3.4 GAME/Tibet

3.4.1. Scientific goals

The energy and water cycles over the Tibetan Plateau play an important role in the Asian monsoon system, which in turn is a major component of both the energy and water cycles of the global climate system. The Tibetan Plateau contains the world's highest elevation relief features, some reaching into the mid-troposphere, and representing an extensive massif extending from sub-tropical to middle latitudes and spanning over 25 degrees of longitude. Due to its topographic character, the plateau surface absorbs a large amount of solar radiation energy (much of which is redistributed by cryospheric processes), and undergoes dramatic seasonal changes of surface heat and water fluxes (Ye and Gao, 1979).

Although the diurnal to seasonal variations and spatial distribution of atmospheric heating were clarified to some extent, based on data from the Qinghai-Xizang Plateau Meteorological Experiment (QXPMEX) in 1979 (Chen et al., 1985; Feng et al.; 1985, Zhu and Fan, 1988; Yanai and Li, 1994), a more exact evaluation of heating and its association with land-atmosphere interactions over the plateau has yet to be investigated. The lack of quantitative understanding of interactions between the land surface and atmosphere makes it difficult to understand the complete energy and water cycles over the Tibetan Plateau and their effects on the Asian monsoon system by numerical models (Webster et al., 1997). Therefore, due to the heterogeneous nature of the land surface and the differential climate features of the plateau (Shi and Smith, 1992), and given the relatively few ground-based observational stations deployed over the plateau, a plateau-scale monitoring system should be developed and validated.

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 expressed as follows:

Objective 1: To improve the quantitative understanding of land-atmosphere interactions over the Tibetan Plateau.

To do so, the following processes will be investigated:

(a) Seasonal variations of radiative energy, heat, and water exchanges at the land surface -atmosphere interface and their spatial distributions, both at the plateau-scale and the mesoscale.

Land surface processes on the Tibetan Plateau are multifold and complicated. Due to the highly complex terrain, wintertime conditions are characterized by irregular snow cover with extensive areas of frozen ground holding large quantities of moisture in the surface layers. Seasonal freezing and melting processes and their spatial distribution lead to time-space variations of surface wetness and to variations of the surface heat balance. Such variations have profound implications for follow-up monsoon behavior and global climate processes (Barnett et al., 1989), (Vernekar et al., 1995, and Yasunari et al., 1991). During the cold season, the frozen surface does not release much water vapor and the plateau acts as an overall heat sink for the atmosphere. Once spring commences, the plateau becomes a heat source through sensible heat tranfer to the atmosphere (Ye and Gao, 1979). By summer, the release of latent heat by monsoon rains becomes significant (Yanai et al., 1992), aided by latent heat transfer from the surface in the wet areas (Smith and Shi, 1992). This is more apparent in the eastern and southern parts of the plateau than in the western and northern parts where the climate is drier, even in summer (Flohn, 1968; Luo and Yanai, 1983, 1984; Nitta, 1983). In addition to these plateau-scale features, the spatial distribution of surface wetness at the mesoscale is also noteworthy, and is considered to play an important role in local circulations of heat and moisture (Avissar and Pielke, 1989 for background on this topic).

(b) Diurnal-seasonal variations of the one-dimensional structure of the PBL, its spatial distribution at the plateau-scale, and the two-and three-dimensional structures at the mesoscale.

Surface fluxes of heat and water vapor are transported to the free atmosphere through the planetary boundary layer (PBL). The diurnal variation of the PBL is characterized by the development of an elevated mixing layer (ML) during the daytime and the return to a nocturnal surface inversion once surface heating diminishes (Luo and Yanai, 1984; Yanai and Li, 1994). Upward water vapor transport extends to the top of the ML leading to boundary layer clouds capping the ML. The associated latent heat release is an important diabatic heating mechanism at the top of the PBL, while sensible heat flux from the surface is consumed by the lower PBL layers as the heating source for building the depth of the ML. At night, radiative cooling acts as a major negative heat source during and after the disappearance of the ML. Notably, this process is modulated by atmospheric humidity. For example, according to a preliminary experiment held during CREQ-93, large water vapor mixing ratios found near the surface at night suppressed radiative cooling in the lower layers of the PBL which led to a weaker nocturnal surface inversions.

In addition to the diurnal variation of the PBL, the seasonal march of the PBL structure and its spatial distribution at the plateau-scale associated with the variation of land surface processes are also important issues (e.g., Smith et al., 1986). The latter can lead to horizontal gradients of the temperature field which maintain baroclinic development of atmospheric circulations. In such situations, horizontal advection (primarily by westerly winds) can contribute significantly to the evolving dynamics. The effect of horizontal advection on PBL structures at the mesoscale is also an important process that deserves more attention.

(c) Radiation and cloudiness over the plateau.

The elevated portion of the plateau is approximately 5,000 msl, playing an important role in governing planetary-scale atmospheric circulations, particularly during the warm season (Krishnamurti, 1985; Murakami, 1987a). This is mostly accomplished through radiative transfer and internal energy budget processes in the land surface-atmosphere system heating or cooling the plateau surface.

