FINNISH METEOROLOGICAL INSTITUTE

The effect of the surface roughness on the snow albedo

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RASCALS campaign: Panu Lahtinen and Aku Riihelä

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- Examples of surface roughness at Greenland and Sodankylä
- Surface roughness measurement
- Relationship of albedo and surface roughness
- Results from RASCALS campaign 2010 at Greenland Summit
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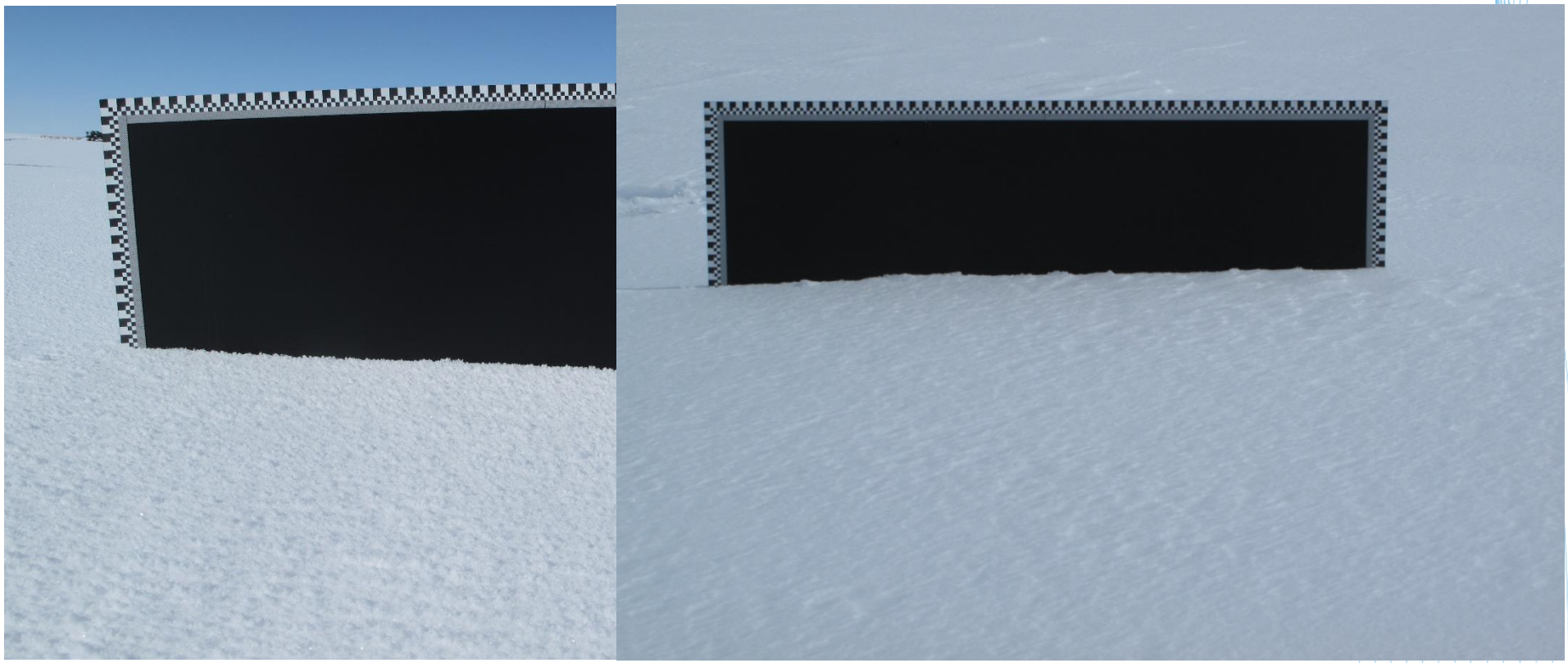
- Conclusions

