CAMS plans and current status and the link to CO_2 estimates in national GHG inventories

Atmosphere Monitoring

Richard Engelen
Deputy Director of CAMS

PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
IMPLEMENTED BY ECMWF

Converting science into user-driven services

Atmosphere Monitoring

EU Climate Law as part of EU Green Deal

Set the long-term direction of travel for meeting the 2050 climate neutrality objective through all policies, in a socially fair and cost-efficient manner

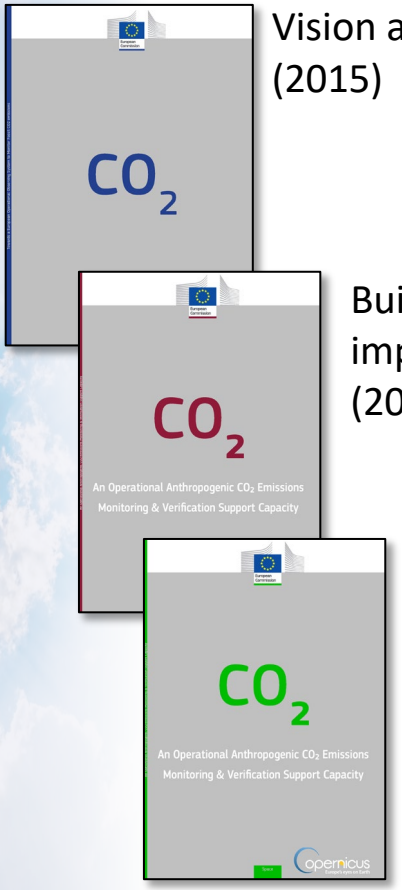
Set a more ambitious EU 2030 target, to set Europe on a responsible path to becoming climate-neutral by 2050

Create a system for **monitoring progress** and take further action if needed

Copernicus can contribute to an EU-coordinated capability for detecting and monitoring global super-emitters, principally via its Copernicus Atmosphere Monitoring Service (CAMS)

European Commission CO2 Monitoring Task Force

Atmosphere Monitoring



Vision and strategy (2015)

Building blocks and implementation (2017)

Role and requirements for in-situ data (2019)

2020

BAMS In Box

Toward an Operational Anthropogenic CO_2 Emissions Monitoring and Verification Support Capacity

G. Janssens-Maenhout, B. Pinty, M. Dowell, H. Zunker, E. Andersson, G. Balsamo, J.-L. Bézy, T. Brunhes, H. Bösch, B. Bojkov, D. Brunner, M. Buchwitz, D. Crisp, P. Ciais, P. Counet, D. Dee, H. Denier van der Gon, H. Dolman, M. R. Drinkwater, O. Dubovik, R. Engelen, T. Fehr, V. Fernandez, M. Heimann, K. Holmlund, S. Houweling, R. Husband, O. Juvyns, A. Kentarchos, J. Landgraf, R. Lang, A. Löscher, J. Marshall, Y. Meijer, M. Nakajima, P. I. Palmer, P. Peylin, P. Rayner, M. Scholze, B. Sierk, J. Tamminen, and P. Veefkind

ABSTRACT: Under the Paris Agreement (PA), progress of emission reduction efforts is tracked on the basis of regular updates to national greenhouse gas (GHG) inventories, referred to as bottom-up estimates. However, only top-down atmospheric measurements can provide observation-based evidence of emission trends. Today, there is no internationally agreed, operational capacity to monitor anthropogenic GHG emission trends using atmospheric measurements to complement national bottom-up inventories. The European Commission (EC), the European Space Agency, the European Centre for Medium-Range Weather Forecasts, the European Organisation for the Exploitation of Meteorological Satellites, and international experts are joining forces to develop such an operational capacity for monitoring anthropogenic CO_2 emissions as a new CO_2 service under the EC's Copernicus program. Design studies have been used to translate identified needs into defined requirements and functionalities of this anthropogenic CO_2 emissions Monitoring and Verification Support (CO_2MVS) capacity. It adopts a holistic view and includes components such as atmospheric spaceborne and in situ measurements, bottom-up CO_2 emission maps, improved modeling of the carbon cycle, an operational data-assimilation system integrating top-down and bottom-up information, and a policy-relevant decision support tool. The CO_2MVS capacity with operational capabilities by 2026 is expected to visualize regular updates of global CO_2 emissions, likely at 0.05° x 0.05°. This will complement the PA's enhanced transparency framework, providing actionable information on anthropogenic CO_2 emissions that are the main driver of climate change. This information will be available to all stakeholders, including governments and citizens, allowing them to reflect on trends and effectiveness of reduction measures. The new EC gave the green light to pass the CO_2MVS from exploratory to implementing phase.

https://doi.org/10.1175/BAMS-D-19-0017.1
Corresponding author: Greet Janssens-Maenhout, greet.maenhout@ec.europa.eu
In final form 21 January 2020
Publisher's Note: This article was modified on 29 September 2021 to correct affiliations for M. Heimann and J. Marshall.

