Perspectives on the atmospheric impacts of the Cumbre Vieja volcanic eruption from the Copernicus Atmosphere Monitoring Service

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Atmosphere Monitoring

ESA Living Planet Symposium 2022, Bonn, 24 May 2022

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What the Copernicus Atmosphere Monitoring Service has to offer

https://atmosphere.copernicus.eu

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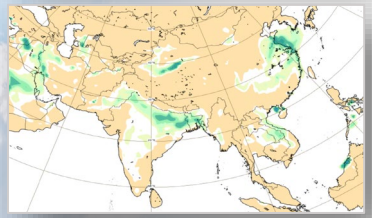

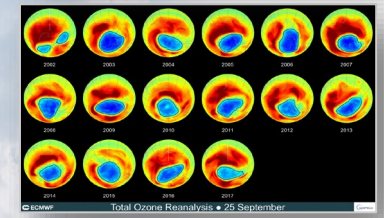

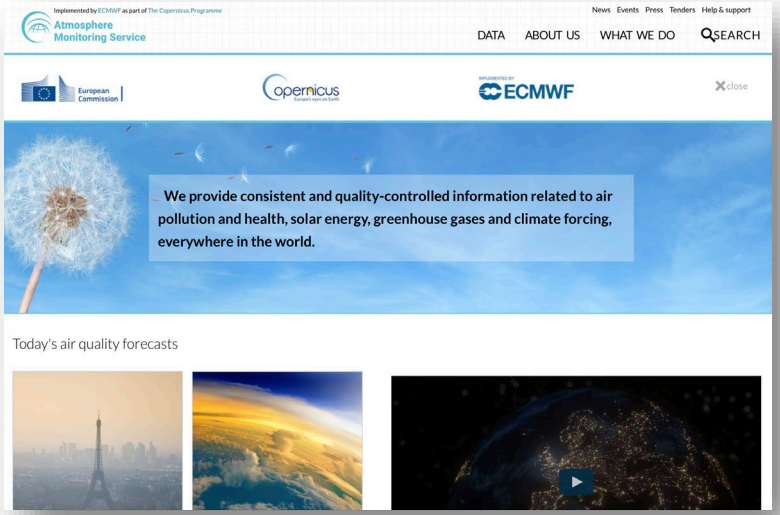

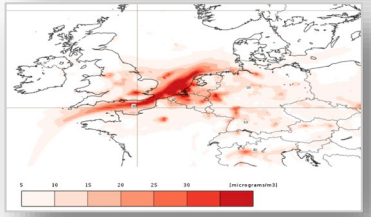

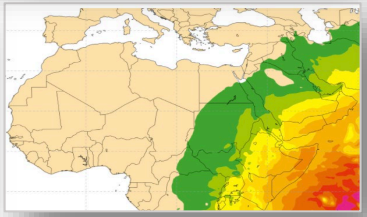

The CAMS portfolio includes Earth Observation based information products about:

- past, current and near-future (forecasts) 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.

Quarterly validation reports of global and regional outputs.

All data are free and open access

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Current use of SO_2 data in CAMS NRT system

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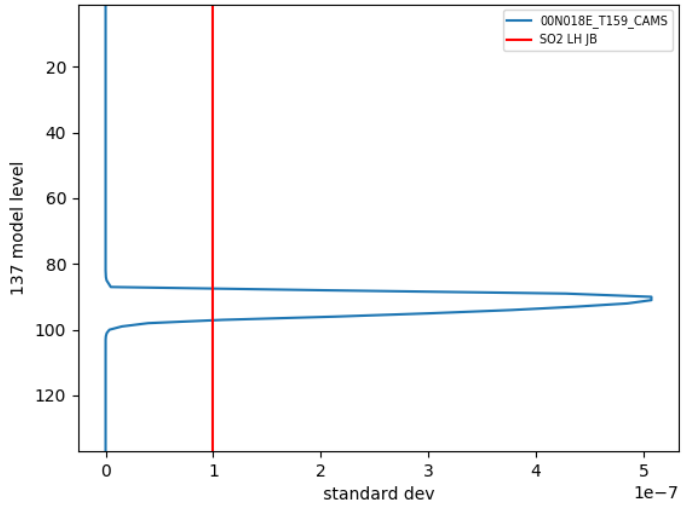
CAMS assimilates GOME-2 (B&C) and TROPOMI total column SO_2 retrievals making use of the volcanic flags provided by data providers (AC-SAF, ESA; algorithm from DLR)

- For operations we need to make assumptions about the plume height if this is not known in NRT
- Default: SO_2 is placed in troposphere at model level 98 (~ 550 hPa, 5 km) using a prescribed bg-error stdv profile
- This can be modified if injection height is known
- Currently: Globally constant injection height

SO2 background error standard deviation



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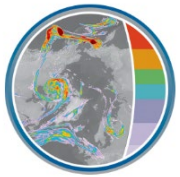
Use of SO_2 Layer Height data in CAMS

- DLR have developed algorithm to provide information about the plume height in NRT from TROPOMI (Hedelt et al., 2019, doi.org/10.5194/amt-12-5503-2019)
- Full-Physics Inverse Learning Machine (FP_ILM) algorithm
- SO2 LH project - one of ESA's S5P Innovation projects
- These data have been tested in CAMS
- Data useful for SO_2 > 20 DU

TROPOMI

sentinel-5p



SO2 Layer height project

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Eruption of Cumbre Vieja volcano: 19 September 2021

