Assessing the current capabilities for the national scale monitoring of CO_2 anthropogenic and biosphere fluxes based on OCO-2 XCO_2 and satellite observations of co-emitted species

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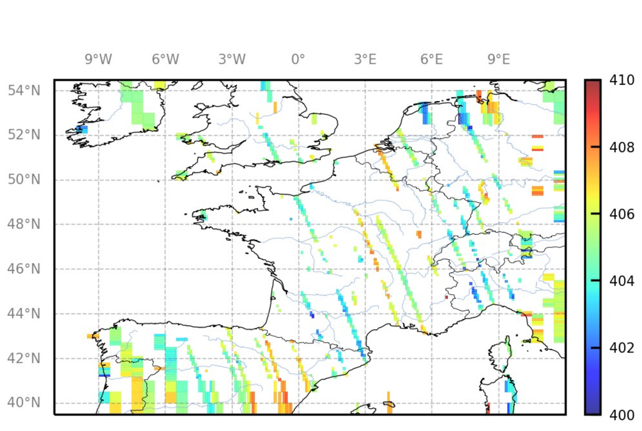
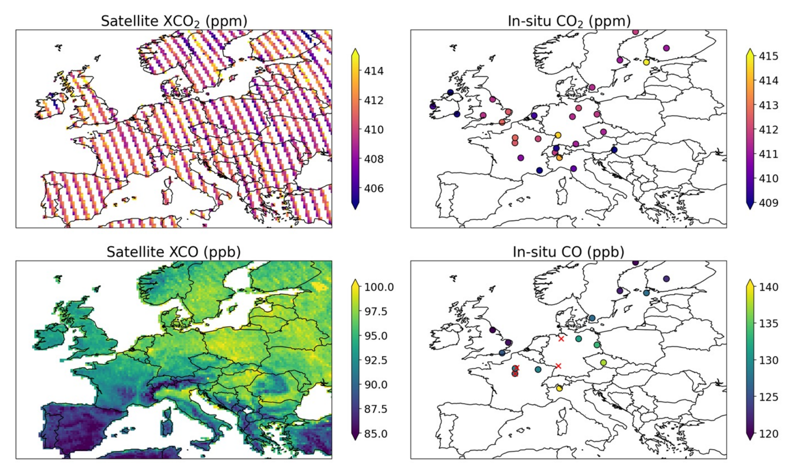
CONTEXT

NASA's OCO-2 total column CO_2 mixing ratio (XCO_2) observations have been used extensively for large-scale mapping of biospheric CO_2 fluxes and for quantifying CO_2 emission hotspots (e.g., industrial plants, cities) using local transects of the corresponding plumes. However, there is a lack of inverse modelling experiments assessing the potential of OCO-2 data for the regular monitoring of biospheric and anthropogenic CO_2 fluxes at the scale of individual countries. Such a capability would be critical to support the national greenhouse gas emission reporting and reduction policies in the frame of the Paris Agreement. This poster provides an overview of the results of three national scale inversions carried out in the framework of the European H2020 CoCO2 project, which supports the development of the operational global and multi-scale Copernicus CO_2 monitoring service.

OBSERVATIONS



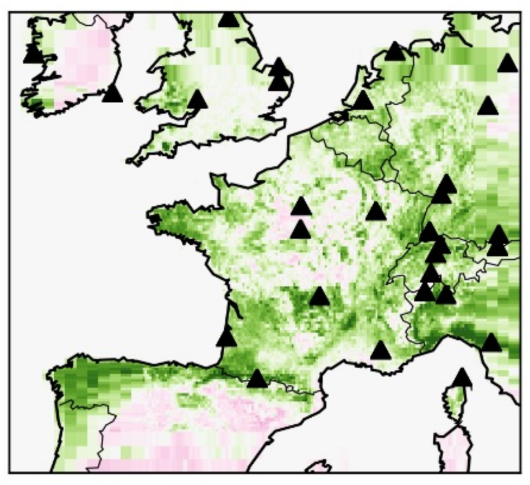
Binning into the CHIMERE zoomed grid of the OCO-2 v11 obs in July 2011



