ENVIRONMENTAL AND ECONOMIC RESEARCH AND DEVELOPMENT PROGRAM

Impacts of Climate Change on Fluxes of Carbon and Water in Northern Wisconsin Lakes and Wetlands

Executive Summary
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FINAL PROJECT REPORT - EXECUTIVE SUMMARY

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Title of Project: Impacts of Climate Change on Fluxes of Carbon and Water in northern Wisconsin Lakes and Wetlands (EERD Research, Project code 3104-01-09)

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Research Category: Environmental and Economic Impacts of Climate Change in Wisconsin Due to Electricity or Natural Gas Use: understand the flux of carbon within Wisconsin's environment, and the ramifications of this understanding for policy development (impacts of climate change on air quality, water quality and forest of agricultural land management.)

Full Project Period: February 2009 through June 2012

Object of Research: Predicted changes in Wisconsin's climate have several implications for our water resources. Precipitation inputs to our lakes, streams and wetlands may increase by as much as 10%, with intense storms generating more runoff. Seasonal precipitation patterns are expected to shift, with less in summer and more in winter. Summer heat waves are expected to become longer and hotter, and night-time winter temperatures may be more moderate. This scenario could trigger more frequent flooding events, more severe summer droughts and higher rates of evaporation. These climatically-induced changes in regional water budgets would also affect fluxes of carbon in lakes and wetlands, potentially exacerbating the greenhouse warming effect. With warmer temperatures, more flooding events and extended dry periods, it is possible that the mobilization of carbon now stored in peatlands will increase significantly. However, the timing and magnitude of carbon export from peatlands to aquatic systems and the atmosphere is difficult to quantify because we lack the data to calibrate predictive models that couple carbon and hydrology in northern Wisconsin.

The object of this research project was to further develop technologies to monitor the fluxes of water and carbon in our lakes and wetlands. It built upon two prior studies still underway in northern Wisconsin. In one prior study (funded by FOE), we developed new technologies to remotely monitor the short-term and long-term effects of rainfall and drought on water fluxes. In a second study funded in part by the National Science Foundation, limnologists at UW-Madison developed methods to remotely monitor internal carbon fluxes in lakes over similar time scales. Here we proposed to link these projects and to develop new technologies to monitor carbon fluxes between lakes and their adjoining wetlands. The resultant data would be applicable to models of the regional carbon cycle and the potential impacts of climatic change.

This project was a cooperative research effort by the Wisconsin Department of Natural Resources (WDNR) and the Center for Limnology, UW-Madison (CFL), in association with the UW-Madison Department of Electrical and Computer Engineering (ECE).

Summary of Key Accomplishments: Two wireless sensor networks (WSNs) were developed and deployed in separate wetland-dominated catchments within the Trout Lake watershed of Vilas County, Wisconsin. Both WSNs were built on low-power micro-processor radio systems (MPRs) that formed an array of sensor nodes embedded in the study catchments to collect data on surface water levels, evaporation, precipitation, peatland water tables, bulk ionic solutes, chromophoric dissolved organic carbon and water temperature continuously at 30 minute time intervals. The sensor nodes were designed to run unattended on battery power for months. They communicated via radio-frequency (RF) signals (rather than wires) through a gateway node to a distant base station.

Based on data collected during wet and dry seasons in the two study catchments, we report highly resolved water budgets (sub-hourly time-steps), transient reversals of hydrologic flowpath, patterns of evapo-transpiration (ET) in peatlands, evaporation rates from surface waters (E), and the temporal dynamics of dissolved organic carbon (DOC, the major solute in many peat-dominated systems). The data indicate that direct precipitation, ET and E dominated the hydrologic budget of both study wetlands, despite their relatively flat geomorphology. Rates of ET from peatlands were comparable to E from open waters but were more variable temporally and more challenging to constrain spatially. Exchange between open waters and riparian peatland varied with antecedent conditions. Precipitation events and intervening periods of dryout caused frequent flowpath reversals across the riparian boundary in both wetland systems, suggesting that flux of solutes, such as dissolved organic carbon, has commensurate complexity.

Field results demonstrate the utility of WSNs in obtaining continuous data on wetland hydrology and bulk water chemistry that can be displayed in near-real-time at a remote location. With respect to technology needs, future wetland observatories would benefit from the further automation and standardization of data handling protocols. Data management, processing and dissemination pose a major challenge because the volume of data from embedded sensor networks can grow rapidly. With respect to wetland science, WSNs show considerable promise. Several challenges remain, however, such as the construction of comprehensive water budgets for peatlands where the spatial variability of critical variables like ET and lateral flow is high. The integration of direct hydrological methods with indirect methods based on energy balance models and micrometeorological techniques is likely going to be essential. With respect to the issue of climatic impacts on wetland ecosystems, data from wetland observatories can facilitate hypothesis testing and the refinement of local and regional climate models. Flashier water tables and gradually declining lake levels may result from a future climate that is both warmer and wetter. If the mobilization of peatland carbon depends on the frequency and magnitude of water level changes, then carbon fluxes between terrestrial, aquatic and atmospheric pools may also be affected, feeding back positively on the warming effect. Wetland sensor networks constitute a useful tool for tracking such climatic impacts over both short and long time-scales. We conclude that the wider deployment of wireless wetland observatories would help to validate and refine environmental hydrologic and carbon cycling models and to foster collaboration that would improve the science of climatic impacts on sensitive water resources.

As an adjunct to the two WSNs, we partnered with a local environmental NGO to develop a parallel Citizen Science Water Level Monitoring Network that trained 26 local volunteers to monitor water levels manually in 26 lakes at weekly time intervals. The purpose of this parallel network was to raise citizen awareness and to augment the high-frequency WSN data with low-frequency data collected over a larger number of water bodies. Volunteer retention has been 100% for 3 years, and coordination with the Wisconsin SWIMS database has been initiated.

<u>Future Research Directions</u>: Data collection from both WSNs will continue for the foreseeable future. Opportunities for introducing WSN technology into the Citizen Science program will be explored.

List of Acronyms

CB	Crystal Bog
CFL	Center for Limnology, University of Wisconsin-Madison
DAQ board	data acquisition board
DOM	dissolved organic matter
ECE	University of Wisconsin-Madison Department of Electrical and Computer Engineering
EERD	Environmental and Economic Research and Development Program of Wisconsin's Focus on Energy
ET	evapo-transpiration
GLEON	Global Lake Ecological Observatory Network
NHLD	Northern Highland Lake District
QA/QC	quality assurance and quality control
RF	radio frequency
SWIMS	Wisconsin Surface Water Integrated Monitoring System
TB	Trout Bog
TLS	Trout Lake Station
WDNR	Wisconsin Department of Natural Resources
WSN	wireless sensor networks