

MARCH 13, 2014

## Mathematical Patterns in Sea Ice Reveal Melt Dynamics

Some people call Ken Golden the "Indiana Jones" of mathematics due to his frequent excursions to remote, harsh parts of the world. Golden, a professor of mathematics at the University of Utah, studies the dynamics of sea ice, and he regularly goes out into the field to test his hypotheses.

BY [GEOFFREY GILLER](#)

*This article was published in Scientific American's former blog network and reflects the views of the author, not necessarily those of Scientific American*

---

Some people call Ken Golden the "[Indiana Jones](#)" of mathematics due to his frequent excursions to remote, harsh parts of the world. Golden, a professor of mathematics at the University of Utah, studies the dynamics of sea ice, and he regularly goes out into the field to test his hypotheses. He has visited the Arctic and Antarctica 16 times to take ice samples and make observations.

Sea ice has declined rapidly in the past decade; in the summer of 2012, Arctic sea ice was at its lowest recorded levels, below even what climate models predicted. "It's particularly unsettling that the world's best climate models have not been able to keep pace with this incredible rate of melting," Golden said during a March 5 talk entitled *Modeling the Melt* at the [Museum of Mathematics](#) in New York City.

That's because sea ice is a crucial factor in global climate change. "Sea ice is not only a very sensitive leading indicator of climate change, but it's also a key player... in Earth's climate system," Golden said. White sea ice helps return energy from the sun back into outer space thanks to the high percentage of sunlight it reflects, known as its albedo. As sea ice decreases, dark ocean water absorbs more of that sunlight, contributing to further warming. "One of the most important parameters in climate modeling is the overall albedo of the ice pack," Golden said.

Despite its importance, modeling the transition of sea ice as it melts and changes from high to low albedo has been difficult. However, in 2012, Golden and his colleagues published a [paper](#) showing that as sea ice melts the ponds that form on its surface can in some ways be treated like fractals, mathematical patterns that remain the same or similar at small and large scales.

As isolated simple ponds grow and connect with others, they form larger, more complex ponds; subsets of these ponds show similarities to the larger complex ponds, just as a fractal does. In addition, as ponds get larger and more complex, the total perimeter of the ponds increases much faster than the total area of the ponds, which is also the case with fractals. "Any kind of information you can get about how [melt ponds] evolve, their geometry, their area coverage ... are the key parameters that go into assessments of albedo," Golden says.

Golden has also looked at the microstructure of the sea ice. Specifically, he has modeled "brine inclusions," or pockets of liquid water within the ice. The formation of these pockets depends on the temperature and crystallographic structure of the ice, which in turn depends on how the sea ice formed. He

found that there is a threshold at which these inclusions become connected to one another and form pathways, allowing drainage of melt ponds or percolation of sea water upward from beneath the ice.

For the most common type of sea ice in the Arctic, this threshold occurs when the percentage of liquid brine inclusions in the ice (called the brine volume fraction) is around 5 percent. When the sea ice salinity is at its typical level, about 5 parts per thousand, the 5 percent brine volume fraction occurs at a critical temperature of -5 degrees Celsius. Golden dubbed this “the Rule of Fives” in a [1998 paper](#) in *Science*.

Although the original Rule of Fives was based on field observations, Golden was later able to confirm the rule through the use of x-ray imaging. By creating 3D models of brine inclusions in ice, Golden and his colleagues showed in a [2007 paper](#) that the connectivity of the brine inclusions does indeed cross a threshold at a brine volume fraction of around 5 percent.

The Rule of Fives has an important effect on ice albedo, Golden said, because the presence or absence of the pools on top of the ice drastically changes the albedo. And the drainage of the ponds “depends upon how easy it is for fluid to flow through the porous microstructure of the ice,” he said. This permeability of the ice also affects algal communities living in the brine inclusions—when the ice is impermeable, the algae don’t get new nutrients from percolating seawater.

