The Anticorrelation of Northern Hemisphere Seasonal Cycle Amplitudes in Column-Averaged CO_2 with High Latitude Surface Temperature

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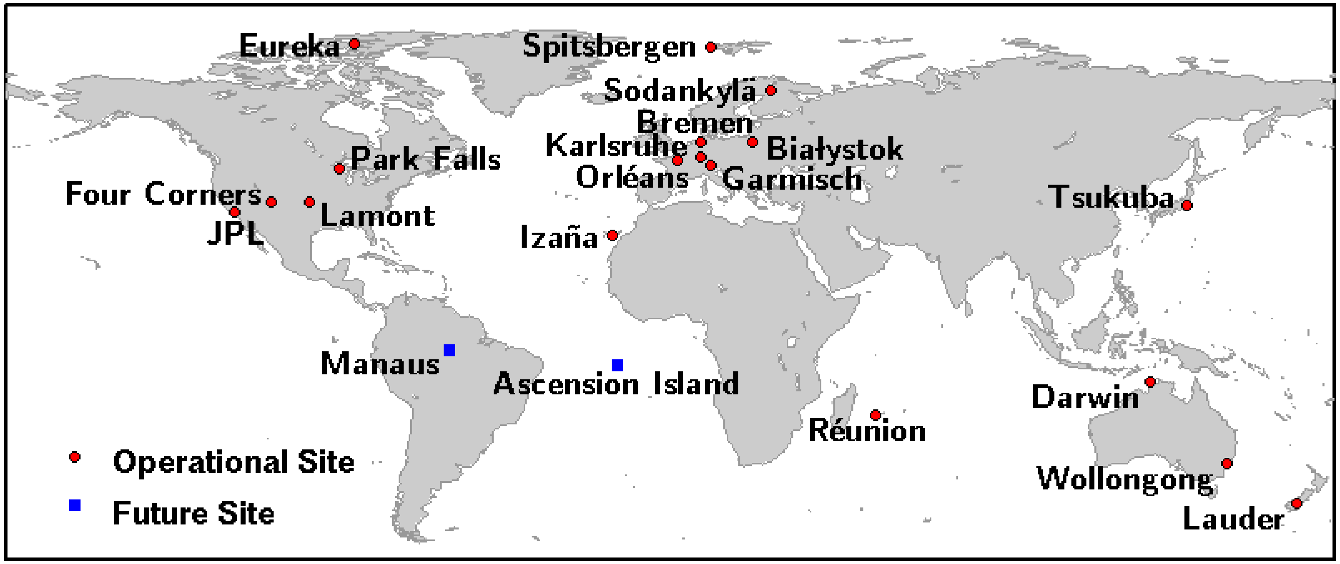
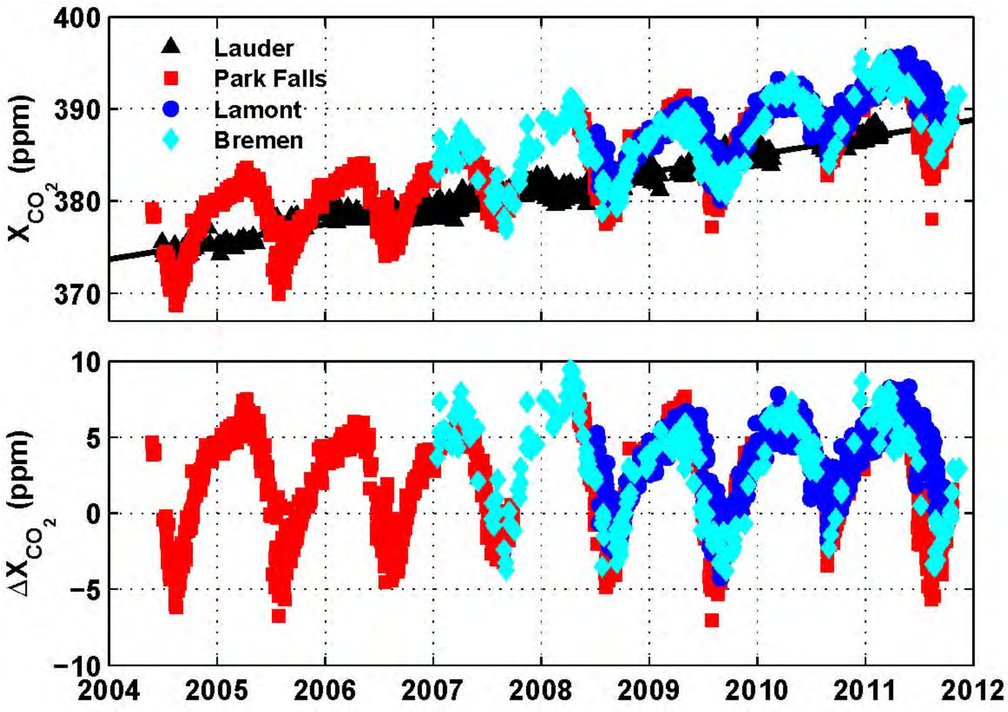
Introduction: Total Column Measurements



