Consistent Monitoring of Greenhouse Gas Emissions: Current Status of the Copernicus CO2MVS Prototype Systems

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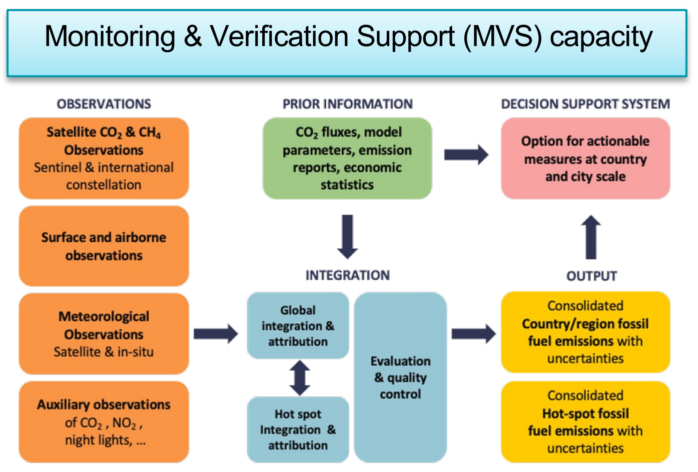
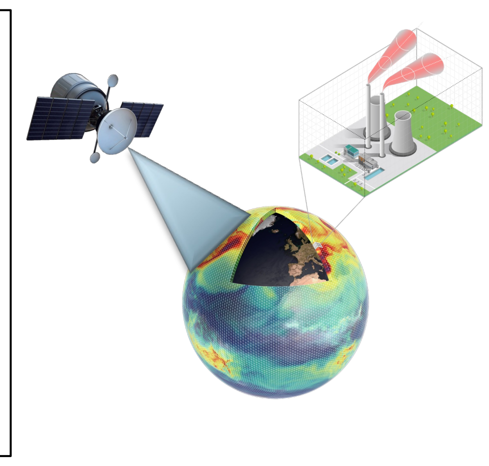
The CoCO2 project – preparing the operational Copernicus service



Project aim:
Deliver prototype systems for the Copernicus anthropogenic CO_2 emissions monitoring & verification support (CO2MVS) capacity.
How:
CO_2 emission estimation systems driven by Earth observations (remote sensing and in-situ) combined with modelling to build an information products portfolio.
Why:
To support and inform the operational implementation of a Copernicus CO2MVS by 2026.

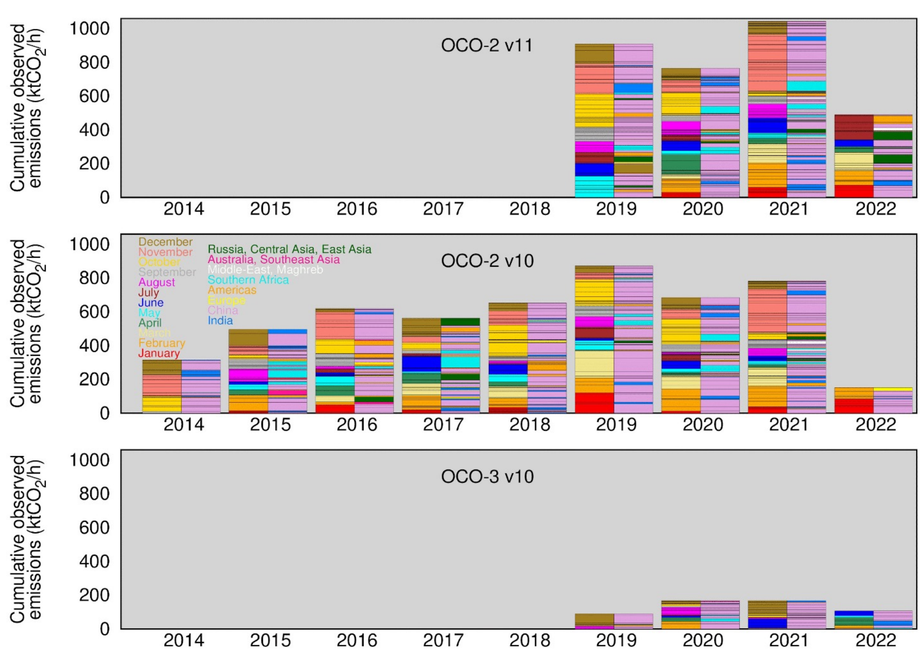
An operational service driven by observations



