Supplement of The Cryosphere, 18, 3017–3031, 2024
https://doi.org/10.5194/tc-18-3017-2024-supplement

The Cryosphere

Supplement of

Assessing the key concerns in snow storage: a case study for China

Xing Wang et al.

Correspondence to: Feiteng Wang (wangfeiteng@lzb.ac.cn)

Snow pile geometry data

Complete and accurate spatial information is indispensable for both volume calculation and variation study of the snow pile. Traditional measurement methods have some inherent shortcomings for the irregularly shaped snow pile. We therefore used a laser technique in the snow storage events, which is widely applied in other fields. The repeated snow pile geometry data was obtained with a *Riegl* VZ®-6000 Class 3B terrestrial laser scanner (TLS). This TLS emits a near-infrared laser beam and receives a reflected laser beam to measure the object distance based on the time-of-flight distance measurement method with a much longer effective measurement range and reduced spurious point noise. The point clouds of the interesting region were produced by rotating a lightweight mirror (vertical scan) and a head (horizontal scan). The TLS can reach a 15 mm accuracy and a 10 mm precision.

We collected four temporal terrestrial laser scanning data at the Big Air Shougang on 16 January (TLS1), 18 February (TLS2), 9 March (TLS3), and 15 April (TLS4) 2022, respectively. A scan station on the roof 21 m above the snow pile was chosen to capture the point clouds and avoid data gaps at the top surface of the snow pile. At the National Biathlon Center, one terrestrial laser scanning survey was performed on 20 January 2022, and no additional data was available for the following time. A scan station 11 m above the snow pile was erected on the para track for the same purpose as the roof scan station. Multiple scans (more than five) are essential for each survey to deal with obstacles, obtain complete point clouds, and increase point density in different orientations. The point clouds of snow piles from adjacent scan stations must be partially overlapped to facilitate subsequent registration in a software.

In each survey, at least six temporary ground control points (GCPs) were set up for accurate spatial information on point clouds. The ground control points were less than 15 m away from scan stations. We determined the GCPs locations with a differential global position system (dGPS) (Trimble R10). The 3-D coordinates were acquired in a UTM 50N coordinate system at the two snow storage sites. The TLS scanned reflectors to identify the point clouds of GCPs, which color are red in a reflectance mode. The laser pulse repetition rate was 300 kHz with a 3300 m max-measurement range. The angular measurement resolution was first set to 0.04° to obtain a horizontally centered 0–360°

view on the scan station. Then, a fine scan began by manually selecting a field that contained the snow pile. The fine scan applied a 0.01° angular resolution to capture sharp details on snow pile geometry information but was more time consuming. The scan parameters mentioned above are identical in the Big Air Shougang and the National Biathlon Center. Due to the long scanning time caused by the high angular resolution, some scans were executed at night to obtain the complete point clouds of the snow piles in time. Additionally, all scans were executed under suitable meteorological conditions.

Snow pile thermal data

We set up a series of sensors to continuously monitor the thermal conditions of snow piles. The temperature of the internal snow pile is affected by external conditions. However, with increasing depth, the temperature changes tend to be stable. It is noted that the internal temperature gradient has a significant effect on vapor migration and crystal growth in the snow layer. Thus, a temperature chain consisting of ten high sensitivity thermistor sensors at a 0.25 m interval was applied. On 16 January 2022, we used an ice core drilling to drill three holes on the top surface of the snow pile at the Big Air Shougang, two of which were put into the temperature chain. The top sensor was 0.2 m below the snow surface, i.e., the temperature data at 0.2 m, 0.45 m, 0.7 m, 0.95 m, 1.2 m, 1.45 m, 1.7 m, 1.95 m, 2.2 m, and 2.45 m depths were recorded. The Neumann and/or Dirichlet conditions for the entire snow pile and snow pile excluding the cover were monitored. A small cylindrical thermistor sensor Pt100 (height: 30 mm, diameter: 4 mm) was inserted at the top snow-geotextile interface to reflect the snow surface temperature with the cover protection. Moreover, Neumann conditions at the top snow-geotextile interface were obtained by a thin self-calibrating foil heat flux sensor FHF02SC. Additionally, we determined the external geotextile surface temperatures of two long snow pile sides using the infrared radiometer sensors SI–111–SS, which can avoid the influence of solar radiation and the gap on the traditional contact type sensor. Based on the above data, it is possible to analyze the thermal conditions of the entire snow pile and can be used for model suitability analysis. The data logger recorded snow pile thermal data at a 60–minute resolution.

