Observed carbon-water interactions in three north-temperate wetlands

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Introduction: Future terrestrial carbon fluxes are a major source of uncertainty in climate predictions. Temperate and boreal wetlands contain a significant proportion of the world's carbon reserves, and are sensitive to changes in both temperature and hydrology. Future climate simulations predict a net drying of temperate and boreal regions. We present eddy-covariance measurements of carbon flux at three wetlands in northern Wisconsin, one with a long-term trend of declining water table.

Lost Creek

Shrub fen, dominated by alder and willow with an understory dominated by sedges.

Located in the Northern Highlands State Forest in north central Wisconsin, USA.

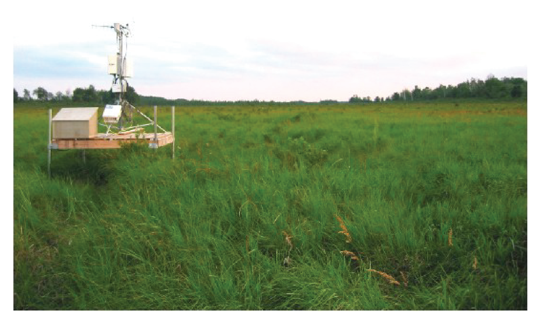
The site was established in 2000, and seven years of eddy covariance flux data are available. The water table has declined by an average of 9 cm/year over the record. Shrub biomass has increased significantly over the record.

Wilson Flowage

Wet meadow/marsh, dominated by sedges and wetland grasses

Located in Chequamegon-Nicolet National Forest, Medford-Park Falls District, North-Central Wisconsin

Eddy-covariance fluxes measured with a portable system over growing seasons of 2005-2007, in two week periods alternating with South Fork. Water table measurements are available for 2005 and 2006.

