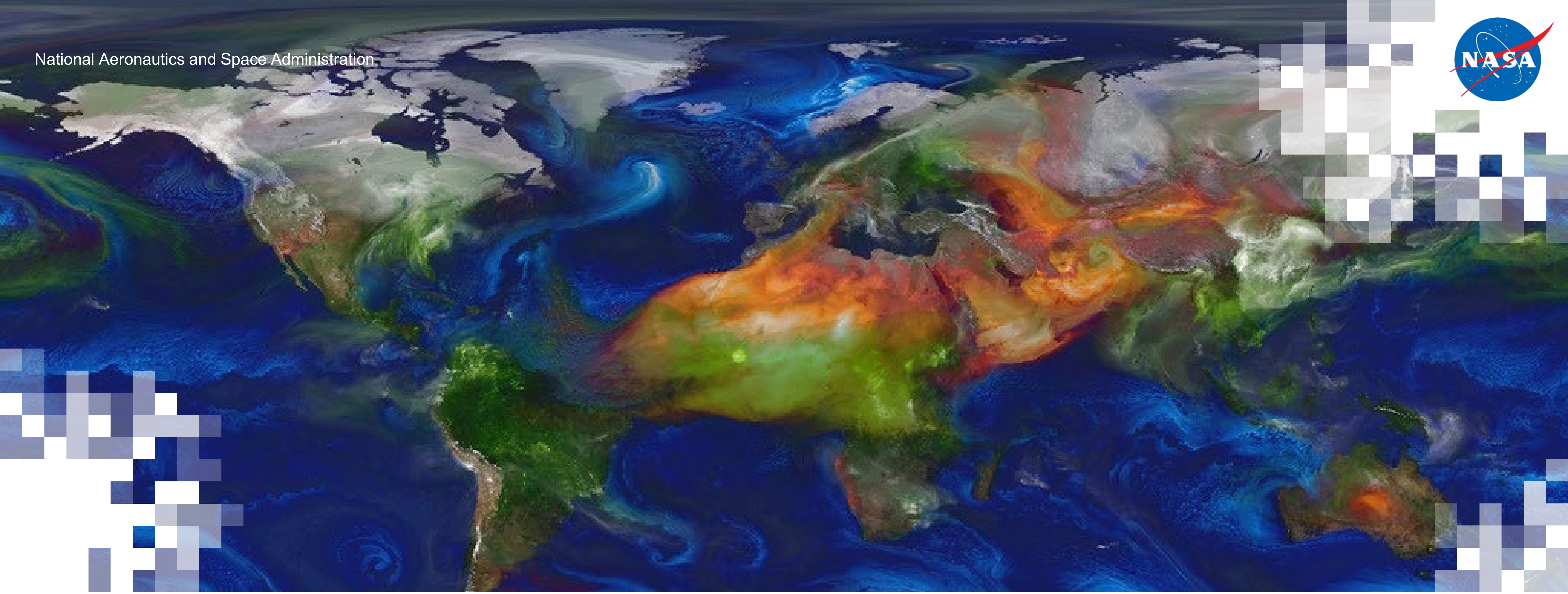
National Aeronautics and Space Administration

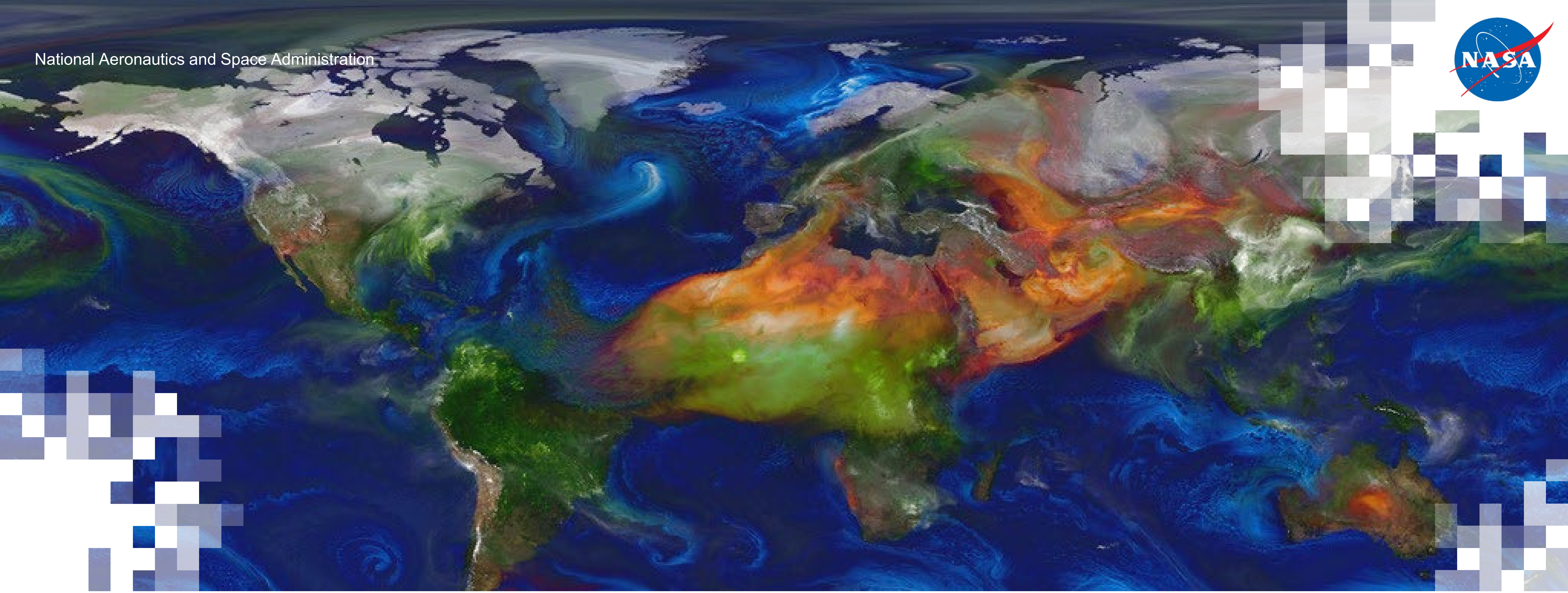


2021 ARSET Health & Air Quality

Part 3: Global Air Quality Forecasting by Copernicus Atmosphere Monitoring Service (CAMS)

Mark Parrington (mark.parrington@ecmwf.int)

September 30, 2021



Introduction and Access to Global Air Quality Forecasting Data and Tools

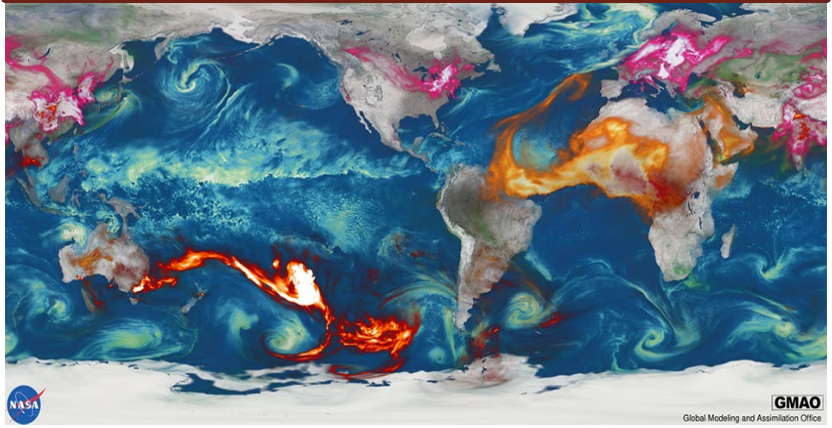
Mark Parrington and Chris Stewart

September 23, 2021 - September 30, 2021

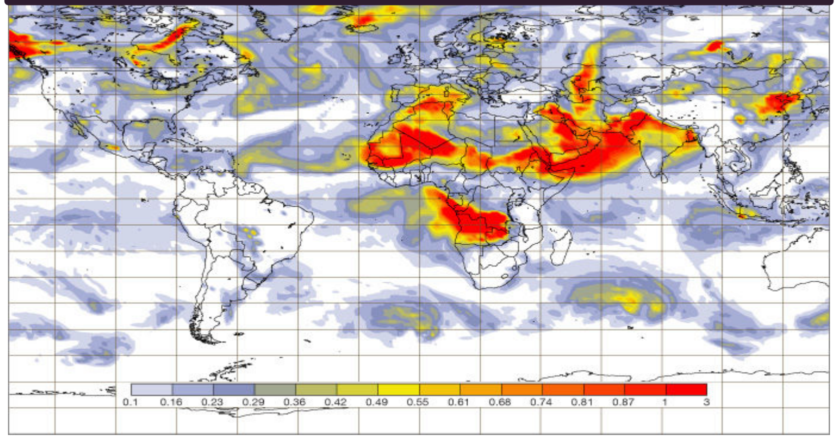
Webinar Agenda

**Session 1:
Air Quality (AQ) Basics**

**Session 2:
NASA GEOS Model**

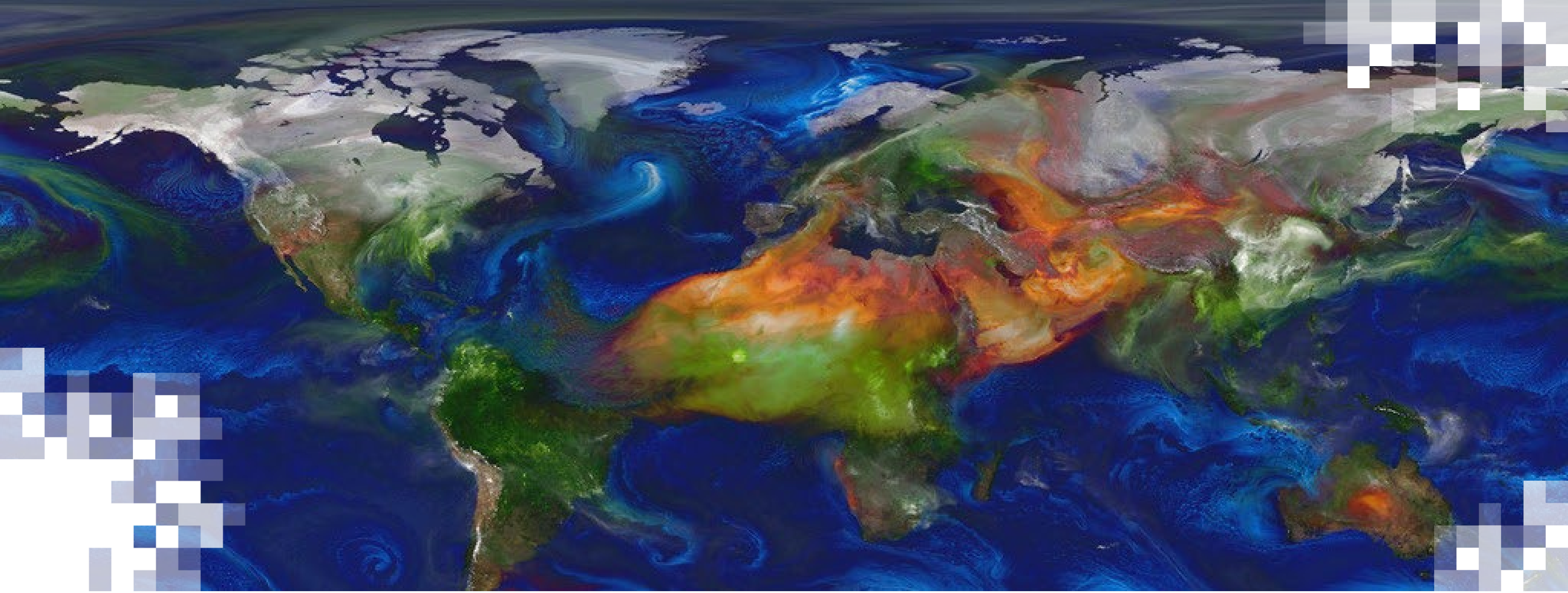


**Session 3:
ECMWF CAMS Model**



Learning Objectives

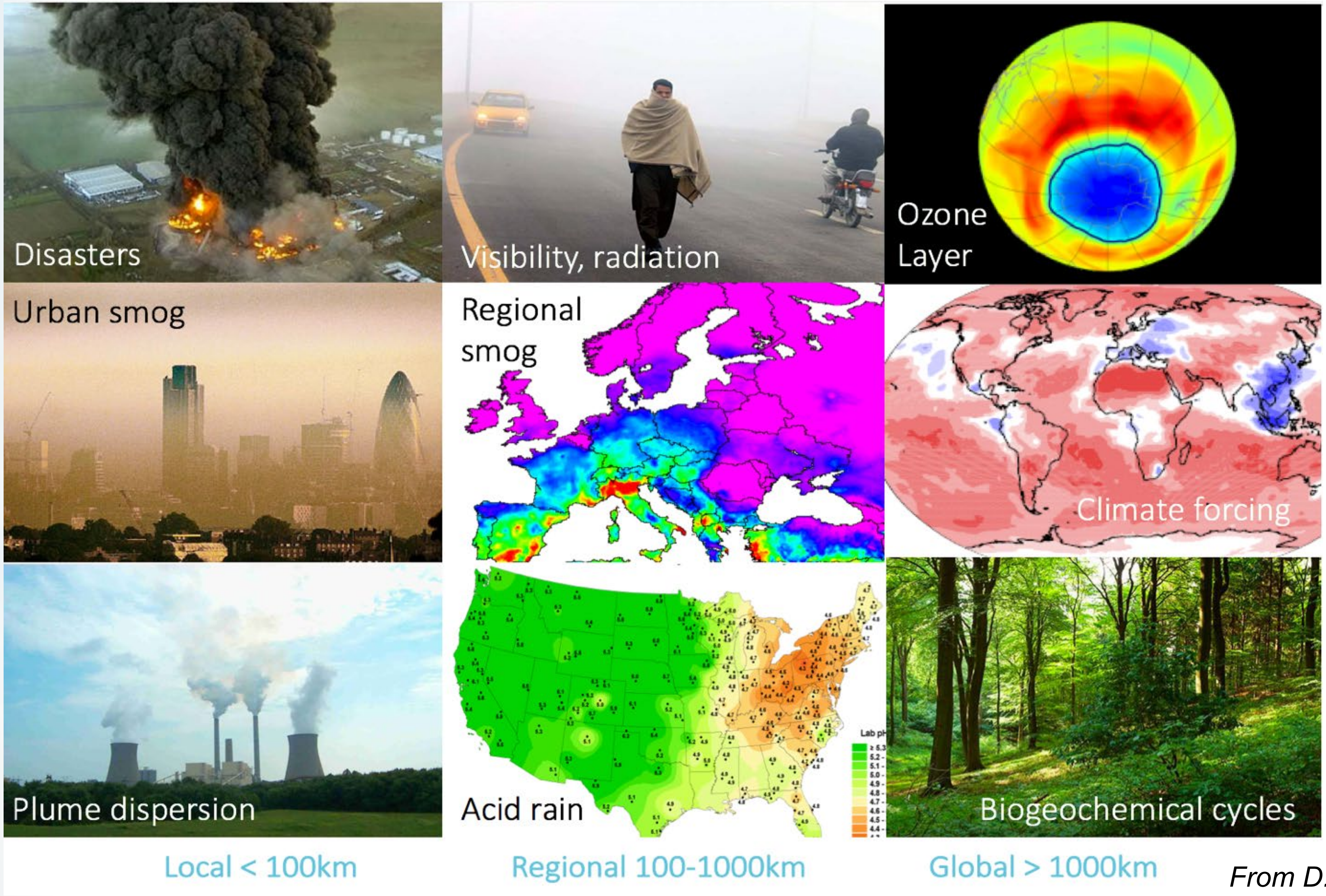
- Identify the different Atmospheric composition and Air Quality (AQ) relevant datasets available from the Copernicus Atmosphere Monitoring Service
- Understand the difference between forecast, analysis and reanalysis
- Understand how satellite observations are used for forecasting, reanalysis, and evaluation
- Discover how to subset and visualize reanalysis and forecast outputs



Session 3: Global Air Quality Forecasting by Copernicus Atmosphere Monitoring Service (CAMS)

Why monitor atmospheric composition?

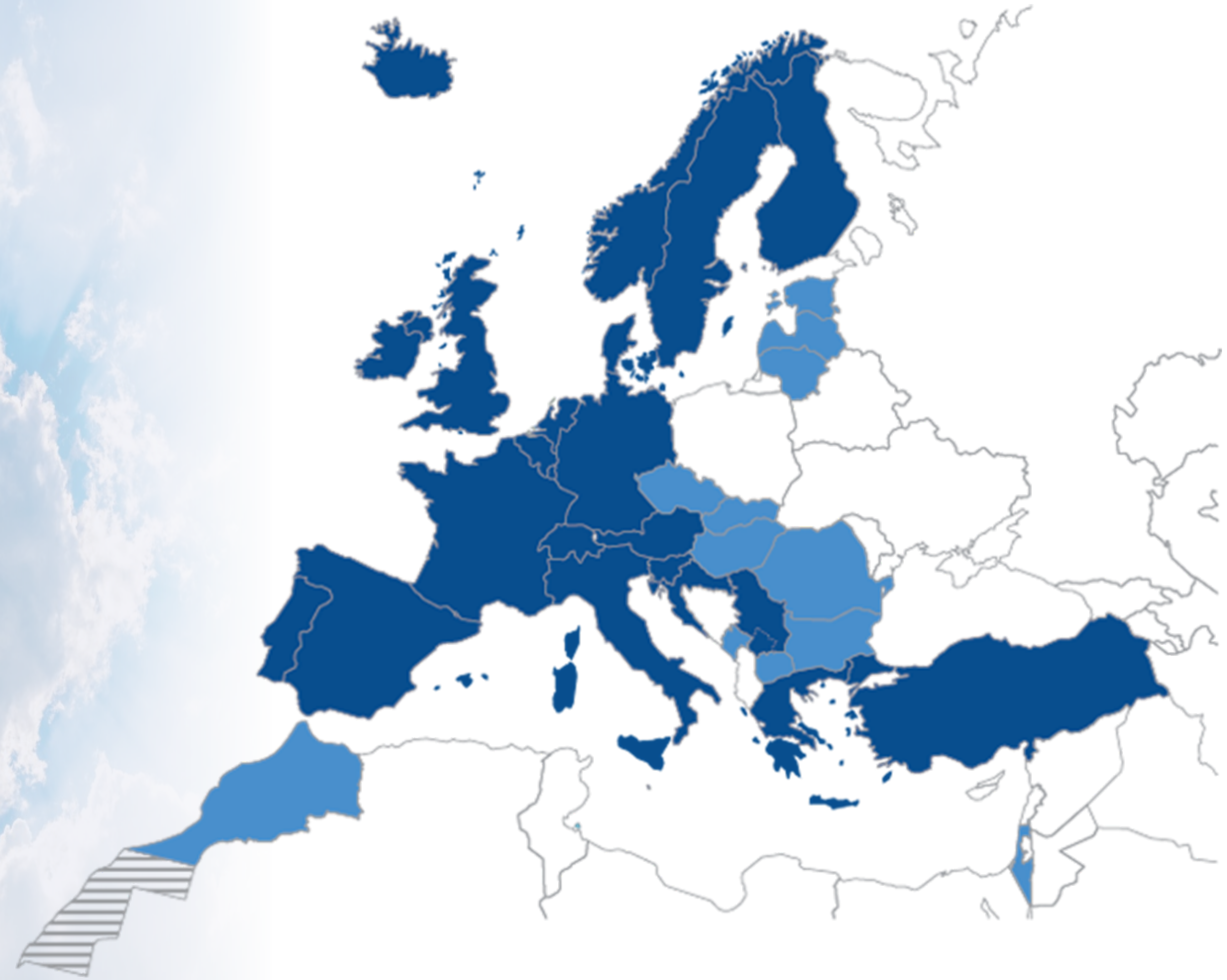
Atmosphere Monitoring



From D. Jacob (Harvard)

European Centre for Medium-Range Weather Forecasts

ECMWF

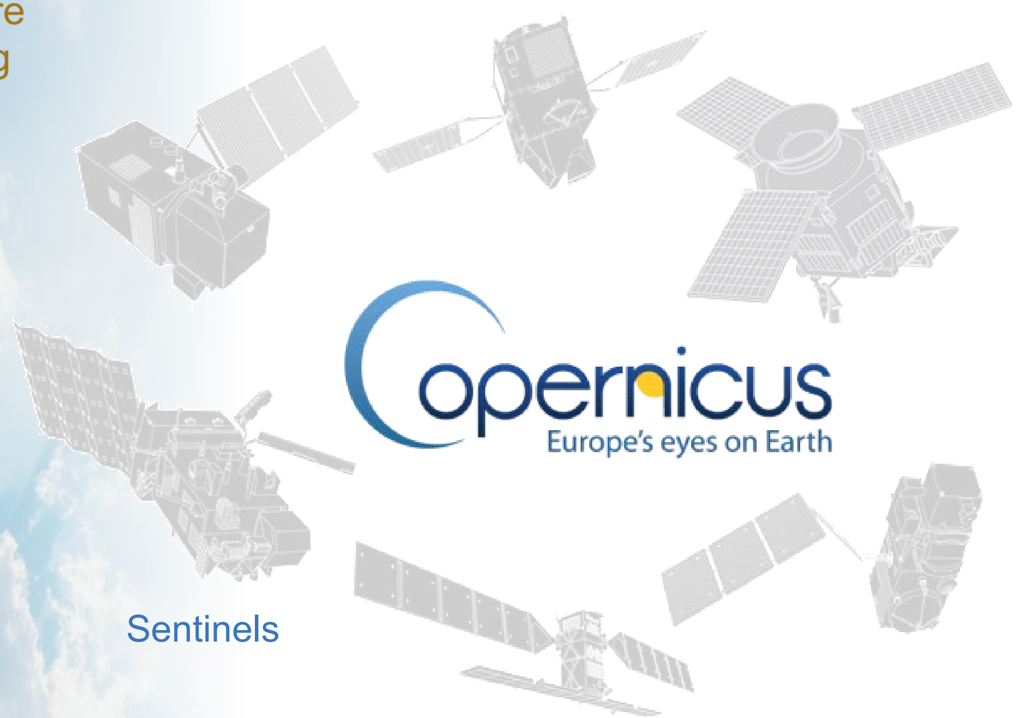


ECMWF's role is to address the most critical and most difficult research problems in medium-range Numerical Weather Prediction (NWP) that no one country could tackle on its own.

- Created in 1975
- 34 member and co-operating states
- 340 staff from 30 countries
- Based in Reading, UK
- Partnerships around the world
- http://www.ecmwf.int

Atmosphere Monitoring

Copernicus and ECMWF



Observations feeding into value-added Services

- Atmosphere
- Climate
- Land
- Marine
- Emergency
- Security

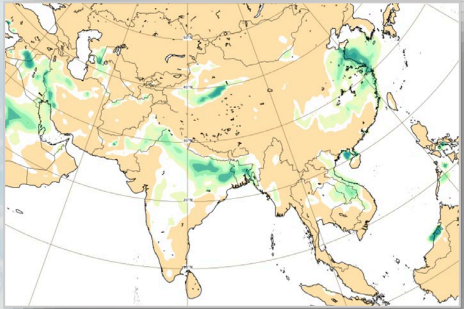
Copernicus is the European Union's operational Earth Observation and Monitoring programme, looking at our planet and its environment for the ultimate benefit of all citizens.

