Inverse modelling as a tool for supporting national greenhouse gas monitoring

GUILLAUME MONTEIL, CARLOS GOMEZ-ORTÍZ, MARKO SCHOLZE

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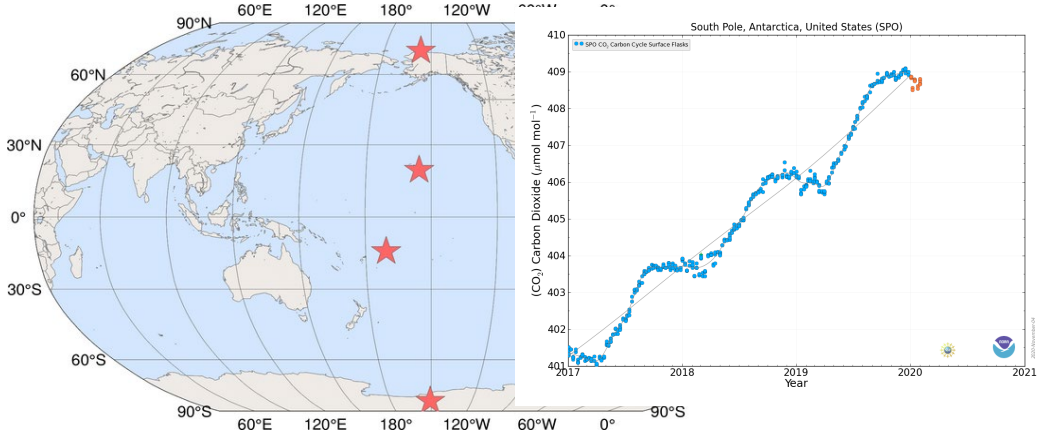
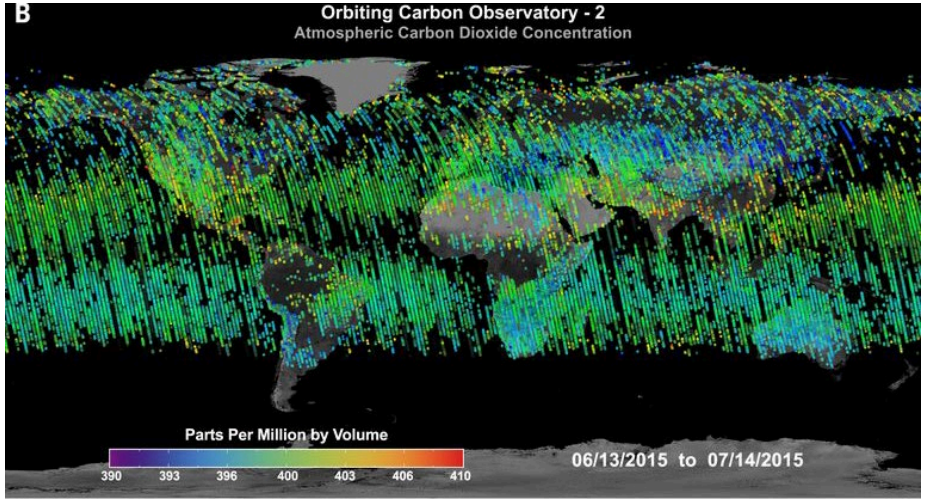
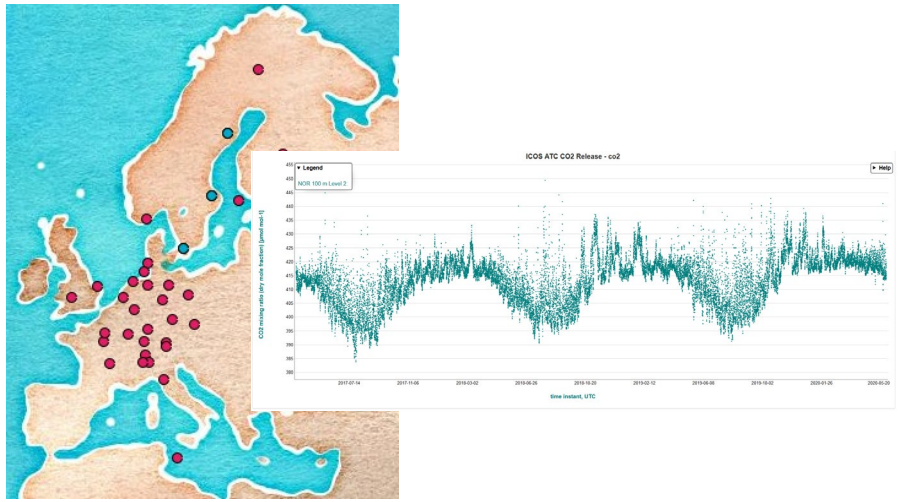
GHG observing systems