Examples of surface roughness at Greenland Summit in June - July 2010

July 3, 2010

July 16, 2010

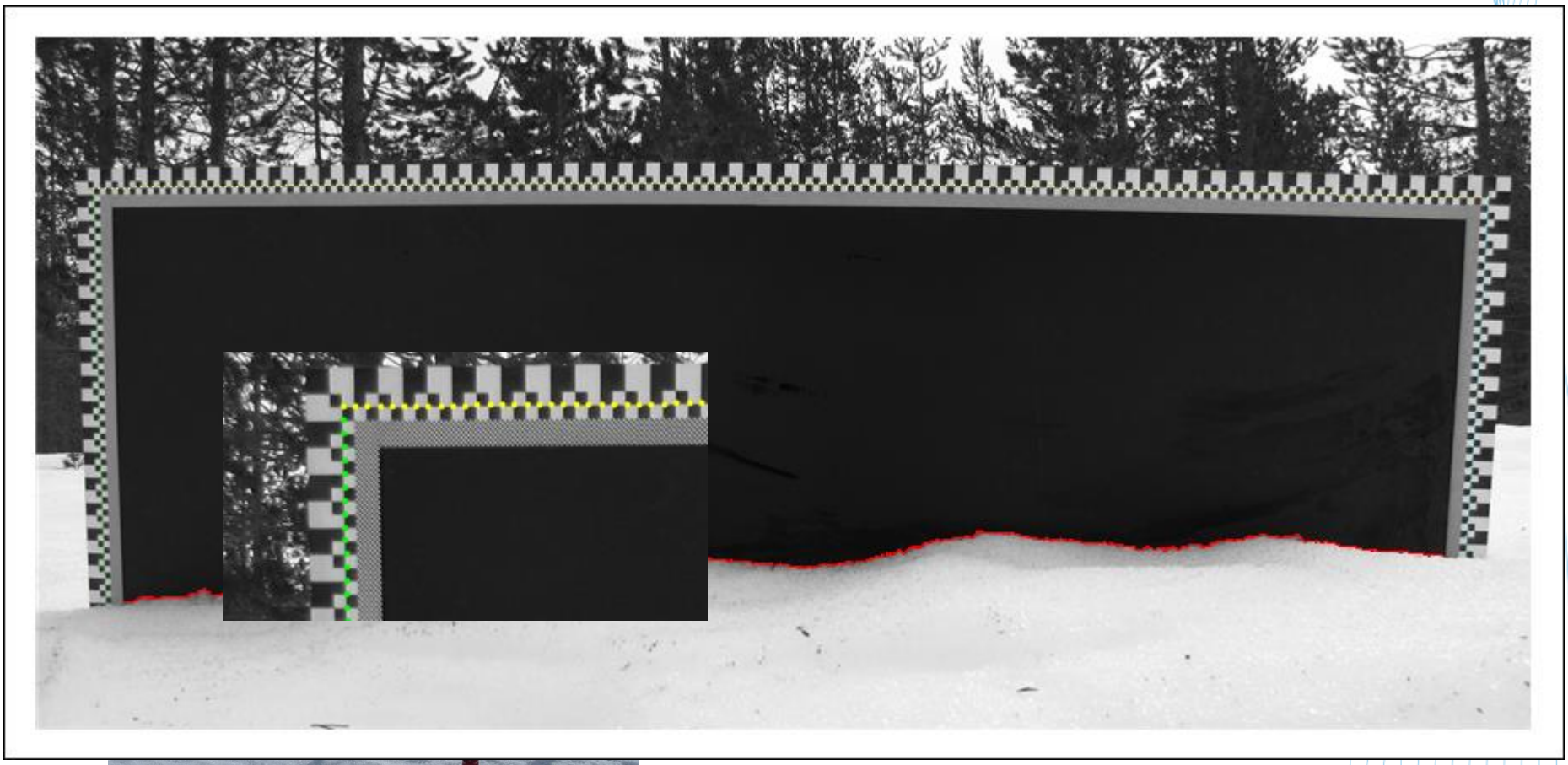


https://helda.helsinki.fi/bitstream/handle/10138/28678/2011nro8.pdf;sequence=1

Examples of surface roughness at Sodankylä in 2009 - 2010

https://helda.helsinki.fi/bitstream/handle/10138/135970/2014nro7.pdf?sequence=1

Snow surface roughness measurements



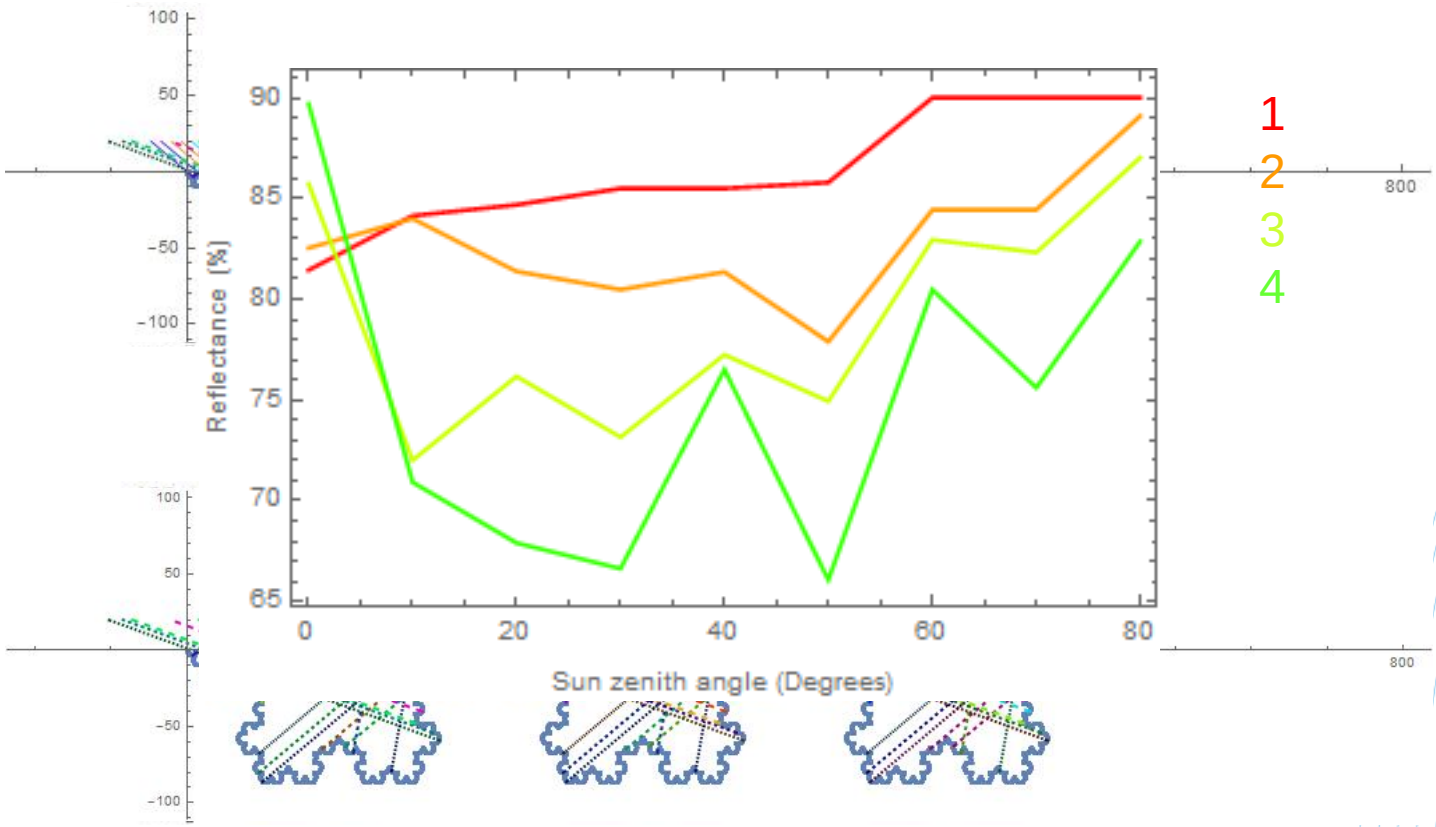
Surface roughness and geometric optics

Incoming, reflected and escaping radiation

Koch like fractal surface

$\theta_i = 50°$

$R = 0.9$



Albedo and bidirectional reflectance

$$\alpha(\theta_0) = \int_0^{\pi/2} \int_0^{2\pi} BRF(\theta_0, \theta, \varphi) \sin\theta \, d\,\theta d\varphi$$

$$\alpha \approx \frac{\sum_i^n f(\theta_i)\Delta A(\theta_i) R^{m_i}}{\sum_i^n f(\theta_i)\Delta A(\theta_i)}$$

$$R = reflectance,$$
$$m_i = number\ of\ reflections\ for\ ray\ i,$$
$$n = number\ of\ rays$$

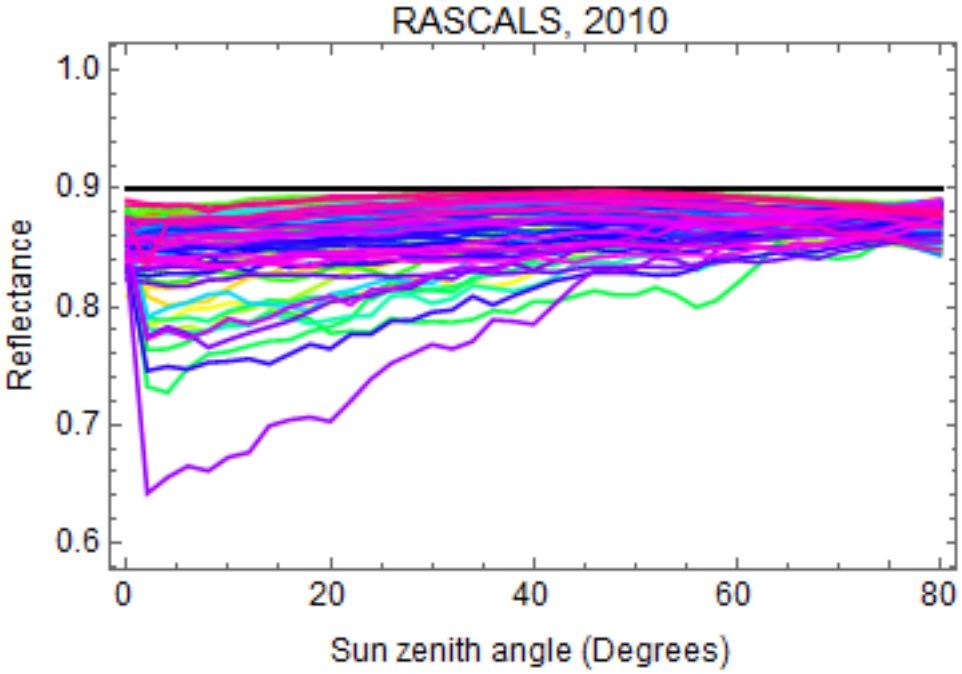
$$\Delta A(\theta_i) = 2\pi \int_{\theta_i - \Delta\theta/2}^{\theta_i + \Delta\theta/2} \sin\theta d\theta$$

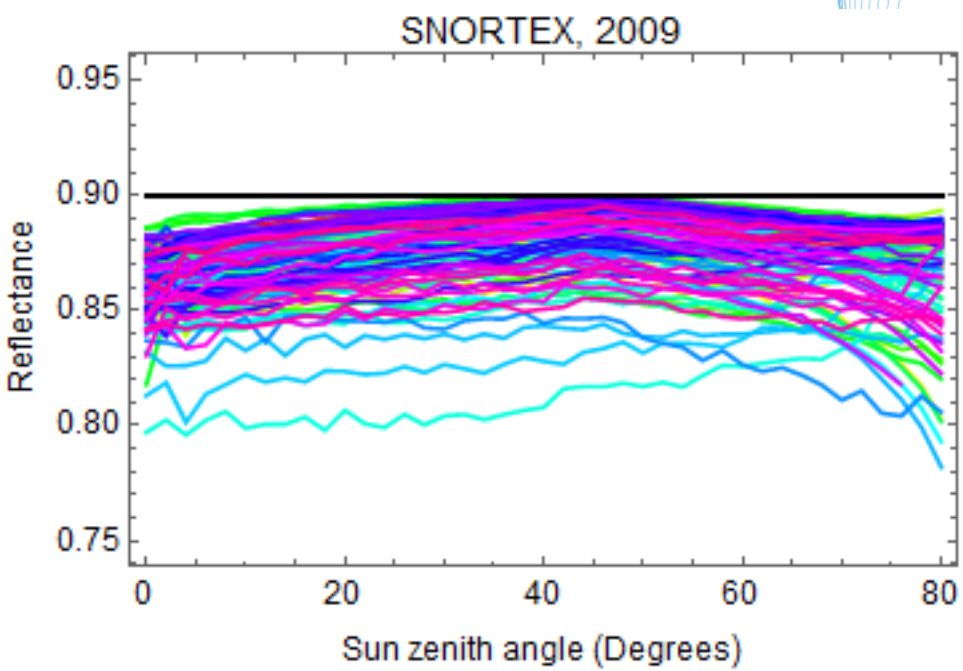
Total albedo α is known from mast measurements, f is the angular frequency of the reflected radiation calculated from the profiles and ΔA is determined by the angular difference of the calculations

