Snow Microstructure Measurements During SnowEx

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Why Quantitative Snow Microstructure?

• Traditional grain size estimates are subjective and prone to inconsistency between observers

• Many applications require snow microstructure variables (specific surface area; correlation length) that can only be derived by objective measurements

• Significant progress in field measurements of snow microstructure have occurred over the past decade:
  - *micro-CT*
  - NIR photography
  - Contact spectroscopy
  - *Integrating sphere/SWIR laser*
  - *Snow MicroPenetrometer*
Why Quantitative Snow Microstructure?

Tools like the SMP allow spatial extension of snowpit measurements with minimal effort.
SnowEx provided an opportunity for inter-comparison of microstructure techniques:
- IRIS versus IceCube; IceCube versus IceCube
- Multiple SMP’s
- Casting for micro-CT of SMP and IceCube profiles
Snow Microstructure Instrumentation: Snow MicroPenetrometer

- Very high vertical resolution measurements of force (N)
- ~200 measurements per mm
- 120 cm maximum depth (profiles can be stacked)
- Force measurements converted to microstructure parameters (density, SSA, correlation length) provided some site specific analysis with other measurements (i.e. micro-CT) is performed

Proksch et al. (2016)
Snow Microstructure Instrumentation: IRIS and IceCube

- SSA = surface area per unit mass
- calculated from reflectance at 1310 nm
- original relationship derived using CH4 adsorption

Gallet et al. (2009)
SnowEx Microstructure Sampling

SMP: 1123 profiles (62 SnowEx pits; 1061 transect measurements; 2 scaling experiments; measurements to support GBRS

SSA: 96 profiles at SnowEx pits/trenches

Casting: 4 profiles + 1 instrument inter-comparison site
### SMP Data in the SnowEx Archive

- Because of the large number of SMP profiles, a single index file was created with standard reference information for each profile

<table>
<thead>
<tr>
<th>SMP_ID</th>
<th>Date</th>
<th>SMP Observer</th>
<th>SSA</th>
<th>Transect/Pit</th>
<th>SnowEx_Ref</th>
<th>SMP_sampling_point</th>
<th>Spacing (m)</th>
<th>File_name</th>
<th>Pen_depth (mm)</th>
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</table>
SMP Data in the SnowEx Archive

- Original binary files in proprietary format merged with header information
- .csv file for each profile, with corresponding quicklook .png

```
# SMP Serial: 2
# 2017-02-09
# 19:49:35
# Lat: 39.0105781555
# Lon: -108.18523407
# Total Samples: 157300
# Depth (mm) Force (N)
   0  0.251252
   0  0.004132
   0  0.051303
   0  0.008264
   0  0.051303
   0  0.012397
   0  0.051303
   0  0.016529
   0  0.051303
   0  0.020661
   0  0.052618
   0  0.024793
   0  0.052618
   0  0.028926
   0  0.052618
   0  0.033058
   0  0.053934
```
Additional SMP Tools (Github)

https://github.com/m9brady/SMP_to_CSV
Additional SMP Tools (Github)
**Not science ready microstructure retrievals**

S34M1273

Density (kg m\(^{-3}\))

Exponential Correlation Length (mm)

Correlation Length (mm)

Specific Surface Area (mm\(^{-1}\))
SSA Data in the SnowEx Archive (IRIS and IceCube)

- Reflectance is the raw measurement
- SSA derived from reflectance using instrument specific calibrations
- Equivalent diameter (Do) calculated from SSA: $D_o = \frac{6}{(\text{SSA} \times \rho_{\text{ice}})}$
- 5 cm vertical resolution
SSA Data in the SnowEx Archive

- .csv file for each profile, with corresponding quicklook .png

# Date (yyyy-mm-ddTHH:MM): 2017-02-15T20:07
# Name field campaign: SnowEx_Week2
# Snowpit ID: 39S
# UTMN: 4321393
# UTME: 752112
# UTM Zone: 12
# Instrument: IceCubeNU
# Operator: Nick Rutter
# Timing: 60 mins
# Notes: N/A
# Total snow depth (cm): 124

<table>
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<tr>
<th>Sample signal (mV)</th>
<th>Reflectance (%)</th>
<th>Specific surface area (SSA)</th>
<th>Top Depth (cm)</th>
<th>Do (mm)</th>
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Snow Microstructure: Casting for MicroCT

<table>
<thead>
<tr>
<th>Pit Location</th>
<th>Date</th>
<th>Snow Depth (cm)</th>
<th>Notes</th>
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</thead>
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<tr>
<td>LSOS Pit</td>
<td>14-Feb-17</td>
<td>122</td>
<td>*missing several samples</td>
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<tr>
<td>28N</td>
<td>16-Feb-17</td>
<td>139</td>
<td>*missing 127-117</td>
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<td>1W</td>
<td>17-Feb-17</td>
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<td>68E</td>
<td>17-Feb-17</td>
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<tr>
<td>Fraser Ex Forest</td>
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</table>

- One cooler containing samples from LSOS pit and 28N pit was lost in shipment.
- Rest of samples in remaining pits are being prepped and scanned, with scans to be completed by December 2017.
- Calculating average SSA (as related to the calculated object surface to volume, S/V, ratio from the reconstructed microCT data) per sample volume and as a profile along vertical axis of sample.
- Resolution of scans is 8 to 25 microns (doing sub-scans of some layers depending on grain size).
- Will archive microstructure data including S/V ratio, porosity, anisotropy, interconnected pore and snow structures, etc., in .csv files.
- Snow scan images will be available as greyscale or thresholded stacks (2000 images per sample, ~30GB of data per sample, ~50-100 GB per pit).
Status

- SMP data submitted to NSIDC in May; ready to run file-level metadata at ECCC

- IceCube and IRIS data (*.csv) were quality controlled and submitted to NSIDC in May

- Casts currently being processed at CRREL for micro-CT

- Collectively, the SMP, SSA, and snow cast datasets represent a unique set of quantitative snow microstructure measurements which complement the traditional SnowEx snowpits