Multi-Sensor Ground-based Microwave Snow Experiment at Altay, CHINA

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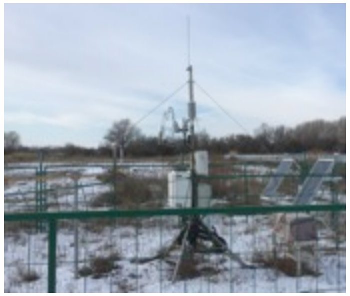
Ground Based Snow Experiment

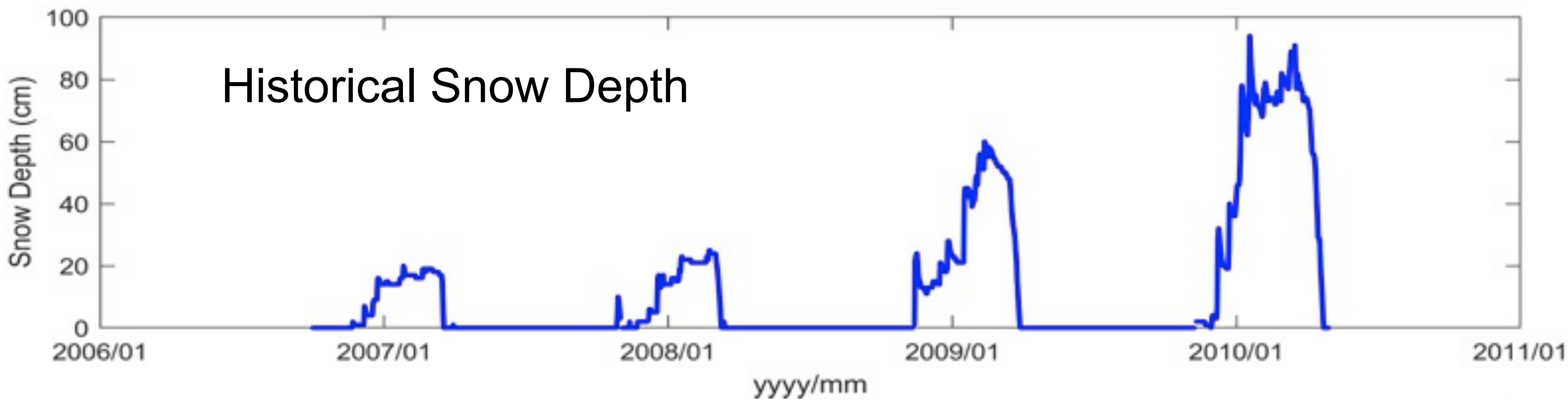
- **Purposes:**
  - Time series active and passive microwave remote sensing signal of snow and frozen soil
  - Modeling and retrieval algorithm tests for **WCOM**
  - Snow melting model development
- **Time:** Oct. 2017 to Mar. 2018
- **Location:**
  - National Reference Meteorological Station at Altay, Xinjiang, China

Landuse map 2010 from the National Geomatics Center of China (NGCC)

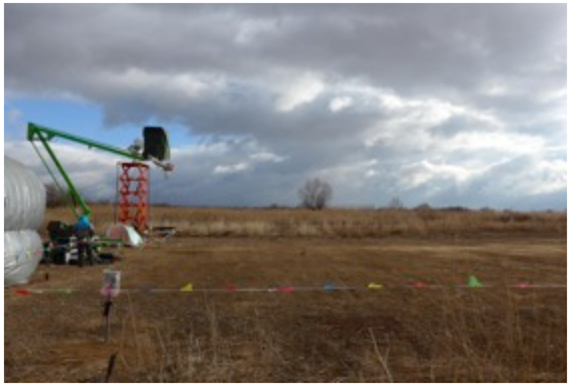
Meteorological Station Measurements



- Hourly Air temperature, Relative Humidity, Wind Speed, Precipitation (include snowfalls)
- Net Radiation, Solar Radiation
- Near Surface Temperature (6 cm above ground)
- Daily Snow Depth
- 5-Day SWE

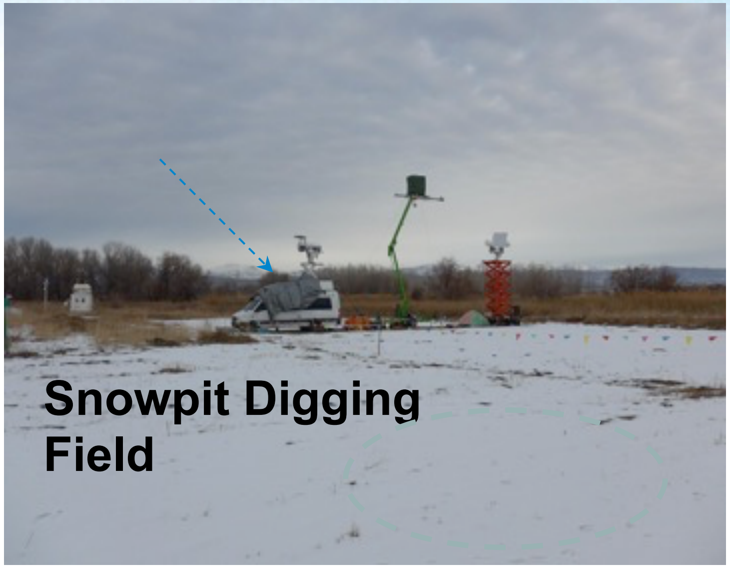


Field Measurements



Before the snowfalls,cut dry grass and installed soil measurement instrument

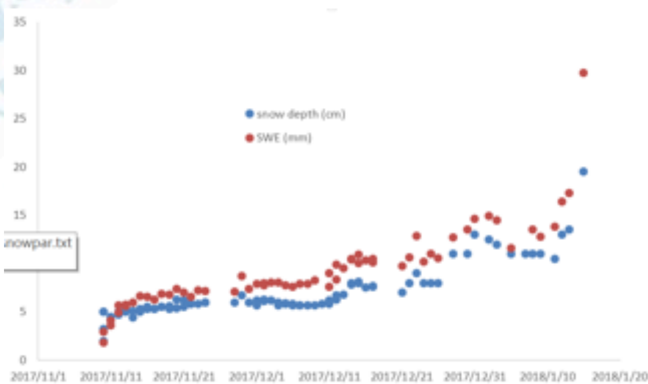
EM-50 Measurements:
Soil Moisture & Temperature at -2, -5,-10 cm