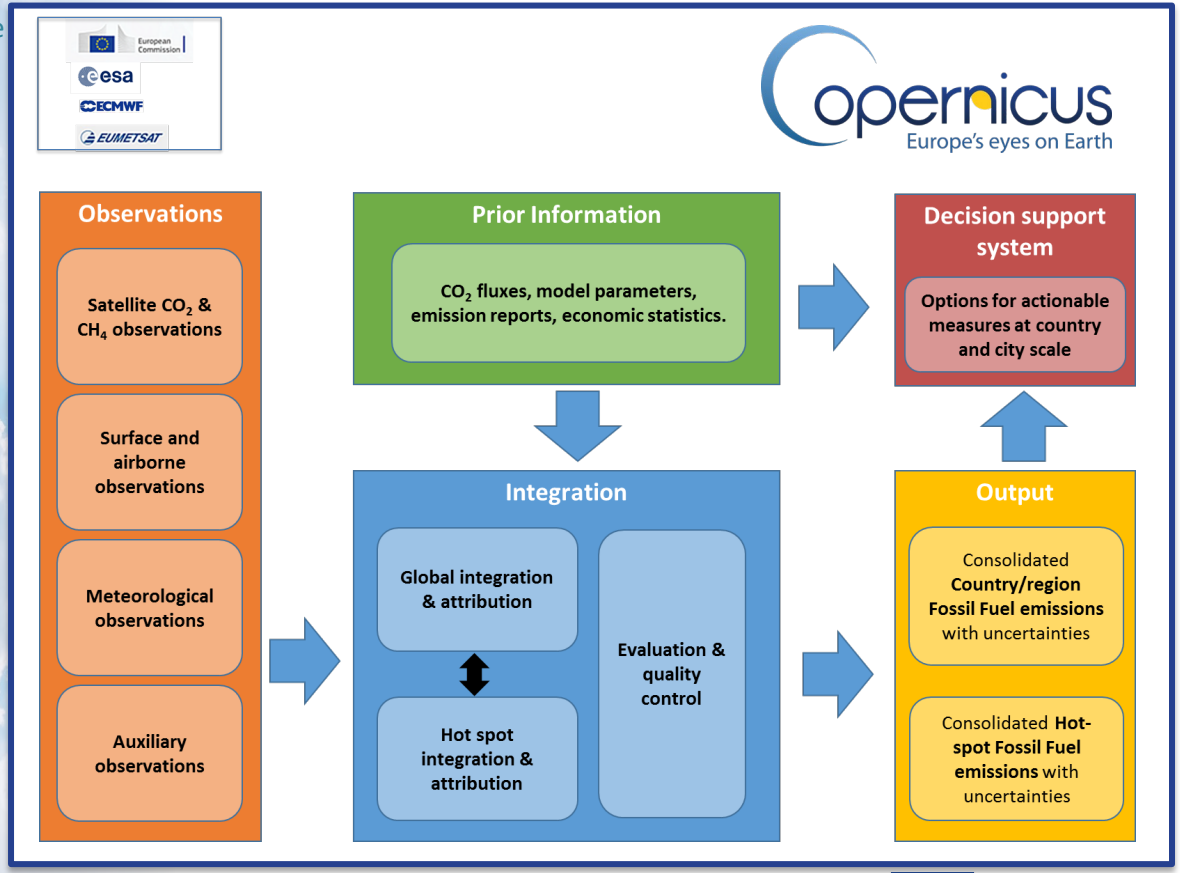
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Atmosphere Monitoring

Developing a new Copernicus emission monitoring service



Atmosphere Monitoring Service

atmosphere.copernicus.eu

An **integrated system approach** based on experience in NWP and air quality monitoring & forecasting.

Same system (in potential different configurations) for greenhouse gases and atmospheric pollutants.

PROGRAMME OF THE EUROPEAN UNION

opernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF


PROGRAMME OF THE
EUROPEAN UNION
opernicus
Europe's eyes on Earth
co-funded with
esa
CO2M
Copernicus Anthropogenic
Carbon Dioxide Monitoring

Atmosphere Monitoring

High-level aims

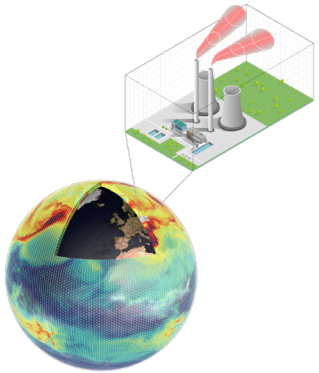
High-level requirements for the CO_2MVS for policymakers	Technically implied accuracy requirement[a]	Space and time resolution
Detection of emitting hot spots such as megacities or power plants	46 kton CO_2 yr^{-1} km^{-2}	2 km x 2 km pixel; daily
Monitoring the hot-spot emissions to assess emission reductions/increases	1 kton CO_2 yr^{-1} km^{-2}	2 km x 2 km pixel; daily
Assessing emission changes against local reduction targets to monitor NDCs	0.2 kton CO_2 yr^{-1} km^{-2}	0.1° x 0.1°; monthly
Assessing the national emissions and changes in 5-yr time steps for the GST	0.2 kton CO_2 yr^{-1} per country	Country area; yearly

