Observational Studies at the Khuwae Noi River Basin in Thailand and Regional Water Balance Analyses by using the Distributed Tank Model

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Abstract

Observational studies at Khuwae Noi River Basin (Thailand) with catchment area of 4,841km^2 were developed from 1996. A hydrometric network consisting of five automatic weather stations, an automatic water level station and eight rainfall stations was established in this basin. The observations gave much information about the spatial and temporal distribution of the rainfall and the evaporation characters in this tropical area. They were compared with those from GAME reanalysis data-set and also those from TMD observation data. The evaporation data derived from the GAME data-set are verified to be reliable, but the rainfall data from GAME data-set need to be improved in this area. The study shows that the TMD rainfall data can be interpolated into grid data for regional water balance analyses and the analyses results are in good agreement with the observations. The discharge of this basin was simulated by using the Distributed Tank Model with temporal resolution of one hour and spatial resolution of 0.1 degree. These results confirm that the Distributed Tank Model is suitable for regional water balance analyses.

Keyword: observational studies, regional water balance, distributed tank model

1. Introduction

In the majority of cases, hydrological models are employed to estimate the water balance of a basin according to the observed data, such as rainfall, evaporation, soil moisture, and so on. But it was known that the observation data are temporally and somewhere spatially sparse in tropical regions. This prevents hydrological models from facilitating its application to tropical areas. In order to study the water balance, and the variation patterns of discharge, rainfall and the evaporation in a tropical area, a hydrometric network consisting of five automatic weather stations, one water level station and eight rainfall stations was established in 1996 at Khuwae Noi River Basin under a cooperative project between the National Research Institute for Earth Science and Disaster Prevention (NIED) of Japan and the Royal Irrigation Department (RID) of Thailand (Nakane, et. al. 2001). These observations were successfully analyzed with the Distributed Tank Model of 0.1-degree resolution in space and an-hour resolution in time.

1.1. Geographical Condition of Khuwae Noi River Basin

Khuwae Noi River Basin (see Fig.1), which is a tributary of the Nan River in the northeast of the Chao Phraya Basin, is located to the east of Phitsanulok, Thailand with catchment area of 4,841km^2. Some 77 percent of this basin is occupied by forest and the rest other is cropland and pasture. There are mountains ranging from 1,400 to 2,100 meters in height in the northern area and mountains ranging from 1,500 to 1,750 meters in the east part of the basin (see Fig.2).

1.2 The Distributed Tank Model

The Tank Model, which is a conceptual model and was developed by Sugawara (1972), has been one of the popular hydrological models for analyzing the water balance in a river basin. It appeared firstly as a lamped hydrological model, and in recent years has been generalized to be a distributed one by Nakane (2001) so as to study the regional water balance model in a continental scale.

The terrains in the considering area are classified into four types, namely mountainous area, hilly area, diluvial area and alluvial area. The land-use is classified into ten types according to the information of USGS (U.S. Geological Survey). Each grid of the analyzing area is the combination of two kinds of tank models: field tank and ground water-river tank, which represent the land surface and the river respectively. All the parameters in this model need to be calibrated with try-error method manually or optimization method automatically.

2. Components of the observations

Totally 14 hydrometric stations were established in Khuwae Noi River Basin. Five automatic weather stations (W1-W5), an automatic water level station (H1) and eight rainfall stations (R1-R8) are sited in the different topographic region, namely the mountains, hilly land, higher alluvial plain and lower alluvial plain. Three of the five weather stations (W1-W3) had also acted as soil moisture station. The locations of the stations are shown in Fig.2 and the details of observation components are listed in Table 1. Additionally, three existing discharge stations of RID, namely N22 (the same station as H1), N36 and N58 are used for evaluation with Distributed Tank Model. The details of the discharge stations are shown in Table 2.

The dense observations had been successfully carried out from April 1996 (some from May 1997) to March 2000. The five automatic weather stations, as well as the automatic water level station, record data every 20 minutes continuously, and the rainfall was measured on 10-minute base in the eight rainfall stations.

