Atmosphere Monitoring

Assimilation of atmospheric composition observations in the global Copernicus Atmosphere Monitoring Service (CAMS) system
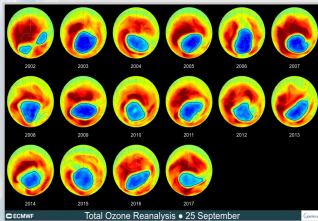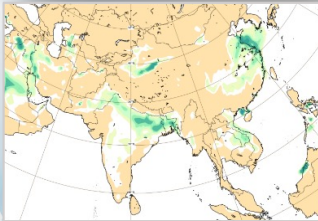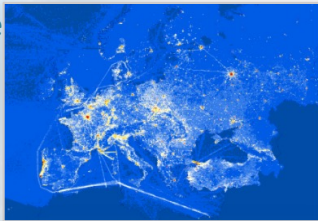
Antje Inness (ECMWF)
Thanks to the ECMWF CAMS team

What the Copernicus Atmosphere Monitoring Service has to offer

Atmosphere Monitoring

The CAMS portfolio includes Earth Observation based information products about:

- global atmospheric composition;
- the ozone layer;
- air quality in Europe;
- emissions and surface fluxes of key pollutants and greenhouse gases;
- solar radiation;
- climate radiative forcing.
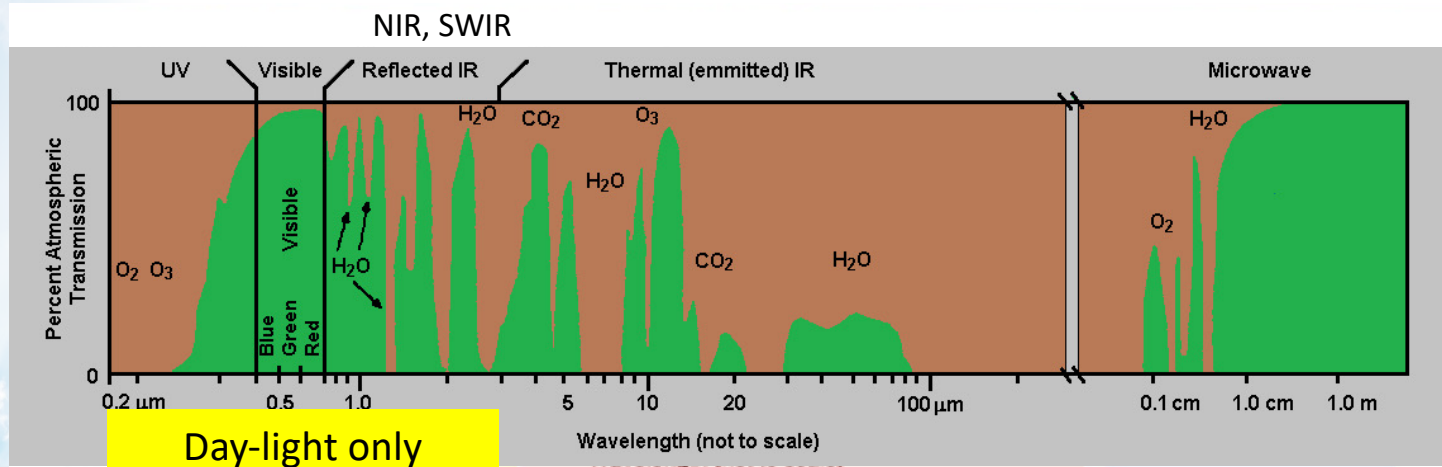- reanalysis of atmospheric compositon

Quarterly validation reports of global and regional outputs.

