Jet Propulsion Laboratory
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Progress in Understanding the Natural Carbon Cycle with Remote Sensing CO_2 Observations

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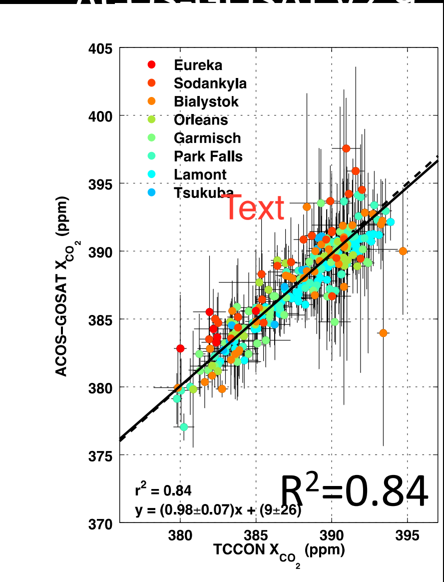
Steady Improvement in X_{CO2} Retrievals

ACOS-GOSAT v2.9



Wunch et al., 2011

OCO-2

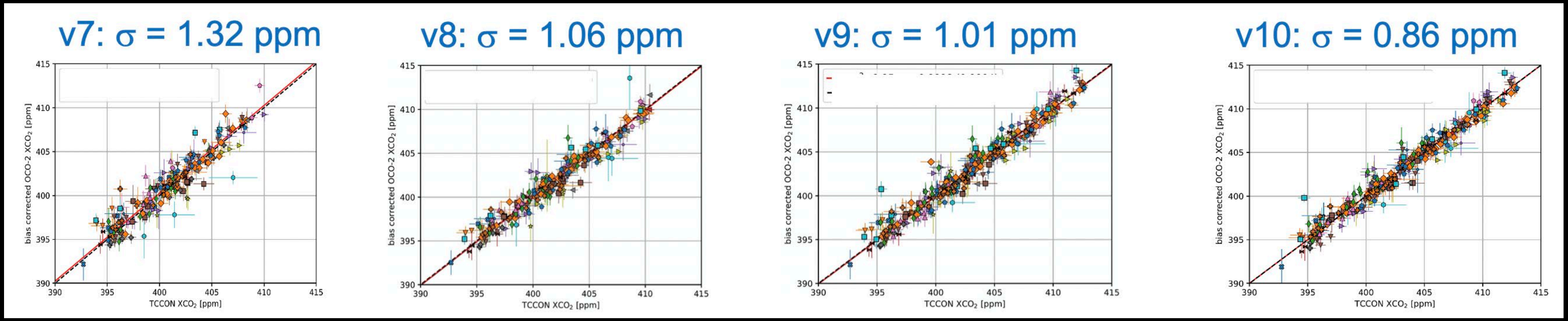
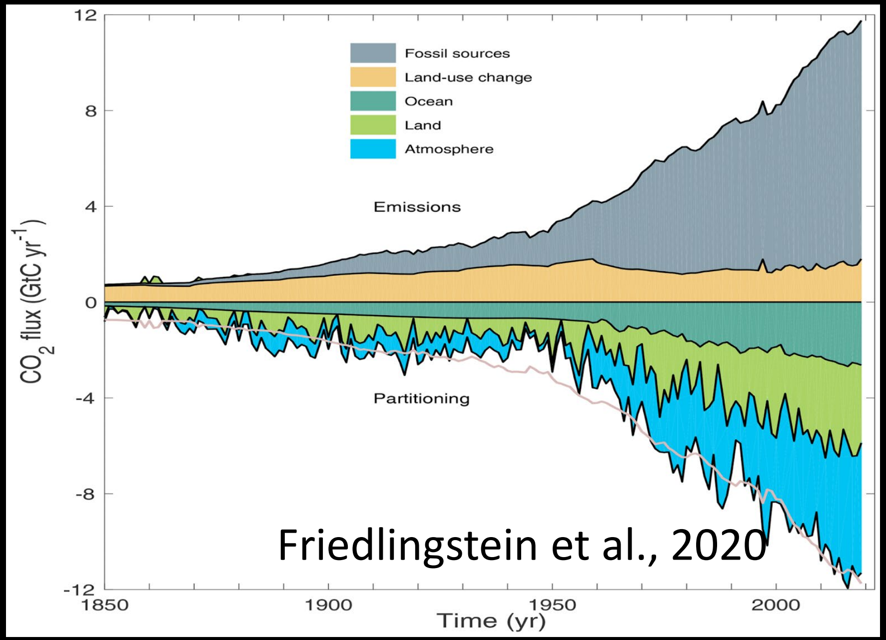
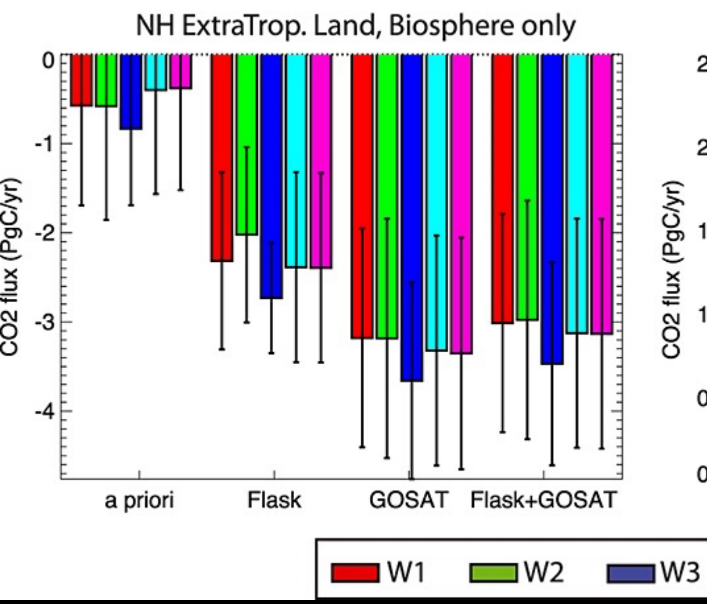


Figure Courtesy: M. Kiel and C. O'Dell

- Natural Carbon Sink has Offset more than 50% of Anthropogenic Emissions so far;
- **How much progress have been made in understanding the terrestrial biosphere carbon cycle with remote sensing CO_2 observations?**
- **What are the challenges and opportunities ahead ?**

