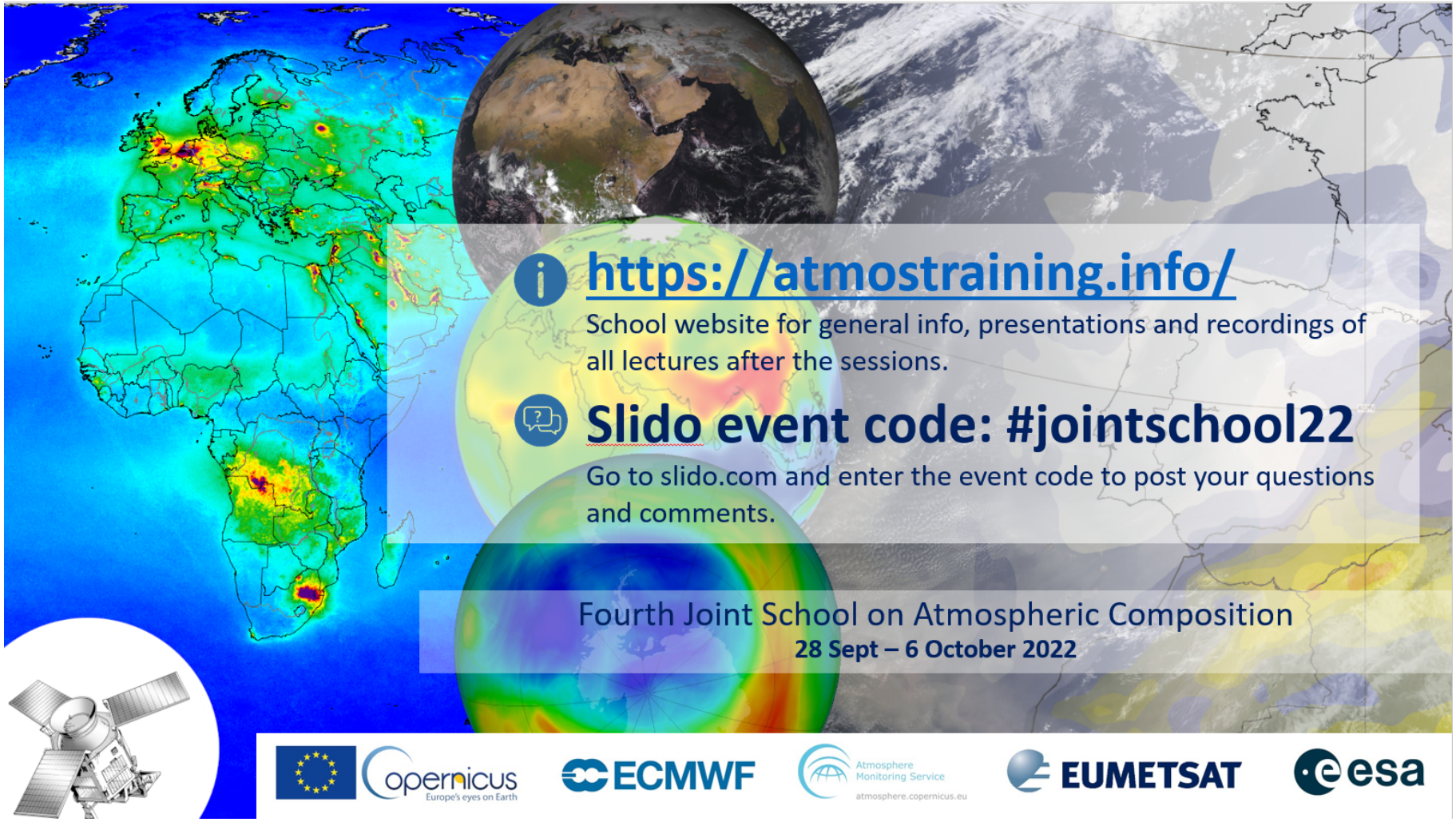
Welcome to the fourth joint school …



The program for these 2 weeks

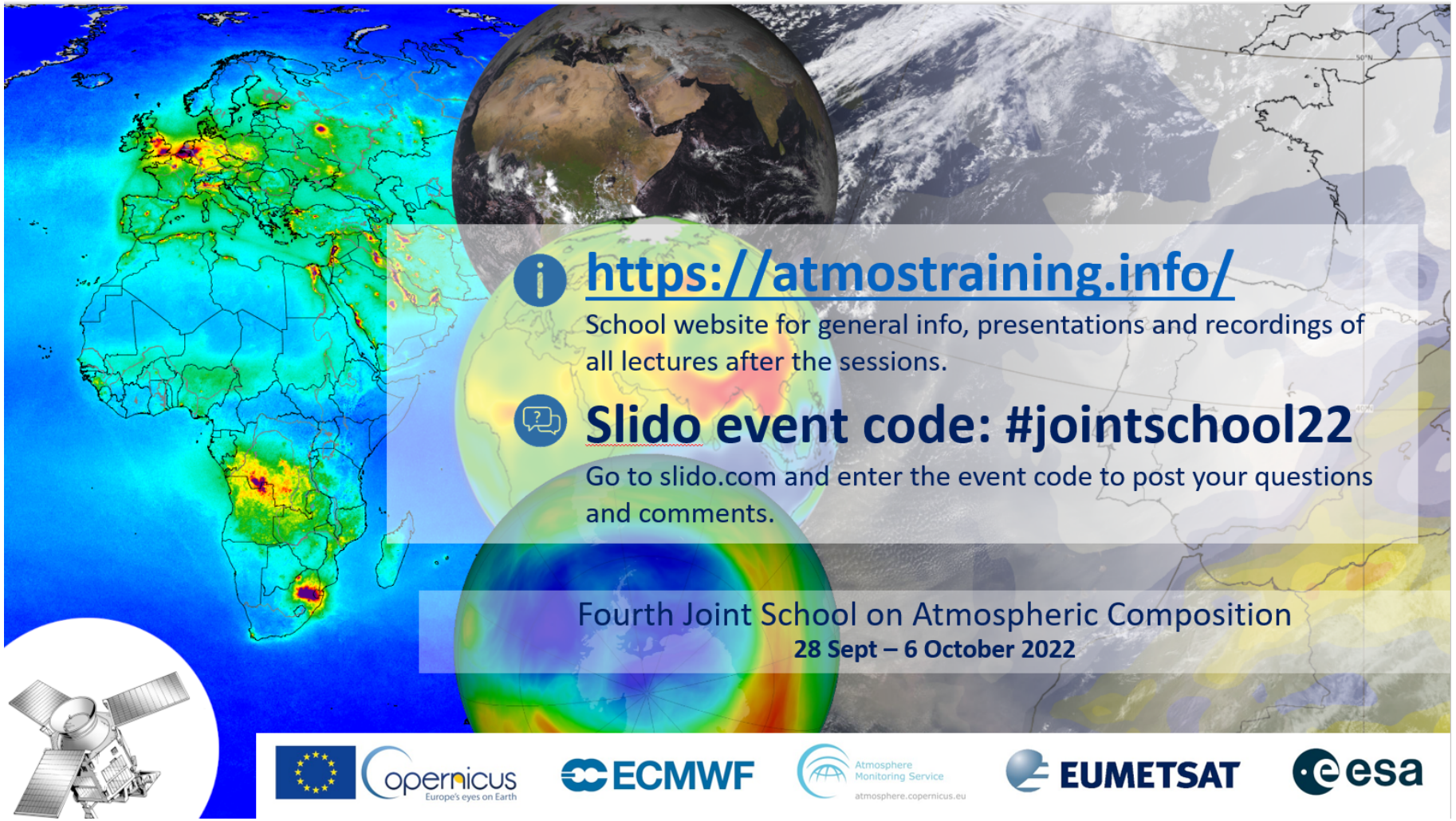
FOURTH JOINT ESA/EUMETSAT/ECMWF TRAINING COURSE ON ATMOSPHERIC COMPOSITION
Integrating data for climate applications
Preliminary program

		Wednesday, Sep 28		Thursday, Sep 29		Friday, Sep 30		Tuesday, Oct 4		Wednesday, Oct 5		Thursday, Oct 6	
10:00	10:55	Introduction. How the Copernicus program addresses monitoring and understanding air composition	Federico Fierli with organising committee	Basics of aerosol and trace gas retrievals from UV-VIS-type satellite instruments.	Anu-Maija Sundstrom	Global climate models for chemistry and aerosol.	Julia Marshall	Practicals		Practicals		Practicals	
11:00	11:55	The storyline approach to explaining extreme events and articulating plausible futures.	Ted Shepherd	Generation of climate data records from satellite observations.	Marie Doutriaux-Boucher	The Copernicus atmospheric monitoring service: modeling, data assimilation - an example on wildfires.	Mark Parrington						
12:00	12:45	Questions corner		Questions corner		Questions corner						Questions corner	
				Break									
14:00	15:00	Current and future satellite programs on atmospheric composition.	Christian Retscher and Federico Fierli	What can we see using the IASI infrared remote sensor?	Cathy Clerbaux	Data assimilation: Integrating satellite data into the CAMS global system.	Antje Inness					Presentations from participants	
15:00	15:30	Science background and link to policy OMI and TROPOMI achievements Future satellite capabilities	Pieternel Levelt	Questions corner		Questions corner		Questions corner		Questions corner			
15:30	16:00					Intro to practicals							
16:00	16:30	Questions corner											

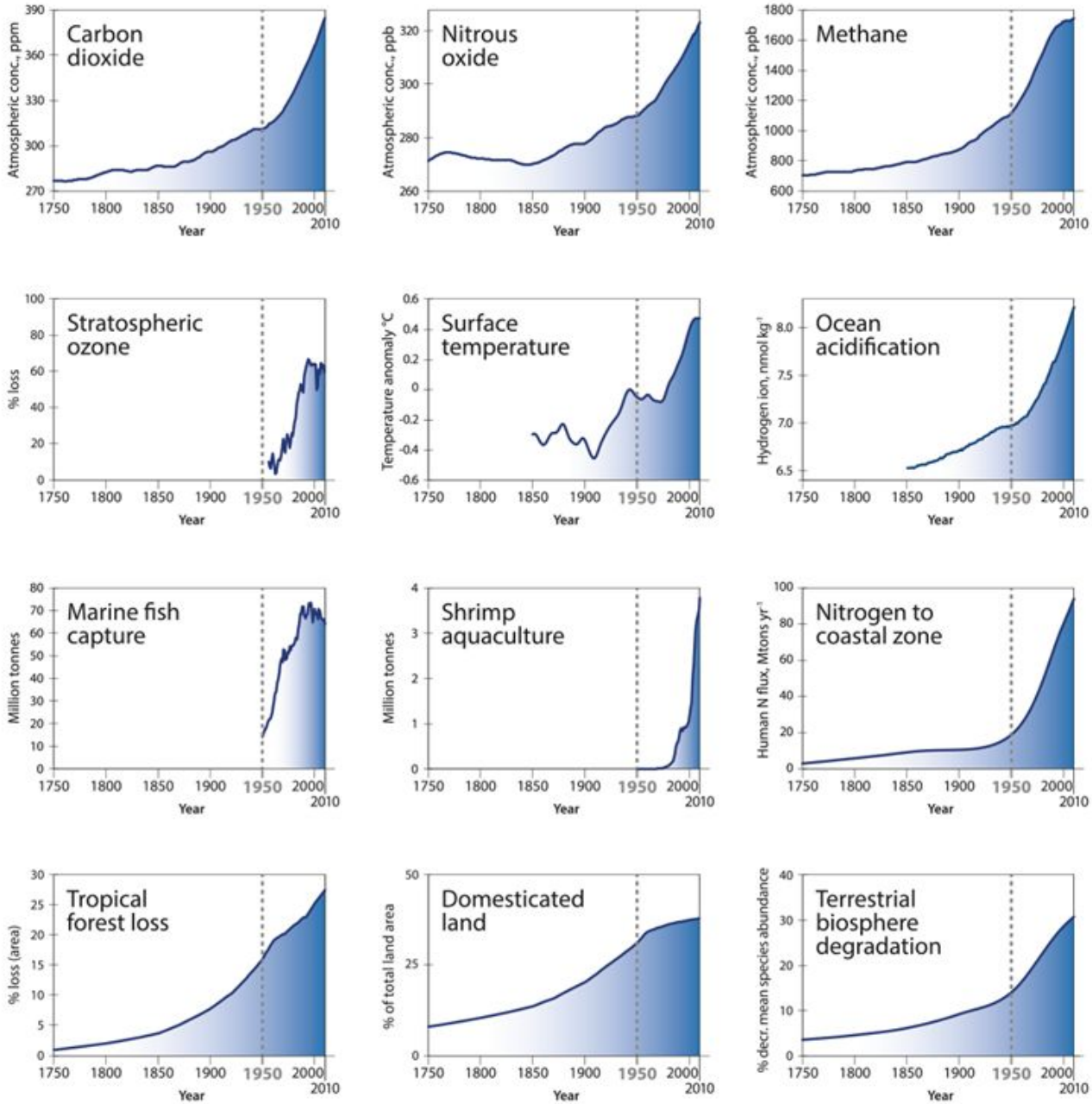
Frontal Lectures
Open discussion
Practical sessions

Introduction to the IV school

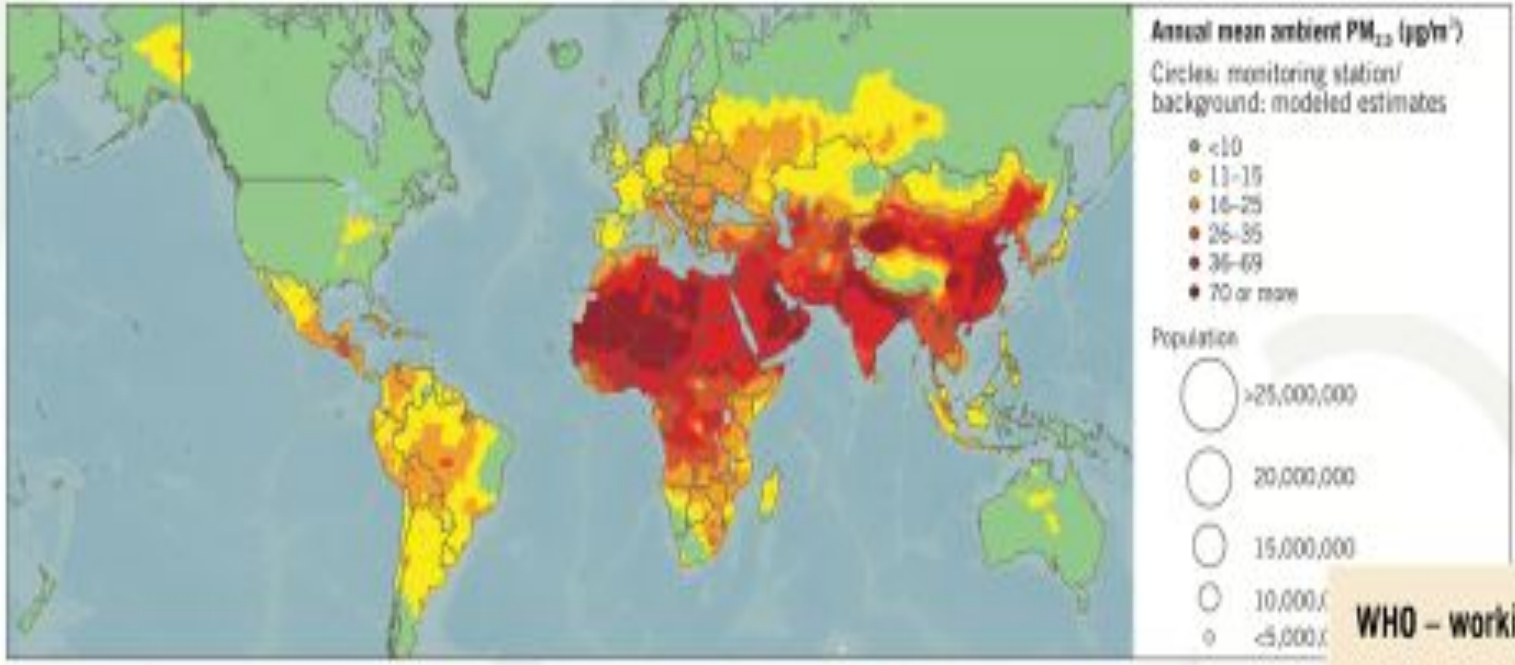
F. Fierli, C. Retscher, M. Parrington, C. Stewart + many contributors



