Atmosphere Monitoring

Use of TROPOMI data in the near-real-time global CAMS assimilation system

Antje Inness (ECMWF)

Melanie Ades, Anna Agusti-Panareda, Nicolas Bousserez, Richard Engelen, Johannes Flemming, Sebastien Garrigues, Zak Kipling, Joe McNorton, Mark Parrington, Vincent-Henri Peuch and Roberto Ribas (ECMWF)

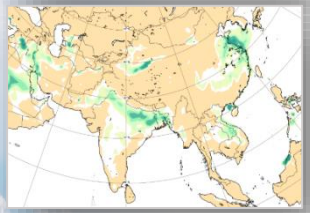
PROGRAMME OF THE EUROPEAN UNION

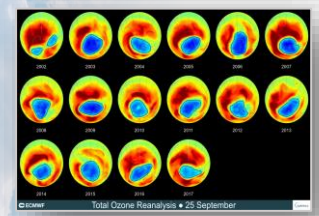
Copernicus Europe's eyes on Earth

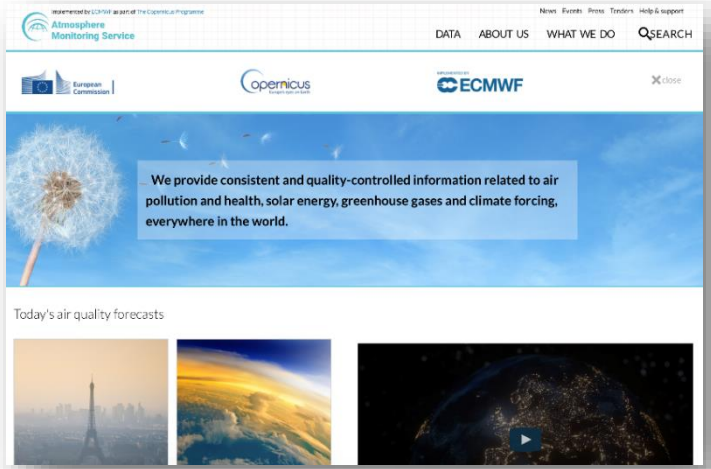
IMPLEMENTED BY ECMWF

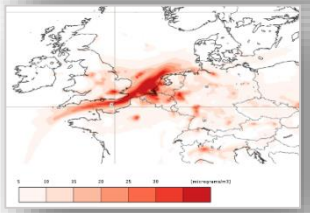
Copernicus Atmosphere Monitoring Service

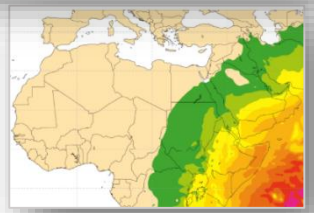
Atmosphere Monitoring











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

This is done by assimilating **satellite retrievals of atmospheric composition** into ECMWF's IFS (in addition to meteorological observations) - **Including TROPOMI data**

