



# global glimpses

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## GLOBE: A New Model in K–12 Science Education

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### What is GLOBE?

The Global Learning and Observations to Benefit the Environment (GLOBE) Program is an international, hands-on, inquiry-based environmental science and education partnership. It brings together students, educators, scientists, schools, communities and countries in environmental studies and cross-cultural enrichment. GLOBE stands out among many excellent environmental education programs because it provides unique educational and scientific benefits around the world. GLOBE provides the opportunity for all students in K–12 classrooms to engage in authentic hands-on Earth science research. Students essentially learn science by doing science.

The original concept for the GLOBE program was first introduced in former Vice President Gore's book *Earth in the Balance* (1992): "Central to any strategy for changing the way people think about the Earth must be a concerted effort to convince them that the Global Environment is part of their 'backyard' ...I propose a program including as many countries as possible that will use school teachers and their students to monitor the entire Earth." The GLOBE Program was initiated in April 1994, in conjunction with the annual celebration of Earth Day (Finarelli, 1998).

### Goals of the GLOBE Program:

- to improve students' achievement in science, use computer and network technology, and help teachers meet local education standards,
- to expand the pipeline of potential future scientists and researchers for industry, academia and government,
- to increase student awareness of the global environment from a scientific viewpoint, without advocacy relative to issues, and
- to improve student understanding of science by involving them in performing real science—taking measurements, analyzing data, and participating in collaborative research with scientists.

### Inside this Issue:

- ◆ Recipients of the 2001 Student Research Grant Awards
- ◆ Articles by past recipients
  - ❖ Sveta Yamin and Michael Koskey, *Department of Anthropology*
  - ❖ Mark Herzog, *Institute of Arctic Biology*
  - ❖ Jack McFarland, *Department of Biology and Wildlife*
  - ❖ Shad O'Neel, *Department of Geology and Geophysics*
- ◆ Arctic Climate Impact Assessment: ACIA

In the United States, GLOBE is an interagency program of the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, National Science Foundation, Environmental Protection Agency, and Departments of Education and State. Implementation in the United States depends upon the efforts of 140 partner organizations consisting of colleges, universities, state and local school systems and non-government organizations. GLOBE has been adopted by schools in every state. Worldwide partnerships were established through bilateral agreements between the United States and its international partners, which are then responsible for designing program implementation in their own countries. To date, more than a million K–12 students in more than 10,000 schools and 16,000 teachers in over 95 countries are participating in this program.

In Alaska, the GLOBE program was established in November 1996 through a cooperative agreement between GLOBE and the University of Alaska Fairbanks (UAF) through the Center for Global Change and Arctic System Research. Elena Sparrow, coordinator of the Alaska Global Change Education Program, has been the UAF Alaska GLOBE program coordinator since its inception. The UAF-GLOBE Partnership has trained 100 teachers in 73 schools, four school administrators, three education specialists, four environmental educators, and five environmental specialists from Alaska Tribal Councils, in the GLOBE program.

(Continued on p. 2)

## GLOBE protocols

Scientists and educators comprise the GLOBE science/Education Teams for each discipline area: Atmosphere/Climate, Hydrology, Soil, Land Cover/Biology and Plant Phenology. The teams developed age and skill level-appropriate and scientifically valid protocols for standardized measurements and support materials. GLOBE protocols were chosen based on the following criteria:

- the data have research significance
- the procedures can be done by primary and secondary school students
- the equipment need is inexpensive enough for schools to purchase

Professional development workshops enable GLOBE teachers to guide their students in taking scientific measurements at or near their schools, in using the Internet to report and analyze scientific data, and in collaborating with scientists and GLOBE students worldwide.

## Benefits for Students

“GLOBE is the quintessentially ideal program for involving kids in science,”—Nobel laureate Dr. Leon Lederman (GLOBEonline, 2001). GLOBE students gain first-hand science knowledge and experience through their observations, accurate data collection and use of the data in their investigations, instead of just reading about it. An Alaska Native student from Innoko River School in Shageluk, said “The thing I liked best about GLOBE was that we had to use our hands on such things as measuring trees and oxygen testing of the water. This is the best science class I ever took in my life.” Another Alaskan student said that she would recommend GLOBE to other students and that it made her look at the environment differently.

GLOBE is good for all students, including those who may be uninterested in science or shy away from science. According to Kathleen Meckel, a Fairbanks teacher, the GLOBE phenology activities were especially good for Native students who tend to be quiet learners and not as articulate in class discussions. She found the students to be competent in taking the GLOBE measurements and they enjoyed doing it. According to another Alaska teacher, Cherie Stihler, GLOBE does more than benefit the environment. It also benefits eager young minds. “Never in all my years of teaching have I seen such excitement. Students who have never taken an interest in or enjoyed science and math now eagerly await our GLOBE work.”

In addition to specific protocols, GLOBE students of all ages learn:

- to work together in teams
- to see a relationship between their work and the work of scientists and other students
- to see the relationship of their observations and long-term patterns taking place at their study sites, their neighborhoods, their regions and the world
- to answer questions based on their measurements and observations, rather than simply from textbooks
- to sometimes question those answers
- to appreciate that some questions do not yet have answers
- to use methodologies, analyses and other skills required by many state education standards
- to realize that science is a process and not the answer

A 1996-97 evaluation by SRI International, a California firm with world-renowned expertise in education evaluation, found that GLOBE is characterized by strong teacher and student enthusiasm, strong adaptability to a wide range of grade levels and contexts, and compatibility with collaborative and inquiry learning models. Students in active GLOBE classrooms have a very positive view of the importance of their GLOBE activities: 83 percent think GLOBE will help people better understand the Earth and 78 percent believe that the data they are collecting are important to scientists.

From GLOBE Year 2 evaluation (Means, 1997), GLOBE

teachers’ perceptions of the biggest impact of GLOBE on student learning are in the following areas: observations skills (69%), measurement skills (68%), technology skills (60%), understand data (50%), work in small groups (50%), critical thinking (36%), and map skills (30%). GLOBE students performed better than their peers in non-GLOBE classes on assessments of their knowledge of measurement procedures, sampling and measurement principles, interpreting data and applying concepts, and interest in pursuing a career in science (Means, 1997).