From: Janssens-Maenhout et al., 2020

Atmosphere Monitoring

An operational service

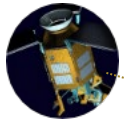
- Operational long-term perspective
- Continuous monitoring for fast-response information
- Re-processing for most accurate observation-based information
- Worldwide country/regional scales and facility/city scales
- Evaluation & quality control
- User support
- Contributing to CEOS, WMO, and other international coordination efforts



Timeline of CAMS Emission Services

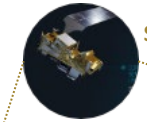
Atmosphere Monitoring

ECMWF esa EUMETSAT



Sentinel 5p

Sentinel 4



Sentinel 5

CO_2 Mission

SATELLITE MISSIONS

Air Quality emissions 2025

Operational ramp-up in CAMS

SERVICE COMPONENTS

2026

CO_2 Monitoring & Verification Support (CO_2MVS)

2015

CO2 TASK FORCE GUIDANCE DOCUMENTS

2017

2019

2017

CO_2 Human Emissions

2018

VERIFY

2021

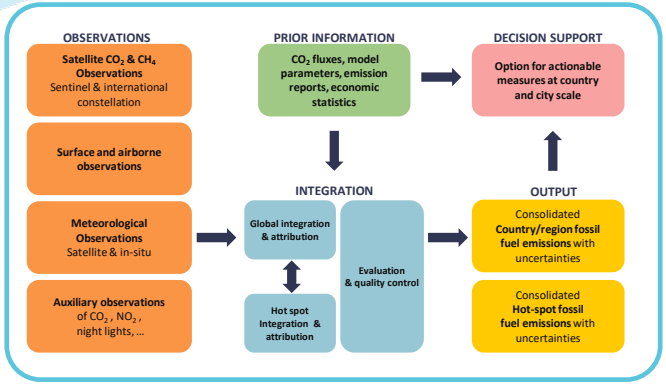
CoCO2 Prototype system for a Copernicus CO_2 service

2022

horizon europe

ICOS Cities

RESEARCH AND PREPARATORY PROJECTS



PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Atmosphere Monitoring

Research & Innovation to support implementation

Horizon 2020

Greenhouse gases

- CO_2 Human Emissions
- CoCO2 Prototype system for a Copernicus CO_2 service
- VERIFY
- ICOS Cities

Atmospheric pollutants

- SEEDS Sentinel EO-based Emission and Deposition Service

Horizon Europe

Greenhouse gases

- CORSO CO2MVS Research on Supplementary Observations
- AVENGERS
- EYE-CLIMA
- PARIS

Atmospheric pollutants

- CAMEO

Atmosphere Monitoring

Some examples of current development

- Development of global mosaic emission data set (CoCO2)
- Development of temporal profiles based on country-specific information (CoCO2)
- Development of emission models (CoCO2)
- Collaboration with Carbon Monitor

- Interface to policy users (VERIFY, CoCO2, CAMS, Global Carbon Project)

- Development of CO2M mission (ESA, EUMETSAT)
- Increased use of in situ data (ICOS-Cities, CORSO)
- Use of other satellite data (CORSO)

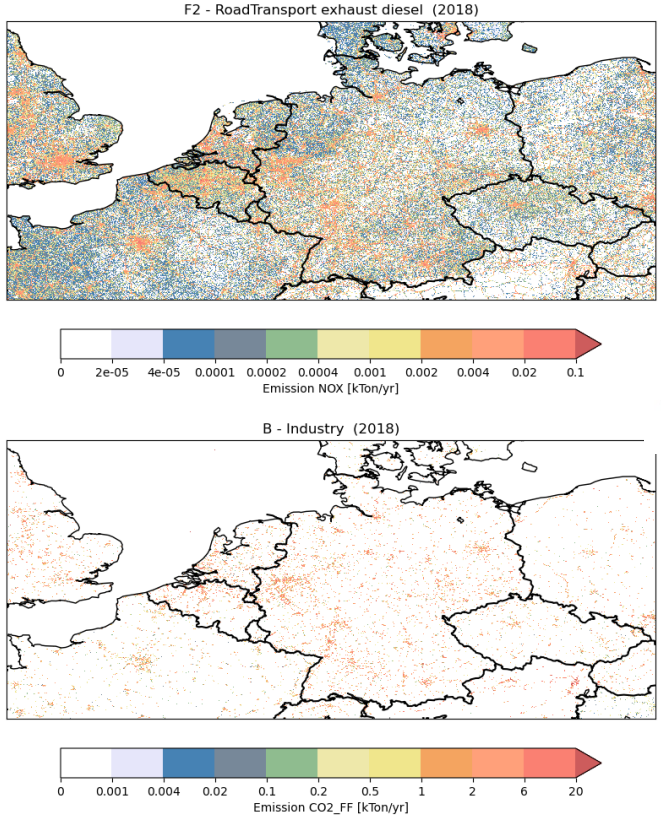
- Development of global data assimilation system (CoCO2)
- Development of plume estimation systems (CoCO2)
- Development of regional benchmark system (CAMS, ICOS-Cities)
- Evaluation & quality control (CoCO2, CAMS)

