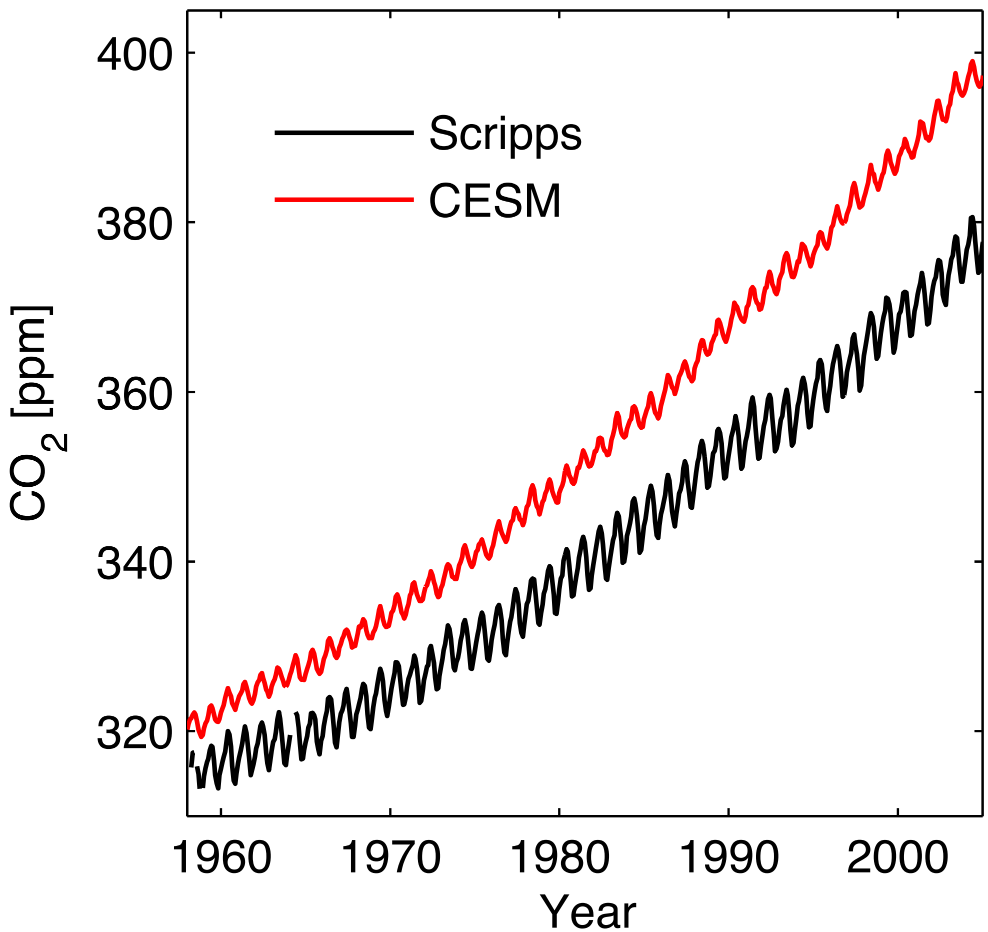
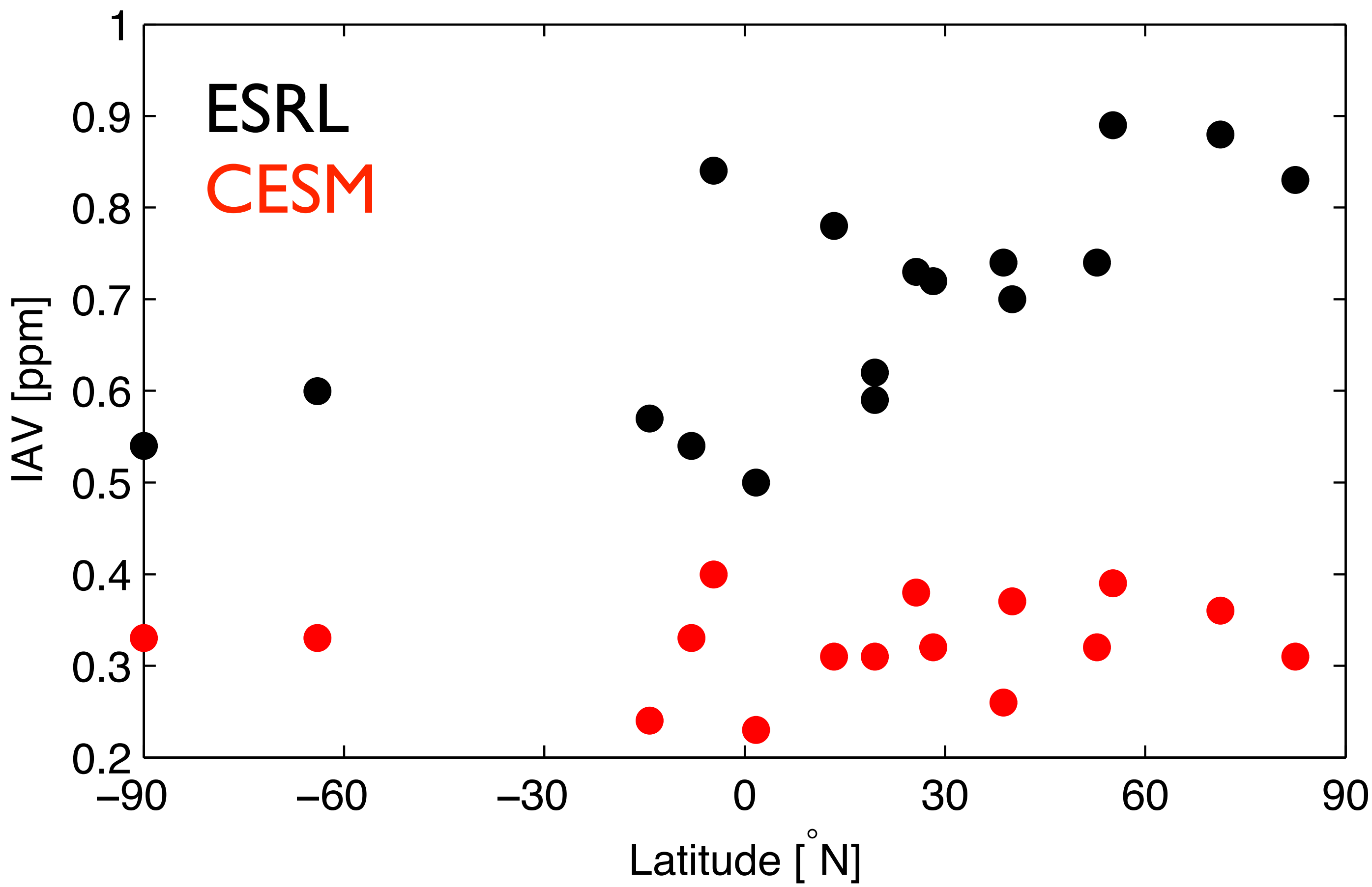
Constraints on ecosystem functional responses from atmospheric CO_2



