Copernicus Atmosphere Monitoring Service

Atmosphere Monitoring

Melanie Ades, Enza Di Tomaso, Samuel Remy, Angela Benedetti, Will McLean, Samuel Quesada Ruiz, Johannes Flemming, Mark Parrington, Roberto Ribas

Richard Engelen, Vincent-Henri Peuch

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Aerosols at ECMWF

Atmosphe
Monitor

CAMS

Melanie Ades
Aerosol data assimilation
Background errors
Dust assimilation

Enza Di Tomaso
Aerosol data assimilation
AOD Observation updates
GFAS fire assimilation

Johannes Flemming
Principal Scientist
Air quality

Mark Parrington
Outreach/event monitoring
Fire assimilation

Roberto Ribas, Zak Kipling, Mihai Alexe and others

HYGEOS

Samuel Remy
Aerosol model developments
CAMAERA lead

NWP

Angela Benedetti
Infrared Team Leader Earth System Assimilation
DOMOS lead
Lead for Aeolus backscatter assimilation
CAMEO WP lead for radiance assimilation

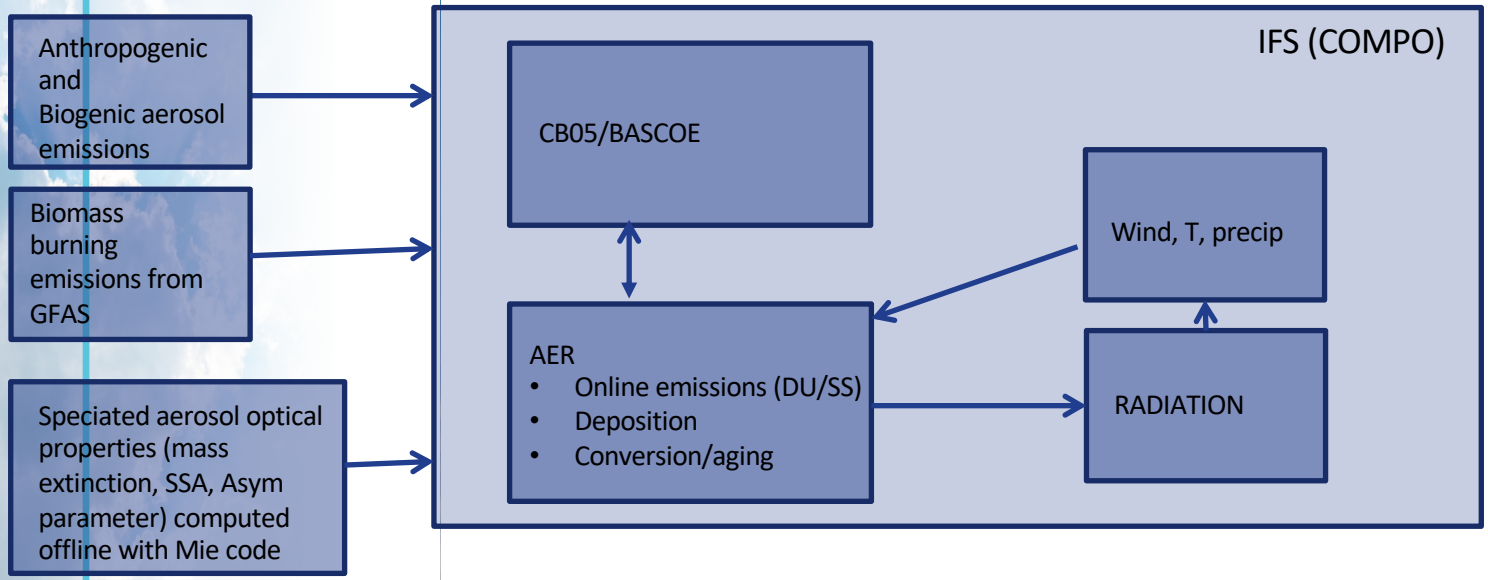
Will McLean
Aeolus backscatter assimilation

Samuel Quesada Ruiz
Aerosol radiance assimilation

Robin Hogan
Radiation

Ramiro Checa-Garcia
Radiation

CAMS Aerosol Forecasting and Assimilation



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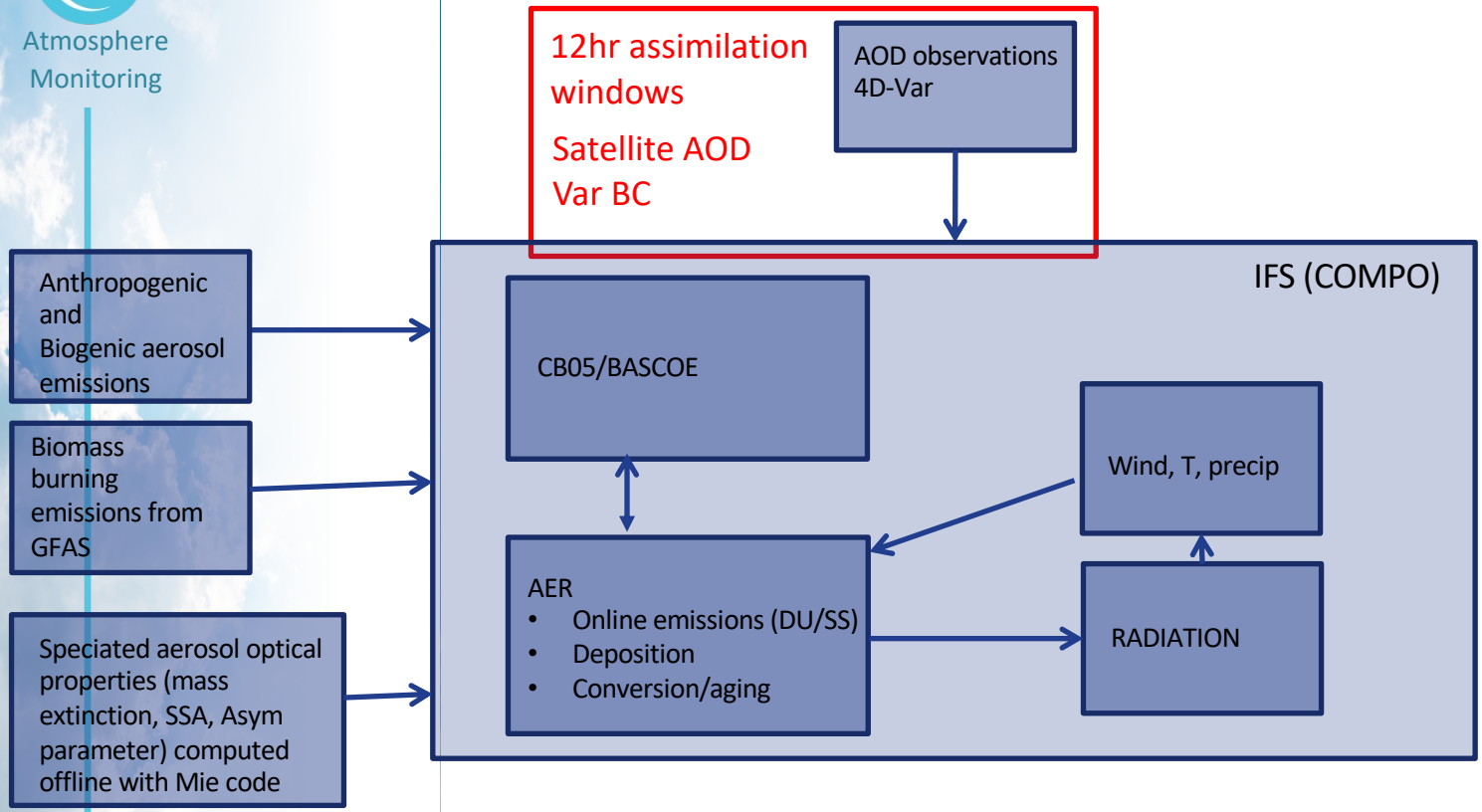
Latest model version (CY48R1) implemented on 27th June 2023

