Net Carbon Dioxide Losses of Northern Ecosystems in Response to Autumn Warming

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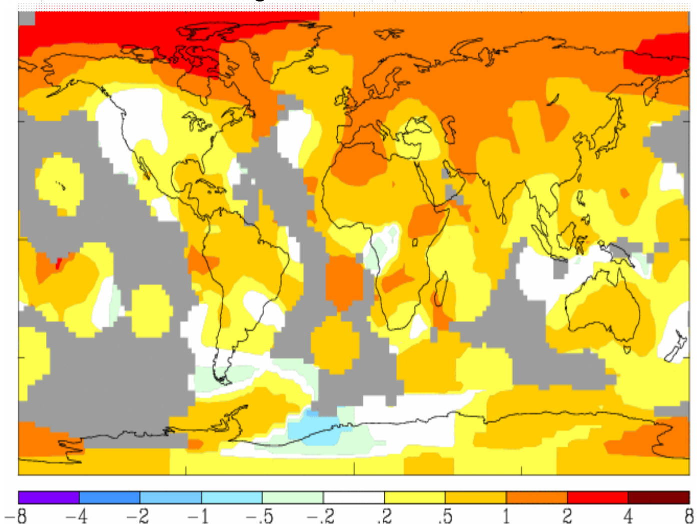
IPSL

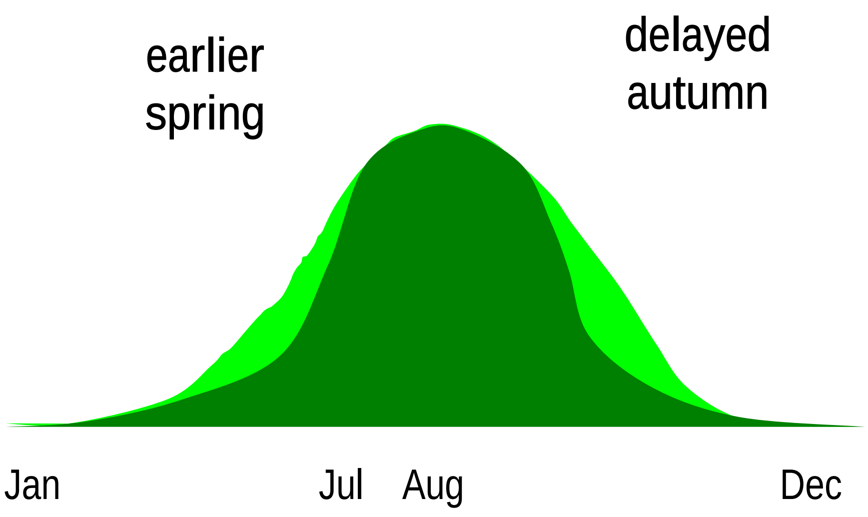
Global Carbon Project

Background

Autumn warming since 1960-80 NASA/GISS



As temperature is rising, the length of the growing season usually increases



How does the Carbon Uptake Period respond to rising temperature?

Spring: beginning of the growing season:

Increasing temperature and light availability

The snow melts

Thawing of soil organic horizons

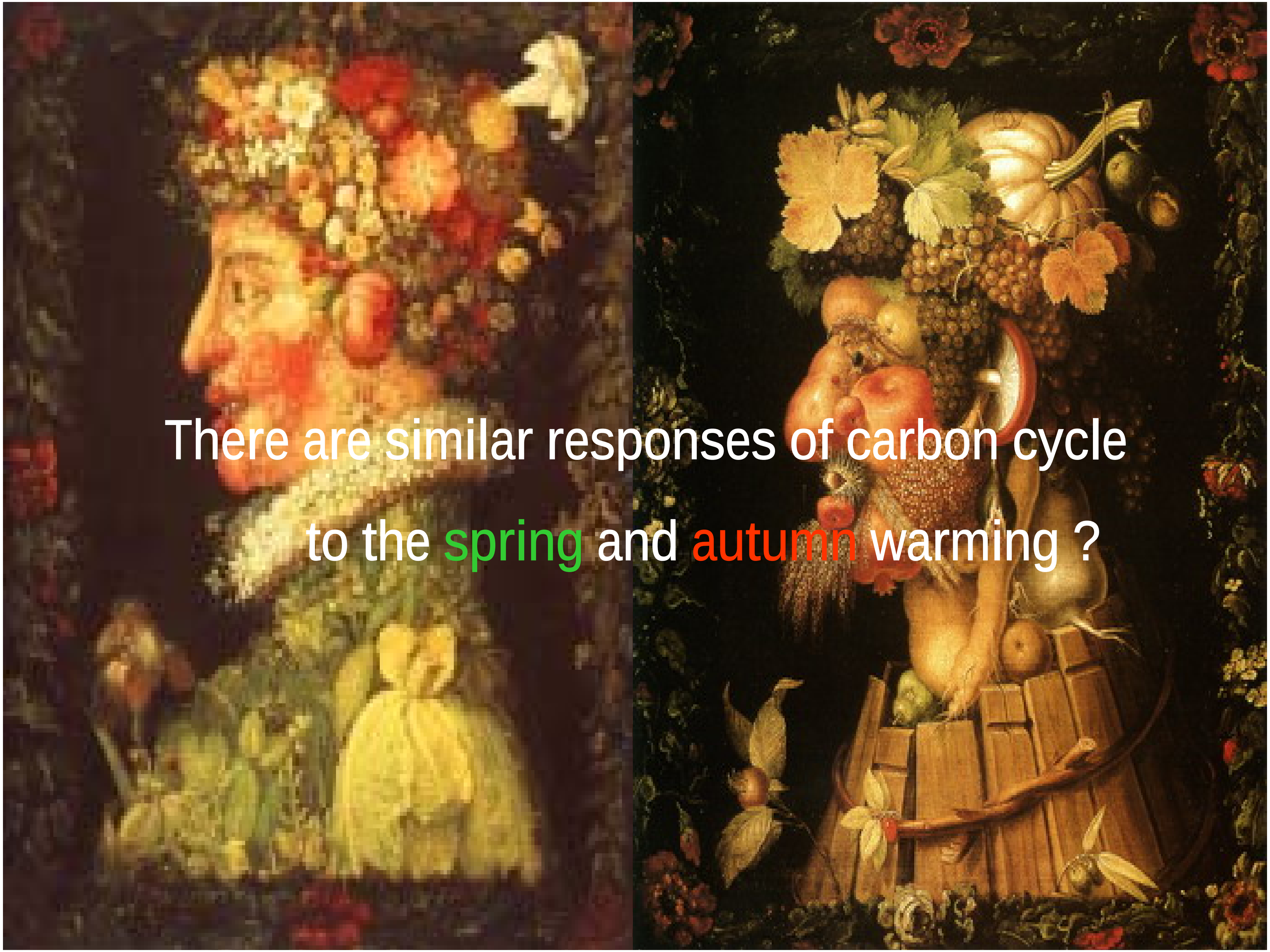
Onset of photosynthesis

Autumn: end of the growing season:

