# The Changing Carbon Cycle
# focus: land


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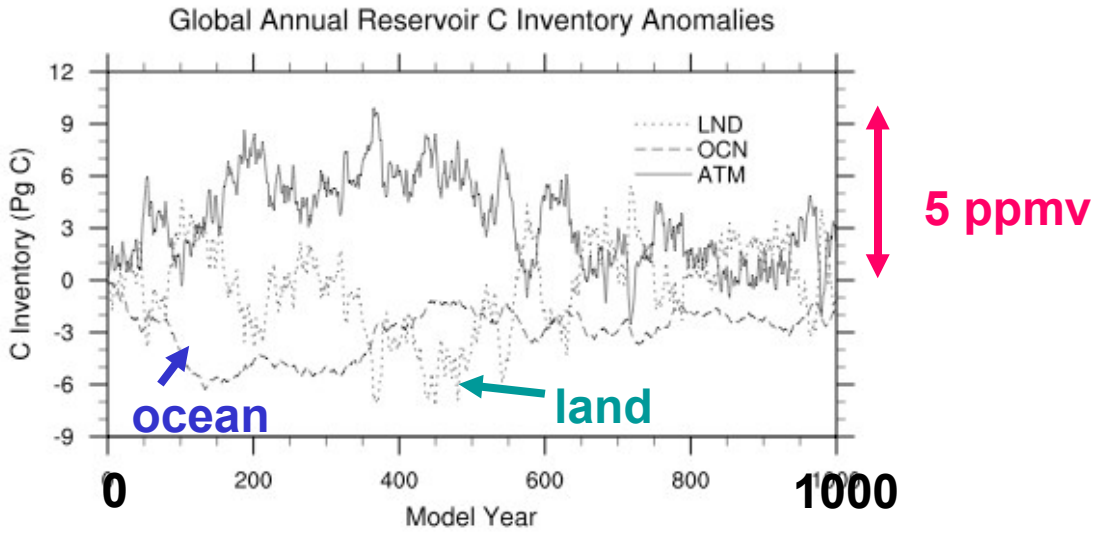
# Three Views of Changing C Cycle

## I. Contemporary observations: $CO_2$, NDVI, T, Precip, …

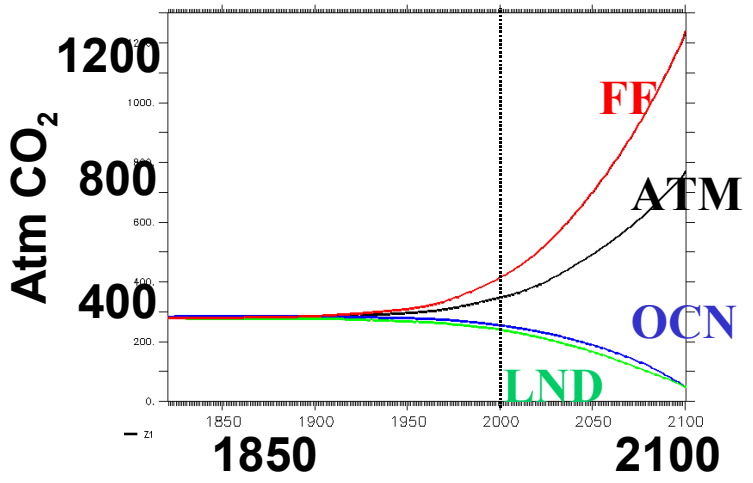
### I. 1000 year control run of the NCAR Carbon-Climate Model

Doney et al. J Clim (in rev)



