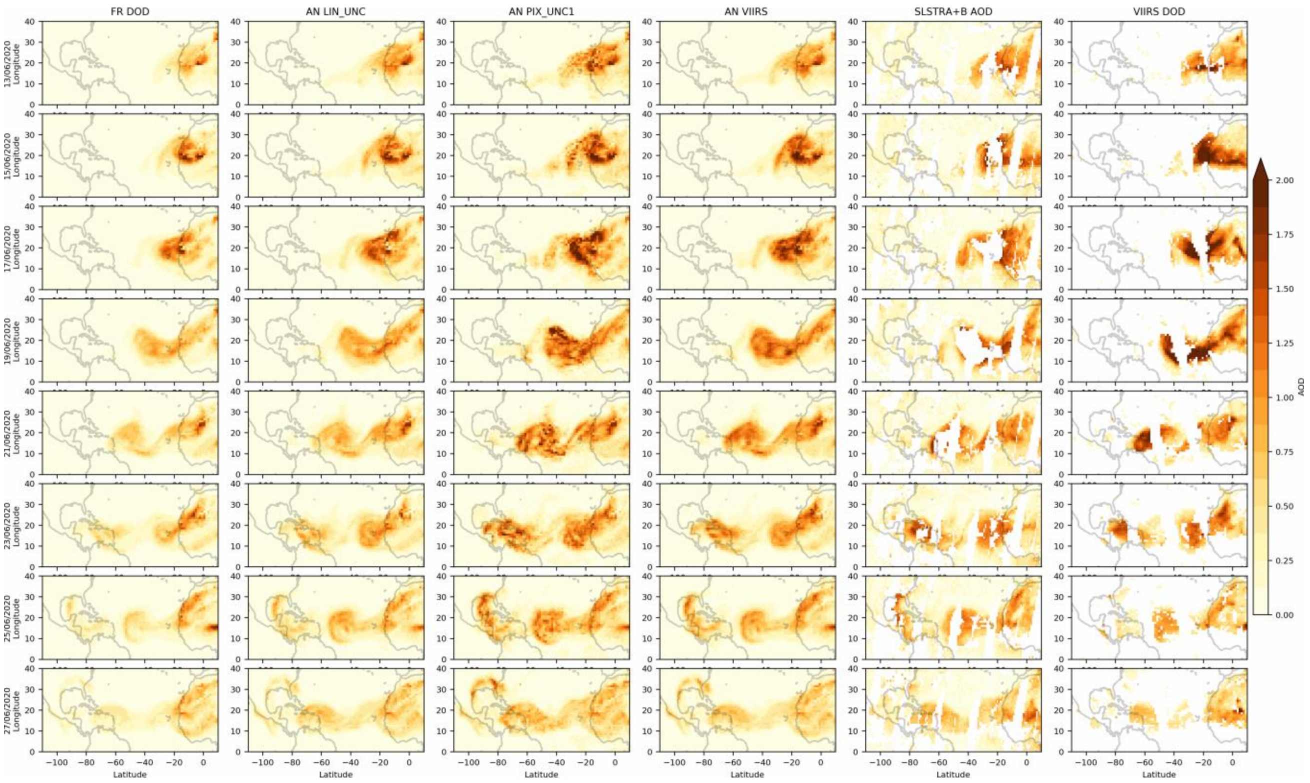
Local Ensemble Transform Kalman Filter (LETKF):

- 20 members, dust emission and meteorological ensemble perturbations (as in Escribano et al., 2022)

