Extinction of Microwave Radiation in Snow

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Background

- Microwave Remote Sensing of Snow
- Helsinki University of Technology (HUT) snow emission model

Project Aims

Arctic Snow Microstructure Experiment (ASMEx)

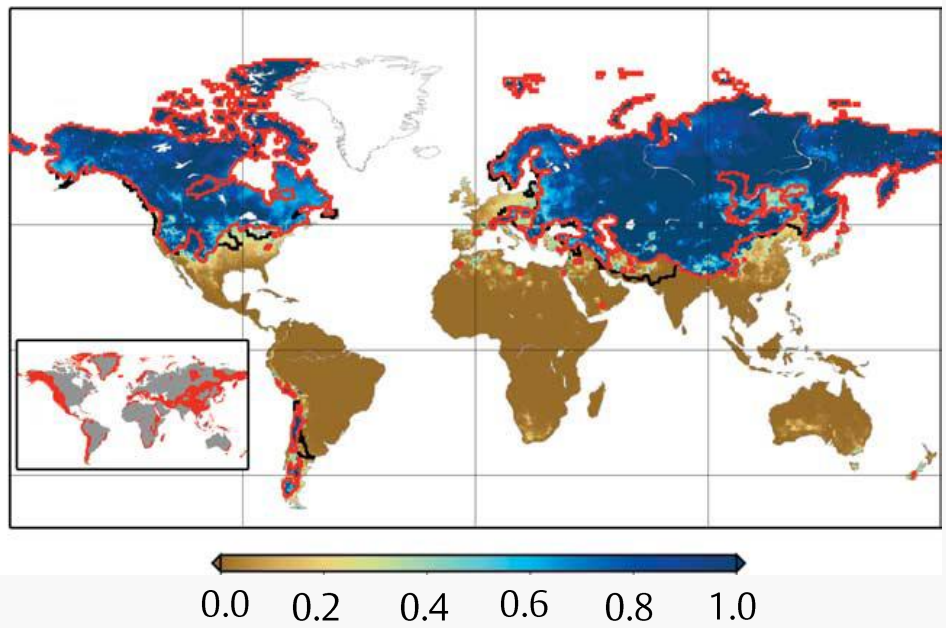
Preliminary Results

Summary

Why is snow important?

Snow plays an important role in numerous global cycles and interactions.

- Hydrological, Meteorological, and Climatological
- Hydropower production
- Freshwater and Flood Forecasting



1/6 of worlds population rely on snow melt for their water supply (Barnett et al, 2005)

Microwave emission from snow

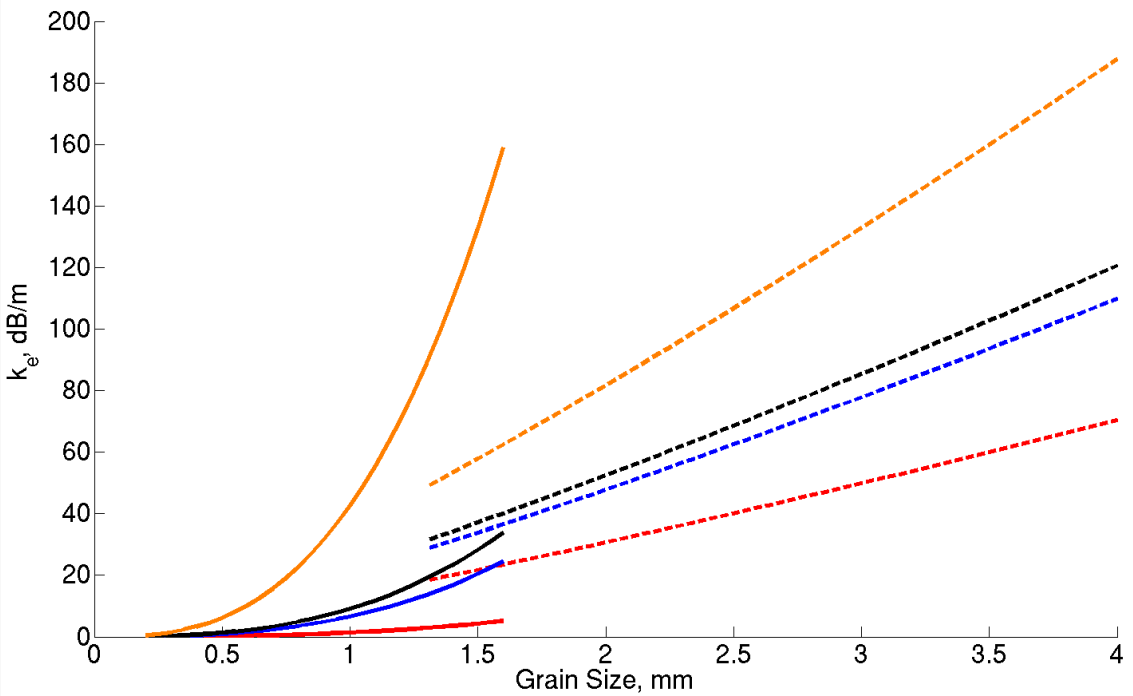
Microwave emission from snow consists of two separate contributions

