The Present Status and Future of Research of the East Asian Monsoon

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ABSTRACT

The weather and climate in China are greatly affected by the East Asian monsoon. For long time the Chinese meteorologists have undertaken numerous works regarding research and prediction of the East Asian monsoon, and made great achievements that are well noted for the world and in China. In the future 5~10 years, the research on the East Asian monsoon will be strengthened and the thus obtained achievements will be gradually transferred into the operational capability, eventually leading to an improvement of weather and climate prediction in East Asia.

The present paper has firstly made an overview of the present status of research on the East Asian monsoon, illustrating the 4-stage developmental process of monsoon study in China and major achievements thus obtained. Then the major problems related to the study of the East Asian monsoon are scientifically indicated, and the monsoon-related ongoing and future scientific field experiments and study projects the Chinese scientists have initiated or participated are briefly described. It may be expected that a new breakthrough in the problem of the East Asian monsoon in the future ten years will be made with these efforts and intensive research works. Finally, it is pointed out that, to accomplish this new breakthrough, a key problem is to carry out the extensive cooperation, in particular the scientific cooperation of the scientist across the Taiwan Strait as well as countries over the surrounding regions.

Key words: East Asian monsoon, Monsoon experiment, Cooperation

I. INTRODUCTION

At present time, over 60% of the world population lives in the monsoon regions. China is situated in the Asian monsoon region and its weather and climate, in particular large-scale rainfall distribution, shift of major rainbelt and drought / floods disasters every year, are greatly affected by the summer monsoon. Exampled are the two months long-persistent, excessively heavy rainfall over the Yangtze-Huaihe River Basins during the 1991 Meiyu season and the heavy rainfall in South China in June-July,1994. The former brought about the serious losses of about 100 billion Chinese Yuan and numerous lives, and the latter occurred once in 100 years. Both of these two events were closely related to the unusual activities of the summer monsoon. Therefore, the research of the monsoon provides an important approach to the development and improvement of prediction of precipitation and drought / flood during flooding season, which has a significant implication for national economic development, especially for agricultural production.

For a long time, the Chinese meteorologists have undertaken numerous works regarding the research and prediction of the Esat Asian monsoon, and made great achievements that are well known for the world and in China (Tao and Chen, 1987; Chen et al., 1991; Ding and Murakami, 1994; Ding, 1994). The present paper will discuss the four-stage developmental process of the monsoon study in China and major achievements thus obtained. The second section will be focused on the East Asian monsoon-related field experiments and scientific projects Chinese scientists have initiated or participated in the future 5–10 years. Finally, the technological prerequisite and coordination problem for successful implementation of these experiments and projects will be put forward.

