

Solving the problem of sea ice thickness distribution using molecular concepts

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Arctic ice, in 1957. Credit: Norbert Untersteiner

Yale University scientists have answered a 40-year-old question about Arctic ice thickness by treating the ice floes of the frozen seas like

colliding molecules in a fluid or gas.

Although today's highly precise satellites do a fine job of measuring the area of sea ice, measuring the volume has always been a tricky business. The volume is reflected through the distribution of sea [ice thickness](#)—which is subject to a number of complex processes, such as growth, melting, ridging, rafting, and the formation of open water.

For decades, scientists have been guided by a 1975 theory (by Thorndike et al.) that could not be completely tested, due to the unwieldy nature of [sea ice thickness](#) distribution. The theory relied upon an intransigent term—one that could not be related to the others—to represent the mechanical redistribution of ice thickness. As a result, the complete theory could not be mathematically tested.

Enter Yale professor John Wettlaufer, inspired by the staff and students at the Geophysical Fluid Dynamics Summer Study Program at the Woods Hole Oceanographic Institution, in Massachusetts. Over the course of the summer, Wettlaufer and Yale graduate student Srikanth Toppaladoddi developed and articulated a new way of thinking about the space-time evolution of sea ice thickness.

The resulting paper appears in the Sept. 17 edition of the journal *Physical Review Letters*.

"The Arctic is a bellwether of the global climate, which is our focus. What we have done in our paper is to translate concepts used in the microscopic world into terms appropriate to this problem essential to climate," said Wettlaufer, who is the A.M. Bateman Professor of Geophysics, Mathematics and Physics at Yale.

Wettlaufer and co-author Toppaladoddi recast the old theory into an [equation](#) similar to a Fokker-Planck equation, a partial differential

equation used in statistical mechanics to predict the probability of finding microscopic particles in a given position under the influence of random forces. By doing this, the equation could capture the dynamic and thermodynamic forces at work within polar [sea ice](#).

"We transformed the intransigent term into something tractable and—poof—solved it," Wettlaufer said.

The researchers said their equation opens up the study of this aspect of climate science to a variety of methods normally used in nonequilibrium statistical mechanics.

Provided by Yale University

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