Research Statement

James M. Russell

We are only beginning to understand the Earth's climate history. A few decades ago we believed that the Earth's climate changed slowly, and that the climate of tropical regions changed very little as compared to the high latitudes. We now recognize that the Earth's geologic record is replete with indications of abrupt climate events, including evidence for substantial changes at all time-scales in the tropics. The Holocene in tropical Africa, for instance, is a succession of wet and dry episodes driven by large-scale variations in the position and intensity of the tropical monsoons. The tropical monsoons release energy and water vapor to the atmosphere, perturbing and energizing the atmosphere's moisture and heat budgets in ways that affect global atmospheric circulation and climate. Understanding the causes of past climate variability and the impacts of tropical climate change on global circulation will require a network of paleoclimate records with a geographic and chronologic resolution adequate to analyze past patterns of atmospheric dynamics. By linking paleoclimate records we can achieve a mechanistic understanding of the interactions of different parts of the Earth's climate system, with the ultimate goal of predicting future severe climate events in light of anthropogenic climate forcing and natural climate dynamics.

My research addresses these needs through the analysis of lake sediments. Lakes respond to climatic and landscape perturbations through changes in their water level, chemistry, biology, and circulation, and leave a record of these changes in sediments accumulating at their bottoms. In my research, I use a diverse set of techniques, including lithostratigraphic, stable isotopic, biogeochemical, microfossil (diatom-based), and geophysical methods to reconstruct changes in lacustrine environments and their climatic causes. Highlights of this research include:

- **The Paleoclimatology of Lake Edward, Uganda-Congo.** My research on Lake Edward combines biogeochemical analyses of piston cores with analyses of the stable isotopic and elemental composition of calcite to develop a detailed record of climate change and ecosystem response. Highlights of this research include: 1) the elucidation of a pronounced 725-yr cycle in the moisture balance of Lake Edward during the late Holocene, a cycle that appears linked to high-latitude climate variations, 2) substantial climate variability during the past 1,000 years, including events during the Little Ice Age and Medieval Climate Anomaly, and 3) pronounced changes in the cycling of nutrients such as Si and N during wet/dry episodes, with concomitant effects on lake productivity and organic matter burial.
- **Analysis of piston cores from Lake Bosumtwi, Ghana**. AMS ^{14}C dating of multiple sediment fractions and high-resolution analyses of the isotopic composition of sedimentary organic matter showed that an abrupt shift from a wet early Holocene to a more arid late Holocene in West Africa occurred about 3,000 years ago. This change at Lake Bosumtwi appears to be associated with windier, more seasonal conditions that influence the lake's stratification, nutrient cycling, and algal production. This transition in West African lags similar shifts in North and East Africa by about 2,000 years, highlighting the importance of local feedbacks in determining regional climate response to external forcing.
- **Methodological developments in Paleolimnology.** The science of paleolimnology is still in its infancy, and many of the tools we use to reconstruct climate history from lake sediments

are still being developed. Together with collaborators at the Limnological Research Center, I have developed new protocols for the analysis of lake cores, including the development and implementation of a classification system for lacustrine sediments. I designed a light-weight piston coring system for use in small, very deep lakes. Lastly, I am strongly interested in the development of novel climate proxies, and am involved in analyses of the geochemistry of sedimentary sulfur and its relationship to paleohydrologic variability in Lake Edward.

I am currently involved in several projects on large and small lakes in tropical East Africa. These projects include:

1. Analysis of piston cores and seismic data from Lake Tanganyika, Africa. In the summer of 2004, in collaboration with researchers from the University of Arizona and the University of West Brittany, France, I collected a suite of piston cores and 300 km of multichannel seismic data from the Kalya region, central Lake Tanganyika. As part of this project I mentored eight students on projects ranging from paleoecological analyses of fossil diatoms in these cores to interpreting lowstand depth from seismic reflection data. Future multiproxy analyses of these cores will include biogeochemical measurements as well as more sensitive analysis of the stable isotopic composition of biomarker compounds as a proxies for water balance, temperature, wind speed and upwelling, and biogeochemical cycling within the lake over the past 30,000 years. Future fieldwork at Lake Tanganyika will include seismic analysis and piston coring to prepare for eventual scientific drilling operations that should recover sediments of Pliocene age.

2. The paleoclimatology of Lake Edward, Uganda-Congo. My current research is focused on resolving a century-scale paleoclimate record of Lake Edward from sediments spanning the early Holocene, and developing a very high-resolution paleoclimatology of the past 1,000 years. The latter involves comparative research on piston cores from Lake Edward as well as several small fresh and saline crater lakes within the Edward basin. These projects will utilize a variety of organic and inorganic geochemical techniques to analyze the interactions between high latitude climate variability, solar forcing, and the tropical monsoons. Future work on Lake Edward will likely require new coring and seismic expeditions to the lake. Existing cores from the lake only penetrate to 11,000 cal yr BP, and fairly simple, shallow coring could provide material to test for evidence of a Younger Dryas-age event at Lake Edward, a time period of unresolved controversy in equatorial Africa. In fact, more than 4 km of sediment lie beneath Lake Edward waiting to be drilled. Even a shallow core, tapping the past 400,000 years, could reveal a fascinating record of the response of equatorial rainfall to glacial cycles and orbital forcing. Secondly, the modern hydrology and hydrochemistry of Lake Edward are poorly known, and our lack of understanding hampers efforts to quantify the climate variability seen in paleorecords from the lake. Developing a hydrochemical model of Lake Edward will require collaboration between hydrologists, meteorologists, and limnologists.