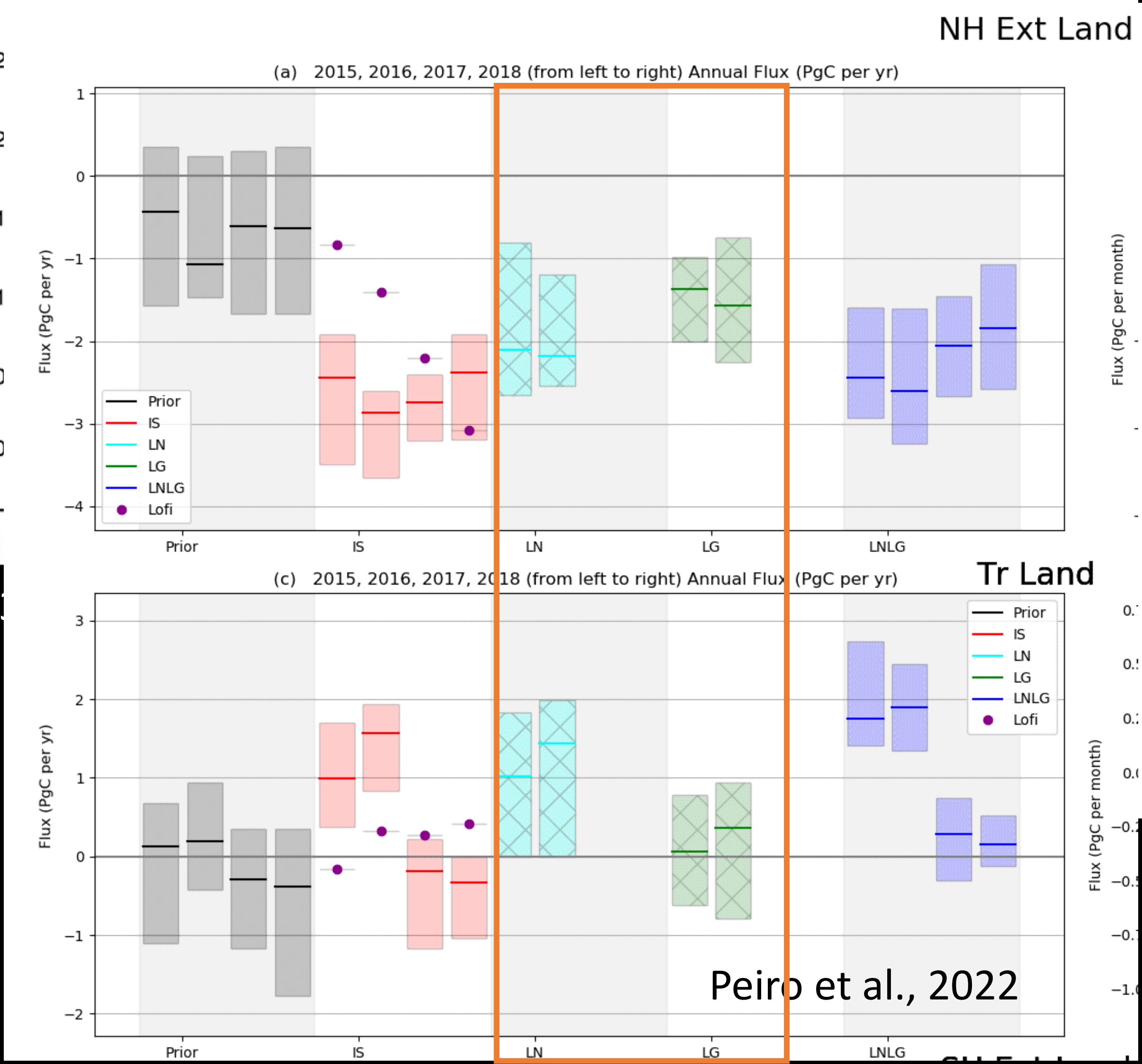


Hemispheric Flux Estimation



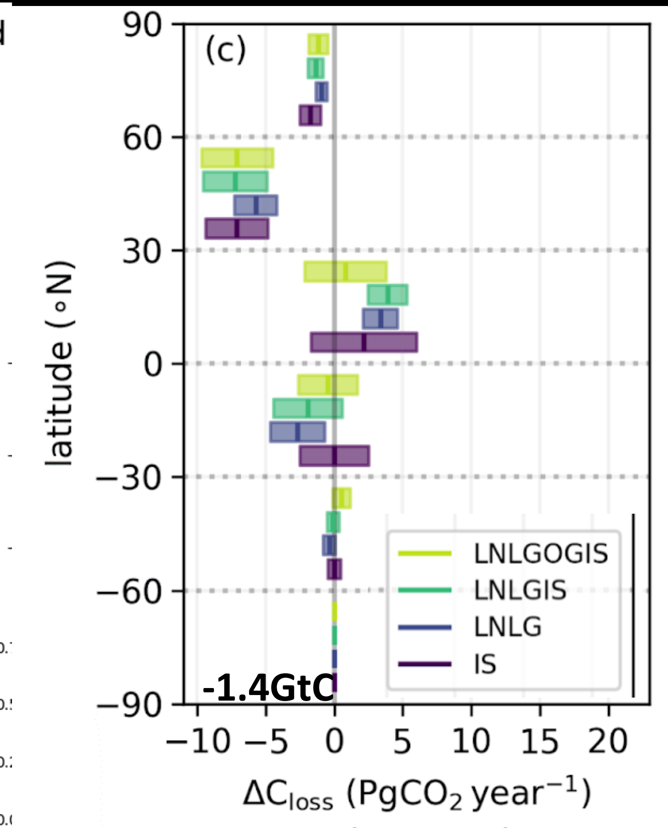
Houweling et al., 201

- ~1GtC difference in NH Extra Trop and Tropical fluxes between flask and GOSAT inversions;
- Uncertainty is more than 1.0 GtC;



Peiro et al., 2022

- Difference between IS and OCO-2 v9 is ~0.5 GtC over tropics;
- Uncertainty becomes smaller from V7 to V9;

