Sea Ice Properties Observed With Helicopter-borne Sensors and ENVISAT ASAR Imagery over the Eastern Beaufort Shelf

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In April-May 2004, a field survey of sea-ice thickness and ice-surface roughness using helicopter-borne sensors was conducted over the eastern Beaufort shelf near Franklin Bay (Fig. 1) as part of the Canadian Arctic Shelf Exchange Study (CASES). Sea ice thickness and roughness profiles were collected with an electromagnetic-laser system (Ice Pic) fix-mounted on the front of a helicopter, and video data were frame-grabbed in real-time using a downward-looking video camera mounted on the helicopter skids. Advanced synthetic aperture radar (ASAR) images were also acquired from the recently-launched satellite ENVISAT, which can provide dual-polarization data. The field and satellite data were collected to assess the improved capabilities of dual-polarization SAR data for monitoring sea-ice type and ice-surface topography, and ultimately for developing and validating ice-classification algorithms based on SAR data.

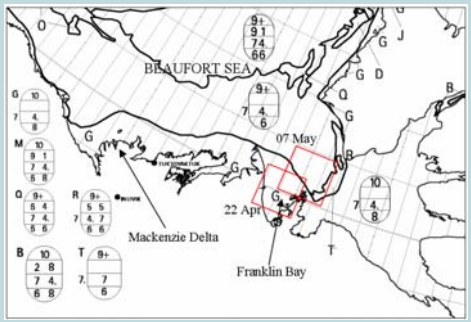

Figure 1. The ice chart (Canadian Ice Service) for May 15, 2004 shows landfast or compact ice (10-tenths concentration) in Frankin Bay, mobile thick first-year ice (>9-tenths concentration) to the north, and a narrow region ("T") of first-year ice to the northeast along the eastern edge of the Bathurst polynya. The red squares represent the locations of the SAR images shown in Figures 3 and 4.

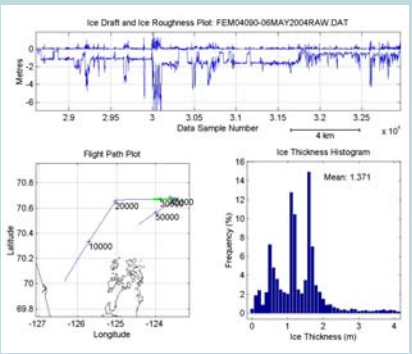

Figure 2. Ice thickness and roughness data collected with the fix-mounted electromagnetic (FEM)-laser system are plotted along a 20km line leading up to and including the thin first-year ice region. Three regions having modal ice thicknesses of 1.1m, 1.6m and 0.5m are observed from west to east; a few refrozen leads covered with thin ice (10-30cm) are also present. The snow-ice surface roughness measured with the laser altimeter increased at locations where the EM sensor detected deep ice features, as expected for ridges.

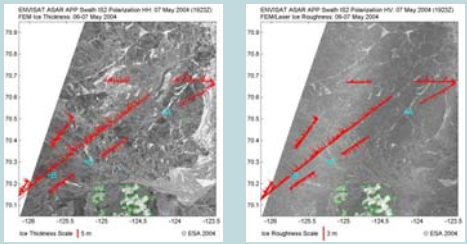

Figure 3. An example of an ENVISAT dual (alternating) polarization ASAR image (90km x 90 km) from the mobile ice region is shown, with the HH (horizontal transmit, horizontal receive) data in the left panel and the HV (horizontal transmit, horizontal receive) data in the right panel. FEM-measured ice thickness data obtained on May 6-7 are overlain in red on the HH image, and laser-measured ice roughness data are overlain on the HV image. Ice thickness and roughness are plotted relative to the straight line representing the location of the flight path, and the scale is shown below the image. Points A-C represent the locations of video images shown in Figure 5.

In the HH-polarization image, the dark-toned areas represent smooth thick first-year ice, with thicknesses of about 2m. The narrow bright-toned areas represent newly-frozen leads, with thicknesses of less than 30cm; the high backscatter is due to frost flowers. The large bright area on the right side of the image represents thin first-year ice (30-70cm), as shown in the ice chart. The HV image contains a range-dependent variation in backscatter due to the low signal-to-noise ratio combined with the antenna pattern correction. The newly-formed leads appear bright, but there is less contrast among the other ice classes than in the HH image.

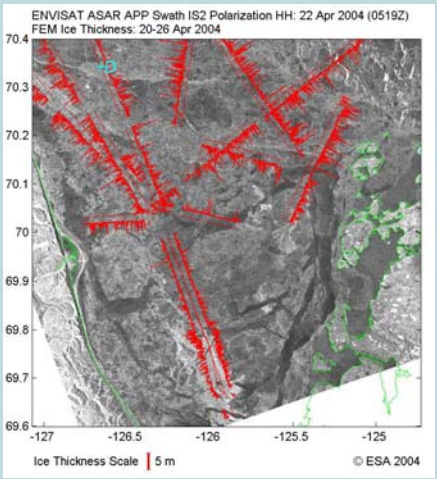

Figure 4. This ENVISAT HH-polarization ASAR image from April 22, 2004 (80 x 80km) is mainly from the landfast ice region in Franklin Bay, with mobile pack ice north of about 70.2°N. Ice thickness data are overlain in red. As in the previous example, the bright-toned areas in the upper right of the image represent newly-frozen leads and the dark-toned areas represent smooth thick first-year ice. Points D represents the location of a video image shown in Figure 5.

