Assessing Melt Dynamics over the Canadian Arctic Archipelago Utilizing SeaWinds/QuikSCAT

Stephen Howell(selhowel@ucalgary.ca), Adrienne Tivy, John Yackel, and Randall Scharien
Department of Geography • University of Calgary • Calgary, Alberta, Canada

INTRODUCTION

The Canadian Arctic Archipelago (CAA) is an intricate series of islands located on the North American continental shelf, separated by the Parry Channel with the Queen Elizabeth Islands (QEI) located to the north (Figure 1). The Northwest Passage (NWP) lies in the middle of this region linking the Atlantic and Pacific oceans. The projected decline in sea ice extent by Global Climate Model's has raised many questions about the potential of the NWP becoming a viable shipping route. Considering this route is significantly shorter than both the Panama Cannel and Cape Horn, improved spatio-temporal ice decay information within the CAA would better facilitate safer and efficient shipping strategies.

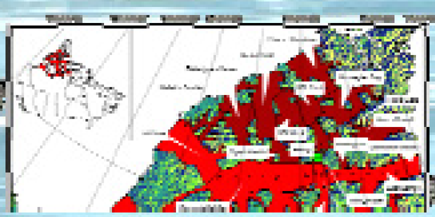

Figure 1. The Canadian Arctic Archipelago and its sub-regions.

As the sea ice evolves physically and thermodynamically changes also occur in its electrical properties, termed an electro-thermophysical-relationship and thus the temporal evolution of time series microwave remote sensing can be utilized for estimating the thermodynamic state of sea ice (Barber et al., 2001) (Figure 2). To date, methods for estimating ice decay over broad-scale areas have relied on passive microwave data from the Special Sensor Microwave Imagery (SSM/I) and Scanning Multi-channel Microwave Radiometer (SMMR) (Drobot and Anderson, 2001). The problem with passive microwave data is its coarse spatial resolution and its in ability to accurately identify the more thermodynamically advanced ice decay states.

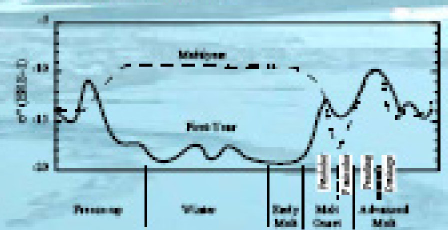

Figure 2. Evolution of σ° from the ERS-1 SAR for thick first year and multi-year sea ice over the seasonal periods spanning the annual sea ice cycle.

SeaWinds/QuikSCAT (QuikSCAT) Scatterometer Image Reconstruction (SIR) active microwave data has large areal coverage (1 800 km swath) and high spatial and temporal resolution making it ideally suited for mapping advanced ice decay dynamics over broad-scale regions. This study (1) presents the development and application of a QuikSCAT sea ice decay algorithm to the CAA and (2) examines spatial coupling between ice decay and radiative forcing from spatial autocorrelation indices.

DATA

QuikSCAT SIR egg data at HH was obtained for 2000 to 2004. This image product provides the best spatial resolution with the minimal amount of noise for thermodynamic estimates (Howell et al., 2005). The extended Advanced Very High Resolution Radiometer (AVHRR) Polar Pathfinder (APP-x; Wang and Key, 2005) satellite derived air temperature (T_a), incoming shortwave radiation (K↓), outgoing shortwave (K↑), incoming longwave radiation (L↓), and outgoing longwave (L↑) data were also obtained for 2000 to 2004. Corresponding *in situ* data from the Collaborative Interdisciplinary Cryospheric Experiment (C-ICE) and the Canadian Arctic Shelf Exchange Study (CASES) were used as validation (Table 1)

*Table 1. APP Data Pearson Correlation Coefficients against C-ICE and CASES in situ Meteorological Data (*significant at the 0.01 confidence level)*

Region/Year	T_a	K↓	K↑	L↓	L↑
C-ICE 2000	0.907*	0.01	0.156	0.412*	0.772*
C-ICE 2001	0.889*	0.715*	0.840*	0.879*	0.725*
C-ICE 2002	0.828*	0.377*	0.091	0.680*	0.864*
CASES 2004	0.926*	0.959*	0.920*	0.803*	0.920*

