

# **Enhanced RADARSAT Geophysical Processor System (RGPS) Products over the SHEBA Ice Camp**

Ron Kwok  
MS 300-235  
Jet Propulsion Laboratory  
California Institute of Technology  
4800 Oak Grove Drive  
Pasadena, CA 91109  
phone: (818) 354-5614 fax: (818) 393-3077 email: [ron.kwok@jpl.nasa.gov](mailto:ron.kwok@jpl.nasa.gov)

Award Number: N00014-01-F-0014

## **LONG-TERM GOALS**

To understand the dynamics associated with the opening and closing of leads over the ice cover of the Arctic Ocean.

## **OBJECTIVES**

The objective is to compile a dataset of the linear deformation patterns over the SHEBA ice camp that is suitable for use in understanding and parameterization of sub-grid scale deformation processes and their role in atmosphere/ocean interactions.

The specific objectives are to:

1. Classify the Linear Kinematic Features (LKFs) identified in the time-sequential kinematics dataset derived from RADARSAT into one of five categories and characterize their development over the winter.
2. Correlate the directions of the five categories of LKFs with the principal directions of strain rate at the aggregate scale (derived from RGPS ice motion).

As part of this work, we will produce a year-long data set of the classified linear features around the ice camp which would be made available for use in process studies and model validation.

## **APPROACH**

The RADARSAT Geophysical Processor System produces Lagrangian descriptions of material elements on the ice cover from sequential SAR imagery acquired by the RADARSAT satellite [Kwok, 1998]. The material elements (hereafter referred to as cells) are enclosed within four-sided polygons. Initially, a regular array of points and the cells they define are created on the first set of images covering a region. The ice features in the neighborhood of these points are identified on all subsequent SAR imagery by an ice motion tracker. As a result, each point acquires its own trajectory as these features move with the ice cover. The deformation of a cell is computed from the velocity gradients at the vertices defining the cells. The same set of points are followed over an ice season, giving a densely

sampled picture of Lagrangian ice motion identical to the trajectories derived from drifting buoys, as well as the time history of deformation of a particular cell.

Using the special products around the SHEBA camp, we will divide the LKFs into five categories relative to the ice motion perpendicular and parallel to the linear feature. They are:

1. *Opening* – perpendicular motion with net opening along the linear feature.
2. *Opening with shear* – variable perpendicular and parallel motion with net opening along the linear feature.
3. *Shear* – no perpendicular motion with no net opening or closing. This is typically observed as slip lines on the ice cover.
4. *Closing with shear* – variable perpendicular and parallel motion with net closing along the linear feature.
5. *Closing* – perpendicular motion resulting in net closing over the linear feature.

With these classifications, the following spatial and temporal statistics regarding these LKFs will be collected:

1. *Spatial distribution and density* of these LKFs over the SHEBA ice camp.
2. *Openings/closings* at a given LKF. It is important that we distinguish these because it is the opening part that produces the most ice growth, the most turbulent heat flux to the atmosphere and the most salt flux to the ocean, and it is the closing part that is important to ridging and rafting.
3. *Orientation/extent* of the LKFs relative to the large-scale strain rate. The linear extent and orientation of these features are important because they determine the mechanical properties of the ice cover. Since the ice is weaker along these features, the ice cover becomes anisotropic, and its mechanical properties are no longer identical in all directions. Subsequent responses of the ice cover to external forcing would be dependent on the development of these features.
4. *Temporal development* of these LKFs. Their persistence and time history.
5. *Lead Systems*. We propose to analyze the characteristic length scale of spatial separation between the LKFs.

