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SnowAPP:

Modelling of the Snow microphysical-radiative interaction and its APPlications

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Objective of the SnowAPP project (2019-2022)

Develop a model frame with a unified treatment of the snow microphysics in the optical and microwave (MW) wavelength regions

Applications:

- model-based methods to retrieve snow properties from combinations of ground-based optical and MW sensors (e.g. snow albedo and melt on/off)
- Improve the representation of snow microphysical and radiative properties in climate and NWP models

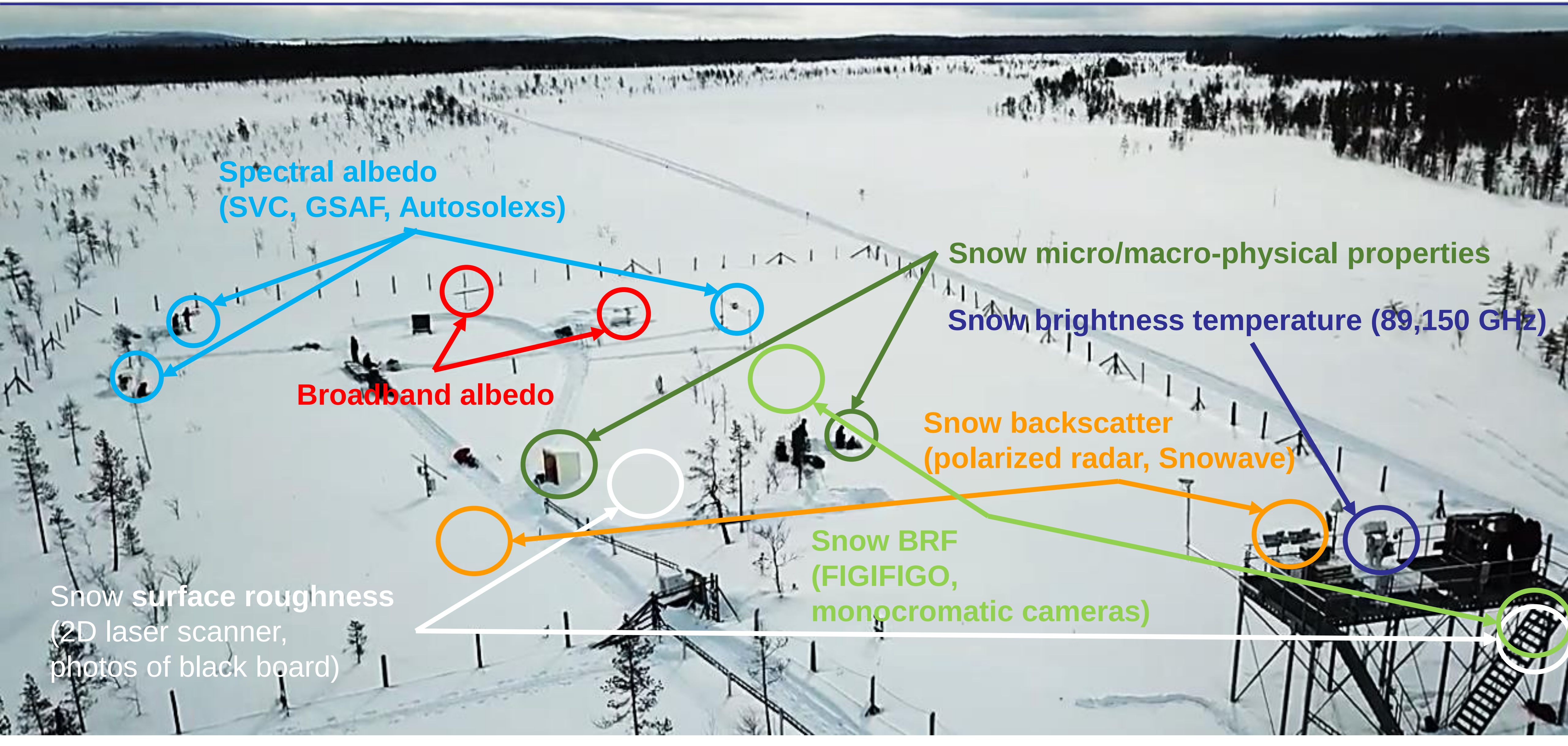
Field campaigns

4 weeks of continuous observations

in **2019** (18.3-12.4), **2020** (16.3-9.4), and **2021** (15.3-18.4) at the

Arctic Space Centre, **Sodankylä, Finland** (68.37° N, 26.63° E)

Field campaigns



Preliminary results

1. Continuous Bidirectional Reflectance Factor (BRF) of snow from nadir time-lapse photos

2. Snow microstructure profiles

3. Continuous spectral albedo measurements

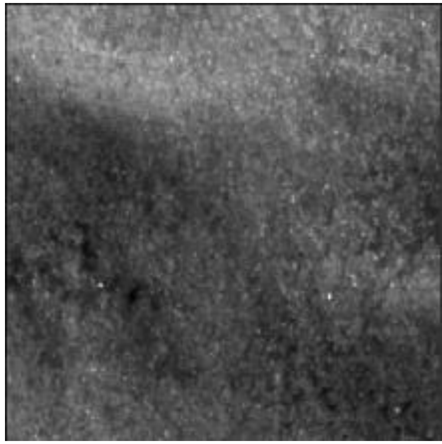
4. Microwave and optical radiative transfer modelling

Continuous BRF of snow from time-lapse photos

Terhikki Manninen, Kati Anttila, Roberta Pirazzini, Petri Räisänen, Leena Leppänen, Anna Kontu and Jouni Peltoniemi: ***Continuous bidirectional reflectance (BRF) measurement of snow using monochromatic camera****.*
Accepted in Cold Regions Science and Technology

- The Imaging Source DMK23U445 monochromatic camera, 6 mm F1.2 objective, CCD solid-state image sensor, 1.25M effective pixels, filtered to the 700 - 1000 nm
- **cost-effective approach for operational measurements of the directional reflectance of nadir illumination**

Height: 143 ± 2 cm
Analyzed surface area: 26.7(±5) x 26.7(±5) cm (300x300 pixels)
Resolution of the photos: 0.89 ± 0.02 mm