Earth system trends



Global ambient air pollution, WHO Guideline values (annual mean), $PM_{2.5}$: 10 µg/m³, PM_{10}: 20 µg/m³



HEALTH & SUSTAINABLE DEVELOPMENT GOALS

PREVENTING DISEASE THROUGH ACTIONS ACROSS THE SDG SPECTRUM

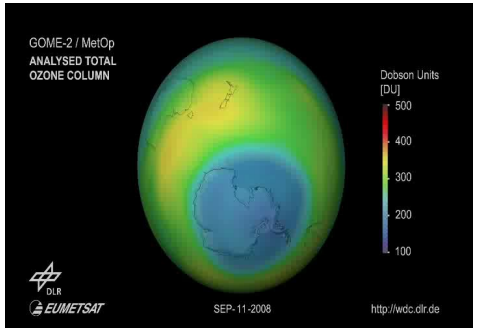
World Health Organization

WHO – working at country level to:

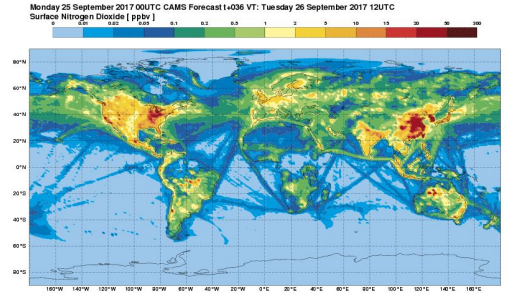
- Increase national and city government commitments to attain WHO Air Quality Guidelines
- Conducting rapid situational assessment for clean household energy in Nepal, Peru, Ghana and Kenya.
- Assist with assessment of national and sub-national disease burden from air pollution in 70 countries through online AirQ+ tool
- Assess air and health quality impacts of transport, household energy and waste interventions in Ghana and Nepal.

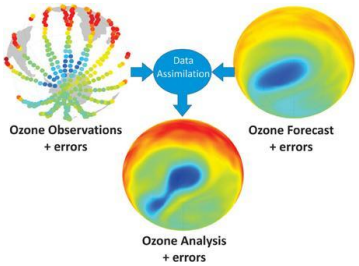
What are the main Areas?

Monitoring Atmospheric Composition and Climate



Support to Air Quality Monitoring & Impacts

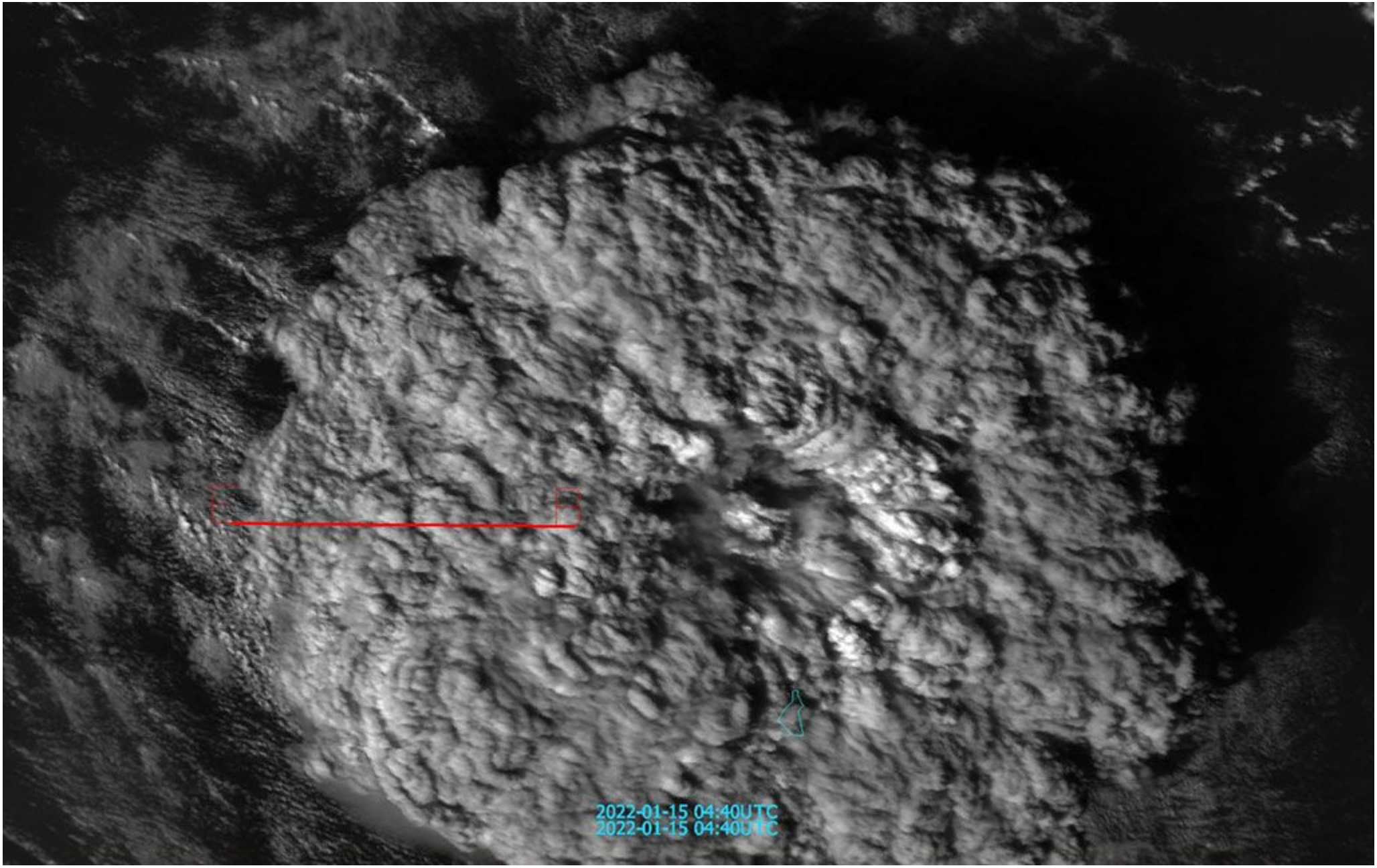




Data assimilation

Natural Hazards Monitoring Fires Dust and Volcanic Ash

Support to Emissions Monitoring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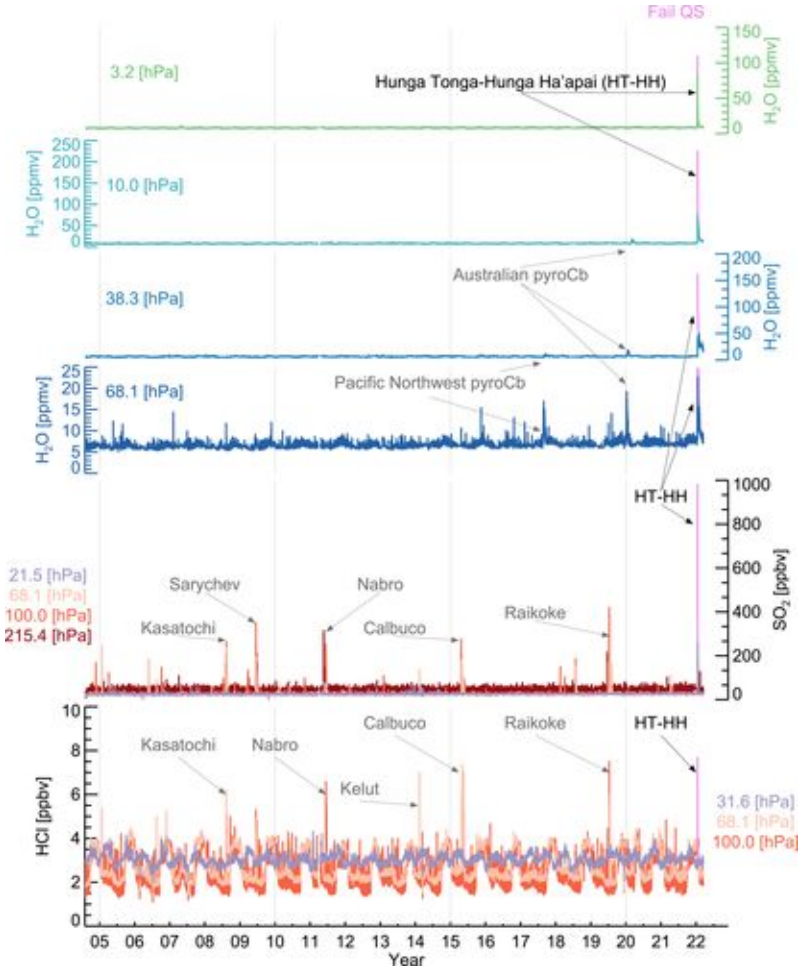
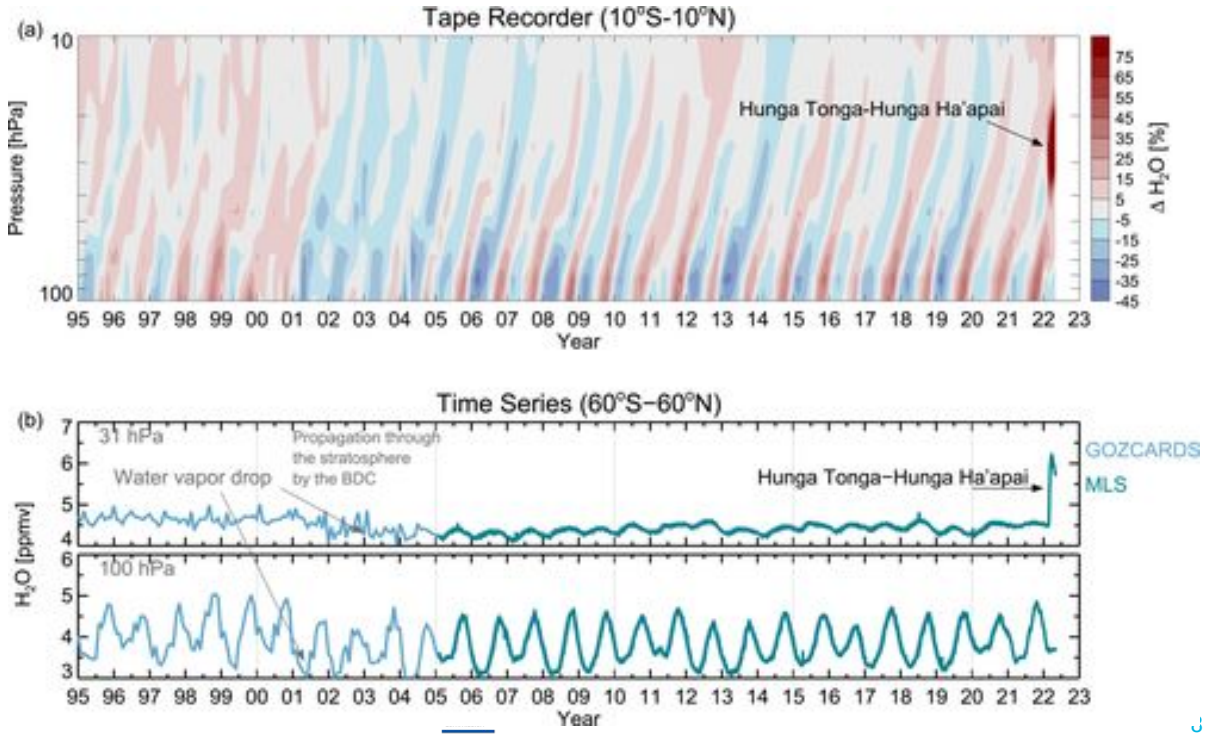
Climate (processes) monitoring: volcanic eruptions



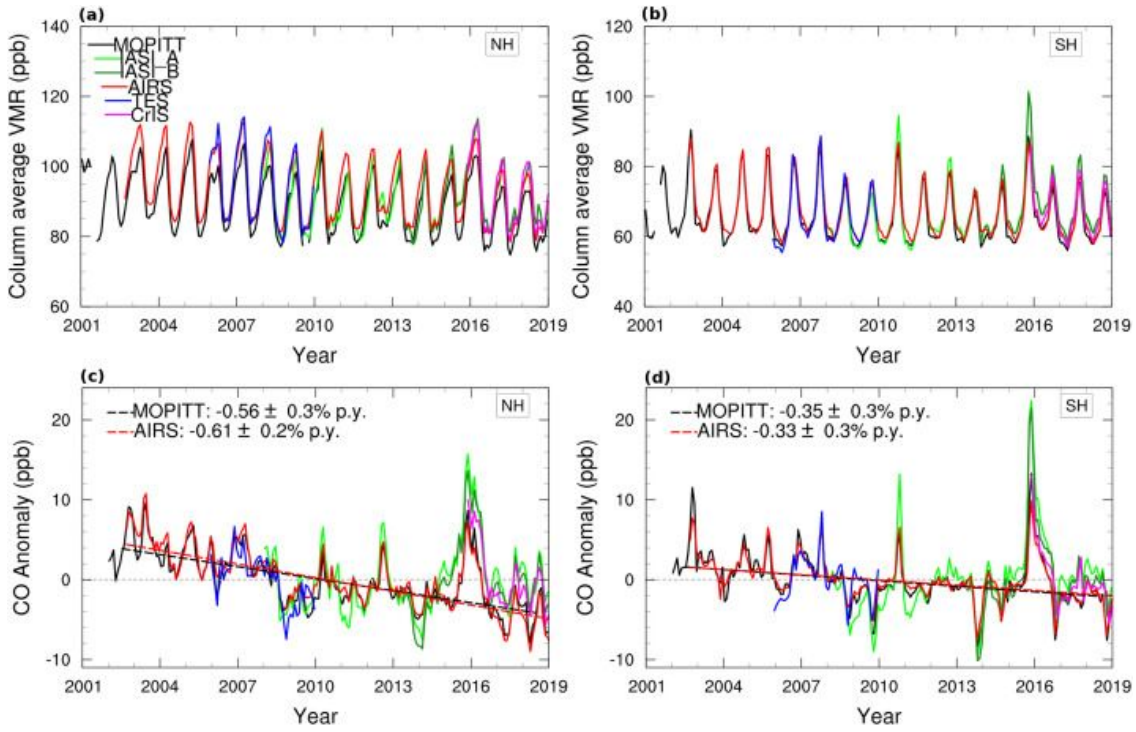
The Hunga Tonga-Hunga Ha'apai Hydration of the Stratosphere

L. Millán,M. L. Santee,A. Lambert,N. J. Livesey,F. Werner,M. J. Schwartz,H. C. Pumphrey,G. L. Manney,Y. Wang,H. Su,L. Wu,W. G. Read,L. Froidevaux

