Attribution of inhomogeneous glacial fluctuation in High-Mountain Asia

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Glacier shrinkage under global warming have significant contribution to global sea level rise. Particularly in Asia, water demand exceeds supply due to rapid population growth, with glacier meltwater being a crucial water resource in some river basins. Recent studies of Asian glaciers elucidated that Karakoram glaciers were slightly gaining mass while nearby Himalayan glaciers were rapidly losing mass. These different glacial behaviors have been attributed to one of two possible causes: inhomogeneity in recent climate change9-11 or differing glacial responses to climate change. We examined both the climate forcing and the response causes, specifically, we calculate the mass-balance sensitivity to temperature change in high-mountain Asia. Then, in support of the response cause, we find a strong correlation between observed glacier-surface-elevation changes and glacial mass-balance sensitivity. It suggests that spatial heterogeneity of climate change could not be the main cause of that in glacier mass change.

Keywords: High Mountain Asia, glacier fluctuation, climate change, mass balance

Exploration of basal condition in winter by numerical glacier hydrological model -Preliminary results-

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Ice surface speed is a combination of ice deformation and basal sliding (including sediment deformation under the glacier). Well-known spring/summer speed-up cannot be explained by ice deformation and can only be induced by basal sliding. Faster basal sliding is attributed to higher basal water pressure, which reduces the effective pressure (ice-overburden pressure minus basal water pressure) and lubricates the interface between ice and bed. Many observations and modeling have been performed so far, and basal condition plays a key role in driving seasonal changes in ice speed.
Applying offset tracking method to satellite radar images, we found winter speed-up signals of surge-type glaciers at two distinct setting, Yukon Territory in Canada (Abe and Furuya, 2015) and West Kunlun Shan, in Northwestern Tibet (Yasuda and Furuya, 2015). In Yukon, the winter speed-up from fall to winter was seen at many surge-type glaciers during their quiescent phases. In West Kunlun Shan, seasonal modulations were identified at two active surging glaciers, which are faster from fall to winter and slower from spring to summer. These findings tell us that we have to consider some mechanisms that can increase basal water pressure even at low water flux in winter.
Werder et al (2013) developed the 2D subglacial drainage system model (GlaDS), which consists of R-channel conduit and distributed cavity system. Using this model, we have examined how the drainage system evolves from spring to summer, and how it does in the following winter, as well as effective pressure changes. We could show that the effective pressure drops at the same time as the onset of meltwater input. After that, the subglacial drainage system evolves and reaches a steady state. Immediately after the onset of the melting season, spring/summer speed-up event occurs. At the end of the season, when meltwater input ceases, the effective pressure remains a high value in winter. This is because there is no water input and the channels close due to creep closure.
In our presentation, we will show the time evolution of the drainage system during melting season, and discuss how it does in winter with some assumptions.

Keywords: Glacial hydrology, Numerical modeling, Basal condition, Winter

A study on the glacial dynamics in central Karakorum

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The regions of high-mountains are frequently called ‘‘water towers’’ for the lowlands and a precise knowledge of the characteristics is required for their proper management. The glaciers provide water by melt down not only to the people living close to the mountains but also contribute runoff to the lowlands and recharge the river fed aquifers and finally effect the global sea level change. After Alaska and Arctic regions, the Karakorum-Himalaya (K-H) area constitutes the second largest glacial cover of the Earth. The Karakoram glaciers are fed by precipitation and avalanche. Based on previous studies, surges and slight gain in the mass of central Karakorum glaciers has been reported. The surges of individual glaciers are generally out of phase, indicating a limited climatic control on their dynamics. In the present research, the focus is to observe the effect of seasons and earthquake events on the glacial dynamics, in this region.

Keywords: SAR, Pixel Offset, Glacial Dynamics

Remote sensing observations for a catastrophic avalanche collapse in Langtang induced by the Gorkha, Nepal earthquake