3. Evaluations

3. 1. Spatial Distribution of the Rainfall

The rainfall in this river basin, both monthly one and the sum of the rainy season varies quite a lot along with the terrain, as shown in Fig. 3 (the terrain is shown in Fig. 2). Generally, the rainfall in mountainous area is more than that in plain area.

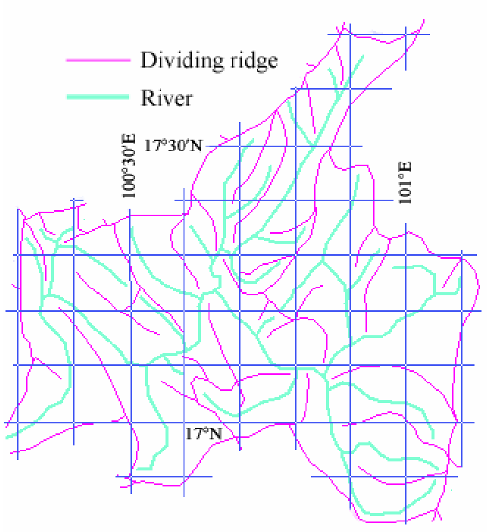


Fig. 1: Khuwae Noi Basin

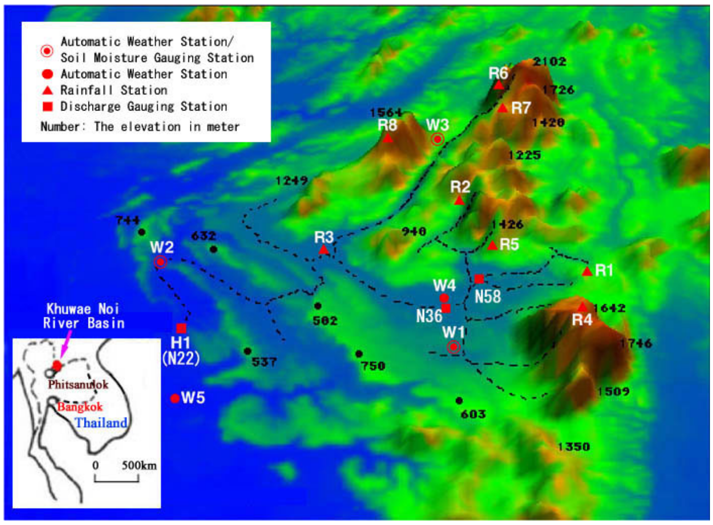


Fig. 2: Hydrometric Stations in Khuwae Noi Basin

Table 1: Details of stations and observation components

Station No.	Longitude (E)	Latitude (N)	Elevation (m)	Components						
				Wind	Radiation	Temperature	Rainfall	Water Level	Soil Moisture	Soil Temperature
W1	100°48′09″	16°59′28″	290	*	*	*	*		*	*
W2	100°20′00″	17°14′10″	90	*	*	*	*		*	*
W3	100°50′10″	17°31′58″	340	*	*	*	*		*	*
W4	100°45′52″	17°05′12″	200	*	*	*	*		*	*
W5	100°22′55″	16°50′01″	44	*	*	*	*		*	*
H1	100°22′32″	17°02′07″	52				*	*		
R1	101°03′19″	17°13′46″	180				*			
R2	100°52′45″	17°22′05″	460				*			
R3	100°37′05″	17°15′49″	240				*			
R4	100°59′33″	17°00′15″	1,105				*			
R5	100°56′05″	17°15′16″	989				*			
R6	100°55′09″	17°41′17″	515				*			
R7	100°53′43″	17°36′31″	680				*			
R8	100°40′30″	17°25′56″	840				*			

Table 2: Details of existing discharge stations

Station No.	Longitude *(E)	Latitude* (N)	Catchment Area (km^2)
N58	100°56′06″	17°08′33″	322
N36	100°49′55″	17°04′59″	1,651
N22 (H1)	100°22′32″	17°02′07″	4,841

(* The original format provided by RID is in degree)