I plan to continue my efforts to unravel the climate history of tropical Africa, and look forward to the opportunity to involve students in this research. Furthermore, I am currently developing paleoclimate projects analyzing annually laminated sediments from central Minnesota, as well as cores from numerous large and small lake basins across Africa. I look forward to collaborative opportunities using either lacustrine records or other terrestrial archives of past climate variability at sites across the globe.

Teaching Statement

James M. Russell

My career in science grew out of a curiosity about our environment, and as a scientist and educator I seek to instill my enthusiasm for the environmental sciences in others. Throughout my career I have striven to gain pedagogical experience to prepare myself for the educational aspects of an academic career. These experiences have greatly benefited my research, and have taught me valuable lessons about the role of an educator.

Teaching Experiences and Courses of Interest

I have had the opportunity to lecture and assist in course development as a teaching assistant for upper-level courses in Limnology and Evolution, have advised and mentored undergraduate senior projects in the fields of biogeochemistry and paleoclimate, and have organized and facilitated graduate-level short courses and seminars in paleolimnologic methods as well as interdisciplinary seminar series. I received overall ratings of very good to excellent as TA for both Limnology and Evolution. I have also served as instructor and mentor in paleoclimatology for the Nyanza Project, a research-training course for undergraduate and graduate US and African students conducted on Lake Tanganyika, East Africa.

I feel that my research and pedagogical experiences have qualified me to teach a variety of courses depending on departmental needs. In addition, the interdisciplinary nature of my field lends itself as well to team-taught courses, and I would be happy to participate as part of a teaching team or as a single lecturer. Courses of interest include, but are not limited to:

- **Lower level courses in Earth System Science, Global Change, and Aquatic Sciences**
  Human-induced global climate change is one of most important environmental issues facing society, and understanding the broad-ranging impacts of humans on the environment requires an interdisciplinary framework such as the Earth Systems perspective. I am interested in teaching courses in these topics for both majors in earth and environmental science disciplines as well as non-majors with an interest in global change and the environment, and would feel comfortable teaching courses in either Limnology or Oceanography.

- **Upper-level courses in Paleoclimatology, Paleolimnology, and Biogeochemistry**
  I am interested in developing lecture and lab-based coursework in Paleoclimatology emphasizing current knowledge, techniques of climate reconstruction, and future directions, as well as graduate seminars emphasizing specific techniques, timescales, or regions. I am also interested in developing coursework in paleolimnology and biogeochemistry, including field and lab-based courses in paleolimnologic and paleoenvironmental reconstruction.

Teaching Philosophy

Based on my experiences as a student throughout college and graduate school, I was most motivated by courses that were challenging, and as an instructor I seek to challenge students' intellects and senses of curiosity. At the same time, it is important to recognize individual students' limitations and learning styles, and to make the classroom and laboratory enjoyable. This is best accomplished by ensuring that the educator is approachable and readily available outside the classroom and requesting and acting on frequent student feedback. I have maintained frequent office hours in the courses in which I have been involved, and have solicited feedback from students early and often in the course to adjust to students' learning styles and interests. In their evaluations, many students commented on my approachability outside of the classroom, and rated me 4.4 out of 5.0 points on this as TA for Limnology.

Global change researchers have a key role to play in facilitating the public's understanding of environmental science and the scientific method, as well as educating future generations of research scientists. Moreover, the rapid pace and varied theories in the science of global change provide a perfect platform to teach and interest non-science students how scientists think and work. The most important thing a teacher can teach is not what, but how to learn, and as a scientist this means educating students in the scientific method. For students not pursuing careers in the sciences, scientific education best serves society's interests not through rote learning of facts and data but through emphasis of scientific principles, methods of observation, and critical analysis. I feel that entry-level science courses should focus on developing these skills by introducing students to current advances in a socially relevant topic within a given scientific field and explaining not only scientific results but analytical methods, hypothesis development and testing, and rationale.

To this end, I feel that our role as educators is best-accomplished at all academic levels when science education is intertwined with scholarship and research. This philosophy is epitomized by the Nyanza Project, which introduces students to tropical lake studies through their participation in individual, guided research projects. Such instruction necessarily requires a huge field and/or laboratory commitment, but it is nevertheless possible to mix research and instruction in the classroom. I keep abreast of current topics in popular scientific literature, and educate students in the classroom about new advances and divergent theories on popular topics in the news and in the scientific literature. For instance, the introduction of new legislation regulating phosphorus use in Minnesota in 2002 served as an excellent springboard to introduce students to the global phosphorus cycle and the impacts of phosphorus on aquatic environments.

I find that coursework is most effective when it requires regular, engaging activity by the students inside and outside the classroom. Individual and group problem sets and writing assignments, given both in class and as homework, encourage student participation and inquiry, and develop analytical skills that are as essential to scientists as they are to any member of society. Informal, in-class 'pop quizzes' graded by participation only, that ask students to analyze and discuss a scientific problem with their peers then write a short answer, graded by participation only, is a concrete example of the kind of methods I use to encourage participation while developing critical thinking skills. Group projects and problem sets encourage debate and collaboration that is the backbone of interdisciplinary global change science.

It is very important that the educator keep abreast of technical advances that facilitate learning in and outside the classroom. As a teaching assistant for Limnology, I developed and maintained a course website that allowed us to post MS PowerPoint notes and lectures ahead of class on the internet, so that students could spend classroom time listening rather than frantically scribbling. Furthermore, we developed a final review session given to students in the format of the game-show "Jeopardy," that actively engaged students while reminding them of what material they most needed to review. These teaching philosophies put the onus on the educator to have thorough knowledge of both background and current developments in the discipline and in pedagogy, and to provide critical feedback while still encouraging independent thought and inquiry.