Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

ACG38-01 Room:101A Time:May 21 09:00-09:15

Sinking fluxes of siliceous phytoplankton in the Northwind Abyssal Plain, Oct. 2010-Sep. 2012

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Time-series sinking fluxes of siliceous phytoplankton (diatom, silicoflagellate, chrysophyte cyst, endoskeletal dinoflagellate Actiniscus, and edridian) were studied at Station NAPt in seasonal sea-ice area of the Northwind Abyssal Plain (75N 162W, 1975m water depth) from 4 Oct. 2010 through 18 Sep. 2012. Total of 51 sediment trap samples obtained at 180m water depth were applied in this study. Sinking flux of total mass (mainly composed of lithogenic materials) was relatively high in Nov.-Dec. 2010, July-Aug. 2011, and Nov.-Dec. 2011. However, total mass and siliceous phytoplankton fluxes in summer 2012 were relatively low compared to those in 2011. High diatom flux was observed in early winter (Nov.-Dec.) and Aug.-Sep. 2011. The diatom sinking flora except for Aug.-Sep. 2011 was mainly composed of *Chaetoceros* spp., their resting spores, and *Thalassionema nitzschioides*. This flora is similar to the diatom assemblage in the Canada Basin. The diatom sinking flora in Aug.-Sep. 2011 was mainly composed of *Fossula arctica* and *Fragilariopsis oceanica*. In this period, abundant gelatinous house of Appendicularia was also contained in the samples. The high abundances of *Fossula*, *Fragilariopsis*, and Appendicularia were not observed in summer 2012. Silicoflagellate flux showed maxima in early winter and summer both 2011 and 2012. Based on the comparison of diatom sinking flora around the study area, the absence of diatom flux peak in summer 2012 is probably due to significant influence of Beaufort Gyre waters rather than shelf waters. Chrysophyte cysts and heterotrophic siliceous dinoflagellate genus *Actiniscus* were observed throughout the sampled duration. The sinking flux of ebridian *Ebria tripartita*, which is mainly observed in the outer continental shelf of Chukchi Sea, increased in Nov. 2010. The high biogenic flux in early winter did not reflect the high primary production at Station NAPt due to limited light condition in polar night. The large portion of high total mass flux in every early winter is probably explained by lateral particle transportation into the Northwind Abyssal Plain from the Chukchi Sea shelf.

Keywords: diatom, phytoplankton, sinking particle flux, sediment trap, the Northwind Abyssal Plain, the Arctic Ocean

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ACG38-02 Room:101A Time:May 21 09:15-09:30

Maintenance Mechanism of the Western Pacific Teleconnection Pattern and Its Impact on Sea Ice

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The Western Pacific teleconnection pattern (WP pattern; Wallace and Gutzler, 1981) that accompanies north-south dipolar anomalies in pressure over the Far East and western North Pacific is often observed in association with a cold outbreak over East Asia. It is known that during a prominent positive event of the WP pattern, whose northern center of action is anticyclonic anomaly, sea ice concentration tends to decrease in the Sea of Okhotsk and in the western Bering Sea, while it tends to increase in the eastern Bering Sea. Although the WP pattern has substantial influence on climate over the Far East, its maintenance mechanism has not yet been clarified.

We evaluated kinetic and available potential energy (KE and APE) conversions of the positive WP pattern to investigate maintenance mechanism of the WP pattern. The evaluation is based on a composite map of 32 strong positive monthly events in winter (DJF) for the period of 1948 - 2010. We found that baroclinic energy conversion (i.e., APE conversion from climatological-mean fields to anomalies of the WP pattern) works most efficiently to the maintenance of the WP pattern, and barotropic conversion (i.e. KE conversion from climatological-mean fields to anomalies) and feedback forcing of transient eddies through their momentum transport work less. Most of previous works have paid attention to the latters, but not to the former. This is because teleconnection patterns over the ocean have been considered to have equivalent barotropic structure, thus the barotropic conversion and feedback forcing of transient eddies have only been focused. In contrast to other teleconnection patterns, we have revealed that the composited monthly anomalies of the WP pattern exhibit baroclinic structure with their phase lines tilting southward or southwestward with height at the lower troposphere. The baroclinic structure of the positive WP pattern accompanies westward heat flux from the warmer Pacific ocean to the colder Eurasian continent around its northern center of action, which brings efficient baroclinic conversion. Anomalous heat exchange with the underlying ocean and release of latent heat by precipitation due to anomalous storm track dissipate APE of the WP pattern. Even if these dissipating processes being included, KE and APE conversions from climatological-mean field and barotropic feedback by transient eddies maintain and reinforce the anomalous field of the WP pattern.

Keywords: Teleconnection Pattern, Western Pacific Pattern, Sea of Okhotsk, Bering Sea, Baroclinic Energy Conversion

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ACG38-03 Room:101A Time:May 21 09:30-09:45

An Intense Arctic Cyclone in August 2012: A Transition Mechanism to Arctic Cyclone

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An intense arctic cyclone in August 2012 is investigated in this study. Especially, we analyzed i) three dimensional structures and ii) mechanisms of the development focused on a transition process to arctic cyclone from extratropical cyclone.

The center pressure of the arctic cyclone decreases to 965 hPa, which is an all-time minimum in August arctic cyclones. In the early phase, the arctic cyclone is a shallow baroclinic cyclone originated with an arctic front of 60 degree north. Then the baroclinic cyclone undergoes the transition process of the arctic cyclone due to the merger with a relatively weak (990 hPa) preceding arctic cyclone. The shallow baroclinic cyclone becomes a deeper and wider barotropic cyclone with a couple of stratospheric warm core and tropospheric cold core. Analyses show that the transition to arctic cyclone plays some important role in the development of the arctic cyclone.

Keywords: arctic cyclone, extratropical cyclone, transition process

Japan Geoscience Union Meeting 2013
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ACG38-04 Room:101A Time:May 21 09:45-10:00

The contribution of sub-grid snow distributions to climate change and polar amplification in a quadrupled CO2 world.

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Snow cover evolution is an important factor in snow albedo feedback processes and thus "Polar amplification" within future climate projections simulated using general circulation models (GCMs). In the present study, we introduce a sub-grid snow distribution submodel (SSNOWD; Liston 2004) into the Minimal Advanced Treatments of Surface Interaction and RunOff (MATSIRO; Takata et al. 2003, Nitta et al. in preparation) land surface scheme, which is coupled interactively with a GCM known as the Model for Interdisciplinary Research on Climate (MIROC; Watanabe et al. 2010).

