# EFFECT OF SNOW TEXTURE ON SNOWPACK SETTLEMENT RATES

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[ EXTENDED ABSTRACT ]

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## 1 INTRODUCTION

During the exceptional winter 98/99, 7 specially designed sensors were used to record continuously both snowpack settlement and snow temperature in situ at the SLF study site Weissfluhjoch/Davos, 2540 m a.s.l. The viscous behavior of quite different snow layers could thus be monitored under large and rapid natural loading.

It is well known that snow texture effects settlement of the snowpack. New snow, layers of either small rounded grains or larger faceted and cup-shaped crystals as well as wet snow all show different viscous behaviors. In snow-cover models, this effect is taken into account either assigning each type of snow a distinct viscosity law, or e.g. as function of temperature and density or by modeling snow viscosity completely in terms of microstructure parameters such as grain and bond size, bond neck length, coordination number and density. The latter approach was chosen in the Swiss snow-cover model SNOWPACK.

These in situ measurements as well as experiments done in the cold laboratory allowed to find a consistent set of parameters to improve model performance.

## 2 IN SITU MEASUREMENTS

One of the sensors used for this study is shown in Figure 1. It consist of a balsa wood frame across which a continuous tungsten wire is stretched to record temperature. Its side arms are clipped to two vertical wires serving as both guides and electric connectors to determine the sensor's depth. As snowfall buries the sensor in, the latter settles with the underlying snowpack (Weilenmann, 1999).

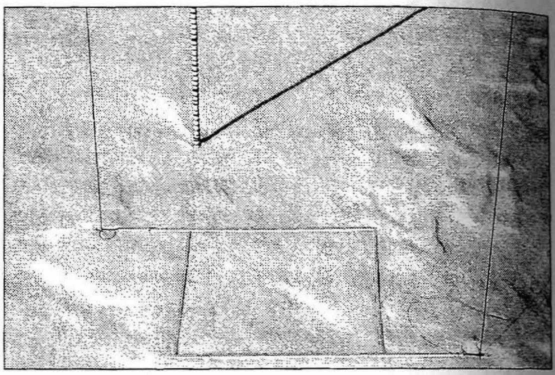

*Figure 1 : Settlement and temperature sensor laid on top of the snowpack before a snowfall. The sensor is clipped onto the vertical guiding and depth measuring wires.*

## 3 SNOW COVER MODELING

A full description of SNOWPACK is beyond the scope of this paper and the reader is referred to the publication by Lehning et al. (1999). Nevertheless it is worth mentioning that important properties and processes such as thermal conductivity and viscosity as well as bond and grain growth are based on micro-structural model formulations. Each of these has its own free parameter which has to be adjusted from experimental data. However, because e.g. conductivity and bond growth are related, a consistent set of parameters must be found.

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### 3.1 Kinetic bond growth (TG)

*Figure 2 : 9.6 by 9.6 mm$^2$ part of a disaggregated grain picture showing selected bonds (white bars marked by arrows).*

To calibrate the kinetic bond growth routine, the raw picture data of Baunach and Fierz (2000) are used. Although the pictures show mostly disaggregated grains, a large enough number of bonds can be identified and measured (see Figure 2).

Now, using thermal conductivity measurements as an additional check, parameters for kinetic grain and bond growth are adjusted for a wide range of conditions. The obtained parameter set is then used for the simulation run below.

### 3.2 Simulation run

A snow profile taken on 29 November, 1998 provides the initial conditions for SNOWPACK which runs trough till the ground becomes free of snow. Forcing data are the snow surface temperature, the incoming short wave radiation as well as snow depth measurements during accumulation periods.

By tagging model layers corresponding to the buried sensors, a direct comparison of model output with measurements allows to finally adjust viscosity and therefore control settlement. Notice however that viscosity depends strongly on the ratio of grain to bond size and is thus not independent of the set of parameters found above.