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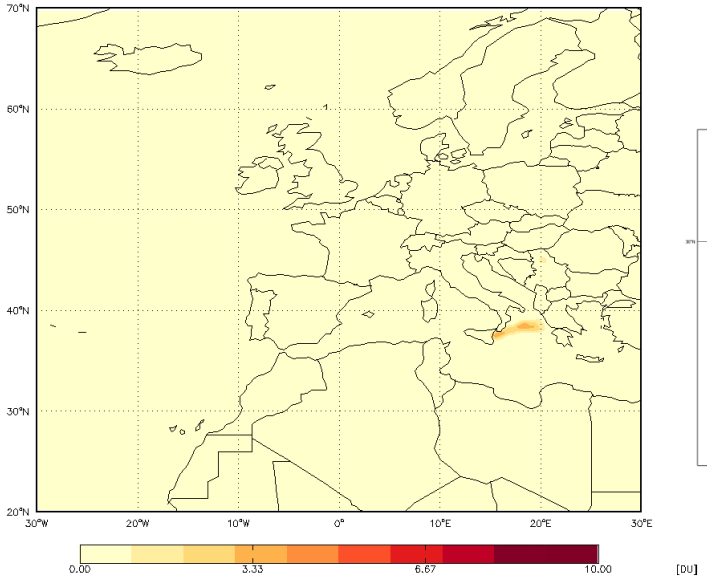
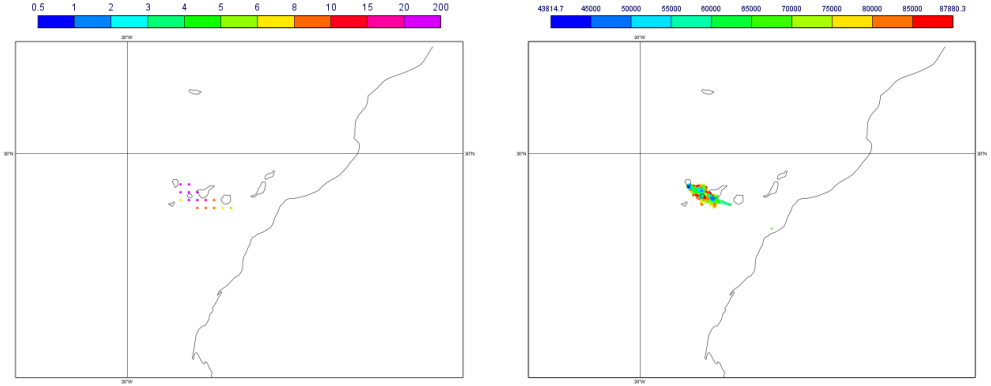
- Cumbre Vieja volcano on La Palma erupted on 19 September 2021 for first time since 1971
- First SO_2 detections from GOME-2 & TROPOMI assimilated by CAMS at 06z on 20 September
- TROPOMI layer height ~600 hPa
- Initial transport to the NW across N Africa, Europe and Mediterranean

CAMS $TCSO_2$ analyses (DU): 19-29 September



Assimilated S5p $TCSO_2$ (left) & layer height (right) obs on 20 Sept



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SO_2 emissions and injection height

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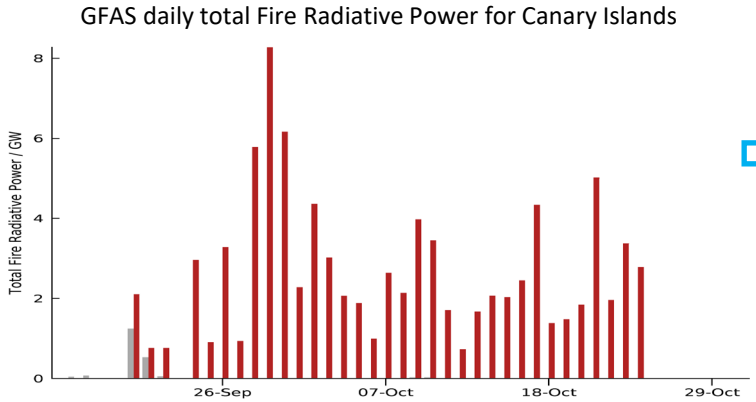