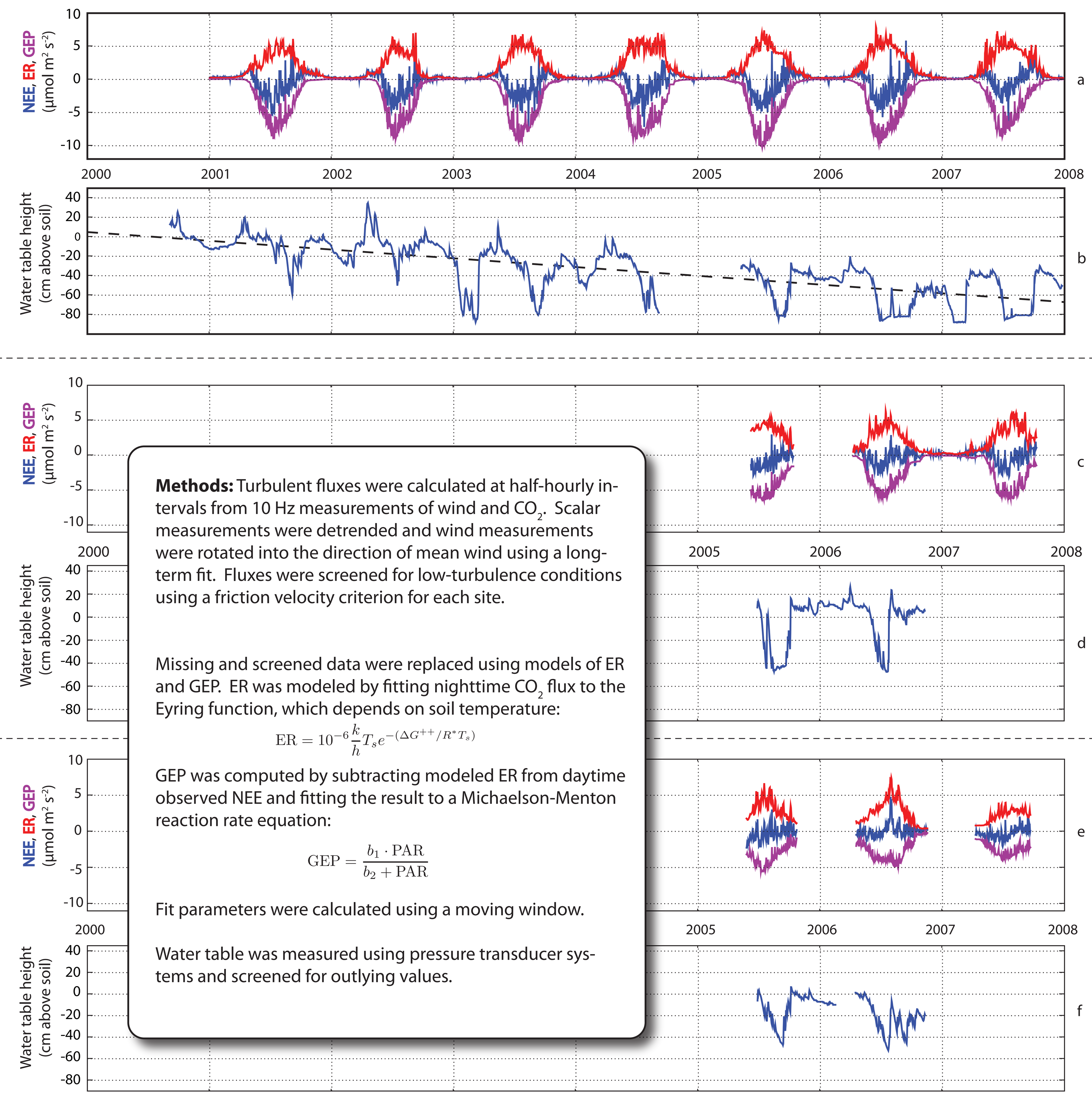


South Fork

Sphagnum bog with labrador tea and leatherleaf, with invading black spruce around the edges

Located in Chequamegon-Nicolet National Forest, Medford-Park Falls District, North-Central Wisconsin

Eddy-covariance fluxes measured with a portable system over growing seasons of 2005-2007, in two week periods alternating with South Fork. Water table measurements are available for 2005 and 2006.



Methods: Turbulent fluxes were calculated at half-hourly intervals from 10 Hz measurements of wind and CO_2. Scalar measurements were detrended and wind measurements were rotated into the direction of mean wind using a long-term fit. Fluxes were screened for low-turbulence conditions using a friction velocity criterion for each site.

Missing and screened data were replaced using models of ER and GEP. ER was modeled by fitting nighttime CO_2 flux to the Eyring function, which depends on soil temperature:

$$ER = 10^{-6}\frac{k}{h}T_s e^{-(\Delta G^{++}/R^* T_s)}$$

GEP was computed by subtracting modeled ER from daytime observed NEE and fitting the result to a Michaelson-Menton reaction rate equation:

$$GEP = \frac{b_1 \cdot PAR}{b_2 + PAR}$$

Fit parameters were calculated using a moving window.

Water table was measured using pressure transducer systems and screened for outlying values.

Figure 1: Time series of daily average ecosystem respiration (red), gross ecosystem production (purple), and net ecosystem exchange (blue) (a, c, e) and water table (b,d,f). Lost Creek (a,b) was observedfor seven years. Wilson Flowage (c,d) and South Fork (e,f) were measured with a portable eddy-covariance system for three growing seasons, but water table measurements are only available for 2005-2006. Positive fluxes denote emission of carbon dioxide from the ecosystem. Positive water table numbers denote water above the soil surface.

Lost Creek water table and yearly precipitation had a correlation coefficient of 0.87

Total precipitation and average water table were not significantly different between 2006 and 2007, but growing-season precipitation was much lower in 2007, the year when Lost Creek was a net carbon emitter.

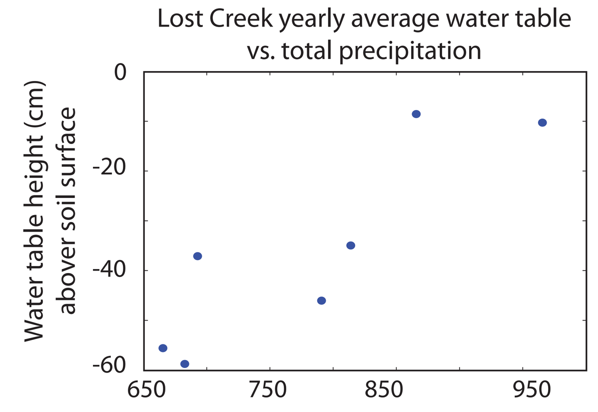


Figure 2: Lost Creek yearly average water table versus yearly total precipitation as measured at the NCDC Minocqua station.

