THE UNIVERSITY OF UTAH®

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Welcome to the University of Utah, one of the nation's premier public institutions of higher education.

The U has long attracted students looking for an inspiring backdrop to their educational experience. For those in the know, Utah offers stunning recreation choices: freshly powdered slopes, desert red rock, crystalline lakes. But the U offers much more than a great place to recreate; it is a powerhouse of academics, research, and service.

As a university increasingly focused on internationalization, we strive to prepare all of our students to assume roles of leadership and responsibility throughout the world. Our international emphasis helps students immerse themselves in different cultures, languages, and systems of governance; to become socially and politically literate and economically aware—all in an effort to further expand their view of the world. For example:

The University's Middle East Center is one of only fifteen national resource centers in the U.S. devoted to the academic study of the region. Resident experts routinely inform policymakers and educators through conferences, publications, and interviews.

Our new Confucius Institute augments a historic partnership between Sichuan University and the University of Utah to promote Chinese language and culture, and to strengthen mutual understanding between China and the United States.

Since the 1960s, the Hinckley Institute of Politics has connected University students with the politics of our country and the world. Whether through its long-established internship program in Washington D.C., or the new Campaign Management Minor, HIP engages university students in the political process.

The International Opportunities Assistance Fund, launched by ASUU, Undergraduate Studies, Study Abroad, and the Hinckley Institute of Politics, offers financial support to students eager to live and learn in an international setting.

Reach for more information about the U's international opportunities by using the International Gateway website at http://international.utah.edu. Then drop by the University's A-Z index and explore even more of this great institution. Or schedule a campus visit and discover for yourself why I believe the University of Utah is a place where extraordinary people are daily achieving extraordinary things.

Sincerely,

Michael K. Young

Michael K. Young
President

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MESSAGE FROM THE PRESIDENT

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UNIVERSITY BRIEFS

Ken Golden coring sea ice. Photo credit: Adam Gully

ANTARCTIC SEA ICE GIVES GLOBAL WARMING CLUES

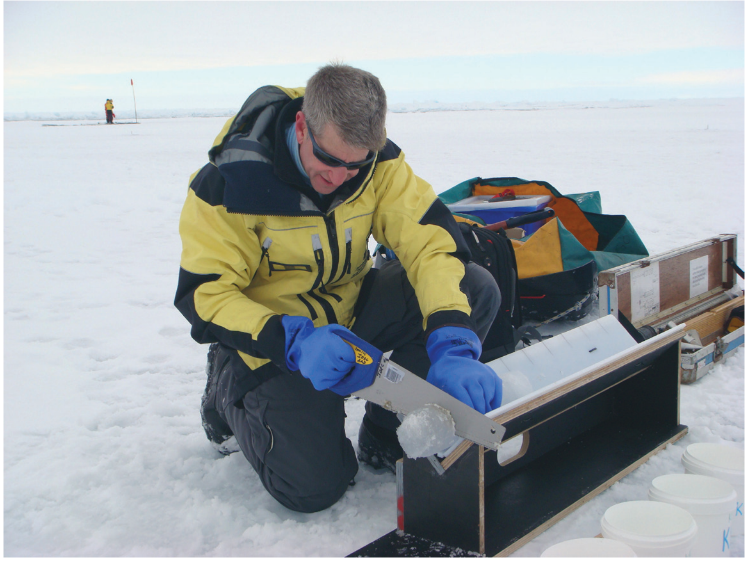
Jamie Bowen

In 1998, Ken Golden made his third expedition to Antarctica aboard the Aurora Australis, an Australian icebreaking research vessel. He was rudely awakened one night to the sound of fear. The first mate of the ship announced to the crew in his thick Scottish accent, "Please don't be alarmed, but we have an uncontrollable fire in the engine room." Fifteen minutes later, the first mate got up in front of the group again and made another announcement: "Please don't be alarmed, we are lowering the life boats."

Starting from about 100 miles off the Antarctic coast in pack ice where the blaze occurred, the crew made it safely back to Australia on a back-up engine. "Quite an exciting experience" is how Golden remembers that first expedition aboard the Aurora, which was covered worldwide by CNN and many Australian newspapers. He said the first expedition "was over before it even started," but it was the start of many expeditions that would change the way the field of mathematics and the world look at global warming in the Arctic and Antarctic icecaps.

Golden first became interested in climate change and ice packs, or frozen sea ice, when he was a junior in high school in Maryland and pondered questions like: What sort of changes in climate make the ice packs recede? "If you hear that global temperatures have risen on average by a degree over many years you may not worry about climate change. However, if you see satellite images that show that 40 percent of the summer Arctic sea ice pack has disappeared in just a few years then this geographical perspective makes you realize how serious climate change really is," he said.

Golden used to go over to NASA when he was in high school and study sea ice. Golden, who is now a professor in the Department of Mathematics at the University of Utah, has been studying sea ice using mathematics for more than 30 years. His research focuses on the effects of climate change on sea ice.


Ken Golden taking a sea ice sample to measure its salinity. Photo credit: Adam Gully

Sea ice makes up between 7 and 10 percent of the Earth's ocean surface. It is the boundary between the ocean and the atmosphere and it can serve as a big indicator of global warming and climate change. Sea ice is what protects the polar oceans from solar radiation. When the radiation enters the atmosphere it is reflected by the sea ice and absorbed by the continents and ocean water.

