Validation of soil moisture contribution to near surface temperature by numerical sensitivity experiment in Northeastern Asia

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Variations of near surface temperature of June-August due to difference soil moisture (SM) product is investigated by numerical experiments utilizing WRF model in Northeastern Asia. A 30-year (1981-2010) numerical experiment has conducted using ERA-interim reanalysis data as an initial and boundary condition to clarify the importance of SM contribution to the JJA extreme temperature and heat wave (HW). SM is known to be an important parameter to influence temperature by regulating surface energy balance through latent and sensible heat fluxes. To evaluate SM contribution to JJA temperature under similar atmospheric circulation, two experiments, reanalysis-SM (R-SM) as a control and satellite-SM (S-SM), have been compared. Both experiments were conducted during 20th May through 1st September. The S-SM experiment used initial SM condition derived from European Space Agency-Climate Change Initiative (ESA-CCI) dataset. During the numerical integration, SM can evolve as a result of atmosphere-land interaction. The model experiment has successfully generated the increasing trend of HW for frequency and intensity in R-SM. The result shows that S-SM experiments have improved the maximum surface air temperature and HW by 1.1˚C and 0.7 days year^{-1} on average during 1981-2010 in Mongolia. The amount of rainfall is reduced due to using S-SM as an initial condition in comparison to R-SM. In addition to rainfall, enhanced interaction of land and atmosphere is simulated in S-SM run, which higher positive anomaly at 500 hPa has developed in S-SM than R-SM by major HWs. Therefore sensitivity experiments confirm that ERA-interim estimates more SM in Northeastern Asia which results underestimate temperature and overestimates rainfall by model.

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Time-lag effects of forest ecosystem response to climate change in continental dry climate zones over the circum-Arctic; a multiple approach using satellite images and tree-rings analyses

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Circumboreal forest ecosystems are exposed to a larger magnitude of warming in comparison with the global average, as a result of warming-induced environmental changes. Understanding the sensitivity of tree growth to climate in these ecosystems is an important factor in the accuracy of future projections of the terrestrial carbon cycle, and also of global climate. However, it is not certain how these ecosystems respond to these changes.
In this study, we compared past 30 years spatio-temporal variation of Global Inventory Modeling and Mapping Studies (GIMMS) satellite derived normalized difference vegetation index NDVIg, its recent successor version NDVI3g, and tree-ring width index (RWI) on International Tree-Ring Data Bank (ITRDB) over circum-arctic region (>50N) with respect to relationship with climate change. The comparisons are conducted for linking those indices each other and for obtaining better estimate of vegetation activity response to climate change.
We calculate correlation coefficients between those indices and both previous and current year meteorological data, for each grid/site, and higher correlation coefficients were considered as actual response of forest ecosystem. Given the time lag effects of RWI or NDVI response to climate change, above indices in continental dry regions such as inner Alaska and Canada, southern part of Europe and southern sections of the Rena river basin in eastern Siberia tend to show significant negative correlation with summer temperature of previous year, suggesting further reduction of ecosystem carbon uptake with future warming.
Our findings highlight that the time lag effects of forest ecosystem response to climate change significantly affects relationships between both NDVI and RWI, and climate variables and it therefore should be incorporated into future carbon cycle studies. Otherwise, future projection of forest ecosystem carbon uptake may be overestimated under expected future further warming.

Keywords: Arctic and sub-Arctic ecosystems, carbon cycle, tree ring, remote sensing

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The role of vegetation change upon polar amplification in warm climate by feedback analysis

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Previous studies revealed that vegetation change in high latitude (e.g. from tundra to forest) in warm climate strengthen a polar amplification. This is due to lower vegetation albedo of forest then tundra, snow-albedo feedback caused by early snow melt due to forest coverage and ocean heat emission in autumn and winter. In the present study, we run a vegetation–coupled general circulation model with a slab-ocean, MIROC-LPJ, for two kinds of warming experiments. One is due to higher atmospheric CO2 concentration (2xCO2 and 4xCO2) and the other is due to the difference of the Earth’ s orbit (mid-Holocene and the Last Interglacial). The result shows different mechanisms of warming amplification between CO2-induced vegetation feedback and orbit-induced vegetation feedback. We also try to apply a feedback analysis (Cai and Luo 2009; Yoshimori et al. 2014) to result of MIROC-LPJ experiments.

Keywords: polar amplification, vegetation, paleoclimate

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Projecting future greenhouse gas release by global land surface-vegetation coupled model with explicit permafrost dynamics

