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JAMSTEC-IARC international collaboration enhancing understanding of the Arctic climate system

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Collaborations amongst researchers from the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan and the International Arctic research Center (IARC), University of Alaska Fairbanks (UAF), U.S., have been on-going since 1998 and resulted in a great number and magnitude of accomplishments that could not have been achieved without this close partnership. The Arctic represents an important region for Japan, the U.S. and the world, and many opportunities and challenges press for immediate understanding to enable wise decisions and policy making. We have many common interests and our countries face many common problems and goals. Addressing the tremendous scientific challenges of the Arctic requires such massive investment of manpower and resources that sharing efforts, data and working together on expeditions are in our mutual best interests.

This issue presents a compilation of selected results on recent analyses conducted in the five-year (2009-2014) research term related to observational studies, model development and remote sensing applications of the Arctic Ocean, adjacent marginal seas, and the surrounding terrestrial regions. All of these studies are intended to provide a better understanding of how individual components and processes interact to form a complex and dynamic arctic system. Through these collaborations, Japanese and UAF Arctic researchers can achieve our goals of developing a quantitative understanding of the Arctic System.

Structure of the Fram Strait branch of the boundary current in the Eurasian Basin of the Arctic Ocean

Andrey V. Pnyushkov*, Igor V. Polyakov, Vladimir V. Ivanov, Takashi Kikuchi

Recent mooring-based observations at several locations along the continental slope of the Arctic Ocean's Eurasian Basin showed a transformation of the Boundary Current (BC) from a mostly barotropic flow in Fram Strait to a jet-like baroclinic current northeast of Svalbard, and the reemergence of the barotropic structure of the flow in the eastern Eurasian Basin. This transformation is accompanied by a weakening of the flow from ~24 cm/s in Fram Strait to ~5 cm/s at the Lomonosov Ridge. The maximum of the baroclinic component of the BC at an intermediate depth (~200–370 m) is associated with the Atlantic Water core. The depth range of the baroclinic current maximum is controlled by cross-slope density gradients above and below the baroclinic velocity maximum as follows from the geostrophic balance of forces. According to the model simulations, the BC splits into shallow and deep branches in the proximity of Svalbard due to a divergence of isobaths, confirming topographically-controlled BC behavior. The shallow branch is located at a shelf break with a typical bottom depth of ~200 m and current speed of up to ~24 cm/s. The discussed results, which provide insight on some basic aspects of the dynamics of the BC (the major oceanic heat source for the Arctic Ocean), may be of importance for understanding of the ocean's role in shaping the arctic climate system state.

Configuring high frequency radar observations in the Southern Chukchi Sea

Gleb Panteleev*, Max Yaremchuk, Oceana Francis, Takashi Kikuchi

In recent years, monitoring offshore surface circulation in the Arctic Ocean with high frequency radars has become an issue of increasing practical importance. In this study, radar positions are optimized by minimizing the reconstruction errors of the surface currents in the Southeastern Chukchi Sea. By means of an adjoint sensitivity technique it is shown that in the case of a pair of radars, their optimal (i.e. most favorable) location is at Kivalina, a settlement near the strongest outflow of the Alaskan Coastal Current from the monitored domain. The least favorable location is at Shishmaref, a settlement near relatively weak inflow into the region as observed from the coast. However, if two pairs of radars are available, the best locations are Kivalina and Shishmaref. The results are verified using observational system simulation experiments (OSSEs) performed in the framework of a 4-dimensional variational assimilation of simulated radar observations into a numerical model. It is shown that correct specification of the first guess solution is of primary importance for obtaining realistic results from both adjoint sensitivity analysis and OSSEs. This emphasizes the necessity of obtaining accurate high resolution climatologies for future ice-free offshore regions in the Arctic.

Partitioning and lateral transport of iron to the Canada Basin

Ana M. Aguilar-Islas*, Robert Rember, Shigeto Nishino, Takashi Kikuchi, Motoyo Itoh

The concentration of dissolved iron (DFe) and suspended leachable particulate iron (LPFe) in the water column of the western Beaufort Sea were investigated during the late summer of 2010. Elevated concentrations of surface DFe (0.49–1.42 nM) were similar to those reported in resent studies, likely reflecting input from melting sea ice and river discharge. The rapid decrease in DFe (5.20–0.48 nM) and LPFe (88.2–1.83 nM) values observed from inshore to offshore in Pacific influenced waters, suggest scavenging processes limit the input of DFe from the shelf to the deep basin. However, frequent eddies found in this region are likely important in promoting lateral advection, as suggested by higher surface DFe concentrations at an offshore station in the vicinity of a warm-core eddy. Within the Atlantic layer, relatively homogeneous DFe (0.69–0.80 nM) and LPFe (1.18–2.13 nM) concentrations were observed at all the stations, reflecting a balance in the interplay between input and removal processes within this watermass. An input of DFe east of the Lomonosov Ridge was inferred by comparing DFe values within the core of Atlantic water between the Eastern and Western Arctic.

