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Editorial: Anthropogenic emission monitoring with the Copernicus CO_2 monitoring mission

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Editorial on the Research Topic
Anthropogenic emission monitoring with the copernicus CO_2 monitoring mission

Need for a monitoring and verification support capacity

Humanity is facing one of its biggest, contemporary challenges, which is the eminent crisis that results from climate change. Following the Paris Agreement, which was signed in 2015 between UNFCCC parties, the signatories aim to restrict the rise in global temperatures caused by the increased presence of greenhouse gases due to anthropogenic emissions. The two main contributing greenhouse gases are carbon dioxide (CO_2) and methane (CH_4). For the observed increase in atmospheric CO_2 concentrations, the largest contributions come from emissions due to the combustion of fossil fuels, production of cement, and land-use change. Reduced uncertainties associated with these anthropogenic emissions at national, regional, and local scales will contribute to better-informed policy decisions and help assess the effectiveness of CO_2 emission reduction strategies. As part of the Copernicus Programme, the European Commission (EC), the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the European Centre for Medium-range Weather Forecasts (ECMWF) are jointly developing a CO_2 monitoring and verification support (MVS) capacity to address these needs. ESA develops a dedicated satellite mission to provide the space-based measurements required for fossil CO_2 emission monitoring as a component of the overall Copernicus Space Component. In partnership, EUMETSAT develops the operational ground segment and will operate the mission.

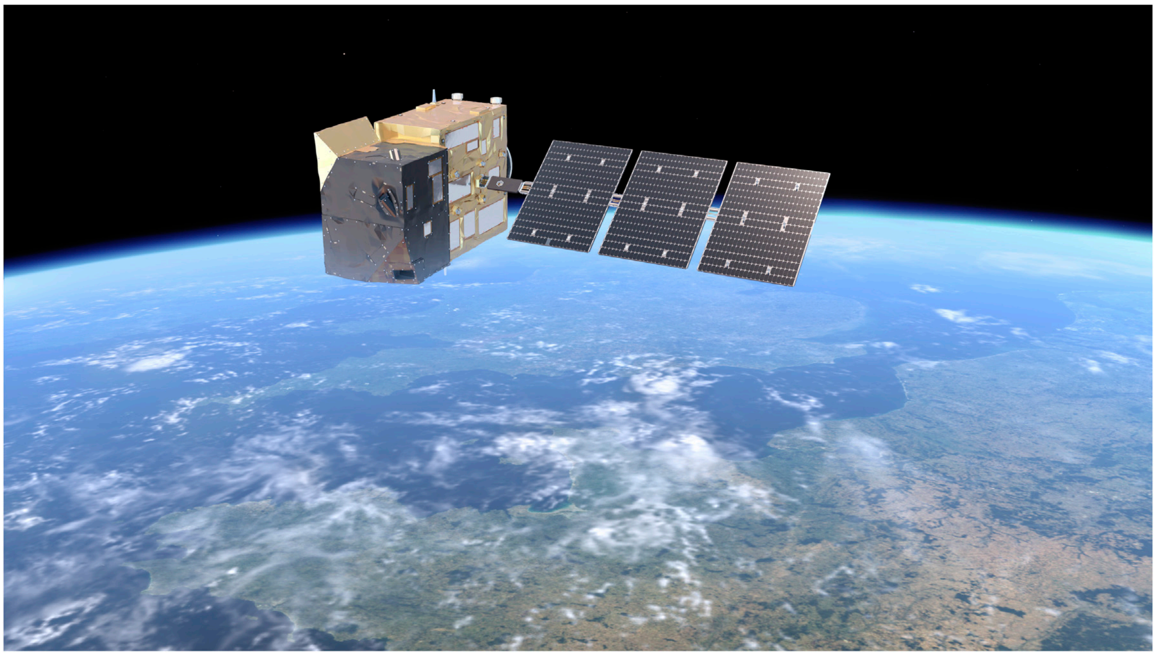

FIGURE 1
Artist's impression of a Copernicus CO2M satellite measuring CO_2, CH_4, NO_2 and clouds in nadir, and in multi-angle with its aerosol instrument. Reproduced from ESA/Mlabspace, Copernicus Carbon Dioxide Monitoring mission, https://www.esa.int/ESA_Multimedia/Images/2023/06/Copernicus_Carbon_Dioxide_Monitoring_mission, licensed CC BY-SA 3.0 IGO.

Satellite and *in-situ* measurements of CO_2, in addition to bottom-up inventories, will enable transparent and consistent quantitative assessment of CO_2 emissions and their trends at the scale of large point sources, megacities, regions, countries, and the globe. The MVS capacity will include advanced modelling, data assimilation and inversion tools. It will provide the European Union and other countries with a unique and independent source of information, which can be used to assess the effectiveness of policy measures, and to track their impact towards decarbonizing the world and meeting national emission reduction targets. Furthermore, there will be potential synergies at international level with observing systems under development by third parties.