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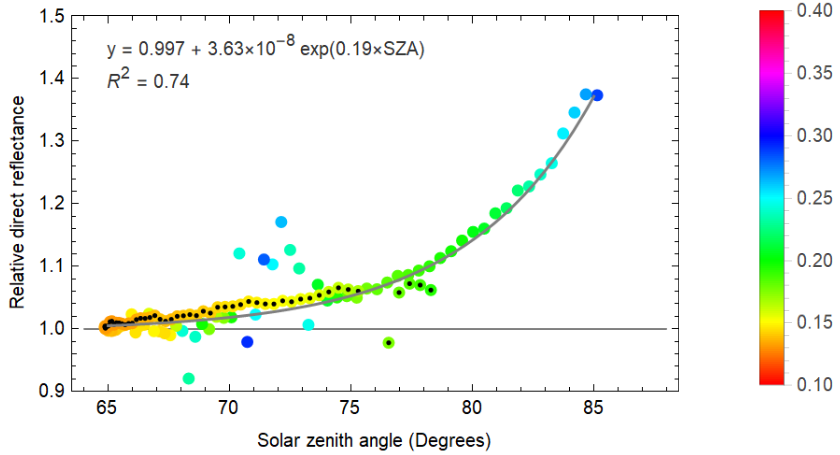
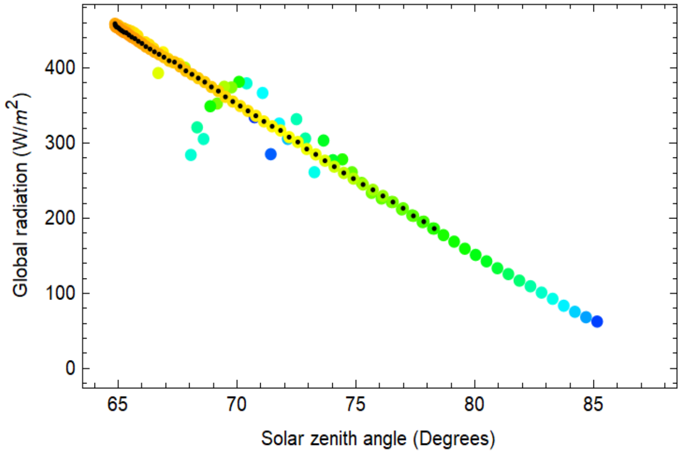
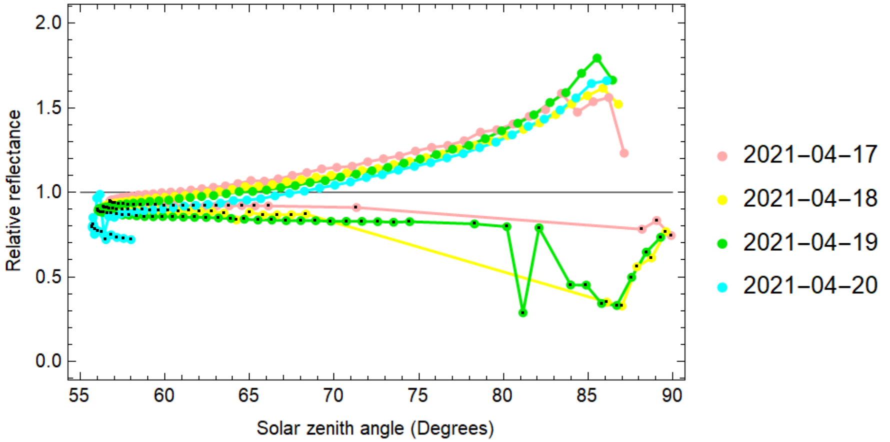
Continuous BRF of snow from time-lapse photos

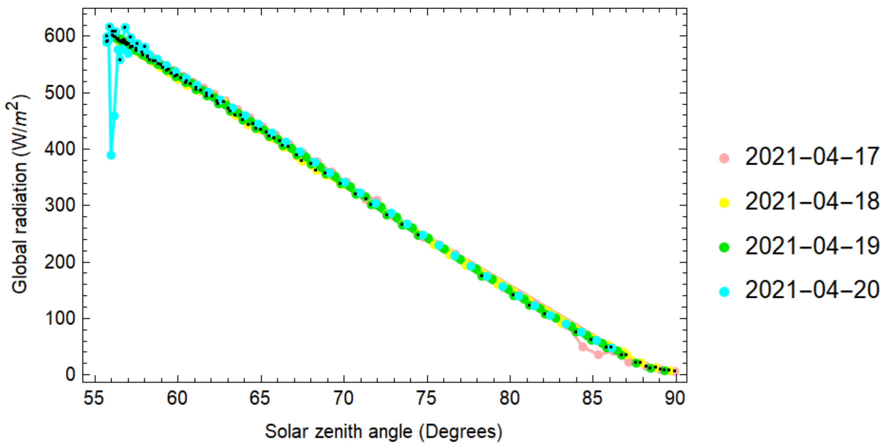
Dry snow





Melting snow

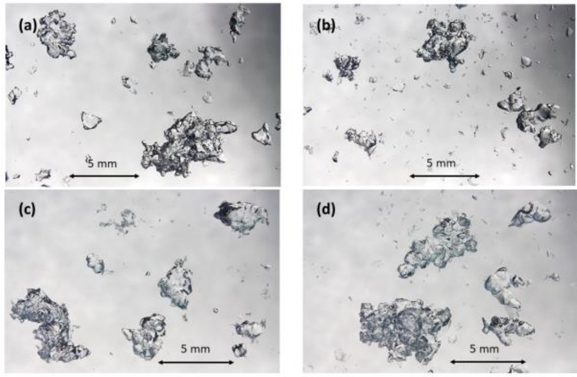




During melting:

- Nocturnal freezing and diurnal melting caused the strong BRF decrease during the day

Early-morning surface snow crystals after freezing:



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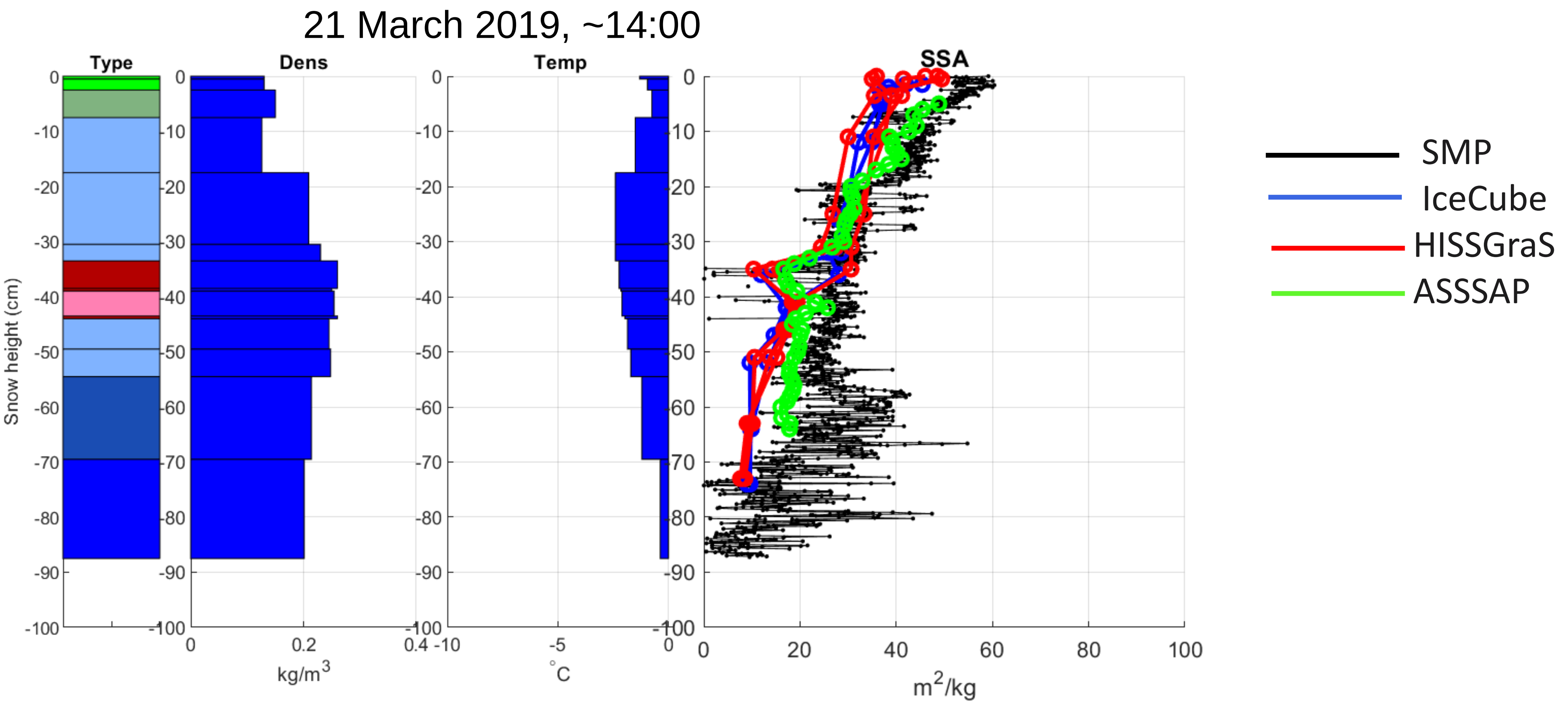
Snow microstructure profiles, raw data

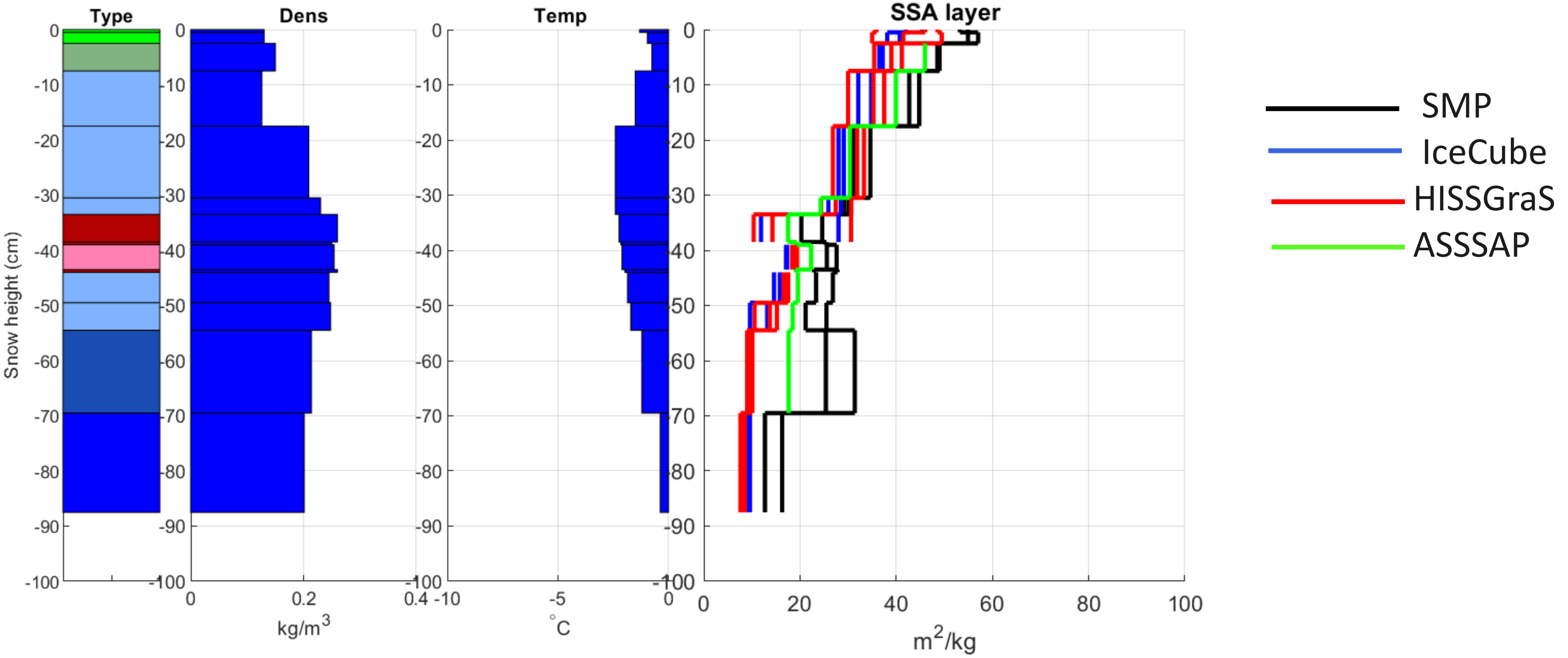
Green = PP (new snow)
Red = ice/crust
Pink = RG
Light blue = FC
Dark blue = DH



