FINNISH METEOROLOGICAL INSTITUTE

University of Reading

Arctic Snow Microstructure Experiment

ASMEx

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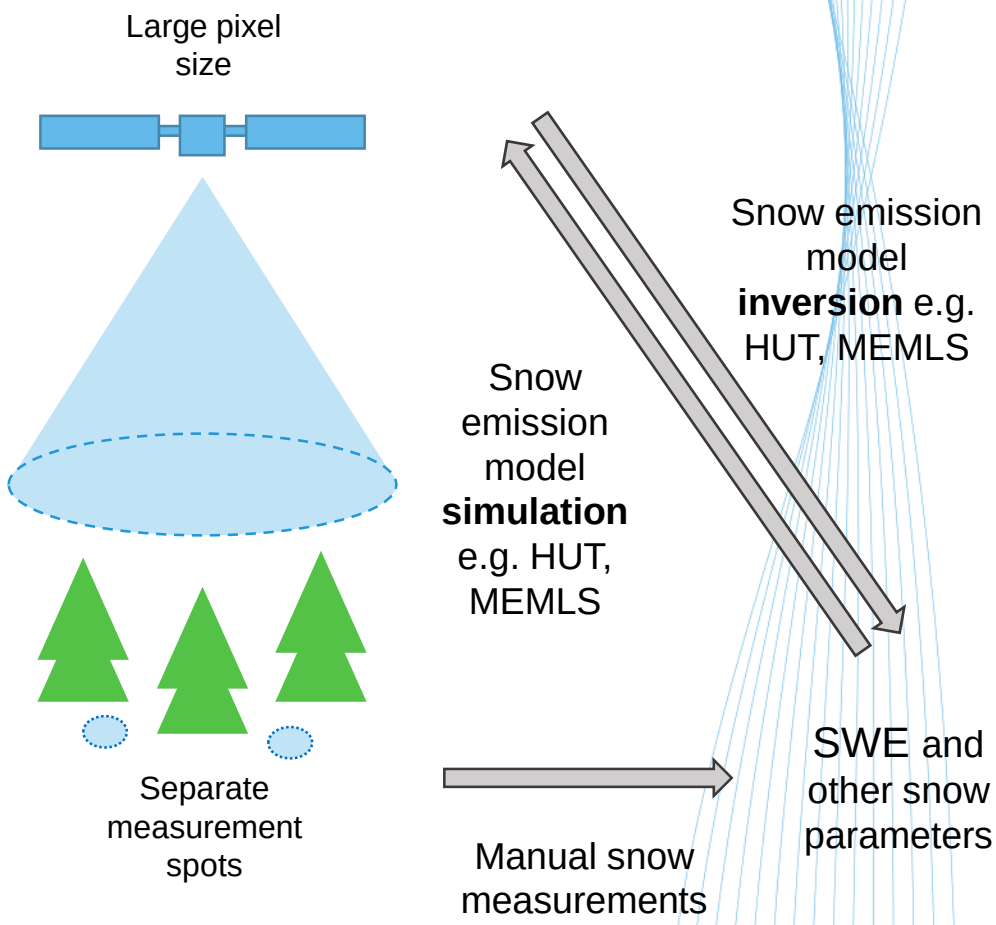
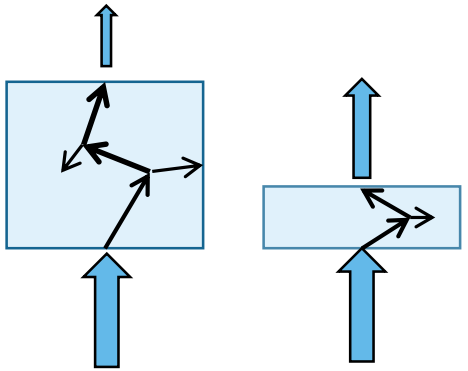
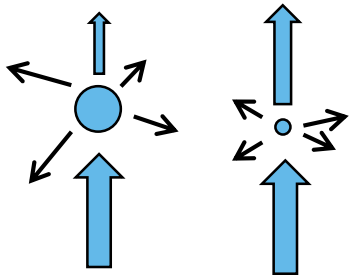


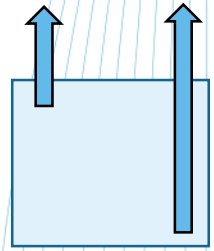
Scattering within snow

- Emission of microwave radiation originated from ground and snow (brightness temperature) is measured with microwave radiometer
- More scattering in snowpack ⇨ smaller brightness temperature observation

- Scattering
  - Snow depth
  - Grain size
  - Frequency







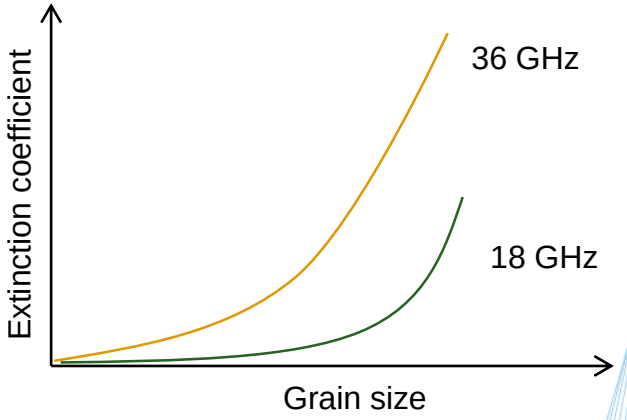
High freq. Low freq.

