ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

SnowAPP:
Improvement of the snow albedo retrieval combining optical and microwave sensors



Roberta Pirazzini[1], Petri Räisänen[1], Juha Lemmetyinen[1], Terhikki Manninen[1], Teruo Aoki[2], Ghislain Picard[3], Jouni Peltoniemi[4], Martin Schneebeli[5], Henning Löwe[5], Marco Pasian[6], Masashi Niwano[7], Henna-Reetta Hannula[1], Kati Anttila[1], Anna Kontu[1], Leena Leppänen[1], Pedro Fidel Espin Lopez[6], Amy Macfarlane[5], Outi Meinander[1], Ines Ollivier[3], Teijo Arponen[1], Jonas Svensson[1], Jianwei Yang[8], Lorenzo Silvestri[6], Aleksi Rimali[1], Laurent Arnaud[3], Alexander Kokhanovsky[9]

[1]Finnish Meteorological Institute, Finland; [2] National Institute of Polar Research, Japan;
[3]Université de Grenoble Alps/CNRS, Institute of Environmental Geosciences (IGE), France;
[4]Geospatial Research Institute, Finland; [5]WSL Institute for Snow and Avalanche Research SLF, Switzerland;
[6]University of Pavia, Italy; [7]Meteorological Research Institute, Japan Meteorological Agency, Japan;
[8]Beijing Normal University, China; [9]VITROCISET, Germany

ESA Sentinel-3

OLCI (Ocean and Land Colour Instrument): 300m, 21 bands [[0.4-1.02] µm
SRAL (Ku/C Radar Altimeter) 1.9 KHz (LRM), 17.8 KHz (SAR)
MWR (MicroWave Radiometer): 23.8 / 36.5 GHz



Objective of the SnowAPP project (2019-2022)

- **O1** ***Develop a model frame with a unified treatment of the snow microphysics in the optical and MW wavelength regions***

Central aim of SnowAPP, pre-requisite for O2 and O3.

- **O2** ***Develop model-based methods to retrieve snow properties from combinations of ground-based optical and MW sensors***

Focus on **snow albedo** and **melt on/off**

- **O3** ***Improve the representation of snow microphysical and radiative properties in climate and NWP models***

Apply the state-of-the-art snow microphysics and albedo scheme to a climate model and to a NWP model, and evaluate the sensitivity of climate and weather simulations to these improvements

Coupling of optical and microwave modelling

DIRECT SNOW OBSERVATIONS

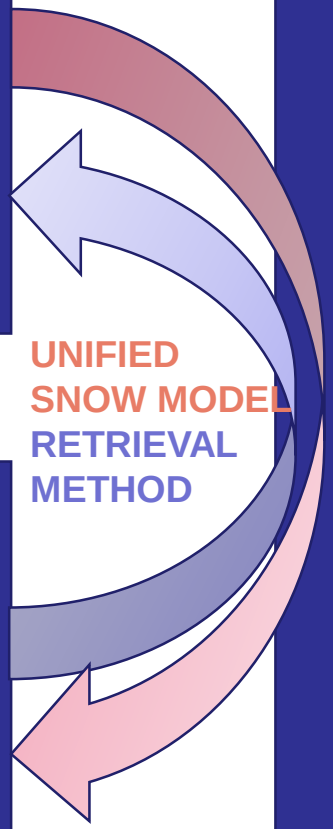
- **grain size metric distribution** (chord length or correlation function)
- **WET snow surface roughness (**mm-cm)
- **DRY Snow anysotropy**

GROUND-BASED REMOTE SENSING

Snow albedo

Snow brightness temperature

Snow backscatter



MODELLING

SURFACE ROUGHNESS

- 3D Analytic photon re-collision method [1]
- multiscale IEM [2]