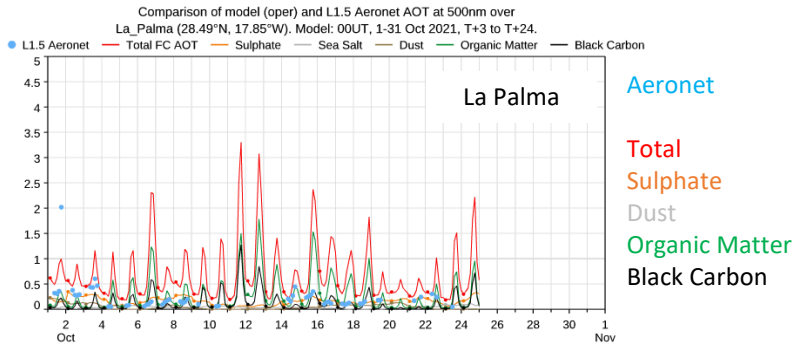

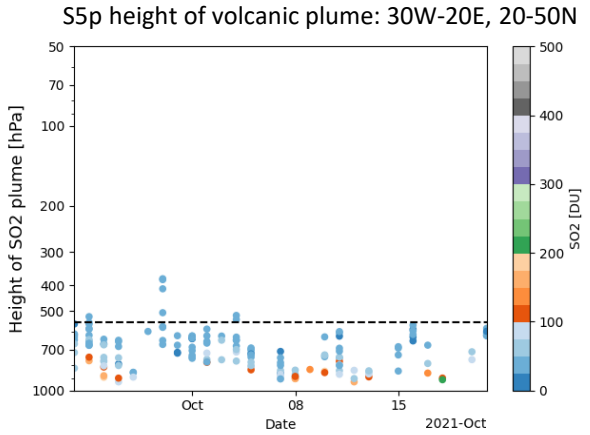

- Thermal anomaly from Cumbre Vieja detected by Terra+Aqua MODIS and assimilated in GFAS.
- Changes in TROPOMI observed SO2 layer heights correlate roughly with daily FRP data.
- Typical heights between 700-500 hPa below operationally assumed initial layer height at 500 hPa.
- False fire emissions in GFAS led to artificially high AOD (dominated by OM+BC) at La Palma.
  - Not seen at other Aeronet sites

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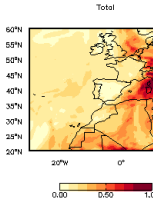
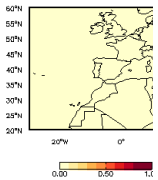
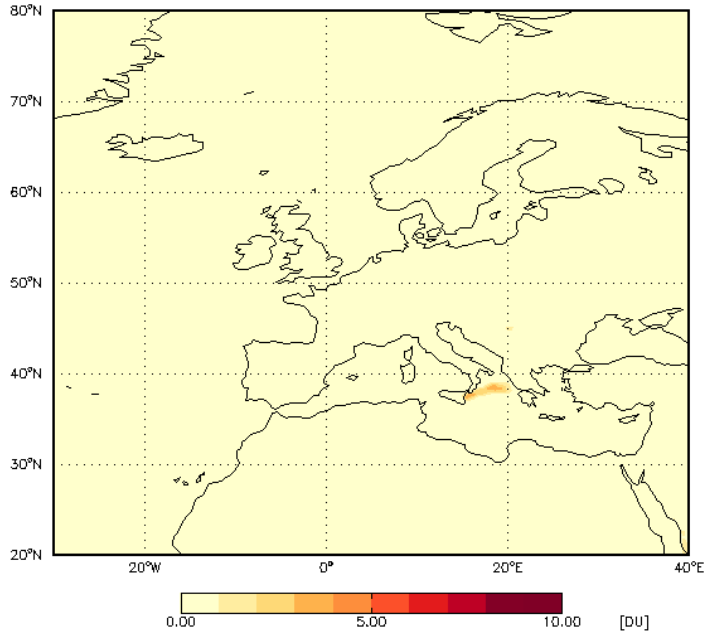
Sulphate aerosol formation

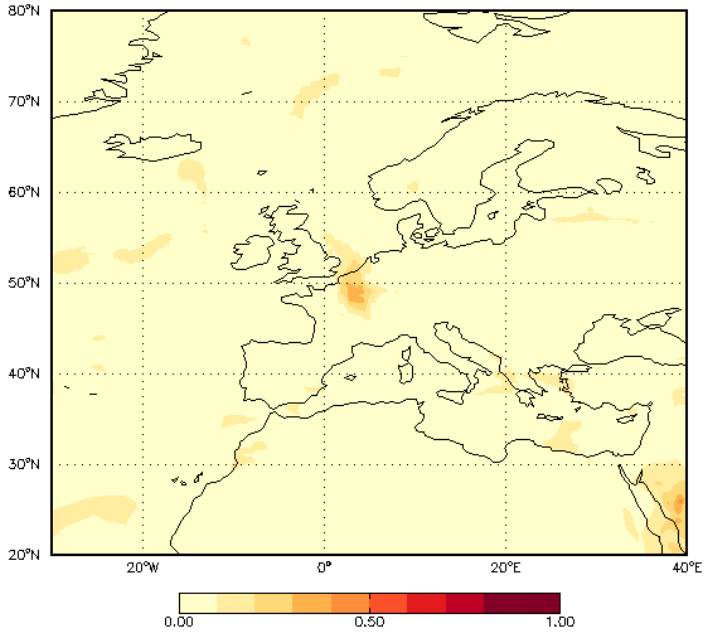
CAMS $TCSO_2$ analyses (DU): 19-29 September

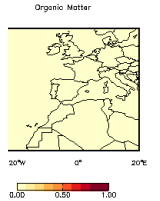


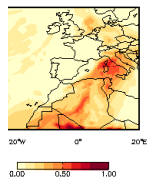




CAMS Sulphate AOD analyses: 19-29 September







- Sulphate aerosol formation in volcanic plume appears after 2-3 days in operational forecasts (via interactive model chemistry) reaching E Europe to north of Saharan dust plume.

