



Atmosphere Monitoring

CAMS reactive gases and aerosol data assimilation activities

*Antje Inness and the CAMS Development Section
(ECMWF)*



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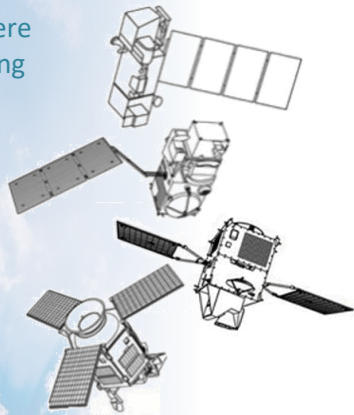
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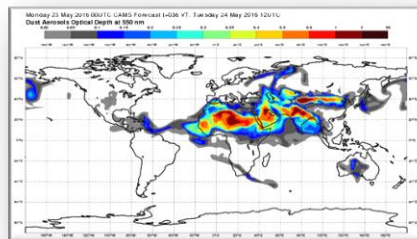
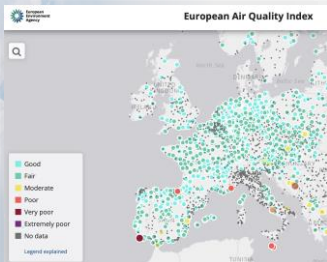


CAMS information flow

Atmosphere Monitoring

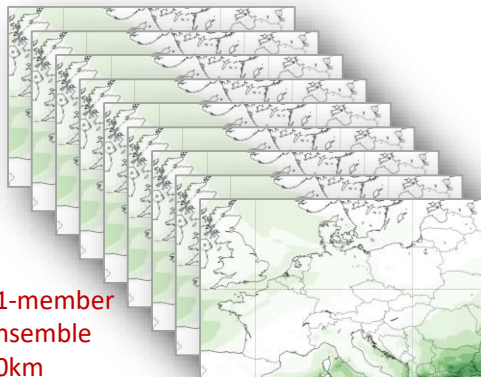


Earth Observation from satellite (>75 instruments) and in-situ (regulatory and research)



IFS 40km (oper) / 80km (rean) Globe

CAMS main operational data assimilation and modelling systems



11-member ensemble
10km Europe



CAMS users

- Applications
- Policy products

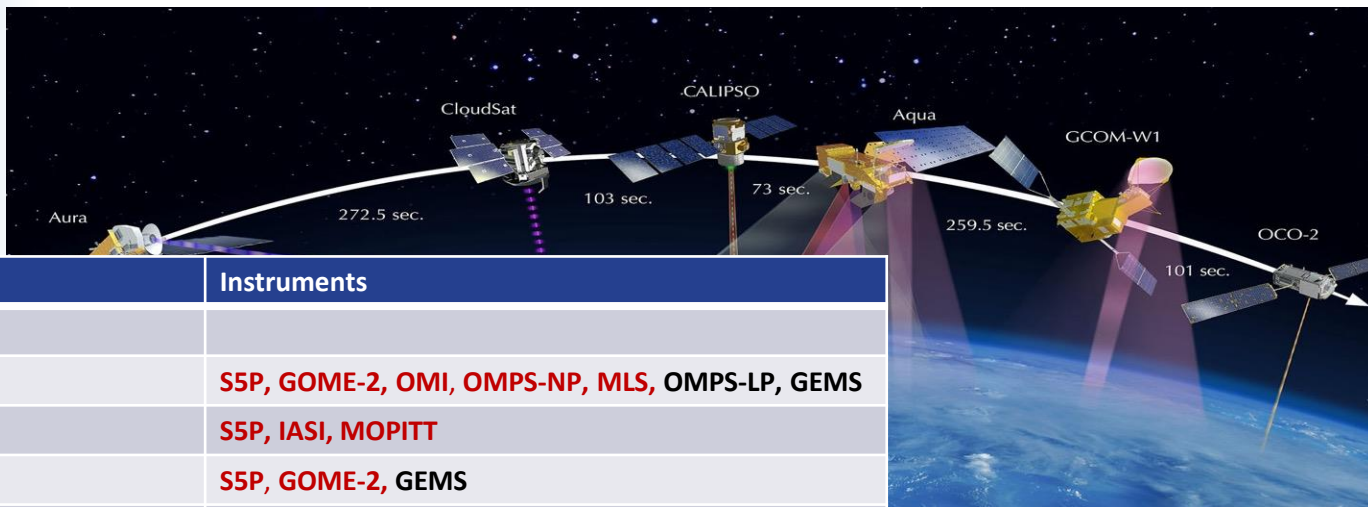
The collage features several user interfaces and logos:

