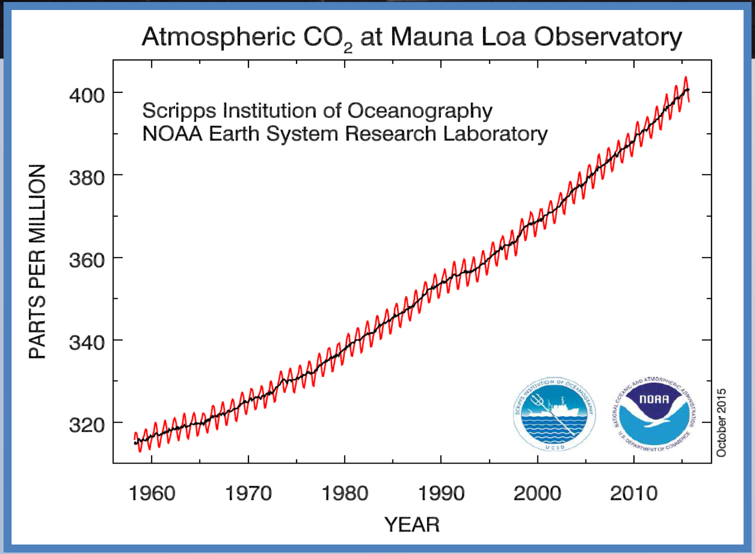
On the Role of Space-Based Observations in Understanding Atmospheric Carbon



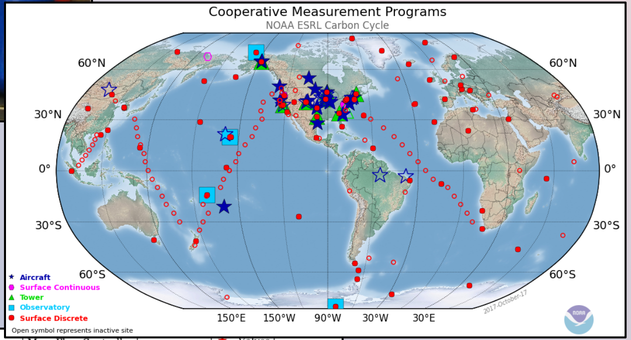
Lori M. Bruhwiler

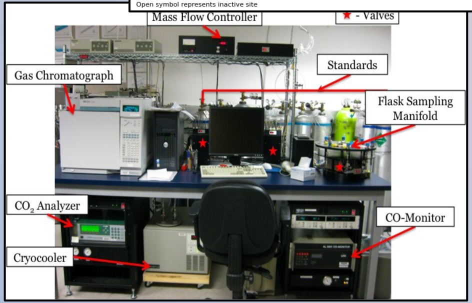
NOAA Earth System Research Laboratory,

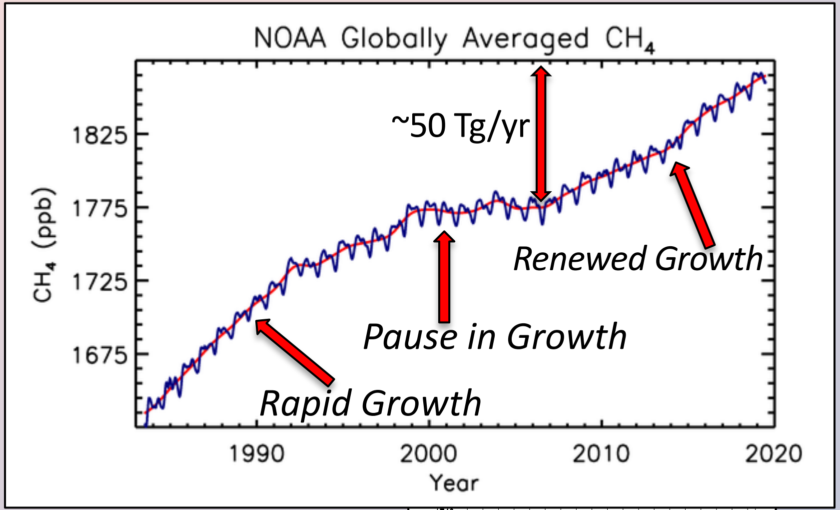
Global Monitoring Division

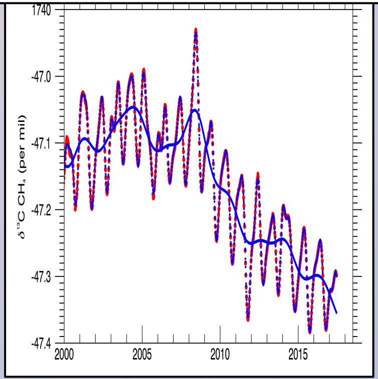
Carbon Cycle and Greenhouse Gas Group

The NOAA Cooperative Air Sampling Network: Long-Term Observations are Essential









Globally Averaged $\delta^{13}CH_4$
(Strong Hints that Growth is due to Microbial Sources, and mostly at low latitudes)