Another major benefit in GLOBE is the opportunity for students to reach out beyond their countries, learn about geographic conditions (besides gaining hands-on experience to develop geographic skills such as understanding scale, latitude, longitude, map elements and spatial analysis), natural resources and cultural characteristics of other regions in the world.

## Benefits for Teachers

According to Dr. Diola Bagayoko, GLOBE partnership coordinator at the Southern University and A & M College in Baton Rouge, Louisiana, GLOBE provides a comprehensive, coherent, flexible tool for the actual implementation of the



*GLOBE students display hand-made clinometers for measuring tree height and slope of the land.*

prevailing science and mathematics reform blueprints, including the Benchmarks of Science Literacy, some NCTM Standards, and the National Science Education Standards (GLOBEonline, 2001). In North Carolina the state education department's newly revised standards embraced the GLOBE program since GLOBE best fits the competency goals in middle school (GLOBEonline, 2000). The University of Montana at Missoula has incorporated GLOBE training into the curriculum for pre-service elementary and high school teachers, while the Georgia Institute of Technology is using GLOBE to help teachers find meaningful educational classroom applications for computers and the Internet.

Because GLOBE has an integrated approach, teachers use GLOBE activities to promote skill development and to meet standards in not only math and science but also reading, writing, computer literacy, language arts, foreign language, geography and "life-long learning" skills. Nancy Johnson in Palmer, Alaska uses GLOBE activities in lessons and units in language arts for middle school students, while in Idaho elementary students correspond in Spanish with GLOBE students in Argentina.

Benefits for teachers include university credit (when they are GLOBE trained) for continued teacher accreditation or for use in a graduate degree they are pursuing. Teachers also receive educational materials (such as the GLOBE Teacher Guide, cloud chart, tree guide, videos on remote sensing, and GLOBE protocols on Hydrology, Soils, and Land Cover/Biology). Teachers have continued support through the GLOBE web site (<http://www.globe.gov>), managed by teams of technology experts to keep the site on the cutting edge while being user friendly, teacher list-serve, emails, phone calls and GLOBE web chats and the GLOBE Help Desk. There are other opportunities for professional development through additional workshops/conferences and for collaboration with scientists and with other GLOBE teachers locally, statewide, nationally and worldwide. Additionally, teachers are given the opportunity to make a difference in the lives of their students through an integrated science education approach, and contribute to knowledge about the earth and earth systems. Stipends and GLOBE instrument kits may also be available to GLOBE teachers depending on availability of funding for GLOBE-related projects.

### Benefits for Scientists

GLOBE, which tightly couples a science research program and a science education program, has addressed the issue of student data quality for scientific investigations (Budd et al., 1996; Rock and Lawless, 1997; Becker et al., 1998; Mims, 1999). Carefully designed scientific measurements, if properly followed, ensure accurate data. Accuracy and consistency are prerequisites for scientific use of data and

persistence and coverage also contribute to the scientific value of data (GLOBE, 1999). GLOBE also employs electronic screening of data to limit sources of error. Valid student-collected data benefits not only the students, who gain first-hand science knowledge and experience, but also the scientists, who gain a large database (Congalton and Becker, 1997) at reduced cost and time involved in collecting the

needed large quantities of data.

Meteorologists working on a haze-monitoring program found that data collected using LED-based Sun photometers by GLOBE students at a high school near NASA's Goddard Space Flight Center (GSFC)

compared favorably against aerosol optical thickness measurements from Sun photometers used at GSFC, demonstrating that students can reliably make the required measurements (Brooks and Mims, 2000). Becker et al. (1998) found that land cover reference data collected by students using GLOBE protocols are at least as accurate as those collected by professionals. "The comprehensive suite of GLOBE measurements that is being collected by students is critical for Earth science research—for assessing current conditions, for monitoring changes and for driving, testing, and creating models for predictions into the future" according to Dr. Elissa Levine, a soil scientist at NASA's Goddard Space Flight Center in Maryland (CERPS, 1999). GLOBE student daily surface-based cloud cover observations are potentially the only reliable comprehensive sky observations available to scientists who study clouds and their effects, according to Dr. Paul Ruscher of Florida State University.

The gathering of accurate ground validation/reference data is fundamental to use of remotely sensed data for land cover classification and mapping (Congalton and Becker, 1997, Fried et al., 1996) and for observations across large areas, of important plant stages and changes in the plant growing season length which may be used as signals of short- and long-term climate variability and help determine appropriate greenness values for different regions (Verbyla et al., 1999; White et al., 2000).

Through the efforts of GLOBE students, an accurate determination of the location and extent of forests, wetlands, grasslands, farmland, roads, buildings and other natural and human-made land use is being accomplished, enabling students and scientists to track how land uses change with time (GLOBEonline, 2001).

### Benefits for Others

The GLOBE learning community has grown to include not only young students but also retirees (GLOBE Offline, 2001). For example, as any GLOBE student, Florence Martin learned to read and record measurements from her study site instrument shelter. Yet unlike most students she turned 90 on the day that Mobile, AL measured a record high of 105°F last summer. She and other seniors say that they have enjoyed the

"The comprehensive suite of GLOBE measurements that is being collected by students is critical for Earth science research—for assessing current conditions, for monitoring changes and for driving, testing, and creating models for predictions into the future."

—Dr. Elissa Levine, Goddard Space Flight Center

opportunity to master GLOBE scientific protocols, to satisfy their curiosity about the environment and to make a contribution. Anne Marshall, a certified therapeutic recreation specialist, found that GLOBE senior participants showed a measurable improvement in psychological well-being compared to a control group. The GLOBE program helps to achieve the goal of meaningful activity in that the work is useful to others. GLOBE director Tom Pyke says, "GLOBE is not only about lifelong learning but also about lifelong contributions to knowledge of the world."

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(Continued on p. 11)

## 2001 Student Research Grant Recipients

The following students are recipients of this year's Student Research Grant Awards from the Center for Global Change and Arctic System Research. For the second year in a row, two of the awards (Hector Douglas and Dmitriy Dukhovskoy) are being funded through a partnership with the Alaska Sea Grant College Program. We are grateful for their continued support!

