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Promoting international, multidisciplinary efforts in detecting and understanding high-latitude changes, and searching for their global impacts

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Rapid and dramatic climate changes in the Arctic and the projection of their impacts on lower-latitude regions require careful evaluation, understanding, and use of multidisciplinary, internationally coordinated efforts. The Third International Symposium on Arctic Research (ISAR-3), devoted to these objectives, was held on January 14-17, 2013 in Tokyo, and was an essential step in this direction. The pool of papers that make up this Special Issue provides an insight into the discussions conducted during the ISAR-3 meeting.

Case study on microphysical properties of boundary layer mixed-phase cloud observed at Ny-Ålesund, Svalbard: Observed cloud microphysics and calculated optical properties on 9 June 2011

Akihiro Uchiyama, Akihiro Yamazaki, Masataka Shiobara, Hiroshi Kobayashi

Cloud radiation interactions are important in the global climate system. However, an understanding of mixed-phase boundary layer clouds in the Arctic remains poor. During May-June 2011, ground-based in situ measurements were made at Zeppelin Station, operated by the Norwegian Polar Institute (altitude 474 m) in Ny-Ålesund (78.9° N, 11.9° E), Svalbard. The instruments used comprised a Cloud, Aerosol and Precipitation Spectrometer (CAPS), and a Cloud Particle Microscope imager. The CAPS incorporated a Cloud and Aerosol Spectrometer and Cloud Imaging Probe (CIP). During the observation period, clouds associated with cyclonic disturbances and those associated with outbreaks of westerly cold air masses from the sea were observed. Atmospheric temperature during all measurements ranged from 0 to −5° C. In every case, columns were the major type of ice particle measured by the CAPS-CIP. Cloud microphysical properties were observed continuously on 9 June 2011. Size spectra, liquid/ice water content, and particle effective size changed depending on progress stages. Based on the observed microphysics, optical properties were calculated and investigated. Optical properties were determined mainly by those of liquid water particles, even during periods when the relative contribution of ice particles to total water content was at the maximum. It was confirmed that the wavelength region of 1.6 and 2.2 μm can be used in remote sensing. This study shows that it is possible to measure detailed changes of cloud properties in the Arctic region by using instruments installed at a ground-based mountain station.

Assessing algal biomass and bio-optical distributions in perennially ice-covered polar ocean ecosystems

Samuel R. Laney, Richard A. Krishfield, John M. Toole, Terence R. Hammar, Carin J. Ashjian, Mary-Louise Timmermans

Under-ice observations of algal biomass and seasonality are critical for understanding better how climate-driven changes affect polar ocean ecosystems. However, seasonal and interannual variability in algal biomass has been studied sparsely in perennially ice-covered polar ocean regions. To address this gap in polar ocean observing, bio-optical sensors for measuring chlorophyll fluorescence, optical scattering, dissolved organic matter fluorescence, and incident solar radiation were integrated into Ice-Tethered Profilers (ITPs). Eight such systems have been deployed in the Arctic Ocean, with five profilers completing their deployments to date including two that observed an entire annual cycle in the central Arctic Ocean and Beaufort Sea respectively. These time series revealed basic seasonal differences in the vertical distributions of algal biomass and related bio-optical properties in these two regions of the Arctic Ocean. Because they conduct profiles on daily or sub-daily scales, ITP bio-optical data allow more accurate assessments of the timing of changes in under-ice algal biomass such as the onset of the growing season in the water column, the subsequent export of particulate organic matter at the end, and the frequency of intermittent perturbations, which in the central Arctic Ocean were observed to have time scales of between one and two weeks.

