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Analysis of IceCube and QualitySpec Trek derived SSA from vertical profiles of snowpack in Sodankylä, Finland

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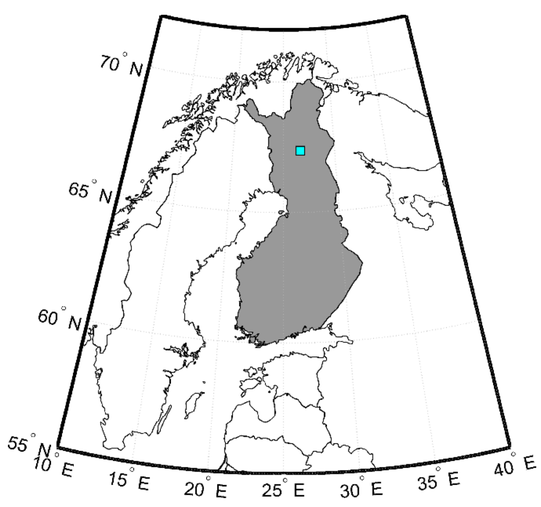
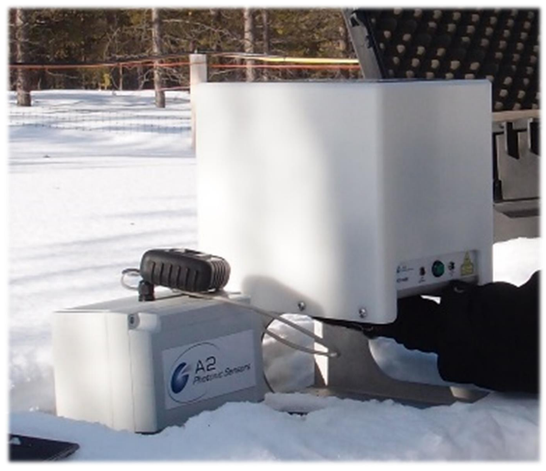
Introduction

Snow microstructure (shape, size, orientation and bonding of the snow grains) is important for microwave and optical remote sensing of snow. One parameter describing it is specific surface area (SSA), which is defined as volume to surface area ratio of snow grains. Several measurement methods are developed to measure it, including reflectance derived methods. Reflectance at NIR an SWIR wavelengths is sensitive to grain size and SSA.



Above: Measurement site locates in Sodankylä, northern Finland. Snow pit measurement site is in clearing of sparse pine forest.

Below: IceCube (left) and QualitySpec Trek (right)



	RMSE (m^2/kg)			R			Ratio (m^2/kg)	
	IC-QST profile	IC-QST samples	QST profile-samples	IC-QST profile	IC-QST samples	QST profile-samples	IC/QST profile	IC/QST samples
22 Feb 2017	4.45			0.79			1.27	
7 Mar 2017		6.23			0.96			1.26
16 Mar 2017	5.55			0.86			1.39	
21 Mar 2017	5.63	7.19	4.41	0.84	0.88	0.77	1.28	2.32
3 Apr 2017	2.63	1.84	1.77	0.91	0.96	0.92	1.14	1.11
Average	4.56	5.09	3.09	0.85	0.93	0.85	1.27	1.56

Above: Bias, RMS error, Pearson correlation coefficient (R) and ratio for SSA from IceCube (IC) and QST measurements.

Below: SSA derived from QST and IceCube measurements from three samples of precipitation particles in surface and faceted crystals in bottom of the snowpack. Standard deviations (STD) and relative standard deviations (RSD) are calculated for both surface and bottom.