- Operational long-term perspective with continuous monitoring
- Re-processing for most accurate observation-based information
- Covering facility/city to regional to global scales
- Evaluation, quality control & user support
- Satellite observations of atmospheric greenhouse gas concentrations, especially from the new CO2M mission, are a key input
- European efforts on key in situ observations are scaled up as part of the ICOS-RI

Large point source fossil fuel CO_2 emissions based on satellite observations

Tracking emission hot-spots over the globe



Cumulative emissions observed using NASA's OCO-2 column retrievals version 11 (top), version 10 (middle), OCO-3 version 10 (bottom). Each rectangle corresponds to a validated individual CO_2 fossil fuel emission retrieval by the CoCO2 algorithm. Its colour reflects the month of the year (left part of the bars, starting from January or the earliest month at the bottom of each stack) or the geographical location (right part of the bars). Central Asia and East Asia include the validated emission retrievals from Japan, Kazakhstan, Mongolia, South Korea. South East Asia is for the Philippines and Thailand. Europe is for the 27-member European Union, Moldova, Serbia and the United Kingdom. For Middle-East and Maghreb, only cases in Morocco, Syria and Turkey are found so far. Americas is only for Mexico and the USA. Southern Africa includes the cases found in South Africa and Zimbabwe.

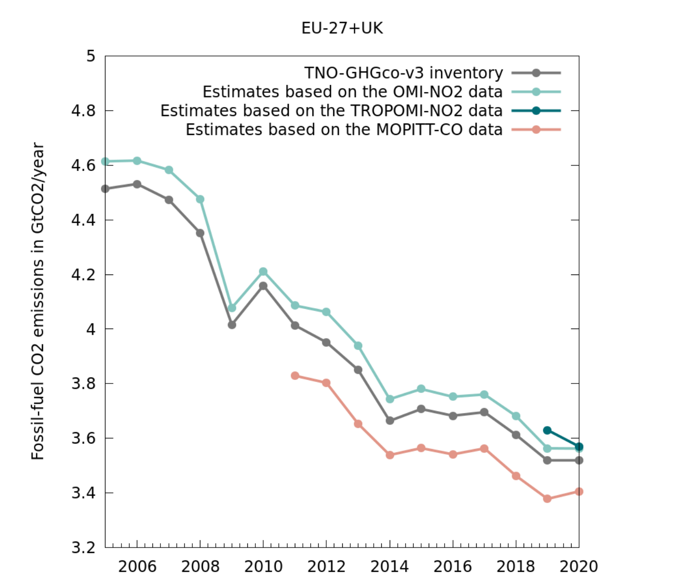
Method

- Selection of isolated CO_2 column enhancements along satellite orbits, potentially corresponding to emission plume transects.
- Simple Gaussian plume modeling combined with wind speed to estimate the fossil fuel CO_2 emissions.

