DETECTION AND REGISTRATION OF WATER WAVES IN A NATURAL SNOW COVER

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ABSTRACT

Based on multiple years experience with long-term water percolation measurements made on columns of repacked snow, dielectric sensors have been developed to automatically record the local water content at various depths. Recent long-term measurements of timely and spatial variations in snow wetness are reported. The experiments have been carried out in the Stubai Alps, 3000 m a.s.l, and at the Seegrube, 2000 m a.s.l., near Innsbruck, Austria. The field experiments have been made using simultaneously operated dielectric probes, installed at different depths in a natural snow cover. Percolating melt- and rainwater waves have been detected. At higher water flow rates - produced by a short but heavy rainfall on a relatively wet snow cover - the formation and movement of water shock-fronts has been observed. In addition, the distribution and daily variation of wetness in the uppermost layers of a natural snow cover have been recorded with a high spatial resolution: 4 sensors have been installed with a vertical spacing of only 10 cm, and with a horizontal displacement of 20 cm.

INTRODUCTION

Knowledge of liquid water content and distribution in a natural snow cover is helpful in modelling and forecasting snowmelt runoff, in interpreting remotely sensed snowfield data, and is also usefull for wet snow avalanche and snow stability studies. As liquid water content and distribution is highly variable over time (Brun and Rey, 1986; Kattelman, 1990), microcomputer controlled capacitive sensors have been developed to monitor and register long-term wetness variations (Denoth and Wilhelmy 1988, Denoth and Griessmair,1990). The plate-like design of these sensors allows nearly non-destructive measurements of both surface

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and volume wetness. In this paper field observations of long-term snow wetness variations and the formation and movement of water waves in snow are reported.

INSTRUMENTATION

The basic description of the snow wetness measurement system has been given by Denoth and Griessmair (1990). With the aim of reducing system complexity, reducing system power consumption for long-term field applications, and with the aim of improving system handling and data transfer to a PC, the electronic configuration has been redesigned partly. The built-in microcumputer allows the simultaneous operation of up to 4 capacitive sensors, the measurement data are stored in a 32k RAM. The time interval between individual measurements can be pre-selected: the minimum is 20 seconds per sensor operated (i.e. 80 seconds in the case of simultaneous operation of 4 sensors), the maximum time interval is 4 hours. The built-in rechargeable battery allows a continuous operation of 15 hours; long-term measurements exceeding this limit can easily be made using an external power supply.

Fotographs of the measurement systems used for the field experiments are shown in the Figures 1 and 2.

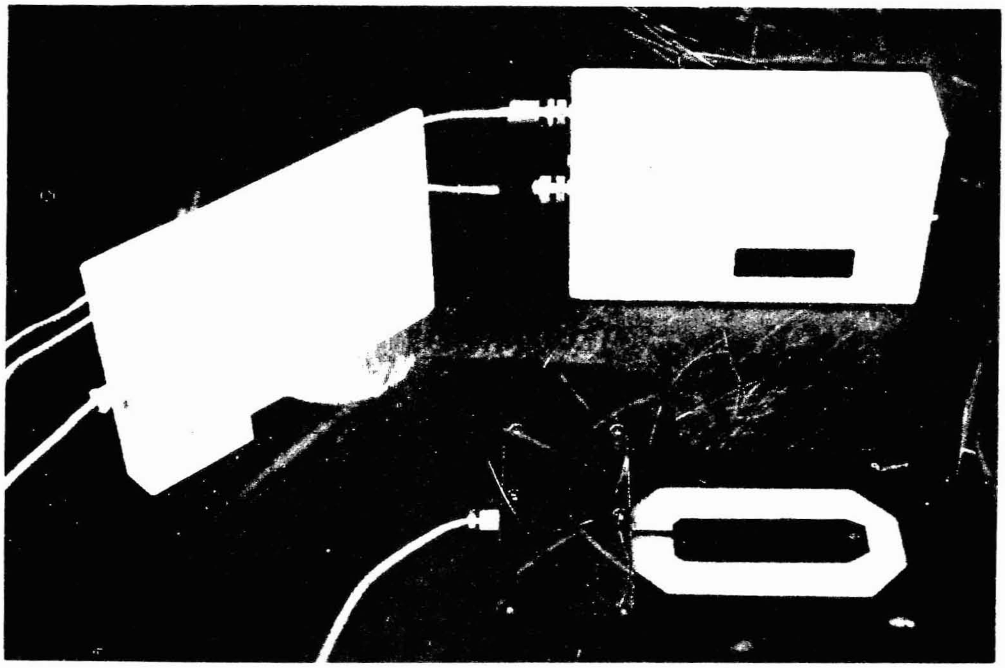

Figure 1. Microcomputer controlled snow wetness measurement device with 2 sensors connected.