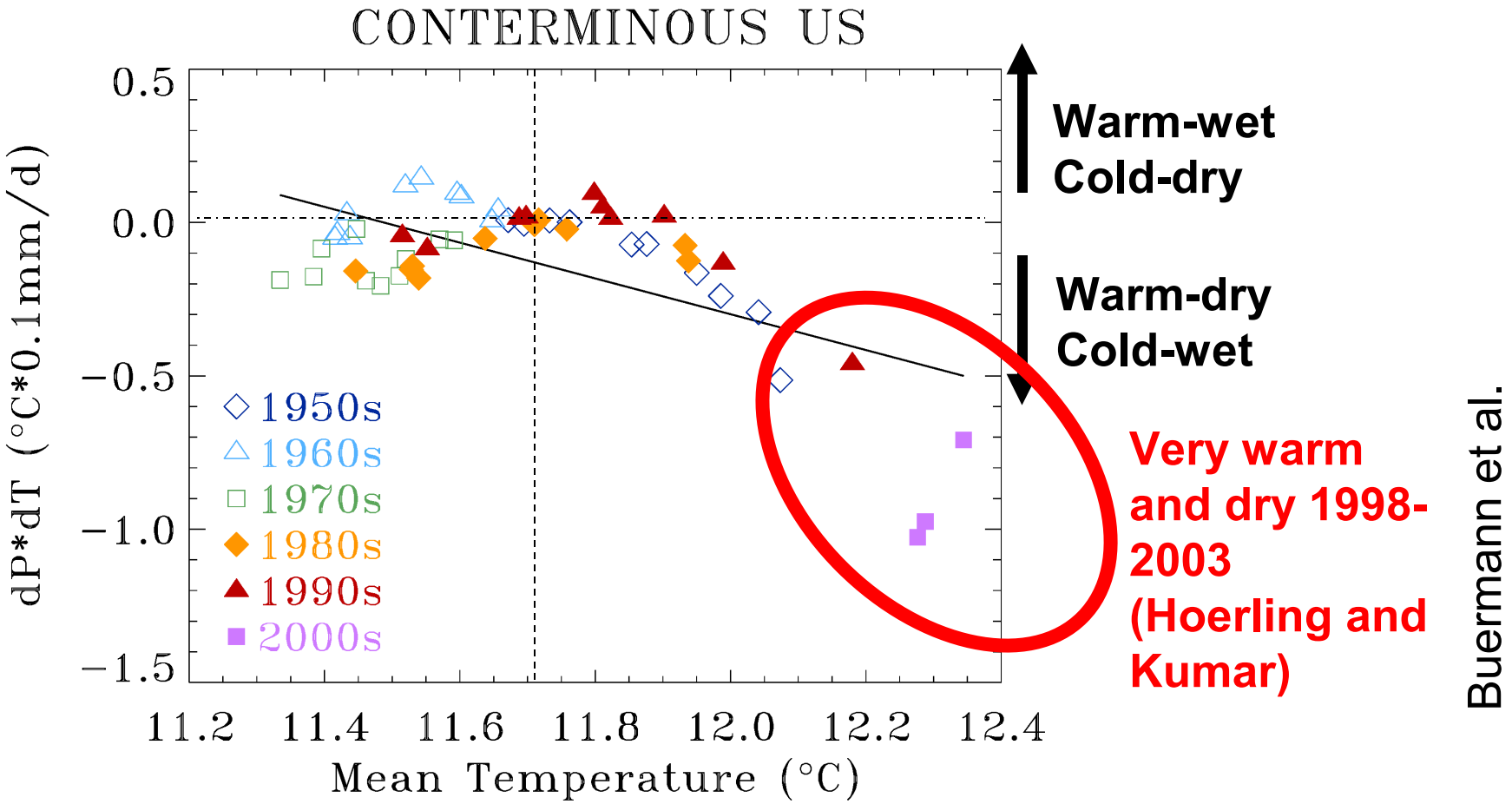

### I. Projection to 21st century using the NCAR C-Climate Model (FF forcing)

Fung et al. PNAS 2005




**Poster: Doney (EC-322)**

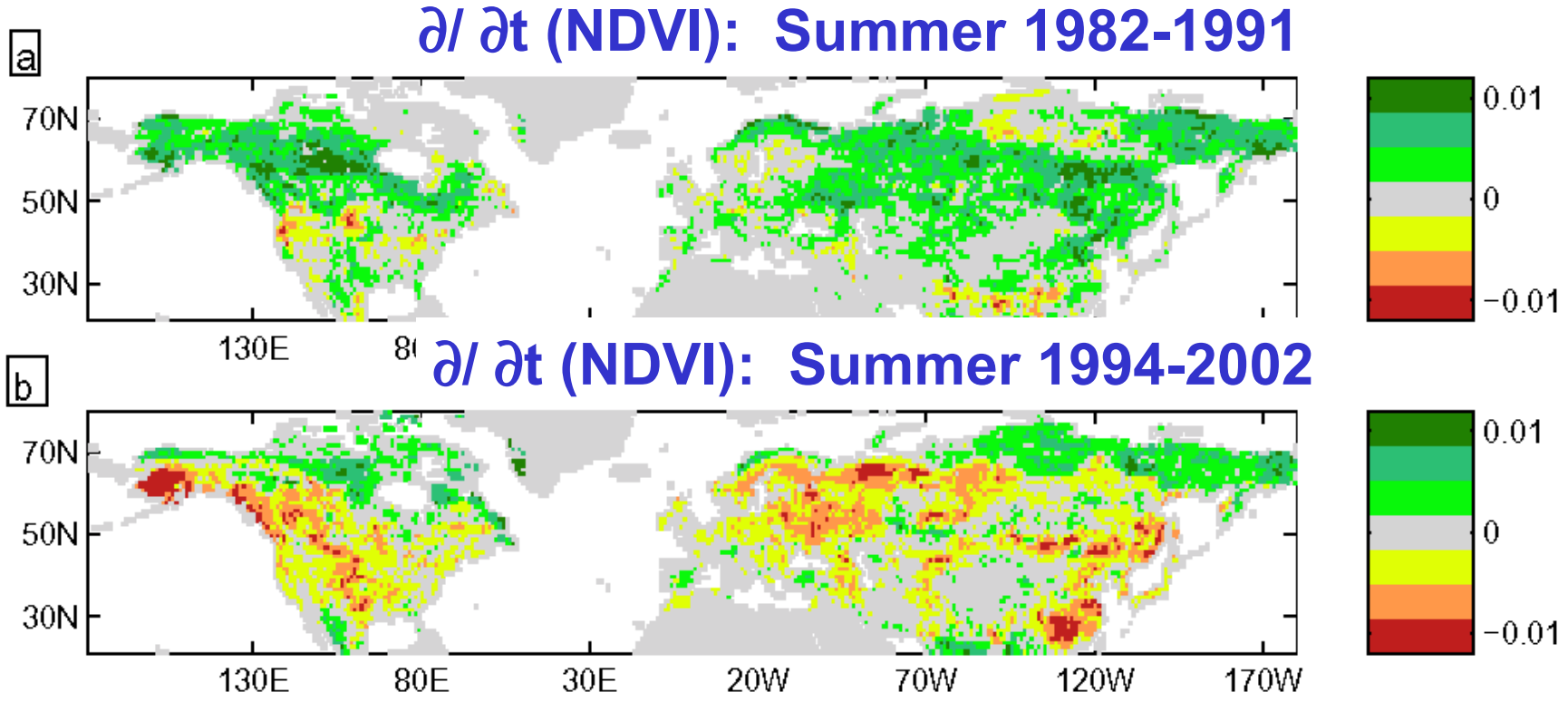
# Recent Drought: Co-Variations of ΔT and ΔPrecip




Global distribution of droughts:

Dai, A., K. E. Trenberth, and T. Qian "A global data set of Palmer Drought Severity Index for 1870-2002: Relationship with soil moisture and effects of surface warming" *J. Hydrometeorology*, 2005.

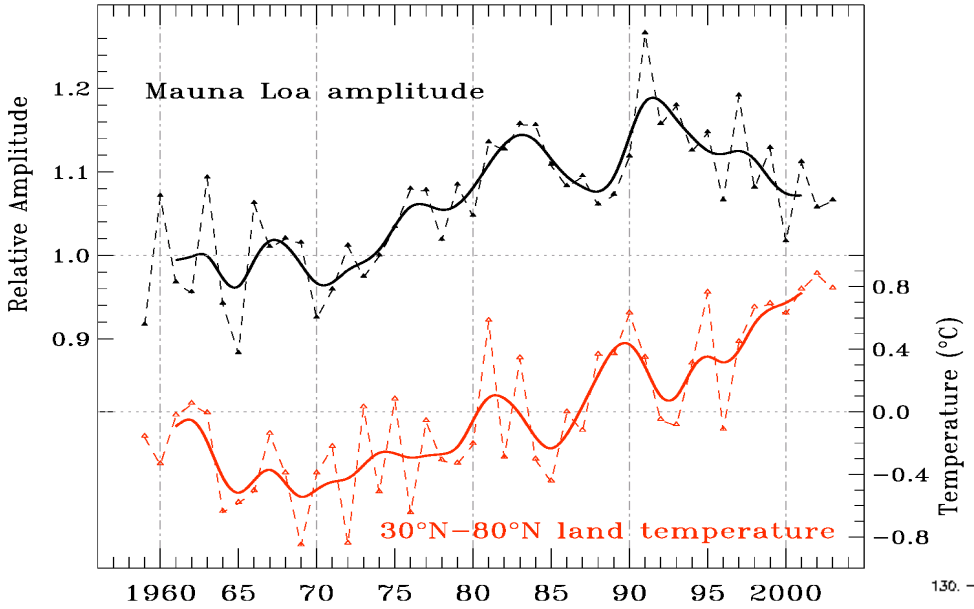
# Observed Halting of the Greening Trend