Surface solar radiation is extremely intense in the pre-monsoon and monsoon seasons, due to small shortwave optical thicknesses of the atmosphere and the relatively low-latitude position of the plateau (Zhou, 1987). Recent observational studies have noted the important role of elevated surface skin temperatures of the plateau surface (produced by the strong insolation) on the net longwave radiation fluxes in the planetary boundary layer. The high skin temperatures are not only responsible for strong sensible heating near the surface, but at the same time cause significant reduction of longwave radiative divergence of the lower troposphere, even producing net infrared radiative convergence at certain times of the day (Smith and Shi, 1992). In addition, as noted, recent observations have indicated the formation of a low level moist layer (~500-400 hPa) at night, which can lead to significant changes in the net longwave radiation divergence profile. Therefore, it is evident that the radiation and energy budgets of the plateau atmosphere are controlled by temperature-moisture conditions at the surface.

Cloudiness also has a major impact on atmospheric radiative heating and cooling (e.g., Mehta and Smith, 1997). Cloud radiative forcing over the plateau appears to be negative, although through a process which is spectrally reversed from the negative cloud feedback mechanism found to occur over sea level type environments (Smith and Shi, 1995). Different cloud types and amount strongly affect the intensity of shortwave radiation through multiple scattering and reflection between cloud bases and high-albedo surfaces (e.g., snow cover). Very recently, high level cloudiness possibly of the stratus type, has been noted to occur over the dry western plateau in May. This may be a crucial factor in determining the radiation balance of this area, since it is during this month that solar insolation reaches its maximum over the annual cycle.

(d) Water vapor transport and water cycle over and around the plateau.

Although much of the Tibetan plateau exceeds an altitude of 4,000 msl, deep cumulus convection and the associated release of latent heat is very prevalent during the monsoon season (He et al., 1987). Furthermore, the space-time variations of convection and latent heating are large both seasonally and intra-seasonally. In the pre-monsoon season, cloud formation is very frequent in the western plateau, while convective activity during the monsoon season is concentrated in the eastern and southern half of the plateau (Yanai and Li, 1994).

A key problem concerns how water vapor is transported to and/or is supplied to the high plateau region. Recent observational studies have noted a very moist layer near the surface of the plateau occurring during the monsoon season, particularly at night. This feature appears to play an important role on diurnal convective activity as well as the radiation balance over the plateau, although the mechanism for producing this feature has not yet been explained.

One essential process is water vapor transport into the plateau from surrounding areas, particularly through the southeastern periphery (Luo and Yanai, 1983). This is accomplished by means of the thermally-induced plateau-scale circulation containing diurnal to seasonal scales. In the process, the nature of the underlying multi-scale interactions between orographically-induced local convection and mesoscale flows and the plateau-scale monsoon circulation, remains as an important and unresolved problem. The role of the diurnal circulation on the mean transport of water vapor into the plateau is also an interesting and unsolved problem.

The other important moistening process is in-situ water vapor transfer from the plateau surface itself. This process includes melting of snow cover and permafrost, evaporation, and water recycling through precipitation-evaporation. The nature of this process changes from period to period during the course of an annual cycle. In the pre-monsoon phase, this process is important for building up monsoon-onset conditions. During the middle phase of the monsoon, this process then contributes to the maintenance of the monsoon circulation over the plateau.

The origin of water vapor, its trajectories, and the quantitative water vapor transports through these two processes and their interactions, represent challenging problems to be solved through intensive observational and modeling studies.

(e) Spatial and temporal variation of precipitation and mesoscale/synoptic-scale disturbances over the plateau.

Large scale disturbances over the Tibetan Plateau, analogous to the so-called "synoptic scale disturbances" in the mid-latitudes, have been categorized as westerly disturbances in non-monsoon periods and thermal depressions during the monsoon season. On the other hand, rainfall is generated by precipitation cells with a spatial scale of the order of several tens of km, embedded within mesoscale disturbances, all of which are organized within the synoptic-scale convection field (Liu et al., 1996). Strong radiative forcing and large diurnal variations of the precipitating cloud systems suggest that water vapor not only intrudes from regions outside the plateau, but is also generated through water recycling within the plateau.

GAME-Tibet aims to understand the structure of precipitating clouds associated with mesoscale disturbances by a Doppler-radar system. Three-dimensional Doppler data combined with intensive aerological data, can be used to directly observe the microphysical development of precipitating systems affected by thermal and orographic effects and the accompanying monsoon circulations. Satellite measurements can also be used to help evaluate the representativeness of observation points in the synoptic field. Systematic intensive observations are planned several times during the pre-monsoon and monsoon periods to compare seasonal changes in the structure of precipitating systems.

Precipitation amount determines total latent heat release and the nature of the surface water budget. In GAME-Tibet, effective estimation methods of areal-mean rainfall will be carried out by combining measurements from the plateau-wide rain gauge network with remotely sensed rain estimates from the radar and satellites.

Objective 2: To develop process models and methods for applying them over large spatial scales.

Field observations of important processes under a wide range of meteorological, hydrological, and ecological conditions motivate the development and testing of key process models describing flux exchange at the surface-atmosphere interface, boundary layer flux profiles, radiative transfer, and cloud formation. Mesoscale meteorological studies combined with hydrological analysis will allow scaling up and application of the process models at the plateau scale and ultimately the global scale. The following three modeling studies will be conducted:

(a) One-dimensional modeling of land-atmosphere interactions

One-dimensional land surface models that describe the exchanges of radiation, heat, and moisture, as well as the infiltration, storage, and discharge of water will be developed and improved based on quantitative understanding of detailed land surface processes revealed by the acquired data. These models will include the effects of snow cover and frozen ground, which are characterized by large seasonal variation and long retention of water.