Annual mean CO_2 and CO satellite (binned at the model res.) and in situ data assimilated by GEOS-Chem over 2018-2021

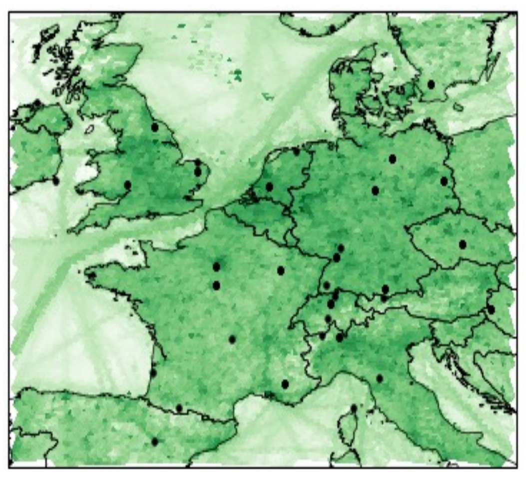
THE THREE NATIONAL SCALE INVERSION SYSTEMS

- European to national coverages, **0.3° to 10 km resolution**
- Variational and EnKF inversion frameworks
- **Separate control of the anthropogenic and natural fluxes**
- **Assimilation of OCO-2 XCO_2, TROPOMI CO and surface (incl. ICOS and DECC) CO_2 and CO observations**
- Assess the potential of co-assimilating CO co-emitted with CO_2 during combustion
- Prior estimates of the fluxes: CoCO2 database including **TNO inventory of Fossil and Biofuel emissions at 6 km res., VPRM terrestrial ecosystem fluxes at 1 km res. and CAMS boundary conditions**



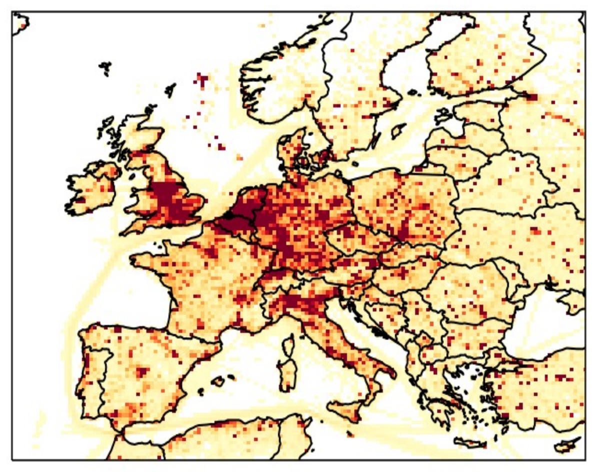
CIF-CHIMERE VAR CO_2 at 10 km res (LSCE)[a,b,c]

Sequence of 1-month inversions controlling
- anthropogenic emissions for 5 large sectors per administrative region and day (with 50% prior uncertainty in regional / 1-day budgets)
- ocean fluxes and NEE at 10 km / 6 hour resolution (with 100 km correl in prior uncertainty scaled by Hresp)
- initial and boundary conditions



ICON-ART CTDAS EnKF CO_2 at 13 km res (EMPA)[a,d]