- Global ground-based measurements of Xco_2 from the Total Carbon Column Observing Network (TCCON)
- Solar-viewing Fourier transform spectrometers
- High spectral, temporal resolution
- Calibrated to WMO through aircraft intercomparisons
- Accurate and precise to 0.25% (0.8 ppm) in Xco_2
- Data from Park Falls (USA), Lamont (USA), Bremen (Germany) and Lauder (New Zealand) used in this study

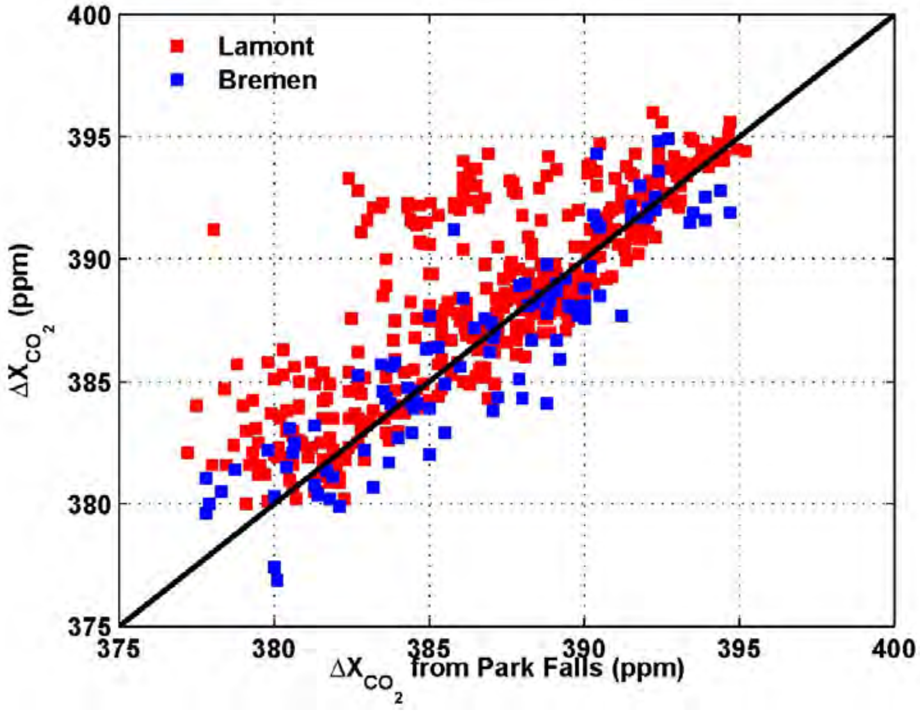
Measurements of the Xco_2 record

- Top panel shows Xco_2 from a southern hemisphere site (Lauder), and three northern hemisphere sites (Park Falls and Lamont, USA and Bremen, Germany)
- Lower panel shows de-trended Xco_2 in the northern hemisphere
- Obvious interannual variability tracked by the three data records
- 2009 had a strong drawdown
- 2010 had a weak drawdown



Total Columns and the Hemispheric Signal

- X_{CO_2} at Lamont, Bremen and Park Falls are well-correlated
- These three sites represent the hemispheric signal in X_{CO_2}
- Range is ~15 ppm over several years (secular increase + seasonal cycles)



Total Columns and the Hemispheric Signal

- Hemispheric signal from the three TCCON stations expected from models.
- Hemispheric-scale forcings lead to increases in the Xco_2 at all northern hemisphere sites
- (a) Amplification to the seasonal cycle amplitude.
- (b) The estimated Xco_2 increases proportionally at each of the TCCON sites.
- We anticipate that the seasonal cycle amplitudes will change in the same way for all sites.

