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

First season

Roger De Roo, Eric Haengel, Steve Rogacki, Chandler Ekins and Seyedmohammad Mousavi
Climate and Space Sciences and Engineering

OBJECTIVE

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

IMPORANCE

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

MEASUREMENT METHODS

<table>
<thead>
<tr>
<th>Snow Parameter</th>
<th>Sensor Parameter</th>
<th>Sensor</th>
<th>Common Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow Density</td>
<td>900 MHz resonator</td>
<td>Resonant Frequency</td>
<td>Air &amp; n-heptane</td>
</tr>
<tr>
<td>Snow Wetness</td>
<td>900 MHz resonator</td>
<td>Resonant Bandwidth</td>
<td>Air &amp; n-heptane</td>
</tr>
<tr>
<td>Grain Size</td>
<td>880 nm optical link</td>
<td>Transmissivities</td>
<td>Glass Spheres</td>
</tr>
<tr>
<td>Temperature</td>
<td>Electronic thermometer</td>
<td>Analog Voltage</td>
<td>Thermal Chamber</td>
</tr>
</tbody>
</table>

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
-------------------------|-------------------------
0 cm (on ground) 2016 Oct 02  | 40DC14: 2017 May 30
47 cm 2016 Dec 15            | 40F404: 2017 May 04
82 cm 2016 Dec 16            | 40142B: 2017 May 04
125 cm 2016 Dec 17           | 40883F: 2017 May 04
134 cm 2017 Feb 20           | 40642A: 2017 Feb 25
134 cm 2017 Feb 22           | 40EB2A: 2017 Feb 25

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. The double difference is of near minus far photodetector, each with the photoemitter on minus off. The curve is DDS = K a/2 for an arbitrary constant K.

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 day 166, the entire snow pack became wet, resulting in a thermal 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 with any attempt at removal of a moisture signal. Comparison over the course of the winter is clearly visible, until moisture permeates the snow pack around day 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.

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 dero@umich.edu.

ACKNOWLEDGEMENT

Support provided by NASA Terrestrial Hydrology Program contract NNX12AP72G.