PASSIVE POLARIMETRIC REMOTE SENSING OF SNOW AND ICE

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LONG TERM GOALS

In recent years, polarimetric radiometry has shown great potential to revolutionize passive remote sensing of the ocean surface. As a result, several polarimetric radiometers are planned for future space borne systems, and the Navy is currently planning to launch Windsat, a multi-frequency polarimetric radiometer, in 2001. This project explores the possibility of applying this new technology to remote sensing in the Polar Regions by investigating the polarimetric signature of ice and snow.

OBJECTIVES

The objective of the proposed research is to establish a benchmark set of measurements of the polarization coherence of microwave radiation from sea ice and snow. These observations will provide a comprehensive passive polarimetric microwave data set for assessment of microwave emission models and the long-term prospect of improved observation of hydrospheric processes from satellite. Specifically, we will observe the relationship between the polarimetric signature and the physical properties of snow and ice over a broad range of observation configurations.

APPROACH

To establish a benchmark set of measurements of the polarization coherence of microwave radiation from sea ice and snow, we proposed to measure the Stokes parameters, as a function of incidence angle, for growing ice, desalinated ice, new snow, and metamorphosed snow over sea ice. By observing the scene from several angles of azimuth, we proposed to test for anisotropies such as those due to the orientation of ice crystals, brine channels and air pockets.

Although the CRREL facility is well equipped to artificially generate ice (via refrigeration of the outdoor tank) and snow (via snowmaking guns), we preferred to observe naturally occurring snowfall on naturally frozen ice. In reality we were forced to rely on a combination of natural and man-made conditions to achieve the broadest range of surfaces. CRREL personnel assisted us with the characterization of the ice and snow, and verified that they are similar to those found in the Arctic. In situ parameters of interest for ice were thickness, temperature, salinity, density, inclusion size and structure. For the snow cover, in situ measurements included depth, grain size, and temperature.

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ACCOMPLISHMENTS

The experiment took place at the US Army Cold Regions Research and Engineering Laboratory's outdoor facility in Hanover, New Hampshire during the period from January 26, 1997 to February 26, 1997. Prior to our arrival, Dr. Don Perovich and Mr. Bruce Elder prepared an ice sheet for us by covering and refrigerating the tank. After three days of setting up the equipment and installing the radiometers on a hydraulic lift, we began our observations. A hydraulic lift was chosen as a platform because it could raise the instruments to a height that accommodated the far-field requirements of the antennas, while allowing mobility around the pond. Mobility was critical to the experiment because it was the only way to get multiple azimuthal looks at the ice. For each of the experiments listed below, the lift was moved along each side of the pond to fixed locations. Then, the proper instrument azimuth angle and elevation angle were attained using a mechanical positioner. Because the pond was rectangular, the height of the platform was set at each position to place the footprint in the center of the pond. Typically, data were collected at the following azimuth angles: 0, 20, 40, 60, 300, 320, and 340 degrees. The angles of incidence were 45, 55 and 65 degrees. Because of all of the adjustments that had to be made for each pair of angles, it took approximately 3 hours to complete one full data set. During the growth phase experiment, the data set had to be significantly reduced because the ice grows so quickly. Fifty-five degrees was selected as the optimum angle of incidence, and the observations were made on one side of the pond only. This modification to the experiment plan trimmed the time for collection of a single data sweep to about 20 minutes. During the growth phase we collected data nearly continuously for 38 hours. A summary of the month of experiments is presented below.

Date of Observation	Conditions
30-Jan	Bare ice, 13 cm thick
31-Jan	Bare ice during light snow fall, 3mm inch snow accumulation
4-Feb	10cm of ice, 4.5 cm of slush and 3 cm of snow (See figure 1)
13-Feb	Snow/No Snow Experiment. Snowfall on half the pond
18-Feb	Final observation on this ice sheet. Sheet has had snow, thermal cycling and some flooding.
24-Feb	Harvested large middle section of sheet and place some on top of remaining ice to drain
25-Feb	Open water calibration and early growth phase of new ice (See figure 2)
26-Feb	Growth phase of new ice
26-Feb	Old, desalinated ice (See figure 3)

Slight surface melt on the ice sheet, which occurs whenever the air temperatures warm to within 5 degrees of freezing, has a great influence on measured brightness temperature because it effectively masks the ice below. As a result, we did not collect data on warm days or when heavy snowfall or high wind conditions would have endangered the equipment or operator.

The nature of polarimetric radiometry is such that the observations are very sensitive to the polarization planes, i.e. the geometry, of the experiment set up. This means that the observations are very sensitive to errors in all three angles of orientation. The effects of these angular variations can be corrected in post processing if the angles are accurately known. Because this was a movable set up, with the instruments mounted on the lift and driven around the pond, we have undertaken and extensive effort to ensure that these factors have been appropriately handled.

SCIENTIFIC/TECHNICAL RESULTS

To date, it does appear that there is a measurable polarimetric signal that can be associated with sea ice. But, because these were the first observations of this kind, and because the analysis is not yet complete, it would be premature to draw conclusions at this time.

IMPACT FOR SCIENCE (and/or) SYSTEMS APPLICATIONS

If a reasonably robust polarimetric signal is in evidence, we can expect a significant enhancement in the capabilities of passive remote sensing systems observing hydrospheric process. In particular, the detection and delineation of ice age and concentration boundaries or snow depth and structure variability could be improved.

In the shorter term the identification of a polarimetric signal from ice and/or snow could influence the design trade-off decisions for the National Polar-Orbiting Operational Environmental Satellite System Conical Microwave Imaging System (NPOESS/CMIS), particularly with regard to channel selection, channel sensitivity (signal-to-noise ratio), and spatial resolution.

TRANSITIONS

There are no transitions anticipated at this time.

RELATED PROJECTS

The PIs are actively involved with the Navy's Windsat program which will be the first polarimetric radiometer in space. The PIs are also performing internal government studies for the National Polar-Orbiting Operational Environmental Satellite System Integrated Program Office (NPOESS/IPO) on polarimetric radiometry and its application to Earth remote sensing.

Figure 1. The 37 and 10 GHz radiometers, mounted on the hydraulic lift platform, observing snow covered ice.

Figure 2. Sections of the ice harvested from the center section of the pond have been placed upon the remaining ice and allowed to desalinated for several days prior to our observations.

Figure 3. The polarimetric radiometers calibrating, with calm water as a source prior to the growth of the new ice sheet.