Inexpensive in-situ snow pack sensors for temperature, density and grain size: First season

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OBJECTIVE

Demonstrate autonomous collection of local snowpack parameters with inexpensive in-situ electronic sensors (ie. automate a snow-pit)

IMPORTANCE

- support for cal-val for spaceborne microwave remote sensors
- support for snow science with parameter time series

MEASUREMENT METHODS

Snow Parameter	Sensor	Sensor Parameter
Snow Density	900 MHz resonator	Resonant Frequency
Snow Wetness	900 MHz resonator	Resonant Bandwidth
Grain Size	880 nm optical link	Transmissivities
Temperature	Electronic thermometer	Analog Voltage

EXPERIMENTAL METHODS

- 12 completed sensor units (of 30 total) were selected for data logging at SnowEx year 1 Local Scale Observation Site (LSOS) on Grand Mesa, CO
- placed with sensor face vertical and oriented to north (see photo below)
- placed in pairs on top of available surface; snow accumulates around it

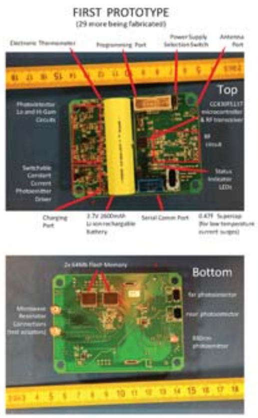
Snow Depth	Deploy Date	S/N: Date of last data	S/N: Date of last data
0 cm (on ground)	2016 Oct 02	40DC14: 2017 May 30	405C3C: 2016 Dec 08[2]
47 cm	2016 Dec 15	40F404: 2017 May 04	403415: 2017 Mar 29[2]
82 cm	2016 Dec 16	40142B: 2017 May 04	41342D: 2017 May 04
125 cm[1]	2016 Dec 17	40B82F: 2017 May 04	41142B: 2017 Feb 05[2]
134 cm	2017 Feb 20[3]	40642A: 2017 Feb 25	41082B: 2017 Feb 25
134 cm	2017 Feb 22[3]	40E82A: 2017 Feb 25	41182C: 2017 Feb 25

[1] Soft snow resulted in deployment within the snowpack at about 115 cm rather than on the snow surface. Measured data from these units (right column of poster) indicates poor contact with snow.

[2] Data ended earlier than intended due to battery discharge. The battery was damaged due to deep discharge during development, and will be replaced.

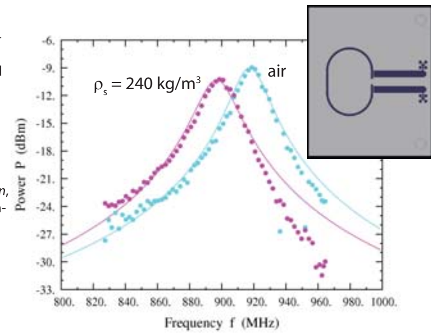
[3] Units were deployed late due to other priorities during the IOP. The small data sets are not shown.

Left: Deployment of units 40F404 and 403415 on 2016 Dec 15 at the Grand Mesa LSOS (Ranger Station). Snow fell overnight to bury them.

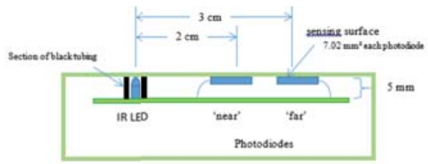


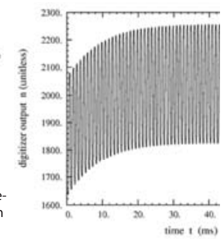
PRELIMINARY CALIBRATION: SNOW DENSITY

An open microwave resonator (far left) is swept from 836 to 964 MHz, and power thru the resonator is measured. The resonance is fit to a Lorenzian shape. The resonant frequency is inversely proportional to the microwave index of refraction, *n*, and thus to the snow density. Absolute references are provided by air (*n*=1.000) and n-heptane (*n*=1.382).



