

c.2 Geographic Environmental Science

Much of the IGERT-related geographic environmental science research at UB is conducted within two large multi-investigator interdisciplinary projects, one pertaining to groundwater modeling, and the other to mass flows on volcanoes. The groundwater project already involves several current IGERT Fellows and faculty, while the volcano project involves one IGERT affiliate, several IGERT faculty, and is expected to include IGERT Fellows as the Geology department joins the IGERT program. Other GIS and environmental modeling projects at Buffalo are described in the last part of this section. The primary site for International Research Internships in this area will be the International Institute for Geo-Information Science and Earth Observation (ITC) in the Netherlands.

c.2.1 Groundwater Research

The UB Groundwater Research Group is a multidisciplinary research group comprised of faculty and students from three departments: Civil, Structural, and Environmental Engineering, Geology, and Geography. Several major ongoing projects are externally sponsored, with support from NSF, the US Environmental Protection Agency, and NASA. The mix of geologists, engineers, and geographers has been essential to the development of new groundwater flow and transport models constructed to better exploit new findings in the GIScience, and to combine them with high-performance computing. The focus of Groundwater Research Group includes the development of high-performance computer models to simulate the movement of groundwater and contaminants at regional scales, as well as the application of such models to environmental management problems. Modeling projects of this nature are inherently multidisciplinary, involving expertise in hydrogeology and measurement (Geology), development and management of large environmental data sets (Geography), and the development and application of high-performance computational models (Environmental Engineering). Recent faculty hires in all three departments are expected to further broaden the activities of the group. A key research partner is UB's Center for Computational Research (CCR), which provides computing hardware and staff support in computational science (Jankovic, 2001).

Because the emerging focus of the group is in the area of regional environmental modeling, the multidisciplinary training of student researchers is critical. In particular, one of the fundamental goals of future research proposals is to broaden the scope of model development activities to include multiple environmental media in such a way as to link groundwater models with models of land surface, surface water, and atmospheric processes and to extend the models to larger domains incorporating multiple watersheds at continental scales.

Recent activities of the group will be summarized in a series of articles scheduled for publication in a special issue of the journal *Ground Water*. Key results include advances in high-performance solution techniques (Craig *et al.*), development of GIS and spatial analysis tools to support regional modeling applications (Becker *et al.*), and development of new calibration tools for large-scale applications (Jankovic and Barnes, 1999; Rabideau *et al.*). Other products of the group include a large set of public domain software developed through the various research projects.

Currently, eight Ph.D. students from three Departments are actively involved in the Groundwater Research Group, including four IGERT fellows. Key IGERT faculty members in the group include A. Rabideau and I. Jankovic (both of Civil and Environmental Engineering), D. Flewelling (Geography), and M. Becker (Geology). Some of the thesis research relates to model development that is grant-funded, while other projects involve innovative 'spin-offs'. Many of the research contributions of the group result directly from its multidisciplinary orientation. Examples include the application of algorithms from computational geometry to improving the computational efficiency of contaminant transport models, and combined use of new line-simplification algorithms and field measurements of stream temperature to develop more accurate and efficient model solutions for stream/groundwater interactions.

Much of the current model development is fueled by the availability of massively parallel computing hardware, and a key strength of the research group is its collective expertise in high-performance computing. The progress of the research was greatly enhanced in 2001 by the purchase of a 32-processor distributed memory workstation cluster, dedicated to the group's projects. Programs developed and benchmarked on this cluster are directly portable to the larger (500 processors) shared clusters maintained by CCR. As part of the IGERT proposal, we are requesting funds to purchase an additional 32 processors to support future work.

c.2.2 Volcanology Research

Another major environmental modeling research project involves the study of mass flows on volcanoes (Sheridan and Macías, 1995; Sheridan *et al.*, 2001). Currently, the core of this research is a large interdisciplinary project sponsored by NSF's Information Technology Research (ITR) program (Sheridan *et al.*, 2002). This project involves researchers from Geology, Engineering, Geography, and Mathematics, and uses high-performance computing to support the visualization, forecasting, and management of debris flows on volcanoes over a large range of spatial scales

The theme of this project is hazard assessment visualization and communication related to large geophysical mass flows (Radke *et al.*, 2000). Such phenomena include avalanches, debris flows, and volcanic flows of various types (lavas and particulate flows). Skills involved include understanding surficial processes of flow, studying case histories of past disasters, creating and evaluating digital elevation models which will form the basis of the evaluation, applying various existing and new physical models to simulate potential mass flows, using various types of data overlays to visualize and quantify the effects of the simulated flows, generating maps, GIS presentations, and animations to portray the results of the studies to critical individuals.