- PREVAIR**: A website interface for air quality information in France, showing maps and text forecasts.
- The Weather Channel**: A logo for a major weather service.
- iOS**: The Apple logo, indicating mobile app availability.
- CNN**: The logo for the news network, showing a weather update segment.
- euro news**: A logo for European news, with the tagline 'IMPLEMENTED BY ECMWF'.
- ECMWF**: The logo of the European Centre for Medium-Range Weather Forecasts, with the tagline 'Europe's eyes on Earth'.
- Low Air Quality**: A circular graphic indicating high concentrations of pollutants.
- Health advice**: A text box providing guidance based on pollution levels (moderate, high, or very high).



AC Observations used in global CAMS system

Atmosphere
Monitoring



Species	Instruments
CAMS NRT	
O ₃	S5P, GOME-2, OMI, OMPS-NP, MLS, OMPS-LP, GEMS
CO	S5P, IASI, MOPITT
NO ₂	S5P, GOME-2, GEMS
Aerosol	MODIS, VIIRS, PMAp, S3
CO ₂	GOSAT, IASI, OCO-2
CH ₄	GOSAT, IASI, S5P
SO ₂ (volcanic)	S5P, GOME-2, IASI
SO ₂ (anthropogenic)	S5P
HCHO	S5P
GFAS fire emissions	MODIS, VIIRS, GOES, S3

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

---- Used

---- Undergoing testing

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Europe's eyes on Earth

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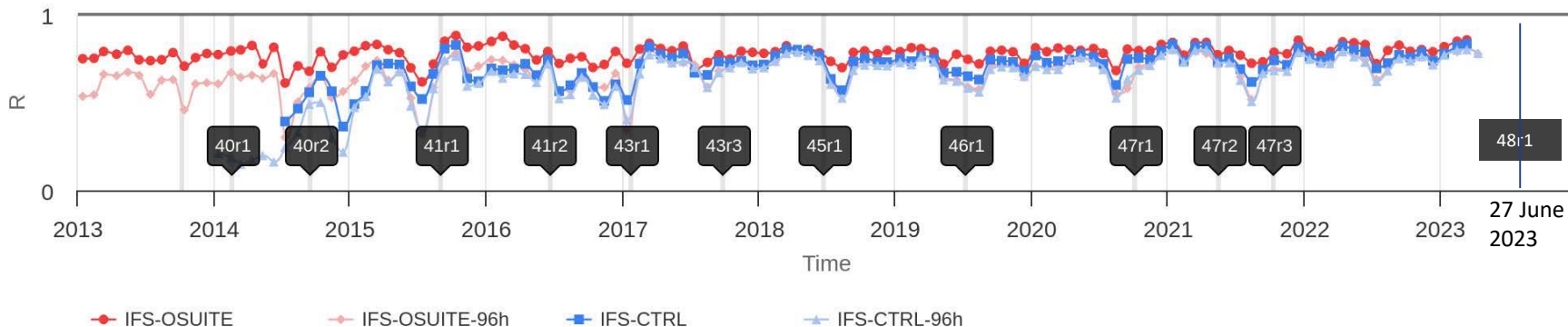


CAMS model upgrades

- CAMS global model runs in NRT and produces 5-day forecasts of AC twice every day
- CAMS model is upgraded once or twice per year, in line with ECMWF model upgrades
- Upgrades can include:
 - upgrading model code (e.g. chemistry routines)
 - adding new data
 - changing the emission datasets
 - meteorological changes
 - resolution changes

AOD - ALL - 2013-2023

AeronetL1.5-d - monthly data (statistics computed from daily values)