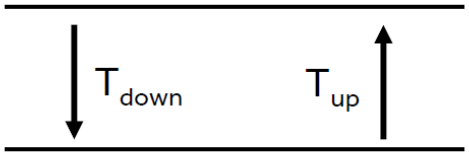
Extinction of microwaves

- Described in models with scattering coefficient and absorption coefficient
- Scattering coefficient depends on snow microstructure (grain size/correlation length) and frequency
- Described in HUT model as $k_e = k_s + k_a$

$$k_s = 0.0018 f^{2.8} D_o^{\ 2}$$

- Simplified two flux method (radiation up and down) by Wiesmann 1998



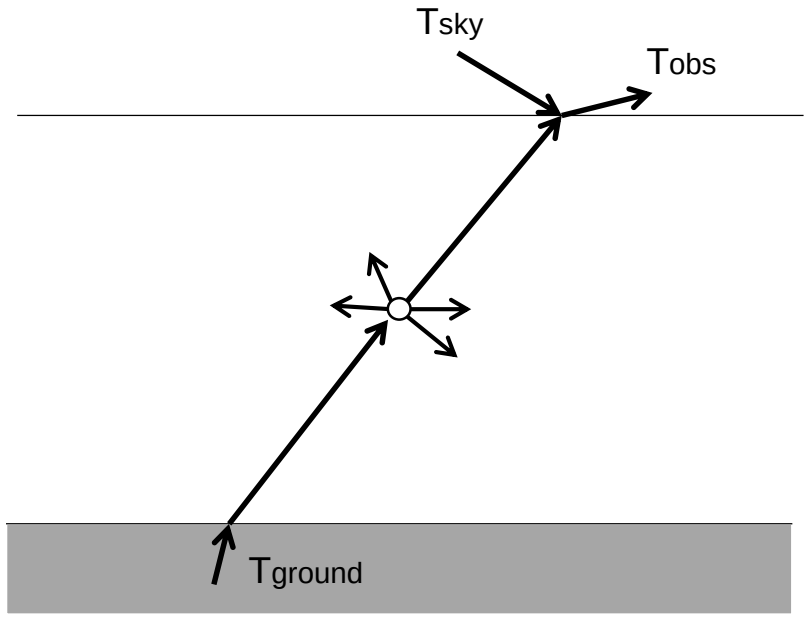


$$\frac{dT_{up}}{dz} = \gamma_a'(T_{phys} - T_{up}) + \gamma_b'(T_{down} - T_{up})$$

$$\frac{-dT_{down}}{dz} = \gamma_a'(T_{phys} - T_{down}) + \gamma_b'(T_{up} - T_{down})$$

Snow emission models

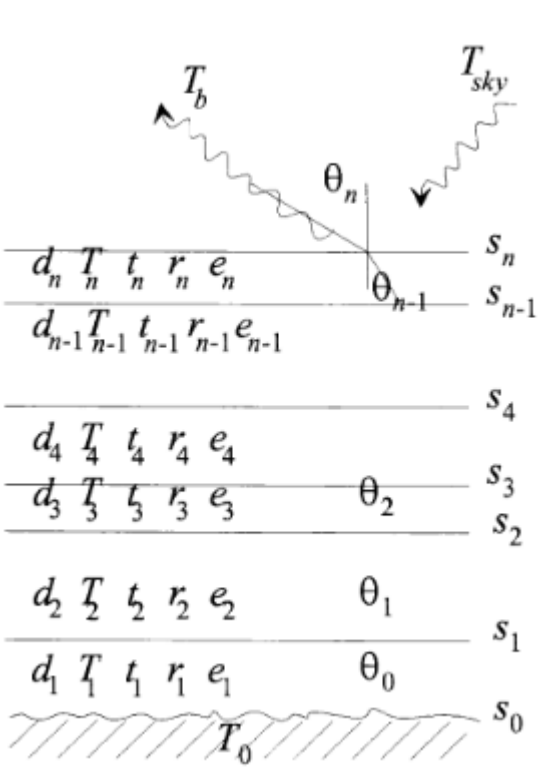
HUT snow emission model

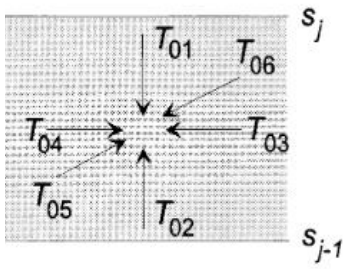


- Helsinki University of Technology snow emission model
- Pulliainen et al. 1999 and Lemmetyinen et al. 2010
- Semi-empirical model
- Radiation is concentrated to the forward direction and only one directional radiation is modelled
- Single layer version and multilayer version

