6.2 IMPACT OF CLOUD COVER ON ARCTIC SEA ICE SURFACE MELT

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1. INTRODUCTION

The objective is to investigate effects of cloud cover on large-scale surface melt over Arctic sea ice. The cloud-ice-albedo feedback mechanism plays a key role in the heat and mass balance of the ice and upper ocean in the Arctic that affects the global climate system. Albedo of snow-covered sea ice has significant changes between phases of freezing and melting during seasonal transition periods. Low values of albedo results in increasing heat absorption and melting over sea ice surface from melt onset to fall freeze-up. Cloud cover interferes with short and long-wave radiation and strongly modifies the net surface heat flux. In summer when sea ice surface is close to the isothermal condition with surface temperatures fluctuating around the freezing point, energy absorption or release associated with net positive or negative heat flux most effectively results in thermodynamic phase changes over sea ice due to melting or refreezing, respectively.

2. APPROACH

Surface melt over sea ice involves thermodynamics processes spanning diurnal to seasonal time scales over the Arctic Ocean, and the use of satellite data is necessary. First, we use RADARSAT-1 data from the Arctic Snapshot program and sea ice products from the RADARSAT Geophysical Processor System (RGPS) to isolate thermal signature from effects due to ice dynamics and ice deformations.

With results from the Surface Heat Budget of the Arctic Ocean (SHEBA), we observe that surface melt characteristics are consistent from the local scale (km) to the aggregation scale (10's of km). This has an important implication: coarse-resolution satellite data with a frequent coverage are applicable to study sea ice surface thermal processes. We apply QuikSCAT/ SeaWinds scatterometer (QSCAT) data to determine the timing of albedo change. We verify the results with in-situ measurements from the Collaborative Interdisciplinary Cryospheric Experiment (C-ICE).

Finally, we determine melt zones associated with net energy absorption or release over the entire Arctic sea ice during summer when surface-heat and ice-mass variabilities are important. We show large-scale patterns of melt zones derived from QSCAT data together with cloud observations from the Advanced Very High Resolution Radiometer (AVHRR) to illustrate cloud effects on surface melt over Arctic sea ice.

3. RESULTS

RGPS tracks sea-ice motion to determine ice divergence/convergence, vorticity, and shear over over the regional scale (100's of km) around the SHEBA field location. This region is divided into Lagrangian cells with an original spacing of 10 km. More than 370 cells are successfully tracked in time with RADARSAT-1 SAR data from May to August 1998 covering the spring-summer melt transition and the summer-fall freeze-up.

Time-series backscatter signatures from RGPS (tracked over same pieces of sea ice) and SHEBA data are presented in Figure 1. The top panel shows backscatter for all of the Lagrangian cells. The black curve is for backscatter over the SHEBA location, and the overlaying orange curve is for undeformed sea ice at SHEBA where cases with significant ice deformations detected by RGPS (second panel in Figure 1) are eliminated. Thus, backscatter signature represented by the orange curve contains changes due to thermal effects rather than ice dynamic effects.

The air temperature plot on the third panel in Figure 1 reveals the timing of melt onset, which is consistent with the drop in backscatter at SHEBA. The freeze-up seen in the sharp increase in backscatter signature is also consistent with the timing of temperature change to sub-freezing conditions. The plots on the bottom panel in

Figure 1 presents the timing of albedo changes and melt pond evolution. Albedo measured at SHEBA has significant changes after melt onset and after freeze-up corresponding to large changes in backscatter signature, which can be used to identify and map the timing of albedo switches over the Arctic. Note that both abedo (bottom panel) and absolute backscatter (top panel) have significant and complex fluctuations in summer. Due to the limited swath of RADARSAT-1 data (400 km), the temporal resolution results in a revisit in 3 days or worse, which may not be adequate to accurately monitor albebo switches and surface melt processes.

To investigate the scale of sea-ice surface melt, we take the backscatter signature containing thermal-effect changes (eliminating ice deformation cases) and cross correlate it with signatures from all other Lagrangian cells located at distances up to 150 km away from the SHEBA locations. Results in Figure 2 shows high correlations for multi-year sea ice and most of first-year sea ice for separation distances even more than 100 km away from the SHEBA site. These results indicate that satellite data with a resolution within 10's km are appropriate to monitor sea-ice surface melt processes.

Based on the basis of the study above, we utilize QSCAT data, with a resolution of 25 km, to monitor the timing and changes due to surface melt. A major advantage is that QSCAT can cover the Arctic two times per day. With such a frequent coverage over the large scale, we can use diurnal effects in backscatter for melt monitoring on the daily basis without relying on complex variabilities and long-term calibration in absolute backscatter.