Temperatures and light availability decrease

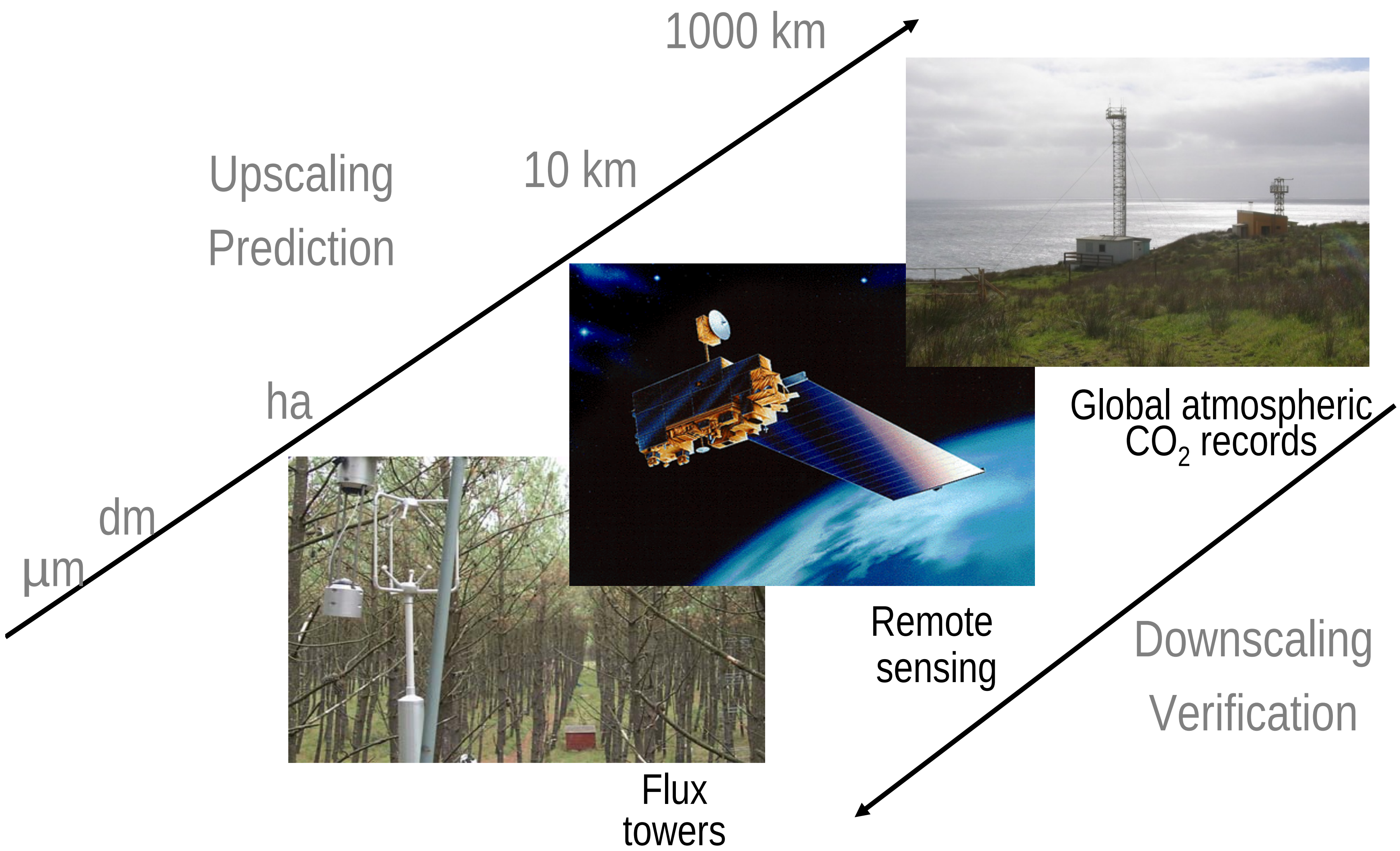
Soils re-freeze

Photosynthesis slows or ceases



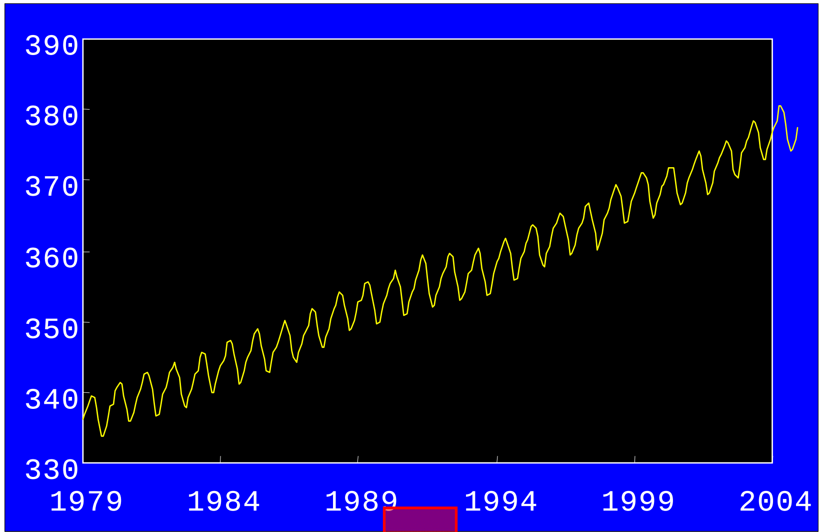
There are similar responses of carbon cycle
to the spring and autumn warming ?

