FINNISH METEOROLOGICAL INSTITUTE

Relationships between snow microstructure and albedo
from measurement and modelling perspectives

R. Pirazzini, P. Räisänen, T. Vihma, M. Johansson, and E.-M. Tastula
Finnish Meteorological Institute, Helsinki, Finland

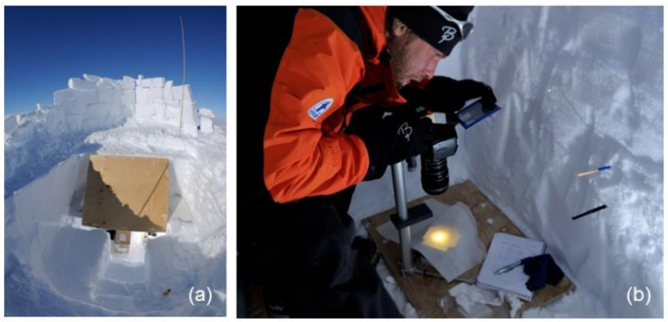
Background

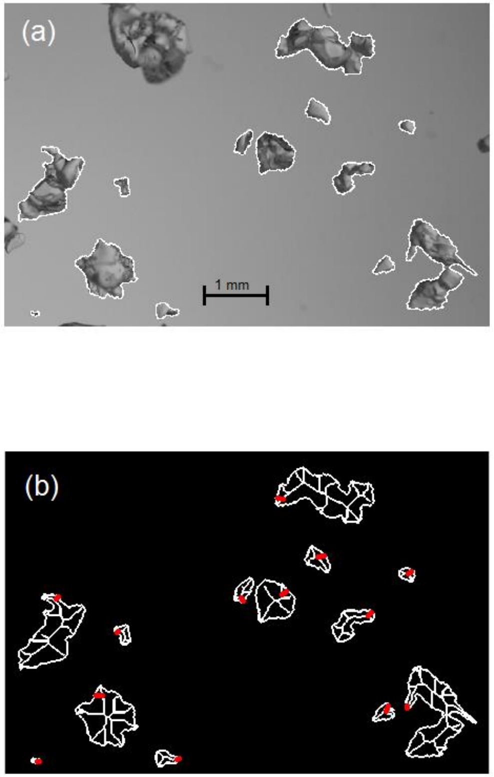
- The snow albedo mostly depends on the scattering properties of snow particles

- The scattering properties of snow particle are mainly determined by their size (cross-section) and shape.

- The measurement of size and shape of snow particles is extremely complex and laborious: snow crystals are often connected to each others forming an irregular 3D structure

Among the available methods to measure snow particle size, we choose **2D macro photos**





From the 2D projections of the snow particles we calculated the **Shortest Skeleton Branches** (SSK)

Effective particle size vs Optical equivalent grain radius

- FROM MEASUREMENTS (SSK distribution): we calculated the **Effective particle size (*r_{eff}*)**:

$$r_{eff} = \frac{\sum r_i^3}{\sum r_i^2}$$

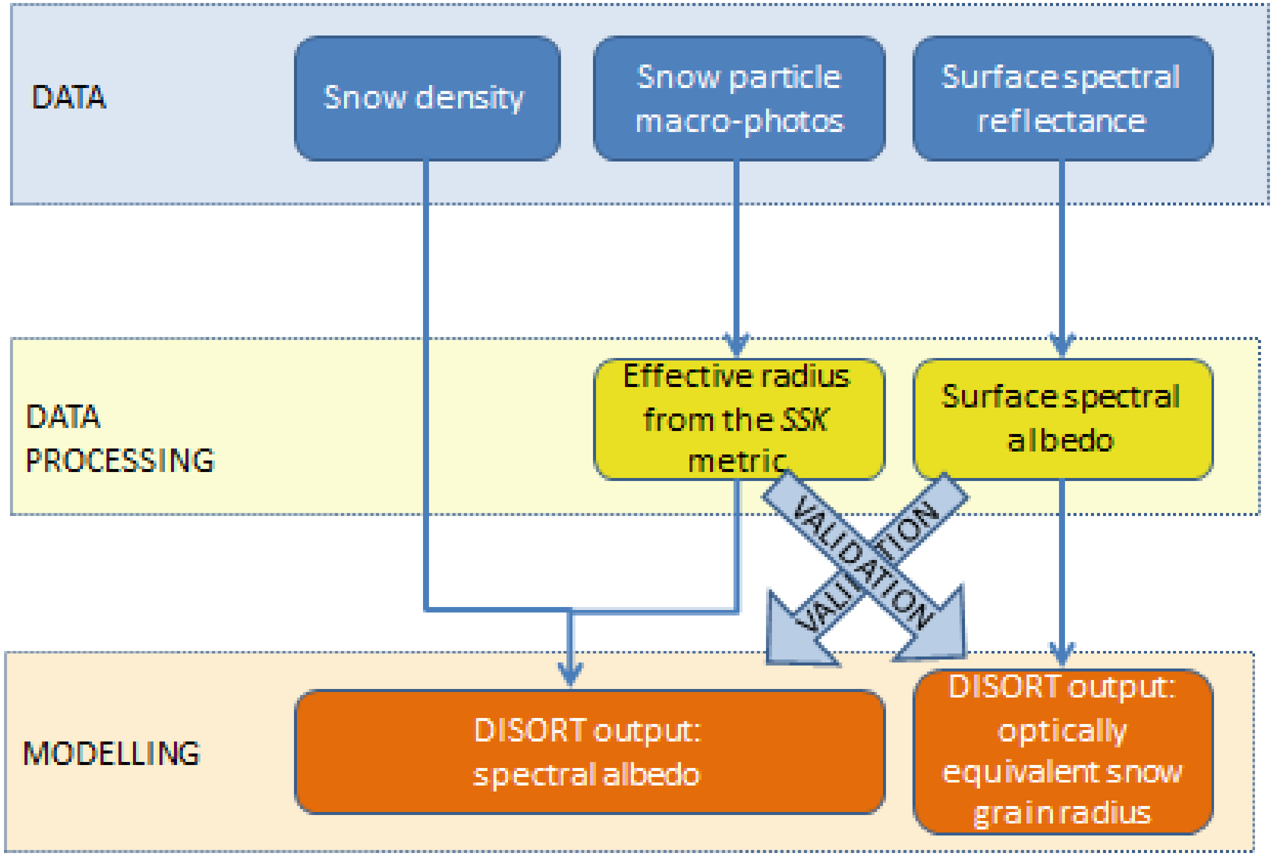
- IN RADIATIVE TRANSFER MODELS: snow grain size is expressed as **Optical equivalent grain radius (*r_{oeff}*)** = radius of a collection of mono-disperse spheres having a total volume-to-surface area-ratio equal to that of the true snow grain population.

Objectives

1) To verify if the measured particle size distribution (SSK) synthetize well the scattering properties of the snowpack at $\lambda > 1.0\ \mu m$.

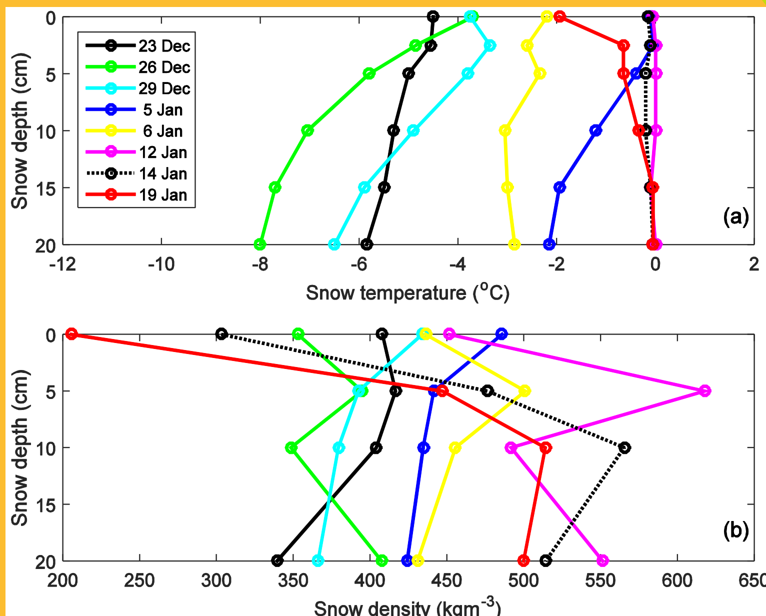
2) To verify if the measured vertical profiles of snow density and particle size distribution gives suitable and sufficient information to model the surface albedo (at $\lambda > 1.0\ \mu m$)

