Implementing a GHG Constellation - Lessons learned from the OCO-2 / GOSAT collaboration

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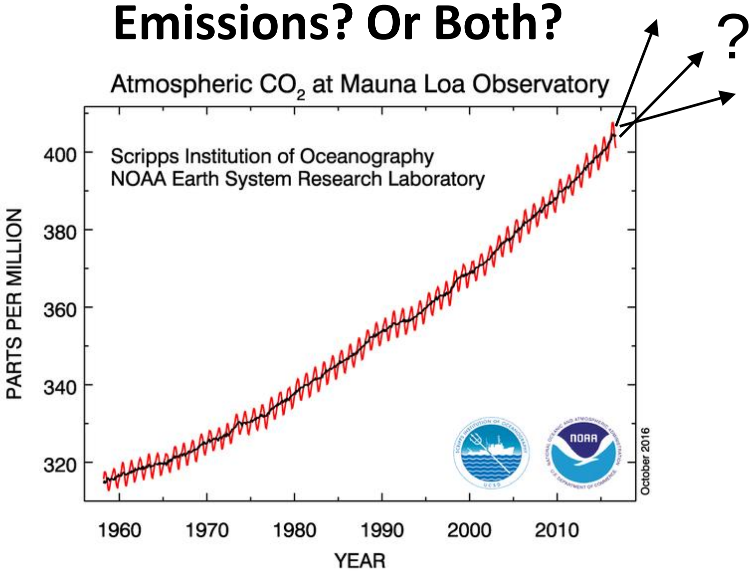
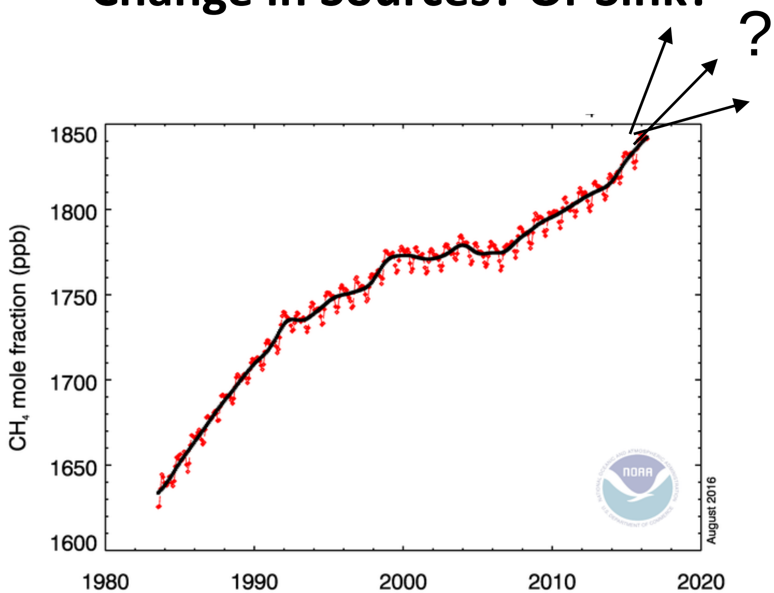
October 14, 2016

Why do we need a GHG Observation Constellation?

Growth Rate Depends on Feedbacks? Or Emissions? Or Both?



