Forests, wetlands, and lakes: comparing drivers of carbon cycling in heterogeneous northern landscapes

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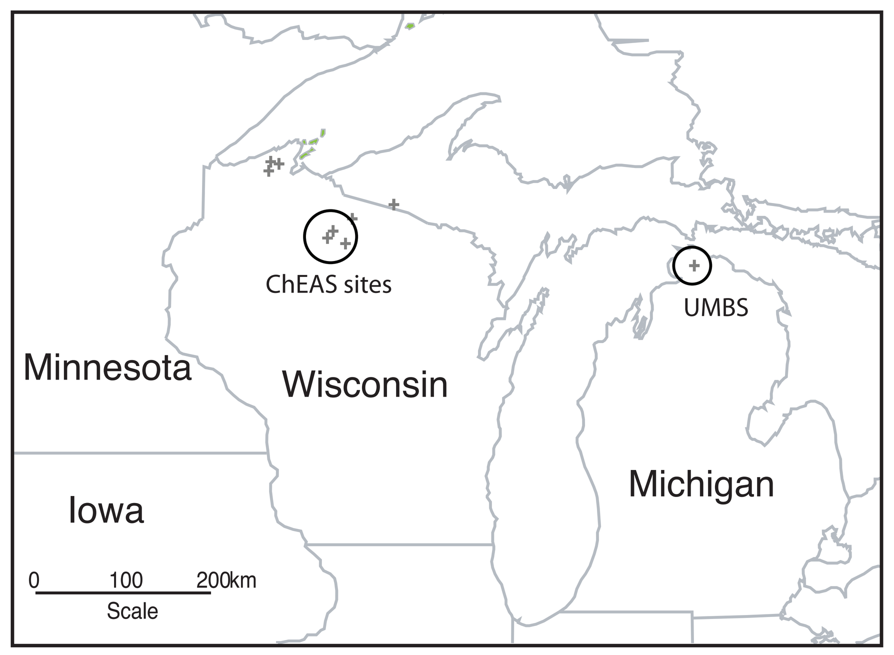
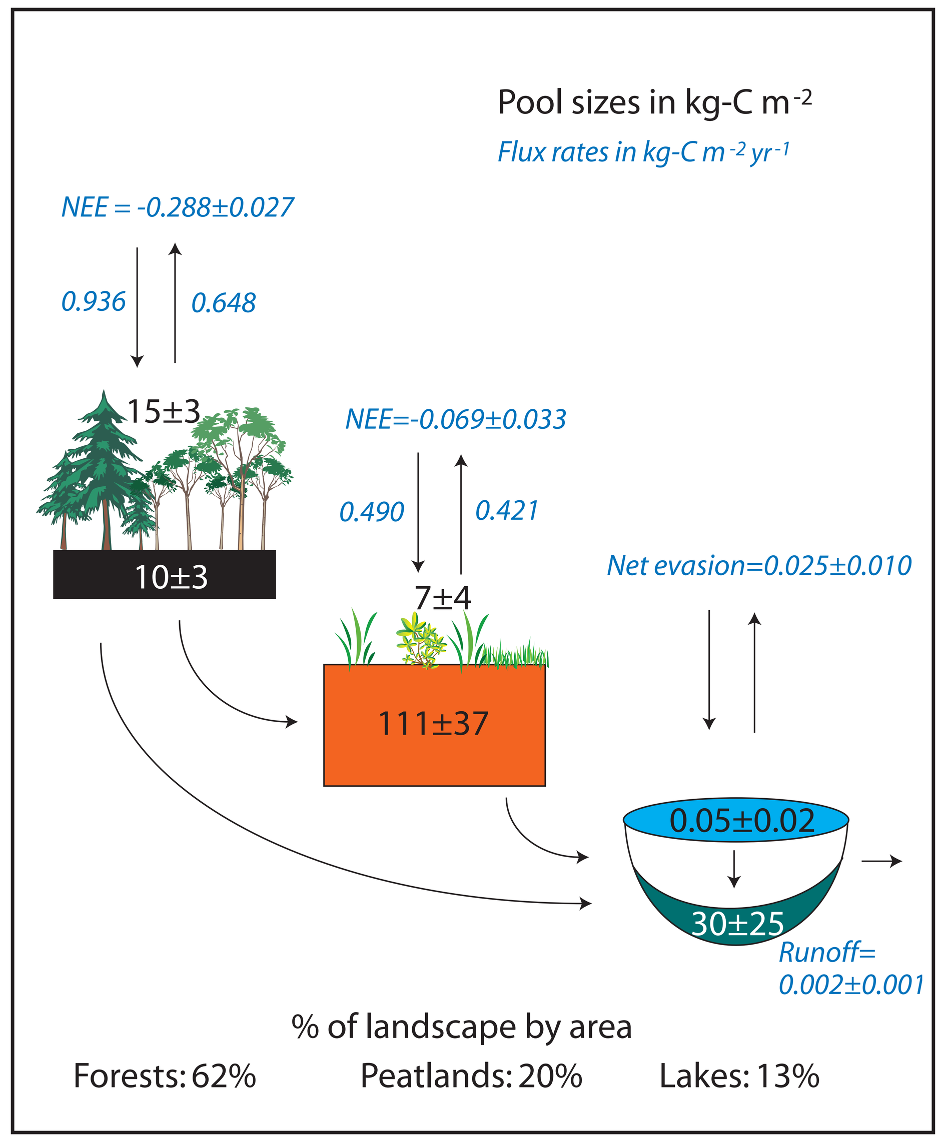
Region

