Reproducibility of the Surface Hydrology in Land Data Analysis of Japanese 25-year Reanalysis

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INTRODUCTION

Land surface processes do important jobs in the Earth's climate system. Soil moisture partitions the net radiation at the surface into sensible and latent heat fluxes, and contributes to vegetation growing and to seasonal predictions as an initial lower boundary condition. In spite of these significances of global-scale land surface processes, estimates computed with a land-surface model have been widely used as a proxy for observations due to observational difficulty at global-scale. These estimates can be obtained from both atmospheric (re-)analysis data (e.g. Coe 2000; Nakaegawa et al. 2007) and offline simulations with observed atmospheric forcing (e.g. Rodell et al. 2004), and their reproducibility has been assessed with limited observations, for instance, soil moisture (Li et al. 2005).

Japanese 25-year Reanalysis data (JRA-25) is produced with the Japan Meteorological Agency's (JMA) latest numerical assimilation system of three-dimensional variational method and specially collected observational data (Onogi et al. 2007). Precipitation in the data is reportedly well reproduced both in time and space. However, the reproducibility of the hydrological processes has not yet been investigated. We will investigate the reproducibility by comparison with observed data.

ESTIMATIONS AND EVALUATION

Estimations

Land-surface hydrological processes in this study are represented by the Land Data Analysis (LDA) of JRA-25, which is the same system used for the same estimations from LDA for seasonal forecast forced with the operational global analysis of JMA (GANAL). LDA uses JMA-Simple Biosphere (SiB; Sellers et al. 1986; Sato and Satoda 1989), which is modified for long-term integration (Tokuhiro 2000; Nakaegawa and Sugi 2001). LDA simulates the hydrological processes with atmospheric forcing obtained from JRA-25 and uses the outputs from the snow depth analysis. More detailed descriptions are found in Onogi et al. (2007) and Nakaegawa et al. (2007).

LDA has a spectral resolution of T106 (equivalent to a horizontal grid size of around 1.125 ^{o}) and a temporal resolution of 6 hour. The evaluation period used is 9-year long from April 1996 to May 2005, same as estimation in Nakaegawa et al. (2007)

Evaluation

We evaluate the reproducibility for the three hydrological variables: soil moisture, river discharge, and TWS. We compared the top 1m soil moisture between JLDAG and the observation archived at Global Soil Moisture Data Bank (Robock et al 2000). The observation stations were selected based on the data availability of the top 1m soil moisture: 124 meteorological stations (grassland and 8-year at most) and 15 agricultural fields (winter wheat and 35- or 56-year) in Russia; a hydrological station, Boissy-le-Châtel (grassland and 6-year) in France; 37 stations(19-year at most) in China; 6 points in Iowa (grassland and 23-year) and 19 points in Illinois (grassland and 23-year) in the U.S.

A dataset of Global Precipitation Climatology Project (GPCP; Huffman et al. 1997) is used for evaluating precipitation of JRA-25. The periods of these dataset differ one another, and we only compare the climatological seasonal variations of the three variables.

Comparison

We compared JRA-25 with JMA-LDA. The same version of SiB and the snow depth analysis are used as the land surface model in both analysises. The differences between the two are three. JRA-25 is used as the atmospheric forcing for JRA-25, while GANAL is for JMA-LDA. The Chinese snow depth data digitized are assimilated in only the JRA-25. The JLDA is a component of the 4-dimensional data assimilation system of JRA-25 and the output is used as initial condition for land surfaces, including the interactions with and JRA-25 and feedbacks on the atmosphere, while JMA-OLDA does not include interactions and feedbacks due to run in offline mode.

RESULTS AND DISCUSSION

Global annual water balance

Table 1 presents the annual climatological value of global water balances for this study and previous studies. The estimates in this study all resemble previously observation-based ones. The precipitation relative difference is only about 2% in comparison with Sellers (1965; S65) and Baumgartner and Reichel (1975; BR75). Evaporation is the largest among but is not far from the previously observation-based estimates. River discharge is very similar to estimate of Oki et al. (1995; O95) and its relative difference against BR75 is 9%. The runoff ratio is the same as in O95 and similar to BR75 and Korzn (1970; K70).