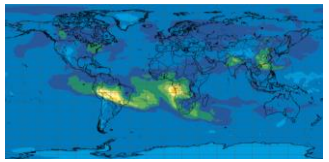
Europe's eyes on Earth

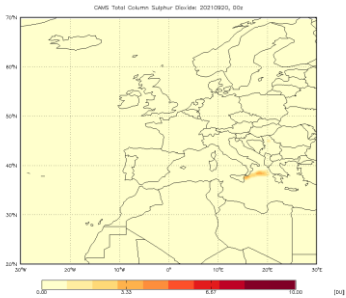
https://atmosphere.copernicus.eu

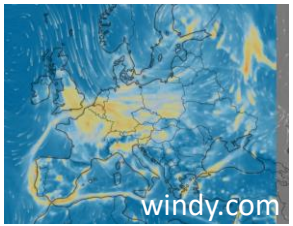
Use of TROPOMI data by CAMS

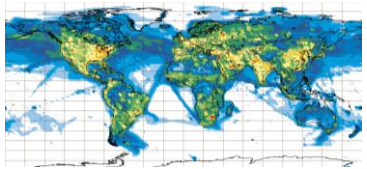
TROPOMI data

CO O3 SO2 CH4 NO2 HCHO

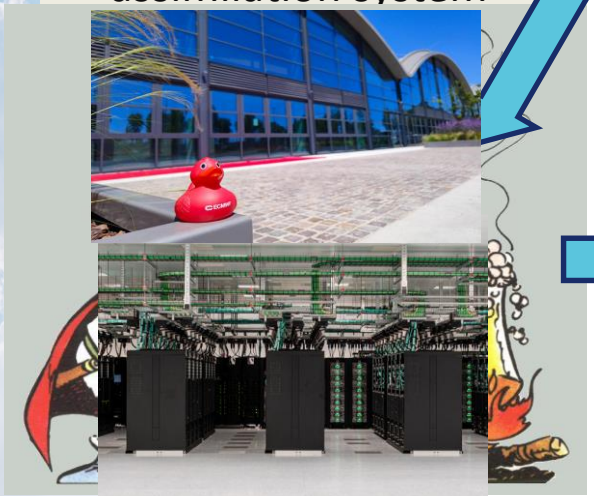


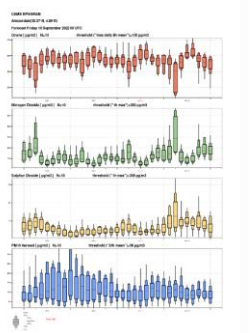


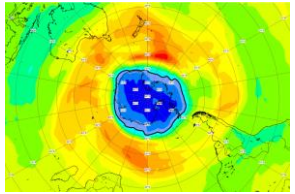




CAMS model and data assimilation system







CAMS products and forecasts

PROGRAMME OF THE EUROPEAN UNION

Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Use of TROPOMI data by CAMS

Species	Status
TCO3	Active since **4 Dec 2018**
TCSO2 (volcanic)	Active since **5 Oct 2020**
Trop column NO2	Passive since 11 July 2018. Biases in early data versions prevented NRT assimilation. Active since **12 Oct 2021**.
TCCO	Passive since 26 November 2018. Biases prevented NRT assimilation. Tests after PDGS upgrade in June 2021 look promising. To be activated in CY48R1 (implementation planned for **Q2/2023**)
CH4 (offline)	Assimilation tests with CAMS GHG analysis. Used for emission inversion.
TCHCHO	Passive 17 December 2018. Will be used to develop biogenic emission inversion framework in HE CAMEO project starting 1 Jan 2023
TCSO2 (PBL)	Used for tests. Waiting for COBRA algorithm implementation before further tests

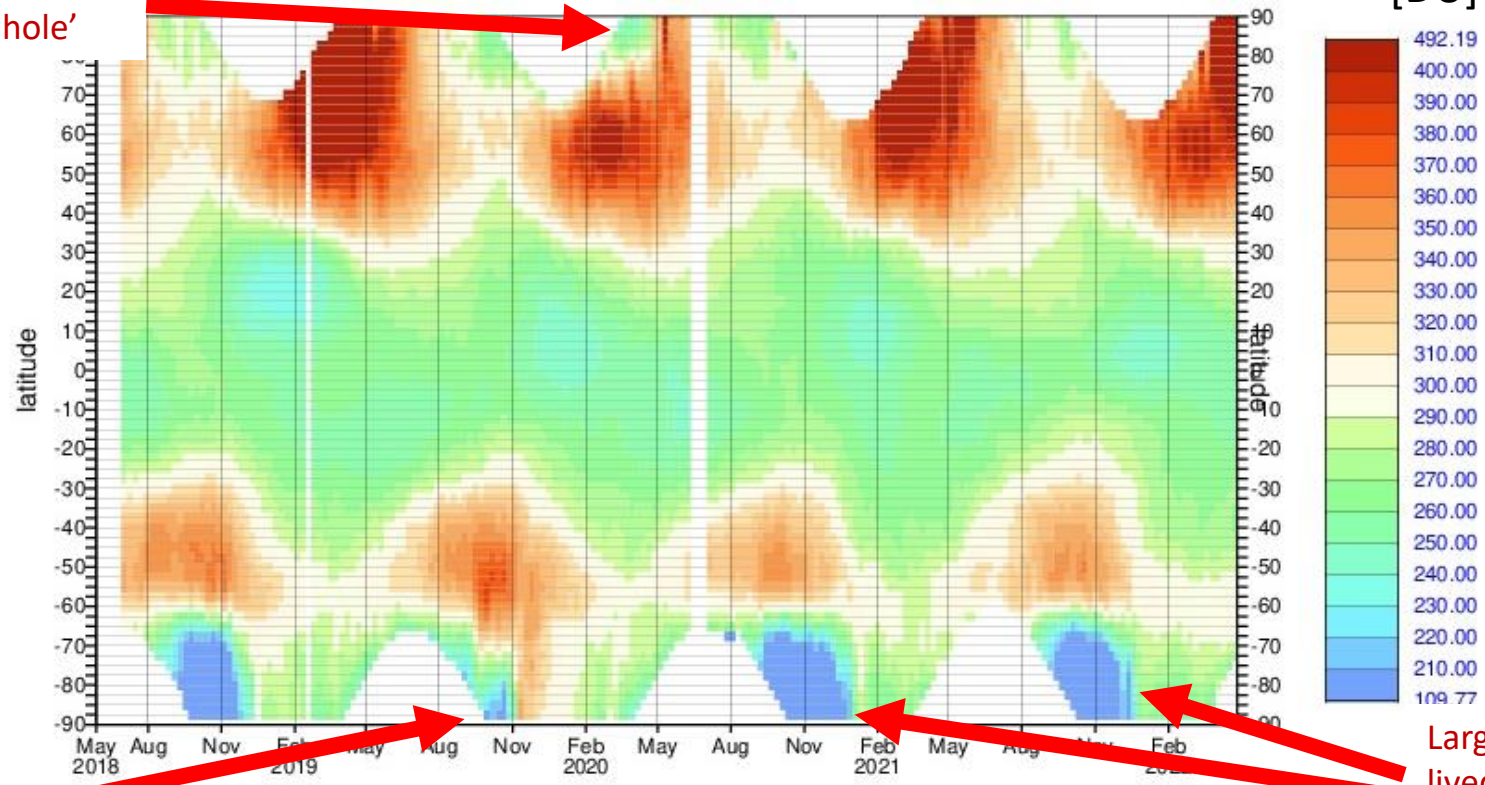
TROPOMI total column ozone

Atmosphere Monit

Weekly means: 20180528 - 20220428

Active since 4 Dec 2018

2020 Arctic 'O3 hole'



[DU]

492.19
400.00
390.00
380.00
370.00
360.00
350.00
340.00
330.00
320.00
310.00
300.00
290.00
280.00
270.00
260.00
250.00
240.00
230.00
220.00
210.00

