4. FOUR DIMENSIONAL DATA ASSIMILATION (4DDA) AT JMA

4.1 Scientific Issues

The four dimensional data assimilation (4DDA) at JMA is an important component of GAME to integrate both of operational and experimental observation data and to produce more comprehensive data of the atmosphere and the surface hydrology. The 4DDA products of objective analyses and model generated fluxes make up a basic database to study the water and energy cycles associated with the Asian summer monsoon and their hydrological and sociological impacts. 4DDA is planned to be conducted as a collaboration between JMA and FRSGC.

During the intensive observation period (IOP) of GAME, enhanced upper air and surface pressure observations will be assimilated to improve the 4DDA products in the Asian monsoon area. Enhanced surface observations including the Asian Automated Weather Station Network (AAN) will also be effective for validating the land-atmosphere interactions expressed in the 4DDA products.

Continuous efforts are being made to develop data assimilation techniques for satellite data. Currently, the ERS-1 and the DMSP are providing the surface wind over the ocean and total precipitable water, respectively. Though unfortunately ADEOS observation was stopped, TRMM has successfully been launched and will provide observation data of precipitation. Assimilating these data will be an important research subject in several years time.

The 4DDA products are open to all scientists participating in GAME. The 4DDA products have physical consistency among variables and uniform resolution in space and time so that they are convenient for undertaking research on the mechanism of the Asian summer monsoon. It is recommended users take notice of the quality of the 4DDA products, because they tend to be affected by climate drifts of the NWP model. Intensive validation using special observations will be a great help to check quality of 4DDA products.

The 4DDA products and special observations are also used for verification of the long-range forecasts of the Asian summer monsoon, paying particular attention to cloud-radiation interactions, deep cumulus convections, land-atmosphere interactions and ocean-atmosphere interactions. Based on both of understanding of the Asian summer monsoon and intensive verifications by special observations, we will improve the long-range NWP models.

4.2 The 4DDA System at JMA

In March, 1996, JMA fully upgraded the global 4DDA system following the replacement of the super computer system. The new version of the global spectral model (GSM9603/T213L30) has an equivalent grid spacing of about 55 km in the horizontal and 30 h (s-p hybrid) layers in the vertical, enough to resolve mesoscale disturbances including tropical cyclones.

Objective analyses are performed on the same h-level and Gaussian grids as used in the global model with an optimum interpolation (OI) method, where the first guess field is 6-hour forecast of the global model running from the previous analysis (6 hourly forecast-analysis cycle). Geopotential height and wind are analyzed with a multivariate OI assuming the geostrophic balance, while temperature and moisture fields are analyzed with a univariate OI except that moisture is set equal to the first guess field above 300 hPa (forecast-forecast cycle). To a great extent, quality of the 4DDA products, depends on the data quality control (QC) system and OI parameters. Thus, we systematically survey errors of all the observational data and 6-hour forecasts (the first guesses to objective analyses) and update the QC and OI parameters.

Variational methods of objective analysis are expected to reasonably address the dynamical constraints of the atmosphere and solve inversion problems from the observation data into the prognostic variables. Now, we are developing the three dimensional variational method (3Dvar) which can include constraint of the equilibrium equations such as gradient wind balance, and assimilate the surface wind observed by ERS-1 and ADEOS. After completing the 3Dvar in a couple of years, we will develop the 4Dvar several years later. The 4Dvar will enable us to include prognostic equations as constraints and to assimilate precipitation data.

4.3 Strategy of 4DDA

During the intensive observation period (IOP) of GAME, we aim to improve the quality of the 4DDA product, especially over the Asian monsoon area by using enhanced observation data.

The observations of upper air and mean sea-level (or surface) pressure, enhanced in time and space, can be directly assimilated and they may be effective especially for diurnal variations and mesoscale disturbances in the Asian monsoon period. Surface winds observed by ERS-1 and total precipitable water by DMSP will be assimilated with the 3Dvar. The precipitation data from TRMM can be assimilated with the 4Dvar. The precipitation data might have large impacts on the analyses of moisture and horizontal divergence.

