Atmosphere Monitoring

The CAMS reanalysis:

Status and plans

Antje Inness (ECMWF)

With thanks to the CAMS team

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What the Copernicus Atmosphere Monitoring Service has to offer

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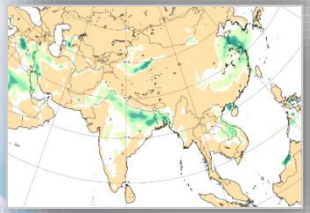

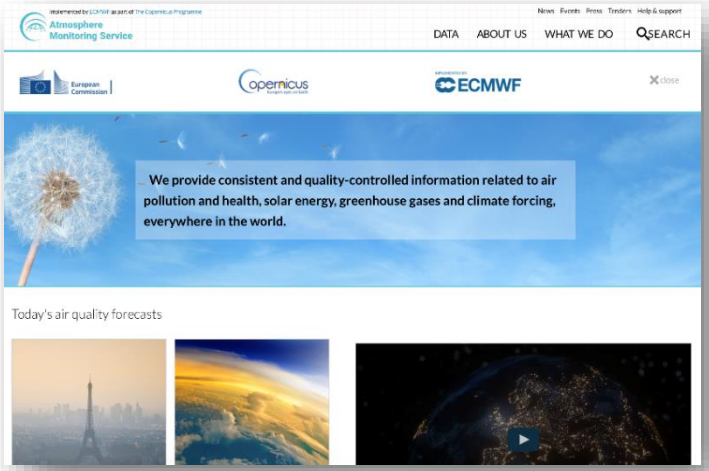

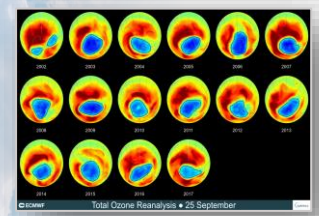

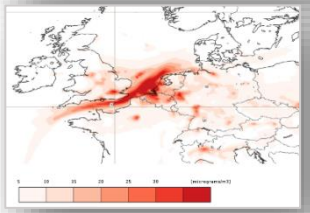

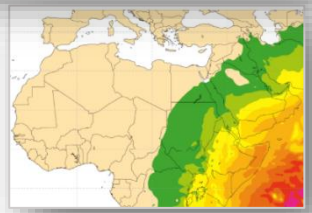

The CAMS portfolio includes Earth Observation based information products about:

- 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 atmospheric composition data into the IFS (in addition to meteorological observations)

https://atmosphere.copernicus.eu

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Near-real time model versus reanalysis

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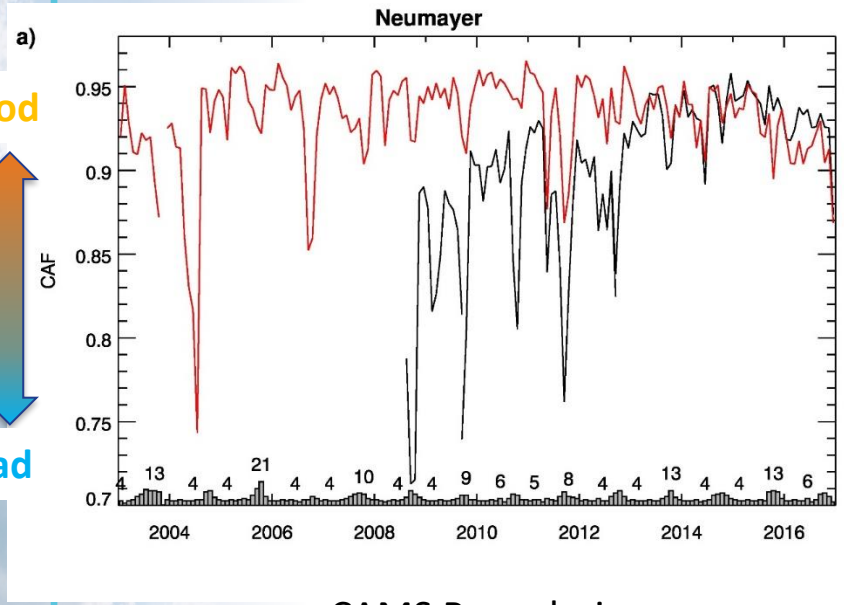
Ozone score



CAMS Reanalysis

NRT CAMS analysis

NRT global CAMS system (daily analyses and 5-day forecasts):

- Evolves with time: Usually 2 model updates per year
- Horizontal and vertical resolution can change
- Observation usage changes
- Emission data sets might change

Reanalysis (retrospective):

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

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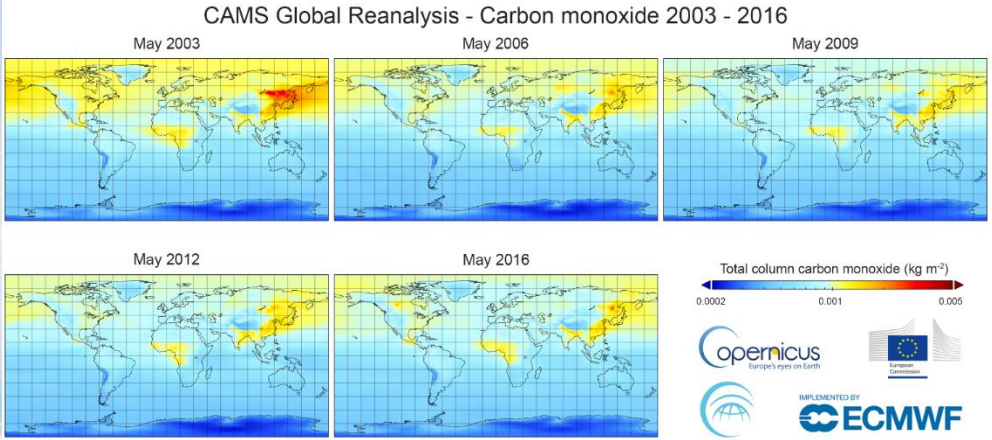
CAMS global reanalysis 2003 – 2020 (updated every 6 months)



Reanalysis
Using a combination of observations and computer models to recreate historical climate conditions.