## **WORK COMPLETED**

Measurement of the deformation of an approximately 1000 km by 700 km area around the SHEBA ice camp over the winter from November 1997 through April 1998. Initial grid spacing is 10 km. The dramatic deformation of the ice cover can be seen in a sample 50 km by 50 km area. The initial and final locations of the grid points defining the areal deformation can be seen. Temporal sampling of the grid points is approximately 3 days. The large divergent event in January of 1998 can be seen in the imagery and the measured small-scale ice motion. A tool to extract the linear kinematic features from the deformation field (derived above) to obtain the orientation and length of the active cells

characterizing the linear features was reported last year. This year, we have prepared this dataset of ice motion and deformation of the 50 km by 50 km grid for general access on the worldwide web. An animation of the material points, the SAR imagery, and the deformation grid as well as the numerical data can be found in URL [http://www-radar.jpl.nasa.gov/rgps/sheba\\_50x50km.html](http://www-radar.jpl.nasa.gov/rgps/sheba_50x50km.html).

## **RESULTS**

In addition to the activity, persistence, orientation, and the length scale of the LKFs mentioned in the previous year, we have performed a comparison of thickness of the lead ice predicted using a simple ice growth model and that measured at the SHEBA ice camp. The ice thickness distribution over the 50 by 50 km Lagrangian element is shown in Fig. 1. Preliminary results show that the ice thickness estimated using the freezing degree-day growth model (at the end of the winter -May), to be within 20 cm of the thickness of ice that opened during a divergent event in the early January.

## **IMPACT/APPLICATIONS**

This is one step toward a more detailed understanding of the large-scale expressions of the deformation of the ice cover. With the advent of high resolution coupled ice-ocean models that approaches the widths of leads, the importance of ice mechanics has become even more significant. Their simulation results can now be examined in detail using the small-scale observations now available. The RGPS observations points to the importance of understanding the consequence of ice pack as an anisotropic material with large-scale oriented fracture patterns. For climate studies, the impact of an anisotropic ice cover is not well understood in terms of the modeled surface heat and mass balance. The RGPS data set is a crucial component in the testing of new models that accounts for the spatial and temporal characteristics of the linear kinematic features observed here.

## **TRANSITIONS**

The dataset is being used by investigators (W. Hibler III, M. Coon, M. Hopkins, and others) for developing new anisotropic sea ice mechanics model of the sea ice cover. This is the first time that such high resolution analyzed observations of the sea ice cover have been produced.