Snow microstructure profiles, layer values

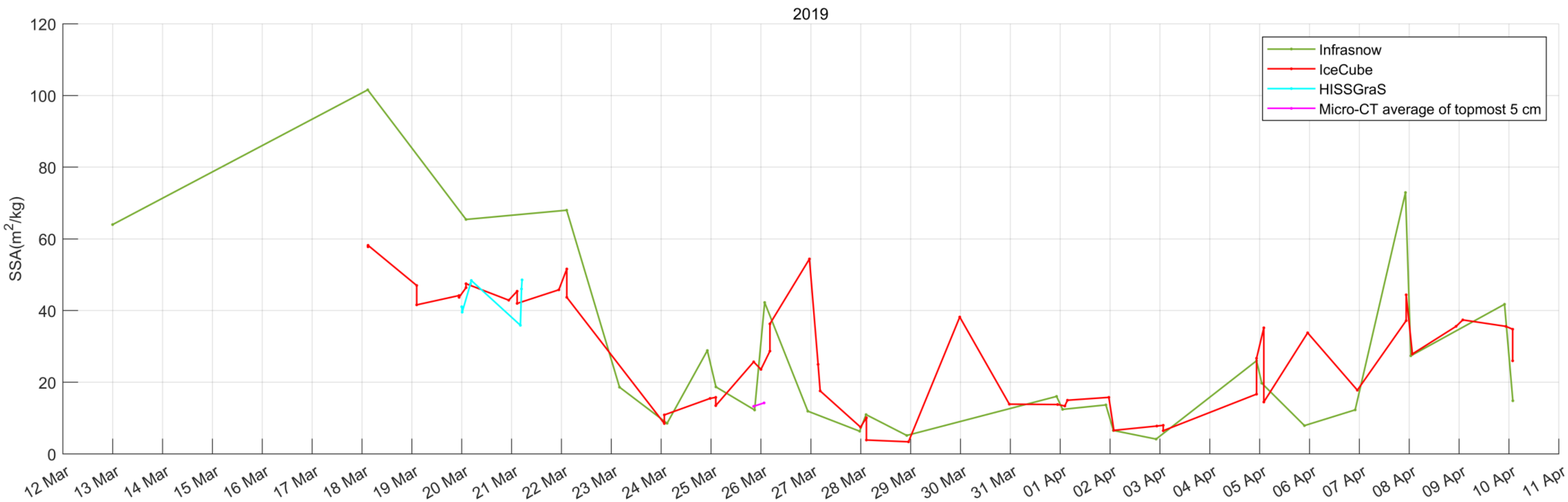
Green = PP (new snow)
Red = ice/crust
Pink = RG
Light blue = FC
Dark blue = DH

21 March 2019, ~14:00



Snow microstructure profiles

Time series of SSA in the uppermost 5 cm



ISSUES:

- Spatial variability of snow layering (in the cm-m-10m scales)
- Errors introduced by the measurement method