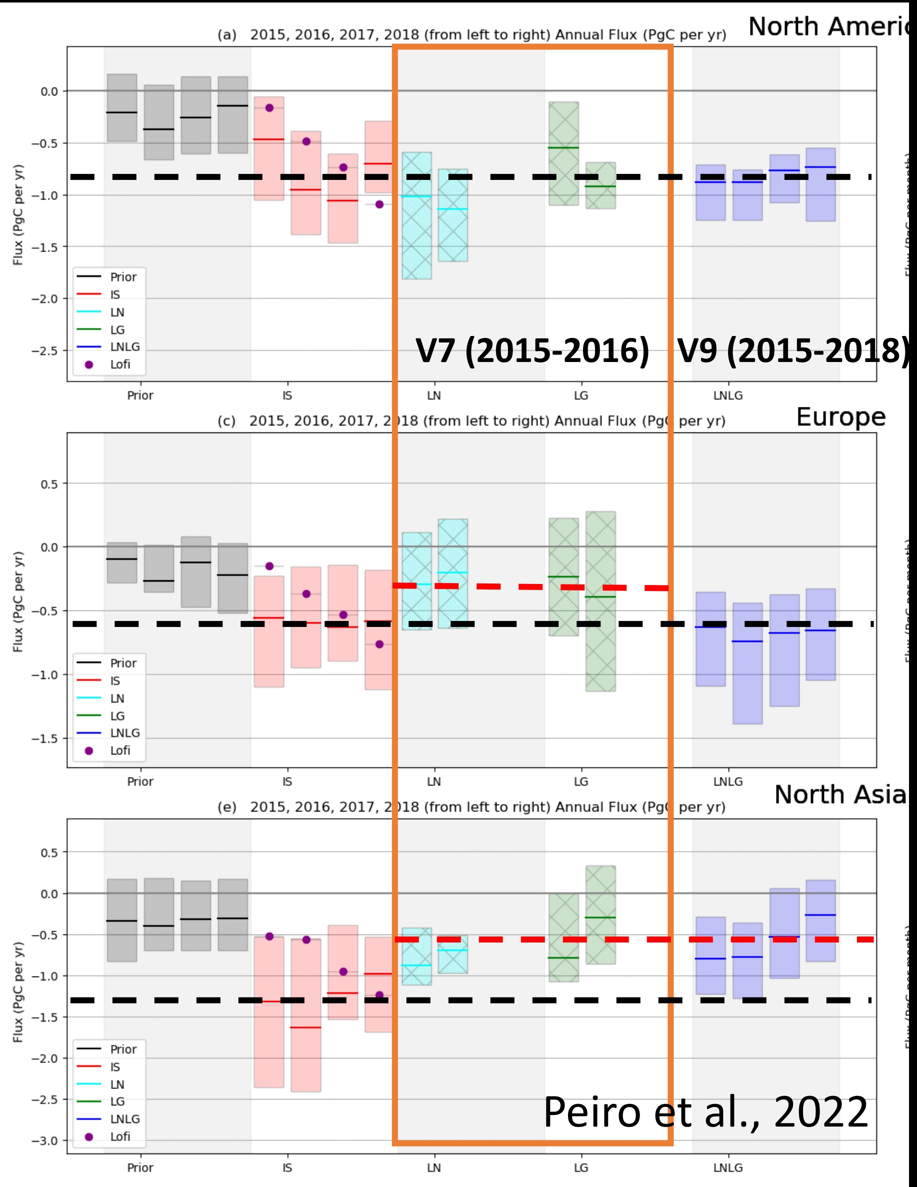


V10 (6 years)

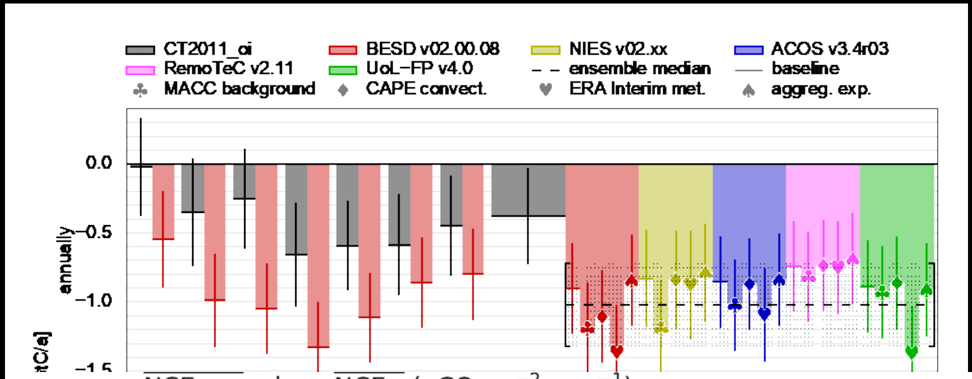
Byrne et al., 2022

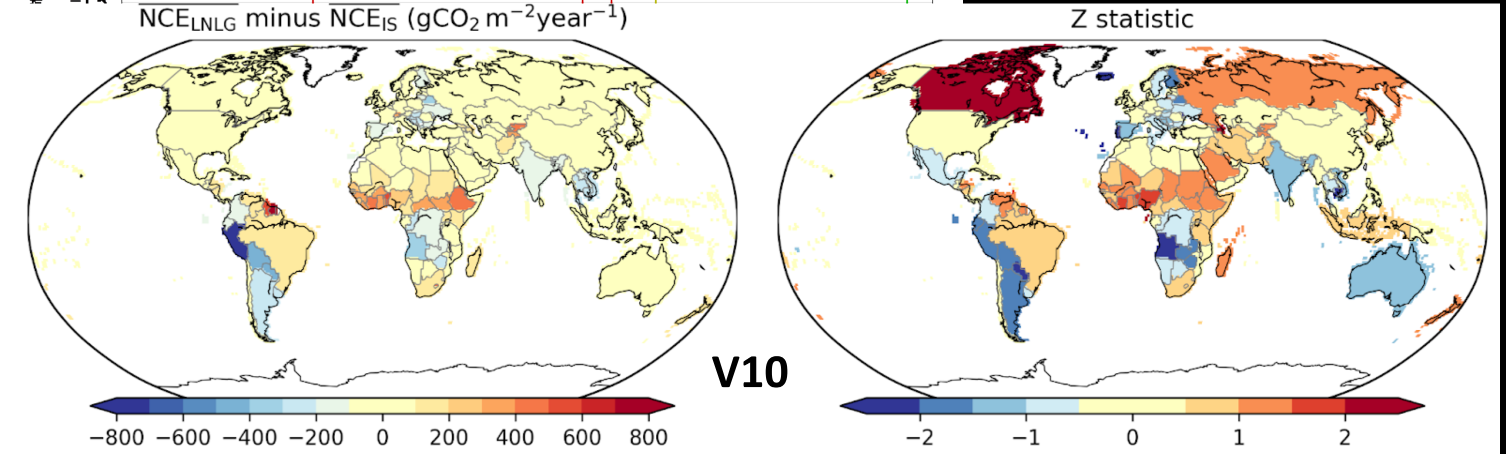
- △C includes lateral C transport;
- Difference between IS and LNLGIS is less than 0.5GtC in NH Ext land, ~0.5 GtC in tropical latitude bands;

Regional Flux Estimation



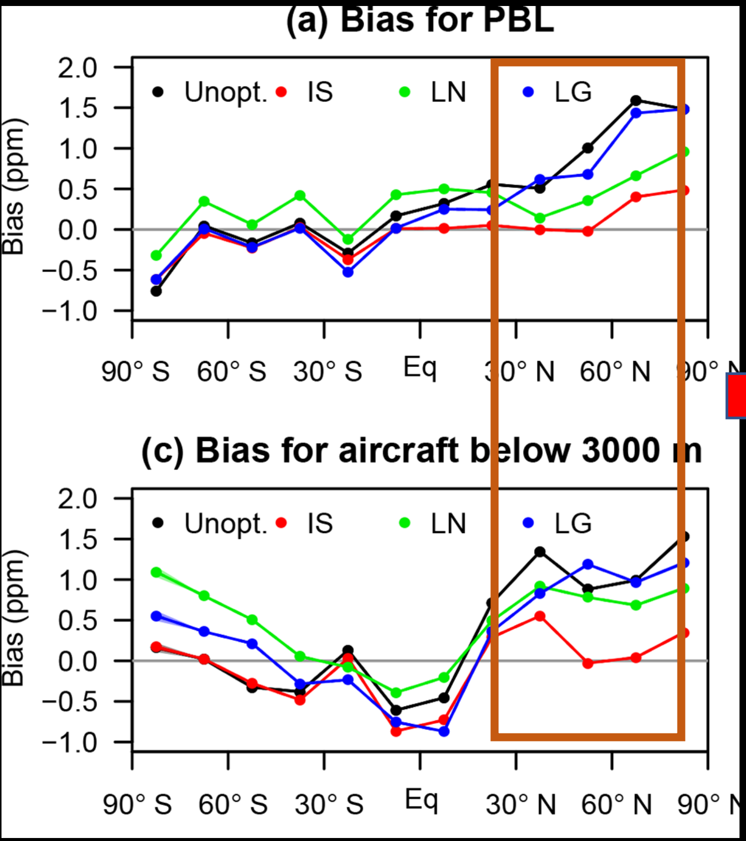
- The flux estimation over Europe becomes more consistent with IS-based inversions from v7 to v9 OCO-MIP inversions, different from results based on early GOSAT retrievals. North Asia shows weaker sink based on satellite XCO2.
- Statistically different flux estimates over small countries over the tropics and high latitudes in V9 OCO-MIP inversions.





