Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

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Influence of Land Cover Change on Regional Water and Energy Field in Eastern Siberia

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According to IPCC AR4, Eastern Siberia is thought as an area of great future change in the environment compared with other area. However, environment change has already occurred, such as water surface expanding and forest area decrease. From meteorological stand points, land surface state can be written by land surface parameters: surface albedo, evaporative efficiency, roughness length, heat capacity and thermal conductivity. With land surface change, these parameters vary and water/energy balance also varies at the same time. Moreover, according to previous study on water recycling ratio, more than 60% of precipitation source is supplied by evapotranspiration from land surface and this trend becomes stronger in Eastern Siberia than Western Siberia. Water movement occurs between land surface and the atmosphere, thus three-dimensional model is required to make clear effect of land surface change on water and energy field.

Our study has two objectives:

1) to make clear what land surface parameter has strong impact on water and energy field
2) to estimate water and energy field change with land surface change.

To achieve first objective, above five land surface parameter impacts on water and energy field is investigated using three-dimensional atmospheric model (JMA-NHM). Using routine station precipitation data, calculation duration is set from 2000/07/07 to 2000/07/17. Here, defining parameter impact as ratio of perturbation of latent heat flux and perturbation of land surface parameter, surface albedo and evaporative efficiency were dominant parameters among five land surface parameters. Calculation duration was changed to June 2000, August 2000, July 2001 and July 2002 (from 7th to 17th) and parameter impact was derived for each durations. Parameter impact of surface albedo and evaporative efficiency took larger value among these durations and there was no dependency on season and year.

Based on first experiment result, water and energy field change with water surface expanding was analyzed. Considering water and grassland area distributes almost 20% of lowland Central Yakutia, water and energy field difference between grassland 20% run and water surface 20% run was investigated. Here, land surface distribution of grassland, water surface and original is denoted as (G, W, O). There was linear increase of latent heat flux with water surface expanding from (G, W, O) = (0.2, 0.0, 0.8) to (0.0, 0.2, 0.8) and degree of latent heat flux increase was 1.2 W m-2 (2.4%). To understand what parameter played important role for this result, each land surface parameter effect was estimated from parameter impact and parameter change. Surface albedo and evaporative efficiency were impactful parameter on water and energy field, however, surface albedo was not effective parameter for water surface expanding because degree of actual surface albedo change was not so large compared with other surface parameters. Surface albedo has higher parameter impact, but its actual parameter change was lower value. Thus it did not become impactful parameter. Similar discussion can be done for thermal conductivity; it had lower parameter impact and higher actual parameter change. On the other hand, evaporative efficiency had larger parameter impact and actual parameter change, thus it was dominant parameter with water surface expanding.

At last, latent heat flux and precipitation change with deforestation and water surface expanding was investigated using parameter impact and virtual land surface data. When all lowland area that was less than 250 m became grassland, latent heat flux increased 0.1 W m-2 from (G, W, O) = (0.2, 0.0. 0.8), however, it was 0.5 W m-2 from (G, W, O) = (0.2, 0.0, 0.8) to (0.0, 0.2, 0.8). Thus land surface change to grassland does not have strong impact to water and energy field, but land cover change that contains water surface enhances latent heat flux strongly.

Keywords: Eastern Siberia, Land Surface Change, Evapotranspiration, Precipitation, Heatbalance

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Evaluation of West Siberian wetland CH4 emission in inverse modeling

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West Siberia contains the largest wetland area in the world with large peat deposits and the wetland area is equivalent to 27% of total area of West Siberia. Recently, Glagolev et al. (2010) published the CH4 emission data from West Siberian wetlands at 0.5 deg resolution, using in situ measurements for each bioclimatic zone and a detailed wetland classification. Annual mean CH4 flux from West Siberian wetlands was calculated to be 3.2 Tg/yr in the updated version of Glagloev et al. (2010) (called Bc7) with strong wetland CH4 flux concentrated in Southern taiga. While a double magnitude of wetland CH4 flux estimated in Bc7 inventory was calculated in GISS inventory of Fung et al. (1991) with strong wetland CH4 flux in Northern and Middle taiga. In GISS inventory, wetland CH4 flux was estimated by emission seasons and emission rates calculated based on the climatology of monthly surface air temperature and precipitation with the global distribution of the simplified five wetland types published in Matthews and Fung (1987).

In this study, we estimate CH4 flux through inverse modeling for West Siberian wetlands with two different bottom-up inventories. Two airborne observations in West Siberia are used in verification for the inversed fluxes: at Surgut over wetlands in Northern taiga and at Novosibirsk near wetlands in Subtaiga. In forward simulations, the individual monthly CH4 surface sources for each region are emitted for a single month then discontinued for the remainder of the 6-year simulation to consider the response of atmospheric CH4, using interannually repeating OH and winds for the analysis year. The NIES transport model (Maksyutov and Inoue, 2000) simulates a total of 288 tracers for CH4, representing a combination of 12 land regions and 12 months for two source categories.