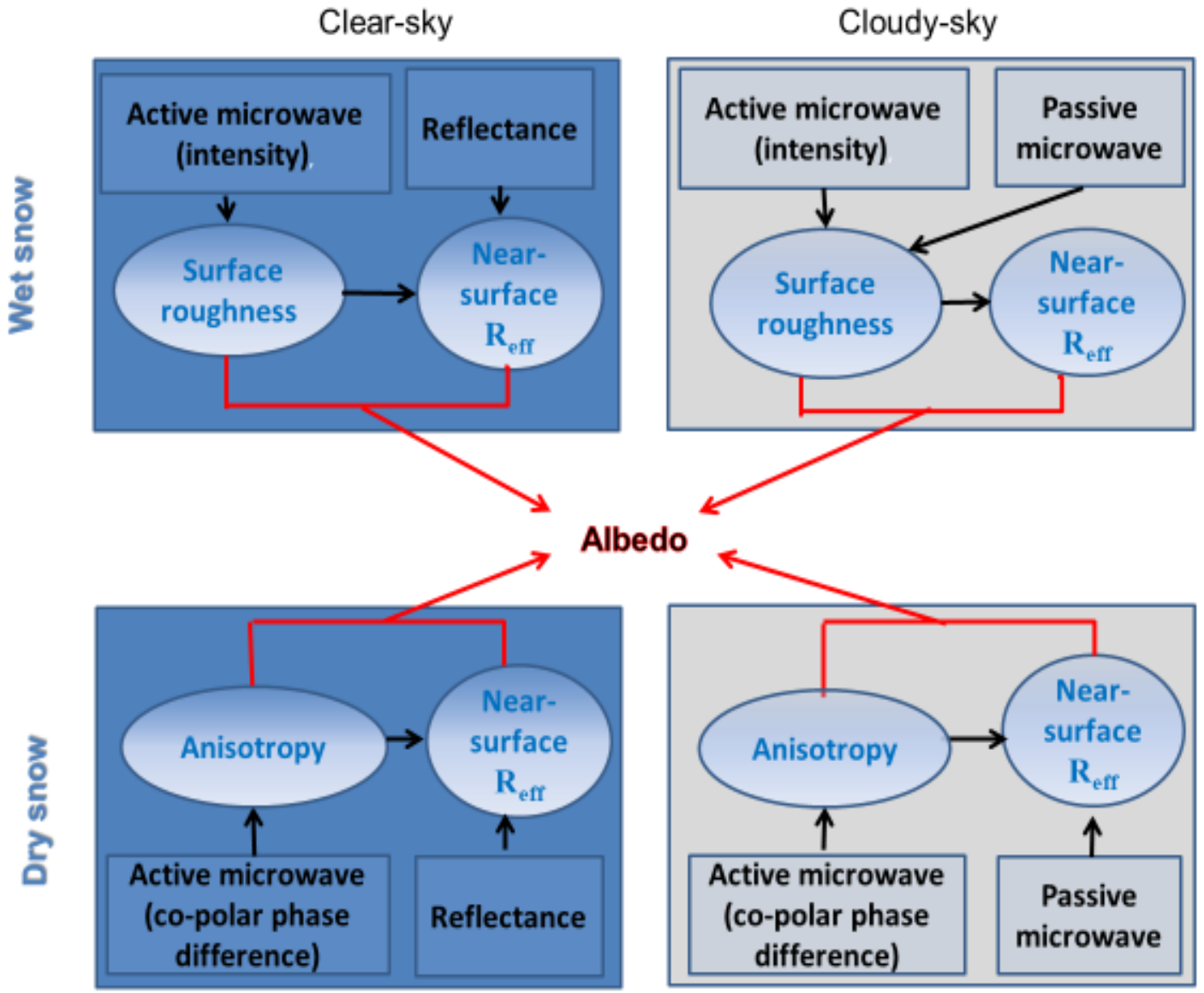
OPTICAL REGION

- DISORT
- Multiple-scattering RT model (Aoki, [3]),
- TARTES (Picard [4]),
- ART (Kokhanovsky [5])

MW REGION

- HUT model [6],
- MEMS3&a [7],
- IEM [2],
- SMRT [8]
- DMRT-ML (Picard, [9])

Albedo retrieval method



Field campaigns



4 weeks of continuous observations in **2019** (18.3-12.4) and **2020** (16.3-9.4);

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

- Snow **broadband albedo** (NIR and VIS bands)
- **Continuous** snow **spectral albedo** (SVC, GSAF, Autosolexs)
- Snow **BRDF** (FIGIFIGO)
- Snow **brightness temperature** (89,150 GHz)
- Snow **backscatter** (4-polarized radar (VV, HH, VH, HV), 1-9 GHz, Snowave (contact radar, 2 frequencies in the range 1-9GHz)
- Snow **micro/macro-physical properties**