(b) Two- and three-dimensional mesoscale modeling of land-atmosphere interaction

To clarify the mesoscale energy and water cycles over the plateau, and to estimate the areal-mean energy and moisture fluxes, mesoscale atmospheric models will be coupled with a distributed hydrological model (which will include one-dimensional land surface and runoff process models). Two kinds of regional atmospheric models can be used for this study. The first is a simple two-dimensional model equipped with radiation, boundary layer turbulence, surface, and soil parameterizations. The second is a three-dimensional regional model with full physics parameterizations.

(c) Development of methods for scaling up land surface process models

The grid sizes of GCM's are too coarse to express the inherent heterogeneities found in land surface hydrological processes. To better understand the role of such processes over the Tibetan Plateau on the Asian monsoon system quantitatively, it is first important to develop methods for scaling up the land surface process models to the GCM grid size. This is accomplished by taking into account the effects of sub-grid scale variations on the grid scale values. The insitu measurements and satellite data will provide data sets to address the issue of spatial variability in land surface properties at horizontal scales ranging from 1 km (a possible resolution for distributed hydrological models) to 100 km (the size of several GCM grid boxes). The scale-up methods will be validated by the areal-mean energy and moisture fluxes derived from the coupled mesoscale atmospheric-hydrological coupled models described above.

In GAME-Tibet, limited-area models will be used to both estimate areal-mean heat-moisture fluxes and to clarify the mesoscale energy and water cycles over the plateau. In this context, the following eight studies will be conducted:

(1) Parameterization of heat fluxes from the surface of the plateau by coupled process models equipped with a one-dimensional soil layer model, a vegetation model, and a surface boundary layer model.
(2) Investigation of: (a) the relationship between the structure of the planetary boundary layer and surface heat fluxes; and (b) methods for calculating the effects of an inhomogeneous surface with complex topography on the atmospheric heat budget.
(3) Estimation of surface parameters from satellite data (e.g., vegetation indices, snow cover, soil wetness, skin temperature, albedo, radiation-heat-moisture fluxes).
(4) Investigation of the relationships between the diurnal variation of local winds and atmospheric water vapor, cloud amount, and precipitation.
(5) Clarification of moisture exchange between the plateau and its surrounding areas.

(6) Estimation of atmospheric heating by sensible heat flux and condensation processes over the plateau.
(7) Investigation of radiation and cloudiness properties in the plateau atmosphere.
(8) Long-term simulations using a limited-area model incorporating hydrology.

Study 5 is especially important for the GAME-Tibet project. This study intends to clarify the amount of moisture supplied from south of the plateau through Bengal and India, over the Himalayan mountain range, and from Central Asia by upper level westerlies. The latter source is related to the large scale circulation of the northern hemisphere, whereas the former two sources would be expected to be more related to the mechanical and thermal effects of topography as well as convection activity in the southern region. One of the important thermal effects of topography is its influence on the formation of heat lows over the plateau.

Since Tibet is the world's greatest mountain region, understanding the effects of its topography is a fundamental problem in the atmospheric sciences (Murakami, 1987b; Broccoli and Manabe, 1992; Endo et al., 1994). Numerical studies using comprehensive mesoscale models aim at understanding the effects of moisture and convection in India and Bengal, the thermal and mechanical effects of the Himalayas, the effects of cloud systems and cloud-radiative forcing over the plateau, sensible heat flux and condensation heating over the plateau, diurnal variations of the boundary layer and heat low formation, effects of the seasonal evolution of the soil moisture field over both the plateau and surrounding areas, and the system feedbacks involving all of these processes.

Objective 3: To develop and validate satellite-based retrieval methods

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-time sampling over the complete plateau are only possible by satellite remote sensing. In turn, the field observations and process studies help serve as sources of ground-truth information for satellite-based retrieval algorithms. To meet the objectives of the process and modeling studies discussed above, GAME-Tibet will focus on the development and validation of satellite algorithms for the following parameters:

(a) Precipitation

In November, 1997, the Tropical Rainfall Measuring Mission (TRMM) satellite was launched as a joint U.S.-Japan project, carrying the first rain radar into space. TRMM retrievals started to provide three-dimensional precipitation structures of atmospheric disturbances (with some degree of diurnal variability) over the southern half of the plateau region. Note that TRMM is a non-sun-synchronous low-flying satellite in a 35 degree inclination orbit. For GAME-Tibet, intensive surface radar observations at the Doppler radar site, synchronized with TRMM overflights, are planned for verification of the TRMM-derived three-dimensional precipitation structures. Structures of precipitation systems can then be acquired over the remainder of the plateau covered by the TRMM orbits, from the TRMM retrievals. These retrievals will provide essential information for understanding precipitation physics over the plateau. Both surface and satellite radar observations of the various types of precipitating clouds over the plateau, can also be used to help to formulate simple algorithms for estimation of rain-cover and rain rate from time sequenced thermal infrared temperatures available from geostationary satellite imagery. Therefore, acquisition of GMS, FY-2, and INSAT geostationary data will be very useful for estimating the detailed diurnal properties of rainfall over the plateau.

