Comparative study of water balance in Asia between Kuo and PAS Schemes simulated by the JMA89 Model

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Abstract

The result of ten year integrations of the JMA89 global model with Kuo scheme and Prognostic Arakawa-Shubert scheme (PAS) were compared. In global, basinwide water balance simulated by PAS scheme was more realistic than that of Kuo scheme, but river runoff of both Kuo and PAS schemes were overestimated than observation. Land surface hydrology in Asia between Kuo and PAS schemes was compared in detail. The results showed that deep convection scheme take large influences to land surface hydrology not only precipitation pattern, but also evapotranspiration through cloud and solar radiation processes.

1 Introduction

Atmospheric general circulation models (AGCM) is a useful tool for studying land-atmosphere-biosphere interactions and for predicting global climatic changes. Typically, AGCM with a land surface hydrology parametrization including the biospheric model have developed such as the biosphere atmosphere transfer scheme (BATS) of Dickinson et al. (1986) and the simple biosphere (SiB) model of Sellers et al. (1986). A primary goal of these parametrizations is to produce realistic surface water balances, those components are precipitation, evapotranspiration, soil moisture storage, and river runoff. However, the observed data available to validate hydrological results of AGCM are lacking.

In particular, river runoff is represented to the water balance of large scale drainage basin, and excellent methods to check the reliability of the global water budget simulated by AGCM long term integrations. The contribution of global runoff has been discussed in several papers. Russell and Miller (1990) was compared model generated river runoff with observations in major rivers, and showed quantitatively well corresponding between them. Sausen et al. (1994) was also compared in 33 major rivers, and it was largely affected by model's precipitation and parametrizations of land surface hydrology. Oki et al. (1995) was estimated water balance in a specific river basin not only for land surface but also for atmospheric vapor flux convergence.

In similar to these former studies, Ichiyanagi et al. (1997) was also compared river runoff between two different deep convective schemes in AGCM. And, it made clear that water balance in major river basins simulated by PAS scheme represented more realistic features than that of Kuo scheme. The purpose of this paper is to compare of water balance not only for river runoff, but also for other hydrological components between these two convection schemes. In particular, effect of deep convective schemes to water cycle in Asia was discussed.

2 Model Description and Observation Data Sets

The AGCM used for the present study is derived from Japan Meteorological Agency for operational weather forecasting model (JMA89). This model is a global primitive equation model using a spectral transform methods, with a triangular wave truncation at wavenumber 42 and 21 vertical levels (T42L21). The horizontal resolution is approximately 2.8 degrees in both latitude and longitude. For the parametrization of land surface processes, SiB model described in Sato et al. (1989) was used. A level-2 closure model for vertical diffusion is used (Mellor and Yamada, 1974). For deep convection, modified Kuo (1974) and Prognostic Arakawa-Shubert (PAS) schemes have been employed. The AGCM with each scheme was integrated for 10 years from January 1, 1979 with observed SST data which is used for the Atmospheric Model Intercomparison Project (AMIP). The 10 years integration output from 1979 to 1988 was averaged in each month and summed up to annual mean value.

River runoff observed at gauging station is provided from the Global Runoff Data Centre (GRDC, 1992; 1996). Long term mean values are calculated from these data by averaging over the available data period in each station. The continental land mass was manually devised into river basins using published world maps. Precipitation observed at gauging station is used Monthly Station Precipitation Data provided from NOAA Baseline Climatological Data Sets. All gauging station data in specific river basin was simply averaged for each month.

3 Results and Discussion

3.1 Water balance in major river basin

The annual mean values of precipitation and river runoff simulated by AGCM have been summarized in each river basin, and compared with observations in Figure 1.

We can see the good correlation between model simulation and observation in precipitation. In specially, precipitation simulated by PAS scheme is surprisingly good (Fig.1a). There are also good correlation between river runoff simulated by PAS scheme and observation data (Fig.1b). But river runoff simulated by Kuo scheme is not so. The results of these comparison show that water balance simulated by PAS scheme is more realistic than that of Kuo scheme in global. Generally, simulated river runoff is overestimated for most of the river basins than observation in both Kuo and PAS schemes, but differences between model simulation and observation are widely spread among each river basins.