### **William R. Bolton, Institute of Northern Engineering**

*Dynamic modeling of the soil moisture and hydrologic processes in areas of discontinuous permafrost*

### **Hector Douglas, Institute of Marine Science**

*Planktivorous auklets as biomonitors of environmental change in marine food webs*

### **Dmitriy Dukhovskoy, Institute of Marine Science**

*Study of the decadal variability of the freshwater flux in the arctic basin - North Atlantic system*

### **Daniel Elsberg, Geophysical Institute**

*Glacier equilibrium line and terminus measurements with an integrated airborne video and laser altimetry system*

### **Jill Johnstone, Institute of Arctic Biology**

*Interactions between fire, climate, and vegetation succession in boreal forest*

### **Chris Larsen, Geophysical Institute**

*Coastal glaciers and sea level change: a case study in the Glacier Bay uplift region, southeast Alaska*

### **Jack McFarland, Department of Biology & Wildlife**

*The role of organic N in the nitrogen economies of terrestrial forest ecosystems: a cross-site approach*

### **Michael Palmer, Institute of Marine Science**

*Groundfish growth response to climate variability in the Bering Sea*

### **Christin Pruett, University of Alaska Museum**

*Global change and song sparrow populations in Alaska: an assessment of temporal and spatial changes using molecular markers*

### **Tina Tin, Geophysical Institute**

*Using shipboard observations to monitor sea ice thickness distribution in seasonal ice zone*

### **Katey Walter, Institute of Arctic Biology**

*Controls on methane flux from thermokarst in Northeast Siberia*

### **Martin Wilmking, Forest Sciences**

*Climate change in the treeline ecotone in interior Alaska's national parks: are the trees really better off?*

## Student Research Grant Reports—Past Recipients

### **Climate Variability in the Bering Strait Region: Written Sources and the Detection of Arctic Climate Change**

by Michael S. Koskey and Sveta Yamin, Department of Anthropology, University of Alaska Fairbanks

As the end of summer gets closer, the residents of a village on the Chukotka Peninsula approach the shaman with questions about the forthcoming winter. To be on the safe side the shaman predicts a cold winter, and advises the people to begin collecting firewood. However, to be certain, he later contacts the local meteorology center for the scientific prognosis. “We can never be sure,” the meteorologist answers, “but most likely cold: just look at all those people collecting firewood” (contemporary folklore).

Such is the nature of our research. The purpose of this study was to obtain new data for climate reconstruction, based on “non-traditional” sources of information for the period from the 1640s to present. Systematically collected empirical data on climate fluctuations based on instrumental observations exist for little more than one century. However, cultural anthropologists routinely deal with sources of information that reach further back in time. Among them are written documents composed by early explorers, traders, missionaries, etc. Such “written histories” are generally easy to interpret for Western scholars, since the authors employ familiar conceptualizations of human/environmental interactions.

This study shows that ethnohistoric data can extend the climatic record for several centuries beyond the limits of scientific observations. To explore the utility of ethnohistoric documents for the issues of global change, we tested a theory of arctic climate fluctuations with independent data derived from written sources pertaining to one particular region of the circumpolar North, the area surrounding Bering Strait. The theory predicts periodic shifts between “cyclonic” and “anti-cyclonic” regimes, which are documented for the last 50 years. Proshutinsky and Johnson (1997) determined a 10–15 year variation in Arctic ice and ocean circulation using a basin-scale model with drifting buoy and hydrographic data. The documented regimes persist for a period of 5–7 years, with cyclonic motion appearing during 1953–1957, 1964–1971, 1980–1983, and 1989–1997, and anti-cyclonic motion appearing during 1946–1952, 1958–1963, 1972–1979, and 1984–1988. The cyclonic regimes are characterized by warm summers and harsh winters, while the anti-cyclonic regimes have narrower temperature amplitudes, with generally milder winters and longer, but cooler, summers. Shifts from one regime to another are forced by changes in the locations and intensity of the Icelandic low and Siberian high. These transformations from one regime to another can be defined as climate shifts in the Arctic Ocean and occur quite rapidly. The results of our study show that this decadal variability is

documented not only in the data sets with scientifically recorded environmental parameters but also in “non-traditional” sources of information.

For the purpose of this study, we focused on sources of information that derive from written accounts of the local environment. Within anthropology, the research method most often employed to analyze such sources is labeled “ethnohistory.” Despite varying definitions of how ethnohistory should be demarcated from “history” and “anthropology” (Krech, 1991), there is consensus that “ethnohistory is an interdisciplinary field that studies past human behavior and is characterized by a primary reliance on documents” (Barber and Berdan, 1998:12). Ethnohistory does not privilege written over oral sources, and we are certain that the future survey of oral sources will significantly expand this investigation. The review and collection of oral histories and accounts of climate change requires extensive archival collection research and travel to relevant locales, ideally on both sides of the Bering Strait. For the sake of feasibility, we focused on the available written sources, while recognizing their limits.

We reviewed a total of 72 written sources of the available literature, which reaches back 350 years in the Russian part and 150–200 years in the Alaskan part of the Bering Strait region. Each reference to climate found in these sources was entered into the database. The authors of the accounts include the Russian collectors of fur taxes, missionaries, and explorers. The variation of detail on climate observation in these accounts ranges from general commentaries on seasonal weather changes to daily documentations of specified conditions. Although the reviewed literature covers 350 years, because of the variable nature of the accounts, not all time periods for which we found data are equally represented. There are also several gaps, for which there is no available climate-related information.

Our database has a total of 469 entries. All climate-related information is organized into two fields. The first one, called “Object of Observation,” refers to specific climatic occurrences, such as wind, sunshine, sea-ice, storm, fog, rain, air temperature, as well as observations of sea mammals. The other climate-related field contains direct quotations from the source. While some quoted observations are brief and very general, such as “sunny” or “windy,” most are fairly detailed, providing quantified measurements and descriptions of wind directions. The database categories also include region and sub-region, year of observation, name of the observer, the publication information, and a direct quote from the source. This organizational structure permitted us to search for all dates and regions associated with particular climatic occurrences.

