GEWEX Asian Monsoon Experiment

GAME Letter No.4 May 2002

A Summary Report of the GAME-Tibet Synthesis

1. Introduction

The GAME-Tibet project is an international land-atmosphere interaction field experiment implemented in the Tibetan Plateau both at the plateau scale and a meso-scale under the framework of the World Climate Research Programme (WCRP) / Global Energy and Water Cycle Experiment (GEWEX) Asian Monsoon Experiment (GAME). The overall goal of GAME-Tibet is to clarify the interactions between the land surface and the atmosphere over the Tibetan Plateau in the context of the Asian Monsoon system. To achieve this goal, the scientific objectives of GAME-Tibet are to improve the quantitative understanding of land-atmosphere interactions over the Tibetan Plateau, to develop process models and methods for applying them over large spatial scales, and to develop and validate satellite-based retrieval methods. GAME-Tibet is an interdisciplinary, coordinated effort by filed scientists, modelers and remote sensing scientists in meteorology and hydrology to address these objectives.

GAME-Tibet started in 1996 progressed rapidly through two experimental phases, the pre-phase observation period (POP) in 1997 and the intensive observation period (IOP) in 1998. It contributed to international research activities in the related science fields by providing the all obtained data through the GAME-Tibet Data Information System (DIS) in 2000. It has now moved on to the most rewarding part of project efforts for the analysis of results and the testing of new theories, models and algorithms.

This summary report is intended to introduce the reader to GAME-Tibet briefly and to summarize some of the significant findings of the science teams of GAME-Tibet, emphasize scientific gains in reference to the GAME-Tibet objectives, and outline some future research directions.

2. Experiment Design

The process-, modeling-, and satellite-based studies were carried out in cooperation with the Chinese national Tibetan Plateau Experiment (TIPEX) and the China-Japan Cooperative Study on Asian Monsoon Mechanisms (JEXAM) under the framework of the Joint Coordination Committee (JCC). Taking into account the importance of seasonal variations in key processes, the experiments at two different scales, the plateau-scale experiment and the meso-scale experiment, were implemented. To understand one-dimensional land surface-atmosphere interaction processes with spatial and seasonal variations, and to develop and validate sophisticated models, the plateau-scale experiment was carried out basically using the automatic weather station (AWS) and radiosonde networks. The meso-scale experiment was implemented in the central plateau, corresponding to the upper reaches of the Nujian basin, by using two- and three-dimensional intensive observing systems. The characteristics of frozen ground vary over a wide range, from continuous permafrost in the north to seasonal permafrost in the south. The details of the experiment design is provided in “GAME implementation Plan” (GAME International Science Panel, 1998).

GAME-Tibet covered the north to south transect observation of the plateau-scale experiment and the whole meso-scale one. The following measurements were done during the IOP by the efforts of GAME-Tibet:

1) Land surface-atmosphere interaction

· Boundary Layer measurements by using the AWSs at the 14 stations, the PBL tower at Amdo, and the turbulent flux measurement at Amdo and BJ site.

· Intensive radiosonde observation at Amdo on selected days to investigate diurnal variations of the PBL in June, July and August.

· Barometer network for local circulation measurement.

2) Precipitation and cloud studies

· 3-D Doppler radar observation about 10 km south of Naqu from the end of May to the middle of September.

· Ground-based precipitation measurement using the rain gauge network in the mesoscale area.

· A snow particle measurement system and a microwave radiometer for measurement of total water vapor and cloud liquid water content at Naqu.

· A GPS receiver for water vapor measurement at Amdo.

3) Land surface monitoring by satellite remote sensing.

· Ground truth data collection of spectral reflectance, soil moisture, surface temperature and surface roughness along the north-south transect and in the west part of the Tibet.

4) Cold region hydrology including permafrost study

· Soil moisture and temperature measurements along the north-south and east-west transects.

· River discharge and evaporation measurements in the meso-scale area.

5) Isotope study on precipitation and surface water

· Isotope sampling for study on the origin of precipitation and its recycling along the north-south and east-west transects.

· Isotope sampling for understanding formation processes of stable isotopic composition in the meso-scale experimental field.

67 scientists, including 37 Japanese, 25 Chinese and 3 Korean, organized the 5 expedition teams for the 5 months IOP from May to September in 1998. Each team covered one month observation by staying in Naqu or Amdo for 35 day including the 5 days overlapping with the next team. The AWSs in the west Tibet were maintained by JEXAM.

3. GAME-Tibet Data Information System (DIS)

According to the GAME-Tibet data policy, "final validated datasets obtained during the POP and IOP will be open to the international science community by June, 2000", a data information system that could serve not only the GAME-Tibet investigators but also wider research communities was generated as a tool for archiving and distributing the complex datasets after the data collection efforts (Tamagawa *et al*., 2001).

The level 2 data (quality checked and uniformly reformatted physical data associated with the detail information on site location, sensors, and observers) were transferred from the raw data obtained during the POP and IOP by the observers. All level 2 data were archived at the GAME-Tibet GIS and are opened through the user-friendly interface of WWW (http://monsoon.t.u-tokyo.ac.jp/tibet/index.html). Several pictures of the site and sensors and figures for the data quick view are also attached with the level 2 data at each site and its documentation for users' convenience.

4. Summary of Results

In this section, the results of the four science groups that were loosely arranged along disciplinary lines: atmospheric boundary layer, hydrology, modeling and remote sensing will be described.

4.1 Atmospheric Boundary Layer

The exchange of sensible and latent heat at the interface of atmosphere and the land surface was directly measured by eddy correlation method based on the measurement of atmospheric turbulence. Four flux sites, Amdo, MS3478, BJ (Naqu) and MS3637, were set up and the measurements were conducted during the IOP. In these sites the radiation budget, soil surface temperature, soil temperature profile, soil moisture profile and soil heat flux were also measured. These measured results serve as a consistent database to study land surface-atmosphere interaction.

With these results both diurnal and seasonal changes of the sensible and latent heat flux were clearly detected at Amdo where the longest and continuous data were obtained. Before the monsoon, the ground surface was very dry and the diurnal change of the surface temperature was as large as 50 degrees Celsius. The latent heat flux was very small and the sensible heat flux was dominant. As the ground surface became wet after the onset of monsoon, the latent heat flux increased and the sensible heat flux decreased. This change was in harmony with the decease of the ground surface temperature. Typical diurnal change of fluxes was also obtained for pre-monsoon, mid-monsoon and late-monsoon periods (Ishikawa *et al*., 1999). Tsukamoto *et al*. (2001) compared the flux observation at four sites. They also showed that the sensible heat flux controls the development of the depth of mixing layer.

At these flux sites, Tanaka *et al*. (2001a, 2001c), Miyazaki *et al*. (2001), Wang (2001) and Kim *et al*. (2001) reported 'flux imbalance'. They suggest that many factors are responsible for the imbalance. They also stress the importance of mean vertical motion of air mass which may be induced by small scale organized disturbances. Tanaka *et al*. (2001c) gave a discussion on the measurement of soil heat flux. They roughly estimated the surface soil heat flux needed to melt the permafrost and to heat the soil layer from April to June using the soil moisture and temperature data. The required surface heat flux was about 30 W/m^2 on average, which was greater than that measured by soil heat plate. Tanaka *et al*. (2001b) examined the performance of a heat plate numerically and suggested that some correction is necessary to the soil heat flux. The surface imbalance problem has not yet been resolved. This severely limits the usefulness of the observed flux data.

The western Tibet is a region where the distribution of meteorological station is very sparse. Two automated meteorological stations were set up at Gaize and Shichuanhe and the continuous measurements of surface boundary layer and some soil variables have been conducted. Haginoya (2001) reported the surface meteorology and fluxes estimated by the Bowen ratio method at these sites. Xu and Haginoya (2001) estimated the monthly averaged surface fluxes at fourteen Tibetan sites using conventional surface observation data. At Amdo site PBL tower observation has been continued after the IOP. Tanaka *et al.* (2001d) compute the bulk transfer coefficient for the sensible heat flux at the site by comparing the tower data with turbulent flux during IOP. The coefficient is obtained as a function of the bulk Richardson number. With this coefficient and the continued tower observation data they computed the sensible heat flux until July 2000. The data suggests the strong interannual variation, even the tower observation failed in Spring, when the sensible heat flux is largest in the year.

4.2 Hydrological Processes

The seasonal march in the Tibetan Plateau is characterized clearly by the rainy period and the dry one. During the rainy season, the active convection associated with a big amount of diabatic heat release plays an important role in the Asian summer Monsoon system. To understand and model the seasonal and interannual variability of the Asian summer Monsoon, it is important to address the hydrological processes, especially the origin and circulation of water vapor at large scale, the precipitation fields, and the land surface hydrological processes in the permafrost in the Tibetan Plateau.

4.2.1 Water vapor transport and water cycle in and around the plateau

Two approaches, the stable isotope study and the observation and modeling of the local circulation were introduced to understand the origin and transport of water vapor.The results of precipitation sample analysis for stable isotope study show the similar temporal variation of ⁇^{18}O in daily precipitation at the six sites in the meso-scale experiment field, the very low value of ?^{18}O in precipitation under the strong monsoon, and the higher ?^{18}O value associated with the convective precipitation (Tian *et al.*, 1999). The two characteristic feature of d-excess, which is often used for estimating the origin of the water, were found from the data obtained at Amdo (Numaguti *et al.*, 1999). One is an increasing trend of d-excess during continuous precipitation periods. The value is about 10 at the beginning phase of each precipitation event and over 20 in later stage. The other is an overall large value of d-excess, about 20, especially under a large-scale disturbance which embarked water vapor from south rather than from west. To explain this phenomena physically, a global isotope circulation model, which does not include fractionation process, was introduced. It suggests the importance of cloud process for high d-excess value.

Kuwagata *et al.* (2001) pointed out an important role of the mountain-valley circulation with the very typical diurnal variation in the water vapor transport in the Tibetan Plateau. Based on the radiosonde observation, the precipitable water decreased in the daytime at the valley area, while that increased during daytime over the mountain range. The magnitude of the diurnal variation ranged from 2 to 6 mm, which varied with time and space. The ECMWF 4DDA product also shows significant daytime decrease of precipitable water appeared in the valley regions around Naqu. Analysis of the GMS-5 water vapor channel image also indicated overall daytime increase of water vapor over the Plateau, but with some valley regions of daytime decrease. This diurnal variation of water vapor was also quantitatively simulated by a two-dimensional numerical model.

4.2.2 Precipitation fields

The intra-seasonal variation of the convective activity at the plateau-scale depends deeply on the variations of mid-latitude baroclinicity and the Tibetan anti-cyclone, while the spatial and diurnal variations of the convection are closely related with the mountain-valley topography in the plateau (Ueno, 1998; Kurosaki and Kimura, 2001). There are three types of meso-scale disturbances: the convective echo structure in daytime associated with vortex generation mechaaanisms, the stratified echo in nightime, and the combined system with frequent weak rainfall (Uyeda *et al.*, 2001; Shimizu *et al.*, 2001).

4.2.3 Land surface hydrological processes in the permafrost

The hydrological variability of permafrost was investigated both in the plateau- and meso- scales in the Tibetan Plateau. The plateau scale soil moisture distribution and its seasonal and interannual variations were observed by the space-based passive microwave remote sensing data. The thawing and freezing processes and their spatial and interannual variations were studied in the plateau scale by using the ground-based soil moisture and temperature profiles and atmospheric forcing data. The satellite synthetic aperture radar (SAR) data is used for detecting the surface soil moisture heterogeneity in the meso scale. A wide range of the meso-scale distribution of soil moisture in the permafrost region was examined by the observed data at several flat areas and on a slope (Koike *et al.*, 2001b).