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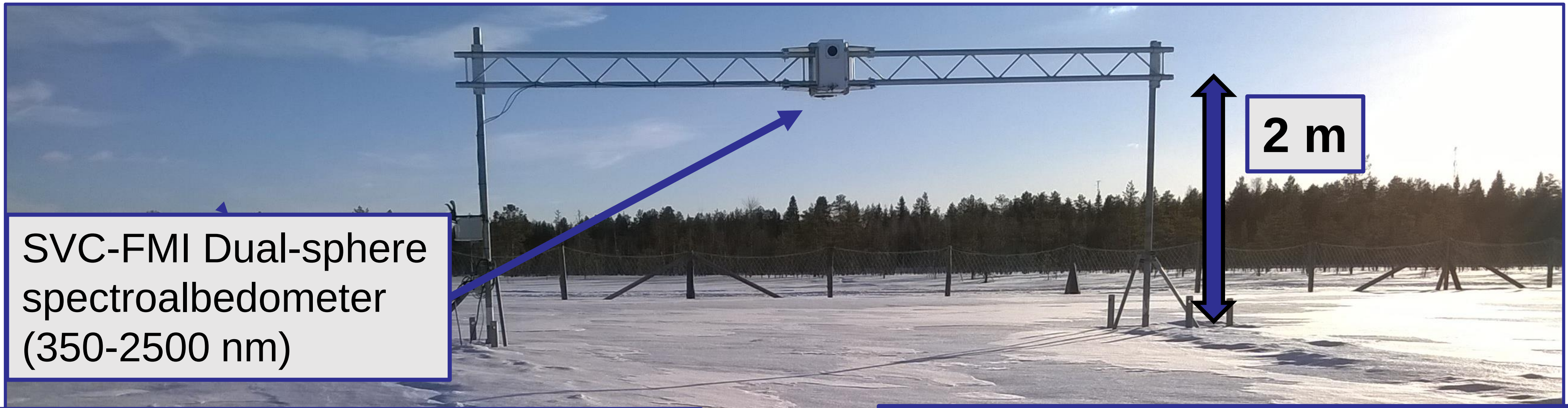
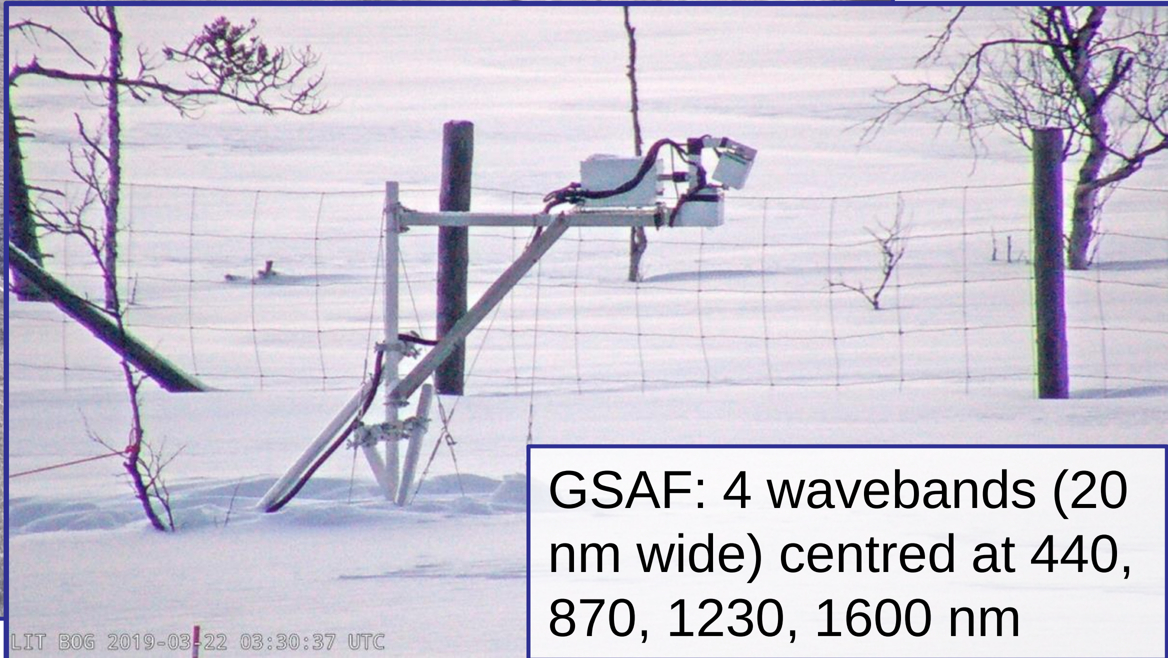
Leppänen et al.: Intercomparison experiment of specific surface area measurements in Sodankylä, Finland. In preparation

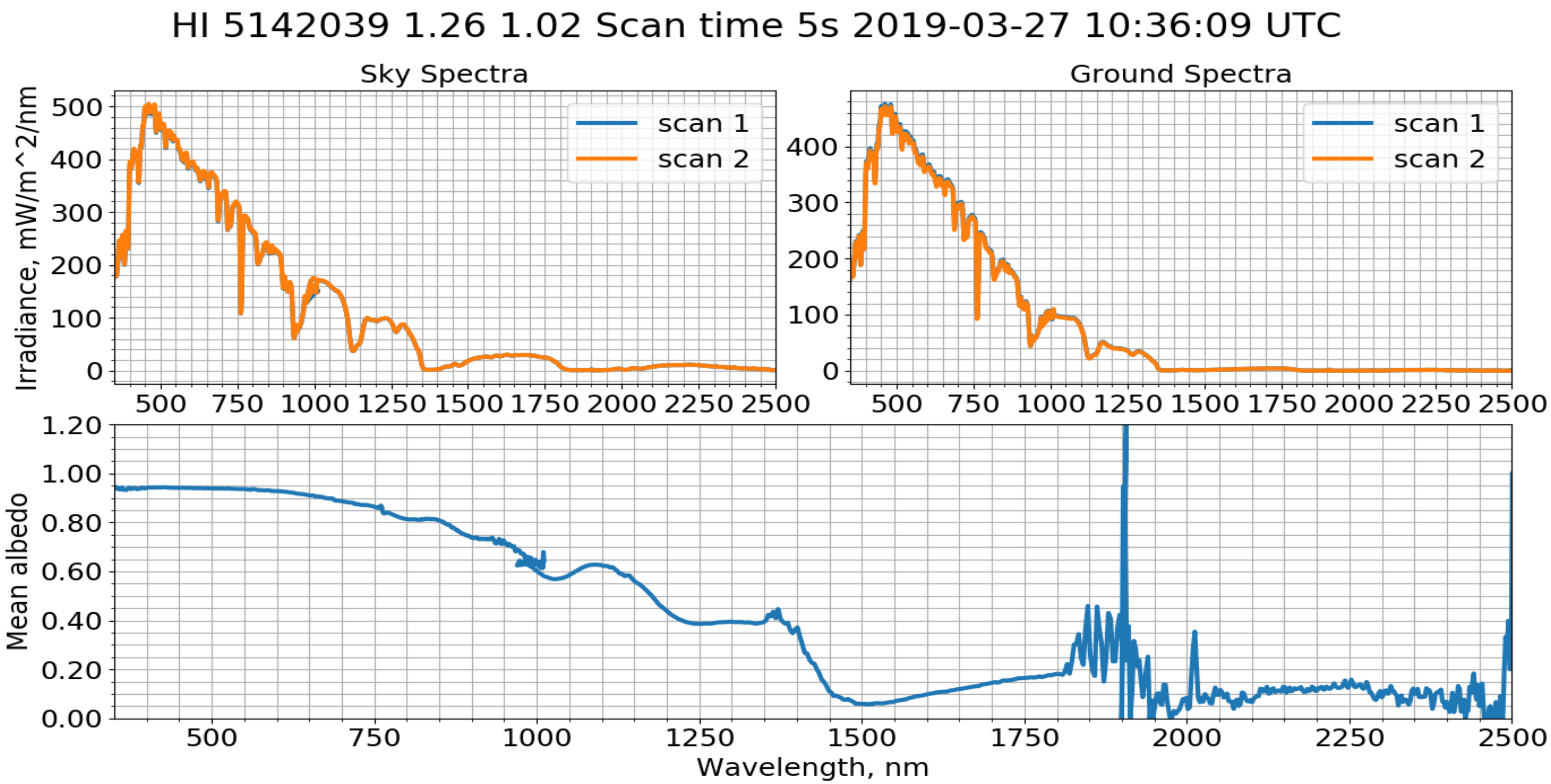
Continuous spectral albedo measurements





Continuous spectral albedo measurements

Example of raw spectra with 8/8 cloud cover



Hannula et al.: Autonomous device for ground-based observations of snow spectral albedo. In preparation

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Optical radiative transfer modelling

SBDART+DISORT is applied to simulate both broadband and spectral albedo.