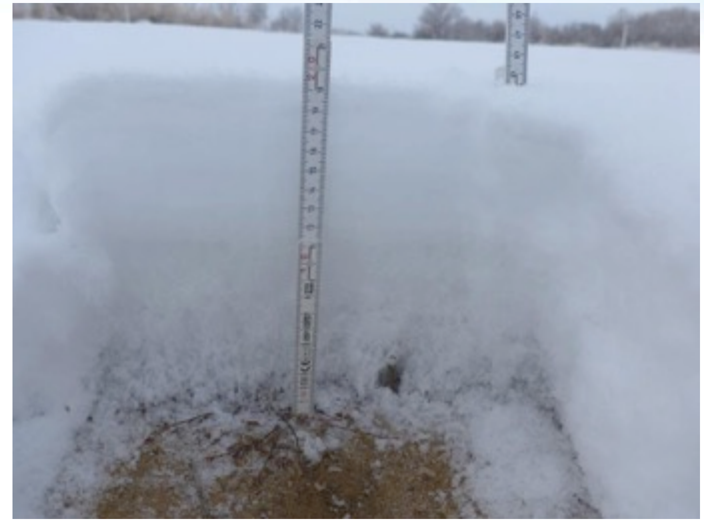


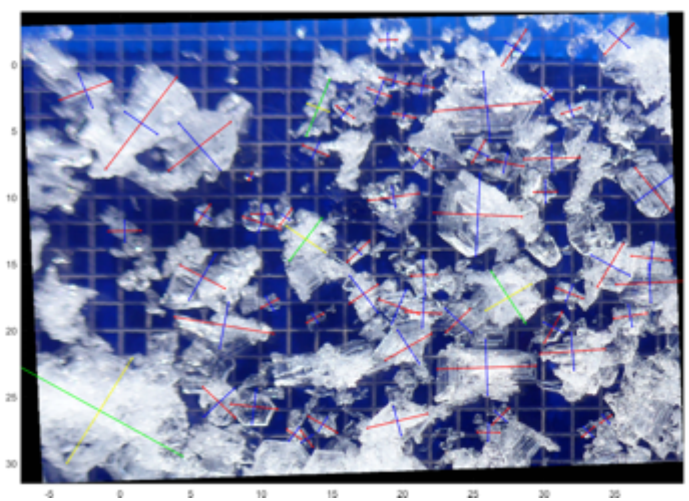
Snowpit Measurements:

- Snow Stratigraphy
- Snow Depth, SWE
- Snow Density & Snow Temp. per 5 cm
- Snow Grain size (D_{max})

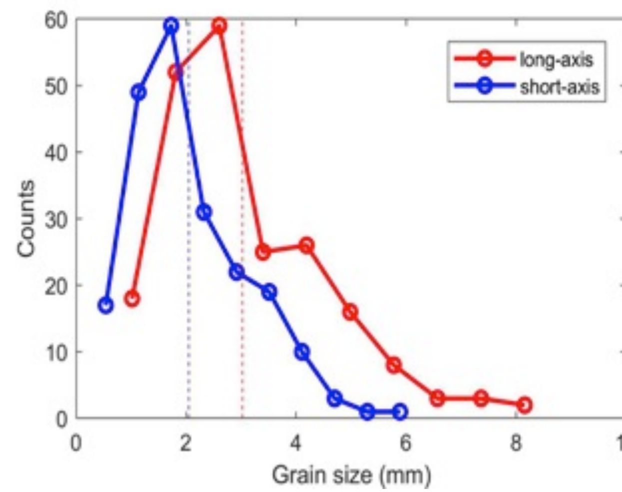
Snow Measurements







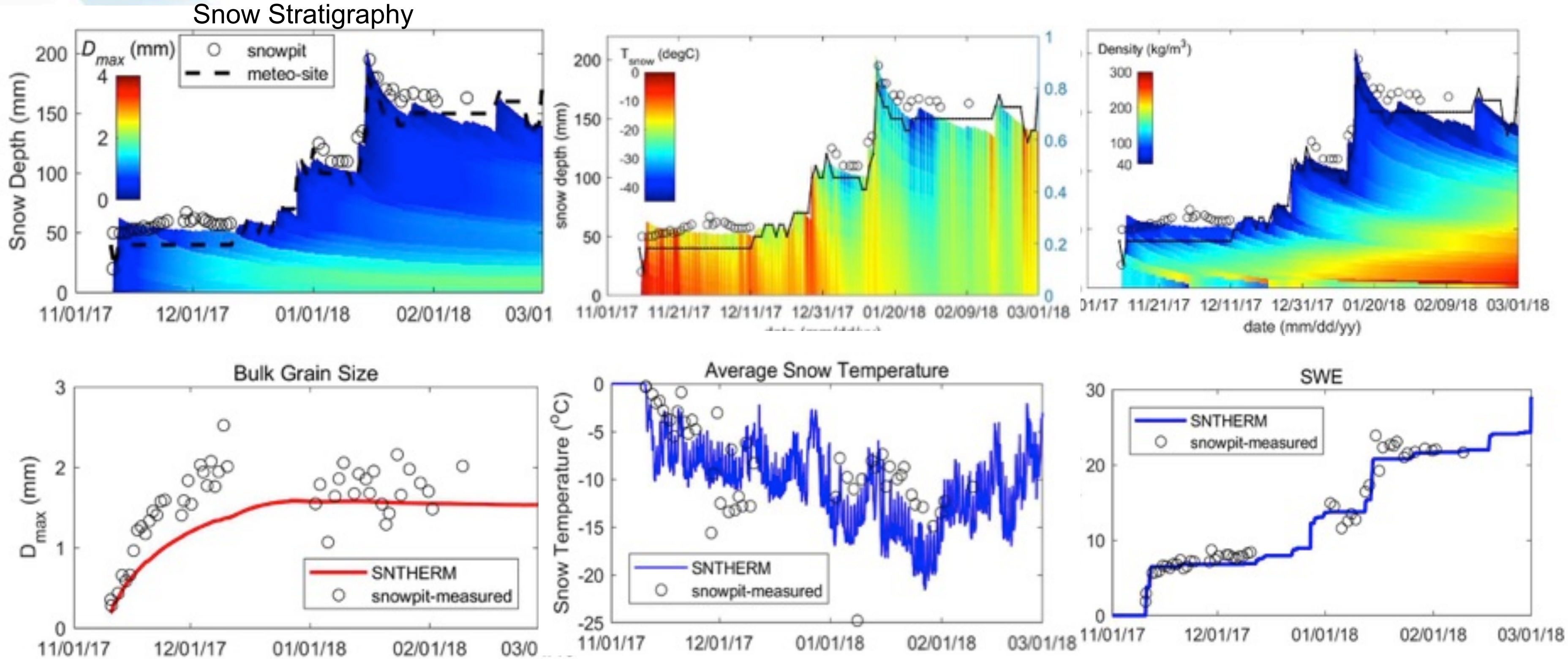
Georeferenced 2-mm Grids & Snow Particles