Gretchen Keppel-Aleks
University of Michigan

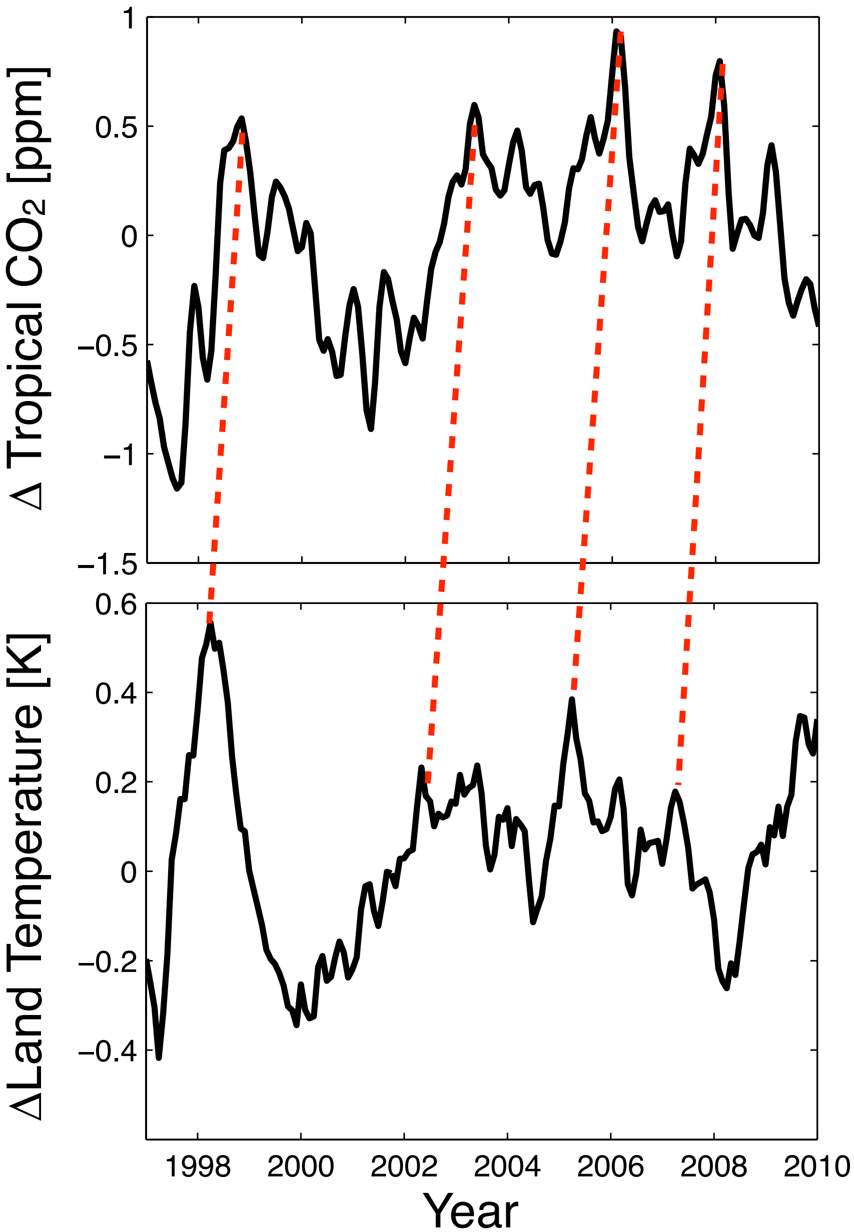
CESM Biogeochemistry Working Group Meeting
February 2014

Interannual Variability in Surface CO_2



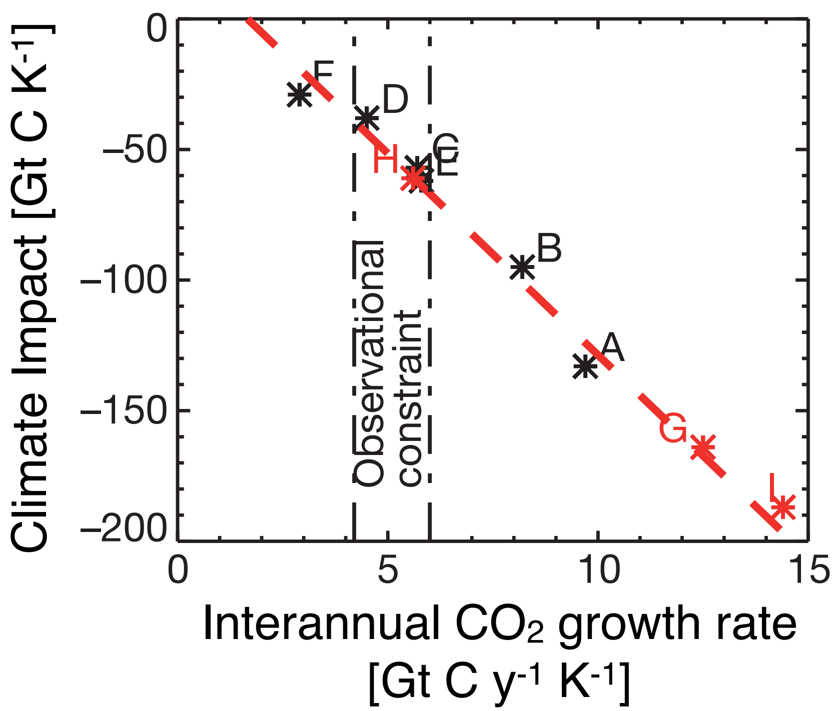
CESM underestimates variability in CO_2 at 2-10 year timescales.

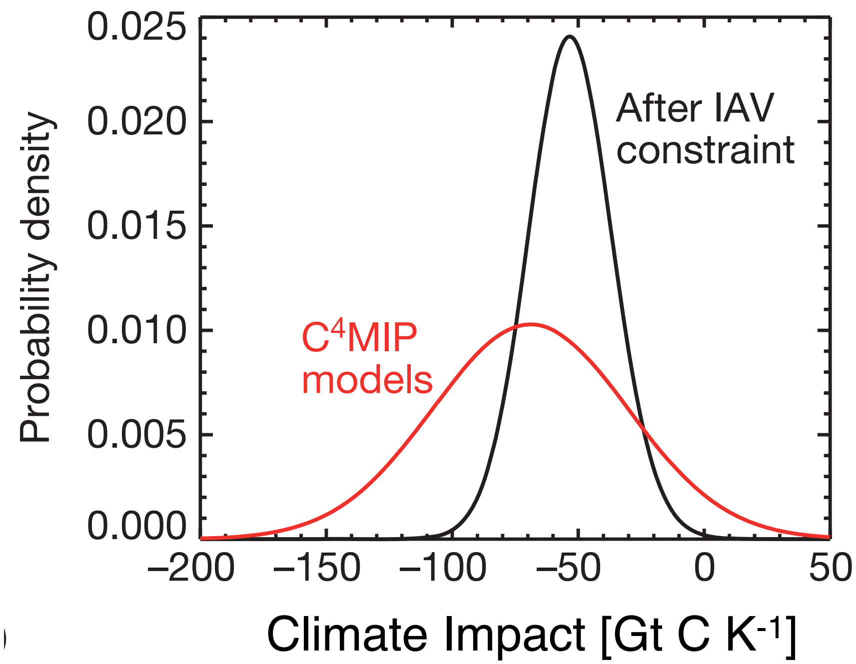
Phasing of interannual variability in CO_2



CO_2 IAV tracks tropical temperature variability.