Seasonal sea ice is melting at an alarming rate due to a process called Ice-Albedo Feedback. Albedo is how much light is reflected by a surface. The process is a cycle in which warming melts the ice which lowers the albedo so that more light is absorbed, which results in more melting of the ice. As the process continues, the ice gets thinner and more and more disappears, Golden said. "When the sun is shining, an ice pack with lower albedo is reflecting less sunlight, and absorbing more radiation. You're in a much thinner regime now and more susceptible to heating and melting."

In the past decade there has been a drastic change in the seasonal sea ice levels, mainly during the summer months. This is due in large part to the Ice-Albedo Feedback, said Don Perovich, a research geophysicist. The areal extent of the winter Arctic ice pack has declined gradually about 10 percent from its average value from 1979-2000. However, in just 10 years the extent of the summer Arctic sea ice pack has declined about 40 percent from its average value. The changes in the seasonal ice pack are believed to be due to two things: 1. the dynamics of the Arctic Ocean which resulted in sea ice being exported into the North Atlantic through Fram Strait, a passage from the Arctic Ocean to the Norwegian and Greenland Seas; and 2. more ice is melting due to the Albedo Feedback.

Though drastic changes in the sea ice have occurred, Golden still feels that we are okay for now. "It appears that we haven't passed the critical threshold, but we have entered into a new regime. Are we going to rebound? Probably not significantly in the near future."

Models included in the 2007 Intergovernmental Panel on Climate Change AR4 report, run from 1950 to 2080 and beyond, projections indicate that the summer Arctic sea ice pack will likely disappear by the end of the century, although some of these models predict a more rapid decline. But as satellite images have shown, the predictive models are drastically underestimating the loss of sea ice. "None of them has actually predicted what happened, although variability in some of the best models comes close," Golden said. "Most of these models don't look at the important processes that we look at in our work."

In his work, Golden uses mathematics to study the effective properties of sea ice as a composite. Sea ice is a composite material with brine, salt, and air. The sea ice is studied on a micro-scale and that is mainly where the math comes into play, although there is also a lot of math that goes into studying sea ice on much larger scales.

Golden's first big discovery came during the 1994 U.S. expedition called the Antarctic Zone Flux Experiment. "In a very powerful storm, I saw water percolating to the surface," Golden said. "The entire sea ice layer became permeable as the storm warmed the ice. As the snow piled up, the weight created a pressure head which forced the water upward, flooding the surface. The water mixed with the snow, and this slushy mixture froze to form sea ice—about a quarter or more of the ice produced in the Southern Ocean forms this way. This was a changing point in my career."

What Golden was discovering was there is a critical threshold for fluid flow in sea ice, where it is impermeable for brine volume fractions below about five percent and increasingly permeable above that. He also discovered that the brine volume fraction also corresponds to a temperature of negative five degrees Celsius for salinity of five parts per thousand, which is known as the Rule of Fives. In a landmark paper published in the journal *Science* in 1998, Golden was able to identify this critical behavior as an example of a percolation threshold, an area of mathematics in which Golden had done a lot of research in previous years.

Sea ice permeability constrains the evolution of melt ponds on Arctic sea ice, which are a key part of the problem in the ice-albedo feedback. They absorb the solar radiation which melts the ice. "If you want to understand the melt ponds, you must understand the permeability," he said. Golden, Hajo Eicken at the University of Alaska Fairbanks, and other colleagues and students have since developed a comprehensive theory of sea ice permeability, as well as X-ray CT imaging methods to study the brine microstructure of sea ice, which controls the permeability. Their work pro-


Ken Golden measuring the fluid permeability of sea ice. Photo credit: Adam Gully

vides the foundation for studying key processes which must be better understood to improve climate models.

Sea ice permeability also controls nutrient replenishment processes which are vital to extensive communities of algae and bacteria that live in the brine inclusions in sea ice. These communities support life in the polar oceans. It has been observed that the levels of microbial activity in sea ice are closely related to the Rule of Fives. Golden's work helps provide the foundation for studies of how microbial ecosystems may respond to climate change.

In his last expedition to Antarctica in 2007, the Australian Sea Ice Physics and Ecosystem Experiment (SIPEX), Golden took one of his students, Adam Gully, to help with the experiments. During the expedition, they performed four different experiments on the ice. They made the first measurements of fluid permeability in Antarctic pack ice by drilling partial holes in the ice and seeing how fast the water filled back in. They extracted vertical cores of sea ice and measured the electrical conductivity to relate sea ice electrical properties to its fluid properties. They also inserted electrical probes into the surface of the ice to reconstruct its electrical profile to help monitor the thickness of the ice, which is a key part in gauging the impact of climate change. Finally, they used tracers poured through extracted blocks of sea ice to examine the flow of fluid through the ice. "A lot of cool stuff came out of these experiments," Golden says.

Golden's research is essential to the mathematics community and he is bridging the gap between mathematicians and climate scientists, Gully said. "I think his research is great and it helps other mathematicians apply these theories," he said. Golden's research is also essential to help the climate models become more accurate. "The work Ken does is really critical to climate modelers," Gully said. With Golden doing the hands-on research, he is helping the climate change modelers change so that they are more accurate.


Ken Golden inspecting a stained block of sea ice. Photo credit: Adam Gully


Math student Adam Gully setting up an electrical measurement. Photo credit: Ken Golden

The icebreaker Aurora Australis in the late polar afternoon. Photo credit: Ken Golden


Math student Adam Gully measuring a stained block of sea ice. Photo credit: Ken Golden