Towards an Operational Capacity to Monitor Anthropogenic CO₂ Emissions

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with contributions from many experts & major international institutions

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Fighting Climate Change requires reducing the GHG emissions, in particular CO₂ (IPCC AR 5).

Ambitious plans from the EU Member States for reduction targets at horizon 2030.

CO₂ emission reporting is based on bottom up approach using national statistics (mainly on fuel consumption) in ex-Kyoto-Annex I countries. Independent datasets would help improving periodicity & reliability as well as reducing uncertainty of the self-reporting exercise.

The impact of Nationally Determined Contributions (NDCs) on CO₂ budget needs to be estimated to help countries in evaluating the effectiveness of their CO₂ emission reduction strategies.
53. Points out that the **use of space-based assets should be considered** in the implementation of measures aimed at mitigating and adapting to climate change, particularly through the **monitoring and surveillance of GHG emissions**;

Urges the Commission to actively contribute to a **global monitoring system for CO\textsubscript{2} and CH\textsubscript{4}**;

Calls on the Commission to promote efforts towards developing an **EU system of measuring GHG emissions** in an autonomous and non-dependent manner, **using and expanding the missions of the Copernicus programme**;
Support a set of recommendations for EC about: "Need and opportunity for an independent European satellite-borne observation capacity for CO$_2$ to monitor the impacts of international climate agreements."

CO$_2$ report: 'Towards a European Operational Observing System to Monitor Fossil CO$_2$ Emissions'

1. What are the **critical uncertainties** and limitations of **current inventories** of anthropogenic CO$_2$ emissions based on fuel use statistics?

2. How could inventories be improved using independent **space-borne measurements of atmospheric CO$_2$**?

3. What are the **current capabilities** of space-borne and in-situ ground-based measurements of atmospheric CO$_2$ in Europe and worldwide?

4. How should these **capabilities be optimized into an operational system** for independent monitoring of anthropogenic CO$_2$ emissions and for improving current estimates at the global, European and country scales?

5. What are the critical elements and a **possible road map** for setting up such a system enabling first operational exploitation at the **horizon of the 2030s**?
Critical uncertainties in CO₂ inventories

Fossil fuel Emissions

CO₂ not yet significantly decreasing

CO₂ emissions from fossil-fuel use and cement production in the top 5 emitting countries and the EU

Emissions uncertainties on the rise

- During the last decade, emerging countries have become the largest emitters.
- The global emissions uncertainty is increasing with time: we are losing our reference baseline.
- No reliable information about spatial & temporal patterns.
- This is a limitation to mitigation policy.
Measurement systems for atmospheric CO₂

Sources and sinks for CO₂ on a gridded basis with temporal changes

UNFCCC Parties

Regional authorities

Industry in Emissions Trading System

Citizen and farmer in Effort Sharing Decision

Improved Inventories

Maps of emissions per sector of human activity

The top-down atmospheric approach

Bottom-up

Emission inventories from statistical data

Inverse modeling

CO₂ emissions of subnational governments / regions need also to be mapped within a regionally complete picture (covering all human activities).
COSMO model simulation on Cray XE6 «Monte Rosa» at Swiss Supercomputing Center CSCS

Simulation: Yu Liu & Nicolas Gruber (ETH)
Animation: Dominik Brunner (Empa)

Anthropogenic CO₂: EDGAR v4.2 (JRC)
Biospheric CO₂: VPRM (MPI Jena)
Independent monitoring of fossil CO$_2$ emissions using inverse modeling and atmospheric measurements is feasible:

- **Dense sampling of selected emissions hotspots**, such as megacities and major industrial areas, large power plants.
- **This can be achieved with satellites measuring column CO$_2$**
- **Separate the fossil CO$_2$ component from the natural fluxes at regional scale**, by measurements of additional trace species, such as radiocarbon ($^{14}$C in CO$_2$), carbon monoxide and/or nitrogen dioxide.
- **This could be achieved in Europe by making $^{14}$C measurements at existing CO$_2$ monitoring tall towers (ICOS and national in-situ networks).**

**Increasing the density and spatial resolution of atmospheric CO$_2$ measurements is needed to quantify emissions.**
Frequent maps of fossil fuel emissions
Attribution to the different human activities, regional drivers
Uncertainties & Trends
Specific measurements of atmospheric CO\textsubscript{2} from space needed for fossil CO\textsubscript{2} emissions monitoring in particular:

- to verify the **trends of the emissions** of emitting hot spots at global scale

- to detect newly **upcoming hot spots** (e.g. new oil production sites)

- to assess whether the **global emission reduction** promised by the "stocktake" is actually measurable in the atmosphere.