DATA DESCRIPTION	
Data type	Gridded
Horizontal coverage	Global
Horizontal resolution	0.75°x0.75°
Vertical coverage	Surface, total column, model levels and pressure levels.
Vertical resolution	60 model levels. Pressure levels: 1000, 950, 925, 900, 850,
Temporal coverage	2003 to 2020
Temporal resolution	3-hourly
File format	GRIB (optional conversion to netCDF)
Versions	Only one version
Update frequency	Twice a year with 4-6 month delay

CAMS global reanalysis (CAMSRA, eac4)

- 2003 –2020, with new years being added
- Aerosols, chemical pollutants, CO_2 & CH_4
- 80 km spatial resolution
- Inness et al. (2019): https://doi.org/10.5194/acp-19-3515-2019
- Wagner et al. (2021): https://doi.org/10.1525/elementa.2020.00171
- atmosphere.copernicus.eu/eqa-reports-global-services
- Available from ADS https://atmosphere.copernicus.eu/data

- CB05 tropospheric chemistry
- Cariolle-Déqué scheme for stratospheric ozone

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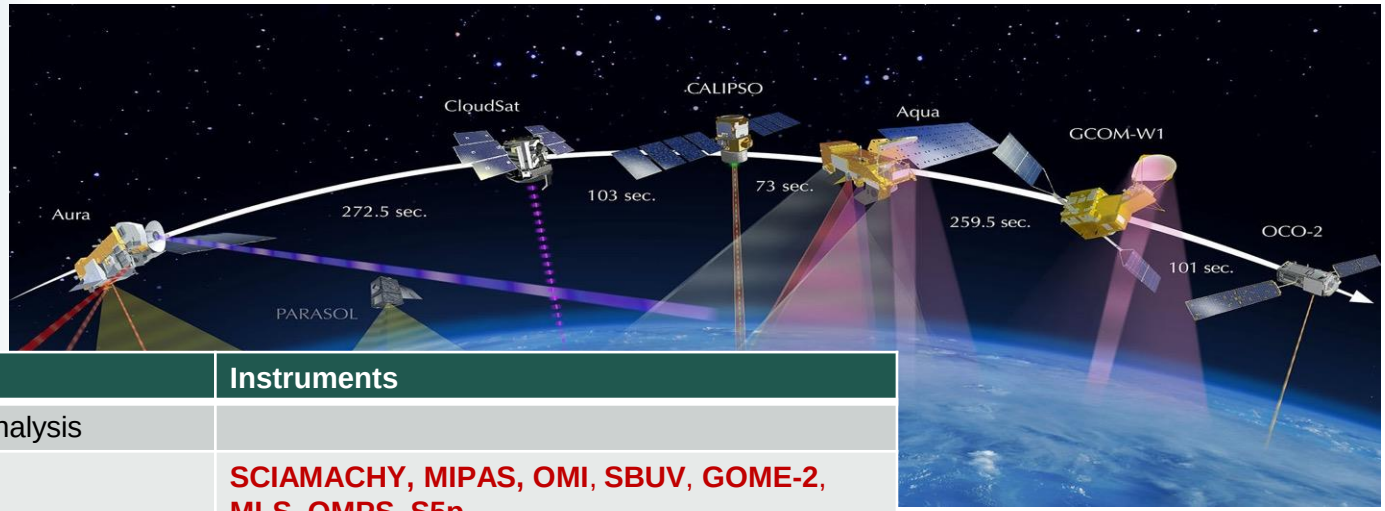
AC Observations used in CAMSRA



Species	Instruments
CAMS Global reanalysis	
O_3	**SCIAMACHY, MIPAS, OMI, SBUV, GOME-2, MLS, OMPS, S5p**
CO	**MOPITT**
NO_2	**SCIAMACHY, OMI , GOME-2**
Aerosol	**AATSR, MODIS**
CO_2	**GOSAT, IASI**
CH_4	**GOSAT, IASI**
GFAS fire emissions	**MODIS**

- Offline/ reprocessed data used in first part
- NRT data used towards the end

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Improvements due to advances in composition modelling, data selection and improved meteorology

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AOD validation against AERONET

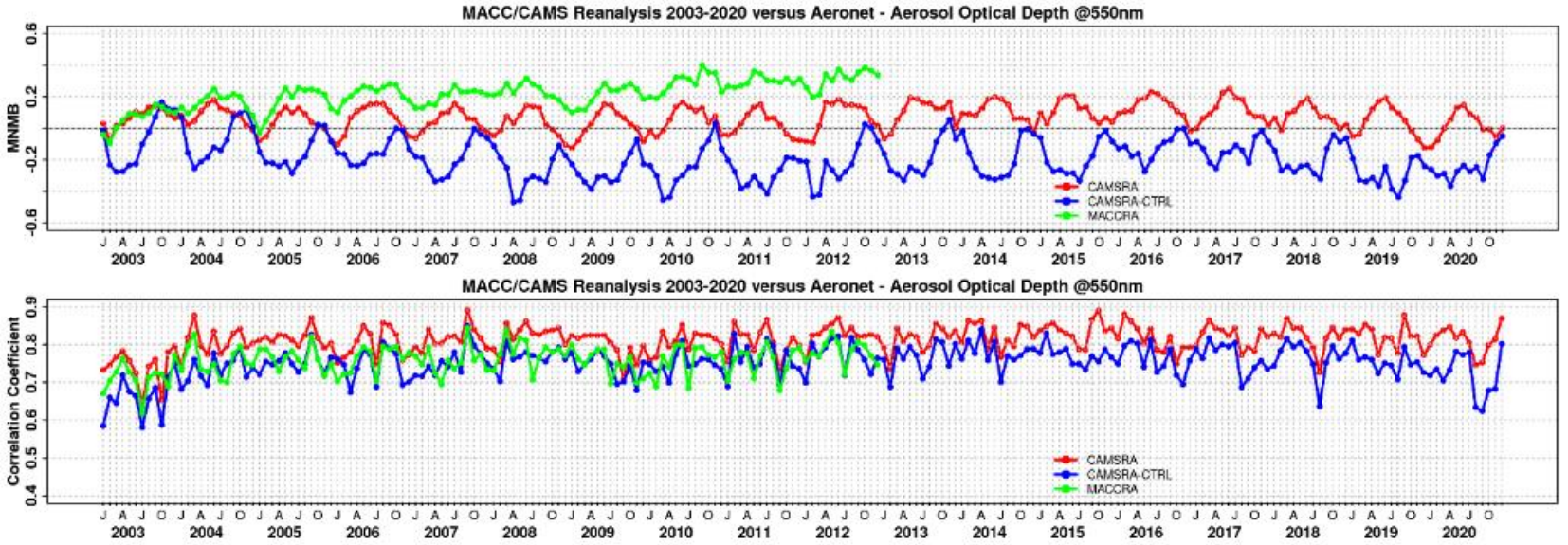
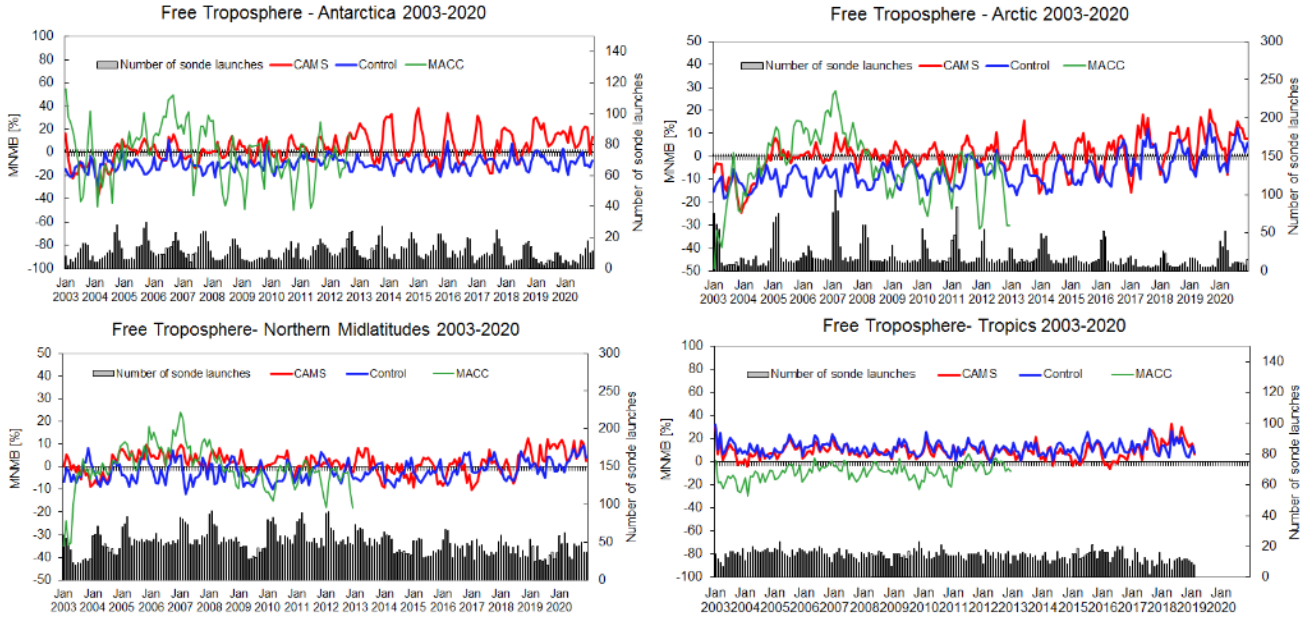