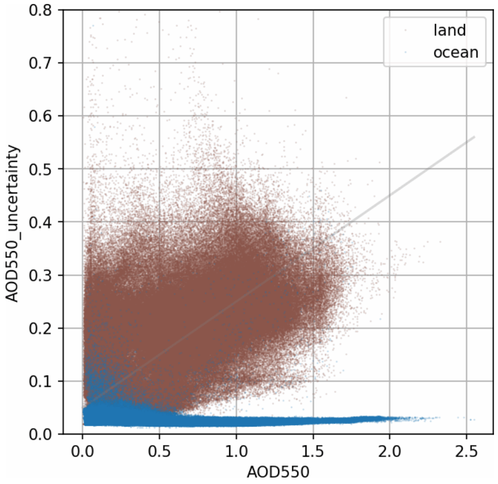


AOD assimilation

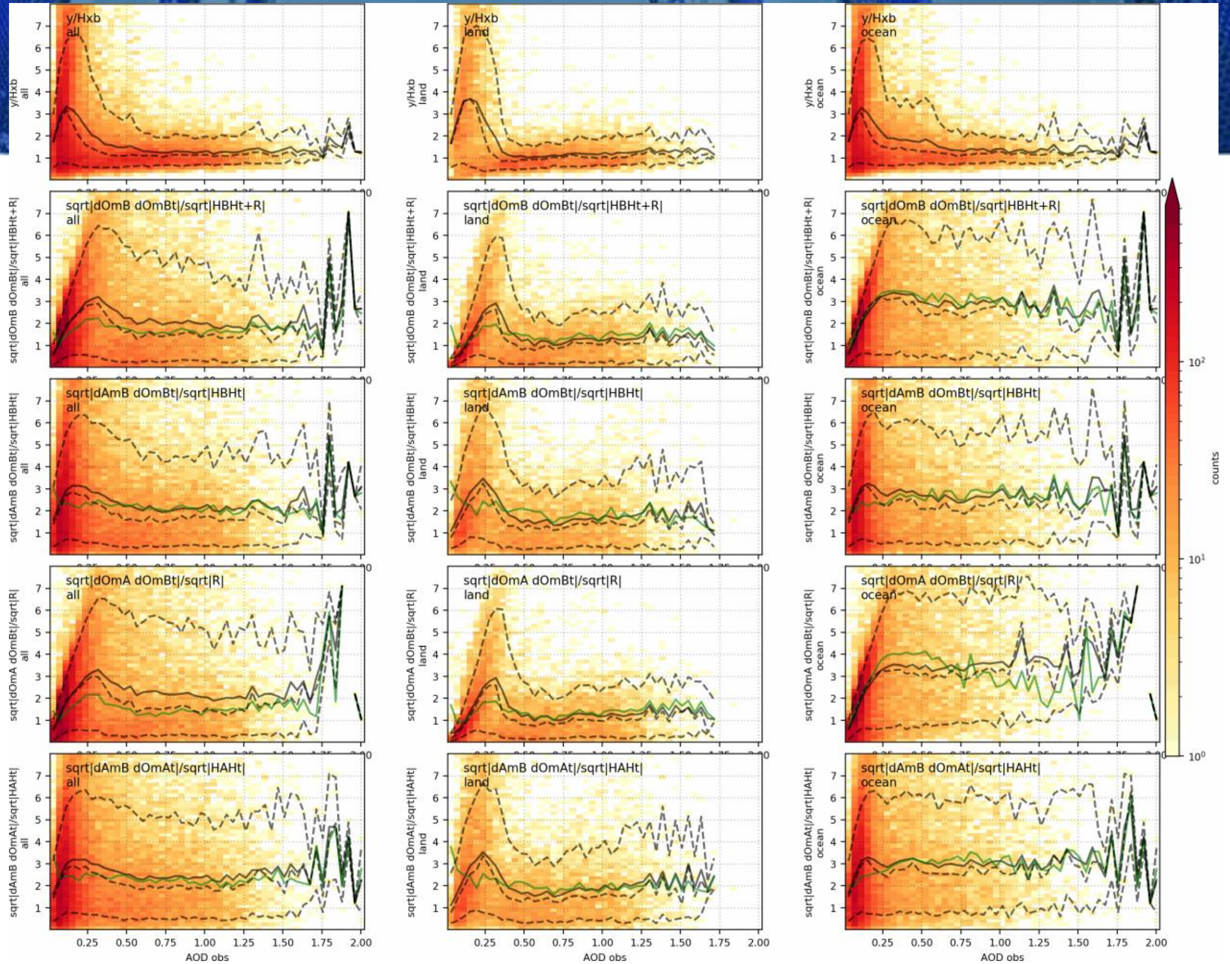
- Improvement of scores with respect to control run
- Consistency with assimilated observations and VIIRS DOD
- Experiment with pixel-wise uncertainty shows better skills than experiment with linear uncertainties
- Comparable with DOMOS VIIRS assimilation exp.
- Small-scale structure in pixel-wise uncertainty assimilation