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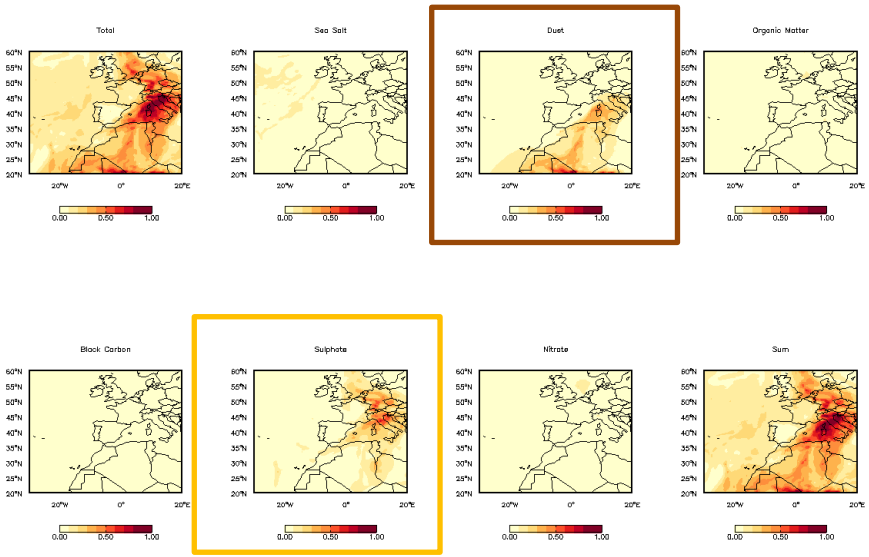
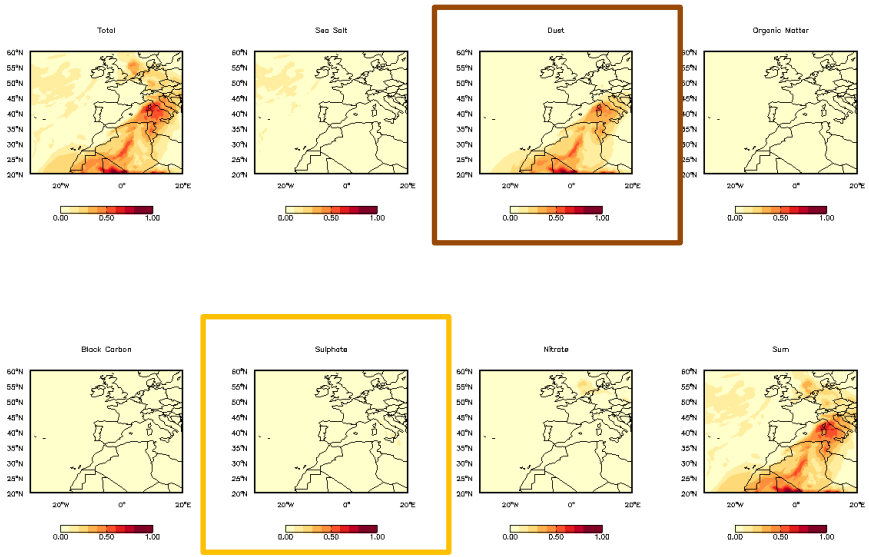
Sulphate aerosol formation

0001, 26 September 2021, 12 UTC



Control (hj7b), 26 September 2021, 12 UTC



- Sulphate aerosol formation in volcanic plume appears after 2-3 days in operational forecasts (via interactive model chemistry) reaching E Europe to north of Saharan dust plume.
- Control experiment (hj7b) shows lower total AOD and corresponding dust plume but not sulphate (indicating origin related to assimilated SO_2).

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Aerosol evaluation with Aeronet over Europe

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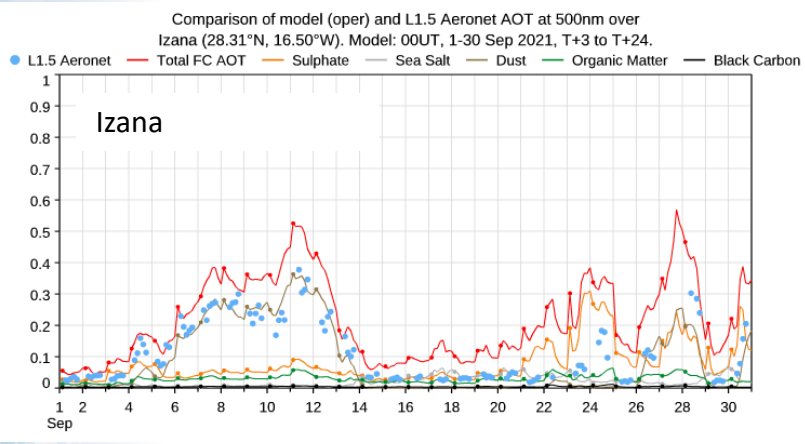