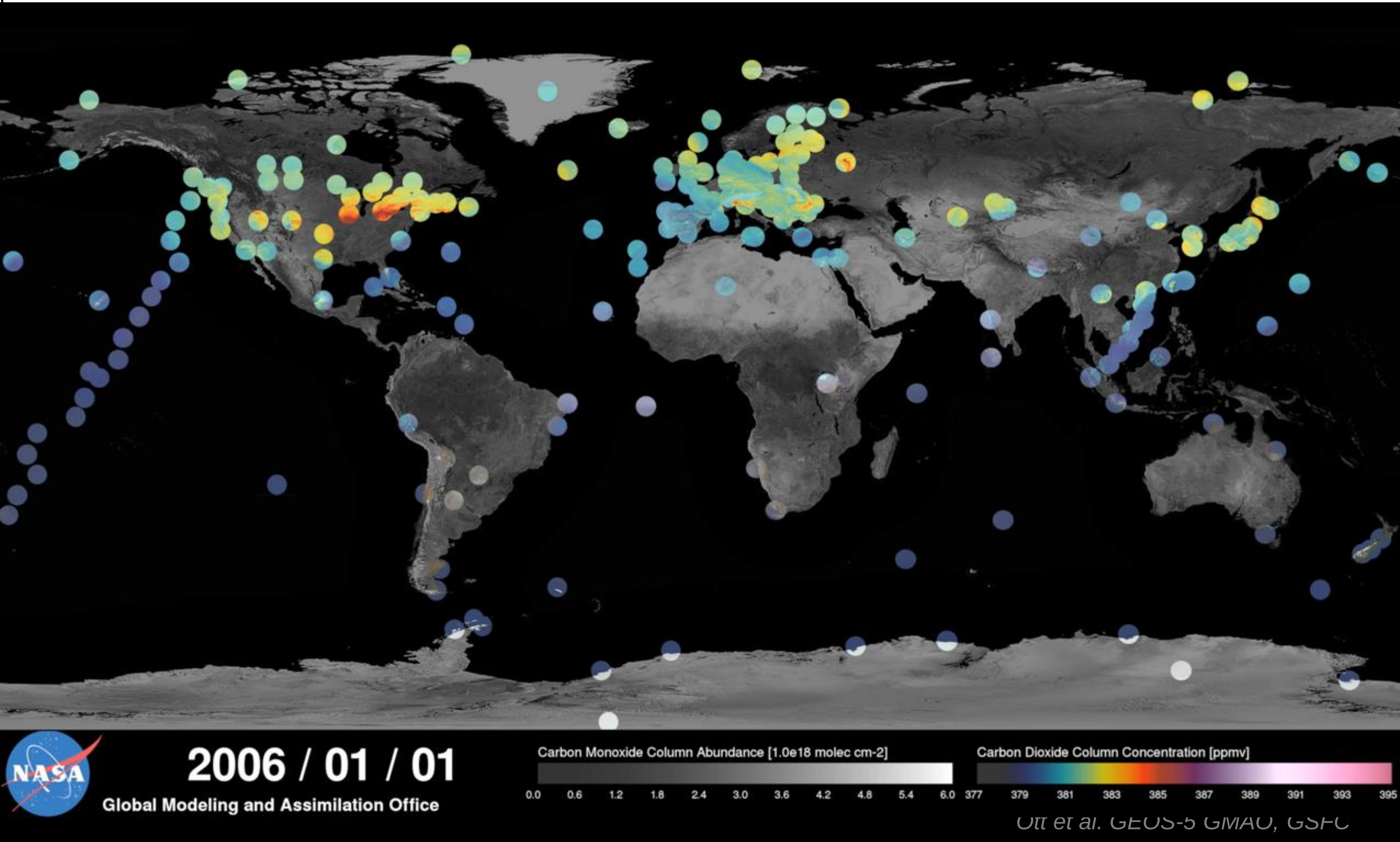
Change in Sources? Or Sink?



Growth rate and future distribution of both CO_2 and CH_4 have large uncertainties and depends on a number of natural and anthropogenic factors

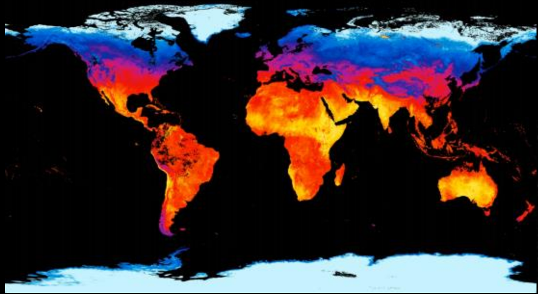
Why do we need a GHG Observation Constellation?
Relating Observed Concentrations to Fluxes to Processes Requires Global Sampling

