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Instruments and Methods

Automatic glacier ablation measurements using pressure transducers

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ABSTRACT. An instrument is described that automatically records ice ablation while eliminating the need for ablation stakes. A pressure transducer placed at the bottom of a hole drilled into the ice is connected by a hose to a bladder lying on the surface. Ice ablation is detected as a reduction in the hydrostatic pressure measured by the transducer.

INTRODUCTION

During the last century mass-balance measurements of glaciers have been carried out using ablation stakes placed in drillholes in the ice. Such stakes proved to be reliable and have become the standard method of surface-based measurements. However, the stake method is laborious and time-consuming. In recent years the introduction of sonic ranging systems by Campbell Scientific has enabled automated recording of surface changes. However, the sensor requires a fixed mount which is usually drilled into the ice. Manageable stakes can only withstand about 4 m of ablation before they bend and break because of prevailing katabatic winds. Ablation stakes therefore require frequent redrilling.

Recently, new methods have been developed in remote sensing for assessing mass-balance variations of glaciers, ice caps and ice sheets (Thomas, 2001). Such observations from space, however, detect absolute elevation changes which are the combined signals of mass-balance and elevation change associated with ice flow. Consequently there is a need for in situ measurements of surface mass loss by ablation.

In recent years the Geological Survey of Denmark and Greenland (GEUS) has focused on developing a system for automatic ablation measurements, which fulfils the following requirements:

1. independence from stakes, so that the installation can withstand several ablation seasons without maintenance;
2. simple, cheap and easy to maintain;
3. automatic data collection;
4. installable by light helicopter operations;
5. minimal borehole diameter (25 mm).

This paper describes an automatic system that is suitable for measurements in large ablation areas such as at the outermost parts of the Greenland Ice Sheet, where access is difficult and expensive.

INSTRUMENT DESIGN AND TESTING

The system developed consists of a 14 mm diameter ventilated stainless-steel pressure transducer (Ørum & Jensen, type NT 1400) connected to a 12.8 mm diameter, fibre-reinforced PVC hose filled with a commercially available 93% vol. alcohol/water mixture. The upper end of the hose is connected to a soft 1-l polyethylene bladder. The bladder is composed of three layers of polyethylene to prevent the mixture from evaporating. The transducer and hose are lowered into a 25 mm diameter borehole and weighed down with a 1 kg iron rod. The polyethylene bladder lies on the glacier surface (Fig. 1). The pressure at the sensor is hydrostatic plus atmospheric pressure. However, the ventilated pressure sensor automatically compensates for atmospheric pressure. The small dimension of the transparent bladder (approximately 150 by 100 mm) prevents the formation of an ice pedestal or hollow beneath the bladder.

The system described above was tested during the 2001 ablation season in south Greenland. The system was installed with the transducer 17.70 m below the glacier surface. The signal cable was connected to a Campbell Scientific CR10X data logger, which also recorded data from an automatic weather station. After approximately 2 days of freeze-in, the system stabilized with consistent and reliable recordings. The data logger recorded all instruments, including the pressure transducer, once every hour. An SR50 Sonic Ranging device was installed to help evaluate the performance of the pressure sensor. However, after 42 days the stake-mounted sonic ranger tipped over and thereafter it produced unreliable values.

DISCUSSION OF RESULTS

The ablation measurements from the two sensors are compared in Figure 2. The comparison gives a correlation coefficient of 0.997 with a standard deviation of 0.027 m. At the end of the 42 day period, the SR50 recorded a total ablation of 1.82 m compared to 1.71 m from the pressure transducer.