Snow emission models

MEMLS





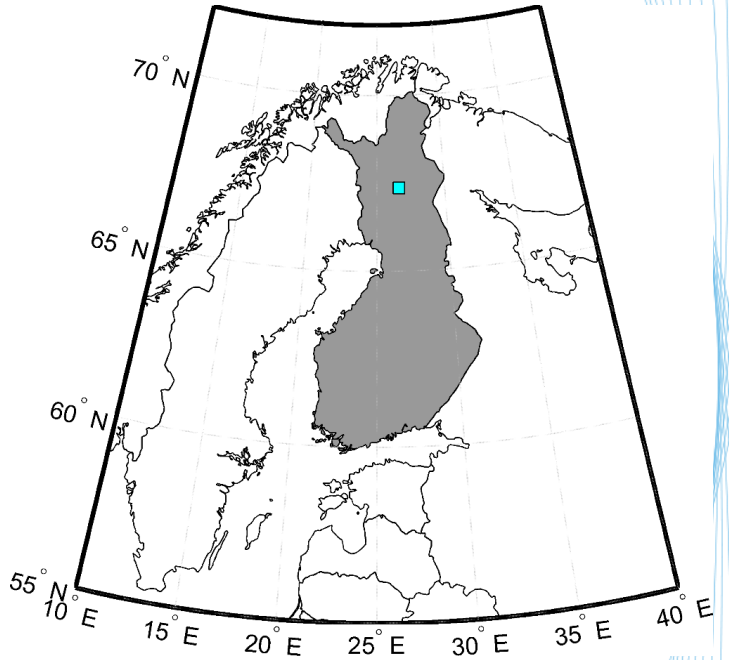
- Microwave Emission Model for Layered Snowpacks
- Wiesmann and Mätzler 1999
- Semi-empirical model
- Model up and down welling radiation in a multilayer snowpack by using six-flux theory

ASMEx

Arctic Snow Microstructure Experiment

ASMEx

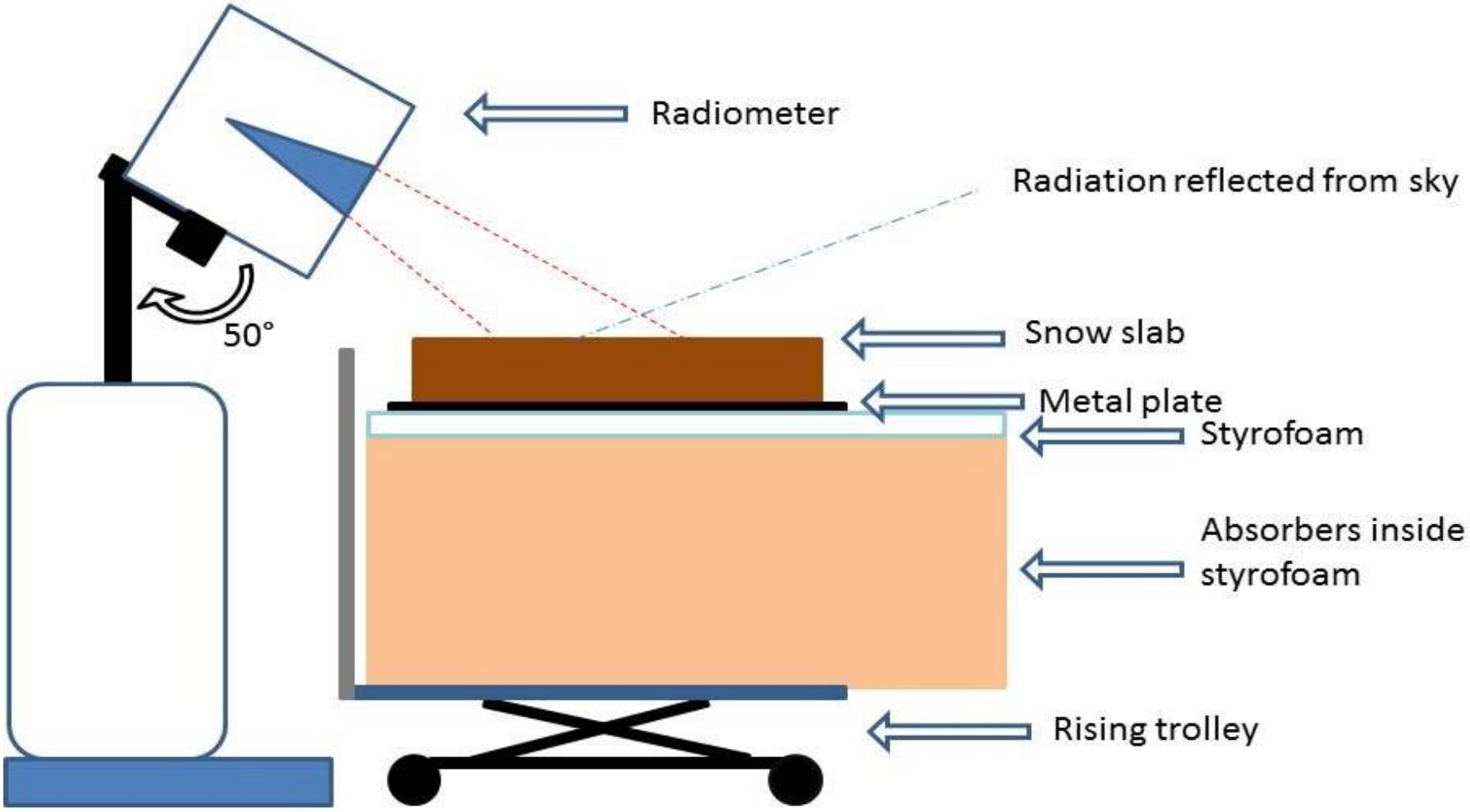
- Location: Sodankylä, Finland
- Measurements during 2 winter seasons 2014-2015
- Radiometer measurements and manual measurements from the same homogenous snow slabs