Annual mean CH4 flux of West Siberian wetlands is estimated to be 2.9 Tg/yr and 2.6 Tg/yr in inversions using GISS and Bc7 inventories, respectively. The inversed wetland flux well constrained is good agreement with the wetland flux in Bc7 inventory, but a large difference of the inversed flux to the wetland flux in GISS inventory. The inversed flux estimated using GISS inventory is only 45.0% of the prior flux with large decrease in June-August and it indicates the overestimated wetland flux in GISS inventory. As compared with the overestimated CH4 concentrations in forward simulations with GISS inventory, the mismatch between observed and predicted CH4 concentrations in inversion using GISS inventory is reduced with the decreased wetland flux by data constraint, but still higher CH4 concentrations at Surgut than observations. Larger mismatch between observed and predicted CH4 concentrations at Surgut is shown in inversion using GISS inventory than that for Bc7 inventory, while CH4 concentrations closer to observations at Novosibirsk are predicted in inversion using GISS inventory. These results suggest that GISS inventory includes the overestimated wetland CH4 flux in Northern and Middle taiga, implying that Bc7 inventory is more reasonable in the spatial distribution of West Siberian wetland CH4 flux with stronger CH4 flux from wetlands over Southern taiga than that for Northern and Middle taiga.

Keywords: Wetland methane emission, West Siberia, Inverse modeling

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Analysis of CH4 and CO2 concentrations simulated by NIES TM over Siberia

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We simulated methane (CH4) and carbon dioxide (CO2) concentration using NIES (the National Institute for Environmental Studies) three-dimensional off-line Transport Model (TM). Used initial distribution, fluxes, sinks and chemical reactions are described in the Protocol for TransCom CH4 intercomparison (Patra et al., 2010) and in the Protocol for CONTRAIL transport model intercomparison (TMI) (Niwa et al., 2008). Current version of the model (denoted as NIES-08i) is implemented on a hybrid isentropic vertical coordinate systems containing 33 levels up to a pressure level of 2 hPa and supplied with a climatological heating rate to calculate the stratospheric diabatic transport. Isentropic vertical coordinate helps to prevent extra mixing between troposphere and low stratosphere, resulting in the mean age of the air in agreement with observation and better vertical distribution simulation. Although the model phenology is driven by reanalysis data (JMA-JCDAS 6-hourly meteorology and 3-hourly planetary boundary layer height from the ECMWF Interim reanalysis (Belikov et. al., 2010)) it is reproducing seasonal cycle phase and amplitude. Tracers growth rates and tropospheric/stratospheric losses are well simulated by the model. The detailed model results analysis and intercomparisons using GLOBALVIEW-CH4 and Siberian aircraft observation data will be shown in the meeting.

Keywords: atmospheric tracer transport modeling, carbon dioxide, methane

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Possible new crops in southern Siberia under climate change

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The southern portion of Siberia is a subboreal forest-steppe and steppe ecozone and is known to have high agroclimatic potential due to favorable climatic and soil resources. Potential northward forest shifts over the plains and upslope in the mountains were modeled using our Siberian bioclimatic vegetation model (SiBCliM) in 2020, 2050 and 2080 coupling climate predictions from the Hadley A2 and B1 scenario projections. At the expense of forests, approximately 40% of Siberia was predicted to be covered by forest-steppe and steppe ecozones by the end of the century. Crops of food, forage, and biofuels primarily reside in steppe and forest-steppe zones in southern Siberia, and these crops are resistant to frequent droughts and the cold climate. Our goals are: 1) to evaluate ongoing climate change in southern Siberia from observed data: pre-1960; in the baseline period 1960-1990; in 1990-2010; and to predict related hot spots of potential agriculture change in the contemporary climate; 2) to predict agriculture in the future from the Hadley 2020, 2050 and 2080 climate change projections; and 3) finally, to develop a new agroclimatic zonation (agricultural regions) based on a new agroclimatic potential that may evolve as climate changes. Potential agricultural lands are modeled to appear in new forest-steppe and steppe habitats, extended and shifted northwards. A Siberian agri-crops model was developed that predicts ranges of major Siberian traditional crops (wheat, barley, vegetables, etc) and some exotic crops (melons and gourds, grapes, horticulture) currently non-existent but potentially important in a warming climate. In the model, four basic climatic constrains control crop distributions: growing degree-days and growing season length represent temperature requirements for plant growth and development, negative degree-days define winter cold tolerance, and a moisture index characterizes resistance to moisture stress. The model was applied to the pre-1960, 1960-1990, 1990-2010, 2020, 2050 and 2080 climates to predict potential distributions for both traditional and new crops in southern Central Siberia. Our analyses show that during the century traditional crops could be gradually shifted as far as 400 km northwards (about 50 km per decade) and new crops may be introduced in the very south with a significantly prolonged growing season and thus enlarged growing degree-days which may necessitate irrigation.

Keywords: southern Siberia, climate change, potential crops, traditional crops, exotic crops