Carbon-climate feedbacks and interannual variability

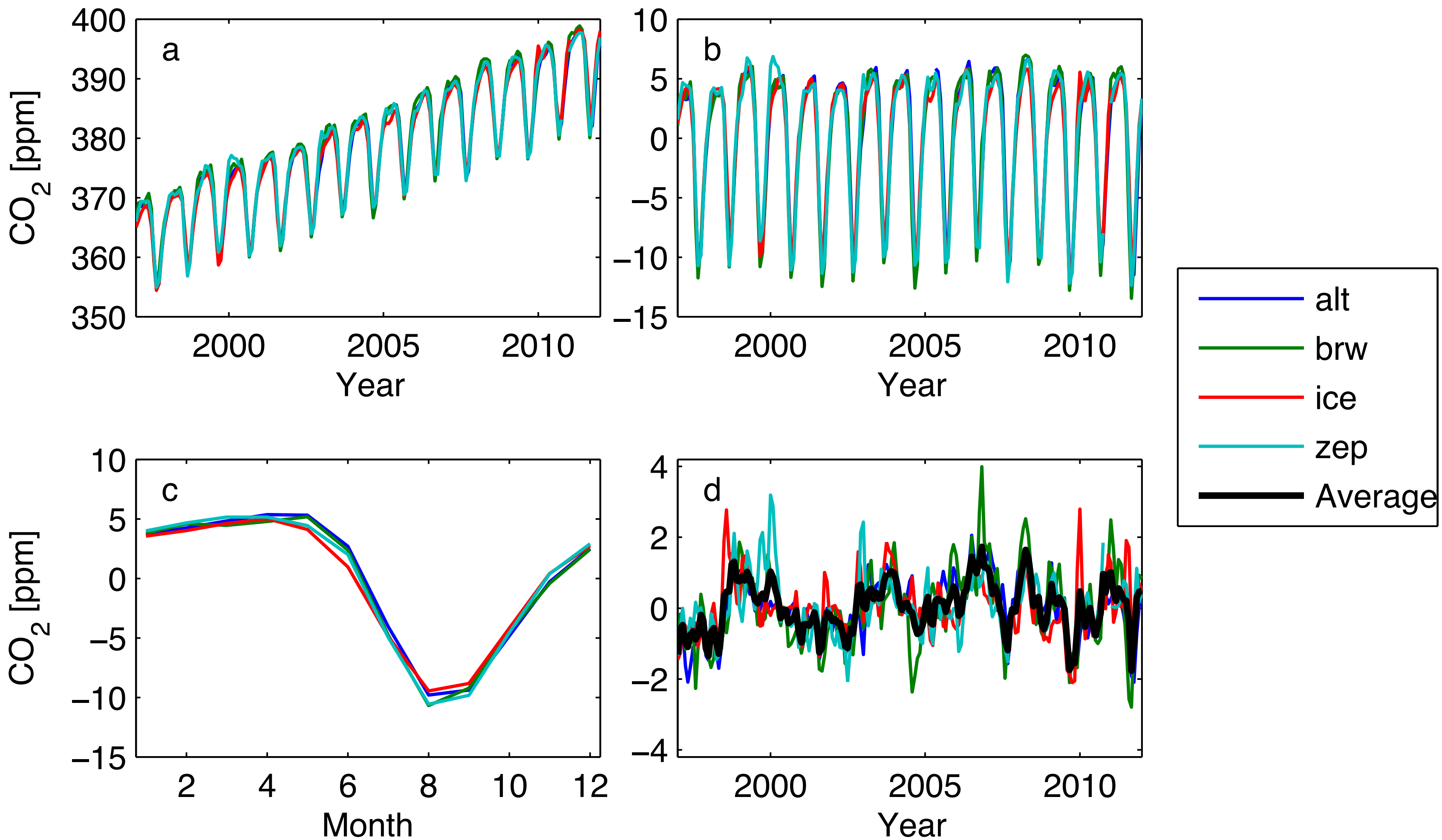




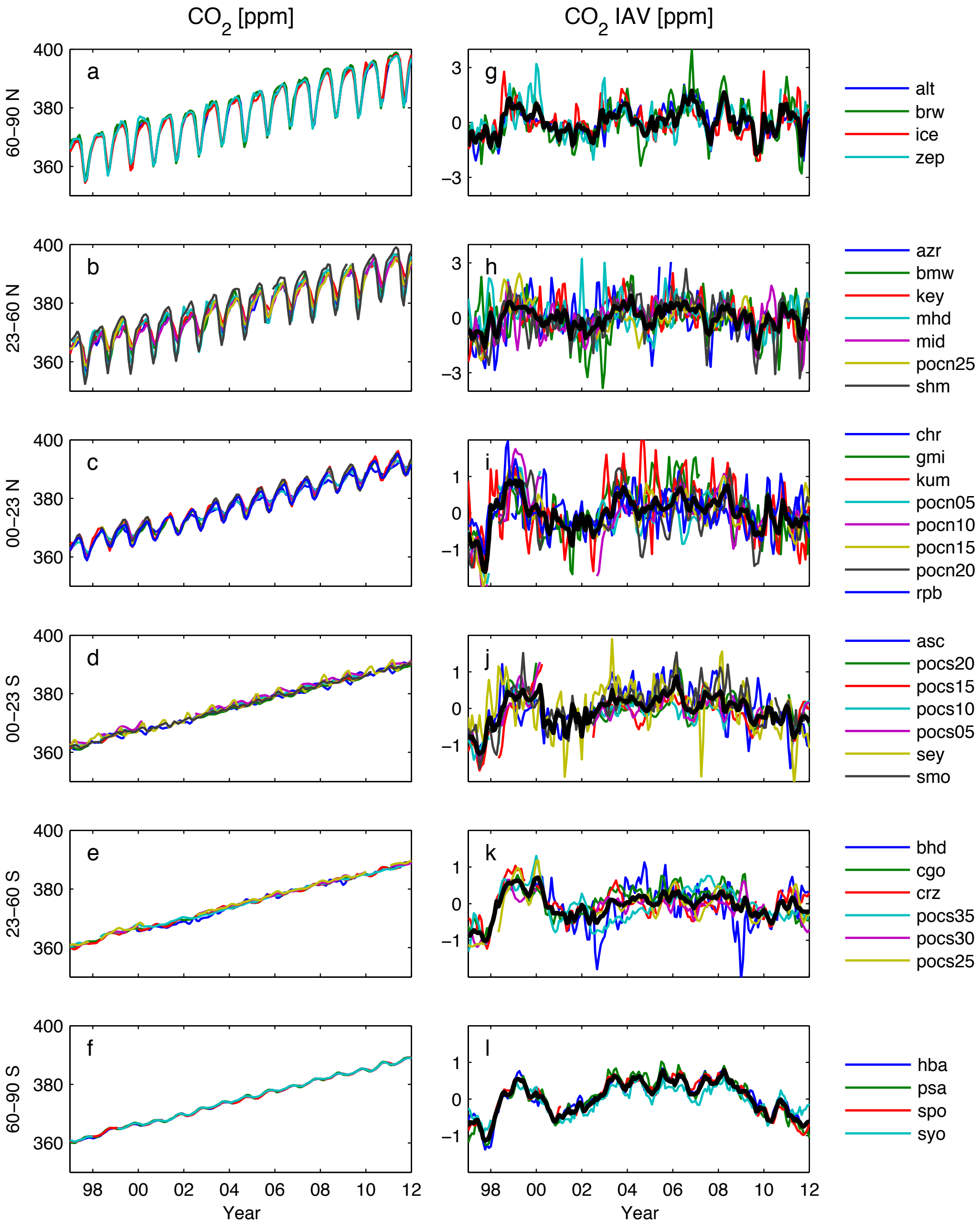
Interannual growth rate in atmospheric CO_2 may constrain the sensitivity of tropical carbon storage to future warming.