Since the main purpose of our analysis was to determine whether the previously documented pattern of cyclonic and

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anti-cyclonic regimes is reflected in our collection of independent data, we first calculated the time periods associated with each regime. Averaging six-year intervals from 1946 (the beginning of the earliest anti-cyclonic regime documented by Proshutinsky and Johnson), we established the approximate shifts through the date of our earliest source of 1647. Thus, the interval of 1940–1945 is presumed to correspond with the cyclonic regime, 1934–1939 with anti-cyclonic, etc. We then searched the database using the variables of wind, temperature, sea-ice, storms, and sea mammals corresponding to the date of the observations for each variable with the predicted time period of either regime.

Despite the previously described gaps in the data sets, the overall pattern clearly reflects the 5–7 year cycles documented by Proshutinsky and Johnson. Around two-thirds of the total entries correspond with the periods calculated as times of cyclonic regimes. The conditions reported in the majority of the accounts for these time periods are cold and long winters, and pleasant summers with warm temperatures and light breeze. While there are longer periods of sea-ice, the meltdowns are more thorough than those during the periods of anti-cyclonic regimes. Of the thirty entries observing fog, twenty-five fall within the cyclonic period. We encountered a total of six observations of walrus, one observation reporting abundance of whales, and one of seals. Although our data on sea mammals is rather scarce and fragmentary, we feel that its exclusive association with the periods of cyclonic regimes demonstrates a great potential for expanding this inquiry to include the analysis of oral histories and ethnographic fieldwork among the Native communities of Alaska and Chukotka, where sea mammal hunting is a predominant subsistence activity and an essential source of livelihood.

Because the anti-cyclonic regime is characterized by comparatively milder conditions with a narrower range of seasonal extremes, the overall number of observations for the corresponding time periods is fewer. We suggest that, from the point of view of the reporting observers, the traits of the anti-cyclonic regime are not as noteworthy as those of the cyclonic regime. Since the majority of our data stems from the traveling logs, it is expected that the harsh weather conditions, which present natural obstacles for the explorers, are more likely to be reported. However, those conditions that are most favorable for the ocean travel are noted, thus providing some data reflecting the anti-cyclonic regime. For example, the account by Nordkvist in the year 1822 (which falls within the anti-cyclonic period) reports the following about the sea-ice conditions in the Arctic Ocean: “Not only in the summer, but in the winter the ocean was free of ice sometimes with a wide strip of water up to at least 200 miles away from the shore” (entry #49).

In addition to confirming that the patterns of Arctic ice and ocean circulation documented by Proshutinsky and Johnson (1997) extend as far back as 350 years, this study also demonstrates the value of a multidisciplinary approach to

research on Arctic climate. Given the concern for global change, we hope that in future investigations on Arctic climate, collaboration between scientists from across various disciplines and the communities living in the Arctic environments will be an integral part of the research.

### Acknowledgments

We thank Dr. Peter Schweitzer for his advising during all phases of the project, as well as for providing numerous sources from his personal collection. We are grateful to Sarah Doetchman for assisting with German sources. This research was enabled by the original work of Drs. Proshutinsky and Johnson and by the financial award from the Center for Global Change and Arctic System Research.

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### Variation in Gosling Growth of Black Brant (*Branta bernicla nigricans*) on the Yukon-Kuskokwim Delta

by Mark P. Herzog, Department of Biology and Wildlife, University of Alaska Fairbanks and James S. Sedinger, Institute of Arctic Biology, University of Alaska Fairbanks

The west coast of the Yukon-Kuskokwim (Y-K) Delta (see Figure 1) is characterized by wet-sedge meadows with little topographical relief (Kincheloe and Stehn, 1991). Elevation increase is typically less than 1 meter from the coast to 10 km inland (Jorgenson, 1996). The Y-K Delta is also one of the most productive high latitude ecosystems (Spencer et al., 1951). The Y-K Delta supports the most diverse and highest density of breeding geese, with the exception of snow goose (*Chen caerulescens*) colonies in Canada. Nearly 90 percent of the world's population of emperor geese (*Chen canagica*) and 70 percent of black brant (*Branta bernicla nigricans*) breed on the Y-K Delta. Geese are a primary food source for indigenous people of the Y-K Delta, particularly in spring when winter food stores become depleted. Historically, geese alleviated starvation, and local people still place a high cultural value upon geese (Klein, 1966; Raveling, 1984; Wentworth, 1994).

Pacific black brant, hereafter “brant,” nest and rear young entirely on the saline *Carex* meadows within the first 10 km of inland coastal habitat (Sedinger et al., 1993). It is this habitat that is also the most susceptible to impacts of global climate change, especially an increase in spring flooding events.

In the past 10 years, increases in brant numbers at the Tutakoke River Colony coincided with a decline in the

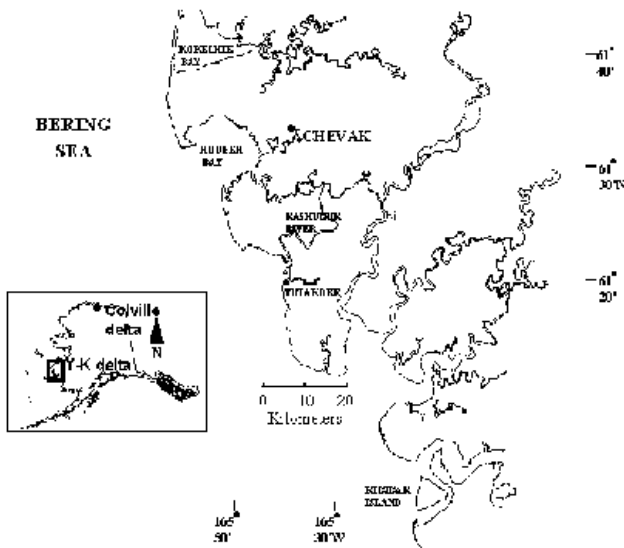


Figure 1. Location of the Tutakoke River black brant nesting colony and research study site.

growth rates of goslings. Because first-year survival is highly correlated with gosling growth (Schmutz, 1993), observed declines in gosling size at banding on the Y-K Delta can be considered a precursor to a subsequent decline in brant recruitment on the Y-K Delta. In addition, other studies have shown the strong relationship between gosling size at fledging and adult body size (Sedinger et al., 1995), which in turn, for female geese, has been shown to play a large role in determining nutrient reserves and fecundity (Cooch et al., 1991; Sedinger et al., 1995).

