Validation study of MATSIRO land surface model using the observed data in tropical monsoon climate of Thailand

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Abstract

The objective of this study is to assess the performance of the land surface model, minimal advanced treatments of surface interaction and runoff (MATSIRO) in tropical monsoon climate of Thailand. The testing of MATSIRO was carried out by offline mode (i.e., decoupled from complex interactions in the full 3D model). Driving and validation data sets were prepared for a one year period in 2003 with 30-min time step, which we've obtained at Tak flux measurement (TFM) site over mixed land use of tropical deciduous forest, grassland and paddy filed. The model was parameterized based on the standard parameter values generally used within 3D version of MATSIRO namely GSWP2 data set. At TFM site there is clear seasonal variation of rainfall that is divided into dry season and rainy season. Sensitivity study of MATSIRO for various soil type showed that the simulated evapotranspiration (ET) for silt and sandy clay soil was well corresponded to that of observed. As the soil consists of sandy clay soil according to our filed survey, we focused on the simulated result for sandy clay soil. The temporal change of simulated surface soil moisture was well corresponded to the observed surface soil moisture when large amount of precipitation occurred. However, the reproducibility of surface soil moisture became bad in prolonged dry period. The observed soil moisture in root zone was lower than that of simulated except the period of near saturation. During the period with successive rainfall, the simulated ET well reproduced the observation while the simulated ET was quite lower than that of observed in dry season.

Keyword: Land Surface Model, Evapotranspiration, Soil moisture, Tropical monsoon climate, Hydraulic conductivity

1. Introduction

The land surface model (LSM) has great role on the land-atmosphere interaction in the general circulation model (GCM). The intercomparison of LSMs has been carried out in the international projects such as the project for intercomparison of land-surface parameterization schemes (PILPS; Henderson-Sellers et al., 1995) and the global soil wetness project (GSWP; Dirmeyer et al., 1999). The offline validation using observational data can identify the serious problems and improve the realism of the LSM. So far, the offline validation of LSMs has been implemented mainly in USA, Europe and Amazon. However there were no such experiments in South-Eastern Asia, where the contrast of dry and wet season is quite remarkable. The objective of this study is to clarify the sensitivity of MATSIRO (Minimal Advanced Treatments of Surface Interaction and RunOff; Takata et al, 2003) for various soil type at Tak flux measurement site (TFM; Kim et al, 2003, 16°56'N, 99°25'E; Fig.1 (a)). Moreover, we aimed to validate the MATSIRO on surface fluxes and conditions at TFM with 1D-offline simulation for improving simulation in tropical monsoon climate.

2. Data, methods and model descriptions

The testing of MATSIRO was carried out offline mode (i.e., decoupled from complex interactions in the full 3D model). Driving and validation data sets were prepared for a one year period in 2003 with 30-min time step, which we've obtained at 30m height of tower in TFM site over mixed land use of tropical deciduous forest, grassland and paddy filed (Fig.1 (b)). The model was parameterized based on the standard parameter values generally used within 3D version of MATSIRO namely data set of GSWP-2 project (Dirmeyer et al., 2002). The spin-up before simulation was carried out as recursive run of the data in 2003 twice.