This is done by assimilating **satellite retrievals of atmospheric composition** into the IFS (in addition to meteorological observations)

https://atmosphere.copernicus.eu

Spectral signature of trace gases

Credit: M. Van Roozendael

SSO
600-800 km
N
equator
S

GEO
35,786 km
N
equator
S

www.esa.int
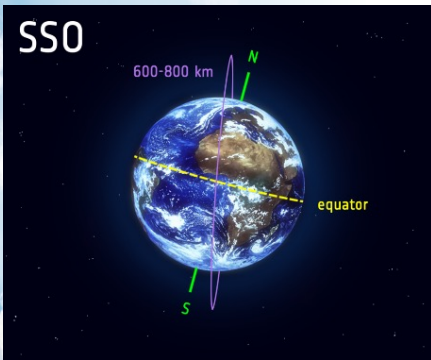
Polar Orbit:
- Low earth orbit (LEO, 600-800 km)
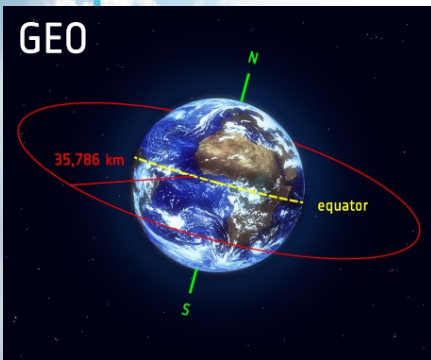- **Sun-synchronous orbit:** overpass over given latitude always at the same local time, providing similar illumination
- Global measurements possible, but fixed overpass time & no observation of diurnal cycle
- Global coverage in a few days (in some cases better)
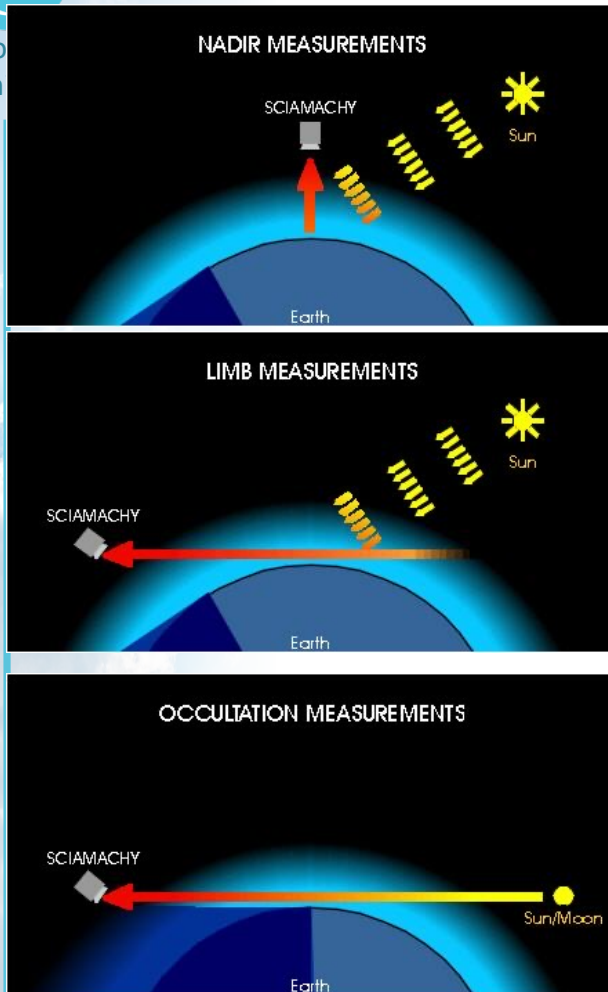
Geostationary Orbit:
- 36000 km flight altitude, equatorial orbit
- Fixed position relative to the Earth,
- Limited area from low to middle latitudes,
- No global measurements possible
- Observations of diurnal cycle
- AC constellation planned (S4, TEMPO, GEMS – already launched)

NADIR MEASUREMENTS — SCIAMACHY, Sun, Earth

LIMB MEASUREMENTS — SCIAMACHY, Sun, Earth

OCCULTATION MEASUREMENTS — SCIAMACHY, Sun/Moon, Earth

www.iup.uni-bremen.de

Nadir measurements (e.g. TROPOMI, IASI):
- Observe atmospheric volume directly under the instrument.
- High horizontal resolution, low vertical resolution.
- Total columns, partial columns, limited sensitivity to PBL

Limb measurements (e.g. MLS):
- Look at the edge of the atmosphere and perform scans at different tangent altitudes over a larger range in horizontal direction.
- Low horizontal resolution, but higher vertical resolution.
- Ideal for stratospheric composition.
- No info about lower atmosphere.