Fifty years of meteo-glaciological change in Toll Glacier, Bennett Island, De Long Islands, Siberian Arctic

Keiko Konya, Tsutomu Kadota, Hironori Yabuki, Tetsuo Ohata

Rapid environmental change has been observed in the De Long Islands, Siberian Arctic, where warming has extensively occurred over the area. To quantitatively evaluate glaciological changes since the 1980s, the climate, mass balance, and the equilibrium line altitude (ELA) of Toll Glacier on Bennett Island were analyzed. Air temperature has increased and solid precipitation has decreased since the 1960s, especially after 2000. The cumulative mass balance of Toll Glacier has had a negative trend since the 1960s and reached approximately −20 m water equivalent (w.e.) in 2000, which is one of the largest changes in the Arctic. These changes are much larger than those in the west Russian Arctic. The warming trend is also correlated with the sea ice distribution in the Siberian Arctic and may lead to feedback effects that cause further Arctic warming.

Geocryological characteristics of the upper permafrost in a tundra-forest transition of the Indigirka River Valley, Russia

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Understanding geocryological characteristics of frozen sediment, such as cryostratigraphy, ice content, and stable isotope ratio of ground ice, is essential to predicting consequences of projected permafrost thaw in response to global warming. These characteristics determine thermokarst extent and controls hydrological regime—and hence vegetation growth—especially in areas of high latitude; it also yields knowledge about the history of changes in the hydrological regime. To obtain these fundamental data, we sampled and analyzed unfrozen and frozen surficial sediments from 18 boreholes down to 1-2.3 m depth at five sites near Chokurdakh, Russia. Profiles of volumetric ice content in upper permafrost excluding wedge ice volume showed large variation, ranging from 40 to 96%, with an average of 75%. This large amount of ground ice was in the form of ice lenses or veins forming well-developed cryostructures, mainly due to freezing of frost-susceptible sediment under water-saturated condition. Our analysis of geocryological characteristics in frozen ground including ice content, cryostratigraphy, soil mechanical characteristics, organic matter content and components, and water stable isotope ratio provided information to reconstruct terrestrial paleo-environments and to estimate the influence of recent maximum thaw depth, microtopography, and flooding upon permafrost development in permafrost regions of NE Russia.

Recent air temperature changes in the permafrost landscapes of northeastern Eurasia

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In the last two decades, climatic change has resulted in increased cryogenic activity in northeastern Eurasia, with adverse consequences for landscapes and socio-economic systems in the permafrost zone. The main purpose of this study was to assess the recent phases of warming, starting with Arctic warming. We performed a spatiotemporal analysis of climatic conditions during phases of maximum warming (i.e., 1935-1945, 1988-1995, and 2005-2009) in northeastern Eurasia and compared the magnitude of warming and its effect on permafrost among these critical periods. Our observations of permafrost landscape dynamics confirmed that the last two warming phases have played major roles in changing the environment. Data analysis has revealed regional patterns in the intensity of warming. Areas south of 60-62° latitude experienced no rise in air temperature during the Arctic warming period (1935-1945), whereas during 1988-1995, the center of warming shifted to the south of northeastern Eurasia. The last phase of warming (2005-2009) was characterized by maximum values of mean annual air temperature and the thawing index, and a decrease in the freezing index throughout northeastern

Eurasia.

Column-averaged CO_2 concentrations in the subarctic from GOSAT retrievals and NIES transport model simulations

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The distribution of atmospheric carbon dioxide (CO_2) in the subarctic was investigated using the National Institute for Environmental Studies (NIES) three-dimensional transport model (TM) and retrievals from the Greenhouse gases Observing SATellite (GOSAT). Column-averaged dry air mole fractions of subarctic atmospheric CO_2 (XCO_2) from the NIES TM for four flux combinations were analyzed. Two flux datasets were optimized using only surface observations and two others were optimized using both surface and GOSAT Level 2 data. Two inverse modeling approaches using GOSAT data were compared. In the basic approach adopted in the GOSAT Level 4 product, the GOSAT observations are aggregated into monthly means over $5° \times 5°$ grids. In the alternative method, the model-observation misfit is estimated for each observation separately. The XCO_2 values simulated with optimized fluxes were validated against Total Carbon Column Observing Network (TCCON) ground-based high-resolution Fourier Transform Spectrometer (FTS) measurements. Optimized fluxes were applied to study XCO_2 seasonal variability over the period 2009-2010 in the Arctic and subarctic regions. The impact on CO_2 levels of emissions from enhancement of biospheric respiration induced by the high temperature and strong wildfires occurring in the summer of 2010 was analyzed. Use of GOSAT data has a substantial impact on estimates of the level of CO_2 interanual variability.