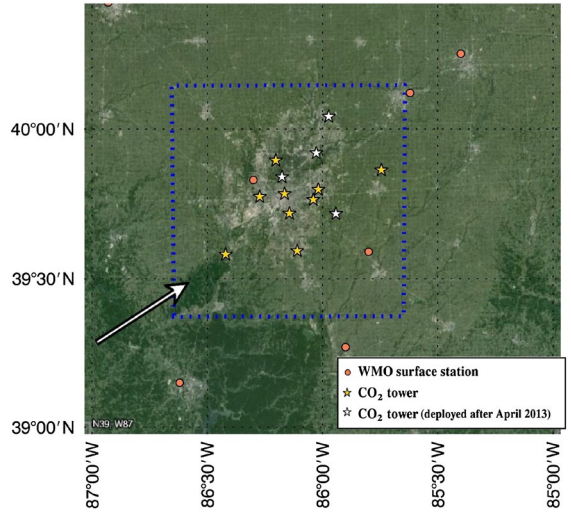
Background measurement sites



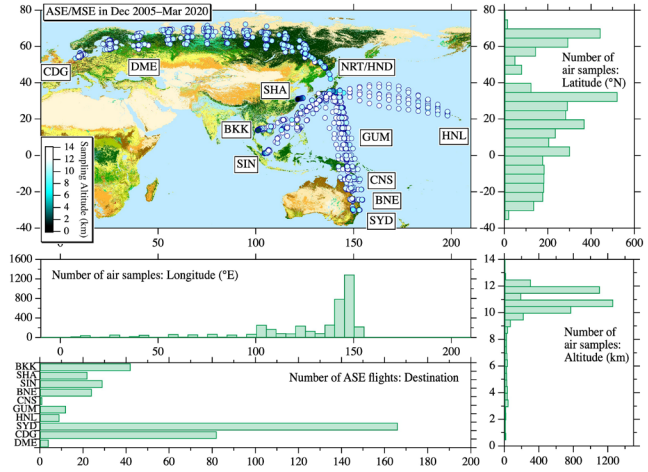
Satellite retrievals



In-situ networks



In-situ measurement campaigns



Mobile platforms

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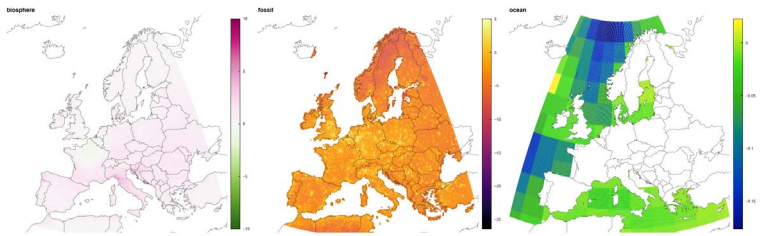
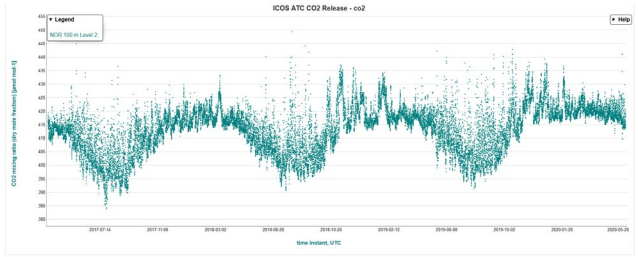
Inverse modelling?

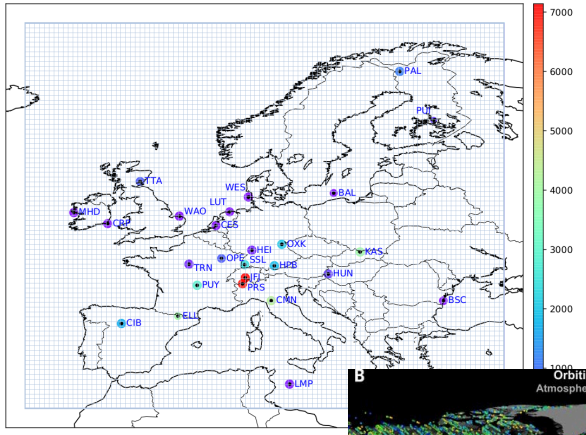


Emissions:

- Process models
- Inventories
- Diagnostic models
- Informed guess
- ...

