MEASUREMENT OF SPECIFIC SURFACE AREA OF FALLING SNOW

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ABSTRACT: Precipitation particles (PP) sometimes form a weak layer in snow cover that may subsequently trigger slab avalanches. The potential for PP to form these weak layers is strongly dependent on the PP riming ratio. The degree of PP riming is therefore a key factor in designing a predictive model for slab avalanches that are triggered by weak PP layers. However, it is difficult to quantify the PP riming ratio because rimed droplets are too small and numerous for objective measurements. The specific surface area (SSA) is a parameter that could potentially characterize the degree of PP riming. However, the influence of riming on SSA has received little attention to date. Here, the SSAs of PP were measured during four winters (2013/2014, 2014/2015, 2015/2016, 2016/2017). The observations were recorded at the Snow and Ice Research Center, National Research Institute for Earth Science and Disaster Resilience, in Nagaoka, one of the areas that receives the heaviest snowfall in Japan, located on the Japan sea coast of Honshu Island. More than 100 SSAs of PP were measured during the study period using the gas absorption method. The measured SSA values ranged from 40 to 140 m² kg⁻¹. Lower SSAs were observed during unrimed and slightly rimed PP conditions, whereas higher SSAs were observed during heavily rimed PP and graupel conditions. These results indicate that SSA is a useful parameter for the prediction of avalanches triggered by a weak PP layer.

KEYWORDS: precipitation particles, specific surface area, the degree of riming, surface avalanche

1. INTRODUCTION

The specific surface area (SSA) of snow is defined as its surface area per unit mass or volume, and includes information relating to the grain size and shape of the snow crystals. It is a key parameter in understanding the exchange of matter and energy between a snow-covered surface and the atmosphere, and in modeling the mass transfer of air or water in snow cover. Temporal variations in the SSA of snow cover are therefore important to accurately simulate physical properties of snow.

Precipitation particles (PP), such as, snow, graupel, and hail, sometimes form a weak layer in the snowpack that may trigger slab avalanches. The development of weak PP layers is strongly dependent on the degree of PP riming (Lachapelle, 1967). Construction on the degree of PP riming is therefore a key factor in designing a predictive model for slab avalanches triggered by weak PP layers. Several studies (Shidei, 1953, Nakamura et al., 2014) have reported that snow cover consisting of unrimed snow crystals was quite fragile and triggered snow avalanches, even when this weak PP layers was shallow in the snowpack. These results indicated the potential to constrain certain avalanche characteristics that have been linked to the weak PP layer. However, the dependence of these avalanche characteristics on PP, which form a necessary in forecasting the potential of a weak PP layer to trigger an avalanche, is still controversial.

We therefore conducted SSA measurements of fallen PP over short intervals in a heavy snowfall area of Japan, and compared our measurements to meteorological data. Here, we introduce a preliminary analysis of these SSA measurements.

2. OBSERVATION SITE

The SSA observations were conducted over four winter seasons, from 2013/2014 to 2016/2017, at the Snow and Ice Research Center (SIRC), National Research Institute for Earth Science and Disaster Resilience (NIED), in Nagaoka, Japan (37°25’N; 138°53’E; 97 m a.s.l.).

The Falling Snow Observatory (FSO) at SIRC has a cold room (-5 °C) with a 1.2 × 0.6 m roof opening (Ishizaka et al., 2013; 2016). This setup allows falling to accumulate snow on a flat table in the cold room under windless conditions. PP photograph are automatically taken in the cold

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room using a belt conveyor system during the winter season. SIRC also acquires basic meteorological measurements (air temperature, relative humidity, wind speed and wind direction, precipitation, incoming and outgoing shortwave/longwave radiations, surface temperature, air pressure, snow height, and snow water equivalent) at various time resolutions (1 min., 10 min., and 1 h) in the field (Yamaguchi et al., 2018).