- Operational and prototype data products (CAMS, CoCO2, VERIFY)
- Access to data (CAMS)

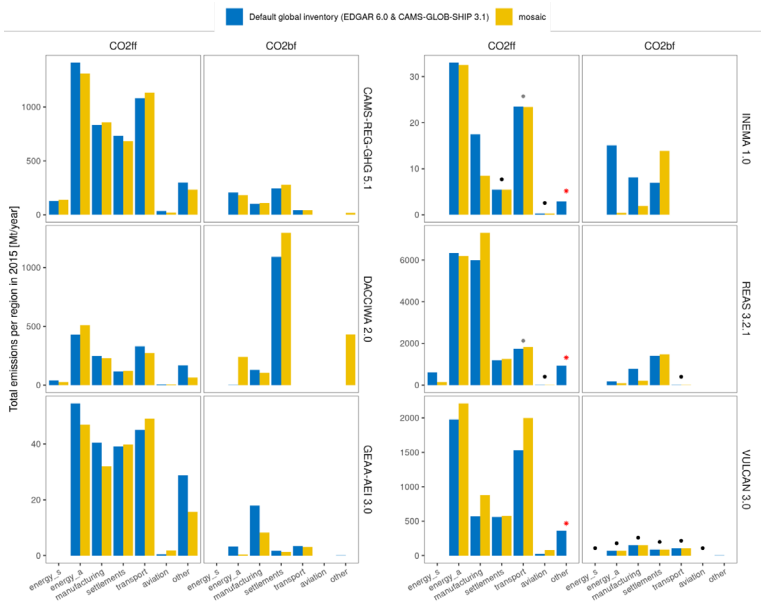
This is merely a sample of R&D activities relevant for the building blocks.

Development of improved emission inventories

Atmosphere Monitoring



CoCO2
Prototype system for a Copernicus CO_2 service



Global mosaic dataset with regional inventories for various parts of the world (lead: Ruben Urraca-Valle, JRC).

High-resolution (1x1km) emission dataset for part of Europe (lead: Stijn Dellaert, TNO).

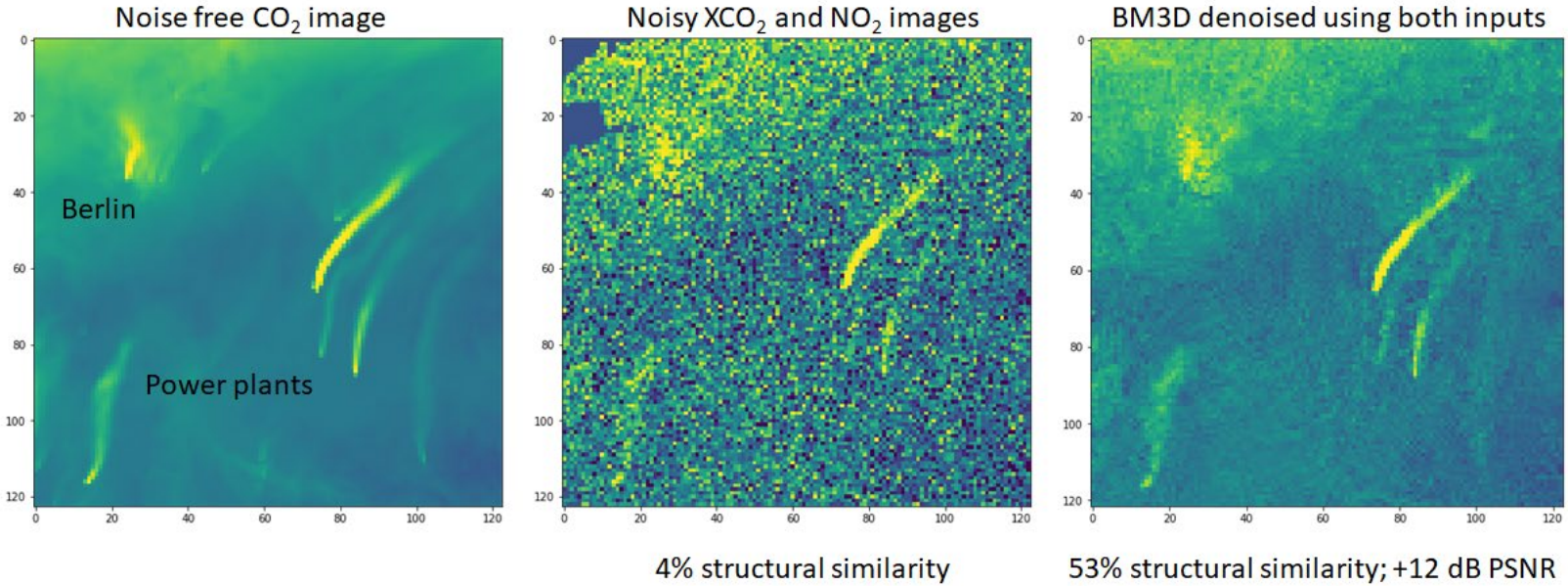
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Atmosphere Monitoring

