



Counting on mathematicians to help save the planet

On a brilliant white ice floe floating in the Arctic Ocean, a group of people in bulky coats adjust to the biting cold, having been dropped off by helicopter. “All of a sudden, I turn around and there’s a polar bear and it starts running at us,” says Jody Reimer, recounting a moment of panic. “Luckily, the helicopter swooped back in to scare the bear off, but I had the adrenaline shakes for the rest of the day,” she adds, laughing.

You might expect such a nail-biting anecdote to come from an explorer, but Dr



Reimer is a mathematician and lecturer at the University of Utah, as well as being part of a community that has swapped cosy classrooms for some of the Earth's most inhospitable wildernesses, in a bid to use numbers to understand global warming.

Their adventures enable them to observe first-hand the processes driving change in the polar regions and validate their mathematical theories of sea ice and its role as a critical component in the Earth's climate system.



Professor Golden, together with other scientists and mathematicians from the University of Utah take ice core samples to measure fluid permeability in Antarctica.

A complex problem

The thickness and extent of sea ice in the Arctic has declined quickly since satellite measurements were first taken in 1979.

Sea ice is the Earth's refrigerator, reflecting sunlight back into space. Its enduring presence is important to our planet's future because, as more ice melts, more dark water is exposed which absorbs more sunlight. This sun-warmed water melts more ice in a self-reinforcing cycle called ice albedo feedback.



While sea ice decline is perhaps one of the most visible large-scale changes connected to planetary warming on the Earth's surface, analysing, modelling and predicting its behaviour and the response of the polar system it supports is incredibly difficult, but mathematicians can help.

Kenneth Golden, a distinguished professor of mathematics and adjunct professor of biomedical engineering at the University of Utah, has built a unique sea ice programme over 30 years. Its combination of mathematics research, climate modelling and exciting field expeditions, has attracted students and postdoctoral researchers, including Dr Reimer, who are focused on using this type of science to help tackle the pressing challenges of a rapidly changing climate.

Factoring in animals

Dr Reimer has studied how polar bears and seals respond to changes in their frozen environment. While she used mathematical models to understand the interactions between these creatures and their habitat, she also took measurements and samples from bears in the Arctic, which was something she never expected to do as a mathematician. "They're not totally sleeping when they are tranquilised; they're groggy," she explains. "One of them freaked me out because it seemed like it could wake up at some point."





Dr Reimer takes measurements from a sedated polar bear in the Arctic.

Their shrinking habitat means polar bears are walking on thin ice, but it's hoped that studies like Dr Reimer's will help experts understand how to protect the majestic predators.

However, it is the “mind-blowing” microscopic world of bacteria and algae that live in salty water pockets inside the sea ice that now excites her. This biological community and its habitat are influenced by changes in temperature, salinity and light, making it difficult to model accurately. In her current work, Dr Reimer constructs models to understand how these factors interact to determine biological activity within the ice. “Understanding how processes on these small scales contribute to macro-level patterns is critical to modelling the impact of a warming climate on polar marine ecology,” she explains.

Crunching the numbers on salty ice

It is the challenge of understanding how the microscopic structure of sea ice affects the behaviour of massive expanses of ice that interests Prof Golden. He has visited the Earth's polar regions 18 times, braving the westerly winds known as the “Roaring Forties” to reach Antarctica by ship and narrowly avoiding plunging into icy waters while measuring sea ice. “One time I was visited by a massive whale about eight feet away, who could easily have broken the thin floe I was on with a casual flick of its tail,” he says.



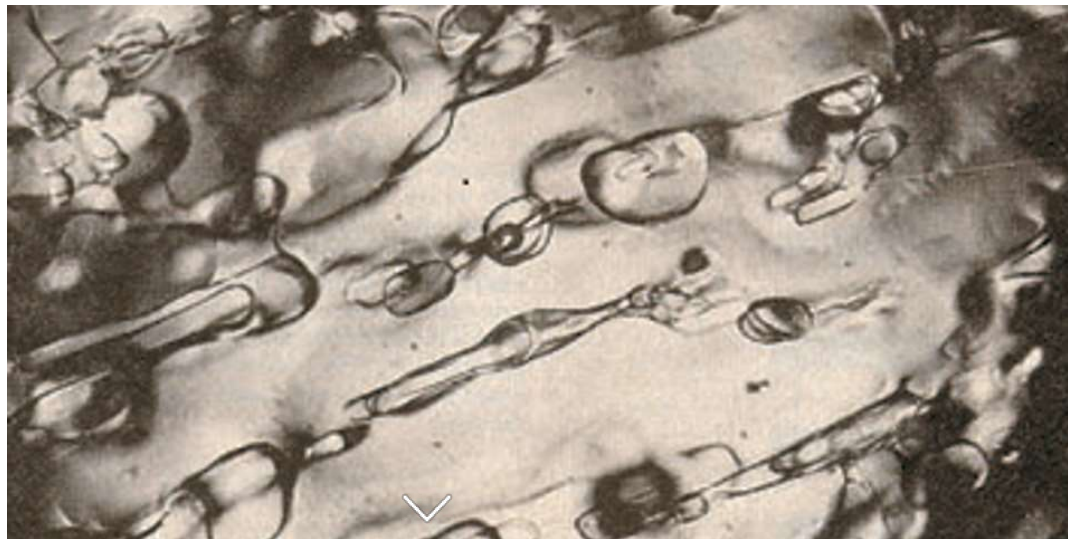


Mathematicians conducting experiments in the polar regions get to experience its awesome wildlife, including whales.

