CoCO2

Prototype system for a Copernicus CO_2 service

The Copernicus anthropogenic CO_2 emissions monitoring and verification support capacity

A brief overview

Co-ordinated by ECMWF

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The Copernicus anthropogenic CO_2 emissions Monitoring and Verification Support capacity – a brief overview

Dissemination Level: Public

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Date: 30/09/2021

CoCO2: Prototype system for a Copernicus CO_2 service

Coordination and Support Action (CSA)
H2020-IBA-SPACE-CHE2-2019 Copernicus evolution – Research activities in support of a European operational monitoring support capacity for fossil CO2 emissions

Project Coordinator: Dr Richard Engelen (ECMWF)
Project Start Date: 01/01/2021
Project Duration: 36 months

Published by the CoCO2 Consortium

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The CoCO2 project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958927.

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1 Introduction

The Paris Agreement, a pivotal milestone of the United Nations Framework Convention on Climate Change to combat climate change and adapt to its effects, entered into force on the 4th of November 2016. Currently, 197 Parties have signed the Agreement committing to reducing global emissions of greenhouse gases, of which 191 have completed the ratification in September 2021. Specifically, the Agreement requests each country to outline and communicate their post-2020 climate actions, known as the Nationally Determined Contributions (NDCs).

To enable the European Union (EU) to move towards a low-carbon economy and implement its commitments under the Paris Agreement a binding target to cut emissions in the EU by at least 40% below 1990 levels by 2030 was set and European Commission (EC) President von der Leyen committed to deepen this target to at least 55% reduction by 2030. This has been further consolidated with the release of the Commission's European Green Deal on the 11th of December 2019, setting the targets for the European environment, economy and society to reach zero net emissions of greenhouse gases in 2050, outlining all needed technological and societal transformations that are aiming at combining prosperity and sustainability.

To independently assess the progress of countries towards their targets, an objective way to monitor anthropogenic CO_2 emissions and their evolution over time is needed. Such a capacity would deliver consistent and reliable information to support informed policy- and decision-making processes, both at national and European level. To maintain independence in this domain, it is seen as critical that the EU establishes an observation-based operational anthropogenic CO_2 emissions Monitoring and Verification Support capacity (CO2MVS) as part of its Copernicus programme.

In advance of the Paris Agreement in 2015, the European Commission (EC) already anticipated these needs and tasked an international group of experts to assess the state-of-the-art for the monitoring of anthropogenic CO_2 emissions. This dedicated Task Force, with support from the institutional partners ESA (European Space Agency), ECMWF (European Centre for Medium-Range Weather Forecasts) and EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) is providing advice for the design of the overall systems, including space-based and ground-based components of the infrastructure. So far, this has resulted in a report outlining the CO2MVS architecture (Ciais et al., 2015), which was then further elaborated in Pinty et al. (2017). More recently, a peer-reviewed paper was published outlining the ideas and recommendations from the CO_2 Task Force (Janssens-Maenhout et al., 2020). In addition, very similar approaches appear in the Integrated Global GHG Information System (IG3IS) of the World Meteorological Organization (WMO) (DeCola and Tarasova, 2019) and the White Paper of the Community of Earth Observation Satellites (CEOS) (Crisp et al., 2018). Furthermore, some heritage already exists, for instance through the Global Carbon Project (GCP, e.g., Friedlingstein et al., 2019; Saunois et al., 2019), which was formed to work with the international science community to establish a common and mutually agreed knowledge base to support policy debate and action to slow down and ultimately stop the increase of greenhouse gases in the atmosphere.

The proposed observation-based CO2MVS will be driven by a new generation of highly accurate and precise CO_2 imaging satellites as part of the Copernicus Sentinel programme. ESA, in collaboration with EUMETSAT and supported by a dedicated Mission Advisory Group, is designing and building this new CO_2 Monitoring (CO2M) mission, which will significantly increase the capabilities of satellite-based sensors. Integral to this new mission is the implementation of a constellation of low Earth orbiting satellites that provide a better than 3-day revisit time at mid-latitudes, at 4 km^2 sampling and a precision better than 0.7 ppm in XCO_2 (the ratio of the total dry-air column of CO_2 to that of dry air). In order to limit the systematic error, the inclusion of a multi-angle polarimeter is foreseen, enabling the CO_2 retrieval process to better account for cloud and aerosol scattering effects. In addition, the

inclusion of coincident measurements of NO_2, a proxy for the plumes of freshly emitted anthropogenic CO_2 from power plants and cities, could significantly increase the accuracy of the inferred CO_2 emission estimates. In parallel, the CO_2 Task Force has produced a report detailing the requirements for the in-situ[1] component of the CO2MVS (Pinty et al., 2019). The report clearly documented the critical importance of the in-situ component and made recommendations regarding the requirements, sustainability and governance.