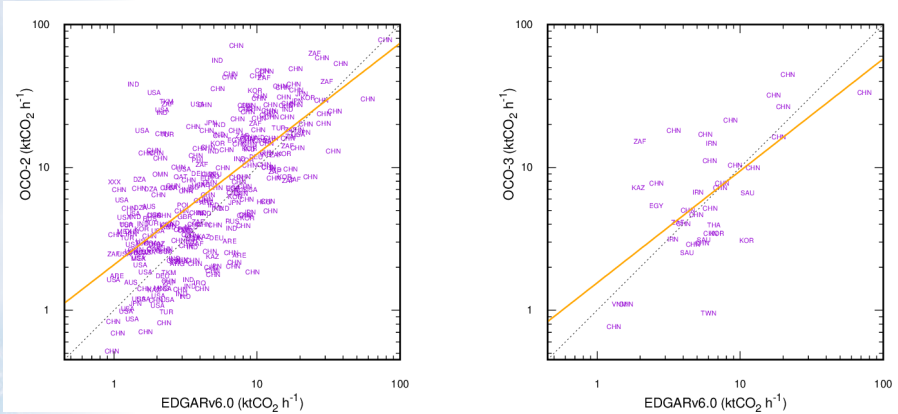
Plume detection



New methodologies to denoise a noisy XCO2 satellite image. (EMPA)

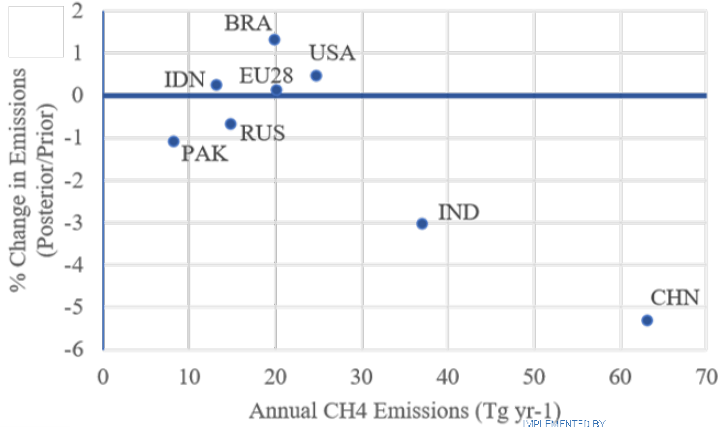
Prototype examples – CO_2 and CH_4

Atmosphere Monitoring



Retrieved **CO_2** emission values vs. EDGAR inventory values for OCO-2 (left) and OCO-3 (right). Each case is represented by the international 3-letter code of the country where the enhancement is located. The orange line is the regression line in base 10 logarithm. (CEA, Chevallier et al., submitted to Geophys. Res. Lett.)

Using ECMWF's Integrated Forecasting System (IFS) to estimate emissions. Regional annual anthropogenic **CH_4** emissions plotted against the posterior adjustment in emissions, as a percentage of the prior. (ECMWF, Adapted from McNorton et al., 2022)