Much of the upper Great Lakes region of the United States is a wet, highly heterogeneous landscape consisting of forests, wetlands, and lakes. All of these landcover types contribute to regional atmospheric fluxes, but each responds to different controlling factors



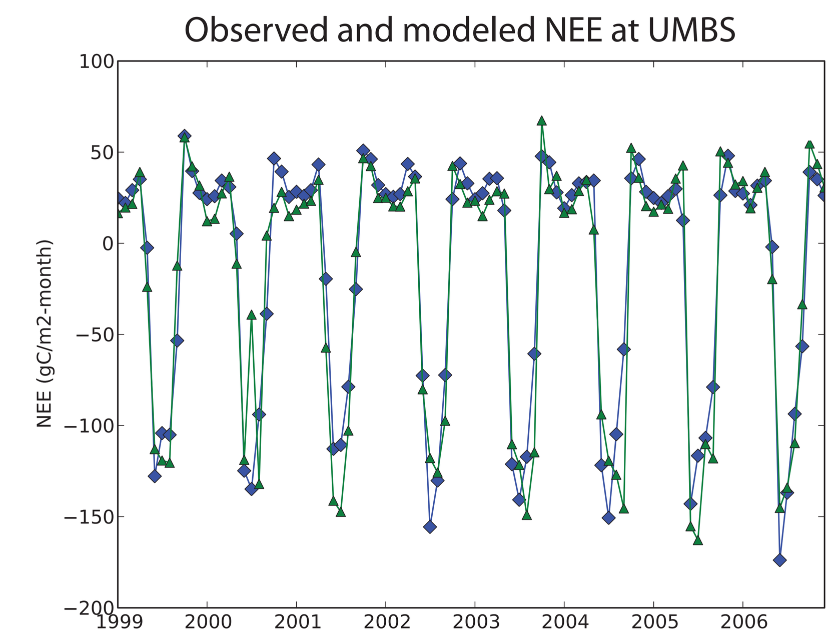


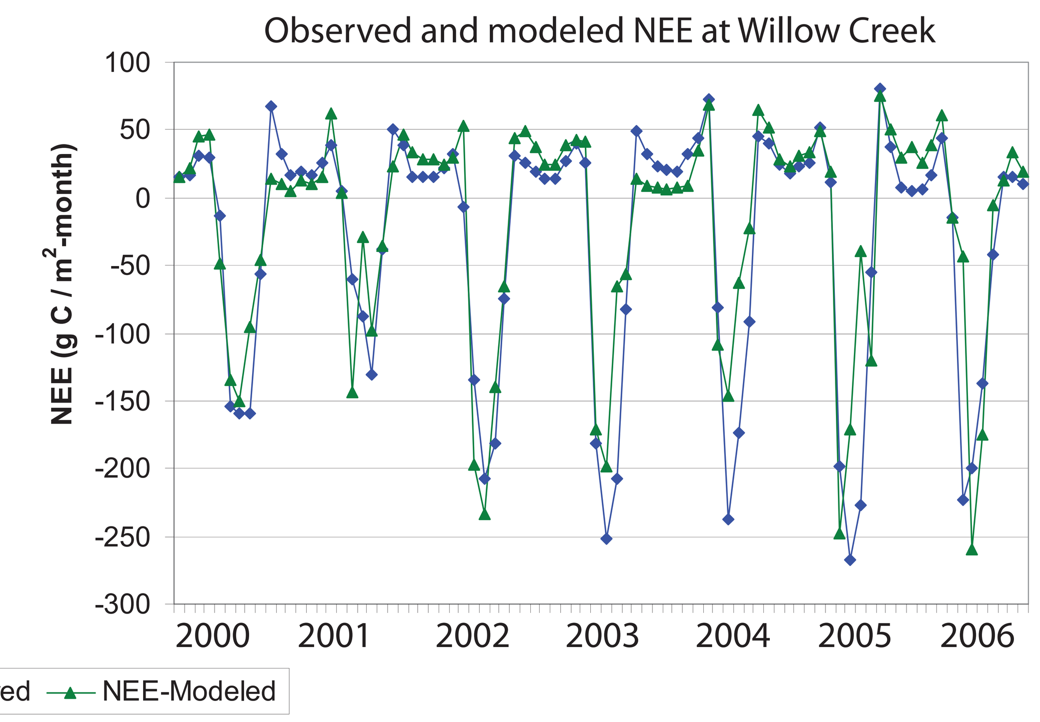
Above: Map of the study sites. The Chequamegon Ecosystem Atmosphere Study (ChEAS; cheas.psu.edu) is a network of sites in northern Wisconsin. The wetland and lake sites presented here as well as the Willow Creek forest site