A Multiyear Program of Airborne Microwave Radiometry of Snow on Lake Ice

Martti Hallikainen[(1)], Matti Vaaja[(1)], Jaakko Seppänen[(1)], Juha Kainulainen[(1)], Annakaisa von Lerber[(1)], Erkka Rouhe[(1)], Juha Lemmetyinen[(2)], and Jaan Praks[(1)]

[(1)]Aalto University, Department of Radio Science and Engineering
P.O.Box 13000, FI-00076 Aalto, Finland

[(2)]Finnish Meteorological Institute
P.O.Box 503, FI-00101, Helsinki, Finland

Microwave radiometers measure the intensity of radiation emitted by all media, usually expressed as brightness temperature values. Target characteristics are retrieved from these data based on either theoretical or semi-empirical emission models. Microwave radiometry of terrestrial snow has been investigated since the 1970's and numerous studies confirm that the regional snow water equivalent (SWE) and other characteristics of dry can be retrieved from radiometer data with reasonable accuracy. Due to variation of the physical properties of snow and land-cover categories, global mapping of dry snow is a complex task and usually requires ground truth data at selected locations. Space-borne microwave radiometry is presently used in several countries to map characteristics of snow cover.

Two factors tend to decrease accuracy of obtained SWE information in northern regions: forests and lakes. During the snowmelt season, the grain size and depth of the snow cover on lake ice may differ from those on land, usually resulting in brightness temperatures that are different from those for adjacent land areas. Additionally, presence of water on top of ice affects brightness temperatures. Especially in lake-rich regions, the effect of snow-covered frozen lakes to the satellite-derived large-scale brightness temperatures must be accounted for in order to obtain adequate accuracy in SWE retrieval. Due to the modest spatial resolution of space-borne radiometers, investigation of the brightness temperature behavior of snow on lake ice can be best done with airborne radiometers.

We have conducted a multiyear airborne data collection program concerning the brightness temperature behavior of snow on lake ice. Airborne radiometer data have been obtained over two lakes near Helsinki since 2004. During 2011-2014 the flight schedule was more intense providing data for a variety of snow and weather conditions, ranging from newly formed ice with little snow on top of ice to mid-winter conditions and to the snowmelt season. A forested area and an open agricultural area next to the lakes provided data in order to compare the results for snow on land with those for snow on lake ice.

Two radiometers were used for data collection: (1) in every campaign we used our HUTRAD system; it operates at five frequencies between 6.9 and 36.5 GHz and provides both vertically and horizontally polarized data at an incidence angle of 50 degrees off nadir, and (2) occasionally, we used our HUT-2D interferometric imaging radiometer, which operates at 1.4 GHz and covers an incidence angle range of up to ±25 degrees off nadir with a swath of 95 % of the flight altitude. The radiometers were accommodated onboard our Skyvan research aircraft. Relevant in-situ data were collected concurrently with airborne measurements.

Our data show that two factors mainly determine the brightness temperature behavior of snow on lake ice: (1) at higher frequencies the brightness temperature mainly depends on snow grain size, and (2) at lower frequencies presence of water on top of ice may cause the brightness temperature to vary substantially from that for dry conditions. We have also compared experimental data for various snow/ice conditions with simulations performed with the HUT Snow Emission Model, resulting in reasonably good agreement with experimental data.