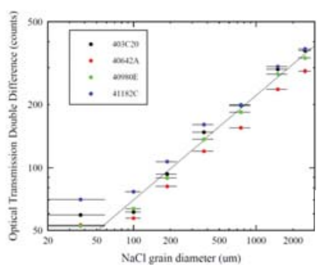
PRELIMINARY CALIBRATION: GRAIN SIZE



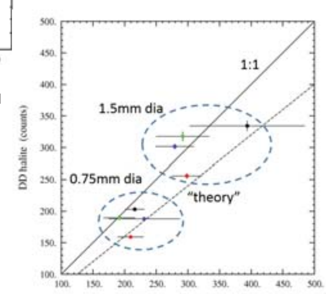


Above: Grain size is obtained from an 880 nm infrared optical link between one photoemitter and two photodetectors (one "near" at 2 cm from the photoemitter and one "far" at 3 cm). Scattering from grain interfaces increases the detector voltage.

Upper right: Since the detectors are also sensitive to ambient light levels, the photoemitter is toggled on and off at 1kHz, and a low pass feedback loop centers the signal on the 12-bit analog-to-digital converter range. The feedback strength is recorded as an indicator of ambient light level.

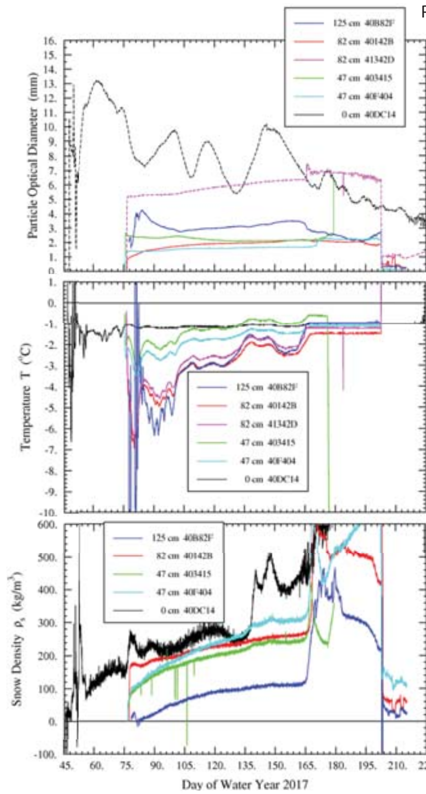


Left: Halite (sodium chloride) ground and sieved into different grain sizes demonstrates the responsivity of the double difference, DD, to grain diameter, 2*a*. The double difference is of near minus far photodetector, each with the photoemitter on minus off. The curve is $DD = K a^{1/2}$ for an arbitrary constant *K*.



Right: Limited measurements of ground distilled water ice generally agree with the measurements of halite. The ice was created the same way as halite: ground and sieved. Only two grain sizes are shown. The dashed curve represents the theoretical expectation derived from Kohkanovsky and Zege, 2004.

PRELIMINARY FIELD DATA

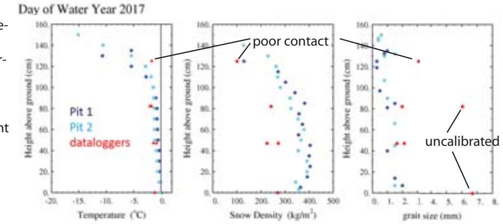


The optical diameter measurements show slow grain growth over the middle of the winter. The dashed curves are not calibrated and should be considered for their trends only. For the lowest unit, oscillations with periods of about a month may be crystal growth directly on the polycarbonate case. The placement of the uppermost unit in (rather than on) the snowpack resulted in poor quality measurements for the first month, at least.

Temperatures of the units show decreasing variations as the units become deeper in the snow pack. Around dowy 166, the entire snow pack became wet, resulting in a themal flat line, and changes in the behavior of the grain size and density measurements. A cold bias is revealed, and is under investigation. When the cold bias is removed, there is excellent agreement between units at the same depth.

The density is derived from the dielectric constant measured by the RF resonator without any attempt at removal of a moisture signal. Compaction over the course of the winter is clearly visable, until moisture permeates the snow pack around dowy 166. The deepest unit also sees moisture earlier in the winter. Again, the uppermost unit is giving anomalous values, likely due to poor contact with the snow pack.

Comparison of measurements on 2017 Feb 14 (dowy 136) with concurrent manual measurements in two snow pits dug at the Ranger Station. General agreement is observed, albeit with some biases.



CONCLUSIONS

12 of about 30 completed sensor units logged their first season of snow in Winter 2017. The deployments revealed a number of issues, some already resolved. We are currently continuing to process this data, improve accuracy, strategize improved deployment methods, and reduce the power consumption. **Some units may be available for evaluation in Winter 2018: contact deroo@umich.edu.**

ACKNOWLEDGEMENT

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