5. NUMERICAL MODELLING

5.1 Scientific objectives

As is explained in the Introduction, the main thrust of GAME is as follows;

(1) to understand the role of the Asian monsoon in the global energy and water cycle, and
(2) to investigate the predictability of the Asian monsoon and to improve the water management over the Asian monsoon region by developing the seasonal prediction capability of the Asian monsoon.

There is no doubt that the monsoon phenomena is caused by the contrast heat between the land and the ocean. In order to achieve these goals, various research topics from large-scale phenomena to turbulence scale phenomena relating to the land-atmosphere interaction should be defined and investigated. However, as understanding of the land-atmosphere interaction is less understood than the air-sea interaction, research on the interaction between the land and the atmosphere is emphasized in GAME. Especially, it should be noted that heterogenous and small-scale features are dominant in the land surface, and these should be integrated into the large-scale model project. As GAME is a climate-related project, the contribution to the time-averaged fields is emphasized. For this purpose, the characteristics are integrated into the large-scale atmospheric circulations. In other words, the multi scale interaction should be intensively investigated. Large scale modelling study will be conducted at CCSR, MRI and FRSGC. Mesoscale modeling which includes mesoscale atmospheric modelling and hydrospheric modelling will be performed by the modelling group in each regional experiment.

5.2 Modelling of Large-scale Phenomena

5.2.1 Predictability of the Asian monsoon

Whether the interannual variability of the Asian monsoon is predictable or not is an interesting scientific and important practical issue, because, if it is predictable, a great improvement can be expected in water resource management. There is much research on this subject. Based on the numerical experiments, Palmer and Anderson (1994) reviewed the possibility of seasonal forecasts, where they confirmed that, while Sahel rainfall seems to be extremely predictable, the Indian monsoon rainfall is much less so. They attributed this to the intra-seasonal fluctuation of the Asian monsoon (so called, active-break phase, and/or 30-60 day fluctuation). The reason why the Asian monsoon rainfall has a chaotic behavior should be further investigated. Especially, Webster (1983) proposed the land-atmosphere interaction is the mechanism for the active-break cycle of the monsoon. This mechanism has not yet been fully investigated and is worth pursuing. During GAME, the intensive flux measurements using the AAN monitoring networks will be planned. This unprecedented dataset will provide a new base for these topics.

At the same time, another possibility exists for the intra-seasonal fluctuation; 30-60 day fluctuation can be considered to be a collective motion of convective system. Usually, it is generated over the Arabian Sea and propagates eastward. Sometimes, it tends to weaken over the maritime continent and redevelop over the Western Pacific Ocean. At the same time, synopic disturbances are generated in accordance with these fluctuations. The organizing mechanism is not yet clearly understood and, although intensive efforts have been conducted (for example, TOGA-COARE), the weakening and re-intensification mechanism is unclear. These issues are also interesting topics to be investigated during GAME.

In short, the following topics should be investigated;

(1) The mechanism for the inter-seasonal fluctuation with special emphasis on the land-atmosphere

interaction,
(2) The life cycle of the depression in the Asian monsoon region,
(3) The weakening mechanism over the maritime continent and reintensification mechanism.

5.2.2 Interaction between ENSO, the Asian monsoon and the Eurasian snowfall

The correlation between the intensity of the Asian monsoon and the Eurasian snowfall has been pointed out for a long time (for example, Hahn and Shukla (1976), Yasunari (1987) and others). At the same time, the linkage between the Asian monsoon and the ENSO has been suggested by many authors (Meehl, 1987; Yasunari,1990, and others). However, the interaction between these three components of the climate system has not yet been fully understood. The main reason is poor observational data over the land surface areas, such as ground wetness, albedo and the amount of snow. However, a tremendous amount of data will become available in GAME, and much new intensive research will be possible.

First, AMIP type numerical experiments should be conducted to investigate the sensitivity of the land-surface condition to the general circulation of the atmosphere. During the AMIP project, only SST was specified. If we can get reliable land surface observations, we can specify both the land surface condition and SST. In other words, we can specify all of the boundary conditions. Then, we can simulate what kind of atmospheric circulation might occur due to this boundary condition. This will clarify various weakness of the present state-of-the-art models.