Sensitivity of the backscatter intensity of ALOS/PALSAR to the above-ground biomass and other biophysical parameters of boreal forest in Alaska

Rikie Suzuki*, Yongwon Kim, Reiichiro Ishii

We investigated the potential of ALOS/PALSAR 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 (150° W) 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.

Variations in fraction of absorbed photosynthetically active radiation and comparisons with MODIS data in burned black spruce forests of interior Alaska

Hiroki Iwata*, Masahito Ueyama, Chie Iwama, Yoshinobu Harazono

Absorption of photosynthetically active radiation (PAR) by vegetation was observed in two burned black spruce forests, one and seven years after wildfire, in interior Alaska along with several vegetation properties. This study considered PAR absorption by mosses by examining the relationship between PAR transmittance and fractional coverage of green vegetation. Our results suggest that mosses absorbed a considerable fraction of incoming PAR in the burned forests, which cannot be neglected in evaluating the fraction of absorbed PAR (FPAR). The relationships between FPAR and vegetation indices revealed that enhanced vegetation index (EVI) may be suitable for expressing the spatial and temporal variation of FPAR,

regardless of stand age after wildfire. The comparison between the observed in situ FPAR and FPAR derived from Moderate Resolution Imaging Spectroradiometer (MODIS FPAR) clearly showed that MODIS FPAR was highly overestimated. The most likely reason for the overestimation was identified as misclassification of land cover type. The current regional estimation of photosynthesis in boreal region based on the light-use efficiency approach and MODIS FPAR is probably overestimated, and an accurate distribution of FPAR is desired for clarifying the regional carbon exchange in boreal forests.

Seasonal changes in camera-based indices from an open canopy black spruce forest in Alaska, and comparison with indices from a closed canopy evergreen coniferous forest in Japan

Shin Nagai*, Taro Nakai, Taku M. Saitoh, Robert C. Busey, Hideki Kobayashi, Rikie Suzuki, Hiroyuki Muraoka, Yongwon Kim

Evaluation of the carbon, water, and energy balances in evergreen coniferous forests requires accurate in situ and satellite data regarding their spatio-temporal dynamics. Daily digital camera images can be used to determine the relationships among phenology, gross primary productivity (GPP), and meteorological parameters, and to ground-truth satellite observations. In this study, we examine the relationship between seasonal variations in camera-based canopy surface indices and eddy-covariance-based GPP derived from field studies in an Alaskan open canopy black spruce forest and in a Japanese closed canopy cedar forest. The ratio of the green digital number to the total digital number, hue, and GPP showed a bell-shaped seasonal profile at both sites. Canopy surface images for the black spruce forest and cedar forest mainly detected seasonal changes in vegetation on the floor of the forest and in the tree canopy, respectively. In contrast, the seasonal cycles of the ratios of the red and blue digital numbers to the total digital numbers differed between the two sites, possibly due to differences in forest structure and leaf color. These results suggest that forest structural characteristics, such as canopy openness and seasonal forest-floor changes, should be considered during continuous observations of phenology in evergreen coniferous forests.

Characteristics of evapotranspiration from a permafrost black spruce forest in interior Alaska

Taro Nakai*, Yongwon Kim, Robert C. Busey, Rikie Suzuki, Shin Nagai, Hideki Kobayashi, Hotaek Park, Konosuke Sugiura, Akihiko Ito

Here, the year 2011 characteristics of evapotranspiration and the energy budget of a black spruce forest underlain by permafrost in interior Alaska were explored. Energy balance was nearly closed during summer, and the mean value of the daily energy balance ratio (the ratio of turbulent energy fluxes to available energy) from June to August was 1.00, though a large energy balance deficit was observed in the spring. Such a deficit was explained partly by the energy consumed by snowmelt.

Ground heat flux played an important role in the energy balance, explaining 26.5% of net radiation during summer. The mean daily evapotranspiration of this forest during summer was 1.37 mm day^{-1} – considered typical for boreal forests. The annual evapotranspiration and sublimation yielded 207.3 mm year^{-1}, a value much smaller than the annual precipitation. Sublimation accounted for 8.8% (18.2 mm year^{-1}) of the annual evapotranspiration and sublimation; thus, the sublimation is not negligible in the annual water balance in boreal forests. The daytime average decoupling coefficient was very small, and the mean value was 0.05 during summer. Thus, evapotranspiration from this forest was mostly explained by the component from the dryness of the air, resulting from the aerodynamically rough surface of this forest.

Application of time-lapse digital imagery for ground-truth verification of satellite indices in the boreal forests of Alaska

Konosuke Sugiura*, Shin Nagai, Taro Nakai, Rikie Suzuki

Satellite remote sensing studies of snow cover in high-latitude boreal forests require ground-truth verification based on ground observation networks. In this study, we used time-lapse digital images to precisely detect the extent of snow cover at nine locations in the boreal forests of Alaska, and to demonstrate the relationship of these ground-truth measurements to satellite indices of snow cover. Our results show that normalized difference vegetation indices (NDVIs) and normalized difference water indices (NDWIs) show significant variations at the end and beginning periods of continuous snow cover: the NDVIs on the last days of continuous snow cover ranged from 0.12 to 0.37, and those on the first days of continuous snow cover ranged from 0.16 to 0.38. The normalized difference snow indices (NDSIs) were also positive during periods of continuous snow cover and negative during periods of no snow cover. The NDWIs varied significantly from the beginning to the end of periods of continuous snow cover. This study confirms that continuous snow cover is important for accurate phenological studies using NDVIs in the region of the trans-Alaska camera network. Simple cameras can be effectively utilized in ground-based networks, functioning not only as a ground-truth verification tools for calibrating satellite indices, but also as a source of data to fill data gaps in satellite records.