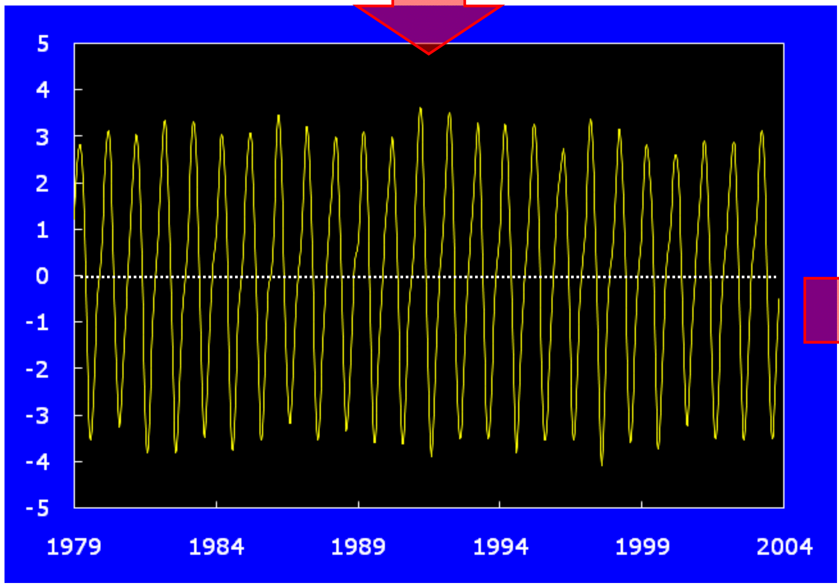
Methods used in this study

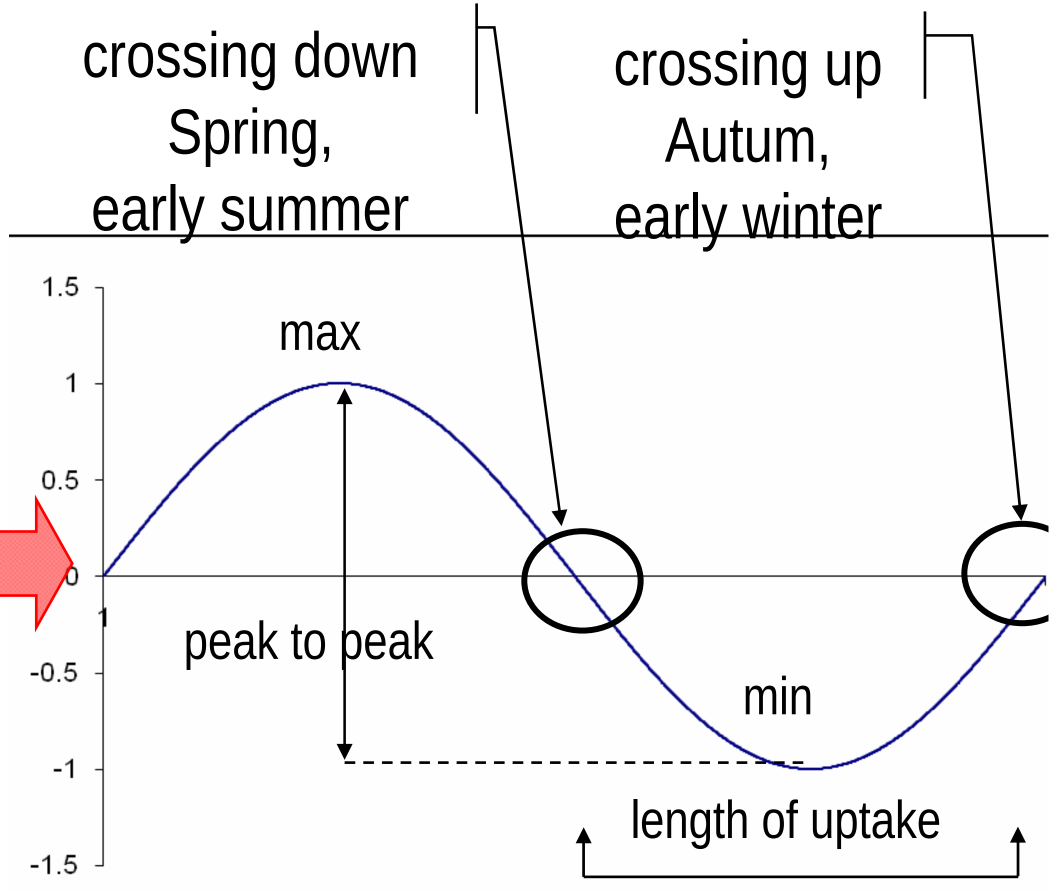


And integration by modeling

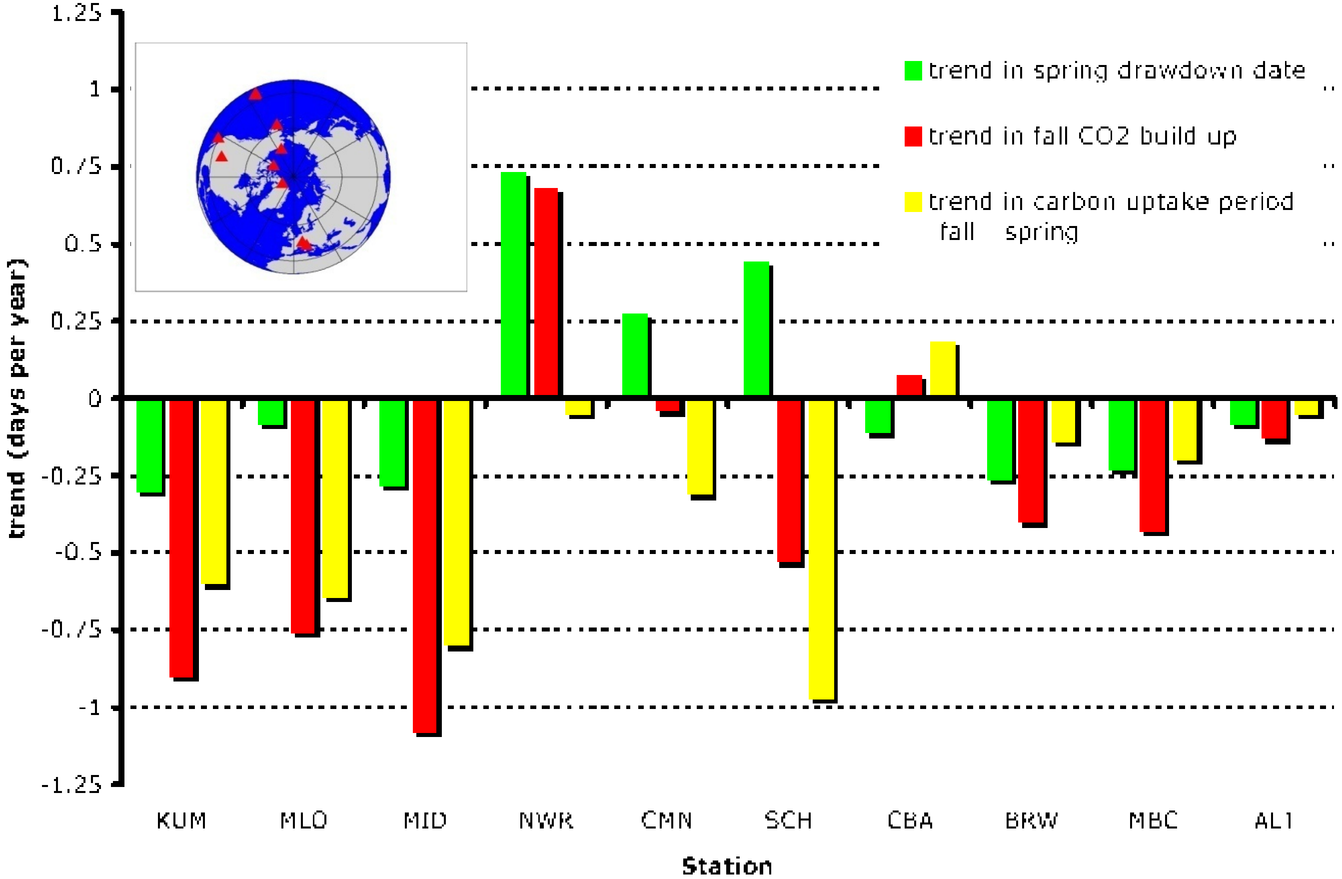
Atmospheric CO_2 long term records







Trends in spring and autumn crossing dates



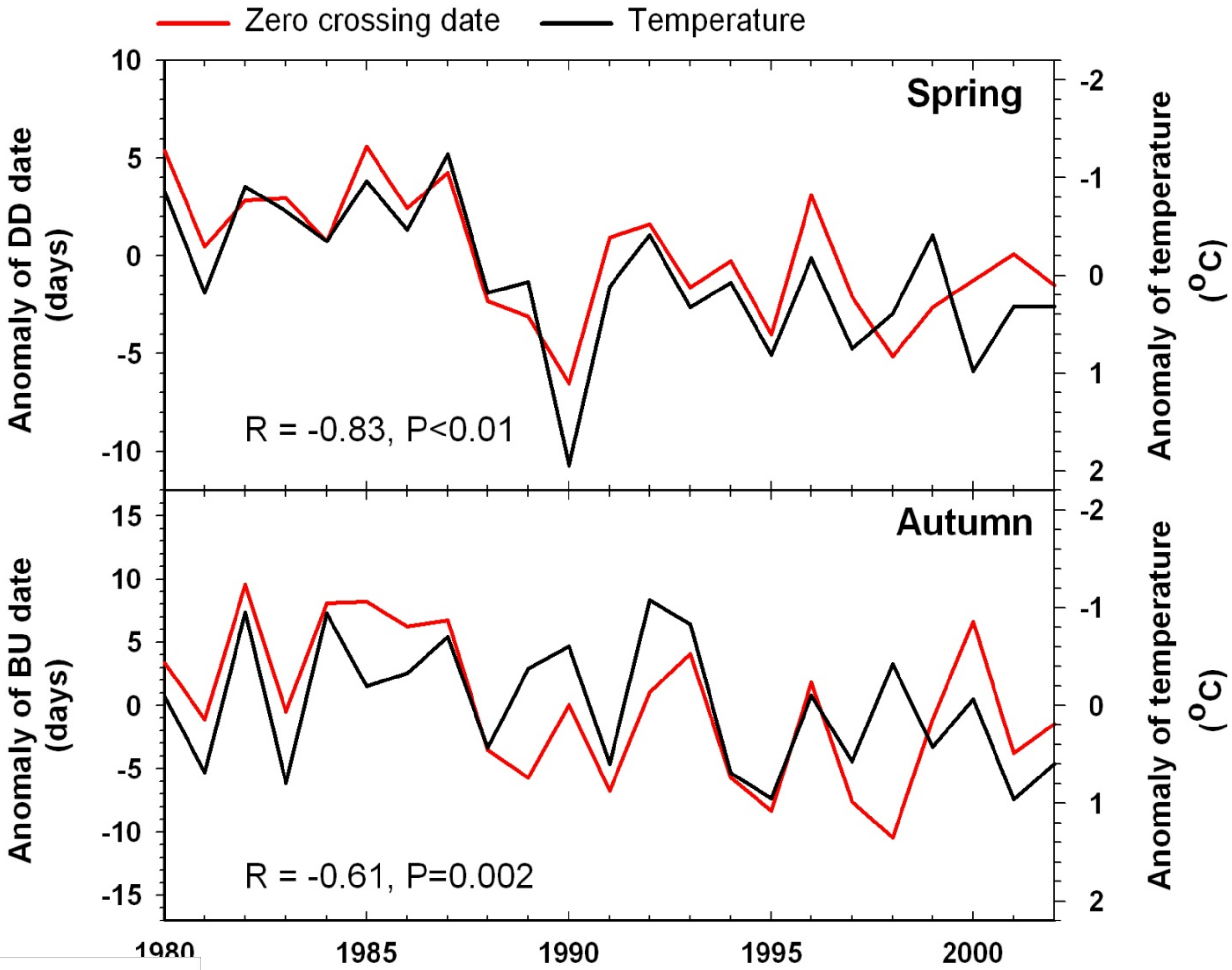
Both an earlier draw down in spring and earlier build up of CO_2 in autumn

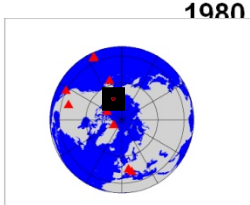
But the autumn trend is stronger than in spring

-> the carbon uptake period shortens

Piao et al. 2007, Nature

Temperature vs. carbon uptake period at BRW





Warmer spring associated with an earlier uptake

Warmer autumn associated with an earlier release

Piao et al. 2007, Nature