Snow slab

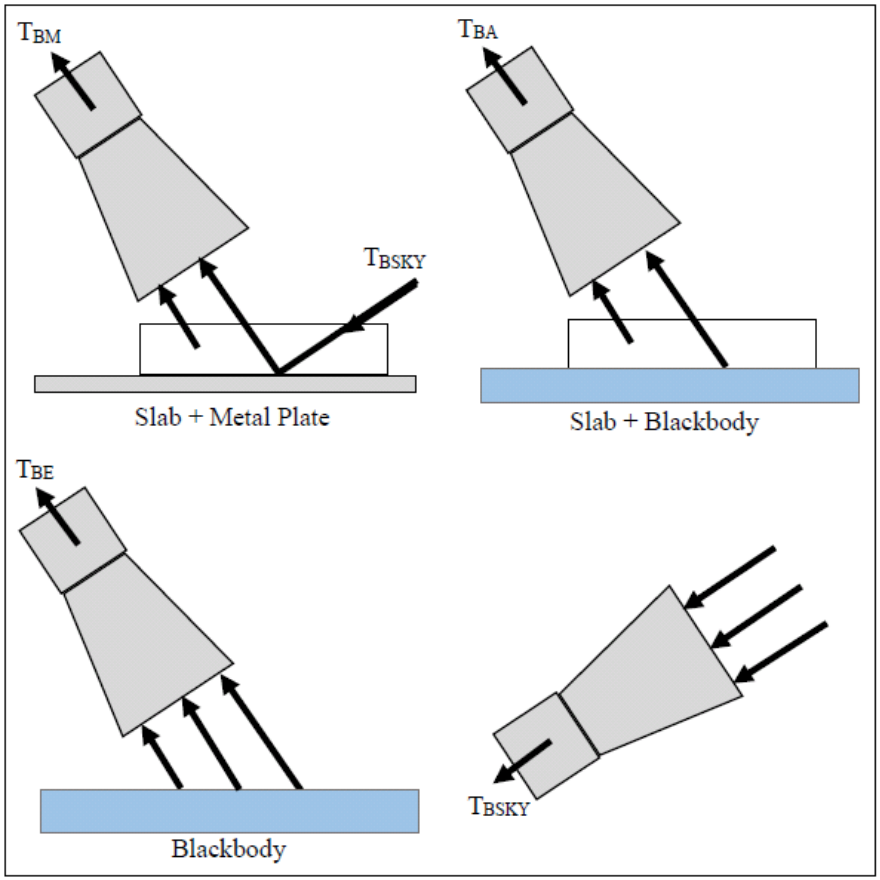
- From natural snowpack
- Homogenous slabs
  - No layers
  - No cracks
- Slabs with different snow types and grain sizes
- Total **14** slabs
  - 13 dry slabs
  - 9 homogenous slabs
- Size 80x60 cm
- Surface of the slabs were artificially smoothened with a metal plate.

Setup for radiometer



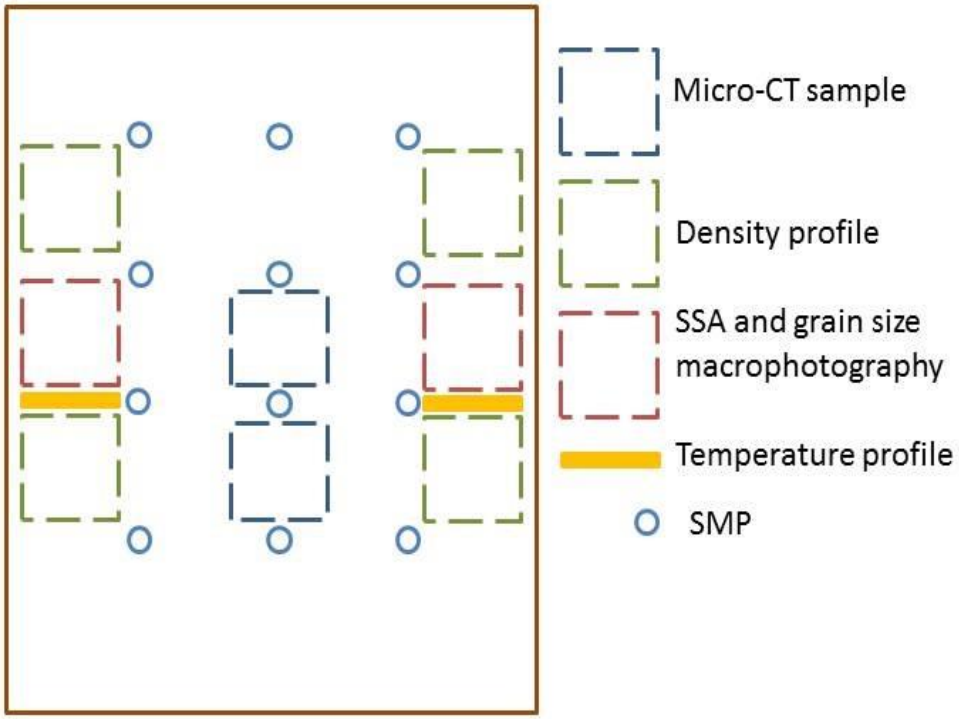
Radiometer measurements

- Brightness temperature measurements with microwave radiometers
- Frequencies: 18.7, 21.0, 36.5, 89.0 and 150.0 GHz
- H and V polarizations
- Inclination angle 50°
- Reflective metal base and absorbing base