Reported uncertainties smaller over ocean than over land



With implications in the error balance of DA system

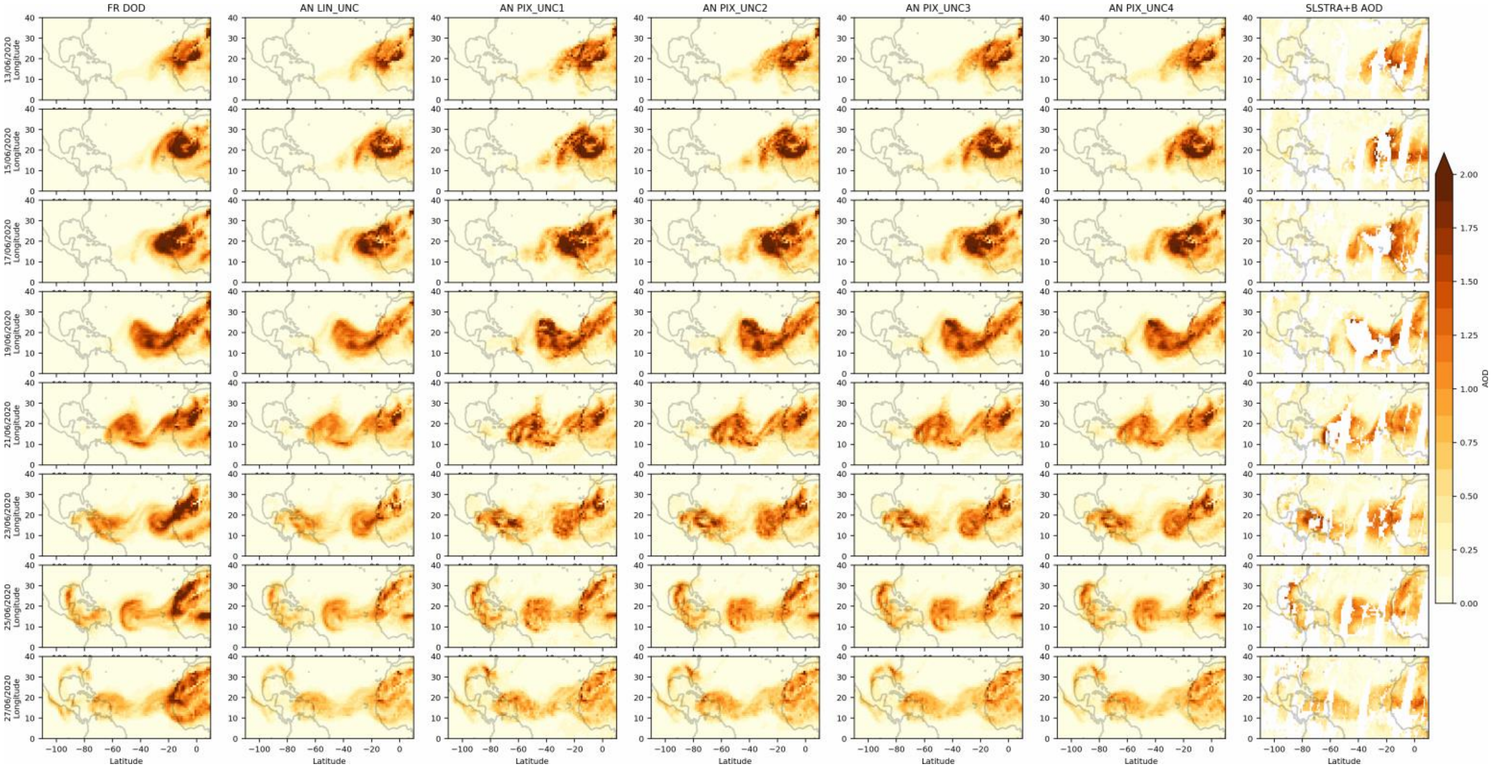


Implementation of Desroziers et al. (2005) diagnostics

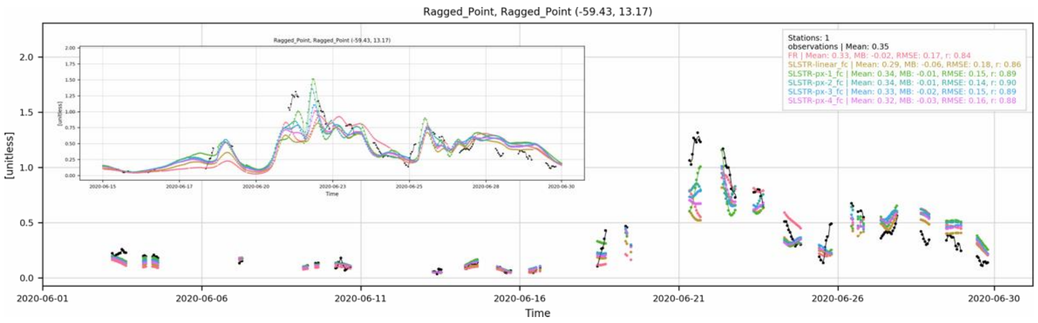
SLSTR DA analyses

Focus on error balance: new runs with larger dust calibration factor (global constant)