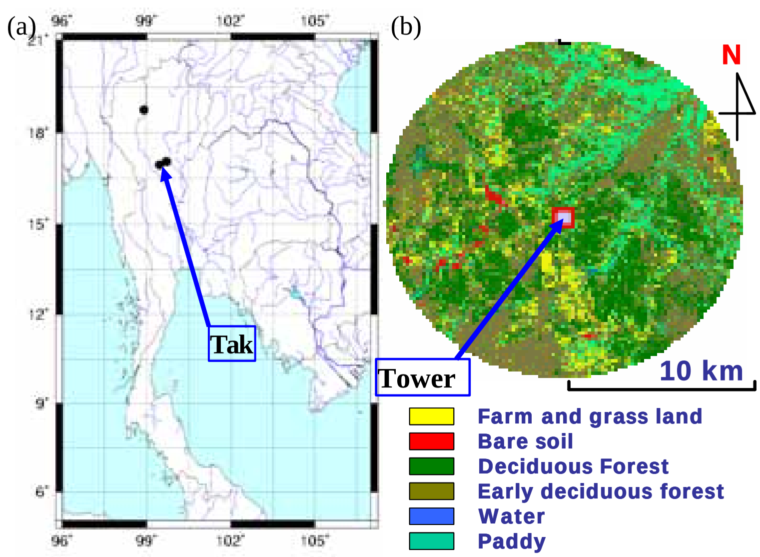

Fig.1: (a) The location map of the TFM site and (b) the land cover around the site.

The data of observed surface fluxes was calculated by eddy-covariance method with coordinate rotation (Wilczak et al, 2001) and density correction (Webb et al., 1980).

The fluxes of MATSIRO are calculated from the energy balance at the ground and canopy surfaces in snow-free and snow-covered portions considering the subgrid snow distribution (Takata et al., 2003). In MATSIRO the stomatal resistance is evaluated on the basis of a photosynthesis-stomatal resistance model (e.g., Farquhar et al., 1980; Ball, 1998; Collatz et al., 1990, 1991, 1992) after the scheme in SiB2 (Sellers et al., 1996). A simplified TOPMODEL (Stieglitz et al., 1997) is used to calculate runoff. The governing equation of MATSIRO uses Richards equation. The hydraulic conductivity and matric potential are calculated based on Clapp and Hornburger (1978) with the modification for frozen soil (Takata et al., 2003). The depth of soil layer was set to 2m. There are five soil layers (0-0.05m, 0.05-0.25m, 0.25-0.5m, 0.5-0.75m, 0.75-2m) in MATSIRO. The root fraction using in this study was arbitrarily defined as 0.35, 0.55 and 0.10 from surface to third layer. The land cover classification, soil type and leaf area index (LAI) were derived from GSWP2 data set. The topographic parameters for simplified TOPMODEL were estimated from GTOPO30 data.

3. Results and discussions

The soil moisture is the one of the most important factor for controlling the soil evapotranspiration (ET). Table 1 shows the soil classification and hydraulic parameters in the GSWP2 data set. In table 1, the W_sat is the saturation soil moisture, Ks is the saturated hydraulic conductivity, W_sat_matp is the saturated matric potential, B is empirical coefficient for slope of the moisture characteristic used for Clapp and Hornburger (1978). The parameters shown here are based on the Cosby et al. (1984).

Table1: Soil classification and hydraulic parameters in the GSWP2 data set

	Soil classfication	W_sat	Ks (m/s)	Phi_sat (m)	B
1	sand	0.373	2.45E-5	-0.05	3.30
2	loamy sand	0.386	1.75E-5	-0.07	3.80
3	sandy loam	0.419	8.35E-6	-0.16	4.34
4	loam	0.476	2.36E-6	-0.65	5.25
5	silt loam	0.471	1.10E-6	-0.84	3.63
6	silt	0.437	4.66E-6	-0.24	5.96
7	sandy clay loam	0.412	6.31E-6	-0.12	7.32
8	clay loam	0.478	1.44E-6	-0.63	8.41
9	silty clay loam	0.447	2.72E-6	-0.28	8.34
10	sandy clay	0.415	4.25E-6	-0.12	9.70
11	silty clay	0.478	1.02E-6	-0.58	10.78
12	caly	0.450	1.33E-6	-0.27	12.93