II. THE PRESENT STATUS AND MAJOR ACHIEVEMENTS OF THE STUDY OF THE EAST ASIAN MONSOON

1. *Progress of the Monsoon Study in China*

Before discussion of the major achievements of reseach on the East Asian monsoon, it is quite necessary to briefly review the progress of the monsoon study in China. The research on the monsoon in China has so far had about 65-yr history, starting from 1930's. The whole time period may be divided into four stages (Zhu, Ding and Luo, 1990). The first stage (before 1950's) was directed to the distributions of monsoon precipitation and the surface airflow, by use of the surface observations and sparse upper-air observations. The representative work at that time is the classical paper entitled "The southeast monsoon and the rainfall amount in China" by Zhu Kezhen (Zhu, 1934). He illustrated seven topics in that paper: records concerning monsoons in the Chinese ancient books; causes of monsoon; Indian monsoon; similarity and difference between the Indian monsoon and monsoon over China; primary driving force of the precipitation in the eastern China; an inquiry into whether or not the poem "Bo-Zhao wind" by Su Dongpo, a noted poem in Song Dynasty, is the true perspective describing monsoons; and the reason why the Bo-Zhao wind can cause droughts. Much progress has been made of these problems during the last half century. But, they are still important issues being now studied. The second stage (from 1950's to the middle of 1970's) placed the stress on the linkage between the surface systems and the upper circulation pattern in the monsoon regions, and classified the macro-scale synoptic processes in East Asia. Many new findings were revealed and new concepts were put forward, such as the splitting and blockage effects of the Tibetan plateau, the distribution features of heat sources and sinks, the seasonal sudden change, the effect of the blocking high, and the formation and characters of the Meiyu rains. After 1970's, the meteorology entered an era of experimental science, with the development of diagnostic analysis, numerical simulation and modern sounding techniques integrated to carry out the "experimental" study of the global atmospheric processes or particular processes over a certain region. In order to respond to the monsoon experiments (MONEX) of FGGE programme, China carried out the first scientific experiment on the Tibetan plateau in the summer of 1979. The thus acquired valuable data in the plateau region have been provided to the various scientific groups for investigation of the effect of the Tibetan plateau on the Asian monsoon. Through a number of researches at that stage, a better understanding of the nature of the East Asian general circulation and the monsoon was made. A number of new evidences have been revealed, for instance, the existence of the East Asian monsoon circulation system and corresponding independent heat source and sink couplet; the earliest onset of the East Asian summer monsoon; the new findings of the activity characteristics and genesis mechanisms of low frequency oscillations; close relationship between the East Asian monsoon and the precipitation and droughts / floods in China; and the formation mechanism of the winter monsoon. The above-mentioned results led to the establishment of the short and medium-range weather numerical predictions and improvement of the prediction of heavy rainfall in China. The fourth stage has started since early in the 1990's. Owing to fruitful achievements made by Chinese scientists in the field of the East Asian monsoon which has a remarkable impact upon the domestic and international scientific communities, and the significant enhancement of scientific and technical facilities, the Chinese scientists have been capable to initiate or play a primary role in monsoon research or monsoon scientific experiments, for example, China–Japan Cooperative Program on the Asian Monsoon Mechanism, China–US Cooperation on Monsoon Research, the South China Sea Monsoon Experiment and Project Initiative on the East Asian Monsoon Research. With these research projects or programs, a better understanding of the East Asian monsoon will be expected, on the basis of which the medium–and long–term prediction of the monsoon and monsoon rainfall will be improved, and the important contributions will be made to improve the international climate models and climate prediction.

2. *Major Achievements in the Study of the East Asian Monsoon*

Due to space limitation, we will focus our discussion on the major achievements in the study of the East Asian summer monsoon. To sum up, the following five aspects will be briefly described.

(1) Discovery of the Existence of the East Asian Monsoon Circulation System

The origin and variations of the summer monsoon over the mainland of China, the South China Sea and the western Pacific were previously attributed to the Indian monsoon. Later, as the research of the monsoon and tropical meteorology in China actively developed, it was found that the relationship between the summer monsoon in China and its associated precipitation and the Indian monsoon was not so close as previously thought. The moisture sources for China do not exclusively come from the Bay of Bengal. In 1982, the new concept of the existence of the East Asian monsoon circulation system was put forward. In 1987, the system was well documented (Tao and Chen, 1987), and its components were further identified (Figure 1). The East Asian monsoon system is independent from the Indian monsoon system and at the same time interacts with each other. This finding corrects misleading that for long time exists in the study of the East Asian monsoon, i.e., the precipitation and droughts / floods as well as the East Asian monsoon are controlled or are taken to be an extension of the Indian monsoon. As a matter of fact, the onset of the East Asian monsoon is the earliest in the whole Asian monsoon region, and it has its own heat source and sink couplet to drive and create unique rainfall patterns, such as the noted East Asian Meiyu.