Atmospheric transport analyses

- Perform three simulations:

S1: only wind was varied (using mean flux from terrestrial and ocean)

S2: wind and flux from terrestrial were varied.

S3: wind, flux from terrestrial and ocean were varied

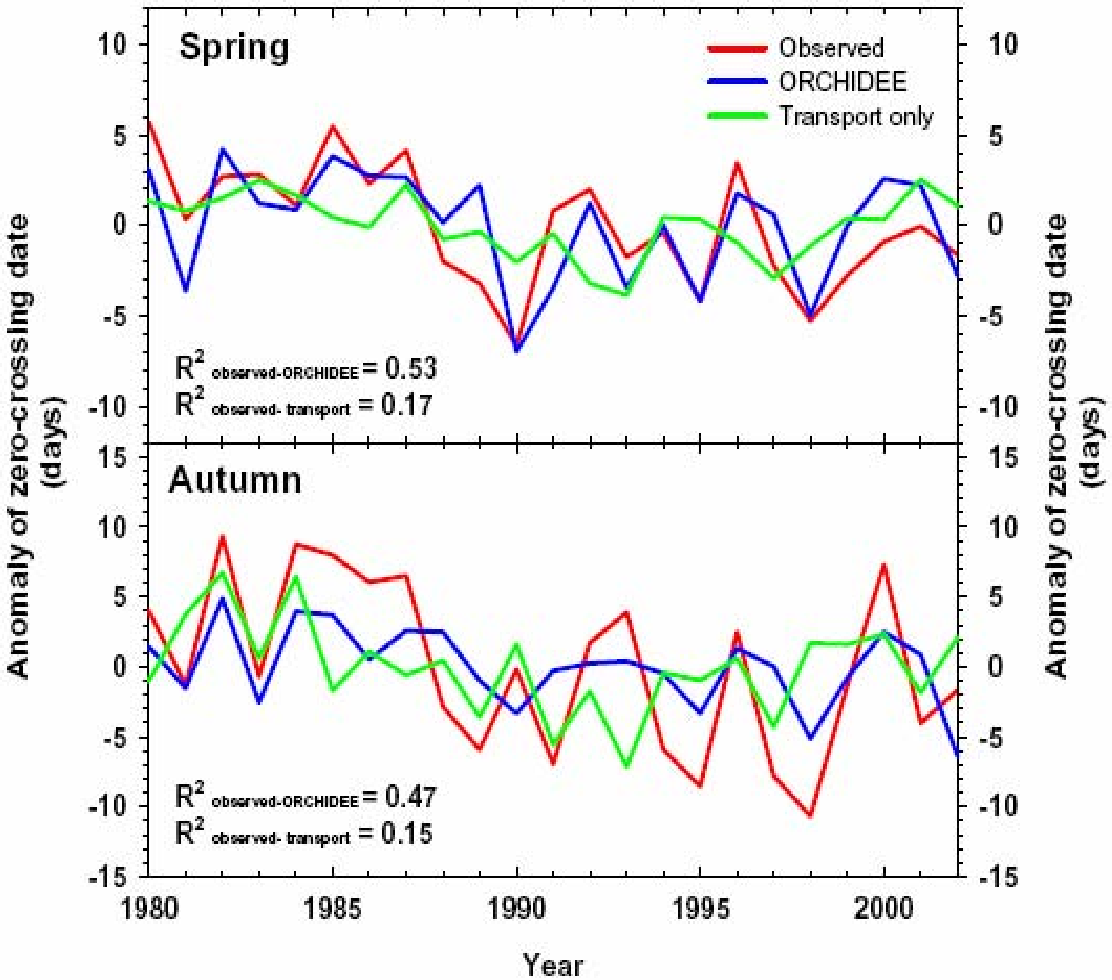
The effects of terrestrial ecosystem on atmospheric CO_2 = S2 – S1

The effects of ocean on atmospheric CO_2 = S3 – S2

- Models used in this study (1980-2002)

ORCHIDEE: simulate C flux from terrestrial ecosystems
PISCES: simulate C flux from ocean
LMDZs: transport model

Drivers of IV in zero-crossing date at BRW



A model of atmospheric transport was prescribed with every-year-the-same or with variable Land atmosphere fluxes