=> R is solved from the equations above

=> α for each profile is then determined as a function of sun zenith angle θ_0

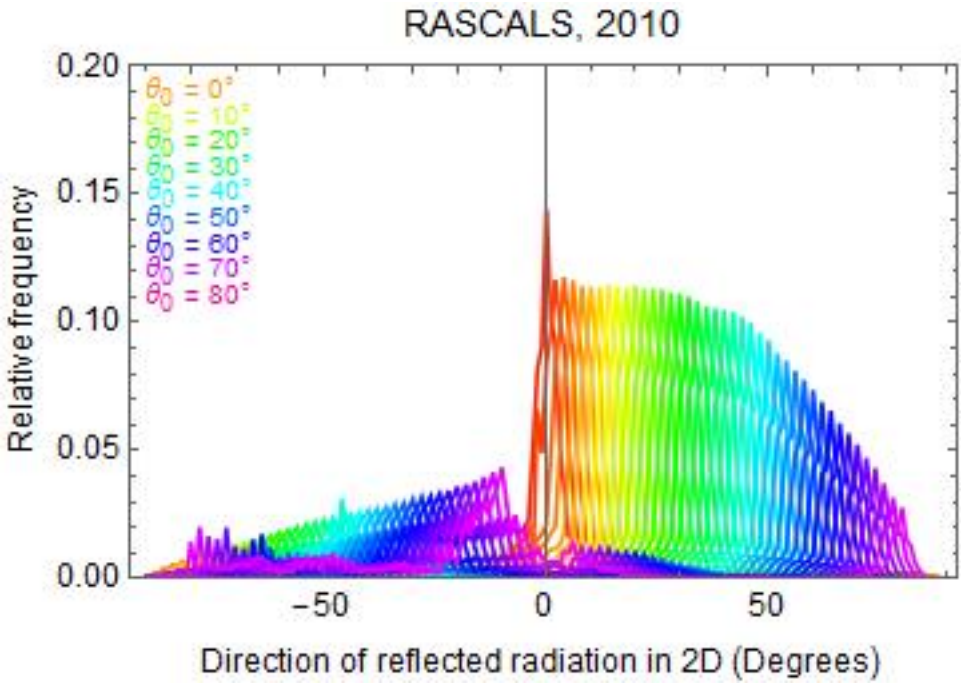
Effect of surface roughness on the mean reflectance of the profile

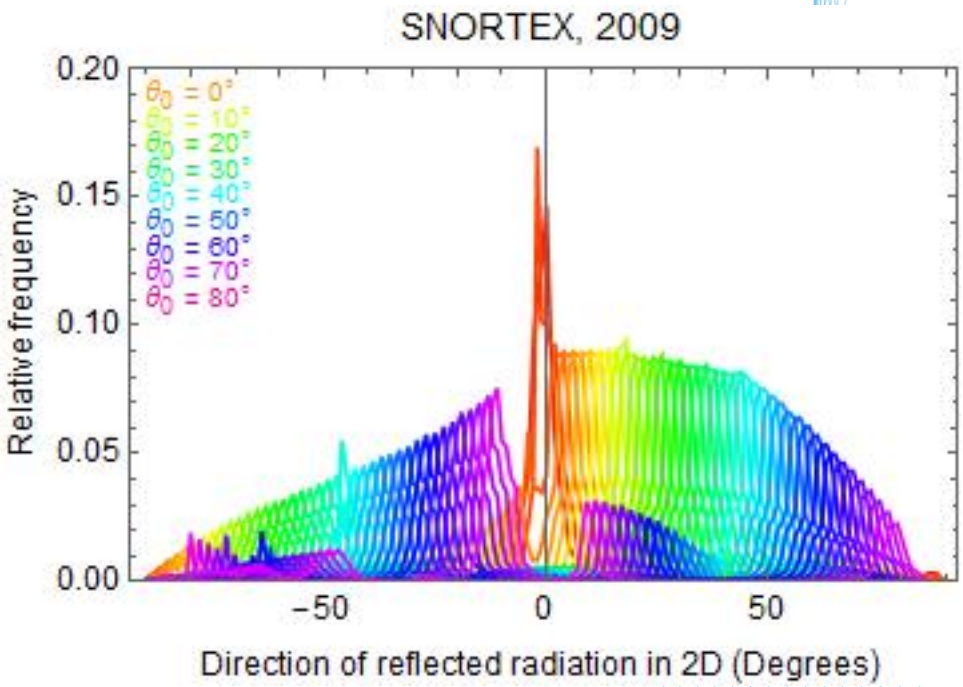




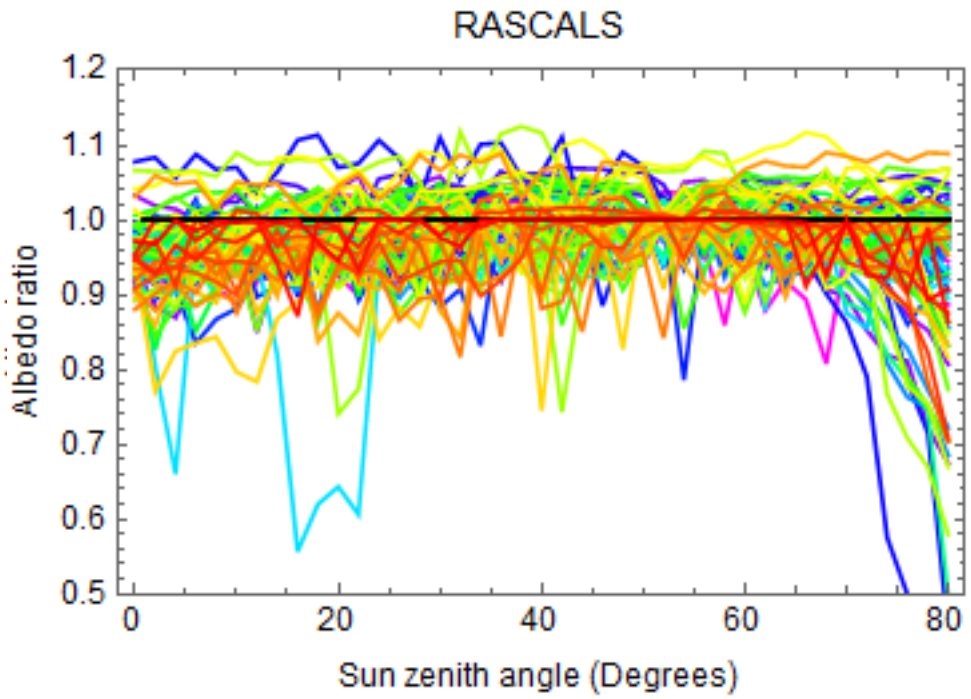
Assuming material reflectance to be $R = 0.9$

Effect of surface roughness on the angular distribution of the reflected radiation