Arctic geese are herbivores (Owen, 1980). With growing seasons less than 100 days, goslings must be able to grow rapidly and fledge before fall freeze-up. Due to their restricted GI tract, and the relatively poor quality of vegetation as a source of nutrients, brant goslings have a digestive bottleneck (Sedinger and Raveling, 1990). They must eat a tremendous amount of vegetation to assimilate nitrogen necessary for growth, but the amount of vegetation that can be eaten is limited by the time required for fiber to pass through the gut. Thus, even with maximal rates of feeding, nitrogen is an important limiting factor in growth of goslings (Sedinger and Raveling, 1984), and gosling growth rate is closely associated with habitat availability and quality.

We examined direct environmental factors that influence growth in brant goslings. These factors included annual variation caused by annual differences in climate patterns, seasonal effects due to a significant decline in forage quality and availability after hatch, and spatial variation in forage quality and availability as well. We also examined the effects of egg size, maternal age and maternal identity. These analyses show the typical seasonal decline in growth rate ( $P < 0.0001$ ). Male goslings were affected by the seasonal decline to a greater extent than female goslings ( $P < 0.020$ ). Additionally, we found that in the most populated brood-

rearing areas, brant goslings declined in growth rate during the late 1980s, probably associated with increasing density, but have generally increased in growth rate during the 1990s ( $P < 0.0001$ ), associated with habitat modification by the geese themselves (Figure 2). Growth rate varied significantly among brood-rearing areas used by brant ( $P < 0.0001$ ), although the pattern was not consistent among years ( $P < 0.0001$ , see Figure 2).

Older females (4 years of age or greater) produced larger goslings than did younger females ( $P < 0.0020$ ). Whether this is a result of better knowledge of brood rearing areas or increased dominance with increased age is currently being investigated. After controlling for female age, gosling size at about 30 days of age was positively correlated with egg size. Overall, models containing only environmental or maternal effects explained 75% of variation in gosling size, indicating that little of the observed variation in size in this population is directly of genetic origin.

We examined heritability of adult size using a sample of individuals that were marked at hatch and subsequently weighed as adults. Heritability did not differ from zero for both mother-daughter and father-daughter regressions, suggesting little genetic influence on final adult body size.

The combination of low heritabilities and large explanatory power of environmental or maternal variables suggests that variation in size in the brant population is primarily of environmental or maternal origin. In addition, our results suggest that selection on body size has been stronger in brant than in other geese, thereby eliminating much of the genetic variation in growth. The combination of limited genetic variation with significant variation associated with environmental conditions suggests brant goslings are highly sensitive to changing climatic conditions, such as global warming. Vegetation communities on the Y-K Delta are regulated by climate, coastal processes and grazing by geese (Jorgenson, 1996; Ruess et al., 1997), and the dynamics of goose populations are inextricably linked to vegetation communities

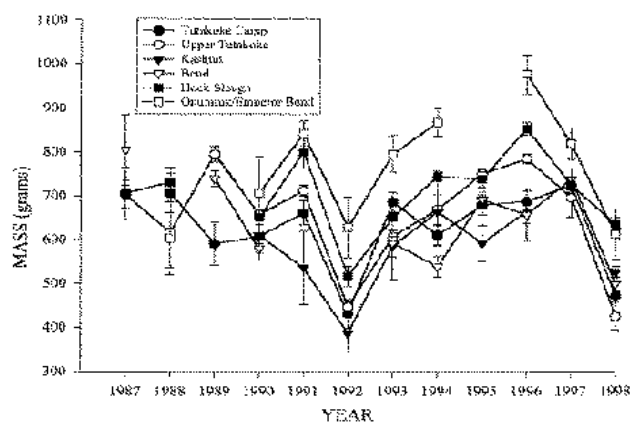


Figure 2. Annual and spatial variation in gosling size at banding (~30 days old) for black brant banded in brood rearing areas associated with the Tutakoke River Colony (1987-1998).

through nutrient availability to growing goslings (Sedinger and Raveling, 1984). Our findings further suggest that improving our understanding of mechanisms used to translate environmental factors into growth, including density-dependent effects, is essential to understanding adaptation by black brant to their changing subarctic environment and can assist in the management of a species important to subsistence users.

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## The Role of Organic N in the Nitrogen Economy of Floodplain Balsam Poplar Stands in Interior Alaska

by Jack McFarland, Department of Biology and Wildlife, University of Alaska Fairbanks

### Background

Nitrogen (N) is the nutrient most often limiting forest ecosystem production (Vitousek and Howarth, 1991), and considerable effort over the past several decades has been directed towards elucidating factors regulating N availability to plants (Melillo et al., 1982; Aber et al., 1991; Hart et al., 1994). Inorganic N is considered the primary source of N for plant uptake, a characterization that is used in regional and global models predicting forest ecosystem response to changing climate or altered land-use patterns (Bonan, 1990; Running and Hunt, 1993; Melillo et al., 1993). However, plants may be accessing other forms of N, particularly in ecosystems where decomposition and N mineralization are constrained by low soil temperatures.

Organic N is the predominant form of nitrogen found in arctic and subarctic soils (Kielland, 1995). In tundra environments, soil concentrations of water extractable free amino acids can range from four to ten times the concentration of ammonium (Kielland, 1995), while taiga soils appear to contain even larger pools of free amino acids (Kielland unpublished). It has been suggested that amino acids may account for the largest proportion of N uptake in many arctic species (Kielland, 1994), essentially providing a “short circuit” to mineral N cycling.

### Objectives

Herein, I demonstrate the contribution of organic N to the N economy of vegetation in a deciduous boreal forest ecosystem and elucidate the pathways for N uptake in that vegetation. My study had three specific objectives. The first was to provide *in situ* experimental evidence that balsam poplar communities along floodplains in interior Alaska can directly utilize an organic N substrate to supplement their nutritional requirements. Secondly, I sought to quantify, at the stand level, the relative importance of inorganic and organic N sources to vegetation within those communities. Thirdly, I assessed the compartmentalization of inorganic and organic nitrogen within the soil and evaluated the competition for these N sources between plants and microorganisms.

