DBM Rainfall-Runoff Modeling of Large Rainforest Catchments in Thailand

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Many headwater catchments in Southeast Asia are still covered by extensive rainforest. In Thailand, these forested headwaters are critical sources of unpolluted, potable water for downstream areas. The management of these headwaters also affects the likelihood of downstream flooding and availability of irrigation waters. The ability to predict the rainfall-runoff relation of large forested catchments is, therefore, critical to proper forecasting and planning of water resources.

In any region, rainfall-runoff behavior is difficult to model using a robust physical interpretation, because of inherent non-linearity in the rainfall-runoff relation. In part this relates to the dependency on the antecedent conditions in the catchment (Hansen *et al.*, 1996; Ye *et al.*, 1997). Within the Data-Based-Mechanistic (DBM) methodology, multiple model structures (including non-linear components) of the relation between incoming rainfall and outgoing rainfall are identified. The optimal structure is then identified by rejection of some using objective statistical inference. Further model rejection is then undertaken where models are seen to be inconsistent with the physical or hydrological theory.

Here, the results of the application of the DBM approach to the 3853 km^2 Mae Chaem catchment in Northwestern Thailand are discussed. The catchment is 86 percent (1998) covered by rainforest and is gauged at the Royal Irrigation Department river station (P14). The analyzed data covered a 10- year series with daily resolution.

A first-order model is analyzed first as it gives only one time-constant (TC) and steady state gain (ssG) which constrains model uncertainty and thus allows for easier interpretation. The time-constant is a measure of the residence time of the rainfall in the catchment, while the steady-state gain shows how much of the rainfall appears as riverflow rather than evapotranspiration losses or subsurface storage. Both a bilinear or store-surrogate submodel (Chappell *et al.*, 1999) and a storage submodel (Young, 2001) are used to capture the non-linearity in the behavior. It is clear from the results shown in Figure 1 that the rising stage, peaks and initial recessions are fitted well, but that the late recessions are poorly captured by the first-order model. By optimizing the models according to the objective function of the R_t^2 (i.e., ratio of the variance in the model residuals to that in the observed riverflow) the model identification routines will always ensure that most of the water mass is fitted, i.e., large storms should be fitted well. There is little additional error (e) introduced if the model poorly fits the low flow periods.

The fact that this first-order model fails to capture the behavior of the longer recessions, may indicate that rainfall reaches the river by more than one pathway. Thus, higher-order models (notably second- and third-order models) were fitted and the improvement in the fit of the late recessions by using these higher-order models is observable (Figure 2). The parameters of second-order models when decomposed into parallel pathways are presented in Table 1. The model indicates that most of the riverflow travels along the fast pathway (i.e., most of the river response is seen shortly after rainfall).

Clearly the DBM approach is able to model the rainfall-runoff behavior of a large catchment in Thailand. Analyses of further large catchments in Thailand, physical interpretation of model parameters and their changes with land-use and climate dynamics are presented in Vongtanaboon (2004).

