Cold Regions Science and Technology 106–107 (2014) 11–21

Contents lists available at ScienceDirect

Cold Regions Science and Technology

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

Detection of snowfall occurrence during blowing snow events using photoelectric sensors

Florence Naaim-Bouvet [a,b,*], Hervé Bellot [a,b], Kouichi Nishimura [c], Christophe Genthon [d], Cyril Palerme [d], Gilbert Guyomarc'h [e], Vincent Vionnet [e]

[a] Irstea, UR ETNA, F-38402 St-Martin-d'Hères, France
[b] Univ. Grenoble Alpes, F-38041 Grenoble, France
[c] University of Nagoya, Japan
[d] LGGE, UJF/CNRS, Saint Martin d'Hères, France
[e] Météo France/CNRS, CNRM-GAME URA 1357, France

ARTICLE INFO

Article history:
Received 23 November 2012
Accepted 24 May 2014
Available online 6 June 2014

Keywords:
Blowing snow
Drifting snow
Snowfall
Precipitation
Sensor
Alps

ABSTRACT

There is a strong need to identify blowing snow events with and without concurrent falling snow and to estimate solid precipitation amounts in mountainous areas and polar regions. For these purposes, we first developed a method using the concomitant analysis of an anemometer and a drifting snow sensors (SPC-S7 and Wenglor/YH03PCT8-YH08PCT8). Photoelectric sensors, such as the SPC-S7 (Snow Particle Counter), specially designed for studying drifting snow, or a simpler photoelectric counter manufactured by Wenglor, were chosen because they had already been tested in previous studies for measuring solid precipitation. They were set up at Lac Blanc Pass, an experimental site dedicated to the study of drifting snow in the French Alps. The data set obtained was compared with the independent database of blowing snow events with or without falling snow collected at the same experimental site, i.e. data on the precipitation amount stemming from heated precipitation gauge and SAFRAN modeling output. The analysis of snow flux and mean diameter according to wind speed allowed us to separate blowing snow events with and without precipitation for moderate wind speed. To reduce the uncertainty at high wind speed, the SPC-S7 must be set up at least 4 m above the snow surface. Similar preliminary results were obtained with the simpler Wenglor photoelectric counter, despite the minimum observable diameter being 200 μm and the particle size distribution unavailable. These results must be confirmed by further experiments. The SPC-S7- estimated precipitation amount is in relatively good agreement with modeled precipitation given the many uncertainties due to the calculation hypotheses. Since the particle size distribution is not available for the simpler photoelectric counter and there are too many uncertainties and hypotheses in calculating solid precipitation, we concluded that the solid precipitation amount cannot be reliably estimated by the simple photoelectric counter.
© 2014 Elsevier B.V. All rights reserved.

1. Introduction

In mountainous areas, drifting snow influences the spatial distribution of the snow cover at the local scale and consequently snowpack stability and avalanche danger. When comparing models with in-situ measurements, it is first necessary to identify blowing snow events with and without concurrent falling snow and to estimate the amount of solid precipitation. In Antarctica, in coastal areas where katabatic winds are strong and frequent, it is difficult to separate blowing snow and precipitation. However, it is important to characterize both variables because of their impact on the mass balance of the ice sheet (positive for precipitation and negative for blowing snow) (Bromwich, 1988; Gallée et al., 2013).

In mountainous areas as well as polar regions, falling snow may be rapidly redistributed by wind (Lehning et al., 2008). In such conditions, not only accurate measurement of the precipitation amount, but also detection of precipitation is a challenge. The blowing snow billow can be very high, up to several hundred meters (Scarchilli et al., 2010). Consequently, the measured precipitation amount suffers from substantial uncertainty whatever the precipitation gauge's position.