were located in this area. The other forest site was located at the University of Michigan Biological Station (UMBS).

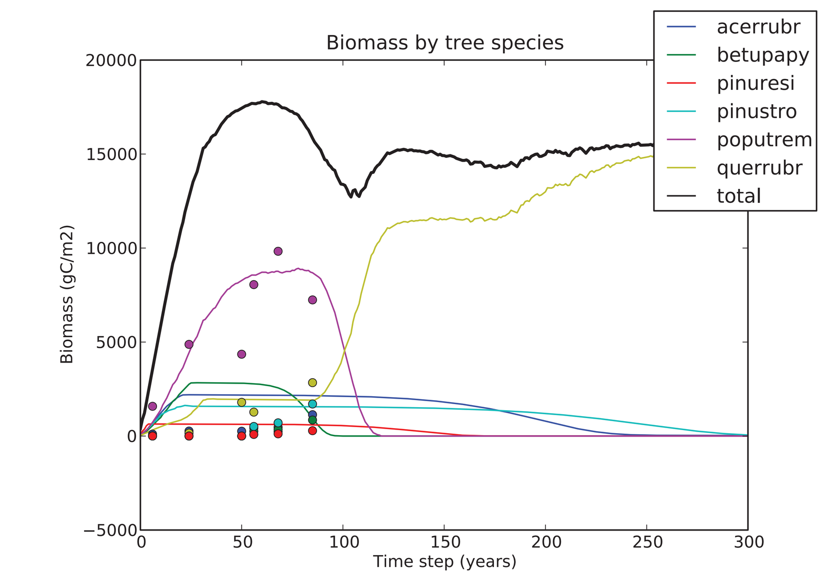
Right: A schematic of carbon pools and fluxes in the Northern Highlands Lake District of Wisconsin (Buffam et al., in prep.). Forests are the largest carbon sink and contain the largest aboveground pool, but wetlands are the largest carbon pool when soil reserves are included. Much of the carbon lost from the other ecosystems in runoff eventually passes into lakes where it is deposited or evades to the atmosphere.

