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Sea ice thickness temporal evolution during the Arctic freeze-up as seen by SMOS

Lars Kaleschke, Xiangshan Tian-Kunze, and Nina Maaß
University of Hamburg, Institute of Oceanography, Center for Marine and Atmospheric Research, Hamburg, Germany (lars.kaleschke@zmaw.de, +49 40 7471)

ESA's Soil Moisture and Ocean Salinity (SMOS) mission is measuring the brightness temperature at 1.4 GHz correspondig to a wavelength of 21 cm. Such long electromagnetic waves are emitted from well inside a low loss media such as pure ice. Sea ice contains liquid brine of high conductivity and is therefore a lossy media. The relative brine volume and thus the dielectric loss factor depends on the initial salt content and the ice temperature. As long as parts of the microwave emission are emerging from the bottom ocean-ice interface to the surface, the measured brightness temperature is a function of the sea ice thickness.

In this study we analyse the intensity of radiation in seasonally ice covered Arctic waters during the Autumn freeze-up from October to December 2010. In order to get an estimate of the maximum ice thickness that can be retrieved from SMOS we calculate approximate sea ice thicknesses from the cumulative freezing degree days by using NCEP reanalysis data and compare these to the corresponding observed brightness temperature. A semi-empiric model is used to calculate the ice thickness $d = -\frac{1}{\gamma}\ln(\frac{I_1 - I}{I_1 - I_0})$ from the measured intensity I and the three parameters I_0, I_1, and γ, with the intensity of the ice-free ocean at the freezing point I_0, the intensity of thick ice I_1 and an attenuation factor γ.

The analysis of the time series at certain positions of the NCEP grid cells allow the following conclusions:

1. both intensities $I_0 = 98.8 \pm 1\,\mathrm{K}$ and $I_1 = 243.8 \pm 1.3\,\mathrm{K}$ exhibit little variability over several weeks;
2. the intensity is monotonically increasing with the ice thickness as expected from model simulations;
3. after the ice concentration has reached 100%, the 1.4 GHz intensity still increases for about three weeks;
4. at a maximum ice thickness of about 0.5 m the intensity reaches I_1 and further ice growth does not increase the brightness temperature;
5. a constant $\gamma \approx 9\mathrm{m}^{-1}$ is a suitable choice for Arctic wide sea ice thickness retrieval with SMOS during the freeze-up period. Correlations between the cumulative freezing degree day thickness and the SMOS ice thickness are as high as $r^2 = 0.96$.

A more thorough validation and further improvement of the retrieval model is ongoing in the framework of ESA's Support to Science Element (STSE) SMOS Sea Ice Retrieval Study (SMOSIce).