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Permafrost is distributed widely over polar region. Polar region is sensitive to climate change owing to the feedback processes related and ice and snow. Increase in permafrost temperature and thickening of active layer of frozen ground (upper layer of permarfrost where frozen ground thaws in summer and freezes again during the autumn) are already observed. In addition, large-scale and irreversible melting of ice-rich permafrost layers called “Yedoma” and their ground subsidence are also reported in various places. Permafrost contains large amounts of organic carbon that has not been decomposed since last ice age, and thus melting of permafrost cause increase in the atmospheric greenhouse gases and possibly contribute to positive feedback to global warming. However, considerable uncertainty remains in the possible effects of permafrost melting on future climate change because global distribution of permafrost and details in the processes of GHG release from the permafrost are not known well. In the three-year project “Assessing and projecting greenhouse gas release from dynamic permafrost degradation” (2-1605, Environment Research and Technology Development Fund of the Ministry of the Environment, Japan: 2016-2018), we aims to assess and project the impacts of greenhouse gas release through dynamic permafrost degradation through in-situ and remote (e.g., satellite and airborn) observations, lab analysis of sampled ice and soil cores, and numerical modeling, by demonstrating the vulnerability distribution and relative impacts between large-scale degradation and such dynamic degradation. In this presentation, we report the status of the numerical modeling. We use a global physical land surface model MATSIRO (Takata et al. 2003, Nitta et al. 2014), which is a component of global climate model MIROC (Watanabe et al. 2010). In addition, a global land vegetation model VISIT (Ito et al. 2012) is coupled to MATSIRO and exchange variables such as soil moisture, temperature, and leaf area index with each other. We improved the physical processes related to permafrost melting (e.g., increasing in numbers in vertical layers; considering of changes in thermal conductivity of frozen/unfrozen soil water, and shielding effect by soil organic layer) in MATSIRO and found that seasonal distributions of permafrost tend to be improved. We also try to implement the carbon dioxide and methane release due to permafrost melting in VISIT to estimate the future greenhouse gas emission.

Keywords: Permafrost, Greenhouse gas, Climate change

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Estimation of the Siberian fire in September 2016 on the concentration of ozone and BC in the Pan-Arctic region using a regional chemical transport model

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Black carbon (BC) particles strongly absorb sunlight, and it has recently emerged as a major contributor to the global climate change, possible second to CO2 and methane. BC is produced both naturally and by human activities as a result of the incomplete combustion of fossil fuels, biofuels, and biomass. It is also known as a component of PM2.5, and influences on the human health. BC also changes the Earth’s albedo by changing the color of ice and snow via deposition into the surface, and the impact of BC on the climate change seems to be larger at polar region than that at the rest of the world. To estimate the impact of biomass burning on the concentration of BC and other pollutants, we had conducted model simulations over the Pan-Arctic region using a regional chemical transport model (WRF-Chem version 3.8.1). The initial and lateral boundary conditions for the meteorology were taken from NCEP-GFS. RACM and GOCART modules were used for the gaseous and aerosol chemistry, respectively. Anthropogenic emissions were based on EDGAR 4.2, and the biomass burning were based on the near-real-time version of FINN for each day. A pyro-convection process was also considered for the estimation of vertical profiles of biomass burning emissions. In the aerosol module of the model, BC particles were assumed to be emitted as hydrophobic BC, and were converted into hydrophilic BC by the folding time of 2.5 days. Biogenic emissions of VOCs were estimated by MEGAN 2.1 which is included in the model to use the meteorology and radiation calculated in the model for each time step. 50-days calculation with 15-days spinup was conducted from August to October 2016, when the Siberian forest fire were estimated to be quite active in the NCAR FINN inventory. To estimate the impact of biomass burning, we have conducted two calculations; 1) full emissions (anthropogenic, biogenic, and biomass burning) and 2) without biomass burning emissions (anthropogenic and biogenic). Meteorological field was compared with the observational data from the ship-based observation on R/V Mirai at the Arctic Ocean and Bering Sea, and model succeeded to reproduce the general variations of meteorological field such as the passage of low pressure systems. BC concentration at the surface level was increased over the Bering Sea after 25 September, and the main cause of the increase was estimated to be the biomass burning at around the Lake Baikal in late September. Biomass burning emissions of NOx and VOCs also increased the concentration of ozone around the source region, and it reaches 40 ppbv as the maximum.

Keywords: Black Carbon, regional chemical transport model, Pan-Arctic, biomass burning

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Weather Conditions During Large-Scale Widespread Forest Fires in Siberia: Conditions in Southern Sakha

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In this vast Russian boreal forest, forest fires occur every year in various places. By analyzing Moderate Resolution Imaging Spectroradiometer (MODIS) hotspot data for more than 10 years, frequent fire regions in the Russian Forest are gradually becoming evident. In this report, we show the results of analyzing weather conditions of large forest fires in the boreal forest of Southern Sakha.
Large-scale forest fires depend on weather conditions after the occurrence of a fire. The authors have already clarified and reported synoptic scale weather conditions for recent large-scale fires in Alaska by analyzing MODIS hotspot data from 2003 to 2015. In Alaska, the top four fire periods occurred under similar unique high-pressure fire weather conditions related to Rossby wave breaking (RWB). Following the ignition of wildfires, fire weather conditions related to RWB events typically result in two hotspot peaks occurring before and after high-pressure systems move from south to north across Alaska. A ridge in the Gulf of Alaska resulted in southwesterly wind during the first hotspot peak. After the high-pressure system moved north under RWB conditions, the Beaufort Sea High developed and resulted in relatively strong easterly wind in Interior Alaska and a second (largest) hotspot peak during each fire period. In addition to these weather conditions, low-pressure-related fire weather conditions occurring under cyclogenesis in the Arctic also resulted in high fire activity under southwesterly wind with a single large hotspot peak.
In boreal forest of Southern Sakha, large-scale forest fires occurred in 2002 and 2012. As a result of examining the weather conditions of four hotspot peaks in July and August of both years, two patterns of high-pressure and low pressure were also confirmed like in Alaska. In the high-pressure type, ridge was formed north of Yakutsk. In the low-pressure type, it became clear that low-pressure system in the Arctic Ocean played important role.

