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

