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Snow Microstructure Measurements During SnowEx

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Why Quantitative Snow Microstructure?

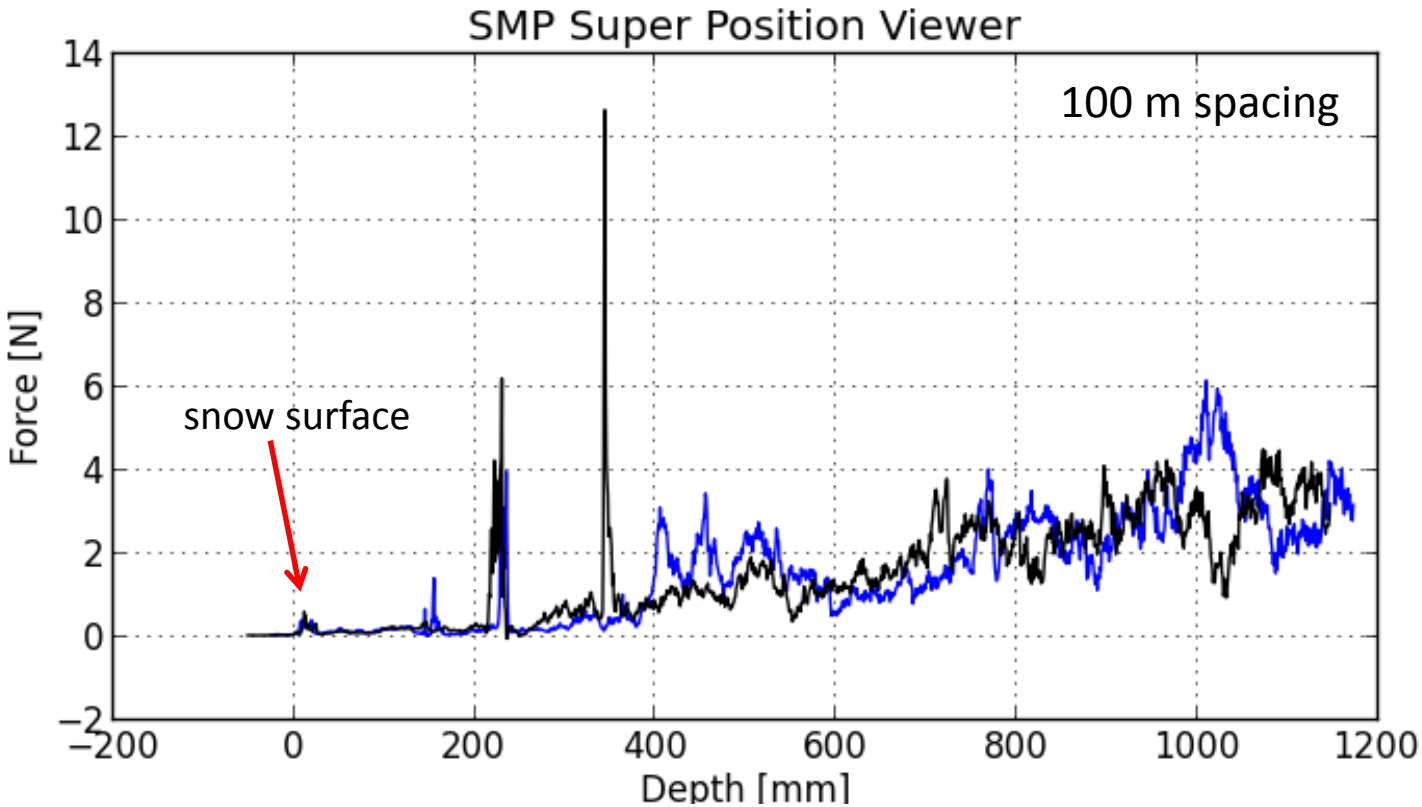
- Traditional grain size estimates are subjective and prone to inconsistency between observers