**Summer drying → reduced photosynthesis → Recent slowing of the land C sink**

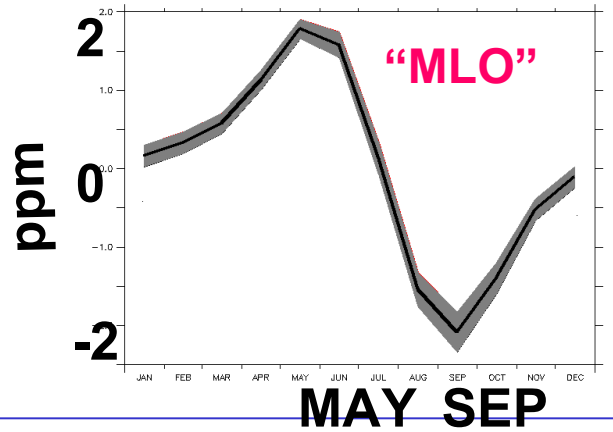
Angert et al. "Drier summers cancel out the $CO_2$ uptake enhancement induced by warmer springs" PNAS 2005

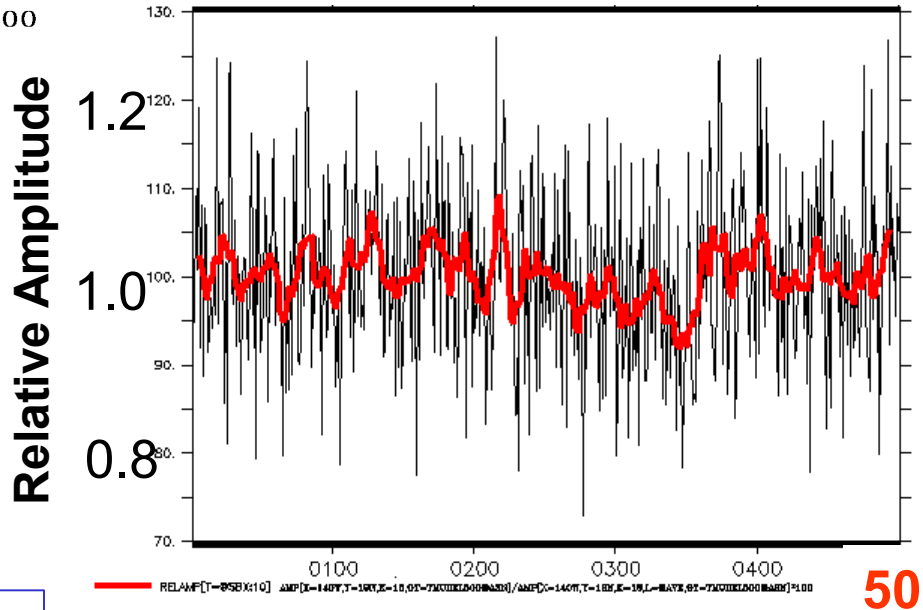
# Amplitude of MLO Seasonal Cycle




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

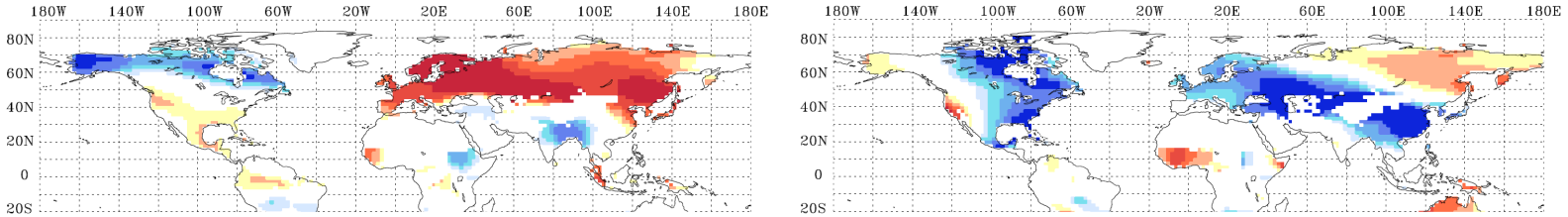
## 1. Trough: Summer drying → reduced photosynthesis