Occultation measurements (e.g. ACE-FTS):
- Use limb geometry but point directly at sun/ moon/ stars. Atmospheric densities are obtained by comparing measurements of the transmitted solar or lunar radiation with the unattenuated source.
- Limited geographical coverage (one sunrise/ sunset per orbit)
- Self calibrating

Earth observation satellites

Atmosphere Monitoring

CloudSat

CALIPSO

Aqua

GCOM-W1

Aura

272.5 sec.

103 sec.

73 sec.

259.5 sec.

OCO-2

101 sec.

All from LEOs

Species	Instruments
Global system	
O_3	OMI, SBUV, GOME-2, MLS, OMPS S5p
CO	IASI, MOPITT, S5p
NO_2	OMI, GOME-2, S5p
SO_2 volcanic	OMI, GOME-2, S5p
Aerosol	MODIS, PMAp, VIIRS, S3
CO_2	GOSAT, IASI, OCO-2
CH_4	GOSAT, IASI, S5p
GFAS fire emissions	MODIS, SEVIRI[*], VIIRS, Sentinel-3, GOES-E/W[*], HIMAWARI-8[*]

Assimilated, Monitored, Future/Testing

CAMS uses Earth Observation data from many satellites for atmospheric composition and weather.

ECMWF Copernicus Europe's eyes on Earth European Commission
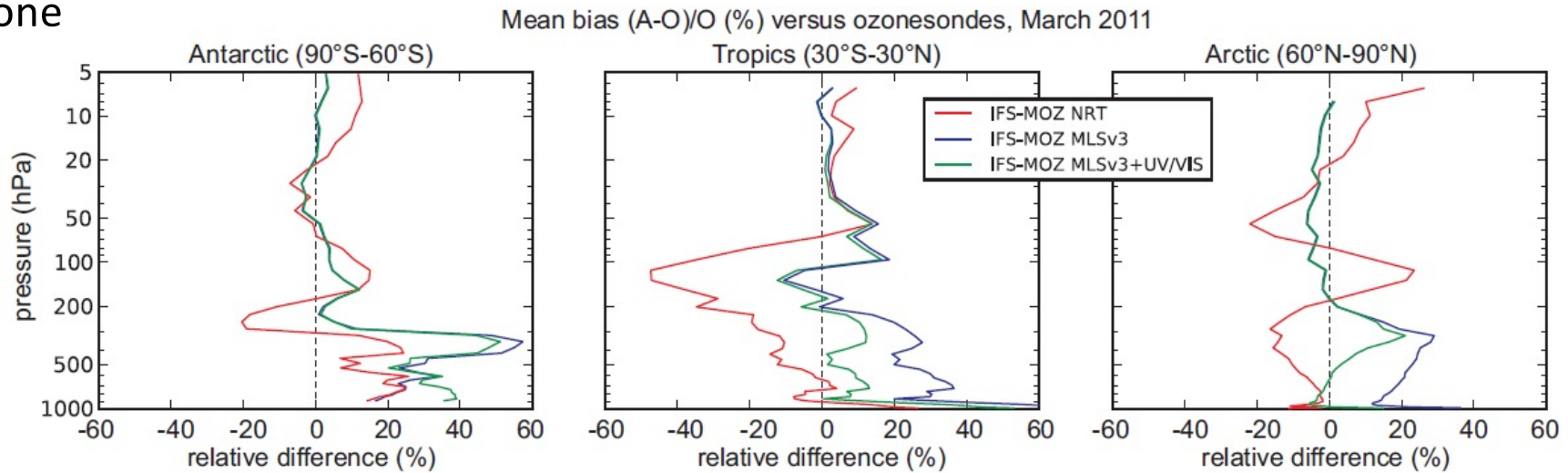
Ozone