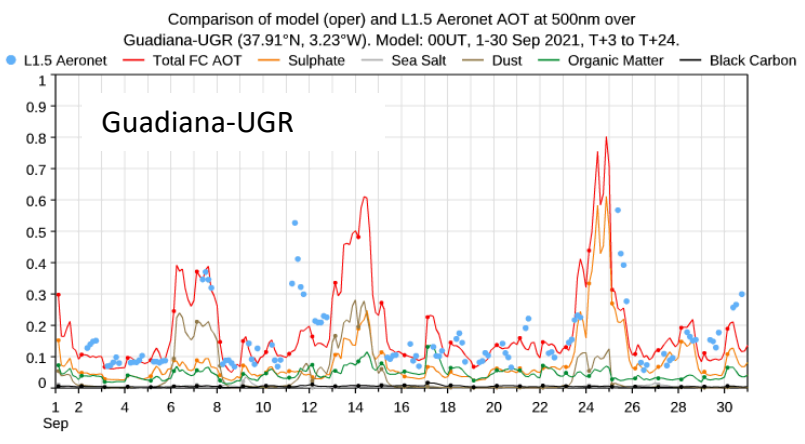

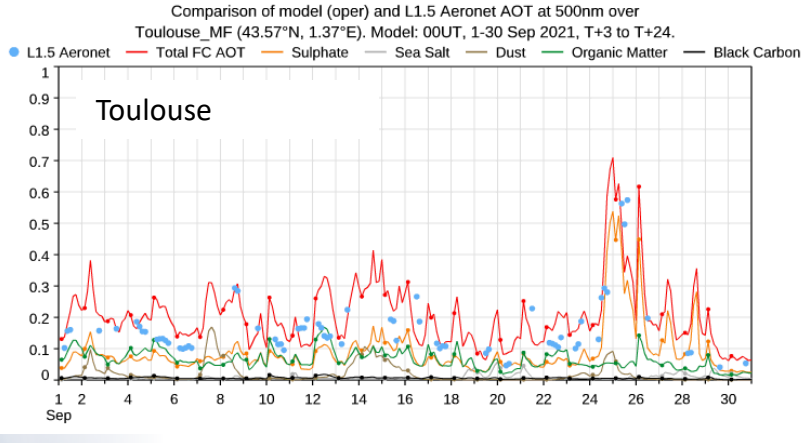

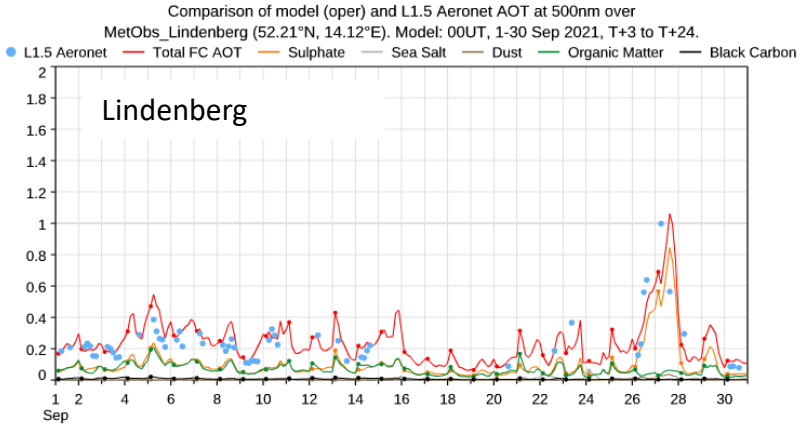

Long-range transport across the Atlantic

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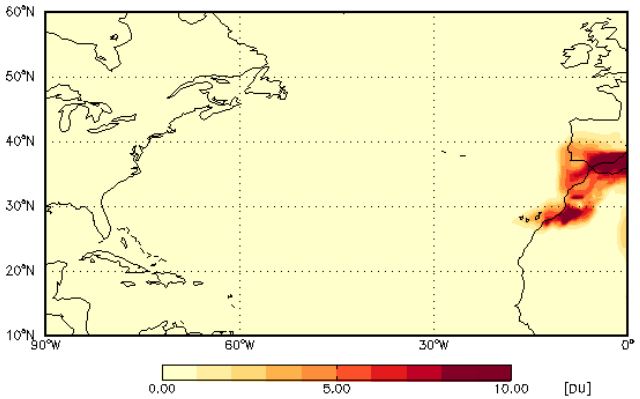
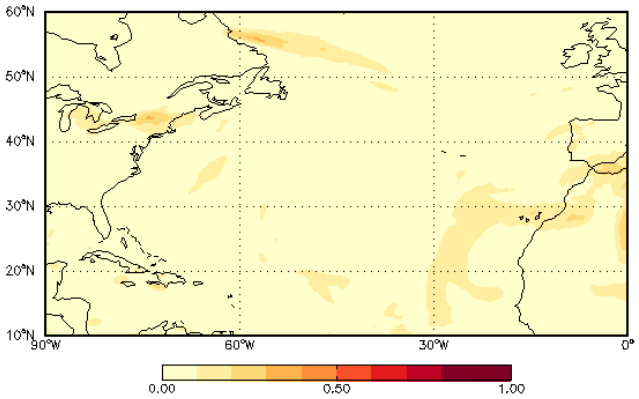
CAMS $TCSO_2$ analyses (DU)

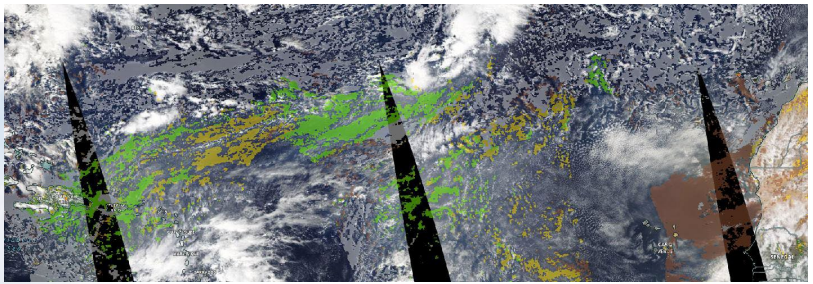


CAMS Sulphate AOD analyses



28 September – 25 October

SNPP-VIIRS aerosol retrievals on 9 October



- CAMS analyses of TCSO2 and sulphate AOD show plume reaching Caribbean on a couple of occasions in October.
- NASA Worldview imagery from 9 October shows mixture of dust and fine mode aerosol in visible imagery & SNPP-VIIRS aerosol type retrievals across the Atlantic

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Reported air quality impacts

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Transport of volcanic plume across the Atlantic coincided with reports of reduced visibility and degraded air quality in:

- 3 Oct - Azores
- 4 & 9 Oct - Puerto Rico
- 10 Oct - Dutch Caribbean Islands

CAMS surface aerosol concentrations

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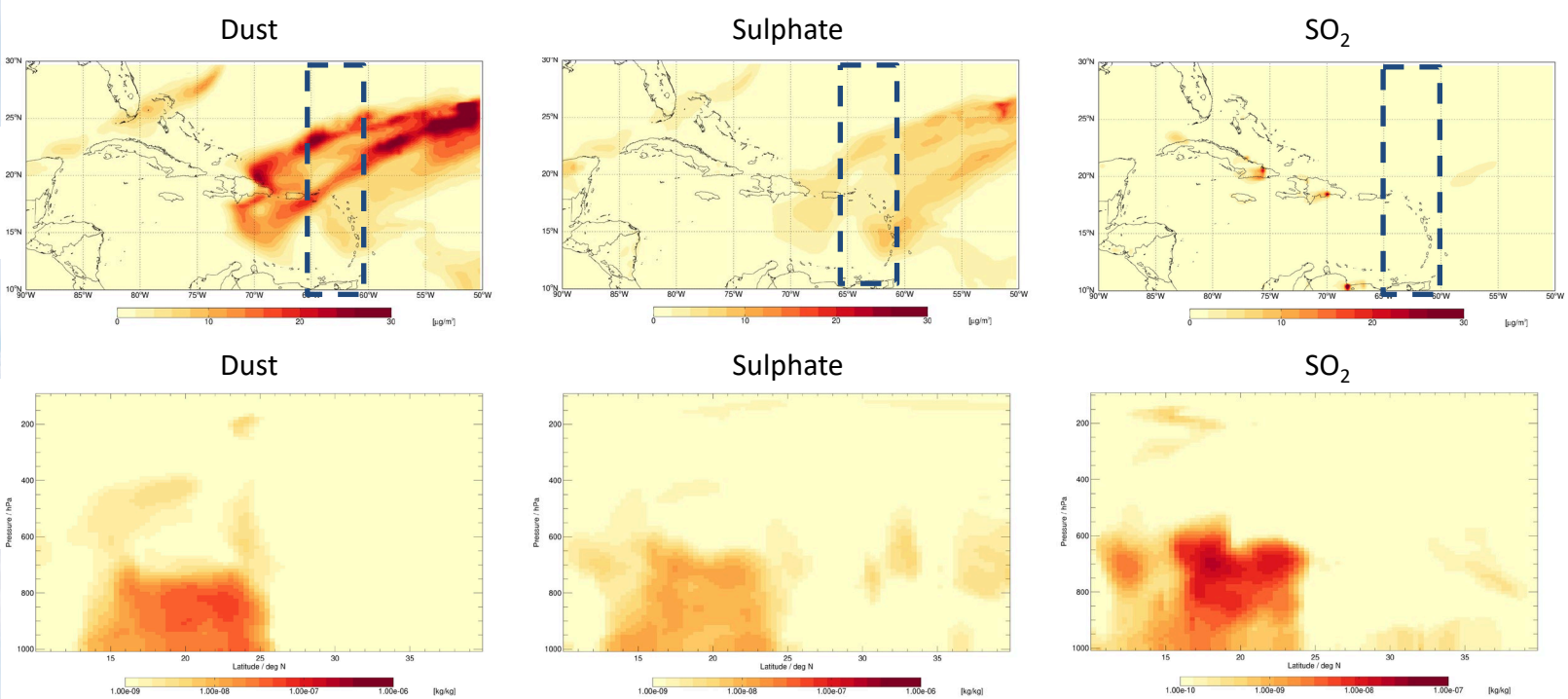
Surface concentration [kg/kg]

65-60W zonal mean cross-section [kg/kg]



- Sulphate aerosol mixed with Saharan dust.
- Highest concentrations in dust ‘gaps’.

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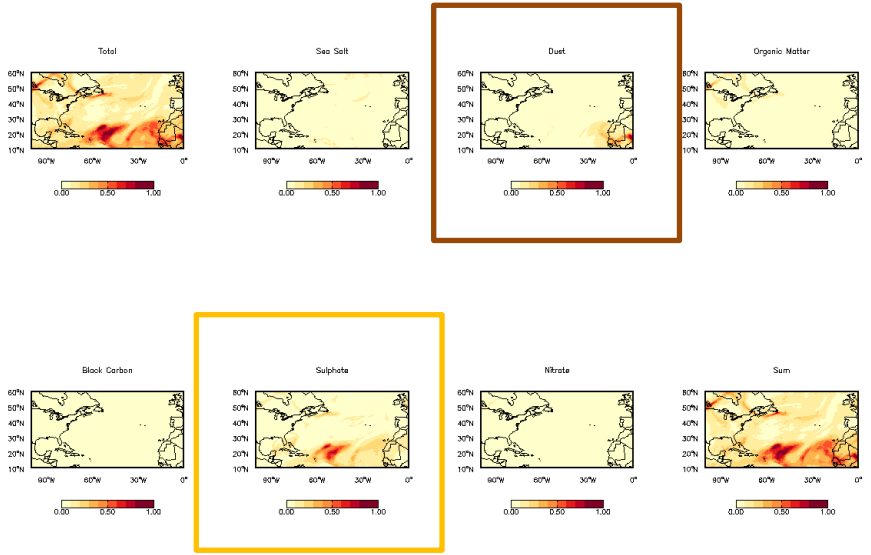
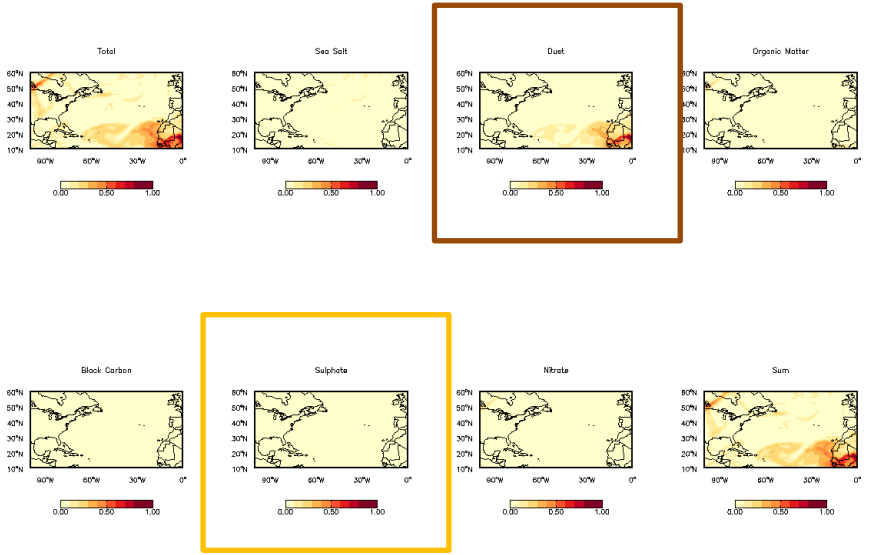
Sulphate aerosol formation