- **Major model updates**

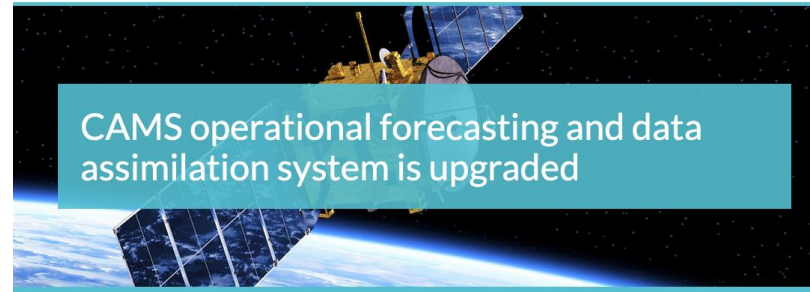
- New species and their chemical interactions:
 - **Stratospheric chemistry** with the BASCOE scheme (57 additional species)
 - Glyoxal, HCN and several other species in CB05
 - Secondary organic aerosols in AER scheme
- Sectorial emissions input for all species for more detailed diurnal cycles and injection heights
- Reviewed dust modelling (less total mass)
- Optical properties, dust a-sphericity
- Simple volcanic aerosol (Sulphate)

- **Update of emission datasets**

- CAMS_GLOB_ANT v5.3
- CAMS_GLOB_BIO v3.1 climatology
- CAMS_GLOB_OCE v3.1 climatology DMS
- CAMS_GLOB_AIR v3.1 CO₂/NO_x (aircraft)

- **Data assimilation updates**

- CO bias correction changed to use IASI-C (and TROPOMI) as anchors.
- Assimilation of TROPOMI CO (and VIIRS AOD)





CAMS internal and external validation

Atmosphere
Monitoring

- Additional external validation by CAMS2_82 team led by KNMI (Henk Eskes)
- Quarterly evaluation reports:
 - <https://atmosphere.copernicus.eu/eqa-reports-global-services>
- Upgrade notifications for model upgrades:
 - <https://confluence.ecmwf.int/display/COPSRV/Implementation+of+IFS+cycle+48r1+for+CAMS>

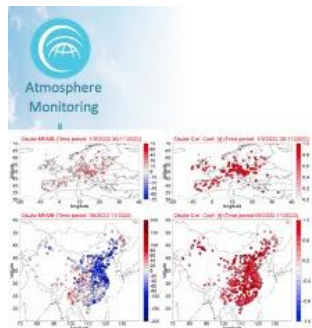


Figure 4.3: Global distribution of the PM2.5 and coarse mode mass (µg/m³) of the winter season (September and October) in 2022 compared to observational data during the period from 1 September to 30 November 2022.

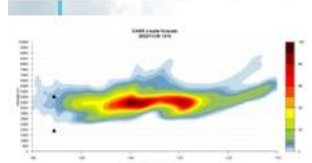


Figure 3.12.8: The CAMS model 500 hPa profile showing sea level to 100 hPa for the area between 10°E and 10°W. The 500 hPa pressure height (500 hPa) is the average height of the Mean Sea Level (MSL) and the 500 hPa pressure height of the surface by CAMS is also 500 hPa on the same day.



Validation report of the CAMS near-real-time global atmospheric composition service

Period September – November 2022

Issued by: KNMI
Date: 16 March 2023
Ref: CAMS-GL-NRRT-DEL-15-R00002



Figure 4.4.2: Seasonal AOD modelled concentrations from the CAMS and comparison with the 3-day AOD for the period of September for the November 2022. Daily AOD (AOD) is shown in the left map and the 3-day AOD with a 1-day lag is shown in the right map.