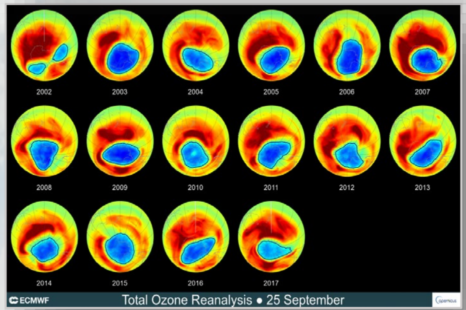
User-driven with free and unrestricted data access

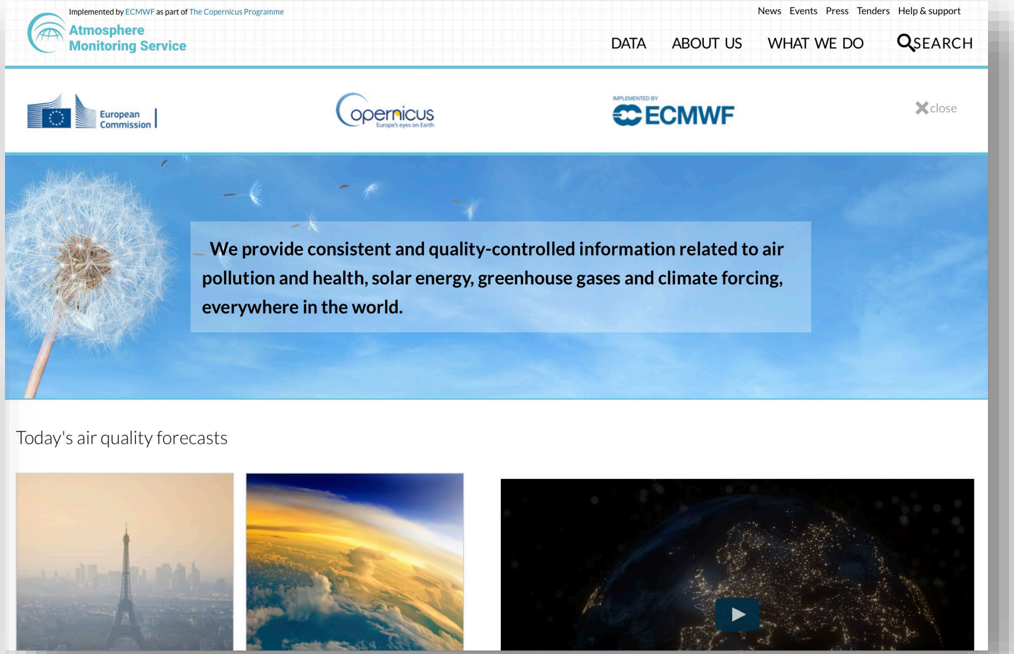
- (solid box) Service is implemented by ECMWF
- (dashed box) ECWMF is contributing to the Service

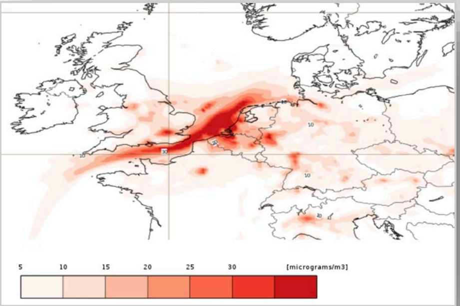
Atmosphere Monitoring

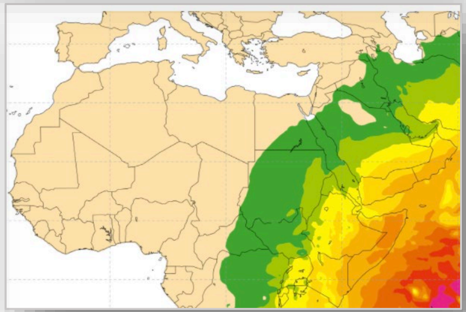
http://atmosphere.copernicus.eu









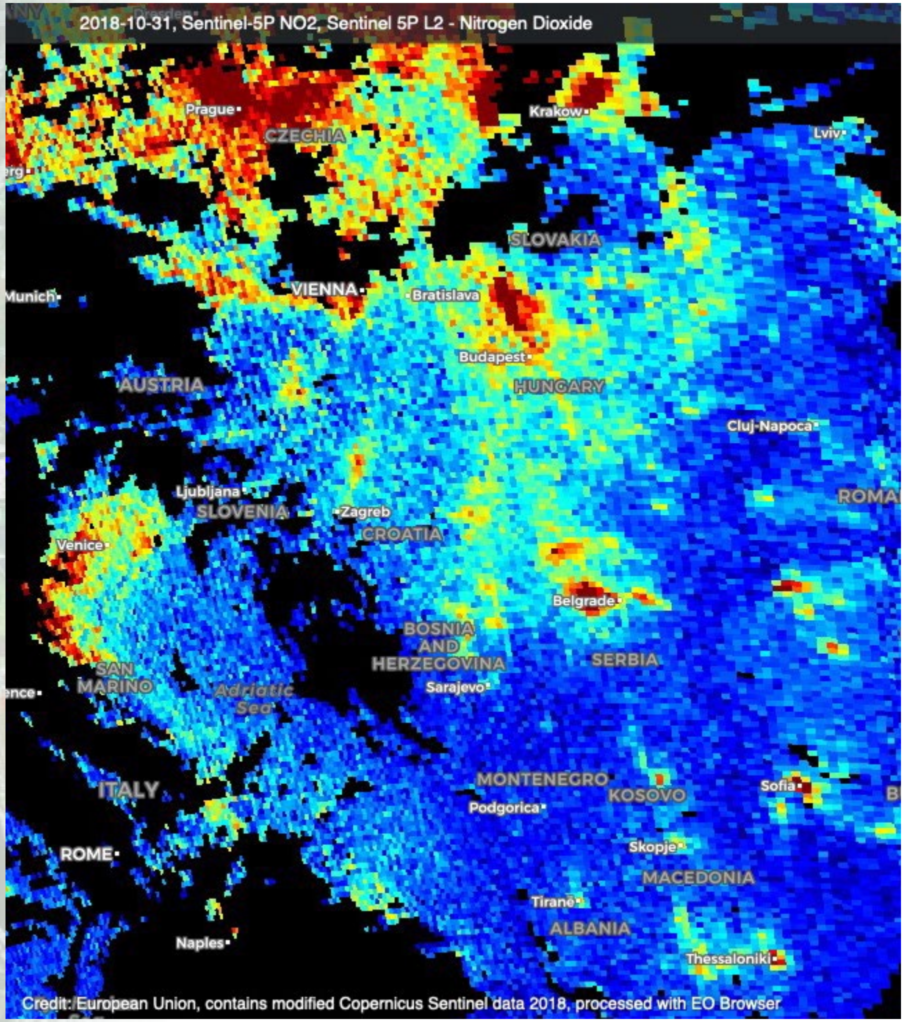


The CAMS portfolio includes Earth Observation-based information products about:

- 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.

This is delivered by a large European consortium (196 entities through 75 contracts).

Why is CAMS needed?



Example: NO_2 tropospheric column from Copernicus Sentinel-5P (31/10/2018)

Observations are essential, but **direct use** is generally **limited**:

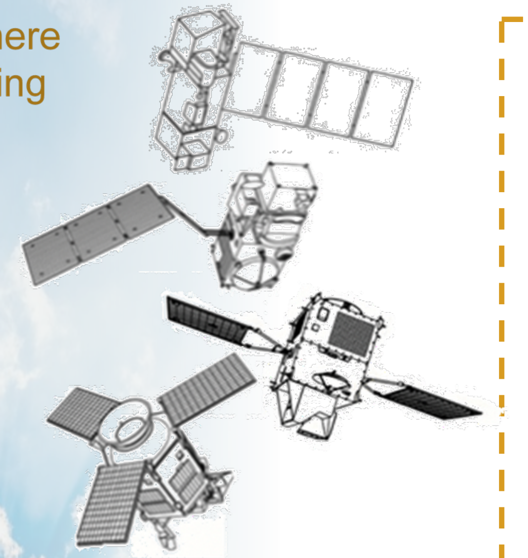
- Gaps in space and time
- Observed quantities may not be directly relevant (vertical column vs. surface concentration)
- Can be complex and numerous

What CAMS Does:

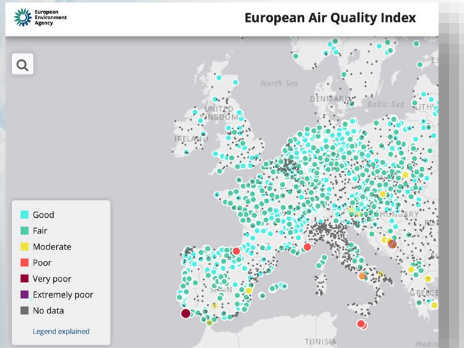
- Blends observations (satellite and non satellite) with model to provide a consistent 3D state
- Forecasts, a few days ahead
- Reanalyses over past years or decades

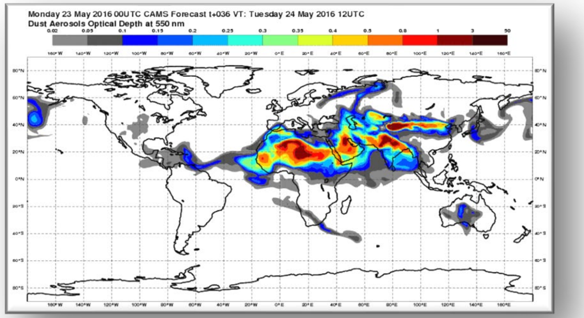
CAMS Information Flow

Atmosphere Monitoring



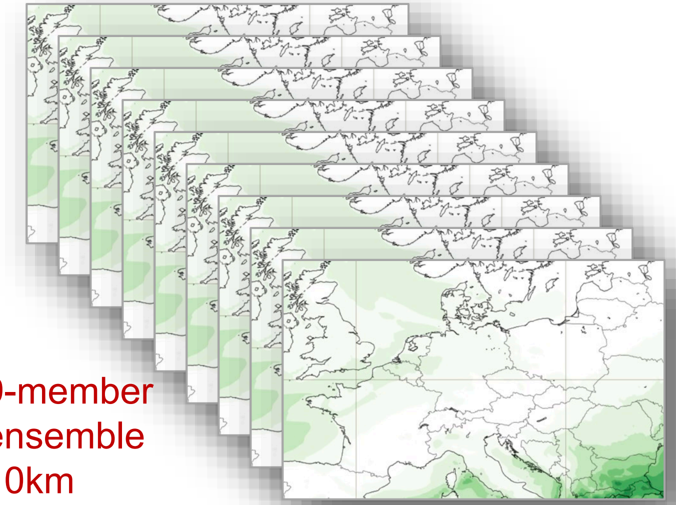
Earth Observation from satellite (>75 instruments) and in-situ (regulatory and research)





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

CAMS main operational data assimilation and modelling systems



9-member ensemble
10km
Europe

CAMS Users

- Applications
- Policy Products

The Weather Channel

iOS

CNN

euronews.

Atmosphere Monitoring

CAMS Data Assimilation System

Built on the ECMWF Integrated Forecast System (IFS)

Extra Information:
- Emissions (e.g., GFAS)
- Fluxes

Chemistry solvers included in IFS, e.g., TM5 (CB05)
57 species, 131 reactions
Photolysis, dry and wet deposition
(simple TL + AD of chemistry for NO_2)

Development of inversion capability

IFS Control Variables

CHEM: O_3, NO_2, SO_2, CO, HCHO

AER: Single or dual control variables (total or fine & coarse mode aerosol mixing ratio)

GHG: CO_2, CH_4

Meteorological Variables

Aerosol model with 14 bins (no TL or AD): dust, sea salt, organic matter, black carbon, sulphate, nitrate, ammonium

GHG Fields

Coupling between aerosols and CHEM

Aerosols & ozone interactive with radiation

Observations
- Observation operators
- Variational bias correction
- Background error statistics

ECMWF Copernicus Europe's eyes on Earth European Commission

ECMWF IFS COMPOSITION CONFIGURATIONS

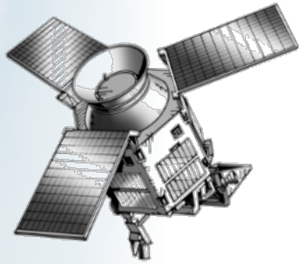
Current Operational Version:

- Based on IFS Cy47r1
- Horizontal: T511 (~40km)
- Vertical: L137

- V. Huijnen et al., Quantifying uncertainties due to **chemistry modelling** – evaluation of tropospheric composition simulations in the CAMS model (cycle 43R1), GMD, https://doi.org/10.5194/gmd-12-1725-2019.
- S. Rémy et al., Description and evaluation of the tropospheric **aerosol scheme** in the Integrated Forecasting System (IFS-AER, cycle 45R1) of ECMWF, GMD, https://doi.org/10.5194/gmd-12-4627-2019.
- A. Agusti-Panareda et al., **Modelling CO_2** weather – why horizontal resolution matters?, ACP, https://doi.org/10.5194/acp-2019-177, 2019.
- A. Inness et al., The **CAMS reanalysis** of atmospheric composition, ACP, https://doi.org/10.5194/acp-19-3515-2019, 2019.

CAMS Information Flow: Ingesting Observations

Atmosphere Monitoring



L1b Data

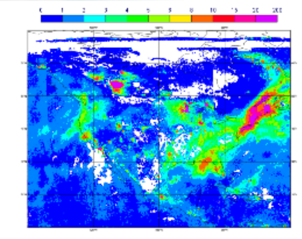
Retrieval Teams

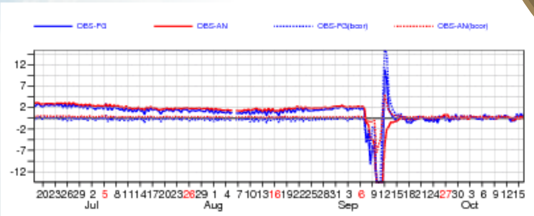
L2 Data

CAMS Analysis and Monitoring Tools

Statistics and Plots

Feedback

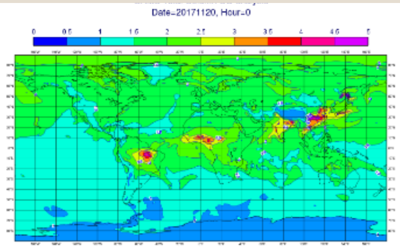




Good Data

Assimilation Tests

NRT Assimilation

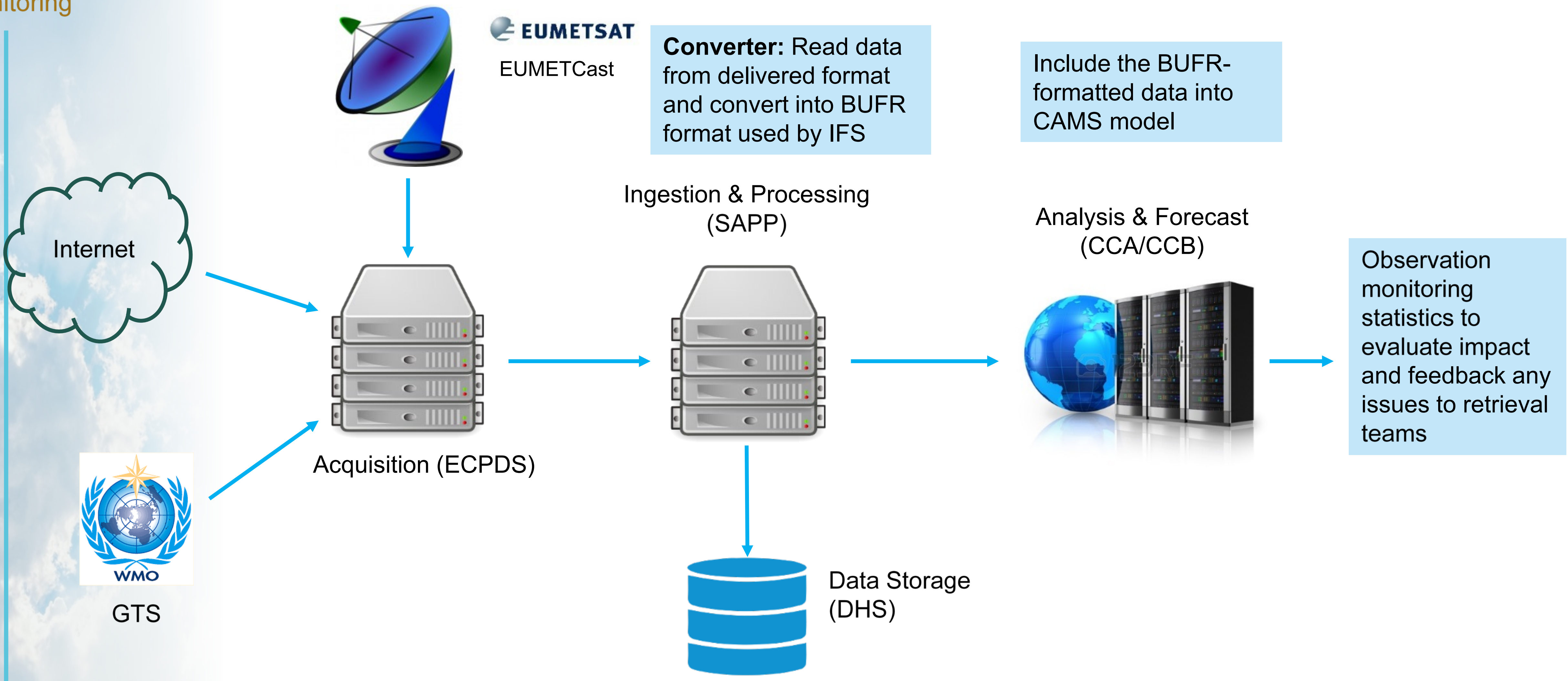


CAMS Analyses and Forecasts

Downstream Services and Users

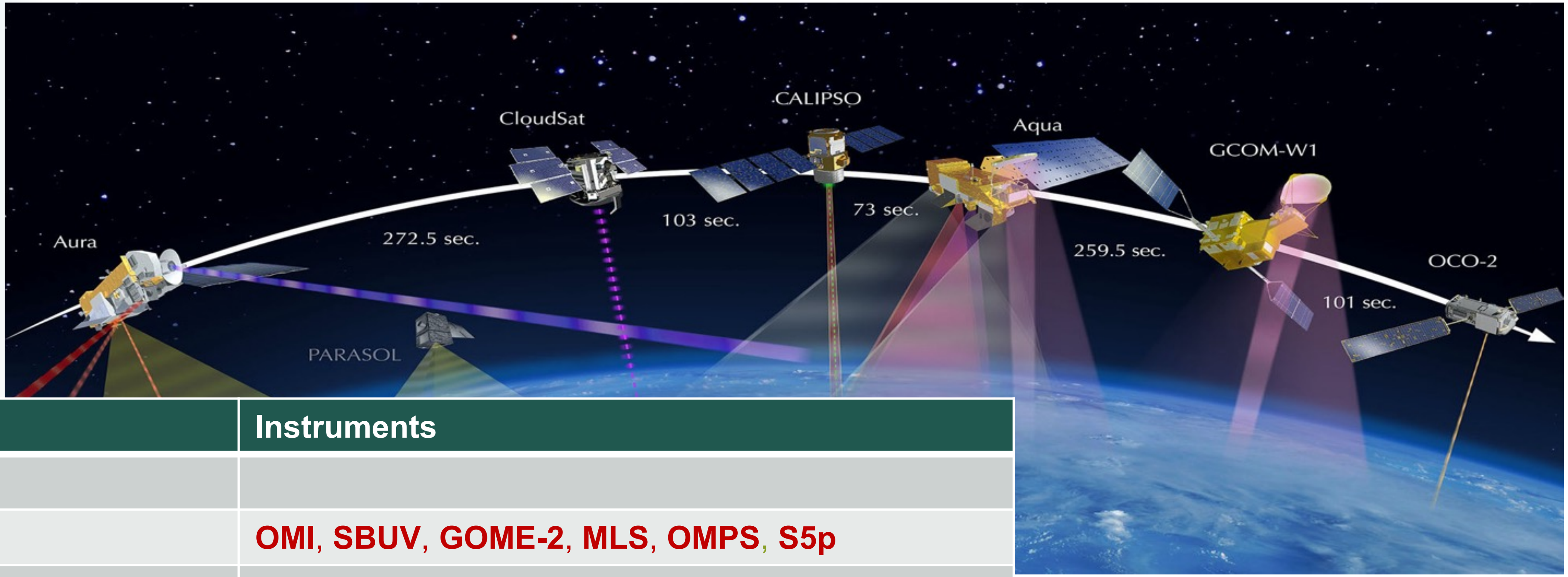
Atmosphere Monitoring

CAMS Observation Data Flow



Atmosphere Monitoring

Earth Observation Satellites

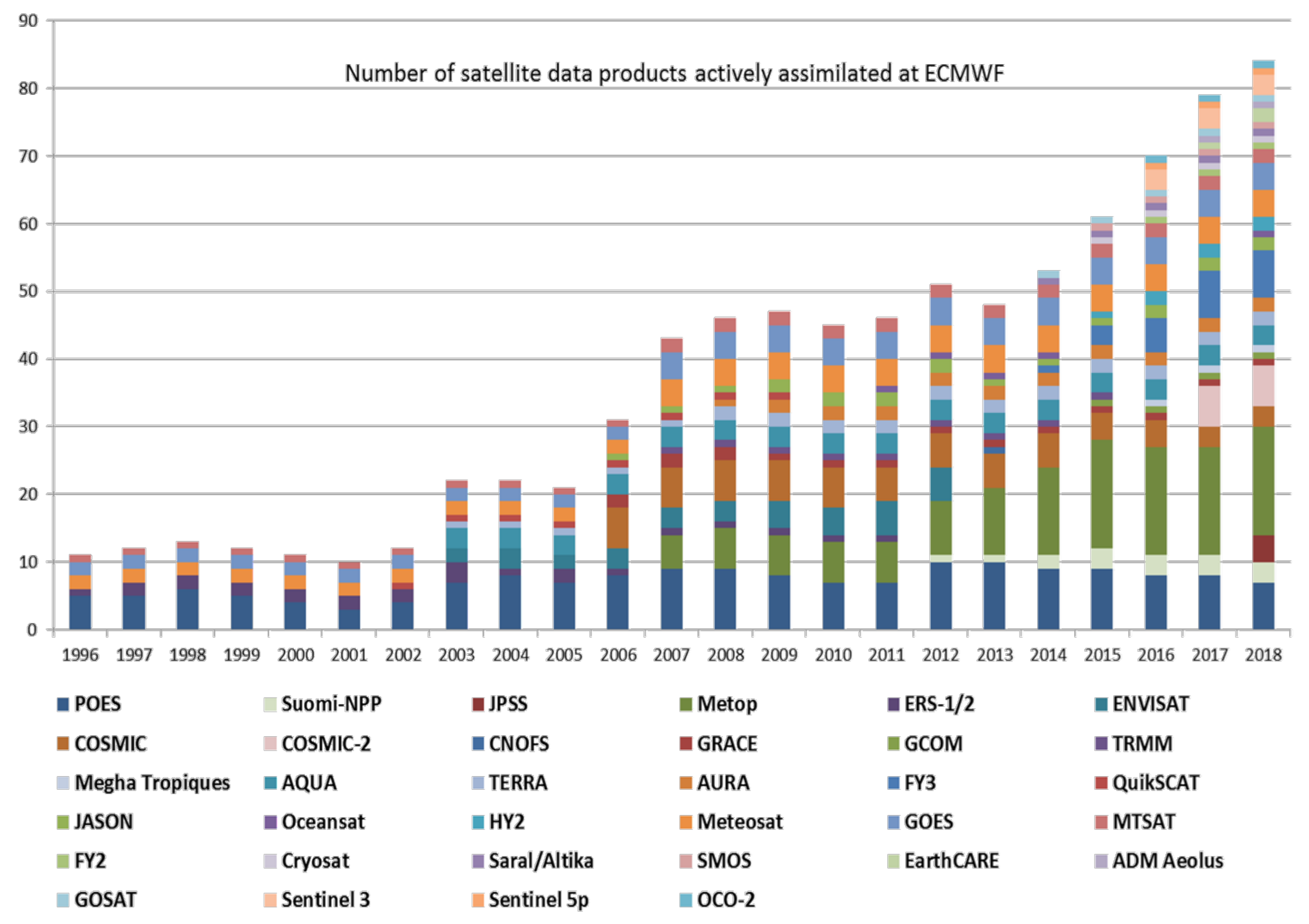


Species	Instruments
Global system	
O_3	**OMI**, **SBUV**, **GOME-2**, **MLS**, **OMPS**, **S5p**
CO	**IASI**, **MOPITT**, **S5p**
NO_2	**OMI**, **GOME-2,** **S5p**
SO_2	**OMI**, **GOME-2**, **S5p**
Aerosol	**MODIS**, **PMAp**, VIIRS, S3
CO_2	**GOSAT**, **OCO-2**
CH_4	**GOSAT**, **IASI**, **S5p**
GFAS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