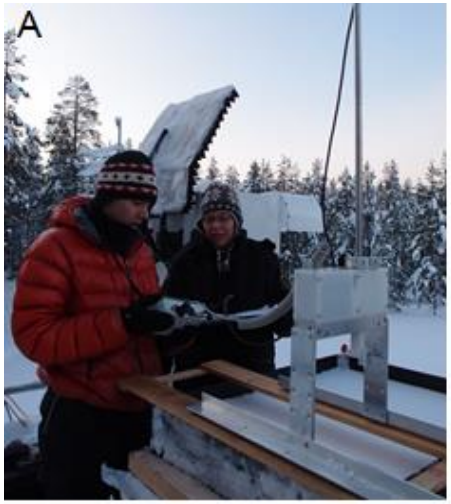
Manual measurements

Snow slab



SMP, SSA, micro-CT are modern methods to study snow microstructure

SMP (SnowMicroPen)



Density

IceCube for SSA (specific surface area)

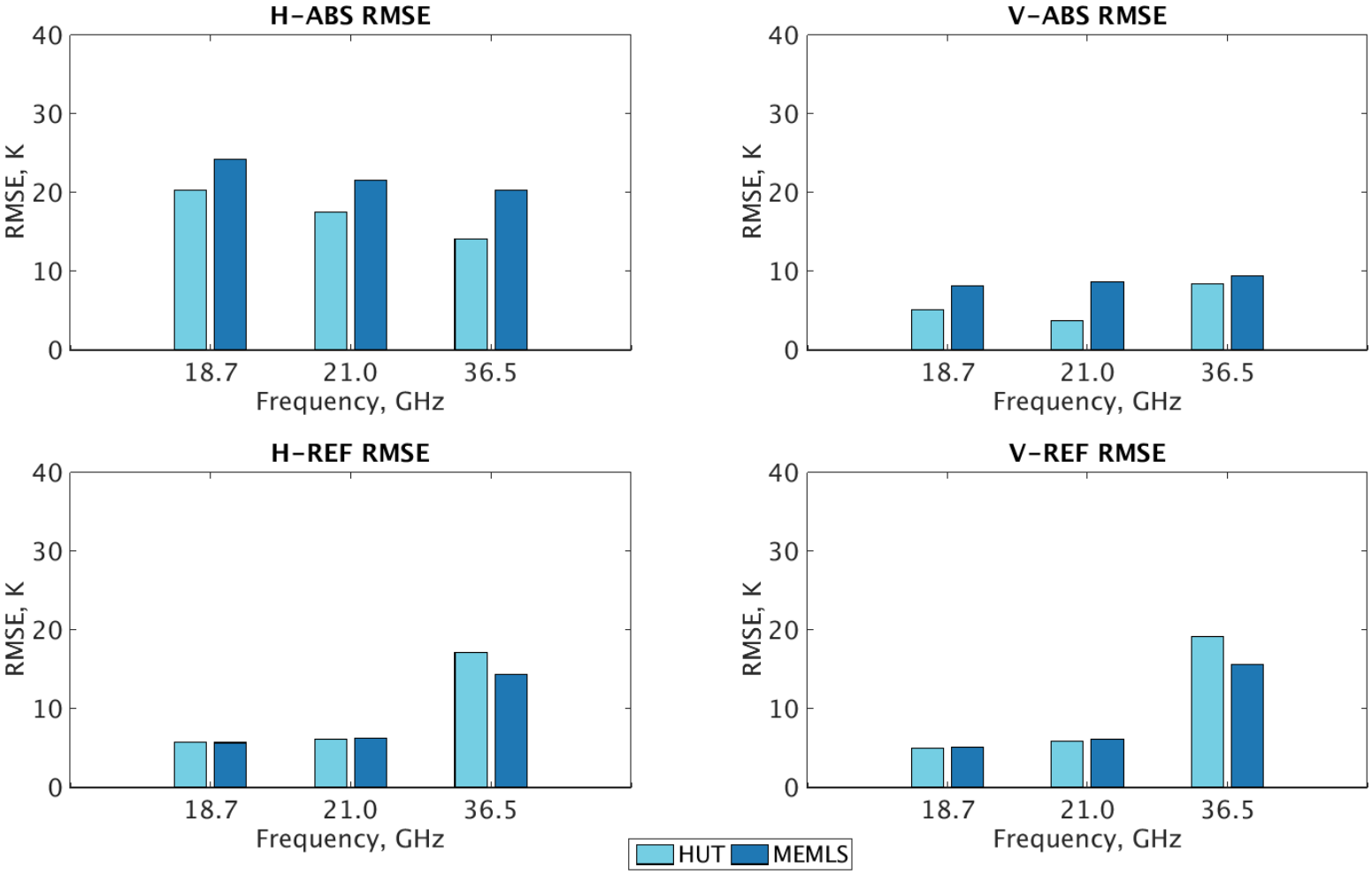
Temperature

Manual measurements

Averaged values of manually measured data

Date	Slab Reference	Snow Temp °C	Density kg/m³	Grain size mm	SWE mm	Depth cm	Homogenous
13/01/2014	A01	-13.1	138	0.5	24.0	17.8	Yes
14/01/2014	A02	-22.2	269	0.7	41.8	15.6	No
11/02/2014	A03	-0.3	228	0.6	34.0	16.6	Yes (Wet)
13/02/2014	A04	-0.5	226	0.9	33.9	18.0	No
03/03/2014	A05	-0.8	287	0.9	44.7	15.6	No