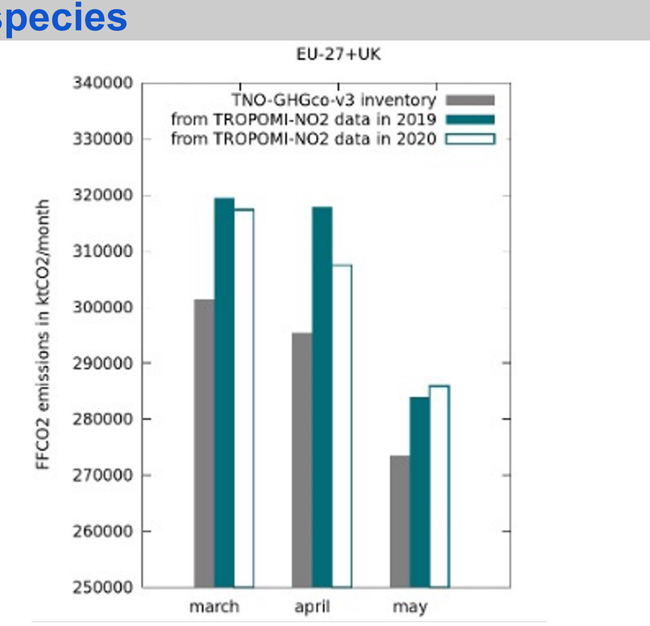
Lessons learned

- Instantaneous CO_2 emissions retrieved for one third of the large emission cells of a global high-resolution hourly inventory.
- Consistent temporal variations of median emissions suggest that trends can be robustly calculated when more data become available.

Fossil fuel emissions from regional inversions using co-emitted species



Estimates of the annual budgets of fossil fuel CO2 emissions from EU27+UK over 2005-2020 from TNO inventory (in grey) and from the regional inversions (colours corresponding to each satellite product).



Monthly fossil fuel CO_2 emissions of the EU-27+UK area (in ktCO$_2$/month) estimated by the TNO-GHGco-v3 inventory (in grey) and from the regional inversions assimilating TROPOMI data (in green). Solid bars correspond to March-May 2019 while thick contour bars correspond to March-May 2020.

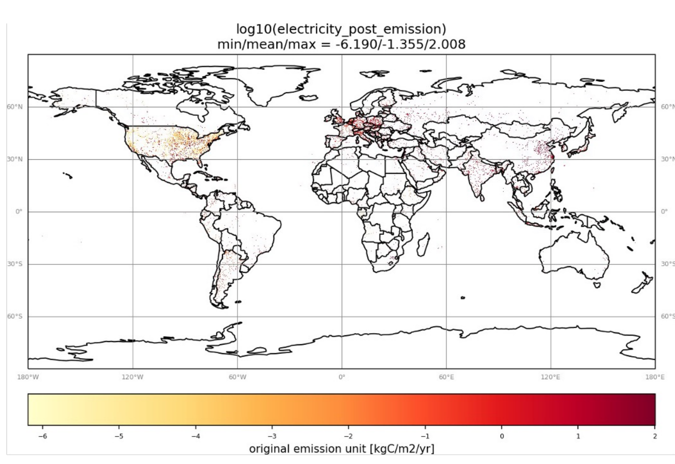
Method

- NO_x/CO inversions over Europe during 2005-2020 correcting the TNO inventory at high temporal/spatial resolution (1-day / 0.5°) to fit satellite NO_2 and CO data.
- Conversion of the resulting NO_x/CO emission budgets per country per month partitioned into 5 sectors into CO_2 emissions.

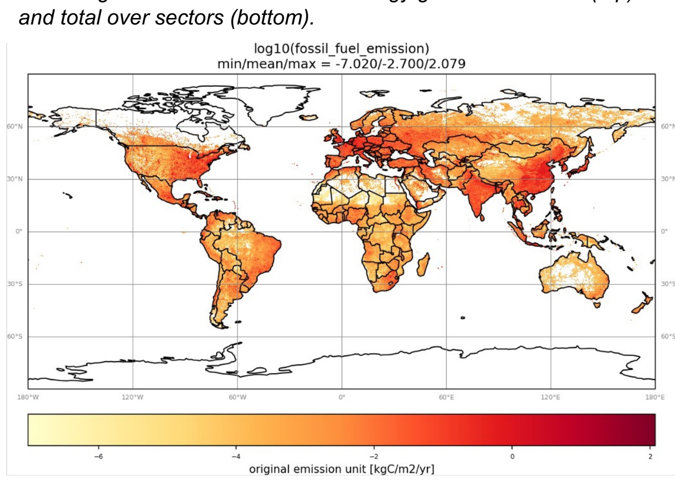
Lessons learned

- National and annual fossil fuel CO_2 budgets derived from the NO_x (CO) inversions are larger (smaller) than that of the inventory.
- Emission reduction in 2020 due to the Covid-19 crisis: missed by inversions based on OMI & MOPITT but shown by inversions based on TROPOMI albeit with a smaller amplitude than generally reported.