Assimilated **Monitored** Under Development *Geostationary Platform

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

OVER 80 SATELLITE DATA STREAMS USED DAILY FOR CAMS OPERATIONS



Satellite observations that are assimilated in the global NRT system

Instrument	Satellite	Space Agency	Data Provider	Species
MODIS	EOS-Aqua, EOS-Terra	NASA	NASA	AOD, FRP
MLS	EOS-Aura	NASA		O3 profile
OMI	EOS-Aura	NASA	KNMI	O3, NO2, SO2
SBUV-2	NOAA-19	NOAA	NOAA	O3 profile
IASI	METOP-A, METOP-B	EUMETSAT/CNES	ULB/LATMOS	CO
MOPITT	EOS-Terra	NASA	NCAR	CO
GOME-2	METOP-A, METOP-B	EUMETSAT/ESA	AC-SAF	O3, SO2
OMPS	Suomi-NPP	NOAA	EUMETSAT	O3
PMAp	METOP-A	EUMETSAT	EUMETSAT	AOD

Satellite observations that are monitored in the global NRT system

Instrument	Satellite	Space Agency	Data Provider	Species
GOME-2	METOP-A, METOP-B	EUMETSAT/ESA	AC-SAF	NO2, HCHO
SEVIRI	METEOSAT	EUMETSAT	LandSAF	O3, FRP
Imager	GOES-11, -12	NOAA	UCAR	FRP radiances

Satellite observations that are planned for the global NRT system

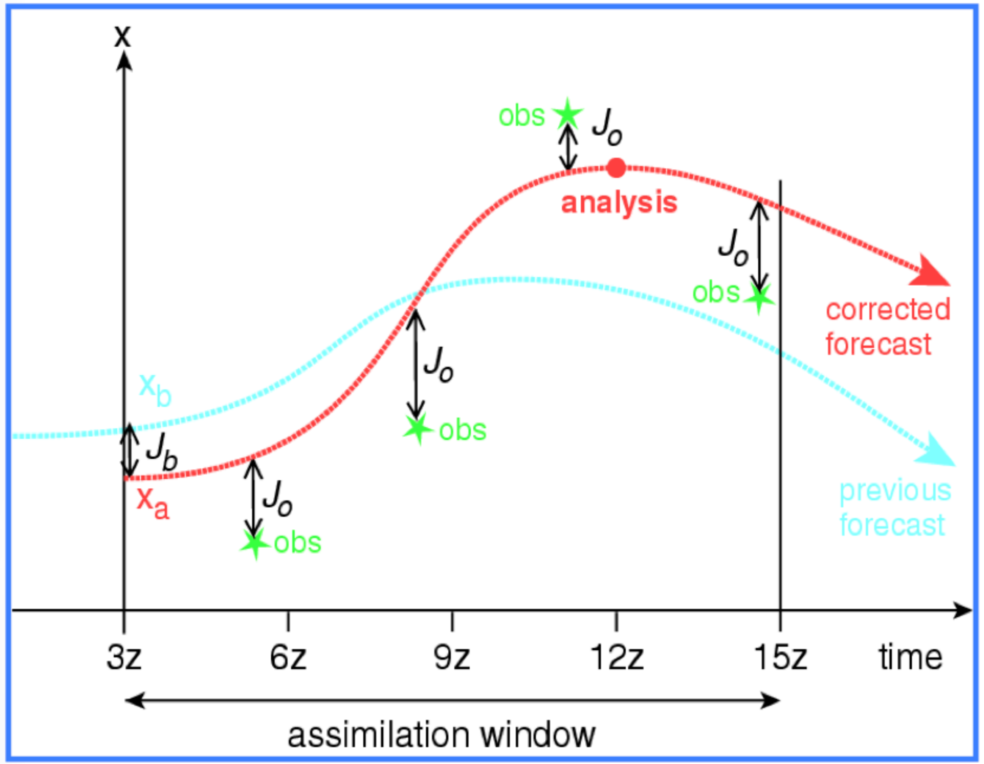
Instrument	Satellite	Space Agency	Data Provider	Species
CALIOP	CALIPSO	NASA		aerosol lidar backscatter
IASI	METOP-A, -B	EUMETSAT/CNES	EUMETSAT	O3 radiances
Imager	MTSAT-2	JMA	JMA	FRP radiances
VIIRS	Suomi NPP	NASA/NOAA	EUMETSAT	AOD, FRP
SEVIRI	MSG	EUMETSAT	ICAR	AOD

https://atmosphere.copernicus.eu/cams-input-data

Atmosphere Monitoring

4D-VAR - Method of Combining Observations with Model

- We need efficient means of combining the information from ~20,000,000 observations with a global model at ~40 km horizontal resolution.
- Data assimilation is the process of merging observations with a background model forecast in a statistically consistent manner.
- We want to minimize a cost function (J) that evaluates the model background (J_b) and observations (J_o).



$$\mathbf{x}_a = \text{Arg min} J$$

$$J(\mathbf{x}) = (\mathbf{x}-\mathbf{x}_b)^T \mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}_b) + (\mathbf{y} - H[\mathbf{x}])^T \mathbf{R}^{-1}(\mathbf{y} - H[\mathbf{x}])$$

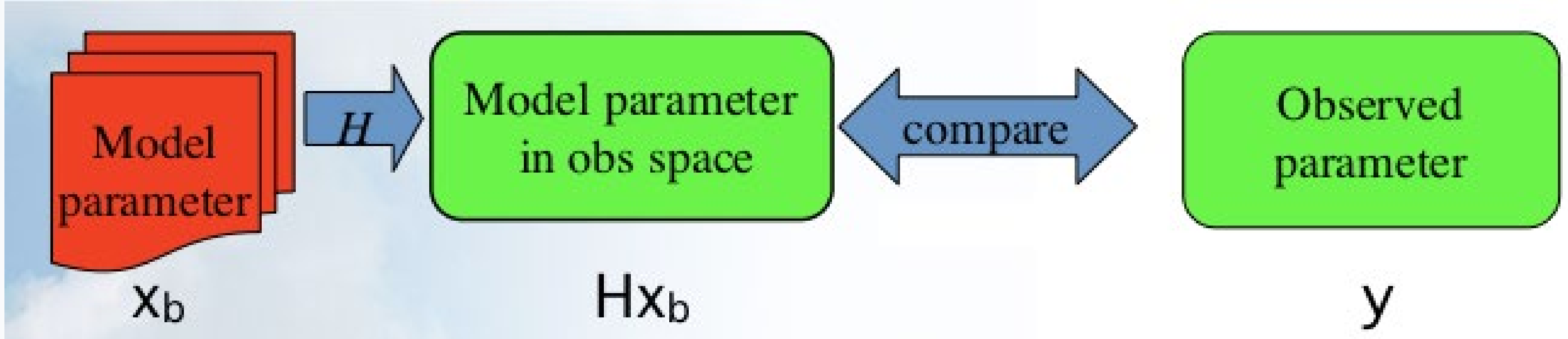
$$= J_b(\mathbf{x}) + J_o(\mathbf{x})$$

Forecast — Observation — Observation Operator

$$\mathbf{x}_a = \mathbf{x}_b + \mathbf{A}(\mathbf{y} - \mathbf{H}\mathbf{x}_b)$$

Analysis — Averaging Kernel

Observation Operator

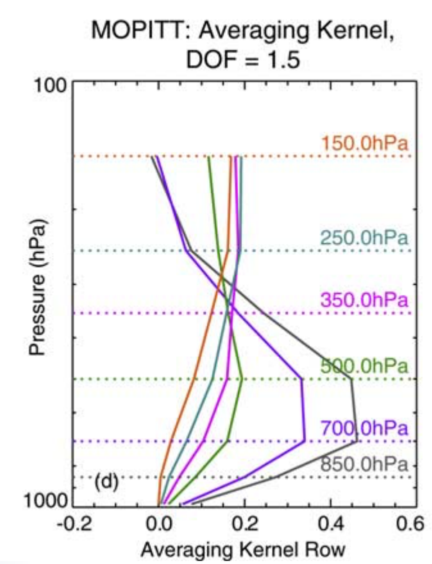


- To assimilate any data, we need a means of directly comparing the model parameter with an observed quantity.
- The observation operator (H) converts a model parameter for comparison against an observation in observation space (i.e., taking into account location, time of day, etc.).
- The simplest form is interpolation from model grid to observation location (e.g., in situ measurements).
  - For satellite observations, it also includes complex transformations based on the physics of the measurement.

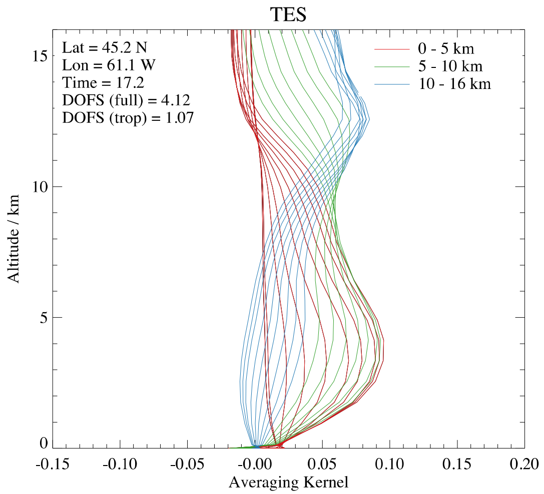
Vertical Sensitivity of Atmospheric Composition Retrievals

Atmosphere Monitoring

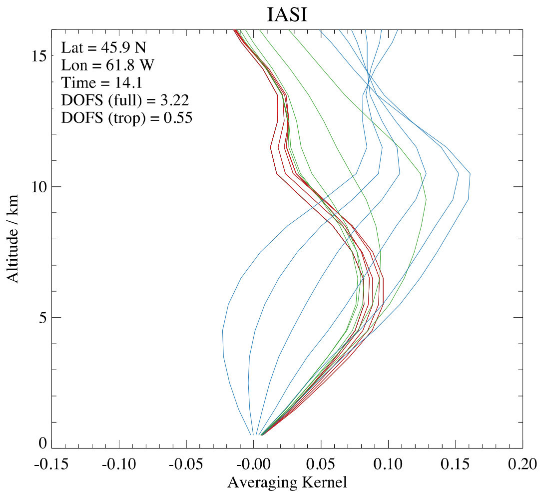
- Averaging kernels provide the information required to directly compare satellite retrievals with models/in situ observations.



MOPITT CO



TES O_3



IASI O_3

- Data assimilation into NWP models redistributes atmospheric composition observations to provide vertical information.

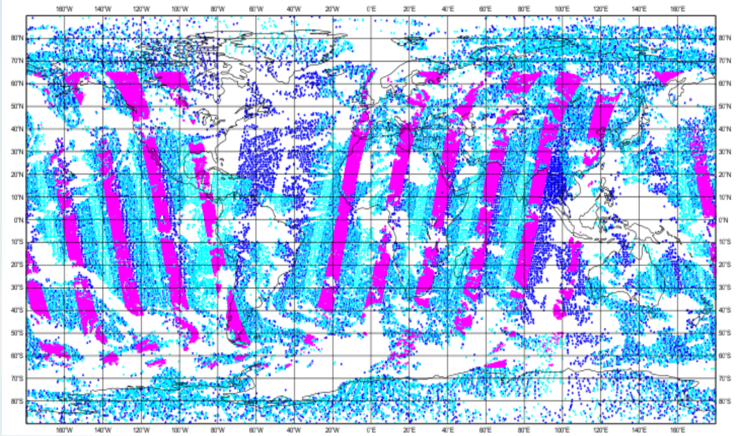
Copernicus Europe's eyes on Earth

European Commission

Atmosphere Monitoring

Assimilated Reactive Gases in CAMS Real-Time System

CO

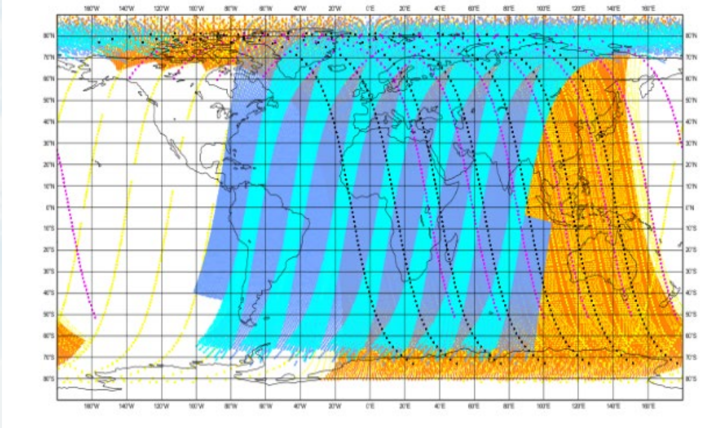


IASI Metop-A

IASI Metop-B

MOPITT TERRA

O3



GOME-2 Metop-A

GOME-2 Metop-B

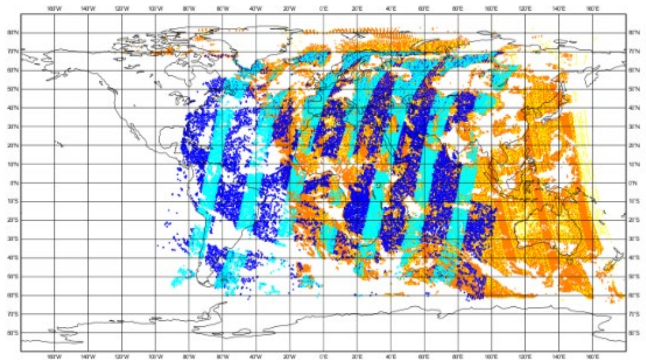
OMI, MLS AURA

TROPOMI S5P

OMPS SNPP

SBUV/2 NOAA-19

Tropospheric NO2



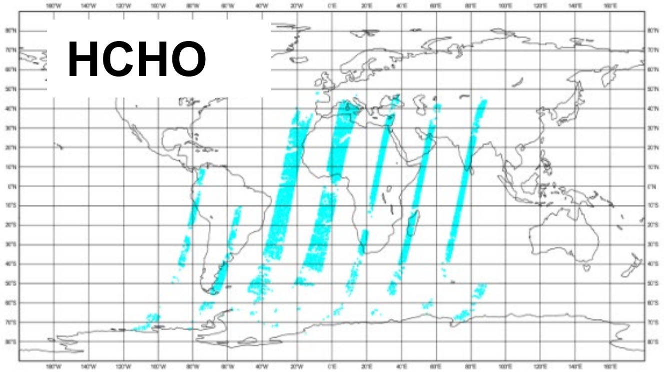
OMI AURA

TROPOMI S5P

GOME-2 Metop-A

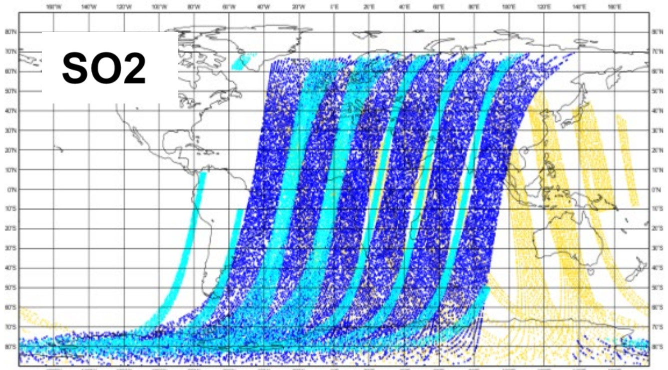
GOME-2 Metop-B

HCHO



GOME-2 Metop-A

SO2



OMI AURA

GOME-2 Metop-A

GOME-2 Metop-B

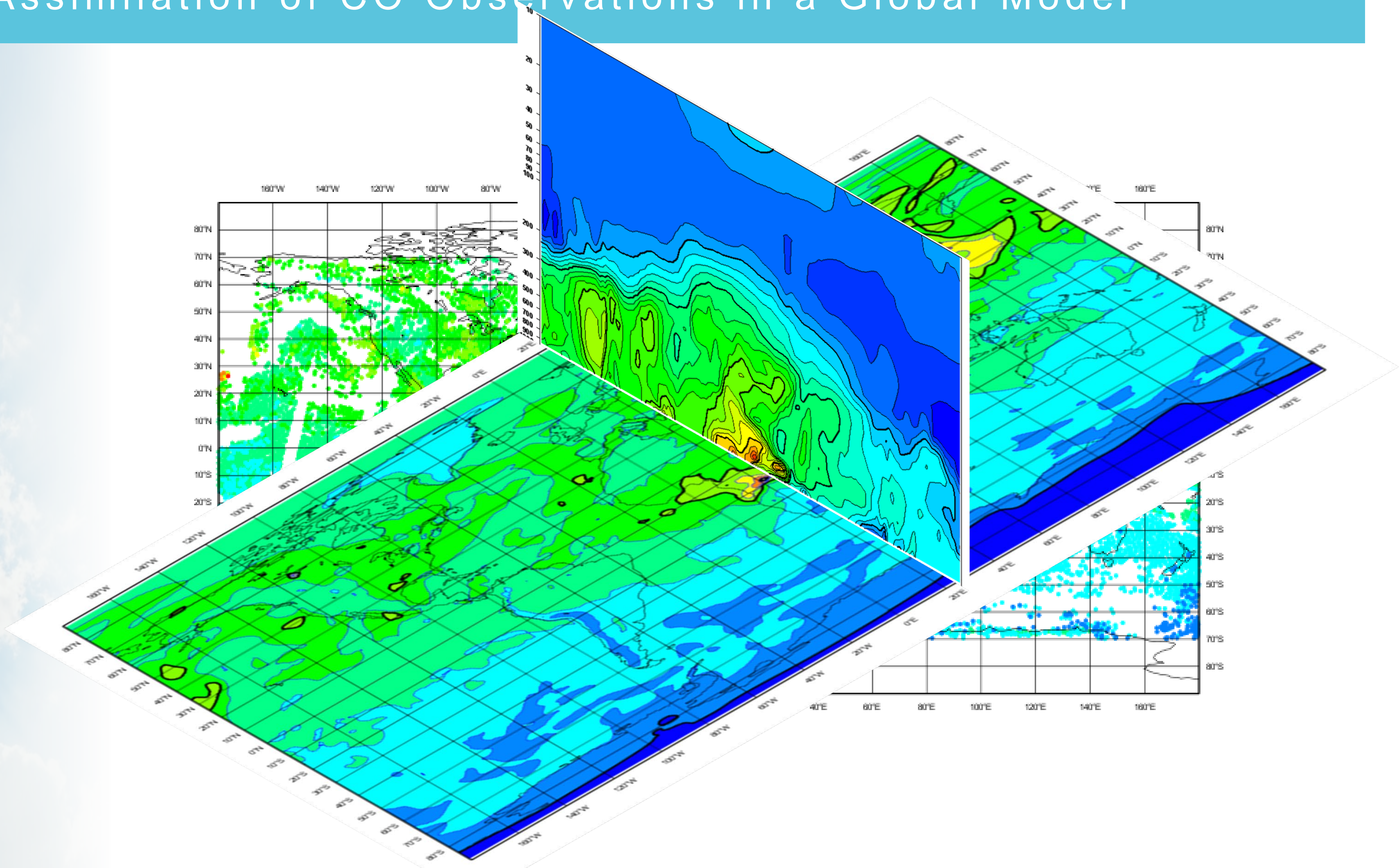
Assimilated

Monitored

https://atmosphere.copernicus.eu/satellite-observations

Atmosphere
Monitoring

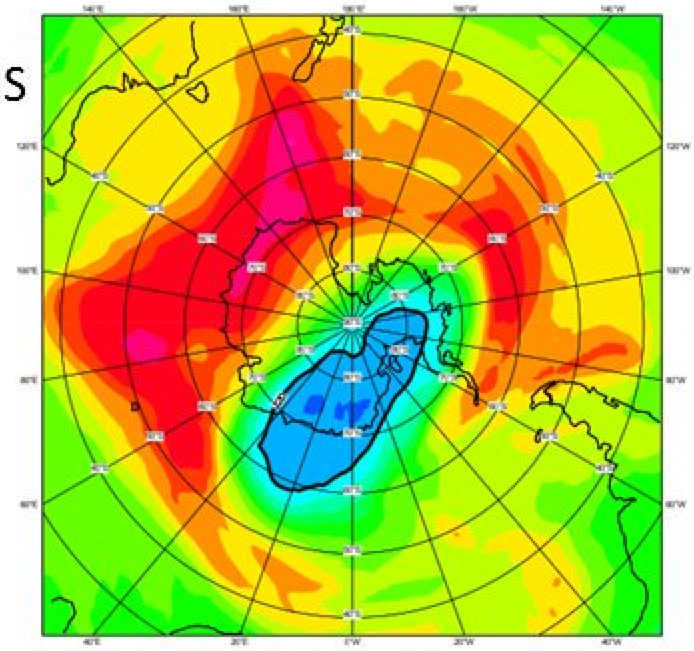
Assimilation of CO Observations in a Global Model



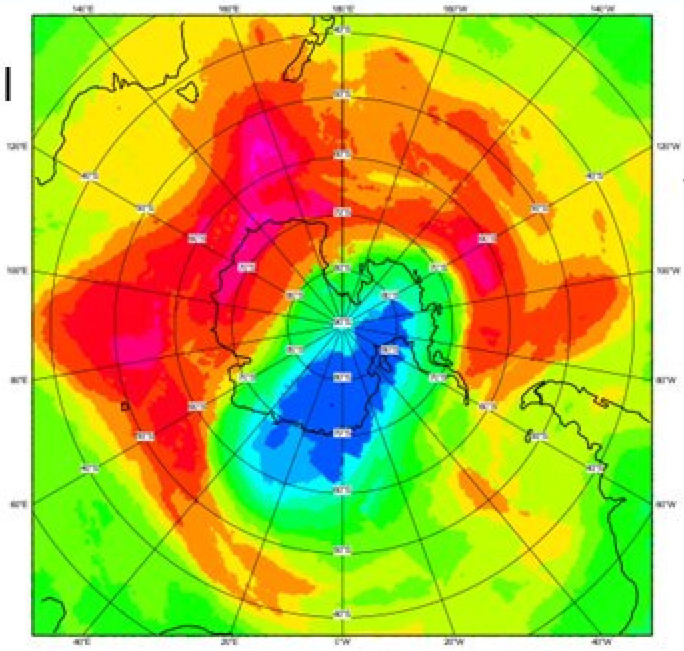
Carbon monoxide (CO) is a tracer of combustion sources.

