axis tilt with respect to the ecliptic led to enhanced maxima and minima in the seasonal insolation. In fact, changes in orbital parameters have a much larger effect on the perennial snow cover distribution than changes in ocean heat transport in models of intermediate complexity (A. Klocker, Bremen).

However, similar configurations of Earth's orbit also occurred well before and well after 2.7 Ma. This suggests that the climate system must have been preconditioned by some other process. Experiments with a zonally averaged atmosphere-ice sheet model forced with varying orbital parameters simulate the inception of glaciation around the correct time only if atmospheric CO_2 is decreasing, as reported by M. Crucifix (Exeter, U.K.). Reconstructions of past CO_2 levels, however, do not support this theory, indicating relatively stable CO_2 concentrations between 200 and 400 ppmv (parts per million by volume) back to the Oligocene (25 Ma), although the uncertainty leaves some room for speculations.

How did the reorganization of the ocean circulation associated with the gateway closure influence the carbon cycle and hence atmospheric CO_2? This was identified as another pressing issue that needs to be addressed with future modeling of the coupled climate-carbon cycle system.

The Pliocene Closure of the Panama Gateway and its Effect on Ocean Circulation, Climate and Evolution workshop was held 11–12 June 2004, in Kiel, Germany.

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—A. Schmittner, M. Sarnthein, H. Kinkel, G. Bartoli, T. Bickert, M. Crucifix, D. Crudeli, J. Groeneveld, F. Kösters, U. Mikolajewicz, C. Millo, J. Reijmer, P. Schäfer, D. Schmidt, B. Schneider, M. Schulz, S. Steph, R. Tiedemann, M. Weinelt, and M. Zuvela

Education and Outreach for the International Polar Year

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If the 65 educators, scientists, and media specialists who gathered at the "Bridging the Poles" workshop in Washington, D.C. last June have their way, a semitrailer truck labeled "Got Snow?" would traverse the country during the International Polar Year (IPY) of 2007–2009 loaded with polar gear, interactive activities, and a snowmaker.

We would significantly increase the number of Arctic residents—especially indigenous Alaskans—with Ph.D.s. We would build exchange programs between inner city youths and polar residents. Polar exhibitions would open at natural history and art museums and zoos. And polar postage stamps, interactive polar computer games, national polar book-of-the-month recommendations, made-for-TV polar documentaries, and a polar youth forum would bring the poles front and center to the public's attention.

The goals of the U.S. National Science Foundation-sponsored workshop were to define strategies that will engage the next generation of polar scientists, engineers, and leaders, and inspire the general public. Through a series of plenary talks and roundtable discussions, the workshop focused on opportunities and needs for different education and interest levels, engaging diverse communities, leveraging the importance and excitement of polar science, and programs that could be featured nationally and internationally over the next 5 years. This was the first effort to develop an integrated education and outreach program that would maximize the potential of the International Polar Year.

Addressing All Levels of Education and Interest

Discussions about opportunities and models for engaging different education and interest levels emphasized capitalizing on the ability of polar themes to attract attention and the need for a broad, interdisciplinary approach. Levels considered included grades K–5, 6–12, undergraduate nonscience, undergraduate and graduate science majors, and the general public.

The poles can encompass multiple content areas ranging from science to culture and heritage. Workshop participants advocated capturing student interest and increasing science literacy in the general public by linking fascination with polar environments to improving science, math, reading, and other skills, while integrating polar themes into state and national standards. Polar science can engage diverse groups of learners in science as a human endeavor, the history and nature of science, science as inquiry, and science and technology. For advanced students, there are exciting opportunities in circumpolar distance learning with Web course delivery, as well as other programs such as the University of the Arctic's Ph.D. networks and collaborative field courses.