Keywords: Widespread fires, MODIS hotspot, Jet stream meandering

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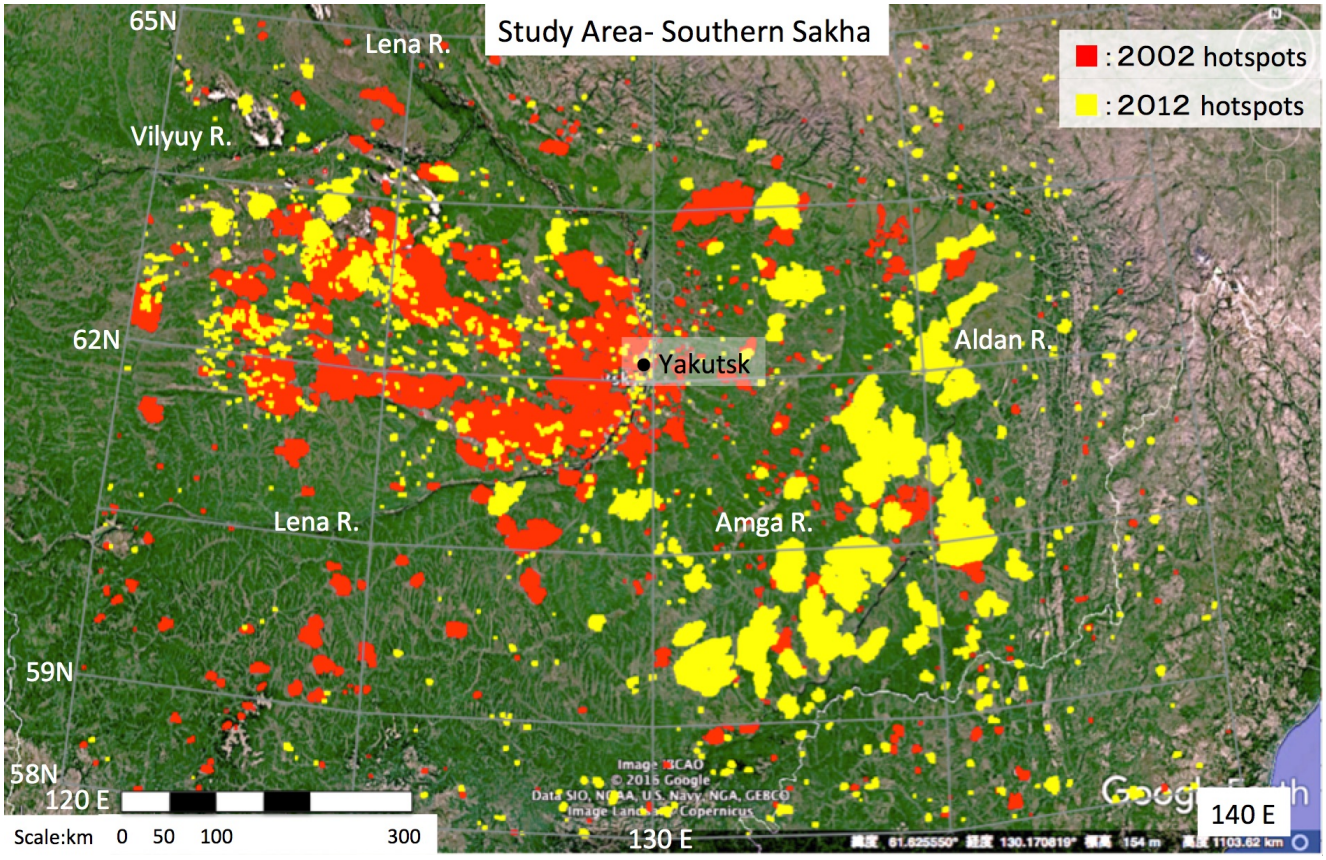

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Interannual variability of summer precipitation over northern Eurasia in multiple climate models