Total column O3 on 20191020 from CAMS, TROPOMI, OMI & GOME-2AB

CAMS

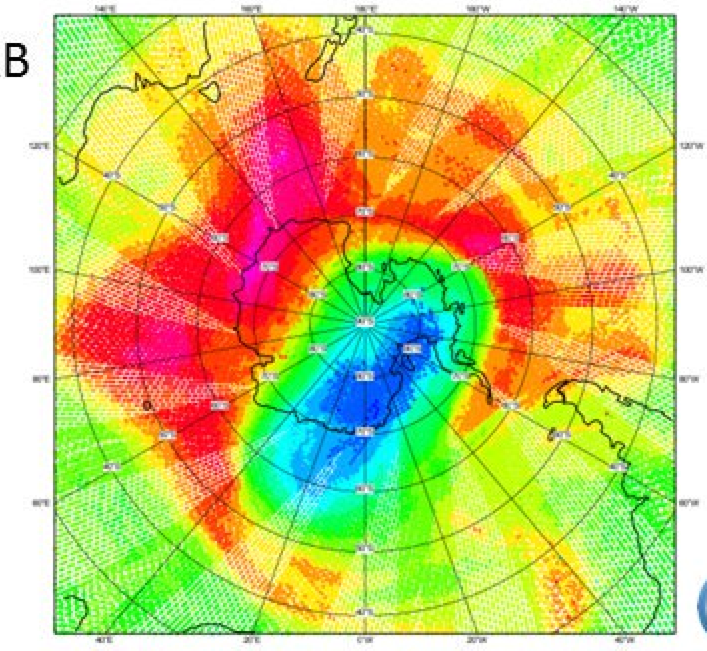


TROPOMI

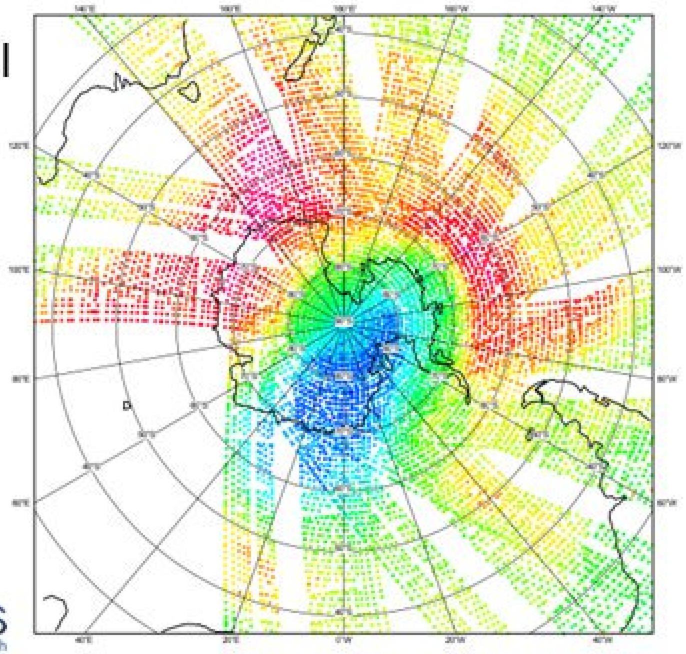


Shown are all total column satellite data available for the CAMS ozone analysis (some at are not assimilated, e.g. at low solar elevations)

GOME-2AB



OMI

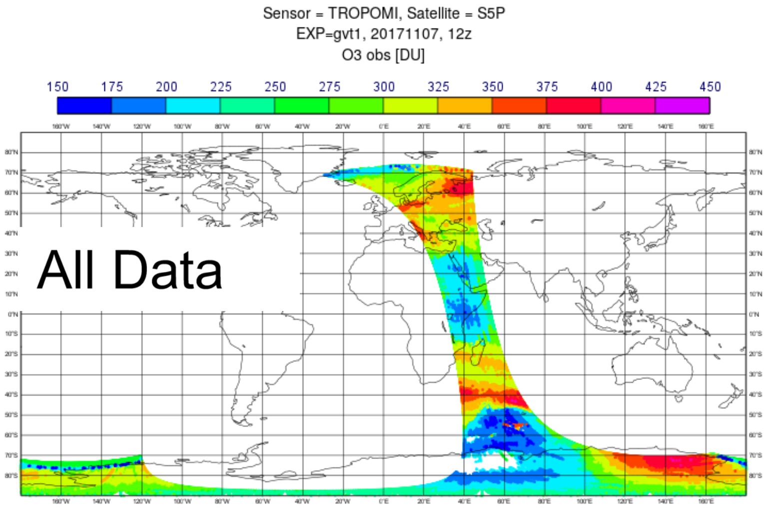


Atmosphere Monitoring

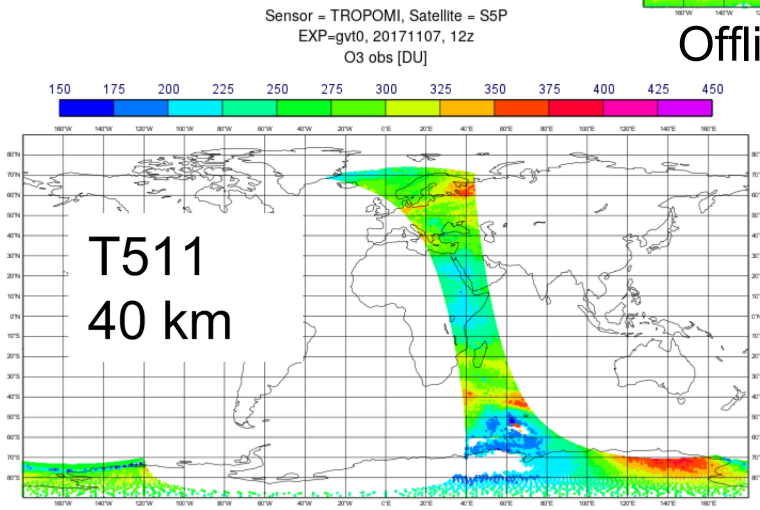
Super-Obbing

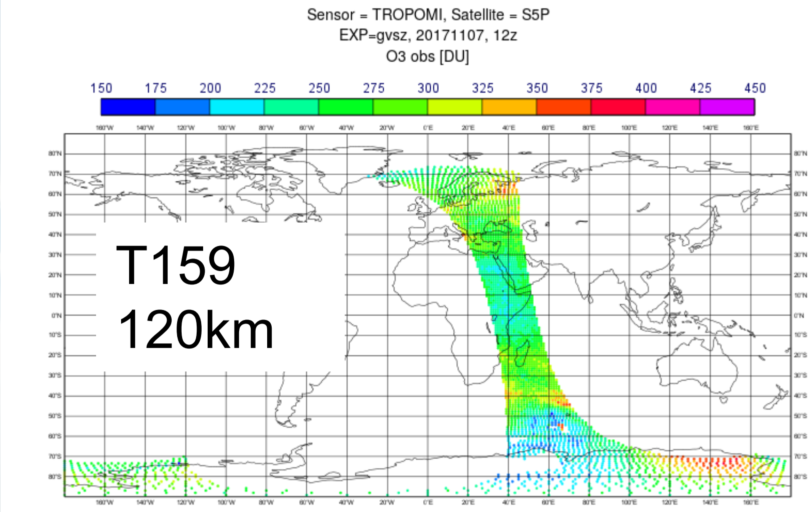
- S5P data volume is a challenge.
- Data Resolution: 7 km x 7 km
- Model Resolution: 40 km x 40 km
- Resolution of Minimisations:
  - 120 km x 120 km
  - 210 km x 210 km
- For other atm. composition data we randomly thin the data.
- We need to thin the data in a clever way.
- Super-Obbing

TROPOMI O3



Offline Data from ODA1 Server

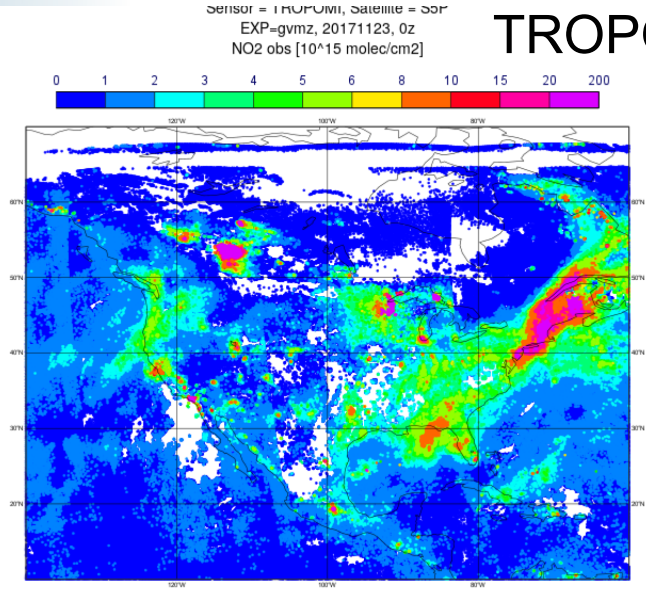




Atmosphere Monitoring

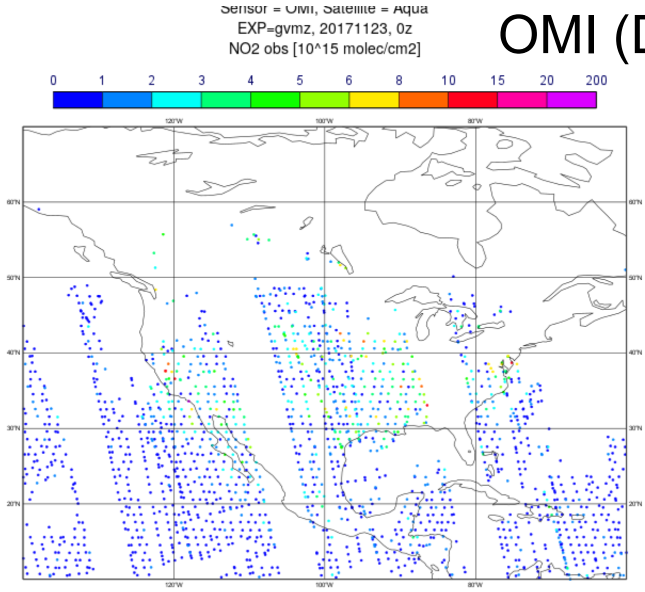
Example NO2 Coverage on 20171123, 0z

TROPOMI (All)

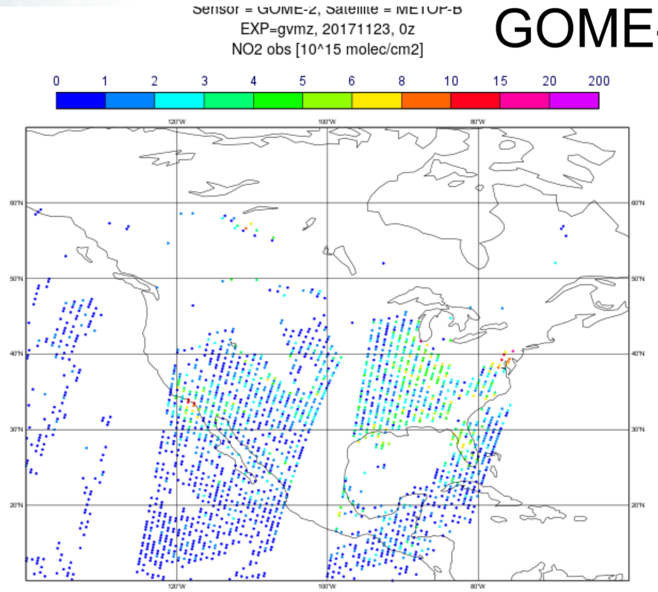


Test data provided by Henk Eskes (KNMI)

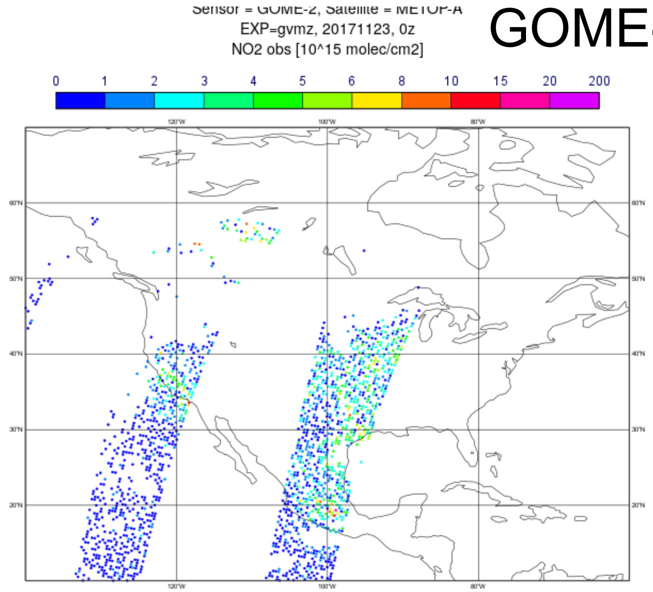
OMI (DOMINO-V2)



GOME-2B (GDP v4.8)



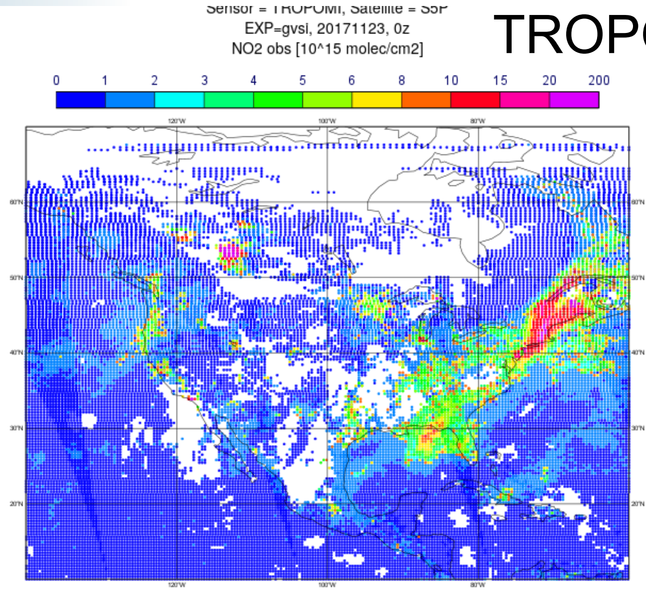
GOME-2A (GDP v4.8)



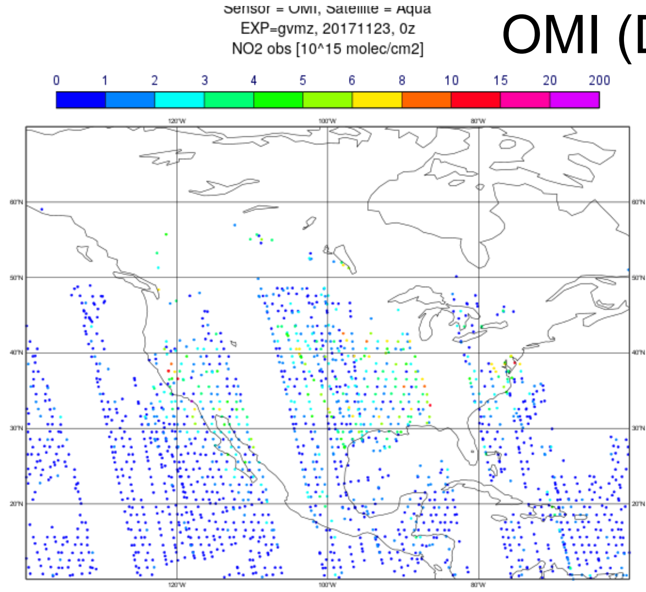
GOME-2 and OMI thinned to 0.5º x 0.5º

Example NO2 Coverage on 20171123, 0z

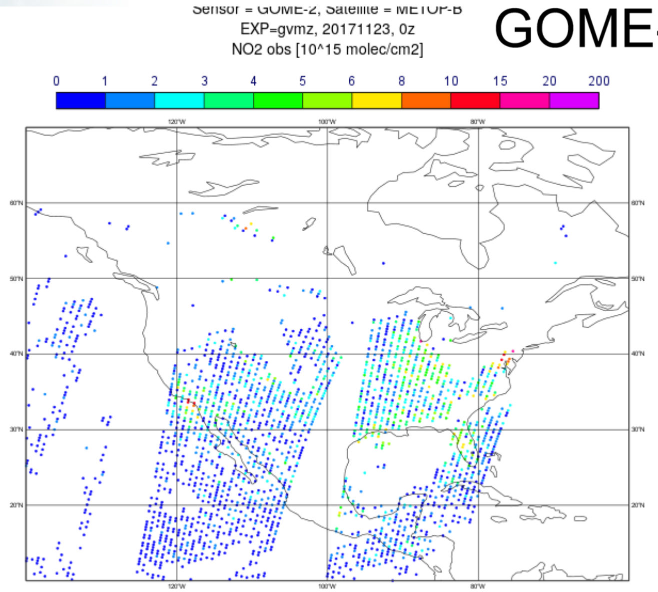
TROPOMI (T511)



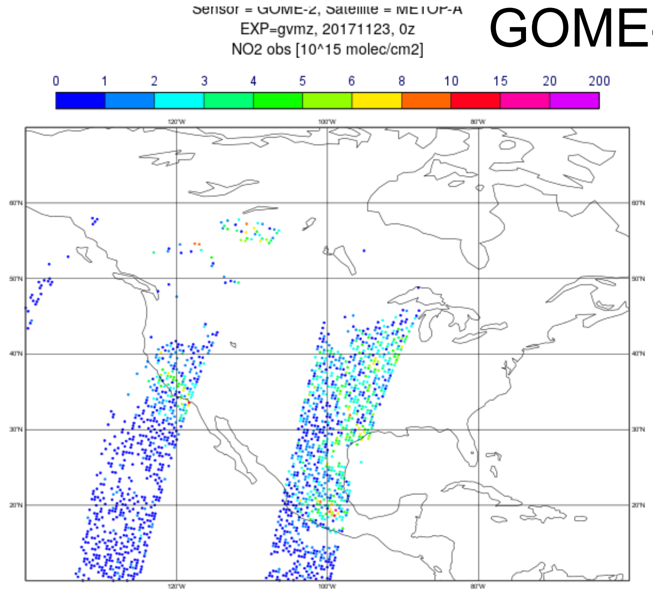
OMI (DOMINO-V2)



GOME-2B (GDP v4.8)



GOME-2A (GDP v4.8)



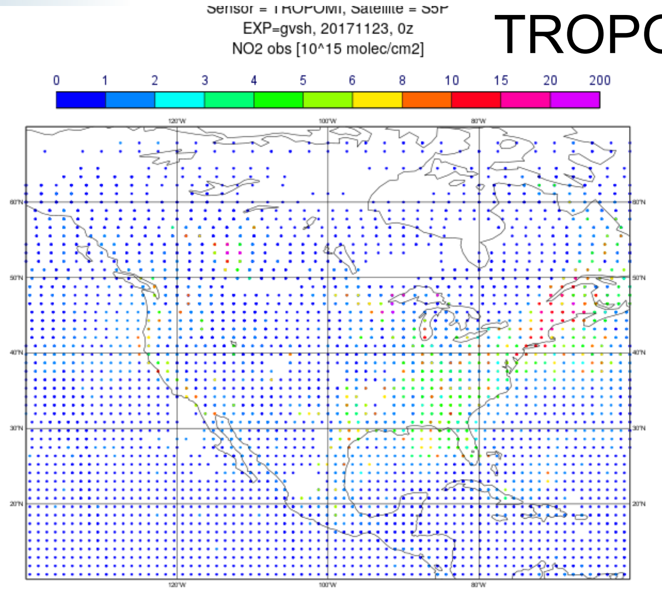
GOME-2 and OMI thinned to 0.5º x 0.5º

Atmosphere Monitoring

Atmosphere Monitoring

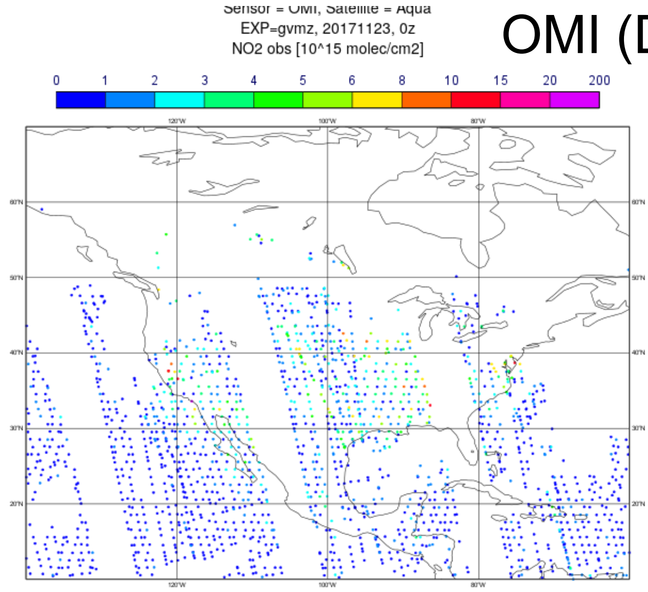
Example NO2 Coverage on 20171123, 0z

TROPOMI (T159)

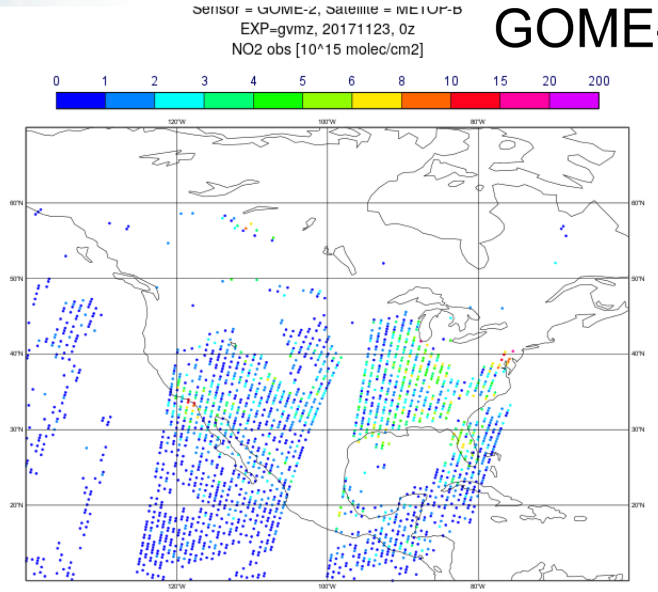


Even at T159, super-obbing the coverage is better than what we currently have.

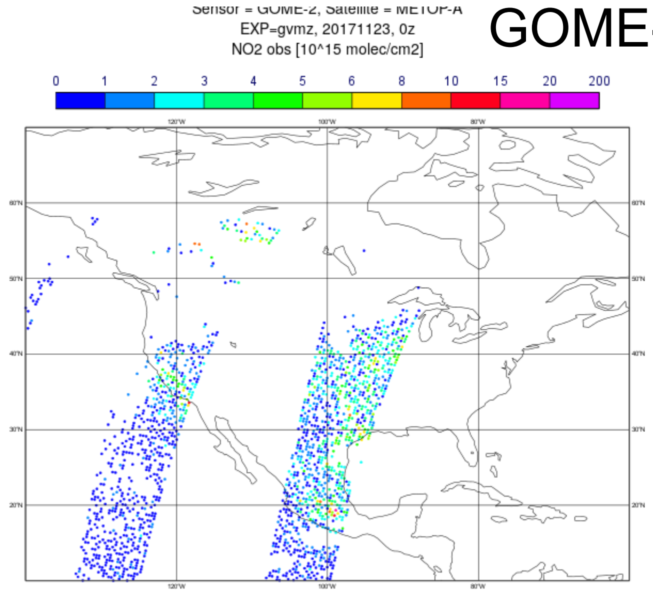
OMI (DOMINO-V2)



GOME-2B (GDP v4.8)



GOME-2A (GDP v4.8)

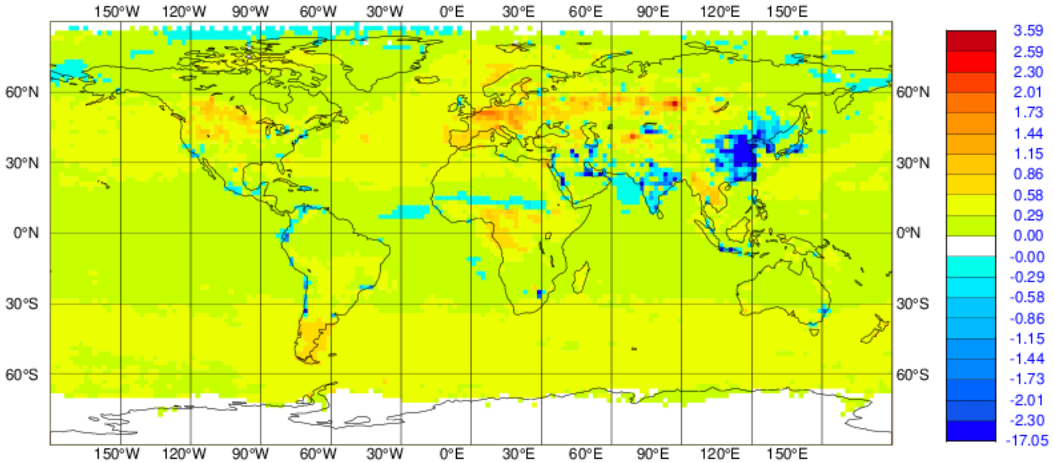


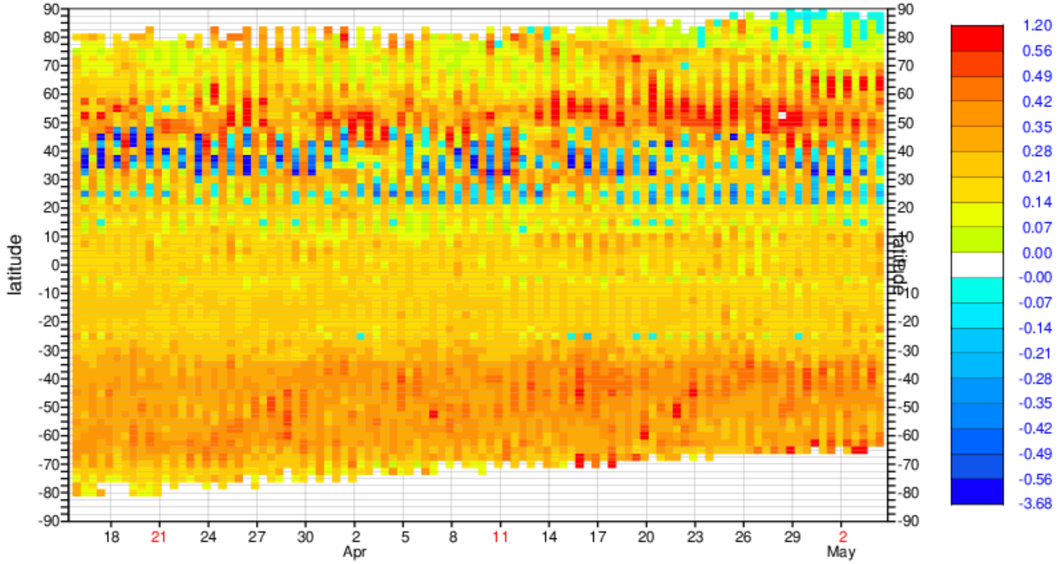
GOME-2 and OMI thinned to 0.5º x 0.5º

Atmosphere Monitoring

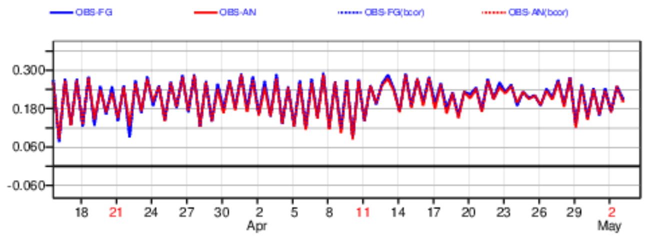
NRT Observation Monitoring: Example of S5P NO_2

First guess (observation minus model) departures, 31 March to 1 May, 2021, shown as maps and hovmoeller plots highlight differences between model and observed values.