The difference in simulated CO_2 between the two runs is the contribution of fluxes, the rest is the contribution of varying winds

Piao et al. 2007, Nature

Ecosystem flux measurements

- Datasets

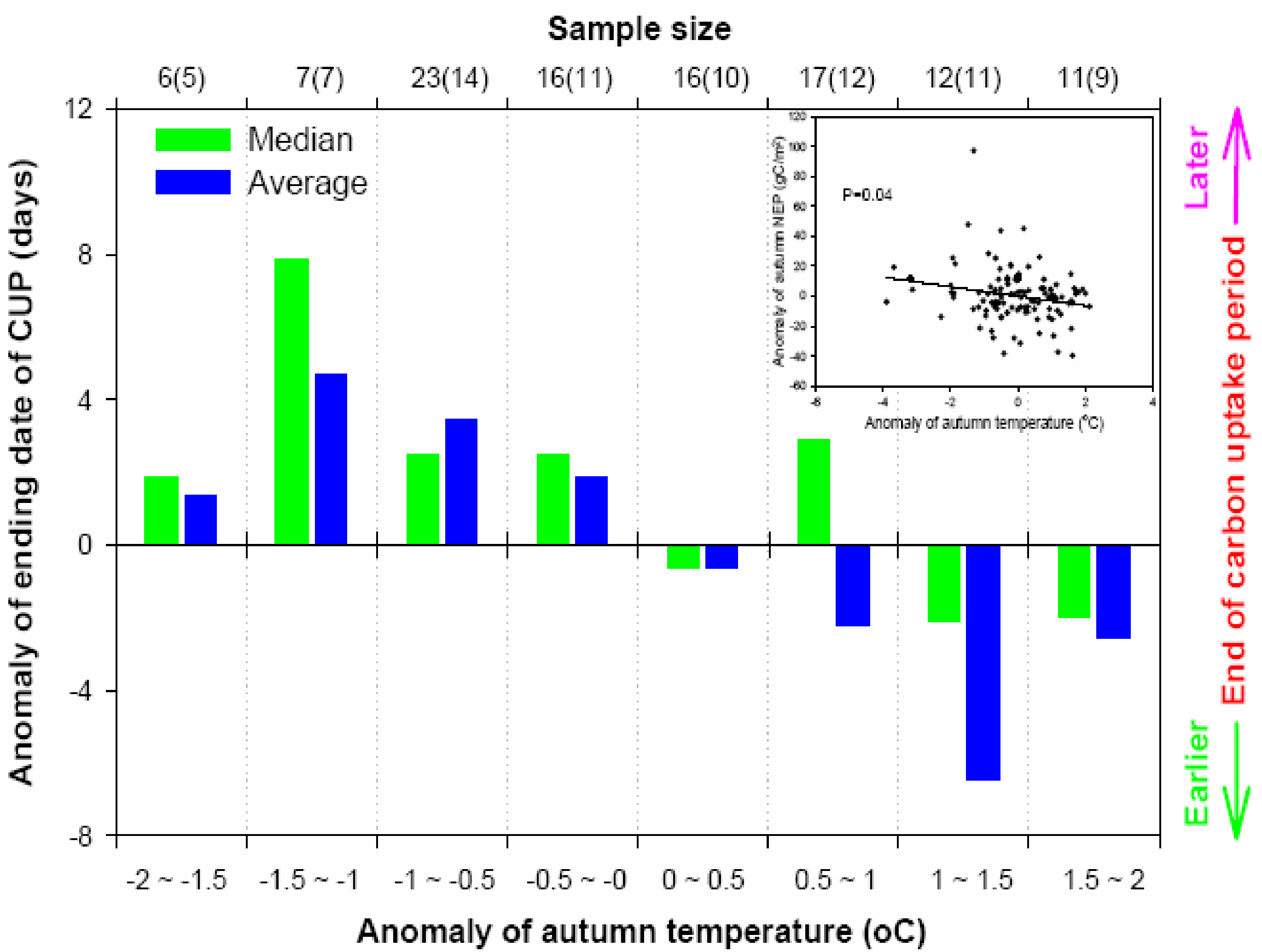
-Analyze the net CO_2 flux data measured by eddy-covariance technique from 24 different northern ecosystem sites

- Methods

- The end of the Carbon Uptake Period is defined as the last day in a year when the NEP 5-day running means exceeds zero.

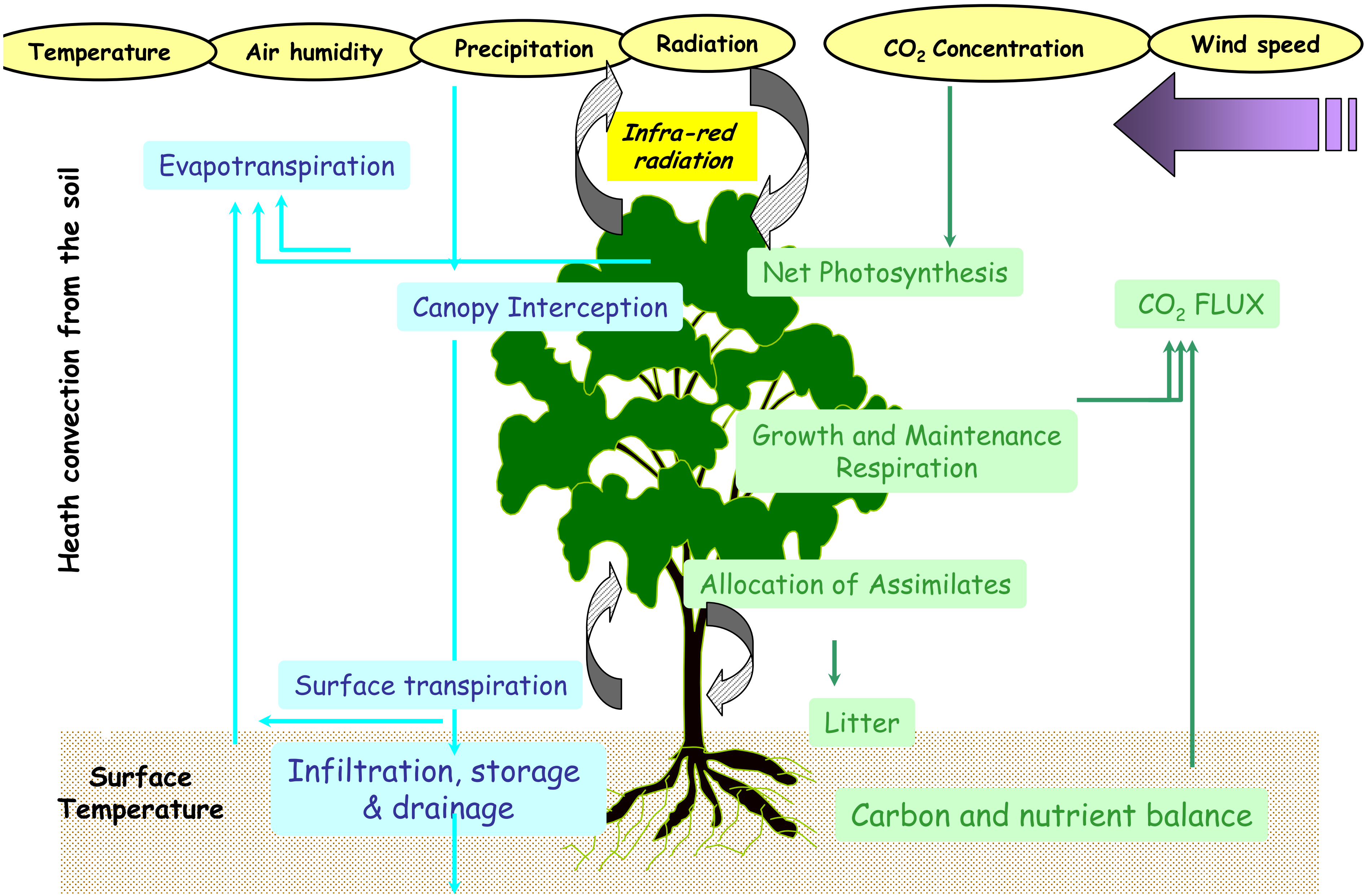
- Autumn is defined as the interval of ±30 days around the average CUP ending date at each site.