Methane's Importance in the Climate System

Methane is the 2nd largest contributor to radiative forcing* after CO_2.

It is about ~25x more powerful a greenhouse gas than CO_2 (over 100 years)

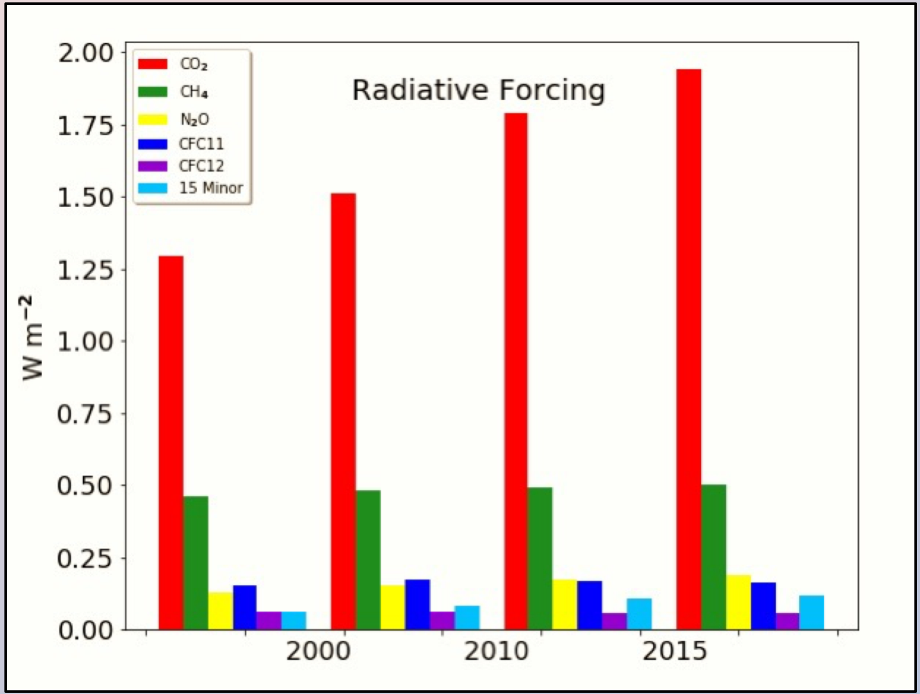
There could be CH_4-climate feedbacks.

CO_2 is the dominant component of radiative forcing, and its contribution is rapidly increasing.

We need to understand GHG sources and sinks. Are there feedbacks between GHG budgets and emissions?

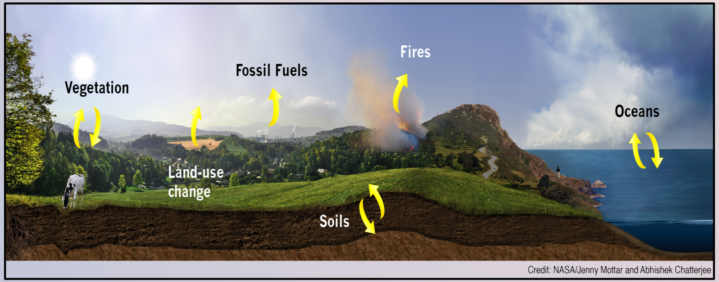
We cannot solve the climate problem by reducing only methane emissions!