Cosby et al. (1984) pointed out that the ratio of clay is the discriminate factor for the B and Ks. The soil hydraulic parameters such as hydraulic conductivity and B parameter are closely related with the simulating soil moisture. Therefore we've carried out the sensitivity test of MATSIRO for ET using all soil type in GSWP2 data set. Table 2 shows the results of sensitivity tests of MATSIRO for cumulative ET during one year in 2003, dry season and rainy season with observed value. The annual precipitation in 2003, dry season and rainy season were 1154 mm, 134 mm and 1020mm, respectively. Generally, the soil with high ratio of sand showed the larger ET than the soil with high ratio of clay. The results using soil type 6 (silt) and 10 (sandy clay) were well corresponded with observation. According to our field survey around TFM site, the soil of surface several tens of centimeters consists of sandy clay which is no. 10 soil in GSWP2 soil classification. Therefore we will show the detailed comparison between simulated using soil 10 and observed data in the following.

Table 2: Results of sensitivity tests of MATSIRO for evapotranspiration with observed value.

Soil No.	E_year (mm)	E_dry (mm)	E_rain (mm)
1	949	385	564
2	1005	427	578
3	1031	436	595
4	678	150	528
5	496	73	423
6	870	277	593
7	949	385	614
8	547	91	456
9	716	158	558
10	842	232	610
11	470	68	402
12	528	77	451
Obs	**890**	**304**	**586**

Figure 2 shows the time series of daily mean volumetric soil water (W) content of simulated (soil-10) and observed at 0.05m with observed precipitation. According to the seasonal variation of precipitation, we defined the first dry, rainy and second dry seasons in January to the end of May, June to the end of October, and November and December respectively. Temporal variation of simulated W was well corresponded with observed value. The increase of W after the rainfall reproduced very well while the decrease of simulated W was slower than observed W. The discrepancy between simulated W and observed value during dry season and break of rainy season is likely related to the treatment of soil water movement in MATSIRO when W decrease after rainfall and low.

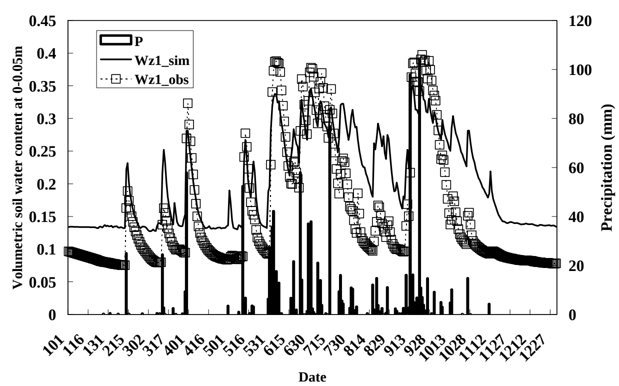

Fig. 2: Time series of daily mean volumetric water content of simulated and observed at TFM in 2003.

To consider the transpiration, the total root zone soil moisture is the most important factor. Figure 3 shows the time series of daily mean simulated and observed W in root zone layer. In MATSIRO the surface three layers (0-0.05m, 0.05-0.25m and 0.25-0.5m) are considered as root zone for grassland. The feature of temporal variation and discrepancy between simulated and observed in root zone

W was resemble to the surface W. In general, the observed W in root zone was larger than the simulated W.

The time series of daily mean simulated and observed evapotranspiration (ET) was shown in Fig. 3. In first dry season, the simulated ET was about half of observed ET except the period with increase of W after rainfall. The simulated ET was corresponded to observed ET in rainy season. In first half of second dry season, the simulated ET was larger than the observed ET while the simulated ET was corresponded to the observed ET in second half of second dry season. These features were consistent with the variation of W. It implies that the discrepancy of ET is caused by the failure of simulation of W. The failure of W in dry season likely related to the parameterization of soil hydraulic conductivity. As noted earlier, the hydraulic conductivity is estimated by Clapp and Hornburger (1978) in MATSIRO. The dry end of moisture characteristic are difficult to model precisely because the hydraulic conductivity is reduced by many orders of magnitude, even a rough approximation in this range may be sufficient (Clapp and Hornburger, 1978).