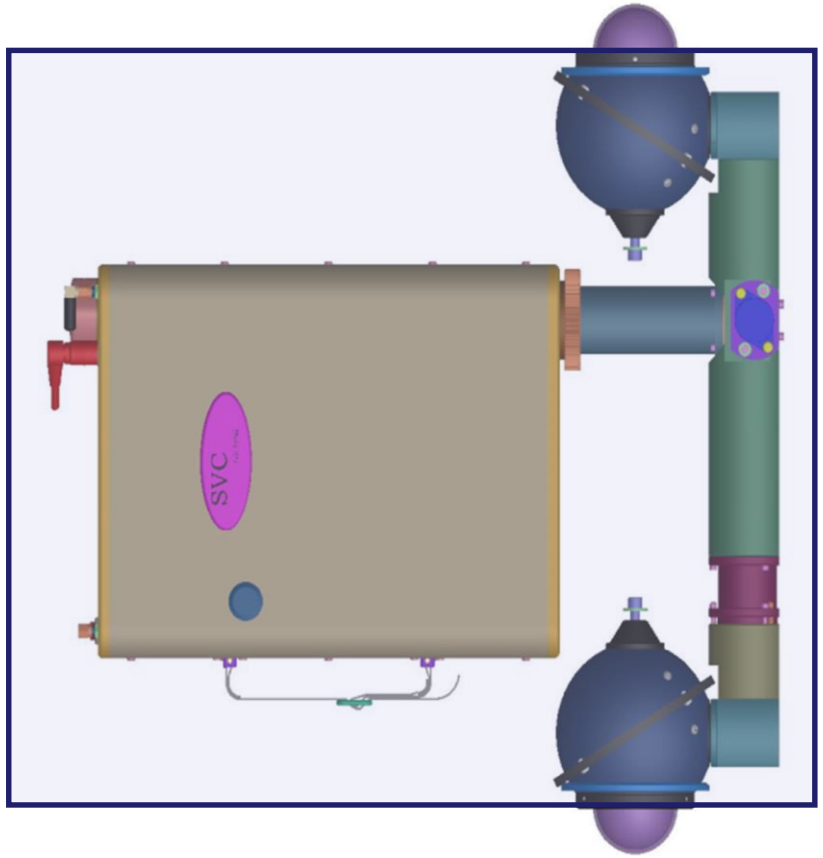
Measured snow variables

Parameter	Instrument	No. of profiles per day
SSA – chord lenght distribution – correlation function profile	IceCube[10], Micro-CT[11], SnowMicroPen[12], InfraSnow[13], HISSgraS, Macrophotos	1–4
Stratigraphy	SnowMicroPen, NIR photography	5–10, 1–2
Density profile	Density cutter, SnowMicroPen, Micro-CT	2–4, 5–10, surface/profile
Liquid water content profile	WISe[14]	1–2
Snow samples for impurity analysis	SP2 and OC/EC analyzer	1
Snow surface roughness	Monochromatic cameras, blackboard + photos	1-2
SWE	Snow tube	1-2

[10] A2 Photonic Sensors, Grenoble, France (Gallet et al., 2009), [11] Heggli et al. (2011), [12] Schneebeli and Johnson (1998), [13] Schneebeli et al. (2009), [14] A2 Photonic Sensors, Grenoble, France

SVC Dual Sphere Spectro-Albedometer

- Built by **Spectra Vista Corporation (SVC)** in co-operation with FMI



Core instrument:

- SVC HR-1024i (350-2500 nm)
- spectral resolution: (3.5 nm @ 700 nm, 9.5 nm @1500 nm, 6.5 nm @2100 nm)

Light collectors:

- integrating spheres with glass domes

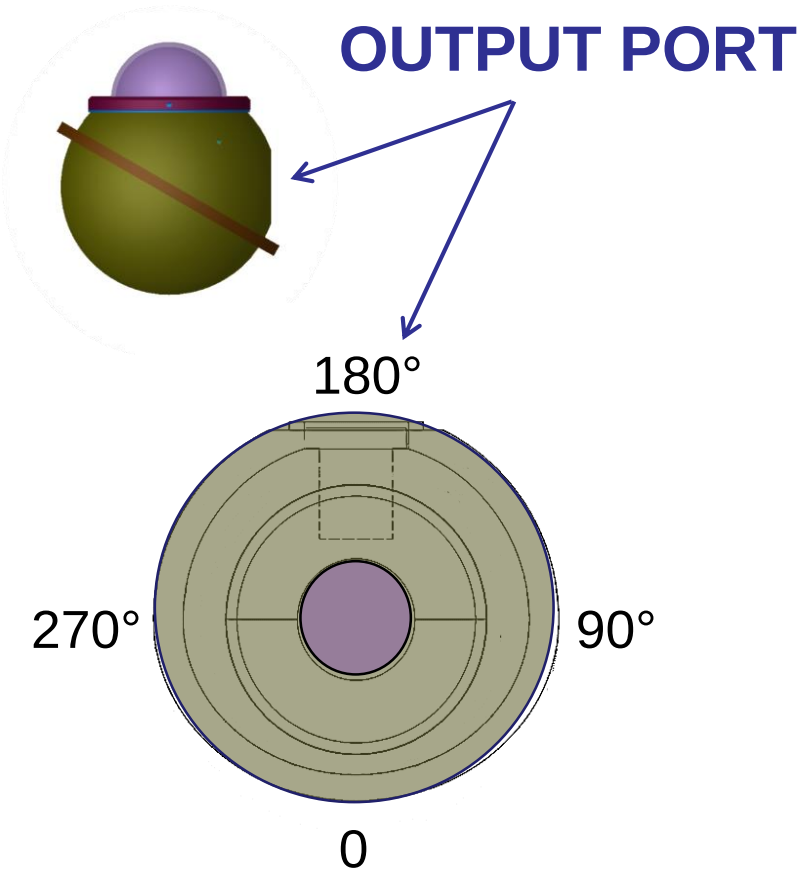
Light switcher: flipping mirror

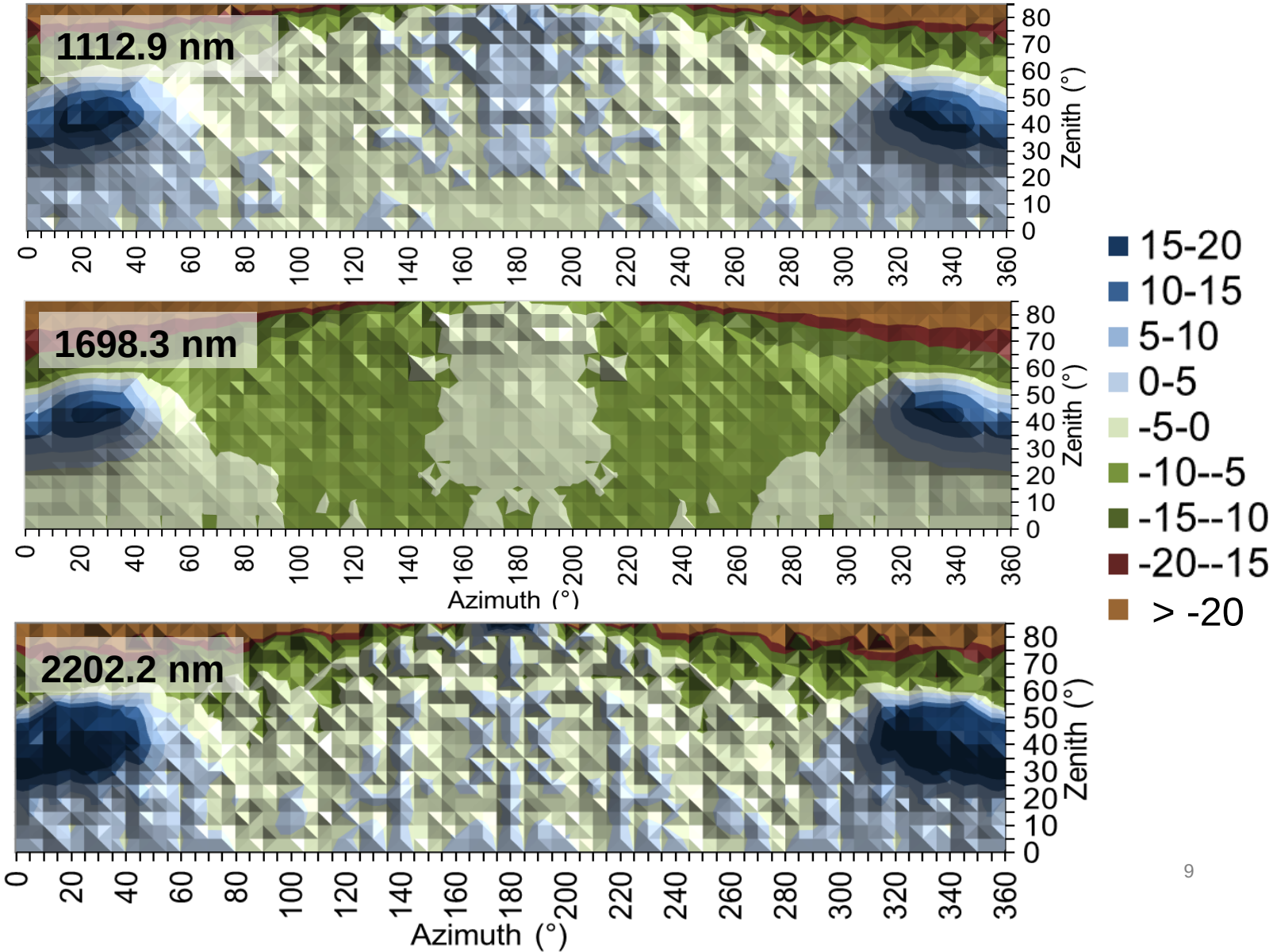
Insulating box:

- aluminium case with ventilation units (to blow air over the domes), insulating foam, and (eventually) temperature stabilizer.