Secondly, numerical experiments with respect to the relation between Eurasian snowfall and monsoon activity should be made. Shen et al. (1996) found the distinct relationship between Eurasian snowfall and the intensity of the Asian monsoon in the CCSR AMIP simulation . In order to confirm this conclusion further studies in this area are necessary, especially, further improvements in the land surface parameterization. During GAME project great improvement is expected in land-surface parameterization. CCSR have a plan to conduct similar experiments by using longer SST data and other land surface parameterization schemes.

Thirdly, further simulation should be made by using a coupled atmosphere-ocean model. It is well known that there exits a strong coupling between the atmosphere and the ocean over the Arabian Sea region. Whether this coupling has a serious impact on the Asian monsoon is also an interesting issue.

5.2.3 Establishment of a one-month prediction of the Asian monsoon

A long-range forecast is a critical issue in the tropical countries. As explained in Sec. 5.2.1, there is a possibility of a chaotic nature in the seasonal forecast. In order to overcome this difficulty, an ensemble forecast system should be established. For this purpose, the present skill of the 1 month forecast should be estimated. Its sensitivity to the initial state should be intensively investigated. At the same time, an efficient and economical way to make ensemble forecasts should be established. Especially, as the parameterization of convective processes plays a key role in the Asian monsoon, its sensitivity to it should be emphasized.

5.2.4 Spring predictability barrier

It is now widely recognized that there exists a predictability barrier of the ENSO forecast in the spring (Webster and Yang, 1992). They suggested that it is related to the onset of the Asian Monsoon. Whether this is a universal result or a model-dependent result should be carefully investigated. If the onset mechanism is very important, it is necessary to understand the mechanism of the warming process of land surface. This may be related to the melting process of snowfall and development of convection. Orographic effects to these processes should be given close attention. These studies should be conducted in GAME.

5.2.5 Validation for satellite data and its use for the large-scale modelling

During the GAME period, unprecedented data will become available including measurement of surface fluxes and radiation fluxes. However, these data are spatially limited and the horizontal extension of these data should be considered. There are two methods to extend these point measurements to the continental scale; (1) using a numerical model and (2) using remote sensing data by satellites. The first method is realized in the 4DDA technique, which has been discussed in Section 4 and will be discussed a little more later. The second method is related to the validation of satellite data which is discussed in Section 2.1. At the same time, a combination of numerical techniques and remote sensing technique is critical for further advance. For this purpose, ground-truth observations are essential. For example, there is a possibility of obtaining the vertical profile of convection by using TRMM measurements. These data are also very effective in validating the model performance.

The water budget is another important issue in discussing the Asian monsoon. However, there are a lot of problems to estimate the moisture fields over the ocean. There is a possibility to improve estimates of the moisture field by using TMI measurements. This coupling between numerical modelling and remote sensing data is most topical, and should be intensively persued in GAME.

5.3 Modelling of Meso-scale Atmospheric Processes

Numerical studies of the mesoscale atmospheric processes are carried out as follows:

(1) Heat and water exchange processes between the atmosphere and land surface, especially detailed heat and water budget in the monsoon region.
(2) Large-scale heat/moisture transport processes in the Asian monsoon system, between land and ocean areas, particularly from the Indian and Pacific Oceans.
(3) Role of diurnal cyles and/or local circulation in the energy and water exchanges over complex terrain of monsoon Asia.
(4) Role of mesoscale convection and topogaraphically induced processes in the monsoon climate system.
(5) Predictability of regional rainfall and circulations in the Asian monsoon region.

The core members of the mesoscale modelling group are providing the following three models to study above items, assisting other research groups who intend to follow a part of the GAME research plan with these mesoscale models.

(1) Simple models: Simple two- or three-dimensional models with radiation and turbulent parametarization including soil surface process, developed by University of Tsukuba. This model will mainly apply to process studies of the land surface and atmosphere interaction.