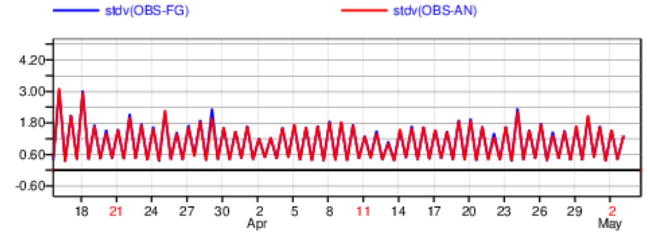




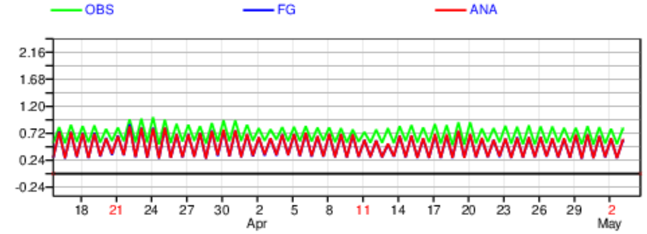
Time series' of monitoring statistics allow us to assess the relative performance of the observations (vs. consistent model) over time.



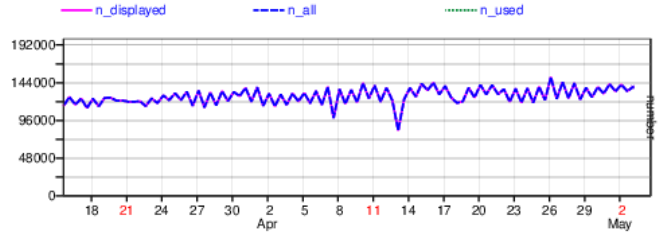
Departures
Obs – First Guess
Obs – Analysis



Standard Deviations
Obs – First Guess
Obs – Analysis



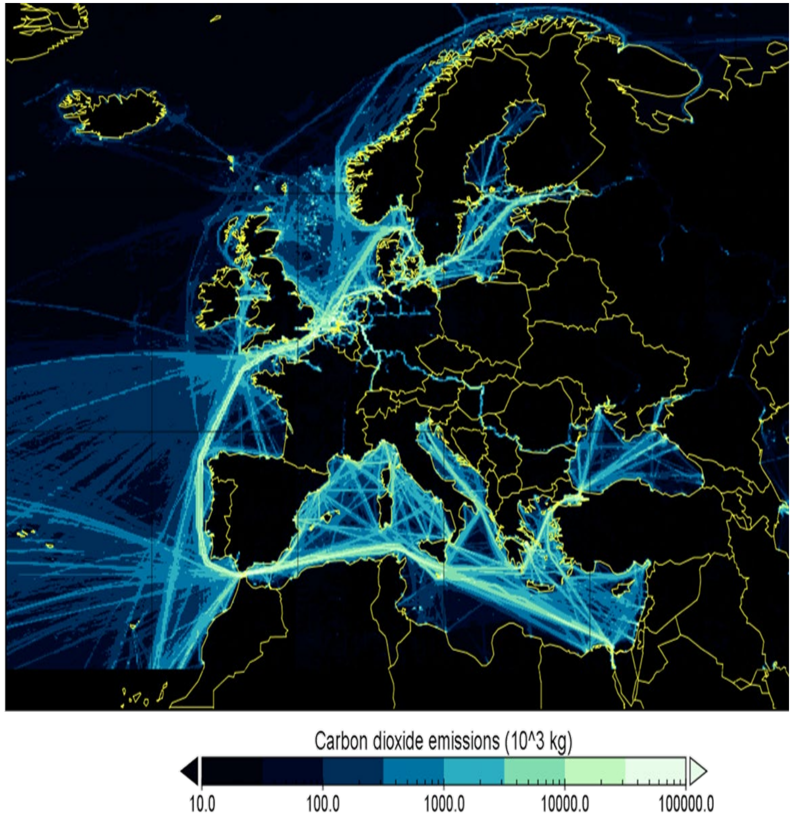
Values
Obs
First Guess
Analysis

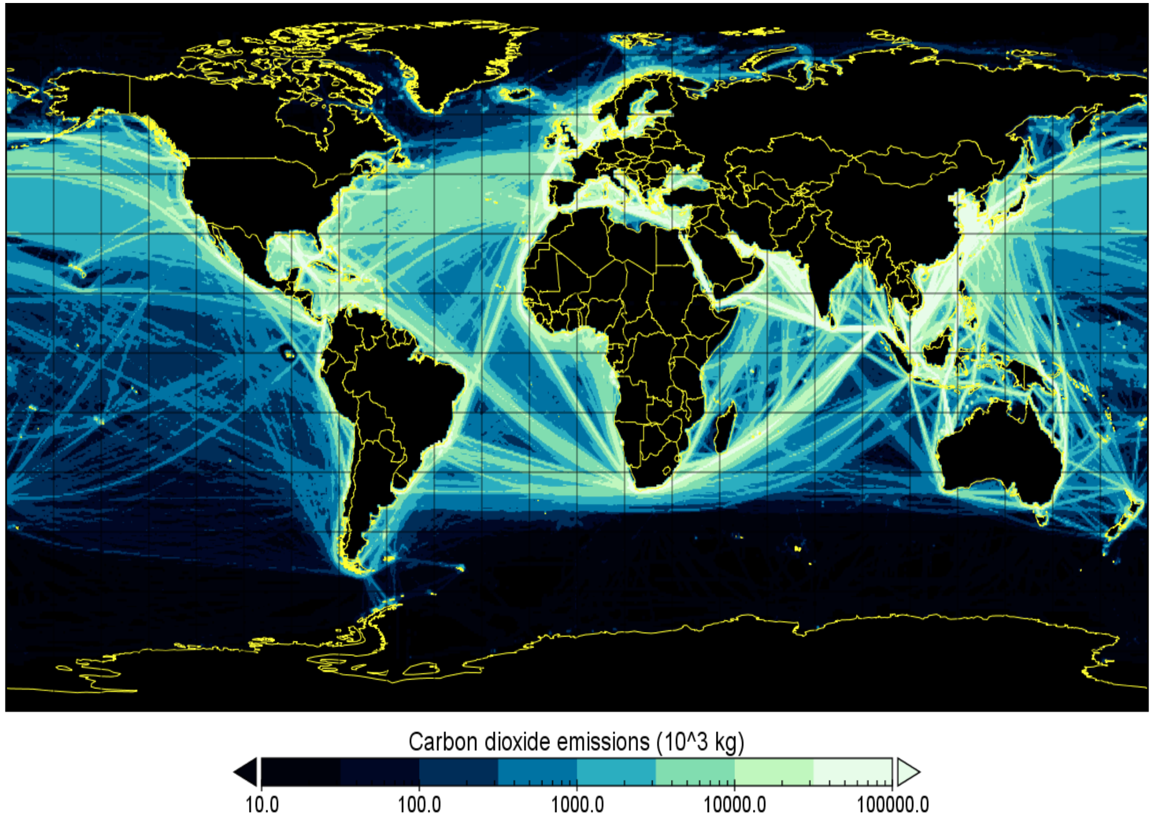


Number of Calues
Displayed
All
Used

https://atmosphere.copernicus.eu/charts/cams_monitoring/

CAMS EMISSIONS INVENTORIES (BOTTOM UP)





Emissions are both an input to CAMS global and regional systems and a popular product. New datasets have been produced covering 2003 to 2020 (extrapolation). Example: CO_2 emissions from shipping activities (Provider: FMI, Finland).

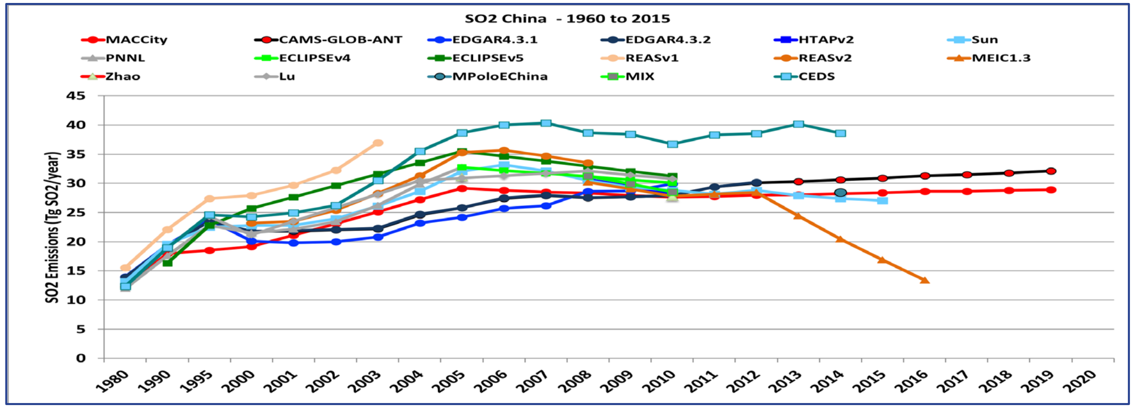
ECMWF

(Granier et al., doi 10.24380/d0bn-kx16)

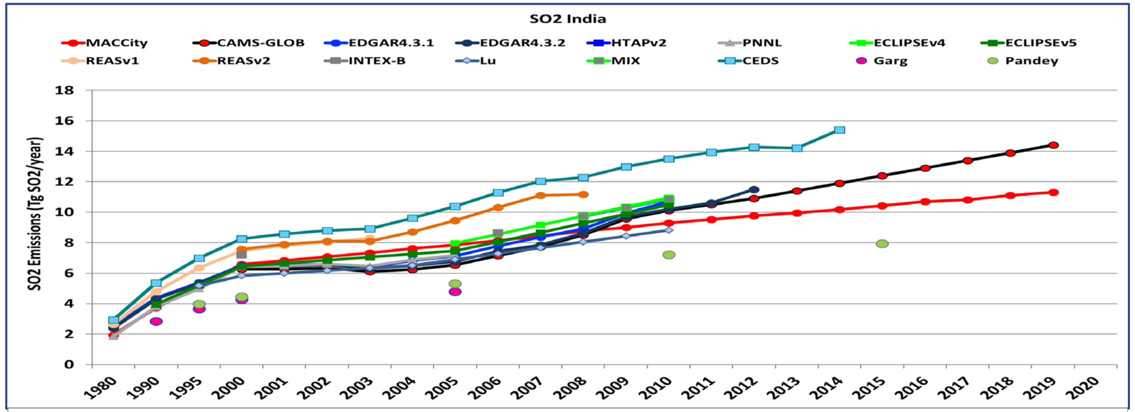
CAMS Emissions Inventories

Atmosphere Monitoring

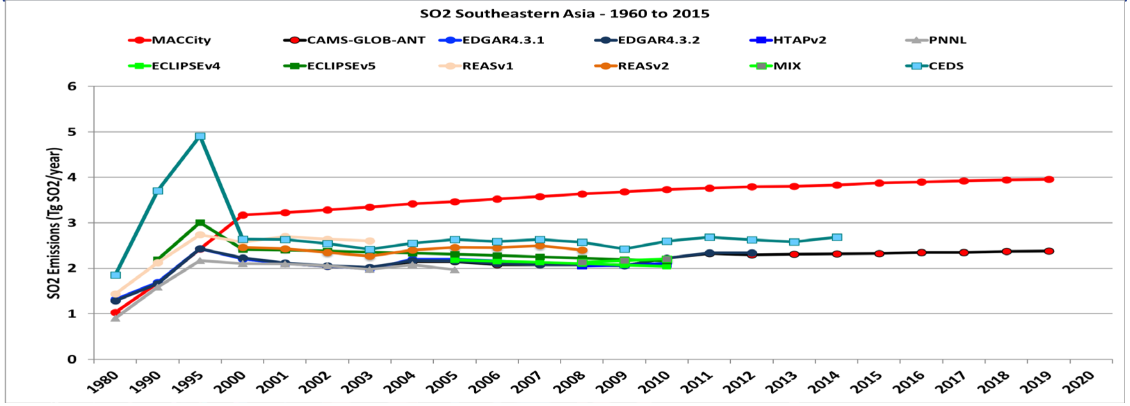
SO_2 China



SO_2 India



SO_2 SE Asia

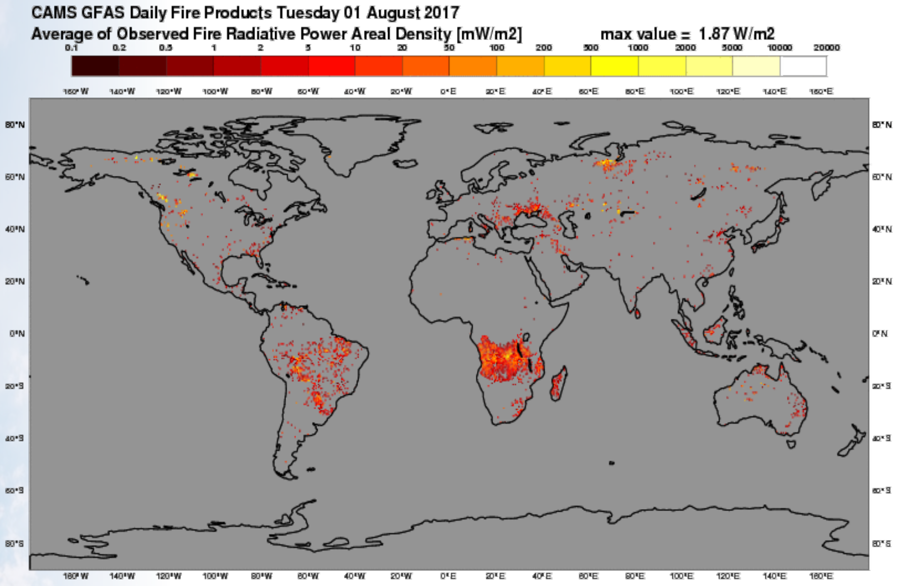


- Global emissions inventories for anthropogenic, biogenic, shipping, volcanic outgassing, soil NO
  - Geographical and sectoral temporal profiles
- Regular updates to include, e.g., specific information on regional (including China, India, & SE Asia) emissions
- Public releases and documentation available via CAMS Atmosphere Data Store
  - https://ads.atmosphere.copernicus.eu/

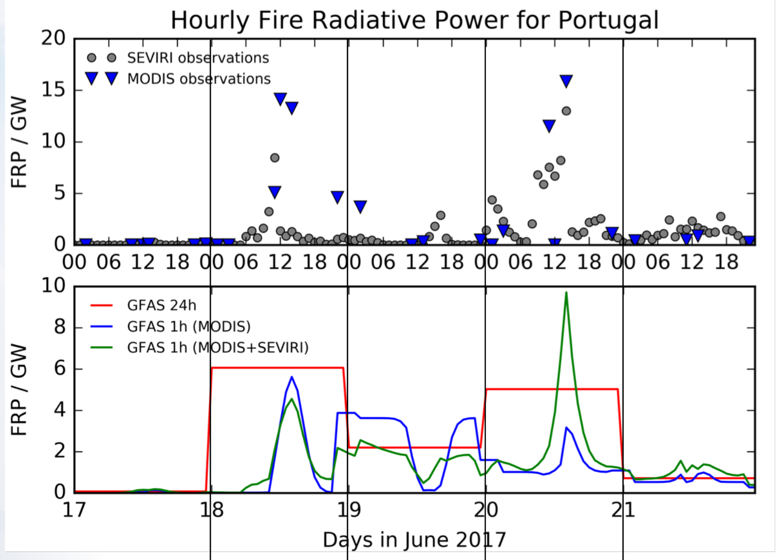
ECMWF Copernicus Europe's eyes on Earth European Commission

Atmosphere Monitoring

Estimating Global Wildfire Emissions in CAMS



Hourly GFAS Data



- Global Fire Assimilation System (**GFAS**); see http://apps.ecmwf.int/datasets/data/cams-gfas/
- Uses satellite observations of Fire Radiative Power (FRP)
  - Currently Aqua and Terra MODIS FRP observations
  - FRP from VIIRS, Sentinel-3, and geostationary satellites are being tested for future implementation
- Global Coverage at ~10km Resolution
  - *Daily Output: 1-day behind NRT*
  - Hourly Output (+24-h means): 7-hours behind NRT
- Emissions of aerosols and gases are estimated using factors dependent on vegetation type.
- Injection heights calculated with Plume Rise Model and IS4FIRES

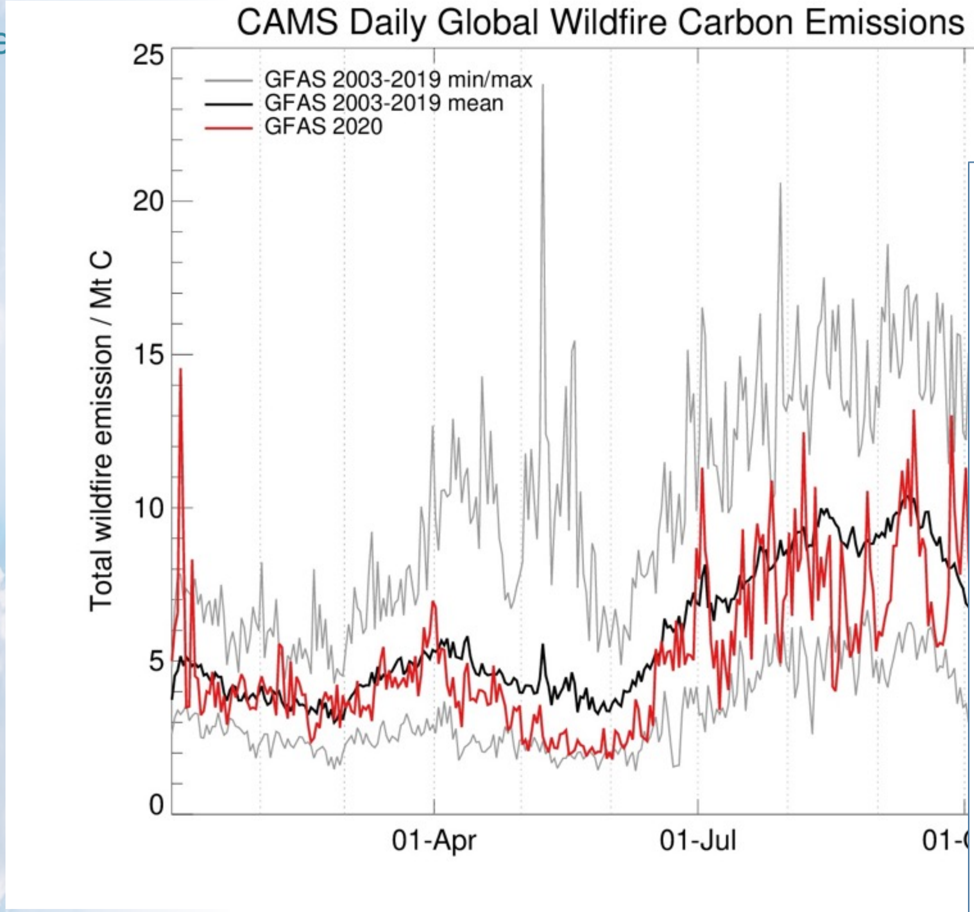
ECMWF Copernicus Europe's eyes on Earth European Commission

Atmosphere Monitoring

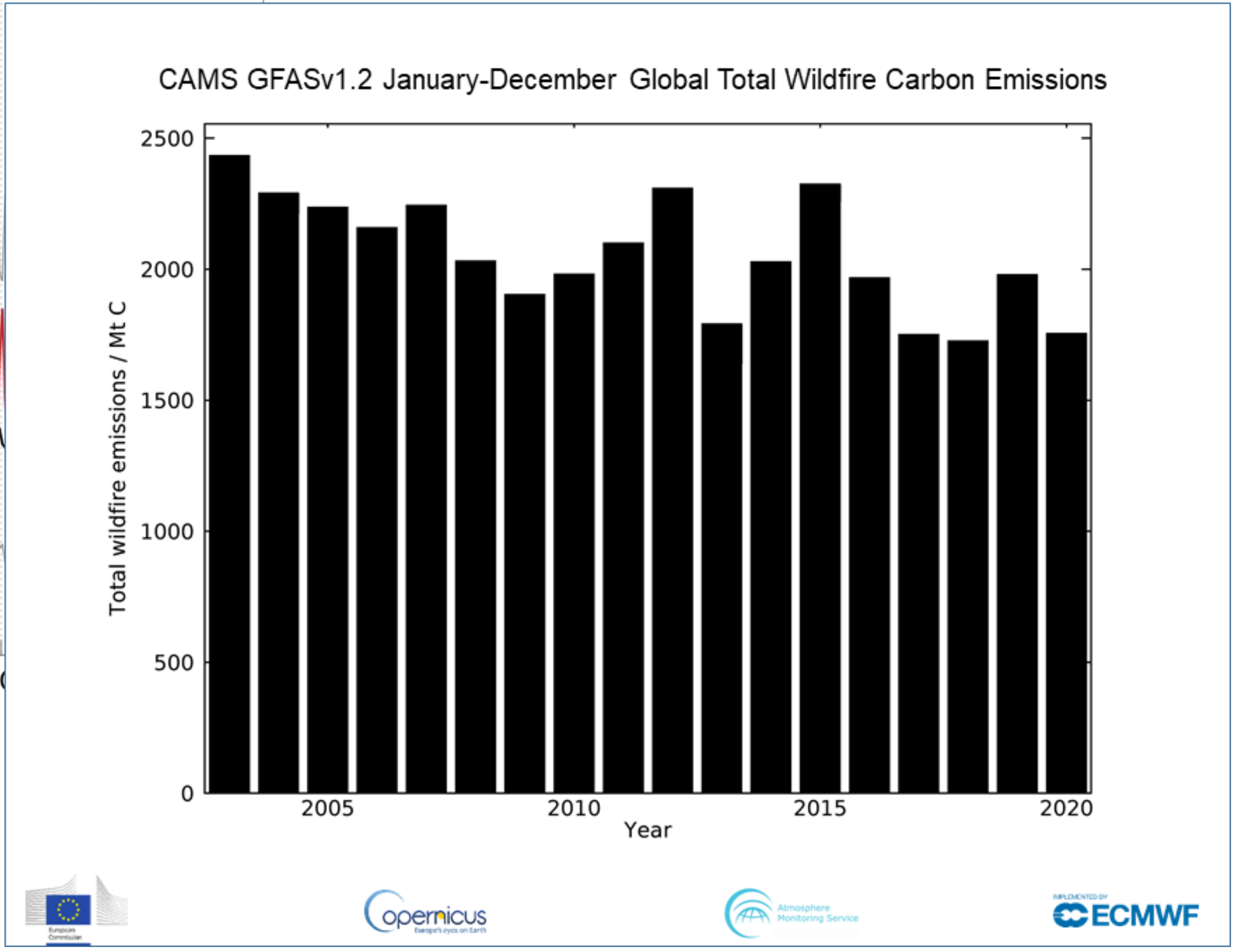
Global Wildfires in 2020

https://atmosphere.copernicus.eu/index.php/how-wildfires-americas-and-tropical-africa-2020-compared-previous-years

Global Wildfire Activity and Emissions



Estimated emissions reflect the scale and intensity of active fires.