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Global warming is projected to be amplified in high-latitude region. Because the Arctic sea ice loss has been already beginning to appear, hydrological cycle in the northern part of Eurasia may be affected by the global warming and the Arctic sea ice reduction. Fujinami et al. (2016) showed summer precipitation increased after 1980 in northern Eurasia, and Hiyama et al. (2016) discussed a possible effect of the recent Arctic sea ice reduction on the modulation of interannual variability of summer precipitation. Such changes are important issues for the current environment including the ecosystem over northern Eurasia In addition, the reliable future projection and understanding of the hydrological cycle system are also important for mitigation and adaptation of future environmental changes.
In this study, we investigated characteristics of interannual variability of summer precipitation in northern Eurasia in 16 climate/earth system models, which have been used for the projection of future climate change, to assess whether recent global warming and the Arctic sea ice reduction affect realistically the northern Eurasian environment in the models. To reduce uncertainty related to oceanic change, we used data of the historical simulations of CMIP5 from 1979 to 2008 with observed sea surface temperature (SST) and sea ice conditions.
The spatial distribution of precipitation averaged for summer (June-July-August) in northern Eurasia in each model is similar to the observed one. Unlike the observed increase in summer precipitation in Siberian region (Fujinami et al. 2016), there is no model showing a remarkable increase trend of summer precipitation averaged over Siberian region. EOF analysis was performed for each model to extract the leading modes of interannual variability of summer precipitation in northern Eurasia. Although the EOF spatial patterns differs among the models, the first three EOF patterns of many models includes a pattern similar to the east-west seesaw pattern, which is a leading mode of the observed interannual variability. Furthermore, Hiyama et al. (2016) showed difference in the interannual variation pattern of observed summer precipitation in the northern Eurasia between the two periods before and after 1990, and also discussed the relationship between this difference and the Arctic sea ice reduction. Then we compared the frequency of EOF score values between the first 10 years (1979-1988) and the last 10 years (1999-2008) in each model. In many models, the mean or variance of score values at an EOF mode changed significantly between the periods. However, the spatial pattern of the EOF where the frequency change of the score value occurred was not similar between models.
As a result, the characteristics of interannual variability in northern Eurasia differ greatly among the models. However, it turned out that the observed east-west seesaw mode was included as one of the interannual variability in almost all of the models. In addition, some models revealed that the interannual variability of summer precipitation in northern Eurasia modulated after 1980, as discussed in Hiyama et al. (2016). In this presentation, atmospheric circulations related to the EOF modes are also shown.

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Research Letters, 11(6), 065001, doi:10.1088/1748-9326/11/6/065001.

Keywords: Interannual variability of summer precipitation, northan Eurasia, global warming

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How Predictable Summer Arctic Cyclones in 2012 and 2016 Were?

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Arctic cyclones (ACs) have a long lifetime and a wandering track in the Arctic region. The structures of the ACs are characterized by the warm and cold cores at upper and lower levels, downward and upward drifts at upper and lower levels, and barotropic relative vorticity. ACs have large impacts on the Arctic systems like the sea water temperature and the sea ice. ACs also have social impacts on the Northern Sea Route of ships and the Polar Route for airplanes. Therefore, accurate predictions of ACs are important for environmental and social concerns.

Extreme ACs occurred in August 2012 and 2016. The AC in 2012 (AC2012) was generated over the north of the Eurasia on 2 August 2012. The minimum sea level pressure (SLP) of 964 hPa for the AC2012 was recorded on 6 August 2012. On the other hand, the cyclogenesis of the AC in 2016 (AC2016) was over the north of the Scandinavian Peninsula on 11 August 2016. The minimum SLP of 967 hPa for the AC2016 was recorded on 16 August 2016. Although the positions of the cyclogenesis were different, both ACs recorded the minimum SLP over the Pacific sector of the Arctic Ocean. In both cases, the AC merged with a cyclone connecting with an upper polar vortex over the Arctic Ocean few days before the development of the AC. Some previous studies indicated that the AC2012 contributed greatly to the record low sea-ice extent in that summer. Similarly, it is thought that the AC2016 could have an influence on the decrease in sea-ice cover, since sea ice extent in early September of that year was the second lowest on record.

In this study, we investigated the predictability of the extreme ACs in August 2012 and 2016, using operational medium-range ensemble forecasts provided by The Interactive Grand Global Ensemble (TIGGE). The minimum SLP of the AC2012 on 6 August was well predicted by CMC, ECMWF, and JMA (NCEP and UKMO) members 2 (3) days in advance. Some ECMWF and NCEP members initialized in late July 2012 also predicted the development of the AC2012. On the other hand, the minimum SLP of the AC2016 was more predictable than that of the AC2012. The development of the AC2016 was well predicted by ECMWF members 6 days in advance and by CMC, JMA, NCEP and UKMO 3 –5 days in advance. Comparisons between higher- and lower-skill members revealed that the accurate prediction for the development of the upper warm core could lead to the accurate prediction of the AC development in both cases. Baroclinic growth and subsequent nonlinear dynamics during the merging contributed to the development of the upper warm core. Even if the baroclinic growth was predicted well, predicted AC did not develop when the merging was not predicted accurately. Therefore, a correct prediction of for the AC track is one of the important factors for accurate prediction of the AC development. The predicted cyclone track was similar to the observed cyclone track when the upper-level wind was predicted well. In conclusion, the accurate prediction of the upper-level wind can lead to the correct prediction of the ACs through the development of the upper warm core.

Keywords: Arctic cyclone, warm core, cyclone merging, ensemble forecast

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Influence of Springtime Eurasian Snow Cover Retreat on Atmospheric Circulation over East Asia

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According to the 5th Assessment Report of the Intergovernmental Panel on Climate Change, springtime snow cover extent over the Northern Hemisphere (NH) is greatly retreating since 1990’s. Recent study also pointed out that vanishing cryosphere may affect extreme summer weather in NH mid-latitudes. In this study, we investigate impacts of springtime Siberian snow cover fraction (SCF) change on atmospheric circulations in Northern mid-latitudes, especially over the East Asia, using a new satellite-observed SCF product by JAXA and the Japanese 55-year Reanalysis dataset.
Composite analysis suggests that, when the SCF over Western Siberia is significantly low in April, upper and middle tropospheric jet stream over Japan shifts southward in April and the following June. Land surface temperature significantly increases and soil moisture significantly decreases over southern part of Western Siberia and Central Asia in June. In addition, sensible heat flux from the surface to the atmosphere significantly increases in May and June, and significantly warms the atmosphere over there. These results suggest that the reduction of snow melted water suppresses evaporation of soil moisture when snow vanished, and causes warmings of the land surface, increases in the sensible heat flux, and warmings of the middle and upper air, which may affect the atmospheric circulation changes.