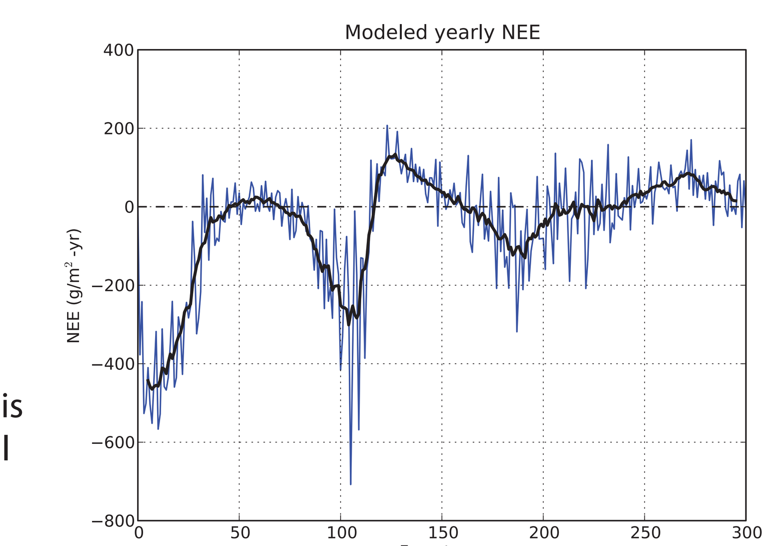
Forests

The major factor controlling forest-atmosphere interactions in the upper Great Lakes region is the legacy of harvesting. Most of the forested area of the region was clear-cut in the early 20th century and has since regrown into early successional species. In the next few decades these species are expected to be replaced by longer lived trees, with important implications for carbon fluxes. We modeled the long-term evolution of the forest using the LANDIS-II forest landscape model (www.landis-ii.org) incorporating the Century model of plant and soil dynamics (Scheller et al., in review). Preliminary results are shown here.









Above Left: Observed monthly NEE at the UMBS Ameriflux tower (blue) and NEE modeled using LANDIS-II (green). UMBS has sandy soils and is dominated by aspen.

Above Right: Observed monthly NEE at the Willow Creek Ameriflux tower in northern Wisconsin. Willow Creek is a mature forest on richer soils than at UMBS, and is dominated by sugar maple, basswood, and green ash.

Upper Right: Aboveground biomass by tree species modeled using LANDIS-II and measured at the UMBS burn chronosequence. The solid lines represent a modeled scenario. The dominance of different species may vary between simulations due to random variability. The black solid line is modeled total aboveground biomass. Circles are measured aboveground biomass at the UMBS chronosequence (Gough et al., 2007). We are still in the process of contraining long-term model behavior, and these results are preliminary.

Lower Right: Modeled annual NEE in a growing forest simulated using LANDIS-II. The model was initialized as a clearcut. In the simulation, the forest is a strong carbon sink during an initial period of rapid tree growth, and approaches a neutral carbon balance as the forest reaches maturity. It briefly becomes a sink again as short-lived trees die out and are replace with later successional species, and then a source as growth slows and dead wood pools increase. The thick black line is a 10-year running average.

