Japan Geoscience Union Meeting 2011
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The signals of anomalous snow accumulation brought about by the Arctic Oscillation as seen with space geodetic data

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The Arctic Oscillation (AO) is a seesaw like fluctuation in sea-level pressure (SLP) between polar and mid-latitude region across 60N, and is a dominant pattern of atmospheric circulation in northern hemisphere in winter season. The trend and scale of AO is represented by the AO index derived from EOF analysis of SLP. When SLP around north polar region becomes lower than usual, the AO index indicates positive values. Then the cold weather is brought to high latitude region and the warm weather to mid-latitude region due to the retention of Arctic cold wave in polar region. Additionally, precipitation anomaly occurs in high latitude region with the enhancement of westerly jet above there. When SLP becomes higher, the AO index indicates negative values. Then it's found the reverse weather changes from positive AO phase. The active outflow of Arctic cold wave makes the weather in high latitude region warm and that in mid-latitude region cold, and the southward meandering of westerly jet brings precipitation anomaly in mid-latitude region. The AO mainly influences winter weathers. Unprecedented extreme negative phase of AO in winter of 2010 brought unusual cold weather and heavy snow in various region of mid-latitude region.

In this study, we have tried to detect the signals of anomalous snow accumulation brought about by the AO in the three pillars of geodesy, i.e. gravity change, surface displacement, and the earth's polar motion. The data used in this study are time-variable gravity change observed by GRACE satellite, surface displacement measured by IGS continuous GPS point, and excitation pole provided by Paris astronomical observatory between 2002 and 2011. Here the secular and seasonal component were removed from all data sets by least square method. First, computing the correlation between the gravity changes and the AO indices in each winter (January to March) throughout all grids of north hemisphere, the regions with latitudes higher than 55N show positive correlations, i.e. higher gravity changes there as the AO index takes larger values, and those from 30N to 55N behave in an opposite way. The regions showing especially high correlation are Western Siberia (+0.94), Black sea (-0.88), Pamir highland (-0.78), and southeastern US (-0.77). The correlations between snow accumulation changes derived from gravity changes and the AO indices were +0.73 in high latitude region (from 55N to 80N) and -0.79 in mid-latitude region (from 30N to 55N). It's recognized that the AO brings a dipole like fluctuation in the distribution of snow accumulation according to its positive and negative phase. Next, computing the correlation between the vertical displacement of GPS point near Pamir (mid-latitude) and the AO indices in each winter, they show strong positive correlation, that is, the ground surface uplifts in positive AO and depresses in negative AO. This kind of vertical displacement is assumed to be the elastic deformation due to the anomalous snow accumulation by the AO. So we calculated the surficial load deformation from the gravity change and compared it with the GPS vertical displacement, and found that they show good agreements both in the phase and amplitude. Lastly, we'll discuss the earth's polar motion. The AO causes large mass redistribution between high and mid-latitude region. The peak-to-peak value of mass movements between there amounts to ~1000 Gt during the studied period. Such a large mass redistribution should excite the earth's polar motion. Here, we compared the excitation pole derived from total mass change of snow accumulation and that provided by Paris astronomical observatory obtained by VLBI and GPS. Then they show in good agreement in phase but the former is about one half in amplitude. Though the cause of disparity in amplitude should need further inspection, there is no doubt that a large mass redistribution brought about by the AO accounts for the excitation of the earth's polar motion.

Keywords: Arctic Oscillation, snow accumulation, space geodesy, gravity change, surface displacement, polar motion

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Intercomparison of three snow metamorphism schemes

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The snow cover plays an important role in the Earth's climate system. For example, snow albedo feedback results in the enhanced warming especially in the Arctic. Therefore, a sophisticated snow process model with high accuracy is needed in general circulation models (GCM) for climate simulations. Recently, some physically based snow albedo models have been developed. These models explicitly consider the physical nature of the snow albedo that the visible albedo strongly depends on snow impurities such as black carbon or dust, while the near-infrared albedo strongly depends on snow grain size. To utilize these physically based snow albedo models in GCM, optically equivalent snow grain radius (r_{opt}), which is a radius of sphere with the same specific surface area (SSA) as that of a non-spherical real snow grain, is required to be calculated in GCM, because r_{opt} is an input parameter for these physically based snow albedo models. We developed a snow metamorphism module for GCM to calculate temporal changes in r_{opt}. It was developed using a one-dimensional snowpack model; Snow Metamorphism and Albedo Process (SMAP) model (Niwano et al., 2011, manuscript in preparation), and validated against measured data in Sapporo, Japan. In the module, the geometric shape of a snow grain was assumed to consist of two connecting spherical ice particles, which have the same radius r_g and are connected by a neck. The temporal changes in r_g were governed by the following four snow metamorphism processes: (1) equitemperature metamorphism, (2) temperature gradient metamorphism, (3) wet snow metamorphism, and (4) snow metamorphism under alternating temperature gradient. We finally obtained r_{opt} by calculating SSA from r_g and neck size of the snow grain. On the other hand, recently, two parameterizations to calculate snow SSA directly have been developed, though they cannot calculate the changes in snow SSA under wet snow condition. The first one is that by Domine et al. (2007), which employs a diagnostic equation as functions of snow grain shape and snow density (hereafter, we refer to it as 'D07'). The second one is that by Taillandier et al. (2007), which employs a prognostic equation as functions of the initial snow SSA, snow age, and snow temperature (hereafter, we refer to it as 'T07'). These two parameterizations were validated in Alaska, and reasonable agreements against observed snow SSA were demonstrated by Jacobi et al. (2010). However, the effects of D07 and T07 on the accuracy of calculated snow albedo are unclear. Therefore, we incorporated these two schemes into SMAP model, and evaluated their performances together with the original scheme of SMAP model using meteorological and snow impurities data measured in Sapporo. Since D07 and T07 do not take wet snow metamorphism into account, the evaluation was conducted during January and February, 2008. We confirmed that root mean square errors of calculated snow albedos were 0.0491, 0.0467, and 0.0449, and the mean errors were -0.0031, 0.0227, and -0.0041 for SMAP original scheme, D07, and T07, respectively. These results indicate that the performances of these three snow metamorphism schemes are comparable for dry snow.