The μP-controlled system is especially used for long-term registration of snow volume wetness with buried sensors, the manually operated system is mainly used for spot measurements of snow surface wetness.

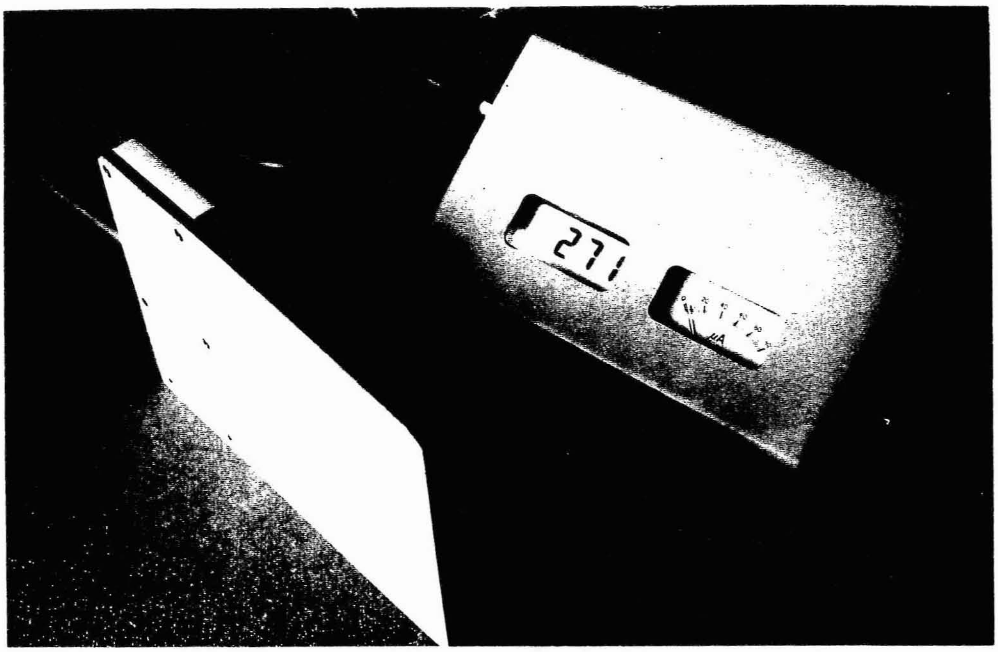

Figure 2. Snow wetness measurement device for manual operation

FIELD EXPERIMENTS AND RESULTS

Long-term measurements of snow volume wetness have been made with these sensors in sommer 1991 and 1992 in the Stubai Alps (3000 m a.s.l.), and at the beginning of the snowmelt season (march 1992) at the Seegrube (2000 m a.s.l.) near Innsbruck, Austria. A typical experimental setup in the field is shown in Figure 3. The sensors are mounted vertically into the snow cover in order to allow the melt/rainwater flux to penetrate more or less undisturbed. Horizontally inserted sensors create new "surfaces" which may affect the local water flow drastically.

The experiments have been made in order to detect and register daily variations in wetness in different depths of a natural snow cover with a high timely resolution. Four sensors have been operated alternatively with a given time difference between individual measurements of only 20 seconds (i.e. nearly simultaneous operation). The time difference between consecutive measurements has been preselected: 10 minutes (high resolution in time) for the precise detection of the movement of meltwater waves, and 30 minutes for the registration of daily variations in snow wetness near the snow surface. Experimental results of these measurements are shown in the Figures 4. and 5.