At this stage, it has been mostly applied **in clear-sky conditions**:

- to check the consistency of the downwelling shortwave observations made with different instruments,
- to identify error sources in the data (due to instrumental deficiencies or impacts of the installation setup),
- to derive data corrections.

Identified error sources in the observations though modelling:

- the spectrally integrated SVC signal is too low compared to modelled and broadband albedo: the underestimation comes from the wavelengths where there is high atmospheric transmittance (weak gaseous absorption), while overestimation occurs where there is low atmospheric transmittance (strong gaseous absorption)

→ **the correction for the deviation from the correct cosine response given by manufacturer was incorrect** (as it is usually the case for most optical sensors!).
→ **We needed to re-measure the cosine correction in the optical lab.**

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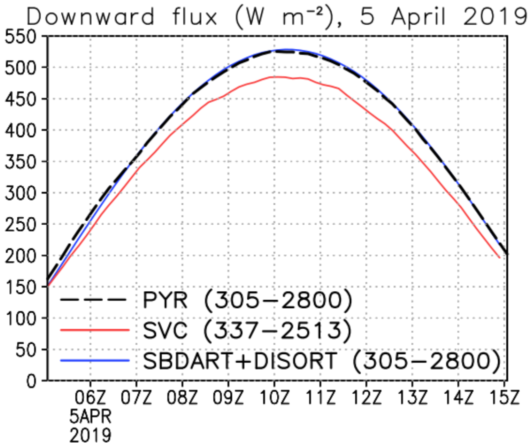
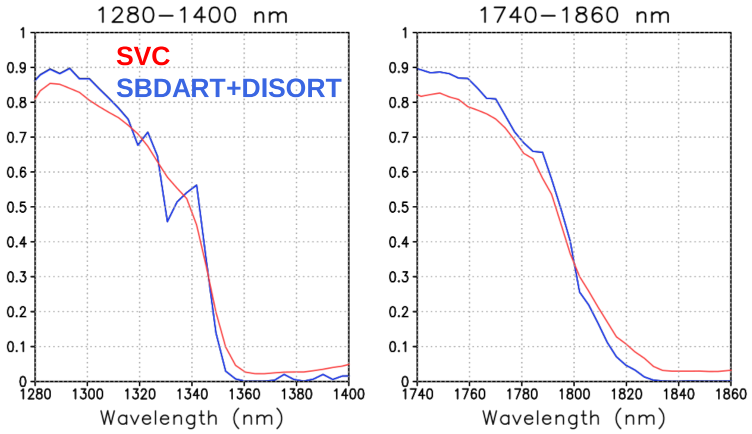
Broadband downward shortwave irradiance

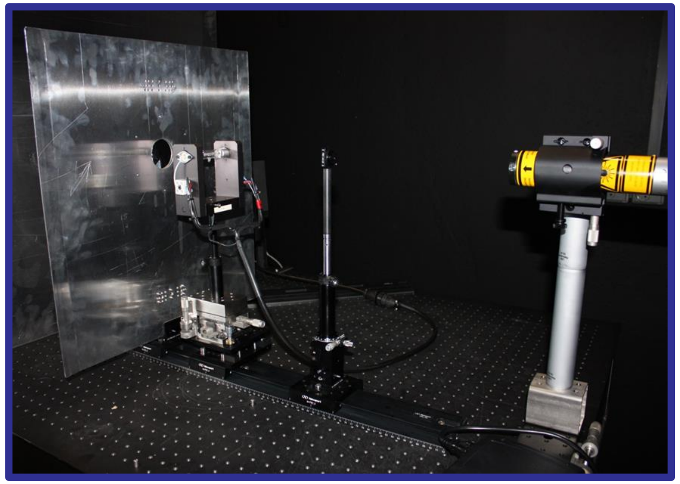


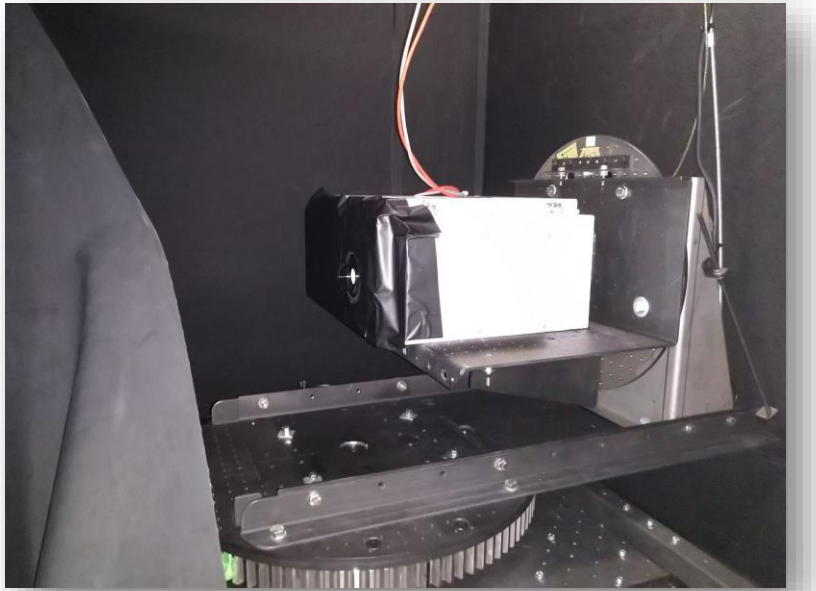
Spectral downward shortwave irradiance



SVC Lab calibration and characterization

- Radiance/Irradiance calibration
- Wavelength calibration
- Cosine response characterization





