Aerosol Monitoring by Assimilation of AOD and Radiances

Part1:

Evaluation of satellite AOD within the Copernicus Atmospheric Monitoring Service (CAMS)

Sebastien Garrigues (ECMWF)

Part 2:

Aerosol Radiance Assimilation Study (ARAS)

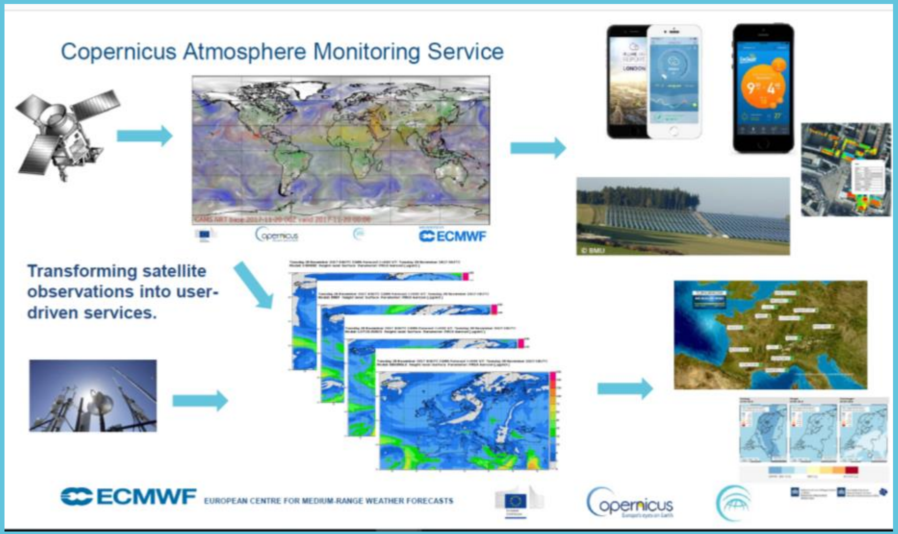
Samuel Quesada-Ruiz (ECMWF)

Atmosphere Monitoring

Satellite Aerosol Optical Depth (AOD) Monitoring within the Copernicus Atmospheric Monitoring Service (CAMS) Data Assimilation System

Garrigues S., Engelen R., Quesada S., Benedetti A., Ades M., Kipling Z., Flemming, J., Inness A., Ribas R., Barre, J., Augusti-Panareda, A., Parrington, M., Peuch V-H.,

Atmosphere Monitoring

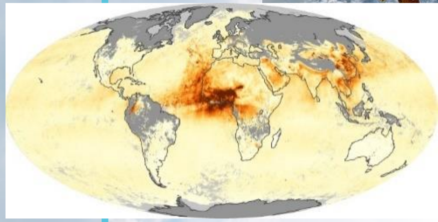


copernicus Europe's eyes on Earth

European Commission

CAMS AEROSOL DATA ASSIMILATION SCHEME

Satellite AOD
MODIS (AQUA, TERRA)
PMAp (METOP A,B,C)

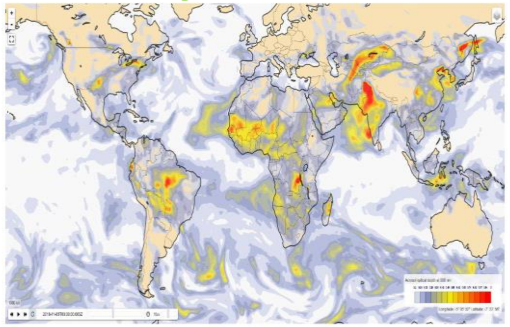


4D VAR data assimilation

IFS-AER:
Integrated Forecasting Sytem -aerosol scheme AER
IFS (ECMWF NWP model):
- Semi-Lagrangian advection model
- 137 atm levels
- 40 km horizontal resolution

AER:
- Bulk-bin scheme
- Species: sea salt, dust, organic matter, black carbon, sulfate, nitrate, amomium
- Emission sources: biomass burning (GFAS), CAMS_GLOB dataset

5 day forecast, reanalysis



AOD, aerosol concentration, PM2.5, PM10

Remy et al., 2019 GMD

INTRODUCTION

- Needs for new observational data streams:
  - more accurate observations,
  - enhanced spatial and temporal coverage,
  - increased resilience to instrument failure.