Assimilation with inflation of AOD uncertainty over ocean: factors 1 to 4



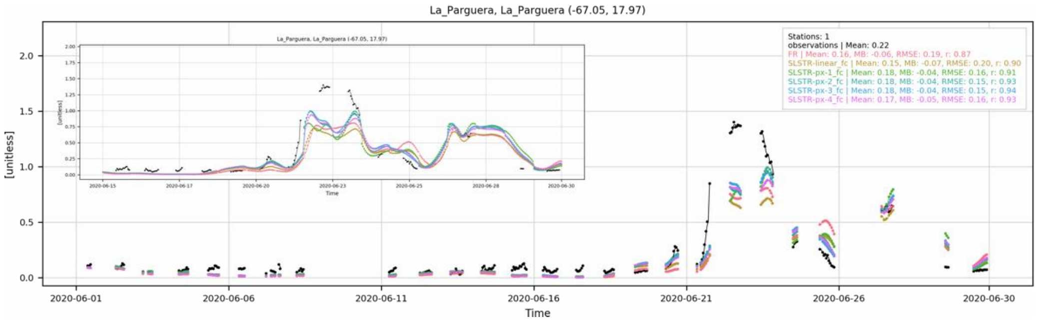
AERONET AOD coarse and AOD (Ang<0.3)



Forecast, coarse AOD

lighter is better

	MB	NMB	MFB (%)	MAE	NME	MFE (%)	RMSE	r
FR	-0.03	-13.23	-30.93	0.09	46.94	69.75	0.18	0.82
SLSTR-linear	-0.05	-23.14	-26.78	0.08	41.42	62.90	0.18	0.87
SLSTR-px1	-0.01	-7.34	-6.30	0.08	42.06	57.63	0.17	0.85
SLSTR-px2	-0.02	-8.97	-13.00	0.08	39.45	59.81	0.16	0.87
SLSTR-px3	-0.02	-10.70	-16.65	0.08	39.31	61.55	0.16	0.88
SLSTR-px4	-0.03	-12.91	-19.49	0.08	39.72	62.49	0.16	0.88



Forecast, AOD (Angstrom<0.3)

lighter is better

	MB	NMB	MFB (%)	MAE	NME	MFE (%)	RMSE	r
FR	-0.04	-8.35	-11.03	0.22	42.16	47.24	0.36	0.73
SLSTR-linear	-0.10	-19.13	-11.47	0.19	36.17	40.25	0.34	0.82
SLSTR-px1	-0.03	-5.07	5.67	0.20	38.72	41.28	0.34	0.78
SLSTR-px2	-0.03	-5.54	4.07	0.19	35.98	40.24	0.32	0.81
SLSTR-px3	-0.04	-7.36	1.73	0.18	35.54	40.24	0.31	0.82
SLSTR-px4	-0.05	-9.06	-0.48	0.18	35.53	40.24	0.32	0.82

Summary

- Godzilla dust event on June 2020
- SLSTR-SU v1.14 AOD assimilated in MONARCH LETKF global dust forecast mode
- Dust AOD and Coarse AOD from retrievals likely to underestimate dust plume
- With standard calibration constant factor (i.e., control run biased low):
    - Assimilation of SLSTR AOD improves scores with respect to the control
    - Performance similar to assimilation performed in DOMOS project (LIVAS and VIIRS)
- With unbiased calibration constant factor :
    - Inflation of uncertainties (~ 2 to 3) over ocean in the LETKF improves forecasts and error diagnostics

A revised version of visible dust AOD from CCI SLSTR retrievals, with their corresponding uncertainty estimates, might benefit dust forecasts, analyses and reanalyses.

WP 5.5.2 Cloud/Aerosol analysis with the ECMWF system

CMUG integration meeting 16.10.2024

Kirsti Salonen and Angela Benedetti

Kirsti.Salonen@ecmwf.int Angela.Benedetti@ecmwf.int

Assessing the impact of CCI AOD and COD in the ECMWF system

COD

- SLSTR L3U data provided by Gareth Thomas (STFC) and Martin Stengel (DWD)
- Not part of the official CCI data sets, but the same algorithms are being used to cover the test periods June 2020 and September 2021