Table 1. Annual climatological value of global water balances. P: precipitation over land, E: Evaporation, R: total runoff, R/P: runoff ratio, Pg: global precipitation. Unit is mm/year except for R/P of which unit is nondimension

	P	E	R	R/P	Pg	Source
JRA-25	731	490	247	0.34	1114	
ERA40	779	510	343	0.44	1200	H05
ERA15	765	557	309	0.40	988	H05
NCEP	772	631	-	-	962	H05
Sellers	720	410	310	0.43	1004	S65
BR75	746	477	269	0.36	973	B75
Korzun	800	485	303	0.38	1130	K70
O 95	704	467	237	0.34	915	O95
GSWP2	836	488	348	0.42	-	D07

However, water imbalance of about 1% (-6mm/yr, soil drying tendency) exists in JLDAG. This is because LDA replaces the predicted snow with that obtained from the snow depth analysis. The re-analysis-based estimates usually have large water imbalance such as -76mm/yr of ERA40 (Hagemann et al. 2005; H05). This good water balance is due to no schemes in JLDAG producing large imbalance such as soil moisture nudging. Therefore, JLDAG satisfactorily estimates the annual climatological value of global water balances as well as the observation-based methods and does well compared with the other re-analysis-based ones.

Soil moisture

Figure 1 depicts the correlation coefficients of the soil moisture seasonal variations between the JRA-25 and the observation. The seasonal variations are generally well reproduced; on the contrary, negative correlations are found in the southern part of central Asia (55°E-80E$^{\circ}$, 35N$^{\circ}$-45N$^{\circ}$) in the eastern part of Lake Baikal, in eastern China along 120°E, at the base of Kola Peninsula. The correlation is high in Illinois, the U.S., while it is negligible in Iowa (figure not shown). JRA-25 well reproduces the seasonal variations of precipitation, which is predominantly responsible for the high soil moisture reproducibility.

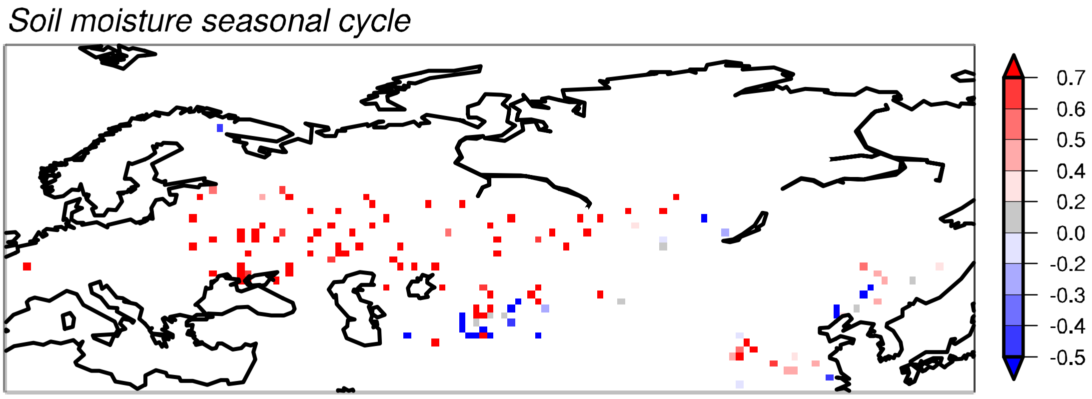

Figure 1. Correlation of the climatological seasonal cycle of soil moisture between JRA-25 outputs and observations.

JRA-25 does better job in reproducing soil moisture than GANAL. The mean correlation coefficient for JRA-25 (GANAL) is 0.45 (0.33) and the number of stations with greater coefficients than 0.75 for JRA-25 (GANAL) is 92 (52). Low reproducibility is found in most of the same stations for both analysises, but 6 stations in the Yangtze River region (106.10°E-119.47°E, 30.68°N-34.27°N, the same region as the eastern part of China in Nakaegawa et al. (2007)) and 17 stations in the southern part of west Siberia, including the midstream region of the Ob River basin and the upstream region of Yenisey River basins (70°E-105°E, 50°N-60°N) have better correlations for JRA-25 than for GANAL. Only Iowa stations and a one at the base of Kola Peninsula have worse reproducibility for JRA-25 than GANAL.