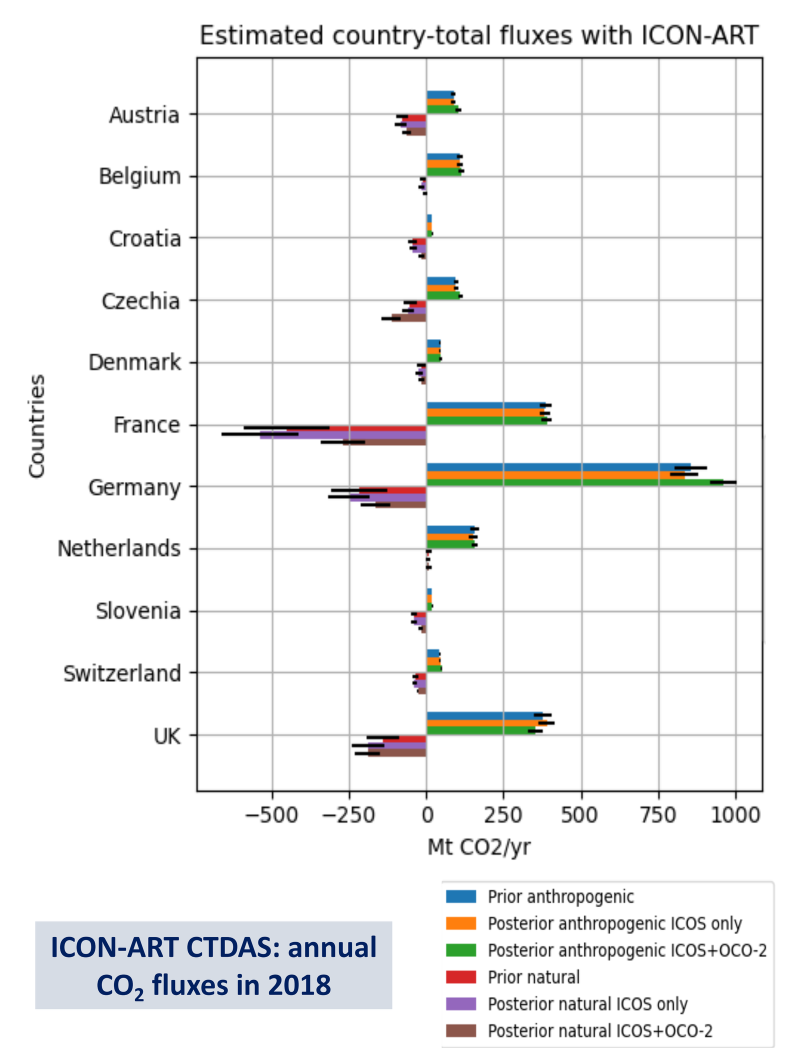
10-day cycles (2 lags) with 180 members controlling
- anthropogenic emissions at 13 km / 10 day resolution (with 50% prior uncertainty incl. 200 km correl at this res.)
- NEE at 13 km / 10 day resolution (with 100% prior uncertainty incl. 300 km correl at this res.)
- boundary conditions



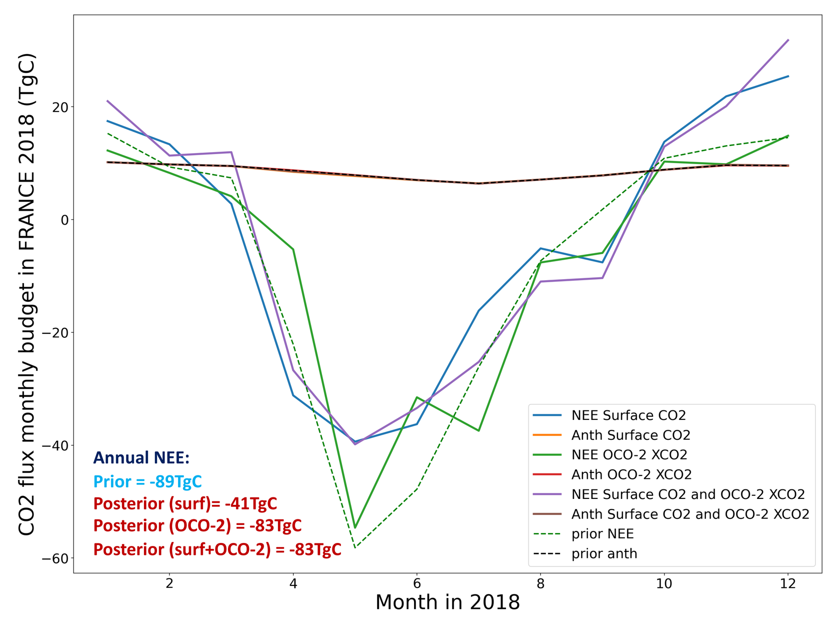
GEOS-Chem EnKF (LETKF) CO_2/CO at 0.25°x0.3° res (UEdin)[a,e,f]