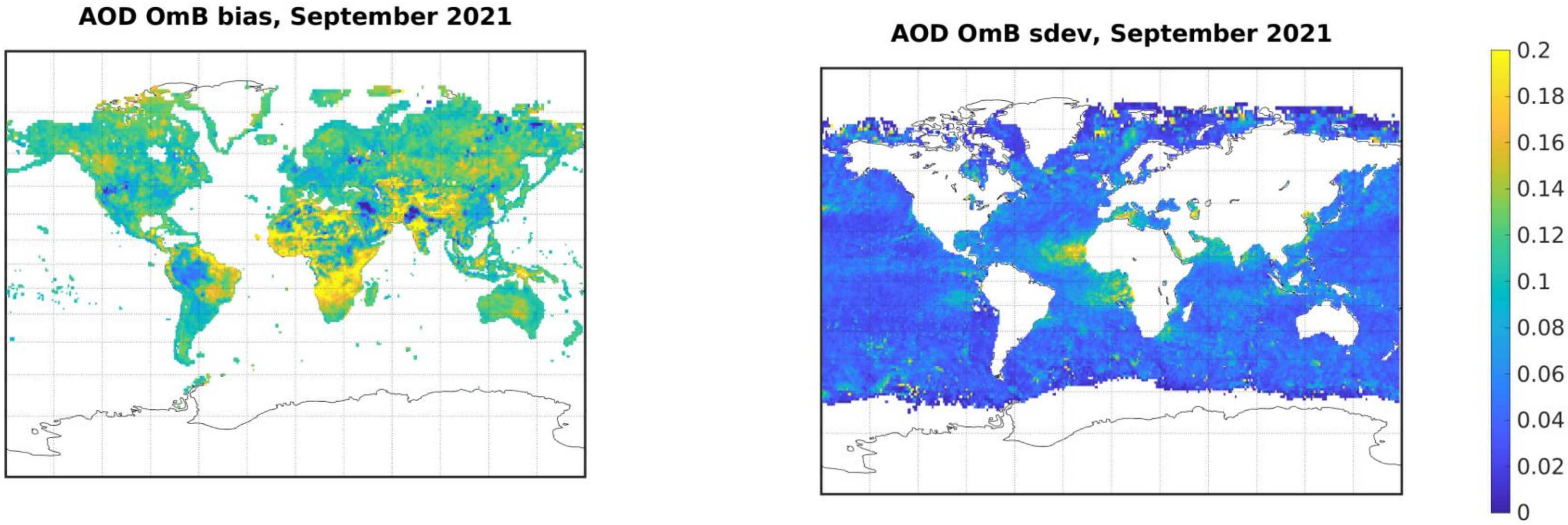
AOD

- Swansea University SLSTR v1.14, contact persons Peter North and Kevin Pearson

1. Data quality assessed with passive monitoring experiments
   - Realistic quality screening
   - Designing observation errors
2. Sensitivity tests in depleted observing system to decide on optimal assimilation setup
3. Joint assimilation of AOD and COD in depleted and in full observing system

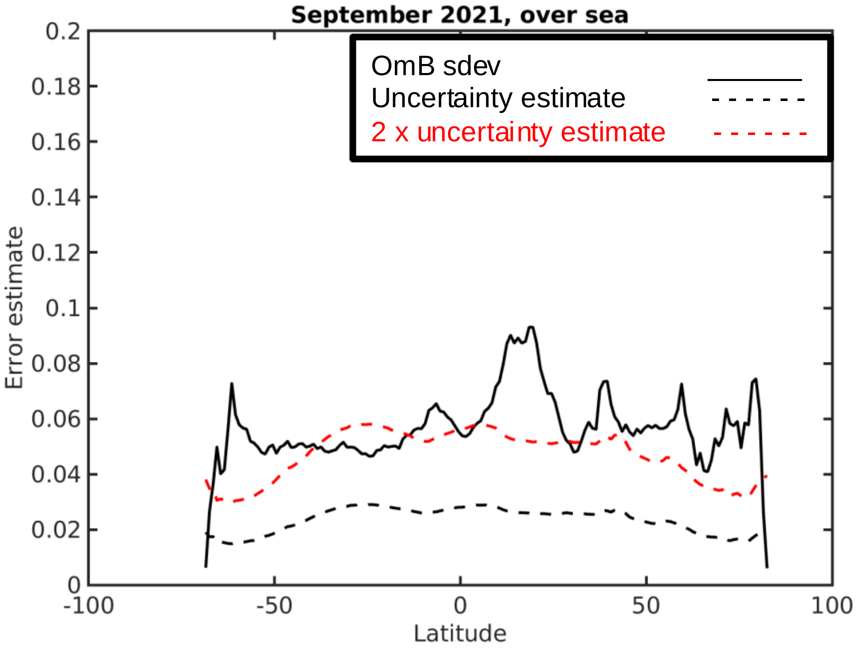
Quality of SLSTR AODs is good and relatively homogeneous over sea