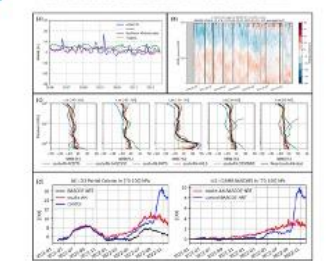


Figure 4.5: (a) 3D PM2.5 profile of concentration in the atmosphere from the near-real-time updated atmospheric data in the near-real-time Copernicus Atmosphere Monitoring Service (CAMS) for the period from 10 September 2022 to 10 November 2022. The comparison is based on the 3D air quality data from the 3D AOD (AOD) of the Copernicus Atmosphere Monitoring Service (CAMS) and the 3D AOD (AOD) of the Copernicus Atmosphere Monitoring Service (CAMS) and the 3D AOD (AOD) of the Copernicus Atmosphere Monitoring Service (CAMS). (b) The same comparison as in (a) but for the period from 10 September 2022 to 10 November 2022. The comparison is based on the 3D air quality data from the 3D AOD (AOD) of the Copernicus Atmosphere Monitoring Service (CAMS) and the 3D AOD (AOD) of the Copernicus Atmosphere Monitoring Service (CAMS). (c) The same comparison as in (a) but for the period from 10 September 2022 to 10 November 2022. 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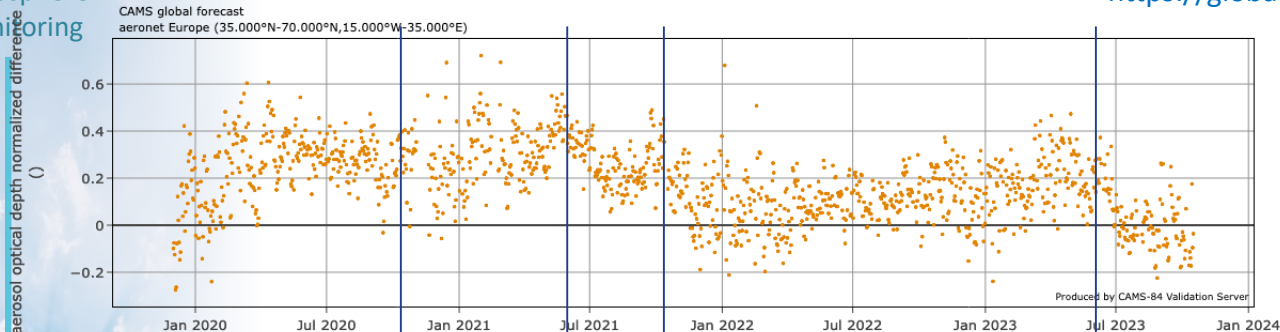


AOD over Europe

Atmosphere
Monitoring

Aerosol Optical Depth normalized bias in Europe

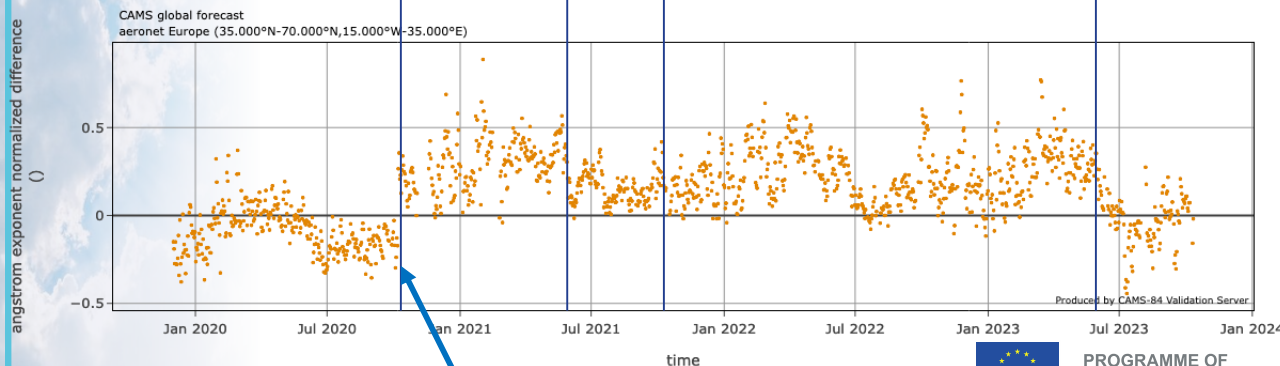
<https://global-evaluation.atmosphere.copernicus.eu/>



47R1 47R2 47R3 48R1

Improving AOD bias over Europe

Angstrom Exponent (440-870) normalized bias in Europe



Increase in SO₄
Decrease in Dust

Higher AE indicative of smaller particles -> illustrates changing aerosol speciation