First published: 01 July 2022 https://doi.org/10.1029/2022GL099381



Climate (processes) monitoring: Carbon monoxide



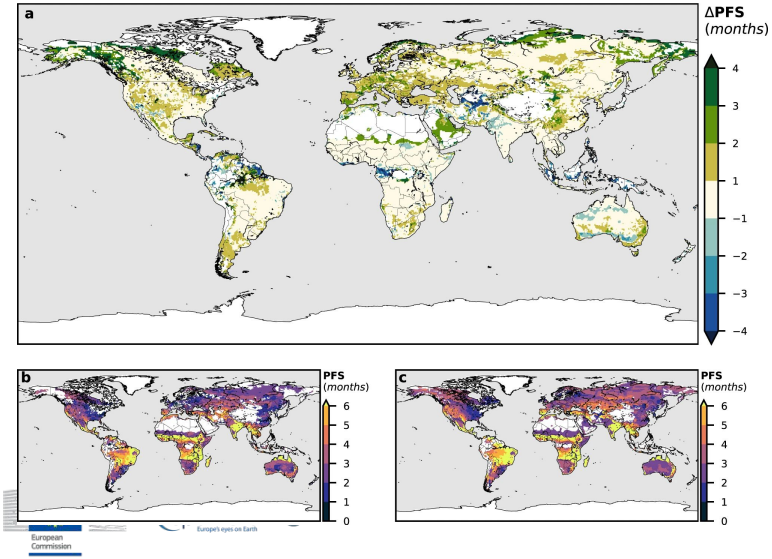
Spatial and temporal expansion of global wildland fire activity in response to climate change

Nature Communications

Emission reduction vs. wildfire increase

Air pollution trends measured from Terra: CO and AOD over industrial, fire-prone, and background regions

Rebecca R.Buchholz



Limited monitoring / uncertain emissions

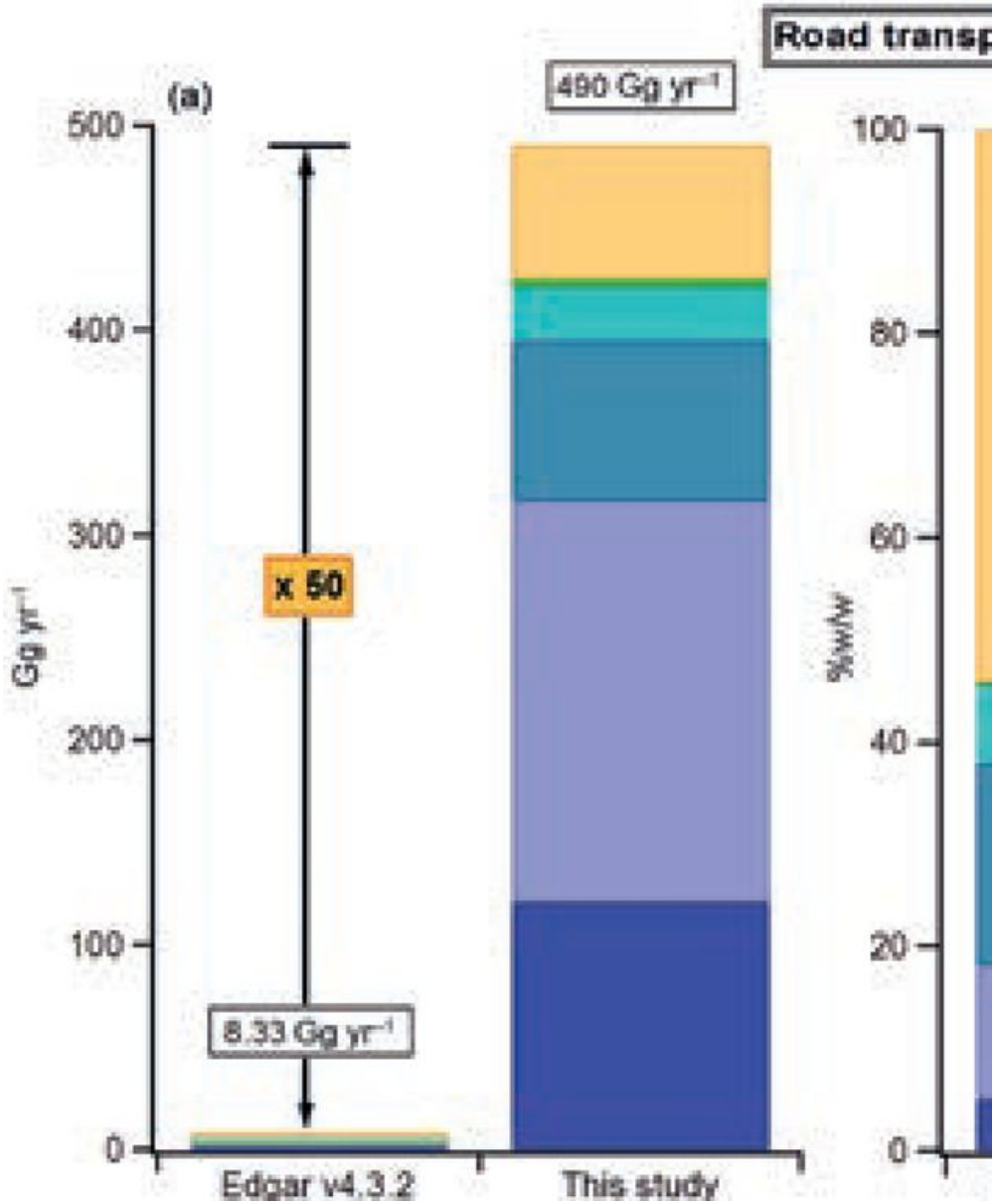
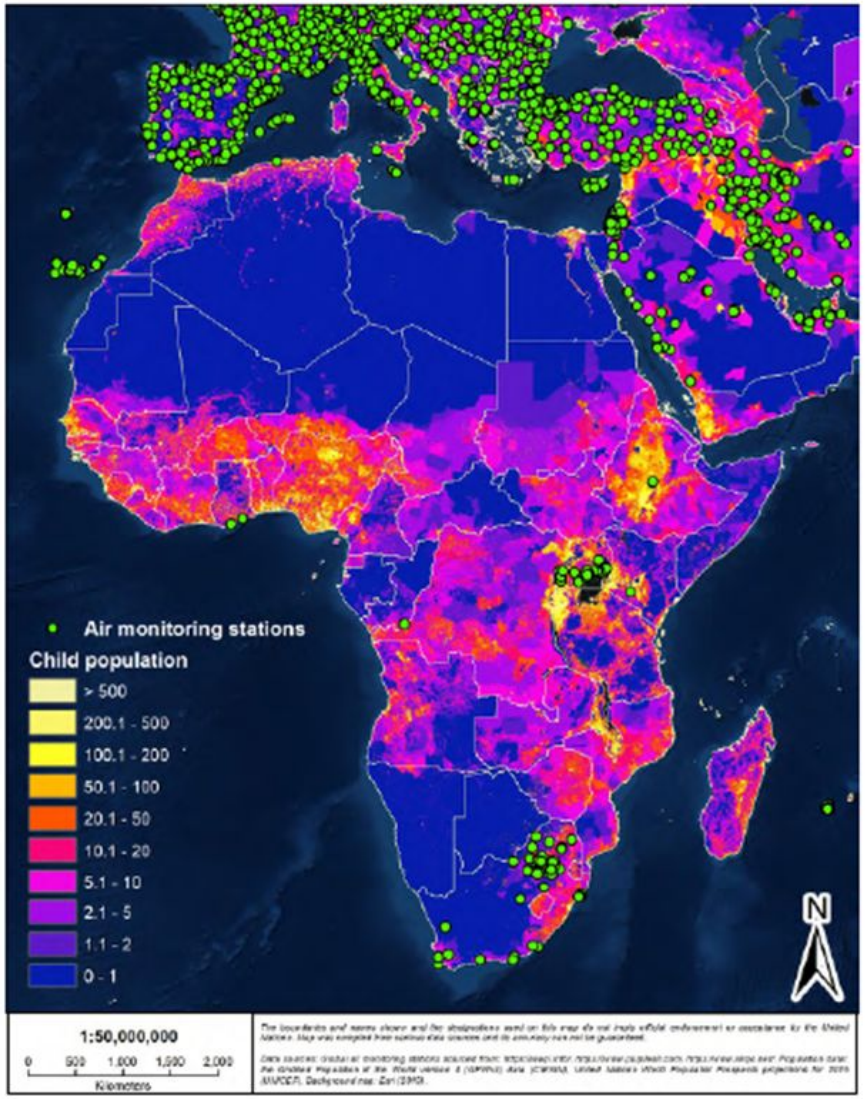


Figure 3: Air pollution monitoring in Africa

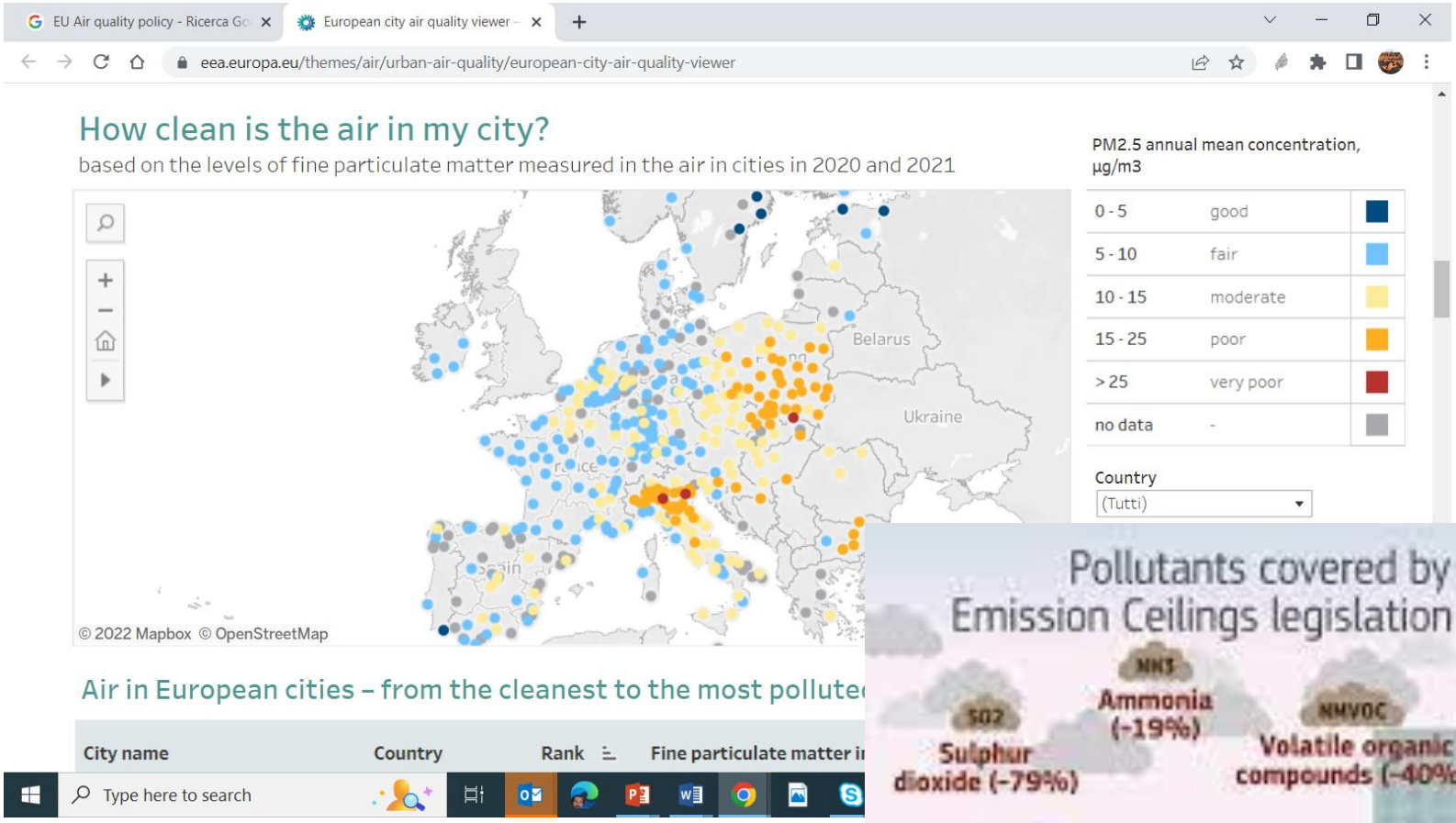


Contribution to climate and policies

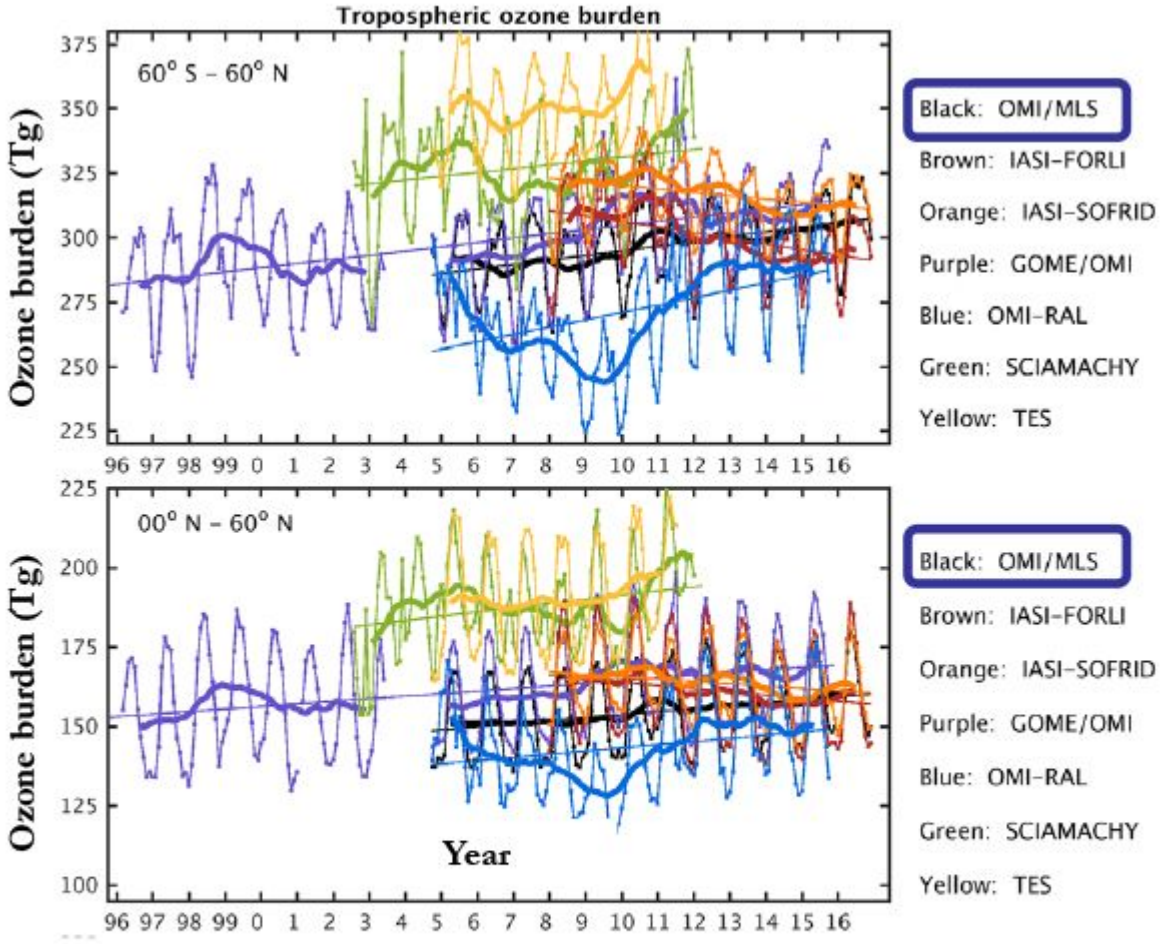
Table 3.1 Applications per environmental theme and user information (UTLS = Upper Troposphere-Lower Stratosphere).