(2) The Study of the Earliest Onset of the East Asian Monsoon and Its Mechanism

The Chinese scientists have pointed out that the summer monsoon in the South China Sea sets in earliest in the Asian monsoon region, around the middle of May (Figure 2). The monsoon then propagates westward to the west coast of the Indian peninsula in the middle of June. Thus, the onset of the Indian monsoon is one month later than that over SCS. Meanwhile, the monsoon advances northward and may affect Japan and Korean regions. This finding is further documented by numerous monsoon climate studies (Matsumoto, 1992; SCSMEX Science Plan, 1994; Ding et al., 1995). The onset of the SCS monsoon marks the arrival of the East Asian summer monsoon and beginning of the major rainy season in China, therefore it has an important implication. On the other hand, post to the onset of the SCS

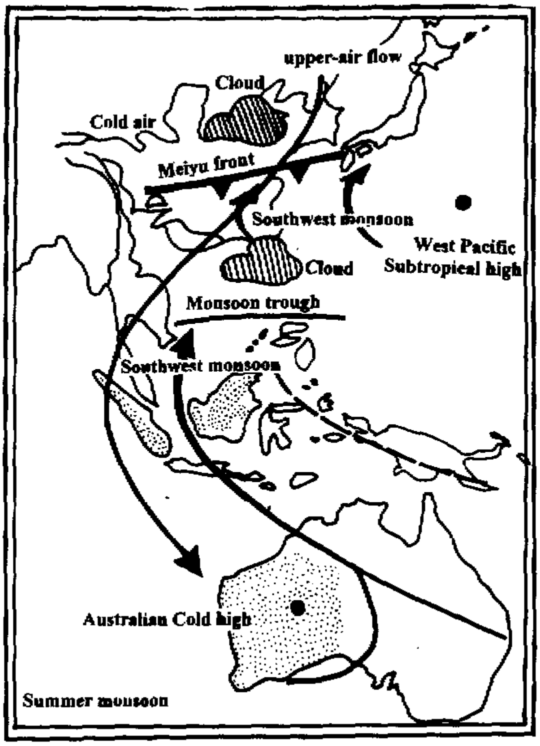

Fig. 1. A schematic of the East Asian monsoon system.

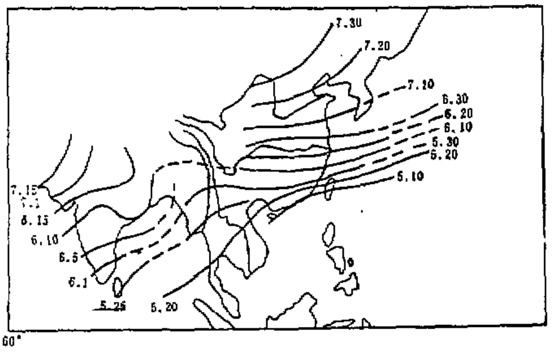

Fig. 2. Average dates of the onset of the East Asian monsoon.

monsoon, the SST over the western Pacific increases and extensive areas of convective clouds develop, and they may exert a significant effect on the weather and climate over remote regions through the teleconnection process (Nitta, 1987; Huang,1988). There has not been a unifying viewpoint on the reason of the earliest onset of the SCS monsoon. One possible explanation is to invoke the early development of the heat source in this region, with the low frequency oscillation being the triggering factor. Another possibility is the influence coming from the temperate zone as well as the interhemispheric interaction.

(3) Discovery of the Heat Source over the SCS and Heat Sink over Australia Maintaining the East Asian Monsoon