Wetlands

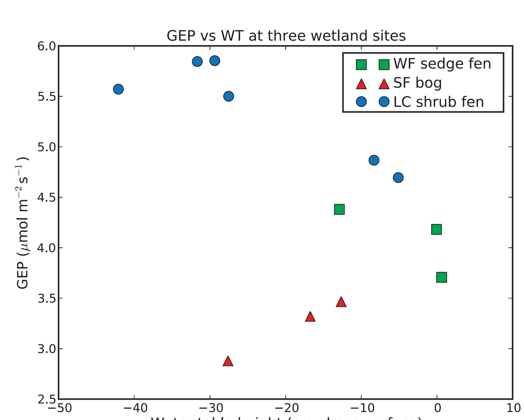
Wetlands are an important part of the regional carbon budget due to their large soil carbon pool. Hydrology is a major controlling factor on wetland succession and atmospheric exchanges. Three wetlands in northern Wisconsin were instrumented with eddy covariance towers and water table measurements in order to determine the interactions between wetland hydrology and carbon and energy exchanges. Two were fens (groundwater fed and rich in nutrients). One was a bog (nutrient-poor, with distinct plant communities from a fen).

Site descriptions:

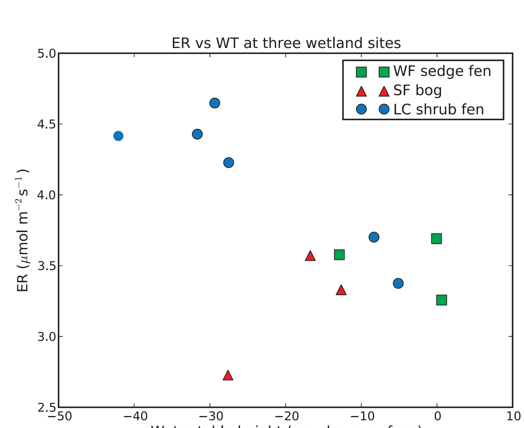
Lost Creek (LC): Shrub fen with six years of eddy-covariance measurements. Water table has declined by approximately 30 cm over the period of study (Sulman et al. 2009).

Wilson Flowage (WF): A sedge fen, measured with a portable eddy covariance system for three growing seasons

South Fork (SF): A moss-dominated bog, measured with a portable eddy covariance system for three growing seasons

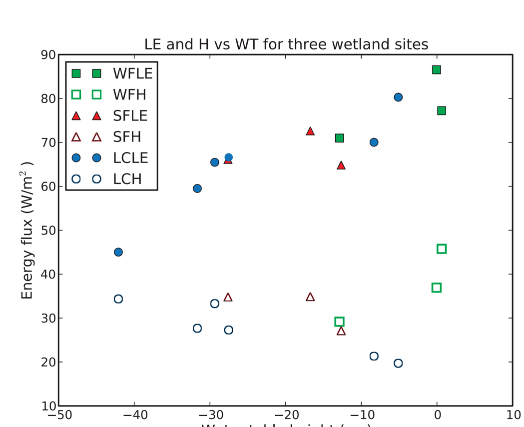


Top: Gross ecosystem production (GEP) at the three wetland sites (growing season averages).



Middle: Ecosystem respiration (ER) at the three wetland sites (growing season averages).

At the fen sites, ER and GEP were higher with lower water table, while the bog site had opposite relationships. There was no significant correlation between NEE and water table.

