Overview of Carbon Cycle Science

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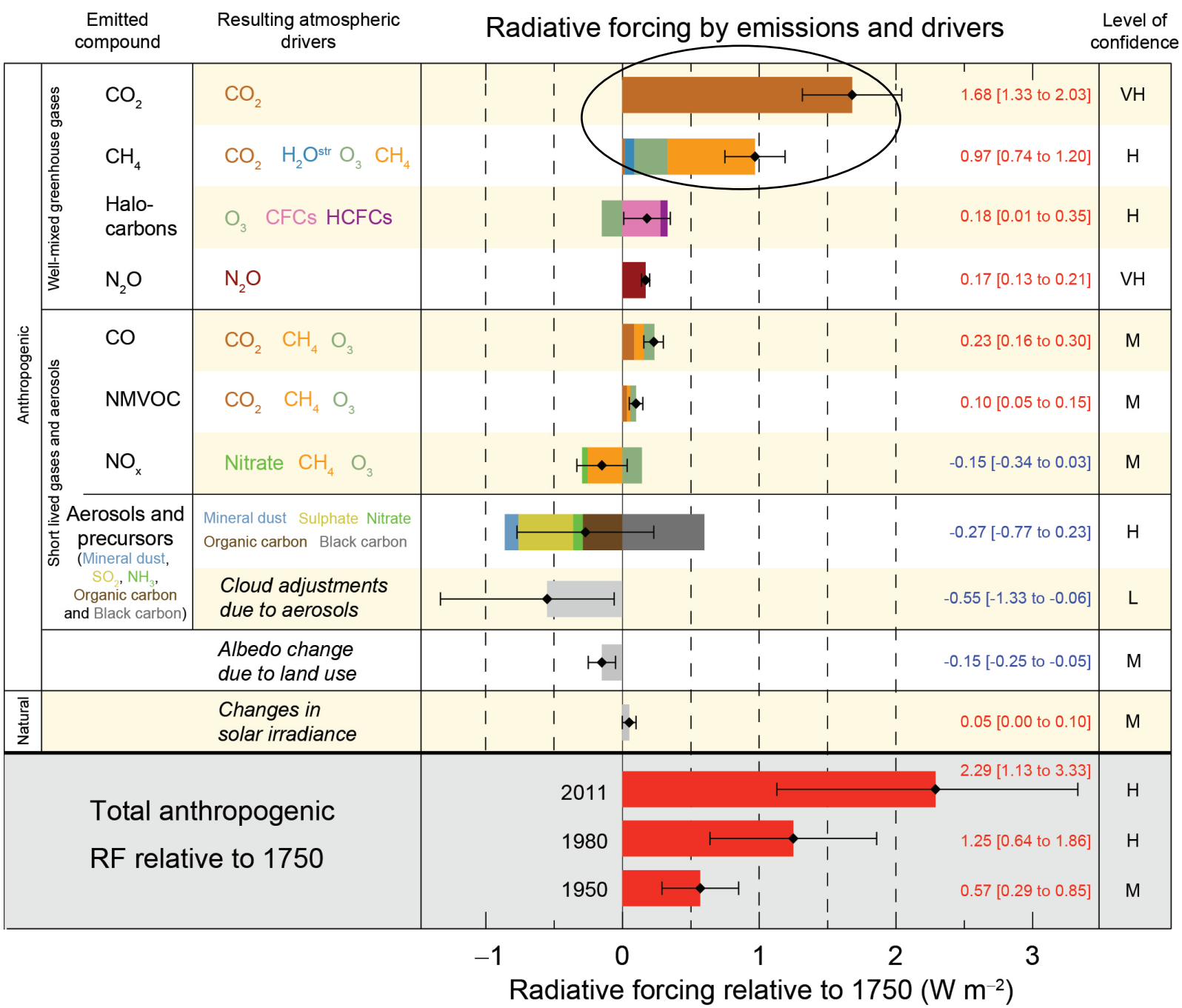
Observing Terrestrial Ecosystems and the Carbon Cycle from Space

