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The Development in modeling Tibetan Plateau Land/Climate Interaction

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Tibetan Plateau (TP) plays an important role in influencing the continental and planetary scale climate, including East Asian and South Asian monsoon, circulation and precipitation over West Pacific and Indian Oceans. The numerical study has identified TP as the area with strongest land/atmosphere interactions over the midlatitude land. The land degradation there has also affected the monsoon precipitation in TP along the monsoon pathway. The water cycle there affects water sources for major Asian river systems, which include the Tarim, Amu Darya, Indus, Ganges, Brahmaputra, Irrawaddy, Salween, Mekong, Yellow, and Yangtze Rivers.

Despite the importance of TP land process in the climate system, the TP land surface processes are poorly modeled due to lack of data available for model validation. To better understand, simulate, and project the role of Tibetan Plateau land surface processes, better parameterization of the Tibetan Land surface processes have been developed and evaluated. The recently available field measurement there and satellite observation have greatly helped this development. This paper presents these new developments and preliminary results using the newly developed biophysical/dynamic vegetation model, frozen soil model, and glacier model.

In recent CMIP5 simulation, the CMIP5 models with dynamic vegetation model show poor performance in simulating the TP vegetation and climate. To better simulate the TP vegetation condition and its interaction with climate, we have developed biophysical/dynamic vegetation model, the Simplified Simple Biosphere Model version 4/Top-down Representation of Interactive Foliage and Flora Including Dynamics Model (SSiB4/TRIFFID), based on water, carbon, and energy balance. The simulated vegetation variables are updates, driven by carbon assimilation, allocation, and accumulation, as well as competition between plant functional types. The model has been validated with the station data, including those measured over the TP. The offline SSiB4/TRIFFID is integrated using the observed precipitation and reanalysis-based meteorological forcing from 1948 to 2008 with 1 degree horizontal resolution. The simulated vegetation conditions and surface hydrology are compared well with observational data with some bias, and shows strong decadal and interannual variabilities with a linear trend associated with the global warming.

The TP region is covered by both discontinuous and sporadic permafrost with irregular snow layers above. A frozen soil model is developed to take the coupling effect of mass and heat transport into consideration and includes a detailed description of mass balances of volumetric liquid water, ice, as well as vapor content. It also considers contributions' of heat conduction to the energy balance. The model has been extensively tested using a number of TP station data, which included soil temperature and soil water measurements. The results suggest that it is important to include the frozen sol process to adequately simulate the surface energy balance during the freezing and thawing periods and surface temperature variability, including its diurnal variation. Issues in simulating permafrost process will also be addressed.

To better understand the glacier variations under climate change scenarios, an integrated modeling system with an energy budget-based multilayer scheme for clean glaciers, a single-layer scheme for debris-covered glaciers and multilayer scheme for seasonal snow over glacier, soil and forest are developed within a distributed biosphere hydrological modeling framework (WEB-DHM-S model). Discharge simulations using this model show good agreement with observations for Hunza River Basin (13,733 km2) in the Karakoram region of Pakistan for three hydrologic years (2002–2004). Flow composition analysis reveals that the runoff regime is strongly controlled by the snow and glacier melt runoff (50% snowmelt and 33% glacier melt) and suggests that both topography and glacier hypsometry play key roles in glacier mass balance. This study provides a basis for potential application of such an integrated model to the entire Hindu-Kush-Karakoram-Himalaya region.