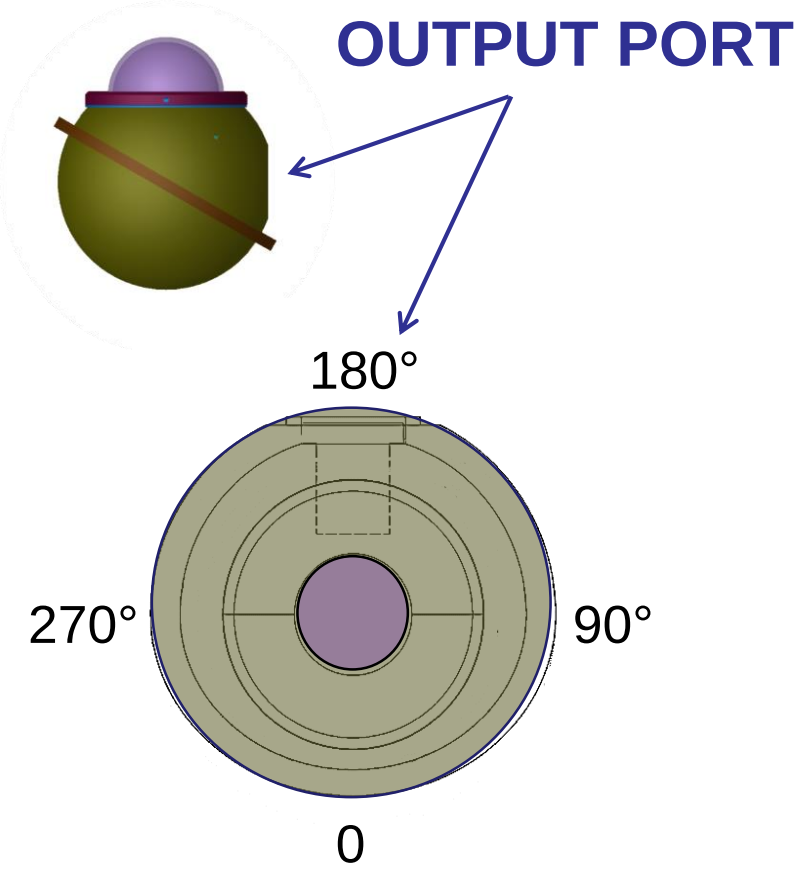
Measurement interval: 2 min

SVC Deviation from cosine response





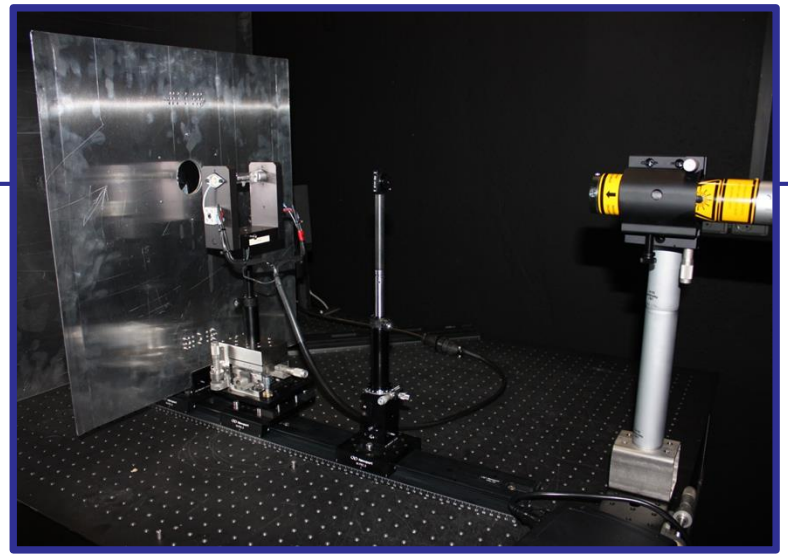
SVC Deviation from cosine response



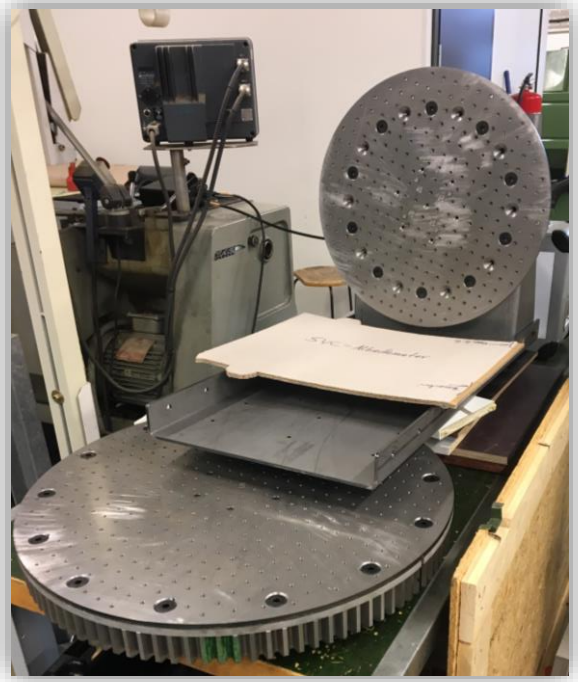
In the incident azimuth 90-270°:

578.5 nm:	Err <5%	for θ ≤ 50˚
	5 ≥ Err ≤10%	for 50 ≤ θ ≤ 70˚
	10 ≥ Err ≤15%	for 70 ≤ θ ≤ 75˚
885.6 nm:	Err <5%	for θ ≤ 60˚
	5 ≥ Err ≤10%	for 60 ≤ θ ≤ 75˚
1112.9 nm:	Err <5%	for θ ≤ 75˚
1698.3 nm:	Err <5%	for θ ≤ 70˚
	5 ≥ Err ≤10%	for 70 ≤ θ ≤ 80˚
2202.2 nm:	Err <5%	for θ ≤ 60˚
	5 ≥ Err ≤10%	for 60 ≤ θ ≤ 75˚