IGERT team members currently involved in this project are: M. Sheridan (Geology), M. Bursik (Geology), C. Renschler (Geography), and D. Mark (Geography). In addition, a much broader group of UB researchers currently are participating in volcanic hazard studies, including B. Pitman from Mathematics and A. Patra, T. Kesavadas, C. Bloebaum, and E. Winer from Mechanical and Aerospace Engineering.

Our current team studying volcanic hazards is interdisciplinary because we need to integrate data from fieldwork on natural phenomena with GIS and apply models that we develop on supercomputers that can be visualized through various platforms. Thus the work includes geoscientists, remote sensing experts, GIS specialists, theoretical modelers, computational researchers, and visualization professionals. Future researchers will be exposed to the culture and processes involved in all of these diverse areas, to prepare them to be effective in modern hazard appraisal research.

In a study of potentially hazardous areas on and near Popocatepetl, an active volcano in Mexico (Sheridan *et al.*, 2001), simulations of pyroclastic flows and rock avalanches were used to create a new hazard map for the current situation at Popocatepetl, augmenting an older map (Macías *et al.* 1995). The display of cities and towns as a layer in the model allows the estimation of sites of potential loss of life and property. Assuming likely source areas, particularly on the northern flank, inundation zones for volcanic debris flows were simulated with ArcInfo using the LAHARZ model developed by Iverson *et al.* (1998).

Current volcanic hazard research at UB has grown from two investigators at UB in the later 1990s to the current team of 10 investigators and 8 to 10 research assistants, and is expected to expand further through outreach to other institutions and research groups. We are presently discussing with the Geological Survey of Canada the possible incorporation of some of our products in their Andean program and we have set up a web interface for communication with research groups in Spain, France, and Mexico. This and several other IGERT-related projects will require the serving of maps and GIS over the internet, going well beyond current web server capacity available; thus

funds for the purchase of such a server are requested in this proposal. The use of remote sensing capabilities and advanced technologies will also continue to grow and we stay at the cutting edge of these fields. The international research collaborators on this project will undoubtedly provide research internship opportunities for IGERT Fellows

Students from the IGERT departments will participate in this program by serving as research assistants in their non-fellowship years, or by creating individual research elements as either term papers or theses in one of the participating departments. They will present their findings at national and international meetings and many end users in the area of geohazards are likely to use their work.

Funds are requested within this proposal to purchase a radiometer to measure the spectral reflectance of earth materials in the field, a specialized piece of research equipment that would be particularly useful to support calibration of remotely-sensed hyperspectral data.

c.2.3 Other Environmental Research

In addition to these two large projects, several other topics provide opportunities for IGERT Fellows to be involved in environmental research using GIS technologies. For example, J. Atkinson (Civil and Environmental Engineering) will continue to develop projects that incorporate remote sensing and GIS techniques in hydrological and surface water quality modeling applications in the Great Lakes basin. Much of this work will be conducted in collaboration with C. Renschler (Geography) and M. Sultan (Geology). Specifically, there is current research interest in developing models for algae growth, particularly toxic strains, and predicting the occurrence and movement of blooms; it is also thought that toxic algae may be linked with the avian botulism problem in Lake Erie. Work also will continue on the thermal bar in Lake Ontario; this research will involve numerical modeling, linked with remote sensing applications. Atkinson, Renschler, and Sultan are also working on hydrological models to evaluate remedial actions to avoid large amounts of sediment loss following a large wildfire burn, with remote sensing and GIS being used to determine the extent of the burn and other areal characteristics.