Figure 12. Mean biases, in %, of three ozone analyses by IFS-MOZART using O₃ sonde profiles as reference, for March 2011. Results are shown for the Antarctic (left), tropics (centre) and Arctic (right) latitude bands using the IFS-MOZART NRT analyses (red lines), the offline experiment assimilating only MLS v3 (blue lines) and another offline experiment assimilating MLS v3 and the UV–Vis observations (green lines). See text for details.
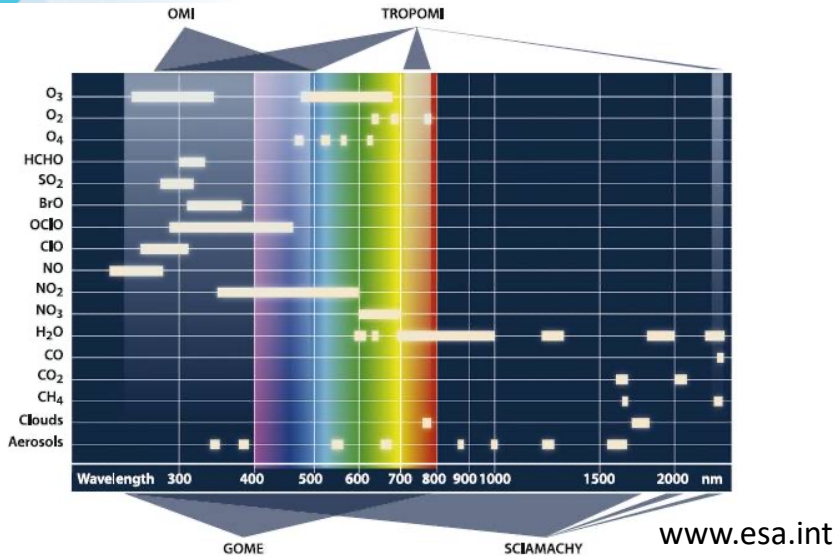
Lefever et al. (2015, doi:10.5194/acp-15-2269-2015)

- Improved quality of ozone analysis if MLS and UV-VIS NADIR obs are assimilated together
- Tropospheric ozone is improved compared to MLS-only assimilation and stratospheric O3 analysis is not degraded

Atmosp
Monito

www.esa.int

TROPOMI & MOPITT AKs

1/1/2018 (86.52° E, 21.87° N)

Martínez-Alonso et al. (2020, AMT)

- CAMS already assimilates MOPITT TIR and IASI CO retrievals
- TROPOMI has ultraviolet and visible (270–500 nm), near-infrared (675–775 nm) and shortwave infrared (2305–2385 nm) spectral bands.

- Retrievals of O3, NO2, SO2, HCHO, CH4 & CO ….

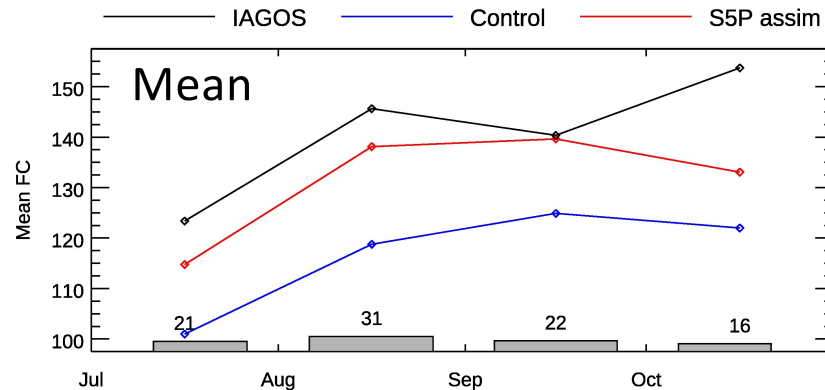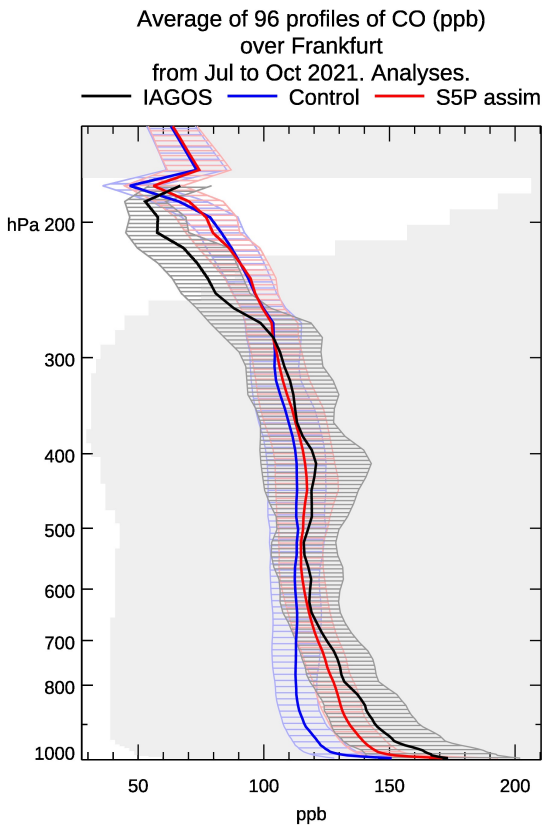- TROPOMI has sensitivity to the CO column
- Clear TROPOMI data have some sensitivity to lower troposphere and PBL

