DENSITY VARIATION IN A SNOWPACK

OF NORTHERN NEW MEXICO

By

Howard L. Gary 1/

Introduction

A better understanding of the metamorphic processes in snowpacks must depend on the accurate measurements of many variables in and near the snow cover. The primary objective of this study was to explore sample variability in density measurements. The study was conducted in 1963-64 from the time of the season' first permanent snow to spring melt in a high-elevation spruce-fir forest.

Study Area and Methods

The study area was located in the Santa Fe National Forest about 16 miles northeast of Santa Fe, New Mexico. The major study plot was in an opening about 40 by 50 feet, with the long axis oriented with the slope. Surrounding trees were between 50 and 60 feet tall. Slope gradient was 35 percent, and elevation about 10,800 feet. In the spring, a few density measurements were also taken in a nearby meadow about 10,400 feet in elevation.

Snow cover in the study area is usually continuous or nearly so from late November to May. Maximum snow depths average about two to three feet under spruce-fir cover, and about four to six feet in openings within the forest. The April 1 snowpack water equivalent averages about 7.1 inches over the Rio en Medio snow course, which is in the immediate vicinity.

Snow profile density samples were taken at roughly two-week intervals in the major study plot. Snow pits were dug at 9:00 a.m., and density sampling was usually completed before 10:00 a.m. The method used to take density measurements generally followed the procedures outlined by Klein et al (1950) and Corps of Engineers (1954). Density samples were obtained with 8-inch sections of 2-inch O.D. clear plastic tubing with 1/8-inch walls. One end of each tube was ground to a long, beveled, knife-like edge. The density sample tubes were individually calibrated for volume, but average volume was about 320 cc. The plastic tubes were used in groups of three at each sample depth (fig. 1); horizontal spacing between tubes was 4 to 5 inches. The vertical distance between sample points was 2 and 4 inches beneath the surface, and at 4 to 6-inch intervals in the interior of the snow cover. When ice lenses were present in the snow profiles, sample points were usually adjusted to avoid them. All snow core samples were put in tared plastic bags, taken to a central location, and weighed to the nearest 0.1 gram on a direct reading balance.

Sample Variability in Density Measurements

In most profile studies, density measurements are limited to one horizontal sample in each snow layer or at each predetermined depth. Three snow samples were taken at each profile depth in the present study in order to estimate within place sampling variability. Errors in weighing were probably in the order of $\pm$ 0.1 gram, and were not considered to affect density determinations.

Snow density data were grouped into four easily distinguishable categories for analysis: new snow, dry snow, wet snow, and depth hoar. Snow one to three days old was considered to be new snow. Dry snow could not be made into a snowball, and was at temperatures below 30°F. Wet snow would hold together as a snowball, and was at temperatures near 32°F. Depth hoar was the coarse-textured formation near the soil surface. The depth hoar formation averaged about 13 inches in depth, and retained its identity through the melting season, although complete prisms and pyramids disappeared soon after melting began. The depth hoar crystals ranged from 2 to 10 mm.

1/ Associate Range Scientist, Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, in cooperation with the University of New Mexico, Albuquerque, New Mexico.

Table 1 summarizes results of triplicate sampling at each location within a profile depth. The standard deviation range among categories was between .0046 and .0060 gm/cm^3 for mean snow densities ranging from .0923 to .3241 gm/cm^3. The standard deviation is uniform for all categories, and would appear to indicate that the variation is due to individual determinations rather than local variability in snowpack. The coefficients of variation are all less than 5 percent. This is undoubtedly a very small component of the total variation over an area.

Samples of new snow showed the largest relative variability. Collapse settlement in sample tubes and cohesion properties were the main difficulties in obtaining good samples in one-day-old snow. Density samples obtained in new snow 2 to 3 days old and after initial settlement and densification were less variable. During the mid-winter period, when snow temperatures were several degrees below freezing, the coarse-textured depth hoar formations were easily disturbed, and commonly collapsed in the sample tubes. After snowmelt began, density samples were less variable in depth hoar layers.