A Carbon Cycle Fossil Fuel Data Assimilation System



2021 fossil fuel emissions inferred by CCFFDAS in kgC m² a⁻¹ on a logarithmic scale. From the energy generation sector (top) and total over sectors (bottom).



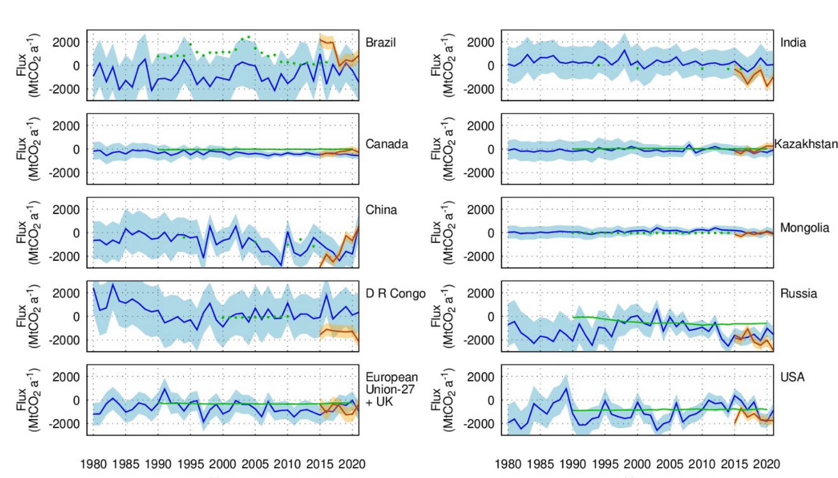
METHOD

- Numerical simulations of global CO_2 atmospheric transport, sectoral fossil fuel emissions and biospheric fluxes.
- Optimises parameters of process-based models against a wide range of observations/data.

LESSONS LEARNED

- Capable of source attribution into emission sectors.
- Capable of using additional observations (e.g. activity data) to constrain sectoral emissions.
- Provides integrated view on the global carbon cycle that is consistent with a range of observations/data

AFOLU emissions from CO2 atmospheric inversions



Annual CO_2 flux (the sum of emissions and removals) from the AFOLU sector in ten large Parties to UNFCCC estimated by the Parties themselves (green lines for the Annex-I parties, green disks for the non-Annex-I parties when available) and from the 1-σ uncertainty envelope of the two latest CAMS inversions (blue for the air-sample-driven inversion and orange for the satellite-driven inversion). Positive values indicate that the party is a source of CO_2 to the atmosphere. For a fair comparison, the surface fluxes from the inversions have been corrected for crop and river fluxes.

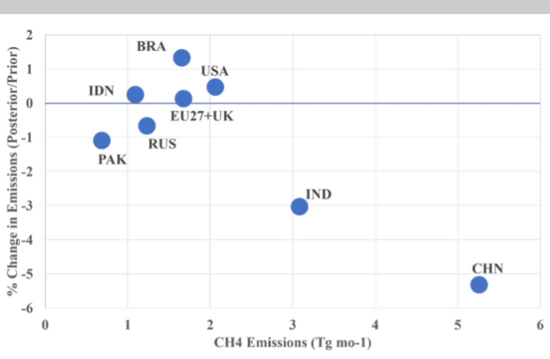
METHOD

- Post-processing of two CAMS global inversion products assimilating: 1) air-sample measurements (1979 onwards); 2) satellite CO_2 retrievals (2015 onwards).
- Aggregation of CO_2 fluxes at the annual national scale and correction to fit the UNFCCC guidelines.
- Comparisons between aggregated fluxes and National Inventory Reports.

LESSONS LEARNED

- Differences between the two CAMS inversions are within their estimated uncertainties.
- Comparison to UNFCCC numbers reveals similarities for the mean value but a larger temporal variability in the CAMS inversions.
- Differences in the timing and processing of available information may explain the observed discrepancies between the CAMS inversions and the reported UNFCCC values.