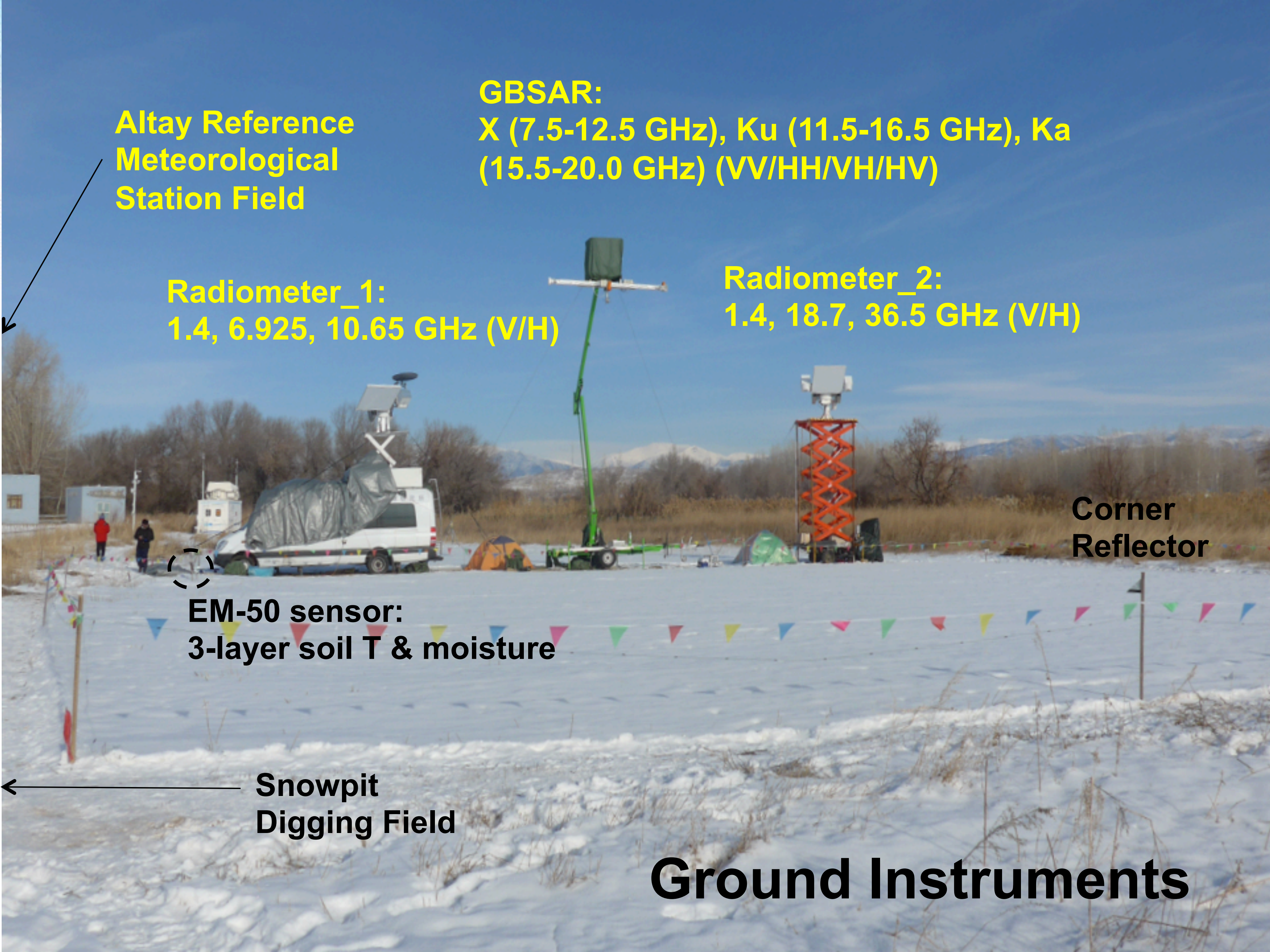
Histograms of Grain Dimensions

SNTHERM-simulations using Altay meteorological data

- Model inputs: T_{air}, Prep, Downward long & shortwave radiation, RH, Wind speed



- Bottom grain size exponentially grows and stops around at 2 mm
- Bulk grain size decreases when snowfall occurs


Altay Reference
Meteorological
Station Field
GBSAR:
X (7.5-12.5 GHz), Ku (11.5-16.5 GHz), Ka
(15.5-20.0 GHz) (VV/HH/VH/HV)
Radiometer_1:
1.4, 6.925, 10.65 GHz (V/H)
Radiometer_2:
1.4, 18.7, 36.5 GHz (V/H)
Corner
Reflector
EM-50 sensor:
3-layer soil T & moisture
Snowpit
Digging Field
Ground Instruments

GBSAR Calibration

- Ground based SAR polarimetric calibration procedure from:

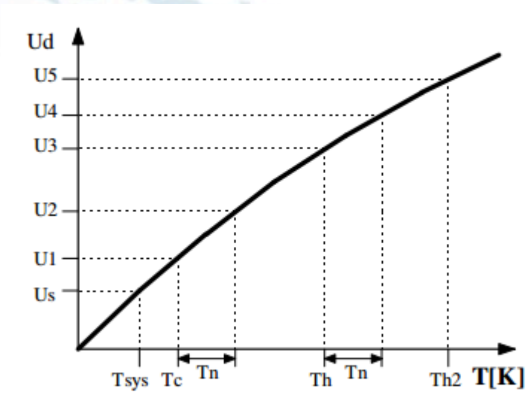
  K. Sarabandi, F. T. Ulaby and M. A. Tassoudji, "Calibration of polarimetric radar systems with good polarization isolation," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 28, no. 1, pp. 70-75, Jan 1990.