Linearized CO simul. (offline chemistry)
14 day cycles (1 month lag window) with 100 members controlling
- anthropogenic emissions of CO_2 / CO at ~0.5° / 14 day res. (with 20% prior uncert. at this res.; correl between prior CO_2/CO errors: 100% or diagnostics from TNO)
- CO_2 NEE at ~0.5°/ 14 day resolution (with 50% prior uncertainty at this res.)
- boundary conditions, CO chemistry prod

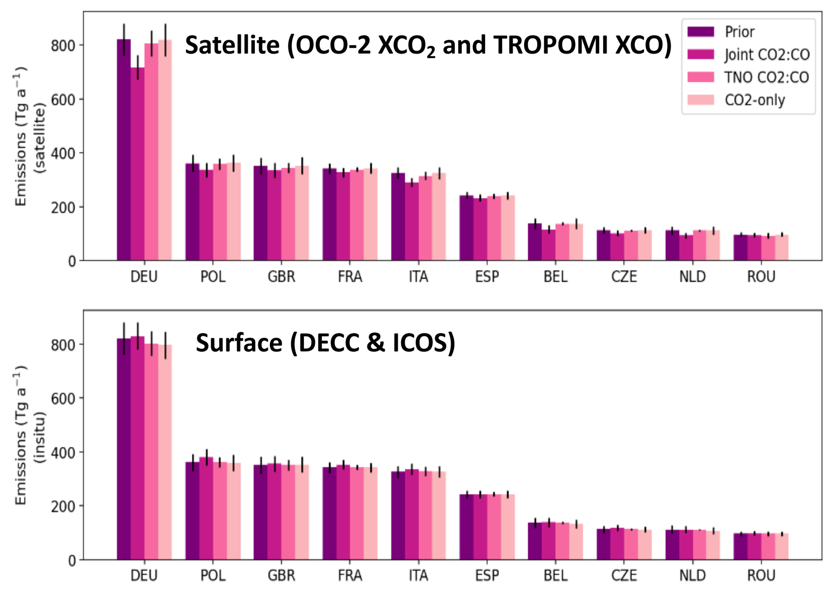
PRIOR AND POSTERIOR ESTIMATES OF THE EMISSIONS, INCREMENTS FROM THE INVERSION



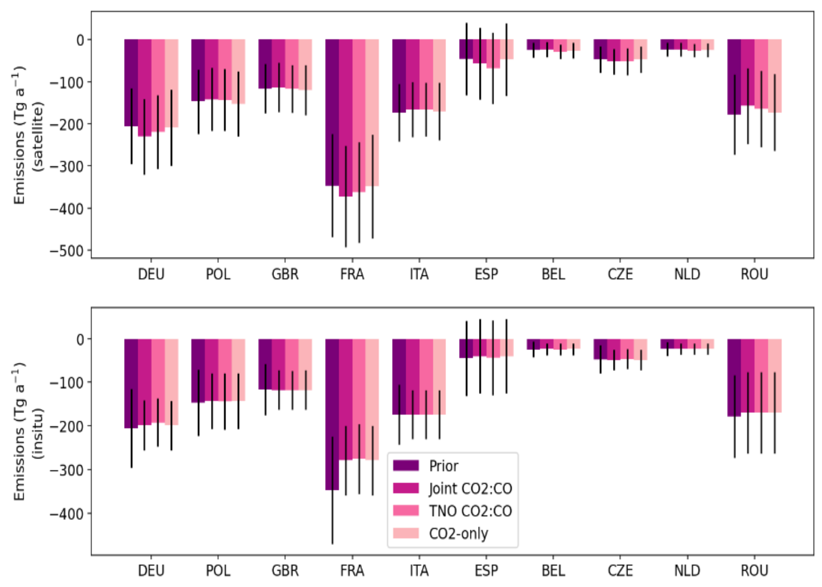
ICON-ART CTDAS: annual CO_2 fluxes in 2018