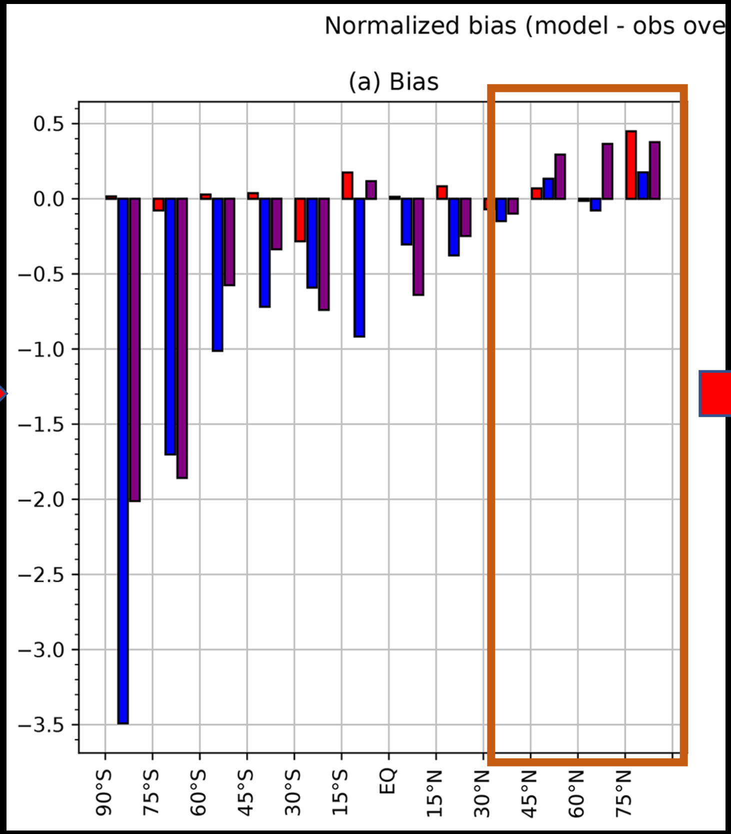
Evaluation against Independent Observations