We take the difference between morning and afternoon QSCAT data. The diurnal backscatter difference detects melting from non-melting surface when the value becomes large (melt condition). For a melting surface, a positive (negative) value indicates more (less) melting in the afternoon compared to the morning conditions. We have presented the details of this diurnal approach elsewhere (*Nghiem et al.*, 2001). We find QSCAT results in detecting surface melt at the C-ICE location to be accurate within a day compared to in-situ measurements.

During the meting time from melt onset to freeze-up (determined by QSCAT), we investigate effects of cloud cover on sea-ice surface melt using scatterometer data. The frequent Arctic coverage of QSCAT data is particularly important for this purpose because cloud cover can change in a short time scale. Derived from QSCAT data, Figure 3 reveals a large-scale cyclonic pattern of sea-ice surface melt with zones of positive (red), neutral (white), and negative (blue) values of the diurnal backscatter difference. These values are associated with energy absorption, neutral, or release over the sea ice cover corresponding to positive, neutral, or negative backscatter difference, respectively.

Since cloud cover interferes with the net surface heat flux, the sea-ice surface melt pattern detected and mapped by QSCAT should be consistent with the dominant cloud cover pattern. We verify this result with an image of cloud cover acquired by AVHRR (Channel 4, NOAA 14, 11 Aug 2001, 03:37 UTC) as presented in Figure 4, which does indeed reveal a cyclonic cloud pattern associated with a low-pressure center located over the Arctic Ocean.

ACKNOWLEDGMENT

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REFERENCE

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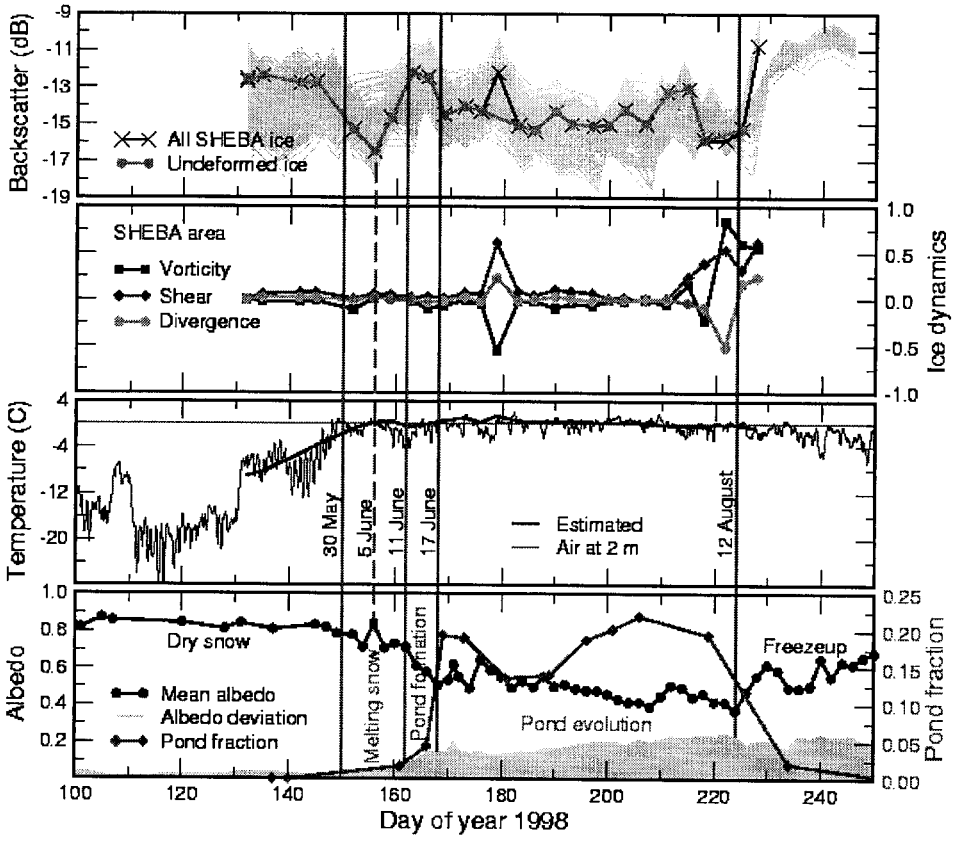

Figure 1: Time-series signatures for backscatter, ice deformation, temperature, and albedo and melt pond fraction at SHEBA field location from May to August 1998.