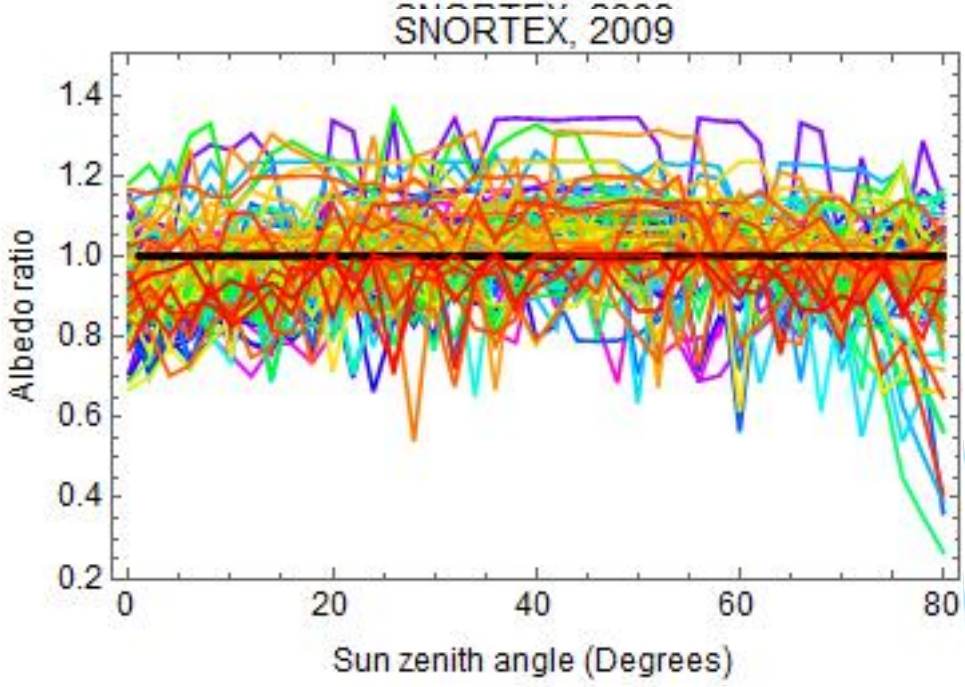




Effect of surface roughness on the albedo

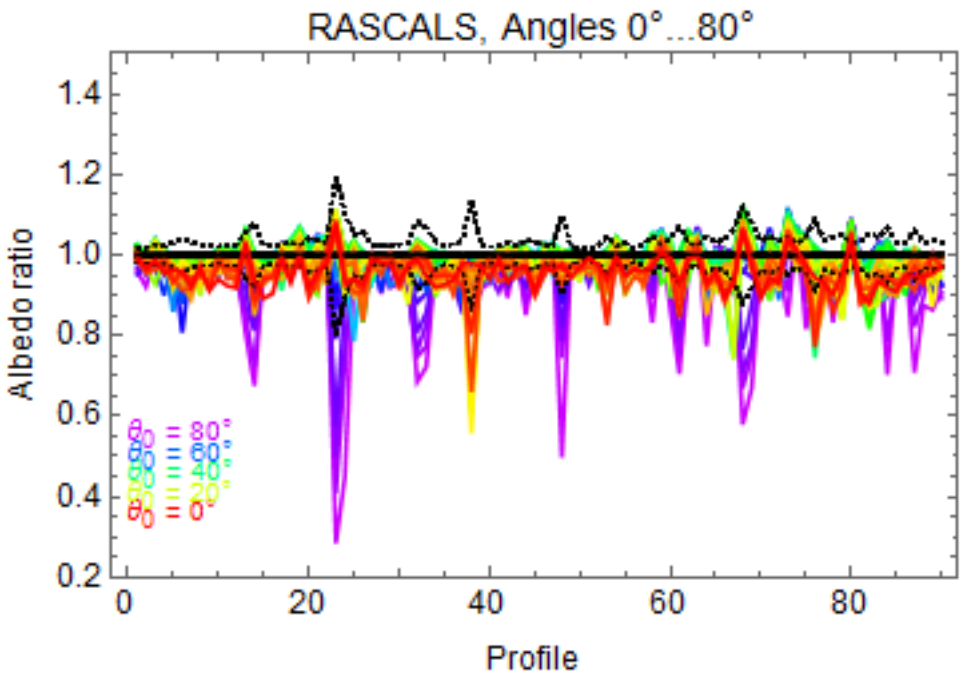


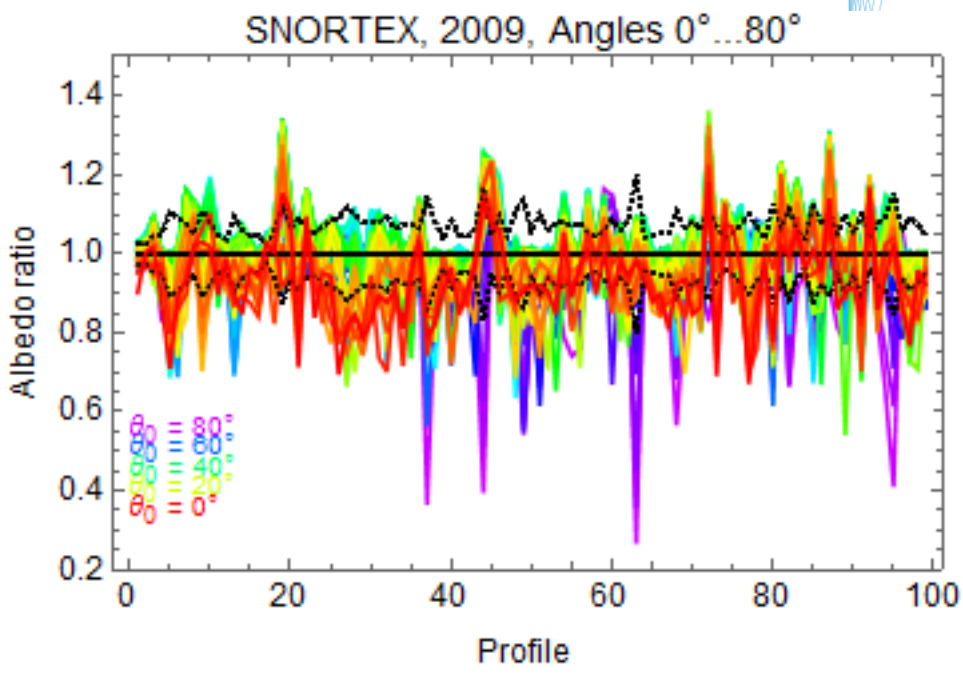
Albedo for each profile from in situ measurements at Greenland Summit



Albedo for each profile from in situ measurements at Sodankylä

Variation of the effect of surface roughness on albedo





1 ± standard deviation / mean albedo value for each profile shown

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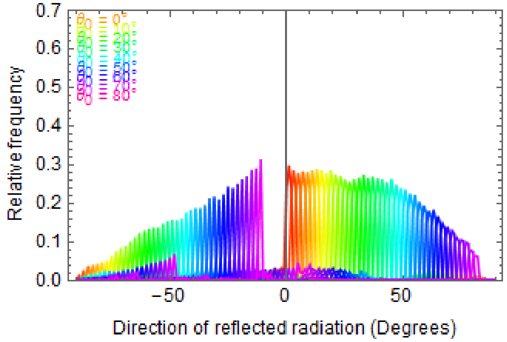
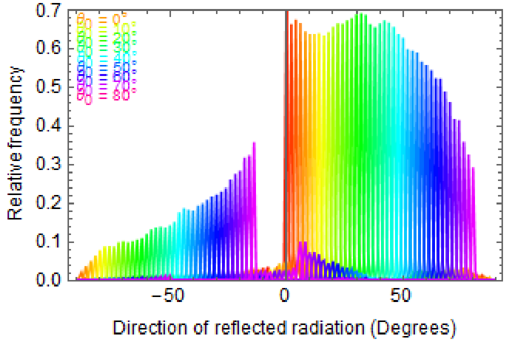
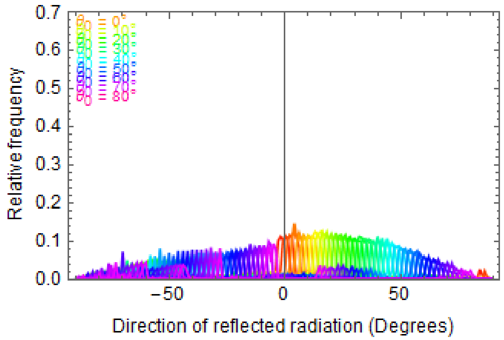
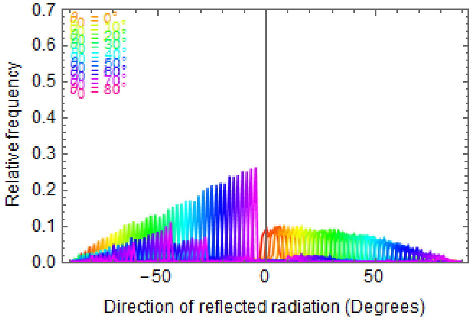
RASCALS: Effect of surface roughness on the angular distribution of the reflected radiation

