The incorporation of organic layer in Noah-MP Land Surface Model and its evaluation over Boreal Old Aspen Forest Flux Site

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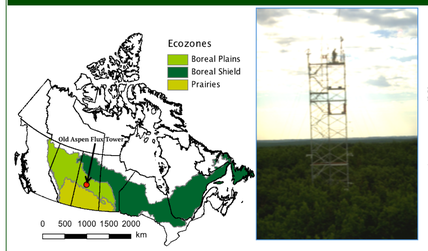
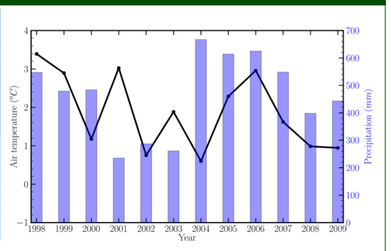
Introduction

The Noah with multi-parameterization options (Noah-MP) LSM is a new-generation community land model, which uses multiple options for many key land-atmosphere interaction processes to represent seasonal and annual cycle of snow, hydrology, and vegetation. Despite continuous evaluation and improvements in Noah-MP, it has not been evaluated in boreal forest region. In this study, Noah-MP was used to identify the most crucial processes for the simulation of a boreal forest site. The test site selected is BERMS Old Aspen Flux (OAS) field station in central Saskatchewan, Canada. In this site, about an 8-10 cm deep surface organic soil layer overlays the top mineral soil layer. Since the original Noah-MP does not include an organic soil option, here a new developed organic soil parameterization scheme in Noah-MP model is added and verified with the observations from OAS site. The new simulation with a top organic soil layer is then compared with the original Noah-MP simulation with mineral soil instead.

Field Site





The Old Aspen Site (OAS, 53.7°N, 106.2°W, altitude 601 m) is a mature deciduous broadleaf forest at the southern edge of Canadian boreal forest in Prince Albert National Park, Saskatchewan, Canada. The 30-min meteorological observations from OAS are used as the atmospheric forcing data to drive Noah-MP in an uncoupled 1-D mode include air temperature, specific humidity, wind speed, pressure, precipitation, downward solar and longwave radiation.The significant climatic feature during the study period is a prolonged drought that began in July 2001 and extended throughout 2002 and 2003. The temperature is also relatively low during that period.

Methodology

Thermal and hydraulic parameterizations for organic soil

Soil carbon or organic fraction for each layer is determined as:

$$f_{sc,i} = \frac{\rho_{sc,i}}{\rho_{sc,\max}}$$

where $f_{sc,i}$ is the carbon fraction of the each layer, $\rho_{sc,i}$ is the soil carbon density, and $\rho_{sc,\max}$ is the maximum possible value (peat density of 130 kg m^{-3}).

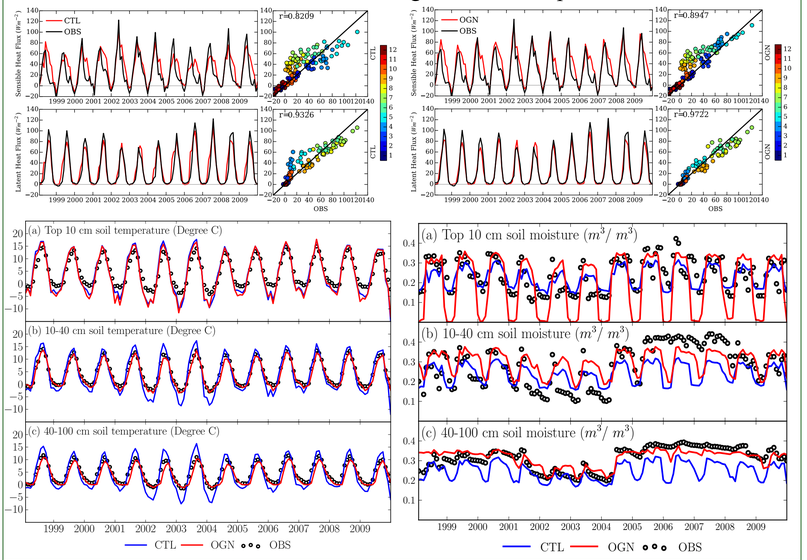
The soil properties for each layer are specified as a weighted combination of organic and mineral soil properties:

$$P = (1 - f_{sc,i})P_m + fP_o$$

Where P_m is the value for mineral soil, P_o is the value for organic soil, and P is the weighted average quantity.