The SSM/I surface soil moisture product shows the seasonal march of the soil moisture distribution in the Tibetan Plateau. The north-east and center parts of the plateau become wet in June while the other part is still dry. The wet area expands to north and west in July and to south in August. The center part keeps wet during the summer. Regarding to the spatial and temporal variation of soil moisture and temperature profiles along the Qinghai-Xizang highway, very clear spatial variability was identified, that is, the dryer and colder north and the wetter and warmer south, while any clear interannual variation between in 1997-1998 and 1998-1999 was not seen (Koike *et al.*, 2001b). The seasonal march of the soil moisture and temperature profile variation at the experimental slope suggested that the wide range of the soil moisture distribution along the slope, that is, wet valley and dry hilltop, was caused by the permafrost hydrological processes on the slope associated with the surface and sub-surface water flow along the slope and the surface energy budget differences due to the soil moisture distribution (Ishidaira *et al.*, 1999). In addition, the wide range of soil moisture distribution and its significant seasonal variation were also observed even at the flat areas. The wetter area appeared in the concaves, while the dryer in the convexes. Hirose *et al.* (2000) pointed out the importance of the interactive processes between the micro-topography and soil moisture in the permafrost region. The detention in the concaves keeps the active layer shallow due to the larger thermal capacity of soil and the larger amount of latent heat flux in the wetter area while the active layer grows more rapidly in the convexes due to the larger amount of soil heat flux.

Intensive observation of pressure head by using tensiometers in subsurface water and sampling of subsurface water at multiple depths were performed to investigate subsurface flow process in monsoon season, 1998. The pressure head of subsurface water ranged from -10 to -100 cmH_2O and zero flux plane was often observed above the depth of 30 cm. The groundwater recharge was very active during this period, thus the groundwater table rose up to the depth of 55 cm in the beginning of September. The ?D and ?^{18}O of shallow subsurface water varied markedly with precipitation and evaporation, whereas those of groundwater were stable. The mean ?^{18}O of groundwater was 3.4 ‰ higher than the volume weighted mean ?^{18}O of precipitation. The difference of ?^{18}O between the groundwater and the precipitation would be caused by isotopic enrichment along with evaporation from the soil surface, and 27 % of precipitation might be lost by evaporation from the soil surface (Tsujimura *et al.*, 2001).

4.3 Modeling

Field observations under a wide range of meteorological and hydrological conditions motivated the development and testing of key process models describing soil moisture and temperature profiles, flux exchange at the surface-atmosphere interface, boundary layer flux profiles, radiative transfer, cloud formation and rainfall. In addition to one-dimensional modeling of land-atmosphere interaction, meso-scale and regional–scale modeling, and methods for scaling up land surface process were investigated.

4.3.1 One-dimensional modeling of land-atmosphere interactions

A new frozen soil parameterization in the land surface scheme was developed by incorporated a modified approximation Stefan solution in the framework of the land surface model - SiB2 to calculate the frost/thaw depth over time, and to estimate the soil moisture and temperature profiles during the freeze-thaw cycle. The structure of the soil model in SiB2 is kept but the governing equations of water balance and surface heat balance are modified to account for soil freezing/thawing. The model was calibrated and validated using the GAME-Tibet observations (Li and Koike, 2001). The new model estimates the frost depth more precisely, predicts the soil temperature reasonably and phase transition time more realistically than original SiB2.

An one-dimensional heat and water flow model was developed to simulate soil moisture and temperature profiles and surface fluxes in detail (Ishidaira *et al.*, 1998). Regarding to heat flow, thermal diffusion in soil is calculated with fine vertical resolution by introducing the thermal conductivity and the heat capacity which are considered as the function of volumetric water content. The ground surface temperature is calculated by surface heat balance and is used as the upper boundary condition. The water transport is expressed by a 5-layer soil model, in which the water budget is calculated by using the change of liquid water in the layer, the amount of water transport between layers, the change of liquid water content associated with thawing and freezing of permafrost and the deifference of the hydraulic conductivity and in the soil matrix potential.

To consider the soil moisture – micro-topography interaction, a detention storage component, which affects on the surface energy budget, was added into the one-dimensional model (Hirose *et al.*, 2000). The performance check of the soil moisture-microtopography interaction component was done, and indicated the variability of surface soil moisture that is consistent to the observed one.

4.3.2 Two- and three-dimensional meso- and regional-scale modeling

To simulate the seasonal variation of the diurnal cycle of the cloud activities over and around the plateau derived by GMS, Regional Atmospheric Modeling System (RAMS) developed at Colorado States University (CSU-RAMS) was applied in two dimensions domain with north-south direction (17N-42N, 90E) (Kurosaki and Kimura, 2001). The characteristic diurnal cycles of cloud, less or no cloud in the morning of the pre-monsoon period and low-level cloud in the morning of the monsoon over the Tibetan Plateau, and frequent low-level cloud over the southern slope of Himalayas, were simulated well.

Yoshikane *et al.* (2001) conducted numerical experiments to investigate the mechanism of the Baiu front by using CSU-RAMS. The location of the Baiu front is speculated to be quite sensitive to the zonal mean flow. The Baiu front accompanied by the low level jet was also represented by numerical experiments without topography, which suggests that the Baiu front could be reproduced by two factors alone, the zonal mean field and the land/sea contrast. The orography, including the Tibetan Plateau, intensifies the precipitation of the Baiu front, especially when the upper-level jet is weak and located northword.

4.3.3 Development of methods for scaling up land surface process models

Due to the non-linear relationship between evaporation and soil moisture, calculated evaporation by using spatially averaged soil moisture is smaller than actual one under dry condition and larger under wet condition. The effects of the wide range of the soil moisture distribution due to the presence of detention storage in the Tibetan Plateau is expressed by a linear function of the standard deviation of soil moisture (Hirose *et al.*, 2000). This result suggests a method for scaling up heterogeneous land surface processes.

4.4 Remote Sensing

Due to the dynamics and constantly changing behavior of the parameters inherent to energy and water cycle processes, and because of the relatively few ground observation stations over the Tibetan Plateau, efficient monitoring and continuity in space and time sampling over the complete plateau are only possible by satellite remote sensing. In turn, the field observations and process studies help to serve as sources of ground-truth information for satellite-based retrieval algorithms. To meet the objectives of the process and modeling studies reported above, GAME-Tibet focused on the development and validation of satellite algorithms for precipitation, radiation budget, surface fluxes, soil moisture and snow.

4.4.1 Precipitation

Quantitative estimation of spatial distribution of precipitation in the Tibetan Plateau is one of the important aspects for understanding the function of water cycle processes and estimation of water resources. Ueno *et al.* (2001) developed an SSM/I algorithm for rainfall by introducing a new scattering index into the existing scattering algorithm detect the weak intensity of precipitation in the plateau. The accumulated monsoon precipitation distribution in 1998 obtained by the new algorithm shows better agreement with the GMS estimated precipitation in the plateau area without screening of the surface condition.

A new algorithm for precipitation over land by deriving the optical thickness from the brightness temperature of the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) (Fujii and Koike, 2001). The effect of land surface controlled by soil moisture emissivity on radiation transfer is taken into account in this algorithm. This means that soil moisture can be estimated at the same time in addition to precipitation. Based on a microwave radiative transfer equation, two indices, *Index* *of Soil Wetness* (ISW) and *Polarization Index* (PI), which remove the effect of land surface physical temperature, are introduced into the algorithm. Surface roughness effects on land surface emissivity are included by using the polarization mixing ratio and the surface roughness. As the results of the algorithm application to the GAME-Tibet meso-scale experimental field, the estimated optical thickness and soil moisture are in good agreement with the patterns of precipitation observed by the 3D Doppler radar, and the observed soil moisture at 4 cm in depth, respectively. A unique relationship between the optical thickness and the observed precipitation by rain gauges can not be seen due to the emission from precipitation layer, the temporal sampling of TMI observation, and the profiles of hydrometeors. A reasonable relationship between the estimated optical thickness, and observed precipitation by rain gauges is obtained after 10 days of longer temporal averaging.

We can produce the diurnal cycle of rainfall because the TRMM satellite has a non-sun-synchronous orbit. Area-averaged rain rate, averaged storm height, proportion of convective rain to all rain in the rectangular area, and the rain area to the rectangular area were calculated from the TRMM Precipitation Radar (PR) data. This rectangular area almost covers the overlapping area of the Naqu hydrological basin and Doppler radar coverage. Totally 87 snapshots of rainfall events were obtained by TRMM PR during the IOP. The results indicate that precipitation with a high storm height developed in the afternoon while the rain area was not large. In contrast, large startiform precipitation developed in the evening and night and the largest amount of rainfall appeared in the night (Shimizu *et al.*, 2001).

4.4.2 Radiation budget and surface fluxes

Estimation of the energy exchange distribution between the land and atmosphere is one of key issues of the GAME-Tibet project. The fluxes of radiation, soil heat, sensible heat and latent heat were estimated by combining the in-situ data, NOAA14 Advanced Very High Resolution Radiometer (AVHRR) data and the radiation transfer model, MORTRAN (Ma *et al.*, 2001). The results show that 1) the very wide range of fluxes due to the complex surface conditions, 2) the estimated components of energy budget are in good agreement with the observed ones except the latent heat flux at one site, 3) the large value of the net radiation due to the high elevation and the land cover condition.

4.4.3 Soil moisture

A new algorithm based on microwave radiative transfer theory was developed for soil moisture using passive microwave sensors (Koike *et al.*, 2001a). It was applied to the data from the TMI and evaluated by using the field data obtained during the IOP (Koike *et al.*, 2001b). The estimated soil moisture corresponds reasonably to the soil moisture observed by the TDR sensor at 4 cm in depth. Just after the heavy rainfall, the satellite derived soil moisture is greater than the ground observations because the TMI only detects the surface moisture, which is much wetter than the observations at 4 cm depth. Conversely, during dryer periods the algorithm underestimates because the soil surface dries more rapidly. The monthly averaged diurnal cycle of the land surface physical temperature calculated by the proposed algorithm shows the same pattern as the ground observations, however with several K bias. The estimated water content of the vegetation also corresponds well to the observations, with an accuracy of 10% or less.

A time series data from the Japanese Earth Resources Satetlite-1 (JERS-1) Synthetic Aperture Radar (SAR) at L-band was used an algorithm for surface soil wetness at fine spatial resolution by using surface roughness measurements during the POP and a microwave backscattering model (Tadono *et al.*, 2000). A surface roughness map was generated by the JERS-1 SAR winter data by applying the scattering model and the relationship between two surface parameters under the perfectly dry condition. A soil moisture distribution in summer was estimated by applying the scattering model and the surface roughness map to a summer SAR data. The estimated distributions of soil moisture in the Tibetan plateau qualitatively correspond to those obtained by field measurement.

4.4.4 Snow

An algorithm for snow was developed by a relationship between the land surface radiation and snow properties derived from the radiative-transfer theory on a scattering dielectric layer over a homogeneous half-space. The total land surface brightness temperature is the sum of the direct component and diffuse component, which corresponds to the reflected sky radiation and the thermal radio emission from the snowpack and soil, and the radiation scattered from the direct and diffuse fields, respectively. By assuming snow grain size, snow density, and radiation from the soil-snow interface, brightness temperatures at two different frequencies, 19 and 37 GHz, were calculated by inputting snow depth and physical temperature. This algorithm was applied to the data from the TMI and evaluated by using the field data obtained in the winter of 1997-1998 (Koike *et al.*, 2001a).The estimated snow physical temperature is in good agreement with ground observations made with infrared thermometers. Snow depth was not validated because of the lack of adequate ground observations.

References

Fujii, H. and T. Koike, 2001: Development of a TRMM/TMI Algorithm for Precipitation in the Tibetan Plateau by Considering Effects of Land Surface Emissivity, *J. Meteor. Soc. Japan*, **79**, 475-483.

Fujinami, H. and T. Yasunari , 2001: Convective Activity over the Tibetan Plateau and Associated Atmospheric Circulation during GAME-Tibet IOP. *Proc. 2nd International Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

GAME International Science Panel, 1998: GAME implementation Plan, 66-80.

