ECMWF research on aerosol update

Julie Letertre-Danczak, Angela Benedetti, Samuel Quesada-Ruiz, Zak Kipling, Melanie Ades, and Rossana Dragani

Julie.Letertre-Danczak@ecmwf.int

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ECMWF

The potential of Atmospheric Composition (AC) for NWP

AC species	Impact on NWP	Mechanism
O_3, Aerosols, GHG	Dynamics	Radiation scheme
Aerosols	Precipitation and clouds	Indirect effects
O_3, CO, Aerosols	Winds	4D-Var tracer mechanism
O_3, CO_2 [, N_2O], Aerosols	Radiance assimilation (Temp,WV)	Observation operator
CH_4	Water Vapour	Oxidation
CO_2	Surface heat fluxes	Land/sea- atmosphere interface exchange

Medium range → **Sub-seasonal range** → **Seasonal range**

Purpose of Atmospheric Composition at ECMWF

- Evaluation of aerosol impacts on the NWP system:

  – Dynamics-aerosol-chemistry-cloud interactions in West Africa (**DACCIWA**) (EU FP7 funded)

- Preliminary studies in support of CAMS:

  – Lidar/Ceilometers profiles assimilation :

  ➤ Aeolus/EarthCARE Aerosol Assimilation Study (**A3S**) (ESA funded)

  ➤ Aerosol Clouds Trace gases Research Infrastructure (**ACTRIS-2**) (EU H2020 funded)

  ➤ European Natural Airborne Disaster Information and Coordination System for Aviation (**EUNADICS-AV**) (EU H2020 funded)

  ➤ E-PROFILE (European ceilometer network) (unfunded)

  – Radiances assimilation:

  ➤ Aerosol Radiance Assimilation Study (**ARAS**) (ESA funded)

What aerosol profile information can we assimilate?

- Different instruments:
    - Satellite lidars (CALIOP, Aeolus, Earthcare…)
    - Ground-based (Lidar, Ceilometer).

- Different Wavelengths:
    - 355, 532, 1064nm.

- Different parameters:
    - Aerosol backscattering (β), Aerosol attenuated backscattering (β_{att}), Aerosol extinction (σ).

Red: enabled in IFS and tests have been carried out.

ACTRIS-2 (finished)

- ACTRIS is the European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases.

- Development of tools for lidar profile assimilation from ground-based

- Development of tools for verification of surface scattering and absorption coefficients from nephelometers observations

- Extension of assimilation for multi-instruments, multi-parameters, multi-wavelength.

Aerosol light scattering verification

One year of verification of CAMS aerosol forecasts using ACTRIS2 nephelometer data has been implemented

This will be operationalized by CAMS

Comparisons between the model and the observation show good model skill with a tendency of the model to overestimate aerosol light scattering
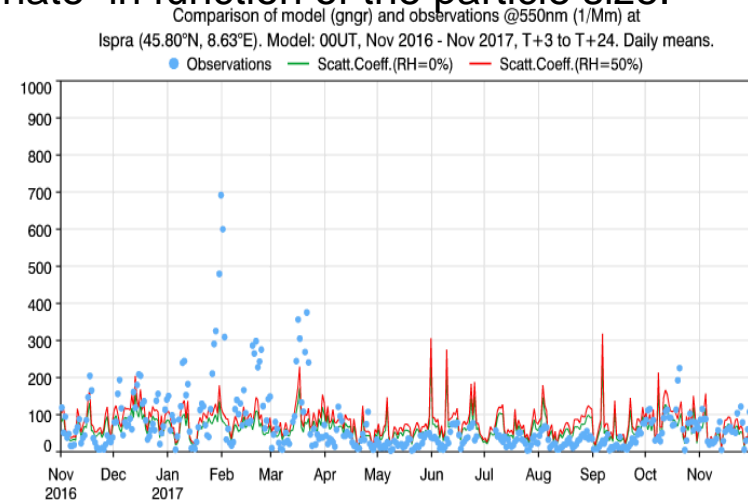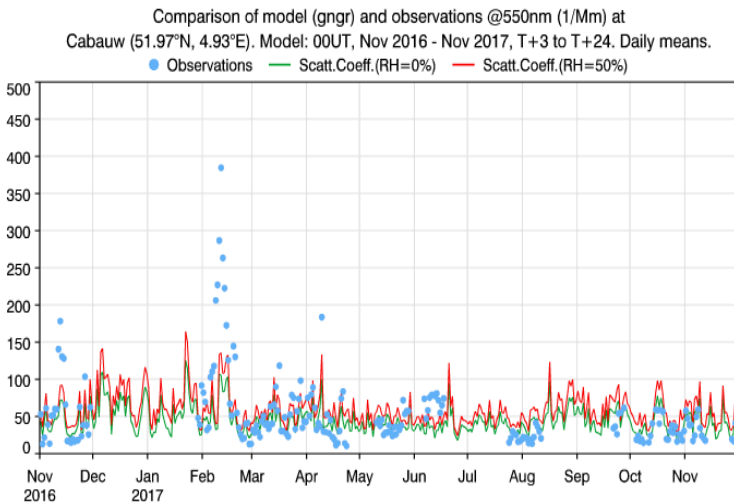
Several aspects are still being investigated:

Optimal comparison between point station & model grid point

Influence of topography (particularly of mountain sites)

Difference in relative humidity between model and obs (adjustments have to be done)

observations are classified in function of the PM cut-off or full aerosol content, while the ECMWF model does not discriminate in function of the particle size.

Comparison of model (gngr) and observations @550nm (1/Mm) at
Cabauw (51.97°N, 4.93°E). Model: 00UT, Nov 2016 - Nov 2017, T+3 to T+24. Daily means.
● Observations — Scatt.Coeff.(RH=0%) — Scatt.Coeff.(RH=50%)

Comparison of model (gngr) and observations @550nm (1/Mm) at
Ispra (45.80°N, 8.63°E). Model: 00UT, Nov 2016 - Nov 2017, T+3 to T+24. Daily means.
● Observations — Scatt.Coeff.(RH=0%) — Scatt.Coeff.(RH=50%)

Assimilation of ground-based LIDAR data in CAMS

- The comparison with AERONET shows some degradation in skill (9 and 11 July) as well as some improvement (12 July) over EUROPE.

- Monitoring capability developed
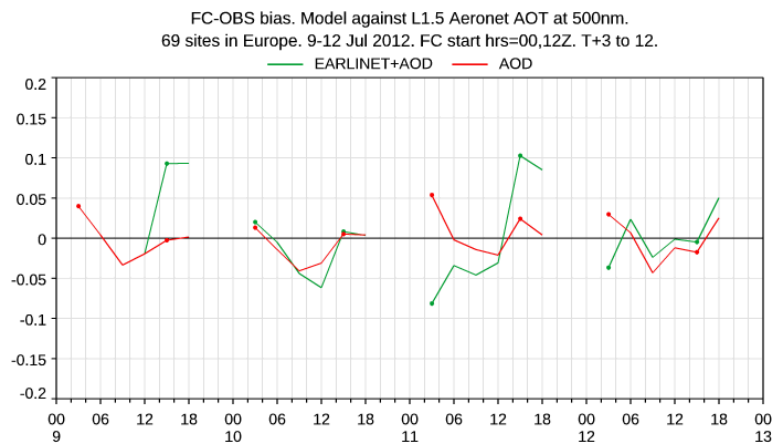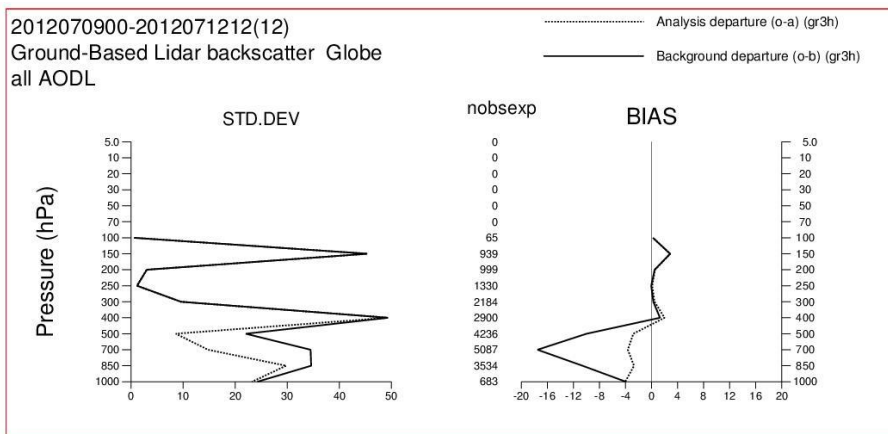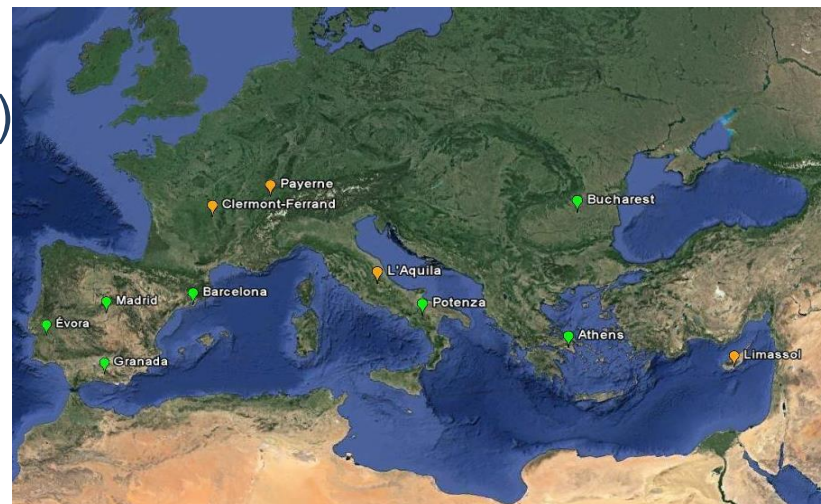
A3S: Aeolus/EarthCARE Aerosol Assimilation Study