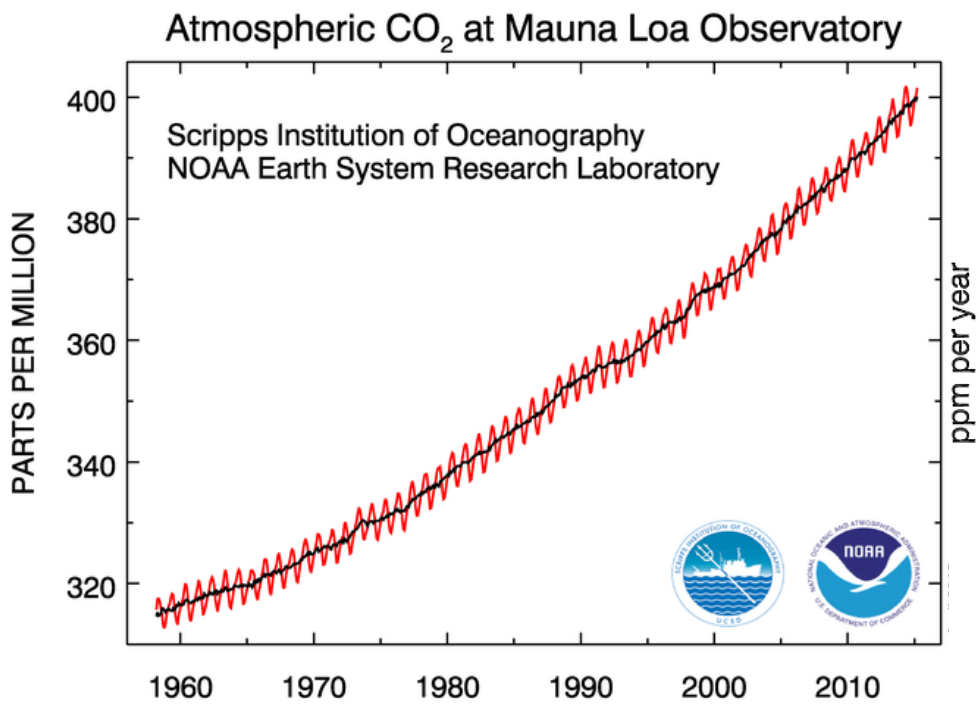
October 5, 2015

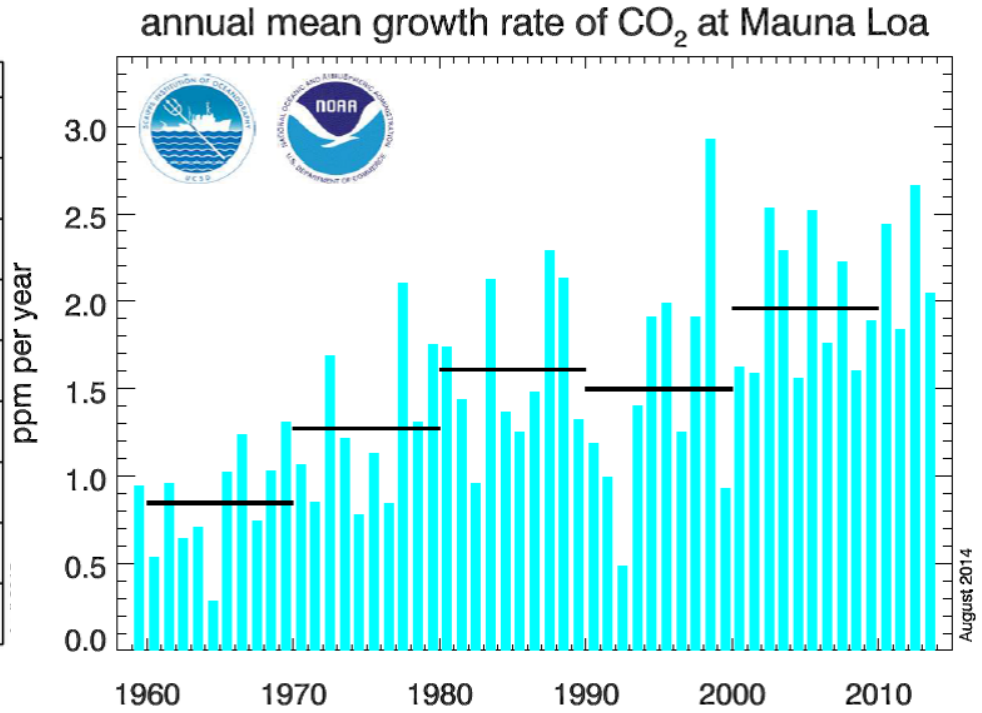
IPCC AR5



http://www.ipcc.ch/

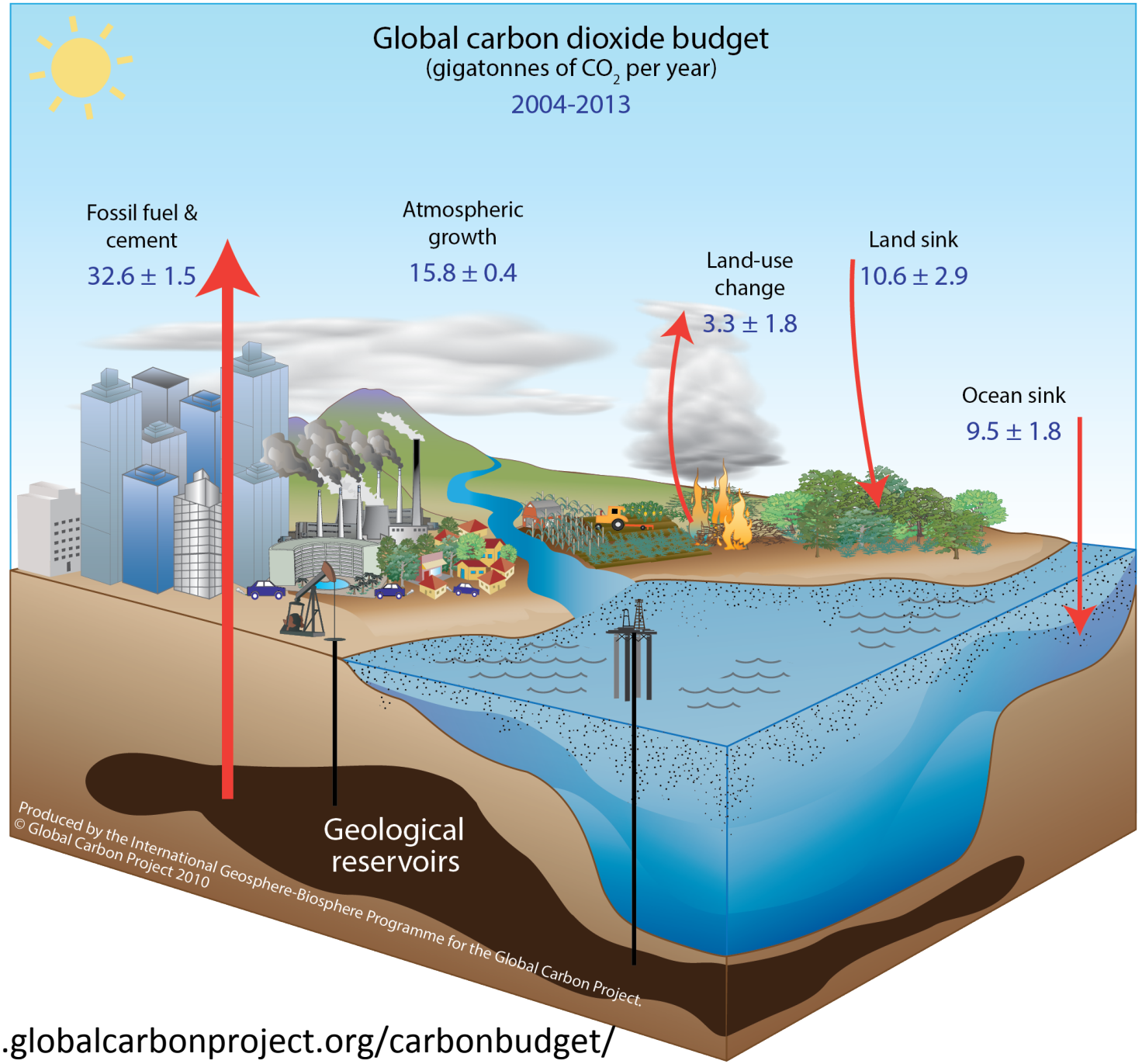
We know CO_2 continues to increase and by about how much