Beyond curricula, the use of polar themes in major competitions, such as the annual National History Day contest for middle and high school students, the National Ocean Sciences Bowl, and the Intel Science Talent Search Competitions for high school students, is a powerful way to expand attention on, and interest in, polar subjects. Other imaginative polar education and outreach ideas discussed at the workshop include polar-themed fast food restaurant meals, following people and animals as they go about "A Day in their Life at the Poles," and junior Arctic and Antarctic councils focusing on resolving international issues.

Engaging More Diverse Participation

Participants articulated the need of the polar science community to fully engage more diverse participation, including Arctic peoples and communities, underrepresented minorities, and women, as well as to broaden economic and geographic involvement. Communication with Arctic indigenous people must extend beyond the simple transmittal of science results. Programs must advance the next generation of researchers from the Arctic who will investigate and communicate northern issues to global populations and decision makers.

This theme of building capacity within communities, together with providing opportunities for personal contact and field experiences, making polar issues relevant at the community level, and developing mentoring and support systems, was articulated by workshop participants for each target group. Common interests can bring diverse communities together. For example, Matthew Hensen, the African American explorer who went to the North Pole with Robert E. Peary in 1909, played a crucial role in polar exploration at the turn of the last century. Yet, since his time, minorities have remained underrepresented in polar science. A first step toward making connections was taken at the workshop when the leader of the Earth Conservation Corps' Matthew Henson Center in Washington, D.C. established contact with Native Alaskans and together they began to plan exchange programs.

Unlike many of the other sciences, polar themes draw a nearly gender balanced audience, according to user data collected through the San Francisco Exploratorium's Web-based Live@Exploratorium, including "Science Live from Antarctica." Polar education efforts should build on this latent interest to develop a more gender-diverse community.

Just as it is important to engage diverse audiences, establishing connections among local scientists, educators, and informal outreach venues also can have long-lasting impacts. These connections build a network that sustains and encourages further engagement on all sides. Especially important is providing opportunities for field experiences for students, teachers, and the media; that can build life-long advocates of the poles.

Leveraging the Importance and Excitement of Polar Science

The workshop identified ways to leverage the importance and excitement of polar science, starting with what people think they know about polar organisms, and then moving beyond the charismatic megafauna of polar bears, penguins, and whales to look at the diversity of adaptations to life in extreme environments. Participants discussed ways in which major emerging science programs can be connected with meaningful education and outreach programming, and presented to the public as media events. Examples include the Antarctic Drilling Initiative (ANDRILL) in the

Ross Sea to recover key paleoclimatic records, and the Ice Cube neutrino observatory at the South Pole.

Polar environmental change—including SEARCH (A Study of Environmental Arctic Change)—links communities around the world with the worlds at the ends of the Earth, and underscores the feedback mechanisms of the poles on and from the global system. "Think globally/act locally" and the complementary "think locally/act globally" will be important themes for local, national, and international IPY programming.

Crucial to ensuring the success of polar education and outreach efforts are the coordination of existing resources, linking communities and developing partnerships, access to data and content from the polar regions, securing funding to develop new programs, and sustaining programs after the conclusion of the IPY. Education and outreach initiatives must be clearly defined with measurable outcomes so that IPY's promise in building capacity in Arctic communities, growing a new generation of polar researchers, and stimulating the public to know more, and to care more, about the poles is realized.

Workshop participants recommended the creation of staffed interagency and international working groups on IPY education and outreach in order to coordinate and leverage programs, and that these working groups be integrated with research plans.

A rich, sophisticated, multidisciplinary, international, and multilingual one-stop Web portal should be developed to host research and education resources, opportunities, and advances; post reports from the field and curriculum material; serve as a central meeting point for a diverse suite of populations; and provide contacts for researchers, educators, the media, and the public at all levels. The media—television, radio, and print—as well as educators, zoos, and museums are eager for timely, accessible, and meaningful content. Access to high-quality content requires improved high-bandwidth communications; this issue emerged repeatedly in the workshop as critical to timely and dynamic connections between the poles, the media, and other communities.