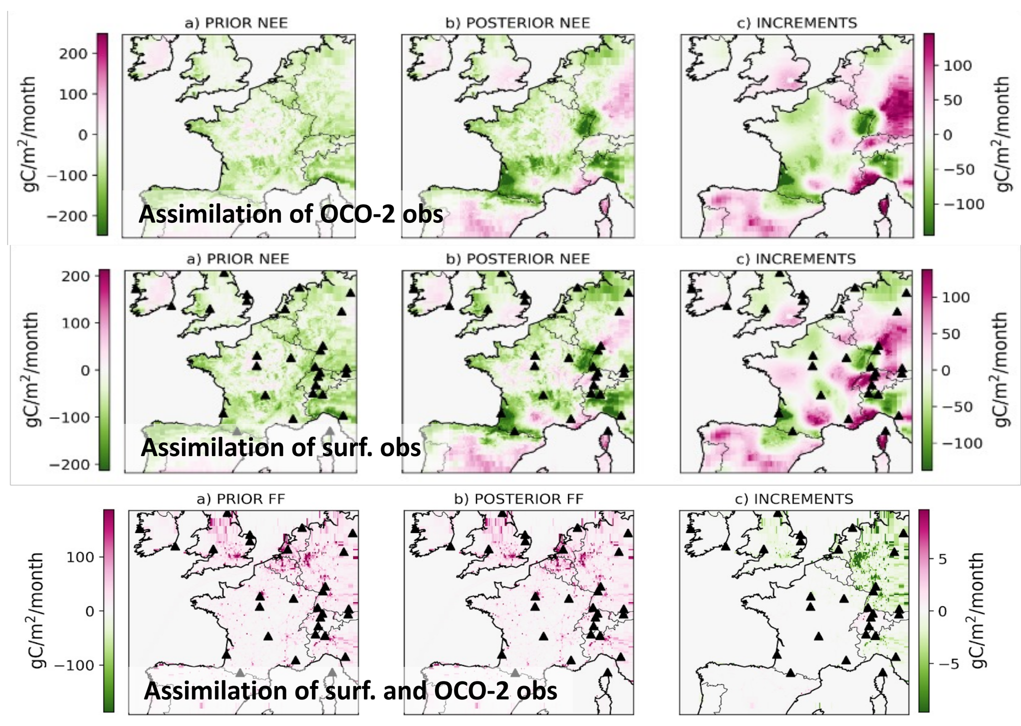
CIF-CHIMERE: monthly and annual CO_2 fluxes in France in 2018



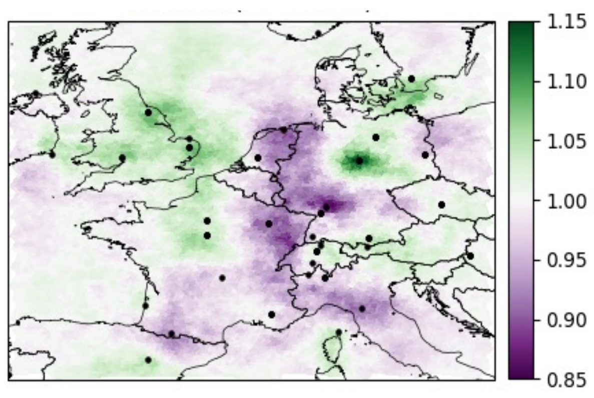
GEOS-Chem: average CO_2 emissions over 2018-2021



