In currently ongoing Arctic-wide research, there are hints at counterintuitive connections between ROS, snow depth, and resulting changes in soil temperatures.

Future Changes in the Frequency and Magnitude of ROS Events

Much of the Arctic has seen rapid recent environmental changes related to global climate change. Even though our understanding of the frequency, magnitude, and spatial distribution of ROS events is still quite limited, it is possible to estimate how the characteristic climatic conditions that lead to currently detected ROS events will change in the future. Results from a fully coupled global climate model under the Intergovernmental Panel on Climate Change (IPCC) A1B climate scenario [*IPCC*, 2000] suggest a significant increase in the area and frequency of ROS events in the next 40 years [*Rennert et al.*, 2009] (Figure 2).

ROS Research Challenges

The current maps and statistical analyses of ROS events are based on limited detection by a surface weather network that is especially sparse in the north. The existing data lack direct evidence of some of the largest known ROS events [e.g., *Putkonen*, 1998; *Rennert et al.*, 2009], which suggests that many more events may have escaped detection. Currently, the greatest need is to create a database for the frequency and distribution of past and present ROS events. This could be produced by reprocessing the archived satellite microwave data with the aid of the recently developed detection method by *Grenfell and Putkonen* [2008] for ROS events.

One of the most immediate challenges is to develop automated equipment that can reliably detect ROS events in the field without becoming incapacitated or confounded by melting snow or freezing water. Such measurement capability would provide much needed surface observations against which the satellite record could be compared.

Major ROS events strongly affect the lives and fates of wildlife, ecosystem, and people in northern snow-covered regions. Without a clear understanding of the processes that lead to ROS events, and without knowledge of past spatial distributions and frequencies of ROS events, it is impossible to chart the impending changes in ROS characteristics and gauge the implications for the Arctic environment in general. The use of the techniques described in this article, in conjunction with modern global climate modeling, offers the potential to anticipate and alleviate the impact of ROS events on northern ungulates and ecosystems and the people who live there.

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A Field Course in the Siberian Arctic: 30 Days, 20 People, 3 Continents, 1 Barge

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As environmental change accelerates in the Arctic, the international scientific community is struggling to keep up with research efforts. To help with this, an innovative project aims to create a new cohort of Arctic researchers by uniting U.S. and Russian undergraduate students and early-career scientists through the Polaris Project, a focused effort to investigate the impacts of climate change in the Siberian Arctic.

Funded by the U.S. National Science Foundation as part of the International Polar Year (IPY), the Polaris Project (http://www.thepolarisproject.org) began in January 2008 with Arctic-focused undergraduate courses at seven participating institutions across the United States (Carleton College; Clark University; College of the Holy Cross; St. Olaf College; University of Nevada, Reno; and Western Washington University) and Russia (Yakutsk State University in Siberia). The students enrolled

