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Evaluation of long-term water, energy, and CO2 budget at two Arctic sites with a coupled hydrological and biogeochemical model

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To quantify the dynamics of water, energy, and CO2 budgets in the Arctic soil-vegetation-atmosphere system, a coupled hydrological and biogeochemical model (CHANGE) was developed and applied to the two Arctic sites (Tiksi and Yaktsuk) of the different climatic and land surface conditions. CHANGE considers processes in vegetation, snow, and soil. Energy budget is solved for the radiative and energy fluxes in the canopy, snow, and soil surfaces. In the soil layers, the thermal and moisture fluxes are solved separately. At each time step, thermal fluxes through the soil layers are solved prior to the prediction of soil layer ice content. Subsequently, moisture fluxes are computed using the estimated ice contents. CHANGE does treat carbon exchange by plants, linking photosynthesis with stomatal conductance. CHANGE also represents spatial heterogeneity in land cover by dividing each grid cell into three land cover types: lake, wetland, and vegetation. The vegetated portion of the grid cell is further divided into several plant functional types. Multiple plant functional types can co-occur in a grid cell so that, for example, a mixed broadleaf deciduous and needleleaf evergreen forest may consist of patches of broadleaf deciduous trees, needleleaf evergreen trees, and other vegetation.

The model performance was validated to the temporal dynamics of water, energy, and carbon budget over 1986 to 2004 at the two sites. Spin-up required about 500 model years, achieved by cycling the 19-a time series of atmospheric forcing. At Yakutsk, four plant functional types were initially established: arctic grasses initially dominated, then declined with increasing trees. However, Tiksi was mainly dominated by arctic grasses. The simulated energy fluxes, snow accumulation and melt, and carbon fluxes at the two sites were generally consistent well with the measurements. The model also simulated well the seasonal and inter-annual variations of soil water and temperature, as well as their differences between sites. It was found that the seasonality of active layer depth was especially well expressed at the two sites, compared to the measurements. The two sites showed different water budget; evapotranspiration at Yakutsk portioned about 70% of annual precipitation, while Tiksi was 40%. The good simulations for hydrological processes under the different climatic conditions suggest that CHANGE can be used to assess quantitatively hydrological, climatic, and biogeochemical feedbacks in the Arctic climate system involved in climate change.