

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

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

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 2001		2. REPORT TYPE		3. DATES COVERED 00-00-2001 to 00-00-2001	
4. TITLE AND SUBTITLE Enhanced RADARSAT Geophysical Processor System (RGPS) Products over the SHEBA Ice Camp				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Jet Propulsion Laboratory, MS 300-235, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91109				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 7	19a. NAME OF RESPONSIBLE PERSON
a REPORT unclassified	b ABSTRACT unclassified	c THIS PAGE unclassified			

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

1. 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 in Fig. 1. 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.

2. 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 has been developed. Fig. 2 shows the visualization of the shear magnitude computed at each cell at three different times. These maps highlight the linear deformation patterns and would allow us to identify groups of cells with similar orientation and characteristics. This information is used to compute the relative motion of the ice cover in directions parallel and perpendicular to the linear feature.

RESULTS

The abundance and scale of these linear features on the ice cover are remarkable. The abundance seems to be related to ice thickness i.e. more of these features in thinner ice regions. These products provide an unprecedented level of spatial and temporal detail of the deformational processes over the winter and part of the summer. We can observe the temporal development of basin-wide LKFs in all its forms i.e. opening, closing, and shear. Their activity, persistence, orientation, and the length scale of the LKFs over the winter are remarkable and interesting.

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 approach 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 point 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

An animation of the deformation of the ice cover around SHEBA was made available to a number of SHEBA investigators.

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.

