Terra Antartica Reports
2008, **14**, 151-154

Snow Surface Characteristics at Dome C, Antarctica

A. Cagnati[1]*, G. Macelloni[2], E. Salvietti[3] & M. Valt[1]

[1]ARPAV-Centro Valanghe di Arabba, Arabba BL - Italy
[2]CNR-Istituto di Fisica Applicata, Firenze - Italy
[3]Dipartimento di Chimica, Università degli Studi di Firenze, Firenze - Italy

**Corresponding author* (acagnati@arpa.veneto.it)

INTRODUCTION

The characterization of snow surface layers is important when analyzing the radiometric response of different snow surfaces. The high albedo, high thermal emissivity and low thermal conductivity of snow strongly affects the overlying atmosphere and thus the polar and global climate. Measurement of the physical and mechanical characteristics of snow can also provide useful data on accumulation-ablation processes and therefore on the mass balance of the polar ice sheet. The structural characteristics of the surface layers of snow in northern Victoria Land were observed in the framework of recent snow-radiometric studies (Cagnati, 1997; Cagnati et al., 2003; Valt, 2000).

Snow measurements on the Antarctic plateau were mainly carried out during the DOMEX experiment that took place at Dome-C, Antarctica, from December 10th, 2004 to January 2nd, 2005. Besides snow measurements, radiometric measurements at different incidence and azimuth angles were taken from a tower. Snowpack profiles were completed at four different sites around Concordia station following conventional methods (Colbeck et al., 1990); one profile was 4 m deep and three were about 1 m deep. In addition to measuring snow density with different types of sampling devices, in some cases the dielectric constant of snow was measured using the Toikka Snow Fork (Tab. 1).

Systematic observations of surface roughness and meteorological conditions were made each day, with special attention to snow deposition. Furthermore, thermometric probes were positioned at different depths (from 5 cm to 10 m)

Tab. 1 - Summary of measured and observed snowpack properties at Dome C.

SITE	DATE	DEPTH	MEASUREMENTS TAKEN
American tower 1 (AT1)	16-17-18-19/12/2004	400 cm	Stratigraphy, Temperature every 10 cm, Density in layers, Density every 10 cm, Hardness indices (up to 89 cm), Dielectric constant
American tower 2 (AT2)	23/12/2004	100 cm	Stratigraphy, Temperature every 10 cm, Density every 10 cm
Meteorological station (AWS)	24/12/2004	105 cm	Stratigraphy, Temperature every 10 cm, Density every 10 cm
Thermometric probes hole (TNP)	28/12/2004	108 cm	Stratigraphy, Temperature every 10 cm, Density every 10 cm, Hardness indices, Dielectric constant

in a 10-meter-deep hole, and snow temperature data were measured every hour by a data logger located in a heated box near the hole. The snow core extracted when the hole was made was summarily examined, and density, grain shape and size were noted. Thanks to a researcher who wintered over at Concordia, snow temperature measurements were taken throughout the year 2005.

SNOWPACK STRUCTURE

Temperature gradient metamorphism is one of the dominant processes responsible for changes in the structure of polar snow (Alley, 1988). In summer, the snowpack at Dome C shows a sequence of soft layers consisting of kinetic growth grains alternating with harder layers of rounded grains. In the more superficial portion of profiles (generally to a depth of 50 cm) the hard layers often have the typical appearance of wind crusts (very hard with a thickness of 0.5 to 1 cm) (Fig. 1). At greater depths the crusts tend to disappear and the hard layers are thicker and formed by larger grains. Kinetic reconstruction of grains is generally evident in all the profiles. This is due to the thermal gradient which, though not particularly high, acts continuously through time. The water vapour flux is partially blocked by the presence of hard layers containing the larger grains. Reconstruction, which leads to the formation of large faceted crystals, is active throughout the year, except when the thermal gradient is reversed (end of February and end of October) and when the snowpack is in quasi-isothermal conditions. In 2005, the drop in temperature that occurred in the second half of August produced another maximum positive thermal gradient (after the first one in April) at the beginning of September (Fig. 2).

