Long-Term, Calibrated In Situ Observations are an Essential Component of a Carbon Emission Monitoring System

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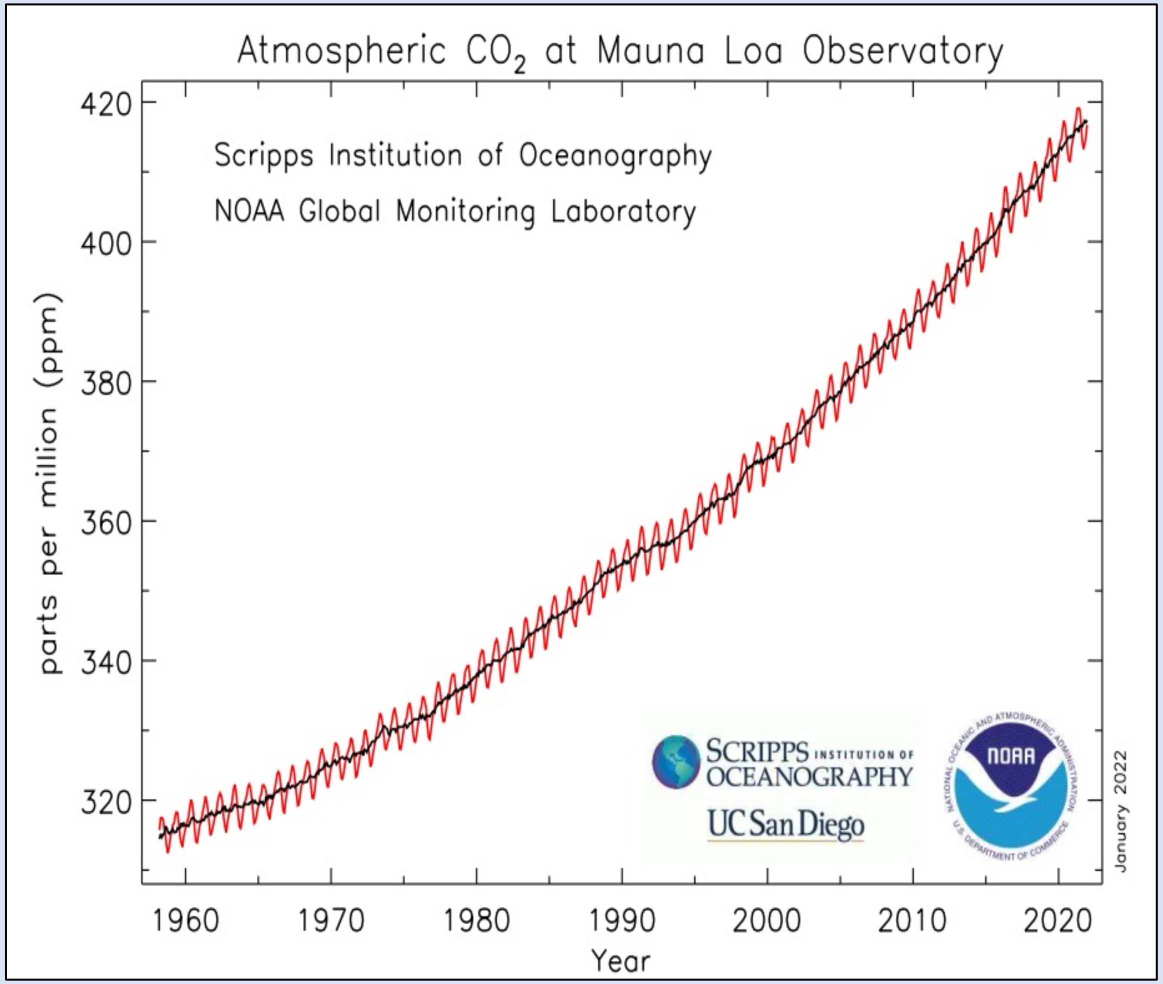
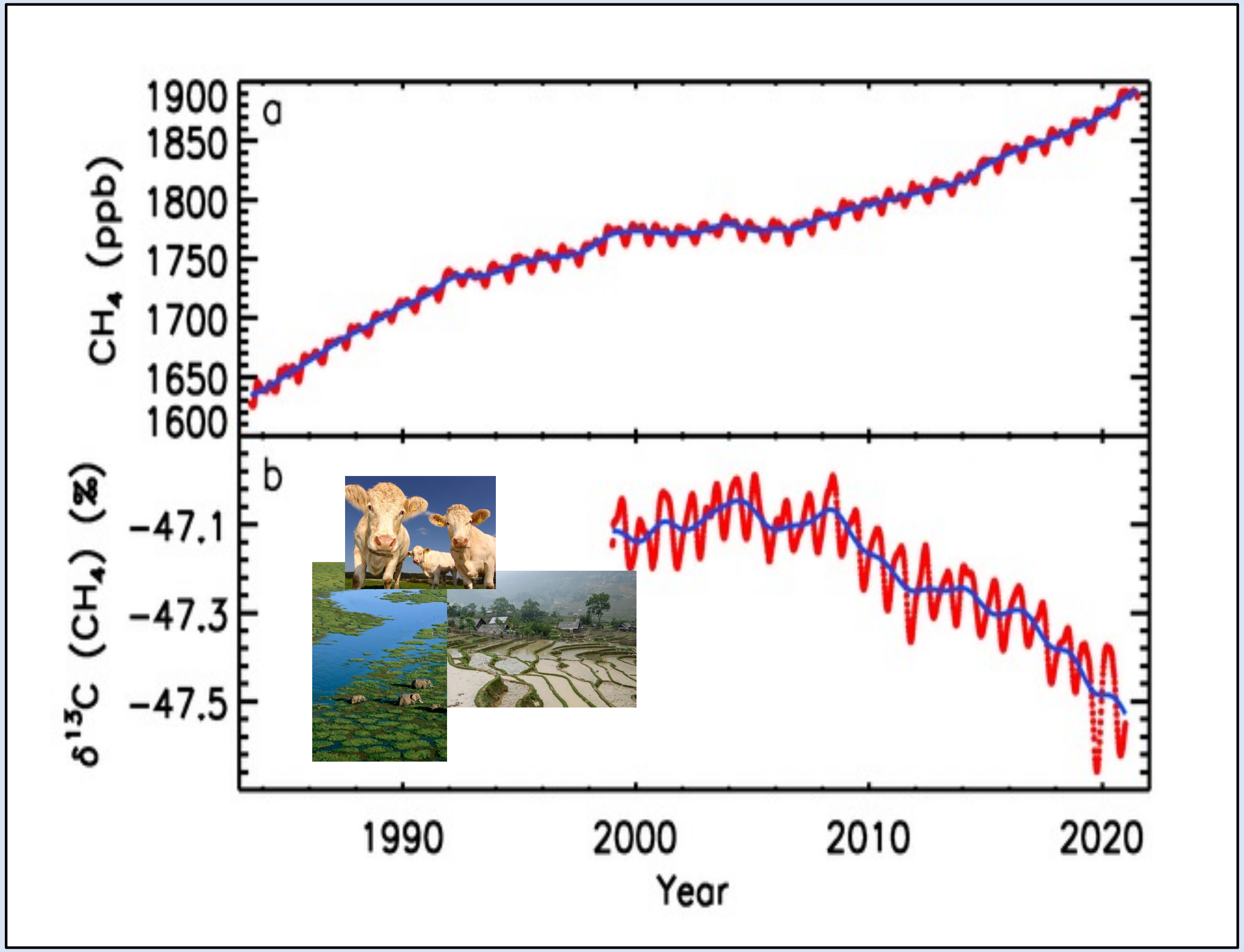
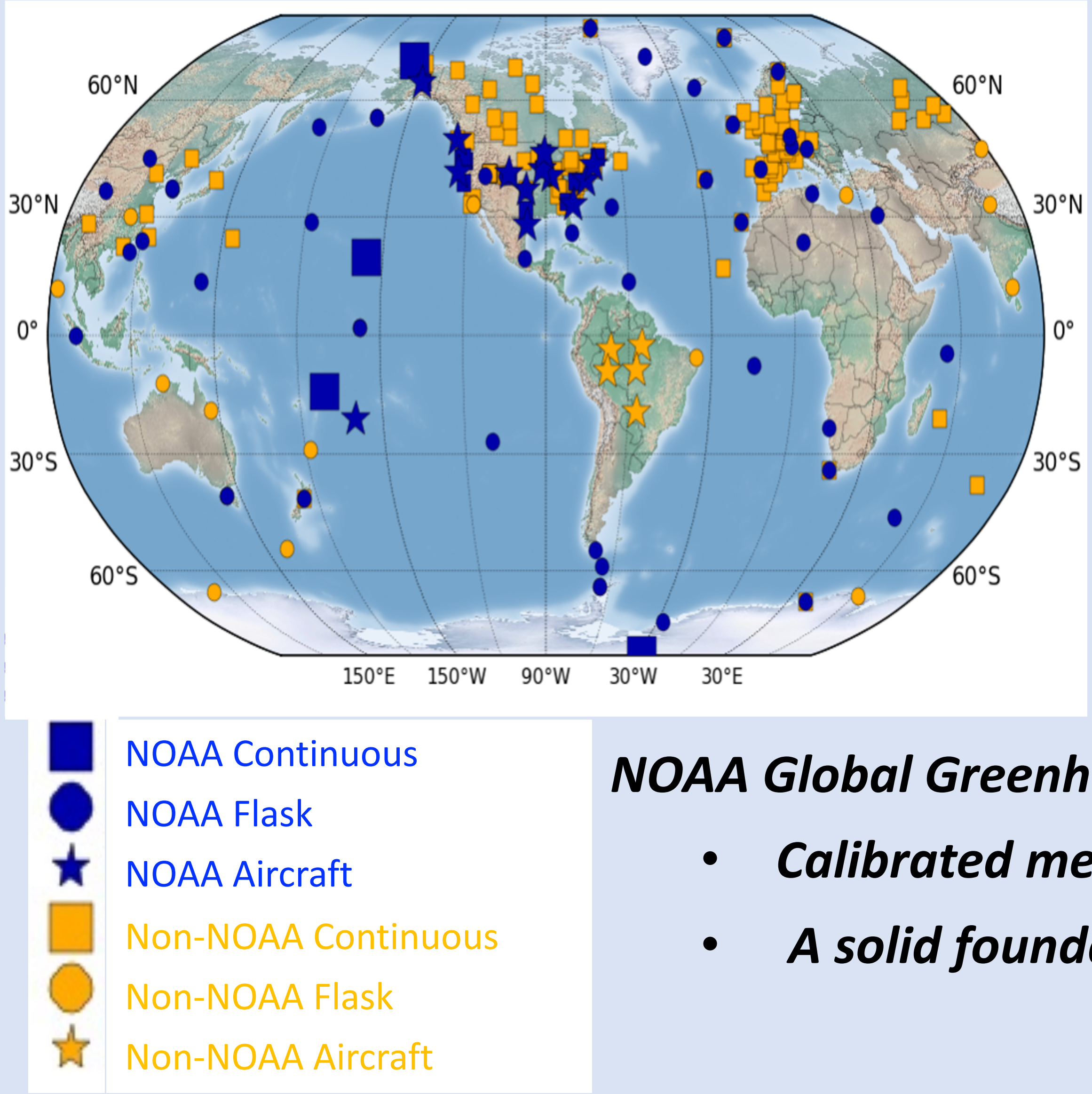
The NOAA Global Greenhouse Gas Reference Network (GGGRN):