Keywords: Global warming, Snow cover, Land and atmosphere interaction

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Variation of recent annual snow depositions estimated on the 2016 pit observation at the East Greenland Ice Core Project (EGRIP) camp

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East Greenland Ice Core Project (EGRIP), which is an international ice coring project led by University of Copenhagen in Denmark, commenced in 2015 to clarify the variations of climate and ice sheet in Greenland. We are participating in the project under the Arctic Challenge for Sustainability project (ArCS), and cooperative research is underway with various countries. We dug two pits with depths of 4.02 and 3.18 m at the EGRIP camp (75°37′N, 35°59′W) to estimate recent annual and seasonal snow depositions and concentrations of chemical species and dust particles in the snow samples. Snow sampling and snow density measurement were carried out at 0.03 m interval in those pits. Currently, measurements of the water stable isotope (δ^{18}O and δD) for the 4.02-m deep pit have been completed. Clear seasonal variations in the stable isotopes of water were observed in the depth profiles, which suggested that snow had accumulated regularly every year. Also, the seasonal cycles of δ^{18}O and δD showed the pit included snow deposition corresponding to nine years covering 2008–2016. The annual snow depositions ranged from 99 to 247 mm water equivalent (w.e.), showing the mean value of 167 mm w.e. The pit observation of 2 m deep conducted at North Greenland Eemian Ice Drilling (NEEM) camp in northern Greenland reported that the mean annual snow deposition was 176 mm w.e. during the years 2006–2008, and the value was on the same level with that at the EGRIP. The profile of snow density in the pit indicated a seasonal variation, in which the density increased in the winter layers and decreased in the summer layers. The same trends were also found at NEEM and Summit in Greenland in the previous studies (Albert and Shultz, 2002; Kuramoto et al., 2011). A wind-pack effect in winter may cause the higher density observed at EGRIP, as discussed in the previous studies. We will also show analyses of the chemical species and dust particles for the 4.02-m deep pit and results of the 3.18-m deep pit on the presentation.

Keywords: Greenland, ice core, mass balance, snowpack, stable isotope ratio

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Seasonal variations of Greenland ice sheet surface reflectance and brightness temperature derived from Terra/MODIS and GCOM-W/AMSR-2

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Dark ice area expansion on the Greenland ice sheet is one of the factors to cause albedo reduction and mass loss of the ice sheet in recent years. Dark ice appears on ablation area in summer and accelerates melting of the ice sheet due to its intense light absorption. Dark ice is due to impurities in the surface ice such as mineral particles, glacial microbes, organic matter and their aggregate called cryoconite granules. Cryoconite granules are formed by microbial activities and are darker than abiotic mineral particles. Since the microbes can be active only on melting ice surface, duration of surface melting on the ice sheet possibly affect the microbial activities and thus formation of cryoconite granules. Therefore, spatio-temporal variation in surface melting is important to understand the darkening process.
We report seasonal variations in surface reflectance and brightness temperature derived from Terra/MODIS and GCOM-W/AMSR-2 satellite images in order to understand relationship between darkening and surface melting processes of the ice surface from April to August in 2013, 2014, 2015 and 2016. Reflectance (660 nm) and brightness temperature (18 GHz Horizontal polarization) were investigated at the nearest neighbor pixel of the Automatic Weather Station (67.07N, 48.83W) installed by PROMICE. The brightness temperature showed similar timing of the onset of surface melting in 2013 and 2015. In these years, the melting onset occurred in early June. On the other hand, the melting onset occurred in mid May in 2014 and 2016. The surface reflectance started to decrease down to around 0.4 in mid July 2013 and early July 2015. In contrast, it rapidly decreased down to around 0.4 in the end of June 2014 and early June 2016. These results suggested that earlier onset and prolonged period of the surface melting causes the earlier appearance of the dark ice surface.

Keywords: Greenland ice sheet, satellite remote sensing, dark ice

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Long-term variability in land snow cover, sea ice extent and ocean color in Arctic region

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Satellite-based observations revealed that sea ice extent and land snow cover in the Arctic region have decreased since 1979 under the influence of warming trend. Reduced sea ice cover increases open water area, a longer growing season, and annual net primary production (NPP) by phytoplankton. The greatest contribution to the Arctic Ocean’ s fleshwater input is the discharge from terrestrial rivers. Because river inflow supplies a large amount of nutrient salts and organic matter to the ocean, change in the discharge affects the Arctic Ocean’ s NPP. Thus, successive observations on sea ice extent and land snow cover are crucial to understand the influence of those area reductions on marine ecosystems in Arctic region. In this study, we used multiple optical and microwave radiometric satellite data for 1978–2015 to analyze land snow cover, sea ice extent and ocean color in the northern hemisphere. Sea ice extent deceased during the observation period with the mean rate of 200 km^2 a^{-1}. Snow cover extent decreased in all seasons (winter, spring, summer and autumn) from 1978 to 2015. Decreases in land snow cover and sea ice extent are likely to affect to seasonal and inter-annual variabilities in the amount of freshwater inflow to the Arctic Ocean. However, no clear trend of the ocean color (chlorophyll-a concentration) was observed with statistically significant in this study. To better understand relationship between spatiotemporal variabilities in these factors and other physical parameters, we also analyze variability in sea surface temperature and meteorological parameters and examine their cross-correlation relationship in space and time.