18/03/2014	A06	-7.6	280	0.8	41.5	14.8	Yes
20/03/2014	A07	-5.1	285	0.9	42.0	14.8	No
02/02/2015	B01	-13.2	140	0.5	19.0	14.8	Yes
05/02/2015	B02	-10.9	160	0.5	23.9	13.9	Yes
19/02/2015	B03	-2.6	234	0.6	32.6	14.9	Yes
11/03/2015	B04	-5.4	268	1.1	43.5	16.2	Yes
12/03/2015	B05	-3.2	337	1.9	18.1	5.4	Yes
24/03/2015	B06	-5.4	317	1.3	45.7	14.5	Yes
25/03/2015	B07	-3.7	283	2.0	43.0	15.2	No

Preliminary results, RMSE

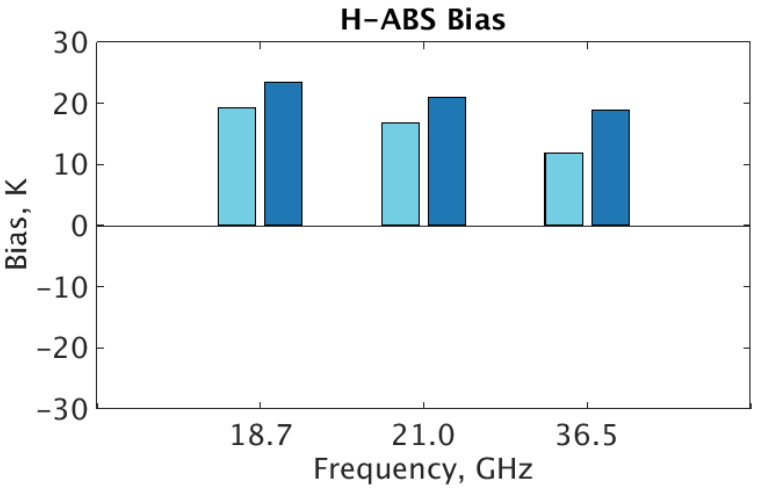


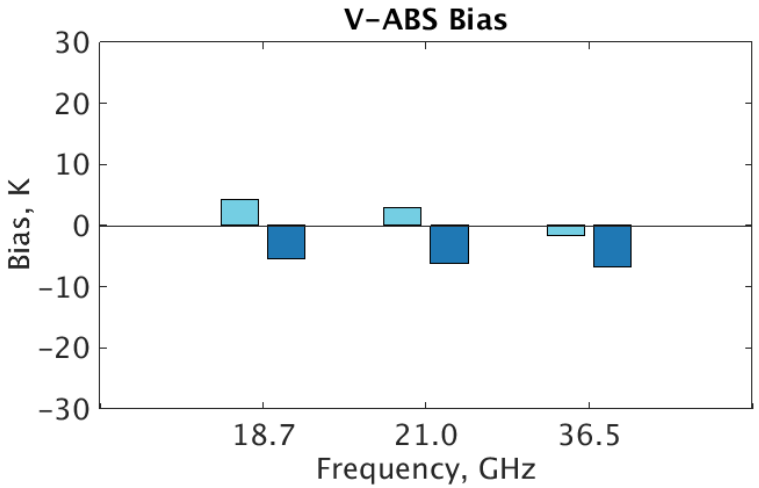
Absorbing base
HUT model produce more accurate simulations

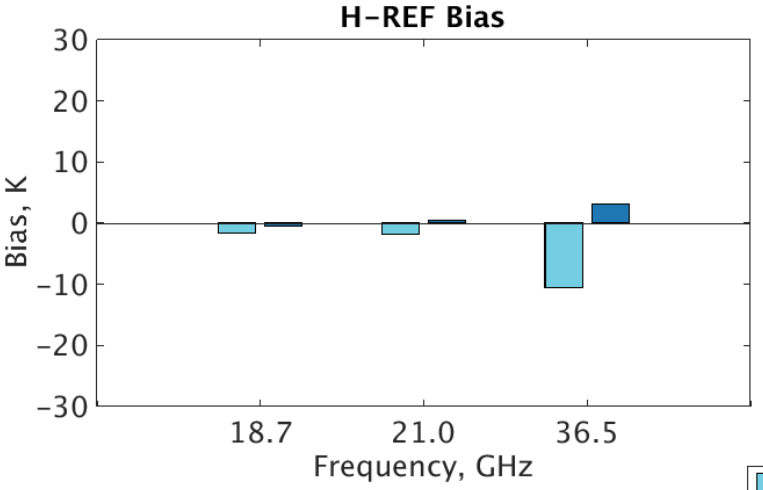
Reflective base
18.7 and 21 GHz simulations are equal