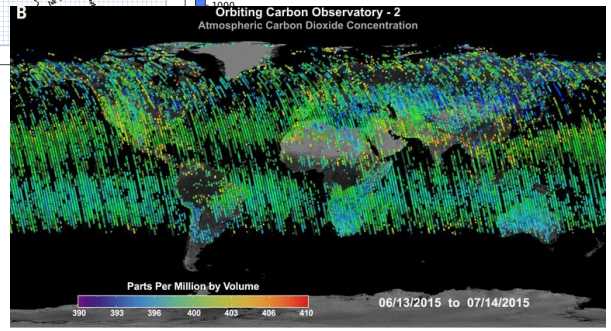
?





Observations:

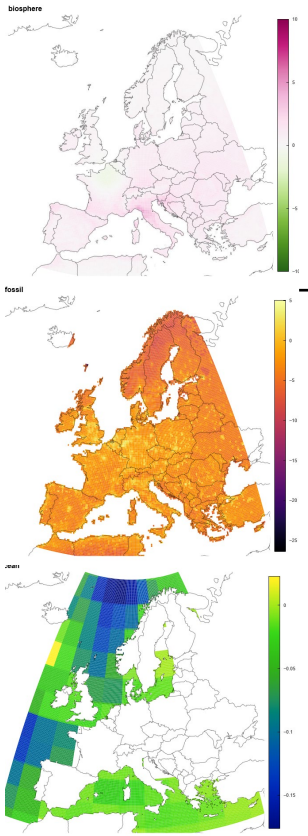
- In-situ networks
- Satellites
- Mobile platforms
- Background sites
- ...

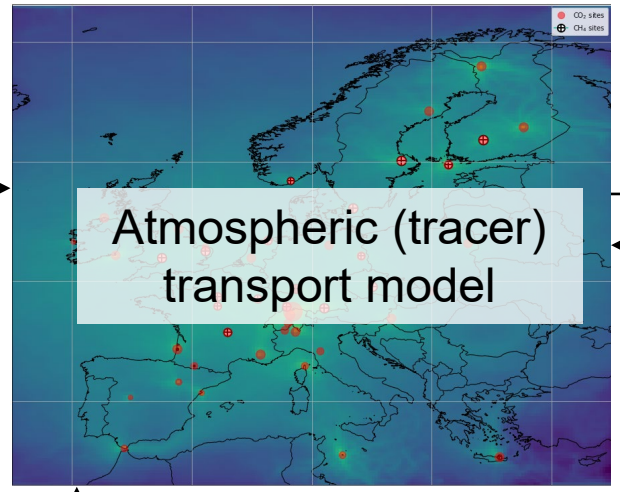


Inverse modelling brings together information from (prior) emission estimates with information from the observations