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Effect of subglacial meltwater plume formation on phytoplankton growth in the fjord of Bowdoin Glacier in northwest Greenland

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In Greenland, marine-terminating outlet glaciers discharge turbid subglacial meltwater into fjords. The area influenced by the turbid water near the calving front is well known as an important foraging hotspot for higher trophic animals. Glaciers may therefore play an important role in ecosystem productivity within the fjords by releasing an essential macronutrient for primary producers. However, since there are few available data on the macronutrient delivery with the meltwater inputs, processes of macronutrient supply to surface waters are poorly understood. Here we present a hydrographic and geochemical dataset from Bowdoin Glacier and its fjord in northwestern Greenland during the summer of 2016.
On the glacier, meltwater contained few macronutrients (<0.5 μM NO_3+NO_2) indicating that supraglacial meltwater is not a significant source of macronutrients in the fjord. At the surface of a meltwater plume near the calving front, water properties were largely different from surface waters outside of the plume. The concentration of surface macronutrients inside the plume was an order of magnitude higher (~12.8 μM NO_3+NO_2) than that outside of the plume (<1.6 μM NO_3+NO_2). Additionally, salinity (~33.0) and the content of suspended particles (~132 mg/L) inside the plume were notably higher than those outside of the plume (salinity ~15.4; suspended particles ~22.3 mg/L), suggesting upwelling of nutrient-rich, saline deep water including substantial sediment derived from subglacial weathering. Oxygen isotopic compositions of the glacial meltwater, plume, and fjord water also indicated that the glacial meltwater upwells as a buoyant flow, drawing the nutrient-rich deep water into the fjord. Within a vertical cross-section along the centerline of the fjord, highly turbid water was observed in sub-surface layer at depths of 10–50 m. Less saline water with low macronutrients concentration was on top of this highly turbid water. Phytoplankton blooms (~6.5 μg/L chlorophyll a) was observed near the boundary between the less saline water and the turbid water. The concentration of macronutrients was sufficiently high (~10 μM NO_3+NO_2) in this area to generate the bloom. Overall, our study results show that turbid meltwater discharge from Bowdoin Glacier affects nutrient availability and the subsequent growth of phytoplankton in the fjord. Upwelling and transport of macronutrients associated with subglacial meltwater plume formation is an important process for phytoplankton growth in the near-surface layer.

Keywords: Greenland, Bowdoin Glacier, Macronutrient, Turbid meltwater discharge

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Fe, Mn, Cd, and Pb Quantitatively Analysed in Sea Ice

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Sea ice plays a significant role in polar oceans. During sea ice formation both dissolved and particulate sea water constituents (trace metals, macro-nutrients, sediments, etc) accumulate through scavenging or suspension freezing (Reimnitz et al., 1992,1993; Nürnberg et al., 1994). This can allow for sea ice to hold trace metal concentrations higher than the underlying water (Grotti et al. 2005; Tovar-Sanchez et al. 2010). Floating (pack) sea ice can then transport incorporated materials into new areas as it melts, seeding the water community below (van der Merwe et al., 2011). Although many studies have looked at sea ice and trace metals, the mechanism and geochemical cycling role for trace metal accumulation is still largely unknown (Kanna et al., 2014). In this study we examined the following metal fractions for Fe, Mn, Cd and Pb: Dissolved (D, <0.2μm), and Labile Particulate (LP, Total Dissolvable - Dissolved) from Chukchi Sea pack ice and the surrounding seawater (shelf and coast). Samples were pre-concentrated utilizing the solid-phase extraction NOBIAS Chelate PA1 resin (Hitachi High-Technologies) following a modification of Sohrin et al. (2008) and Kondo et al. (2016) methods. Finally, samples were analyzed on a Graphite Furnace Atomic Absorption Spectrometer (GFAAS). Applying the modified solid-phase extraction method on sea ice measurements allowed us to accurately detect low levels of trace metals. Utilizing this method allowed us to gain insightful information on the geochemical cycling of trace metals within sea ice.

LPFe, LPMn and LPPb composed 98-99% of Fe, Mn and Pb in Chukchi sea ice where LPCd was 84%. Although Cd and Pb were detectable, the concentrations for the dissolved and labile particulate fractions were very low (0.05±0.04nM –6.3±5.9nM). Overall in sea ice and seawater, the labial particulate fraction had higher concentrations than the dissolved. Sea ice has been shown to have a temporal decoupling of trace metals (i.e. Fe), with the dissolved metals being released with the brine and particulate metals release with advanced melting (van der Merwe et al., 2011). Since our samples were collected during summer, advanced melting could have led to the dominance of the labile particulate fraction.

