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Comparison of Grid and Geomorphology Based Distributed Hydrological Models

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1. Introduction

The traditional and most common distributed hydrological models are based on the regular discrete square grids system which is used for representation of the catchment spatial heterogeneity, such as SHE model [1].The grids are the discrete units in SHE model, the vertical direction is represented by a number of soil column. An alternative type of distributed hydrological model is geomorphology-based model, designated GB model [2, 3, 4, 5], which employs the geomorphological area function and width function to represent the spatial variability by one-dimensional distribution functions. The catchemnt is divided into flow intervals, and each flow interval is represented as a series of hillslope elements. The discrete units in GB model are hillslope elements, the vertical soil column is corresponding to each hillslope element. This paper compares the two models on two aspects, representations of spatial variations and the performances of hydrological simulation.

2. Descriptions of Hydrological Processes in the Two Models

SHE model uses a simple degree-day model for snowmelt, kinematic wave model for surface flow and river flow which is solved by implicit finite difference method, 1-dimensional Richards equation for describing unsaturated water flow that is solved by implicit scheme, and 3-dimensional groundwater flow.

The saturated zone is treated as one-dimension in GB model. The air temperature and snow are distributed according to the elevation in GB model instead of Thiessen polygon used by SHE model. Other hydrological processes are described using same models or governing equations as SHE model. The Richards equation is solved by a modified explicit numerical scheme.

3. Study Area

In order to compare the representation of spatial variations and investigating the performance of both models, we select Seki River as the study area which is located in Hokuriku region of Japan and has an area of 703 km^2. One land use type (forest), one soil type (Kanto loam) and uniform depth of unconfined aquifer are considered within this catchment. In this case, the topography is the only spatial varying information. The DEM resolution which is used by the two hydrological models is 300 m resampled from original 250 m cell size data.

4. Representation of Spatial Variations in the Two Models

The grid size used in SHE model is 300 m, GB model uses 119 flow intervals which have the length of 300-600 m. Table 1 shows the representations of the catchment by the two models. The discrete units are uniform in SHE model, but vary with flow distance in GB model. The total number of grids used in SHE model is 7830 and the total hillslope element number in GB model is 1018. On the elevation and slope gradient of the discrete unit, the minimum values are same in both models; the mean values are very close; but maximum value in SHE model is greater than GB model. The maximum slope gradient in SHE model is 63.4%, but 28.8% in GB model.

5. Comparison of Model Performance

The two models were applied in Seki River with same conditions. The rainfall, air temperature and sunshine hours are from AMeDAS data source. There are four rain-gauges, two of them had the air temperature and sunshine hour records. SHE model runs from November 1, 1994 to December 31, 1995; GB model runs from January 1, 1994 to December 31, 1995. Because of the uniform land use and soil, GB model treats the vertical direction within a flow

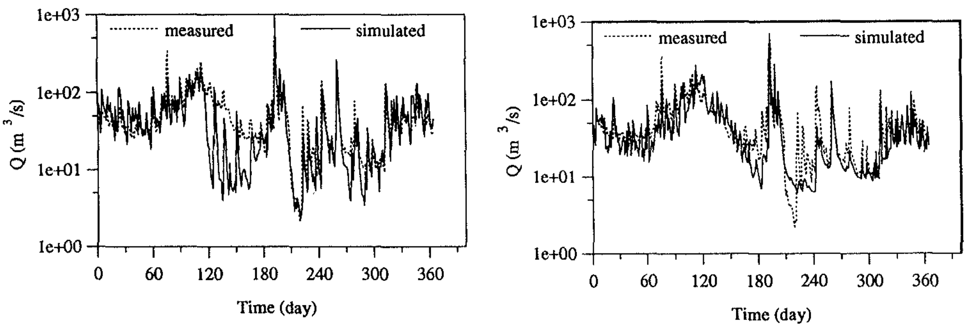
Table 1 Representation of Catchment

Model	Discrete unit			Elevation (m)			Slope gradient (%)		
	number	length (m)	area (km^2)	min.	max.	mean	min.	max.	mean
SHE model	7830	300×300 (uniform)	0.09 (uniform)	9.994	2329.4	712.6	0.0	63.4	14.7
GB model	1018	825.4×480.7 (mean)	0.789 (mean)	10.0	1953.8	730.7	0.0	28.8	13.7

Table 2 Comparison of Model Performance

Model Type	Actual Evapotranspiration (mm)	Total River Outflow (mm)	Error (%)		Computation Time (hr) (Sun 133 MHz work station)
			total outflow	daily discharge	
SHE model	787.0	2164.5	-10.0	17.6	72
GB model	780.8	2050.8	-14.8	17.5	1/6

interval by a single soil column; the number of soil columns is same as flow interval number. SHE model also regroup the soil columns according to the meteorological input, vegetation type and soil type; and the maximum number of unsaturated columns that can be simulated in SHE model is 300. Both simulations output hourly results. Figure 1 shows the comparison of daily hydrographs of 1995 simulated by SHE model and GB model with the observed one. The daily discharge errors from SHE model simulation are manly from April to June, the simulated discharge is smaller than observed one. The snow and air temperature are distributed by Thiessen polygon as same as rainfall in SHE model, this may introduce the above error. The errors from GB model simulation are mainly from end of July to August, the simulated hydrograph is lower than the observed one. Probably, this error is brought by the simpler groundwater description. Table 2 summaries the simulation results of 1995 by both models. The total actual evapotranspiration, total river outflow and the daily discharge error by the two models are very close. We can see that the simulation results by GB model is as good as SHE model, but the computation time of GB model is only 0.3% of that SHE model spent.



a. SHE Model

b. GB Model

Figure 1 Comparison of Daily Hydrographs of 1995 between Simulated and Observed

6. Conclusion

The results shows that GB model is good as the comprehensive distributed SHE model, and it takes much less computation time than SHE model. The good performance of GB model proves that the geomorphological area function and width function are useful to grasp the catchment characteristics. The spatial outputs from SHE model are assigned to each grid, the GB model spatial outputs are written in one-dimensional distribution functions. Following the flow distance, the spatial outputs can return to the original coordinate system. It is necessary to compare the spatial distributions of the hydrological characteristics in a future study.

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