(2) JSM (Japan Spectrum Model) developed by JMA (Japan Meteorological Agency), which is a hydrostatic comprehensive model. This model will mainly apply to the meso-α phenomena and long term simulation. The science team of GAME Japan obtained the permission from JMA to use JSM. The allowed code is a 1988 version, and this has been revised by University of Tokyo.

(3) RAMS (Regional Atmospheric Modelling System) developed by Colorado State University, which is a non-hydrostatic model with full parametarization. This model will mainly be applied to the meso-β and γ phenomena. Three licenses of RAMS were purchased by the GAME project. The CCSR of Univ. of Tsukuba, Kyoto Univ., and Univ. of Tsukuba are the

official users. Since NIES (National Institute for Environmental Science) is already an official user, four institutions related with GAME have licenses. All the national/international researchers involved in GAME can use this model as part of cooperative research programs with one of these groups. Some parameterization schemes, radiation, surface process, initialization, etc., will be modified to fit the GAME area.

Numerical studies using other models or their own models are also expected to carried out by some research groups. The core members will also provide fundamental data such as topography and basic meteorological data. The core members are having frequently hold meetings with GAME mesoscale modellers to discuss their results and future research plans and to help each other to achieve the objectives.

For meso-scale modeling, precipitable water observed by GPS receiver will be usefull for initialization or evaluation of the model. GPS network data by IGS (International GPS service for Geodynamics) will be available.

Cloud-scale modelling and Cloud-scale 4DDA will be also carried out using radar data obtained in IOP.

Modelling studies of four regions are currently underway:

(1) GAME-Tropics

Core member is Dr. Satomura, Kyoto Univ. Studies for the diurnal variation of mesoscale disturbance and 4DDA for the cloud-cluster scale will be carried out using RAMS.

(2) GAME-Subtoropices (HUBEX)

Dr. Tsuboki, Nagoya Univ. is a core member. HUBEX plans two types of numerical modeling; one is a regional-scale meteorological modeling and the other is a cloud-resolving modeling. At the beginning of the research, the Japanese side and the Chinese side of HUBEX will carried out the modeling separately. The Japanese side will use the Japan Spectral Model (JSM) of 1988 version and its modified model for the regional-scale modeling and the Advanced Regional Prediction System (ARPS) which was developed by CAPS (Center for Analysis and Prediction of Storms) UO (The University of Oklahoma) for the cloud-resolving modeling. With respect to the 4DDA, the Chinese side will perform only a regional-scale 4DDA. The region will be 90–140E and 10–50N with a grid size of 30 km. The Japanese side will also make the regional-scale 4DDA and also plans to try a mesoscale cloud-system 4DDA. The grid scale of the former will be 20 km and that of the latter 1km. The latter could be similar to the retrieval method with using a Doppler radar data.

(3) GAME-Tibet

Core members are Dr. Kimura, Univ. of Tsukuba and Dr. Takayabu, Meteorological Research Institute. The former applies the simple models and RAMS to both plateau scale and basin scale. The latter mainly apply the newest version of JSM and studies surface parameterizarion. Science groups in Japan and China will promote cooperative studies on modelling. They both intend to allow US modelling group to join their modelling studies.

(4) GAME-Siberia

Dr. Yamazaki, Tohoku Univ. is a core member. Surface parameterization for Siberian region including permafrost will be investigated using the simple model and others.

5.4 Modeling of Basin-scale Hydrological Processes

The macro-hydrologaical model to be joined with atmospheric models mentioned in 5.3 will be developed to investigate following items:

(1) Heat and water exchange process between the atmosphere and land surface, especially effects of land-use, vegetation and snow cover.
(2) Estimation or correction method for the effects of inhomogeneous surface and complex topography on the atmospheric heat budget.
(3) Development of an estimation method of land surface parameters from satellite data (for example, NDVI and surface radiation temperature and so on).
(4) Impact of initial soil moisture on long term forecast by the models.
(5) Interaction between meteorological phenomena with different scales.
(6) Long term water circulation in basin-scale regions.

Core menbers are Drs. Lu and Koike, Nagaoka of Technology and Dr. Kimura, Univ.Tsukuba.