Stable Isotope Ratios in Carbon and Water Pools and Fluxes in AmeriFlux sites

Chun-Ta Lai, David Hollinger and James Ehleringer

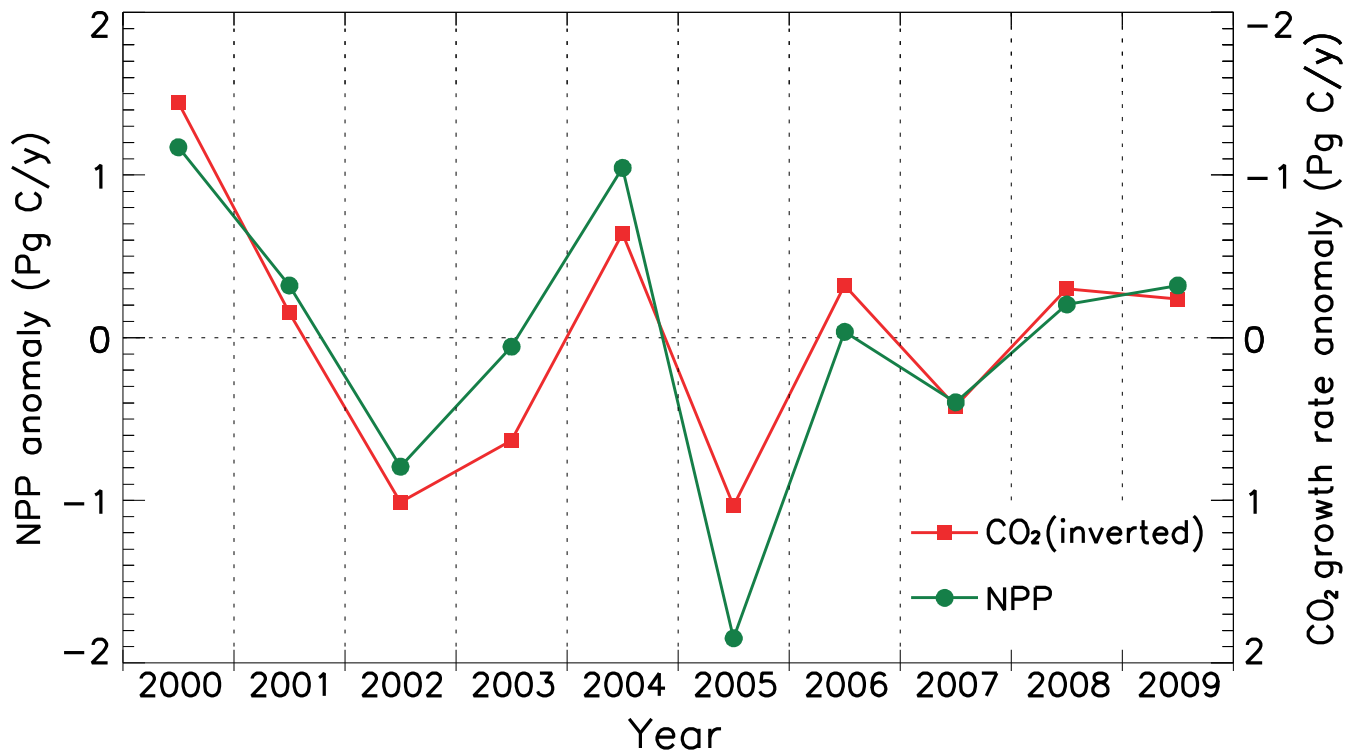
AmeriFlux/NACP Science and All-Investigators Meeting
Jan 31 2011

- Bev Law, Bill Munger, Xuerui Dang and other AmeriFlux investigators
- Ken Bible and Matt Schroeder, Wind River Canopy Crane
- Terrestrial Carbon Processes (TCP) program by the office of Science (BER), U.S. Department of Energy
- NICCR, U.S. Department of Energy
- National Science Foundation
- US Forest Service

Drought-Induced Reduction in Global Terrestrial Net Primary Production from 2000 Through 2009

Maosheng Zhao* and Steven W. Running

Science (2010) 329:940



Why Stable Isotopes in AmeriFlux?

- Quantify contributions of ecosystem component to net fluxes
- Identify sources of origin
- Link carbon and water transfer
- Provide mechanistic understanding of the factors that control gross fluxes

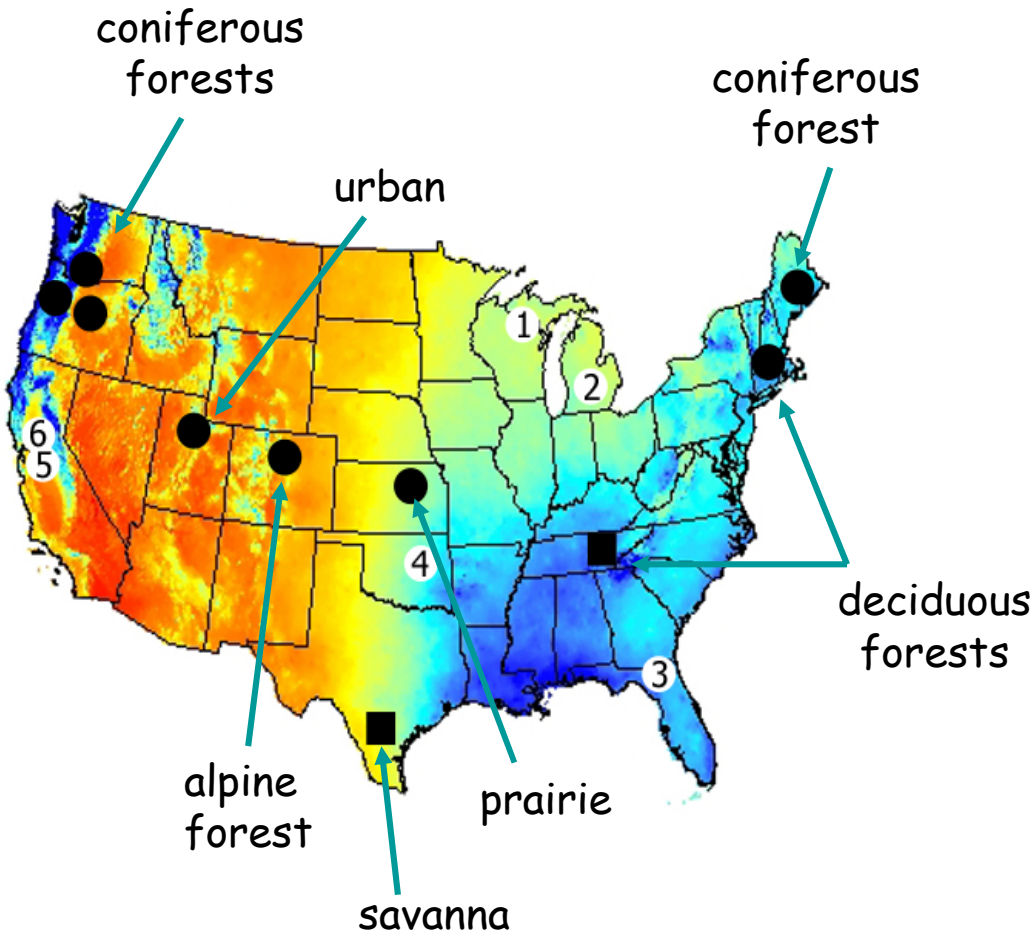
Outline

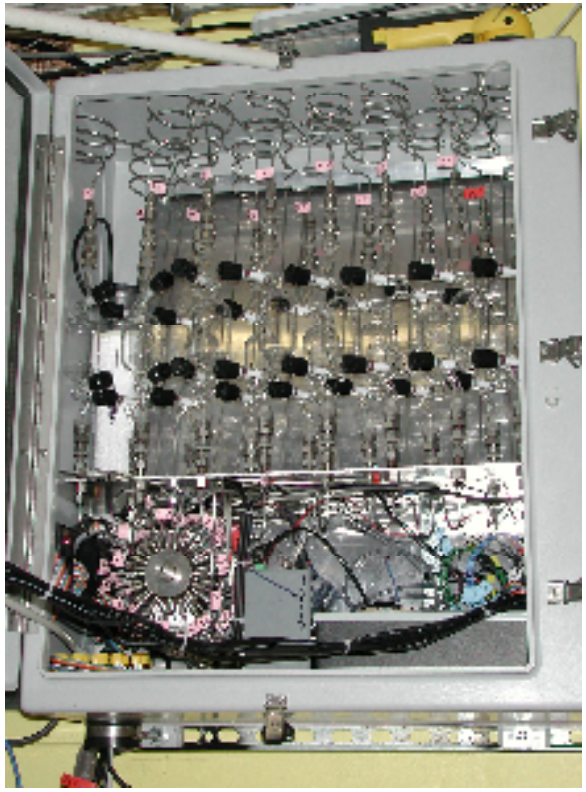
An investigation of carbon-water relations in AmeriFlux sites