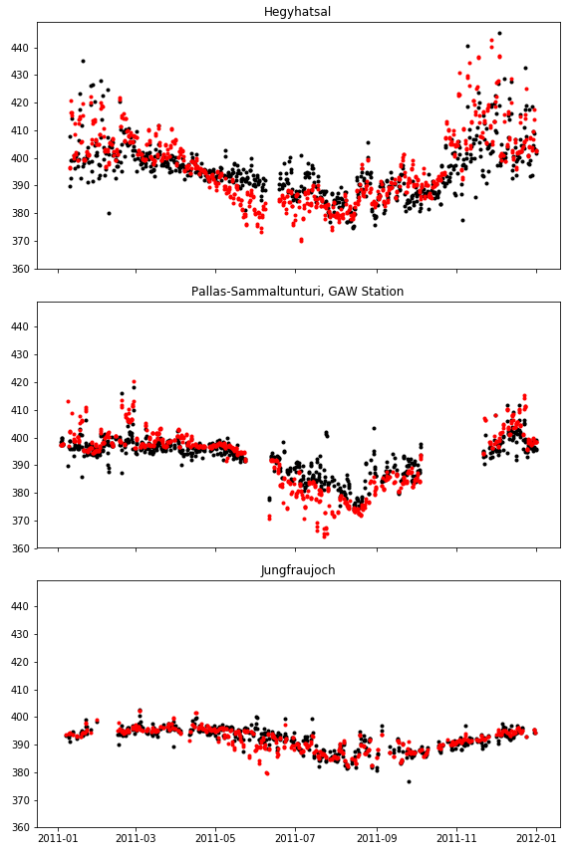
Inverse modelling principle

Emissions

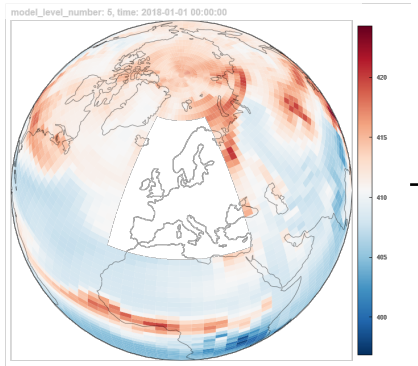




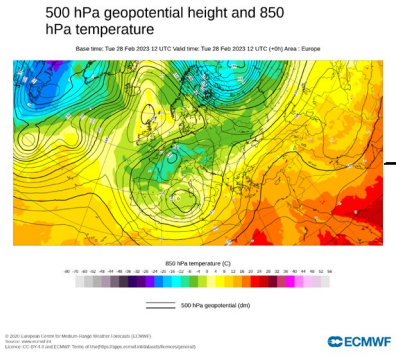
Modelled concentrations



Boundary / initial condition



Meteo data



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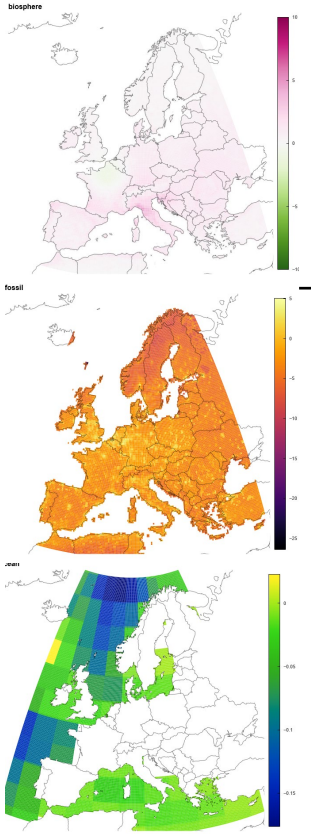
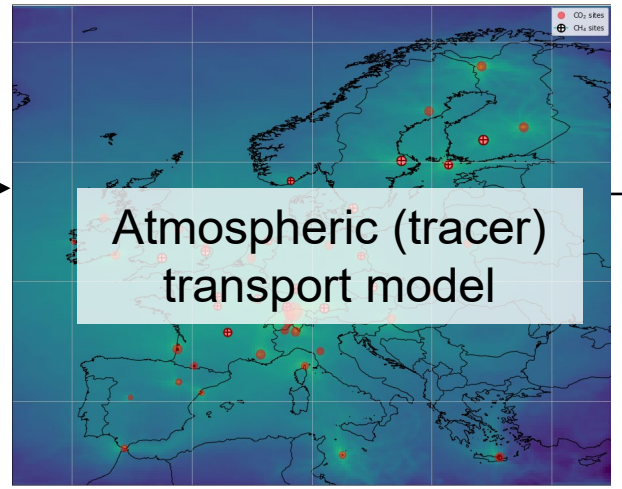
Inverse modelling principle