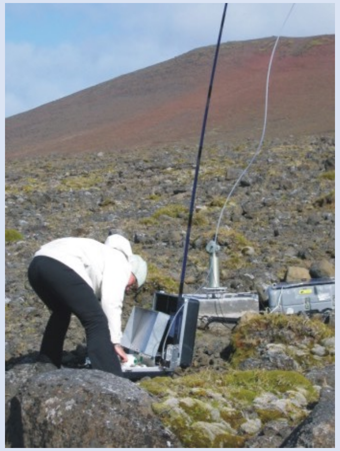
Foundational Measurements of CO_2 and CH_4

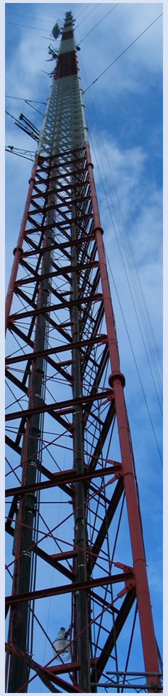




Global, Multi-Decadal Observations of Atmospheric CO_2 and CH_4



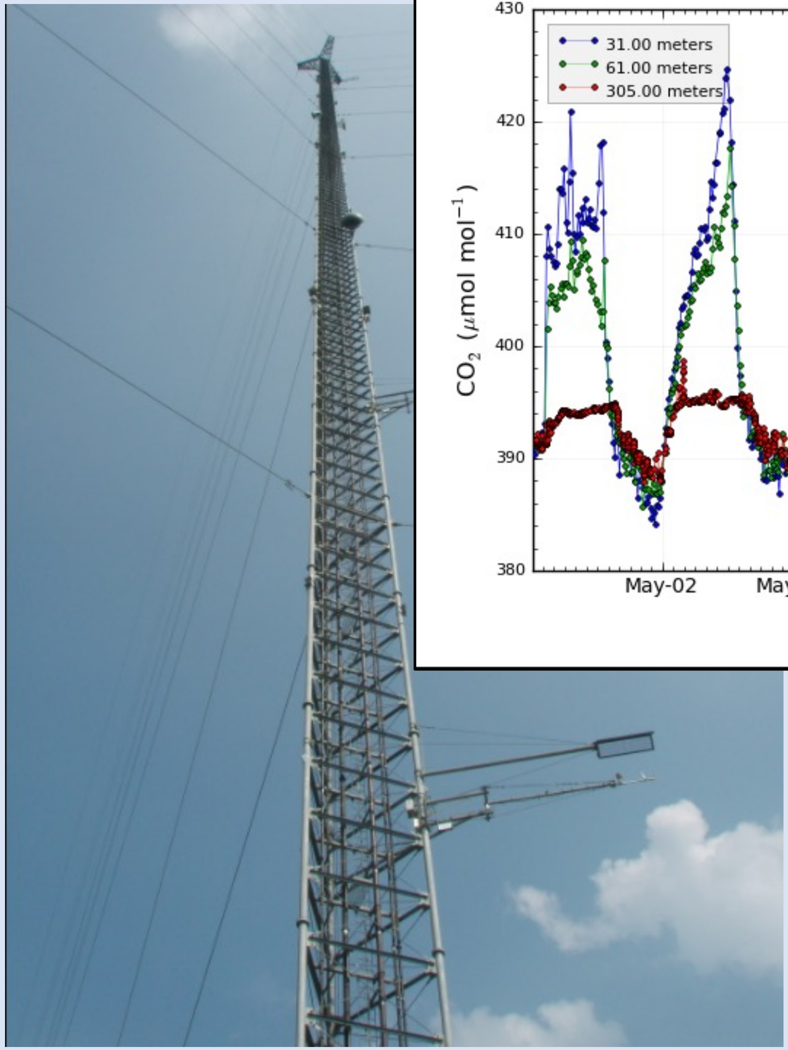


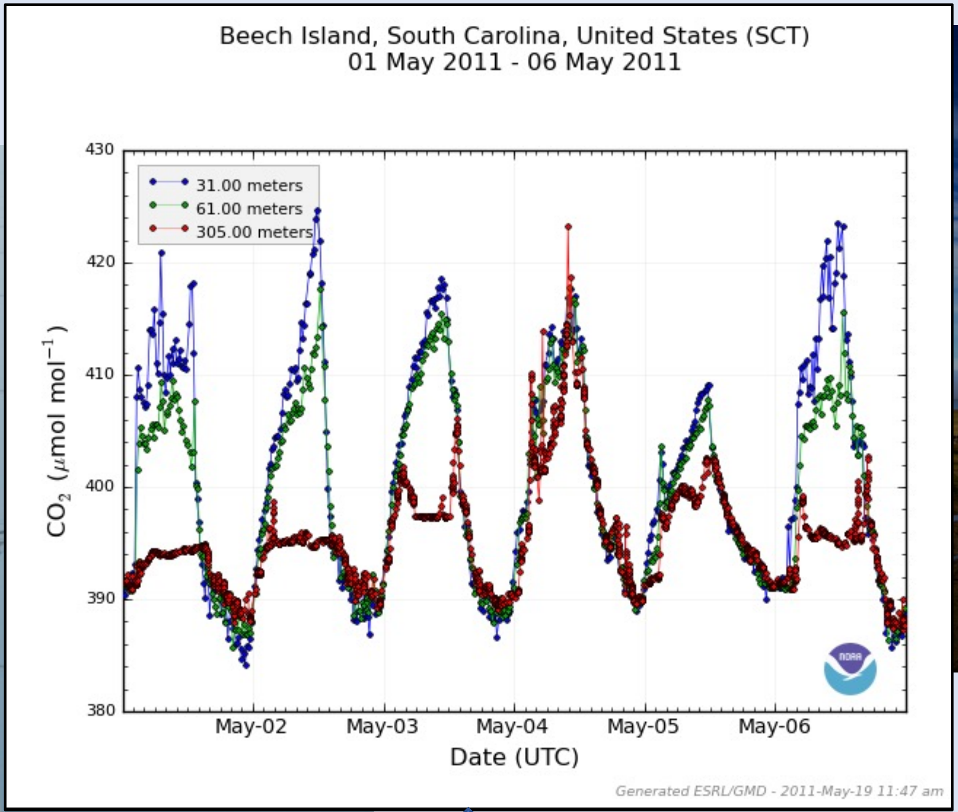


NOAA Global Greenhouse Gas Reference Network Sites (blue symbols)

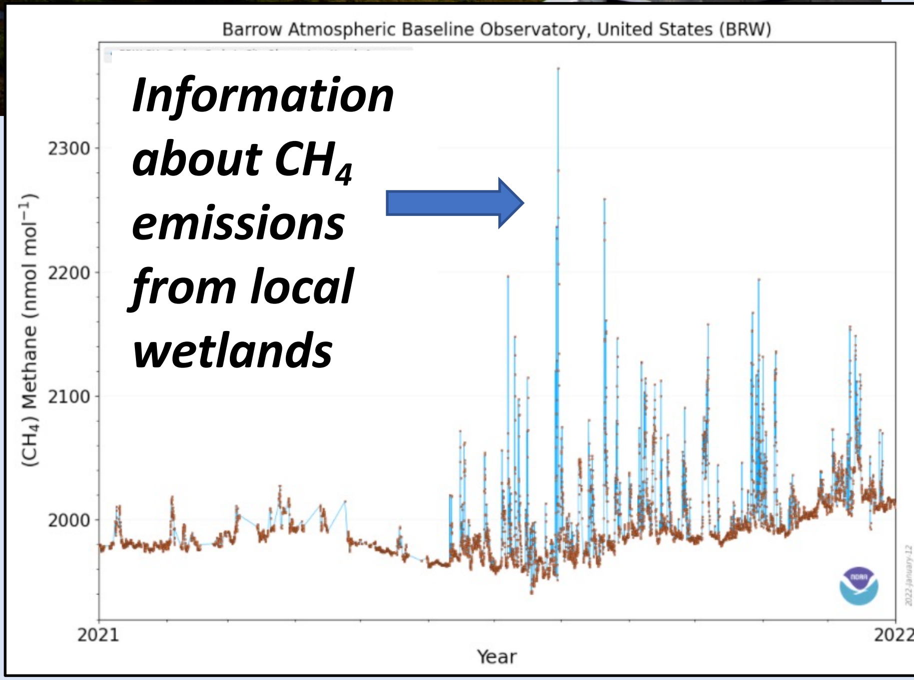
- ***Calibrated measurements of 55 different gases***
- ***A solid foundation for atmospheric GHG measurements.***

