The Changing Carbon Cycle

focus: land

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Three Views of Changing C Cycle

I. Contemporary observations: CO$_2$, NDVI, T, Precip, …

I. 1000 year control run of the NCAR Carbon-Climate Model
Doney et al. J Clim (in rev)

I. Projection to 21st century using the NCAR C-Climate Model (FF forcing)
Fung et al. PNAS 2005

Poster: Doney (EC-322)
Recent Drought: Co-Variations of $\Delta T$ and $\Delta$Precip

Global distribution of droughts:
Observed Halting of the Greening Trend

Summer drying $\rightarrow$ reduced photosynthesis $\rightarrow$ Recent slowing of the land C sink

Angert et al. “Drier summers cancel out the CO$_2$ uptake enhancement induced by warmer springs” PNAS 2005
Increased till 1990, decreased thereafter, despite continued increase in temperature and CO$_2$.

From 1000-year control run

Cross-check of soil C turnover time in model!

Obs changes ~ natural variab in model.
Decreasing trend in MLO Amplitude

1. Trough: Summer drying ➔ reduced photosynthesis

2. Peak: Changing circulation and changing winter net flux

- Chen et al. “Evidence for strengthening of the tropical general circulation in the 1990’s” Science 2002

- Dargaville et al. “Interannual variability in the interhemispheric atm CO2 gradient: contributions from transport and the seasonal rectifier” Tellus 2003

Corr Coeff bet MLO Amp(t) and $\Delta T(x,y,\text{Nov-Apr},1\text{yr lag})$

Amplitude – competition bet Photosynthesis and Respiration, between temp and moisture

Buermann et al. 2005
Correlation: \(\{\Delta T, \Delta \text{soil moisture index}\}\)

1000-yr Control Run

Doney et al. “Natural variability in a stable, 1000 yr global coupled climate-carbon cycle simulation.” J Climate 2005
21st Century Correlations & Regressions:

\[ \text{FF} = \text{SRES A2}; \ \delta = \text{Coupled minus Uncoupled} \]

\[ \delta T, \delta \text{Soil Moisture Index} \]

Warm-wet

Warm-dry

Regression of \( \delta \text{NPP} \) vs \( \delta T \)

NPP decreases with carbon-climate coupling

Fung et al. Evolution of carbon sinks in a changing climate. PNAS 2005
C-Climate Feedback on Land C Storage

FF = SRES A2; Coupled minus Uncoupled

- Tropical warming + drying; high-lat warming + moistening
- NPP more climate-sensitive than $R_h$
- Carbon inventory in tropics and increase at hi lat
- Regional near-cancellation

Fung et al. Evolution of carbon sinks in a changing climate. PNAS 2005

C4MIP: Carbon-climate feedback is positive in all coupled carbon-climate models
Poster: Friedlingstein (EC-238)
Changing Partitioning of FF Emission

With SRES A2 (fast FF emission): as CO$_2$ increases
• Capacity of land and ocean to store carbon decreases (slowing of photosyn; reduce soil C turnover time; slower thermocline mixing …)
• Airborne fraction increases

Fung et al. Evolution of carbon sinks in a changing climate. PNAS 2005
Summary

- Droughts decrease C land uptake, contribute to variability MLO amplitude

- $\Delta T$ and $\Delta$soil moisture are correlated – positively where “cool”, and negatively where “warm” (different correlations on different time scales). Difficult to separate temperature effects from moisture effects in C processes

- 21st C: drying of tropics $\rightarrow$ reduce C uptake $\rightarrow$ accelerate global warming

- FF emission faster than land and ocn uptake bottlenecks $\rightarrow$ accelerate global warming

- Amplitude of CO$_2$ cycle – useful test of terrestrial C dynamics