Haginoya, S., 2001: Study on the Surface Heat Balance in the Tibetan Plateau – Precision of Bowen Ratio Method, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Hirose, N., T. Koike, H.Ishidaira, 2000: Effects of soil moisture heterogeneity on spatially averaged evaporation, *Annual Journal of Hydraulic Engineering, JSCE*, **44**, 169-174.

Ishidaira, H., T. Koike, M. Lu, N. Hirose, 1998: Development of 1-d soil model for heat and water transfer in permafrost regions, *Annual Journal of Hydraulic Engineering, JSCE*, **42**, 133-138.

Ishidaira, H., T. Koike, N. Hirose Y. Ding, Y. Shen, S. Wang, B. Ye, 1999: Observational study on topographic effects of permafrost melting processes, *Annual Journal of Hydraulic Engineering, JSCE*, **43**, 97-102.

Ishikawa, H., T. Hayashi, K. Tanaka, O. Tsukamoto, H. Fudeyasu, I. Tamagawa, J. Asanuma, Y. Qi, J. Wang, Y. Ma, Z. Hu and H.Gao, 1999: Summary and the preliminary results of PBL observation, *Proc. 1st Int. Workshop on TIPEX/GAME-Tibet*, Xi'an, China, 69-72.

Kim, J, J. Hong, Z. Gao and T. Choi, 2001: Can we close the surface energy budget in the Tibetan Plateau?, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Koike, T., H.Fujii, T.Ohta, E.Togashi, 2001a: Development and validation of TMI algorithms for soil moisture and snow, *Proc. Symposium on Remote Sensing and Hydrology 2000, IAHS Publ.*, **267**, 390-393.

Koike, T., N. Hirose, H. Ishidaira, Y. Ding, Y. Shen, S. Wang, B. Ye, M. Yang, 2001b: Hydrological Variability in the Tibetan Permafrost, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Kurosaki, Y. and F. Kimura, 2001: Daytime cloud activitiy around the Tibetan Plateau during GAME-IOP in 1998, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Kuwakgata, T., A. Numaguti, and N. Endo, 2001: Diurnal variation of water vapor over the central Tibetan Plateau during summer, *J. Meteor. Soc. Japan*, 79, 401-418.

Li, G., T. Duan, S. Haginoya and L. Chen, 2001: Estimation of the bulk transfer coefficients and surface fluxes over the Tibetan Plateau using AWS data, *J. Meteor. Soc. Japan*, 79, 625-635.

Ma, Y., J.Wang, T.Koike, H.Ishikawa, O.Tsukamoto, J.Kim, M.Menenti, Z.Su, Z.Hu, J.Wen, Z.Gao, 2001: Determination of Regional Land Surface Heat Flux Densities for Tibetan Plateau Area *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Miyazaki, S., O. Tsukamoto, I. Kaihotsu, T. Miyamoto and T. Yasunari, 2001: The Energy Imbalances Observed in Tibetan Plateau and Mongolian Plateau, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Shimizu, S., K. Ueno, H. Fujii, H. Yamada, R. Shirooka, and L. Liu, 2001: Mesoscale characterictics and structure of stratiform precipitation on the Tibetan Plateau, *J. Meteor. Soc. Japan*, **79**, 435-461.

Shirooka, R., H. Yamada, H. Uyeda, J. Horikomi, 2001: Vertical Structure of Connective Clouds Obtained by a Doppler Radar on Tibetan Plateau, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Tadono, T., T.Koike, J.Shi, Y.Ding, X.Chen, S.Wang, M.Yang, 2000: Development of an algorithm for soil moisture mapping based on single-parameter SAR images in permafrost regions including the effect of surface roughness, *Journal of Hydroscience and Hydraulic Engineering*, **18**, 29-38.

Tamagawa, K., Koike, T., and Fujii, H., 2001: An Introduction to GAME-Tibet Data Information System(DIS), *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Tanaka, K. and H. Ishikawa, 2001a: Estimation of Soil Heat Flux Using in Situ Soil Parameters, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Tanaka, K. and H. Ishikawa, 2001b: The Bulk Transfer Coefficient and Surface Roughness Length in the Eastern Tibetan Plateau Using GAME/IOP Data, *Proc. 2nd Int. Workshop* *on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Tanaka, K., H. Ishikawa, T. Hayashi, I. Tamagawa, and Y. Ma, 2001c: Surface energy budget at Amdo on Tibetan Plateau using GAME/Tibet IOP98 data, *J. Meteor. Soc. Japan*, **79**, 505-517.

Tanaka, K. and H. Ishikawa, 2001d: Long term monitoring of surface energy flux at Amdo in eastern Tibetan Plateau, *Proc. of Int. Workshop on GAME-AAN/Radiation*, Phuket, Thailand, (*Bull. Terrestrial Environ. Res. Cen., Univ. Tsukuba*, No.1 (GAME Publication No.28)), 40-43.

Tian, L., T. Yao, A. Numaguti, M. Tsujimura, and S. Hashimoto, 1999: Stable isotope in precipitation and monsoon activity in the middle of Tibetan Plateau, *Proc. 1st Int. Workshop on GAME-TIBET*, Xian, China, 59-63.

Tsujimura, M., A. Numaguti, L. Tian, S. Hashimoto, A. Sugimoto and M. Nakawo , 2001: Behavior of Subsurface Water Revealed by Stable Isotope and Tensiometric Observation in the Tibetan Plateau. *J. Meteor. Soc. Japan*, **79**, 599-605.

Tsukamoto, O., H. Ishikawa, S. Miyazaki, J. Kim, Y. Ma and Z. Hu, 2001: Diurnal Variation of Surface Fluxes and Boundary Layer over Tibetan Plateau, *Proc. Int. Workshop on GAME-AAN/Radiation*, Phuket, Thailand, (*Bull. Terrestrial Environ. Res. Cen., Univ. Tsukuba*, No.1 (GAME Publication No.28)), 36-39.

Ueno K., 1998: Characteristics of plateau scale precipitation in Tibet estimated by satellite data during 1993 monsoon season. *J. Meteor. Soc. Japan*, **76**, 533-548.

Ueno, K., H.Fujii, N.Grody, R.Ferraro, A.Gruber, 2001: Estimation of Precipitation with Weak Intensity in the Tibetan Plateau by Using SSM/I Satellite Data, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Uyeda, H., H.Yamada, J.Horikomi, R. Shirooka, S.Shimizu, L.Liu, K.Ueno, H.Fujii, and T.Koike, 2001: Characteristics of convective clouds observed by a Doppler radar at Naqu on Tibetan Plateau during the GAME-Tibet IOP, *J. Meteor. Soc. Japan*, **79**, 464-474.

Wang, J., 2001: Surface flux measurements in GAME/Tibet 1998, *Proc. 2nd Int. Workshop on TIPEX/GAME-Tibet*, Kunming, China, (in press).

Xu, J., and Haginoya, S., 2001: An Estimation of Heat and Water Balances in the Tibetan Plateau, *J. Meteor. Soc. Japan*, **79**, 485-504.

Yoshikane, T., F. Kimura, S.Emori , 2001: Numerical study on the Baiu front genesis by heating contrast between land and ocean, *J. Meteor. Soc. Japan*, **79**, 671-686.

AAN Report

[Heat budget group]

1. Background and General Information

The Eurasian continent plays a predominant role on the seasonal cycle of the planetary-scale surface energy exchange and transport in the climate system. The diverse land surfaces and vegetation characterize the extremely large seasonal and spatial variation of surface sensible and latent energy fluxes over the continent, which in turn may produce the regionality and asymmetries in the seasonal cycle over the continent. Despite its importance, available basic data have been quite limited to study these issues. To remedy this situation, at least partially if not completely an automatic weather station (AWS) which has a capability to measure not only the regular meteorological and hydrologic variables but also surface fluxes of momentum, heat, water vapor and radiation as well as soil moisture status, have been installed over the Asian countries since 1996 as a part of GAME activities. Currently 15 stations are in operation (see Fig.1) and valuable data

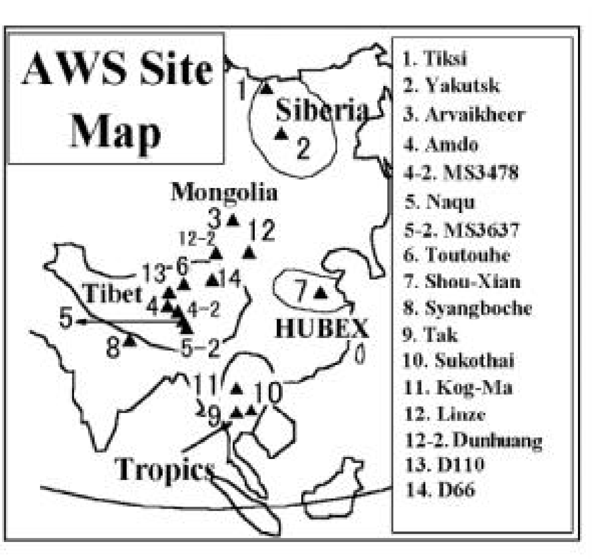


Fig. 1 A map showing the location of GAME-AAN flux stations currently in operation. Triangles indicate those stations expected to operate through phase II of GAME-AAN, while circles represent those that will operate only during phase I.

have been accumulated and analyzed in the framework of GAME-AAN project. Currently, the project is in the beginning of its Phase II (Monitoring phase) which has started in the year 2000, and this will be the period for a long term monitoring to determine mean, seasonal and annual variations of surface variables. Phase I (Installation phase) had been for the development of the AWS system and initial study period.

2. Phase I activity summary

- AWS test and operation

As mentioned, Phase I has just been completed. In general, initial plan of the test and installing AWSs in GAME areas achieved as planned. However, there were problems, both expected and unexpected, that interrupted field measurements and resulted in unavailability of relevant data during the intensive observation periods of GAME in some areas. Problems came from probably two separate reasons. First one is that in AWS systems, particularly PAM III station developed and produced by National Center for Atmospheric Research in the U.S. are very sophisticated and require a careful maintenance and operation, although they have strong capability to produce very accurate measurements with a modest cost when compared with other AWS systems. Although we could get a long term data of turbulent fluxes through direct measurements with the PAMIII when it works well, unfortunately we had more missing data than the other AWSs (see Fig.2 and Fig.3). Most of the missing data was caused by the unstable and incomplete system of data acquisition system of PAMIII, while most of sensors were working properly. Some other reason for such trouble is that in GAME scientists and local counterpart personnel to operate AWS systems did not have adequate time to get accustomed to the system due to the quite complicated systems. Thus when a technical problem occured in some remote area, it took a long time to solve it. These problems, however, have occurred gradually less frequently and continuous measurements become more common at some stations, after we modified the system of PAMIII based on the discussions between NCAR and GAME scientists in the workshop held at Boulder, U.S. in July, 1999 (see detail in our website: http://www.suiri.tsukuba.ac.jp/Project/aan/meeting-ws/ws-PAM99.html). Both GAME scientists and counterparts have got a better knowledge of the system and an additional backup data acquisition system was installed in 2000-2001 for a reliable long-term measurements.

- The AAN data

The data have been, and will be, checked and processed as they are provided from each station for archiving at the AAN data center at Terrestrial Environment Research Center of the University of Tsukuba. Each station has four types of dataset within the data archives. They consist of (i) the station documentation, (ii) the dataset documentation, (iii) the data inventory and (iv) actual dataset. To produce these datasets and to provide them in AAN data center have the responsibility by PIs of each station. At the moment, for most stations (i)-(iii) are available (see Fig. 4-6 as examples), through the AAN website (http://www.suiri.tsukuba.ac.jp/Project/aan/aan.html). The actual data (iv) are now being distributed within the GAME community for the 1998 data sets, and will soon be open to a wider scientific communities based on GAME data policy. However, there are some stations which lack an adequate description of the data sets or the station. There are also some station which has not produced complete data sets from the original measurements. These variables often include the latent and sensible heat fluxes which require a careful quality check of the data and processing of the measured values before they can be used with confidence.

