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

ACC03-01 Room:101B Time:May 22 09:00-09:20

Polar amplification: major drivers and implications for global climate

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Surface albedo feedback is widely believed to be the principle contributor to polar amplification. However, a number of studies have shown that coupled ocean-atmosphere models without ice albedo feedbacks still produce significant polar amplification in 2xCO2 runs due to atmospheric heat transports and their interaction with surface conditions. The relative importance of atmospheric heat transport and surface albedo is assessed in a hierarchy of models. While both processes are shown to contribute to the polar amplified response of the model, feedback analysis points to a tendency for surface albedo to mask the effect of atmospheric heat transport in the full model.

Global climate models predict polar amplified pattern of warming in the Northern Hemisphere (NH) high- to middle latitudes during boreal winter. However, recent trends in observed NH winter surface land temperatures diverge from these projections. For the last two decades, large-scale cooling trends have existed instead across large stretches of eastern North America and northern Eurasia. We argue that this unforeseen trend is probably not due to internal variability alone. Delayed freeze-up in the Arctic and the consequent heat input in the atmosphere lead to significant changes in the circulation caused by a number of factors. Those factors include a direct response to the heat anomaly over the open ocean and a dynamic response to changes in the snow cover in northern Eurasia. Understanding this counterintuitive response to radiative warming of the climate system has the potential for improving climate predictions at seasonal and longer timescales.

Keywords: global warming, polar amplification

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Coupled Hydrological and Thermal Modeling of Permafrost Dynamics: Implications to Permafrost Carbon Pool

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Thawing and freezing of Arctic soils is affected by many factors, with air temperature, vegetation, snow accumulation, and soil moisture among the most significant. To investigate how changes in these factors influence permafrost dynamics in the Arctic, we developed a Geophysical Institute Permafrost Lab (GIPL) permafrost dynamics model. This model simulates soil temperature dynamics and depth of seasonal freezing and thawing by solving a non-linear heat equation with phase change numerically.

Although the GIPL model is helpful for understanding the effects of climatic and landscape factors on heat flow and phase change in soil retrospectively and prognostically, it does not simulate soil moisture dynamics and storage across diverse landscapes. Coupling of the GIPL model with a suitably-scaled hydrological model captures thresholds and highly non-linear feedback processes induced by changes in hydrology and the temperature regime over the pan-Arctic. We developed a robust coupling of a GIPL Permafrost Model and modified version of the pan-Arctic Water Balance Model (P/WBM) developed at the University of Alaska Fairbanks and the University of New Hampshire, respectively. Through explicit coupling of the Permafrost Model with the PWBM we are able to simulate the temporal and spatial variability in soil water/ice content, active layer thickness, and associated large-scale hydrology that are driven by contemporary and future climate variability and change.

We assess the changes in permafrost characteristics in Northern regions of Eurasia using a coupled, large scale, grid-based water balance/permafrost model that simulates hydrological budgets, the distribution of soil temperature and active layer dynamics, permafrost thawing and freezing, using a number of projections of future climate for the next century. The model takes into account the geographic distribution of organic soils and peatlands, vegetation cover and soil properties, and is tested against a number of permafrost temperature records for the last century. We report results of simulations for a number of different climate scenarios derived from IPCC climate models outputs. Despite the slower rate of soil warming in peatland areas and a slower degradation of permafrost under peat soils, a considerable volume of peat (approximately 20% of the total volume of peat in Northern Eurasia) could be thawed by the end of the current century. The potential release of carbon and the net effect of this thawing will depend on the balance between increased productivity and respiration, and will be mitigated by peat moisture.