Prof Golden studies the microstructure of sea ice to calculate how easily fluid can flow through it. “Sea ice is salty. It has a porous microstructure of brine inclusions which is very different from freshwater ice,” he says.

Prof Golden has led interdisciplinary teams to predict the critical temperature at which the brine inclusions connect up so that fluid can flow through sea ice, and to develop the first X-ray tomography technique to analyse how the geometry of the inclusions evolves with temperature. “Understanding how seawater percolates through sea ice is one of the keys to interpreting how climate change will play out in the polar marine environment,” he explains.

Discovering this “on-off switch” has helped scientists better understand processes such as how nutrients that feed algal communities living in the brine inclusions are replenished.





Professor Golden studies show how easily fluid can flow through sea ice, which has a porous microstructure of brine inclusions (pictured). W. F. Weeks and A. Assur, CRREL (U.S. Army Cold Regions Research and Engineering Lab) Report 269, 1969

The brine in sea ice also affects its radar signature, which affects satellite measurements of parameters like ice thickness used to validate climate models. These models are important because they predict future changes to our climate and are used by world leaders and scientists to come up with mitigation strategies.

Coming in from the cold

The variety of ice presents a challenge, but diversity among researchers, teachers and students creates the perfect environment for fresh ideas. In the US, just one quarter of doctoral degrees in mathematics and computer sciences were awarded to women in 2015, but schemes such as the University of Utah's ACCESS programme are nurturing talented female mathematicians by helping them unlock opportunities such as mentoring and hands-on research. Expeditions to the Arctic not only give students an elevated experience, but ensure mathematicians are involved in cutting-edge research and solutions, alongside climate scientists and engineers.

When they are not battling blizzards, Dr Reimer and Prof Golden work on collaborative, interdisciplinary projects and co-mentor female undergraduate students as part of the ACCESS programme. After refreshing the mathematics component in 2018 to include climate change, Prof Golden has seen roughly triple the number of ACCESS students interested in taking a maths major or research placement than before.

Rebecca Hardenbrook, who is one of Professor Golden's PhD students, says: "focusing on pressing issues like climate change attracts more of the people we want into mathematics, which is everyone, but in particular, women, people of colour, queer people; anyone from an underrepresented background."



Pooling resources

Hardenbrook joined the ACCESS program ahead of her first year as an undergraduate, spending the summer in an astrophysics lab, which opened her eyes to the possibility of doing research. "It was really life changing," she says, not least because she further decided to pursue a PhD in mathematics with Prof Golden after studying thermal transport through sea ice as an undergraduate.



Rebecca Hardenbrook teaches math to students at the University of Utah in Salt Lake City.

She now inspires younger students on the ACCESS scheme as a teaching assistant, as well as modelling melt ponds, which are pools of water on the Arctic sea ice. These ponds play a decisive role in determining the long-term melting rates of the Arctic sea ice cover by absorbing solar radiation instead of reflecting it. As they grow and join together, they undergo a transition in fractal geometry, effectively creating a never-ending pattern that can be modelled by mathematicians.

Hardenbrook is building upon a decade of work on melt ponds by Prof Golden and previous students and researchers at the university by adapting the classical



and previous students and researchers at the university by adapting the classical Ising model, which was developed more than a century ago and explains how materials can gain or lose magnetism, to model melt pond geometry. “I hope to make the model for sea ice more physically precise so that it can be put into global climate models to create a more accurate approach of addressing melt ponds, which have a surprising effect on the albedo of the Arctic,” she explains.

Adding to the big picture

Mathematicians have already solved the conundrum of how to define the width of the undulating marginal sea ice zone, which extends from the dense inner core of pack ice to the outer fringes, where waves can break the floating ice.

Court Strong, who is an atmospheric scientist and one of Prof Golden’s colleagues at the University of Utah, drew inspiration from an unusual source: the cerebral cortex of a rat’s brain. He realised they could use the same mathematical method to measure the width of the marginal ice zone as they do for measuring the thickness of the rodent’s bumpy brain, which also has a lot of variation. With the aid of this simplified model, the team was able to demonstrate that the marginal ice zone has widened by around 40% as our climate has warmed.

The university of Utah’s ACCESS scheme, including its hands-on research, immerses students in an interdisciplinary environment where maths is part of a bigger picture. It encourages cross pollination, where methods and ideas from seemingly unrelated areas of science can be used to solve problems when the underlying mathematics is essentially the same.

“When you’re presented with an unusual situation, you need different kinds of minds to look at a problem clearly and come up with solutions,” says Prof Golden.

The loss of sea ice seen in the Arctic has happened over just a few decades and continues at an alarming pace.

“We need all the good brains and different ways of thinking that we can get, and we need them fast,” he says.



This article has been reviewed for the University of Utah, National Science Foundation and Office of Naval Research by Elvis Bahati Orlando, International Foundation for Science, Stockholm and Dr Magdalena Stoeva, FIOMP, FIUPESM.

Discover other 'Beyond the lightbulb' stories



Inside the fight to save the Great Barrier Reef



Food for thought: How autonomous technology could change your day-to-day



Printing solutions to pollution at sea



What do Ireland's shipwrecks have to do with renewable energy?



How collaboration and new drugs could beat malaria



Is the future of farming indoors?





How one of the world's cleanest cities is getting even cleaner



From educators to inventors