Average of 96 profiles of CO (ppb) over Frankfurt from Jul to Oct 2021. Analyses.
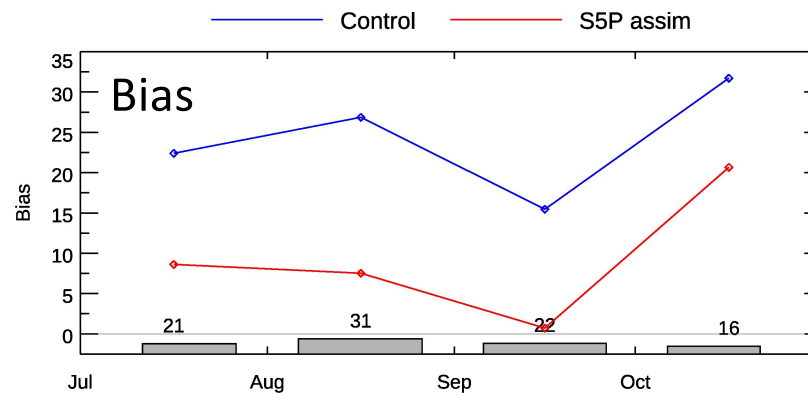
1000-700 hPa

Reduced bias in lower troposphere (1000-700 hPa) at Frankfurt airport if TROPOMI CO is assimilated

Assimilation of TROPOMI CO can give additional information in lower troposphere in DA system that already assimilates MOPITT TIR and IASI CO retrievals

European Commission

Atmosphere
Monitoring

- CAMS aerosol model has 14 aerosol bins:
  - 3 size bins each for sea-salt and desert dust
  - 2 bins (hydrophilic and hydrophobic) each for organic matter and black carbon
  - 1 bin for sulphate
  - 2 bins (fine and coarse) for nitrate
  - 1 bin for ammonium
- Assimilated observations are AOD at 550 nm from MODIS (Aqua and Terra) over land and ocean & PMAp (Metop-BC) over ocean
- Assimilation tests with VIIRS and SLSTR AOD
- Control variable is formulated in terms of the total aerosol mixing ratio.
- Analysis increments are repartitioned into the species according to their fractional contribution to the total aerosol mixing ratio.
- The repartitioning of the total aerosol mixing ratio increment into the different bins is difficult