CAMS Aerosol Forecasting and Assimilation



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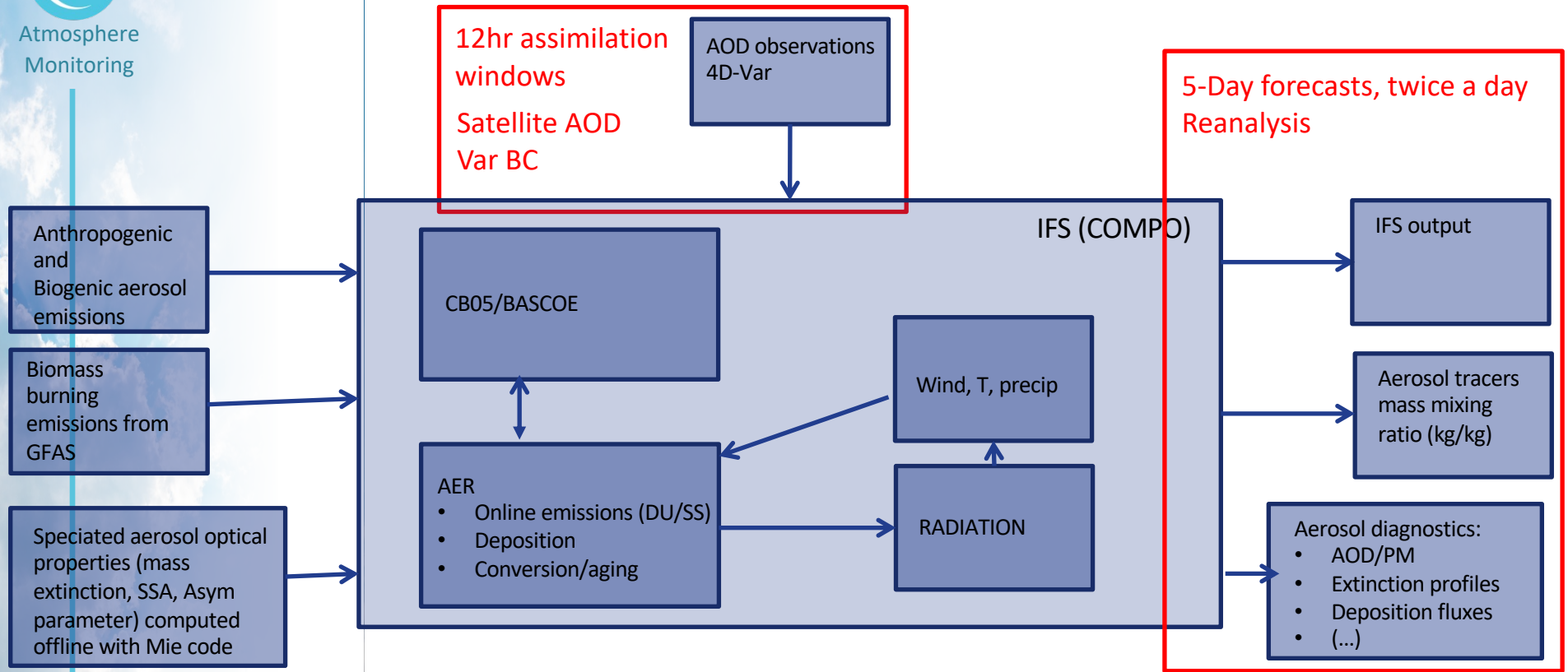
CAMS Aerosol Forecasting and Assimilation

Atmosphere Monitoring



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CAMS Aerosol Model

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- 8 species considered:
  - Desert dust (DD): 3 tracers
  - Sea-salt aerosol (SS): 3 tracers
  - Organic Matter (OM): 2 tracers
  - Black carbon (BC): 2 tracers
  - Sulfate (SO4) + precursor SO2 when running uncoupled from chemistry
  - Nitrate: 2 tracers (from gas/particle partitioning, and from het. reactions)
  - Ammonium: 1 tracer
  - SOA: 2 tracers (biogenic and anthropogenic) since cycle 48R1
- Bulk/bin approach : bulk for OM/BC/SO4, 3 size bins for SS/DD
- For OM and BC, hydrophobic (fresh) and hydrophilic (aged) components are considered
- Sea-salt aerosol and Sulfate are also hydrophilic
- 16 tracers representing dry aerosol mass mixing ratio **except for sea-salt aerosol: mass mixing ratio at 80% RH**

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Observation updates since 2022

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Assimilated observations

Instrument	Satellite	Assimilated	Super-obed	Surface-type	VarBC
MODIS	Aqua	Y	Filtered	Land/Sea	Y
MODIS	Terra	Y	Filtered	Land/Sea	Y
VIIRS	SNPP	Y	Y	Land/Sea	Y
VIIRS	NOAA-20	Y	Y	Land/Sea	Anchor
PMAp	MetOp-A	N	-	-	-
PMAp	MetOp-B	Y	Filtered	Sea	Y
PMAp	MetOp-C	Y	Filtered	Sea	Y
SLSTR	Sentinel-3A	N	-	-	-
SLSTR	Sentinel-3B	N	-	-	-

- VIIRS AOD observations now used operationally
- Bias correction can be applied individually to each sensor

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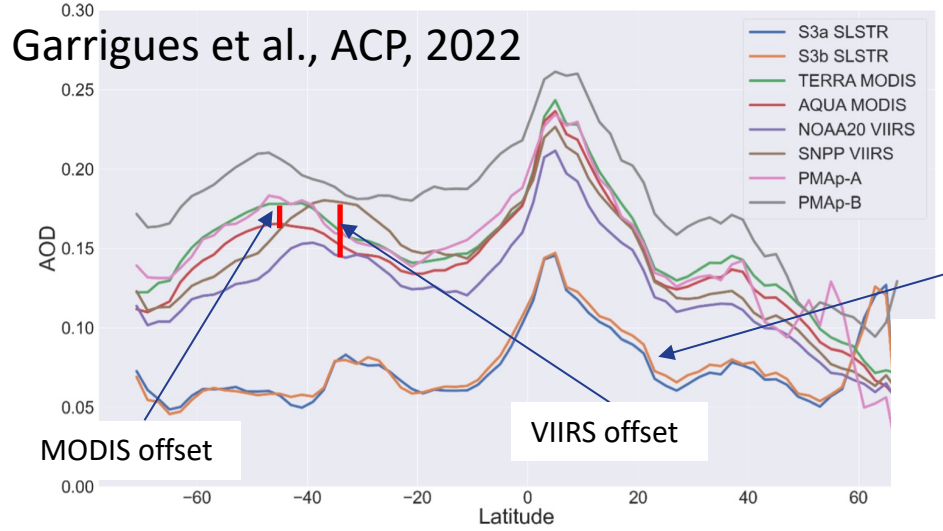
Latest model version (CY48R1) implemented on 27th June 2023

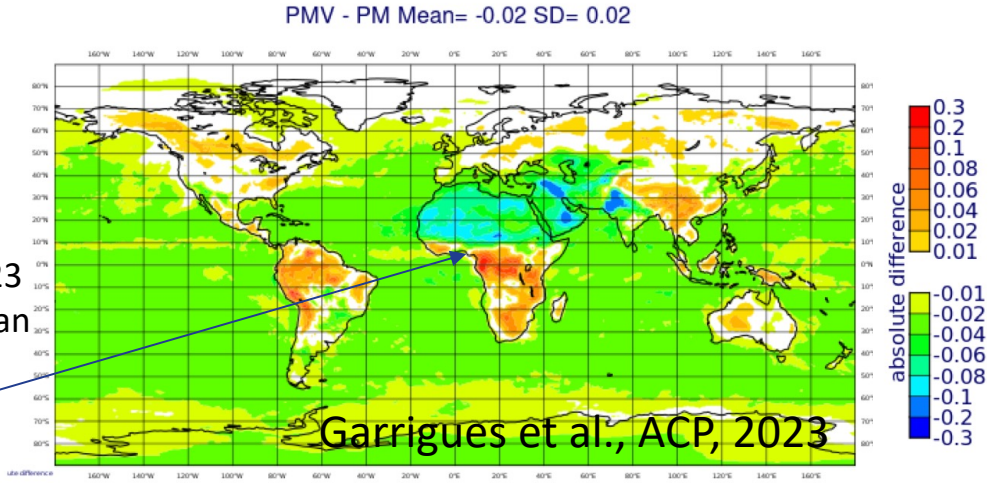
Assimilated Observations

Thanks to Sebastien Garrigues

Latitude cross-section of temporal mean satellite AOD for the DJF (2019-2020) period over ocean