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

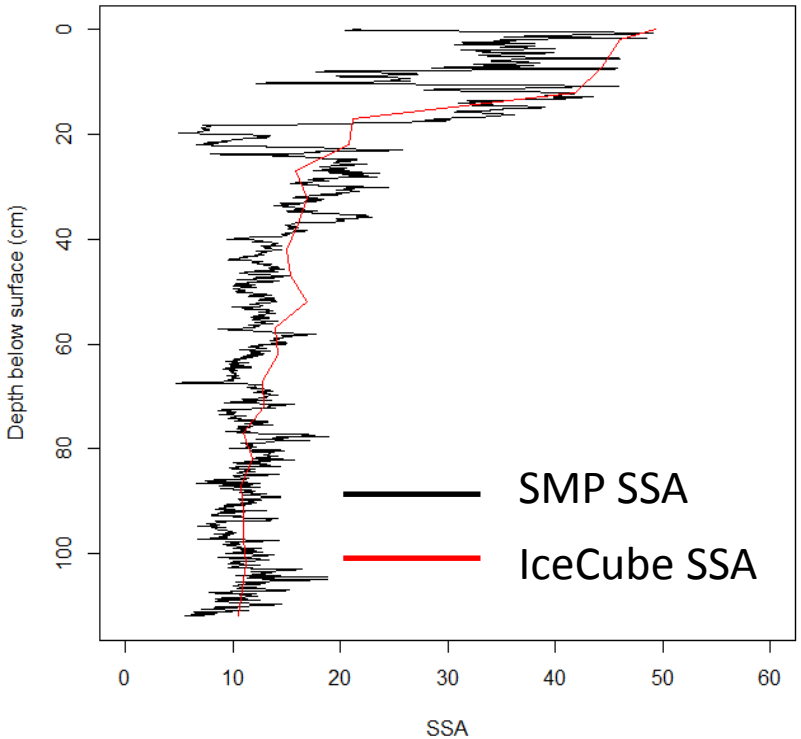
- Significant progress in field measurements of snow microstructure have occurred over the past decade:
  - -***micro-CT***
  - -NIR photography
  - -Contact spectroscopy
  - -***Integrating sphere/SWIR laser***
  - -***Snow MicroPenetrometer***

Why Quantitative Snow Microstructure?

Tools like the SMP allow spatial extension of snowpit measurements with minimal effort



Why Quantitative Snow Microstructure?

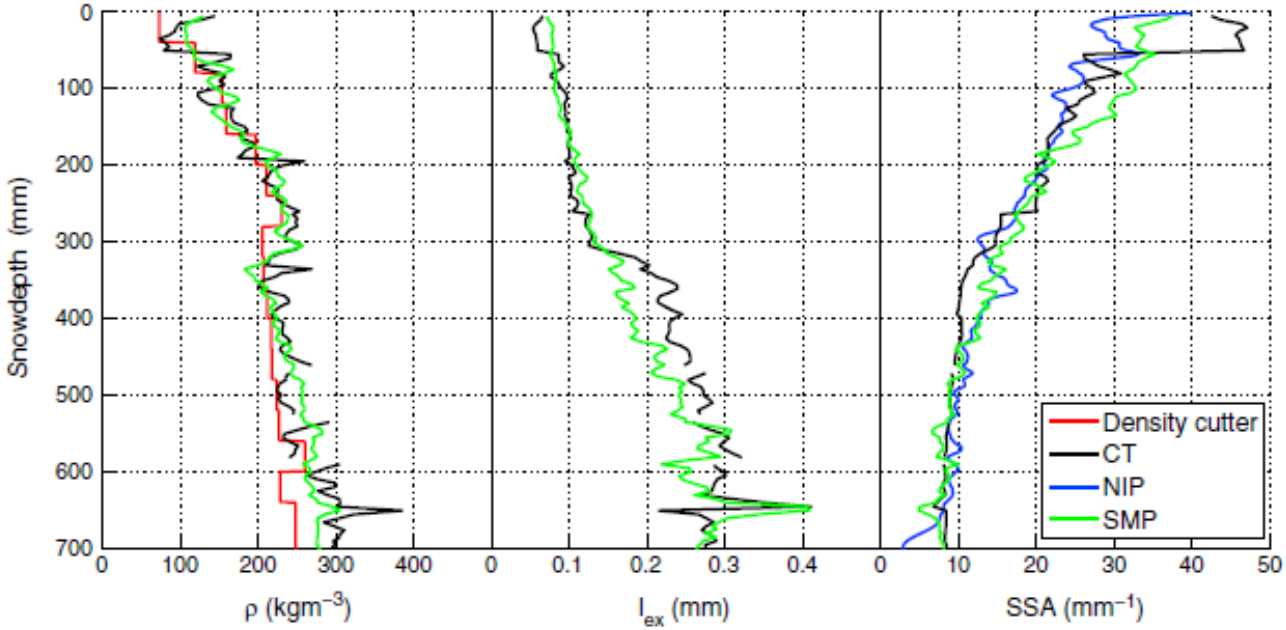


SnowEx provided an opportunity for inter-comparison of microstructure techniques:

- IRIS versus IceCube; IceCube versus IceCube
- Multiple SMP's
- Casting for micro-CT of SMP and IceCube profiles

Snow Microstructure Instrumentation: Snow MicroPenetrometer

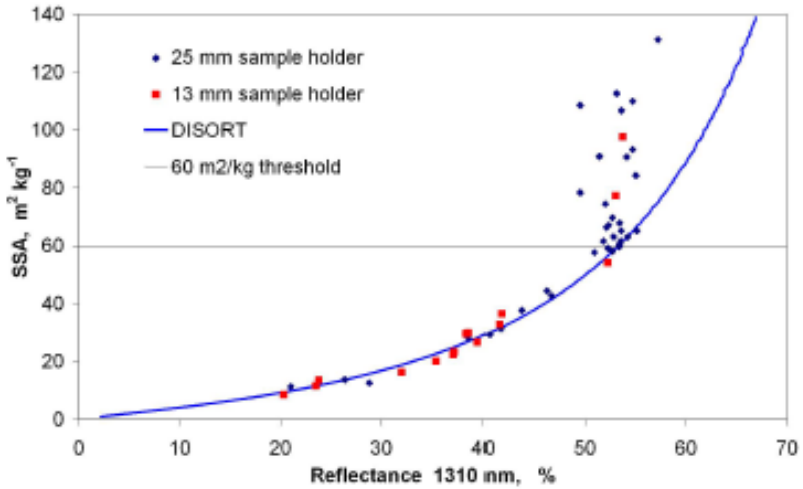
- Very high vertical resolution measurements of force (N)
- ~200 measurements per mm
- 120 cm maximum depth (profiles can be stacked)
- Force measurements converted to microstructure parameters (density, SSA, correlation length) provided some site specific analysis with other measurements (i.e. micro-CT)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



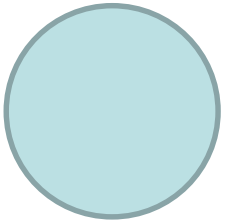
Proksch et al. (2016)

Snow Microstructure Instrumentation: IRIS and IceCube

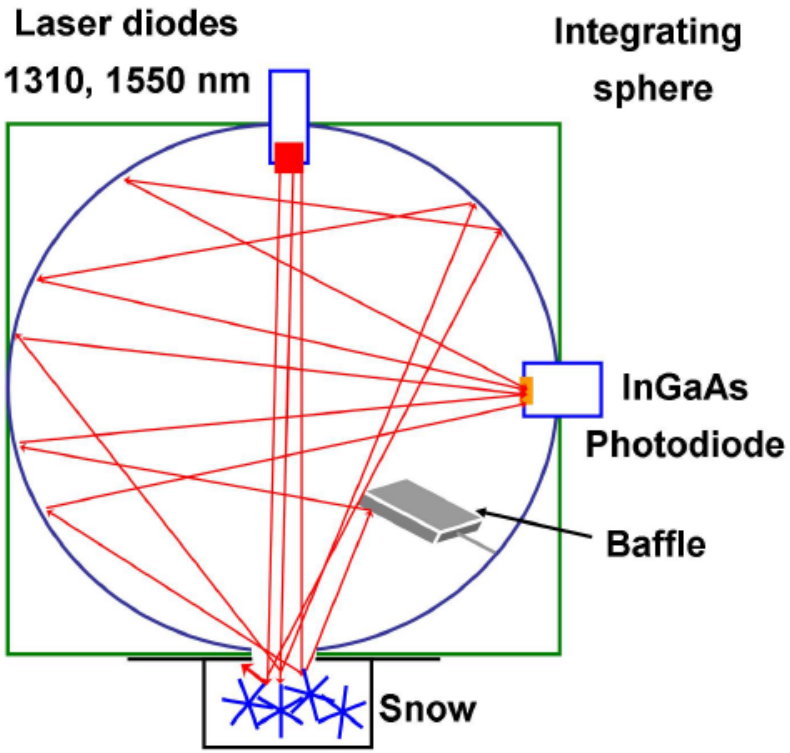
- SSA = surface area per unit mass
- calculated from reflectance at 1310 nm
- original relationship derived using CH4 adsorption