- Scientific Issues

To summarize and wrap-up the Phase I activities and to address future needs of AAN activities, the International Workshop on GAME-AAN/Radiation was held at Phuket in Thailand on March 7-9, 2001 with about 100 participants and 40 oral presentations. Some of presentations were already published to scientific journals (e.g., Aoki *et al.,* 1998; Ohta *et al.,* 1999, 2001; Toda *et al.,* 2001). Below some important topics discussed in this workshop are summarized as follow:

One of the issues that has emerged in the process of deploying AWSs and the data analysis is the so-called energy imbalance problem. Theoretically, the sum of latent and sensible heat fluxes should be balanced with net radiation and soil heat flux. However, in many AAN sites this turned out not to be the case, although some sites reported close to perfect balance (see Fig.7). Current consensus appears that the closure problem is site specific and that up to 20-30% of the net radiation may not be able to accounted for from measurements. Possible reasons have been identified as a problem of turbulence measurements technique, sampling error of the soil heat flux and the net radiation measurements, and a mismatch of foot print of equipments used to measure energy balance components. Intensive discussions at scientific meetings, both at the international workshop and other related meetings, took place, and as a result, an additional field observation initiative has started in which 5-10 eddy flux measurement systems were installed side by side at a well maintained and controlled site, and their difference, and possible causes for the imbalance problems are being investigated.

Although Phase I is for the test and deployment of AWS systems, some initial results of a long term measurements are being reported. Figs.8-9 which indicates that three geographically very different locations showed difference in variations of surface energy partition regime, both in time and in magnitude (Miyazaki *et al.*, 2001).

Additionally, some interesting and encouraging results were reported with the Phase I AAN data set. Figs. 10 and 11 illustrate such two examples. Figs.10 and 11 give comparisons of the surface fluxes obtained from one AAN surface station and from GAME and ECMWF reanalysis data (Yatagai *et al.*, 2001). For the reanalysis data, flux values of the nearest grid were used. The comparison indicates reanalysis very good agreement of the measurements and model derived values. This tends to indicate, in the viewpoint of the surface station, that a point measurement of the station represents somehow a region surrounding the station. This is encouraging for the use of the AAN data and actually may not be too surprising given the fact that each station site was selected so as not to be too local and not to be too different from its surrounding areas. Fig. 12 illustrates one example of the use of AAN data for the model validation (Sugita *et al.*, 2001, Sugita, 2001). Because AAN sites cover a wide range of geographical areas and climates, a comparison of any variables produced from a model or from a satellite against the AAN data sets should give opportunity for a thorough validation of these data (and, in turn, the model or the satellite measurements themselves).

3. Future Plan

Curretly 9 stations are planed to keep operation through Phase II of the AAN to obtain a long-term trend of surface variables. At the moment, proposals to get adequate funding and resources for the operation are under consideration.

In addition to the continuation of the measurements, an urgent task to be made is to update and complete the AAN data sets. This should include strong efforts of the AAN data center to obtain the data and the derived values by each PIs for distribution among the scientific communities. Also, for those scientists who do not have easy access to the Internet, data distribution by some medias (e.g., CD-ROMs) are also being considered.

References

Aoki, M., T.Chimura, K. Ishii, I. Kaihotsu, T. Kurauchi, K. Musiake, T. Nakaegawa, N. Ohte, P. Panya, S. Semmer, M. Sugita, K. Tanaka, O. Tsukamoto, and T.Yasunari, 1998: Evaluation of surface fluxes over a paddy field in tropical environment: Some findings from preliminary observation of GAME, *J. Japan Soc. Hydrology & Water Resour.*, **11**, 39-60.

Ma, Y., O.Tsukamoto, I.Tamagawa, J.Wang, H.Ishikawa, Z.Hu and H.Gao, 2000: The study of turbulence structure and transfer characteristics over the grass land surface of Tibetan Plateau, *Chinese J. Atmos. Sci.*, **24**, 456-464.

Miyazaki, S., O.Tsukamoto, M. Toda, N. Ohte, K. Tanaka, I. Kaihotsu, T. Miyamoto, and T. Yasunari, 2001: A comparative study of seasonal variation of surface heat flux in Asian Monsoon region, *Proc. Int. Workshop GAME-AAN/Radiation, GAME Public.*, No.28 (*Bull. Terrestrial Environ. Res. Cen., Univ. Tsukuba*, No. 1), Pucket, Thailand, 95-97.

Ohta, T., K. Suzuki, Y. Kodama, J. Kubota, Y. Kominami and Y. Nakai, 1999: Characteristics of the heat balance above the canopies of evergreen and deciduous forests during the snowy season, *Hydrological Processes*, **13**, 2383-2394.

Ohta, T., T. Hiyama, H. Tanaka, T. Kuwada, T. C. Maximov, T. Ohata and Y. Fukushima, 2001: Seasonal variation in the energy and water exchanges above and below a larch forest in Eastern Siberia, *Hydrological Processes*, **15**, 1459-1476.

Sugita, M., 2001: Estimation of large scale evaporation by a complementary relationship with a simple ABL model. *Proc. Int. Workshop GAME-AAN/Radiation, GAME Public.*, No.28 (*Bull. Terrestrial Environ. Res. Cen., Univ. Tsukuba*, No. 1), Pucket, Thailand, 91-93.

Sugita, M., J. Usui, I. Tamagawa, and I. Kaihotsu, 2001: Complementary relationship with a convective boundary layer model to estimate regional evaporation, *Water Resour. Res.*, **37**, 353-365.

Toda,M., N.Ohte, M.Tani and K.Musiake, 2001: Observation of evergy flux and evapotranspiration over terrestrial complex land in the tropical monsoon region, *J. Meteor. Soc. Japan*, (submitted).

Yatagai, A., S. Miyazaki, M. Sugita, O. Tsukamoto, N. Ohte, M. Toda, 2001: A comparative study of surface fluxes derived from four-dimensional data assimilation products with AAN observations. *Proc Int. Workshop GAME-AAN/Radiation, GAME Public*., No.28 (*Bull. Terrestrial Environ. Res. Cen., Univ. Tsukuba*, No. 1), Pucket, Thailand, 25-28.

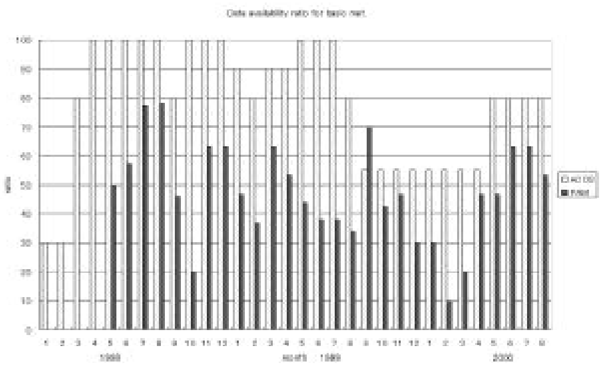


Fig. 2 Time series of the data availability for basic meteorological elements (e.g., air temp., precipitation, wind speed) obtained by ACOS (Automated Climate Observing system) and PAMIII. These values were calculated by using raw data for ACOS but processed data for PAMIII.

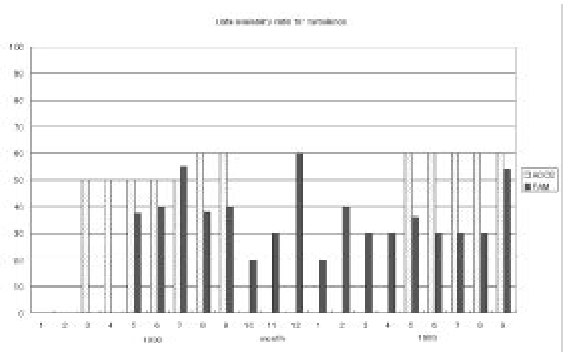
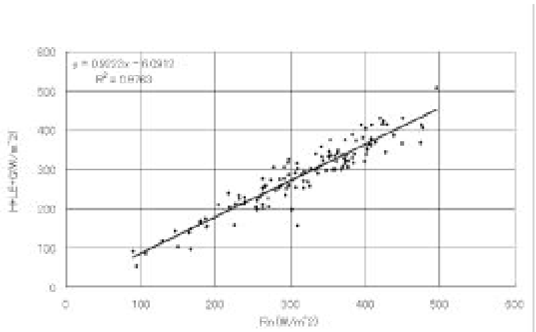


Fig. 3 Same as Fig.3 but for surface fluxes (sensible heat flux, latent heat flux, momentum flux).



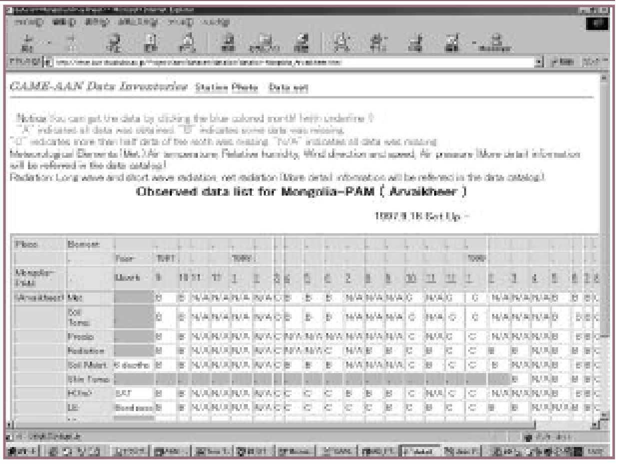


Fig. 4 An example of the GAME-AAN data inventory list as seen on the AAN web site.

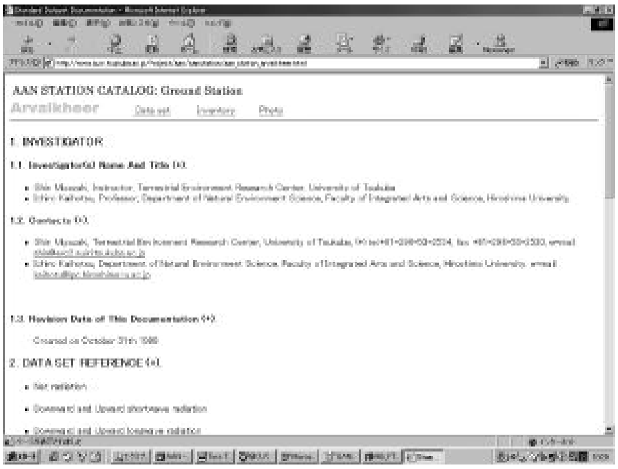


Fig. 5 Same as Fig.4 but for dataset documentation.

Fig. 6 Same ad Fig.4 but for station documentation.

Fig. 7 (left) An example of energy balance closure as reported from an AAN station located in Mongolia.