Small and short-lived 2019 O3 hole

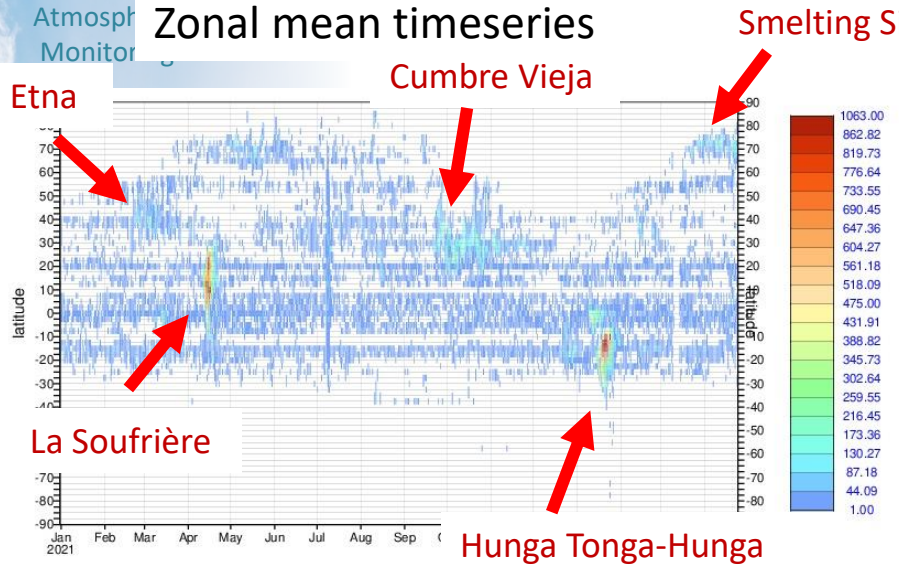
Large and long-lived 2020 & 2021 O3 hole

TROPOMI volcanic SO2

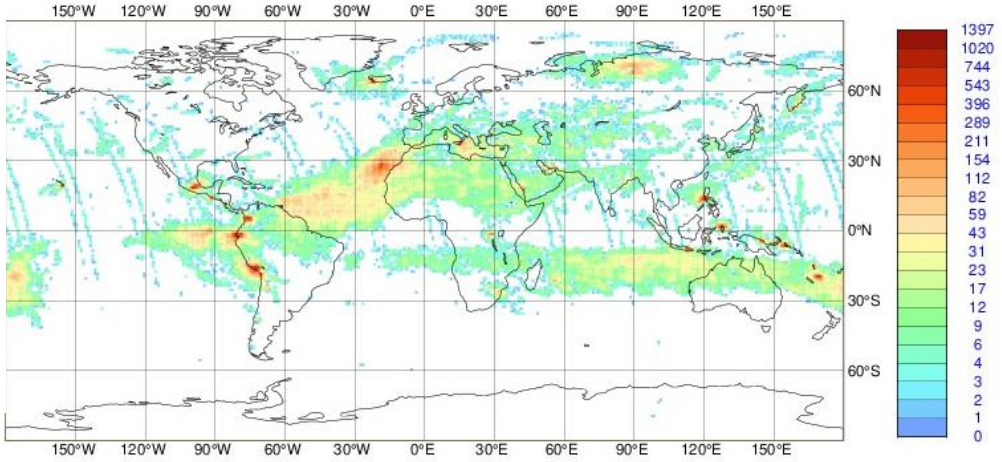
Atmosph
Monitor

Zonal mean timeseries

Active since 5 Oct 2020



Averaged number of obs



Shown are the number of volcanic TROPOMI SO2 observations for the period:
20210101 - 20220424

PROGRAMME OF THE EUROPEAN UNION

Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Current use of SO2 data in CAMS NRT system

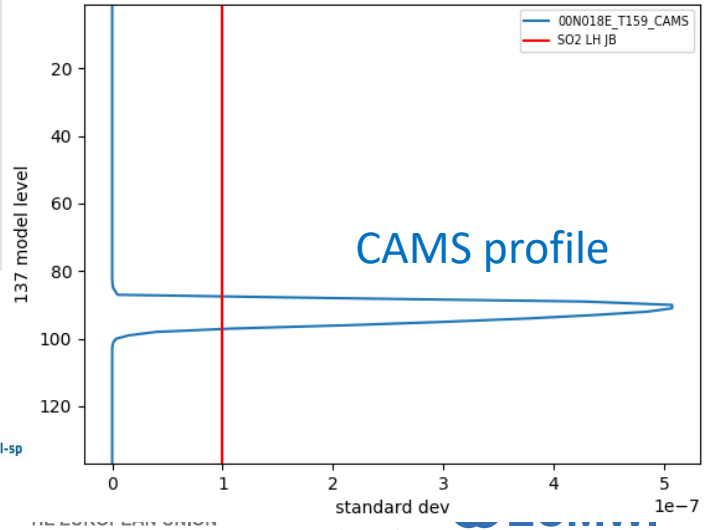
Atmosphere Monitoring

- CAMS assimilates **GOME-2BC** and **TROPOMI** TCSO2 retrievals making use of the volcanic flags provided by data providers (AC-SAF, ESA; algorithm from DLR)