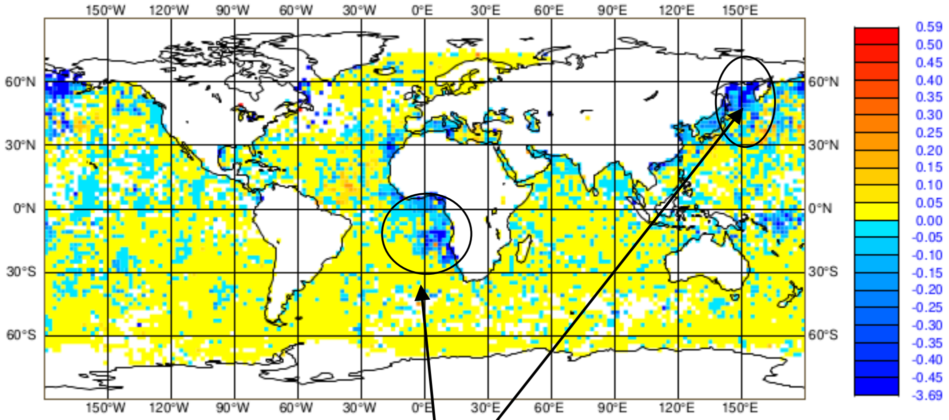
- Use of the IFS data assimilation system to monitor and evaluate new aerosol satellite products

EVALUATION OF SATELLITE AOD VERSION

PMAp-B: v2.2c versus 2.2b

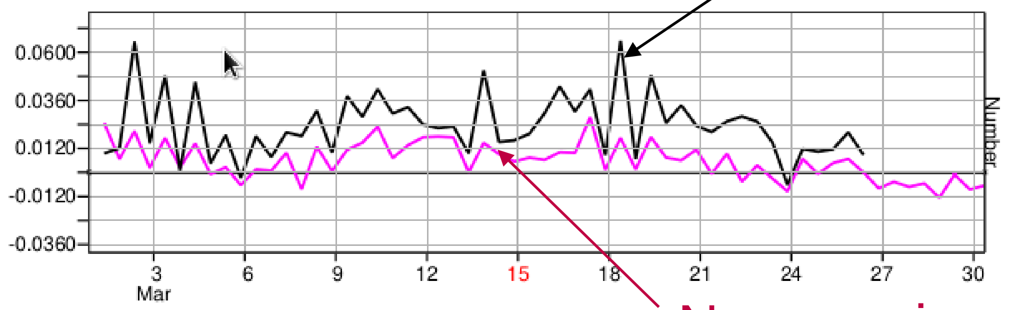
V2.2c (new)-v2.2b (old)