- Emission from the snowpack / Emission from the underlying ground (Chang et al, 1987, and Wiesmann and Mätzler, 1999)

Snow crystals act as scattering centres for upwelling radiation

- Deeper snow leads to more scattering
- Larger grains leads to more scattering

Extinction of Microwave in Snow



10.7GHz – Red

18.7 GHz – Blue

21.0 GHz – Black

36.5 GHz - Orange

$k_e = 0.0018 f^{2.8} d^2$ Hallikainen et al, 1987(solid)

$k_e = \gamma (f^4 d^6)^{\delta}$ Roy et al, 2004 (dashed)

Project Aims

The aims of my PhD are as follows:

- Take natural snow samples over 2 winter campaigns.
- Develop a revised model for the amount of extinction (scattering and absorption) within a natural snow pack.
- Use the revised model within the HUT snow emission model, to improve its accuracy.

HUT snow emission model

Semi-empirical model, based on radiative transfer theory

- The basic assumption of the HUT model is that scattering is concentrated in the forward direction.

$$T_B(d^-,\theta) = T_{B,g} + T_{B,s\uparrow}$$

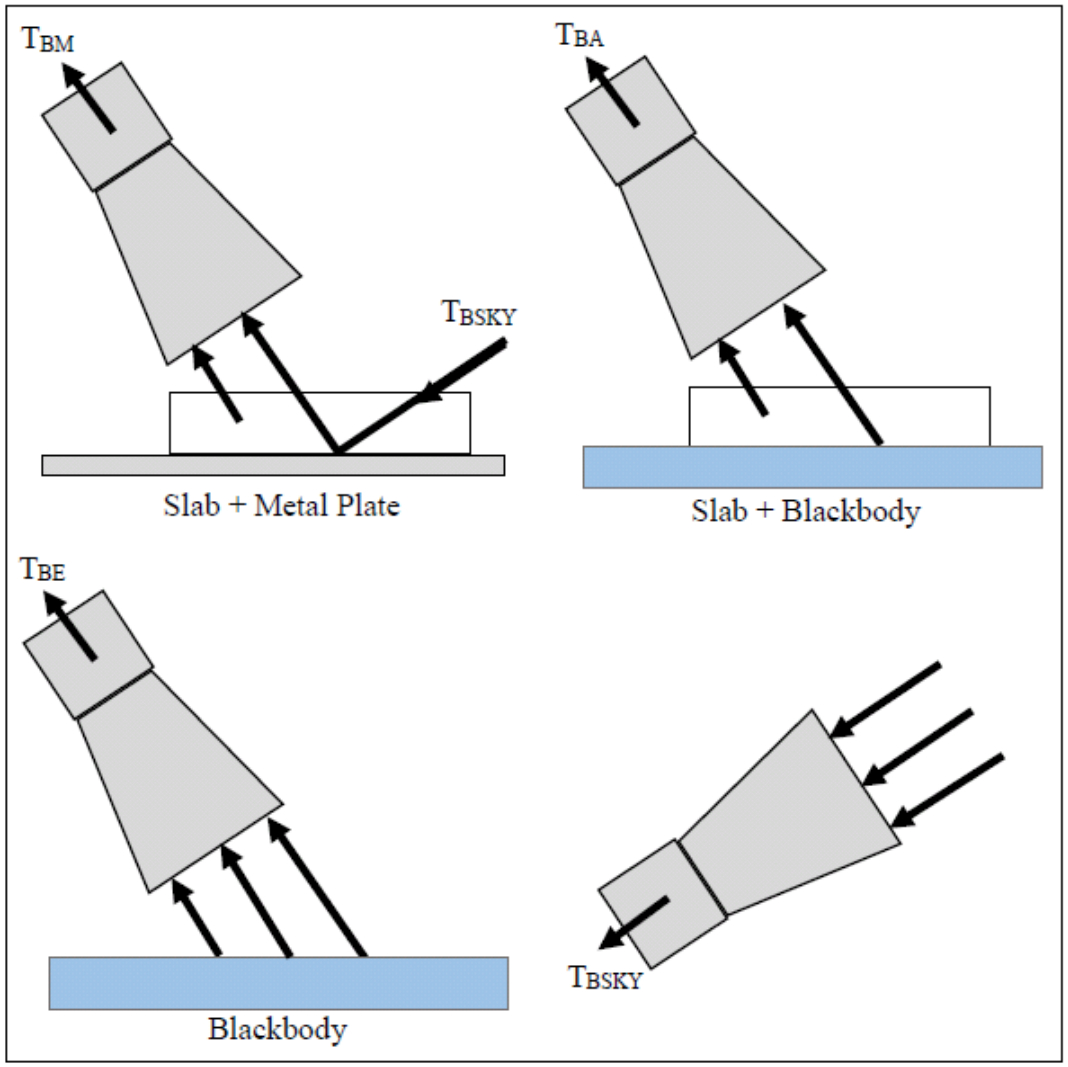
$$T_B(d^-,\theta) = T_B(0^+,\theta)e^{-(k_e-qk_s)dsec\theta} + \frac{k_a T_S}{k_e-qk_s}(1 - e^{-(k_e-qk_s dsec\theta)})$$