### Methods and Results

In August 1998, I initiated a multiple isotope tracer experiment to quantify organic and inorganic N uptake *in situ*. The experiment was conducted in mature balsam poplar (*Populus balsamifera*), a rapidly growing, ectomycorrhizal infected species found as discreet stands throughout floodplain successional forests in interior Alaska (Van Cleve et al., 1993; Viereck, 1993). These study sites are part of the Bonanza Creek Experimental Forest, a Long Term Ecological Research (LTER) site approximately 20 miles south of Fairbanks. N mineralization rates in these and later successional white spruce and black spruce floodplain forests have

been shown to be limited by low soil organic matter quality (Flanagan and Van Cleve, 1983).

I established 3 replicate soil injection grids for each of 3 treatment solutions within a 30 × 30 m plot. The entire design was replicated across 3 poplar stands distributed along the Tanana River floodplain. Each injection grid consisted of 6 cores (5.5 cm diameter) injected with one of 3 treatment solutions to a 10 cm soil depth. Treatment solutions were (1)  $^{15}\text{NH}_4^+$  plus  $^{13}\text{C}$ -glycine, (2)  $\text{NH}_4^+$  and  $^{13}\text{C}^{15}\text{N}$ -glycine, or (3) distilled water. Cores within each grid were harvested to 12 cm at 1, 2, 12, and 24 hours, and 7 and 14 days and split vertically into 2 equal halves. One half was used for sorting, washing and freezing roots for  $^{13}\text{C}$  and  $^{15}\text{N}$  analysis. The other half was used for  $^{13}\text{C}$  and  $^{15}\text{N}$  analysis of (1) total C and N, (2) dissolved inorganic and organic N, and (3) microbial N.

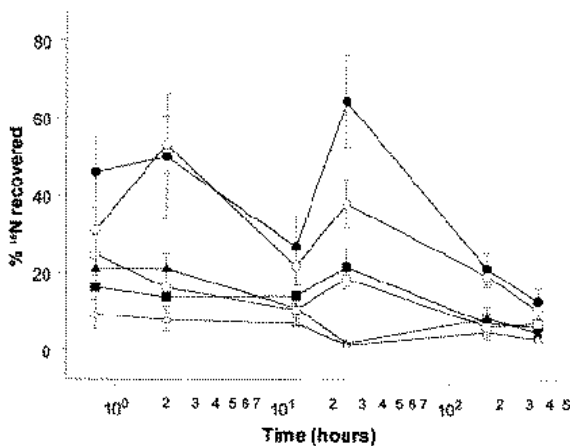


Figure 1. Percent recovery of added  $^{15}\text{N}$  as DIN, DON, or microbial N pools over time. Symbols are as follows: circle = microbial N pool; square = DON pool; triangle = DIN pool. Open and solid symbols represent ammonium ( $^{15}\text{NH}_4^+$  +  $^{13}\text{C}$ -glycine); and doubly labeled glycine ( $^{14}\text{NH}_4^+$  +  $^{13}\text{C}^{15}\text{N}$ -glycine) treatments, respectively. Data are means  $\pm$  1 s.e.m.

Microbial biomass accounted for the largest portion of labeled nitrogen regardless of the N source. From my results, it is clear that glycine represents a relatively labile N source for microbial assimilation, as recovery rates for glycine  $^{15}\text{N}$  were of the same magnitude as those for  $^{15}\text{NH}_4^+$  (Figure 1). Moreover, plots for each treatment varied more-or-less in concert over time, though recovery rates were generally higher in the ammonium treatment. In contrast,  $^{15}\text{N}$  did not remain in the dissolved inorganic N (DIN) pool very long after injection. Initial recoveries of  $^{15}\text{N}$  varied from 9% for glycine-amended cores to 21% for those receiving ammonium. Immobilization was rapid within the ammonium treatment, as most of the tracer disappeared from the DIN pool within 24 hours after injection. Across all sampling periods, less than 10% of the label was recovered as DIN in soils receiving glycine. Still, recovery of glycine  $^{15}\text{N}$  was highest in the first sampling period, emphasizing how quickly this substrate is mineralized and released as inor-

ganic nitrogen. Label recovered as dissolved organic N (DON) averaged between 16 and 25% at the first sampling period. These values declined slowly for both treatments, until the fourth sampling period (24 hrs) during which % recovery of  $^{15}\text{N}$  increased rapidly for both N sources. This sharp enrichment of  $^{15}\text{N}$  in the DON pool after 24 hours corresponds to a concomitant increase in microbial biomass  $^{15}\text{N}$  and a decrease in extractable inorganic- $^{15}\text{N}$ . At the end of two weeks, however, the amount of label recovered as DON had fallen to around 6–7%, similar to values observed for the DIN pool.

I suspect that the fluctuations in recovery of  $^{15}\text{N}$  in the soil N pools are linked to N turnover within the microbial pool. One possibility is that some of the immobilized  $^{15}\text{N}$  might be used in enzyme synthesis and then released extracellularly to decompose more recalcitrant organic substrates for carbon acquisition. This would account for the temporary decline in  $^{15}\text{N}$  recovery for both treatments, 12 hours into the experiment. All three soil N pools show an overall decline in  $^{15}\text{N}$  at the end of our sampling regime. Furthermore, analysis of the  $^{15}\text{N}$  content of the bulk soil (soil from which only roots are removed) reveals no significant change over time for either treatment. Taken together, these observations suggest that most of the label lost from the microbial and soluble N pools is eventually incorporated into soil organic matter, becoming part of a more recalcitrant pool of soil N. Others working in boreal forest ecosystems have found a similar relationship between the  $^{15}\text{N}$  content of soil biota and the amount of label retained within the soil's organic profile (Nasholm et al., 1998).