March 2015



Satellite – model AOD

Old version 2.2b



New version 2.2c

reduction of
unrealistic AOD hotspots

Reduction of departure between observation and modelled AOD

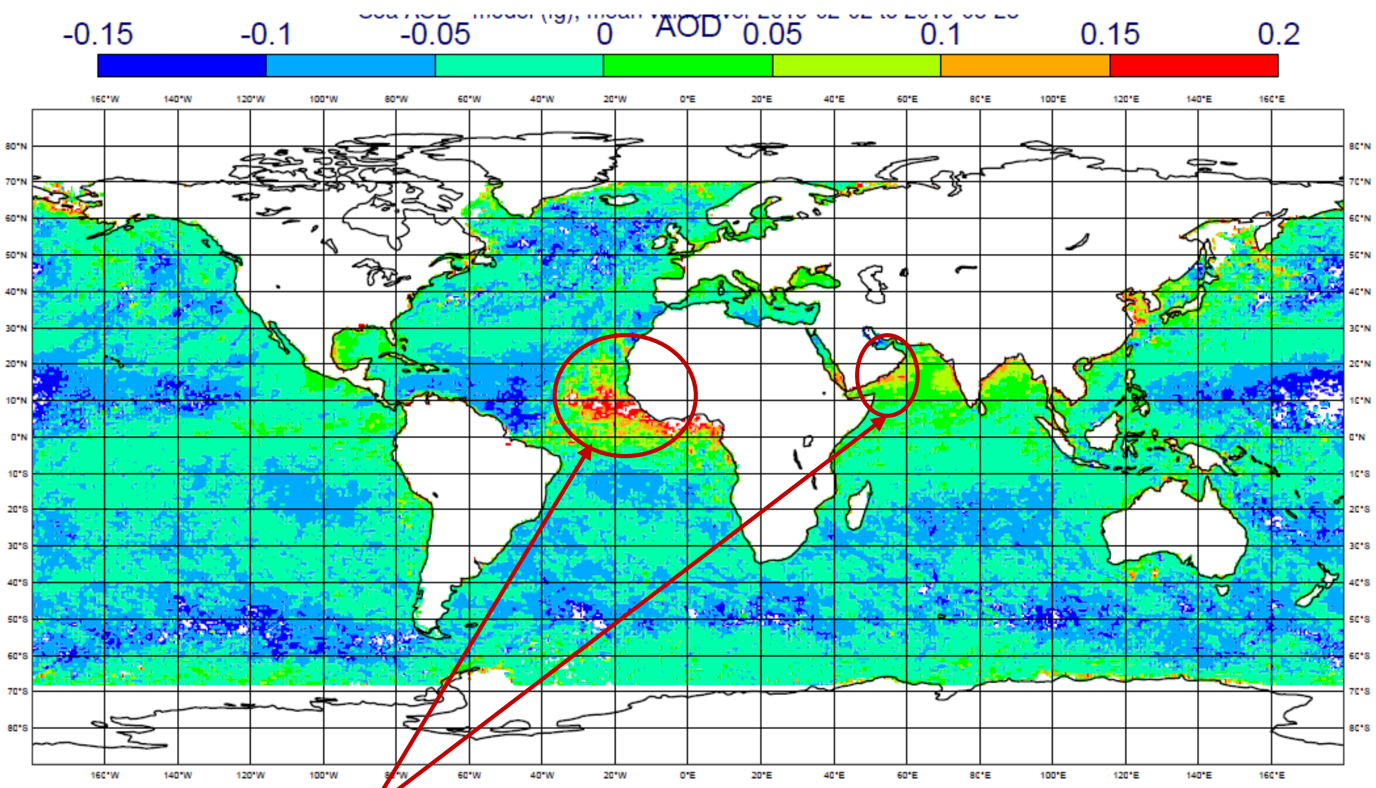
Impact of cloud contamination

Atmosphere Monitoring

SENTINEL-3/SLSTR (S3a) over Ocean

S3a satellite AOD – modelled AOD

Feb-March 2019 average over ocean



Overestimation of dust AOD

Impact of radiance calibration in the SWIR

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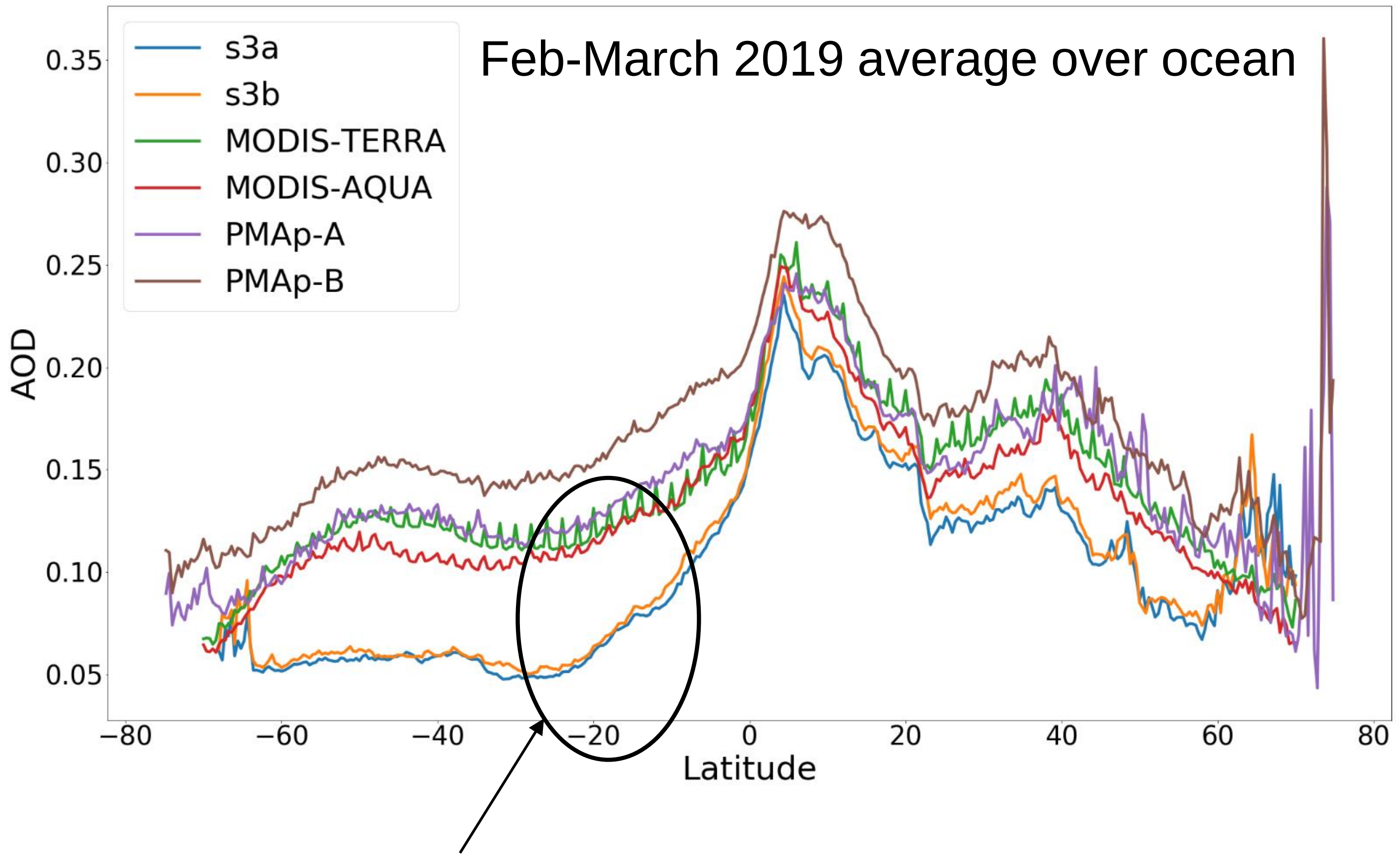
S3 vs TERRA, AQUA, PMAp over ocean