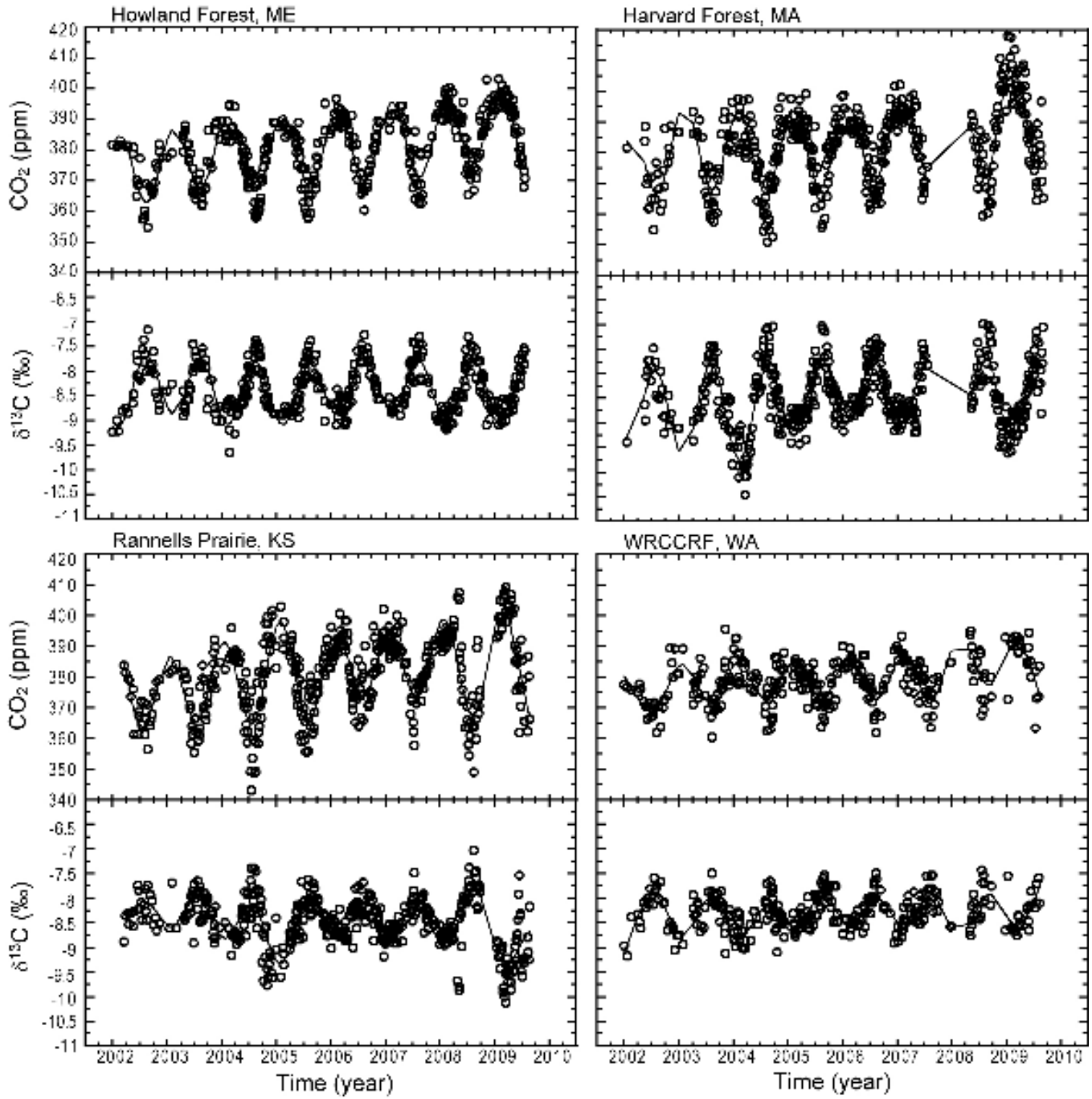
1. Ecosystem physiology using ^{13}C
2. Evapotranspiration using ^{18}O and ^{2}H
3. Regional estimates of carbon fluxes

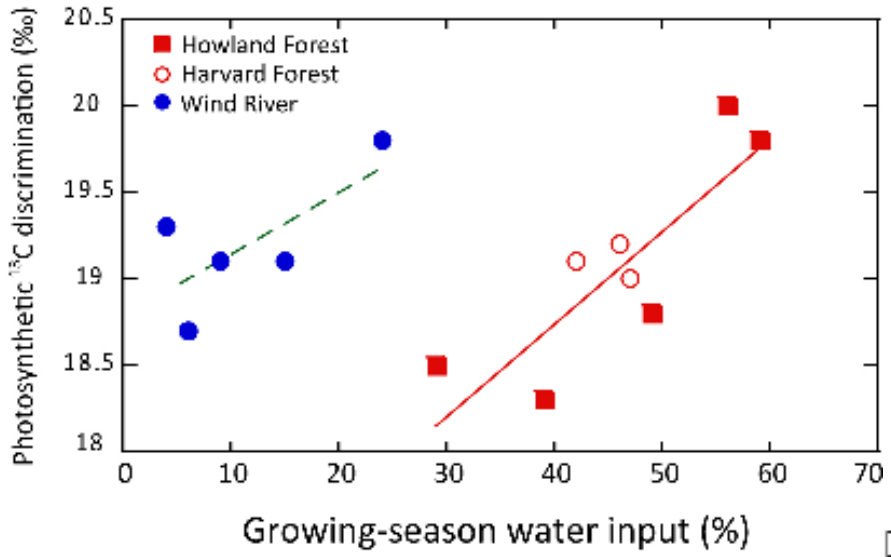
Isotope air sampling

in AmeriFlux sites





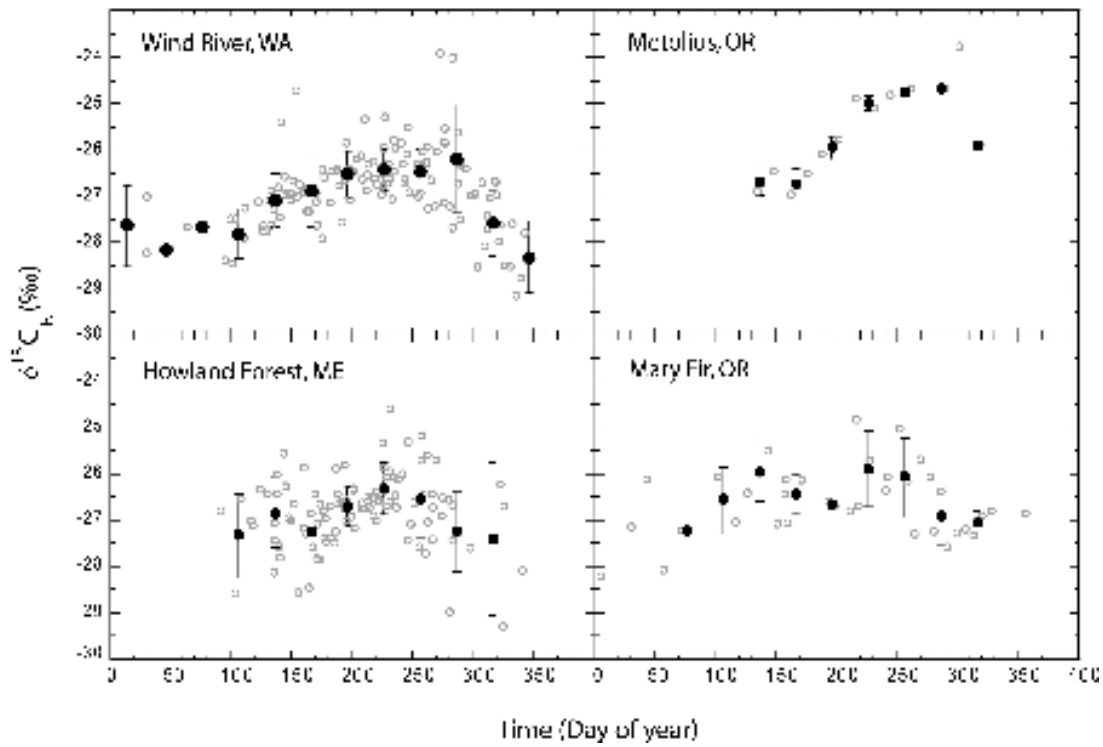

Howland Forest, ME
Harvard Forest, MA
Rannells Prairie, KS
WRCCRF, WA
CO2 (ppm)
δ13C (‰)
Time (year)
2002
2003
2004
2005
2006
2007
2008
2009
2010



Terrestrial plant ^{13}C discrimination varies with water availability

This relationship was detected at seasonal and interannual scales.