Latitudinal distribution of soil CO_2 efflux and temperature along the Dalton Highway, Alaska

Yongwon Kim*, Seong-Deog Kim, Hiroyuki Enomoto, Keiji Kushida, Miyuki Kondoh, Masao Uchida

In this paper, we investigate spatial variations in soil CO_2 efflux and carbon dynamics across five sites located between 65.5° N and 69.0° N in tundra and boreal forest biomes of Alaska. Growing and winter mean CO_2 effluxes for the period 2006-2010 were 261 ± 124 (Coefficients of Variation: 48%) and 71 ± 42

(CV: 59%) gCO_2/m^2, respectively. This indicates that winter CO_2 efflux contributed 24% of the annual CO_2 efflux over the period of measurement. In tundra and boreal biomes, tussock is an important source of carbon efflux to the atmosphere, and contributes 3.4 times more than other vegetation types. To ensure that representativeness of soil CO_2 efflux was determined, 36 sample points were used at each site during the growing season, so that the experimental mean fell within ±20% of the full sample mean at 80% and 90% confidence levels. We found that soil CO_2 efflux was directly proportional to the seasonal mean soil temperature, but inversely proportional to the seasonal mean soil moisture level, rather than to the elevation-corrected July air temperature. This suggests that the seasonal mean soil temperature is the dominant control on the latitudinal distribution of soil CO_2 efflux in the high-latitude ecosystems of Alaska.

The role of declining Arctic sea ice in recent decreasing terrestrial Arctic snow depths

Hotaek Park*, John E. Walsh, Yongwon Kim, Taro Nakai, Tetsuo Ohata

The dramatic decline in Arctic sea ice cover is anticipated to influence atmospheric temperatures and circulation patterns. These changes will affect the terrestrial climate beyond the boundary of the Arctic, consequently modulating terrestrial snow cover. Therefore, an improved understanding of the relationship between Arctic sea ice and snow depth over the terrestrial Arctic is warranted. We examined responses of snow depth to the declining Arctic sea ice extent in September, during the period of 1979-2006. The major reason for a focus on snow depth, rather than snow cover, is because its variability has a climatic memory that impacts hydrothermal processes during the following summer season. Analyses of combined data sets of satellite measurements of sea ice extent and snow depth, simulated by a land surface model (CHANGE), suggested that an anomalously larger snow depth over northeastern Siberia during autumn and winter was significantly correlated to the declining September Arctic sea ice extent, which has resulted in cooling temperatures, along with an increase in precipitation. Meanwhile, the reduction of Arctic sea ice has amplified warming temperatures in North America, which has readily offset the input of precipitation to snow cover, consequently further decreasing snow depth. However, a part of the Canadian Arctic recorded an increase in snow depth driven locally by the diminishing September Arctic sea ice extent. Decreasing snow depth at the hemispheric scale, outside the northernmost regions (i.e., northeastern Siberia and Canadian Arctic), indicated that Arctic amplification related to the diminishing Arctic sea ice has already impacted the terrestrial Arctic snow depth. The strong reduction in Arctic sea ice anticipated in the future also suggests a potential long-range impact on Arctic snow cover. Moreover, the snow depth during the early snow season tends to contribute to the warming of soil temperatures in the following summer, at least in the northernmost regions.

Relationships between variations of the land-ocean-atmosphere system of northeastern Asia and northwestern North America

John E. Walsh*, Hotaek Park, William L. Chapman, Tetsuo Ohata

This study is a broad-scale synthesis of information on climate changes in two Arctic terrestrial regions, eastern Siberia and the Alaska-Yukon area of North America. Over the past 60 years (1951-2010), the trends of temperature and precipitation in the two regions are broadly similar in their seasonality. However, atmospheric advection influences the two regions differently during winter. The differential advective effects are much weaker in the other seasons. The Pacific Decadal Oscillation is the strongest correlator with interannual variability in the two regions, followed by the Arctic Oscillation and the El Niño/Southern Oscillation.

Projected changes by the late 21st Century are qualitatively similar to the changes that have been ongoing over the past 60 years, although the rate of change increases modestly under mid-range forcing scenarios (e.g., the A1B scenario). The greatest warming is projected to occur farther north over the Arctic Ocean in response to sea ice loss. Precipitation is projected to increase by all models, although increases in evapotranspiration preclude conclusions about trends toward wetter or drier land surface conditions. A notable feature of the future climate simulations is a strong maximum of pressure decreases in the Bering Sea region, implying further advective changes.