By using this new version of MIROC GCM with SSNOWD, we compare and evaluate the warming in a quadrupled CO2 experiment with a pre-industrial control experiment. We also compared a quadrupled CO2 experiment with a control using the original version of MIROC which assumes a simple empirical relation between snow amount and snow cover in a grid-cell. We finally estimate how the introduction of the sub-grid snow distribution representation contributes to the large-scale climate change and the polar amplification in the quadrupled CO2 world.

Keywords: snow cover, GCM

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ACG38-05 Room:101A Time:May 21 10:00-10:15

Relative contribution of feedback processes to Arctic amplification of temperature change in MIROC GCM

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The finding that surface warming over the Arctic exceeds that over the rest of the world under global warming is a robust feature among general circulation models (GCMs). While various mechanisms have been proposed, quantifying their relative contributions is an important task in order to understand model behavior and operating mechanisms. Here we apply a recently proposed feedback analysis technique to a GCM under different external forcings including elevated and lowered CO_2 concentrations, and increased solar irradiance. First, the contribution of feedbacks to Arctic temperature change is investigated. Surface air temperature response in the Arctic is amplified by albedo, water vapor, and large-scale condensation feedbacks from that without a feedback although a part of it is suppressed by evaporative cooling feedback. Second, the contribution of feedbacks to Arctic amplification (AA) relative to global average is investigated. Under the positive radiative forcings, the albedo feedback contributes to AA predominantly through warming the Arctic more than the low latitudes while the evaporative cooling feedback contributes to AA predominantly by cooling the low latitudes more than the Arctic. Their relative effects vary with the applied forcing, however, and the latter dominates over the former in the increased solar irradiance and lowered CO_2 experiments. The large-scale condensation plus evaporative cooling feedback and the dynamical feedback contribute positively and negatively to AA, respectively. These results are consistent with an increase and a decrease of latent heat and dry-static energy transport, respectively, into the Arctic under the positive radiative forcings. An important contribution is thus made via changes in hydrological cycle and not via the 'dry' heat transport process. A larger response near the surface than aloft in the Arctic is maintained by the albedo, water vapor, and dynamical feedbacks, in which the albedo and water vapor feedbacks contribute through warming the surface more than aloft, and the dynamical feedback contributes by cooling aloft more than the surface. In our experiments, ocean and sea ice dynamics play a secondary role. It is shown that a different magnitude of CO_2 increase introduces a latitudinal and seasonal difference into the feedbacks.

Keywords: Arctic amplification, global climate model

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ACG38-06 Room:101A Time:May 21 10:15-10:30

Arctic Amplification and Arctic Oscillation

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Recent rapid Arctic warming is regarded as a research frontier in the study of global warming. Arctic amplification in the context of global warming has been a common feature in climate model predictions and in observational facts in 21th century. Arctic sea ice is melting drastically in 2007 and 2012, exceeding IPCC projections. Although ice?albedo feedback plays an important role in the Arctic amplification, it must be just an amplifier of certain warming processes in the Arctic. Enhanced northward heat transport by the atmosphere and ocean may be a response to the anthropogenic global warming. Long-term natural (internal) variability of the climate system may be another candidate of the Arctic amplification. It is difficult to quantitatively evaluate the internal variability from the long-term integration of climate models. When models are fully coupled with all climate subsystems such as ocean, cryosphere, and ecosystem, the internal variability is expected to become larger. Significant negative trend of Arctic Oscillation (AO) index in the recent years is a manifestation of the internal variability associated with the warming in the Arctic Ocean. North Atlantic warming and the increase in the Atlantic water temperature to the Arctic basin are responsible for melting of a significant portion of arctic sea ice. It may be important to realize that such an Arctic amplification is the most efficient cooling mechanism of the earth in response to the anthropogenic global warming. Moreover, the Arctic amplification results in the AO negative, causing warm Arctic and cold mid-latitudes to cool the entire earth system to decelerate the global warming. We need to aware the fact that the global warming is decelerated in conjunction with the enhanced Arctic amplification and AO negative trend in recent years.

Keywords: Arctic, Arctic Oscillation, Global Change, Arctic Amplification, Ice-Albedo Feedback, Heat Transport

Japan Geoscience Union Meeting 2013
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ACG38-07 Room:101A Time:May 21 11:00-11:15

Darkening glaciers and ice caps in Greenland by cryoconite

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Studies have revealed that a part of the bare ice surface of the Greenland Icesheet appeared to be dark coloration compared with those in the surrounding surface. The area, dark region, is likely to melt greater because the dark-colored surface can absorb more solar radiation compared with the white clean ice. The possible causes of the darkening are impurities on the ice, such as mineral dust, black carbon, and organic matter. In particular, organic compornent derived from snow algae, cyanobacteria, and bacteria, may have significant effet of darkening since they usually contain substantial amounts of dark-colored humic substances. However, it is still unknown that where the impurities came from and how they appear and distribute on the surface. To understand dynamics of impurities and formation process of organic matter on the glacier, we investigated characteristics of impurities on Qaanaaq Ice cap located in the north-westen part of the Greenland in melting season of 2012.

Substantial amounts of impurities were found on both snow and ice surfaces. Microscopy revealed that the impurites consisted of mineral dust, snow algae, and other organic matter. In the ice area, they formed granular aggregates: cryoconite granules. The amount of impurities (dry weight) was greatest on the bare ice surface at the middele part of the ice cap, while that was smallest at the lowest site close to the terminus. In the snow area, red snow algae were blooming and visibly recognized. The red algal blooms were comfirmed from the snow line to the top of the ice cap, indicating that the algae appeared on the entire surface of the ice cap. Results suggest that organic matter deribed from snow algae plays a substantial role to darken the surface of the glacier.

Keywords: greenland, glacier, icesheet, microbes, albedo

Japan Geoscience Union Meeting 2013
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ACG38-08 Room:101A Time:May 21 11:15-11:30

Possible effects of snow grain size and snow impurity concentration on the albedo measured at SIGMA-A in Greenland

Teruo Aoki[1*], Sumito Matoba[2], Satoru Yamaguchi[3], Tomonori Tanikawa[4], Masashi Niwano[1], Tetsuhide Yamasaki[5], Katsuyuki Kuchiki[1], Hideaki Motoyama[6], Masahiro Hori[4]