- Individual bias correction needed to allow for differences between the same instrument mounted on different satellites
- S3 currently monitored due to offset from other satellite observations



Difference in mean SON 2020 AOD daily analysis when VIIRS is assimilated (PMV) in addition to Modis/PMAp (PM)

- VIIRS has been assimilated since 1st Feb 2023
- VIIRS NOAA-20 has been the anchor since 27th June 2023
- Additionally assimilating VIIRS decreases AOD over ocean
- Over land, assimilating VIIRS leads to an increase over biomass burning regions and a decrease over source regions
- Reduction in bias when assimilating VIIRS in comparison to Aeronet

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Model updates since 2022

Thanks to Samuel Remy

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Evolution of IFS-AER

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2019 Cycle 46R1

Nitrate and ammonium+new dust emission scheme

Adapted from Marticorena and Bergametti (1995) and Kok et al. (2011) size distribution

2020 Cycle 47R1

New dust source function, new sea-salt aerosol emission scheme

Improves simulated PM10 over Europe

2021 Cycle 47R3

New dry and wet deposition schemes

Significantly impacts the simulation of dust plumes after emission

2023 Cycle 48R1

Secondary organics+ New dust/OM optical properties + dust rebound

Improves the simulated dust absorption and extinction.

2024 Cycle 49R1

Stratospheric sulphate, EQSAM4Clim Dust asphericity and hydrophilic growth

Experimental output of aerosol acidity, use in relevant chemical processes

202? Cycle 50R1

Review of the definition of dust bins and of sedimentation

Tests with 6 dust bins instead of 3. Review of the sedimentation process to limit numerical diffusion for super coarse particles.

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implemented on 27th June 2023

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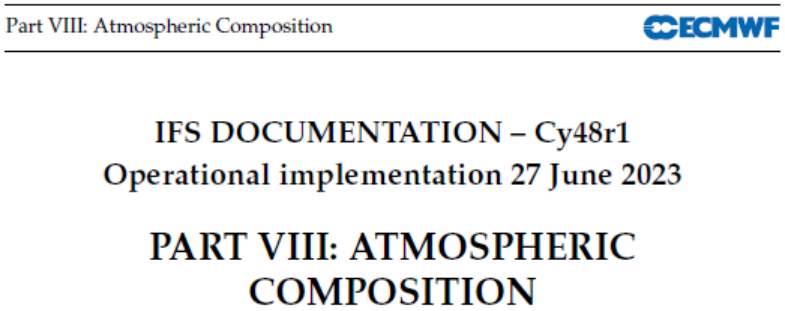
IFS-AER in cycle 48R1

Cycle 48R1 main aerosol related developments:

- **New secondary organic aerosol species and production module**
- New optical properties for OM (brown carbon effect)
- **Desert dust developments**
- Use of sectoral emissions

Documentation available at :

https://www.ecmwf.int/en/elibrary/81374-ifs-documentation-cy48r1-part-viii-atmospheric-composition


Part VIII: Atmospheric Composition ECMWF

IFS DOCUMENTATION – Cy48r1
Operational implementation 27 June 2023

PART VIII: ATMOSPHERIC COMPOSITION

Thanks to Samuel Remy

SOA in IFS-AER cycle 48R1

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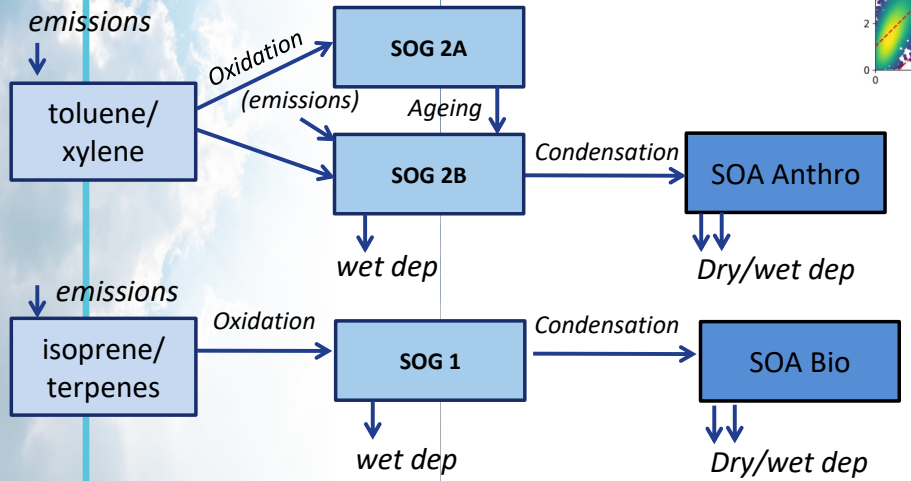
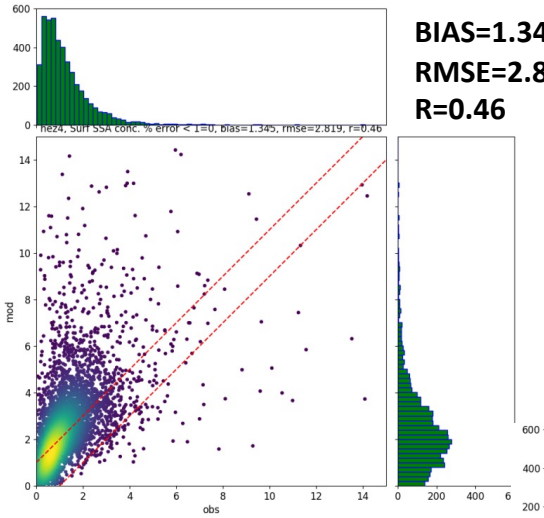
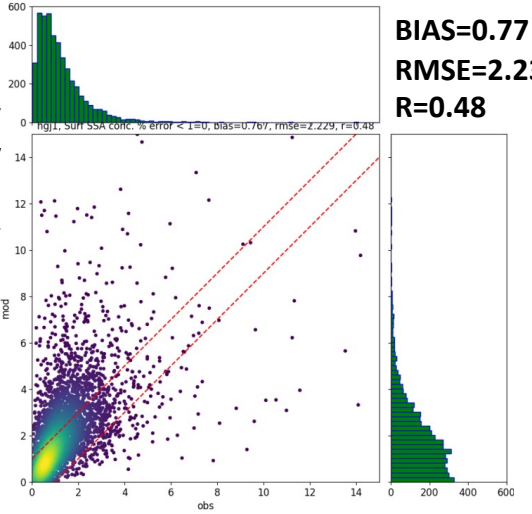
In cycle 48R1, implementation of a distinct SOA species with three precursors, coupled with IFS(CB05)





BIAS=1.34
RMSE=2.82
R=0.46

Bias reduction



BIAS=0.77
RMSE=2.23
R=0.48

January-October 2017: density scatterplot of three-day simulated vs observed total organic carbon (primary + secondary) surface concentration over stations of the IMPROVE network with an altitude < 500m.