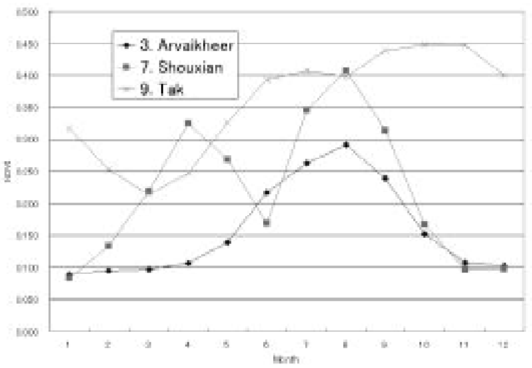


Fig. 8 Seasonal variation of NDVI at three AWS locations as given with 20-year means. (see Fig.1 for the exact location)

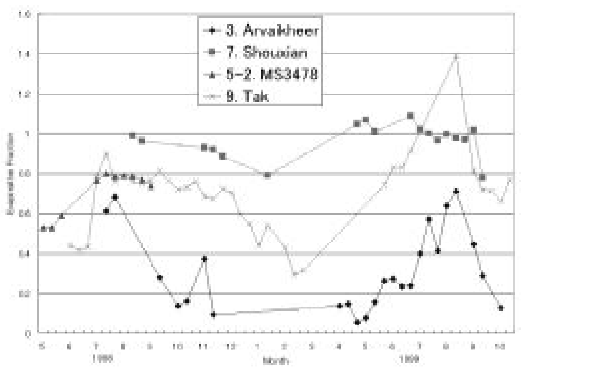


Fig. 9 Seasonal march of evaporative fraction [=LE/(Rn-G), the ratio of latent heat flux and available energy]

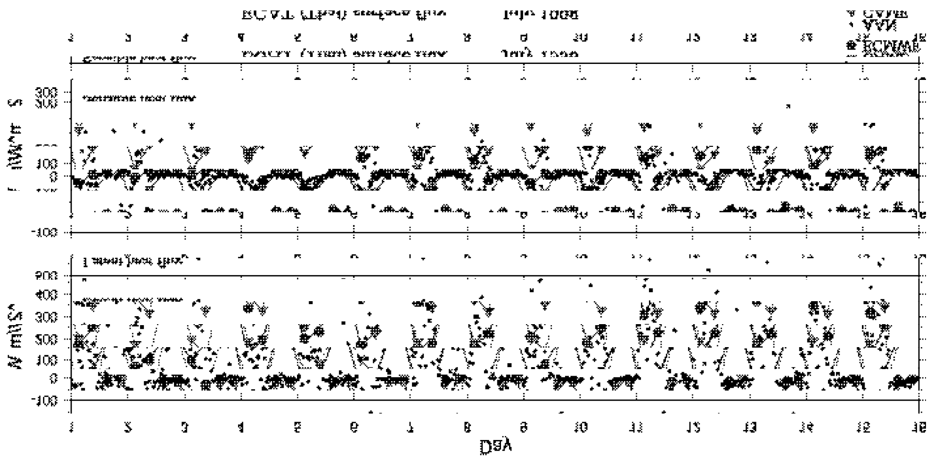


Fig.10 Comparison of sensible heat flux (upper panel) and latent heat flux (lower panel) between GAME reanalysis Ver. 1.1, ECMWF operational dataset and AAN observation (EGAT tower at Tak in Thailand). Small dots indicate AAN observation (every 30 minutes); triangles, GAME reanalysis; and circles, ECMWF operational dataset.

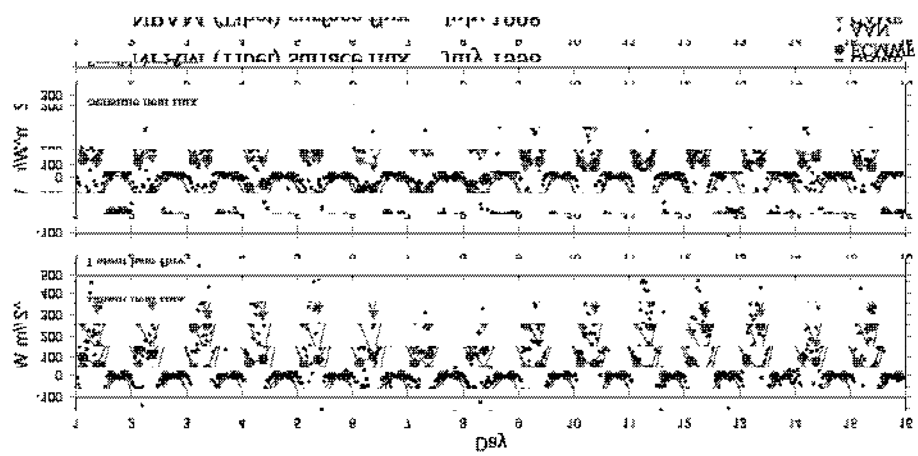


Fig. 11 Same as Fig. 10 but for the site of AAN observation (north PAMIII on Tibetan Plateau).

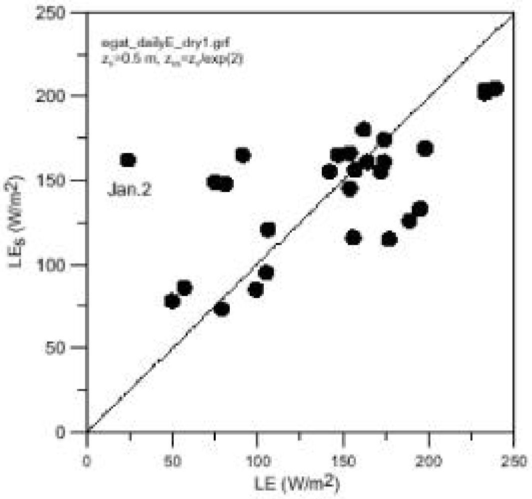


Fig. 12 Comparison of model derived latent heat flux (LEs) and AAN measurements at Tak in Thailand during dry season (Sugita et al., 2001).

[Radiation group]

1. Objectives of the GAME Radiation Study

Investigation of the earth's radiation budget is important for understanding the energy and water circulation processes in the GAME region. It is also important to study the impact of large scale air pollution in the Asian region to understand the impact of anthropogenic aerosols to the global warming phenomenon through investigation of the radiative properties of aerosols and clouds (Emori *et al.*, 1999). In this program, the following tasks are considered to attain these researches:

1) Developing an accurate method to estimate the surface radiation budget from satellite data. The wide area distribution of solar insolation flux at surface is desirable to obtain from the GMS satellite data.

2) Establishing an accurate radiation budget monitoring at several sites in the GAME area for validation of the radiation budget derived from satellites. In this activity, BSRN (WMO Baseline Surface Radiation Network) type instrumentation is introduced for accurate measurements of the surface radiation budget. A microwave radiometer and a sky radiometer instrumentation to retrieve the cloud and aerosol radiative properties which are indispensable for theoretical simulation of the radiation budget. The data are being archived to provide surface shortwave and longwave radiation budget at these sites.

3) Investigation of the effect of cloud and aerosol radiative forcing. Direct and indirect climate effects of anthropogenic aerosols have become recent important topics for improving the global warming simulation. Data from the sky radiometer network called SKYNET which includes GAME radiation sites and satellite radiance data of AVHRR, SeaWiFS and MODIS have been analyzed to derive the radiative properties of aerosols and clouds useful to depict the aerosol climate effects.

The final goal of the radiation activity is to reduce uncertainties involved in the estimation of the earth and surface radiation budget, especially due to clouds and aerosols in the Asian region. The uncertainty of the radiation budget coming from cloud and aerosol is said to be 20 to 30 W/m^2, which is 6 to 8 % of the total incoming solar radiation.

2. Activities of the GAME Radiation Group

In order to pursue the previously mentioned three objectives, the following activities have been performed.

- SKYNET and GAME high precision radiation Sites

The SKYNET is a network of a sky radiometer, which is similar to the NASA AERONET sun/sky photometer network (Holben *et al.*, 1998), to measure the sky radiance distribution as well as the direct solar irradiances at several wavelengths from 360 nm to 1020 nm, from which aerosol size distribution and optical thickness are retrieved. A pynanometer is also required at the sites for measuring the downward solar radiative flux. SKYNET sites are shown in Fig. 1. Sri Samrong (Thailand, 16.9N, 99.8E, since July 1997), Shou-Xian(China, 32.6N, 115.8E until March 1999) /Hefei (China, 31.9N, 116.9E, from April 1999) are the GAME-AAN High Precision Radiation sites, where full instrumentation of the surface radiation budget and cloud/aerosol measurements have been installed. A lidar, and a microwave radiometer were installed at Sri Samrong. Takayabu *et al.* (1999) studied the radiation budget in Tsukuba with data from similar instrumentation as shown above.

- Solar flux distribution from GMS satellite

The surface solar radiation was estimated from GMS visible and infrared radiance data (Fig. 2) and compared with the values observed at the GAME High Precision Radiation sites and SKYNET sites (Fig. 3). Monthly mean values of the surface radiation flux in 1997, 1998, and 1999 are basically in good agreement with the observation. Detailed comparison shows, however, a minor difference which is considered to relate to the aerosol optical thickness and the diffused light intensity. When the aerosol optical thickness is large the surface radiation flux is correctly estimated, but the satellite value underestimates the surface-measured value when the aerosol layer is thin. This suggests that an adequate introduction of aerosol loading is important for accurate estimation of the surface solar radiative flux from satellite radiances.

- *Lidar measurements*

From the lidar monitoring, the cloud base height statistics was obtained. The results show that the cloud base height is dominant at around 1.5 km altitude and the cloud is detected in 90 % cases in rainy season (July and August), whereas clouds tends to be double layered with peak altitude at 1.5km and at an altitude higher than 6 km in dry season (Fig. 4).

-*Aerosol characterization by surface measurements*

From the model simulation, it is known that each aerosol has a different effect to the earth radiation budget. Light absorbing aerosols such as black carbon and soil dust aerosols have a warming effect, but other aerosols such as sea salt and sulfate aerosols show a cooling effect (Fig. 5). It is important to obtain a large scale distribution of the aerosol optical radiative properties, especially the single scattering albedo, to attain an accurate estimation of the radiative forcing of the direct effect of the anthropogenic aerosols. In February, dry season in Thailand, the effect of biomass burning was outstanding. The size distribution from the sky radiometer, showed a large optical thickness and smaller size distribution with smaller single scattering albedo than those in rainy season (Fig. 6). Chemical analysis of sampled aerosols gave a large black carbon (BC) concentration in the dry season, which is considered to be due to biomass burning. The large absorption by black carbon is reflected in the single scattering albedo as low as 0.75 in the beginning of the period, whereas the single scattering albedo started reaching 0.9 when the optical thickness becomes small in the latter period.

The radiative properties of aerosols were also monitored in the West Pacific region in a cruise of the research vessel Mirai. The latitudinal dependence of the aerosol size distribution shows that fine particles (larger Angstrom exponent) are dominant in the region to the north of 20N due to industrial sources located in the middle and high latitudes. This is also reflected in the single scattering albedo value observed by the Mirai cruise (Fig. 7). The northern area has a single scattering albedo as low as 0.8, whereas the subtropical and tropical area has a value close to the unity, indicating the effect of the black carbon is significant in the large area of the northern hemisphere.

- *Satellite remote sensing of aerosols and clouds*

An algorithm of retrieving the aerosol optical thickness and Angstrom exponent were developed (Higurashi and Nakajima, 1999) and applied to channel 1 and 2 radiance data of AVHRR (Nakajima and Higurashi, 1998; Nakajima *et al.*, 1999b; Higurashi *et al.*, 2000). It is found that the resulted characteristic distribution of small-size and large-size aerosols are consistent with model results from the aerosol transport model of Takemura *et al.* (2001) although the satellite-derived aerosol optical thickness somewhat overestimate the model values due to cloud screening problem. The model results, on the other hand, may have an error due to an uncertainty in the emission source assumption. The radiative properties of biomass burning aerosols were investigated for the Indonesian forest fire event in 1997 (Nakajima *et al.*, 1999a). The single scattering albedo shows a value around 0.9 in this Indonesian case, which is slightly larger to the Thailand biomass burning case shown in the previous subsection. This may be explained that Indonesian aerosols included sulfate particles generated from the peat bog burning.

Cloud microphysical parameters were also retrieved in this study with the solar reflection method (Kuji *et al.*, 2000; Kawamoto *et al.*, 2001). The radiative forcing of the indirect effect of anthropogenic aerosols was further estimated by Nakajima *et al.* (2001) using the correlation between aerosol and low cloud microphysical parameters derived from AVHRR remote sensing. It is found, for example, the columnar aerosol number density has a correlation with that of low clouds as ?log10 Nc $\approx$0.5 ? log10 Na. These correlations thus obtained give an estimate of the indirect forcing of anthropogenic aerosols as RF= -0.7 to -1.7 W/m^2 over ocean.