In Situ Analyzers Provide Continuous Data



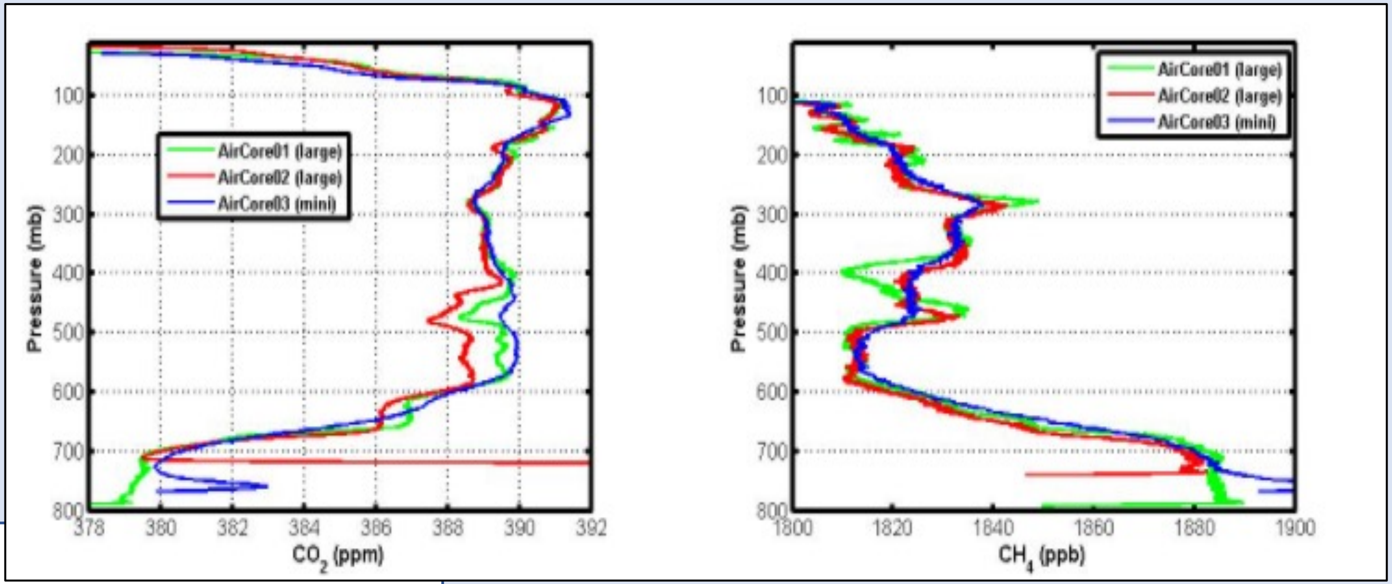


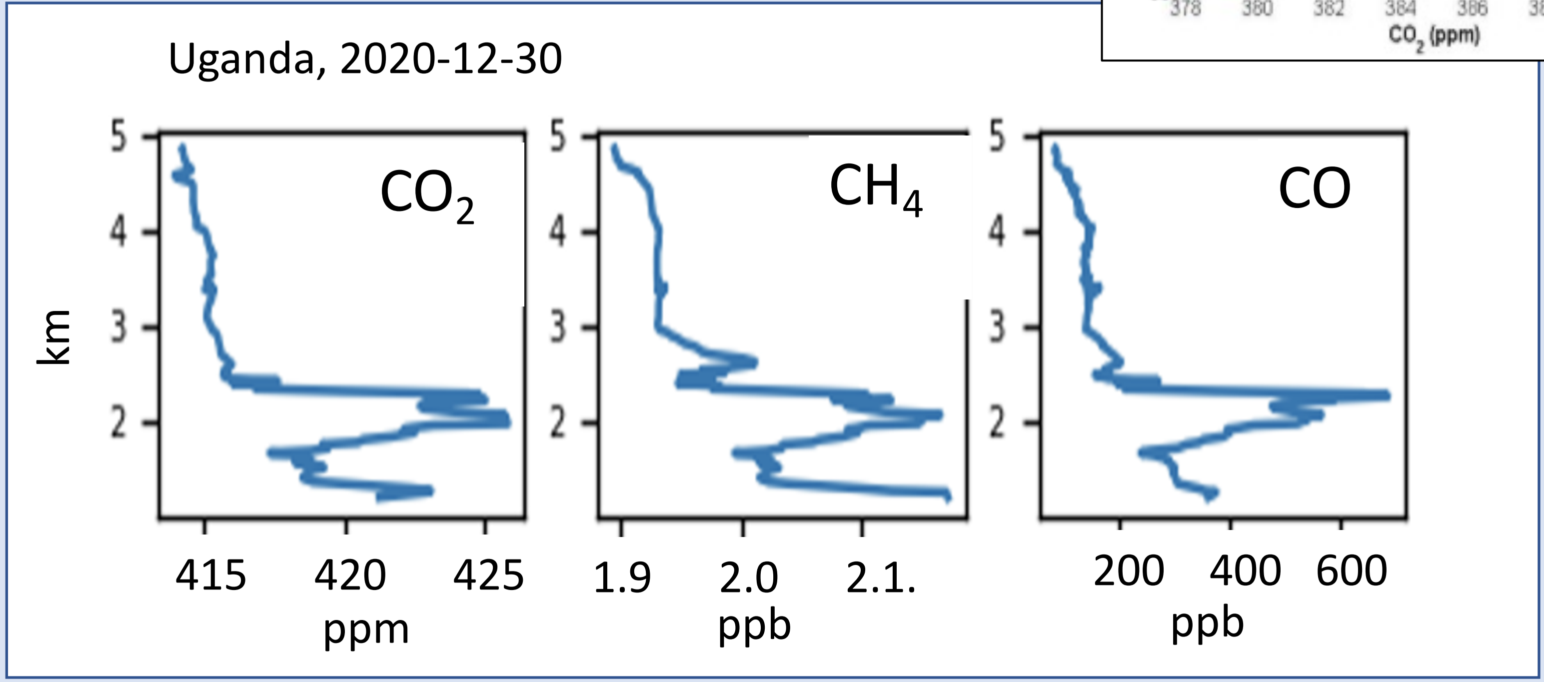
Information about the CO_2 diurnal cycle and how it's propagated vertically



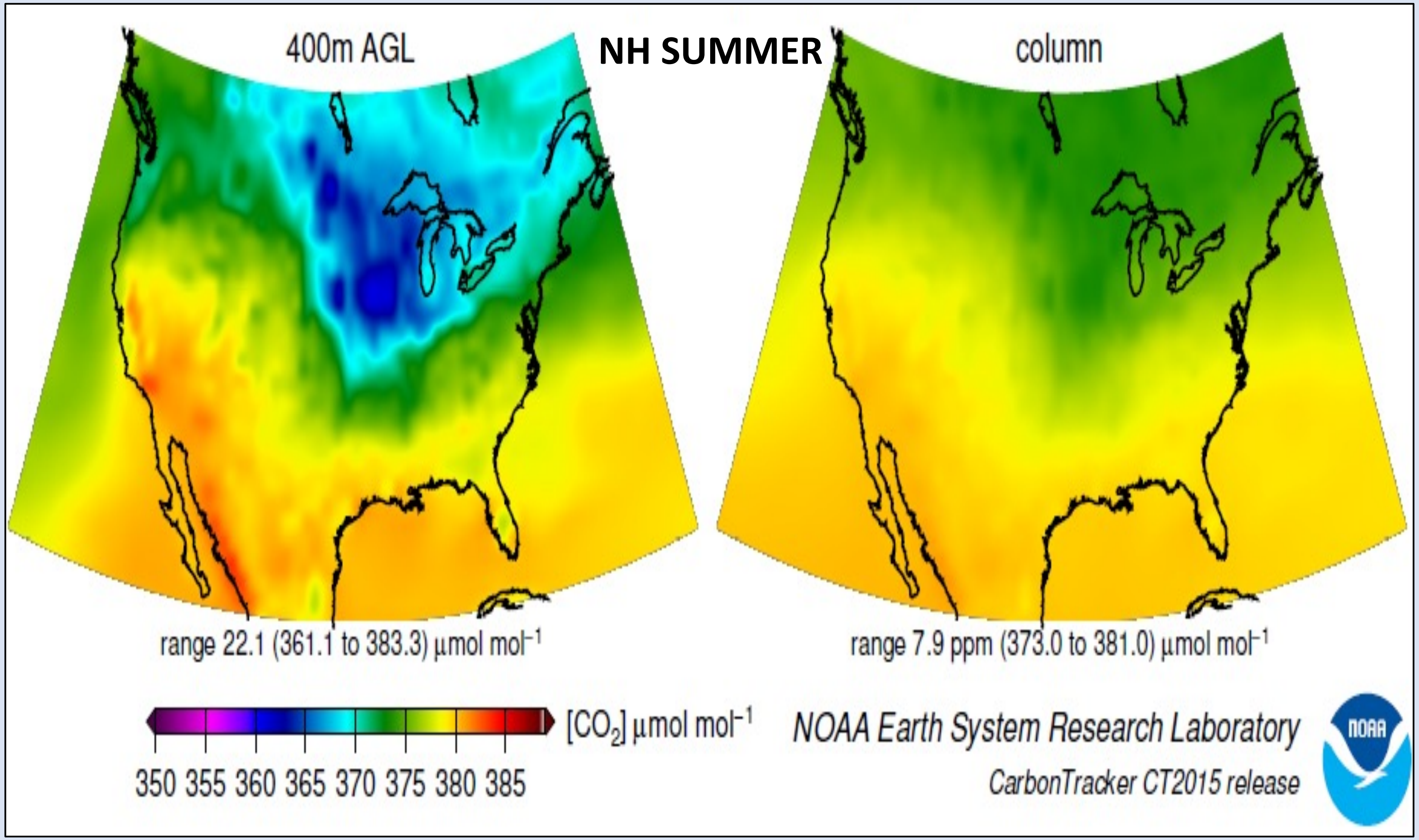
Information about CH_4 emissions from local wetlands

