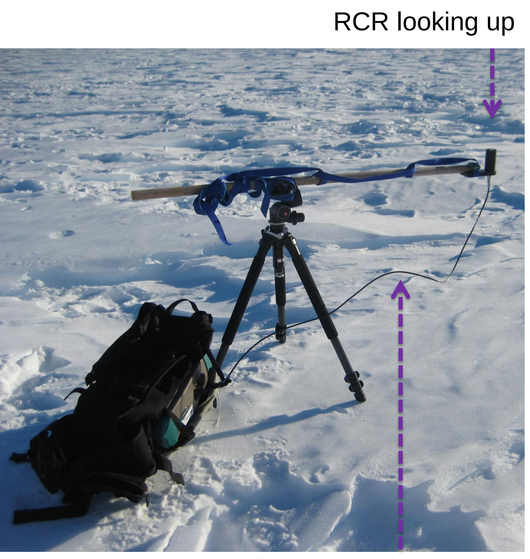
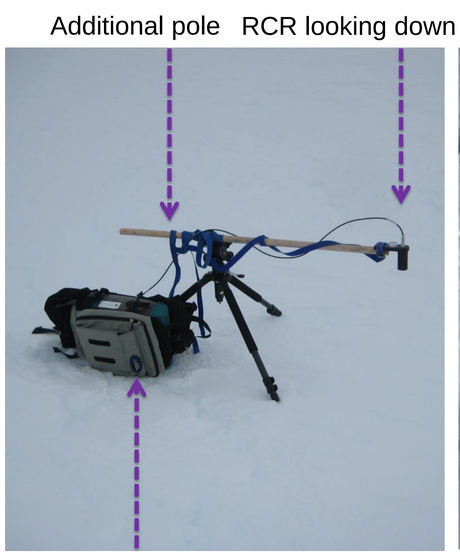
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Spectral albedo measurements over the ice sheet in Queen Maud Land, Antarctica

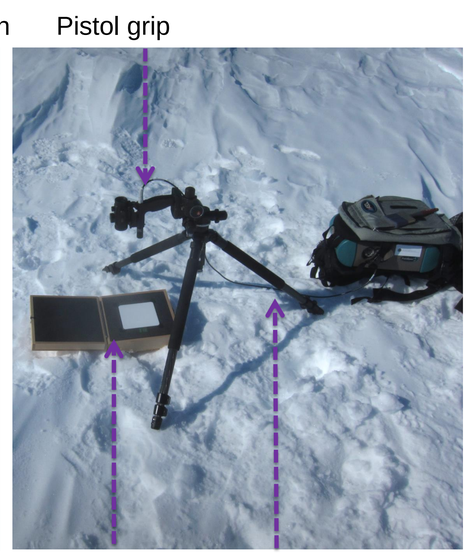
Leena Leppänen, Roberta Pirazzini, Panu Lahtinen
Finnish Meteorological Institute, Arctic Research, Sodankylä, Finland



