A comparative study of surface fluxes derived from four-dimensional data as similation products with AAN observations

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1. Introduction

The surface sensible heat flux and the latent heat flux are important factors for determining the global energy and water cycle. As a lower boundary condition of the global atmosphere, the land areas may be less important than the ocean areas because they are smaller and store less thermal energy. However, land varies more than the oceans for many of the important coupling processes, especially in moisture exchange. The surface fluxes and albedo vary with types of surface cover. Since land surfaces are complicated, global-scale observation and modeling as well as surface accurate and long-term measurements are both significant for accurately determining surface fluxes on a global scale.

Therefore, this study aims to compare surface sensible and latent heat flux derived from high-resolution four-dimensional data assimilation (4DDA) products with those derived from AAN surface flux observations.

2. Data

The following data are mainly used in this study.

- AAN surface observation dataset, April to October 1998
- GAME reanalysis Ver. 1.1 (0.5 degree grid analysis dataset) , April to October 1998, four times daily
- GAME reanalysis Ver. 1.1 (1.25 degree grid forecast (physical) dataset), April to October 1998, four times daily
- European Centre for Medium-range Weather Forecast (ECMWF) operational dataset (0.5 degree grid analysis dataset), April to September 1998, four times daily
- ECMWF operational dataset (0.5 degree grid supplementary (forecast) dataset), April to September 1998, four times daily

For this abstract, we primarily report comparisons at Tak in Thailand, and at North PAM III station in Tibetan Plateau for July 1998. Results of other stations and other periods will be presented in the workshop.

Before showing some results, we introduce GAME reanalysis in the next session. The basic characteristics and comparison between GAME reanalysis and ECMWF operational dataset of 1998 are shown in Table 1.

3. GAME Reanalysis

In a cooperative study of the Meteorological Research Institute of Japan Meteorological Agency (MRI/JMA), Numerical Prediction Division of JMA (NPD/JMA) and the Earth Observation Research Center of National Space Development Agency of Japan (EORC /NASDA), we produced reanalysis products using the JMA 4DDA system for April to October 1998. This dataset has the advantage of including the GAME special observation off-line radio-sonde dataset. Figure 1 shows the location of stations we assimilate in the GAME 4DDA products.

Table 1 Basic characteristics of GAME reanalysis Ver.1.1, Ver. 2 and ECMWF operational data for 1998

	GAME reanalysis Ver. 1.1	GAME reanalysis Ver. 2	ECMWF operational
Assimilation Scheme	OI	3D-Var	4D-Var
Resolution	T213 level 30	T213 level 40	T_L319 level 31
Cumulus Parameterization	Prognostic Arakawa-Shubert	Prognostic Arakawa-Shubert	Tiedtke
GAME-IOP radio-sonde (Mainly over China and Southeast Asia)	Used	Used +SCSMEX off-line data	Not used (data sent by GTS are used)
Micro wave (moisture)	Not used	TMI	SSM/I (29 June -)
TOVS (moisture)	Not used	Not used	Used (29 June -, over land)

Over Thailand, the GAME intensive observing period (IOP) dataset has already been assimilated in other weather centers because it had already been reported via the GTS network. However, most IOP datasets of China were not used in other 4dda datasets except for our GAME reanalysis. Details are shown in Yamazaki et al. (2000) and Yatagai et al. (2000).

The GAME reanalysis Ver. 1.1, which was produced in October 2000, was made using the Optimum Interpolation (OI) scheme. Recently, most assimilation centers have been using the variational method instead of OI because it has strong merit of assimilating parameters which are not linearly related to analysis variables (wind, temperature… etc). The three dimensional variational (3D-Var) method is necessary to assimilate satellite brightness temperature.

Therefore, the GAME reanalysis team will produce the next version using 3D-Var and moisture information by TRMM/TMI in March 2001. Furthermore, GAME reanalysis Ver. 2 will assimilate SCSMEX off-line data, and land-surface data will be much improved. For land surfaces, Ver. 1.1 still uses climatological snow depth and soil temperature. However, in Ver. 2, soil temperature succeeded the forecasted soil temperature from the previous period (six hours before), and snow depth will be deduced from satellite products.

For this report, we present only the results of GAME reanalysis Ver. 1.1 and use the ECMWF operational dataset for comparison. However, we may present some results using GAME reanalysis Ver. 2 at the conference in March.