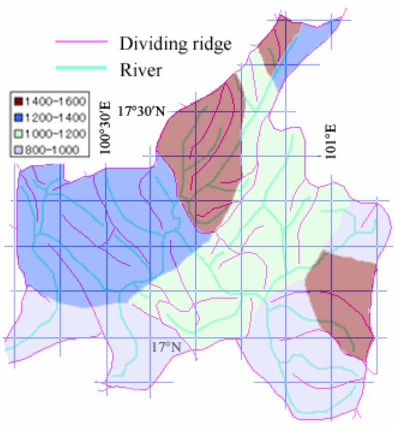
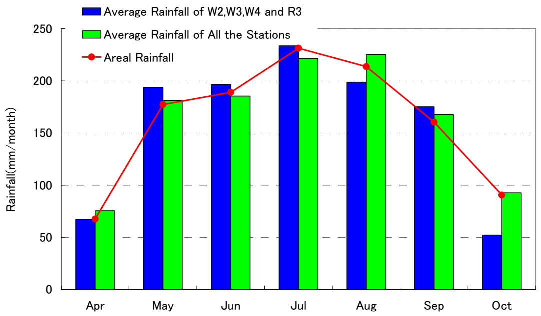


Fig. 3: Spatial Distribution of the Rainfall in 1998 (unit: mm)

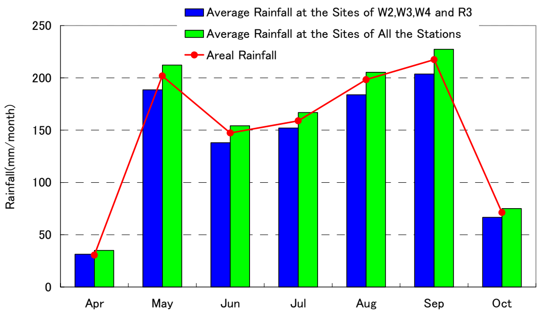
For the whole basin, because about 60 percent of area is under the elevation of 450m, it is reasonable to suppose that the areal rainfall of this basin mainly depends on the rainfall from the stations below 450m. The areal rainfall, the average rainfall of all the stations and the average rainfall of those below 450m (W2, W3, W4 and R3) are shown in Fig. 4. It can be seen in Fig. 4a that the monthly areal rainfall is very close to the average rainfall of all the 13 stations (station W5 was removed because of its much absence of observations), and it can be almost represented by the average value of the stations W2, W3, W4 and R3. i.e. W2, W3, W4 and R3 can be considered as the control stations of the whole basin.

3.2. Temporal Distribution of the Rainfall

The monthly distribution pattern of the rainfalls from GAME (GEWEX Asian Monsoon Experiment) reanalysis data, which were developed by Meteorological Research Institute, Japan, is shown in Fig. 4b. It is much different from that of the observed, as shown in Fig. 4a. Further more, the rainfall at station W3 is studied in Fig. 5. The rainfall of observations, the GAME reanalysis data and the TMD (Thai Meteorological Department, Thailand) observation data are all used for the comparisons. All the time steps were converted into three-hour base, even though the original one of the observations, GAME reanalysis data and the TMD observations is one hour, six hours and three hours respectively. The rainfall values of GAME at station W3 are interpolated from the original GAME data-set with spatial resolution of 1.25 degrees and those of TMD are interpolated from the TMD observation data with Angular Distance-weighted method (New, 2000).

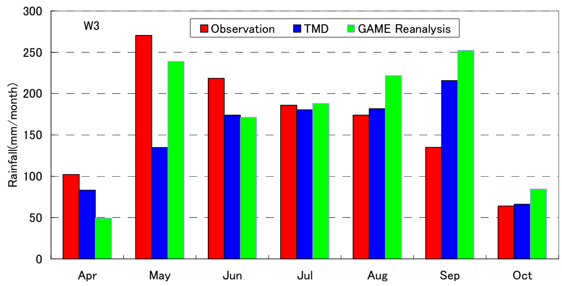


a) Observations

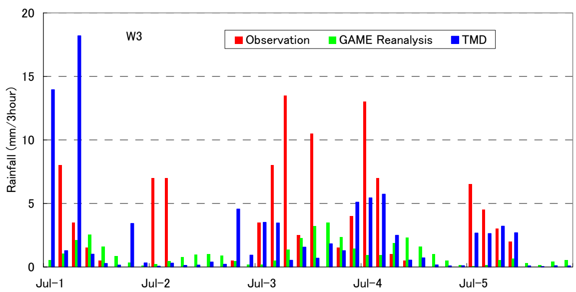


b) GAME reanalysis

Fig. 4: Comparisons of Areal Rainfall and the Average Value of Some of the Stations (April-October, 1998)