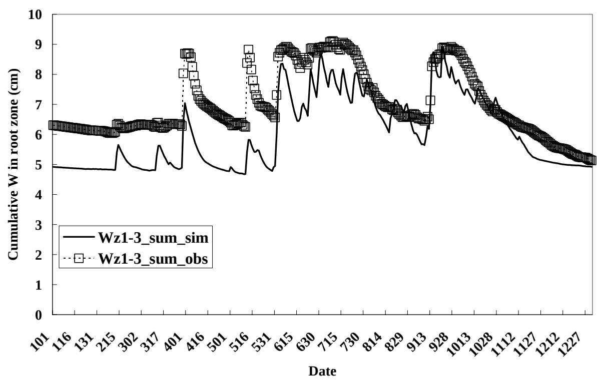

Fig. 3 Time series of daily mean volumetric soil water content of simulated and observed at TFM in root zone layer in 2003

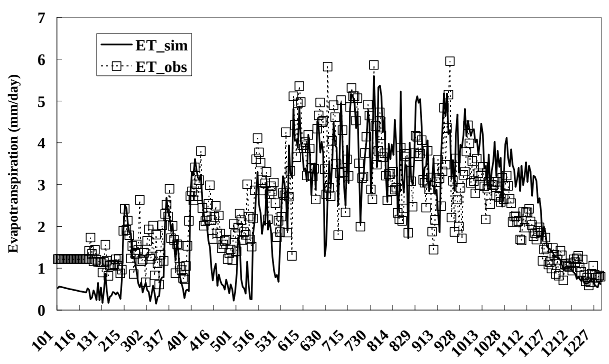

Fig. 4: Time series of daily mean evapotranspiration of simulated and observed at TFM site in 2003.

The runoff is also important factor on the water budget. Fig. 5 shows the time series of daily precipitation and simulated total runoff. Almost all runoff consisted of the infiltration excess runoff (Horton runoff). The runoff was occurred after the rainfall when it exceeded 20 mm per day or successive rainfall.

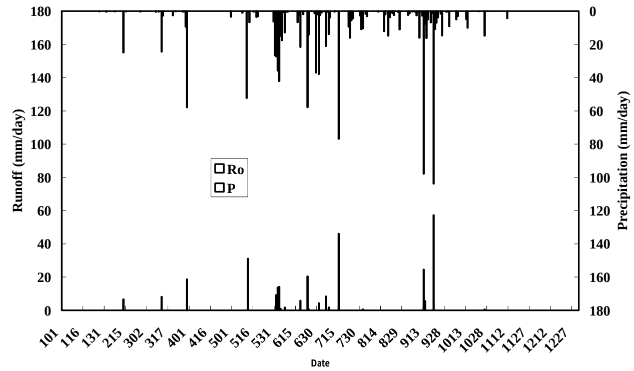

Fig. 5: Time series of daily precipitation and simulated runoff in 2003.

4. Concluding remarks

The 1D-offline test of MATSIRO was carried out at TFM site in tropical monsoon climate. The sensitivity test of MATSIRO for various soil types showed that the simulated annual ET for silt and sandy clay was well corresponded to the observed ET. The soil at TFM site was sandy clay defined by our filed survey. The detailed analysis was made for simulated results for sandy soil. The simulated surface W was well corresponded to the observed surface W in rainy season or the period with rainfall in dry season. The reproducibility of simulated surface W was bad in dry season and the phase of decreasing W, which suggests the faire of simulation of hydraulic conductivity in near dry end of soil. The simulated totals root zone W also showed similar feature to the surface soil moisture. The simulated ET in dry season and the prolonged dry period had large discrepancy with observed ET, while the simulated ET was well corresponded to the observed ET in rainy season and large rain in dry season. Instead of Clapp and Hornburger (1978), the other theory for estimating hydraulic parameters such as van Genuchten (1980) will be useful to clarify the reason for the problems in dry period.

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