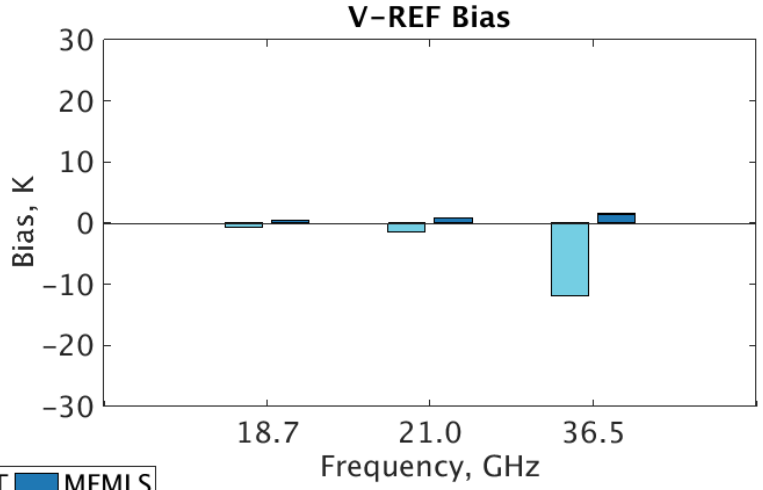
MEMLS produce more accurate simulations for 36 GHz

Preliminary results, bias





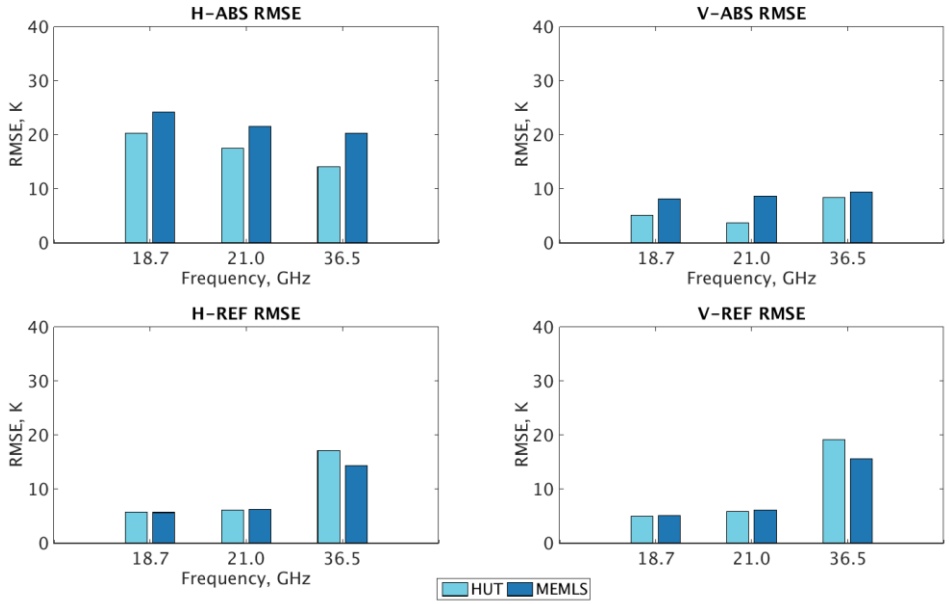




Bias is **largest for absorbing** base **horizontal** polarization (simulation overestimates brightness temperature)