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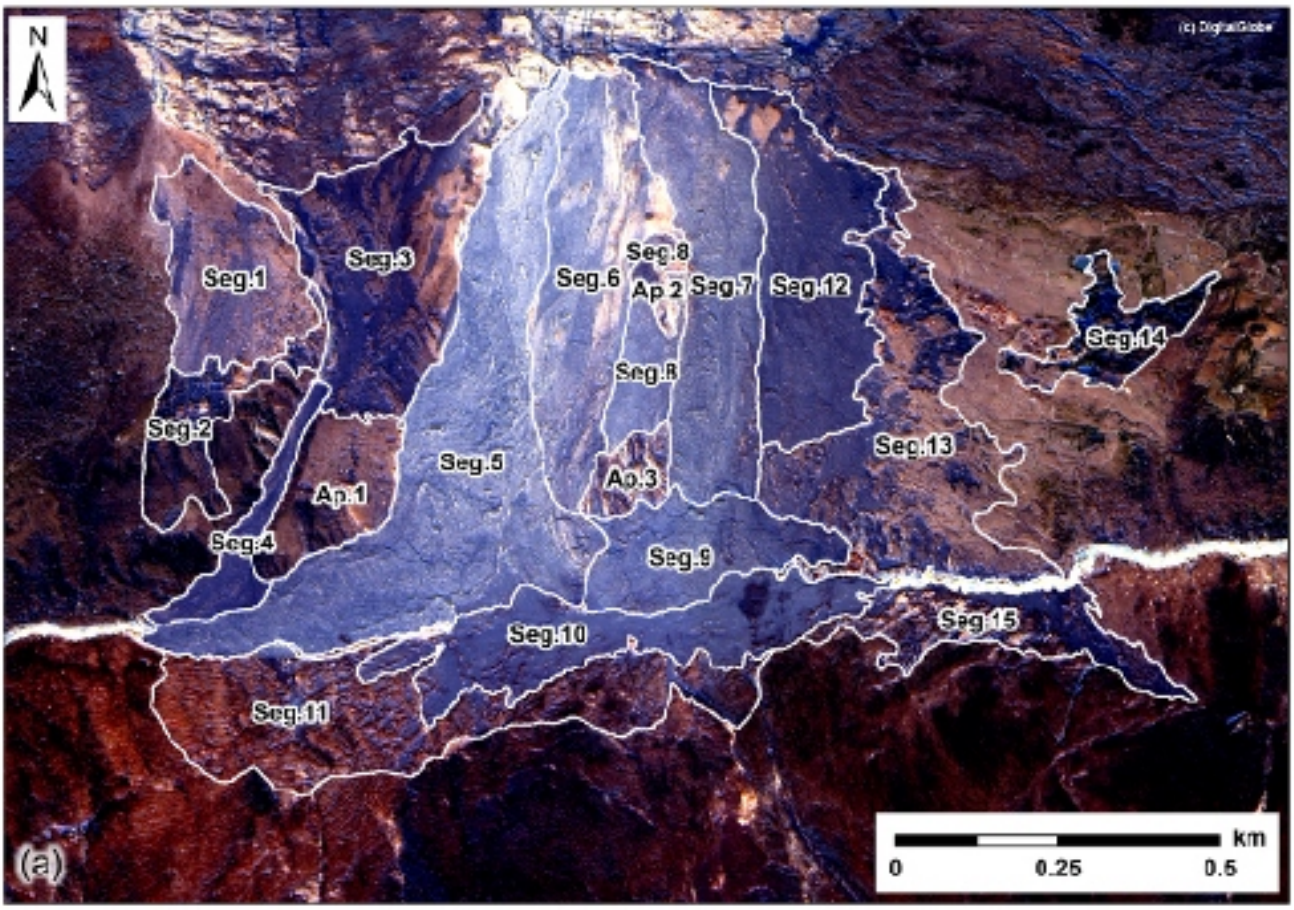
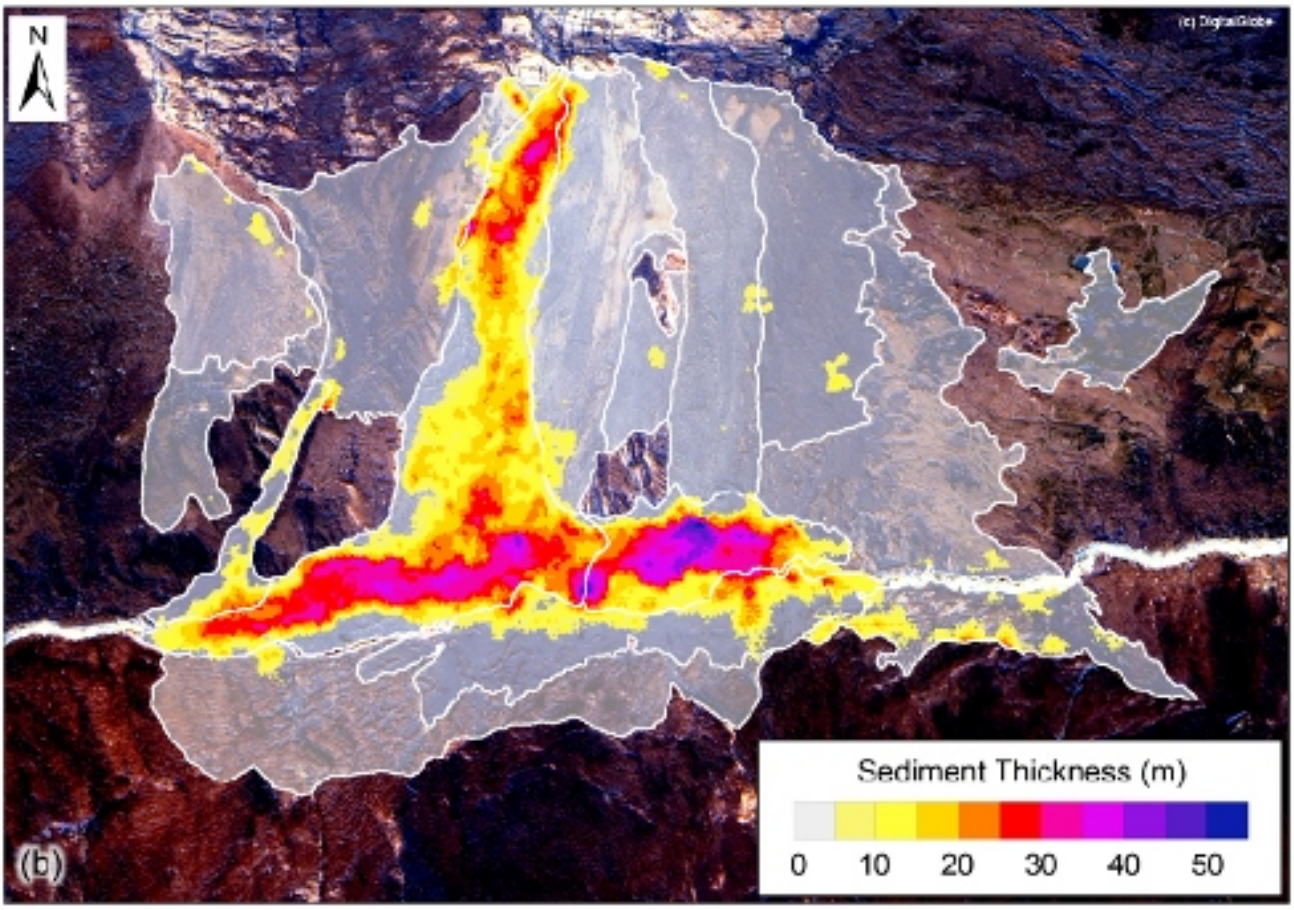
We demonstrated an assessment of the sediments caused by a catastrophic avalanche, induced by the main shock of the 2015 Gorkha Earthquake in Nepal. Calculation of decreasing coherence and visual interpretation of amplitude images by means of the Phased Array-type L-band Synthetic Aperture Radar-2 (PALSAR-2) have a high potential for delineating the hazardous zone. These delineated outlines area highly consistent with that from a high-resolution optical image of WorldView-3 (WV-3). The delineated sediment collapse areas were estimated as 0.63 km^2 (PALSAR-2 coherence calculation), 0.73 km^2 (PALSAR-2 visual interpretation), and 1.09 km^2 (WV-3), respectively. In the WV-3 image, surface features were classified into 15 segments, with the flowing, scattering, and other characteristics implying different physical properties; the different features suggest sequential collapse from multiple sources. Differences in the surface elevations of the collapse events estimated the total volume of the sediments as 5244.5 $\times 10^3$ m^3, with a error possibility between 3652.4$\times 10^3$ to 10687.4$\times 10^3$ m^3, most of which are distributed along the river bed and the water stream. Further elevation measurements after ice/snow melting would reveal a contained volume of melting ice and snow, which will contribute to numerical avalanche simulation and source considerations.