ASMEx Location

Based at the FMI Arctic Research Centre, Sodankylä

~100 km North of Arctic Circle

ASMEx Set Up


T_{BM}
T_{BSKY}
Slab + Metal Plate
T_{BA}
Slab + Blackbody
T_{BE}
Blackbody
T_{BSKY}

Radiometric Measurements

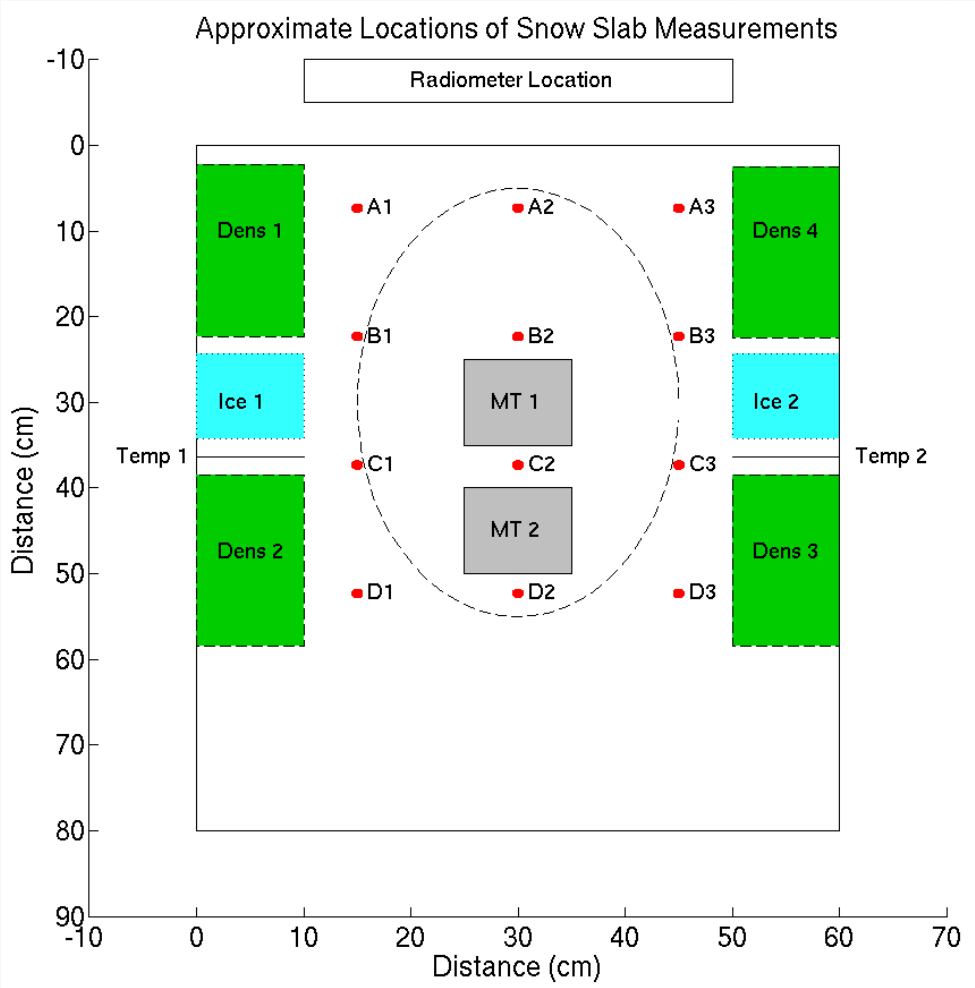
6 frequencies

- 10.7-, 18.7-, 21.0-, 36.5-, 90.0-, and 150.0 GHz
- Both Horizontal and Vertical Polarisation
- Angles: 45°, 50°, and 55°

