

Supplement to RCN: Advancing lake ecology by building an international community to exploit innovations in sensor network technology

Background

Freshwater lakes provide a number of important ecosystem services including supply of drinking water, support of biotic diversity, transportation of commercial goods, and opportunity for recreation. They also play a critical role in “plumbing” the transport and transformation of carbon from terrestrial systems to the atmosphere (Cole et al. 2007). Understanding how changes in land-use, human population, and climate interact with lake dynamics at local, regional, continental, and global scales is one of the greatest challenges for lake ecologists over the next decade. Developing this understanding across such scales is a formidable challenge, in part because ecological systems are characterized by high spatial and temporal variability (Kratz et al. 2003), non-linear dynamics (Carpenter et al. 1999, Scheffer et al. 2001), and coupled physical/biological processes (Hamilton and Schladow 1997). In lakes, this complexity is manifested in phenomena such as sudden and short-lived algal blooms, changes in frequency and response to disturbances such as mixing events caused by typhoons, and the inter-dependency of biota and biogeochemical processes (Carpenter 2003).

A number of recent developments will make understanding the interactions of lake dynamics with multiple drivers across scales more tractable. First, sensors capable of measuring key features of lakes, such as water temperature, water movement, dissolved gases, pH, conductivity, and chlorophyll fluorescence have been developed over recent decades and are being deployed for a variety of scientific and management objectives. Second, advances in cyberinfrastructure, such as wireless sensor networks, have led to the increasing occurrence of in situ continuous measurements in lakes worldwide. Third, during the past decade an increased importance has been placed on understanding the coupling of physical and biological lake processes, for example, how circulation patterns, internal waves and stream intrusions influence nutrient cycling, lake-wide metabolism, and the wax and wane of algal blooms in lakes (e.g. Kratz et al. 2005). As a result of these advances and in particular the improvements in data input to simulation models, there is greater potential to predict how lake ecosystems respond to natural- and anthropogenic-mediated events.

In response to the challenges and opportunities for integrated real time measurements, a number of limnologists, information technology experts, and engineers joined forces in 2005 to create a new, grassroots, international network, the Global Lake Ecological

Observatory Network (GLEON, gleon.org). The goal of GLEON is to build a scalable, persistent network of lake ecology observatories (Kratz et al. 2006). Data from these observatories will allow us to better understand key processes such as the effects of climate and landuse change on lake function, the role of episodic events such as typhoons in resetting lake dynamics, the rapid wax and wane of algal blooms, and carbon cycling within lakes and across landscapes. The observatories will consist of instrumented platforms on lakes around the world capable of sensing key limnological variables and information systems to move the data in near-real time, often through wireless networks, to web-accessible databases. A common web portal is envisioned to allow easy access to data and information by researchers and the public. A series of web services that could be supported by this portal are being developed to allow automation of processes associated with instrument management and data processing and analysis such as computation of metrics based on the high frequency data. Such metrics would include, for example, estimates of rates of important processes such as gross primary production and respiration, or physical stability of the water column.

The following tenets have been instrumental in guiding GLEON's development:

- Science is increasingly global in scale. Scientific issues critical to society, such as change in the quality and quantity of freshwater resources and the importance of lakes and reservoirs in regional and global carbon balances transcend national boundaries.
- Comparative lake studies are critically important. Understanding dynamics of important lake processes, such as metabolism and atmospheric exchanges, can benefit immensely from comparative studies of lakes that have different climatic, geologic, morphometric, and cultural characteristics.
- A global network of instrumented research sites is attainable in the near future. Such sites would record the dynamics of lakes at relatively high frequency and make data available in near real time to the scientific community and general public.
- Multidisciplinary partnerships are essential. A strong partnership among lake scientists, engineers, computer scientists, educators, and information technology and management experts from multiple institutions throughout the world is required to make the goal of a global network of lake observing systems a reality.

We believe that expanding GLEON to include sites and expertise from Argentina and Chile is an obvious mechanism of collaboration that can pay immediate benefits and

lead to a long-term collaborative research agenda between US scientists and our colleagues in southern South America.

