Atmosphere Monitoring

Considerations for CO_2 AIFS

Anna Agusti-Panareda

8/1/2024

PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
IMPLEMENTED BY ECMWF

Atmosphere Monitoring

CO2 AIFS: Questions and challenges

Some questions:

- **Target**: 3D atmospheric CO_2 , 2D CO_2 sources/sinks, specific source/sink sectors? Atmospheric transport, land surface, ocean
- **Reference f**or training the ML model: inventory datasets, model simulations/analyses, atmospheric inversions?
- **Input** data: remote sensing data, in situ data, NWP + AC analysis, activity data ?
- **Metrics** to assess the model performance?

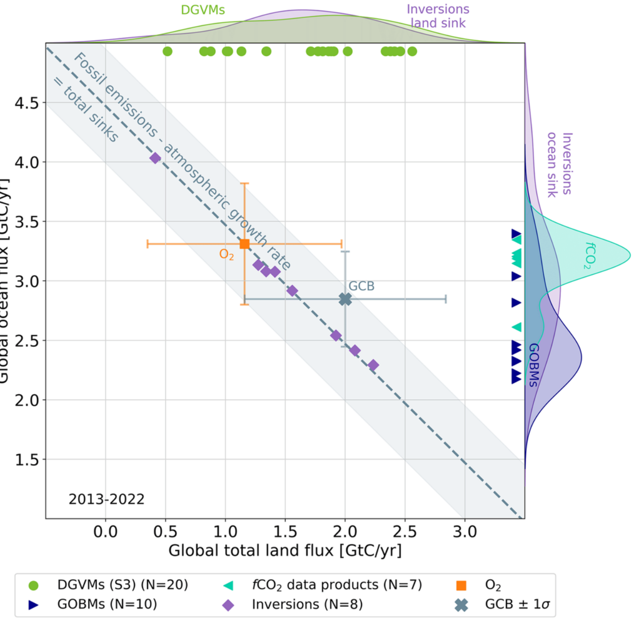
Some challenges:

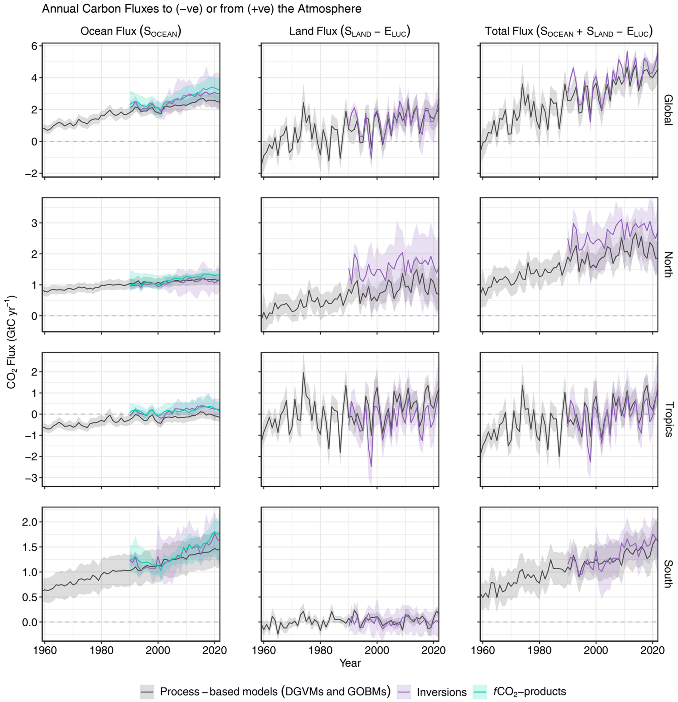
- **Reference datasets** for training can have systematic errors (observations/analysis)
- **Atmospheric transport**: Basic requirement of **mass conservation** and closing budget (changes in atmospheric mass need to be matched with sources/sinks).
- **Bias/variance trade-off:** zero global bias in total CO_2 flux while having to represent large/temporal spatial variability associated with emission hotspots and vegetation.
- **Representation of trends** outside training period (NN OCO-2 and IASI CO_2 retrievals, FLUXCOM)

