On retrieving sea ice thickness using SAR and MODIS data

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In this presentation we will discuss under which sea ice and weather conditions we can hope to obtain meaningful information about the ice thickness using SAR and thermal infrared (TIR) data. The radar response at C-band from first-year sea ice (FYI) is dominated by the surface scattering. For multi-year ice and practically saline free ice, like the fast ice areas in the Baltic Sea, the volume scattering is of significance due to the larger penetration depth of the radar signal and the greater porosity of ice. The snow layer affects the radar response when it is moist. Hence, we will restrict our attention in (FYI) drift ice areas under cold weather conditions.

We will base our discussion on the analysis results obtained using the CryoSat Cal/Val campaign data which took place in March 2005 in the Baltic Sea. Airborne laser scanner (ALS) measurements were conducted in the campaign. Later 3-D ice surface topography along transects with a total length about 150 km, width 300 m and a resolution of 3 m^2 was constructed from this data set. It was then compared to the nearly co-incident ENVISAT ASAR images. The analysis results showed that the mean backscatter coefficient ($\sigma°$) increases almost linearly when the fraction of deformed ice grows inside the analysis window (300 m by 300 m). A statistical model was established to predict the ice freeboard (h_f) on the basis of $\sigma°$, the dominant thickness of the parent ice sheet for the deformed ice and the magnitude of the incidence angle. h_f can be converted to ice thickness. For this limited data set the model yielded good results. The uncertainty of the estimates was quantified using the predictive distributions (a Bayesian approach). The obtained results implicate that one can expect reasonable ice thickness class estimates if the large scale ice surface roughness is strongly correlated with the ice thickness. Another requirement is that we through thermodynamic modeling or in situ-data can estimate the thickness of thermodynamically grown ice. In the clear sky conditions this is possibly also using the TIR channels of MODIS [1]. From the TIR channels one obtains the ice surface temperature which is used to calculate the ice surface heat budget, one also needs at least the modeled air temperatures and wind speeds (e.g. HIRLAM or ECMWF). The resulting ice thickness estimate is called the thermal ice thickness and the algorithm gives the correct order of ice thickness classes up to 1 m (a saturation thickness).

The determination of the dominant local level ice thickness is, however, problematic due the different resolution of MODIS (1 km) and ENVISAT ASAR data (30-100 m). The complicating factor is that usually the TIR pixels cover as well level ice as deformed ice areas with varying spatial extent. The ice surface temperature for these ice categories differ significantly from each other. We will outline a strategy to overcome this restriction. We will also discuss application of our sea ice thickness estimation method to Arctic Seas (e.g. Kara Sea).

Reference

[1] Y. Yu, and D.A. Rothrock, “Thin ice thickness from satellite thermal imagery,” *J. Geophys. Res.*, vol.101, no. C11, pp. 25,753–25,766, 1996.