Figure S.1: a) Aerosol optical depth at 550nm in IFS 00Z model simulations for 2003–2020 against daily matching Aeronet Version3 level 1.5; (top) b) Modified normalized mean bias (MNMB); CAMS reanalysis (red) and control run (blue); MACC reanalysis (green); (bottom) Corresponding correlation coefficient.

Improvement compared to older MACC reanalysis

https://atmosphere.copernicus.eu/sites/default/files/2021-06/CAMS84_2018SC3_D5.1.1-2020_reanalysis_validation.pdf

Tropospheric ozone validation

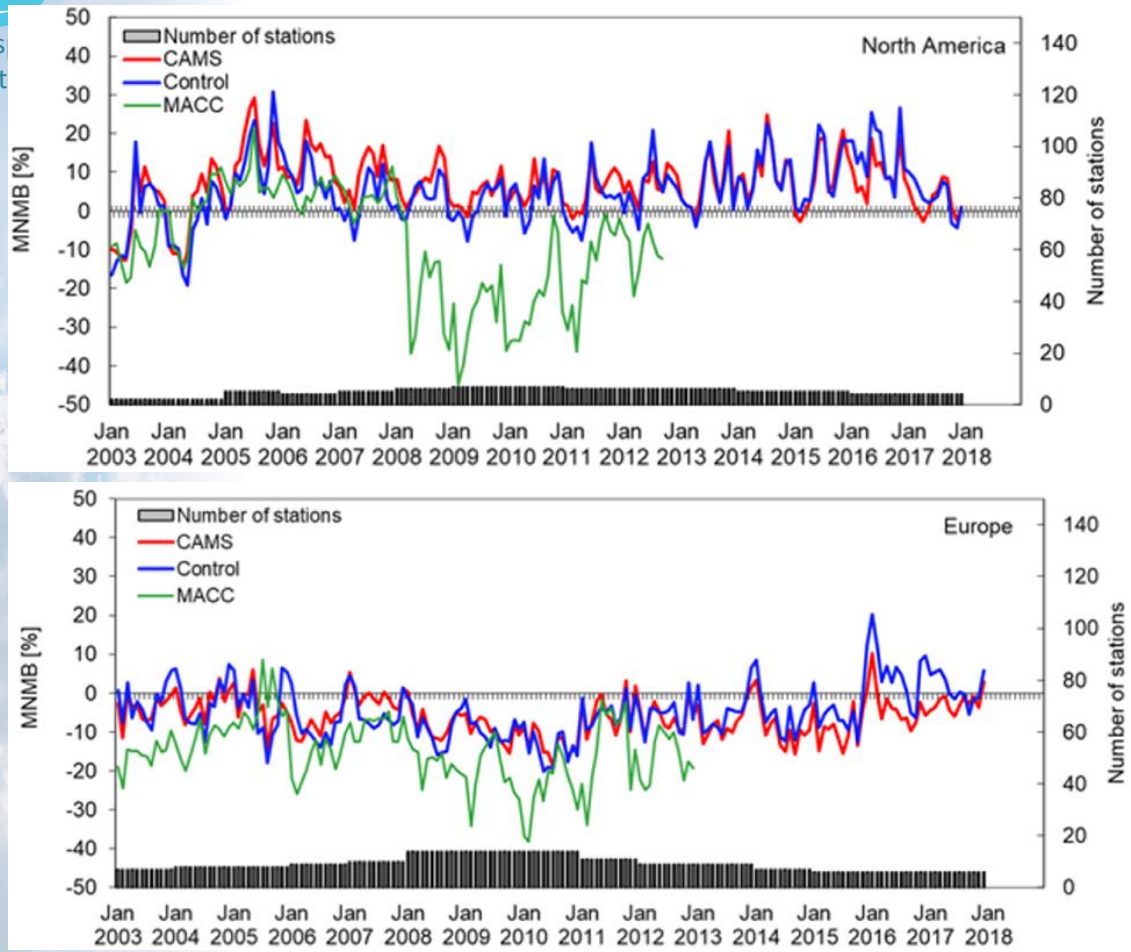


- Comparison against O3 sondes shows improvement in CAMSRA
- MACCRA suffered from drifts due to problems with the bias correction of MLS ozone data

Figure S.3: Comparison with ozone sondes in the free troposphere, period 2003-2020: MNMBs for 4 regions (first row left: Antarctica, first row right: Arctic, second row left: Northern Midlatitudes, second row right: Tropics) in the free troposphere. Red: CAMS reanalysis, green: MACC reanalysis, blue: Control run.

https://atmosphere.copernicus.eu/sites/default/files/2021-06/CAMS84_2018SC3_D5.1.1-2020_reanalysis_validation.pdf

CO validation against IAGOS aircraft data



- Validation against IAGOS data shows large change in MACCRA bias when assimilation of IASI CO started in 2008
- CAMSRA more consistent over time; uses only MOPITT CO

From Wagner et al. (2021)

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Examples of CAMSRA data usage