V7



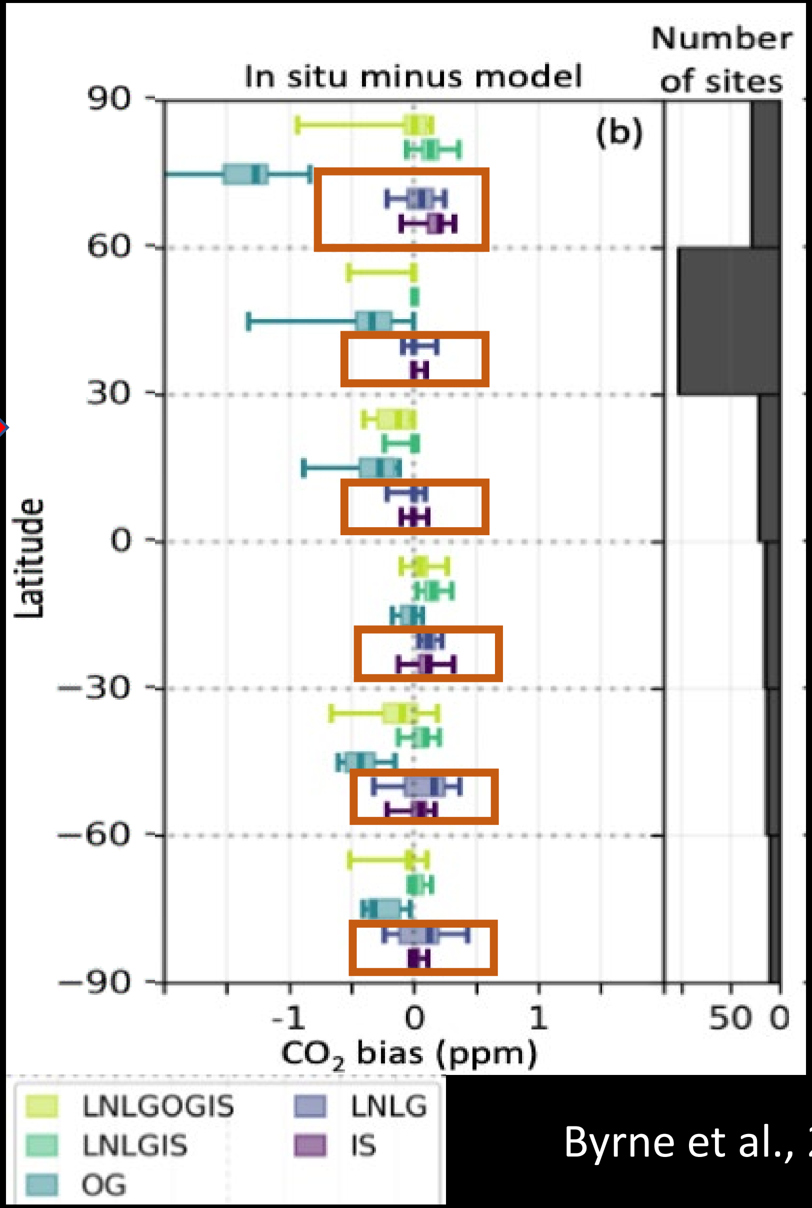
Crowell et al., 2019

V9



Peiro et al., 2022

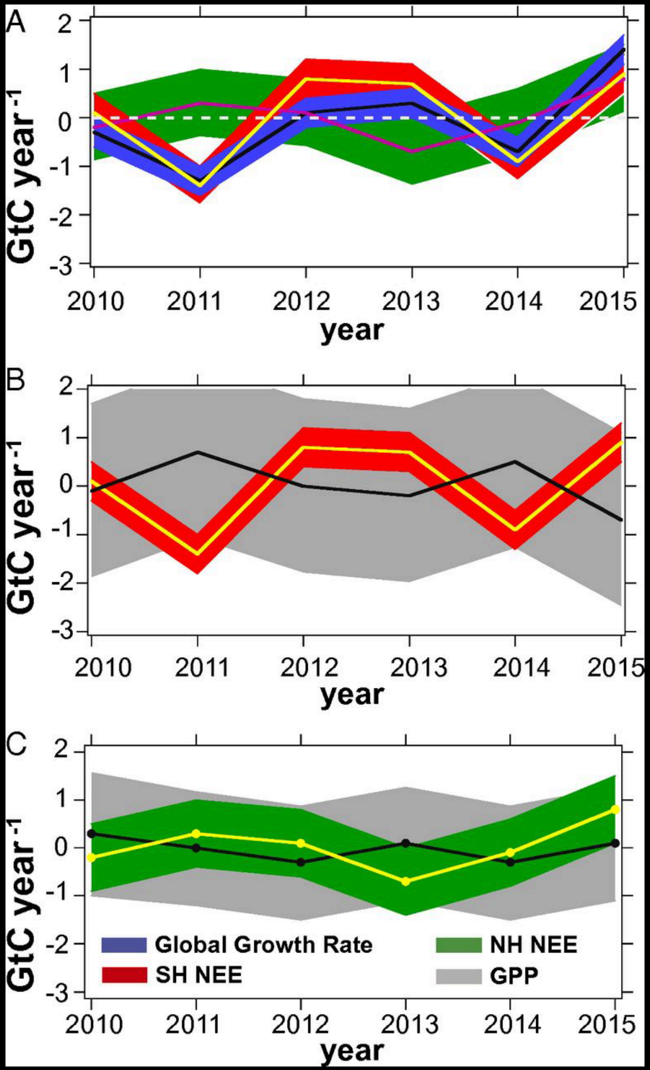
V10



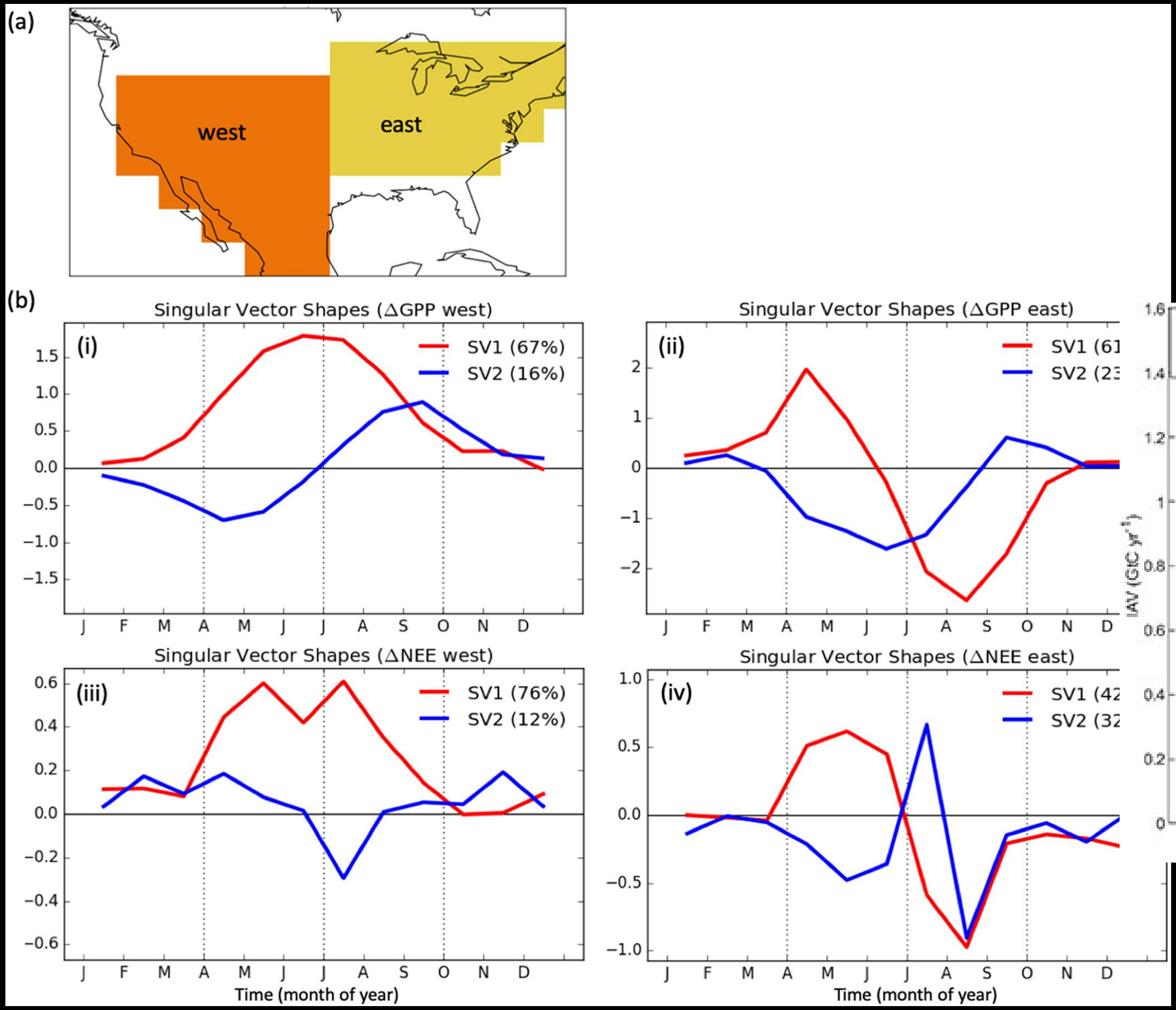
Byrne et al., 2022

- From V7 to V9 inversions, the posterior CO2 biases become much smaller over NH mid to high latitudes;
- From v9 to v10 inversions, the posterior CO2 biases are comparable between IS and LNLG experiments.