Environmental Theme / Information	**Ozone Layer & Surface UV radiation** **A**	**Air Quality** **B**	**Climate** **C**
Protocols **1**	UNEP Vienna Convention; Montreal and subs. Protocols CFC emission verification Stratospheric ozone, halogen and surface UV distribution and trend monitoring	UN/ECE CLRTAP; EMEP / Göteborg Protocol; EC directives EAP / CAFE AQ emission verification AQ distribution and trend monitoring	UNFCCC Rio Convention; Kyoto Protocol; Climate policy EU GHG and aerosol emission verification GHG/aerosol distribution and trend monitoring
Services **2**	Stratospheric composition and surface UV forecast NWP assimilation and (re-) analysis	Local Air Quality (PBL); Health warnings (PBL) Chemical Weather (PBL/FT) Aviation routing (UT)	NWP assimilation and (re-) analysis Climate monitoring Climate model validation
Assessments **3**	Long-term global data records WMO Ozone assessments Stratospheric chemistry and transport processes; UV radiative transport processes Halogen source attribution UV health & biological effects	Long-term global, regional, and local data records UNEP, EEA assessments Regional & local PBL AQ processes; Tropospheric chemistry and long-range transport processes AQ source attribution AQ Health and safety effects	Long-term global data records IPCC assessments Earth System, climate, rad. forcing processes; UTLS transport-chemistry processes Forcing agents source attribution Socio-economic climate effects

Contribution to climate and policies - Pollutants emissions at EU

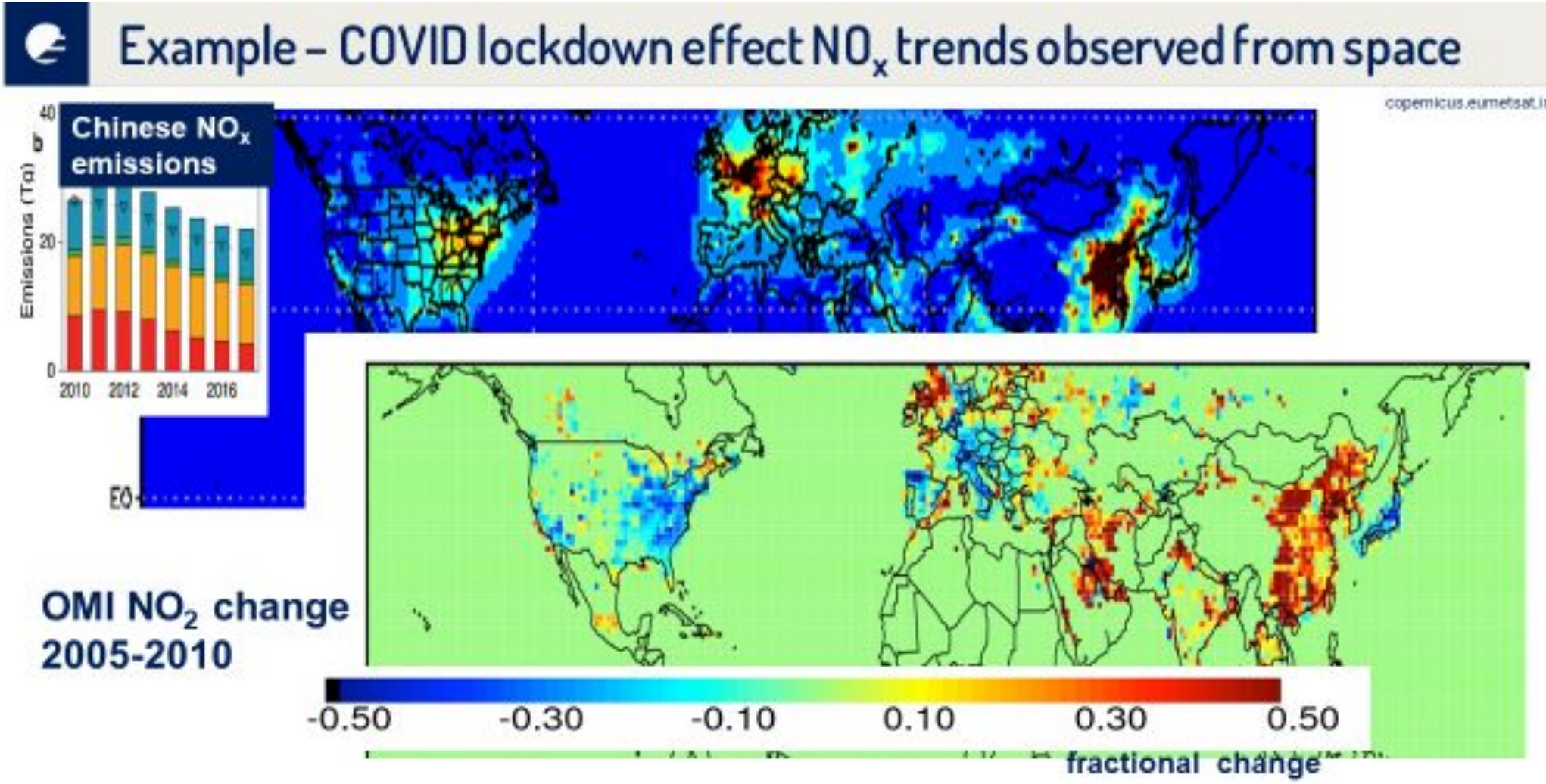


Contribution to climate and policies: TOAR trends

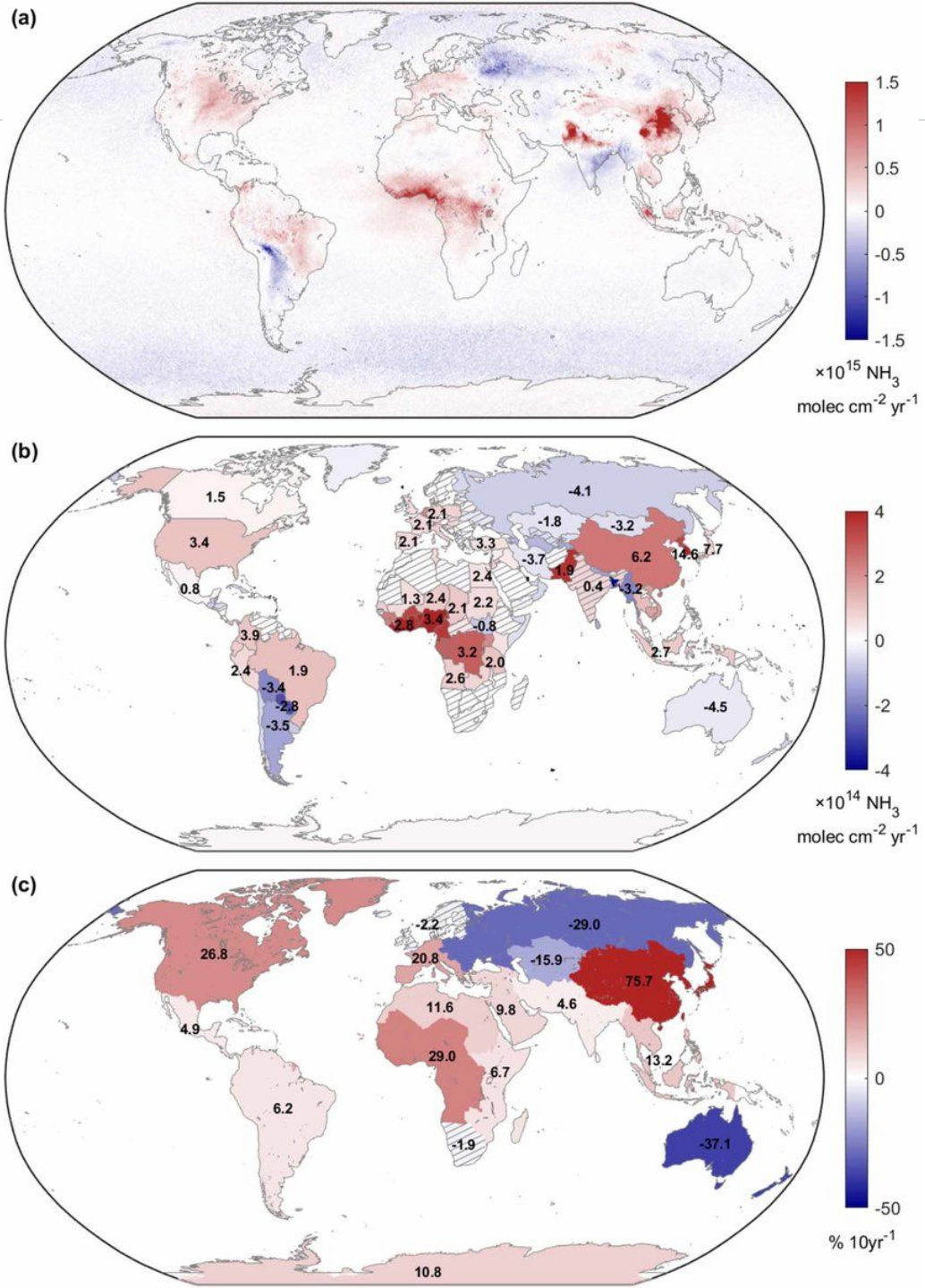


- **Black curve is NASA Goddard OMI/MLS TCO product.**
- OMI/MLS tropospheric ozone burden for 60S–60N was an average of 291 Tg in 2004 and 306 Tg for 2016, a statistically significant net increase of ~ 5%.

Nitrogen dioxide trends



Ammonia trends



CO2 Emission sources

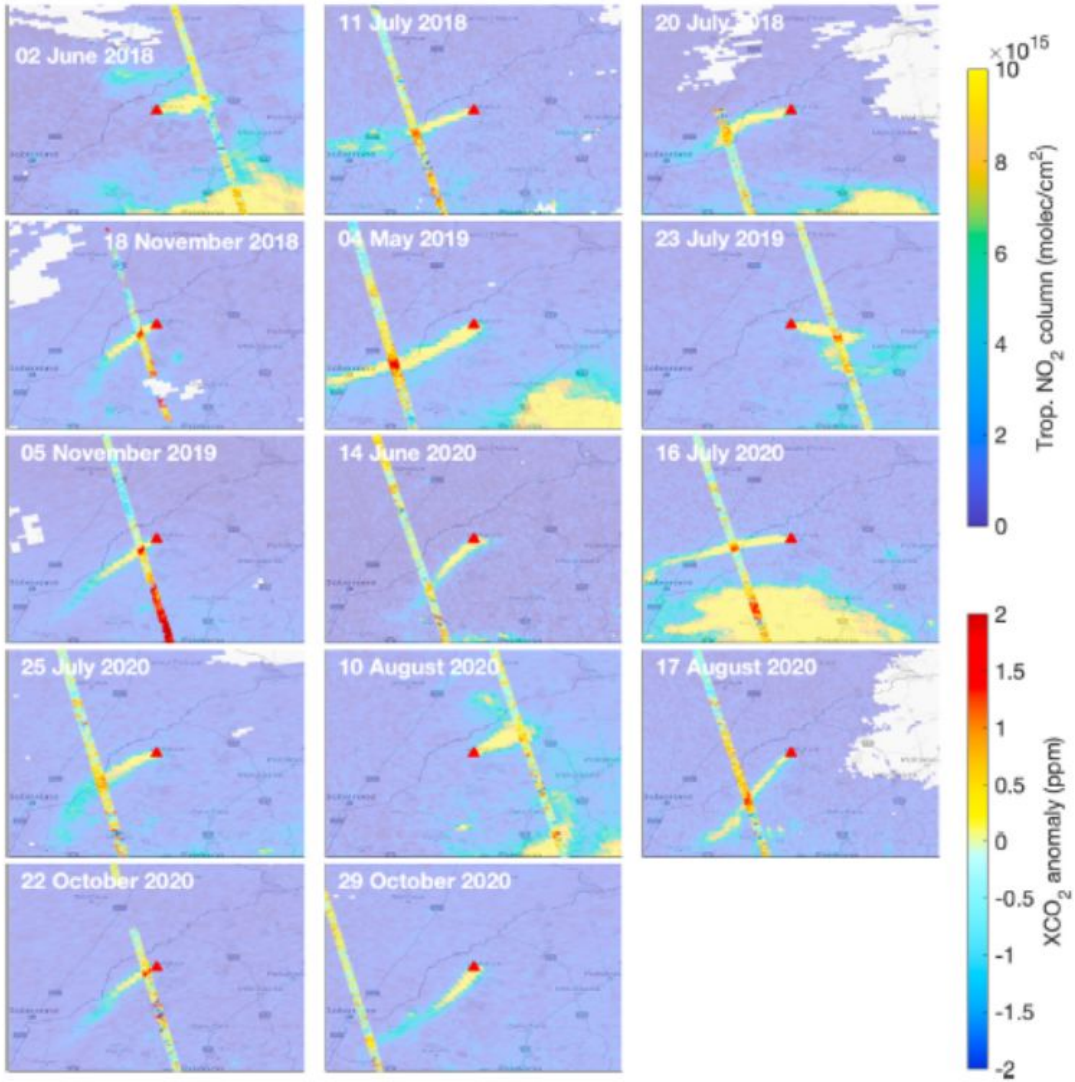
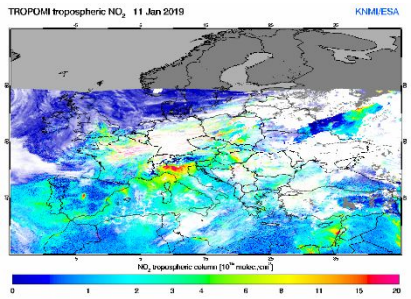
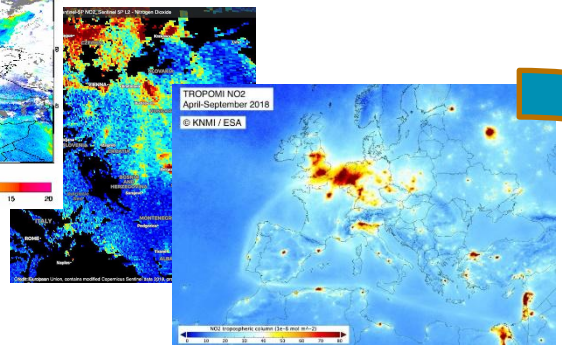


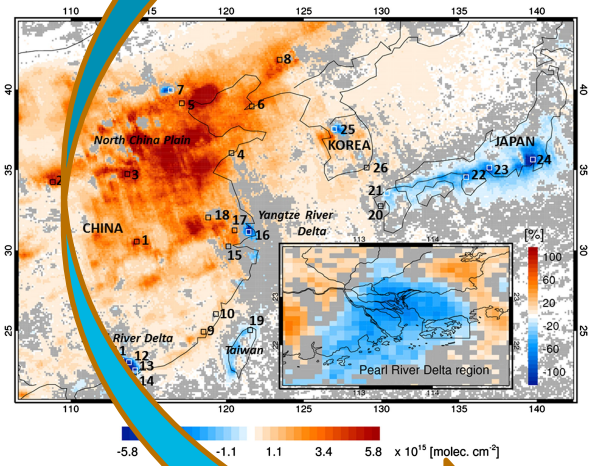
Fig. 1. OCO-2 and TROPOMI observations near Matimba power station (red triangle) in South Africa between May 2018 and November 2020.

