Effects of topographic relief on the snow depth distribution in a mountainous slope

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1. Introduction

It is well known that the snow depth is influenced by elevation, gradient and aspect of the slope. In addition, we know empirically that snow depth is associated with topographic relief, that is, it is shallow on ridges and deep in valleys. However, there are few quantitative studies on this relationship. In the present study, we calculated some indexes to describe the topographic relief and compared them with conventional indexes from surface profile data measured by an airborne laser scanner, and evaluated their relationship to snow depth distribution.

2. Analysis methods

The study area was a slope in the Gamahara-zawa watershed located on the prefectural boundary between Niigata Pref. and Nagano Pref. (latitude 36.9 north and longitude 137.9 east). We measured the surface profile of snow cover on Feb. 26, 2003, and of the ground on Nov. 23, 2004 by airborne laser scanner, and calculated the snow depth distribution by the vertical difference between them. Initially, we analyzed the relationships between the elevation and snow depth for the entire area (10.2 sq. km). The relationship between them was too strong to make other topographic relations indistinct.

To solve this problem, we extracted two small sections (0.36 sq. km = 0.6 x 0.6 km) which express the typical topographic characters of the whole area. One of them is located in the downstream area, and has steep slopes with many erosional valleys (Section A), and the other is located in the upstream area, and has gentle slopes such as lava plateaus (Section B). We divided each section into 14400 cells with 5 m meshes, and calculated five indexes as (a) elevation, (b) aspect, (c) gradient, (d) local shelter (LSHEL), and (e) local relief (LRLF) for each cell (Lapen and Martz, 1996).

Indexes (a) to (c) are conventional indexes, and indexes (d) and (e) describe the topographic relief. Here, index (d) local shelter (LSHEL (%)) indicates the ratio to be judged as the shelter in 24 cells around the objective cell. (e) Local relief (LRLF (m)) indicates the differences in height between the object cell and the 24 cells around it.

3. Results and Discussion

The whole area analysis showed that snow depth kept increasing as the elevation increased until around 1200 m ASL, above which it decreased. One possible reason why the snow depth decreased over 1200 m ASL may have been that the strong winds prevented the snow from accumulating on the ground in the high elevation area with the gentle slopes.

In the two small areas (sections A and B), elevation had different effects. As the elevation increased, the snow depth increased in section A, and decreased in section B. These opposite phenomena derived from the difference in the slope composition, as mentioned above. The snow depth was higher on the north-facing slopes and lower on the south-facing slopes. This aspect was somewhat stronger in section A than section B. The snow depth increased precipitously on the slopes with an inclination of more than 45 degrees in both A and B. These conventional indexes agreed with previous results.

The snow depth increased as the local shelter (LSHEL) increased, particularly when LSHEL exceeded 40 % in section A; in other words, the snow depth increased dramatically when the cell was surrounded by topographic obstacles exceeding a fixed value on a steep slope. The snow depth increased as the local relief (LRLF) increased. In section B, it increased rapidly when LRLF exceeded 2 m, which meant the snow depth increased dramatically when the cell had formed a certain level of depression terrain on a gentle slope.

References

Lapen, D., R. and Martz, L., W. (1996): An investigation of the spatial association between snow depth and topography in a Prairie agricultural landscape using digital terrain analysis, Journal of Hydrology, 184, 277-298.