3. Future Prospect

More comparison between surface radiative flux observed at the radiation sites and satellites is required in order to reduce the uncertainty in the surface radiation budget. Model calculations of the surface radiation budget with the radiative properties of aerosols and clouds retrieved from surface and satellite measurements are also important to understand the role of clouds and aerosols to determine the radiation budget. The vertical structure of aerosol and cloud stratification observed by lidar data should be incorporated with such analysis and model calculation of the surface radiation budget, especially for the longwave radiation. From a logistic view point, we need more stable instrumentation at the existing radiation sites to generate long-term and complete data sets from all the instruments. We may need 2 to 3 more stations to cover the GAME region for the radiation studies. Development of aerosol remote sensing over land is one of high priority issues to pursue. In this regard it should be pointed out that the recent TERRA/MODIS aerosol product over land will be useful to be combined with the GMS retrieval algorithm of the surface radiation budget, because it is found that a suitable aerosol loading should be introduced in the retrieval algorithm. Data from the coming satellites, ENVISAT, AQUA, and ADEOS-II, will increase our ability for retrieving the earth and surface radiation budget as well as the global distribution of aerosol and cloud parameters (T.Y. Nakajima, 1998; King *et al.*, 2000; Kuji and Nakajima, 2001).

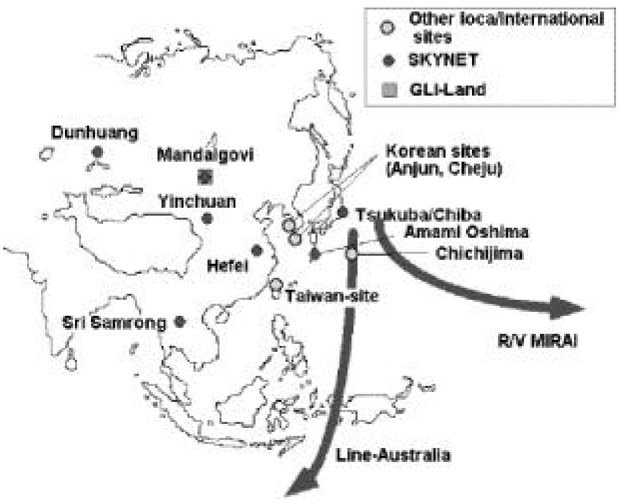


Fig. 1 Radiation observation sites.

Major publication list for the contribution to the GAME radiation studies (1998-2000)

Emori, S., T. Nozawa, A. Abe-Ouchi, A. Numaguti, M. Kimoto and T. Nakajima, 1999: *J. Meteor. Soc. Japan*, **77**, 1299-1307.

Higurashi, A., and T. Nakajima, 1999: *J. Atmos. Sci.*, **56**, 924-941.

Higurashi, A., T. Nakajima, B. N. Holben, A. Smirnov, R. Frouin, B. Chatenet, 2000: *J. Climate*, **13**, 2011-2027.

Holben, B. N., T. Nakajima, et al, 1998: *Remote Sens. Environ.*, **66**, 1-16.

Kawamoto, K., T. Nakajima, and T.Y. Nakajima, 2001: *J. Climate*, **14**, 2054-2068.

King, M. D., Y. J. Kaufman, D. Tanre, and T. Nakajima, 1999: *Bull. Amer. Meteorol. Soc.*, **80**, 2229-2259.

Kuji, M., T. Hayasaka, N. Kikuchi, T. Nakajima and M. Tanaka, 2000: *J. Appl. Meteor*., **39**, 999-1016.

Kuji, M., and T. Nakajima, 2001: *SPIE*, **4150**, 225-234.

Nakajima, T., and A. Higurashi, 1998: *Geophys. Res. Lett*., **25**, 3815-3818.

Nakajima, T., A. Higurashi, N. Takeuchi, and J. R. Harman, 1999a:. *Geophys. Res. Lett*., **26**, 2421-2424.

Nakajima, T., A. Higurashi, K. Aoki, T. Endoh, H. Fukushima, M. Toratani, Y. Mitomi, B. G.

Mitchell and R. Furuin, 1999b: *IEEE Trans. Geosci. Remote Sensing*., **37**, 1575-1585.

Nakajima, T., A. Higurashi, K. Kawamoto, and J. E. Penner, 2001: *Geophys. Res. Lett*., **28**, 1171-1174.

Nakajima, T. Y., T. Nakajima, M. Nakajima, H. Fukushima, M. Kuji, A. Uchiyama, and M. Kishino, 1998: *Appl. Opt*., **3**, 3149-3163.

Takayabu, Y.N., T. Ueno, T. Nakajima, I. Matsui, Y. Tsushima, K. Aoki, N. Sugimoto, and I. Uno, 1999: *J. Meteor. Soc. Japan*, **77**, 1007-1021.

Takemura, T., H. Okamoto, Y. Maruyama, A. Numaguti, A. Higurashi, and T. Nakajima, 2000: *J. Geophys. Res*., **105**, 17853-17873.

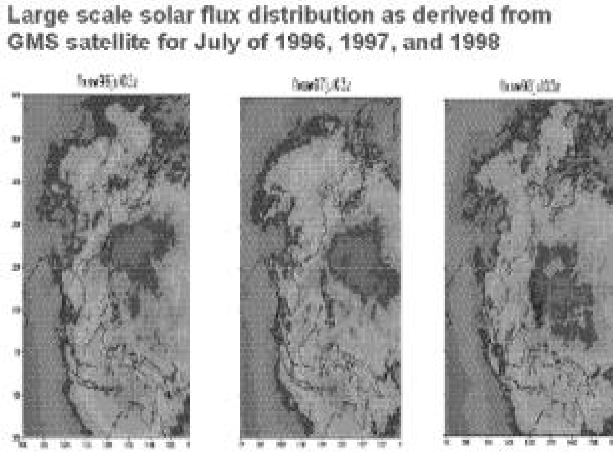


Fig. 2 Surface solar radiation was estimated from GMS data.

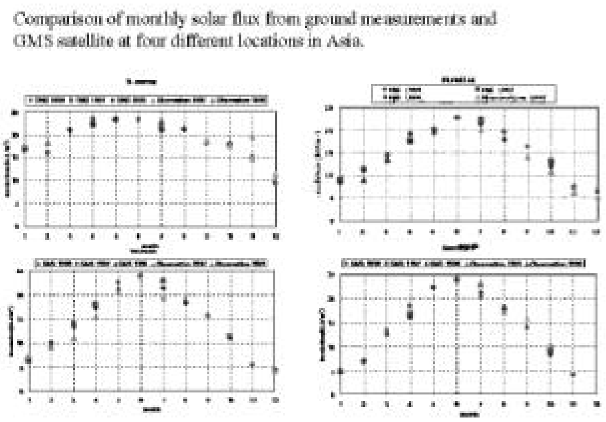


Fig. 3 Comparison of monthly solar radiation flux from the ground measurement and GMS data.

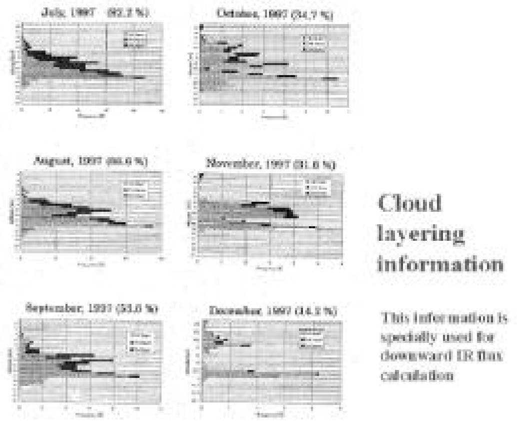


Fig. 4 Histogram of cloud height observed by lidar.

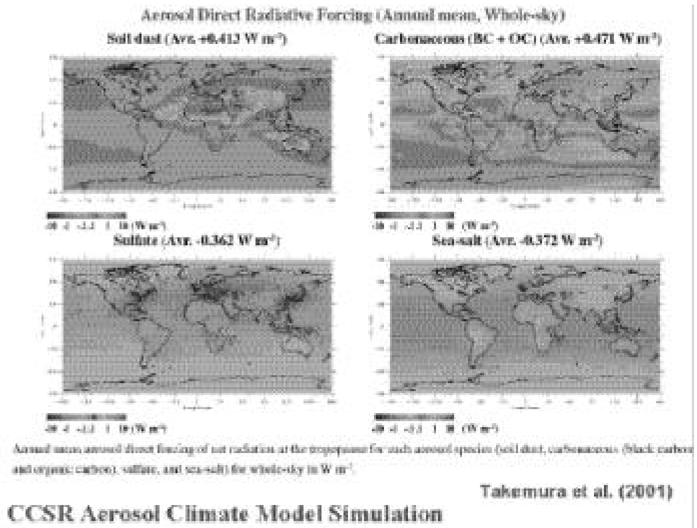


Fig. 5 Aerosol direct radiative forcing (annual mean).

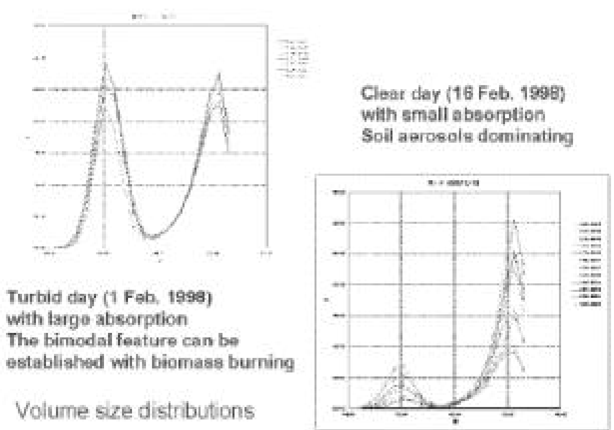


Fig. 6 Aerosol size distribution.

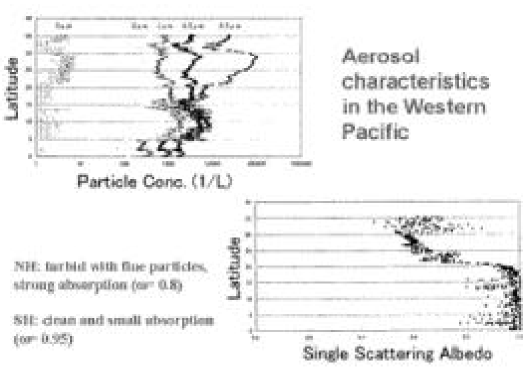


Fig. 7 Aerosol characteristics in the Western Pacific.

Summary of GAME modelling activities

1. Introduction

When the GAME was started, the objectives of the modelling component was defined as follows;

1) By conducting the flux observations in the various regions over the Asian Monsoon area, we can develop/ improve a land-atmosphere interaction scheme, which is now used in GCM.
2) By applying the improved parametarization scheme, we can improve the prediction skill of the atmospheric flow and precipitation in the Asian Monsoon region.
3) Based on the improved models described above, we can contribute to the improvement of seasonal prediction and water-resource management, and present the detailed information about the change of water cycle in the Global Warming situation

In order to achieve these objectives, the research activities were organized in the three components;

4) One dimensional study: the land-atmosphere interaction is investigated by comparing the observations conducted in the GAME IOP and the various models such as SiB2 and the bucket model.
5) Two-dimension study: the land-atmosphere interaction is investigated by using the non-hydrostatic meso-scale model such as the RAMS and the NHM developed at the NMI/JMA. Emphasis is placed on the interaction between detailed orography and convection.
6)Three-dimensional study : the land-atmosphere interaction is investigated by using the CCSR AGCM and the CCSR/NIES Climate model.

It should be noted that research relating to study 4) and 5) is conducted in the regional studies of the GAME activities and many results are described in the other sections. Here, we will briefly summarize the achievement of the modelling component.