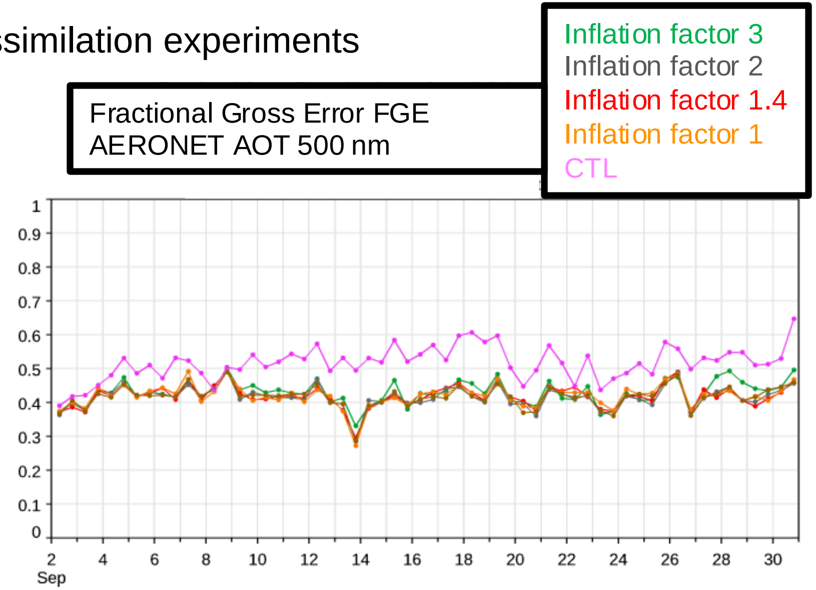
- Observation – model (OmB) background statistics indicate bias over land, magnitude depends on location and season
- Random errors are more homogeneous over sea than over land and significantly lower in magnitude



Sensitivity tests indicate 1.4 – 2 inflation factor for uncertainty to be used as observation error

- OmB sdev statistics indicate larger errors than the uncertainty estimates provided with the AOD data
- Inflation factor 1.4 chosen to be used in the joint assimilation experiments

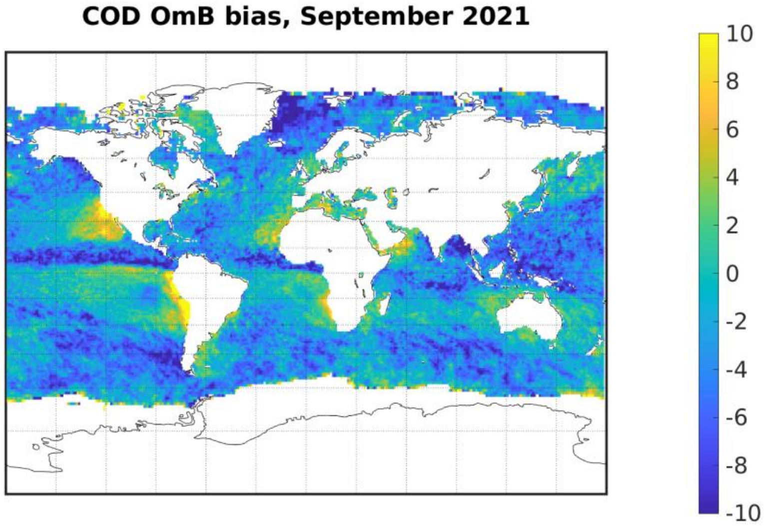


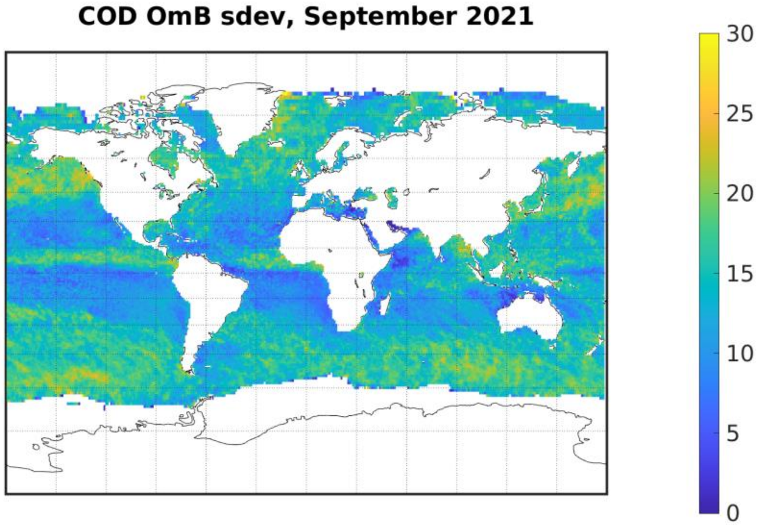


$$FGE = \frac{2}{n}\sum_{i=0}^{n}\left|\frac{AOD_i^m - AOD_i^o}{AOD_i^m + AOD_i^o}\right|$$