a) Monthly Rainfall at W3 (April-November)



b) 3-hour Rainfall at W3 (Jul.1-5th)

Fig. 5: Comparisons of Temporal Distribution of Different Data-sets in 1998

It can be seen that even though the amount of different datasets is almost the same on middle-sized base such as monthly interval, the distribution pattern become quite different if they are zoomed into small-sized base, 3-hour interval in this study. Briefly, the smaller the temporal base is, the sharper and more uneven the hyetograph becomes. Fig. 5 also shows that the rainfall interpolated from the TMD observations is relatively close to that of the observation in the basin.

3.3. Areal Evaporation

As necessary input data for the Distributed Tank Model, potential evaporation was carefully studied and calculated by using Priestley-Taylor method (Priestley, et. al. 1972). In this method, the calculation of the equilibrium evaporation is needed.

Fig. 6 shows the comparisons of the equilibrium evaporation derived from the observed heat data and GAME reanalysis data in the basin. Both in May and in September of 1998, the calculated equilibrium evaporation by using GAME reanalysis data agrees with that from observations very well. It tells that the GAME reanalysis data on heat balance analysis is reliable and it is feasible to compute the grid evaporation from GAME data in the regional water balance analyses.

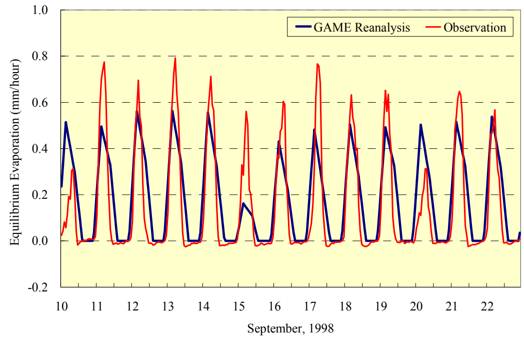


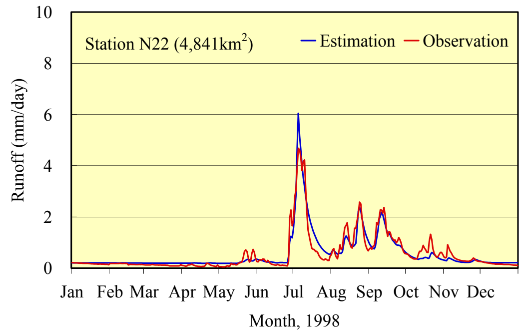
Fig. 6: Comparisons of Equilibrium Evaporation Derived from the GAME Reanalysis and Observations

3.4. Water Balance Analyses with Distributed Tank Model

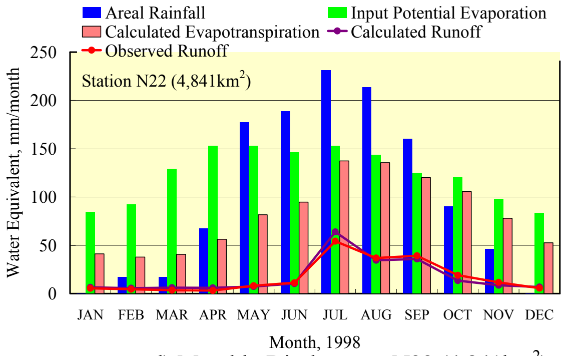
The Distributed Tank Model with spatial resolution of 0.5 degree and temporal resolution of one day had been successfully applied to the regional water balance analyses for the continental scale hydrology (Nakane, 2001). In this study the resolution was improved for the first time to 0.1 degree in space and one hour in time in this hydrological model.