SVC Lab calibration and characterization



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



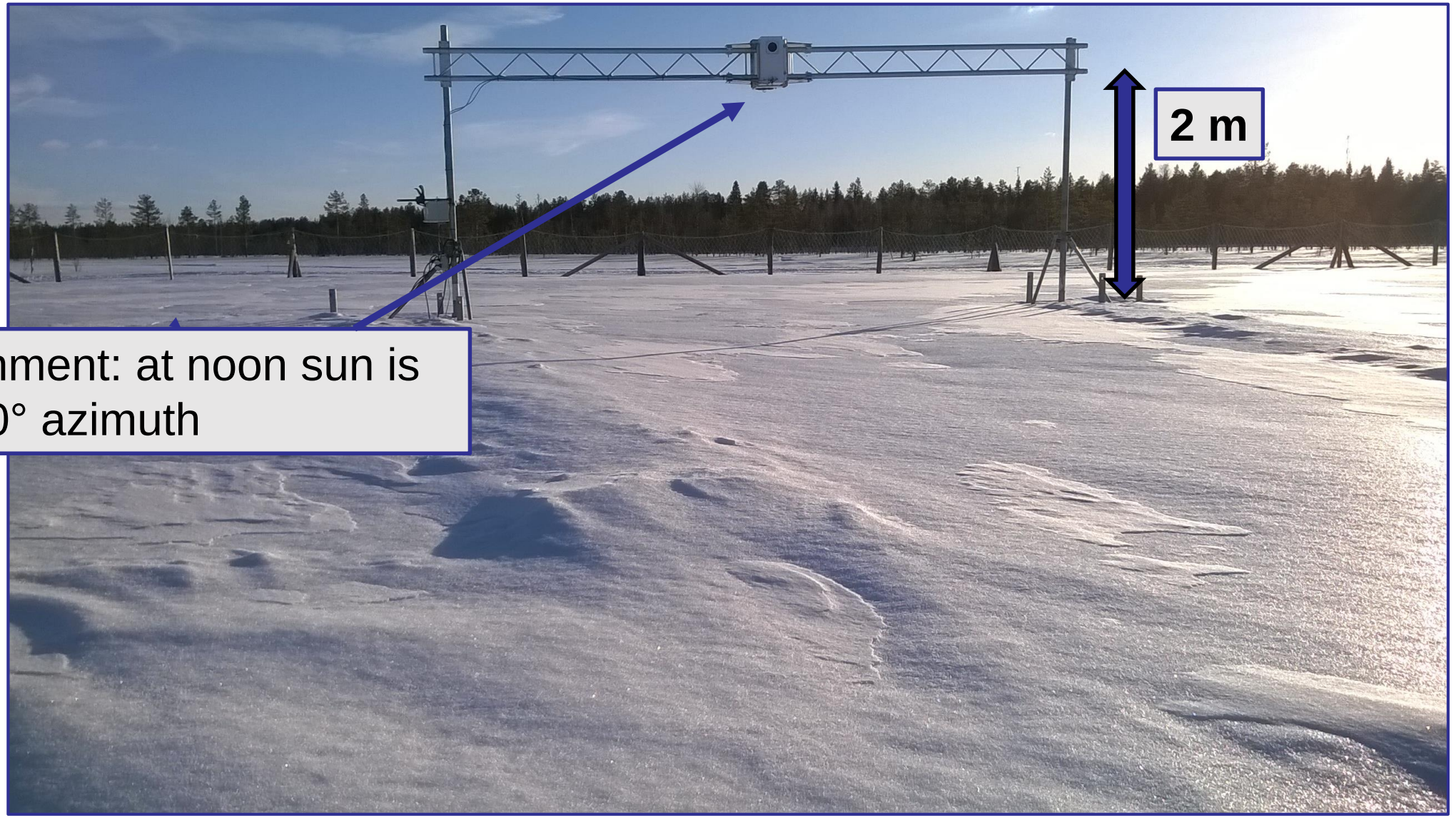
Temperature dependence of spectrometer's sensitivity (-30˚C ÷ +20˚)