Profile Data from Aircraft, Balloons and Tall Towers





A Challenge for Detecting Changes in Fossil Fuel Emissions from Space: the Signal of Interest is at the Surface



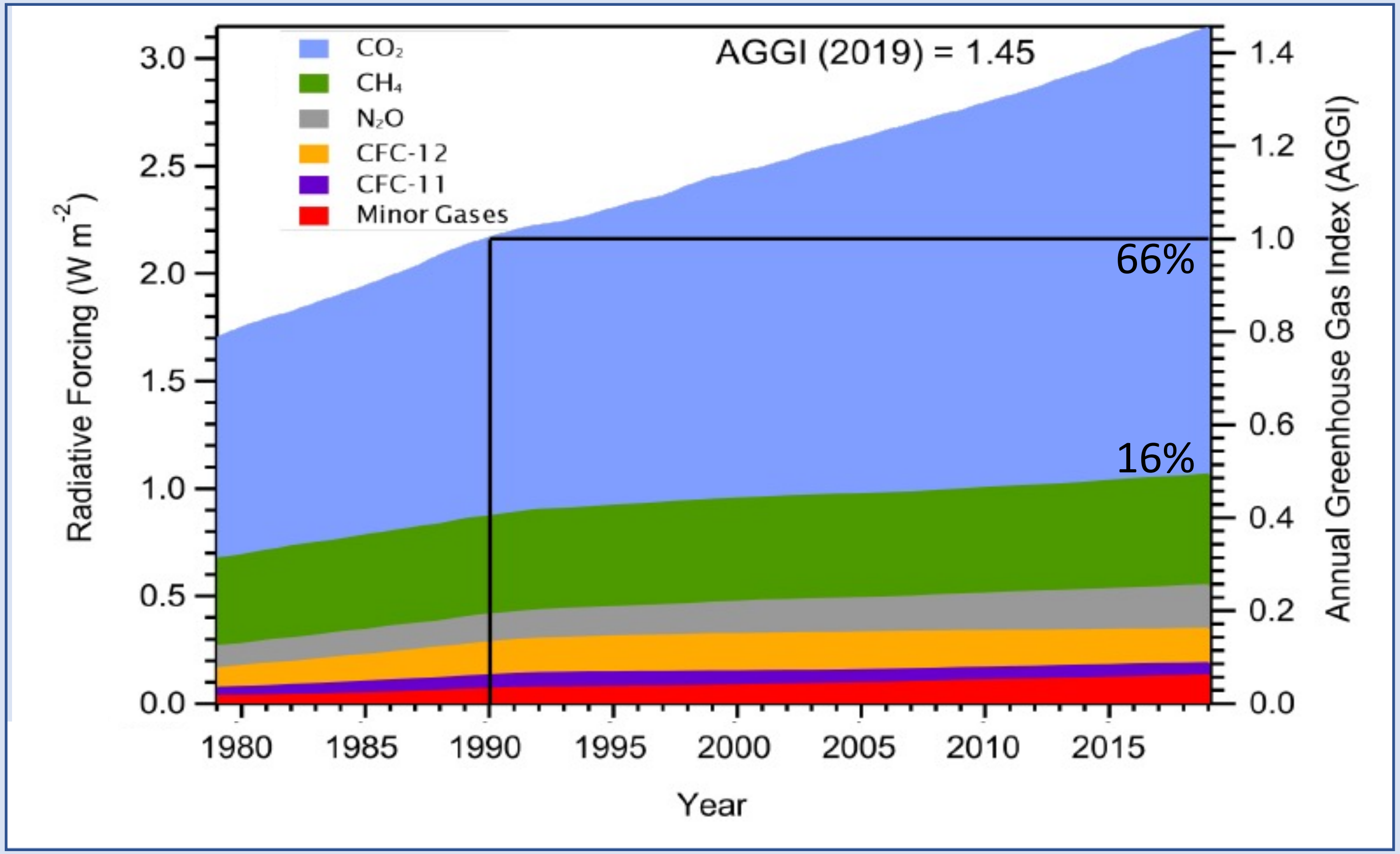
Satellite sensors retrieve total column CO_2.

Column average source/sink signals are weak.

Biases/errors could be large compared to key signals.

Fossil fuel emissions dominate long-term CO_2 growth, but variability is dominated by the biosphere.

Long-Term Atmospheric Observations Help us to Understand the Earth's Changing Energy Budget



Radiative Forcing calculated using NOAA's long-term global network observations (GGGRN).

The CO_2 contribution is rapidly increasing
(2x emission time ~ 30 yrs.!)

The GWP-100 of CH_4 is 28-36, but there is less of it in the atmosphere.