Keywords: the Gorkha, Nepal earthquake, avalanche, PALSAR-2, ALOS, WorldView-3, remote sensing





Characteristics of cryoconite on the Lewis Glacier in Mt.Kenya Africa

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There are glaciers in the high mountains around the equator of East Africa because of low temperature throughout the year and heavy snowfall in wet season. As glaciers and ice sheets worldwide have shrunk recently, the tropical glaciers in Africa has also been reported to shrink significantly. Although melting of glaciers is usually believed to be caused by temperature rise with global warming, it is also caused by decrease of the surface albedo of glaciers. The albedo reduction is cause by impurities in snow and ice, such as cryoconite. Cryoconite is dark-colored materials consisting of mineral particles and organic matter on glacier surface. These mineral particles and organic matter often form spherical aggregates called cryoconite granules. The dark coloration of cryoconite is due to humic substances produced by bacterial activity. As cryoconite decreases surface albedo of glacier and accelerates melting of the glacier, it is important to know their physical, chemical, and biological characteristics. However, there is little information of cryoconite on African glaciers. This study aims to describe characteristic of cryoconite on Lewis glacier in Mt.kenya, Africa.
Microscopy of the cryoconite revealed that its characteristics were distinctive between the lower and upper areas of the glacier. Cryoconite consisted of mineral particles and filamentous cyanobacteria, but cryoconite granules were formed only in the lower site. The amounts of organic matter in cryoconite were more abundant in the lower site than in the upper site. Optical analyses of cryoconite showed that spectral reflectance of cryoconite in the lower site was low and constant in the visible and near-infrared wavelength range while that in the upper site was relatively higher. The difference is probably due to effect of organic matter, which can darken cryoconite. The reflectance of mineral particles in cryoconite was similar to that of cryoconite in the upper part, indicating less effect of organic matter on the reflectance. The factors causing the different characteristics of cryoconite between upper and lower sites are uncertain, but they may affect surface albedo and melting of the glacier surface.

Keywords: Cryoconite, East Africa

The cell morphology and pigment composition of red snow algae in Japanese and Alaskan mountain ranges

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Snow algae are photosynthetic microbes that adapt to low temperature environment and grow on snow and ice surface. When they bloom, they can change color of snow from white to red or green. This phenomenon is known as “red snow” or “green snow”. The coloring snow is caused by various pigments in algal cells. The algal pigments mainly consist of chlorophylls and carotenoids and have physiologic functions in their cells. Variation in snow color may be associated with environmental conditions and/or taxa of the algae. Red snow can be seen at snowfield or glaciers all over the world. However, there has been still limited information of their pigment composition and relationship with the environmental condition. In this study, we analyzed microscopic cell morphology and pigment compositions of red algal snow collected in the melting season of Japanese and Alaskan mountain regions. We aim to understand the relationship between environmental conditions and pigments of algae in each region.

Red snow sample collections were carried out in Mt. Tateyama, Toyama prefecture, Japan in June and July 2015, and on Gulkana Glacier in Alaska Range in August 2015. Algae in the samples were observed with an optical microscope. To analyze pigment composition, another samples of snow algae were filtered through a grass-fiber filter and pigments were extracted with N, N-dimethylformamide as a solvent, and then absorption spectra were measured. Pigment compositions were also analyzed using high-pressure liquid chromatography (HPLC).

Microscopy of the red snow revealed that there were various morphologies of algal cells. Red sphere, orange sphere and green sphere cells accounted for a high proportion. Green oval and orange oval cells were also present but had low abundance. Small amounts of red sphere cells, which crust shaped like petals, and red oval cells were only observed in the samples of Gulkana Glacier. Absorption spectra of pigment extracted from red snow were different among the samples and can be classified into 4 types (Type A~D) based on the absorption features. The HPLC pigment analysis showed that there were at least three major pigments (Chlorophyll *b,* Astaxanthin and Lutein) in all spectral types, and no difference in their composition among the types. The HPLC analysis revealed that the astaxanthin had two chemically distinct structures: free and ester bodies. In addition, the content of astaxanthin differed among the spectral type: a high proportion of ester body were present in Types A and C, free body and ester body were present in Type B, a high proportion of free body were present in Type D.

There was no difference in cell morphologies, but significantly different in pigment composition between Japanese and Alaskan red snow. Four spectral types (Type A~D) were present in Japanese red snow, while Type A was only present in Alaskan snow. The results indicate that red snow contains more diverse algal cells in Japan compared with in Alaska in terms of pigment compositions, probably due to different species and environmental conditions.

Keywords: snow algae, red snow, pigment composition, Astaxanthin

Can snow impurities be detected on Greenland ice sheet by satellite remote sensing?