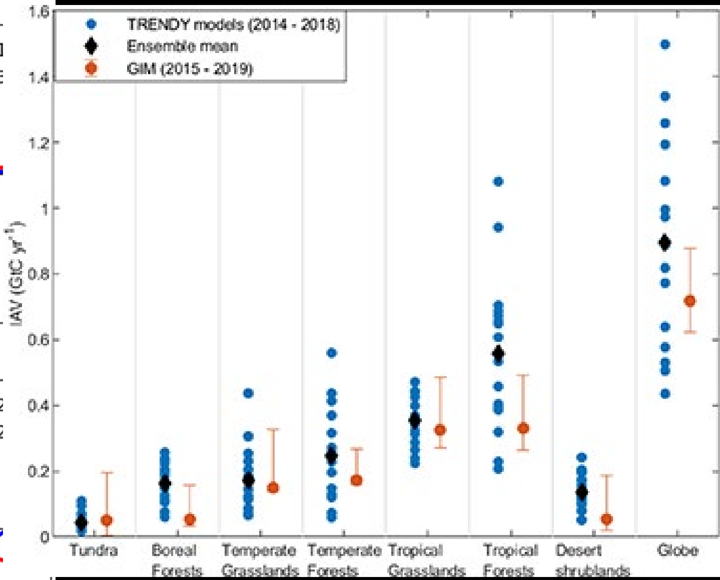
Interannual Variability



Sellers et al., 2018



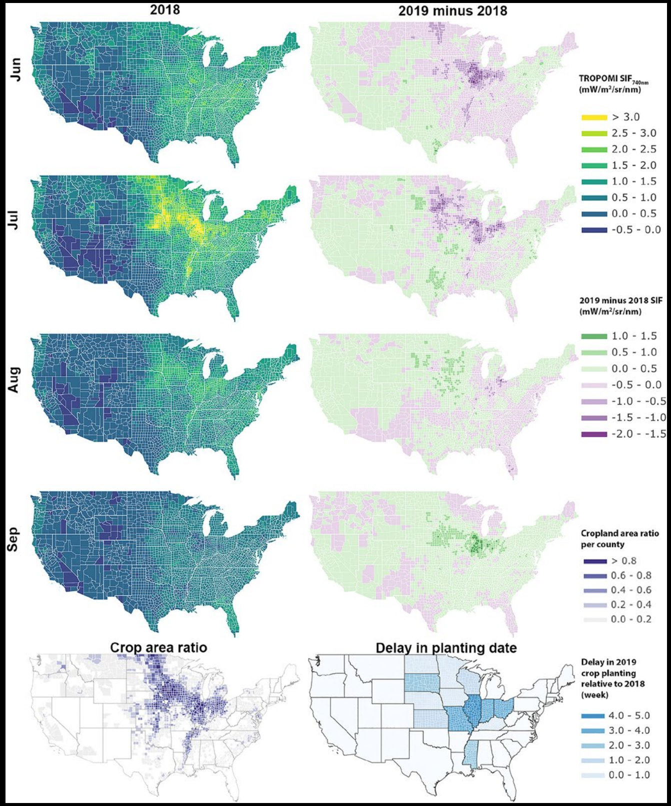
Byrne et al., 2021

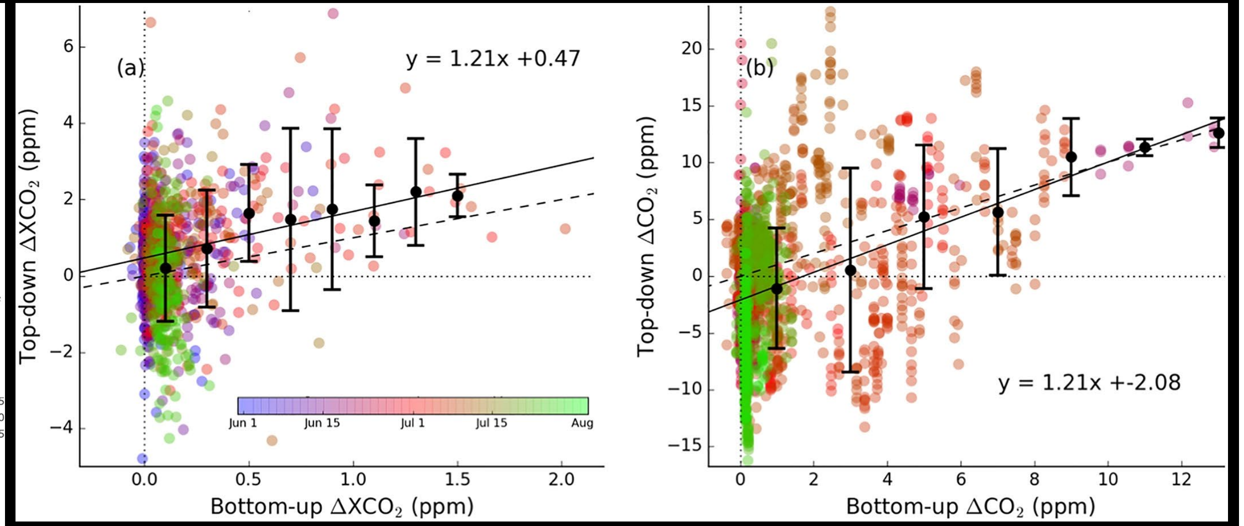


Chen et al., 2022

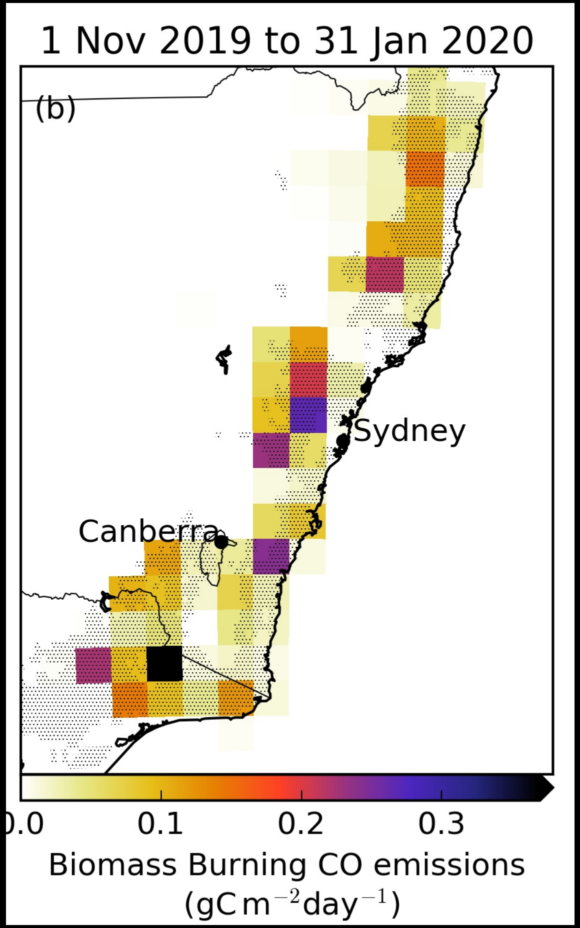
- Large hemispheric variability => regional => process understanding