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Europe's eyes on Earth

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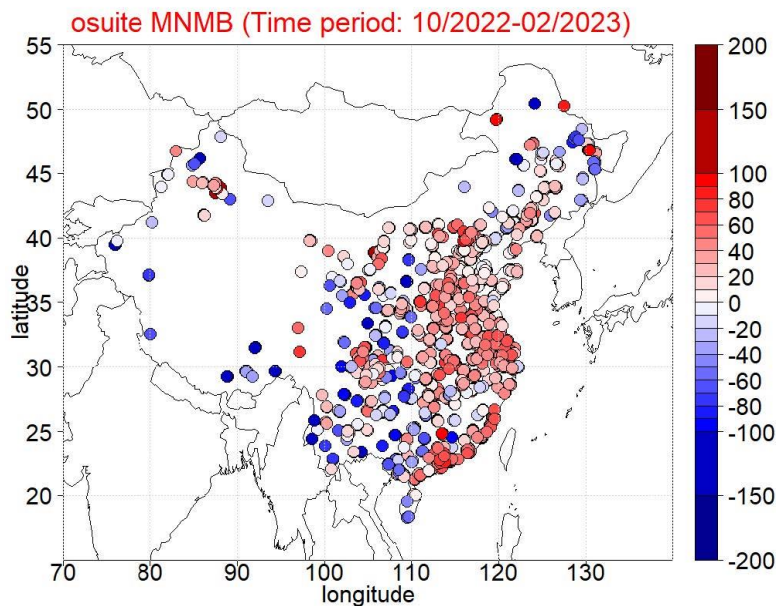
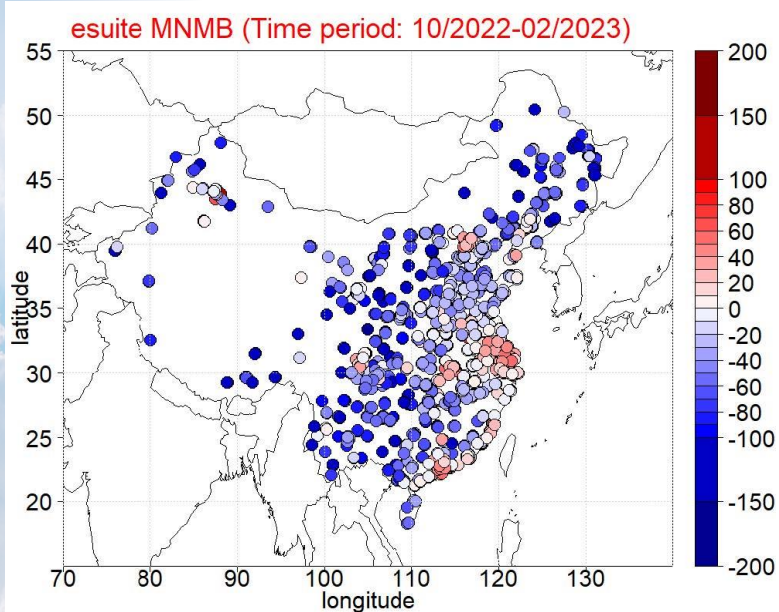
Evaluation of surface NO₂ over China

Atmosphere
Monitoring

Cy48R1

Oct 2022 – Feb 2023

Cy47R3



MNMB against NO₂ surface observations in China from the China National Environmental Monitoring Center.

Reduction in positive bias over Chinese mega cities.
Mainly due to improved emissions



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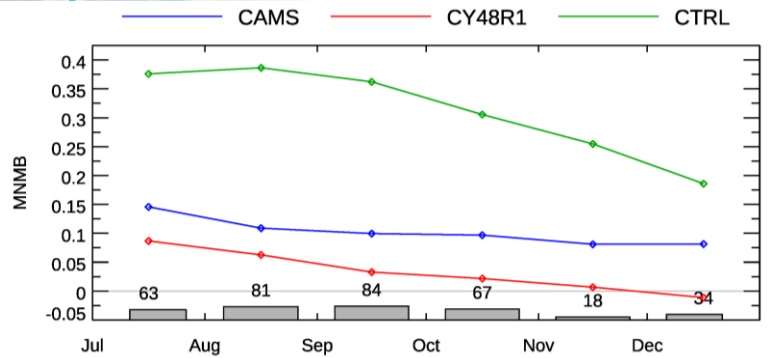
Credit: 48R1 upgrade verification note



Activation of TROPOMI CO in CY48R1

- TROPOMI CO activation became possible after algorithm upgrade in July 2021
- TROPOMI retrieves CO in the SWIR and has sensitivity to the CO column; clear-sky TROPOMI retrievals have some sensitivity to the lower troposphere and PBL
- Can give additional information in the lower troposphere in CAMS analysis that already assimilated MOPITT TIR and IASI CO retrievals