There are obvious disputes about the distribution and the intensity of atmospheric heat sources in the Asian region. With numerous estimates of the heat source and sink, it is clarified that there are two couplets of heat source and sink: one consists of the heat source over the Tibetan Plateau and the Bay of Bengal and heat sink over Madagascar (Figure 3), which is the driving force for the Indian monsoon system; the other consists of the heat source over the South China Sea and the western Pacific, and heat sink over the Australian region, which drives the East Asian monsoon system. This finding is critical for documentation of the existence of the East Asian monsoon circulation system. Figure 4 further illustrates the condition of heat sources over the SCS. Although it is a case of individual year, it is rather representative. It can be seen that during late spring prior to the onset of the SCS monsoon (April) (Figure 4A), the heating field (Q1) is located in the southeastern part of the Tibetan Plateau and Borneo region. During the period of the first ten days of May (the preceding period of the onset of the SCS monsoon), the extensive area of heat source over the Indo–China peninsula was observed, which represents the beginning of the seasonal transition from winter to summer. During the period of the monsoon onset (the middle and last ten days of May), the heating field rapidly sets up over the SCS region and its magnitude significantly augmented, thus forming an independent heat source center. In June when the SCS monsoon culminated, the intensity of the heat source continued to rapidly increase. According to the comparison of the magnitudes and characters of vertical distribution of Q1 and Q2, the vigorous development of convective cloud systems and release of latent heat played a primary role in creation of the heating field.

(4) The Study of Low Frequency Oscillation (LFO) and Their Formation Mechanism

LFO is generally defined as the periodic or quasi–periodic variations of the atmospheric

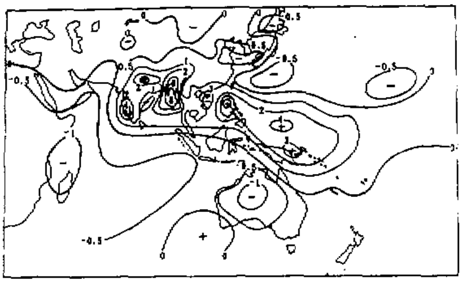

Fig. 3. The mean July atmospheric heat source. Positive (negative) values represent heat sources (sinks). Unit: °C / day.

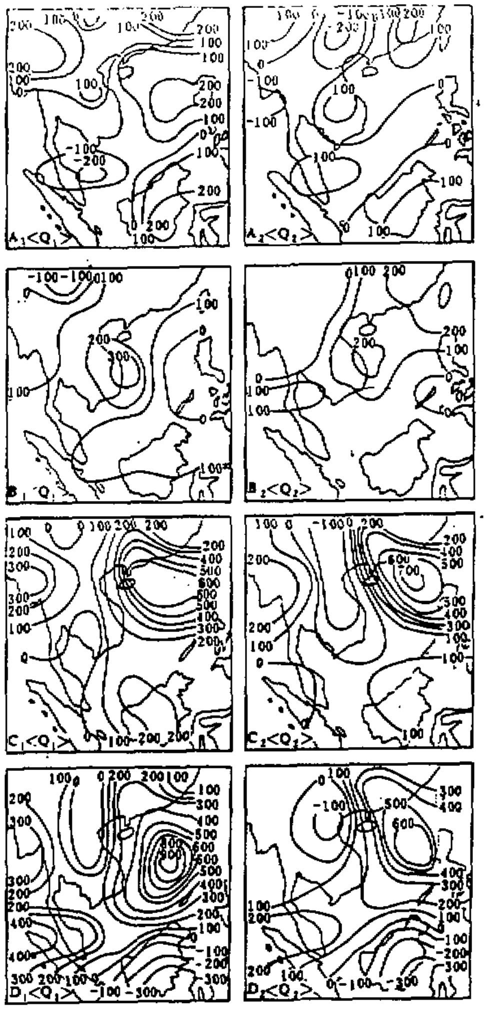

Fig.4. The horizontal distributions of Q1 (apparent heat source) and Q2 (apparent moisture sink) at different stages for 1981 summer. (a) April; (b) prior to the onset of the summer monsoon (early May); (c) post to the onset of the summer monsoon (middle and last May); and (d) June. Unit: W/m^2.

circulation with time scale greater than 7–10 days. At present time, a number of works have been directed to 10–20 day and 30–60 day oscillations. These two LFOs interact with each other and most marked in the monsoon region. Their activity is closely related to the medium–range variations in monsoon circulation and precipitation (onset, break, active period, and withdrawal of the monsoon). Figure 5 demonstrates the nearly 30–day oscillation of the precipitation in South China. Wang and Ding (1992) have recently made a summary and review of the present status of the study of LFO. Between 20° and 30°N there is a confluence