Dust transport February 2021

Credit: Melanie Ades

CAMS Total AOD at 550nm 12hr forecast valid at 20210222 12hr
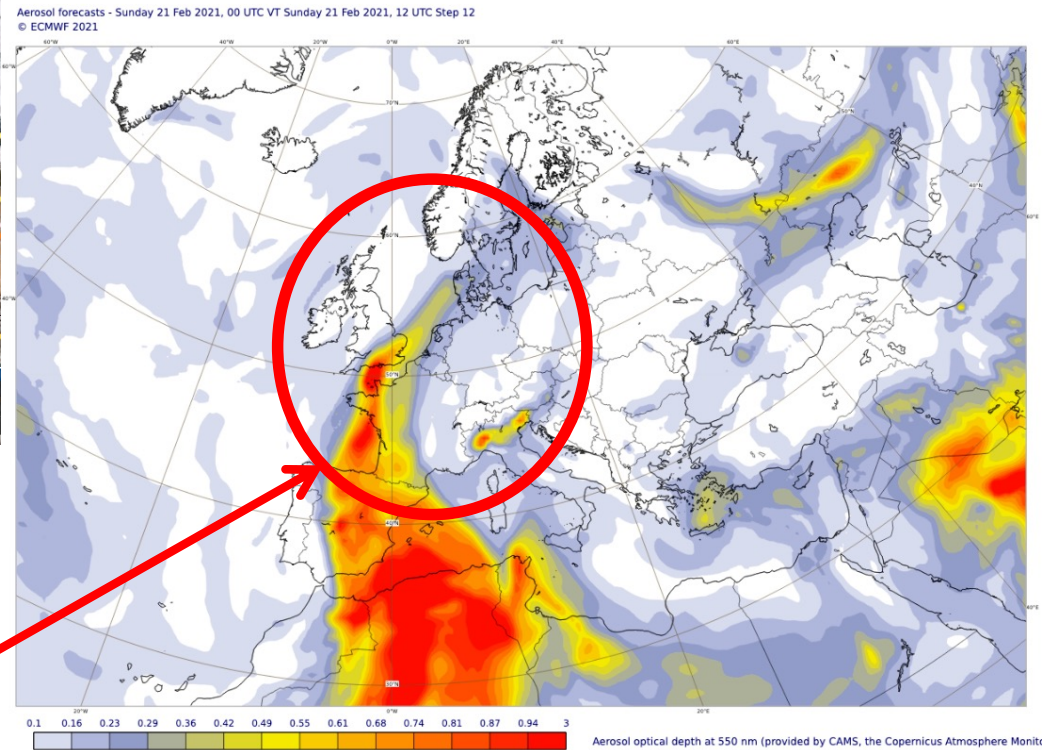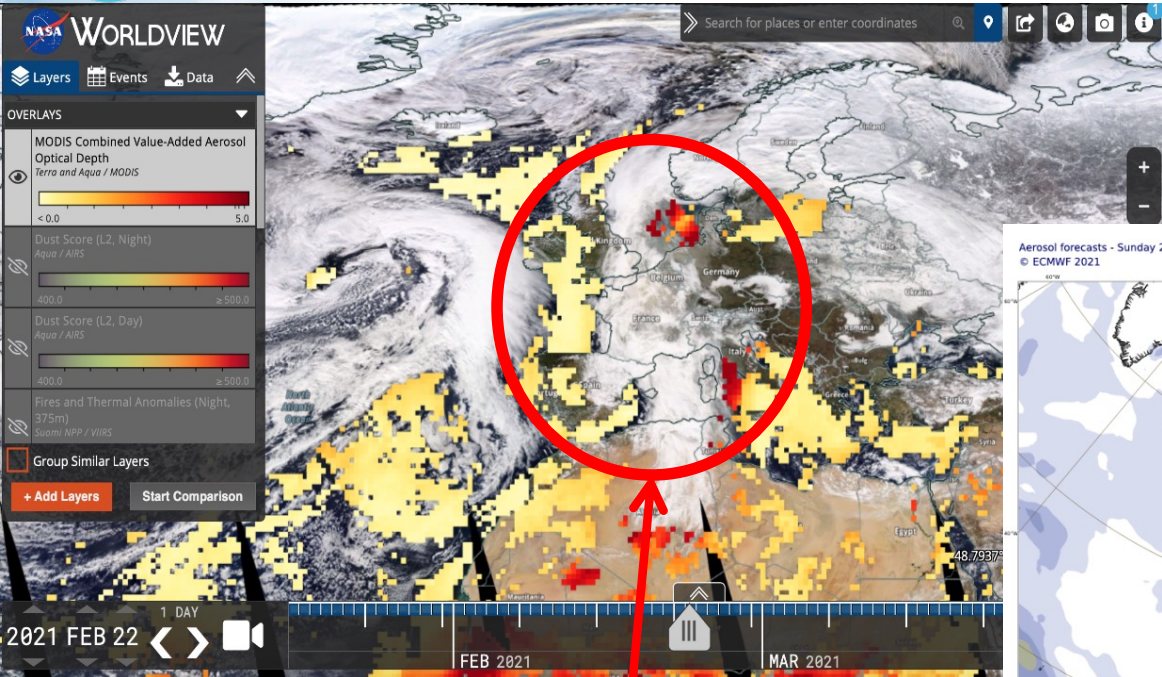
NASA Worldview – MODIS Aqua and Terra AOD 550nm observations for 20210222