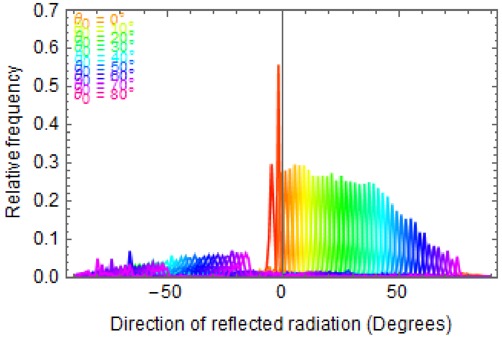


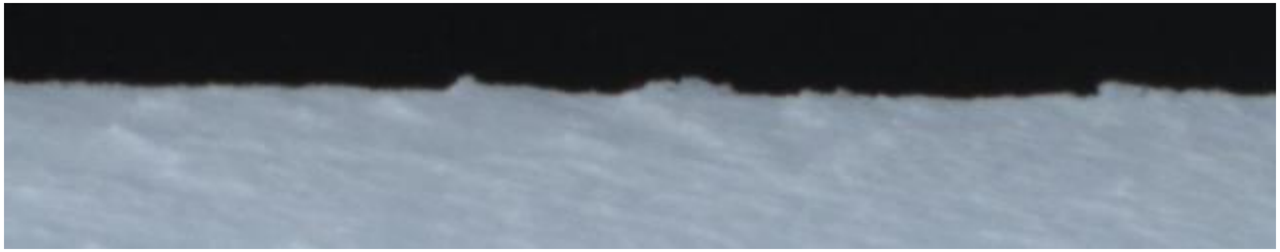


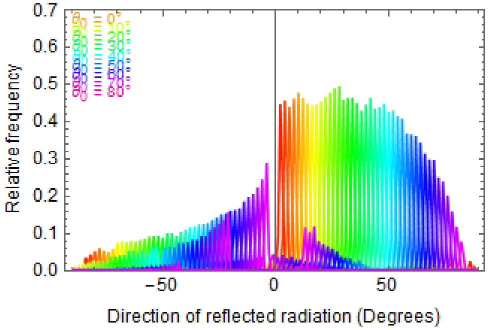


RASCALS: Effect of surface roughness on the angular distribution of the reflected radiation

