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Results from Arctic Snow Microstructure Experiment (ASMEx) 2014

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Introduction

Snow is an important freshwater source for agriculture, manufacturing, and drinking for large regions around the world. Global observations of snow are vitally important in the studies of hydrological, meteorological, and climatological cycles and processes. Snow mass can be estimated from naturally emitted microwave radiation. However, these estimates can have large errors associated with them, due to uncertain extinction properties within the snowpack. Snow slabs from the natural snowpack were observed using the FMI SodRad Radiometers in Sodankylä, Finland. Data collected is used with two single layer semi-empirical models, HUT and MEMLS, to calculate the brightness temperature errors.

Snow Emission Models

HUT Snow Emission Model

The HUT single layer snow emission model [1] is a semi-empirical model, based on radiative transfer theory. It's basic assumption is that the scattering is concentrated in the forward direction, and treats the total emission from the snow pack as the sum of the emission from the underlying ground and the snow itself, as shown below:

$$T_B(d^-,\theta) = T_B(0^+,\theta)e^{-(k_e - qk_s)d\sec\theta} + \frac{k_a T_S}{k_e - qk_s}\left(1 - e^{-(k_e - qk_s d\sec\theta)}\right)$$

MEMLS

MEMLS [2] is a semi-empirical model, based on a two-flux sandwich model (up and downwelling radiation), derived from a six-flux model (fluxes in the horizontal and vertical directions).

$$\frac{dT_\uparrow}{dz} = -k_a\left(T^\uparrow - T\right) - k_{sb}\left(T^\uparrow - T^\downarrow\right)$$

ASMEx Outline

ASMEx consisted of radiometric, stratigraphic, and in situ measurements of snow slabs extracted from the natural snowpack. The measurements included:

- Six frequencies (10.7, 18.7, 21.0, 36.5, 89.0, and 150 GHz)
- Two different bases (absorber and reflector)
- Temperature, Density, Specific Surface Area (measured with an IceCube machine [3]), SnowMicroPen [4], Micro-tomography, grain-size profiles

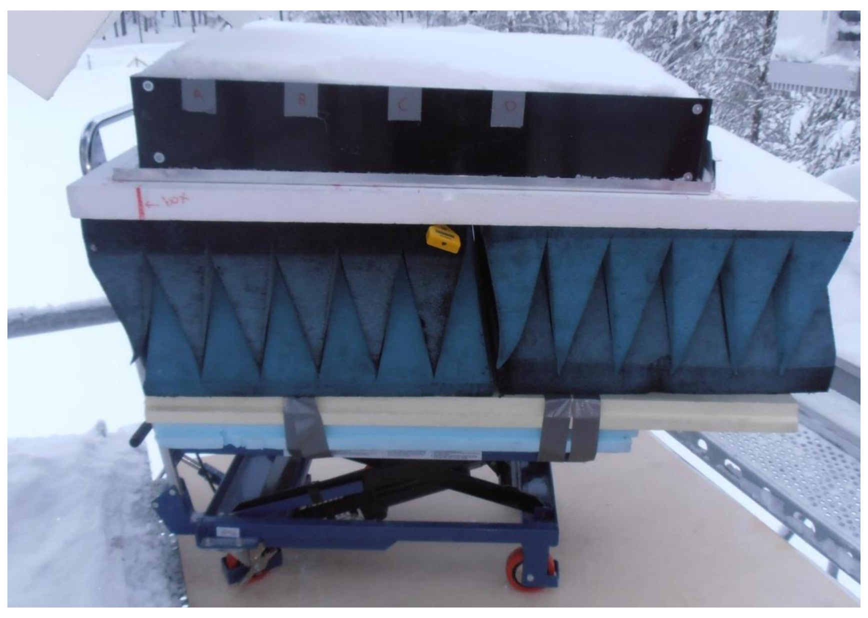

Figure 1: Slab A01 on the reflecting metal base.