- two trihedral + one dihedral, carefully leveled and centered to antenna. Antennas are pointing vertically down.
- Trihedral radar responses were measured at anechoic chamber.
- Using time (range) gating to find the radar response of trihedral or dihedral.
- Background scattering is subtracted using background measurement.

Radiometer Calibration

- For C - Ku band

using a set of scan angles for sky tipping



$$U = GP^{\alpha} \quad 0.9 \leq \alpha < 1$$

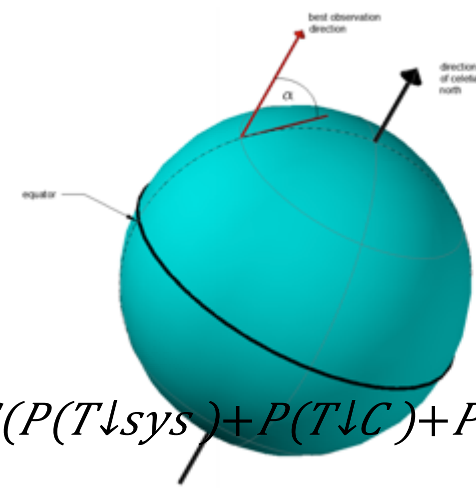
$$P(T_R) \cong \frac{1}{e^{\frac{h\nu}{k_B T_R}} - 1}$$