Cox et al., 2013

Calculating interannual variability in observations

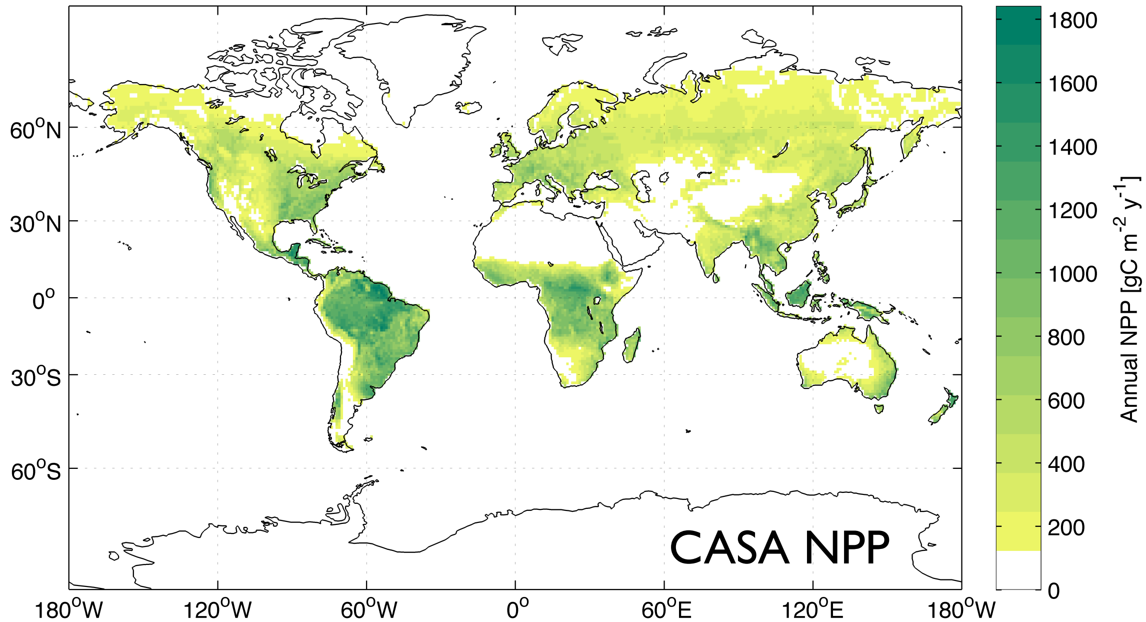


Interannual variability in CO_2 observations



CO_2 growth rate shows has spatial and temporal patterns.

Building Basis Fluxes for NEE and Fire



Temperature Stress

$$NEE_{\Delta T} = \alpha \cdot NPP_{ann} \left(T - \overline{T_m}\right) \cdot Q_{10}^{\frac{\overline{T_m} - 20}{10}}$$