High SSA

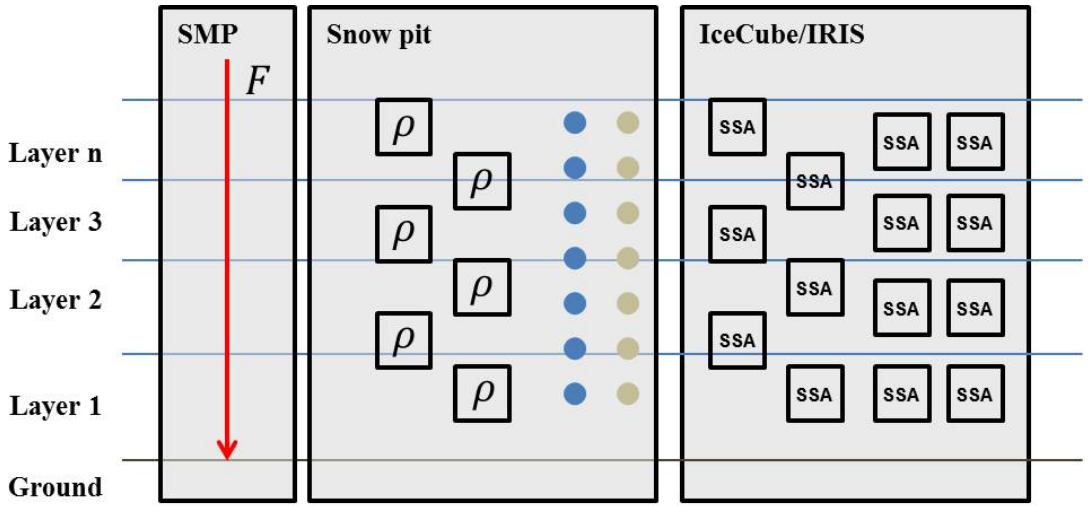


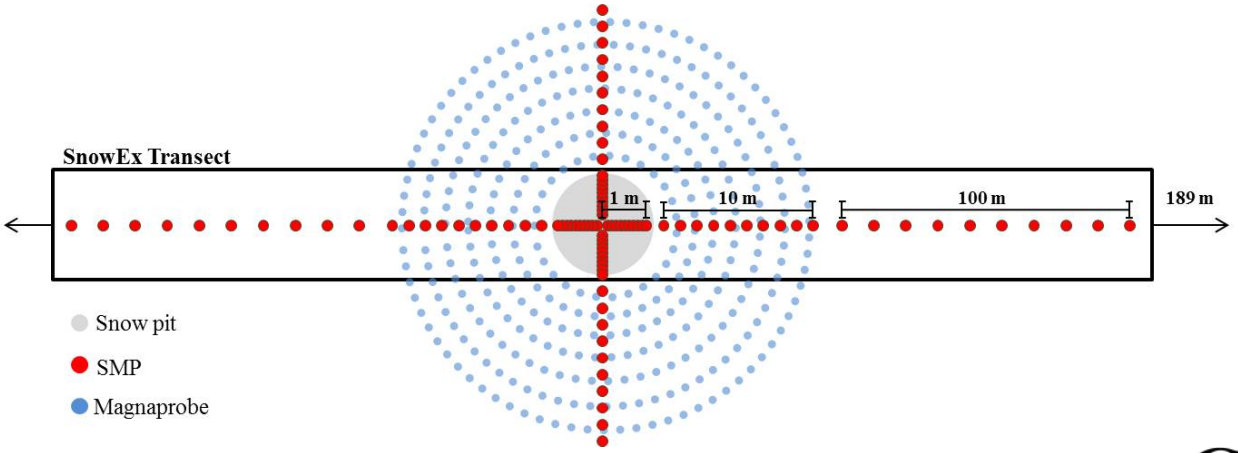
Low SSA



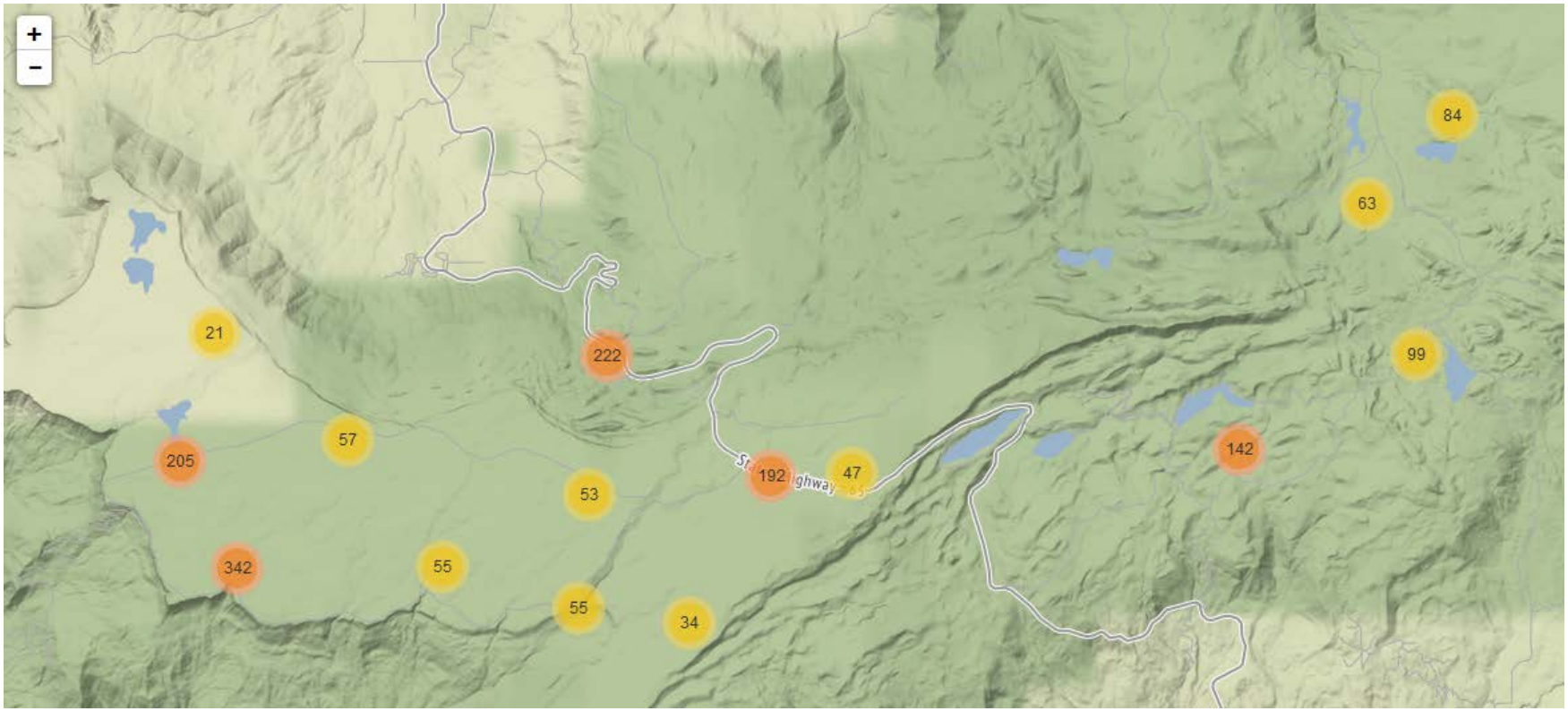
Gallet et al. (2009)