Mauna Loa CO_2 record and inferred atmospheric growth rate from 1950s to present

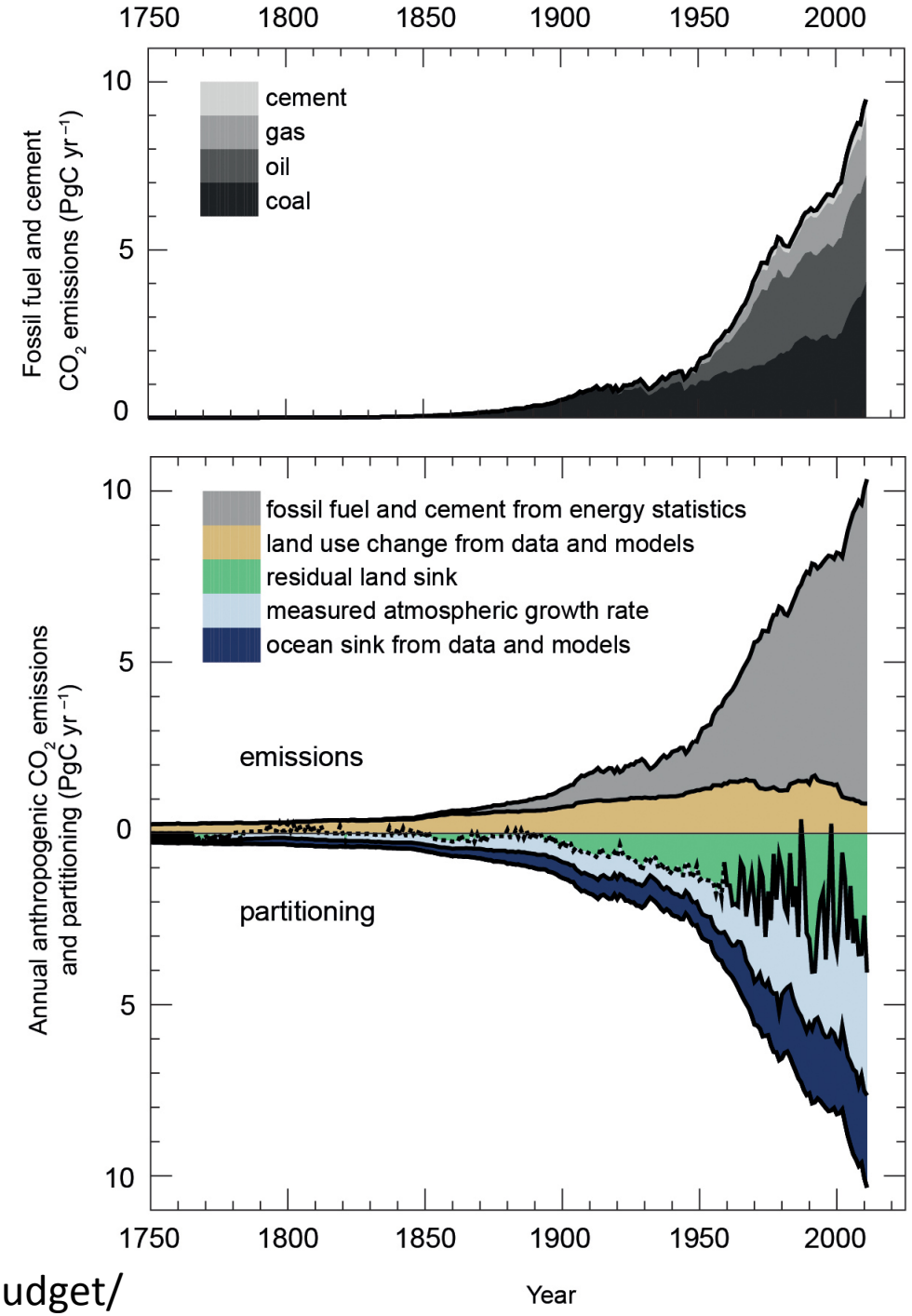
http://www.esrl.noaa.gov/



http://www.globalcarbonproject.org/carbonbudget/

Current Understanding of CO_2 budget

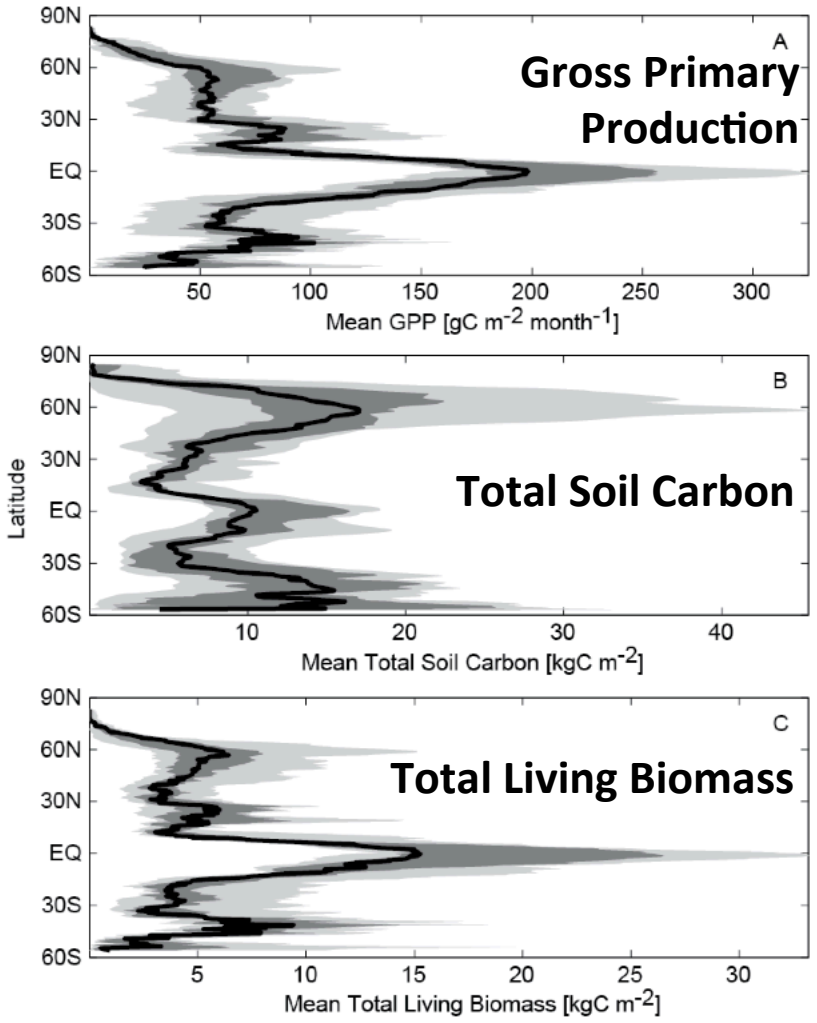
- With information on fossil fuel usage, model estimates of ocean carbon flux, and surface obs, we can estimate how much carbon the land is absorbing



http://www.globalcarbonproject.org/carbonbudget/

Uncertainty in Land Carbon Flux

- Though we can estimate the magnitude of the land sink, its global distribution and the processes controlling it remain very uncertain
- Results from the Multi-scale Terrestrial Model Intercomparison Project (MsTMIP) underscore this uncertainty

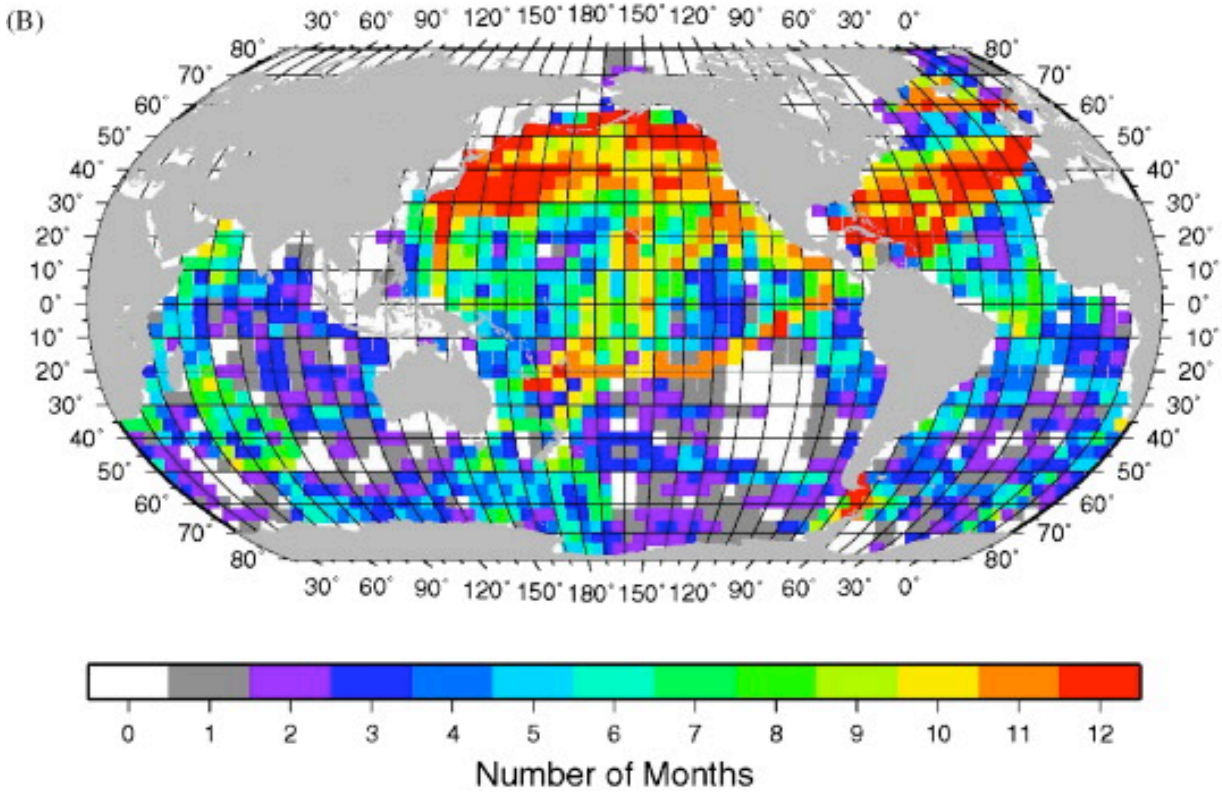


Huntzinger et al., 2013, GMDD

We think we understand ocean CO_2 flux better... but do we?

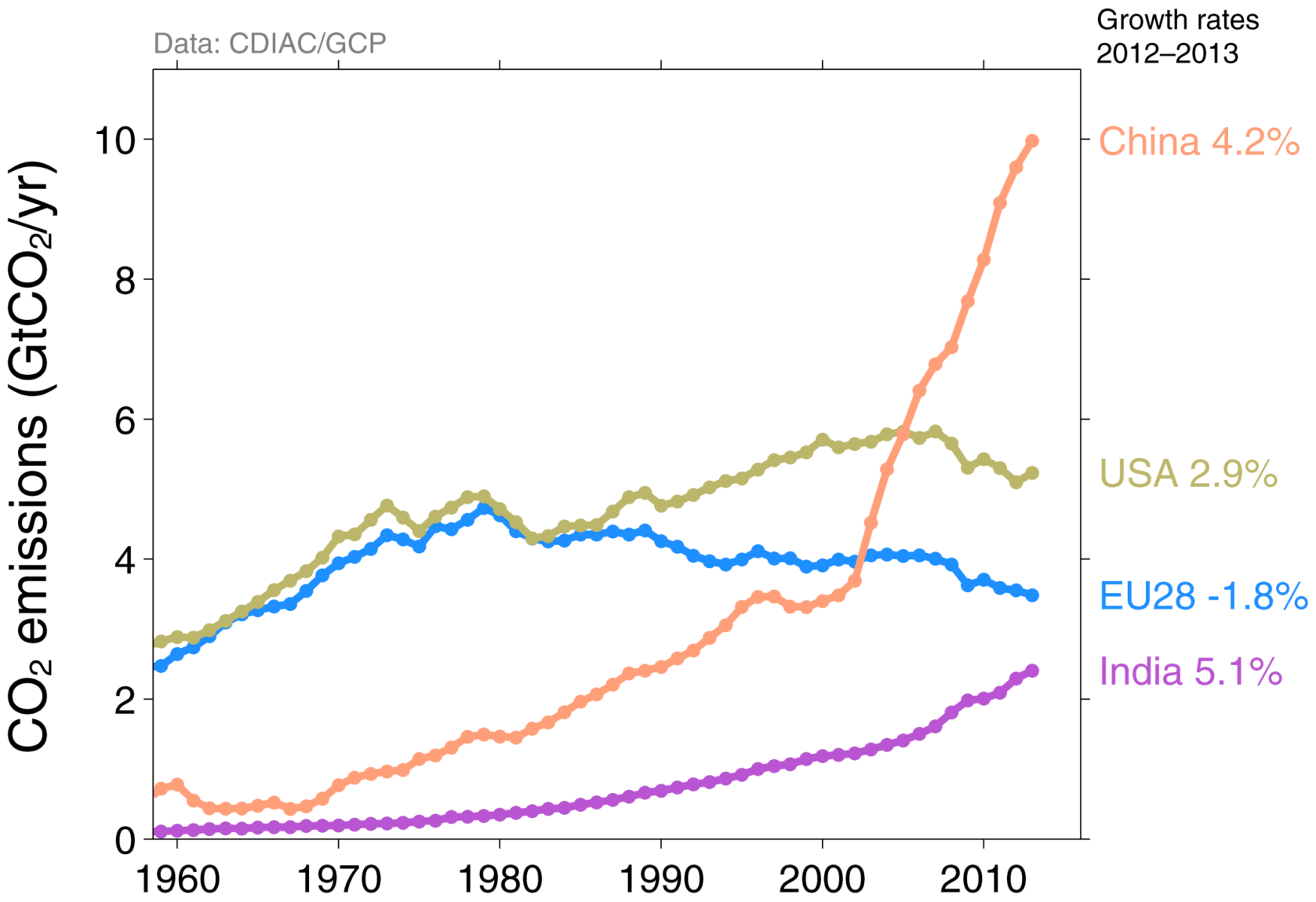
- Observational estimates computed from ocean pCO_2 samples
- Climatology based on ~3 million samples from 1970-2007 compiled by Takahashi et al.