4

What Users may need …







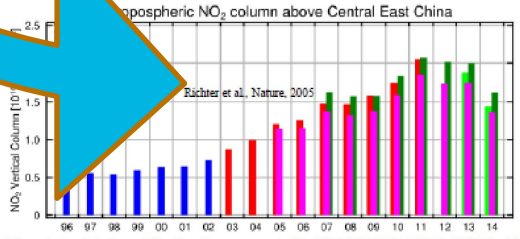
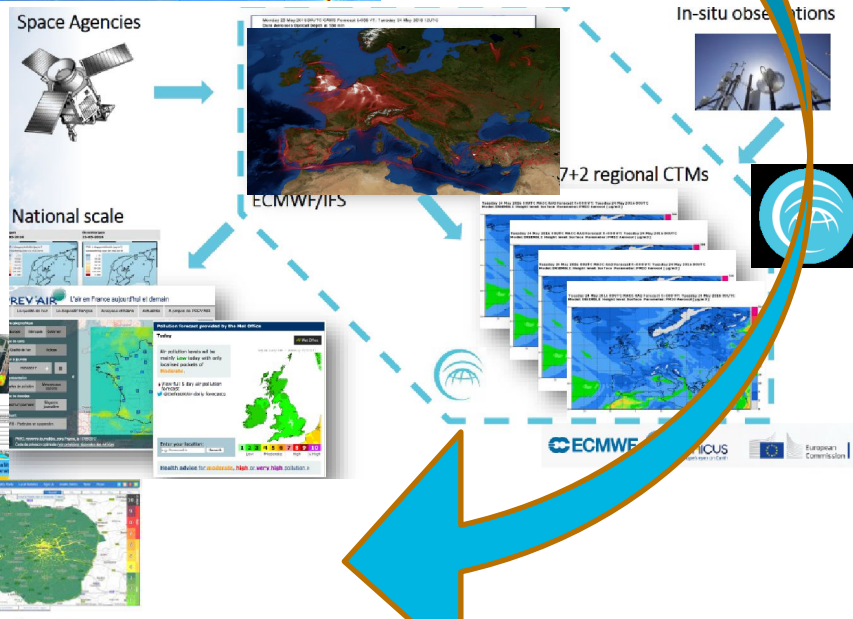


Figure 2: Tropospheric vertical columns of NO_2 retrieved from measurements of the GOME, SCIAMACHY, GOME-2 A, GOME-2 B and OMI instruments over East Central China (30°N - 40°N, 110°E - 123°E). All data are IUP retrievals using the same AMF and reference sector stratospheric correction and a cloud screening of 0.2.

Andreas Richter EGU 2015



vnstream applications

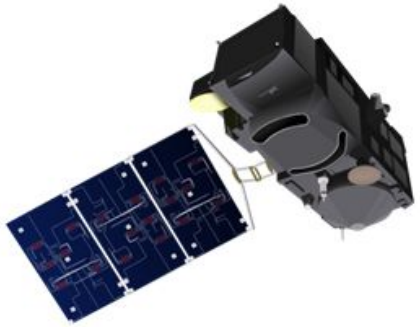
European Commission Copernicus EUMETSAT

What is Copernicus ?

Observations Infrastructure

Services

Unique ensemble of existing and upcoming data

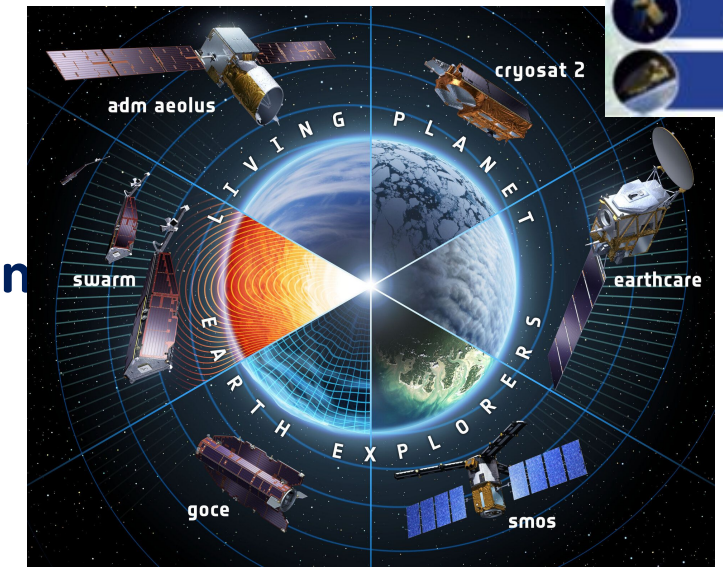


EUMETSAT

Copernicus
Europe's eyes on Earth

esa

SENTINEL-1:	4-40m resolution, 3 day revisit at equator	S1A and 1B in orbit
SENTINEL-2:	10-60m resolution, 5 days revisit time	S2A and 2B in orbit
SENTINEL-3:	300-1200m resolution, <2 days revisit	S3A and S3B in orbit
SENTINEL-4:	8km resolution, 60 min revisit time	1st Launch 2022
SENTINEL-5p:	7-68km resolution, 1 day revisit	S5P in orbit
SENTINEL-5:	7.5-50km resolution, 1 day revisit	1st Launch 2023
SENTINEL-6:	10 day revisit time	1st Launch 2020



Current and future missions on Atmospheric composition

- Operational satellites
- Sentinels
- Earth Explorers

Sentinel Data Policy, Production and Dissemination

esa

Copernicus is the largest producer of EO data in the world

Copernicus observes ALL global landmass every 5 days at 10m resolution

20 TB of Daily Sentinel Data Production

300 TB of Daily Sentinel Data Dissemination

Copernicus – state-of-the-art EO to understand Earth

esa

> **370.000** registered users

= tip of the iceberg

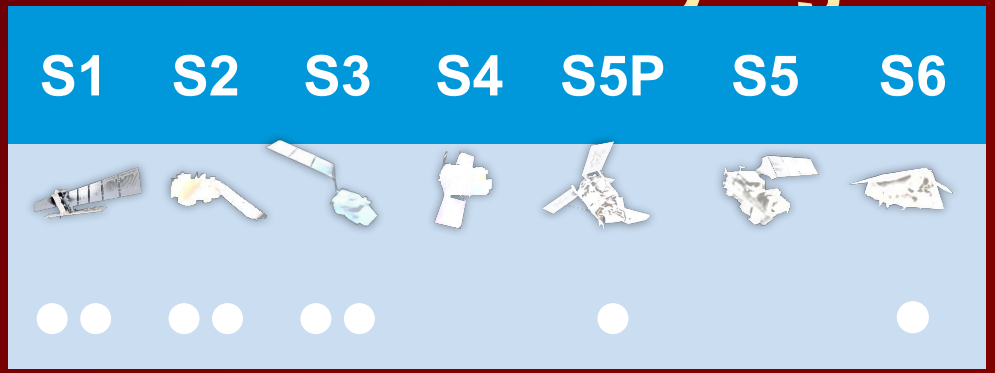
6 operational services

Land | Atmosphere | Ocean | Climate | Disaster | Security

250 TB satellite data distributed per day

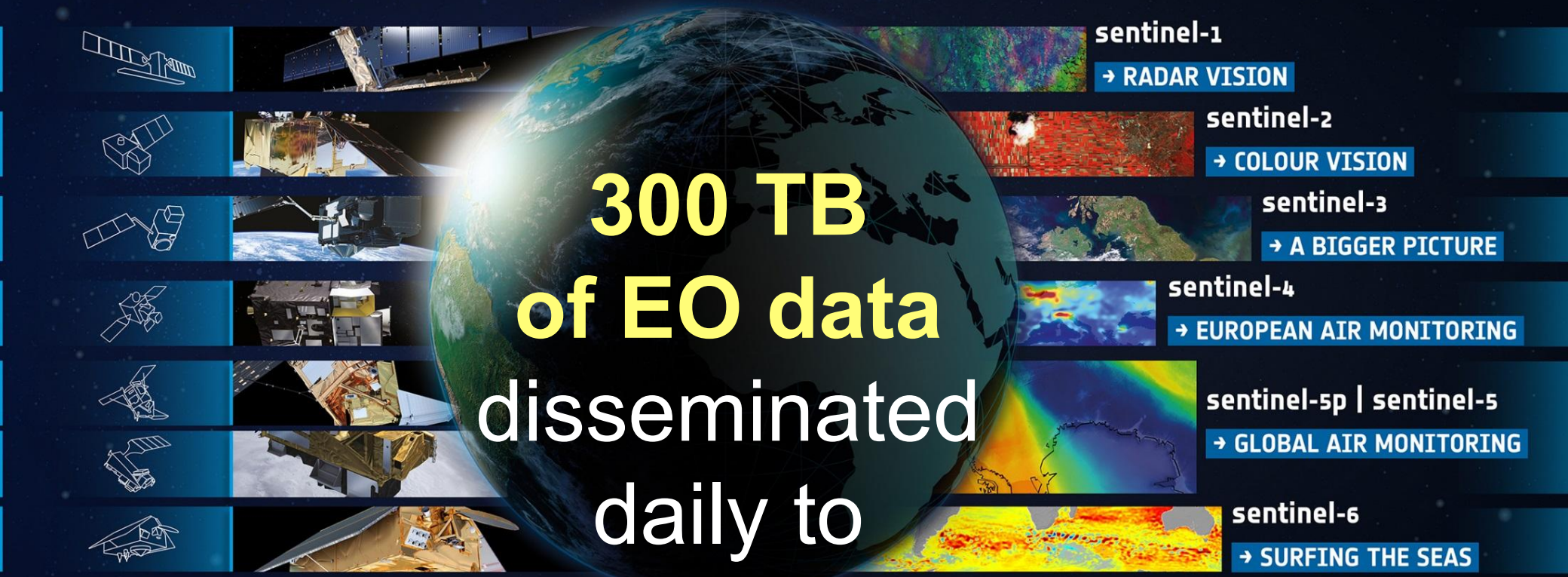
full, free & open data policy

8 Sentinels flying



preparing Copernicus 4.0

Copernicus Sentinels (First Generation)



CHARTING

Copernicus Sentinel Status

S-1

Radar

A	3 Apr. 2014
B	25 Apr. 2016
C	2022
D	> 2024

S-2

High Res. Optical

A	23 Jun. 2015
B	6 Mar. 2017
C	2022
D	> 2025

S-3

Medium Res. Optical & Altimetry

A	16 Feb. 2016
B	25 Apr. 2018
C	2023
D	> 2025

S-4

Atmospheric Chemistry (GEO)

A	2023
B	2030

S-5

Atmospheric Chemistry (LEO)

A	13 Oct. 2017

S-5

Atmospheric Chemistry (LEO)

A	2023
B	2030
C	2037

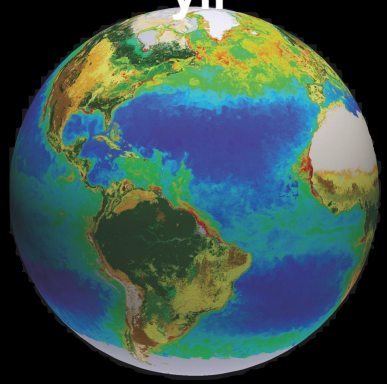
S-6

Altimetry

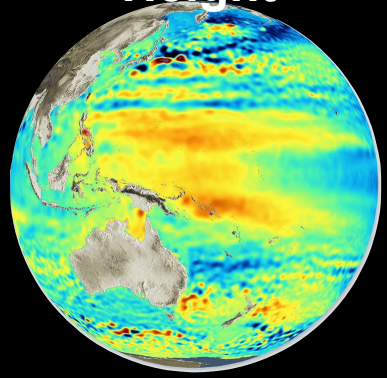
MF	21 Nov. 2020
B	2025

Global & System View by Copernicus

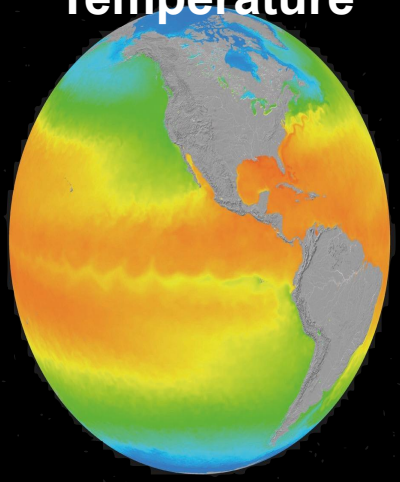
Chloroph
yll

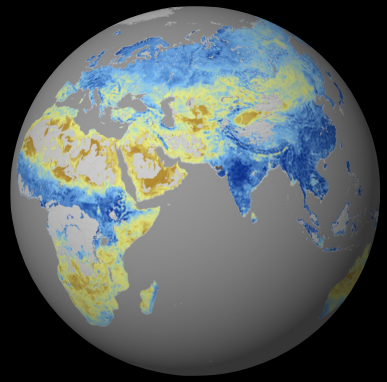


Sea Level
Height

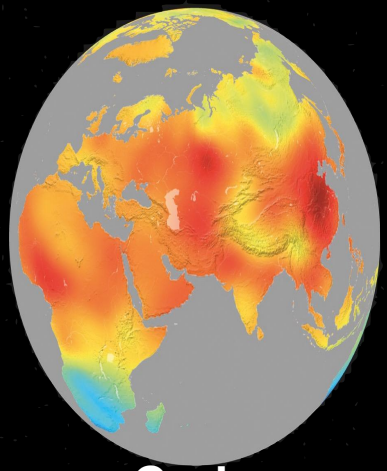


Sea Surface
Temperature

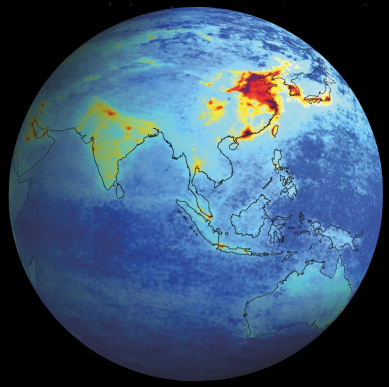




Soil
Moisture



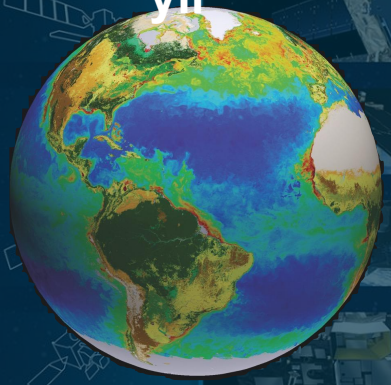
Carbon
Dioxide



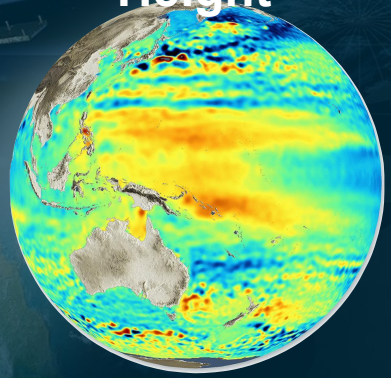
Nitrous
Oxyde

Global & Systems View by Copernicus

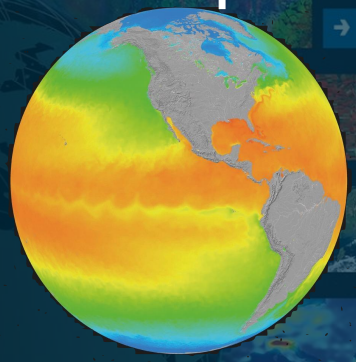
Chlorophyll



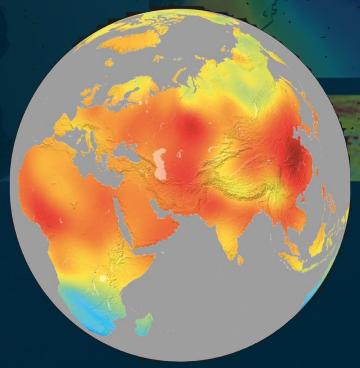
Sea Level Height

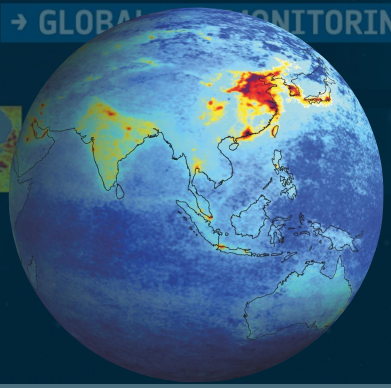


Sea Surface Temp.