Scientific motivation:

- Aeolus and EarthCARE will provide near-real-time (NRT) aerosol products from the ALADIN and ATLID lidars

- Data will be delivered to operational centres with interest in aerosol prediction and forecasting such as ECMWF

- ECMWF has been working on assimilation of profiling data from the CALIOP lidar on board of CALIPSO in the context of the Monitoring Atmospheric Composition and Climate projects (now the Copernicus Atmosphere Monitoring Service, CAMS).

- Great interest in assessing the scientific relevance of aerosol data from Aeolus (prevalently a wind mission) and EarthCARE (a cloud&aerosol mission)

- ECMWF/CAMS provide daily aerosol forecasts up to day 5

- NASA MODIS and EUMETSAT PMAp Aerosol Optical Depths (AODs) are assimilated operationally

- No profiling observation is currently used – large uncertainty on aerosol vertical structure
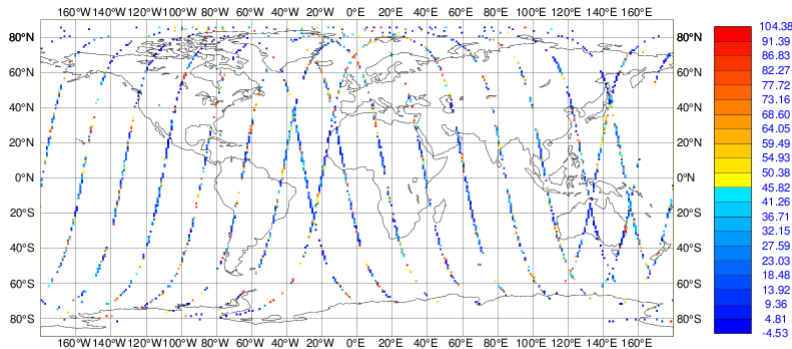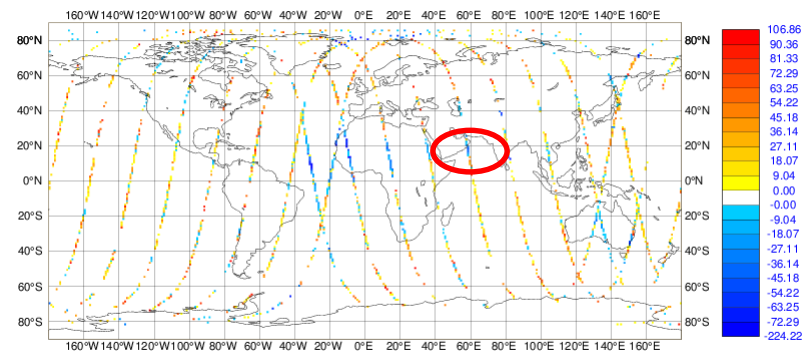
AEOLUS BACKSCATTER

13 JAN 2019(*)

700-1100hPa

Backscatter observations

Observations - First guess (mean=13.7)

