Products and validation of GAME re-analyses and JRA-25: Precipitation

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INTRODUCTION

Evaluating simulated precipitation from four-dimensional data assimilation (4DDA) systems is important. First, such evaluations show the performance of the whole 4DDA system. Precipitation is accompanied by latent heat release, which plays a key role in atmospheric circulation. In 4DDA systems, the forecast field affects the dynamics itself, which in turn affects the next analysis/forecast. We need to know how well precipitation is simulated, because it is one of the synthetic indices of the 4DDA system. Second, simulated precipitation data are input to the land-surface models that are coupled with the 4DDA system. Therefore, any spatial misplacement in the simulated precipitation causes a shift in the land-surface fluxes, which also affects the next forecast or analysis. Third, forecast precipitation sometimes gives better estimates than remote sensing data. For example, the well-known Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP; Xie and Arkin, 1997) uses precipitation data that have been forecast from the NCEP reanalysis as an input source for desert areas.

However, we do not have enough accurate observed precipitation datasets for land areas over most of Asia. Therefore, we first created a rain-gauge–based daily grid precipitation dataset based on the algorithm of Xie et al. (2007) by using approximately more than 4000 additional stations to collect daily rain gauge precipitation data for East, Southeast, and South Asia. Here we use our new precipitation analysis and show preliminary validation of the precipitation data from the Japanese reanalysis project JRA-25 (Onogi et al., 2007). Before JRA-25, the Japan Meteorological Agency conducted the GAME reanalysis project, and they have already produced two versions of fine-resolution 4DDA products for April–October 1998 (Yatagai et al., 2007).

In this paper we briefly describe the GAME reanalysis and JRA-25, as well as our precipitation analysis. We then show preliminary validation results of the precipitation derived from the GAME re-analyses and JRA-25 over the Asian monsoon region for the year 1998.

GAME re-analyses and JRA-25

JRA-25 is the 25-year reanalysis being carried out by the Japan Meteorological Agency (JMA) and Central Research Institute of Electric Power Industry (CRIEPI) in Japan (http://www.jreap.org/indexe.html; Onogi et al., 2007). Before this long-term reanalysis project began, JMA had made two versions of reanalysis products by using their 4DDA system for the intensive observing period (IOP) of the GEWEX/Asian Monsoon Experiment (GAME):

GAME reanalysis Ver. 1.1

This release of the reanalysis product incorporating GAME IOP data used the December 1999 version of the JMA numerical weather forecast system (ver. 9912). The radiosonde observations used for this version were summarized by Yamazaki et al. (2000), and more precise specifications of this version are given in Yatagai et al. (2000). The horizontal resolution of the model is T213, which corresponds to about 55 km. An optimum interpolation scheme (OI scheme) is employed to interpolate observations and background forecasts to obtain the initial analysis values. The cumulus parameterization used in the atmospheric model in the JSM ver. 9912 was the Prognostic Arakawa-Schubert Precipitation rate for the 12- to 24-hour forecasts (from 0000 and 1200 UTC start times) archived in the dataset of 1.25-degree–grid physical monitor data.

GAME reanalysis Ver. 1.5

The differences between Ver. 1.1 and Ver. 1.5 are summarized in Table 1 of Part I (Yatagai et al., 2007). The radiosonde observations used in the two versions of GAME reanalysis are shown in Figure 1. The overall 4DDA system (OI scheme, resolution, and cumulus parameterization) is the same as that of Ver. 1.1. The forecast times of the precipitation rates that have been officially released as GAME reanalysis Ver. 1.5 are different from those of Ver. 1.1. They are 12- to 18-hour forecasts (from 0000, 0600, 1200, and 1800 UTC start times).