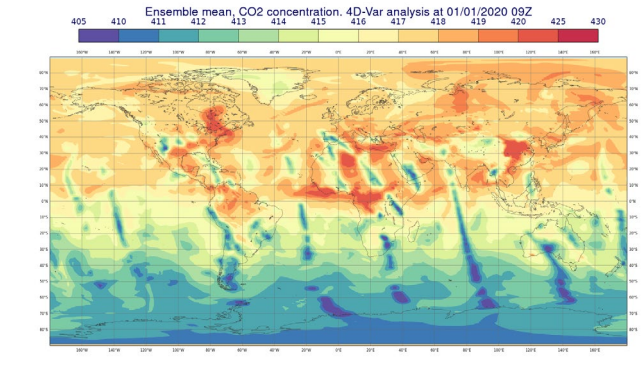


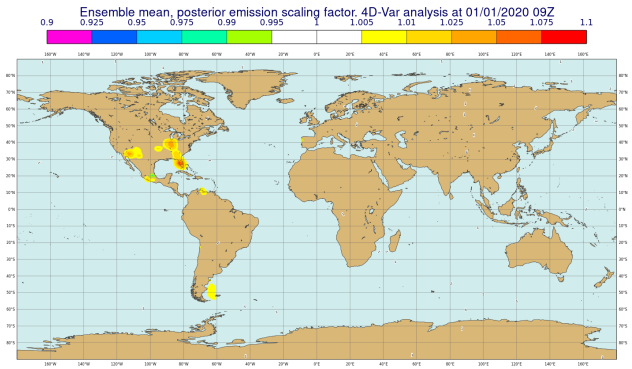
CoCO2
Prototype system for a Copernicus CO_2 service

PROGRAMME OF THE EUROPEAN UNION
Copernicus
IMPLEMENTED BY ECMWF

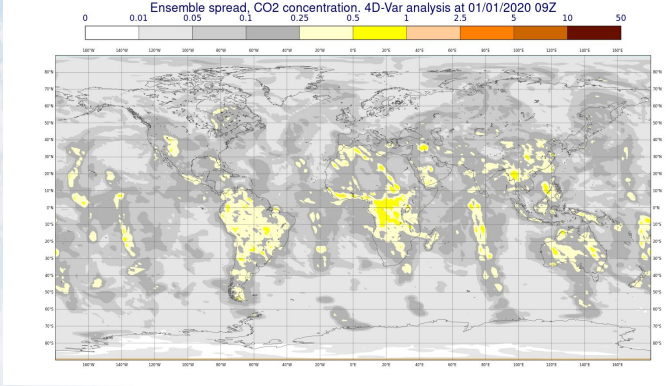
Uncertainties – Ensemble of Data Assimilation

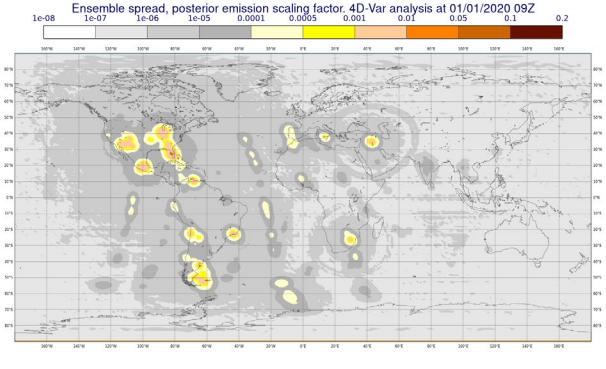
Atmosphere Monitoring





Mean





Spread

Atmospheric concentrations

Emission scaling factors

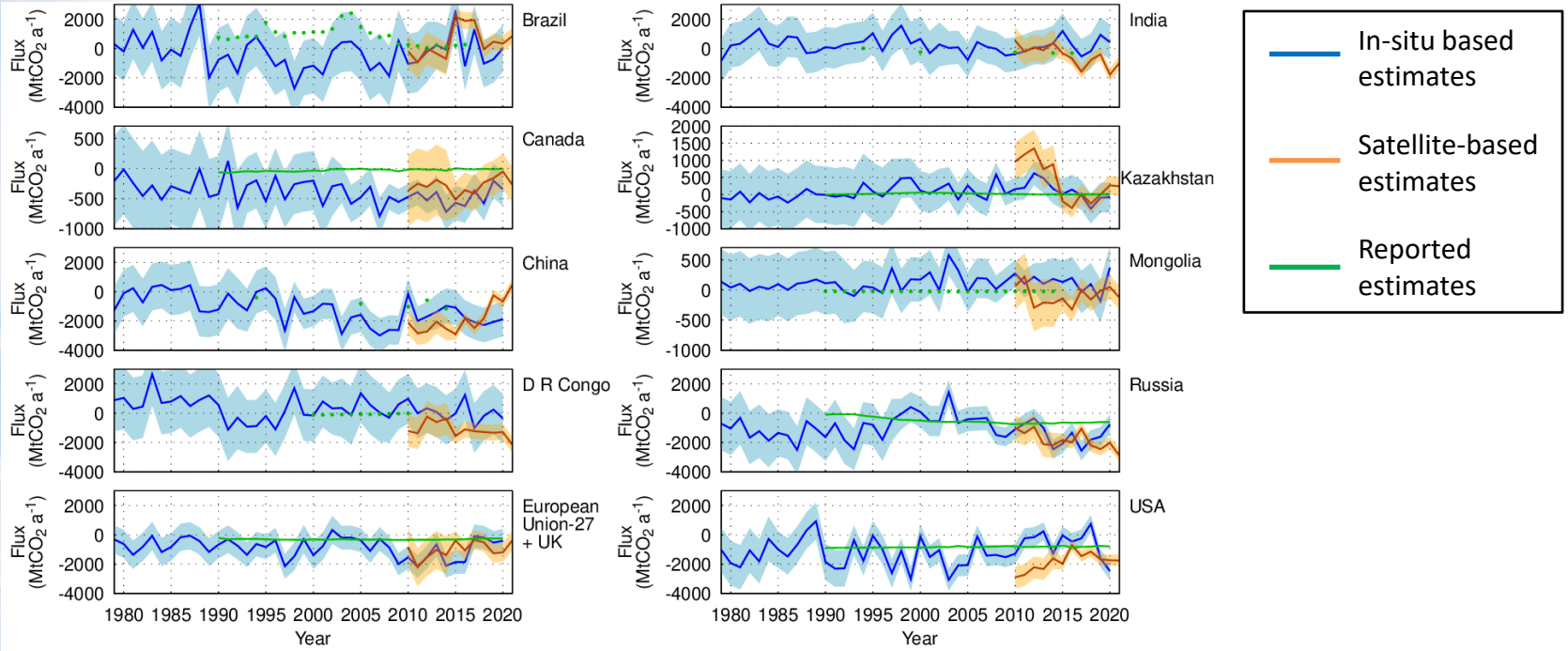
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Atmosphere Monitoring