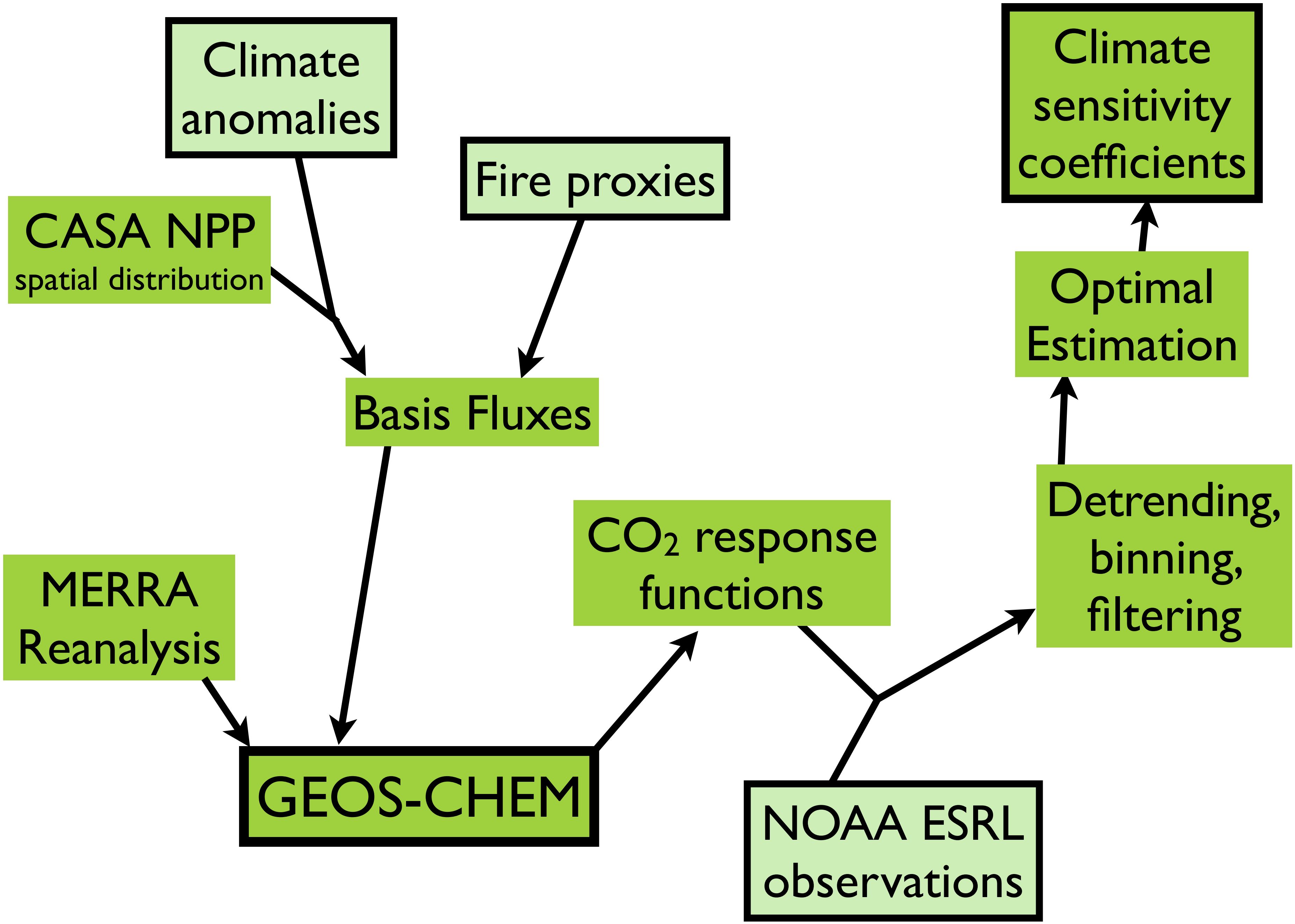
Drought Stress

$$NEE_{\Delta P} = \alpha \cdot NPP_{ann} \left(P - \overline{P_m}\right)$$

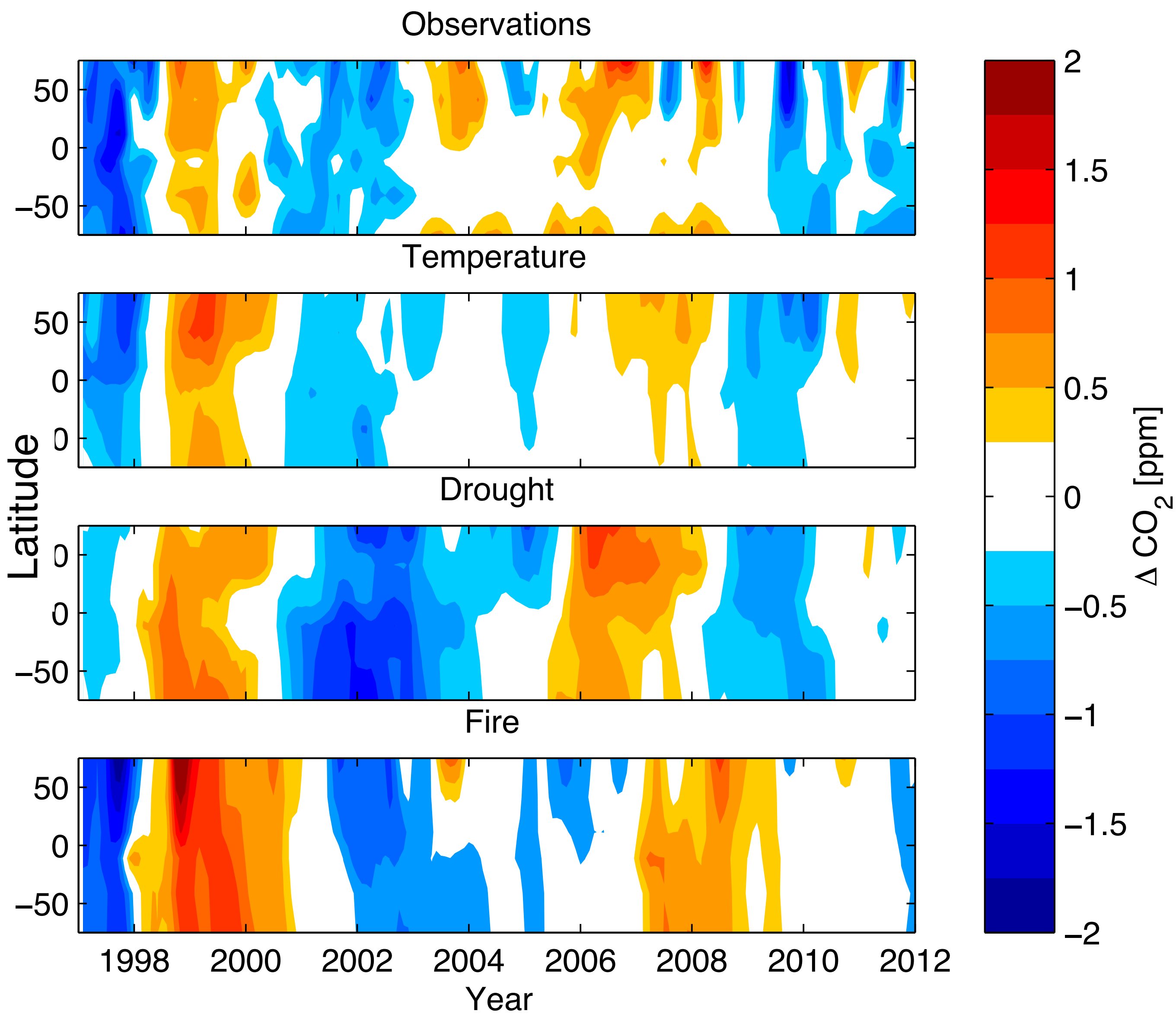
Fire Emissions

GFED emissions, ATSR Fire Counts

Experimental Design

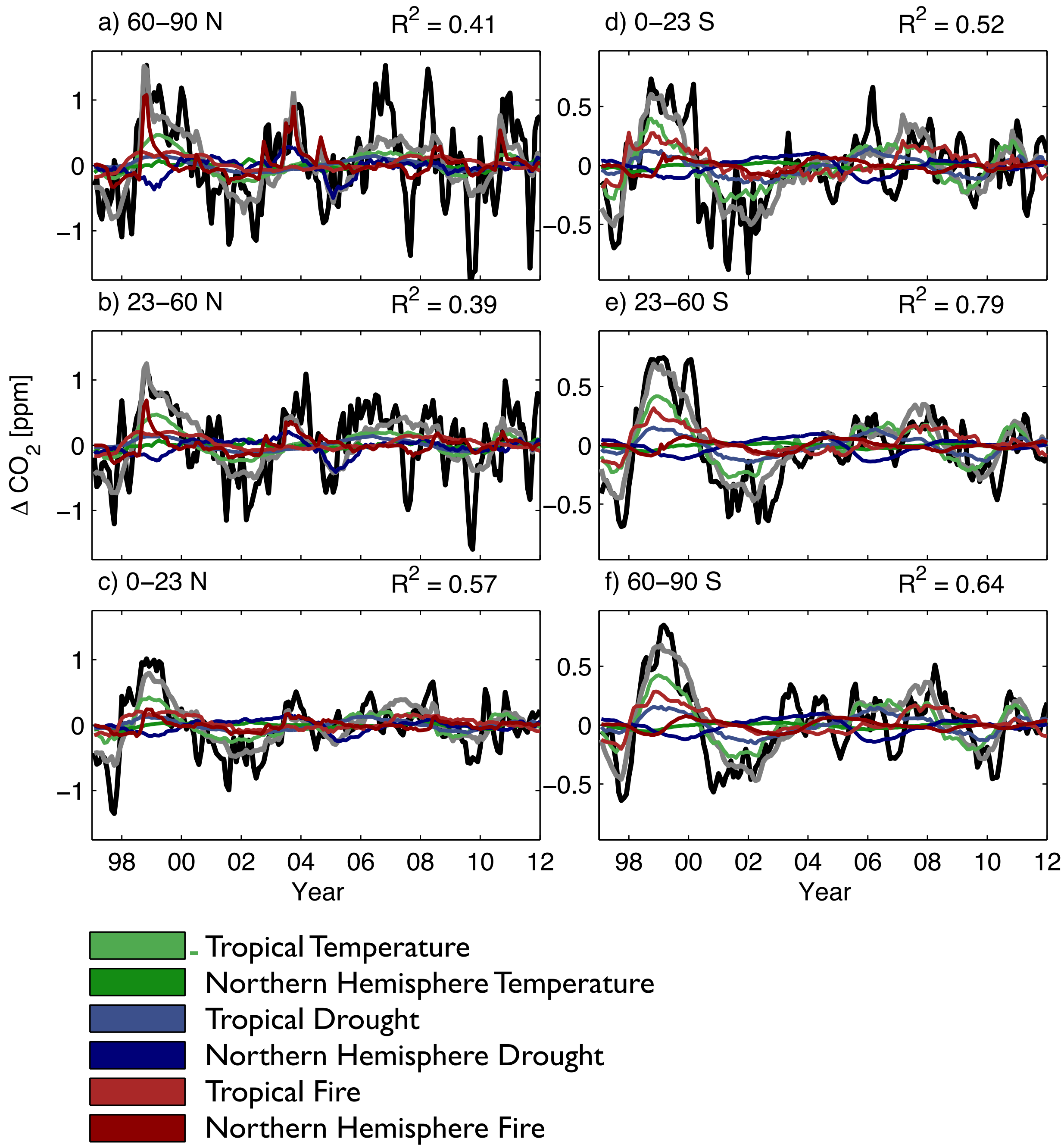