The CAMS forecast does a good job of forecasting the AOD plume from Africa over Northern Europe
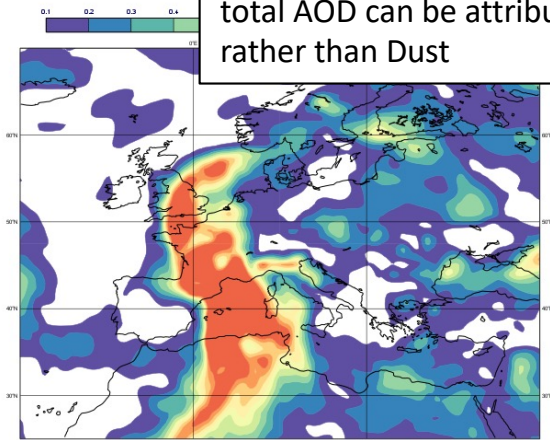
Credit: Melanie Ades

Dust

Sulphate

Closer examination shows that some of this total AOD can be attributed to Sulphate, rather than Dust
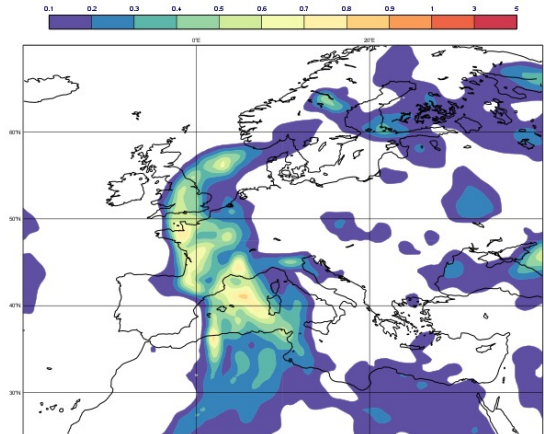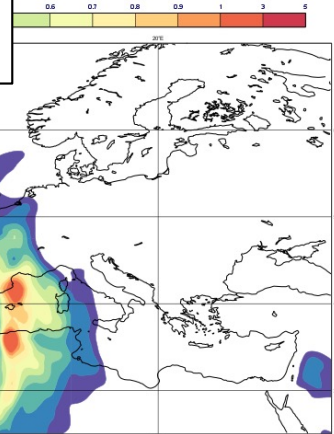
AOD at 550nm

Total AOD at 550nm: 20210222 03hr

Increments

- AOD increments are attributed to the different species according to their proportion in the nonlinear forecast.
- If there is no dust in the forecast in a specific location then the increment will be given to whatever species are there – in this case Sulphate
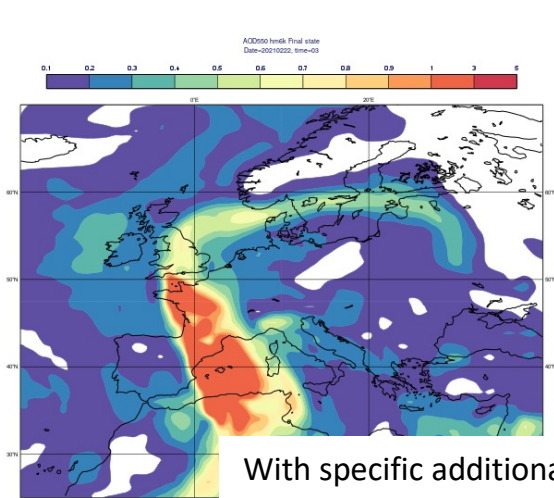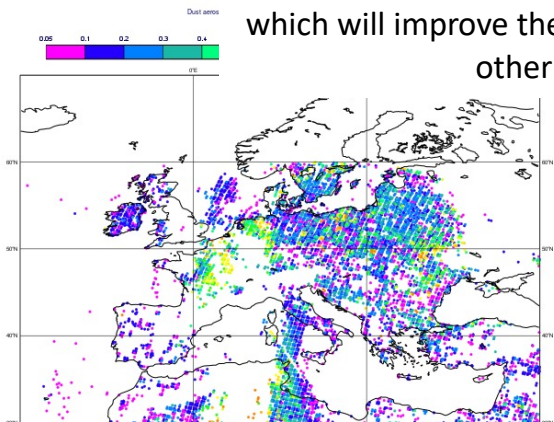
AOD incr at 550nm