Chukchi seawater (shelf and coast) samples also showed the same trends where Fe and Mn had higher concentrations than Cd and Pb. LPFe and LPPb composed 99-100% of Fe and Pb in Chukchi seawater. One interesting point was that Pb was detectable in sea ice for both the dissolved and labile particulate factions but only detectable as LPPb in seawater. Mn and Cd composition in Chukchi seawater was dominated by the dissolved fraction (75% and 43% respectively). DFe is removed from seawater by oxyhydroxide formation and particle scavenging, which can give it have lower concentrations than DMn (Landing and Bruland, 1987).

Keywords: Sea Ice, Trace Metals, Dissolved, Labile Particulate

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Distribution of the Anadyr Water near the Gulf of Anadyr and the Bering Strait

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Primary production in the Bering Strait (BS) especially in the Russian side is extremely high and it is found not only in spring but also in summer and autumn seasons. It has been suggested that the continuous high phytoplankton activity is attributed to rich amount of nutrients in the Anadyr Water (AW). Although some literatures reported higher nutrients concentration in the Gulf of Anadyr (GA), similar level of primary production as the BS is difficult to be observed in the GA. In this study, we obtained a historical CTD dataset (1930–2005) compiled at the Far Eastern Regional Hydrometeorological Research Institute (FERHRI) in Russia and investigated water mass structure form the GA to the BS. We analyzed the dataset climatologically because stations of each cruise distribute sparsely. In August, while the AW with high salinity (>35 PSU) distributed near the bottom of the GA, the Bering Shelf Water was covered the surface of the Gulf. The AW was spread along coast of Russia and a part of it was found in the surface of BS. The water mass structure in this study suggests that the AW from the AG continuously supports high primary production in summer of the BS.

Keywords: Gulf of Anadyr, Anadyr Water, Bering Strait

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Interannual variability of bottom oxygen concentration and primary production in the southern Chukchi Sea biological hotspot

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Hope valley located in the southern Chukchi Sea is known as one of the biological hotspot (southern Chukchi Sea hotspot, SCH). Large benthic biomass in the SCH is supported by high primary productivity of the water column. The dissolved oxygen (DO) sharply decreases at the bottom toward fall as a result of the high sediment community oxygen consumption in the benthic fauna, while it is saturated during winter. We examined annual/inter-annual variability of bottom DO and its mechanisms analyzing ship-board and mooring hydrographic data, satellite derived primary production, and ecosystem model. The bottom DO showed large interannual variability (104–300 μM) and it was negatively and significantly correlated with cumulative primary production (r = -0.66, $p < 0.05$). Such negative correlation suggests organic carbon flux to the sea floor drives the activity of the benthic community. Environmental process of decreasing in DO was assessed using one box ecosystem model optimized for the SCH bottom layer. The model also captured bottom DO is sensitive to the flux of primary production from the upper layer. Our results suggest inter-annual variability of primary production is a key factor determining the recent changes in biomass and distribution of the benthic organisms.

Keywords: biological hotspot, primary production, bottom oxygen concentration

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Annual monitoring on lateral advection of shelf materials off the Barrow Canyon, western Arctic Ocean

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Lateral transportation of heat and materials from shelf to basin is important keys to understand ecosystem and biogeochemical cycles in the southwestern Canada Basin. The physical oceanographic model suggested that the westward advection of oceanic eddies from off the Barrow Canyon contributed to the temporal increase of high settling particle flux at Station NAP in the southern Northwind Abyssal Plain (75˚ N 165˚W). In order to monitor the shelf-basin interaction in upper stream area of Station NAP, annual bottom-tethered mooring with sediment trap and hydrographic sensors were deployed off the Barrow Canyon (Station NBC15t, 72.47˚N 155.41˚W) from October 2015 to September 2016. The trapped particles contained abundant lithogenic matters which were derived from continental shelf. Total mass flux at ~243 m depth where sediment trap was deployed at NBC15t ranged from 14.6 to 3413.9 mg m^{-2} d^{-1} before the trap clogged in June 2016. The maximum of total mass flux was one order higher than that at Station NAP. The maxima of total mass flux were observed in the periods of 5-18 October 2015 and 12-24 May 2016. In addition, the underwater camera mounted on sediment trap recorded an image with abundant particles in September 2016. The comparison with hydrographic sensor data and the video record of underwater camera suggests that shelf material component of trapped particles in October 2015 and September 2016 were supplied by intensified lateral water current in subsurface layer shallower than the deployment depth of sediment trap. The high particle flux in May 2016 is explained by intensified water current containing abundant particulate matters in limited subsurface layer between the ADCP (~125m depth) and sediment trap depths.

Keywords: Arctic Ocean, Canada Basin, Settling particle flux, Shelf-basin interaction

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Impacts of terrestrial river heat flux on the declining Arctic sea ice

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In the Arctic, the recent warming speed of surface air temperatures are the fastest among the past historical records. The consequent influences are found in changes in the Arctic freshwater system, such as increasing river discharge, changing river-ice phenology, and warming of river water temperature. The warming water temperature can result in higher heat flux flowing into the Arctic Ocean, combining with the larger river discharge, which likely enhances the melt of sea ice in the shelf area. However, very few studies quantitatively assessed influences of the river heat flux on the Arctic sea ice are available. A land surface model (CHANGE) coupled with models of river discharge, ice-cover, and water temperature through channel network was applied to the Arctic river basins over the period 1979–2013, and then we assessed influences of the river processes on sea ice, including trends of river discharge, water temperature, and heat flux. The simulation indicated obvious increases in river discharge and water temperatures over the pan-Arctic rivers, consequently flowing considerable amount of heat to the ocean. The heat fluxes were significantly correlated with changes of sea surface temperature and sea ice concentration in the coastal areas of the Arctic Ocean, especially in the spring season when the sea ice begins to melt. This emphasizes that the heat flux of terrestrial freshwater is an important factor influencing the melting process of sea ice at specifically seasonal and local scales.

