

WIND SLAB FORMATION:
WILL NEW EXPERIMENTS IMPROVE IMPLEMENTATIONS IN SNOW-COVER MODELS?

Christian G. Sommer^{1,2*}, Charles Fierz¹ and Michael Lehning^{1,2}

¹WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland

²CRYOS, School of Architecture, Civil and Environmental
Engineering, EPFL, Lausanne, Switzerland

ABSTRACT: Wind slabs are widespread in snow environments but the physics of what is often called wind-packing is poorly understood. Yet, wind slabs are of significant importance. An obround wind tunnel that mimics an infinitely long snow surface was developed to study the process of wind slab formation. The surface hardness increases - if at all - only slowly when the wind speed is kept below the drifting snow threshold. On the contrary, surface hardness increases typically from about 0.1 N to around 0.3 N during drifting snow events with surface density increasing from 60 kg m⁻³ to about 170 kg m⁻³. This indicates that saltation is a necessary condition for wind-packing. Currently, the snow cover model SNOWPACK is able to reproduce reasonably well the results from experiments without drifting snow but cannot replicate yet the observations during drifting snow events. A better representation of wind-packing in snow models is desirable because it will improve stability assessments. Understanding the formation of wind slabs is also required to comprehend snow deposition in polar regions and therefore contributes to the assessment of ice sheet and sea ice mass balances.

KEYWORDS: wind tunnel, wind-packing, drifting and blowing snow.

1. INTRODUCTION

Wind-packed snow (slabs or crusts) is often part of alpine or polar snow covers. At the surface, such a layer influences the interaction between the snow-pack and the atmosphere. Wind-packing affects the mass balance in polar regions, because snow is often only immobilized through this process (Groot Zwaafink et al., 2013).

There are many qualitative descriptions of wind-hardened surface layers (e.g. Benson, 1967; Alley, 1988). Many formation processes have been proposed but real evidence is scarce and it remains unclear which process dominates. Mechanical fragmentation of the snow crystals by the wind is mentioned most often (e.g. Kotlyakov, 1966). Some authors also maintain that a crust can form without drifting snow (e.g. Seligman, 1936).

The goal of our project is to determine the physical processes in wind-packing. This paper presents a new experimental setup designed to study wind-packing and first results. The results are then compared to SNOWPACK simulations.

2. DESIGN AND OPERATION OF THE WIND TUNNEL

Wind-packing is a process that takes place at a time-scale of minutes to hours and saltation may play an important role. Therefore, it has to be studied in a closed-circuit wind tunnel because saltating particles are ejected within seconds from an open-circuit tunnel.

An obround (stadium-shaped) wind tunnel was developed (Fig. 1). The idea behind the obround shape was not only to obtain a closed-circuit configuration but to simulate an infinite fetch.

The complete floor is covered with undisturbed, natural snow. The channel is 0.2 m wide and 0.5 m high. The straight sections are 1 m long and the overall width of the facility is 1.2 m. The airflow is generated by a model-aircraft propeller driven by an electric motor. The propeller rotates at up to 12000 rpm and free stream wind speeds up to 8 m/s can be reached. However, the wind tunnel is rarely operated at velocities above 7 m/s because the centrifugal effects become too strong.

Fresh snow is collected on a pair of wooden trays outside the building. A cart is used to transport the trays into the building after 10-20 cm of snow have accumulated. The wind tunnel is lifted by a crane and the trays are arranged beneath it. Then, the bottomless tunnel is lowered onto the snow.

* Corresponding author address:

Christian G. Sommer, WSL-SLF,
Flüelastrasse 11, Davos Dorf, Switzerland;
tel: +41 81 417 02 85;
email: sommer@slf.ch

The instrumentation is located in one of the straight sections (main test section) and consists of sensors to measure wind speed, air temperature and humidity at three heights, snow surface temperature and snow temperature. A camera detects drifting snow and a SnowMicroPen (Schneebeli and Johnson, 1998) is used to measure the hardness and thickness of formed wind slabs/crusts.



Fig. 1: The obround wind tunnel. The platform below is 1.5 m wide and 2.5 m long. The main test section is on the left.

3. RESULTS

The experiments carried out during winter 2015 suggest that saltation is a necessary condition for wind-packing. Below, we present two representative experiments, one without and one with drifting snow.

3.1 *Without drifting snow*

Fig. 2 shows the evolution of wind speed and snow temperature during the experiment. There were four wind periods. SMP measurements were acquired before and after each one (Fig. 3). The air temperature was slightly above freezing and the snow temperature continuously increased to about -0.5°C . The snow surface temperature reached 0°C during the night and some melting occurred. The SMP measurements show how the snow settled. The snow height decreased by about 3.5 cm overall (SMP5 in Fig. 3). No crust was formed at the surface but the hardness of the whole snow cover increased slightly.