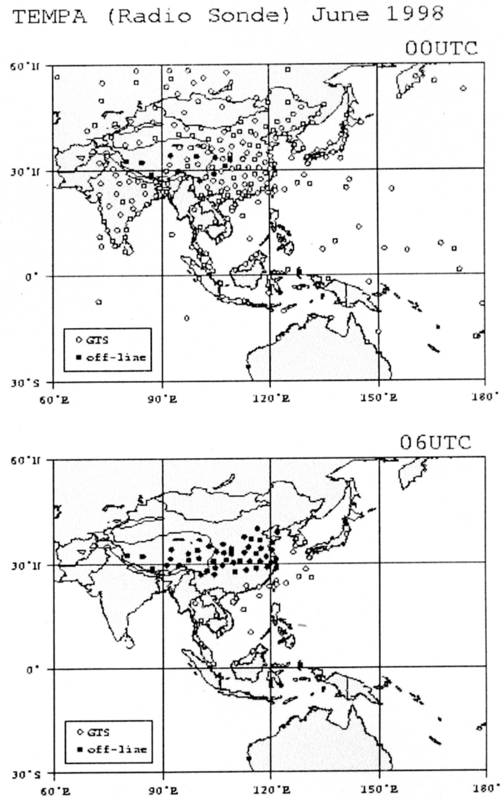

Fig. 1 Radio-sonde stations used for GAME reanalysis Ver. 1 for June 1998. Upper: 00 UTC, Lower: 06UTC.

Table 2 GAME reanalysis product ver. 1.1 released in September 2000

	Analysis over the Asian region	Global analysis		Global physical monitor (12-18, 18-24 hour forecast)	
Region	30E-180, 30S-90N	Whole Globe (0-358.75, 90N-90S)	Whole globe (0-357.5, 90N-90S)	Whole globe (0-358.75, 90N-90S)	Whole globe (0-357.5, 90N-90S)
Horizontal resolution	0.5 x 0.5 degree grid	1.25 x 1.25 degree grid	2.5 x 2.5 degree grid	1.25 x 1.25 degree grid	2.5 x 2.5 degree grid
Period, Time resolution	April-October in 1998 4 times a day (6 hourly)				
Vertical levels	17 layers (1000 925 850 700 600 500 400 300 250 200 150 100 70 50 30 20 10 hPa) and the surface (the model bottom layer)			Two-dimensional physical monitor (at the surface or vertically integration)	
Elements	Geopotential height, horizontal wind, temperature, specific humidity at the mandatory levels Pressure, horizontal wind, temperature, specific humidity the surface at the model bottom layer Sea level pressure			runoff, transpiration, interception, convective precipitation, large-scale precipitation, precipitable water(instant), vertically integrated water vapor flux and the divergence, latent and sensible heat flux at the surface, radiative flux at the surface and the top of the atmosphere (downward shortwave, upwards shortwave, downward longwave, upward longwave), total cloudiness, cloud radiative forcing (shortwave, longwave)	