$$U1 = G(P(T_{sys}) + P(T_C))^{\alpha}$$

$$U2 = G(P(T_{sys}) + P(T_C) + P(T_n))^{\alpha}$$

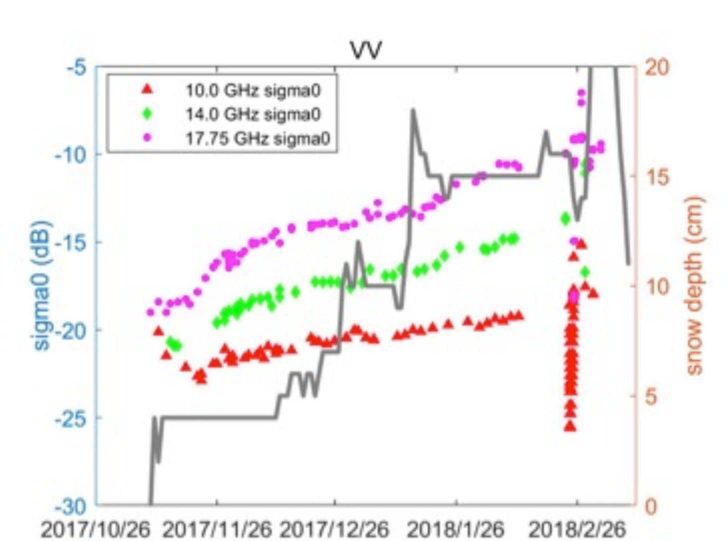
- For L band

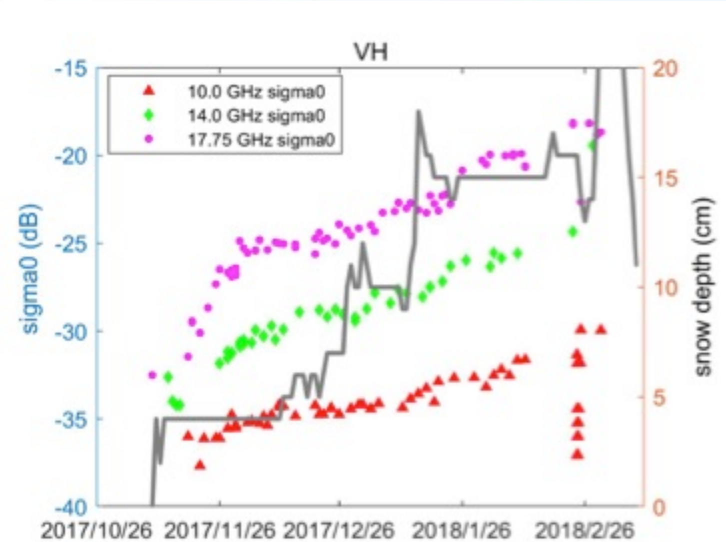
using a single scanning point

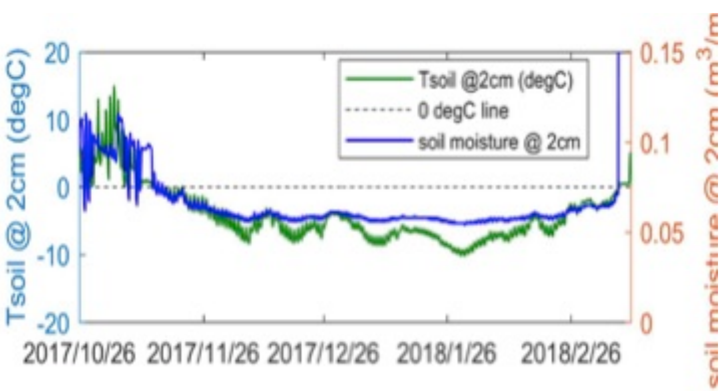


Four unknown parameters: G, α, Tsys, Tn

Time-series Measured Sigma0 at 40°

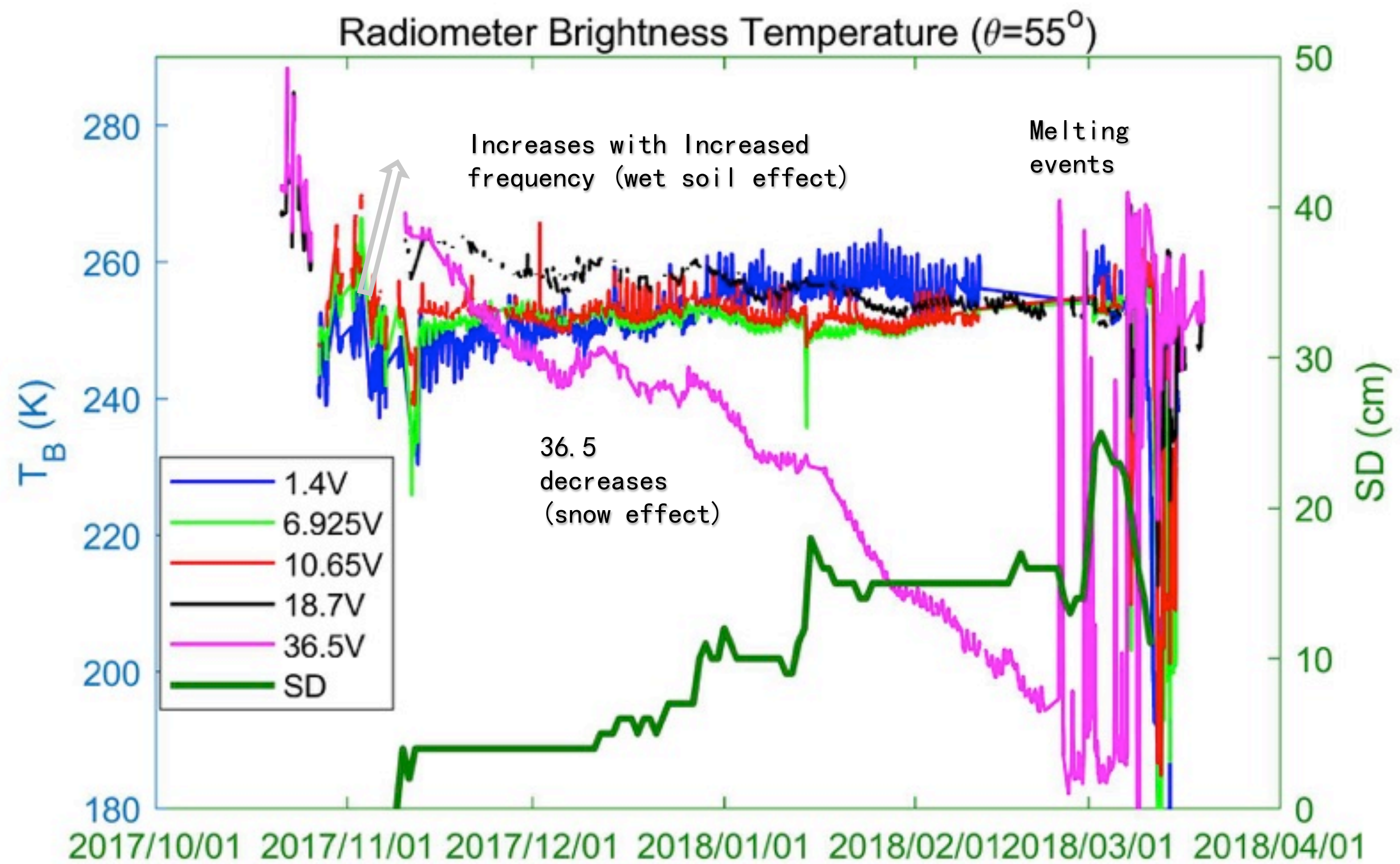






- Sensitivities of frequency dependence of snow volume backscattering to grain size and mass;
- Is the X-band backscattering time-series resulted from soil frozen process?
- Other possibilities?

T_B measurements at V-pol.



Comparison of Different Models

- Snow properties are used within the ground measurement range;
- Three physical based microwave snow models are compared with both Active/Passive measurements:

1. MEMLS;
2. DMRT/QCA – Dense Media Vector Radiative Transfer Model
3. VRT-Bic – Bicontinue Vector Radiative Transfer Model

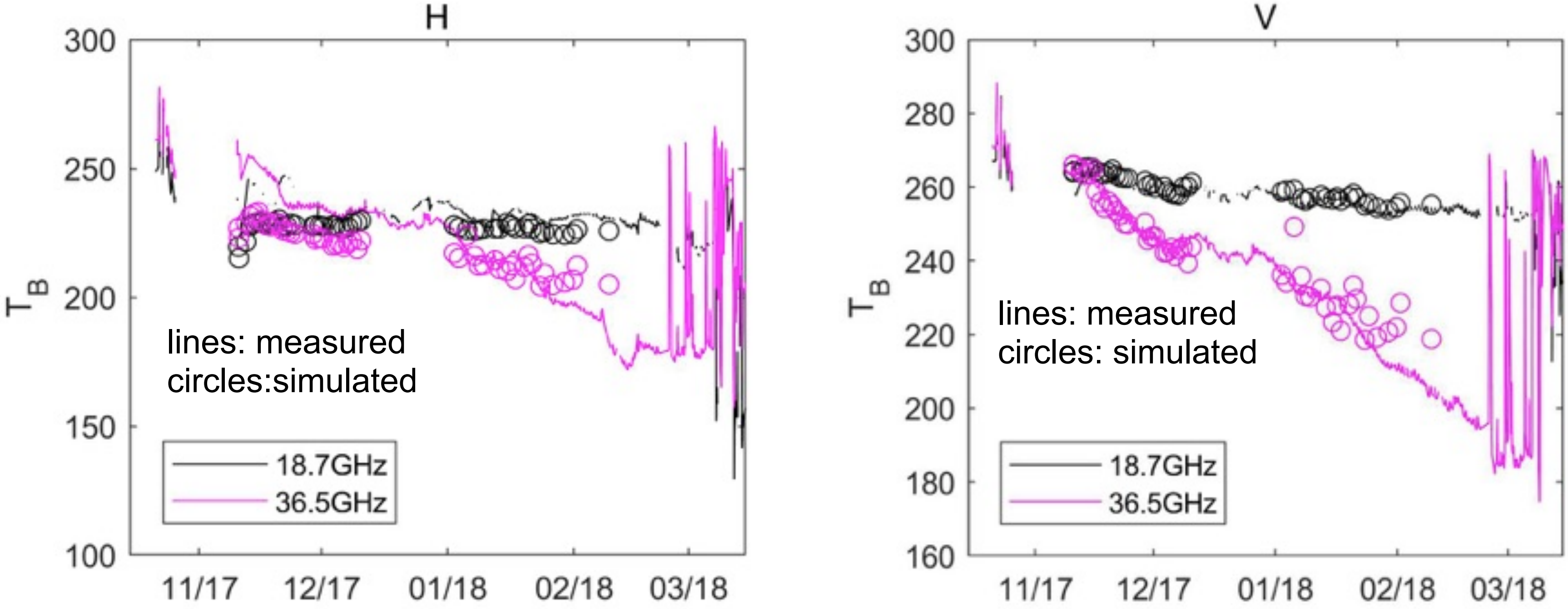
(1) Model Comparisons – MEMLS

Passive Brightness Temperatures

Model (1): MEMLS3&a with Improved Born Approximation

(Matzler&Wiesmann,1999; Proksch et al., 2005)