Frankfurt airport

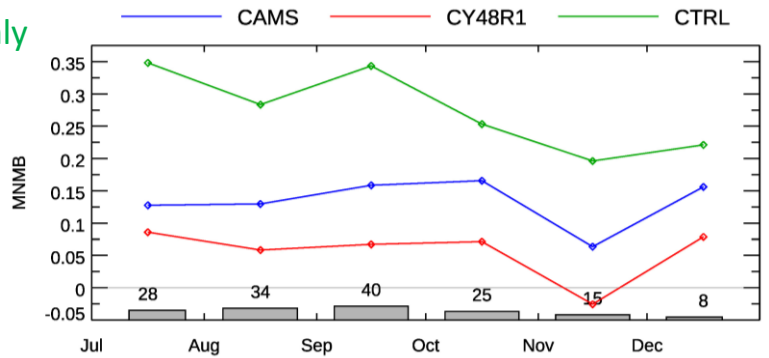


CY48R1- With S5P CO
 CY47R3 - No S5P CO
 CY48R1- Model only

MNMB
 1000-500 hPa



North American airports



Comparison with IAGOS aircraft data in 2021





Comparison with ACE-FTS Oct 22 – Feb 23

Atmosphere
Monitoring

O3

H2O

NO2

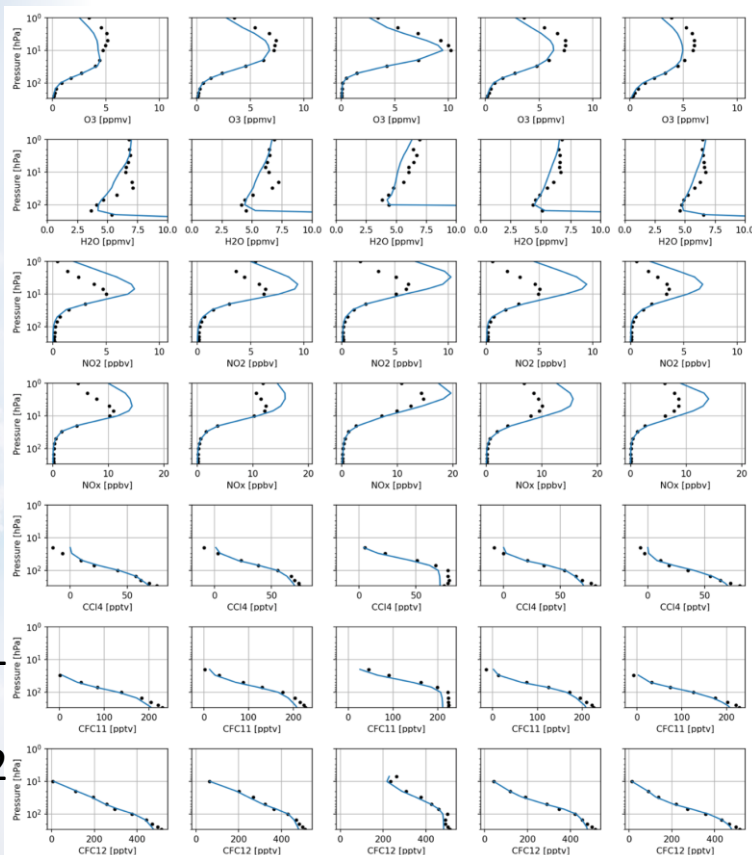
NOx

CCL4

CFC11

CFC12

90°S-60°S 60°S-30°S 30°S-30°N 30°N-60°N 60°N-90°N.



