"The Seasonal Evolution of Sea Ice Floe Size Distribution"

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LONG-TERM GOALS

This work is motivated by the desire to improve the understanding of processes governing the evolution of the marginal ice zone that forms seasonally in the southern Beaufort and Chukchi Seas region.

OBJECTIVES

The objective of this work is to determine the seasonal evolution of the floe size distribution (Figure 1), paying particular attention to the role of winter preconditioning of the ice on summer floe breakup. To achieve this objective we will:

1. Develop a mathematical framework for the floe size distribution.
2. Calculate the floe size distribution at several times during spring and summer.
3. Determine the floe breaking function by tracking individual floes using high resolution imagery.
4. Estimate lateral melt rates from high resolution imagery.
5. Investigate the roles of wave action and ice preconditioning in floe breakup.
6. Assess the relative contributions of dynamics and thermodynamics to changes in the floe size distribution

APPROACH

We plan to address the evolution of the floe size distribution by acquiring a library of high resolution images following the same groups of floes from early spring through late summer. This will include the imagery acquired as part of the ONR MIZ DRI, which is expected to include images from the MEDEA/National Security and Climate Change Research Program and the Center for Southeastern Tropical Advanced Remote Sensing (CSTARS). The high resolution imagery will allow us to follow flaws formed in winter and spring and assess their impact on the summer breakup of the ice cover. Large-scale, lower resolution imagery from MODIS and other platforms will also be analyzed to determine changes in floe size distribution.

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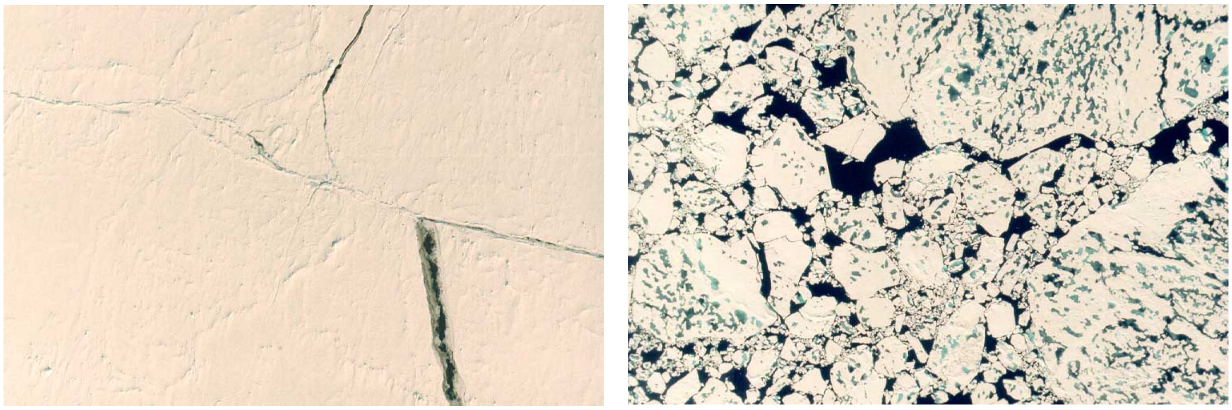

Figure 1. Aerial photographs illustrating the of the profound changes that occur in the appearance and morphology of the Arctic sea ice cover over and annual cycle. These photos were taken over the pack ice near SHEBA in May (left) and August (right) taken at an altitude of 1800 m. The scale is the same in both images.

After obtaining the imagery we will first use image processing software to partition the high resolution images into ice and ocean. The next step will be to compute floe parameters including area, perimeter, and shape factor from the partitioned images. Individual floes will be tracked to investigate how floes break. A central focus will be examining the impact of preconditioning of the floes during winter and spring to the breakup observed in summer. This information will contribute to determining the breaking function and to assessing the role of wave action in breakup. Key issues concerning breakup include; what floes are likely to break, when do they break, and what causes them to break. Estimates of solar heat input to the ice – ocean system will be calculated and used to determine lateral melt rates. A time dependent floe size distribution governed by lateral melting and a breaking function will be determined.

WORK COMPLETED

This project is a new start in FY13, with funds awarded in April 2013. To date we have:

(1) Determined the seasonal evolution of floe size distribution using aerial photography from the Surface Heat Budget of the Arctic Ocean (SHEBA) field campaign.

(2) Obtained high resolution visible imagery from the MEDEA/National Security Climate Change Research Program and SAR imagery from the Center for Southeastern Tropical Advanced Remote Sensing (CSTARS). This imagery tracked a cluster of drifting ice-based buoys located in the southern Beaufort Sea during summer 2013.

(3) Initiated the analysis of the satellite imagery from (2).

(4) Selected a graduate student to work on the project.

RESULTS

Using aerial photographs from the SHEBA field experiment, we examined the seasonal evolution of the floe size distribution. Based on earlier studies, we assumed the floe size distribution could be represented by a two-parameter power law $n(D) = \beta D^{-\alpha}$, where D is the floe diameter and α and β are parameters estimated from measurements of total ice area and perimeter.