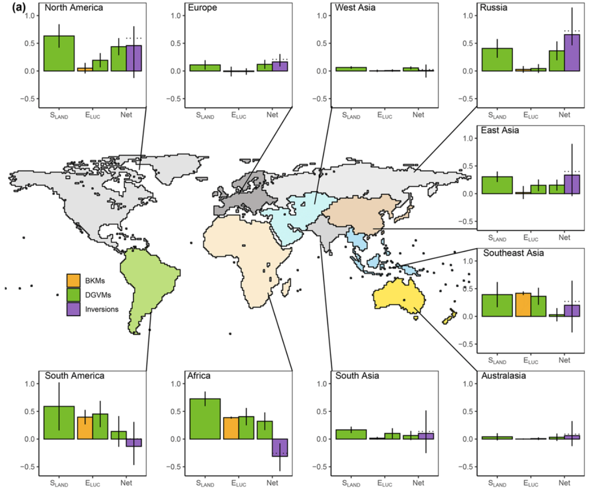
Atmosphere Monitoring

Uncertainty in analysis reference datasets

- IFS CAMS GHG NRT analysis, IFS CAMS GHG HR FC, IFS CAMS GHG re-analysis (Massart et al., 2014, 2016; Agusti-Panareda et al., 2022; Agusti-Panareda et al.,2023), IFS CAMS inversion in development (CHE, CoCO2 and CORSO projects)
- CAMS inversion dataset (Chevallier et al., 2010, 2019, available from ADS)
- GCP inversion products (Friedlingstein et al., 2023)





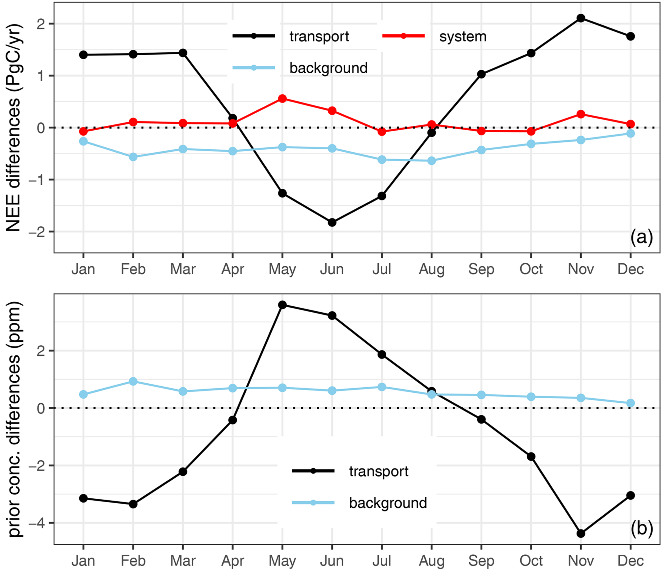


Friedlingstein et al. (2023)

Why do inverse models disagree?

Munassar et al., 2023

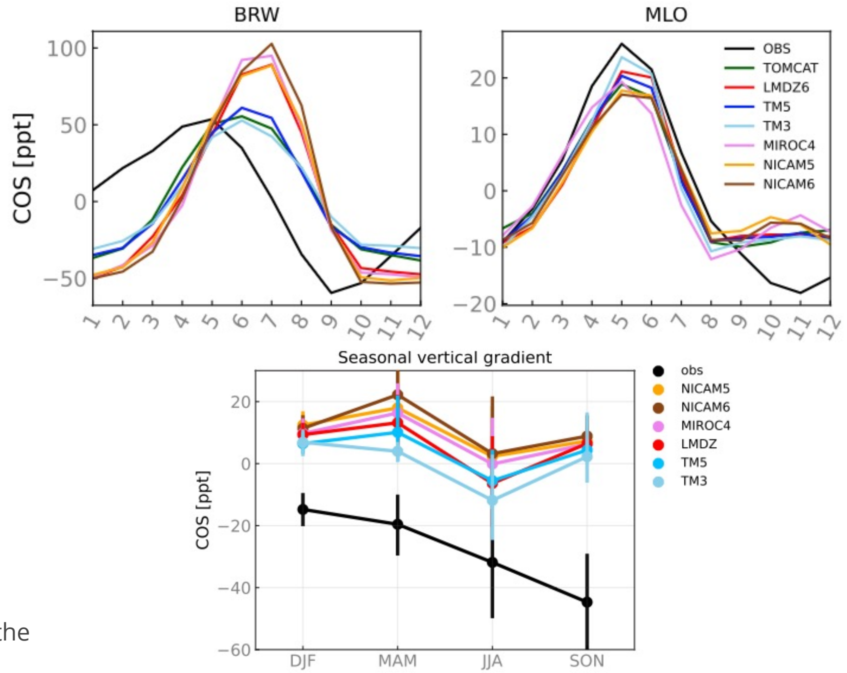
Intercomparison of two European inversions



Differences in optimized fluxes **(a)** and prior concentrations **(b)** calculated with the regional transport models STILT and FLEXPART (CS3-CF3) and background provided through TM3 and TM5 (CS3-CS5). "system" refers to the differences between CSR and LUMIA inversion for optimized fluxes (CS5-LS5).

