Development of a high-resolution prediction model for spatio-temporal dynamics of snowmelt using time-lapse camera images at west side of Mt. Tateyama

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The vulnerability of alpine ecosystems to climate change was pointed out (IPCC, 2007). The Japanese alpine zone is characterized by extreme snowfall, and snowmelt time is a key factor in the growth of alpine ecosystems. Habitats of alpine plants have high diversity within small areas reflecting complex snow cover distribution due to the complex topography and various environmental conditions. It is required to predict snowmelt timing at high-resolution (i.e. plant community level) for understanding the alpine ecosystems. However, meteorological observations are difficult to perform in alpine zones, in addition, the spatial resolutions of current regional climate models are at most 2km. Therefore, in 2011, the National Institute for Environmental Studies (NIES), Japan, launched long-term monitoring of snowmelt time and ecosystems in the Japanese alpine zone using automated digital time-lapse cameras. Twenty-nine monitoring sites are currently in operation. The objectives of this study were to construct models to predict spatial and temporal dynamics of snowmelt at fine resolution based on image analysis of the time-lapse cameras.

The study area was the west side of Mt. Tateyama range in the Japanese Northern Alps (at c.a. 2400-3000m a.s.l., c.a. 1.8km square). The area was captured within the images of time-lapse camera installed at Tateyama-Murodou-Sansou Mountain Lodge (Toyama Prefecture). We used about two thousand images which were taken by the camera with 21 million pixels in jpeg format every hour during daytime in May to August in year 2015-2017.
First, red, green, and blue (RGB) digital numbers were derived from each pixel within the images automatically, and based on the intensity of the grayscales, snow-cover and snow-free pixels are classified into binary images using a statistical discriminate analysis. Next, pixel-wise snowmelt dates were determined with timeseries of the binary images and demonstrated as snowmelt maps. Then the snowmelt maps were transformed to orthophotos, by being projected on the digital elevation map (DEM) with 5m mesh.

Snow cover distributions showed almost the same spatial pattern among years depending on the local microtopographic characteristics due to strong westerly monsoon. While, the speed of snowmelt differs from year to year depending on yearly meteorological conditions. Therefore, the spatial distribution of snow cover was analyzed statistically in relation to microtopographic parameters, and the snowmelt speed was analyzed using in-situ meteorological parameters, respectively.
As results, spatial distribution of snow cover was well predicted using Random Forest regression with microtopographic parameters such as tilt angle and curvature at various scales of averaged elevation. In addition, snowmelt speed was well regressed with the sum of daily temperature (degree days method) and yearly snow depth (by Univ. of Toyama) using multiple-regression analysis. By these integrated statistical models, daily snow cover distribution at west side of Mt. Tateyama was predicted at 5m-resolution with high accuracy, which was validated by comparison with high-resolution satellite images.

The model enables to predict the spatio-temporal dynamics of snowmelt in alpine zone at high precision by only given snow depth and daily mean temperature data. Although prediction was not performed for

the shaded areas of camera view in this study, modelling for wider area can be realized by similar analyses at various fields and use of satellite images. The assessments for impacts of climate changes on alpine ecosystems are expected by further studies using the local vegetation maps and future climate.

Keywords: Image analysis, Snow discrimination analysis, Microtopography, Random forest, Degree-day method

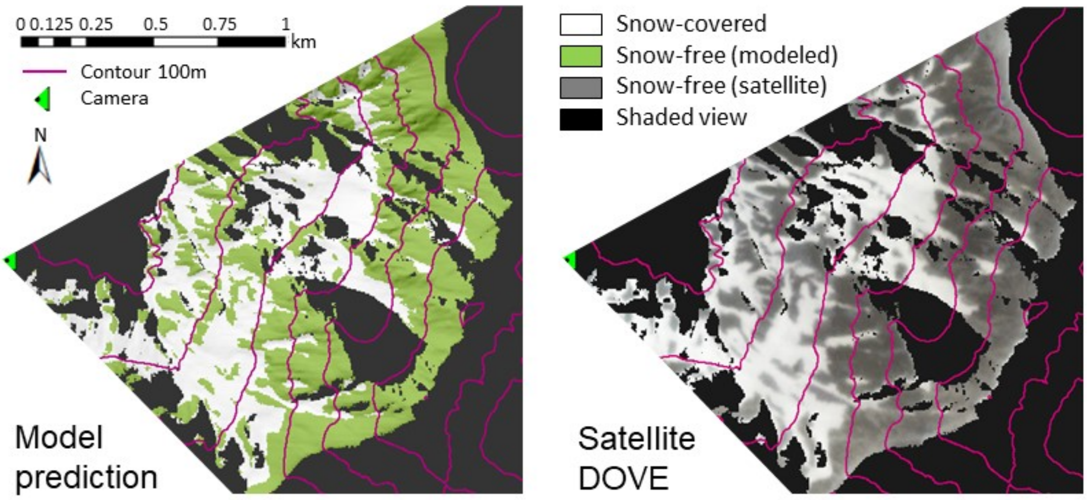

Fig. Snow cover distribution of model prediction (left) and satellite image (right) on 3 July 2019.