Global fingerprints from fluxes with 1 Pg C y^{-1} variance



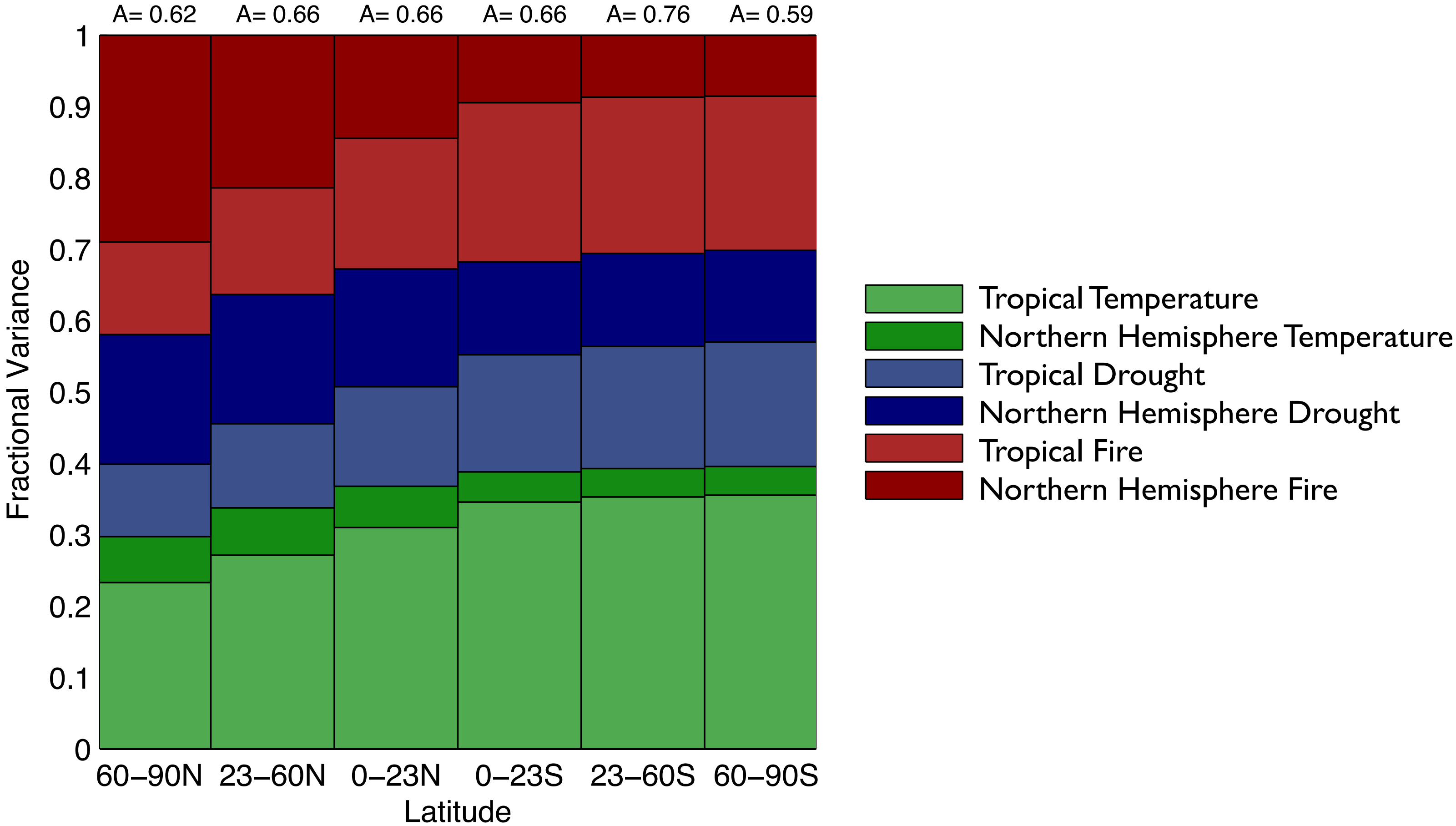
Climate-mediated processes leave fingerprints on atmospheric CO_2.

Modeling variability with multiple drivers



Relatively simple models can account for a high fraction of variability in atmospheric CO_2 growth rate.