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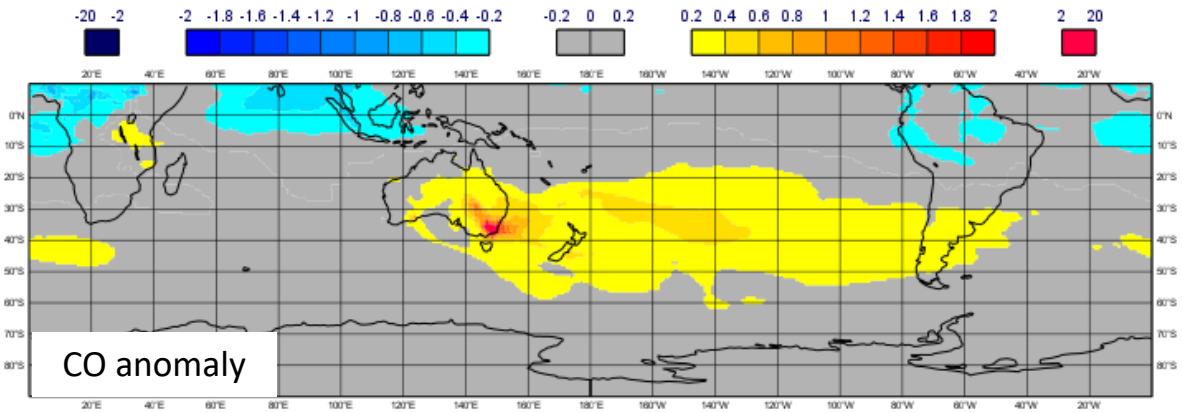
January 2020 anomalies of CO and AOD



Impact of Australian fires

CO in 10^{18} molec cm^{-2}
AOD is unitless

Anomalies calculated against the 2003-2019 January means from the CAMS reanalysis

CAMS reanalysis 2003-2019 data available from:
https://atmosphere.copernicus.eu/data

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Study of CO trends

CO burdens

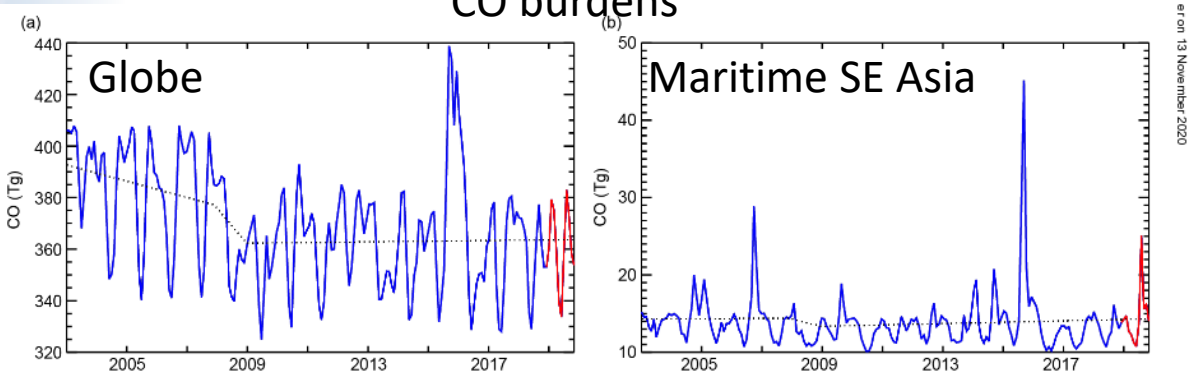

Fig. 2.60. Time series of monthly CO burdens (Tg) for (a) the whole globe and (b) over Maritime Southeast Asia from the CAMS reanalysis for 2003–19 (2019 is shown in red) and a piecewise linear trend (dotted line) for the periods 2003–07, 2008, and 2009–19.

Comparison of xCO with TCCON at Parkfalls

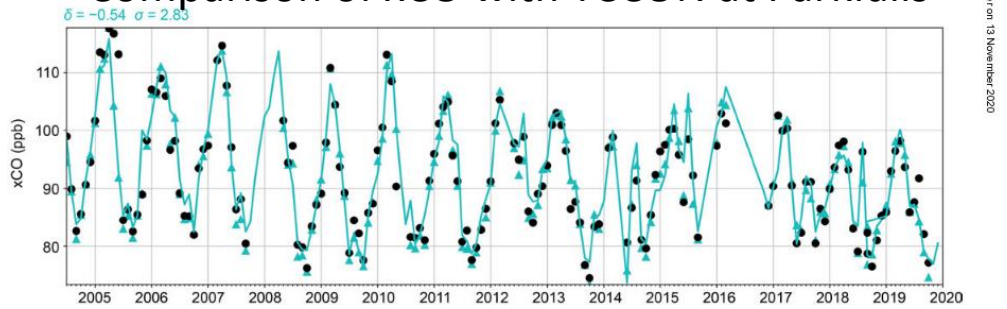

Fig. 2.62. Column-averaged CO (xCO, in ppb) at the Park Falls TCCON station. Monthly mean observations are shown by the black dots, and corresponding monthly mean xCO columns calculated using the TCCON-averaging kernels are shown by the blue triangles. The continuous blue line is the monthly xCO from the CAMS reanalysis.

Flemming et al. (2020), BAMS State of Climate 2019

TCCON data from: https://tccondata.org/

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Arctic March TCO3 trends

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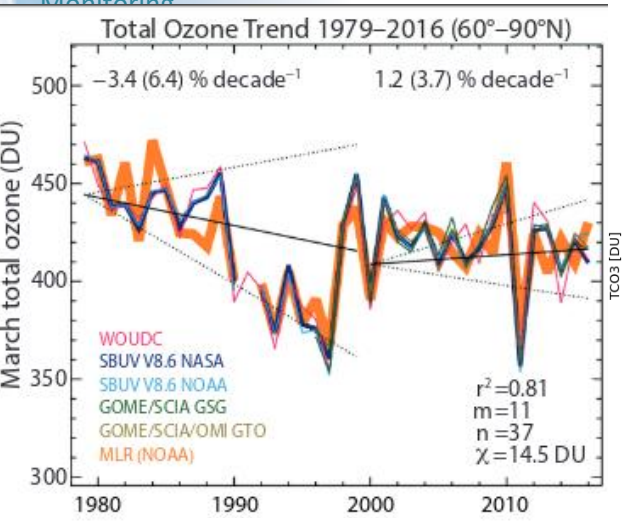
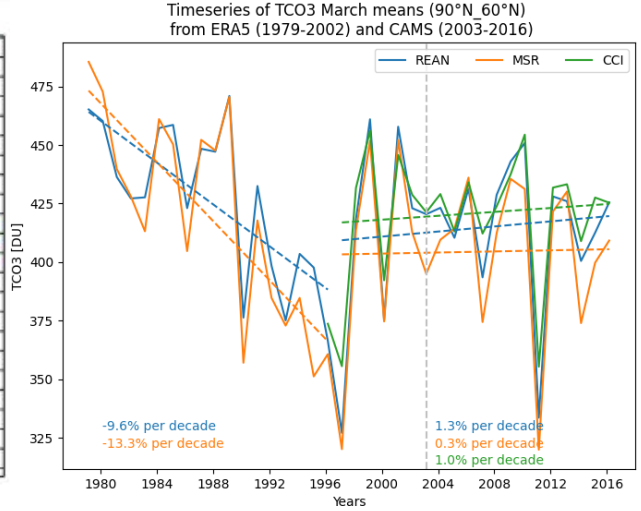
1979-2016