Irradiance** measurement with **RCR



Reflectance** measurement with **RCR

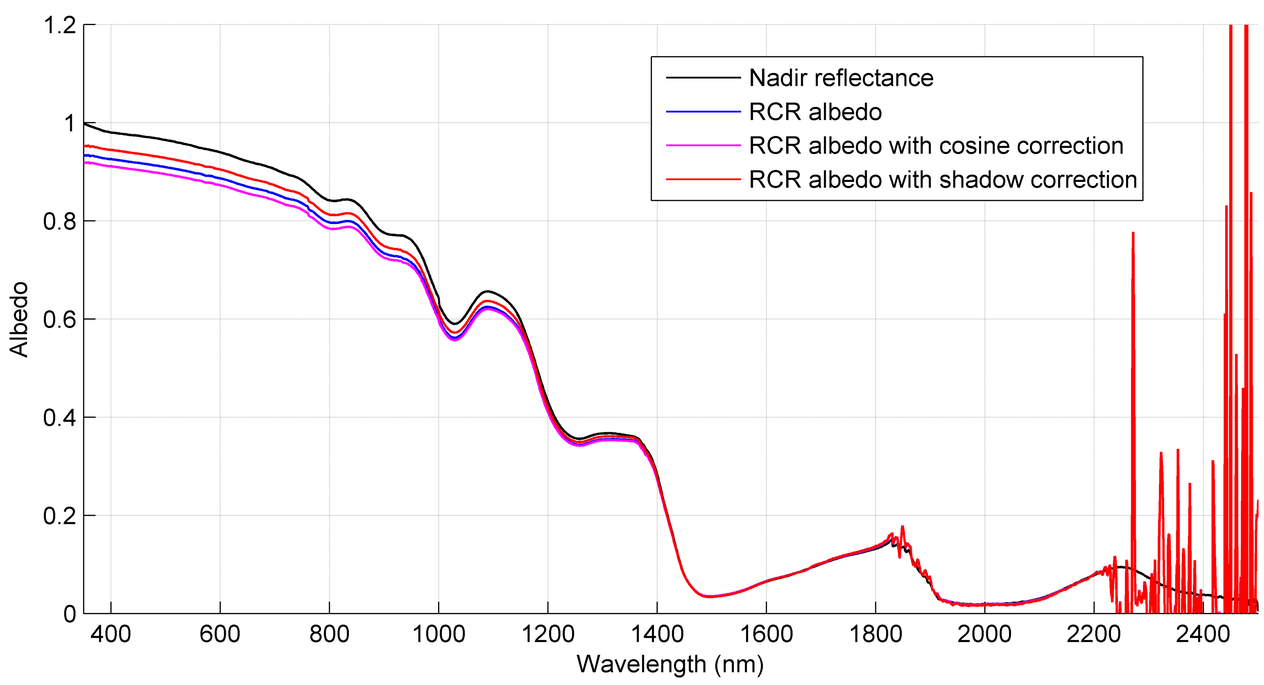


*Spectralon measurement with **pistol grip***

***Snow measurement site** 3 km away from Basen nunatak*

Instrument

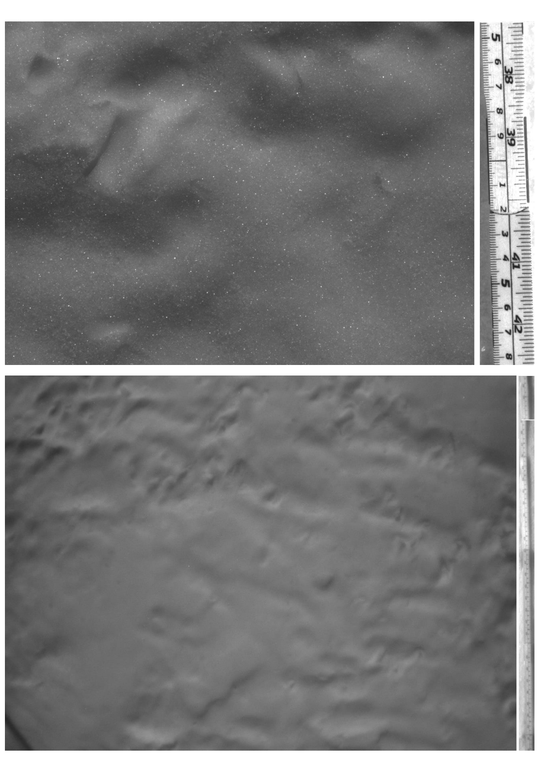
- Analytical Spectral Devices (ASD) spectrometer Field Spec Pro JR. manufactured by PANanalytical, Colorado, USA
- Fiber optic cable receives VNIR/SWIR radiation of **350-2500 nm**. It is used with RCR or pistol grip.
- **Remote Cosine Receptor** (RCR) measures hemispherical reflected radiance or hemispherical irradiance from sun
- **Pistol grip** with **fore optics of 8 degree field of view** is for nadir reflectance measurements. Reflectance standard (spectralon) measurements are made before or after nadir reflectance measurements.

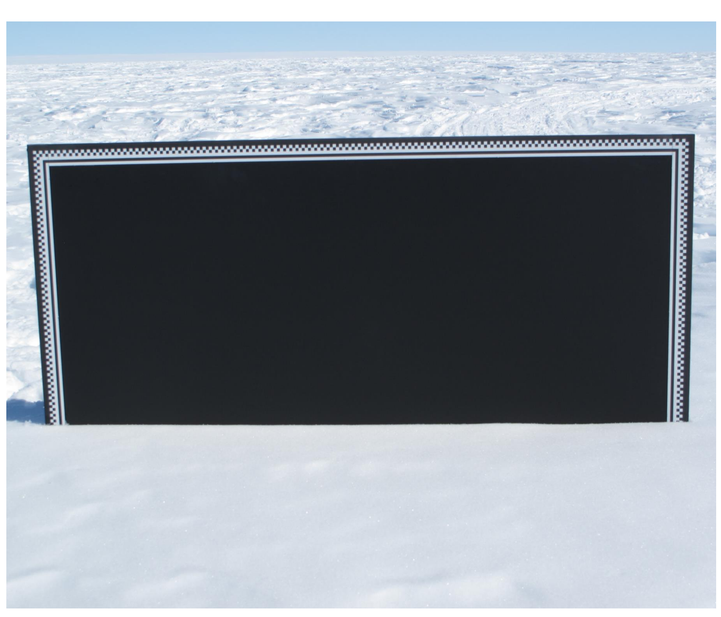


Spectral albedo and reflectance measured in 16 December 2014 11:05 UTC.