Biomass





Soil Moisture

Land cover Type

Carbon Dioxide

Nitrous Oxyde

Copernicus Sentinel Satellites

Sentinel 1 (A/B/C/D)
SAR Imaging

All weather, day/night applications, interferometry

Sentinel 2 (A/B/C/D)
Multispectral Imaging

Land applications: urban, forest, agriculture, … Continuity of Landsat, SPOT

Sentinel 3 (A/B/C/D)
Ocean & Global Land Monitoring

Wide-swath ocean colour, vegetation, sea/land surface temperature, altimetry

Sentinel 4 (A/B)
Geostationary Atmospheric

Atmospheric composition monitoring, pollution; instrument on MTG satellites

Sentinel 5 (MF/B/C) & Precursor
Low-Orbit Atmospheric

Atmospheric composition monitoring; instrument on MetOp-SG satellites

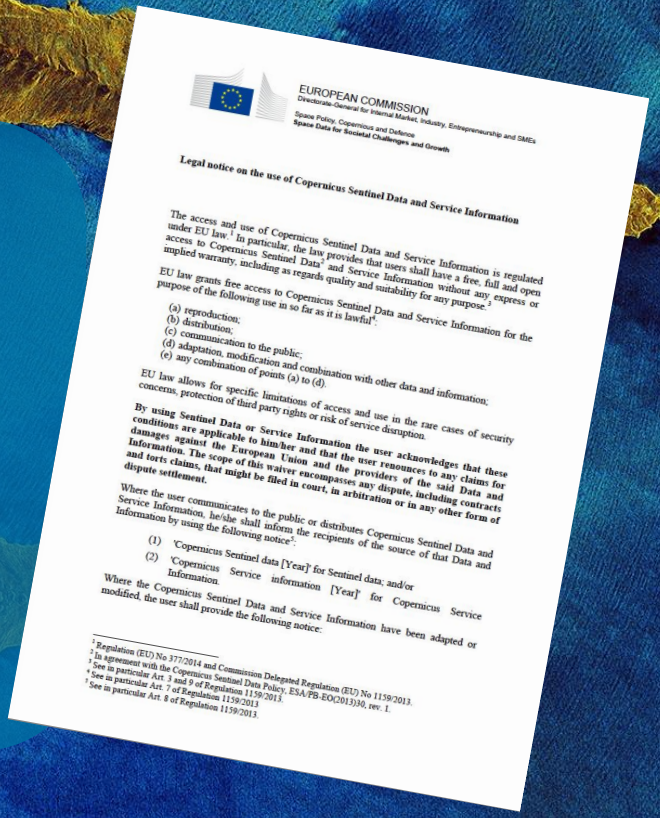
Sentinel 6
Jason CS (A/B)

Altimetry reference mission

Copernicus Sentinel Data Policy

Sentinel data are available:

- ✔ Free, Full and Open*
- ✔ Over very long term
- ✔ Systematically, Operationally



EUROPEAN COMMISSION
Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
Space Policy, Copernicus and Defence
Space Data for Societal Challenges and Growth

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(e) any combination of points (a) to (d).

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By using Sentinel Data or Service Information the user acknowledges that these conditions are applicable to him/her and that the user renounces to any claims for damages against the European Union and the providers of the said Data and Information. The scope of this waiver encompasses any dispute, including contracts and torts claims, that might be filed in court, in arbitration or in any other form of dispute settlement.

Where the user communicates to the public or distributes Copernicus Sentinel Data and Service Information, he/she shall inform the recipients of the source of that Data and Information by using the following notice[5]:

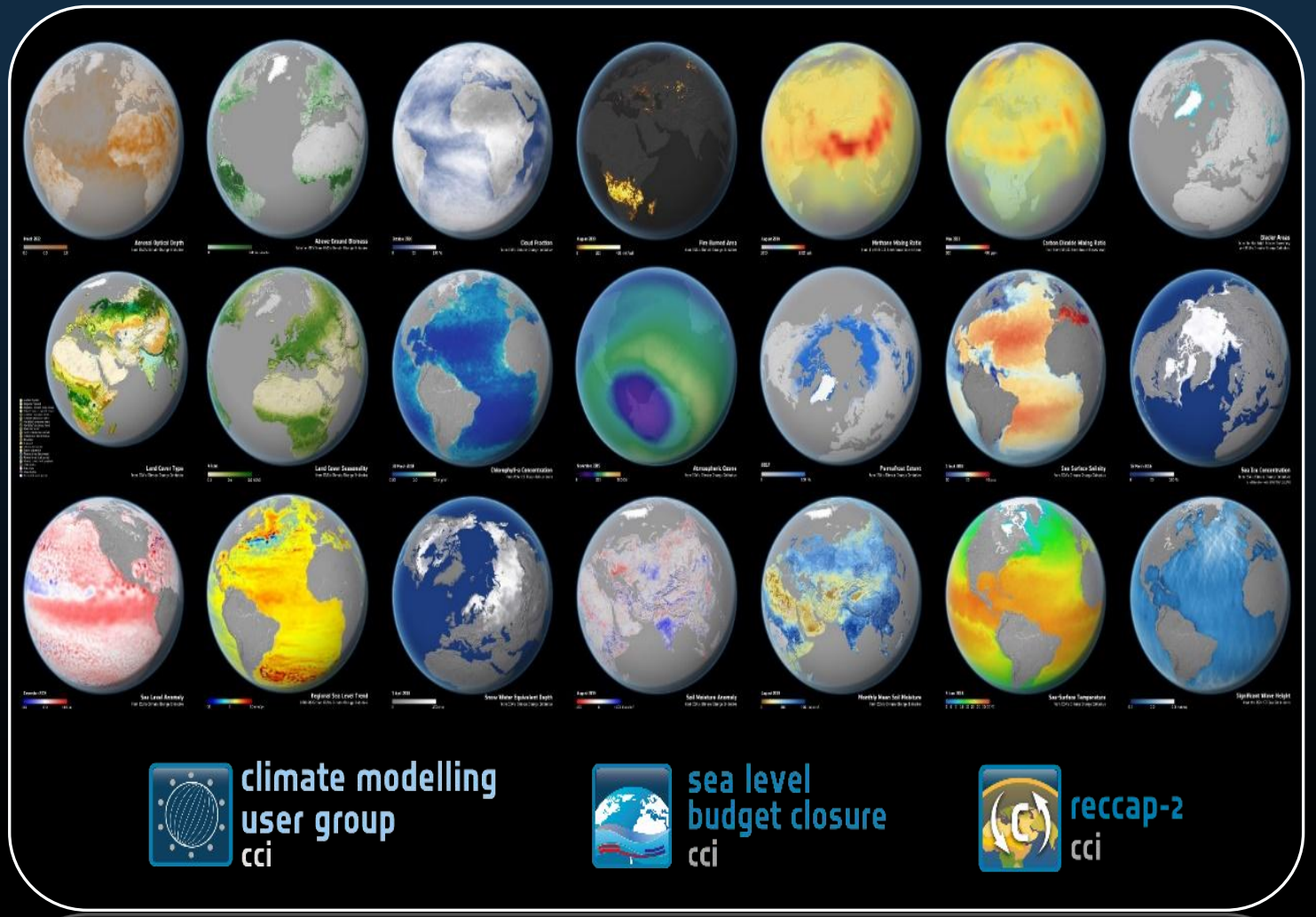
(1) 'Copernicus Sentinel data [Year]' for Sentinel data; and/or
(2) 'Copernicus Service Information [Year]' for Copernicus Service Information.

Where the Copernicus Sentinel Data and Service Information have been adapted or modified, the user shall provide the following notice:

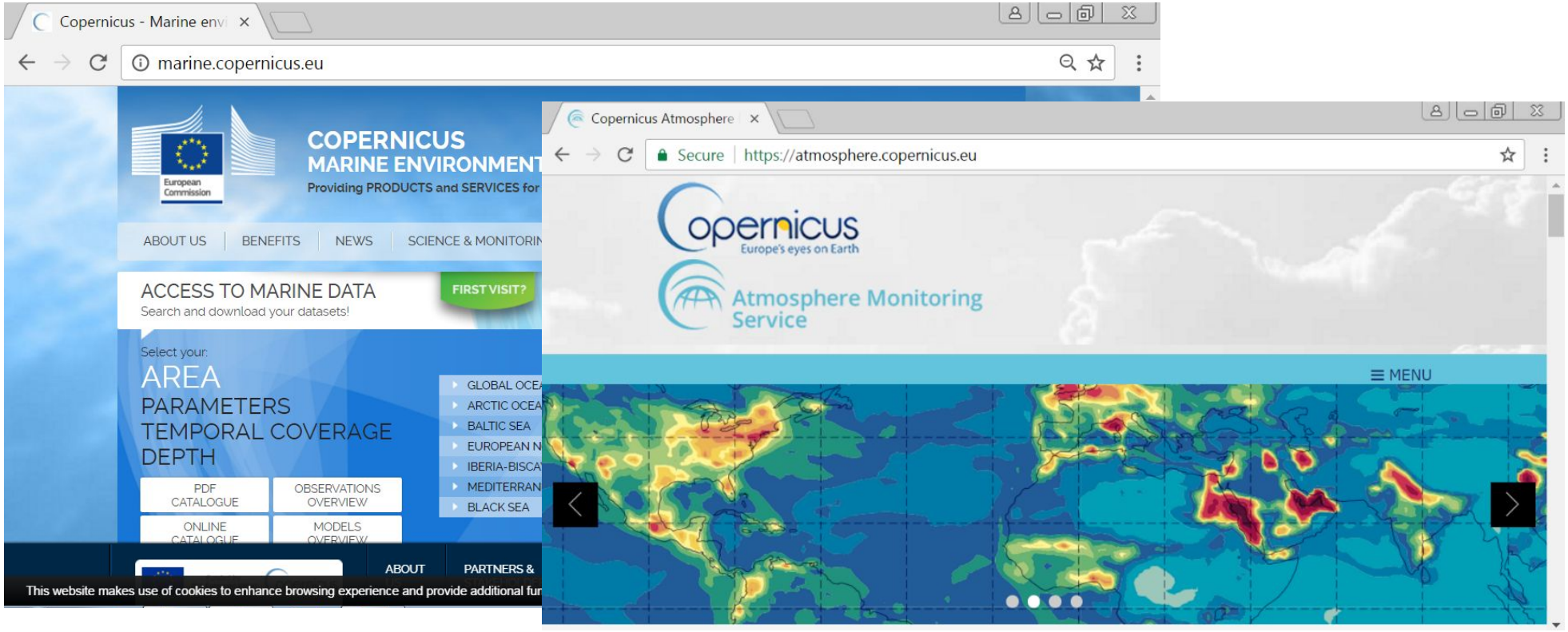
[1] Regulation (EU) No 377/2014 and Commission Delegated Regulation (EU) No 1159/2013.
[2] In agreement with the Copernicus Sentinel Data Policy, ESA/PB-EO(2013)30, rev. 1.
[3] See in particular Art. 3 and 9 of Regulation 1159/2013.
[4] See in particular Art. 7 of Regulation 1159/2013.
[5] See in particular Art. 8 of Regulation 1159/2013.

ESA Climate Change Initiative: 21 Essential Climate Variables (ECV) Being Monitored

- CCI is a response to UNFCCC's need for **systematic global climate observation**
- ECV datasets provide **long-term empirical evidence** to predict & understand key parts of the climate
- 54 defined ECVs, 36 monitored from space, **21 under development** by ESA



Data for Copernicus Services



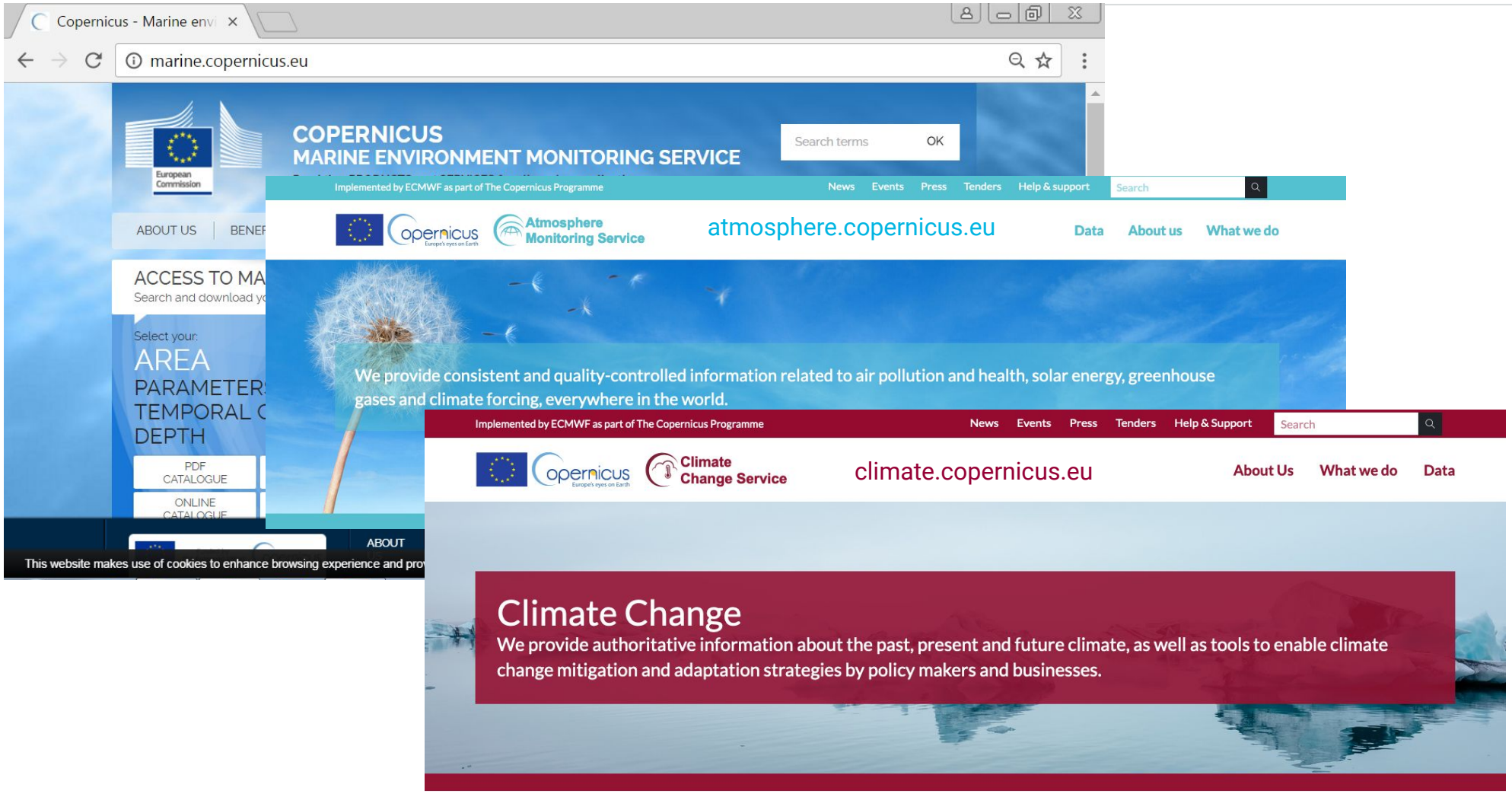
Build an innovative data value chain

A wide range of unique data and products

To be applied in different domains

To fit with different application and needs

Data for Copernicus Services



Build an innovative data value chain

A wide range of unique data and products

To be applied in different domains

To fit with different application and needs

COPERNICUS ATMOSPHERE MONITORING SERVICE

Atmosphere Monitoring

CAMS is one of six thematic information services provided by the Copernicus Earth Observation Programme of the European Union.