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Dust in IFS-AER cycle 48R1

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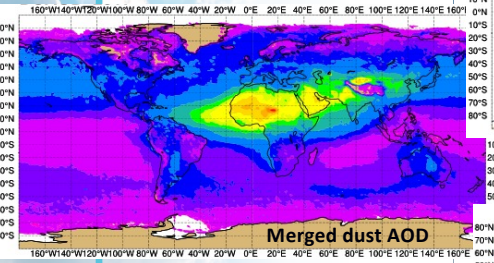
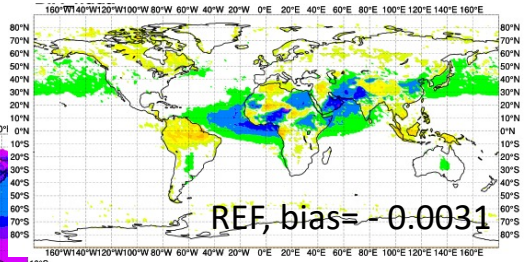
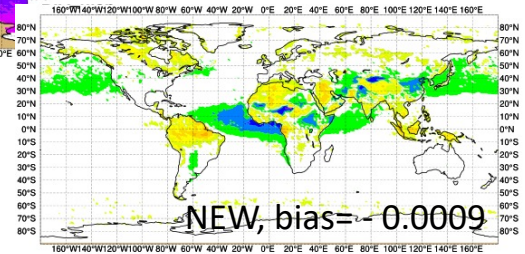
- New dust optical properties
- New monthly varying dust source function which modulates dust emissions
- Dust rebound effect (only for super coarse dust over continental surfaces)
- Higher emissions, less extinctive (and absorbing) dust

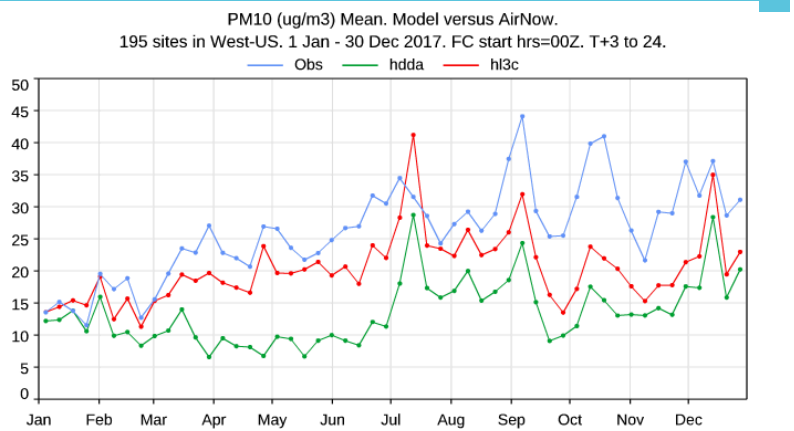


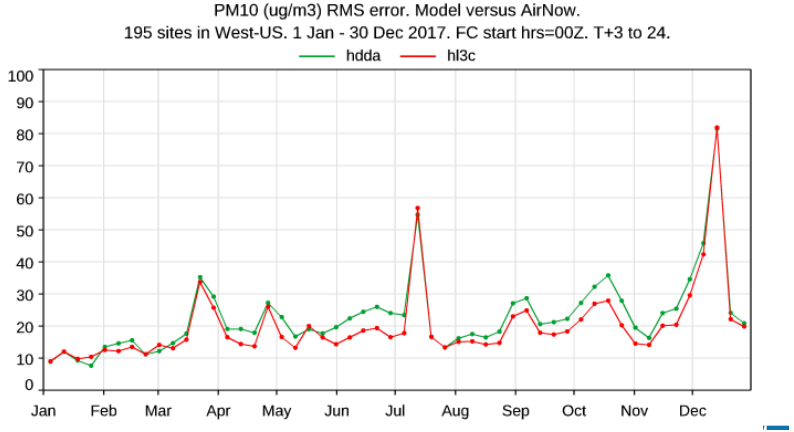




Evaluation of simulated AOD at 550nm against dust AOD derived from the merged AOD product from FMI in 2017

Thanks to Samuel Remy





Evaluation of simulated weekly PM10 in the Western U.S.
Cycle 47R3 (green) vs 48R1 (red), without data assimilation

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Future plans for 2024

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Model updates in cycle 49R1

- Cycle 49R1 is planned to become operational in the summer of 2024. The cycle is frozen and evaluations are underway.
- **Cycle 49R1 will be the one used for next CAMS reanalysis.**

- Cycle 49R1 main aerosol related developments:
  - New optical properties for sulfate
  - New ageing scheme for OM/BC
  - **Update and use of EQSAM4Clim for gas/particle partitioning**
  - Aerosol acidity from EQSAM4Clim used in aqueous chemistry and wet deposition
  - Common aerosol/chemistry wet and dry deposition
  - Desert dust developments:
    - Hydrophilic dust
    - Aspherical optics
  - Simple representation of stratospheric sulphate