In Situ Measurements

Various in situ measurements taken:

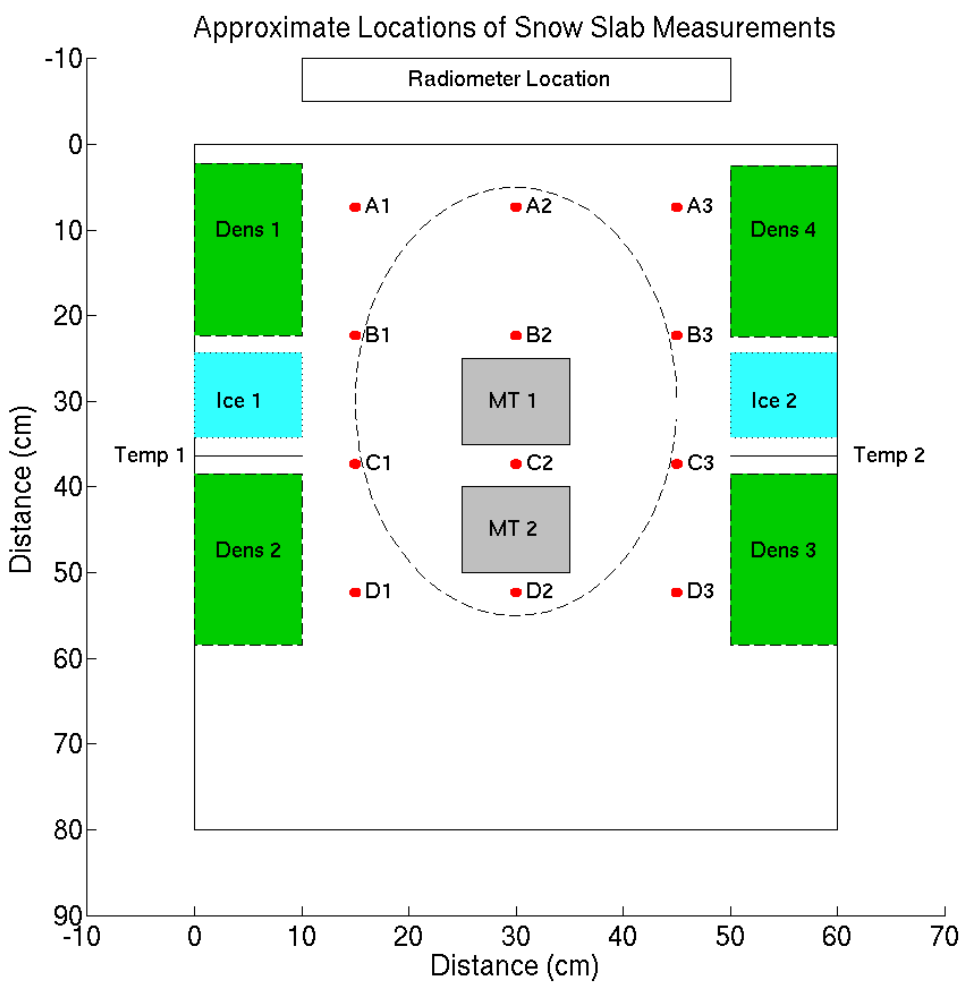
- Temperature
- Density
- Grain size
- SSA profiles



Stratigraphy Measurements

Various stratigraphy measurements:

- SnowMicroPen (SMP)
- Micro-tomography



Problems faced

Inconsistent radiometer measurements

- 36.5 GHz broke after 2nd slab (A02)
- 90- and 150 GHz available after 4th slab (A05)