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Warren (2013) pointed out that attempts to use satellite remote sensing to estimate the black carbon (BC) content of snow are unlikely to be successful, except in highly polluted industrial regions, with the reasons as follows. The possible albedo reductions for the shortwave and visible wavelengths due to the typical concentration of BC (3–30 ppbw) in remote areas of the Northern Hemisphere are 0-1 % and 0-2 %, respectively for cold fine-grained snow, and 0–3% and 1–6%, respectively for melting snow. Compareing to these small albedo reductions typical errors in surface albedo inferred from satellite measurements are comparable (a few percent), which are attributed to uncertainties of undetected thin clouds, atmospheric aerosols, vertical profile of snow grain size, surface roughness, and subpixel heterogeneity of the thin and patchy snow cover as well as satellite sensor calibaration and bidirectional reflectance distribution function (BRDF) model of snow surface used in the retrieval algorithm.
We are challenging to develop the satellite remote sensing algorithm to retrieve snow impurities on Greenland ice sheet (GrIS) to estimate the possible contribution to the recent albedo reduction. The algorithm is based on look-up table method in which BRDFs are tabled as functions of solar and satellite zenith angles and relative azimuth angle, snow impurity concentration and snow grain size. Our algorithm employed a two-snow layer model by which the effect of vertical inhomogeneity of the snow parameters is taken into account. To examin the possibility of satellite remote sensing of snow impurities with our algorithm on GrIS, we estimated the albedo reduction due to BC on GrIS with physically based snow albedo model (Aoki et al., 2011). The albedo reduction for melting snow for the BC concentration range previously measured (0.55-20 ppbw) on GrIS is 0.02-2.6% and 0.03-4.8% for the shortwave and visible wavelengths, respectively. On GrIS there are no uncertainties of subpixel heterogeneity of the thin and patchy snow cover. The surface roughness is also very small in summer season over acculuration area on the ice sheet. The atmospheric aerosols effect are generally small. Hence, the major uncertainties are satellite sensor calibaration, thin cloud effect, and BRDF model used in the algorithm. These issues were improved by employing the latest MODIS C6 data set, new cloud detection algorithm (Chen et al., 2014), and Voronoi snow shape model for BRDF calculation in our algorithm. The retrieval results of monthly mean BC-equivalent concentration of snow impurities from 2000 to 2015 on GrIS in summer season were 8-34 ppbw which are same or somewhat higher than the previous in-situ measurements (0.55-20 ppbw). However, those in spring reason were too high (29-383 ppbw) compared to the in-situ measurements. The inter-annual trend of the concentration in summer was small increase of 10-30%/decade. From this result, there is a possibility to detect snow impurity on GrIS in summer season by satellite remote sensing.
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Keywords: snow impurities, black carbon, albedo, satellite remote sensing, Greenland ice sheet

Metamorphism of layered firn at Dome Fuji, Antarctica: Evolution of relations between Near-infrared reflectivity and the other textural/chemical properties

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Evolution of polar firn was investigated at sites at Dome Fuji, to better understand signals of deep ice cores. Using samples from a 4-m-deep pit and a 122-m-deep core, relations between major textural and chemical properties, such as Near-infrared light reflectivity R, density ρ, microwave dielectric anisotropy Δε, and concentration of major ions, were investigated at a depth range of 0 –122 m, with high spatial resolutions. At the near-surface depths, we found: (i) Fluctuations of R , ρ, and Δεare positively correlated; (ii) Δεranges 0.03 –0.07 at depths immediately below the snow surface at ~0.1 m; (iii) These properties of R, ρ, and Δεare not correlated to major ions. With increasing depths during reported phenomena of density crossover, the positive corrlation of R to Δεpersistently remains with a slight decrease. Besides, R becomes weakly negatively correlated to concentration of Na^+ which is the sea salt marker. These facts suggest that textural features of the near-surface depths are preserved in both R and Δεat a depth range immediately below bubble-close-off, being weakly affected by reported softening of ice by Cl- ions. We therefore suggest that optically layerd features in ice cores are directly linked to the metamorphism.

Keywords: Antarctica, snow, firn, metamorphism, ice sheet

The relationship between natural climate modes of variability and Antarctic sea ice interannual variability/trends

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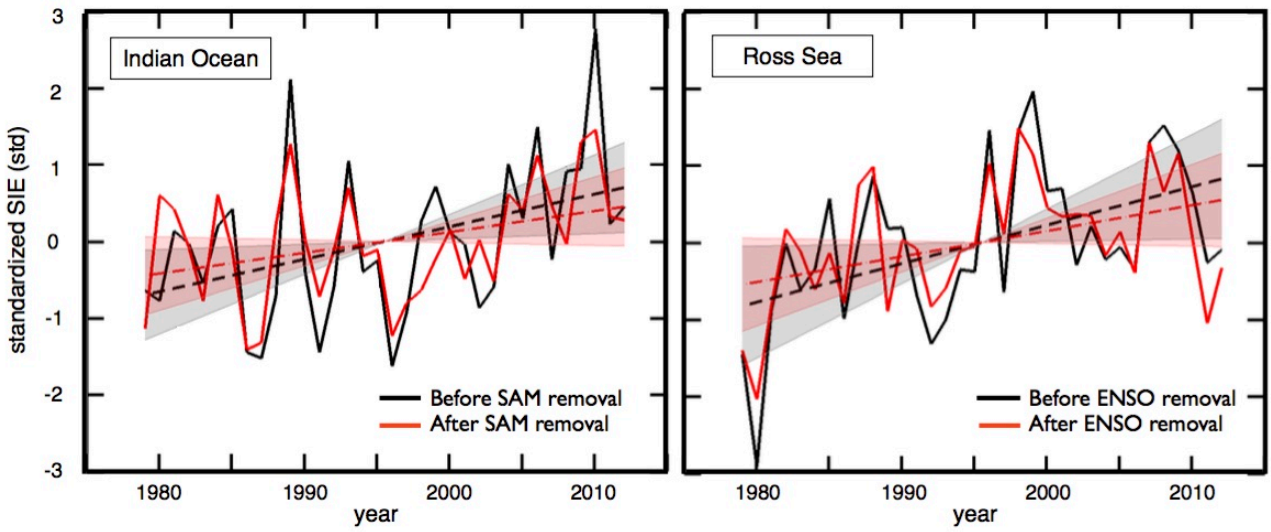
The relationship between climate modes and Antarctic sea ice is explored for interannual variability and trends. On the interannual time scale, El Niño Southern Oscillation (ENSO) and Southern Annular Mode (SAM) are important, but a large fraction of sea ice variance can also be explained by Rossby wave-like structures in the Drake Passage region. After regressing out the sea ice extent variability associated with ENSO, the observed positive sea ice trends in Ross Sea and Indian Ocean during the satellite era become statistically insignificant. Regressing out SAM makes the sea ice trend in the Indian Ocean insignificant. Thus, the positive trends in sea ice in the Ross Sea and the Indian Ocean sectors may be explained by the variability and decadal trends of known interannual climate modes.