(b) Radiation budget

To evaluate radiative heating-cooling of the atmosphere over the Tibetan Plateau, the radiation budget should be measured both at the top-of-atmosphere and at the surface. The radiation budget at the top-of-atmosphere can be obtained by using NOAA AVHRR and GMS VISSR data, combined with data from the International Satellite Cloud Climatology Project (ISCCP). There is a difficulty associated with estimating the surface infrared fluxes because of the great difficulty in estimating the heights of cloud bases. Therefore, statistics of cloud-base heights obtained from ad hoc lidar observations are very useful in this regard, and would help improve satellite algorithms needed for closing the complete surface radiation budget.

(c) Soil moisture

Area-wide means and variances of soil moisture at the mesoscale are essential for understanding land surface-atmosphere interaction processes. Brightness temperatures at 19 and 37 GHz measured by SSM/I can identify very wet areas and their seasonal variation at a scale of several tens of kilometers. A time series of JERS-1 SAR data from winter to summer shows the possibility of monitoring surface wetness at fine spatial resolution by using surface roughness measurements and a microwave backscattering model. Development of a combined algorithm for retrieving area-wide means and variances of surface wetness at the mesoscale based on passive microwave instruments onboard the DMSP, TRMM, and ADEOS-2 satellites, as well as synthetic aperture radars on JERS-1, EERS-2, RADARSAT, and ENVISAT satellites, can be accomplished given field measurements of the spatial distribution of soil moisture at the mesoscale. Therefore, passive and active microwave remote sensing presents an effective basis for monitoring the space-time distributions of the hydrological state of frozen soil.

(d) Snow water equivalent

For the dry snow case, snow water equivalent can be estimated using SSM/I brightness temperatures at 19 and 37 GHz by assuming several snow parameters. Furthermore, simulation studies using microwave backscattering models demonstrate the possibility for estimation of dry snow water equivalent given that several snow parameters can be identified. Thus, climatological characteristics of snow parameters on the plateau obtained by field measurements will be useful for development of snow retrieval algorithms using passive microwave radiometers and SAR's. Moreover, the algorithms can be validated by the field measurements.

3.4.2 Strategy of experiments

The process-, modeling-, and satellite-based studies described in the previous section will be carried out in cooperation with the Chinese national project, the Tibetan Plateau Experiment (TIPEX), and the China-Japan Cooperative Study on Asian Monsoon Mechanisms (JEXAM). GAME-Tibet, TIPEX, and JEXAM are to be coordinated by the Joint Coordination Committee (JCC). Scientists in Australia, the United States, Korea and Germany who have plans for joining the GAME-Tibet project will be invited as experts to the JCC meetings.

Taking into account the importance of seasonal variations in key processes, experiments at two different scales, the plateau-scale experiment and the mesoscale experiment, have been planed.

3.4.2.1 Plateau-scale experiment

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 will be carried out using various observational networks. Some of these are existing and some will be installed along the north-south and east-west transects indicated in Figure 3-4-1. Systems to be installed include the special radiosondes, the AWS's equipped with soil temperature-moisture measuring capability, the PBL towers, and the precipitation sampling systems including those for isotope studies. The diagnostic studies of the energy and water cycles over the plateau,