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Snow and ice in the Arctic are presently undergoing drastic changes. The snow surface albedo strongly depends on snow grain size and mass concentration of light absorbing impurities. To clarify the contributions of light absorbing snow impurities to recent abrupt melting of snow/ice in Greenland, intensive observations of meteorological and snow parameters have carried out at the site SIGMA-A (78^{o}03'N, 67^{o}38'W, 1,490 m a.s.l.) on northwestern Greenland ice sheet during the intensive observation period (IOP) from June 26 to July 16, 2012. We installed automatic weather station to measure the meteorological elements, radiation budget, snow temperatures, and relative snow height. We have also performed snow pit work and snow samplings for light absorbing snow impurities. During the IOP no precipitation was observed in the first two weeks and a large amount of rainfall with remarkable lowering of snow surface was observed in the middle of July, when a melting event of surface snow/ice over 97% of Greenland ice sheet occurred. Snow grain shapes observed from snow pit work for snow layer of about 80 cm (annual accumulation) changed from melt forms for upper layer and depth hoar beneath that to melt forms for all layers during the IOP. Light absorbing snow impurities found from snow samples were black carbon (BC) and mineral dust, whose concentrations at surface were both increased from 0.9 ppbw to 4.9 ppbw and from 102 ppbw to 1327 ppbw during the IOP, respectively. We calculated the possible albedo reduction by the measured snow impurity concentrations using a physically based snow albedo model. The maximum albedo reduction due even to EC of 4.9 ppbw is less than 0.01 for typical grain size of melt forms, while it could be enhanced by the effect of dust of 1327 ppbw. BC equivalent total impurity concentration is estimated to be about 15 ppbw (albedo reduction -0.015). This result was consitent with the albedos measured during the IOP. The particle size of mineral dust found in surface snow during the latter half period of IOP was larger than 5 micrometers. This indicates a possible transport of mineral dust onto ice sheet surface. Mineral dust is important as nutrient salt for glacial microbial activities, which reduce the albedo in ablation area and could accelerate the melting of ice sheet.

Keywords: Greenland, albedo, snow grain size, light absorbing snow impurities, black carbon, dust

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ACG38-09 Room:101A Time:May 21 11:30-11:45

Assessing the extreme surface melt at SIGMA-A, northwestern Greenland during 2012 summer using a physical snowpack model

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It is reported that extreme surface (or near surface) melt occurred on the Greenland Ice Sheet (GrIS) across 98.6 % of its entire extent on around 12 July 2012. At the site SIGMA-A (78^{o}03'N, 67^{o}38'W, 1,490 m a.s.l.), which locates on northwest part of GrIS, we also observed near-surface melt, and accompanying rapid surface lowering especially during the latter half of our intensive field observation carried out from 26 June to 16 July. In this study we focus extreme near-surface melt occurred during 10 to 13 July at SIGMA-A. During the period average air temperature rose noticeably compared to the first half of the expedition period (30 June to 9 July) by about 1.6 ^{o}C, and we encountered heavy rain on snow event. Furthermore, near-surface mass concentrations of snow impurities (black carbon and dust) slightly increased to about 4.9 ppbw and 1327 ppbw, respectively.

In order to understand the detailed mechanism of the extreme near-surface melt, we employed a physically based 1-D snowpack model named Snow Metamorphism and Albedo Process (SMAP) forced by in-situ meteorological and snow data, and performed numerical sensitivity tests to assess relative contributions of temperature rise (Test-I), rain fall (Test-II), and snow impurities (Test-III), which can heat near-surface snowpack. SMAP with the default setting (CTL) was already tested using these data and we obtained reasonable results (root mean square errors for shortwave albedo and snow surface temperature were 0.024 and 0.373 ^{o}C, respectively) during 30 June to 14 July. In the Test-I input air temperature was reduced by 1.6 ^{o}C and downward longwave radiant flux was also modulated accordingly. For the Test-II we input no precipitation. Finally, in the Test-III we performed "pure snow" run where no snow impurities were input to drive SMAP.

Comparing each result by these sensitivity tests (Test-I, Test-II, Test-III) against that by CTL, and found average reductions in shortwave albedo (0.000, -0.003, and -0.013) and average increases in snow surface temperature (0.106 ^{o}C, 0.000 ^{o}C, and 0.002 ^{o}C) due to temperature rise, precipitation, and snow impurities, respectively during 10 to 13 July at SIGMA-A. These results indicate that albedo reduction is mainly caused by snow impurities, however, its extent is not sufficiently large to modulate surface energy balance dramatically. Instead, temperature rise increases net longwave radiant flux and sensible heat flux at the snow surface and heat the surface significantly, suggesting that temperature rise played an important role in the extreme surface melt at SIGMA-A during 10 to 13 July.

Keywords: Greenland, extreme melt event, snowpack model, snow albedo, snow surface temperature

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ACG38-10 Room:101A Time:May 21 11:45-12:00

Crustal rebound in Greenland inferred form ice sheet history derived from three-dimensional ice sheet modelling

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It is very important to determine the temporal variation of meltwater volume and the spatial extent of ice sheets in late Quaternary for studying past and future climate changes and for constraining mantle rheology. Most of the melting histories of ice sheets from Last Glacial Maximum have been inferred on the basis of geophysical and geological constraints (e.g., Peltier, 2004) using the glacial isostatic adjustment (GIA) modelling. However, such reconstructions have ice thickness that is unconstrained in regions from which the required geophysical data are unavailable and furthermore insufficient constraint that might support them to be glaciologically self-consistent. And also there are some difficulties in the geophysical reconstructions that are the ambiguity between ice load magnitude and the timing of ice load removal.

On the other hand, three-dimensional ice-sheet modelling (e.g., Abe-Ouchi et al. 2007) produces physically self-consistent ice sheet which further constrains the history and spatial variations of the load, but have difficulties due to their high sensitivity to the various climate forcing as well as from uncertainties associated with basal processes. However, it is clear that the combination of these two approaches would be expected to lead to a much more highly constrained reconstruction of ice sheet history.

In this study, we try to combine the two methodologies based on the three-dimensional thermo-mechanically coupled ice-sheet model and the bedrock deformation derived from GIA model. As a first step, we evaluate the crustal deformation in Greenland based on the ice models deduced by IcIES (Ice sheet model for Integrated Earth system Studies: Abe-Ouchi et al., 2007). Crustal deformation includes vertical uplift and subsidence, geoid height variations, and regional sea level variations along the coasts of Greenland. We compare the sensitivity of the adoption of ice sheet histories. In particular, we clarify the effect of Laurentide ice sheet on crustal deformation in Greenland.

Keywords: Greenland Ice Sheet, ice sheet modelling, isostasy, crustal deformation, sea level change

Japan Geoscience Union Meeting 2013
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ACG38-11 Room:101A Time:May 21 14:15-14:30

Weather Conditions for Large Scale Forest Fire Occurrence in Alaska

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Under a rapid climate change in recent years, a frequent occurrence tendency of a large-scale forest fire is seen in Alaska. Behind this tendency, it is thought that there is an influence of the increased number of lightning flashes under the global warming trend. In the present study, the fire data from 1956 and the thunder data from about 2000 provided by Alaska fire service (AFS) were analyzed, the occurrence characteristic of a fire of Alaska was clarified, and then the weather condition for large-scale fire occurrence was discussed.