The only visual evidence for cause of sample variability in dry snow was occasional slight difficulty in pushing sample tubes into the snow profile. Insertion of sample tubes was more difficult in the wet snow than in any other category. It was often necessary to tap the tubes with a hammer to fully insert them in the wet snow.

Comparison of Sample Tubes

The sample tubes generally used to obtain density measurements in snow profile studies are the Canadian type and the Corps of Engineers type. The Canadian type has an internal volume of 250 cc, and is equipped with a handle and removable back cover plate. Some Canadian sample tubes also have a serrated cutting edge for sampling "hard snow". The Corps of Engineers type has an internal volume of 500 cc. The sample tubes are made from 1/32-inch wall steel tubing with an inside diameter of about 2-9/32 inches, and are about 7-7/16 inches in length. One end of the tube is also sharpened to a knife edge.

The plastic tubes used to sample density in the present study were compared with the 500 cc Corps of Engineers tubes on two occasions. The plastic tubes had an inside diameter of about 1-3/4 inches, and were about 8 inches long. The samples were taken in snowpacks 39 and 59 inches deep in a shaded meadow near a snow course network. Three snow samples were taken with each type of sample tube at vertical intervals ranging from 4 to 7 inches. Horizontal spacing between sample tubes was 5 to 6 inches. Some differences in density values between the two types of samplers were expected, since slightly different snow masses were sampled. In both tests, density differences were small, and the correlation coefficients for density values between the two types of sample tubes ranged from 0.966 to 0.997 (Figure 2). The two comparison tests indicate that good density measurements can probably be obtained with any type of thin-walled, small-diameter tubes of known internal volume. An advantage of clear plastic tubes is that a snow core can be inspected for voids or foreign matter and either accepted or rejected before it is weighed. Disadvantages of plastic tubes are wall thickness necessary for strength, high friction coefficients because of wall thickness and scratches on the tube walls, and breakability. Steel tubing probably makes the best all-around sample tube, because it is available in small diameters with thin walls, it can be sharpened to a better cutting edge or serrated, and is unbreakable.

Horizontal versus Vertical Sampling

In the 59-inch snowpack, density values for 4- to 6- inch vertical sections of the snowpack centered above and below the position used for the two types of samplers were also obtained (Table 2). Data for individual depth intervals show density differences ranging from minus 8.4 to plus 5.6 percent. Differences of the same magnitude were observed by Work (1948) in deep snow layers at Crater Lake, Oregon. Some variance between vertical and horizontal density values would be expected because of several factors, such as time of sample collection, age of snow, thickness of snow layers, and refreezing of melt water. In this particular snow profile, average density determined vertically was 0.2917 gm/cm^3. The weighted average density for the complete profile, based on density values obtained with the 320 cc plastic tubes and 500 cc steel tubes, was 0.2934 and 0.2876 gm/cm^3, respectively. The weighted average density values largely compensated for the difference between snow samples obtained vertically and horizontally.

Figure 1. Sample tubes inserted into the face of an exposed snow profile for density measurements. A cap and plastic cutoff plate are in place on one tube, and the enclosed snow sample is ready for removal