Thanks to Samuel Remy

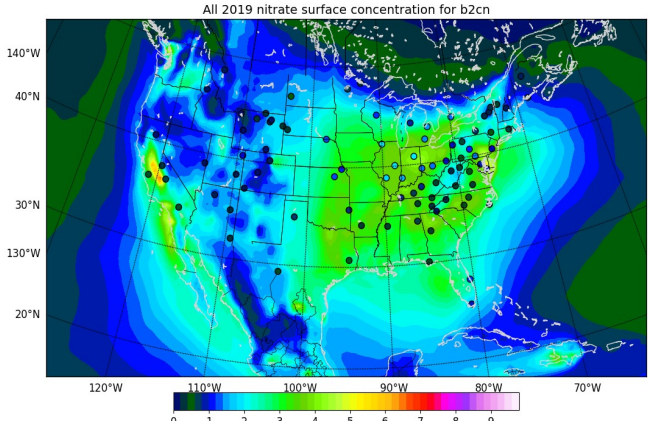
Model updates in cycle 49R1

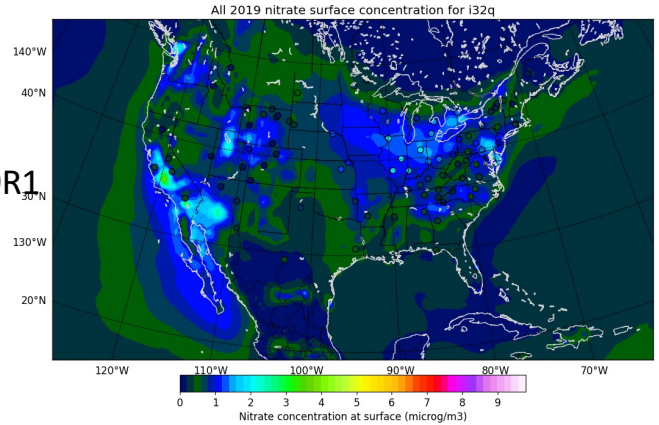
Atmosphere

48R1

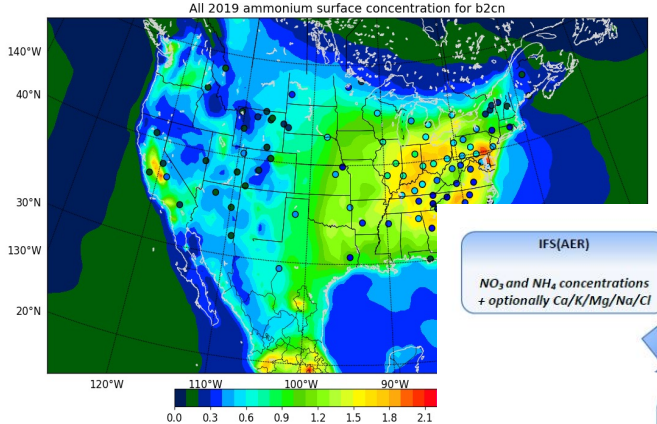
re 49R1

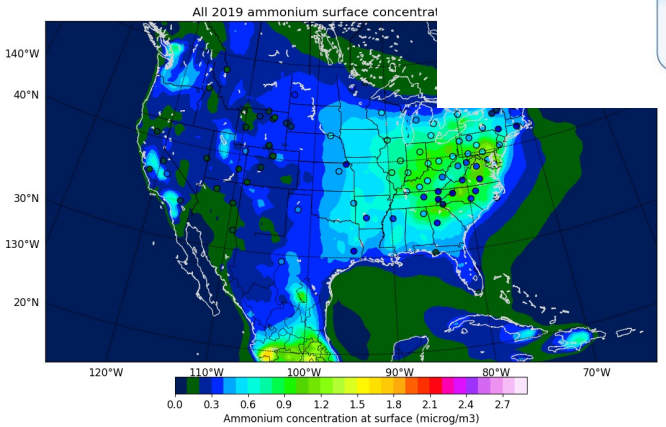
Surface Nitrate



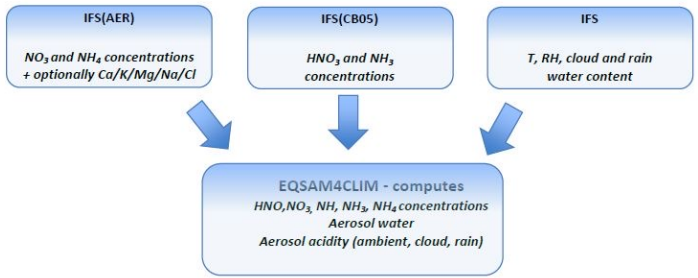


Surface Ammonium





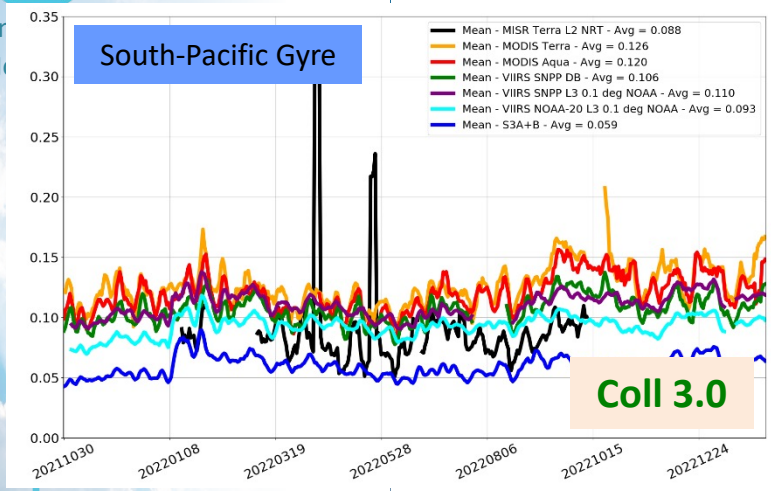
EQSAM4Clim (Metzger et al 2016, 2018) is a simple and fast thermodynamical model based on EQSAM, implemented in the IFS in cycle 48R1, updated and used operationally in cycle 49R1.



2019 average of observed (CASTNET) vs simulated (fc only)

Observation updates in cycle 49R1

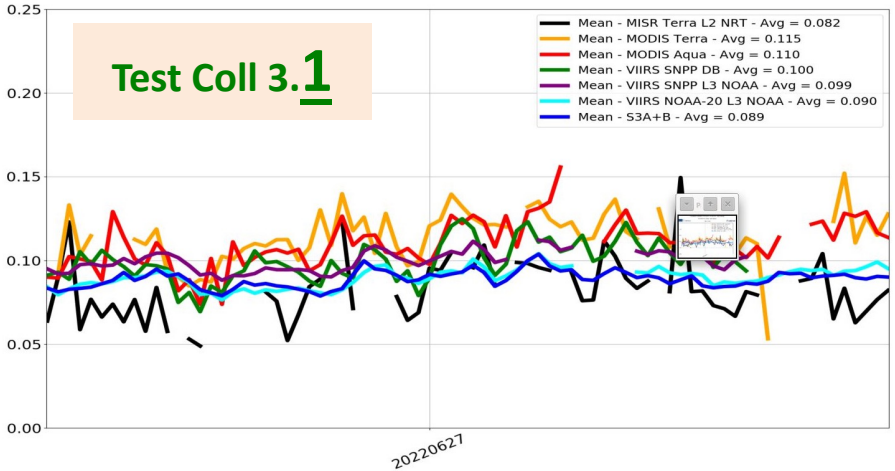
Sentinel-3 AOD observations



- Currently S3 Collection 3 observations are monitored
- Lowest values compared to other satellite AOD observations
- Negative bias over (very) oligotrophic waters (South pacific Gyre), and South Amsterdam island.

Baseline redesign:

- New Ocean Colour LUT, based on OLCI L3
- Activate red (green tbc) channels over water



Collection 3.1 will be tested in cycle 49R1

- VIIRS only covers the afternoon overpass, including S3 means the morning overpass will also be covered should MODIS fail

Thanks to Julien Chimot – see talks on Thursday morning

Atmosphere Monitoring

Additional work

Atmosphere Monitoring

DOMOS project

Dust and **O**cean **M**odelling and Observing Study (DOMOS)

- Consortium project to address the dust interactions with the ocean using an integrated modelling and observing approach

Three key science questions:

1. To what extent dust deposition over the Atlantic has changed over the last 20 years?

2. What is the contribution of anthropogenic and natural sources of dust compared to biomass burning and anthropogenic aerosols to soluble iron deposition over the Atlantic?

3. What are the impacts of changes in dust deposition on marine biogeochemistry and their potential effects on ecosystems?

Name	Location	Produced by
2D monthly deposition fields for dust and soluble iron at the global scale from the DOMOS reconstruction with EC-Earth3-Iron	Release date March 2024	BSC Contact: María Gonçalves (maria.goncalves@bsc.es)
ESA-DOMOS Dust Optical Depth at 532nm and Dust Deposition Rate	Release date March 2024	NOA Contact: Emmanouil Proestakis (proestakis@noa.gr)
Buoy dust concentration data (Carmen and Laura)	Release date: September 2024	NIOZ Contact: Jan-Berend Stuut (jan-berend.stuut@nioz.nl)

Thanks to Angela Benedetti

ECMWF, UoC, Met Norway, NIOZ, NOA, BSC and others…

Dust control variable

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Introducing a dust control variable

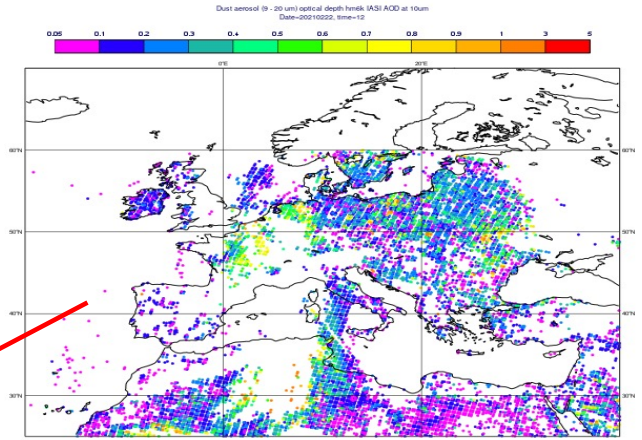
CAMS control variables
GO3
CO
NO2
SO2/SO2VOLC
HCHO

Total aerosol

→

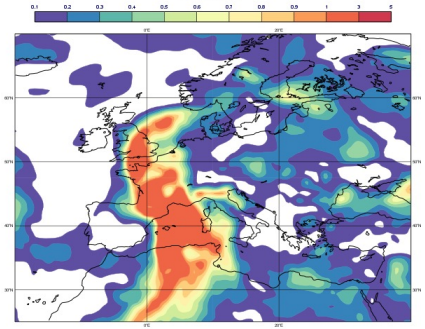
CAMS control variables
GO3
CO
NO2
SO2/SO2VOLC
HCHO