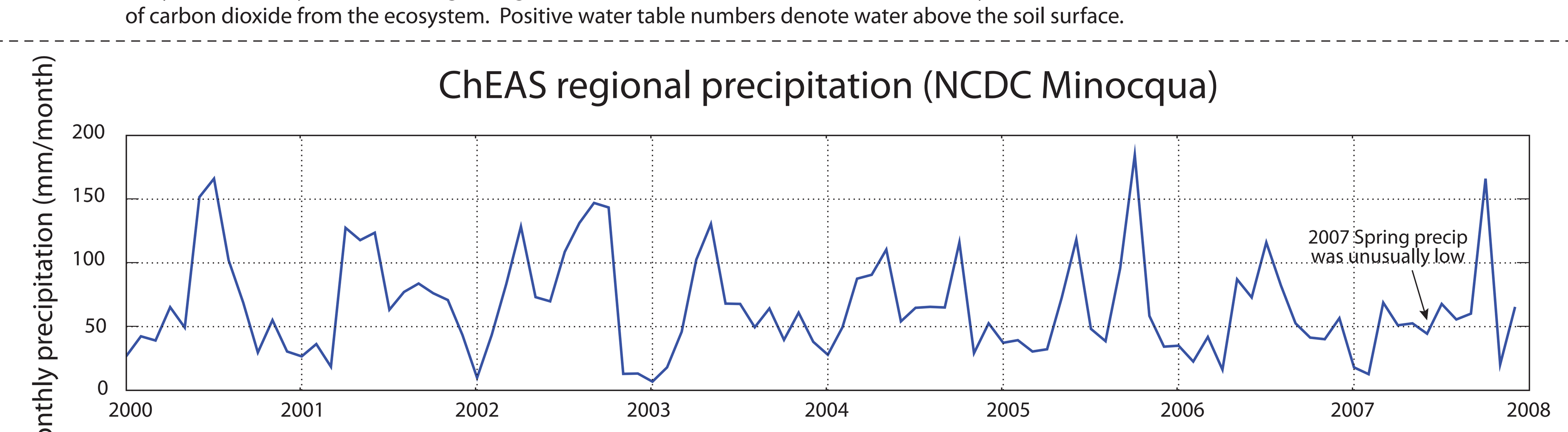


Figure 3: Time series of monthly total precipitation measured at the National Climate Data Center MInocqua site. Growing-season precipitation in 2007 was significantly lower than usual. In 2007, GEP at Lost Creek was also significantly lower than in the other years, resulting in a net emission of carbon for the year.

Lost Creek ecosystem respiration (ER) and gross ecosystem production (GEP) showed similar responses to changes in water table. Both ER and GEP were suppressed at high water table relative to low water table (Fig. 4a). The competing responses resulted in net ecosystem carbon exchange (NEE) being independent of water table (Fig. 4b).

In 2007, July and August GEP were significantly lower than usual, while ER was within normal levels. The result was anomolously high NEE.

Total yearly precipitation and average water table in 2007 were not significantly different from previous years, but growing-season precipitation was much lower (Fig. 3). This suggests that the timing of precipitation is an important control on wetland GEP and NEE.

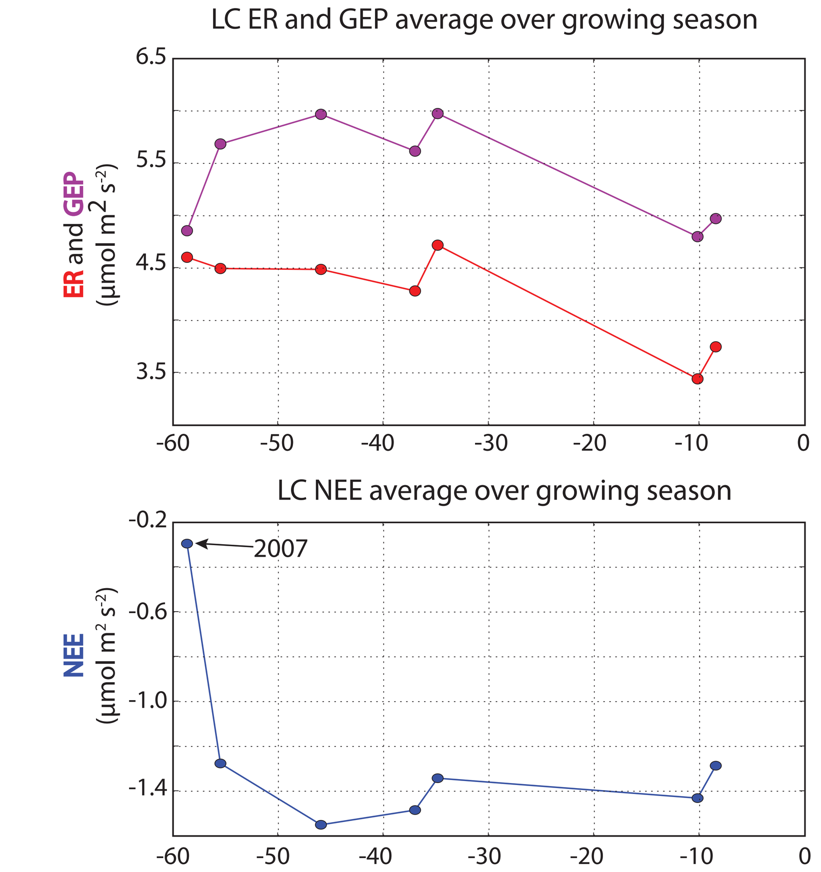


Figure 4: Growing-season average ER (red) and GEP (purple) (a), and NEE (b) for Lost Creek plotted against yearly average water table over the seven-year period.