## 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 ΔT(x,y,Nov-Apr,1yr lag)**

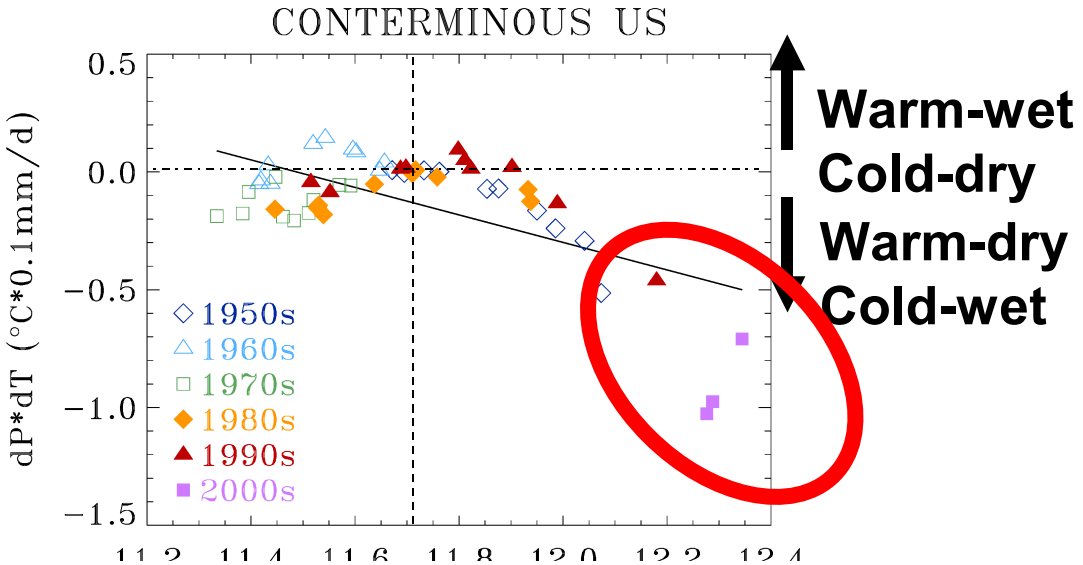
**1982-1993** **1994-2003**



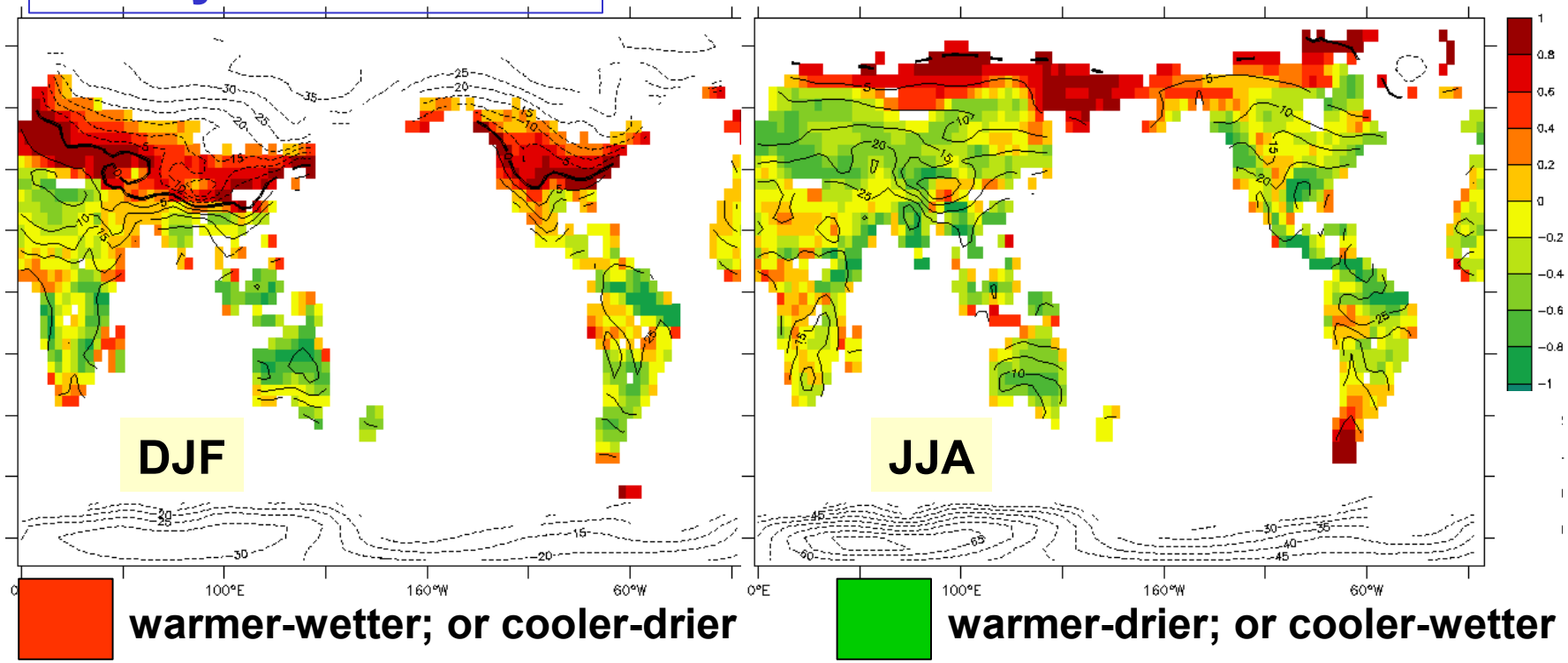

Buermann et al. 2005

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