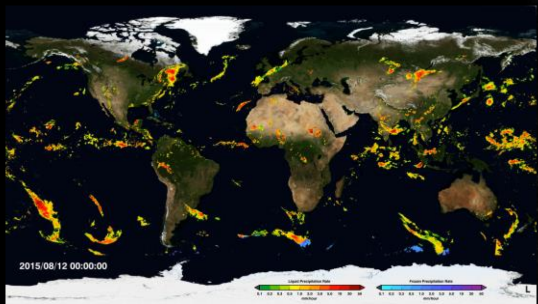
Ott et al. GEOS-5 GMAO, GSFC

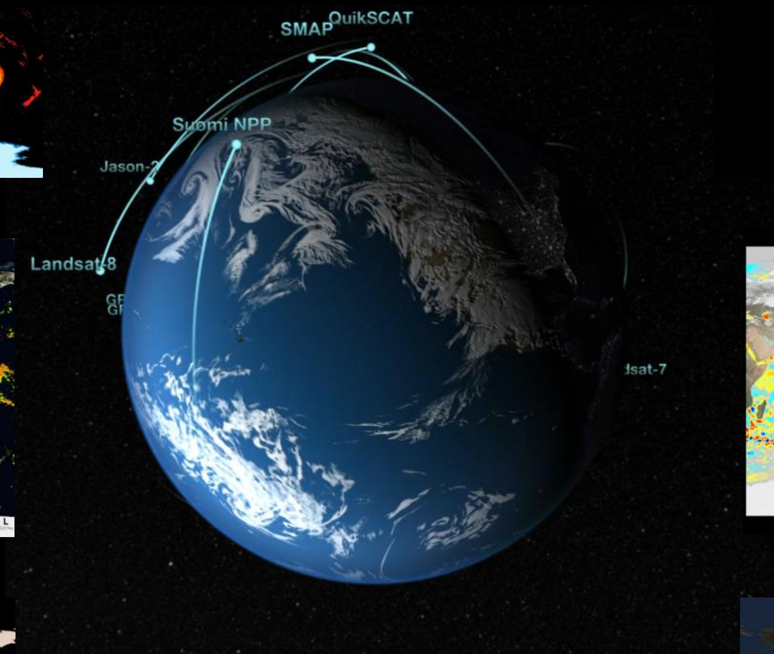


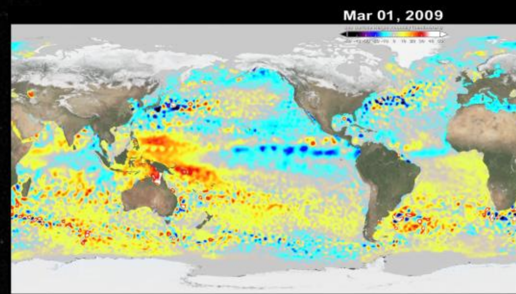
Ott et al. GEOS-5 GMAO, GSFC

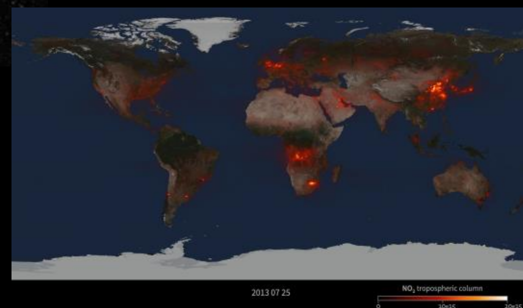
Using the Space Based Vantage Point

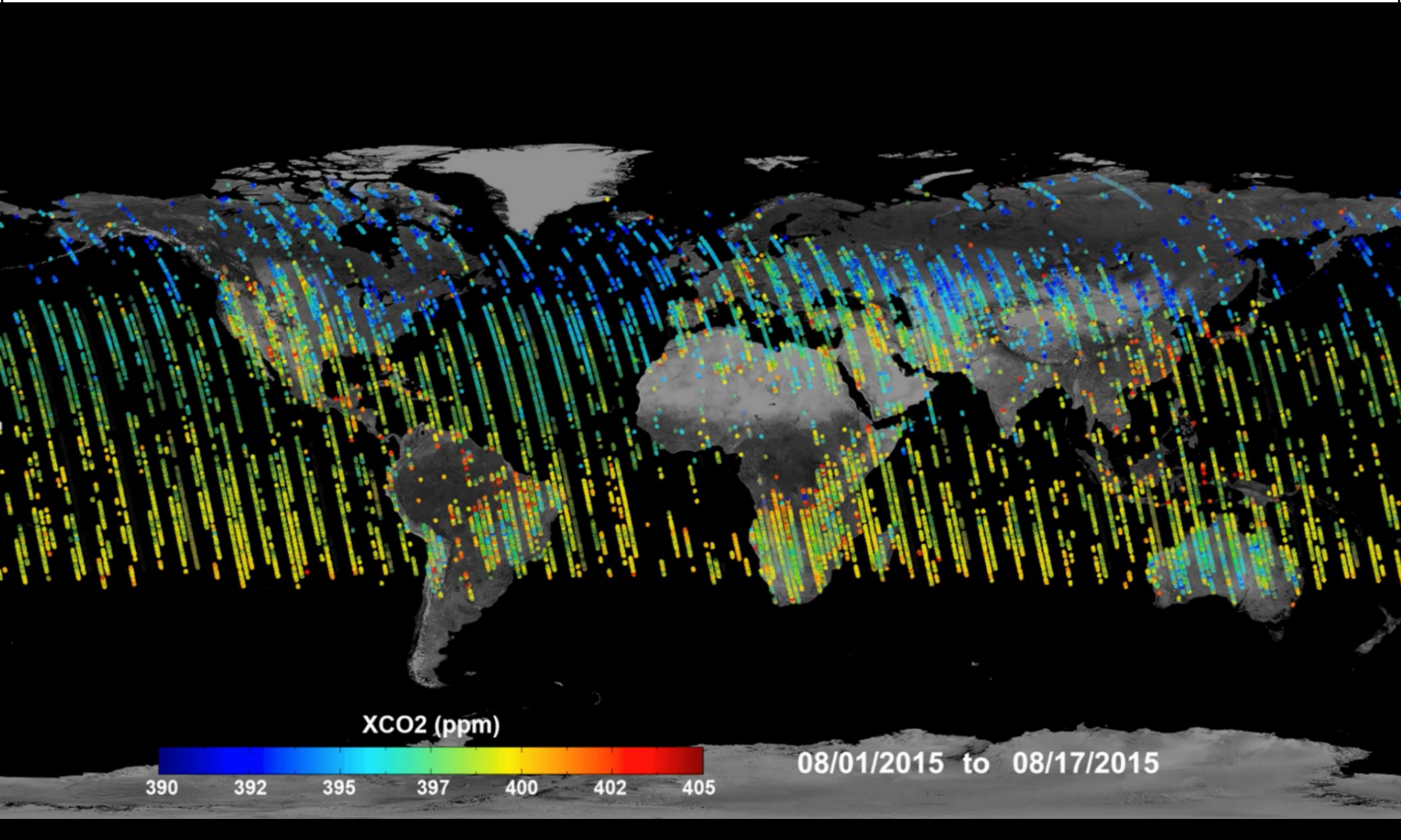






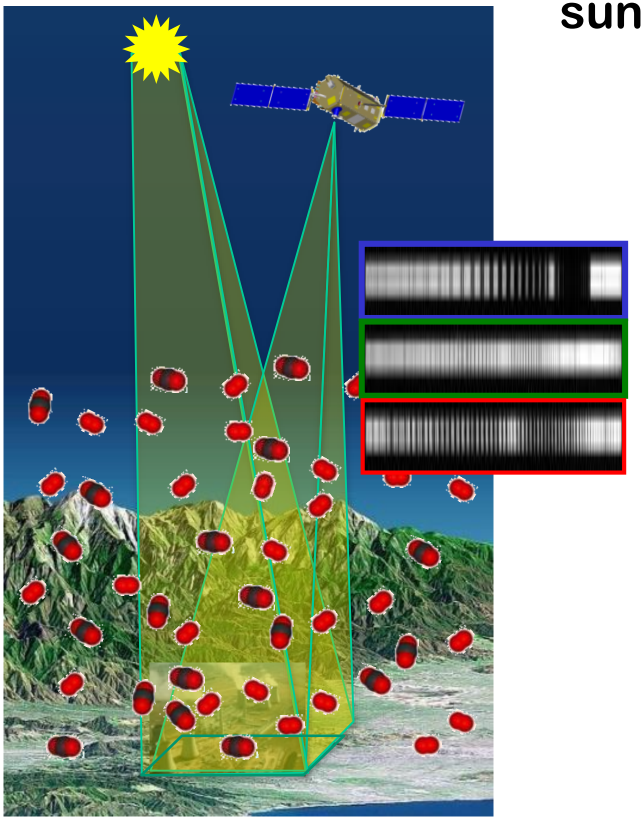