Number of Months with Observations in Takahashi Climatology



Takahashi et al., 2009, Deep Sea Research II

Fossil Fuel Emissions

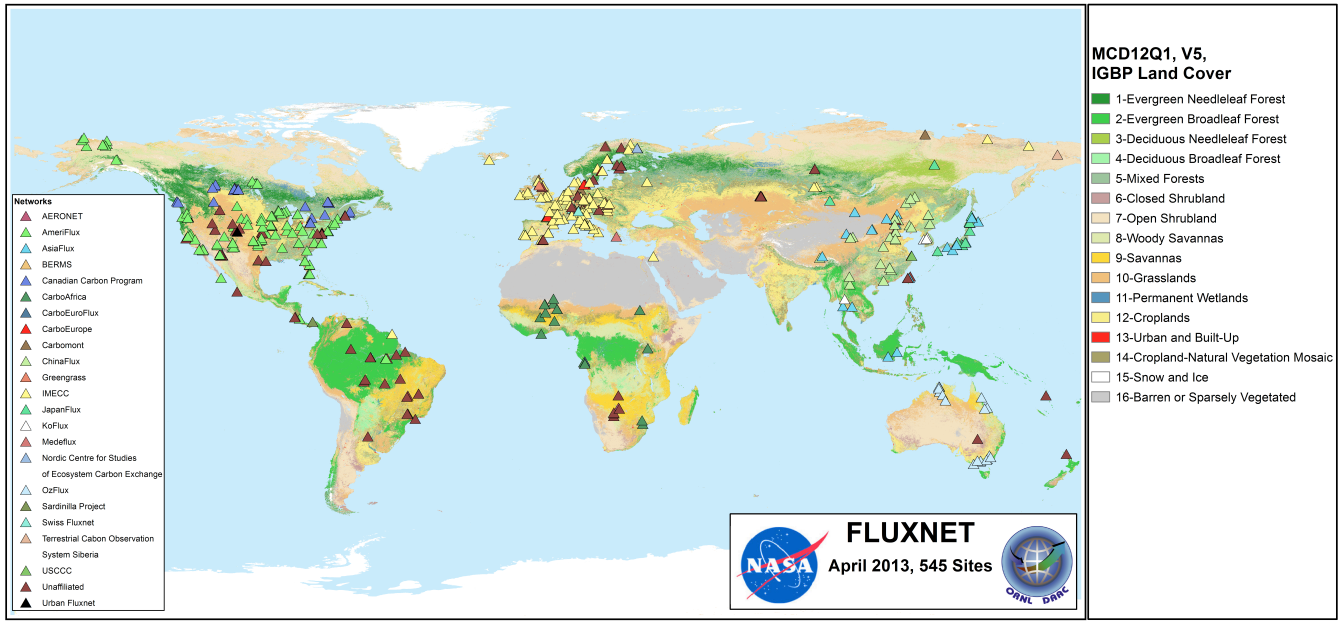


http://www.globalcarbonproject.org/carbonbudget/

Can we measure fluxes directly?

- Model differences are large because of lack of direct observations
- Flux towers provide valuable information on local scale fluxes but many regions not covered