JRA-25

JRA-25 is the 25-year reanalysis currently being carried out in Japan. The specifications of this reanalysis are described at http://www.jreap.org. As described by Yamazaki et al. (2000) and Yatagai et al. (2007), in a sense we consider the 1998 data as Ver. 2 of the GAME reanalysis, because (1) GAME IOP data for April to October 1998 are included for the period covered by JRA-25, and (2) although the GAME reanalysis Ver. 2 was planned to be made by using a three-dimensional variational method (3d-var), it has not yet been created. JRA-25 employs 3d-var as its assimilation method. The JMA model is similar to that used in the GAME reanalysis, although the resolution of JRA-25 is T106 (approx. 100 km). Since JRA-25 includes only 6-hour forecasts at present, we use the 6-hourly precipitation data from their archives. The major differences between JRA-25 (for 1998) and the GAME re-analyses are also summarized in Table 1 of Part I. Although there are some differences in the input data, land surface schemes, and forecast times for the precipitation amounts in the officially released versions, we also compare the JRA-25 because it uses GAME IOP data for 1998 and because the 6-hour forecast precipitation of JRA-25 best represents the global pattern of monthly precipitation compared with the other long-term reanalyses (NCEP R-1, NCEP R-2, ERA-15, and ERA-40) (Onogi et al., 2007).

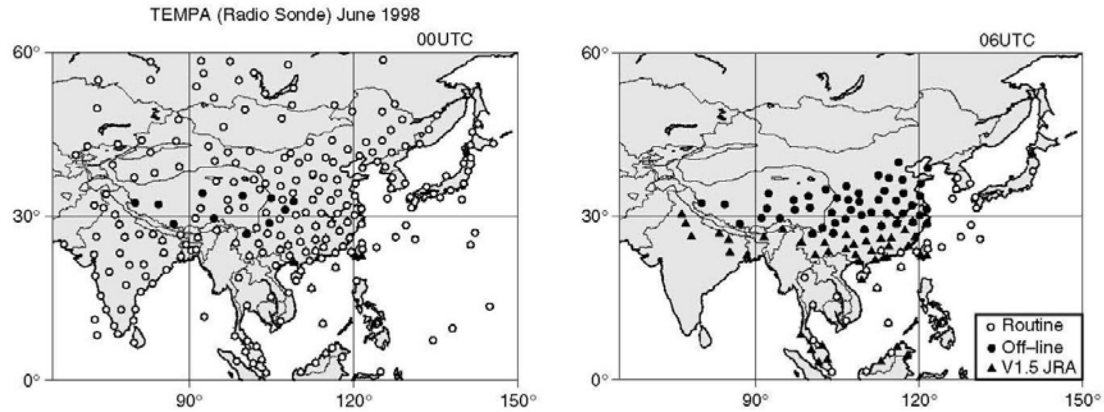

Figure 1

A sample of the radiosonde stations used for the GAME reanalysis (June 1998). Left: 0000 UTC; Right: 0600 UTC. The distributions for 1200 and 1800 UTC are approximately the same as those for 0000 and 0600 UTC, respectively. Open circles indicate station data sent via the GTS network. Black circles denote off-line data used only for the GAME reanalyses. Black triangles represent stations not used in Ver.1.1, but used in Ver.1.5.

Rain-gauge-based precipitation analysis over Asia

APHRODITE's Water Resources (Asian Precipitation – Highly Resolved Observational Data Integration Towards the Evaluation of Water Resources) is a project aimed at developing a long-term rain-gauge–based daily precipitation dataset for the whole of Asia. It is based on the algorithm presented by Xie et al. (2007) to create a daily grid-based precipitation analysis over East Asia, but there is a difference in terms of the method: we used the algorithm of Shepard (1968) for interpolation, whereas Xie et al. (2007) used an optimum interpolation (OI) technique As also shown in an earlier version of the enhanced analysis for 1998 (Yatagai and Xie, 2006), Marked differences between analyses (Xie et al., 2007 [V0409] and an earlier enhanced analysis [V0711]) are observed over Nepal, Myanmar and Thailand when additional data are input for those countries. Our updated version for 1998 over Monsoon Asia (APHRO_V0711) uses even more rain-gauge observation data collected from over East, Southeast, and South Asia. We collected more than 4000 additional station data over Monsoon Asia (lat. 0°N–65°N, long. 60°E–160°E) (Fig. 2). Figure 3 is an example of the APHRO_V0711, and the original base product for precipitation on 23 July 1998. Using more than 2000 additional rain-gauge data points for India, V0711 shows the precipitation pattern in more detail. The orographical precipitation along the Himalayas is clearly observed in V0711, and precipitation patterns in South Asia have been made clearer.