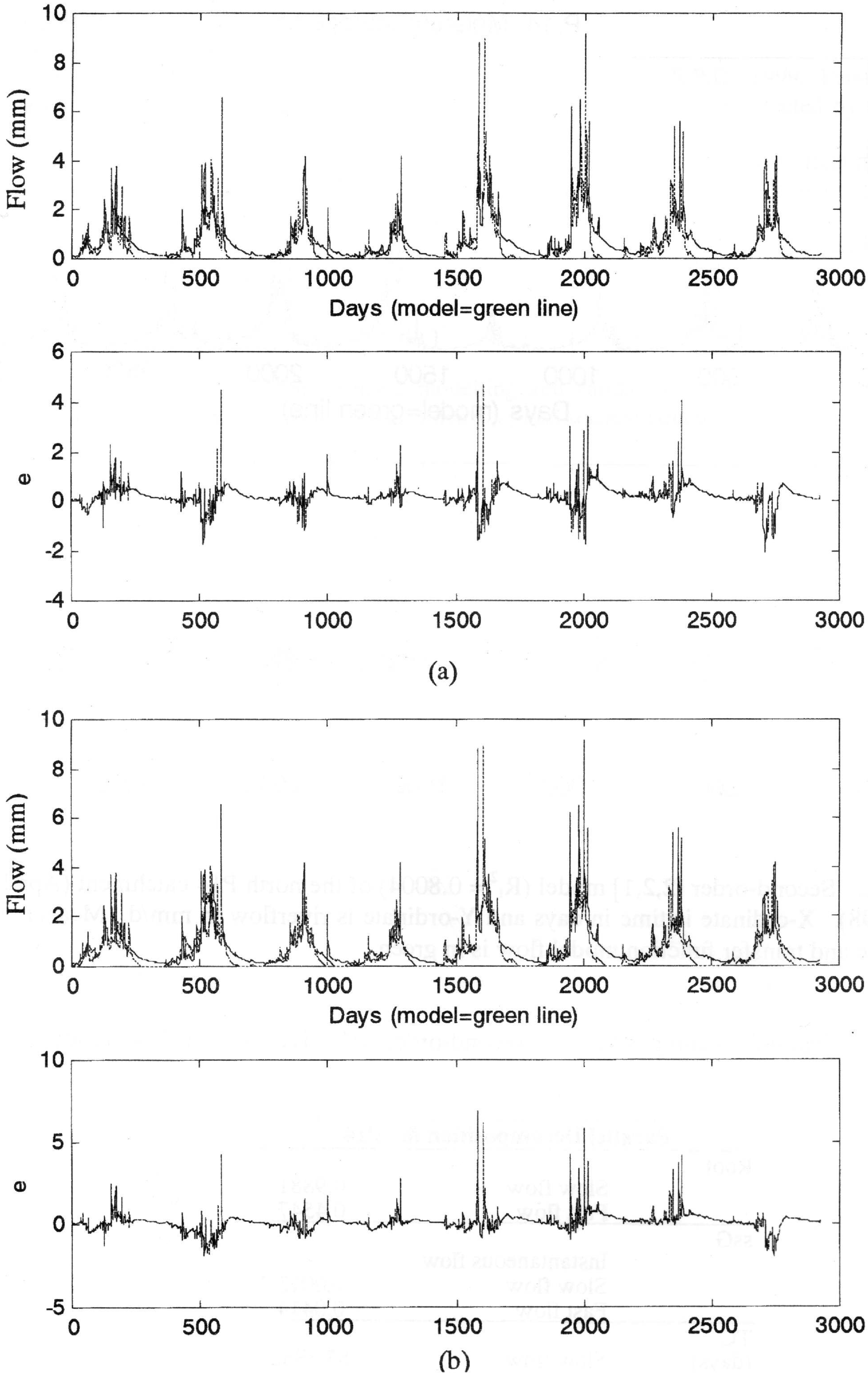

Figure 1. First-order [1, 1, 0] model of the P14 catchment from April 1990 to March 1998. (a) the model with the bilinear submodel, where the green line is the model and blue line the observed daily data in the upper plot and model residuals (mm/day) in the lower, and (b) the same for the storage nonlinear submodel.