2. One dimensional study

- Evaluation of SiB2

Takayabu(MRI/JMA) are collecting observational data from the regional experiments and making a standard data set for comparising and evaluating the one dimensional flux schemes. He compared the observed data in the Tibet by the SiB2 result.

3. Two dimensional study

- Relation between orography and convection by two-dimensional RAMS

Sataomura (2000) investigated the diurnal variation over the Indo-China Peninsula using the two-dimensional RAMS, which is a nonhydrostatic cloud-resolving numerical model. He found out that solar-synchronized life cycle of the squall lines and their eastward movement cause the nighttime maximum of the precipitation over the inland area of the Peninsula, which has been actually observed.

Kurosaki and Kimura (2001) carried out some two-dimensional numerical experiment over a cross-section over Himaraya and Tibetan Plateau (Fig.1). The model shows the clear diurnal variation of convective clouds over some dominant mountain ranges in the Plateau, which agree well with the satellite observations.

4. Three dimensional study

GCM study has been conducted by using the CCSR/ NIES GCM. As you may expect, it is impossible that the new scheme is proposed immediately after the IOP was over. Then, emphasis is placed on the understanding of the atmosphere-land interaction by using the present CCSR/NIES GCM. Regional and mesoscale modeling are also conducted using RAMS and other numerical models.

- 1997 and 1998 Asian Monsoon Study

1997 and 1998 was the El-Nino year and the influence of the El/Nino to the Indian Monsoon was investigated by Xhen and Kimoto (1999). Besides that, it was the abnormal year when the heavy rainfall occurred in the Yantzen River. This topic was investigated by using the 1998 SST. It is concluded that SST in the Indian Ocean has a strong effect on the anomouraous precipitation over the Asian region (Kimoto *et al.*, 2000).

- Sensitivity study to the horizontal resolution for the atmosphere-land interaction

Atmosphere - land Interaction Sensitivity to the horizontal resolution is now being conducted by using T42 and T106 CCSR/NIES AGCM . The simulation was stared from the April 1, 1998 and integrated until the end of August. Sensible and latent fluxes and precipitation in the two models were compared over the different regions, such as the Tibetan lateau (80-100E,27.5-35N),Thai (100-

106E,15-20N) and China (115-120E,30-35N). Over the Tibetan region, difference are about 20 W/m^2 in the monthly mean. The large differences are noted in May, which are due to the differenece of the large scale flow. In China, a large difference of precipitation is noted in June. However, difference of fluxes are about 20 W/m^2 in these areas. In order to estimate the differenecs due to the internal fluctuation of model simulation, the ensemble experiment will be conducted.

- *Sensitivity study to the land scheme for the Asian Monsoon Flow*

As it takes some time for the new scheme to appear, we decided to use the other scheme developed at other place. We has chosen the MATSHIRO, which is now being developed by the researchers in Japan. Now the MATSHIRO model is being implemented and tested. After that, simulation study will be conducted.

- *Baiu/Meiyu Front and heat contrast between Asian continent and Ocean*

Yoshikane *et al.* (2000) clarified one of the formation mechanism of the Baiu Front. By a regional climate model, they showed that one of the most important mechanism of the Baiu Front is the heating contrast between land and ocean. The Baiu Front can be formed only by the interaction between global scale zonal mean flow and the contrast between them. Surface moisture of the Asian continent may affect the position and intensity of the Baiu Front.

- *Hydrological and Atmospheric Modeling Studies in HUBEX*

The modeling study of HUBEX (the Huaihe River Basin Experiment) includes hydrological and meteorological modelings. In particular, their coupling and water cycle modeling experiment using a coupled model are most important objectives of HUBEX. In the hydrological modeling, SiBUC (the Simple Biosphere Model including Urban Canopy) has been progressed in Kyoto University. A coupling experiment of SiBUC with a mesoscale atmospheric model was performed. To simulate movement of ground water, a runoff model also has developed. Simulation experiment of water discharge using the runoff model showed good an agreement between simulated and observed runoffs.

In the meteorological modeling study, a mesoscale simulation using JSM (the Japan Spectral Model) which was developed by the Japan Meteorological Agency has been performed to study a regional water cycle and precipitation.

Cloud and precipitation studies are the most important objectives in HUBEX. In order to study dynamics and evolution of convective clouds over the China continent, we now develop the Cloud Resolving Storm Simulator (CReSS). We performed the simulation experiment of the observed squall line using CReSS with very high resolution in a large three-dimensional domain. The inhomogeneous initial field was given by the dual Doppler radar observation and the sounding. The experimental design is as follows. The horizontal and vertical grid sizes were 300 m and 300 m, respectively with a domain of 170 km × 120 km. Cloud microphysics was the cold rain type. The boundary condition was the wave-radiating type. The result of the simulation experiment shows that CReSS successfully simulated the development and movement of the squall line (Fig.2). The convective reading edge was maintained by the replacement of new convective cells and the simulated squall line moved to the northeast which is similar to the behavior of the observed squall line. Convective cells reached to a height of about 14 km with large production of graupel above the melting layer. The rear inflow was significant as the observation. A stratiform region extended with time behind the leading edge. Cloud extended to the southwest to form a cloud cluster.

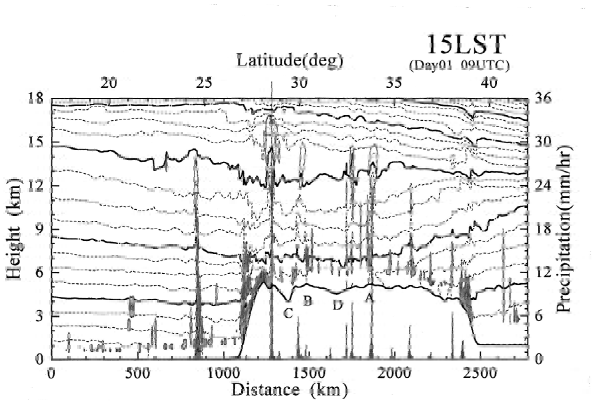


Fig. 1 Vertical cross-section of potential temperatur (broken lines), liquid/ice water content (thin lines) and precipitation (bars) at 1500 LST over Himaraya and Tibetan Plateau, simulated by the two-dimensional RAMS. Grid interval is 2 km.

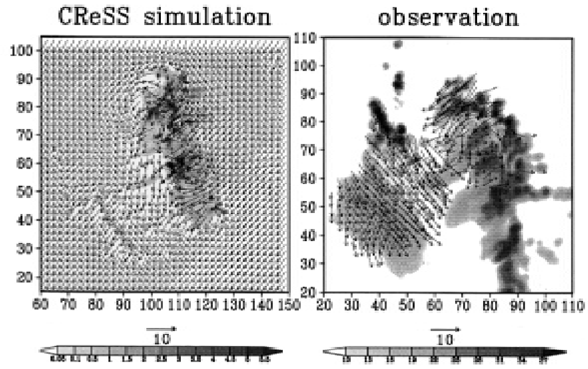


Fig. 2. Horizontal displays of the simulated squall line (left panel) and the observed squall line (right panel) at 1204UTC, 16 July 1998. Gray levels indicate total mixing ratio (g/kg) of rain, snow and graupel in the left and radar reflectivity (dBZ) in the right. Arrows are horizontal velocity.

Report on the GAIN activity

Kiyotoshi Takahashi (MRI)

GAIN is an abbreviation of Game Archive & Information Network. Its function is divided into two parts, that is, establishment of the GAME data management policy and construction of the system that disseminates GAME data and information.

The first work as GAIN was to work out the GAME data management policy. GAME is an international research project, so international cooperation is crucial for its success. The data policy is the base of such an international cooperation, and gives the guideline for various aspect concerning the GAME data, for example, definition of the GAME data and basic strategy of data provision, and so on. The original draft of the data policy was prepared mainly by the late Dr. M. Murakami, and was proposed in the 2nd GAME International Science Panel for the first time. Finally this GAME data policy was adopted at the 3rd GISP in January 1998 just before the GAME IOP(Intensive Observation Period).

One of an important matter in this data policy is the time schedule of the GAME data release to the international research communites. We finally reached the following agreement.

Data obtained as part of the observations during the IOP will be made available according to the following schedule.

1) By the end of June 1999 (6 months after the IOP), for the participating institutes and scientists.
2) By the end of June 2000 (one year later), for the international research community.

Data obtained as part of the GAME observations during the non-IOP will be made available according to the following schedule.

3) By the end of one year after the observation, for the participating institutes and scientists.
4) By the end of two years after the observation, for the international research community.

At present (April 2001), the GAME data basically have been open to the international research communities after June 2000 according to the above-mentioned agreement. But it is delayed for the HUBEX data and some part of data concerning the Tibetan plateau (TIPEX, JEXAM) to be open due to their local data policies. However they are also going to be open until the summer of 2001, three years after their observation.

In addition, recently we requested supplementary data (surface station data) mainly to the southeast asian countries to use the validation of the GAME Reanalysis data. Some countries kindly provided us the data in response to our request.

Next, we will move onto the second function of GAIN. In the data policy main means for data provision is planned to be the online access via Internet, and each sub-project group is requested to have his own responsibility in data provision.

The GAIN system is composed of GAIN-hub and GAIN-DAACs as shown in Fig. 1. The function of the GAIN-hub is to offer catalogue information for GAME data and some selected data, mainly GAME-reanalysis data. Presently most of sub-groups have started to operate ftp or web sites for data dissemination since the summer of 2000. Everyone who is interested in the GAME data can obtain data and information by starting from this gain-hub (http://gain-hub.mri-jma.go.jp).

Besides the online provision, CD-ROMs were also produced especially for GAME-Tibet and GAME-reanalysis, and distributed in the world. Now it is planned to produce CD-ROMs for other GAME data resources because CD-ROMs are very useful in the case that the online access is unavailable.

As mentioned in the above, the GAIN system is almost successfully being operated. However all GAME data haven't yet been accessible. We need to complete the GAIN system in a hurry as soon as possible.

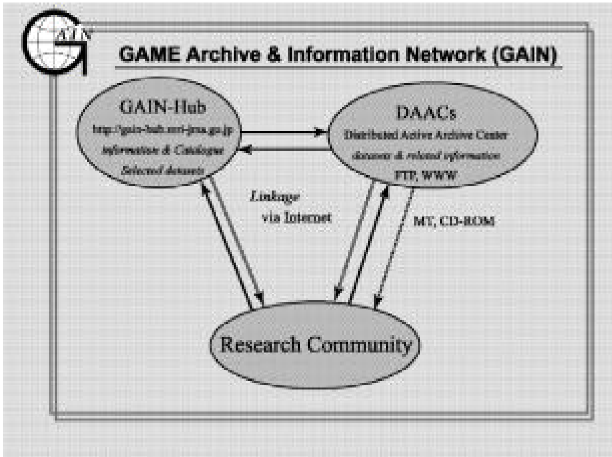


Fig. 1 GAIN system

Toward GAME Synthesis

Tetsuzo Yasunari

Institute of Geoscience, University of Tsukuba, and

Frontier Research System for Global Change

1. Introduction

Nearly five years have passed since GAME started in 1996. The regional experiments on energy and water cycle processes have been conducted in Thailand (GAME-Tropics), in the Huai-he river basin in China (GAME-Hubex), in the Tibetan Plateau (GAME-Tibet) and in the Lena river basin in Siberia (GAME-Siberia). The long-term radiation and energy fluxes in various sites of the monsoon Asian region have been operated by the automatic weather stations (AWS) as the Asian AWS Network (GAME-AAN).