- (*) it was not technically possible to use data for 2019 with the old model version used in A3S, so the model was tricked into thinking it was 2007
- **Lots of clouds present despite the screening, especially at high latitudes**
- Analysis departures are reduced by the assimilation with respect to first guess
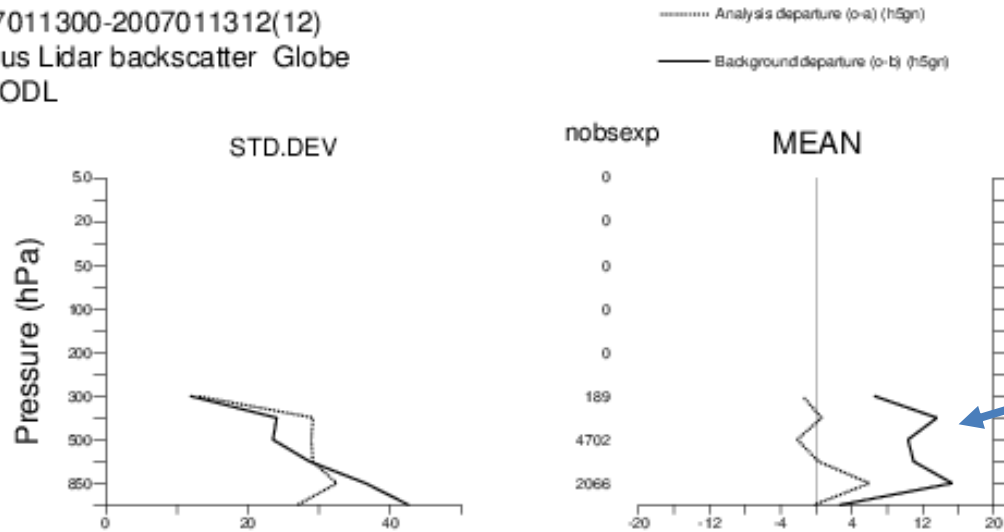
Observations – Analysis (mean = 4.3)
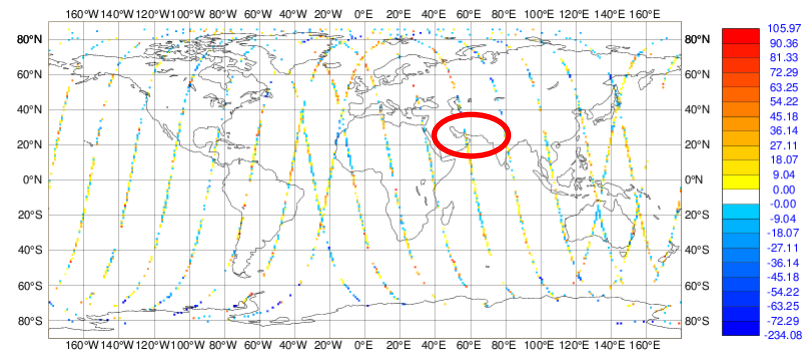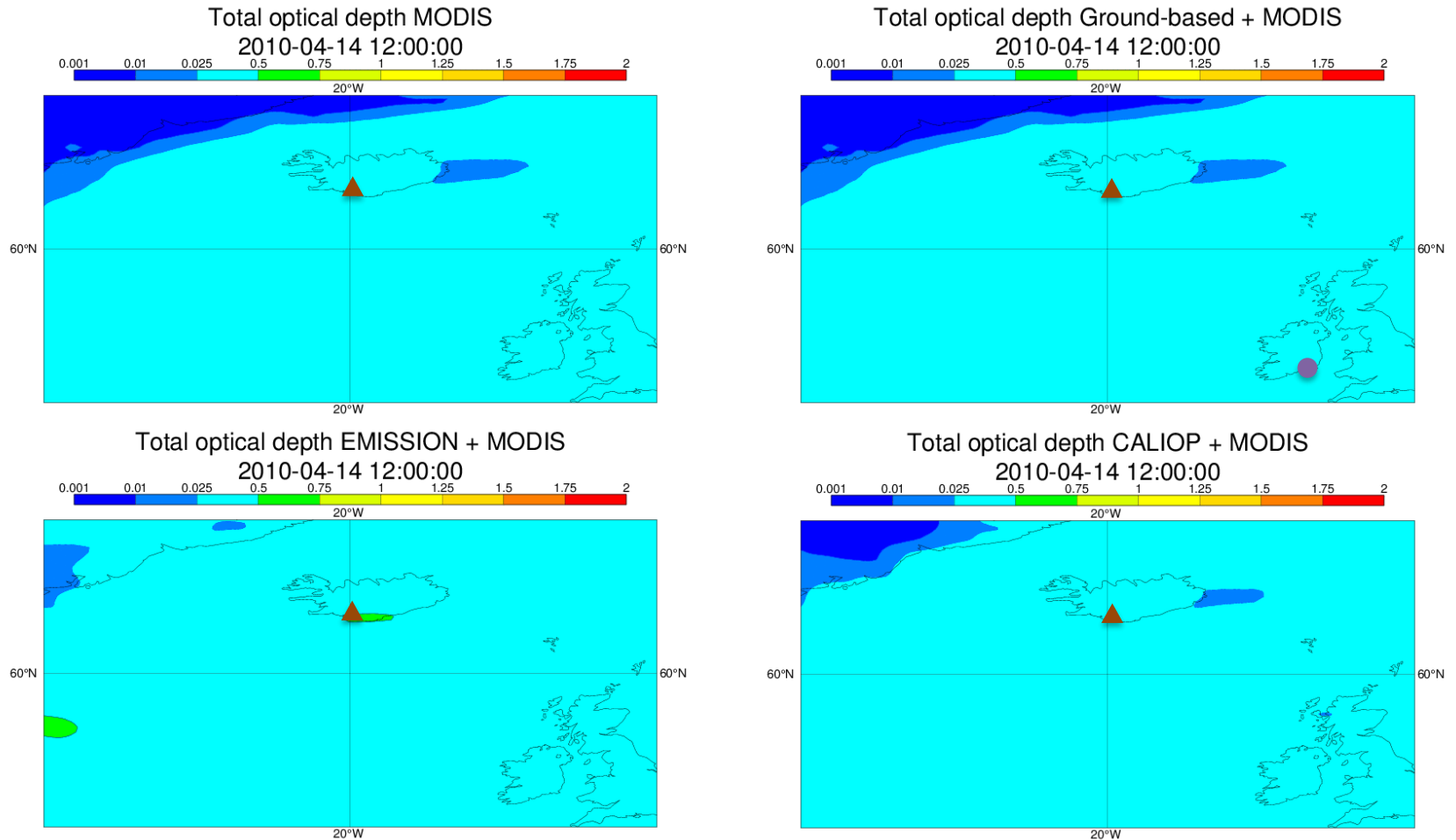