GMD Annual Greenhouse Gas Index

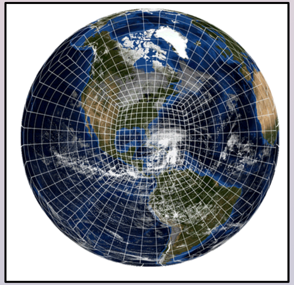


CarbonTracker NGGPS (funded by NOAA CPO AC4)

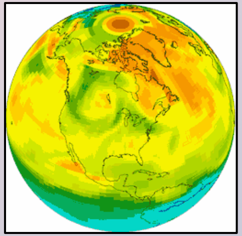
Carbon Flux Models

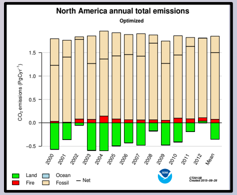


Earth System Model
With Data Assimilation
Now: TM5
Future: NGGPS, UFS, FV3-GFS



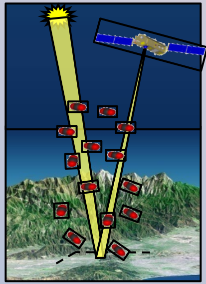
GHG Analyses



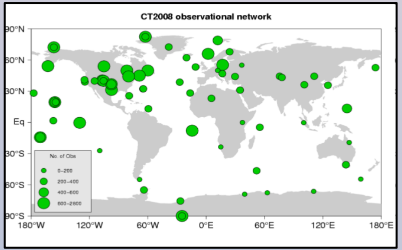


Estimated Fluxes

Remotely- Sensed Column Data

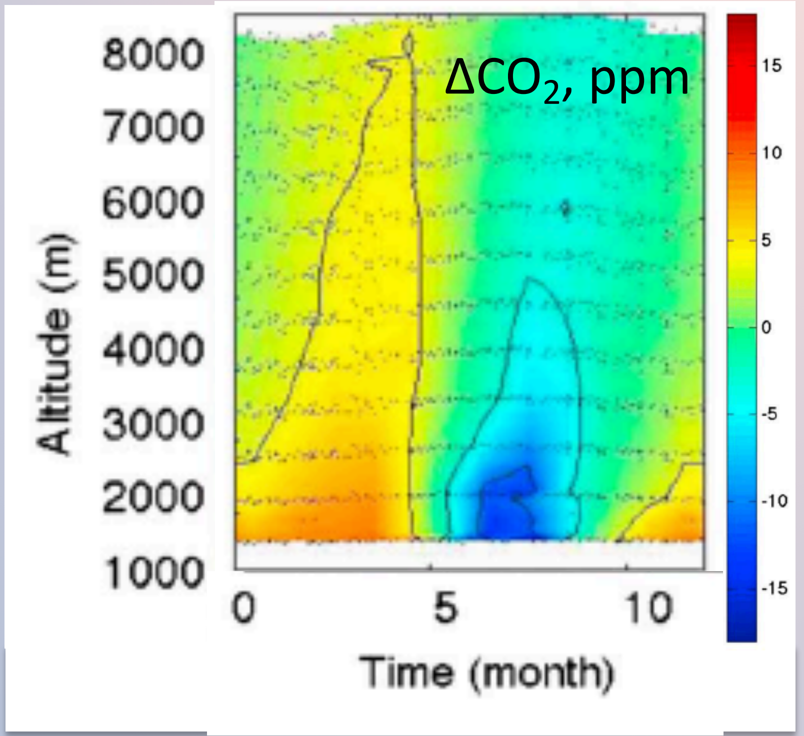


In Situ Surface Network Data



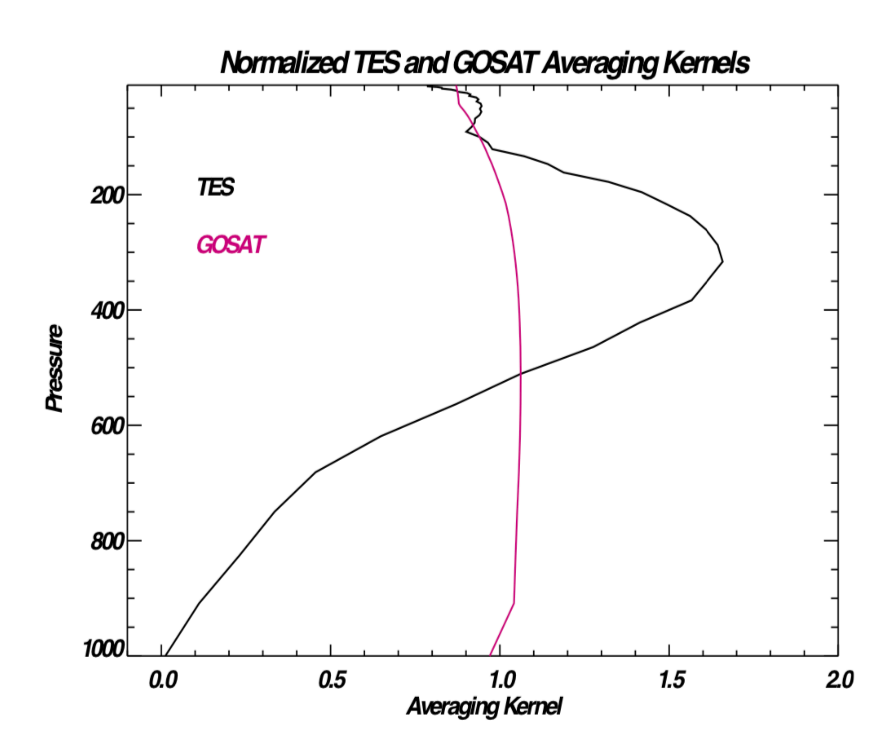
www.esrl.noaa.gov/gmd/ccgg/carbontracker/
www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/