Proposed Activities

In this supplemental proposal we request funds to initiate collaboration and establishment of one or more GLEON sites in Argentina and Chile. Argentina and Chile each have lake-rich regions which bear remarkable similarity to lake-rich landscapes in the glaciated regions of the northern hemisphere (Figure 1). This similarity will allow us to address a number of interesting research questions immediately. These questions include, for example:

- To what extent does lake landscape position (*sensu* Kratz et al. 2006b) predict carbon dynamics (i.e. productivity, carbon flux to atmosphere and sediments) in neighboring lakes in each region.
- Lakes in Argentina do not freeze and thus are warm, monomictic lakes whereas those in Wisconsin tend to be dimictic. Do short-term, storm-induced mixing events influence lake metabolism and diel surface water oxygen dynamics similarly or differently in the two regions?
- Within a lake-rich landscape (i.e. portions of Wisconsin or Argentina or Chile) what controls the among-lake variance in dissolved gas dynamics and lake metabolism? Which landscape has the highest, or lowest, among lake variance in these properties, and why?
- What steps are necessary to establish a functioning information management system that allows all users to share data seamlessly. Will the information management installation just completed by a GLEON SWAT team for Lake Erken (see http://www.gleonrcn.org/media/Erken_Report.pdf) be seamlessly transferable to systems in Argentina and Chile? If not, what adjustments need to be made?

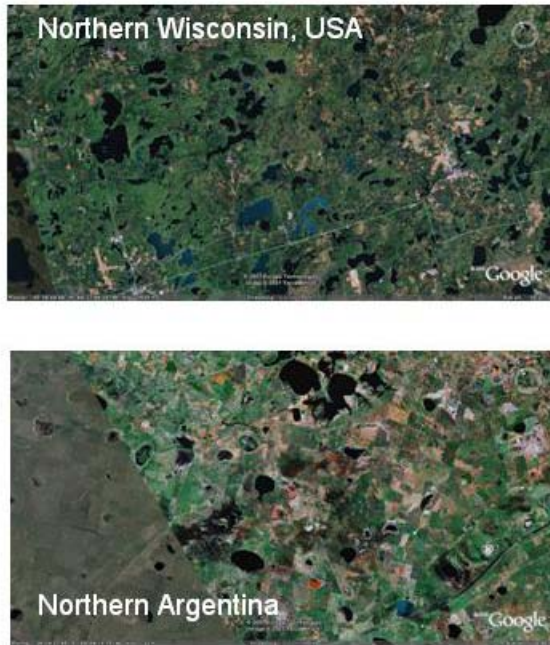


Figure 1. Google Earth images from areas of northern Wisconsin, USA (upper) and northeastern Argentina (lower). Dark objects in each panel are surface waters. Both regions are areas of lake-rich landscape, facilitating comparison of the two regions at multiple spatial scales. Each panel represents an area of approximately 50km x 30km.

Workplan. We propose to conduct three major activities over the next two years as part of this supplemental request.

1. We will assemble a GLEON SWAT team consisting of two aquatic ecologists, two information technology experts and two graduate students to make a 12-day initial reconnaissance visit to Argentina. During this visit we will work with Dr. Maria Cintia Piccolo, our lead Argentine collaborator on this project to visit likely research lakes, deploy sensors for up to a week, and learn more about the existing information management and information technology systems currently in place. Dr. Piccolo is the Director of the Instituto Argentino de Oceanografía (IADO), and a professor in the Geography Department at Universidad Nacional del Sur in Bahía Blanca. Dr. Piccolo's cv is attached to this supplemental request. Both she and her colleague, Dr. Gerardo M. E. Perillo, also from IADO, have several graduate students doing research projects on lakes in the Bahía Blanca area. Drs. Piccolo and Perillo have also contacted other groups working in shallow lakes that will be interested in participating both on the field experience and future integration of US and Argentine teams.