## **RELATED PROJECTS**

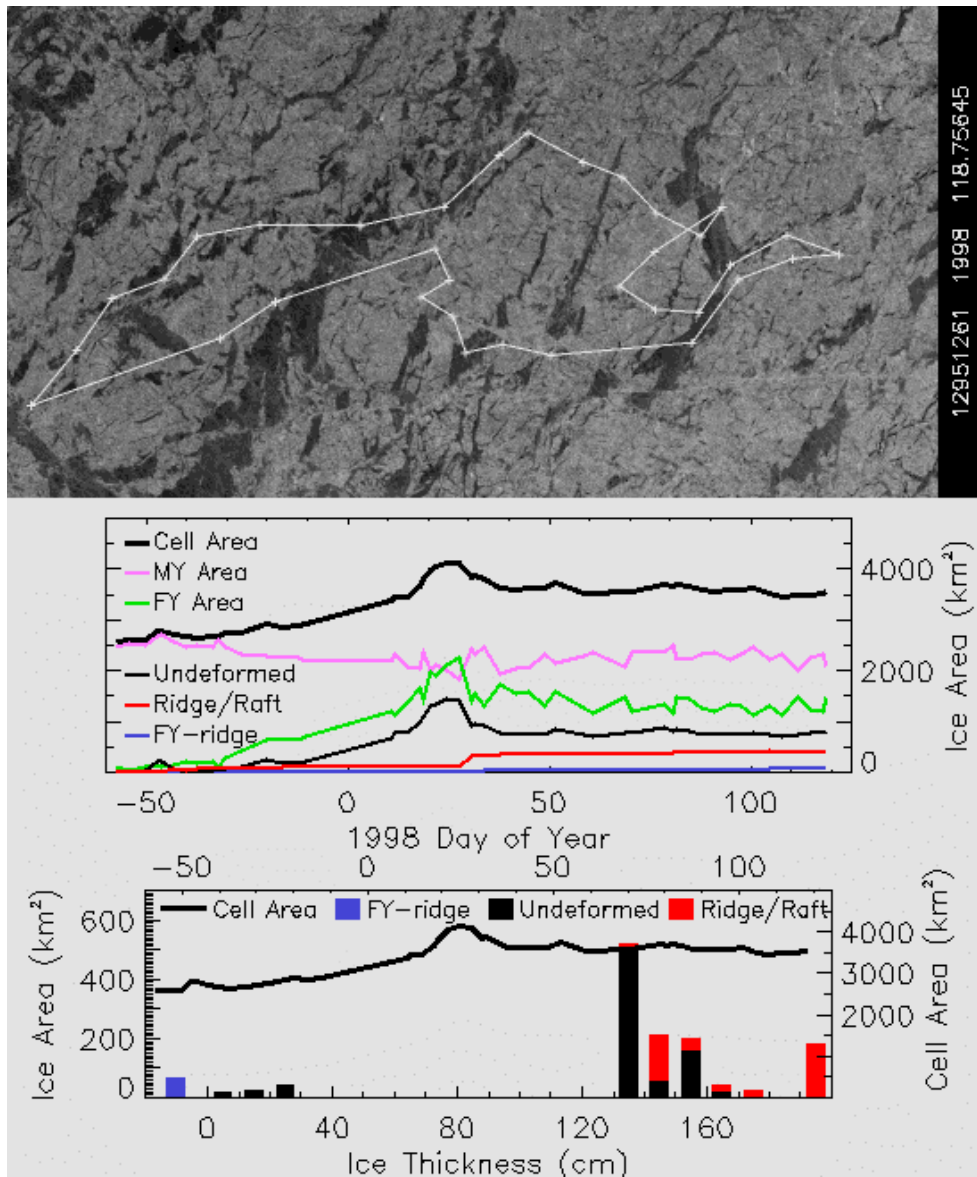
This work is closely related to the RGPS program (<http://www-radar.jpl.nasa.gov/rgps/radarsat.html>) funded by the National Aeronautics and Space Administration. The ideas and analysis methodology will directly benefit the analysis of basin scale deformation field currently produced by the RGPS program.

## **REFERENCES**

Kwok, R., G. F. Cunningham, N. LaBelle-Hamer, B. Holt, and D. A. Rothrock, Sea ice thickness from high-resolution SAR imagery, *Eos, Trans. AGU*, 80(42), 495-497,1999.

Kwok, R., D. A. Rothrock, H. L. Stern and G. F. Cunningham, Determination of Ice Age using Lagrangian Observations of Ice Motion, *IEEE Trans. Geosci. Remote Sens.*, Vol. 33, No. 2, pp. 392-400, 1995.

Kwok, R. The RADARSAT Geophysical Processor System. in *Analysis of SAR data of the Polar Oceans: Recent Advances*, Tsatsoulis, C. and R. Kwok, Eds., 235-257, Springer Verlag, 1998.



**Fig. 1** Total deformation of the sea ice cover in the vicinity of the SHEBA ice camp on April 28, 1998. The initial dimension of the box (on Nov 3, 1997) around the camp is 50 km by 50 km. sampled every three days – only two are shown here. The development of the ice characteristics within the material element (area, seasonal thickness distribution, coverage of undeformed/deformed ice) are shown in the bottom panel. The thickness distribution is represent the that ice produced by kinematics (openings and closings) over the winter from November to April.

## **PUBLICATIONS**

Kwok, R., Deformation of the Arctic Ocean sea ice cover: November 1996 through April 1997, in *Scaling Laws in Ice Mechanics and Dynamics*, edited by J. Dempsey and H. H. Shen, Kluwer Academic, 315-323, 2001.

Kwok, R., Arctic Ocean sea ice area and volume production: A contrast of two years – 1996/97 and 1997/98. *Ann. Of Glacio.* 34, 447-453.

Kwok, R. and G. F. Cunningham. Seasonal ice area and volume production of the Arctic Ocean: November 1996 through April 1997, JGR-Oceans, in press.