In conclusion, to maximize the potential of the International Polar Year, participants recommended integrating research, education, and outreach efforts at the international and national levels, with the goal of building a coherent and exciting public presence during 2007–2009.

Requests for funding proposals (RFPs) for the International Polar Year should encourage a broad spectrum of research, education, and outreach projects. The RFPs should be written to allow maximum flexibility in design and size; not all research programs need to have a major education component, and not all outreach programs need to have a major research component. Expensive, collaborative projects can have major national or even international impact when science programs are connected with press events, educational programming, and spin-offs of local programs. But small, individual projects can produce sustained transformation of local or target communities.

There is a pressing need to start now to develop an integrated research/media/education strategy; establish partners among the research, media, and education communities; and diversify participation and audiences. Just as it takes time to define a research program and establish the logistics to carry it out, effective education and outreach programs take years to develop.

The Bridging the Poles Workshop was held on 23–25 June 2004, in Washington, D.C. The workshop report is available for online comment and community input until 3 January 2005, with a target publication date of late winter 2004–2005 (for updates, see the workshop Web site: http://www.ldeo.columbia.edu/~mkt/PolarED_Web.htm).

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FORUM

Make Earth Science Education As Dynamic As Earth Itself

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The images of rivers spilling over their banks and washing away entire towns, buildings decimated to rubble by the violent shaking of the Earth's plates, and molten lava flowing up from inside the Earth's core are constant reminders of the power of the Earth. Humans are simply at the whim of the forces of Mother Nature—or are we?

Whether it is from a great natural disaster, a short-term weather event like El Niño, or longer-term processes like plate tectonics, Earth processes affect us all. Yet, we are only beginning to scratch the surface of our understanding of Earth sciences. We believe the day will come when our understanding of these dynamic Earth processes will prompt better policies and decisions about saving lives and property. One key place to start is in America's classrooms.

There is growing support to boost Earth science education in K-12 curriculum. In the U.S. National Research Council's National Science Standards, a wide range of scientists in fields from chemistry to life sciences stressed the importance of educating students on the basics of Earth science. They understand that in addition to contributing significantly to many issue-based concerns, Earth science provides important context and meaning for further knowledge in life and physical sciences. The newly released report of the U.S. Commission on Ocean Policy devotes an entire chapter to the importance of ocean education.

Earth science is a powerful tool because it offers experience in a diverse range of interrelated scientific disciplines. Because Earth itself is made up of countless interconnected and dynamic systems, it takes exactly this kind of broad focus to begin to understand it. In fact, complementary U.S. and global Earth observation systems are now emerging to take Earth's pulse everywhere it beats—which is all over the globe. Only technology and information that is as linked and interrelated as our land, sea, and atmosphere will enable us to do this effectively. Until the gaps in our scientific knowledge are addressed, there will always be blind spots and uncertainties in our understanding of Earth and how best to address accelerating 21st century challenges.

Furthermore, Earth science is related closely to students' natural surroundings. It offers students subject matter that has direct application to their lives and the world around them. It offers many opportunities to collect data, hypothesize, experiment, and draw conclusions, both within school and outside environments. It can be both a teacher's and a student's dream.

Fortunately, many U.S. state science frameworks across the country recognize that Earth science is necessary for all students and that schools should include Earth science topics in the curriculum from kindergarten through grade 12. Nearly half of all states include Earth science content in state-mandated high school exams and 37 states apply Earth science courses toward high school graduation requirements.

Yet, in some states and school districts we find students without the opportunity to study this important science discipline. In 2001, a report issued by the Council of Chief State School Officers indicated that of this country's roughly 13 million high school students, less than 7%, or 860,000, are taking a high school Earth and space science course, a number far fewer than the 88% of students taking biology. In 1962, about 8.5% of students took a high school Earth and space science course. Enrollment is going down at the same time Earth science challenges are escalating.

By 2025, eight billion people will live on Earth. If we are to continue to maintain a high quality of life, we need to delve much more deeply into our planet, its processes, its