Plateau Scale Experiment

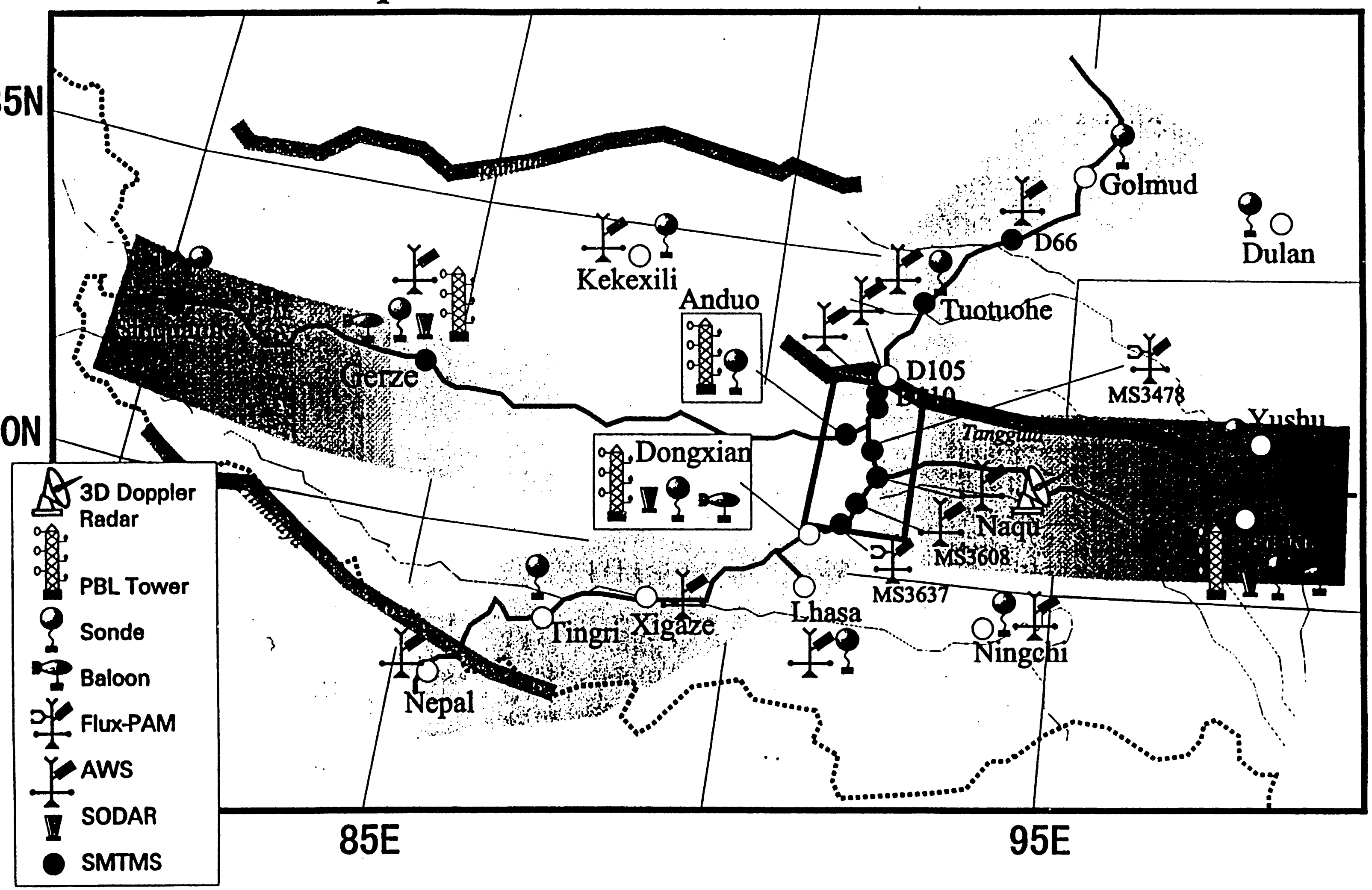

Figure 3-4-1 Plateau Scale Experiment.

and their effects on Asian Monsoon variability, will be accomplished using regional-nested models and global 4DDA based on the acquired measurements.

(1) Observation networks

(a) Radiosonde network

In addition to the radiosonde observations at the nine existing operational stations operated by TIPEX (Changdu, Linzhi, Lasa, Naqu, Dingri, Toutouhe, Yushu, Germu, and Dulan), two special radiosonde stations will be deployed at Gaize and Shiquanhe in west Tibet by JCC. Four times a day measurements at the special stations from May 5 to August 5 are planned for investigation of the diurnal variation of the PBL and for obtaining inputs needed to generate global 4DDA products. At Anduo in central Tibet, another radio station is to be deployed by GAME-Tibet. In Kekexili in the north-west region of the plateau, where there is no observational site, one special radiosonde station is planed for operations from May to July in 1998.

(b) AWS network

In order to optimally sample the considerable inhomogeneity in land surface properties, a number of AWS's have been installed along the east-west and north-south intense observational transects, as shown in Figure 3-4-1.

Four sets of advanced AWS's have operated at Lasa, Naqu, Rikeze, and Linzi since 1993. Other two sets of similar equipment were set up at Gaize and Shiquanhe in the summer, 1997. These six stations comprise the JEXAM AWS network along the east-west transect. Two sets of AWS's have operated in the Tanggula mountains and the Himalayan mountains in Nepal by the CREQ/CREH project since 1992 and 1994, respectively. They will continue to be operated by GAME-Tibet. Thus a total of eight AWS's will provide surface layer profile measurements as well as surface fluxes obtained by applying flux algorithms to the raw AWS measurements.

The four AWS's which were used for the Heihe River basin experiment in the northern part of the plateau, are deployed along the north-south transect by GAME-Tibet. These are one-level observing systems. A set of eddy correlation systems, which consist of a sonic anemometer, a fast response thermocouple, and an infrared hygrometer will be operated during the IOP's as portable eddy flux systems around the four fixed one-level AWS stations. Using the eddy correlation fluxes as validation data, surface flux algorithms for the one-level measurement systems will be developed, which will be optimal for applications over the plateau. Thus, in addition to the two AWS stations in the Tanggula mountains and Nepal, these four stations make up the six-station GAME-Tibet AWS network along the north-south transect.

In Kekexili, where there is no observational site, one AWS will be operated from May to July in 1998.

(c) PBL tower network

A PBL tower, which consists of a three-level meteorological sensor profile system, a pyranometer, a barometer, and sensors for soil temperature-moisture measuring, in which the moisture measuring is done with time domain reflectometry (TDR), is deployed at Anduo by GAME-Tibet. In addition, two more PBL towers will be deployed at Gaize and Naqu by TIPEX. The PBL tower network will thus consist of three sites, all located along the north-south and east-west intensive observational transects, as shown in Figure 3-4-1.

(d) Permafrost observations

Eight sets of soil temperature-moisture profile measurement systems and one set of soil temperature measurement system are deployed along the north-south transect in addition to the soil moisture measurement systems attached with the AWSs. TDR systems are used to measure the soil moisture profile.

(e) Ground truth data collection for satellite remote sensing

Soil moisture, surface temperature, spectral reflectance, surface roughness will be measured in the different scales once a month along the north-south transect and two times in 1998 along the west-east one.

(f) Sampling network for isotope study on water cycle

The origin of precipitation and its recycling will be studied by sampling both surface rainfall and river water along the north-south and east-west intensive observational transects.

(2) Diagnostic studies by using regional-nested models and global 4DDA

To understand two- and three-dimensional processes associated with the energy and water cycles over the plateau through diagnostic analysis, the following three models will be provided for the GAME-Japan community.

(a) Simple two- and three-dimensional models with radiation, boundary layer turbulence, surface, and soil parameterizations, will be provided by the University of Tsukuba.