Keywords: Antarctic sea ice, El Niño Southern Oscillation, Southern Annular Mode



Comparison of thermodynamics solvers in the polythermal ice sheet model SICOPOLIS

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In order to model the thermal structure of polythermal ice sheets accurately, energy-conserving schemes and correct tracking of the cold-temperate transition surface (CTS) are necessary. We compare four different thermodynamics solvers in the ice sheet model SICOPOLIS (www.sicopolis.net). Two exist already, namely a two-layer polythermal scheme (POLY) and a single-phase cold-ice scheme (COLD), while the other two are newly-implemented, one-layer enthalpy schemes, namely a conventional scheme (ENTC) and a melting-CTS scheme (ENTM) (Blatter and Greve, 2015, Polar Sci. 9, 196-207). The comparison uses two scenarios of the EISMINT Phase 2 Simplified Geometry Experiments (Payne and others, 2000, J. Glaciol. 46, 227-238), one with no-slip conditions at the base and one with basal sliding. In terms of temperate ice layer thickness, CTS positioning and smoothness of temperature profiles across the CTS (a requirement for the assumed case of melting conditions), the POLY scheme performs best, and thus its results are used as a reference against which the performance of the other schemes is tested. Both the COLD scheme and the ENTC scheme fail to produce a continuous temperature gradient across the CTS, and both overpredict temperate ice layer thicknesses to some extent (the COLD scheme more). In the ENTM scheme, a continuous temperature gradient is explicitly enforced. This scheme is more precise than ENTC for determining the position of the CTS, while the performance of both schemes is good for the temperature/water-content profiles in the entire ice column. Therefore, the one-layer enthalpy schemes ENTC and ENTM are viable, easier implementable alternatives to the POLY scheme with its need to handle two different numerical domains for cold and temperate ice.

Keywords: Ice sheet, Thermodynamics, Polythermal ice, Enthalpy method, Modeling

Accuracy of the SMAP model-simulated snow density, temperature, and grain shapes at Sapporo, Japan

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A multi-layered physical snowpack model has a special feature that it can calculate temporal evolution of detailed snow internal stratigraphy. This characteristic is a considerable advantage of such a model, because it is impossible for a typical land surface model to simulate realistic layer structure of the snowpack. In the present study, we evaluated a 1-D multilayered physical snowpack model SMAP (Snow Metamorphism and Albedo Process) in terms of snow density, temperature and grain shapes using in-situ data obtained at Sapporo (43°05'N, 141°21'E, 15 m a.s.l.), Japan from the 2005 to 2015 winters (November to April). The model was driven by quality controlled 30-min averaged data for air temperature, relative humidity, wind speed, surface pressure, snow depth, liquid precipitation, downward and upward shortwave radiant flux, downward longwave radiant flux, and ground surface soil heat flux measured with an AWS installed at Sapporo.
Before investigating accuracy of the model-simulated snow internal physical properties, the SMAP model was evaluated in terms of column-integrated snow water equivalent (SWE) and snow surface temperature in order to check the mass and surface energy balances are calculated adequately. At Sapporo, SWE data was obtained by snow pit measurements, while snow surface temperature was observed with the AWS. Comparison of observed and simulated column-integrated SWE revealed that the model tended to underestimate SWE (mean error; ME was -19 mm); however, root mean square error (RMSE) was 34 mm, and these scores are better than those for simulations driven by not snow depth but precipitation (ME was less than -25 mm and RMSE was more than 40 mm). It suggests that the correction technique for precipitation measurements considering catch efficiency of a rain gauge is still insufficient. As for snow surface temperature simulated by the SMAP model, systematic overestimation nor underestimation was not found (ME = 0.4 ºC), and obtained RMSE was also in a sufficiently low (1.6 ºC). Overall, these results assure that the mass and surface energy balances of the snowpack at Sapporo were modeled and calculated reasonable enough by the SMAP model.
In the model validation in terms of snow internal physical properties, accuracy of the model-simulated snow density and temperature were investigated first using the in-situ measured data from snow pit works. Validation results indicated that the model tended to underestimate snow density (ME = -51 kg m^{-3}) and overestimate snow temperature (ME = 0.4 ºC); however, RMSE for both properties were sufficiently small (88 kg m^{-3} and 1.6 ºC, respectively). In order to permit higher precision of the model, it would be necessary to develop physically based schemes for new snow density and effective thermal conductivity of the snowpack. Next, snow grain shapes simulated by the SMAP model was evaluated using the manually measured data obtained from snow pit works. During accumulation period (November to February), precipitation particles, decomposing and fragmented precipitation particles, rounded grains, and melt forms were mainly observed at Sapporo. Generally, they were stratified from the surface to the bottom of the snowpack. On the other hand, during ablation period (March and April), melt forms were principally observed in the snowpack every winter period. Basically, these above mentioned features could be reproduced by the model; however, faceted crystals and depth hoar, which are generally developed through the temperature gradient metamorphisms, were not simulated by the model at all. It suggests that improving physical processes under the temperature gradient metamorphism, and reconsidering the method to diagnose snow grain shape from snow physical properties such as geometric grain size and water content are

quite necessary.

Keywords: the SMAP model, snow metamorphism, snow internal physical properties

Measurements of the coefficient of dynamic friction for Cross-country skiing

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In cross-country skiing, the result of competition depends on the preparation whether we can prepare the skiing equipment having an appropriate friction between the ski and the snow surface. The previous researches on the friction reported that coefficient of dynamic friction (μ) is associated with the material and the shape of ski. The selection of the shape and materials is possible to prepare in advance. On the other hand, the wax also related to the μ, has been selected empirically by the weather conditions. According to the previous report, μdepends on temperature and snow temperature; μis under (over) 0.05 (0.10) when the temperature is one (seven) degrees and snow temperature is minus four (zero) degrees, respectively. The selection of optimum wax should be judged form the physical results of quantitative measurements. It would be desirable to measure the μat the site of the venue. Although there have been reports of the μmeasurements in the laboratory, the difficulty arises when we use in the venues because the instruments are too large (6m length). Our study aims 1) to develop a compact instrument to measure the coefficient of dynamic friction between ski and snow surface, and 2) multi-point meteorological observations on the venue for cross-country skiing. This study focused on 1).
The ski carrying on the weight of 5Kg is connected to the force gauge. To develop a compact instrument, it has become the 90 degrees bending structure by pulley. The weight was moved 1m at a constant speed using an electric reel. The tension measured by force gauge was recorded by intervals of one tenth second. The average tensile force as F, we deduced the coefficient of dynamic friction μ, using the equation of μ= F / 5 (Kg) ×9.8.