ALGORITHM DEVELOPMENT

The temporal evolution of σ° from time series synthetic and real aperture is strongly linked to the thermodynamic state of first-year sea ice (FYI) and multi-year sea ice (MYI). This σ° temporal evolution can be partitioned into distinct thermodynamic states: winter, melt onset (MO), pond onset (PO) and drainage. Please see Howell et al., (2005) for a complete description of processes and linkages related to QuikSCAT data. In order to establish a representative stable winter baseline σ° values, each pixel was averaged from year day (YD) 90 to 120. The following data analysis was then used for each pixel:

(1) If $\sigma^\circ \leq -18$ or $\sigma^\circ \geq -11$, then it is assumed winter conditions for FYI and MYI, respectively.

(2) If $\Delta\sigma^\circ$ from winter ≥ 2, then it is assumed melt onset conditions

(3) If $\Delta\sigma^\circ$ from winter ≥ 5, then it is assumed pond onset conditions

(4) If $\Delta\sigma^\circ$ from PO ≥ 4, then it is assumed drainage conditions

Inherently some pixels are missed by these conditions and thus an ordinary kriging routine is applied to fill in gaps and create a continuous thermodynamic state surface.

RESULTS

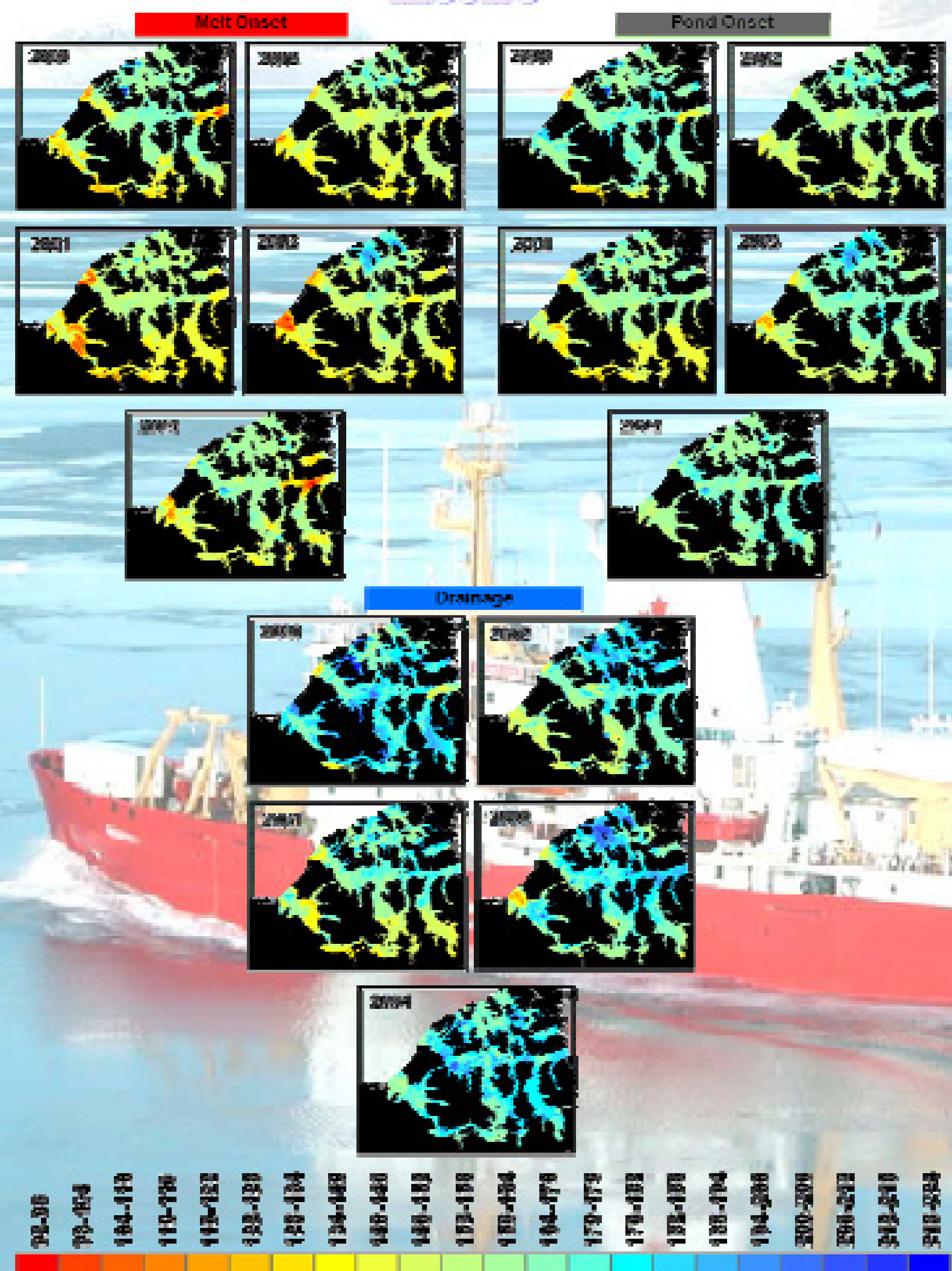

Figure 3. QuikSCAT determined thermodynamic estimates of melt onset, pond onset and drainage maps for the Canadian Arctic Archipelago, 2000-2004. Legend is in year day (YD).

RESULTS CON'T

Figure 3 shows the results of the QuikSCAT thermodynamic algorithm for the CAA from 2000-2004. For regions located in the southwestern part of the CAA, decay transition timing is fairly consistent from 2000 to 2004 (Figure 3). The more southerly regions (especially the Cape Bathurst Polynya in the Amundsen region) reached the MO stage earlier from 2000 to 2003 whereas, 2004 experienced a longer transition time to MO (Figure 3).

Table 2. Moran's I p-values for potential factors affecting MO, PO and Drainage in the CAA. All p-values are positively spatially autocorrelated unless followed by a "-" sign indicating a negative spatial autocorrelation.

CONCLUSIONS