(b) The Japanese Spectral Model (JSM), a regional model with full physics parameterization, will be provided by the Japan Meteorological Agency.

The fully upgraded 1996 global 4DDA system of the JMA will be used for the modeling studies. Based on enhanced surface and upper air data to be obtained during the GAME/Tibet IOP, the JMA is planning the following four modeling projects concerning 4DDA.

(1) Stand-alone time-integrations of a simple biosphere model
(2) Validation of 4DDA products
(3) Assimilation of special observations
(4) Assimilation of satellite data

Every six hours, diagnostic quantities obtained through time integration of the forecast models using 4DDA will be fully archived together with the basic prognostic variables of wind, temperature, and moisture. The archived products will consist of surface fluxes (latent heat, sensible heat, stress, etc.), radiative fluxes (OLR, albedo, cloud radiative forcing, etc.) and three-dimensional diabatic forcing variables (radiative heating rates, released latent heat, vertical diffusion, etc.). The model outputs will be validated with observations in order to determine the underlying systematic errors and to improve the model parameterizations. The model outputs will also serve as a basic dataset to study the physical mechanisms associated with the large scale energy and water cycles. This dataset will be available to any requesting GAME-Tibet scientist through off-line access.

(3) U.S. Component to GAME-Tibet: Resolving distribution of heat-moisture fluxes by use of global and limited-area models

The U.S. component to GAME-Tibet is designed to develop a better quantitative understanding of the distribution of heat and moisture fluxes, including both surface fluxes and their vertical distribution within the Tibetan Plateau atmosphere, and to determine their impact on mesoscale and large scale circulations through the use of regional and global scale models. To accomplish these goals, the U.S. group has proposed to participate in the GAME-Tibet experiment in the role of diagnostic analysis, modeling, and remote sensing specialists. They will use a combination of data analysis techniques, satellite remote sensing techniques, biosphere-atmosphere process modeling techniques, and numerical prediction modeling techniques to accomplish their main goals, and to address various specific questions about plateau meteorology that have resisted understanding because of the lack of detailed information on the time-space distribution of heat-moisture fluxes.

3.4.2.2 Mesoscale experiment

The mesoscale experiment will be implemented in the central plateau by using two- and three-dimensional intensive observing systems including a three-dimensional Doppler radar, mobile radio-controlled aerosondes, the radiosonde network, and the AWS network as shown in Figure 3-4-2. The scientific objectives of the mesoscale experiment are:

(1) to understand mesoscale processes associated with land-atmosphere interactions (including the effects of the spatial distribution and advection of one-dimensional processes)
(2) to develop and validate mesoscale atmospheric-hydrological coupled models
(3) to devise methods for scaling up land surface process models and satellite remote sensing algorithms.

Intensive observations are planned in the upper reaches of the Nujian basin, as shown in Figure 3-4-2. There are two spatial scales inherent to this basin. The catchment area of the overall basin is approximately 10^5 km^2; this is the larger basin scale. A smaller basin, about 10^3 km^2, is also embedded in the larger one. The characteristics of frozen ground vary over a wide range, from continuous permafrost in the north to seasonal permafrost in the south. The distribution of land surface wetness is directly affected by the permafrost distribution. Precipitation has also been suggested to depend on the distribution of permafrost coupled with orographic effects. Characteristic diurnal variations in the surface temperature fields have already been documented using GMS imagery in the vicinity of the proposed mesoscale experimental area.

(1) Observational networks

(a) Three-dimensional Doppler radar and precipitation gauge network

An X-band three-dimensional Doppler radar has been developed by NASDA to obtain ground truth data for TRMM observations, to understand mesoscale precipitation process over the plateau, and to develop and validate a mesoscale coupled atmospheric-hydrological model which includes cloud physics. The radar system was tested in Nagaoka, Japan from December, 1996 to March, 1997 and in Naqu, the Tibetan Plateau from August 31 to September 9, 1997.

The precipitation observing approach is based on combining measurements taken from a rain gauge network, along with rain estimates made with radar and satellite remote sensing techniques. Approximately ten weighing-type gauges and five tipping bucket gauges are planned for deployment along the north-south and east-west transects, representing different slope aspects within the larger basin. These sites must be easily accessible for continuous maintenance. A specially designed precipitation gauge with a double fence will be installed near the Doppler radar site, along with a disdrometer, a snow particle measurement system, and a microwave radiometer for measurement of total water vapor and cloud liquid water content.

The Doppler radar and other instruments will be deployed about 10 km south of Naqu in 1998. A continuous and intensive observation period (IOP) has been planned for May to September, 1998. Five international teams will operate the radar and the other systems. Each team consists of two Japanese scientists and two Chinese scientists, who will operate the instruments for one-month periods.