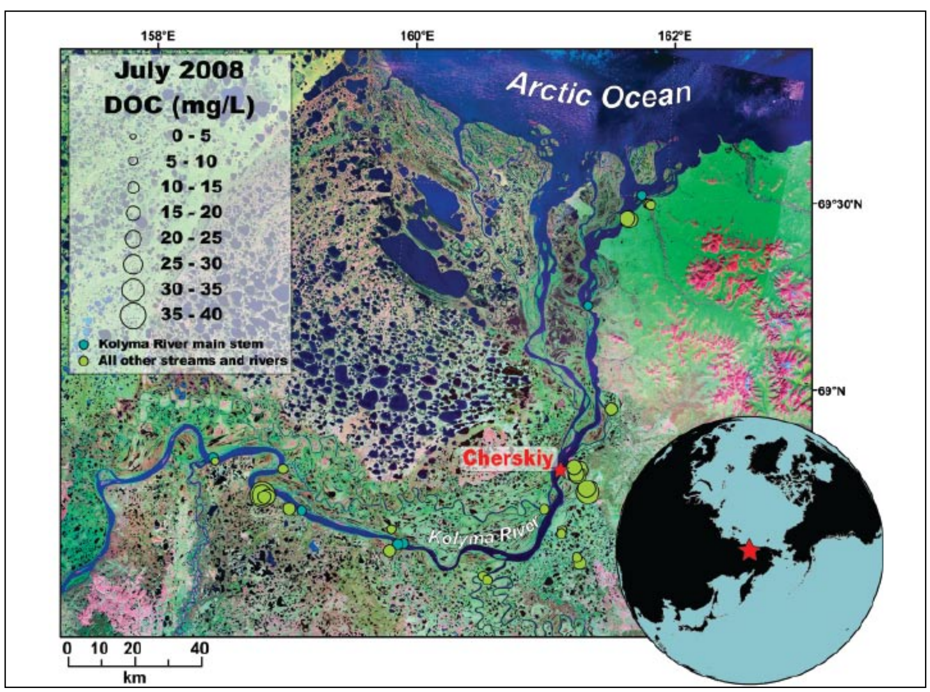

Fig. 1. Sampling locations during the inaugural 2008 Polaris Project field course, which stretched about 250 kilometers along the length of the Kolyma River in northeastern Siberia (the largest Arctic river completely underlain by permafrost). Although dissolved organic carbon (DOC) concentrations, measured in milligrams of DOC per liter of water, are relatively low for the Kolyma River main stem, the high variability of DOC concentrations in nearby smaller streams and rivers stresses the importance of measuring a variety of watersheds to further the understanding of carbon cycling throughout the region. The heterogeneity of the Kolyma River basin enables these types of valuable investigations.

in these on-campus courses were then eligible to apply for a summer field program in Siberia, the first of which was launched in July 2008 as a group of students and faculty traveled from the United States to Moscow, then to Yakutsk, and finally to Cherskiy in the Republic of Sakha (Yakutia), Siberia (Figures 1 and 2a).

The unifying scientific theme of the Polaris Project field program is to study the transport and transformation of organic matter and nutrients as they move with water from terrestrial uplands to the Arctic Ocean. Project organizers were determined to stage the field program in the Siberian Arctic: The majority of the Arctic lies within Russia, yet Western scientists have a sparse history of research there, potentially biasing scientists' knowledge of the Arctic system. In this regard, the Siberian Arctic provides a critical, under-studied field laboratory to investigate the ecological and biogeochemical ramifications of climate change.

The Siberian home of the Polaris Project, the Northeast Science Station, near Cherskiy, is at 68°N, just 80 kilometers south of the Arctic Ocean on the Kolyma River. The station has access to a wide variety of ecosystem types, including mountainous uplands, boreal forests, tundra, lakes, streams, rivers, an estuary, and the coastal Arctic Ocean (Figures 1 and 2)—few Arctic field stations provide access to such a diverse range of ecosystems. While at the station, the Polaris Project is housed on a 30-meter barge (Figure 2e), which can be towed hundreds of kilometers along the Kolyma River during multiple-day excursions.

Several research projects were initiated during the inaugural 2008 field course including a survey of organic matter and nutrient concentrations in lake and stream ecosystems (e.g., Figure 1), an examination of the impacts of permafrost degradation on aquatic biogeochemistry, and the use of dendrochronology and remote sensing to assess lake drainage rates. These preliminary efforts resulted in two student-led presentations at the 2008 AGU Fall Meeting in San Francisco, Calif.

The next Polaris Project field expedition begins on 2 July 2009. Planned activities include experimental nutrient additions to stream and lake ecosystems to investigate controls of productivity as well as continued surveys of organic matter and nutrient fluxes across environmental gradients. Near–real time reports will be posted on the interactive project Web site at http://www.thepolarisproject.org.