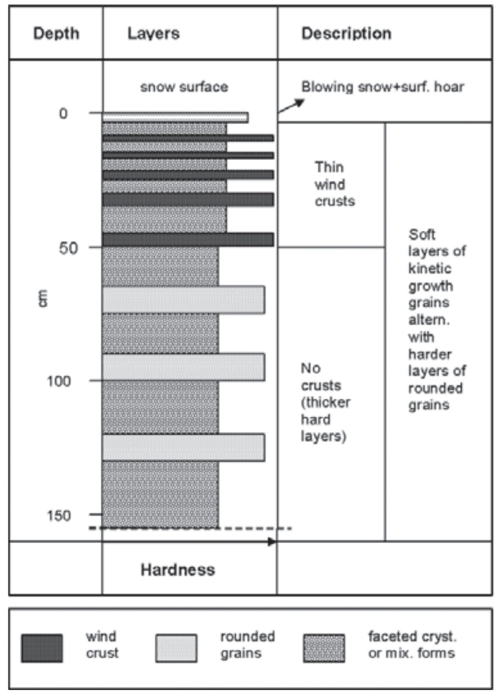

Fig. 1 - Schematic snowpack structure at Dome C (surface layers).

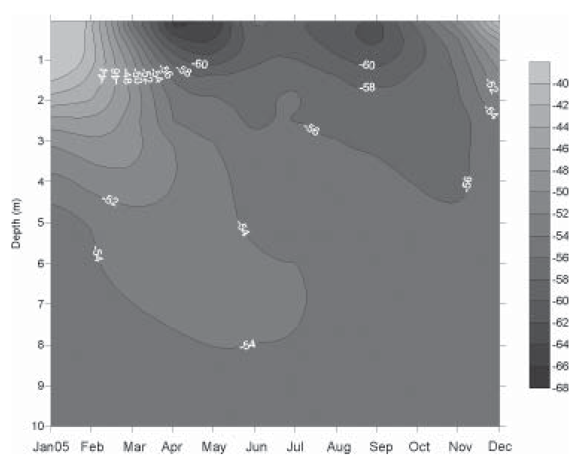

Fig. 2 - Map of snow temperature at different depths during the year 2005.

Tab. 2 - Characteristics of observed snow grain typologies (classification according to Colbeck).

Shape	Class	Max. dimensions (mm)	Sphericity	Dendricity
V	7a	0.5	0.5	1.0
•	9d, 3a, 3b	0.2-0.7	0.9	0.1
☖	4c	0.7-1.5	0.3	0.3
* Λ	4a, 5a	2-3	0.1	0.1

GRAIN SHAPES AND DIMENSIONS

According to the IASH classification (Colbeck et al, 1990), the kinetic reconstruction of grains can be ascribed to mixed forms (sub-class 4c) 0.7 to 1.5 mm in diameter, or to faceted crystals (sub-class 4a) up to 2.5 - 3 mm in diameter. These grain typologies clearly predominate along all the examined profiles, giving the snowpack an incoherent appearance. The presence of depth hoar (sub-class 5a) was noted in one case only (at the AWS site), with crystal dimensions of 2-3 mm in the rounding phase. The presence of depth hoar can perhaps be attributed to the lower accumulation, which determines a long exposure to strong thermal gradient. Surface hoar (sub-class 7a) particles about 0.5 mm in size are almost always present on the snowpack surface. Wind crusts (sub-class 9d), instead, generally consist of small rounded grains with dimensions of about 0.2 – 0.3 mm. In the layers formed by rounded grains (sub-classes 3a and 3b), grain dimensions tend to increase up to a maximum of 0.7 mm. Table 2 summarizes the identified grain typologies with their measured dimensions (maximum dimension), as well as the estimated sphericity and dendricity. As demonstrated by previous studies (Gay et al., 2002), grain dimensions generally increase with depth (Fig. 3), with some discontinuities due to the succession of layers with different characteristics.