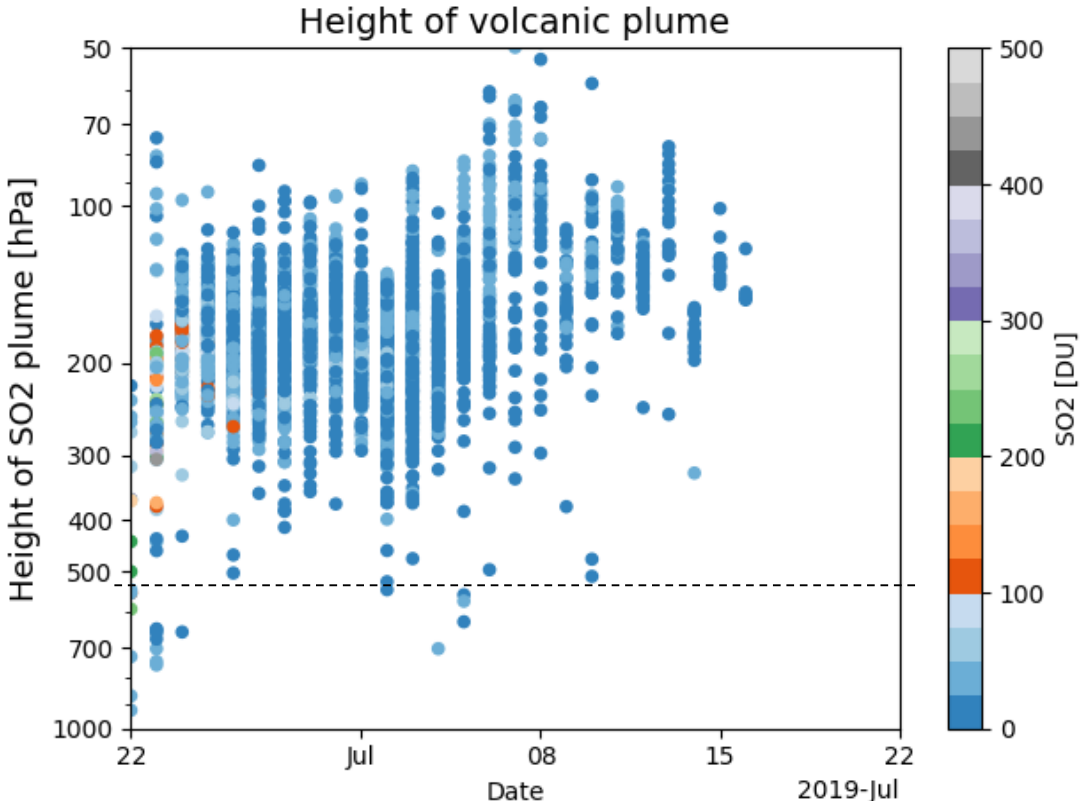
- We need to make assumptions about the plume height if this is not known in NRT
- Default: SO2 is placed in troposphere at model level 98 (~ 550 hPa, 5 km) by using a prescribed bg-error stdv profile
- This can be modified if injection height is known
- Currently: Globally constant injection height
- 'Baseline configuration: BLexp'

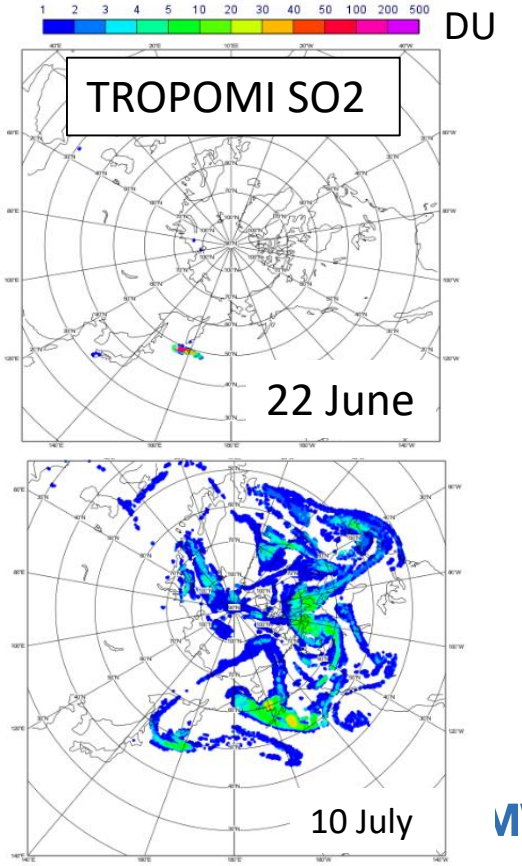
- DLR have developed algorithm to provide information about the plume height in NRT from TROPOMI (Hedelt et al., 2019, doi.org/10.5194/amt-12-5503-2019)
- SO2 LH project - one of ESA's S5P Innovation projects
- Data useful for SO2 > 20 DU
- CAMS is testing the use of these data: 'LHexp'