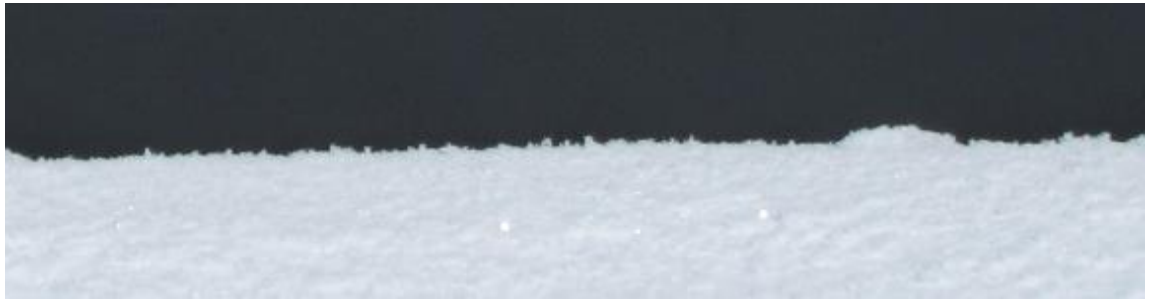


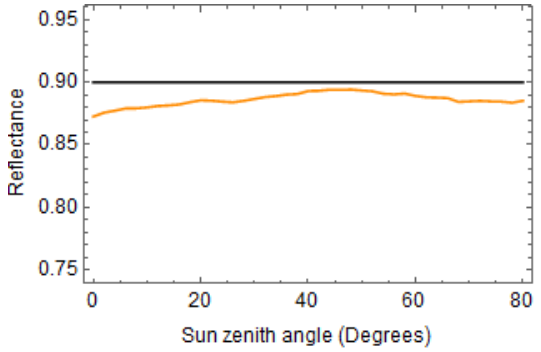


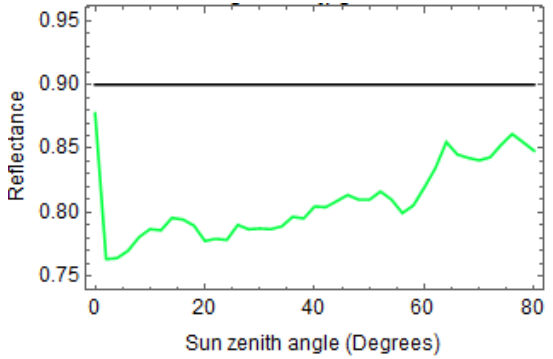


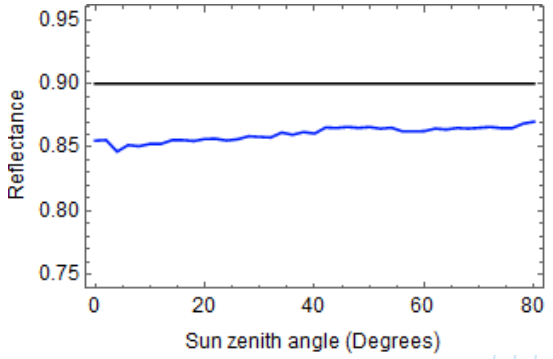


RASCALS: Effect of surface roughness on the mean reflectance

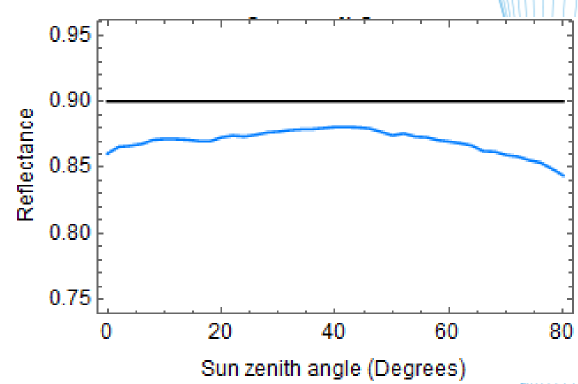


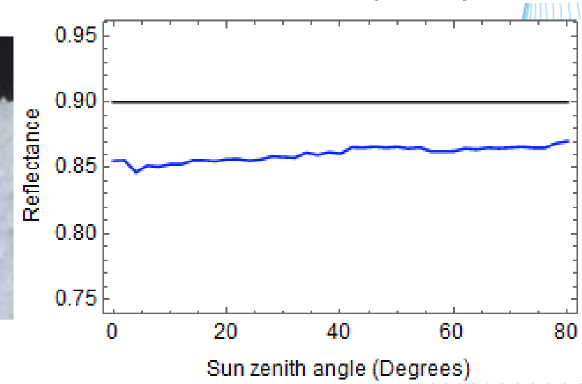


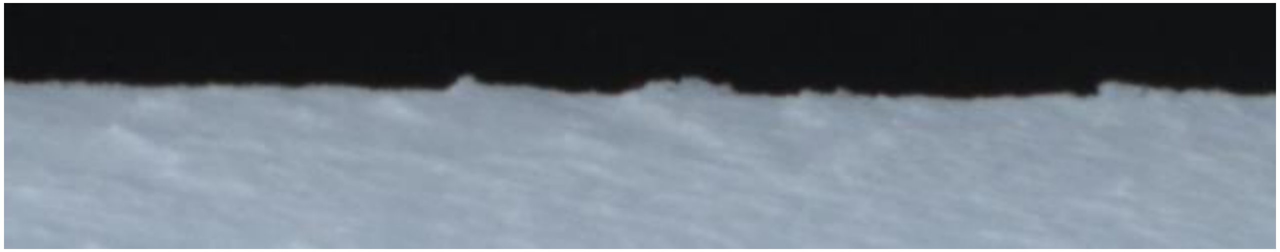


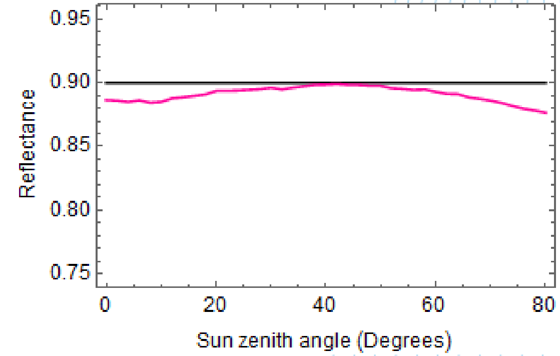


RASCALS: Effect of surface roughness on the angular distribution of the reflected radiation

