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Spectral Reflectance of Natural Snow as Derived from Controlled Measurements in Laboratory Conditions

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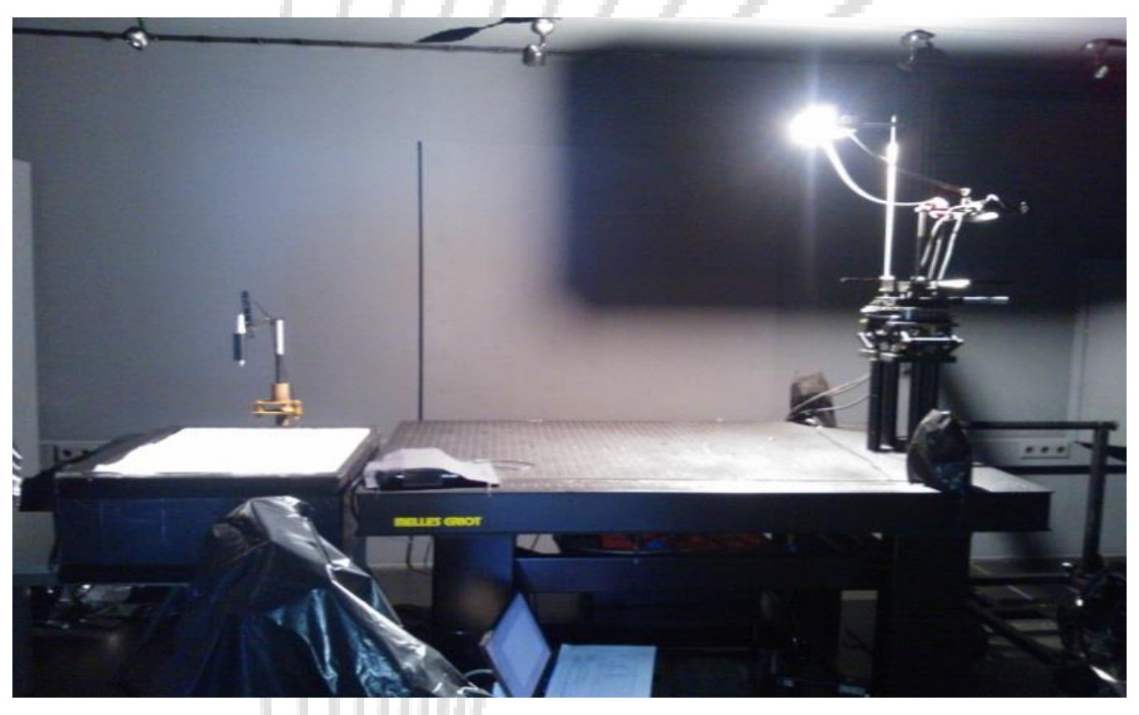


Snow covered area (SCA) estimation via optical satellite data

- Snow is highly reflective in relation to other land features
- Snow reflectivity is dependent on snowpack characteristics, viewing and illumination geometry, vegetation (forests), surface impurities, topography, atmosphere, and cloud cover.
- The most important **uncertainties** in operational SCA map products are related to **forested areas, low sun elevation angles** and periods of **partial or thin snow** cover
- For accurate SCA mapping the reflective characteristics of the surface must be known, since only part of the spectral BRDF can be measured from the satellite [1].