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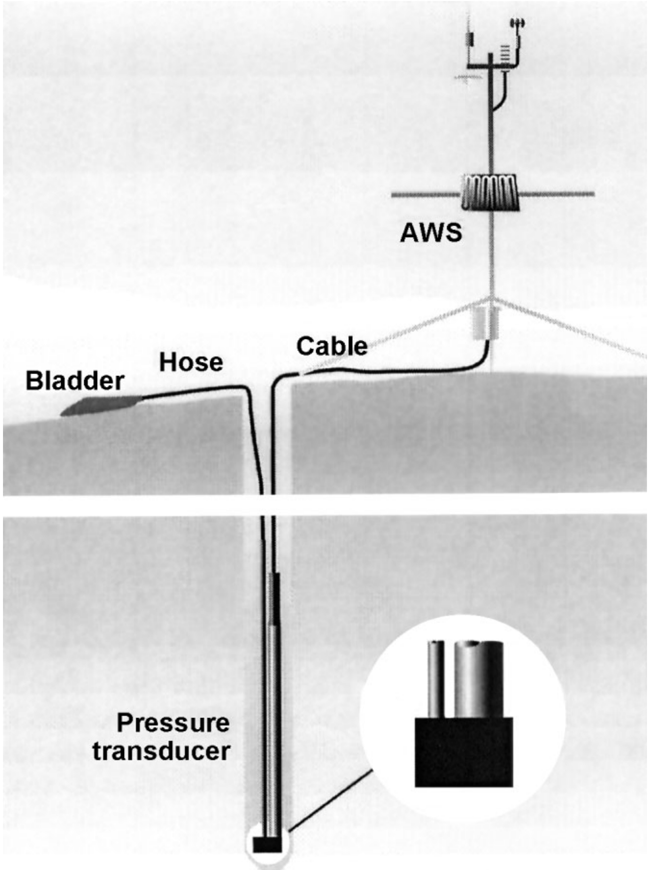

Fig. 1. Design and installation of the newly developed pressure transducer for automatic ablation observations.

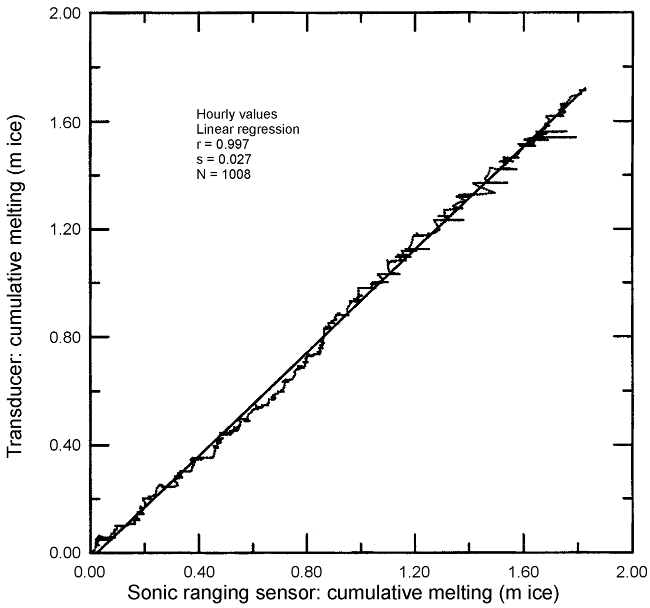

Fig. 2. The observed ablation using the pressure transducer plotted against SR50 observations.

This difference does not originate from alcohol with 80% of the mass of water. The 11 cm difference is comparable to those between manual measurements obtained between 1985 and 1987 by the former Geological Survey of Greenland (GGU; now GEUS) at a farm of five stakes located in a 10 m radius circle on an ice cap south of Kangerlussuaq (Olesen and Braithwaite, 1989). The largest difference between two of the stakes for a similar 42 day period was as much as 26 cm during part of one ablation season (GEUS, unpublished data).

A total error of ±3 and ±10 mm can be expected from specifications of the pressure sensor and the sonic ranger, respectively. This is well below the observed difference of 11 cm mentioned above. However, measurements from both Canada (Müller and Keeler, 1969) and North Greenland (Bøggild and others, 1996) show rapid spatial changes in microrelief and development of a weathering crust which enhance both the spatial and temporal variability in ablation. In extreme cases the short-distance spatial variability in ablation can be as much as 8.4 mm d^{-1} which is well beyond the specified ±3 mm tolerance of the pressure sensor. Our experience shows that, due to development of weathering crusts, stake measurements of ablation cannot be determined with greater accuracy than 30 mm which is equal to the daily ablation at many sites on the margin of the Greenland Ice Sheet.

The system also collected data during the accumulation season 2001/02, and these data show an increase in observed pressure due to snow accumulation. Fluctuations in the pressure measurements indicate that the system is not suited for determining snow accumulation.

The season of ablation measurements and the error analysis suggest that the surface lowering data from the pressure-sensor system are comparable to the results from the sonic ranging system. Given the simplicity and rugged design, we have confidence in the reliability of the system. The prospect of having an automatic ablation-monitoring system for long-term measurements, combined with a satellite link for data transmission, brings us much closer to being able to monitor ablation around the entire ice sheet.

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