US Forest Service Tower

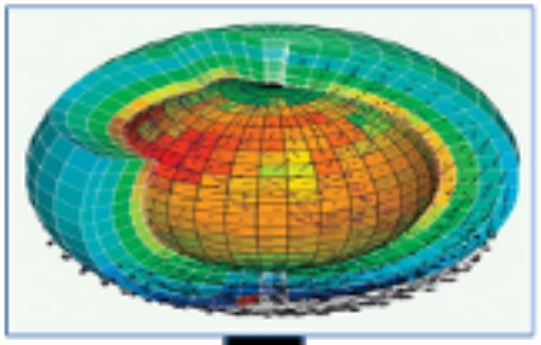


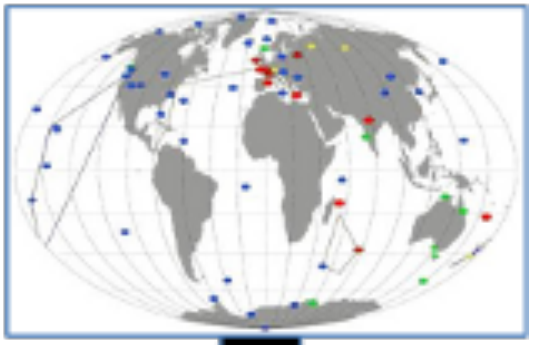
CO_2 Inversion Setup

PRIOR FLUXES

TRANSPORT MODEL

OBSERVATIONS

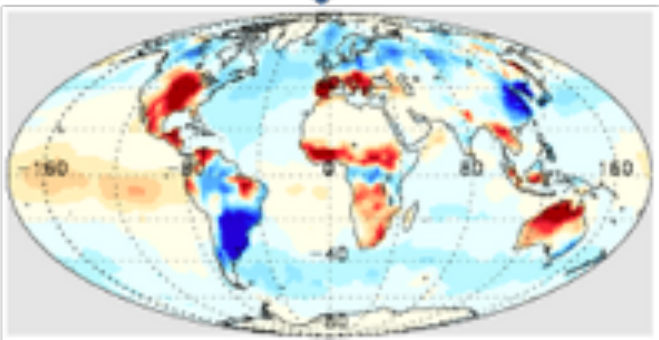




967701.02.04.01.63

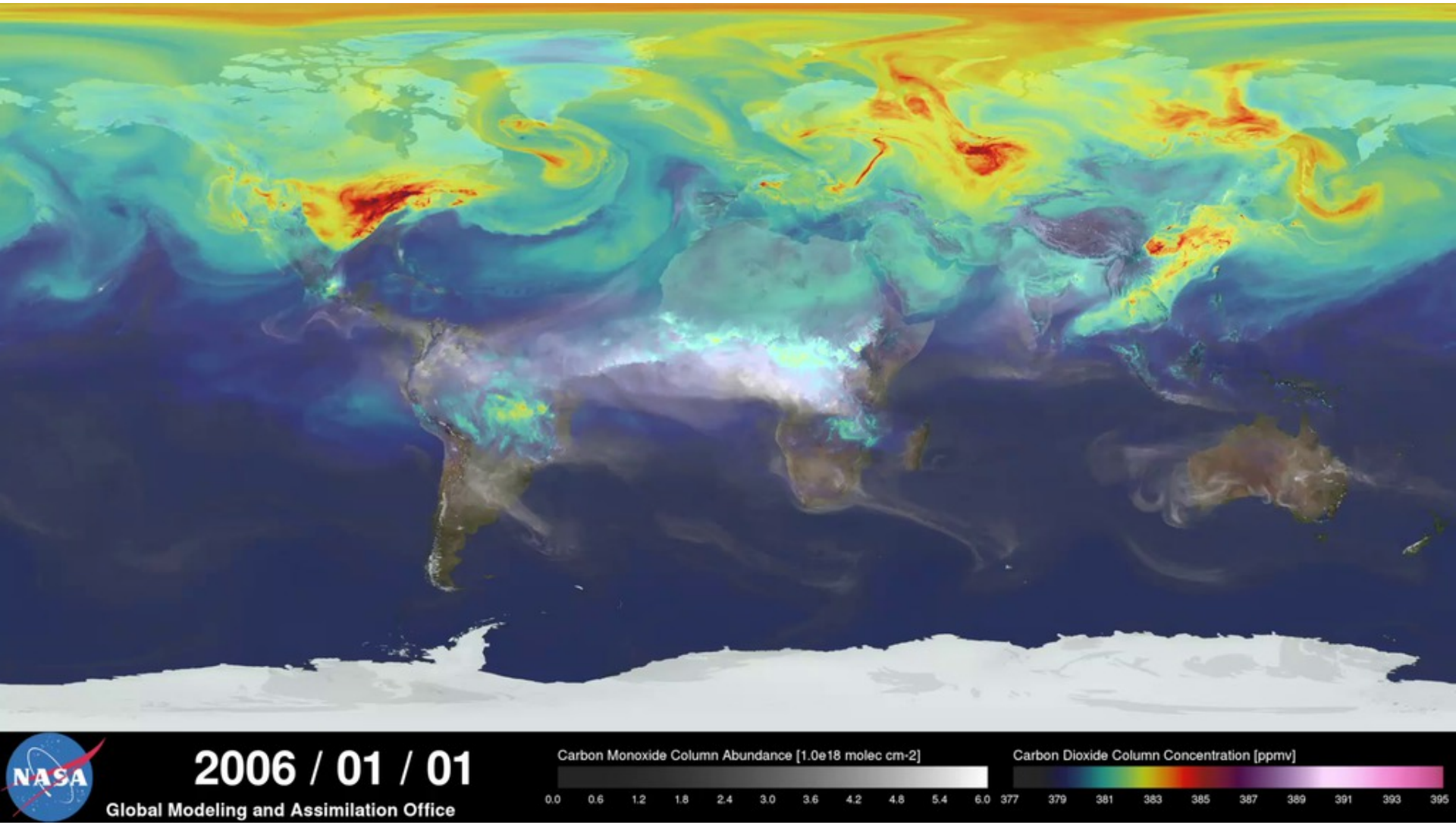
INVERSE PROCEDURE

OPTIMIZED FLUXES



http://www.globalcarbonatlas.org

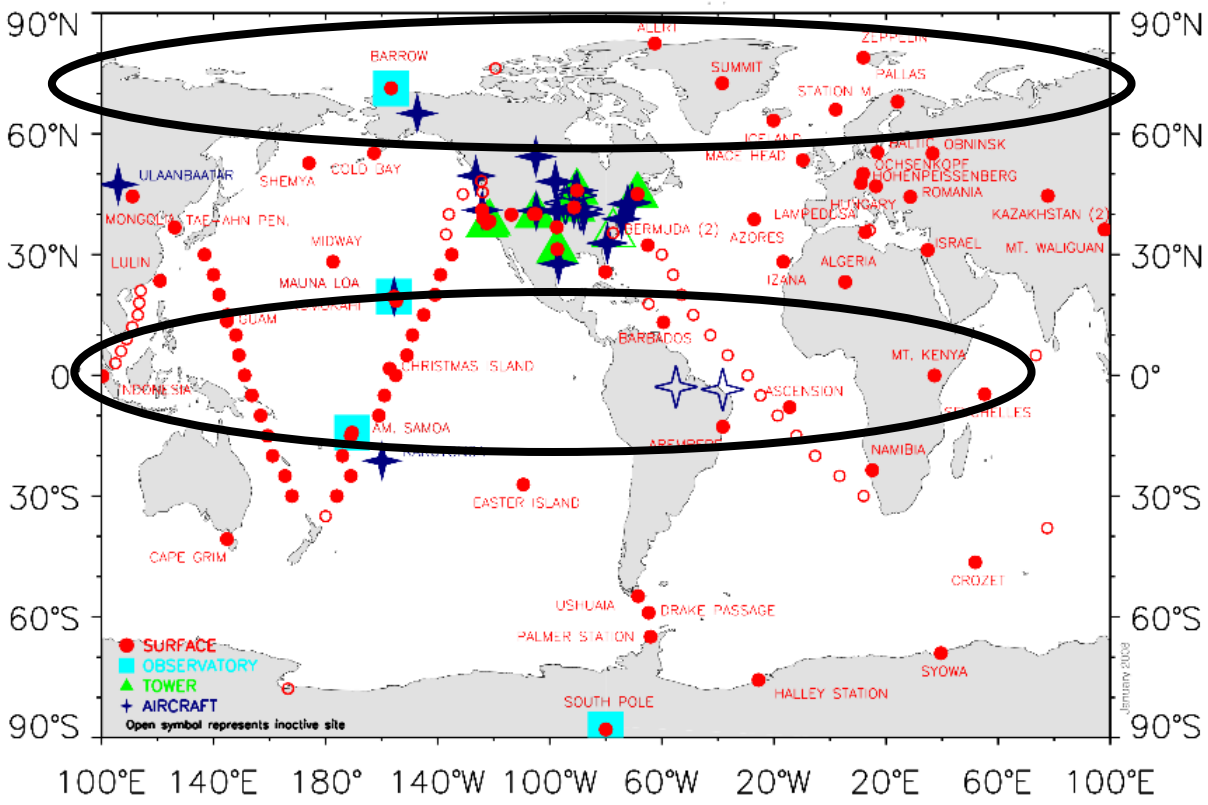
GEOS-5 Nature Run



Movie available at http://svs.gsfc.nasa.gov/goto?11719

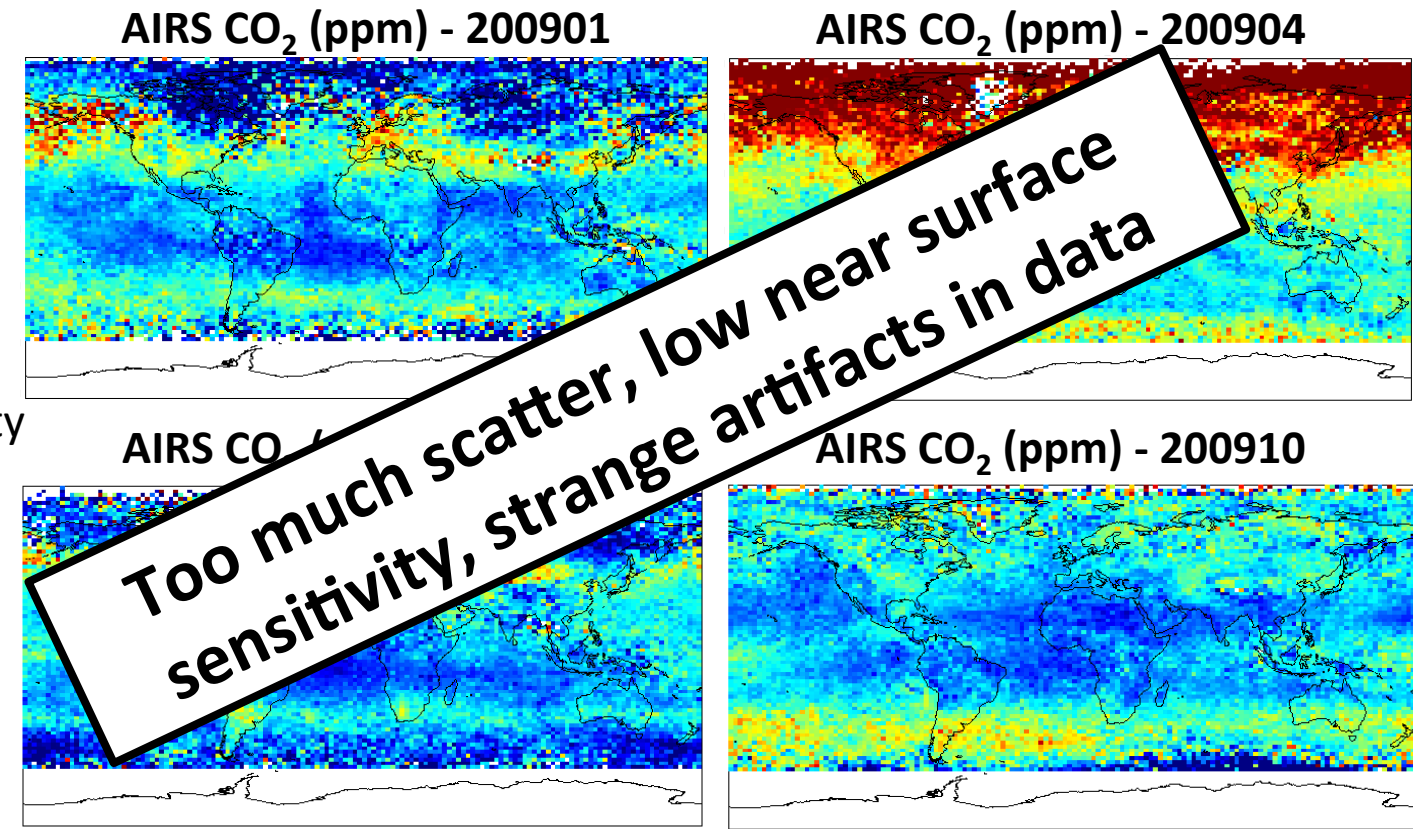
Current observing systems for CO_2

- **Surface observations coordinated by NOAA designed to monitor background levels of CO_2**
- **Few observations is regions with greatest flux uncertainty including tropics, high latitude land masses**