# Correlation: {ΔT, Δ soil moisture index}




## 1000-yr Control Run



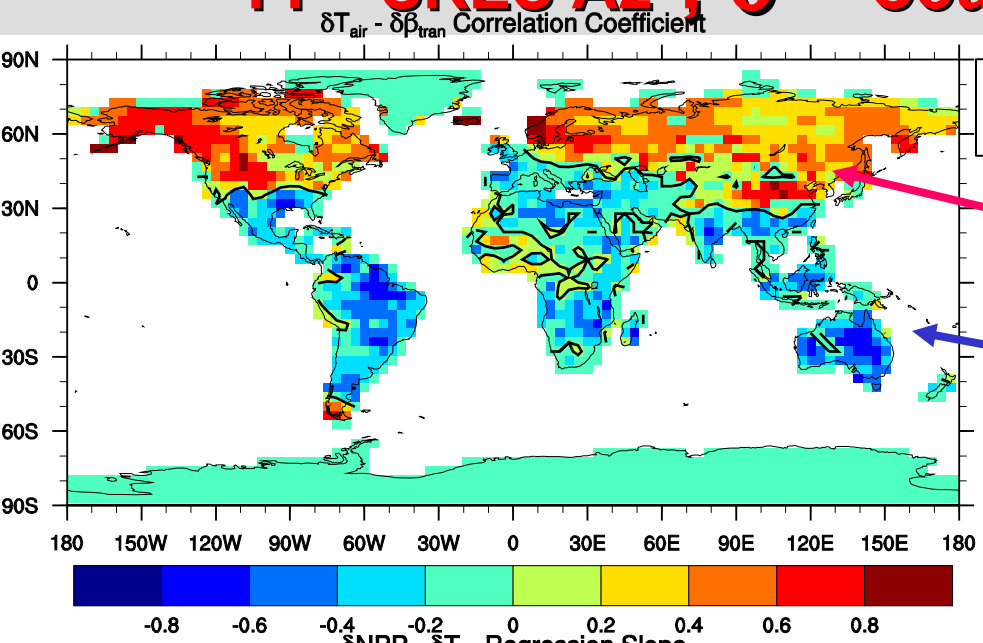

warmer-wetter; or cooler-drier

warmer-drier; or cooler-wetter

Doney et al. "Natural variability in a stable, 1000 yr global coupled climate-carbon cycle simulation. J Climate 2005