Measuring natural snow reflectance in a controlled environment

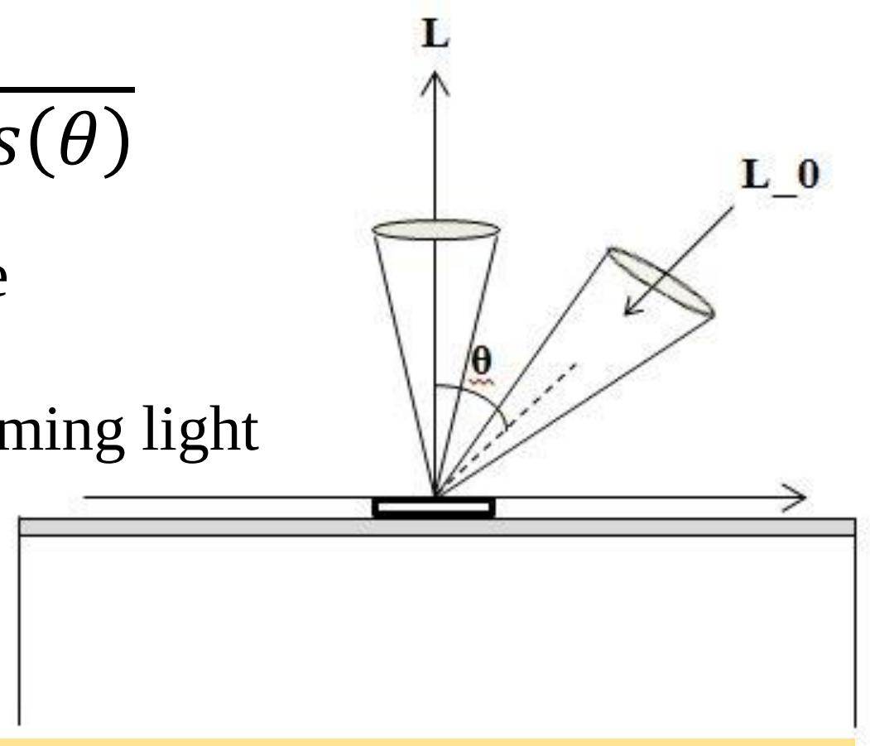
- 4 snow types sampled during spring 2013
- Dark laboratory room
- Calibrated 1000 W Tungsten halogen lamp as a light source
- Two low illumination angles (25 and 35 degrees)
- At nadir view direction
- Snow sampled in the immediate vicinity of the building
- Spectral radiance measured by ASD Field Spec Pro JR Spectroradiometer (ASD Inc.) between 350-2500 nm
- Spectral reflectance resolved by measuring a white reference target (Spectralon®) in the same view and illumination geometry,
- The calculated reflectance values approximate the conical-conical reflectance factor (CCRF), the measurable quantity of the bidirectional reflectance factor (BRF).