Keywords: Permafrost, Active Layer, Hydrology, Modeling, Peatland

ACC03-03 Room:101B Time:May 22 09:40-09:55

Global warming and changes in Siberian terrestrial environments

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High levels of precipitation in the Lena River Basin, Siberia, from 2005 to 2008 led to tremendous changes in terrestrial environments. The changes observed include a deepening and moistening of the active layers, hindrance of tree growth, and the expansion of water surfaces due to floods. The anomalously wet condition of forest soils caused larch trees to wither at our forest monitoring site in the middle part of the basin. However an analysis of satellite data revealed that such tree withering occurred only at certain points. On the basis of our permafrost-ecosystem models, we have identified increases in thawing depth and surface soil moisture, and an increase in net primary production. The annual maximum thawing depth (AMTD) was revealed to have gradually increased (deepened) on a decadal scale. Increase in terrestrial water storage in the Lena River Basin generated increases in river base flows during the open water season. Our results also indicated that between 1950 and 2008 the basin-scale AMTD increased at an average rate of approximately 1 cm/year in the region. Moistening and warming of surface soil affect methane emissions from Siberian terrestrial ecosystems. Regional methane fluxes were estimated using an inversion model with data collected from aircraft and tower measurements in Siberia. In 2007 and 2008, enhanced methane fluxes from the wetlands in Western Siberia were estimated under relatively wet conditions with high temperatures. Interestingly, methane fluxes after 2008 have gradually decreased but those in Eastern Siberia have increased unsymmetrically. Such an unsymmetrical (seesaw) pattern between Western and Eastern Siberia has also been observed for carbon dioxide exchanges in terrestrial ecosystems. Gross primary production and ecosystem respiration in the 2000s were estimated using our permafrost-ecosystem models, which showed a decreasing trend in Western Siberia and an increasing trend in Eastern Siberia. These differences were primarily due to the differences in the trends of temperature and precipitation between the two regions.

Keywords: global warming, waterlogging, permafrost, thawing, green-house gases

ACC03-04 Room:101B Time:May 22 09:55-10:10

Climatological features of atmospheric and terrestrial water cycles in the three great Siberian rivers

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We examined several climatological features of atmospheric and terrestrial water cycles including river discharge, net precipitation (precipitation minus evapotranspiration) and moisture transport in the three great Siberian rivers; Lena, Yenisei and Ob. River discharge at the mouth of the river is outflow of water into the Arctic Ocean. On the other hand, net precipitation averaged over a river basin is net inflow of water from atmosphere to surface. In this study, the net precipitation is estimated by six atmospheric reanalyses (JRA25, ERA40, ERAI, MERRA, NCEP2 and CFSR) by means of atmospheric water budget method without using P and E datasets.

As expected from the terrestrial water budget, on average during 1980-2008, the amounts of net precipitation over the basins of the Lena, Ob and Yenisei Rivers were found to be comparable in magnitude to the observed river discharges at the mouths of each river. This indicates that the estimation of net precipitation on the basis of the atmospheric reanalysis is an effective way to evaluate and quantify the atmospheric and terrestrial water cycles of a large river basin. While the precipitation over the Ob River basin is largest among the three Siberian rivers, the river discharge and net precipitation of the Ob are smallest among them. The river discharge and precipitation of the Lena are smaller than that of the Yenisei, while the net precipitation over the Lena is as large as that over the Yenisei. These results indicate that the regional differences in evapotranspiration over Siberia result in those differences in river discharges and net precipitation among the Siberian rivers.

Seasonal cycles of the Lena, Yenisei and Ob River discharges show maximums in June due to river ice melting. While the precipitations over the three river basins show maximums in July, the net precipitations in that month show minimums at nearly zero flow over the Lena and Yenisei, and at large negative flow over the Ob. This indicates that the evapotranspirations in the warm season are as large as the precipitation over the Lena and Yenisei, and much larger than the precipitation over the Ob. Because these basins are covered with vast area of boreal forest, the transpiration from the forest may account for large part of the evapotranspiration and which plays an important role for the terrestrial water cycles.

During the past three decades, the annual mean river discharge of each of the three Siberian rivers is positively correlated with the net precipitation over each of the basins, respectively. While the annual mean discharge of the Lena corresponds to the net precipitation over the basin, those of the Yenisei and Ob Rivers show some differences. The correlation coefficients between the river discharge and net precipitation of the two basins are weak and amplitudes of the discharge are smaller than that of the net precipitation. We consider these differences are mainly due to the time lag between the river discharge and net precipitation. In addition, these variables do not show any significant trends during the past three decades (1980-2008).

Keywords: Siberia, Water Cycle, River Discharge, Net Precipitation, Atmospheric Reanalysis data

ACC03-05 Room:101B Time:May 22 10:10-10:25

Land Surface Phenologies and Seasonalities Using Earthlight to Monitor Changes in High-Latitude Croplands

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Phenology and seasonality are complementary aspects of ecosystem functioning: phenology deals with timing of biotic phenomena; whereas, seasonality concerns temporal patterns of abiotic variables. Enhanced land surface parameters derived from passive microwave data enable improved temporal monitoring of agricultural land surface dynamics compared to the vegetation index data available from optical data. Despite a coarser spatial resolution, the AMSR-E data products are more sensitive to intra-seasonal changes in surface moisture than MODIS data products. Accordingly, the AMSR-E data are better able to detect both flash droughts and the onset of drought. We compare and contrast land surface phenologies using data from 2003-2010 in the Volga River Basin of Russia, and the spring wheat belts of the USA and Canada. We find reasonable relationships between retrieved air temperature, fractional open water, surface moisture, and vegetation optical depth at three microwave frequencies. We focus in particular on the extraordinary heat wave that impacts Russia in 2010. The results suggest possible applications for data from the new microwave radiometer AMSR2 launched in 2012.