Although Alaska is located at around 60 degree north in latitude, maximum air temperature in summer exceeds 30 degree C. and lightning occurs. There is a day when number of lightning flashes exceeds 10,000 or more in a day and a fire in the boreal forest caused by lightning could occur. Actually, the area of 26,700km2 burnt in the most disastrous fire year for Alaska in 2004 due to large-scale lightning caused fires. The nine large-scale fires that exceed burnt area of 1,000 km2 occurred under a record-high temperature and a strong drought.

Total burn area in 2004 was the largest since record-keeping began in Alaska in 1956. Combined with an additional 19,000km2 burned in 2005, the area accounted for 10% of Alaska’s boreal forests in just two years.

To clarify weather condition of active fire year, past fires during about half a century from 1956 to 2012 were analyzed. The number of active fire years that exceed burnt area of 5,000km2 was 11 years in above-mentioned 2004, 2005, etc. It became clear from the fire occurrence tendency of these years that the large-scale fire has mainly started from June in Alaska. In addition, other conditions between fire and weather condition of 11 large-scale years were examined in detail.

Keywords: Forest Fire, Lightning, Alaska

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ACG38-12 Room:101A Time:May 21 14:30-14:45

Sensitivity of backscatter intensity of ALOS/PALSAR to biophysical parameters of boreal forests in Alaska

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We investigated the sensitivity of ALOS/PALSAR backscatter intensity for estimating the above-ground biomass (AGB) and other biophysical parameters (tree height, diameter at breast height (DBH), and tree stand density) in the boreal forest of Alaska. In July 2007, forest surveys were conducted along a south-north transect (150W) to profile the ecotone from boreal forest to tundra in Alaska. In situ parameters were measured in 29 forests by a combination of the Bitterlich angle-count sampling method and the sampled-tree measuring method. These in situ values were compared with the backscatter intensity of ALOS/PALSAR. A strong positive logarithmic correlation was found between the backscatter intensity and the forest AGB, with the correlation being stronger in the HV than in the HH polarization mode. No obvious saturation was found in the sensitivity of the HV mode backscatter intensity to the forest AGB up to 120.7 Mg ha-1. Similarly, a robust sensitivity was found in the HV backscatter intensity to both tree height and DBH, but weak sensitivity was observed for tree density. The regression curve of HV backscatter intensity to the forest AGB appeared to be intensified by the uneven forest floor, particularly for forests with small AGB. The geographical distribution of the forest AGB was mapped, demonstrating a generally south-rich and north-poor forest AGB gradient.

Keywords: ecotone, black spruce forest, forest above-ground biomass, synthetic aperture radar, Bitterlich method

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ACG38-13 Room:101A Time:May 21 14:45-15:00

Estimation of biomass change by multi-temporal airborne laser profiling along S-N 750 km transect in northwestern Canada

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Multi-temporal airborne laser profiling missions over S-N 750 km transect along the Dempster highway from Dawson (64.0 degrees N, 138.8 degrees W), Yukon Territory to Inuvik (68.3 degrees N, 133.5 degrees W), Northwest Territories in Canada were conducted in summer of 2003 and 2011 for estimating terrestrial biomass change and monitoring how northern plants respond to possible global warming. By processing original surface profiles of the term-head and end missions, vegetation profiles were obtained as a difference between surface and ground profiles. Then standing stock, and aboveground biomass every 100 m along transect at the term-head and end were obtained by applying equation those vital indices measured at 80 sample plots on ground against average laser vegetation height. Average vegetation height, standing stock and biomass entire 750 km transect were increased from 0.51 m, 15 m^3/ha and 9.0 ton d.m./ha in 2003 to 0.81 m, 23 m^3/ha and 14.0 ton d.m./ha in 2011 as average annual increment of 0.037 m, 1.1 m^3/ha and 0.64 ton d.m./ha. Biomass increment was much larger in forest dominated section (0-70 km from Dawson; nearly 2 ton d.m./ha/year) than tundra dominated section (450-550 km from Dawson; 0.1 ton d.m./ha/year). Air temperature and warmth index in recent 25 years have been rising 0.34 degrees and 1.2 degrees-month (more than 0 degrees Celsius in mean monthly temperature) in Dawson, 0.63 and 0.3 in Eagle plains (the middle point of transect), and 0.78 and 1.9 in Inuvik respectively and which supports soil temperature should have also been rising in this area. Both the air and soil temperature rising causes the releasing growth limitation of plants in this region. However, biomass carbon loss from forest fire seems not significant at least along the laser transect from year 2003 to 2011 from the combination of analysis of multi-temporal airborne laser profiling data set, fire history map from Yukon Territory, and observation from the air and ground.

Keywords: Canadian boreal forest, circumpolar, global warming, biomass change, airborne laser altimetry, multi-temporal measurement

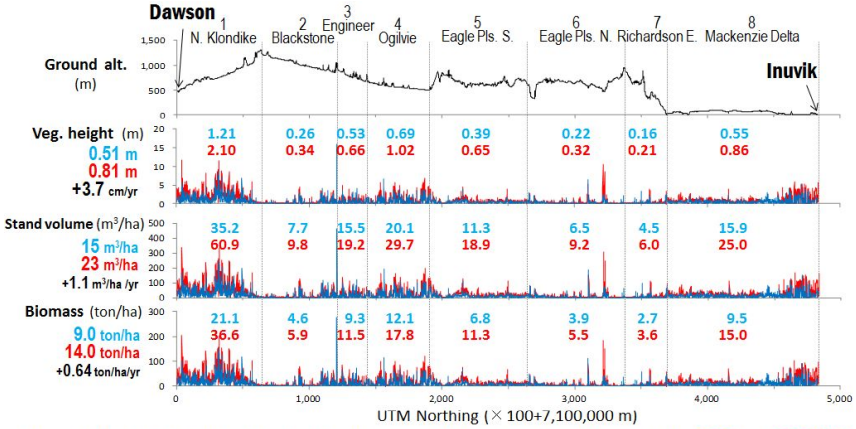

Figure Vegetation height, stand volume, and aboveground biomass in 2003 and in 2011

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ACG38-14 Room:101A Time:May 21 15:00-15:15

Changes in the Lena River discharge and net precipitation over the basin during 2005-2008

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River discharge from the Lena River in eastern Siberia is one of the large sources of freshwater in the Arctic Ocean, which plays important roles for sea ice formation and the ocean conveyor belt. It accounts for about 7% of the total freshwater inflow to the Arctic Ocean including total river discharge, net precipitation (P-E) over the ocean and ocean current. In the middle part of the Lena River basin, precipitation was high during 2005-2008 and associated several drastic changes in terrestrial water cycle were observed: extended flood, deepening of active layer and so on. On the other hand the Lena River discharge at the mouth and net precipitation over the basin were also high level during the same period. In this study, we attempt to reveal relationship between the local and basin-wide changes, and those causes associated with moisture transport and large-scale atmospheric circulation.