0001, 8 October 2021, 12 UTC



Control (hj7b), 8 October 2021, 12 UTC



- Sulphate AOD is dominant source in CAMS operational forecasts with limited dust AOD transport across the Atlantic.
- Control experiment (hj7b) shows corresponding dust plume but not sulphate (indicating origin related to assimilated SO2).

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Aerosol evaluation with Aeronet over Atlantic and Caribbean

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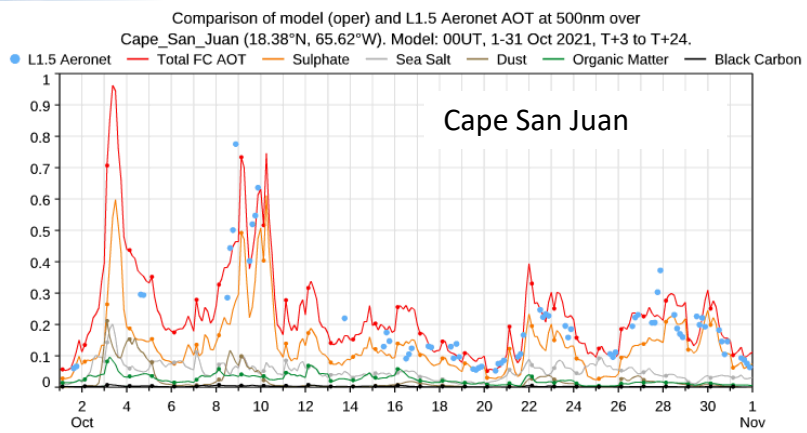