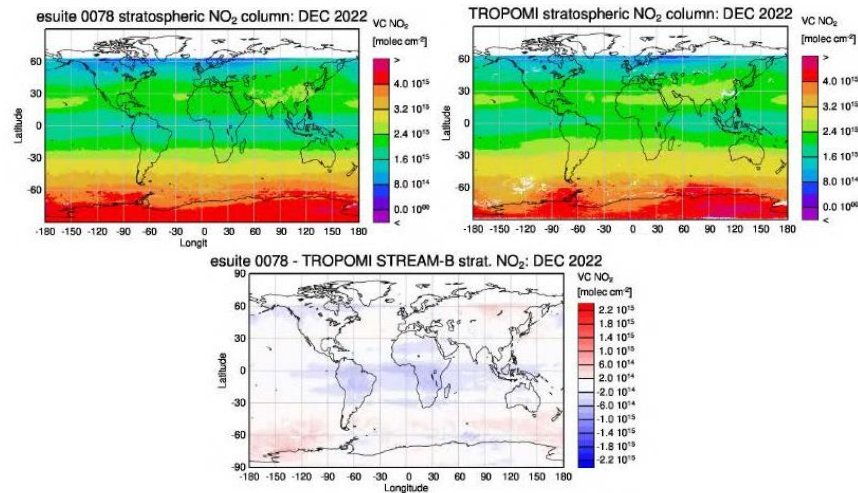
ACE-FTS limb sounder data

Credit: CAMS2_82 team/ BIRA-IASB

Stratospheric species available
since upgrade to CB05-BASCOE
scheme in June 2023

CAMS strat NO2

S5P strat NO2



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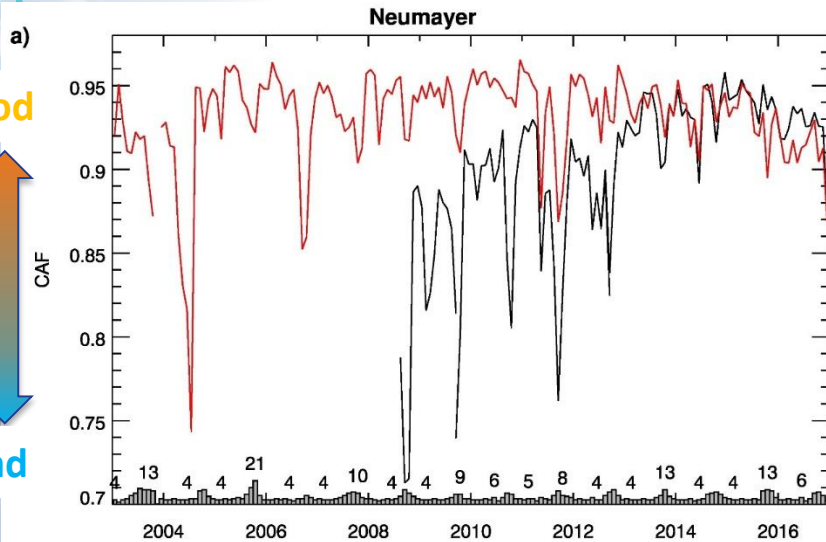


Atmosphere
Monitoring

CAMS reanalysis

CAMS is also producing a reanalysis in addition to global NRT CAMS system

Ozone score



— CAMS Reanalysis
— NRT CAMS analysis

Reanalysis (retrospective):

- Consistent long-term dataset produced with one model version (from 2003 onwards)
- Consistent emissions
- Consistent, reprocessed observations
- Can be used for trend analysis

Currently we are still continuing CAMS reanalysis EAC4



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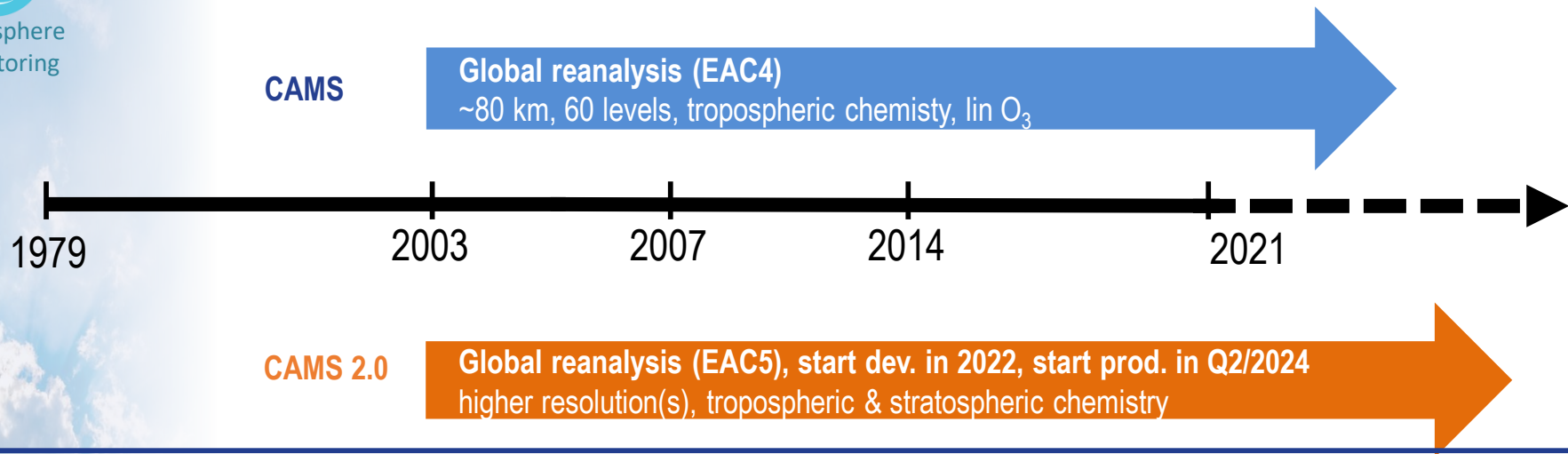
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Plans for CAMS 2.0 reanalysis (EAC5)