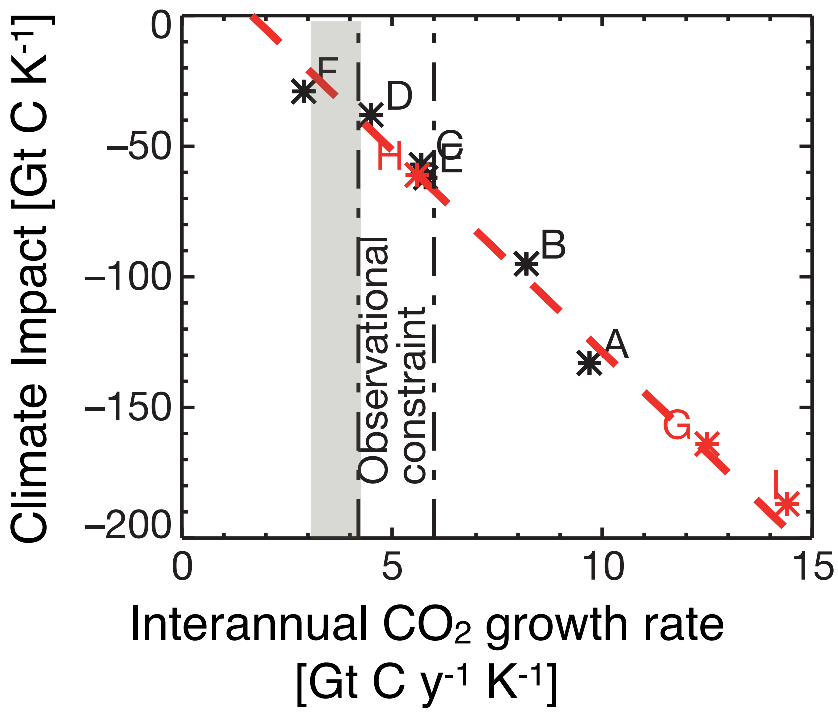
Modeling variability with multiple drivers



Fire, with a strong anthropogenic component, contributes significantly to variability in all latitude bands.

What can we say about climate sensitivity?

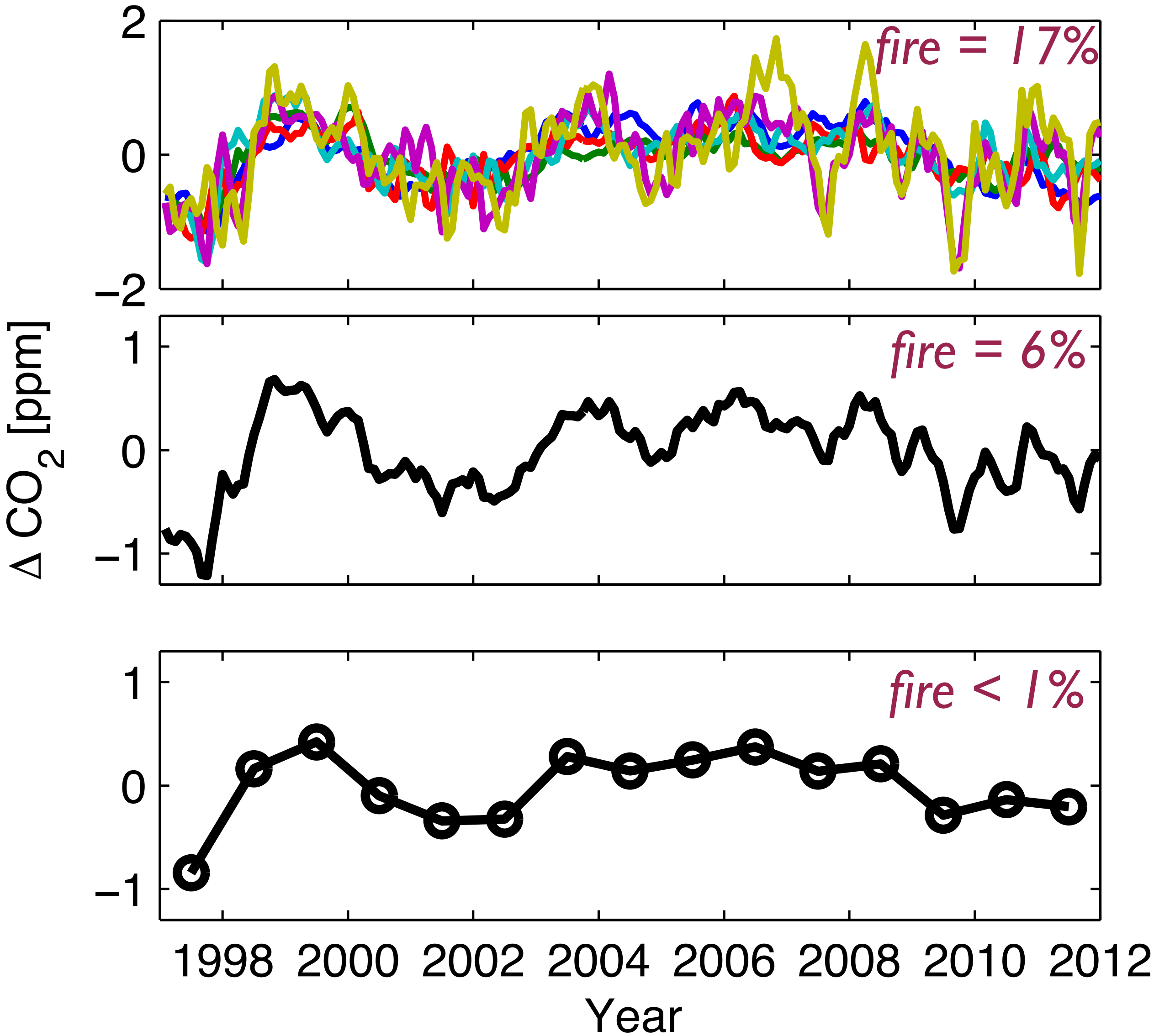
Model Case	Sensitivity factor
Tropical NEE response to temperature	3.9 ± 0.9 Pg C y^{-1} K^{-1}
Tropical NEE response to temperature, accounting for fires	2.9 ± 0.9 Pg C y^{-1} K^{-1}
Tropical NEE response to drought	-1.1 ± 0.3 Pg C y^{-1}
Tropical NEE response to drought, accounting for fires	-0.8 ±0.3 Pg C y^{-1}



Accounting for fire emissions reduces the apparent climate impact of tropical NEE, inferred from atmospheric observations.