3.2 Distributions in Asia

Simulated differences more than 100 mm/year between Kuo and PAS schemes in convective precipitation, large scale precipitation, transpiration and interception, evaporation from bare soil, soil moisture in both surface and root zones and river runoff fields are shown in Figure 2.

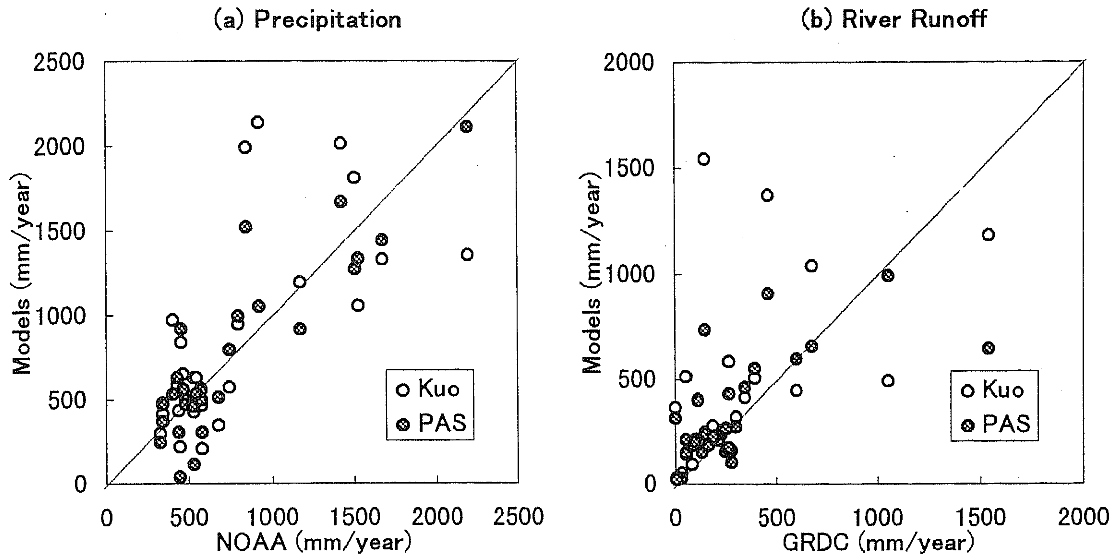

Figure 1. Comparison between AGCM simulations and observation.

The differences between Kuo and PAS schemes are clearly appearing in both convective precipitation and large scale precipitation fields (Fig.2a,b). Over ocean, convective precipitation simulated by PAS scheme is larger, but large scale precipitation simulated by Kuo scheme is larger. Over land, both convective and large scale precipitation simulated by Kuo scheme are larger than those of PAS scheme. Only in East India, Indochina Peninsula and Tibetan Plateau, convective precipitation simulated by PAS scheme is larger. Distribution of transpiration and interception field is similar to that of evaporation from bare soil field (Fig.2c,d). Evaporation simulated by Kuo scheme is larger in China and West India, and in Tibetan Plateau that by PAS scheme is larger, respectively. Soil moisture simulated by Kuo is larger in Tropical Region (Fig.2e). Distribution of river runoff field is similar to that of convective precipitation field (Fig.2f), except in Tibetan Plateau where river runoff simulated by Kuo scheme is larger than convective precipitation.

There are three areas where characteristics of anomaly fields are different in Figure 2. First one is an area where Kuo > PAS in both convective and large scale precipitation fields (e.g. West India and China). Corresponding to precipitation fields, transpiration and interception, evaporation from bare soil, soil moisture and river runoff fields are all Kuo > PAS. Second one is an area where Kuo < PAS in convective precipitation field (e.g. East India and Indochina Peninsula). Both transpiration and interception field and evaporation from bare soil field are Kuo equal to PAS. And, river runoff field is almost same to precipitation fields. These two patterns show good correlation between precipitation and river runoff. Third one is an area where Kuo < PAS in convective precipitation field, and Kuo > PAS in large scale precipitation field (e.g. Tibetan Plateau). Both transpiration and interception field and evaporation from bare soil field are Kuo < PAS, and also same to convective precipitation field. But, soil moisture and river runoff fields are Kuo > PAS, and also same to large scale precipitation field. Third area is more complex to understand formation processes of this relations than those for former two areas.