As illustrated in Figure 1, the CO2MVS capacity will combine information from these satellites and in-situ observations with detailed computer simulations of the atmosphere and biosphere to estimate anthropogenic emissions of CO_2. This combination of observations and modelling will provide the added value to what we already know in terms of emissions from human activities, monitoring CO_2 emissions in much more detail, both in space and time.

To support the Commission and the CO_2 Task Force with designing and ultimately building the CO2MVS, the CO_2 Human Emissions (CHE) project was funded through the H2020 programme. The project started in October 2017, bringing together a consortium of 22 European partners and lasting for over three years. The project, coordinated by ECMWF, has carried out various scientific studies supporting the design of the CO2MVS, resulting in clear recommendations described in a set of reports. In parallel, the Commission has been funding through H2020 the VERIFY project, which runs from February 2018 until January 2022. VERIFY, coordinated by the Laboratoire des Sciences du Climat et de l'Environnement (LSCE), is developing a system to estimate greenhouse gas emissions in European countries to support countries' emission reporting to the UN Climate Change Convention Secretariat. The emissions are estimated based on existing land, ocean and atmospheric observations. VERIFY focuses on the three major greenhouse gases responsible for global warming: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The H2020 CoCO2 (2021-2023) project, coordinated by ECMWF, will transfer the results from these projects into a pre-operational framework that can then be further developed into a fit-for-purpose operational system.

[1] In the current Copernicus Regulation, in-situ observations are defined as follows: ‘Copernicus in-situ data’ means observation data from ground-based, seaborne or airborne sensors, as well as reference and ancillary data licensed or provided for use in Copernicus