In Situ Analysis

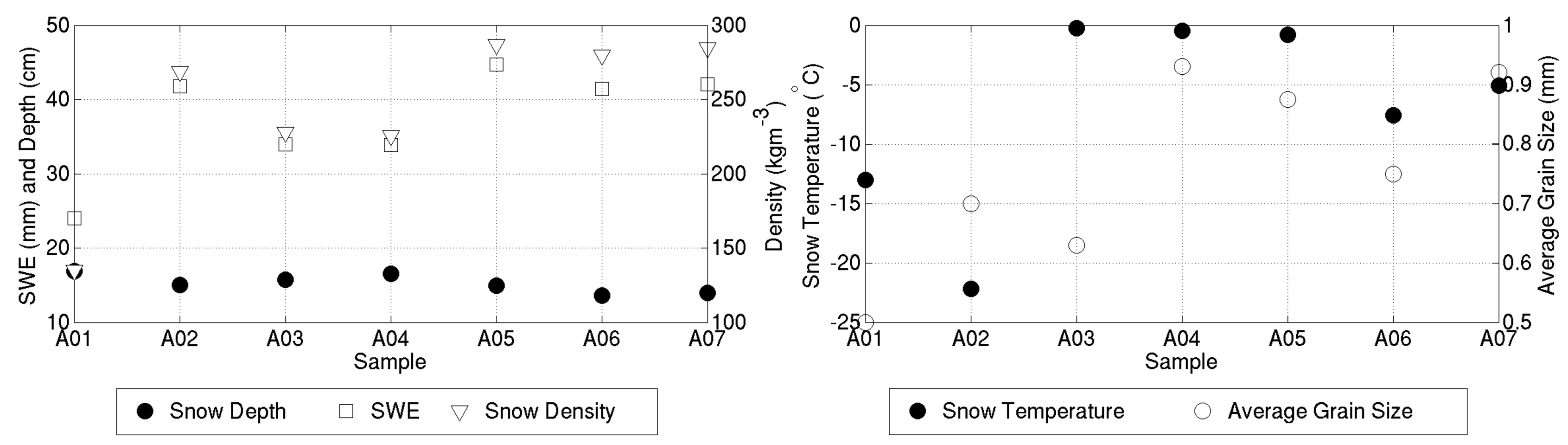

Figure 2: In Situ properties of the 7 slabs.

Radiometric Analysis

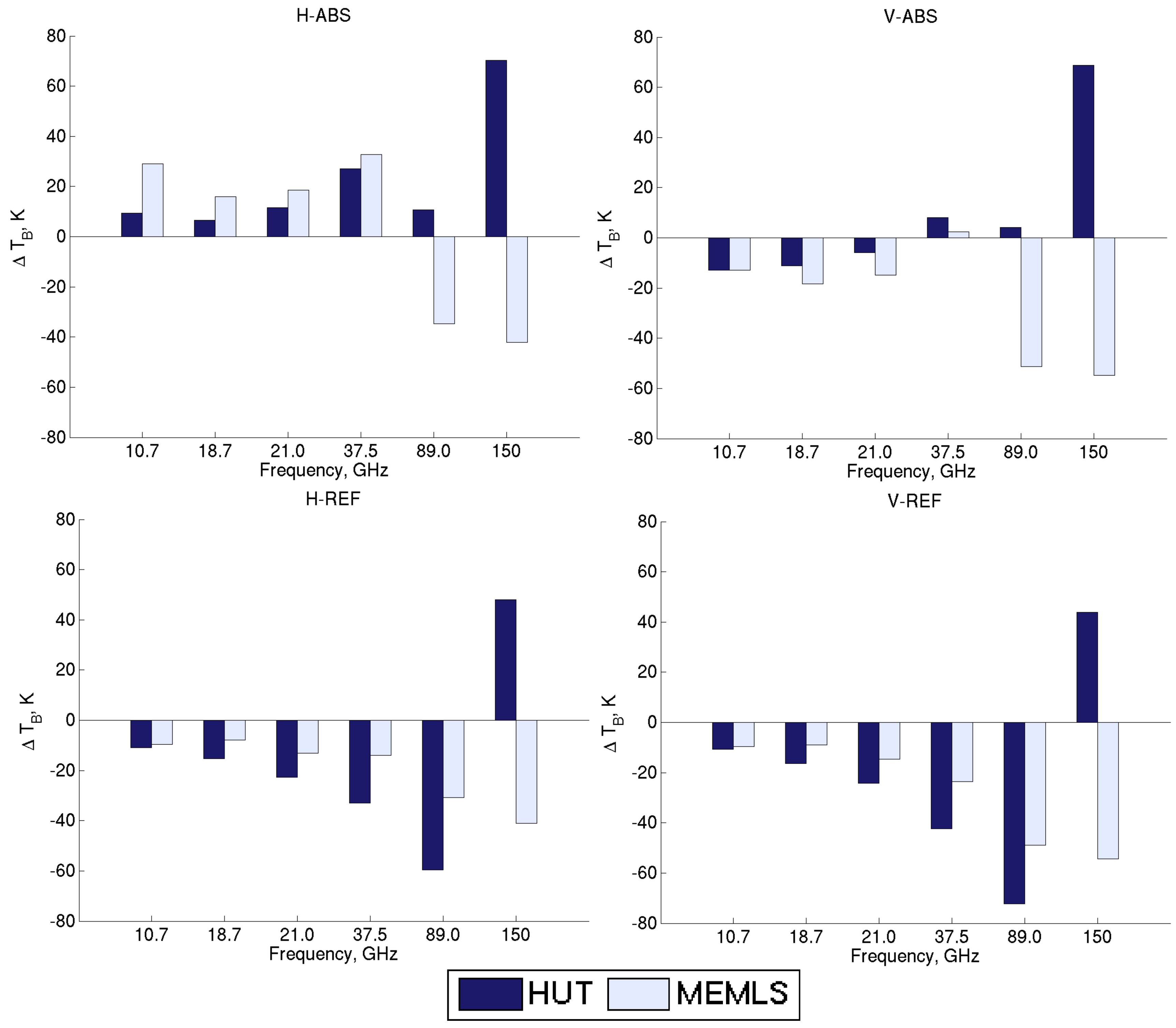

Figure 3: Mean brightness temperature errors at horizontal (H) and vertical (V) polarizations, for the absorbing (ABS) and reflecting (REF) bases.

It can be seen that, for the absorbing base cases, HUT provides a more accurate simulated brightness temperature than that from MEMLS, across all frequencies with the exception of 150 GHz. MEMLS provides more accurate estimations for the reflective base cases.

Current models can produce brightness temperatures similar to those of observed snow slabs, although unaccounted internal scattering can produce large errors. These large errors will be reduced in the future, via an improved extinction coefficient calculated from microstructure, in situ, and radiometric data collected from ASMEx 2014 and 2015.

References

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