Impact of Extreme Climate Events





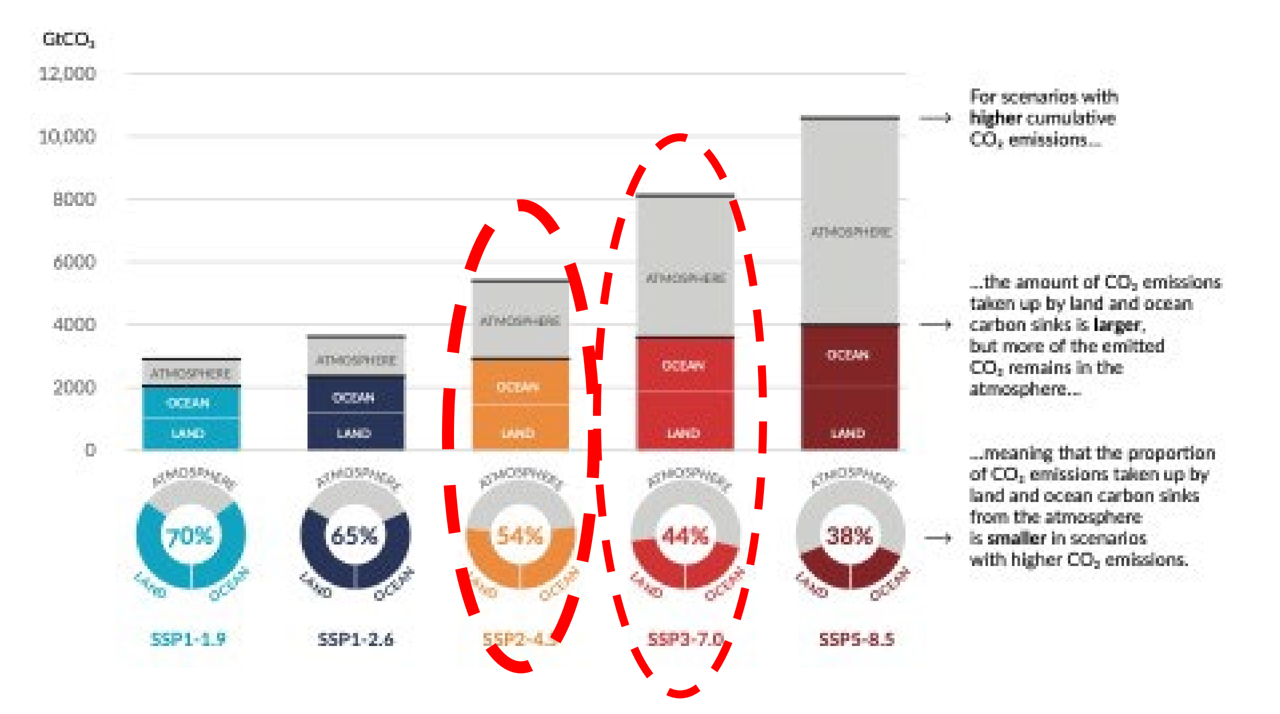
Yin et al., 2020

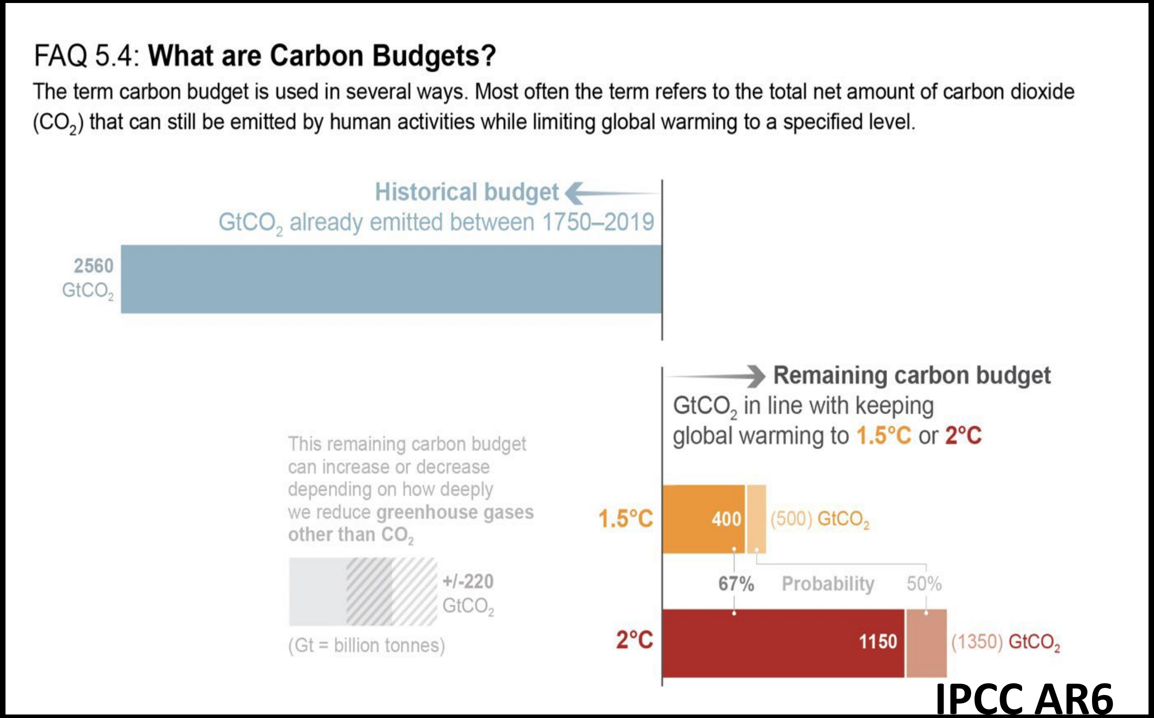


Byrne et al., 2021

- In combination with data from other sources, satellite XCO2 are used to quantify carbon flux anomaly due to the impact of extreme events **over small region**;

Remaining Carbon Budget Depends on Changes of Natural Carbon Sink with Climate as well as Anthropogenic Emissions

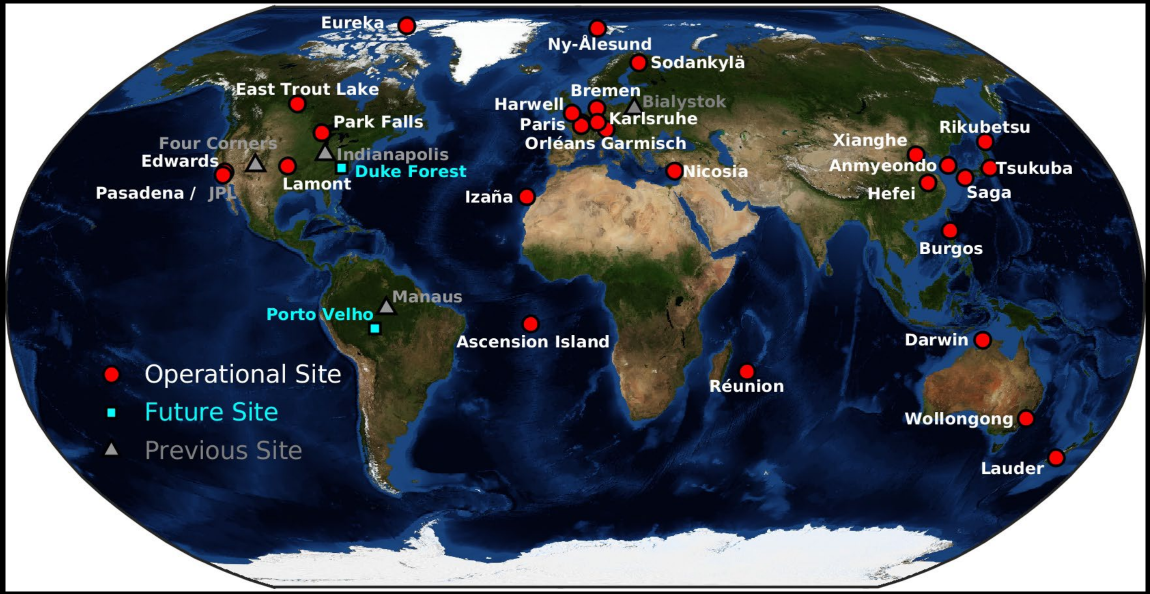


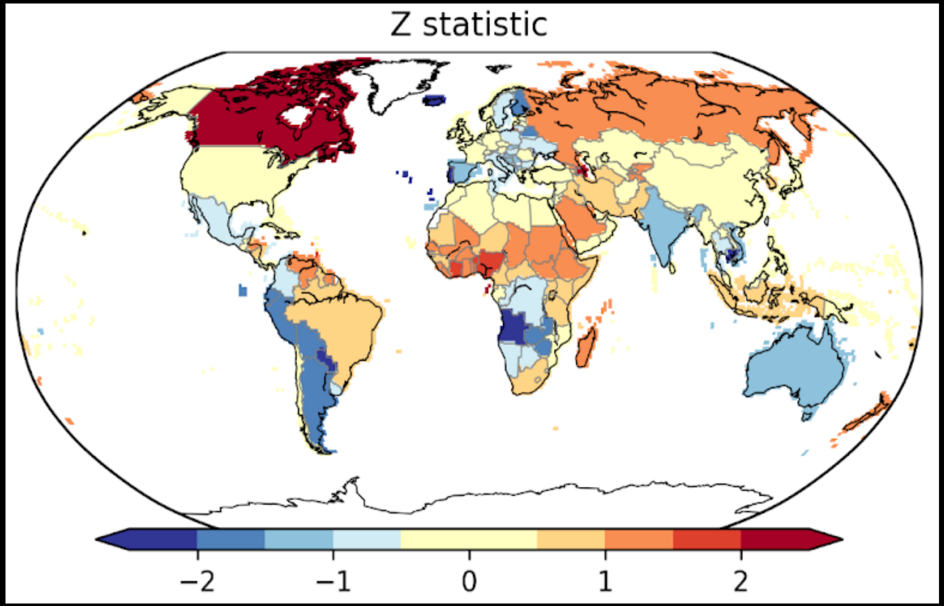


IPCC AR6

- More fraction of emitted CO_2 remains in the atmosphere with high cumulative CO_2 emissions;
- Understanding spatiotemporal distributions of the natural carbon sources and sinks and its changes with climate are as important as monitoring anthropogenic emissions to achieve climate goals.