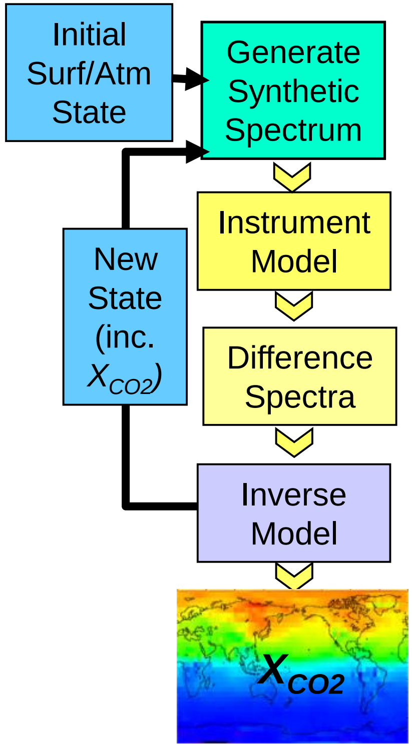

XCO2 (ppm)
390
392
395
397
400
402
405
08/01/2015 to 08/17/2015

Measuring CO_2 from Space

- **Record** spectra of CO_2 CH_4, and O_2 absorption in reflected sunlight



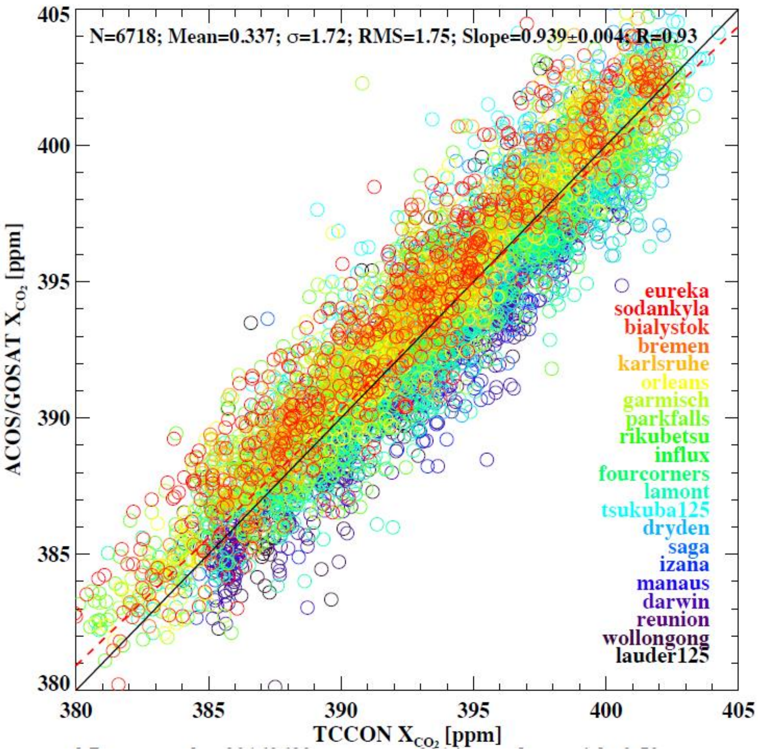
Retrieve variations in the *column averaged CO_2 anxd CH_4 dry air mole fraction* over the sunlit hemisphere