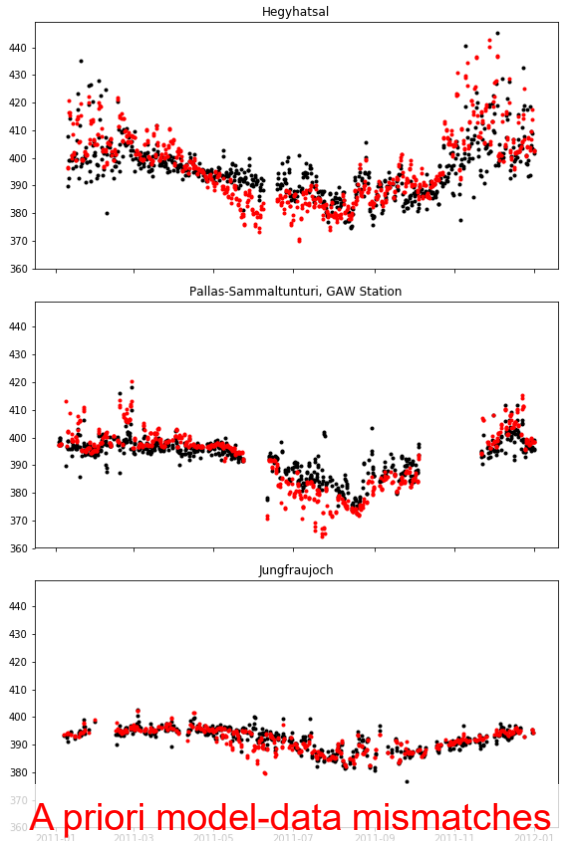
Emissions



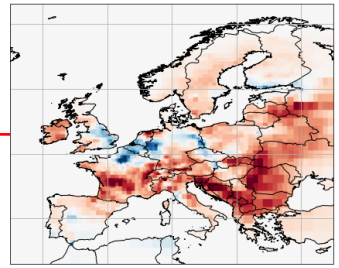
A priori emissions
+ uncertainties

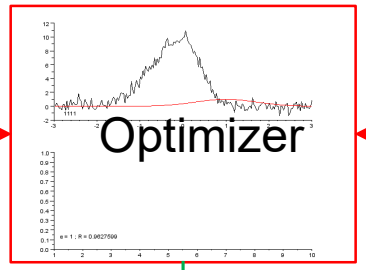


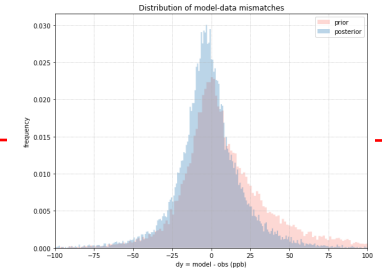
Modelled concentrations



A priori model-data mismatches
+ uncertainties







Posterior emissions (+ uncertainty)

A posteriori fit to the data

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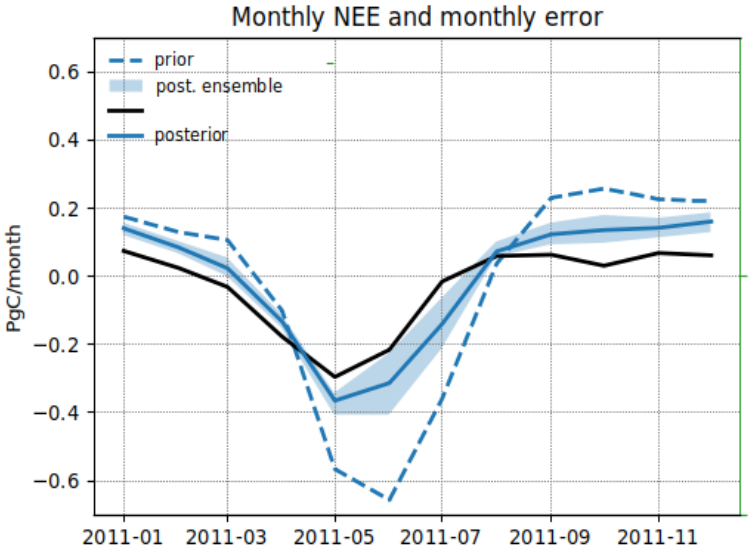
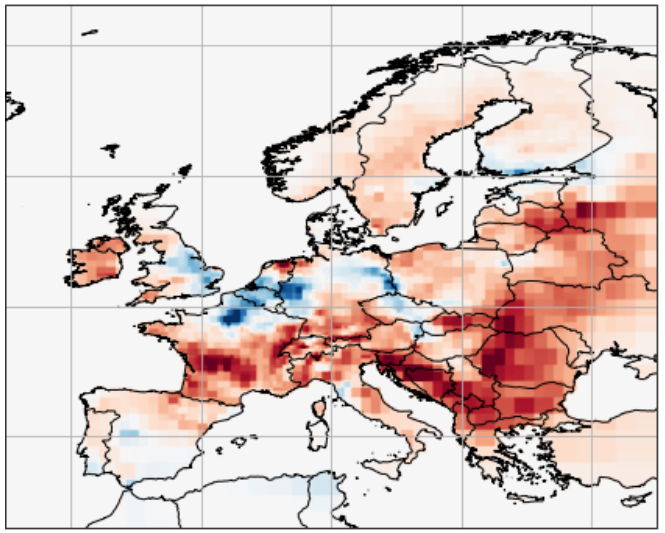
What do we get from it?