During the WMO (World Meteorological Organization) Solid Precipitation Measurement Intercomparison Project (Goodison et al., 1998), automatic precipitation gauges, including weighing and tipping bucket types, were tested at several evaluation stations and compared with the Double Fence Intercomparison Reference (DFIR). The intercomparison confirms that the precipitation measurements must be adjusted for wetting loss, evaporation loss and for wind-induced undercatch before the actual precipitation at the ground level can be estimated. Wind is the most important environmental factor contributing to the systematic underestimation of the solid precipitation amount; the amount of

* Corresponding author at: Irstea, UR ETNA, F-38402 St-Martin-d'Hères, France.
E-mail address: florence.naaim@irstea.fr (F. Naaim-Bouvet).

http://dx.doi.org/10.1016/j.coldregions.2014.05.005
0165-232X/© 2014 Elsevier B.V. All rights reserved.

underestimation depends on the terminal fall velocity of the particles and the aerodynamic properties of the gauges. At 6 ms^{-1} catch efficiency can vary from −20% to −70% depending on the gauges and field configurations (Goodison et al., 1998). It is also recognized that blowing snow during a period or part of the precipitation event will affect the actual precipitation measurements, and therefore further investigation is required. Even with the DFIR, some bias could appear: One of the disadvantages of effective wind shielding is the reduction of wind speed around the precipitation gauge potentially causing blowing snow to be mistakenly measured as precipitation (Rasmussen et al., 2012). Golubev and Simonenko (1992) investigated the account of false precipitation due to drifting snow in the WMO Solid Precipitation Measurement Intercomparison final report (Goodison et al., 1998) and concluded that wind speed higher than 4.2 ms^{-1} can result in false precipitation. Later, during a precipitation gauge intercomparison experiment under Arctic conditions (Barrow, Alaska), Sugiura et al. (2003) showed that nearly four million snow particles per second per square meter could reach a higher point near the bucket orifice height during the WMO comparison.

Nonintrusive sensors with optical or small radar devices are being evaluated, but have not been successfully calibrated for the measurement of winter precipitation at this time. Optical disdrometers were used in several studies (Bellot et al., 2011; Leonard et al., 2008). Most of them, such as the Biral VPF730 and the Campbell Present Weather Sensor 100 (PWS100), detect the size distribution and the number of particles. With this information, the precipitation rate was calculated. But at the present time and without any additional treatment, they are unable to distinguish between falling and blowing snow (Bellot et al., 2011).

Radars were also used to measure snowfall (Collier and Larke, 1978; Sheppard and Joe, 2008) using a Z–R relationship, where Z is the radar reflectivity factor and R the precipitation rate. An advantage of radar is that the sampling volume is less disturbed by the instrument compared to optical disdrometers (Nešpor et al., 2000). Recently, a sensor called a hotplate precipitation gauge has been developed (Rasmussen et al., 2010). It consists of two thermally isolated, independent heated plates, one facing upward and the other downward. Precipitation rate is estimated by calculating the power required to either melt or evaporate snow or to evaporate rain on the upward-facing plate, compensated for wind effects by subtracting out the power on the lower, downward-facing plate. However, as far as we know, the influence of blowing snow, which can hit the lower plate as well as the upper one, was not evaluated for these sensors. Consequently, detection of snowfall and evaluation of solid precipitation when wind blows remains an open question.

Our objective is therefore to discriminate between blowing snow events with and without concurrent falling snow. Contrary to snowfall, snow transport is driven by wind. There is a strong relation between wind speed and drifting snow characteristics. The hypothesis tested in this study is the following: combining the anemometer and the drifting snow sensor, one can distinguish between precipitation and blowing snow events and can evaluate solid precipitation amount.

This paper is organized as follows. Section 2 introduces the two optical drifting snow sensors, the Snow Particle Sensor SPC-S7 and the Wenglor sensors (YH03PCT8 and YH08PCT8), that have already been tested for measuring precipitation. The methodology used to test the hypothesis is presented in Section 3. The signature of precipitation and blowing snow events with regard to size distribution and snow flux as a function of wind speed are identified. The estimation of "true" precipitation, which is a key parameter in our analysis, by SAFRAN modeling is introduced. Then the Col du Lac Blanc site, where optical drifting snow sensors and anemometers have been set up, is described in detail. Finally the ability of the sensors to identify and quantify the solid precipitation amount is evaluated and discussed in Section 4.