Some of the N released from the microbial pool was available for plant uptake. Overall plant  $^{15}\text{N}$  uptake during the course of the experiment was low (<2% recovery) in comparison to microorganisms (12–64% recovery), yet it

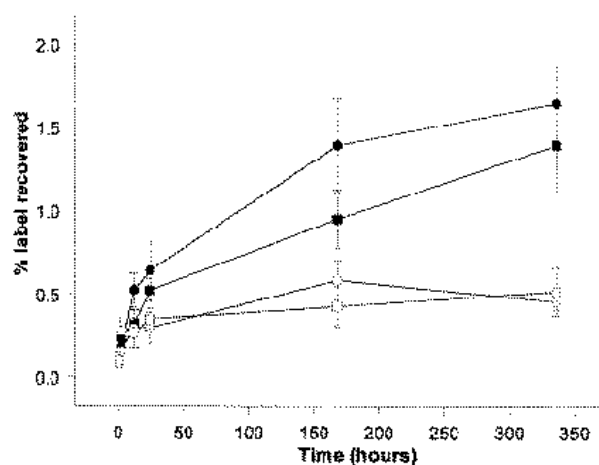


Figure 2. Percent recovery of added  $^{13}\text{C}$  and  $^{15}\text{N}$  in root carbon and nitrogen pools over time. Symbols are as follows: circle = labeled ammonium treatment ( $^{15}\text{NH}_4^+$  +  $^{13}\text{C}$ -glycine); square = doubly labeled glycine treatment ( $^{14}\text{NH}_4^+$  +  $^{13}\text{C}^{15}\text{N}$ -glycine). Open and solid symbols represent root carbon and root nitrogen respectively. Data are means  $\pm$  1 s.e.m.

was the only pool that was increasing in enrichment after 14 days (Figure 2). Moreover, short-term uptake patterns (<24 hours) show that plants can compete to a limited extent for amino acid nitrogen directly. Our results indicate a 2‰ increase in the  $^{13}\text{C}$  content of fine roots within 24 hours after the label was applied to the soil.  $^{13}\text{C}$  enrichment of this pool ceased by the fifth sampling period 6 days later (Figure 3). It seems that in the initial hours of the experiment fine roots compete directly for amino acid N, taking up the doubly labeled amino acid intact. Between two and twelve hours after the initiation of the experiment, roots stop sequestering intact amino acid and begin to assimilate  $^{15}\text{N}$  released from microbial or mycorrhizal mineralization of the organic N substrate.

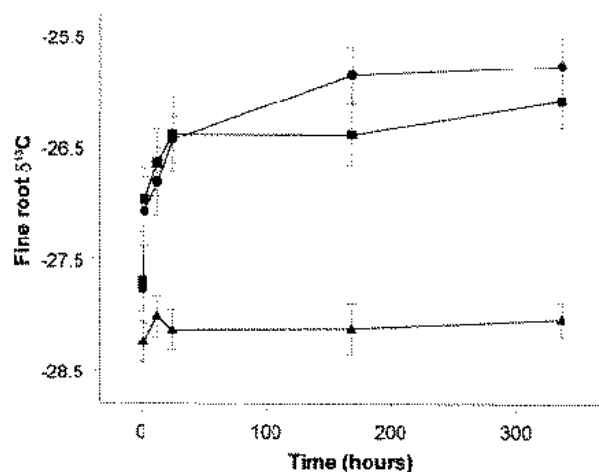


Figure 3. Change in  $\delta^{13}\text{C}$  values of the fine root carbon pool over time. Symbols are as follows: circle = labeled ammonium treatment ( $^{15}\text{NH}_4^+ + ^{13}\text{C}$ -glycine); square = doubly labeled glycine treatment ( $^{14}\text{NH}_4^+ + ^{13}\text{C}^{15}\text{N}$ -glycine); triangle = deionized water. Data are means  $\pm$  1 s.e.m.

## Summary

Nitrogen cycling is an important component in understanding the carbon balance of terrestrial ecosystems. Our expanding knowledge of the mechanisms by which carbon cycles between atmospheric and terrestrial pools has yielded a sense of how elevated atmospheric  $\text{CO}_2$  concentrations and climate change interact to affect forest ecosystem processes such as primary productivity, decomposition rates, and nutrient cycling patterns. It is our belief, however, that quantitative relationships between production and the availability of growth-limiting resources, such as N, cannot be established until reliable and accurate estimates of organic N cycling and uptake by plants are obtained. Here, I've presented evidence that plants in a predominantly ectomycorrhizal boreal forest utilize simple organic N substrates with the same efficiency as they do inorganic N. I've also confirmed what similar studies have shown; soil microbes play an important role in N cycling processes both as mediators of N availability to plants and as regulators for ecosystem N retention. Together, these two points contribute to our knowledge of patterns for

N cycling among boreal forest ecosystems and bring us closer to completing our understanding of terrestrial nitrogen cycles.

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## Mendenhall Glacier Research Project

by Shad O'Neel, Department of Geology and Geophysics, University of Alaska Fairbanks

## Introduction

Mendenhall Glacier, located north of Juneau, Alaska, has gained status as being Alaska's most-visited glacier, yet little research has been conducted there. It is part of the Juneau Icefield System, North America's fifth-largest icefield

system. The glacier covers approximately 120 km<sup>2</sup> of its 220 km<sup>2</sup> drainage basin, and spans an elevation range from 20 to 2100 meters above sea level. Its current retreat began at the end of the Little Ice Age (late 1700s), and the rate of retreat has increased in recent history. Easy logistics and an extensive interpretive program by the U.S. Forest Service make Mendenhall Glacier a desirable study object. Properties such as surface velocity, ice thickness, glacier geometry, and mass balance have been measured and provide information necessary to interpret glacier–climate interactions in Southeast Alaska.

### Glacier Geometry

Classically, changes in terminus position are used to make qualitative statements about climate change. However, caution is necessary because a time-varying portion of Mendenhall Glacier terminates in a lake. Consequently, retreat rates are significantly higher over the lake-terminating portion of the snout because of iceberg calving. In addition, glacier geometry may take 40 to 60 years to respond to climate forcing. Given these cautionary statements, however, comparison of modern and historic retreat rates shows an accelerated retreat in recent history, most likely directly related to climate change.