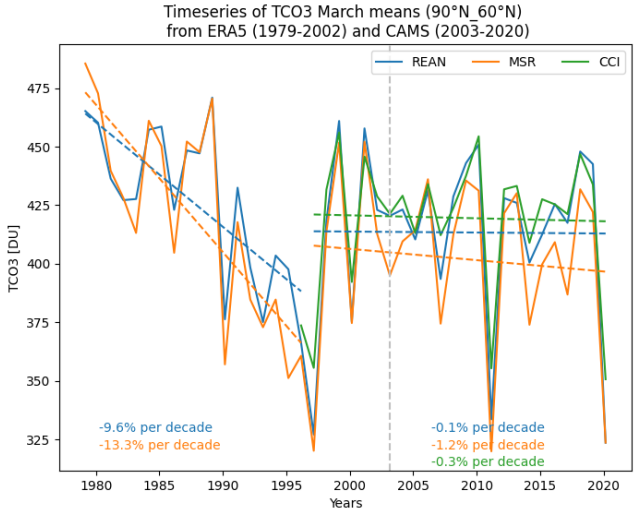


WMO (2018)

1979-2016



1979-2020



ERA5 (1979-2002) & CAMSRA (2003 ->)

Linear trends calculated for periods 1979-1996, 1997-2020

- Good agreement
- Trend depends strongly on turnaround year and length of dataset

CCI merged data set and Multi Sensor Reanalysis from:
cds.climate.copernicus.eu

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Antarctic October TCO3 trends

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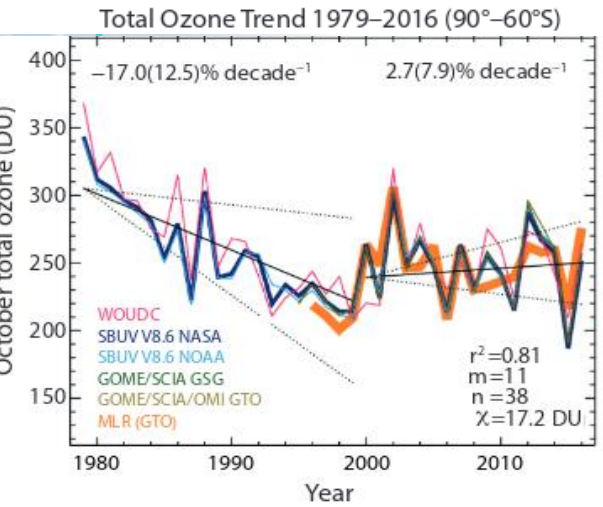
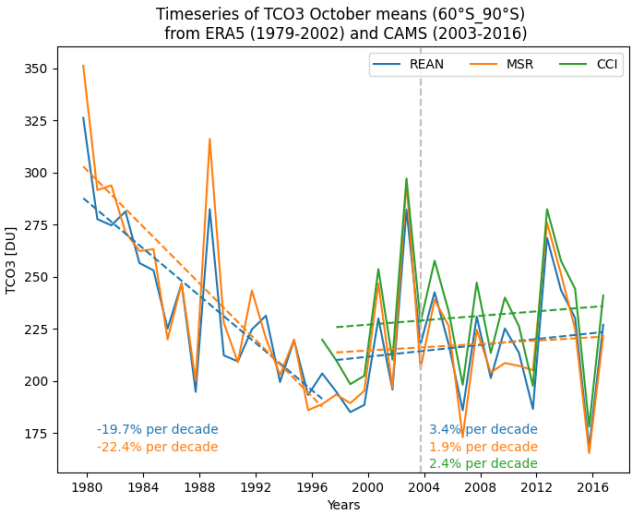
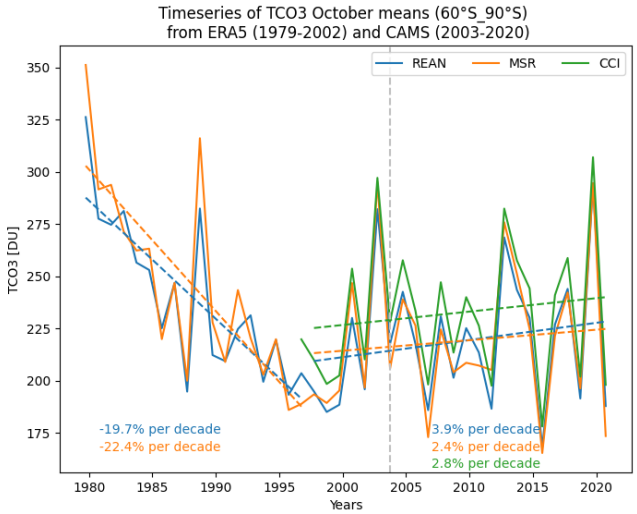
1979-2016



1979-2016



1979-2020



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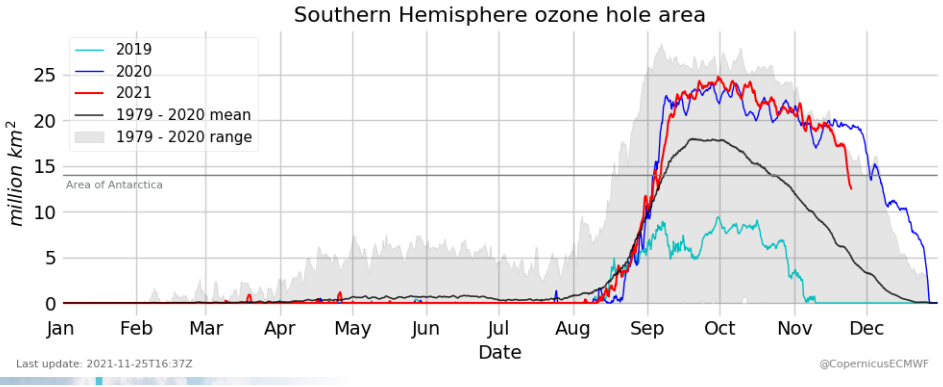
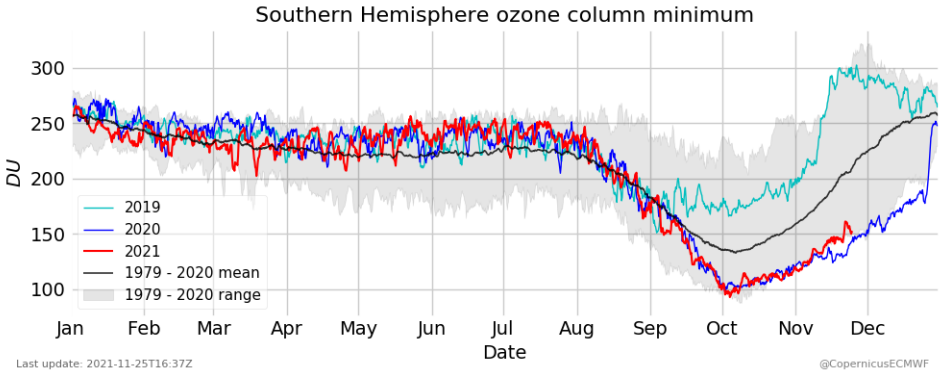
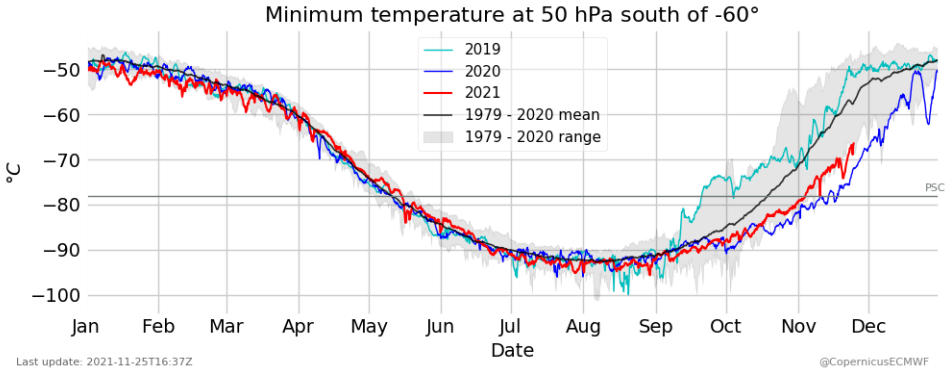
Antarctic ozone hole 2019, 2020 & 2021