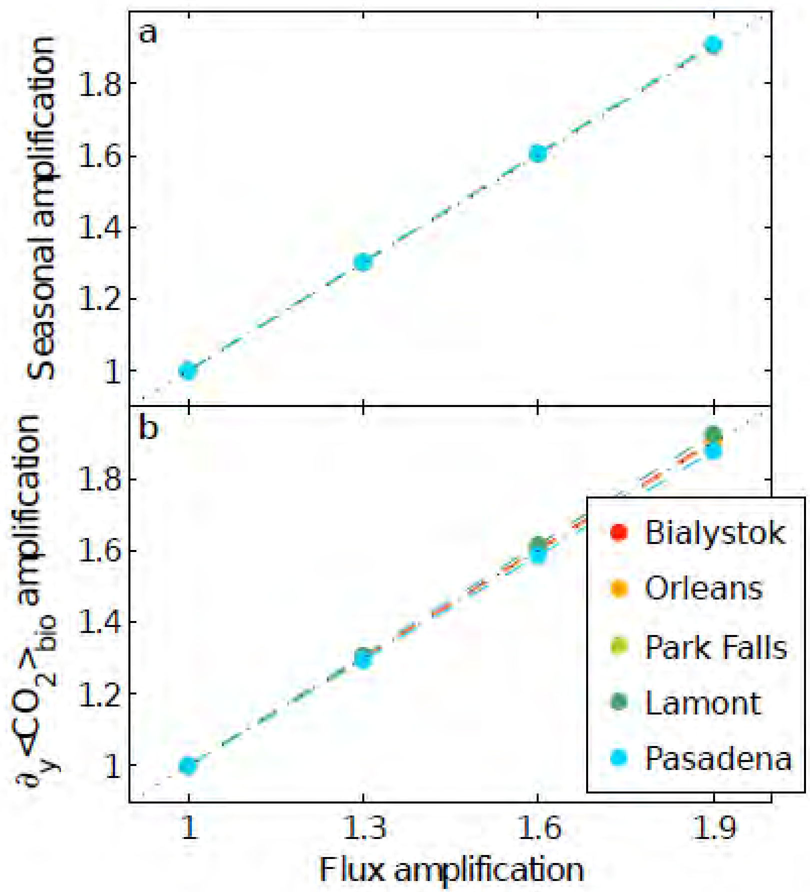
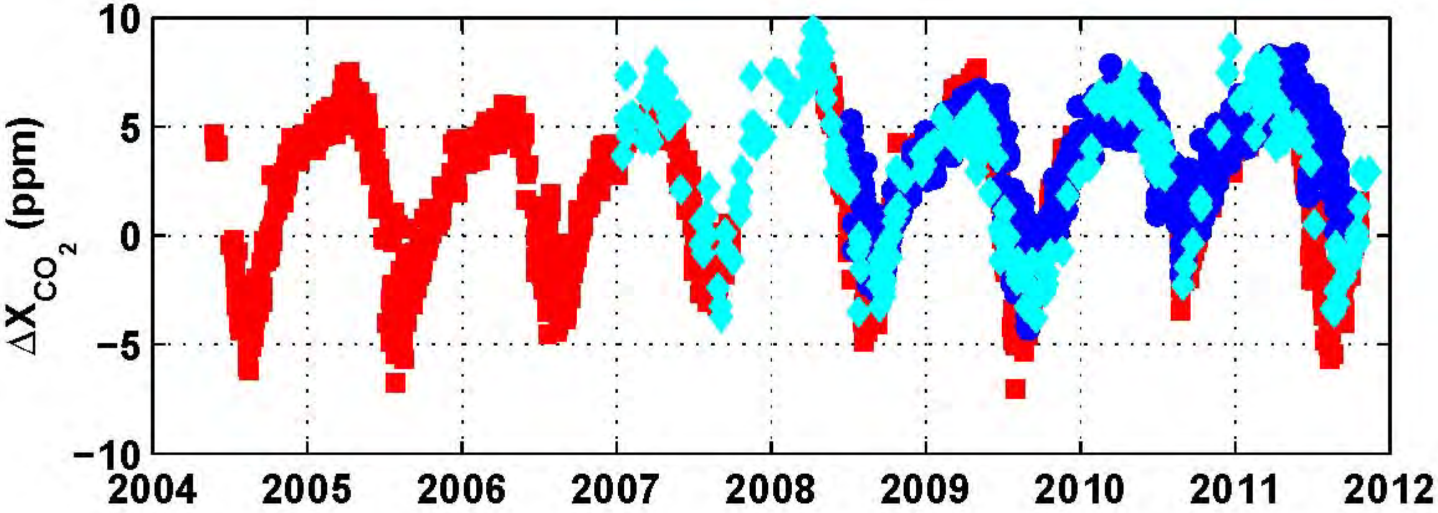


Fig 8, Keppel-Aleks, G., Wennberg, P. O., & Schneider, T. . *ACP*, 2011.

Amplitude changes in the Xco_2 record

- We have ~4 ppm change in seasonal cycle minimum from year-to-year: 2 Pg C change.
- Using the CASA growing season respiration field, scaled by Keppel-Aleks, Wennberg and Schneider (2011) weights to increase NEE to match column observations, the NH has a flux of ~9 pg C
- This represents a ~20% change in C from year to year!