Carbon exchange rates in Polytrichum juniperinum moss of burned black spruce forest in interior Alaska

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The Boreal black spruce forest is highly susceptible to wildfire, and postfire changes in soil temperature and substrates have the potential to shift large areas of such an ecosystem from a net sink to a net source of carbon. In this paper, we examine CO_2 exchange rates (e.g., NPP and Re) in juniper haircap moss (Polytrichum juniperinum) and microbial respiration in no-vegetation conditions using an automated chamber system in a five-year burned black spruce forest in interior Alaska during the fall season of 2009. Mean ± standard deviation microbial respiration and NEP (net ecosystem productivity) of juniper haircap moss were 0.27 ± 0.13 and 0.28 ± 0.38 $gCO_2/m^2/hr$, respectively. CO_2 exchange rates and microbial respiration showed temporal variations following fluctuation in air temperature during the fall season, suggesting the temperature sensitivity of juniper haircap moss and soil microbes after fire. During the 45-day fall period, mean NEP of P. juniperinum moss was 0.49 ± 0.28 MgC/ha following the five-year-old forest fire.

On the other hand, simulated microbial respiration normalized to a 10° C temperature might be stimulated by as much as 0.40 ± 0.23 MgC/ha. These findings demonstrate that the fire-pioneer species juniper haircap moss is a net C sink in the burned black spruce forest of interior Alaska.

CH4 and N2O dynamics of a Larix gmelinii forest in a continuous permafrost region of central Siberia during the growing season

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Forest soils are generally sinks of CH_4 and sources of N_2O. To characterize the dynamics of these major greenhouse gases in central Siberia during the growing season, we measured fluxes from forest soil and assessed the relationships between CH_4 and N_2O fluxes and forest floor vegetation types, soil temperature, and moisture conditions. At the soil surface, both CH_4 uptake and emission (−6.6 to 3.1 μg CH_4-C m^{-2} h^{-1}) were observed, and CH_4 fluxes did not differ among vegetation types. CH_4 flux was positively correlated with soil moisture, but not with soil temperature. The small CH_4 uptake compared with previous reports was due to CH_4 production in response to high precipitation. N_2O was also emitted and taken up by soil (−0.2 to 0.4 μg N_2O-N m^{-2} h^{-1}), and N_2O fluxes did not differ among vegetation types. N_2O flux was negatively correlated with soil moisture and not correlated with soil temperature. Our findings suggest that high soil moisture and low availability of mineral nitrogen resulted in N_2O uptake due to denitrification. Furthermore, both CH_4 and N_2O were emitted from a river at the site; these were produced in the basin of the riverbank rather than deep in the soil.

Interannual and seasonal variations in energy and carbon exchanges over the larch forests on the permafrost in northeastern Mongolia

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The larch forests on the permafrost in northeastern Mongolia are located at the southern limit of the Siberian taiga forest, which is one of the key regions for evaluating climate change effects and responses of the forest to climate change. We conducted long-term monitoring of seasonal and interannual variations in hydrometeorological elements, energy, and carbon exchange in a larch forest (48° 15′ 24′′ N, 106° 51′ 3′′ E, altitude: 1338 m) in northeastern Mongolia from 2010 to 2012. The annual air temperature and precipitation ranged from −0.13° C to −1.2° C and from 230 mm to 317 mm. The permafrost was found at a depth of 3 m. The dominant component of the energy budget was the sensible heat flux (H) from October to May (H/available energy [Ra] = 0.46; latent heat flux [LE]/Ra = 0.15), while it was the LE from June to September (H/Ra = 0.28, LE/Ra = 0.52). The annual net ecosystem exchange (NEE), gross primary production (GPP), and ecosystem respiration (RE) were −131 to −257 gC m^{-2} y^{-1}, 681–703 gC m^{-2}

y−1, and 423–571 gC m−2 y−1, respectively. There was a remarkable response of LE and NEE to both vapor pressure deficit and surface soil water content.

