Cold Regions Science and Technology 82 (2012) 30–35

Contents lists available at SciVerse ScienceDirect

Cold Regions Science and Technology

journal homepage: www.elsevier.com/locate/coldregions

Development of an automatic blowing-snow station

K. Nishimura [a,*], T. Ishimaru [b]

[a] Graduate School of Environmental Studies, Nagoya University, Furo-cho, Nagoya, Aichi, 464-8601, Japan
[b] Niigata Electric Co., Ltd., 3535-41, Sawada 1-chome, Nagaoka, Niigata, 940-1101, Japan

ARTICLE INFO

Article history:
Received 28 December 2011
Accepted 8 May 2012

Keywords:
Blowing snow
Antarctica
Snow particle counter (SPC)
Automatic blowing-snow station (ABS)

ABSTRACT

Blowing snow is a significant component of the mass and energy balance of the Antarctic ice sheet, and is an important factor when predicting the likely effects of global climate change. Nishimura and Nemoto (2005) carried out blowing snow observations at Mizuho Station, Antarctica in 2000 using Snow Particle Counters (SPCs) able to sense particle diameter as well as particle number. However, the SPC requires a large power supply and data are stored on computer. Deployment of an SPC is therefore not always practical for unmanned observations, particularly under the severe conditions in Antarctica. In this study, we developed a simpler device – the automatic blowing-snow station (ABS) – that measures the attenuation of light intensity, which is strongly influenced by the blowing snow flux. A small wind turbine and a cold-proof battery are used as the power source. We tested the performance of the ABS system in a cold wind-tunnel, in comparison with the SPC. We also undertook field testing of the ABS during the winter of 2009–2010 at Ishikari, Japan, which showed that the system performs well.

1. Introduction

On the Antarctic ice sheet, strong katabatic winds blow throughout the year, and although little studied, a large amount of snow is continuously mobilised and removed. This process constitutes a significant component of the mass and energy balance of the ice sheet, and requires novel methods of quantification to predict the likely effects of global climate change. Recent experimental work has revealed that snow drift sublimation can lead to significant mass losses during strong winds, which can be an important factor in the surface mass balance of the Antarctic ice sheets (Bintanja and Reijmer, 2001; Frezzotti et al., 2007; King et al., 2001).

Nishimura and Nemoto (2005) carried out blowing snow observations at Mizuho Station, Antarctica in 2000. A blowing snow observation system, including four snow particle counters (SPCs), was established on a 30-m tower, measuring both particle number and diameter. SPC was originally developed by Schmidt (1977) and was improved by Kimura et al. (1993) by using a laser diode with collimator (SPC-S7, Niigata Denki Co.). Particles that pass through the sampling area ($2 \times 25 \times 0.5$ mm) are divided into 32 classes depending on their diameter (50–500 μm). Spinning wires of different diameters are used in the sensor calibration (Sato et al., 1993). The SPCs operated successfully and the data revealed the profiles of mass flux and particle size distributions as a function of the friction velocity (an index of wind speed). However, SPCs require a large power supply and data collected by the devices are stored electronically on a computer; consequently, it is not always possible to deploy SPCs for automatic data collection (i.e., at unmanned stations), especially under the harsh conditions of Antarctica. Acoustic sensors such as Flowcapt also operated successfully in Antarctica (Scarchilli et al., 2010), but the accuracy of the data obtained is still questionable (Cierco et al., 2007).

We have developed the automatic blowing-snow station (ABS), which is a simpler device than the SPC. The ABS measures the attenuation of light intensity as a function of the presence of blowing snow particles, and is powered by a small wind turbine and cold-proof battery. Here, we first outline the ABS system itself, and then describe some preliminary operational tests performed under both controlled and field conditions.

2. Specifications of the ABS system

Fig. 1 shows a photograph and a schematic representation of the ABS sensor. The device is roughly 150×100 mm^2 in size, which is slightly smaller than an SPC (175×211 mm^2). The sensor consists of a light source that emits a red light beam of 640 nm wavelength, and a receiver with a sensitive volume of $102 \times 7 \times 3$ mm^3.