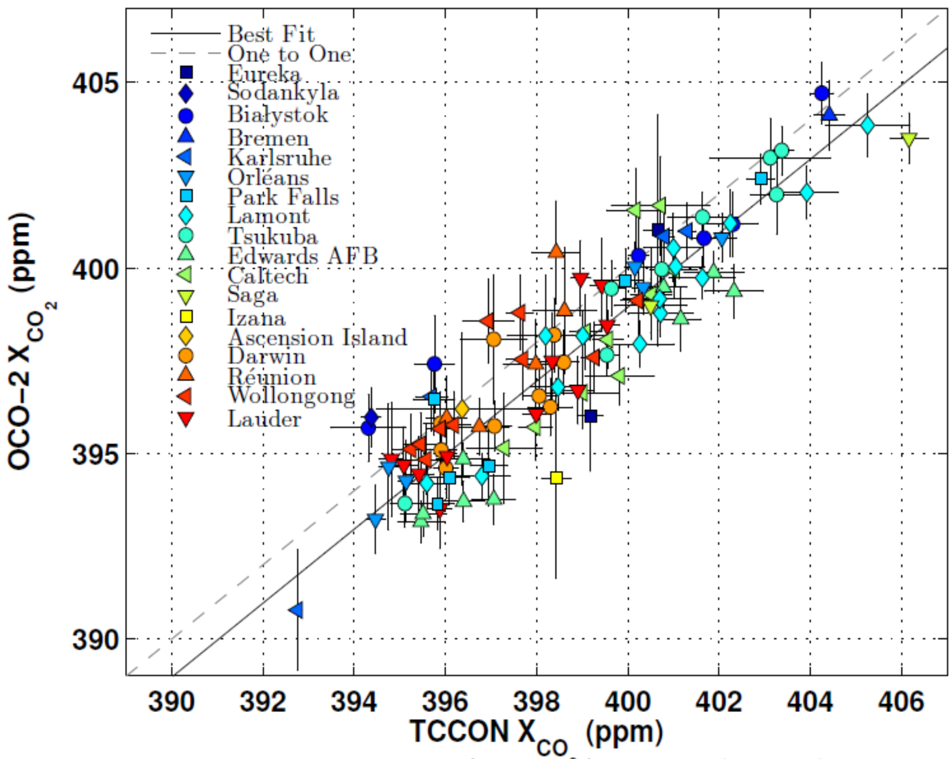
Validate measurements to ensure X_{CO2} and X_{CH4} accuracy of 1 ppm and 8 ppb respectively