Large departure between S3 and other products in Southern oceans

TAKE HOME MESSAGES(1/2)

Contribution of aerosol data assimilation system to CEOS:

- Consistent intercomparison of satellite products by comparing model equivalent of satellite AOD
- Identify deficiencies in satellite products.
- Development of future products (3MI, MAIA…).
- Feedbacks for the design of future missions.

TAKE HOME MESSAGES(2/2)

Needs for operational NRT aerosol forecast system

- Exchange of AOD algorithm expertise
- AOD product intercomparison
- Uncertainty and bias quantification

Aerosol Radiance Assimilation Study (ARAS)

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CEOS AC-VC-16

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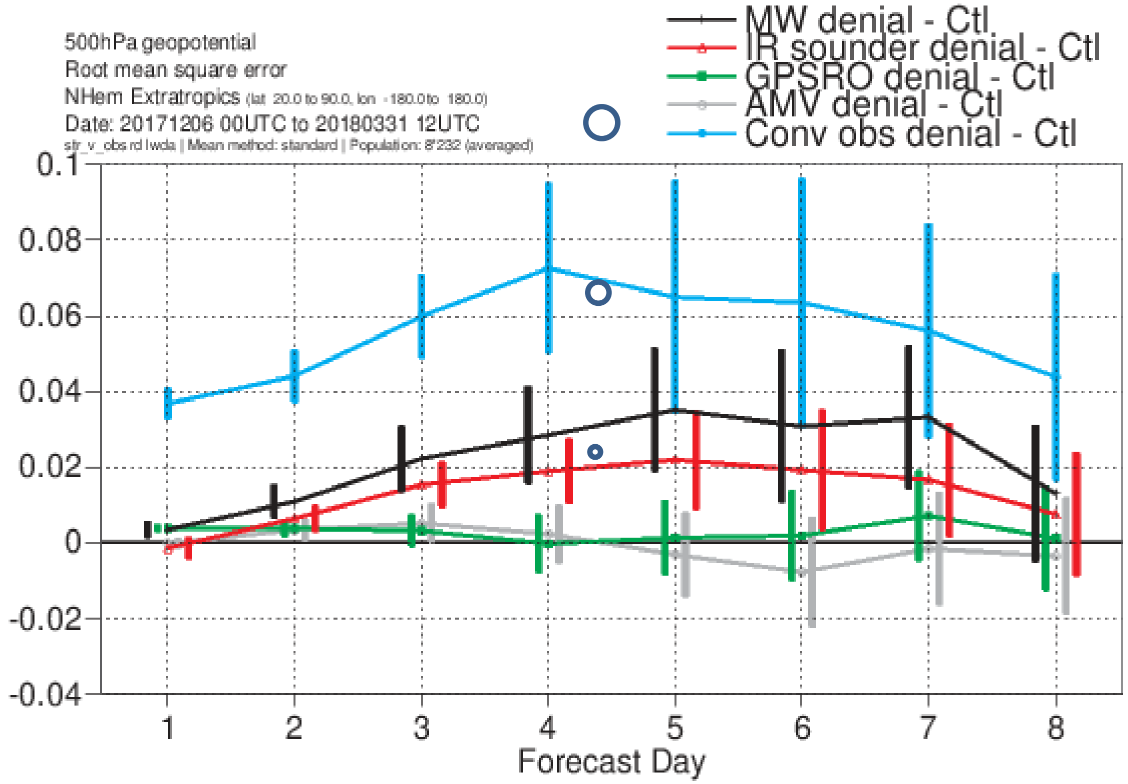
(ESA project officer)