Fig. 2 shows a block diagram of the ABS system. The system can be divided into two main components: the sensors and the data processing system. The ABS sensor (Fig. 1), wind generator, and an anemometer are positioned outside (Fig. 3). The light signal from the source to the receiver of the sensor is transmitted to the data processing system via an optical fibre. Then, by way of several convertors, integrators, and the central processing unit (CPU), the flux of blowing snow is estimated and data are stored on a compact flash (CF) memory card along with GPS data.

* Corresponding author. Tel./fax: +81 52 7893480.
E-mail address: knishi@nagoya-u.jp (K. Nishimura).

0165-232X/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.coldregions.2012.05.005

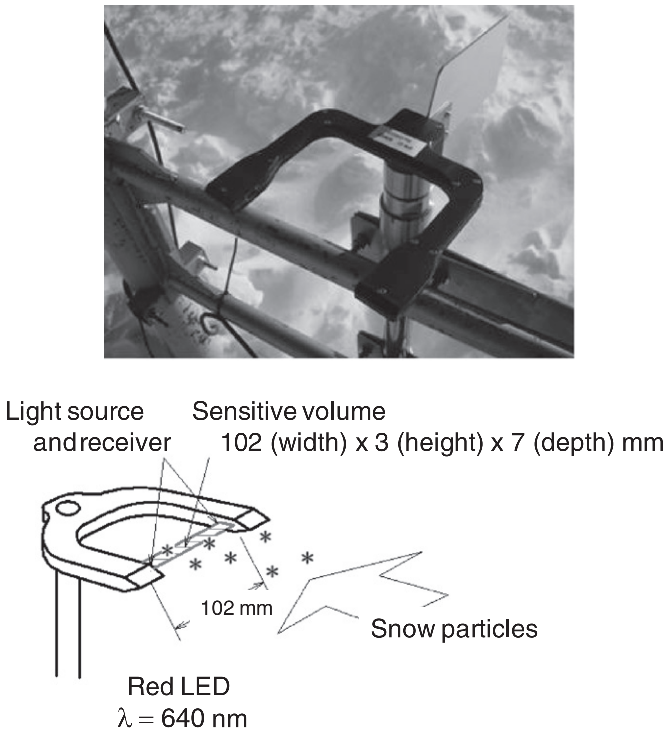

Fig. 1. Photograph and schematic view of the automatic blowing-snow station (ABS).

Fig. 4 shows the output schematic when blowing snow particles pass through the sampling area, and the sensor output changes according to the variation in light intensity. Output is then integrated for each 1-s interval (Fig. 4), and stored on the memory card. Although the processing system (including the cold-proof battery of Hawker Energy Cyclon G26EPX) is positioned in an insulating box beneath the snow surface, performance of the set-up can be checked remotely via wireless LAN.

3. Wind-tunnel calibration

The SPC is able to detect both snow particle number and size distributions. Thus, mass flux can be obtained directly. The ABS measures the attenuation of light intensity due to the passage of blowing snow particles; ABS output must be converted to determine snow particle mass flux. To do this, the performance of the ABS was first tested and calibrated with the SPC in a cold wind-tunnel at the Cryospheric Environmental Simulator (CES) in Shinjo, Japan. The test section of the wind-tunnel was 14 m long, 1 m wide, and 1 m high. The temperature was kept at constant −15 °C. In order to initiate and maintain steady saltation, seed particles were supplied from the bottom of the wind-tunnel entrance at a constant rate. Further details of the wind-tunnel are described in Sato et al. (2001). The ABS and SPC were set at a same height of 0.08 m in the wind-tunnel (Fig. 5), and measurements were taken under varying conditions of wind speed from 7 to 20 ms^{-1} at the centre of wind tunnel and supply rate of seed particles from 0.02 to 0.2 $\mathrm{kg\,m}^{-2}\,\mathrm{s}^{-1}$.