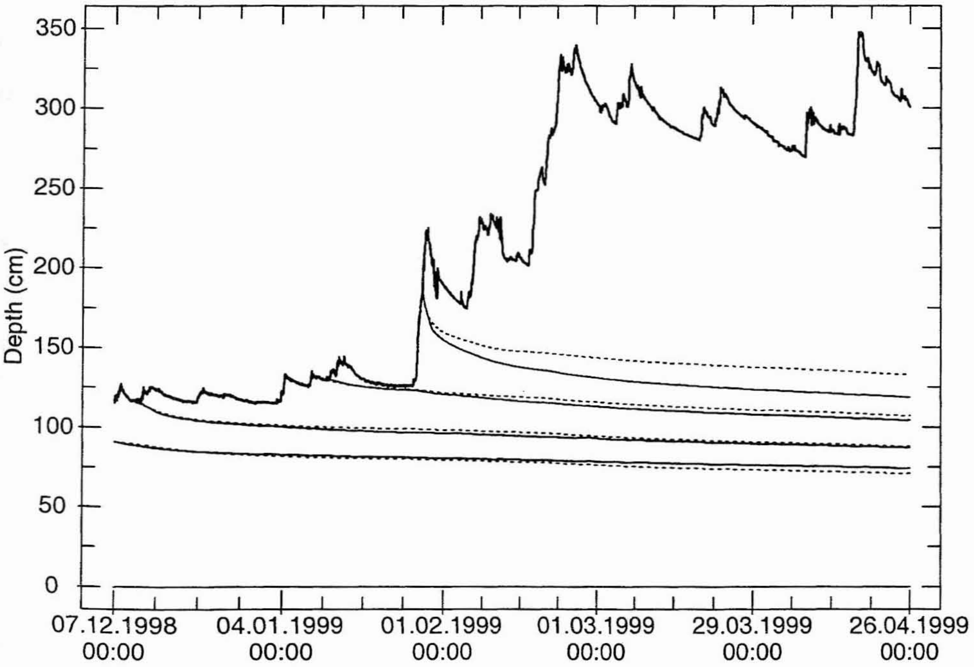

*Figure 3 : Measured and modeled settlement in the snowpack. Solid and dotted lines are measured and simulated sensors depth, respectively. Thick line is measured snow depth.*

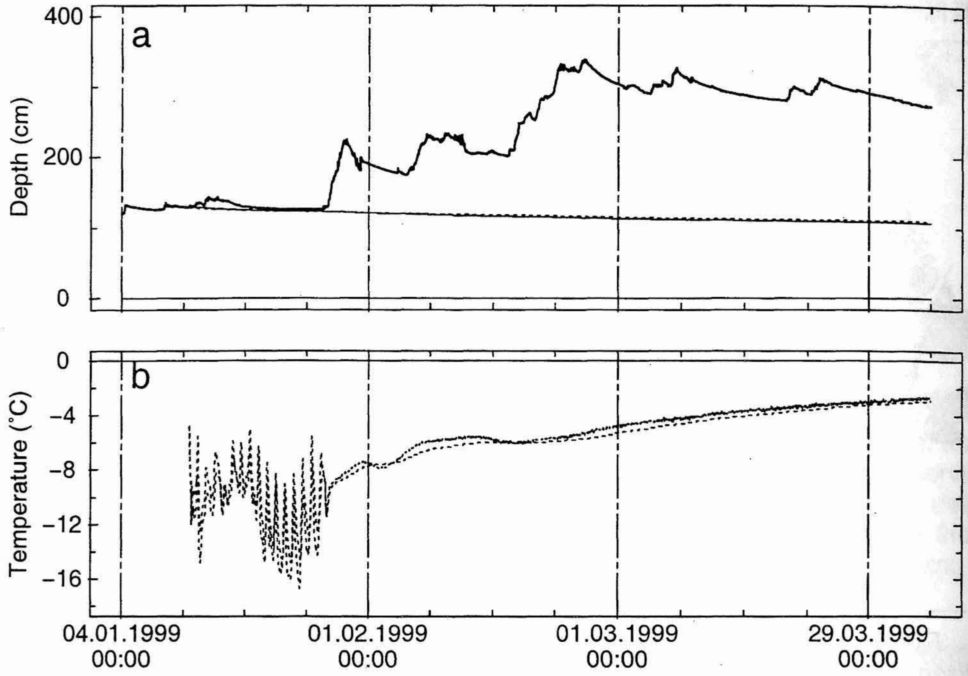

*Figure 4 : Measurement (solid line) vs. simulation (dotted line) for one sensor: a) Settlement, b) Temperature. The thick solid line in a) is snow depth.*

## 4 DISCUSSION

A 'best fit' solution is shown in Figure 3 for the dry snow season extending up to the end of April 1999. Good agreement is reached within the lower part of the snowpack while initial settling during heavy snowfalls may be slightly underestimated and leads to larger errors in the upper half. However, crosschecking simulated with measured temperatures in the lower half of the pack strongly supports the consistency of the parameter set used (see Figure 4).

## 5 CONCLUSIONS

Using both laboratory and field experiments, a consistent set of parameters is found for the micro-structural formulation of thermal conductivity, viscosity as well as kinetic grain and bond growth in SNOWPACK. A correct modeling of grain and bond growth, however, is a prerequisite for further investigations such as the mechanical stability of a snowpack, e.g.

Further detailed analysis will now be directed towards the first stage of freshly fallen snow metamorphism under various meteorological and load conditions.

## ACKNOWLEDGEMENTS

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## REFERENCES

Baunach, T. and C. Fierz. 2000. A model for kinetic grain growth. *Ann. Glaciol.*, **32**, in press.

Lehning, M., P. Bartelt, B. Brown, T. Russi, U Stöckli and M. Zimmerli. 1999. SNOWPACK model calculations for avalanche warning based upon a new network of weather and snow stations. *Cold Reg. Sci. Technol.*, **30**, 145-157.

Weilenmann, P. and F. Herzog. 1999. Entwicklung und Betrieb einer Temperatur- und Setzungsmessung in der Saisonschneedecke [Continuous settlement and temperature measurements in a seasonal snowpack]. *Interner Bericht*, 722. Swiss Federal Institute for Snow and Avalanche Research. 39pp.