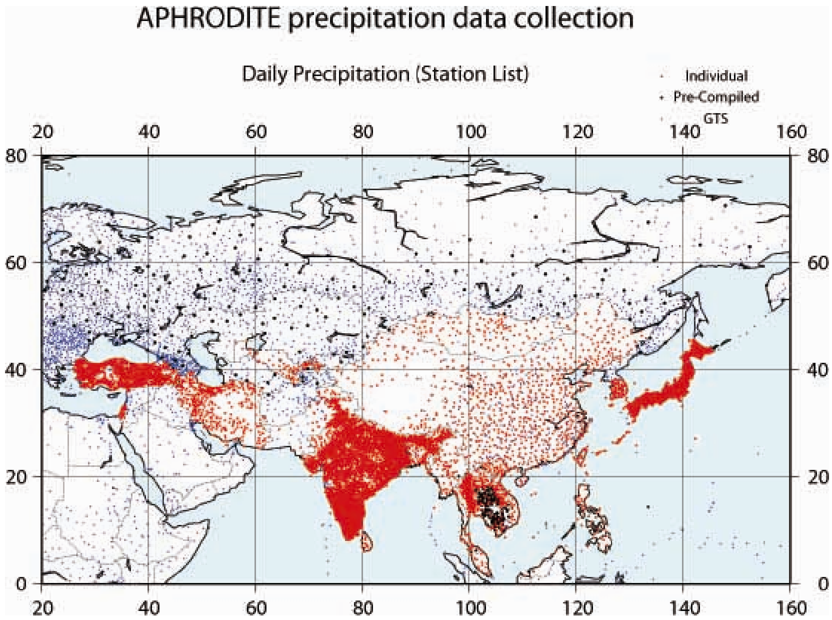

Figure 2.
Data points used in the enhanced analysis (V0711). Red dots show individual data points in the APHRODITE project, black dots show pre-compiled datasets, and blue dots show data points in the global telecommunication network (GTS).