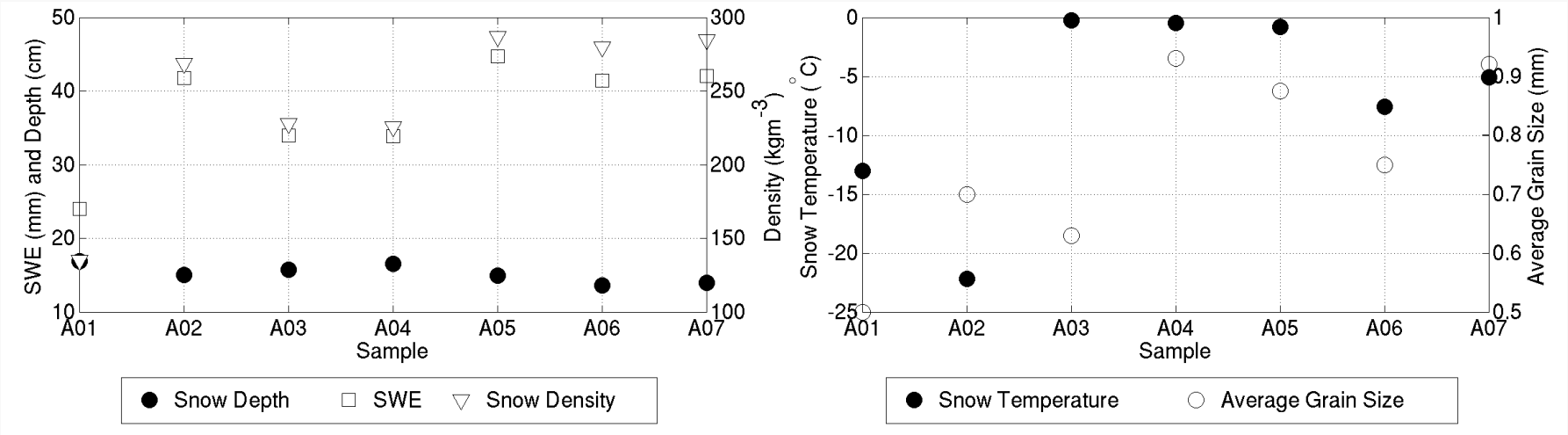
Above average temperatures limited potential "dry" days

- February 2014, 9°C warmer than 1981 – 2010 average
- March 2014, 4°C warmer than 1981 – 2010 average

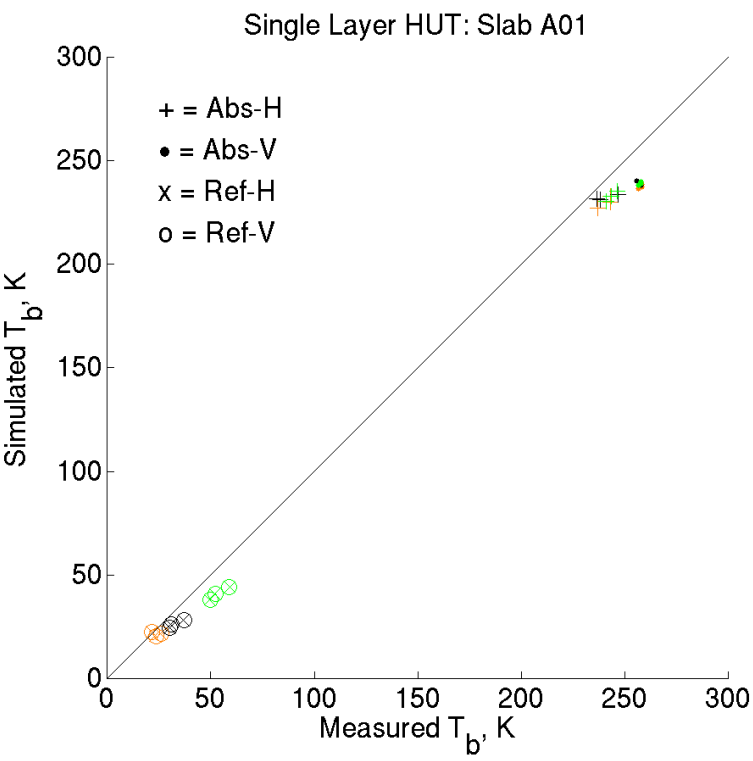
In Situ Analysis

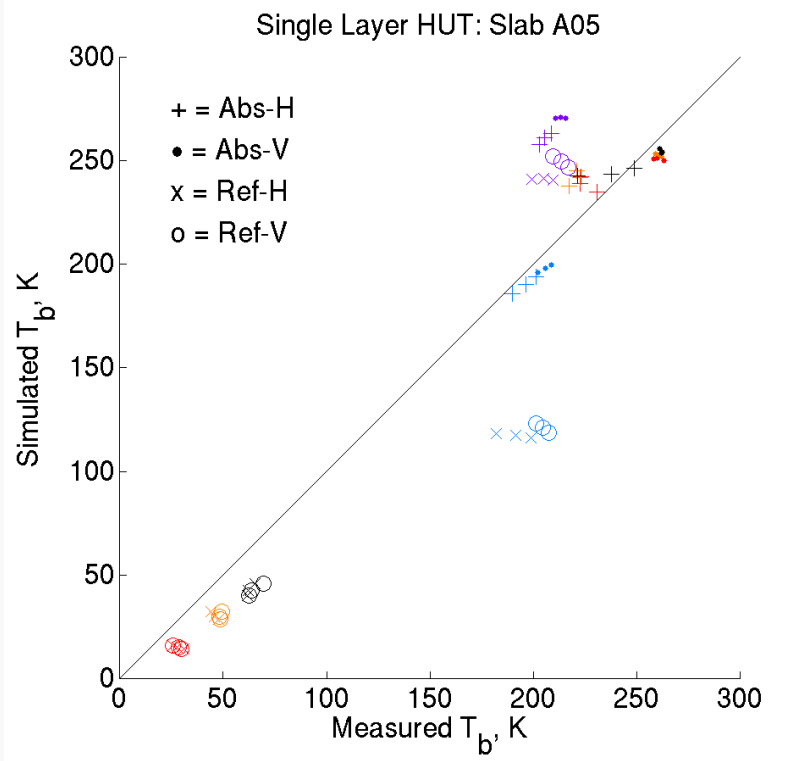
In total, 7 slabs were measured during ASMEx 2014