		QST			**IceCube**		
	Density (kg/m^3)	SSA 1310 nm (m^2/kg)	STD (m^2/kg)	RSD (%)	SSA (m^2/kg)	STD (m^2/kg)	RSD (%)
	225.0	3.16			39.8		
Surface	309.9	26.62	12.95	110.5	41.6	1.04	2.5
	352.4	5.38			41.6		
Average		**11.72**			**41.0**		
	338.2	6.94			7.9		
Bottom	409.0	6.57	2.31	28.5	8.2	0.25	3.2
	394.9	10.73			7.7		
Average		**8.08**			**7.93**		
Average			**7.62**	**69.5**		**0.65**	**2.9**

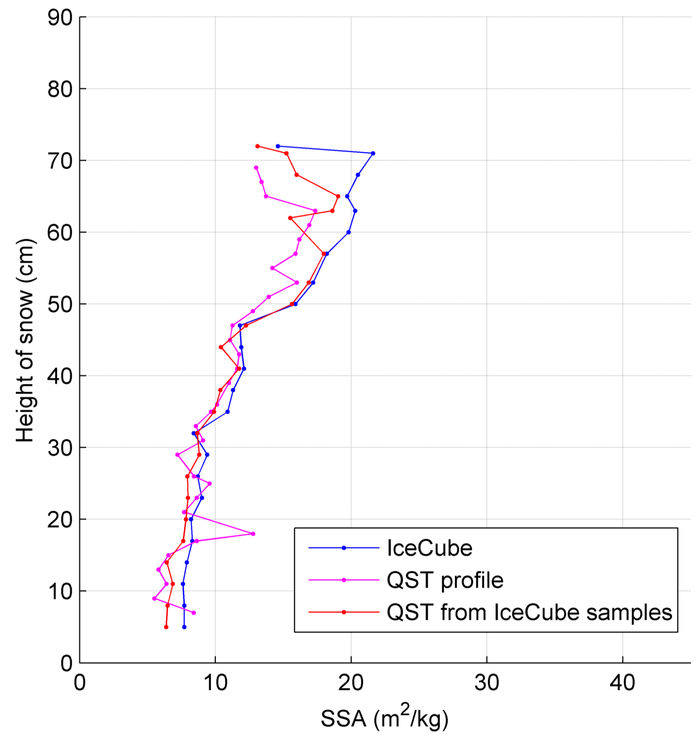
IceCube

IceCube (A2 Photonic Sensors, France) measures hemispherical reflectance of 1310 nm laser from snow sample surface. The snow sample is taken to a sample holder with a spatula, packed to reach density minimum 200 kg/m^3, and surface is smoothened. Samples are taken with 3 cm interval from vertical profile of the snowpack. The software converts observed values to reflectance and SSA.

QualitySpec Trek

The QualitySpec Trek (QST) is a portable spectrometer manufactured by ASD Inc., US. The QST measures reflectance of visible and shortwave infrared radiation from 350-2500 nm with spectral resolution of 9.8 nm at 1400 nm. The instrument has internal light source and internal white reference for optimization and calibration. Additional calibration is made before every measurement occasion with a separate white reference plate. A single measurement is stored by pushing a trigger. Integration time was set to 10 or 20 seconds, when instrument needed to be steady.

The measurements were made from vertical snow profile by pushing the instrument window against the snow pit wall with approximately 2-5 cm intervals. The IceCube samples were also measured with the QST by pushing the window against snow in the middle of sample surface. The coefficient 0.75 is used to convert the QST reflectance to SSA.



Example of observed SSA profiles from 3 April 2017. 0 cm height of snow is on ground.

Conclusion

The SSA from IceCube is on average 1.5 times larger than QST derived SSA with average bias of 3-4 m^2/kg. However, correlation coefficient between the measurements is good, approximately 0.89. Therefore, QST is assumed to be suitable instrument to fast measurement of snow reflectance and SSA without snow removal for sampling.

IceCube sampling procedure has low affect to the QST derived SSA compared to measurements directly from snowpack vertical profile (correlation coefficient 0.85 and RMSE 3.0 m^2/kg). Based on that, is assumed that IceCube sampling procedure has no significant effect to microstructure of the snow in the sample.

Measurement errors were tested with repeated IceCube measurement test and repeated IceCube sampling test. The first one gave error (relative standard deviation) of 2.0 % for the IceCube measurements. The second test resulted smaller error for IceCube (2.9 %) than for QST (28.5 %).

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