SO2 background error standard deviation



Raikoe eruption 22 June-21 July 2019



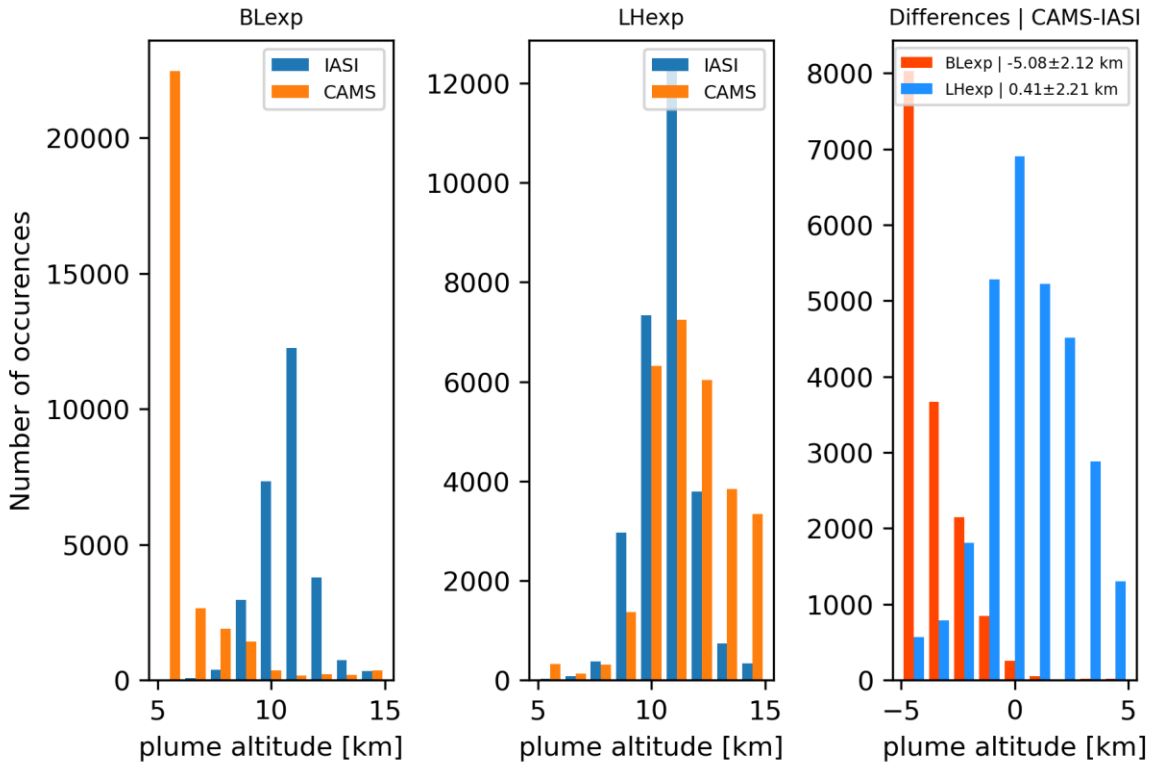


Default of placing the SO2 signal around 550 hPa is clearly wrong in this case

PRO THE

MWF

Comparison of CAMS plume height with IASI



Period:
22 -29 June2019

CAMS SO2 analysis shows improved agreement with IASI LATMOS/ULB SO2 altitude data if TROPOMI SO2 LH data are used

Biases against IASI:

BL exp: -5.1 ± 2.1 km

LH exp: 0.4 ± 2.2 km

Using the LH data leads to improved SO2 analyses and forecasts

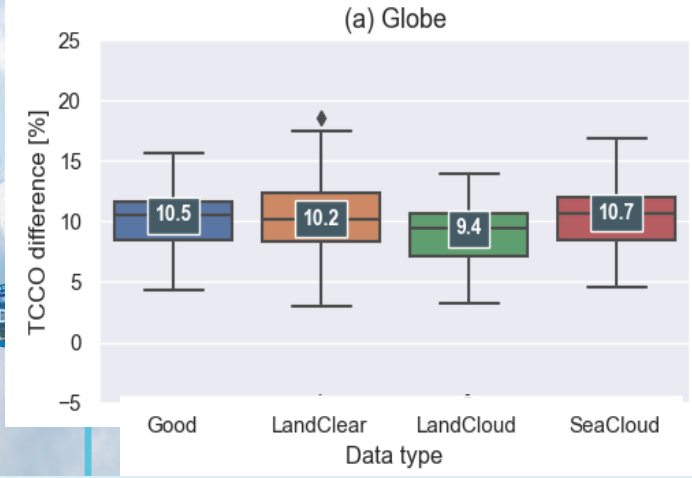
Plot provided by MariLiza Koukouli

IASI SO2 altitude retrieval from LATMOS/ULB

Inness et al. (2022): doi.org/10.5194/gmd-15-971-2022

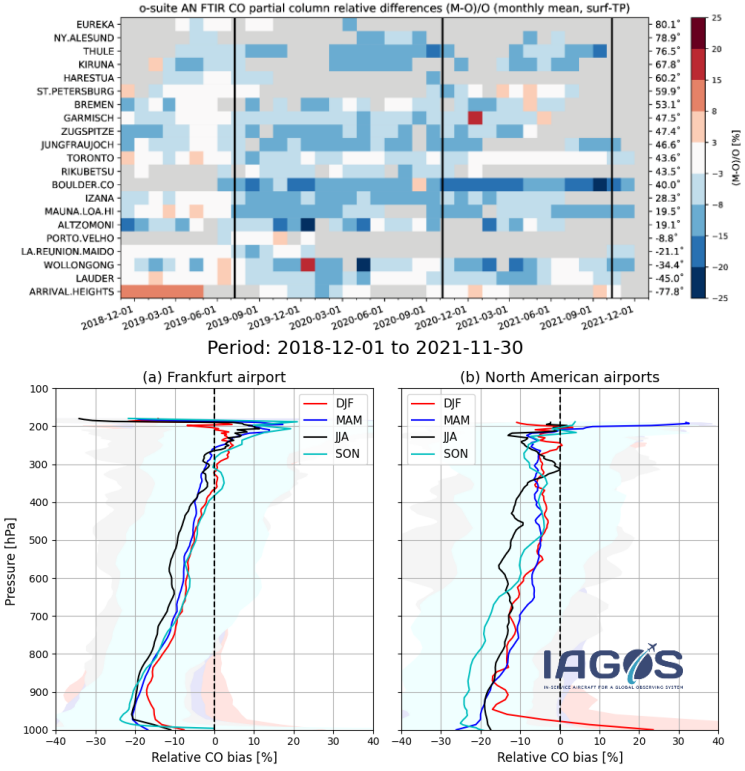
CAMS CO analysis

Relative difference TROPOMI – CAMS CO 20181119-20211231



- TROPOMI TCCO is about 10% higher than CAMS in global mean
- CAMS CO also has a negative bias wrt other data