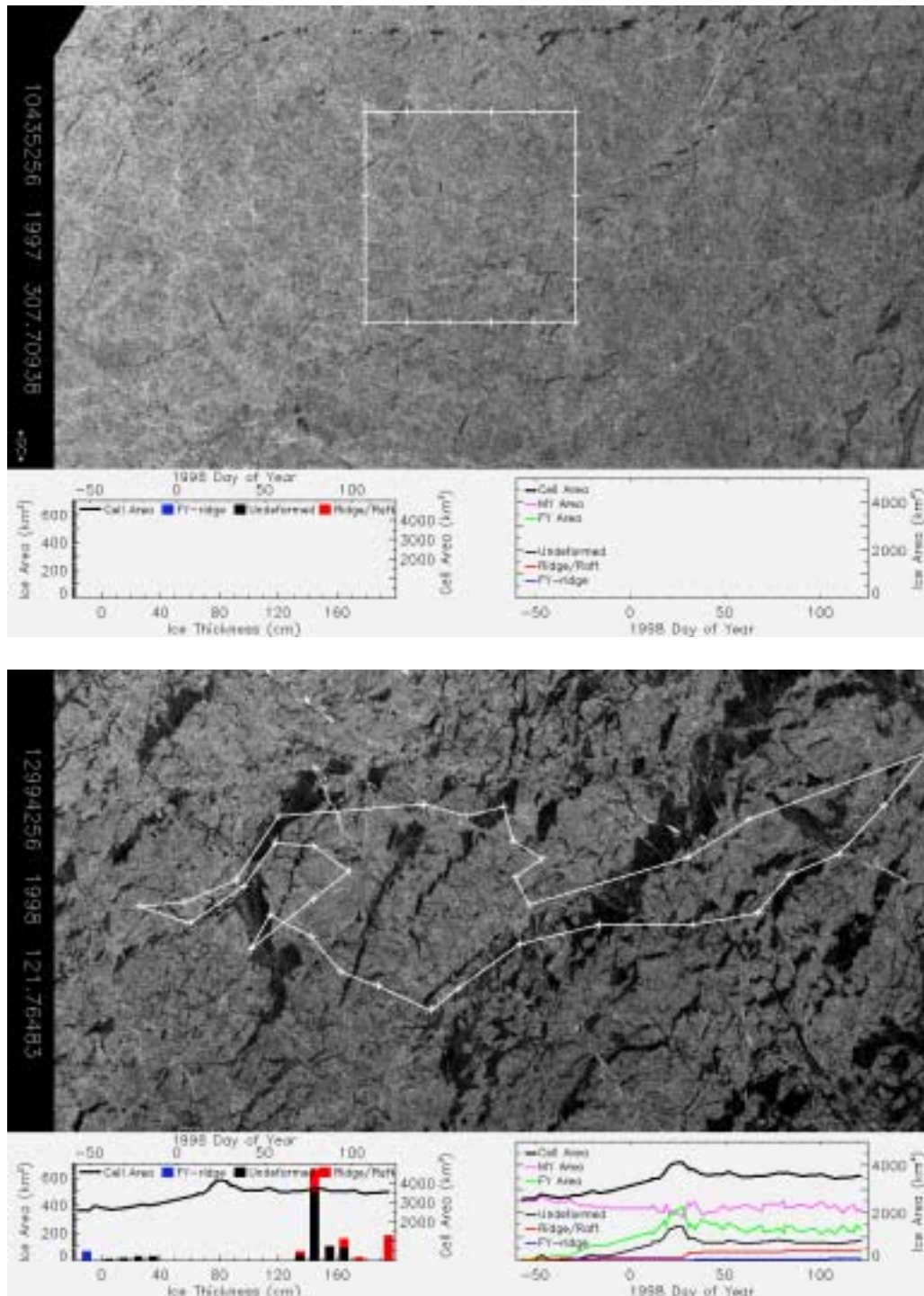


Fig. 1 Total deformation of the sea ice cover in the vicinity of the SHEBA ice camp on May 1, 1998. The initial dimension of the box (on Nov 3, 1997) around the camp is 50 km by 50 km. The RADARSAT SAR imagery shows the ice over at the two different times. The deformation pattern is sampled every three 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.

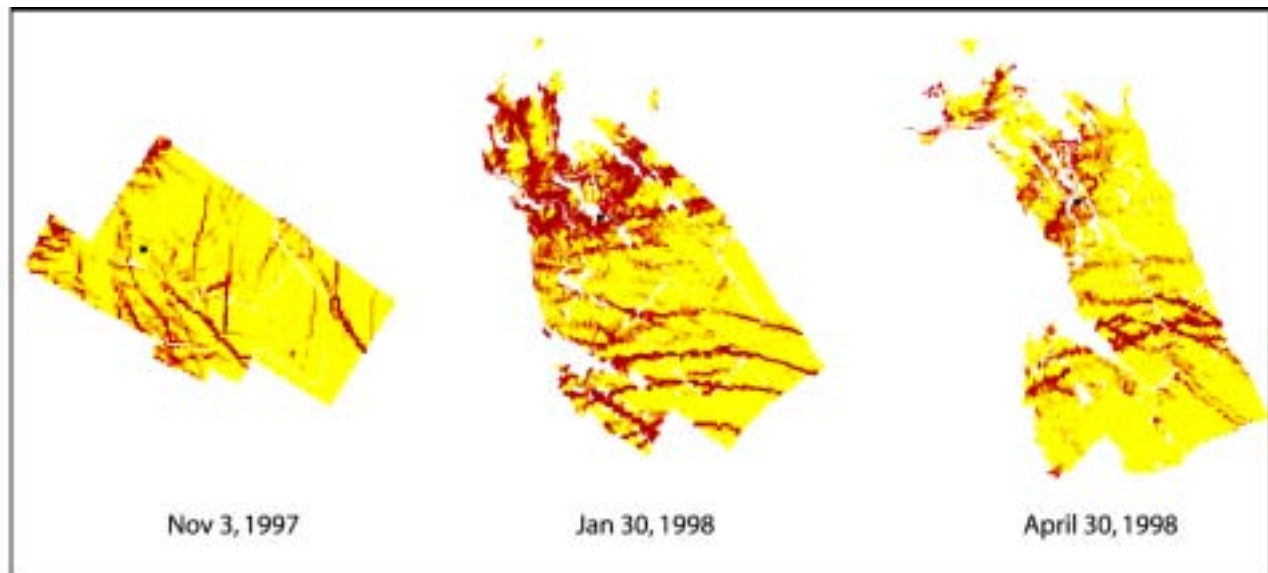


Fig. 2 The linear deformation features derived from the small-scale ice motion derived from RADARSAT imagery. The intensity of the color red indicates the magnitude of shear computed at each RGPS cell. We have developed this tool to group and extract the kinematic and orientation information associated with a linear pattern.

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, Kluwer Academic, in press.

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

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.