Meso Scale Experiment

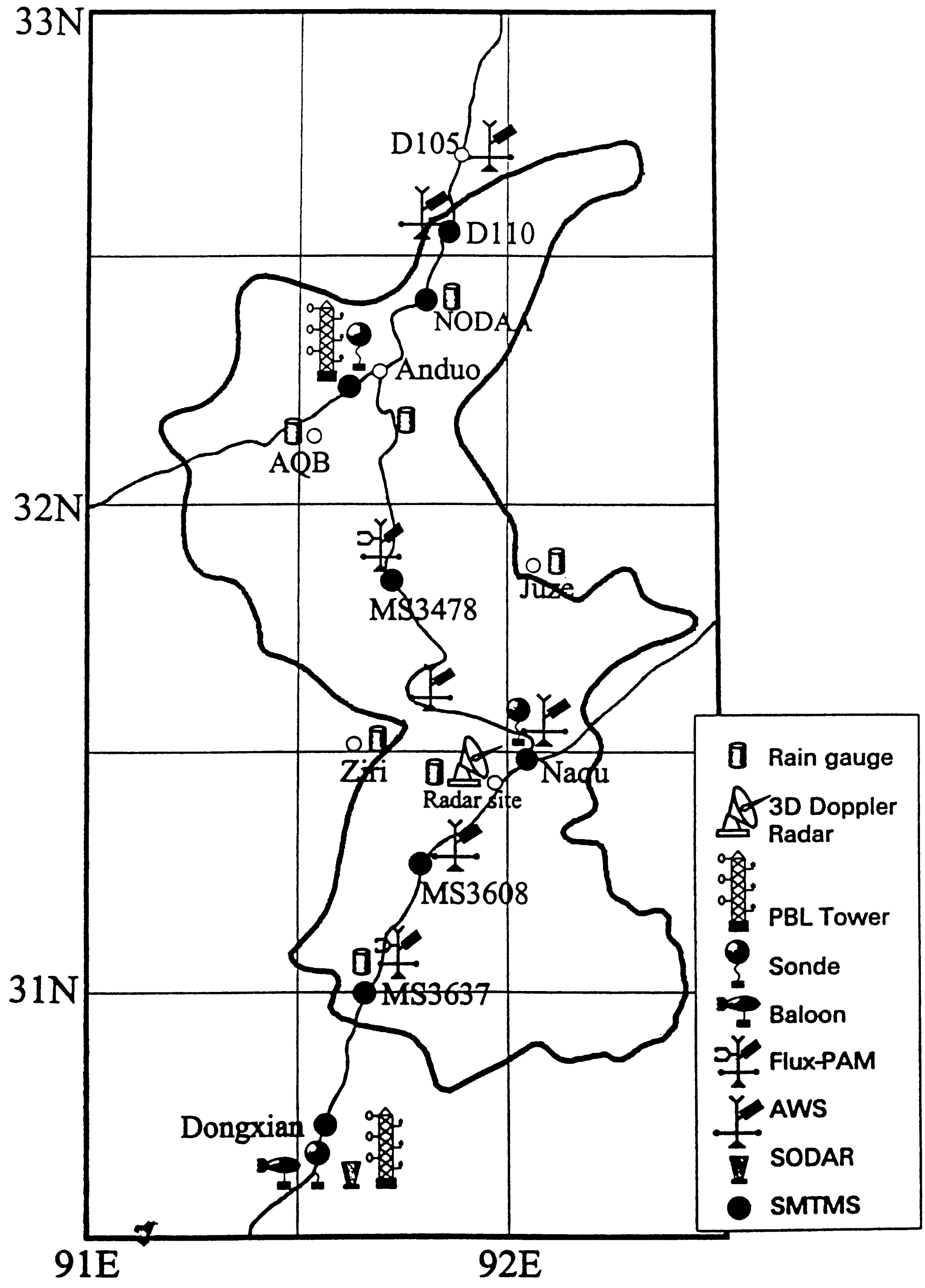

Figure 3-4-2 Meso Scale Experiment

(b) Radiosonde network

In addition to the operational radiosonde station at Naqu and as discussed previously, a special sounding station will be set up at Anduo in the mesoscale experimental area by GAME-Tibet. Thus, these two radiosonde stations will be positioned so that atmospheric variations along the north-south transect over the mesoscale experimental area can be monitored directly. The radio sounding at Anduo will be operated two times a day from May to August. Specially intensive observation, six times a day, is planed on selected days (Core Periods, from June 1 to 10 and from June 21 to 30) to investigate diurnal variations of the PBL.

(c) Aerosonde observations

Aerosondes, which are radio controlled mobile aircraft with sensors, will be used to sound the lower boundary layer. This operation will be conducted as a cooperation among the Australian group, GAME-Tibet and TIPEX.

The three types of operation are planned as follows:

(1) Operation A: PBL 2-D operation in Ando region
Base: Ando
Operation: Clear and Fine days
Flight Pattern:
cooperate with PBL intensive observation (PBL tower, turbulent flux observation, radiosonde, soil moisture obsservation). Horizontal butterfly pattern (X shape) at the two (or more) altitude (500 m, 1500 m above ground) over the 20 km x 20 km square region with PBL tower at the center.

(2) Operation B: Meso-circulation study operation in Naqu basin
Base: Naqu radar site
Operation: Clear and Fine days
Flight Pattern:
80 km N-S line over ground stations (Ando PBL (maybe), MS3478PAM, MS3608AWS, MS3637AWS) and EW line perpendicular to it. At the two altitudes (500 and 1500 m above the ground). Ando PBL is optional depending on UHF connection.

(3) Operation C: Operation with 3D doppler radar
Base: Naqu radar site.
Operation: Rainy days, or days with disturbances expected
Flight Pattern:
Event-based flights on the occurrence of mesoscale disturbances detected by the 3D doppler radar. Detailed flight path will be decided with the radar information; inside or around the disturbances.