Growth and physiological responses of larch trees to climate changes deduced from tree-ring widths and $\delta^{13}C$ at two forest sites in eastern Siberia

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Tree-ring chronologies of ring width and stable carbon isotope ratios ($\delta^{13}C$) over the past 160 years were developed using living larch trees at two forest sites, each with different annual precipitation, in eastern Siberia: Spasskaya Pad (SP) (62° 14′ N, 129° 37′ E); and Elgeeii (EG) (60° 0′ N, 133° 49′ E). Intrinsic water-use efficiency (iWUE) was derived from tree-ring $\delta^{13}C$. The physiological responses of the larch trees to climate varied between these sites and over time. Ring widths correlated negatively with summer temperatures at SP, where summer precipitation is lower than at EG, probably due to temperature-induced water stress. Since the 1990s, however, the negative effect of warming has been more severe at EG, where the productivity of larch trees is higher than at SP. A greater reduction of larch tree growth and higher increase rate of iWUE at EG reflects greater temperature-induced water stress, which is incident to the larger forest biomass. Our results suggest that effect of increase in atmospheric CO_2 on larch tree growth is not sufficient to compensate for temperature-induced water stress on larch growth in eastern Siberia and differences in precipitation and forest productivity largely affect the larch tree response to changing climate in eastern Siberia.

Potential of Svalbard reindeer winter droppings for emission/absorption of methane and nitrous oxide during summer

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Droppings of Svalbard reindeer (Rangifer tarandus platyrhynchus) could affect the carbon and nitrogen cycles in tundra ecosystems. The aim of this study was to evaluate the potential of reindeer droppings originating from the winter diet for emission and/or absorption of methane (CH_4) and nitrous oxide (N_2O) in summer. An incubation experiment was conducted over 14 days using reindeer droppings and mineral subsoil collected from a mound near Ny-Ålesund, Svalbard, to determine the potential exchanges of $CH_4$and N_2O for combinations of two factors, reindeer droppings (presence or absence) and soil moisture (dry, moderate, or wet). A line transect survey was conducted to determine the distribution density of winter droppings at the study site. The incubation experiment showed a weak absorption of CH_4 and a weak emission of N_2O. Reindeer droppings originating from the winter diet had a negligible effect on the exchange fluxes of both CH_4 and N_2O. Although the presence of droppings resulted in a short-lasting increase in N_2O emissions on day 1 (24 h from the start) for moderate and wet conditions, the emission rates were

still very small, up to 3 μg N_2O m^{-2} h^{-1}.

Fungal colonization and decomposition of leaves and stems of Salix arctica on deglaciated moraines in high-Arctic Canada

Takashi Osono, Shunsuke Matsuoka, Dai Hirose, Masaki Uchida, Hiroshi Kanda

Fungal colonization, succession, and decomposition of leaves and stems of Salix arctica were studied to estimate the roles of fungi in the decomposition processes in the high Arctic. The samples were collected from five moraines with different periods of development since deglaciation to investigate the effects of ecosystem development on the decomposition processes during the primary succession. The total hyphal lengths and the length of darkly pigmented hyphae increased during decomposition of leaves and stems and were not varied with the moraines. Four fungal morphotaxa were frequently isolated from both leaves and stems. The frequencies of occurrence of two morphotaxa varied with the decay class of leaves and/or stems. The hyphal lengths and the frequencies of occurrence of fungal morphotaxa were positively or negatively correlated with the contents of organic chemical components and nutrients in leaves and stems, suggesting the roles of fungi in chemical changes in the field. Pure culture decomposition tests demonstrated that the fungal morphotaxa were cellulose decomposers. Our results suggest that fungi took part in the chemical changes in decomposing leaves and stems even under the harsh environment of the high Arctic.