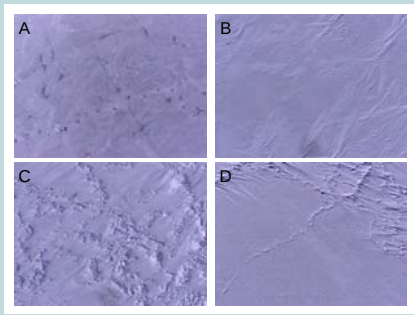

Figure 5. These examples of video images were collected at points A-D in Fig. 2 and 3. "A" represents a newly frozen lead, with a number of seal holes visible in the ice; ice thicknesses are less than 30cm. "B" represents smooth thick first-year ice, with thicknesses of about 2m. "C" represents deformed ice in the shear zone containing ridges and rubble; thicknesses are generally 2 m with peaks up to 10m, and the ice roughness is as high as about 3m. "D" represents consolidated brash ice, with thicknesses of 1.5 to 2m.

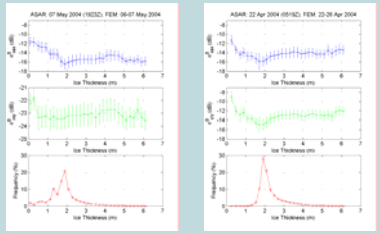

Figure 6. The mean radar backscattering coefficient σ^0 is plotted as a function of FEM-measured ice thickness for HH and HV polarizations (left, 07 May 2004 image) and HH and VV polarizations (right, 22 April 2004 image). The HV data were corrected for the range-dependent variation. The vertical lines represent the mean ± 0.5 standard deviations. Ice thickness frequency is shown in the bottom plots. The mode of ice thickness is 1.9m on both dates, and represents the dominant level ice thickness; a secondary mode is visible for the May image at an ice thickness of about 1.3m. Thicknesses of 0-40cm represent newly-frozen leads, while thicknesses greater than 2m represents deformed ice.

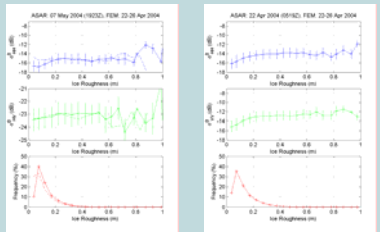

Figure 7. Mean radar backscattering coefficient σ^0 as a function of laser-measured ice roughness for HH and HV polarizations (left, 07 May 2004 image) and HH and VV polarizations (right, 22 April 2004 image) for the landfast ice region. The vertical lines represent the mean ± 0.5 standard deviations. Ice roughness frequency is shown in the bottom plots. The dashed lines on the left show the curves for the mobile ice region.

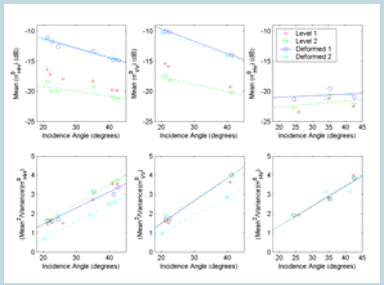

Figure 8. Mean backscattering coefficient as a function of incidence angle for level and deformed ice in Franklin Bay (upper panels). The HH, VV and HV polarizations are shown in the left, centre and right panels respectively. The corresponding Mean²/Variance is shown in the lower panels.

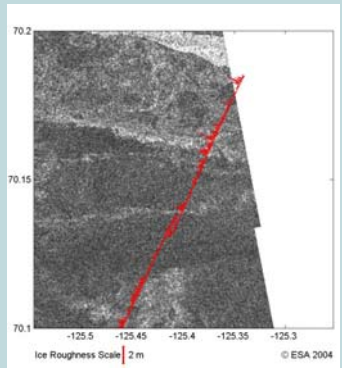

Figure 9. Ice surface roughness profile collected with the laser altimeter of the Ice Pic near the edge of the landfast ice in Franklin Bay on April 23, 2004. The profile is overlain on an ENVISAT ASAR APP Image (Swath IS6, VV polarization, 22km by 22km) acquired on May 10, 2004.

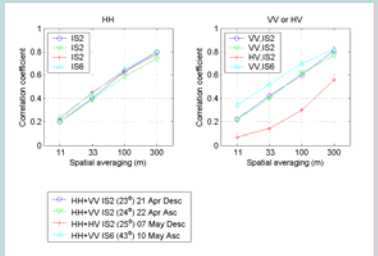

Figure 10. Correlation coefficients between mean ice surface roughness and mean SAR intensity for different spatial averaging, polarizations and incidence angles for the 20km-long roughness profile shown in Fig. 9. The highest correlations were obtained for the IS6 swath and VV polarization, and the lowest correlations were obtained for the HV polarization.

For More Information:
http://www.mar.dfo-mpo.gc.ca/science/ocean/seaice/public.html

Acknowledgements: The work was funded through the Canadian Federal Panel of Energy Research and Development (PERD) and the Canadian Space Agency. It was supported by the European Space Agency and the Canadian Arctic Shelf Exchange Study (CASES). ENVISAT ASAR data were provided by the European Space Agency under AO Project 178.