Current operational products: AFOLU flux estimates



Annual CO_2 flux from the Agricultural, Forestry and Other Land Use (AFOLU) sector in ten large countries or groups of countries estimated by the 1-σ uncertainty envelope of the two CAMS atmospheric inversions. CAMS/CoCO2, Frederic Chevallier, LSCE

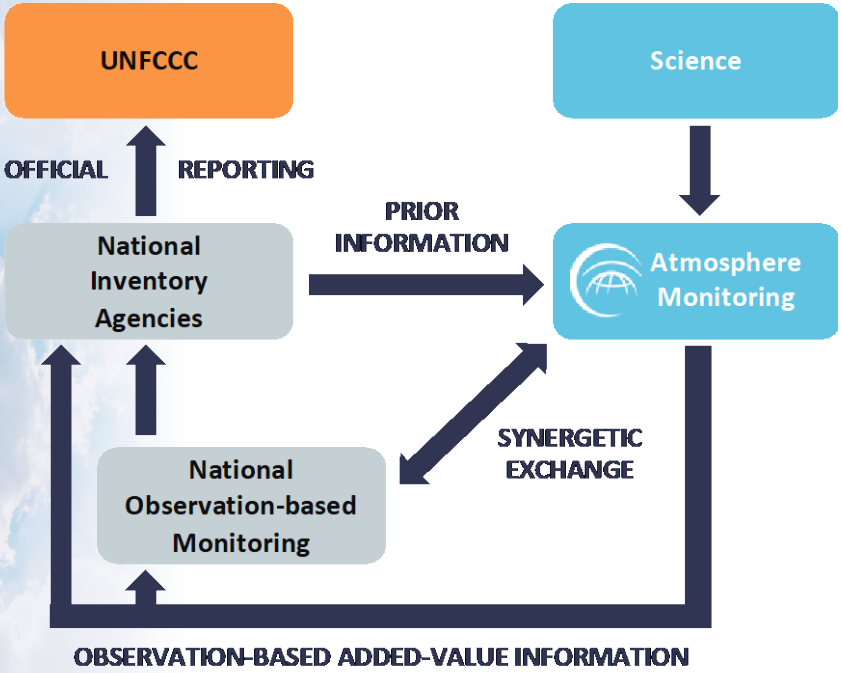
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Atmosphere Monitoring