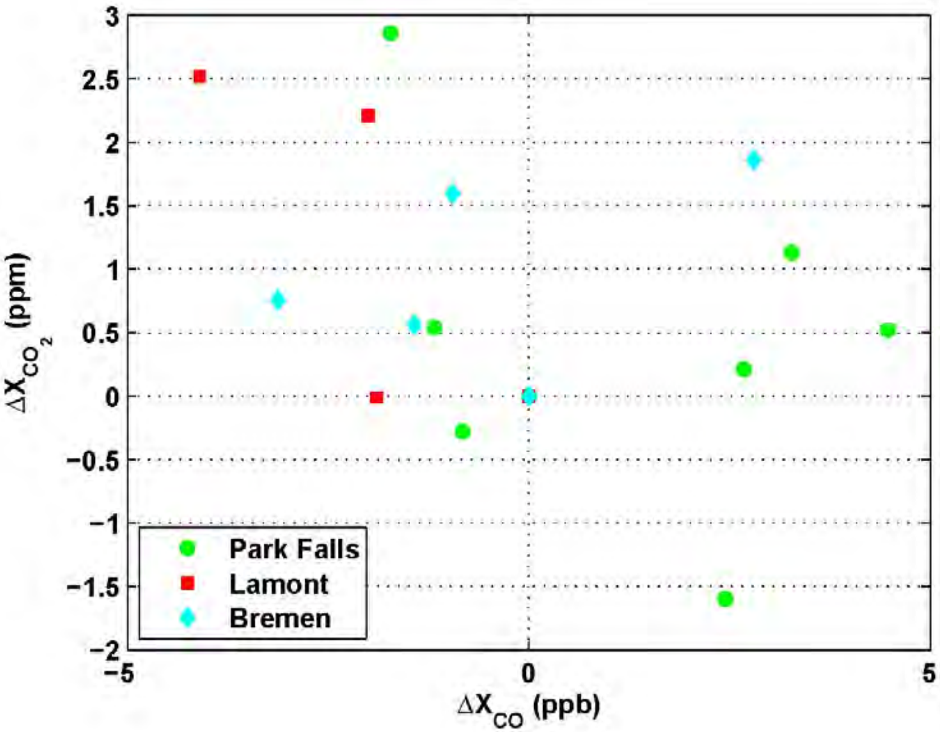


Possible Causes for the Interannual Variability in Xco_2

- Interannual variability in **atmospheric dynamics** could cause interannual variability in Xco_2
  - This is shown to be unlikely in Keppel-Aleks et al. 2011, but we will pursue this further using GEOS-CHEM.
- When **fires** are present, more CO_2 is released into the atmosphere
- As the biospheric **respiration** increases, atmospheric CO_2 increases
- As the soil moisture decreases, net **primary productivity** decreases, removing less CO_2 from the atmosphere

Fires?

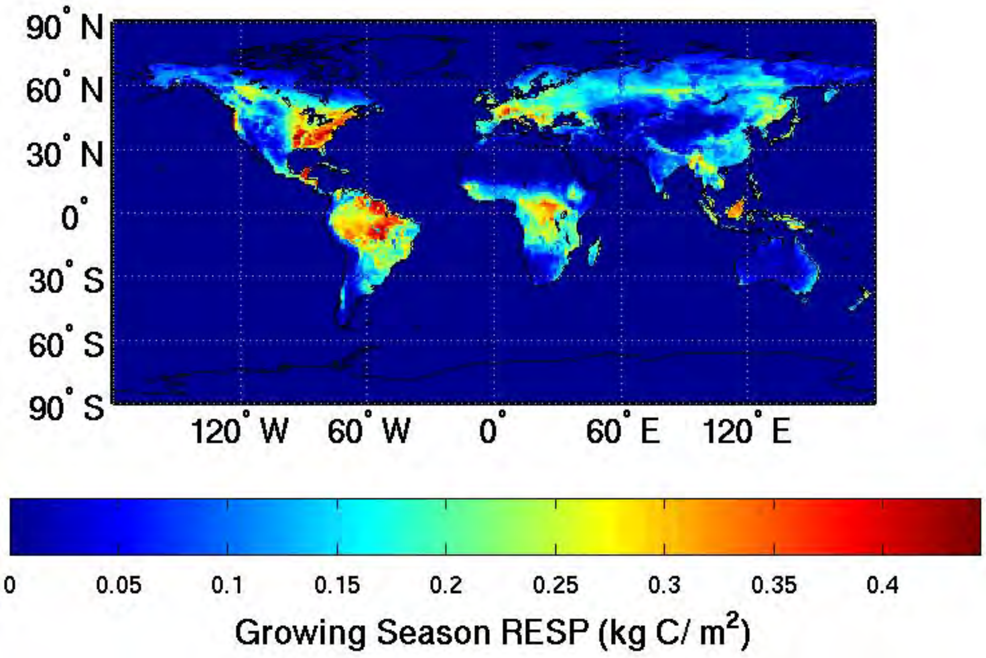
- The Xco_2 anomalies do not correlate well with the Xco anomalies
- The correlation is weak, and of the wrong sign!
- Further work will involve including GFED in the simulations to test the sensitivity of the Xco_2 to fires