Temperature dependence of spectrometer’s sensitivity (-30˚C ÷ +20˚)

Temperature dependence of wavelength calibration (-30˚C ÷ +20˚)

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Hannula et al.: Autonomous device for ground-based observations of snow spectral albedo. In preparation

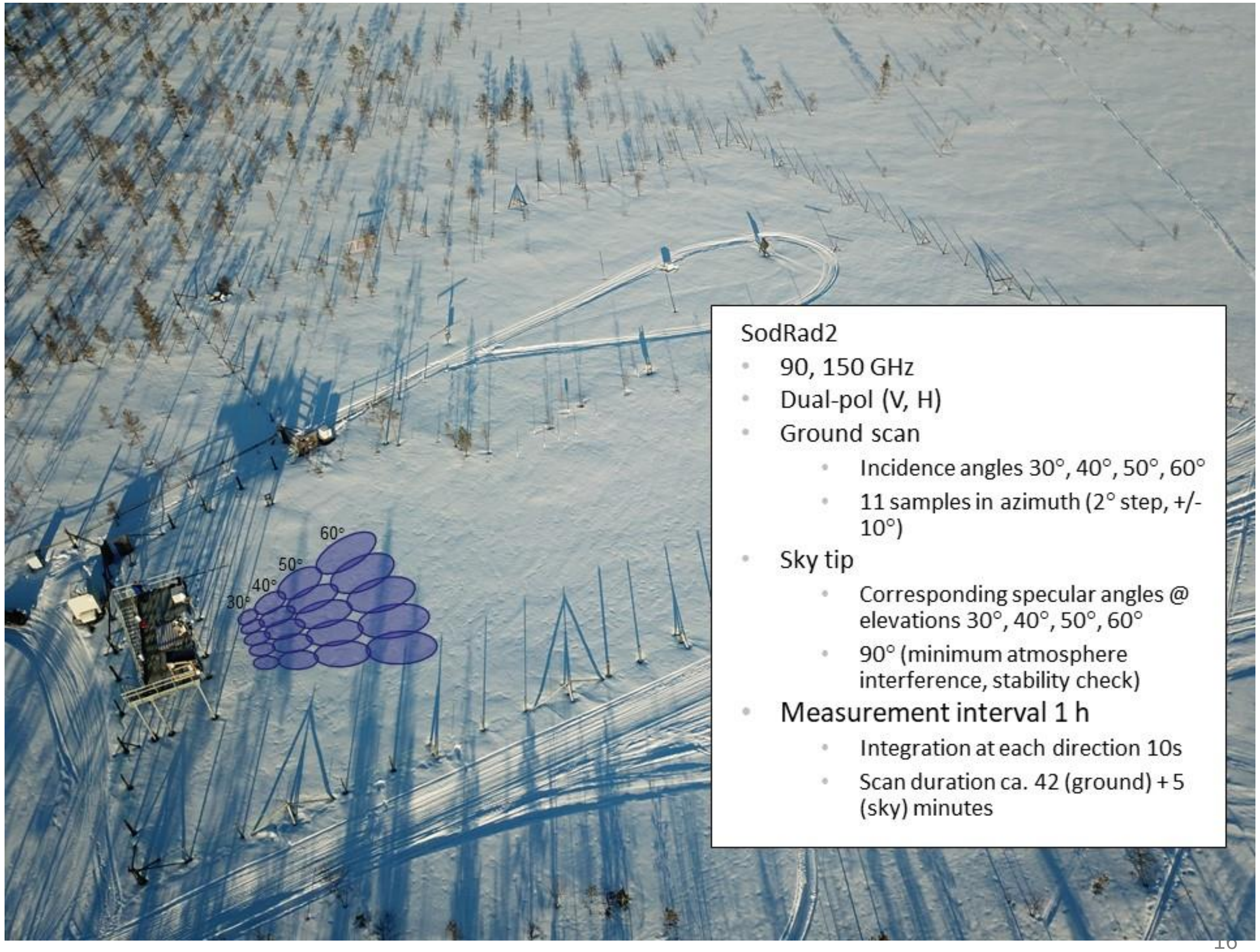
Optical radiative transfer modelling

Next step:

invert SBDART+DISORT to extract SSA from the measured broadband and spectral albedo

Time series of microwave brightness temperatures

- Time series of brightness temperatures at 90 and 150 GHz
- Sensitive to changes in snow surface properties (microstructure)
- Downwelling atmospheric component must be accounted for



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Time series of microwave brightness temperatures