User engagement for co-designed user services

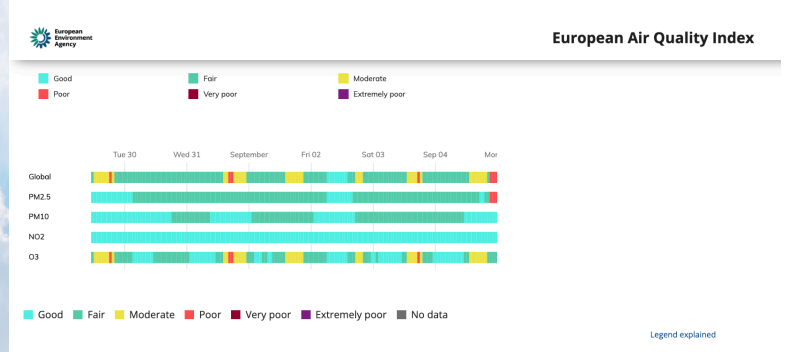


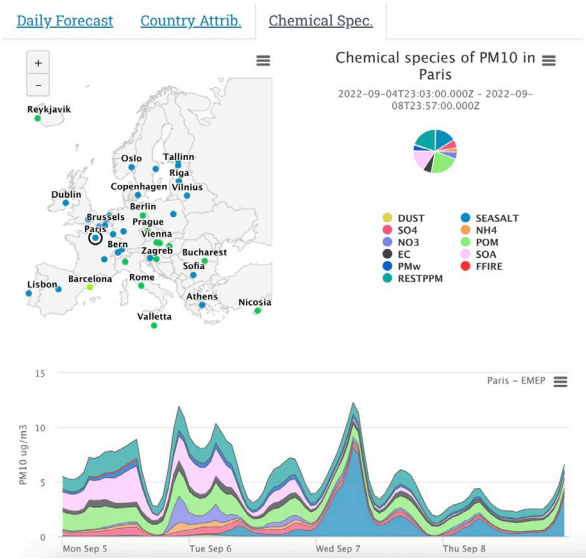
- Provide monitoring information to EC
- Support member states with national emission estimates
- Support member states with input data for national activities
- Support EEA with verification of member state national estimates
- Support developing countries with emission estimates
- Support downstream commercial activities with operational monitoring

The air quality analogy

Atmosphere Monitoring

User feedback led to much improved services over the last decade.



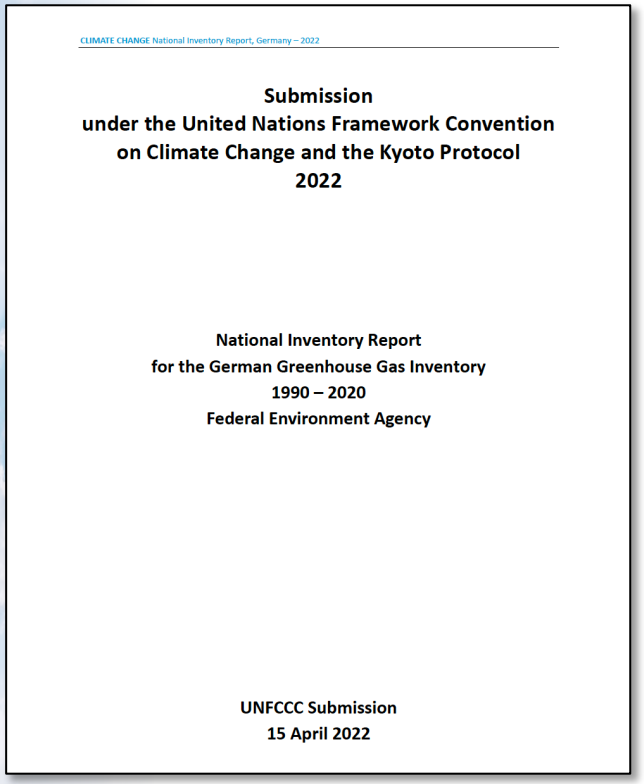


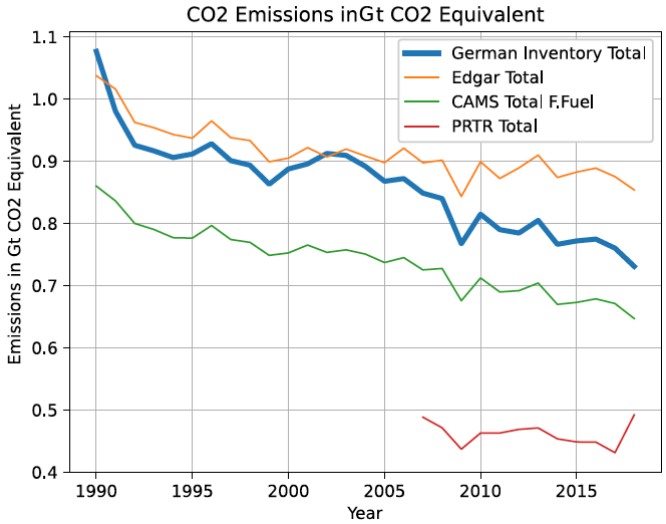
Monitoring of regulatory threshold exceedances with in-situ observations

- Daily national-scale air quality forecasts
- Annual re-assessments of previous year
- Rapid analysis of air quality episodes based on the combination of models and observations

Working with national inventory agencies

Atmosphere Monitoring





Already good discussions and interactions with various EU member states.

PROGRAMME OF THE EUROPEAN UNION
opernicus
IMPLEMENTED BY ECMWF

Atmosphere Monitoring

Conclusions

- **Interaction with users during development of new services is critical. This is an iterative process!**
- **Global coordination efforts, such as WMO, CEOS, GCOS, and GEO, is important. Requires proper benchmarking and quality control.**
- **Think out of the box! Not everything will work (as expected), but knowledge supports decision making and the more the better.**

Thank you

Atmosphere Monitoring

PROGRAMME OF THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

IMPLEMENTED BY ECMWF