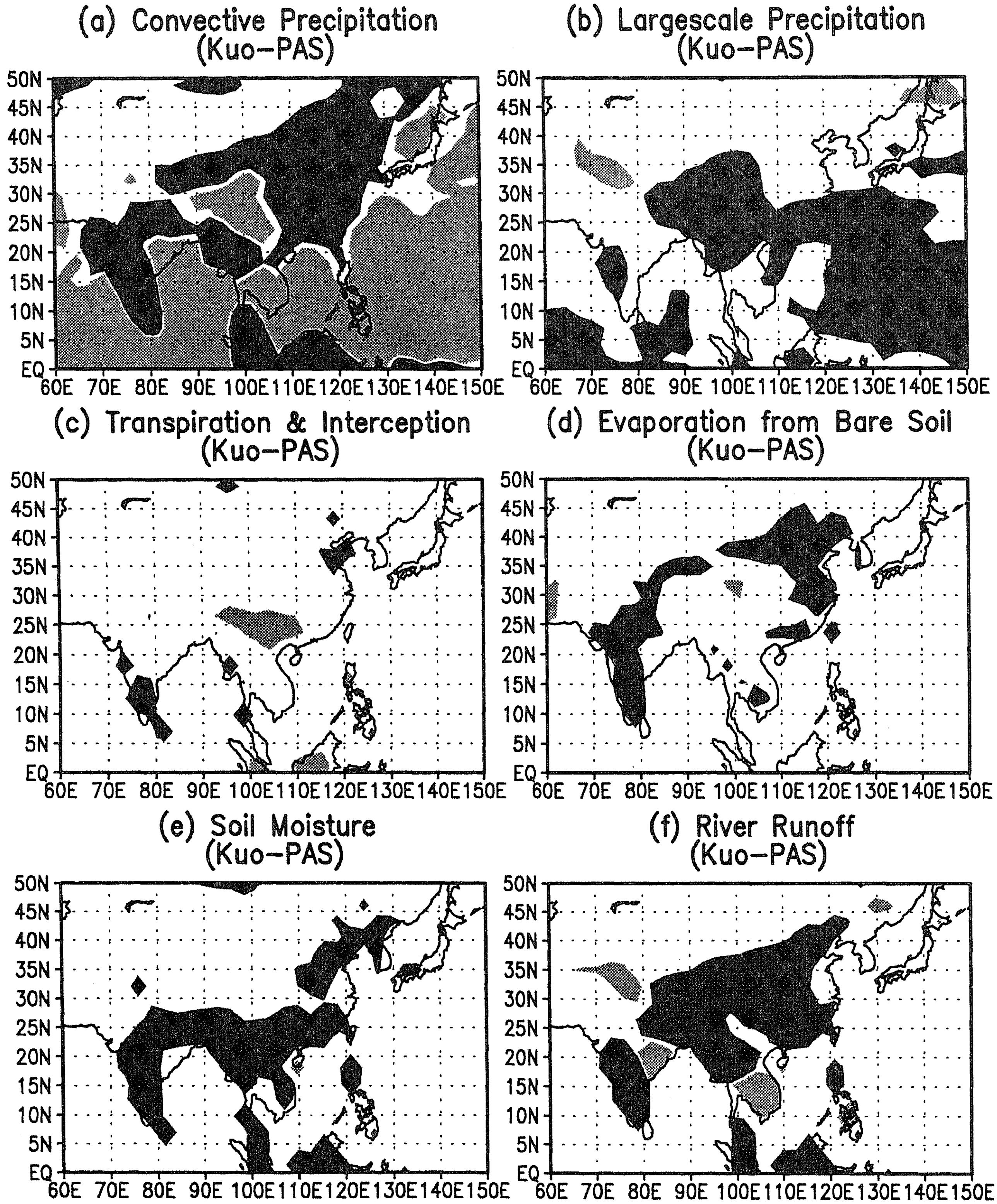

Figure 2. Distributions of differences between Kuo and PAS schemes more than 100 mm/year. Deep and shallow shadings show Kuo > PAS and Kuo < PAS, respectively.