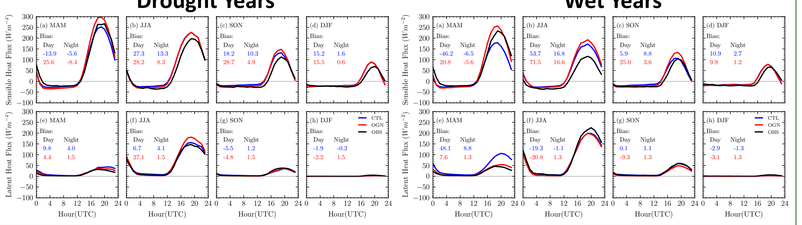
Evaluation results

CTL : the simulation without incorporating organic soil
OGN: the simulation with organic soil incorporated

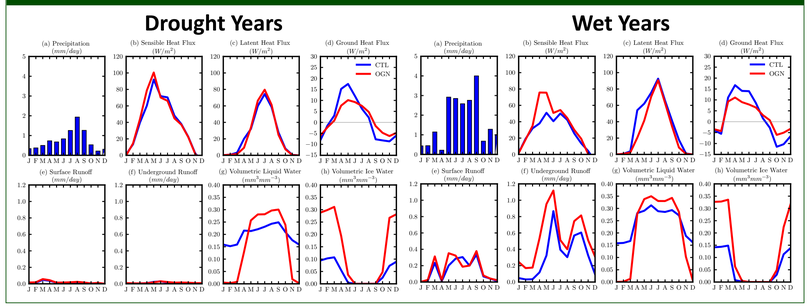


Impact of organic soil on diurnal cycle of surface energy and hydrology

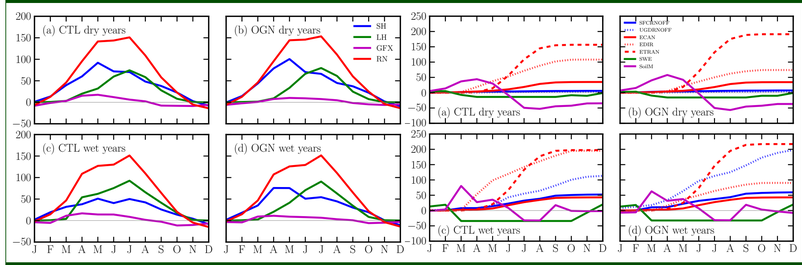
For the 12-year simulation period, the study site experienced a prolonged drought, which began in July 2001 and extended throughout 2002 and 2003. We then choose year 2002 and 2003 to represent typical drought years, and year 2005 and 2006 to represent typical wet years



Impact of organic soil on annual cycle of surface energy and hydrology



Energy and Water Budget



Conclusions

In this study, Noah-MP is evaluated at BERMS Old Aspen site.The OAS site has an about 8-10 cm deep surface organic soil layer overlaying to the top mineral soil layer. Adding a top organic soil layer alters the soil's thermal and hydraulic properties, and significantly improved the simulation of the thermal and hydrological components. The new Noah-MP model with an organic soil layer was then verified against observation data and compared with the original Noah-MP with only mineral soil.

- The inclusion of the organic soil layer reduces the simulated summer soil temperatures while increases the winter soil temperatures, which matches the observation much better, due to its lower thermal conductivity which changes surface energy budget changed.
- The incorporation of an organic top soil layer also improves the deep layer soil moisture simulation. The increase of the porosity and hydraulic conductivity of the organic soil increases soil moisture while decreases the surface evaporation at the same time.
- With a top organic soil layer, the simulation of the diurnal surface heat flux is also improved, especially in spring, as well as the simulation of the annual cycle of the surface energy and hydrology components under different climate regimes, especially for drought years.
- For dry years, the impact of the organic soil on surface and sub-surface runoff is not significant. The increase of the latent heat flux and sensible heat flux in summer are compensated by a decrease in soil heat flux, the evaporation becomes very important. While for wet years, the impact of the organic soil on surface and sub-surface runoff is very significant, the runoff increases a lot, and at the same time the ground evaporation is reduced.

References

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