- to acquire uniform, homogeneous and indisputable global datasets made available to monitor man-made CO\textsubscript{2} emissions and therefore **support the national/local emission reduction strategies**.
Opportunity for a CO$_2$ Space Capacity

The Copernicus context

- The **Copernicus programme** constitutes the appropriate frame for supporting an operational European CO$_2$ space initiative through its space component and its **Climate Change Service** (C3S) and **Atmosphere service** (CAMS) components.

- The CO$_2$ initiative is integrated in the context of the **Copernicus Space Component evolution plan** (supported by ESA through EOEP-4 & 5 programmes).

- A **CO$_2$ monitoring task force** has been nominated to address the **space component** and the required **ground-based infrastructure** – an end-to-end operational emission monitoring system - (involving a few DGs, ESA, Eumetsat, ECMWF & world class experts).

- This task force is supporting the **consolidation of technical requirements**. Conditioned by appropriate political & financing decisions beyond 2020.
**Average surface air temperature**

**October 2016**

- **October 2016:** 0.57°C higher relative to October average for 1981-2010
- **12 last months (November 2015 to October 2016):** 0.64°C higher relative to 1981-2010

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**Average surface air temperature anomalies for the last 12 months (Nov 2015 until Oct 2016)**
20161001 03 UTC
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Space based CO₂ measurement objectives

Proposed Strategy

Independent verification of emissions
Improved UNFCCC reporting
Assess effectiveness of voluntary emission reductions (regions, cities)
Carbon management

XCO₂ sounders (GOSAT, OCO2)

Precursor mission XCO₂ imager LEO

Space infrastructure

In-situ rural CO₂ stations (ICOS, GAW)
Pilot urban CO₂ networks

Systematic ¹⁴C isotope monitoring infrastructure
Urban CO₂ networks

Data infrastructure

Global & regional transport models
Inversion system

High resolution Global transport models
Inversion system

Operational Inverse modeling of emissions

Operational Emissions maps per sector + errors (≈ 1km / hourly)

Decision Support system
Constellation of LEO imagers
GEO

In-situ urban CO₂ + ¹⁴C monitoring infrastructure

Phase 1

2015
research

Phase 2

2025
Pre-operational

Phase 3

2030-35
Operational Robust emission maps + uncertainties
1.2. Advancing the EU space programmes and meeting new user needs

• Additional services will be considered to meet emerging needs in specific priority areas, including (i) climate change and sustainable development, to monitor CO2 and other greenhouse gas emissions, land use and forestry, and changes in the Arctic with Copernicus;

• In addition, the Commission will use EU space programmes to contribute to and benefit from international efforts through initiatives such as the Global Earth Observation System of Systems (GEOSS) and the Committee on Earth Observation Satellites (CEOS) with Copernicus or the Search and Rescue initiative (COSPAS-SARSAT) with Galileo. It will also support the EU’s neighbourhood and development policies, as it already does in Africa with Copernicus and EGNOS, and the monitoring of sustainable development goals.
1. **Limitations of current inventories** to assess the effectiveness of mitigation policy.

2. **Inverse modeling** with dense atmospheric CO\(_2\) measurements makes it possible to improve the reporting on fossil fuel CO\(_2\) emissions.

3. Current capabilities need to be expanded to refine **the four pillars** of a future operational CO\(_2\) emission monitoring system by 2030.

4. This system will require frequently updated bottom-up emission maps, an operational Fossil Fuel Data Assimilation System and adequate space-based and in-situ CO\(_2\) observations, with a **first space instrument launched before 2025**.

5. The **Copernicus programme** provides the appropriate frame for such a system development.
20161001 03 UTC

Column-averaged dry-air mole fraction of CO₂