Preliminary CO_2 and CH_4 flux estimates based on the global CAMS system



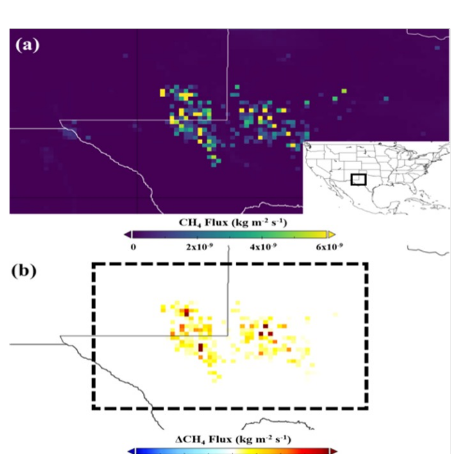
Posterior CH_4 emissions (x-axis) for several major emitting countries and difference between posterior and prior emissions (y-axis) averaged between January and June 2019, derived from the global system.

METHOD

- Variational global CH_4 flux inversion based on satellite observations.
- 80km resolution
- At country scale and regional scale.

LESSONS LEARNED

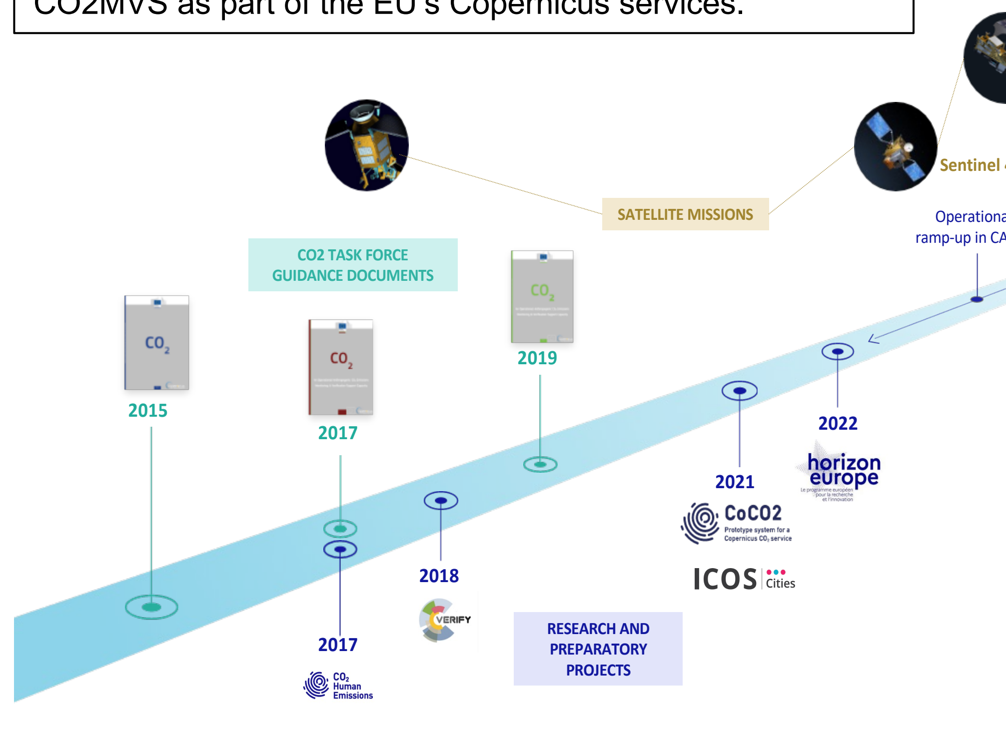
- While the corrections to the prior emission inventories are small (< 1%) for most countries at this temporal scale, they are more significant for India and China, with a decrease by 3 and 5%, respectively. This overestimation in China's CH_4 emission inventories is in agreement with previous findings.
- Posterior CH_4 emissions (2.5 $Tg.yr^{-1}$) over Permian Basin 30% larger than in prior inventory.



(a) Average prior Permian Basin CH_4 emissions for 2019. (b) Average posterior minus prior anthropogenic CH_4 emissions over the Permian Basin for January–June 2019, derived from the IFS 4D-Var system.

The road to operational monitoring of anthropogenic emissions

The CoCO2 prototype methodologies and examples are used to support the operational implementation of the CO2MVS as part of the EU's Copernicus services.



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