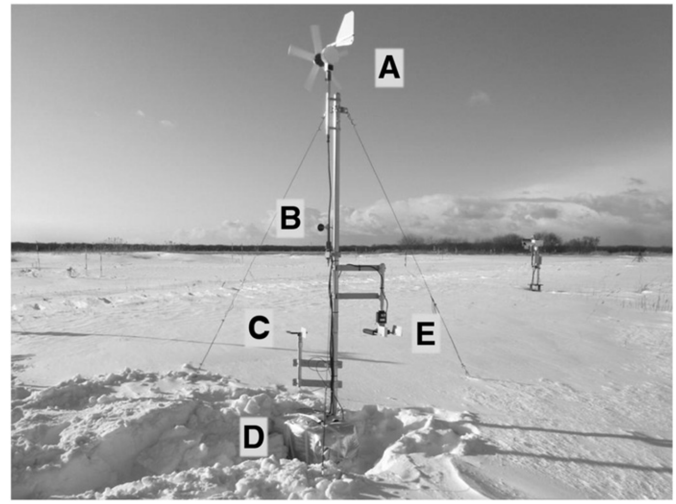

Fig. 3. Photograph of the ABS and SPC set-up at the Ishikari Blizzard Experimental Station. A: wind generator, B: anemometer, C: ABS sensor, D: ABS data processing system (the container is set under the snow), E: SPC sensor.

Fig. 6 shows the relationship obtained between the ABS output and the mass flux measured using the SPC. A strong linear correlation was obtained, as follows:

$$F = 1.146 \times 10^{-5} V + 1.38 \times 10^{-3} \quad (R = 0.995, \quad P < 0.0001) \qquad (1)$$

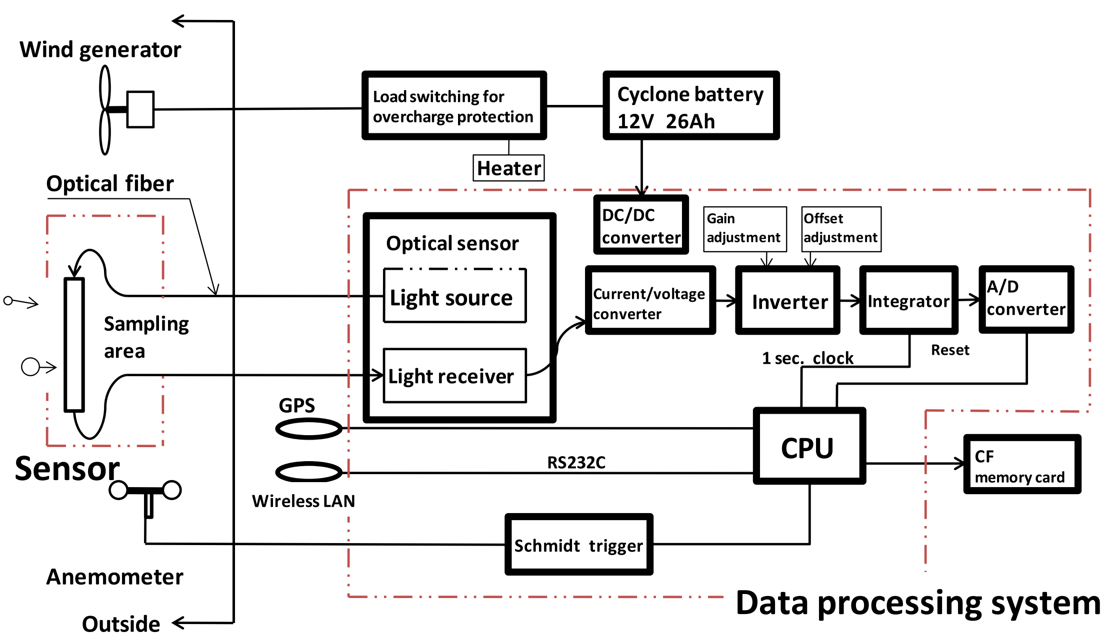

Fig. 2. Block diagram of the automatic blowing-snow station (ABS).