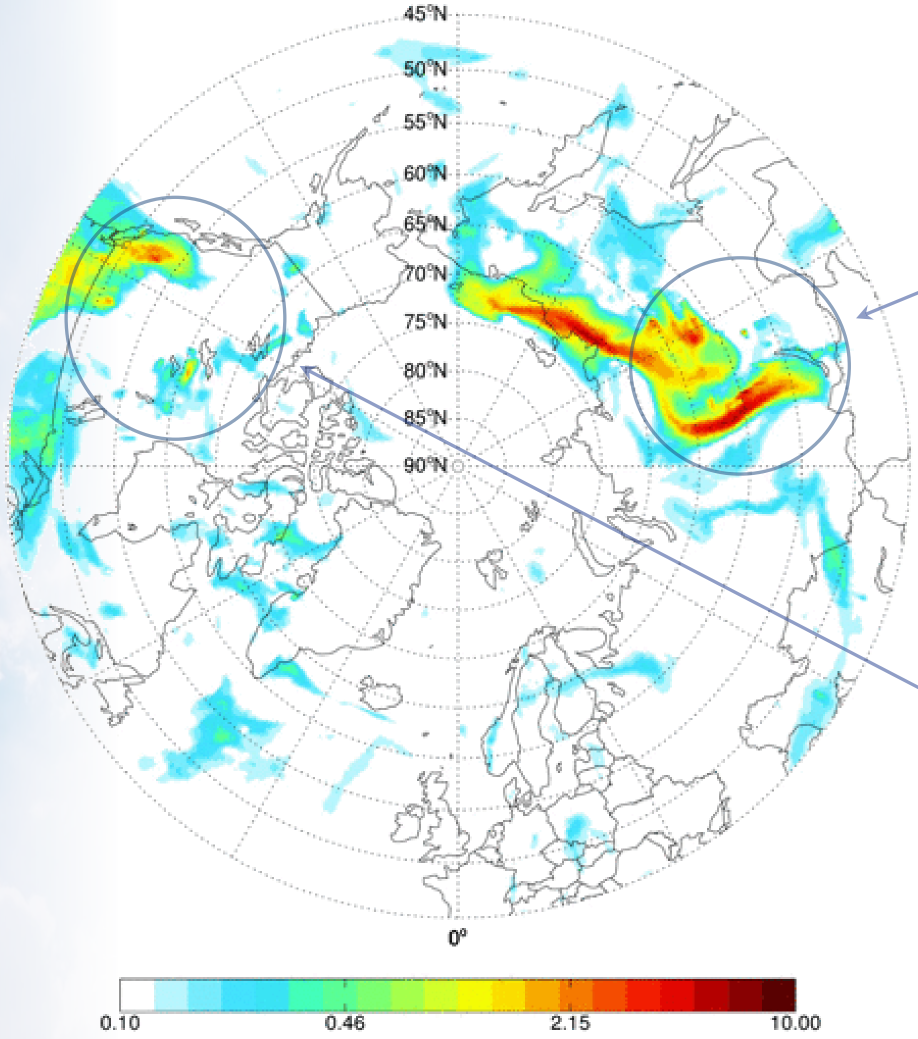


- Radiative energy of fires can be observed by satellites and can be used to estimate emissions of pollutants.
- 2020 was generally an average year for wildfire activity at the global scale.
- However, there was notable activity in the Arctic Circle and Siberia, parts of the Amazon, Western US, and Australia.

Boreal Fires and Long-Range Transport, August 2017

Atmosphere Monitoring

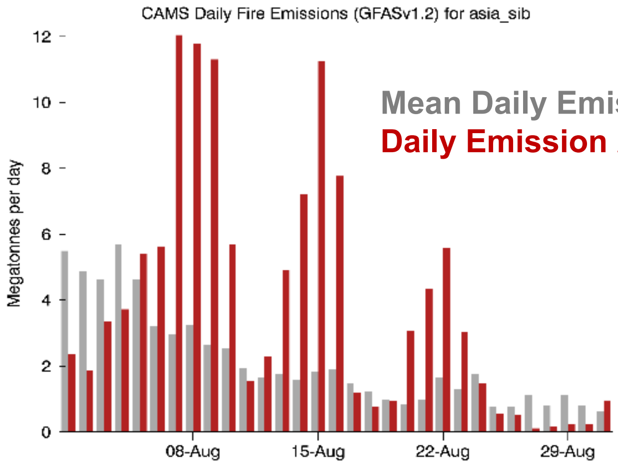
CAMS Analysis Organic Matter AOD at 550nm: 20170810, 00z



Fires in Siberia

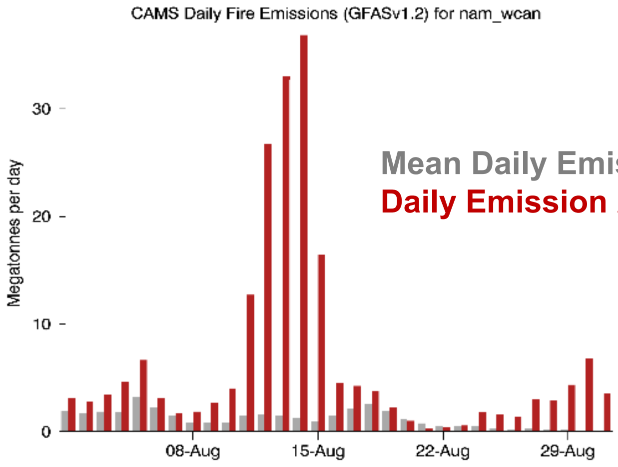
Fires in Canada

CAMS Daily Fire CO_2 Emissions (GFASv1.2)



Mean Daily Emission 2003-2016

Daily Emission 2017



Mean Daily Emission 2003-2016

Daily Emission 2017

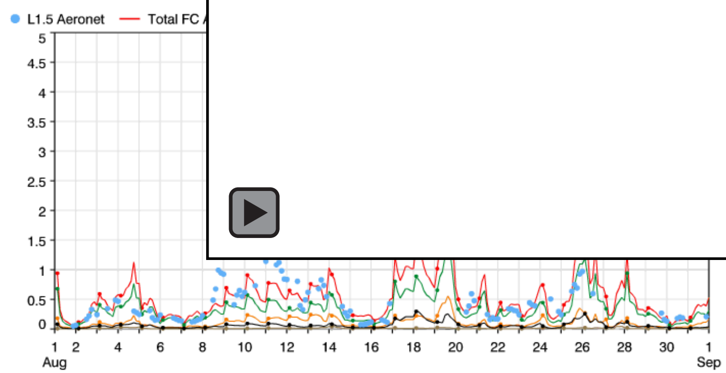
ECMWF Copernicus Europe's eyes on Earth European Commission

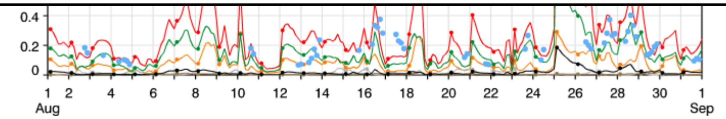
Atmosphere Monitoring

Long-Range Transport of Boreal Fire Emissions, August 2018

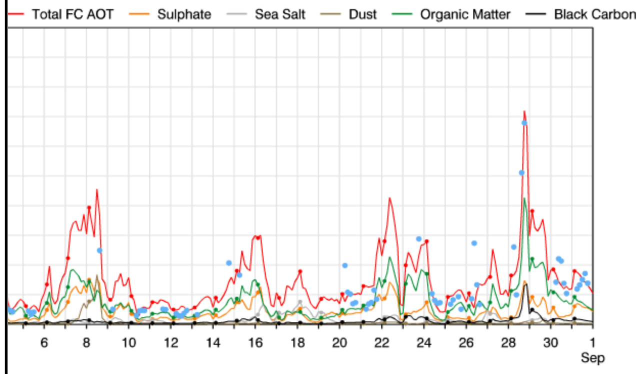
eading to significant

monitored by CAMS and

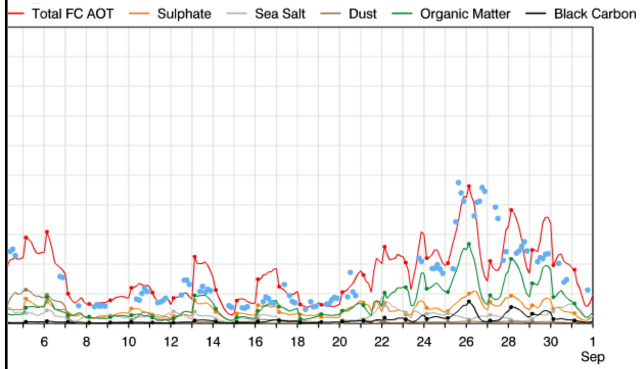




Birkenes, Norway



Graciosa, Azores

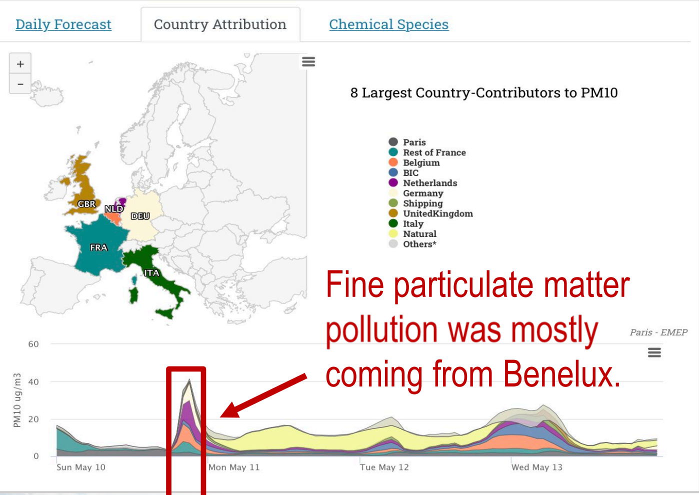


ECMWF Copernicus Europe's eyes on Earth European Commission

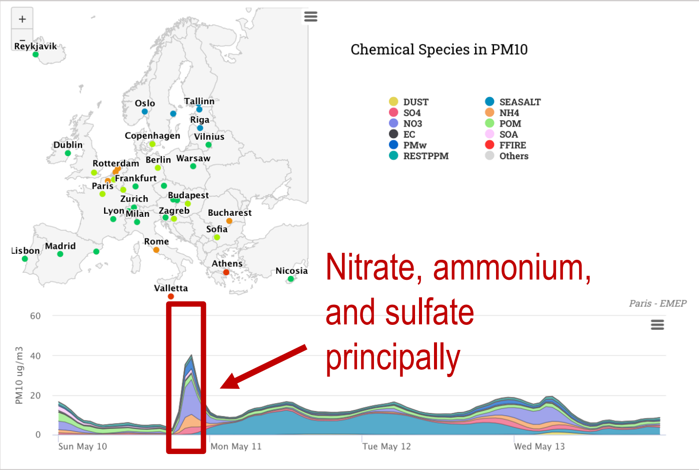
CAMS in Action: European Air Quality

Atmosphere Monitoring

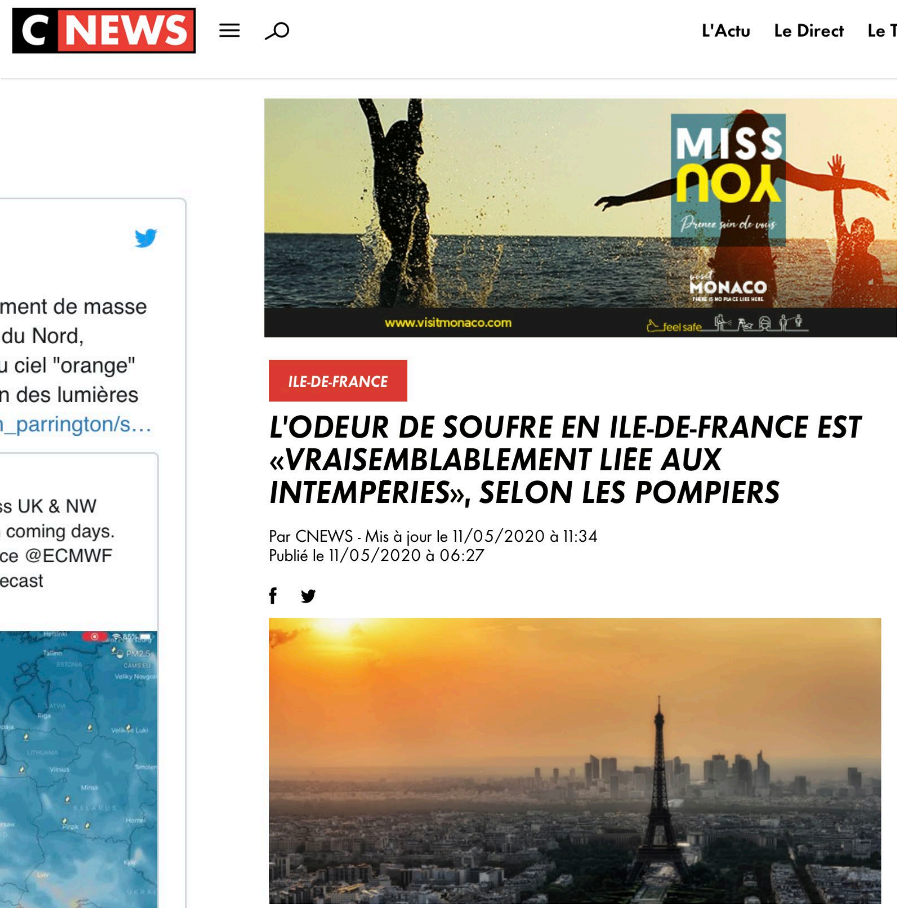
On the evening of Sunday, May 10, strong sulphurous smells were experienced in the Paris area. CAMS was used to bring the first insights about the situation.



Fine particulate matter pollution was mostly coming from Benelux.



Nitrate, ammonium, and sulfate principally



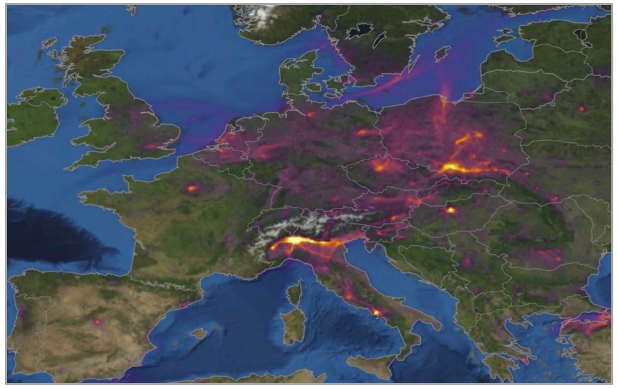
https://policy.atmosphere.copernicus.eu/DailySourceAllocation.php

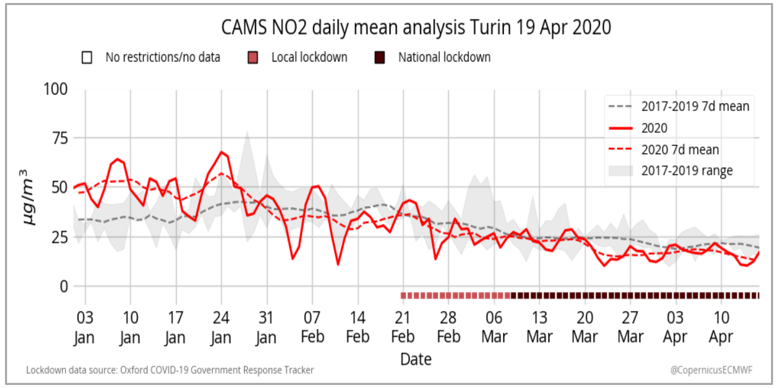
CAMS in Action: CAMS COVID-19 Minisite

Atmosphere Monitoring

https://atmosphere.copernicus.eu/european-air-quality-information-support-covid-19-crisis

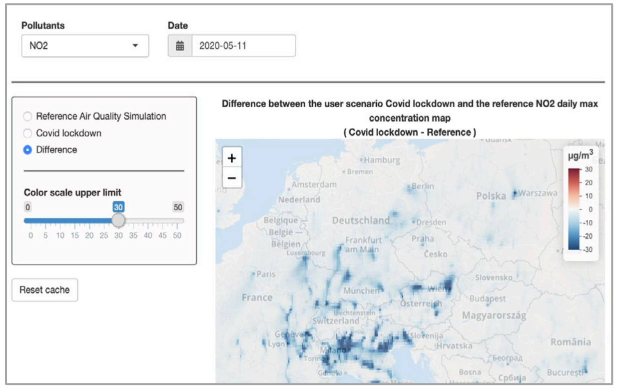
Maps and animations of the latest situation in Europe

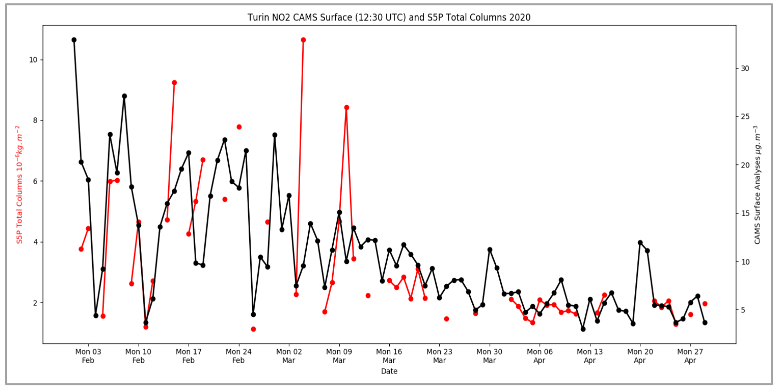




Air pollution across Europe compared to 2017-2019 and as a function of lockdown measures

Forecast model estimate of reduction in air pollution is expected on a daily basis, accounting for weather effects.





How consistent are surface and satellite measurements?

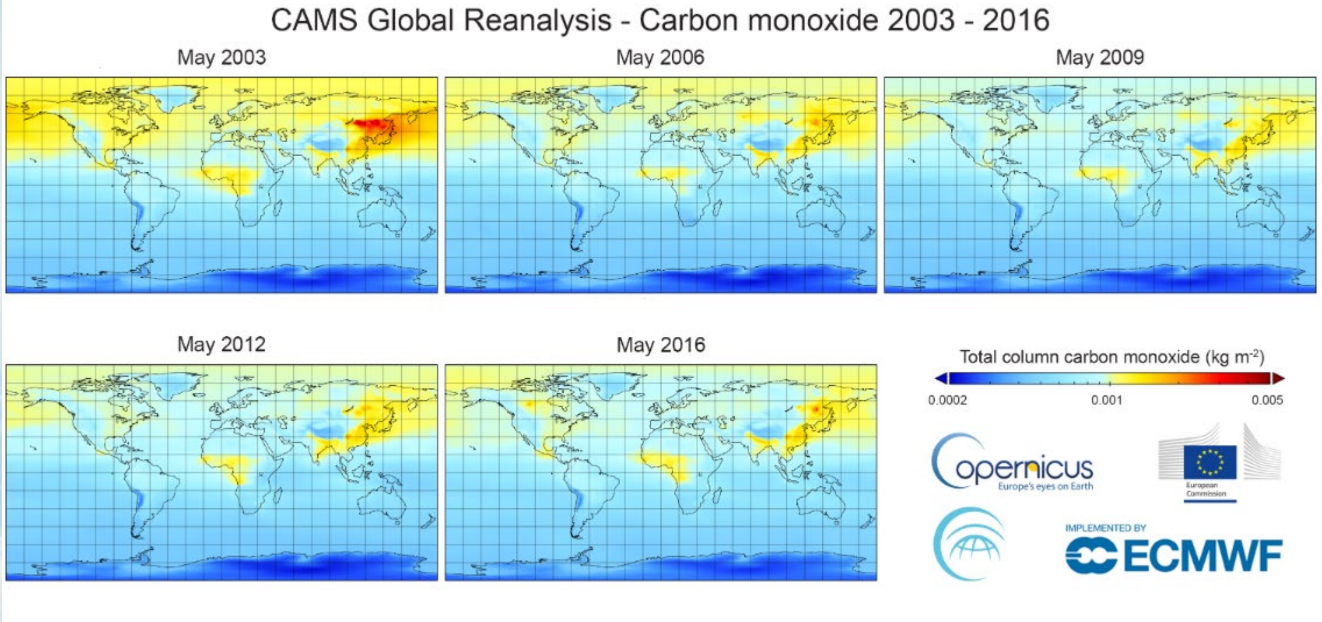
CAMS currently contributes to a number of epidemiological studies trying to evaluate the links between air pollution and COVID-19 (effects of long- and short-term exposure; fine particulate matter as a potential vector in air for the virus?...).