3.3 Seasonal variation

To make clear the influence of deep convection scheme to land surface hydrology, seasonal variations of precipitation, river runoff, downward solar radiation on three regions were shown in Figure 3.

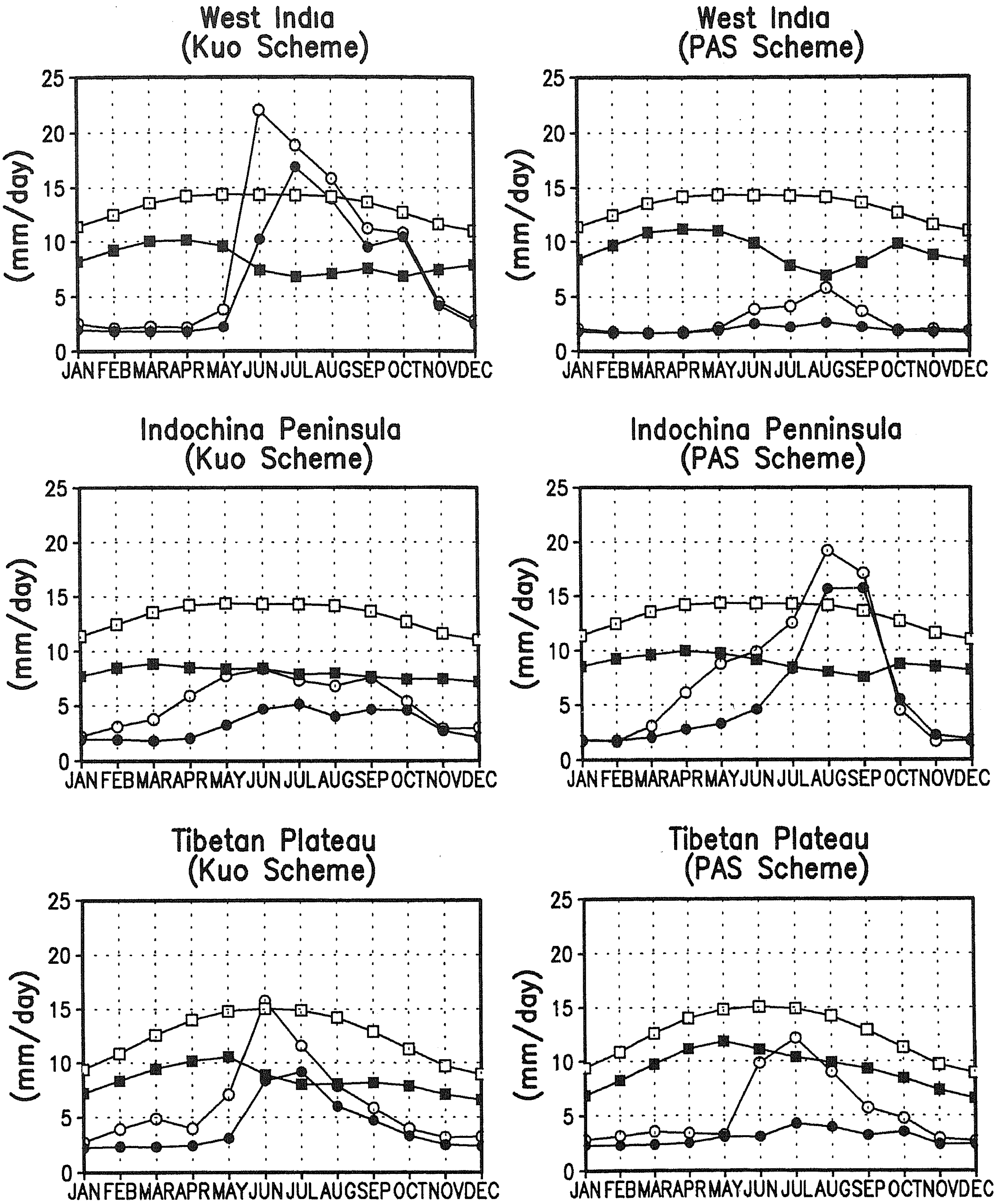

Figure 3. Seasonal variations of land surface hydrology and solar radiation in three regions. Open and solid circles show precipitation and river runoff, and open and solid squares show downward solar radiation on top and bottom of atmosphere, respectively.