Annual mean river discharge and net precipitation of the Lena River show strong positive correlation during the past three decades, while they have a time lag of about three months. The discharge and precipitation over the basin also show strong positive correlation during the past seven decades. These results indicate that the interannual variation of the Lena River discharge is controlled by that of the precipitation, while effects of changes in evapotranspiration and land water storage are minor.

On the monthly time scale, net precipitation is positively correlated with precipitation and moisture flux convergence over the Lena River basin. In addition, the monthly mean precipitation shows strong positive correlation with number of days (NOD) in heavy precipitation category. During 2005-2008, the precipitation was high in several months that is consistent with observed results in/around Yakutsk. The NOD was lower in 2005 and 2006 and higher in 2007 compared to the other years. This suggests that the processes associated with the high precipitation were different in each year and in each month.

In August 2005 and August 2006, both of the precipitation and moisture flux convergence are high and heavy precipitation was frequent. However contributions of moisture flux components were different in the two periods. Stationary flux convergence dominates the total flux convergence in August 2005, while transient flux convergence contributes largely to the total flux convergence in August 2006. These results indicate that the moisture transport associated with cyclone activity affects the heavy precipitation in August 2005, while the moisture transport associated with the mean flow of large-scale atmospheric circulation affects the heavy precipitation in August 2006.

In the next step, we will analyze relationships among cyclone activity, heavy precipitation and transient moisture flux (convergence). In addition, the other events of high precipitation during 2005-2008 will be our future work.

Keywords: Easern Siberia, Recent Change, River Discharge, Net Precipitation, Cyclone Activity

Japan Geoscience Union Meeting 2013
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ACG38-15 Room:101A Time:May 21 15:15-15:30

Ecological changes and their influences of wild reindeer populations in eastern Siberia

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Reindeer *Rangifer tarandus*, known for large-scale seasonal migration, is widely distributed in the Arctic and sub-Arctic regions, and the northern indigenous peoples have been living with them. Though reindeer may be influenced by changes in hydrological cycle and vegetation with global warming, there is little information about the present status of wild reindeer in eastern Siberia. In our preliminary survey (interviews to local people) in the Sakha republic, each local population has changed in its number and distribution by plural factors originated in the climate change. Therefore, we started tracking 15 wild reindeer (7 males and 8 females) in their summer range of the upper Olenek area by using the ARGOS satellite positioning system from August 2010. We found that this summer range is used by at least two populations; a northbound migration group (NMG) and a southbound migration group (SMG). Their migrating distances and their wintering landscapes are quite contrastive; forested area (tyga) 500km far from the capturing points for SMG, and open land (tundra) about 1000 km for about NMG. The wintering range of SMG is forested area which has been thought as that of other subspecies, forest reindeer *R. t. fennicus*. We should analyze their genetic status (tundra, forest, or crossing), because there is a ”conservation dilemma” in the overlap area of these 2 subspecies. And also the genetic analysis should be needed between these 2 migration groups and semi-domestic reindeer, because large scale abductions of semi-domesticated reindeer by the wild may occur along these unknown new migrating routes. Each reindeer population used different habitat and different route every year, and showed frequent wandering behavior in small number. These ecological changes of reindeer populations are introducing their low growth rate, local high foraging pressure on vegetation, strong competition with musk ox, high-cost reindeer hunting, expansion of wild wolf range, and high predation pressure on domestic reindeer and horses. Thus, we need more complex conservation policies, with ecosystem-level management and rights protection of northern minorities.

Keywords: eastern Siberia, wild reindeer, migration, global warming, northern indigenous peoples, vegetation

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ACG38-16 Room:101A Time:May 21 15:30-15:45

CRYOSPHERIC STUDY IN THE GRENE-ARCTIC PROJECT

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During the first intensive observing period in 2012, glacier research in Siberia and ice sheet research in Geenland are carried out. Snow cover research and local weather research groups set the instruments in the various research fields, in Scandinavia, Alaska and Siberia. This study tries to overviews the regional variations of cryospheric conditions from the Arctic climate system. Regional cryospheric reports and circum-Arctic weather conditions in 2012 summer indicates a trans-Arctic cryosphere-weather conditions, connecting Greenland melting, Siberian dry and hot summer, and instabilities of Siberian coast, northern Greenland and Japanese monsoonal weather. Alternative temperature patterns and over Arctic regions causes regional warm/cool area and temperature gradient zones.

Keywords: Arctic, Cryosphere, snow, glacier, ice sheet

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ACG38-P01 Room:Convention Hall Time:May 21 18:15-19:30

The variation of the Siberian cryosphere in the Last Millennium experiment using MIROC-ESM

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In this study, we analyze the result of Last Millennium (LM) Experiment using GCM and ESM, to verify the response of the cryosphere to the hundereds-year-scale climate change. In addition to the sensitivity analysis between the forcing conditions, comparison with existing climate/paleoclimate data. The period of the LM experiment covers the Little Ice Age and Medieval Climate Anomaly, and responses of the cryosphere during those periods are of interest.

The models used in this study are the Atmosphere-Land-Ocean General Circulation Model MIROC and the Earth System Model MIROC-ESM. Resolution of atmosphere/land components are T42 (ca 2.8?) in horizontal, 80 layers in vertical. Ocean component has a resolution of 1.4? (longitude) by variable 0.56?1.4? (latitude) in the horizontal and 44 levels in the vertical. As an ESM, MIROC-ESM has a carbon-cycle components for the land and ocean ecosystems. Setup of the experiments follow the protocol of model inter-comparison CMIP5/PMIP3.

As preliminary results, temporal variations in surface air temperature, snow amount, and snow/rain ratio for Siberia region was analyzed. Winter warming during 20th century is clear. Signatures are shown in rise of February Temperarure, decrease in snow amount, increase in runoff during spring. Ratio of Snow fall / Precipitation is sensitive to the temperature, which may caused the above-mentioned trends in snow.