CAMS regional air quality forecasts: Météo-France, Ineris (FR)
CAMS COVID-19 scenario forecasts: Ineris (FR)
CAMS website: ECMWF

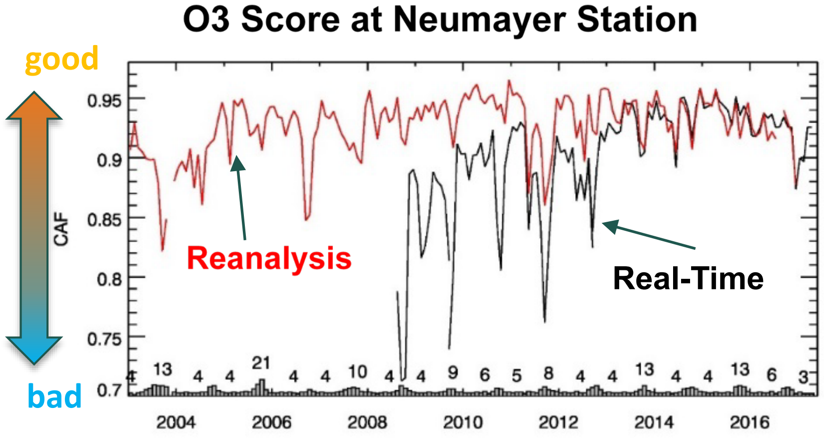
CAMS Global Reanalysis 2003 – 2020 (Updated Yearly)

Atmosphere Monitoring

https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-global-reanalysis-eac4



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

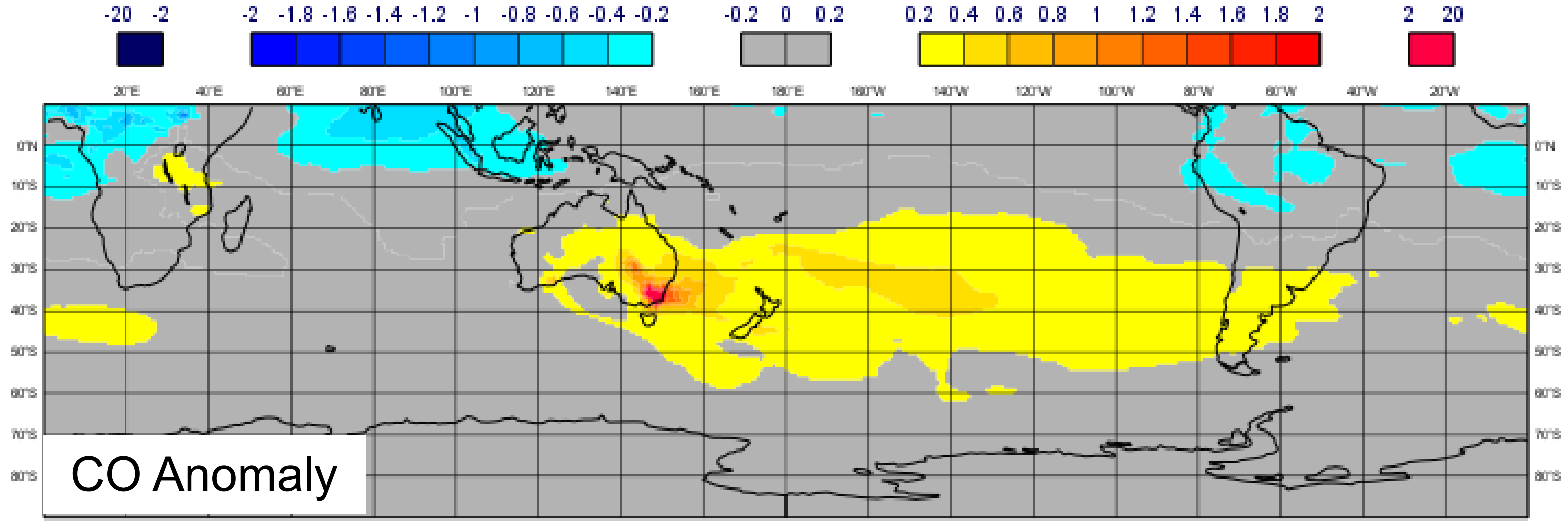


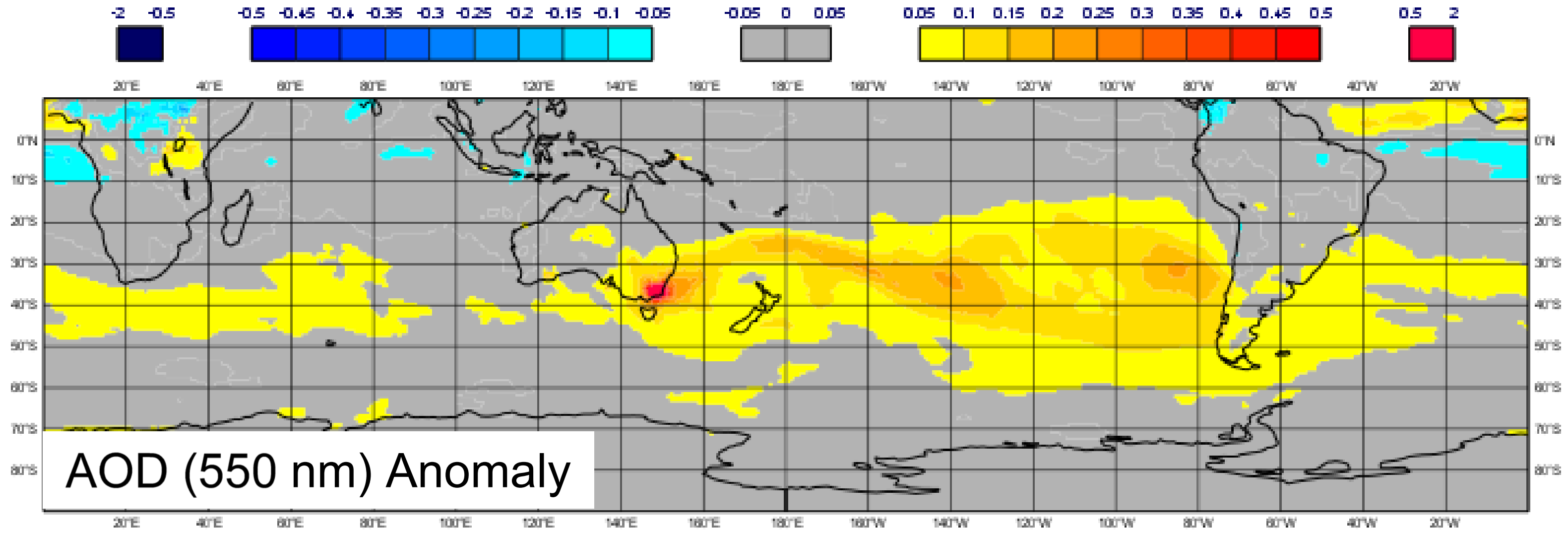
CAMS Global Reanalysis:

- 2003 – 2020, with new years being added
- Aerosols, 13 chemical pollutants, CO_2 & CH_4
- 80 km spatial resolution
- Inness et al. 2019, https://doi.org/10.5194/acp-19-3515-2019

Atmosphere Monitoring

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

ECMWF Copernicus Europe's eyes on Earth European Commission

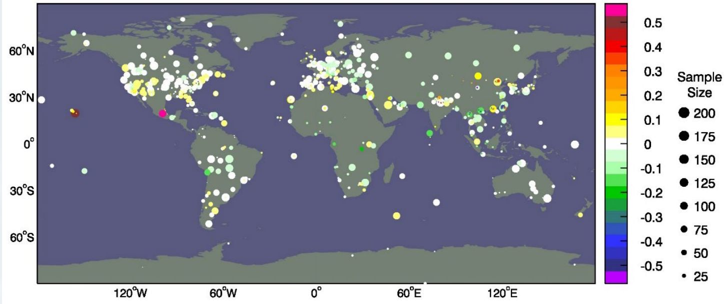
Now and Back to 2003

Atmosphere Monitoring

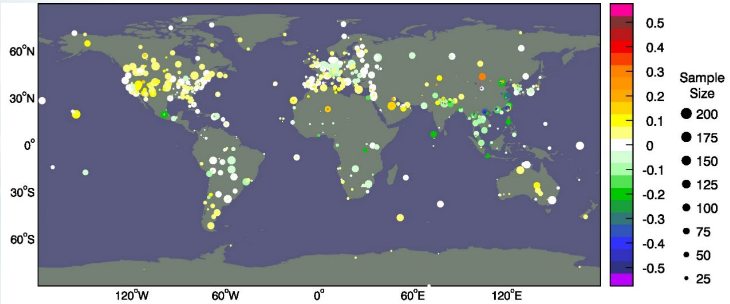
The **CAMS global reanalysis** covers the period from 2003 to the end of 2017 (2018 available soon). It is a marked improvement over our previous datasets (**MACC reanalysis** and **CAMS interim reanalysis**).

Evaluation of Aerosol Optical Depth

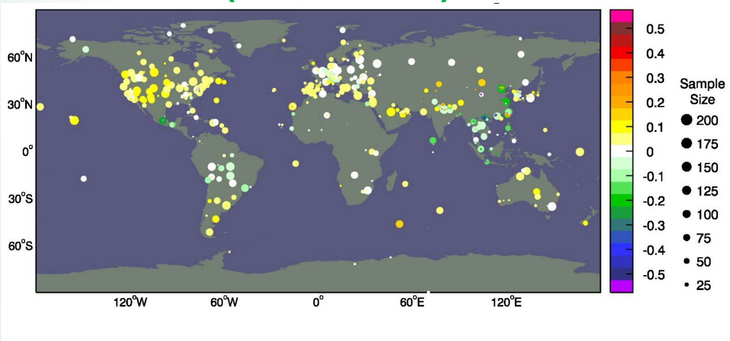
CAMSRA (2003-2016)



CIRA (2003-2016)

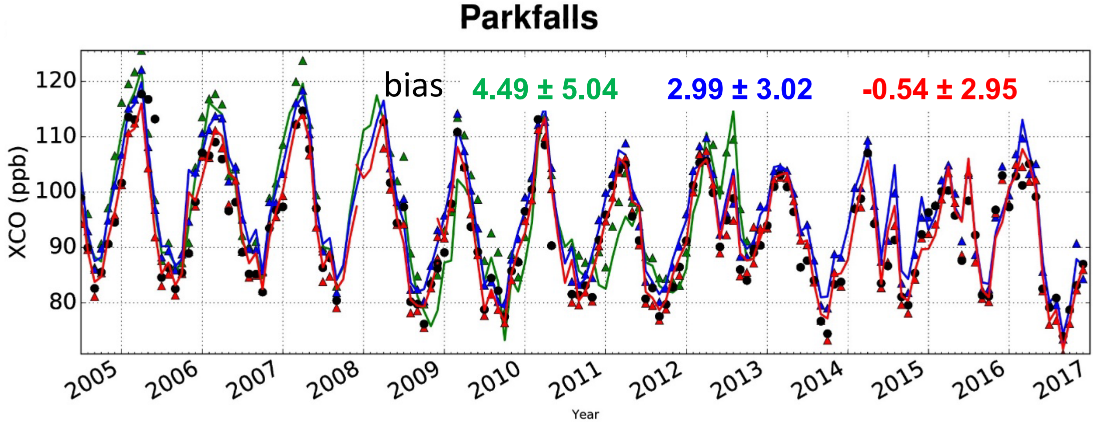


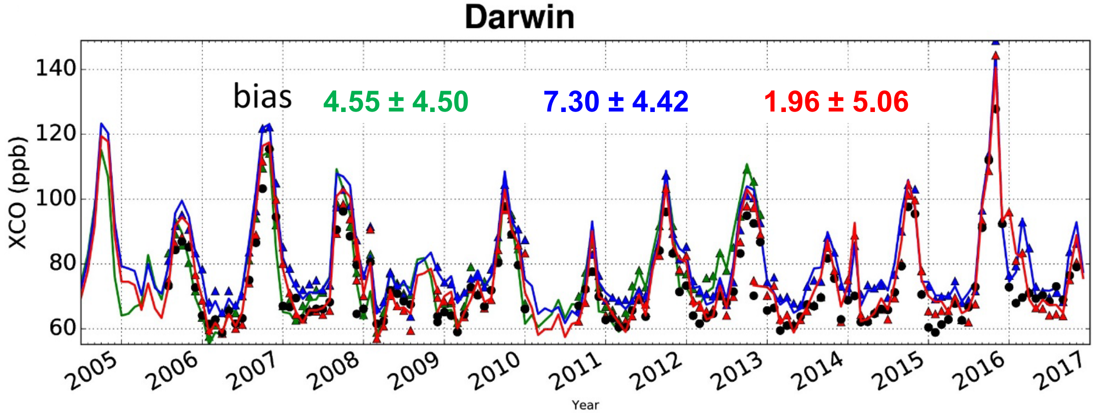
MACCRA (2003-2012)



Evaluation of Total Column CO

TCCON total carbon column observing network

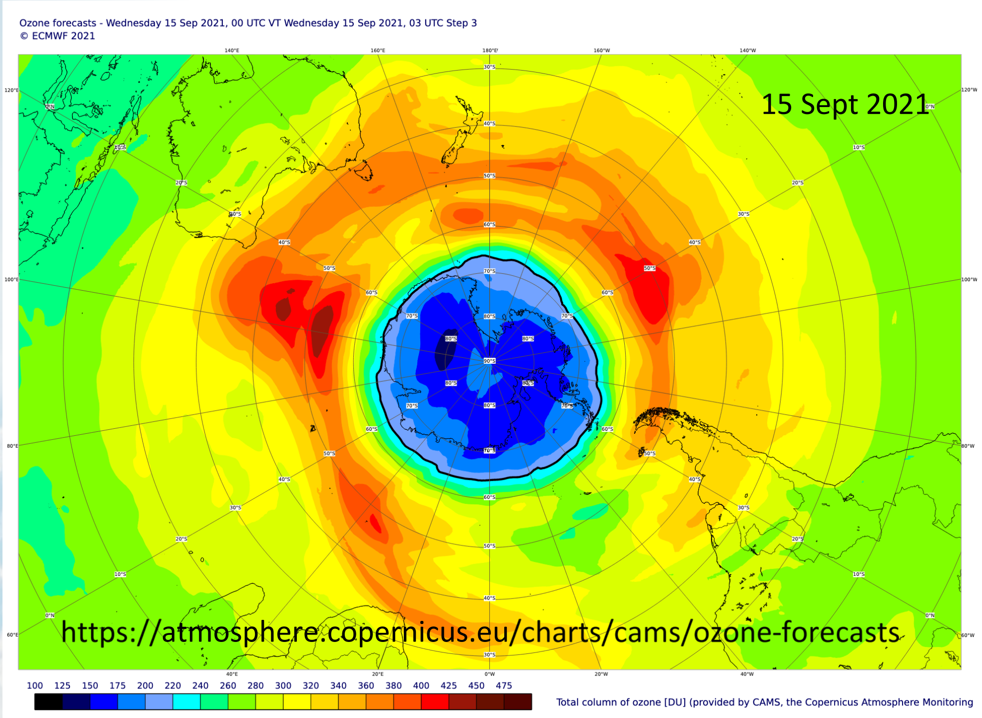


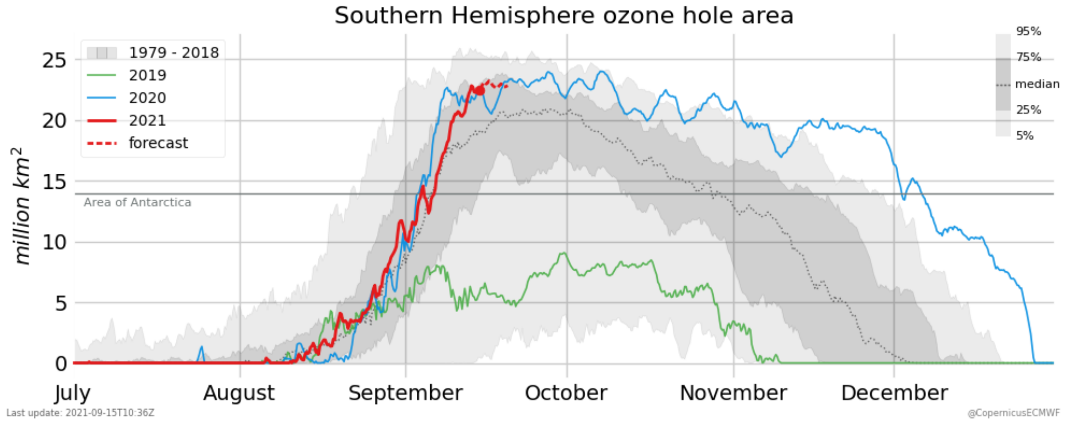


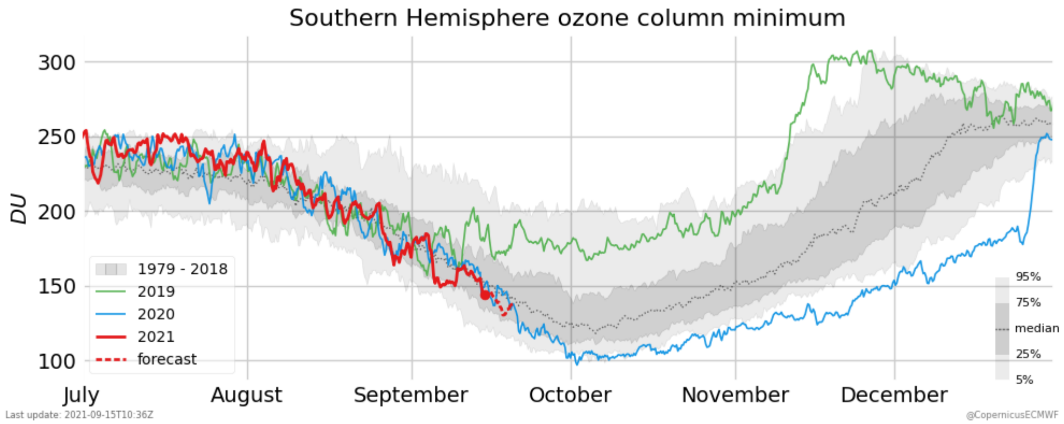
ECMWF

Atmosphere Monitoring

CAMS in action: Monitoring the Antarctic Ozone Hole







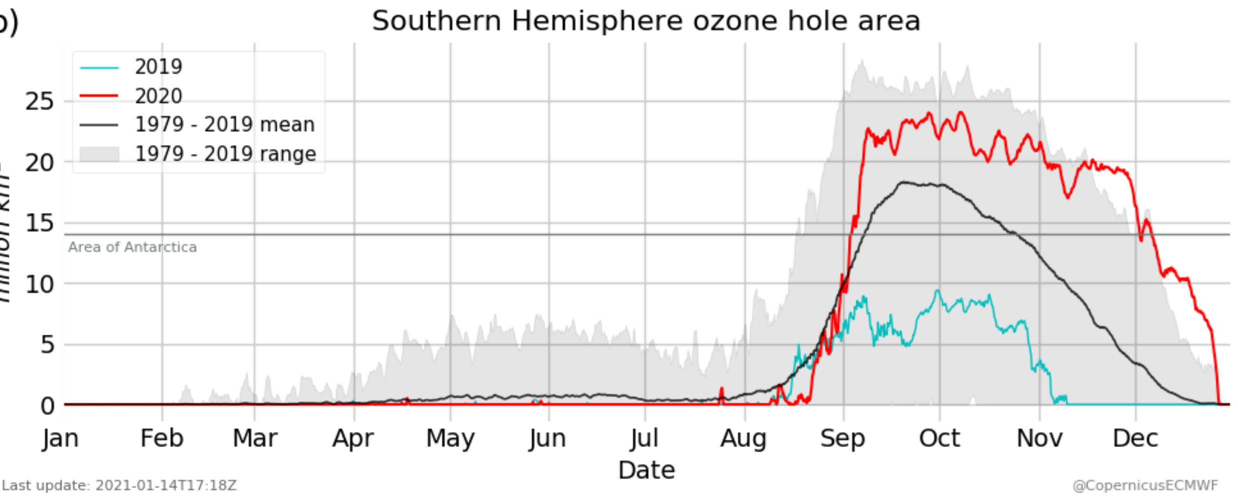
- CAMS monitors the area and values within the Antarctic ozone hole throughout its development in the Austral spring.

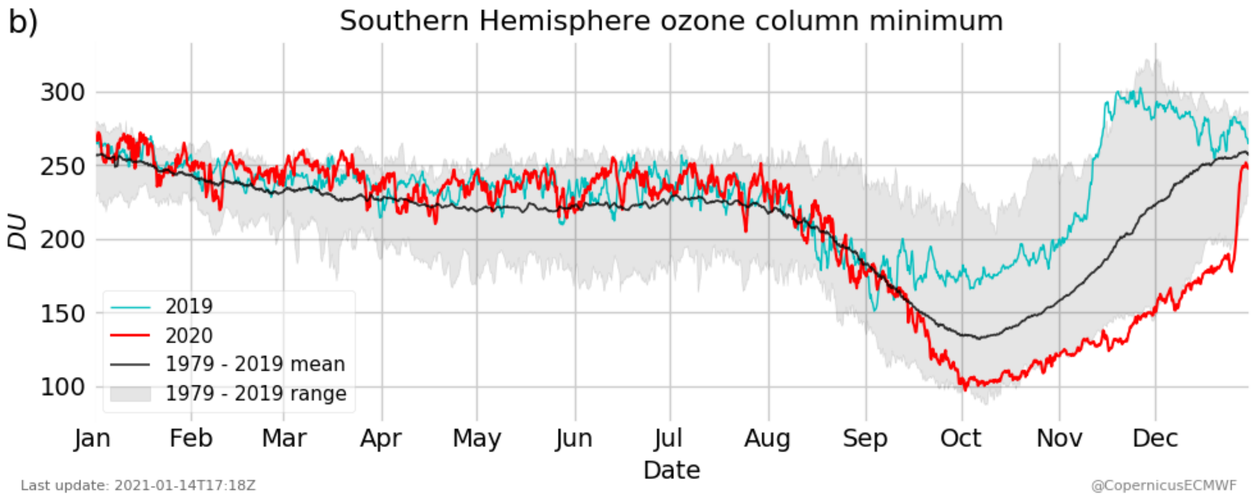
https://atmosphere.copernicus.eu/monitoring-ozone-layer

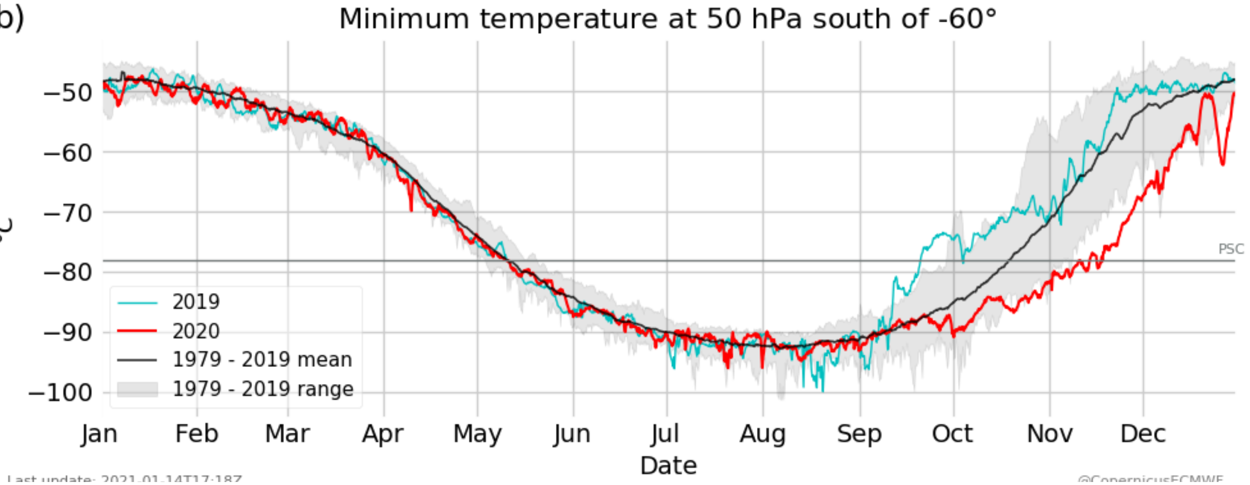
Antarctic Ozone Hole 2019 & 2020

Atmosphere Monitoring

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



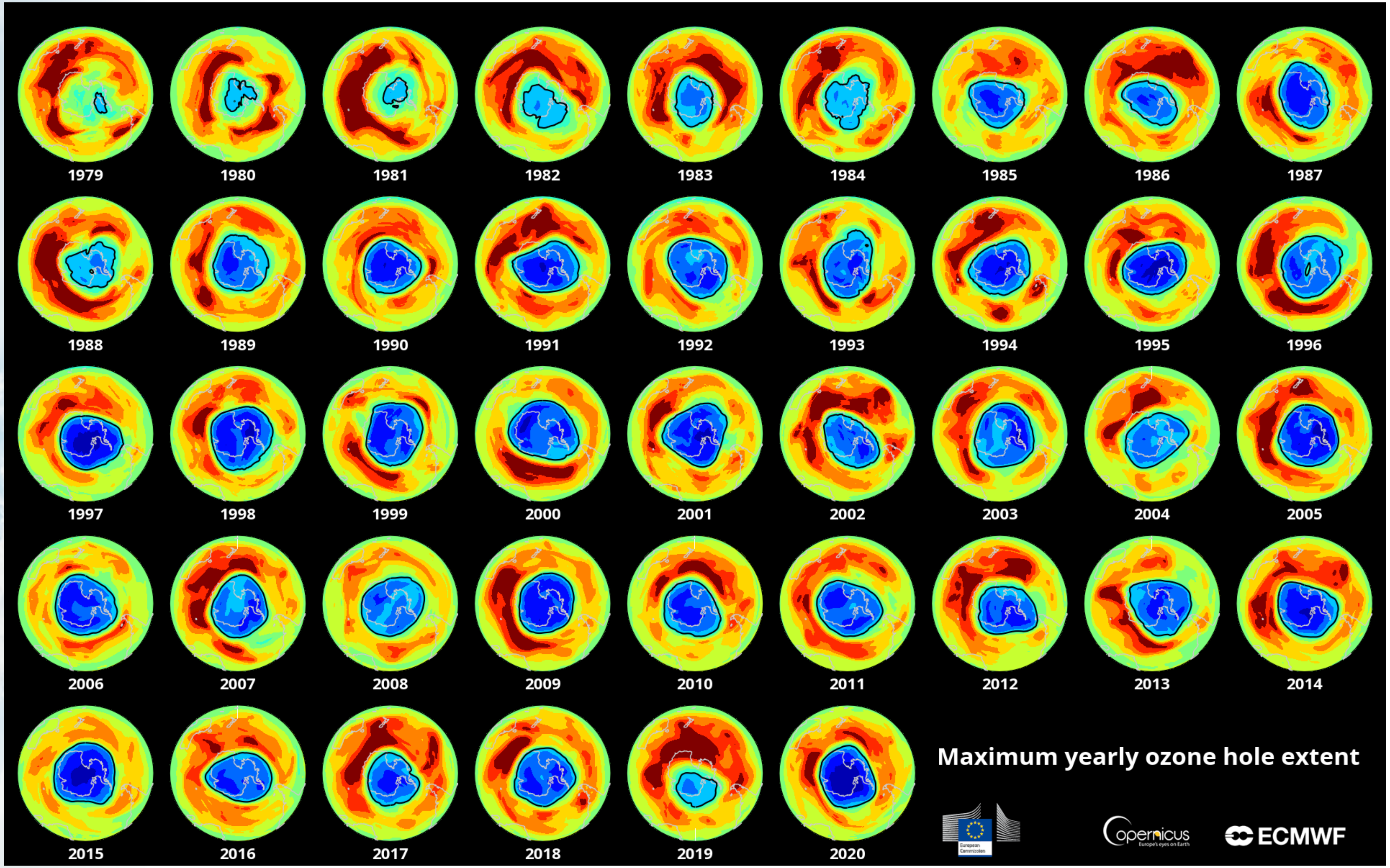




- Both **2019** and **2020** had exceptional Antarctic ozone holes.
- **2019** was small and short-lived because of unusual stratospheric warming.
- **2020** was deep, big, & long-lived due to very cold stratosphere and stable polar vortex.