The main goals of this initial 12-day visit will be a) continue to build the relationships among the US and Argentine scientists involved in this collaboration, b) identify specific research questions and study sites for a more extended research visit by US graduate students, c) collect preliminary data with sensors brought by US scientists, including high-frequency measurements of water temperature profiles and dissolved oxygen dynamics at selected depths or horizontal locations, and d) develop plans for joint development of an information management system that will allow access to data from both the US and Argentina to be shared among all collaborators. We expect this research visit will occur during a 12-day period between late February and mid-April. Kratz will lead the US team. Other participants will be selected from US GLEON members depending on expertise, availability and interest. We will likely draw on members of the US-led GLEON SWAT team that visited Lake Erken, Sweden in July, 2007; Paul Hanson and Luke Winslow of the University of Wisconsin-Madison and Sameer Tilak of the University of California-San Diego. Graduate students will be selected through an open competition organized by the GLEON graduate student association, which will have its first meeting at the International Society of Limnology (SIL) triennial meeting this August in Montreal.

We also have been in contact with other US representatives who attended the PASEO meeting in July 2007. Drs. Tom Harmon, Bill Kaiser, and Jim Bonner have expressed an interest in participating in this initial 12-day research visit. In particular they are keen to deploy their sensor packages on the selected study lakes to test their portability and the issues involved in allowing the different sensor packages to use the same communications backbone to send data from the sensors to an internet point of presence. They will be initiating separate supplemental requests to cover the costs associated with their visits.

2. The second major activity will be a six-week research visit during the North American summer, 2008 by the two graduate students who participated in the 12-day visit in spring, 2008. During this extended visit each student will conduct a research project that is complementary to their thesis research. The students will work in concert with graduate students in the labs of Drs. Piccolo and Perillo who have ongoing research activities on the study lakes.
3. The third major activity will be followup visits by senior scientists in early 2009 to Argentina to evaluate the previous year's experience and plan for the next steps in the collaboration. These scientists will also make a trip to Chile to meet

with the research group of Dr. Oscar Parra, a Chilean scientist at the University of Concepción who has expressed an interest in participating in GLEON (see attached letter of interest and CV).

In addition to these activities on the US side, we expect to host an Argentinian delegation to the GLEON meeting to be held at the Archbold Biological Station in February 2008, just before the planned 12-day visit to Argentina. We also expect that US GLEON sites will host graduate student visits from Argentina and, perhaps, Chile as a result of this collaboration.

Expected Outcomes

This supplement will lead to a number of tangible and intangible outcomes. Some are listed here.

- **Improved research collaboration.** This work will lead directly to greater contact between the US and southern South American limnological and IT communities, especially Dr. Maria Cintia Piccolo's laboratory at the Instituto Argentino de Oceanografía in Bahía Blanca, Argentina and Dr. Oscar Parra's laboratory at the University of Concepción in Concepción, Chile.
- **Enhance GLEON community building.** Strong international networks require an explicit focus on building the research community. Such community building will be enhanced by new GLEON participation by research groups in Argentina and Chile. We hope this participation will lead directly to a GLEON-wide meeting held in South America that will attract even more South American interest and engagement in GLEON.
- **Established student exchanges.** We envision a pair of US students conducting a six-week research project on selected lakes in Argentina. In addition, we will encourage Argentinian and Chilean students to spend time at US GLEON sites in Wisconsin, San Diego, New York, Kentucky, Florida or elsewhere.
- **Enhanced sensor network IT.** This supplement will lead directly to enhancement of IT necessary to integrate sensor networks globally. GLEON is a partnership between lake scientists and IT experts. We believe this IT will be complementary to the larger, more top-down initiatives such as NEON or WATERS.
- **Gained scientific knowledge.** We expect this collaboration to lead directly to a number of peer-reviewed publications. We expect one or more papers on such topics as the details of how physical and biological process interact to cause high-frequency (i.e. scale of 10s of minutes) dynamics in dissolved oxygen in surface

waters in lakes, or understanding the controls of among-lake variability in lake metabolism within lake-rich landscapes on two continents. We also expect one or more papers on the integration of data and models across a series of federated sites within a network.

- **Demonstrated global team model.** We believe GLEON can serve as a model for grassroots, international networks in the ecological sciences as well as a model of globally distributed, team science in general.
- **Gained knowledge on deployments:** By deploying a sensor network, we will gain new insights to what it takes to deploy systems under a variety of conditions. This knowledge will be document on our website. This will assist local scientists deploy systems locally, thus transferring technology and knowledge.
- **Enhanced leverage for South American colleagues.** We also expect this effort will lead to further funding opportunities for our Argentine and Chilean colleagues through their national funding organizations.

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