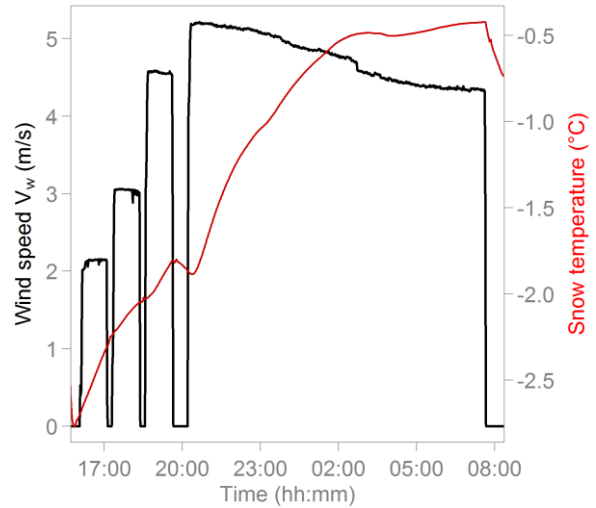


Fig. 2: Wind speed and snow temperature during the experiment without drifting snow.

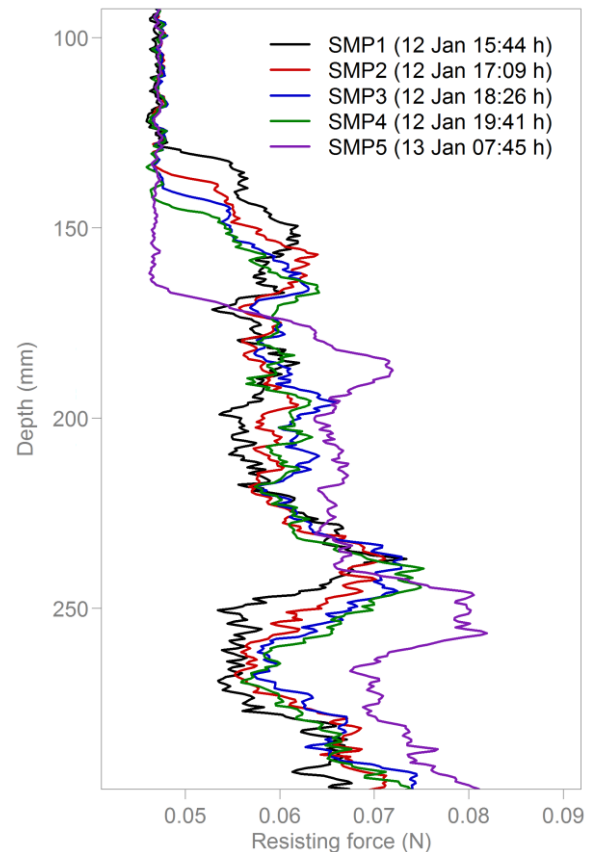


Fig. 3: SMP measurements during the experiment without drifting. There was settling but no hardening.

3.2 With drifting snow

Fig. 4 shows the wind speed and the snow depth during the first two wind periods of an experiment with drifting snow. There was erosion in the test section during the first period and deposition during the second period. The snow depth is taken from the SMP measurements (Fig. 5) and is assumed to vary linearly during the wind periods. There was no hardening during the first wind period. The deposition during the second wind period led to the formation of a crust.

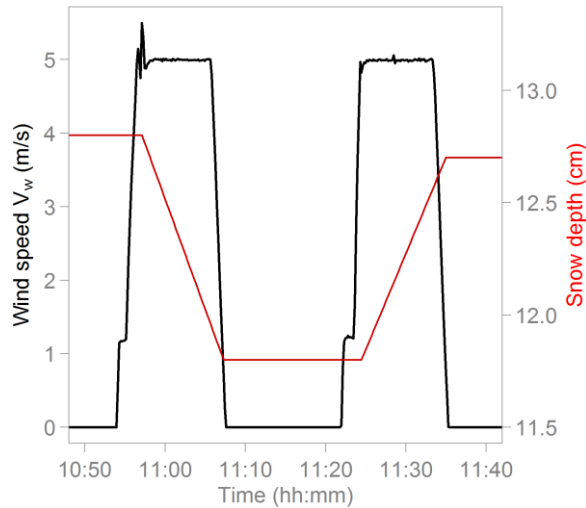


Fig. 4: Wind speed and assumed snow depth during the experiment with drifting snow.