Keywords: cross-country skiing, coefficient of dynamic friction

Development of snow algorithm based on the microwave radiative transfer model for multiple layers and various land surface parameters

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Many snow retrieval algorithms based on the microwave remote sensing uses the microwave radiative transfer model (RTM) for a single snow layer structure and a lot of assumption for land surface parameters. We could not achieve the high estimation accuracy because our algorithm also has used same structure. Therefore, our RTM was modified as follows: Until now, the combined model of the Dense Media Radiative Transfer model (Tsang, 1992) and the 4-Stream fast model (Liu, 1988) was used in our RTM. In this study, the Advanced Integral Equation Model (AIEM; Chen, 2001) was added to RTM in order to evaluate the land surface scattering, and the multiple layer for snow and soil was applied in order to evaluate various parameter. For the vegetation, a vegetation water content is calculated by the Paloscia and Pampaloni (1988)'s empirical formula, and a vegetation optical thickness is calculated by Jacson and Schmugge (1991)'s empirical formula. Thereafter, it is evaluated by the Omega - Tau model (Mo et al., 1982). Furthermore, ice's component was added into the Dobson et al. (1985)'s empirical formula in order to evaluate the soil freezing. Afterward, the sensitivity of RTM was checked in order to reduce of assumption parameters. In consequence, the porosity, ice content, snow temperature gradient for soil and the LAI and vegetation fraction for vegetation were applied as the land surface parameters. Subsequently, the lookup tables (LUT) for each land surface parameter were calculated by the modified RTM, and the snow retrieval algorithm, which estimates snow depth using the brightness temperature for 18.7/36.5GHz, was developed. Snow particle size was calculated by the snow grain growth model (Sturm and Benson, 1977), and snow temperature is calculated by the Richard (2003)'s empirical formula using the AMSR2 brightness temperature for 18.7(v), 23.8(v), 36.5(h) and 89.0(v) GHz. Furthermore, the Harmonized World Soil Database, the NSIDC Permafrost global map, the MODIS LAI map, the ESA Glob Cover Dataset were applied as the global ancillary data. Algorithm performance was validated from October 2012 to February 2013 at the Siberia 11 ground-based stations over the Siberia region (N55-65°, E125-135°), and the estimated snow depth was in good agreement with the in situ data. In the result, the developed algorithm was achieved MAE (Mean Absolute Error):9cm, Bias:1.5cm and RMSE:14cm.

Keywords: Snow, Microwave remote sensing, Algorithm

A 30-year trend of snow cover duration in the Northern Hemisphere derived from satellite-borne optical sensors

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Snow cover extent (SCE) has been an important observation target from space for weather prediction since 1960's. The National Oceanic and Atmospheric Administration (NOAA) has produced a historic record of weekly SCE charts in the Northern Hemisphere over three decades. The NOAA SCE has been widely used for climate studies. However, the production method of SCE has not been unified during the long-term operations. Thus, the accuracies of SCE detection are considered changeable. As an alternative product, a 30-year long SCE was derived in this study from radiances acquired with optical sensors onboard polar orbiting satellites by employing an objective analysis method. That is, only five spectral channels which are available during the whole analysis period were used for SCE detection. In addition to SCE, snow melt date (SMD), first snow date (FSD), and snow cover duration (SCD) were also derived from the SCE. The derived SCE exhibits negative trends in all seasons, which is partly inconsistent with those derived from NOAA SCE. The causes of the inconsistency are considered due to the coarser spatial resolution of NOAA SCE (i.e., pixel size is approximately 190 km whereas this study's SCE has 5km spatial resolution) and also due to the changeable snow detection accuracy. The trend of the derived SCD exhibits spatially asymmetric pattern over the Northern Hemisphere. That is, significant shortening occurs in western part of Eurasian Continent (EC), whereas weak shortening or even lengthening occurs in eastern EC and western North America Continents. From the comparison with SMD and FSD, the significant shortening in western EC is considered to be caused mainly by the delay of FSD toward later dates in autumn and partly by the advancement of SMD toward earlier dates in spring. The long-term SCE dataset will be used as a climatological baseline for a Japanese satellite mission named "Global Change Observation Mission-Climate" (GCOM-C) to be launched in 2017.

Keywords: Snow Cover, Snow Cover Duration, Remote Sensing, Climate, GCOM

Movement analysis of curling stone

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youtube on curling world championship was analyzed. curl distance c, angle of spin n and sliding distance s are measured as a function of sliding time t. in initial stage, stone went to linearly, and curl started at middle stage in the neighborhood of 12 second before stop. curl distance (lateral displacement) increased linearly to sliding time t, reached abut 1 m at end. stone turned at 6 to 10 second as increasing time with sliding. coefficient of friction for spin was extremely small and estimated to order of 0.0001 to 0.00001. coefficient of friction f was value of 0.009 to 0.02 with increasing as decreasing velocity. curves c-s, f-s and f-v were derived.

Keywords: curling, ice, curl

Development of a simple snow load gauge using plastic bottles (part 2)

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Imanishi and Oi (2015) developed a simple snow load gauge using plastic bottles with the purpose of correcting hydrological effects on precise gravity observations. So far we have made laboratory tests by artificially loading the instrument as well as field experiments near the Kamioka gravity station. However, there have been no opportunities of comparing it with other instruments or visually inspecting the status of the instrument under snow load. In this winter, we have installed the instrument at the Oshirakawa Meteorological Station, jointly maintained by Niigata University and East Japan Railway Company, in order to make parallel observations with a snow pressure pillow (metal wafer). As of this writing, the plastic bottle instrument is indicating temporal increase of load that is likely to correctly reflect accumulation of snow. Results of detailed comparison with the snow pressure pillow will be presented.

