Submittee: Kenneth Golden
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Title: Conference on the Mathematics of Sea Ice
Event Type: Conference-Workshop

Location:
Simon Fraser University at Harbor Centre

Dates:
9/24/15 - 9/26/15

Topic:
The main topic of this conference was the mathematics of sea ice and climate. Specifically, the goal was to explore how various branches of mathematics are being applied to further our understanding of sea ice and advance how sea ice is represented in climate models. In particular, we focused on topics which include the following: sea ice and global climate models, sea ice processes and the climate system, linkage of scales - homogenization of effective properties, bifurcations in low order nonlinear models of polar climate, biogeochemistry of sea ice, and climate change.

Methodology:
Lectures and Poster Sessions.

Objectives Achieved:
With a focus on improving our understanding of the mathematics of sea ice, one of our major objectives was to help build a solid community of mathematicians and theoretical sea ice scientists who can share ideas and spur new developments. Throughout the conference, it was apparent that vigorous and productive discussions took place amongst the attendees. Moreover, a broad range of cutting-edge ideas, perspectives, methods, and key aspects of sea ice research were presented and exchanged at the meeting in a welcoming, relaxed environment.

Scientific Highlights:
Sea ice is an important component of the Earthâ€™s climate system and accurate models of sea ice are critical to ensure reliable long term predictions of climate change. While all of the presentations given at this conference were of scientific significance, with many of them excellent from a scientific as well as pedagogical perspective, a few important areas of current sea ice research stood out: theories of the sea ice thickness distribution function, idealized multiscale models of sea ice fracture and mechanics, the evolution of melt ponds in climate models, dynamical systems models of sea ice retreat, and wave-ice interactions. The advances presented at the meeting are briefly discussed below.

The standard equation for the sea ice thickness distribution, given by Thorndike et al. (1975), has been widely used for years. However, a general treatment of the full theory has been limited by a poor understanding of the so-called mechanical redistribution function. John Wettlaufer presented work which shows that one can transform the standard theory into a Fokker-Plank type equation, whose steady solution can be used to show that the thickness distribution function is controlled by both thermodynamics and mechanics in low thickness regimes, and only by mechanics in high thickness regimes. This approach provides a framework for study of the large scale structure of the ice pack using methods of broad relevance in statistical mechanics. Jerome Weiss described powerful scaling laws and a multiscale theory for sea ice mechanics, while Agnieszka Herman treated sea ice as a granular material and presented computationally efficient particle models for ice pack dynamics.

Melt ponds and ice albedo feedback have long been known to be important factors in determining the rate of melting of the Arctic ice pack. To date, many large scale sea ice models have used albedo as a tuning parameter and typically underestimate the rapid decline in summer sea ice extent. New work by Daniel Feltham and Daniela Flocco addresses this issue and represents some of the first efforts to include an albedo parameterization in the widely used CICE model which physically represents melt ponds. It was shown that this inclusion, as well as the inclusion of anisotropic rheology of the ice pack, greatly improves predictions. A very different approach to the issue of the melting of the Arctic sea ice pack was taken by Mary Silber, who presented a low order dynamical systems or tipping point model for Arctic sea ice loss. Renate Wackerbauer described a related thermodynamic lattice model for ice loss, where on the local scale the model reveals bistability in sea ice loss, and at the regional scale, ice edge stability varies with the albedo parameterization.

Wave-ice interactions play a critical role in sea ice extent and in determining the floe size distribution of the ice pack. It has been long established that ocean waves have the ability to break the ice and that floes themselves influence how far waves can propagate through the ice pack, yet these processes have not been included in climate models. A presentation by Alison Kohout highlighted new data on wave attenuation in Antarctic sea ice, as well as the various approaches being used to better understand wave-ice interactions. This talk served to open new lines of inquiry into the problem while highlighting the key challenges and successes. Further discussion of the wave-ice problem took place in a parallel session later that evening where various approaches were debated and discussed in detail. Chris Horvat also presented a new prognostic model of the evolution of the joint floe size thickness distribution (FSTD) which includes fracture by surface ocean waves. Using this model, he found that the fracture of the ice by waves coupled with the thermodynamic response of the FSTD can lead to significant changes in the sea ice cover and ocean state.

Organizers:
Golden, Kenneth M., Department of Mathematics, University of Utah, USA

Bitz, Cecilia, Department of Atmospheric Sciences, University of Washington, USA

Eisenman, Ian, Scripps Institution of Oceanography, University of California, San Diego, USA

Meylan, Mike, School of Mathematical and Physical Sciences, University of Newcastle, AU

Worster, Grae, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK

Speakers:
See uploaded pdf.

Links:

Comments / Miscellaneous:
This conference was held at the Harbour Centre Campus of SFU from September 24 to 26. It brought together many of the world's leading sea ice theorists, as well as interdisciplinary students, postdocs and early-career investigators, to focus on the mathematical aspects of research on sea ice and its role in Earth's climate system.

A broad range of powerful methods and tools spanning many different areas of mathematics and theoretical physics can be applied to sea ice. These mathematical techniques can help improve our understanding of sea ice structures and processes, advance how sea ice is represented in global climate models, and ultimately improve projections of climate change and the fate of Earth's ice packs.

The major goals of this conference were to explore how these many areas of mathematics can, and are, being applied to sea ice, and to spur new advances through the sharing of different ideas, approaches and perspectives. This was accomplished by bringing together researchers -- all with an interest in sea ice -- from different mathematical and scientific backgrounds, including partial differential equations, numerical analysis, large scale models, dynamical systems and bifurcation theory, fractal geometry, diffusion processes and statistical physics.

Over an intensive three-day schedule a wide variety of relevant subjects were explored, ranging from small scale processes and the fundamental physics of sea ice to large scale processes and the role of sea ice in global climate. Lunchtime and evening discussions on new research ideas were common amongst the attendees. A mix of well-established and early-career speakers ensured that a vibrant array of new ideas and perspectives were shared, fostering new professional relationships and developments in the field. By the end of the conference, perspectives were broadened, interesting new questions emerged and a new community in the mathematics of sea ice was solidified.

File Uploads:
Additional Upload 1: http://www.pims.math.ca/files/final_report/PIMS_Speakers_Titles_Abstracts.pdf

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