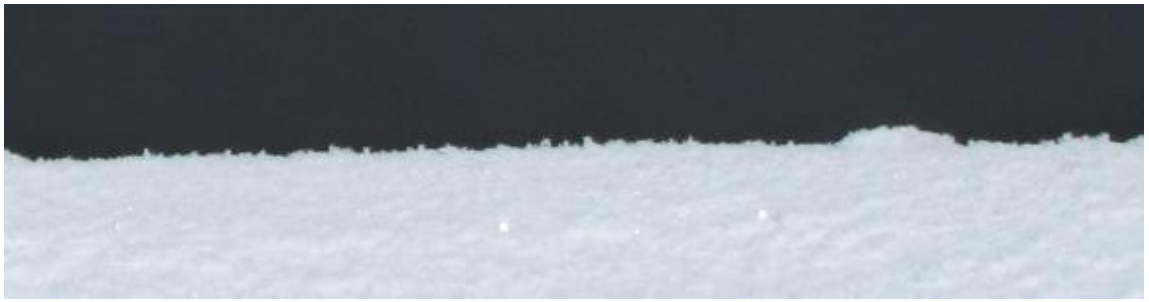


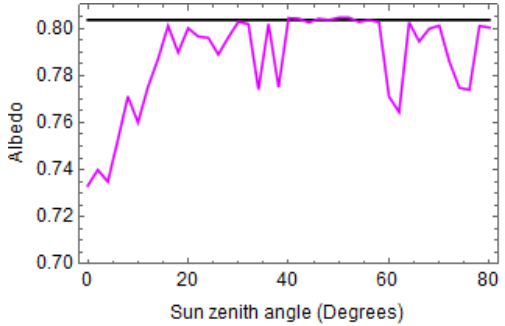


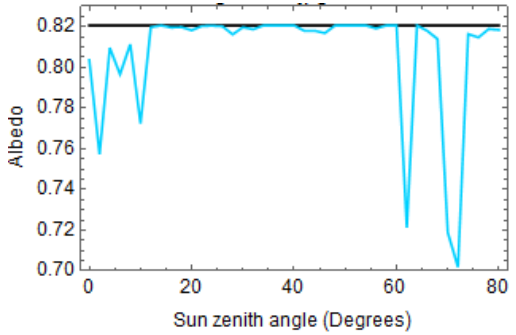


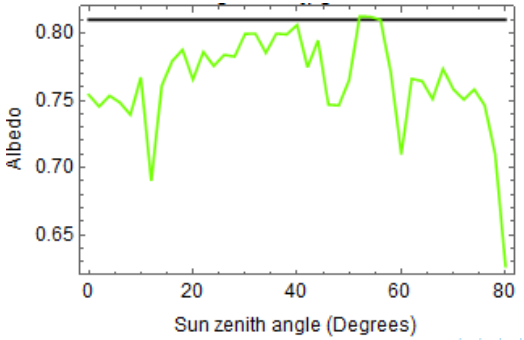


RASCALS: Variation of the albedo vs. sun zenith angle

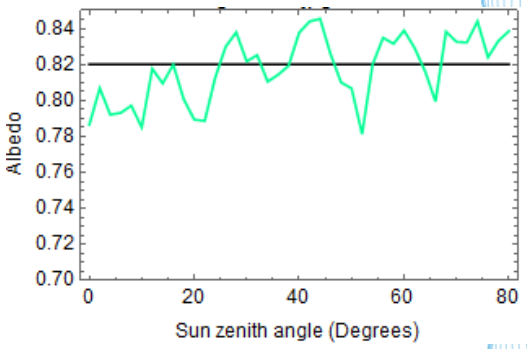


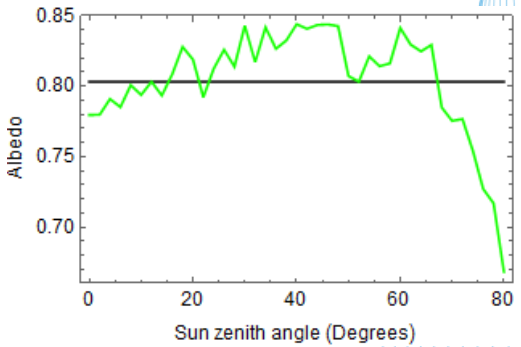


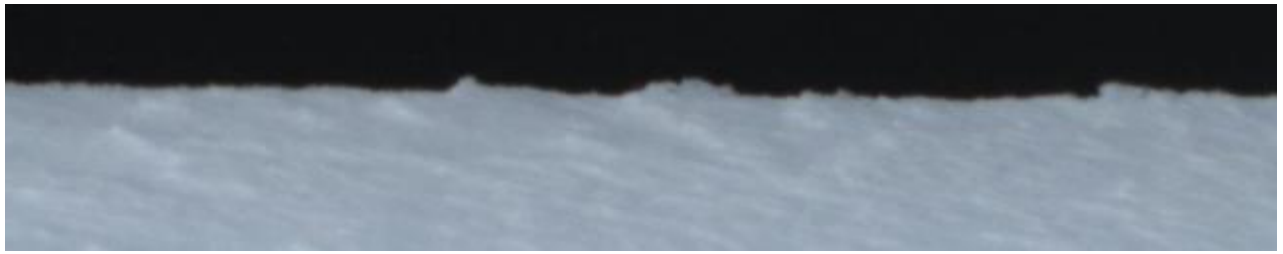


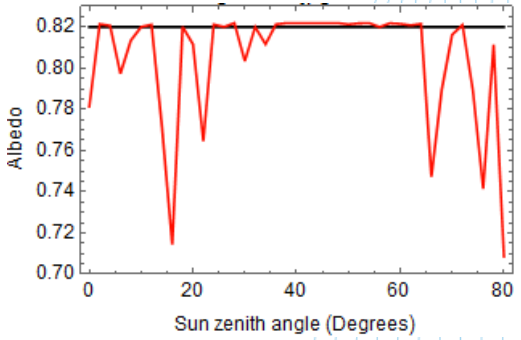


RASCALS: Variation of the albedo vs. sun zenith angle

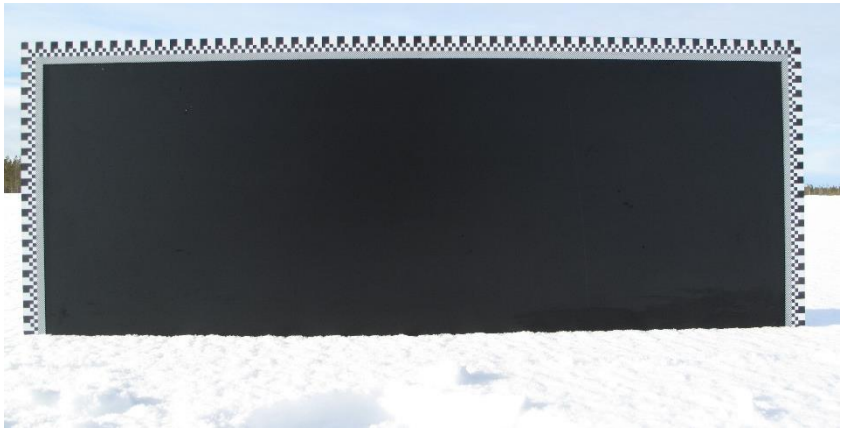


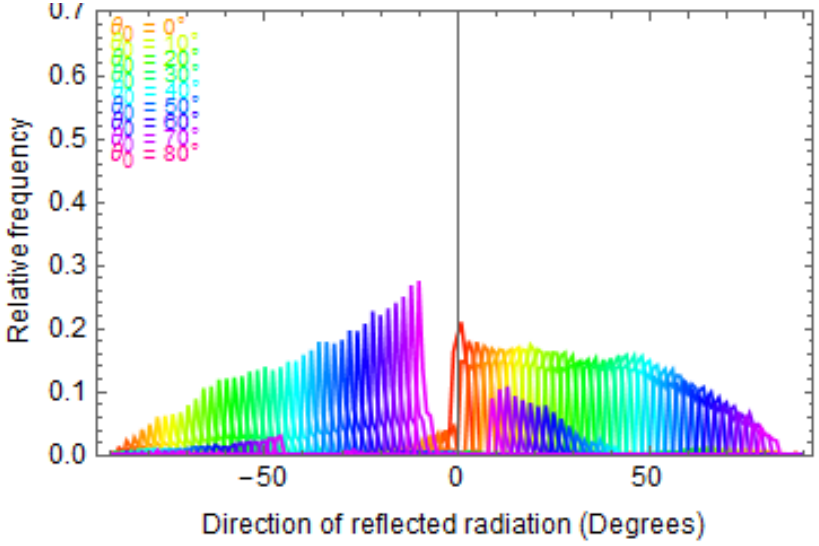


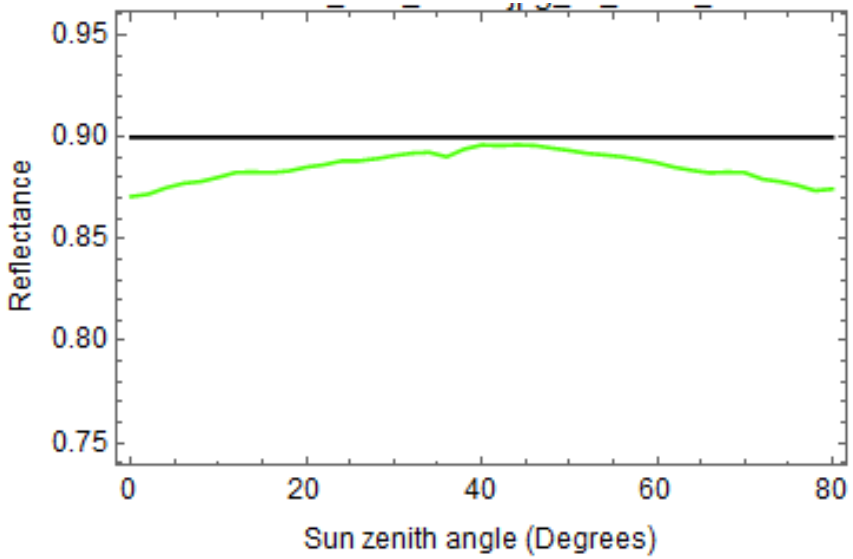


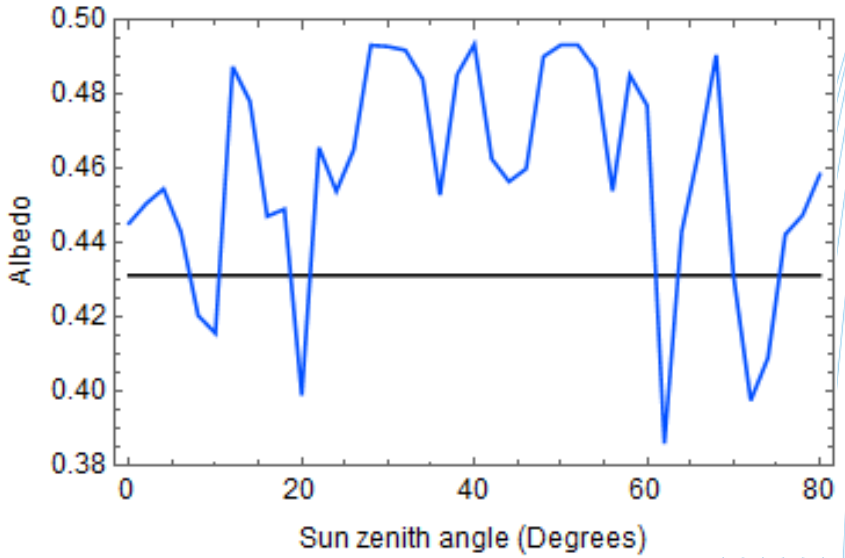


SNORTEX, March 18

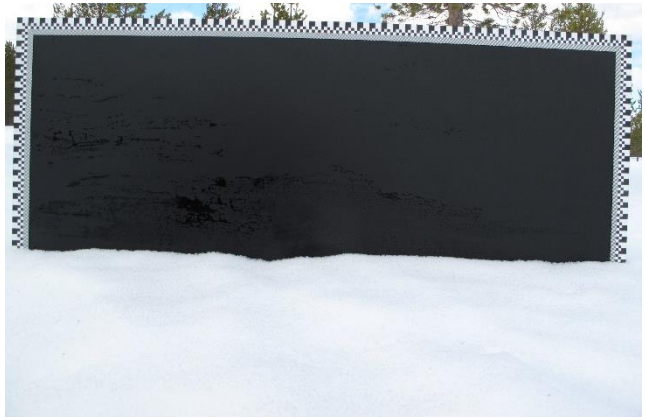


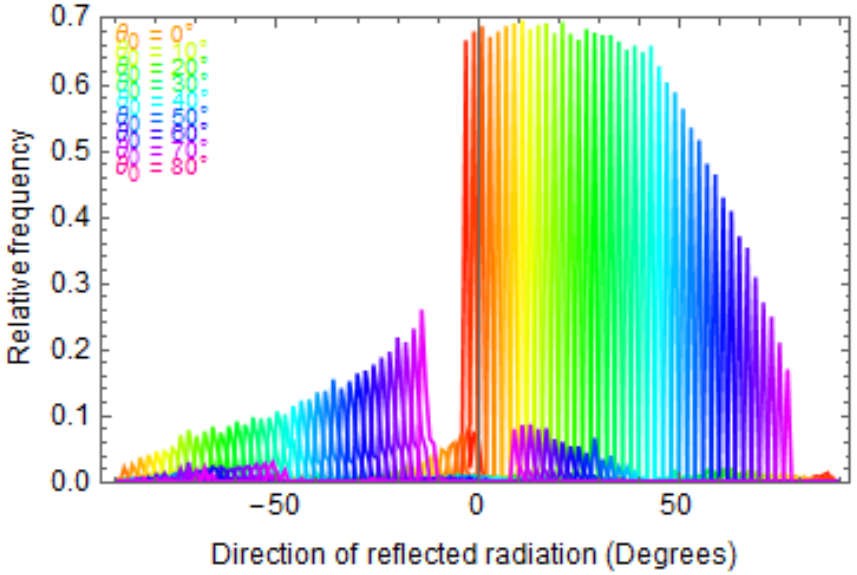


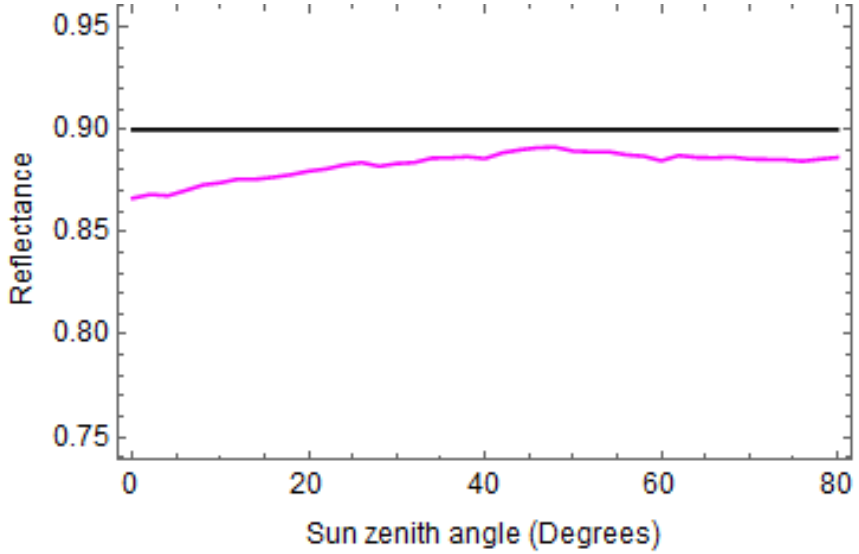


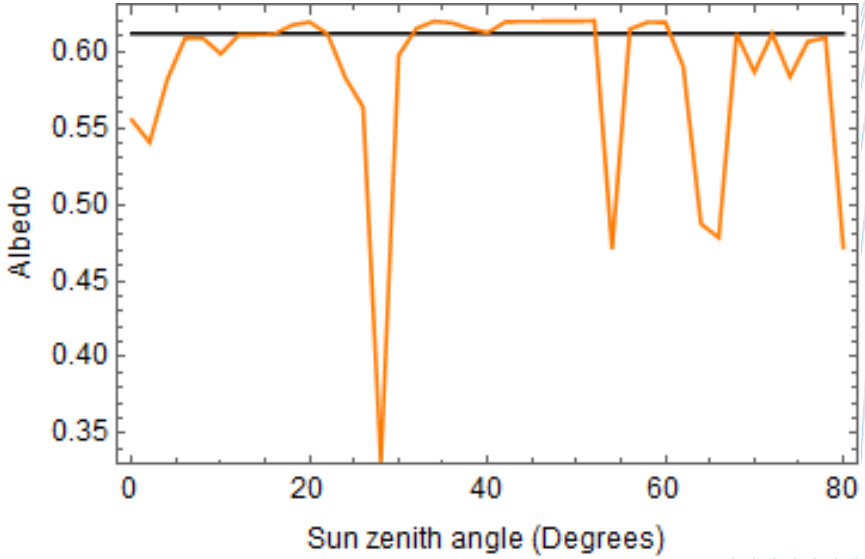


