Carbon and water cycle interactions in a temperate wetland

Modeling and measuring the impact of a declining water table on regional biogeochemistry

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Benjamin N. Sulman, Dept. of Atmospheric & Oceanic Sciences, University of Wisconsin-Madison, Madison, WI
Ankur R. Desai, Dept. of Atmospheric & Oceanic Sciences, University of Wisconsin-Madison, Madison, WI
D. Scott Mackay, Dept. of Geography, State University of New York - Buffalo
Sudeep Samanta, Woods Hole Research Center, Woods Hole, MA
Bruce Cook, Dept. of Forest Resources, University of Minnesota-Twin Cities, Minneapolis, MN
Nicanor Saliendra, Northern Research Station, U.S. Forest Service, Rhinelander, WI
Talk outline

• Why study wetlands?
• What is our site like?
• How does water table interact with carbon?
• How does water table interact with water use efficiency?
• What does this all mean for climate change scenarios?
Why study wetlands?

Wetlands are an important part of the global carbon inventory.
Wetlands are important

- Up to 1/3 of total global soil carbon is in wetlands
- Wetlands are highly dependent on water and temperature dynamics

Mitra et al., 2005, Curr. Sci.
Future land carbon uptake is not well characterized

Friedlingstein et al., 2005, J. Clim
How will wetlands respond to changes in hydrology?

Underwater (anoxic, acidic)

Above water (oxygenated)
Global distribution of wetlands...

Matthews and Fung, 1987, GBC
Multi-model projected changes in DJF precipitation

IPCC working group 1, 2007
On to our study in Northern Wisconsin:

Legend
MODIS IGBP 1km landcover

- Water
- Wetland
- Cropland/Natural Mosaic
- Cropland
- Grassland
- Woody Savanna
- Urban
- Open Shrub
- Closed Shrub
- Mixed Forest
- Deciduous Broadleaf
- Deciduous Needleleaf
- Evergreen Broadleaf
- Evergreen Needleleaf

Jiquan Chen group:
Mature hardwood
Intermed. hardwood
Young hardwood
Mature red pine
Intermed. red pine
Young red pine
Pine barren (2)
Our sites and data
Eddy Covariance

Equipment:
- 3D sonic anemometer
- Open or closed path gas analyzer
- 10Hz temporal resolution
- Multiple level CO₂ profiler
Carbon data products

• Net Ecosystem Exchange (NEE)
  – Total net carbon flux (measured)
• Ecosystem Respiration (ER)
  – Carbon released to atmosphere
  – Calculated based on nighttime NEE
• Gross Ecosystem Production (GEP)
  – Carbon absorbed from atmosphere
  – Calculated based on NEE - ER
Other data

- Water table (WT, height above soil surface)
- Precipitation
- Air and soil temperature
- Photosynthetically active radiation (PAR)
- Latent and sensible heat flux
Our Sites: ChEAS
Chequamegon Ecosystem Atmosphere Study
http://flux.aos.wisc.edu

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Legend:
+ CO₂ Flux tower
* High-precision CO₂
Our Sites: Lost Creek

- Alder-willow fen
- Six years of flux data
Our sites: Willow Creek

- Upland hardwood forest
- Eight years of data
Our sites: South Fork and Wilson Flowage

- Wetland sites
- SF: Ericaceous bog
- WF: Grass-sedge-shrub fen
- Two years of growing season flux data with roving tower
- Switched between sites every two weeks
- Much less data than LC and WC
Data timeseries (Lost Creek)

Time series of NEE, ER, and GEP (daily averages)

Water Table

Year
Results:

Water Table and Ecosystem Respiration
Respiration vs Temperature

Lost Creek Respiration

South Fork Respiration

Wilson Flowage Respiration

Willow Creek (upland) Respiration
Respiration vs WT

- ER has a threshold response to WT
- More sensitive at moderate temperatures than very high or low
- The moral: lower WT leads to higher ER at moderate temperatures
How should WT affect GEP?

• Water-stressed plants photosynthesize less efficiently?

 OR

• Lower WT gives plants easier access to nutrients, boosting photosynthesis?
Photosynthesis by Month

Lost Creek photosynthesis

Month

South Fork photosynthesis

Month

Wilson Flowage photosynthesis

Month

Willow Creek photosynthesis

Month
NEE dependence on WT

- NEE = ER - GEP
- Respiration significantly affected, with temperature dependence
- Photosynthesis weakly affected
- Net effect: No significant dependence of NEE on WT
How should WT affect Water Use Efficiency?

• Plants photosynthesize by trading water for carbon

\[
WUE = \frac{\text{Photosynthesis}}{\text{Transpiration}}
\]

• WUE is a property of a plant, and should not change easily in response to environmental conditions
Transpiration and WT

Transpiration and water table

Year

Transpiration (kg/m^2-s)

Water table height (cm)
WUE and WT

Water use efficiency vs water table height
Conclusions: the effect of water table

Lower water table leads to:

→ Higher respiration

→ Little effect on photosynthesis

→ No significant effect on NEE

→ Less transpiration

→ Higher water use efficiency
Where do we go from here?

- WT affects respiration. What affects WT?
- Integrate WT into ecosystem and climate models
- Methane: the other half of the story
- Regional upscaling
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TREES ecosystem model

“Terrestrial Regional Ecosystem Exchange Simulator”

- Hydrologic model for upland forests
- We are adapting it for carbon and wetlands
- Also plan to do parameter estimation using flux tower data
TREES preliminary results

![Graphs showing modeled NEE and ET against measured values for Lost Creek, ChEAS. The graphs depict data points categorized by water table depth: Water Table Above Surface, Water Table 0 to 5 cm, Water Table 5 to 20 cm, and Water Table > 20 cm.](image)