ER at Wilson Flowage and South Fork was negatively correlated with water table, following the same pattern as Lost Creek (Fig. 5a, red lines).

GEP at Wilson flowage was also negatively correlated with water table, as at Lost Creek (Fig. 5a, purple circles), but South Fork GEP was positively correlated with water table (purple squares). South Fork's different behavior is not unexpected because South Fork is a bog, while Lost Creek and Wilson Flowage are fens.

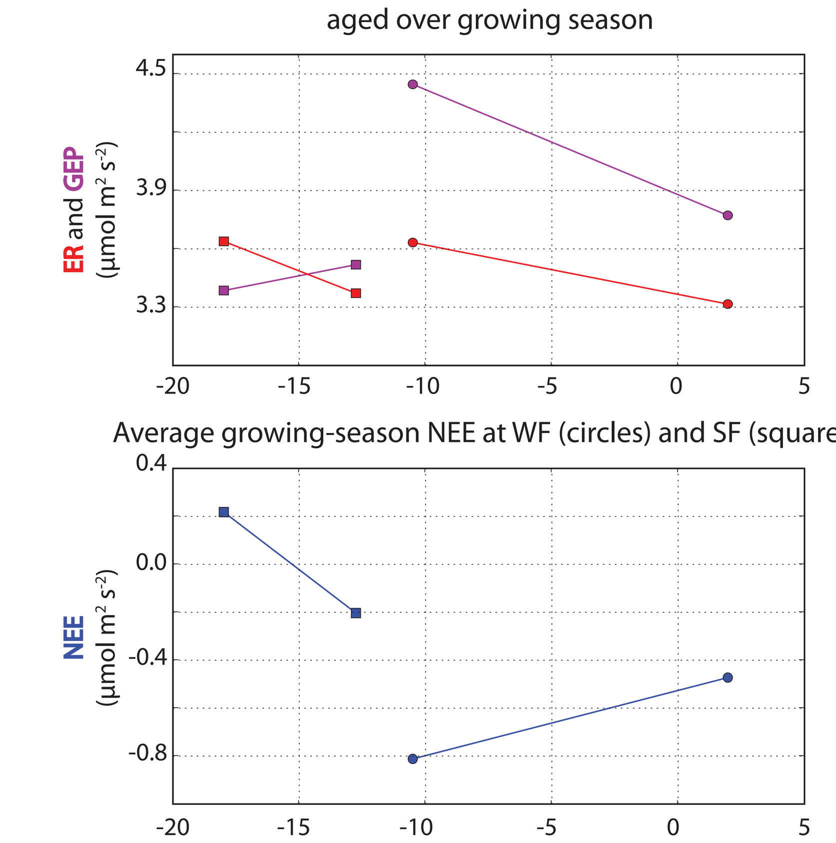


Figure 5: Growing-season average ER (red) and GEP (purple) (a), and NEE (b) for Wilson Flowage (circles) and Lost Creek (squares) plotted against yearly average water table for 2005 and 2006. 2007 is not shown because water table measurements were not available for that year.

References:
Sulman, Benjamin N., Desai, A. R., Cook, B. D., Saliendra, N., Mackay, D. S., 2008 (in preparation). Observations of northern temperate wetland fluxes under a declining water table. Biogeosciences.
Cook, B. D., P. V. Bolstad, F. A. Heinsch, K. J. Davis, W. Wang, R. M. Teclaw, and D. D. Baumann, 2008. Cloudiness and water table measurements improve MODIS GPP predictions in a shrub wetland. Journal of Geophysical Research-G (accepted with revisions).

Conclusions: All three wetlands exhibited an increase in ecosystem respiration with decreasing water table. Gross ecosystem production also increased with decreasing water table in the two fens, with the result that net ecosystem exchange was independent of water table. The exception was Lost Creek in 2007, a year with an unusually dry growing season, when suppressed ecosystem production resulted in a net loss of carbon for the year. We conclude that interannual changes in water table are not closely linked to wetland NEE, but that changes in the timing of precipitation can have large impacts on NEE.

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