SnowEx Microstructure Sampling Plan





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

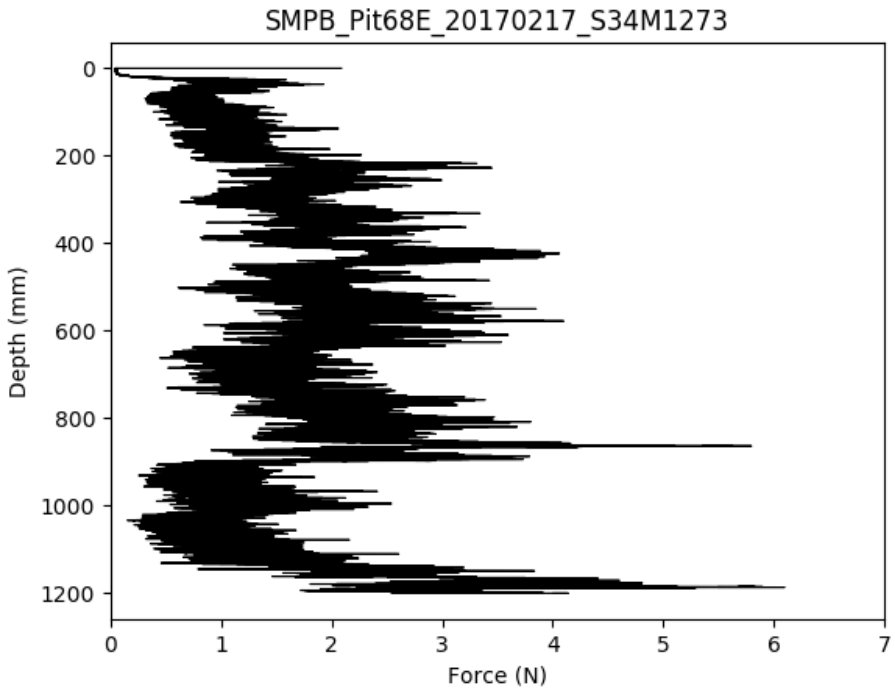
SMP Data in the SnowEx Archive

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

SMP_ID	Date	SMP Observer	SSA	Transect/Pit	SnowEx_Ref	SMP_sampling_point	Transect Spacing (m)	File_name	Pen_depth (mm)	Snow_depth (mm)	OL	Notes
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-SSA-A		S34M1264	1200	1670	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-SSA-B		1265	1200	1670	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-SSA-C		1266	1200	1670	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-mid		1267	1200	1670	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-dens-right		1268	1200	1670	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-dens-left		1269	1200	1670	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-dens-C		1270	1200	1670	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-SSA-B		1271	1200	1200	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-SSA-C		1272	1200	1200	1	Cast here
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-dens-right		1273	1200	1200	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-dens-left		1274	1200	1200	0	
SMP_B	20170217	C. Derksen	IRIS	P	68E	68E-dens-C		1275	1200	1200	0	