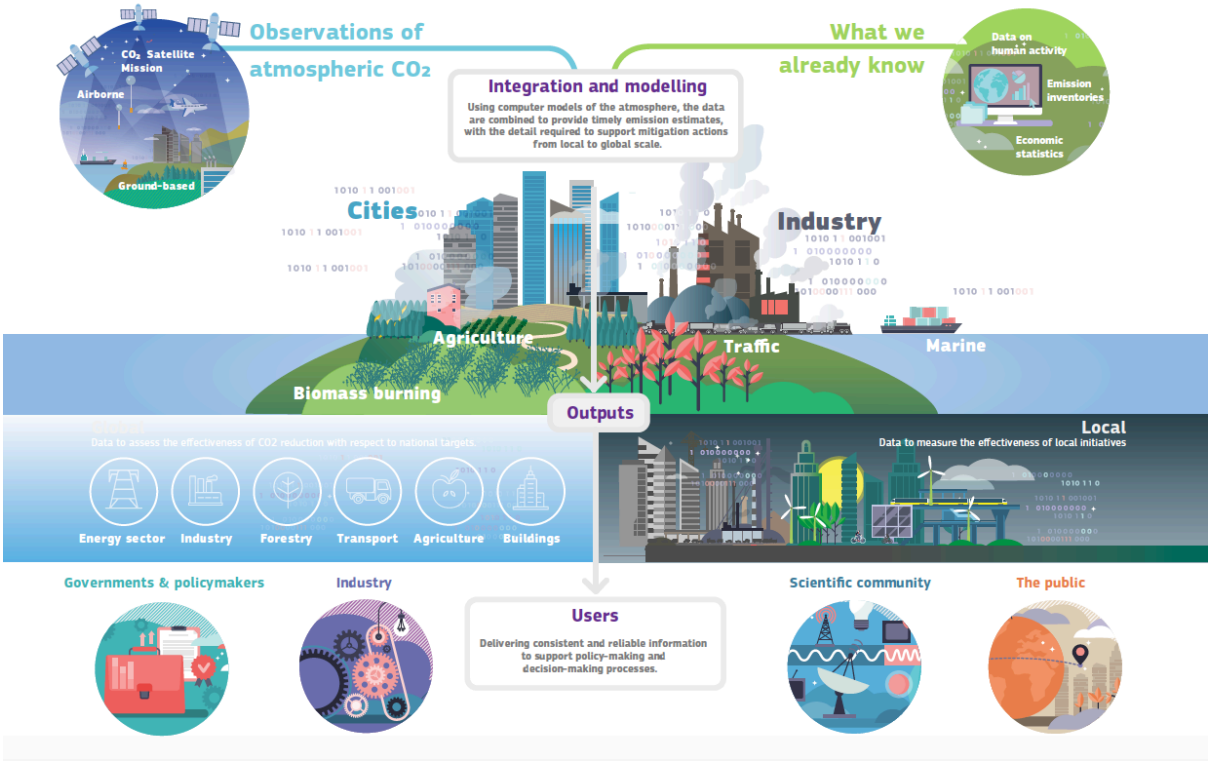

Figure 1 Illustration of the components of the planned anthropogenic CO_2 emissions Monitoring and Verification Support (MVS) capacity

2 The CO2MVS as part of the Copernicus Atmosphere Monitoring Service

The operational implementation of the anthropogenic CO_2 Monitoring and Verification Support (MVS) capacity is foreseen as part of the Copernicus Atmosphere Monitoring Service (CAMS) portfolio. A high-level functional architecture for CAMS is depicted in Figure 2. Compared to phase 1 of CAMS, it contains several new building blocks. Most notably for this note are the CO_2 service element and the air quality emissions. These two new activities will be strongly linked ensuring full benefit of the similarities and complementarities.

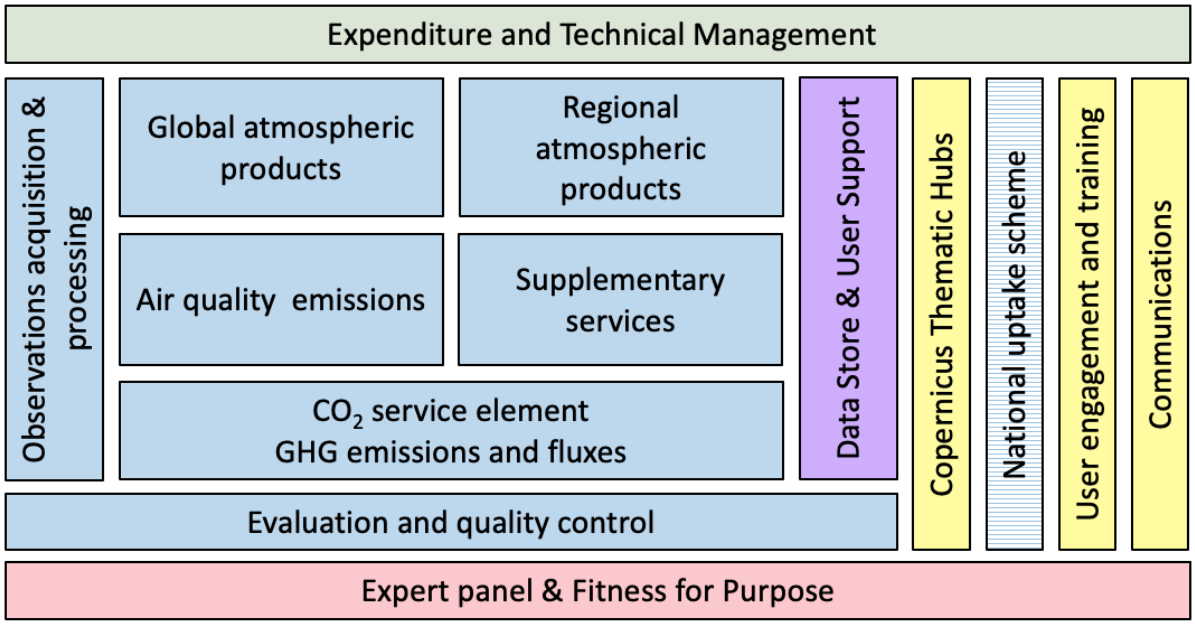

Figure 2 High-level functional architecture of the 2nd phase of the Copernicus Atmosphere Monitoring Service (2021 - 2027)