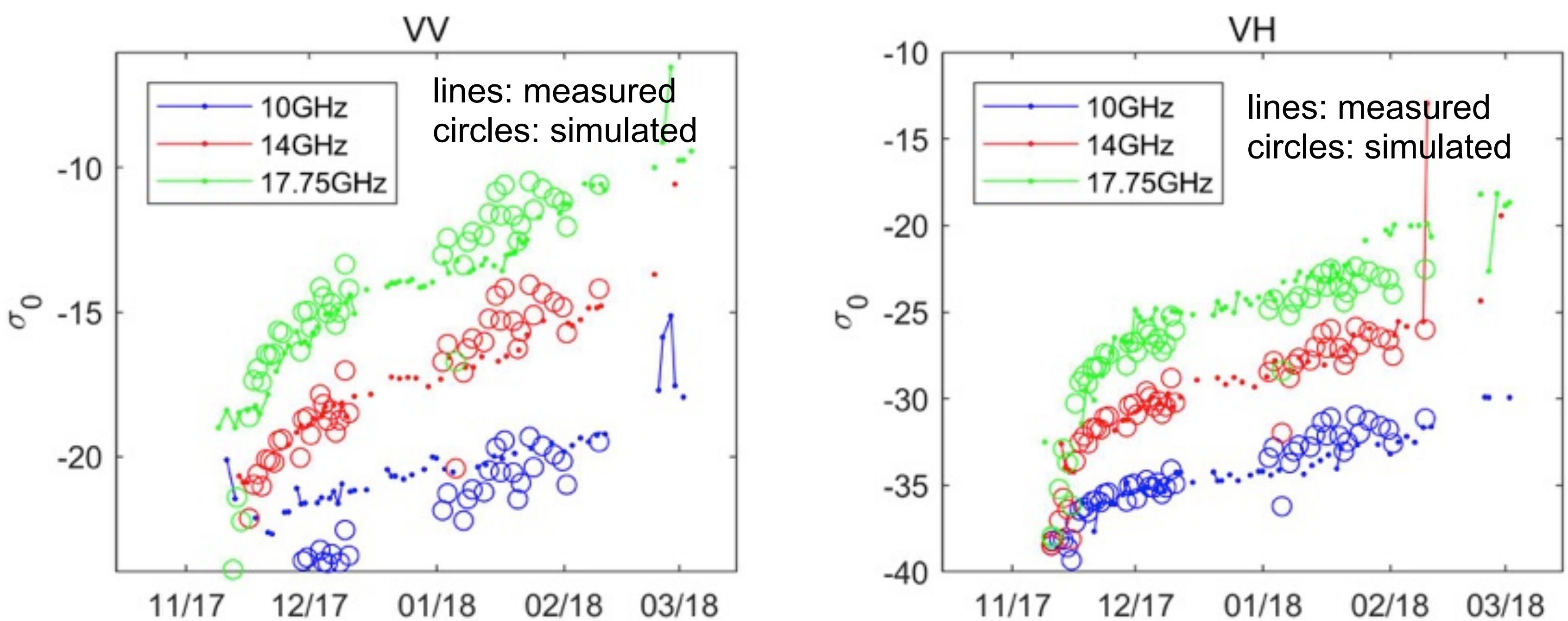
setting: grain diameter=1.2* [0.18+0.09*log(D_{max})]



(1) Model Comparisons – MEMLS

Radar measurements

inputs: pex_passive=1.2* [0.18+0.09*log(D_{max})]
pex_active=pex_passive*1.4 (compensate for the **backscattering enhancement**)
m=0.1; q=0.05;
smooth soil surface; 95% coherent component (compensate for **empirical soil model error**)



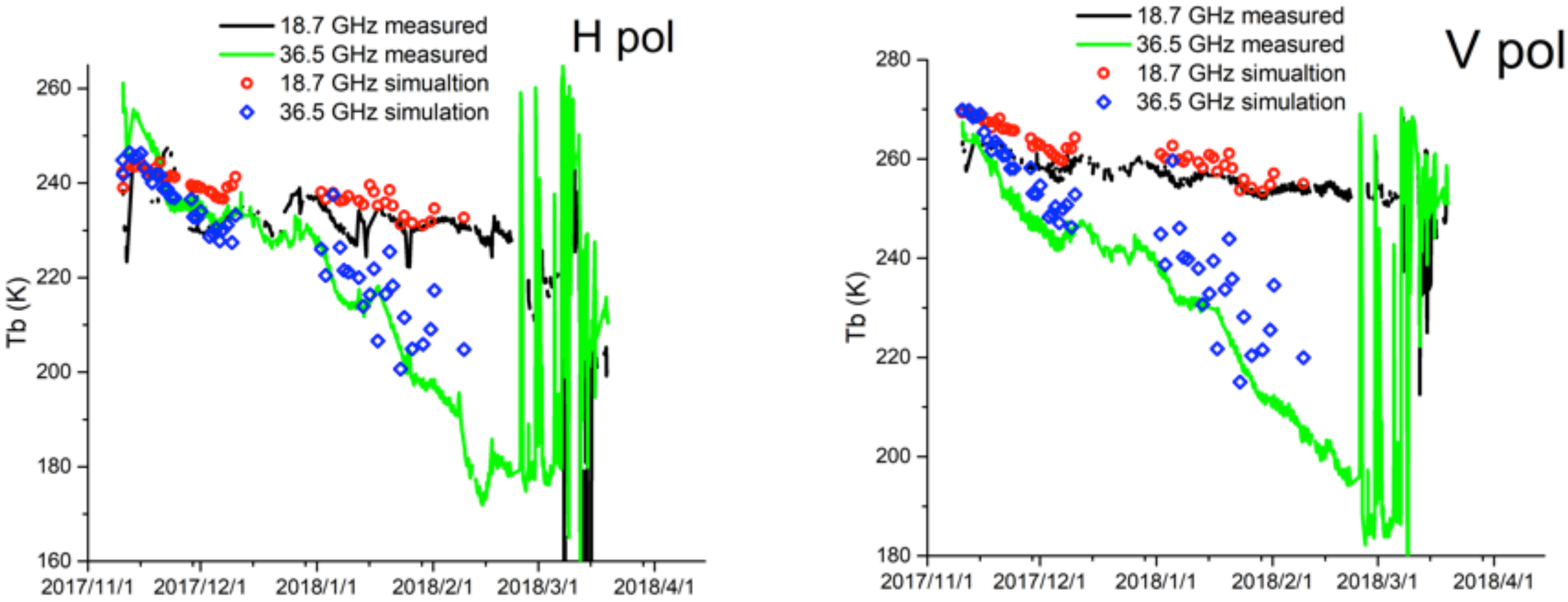
A adjustable parameter of "q" is used to parameterize the relationship between VH and VV