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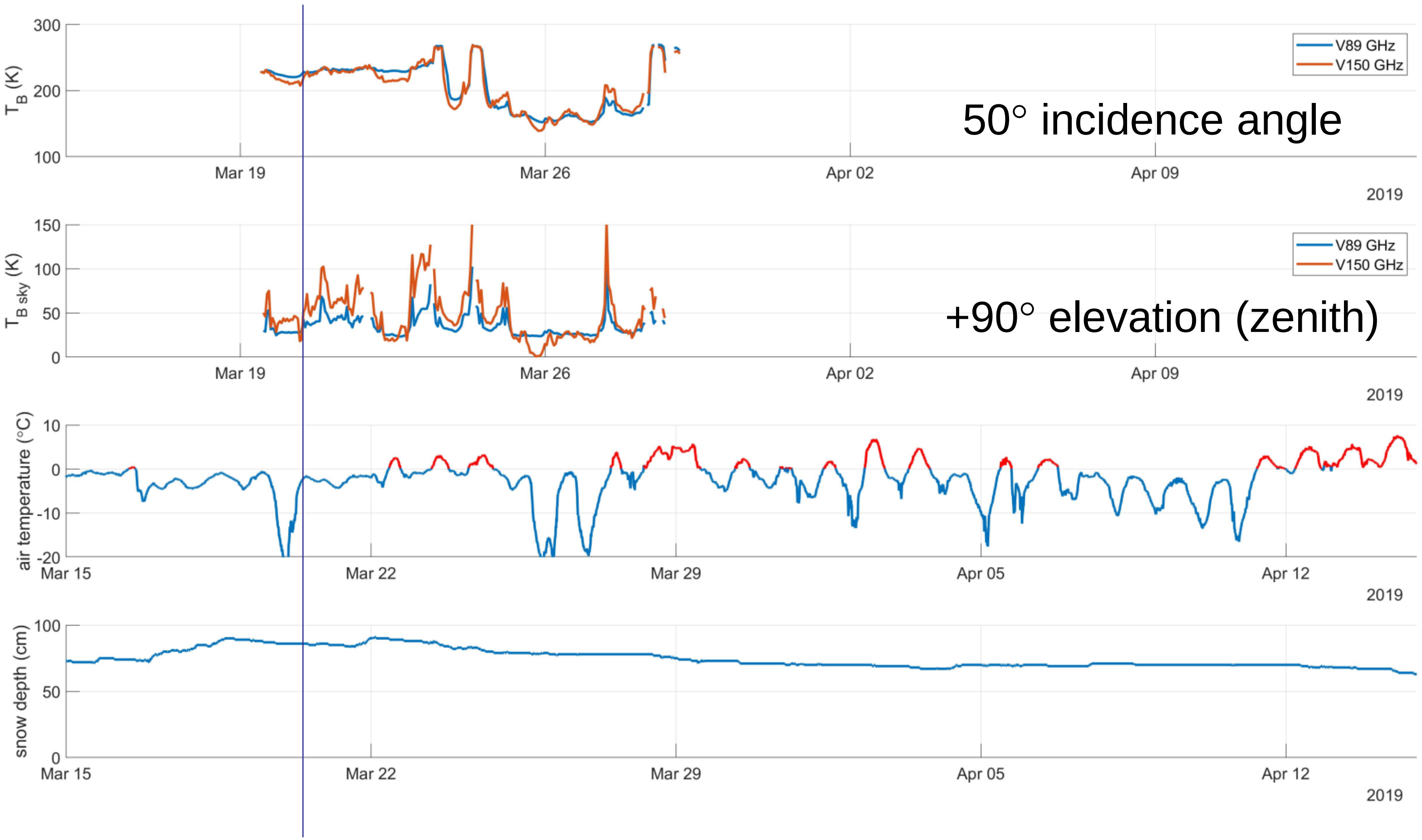
Spring 2019



March 19, 2019 (simulation example)

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Time series of microwave brightness temperatures

Spring 2020

- Time series of brightness temperatures at 90 and 150 GHz
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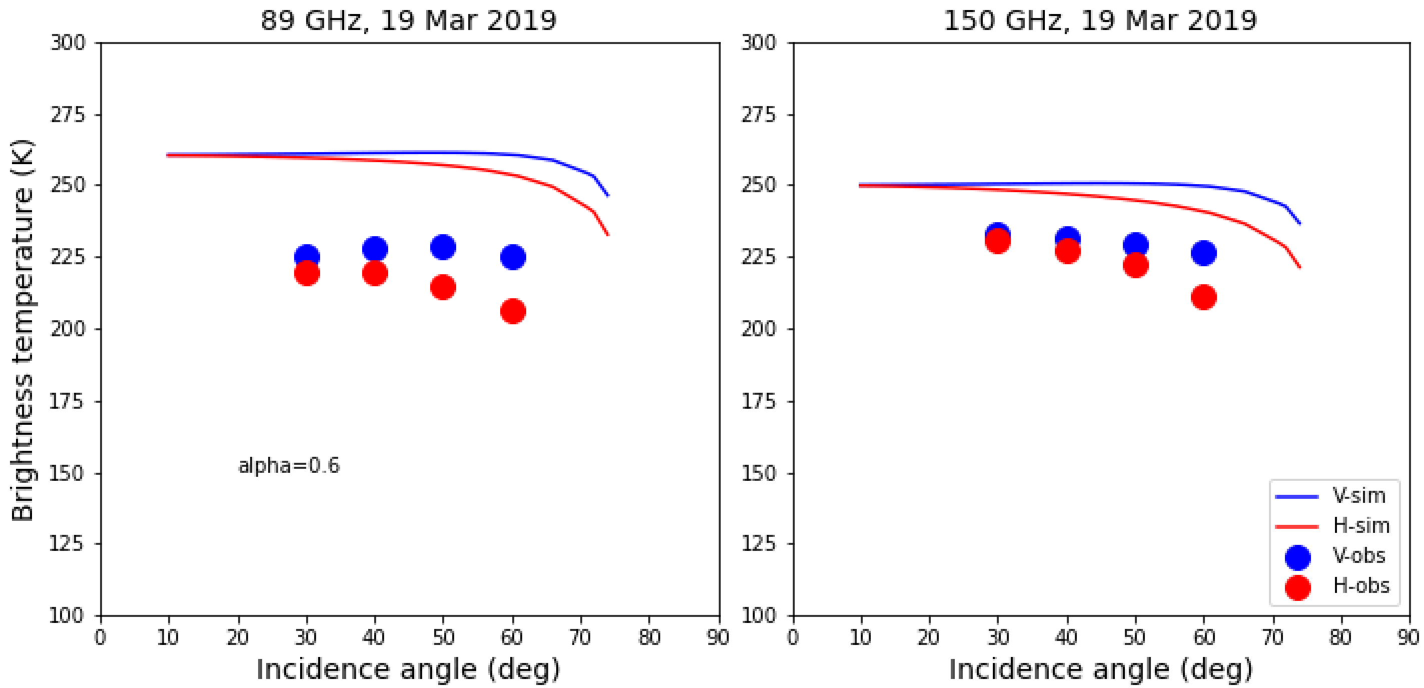
Microwave radiative transfer modelling

- SMRT applied to simulate TB at 89 and 150 GHz using snow pit data as starting point (forward simulaition)
- Downwelling TB from cosine modification of Zenith measurements
- Improved Born Approximation applied (microstructure represented by exp. correlation length) + DORT
- Snowpit data ”as is”, but p_exp modified by multiplier α

```
p_exp = alpha.*3.*(1- rho_snow/rho_ice)
./(SSA.*917)
```

- Example date **March 19, 2019**



- Variation of ”alpha” used to retrieve effective microstructure for each frequency (different penetration depths)

Thank you!

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