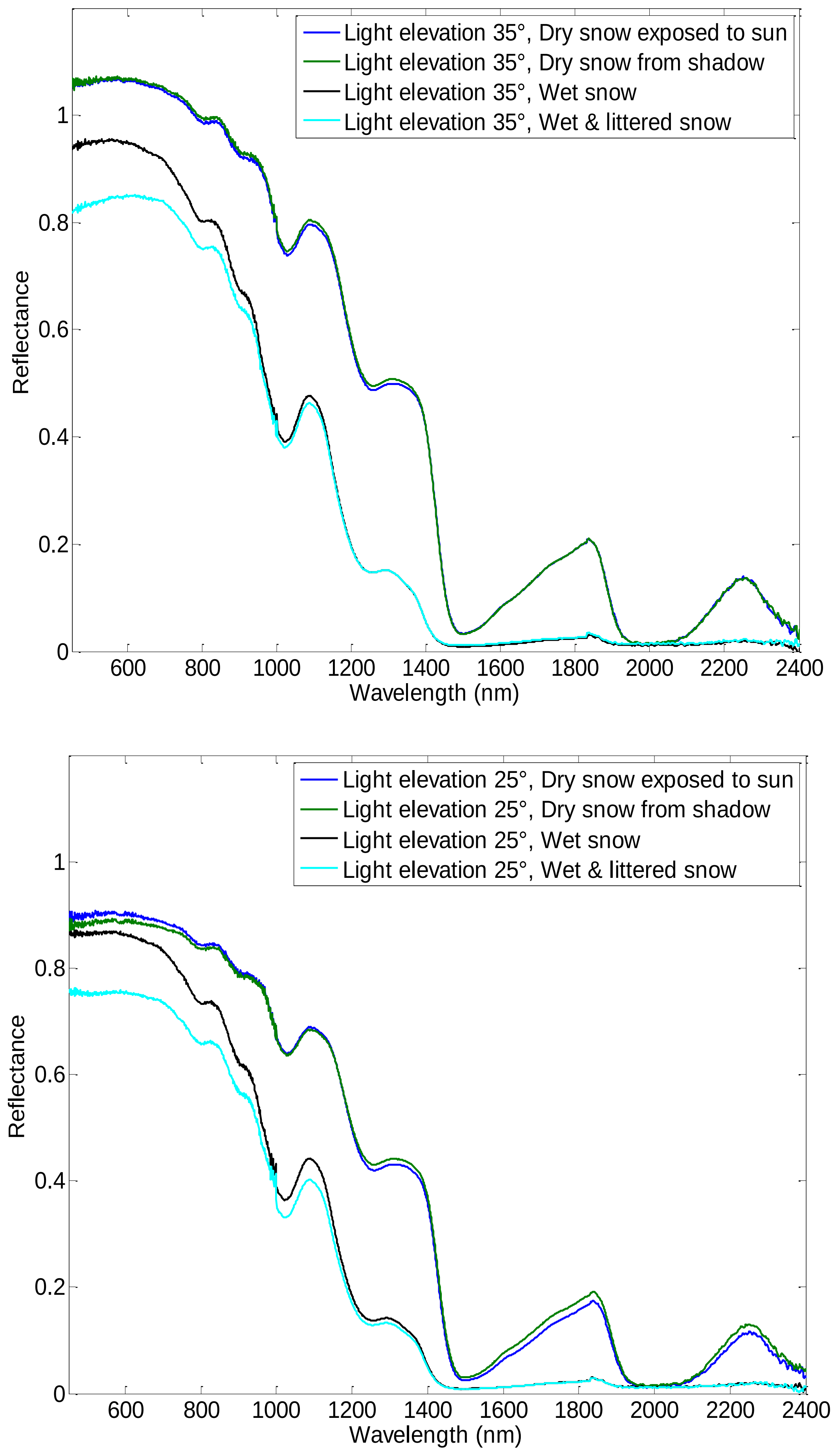
Objective

- Confirm the results obtained via modelling and in the field
- Define spectral reflectance signatures of several different snow types
- Investigate the effects of snowpack characteristics, illumination conditions and surface organic matter

$$R(\lambda,\theta) = \pi * \frac{L(\lambda,\theta)}{L_0(\lambda) * cos(\theta)}$$

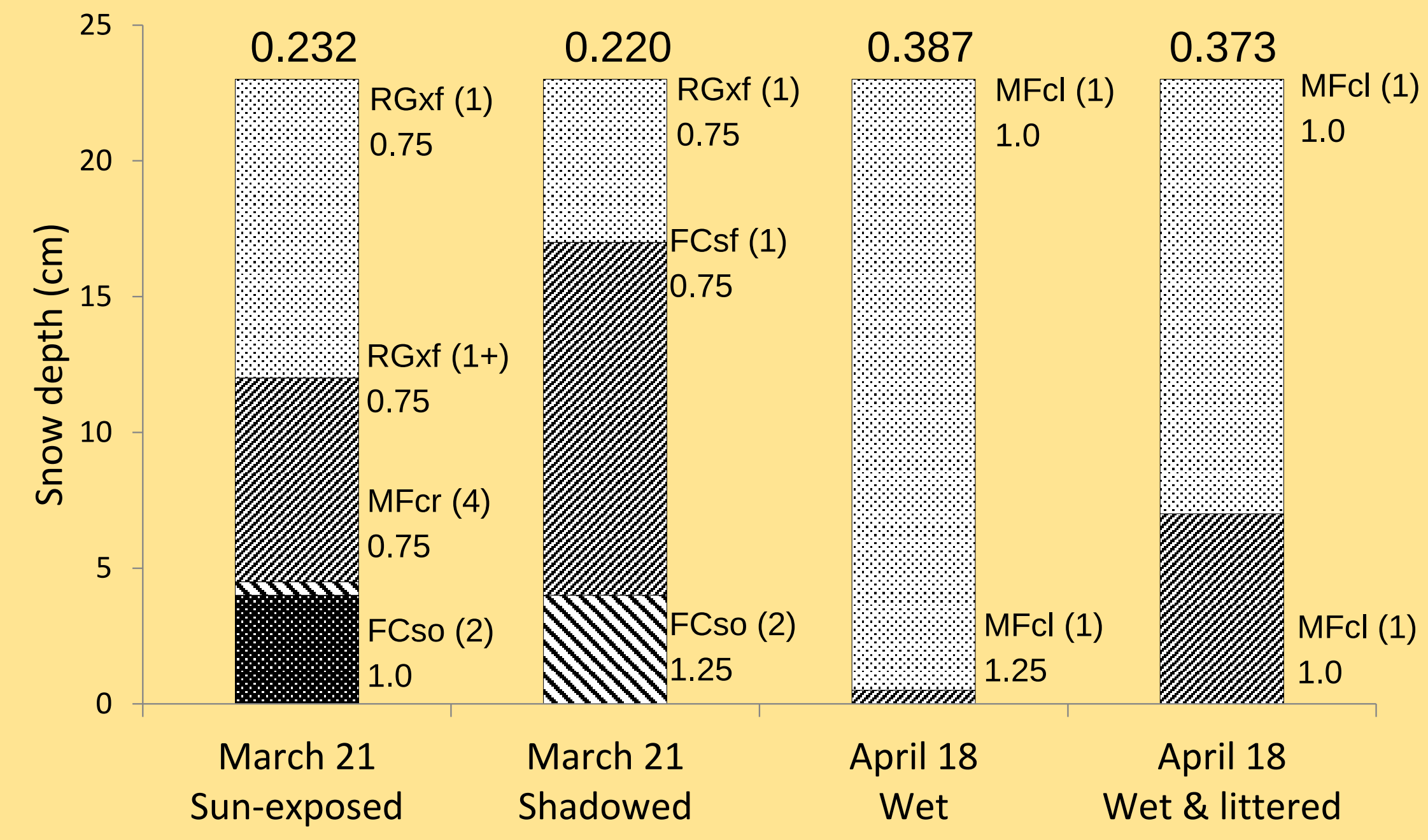
$R(\lambda,\theta)$ = average absolute reflectance
$L(\lambda,\theta)$ = radiance of snow
$L_0(\lambda) * cos(\theta)$ = radiance of the incoming light