L. Bian (Geography) is working in two main research areas that will involve interested IGERT Fellows over the next five years. The first is the development of spatially explicit epidemiological models of infectious diseases, based on the tracking of individuals. The modeling focuses mobile individuals and the dispersion of diseases through the network of contact between these individuals in space and time. Her second research topic is semantic compatibility of different frameworks for hydrologic modeling. This research, which builds upon results in geospatial ontology described earlier in this proposal, addresses the representation of features of hydrological processes in computational models.

M. Sultan (Geology) is conducting several research projects that will provide good opportunities to involve IGERT Fellows in research. One project, funded by NASA, is developing an integrated systems approach (involving remote sensing, geochemical and ecological analyses, and hydrologic modeling) to assess, monitor, and model the recent and future impacts of changes in the landscape and land cover associated with major agricultural development projects in Saharan Africa. This work will be conducted jointly with scientists from Cairo University, the Egyptian Ministry of Irrigation and Public Works and the Egyptian Geological Survey, and will build on two decades of collaborative research efforts with Egyptian colleagues. NSF's International Division is funding Sultan's collaborative research on the Hydrology of Lake Nasser, Egypt, developing and calibrating regional groundwater and surface water flow models (1) to examine the validity of our preliminary findings over the entire lake and its surroundings, (2) to analyze the interaction between surface water and groundwater in the study area, and (3) to evaluate and quantify the impact of decreasing recharge rate on the Lake water level and on the surface water diversion scenarios in the surrounding area. Topics for future research include land cover and land use change and water cycling in the Middle East, relations of these to the development of renewable ground water resources in arid lands.

Sultan's research collaborations with Egyptian colleagues at Ain Shams University and elsewhere are expected to provide international internship opportunities to IGERT Fellows.

C. Renschler (Geography) leads a Landscape-based Environmental System Analysis and Modeling (LESAM) research group which pursues the development and integration of appropriate GIS-based analysis and modeling techniques and environmental modeling tools with readily or commonly available data sets for practical decision-making purposes in natural resources management and natural hazard mitigation. One current project studies post-fire soil erosion assessment. These applications have a common geo-spatial data sharing, processing, modeling and visualization platform that integrates GIScience, remote sensing, and process-based environmental models. This platform will be available to support fundamental and applied GIScience research by future IGERT fellows and others.

C. Larsen (Geography) is conducting several IGERT-related research projects in biogeography, exploring relations between ecological conservation, ecosystem dynamics and the appreciation of nature, leading three specific research projects based on this approach. One combines studies of ecosystem dynamics and ecological restoration with the mapping of landscape aesthetics in the Niagara Gorge. A second line of research combines studies of old growth forest representation and forest dynamics in Western New York with studies of old growth aesthetics. And a third project is creating a handbook of the rare and endangered species and communities in New York State that, for each entity, will contain four pieces of information: objective information about the biology of that individual species or community; objective information about the geographic and ecological context of the species or community; subjective social information about how humans have used that species or community; and subjective, personal reflections by local people about what that species or community means to them. These projects provide a bridge between environmental GIScience research and topics in geographic information and society regarding how nature and society are represented in information systems.

S. Mackay will join the Geography department at UB in Fall 2003. He is involved in two environmental projects relevant to our IGERT program. The first involves measuring and modeling of bioavailable phosphorus in agricultural watersheds. Agricultural inputs of phosphorus and nitrogen are major contributors of nonpoint source pollution to surface waters. At sufficiently high levels of bioavailable phosphorus, eutrophic conditions and associated water quality problems develop. Mackay and colleagues are seeking to quantify, spatially, long-term phosphorus losses from variable source areas and transport pathways. His other project studies spatial gradients in biophysical controls on water and carbon fluxes in terrestrial systems. The conceptual underpinnings to measuring and modeling earth systems have led to unnecessary simplifications that ignore spatial gradients in species response to natural and anthropogenic factors. Recent advances in spatial statistics, flux monitoring systems, modeling, and EOS-era remote sensing make it possible to evaluate these simplifications. Mackay and others are explicitly evaluating spatial gradients of biophysical controls on water and carbon fluxes in a variety of forest ecosystems.