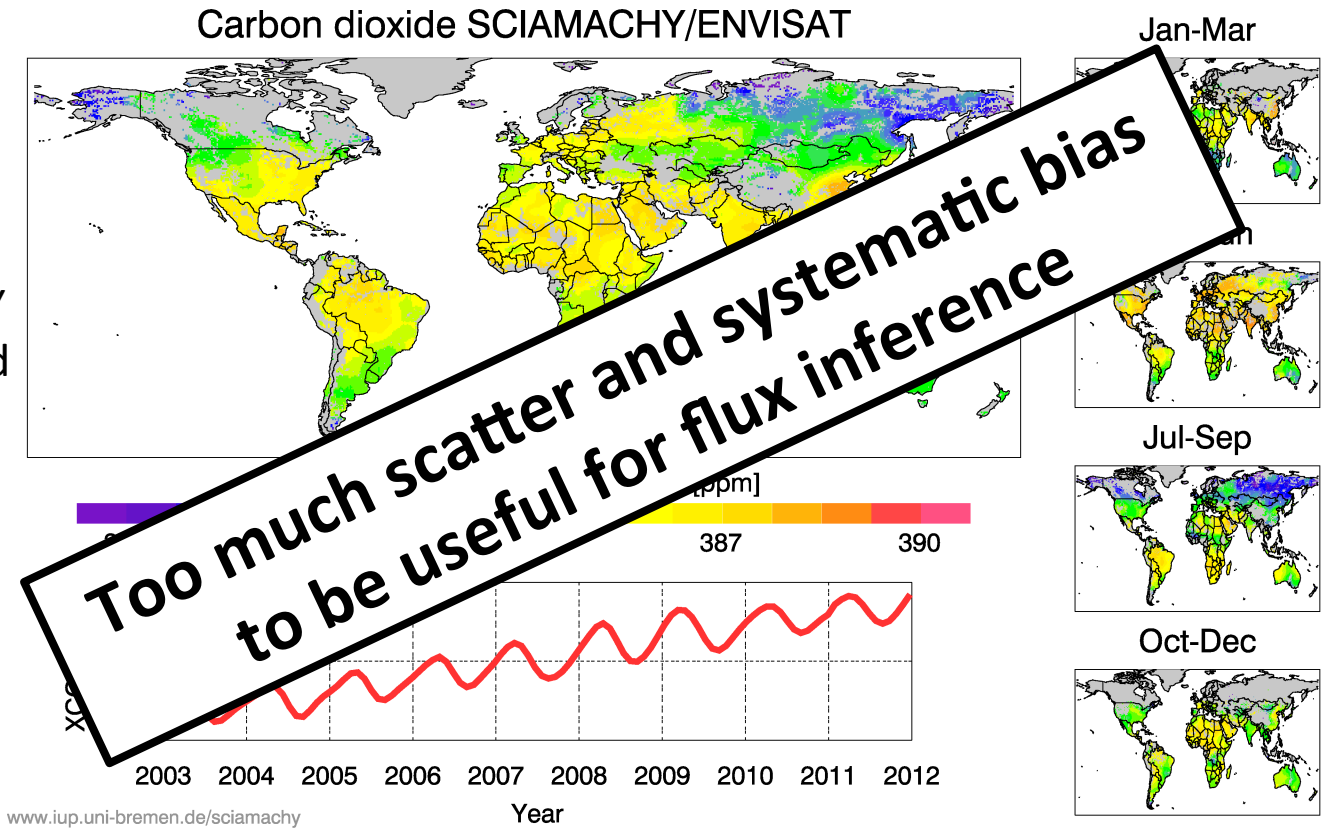
Current observing systems for CO_2

AIRS data provide some information about CO_2 in the mid-troposphere but has very limited sensitivity near the surface where flux signals are the strongest



Current observing systems for CO_2

ESA instrument SCIAMACHY among the first space-based CO_2 measurements...