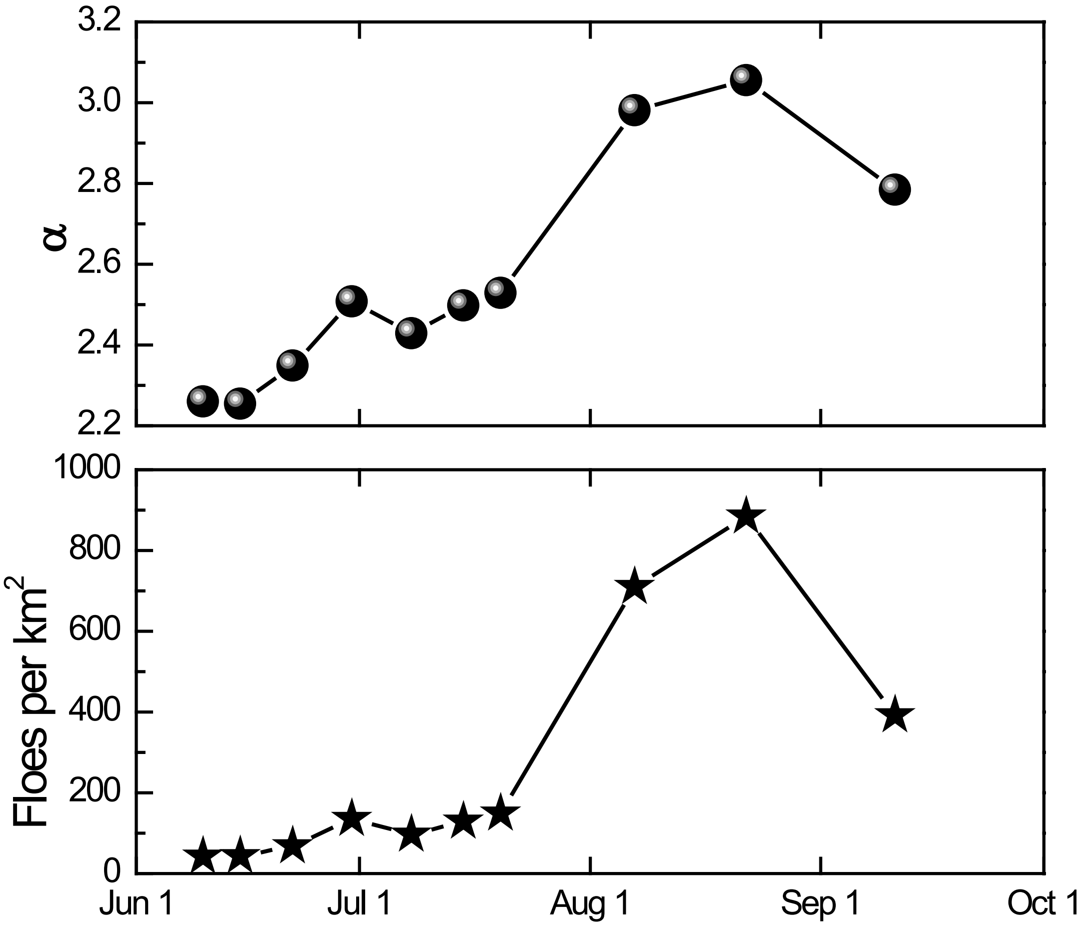

Figure 2.Time series of power law exponent (α) and number of floes per km² from the SHEBA field campaign in the summer of 1998.

The seasonal evolution of the floe size distribution from spring through summer exhibits several characteristics (Figure 2). There is a general trend towards more floes and smaller floe diameters, resulting in an increase in the exponent (α) of the power law floe size distribution. At SHEBA, changes in floe size distribution were small for much of the summer until a divergence event happened in late July. Associated with this divergence event was extensive floe breaking resulting in a large increase in the number of floes and the total floe perimeter as well as a decrease in the size of floes. There were also several meters of lateral melting associated with this event. The combination of increased floe perimeter and increased lateral melt rates resulted in large ice losses due to lateral melting.

Changes in the floe size distribution are due to a combination of thermodynamic and dynamic processes. Dynamics breaks floes, decreasing the floe size and increasing the total floe perimeter and the number of floes. Increasing the total floe perimeter increases the total amount of lateral melting.

Lateral melting also decreases floe size and perimeter and may reduce the number of floes by eliminating smaller floes.

IMPACT/APPLICATIONS

Identifying the processes that govern the evolution of the floe size distribution is a key to understanding the evolution of the marginal ice zone that forms seasonally in the southern Beaufort and Chukchi Sea region. The floe size distribution directly impacts the partitioning of the solar radiation absorbed in the upper ocean. The absorbed sunlight contributes to warming the water, melting on the underside of the ice and melting at the lateral edges of the floes. The warming water and melting ice leads to a significant positive feedback, causing more open water, a thinner ice cover and more solar energy absorbed. These changes, in turn, affect the arctic ecosystem. The improved understanding of the evolution of the floe size distribution will ultimately contribute to improvements in the ability to model the future condition of the sea ice cover on both the seasonal and decadal time scales.

RELATED PROJECTS

- ONR Marginal Ice Zone Departmental Research Initiative:

http://www.onr.navy.mil/en/Science-Technology/Departments/Code-32/All-Programs/Atmosphere-Research-322/Arctic-Global-Prediction/Marginal-Ice-Zone-DRI.aspx

The goal of this five-year DRI, (FY12-FY16) is to improve the knowledge and understanding of the physics of the retreating summer ice edge and Marginal Ice Zone (MIZ) in the Beaufort and Chukchi seas. The approach will be to integrate data from *in situ* sensing platforms, remotely-sensed observations, and integrated process models to develop a comprehensive, quantitative picture of open-ocean, ice edge and MIZ processes, interactions and feedbacks as the ice retreats.