esa
European Space Agency

Scientific motivation of ARAS

IR observations provide significant forecast skill
(rejection: ~ < 5% for aerosols & ~ > 80% for clouds)

Can we exploit visible radiances?



Heather Lawrence, Jacky Farnan and Niels Bormann Applicate Study (image from Tony McNallys's PreSAC 2018)

Radiance assimilation

vs

AOD assimilation

- Difficult to characterize the relative uncertainties of AOD products (new instruments)

- Easier **error characterization**
- **Consistent** assimilation assumptions (same aerosol model used from emissions to TOA radiances)
- Easier to add constraint to other **aerosol parameters**
- Application of **visible** radiance developments to **cloud** assimilation

Technical challenges, data and tools

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

A radiative transfer model is needed to convert the model state into top-of-atmosphere radiance

IFS uses RTTOV for thermal-IR radiance generation, which does *not yet* have visible capabilities

For the IFS, ARAS represents the first time that …

… visible wavelength radiances are assimilated

… dual control variable is used for AOD

Radiative Transfer Model in the visible: Observation operator (Forward / Tangent-Linear / Adjoint)

Aerosol data from Aqua & Terra MODIS collection 6 (Levy et al. 2013)

Level-2 (regridded and cloud-cleared) radiances @ 670 and 866 nm

AOD @ same wavelengths

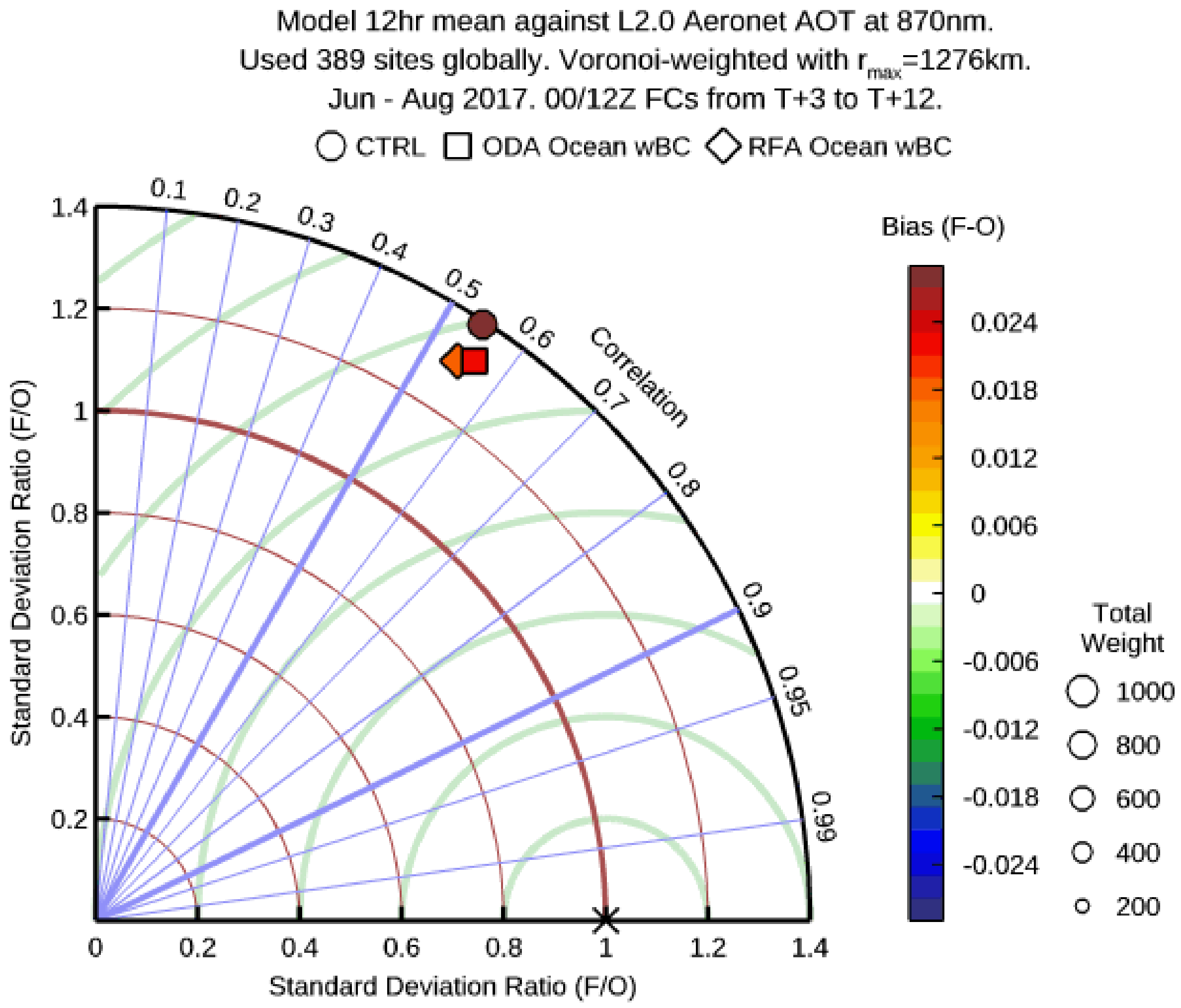
operational CAMS system uses single control variable