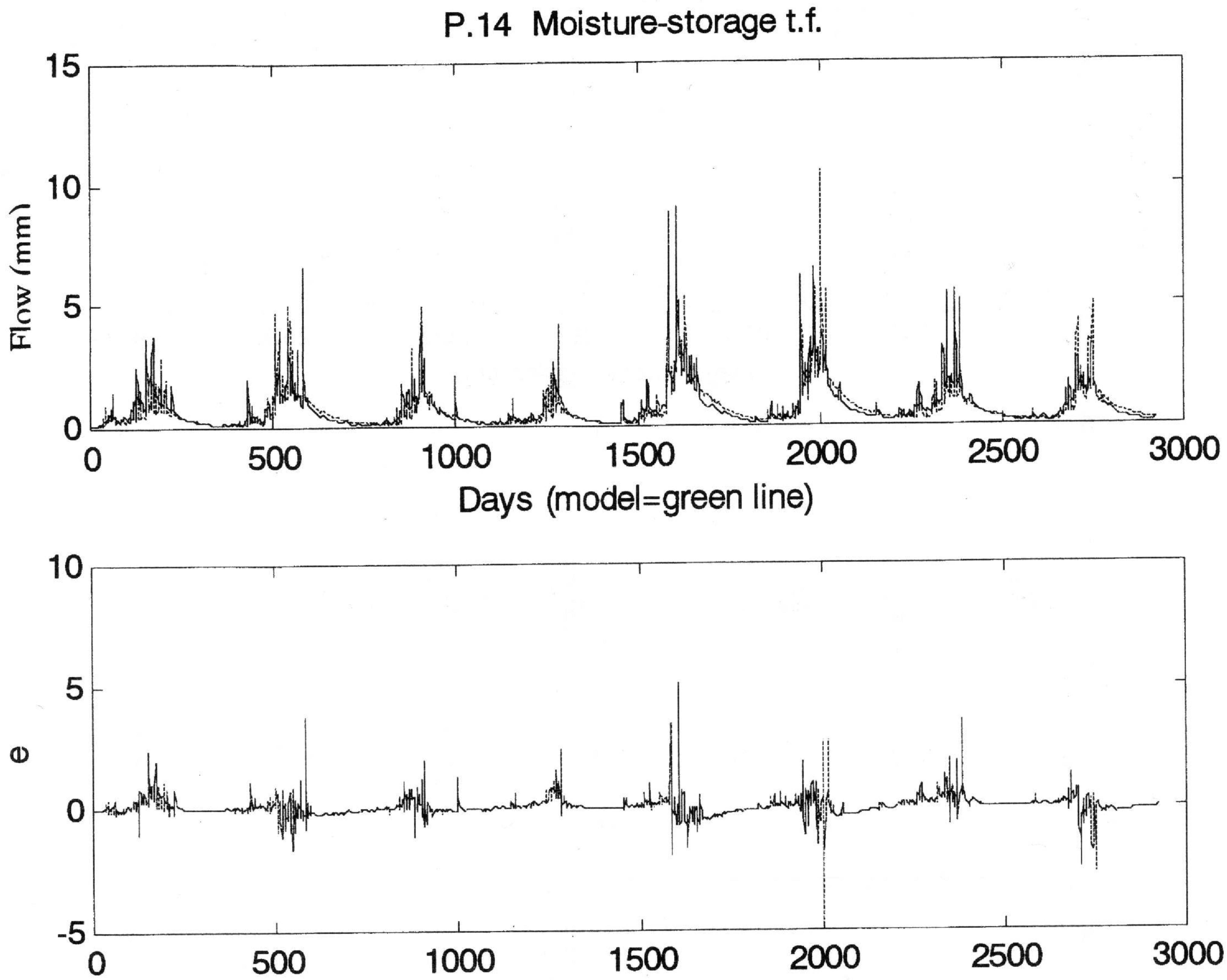

Figure 2. Second-order [2,2,1] model ($R_t^2 = 0.8004$) of the north P14 catchment (Apr 1990 - Mar 1998). X-ordinate is time in days and Y-ordinate is riverflow in mm/d. Measured flow is in blue and transfer function model flow is in green.

Table 1. Parallel decomposition of second-order effective rainfall-flow model for P14 catchment

Parallel Decomposition for P14		
Root		
	Slow flow	0.9881
	Fast flow	0.4547
ssG		
	Instantaneous flow	-
	Slow flow	0.0013
	Fast flow	0.0414
TC (days)	Slow flow	83.3882
	Fast flow	1.2689
Flow proportion	Instantaneous flow	-
	Slow flow	0.0298
	Fast flow	0.9702

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