Increasing Independent observations

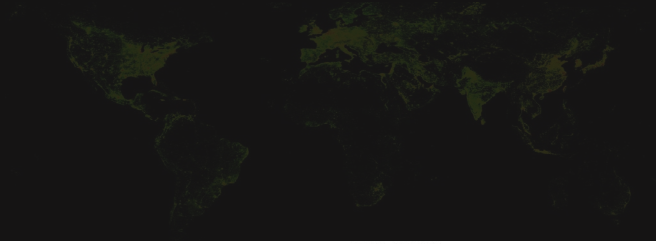


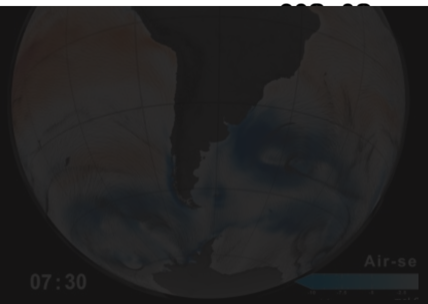


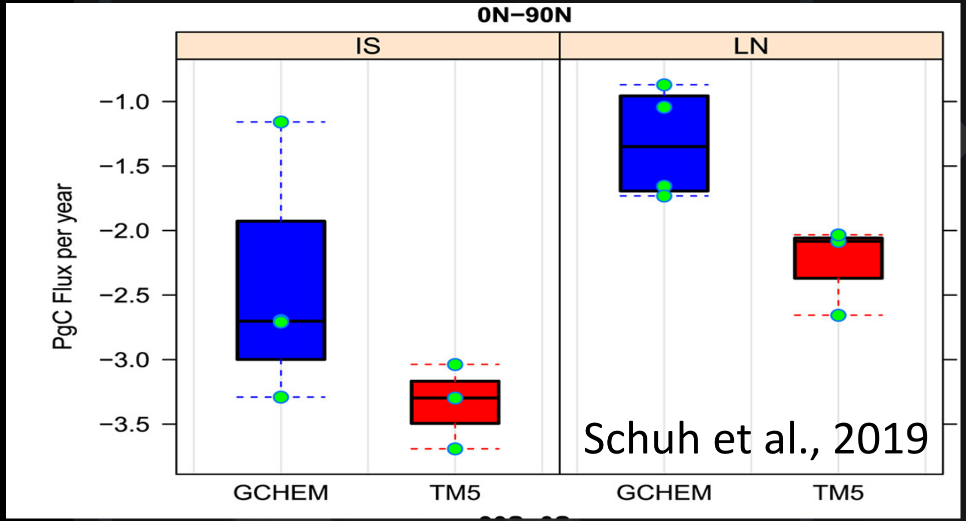
- Regions with no independent observations collocate with large flux differences between LNLG-based and IS-based results.

Continue Improving Atmosphere Transport and Flux Inversion Infrastructure

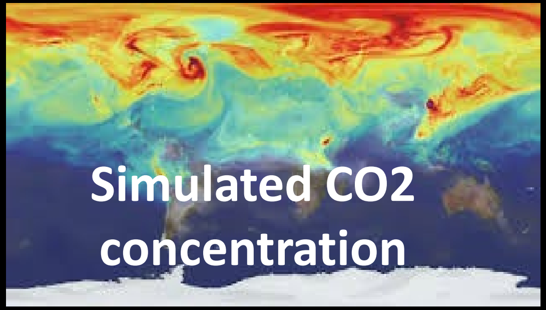
Bottom-up models and uncertainties





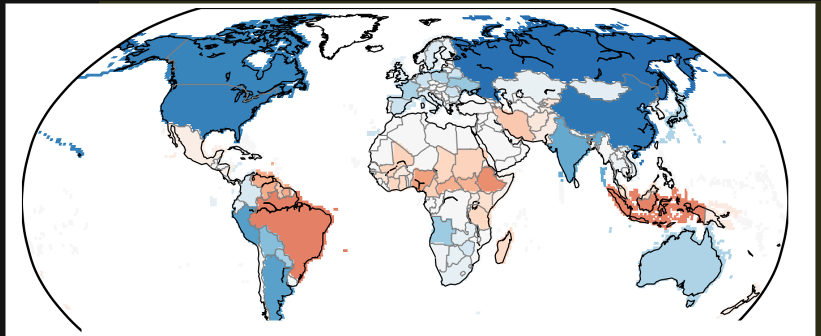


Atmosphere Transport Model

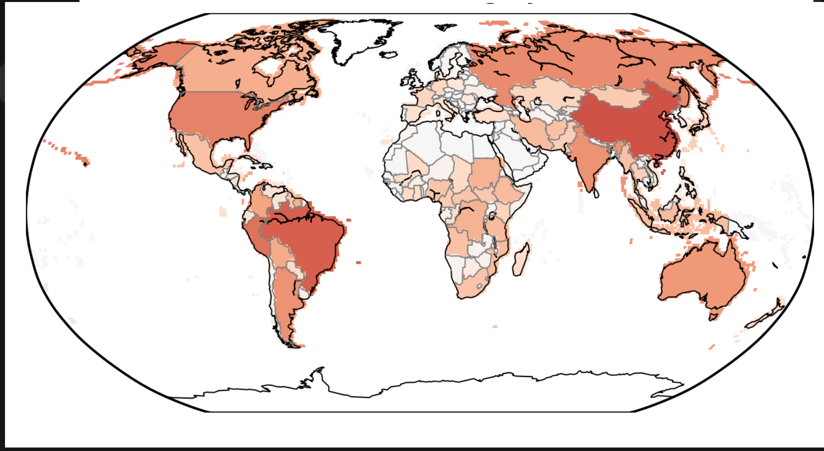


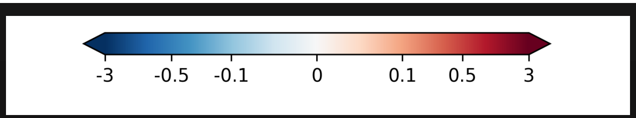
Atmospheric inverse model

$$J(x) = (x - x^b)^T B^{-1}(x - x^b) + \sum_{i=1}^{n} (y - h(x))_i^T R^{-1}(y - h(x))$$

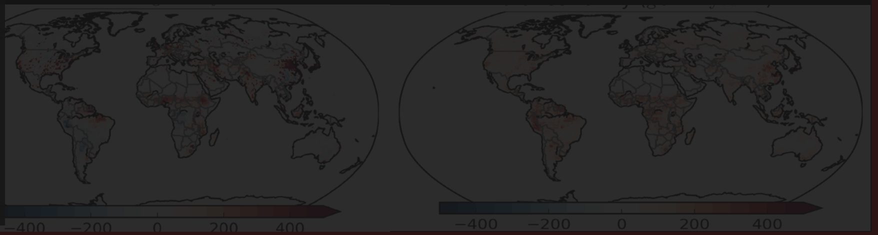


Terrestrial biosphere carbon flux (GtC/year)





Posterior fluxes and uncertainties



Science analysis and applications