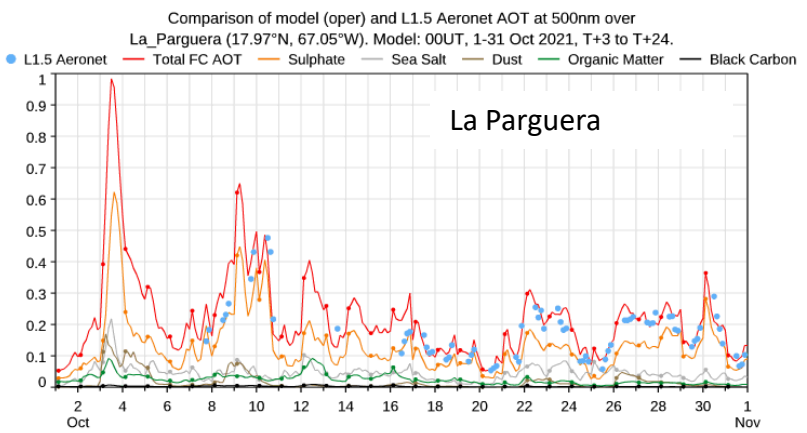

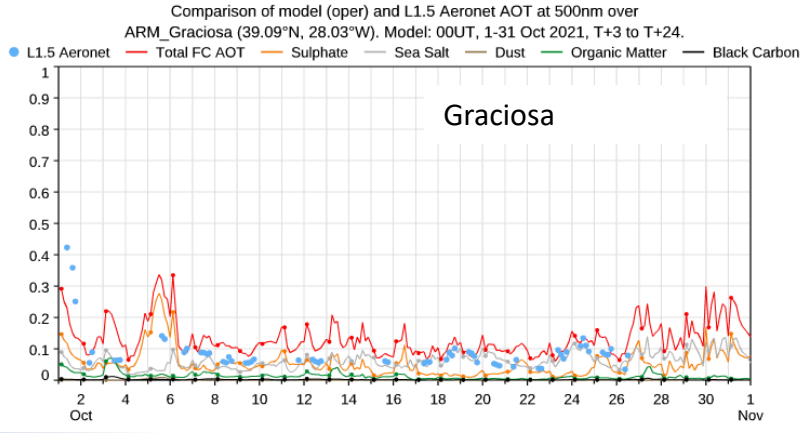

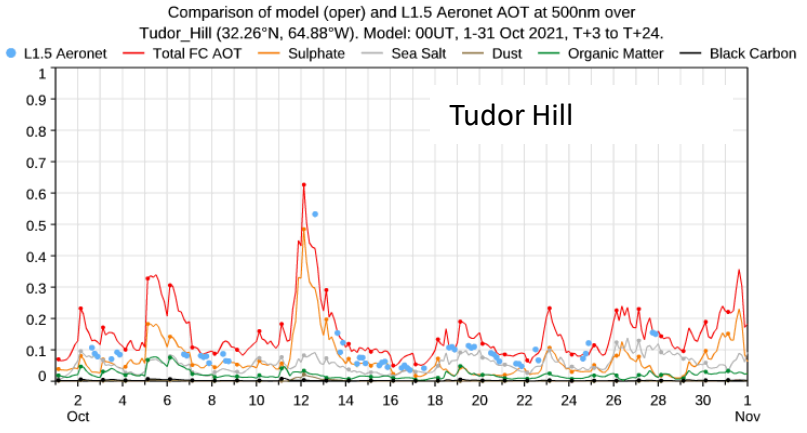

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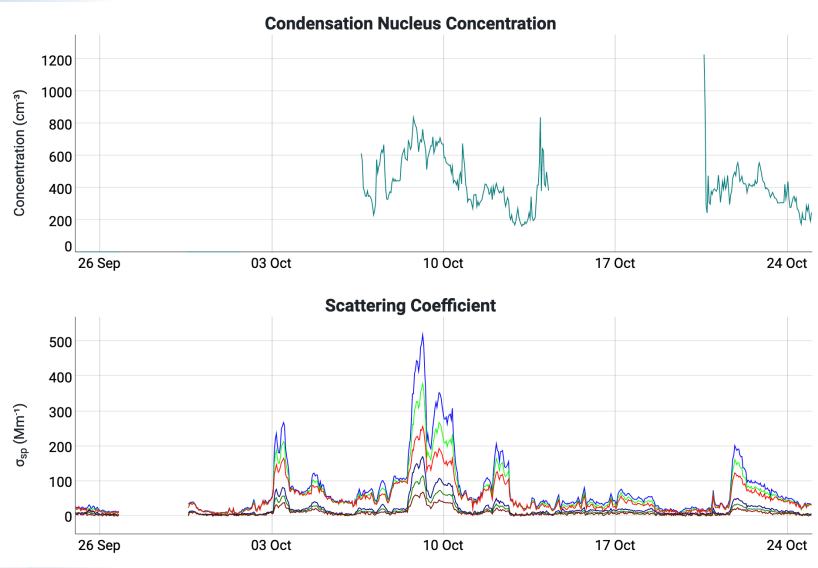
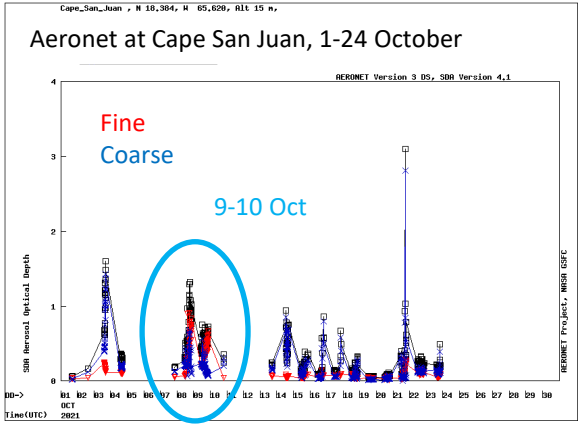
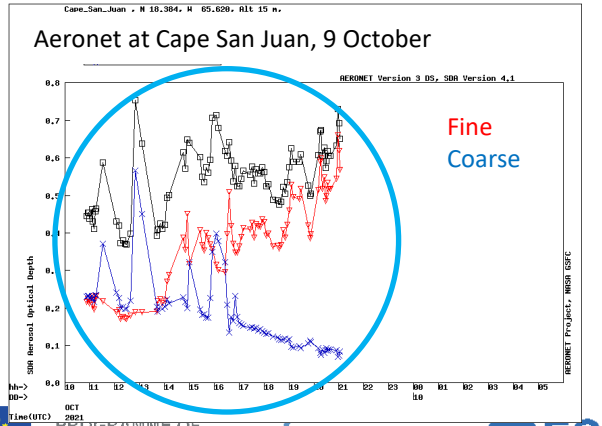
Air quality in the Caribbean: aerosol properties & AOD at Cape San Juan, PR







- Aerosol optical property measurements from NOAA aerosol network site
  - https://gml.noaa.gov/aero/net/getplot.php?key=overview&sta=cpr&type=avg
- Aeronet fine vs. coarse AOD
  - https://aeronet.gsfc.nasa.gov/cgi-bin/data_display_aod_v3
- Presence of fine-mode aerosol indicates potential sulphate aerosol contribution to observed air quality

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Summary

- CAMS is able to monitor atmospheric impacts of volcanic eruptions through assimilation of total column SO_2 and AOD observations.
  - *Inventory of outgassing emissions based on in situ measurements.*
- Following eruption of Cumbre Vieja, CAMS analyses and forecasts provided information on the transport of total column SO_2 across Europe and the Atlantic.
- Conversion of SO_2 into sulphate aerosol through model chemistry results in good agreement in enhancement of total aerosol optical depth vs. Aeronet across Europe and the Atlantic.
- Potential surface air quality impacts in the Caribbean through episode of fine-mode aerosol on 9-10 October.
  - *Ongoing investigation into quantifying the impacts.*
- Some questions remain for the aerosol speciation in the assimilation – could be better resolved with observations of aerosol type (e.g., dust from IASI).
- Future operational assimilation of observed SO_2 layer height information will improve forecast initialization over fixed background errors