Vertical Information Can Help Us to Constrain Sources and Sinks of GHGs



Average Seasonal Cycle, Homer, IL

Sweeney et al., JGR, 2015



(Figure: Worden et al., 2015)

Reduced Information about Surface Sources/Sinks in Column Average Observations

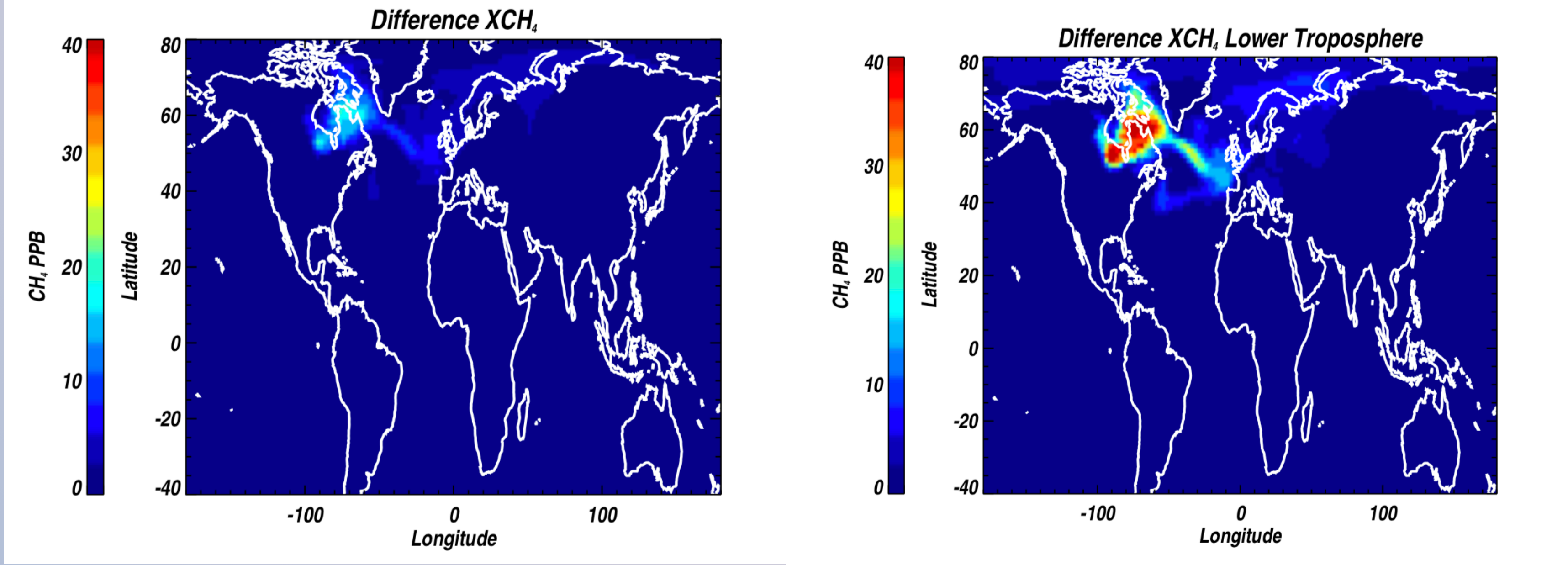
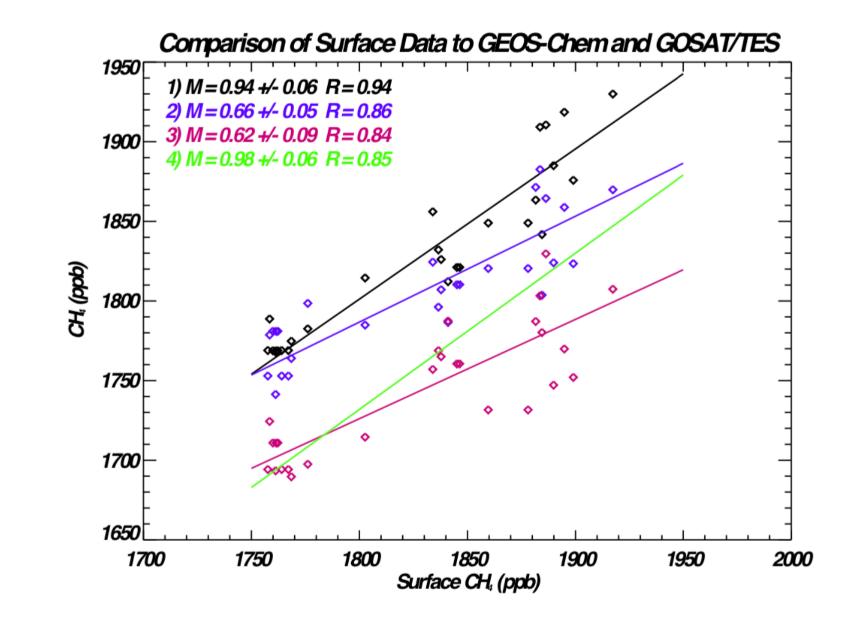
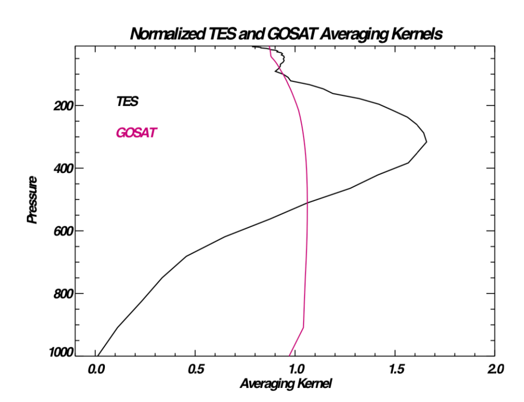