** Radiative Forcing = human impact on Earth's energy budget since pre-industrial times. Units are Watts/meter^2.*

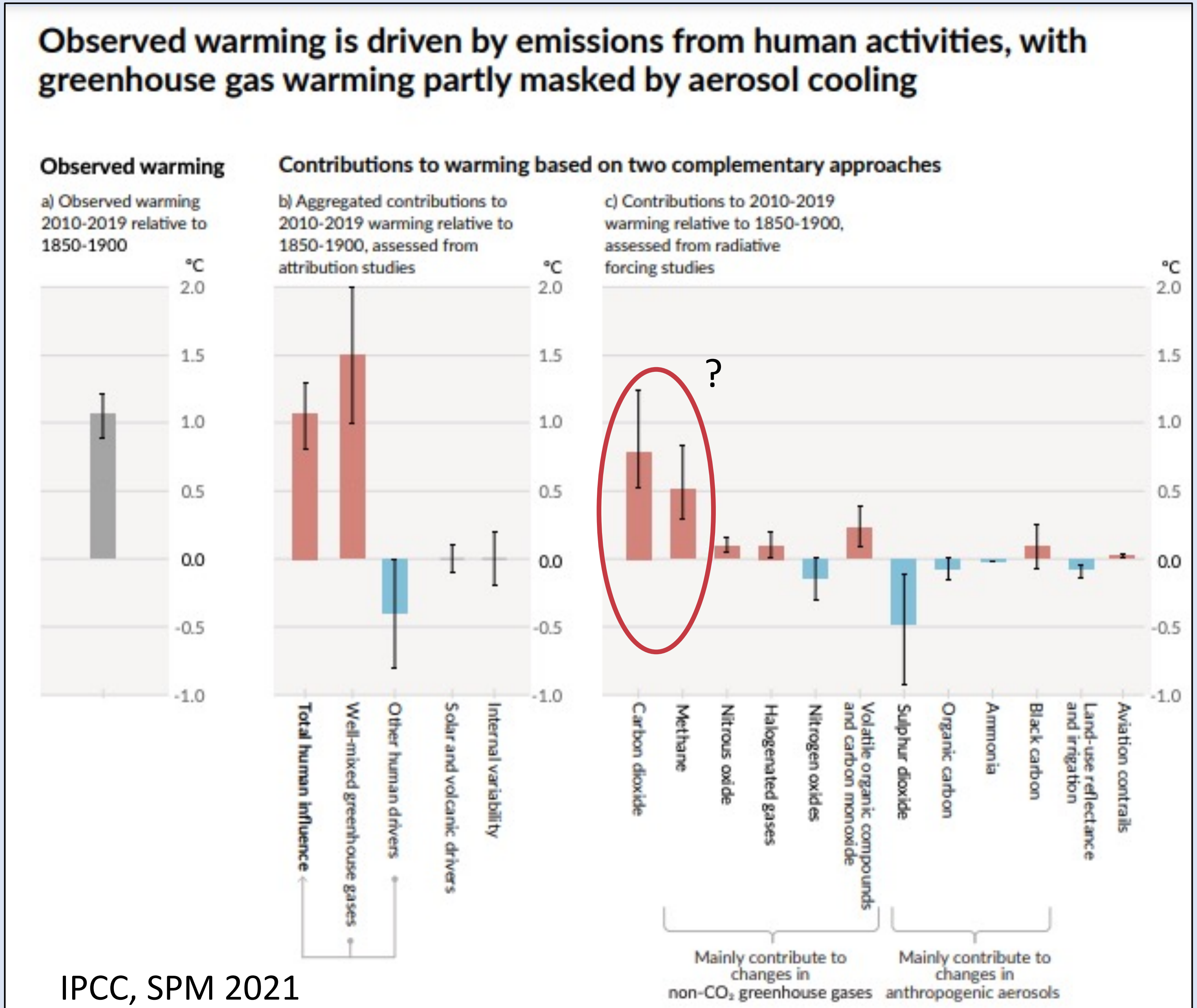
www.esrl.noaa.gov/gmd/aggi, (fig: Bruhwiler et al., 2021)

High Quality, Long-Term Data are Needed to Evaluate and Improve Climate Models

Model Spread:

CO_2 – Climate sensitivity differences including feedbacks (clouds, carbon cycle)

CH_4 – Effects on other radiative forcers (ozone, stratospheric water vapor, aerosols).



IPCC, SPM 2021

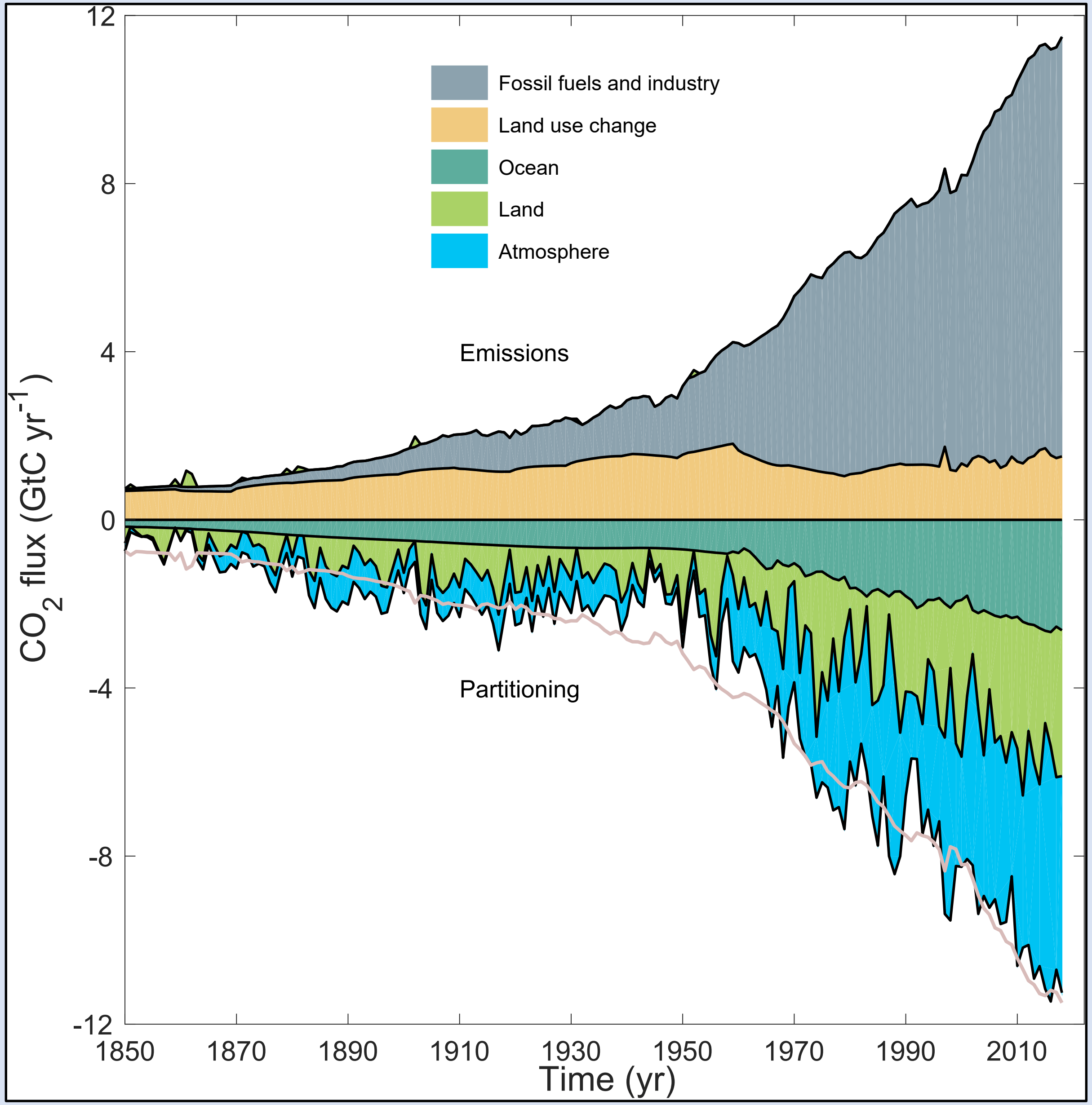
We Should Not Ignore Terrestrial and Ocean Carbon Fluxes

Land and Oceans Take up ~ ½ of the CO_2 emitted, the rest accumulates in the atmosphere.