Operation C will be carried out on the days when the disturbances are expected. Tentative flight schedule is as follows:

June 1-5	Operation A	base: Ando
June 6-10	Operation B	base: Naqu
June 21-25	Operation B	base: Naqu
June 26-30	Operation A	base: Ando

The days in the middle (June 11-20) are planned for rest of operators and instruments preparation, but can be used for Operation C.

Basically four aerosondes will be deployed to observe mesoscale phenomena. Cross-sections will be obtained by continuous observations taken by two aerosondes.

(d) PBL tower

The PBL tower at Anduo, which was discussed in Section 3.4.2.1, will also be used for the mesoscale experiment. In addition to the turbulent flux measurements at Anduo PBL tower site, another flux measurement system will be deployed near Naqu by Korean group.

(e) AWS network

In addition to the two AWS's in the mesoscale study area, which have been discussed in Section 3.4.1, two sets of flux-PAM systems manufactured by the National Center for Atmospheric Research (NCAR) are planned for deployment, as shown in Figure 3-4-2. These systems will be used to measure radiative, sensible, and latent heat fluxes. They will also monitor land surface hydrological conditions by measuring the vertical profile of soil temperature and moisture.

(f) Barometer network

The measuring objective for this observing system is to record detailed variations in the surface pressure field generated by mesoscale events, i.e., thunderstorms, gust fronts, mesoscale fronts, etc., such that the measurements coincide with the areal-mean heat fluxes taken over complex terrain scenes within the mesoscale study area. The heat fluxes will be obtained every hour on calm-clear days during the observation periods. The fluxes are expected to represent an area of several ten's of square kilometers. To satisfy the measuring objective, the barometers must be deployed at different sites over a range of elevations, but all located in an area within a radius of approximately 20 km. For estimation of characteristic heat flux gradients, the barometer network must include several stations situated in an area whose radius is less than 20 km. The maximum difference of elevation between the stations should be as large as possible. For the pressure observations to coincide with the observed mesoscale events, the barometer network must be deployed within range of the Doppler radar.

(g) River water level and discharge

In addition to the operational hydrological station near Naqu, an experimental station is planned near Anduo. At these two stations, river water levels will be measured continuously, while river discharge will be measured periodically.

(h) Sampling network for isotope study on water cycle

The origin of precipitation and its recycling will be studied by sampling both surface rainfall and river water in the mesoscale experimental area. Evaporation rate will be also measured by using pans.

3.4.2.3 Schedule

(1) Installation of the observational systems from July to September, 1997
(2) Two pre-phase observation periods (POP's) in mesoscale experiment area:
    August 6 to 16, 1997 for PBL observation.
    August 31 to September 9 for 3D Doppler Radar observation.
(3) 1st sensor inter-comparison: August, 1997
(4) 2nd sensor inter-comparison: April, 1998.
(5) Intensive Observation Periods (IOP's): the following three IOP's are scheduled in 1998.
    (a) Radiosonde IOP: May 5 to August 5 (3 months).
    (b) Radar IOP: May to September (5 months).
    (c) Land-atmosphere interactions IOP: May to September (5 months).

3.4.3 Data policy

The JCC continues to discuss a common data policy among the three projects: (1) GAME-Tibet; (2) TIPEX; and (3) JEXAM. The Chinese side will establish a TIPEX data center for data collection, data processing, data management, and data exchange. GAME-Tibet will also establish a similar data center in the framework of the GAME Data Archive and Information Network (GAIN).

GAME-Tibet has established the following data policy:

1) Final validated datasets obtained during the Pre-phase Observation Periods will be open to all GAME-Tibet scientists by October, 1998.
2) Final validated datasets obtained during the POP and the IOP's will be open to all GAME-Tibet scientists by June, 1999.
3) Final validated datasets obtained during the POP and the IOP's will be open to the international science community by June, 2000.

The JCC approved the following data policy:

The observation data obtained through cooperation will be provided:

1) to three parties of the JCC one year after the IOP for (IIB) datasets
2) to three parties of the JCC two years after the IOP for (IIIB) datasets
3) to international communities three years after the IOP based on the additional negotiation and discussion.

3.4.4 Participating institutions

(1) Japan

Institute of Geoscience, University of Tsukuba
Nagaoka University of Technology
Disaster Prevention Research Institute, Kyoto University
University of Shiga Prefecture
Faculty of Science, Okayama University
Center for Climate Systems Research, University of Tokyo
Institute of Hydrospheric-Atmospheric Sciences, Nagoya University
Department of Geophysics, Hokkaido University
Faculty of Agriculture, Kyushu University
National Space Development Agency of Japan
Meteorological Research Institute, Japan Meteorological Agency (JMA)
Division of Numerical Weather Prediction, JMA
National Institute for Earth Science and Disaster Prevention
Frontier Research System for Global Change

(2) China

Chinese Meteorological Administration (CMA)
Chinese Academy of Meteorological Sciences (CAMS)
Institute of Atmospheric Physics
Department of Science, Technology and Education
National Climate Center, CMA
State Oceanic Administration

Peking University
Chinese Academy of Sciences (CAS)
Lanzhou Institute of Glaciology and Geocryology, CAS
Lanzhou Institute of Plateau Atmospheric Physics (LIPAP), CAS

(3) Other Countries

Bureau of Meteorology Research Center, Australia
University of California, Los Angeles, USA
University of California, Santa Barbara, USA
Florida State University, USA
Rutgers University, USA
Yonsei University, Korea
WCRP