SNORTEX, April 23

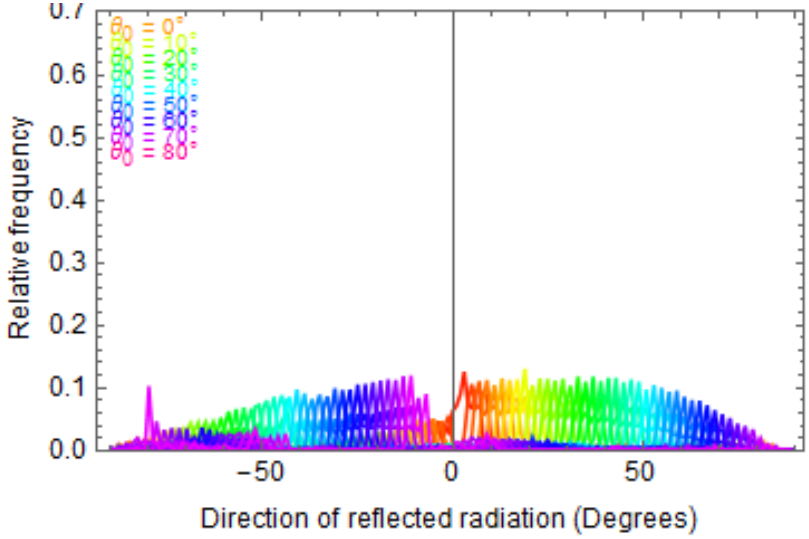


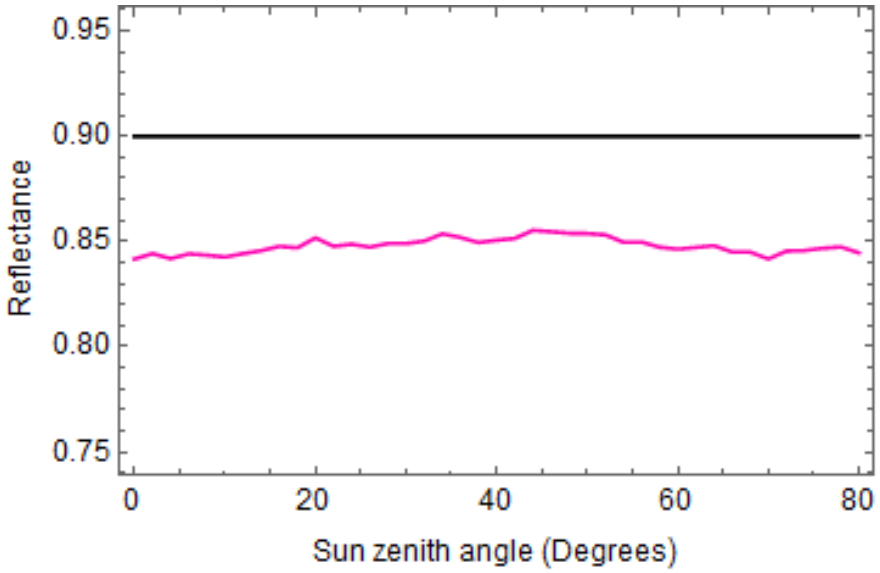


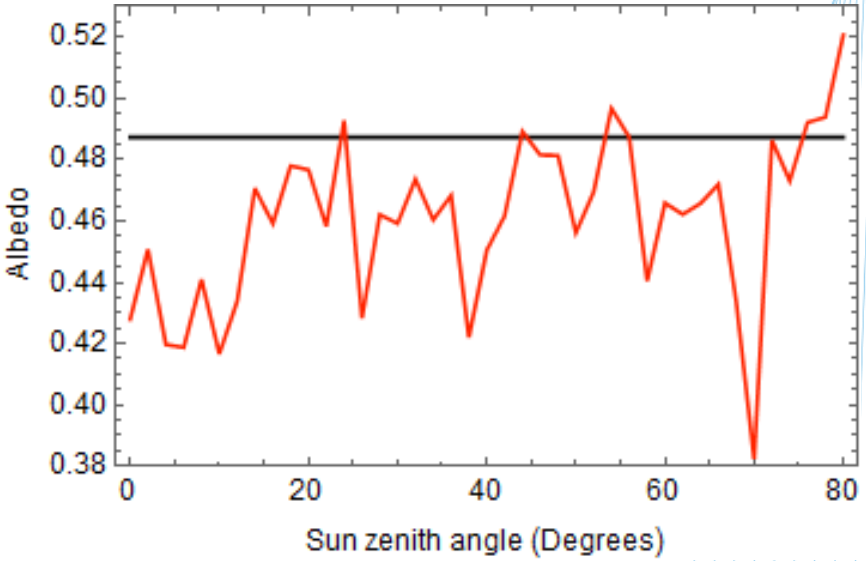




SNORTEX, April 27







Conclusions

- Surface roughness reduces the albedo of the surface due to multiple reflection and in some cases by trapping the incoming radiation completely.
- For theoretical reflectance of 0.9 the effect of surface roughness on the mean reflectance was of the order of 4%
- The effect increases with increasing roughness and decreasing reflectance.
- The effect of surface roughness on albedo typically increases with gradual melting of snow.
- Surface roughness has to be taken into account, if the surface albedo is modelled within the target accuracy defined by GCOS.

Thank you for your attention!