Temperature vs. carbon uptake period

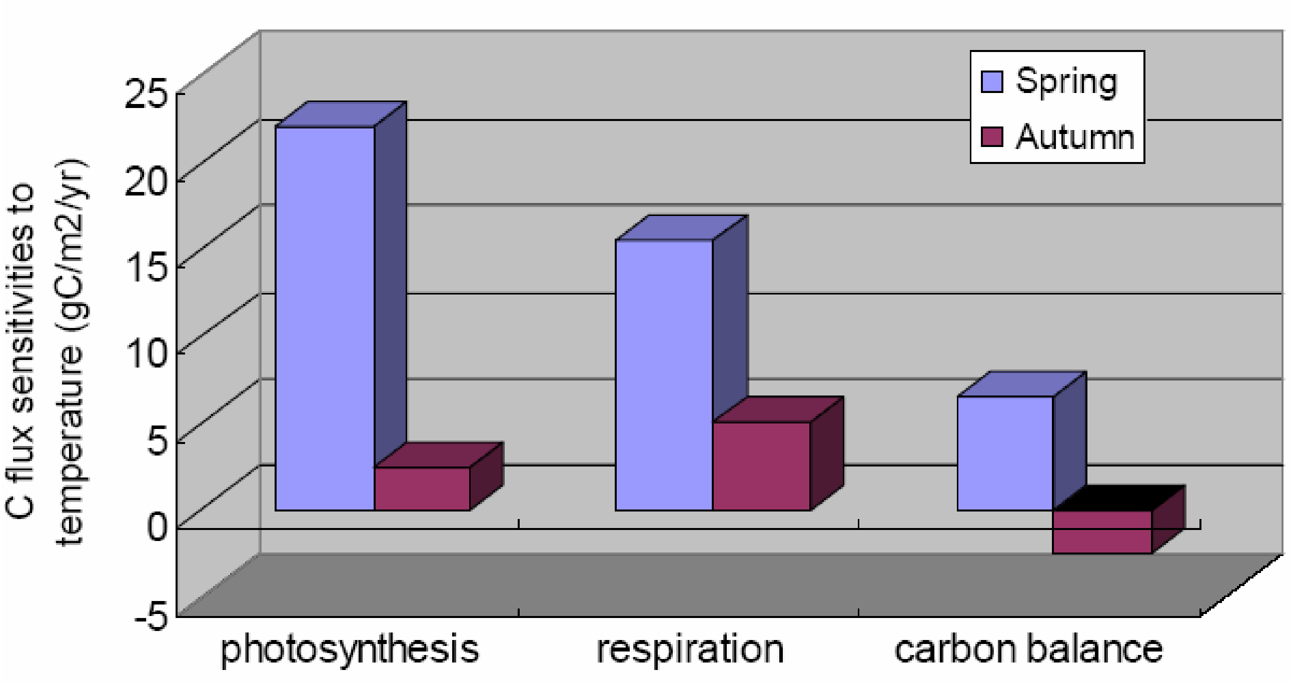


Piao et al. 2007, Nature

Global ecosystem model ORCHIDEE



Temperature vs. gross C Fluxes in NH (>25°N)

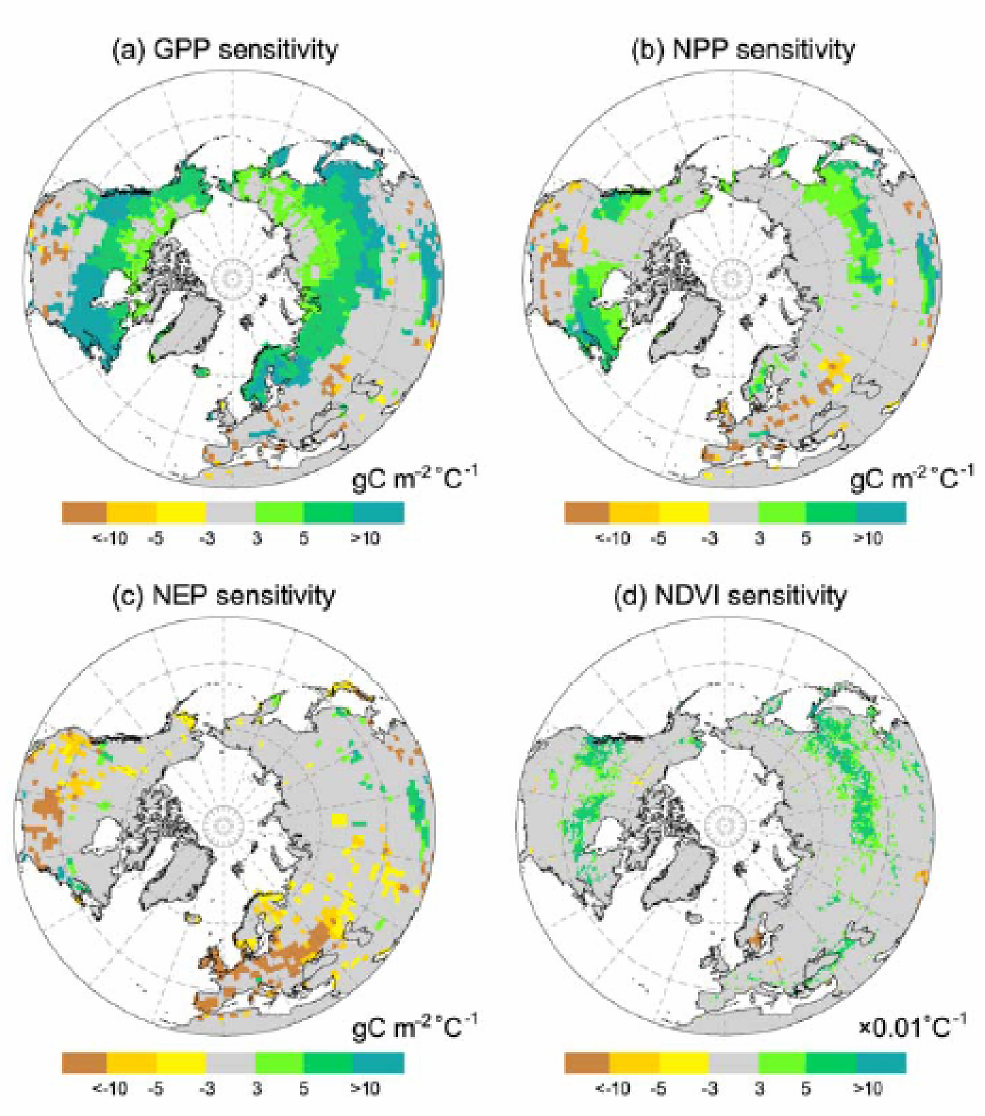


Spring: Warm temperatures accelerate growth more than soil decomposition. The annual relationship of NEP to temperature is positive
=> Warming enhances carbon uptake