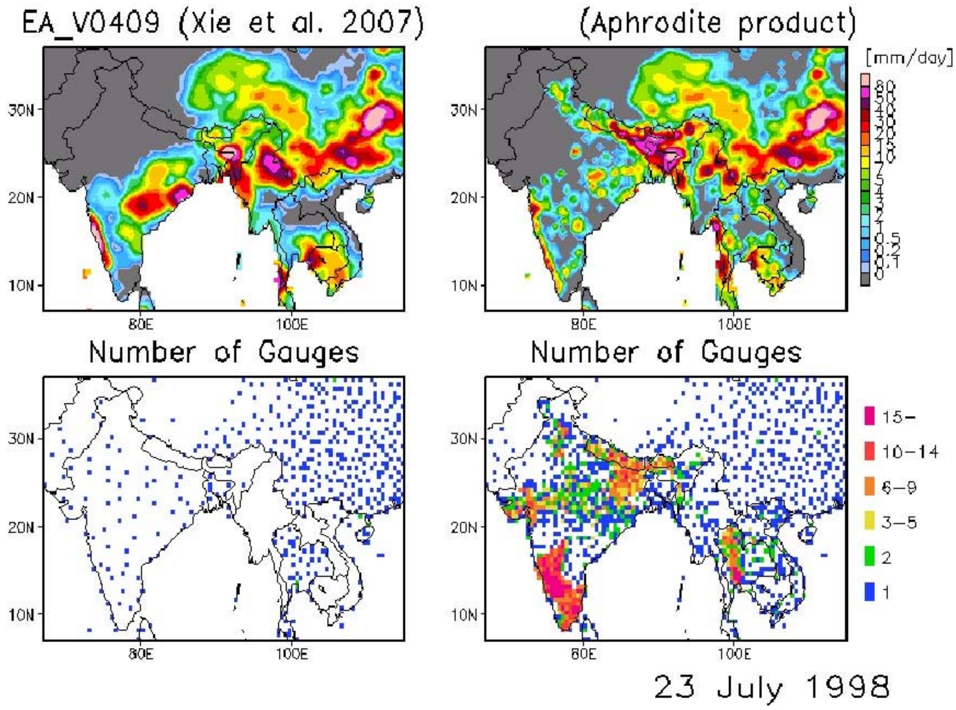

Figure 3.
Daily precipitation (top, mm/day) and number of gauges in a 0.5-degree grid cell (bottom), for analyses with and without additional rain-gauge data.

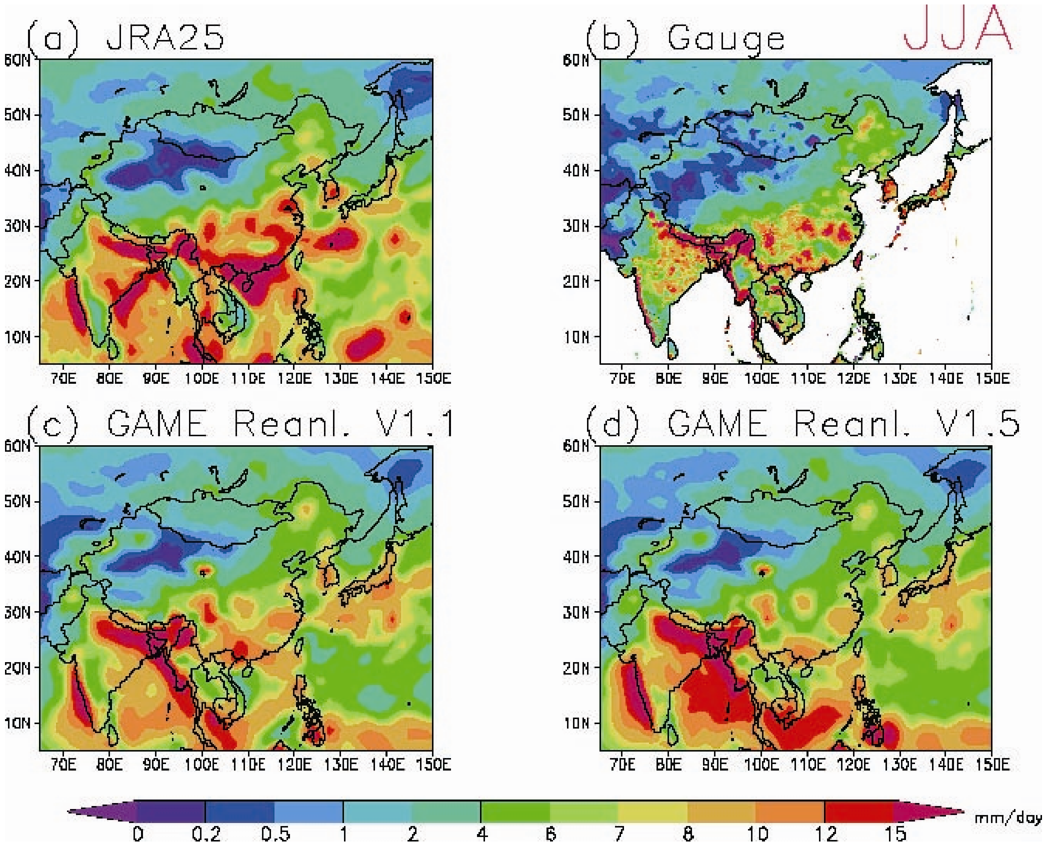

Figure 4 Seasonal precipitation patterns from June to August 1998. (a) JRA-25, (b) Rain-gauge–based analysis (V0711), (c) GAME reanalysis Ver. 1.1, and (d) GAME reanalysis Ver. 1.5. Units: mm/day.