Global ^{13}C inversion analysis should consider these variability in global land-ocean CO_2 partitioning.



Laser $^{13}CO_2$ measurements in the Forest Service Climate Change Tower Network

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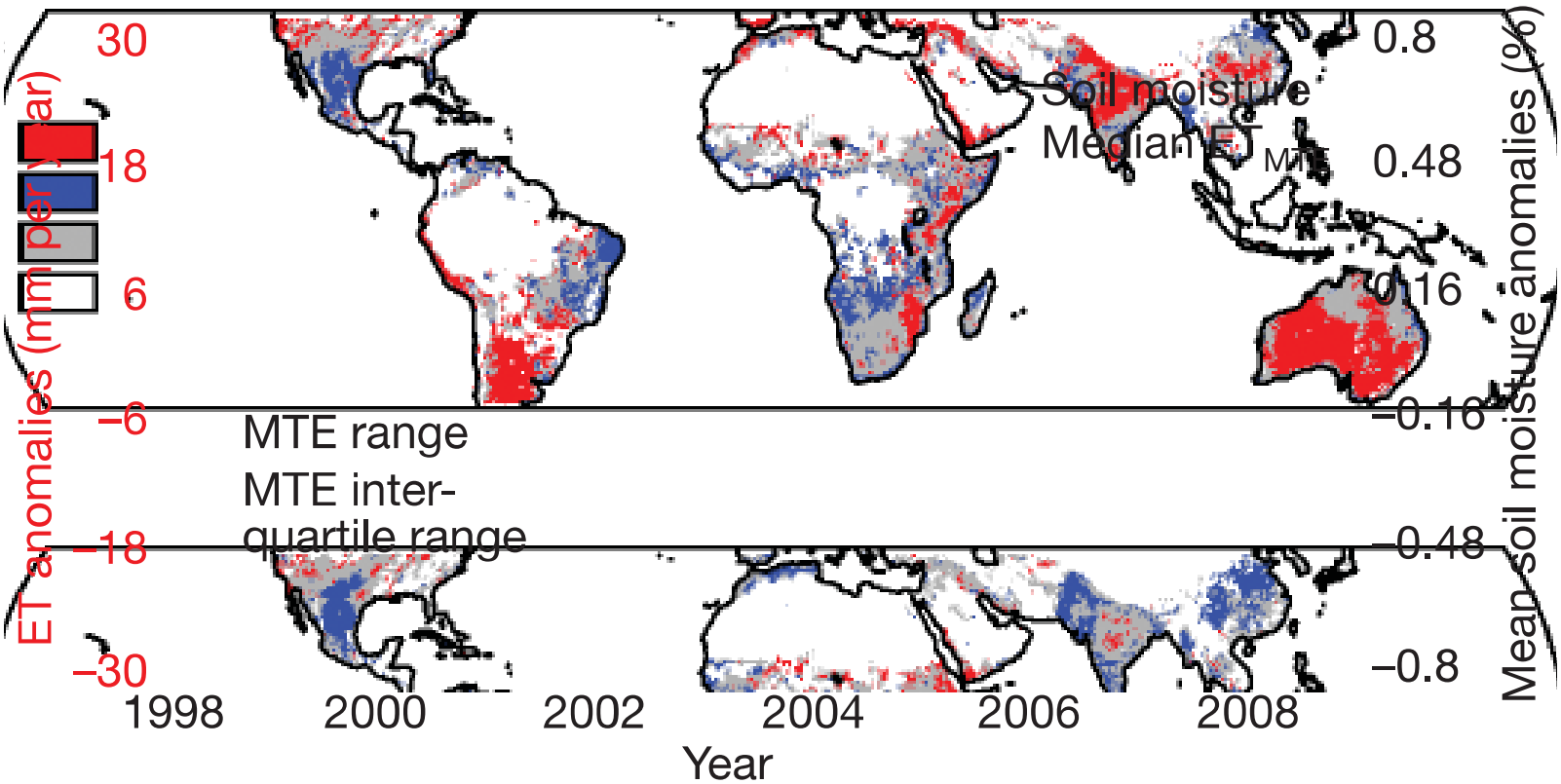
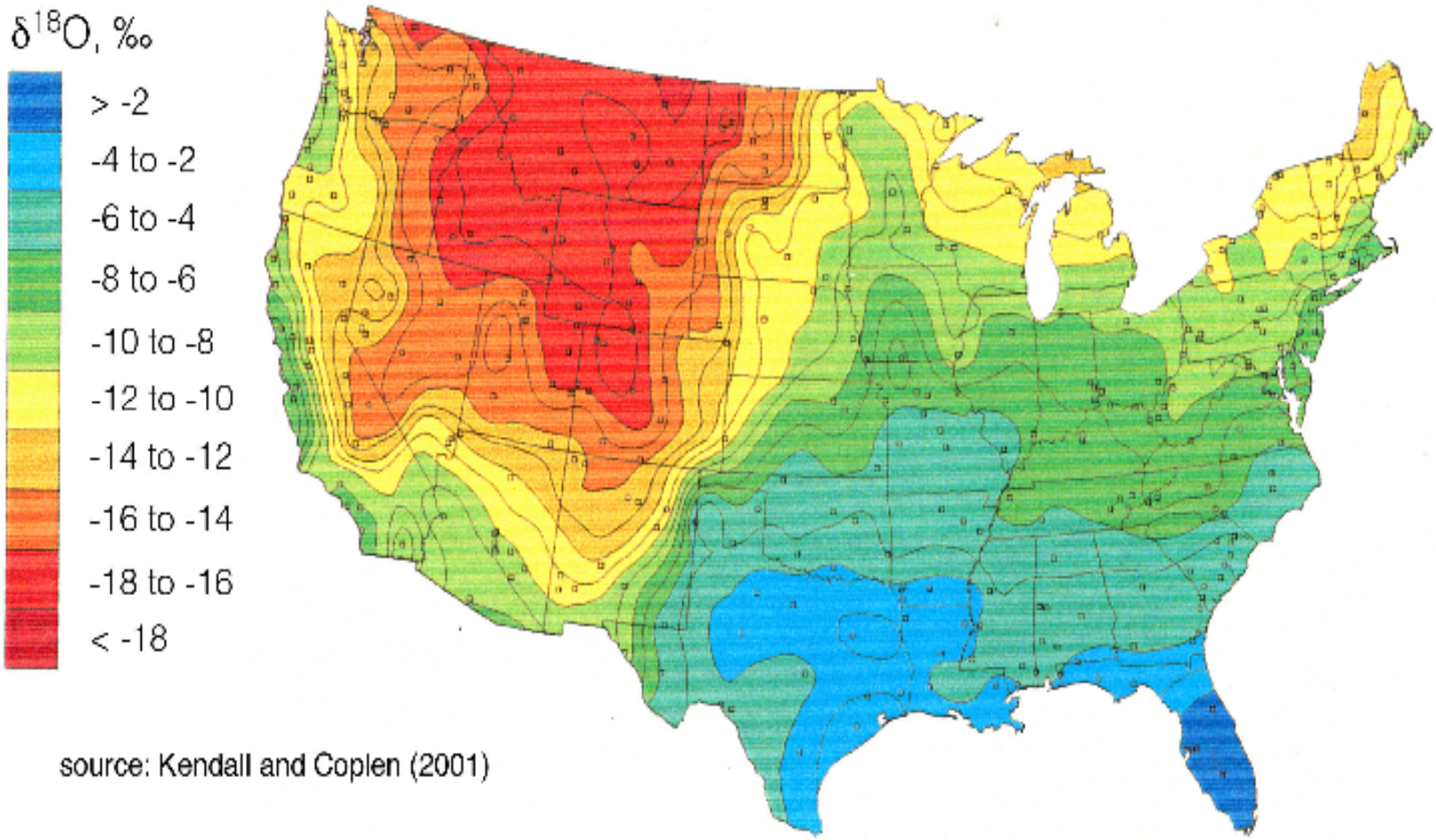
Recent decline in the global land evapotranspiration trend due to limited moisture supply