The regional mean of the correlation coefficients in the Yangtze River region is improved from 0.32 for GANAL to 0.43 for JRA-25. The regional mean of the correlation coefficients for precipitation is very high, about 0.95 for both, but that of the root-mean-square error (RMSE) is slightly degraded from 0.32 for GANAL to 0.36 for JRA-25. For example, correlation coefficients are improved from negative value to positive and large one in Xuzhou and Lushi, which is due to improvement in soil moisture reproducibility during summer, June to August, which are clearly depicted in Fig. 2). Improvement in precipitation during summer in Lushi and about 30 mm/month overestimation in Xuzhou are responsible for the improvement. In addition, the Chinese snow depth data assimilated in only the JRA-25 on the soil moisture do not affect soil moisture in the stations, since the difference in soil moisture for snow-melting season between JRA-25 and GANAL is negligible.

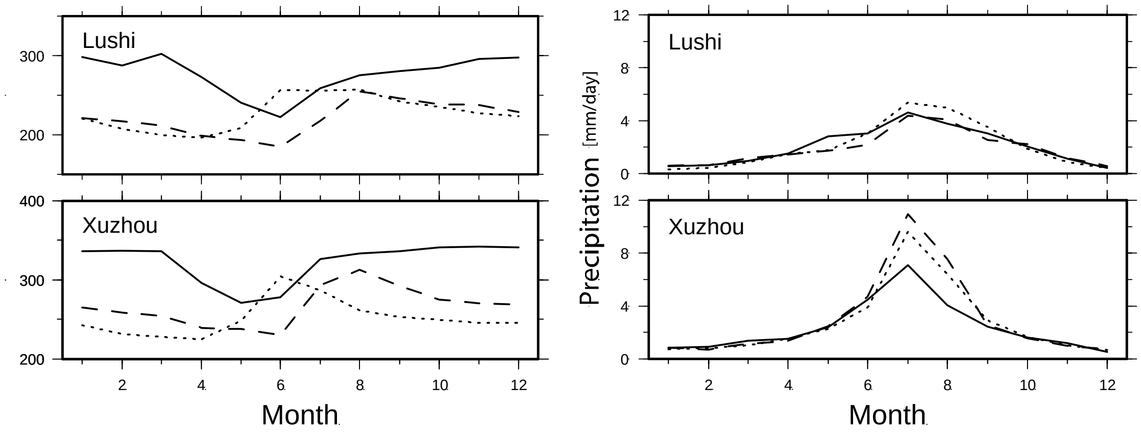

Figure 2 Seasonal cycle of (left) soil moisture and (right) precipitation at (upper) Lushi and (lower) Xuzhou. Solid line denotes observation, while dotted and dashed lines represent GANAL and JRA-25, respectively.

The regional mean of the correlation coefficients southern part of west Siberia is improved from 0.09 for GANAL to 0.57 for JRA-25. The precipitation reproducibility is same features as for the Yangtze River region: high correlation coefficient of about 0.8 and RMSE 0.25 for both the analysises. Causes for the improvements vary with stations as well as in the Yangtze River region, though detailed examinations are omitted.

In Iowa, the correlation for JRA-25 is lower than that for GANAL. The improvement in precipitation correlation from 0.86 for GANAL to 0.94 for JRA-25, but the annual precipitation for JRA-25 is more overestimated by 1.18 than that for GANAL by 1.09. This overestimation mostly comes from too much precipitation in April to June, which deteriorates the reproducibility of the soil moisture seasonal variation.

SUMMARY

The present study investigates the reproducibility of top 1-m soil moisture in LDA of JRA-25. JRA-25 well reproduces the annual means of the global terrestrial water balance in comparison with previous observation-based estimates, and does it best among the re-analyses. JRA-25 also well reproduces the seasonal variations of observed soil moisture; in addition, JRA-25 generally reproduces them better than GANAL.

Insufficient precipitation reproducibility tends to low hydrological reproducibility; therefore, precipitation improvement is a key to further improvement in hydrological processes of JRA-25. On the other hand, insufficient hydrological reproducibility is found in some observation sites, despite high precipitation reproducibility. In the Amazon River basin, the atmosphere-land interactions produced soil moisture dryness as reported in Onogi et al. (2007). These results suggest that better reproducibility of re-analyses including JRA-25 requires the sophisticated representation of the hydrological processes. With the knowledge of reproducibility for a specific site or a region, JRA-25 dataset may be applied to studies relevant to hydrology and water resources.

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