Autumn: Warm autumn accelerate growth less than soil decomposition. The annual relationship of flux to temperature is negative.
=> Warming reduces carbon uptake

Piao et al. 2007, Nature

Autumn (SON) temperature vs. C Flux

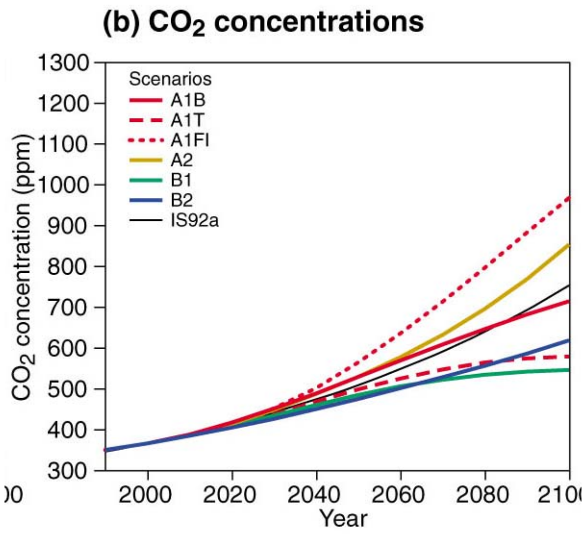


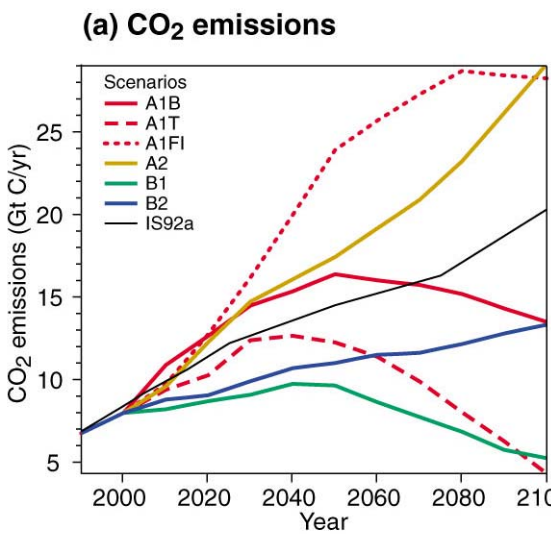
- Warmer autumns coincide with greater than normal GPP
- Due to a concurrent stimulation of plant respiration, the geographical area where autumn NPP increases with temperature is much less extensive than the area where GPP increases
- The 'extra' fall NPP is being accompanied by even more modeled respiration in response to warming, so that the NEP response shows systematic anomalous carbon losses during warmer autumns

Piao et al. 2007, Nature

Why do we need to know the mechanisms?

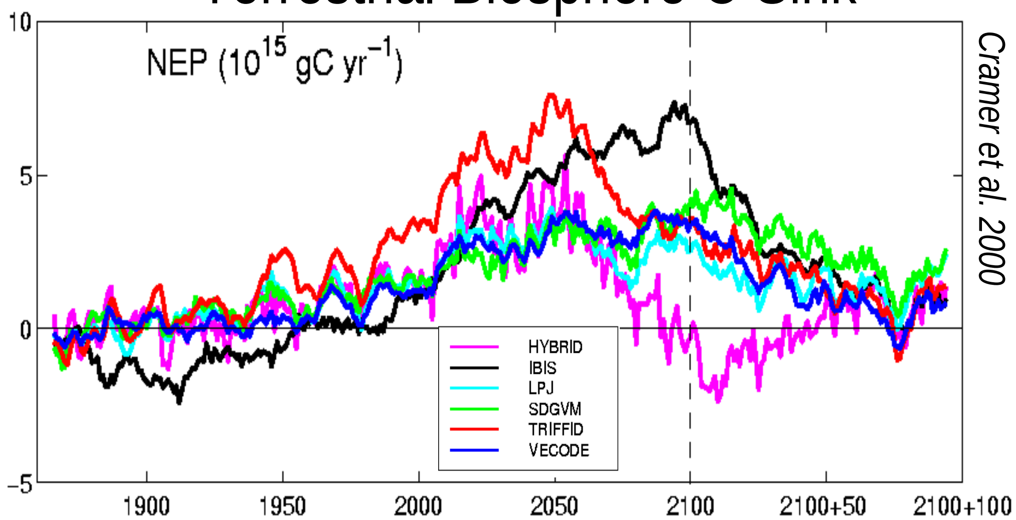
Future atmospheric CO_2 concentrations and stabilization scenarios