In GAME, valuable ground truth data will be available from the AAN and the enhanced surface station network. Observed data of the soil wetness, snow mass and soil temperature can be used in the data assimilation of the ground hydrological processes. In this regard, we must study the way of estimating mean grid values of the prognostic models from the observations, because these tend to represent local characters.

Model-generated precipitation and fluxes are important products of 4DDA in promoting monsoon research. The quality of these products is significantly dependent on the performance of the NWP model. Thus, in order to improve the 4DDA products, we must refine the NWP model through validation with special observations. To this end, the following projects are under planning;

(1) Surface water and energy cycles

Advanced observations of precipitation and surface fluxes including the Bowen ratio can be used as truth data for validation of the 4DDA products. Fig. 4.3-1 shows the diurnal variations of precipitation, horizontal moisture flux convergence and evaporation obtained through 4DDA. Although those diurnal variations look reasonable, they may be subject to drifts in climate of the NWP model. The AAN and the TRMM satellite will enable us to validate the detailed diurnal variation and the geographical distributions of precipitation, respectively.

(2) Radiation budgets

Most GCMs significantly over-estimate the downward shortwave fluxes at the ground surface possibly due to over-estimation of absorption and/or scattering by water vapor, clouds and aerosols (Wild et al., 1995). In summer, such error causes too large land-sea contrast of the surface heat fluxes and over estimates the activity of Asian summer monsoon. It is desirable that the radiation scheme should be validated with advanced observation of the surface radiation, in conjunction with the subprojects of the WCRP, the BSRN (Baseline Surface Radiation Network)

(3) Stand-alone time-integration of a simple biosphere (Sib) model

In the JMA's global model, the ground hydrological processes are described by the simplified biosphere model. To advance the Sib model, we are undertaking experiments on stand-alone long-term integrations of the model. The driving forces for the model are observed data of downward radiation, precipitation and surface wind, while validation data of the prognostic variables are those of soil moisture, snow mass and surface fluxes of latent and sensible heat. In this experiment, we can make maximum use of the AAN data, focusing on the land-atmosphere interactions in four different regions ranging from the tropics to the tundra.