Bias CAMS - NDACC FTIR



Credit:
B. Langerock

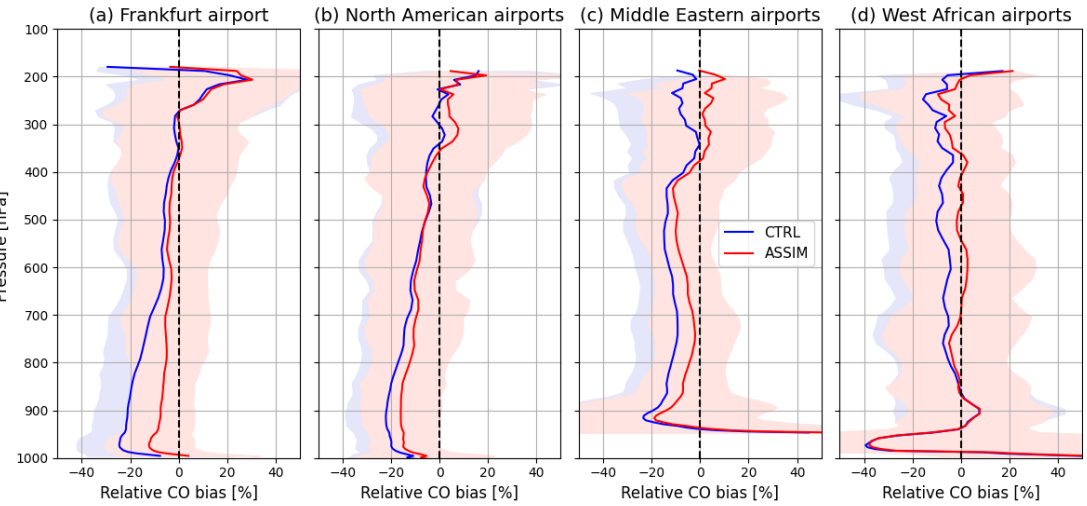
- TIR MOPITT and IASI-BC data are routinely assimilated by CAMS
- CAMS CO analysis has negative bias which is largest in the lower troposphere

Results from S5P CO assimilation tests

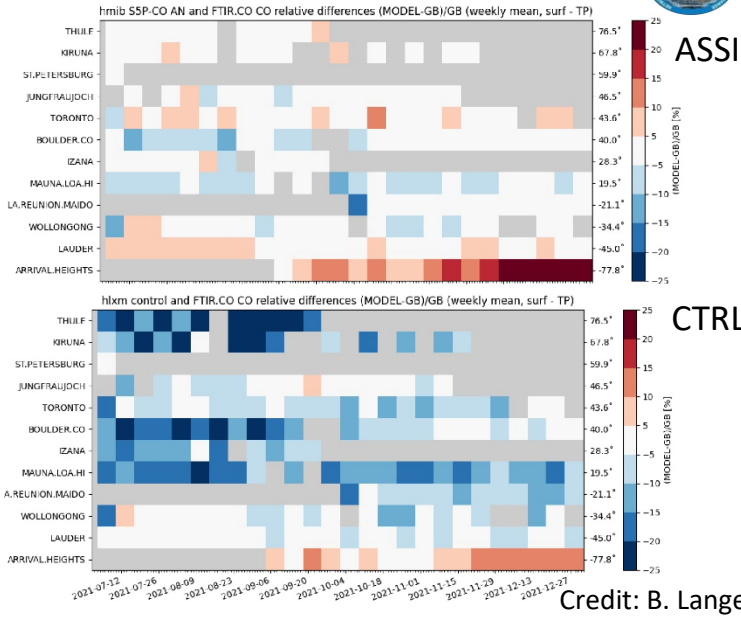
Atmosphere

Comparison with IAGOS aircraft data

Period: July - December 2021



Comparison with NDACC FTIR data



ASSIM

CTRL

Credit: B. Langerock

- Assimilation of TROPOMI CO leads to improved fit to independent data, especially in the lower troposphere.
- To be activated in next CAMS model upgrade (CY48R1, Q2/2023)
- Assimilation of TROPOMI CO can give additional information in lower troposphere in DA system that already assimilates MOPITT TIR and IASI CO retrievals