Will this continue?

If not, do we need to adjust our emission mitigation strategies?

How can carbon dioxide removal and other mitigation efforts succeed when fundamental understanding of "natural" carbon sinks is lacking?



Global Carbon Project, Friedlingstein et al, 2019

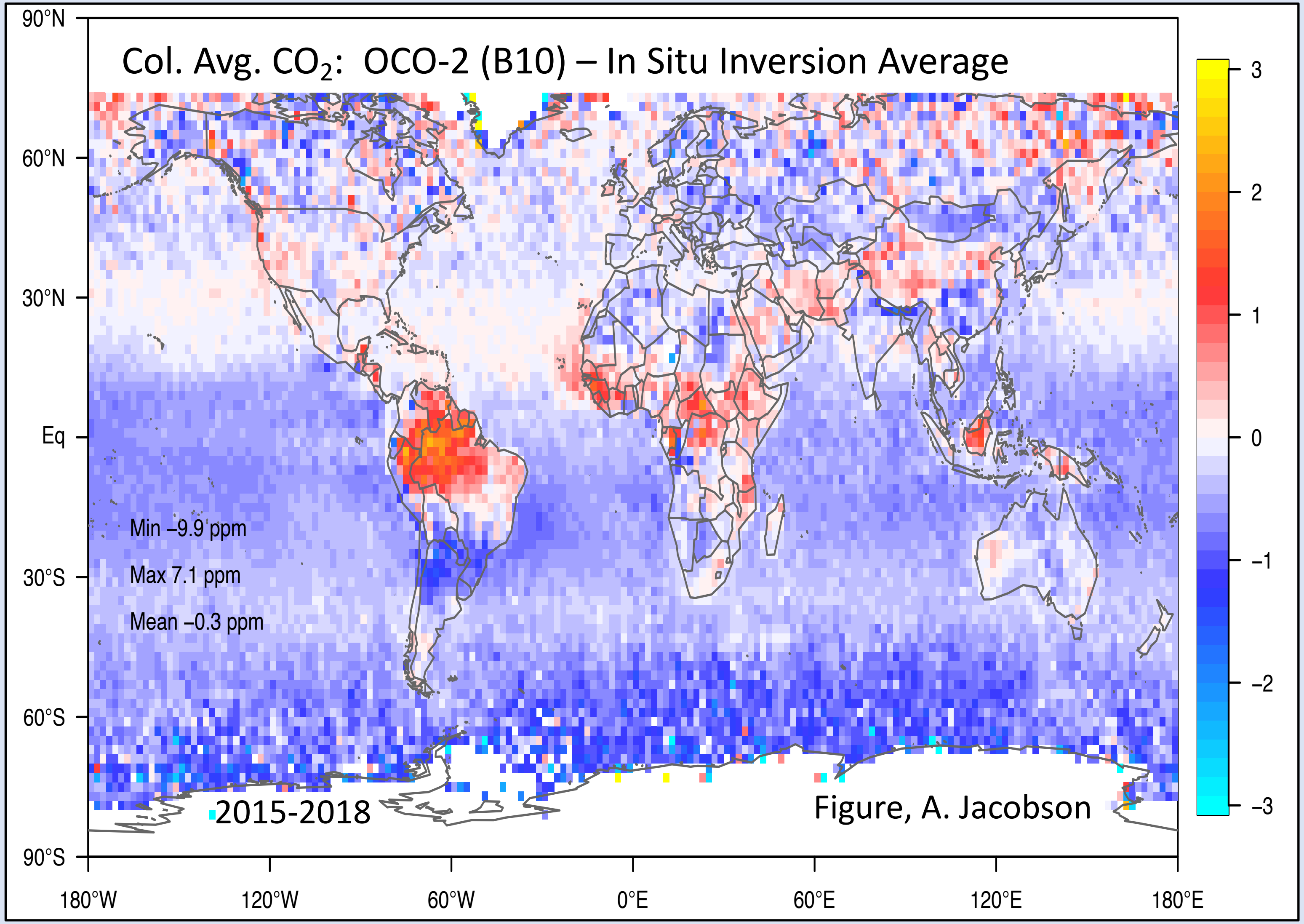
High Quality, Long-Term Measurements are Essential For Detecting Carbon-Climate Feedbacks

The amount of carbon in Arctic permafrost Soils is ~4x what humans have already emitted.

Arctic CH_4 emissions could double over this century with accelerating increases next century.

Will the Tropics take-up or emit more carbon in the future?

In Situ Observations are Complementary to Satellite Data

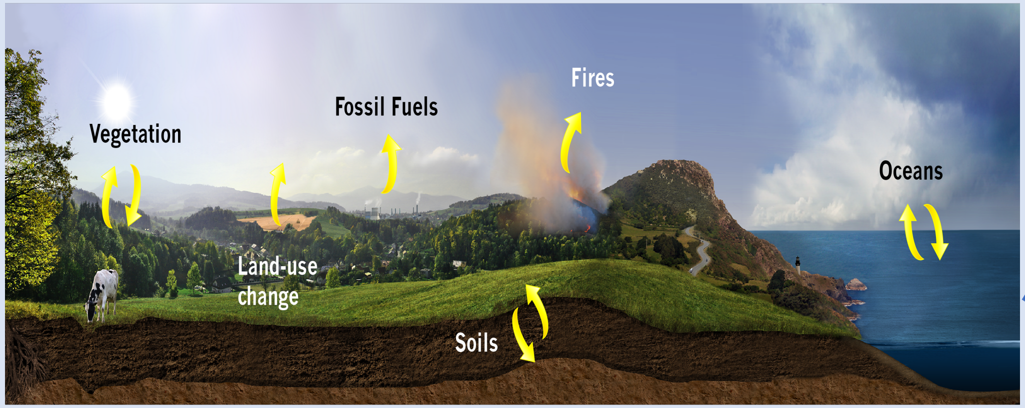


Large differences between in situ observations and satellite retrievals in the Tropics where we don't have many in situ obs.

These areas should be priorities for in situ observations.