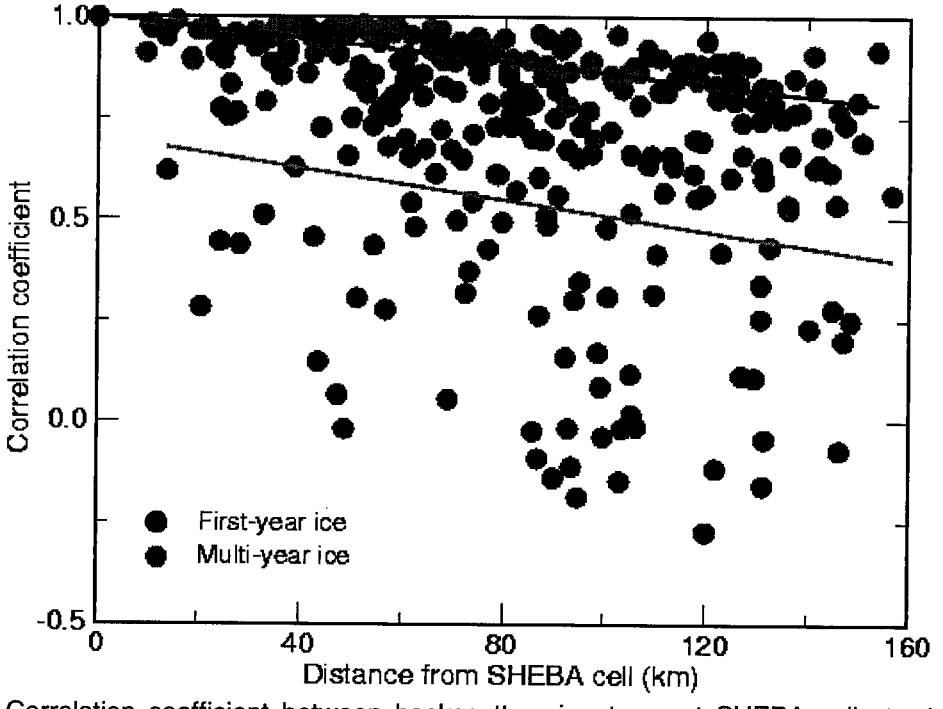

Figure 2: Correlation coefficient between backscatter signatures at SHEBA cell at other cells around SHEBA for multi-year (red) and first-year (blue) sea ice. Continuous curves are linear fits.

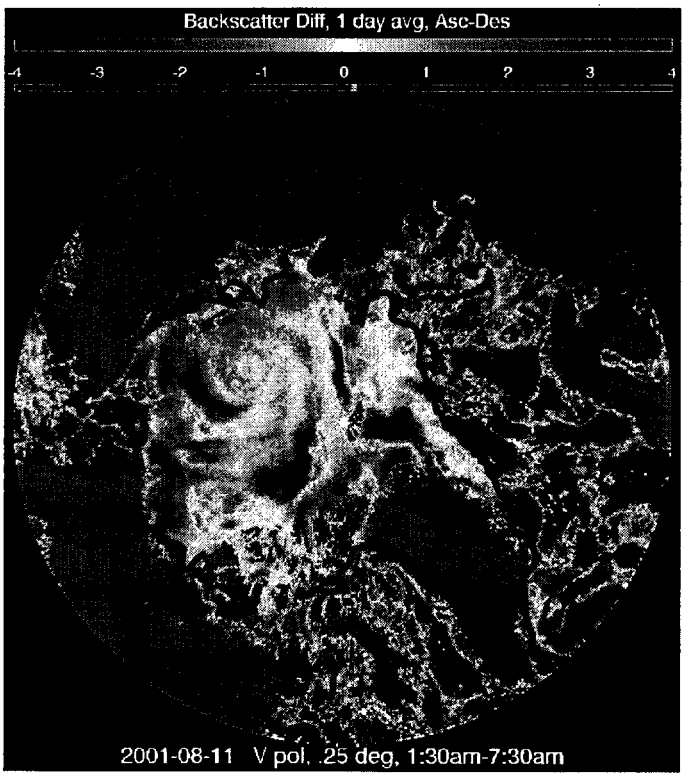

Figure 3: Cyclonic pattern of surface melt over Arctic sea ice observed by QSCAT on 11 August 2001. The ice extent, also identified and mapped by QSCAT, is defined with the brown boundary.

Figure 4: AVHRR Channel-4 image of cloud cover showing a cyclonic pattern around a low-pressure center over the Arctic Ocean on 11 August 2001.