Figure 3 illustrates in more detail the building blocks of the new CO_2 service element, with a similar approach for the air quality emission estimates, comprising an integration system capable of inferring emissions from observations (space and in-situ), prior information (such as bottom-up emissions estimates from inventories and reporting) and modelling as well as data assimilation capabilities. A similar architecture has already been successfully applied to the current CAMS air quality services and is therefore apt to fully exploit synergies between the existing CAMS infrastructure for atmospheric composition monitoring and forecasting, the relevant activities within the Copernicus Climate Change Service (C3S), and the new CO2MVS service element.

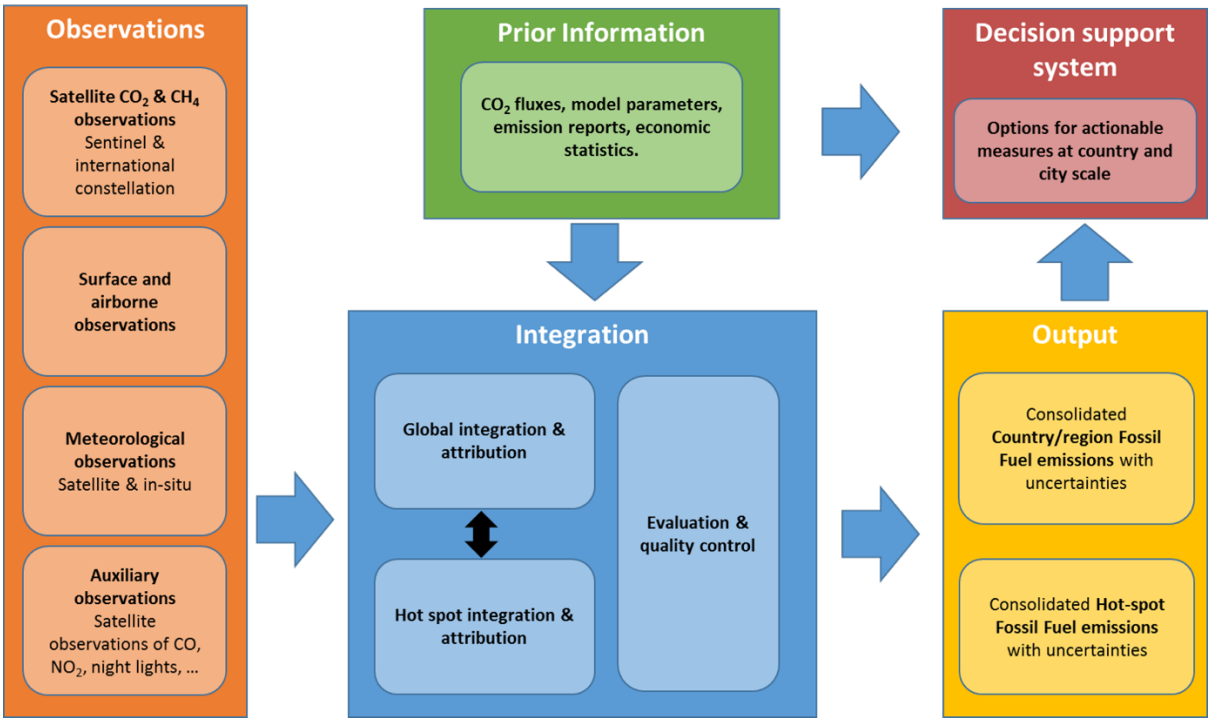

Figure 3 Main building blocks of the functional architecture of a future CO2 human emissions monitoring system

The top three priorities for the new CO_2 service element are:

- to transform the various related research activities into a mature pre-operational (and then operational) system that can deliver the required monitoring and verification support capacity;
- to support EU member states with the Global Stocktake in 2028 using Earth Observation data and state-of-the-art modelling capabilities in order to provide accurate and globally consistent estimates of emissions, their uncertainties and their reductions;
- to ensure alignment with and acceptance from the European and international policy, science and Earth observation frameworks.