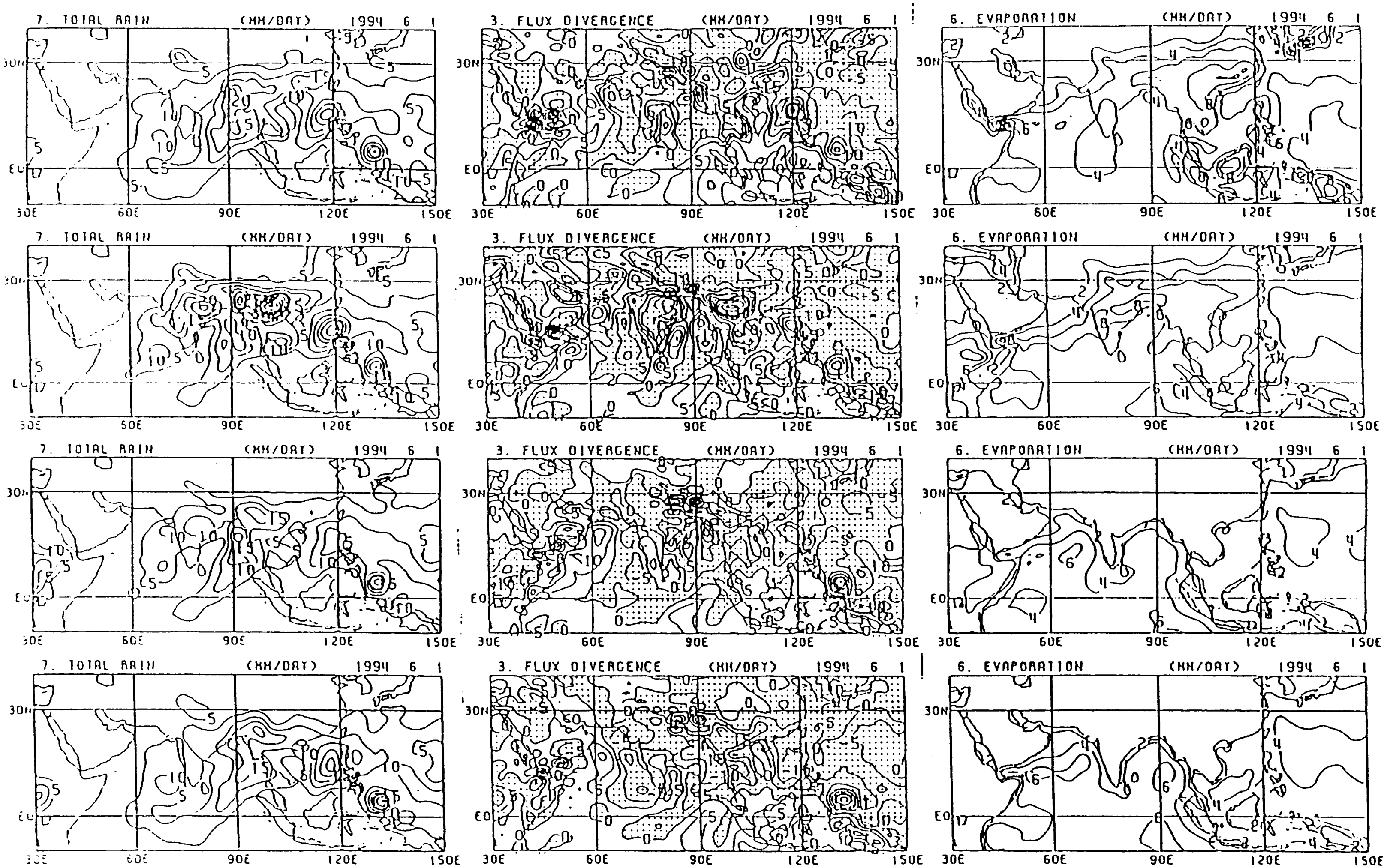

Fig.4.3-1 6-hourly (0-6, 6-12, 12-18 and 18-0UTC) geographical distributions of precipitation (left), divergence (middle) and evaporation (right) averaged over June, July and August, 1994, where contour intervals are 5 mm/day for precipitation and divergence and 2 mm/day for evaporation.

(4) Long-range forecasts of the Asian summer monsoon

One of the ways of improving the 4DDA system is to reduce the systematic errors in the NWP model used in the data assimilation. This will also improve the long-range forecast model. In March, 1996, JMA started one month ensemble forecasts by using a T63L30 version of the global model with the same physical parameterization schemes. Detailed analyses will be made of the forecast performance of the Asian summer monsoon by comparing to the 4DDA products and individual observations. According to these, we will improve the parameterization schemes of the NWP model. For this purpose, we will also benefit from the understanding of the Asian monsoon achieved in GAME.

4.4 Data Archives

The 4DDA products will be released to all scientists participating in GAME. These archives are of two and three dimensional grid-point data every 6 hours. Objective analyses provide prognostic quantities and 6-hour integrations of NWP model do diagnostic quantities. Diagnostic quantities include radiative fluxes, atmospheric hydro-budgets, surface fluxes, ground hydrological parameters and three dimensional diabatic forcings as listed below.

Prognostic variables of the atmosphere
(2D: surface pressure, 3D: temperature, wind and humidity)
Radiative fluxes
(2D: OLR, albedo, upward and downward surface radiations, cloud radiative forcings at the top and bottom)
Atmospheric water budgets
(2D: total precipitable water, total horizontal moisture flux)
Surface fluxes
(2D: latent and sensible heat fluxes, surface stresses, precipitation, etc.)
Ground hydrological parameters
(2D: run off, soil water, snow, deep soil temperature, roughness, etc.)
Diabatic forcings
(3D: heating rate due to radiation, PBL and condensation, moistening rate due to PBL and condensation, acceleration due to PBL and gravity wave drag)