Monthly mean seasonal cycle minimum ΔXco_2 versus ΔXco

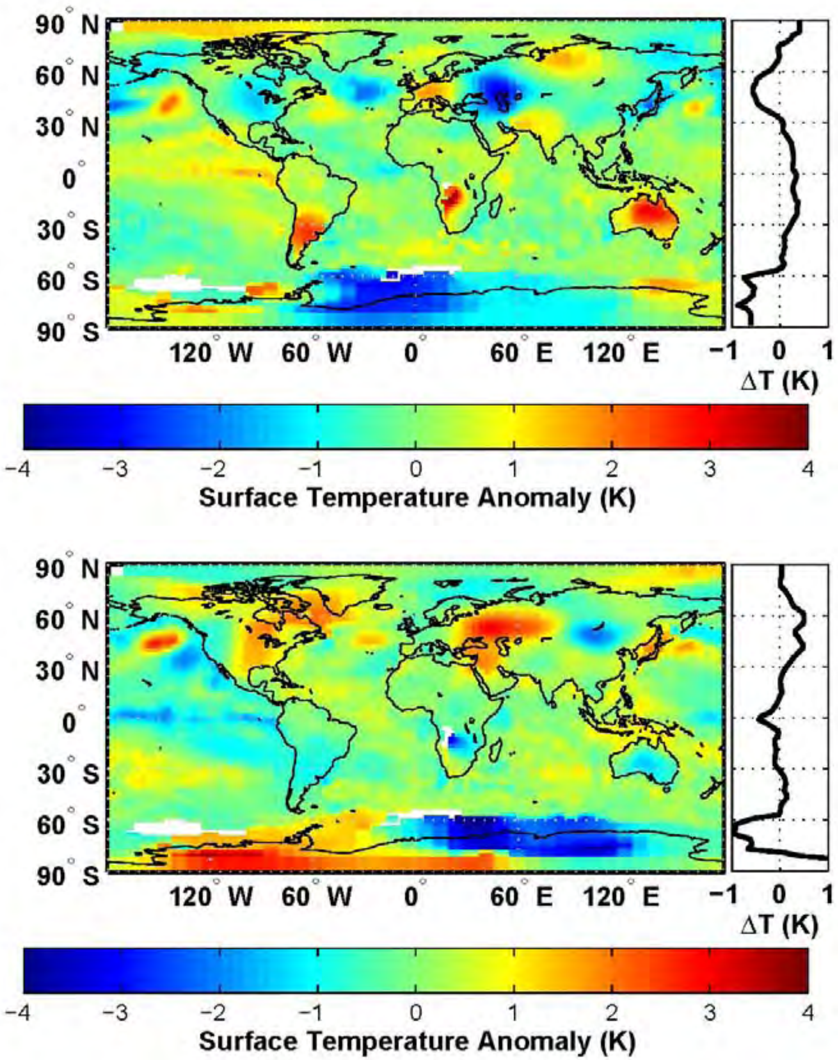
Respiration?

- Respiration is known to be strongly modulated by surface temperature
- Is the seasonal cycle amplitude correlated with surface temperature in regions with significant NEE?



Measurements of Surface Temperature Anomaly

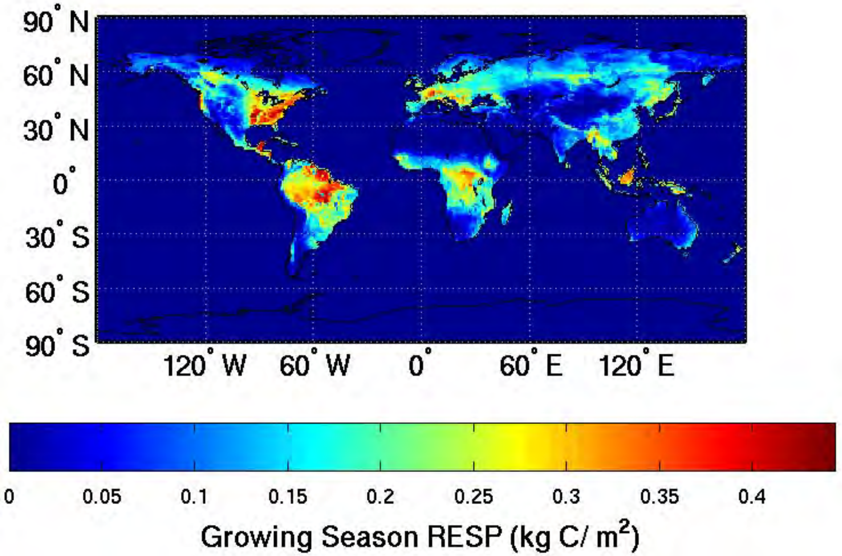
- Surface temperature anomalies from GISS show differences in northern hemisphere temperatures between 2009 (top) and 2010 (bottom)
- 2009 was a cold year
- 2010 was a warm year
- (Recall that 2009 had a strong drawdown, and 2010 had a weak drawdown)

