

VALIDATION OF SOIL MOISTURE ESTIMATED BY LAND SURFACE SCHEME COMPARING WITH IN SITU OBSERVATION

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ABSTRACT

Soil moisture has a great role of partitioning of land surface fluxes. Understandings of the state of soil moisture are one of the essential ways to improve the accuracy in climate predictability on seasonal or annual time series. To applying estimated soil moisture by land surface schemes to climatology, estimated soil moisture field is validated with observation. To understand the time series accuracy in soil moisture field, two correlation coefficients are calculated between estimated soil moisture and observed soil moisture. From the correlation analysis, there are the regional differences of land surfaces schemes ability to estimate soil moisture field. It is assumed that there are key features of reproducing soil moisture. For investigating the essential factors for reproducing seasonal cycle of soil moisture, analysis of water balance components are carried out. Water balance analysis leads to the assumption that soil moisture estimation has a good performance because soil moisture has clear seasonal cycle caused by the fact that the seasonal cycle phase of precipitation is different from that of evapotranspiration. Furthermore, there is higher fraction of precipitation to evapotranspiration in other insufficient performance regions. It is assumed that precipitation is almost converted to evaporation and a few amount of water is infiltrated to soil layer.

1 INTRODUCTION

Soil moisture has a great role of partitioning of land surface fluxes. Understandings of the state of soil moisture are one of the essential ways to improve the accuracy in climate predictability on seasonal or annual time series. However, it is difficult to derive long term or spatial distributed soil moisture in situ observation. Furthermore, remote sensing technique can be applied partly to bare soil or short vegetation land use area. Therefore, one of effective method is to estimate soil moisture field by land surface schemes.

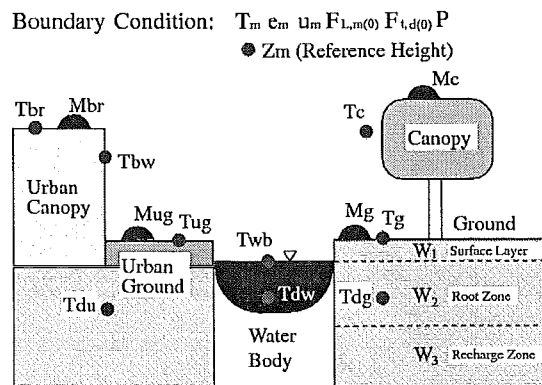


Figure 1. Schematic image of surface elements and prognostic variables in SiBUC

To produce state-of-the-art global data sets of land surface hydrological variables, Global Soil Wetness Project (GSWP) has been implemented. The goal of GSWP is understandings of the global field of soil moisture during long period by integration of one way uncoupled land surface scheme (Dirmeyer *et al.*, 2002). Simple Biosphere including urban canopy (SiBUC) is one of participants of 2nd GSWP and SiBUC has estimated the global distribution of land surface hydrological variables including soil moisture under the framework of GSWP2 (Yorozu *et al.*, 2004). For applying these products to other researches, it is important to understand spatial or temporal accuracy in land surface hydrological variables.

2 DATA DESCRIPTION

2.1 Basic concept of land surface scheme, SiBUC

In the atmospheric boundary layer, the radiative energy absorbed from the sun and the atmosphere is partitioned into fluxes of sensible, latent and ground. This surface flux partitioning (redistribution of absorbed energy) is strongly dependent on both the land cover characteristics and its hydrological state. Especially, heat budget characteristics of water body and urbanized area are much different from those of vegetation and soil surface. Thus, they may have significant effects even when their coverage areas are not so large. Land surface schemes (LSSs) should have a framework of treating the urbanized area, inland water. However, these kinds of land use are usually omitted in the existing LSSs without enough investigation about how they act in regional and global climate systems.

From such considerations, the SiB (Simple Biosphere) model (Sellers *et al.*, 1986) was expanded to the SiBUC model. The SiBUC model has been developed at DPRI Kyoto University (Tanaka, 2004) and has three sub-models (green area, urban area, water body) for each grid box. SiBUC is aimed to describe the basin-scale land surface processes more realistically than existing models. Figure 1 shows a schematic image of surface elements in SiBUC.

2.2 Simulation design

The domain of simulation in this study covers the whole world. The integration time is 10 years from 0000UTC 1 Jan 1986 to 0000UTC 1 Jan 1996 at a spatial resolution of 1 degree and time step of 1 hour is used. All input data set for model are specified from the ISLSCP (International Satellite Land-Surface Climatology Project)

initiative II data set (Hall *et al.*, 2004). The SiBUC is integrated from 0300UTC 1 July 1982 because of implementation of spin-up process for the 3.5-year period. The conditions of spin-up at beginning are soil wetness at 75% of saturation, no snow cover and specified soil temperature (provided). As a result of spin-up, the initial conditions of the evaluation period are calculated. Then, the SiBUC is integrated globally for the 10-year period 1986-1995 (Yorozu *et al.*, 2005).