The monitor system and sensor types of the National Biathlon Center are the same as the Big Air Shougang. On 18 January 2022, A hole in the top surface was put into the temperature chain. Unlike the Big Air Shougang, the short and long sides of the snow pile, opposite sides of the tracks, were the targets for the infrared radiometer sensors. In addition, the top sensor on the temperature chains was 0.25 m below the snow surface.

Snow density data

Snow density is an essential parameter for the snow pile, in which the intrinsic permeability, thermal conductivity, diffusivity, and strength vary sharply with density. In January 2022, the snow density was measured 3 m below the top surface using an ice core drilling with extension rods at the Big Air Shougang and the National Biathlon Center. The drilling produced non-fractured snow cores with a length of about 1 m and an inner diameter of 0.074 m. An electronic scale weighted the total drilling and a snow core to calculate the snow density. We believe these heavy snow cores are less affected by operations to obtain accurate snow densities. On 16 January, three groups of snow cores were extracted from the top surface of the snow pile and then put into the temperature chains at the Big Air Shougang. Similarly, we collected a group of snow cores and put the temperature chain into a hole at the National Biathlon Center on 18 January. Beyond that, no density data is available for the Big Air Shougang and the National Biathlon Center.

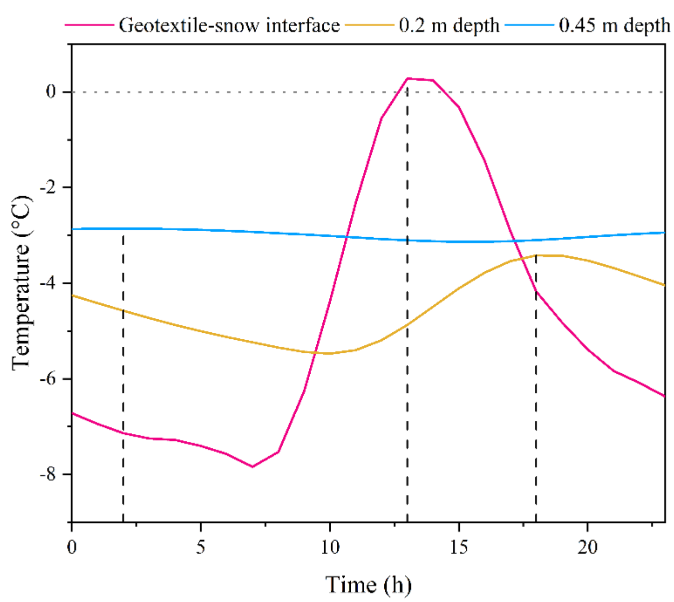

Figure S1: Mean hourly measured temperature at the top geotextile snow interface and different depths in the BAS snow pile from TLS1 to TLS2 (The vertical dashed line represents the maximum temperature).

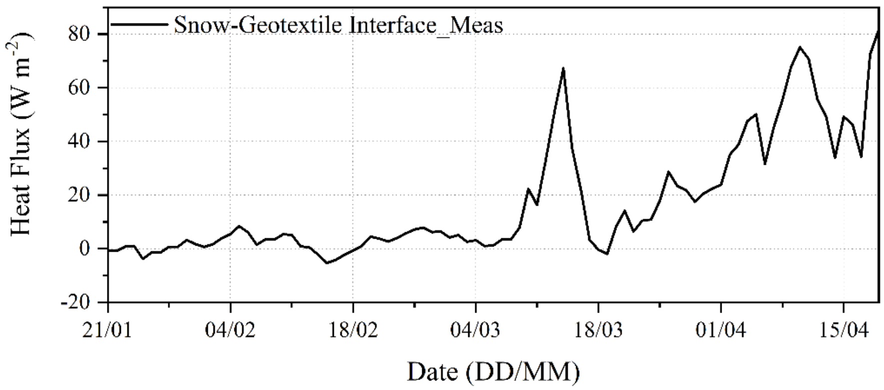

Figure S2: The top geotextile snow-interface heat flux at the Big Air Shougang.

Figure S3: Difference on the southwest side of the snow pile between covered and uncovered on 7 February 2022 at the Big Air Shougang.