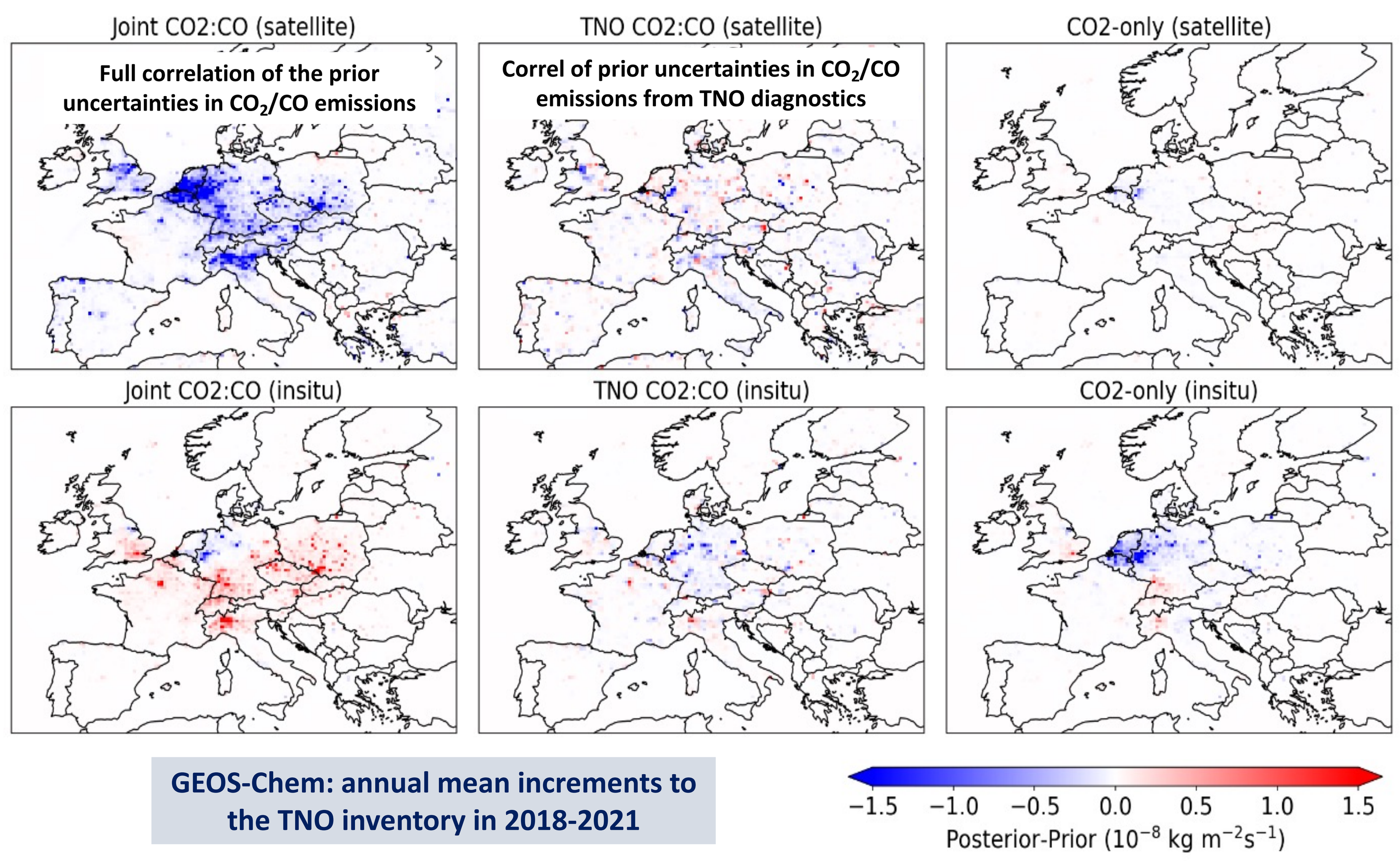
GEOS-Chem: average CO_2 NEE over 2018-2021



CIF-CHIMERE assimilating surface and OCO-2 obs: maps of the NEE and anthropogenic emissions in France in July 2018



ICON-ART CTDAS assimilating surface obs: annual relative corrections to the TNO inventory in 2018



