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L-band radiometry for sea ice applications

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Although sea ice remote sensing has reached the level of operational exploitation with well established retrieval methods, several important tasks are still unsolved. In particular during freezing and melting periods with mixed ice and water surfaces, estimates of ice concentration with passive and active microwave sensors remain challenging. Newly formed thin ice is also hard to distinguish from open water with radiometers for frequencies above 8 GHz. The SMOS configuration (planned launch 2009) with a radiometer at 1.4 GHz is a promising technique to complement observations at higher microwave frequencies. ESA has initiated a project to investigate the possibilities for an additional Level-2 sea ice data product based on SMOS. In detail, the project objectives are (1) to model the L band emission of sea ice, and to assess the potential (2) to retrieve sea ice parameters, especially concentration and thickness, and (3) to use cold water regions for an external calibration of SMOS.

Modelling of L band emission: Several models have are investigated. All of them work on the same basic principles and have a vertically-layered, plane-parallel geometry. They are comprised of three basic components: (1) effective permittivities are calculated for each layer based on ice bulk and micro-structural properties; (2) these are integrated across the total depth to derive emitted brightness temperature; (3) scattering terms can also be added because
of the granular structure of ice and snow. MEMLS (Microwave Emission Model of Layered Snowpacks (Wiesmann and Matzler 1999)) is one such model that contains all three elements in a single Matlab program. In the absence of knowledge about the internal structure of the sea ice, three-layer (air, ice and water) dielectric slab models which take as input a single effective permittivity for the ice layer are appropriate. By ignoring scattering effects one can derive a simple analytic expression for a dielectric slab as shown by Apinis
and Peake (1976). This expression was used by Menashi et al. (1993) to derive the thickness of sea ice from UHF (0.6 GHz) radiometer.

Second, retrieval algorithms for sea ice parameters with emphasis on ice-water discrimination from L-band observations considering the specific SMOS observations modes and geometries are investigated. A modified Menashi model with the permittivity depending on brine volume and temperature suggests a thickness sensitivity of up to 150 cm for low salinity (multi year or brackish) sea ice at low temperatures. At temperatures approaching the melting point the thickness sensitivity reduces to a few centimetres. For first year ice the modelled thickness sensitivity is roughly half a meter. Runs of the model MEMLS with input data generated from a 1-d thermodynamic sea ice model lead to similar conclusio. The results of the forward model may strongly vary with the input microphysical details. E.g. if the permittivity is modelled to depend in addition on the sea ice thickness as supported by several former field campaigns for thin ice, the model predictions change strongly.

Prior to the launch of SMOS, an important source of observational data is the SMOS
Sea-Ice campaign held near Kokkola, Finland, March 2007 conducted as an add-on of the POL-ICE campaign. Co-incident L-band observations taken with the EMIRAD instrument of the Technical University of Denmark, ice thickness values determined from the EM bird of AWI and in situ observations during the campaign are combined.

Although the campaign data are to be use with care, for selected parts of the flights the sea ice thickness can be retrieved correctly. However, as the instrumental conditions and calibration were not optimal, more in situ data, preferably from the Arctic, will be needed before drawing clear conclusions about a future the sea ice thickness product based on SMOS data. Use of additional information from other microwave sensors like AMSR-E might be needed to constrain the conditions, e.g. on sea ice concentration and temperature.

External calibration: to combine SMOS ice information with statistics on temperature and
salinity variations derived from a suitable ocean model to identify ocean targets for a vicarious target calibration of the SMOS radiometer. Such a target can be identified most reliably in cold waters as suggested by Ruf (2000) before. At higher microwave frequencies the advantage of the Ruf method is that the absolute minimum of the observed brightness temperatures is a universal constant and can be used for external calibration. However, in the L band the salinity variations may shift the minimum to both directions so that suitable regions of low salinity variations need to be identified. For finding areas with fairly stable, at least known cold temperatures, one has to analyze existing prior (external) knowledge available from ocean observations (in situ and satellite) and from numerical models. From statistics based on daily AMSR SST fields and model simulations, the best area seems to be between Svalbard and Ocean Weather Ship Station (OWS) Mike, at 66N, 02E. However, variations in SST are still comparably large and the area can hardly be used for instrument calibration. It is suggested to deploy a number of drifters in a limited area representing a SMOS footprint to obtain accurate estimates of SSS and SST.