In addition to long-term recovery there is a lot of interannual variability







- 2019 and 2020 both had exceptional Antarctic ozone holes
- 2019 small and short-lived because of unusual stratospheric warming
- 2020 deep, big & long-lived due to very cold stratosphere and stable polar vortex
- 2021 very similar to 2020

(1979-2002 from ERA5; 2003-2020 from CAMSRA; 2021 CAMS NRT)

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Potential benefits for NWP & Climate

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Potential benefits for NWP & Climate

- Impact of interactive aerosols and ozone
- Climatology of biomass burning emissions for use in forecasts
- Aerosol climatology/distribution for use in forecasts
- CONFESS will exploit CAMS data
  - CAMSRA aerosol data to provide harmonized CAMS and CMIP6 datasets for aerosols
  - Create biomass burning emission dataset from the CAMS Global Fire Assimilation System (GFAS)

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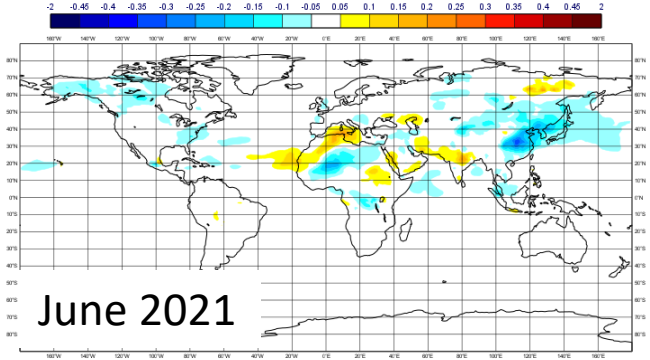
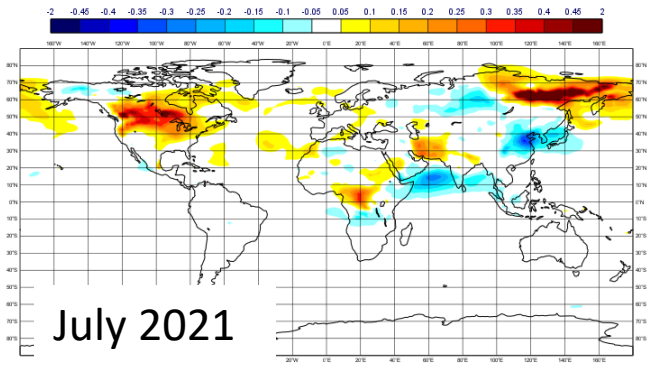
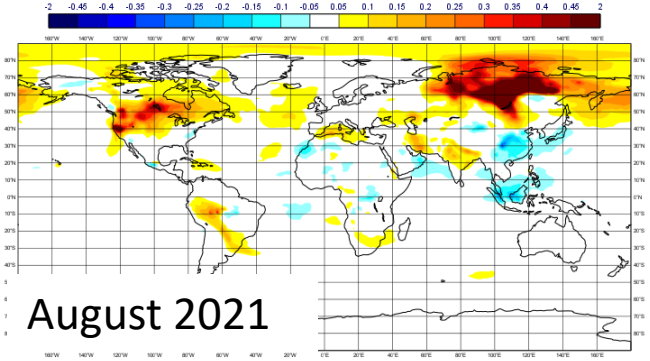
AOD anomalies and boreal wildfires 2021