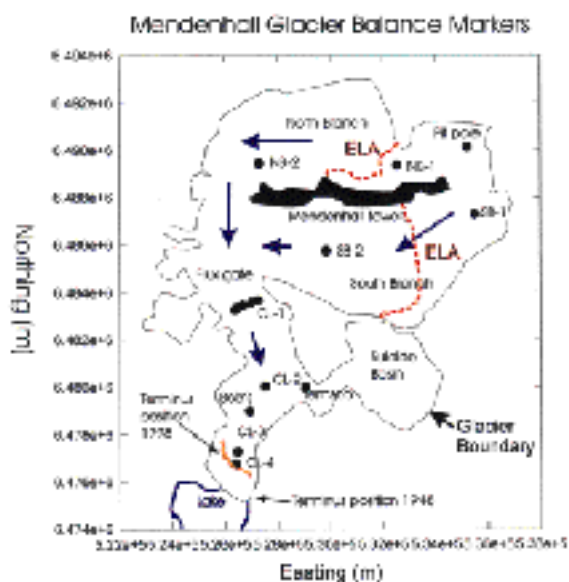


Figure 1. Mendenhall Glacier boundary and terminus positions; measurement locations (black dots); and generalized flow patterns (arrows).

### Mass Balance

Glacier health is determined by measuring its mass balance, that is, the net change in mass over a specified time interval. Normally, a negative balance leads to thinning and terminus retreat, while a positive balance will have opposite effects. Point measurements of accumulation and ablation are extrapolated over the glacier's elevation range, and then integrated over the entire glacier. During 1998, eleven

balance markers were drilled into the glacier at approximately 300-meter elevation intervals covering both main branches of the glacier (Figure 1). The balances ranged from –11.5 m water equivalent (WE) melt at the terminus, to +1.6 m WE accumulation at the glacier head. Averaged over its entire surface, the glacier lost 1.2 m of WE in the 1998 balance year, indicating that at least during this year, the glacier was grossly undernourished.

Further evidence for a negative balance trend is the upward migration of the equilibrium line altitude (ELA). This line marks the elevation where accumulation equals ablation. Comparison of the current position of the ELA (Figure 1) with a regional long-term average reported by Pelto and Miller (1990) yields a 2°C warming, assuming precipitation has remained constant during this time interval.

If ice velocity, thickness and mass balance are known at any glacier cross-section, an ice flux may be calculated and compared to a steady state ice flux. At the Mendenhall Glacier flux gate (Figure 1), the difference between the calculated ice flux and steady state flux suggests a thinning rate of 30 cm/yr over the accumulation area. Indeed, trimline observations suggest thinning at this rate or greater.

### Conclusion

Glaciological studies on Mendenhall Glacier have helped shed light on climate change in Southeast Alaska. Measurements of mass balance, surface velocity and ice thickness were made in 1997–98. These and other observations indicate that the glacier has been in a state of retreat since the late 1700s, with the rate of retreat increasing in the recent past. This may indicate a trend towards increasing mass loss in recent time. The 1998 data show a strongly negative balance of 2.9 m of water loss over the entire glacier. Ice flux calculations and ELA observations agree with the balance data. The glacier is rapidly losing mass, primarily in response to a warming climate, and secondarily to calving.

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## Arctic Climate Impact Assessment (ACIA)

A Progress Report by Gunter Weller, Executive Director, ACIA Secretariat, an activity of the Center for Global Change and Arctic System Research

### Objectives of ACIA

An international project entitled "Arctic Climate Impact Assessment" or ACIA commenced in 2000 under the auspices of two of the Arctic Council's working groups, the Arctic Monitoring and Assessment Programme (AMAP) and Conservation of Arctic Flora and Fauna (CAFF), and the International Arctic Science Committee (IASC). Its goal is to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences. Climate variability and change, and more recently, notable increases in UV radiation, have become important issues in the Arctic over the past few decades. The ACIA will examine possible future impacts on the environment and its living resources, on human health, and on social and economic activities, as well as possible adaptations and responses. This assessment will provide useful information to the governments, organizations and peoples of the Arctic to help meet such changes.

### Lead and Contributing Authors

Experts from many different disciplines and countries are participating in ACIA. Writing will be done by lead and contributing authors guided by the ACIA Assessment Steering Committee (ASC); consulting authors will help with small writing tasks in their fields of expertise, and in the review process. Several first workshops of the chapter writing groups have already taken place.

### Climate Scenarios and Models

ACIA will work with a single IPCC-type scenario, the SRES B2. This is a "moderate" climate change scenario and contains projections out to the year 2100. The B2 scenario will be implemented on five climate models readily available to scientists in North American and European centers: Canadian Climate Centre, NCAR, GFDL, Hadley Centre, and Max Planck Institute. ACIA will use time slices around 2020, 2050 and 2080, the same as those being used by the IPCC.

### Management and Funding

The Arctic Council and the three sponsoring bodies (AMAP, CAFF, and IASC) have established an Assessment Steering Committee (ASC) to provide an ongoing oversight mechanism for the assessment. The members of the ASC include all the lead authors, several scientists appointed by the three sponsoring bodies, and two individuals appointed by the indigenous organizations in the Arctic Council. Further, the three sponsoring bodies have established oversight processes for the ACIA. Finally, the Arctic Council, including its Senior Arctic Officials, provides oversight through progress reports and documentation at all of the Arctic Council meetings.

ACIA is funded through support by each of the eight Arctic-rim nations, with the US providing financial support through NSF and NOAA to establish a Secretariat at the University of Alaska Fairbanks. Each country supports the involvement of its citizens in the ACIA and provides contributions such as local costs of hosting meetings and workshops.

### Web Site

More information can be found on the ACIA Web Site at <http://www.acia.uaf.edu/>.

## *Publications Available*

### ***Assessing the Consequences of Climate Change for Alaska and the Bering Sea Region***

Proceedings of a Workshop  
University of Alaska Fairbanks  
29–30 October 1998

### ***Impacts of Global Climate Change in the Arctic Regions***

Report from a Workshop on the  
Impacts of Global Change  
25–26 April 1999  
Tromsø, Norway

### ***Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change***

A Report of the Alaska Regional Assessment Group  
for the U.S. Global Change Research Program  
(published December 1999)

### ***Global Climate Change and Alaska***

18" x 24" full-color poster illustrating  
the potential effects of climate change in Alaska



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