- A03 was classified as "wet" due to the air temperature rising above 0°C during the radiometric measurements.



Modelling Analysis





10.7 GHz = Red

18.7 GHz = Orange

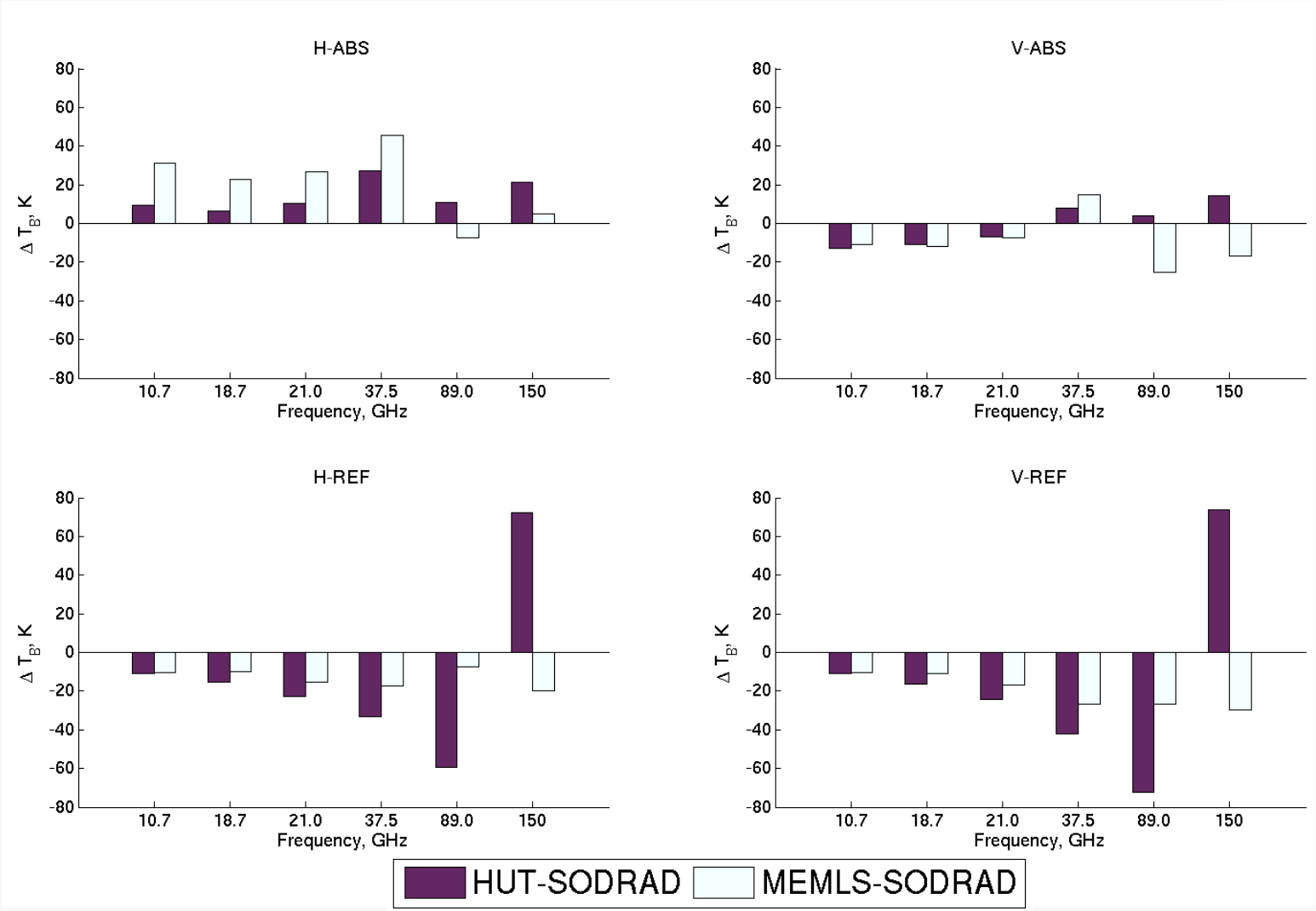
21.0 GHz = Black

36.5 GHz = Green

90.0 GHz = Blue

150.0 GHz = Purple

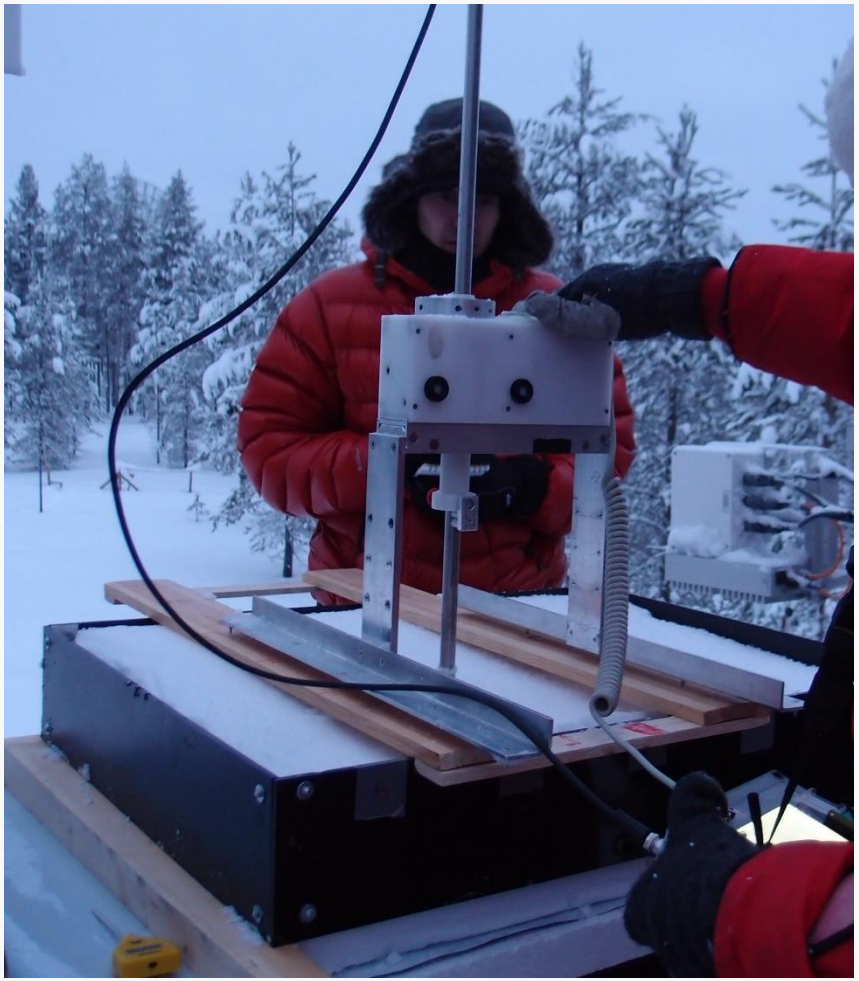
Modelling Analysis



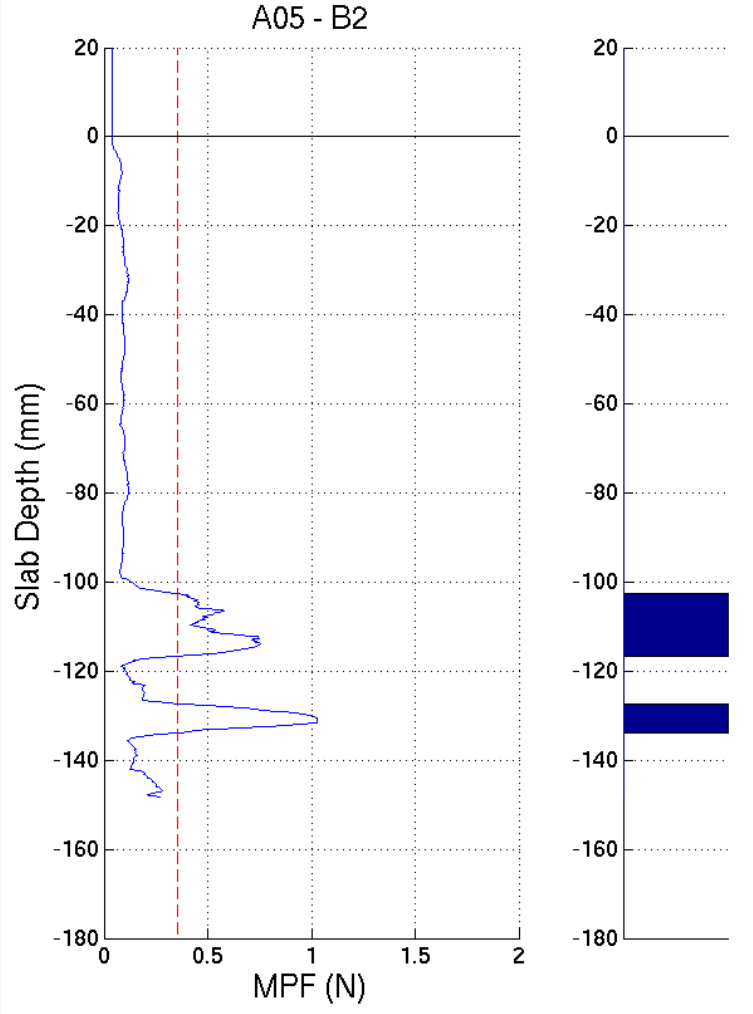
SnowMicroPen (SMP) Analysis