Total aerosol
Coarse dust bin 3

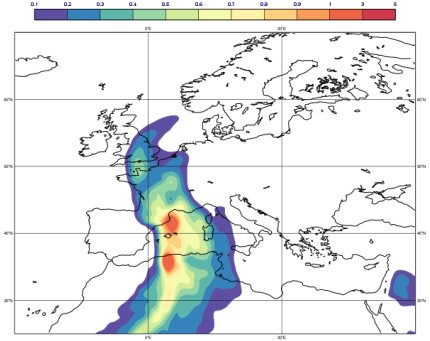


LMD IASI 10um obs 20210222 12hr

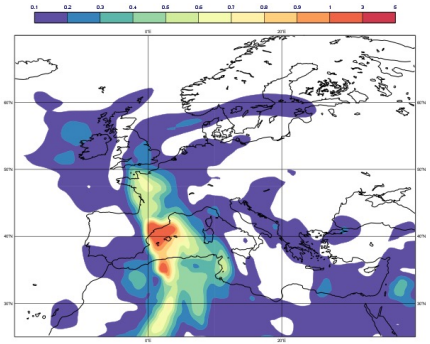
Total AOD at 550nm:
20210222 03hr



Dust AOD assimilating MODIS/PMAP



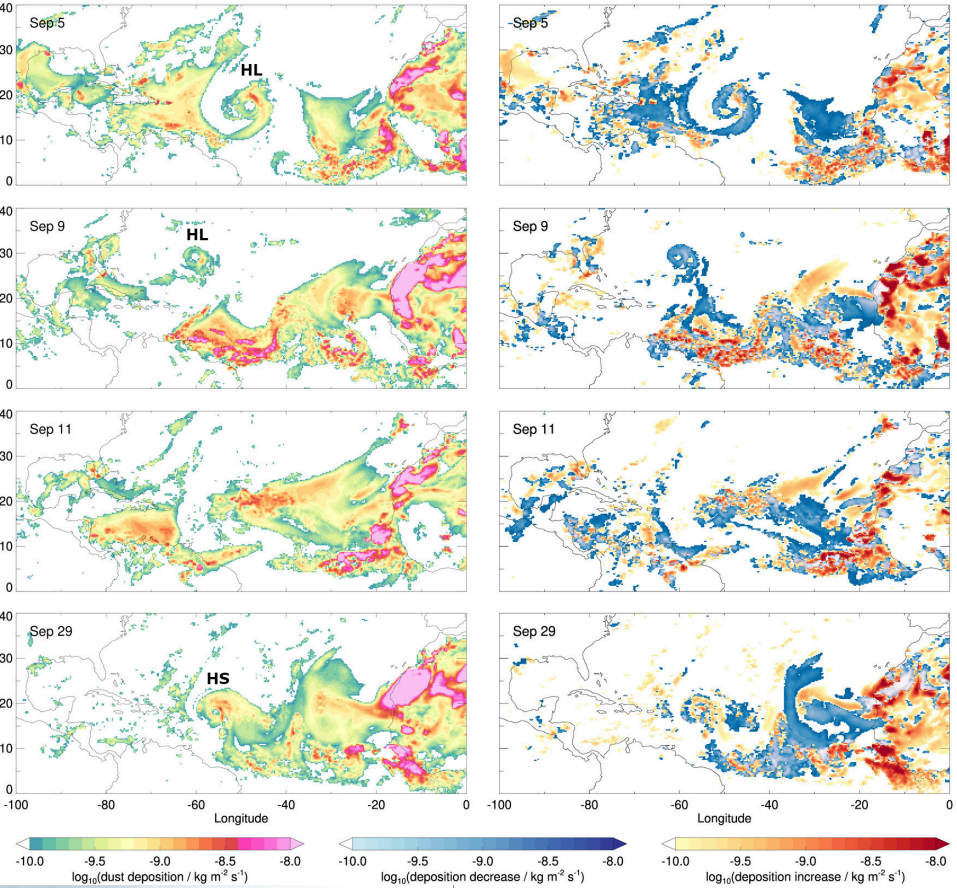
Dust AOD assimilating IASI 10um



With specific dust observations, the dust can be increased in the relevant locations which then improves the spurious increments of other species

Dust deposition (AOD assim)

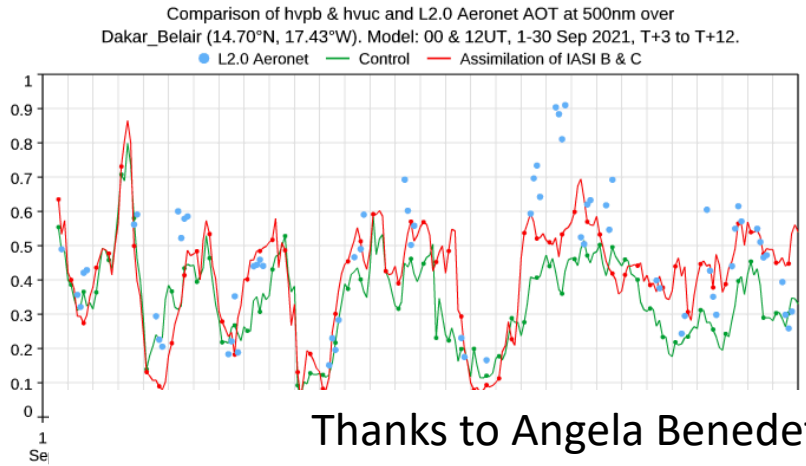
Diff (AOD at 10um assim)



Difference in diagnosed dust deposition between control run (MODIS + PMAP AOD assimilation) and DOMOS experiment (IASI ULB dust optical depth at 10 micron assimilation) for selected days in September 2021.

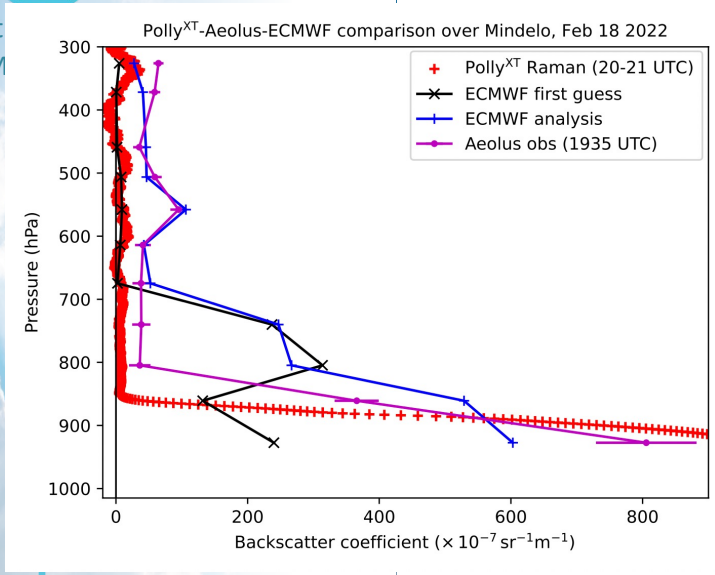
Note the large impact on the deposition fields when different dust observations are used in the assimilation.

Independent verification with AERONET data shows that the analysis with IASI ULB data (red curve) is more able to capture the dust peaks at some locations close to the sources (Dakar shown as an example).

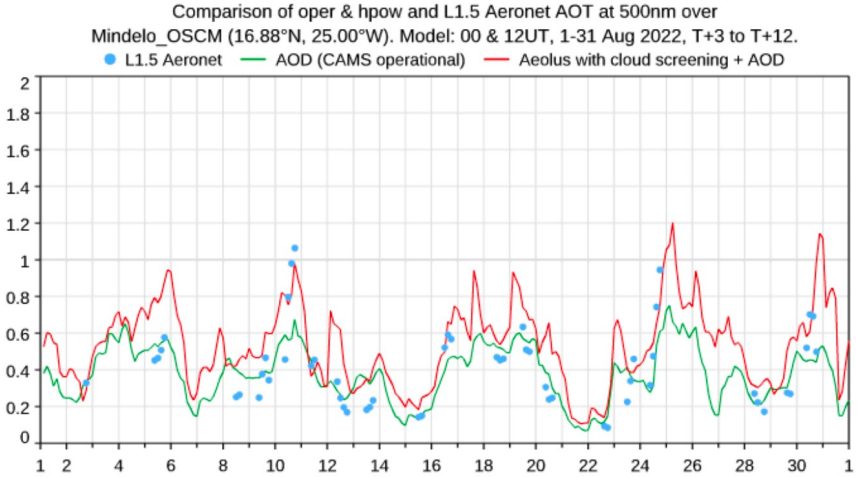


Thanks to Angela Benedetti

Aeolus L2A particle backscatter assimilation



- AOD is column integrated, so does not provide information on the vertical distribution of aerosols. Lidar gives us the vertical information, and the backscatter product is assimilated on top of a setup mirroring that used by CAMS.
- The backscatter values are compared with ground-based data, such as the Polly^{XT} lidar (credit to Holger Baars, TROPOS), where the ECMWF analysis (blue), which assimilates the L2A particle backscatter, is drawn towards the observation (purple) at higher altitudes.



AERONET values in blue for August 2022 at Mindelo, Cabo Verde, compared to the AOD calculated from AOD+Aeolus backscatter in the assimilation in red, and AOD from the CAMS setup in green

- The AOD values calculated from these experiments are compared with the CAMS product and verified against ground-based AERONET measurements.
- Ongoing work includes the testing of new retrieval products, error analysis, bias monitoring and correction, improving the cloud screening, and comparing with ground-based lidar and AOD measurements.