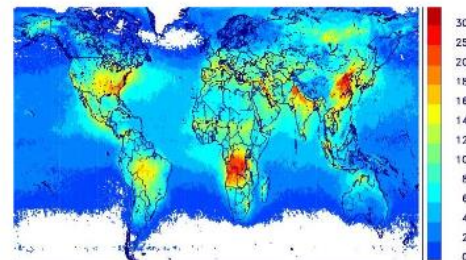
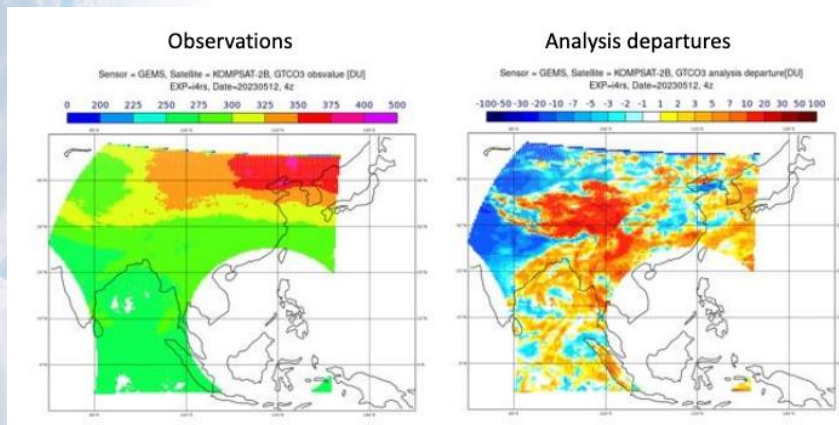
Preparations for EAC5 have started

- Improvements to chemistry (CB05-BASCOE, including stratospheric chemistry)
- Newer/ improved IFS version (better meteorology), CY48R2/CY49R1
- Increased resolution (137 vertical levels; horizontal resolution still tbd)
- Acquisition of reprocessed observations has started
- Improved QC for assimilated data
- No emission inversion yet

Production
to start in
Q2/Q3 2024



- CAMS2.0 reanalysis EAC5
- Ongoing work on emission inversion prototype for IFS
- Assimilation tests with dust AOD retrievals
- Use of geostationary air quality data (GEMS, TEMPO, Sentinel-4)
- Biogenic emission inversion using TROPOMI HCHO
- Explore radiance assimilation for aerosols
- HE projects: CAMEO, CAMAERA, CATRINE, CORSO



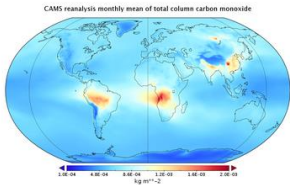
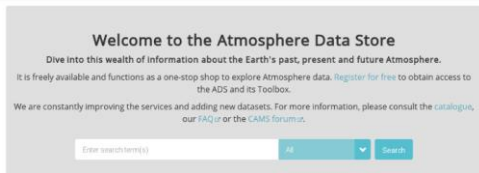


Atmosphere
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The Atmosphere Data Store (ADS)

All CAMS data are freely available

<https://atmosphere.copernicus.eu/data>



Documentation of atmospheric composition in IFS:

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

<http://atmosphere.copernicus.eu>

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