Preliminary validation results

Figure 4 shows summertime precipitation (June–August) as simulated by GAME re-analyses Ver. 1.1 and Ver. 1.5 and by JRA-25, as well as our rain-gauge–based analysis (APHRO_V0711). Comparisons are made only over land areas. Generally, all three re-analyses overestimate precipitation. GAME reanalysis Ver. 1.1 does not show the maximum precipitation band along the Yangtze River (lat. 30°N, long. 100°E–120°E) but it does show the characteristics of precipitation over South East Asia well. It does not show precipitation maxima over the Indian Peninsula well. Compared with Ver. 1.1, Ver. 1.5 shows a better pattern over the Indian peninsula, but orographical precipitation along the Himalayas shifts southward. Over China, it shows a similar problem with that of Ver. 1.1. JRA-25 shows the precipitation pattern over China well, but it over estimates the gauge values. Over Southeast Asia, it does not show the minimum precipitation zone over Thailand, although the GAME re-analyses reproduced this well. Over South Asia, it shows the location of the maximum in the central part of India well; however, precipitation along the Himalayas is again shifted southward. This shift is a common error for JMA's reanalysis models, although JMA's 20-km–mesh atmospheric general circulation model reproduces the location of the precipitation along the mountains well (Yatagai et al., 2005).

Figure 5 shows the seasonal variations in the monthly precipitation for 1998 in four areas (the Himalayas, Central India, Central China, and Southeast Asia). Generally, JRA-25 overestimates the observed summertime precipitation. Over Central India and Southeast Asia, it also overestimates the observed precipitation in spring. Over the Himalayas, the maximum precipitation zone is shifted in JRA-25, so the main zone of overestimated precipitation is not included in the area that we chose (lat. 25°N–35°N, long. 75°E–100°E).