European Commission
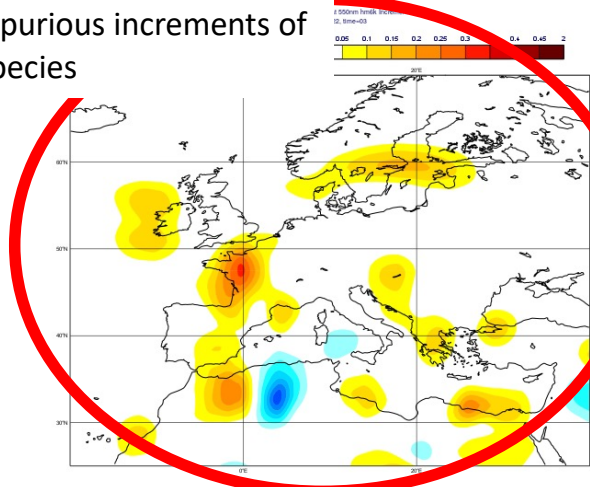
Credit: Melanie Ades

Dust

Sulphate

AOD at 550nm

With specific additional Dust observations, the Dust can be increased in the relevant locations which will improve the spurious increments of other species

AOD incr at 550nm

LMD IASI 10um obs 20210222 12hr
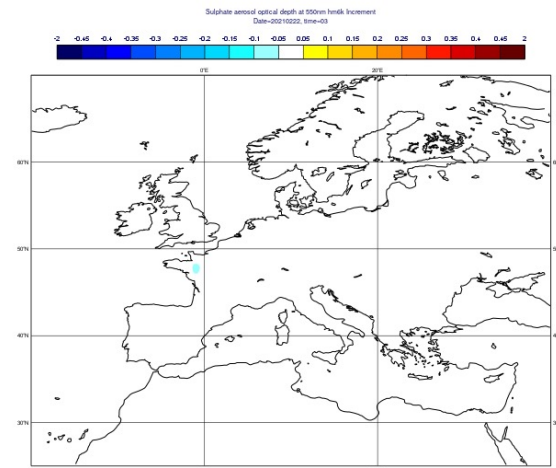
Gaps and limitations of AC observations

Atmosphere
Monitoring

- Spatial resolution (horizontal and vertical); small scales not resolved
- Lack of vertically resolved AC observations (e.g. lower troposphere, UTLS)
- Lack of limb-sensor data for the continued monitoring of stratospheric composition (only ALTIUS to come)
- Revisit time (diurnal cycle); will improve with upcoming GEO missions
- Provision of data during night/ polar night
- Information about aerosol speciation in addition to AOD (e.g. dust, smoke…)
- Latency (NRT data needed within 3 hours)
- Availability of good quality validation data (regular, dense networks, close to NRT, common data formats, qc information)
- General data availability and accessibility. Easy access to data is important.
- Long-term consistent data sets & temporal continuity (also extending back in time & reprocessing for use in reanalyses)
- Past AC datasets: Difficult to go back further than early 2000s for species other than O3 or AOD

ECMWF Copernicus European Commission
Europe's eyes on Earth

The Atmosphere Data Store (ADS)

All CAMS data are freely available

https://atmosphere.copernicus.eu/data

https://atmosphere.copernicus.eu