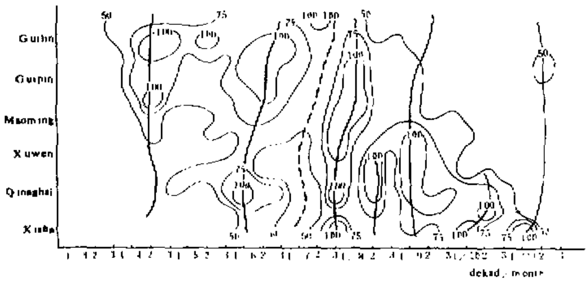

Fig. 5. Latitude–time cross–section along 110°E of 10–day accumulated precipitation amount in South China, averaged for 1976–1980. Unit: mm.

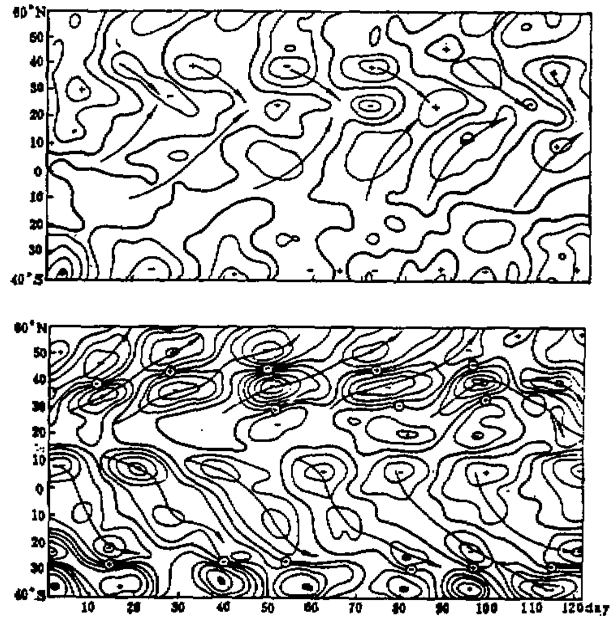

Fig. 6. Latitude–time cross–section along 120°E of low–frequency (30–60 day) wind for June–September, 1981. (a) 850 hPa meridional wind, with interval of isolines of 1 m / s. (b) 200 hPa zonal wind, with interval of isolines of 2 m / s. "+" and "–" denote positive and negative centers of geopotential height fields. The arrows are the propagation direction. Bold full lines are zero lines.

zone of meridional propagation of LFO of the meridional wind at lower level (He at al., 1990). To the north of this zone, the LFO at mid– and high latitudes propagates from northwest southeastward, while in the near–equatorial and tropical regions to the south of the zone the LFO propagates from southwest northeastward (Figure 6a). The low–frequency zonal wind near 10°S in the Southern Hemisphere may propagate up to the southern region of China. At upper level (Figure 6b), there is a diffluent zone of propagation of the low–frequency meridional wind. Therefore, the direction of propagation of LFO to the south of the northern tropics at lower level is opposite to that at upper level. The meridional propagation has an important role for occurrence of droughts / floods in China, in particular occurrence of droughts / floods in the Yangtze–Huaihe River basin. Recently, it is revealed that the 1991 excessively heavy rainfall over the Yangtze–Huaihe River basin occurred under the interaction of the 10–20 day LFO at low and middle latitudes (Lu and Ding, 1996).

