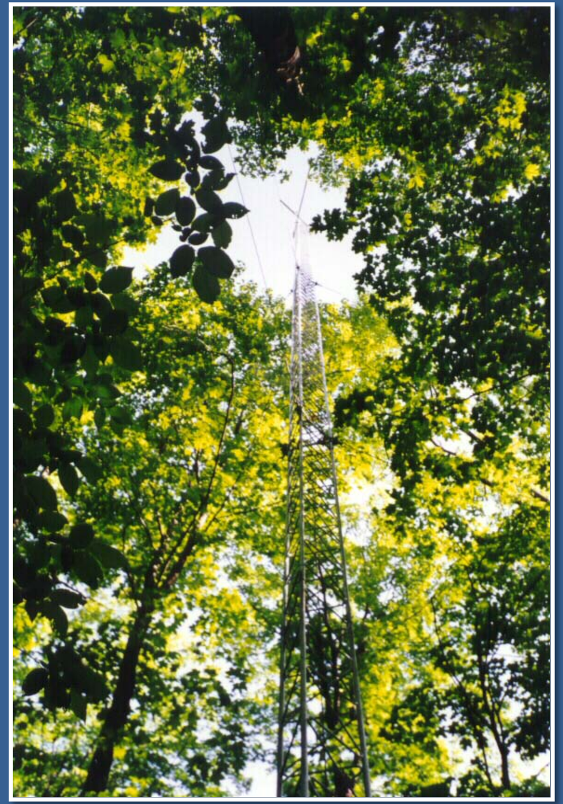
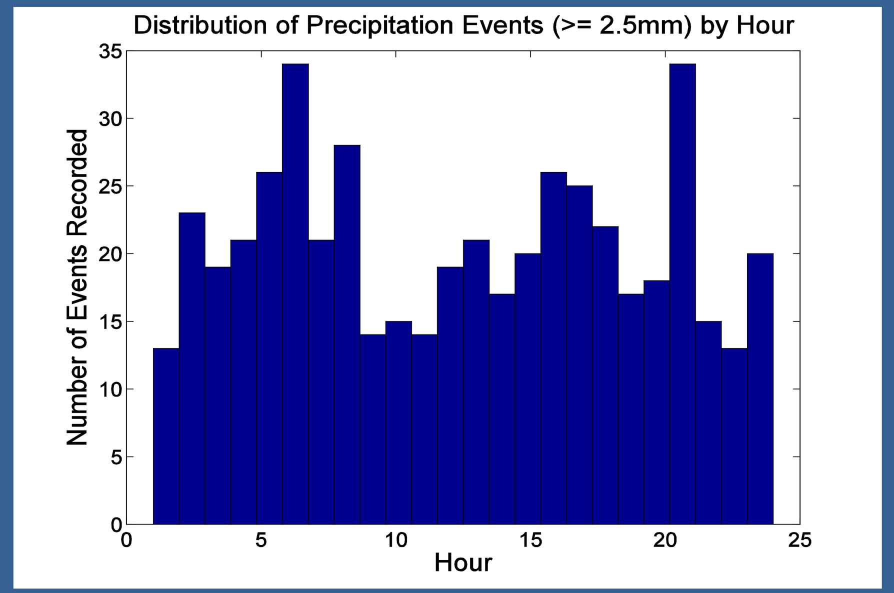
Do precipitation pulses drive anomalous carbon dioxide ecosystem exchange in temperate ecosystems?

Austin Thomas and Ankur Desai, University of Wisconsin-Madison, Center for Climatic Research