Jung et al. Nature (2010) 467:951



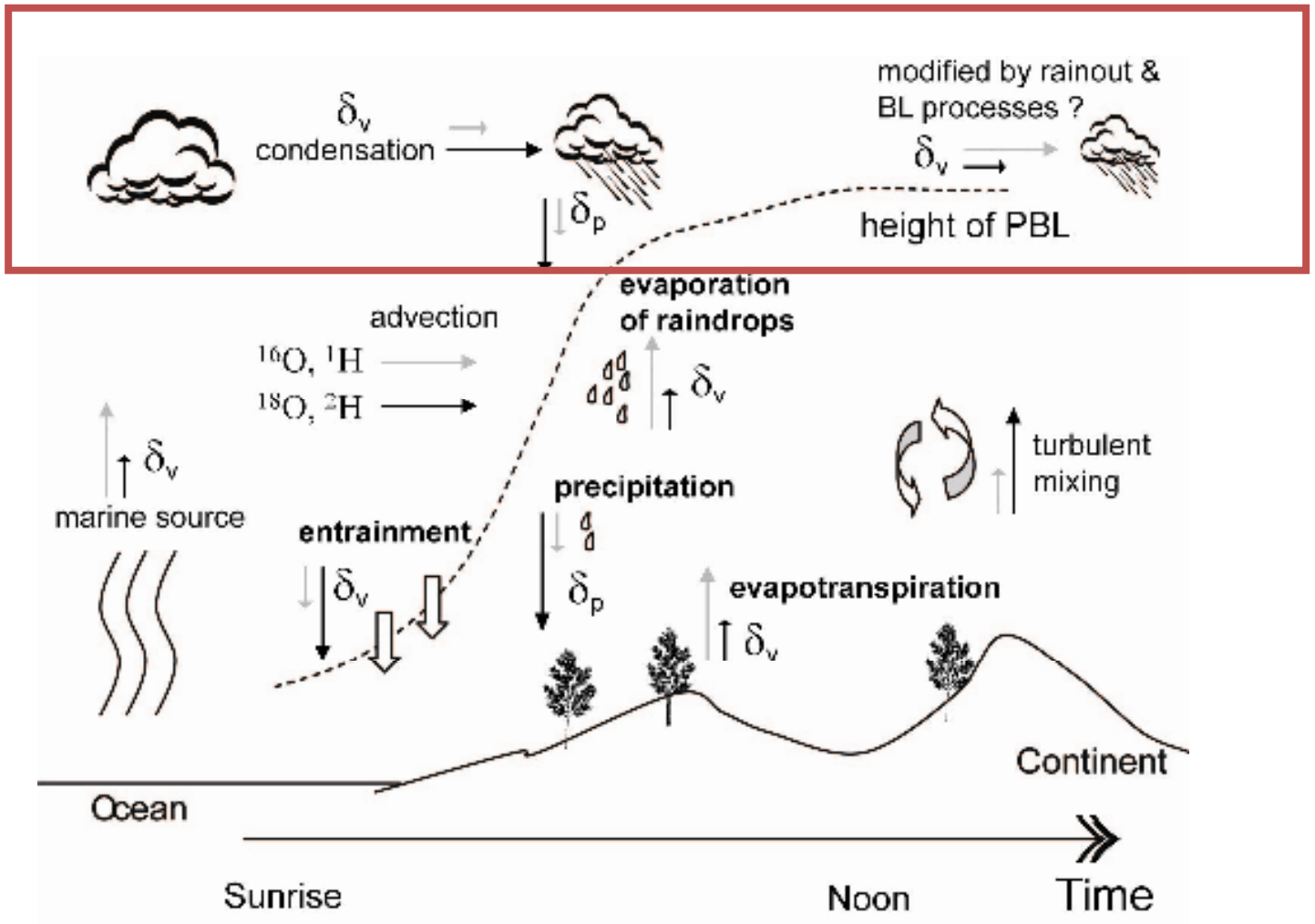
Regional distribution of $\delta^{18}O$ in precipitation



source: Kendall and Coplen (2001)

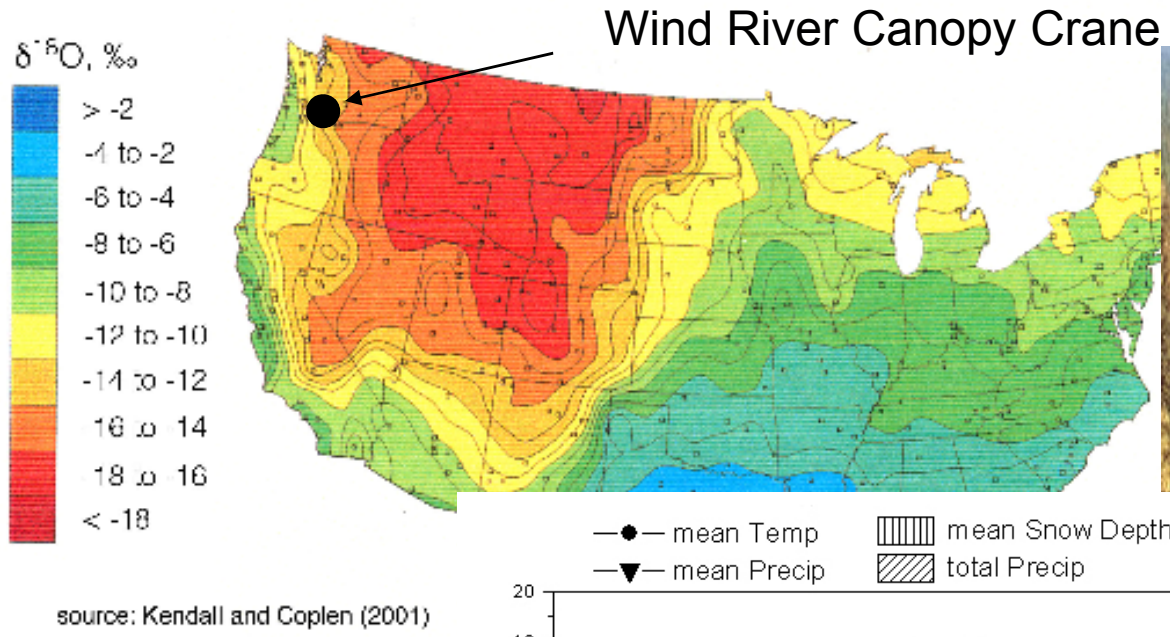
This rain signal is then picked up and recorded by biological organisms

Major processes that influence vapor isotopes in the atmosphere over terrestrial landscape

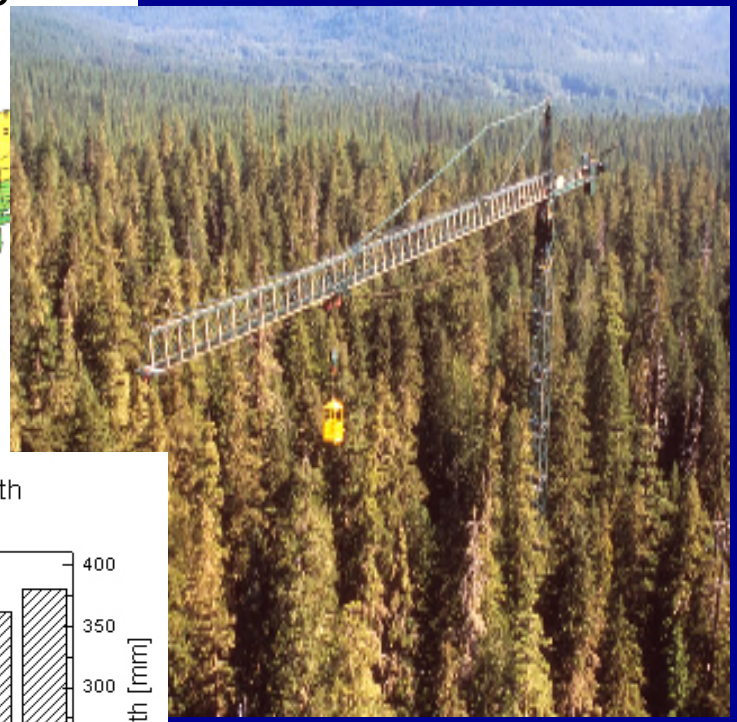


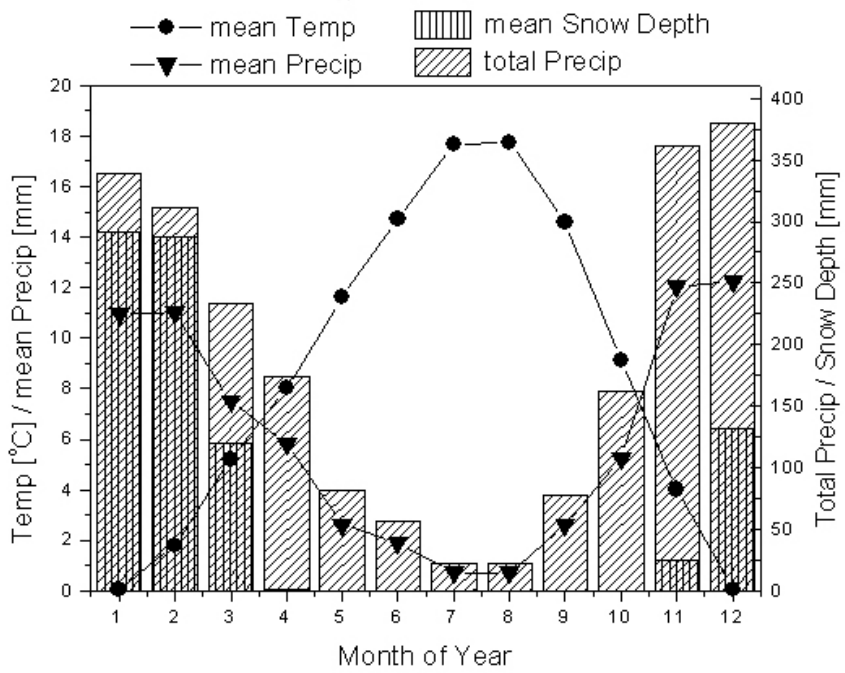
Lai and Ehleringer (2011) Oecologia 165:213-223