(2) Model Comparisons – DMRT

Passive Brightness Temperatures

Model（2）: multiple layer DMRT-QCA

Inputs: snow parameters from snowpits; grain diameter = 0.25*Dmax; stickiness = 0.1

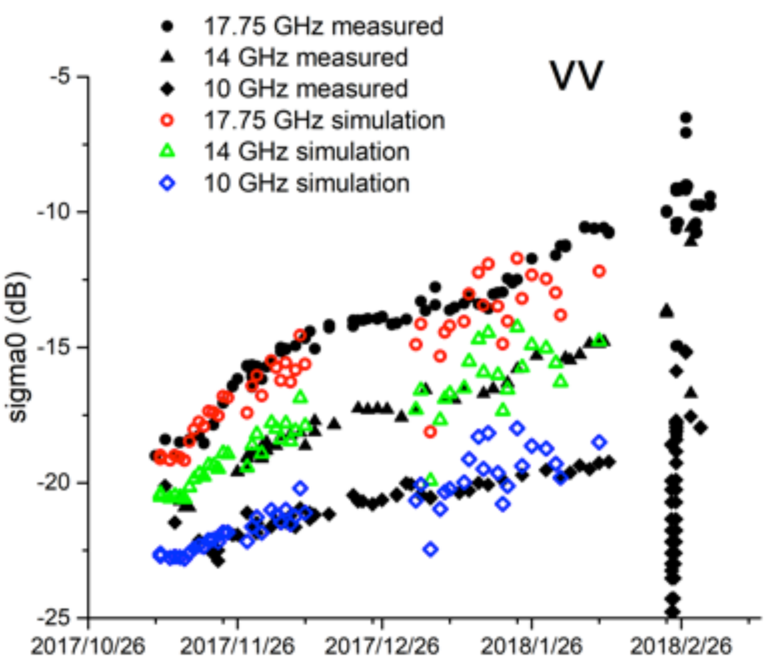


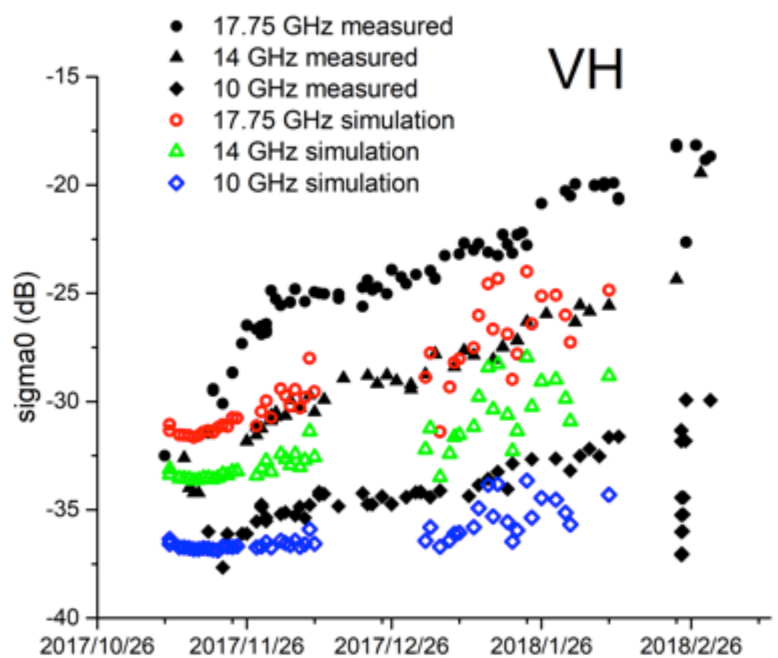
(2) Model Comparisons – DMRT

Radar measurements

Model (1): multiple layer DMRT-QCA, Oh rough surface scattering model

Inputs: snow parameters from snowpits; grain diameter = 0.25*Dmax; stickiness = 0.1





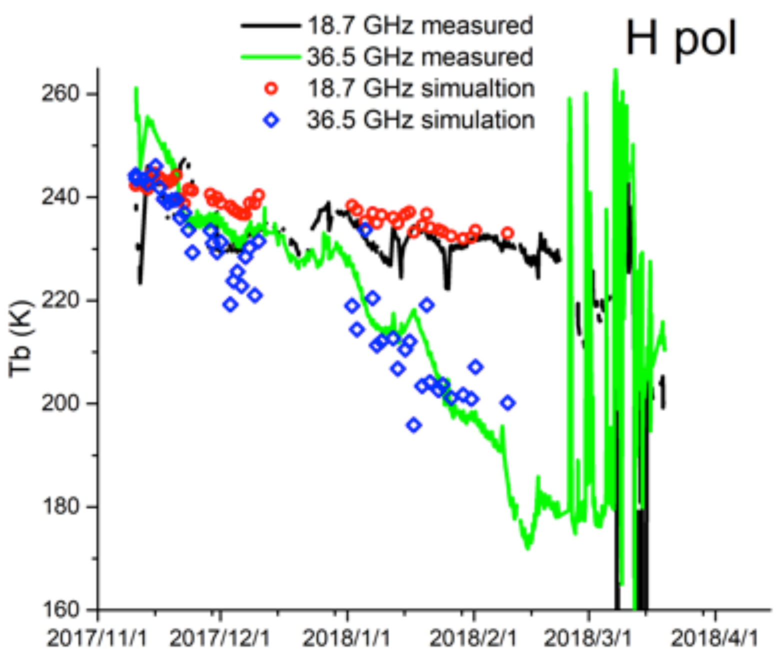
DMRT-QCA model significantly underestimated the VH backscattering