TCCON Serves as the Validation Standard for both GOSAT and OCO-2

GOSAT B7.3 vs TCCON



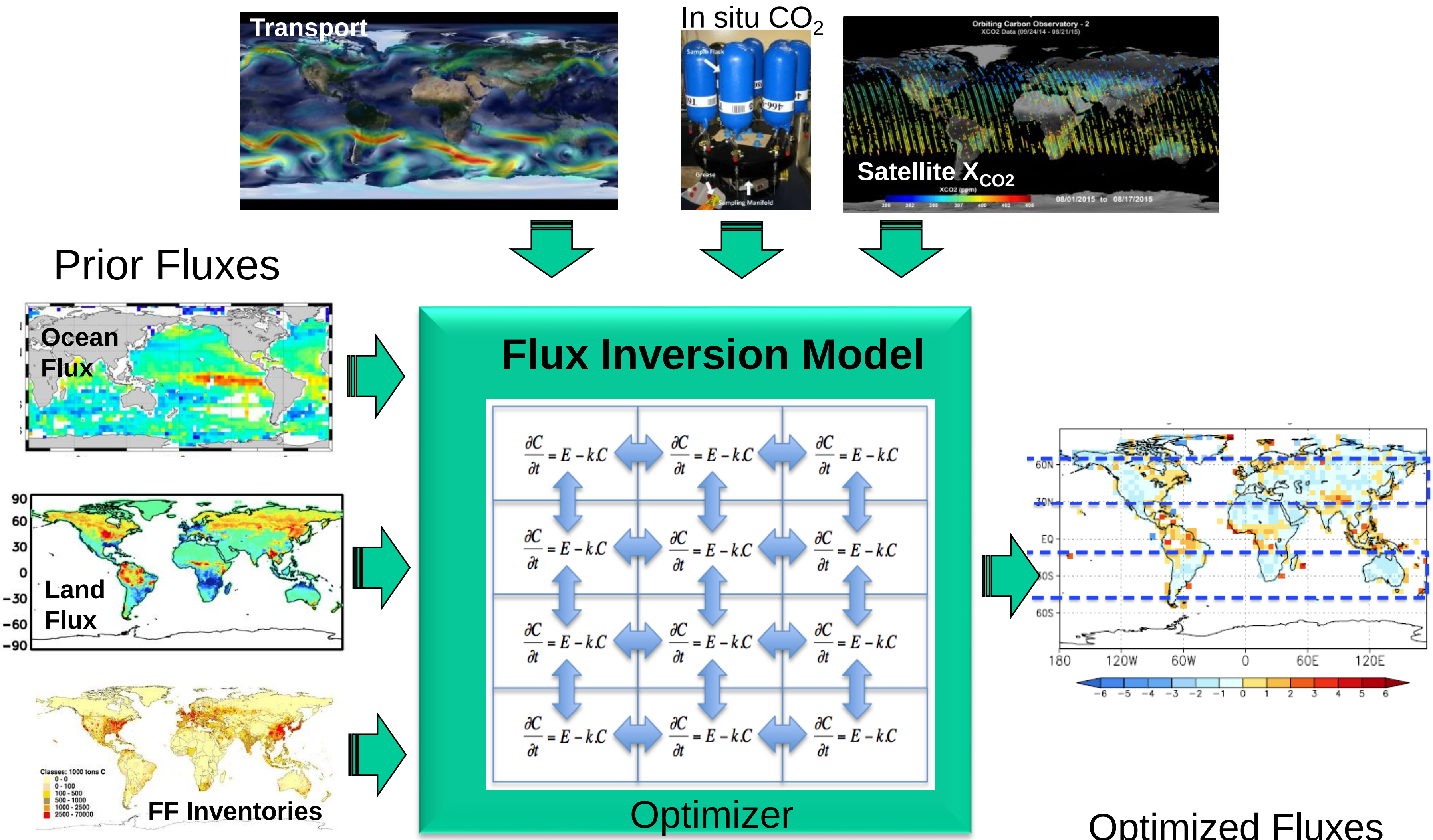
OCO-2 vs TCCON



TCCON / OCO-2 comparisons indicate 1 ppm accuracy can be achieved and can likely be improved upon

Wunch et al., 2016 AMTD; Connor et al 2016 AMTD; Worden et al., 2016 AMTD

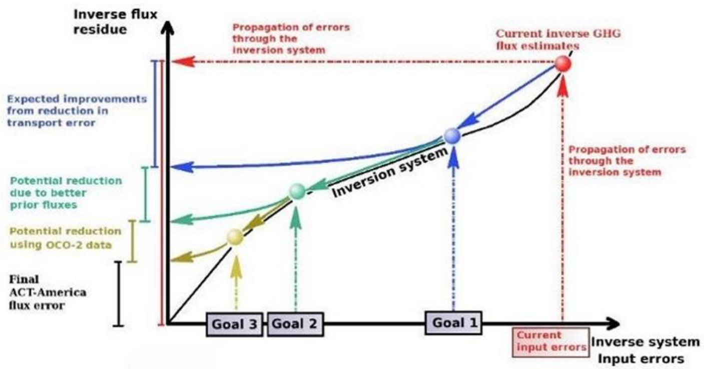
“Top-Down” Flux Inversion Estimates Are Problematic Despite Achieving 1 ppm XCO2 Accuracy



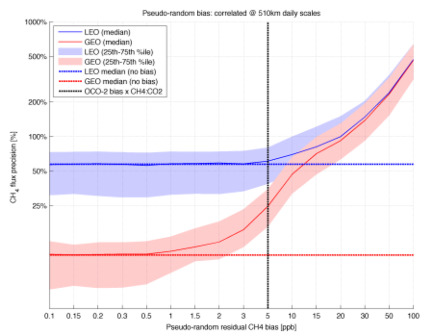
Model Errors and Data Biases Are the Major Driver of Flux Errors

We still need significant work to evaluate (for example) how transport, a priori distribution of emissions/fluxes, and role of data correlations / biases affect flux calculations and subsequent characterization of carbon cycle processes

NASA Atmospheric Carbon and Transport Campaign will Evaluate Role of Transport on Carbon Fluxes