Other reference measurements

- **Surface roughness** with black board and with monochromatic cameras
- **Snow pit** measurements (**grain size** macrophotography, **temperature** and **density** profiles, **stratigraphy** with traditional grain size, hardness and wetness)
- Automatic measurements: wind, air temperature and humidity profiles, snow temperature profile, shortwave and longwave radiation, and broadband albedo





Surface roughness measurements from 16 December 2014
Left: photos from monochromatic cameras (narrow and wide angle) with ruler
Right: black board (a black/white grid in the edge is 0.5 cm)

Measurements

- Measurements were performed in December 2014 and January 2015 during FINNARP2014 expedition in Finnish Antarctic station Aboa in Queen Maud Land
- Measurements in **clear sky** and **overcast** conditions
- Total **71** spectrometer measurements from **10** days and 16 measurement occasions.

Error sources

Shadow

- Shadow of measurer was eliminated by standing far enough from the instrument and opposite direction as the sun
- Shadow of instrument bag and tripod was reduced with setting the instrument bag to opposite direction as the sun and sensor looking towards the sun
- Additional pole was used with RCR to locate the sensor away from the tripod
- Shadow corrected albedo from RCR with assumption that albedo of tripod and instrument bag is 0.1

$$\alpha_{shadow} = \frac{\alpha_{original} - 0.1 \cdot s}{1 - s}$$

where $s = 0.0224$ (based on measurements with and without instrument bag)

Cosine response of RCR

- Cosine response of RCR differs from the ideal cosine response
- Correction presented by Grenfell et al. 1994 is used for calculation of true albedo

$$\alpha_{true} = \frac{C_\lambda \cdot ref}{C_\lambda \cdot x \cdot irr + \frac{irr(1-x)}{1+\varepsilon}}$$

$$\alpha_{true} = \frac{ref}{irr} \cdot \frac{1+\varepsilon}{x + e \cdot x + {}^{1}/_{C_\lambda} - {}^{x}/_{C_\lambda}}$$

where x is ratio between direct and diffuse radiation, irr is measured irradiance and ref is measured reflectance, and

$$C_\lambda = \frac{0.5}{\int_0^1 \mu(1+\varepsilon)d\mu}$$

$$\mu = cos(\theta)$$

where θ is solar zenith angle and from Carmagnola et al. 2013

$$\varepsilon = \begin{cases} 0.28 \cdot \cos(\theta) - 0.28 \text{ , for } \lambda < 1000 \text{ mn} \\ 0.1 \cdot \cos(\theta) - 0.1 \text{ for } \lambda > 1000 \text{ nm} \end{cases}$$

Temperature of instrument

- Warm up time was minimum 30 min
- SWIR1 detector is used to correct data from SWIR2 and VNIR detectors
- Parabolic correction from instrument documentation is applied
  - If $724 < x < 1021$

$$y = \frac{(x-725)^2(y_{1021} - y_{1020})}{y_{1020}(1020-725)^2} + 1$$

  - If $1800 < x < 1951$

$$y = \frac{(x-1950)^2(y_{1801} - y_{1800})}{y_{1800}(1800-1950)^2} + 1$$

  - Else $\mathrm{y} = 1$

where x is wavelength and y is measured radiance.

COST ES1404 Albedo workshop 24-25 August 2016 Helsinki Finland
Leena Leppänen
Email: leena.leppanen@fmi.fi

Carmagnola, C. M., Dominé, F., Dumont, M., Wright, P., Strellis, B., Bergin, M., Dibb, J.,. Picard, G., Libois, Q., Arnaud, L., and Morin, S.: Snow spectral albedo at Summit, Greenland: measurements and numerical simulations based on physical and chemical properties of the snowpack, *The Cryosphere*, 7, 1139-1160, doi:10.5194/tc-7-1139-2013, 2013.

Grenfell, T. C., Warren, S.G., and Mullen, P. C.: Reflection of solar radiation by the Antarctic snow surface at ultraviolet, visible, and near-infrared wavelengths, *Journal of Geophysical Research: Atmospheres*, *99*(D9), 18669-18684, 1994.