Keywords: snow load gauge, superconducting gravimeter, plastic bottle

Monitoring of snow albedo and ice surface temperature in the North-West Greenland using MODIS data

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Much works in the Greenland ice sheet (GrIS) have reported recent Arctic warming. The GrIS has been experiencing extensive melt. The surface melt extent can be seen especially in northwestern Greenland. Such an event results in increasing the ice surface temperature as well as decreasing the snow surface albedo. It makes a large contribution to the ice-albedo feedback in the total melt energy. Thus, the monitoring of snow surface albedo and the ice surface temperature in the northwestern GrIS by using NASA's optical sensor MODIS data are important. We developed algorithms to retrieve the snow surface albedo and the ice surface temperature based on the radiative transfer model of atmosphere-snow system. We employed the MODIS (Collection 6) images to show temporal and spatial variation in more detail. We built monthly composite MODIS images by collecting clear day (cloud-free) pixels, and then estimated the snow surface albedo and the ice surface temperature from 2002 to 2014. Results show that the edge of the ice sheet was confirmed to be both low visible and near-infrared albedo through May to September in common. This implies that there are a dark region and a surrounding blue ice area. These low-albedo areas were gradually expanded toward the inland during recent 13 years. For the ice surface temperature, the edge of the ice sheet was measured to be almost melting point, and these areas were also gradually expanding toward the inland. This means that there is a potential of melting the ice sheet and increasing snow grain size over a wide area, resulting in the accelerate near-infrared albedo reduction more rather now. At SIGMA-A site (N78º03'06"/W67º37'42"; 1490 m a.s.l.) where an automate weather station was installed in 2012, a significant negative trend in both visible and near-infrared albedo reduction can be seen in the melting season. Both albedo reduction was largest in August. As corresponding to albedo changes, the positive trend of the ice surface temperature can be seen in the melting season. Comparison between SIGMA-A site and NEEM (N77º30'08"/ W58º04'22"; 2454 m a.s.l.) site shows that the positive (negative) trends for the near-infrared albedo (ice surface temperature) were common each other while that for the visible albedo were different. In NEEM site, small positive trends can be seen in the visible albedo. If major surface melt events such as 2012 summer and increasing the ice surface temperature trend will be measured in the near future, it may cause the expansion of the melting snow area toward the inland, and thereby decreasing the snow surface albedo can be observed in the NEEM site as well after increasing the snow grain size. So, we will continue to focus on these areas to monitor snow physical parameters. In addition we will attempt to use a Japanese satellite mission named "Global Change Observation Mission-Climate (GCOM-C)" to be launched in 2017 which may help to be aimed at a more temporal/spatial detailed monitoring of these parameters.

Keywords: Snow albedo, Ice surface temperature, Greenland, Remote sensing

Spatial distribution of mountain permafrost in northern Tien Shan, Central Asia

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To clarify the current state of mountain permafrost, we researched the distribution, classification, and movement of rock glaciers as an indicator of mountain permafrost in the Kyrgyz Ala-Too Range using field survey, GIS/RS techniques and aerial photograph interpretation. At the examined site, MAAT is -4.62 and MAGST is -1.47 on rock glacier (3500 m asl.) showing environment of mountain permafrost. The distribution of rock glaciers shows the discontinuous permafrost zones are located above 2800 m a.s.l. on the north part and above 3200 m on the south part of the Kyrgyz Ala-Too Range.

Keywords: mountain permafrost, rock glacier, DInSAR

Estimation of sulfur source contribution to sulfate aerosol in surface snow in East Antarctica using sulfur isotope analysis

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Sulfur stable isotope ratio ($\delta^{34}S$) of sulfate aerosol provides important information to assess contributions from various sources. Despite several observations in Antarctica, spatial distribution of sulfur isotopes in Antarctica, however, still remain unclear. Here, we present the first sulfur isotope data of surface snow along latitudinal transect in east Dronning Maud land, East Antarctica. The $\delta^{34}S$ values showed homogeneous values without significant relationship between $\delta^{34}S$ and latitudes, suggesting that isotopic fractionation during transportation is insignificant. Based on the $\delta^{34}S$ value and ion concentrations, the contribution of marine biogenic sulfur to sulfate aerosol is dominant.

Keywords: sulfate aerosol, Antarctica, sulfur isotope

Downwasting of debris-covered ablation area of Lirung Glacier in Langtang Valley, Nepal Himalayas since 1979

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Larger number of glacier system in Himalayas plays important role to water supply in surrounded country and global sea level rise. Extensive glacier mass change have been measured in various scale/method (ex. laser altimetry and stereo photogrammetry) and projected using model with climate gridded data. However, extensive measurement without field-based validation has uncertainty inherent with sensors. And information about behavior of debris-covered glacier is not enough for incorporating extensive model projection. Here we present detail investigation about recent mass balance of debris-covered type glacier of Lirung Glacier in Langtang Valley, Nepal Himalayas, from elevation change by remotely sensed multi-temporal digital elevation models calibrated by field measurement and surface flow velocity by phase only correlation. Surface lowering (-1.3--1.8 m a^{-1}) are observed all over ablation area of Lirung Glacier. From mass balance calculation by continuity equation reveals it mainly caused by ablation. In upper ablation area, recent accelerated decrease of emergence velocity (+0.3 and 0.0 m a^{-1} before and after 2000 respectively) also contributes to the surface lowering. Energy mass balance model using gridded climate datasets and weather observation. The calculated decrease of emergence velocity could caused by delayed response to accumulation decreasing from 1980s to 1990s. In this context, upper ablation area will accelerated downwasting due to positive feedback between surface lowering and flow velocity decelerating.

Keywords: Himalaya, Glacier, DEM

Ensemble forecast error covariance and correlation structures in coupled land-atmosphere modeling systems

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Coupled numerical models address interactions between processes in the atmosphere, ocean, land surface, biosphere, chemistry, cryosphere, and hydrology. Including the interactions between such processes can potentially extend the predictability and eventually help in reducing the uncertainty of the prediction. Coupled data assimilation is a branch of data assimilation that deals with coupled modeling systems. In this article the fundamentals of coupled data assimilation are first described through a mathematical example of a model including two coupled components. Then, through a series of single observation experiments, we analyze the forecast error covariance and correlation structures using the Maximum Likelihood Ensemble Filter (MLEF) data assimilation system with coupled atmosphere-land surface Weather Research and Forecasting (WRF) model . The atmospheric WRF component has been coupled with two land surface models: Noah and Noah-MP. Two observation locations with different precipitation regimes have been considered. Through this study, we found that error covariance and correlation were dependent on both location and land surface scheme. Snow precipitation likely caused more complex structures in error covariances and correlations compared to the precipitation-free site. The employment of a more realistic snow model was found to reduce the error covariance and error correlation between the atmosphere and the soil in the coupled system. We also have demonstrated, for the first time in a data assimilation study, that correlation structures can be useful in understanding the physical meaning of the forecast error covariance and as a basis for selecting the most important forecast error covariance components for the coupled data assimilation system. Overall, the complexity and structure of ensemble-based forecast error covariance appears to be meaningful, which is encouraging for the future applications of coupled atmosphere –land surface data assimilation.