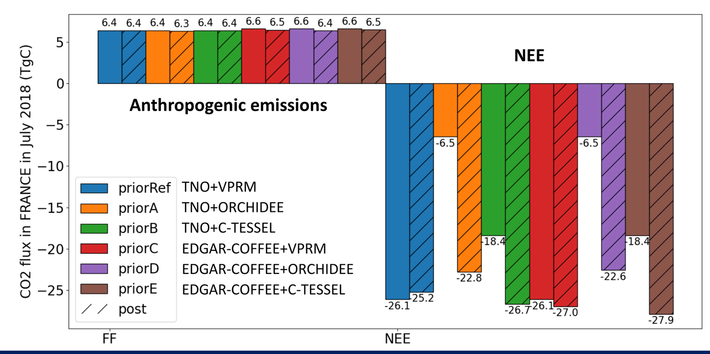
GEOS-Chem: annual mean increments to the TNO inventory in 2018-2021

Lack of control of the CO_2 anthropogenic emissions at the annual/1-month – national scale
→ despite some control at local scale and sensitivities of the NEE inversion to the prior estimates of the emissions

Potential of the co-assimilation of co-emitted species
→ some promising insights from GEOS-Chem CO_2-CO inversions (and from CIF-CHIMERE NO_x and CO inversions not shown here)
→ but dependence on the assumptions regarding the correlation between prior uncertainties in NO_x/CO and CO_2 emissions

Spread of the CO_2 NEE estimates
→ Contrast between results based on surface CO_2 vs. OCO-2 vs. both, spread of the results across the systems

CIF-CHIMERE assimilating surface and OCO-2 observations: anthropogenic emissions and NEE in France in July 2018 using different sets of prior estimates



CONCLUSIONS AND PERSPECTIVES

- **Analysis of regional CO_2 NEE estimates:** resuming past regional scale intercomp. (e.g. EUROCOM) at higher spatial res.
  → need for tests with modular systems (such as the CIF) to assess the spread from each inversion component
- **Lack of control of the anthropogenic emissions at large spatial and temporal scales**
  → need to increase transport and control res., assimilating peri-urban sites, to progress on the CO/NO_2 data assimilation
  → challenge of defining suitable prior uncertainties: need to maintain efforts for analyzing uncertainties in the gridded inventories; **key step with spatially resolved CO:CO_2 error correlation analysis by TNO**
- **Assimilation of surface data more mature than the assimilation of satellite data**
- **CO2M should critically increase the ability to solve for anthropogenic emissions and decrease uncertainties in CO_2 NEE**
- **CoCO2: 11 national scale systems** (different res., approaches) → basis for assessment & dev. of national scale capabilities

References:

a) Marshall et al., 2023, CoCO2 report D4.6 Intercomparison of national scale inversions, https://coco2-project.eu/resources
b) Berchet, et al., The Community Inversion Framework v1.0: a unified system for atmospheric inversion studies, Geosci. Model Dev., 14, 5331–5354, https://doi.org/10.5194/gmd-14-5331-2021, 2021.
c) Monteil et al., The regional European atmospheric transport inversion comparison, EUROCOM: first results on European-wide terrestrial carbon fluxes for the period 2006–2015, Atmos. Chem. Phys., 20, 12063–12091, https://doi.org/10.5194/acp-20-12063-2020, 2020.
d) Steiner et al., European CH_4 inversions with ICON-ART coupled to the CarbonTracker Data Assimilation Shell, Atmos. Chem. Phys., 24, 2759–2782, https://doi.org/10.5194/acp-24-2759-2024, 2024.
e) Scarpelli et al., Verifying national inventory-based combustion emissions of CO_2 across the UK and mainland Europe using satellite observations of atmospheric CO and CO_2, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-416, 2024.
f) Super et al., Improved definition of prior uncertainties in CO_2 and CO fossil fuel fluxes and the impact on a multi-species inversion with GEOS-Chem (v12.5), EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-2025, 2024.

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