Thanks to Will McLean

CAMS Service evolution: CAMEO

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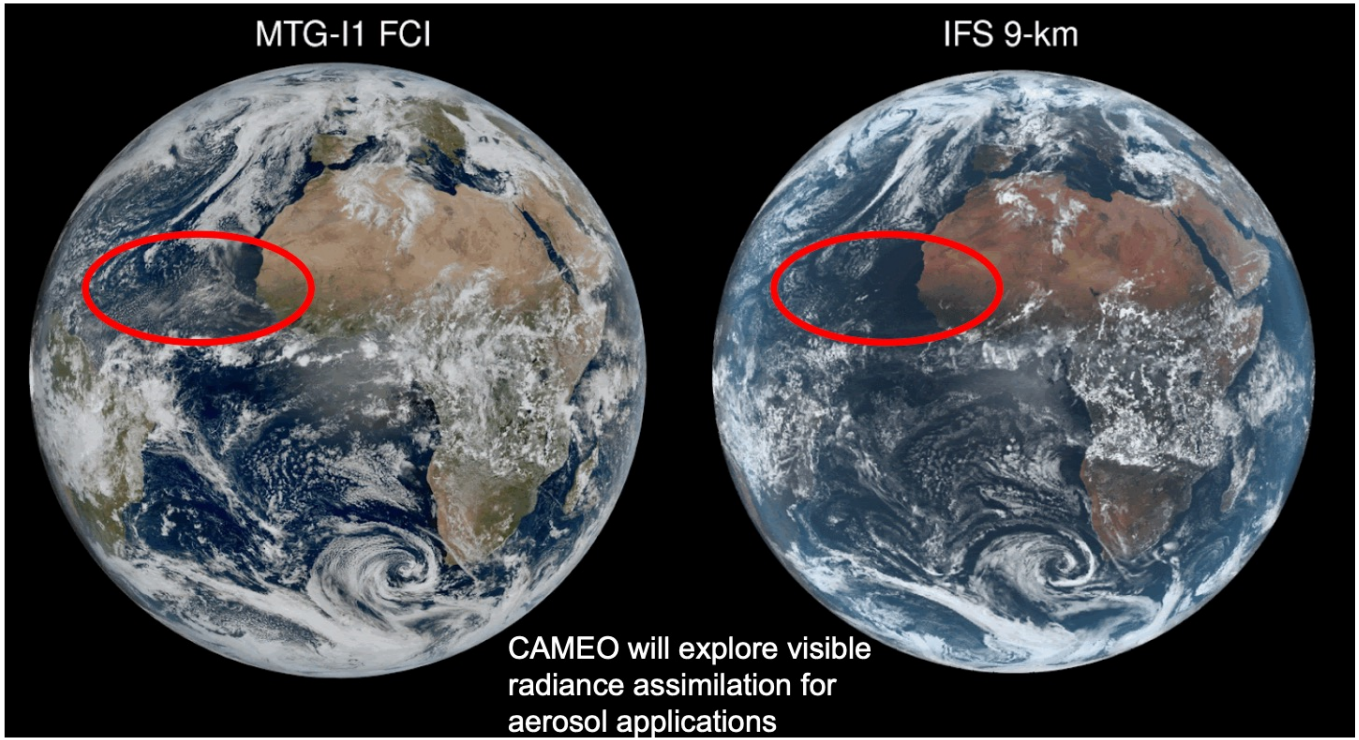
CAMEO project (2023-2025), coordinated by ECMWF



Thanks to Samuel Quesada Ruiz

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CAMS Service evolution: CAMAERA

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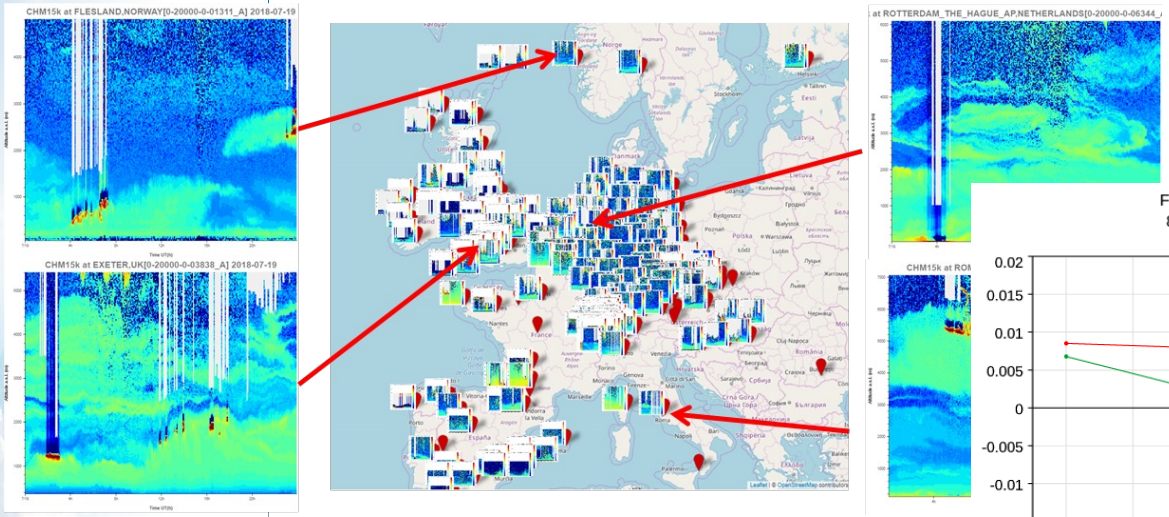
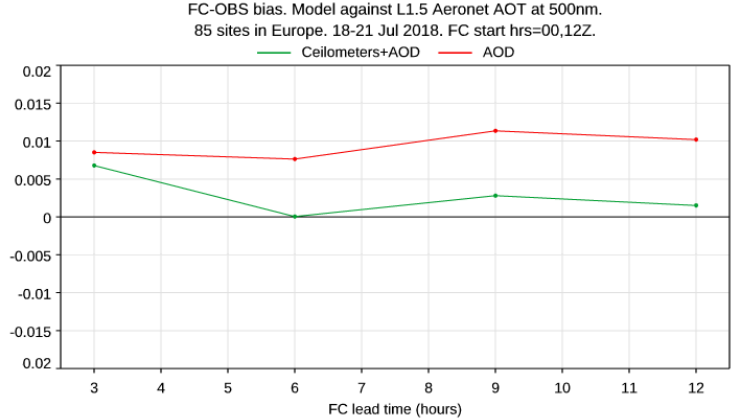
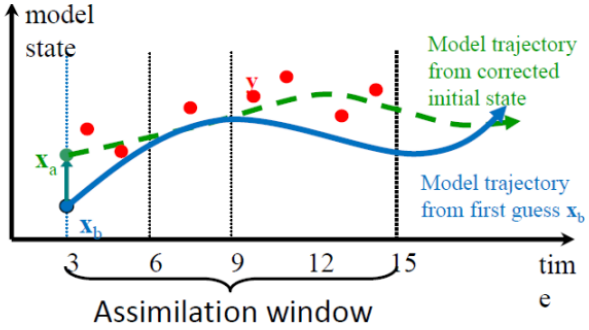


E-PROFILE Ceilometers network



Current 4Dvar assimilation only adjusts the initial condition – can we improve on this using the dust control variable by also updating emissions