COD monitoring indicates areas of large OmB mean differences

- Areas of significant OmB mean differences
  - Positive mean difference, i.e. observed COD higher than model bg, over regions where typically persistent marine stratus
  - Negative mean differences and increased OmB sdev in the inter-tropical convergence zone

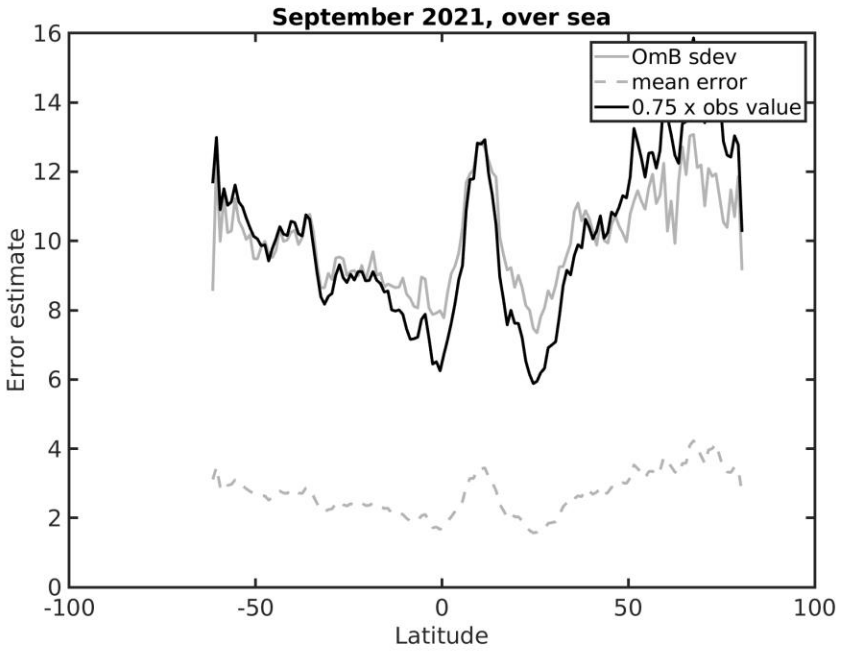




Uncertainty estimate provided with COD is underestimating the observation error

- OmB sdev is 6 times larger in magnitude than the provided uncertainty estimate, even for the quality screened data.

- In the assimilation experiments 0.75 x obs value is used as observation error.

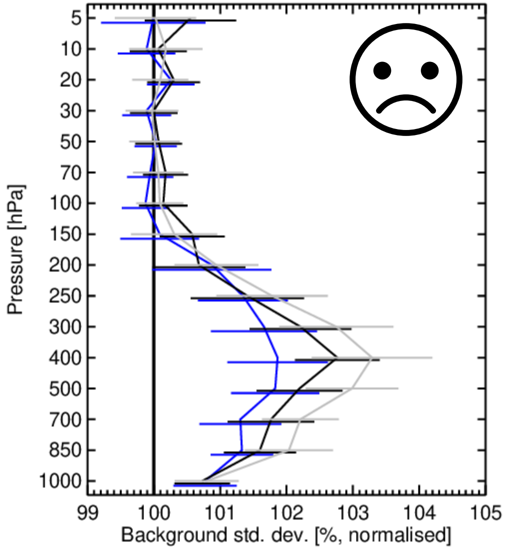


Assimilation of COD degrades the temperature forecasts in depleted observing system

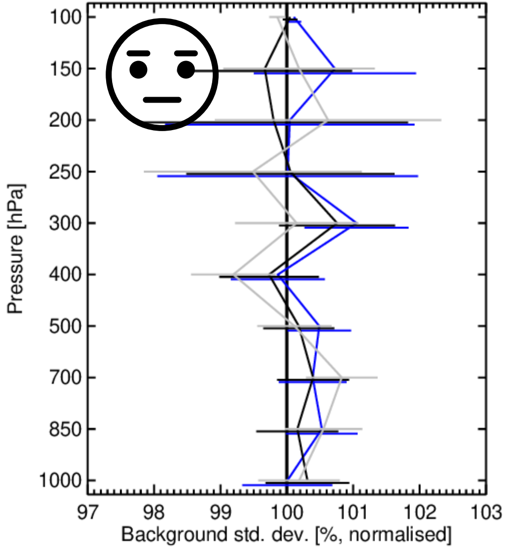
- Assimilation of <u>all COD observations</u> degrades the short range temperature forecasts, impact on humidity is rather netural.
- Limiting the assimilation to <u>COD values 0.5 – 10</u> or <u>blackisting data over tropics</u> slightly improves the temperature forecasts.