Keywords: Earth System Model, Last Millennium, climate change, cryosphere

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ACG38-P02 Room:Convention Hall Time:May 21 18:15-19:30

Vegetation distribution along environmental gradient at taiga-tundra boundary ecosystem in eastern Siberia

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Climate change is expected to cause extensive vegetation change in the Arctic. The studies from high latitude region, Alaska or northern Europe region, reveals impact of climate warming on vegetation change. However, not many studies have been done in northeastern Siberia region. We observed vegetation and species composition along the 50m transect then analyzed relation among vegetation-soil moisture-topographical level. We measured leaf delta 13C and delta 15N, leaf area index (LAI), and dry weight of above ground biomass in 10 plots along transect. Vegetation was categorized into 4 types of plant communities: driest Tree mound(Larix , Orthilia etc.), Shrub(Betula etc.), Sphagnum(Petasites etc.), wettest Hollow (Carex etc.). Isotope ratio showed species specific or taxonomic group specific character. Delta 13C of Salix, herbaceous eudicots and bryophytes increased with soil moisture. N content of eudicots plants and bryophytes were low in mid-wet area (Shrub and Sphagnum area). We suggested that recalcitrance of sphagnum litter provide low N condition, and make lower N content of leaves.

Keywords: arctic vegetation, C / N isotope, Larch forest, environmental gradient, ecosystem change, peatland

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ACG38-P03 Room:Convention Hall Time:May 21 18:15-19:30

Tree growth and tree-ring delta-13C over the past 150 years at two larch forests in eastern Siberia

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Global climate change scenarios predict an increase in average global precipitation in the present century and this change will be most pronounced in high latitudes [IPCC, 2007]. Previous studies reported that decrease in precipitation with global warming cause quite severe drought stress and consequently significant reduction of tree growth [e.g. Barber et al., 2000; Sarris et al., 2007]. However, it is not clear whether increase in precipitation causes better tree growth even under global warming, especially in dry region like as eastern Siberia. Here, we report an analysis of larch tree-ring width and delta-13C over the past 150 years in eastern Siberian.

Radial growth and delta-13C of larch tree rings were measured at two larch dominated forests; Yakutsk (YK; 62N, 129E) and Elgeeii (EG; 60N, 133E) in eastern Siberia.

Negative responses of larch tree growth to summer temperature were observed in YK for the past 100 years, which may be explained as temperature-induced drought stress [Barber et al., 2000]. On the other hand, larch trees in EG had shown no negative response to summer temperature probably due to large summer precipitation until 1990. However, the negative response with rapid temperature rise was observed after 1990 even in EG. Since 1990, higher tree ring delta-13C reveled iWUE (intrinsic water-use efficiency) improvements at both two sites sharply. These results indicate that higher temperature after 1990 cause more severe drought resulting in great improvement of iWUE and reduction of tree growth, suggesting that the improvement of iWUE seem to be insufficient to compensate for the negative effects of the increasing water limitation on growth.

Therefore, even if precipitation increases, reduction of larch tree growth and in consequence the fall of the carbon assimilation of a forest in eastern Siberia under global warming might is expected.

Keywords: Taiga forest, Larch, Tree ring, Carbon isotope ratio, Global warming, Drought

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ACG38-P04 Room:Convention Hall Time:May 21 18:15-19:30

Carbon dioxide exchange of larch forest at eastern Siberia - effect of canopy structure and soil environment

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To improve our understanding of CO_2 exchange over eastern Siberia boreal forest, two observation sites at a larch dominated forest were compared. The dominant species in the forest is larch composing the upper canopy, mixed with mainly birch and willow, although distribution ratio differs at each forest. The difference in atmospheric environment was small at 2 sites, but soil properties such as soil thawing ratio and soil water content was different. There was difference in 1.5 times between the CO_2 uptake fluxes in 2 sites, although a difference was not found in ability for photosynthesis of the unit leaf scale. The difference in canopy scale response to environmental condition such as solar radiation, air temperature, and humidity between the sites, which might reflect the dominant species and canopy structure in each forest, was observed. Environmental factors to explain a temporal variability of CO_2 uptake flux extracted by a multiple regression analysis, was different for each sites. Variability including difference in sites was explained mainly by soil water and ground temperature.

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ACG38-P05 Room:Convention Hall Time:May 21 18:15-19:30

Observations on stable water isotopes in permafrost and surface water in taiga-tundra boundary ecosystem of northeastern

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Eastern Siberia is covered by permafrost which is the largest and the deepest in the world, and permafrost plays an important role for hydrologic cycles in the area. Degradation of permafrost system, therefore, may have a great impact on the hydrologic regime, consequently, on the material cycling including greenhouse gas emission, through vegetation changes. Isotopic composition of water is powerful tool for investigation of hydrological processes.

Observations on the water isotope ratios of soil moisture and permafrost ice were conducted near Chokurdakh, Russia. Indigirka river water and precipitation were also sampled, in order to know the hydrological processes in the area.

Landscape of the Observational site consists of various types of wetlands (wet area) and hummocks which includes micro ridge growing larches (tree mound). At an intensive observation site (site K), 15m or 30m transect including different vegetation types were set and obtained permafrost cores down to 1m.

The isotope ratios of Indigirka river water showed the clear seasonal variation; decrease was found in spring with a runoff of snow melt water. The isotope ratios of Indigirka tributary showed year to year variation. In 2010 and 2012, it was higher than that of mainstream, while it showed the same values as that of mainstream in 2011, when the river water level was unusually high. This result shows water from mainstream flowed into the tributary.

The water contents of permafrost soil depended on the surface vegetation. Ice rich layers were found below the tree mounds. The ice rich soil layer showed higher delta value than the layers above and below. This may be caused by an isotopic fractionation during freezing. Ice rich or pure ice layers at the top of the permafrost or the bottom of active layer showed low delta values, suggesting snow melt water infiltration and freeze on the top of permafrost layer.

Keywords: eastern Siberia, Indigirka river, stable water isotopes, permafrost

Japan Geoscience Union Meeting 2013
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ACG38-P06 Room:Convention Hall Time:May 21 18:15-19:30

Spatial scale-dependent characteristics of the fraction of absorbed photosynthetically active radiation

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The fraction of absorbed photosynthetically active radiation (FAPAR) is a ratio of absorbed PAR to incident PAR in plant canopies and is an important vegetation parameter and is widely used for the gross primary production estimation. The absorbed PAR and incident PAR are both spheradiances (actinic fluxes). The FAPAR definition that ignores the horizontally incident PAR component (FAPAR1d) results in unrealistic FAPAR estimates in heterogeneous forest when looking at high spatial resolution. We investigated the spatial-scale dependence of the relationship between FAPAR1d and the normalized difference vegetation index (NDVI) in highly heterogeneous Alaskan black spruce forest. We collected most of the necessary forest structural datasets used for three-dimensional radiative transfer simulation. At high spatial resolutions (0.1 m), FAPAR1d reaches 6. As the pixels are merged, it converges on the domain-average values. To estimate a domain-average FAPAR from satellite data, 5-meter or coarser resolution is required in sparse forests, depending on the canopy structural conditions and solar geometry.