In this paper, we provide a brief overview of the CO_2 monitoring mission, its mission objectives, the observational requirements on CO_2 and CH_4 and auxiliary measurement capabilities, which serves as the editorial introduction to the collection of research papers published under this Research Topic (for further in-depth details, see ESA, 2023).

Copernicus CO2M satellite mission

Current satellite missions aim to address the biogenic carbon dioxide cycle. On the other hand, operational monitoring of anthropogenic emissions requires the development of a new and dedicated satellite mission, which is the objective of the Copernicus anthropogenic CO_2 Monitoring mission (or CO2M Mission in short). A constellation of 2–3 satellites aims to provide worldwide high precision CO_2 (0.7 ppm) and CH_4 (10 ppb) observations at 4 km^2 spatial samples over 250 km swath width, which will provide 2–3 days geometrical revisit time at mid latitudes. These observations are supported by 1) multi-angle polarimeter (MAP) observations of aerosol parameters, to minimize biases due to incorrect light path corrections in the retrieval, 2) nitrogen dioxide (NO_2) observations, as tracer for high temperature combustion improving emission estimates of the fossil component of CO_2, and 3) cloud imager observations to filter out measurements impacted by low clouds and high-altitude cirrus. The mission targets to be operational in 2026. An artists' impression of the CO2M mission is provided in Figure 1.

Research activities and developments toward emission monitoring

The EC initiated the design and development for a CO_2 MVS capacity for anthropogenic CO_2 emissions, which will be a new Copernicus service element. The CO_2 Human Emissions (CHE) project successfully coordinated efforts to advance the development of the European capacity. Balsamo et al. describe several project achievements. Kaminski et al. explored the impact of assimilating, in their Carbon Cycle Fossil Fuel Data Assimilation System (CCFFDAS), simulated CO2M observations of CO_2, NO_2, and aerosols on estimating CO_2 emissions in an area around Berlin. Their assessments showed a considerable contribution of the aerosol observations to the constraint of the CO_2 measurements on emissions on all spatial scales. NO_2 measurements onboard CO2M also provided a powerful additional constraint. Hakkarainen et al. applied an adapted version of their divergence method to derive both CO_2 and nitrogen oxide (NO_x) emissions of cities and power plants from a CO2M satellite constellation by using synthetic observations from the COSMO-GHG model. This makes it a promising, alternative tool for estimating CO_2 emissions.

Algorithm and validation advances for exploiting CO2M measurements

To make use of the added value of MAP aboard the CO2M mission, the Remote sensing of Trace gas and Aerosol Product (RemoTAP) algorithm is developed to perform simultaneous retrieval of trace gas and aerosol properties. Lu et al. evaluated the performance of the RemoTAP algorithm based on synthetic orbit measurements of realistic atmospheric and geophysical scenes over land. They demonstrated that a combined retrieval method is able to reduce the aerosol-induced retrieval error in CO_2 by more than a factor of 2. By the inclusion of MAP measurements, the large aerosol-induced biases can be mitigated, resulting in the retrievals that meet the mission requirement (precision < 0.7 ppm and bias < 0.5 ppm). Satellite measurements require careful validation, as for CO_2 and CH_4, where concentration gradients are minute challenging the goal to quantify and monitor anthropogenic emissions. Butz et al. showcase the potential of the mobile EM27/SUN as a valuable asset to contribute to the validation activities for CO2M. Kuhlmann et al. analyzed the feasibility of quantifying emissions using synthetic CO_2 and NO_2 observations for a constellation of CO2M satellites. They demonstrated that NO_2 observations were essential for estimating CO_2 emissions as they helped detecting and constraining the shape of the plumes. Adding a third satellites would double the number of point sources that could be quantified. Nassar et al. demonstrate the capability of using existing satellite observations to quantify CO_2 emissions using NASA's Orbiting Carbon Observatory missions (OCO-2 and OCO-3). Their emission estimates reveal consistent trend results that also agree with bottom-up estimates. The results are informative for understanding the expected capability and potential limitations of the CO2M mission.

Author contributions

YM drafted the initial editorial with contributions and review from co-authors. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Reference

ESA (Y. Meijer, Mission Scientist) (2023). Copernicus CO_2 monitoring mission requirements document (MRD). Tech. rep. Version 3.0. Available at: https://esamultimedia.esa.int/docs/EarthObservation/CO2M_MRD_v3.0_20201001_Issued.pdf (Last access April 26, 2023).