All COD
COD 0.5 - 10
COD blacklisted over tropics

Radiosonde T



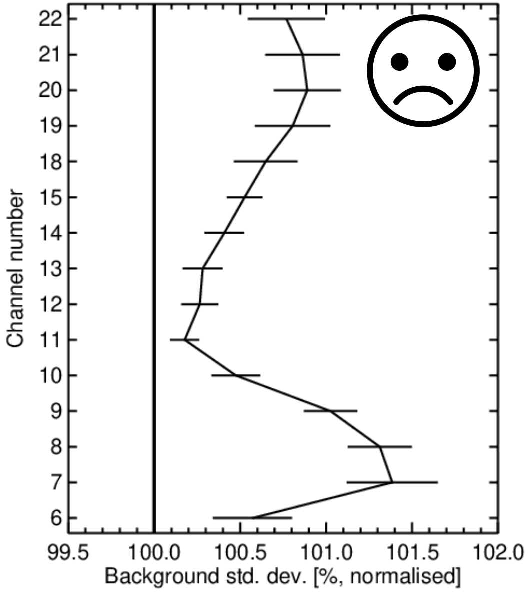
Radiosonde humidity



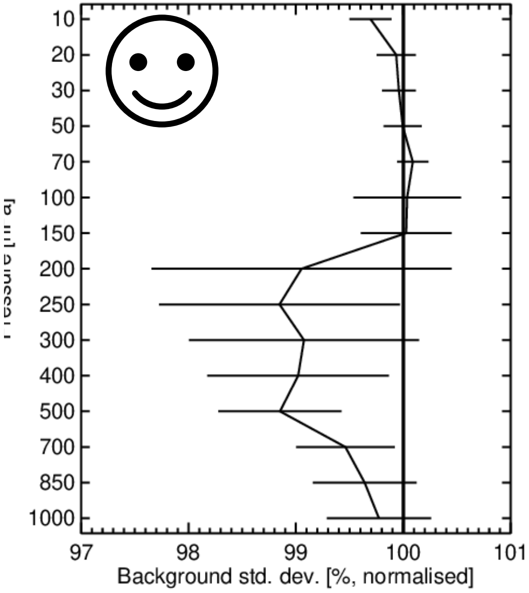
ECMWF

Assimilation of COD + AOD in full observing system generally degrades temperature and humidity forecasts but some improvements are seen for short range wind forecasts and against AERONET

ATMS

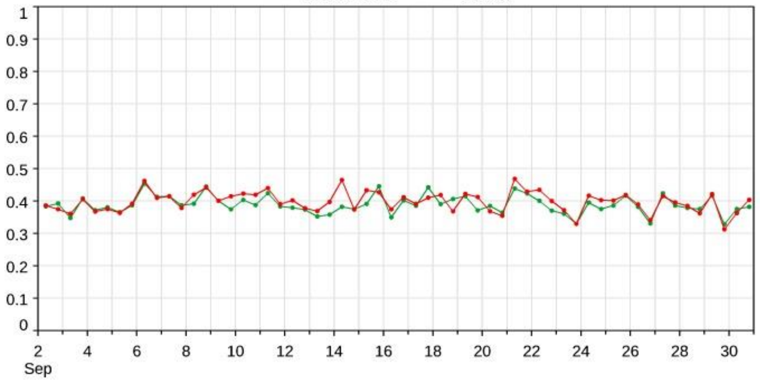


Wind



Fractional Gross Error against AERONET 2.0
AOT at 500 nm

Baseline (all operationally used observations)
Baseline + AOD and COD



Conclusions and ideas how to improve the impact

- Quality of AOD is good and relatively homogeneous over sea.

- COD has some large differences from its model counterparts especially over areas where there is typically marine stratus and over intertropical convergence zone.

- Joint assimilation of AOD and COD indicates degradation in temperature and humidity forecasts but some improvements seen for wind. Verification against AERONET AOT indicates positive impact.

- Ideas to improve the impact obtained from the COD assimilation
  - User has quite limited tools to do the quality screening of the observations. More informative quality flag provided with the COD data would be useful.
  - Assimilation of CODs could be improved with more strict first guess check
  - In these experiments no variational bias correction was applied, this could potentially improve the impact
  - Developing more sophisticated approach for the observation error could also help