Observational and Theoretical Foundation for the Dynamics in a High-resolution Sea Ice Model

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LONG-TERM GOALS

The overall goal is to provide the observational and theoretical foundation for ice dynamics in a high resolution sea ice model, based on the concepts of sliplines and granular plates and using buoy and SAR observations from SIMI and SHEBA.
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OBJECTIVES

The main objectives in this project are:

- Further understand the scale interaction between the multiple floe scale (<10 km), the regional granular continuum scale (10-200 km), and the sub-basin scale (>200 km).
- Create at least five test cases for the development and evaluation of a new version of the Navy's Polar Ice Prediction System model (PIPs 3.0).

APPROACH

Our approach is to build on the insights we have gained into the ice mechanics at a regional scale, from observations made during the Sea Ice Mechanics Initiative (SIMI) and the Surface Heat Budget of the Arctic Ocean (SHEBA) field programs (Overland et al.,1998; Richter-Menge and Elder, 1998; Richter-Menge et al., 1998). These observations are derived from stress and deformation arrays we deployed during the field programs, and interpretation of SAR-derived ice motion vectors. From these data, it appears that the ice pack behaves as a granular plastic material, where the fundamental component is the multiyear floe. The system's plasticity is established by the interaction of the floes, which move together in aggregate plates separated by narrow sliplines.

There is significantly more work to be done with both the SIMI and SHEBA data sets. We will continue the analysis of stress and deformation measurements made during SIMI and SHEBA. The characteristics of internal ice stress will be evaluated as a function of slipline properties, including the location and orientation of the slipline relative to the stress measurement site. Results will provide insight on the development of aggregate plates within this fundamentally granular system. We will

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develop a strategy for investigating the stress-strain relationship in greater spatial detail on a semi-quantitative basis, considering the application of techniques to deconvolve the internal ice stress term into components that can be compared with hindcast values from the PIPS 3.0 model. Results from this effort will lead to a mathematical description of our results that can be used for validation of the PIPS 3.0 sea ice dynamic model. We look to combine a number of assets to develop a better understanding of the scale interaction, including direct field measurements and remote sensing tools. These assets provide information on ice dynamics processes over a wide range of scale, from the individual floe to the basin scale.

WORK COMPLETED

We have completed an initial analysis of the spatial variability of ice stress measurements made during the SIMI and SHEBA field programs. We have also used the stress time series to identify periods of extreme activity (both convergence and divergence) to assess the relationship between ice stress and deformation. We anticipate these events will be used as test cases for model validation. We have begun collaborations with Jinro Ukita, an investigator with Japan's Frontier Program, who will work with us to evaluate PIPs 3.0 by considering the elemental components of the stress divergence term.

RESULTS

Early results from our analysis confirm that the process of stress transmission is complex, due to the granular nature of the ice pack. For instance, we found that the correlation between the stress time series from measurement sites on different floes was stronger than the correlation between sites on the same floe. This result also validates our approach to measuring stress in the ice cover, where multiple sites are deployed to generate a statistically accurate assessment of periods of high stress activity. Applying this technique, we can clearly demonstrate that there is a measurable relationship between ice stress and deformation. On a very basic level, it is observed that during periods of divergence there is no stress and during periods of convergence there is stress (Richter-Menge et al, 1998). These results support the hypothesis that the fundamentally granular ice cover behaves as a mechanical continuum at a regional scale of 10 km to 150 km (Overland et al, 1998).

IMPACT/APPLICATION

The result of a measurable relationship between ice stress and deformation is a strong indication that our goal of applying direct observation from field measurements and satellite imagery to validate the model results from PIPS 3.0 is achievable. We are specifically interested in considering the rheology used to describe the mechanical behavior of the ice cover, which is a fundamental component of the model's governing equation. Direct validation of the rheology is likely to lead to improved modeling capabilities, including increased model resolution.

TRANSITIONS

These results will be used to develop and validate the latest version of the Navy's PIPs model. We will work directly with the modelers involved in this project to determine and assess validation tests.

RELATED PROJECTS

1) SHEBA ice stress and deformation measurements are also being used in the SHEBA project, which is focused on improving models of climate variability. The SHEBA program is sponsored by NSF and ONR. Our work in this program is focused on improving the understanding of the processes that govern ice motion, which are important for determining the thickness distribution of the ice cover. The thickness distribution of the ice cover has a significant impact on heat and energy exchange between the atmosphere, ice, and ocean.

2) I am working with Mark Hopkins (CRREL), who is receiving support from NSF and NASA to continue development of a discrete element model of the ice cover. This model is unique in its ability to consider floe-floe interactions and provide a more detailed characterization of ice distribution.

REFERENCES

Overland, J.E., S.L. McNutt, et al., 1998: Arctic sea ice as a granular plastic. *J. Geophys. Res.*, 103: 21845-21867.

Richter-Menge, J.A. and B.C. Elder, 1998: Characteristics of pack ice in the Alaskan Beaufort Sea, *J. Geophys. Res*, 103(C10): 21,817-21,829.

Richter-Menge, J.A, J.E. Overland, and S.L. McNutt, 1998: Relating Measurements of Pack Ice Stress and Deformation in the Alaskan Beaufort Sea, *AGU 1998 Fall Meeting*.