Assignment 3: Snow Survey Data Analysis

Due: Wednesday, 13 February 2019

1 Objectives

For this assignment you will analyze snow survey data in forested and open plots to examine differences in snow depth, snow water equivalent (SWE), density, and temperature characteristics of the snow.

2 Background

The winter snowpack represents an important storage element for freshwater in the Northern Hemisphere and for many mountain environments. Adequate measurements of snow water equivalence (SWE) and snowpack properties are essential to estimate the quantity and timing of surface runoff from catchments with a significant portion of snowcover.

Snowcover comprises the net accumulation of snow on the ground resulting from precipitation, typically during the winter season. Snow is an incredibly complex material with physical properties that vary greatly in time and space. Factors that make this medium complex include variable weather conditions during snowfall and during the period of snowcover. Snow can be subsequently eroded and deposited due to wind. Radiative exchanges may alter the structure, density, and optical properties of the snow. Strong temperature gradients can metamorphose snow due to the transport of water vapor through the snowpack. In addition, vegetation may alter total snow depth and energy receipt to the snowpack (by minimizing incoming shortwave energy or enhancing longwave energy from vegetation).

Snowcover properties vary on different scales: the macroscale, mesoscale and microscale. This field exercise is designed to give you an understanding of the microscale and mesoscale spatial variability of snowcover.

There are no universally accepted instruments for measuring snow depth, density and water equivalent. Methodologies may even vary widely with the user and site conditions. Several methods used in North America to measure these snow parameters are summarized below.

2.1 Snow Depth Measurements

A number of instruments are used to measure snow depth including snow rulers, graduated rods and aerial snow markers. A ruler or rod is pushed through the snowpack to the ground surface and the depth measured directly. Aerial snow markers are sometimes also used to estimate snow depth.

2.2 Snow Density Measurements

To measure snow density, snow pits and gravimetric samples may be employed. A pit is dug to the bottom of the snowpack and individual snow strata (layers of snow having distinctive properties such as snow density, hardness and grain size) are identified and their thickness measured. A sampler with a known volume is used to remove samples of snow from each layer and these samples are weighed to determine density. The average density for a snowpack can be obtained by dividing the sum of the densities for the layers weighted according to layer thickness by the depth of snow. This technique is straightforward and accurate but is labour intensive.

2.3 Snow Water Equivalence Measurements

Snow water equivalent may also be recorded directly using gravimetric samples. A snow corer, a graduated, hollow tube is used to obtain a vertical core of snow. The water equivalent of the core is determined either by melting it or by weighing it. The operator must be careful to obtain a full core of snow without spillage. This is often difficult where woody vegetation underlies the snowpack or where a layer of large, unconsolidated snow crystals exists at the base of the pack. Water may drain from extremely wet snow in the tube. The gravimetric technique is presently the most commonly-used snow water equivalent measurement.

2.4 Snow Surveys

Snow surveys are generally made at regular intervals throughout winter at designated stations along a permanently marked traverse (snow course) to determine depth, vertically-integrated density, and snow water equivalent. The length of a snow course and the distance between sampling points vary depending on site conditions and uniformity of snowcover. A snow course is generally 120 to 270 m long, with observations taken at 10-30 m intervals. Site selection should exclude regions affected by snow removal operations or other artificial control of snow conditions.

3 Methods

3.1 Equipment Used

1. Mount Rose snow sampler
2. Spring scales
3. Meter sticks and tape measures
4. Shovels

5. Snowshoes
6. Thermometers
7. GPS

3.2 Procedure

Two groups performed the snow surveys at the Ancient Forest on 2 February 2011. One group completed the forested snow survey and the other completed the open snow survey near a weather station. For each survey, the two groups made six snow depth measurements along six, 50 m long transects, for a total of 36 measurements per plot. For each transect they measured once the snow water equivalence using the Mt. Rose snow sampler, for a total of six SWE measurements.

A snow pit was also dug in the forested and non-forested plots to characterize the snow layering, density, and temperature of the snowpack.

Conditions at the time of the snow survey were mild at $-5°C$, with calm winds and cloudy conditions.

4 Data Compilation

In the lab directory on the course website you'll find Excel spreadsheet templates with the snow survey data:

- Snow-Pit-Open-AF.csv
- Snow-Pit-Forest-AF.csv
- Snow-Survey-Open-AF.csv
- Snow-Survey-Forest-AF.csv

5 Assignment Questions (25 marks)

Answer the following questions in your write up:

1. What is the average and standard deviation of snow depth of the forested and non-forested plots? Do the average depths differ among transects? [5 marks]
2. Examine how the coefficient of variation (CV) of snow depth varies as a function of sample size for the forested and non-forested plots. How many samples are required in each land cover type before CV stabilizes? For this question, examine the R file `cv.r` on the course website that describes how to do this calculation. [5 marks]

3. What is the average and standard deviation of SWE data for the forested and non-forested plots? Using the six SWE and corresponding snow depth measurements, estimate the bulk density of the snowpack. [5 marks]

4. Plot the snow temperature with depth for the snow pits in the forested and open plots. Discuss factors that might explain the differences you see between the two snow pits. [5 marks]

5. Calculate snow temperature gradients (in units of $^{\circ}C\ m^{-1}$) for each snow pit. What type of snowpack metamorphism would you associate with these gradients? Do the crystal sizes found in the pits make sense? [5 marks]