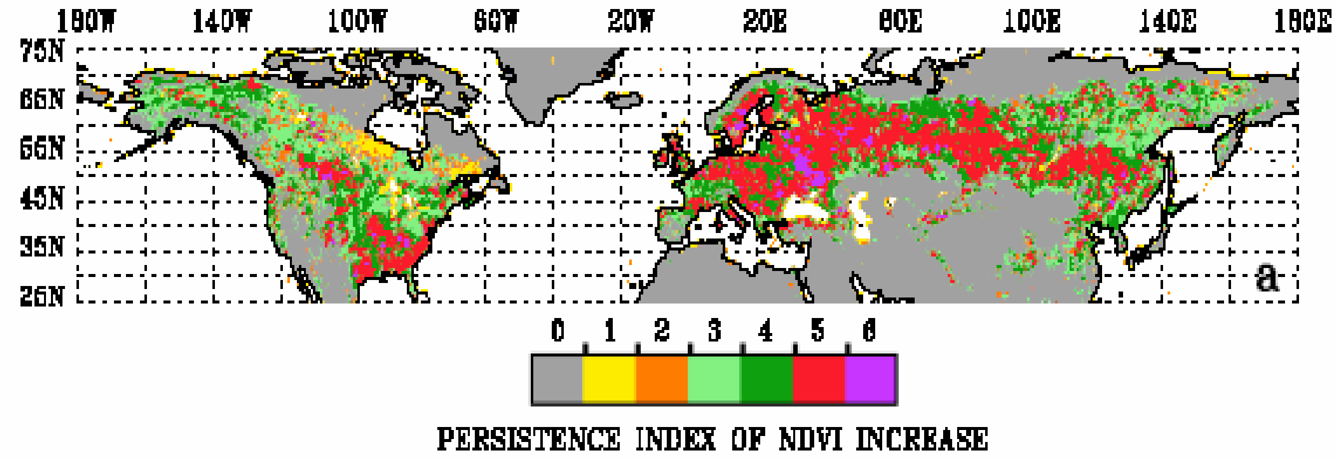
IPCC 2001

Terrestrial Biosphere C Sink



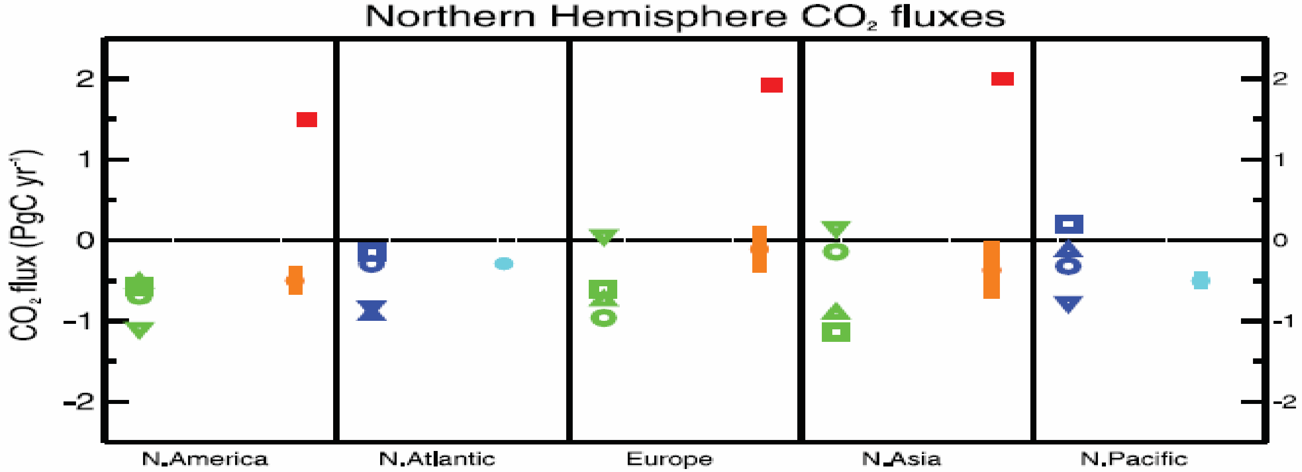
Cramer et al. 2000

Spatial patterns of C sink and greening trend



Greening trend in Eurasia > North America

Zhou et al., (2001)



C sink of Eurasia > North America

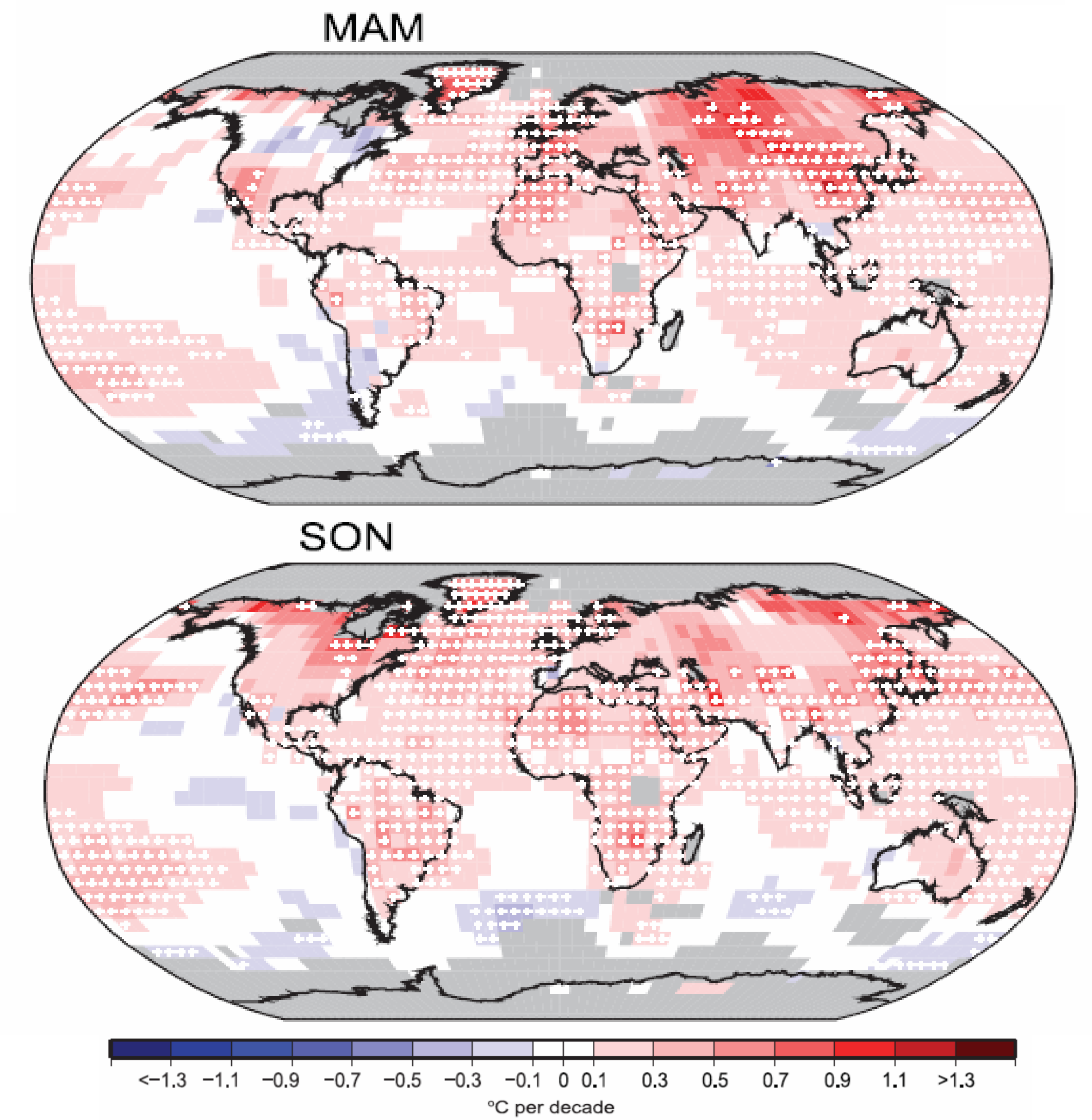
IPCC 2007

Why?

C sink of Eurasia > North America

Greening trend in Eurasia > North America

Spatial patterns of current temperature change



The warming trend is more pronounced in spring over Eurasia

The warming trend is more pronounced in autumn over North America

IPCC 2007

Conclusions (i)

Observations =

- Evidence from atmospheric CO_2 long-term data for a shorter Carbon Uptake Period
- Paradoxial observation with high latitude greening

Hypothesis =

- Warming in Autumn increases respiration more than photosynthesis

Analysis =

- Simulation of CO_2 data using transport model shows that the atmospheric signal is caused by fluxes, not transport
- Eddy flux towers show positive correlation between carbon losses and warmin in Autumn
- ORCHIDEE model simulations confirm that longer green seasons in warmer autumns coincides with carbon losses

Conclusions (ii)

- Possible explanation for a greater Eurasia than North American sink (warming trend in Autumn is larger in North Amerca)

- A positive feedback of climate warming in the future

References

- IPCC. Climate Change 2007: The physical Sciences Baiss: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press, Cambridge, 2007).

- Piao, SL, Ciais P, Friedlingstein P, Peylin P, Reichstein M, Luyssaert S, Margolis H, Fang JY, Barr L, Chen AP, Grelle A, Hollinger D, Laurila T, Lindroth A, Richardson AD, Vesala T (2007), Net carbon dioxide losses of northern ecosystems in response to autumn warming. NATURE doi:10.1038/nature06444

- Zhou, L. M., C. J. Tucker, R. K. Kaufmann, D. Slayback, N. V. Shabanov, and R. B. Myneni (2001), Variations in northern vegetation activity inferred from satellite data of vegetation index during 1981 to 1999. *J. Geophys. Res., 106,* 20,069-20,083

Thank you!