Figure 4. Top: difference in XCH_4 between a reference GEOS-Chem run and another in which the Hudson Bay lowland flux (48 to 66° N and 100 to 70° W) has been reduced by half. Bottom: same as in top panel but for the lower troposphere.

Zhang et al., 2018

Multi-Spectral Approach for Retrieving Lower Tropospheric CH_4





Precision: 10-30 ppb (monthly averages)

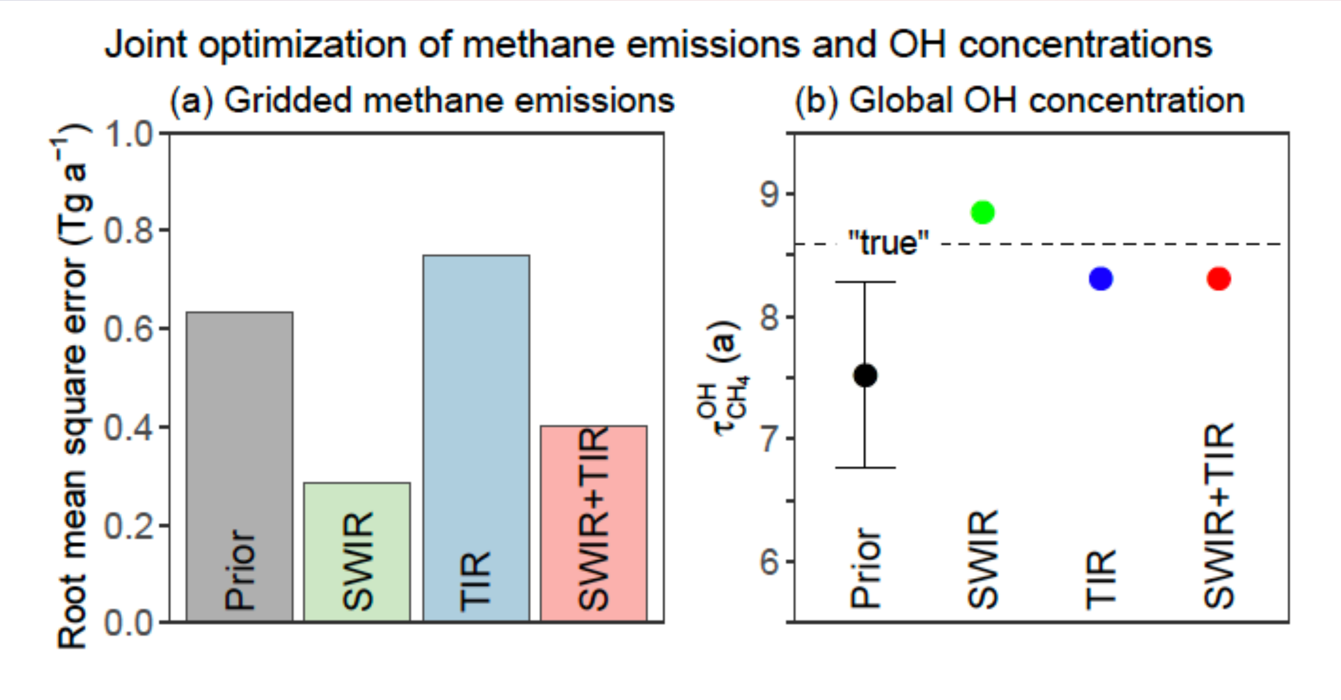
Bias vs. Model: 65 ppb

Accuracy: 6 ppb (after bias removal)

Worden et al., 2015

Satellite observations could be useful in the tropics where *in situ* observations are especially scarce.

Can we use TIR and SWIR soundings to jointly constrain CH_4 emissions and the CH_4 lifetime?

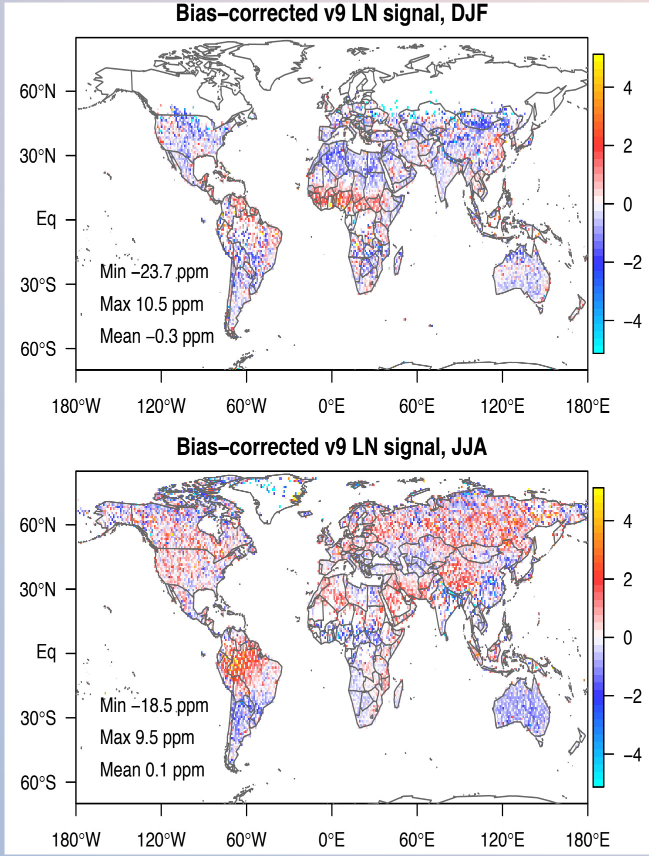


Zhang et al., 2018

Resolution of Emissions – 4x5

Error bars very small

Steps Towards Including TIR (and SWIR) retrievals in Carbon Data Assimilation Systems