(1979-2002 from ERA5; 2003-2019 from CAMSRA; 2020 CAMS NRT)

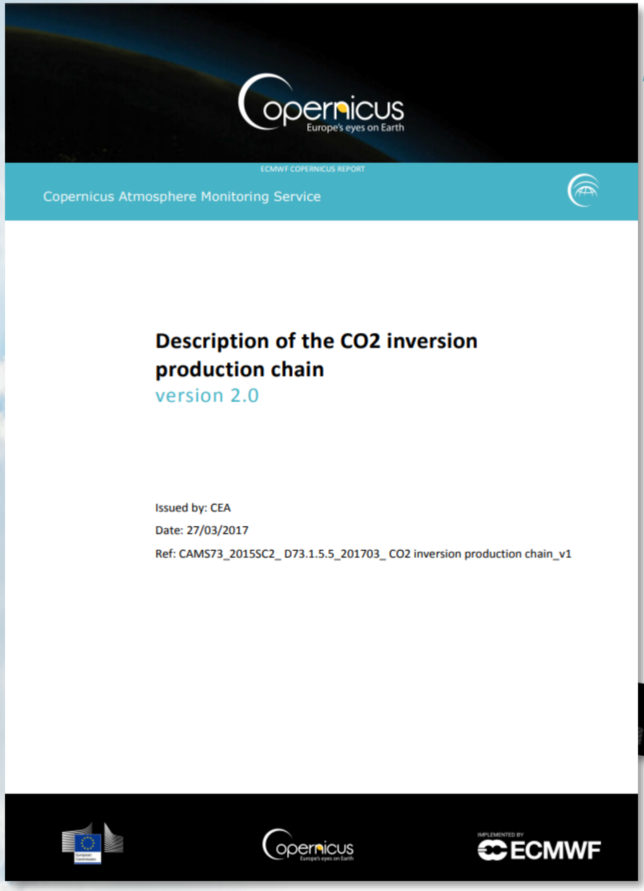
Reanalysis in Action: 4 Decades of the Antarctic Ozone Hole



42 years of Antarctic ozone hole data merging ERA-5 and CAMS Reanalysis data

https://atmosphere.copernicus.eu/monitoring-ozone-layer

Documentation & Quality Control


Copernicus
Europe's eyes on Earth
ECMWF COPERNICUS REPORT
Copernicus Atmosphere Monitoring Service

Description of the CO2 inversion production chain
version 2.0

Issued by: CEA
Date: 27/03/2017
Ref: CAMS73_2015SC2_ D73.1.5.5_201703_ CO2 inversion production chain_v1

Copernicus
ECMWF

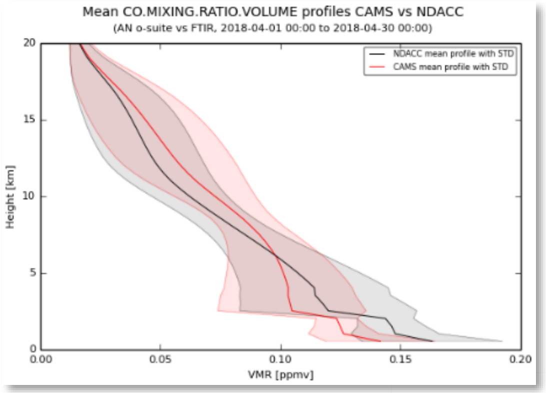

ECMWF COPERNICUS REPORT
Copernicus
Europe's eyes on Earth
Copernicus Atmosphere Monitoring Service

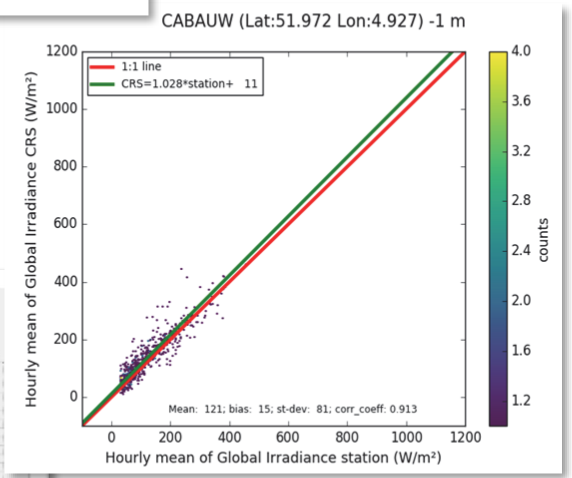
Validation report of the CAMS near-real time global atmospheric composition service

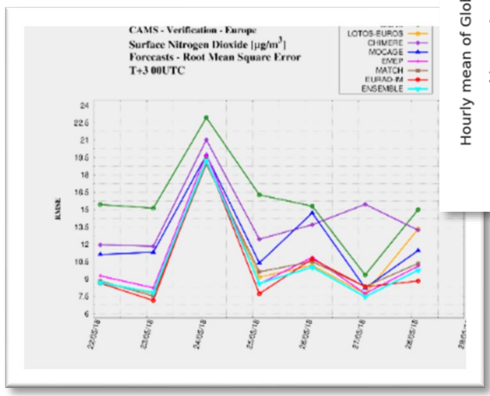
September - November 2017

Issued by: KNMI
Date: 7/3/2018
Ref: CAMS84_2015SC3_D84.1.1.10_2017SON_v1

Copernicus
ECMWF





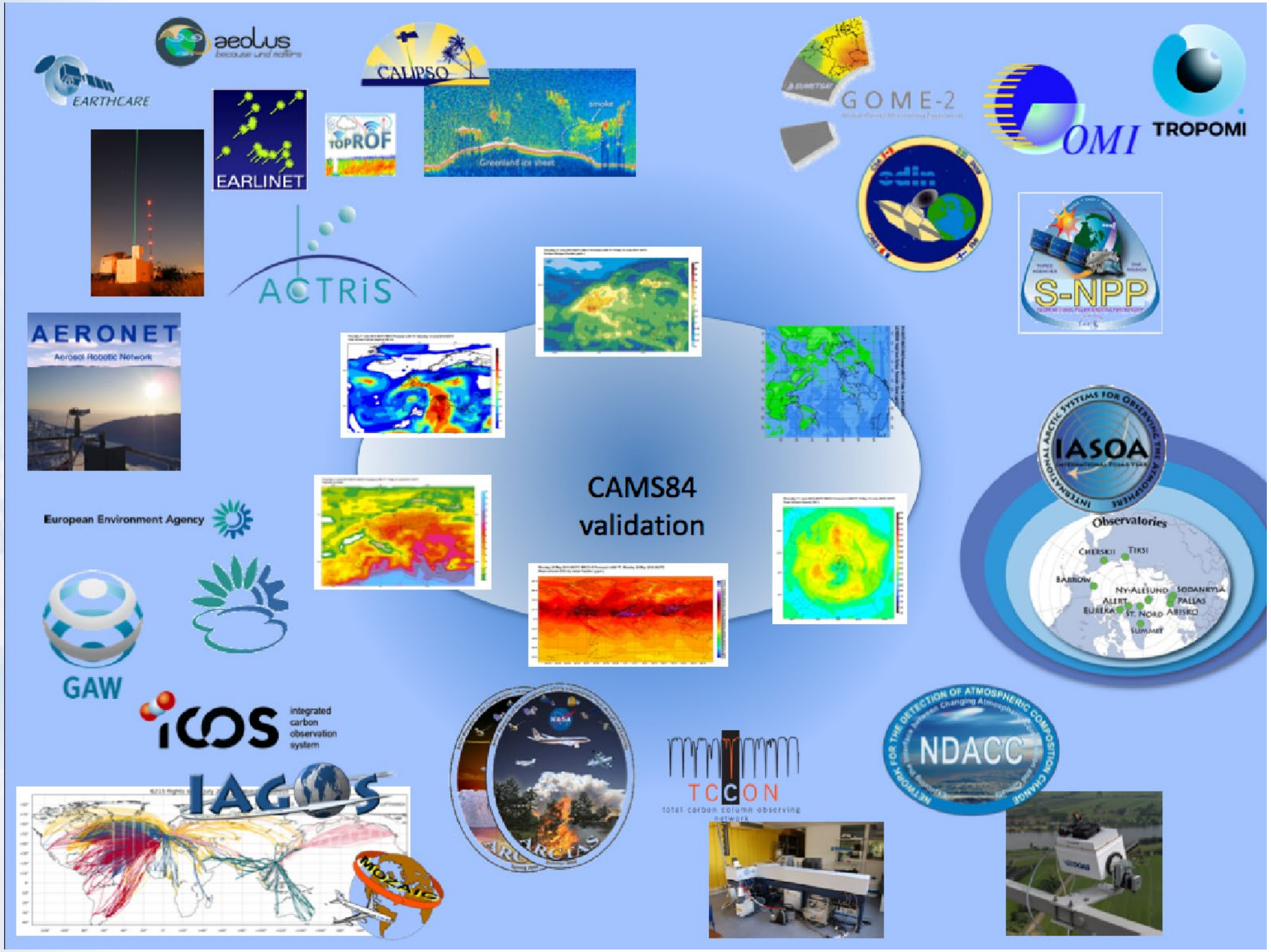


CAMS provides detailed information about how its products are produced and what the quality is.

https://atmosphere.copernicus.eu/user-support/validation/verification-global-services

Atmosphere Monitoring

Independent Observations for Validation



Copernicus
Europe's eyes on Earth
European Commission

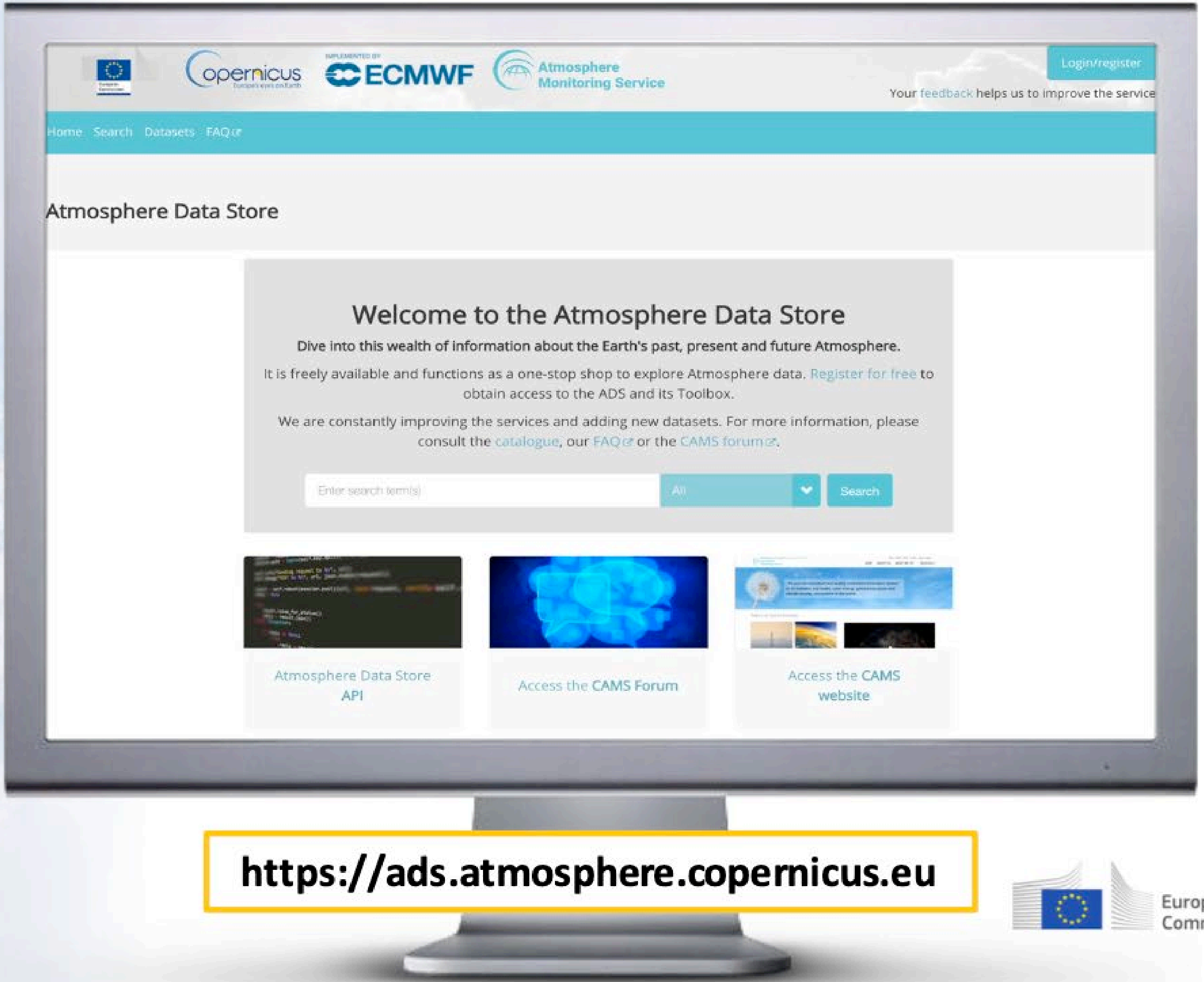
Independent Observations for Validation

Species, vertical range	Assimilation	Validation
Aerosol, optical properties	MODIS Aqua/Terra AOD	AOD, Ångström: AERONET, GAW, Skynet, MISR, OMI, lidar, ceilometer
Aerosol mass (PM10, PM2.5)	MODIS Aqua/Terra	European AirBase stations
O_3, stratosphere	MLS, GOME-2A, GOME-2B, OMI, SBUV-2	Sonde, lidar, MWR, FTIR, OMPS, ACE-FTS, OSIRIS, BASCOE and MSR analyses
O_3, UT/LS	MLS	IAGOS, ozone sonde
O_3, free troposphere	Indirectly constrained by limb and nadir sounders	IAGOS, ozone sonde
O_3, PBL / surface	-	Surface ozone: WMO/GAW, NOAA/ESRL-GMD, AIRBASE
CO, UT/LS	IASI, MOPITT	IAGOS
CO, free troposphere	IASI, MOPITT	IAGOS, MOPITT, IASI, TCCON
CO, PBL / surface	IASI, MOPITT	Surface CO: WMO/GAW, NOAA/ESRL
NO_2, troposphere	OMI, partially constrained due to short lifetime	SCIAMACHY, GOME-2, MAX-DOAS
HCHO	-	GOME-2, MAX-DOAS
SO_2	GOME-2A, GOME-2B (Volcanic eruptions)	-
Stratosphere, other than O_3	-	NO_2 column only: SCIAMACHY, GOME-2
CO_2, surface, PBL		ICOS
CO_2, column		TCCON
CH_4, surface, PBL		ICOS
CH_4, column		TCCON

Aerosol
Ozone
CO
NO2
SO2
CO2
CH4

UT/LS
Free trop
PBL, surface

Migration to the Atmosphere Data Store



https://ads.atmosphere.copernicus.eu

The **Atmosphere Data Store (ADS)** is the main point of access to all of the **CAMS data**

European Commission | Copernicus Europe's eyes on Earth ECMWF

More than just another data portal

- all CAMS data can be downloaded from **one place**
- physical location and specific data server technology are **hidden** from users by utilising dataset-specific **adaptors**
- **interactive** and **programmatic access** (Python or bare-bone REST API) available
- using only a few standard and harmonised **data formats**
- **queueing system** with quality-of-service (QoS) rules in place to protect the service and offer equitable access
- **effective caching** of popular data subsets to improve throughput
- regular **bug-fixes**, **updates** and **improvements**

ADS in numbers (June 2021)

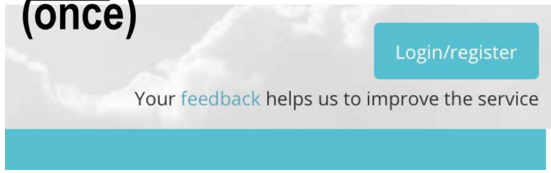
- launched in **June 2020**
- **11** published datasets, **2** more are close to being ready
- total volume of published datasets ~ **1.5 PB,** with **120 TB** on disks, the rest on tapes
- more than **5600** registered users from **148** countries
- **150** active users / day
- ~**25,000** requests / day
- on average **1.5 TB** of data per day

OPENING OF THE ATMOSPHERE DATA STORE

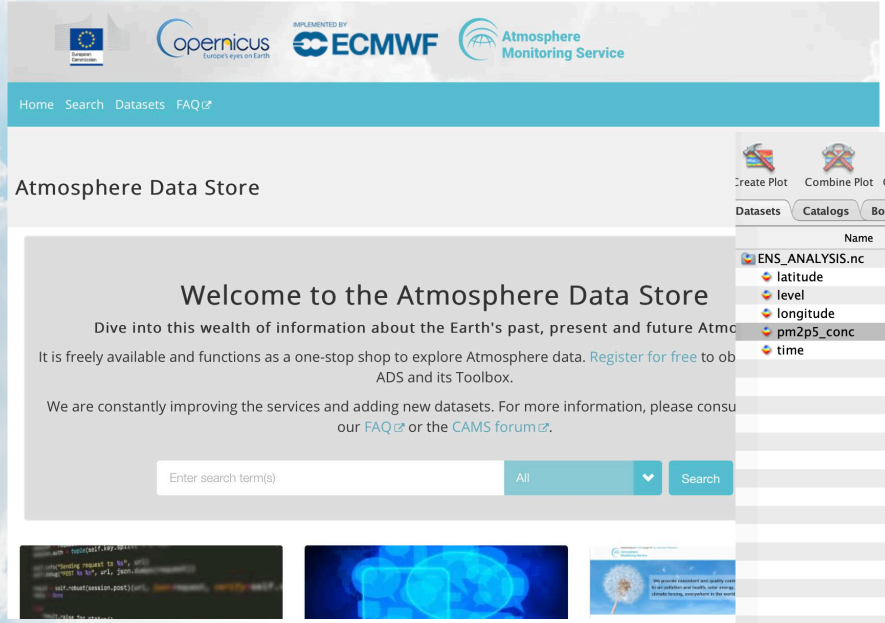
Atmosphere Monitoring

Based on CDS

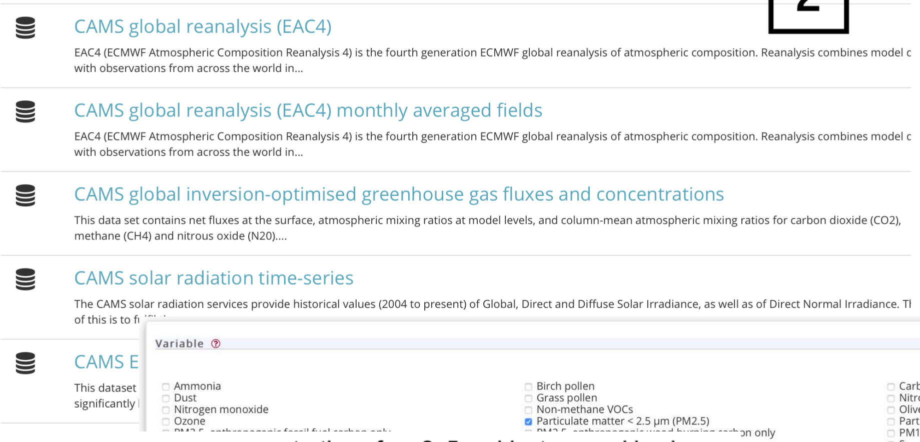
1 **Register (once)**

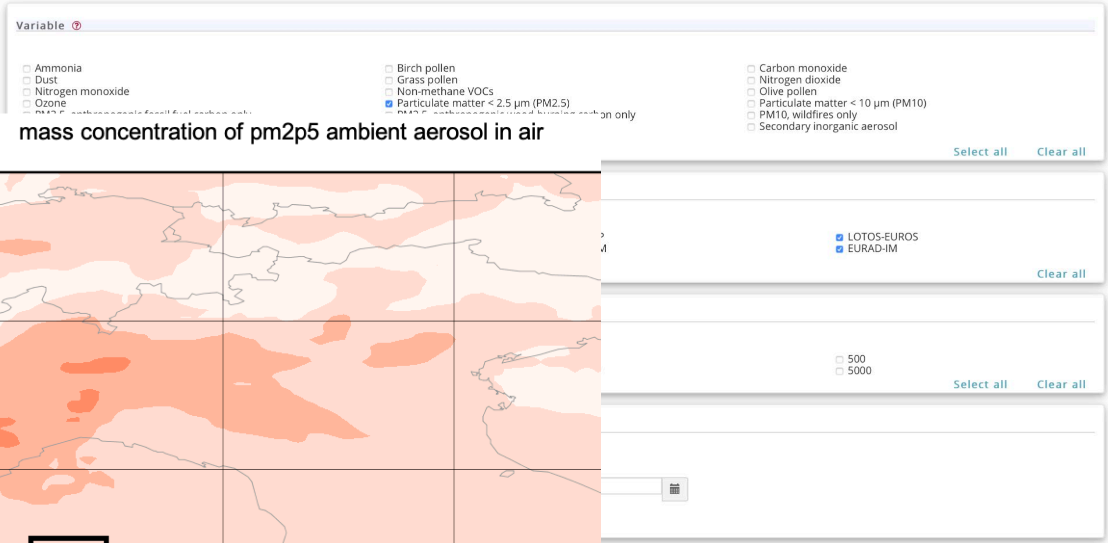


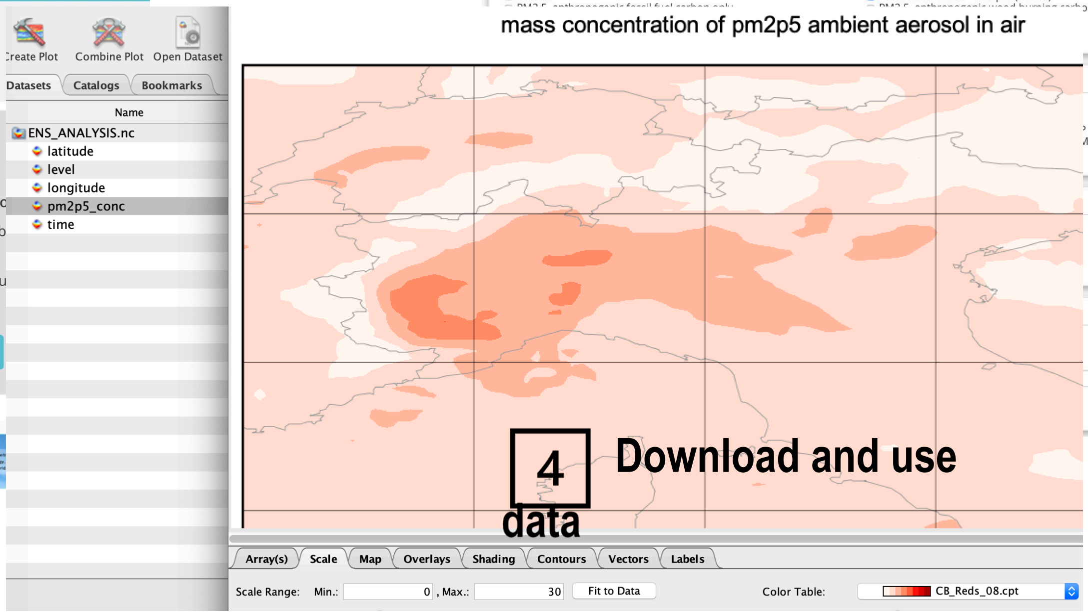
http://ads.atmosphere.copernicus.eu



2 **Search catalogue**







4 **Download and use data**

3 **Fill-in form**

Thank You!