# 21st Century Correlations & Regressions:

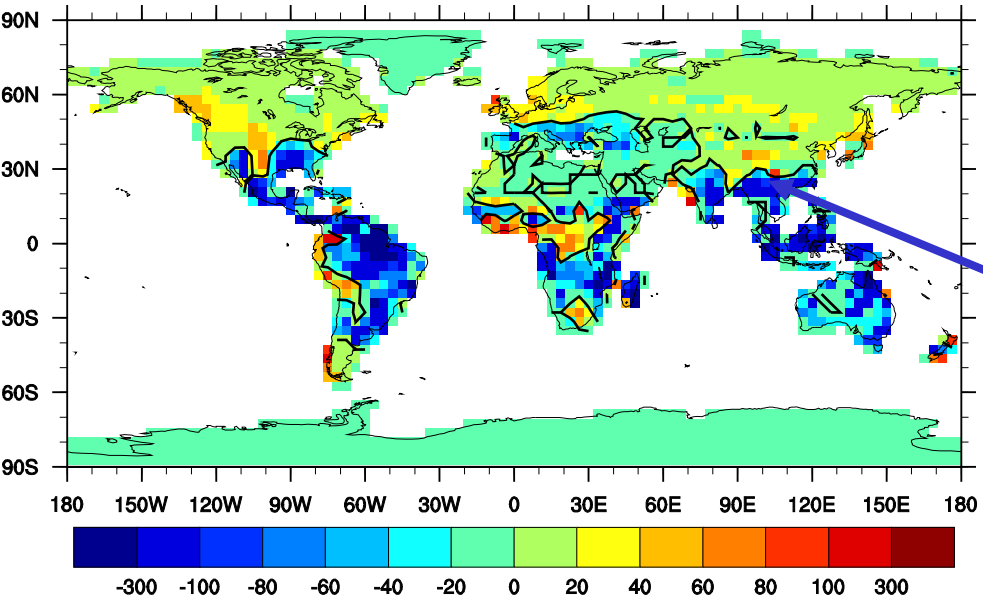
## FF= SRES A2 ; δ = Coupled minus Uncoupled