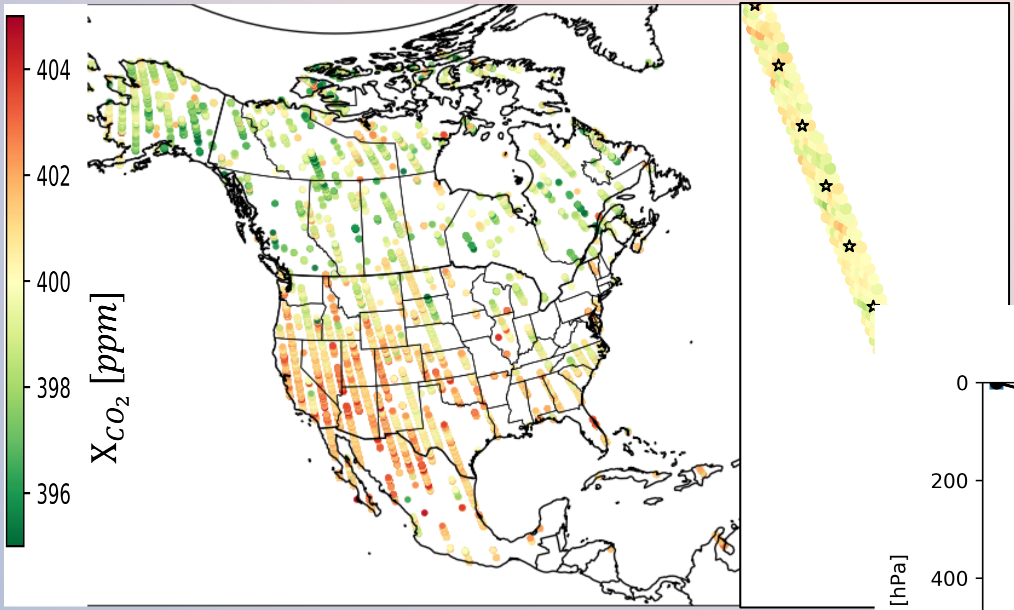


1: Evaluation against available observations:

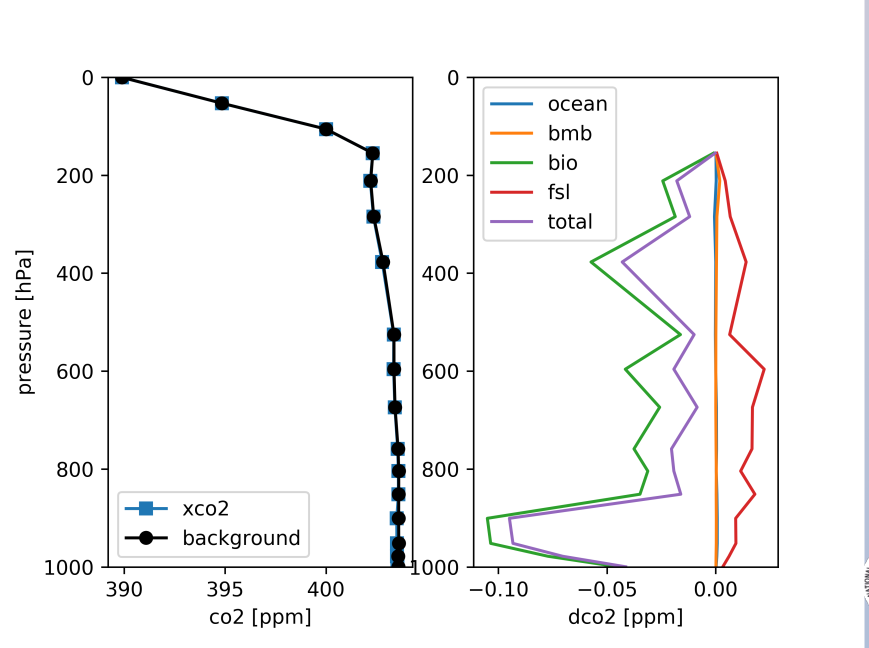
- *TCCON (Total Carbon Column Observing Network) XCO_2, XCH_4, XCO*
- *NOAA GMD Aircraft Monitoring Profiles*
- *ATom (Atmospheric Tomography Campaign) observations*
- *NOAA GMD profiles*

2: Comparisons with carbon data assimilation systems that don't assimilate satellite data – how would such data revise flux estimates?

Regional scale bias identification



- Compare OCO-2 retrieved columns to XCO_2 simulated using CT-Lagrange posterior fluxes constrained by *in situ* observations.
- Stratospheric CO_2 constrained by aircore measurements.
- Background from multiple global inverse models.



Most of the signal in XCO_2 is due to the background

[1]Hu, Lei, et al. "Enhanced North American carbon uptake associated with El Niño." *Science advances* 5.6 (2019).