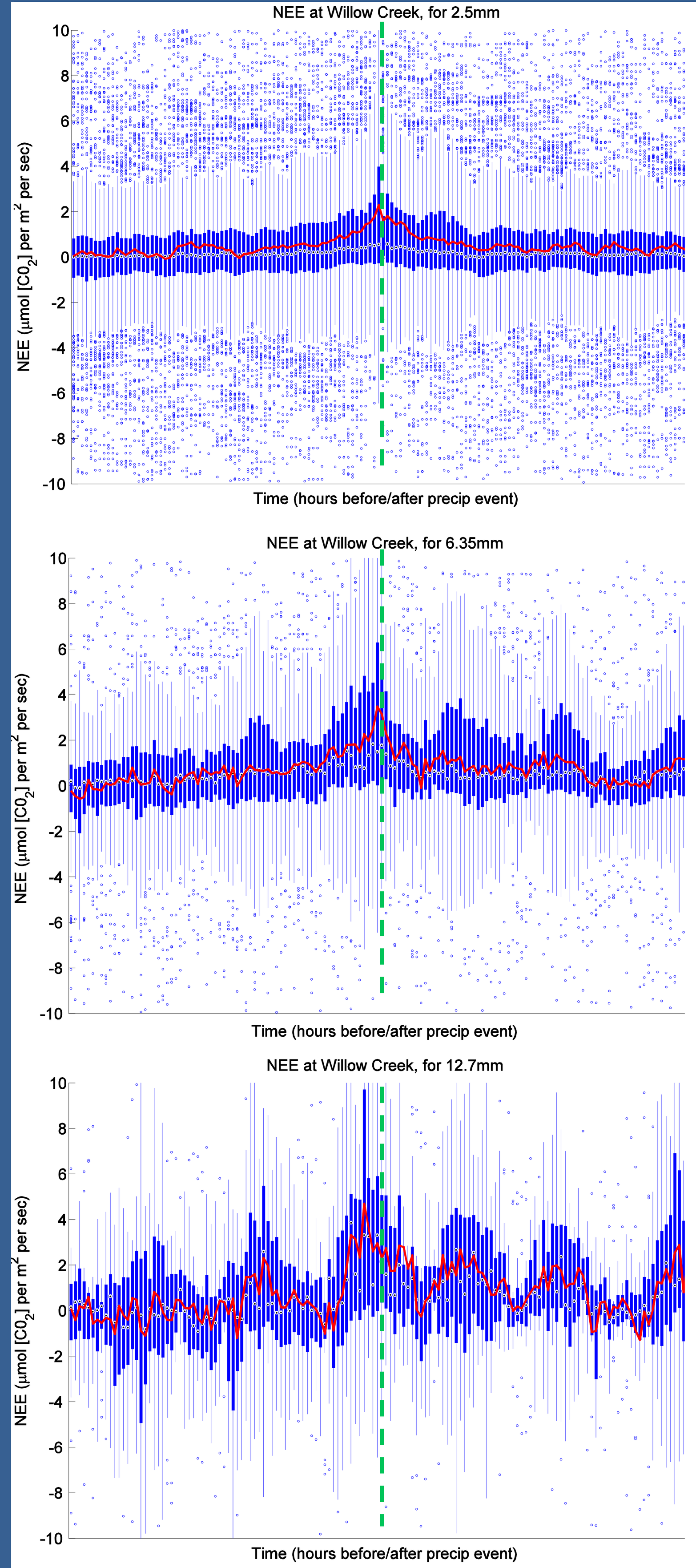
Recent studies [Huxman et. al. 2004, Sponseller 2006] in semi-arid systems have identified that precipitation pulses can lead to increased emissions of carbon dioxide from the soil. However, this has not been demonstrated in temperate ecosystems. Here we seek to ask how anomalies of net ecosystem exchange (NEE) of carbon dioxide are related to precipitation occurrence, magnitude, and timing. We suspect that carbon dioxide NEE will respond to precipitation events and that NEE will trend towards decreased ecosystem carbon uptake as a result.

Eddy covariance hourly NEE collected at two different sites in northern Wisconsin for eight years, one a hardwood forest (Willow Creek) and the other a wetland (Lost Creek). Positive NEE values imply uptake of CO2 is surpassed by release, while negative values imply ecosystem carbon uptake. Precipitation data were recorded at Lakeland Airport (KARV) in Woodruff, WI.