2. Blowing snow sensors and snowfall estimation

In previous studies (Leonard and Cullather, 2008; Sugiura et al., 2009) two sensors, dedicated or used for measuring drifting snow mass flux, were tested for measuring precipitation. They are both photoelectric sensors.

2.1. Snow Particle Counter SPC-S7

The Snow Particle Counter (SPC-S7, Niigata Electric) (Fig. 1a) is an optical device (Nishimura and Nemoto, 2005). The diameter and the number of blowing snow particles are detected by their shadows on photodiode. Electric pulse signals of snow particles passing through a sampling volume (2 mm × 25 mm × 0.5 mm) are sent to an analyzing logger. In this way the Snow Particle Counter detects particles between 40 and 500 μm in mean diameter. It divides them into 32 classes and records the particle number every 1 s. The SPC-S7 has a self-steering wind vane. The sampling area, perpendicular to horizontal wind vector is 50 mm^2 (2 mm × 25 mm) (Fig. 1b). If the diameter of a snow particle is larger than the maximum diameter class, the snow particle is considered to belong to the maximum diameter class. Assuming spherical snow particles, the horizontal snow mass flux q_h is calculated as follows:

$$q_h = \sum_{d=1}^{32} q_{hD} = \frac{\sum_{d=1}^{32} n_d S_d \frac{4}{3}\pi\left(\frac{D_d}{2}\right)^3 \rho_p}{S*t} \quad (1)$$

where q_{hD} is the horizontal snow mass flux [kgm^{-2} s^{-1}] for the diameter D [m], n_d is the number of drifting snow particles of the d-th class [m^{-2} s^{-1}], S the sample area [m^2], t the sample period [s], S_d is the shape factor of snow particles of the d-th class, which is the ratio of a spherical cubic volume to the snow particle cubic volume, and ρ_p the density of the drifting snow particles [kgm^{-3}]. S_d is usually assumed to be 1. Usually, the snow particles blow as individual grains, not

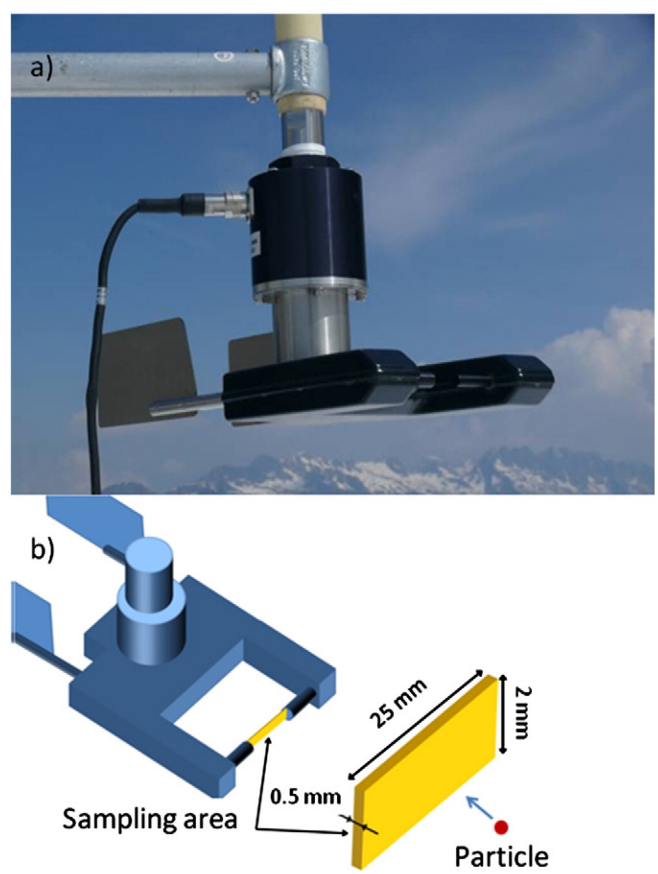

Fig. 1. a) Snow particle counter (SPC-S7) set up at Lac Blanc Pass (H. Bellot/Irstea). b) Schematic diagram of SPC-S7.

Download English Version:

https://daneshyari.com/en/article/6426864

Download Persian Version:

https://daneshyari.com/article/6426864

Daneshyari.com