ORAC forward model, developed at RAL and Univ. Oxford (McGarragh et al. 2018)

Look-up table approach

Evaluation of the analyses against AERONET AOD

summer 2017 (JJA) @ 870 nm



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

Results:

The reflectance assimilation **performance** is **comparable** to that of the AOD

Conclusions:

Extremely successful project

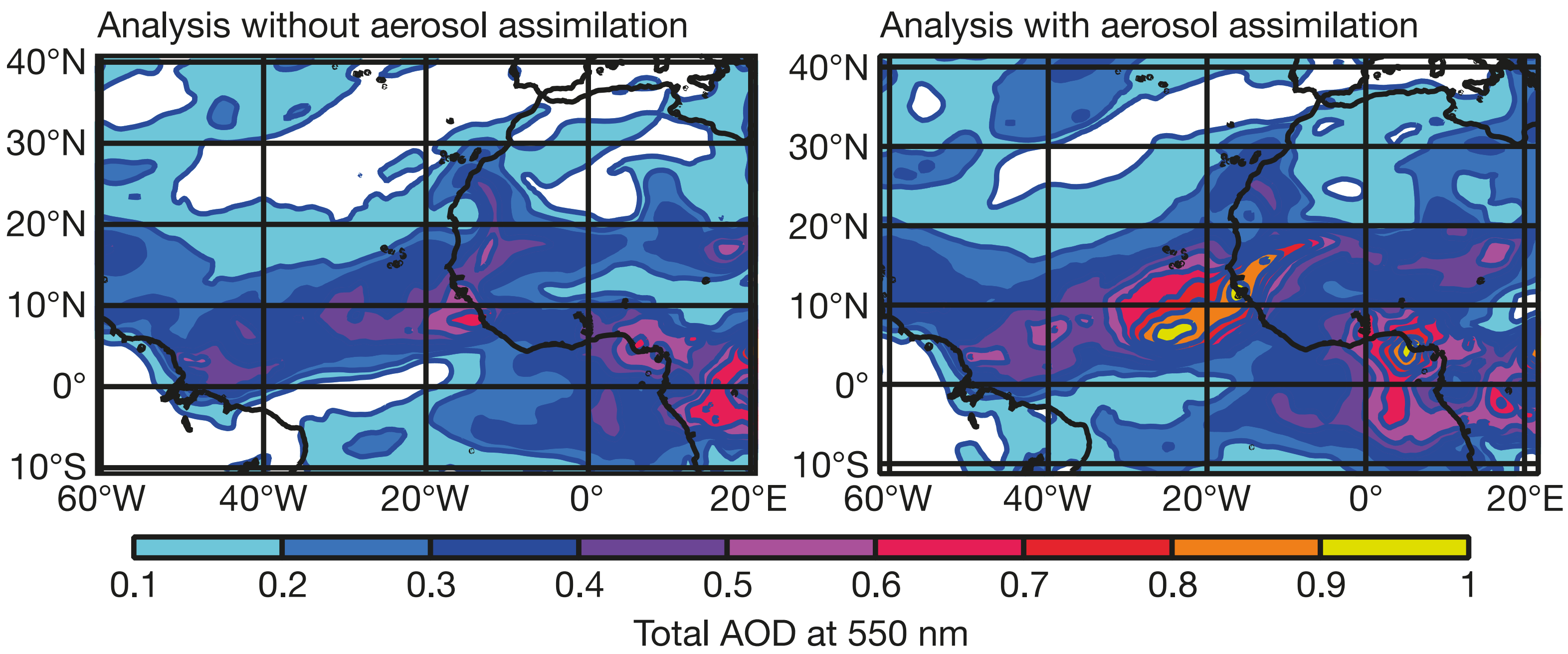
Remarkable performance for being a new development

