Polarimetric analyses of dominant radar backscattering mechanisms for iceberg detection

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Iceberg detection in sea-ice covered waters using single polarization SAR is hampered by similarities between backscattering signatures of icebergs and sea ice deformation structures. Therefore, we investigated whether iceberg detection is more robust when polarimetric SAR images are used. From the science point of view, the advantage of such data is that they indicate the dominant backscattering mechanisms. For our study we have five RADARSAT-2 images available, recorded in the Bellingshausen and the southern Weddell Seas. Within the images, overall 683 icebergs of various sizes and 357 sea-ice regions of interest (ROIs), separated into three different sea ice classes, were identified. For icebergs and sea ice ROIs, the polarization ratio, the co-polarized phase difference and correlation coefficient, and entropy, anisotropy and alpha angle were calculated, compared and analyzed.
The co-polarization ratios of icebergs (σ_{VV}/σ_{HH}) are close to one, which can be explained by scattering from larger surface elements (modeled by Geometrical Optics) and/or volume scattering from spherical air inclusions in the ice. Only the ratio values of smooth sea ice differ significantly from the ones of icebergs. Icebergs reveal high depolarization ratios (σ_{HV}/σ_{HH} and σ_{VH}/σ_{VV}) and low correlation coefficients (ρ_{HHVV}), which is typical if multiple scattering occurs. The phase difference (ϕ_{HHVV}) of icebergs is significantly larger than zero (about +50°), which can be explained by different propagation velocities of horizontally and vertically polarized waves and double-bounce reflections in the ice volume. The phase difference (ranging from -180° to 180°) of sea ice is around zero or shifted to slightly negative differences (max. -25°). The anisotropy is useful for the discrimination of scattering processes for which the entropy is >0.7. Since only a small number of our observations fulfill this criterion, we used an unsupervised entropy-alpha decomposition for the determination of the major backscattering mechanisms. Icebergs are dominated by dipole scattering in both areas of investigation. Sea ice signatures vary between the two areas because of differences in the ice type distribution. In the Bellingshausen Sea, the sea ice backscattering is dominated by scattering from rougher surfaces but includes also contributions from the volume. In the Weddell Sea region, the backscattering of sea ice is characterized by surface scattering. The signatures are influenced by the radar incidence angle. The Weddell Sea images are recorded at lower incidence angles (18-20°), at which surface scattering is more distinct. In the Bellingshausen Sea, the incidence angles are 47.5 to 48.7° and 40.2 to 41.6°, at which volume scattering contributions cannot be neglected. The analyses show that the incidence angle impact on the polarimetric parameters is larger for sea ice than for icebergs, and that lower incidence angles are preferable for iceberg detection. The separation of deformed sea ice and icebergs is

improved if the phase difference, entropy, and alpha parameters are used as additional classifiers besides radar intensity.