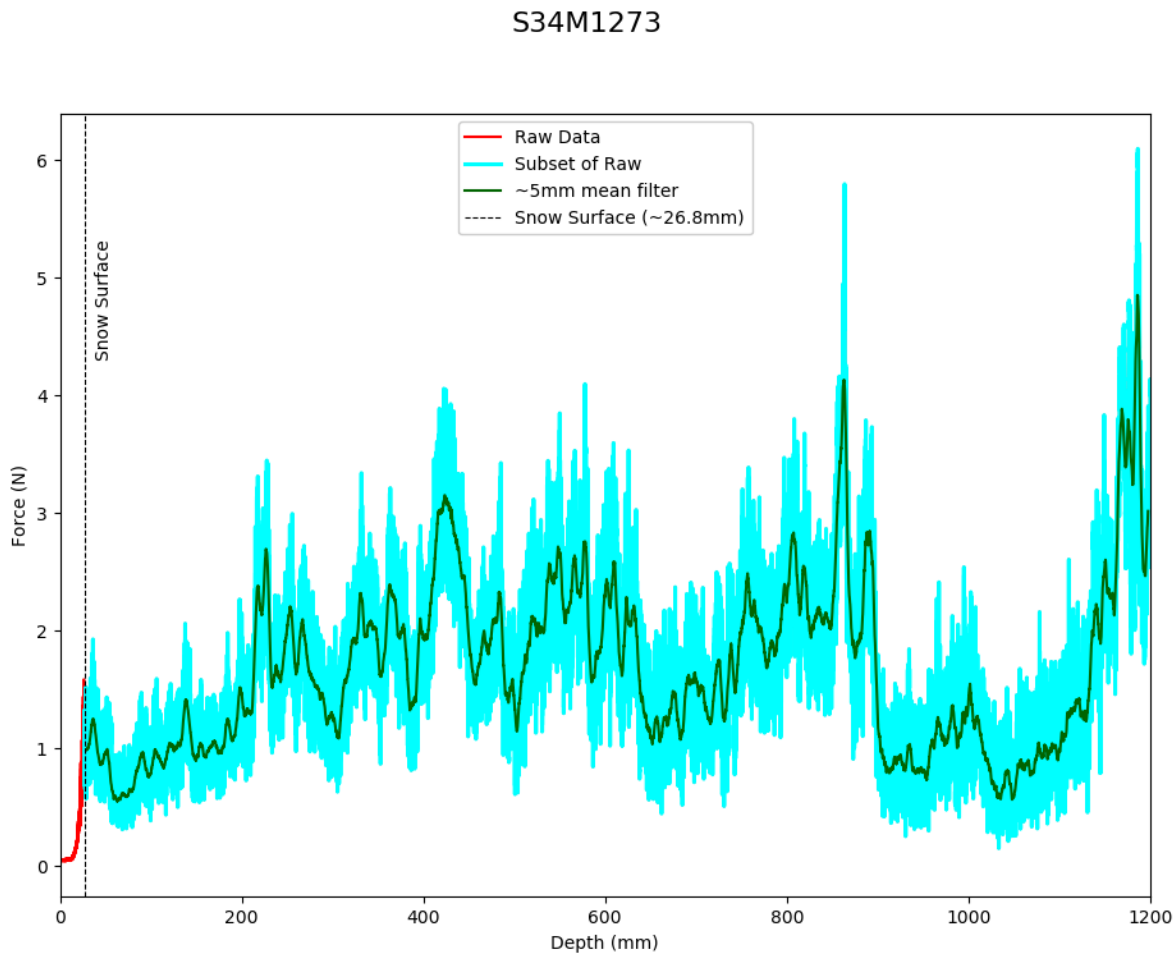
SMP Data in the SnowEx Archive

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



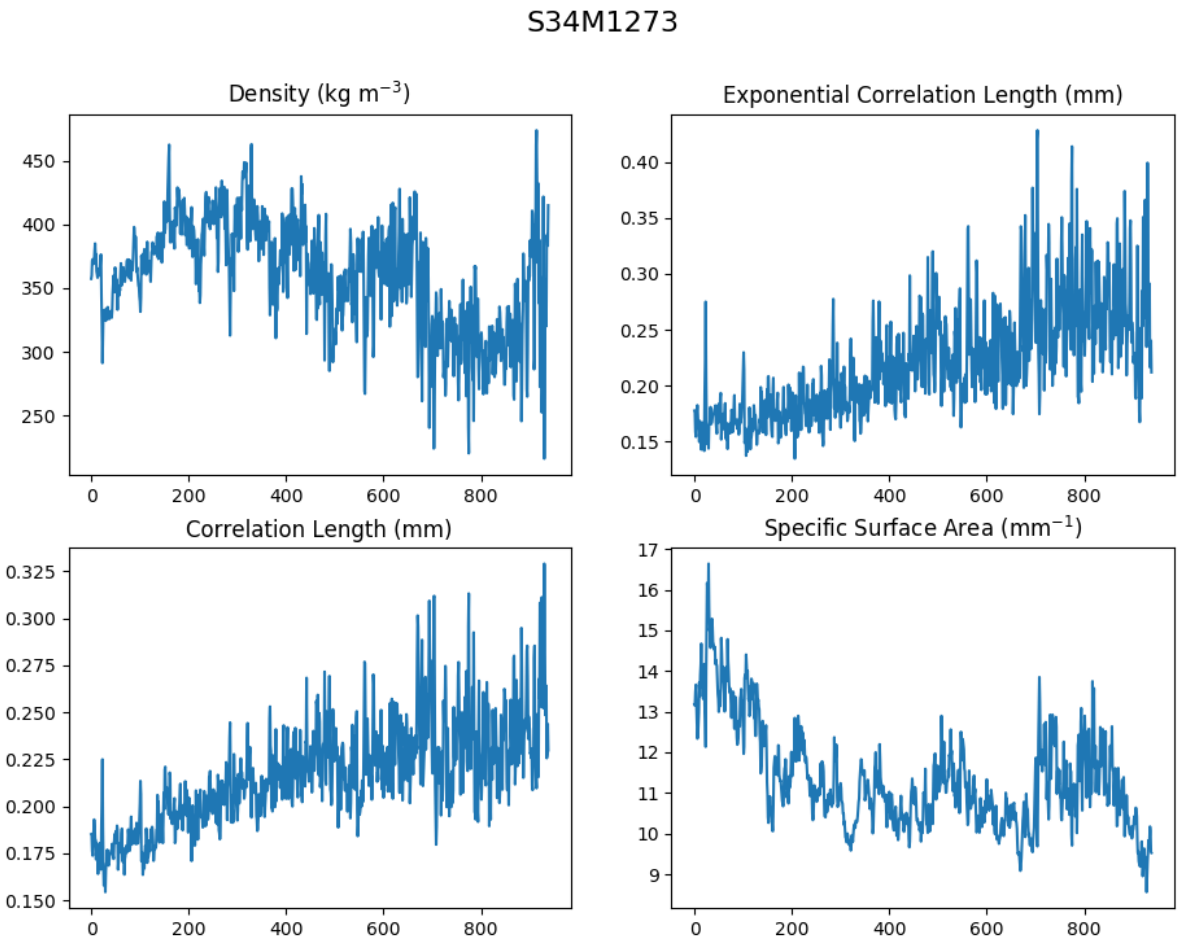

```
# SMP Serial: 2
# 2017-02-09
# 19:49:35
# Lat: 39.0105781555
# Lon: -108.18523407
# Total Samples: 157300
# Depth (mm)  Force (N)
          0   0.251252
   0.004132   0.051303
   0.008264   0.051303
   0.012397   0.051303
   0.016529   0.051303
   0.020661   0.051303
   0.024793   0.052618