Work flow diagram

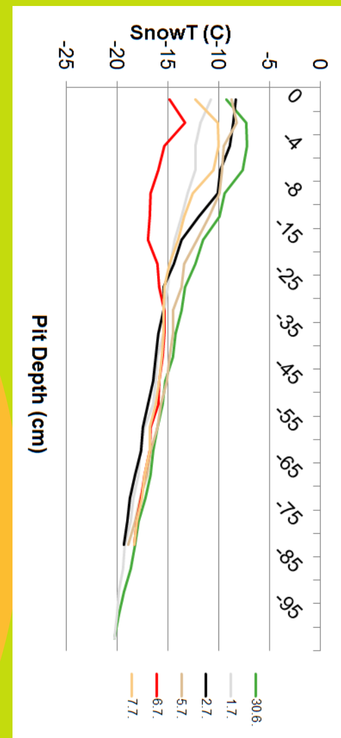


Case studies

Antarctic ice sheet

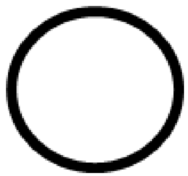


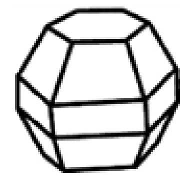
Greenland ice sheet



Modelling strategy

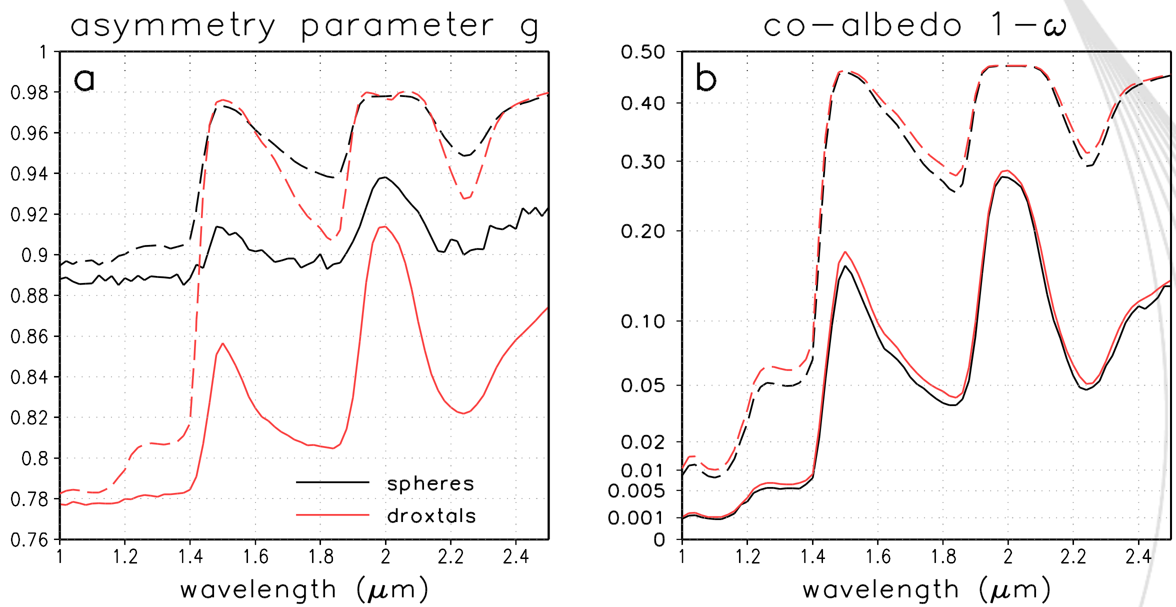
Albedo was modelled with DISORT, using observed particle sizes and spherical/droxtal particle shapes:

SPHERE: 

DROXTAL: 

INPUT: -effective grain size (meas.)
-snow density (meas.)
- ice refractive index (from Warren and Brandt, 2008)

Single scattering properties of spheres and droxtals: **droxtals have smaller g, and therefore they give higher snow albedo**

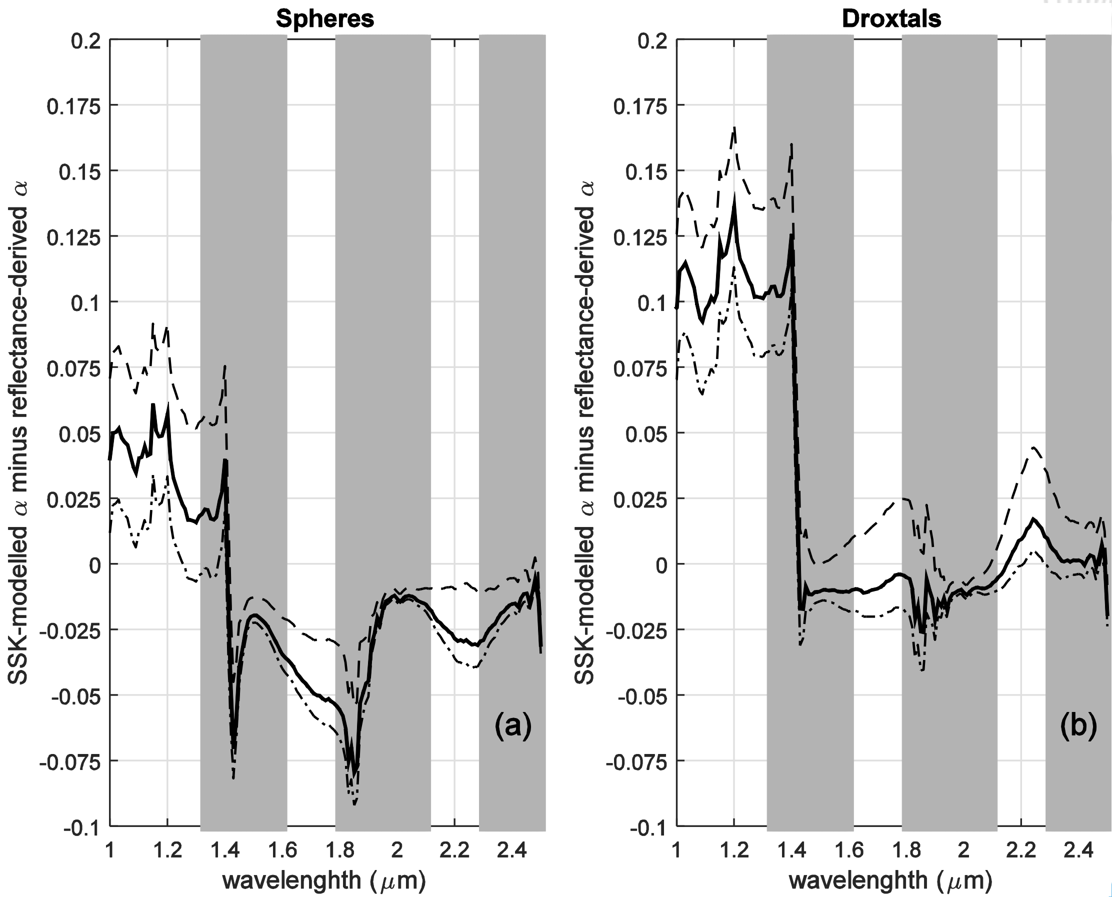


r = 50 μm (solid lines),r = 500 μm (dashed lines)