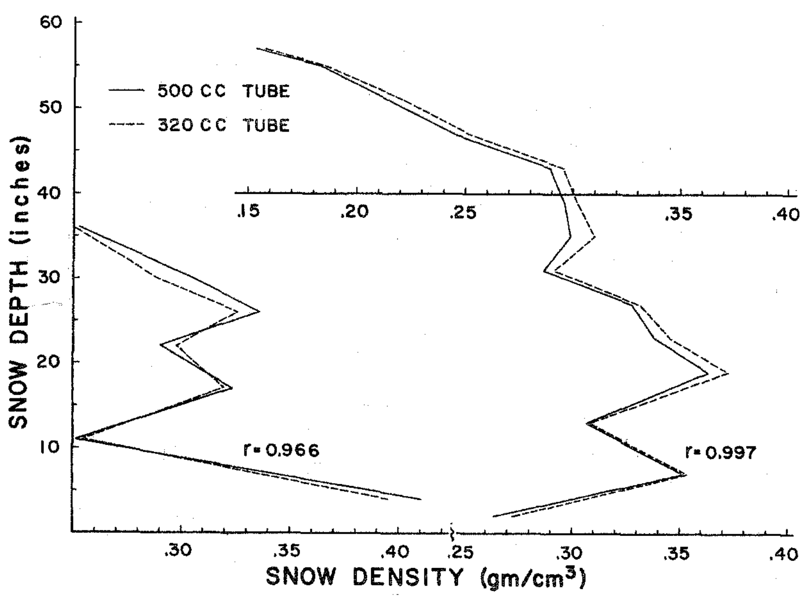

Figure 2. Comparison of density values obtained with 500 cc steel tubes and 320 cc clear plastic tubes on two dates. Three snow samples were taken with each type of tube at each sample depth.

Table 2 was presented to show that horizontal density measurements within a snow profile are point samples, and can be used as a relative index of actual snow density for various snow layers.

Comments

Sample variability in density measurement was apparently related both to the mechanics or difficulties in obtaining snow samples and natural density variations in a snow layer. It is recommended that one density sample be taken when snow cores are easily obtained. When snow cores become difficult to obtain, three or more samples should be taken for that depth or layer.

REFERENCES

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TABLE 1

Summary of density sampling on four snow categories

Number of observations	Time period	Snow Density range (Avg./three samples)	Mean snow density	Pooled standard deviation	Coefficient of variation
		gm/cm^3			percent
		New Snow (one to three days old)			
11	1/ 8 - 4/ 8	.0555 - .1254	.0923	.0046	4.98
		Depth Hoar (wet and dry snowpack)			
37	12/18 - 5/28	.1949 - .3673	.2398	.0060	2.50
		Dry Snowpack (excluding depth hoar)			
24	11/22 - 4/ 8	.1331 - .3027	.2113	.0051	2.41
		Wet Snowpack (excluding depth hoar)			
23	4/23 - 5/28	.2009 - .4375	.3241	.0054	1.67

TABLE 2

Comparison of density values obtained vertically at selected depth intervals and horizontal density samples taken near the center of the respective depth intervals

Vertical samples		Horizontal samples			Horizontal density as percent of vertical density	
			Snow density			
Depth interval	Snow density	Sample depth	320 cc tubes	500 cc tubes	320 cc tubes	500 cc tubes
inches	gm/cm^3	inches	gm/cm^3		percent	
0[1] - 4	0.1488	2	0.1572	0.1531	105.65	102.89
2 - 6	.1857	4	.1851	.1827	99.68	98.38
6 - 10	.2138	8	.2215	.2142	103.60	100.19
10 - 14	.2585	12	.2519	.2450	97.45	94.78
14 - 18	.3064	16	.2956	.2895	96.48	94.48
18 - 22	.3076	20	.3020	.2960	97.18	96.23
22 - 26	.2977	24	.3100	.2988	104.13	100.37
26 - 30	.3045	28	.2914	.2865	95.70	94.09
30 - 34	.3580	32	.3315	.3278	92.60	91.56
34 - 38	.3603	36	.3452	.3380	95.81	93.81
38 - 43	.3535	40	.3728	.3632	105.46	102.74
43 - 49	.3269	46	.3086	.3068	94.40	93.85
49 - 55	.3450	52	.3538	.3518	102.55	101.97
55 - 59	.2794	57	.2719	.2640	97.32	94.49
Average density	.2917		.2934[2]	.2876[2]		

1/ Snow-air interface

2/ Weighted average