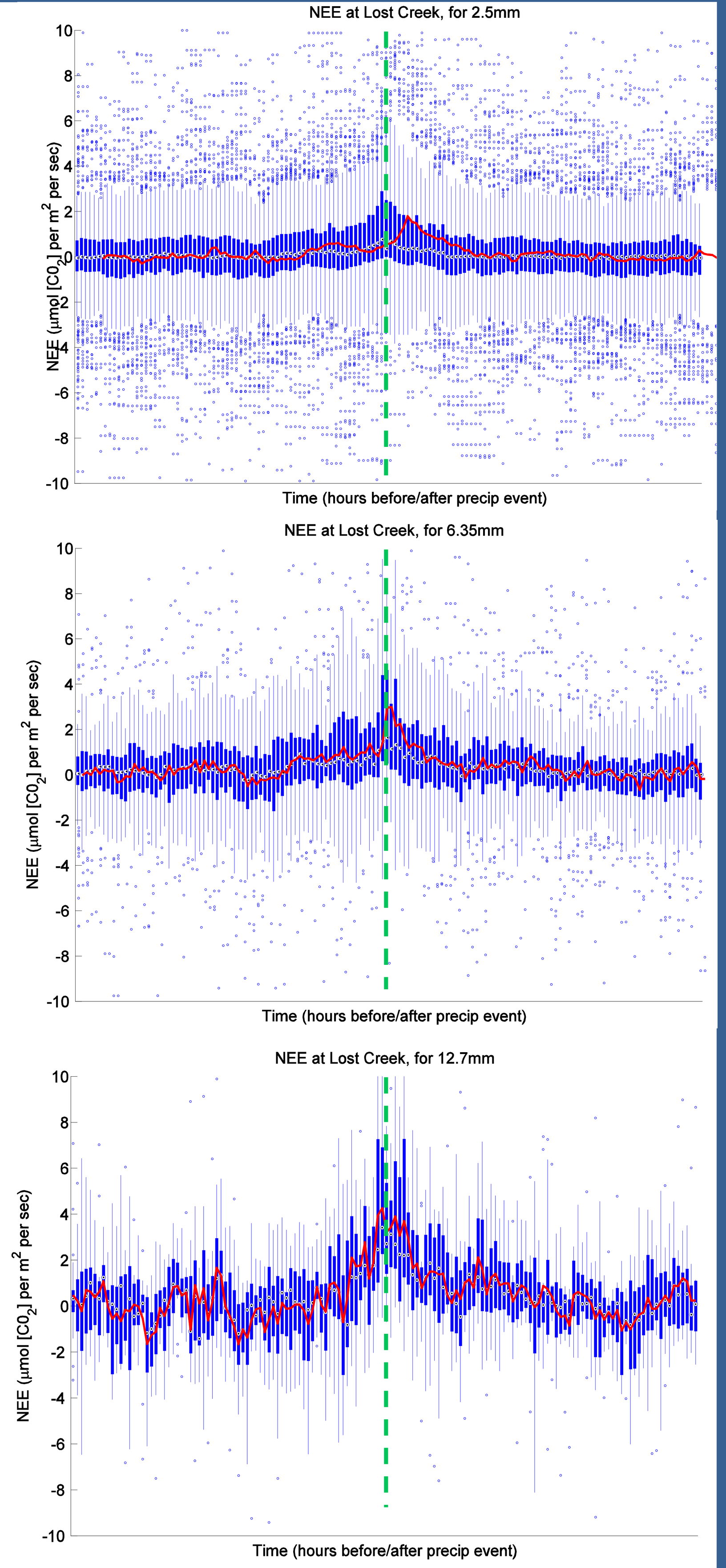




Any hour in which rainfall exceeded a given threshold was matched to a range of NEE data recorded from 72 hours before until 72 hours after the precipitation event. A set of 145 hourly bins of data was analyzed statistically for trends in NEE versus time. Figure 1 (left) shows the distribution of precipitation events greater than 2.5mm by hour for 2000 through 2011.



Figures 2A through 2C (at left, from top to bottom) show the final analyses for each precipitation threshold from Willow Creek, while figures 2D through 2F (at right, from top to bottom) show the same analyses from Lost Creek. Each of the six plots is a time series of NEE distributions spanning 144 hours, centered on 0 hours (the precipitation pulse, marked in green on each plot). Each hourly time step has a box plot regression analysis (blue bars with blue dots as outliers) of the NEE values recorded for each precipitation event.



Median values (black dots) and average values (red line; connected across time steps) are shown for each hour.

For both tower sites, and for all precipitation thresholds, positive departures in NEE are evident around and shortly after the introduction of the precipitation pulse at 0 hours. The signal tends to persist for several hours, before subsiding. Pronounced rises in NEE appear to also grow linearly larger as precipitation threshold increases. This suggests that carbon dioxide uptake by the ecosystem is at least temporarily suppressed, if not reversed, during and after precipitation pulses.

This study represents an initial look at the coupling between forest ecosystems and short duration mesoscale weather phenomena, Broader work of characterizing land and atmosphere greenhouse gas exchanges is accelerating quickly, and projects like these can help steer more ambitious work in the future.

Our results bring arise to several questions for future work:

- When averaged over many events, NEE is shown to not respond discontinuously, suggesting that in the hours immediately preceding the precipitation pulse, NEE experienced a comparatively small but significant upwards trend. What factors are contributing to this "precursor" trend?
- How do precipitation events that span multiple hours with threshold-exceeding rainfall confound the results?
- Do NEE fluctuations produced by thunderstorms (deep convection) differ from those occurring in sustained showers (stratoform or shallow convection)?

Variables such as wind speed, pressure fluctuations, solar radiation, and soil moisture likely co-vary with our result and should be included to better test these questions.

I would like to thank Professor Desai for his guidance and support during this project. This research was conducted during a NSF Research Experience for Undergraduates (REU) appointment with the Desai Lab Group at the University of Wisconsin-Madison. Funding for the REU was provided by the National Science Foundation Biology Directorate grant #DEB-0845166.

I also acknowledge the North Temperate Lakes (NTL) Long Term Ecological Research (LTER) site for the precipitation observations. Flux observations were collected with assistance of Jonathan Thom at UW-Madison.

Contact me at:
awthomas@wisc.edu

For more information, visit:
flux.aos.wisc.edu