{δT, δSoil Moisture Index}

Warm-wet

Warm-dry

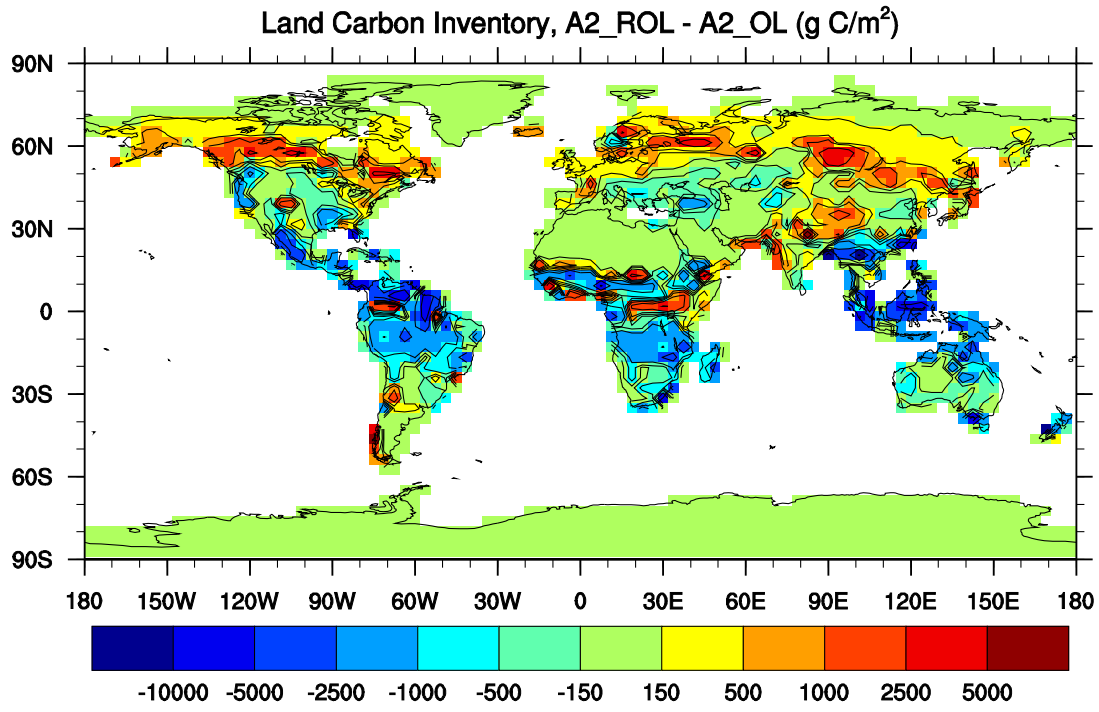



Regression of δNPP vs δT

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



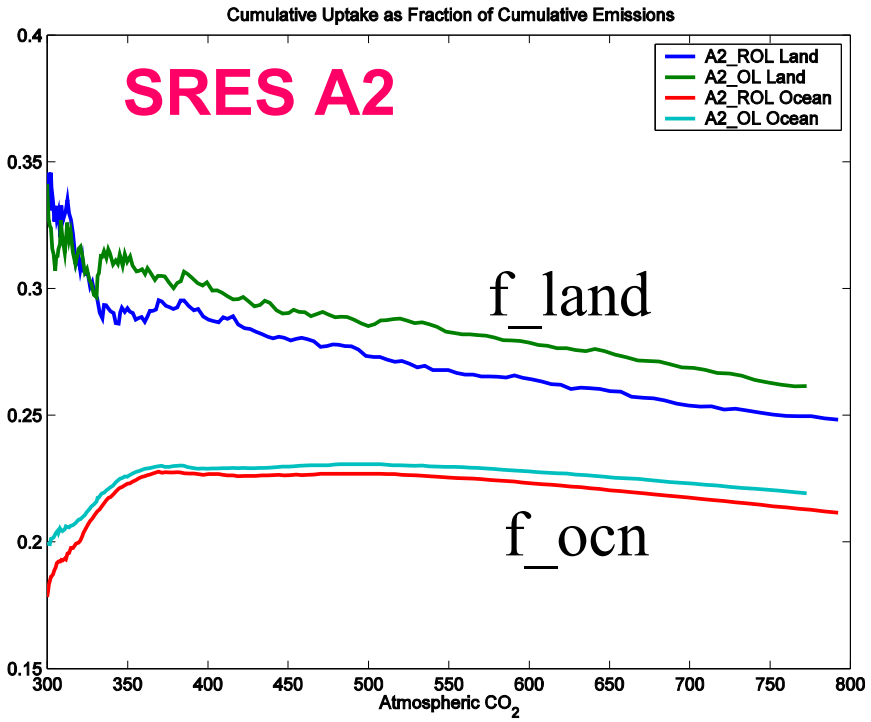

Fung et al. Evolution of carbon sinks in a changing climate. PNAS 2005

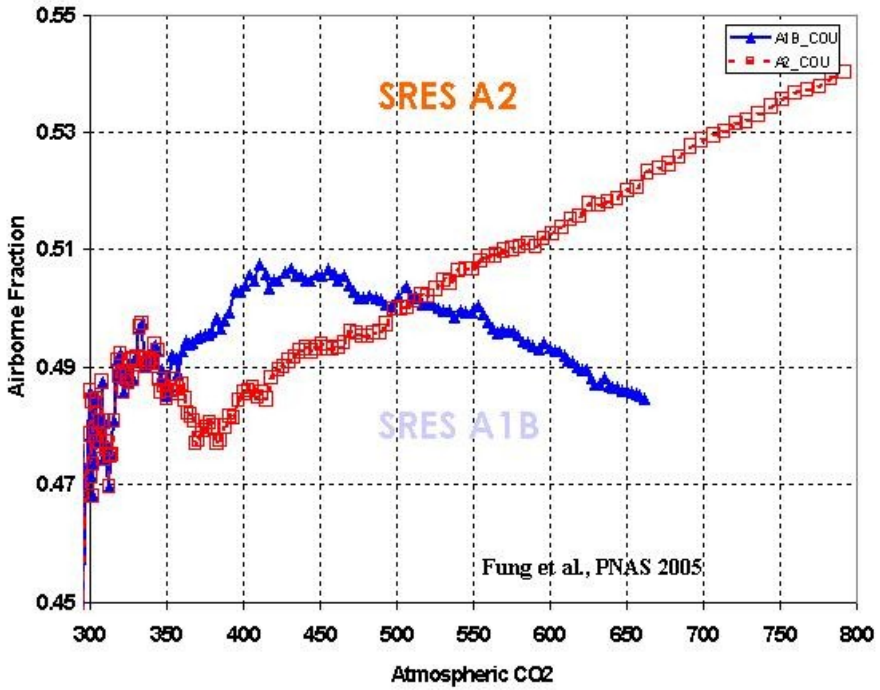
- **Tropical warming + drying; high-lat warming + moistening**
- **NPP more climate-sensitive than $R_h$**
- **Carbon inventory in tropics and increase at hi lat**
- **Regional near-cancellation**

**C$^4$MIP: 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 → reduce C uptake → accelerate global warming
- FF emission faster than land and ocn uptake bottlenecks → accelerate global warming
- Amplitude of $CO_2$ cycle – useful test of terrestrial C dynamics