Improvement in runoff reproducibility of a land surface model and its implications for the energy-water balances on land

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Land surface hydrological processes are widely recognized as important elements in climate change studies, and land surface models have been developed by many research groups since the 1980s. MATSIRO (Takata et al., 2003; Nitta et al., 2014) is one of them; it calculates the surface and soil temperatures, evaporation, runoff, soil moisture, etc., based on the energy water balances, taking into account the effects of vegetation such as reflection and absorption of radiation, photosynthesis, transpiration, water uptake from roots, etc. The model has, however, had the strong bias of underestimation in runoff, for many years, compared to observed values. Until today, Hirabayashi et al. (2005) examined and revised the parameter for base runoff, and Yoshimura et al. (2006) improved the algorithms of groundwater level diagnosis. Nevertheless, MATSIRO is still one of the models producing least runoff among others (Haddeland et al., 2011).

We found that the diagnosed groundwater level that was used for calculation of surface runoff (Dunne flow) and base runoff tended to be too deep. Therefore, we tried a simple method to forcibly raise groundwater levels to examine its effect in this study. Specifically, we changed the condition for saturation judgment. In the base experiment (EP.0), a soil layer was judged saturated when soil moisture averaged over a grid cell was almost equal to saturation. In the sensitivity experiments, the condition was relaxed to about 75% (EP.1), 50% (EP.2), 25% (EP.3), and 0% (EP.4) of saturation. A series of numerical experiments was conducted in the Chao Phraya River basin (CP) in Thailand as a case study. The meteorological data from 1981 to 2004 at a horizontal resolution of 5 arc-minutes (i.e., approximately 9 km) (Kotsuki et al., 2013) was used.

The calculated monthly and daily river flow in EP.2 agree well with observation at the Bhumibol Dam (BB) on the Ping River in the northwestern part of CP. The groundwater level in the catchment of BB in EP.2 were much shallower (seasonal range was 1-3 m) than that in EP.0 and EP.1 (5-6 m). The seasonal changes in the vertical profiles of monthly mean soil moisture, and the monthly Bowen ratio were also improved.

The overall behavior of the model was dramatically improved by changing the condition of saturation judgment. The improvements in the Bowen ratio and soil moisture suggests that those impacts will be amplified when the land surface model is couled to the other components of climate models. In the results above, the streamflow and Bowen ratio agreed well with the measurements when the saturation threshold was at about 50% of saturation (EP.2). The good agreement in the experiment with the relaxed threshold implies that there are processes that yield large runoff at a sub-grid scale due to inhomogeneity of land surface, such as macro pore, landscape, land use, etc. An optimum saturation threshold is expected to exist, that simulates such local runoff.

Keywords: Runoff, Water table depth, Land surface model, land energy-water balances

