Polarimetric C- and X-band SAR observations of multi-year sea ice: towards the retrieval of sea ice surface roughness and thickness

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ABSTRACT

Over the past three decades dramatic declines in Arctic sea ice extent and age have been documented using passive microwave observations; however, observations of sea ice surface roughness and thickness have been limited both spatially and temporally. Recently, pan-Arctic observations of sea ice thickness have been achieved using satellite altimetry; however, these data are typically gridded at coarse spatial resolution and averaged at monthly time scales, limiting their suitability for applications that require data at high spatial resolution or in near-real time (e.g. short-term sea ice forecasting, marine operations). Given recent advances in synthetic aperture radar (SAR) technology, specifically the availability of multiple polarizations and frequencies, there is a need to reassess the potential to derive sea ice roughness and thickness from SAR data. In this study, polarimetric C- and X-band SAR data are compared to in situ and airborne observations of ice roughness and thickness to determine if these parameters can be inverted from SAR data. Quad-pol RADARSAT-2 and dual-pol TerraSAR-X images were acquired in March-April 2012 and 2013 in the Lincoln Sea, a region of predominantly multi-year ice (MYI). In situ measurements include laser level surveys of sea ice surface roughness and ice thickness measurements from drilling and electromagnetic (EM) induction sounding. Airborne measurements were acquired using an airborne EM system and by NASA’s Operation IceBridge. Areas of deformed ice were identified in IceBridge digital elevation models (DEM). The fraction of deformed ice in each DEM frame was strongly correlated (r > 0.6) with C-band backscatter intensity at all linear polarizations and with some depolarization parameters, indicating high volume scattering contributions from deformed ice. Correlations were consistently weaker at X-band. An empirical multiple-linear regression equation was used to predict the deformed ice fraction in RADARSAT-2 imagery, which was used to mask pixels containing deformed ice. For undeformed ice pixels, a threshold of -12.5 dB was applied to the total backscattered power to distinguish between FYI and MYI. MYI pixels were then compared to coincident ice thickness observations. We hypothesize that thick MYI will have a deeper desalinated upper ice layer than thin MYI, due to its higher freeboard, and will therefore have greater volume scattering contributions and higher backscatter. In 2012 correlations were strong between ice thickness and C-band backscatter intensity at all linear polarization and with depolarization parameters, including the cross-polarization ratio. Once again, correlations were weaker at X-band. In contrast with the results from 2012, correlations between MYI thickness and SAR parameters were insignificant in 2013. It is hypothesized that strong surface melt observed in the summer of 2012 “reset” the deteriorated upper ice layer of the MYI within this region, causing all MYI floes to have deteriorated layers of similar thickness and density. These results suggest that the development of empirical ice thickness inversion algorithms require calibration and validation in each study year. It is recommended that future studies include L-band SAR data to improve the discrimination of deformed ice from MYI, and that they include analysis of circularly polarized parameters, which will be available at wide swath widths from the next generation of SAR sensors.