Keywords: passive microwave, land surface phenology, croplands, Russia, North America, 2010 heat wave

ACC03-06 Room:101B Time:May 22 10:25-10:45

Projected impacts of the 21st century climate change on the forests and major conifer species in Russia

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Global simulations have demonstrated the potential for profound effects of GCM-projected climate change on the distribution of terrestrial ecosystems and individual species at all hierarchical levels. We modeled progressions of potential vegetation cover, forest-forming tree species and forest types in Russia in the warming climate during the 21st century. Large-scale bioclimatic models were developed to predict Russian zonal vegetation (RuBCliM), forests, forest-forming tree species and forest types (ForCliM). A forest type was defined as a combination of a dominant tree conifer and a ground layer (2-3 dominant species). Distributions of vegetation zones (zonobiomes), conifer species and forest types were simulated based on three bioclimatic indices (1) growing degree-days above 5 degrees Celcius; (2) negative degree-days below 0 degrees Celcius; and (3) an annual moisture index (ratio of growing degree days to annual precipitation). Additionally, the presence or absence of continuous permafrost, identified by active layer depth of 2 m, was explicitly included in the models as limiting the forests and tree species distribution in Siberia. All simulations to predict vegetation change across Russia were run by coupling our bioclimatic models with bioclimatic indices and the permafrost distribution for the baseline period 1971-2000 and for the future decades of 2011-2020, 2041-2050 and 2091-2100. To provide a range of warming we used three global climate models (CGCM3.1, HadCM3 and IPSLCM4) and three climate change scenarios (A1B, A2 and B1). The CGCM model and the B1 scenario projected the smallest temperature increases, and the IPSL model and the A2 scenario projected the greatest temperature increases.

With these projected climates, the zonobiomes would need to shift far to the north in order to reach equilibrium with the change in climate. Under the warmer and drier projected future climate, at least half of Russia would be suitable for the forest-steppe ecotone and grasslands rather than for forests. Water stress tolerant light-needled taiga (Pinus sylvestris and Larix spp.) would have an increased advantage over water-loving dark-needled taiga (Pinus sibica, Abies sibirica, Picea obovata) in a new climate. The permafrost-tolerant L. dahurica taiga would remain the dominant forest type in the many current permafrost areas because permafrost would not retreat fast. An increase in severe fire weather would lead to increases in large, high-severity fires, especially at the southern forest border and in interior Siberia (Yakutia), which are expected to facilitate vegetation progression towards equilibrium with the climate.

Adaptation to climate change may be facilitated by: (1) assisting migration of forests and tree species by seed transfer from locations where current climate is most similar to that projected in the future in order to establish genotypes that may be more ecologically suited as climate changes; and (2) introduction of suitable agricultural crops that currently may not be present in the region but may be potentially used in a warmer climate in steppe and forest-steppe areas that are expected to replace the retreating forests.

Keywords: Vegetation, forest types, forest-forming trees, bioclimatic modeling, climate change, 21st century, Russia

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ACC03-07 Room:101B Time:May 22 11:00-11:30

A Modeling Analysis of Carbon and Water Cycles in Northern Eurasia during the Past and This Century

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The temperature increase and extreme climate change occurred in the past century are projected to continue during this century in northern Eurasia according to climate models. The changing climate may expedite permafrost thawing and intensify the hydrological cycle, in turn, accelerate the carbon greenhouse gas cycling in this region. Using a suite of hydrology, permafrost, biogeography, biogeochemistry and climate models, we explore how vegetation distribution, landscape (wet vs. dry), permafrost, hydrology, and carbon cycle have changed in the last century and will be affected during the 21st century. Our preliminary analyses indicate that the region was a consistent methane source in the past century and the source strength will increase by 60%. In contrast, the region was a carbon sink and the sink will double by the end of this century. As a result, the region will act as a strengthened greenhouse gas sink during this century. In the presentation, I will also present how regional water cycle is modeled considering the effects of climate, plant physiology, and snow and permafrost dynamics in various landscapes.