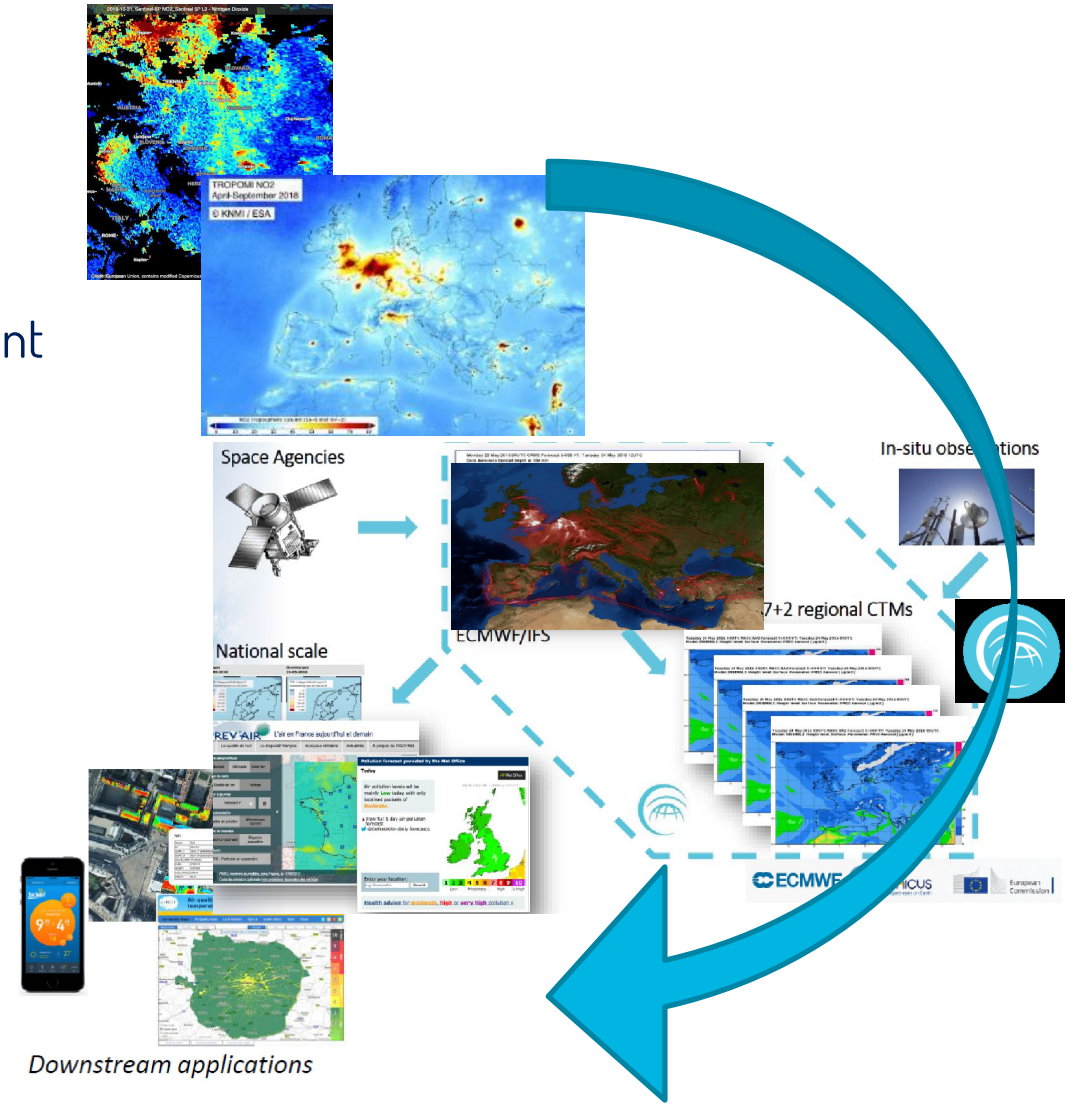
From data to applications

Observations are essential, but require care:

Gaps in space and time

Observed quantities may not be directly relevant
 Is that what I need ?
Complex and numerous

Copernicus improves usability:
Integrate observations
 satellite and non satellite, models
Understand User's needs
Generate added value products
Provide Guidance
Ensure Quality and usability



Earth observation data essential for monitoring and forecasting atmospheric composition

Atmosphere Monitoring

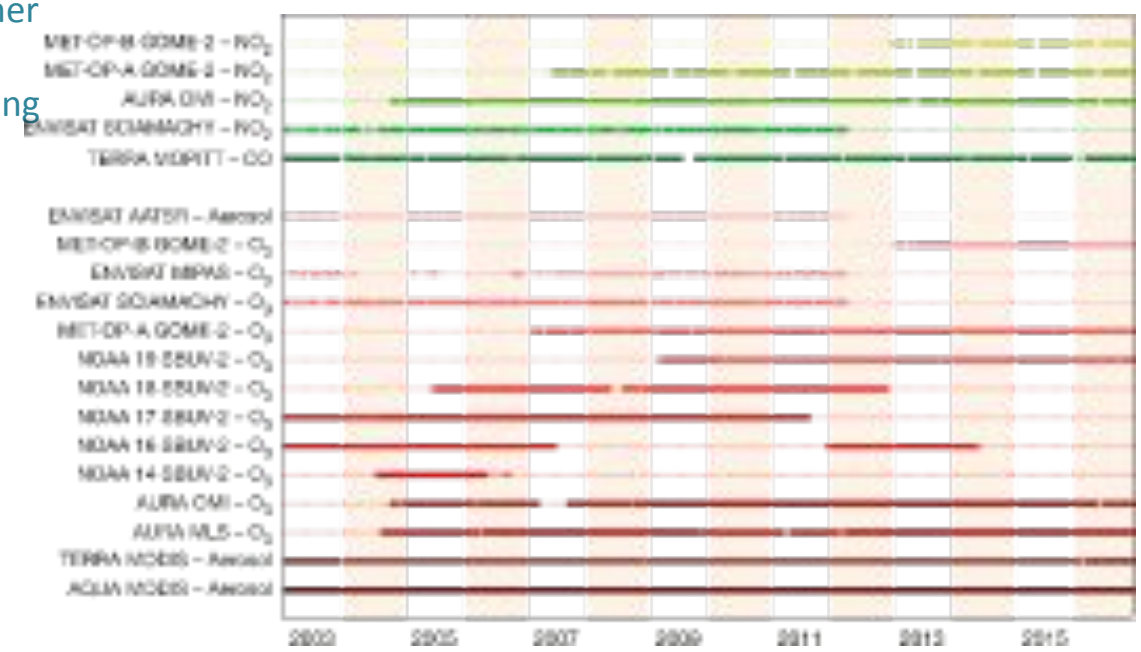
Species	Instruments
Global system	
O_3	**OMI, SBUV, GOME-2, MLS, OMPS S5p**
CO	**IASI, MOPITT, S5p**
NO_2	**OMI, GOME-2, S5p**
SO_2	**OMI, GOME-2, S5p**
Aerosol	**MODIS, PMAp,** VIIRS, S3
CO_2	**GOSAT, OCO-2**
CH_4	**GOSAT, IASI, S5p**
GFAS fire emissions	**MODIS, SEVIRI*, VIIRS,** Sentinel-3, GOES-E/W*,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

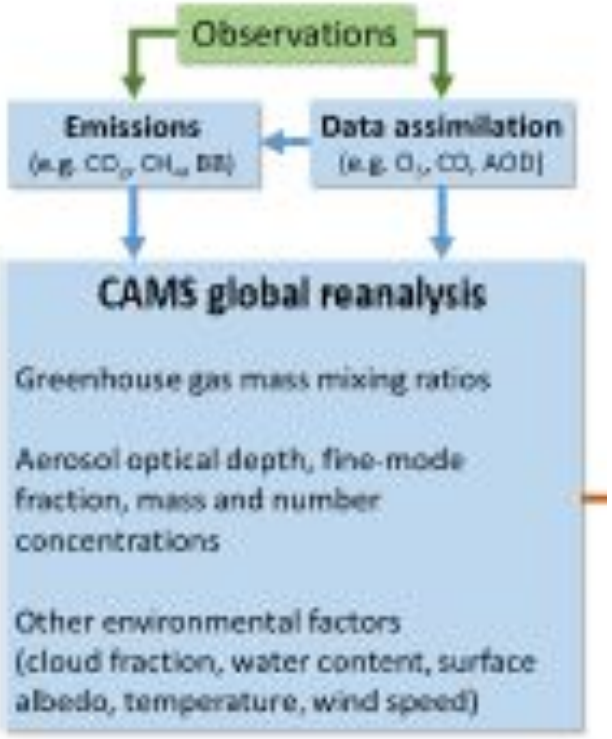
Assimilated **Monitored** Under development *Geostationary platform

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

CAMS – Generate global reanalysis

Atmosphere Monitoring

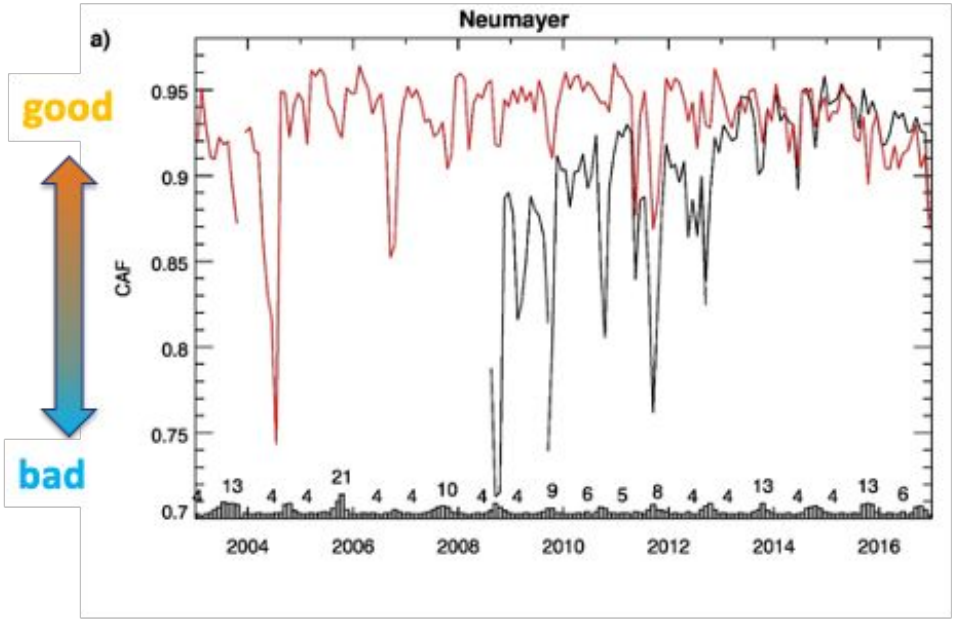




Near-real-time versus reanalysis

Atmosphere Monitoring

Ozone score



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

CAMS global reanalysis

- 2003 – 2018, 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

EMISSION MONITORING - AMBITIONS OF THE EUROPEAN COMMISSION

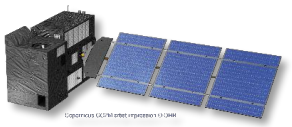
Atmosphere Monitoring

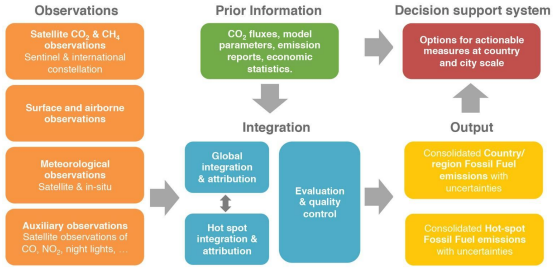
Ursula von der Leyen: "You should explore ways in which we can make the most of
our assets to deliver on climate objectives, including the use of Copernicus to monitor
CO_2 emissions."

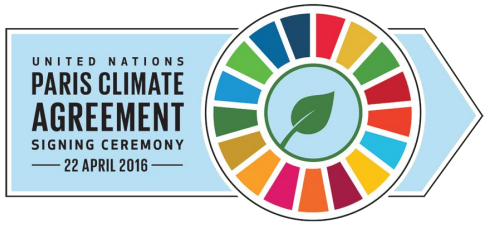
TIMELINE OF COPERNICUS CO2MVS

Atmosphere Monitoring

From expert groups through dedicated research funding to operational services.



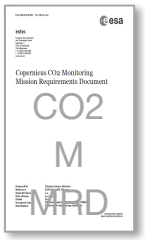




Atmosphere Monitoring Service
atmosphere.copernicus.eu

2021

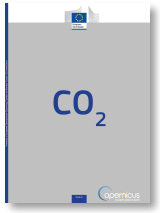
2026



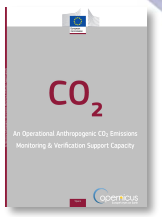
2018

CoCO2
Prototype system for a Copernicus CO_2 service

2021



2015



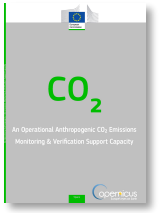
2017

CoCO2
Prototype system for a Copernicus CO_2 service

2017

VERIFY

2018



2019

esa

ECMWF

EUMETSAT

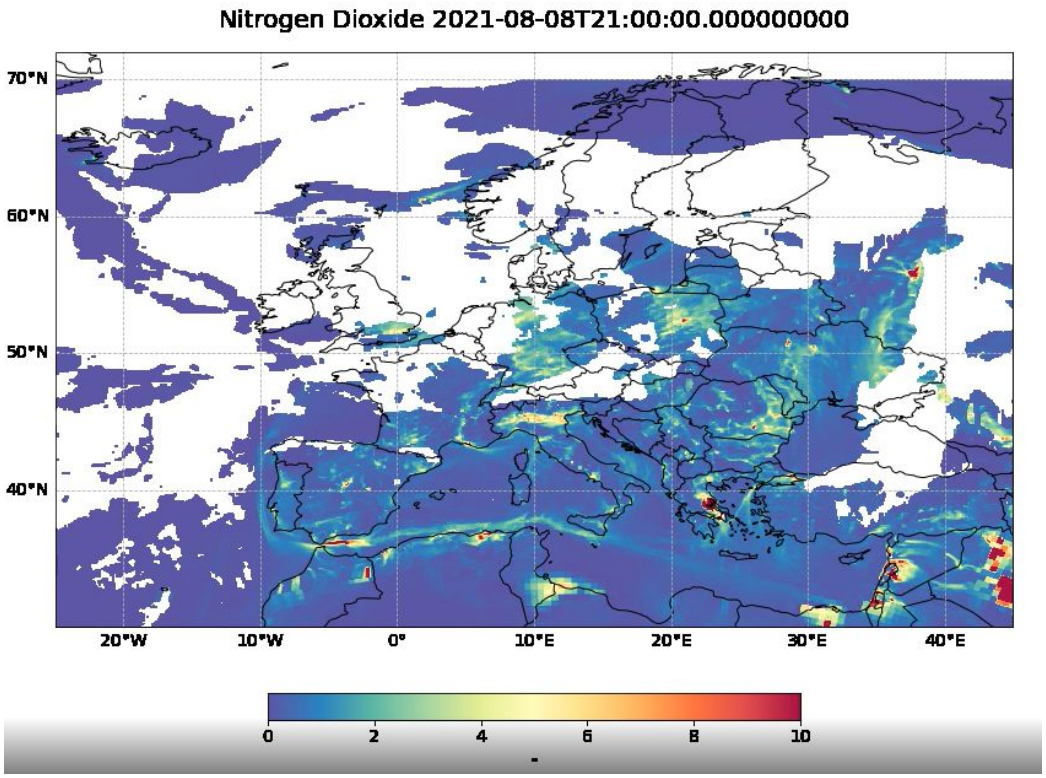
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