Wind River Canopy Crane, Washington State, U.S.A



source: Kendall and Coplen (2001)





Mass conservation of $H_2{}^{18}O$ in a plant canopy

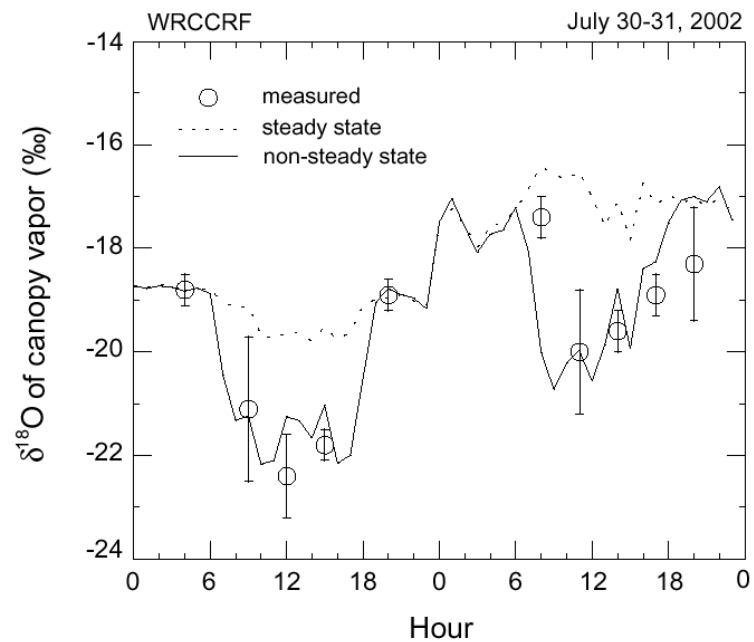
$$M_c v_c \frac{d\delta_c}{dt} = (\delta_+ - \delta_c)F_+ + (\delta_T - \delta_c)F_T + (\delta_E - \delta_c)F_E$$

Isoflux – atmosphere above

Isoflux – transpiration

Isoflux – soil evaporation

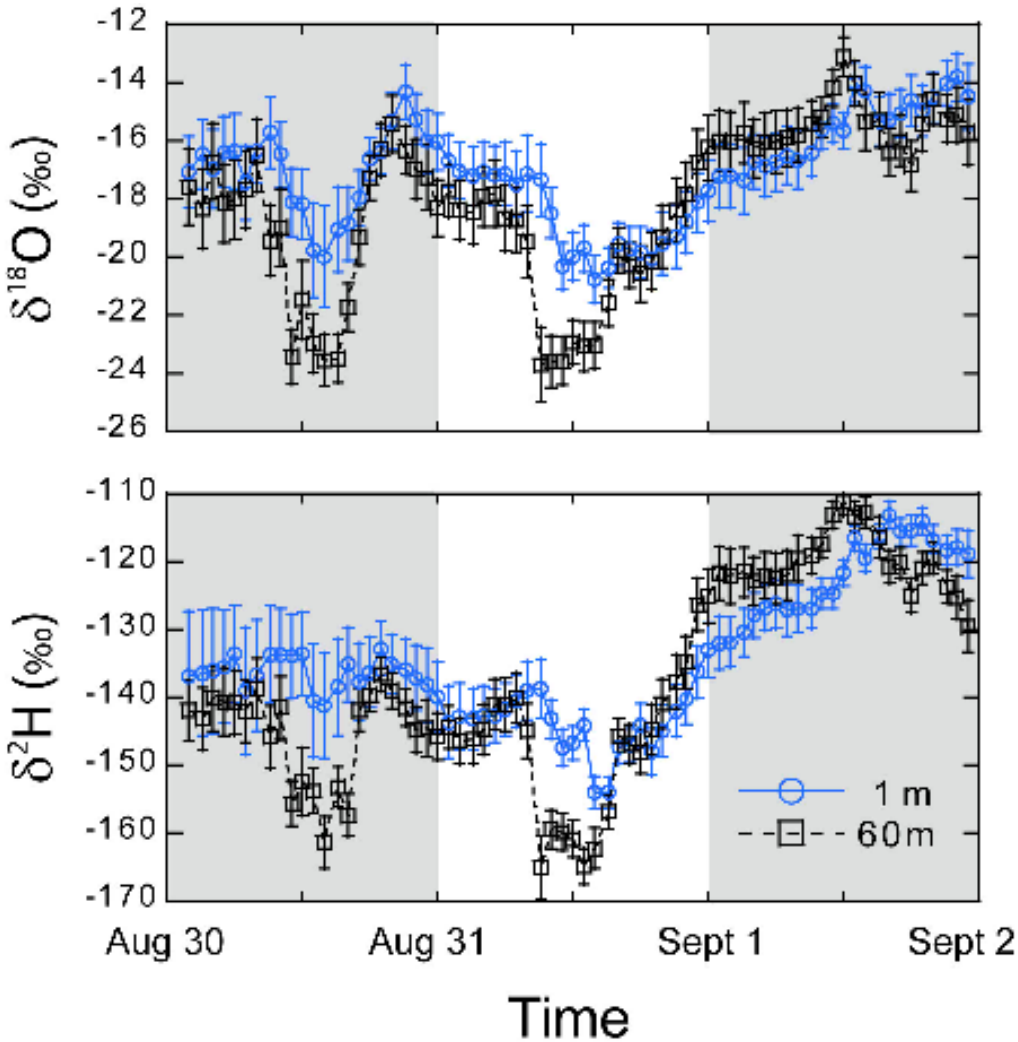
A positive isoflux increases the $\delta^{18}O$ ratio of water vapor in the atmosphere



Lai et al. (2006) Plant Cell Environ 29:77-94

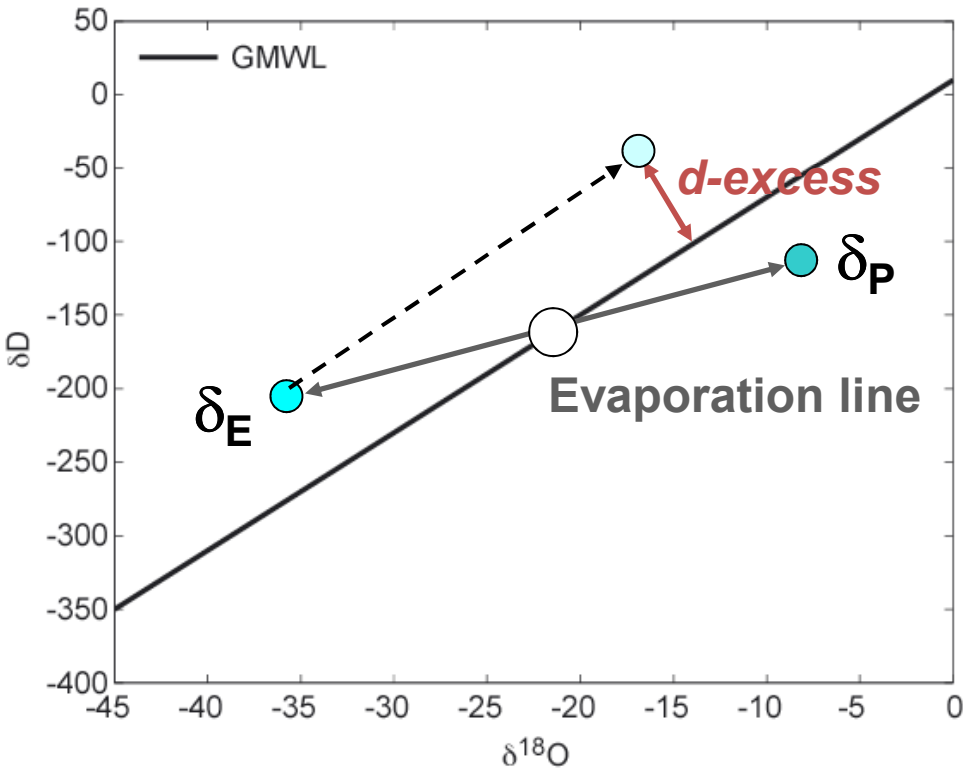
What is the source of air moisture?