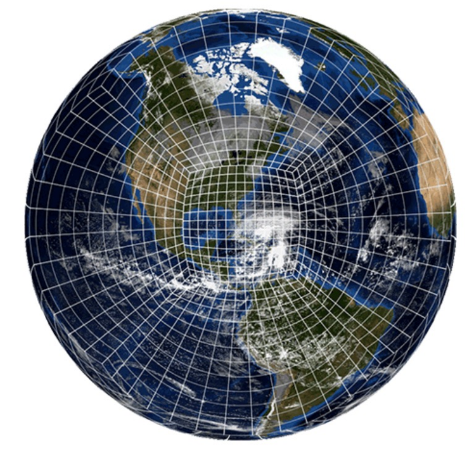
Atmospheric Carbon Data Assimilation/ Flux Inversion: NOAA's CarbonTracker

Carbon Flux Models (inventories , wetland models)

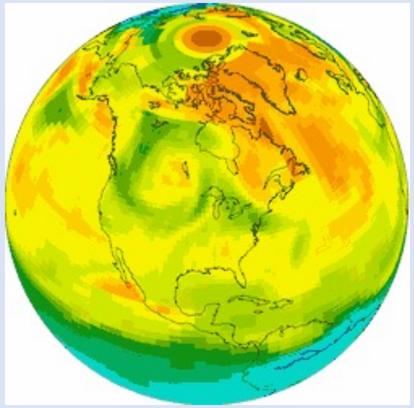


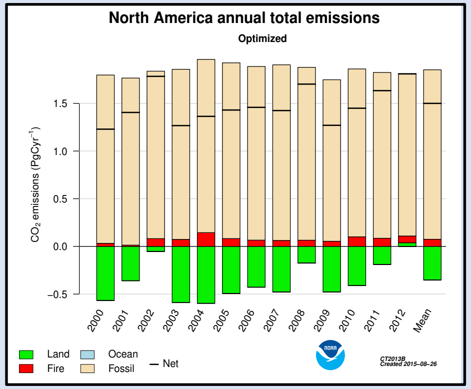
Credit: NASA/Jenny Mottar and Abhishek Chatterjee

Atmospheric Transport Model+ DA/Inversion Techniques (FV3 Development!)



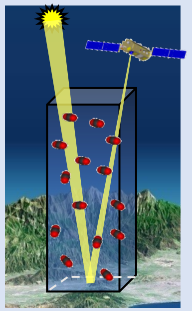
Carbon Analyses





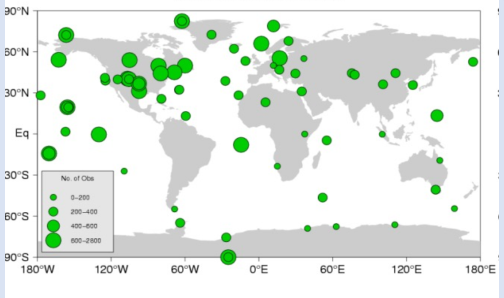
Estimated Fluxes

Remotely- Sensed Column Data



Profiles

In Situ Surface Network Data

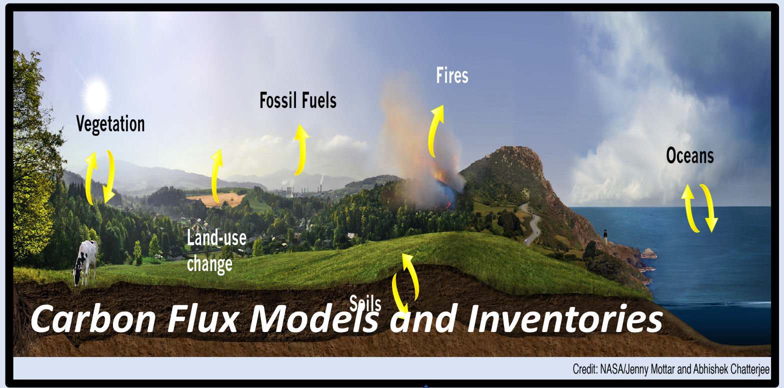


www.esrl.noaa.gov/gmd/ccgg/carbontracker/

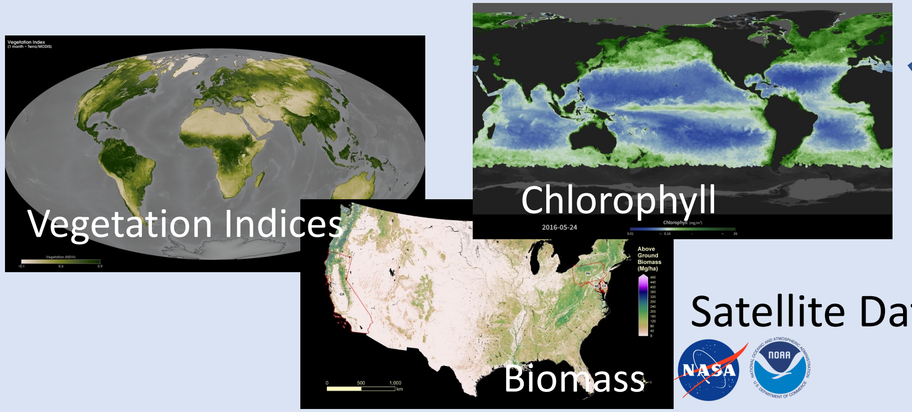
www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/

Federal Research Agencies Have a Lot of Infrastructure for Understanding the Carbon Cycle

Ocean Surveys

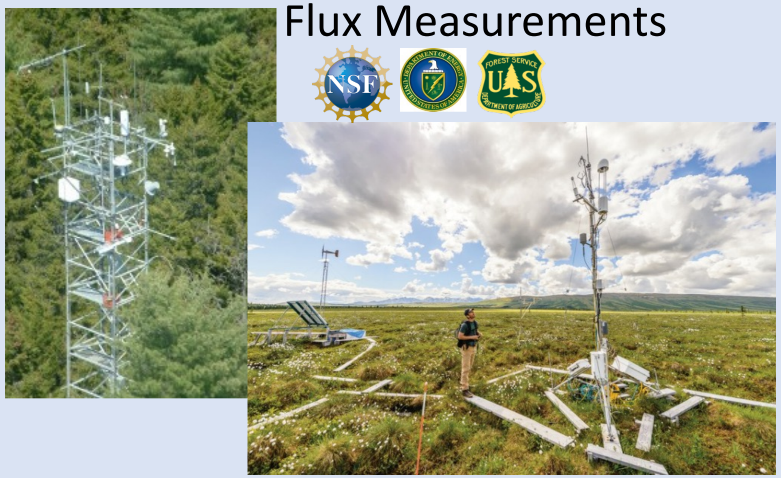


Inventories



Satellite Datasets

Flux Measurements



What Would Help: Increased International Coordination
Could we do this for CO_2 and CH_4?

What we have for weather forecasting

What could we learn about the carbon cycle if we could fly GHG analyzers on commercial aircraft?

NOAA, Boeing team up to test greenhouse gas-measuring technology

Scientists with NOAA's Global Monitoring Laboratory will evaluate the optimal placement of greenhouse-gas sampling inlets on a Boeing 737 flying testbed owned by Alaska Air during Boeing's 2021 ecoDemonstrator technology development...

- *Long-Term, high quality in situ datasets are essential for:*
  - ***Improving climate projections to support mitigation and adaptation efforts***
  - ***Fully exploiting data from satellite missions***

- *Greenhouse gas emissions are a global issue that requires international commitments to long-term observations and infrastructure for timely data sharing.*
  - ***Establishing and maintaining monitoring sites in developing nations should be a high priority.***
  - ***International sharing of data should be facilitated.***

- *US Federal agencies have developed many new capabilities that are still rapidly evolving.*
  - ***We need a plan to transition to sustained operations and to develop next generation data products and services to support mitigation and adaptation efforts.***