Keywords: river heat flux, sea ice retreat, land surface mode, sea ice concentration

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Interannual variation of solar heating in the Chukchi Sea, Arctic Ocean

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Arctic sea ice cover in summer has declined rapidly over the past few decades. The albedo of sea ice is much higher than that of open water; reduction of sea ice cover is associated with increase of solar heating in the Arctic Ocean. In this study, we focus on solar heating in the Chukchi Sea located in the Pacific side of the Arctic Ocean where remarkable sea ice reduction has occurred. The Chukchi Sea is a pathway of Pacific Water from the Bering Strait to the Arctic Basin. The heat transport of the Pacific Water through the Bering Strait, which has increased recently, plays an important role in a decrease in sea-ice formation during winter as well as sea-ice melt in summer in the Canada Basin. Although the Pacific Water heat transport through the Bering Strait is becoming clearer, we expect that solar heating significantly modifies the Pacific Water in the Chukchi Sea. Therefore, we estimate solar heating in the Chukchi Sea through analysis of satellite-derived sea ice concentration data as well as reanalysis data of shortwave radiation, and discuss the role of the solar heating in the Chukchi Sea in the heat transport into the Arctic Basin. We also use in-situ shortwave radiation data obtained by R/V Mirai to validate the reanalysis data of shortwave radiation in the Chukchi Sea.

Keywords: Chukchi Sea, solar heating

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Pacific water fluxes through the Barrow Canyon and its effect on warming in the Arctic Ocean

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Over the past few decades, sea ice retreat during summer has been enhanced in the Pacific sector of the Arctic Basin, in part due to increasing summertime heat flux of Pacific-origin water from the Bering Strait. Barrow Canyon, in the northeast Chukchi Sea, is a major conduit through which the Pacific-origin water enters the Arctic Basin. Our study focuses on the quantitative estimate of volume, heat and freshwater fluxes through Barrow Canyon by mooring observations and its role in warming of upper layers in the Canada Basin. We conducted year-round mooring observations from 2000 to 2016 in the mouth of Barrow Canyon. The annual mean poleward volume, freshwater and heat fluxes through Barrow Canyon were 0.43 Sv, 31 mSv and 2.12 TW. The annual averaged heat flux displayed substantial interannual variability, ranging from 0.93 TW to 3.34 TW. Comparing heat content in the Barrow Canyon and satellite derived sea surface temperature around Barrow Canyon, we derive and assess a proxy for estimating heat content in the canyon for the summer time period, which is when most of the heat passes northward towards the basin. The estimated heat content shows increasing trend from 1980 to 2015 and 1.5 times larger than the average value from 1980s to 2010s. Measurements from hydrographic surveys since 1990 reveals that warming of Pacific summer water layer in the Canada Basin tended to be enhanced around 2010s, probably due to higher heat transport via Barrow Canyon into the basin in 2007, 2010 and 2012.

Keywords: Arctic Ocean, Ocean warming, Sea ice reduction

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Seasonal variability of near-inertial internal waves and its kinetic energy in the ice-diminishing Arctic Ocean

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In the Arctic ocean, the internal wave activity and its contribution to the turbulent mixing has been considered to be quite low. In the modern era, the Arctic sea-ice extent has been dramatically diminishing, and therefore there is an increased chance of kinetic energy input from the air at ocean surface. In this study, the seasonal change of near-inertial internal wave (NIW) kinetic energy is examined in comparison with local sea ice compactness and draft thickness. The local sea-ice information was obtained using an ice profiling sonar mounted at top of a moored instrumentation in the Northwind Abyssal Plain. The band-passed kinetic energy was recorded with a moored ADCP for depths within upper 110 m. The data clearly documented that the depth-integrated NIW kinetic energy varied in line with the ice seasonality, i.e., ice thickness and mobility. During ice covered months, the upper water NIW kinetic energy was approximately 1/10 of the Garrett-Munk (GM) canonical level. In the meantime, during the ice absent months of September and October, the kinetic energy levels built up closer to the GM level. The fine-scale parameterization (Gregg, 1989) estimates the turbulent mixing dissipates the incident wave energy at a rate of $O(10^{-10} - 10^{-9}$ W kg$^{-1})$. According to a mixed layer slab model (Pollard & Millard 1970), the energy input from the ice movement was 1.6 kJ m^{-2}, in which 13% was presumably dissipated through the wave-wave interaction in the upper 110 m. The ice-water combined velocity data also indicated that the mobility of sea ice floes can affect the kinetic energy amount in the upper water, suggesting the occurrence of increased turbulent energy as more unconsolidated ice exists in the future.

Keywords: Arctic Ocean , Near-inertial internal wave, Sea ice retreat

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