Results for the Antarctic cases

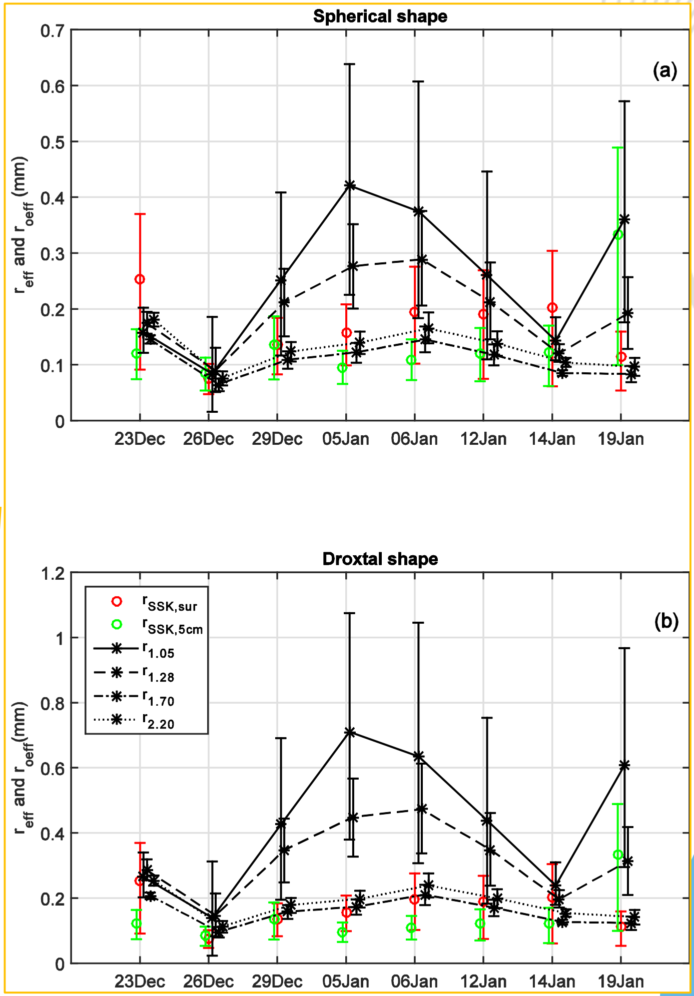
- For **λ>1.4 µm**, the SSK metric provides albedo values that agree well with observations, especially for droxtal shapes .

- For **λ<1.4 µm**, a good fit between the modelled and the observed albedo was still present in some cases, but, on average, a large positive bias was observed.



Results for the Antarctic cases

- In case of smooth and homogeneous surface because of fresh or drifted snow, r_{eff} corresponded to r_{oeff} remarkably well at all wavelengths, particularly for droxtal.
- In the other cases, r_{oeff} depended on wavelength: for **λ>1.4 µm** r_{eff} still corresponded to r_{oeff}, for **λ<1.4 µm** r_{eff} was significantly smaller than r_{oeff}.



Effective snow particle radius r_{eff} obtained from the distributions of shortest skeleton branches at the surface (red circles) and at 5 cm depth (green circles), and r_{oeff} derived with DISORT from spectral albedo observations at the wavebands centered on 1.05, 1.28, 1.70, and 2.20 µm during eight case studies, for spherical (a) and droxtal (b) shapes.

Interpretation of the results

1) Because of the different penetration depth of light at different wavelengths, **in case of mixed-size particle population** (large faceted particles with small protrusion + small particles) **the albedo is predominantly affected by different particle sizes at different wavelengths.**

2) **When millimetre and centimetre-scale surface roughness is present**, the walls of the small cavities absorb part of the reflected radiation. Thus, **albedo is reduced, particularly at the shortest wavelengths**.

Conclusions

In case of smooth and homogeneous surfaces:

1) the method applied to measure snow particle size is adequate for optical applications.
2) the *SSK* metric offers a good synthesis of the particle's physical dimension relevant for light scattering.
3) the droxtal shape represents the scattering properties of the snow particles better than the spherical shape.

In case of rough surfaces with heterogeneous particle population:

1) the *SSK* metric characterizes the scattering by snow only for $\lambda > 1.4$ µm.
2) For $\lambda < 1.4$ µm a larger metric should be applied.
3) The impact of millimetre-scale snow surface roughness on the surface albedo needs to be better investigated.

Thank you for your attention!