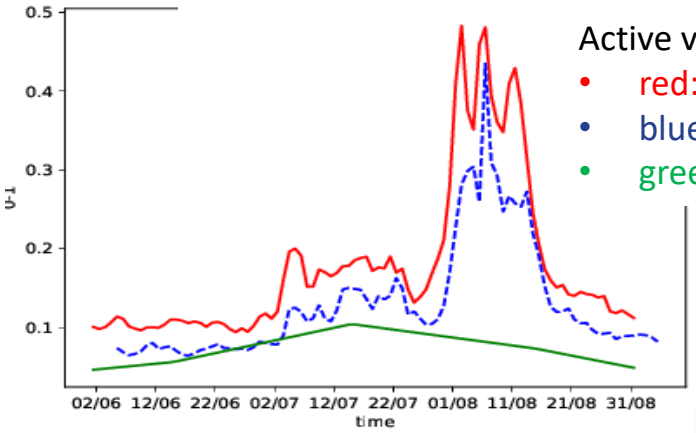


AOD anomalies due to Siberian and N-American wildfires in JJA 2021



Anomalies calculated against 2003-2020 monthly means from CAMS reanalysis

AOD mean Artic JJA 2021



Active vegetation fires in Siberia

- red: AOD analysis,
- blue: 108 h forecast
- green: climatology

Credit: Johannes Flemming

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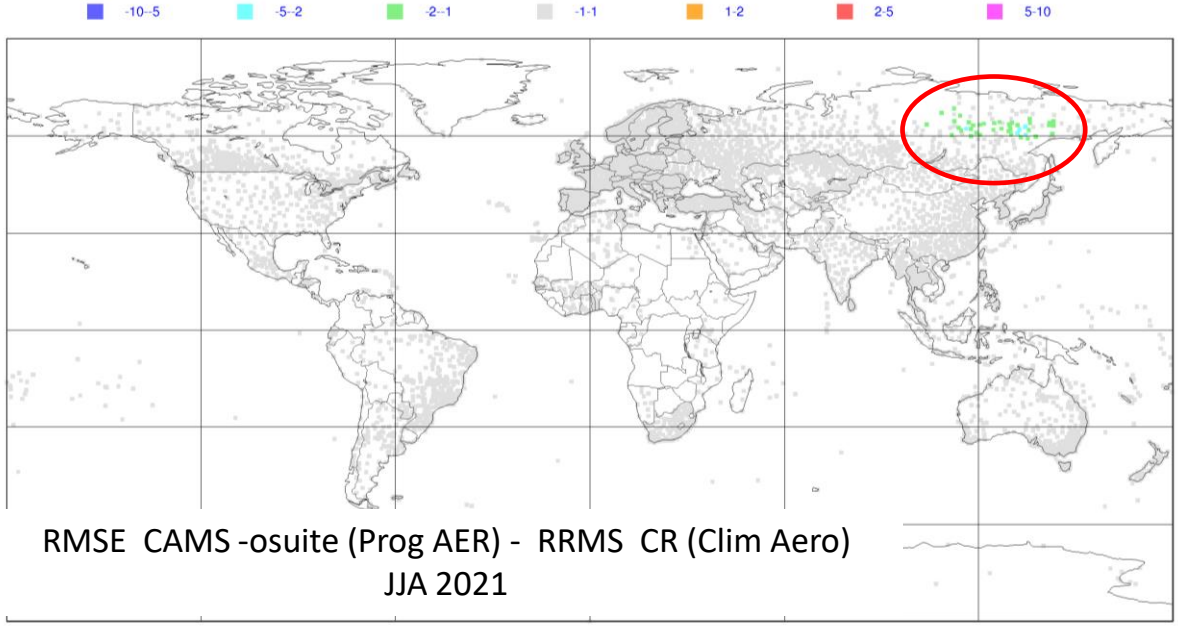
Impact on Artic wildfires on 2m temperature forecasts (JJA 2021)



RMSE CAMS -osuite (Prog AER) - RRMS CR (Clim Aero)
JJA 2021

Using prognostic aerosols leads to decrease in 2m temperature RMSE against synop observations

Credit: Johannes Flemming

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Future Plans

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PLANS FOR a CAMS2.0 REANALYSiS

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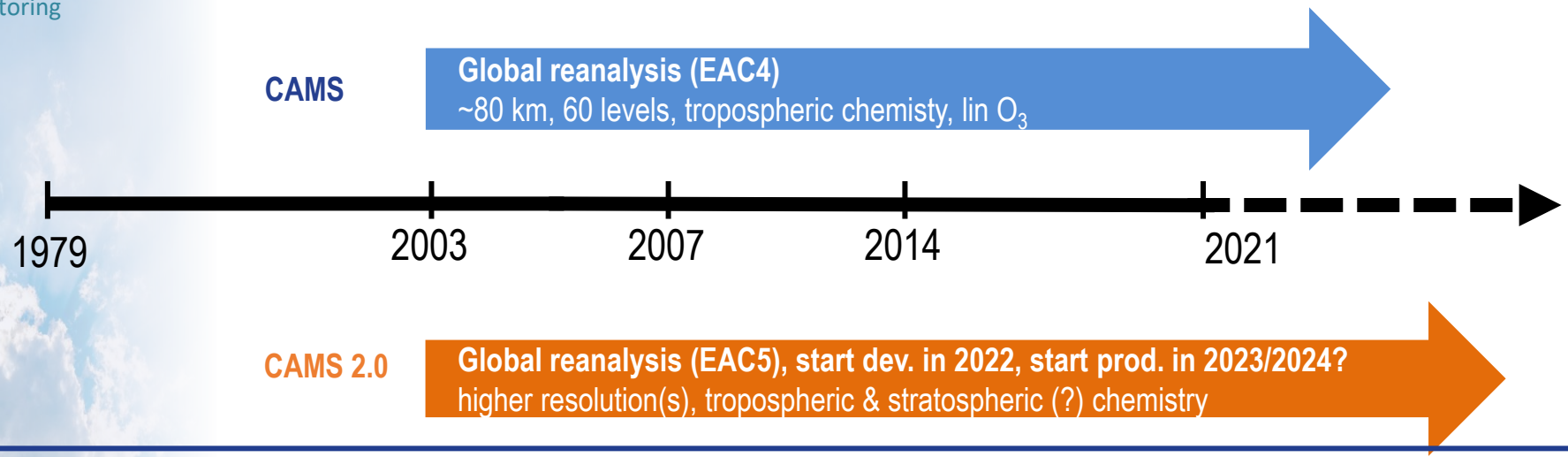

- Improvements to chemistry (+ stratospheric chemistry?)
- Newer/ improved IFS version (better meteorology)
- Increased resolution
- Better, reprocessed observations
- Improved QC for assimilated data
- Continued use of reprocessed observations instead of switch to NRT data (?)

PLANS FOR a CAMS2.0 REANALYSiS

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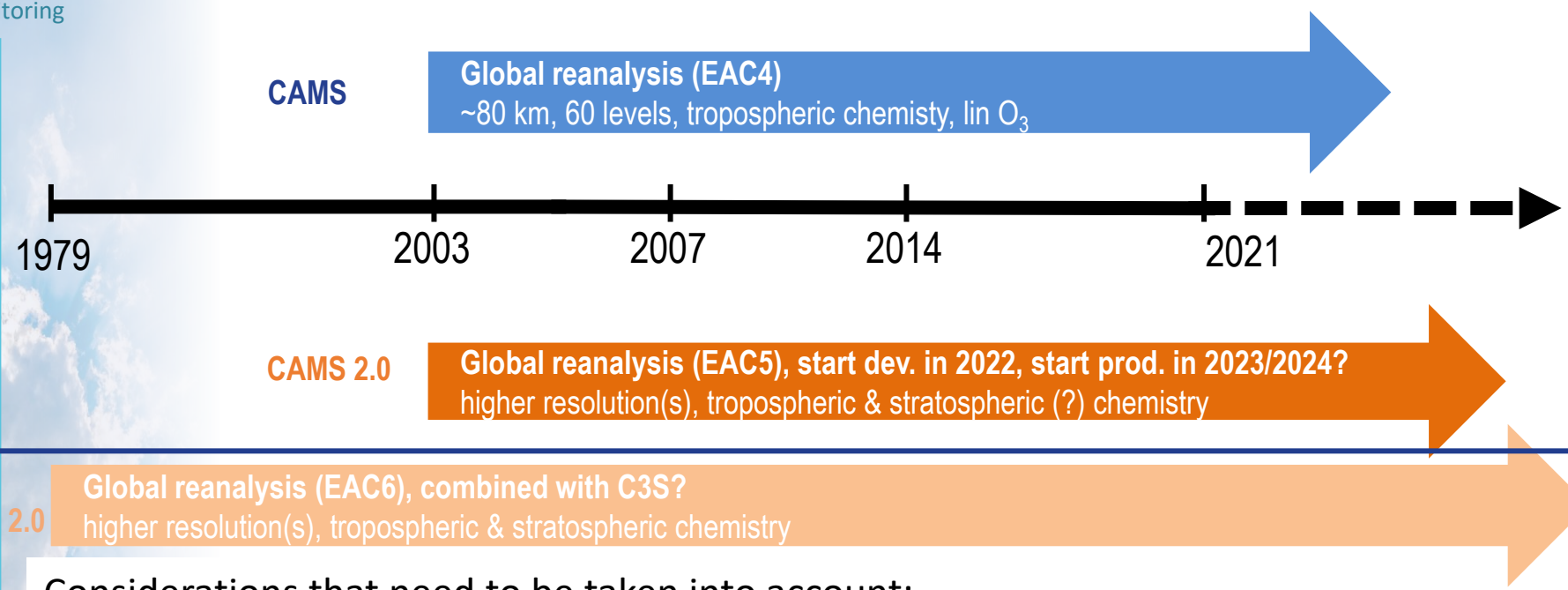