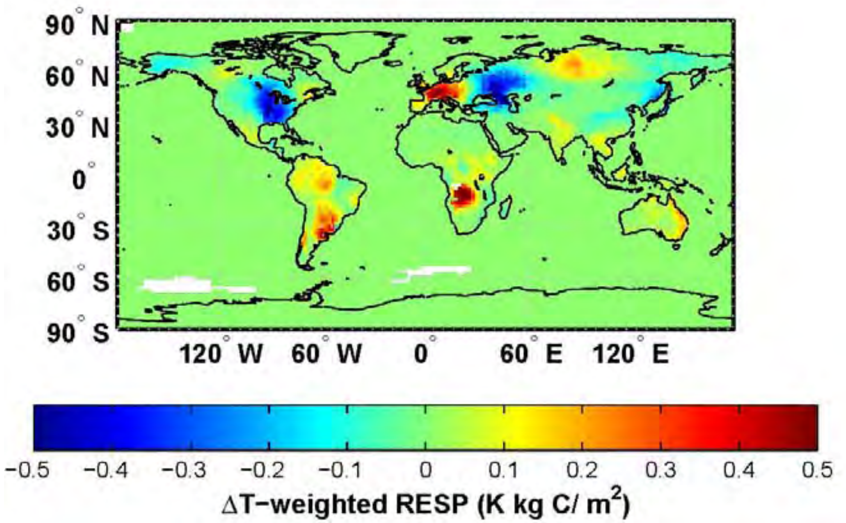


Hansen, J., Ruedy, R., Sato, M., & Lo, K. (2010). *Rev. Geophys*

Surface Temperature and Seasonal Cycle Minima

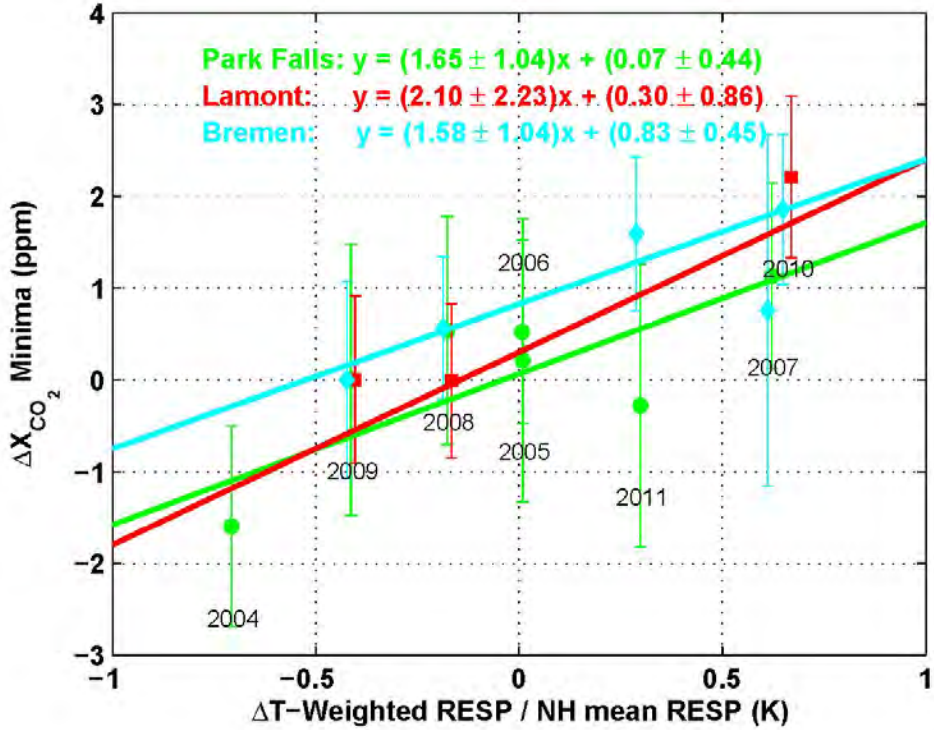
- Since Xco_2 is related to fluxes, the surface temperature anomalies should be important only where there is significant respiration
- Top figure is integrated growing season respiration from CASA
- Bottom figure weights the respiration with the 2009 temperature anomaly

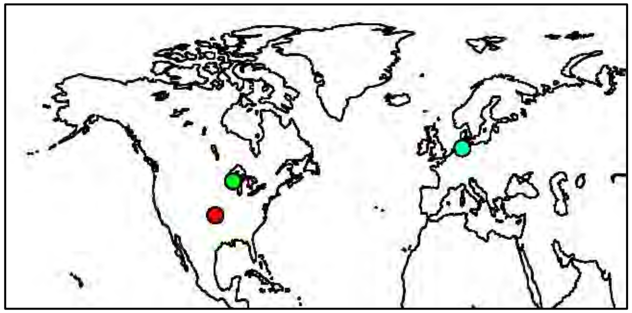




The Relationship between Xco_2 Minima and R-weighted Temperature

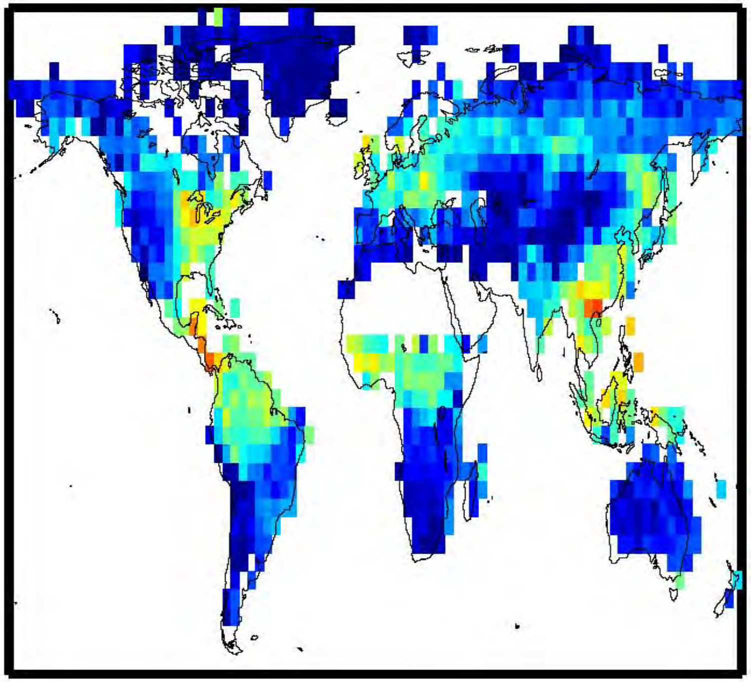
- Remarkably similar relationship at three mid-latitude sites
- Results in a relationship of ~1.6 ppm/K
- Lamont is at 36°N, sometime in the subtropics, which could lead to the small discrepancy
- If we use scaled CASA respiration, "Q10" is 2.7 [1.4,4.8].
- R a likely candidate for accounting for much of the interannual variability