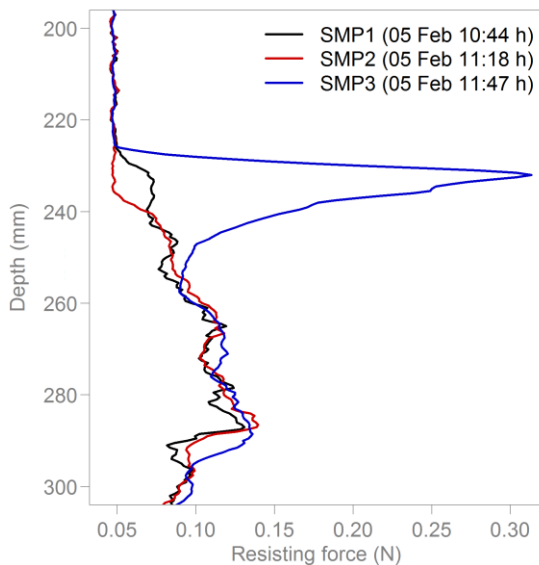


Fig. 5: SMP measurements during the experiment with drifting snow. There was no hardening during the period with erosion. Deposition led to the formation of a crust.

4. SNOWPACK SIMULATION

SNOWPACK was used to simulate the experiment without drifting. Fig. 6 shows the evolution of the modelled and measured snow depth. The model produces some settling but the settling rate is underestimated, especially early in the experiment. The discontinuities in the modelled snow depth are due to the removal of melted layers.

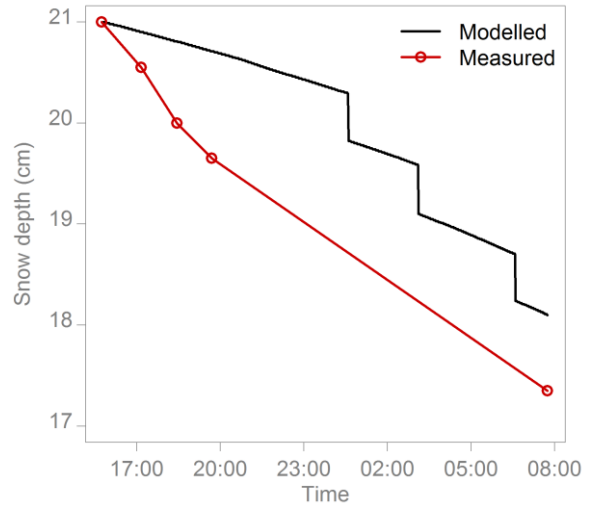


Fig. 6: Modelled and measured snow depth during the experiment without drifting.

5. DISCUSSION & CONCLUSIONS

The main result is that drifting is a necessary condition for the formation of a wind crust. Wind below the drifting threshold only leads to settling and the associated slight increase in hardness. We performed experiments with a bowl of water embedded in the snow to increase the humidity and the chance of crust formation. Locally, there was a slight hardening effect but only just downstream of the bowl and the hardness remained below 0.1 N.

SNOWPACK was able to replicate the experiment without drifting fairly well. Settling and some melting at the surface occurred as expected, although the modelled settling rate was too low. We are now investigating in how far current wind densification routines in SNOWPACK (Groot Zwaafink et al., 2013; Schmucki et al., 2014) are able to reproduce our experiments with drifting snow. First attempts would suggest that an adaptation of the routines is necessary. This will be described in detail in a future paper.

REFERENCES

- Alley, R. B., 1988: Concerning the deposition and diagenesis of strata in polar firn, *Journal of Glaciology*, 34, 283-290.
- Benson, C. S., 1967: Polar Regions Snow Cover, Physics of Snow and Ice : proceedings, *Eleventh Pacific Science Congress*, Tokyo, 1039-1063
- Groot Zwaafink, C. D., A. Cagnati, A. Crepaz, C. Fierz, G. Macelloni, M. Valt, and M. Lehning, 2013: Event-driven deposition of snow on the Antarctic Plateau: analyzing field measurements with SNOWPACK, *The Cryosphere*, 7, 333-347.
- Kotlyakov, V., 1966: *The Snow Cover of the Antarctic and its Role in the Present Day Glaciation of the Continent*, Israel Program for Scientific Translations, 256 pp.
- Schmucki, E., C. Marty, C. Fierz, and M. Lehning, 2014: Evaluation of modelled snow depth and snow water equivalent at three contrasting sites in Switzerland using SNOWPACK simulations driven by different meteorological data input, *Cold Regions Science and Technology*, 99, 27-37.
- Seligman, G., 1936: *Snow structure and ski fields: being an account of snow and ice forms met with in nature, and a study on avalanches and snowcraft*, Macmillan, 555 pp.