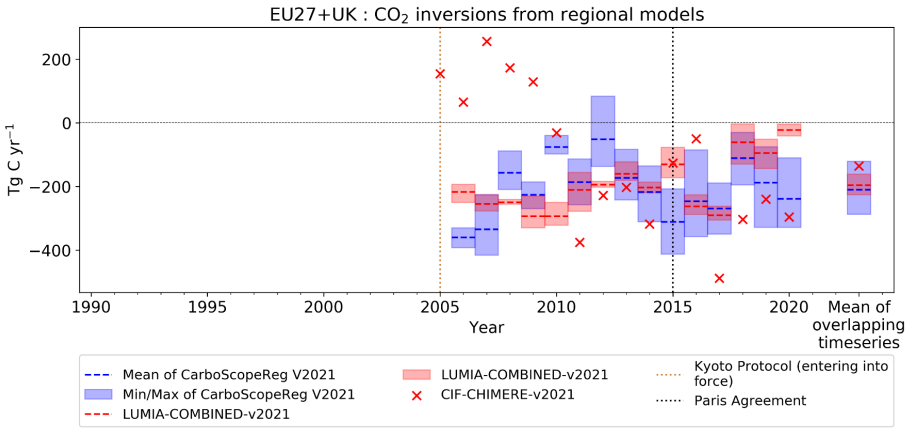
- Posterior estimate quality can vary in space and time and depends on:
  - Density of the observational coverage
  - Accuracy of the transport model, boundary condition, meteo data, etc.
  - How well we setup the inversion (uncertainties, definition of the variables to optimize, etc.)
- Resolution of the inversion << resolution of the emissions
- Not really category-specific
- Result is probabilistic!

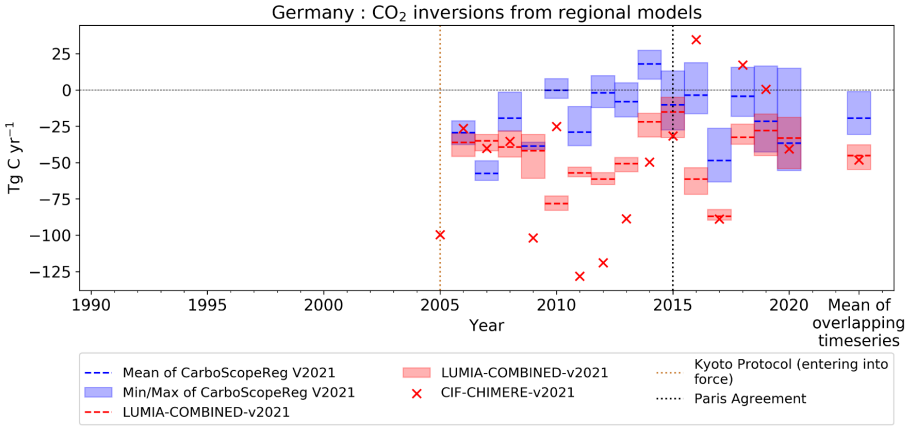




Inverse modelling at LU

- LUMIA system:
  - Transport model: FLEXPART
  - Boundary condition: TM5
  - Variational inversion approach (iterative)
  - European inversions with ICOS-like data
  - For CO2 and CH4
  - Current developments in multi-tracer inversions:
    - CO2 + Black-Carbon aerosols
    - CO2 + 14CO2





Petrescu, A. M. R., et al.: The consolidated European synthesis of CO_2 emissions and removals for the European Union and United Kingdom: 1990–2018, Earth Syst. Sci. Data, 13, 2363–2406, https://doi.org/10.5194/essd-13-2363-2021, 2021.