Units: 10-7 sr-1 m-1

AVERAGE PROFILES

Units: 10-7 sr-1 m-1

- First guess profile clearly shows cloud contamination at upper levels
- **Height and backscatter screening needs rethinking**

EUNADICS-AV
## Case of the Eyjafjallajökull (April-May 2010): Impact of Lidars on IFS (AOD)

Total optical depth MODIS
2010-04-14 12:00:00

Total optical depth Ground-based + MODIS
2010-04-14 12:00:00

Total optical depth EMISSION + MODIS
2010-04-14 12:00:00

Total optical depth CALIOP + MODIS
2010-04-14 12:00:00

Impact of Lidars on IFS (AOD)

FC-OBS bias. Model against L2.0 Aeronet AOT at 500nm.
186 Voronoi-weighted sites globally (r_{max}=1276km).
14-30 Apr 2010. FC start hrs=00,12Z. T+3 to 12.

— MODIS   — CALIOP + MODIS   — GB + MODIS   — SOURCE + MODIS
— sat + GB lidars + MODIS
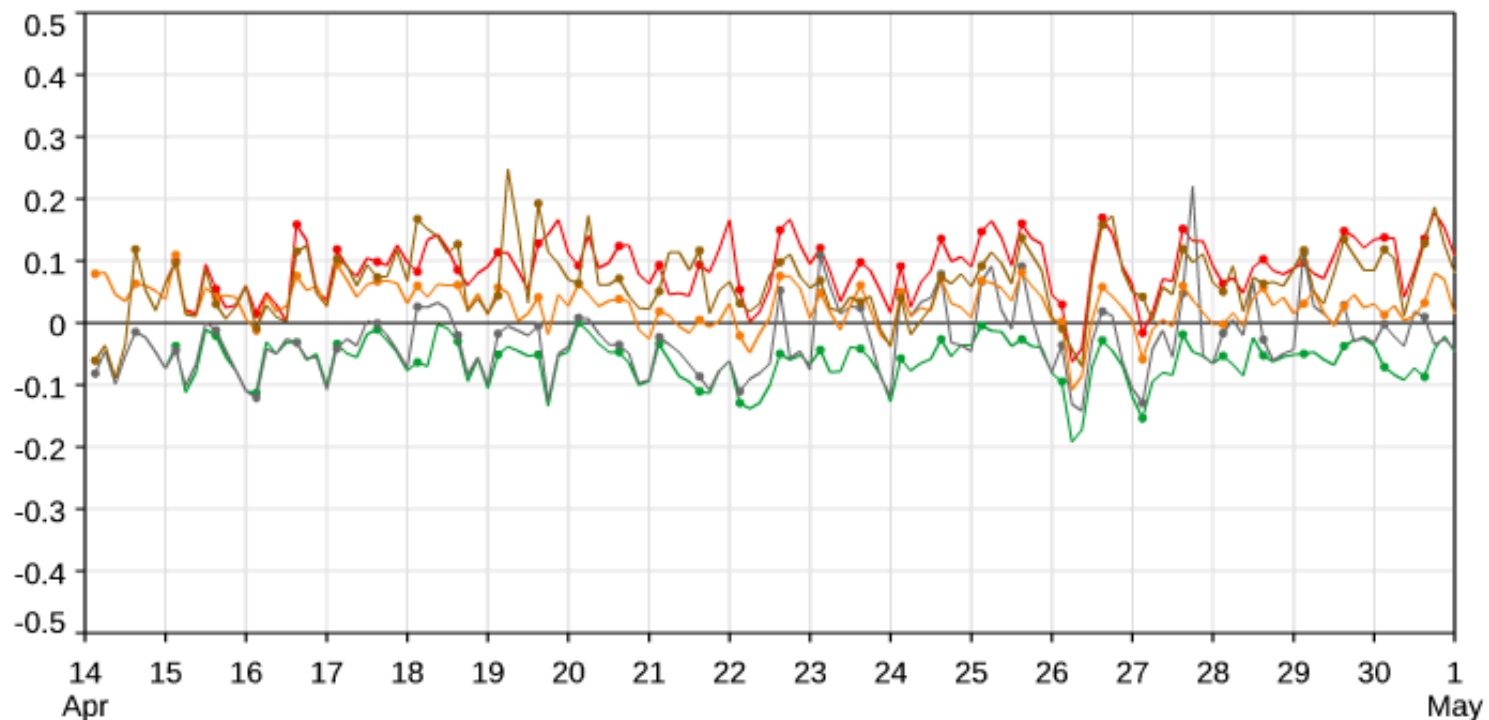
ESA-funded Aerosol Radiance Assimilation Study (ARAS): Scientific motivation
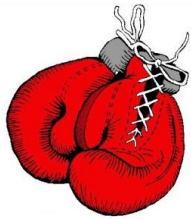
AOD assimilation	**vs**	Radiance assimilation

- New satellite instruments are coming up – difficult to characterize the relative uncertainties of AOD products. Using radiances could be more straightforward (once implemented)

- Use of aerosol affected radiances allows for further developments and easier uptake of new satellite instruments such as those on the Sentinel satellites

- The error characterization of radiances is easier than that of products and assimilation assumptions are all consistent (i.e. the same aerosol model is used from emissions to TOA radiances)

- 10+ years from Weaver et al 2007 (first study to assimilate MODIS reflectance) -> promising study, but no follow-on until now

Direct assimilation of aerosol-sensitive radiances in an **online 4D-Var system** has never been successfully implemented

ARAS: Expectations

ARAS is an exploratory project to assess the benefits of the assimilation of aerosol-sensitive radiances

✓ Implementation of fast radiative transfer code for aerosol assimilation (ORAC LUTs in RTTOV framework)

✓ First comparisons of long-term global assimilation experiments of reflectance assimilation versus AOD assimilation in a full 4D-Var system

✓ Technical outputs (visible radiative transfer code in IFS) might be adapted to other aerosol sensors/satellites

✓ All developments can serve to inform CAMS in a possible future operational implementation of the aerosol radiance assimilation in the system