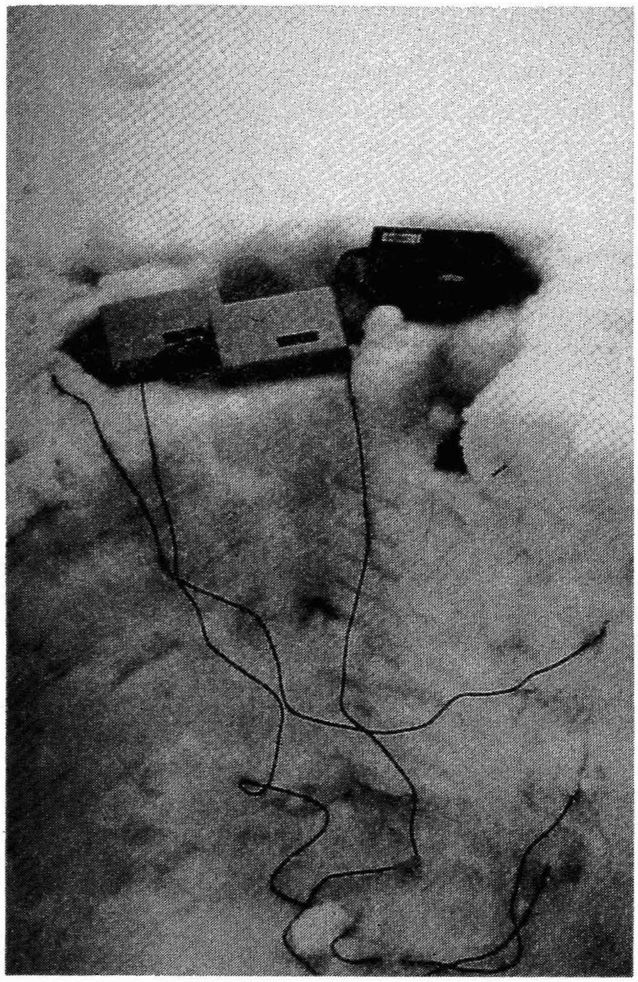

Figure 3. Experimental setup in the field

Figure 4. shows the formation and percolation of water waves in snow. The measurements have been made in the Stubai Alps in July 1991: strong solar radiation caused surface melting on a relatively coarse grained snowfield (grain size ≈1mm). The sensors have been installed at different depths of 10 cm, 50 cm, 100 cm, and 200 cm, respectively; the data have been collected continuously on a 10 minute time scale, starting at 09:00. Because of relatively cold nights, the uppermost snowlayer (0..≈15 cm) was dry. Surface melting begun at ca 10:30; the maximum amount of liquid water was produced at approx. 14:00, and ranged between 4 and 5 Vol%. The percolating meltwater wave was recorded by the other sensors with a time delay of approx. 3 to 4 hours per meter, corresponding to a water flux between 10^{-6} m/s and 10^{-5} m/s. A short but heavy rainfall at 14:50 of the third day of continuous wetness registration caused the formation of a water shockfront: the maximum amount of liquid water near the snow

surface exceeded 9 Vol% (the measurement limit of the sensor) and the corresponding water wave percolated at a significant higher speed between 10^{-5} m/s and 10^{-4} m/s through the snow cover.