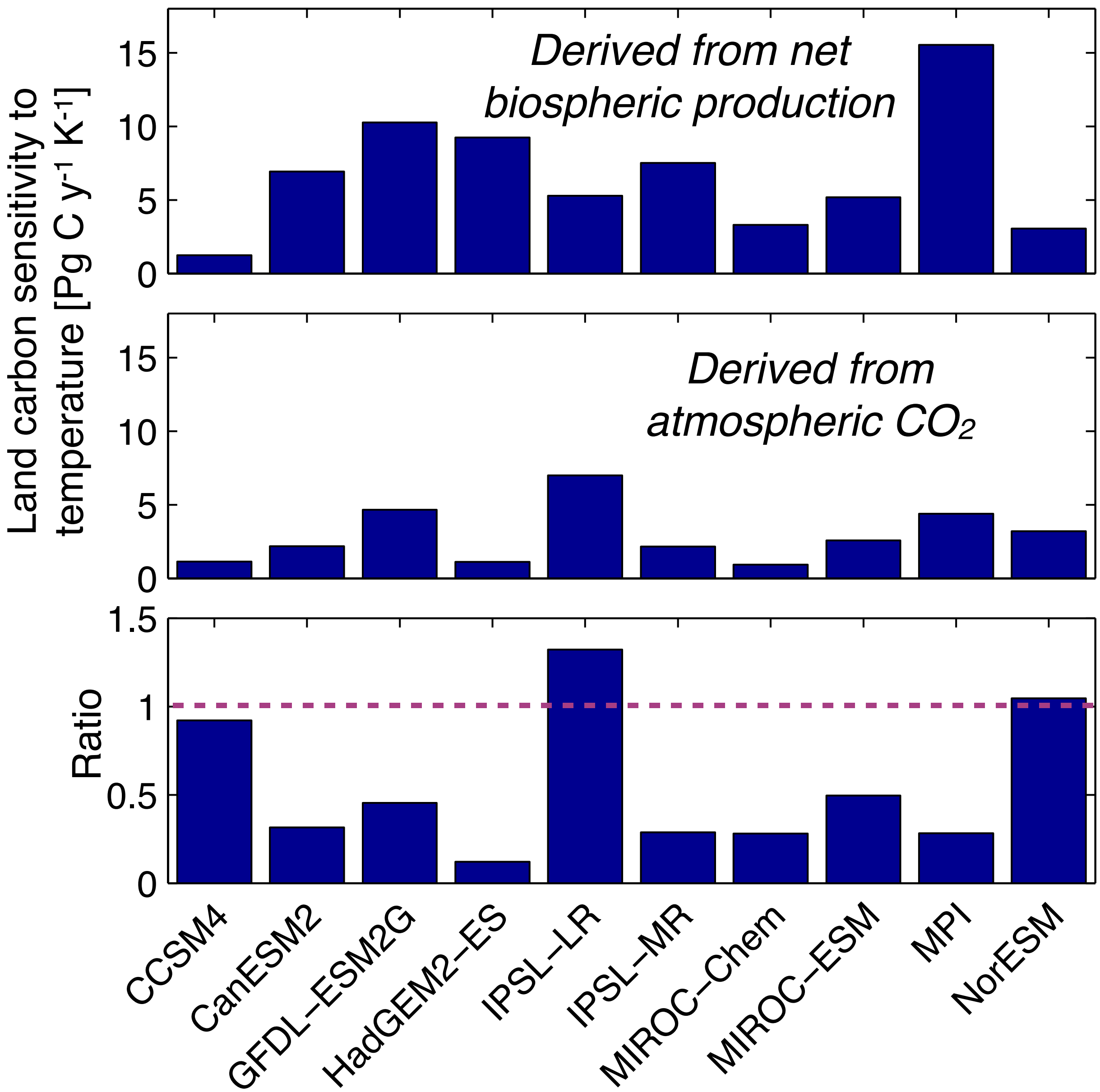
Cox et al., 2013

Are we attributing variability to the right mechanisms?



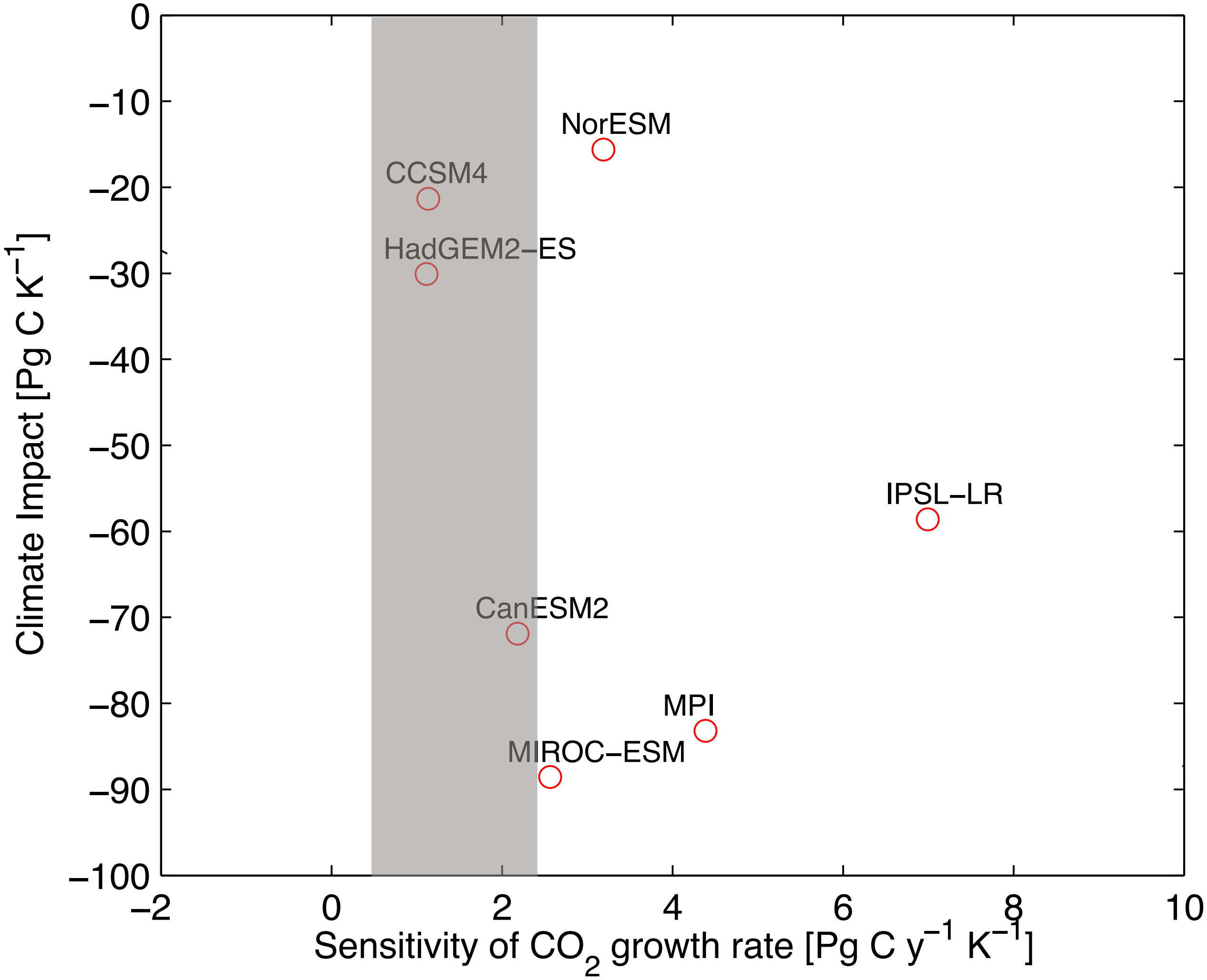
Degree to which observations are averaged can affect our mechanistic interpretation of sources of variability.

Sensitivity from land vs atmospheric diagnostics



Using model-derived atmospheric, rather than land, carbon anomalies damps the apparent climate sensitivity.

Modeling variability with global fluxes



Across CMIP 5 ensemble, no emergent constraint on carbon fluxes.

Climate impact from Arora et al., 2013

Discussion and Conclusions

Including the proper mechanisms to account for carbon cycle variability is necessary for a prognostic ESM.

Temperature, drought, and fire covary, with contributions from drought and fire dominating CO_2 IAV.

Method of calculating diagnostics for climate sensitivity is crucial for developing consistent constraints