Inness et al. (2022b): doi.org/10.5194/acp-2022-458, in review

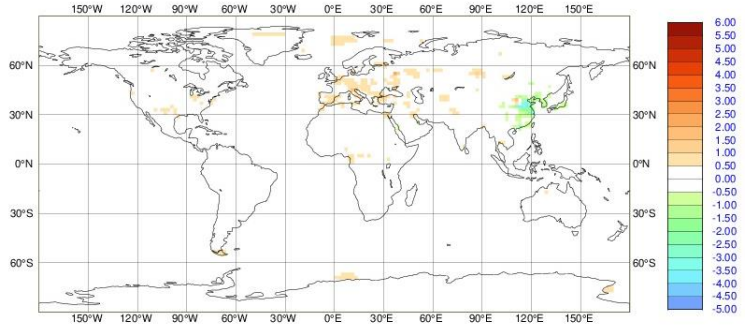
TROPOMI tropospheric NO2

Atmosphere Mo

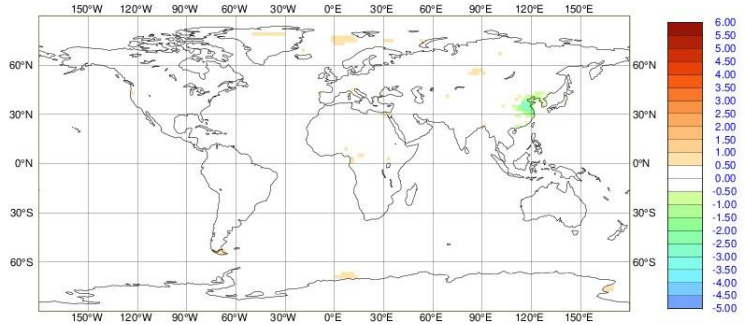
Period: 20211101-20220430

Active since 12 Oct 2021

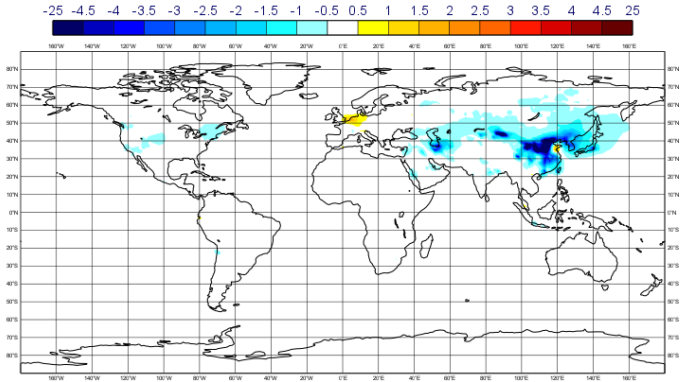
S5P NO2 **first-guess** departures



S5P NO2 **analysis** departures



ASSIM minus CONTROL



ASSIM also assimilates GOME-2BC NO2

Assimilation of TROPOMI NO2 (and GOME-2BC) data reduces the CAMS NO2 analysis over Asia where it is known to have a positive bias

PROGRAMME OF THE EUROPEAN UNION

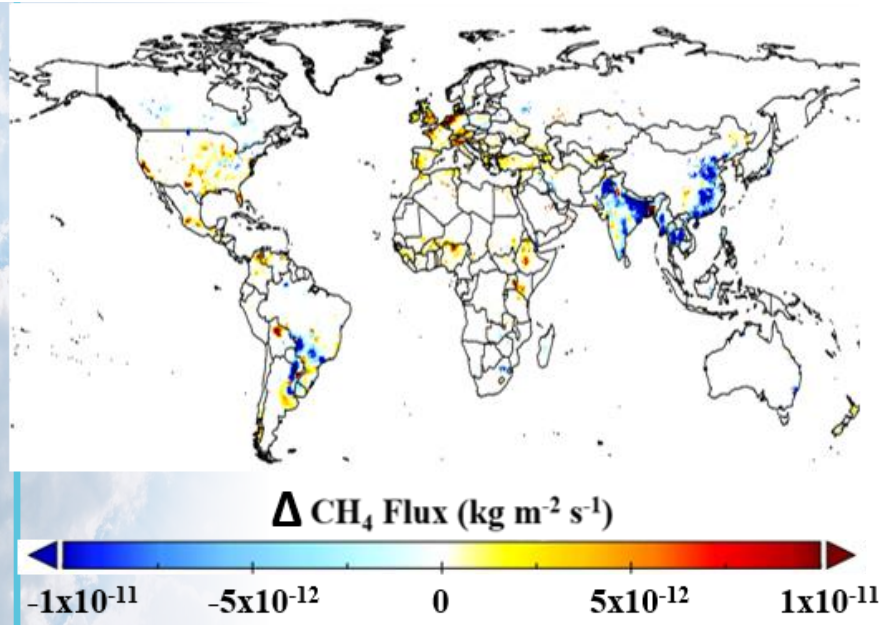
Europe's eyes on Earth

IMPLEMENTED BY ECMWF

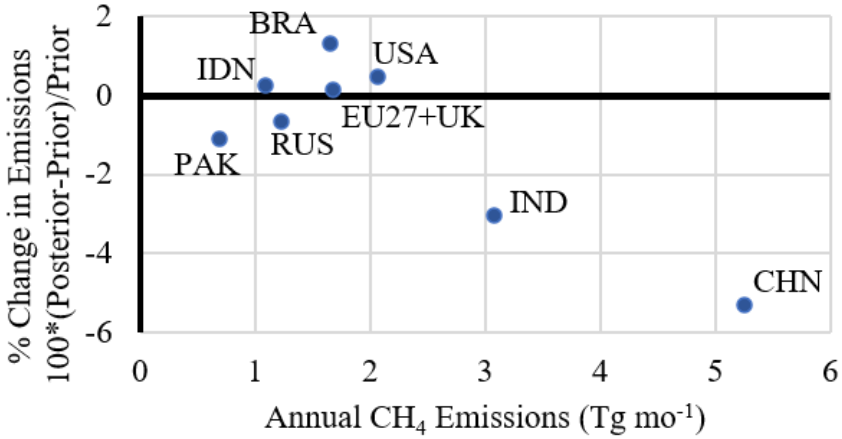
TROPOMI CH4 in IFS emission inversions

Credit: Joe McNorton

TROPOMI, alongside GOSAT and IASI, has been used to perform short-window (24 hour) 80 km global inversions using an extension of the current 4D-Var system.