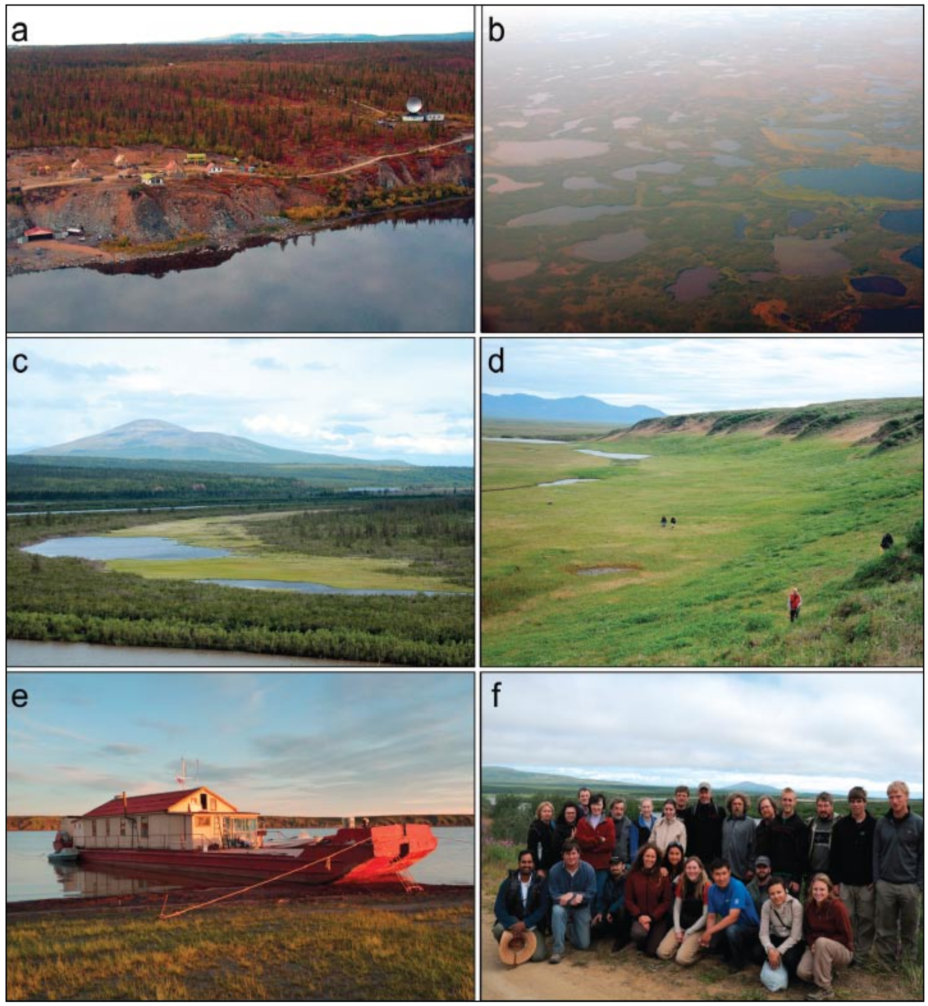

Fig. 2. The Northeast Science Station provides an ideal outdoor research laboratory for studies involving hydrological and biogeochemical impacts of Arctic climate change, owing to its diverse range of environments throughout the region. (a) Aerial view of the Northeast Science Station. (b) Lakes are ubiquitous across the landscape (yet biogeochemically diverse, as apparent in their vast array of colors). (c) A view of the topographic variability throughout the region, much of which is covered by larch-dominated boreal forest. (d) A day trip north of Cherskiy brings one north of the tree line into the tundra region. (e) The barge that transported the science team to most of their sampling locations during the field expedition. (f) The Polaris Project team (consisting of both U.S. and Russian undergraduate students and project scientists).

Although the IPY is coming to a close, the Polaris Project will continue at least through 2010 and hopefully longer. The Polaris Project already provides undergraduate students and early-career scientists the educational background, field research experience, and international connections that are essential for successful implementation of future research projects in this vast yet under-studied region of the Arctic. To quote an undergraduate participant, "I learned more during my month in Siberia than in all my science classes combined."

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