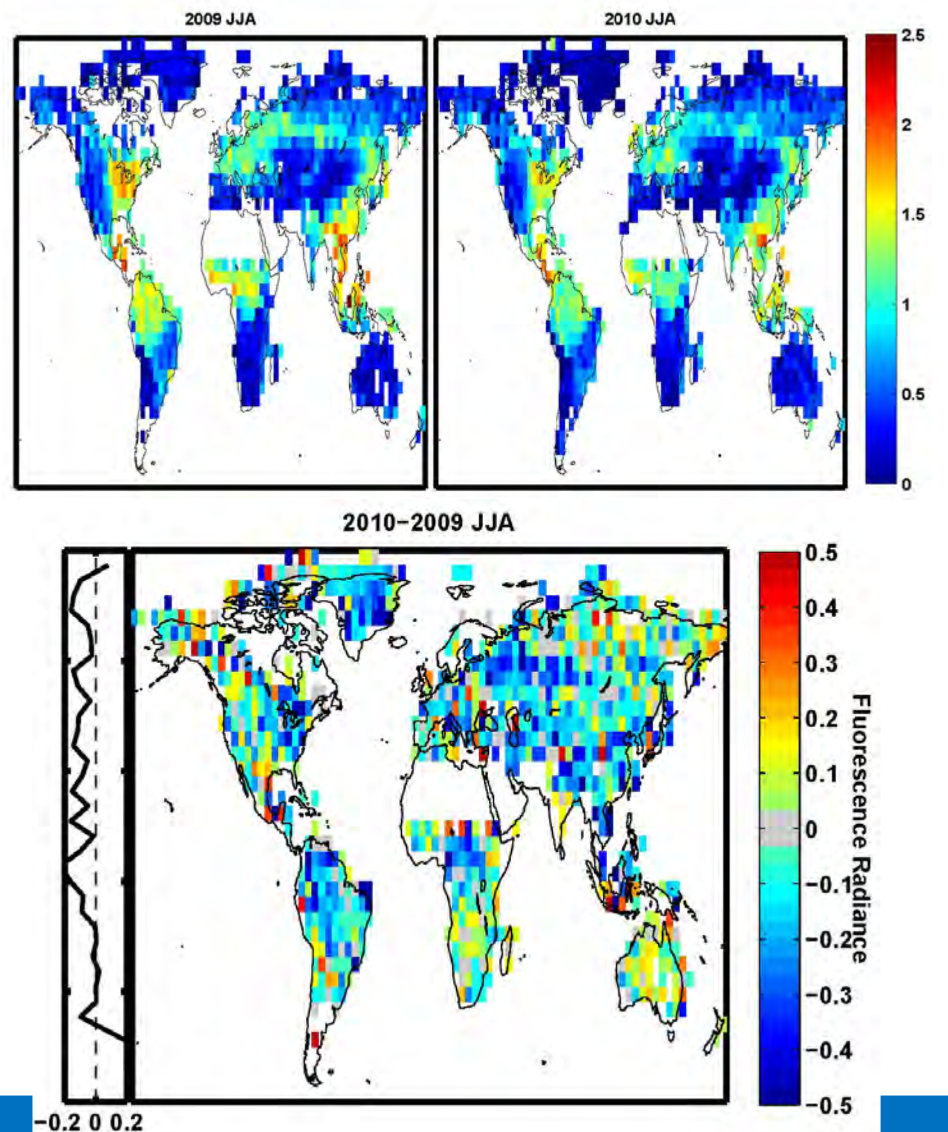
Gross Primary Productivity?

- Drought and temperature are known to be correlated
- Drought can suppress GPP
- Can we see difference in GPP between 2009 and 2010?



Measurements of Chlorophyll Fluorescence Show Interannual Variability

- Chlorophyll fluorescence radiances measured from GOSAT data show differences between 2009 (left panel) and 2010 northern hemisphere summertime
- 2009 shows more fluorescence, hence more vegetation (or GPP)
- Consistent with a stronger 2009 drawdown