   0.028926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

Additional SMP Tools (Github)



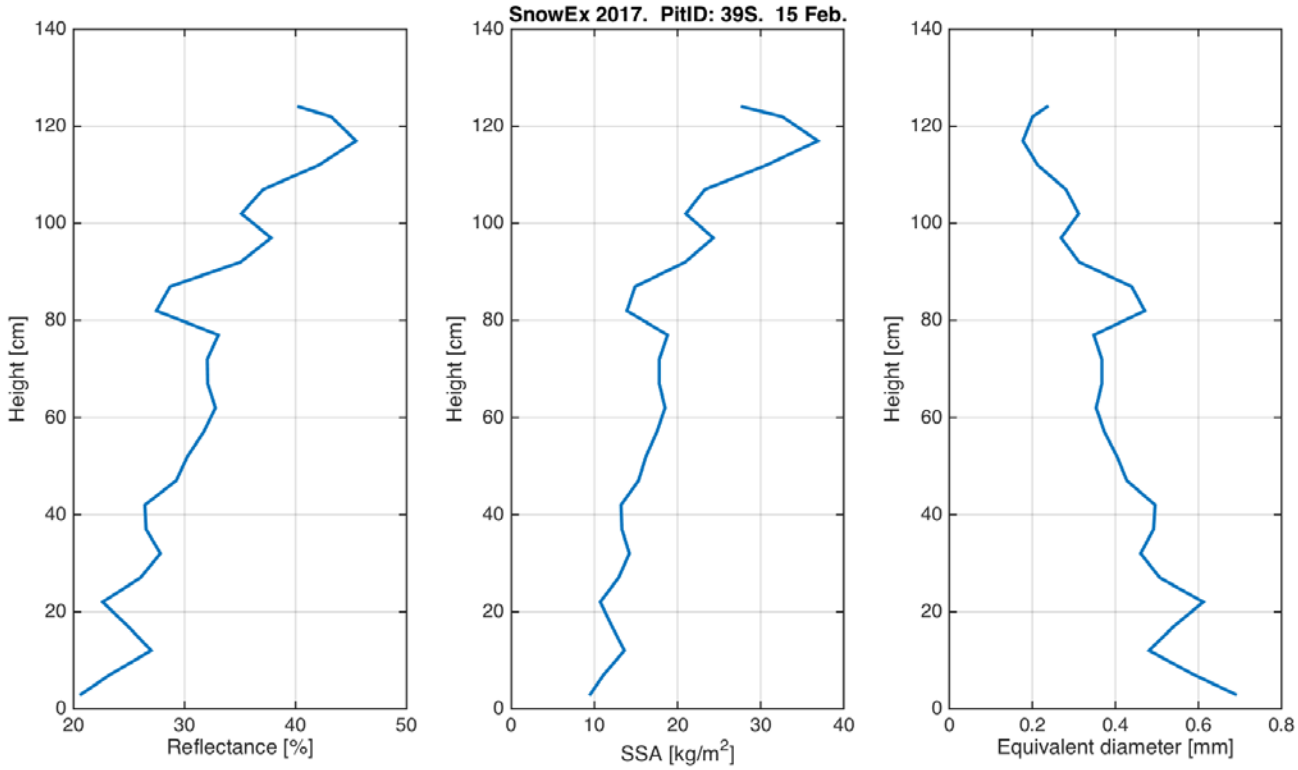
https://github.com/m9brady/SMP_to_CSV

Additional SMP Tools (Github)
Not science ready microstructure retrievals



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: $Do = 6 / (SSA \times \rho_{ice})$
- 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
#

# Sample signal (mV)	Reflectance (%)	Specific surface area (SSA)	Top Depth (cm)	Do (mm)	Comments
447.1	40.29	27.8	124	0.2354	
479.6	43.19	32.6	122	0.2007	
505.8	45.44	36.9	117	0.1773	
467.1	42.09	30.7	112	0.2131	
412.7	37.08	23.3	107	0.2808	

Snow Microstructure: Casting for MicroCT

Pit Location	Date	Snow Depth (cm)	Notes
LSOS Pit	14-Feb-17	122	*missing several samples
28N	16-Feb-17	139	*missing 127-117
1W	17-Feb-17	90	
68E	17-Feb-17	161	
Fraser Ex Forest	20-Feb-17	68	

- 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***