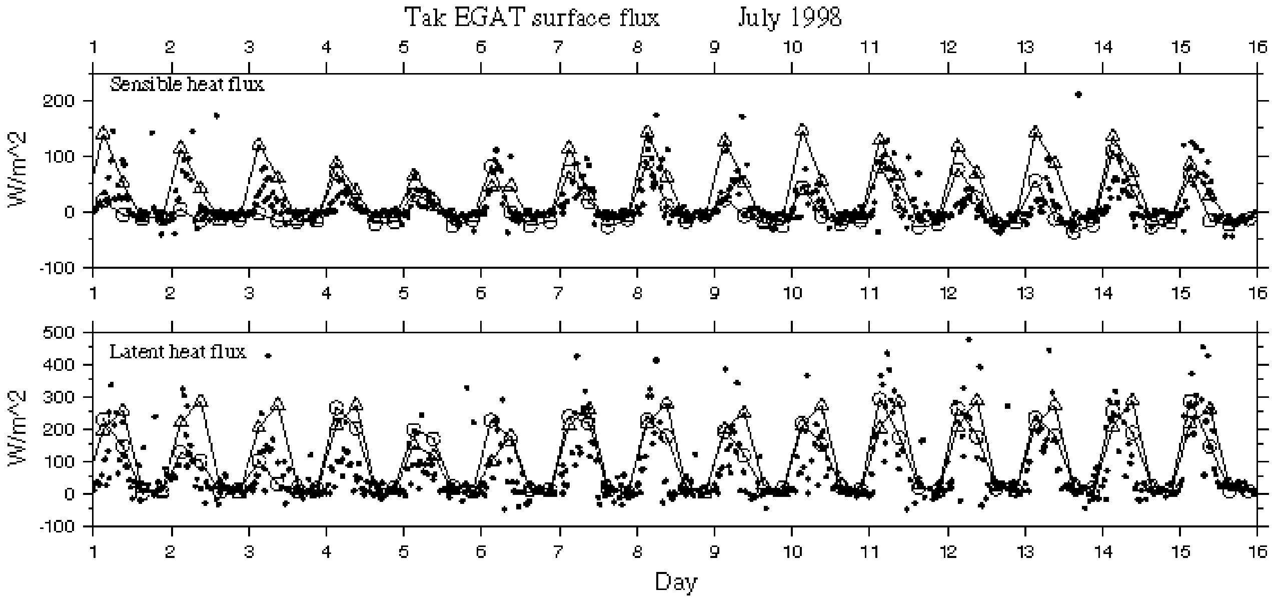

Fig. 2 Comparison of sensible heat flux (upper panel) and latent heat flux (lower panel) between GAME reanalysis Ver. 1.1, ECMWF operational dataset and AAN observation (EGAT tower at Tak in Thailand). Small dots indicate AAN observation (every 30 minutes); triangles, GAME reanalysis; and circles, ECMWF operational datasets.

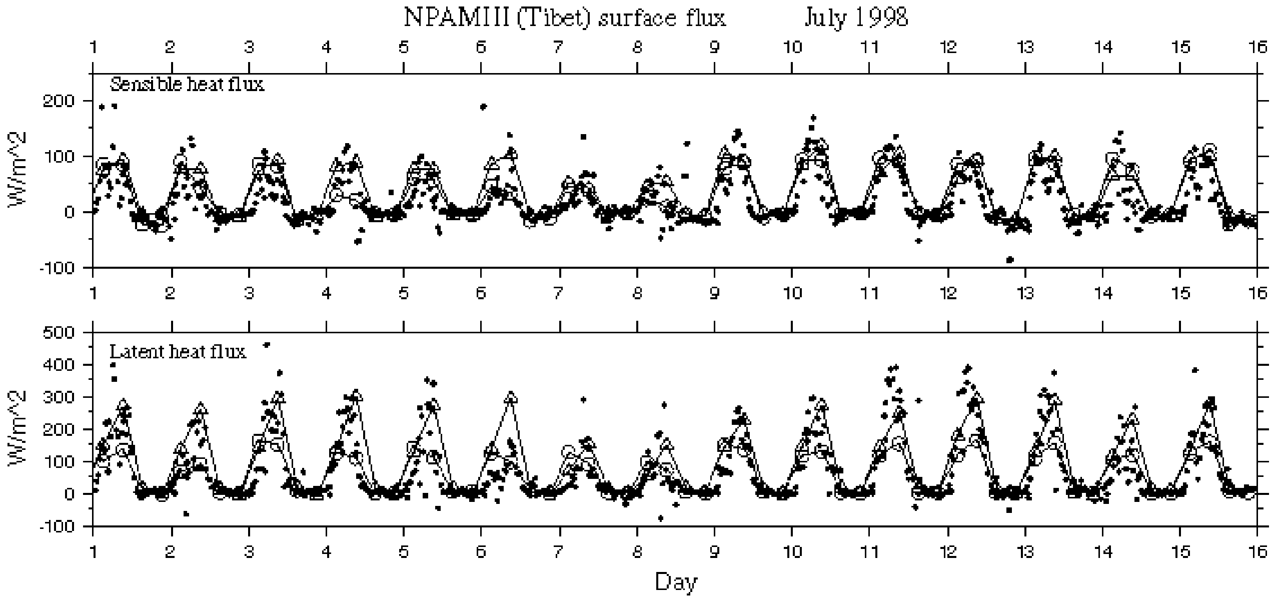

Fig. 3 Comparison of sensible heat flux (upper panel) and latent heat flux (lower panel) between GAME reanalysis Ver. 1.1, ECMWF operational dataset and AAN observation (north PAMIII on Tibetan Plateau). Details are the same as in Fig. 2.