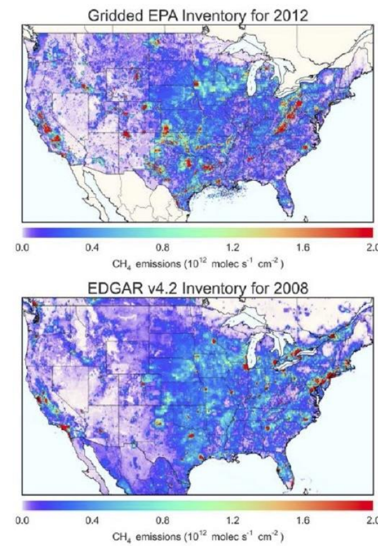


Interference Variability and Error, More Important that Data Precision



Bloom et al., ACPD 2016

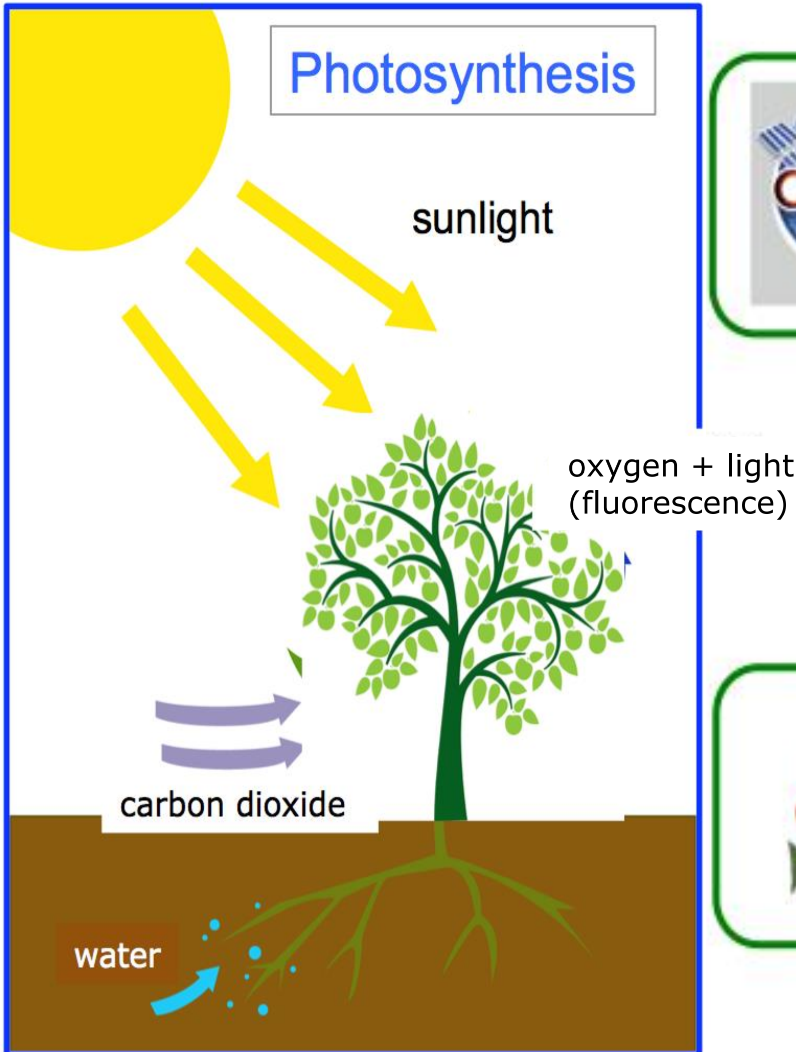
Emission A Priori Errors Introduce Non-Linearities in Flux Estimates



Maasakkers et al. EST, 2016

Combining XCH_4 and XCO_2 with other measurements of the water and carbon cycle are critical for relating fluxes to processes