ARAS: Preliminary results (Reflectances over Ocean)
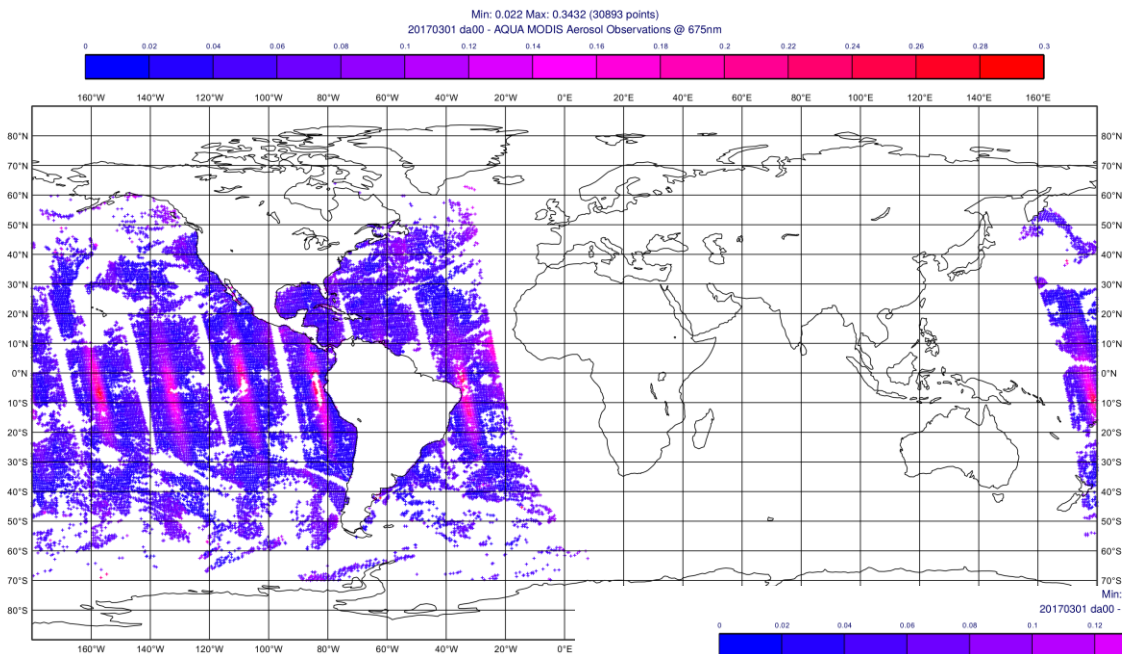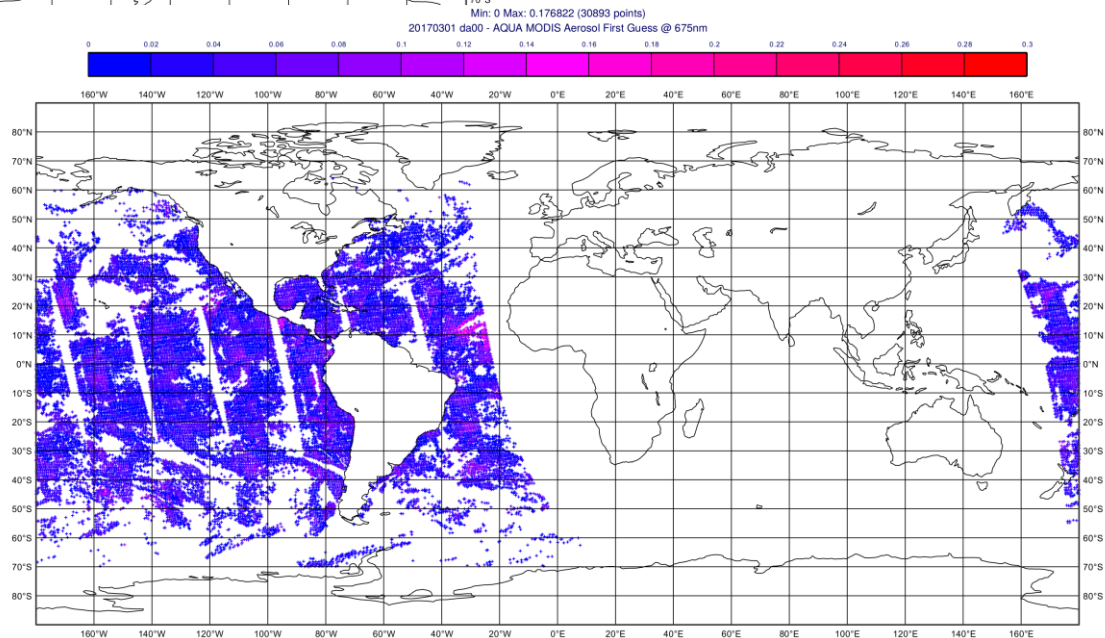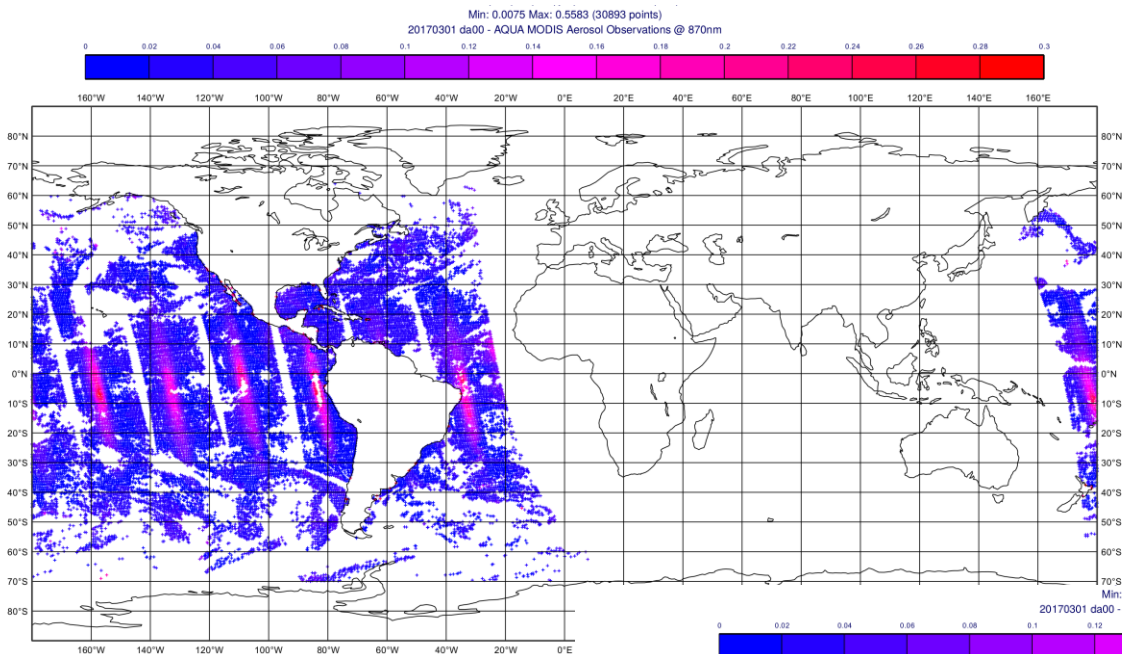