Other Types of Satellite Observations that Can Help Constrain Carbon Budgets

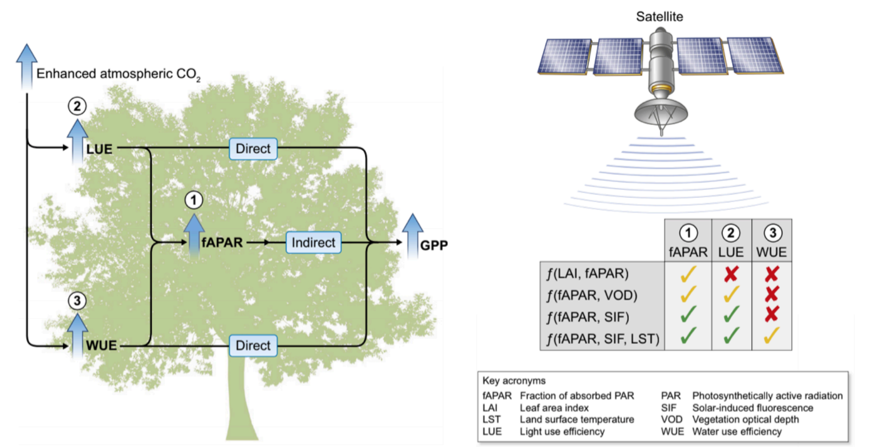


Fig. 1 Schematic of the pathways by which CO_2 fertilization effects (CFE) can increase gross primary productivity (GPP) and the potential ways satellite observations could be combined to constrain the CFE pathways. We define CFE pathways to include increases in light use efficiency (LUE), increases in water use efficiency (WUE), and increases in the fraction of photosynthetically active radiation (fAPAR). Satellite indices include leaf area index (LAI) and fAPAR, land surface temperature (LST), vegetation optical depth (VOD) and solar-induced Chl fluorescence (SIF). We show different combinations of these satellite records and indicate their potential to globally constrain (green ticks), regionally constrain (yellow ticks) or fail to constrain (red crosses) a given CFE pathway. Regional constraints (yellow ticks) are most often limited by atmospheric effects and/or signal saturation in dense canopies, such as tropical forest ecosystems.

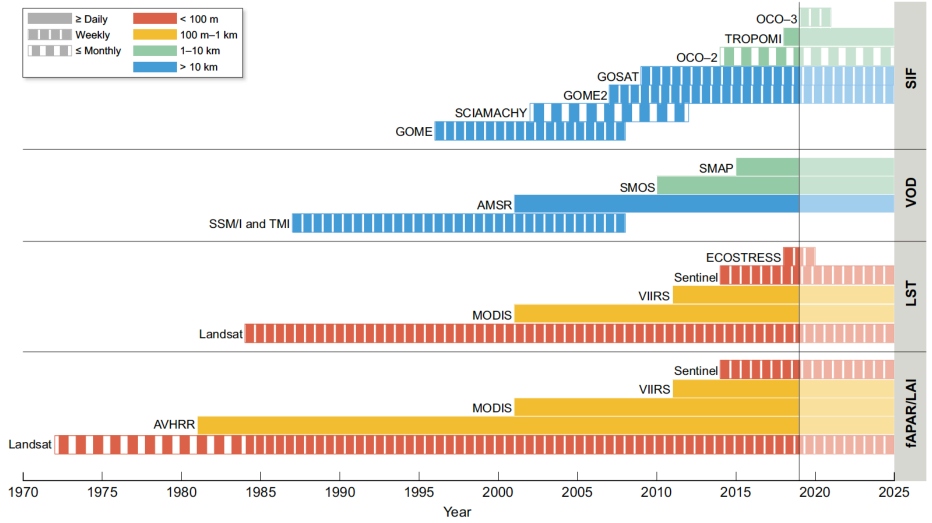


Fig. 2 A timeline of satellite observations of leaf area index (LAI) and fraction of photosynthetically active radiation (fAPAR), land surface temperature (LST), vegetation optical depth (VOD) and solar-induced fluorescence (SIF). Observation timelines are provided for context and are not meant to provide a comprehensive overview of all available sensors. This timeline clearly demonstrates the availability of diverse, multidecadal satellite observation records that are rapidly increasing in spatiotemporal resolution.

Smith et al., 2019
Can we learn about carbon fertilization using space-based data records?

Some User Needs

- User friendly data files containing only information essential for use in carbon modeling (e.g. like “OCO-2 Lite” files).
- Averaging kernels and prior profiles are essential.
- Data on pressure levels rather than altitude.
- Only give independent information, not 100-layers. (This can also reduce misuse of data).