This study presented the development of a QuikSCAT ice decay algorithm applicable to landfast FYI and MYI within the CAA. From 2000 to 2004 the algorithm estimated MO, PO and Drainage decay states for the CAA. Ice decay spatio-temporal variability within the CAA was apparent with some years yielding significant decay clustering or checkerboard patterns that are spatially linked with various radiative forcing parameters. A more comprehensive analysis of this work will soon be available in Howell et al. (accepted).

ACKNOWLEDGEMENTS

The authors wish to thank Steve McCourt (Canadian Ice Service) for providing the Canadian Arctic Archipelago sub-region files. We also would like to thank all field personnel who participated in C-ICE 2000, 2001, and 2002 and CASES 2003-2004. This research was supported by the Natural Sciences and Engineering Research Council (NSERC) PGS-B grant to S. Howell and a NSERC Discovery grant and Cryospheric System in Canada (CRYSYS) project (B. Goodison, PI) grant to J. Yackel.

REFERENCES

Barber, D.G., J.J. Yackel, and J.M. Hanesiak (2001). Sea Ice, RADARSAT-1 and Arctic Climate Processes: A Review and Update, *Canadian Journal of Remote Sensing*, Vol. 27, No. 1, pp 51-61.

Drobot, S. D., and M. R. Anderson (2001). An improved method for determining snow melt-onset dates over Arctic sea-ice using Scanning Multichannel Microwave Radiometer and Special Sensor Microwave/Imager data. *Journal of Geophysical Research*, Vol.106 (D20), pp 24033–24 049.

Howell, S.E.L., A. Tivy, J.J. Yackel, and R. Scharien (accepted). Application of a SeaWinds/QuikSCAT sea ice decay algorithm for assessing melt dynamics in the Canadian Arctic Archipelago. *Journal of Geophysical Research-Oceans.*

Howell, S.E.L., J.J. Yackel, R.A. De Abreu, T. Geldsetzer, and C. Breneman (2005). On the utility of SeaWinds/QuikSCAT for the estimation of the thermodynamic state of first-year sea ice, *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 43, No. 6, pp 1338-1350.

Wang, X., and J.R. Key (2005).Arctic surface, cloud, and radiation properties based on the AVHRR Polar Pathfinder dataset. Part I: Spatial and Temporal Characteristics. *Journal of Climate*, 18, 2575–2593.