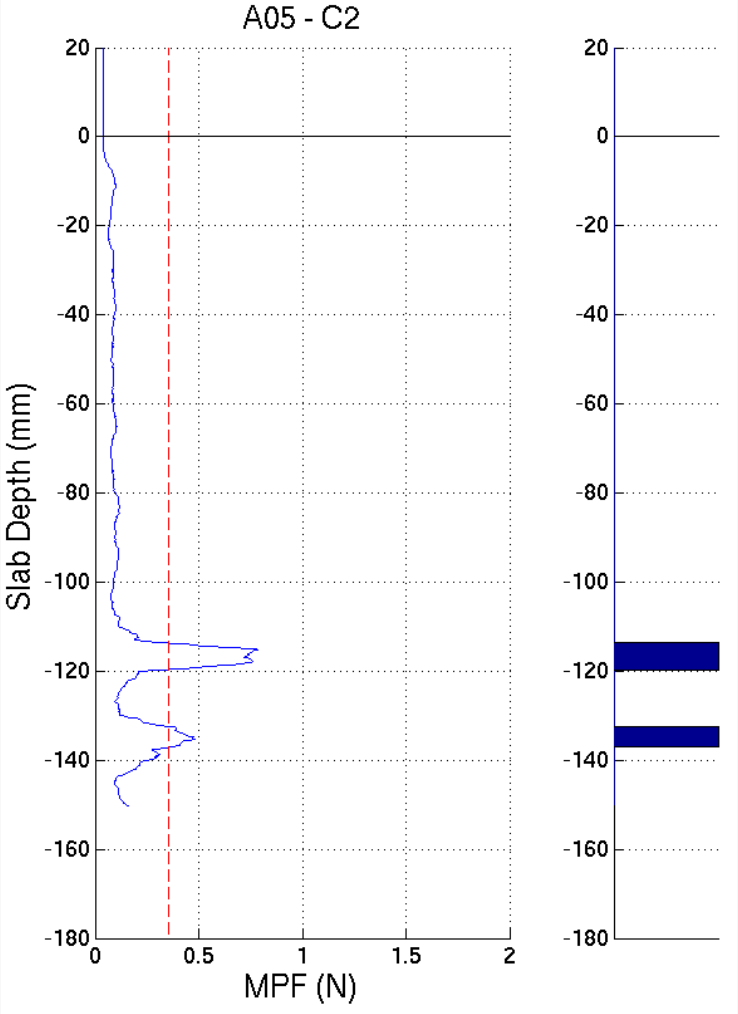
12 Profiles per slab

- Homogeneous slabs :
  - A01, A03, A07
- Non-homogeneous slabs:
  - A02, A04, A05, A06



SMP Analysis





Potential Future Work

- ASMEx 2015 Winter Campaign
  - Aim to take weekly slab samples
- Compare In Situ data with both SMP and MT data
- Extinction Coefficient modelling
  - Following methodology of Wiesmann et al 1999
- Implementation and Evaluation of Extinction Coefficient
  - Natural Snow pack observations and simulations

Summary

- Microwave emissions consist of two contributions
  - Emission from the snow and from the underlying ground
- Snow crystals act as scattering centres for upwelling radiation
- ASMEx and HUT emission model
- HUT model is more accurate for absorbing base simulations
- Lots of work still to be completed