- convection of upstream moisture
- surface evapotranspiration



Deuterium excess

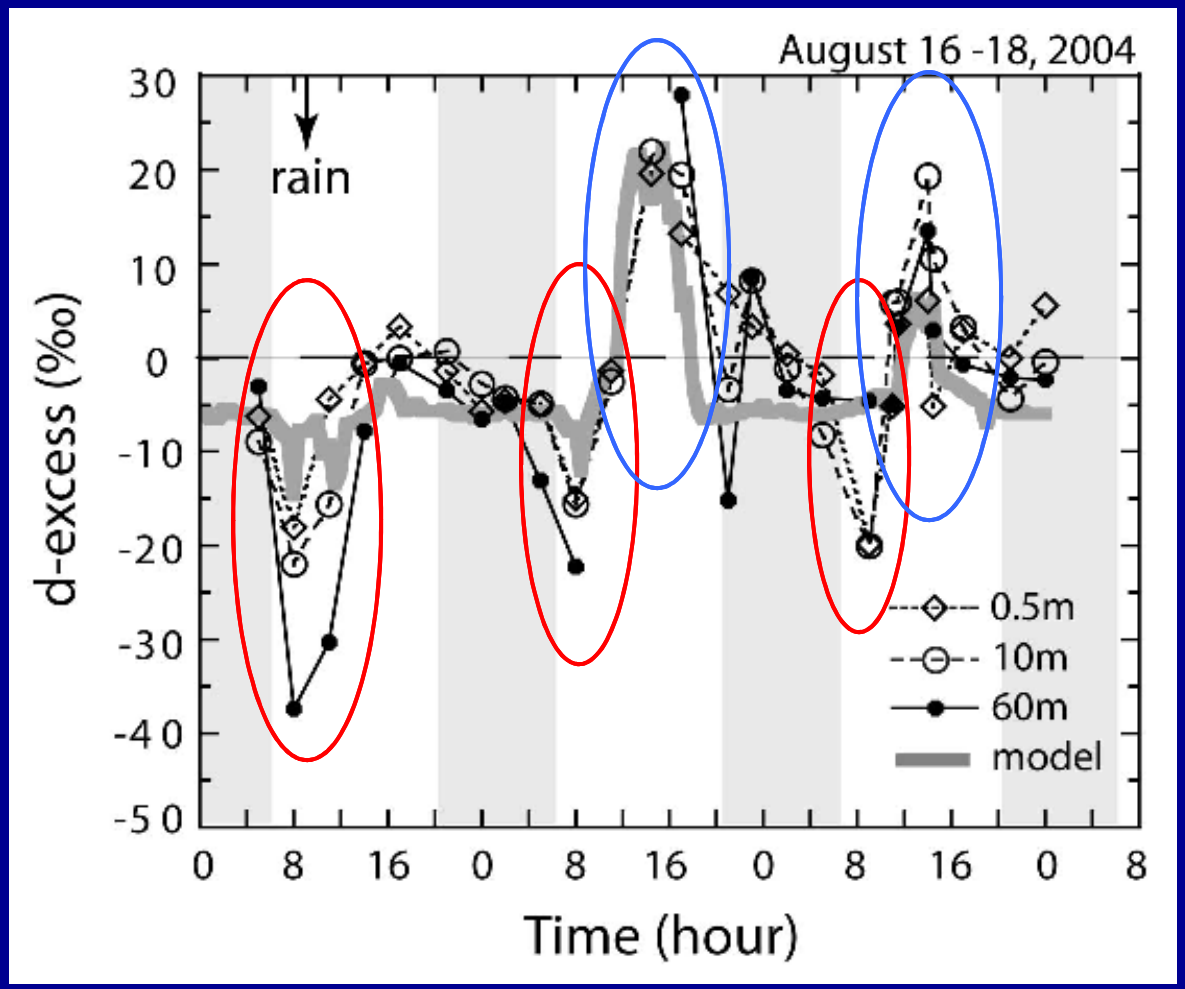
- *d*-excess = $\delta D - 8*\delta^{18}O$ (Dansgaard 1964)
- A diagnostic tracer for the origin of moisture



d-excess is controlled by:

- RH and T at moisture source region
- Kinetic processes

Deuterium excess showed a repeated diurnal pattern: Each day, lowest and highest values occurring in early morning and mid-day, respectively

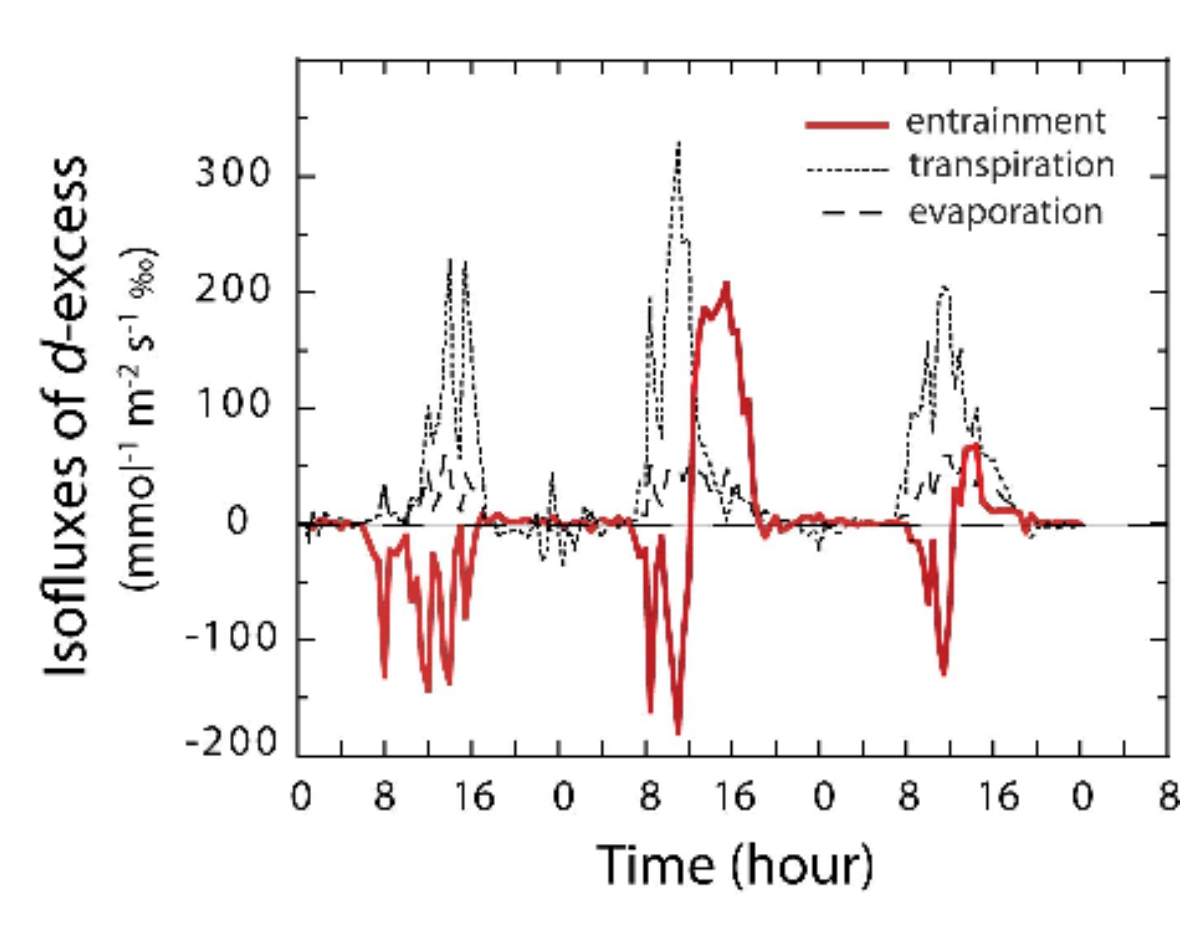


Cryogenic trapping

Lai and Ehleringer (2011) Oecologia 165:213-223

Model simulation suggests that atmospheric entrainment drives the diurnal pattern in *d*-excess

A negative isoflux decreases *d*-excess of water vapor



Lai and Ehleringer (2011) Oecologia 165:213-223

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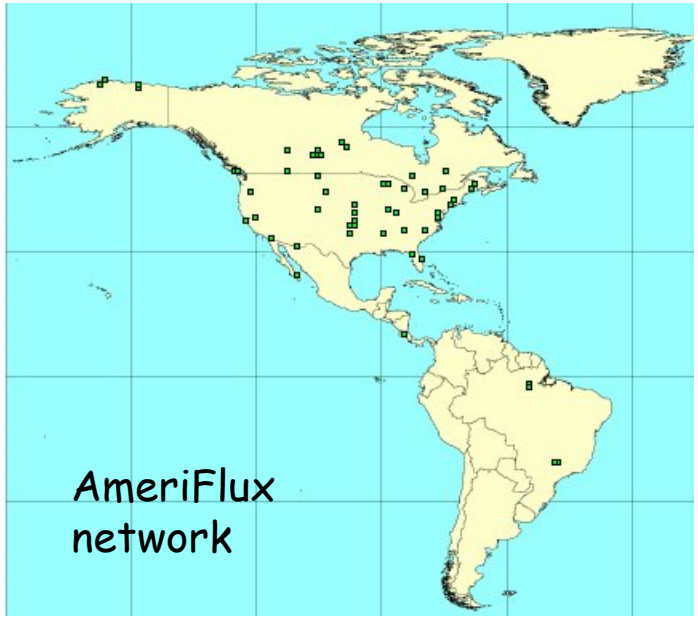
Science issues:

What is the carbon balance of North America?