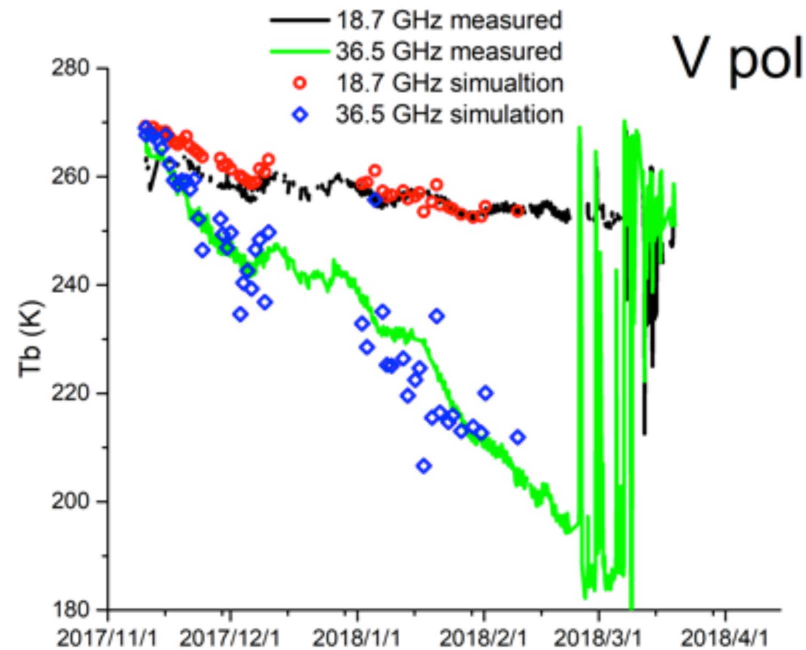
(3) Model Comparisons – VRT-Bic

Passive Brightness Temperatures

Models: multiple layer DMRT-Bic

Inputs: snow parameters from snowpits; Optical grain radius= Dmax/7; b= 1.2





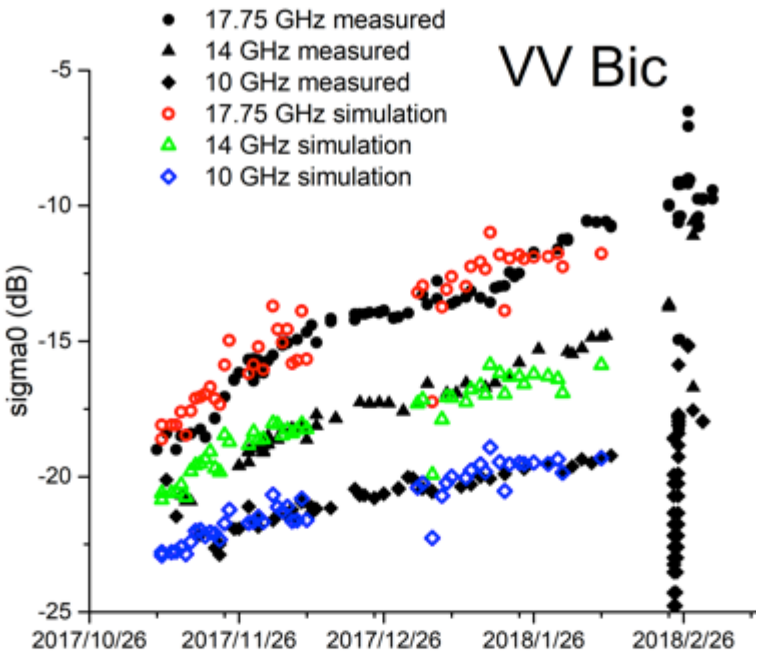
Match active and passive signal **simultaneously !**

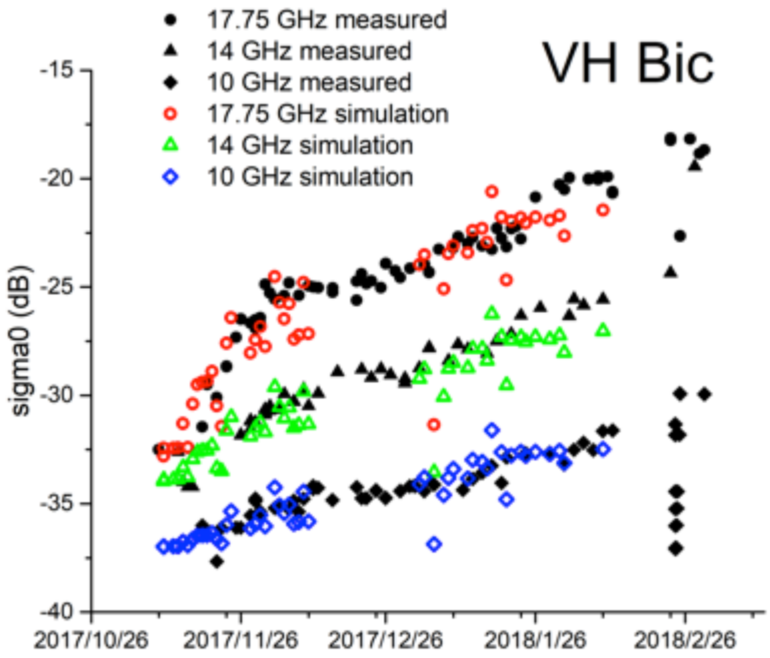
(3) Model Comparisons – VRT-Bic

Radar measurements

Models: multiple layer VRT-Bic, Oh rough surface scattering model

Inputs: snow parameters from snowpits; Optical grain radius= Dmax/7; b= 1.2





Bicontinuous model could generate much stronger VH backscattering

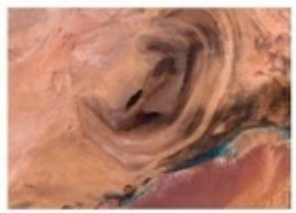
Match VV and VH signal **simultaneously !**

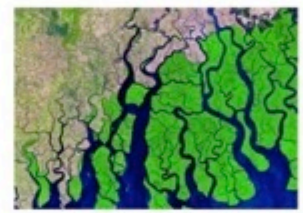
Summary

- Active/Passive retrieval requires the same set of snow properties. However, we showed some models all can fit the measurements, but have to use the different snow parameters.
- VRT-Bic model provide the best fits with the snow parameter
- Coherent justification may be needed for large incident angle measurements
- How many snow layers and frozen/thaw status of underground surface are important, but how?

Thanks!





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(4) Need Coherent Model?