As recommended in the second CO_2 report from the CO_2 Monitoring Task Force, the CO2MVS will deliver the following products as defined by user requirements:

1. Detection of emitting hot spots such as megacities or power plants
2. Hot spot emissions monitoring to assess emission reductions
3. Assessment of emission changes against local reduction targets contained in NDCs
4. Assessment of national emissions and their changes to support 5-yearly global stock takes

The CO2MVS services shall, in the long term and in some well-identified instances and situations, provide additional evidence on the amount of anthropogenic CO_2 emissions reported by national statistical offices and, in particular, help to identify and assess the uncertainties and gaps associated with their emission inventories. More generally, the CO2MVS will provide the European Union with a comprehensive and consistent picture on the actual level of emissions and their reductions by all countries worldwide.

The CO_2 service element is targeted for operational status in 2026 in order to provide support to the 2028 Global Stocktake based on observations from the proposed CO_2 Sentinel satellite constellation. A key requirement for operating the CO2MVS system at full strength is the availability of the dedicated CO_2 satellite sensors as part of the Sentinel programme. Currently, the launch of this mission is targeted for the end of 2025, which means that the ground segment infrastructure (technical and scientific) and required in-situ observation infrastructure must be fully developed by then. However, the service architecture will be developed such that valuable products will be generated already early on with improved specifications as the system becomes more mature and the available observational input data increases. A ramp-up phase from 2021 to 2025 will be used to prepare a pre-operational CO2MVS system.

In addition, based on requirements expressed by several EU Member States, this service element will also further develop the CAMS monitoring capabilities for methane (CH_4). At the end of the first phase CAMS introduced a specific global monitoring capability to detect anomalous values of atmospheric CH_4 concentrations caused by either increased or reduced emissions relative to the nationally reported emissions. This capability was developed to respond to queries from the European Commission to use Earth Observation and the CAMS system to provide more timely information on changes in atmospheric methane and its emissions. Since then, several EU Member States have expressed their interest to see this develop into a full emission estimation capability, aligned with the CO2MVS, to support their obligations for the Paris Agreement and their efforts to mitigate climate change. Using the increased data assimilation capabilities that will be developed for the CO2MVS and by further developing the methane modelling capabilities at global and local scales, a system will be set up that can use observations from Sentinel-5p, Sentinel-5, the CO2M mission and other related satellite and in situ instruments to monitor emissions of CH_4 at global and local scales.

3 Relevance to foreseen user communities

The overall concept of the CO2MVS combines the information from various observational data sets and information from prior knowledge (e.g., actual, estimated or projected emission inventories) with detailed computer models of the Earth system that represent in particular the sources, sinks and transport of CO_2 in the atmosphere in a Bayesian estimation framework, i.e., by minimising a cost function in a mathematically rigorous approach to correctly account for the uncertainties in observations, priors and models to estimate the required outputs, in this case anthropogenic CO_2 and CH_4 emissions at various scales. This will bring the same level of mathematical rigour to the CO2MVS system that has proven critically important in other application areas, such as Numerical Weather Prediction and air quality forecasting.

A critical element of the CO2MVS is the translation of the generated data into user-friendly services. For some user sectors, this could mean providing the raw output data, for other user sectors specific tools need to be developed and put in place. The aim of the CO2MVS is to serve the policy sector at European, national and local scales, to support countries with developing their own specific emission monitoring capabilities, and to stimulate business uptake as part of a green economy. In addition, the output data is seen as a key contribution to the scientific community. Based on experience in the Copernicus programme it is essential to have a dedicated user support and user engagement component as well. CoCO2's aim is to interactively address all these elements, especially with the key user communities, resulting in a co-designed portfolio and user interface.

The main purpose of CoCO2's work package on User engagement is to engage with the various user communities to co-design a fit-for-purpose CO2MVS service portfolio and develop mechanisms and tools to provide diverse, but targeted information to these user communities. This will be achieved by several user consultation meetings and workshops, but also by using existing international communication and planning mechanisms. At local scale, CoCO2 has enlisted ICLEI (Local Governments for Sustainability) to help organising these contacts. Closer links with the IPCC working groups and inventory agencies and other data providers will be established as well as the relevant working groups of DG-CLIMA.

Document History

Version	Author(s)	Date	Changes
V1	Richard Engelen (ECMWF)	30/09/2021	