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

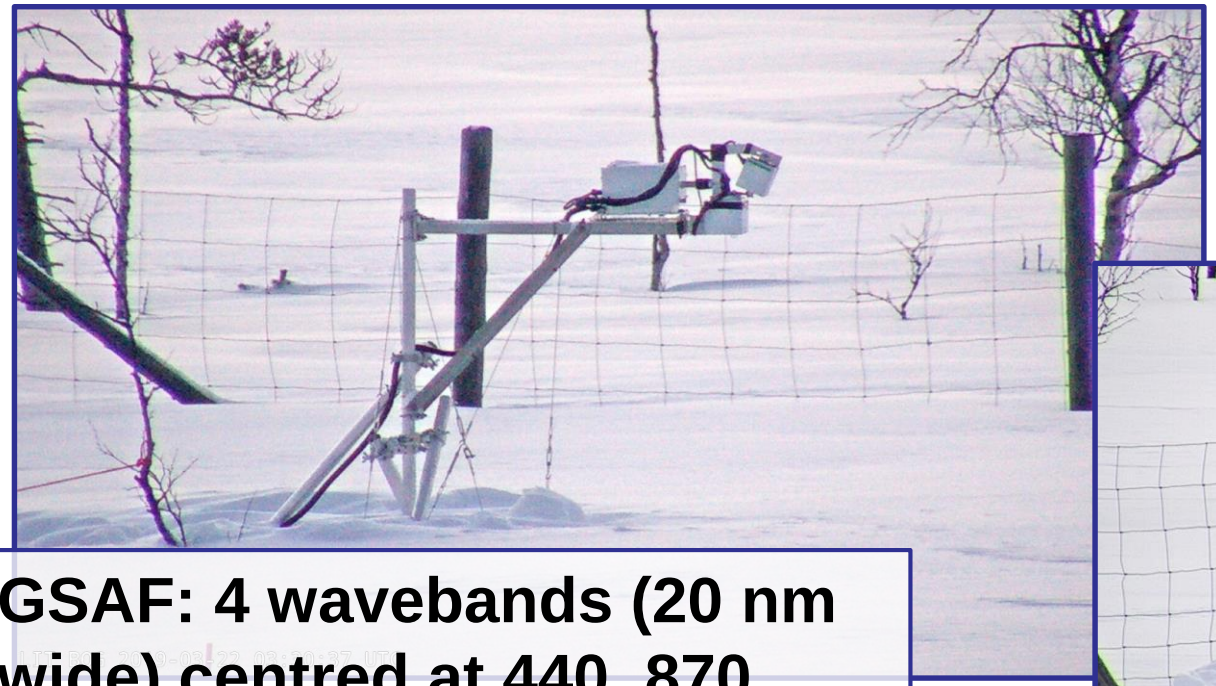


ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

SVC Installation in the field



Comparison with other continuous spectral albedo measurements

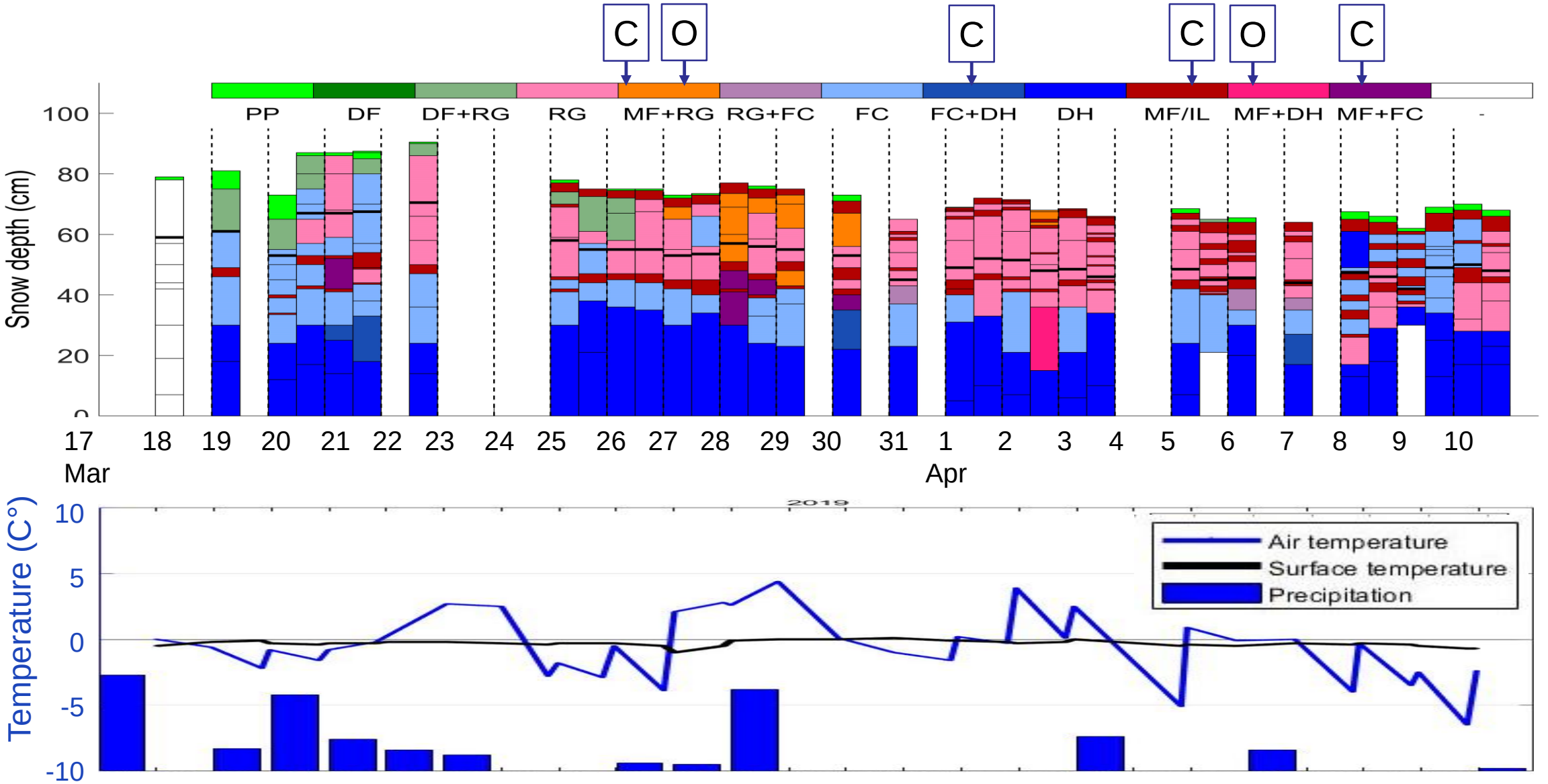


GSAF: 4 wavebands (20 nm wide) centred at 440, 870, 1230, 1600 nm

Autosolexs: 350-1050 nm, at 3 nm resolution

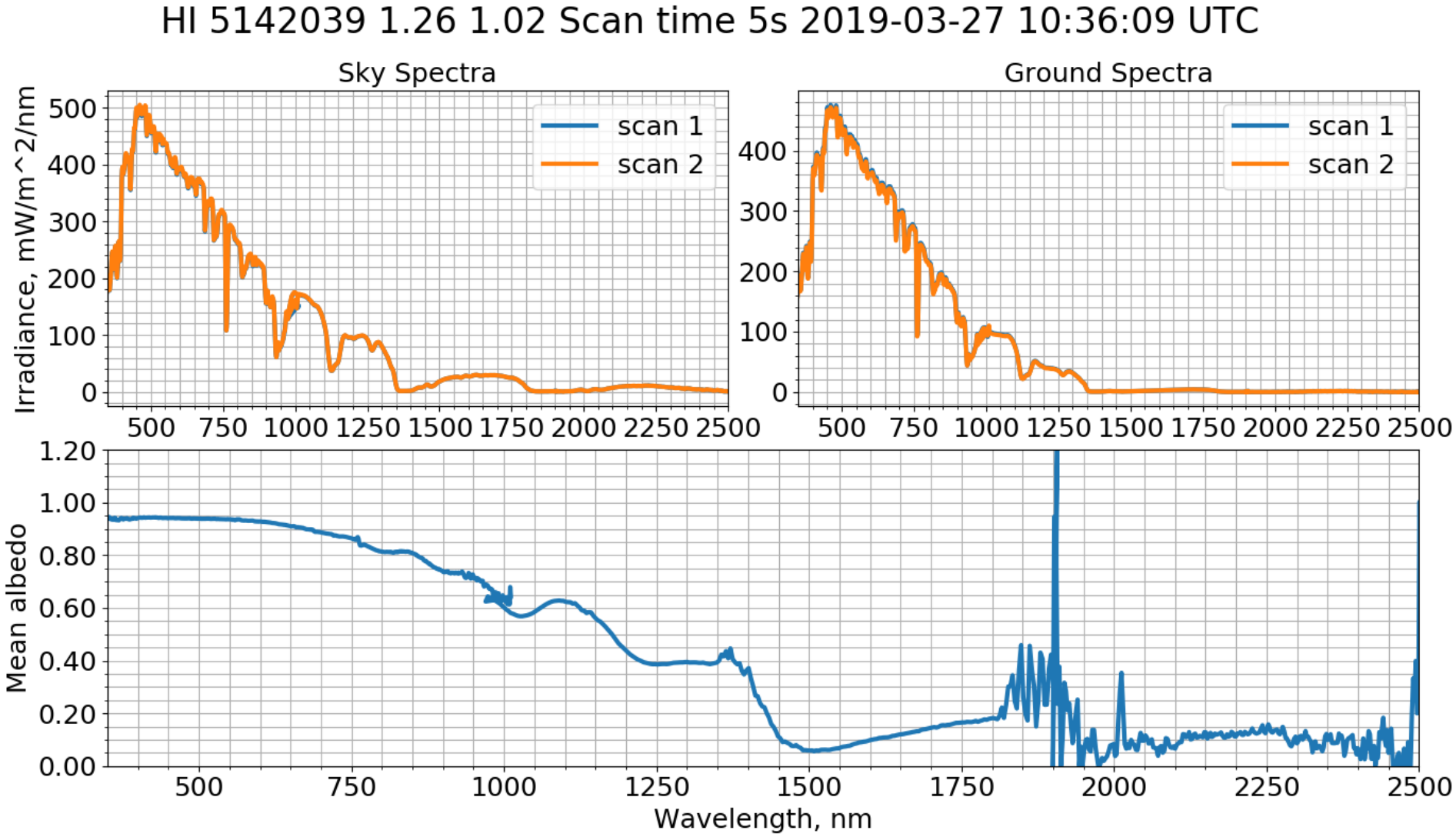


Spring 2019: Evolution of snow properties



Example of SVC data

8/8 cloud cover





ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

References

[1] Stenberg, P. and **Manninen, T**., 2015: The effect of clumping on canopy scattering and its directional properties: a model simulation using spectral invariants Int. J. Remote Sens, 36, 5178-5191.

[2] Fung, A. 1994: Microwave Scattering and Emission Models and their Applications. Artech House, 573 pp.
hikubo, Y. Tachibana, and F. Nishio, 2000: Effects of snow physical parameters on spectral albedo and bidirectional reflectance of snow surface, J. Geophys. Res., 105(D8), 10219–10236.

[3] **Aoki, T**., T. Aoki, M. Fukabori, A. Hac[1] Stenberg, P. and **Manninen, T**., 2015: The effect of clumping on canopy scattering and its directional properties: a model simulation using spectral invariants Int. J. Remote Sens, 36, 5178-5191.