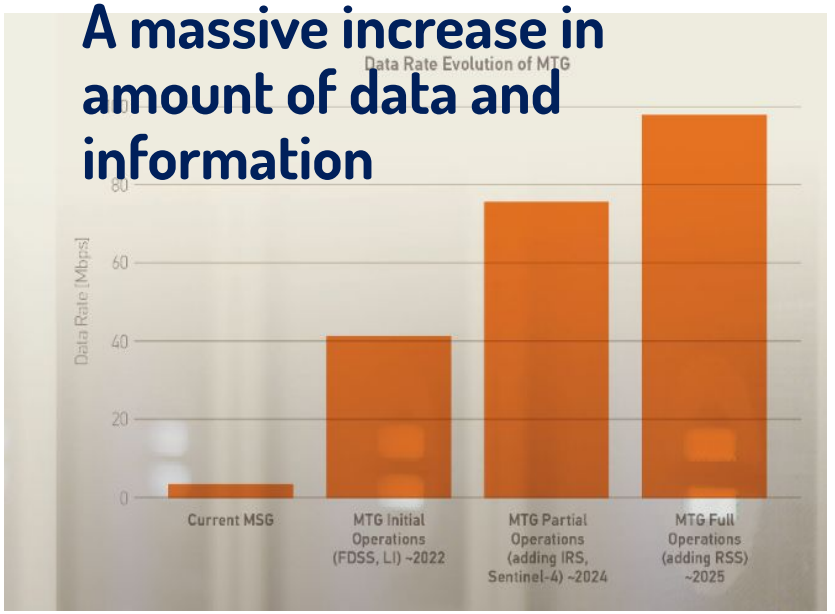
IMPLEMENTED BY ECMWF

New paradigms emerging – data

Sentinel 4 is much awaited as first geostationary instrument …



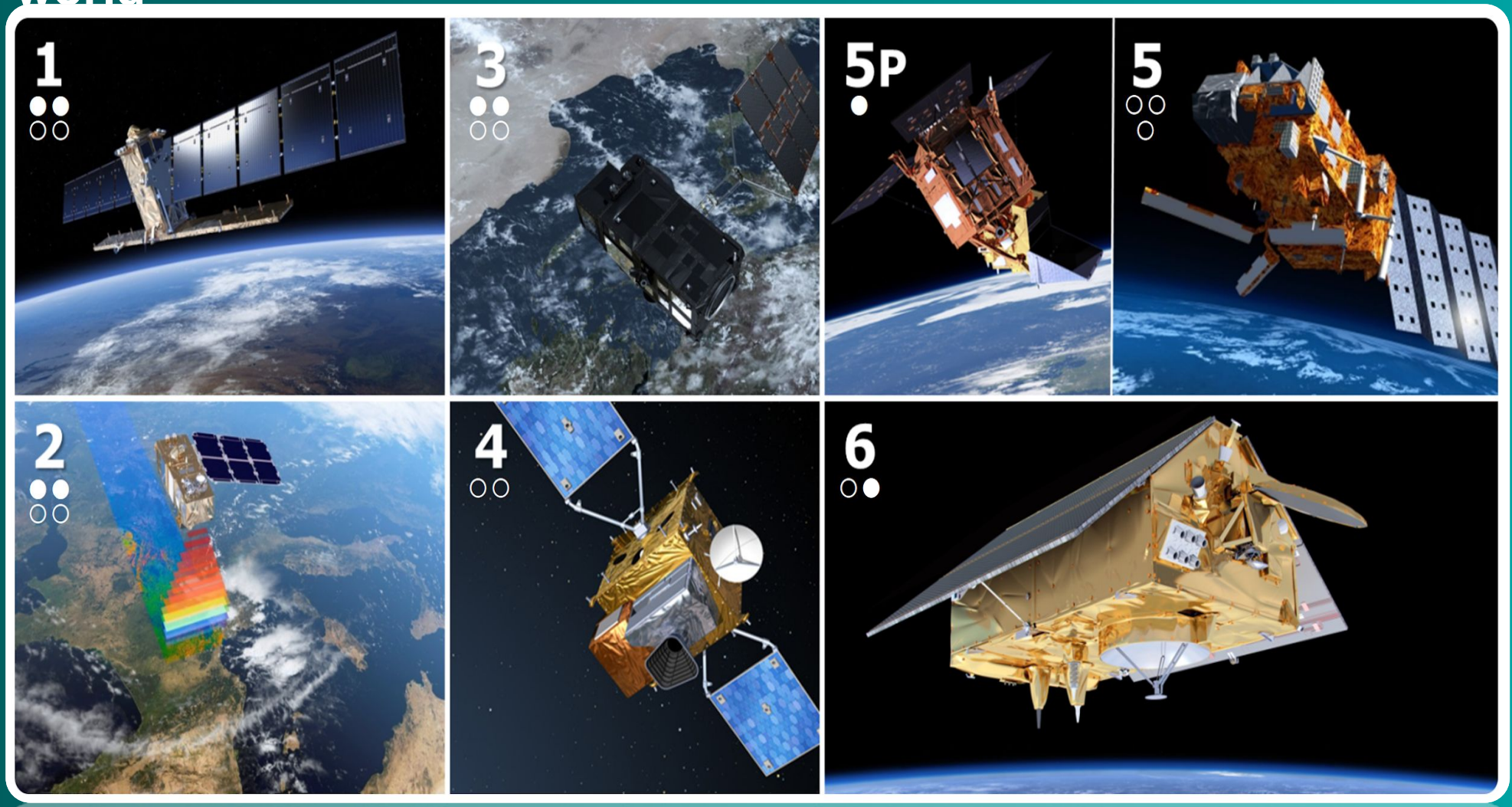
A massive increase in amount of data and information



EUMETSAT
Copernicus
Europe's eyes on Earth
esa

The Big Data Revolution

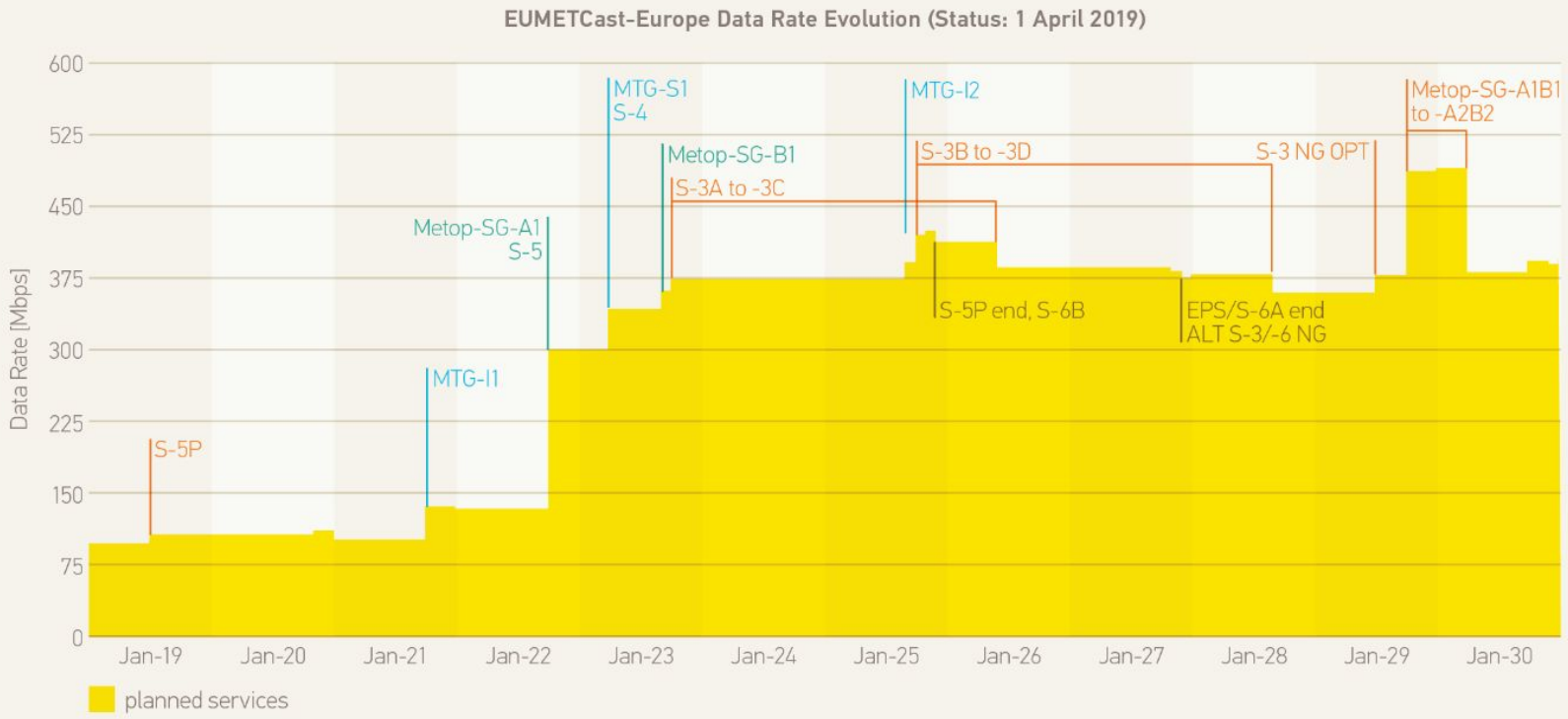
Copernicus is the largest producer of EO data in the world



Amount of data and dissemination

Increased data rates and volume
New format
Adapting local software
Ingesting data and products into applications

Figure 17: EUMETCast-Europe data rate evolution. The full operational MTG capability is planned to be reached by 2026.



Barriers and actions

Barriers

- Awareness
- Context & Terminology
- Technical knowledge
- Fitness for Purpose
- Data Access, handling, volume

Support Actions

- Understand User's needs
- Enable applications
- Provide Guidance
- Ensure Quality and usability

Particularly true for African partners

- Information on existing initiatives
- Possibility to feedback on needs
- Access methods and infrastructure
- Network and trans-national cooperation

Joint schools EUMETSAT-ESA-ECMWF-CAMS

Balance between lectures and practical

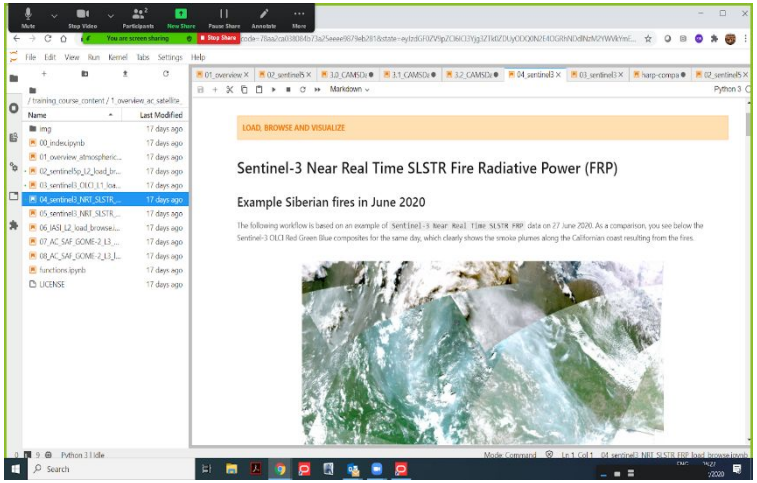
Overall > 800 applications for three events

Limited number of attendees to grant interactivity

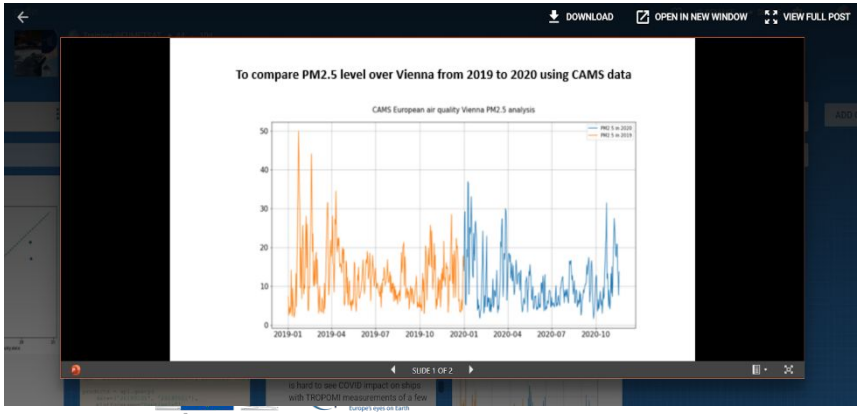
Address a wide range of concepts and data

opernicus Europe's eyes on Earth · ECMWF · Atmosphere Monitoring Service atmosphere.copernicus.eu · EUMETSAT · esa

What typically happens in a course like this ?



Work in groups / teams
Alternate lectures, data discovery, coding
Present real cases
Support to develop small projects from scratch
Support networking



Short Courses and Webinars

Address a wider range of users

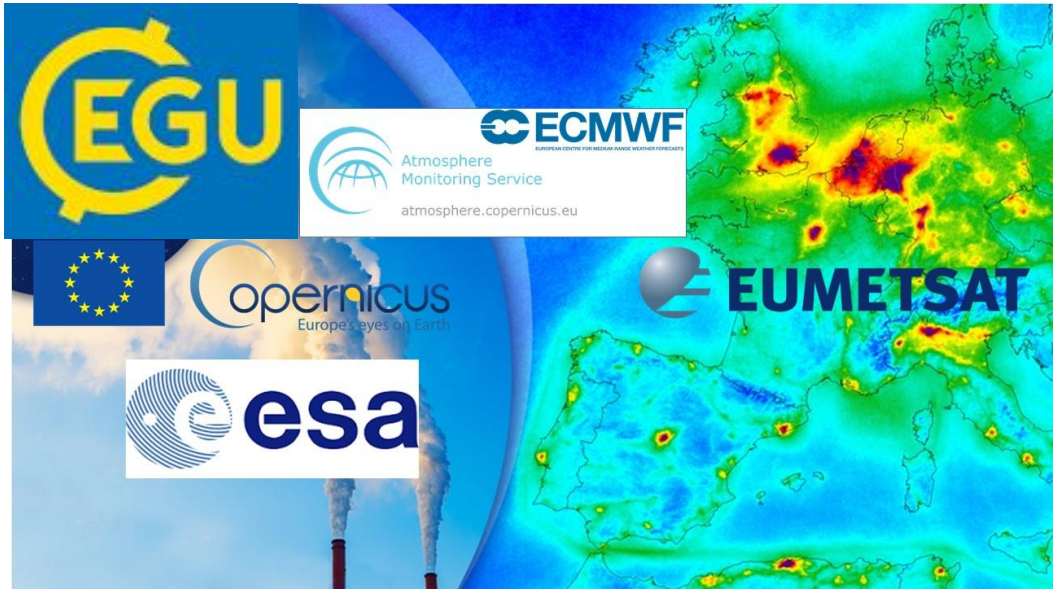
Based on data discovery

On average > 200 Users per event

Since 2019 about 15 events

May be joint with conferences / events

Fitted to discover one dataset and the applications



Massive On-line Courses - most recent ones