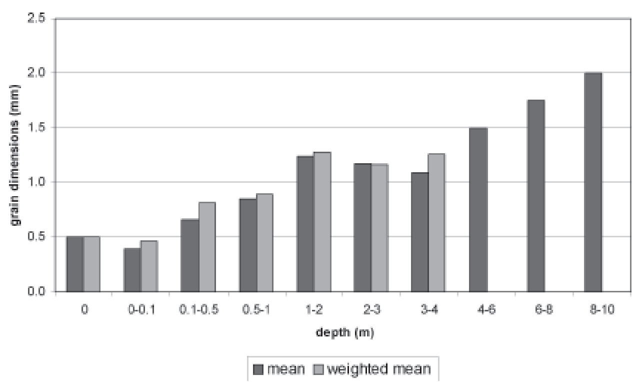

Fig. 3 - Average dimensions of grains for depth classes.

SNOW DENSITY

Snow density values differ according to the characteristics of layers and depend on the typology of the grains which make up the layers. For this reason the trend is rather discontinuous, especially in the first meter. If we consider data collected in the first 10 m (snow profile data in the first 4 m and core data from 4 to 10 m), the density of layers composed of faceted crystals or mixed shapes increases with depth from 300 to 410 kg/m^3 (with minimum values of 260 kg/m^3), whereas that of layers composed of rounded grains is higher, increasing with depth from 370 to 510 kg/m^3 (with maximum values of 520 kg/m^3). On average snow density increases with depth, although rather slowly in the first four meters (from 360 kg/m^3 at a depth of one meter to 390 kg/m^3 at four meters), reaching values of up to 480 kg/m^3 at depths of 8-10 m. The process of kinetic reconstruction, which leads to the formation of large, highly porous grains, clearly prevails with respect to the evolution toward equilibrium forms and to the compacting action of wind. This determines the rather low cohesion of the snowpack, even in the relatively deep layers.

SNOW TEMPERATURE

At a depth of 10 m, snow temperatures are stable at about –54.5/-55.0°C and are not influenced by seasonal variations. Conditions are already nearly isothermal at depths of over 5 m, with maximum variations of 2-4°C. Seasonal variations are particularly evident in the first 4 m, where the difference between the temperature at the surface (at 5 cm depth) and that at a depth of 4 m can exceed 25°C. The thermal gradient is negative during summer and for part of spring, while it is positive during the rest of the year. Surface temperatures vary from maximum values of -20/22°C in December/January to minimum values of -68/70°C in April. Daily variations only occur in the upper 20-30 cm during summer and coincide with significant variations in air temperature. Maximum daily variations occur in January and February, with values of 6-8°C at a depth of 5 cm and of 4-6°C at a depth of 10 cm. Temperature measurements taken every 10 cm along snow profiles reveal a negative thermal gradient toward the end of December which decreases with depth from 0.193°C/cm at one meter to 0.016°C/cm at four meters.

SPATIAL VARIABILITY

The general structure of the snowpack was very similar in all four surveyed sites. At equal depths the main parameters (grain shape and dimensions, density, thermal gradient, hardness, etc.) show slight variations which are part of the normal variability of snow parameters over uniform areas. It can therefore be said that the snowpack at Dome C has low spatial variability.

Acknowledgements – Research was carried out in the framework of the Project on Geophysics funded by the Italian *Programma Nazionale di Ricerche in Antartide* (PNRA) and ESA. This work is a French-Italian contribution to the CONCORDIA Station.

REFERENCES

Alley R.B., 1988. Concerning the deposition and diagenesis of strata in polar firn. *Journal of Glaciology*, **34**, 118, 283-290.

Cagnati A., 1997. Some observations on snowpack features in Northern Victoria Land, Antarctica. *Geografia Fisica e Dinamica Quaternaria*, **20**, 233-239.

Cagnati A., Casacchia R., Salvatori R. & Valt M., 2003. Snowcover in Antarctica: physical and morphological features of surface layers. *Terra Antartica Reports*, **8**, 5-10.

Colbeck S.C., Akitaya E., Armstrong R., Gubler H., Lafeuille J., Lied K., McClung D. & Morris E., 1990. *The international Classification for Seasonal snow on the ground*. International Commission of Snow and Ice, IAHS, 23 p.

Gay M., Fily M., Genthon C., Frezzotti M., Oerter H. & Winther J-G., 2002. Snow grain size measurements in Antarctica. *Journal of Glaciology*, **48**, 163, 527-535.

Valt M., Cagnati A., Casacchia R. & Salvatori R. 2000. Neve e ghiaccio in Antartide. *Neve e Valanghe*, **41**, 46-53.