Eventually, Golden thinks that unifying mathematical concepts will connect sea ice across many scales, from tiny inclusions in the ice to large melt ponds. “I kind of smell something universal,” he says.

The Museum of Math hosts monthly talks by mathematicians as part of its

ongoing [Math Encounters](#) series.

RIGHTS & PERMISSIONS

GEOFFREY GILLER is a freelance science writer based in Ithaca, N.Y., and a former intern at *Scientific American*. His work has also appeared in *Audubon*, *Hakai Magazine* and *The Scientist*. You can follow him on Twitter @GeoffreyGiller.

[More by Geoffrey Giller](#)

# Popular Stories



OPINION | MAY 25, 2024

## How the Guinness Brewery Invented the Most Important Statistical Method in Science

The most common test of statistical significance originated from the Guinness brewery. Here's how it works

JACK MURTAGH

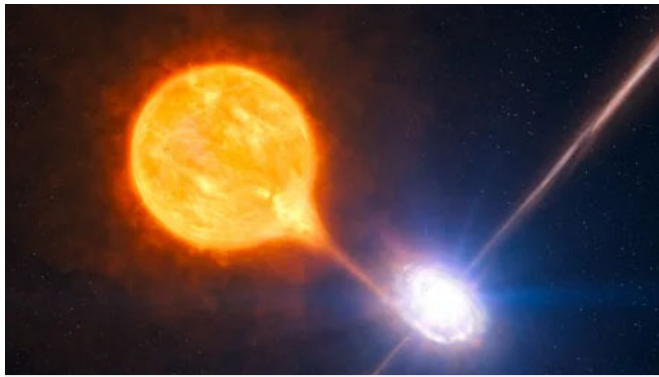


PLANETARY SCIENCE | MAY 22, 2024

## The Great Solar Storm of 2024 Made the Strongest Auroras in Centuries

Northern and southern lights produced by a recent bout of severe space weather may rival the most intense auroras of the past 500 years

SHARMILA KUTHUNUR, SPACE.COM

**BLACK HOLES** | MAY 23, 2024

## We've Finally Seen Matter Plunge Black Ho

For the first time, scientists observed matter's freefall into a black hole's "plunging region"

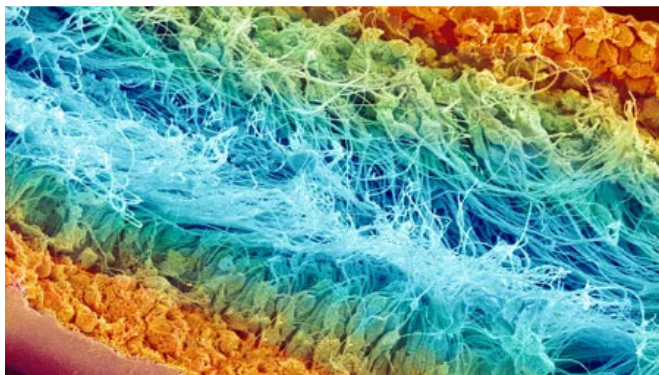
ALLISON PARSHALL

**OPINION** | MAY 23, 2024

## The Emerging Artificial Intelligence Faces a Growing Threat from Di Energy Weapc

Autonomous and AI-enabled systems increasingly rely on optical and radio frequency sensors and significant computer power. They face growing vulnerabilities from directed-energy laser and microwave weapons

DAVID C. STOUDT

**REPRODUCTION** | MAY 22, 2024

## Microplastics Have Now Been Fc Testicles. How Bad Is 1

Evidence shows microplastics can end up in many different organs and may harm reproductive health

ALLISON PARSHALL

**WEATHER** | MAY 24, 2024

## The 2024 Hurricane Season Cou Dangerous O

The National Hurricane Center's hurricane season outlook for the Atlantic Ocean forecasts 17 to 25 named storms in 2024 because of an expected combination of warm ocean temperatures and a La Niña climate pattern

JHORDANNE JONES, THE CONVERSATION US