2.3 Soil moisture observation

Global soil moisture field estimated by SiBUC is compared with soil moisture observation data provided from Global Soil Moisture Data Bank (GSMDDB). GSMDDB data set are divided to five regions; Illinois (United States of America), China, India, Mongolia and Russia (Robock *et al.*, 2000). The observation characteristics are different between each region: method, time interval, number of layer and applied soil depth. Figure 2 shows the difference of observation frequency. In this study, raw data are converted to monthly 1 m soil column water content by summarizing.

3 ANALYSIS

3.1 Comparison between soil moisture estimation and observation

To understand the time series accuracy in estimated soil moisture field, two correlation coefficients are calculated between soil moisture estimation and observation. First, monthly time series of soil moisture are compared for analyzing seasonal cycle accuracy. Second, time series of monthly deviation from annual variation are compared for analyzing the accuracy of inter-annual variation.

Figure 3 shows the distribution of correlation coefficients. It is found that there are spatial patterns of soil moisture accuracy. In Illinois regions, model can estimate both monthly soil moisture and monthly deviation, quite accurately. The similar results are also derived in central part of China region. In India region and west part of Russia region, correlation coefficients show good performance of estimating monthly soil moisture. In addition, in north-east part of China region and east part of

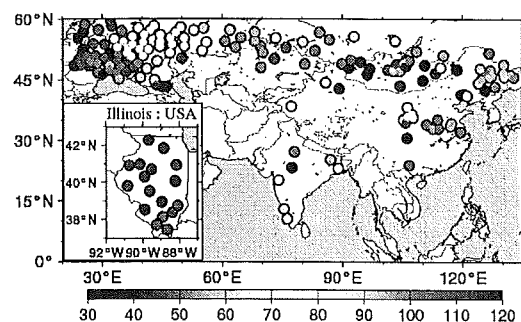
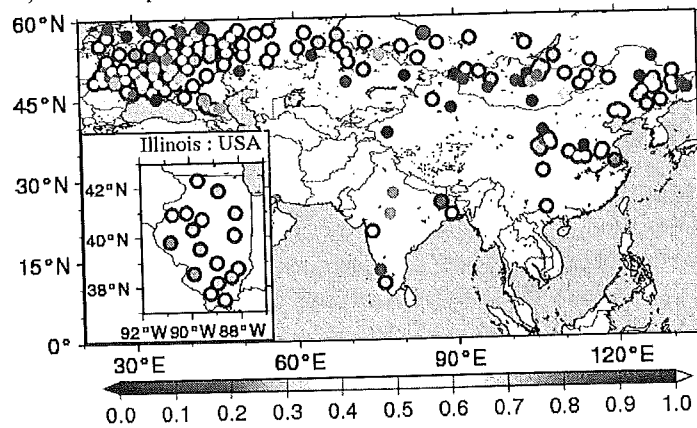


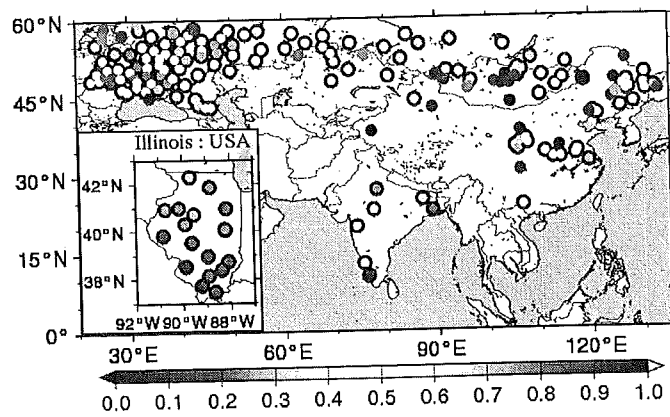
Figure 2. Frequency of monthly observations from 1986 to 1995

Mongolia region, the performance of estimating soil moisture monthly deviation is better than that of monthly field.

These results are derived from comparing between only one model simulation result and observation. However, other LSSs which participant in GSWP2 show similar tendency of accuracy on simulating soil moisture through the multi-model analysis (Guo *et al.*, 2006). In other words, there are the regional differences of LSSs ability to estimate soil moisture field. It may be assumed by differences of hydrological processes, for examples, climatology, land use, soil property, and so on.



(a) Monthly time series



(b) Monthly deviation from annual variation

Figure 3. Correlation coefficient between estimation and observation

3.2 Water budget analysis

For investigating the essential factors for reproducing seasonal cycle of soil moisture, analysis of water balance components are carried out. It is found that soil moisture by SiBUC has a kind of characteristics.