Plant species distribution and physiology



CO_2 & Fluorescence

Evapo-transpiration

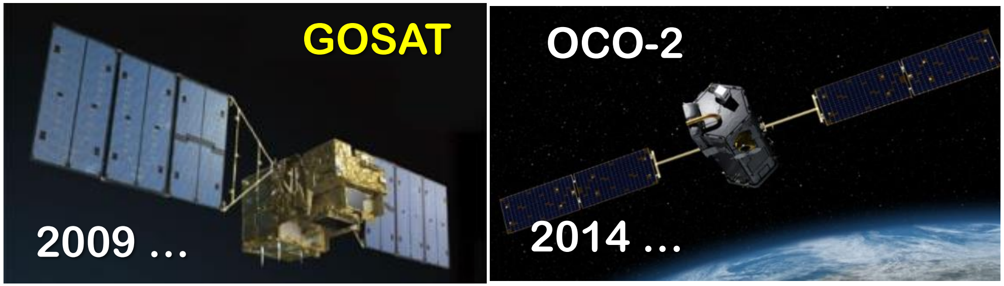
Biomass

The Evolving Near-Infrared Atmospheric Carbon Measurement Capabilities

PAST

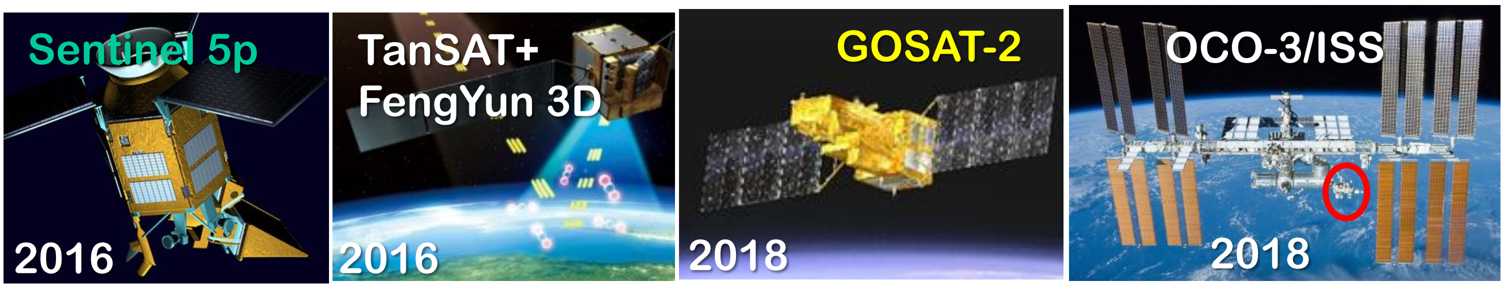
If carefully coordinated, these missions can be integrated into an ad hoc constellation and their measurements can be combined to produce a continuous data record that can relate climatic variability to terrestrial fluxes and processes

PRESENT

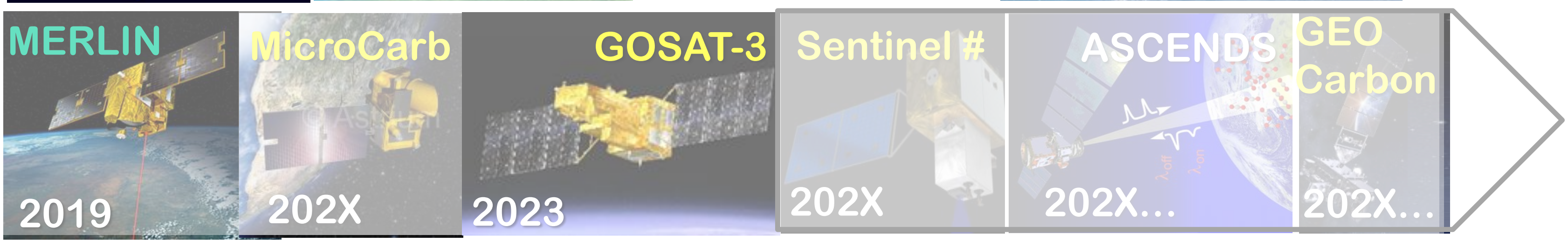


However, none of these missions provides the capabilities needed to quantify fossil fuel emissions and other human activities. For that, we likely need a constellation.

NEAR FUTURE



LATER



Summary

A constellation (LEO + GEO) of satellites is needed to globally sample XCO_2 and XCH_4 with the accuracy and sampling needed to relate observed concentrations to fluxes.

This constellation needs to be augmented with other measurements (e.g. CO, SIF, biomass, ET, inundation, rainfall …) in order to relate fluxes to their anthropogenic and natural emissions and processes. One example of this type of constellation is OCO-3, GEDI, and ECOSTRESS onboard the ISS

OCO-2 and GOSAT and the ground based network of TCCON demonstrates that ~1 ppm and ~8 ppb accuracy is achievable for XCO_2 and XCH_4 measurements respectively → This accuracy is sufficient for looking at regional scale fluxes and to relate them to climatic and hydrological variations as well as isolated anthropogenic emissions (e.g. Los Angeles, Four-Corners).

Improvements to radiative transfer algorithms coupled with ancillary measurements could greatly improve this accuracy and enable finer scale emissions estimates.

Need to continue to improve on model capabilities in order to fully utilize data

Most importantly for CEOS: Continued multi-national calibration and validation of XCO_2, XCH_4, and ancillary measurements are a critical piece of the observing strategy needed to characterize the global carbon cycle and the future distribution of XCO2 and XCH4.

Promise and Prospects for Atmospheric CO_2 and CH_4 Measurements from Space

- Space-based remote sensing instruments hold substantial promise for future long-term, space-based characterization and monitoring of the atmospheric carbon cycle
- The principal advantages of these systems include
  - Spatial coverage (especially over oceans and tropical land)
  - Sampling density (needed to resolve CO_2 weather, point sources)
- Measurements of greenhouse gases pose special challenges
  - Small concentration gradients require high precision and accuracy → OCO-2 has demonstrated that 1 ppm accuracy is achievable but we preliminary flux results suggest that accuracies of 0.5 ppm or better ar eneeded
  - Frequent revisit times are essential, since the atmosphere moves
- To detect and monitor changes in the carbon cycle, existing space based systems must be enhanced to include
  - At least 3 broad swath (>200 km), high resolution Low Earth Orbit (LEO) missions that cover the entire globe
  - At least 3 Geostationary Earth Orbiting (GEO) missions to capture the full diurnal cycle and rapidly varying features

…. We can only manage what we can measure ….

What will it be like to live in a world where greenhouse gas emissions can be routinely measured at high resolution from an international fleet of satellites?

Thank You for Your Attention

Questions?