Keywords: snow albedo, snow metamorphism, snow model, specific surface area of snow

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Evaluation of snowfall interception of boreal forest and sublimation profile

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Introduction Snowfall interception by canopy is an important factor for the variation of snow water equivalent (SWE) of snowy forest watershed. Intercepted snow stays on canopy from several days to a few months, a part of which eventually evaporates back to atmosphere or falls down to ground. The fallen snow from the canopy becomes a part of snowpack on the ground, and the sublimated snow becomes a loss to precipitation. Therefore, it is important to estimate the amount evaporation loss of the intercepted snow. This research aims to evaluate the interception loss by measuring the snow water equivalent inside and outside a boreal forest and discusses on the seasonal variation of the interception coefficient, and their relationship with canopy density and atmospheric conditions.

Observation site and method The observation was carried out at a mixed forest of coniferous and broad leaf trees and a birch forest in the Uryu Research forest of Northern Biosphere Field Research Ceter, Hokkaido University from November 2007 to March 2008. The SWE of inside and outside of forest, canopy sky view factor (SVF), profiles of sublimation from a block of ice are observed with meteorological terms by boundary layer tower. A snow survey was carried by setting a 5 meter grid in a plot of 50 m x 100 m.in the mixed forest, and line measurement of 50 m with 1m interval at the open site. Sublimation profiles ice was measured by measuring the weight change of a block of ice, which hung at several heights on the tower.

Discussion and results The difference in SWE of inside and outside of forest is small at the Birch forest site through the observation period and at the Mixed forest site, it was small in early winter but became larger towards the end of the observation period. The average interception loss is 14.4% for Mixed forest and 7.8% for Birch forest.

The SWE inside the Mixed forest increased with sky view factor (SVF), and the interception fraction is closely related to the canopy density. The SVF within the zenith angles less than 60 degree is better assessed the above result than the SVF within the zenith angle less than 10 degree, therefore, the SWE is related to the canopy density not just above canopies but with wider area.

The profiles of evaporation from ice blocks showed larger rate with height for the period longer than 1 week. This is mainly due to the wind and specific humidity profiles. This result must be concerned in snowfall interception models.

Keywords: Interception loss, boreal forest, snow water equivalent

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New snow albedo parameterizations

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New parameterizations to estimate snow albedo are proposed. The following five methods are discussed: 1) previously studied method using daily mean air temperature and daily amount of precipitation, 2) same formula but coefficients and criterion of snowfall are improved, 3) method with distinction between visible (VIS) and near infrared (NIR), 4) same as method 3) but the ratio of VIS and NIR is estimated from duration of sunshine, and 5) method considering new snow depth. According to data in Sapporo, method 3) is better than methods 1) and 2), also method 4) can obtain similar results as method 3).

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Meteorological and climatological feature influenced on mass balance of Potanin glacier, Mongolian Altai

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. Introduction
Fluctuation of glacier mass balance can be an indicator of climate change. Asian glaciers show outstanding negative trend. There are many glaciers in Altai mountain range. Glaciers in western Mongolia are retreating. However, less information has been obtained for Mongolian Altai because there were few glaciological and climatological observations in and around the glaciated area. In order to understand climatological situation of glaciated area and show it in a climate model, climatological research has done for the glacier area in western Mongolia.

. Method
Ten years temperature fluctuation was examined with station data in Mongolia and Russia, observation at the glacier and NCEP/NCAR reanalysis data for the glaciated area in western Mongolia. Observational data are obtained from the meteorological observation conducted on Potanin glacier and some place between the glacier and Ulgii and compared with the other data.

. Result
.. Air temperature
Warming trend was seen in Mongolia as same as in Russia for last 50 years.
.. precipitation
Number of snow fall days were decreasing although long term snow quantity did not show remarkable tendency.

Keywords: glacier, climate, meteorology, mass balanace, altai

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Paleo-permafrost development on the Darhad basin, northern Mongolia

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Darhad basin, northern Mongolia, is located on the southern boundary of Eurasian continuous permafrost region. The clear lacustrine terraces indicate the presence of large paleo-lake, which has occupied entire the basin. Geomorphic studies have shown that the lake level was controlled by damming of glacier advance and retreat, and that the lake has completely disappeared in 10ka. A number of permafrost affected landforms presently occurred on the former lake floor would be formed after lake disappearance. In order to reconstruct historical permafrost development of this basin, we investigated intensively a well-developed pingo (i.e. perennial, intrapermafrost, ice-cored hill) on the northern basin. This pingo shows elongated form with the two connected mounds, the higher one has relative height of 14m and convex southern slope. DC resistivity tomography delineated the high electrical resistive materials in the entire of this elongated form, suggesting the occurrence of extensive ground ice. We drilled to 35m depth at the highest point, and found massive ice at the depths between 13 to 23 m. River transported materials with sand and rounded gravels at the depths of 6.0 m indicate that pingo formation has initiated after this sedimentary stage, which was dated as 3,350 - 3,246BC by C14 AMS.

Keywords: permafrost, ground ice, pingo, Mongolia, permafrost formation