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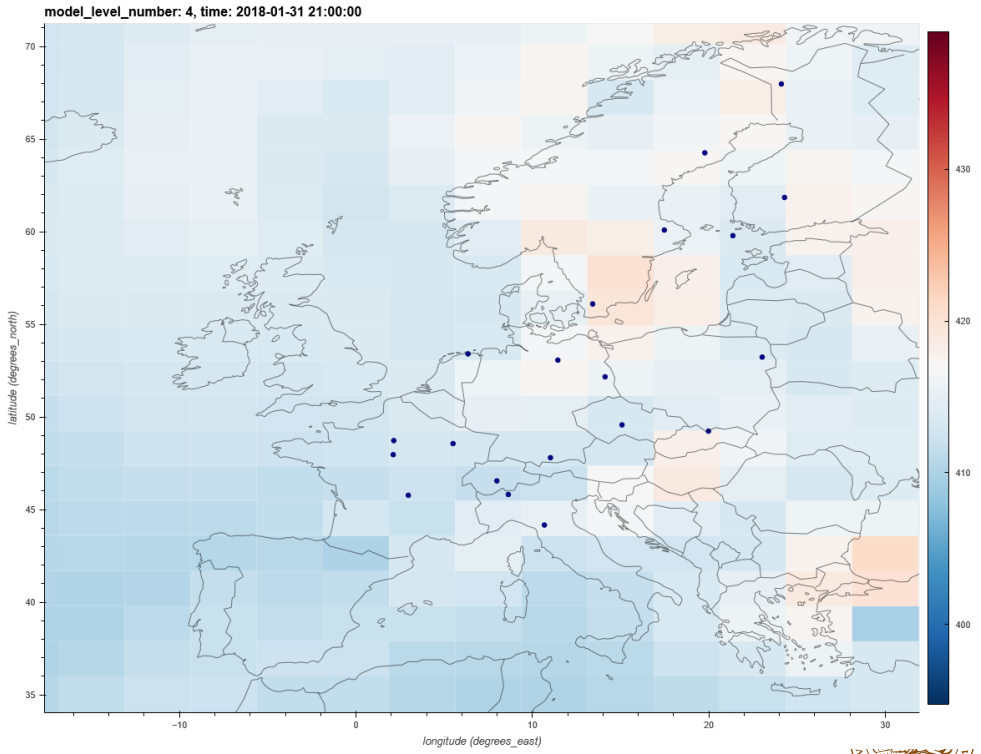
Towards country-scale emission estimates?

- Not a replacement for inventories! Rather a complement
- Dependent on the density of the observation network: not too bad in the Nordic region, but national scale is very challenging
- Developments needed to separate the contributions from different source categories



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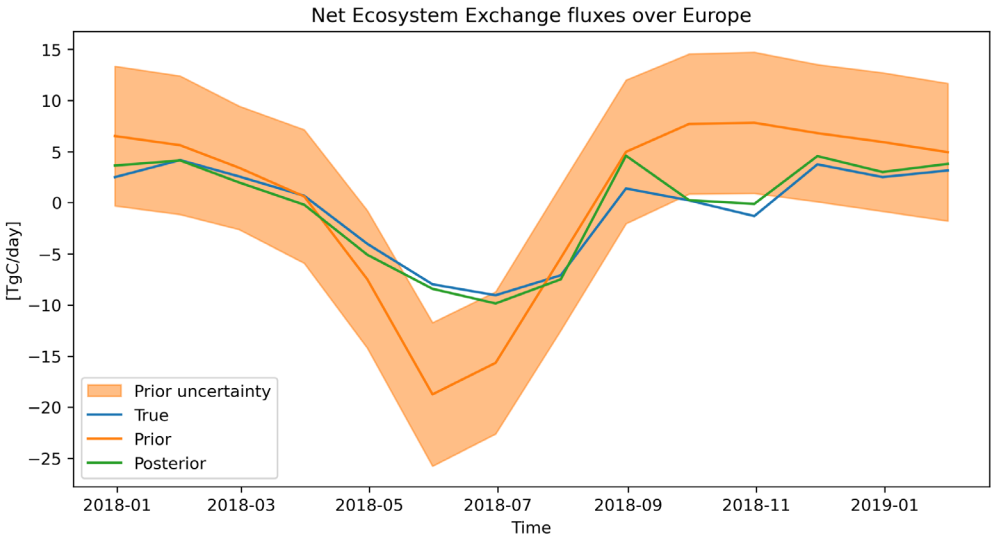
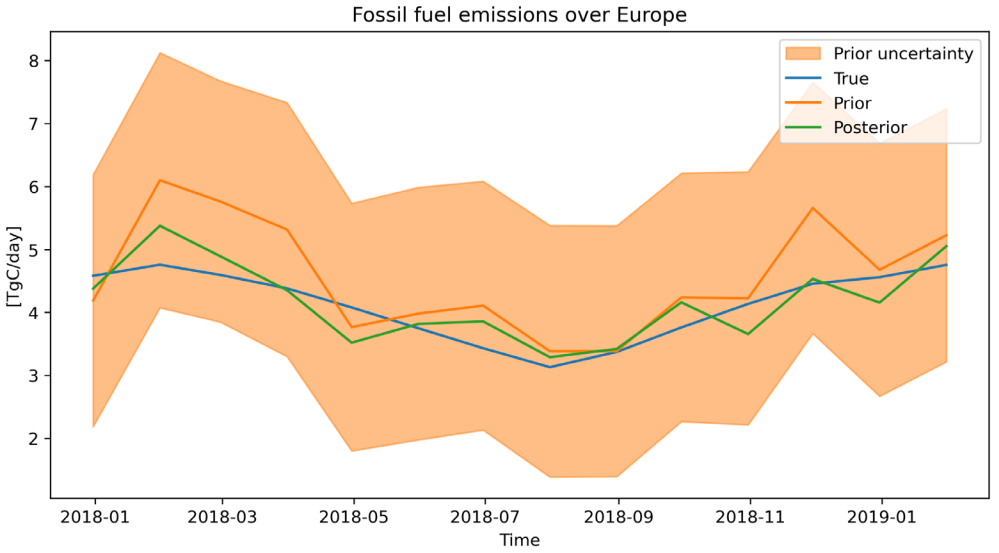
Inverse modelling to estimate anthropogenic emissions