3. SSA MEASUREMENT OF PP

Here, we use the methane gas adsorption method (Domine et al., 2001; 2007, Legagneux et al., 2002) to obtain the SSA measurement of PP. The principles of the methane gas adsorption method have been described in detail by Legagneux et al. (2002). The samples in this study consisted of freshly PP that was deposited on the table in the cold room of the FSO within 1 - 2 h of sample collection. Since our device required a 30 mL sample for each measurement, we sometimes gathered freshly PP deposited on the table in the cold room using a broom, and we put them to the sample case with insufficient deposited height to take a sample directly during measurement interval. Other cases, we directly took the samples from the deposited snow on the table during the measurement interval. Microphotographs of the sample were also taken to determine the crystal types. The measured SSAs in this study were calculated by dividing the measured surface area of the sample by its mass, with the SSA measurements given in m² kg⁻¹.

4. RESULTS AND DISCUSSION

We collected 102 SSA measurements from the samples acquired during four winter seasons (2013/2014 - 2016/2017). The averaged heat of adsorption for the 102 measurements was 2472 ± 199 J mol⁻¹, which was similar to the value of 2540 ± 200 J mol⁻¹ reported by Domine et al. (2007). We therefore considered our measurement results reasonable.

Figure 1 shows the measured SSA values, with the data sorted in ascending order. The wet-bulb temperature (Tw) is also plotted, which is calculated based on the “forward” analytical psychrometric equations (Bohren and Albrecht, 1998) that employ an iterative approach using air temperature, relative humidity and air pressure. We consider Tw a good indicator of whether a sample is affected by melting or not. The “no melt” case occurs when Tw < 0 °C, whereas the “melt” case of melt occurs when Tw ≥ 0 °C.

Large fluctuations in the measured SSA values were obtained, indicative of the freshly PP SSA, with values that usually fluctuated by more than three-fold during the winter season in Nagakoka. Most data that were obtained when Tw ≥ 0 °C hold low SSA values, suggesting that those data were affected by the melt effect. However, some data that were obtained when Tw < 0 °C also yielded low SSA values, even though they did not undergo a melt effect. These results indicate that freshly PP can have smaller SSA values without experiencing a melt effect, such that we

![Fig. 1 Measured SSAs and their associated wet-bulb temperature during four-winter sample period](image-url)

The light-blue bars are the measured SSAs, arranged in ascending order, and the red line represents the corresponding wet-bulb temperature.

The letters (A - D) at the bottom of the figure identify the samples that are illustrated in Fig. 2.
need to consider other factors that control the SSA of PP.

Figure 2 shows the microphotographs of measured samples with different SSA values when Tw < 0 °C. The sample in Fig. 2A consists of unrimed crystals with a small SSA value (46 m² kg⁻¹). The sample in Fig. 2B consists of slightly rimed crystals with also small SSA value (74 m² kg⁻¹), but is larger than that of the unrimed crystal (Fig. 2A). The sample in Fig. 2C consists of heavily rimed crystals with a large SSA value (107 m² kg⁻¹). The sample in Fig. 2D consists of graupels and possesses the largest SSA value (129 m² kg⁻¹) of the four samples. These results indicate that the SSA of PP may be correlated to the degree of riming, with the SSA increasing as the riming level increases. We therefore consider the SSA of PP a good indicator of its riming condition.

5. SUMMARY

We conducted 102 SSA measurements of freshly PP deposited over short period intervals during four winter seasons. These data indicated that the SSAs of PP exhibit a large degree of fluctuation, range from 40 to 140 m² kg⁻¹. We found that unrimed and slightly rimed PP have small SSAs, while heavily rimed PP and graupel have large SSAs. These results indicate that SSA is a useful parameter for describing PP characteristics, such as the degree of riming, which can then be used to improve predictive models for slab avalanches.

ACKNOWLEDGEMENT

This study was supported by JSPS KAKENHI, Grant Numbers JP17K18453, and JP16K01340.

REFERENCE