In the water balance analyses, the input potential evaporation is based on the calculated equilibrium evaporation from GAME reanalysis data. It has been verified to be possible in the above. The calculated discharges of different places in the basin are compared. And the rainfall data from observations in this hydrometric network, GAME reanalysis dataset and the TMD observations are also evaluated with the Distributed Tank Model.

The observed and estimated discharges are shown in Fig. 7. This figure shows that the estimated discharges, both daily and monthly ones, agree well with the observed. It confirms that the Distributed Tank Model has great ability to analyze the regional water balance.

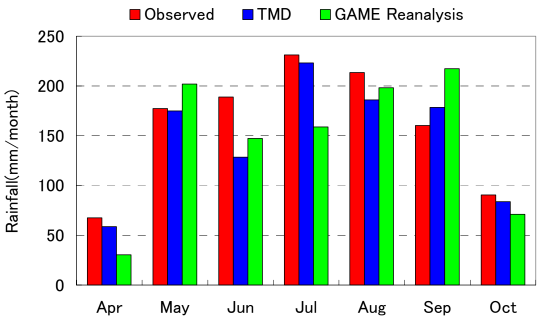


a) Daily Discharge at N22 (4,841km²)

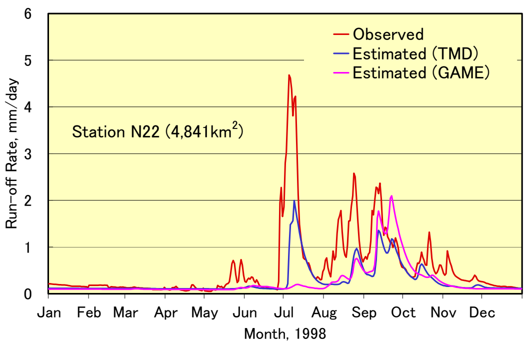


d) Monthly Discharge at N22 (4,841km²)

Fig. 7: Comparisons of estimated and observed discharge in 1998



a) Monthly Areal Rainfall of the Whole Basin in 1998



b) Comparisons of Daily Discharge at N22

Fig. 8: Evaluation of the Rainfall from the Observations, GAME Reanalysis and TMD

The areal rainfalls of the whole river basin calculated from observations in this hydrometric network, GAME reanalysis data and the TMD observation data are shown in Fig. 8a. It can be seen that the rainfall from GAME reanalysis data in this area is away from the observed. It is much less from June to July and greater in September than the observations in this hydrometric network. It leads estimated discharge based on the GAME data to be much less than the observed in June and July. However, the temporal distribution pattern of rainfall from the TMD dataset is roughly follows that from the observations except June, and the estimated hydrograph from the TMD observations is a little better than that from the GAME data (Fig .8b).

4. Conclusions

Fourteen hydrometric stations were established in Khuwae Noi River Basin (Thailand) and observational studies at this river basin were developed from 1996. The observations were compared with the data from GAME reanalysis data-set and also those from TMD observation data. The studies show that the evaporation data derived from the GAME data-set are reliable, but the rainfall data from GAME data-set need to be improved in this area. The studies also show that the TMD rainfall data can be interpolated into grid data for regional water balance analyses. The discharge of this basin was simulated by using the Distributed Tank Model with temporal resolution of one hour and spatial resolution of 0.1 degree. The results confirm that the Distributed Tank Model is a suitable model for regional water balance analyses.

Acknowledgements

The analyses in this study were supported by the project of Prediction of Natural Disasters Caused by Variation in the Atmosphere-land-ocean Hydrological Circulation of East Asia. The observation project in the Khuwae Noi River Basin had also been supported by the project of GAME-Tropics organized by Prof. K. Musiake, Institute of Industrial Science, University of Tokyo, ret. The GAME reanalysis data were provided by GAME reanalysis project conducted by Meteorological Research Institute, Japan Meteorological Agency and Earth Observation Research Center/National Space Development Agency of Japan.

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