Seasonal variation of precipitation simulated by Kuo scheme in West India is clearly showed summer monsoon peak (Fig.3a). But, that of PAS scheme is too small (Fig.3b). In contrast, precipitation simulated by Kuo scheme is too small, and that of PAS scheme is large in Indochina Peninsula (Fig.3c,d). In Tibetan Plateau, precipitation is not different between two schemes, but river runoff simulated by PAS scheme is much smaller than that of Kuo scheme during summer (Fig.3e,f). Difference of downward solar radiation between top and bottom of atmosphere simulated by PAS scheme is much smaller than that of Kuo scheme. It pointed out that solar radiation on land surface is larger, and evapotranspiration is also larger. Therefore, most part of precipitation is evaporated on land surface, thus river runoff becomes smaller in PAS scheme. Above all, deep convective scheme takes much influence to land surface hydrology, not only precipitation input but also evapotranspiration output through cloud and solar radiation processes.

4 Conclusions

Basinwide water balance and regional distributions of surface hydrology in Asia simulated by the JMA89 Model with both Kuo and PAS schemes were compared. The results was summarized as follows: Basinwide water balance in specific river basin simulated by PAS scheme is good corresponding to observations. Deep convection scheme takes much influences to basinwide land surface hydrology, not only by precipitation input but also by evapotranspiration output through cloud and solar radiation processes.

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References

[1] Dickinson, R. E., A. Henderson-Sellers, P. J. Kennedy and M. F. Wilson, 1986: Biosphere-Atmosphere transfer scheme (BATS) for the NCAR Community Climate Model. NCAR, Boulder, CO, Tech. Note/TN-275 + STR.

[2] GRDC, 1992: *Second Workshop on the Global Runoff Data Centre. Report 1*, Bundesanstalt für Gewässerkunde, Federal Institute of Hydrology, 96pp.

[3] GRDC, 1996: Freshwater fluxes from continents into the world oceans based on data of the global runoff database, *GRDC Report No.10, Koblenz, Germany.*

[4] Kuo, H. L., 1974: Further studies of the influence of cumulus convection on large scale flow, *J. Atmos. Sci.*, **31**, 1232-1240.

[5] Ichiyanagi, K., Chiba, M., Sugi, M., Kuma, K. and Sato, N., 1997: Estimation of water balance in major river basins simulated by JMA89 Model, *Tenki*, **44(8)**, 551-554. (*in Japanese*)

[6] Mellor, G. L. and T. Yamada, 1974: A hierarchy of turbulence closure models for planetary boundary layers, *J. Atmos. Sci.*, **31**, 1791-1806.

[7] Oki, T., Musiake, K., Matsuyama, H. and Masuda, K., 1995: Global atmospheric water balance and runoff from large river basins, *Hydrol. Process.*, **9**, 665-678.

[8] Russell, G. L. and J. R. Miller, 1990: Global river runoff calculated from a global atmospheric general circulation model, *J. Hydrol.*, **117**, 241-254.

[9] Sato, N., P. J. Sellers, D. A. Randall, E. K. Schneider, J. Shukla, J. L. Kinter, Y-T. Hou and E. Albertazzi, 1989: Effects of implementing the Simple Biosphere model in a General Circulation Model, *J. Atmos. Sci.*, **46**, 2757-2782.

[10] Sausen, R., S. Schubert and L. Dumenil, 1994: A model of river runoff for use in coupled atmosphere-ocean models, *J. Hydrol.*, **155**, 337-352.

[11] Sellers, P. J., Y. Mintz, Y. C. Sud, and A. Dalcher, 1986: A simple biosphere model (SiB) for use within general circulation models, *J. Atmos. Sci.*, **43**, 505-531.