Average difference between posterior and prior CH_4 emissions for Jan-Jun 2019



Posterior adjustment of anthropogenic CH_4 emissions per country.

McNorton *et al.* (2022): Quantification of methane emissions from hotspots and during COVID-19 using a global atmospheric inversion, ACP

Atmosphere Monitoring

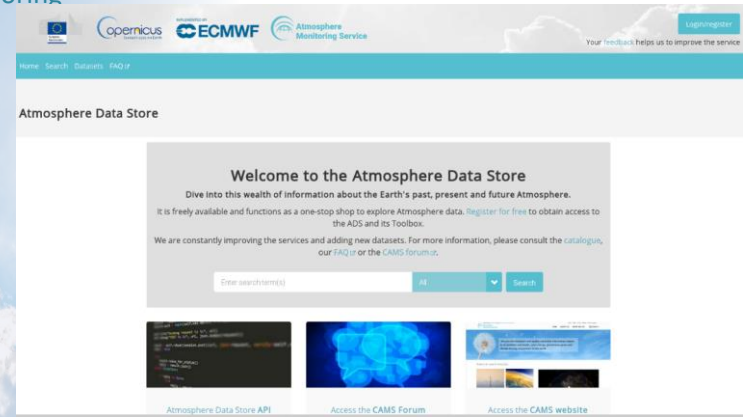
Summary

- CAMS makes use of NRT TROPOMI O3, SO2, NO2, CO, CH4 and HCHO data
- NRT TROPOMI O3, volcanic SO2, NO2 are actively assimilated by CAMS
- Assimilation of TROPOMI CO assimilation improves fit of CAMS analysis to independent data and is planned for next CAMS model upgrade (Q2/2023)
- TROPOMI CH4 used in emission inversion. Routine assimilation tests are carried out with CAMS GHG system
- TROPOMI SO2 layer height data can improve CAMS SO2 analysis and forecasts (for strong volcanic eruptions)
- TROPOMI HCHO will be used to develop biogenic emission inversion framework in HE CAMEO project
- CAMS data freely available from ADS: https://atmosphere.copernicus.eu/data

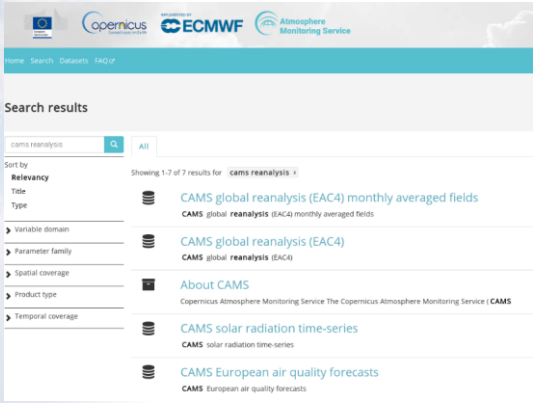
The Atmosphere Data Store (ADS)

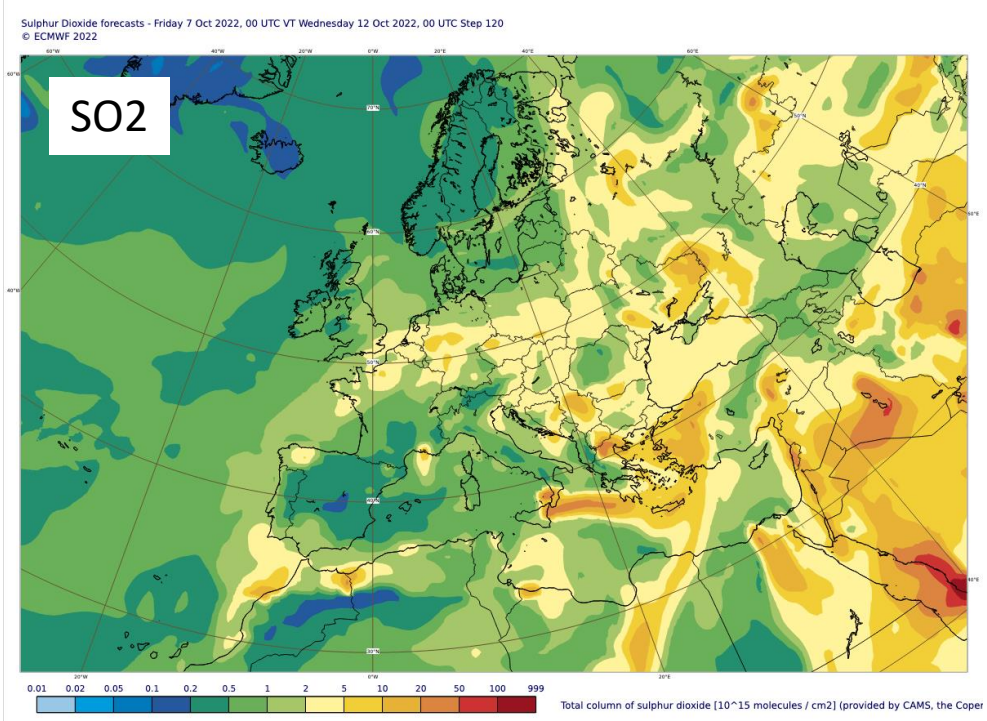
Atmosphere Monitoring

All CAMS data are freely available



https://atmosphere.copernicus.eu/data





https://atmosphere.copernicus.eu

PROGRAMME OF THE EUROPEAN UNION

Europe's eyes on Earth

IMPLEMENTED BY ECMWF