[4] Libois, Q., **Picard, G**., France, J. L., Arnaud, L., **Dumont, M**., Carmagnola, C. M., and King, M. D., 2013: Influence of grain shape on light penetration in snow, The Cryosphere, 7, 1803-1818.

[5] Negi, H. S. and **Kokhanovsky, A**., 2011: Retrieval of snow albedo and grain size using reflectance measurements in Himalayan basin, The Cryosphere, 5, 203-217.

[6] Pulliainen, J. T., Grandell, J., and Hallikainen, M.T., 1999: HUT snow emission model and its applicability to snow water equivalent retrieval. Geosci. Remote Sens., 37, 1378-1390.

[7] Proksch, M., Mätzler, C., Wiesmann, A., **Lemmetyinen, J**., Schwank, M., **Löwe, H**., and **Schneebeli, M.**, 2015: MEMLS3&a, Microwave Emission Model of Layered Snowpacks adapted to include backscattering, Geosci. Model Dev., 8, 2611-2626, https://doi.org/10.5194/gmd-8-2611-2015.

[8] Wiesmann, A., and Mätzler, C., 1999: Microwave emission model of layered snowpacks. Remote Sens. Environ., 70, 307-316.

[9] **Picard, G**., Brucker, L., Roy, A., Dupont, F., Fily, M., Royer, A., and Harlow, C., 2013: Simulation of the microwave emission of multi-layered snowpacks using the Dense Media Radiative transfer theory: the DMRT-ML model, Geosci. Model Dev., 6, 1061-1078.