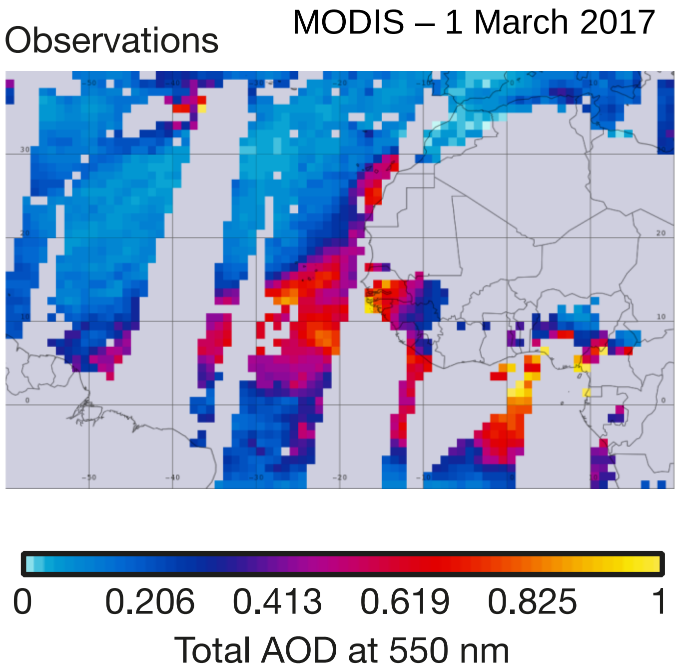
More development is still necessary

Expectations:

Reflectance assimilation will become as mainstream as AOD assimilation (with some investment)

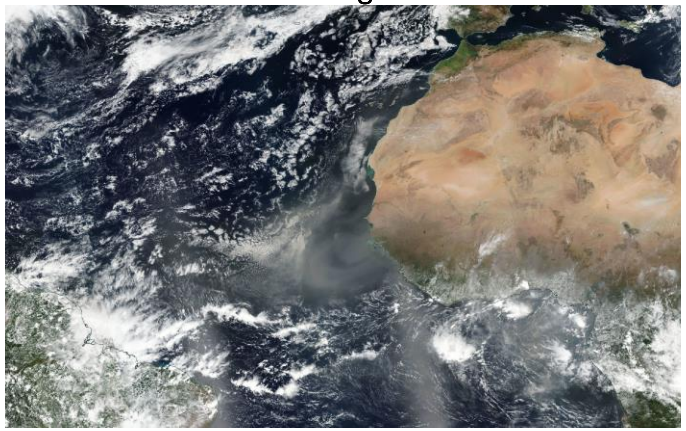
Paving the way towards visible radiances assimilation





Assimilation of level-2 aerosol visible radiances improves representation of dust outflow from the Sahara desert

VIIRS true color image – 1 March 2017



ARAS developments could be adapted for cloud assimilation and open the way towards a fuller exploitation of visible radiances to improve NWP

Web article @ https://www.ecmwf.int/en/about/media-centre/news/2020/progress-towards-using-visible-light-satellite-data-weather
ECMWF Newsletter N162 Winter 2020 @ https://www.ecmwf.int/en/newsletter/162/news/progress-towards-assimilating-visible-radiances