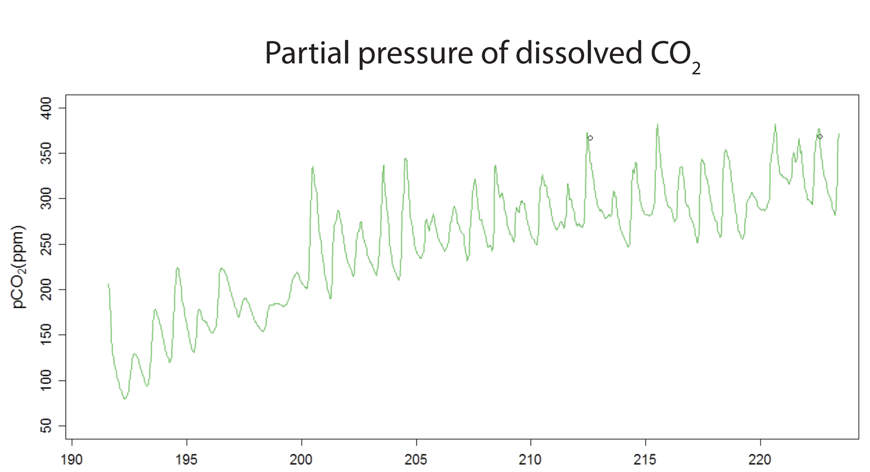


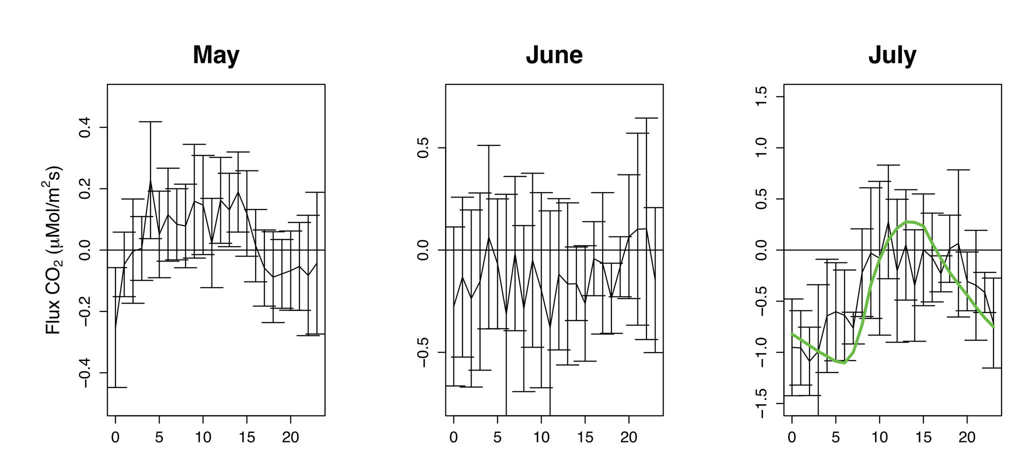
Bottom: Latent heat (LE, filled symbols) and sensible heat (H, open symbols) fluxes at the three wetland sites (growing season averages). LE was higher with higher water tables in a coherent pattern across all three sites, while H was not correlated with water table, indicating a change in energy balance with water table.

Lakes

A buoy on Trout Lake at the North Temperate Lakes Long Term Ecological Research (LTER) site was instrumented with eddy covariance equipment during summer 2009 (left). Measured NEE ranged from -1.0 to 0.3 µmol/m^{2}s (lower right). Analysis of these measurements is ongoing. Preliminary results are shown below.

An alternate method of determining lake-atmosphere fluxes uses partial pressure of dissolved CO_2 (pCO_2, lower left). pCO_2 increased over the measured summer season. The diurnal pattern of pCO_2 is shown (normalized) in green in the July plot on the lower right.





Conclusions

The different landcover types that make up the landscape of the upper Great Lakes region have different characteristic drivers and time scales of major interactions with the atmosphere. Measurements and models that incorporate the differences in these landcover types are necessary in order to fully understand how this complex mosaic interacts with the atmosphere now, and how these interactions will evolve in the future.

The dominant forcing on wetlands and lakes will likely be changes in hydrology, which can occur over decadal or yearly time scales. Lakes may also be affected by changes in temperature, stratification, and biology on even shorter time scales. In contrast, forest carbon budgets are most strongly controlled by past land use and forest succession on a longer time scale of decades to centuries.

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