What is the distribution of sources and sinks?

How do we estimate continental C budget by upscaling tower fluxes ?



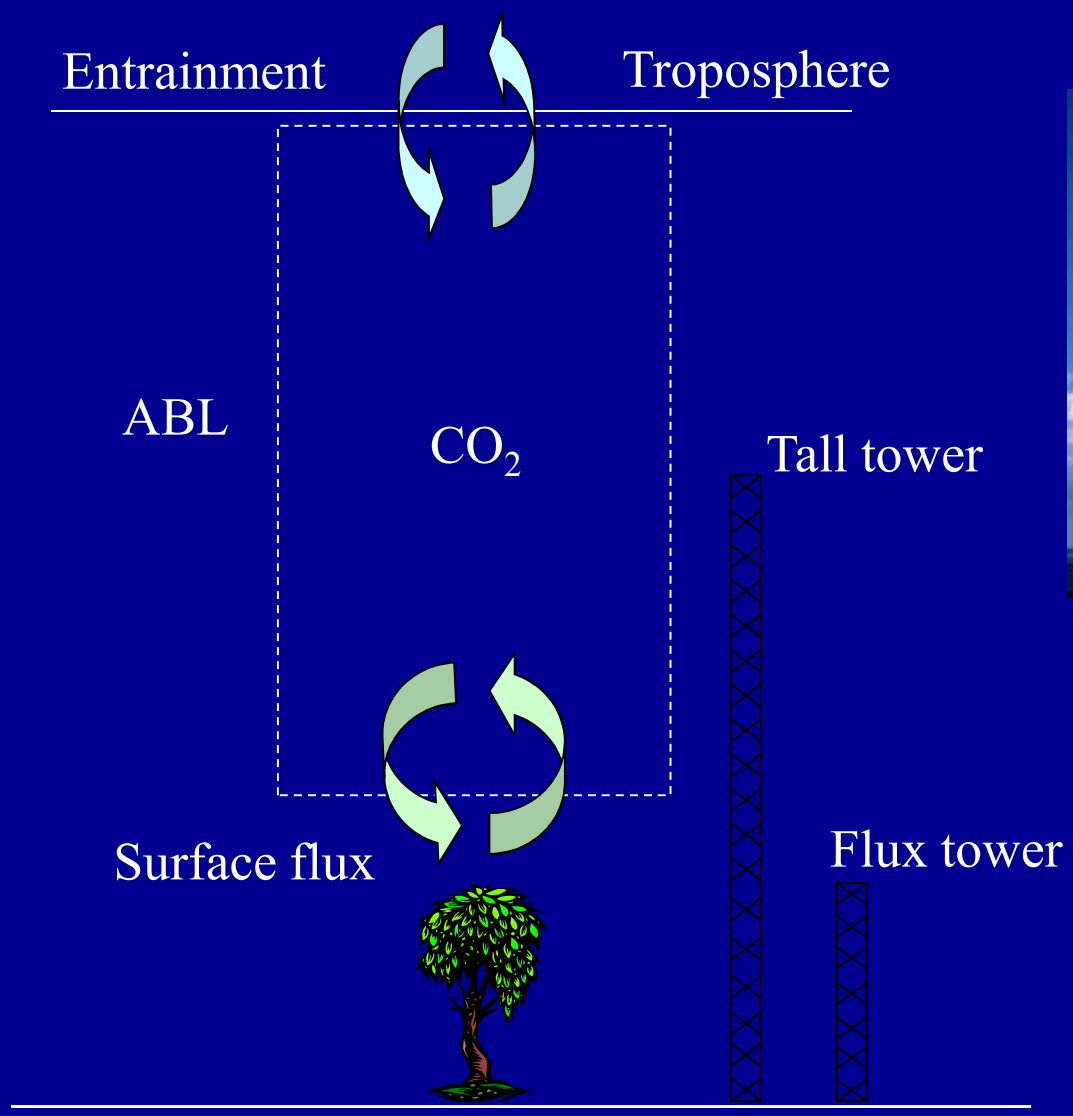
Assessing net ecosystem carbon exchange of U.S. terrestrial ecosystems by integrating eddy covariance flux measurements and satellite observations

Xiao et al. (2011) Agri. For. Meteorol. 151:60

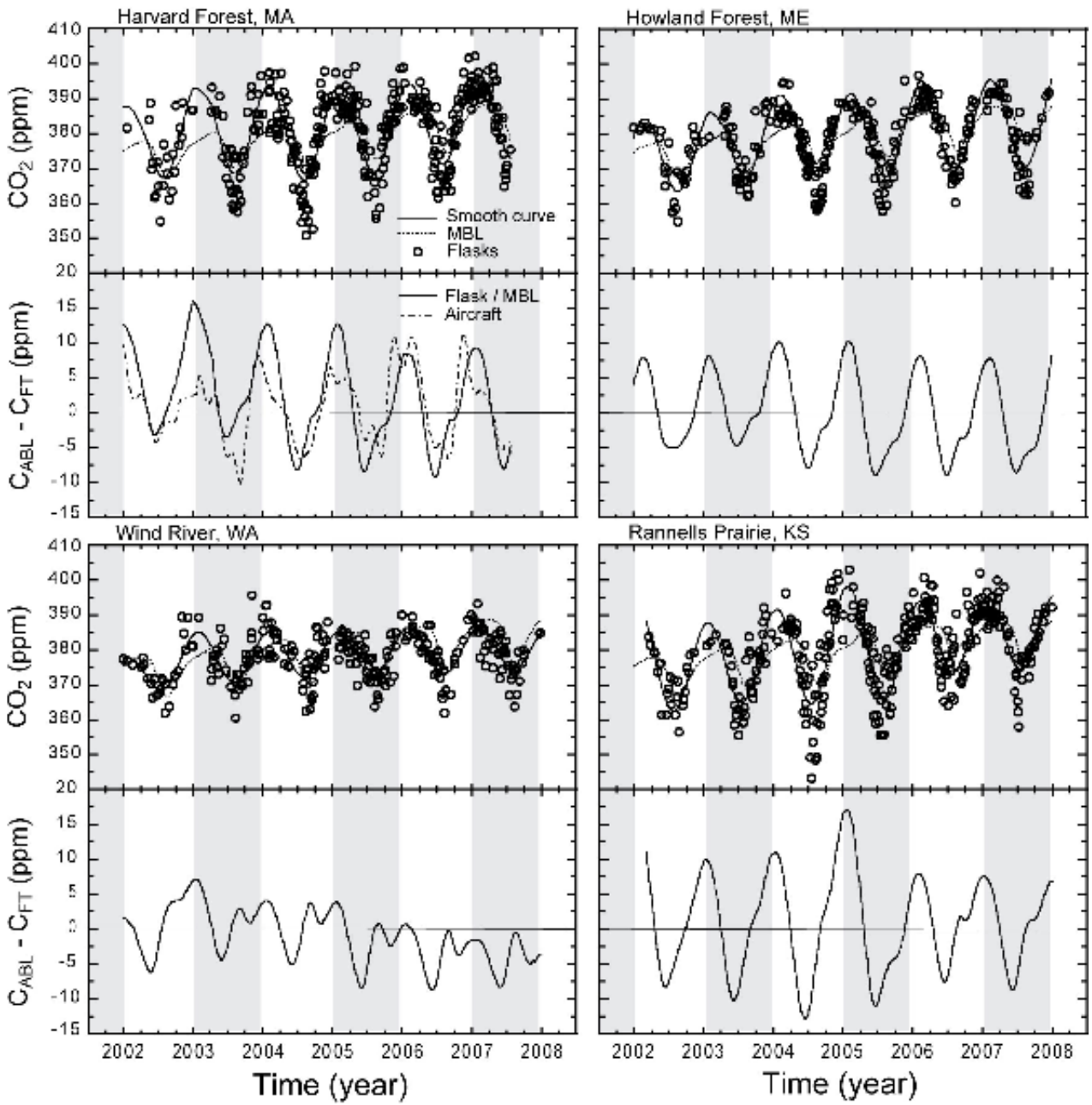
By combining eddy covariance measurements and MODIS data to upscale tower fluxes to continental scales, they estimate a U.S. terrestrial C sink