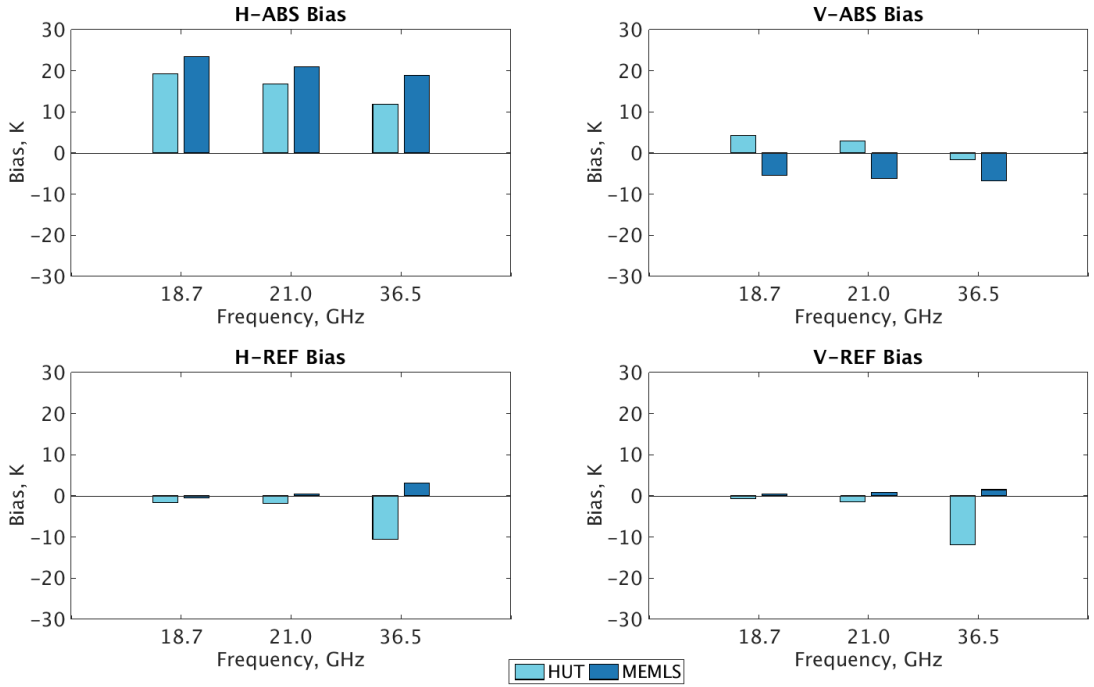
Otherwise biases are small and **HUT** simulation **bias** is **smaller**, exept for reflective base 36.5 GHz (underestimates brightness temperature).

Preliminary results



The errors exist due to internal extinction processes within the snow (imperfectly simulated or not in model input data).

These errors will be reduced in the future, via an improved understanding of internal scattering, and a revised extinction coefficient model.



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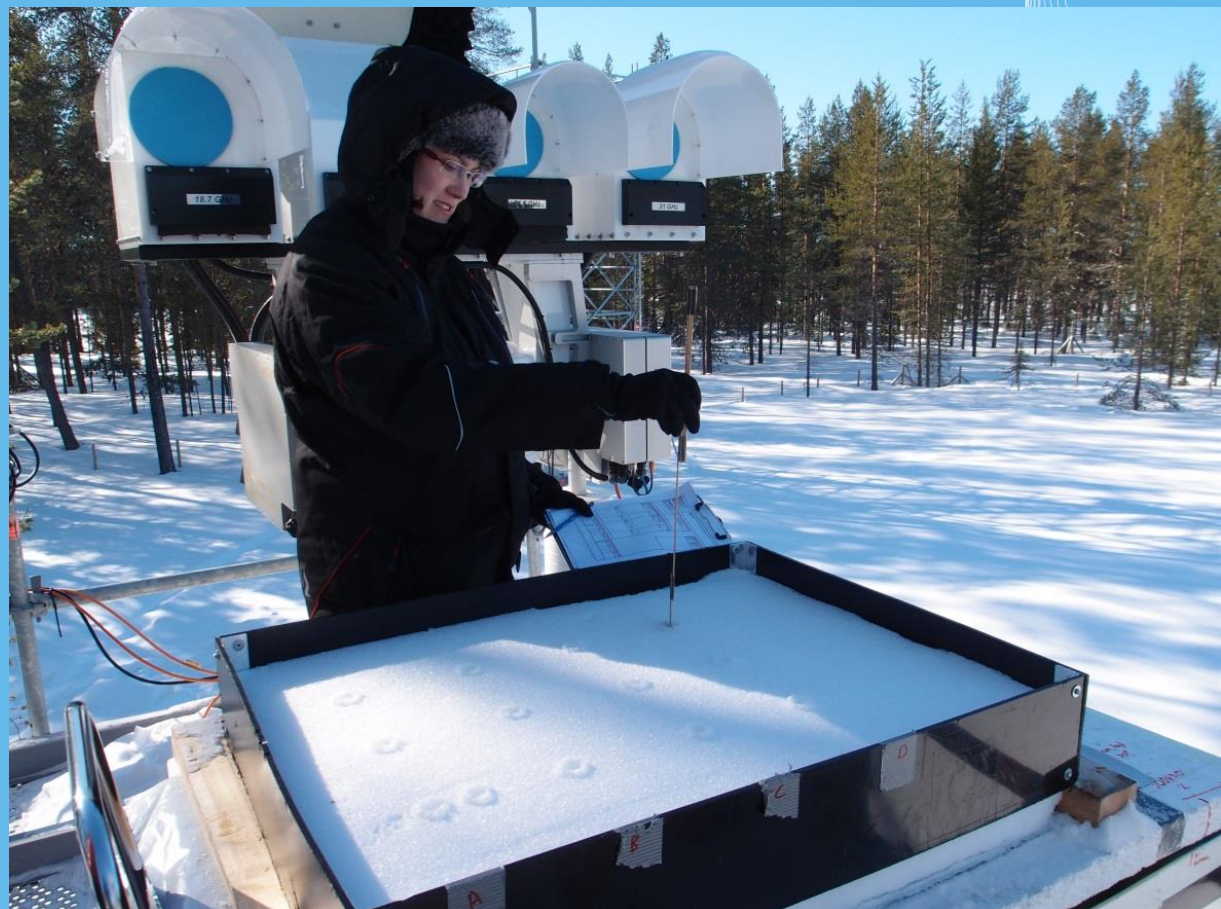

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