Table 2 shows the specifications of GAME reanalysis product Ver. 1.1 used in this study. To compare surface latent heat flux and surface sensible heat flux with those derived from AAN station data, we used the values in global physical monitor of 1.25x1.25 degree grids (underlined in Table 2). Note we use 12 to18 and 18 to 24 hours forecast values. The forecast base time is either 00 UTC or 12 UTC. We used six-hr forecast value of ECMWF operational data, and its resolution is a 0.5-degree grid. In spite of these discrepancies, we will present comparisons of surface fluxes as a preliminary study.

4. Preliminary Results

Figure 2 shows a time series of sensible heat flux (upper panel) and latent heat flux (lower panel) of AAN observation (small dots), GAME reanalysis (triangles) and ECMWF operational datasets (circles) for 1 to 15 July 1998 at Tak (99.15E/16.88N). The sensible heat flux was measured by a GiLL Sonic Anemometer Thermometer (SAT)-R3A, and latent heat flux, by the bandpass covariance method using GiLL SAT-R3A and thermohygrometer (Vaisala 50Y). These observations were performed using PAMIII (Aoki et al., 1998) .The station is set up for surface flux observation at the site representing mixed land cover in central Thailand (Chao Phraya river basin). The vegetation of the surrounding area consists of rice paddies cultivated land, shrubs and deciduous stands. Fluxes were observed at 60 m height level with mounting sensors on the tower of Electricity Generating Authority of Thailand (EGAT) for telecommunication (Toda et al., 2000). An analysis of evaporation using PAMIII at Tak is reported by Toda and Ohte (2001).

The grid points chosen for comparison with GAME reanalysis and ECMWF are 98.75E/17.5N and 99.0E/17.0N, respectively (the nearest grids were chosen). The plots of 4DDA products are basically at the middle of the sis-hour accumulation periods. Focussing on the daytime, three datasets match well, especially for the surface sensible heat flux. During the first decades, ECMWF sensible heat flux matches AAN observation better than GAME reanalysis. However, sometimes (e.g., 9, 12, 13 and 14 July) peaks of sensible heat flux of AAN come later than those of 4DDA products. A large dispersion of latent heaqt flux is seen in AAN observation, especially from 6 to 15 July. Therefore, we must compare averaged AAN flux with six-hourly 4DDA products in the next step. However, the order of latent heat flux of AAN and 4DDA products seems to match well. The peak of latent heat flux of ECMWF is earlier than that of GAME reanalysis. Detailed comparison using many more AAN observations will help to diagnose the diurnal cycle of 4DDA products.

Figure. 3 is basically the same as Fig. 2 but for the station located in the center of the Tibetan Plateau (91.7E/31.9N). This station is called "MS3478", and PAMIII (Aoki et al., 1998) was also equipped for measuring surface fluxes. Computational methods and types of measurement tools are basically the same as those at Tak (Tsukamoto et al., 1999). The surface condition is rough and it is a kind of tundra called earth hammock. The nearest grid points chosen for comparison with GAME reanalysis and ECMWF are 91.25E/32.5N and 91.5E/32.0N, respectively. We can say GAME reanalysis matches AAN observation very well for both sensible and latent heat fluxes. AAN observation shows a relatively large dispersion for latent heat flux, however, its peaks are close to those of GAME reanalysis (except for 6^{th} and 8^{th}). Although GAME reanalysis uses a climatological soil temperature dataset and is from a 1.25 degree grid dataset, it shows coincident time series with AAN observation. Since the this flux value is basically 12 to 18, or 18 to 24 hour forecast values, the flux could have been adjusted with surface and upper air conditions, which were observed intensely.

5. Future Works

We only showed two figures for comparison between 4DDA products (GAME reanalysis and ECMWF operational dataset), and AAN observation at Tak in Thailand and at the center of the Tibetan Plateau for 1 to 15 July 1998. We will next compare these values more quantitatively and statistically. Furthermore we will compare the surface flux values for other seasons as far as data is available. The GAME reanalysis data used here is the Ver. 1.1 product. The second version of GAME reanalysis will be produced in the end of March. If some data of GAME reanalysis Ver. 2 is available before the AAN workshop in Thailand, we will be sure to compare them with AAN observations, because the land surface condition (snow cover, soil wetness, etc) will be important for determining surface fluxes, especially for the spring season, and real snow depth and soil temperature information, which are applied for the second version, will be very important for making and assessing 4DDA products.

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