Recent Advances in Microwave Radiometry of Snow on Lake Ice

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Methods for retrieval of the water equivalent of snow on terrain are mostly based on using space-borne Ku and Ka band microwave radiometer data [1]. Retrieval is only possible when snow cover is dry. In northern lake-rich regions the effect of lakes and, additionally, other land-use categories to the brightness temperature leads to the mixed-pixel problem: the observed brightness temperature includes contributions from forested areas, open areas, frozen lakes, etc. within the antenna beam. Hence, the brightness temperature behavior as a function of snow characteristics has to be known at all used frequencies and separately for each land-use category. The best way to determine these behaviors is to conduct measurements with an airborne multi-frequency radiometer under various snow and weather conditions. The spatial resolution of space-borne radiometers at Ku and Ka band is so modest that detailed information for each land-use category cannot in practice be obtained from space-borne radiometers.

There was some interest in microwave remote sensing of lake ice and its snow cover in the U.S. in the 1980's [2,3] and in Canada 20 years later [4]. Activities in Finland started with the Helsinki University of Technology's (now part of Aalto University) airborne HUTRAD radiometer [5-7]. The main driver is the fact that information on the behavior of the brightness temperature of the snow/lake ice system is needed to correct for the presence of lakes when retrieving snow water equivalent for large areas using space-borne radiometer data.

We have studied the brightness temperature behavior of the snow/lake ice system since 2004 under various weather conditions by conducting airborne radiometer measurements first over a frequency range of 6.9 to 36.5 GHz and, recently, of 1.4 to 36.5 GHz by adding the HUT-2D interferometric radiometer to the sensor suite. The test site includes two lakes of different sizes and, additionally, two terrain areas with different land-use categories (forested and open). This allows us to compare the behavior of the brightness temperature of snow on lake ice with that of snow on terrain.

Our results indicate that radiometer response to the snow/ice system depends primarily on three parameters: frequency, snow grain size, and presence of water on top of the ice layer. At 36.5 GHz the brightness temperature mainly depends on the dry snow surface grain size; during the melting season a thin layer of snow on lake ice may cause a decrease in brightness temperature comparable to that caused by a 50-cm snowpack on terrain. During the melting season, morning (dry snow) and afternoon (moist snow layer on top) measurements may provide drastically different results especially at 36.5 GHz. At low microwave frequencies the presence of water on top of ice may cause the brightness temperature to vary tens of Kelvins from that for dry conditions.

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