In 1998, we conducted the Intensive Observing Period (IOP) in cooperation with many Asian countries and the international/national projects such as South China Sea Monsoon Experiment (SCSMEX), Chinese Tibetan Plateau Experiment (TIPEX) and Korean Monsoon Experiment (KORMEX). The enhanced radiosonde observations, as well as surface hydrometeorological observations, were operated at more than hundred stations in the monsoon Asian countries. We conducted the 4-dimensional data assimilation (4DDA) of the atmospheric field over the whole monsoon Asia, and the first version of this reanalysis data have been released as version 1 of GAME-reanalysis. Some scientific results, particularly from GAME-Tropics and GAME-Tibet were reported in the special issue of Journal of the Meteorological Society of Japan (Yasunari, ed., 2001).

These data obtained through the regional experiments, AAN, including the reanalysis data for the IOP have been compiled and archived as part of GAME Information and Archive Network (GAIN). Some data are being released to the international science community under the data policy of World Meteorological Organization (WMO).

As documented in the GAME Letters (No. 3 and this letter), we have obtained various new scientific results on the hydro-meteorological processes in the Asian monsoon region from the Tropics to the Siberian Arctic region. Particularly, the land-atmosphere interaction processes in some typical climate and vegetation in monsoon Asia have been revealed in diurnal through seasonal time scales. Cloud and precipitation processes have also been scrutinized in the tropical region, the Meiyu-Baiu frontal zone in the subtropical China and on the Tibetan Plateau area.

What we have to do now and from now is to synthesize these scientific results to reach the final goals and objectives of GAME (GAME International Science Panel, 1998). The fifth session of the GAME International Science Panel (GISP) held in June, 2000 in Tokyo proposed the GAME Phase-II for further research, including data analysis, some additional process studies and modeling needed for the synthesis of the overall GAME objectives. Here, I would like to briefly comment on some key issues for the synthesis of GAME.

2. Large-scale land-atmosphere interaction and regional/continental-scale climate

Energy and water cycle processes in various plot-scale and meso-scale regions have been revealed in the diurnal to seasonal time scales. In some areas, year-to-year variability has also been obtained. An important issue, as a next step, may be how to scale-up or integrate these surface processes in a small area to larger-scale processes in the atmosphere. The IOP of GAME-Siberia in the spring/summer of 2000 conducted the aircraft measurement of heat and CO_2 fluxes over the meso-scale region near Yakutsk. These data will help us to understand the time-space structure of the atmospheric boundary layer in terms of the land surface energy and water fluxes. The comparison and validation of surface fluxes in the models and observations are also being conducted, from the viewpoint of scaling-up and down. In this respect, GAME will contribute to modeling activity of the GEWEX Atmospheric Boundary Layer Study (GABLS), which is a new initiative of the GEWEX Modeling and Prediction Panel.

3. Cloud and precipitation processes and large-scale monsoon circulation

Another key issue for the energy and water cycle of monsoon Asia is cloud and precipitation processes and its interaction with large-scale atmospheric circulation. In the GAME region, the interaction with the monsoon circulation, including the influence of surface topography and vegetation is the most important process. As part of GAME-Hubex and GAME-Tibet, the intensive observation of the 3-dimensional cloud/precipitating systems were observed by using the Doppler-radar systems, with the enhanced radiosonde observations. The interaction between the meso-scale cloud/precipitation systems and the large-scale monsoon circulation are being investigated combining the objectively analyzed reanalysis data. The regional 4DDA analysis for the Hubex region is planned for the detailed interactive processes between the meso-scale cloud systems and the ambient monsoon and westerly flow regimes.

Another issue may be the interaction between the cloud/precipitation system and the land surface conditions, including topography and land use/land cover conditions. One important problem we have noticed may the important role of water-fed rice paddy field, which is a typical land surface condition in monsoon Asia, in the development and/or modifying the precipitation systems. The observational as well as model-based evidences of this aspect have been suggested in the tropical (GAME-Tropics) and sub-tropical (GAME-Hubex) region. The large-scale and regional-scale topography is also a key factor controlling the precipitation system in the monsoon region. The observational as well as modeling studies in the tropics (GAME-Tropics) and in the Tibetan Plateau (GAME-Tibet) have presented some interesting processes in the diurnal as well as in the synoptic-scale. The regional model studies are essential for these problems, including improvement of land-surface schemes and the atmospheric boundary layer processes based on the GAME data sets.

4. Key processes related to the interannual variability of the Asian monsoon

GAME has focused the interaction and feedback processes between land and atmosphere. In fact, the observational results of the regional experiments have revealed some important processes on the land-atmosphere interaction, including the roles of snow cover, soil moisture and vegetation. For example, the regional and continental-scale vegetation, such as tropical monsoon forest in southeast Asia, and the boreal forest in east Siberia, have been suggested to play an important role in controlling seasonal surface energy and water balance. This role of vegetation, in turn, modifies the seasonal cycle of the climate and atmospheric circulation. Some model experiments also have strongly suggested these processes.

GAME data sets include the full seasonal data of two or three years since 1997. Particularly, the data of 1998, the IOP year, can be compared, in many aspects, with those of 1999, when the secondary IOP was conducted in GAME-Tropics and GAME-Hubex region. The anomalies of the overall monsoon circulation and precipitation between these two years are well contrastive, so that the inter-comparison of the processes related to the monsoon activity in each region seems to be very beneficial for understanding the interannual variability of the Asian monsoon.

To fully understand the seasonal cycle and interannual variation of the Asian monsoon, we need to include the large-scale atmosphere-ocean processes and their interaction with land surface processes. GAME modeling activity includes these processes using atmospheric GCMs and coupled atmosphere-ocean GCMs. However, almost all the current GCMs have very large systematic errors in simulating the mean monsoon climate and circulation (Kang *et al.*, 2001). For example, the simulated monsoon precipitation on land, particularly near the coast in south and southeast Asia tend to be far larger than the observation, whereas that over the warm pool region in the western Pacific tend to be smaller compared to the observation. These defects in GCMs both in the seasonal cycle and spatial distribution need to overcome by improving land-atmosphere as well as ocean-atmosphere processes. The forthcoming CEOP (Coordinated Enhanced Observing Period) under World Climate Research Programme (WCRP) to be held in 2001 to 2003 will provide us a good opportunity for providing sufficient data for further understanding the Asian monsoon with its interannual variability.

References

GAME International Science Panel, 1998: GEWEX Asian Monsoon Experiment (GAME) Implementation Plan. pp. 136.

Kang, I.-S., et al., 2001: *J. Climate*, submitted.

Yasunari, T. et al., ed.,2001: Special issue, GEWEX Asian Monsoon Experiment (GAME), *J. Meteor. Soc. Japan*, **79**B, 241-605.

KEOP as a KORMEX Follow – on

Jai–Ho Oh and Baek-Jo Kim

Meteorological Research Institute, KMA , Seoul , Korea

jho@metri.re.kr

The Korea Enhanced Observing Period (KEOP) from January 2001 through December 2005 is planned under the Korean Monsoon Experiment (KORMEX) Programme. KORMEX was conducted in collaboration with the GEWEX Asia Monsoon Experiment (GAME), the South China Sea Monsoon Experiment (SCSMEX), and the Huaihe River Basin Experiment (HUBEX). The prime scientific objective is to improve the skills in prediction of severe weather systems in summer such as typhoons and heavy rainfall events associated with the Changma (rainy season in Korea) front. These weather systems account for more than 70 percent of the natural disasters over Korea. Needless to say that for better prediction 3–dimensional atmosphere / ocean / land intensive observations are needed. The sparse observational network over the oceans causes low predictive skills of the mesoscale severe weather phenomena. Hence the main goal of KEOP is to develop continuous 3–dimensional observational system based on remote meteorological monitoring network. This will result in generation of high–resolution observational data needed for the initialization of typhoon track prediction models.

Keeping the above in view intensive field–based experiments will be implemented during the period for 2001-2003 consisting of the observational systems as follows :

1) Short–term surface and upper–air observations during IOP
- Aerosonde , Autosonde and Radiosonde Observations
- Radar and/or Dual Doppler – Radar Observations
- Operational Satellite Observations
- Drifting Buoy Observations

2) Long–term monitoring
- Radiation
- Land – surface heat/water fluxes
- Sea – surface heat/water fluxes

A KEOP Data Centre will be established with the main aim of collecting, compiling, scrutinizing and managing the observational data collected. Besides the field–based experiments and the KEOP Data Centre, this programme also envisages application studies such as investigating the structure and intensity of typhoons, their track prediction, mesoscale and marine meteorological modelling. All these efforts will need collaboration with international projects (e.g., CAMP, ARGO) and co-operation with Japan and China for data from their neighbourhood . It is hoped that this programme will lead to improvement of typhoon prediction (track and intensity) , improvement in long range prediction, better prediction capability of Changma and lead to data exchange between CEOP and KEOP.

Dr. Jai-Ho Oh, Dr. Won-Tae Kwon and Dr. Baek-Jo Kim are the Project Leader, Data Manager and the Secretary respectively of the KEOP Project. More details on this project are available on the website:

http://www.metri.re.kr/monsoon/keop.html

Figure: An outline of the KEOP Project

The Sixth GAME International Science Panel Meeting and The Fifth International Study Conference on GEWEX in Asia and GAME

Kenji Nakamura
Hydrospheric Atmospheric Research Center, Nagoya University, Japan

The Sixth GAME International Science Panel meeting (GISP) was held at the Aichi Trade Center, Nagoya, Japan for 1 and 2 October, 2001 under the auspices of Ministry of Education, Culture, Sports, Science and Technology (MEXT), World Climate Research Programme (WCRP), National Space Development Agency of Japan (NASDA), Center for Climate System Research (CCSR) in the university of Tokyo, and Hydrospheric Atmospheric Research Center (HyARC) in Nagoya University. Total 59 participants including observers/experts from 13 countries joined.

The main subject of this GISP was the future plan for the GAME. According to the last (the fifth) GISP agreement that the GAME should continue for a few more years to accomplish the GAME objectives after reviews of the current GAME results, Dr. R. Lawford and Prof. T.-C. Chen presented their reviews. Generally speaking their reviews are very positive. They, however, pointed out that we need more efforts on cross cutting issues and synthesis of data towards the monsoon system understanding. According to the reviews, the GAME Phase-II was approved. (The current result reports appear in the GAME Letters in No. 3 and this one)

To deal with the issues pointed out in the reviews, considering that (1) objective of GISP changes from coordination, implementation and data distribution policy, to synthesis and analysis of data, data distribution, model study for the original GAME objectives, and (2) some regional study groups have already accomplished the observations, re-organization of GISP was proposed. The re-organization includes establishment of advisory board and new working groups. The new working groups will discuss Water and Energy Balance Study(WEBS; under GHP), land surface processes/ABL/AAN, precipitation processes, monsoon system study (analysis /diagnostic study), monsoon system modeling, re-analysis, satellite utilization, GAIN, GAME-Siberia, and Water Resources Application Project(WRAP; under GHP). The new memberships include chairpersons of working groups and reduced number of country representatives with liaisons to WCRP and CEOP. The proposal was adopted though details such as the number of membership were remained to be determined.

The follow on of GAME was another issue. Coordinated Enhanced Observing Period (CEOP) was the focus of the discussion. Considering that CEOP is a big new project, GISP agreed that CEOP or CEOP/CAMP international science panel should be separated from GISP.

Following the GISP meeting, the Fifth International Study Conference on GEWEX in Asia and GAME was held at the same location for 3-5 October, 2001. About 190 participants from 15 countries joined this conference. The presentations were oral and posters and three volume proceedings were delivered at the conference.

GAME Letter
Published by the GAME International Project Office
Prof. Kenji Nakamura, Director
Editors: Dr. Atsushi Higuchi, Ms. Tomoko Tanaka, and Ms. Yuri Tanaka
Hydrospheric Atmospheric Research Center
Nagoya University
Furocho, Chikusaku, Nagoya 464-8601, Japan
Phone: +81-52-789-5439, Fax: +81-52-789-3436
E-mail: gio@ihas.nagoya-u.ac.jp, URL: http://www.ihas.nagoya-u.ac.jp/game/index.html