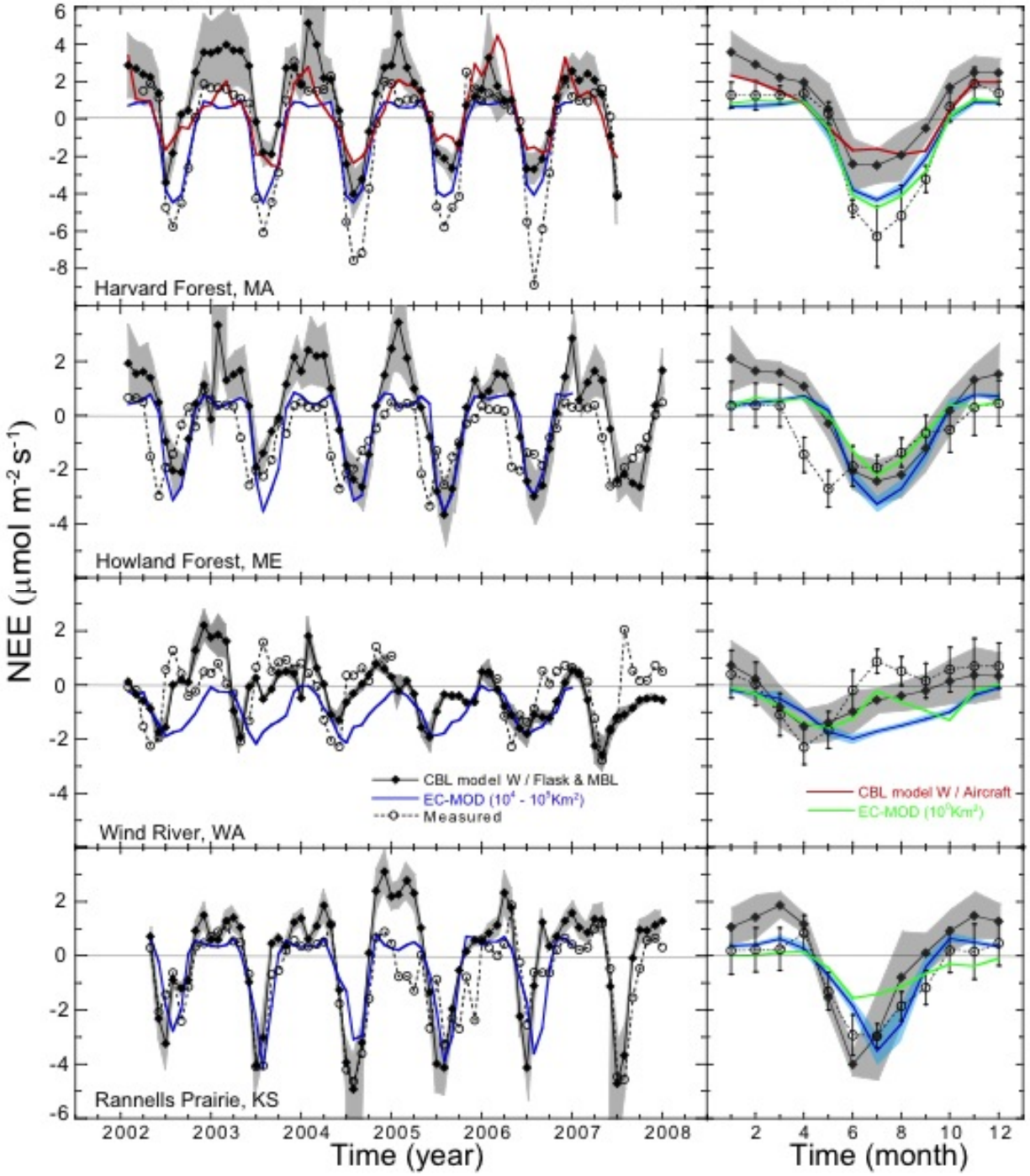
0.63 Pg C yr^{-1}

Atmosphere is an effective integrator of land surface productivity – boundary layer approach



CO_2 gradient between boundary layer and free troposphere





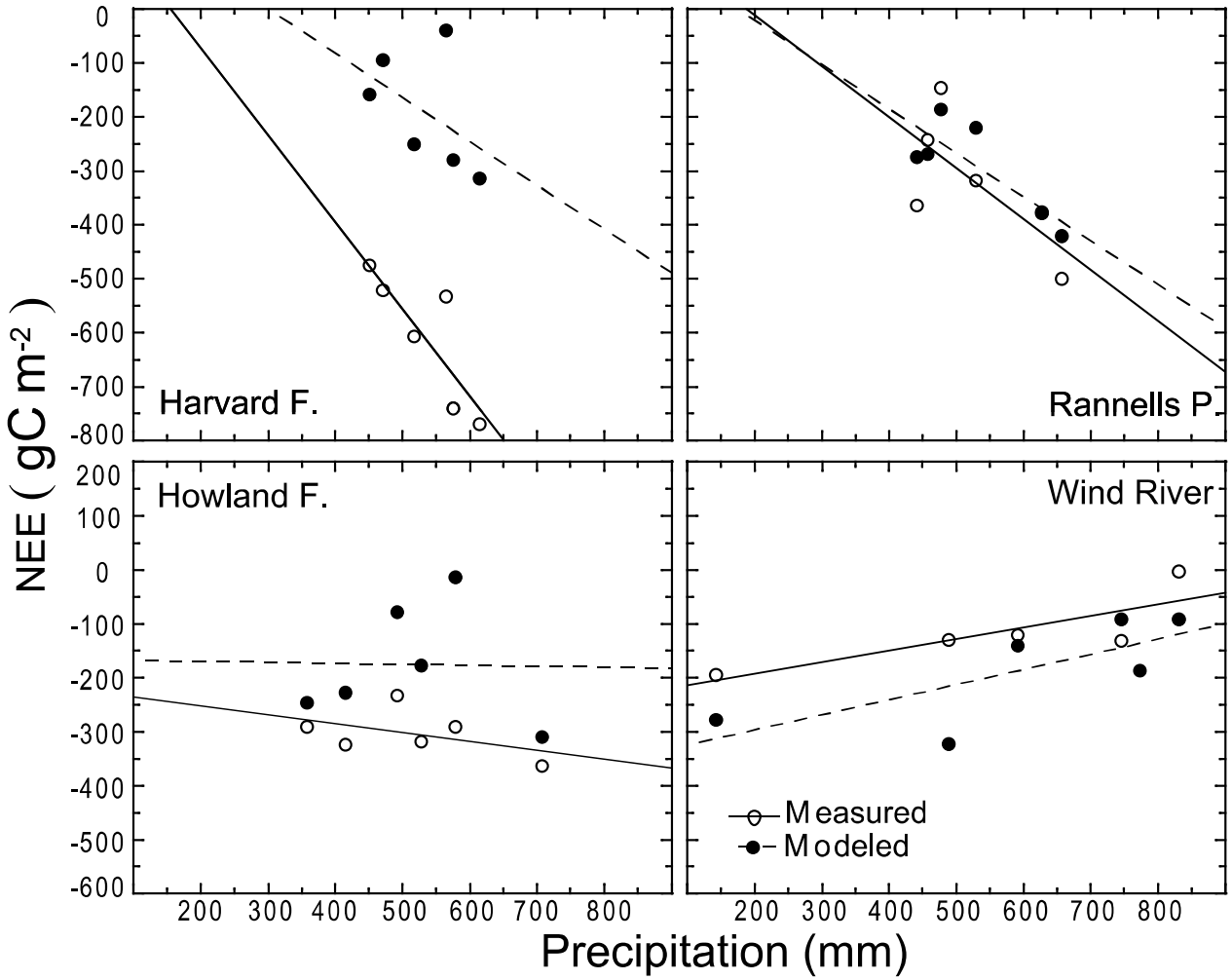
Harvard Forest

Howland Forest

Wind River

Rannells Prairie

Relationship between growing season precipitation and NEE



The effect of water inputs varies among sites and between scales.