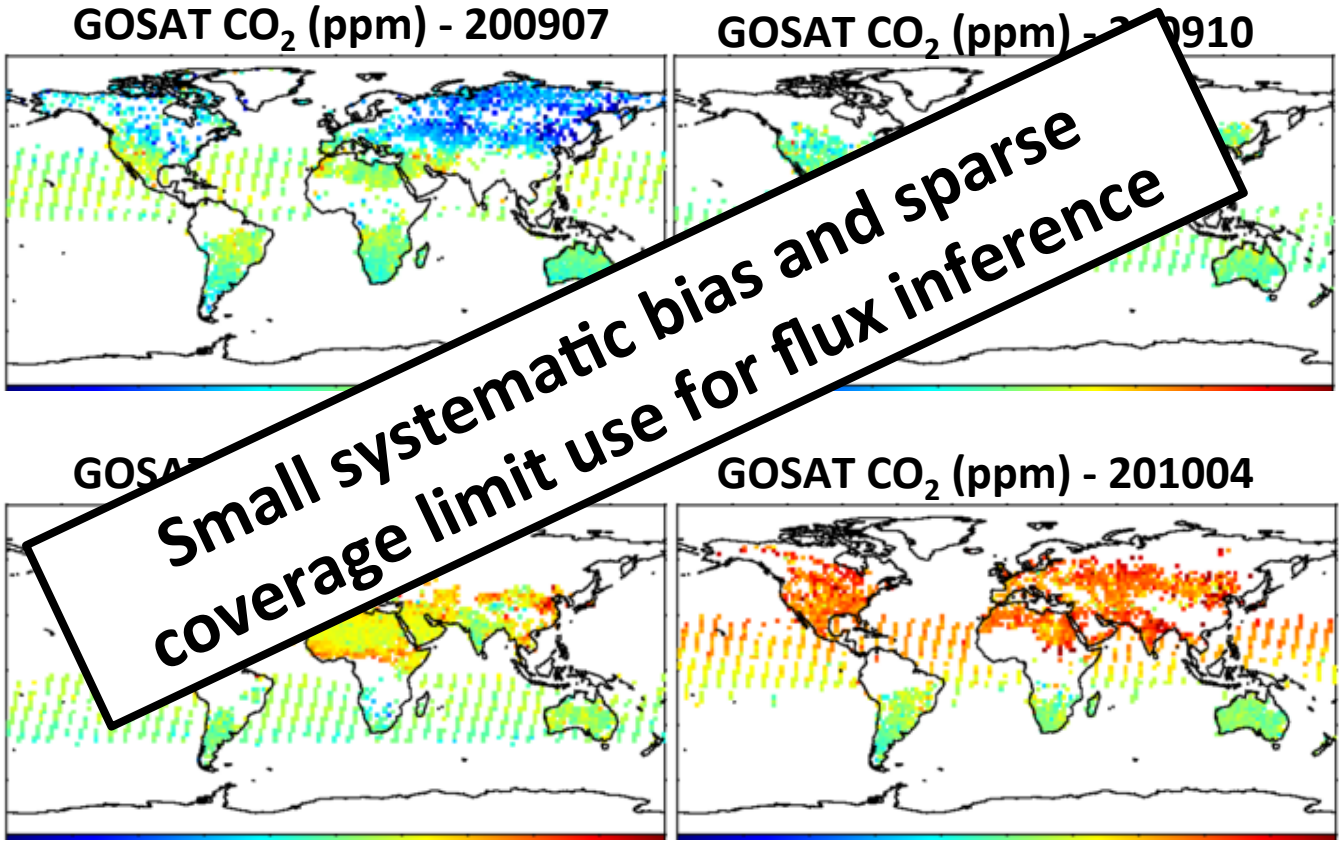


http://www.iup.uni-bremen.de/sciamachy/

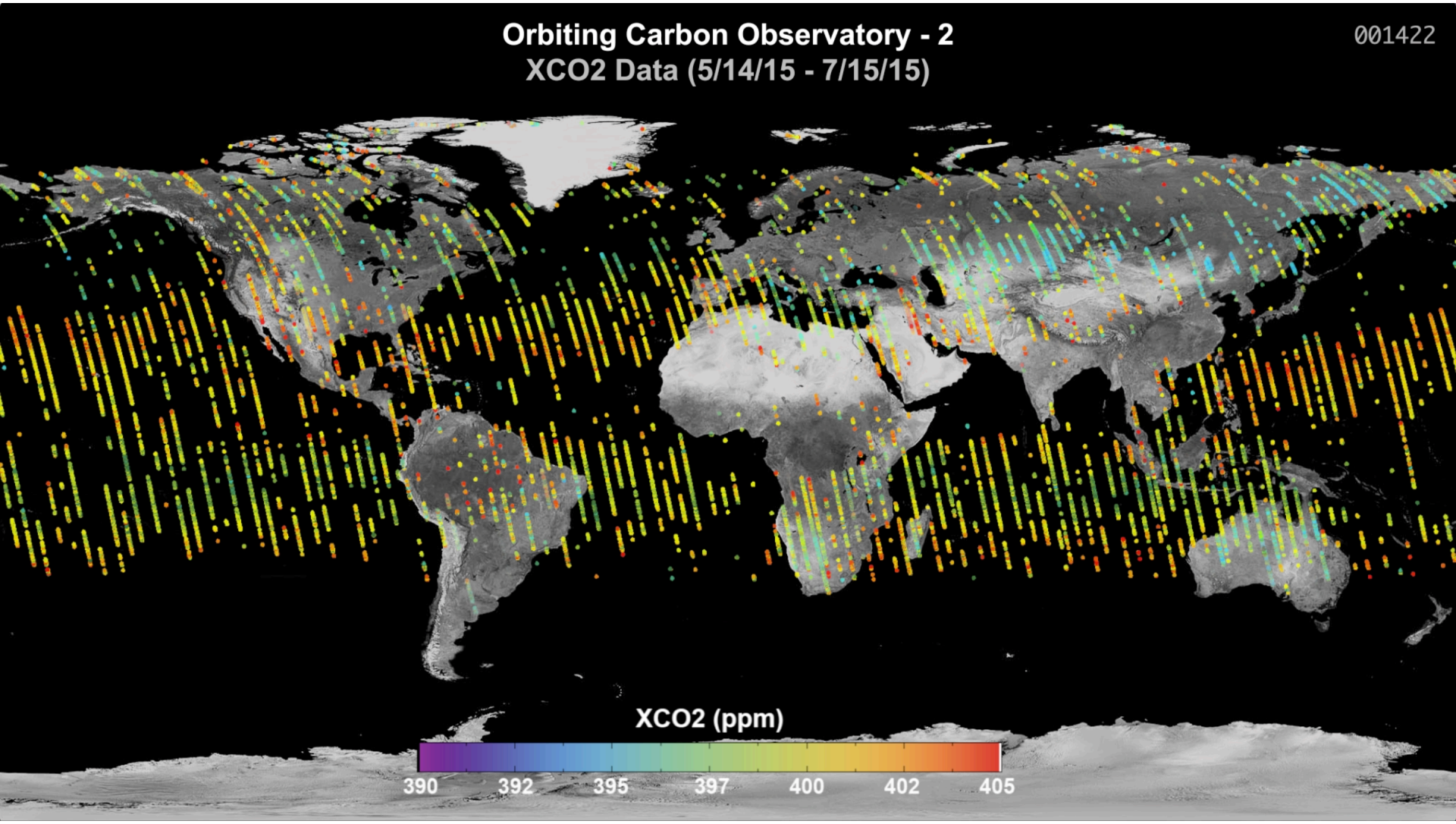
Current observing systems for CO_2

Japan's GOSAT satellite launches in 2009 has provided the best satellite CO_2 dataset to date with considerable improvements in accuracy

Passive technique requires sunlight, limits coverage in persistently cloudy regions, high latitudes during winter



OCO-2 - Spring 2015

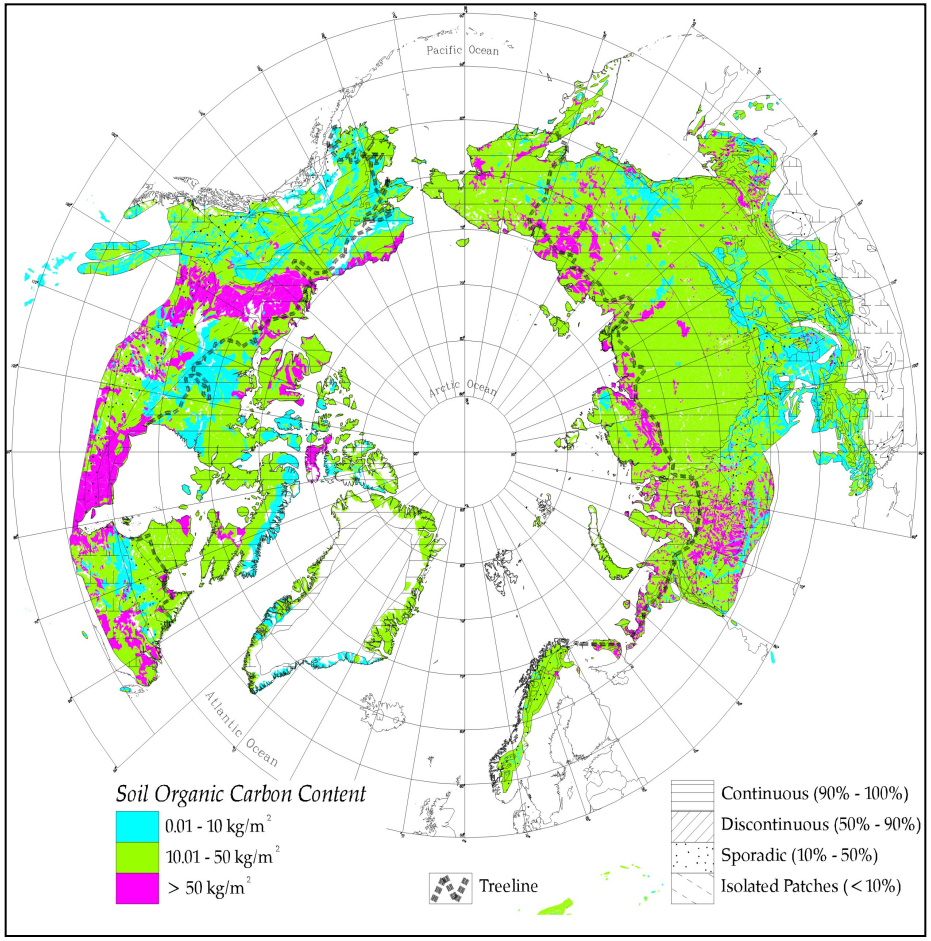


Big questions remaining for the carbon cycle

- Why do bottom-up land models underestimate the land carbon sink?
- Relative magnitudes of sink in N. America/ Tropics?
- How will land carbon flux change in the future?

New Assessment:

Carbon pools in the northern circumpolar permafrost region



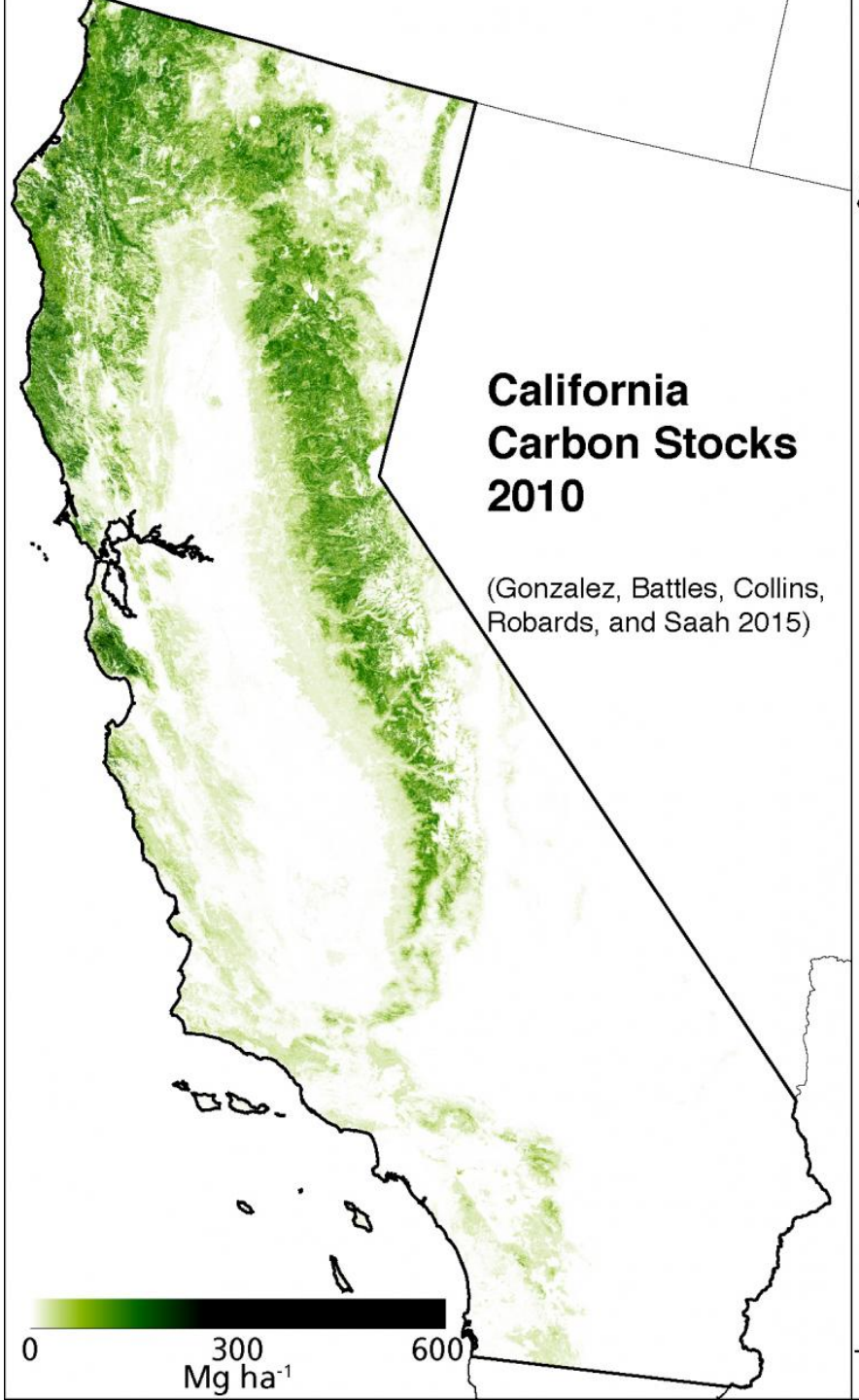
1 Pg = 1 billion tons or 10^{15} g

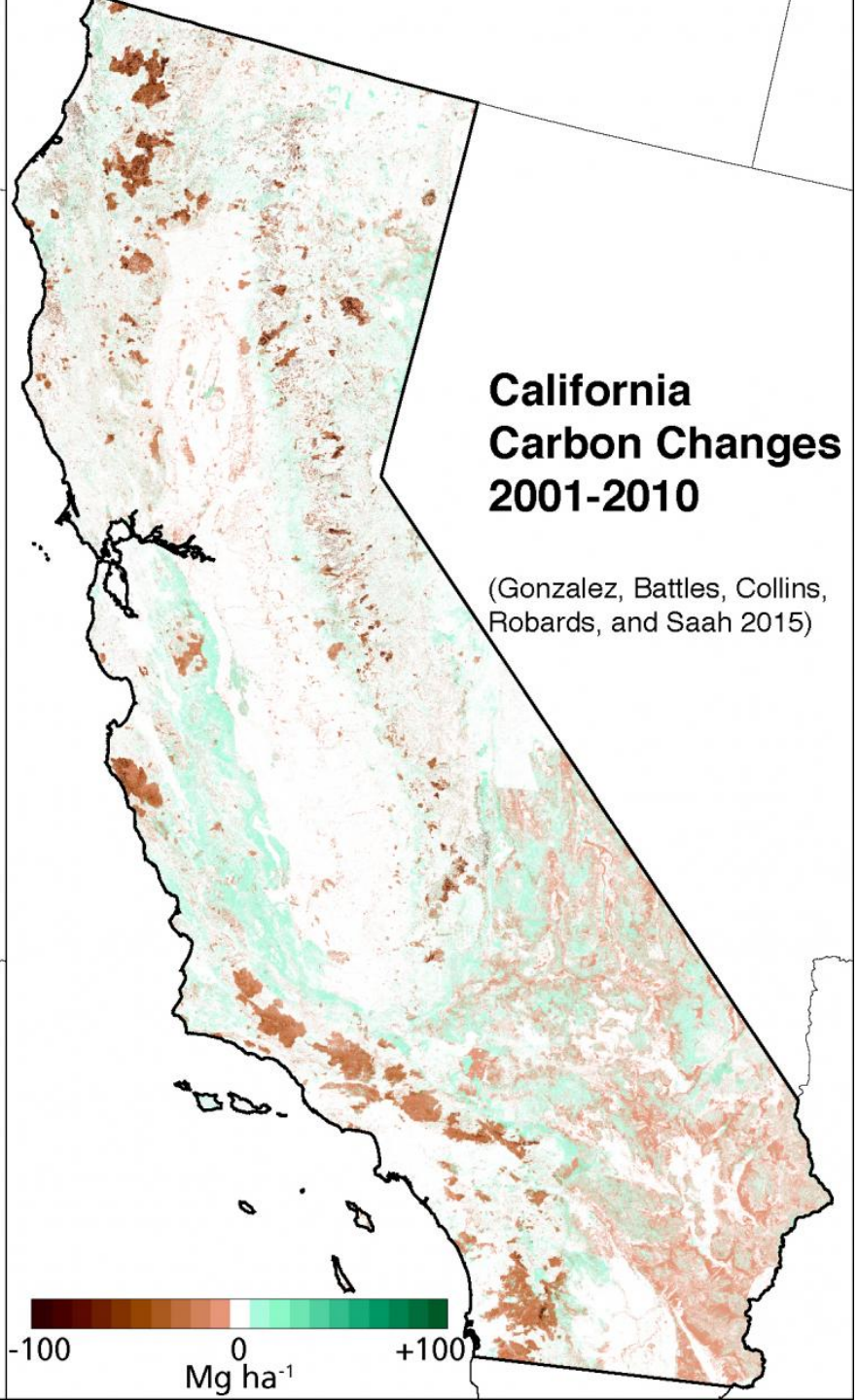
Permafrost zones	0-30 cm	0-100 cm
Continuous	110.38	298.75
Discontinuous	25.5	67.44
Sporadic	26.36	63.13
Isolated Patches	29.05	67.10
Total	**191.29**	**496.42**

Soil or deposit type	**C stocks**
Soils 0–300 cm	**1024**
Yedoma sediments	407
Deltaic deposits	241
Total	**1672**

Global Carbon Project

Tarnocai C, JG Canadell, EAG Schuur, P Kuhry, Mazhitova G (2009) Soil organic carbon pools in the northern circumpolar permafrost region. Global Biogeochemical Cycles 23, GB2023, doi:10.1029/2008GB003327.


California
Carbon Stocks
2010
(Gonzalez, Battles, Collins,
Robards, and Saah 2015)
0
300
600
Mg ha-1


California
Carbon Changes
2001-2010
(Gonzalez, Battles, Collins,
Robards, and Saah 2015)
-100
0
+100
Mg ha-1

Results from **The 2015 Carbon-Climate System** Workshop in Norman, OK

- *Developing and sustaining a time series of global atmospheric CO_2, CH_4, and CO concentrations with sufficiently small and understood biases at spatial and temporal resolutions that allow rigorous evaluation and improvement of models needed to reduce uncertainty in future predictions/projections.*
- *Improving attribution and quantification of patterns of carbon emissions, thereby reducing the growing uncertainty of anthropogenic emissions of carbon.*
- *Acquiring the critical measurements that allow attribution of fluxes to specific mechanisms and processes within terrestrial and marine carbon cycles. Many of these measurements are expected to be priorities for disciplines such as terrestrial ecosystems, ocean biology, biogeochemistry, and climate.*
- *Addressing how the natural dynamics of the carbon cycle and human activities feedback to influence future trajectory of the atmospheric carbon fraction.*

How do we decide the best measurement approach?

- Remote sensing techniques:
  - Passive systems – observations of near-IR spectra in reflected sunlight
  - Active systems – uses laser for illumination
- Orbital options:
  - Low Earth Orbit – global coverage, but observations of particular location limited
  - Geostationary Orbit – more frequent observations but limited coverage
- How do we decide what we need?
  - Modeling teams currently working to define Observing System Simulation Experiments (OSSEs) to determine benefits/weaknesses of different approaches