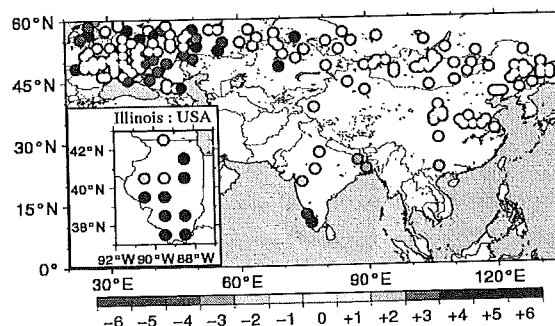


Figure 4. Monthly phase difference between annual cycle of precipitation and one of evapotranspiration

In Illinois, India and west part of Russia regions, there are more than three month phase difference between annual cycle of precipitation and one of evapotranspiration (See Figure 4). In these

regions, soil moisture has clear seasonal cycle because the seasonal cycle phase of precipitation is different from that of evapotranspiration. Furthermore, there is higher fraction of precipitation to evapotranspiration in other regions (China and Mongolia regions). It is assumed that precipitation is almost converted to evaporation and a few amount of water is infiltrated to soil layer. In these regions, many soil layers should be considered in land surface schemes to simulate infiltration accurately.

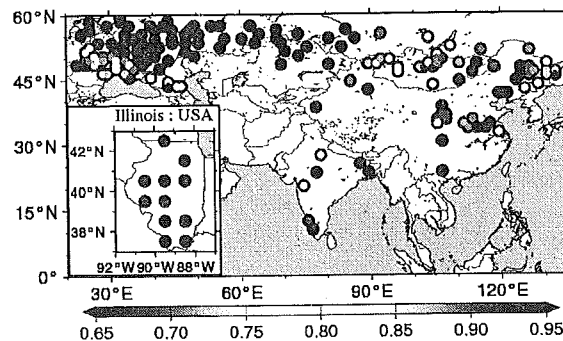


Figure 5. The fraction of precipitation to evapotranspiration.

4 CONCLUSION

In this study, globally estimated soil moisture by land surface scheme SiBUC is compared with in situ observation derived from global soil moisture data bank to validate the accuracy on reproducing seasonal and inter-annual variability of soil moisture. From the correlation analysis, good performance areas can be found in Illinois, India and west part of Russia regions. In other regions, it isn't sufficient to reproduce soil moisture variation by LSS. This result corresponds to the multi-model analysis and validation (Guo *et al.*, 2006). It means that there the regional differences of land surfaces schemes ability to estimate soil moisture field. For investigating the essential factors for reproducing seasonal cycle of soil moisture, analysis of water balance components are carried out. Water balance analysis leads to the assumption that soil moisture estimation has a good performance because soil moisture has clear seasonal cycle caused by the fact that the seasonal cycle phase of precipitation is different from that of evapotranspiration. Furthermore, there is higher fraction of precipitation to evapotranspiration in other insufficient performance regions. It is assumed that precipitation is almost converted to evaporation and a few amount of water is infiltrated to soil layer. It may suggest that many soil layers should be considered in land surface schemes to simulate infiltration accurately.

5 REFERENCES

- Dirmeyer, P., Gao, X., Oki, T., 2002. The second global soil wetness project (GSWP-2) science and implementation plan, IGPO Publication Series No.37.
- Guo, Z., P. A. Dirmeyer, X. Gao, and M. Zhao., 2006. Improving the quality of simulated soil moisture with a multi-model ensemble approach. *Quarterly Journal of the Royal Meteorological Society*, Vol. 133, pp. 731-747.
- Hall, F.G., B.Meeson, S.Los, L.Steyaert, E.Brown de Colstoun, D.Landis, eds., 2004. ISLSCP Initiative II. NASA. DVD/CD-ROM.NASA.
- Robock, Alan, Konstantin Y. Vinnikov, Govindarajalu Srinivasan, Jared K. Entin, Steven E. Hollinger, Nina A. Speranskaya, Suxia Liu, and A. Namkhai, 2000. The Global Soil Moisture Data Bank. *Bulletin of American Meteorological Society*, Vol. 81, pp. 1281-1299.
- Sellers, P.J., Mintz, Y., Sud, Y.C. and Dalcher, A., 1986. A simple biosphere model (SiB) for use within general circulation models, *Journal of the Atmospheric Sciences*, Vol.43, No.6, pp.505-531.
- Tanaka, K., 2004. Development of the new land surface scheme SiBUC commonly applicable to basin water management and numerical weather prediction model, doctoral dissertation, Kyoto University.
- Yorozu, K., Tanaka, K., Ikebuchi, S., 2005. Creating a global 1-degree dataset of crop type and cropping calendar through the time series analysis of NDVI for GSWP2 simulation considering irrigation effect, Proc. of 85th AMS Annual Meeting, 19th conference of Hydrology, 6.8. (CD-ROM)