Considerations that need to be taken into account:

- Including chemistry increases the cost => limitations on resolution
- Emission datasets (incl. fire emissions) needed
- Lack of available atmospheric composition data in early years

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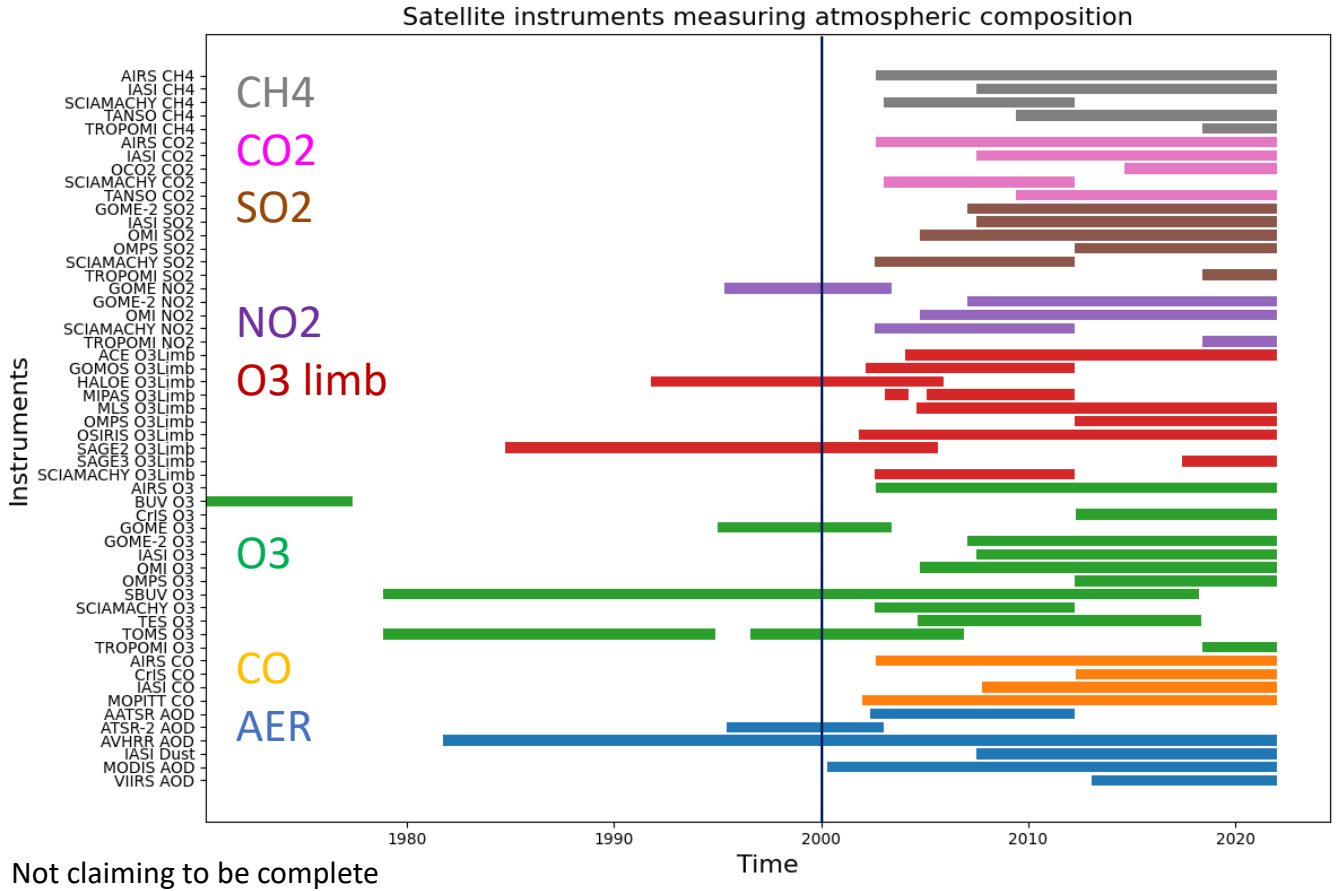
Examples of atmospheric composition data



- Limited data availability before Envisat/Aura period
- Difficult to go back further than 2000 for species other than O3 and AER

Not claiming to be complete

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Summary

- CAMS provides atmospheric composition data at global and European regional scale
- CAMS data freely available from ADS: https://atmosphere.copernicus.eu/data
- CAMS reanalysis covers the years from 2003 onwards
- CAMSRA will be extended until CAMS2.0 reanalysis is in place
- CAMSRA can be used to look at trends and anomalies (e.g. CO, AOD)
- CAMSRA can be used to look at stratospheric ozone, e.g the exceptional ozone holes in 2019 and 2020, O3 trend studies and other atm composition fields
- Benefit for NWP and climate
- CONFESS will exploit
  - CAMSRA aerosol data to provide harmonized CAMS and CMIP6 datasets for aerosols
  - Create biomass burning emission dataset from the CAMS Global Fire Assimilation System (GFAS)
- Plans for CAMS2.0 reanalysis (start 2023/24?) still covering the period from 2003 on

The Atmosphere Data Store (ADS)

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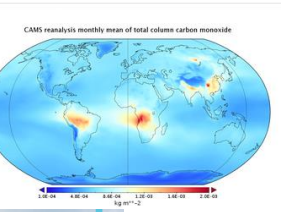
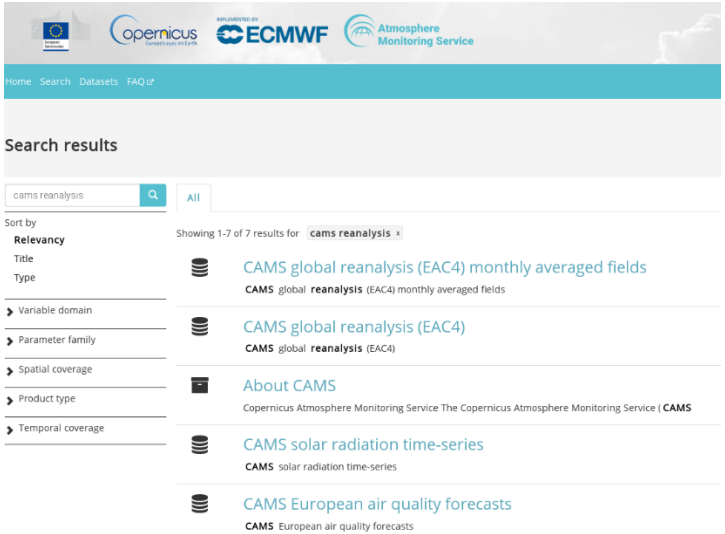
All CAMS data are freely available

https://atmosphere.copernicus.eu/data





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