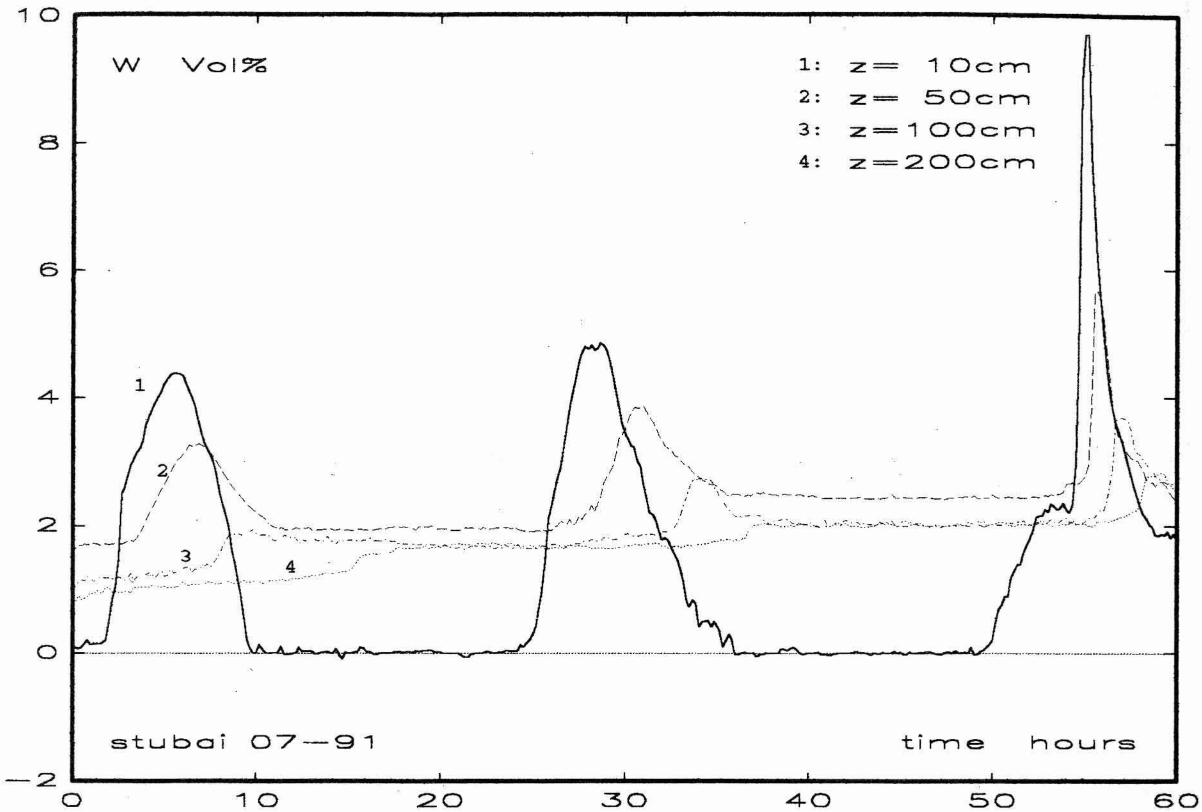

Figure 4. Detection of water waves in snow in four different depths of 10, 50, 100 and 200 cm.

Figure 5 shows a 29 hours registration of wetness variation in the uppermost snow layers: 4 sensors have been installed at different depths of 8 cm, 18 cm, 28 cm, and 40 cm, respectively, whereby the individual sensors have been displaced horizontally (20 cm) in order to minimize mutual influences. The measurements have been made at the Seegrube, 2000 m a.s.l. near Innsbruck in march 1992, at the beginning of the melt season. The snow layer near the surface is characterized by large and rapid changes in wetness, with freezing over night. Wetness in a depth of 40 cm, however, is low (approx. 1 Vol%) and increases slowly, whereby marked variations have not been detected. Therefore, the gradient in wetness (with respect to depth) varies significantely during a day-night cycle.

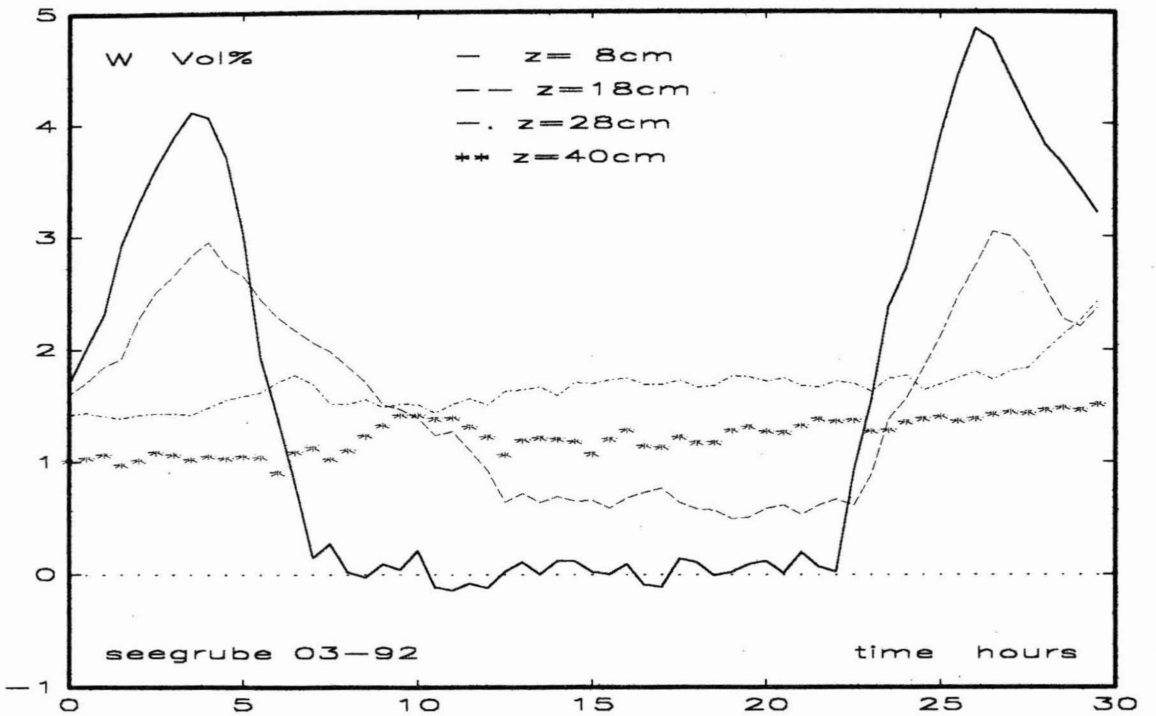

Figure 5. Daily variation of snow wetness near the surface

ACKKNOWLEDGEMENT

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