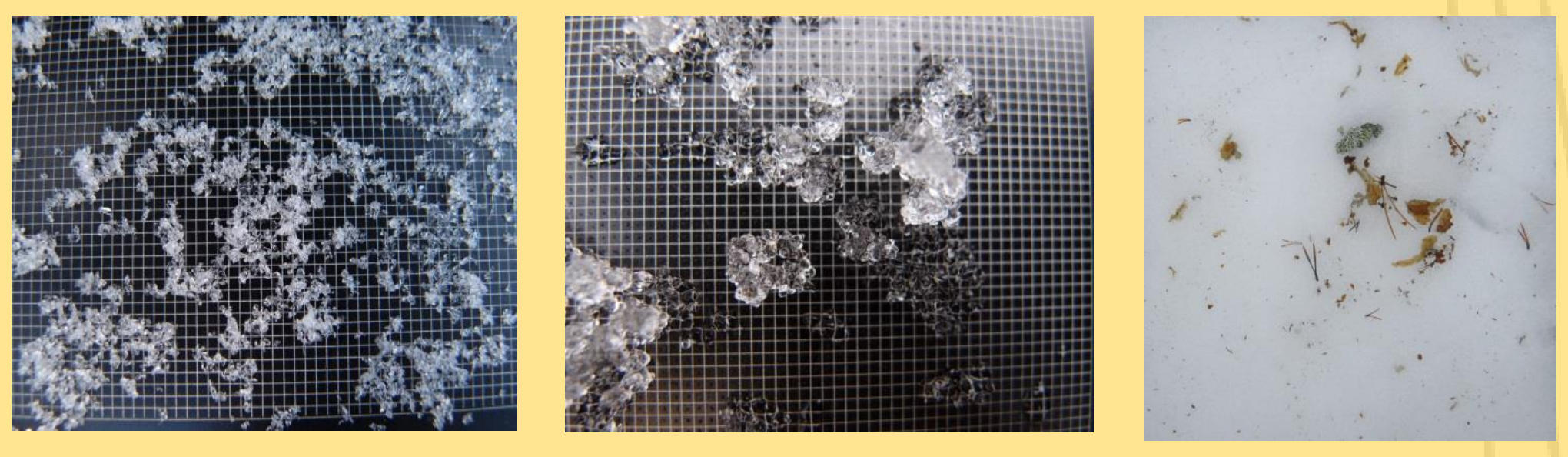
Average spectral reflectance for different snow types measured with a) 35 degree and b) 25 degree light elevation angle.

Reference measurements to record the differences between snow types



Observed layers in the different snow types sampled. On the right hand side are the grain shape, (hand hardness index) and the typical average grain size estimated to the nearest 0.25 mm for each snow layer detected. Average sample density is denoted by the value above the bars (g/cm^3).

- Basic snow pit + SSA (IceCube) + Snow fork measurements



Examples of the snow surface grains in the sample surface. Left: dry snow. Middle: wet snow. Right: snow sample with littered snow surface.

Table. Mean and standard deviation of the MODIS band specific reflectances for different snow types derived from the spectrometer measurements. RC(%) denote the relative changes between wet and wet&littered snow types in relation to dry snow.

	MODIS Band 2			MODIS Band 4			MODIS Band 6		
	Mean	*RC(%)*	SD	Mean	*RC(%)*	SD	Mean	*RC(%)*	SD
25° light elevation									
Dry snow	0.83		0.05	0.90		0.05	0.09		0.01
Wet snow	0.70	*-15.6*	0.06	0.87	*-3.3*	0.07	0.01	*-88.9*	0.00
Wet & littered snow	0.63	*-24.1*	0.14	0.75	*-16.7*	0.16	0.01	*-88.9*	0.00
35° light elevation									
Dry snow	0.97		0.03	1.07		0.03	0.10		0.01
Wet snow	0.77	*-20.6*	0.05	0.95	*-11.2*	0.05	0.01	*-90.0*	0.00
Wet & littered snow	0.72	*-25.8*	0.11	0.85	*-20.6*	0.13	0.02	*-80.0*	0.01

[1] Dozier, J., R.E. Davis, A.T.C. Chang and K. Brown (1988). The spectral bidirectional reflectance of snow. In: 4th International Colloquium on Spectral Signatures of Objects in Remote Sensing (Aussois, France), 87–92.