CAMAERA project (2023-2025), coordinated by HYGEOS

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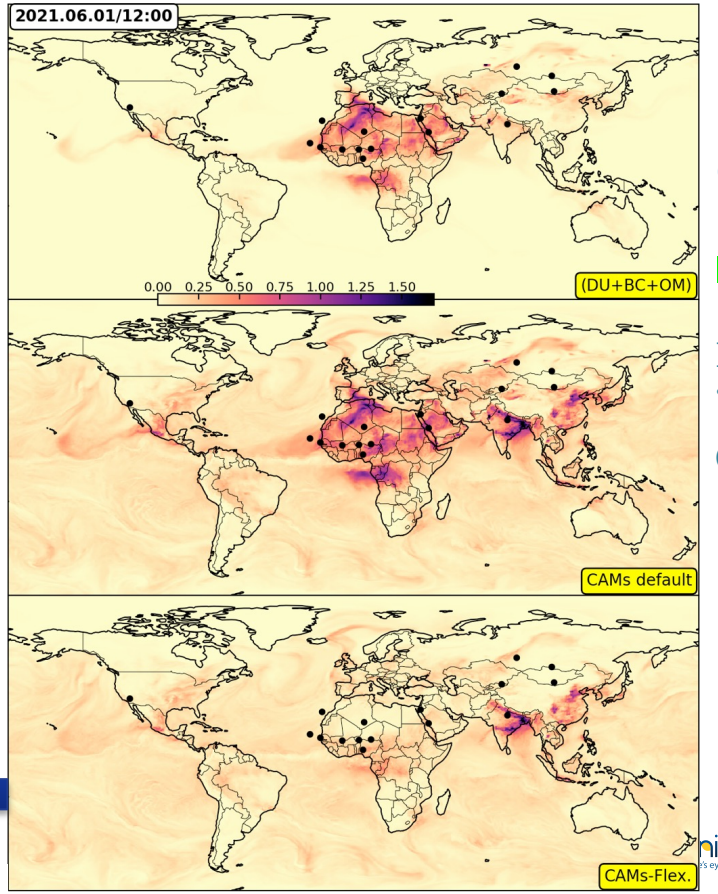
Flexible Aerosols:

What it is:

- New feature to include **custom combination** of prognostic and climatological aerosols species *in the radiation scheme*.

In this example:
Flexible aerosols has
- prognostic DU, BC and OM (only primary)
- climatological all the other aerosols species

This part is represented by a climatological field in this example of flexible aerosols



Prognostic
- Dust,
- Black Carbon
- Primary Organic M.

(one particular flexible aerosols configuration)

LCHEM=OFF

Prognostic
- **all** aerosols species

(CAMs default)

Difference

Thanks to Ramiro Checa-Garcia

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Resources

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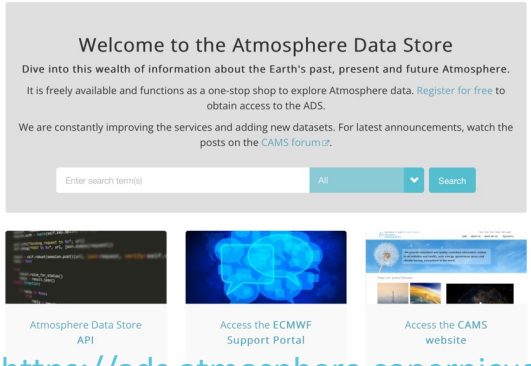
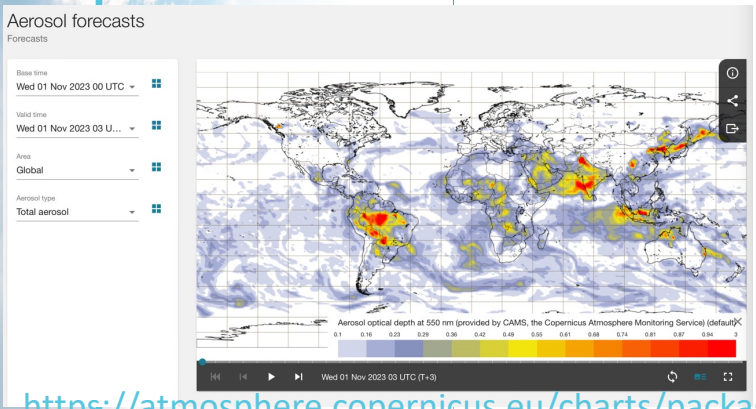
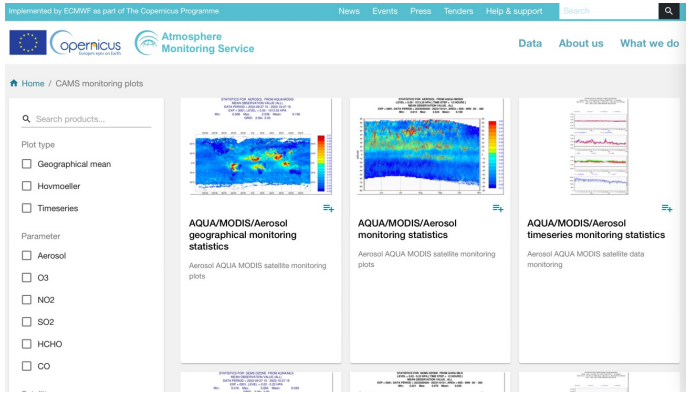


https://ads.atmosphere.copernicus.eu/#!/home

https://atmosphere.copernicus.eu/news

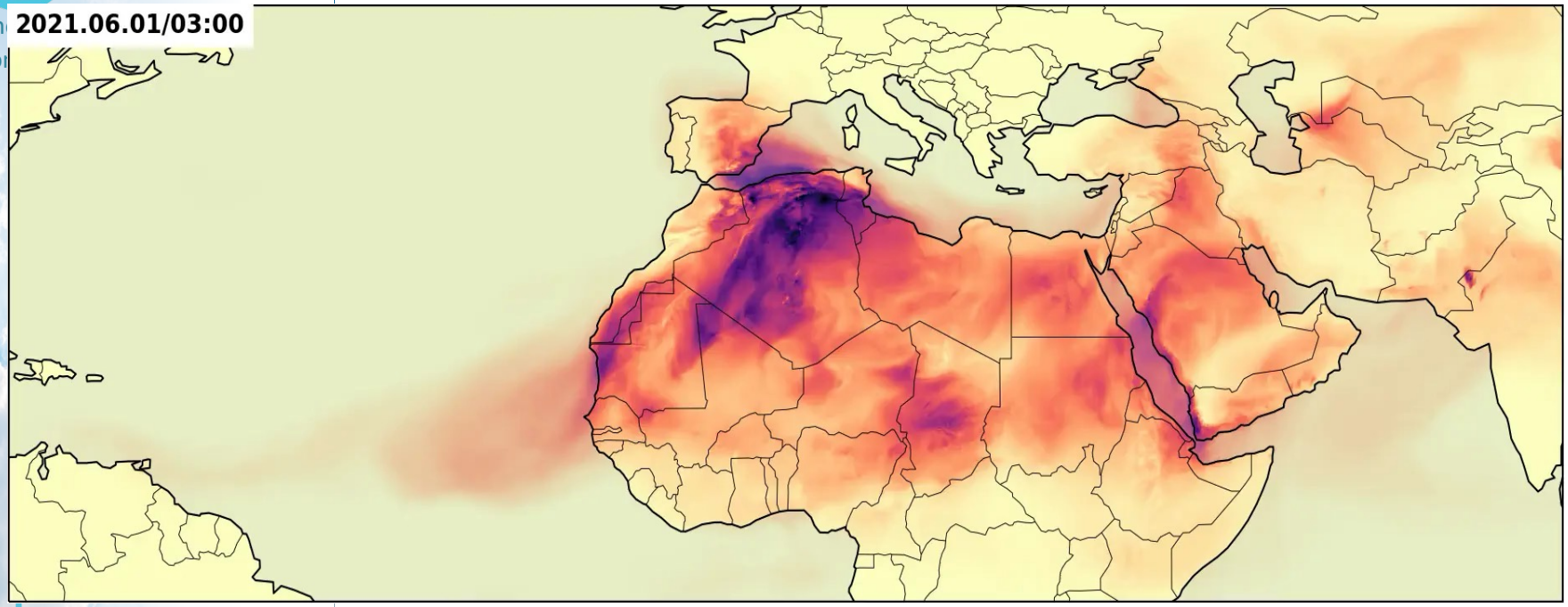


https://atmosphere.copernicus.eu/charts/packages/cams/



https://atmosphere.copernicus.eu/charts/packages/cams_monitoring/

Thank you and any questions



- 4.5km resolution
- dust field run as a flexible aerosol for input to the radiation

Thanks to Ramiro Checa-Garcia

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