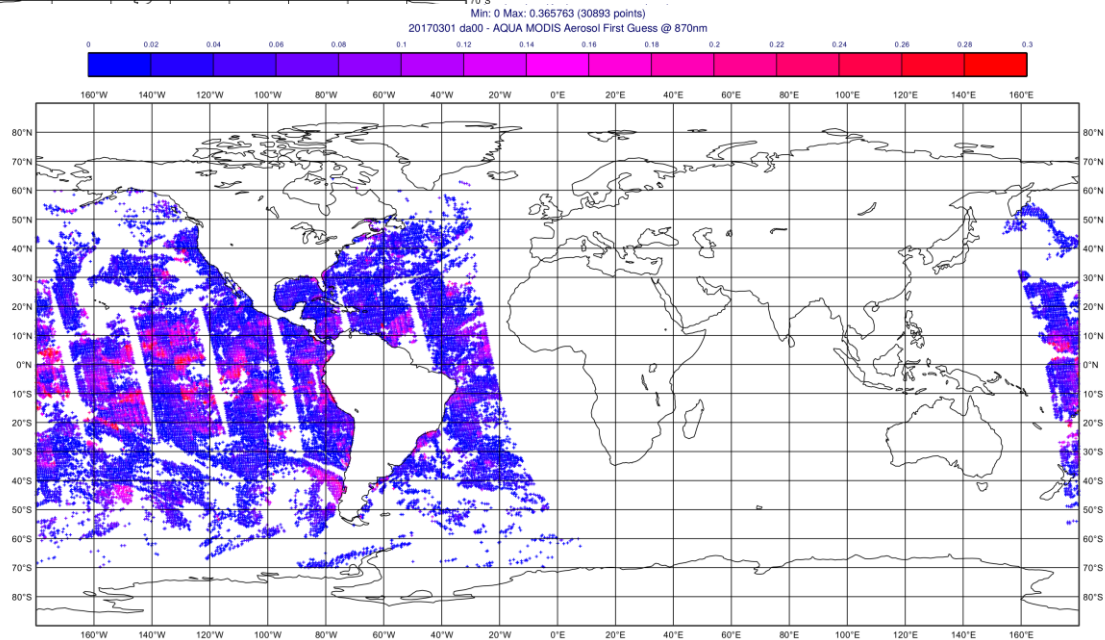

Observations

First Guess

AQUA
675nm
20170301 da00

ARAS: Preliminary results (Reflectances over Ocean)

Observations

First Guess

AQUA
870nm
20170301 da00