- CO2 observations are sensitive to the net CO2 flux (natural + anthropogenic)
- 14CO2 observations (radiocarbon) are sensitive to the origin of CO2 (no 14C in fossil C)

➔ CO2 + 14CO2 inversions can resolve separately anthropogenic and natural emissions

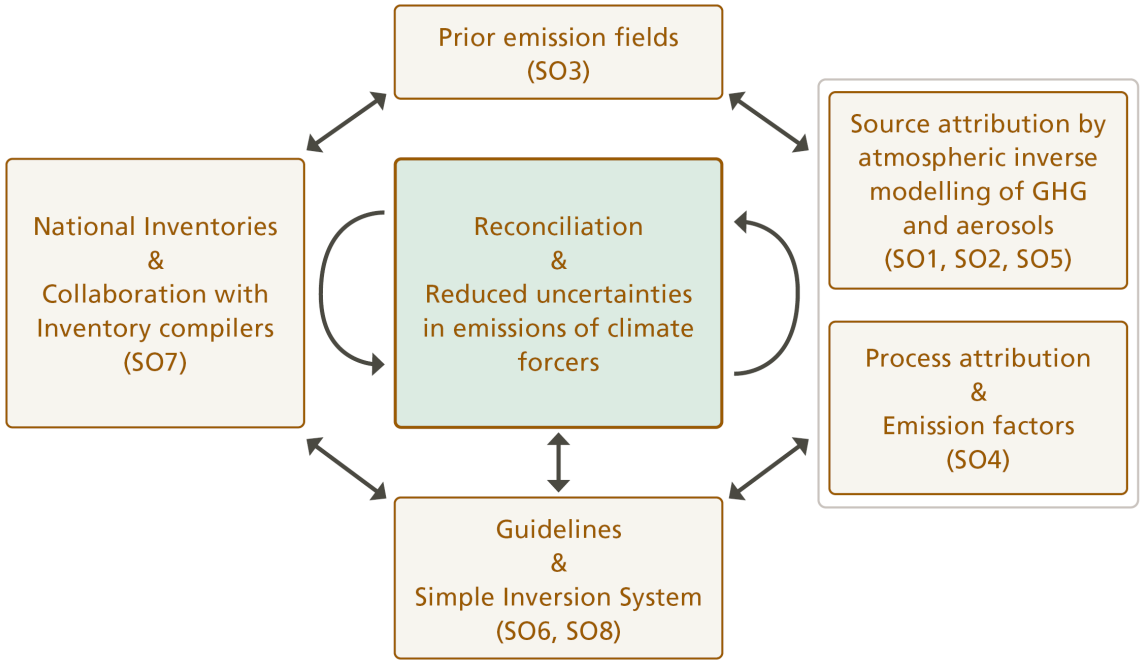
- Other multi-tracer inversions in exploration/development phase (methane isotopologues, black-carbon)





The AVENGERS project

Attributing and **V**erifying **E**uropean and **N**ational **G**reenhouse gas and aerosol **E**missions and **R**econciliation with **S**tatistical bottom-up estimates



To reconcile reported GHG emissions with independent information from atmospheric observations using top-down methods and process-based models, aiming at reducing the most important uncertainties of national emission inventories

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The AVENGERS project

- GHG inventories need to account for variations in GHG emissions across a wide range of scales in space and time based on activity data

  -> activity data may be incomplete and emission factors may not be valid

- Inverse modelling quantifies emissions from atmospheric measurements. But due to atmospheric mixing properties, information contained in atmospheric measurements is easiest to interpret either at very small scale, close to sources, or at very large scale

  -> main target, the national-scale, is most difficult scale to address

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