Conclusions

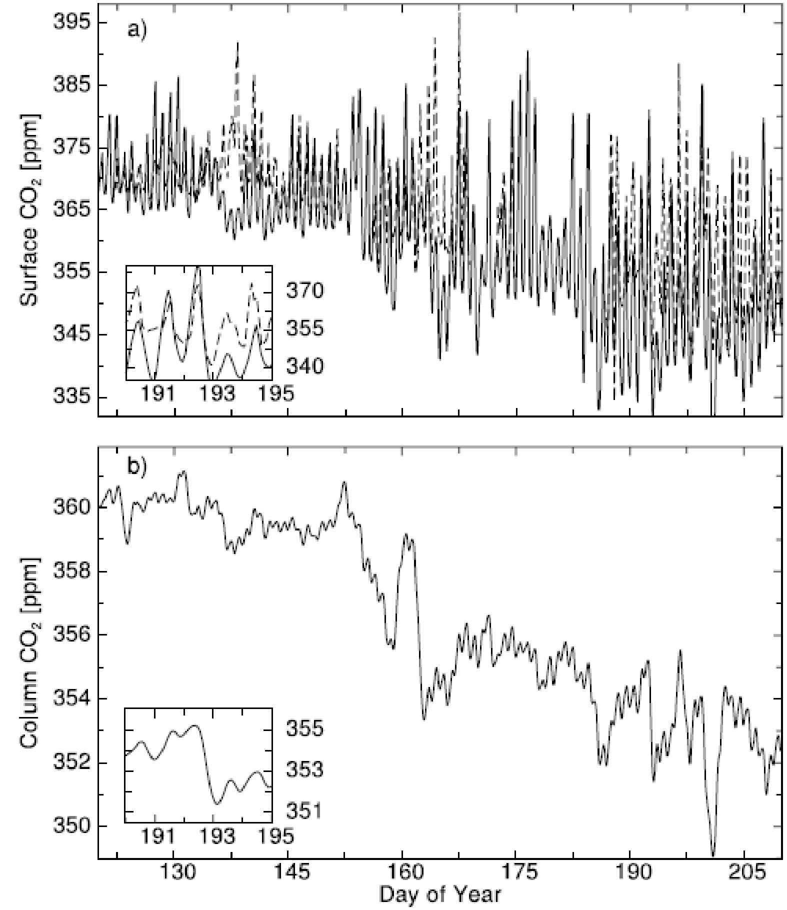
- Column-averaged dry-air mole fractions of CO_2 have an important role to play in understanding the hemispheric fluxes of CO_2
- These measurements show a significant linear relationship between temperature-weighted respiration and the seasonal cycle minima at three independent locations
  - Yields an apparent “Q10” of 2.7
  - Strong temperature dependence, but climate implications will depend on the mechanism
- This relationship could be caused by
  - Atmospheric dynamics – secondary
  - Fires increasing the net CO_2 flux – unlikely
  - Temperature affecting the respiration of the biosphere – likely
  - Temperature affecting the soil moisture and causing drought – likely
- Future work includes further modeling sensitivity studies to disentangle these effects

Future Work

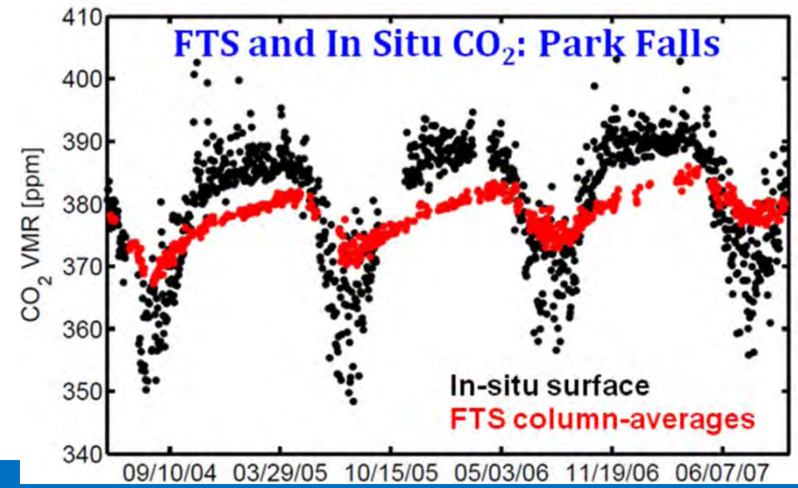
- Surface temperature control on respiration
  - As surface temperatures increase, respiration increases through plant stress increasing CO_2 to the atmosphere
  - If we increase Q10 in a model, can it recreate the observed ΔXco_2- ΔT slopes?
- Effects of soil moisture on the CO_2 fluxes
  - As soil moisture reduces (drought), net primary productivity decreases, taking up less CO_2 from the atmosphere
- Embedding of GFED into model to estimate effect of fires on CO_2 (more fires, more CO_2 released to atmosphere)
- Atmospheric dynamics
  - Investigate whether interannual variability in weather alone can account for the seasonal cycle changes

Column vs. Surface Measurements

- Column measurements of dry-air mole fractions of CO2 (X_{CO_2}) are a useful measure of the regional CO_2
  - X_{CO_2} related to changes on time scales of 2-6 days
- Integrated dry-air mole fraction less sensitive to vertical transport, especially boundary layer height changes, than its surface counterpart



Olsen, S. C., & Randerson, J. T. (2004). J. Geophys. Res.



Column Measurements: More Directly Related to Fluxes

- The column is more related to the fluxes
- Mostly sensitive to fluxes that are remote (hemispheric)
- The column represents the hemispheric signature of Xco_2 and its fluxes