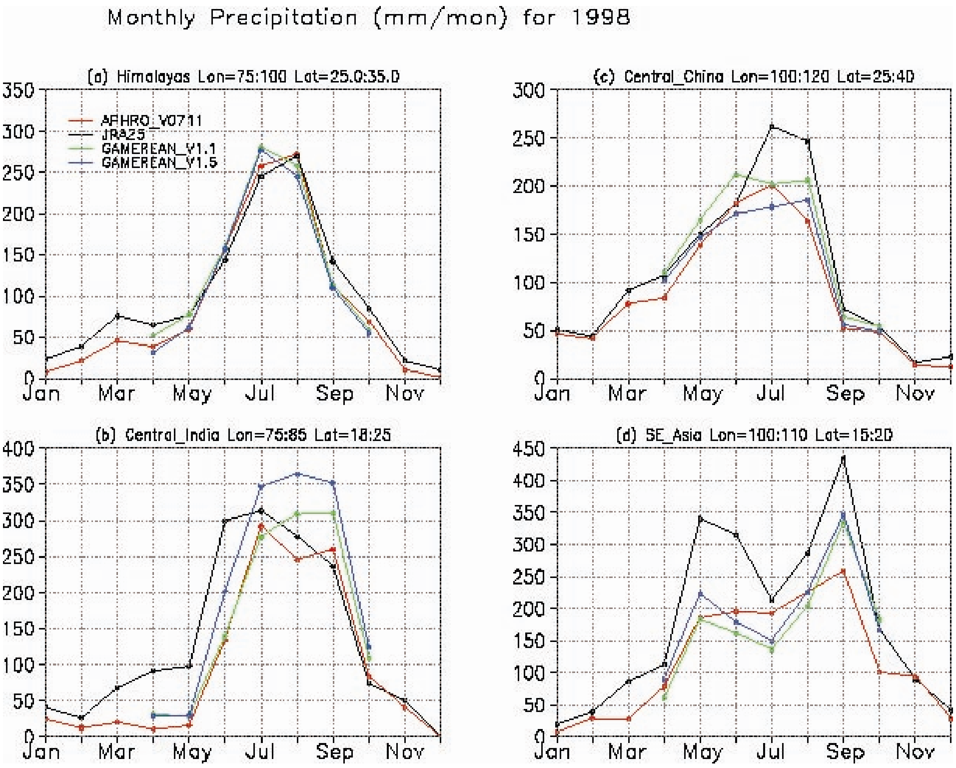

Figure 5.
Change in seasonal precipitation from January to December 1998. Black: JRA-25, Green: GAME reanalysis V1.1, Blue: GAME reanalysis V1.5, Red: Enhanced rain-gauge version (V0711). The domain for averaging precipitation is shown on top of the each panel.

CONCLUSION

- We compared the precipitation in the GAME reanalyses (Ver.1.1 and Ver.1.5) and JRA-25 with a rain-gauge-based precipitation analysis (APHRO-V0711).

- JRA-25 reproduces the time–space structure of precipitation patterns over monsoon Asia, but it tends to overestimate the seasonal average of precipitation against the EA analysis over most of the region. The simulated precipitation along the Himalayas shifts southward.

- In our project (APHRODITE’s Water Resources), we first collect data in 0.05-degree cells, and then regrid the data onto model grids (to reduce computational errors).

REFERENCES

Onogi, K., J. Tsutsui, H. Koide, M. Sakamoto, S. Kobayashi, H. Hatsushika, T. Matsumoto, N. Yamazaki, H. Kamahori, K. Takahashi, S. Kadokura, K. Wada, K. Kato, R. Oyama, T. Ose, N. Mannoji and R. Taira. 2007: The JRA-25 reanalysis. *J. Meteor. Soc. Japan*, **85**, 369–432.

Shepard, D. 1968: A two-dimensional interpolation function for irregularly spaced data. Proc. 23 ACM Nat’l Conf., Princeton, NJ, Brandon/Systems Press, 517-524.

Xie, P. and P. A. Arkin. 1997: Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteorol. Soc.*, **78**: 2539–2558.

Xie, P., A. Yatagai, M. Chen, T. Hayasaka, Y. Fukushima, C. Liu and Y. Song. 2007. A gauge-based analysis of daily precipitation over East Asia. *J. Hydrometeor.*, **8**, 607–627.

Yamazaki, N., N. Yamazaki, H. Kamahori, A. Yatagai, K. Takahashi, H. Ueda, K. Aonashi, K. Kuma, Y. Takeuchi, H. Tada, Y. Fukutomi, H. Igarashi, H. Fujinami and Y. Kajikawa. 2000. On the release of GAME reanalysis products. *Tenki*, **47**: 659–663 (in Japanese).

Yatagai A., N. Yamazaki, H. Kamahori, K. Takahashi, H. Ueda, K. Aonashi, K. Kuma, Y. Takeuchi and H. Tada. 2000. On the GAME reanalysis. *J. Jpn Soc. Hydrol. and Water Resour*. **13 (6)**: 486–495 (in Japanese).

Yatagai, A., Xie, P. and Kitoh, A. 2005: Utilization of a new gauge-based daily precipitation dataset over monsoon Asia for validation of the daily precipitation climatology simulated by the MRI/JMA 20-km-mesh AGCM, SOLA, **1**, 193-196, doi:10.2151/sola.2005-050.

Yatagai, A. and P. Xie. 2006. Utilization of a rain-gauge-based daily precipitation dataset over Asia for validation of precipitation derived from TRMM/PR and JRA-25, *SPIE 2006, 6404–53 doi:10.1117/12.723829.*

Yatagai, A., N. Yamazaki and T. Kurino. 2007. The products and validation of GAME reanalysis and JRA-25 Part 1: Surface fluxes, *Hydrological Processes* **21**, 2061–2073.