Keywords: Ensemble data assimilation, Snow model, Snow precipitation, Single observation experiment

Differences of physical and chemical conditions between green and red algal snow appeared in mountain regions in Japan

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Snow algae are photosynthetic microbes inhabiting alpine and polar snow fields. They usually bloom on melting snow surface and change its color to green or red. The color of snow is determined by pigment composition in the algal cells and is associated with taxa of algae, the stages of algal life cycle, and/or response to the environment conditions. Green or red algal snow appears widely in mountain regions in Japan. However, physical and chemical conditions of the appearance of green or red algal snow is still unknown.
The purpose of this study is to describe the algal community and environment conditions of green and red algal snow appeared in mountain regions in Japan. We collected the colored snow samples in the melting season of 2015 in Mt. Gassan (green snow) in Yamagata prefecture and in Mt. Tateyama (red snow) in Toyama prefecture, Japan. We analyzed microscopic morphology and abundance of snow algal cells, chlorophyll-a concentrations, absorption spectrum of their pigments, and soluble chemical composition in the snow samples. Both green and red snow samples contained abundant snow algal cells. The depth of the snow at the study sites was more than 120 cm. The vertical distribution of algal cells in the snow pack showed that they were abundant at the surface layers. There were significant differences in ammonium and phosphate concentrations in the surface snow between green and red snows. This suggest that nutrient condition is one of the factors to determine the color of algal snow.

Keywords: Snow algae, Mt. Gassan, Mt. Tateyama

Chemical characteristics of glacial melt water in Tienshan Mountains in the central Asia

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In arid or semi-arid regions of the central Asia, melt water from mountain glaciers has played an important role as a water resource for the ecosystems and human societies in the regions. Although a number of studies on contributions of melt water runoff to the local discharge have been conducted in this regions, studies on influence of the melt water on chemical solutes in the discharge is still limited. This study aims to describe the characteristics of the chemical solutes of the snow, ice, and meltwater on a glacier and of the downstream river and rain water in the Tian Shan Mountains, China, and to discuss chemical processes of melt water on the glacier and river.
Fresh snow, old snow, surface ice, running meltwater on Urumqi No.1 Glacier, and water at the glacier terminus, and of the downstream river and rain water were collected in August 2015. Major ions in the collected samples were analyzed with ion chromatography systems.
Results showed that most of chemical solutes were higher concentration in river water compared with those in snow, ice and the meltwater on the glacier. In particular, the concentrations of Mg^{2+}, Ca^{2+}, SO_4^{2-}, K^+ in river water were approximately 6.5 to 19 times higher than those in snow or ice on the glacier. The concentrations of Na^+, Cl^-, NO_3^- were 1.3 - 3.0 times higher in river water compared with those of the glacier. In contrast, concentration of NH_4^+ was higher on snow and meltwater on the glacier, but not detected in river water. These results show that the chemical concentrations does not simply increase as water flow from glaciers to the downstream river, but that chemical processes affecting the concentration are different among the solutes and areas of the basin.

Keywords: biogeochemistry, mountains glacier, melt water

Influence of snow characteristics on the water movement through the snow cover

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It is important to understand the water movement through the snow cover. However, the relationship between the movement of water and snow characteristics is not known well, particularly, in an unsaturated condition, since the process of water movement is so complicated.
In this study we carried out the experiment to reveal how the unsaturated hydraulic conductivity changes with the snow characteristics and compared with the van Genuchten –Mualem model that is a standard model to describe the unsaturated hydraulic conductivity of soil.
Further, the water retention curve (WRC), which shows the relationship between the volumetric water content (θv) and the suction (h), was obtained with the gravity drainage column experiments, and the effect of Black Carbon (BC) in the snow cover on WRC was examined.

Keywords: snow, water movement through snow cover, water retention curve

Features of energy balance for snowmelt during rain-on-snow events in central Japan

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It has been known that various kinds of hazards such as floods, landslides, avalanches can occur during rain-on-snow (ROS) events due to large quantity of melt- and rainwater supplied to the snowpack and the ground. Some previous studies have discussed the features of snowmelt during ROS events based on field observations, however, the temporal and the spatial variations of snowmelt during ROS events still have been poorly understood. For example, Marks *et al*. (1998) showed that larger heat source for melting was supplied to the snowpack during ROS events than non-ROS periods in the Central Cascade Mountains in Oregon, USA, whereas Kojima *et al*. (1973) reported the result showing less heat supply to the snowpack during ROS events in Moshiri basin in Hokkaido, Japan. In this study, we analyzed meteorological data of Oshirakawa, Niigata Prefecture (360 m a.s.l.) from the melt season (from March 1 to the day when snowpack was disappeared) of 2012 to that of 2015 in order to clarify the difference in the features of surface energy balance between ROS events (daily rainfall > 10 mm) and non-ROS periods (the days without rainfall) and their temporal variations. In addition, we also analyzed the meteorological data at Osado Mountains (800 m a.s.l.) in Niigata Prefecture and at Mt. Ontakesan (2195 m a.s.l.) in Nagano prefecture during the melt season of 2015 to discuss the difference in surface energy balance during ROS events between a low-altitude basin and high-altitude mountains.
The result of the observations in Oshirakawa showed that, in average of the four years, less heat source for snowmelt was supplied during ROS events than non-ROS periods due to less shortwave radiation balance. However, the heat source for snowmelt during ROS events showed substantial difference by year as a result of the changes in albedo and air temperature corresponding to the time of occurrence of ROS events. In the high-altitude mountains, larger heat source for snowmelt was supplied during ROS events than in the basin mainly due to larger turbulent heat fluxes resulting from stronger winds. Thus, we can conclude that there is higher risk of snowmelt-induced hazards in high-altitude mountains due to greater water supply into the the snowpack and the ground.

Keywords: rain-on-snow event, snowmelt, energy balance