Remaud et al. (2023)

Intercomparison of Carbonyl Sulfide (TransCom-COS)



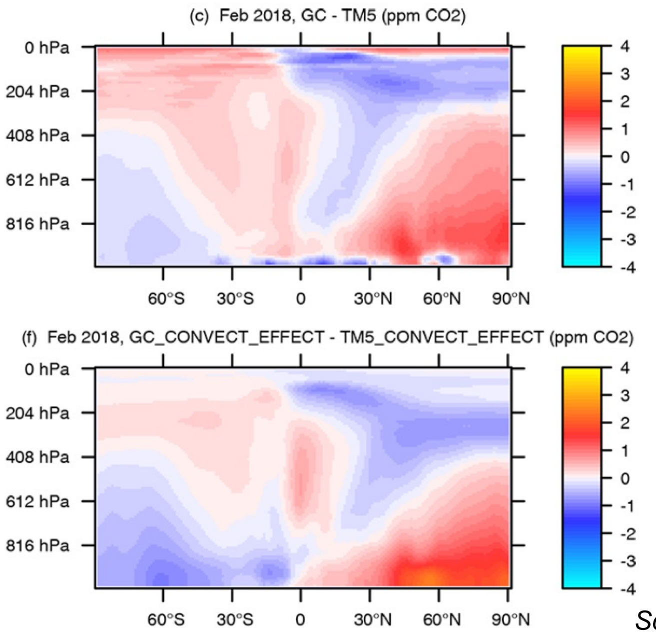
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Systematic errors in tracer transport

- **Advection scheme and resolution**: mass conservation and numerical diffusion (Agusti-Panareda et al., 2017, Eastham & Jacob, 2017)
- **Convective transport** (Schuh and Jacobson, 2023)
- **Turbulent mixing** (Kretschmer et al., 2012)
- **Winds from NWP analyses** (largest in boundary layer and stratosphere) (Yu et al., 2018, Zhang et al., 2021)



Schuh and Jacobson, 2023

Schuh et al. (2019):
"inverse model flux estimates for large zonal bands can have systematic biases of up to 1.7 PgC/year due to large-scale transport uncertainty."

"The research suggests that variability among transport models remains the largest source of uncertainty across global flux inversion systems and highlights the importance both of using model ensembles and of using independent constraints to evaluate simulated transport."

Atmosphere Monitoring

Systematic errors in tracer transport

IFS limitations: atmospheric transport is not mass conserving and **mass fixer** could be responsible for artificially transferring CO_2 horizontally and vertically. The problem becomes more acute close to emission hotspots. The **HE CATRINE project** will be looking at the evaluation of the mass conservation error in more detail and improve numerical schemes to reduce its impact.

- Large improvement in mass conservation with COMADH SL advection (Malardel and Ricard, 2015).
- Bermejo-Conde mass fixer (Diamantakis and Agusti-Panareda, 2017) still required for climate runs and cyclic forecasts, but not for the analysis and flux inversion.

Ongoing and further activities

Land surface fluxes from ECLand

- Marieke Wesselkamp (University of Freiburg)
- Sebastien Garrigues, Patricia de Rosnay (ECMWF)
- Joe McNorton, Francesca di Giuseppe (ECMWF)
- Ewan Pinnington, Patricia de Rosnay (ECMWF)

CO2 retrievals

- XCO_2 from OCO-2 L1 data using neural-network-based approach (David et al., 2021, Breon et al. 2022, CAMS2-52b)
- CO_2 from IAISI L1 data (Crevoisier et al., 2009, CAMS2-52b)

Bias corrections in IFS

- Bermejo and Conde mass fixer (Diamantakis and Flemming, 2014, Agusti-Panareda et al., 2017, Diamantakis and Agusti-Panareda, 2017).
- Biogenic Flux Adjustment Scheme (BFAS) (Agusti-Panareda et al., 2016)