Keywords: remote sensing, polar region, radiative transfer

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ACG38-P07 Room:Convention Hall Time:May 21 18:15-19:30

Ground-truthing for phenological observations by using satellite remote sensing in terrestrial ecosystem in Alaska

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Satellite remote-sensing is an useful tool to detect seasonal and interannual variations in sub- and Arctic terrestrial ecosystems with a high spatio-temporal resolution. However, from the *in situ* ecological research view point, the satellite remote-sensing approach has not been sufficiently tested and validated by ground-truthing. We examined the relationships between seasonal patterns of camera-based canopy surface indices, eddy-covariance-based gross primarily productivity (GPP) and satellite-observed vegetation indices at a daily time step by performing field studies in an open canopy black spruce (*Picea mariana*) forest in Alaska. The ratio of the green digital number to the total digital number, green-excess index, hue (in the hue, saturation, and intensity colour model), GPP, satellite-observed normalized difference vegetation index (NDVI), enhanced vegetation index (EVI) and green-red vegetation index (GRVI) showed bell-shaped seasonal patterns (increasing in spring and decreasing in autumn) and their correlations were detected. Although the upper layer of forest is fully covered by evergreen black spruce, canopy surface images mainly detected seasonal changes in forest-floor vegetation (*Sphagnum* moss and shrubs) and snow cover on the forest floor. These facts suggest the importance of the seasonal patterns of forest canopy and floor status for the observations of satellite-remote sensing in sparse boreal forest in Alaska. Further consideration of parameters such as the degree of canopy openness and the seasonal changes in forest-floor vegetation will therefore be required to accurately detect the intra- and interannual phenological changes in sub- and Arctic ecosystems by using the satellite remote-sensing approach.

Keywords: satellite remote sensing, ground-truthing, phenology, Alaska

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Interannual and regional variations of GRENE Arctic observation sites by Satellite

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GRENE Arctic climate research project has started in 2011, and snow and ice condition has been monitored. This study observes snow and ice conditions at the GRENE Arctic field site and trys to analyze interannual variations and regional differences. The observation area is distributed in Alaska, Greenland, Siberia.This study extracted daily microwave data for ten years period from the observation sites and descried snow conditions. As the snow condition affects many other researches through hydrological process and atmospheric boundary conditions, the seasonal cycle of snow condition is substantial for initiating project. Snow cover and melting periods are indicated and regional and interannual changes are summarized. Melting area and tendencies are investigated in Greenland ice sheet. This study overviews snow and related ground conditions at all major observation sites of GRENE Arctic project by using the satellite microwave data.

Keywords: Arctic, snow, satellite observation, GRENE Arctic project

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Large-scale analysis on long-term changes in the energy-water balance in the Arctic

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The long-term changes in the surface energy-water balance were analyzed at large-scale in the Arctic, using the global datasets of NCEP reanalysis (NNRP) and GPCC precipitation. The Wetness index (WI, Kondo and Xu, 1997) was calculated as the ratio of precipitation (Pr) to potential evaporation (Ep) that is estimated from the energy balance equation at the surface. The trends of WI, Pr and Ep were calculated as linear regression for 1951-2010. In northern Europe, the trend of WI was not significant because the positive trend of Pr is compensated by the positive trend of Ep. In Eastern Siberia, the negative trend of WI was attributed to the positive trend of Ep since the trend of Pr was not significant.

Keywords: surface energy-water balance, long-term changes, Arctic regions, large-scale analysis

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ACG38-P10 Room:Convention Hall Time:May 21 18:15-19:30

Diagnostic analysis of temperature changes in the Arctic region

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The Arctic region is experiencing one of the greatest warming on Earth and is expected to continue doing so in the near future. Because of the specificities of its climate, especially in terms of snow and sea-ice cover, the mechanisms associated with this warming are partly different from the ones of other regions in the world. One obvious contribution comes from albedo effect due to sea-ice retreat, but other specific mechanisms are possibly linked with this specific thermal response, e.g. in terms of cloud cover changes.

In this study, we decompose the surface energetic fluxes locally in order to consider the different factors influencing the temperature changes at the surface. The relative role of the different factors is considered for the Arctic region and for the whole globe separately in order to highlight the specificities of the Arctic warming.

Keywords: Arctic, Surface energetics, climate warming, temperature change

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Influences of the sea ice concentration and sea surface temperature to the atmosphere

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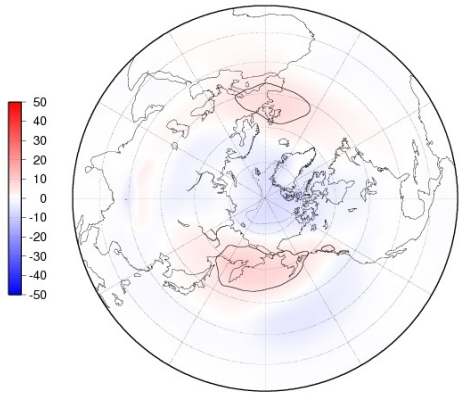
Since 1980s the sea ice extent in the Arctic Ocean has been decreasing. It is important for the climatology in the Arctic whether the sea ice exists or not. The purpose of this study is to investigate the differences of the influences to the atmosphere due to the different conditions in sea ice concentration and sea surface temperature with global atmospheric model NICAM (Nonhydrostatic ICosahedral Atmospheric Model).

Two experiments will be carried out. One is that the monthly climatology of the sea ice concentration and sea surface temperature is used as the boundary condition (normal year), and the other is that the monthly data of them in 2007 is used (less sea ice year). The time integration will be conducted for 50 years for each experiment. The sea ice concentration, sea ice mass and sea surface temperature are fixed within each month during the integration. The horizontal resolution is 112 km (glevel-6) and 40 points are taken for the vertical grid. The experiment is now in progress.

Surface air temperature over the Arctic Ocean on 2007 Experiment is much higher than that on climatological experiment especially in winter. The difference in horizontal distribution of the surface air temperature in summer season is very small compared to in winter season. The maximum difference locates where the sea ice does not exist on September but on January. The strong warming over the Arctic Ocean occurs, the difference is more than 10 degree Celsius. It is found that differences of the sea level pressure in September and January between 2007 experiment and climatological experiment shows positive AO (Arctic Oscillation) distribution, which indicates positive anomaly in mid-latitudes and negative anomaly in Arctic region.