Keywords: Greenhouse gas cycling, biogeochemistry, permafrost, water, hydrology, earth system modeling

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ACC03-08 Room:101B Time:May 22 11:30-11:45

Changes of snow cover characteristics over Eurasia in the context of the ongoing climate changes

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Global changes of the surface air temperature have been well documented for the past 130 years (period of mass instrumental observations). In the past 50 years, global, hemispheric, Arctic, and continental temperatures have been rising {under}decade by decade{/under} and the last decade was the warmest for the past 130 years. Another feature of these changes is a stronger warming in high latitudes than in the tropics, over the continents than over the oceans, and in the cold season than in the warm season. But, in winter the variance of the surface air temperature over Northern Eurasia is about 10 times higher than in summer. This structure of the global warming has led to (a) reduction of meridional surface air temperature gradients, especially in winter, (b) weakening and northward shifts of the major storm tracks, and (c) retreat of the seasonal Arctic sea ice and its transformation from multiannual into a thinner seasonal sea ice cover of lesser concentrations. In the cold season the last feature, like a complete or partial removal of the boiling tea kettle lid, affects heat and water vapor fluxes from the Arctic Ocean into the atmosphere and may generate increases of the frequency of colder anticyclonic weather conditions in the interior of the mid-latitude continents and affect/interact with the seasonal snow cover characteristics, in particular over Eurasia.

Snow cover extent (SCE) over the Northern Hemisphere has not changed substantially in the early winter months and notably decreased in the late spring (especially over Eurasia and Russia). However (probably due to a further sea ice retreat in the Eurasian Sector of the Arctic), in the last two decades late spring SCE over the Russian Federation has stabilized (except the westernmost part of the nation) and several snow cover characteristics have increased. Our analyses show that over most of Russia: duration of the snow cover has decreased while maximum winter snow depth, maximum snow water equivalent, and the number of days with snow depth above 20 cm have increased. At the same time, maximum winter snowpack density has decreased. Thus, in the Russian Federation the tendencies of snow cover changes can be formulated as follows: in the cold season snowpack has become thicker, more porous, and moister but remained on the ground for a shorter period of time.

Associated with snow cover change climatic variables include: (a) the days with thaw defined as the days when the mean daily temperature is above -2 degrees Celsius while snow on the ground is above 5 cm; (b) spring onset characteristics such as the dates of the snowmelt completion, the dates of beginning of the vegetation and no-frost seasons; and(c) duration of the vegetation period. We show that all these characteristics have significantly changed over Belarus, Russia, and Kazakhstan during the post-World War II period.

Keywords: Snow cover, Eurasia, climatic change, snowpack

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Analysis of CO_2 concentrations simulated by NIES transport model and retrieved from GOSAT in the subarctic regions

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The arctic and subarctic regions are large soil carbon reservoirs in the world. Permafrost soils covering about 25% of the land surface in the Northern Hemisphere store almost twice as much carbon as is currently present in the atmosphere. However, the rates of carbon release from permafrost soils due to permafrost thaw and the microbial decomposition of previously frozen organic carbon are highly uncertain. Moreover, the carbon cycle in the subarctic remains poorly investigated due to the insufficient observations. At present, the spatial coverage of direct carbon flux measurements needed to map the fluxes accurately is not enough, especially in the high-latitudes of the Northern hemisphere.

This work describes investigation of carbon dioxide distribution in the subarctic regions using numerical simulation with the National Institute for Environmental Studies (NIES) three-dimensional transport model (TM) and retrievals from the Greenhouse gases Observing SATellite (GOSAT). Simulated by NIES TM with several flux combinations column-averaged dry air mole fractions of atmospheric CO_2 (XCO_2) was compared with GOSAT data for different latitude bands over land in the subarctic. We revealed relatively large deviations between XCO_2 modeled and retrieved from GOSAT with positive bias in spring/summer and negative in autumn, indicating some fluxes inaccuracy, which may be caused by uncertainty in emission/sink of CO_2. We analyzed flux uncertainty reduction and improvements in seasonal cycle reproduction following fluxes optimization with the inverse modeling system. XCO_2 simulated with optimized fluxes was evaluated against the Total Carbon Column Observing Network (TCCON) ground-based high-resolution Fourier Transform Spectrometer (FTS) measurements at two the most northern sites Ny Alesund and Sodankyla. CO_2 distribution obtained through inverse modeling using the ground based, aircraft observations and GOSAT data together appear to be closer to FTS measurements, than without GOSAT data. Thus, we have shown XCO_2 retrieved from GOSAT can be used to evaluate modeled results and as additional constrain in flux optimization with inverse model in the subarctic regions.

Keywords: carbon dioxide, atmospheric forward and inverse modeling, remote sensing