Keywords: Polar amplification, Arctic Oscillation, NICAM, Sea ice



Japan Geoscience Union Meeting 2013
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ACG38-P12 Room:Convention Hall Time:May 21 18:15-19:30

Freshwater and nutrient distribution of the western Arctic Ocean

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In recent years, reduction of sea ice extent in the Arctic Ocean is remarkable and updated the smallest record in 2012. A marine environmental big change is concerned because heat and material become active after sea ice disappears. It is important to understand marine environment in summer as it influences sea ice formation in winter.

In this study, we investigated fresh water distribution which controls the sea ice formation/melting. We also investigated the nutrients distribution to evaluate the contribution of nutrient from porewater to the water column. Hydrographic observations and sampling were carried out in the western Arctic Ocean in 2000 and 2012 for sediment samples and 2004 and 2012 for water samples during R/V Mirai Cruise. Water temperature, salinity, dissolved oxygen, nitrients and oxygen isotope ratios (precision: 0.04 permille) were used as chemical tracers.

Water temperature was 2 degC higher in 2012 than that in 2004 whereas the difference of salinity was not obvious. Pycnocline by the low salinity water were found on the shelf between Bering Strait and Canada basin of the longtitude 168 degree west section . It was remarkable in September in 2012. As a result of calculation of mixing ratio of freshwater and Pacific water in shallower than pycnocline, 15˜30% and 10% of river water flew into the Chukchi Sea through Bering Strait in September and October, 2012 but less than 10 % in 2004. Low dissolved oxygen water was found near the bottom in 2012. It suggests that this low DO water were formed by the pycnocline with the large freshwater input in 2012.

The dissolved nitrogen to phosphate (DIN DIP ratio), salinity less than 33 and DIP $<$ 1umol/kg, increased 11.8 to 14.2 from the Bering Strait to the basin. It suggests that the water flowing from the Bering Strait should mix with nitrogen rich water as moving toward the north. In 2012, 29.3-1241umol/kg of DIN and 0.9-7.17umol/kg DIP were observed in porewater of the surface sediment. They were obviously higher than 16.1-49umol/kg of DIN and 1.04-3.3umol/kg of the bottom water (1m from the seafloor). These results indicate that addition of DIN is likely from the sediment on the continental shelf in Chukchi Sea.

Keywords: Western Arctic Ocean, freshwater distribution, nutrient, oxygen isotope ratio

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Sumilations of interannual variations in Arctic sea ice thickness with a one-dimensional vertical thermodynamic model

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Recently, Arctic sea-ice in summer decreases and the rate of decrease increases. The decrease of Arctic sea-ice affects on the climate not only in Arctic region but also in mid-latitudes, such as Japan. We have investigated the factors affecting on the interannual variations in sea ice thickness around Arctic sea ice by means of numerical experiments with a one-dimensional vertical thermodynamic model, introduced by Bitz and Lipscomb (1999). The model needs four surface flux inputs to calculate the temporal variations of sea ice thickness: downward shortwave radiation, downward longwave radiation, sensible heat, and latent heat. These four inputs are generated from the daily Japanese 25-year Reanalysis (JRA-25) and JMA Climate Data Assimilation System (JCDAS) from 1979 to the present, averaging over the area of 75-90N and 135-225E. The influences of each surface flux input on the interannual variations in sea ice thickness have been examined by conducting numerical experiments with some inputs for some seasons replaced by their 33-year daily climatology. The interannual variability and trend of the sea ice thickness in the control experiment, with all four inputs having interannual variability in all times, are in reasonable correspondence with those of the observed sea ice extent in the area. It is found that this correspondence is mainly attributed to the interannual variations in summertime longwave radiation, and that the interannual variations in summertime shortwave radiation play a role in suppressing the influences of longwave radiation. The recent decrease in sea ice extent brings the increase in upward sensible and latent heat flux from the ocean, and promotes the formation of thick sea ice in cold seasons. However, the promotion is almost canceled by the simultaneous increase in downward longwave radiation, presumably owing to the increase in air temperature and water vapor content. The results obtained with the model exhibits a strong sensitivity of the interannual variations in sea ice thickness to summertime (June and July) downward radiations.

Keywords: one-dimensional vertical model, sea ice thickness, heat balance, interannual variability

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Recent temporal change of Greenland ice sheet surface temperature and reflectance derived from MODIS data

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Rapid Arctic climate changes are reported in recent decades. Greenland ice sheet holds approximately 10% of the fresh water on earth. If it melts all, sea level rises about 7.2meter. It is reported that mass of Greenland ice sheet is decreasing with temperature rising of climate change. However many climate models aren't able to simulate the recent melting of snow and ice in the Arctic including Greenland. One of the possible causes is albedo reduction of snow and ice surface by light absorbing snow impurities such as black carbon and dust and by glacial microorganisms. In addition, there are reports that the dark region darkened with glacial microorganisms has emerged in the southwestern part of Greenland (Wientjes and Oerleman., 2010). However there are few researches for effect of glacial microorganisms in wide area. So it is important to clarify the impact of glacial microorganisms in wide area.

The goal of this study is to clarify the effect of microorganism on Greenland ice sheet surface temperature change using satellite images and observation carried out in northwestern Greenland.

In this paper, we show the temporal change of monthly average ice sheet surface temperature derived from MODIS/Aqua July in recent years, from 2002 to 2010.

We use MODIS LST Product as ice sheet surface temperature. It estimates land surface temperature using Land Surface Temperature Algorithm based on split window method (Wan et al., 1996). We analyzed surface temperature on dark region (68.45N, 49W), downstream of dark region (68.45N, 50W) and upstream of dark region (68.45N, 48W).

Monthly average ice sheet surface temperature is falling in recent years around dark region. The rate of temperature change on downstream is -0.08 degree Celsius per year and the rate of temperature change on upstream is -0.07 degree Celsius per year. The rate of temperature change on dark region is -0.007 degree Celsius per year, it shows less change than the other area. It is considered that low surface reflectance advances solar radiation absorption caused by glacial microorganism. Cooling on the other area seems to be caused by appearance of low temperature ice body under the snow cover especially downstream of dark region. Low temperature ice body controls glacial microorganism growth. Cooling trend on downstream of dark region is caused by suppression of glacial microorganism.

In the future, in order to clarify the relationship between temperature change and glacial microorganism, we will develop product to determine the quantity of glacial microorganism by satellite images.

Keywords: Greenland, Surface temperature, Reflectance, Glacial microorganism