On the other hand, it is also revealed that the LFO is closely associated with the occurrence and evolution of El Nino events. Prior to the onset of El Nino event, the anomalously active and eastward propagating of LFO may be observed, which is favorable to the eastward propagating of the equatorial heating center up to the central Pacific. Post to the occurrence of the El Nino event, the LFO in the Eastern Hemisphere decays or disappears, while in the Western Hemisphere the LFO gets active and may propagate from west to east. The formation mechanism of the LFO is being extensively studied. It is understood that the cold surges coming from the Southern or Northern Hemisphere may penetrate into the equatorial region and induce Kelvin waves which are likely an exterior forcing factor for generation of the LFO.

(5) The Close Relationship between the East Asian Monsoon Activity and Droughts / Floods in China

Climatologically, after the onset of the SCS monsoon, the precipitation situation in China assumes a fundamental change. First, the presummer rainy season in South China comes. Up to around the middle of June, as the East Asian monsoon further intensifies and advances northward, the major seasonal rainbelt in China jumps from South China to the Yangtze–Huaihe River basin, starting the Meiyu in China or Baiu season in Japan. Then, around the early and middle of July, the front of the East Asian monsoon advances up to the Yellow and Huaihe River basin, thus causing the onset of the rainy season in North China.

In the last ten days of July and early in August, the East Asian monsoon may reach 40°–45°N latitude. Therefore, two northward jumps of the seasonal rainbelt are closely related to the northward progress and enhancement of the summer monsoon (Figure 7) (Guo et al., 1981).

The East Asian monsoon assumes the remarkable interannual variability, thus leading to the similar variability of the precipitation in the eastern part of China (Figure 8) (Lu and Lin, 1987). The study has revealed that the background circulation favorable to the occurrence of prolonged heavy rainfalls in the history of China is all associated with the intensification and unusual activity of the monsoonal air flow in East Asia. Here is an example. In 1991 summer the excessively heavy rainfalls occurred over the Yangtze–Huaihe River basin, lasting for about two months, while in June–July 1994 the prolonged drought occurred in this region and at the same time the heavy rainfall and flooding, once in nearly 100 years, occurred in South China. These anomalous disastrous climate events are of great concern for the Chinese meteorologists. The study has indicated (Ding, 1993; Wang and Zhou, 1996) that these two droughts / floods events are closely related to unusual activity of the East Asian monsoon in these two years. In 1991, the onset of the SCS summer monsoon was anomalously late, and post to establishment of the summer monsoon it had an above-normal intensity, while in North China and South China, its intensity was below-normal. However, in 1994 the establishment of the summer monsoon was anomalously early, with weak monsoon observed over the Yangtze-Huaihe River basin and strong monsoon over North China and South China. Figure 9 shows the height-time cross-sections of the zonal wind in April-July for these two years. It can be seen that the structure and activity of the monsoon for these two years were quite different. The onset of the summer monsoon in 1994 was about one month earlier than that in 1991, but after the onset the monsoon in 1994 temporarily broke and rapidly revived early in June, thus causing two episodes of excessively heavy rainfalls which occurred in the middle of June and the middle and last ten days of July, respectively. On the other hand, the LFO in these two year assumes different characters, with three processes of 10-20 day LFO observed in 1991, thus leading to three monsoon surges and corresponding rainfall episodes, and with the 30-day LFO being the dominating mode in 1994, which is closely related to two

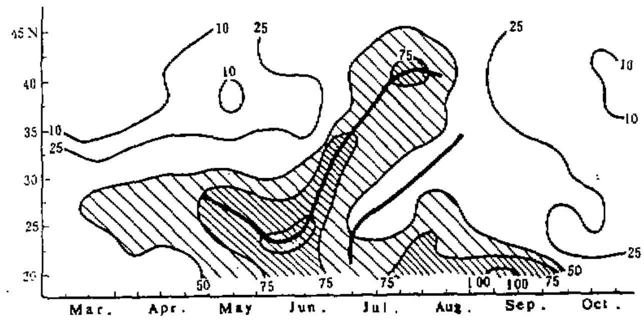

Fig. 7. Latitude-time cross-section of the 10 day accumulated rainfall amount in East China averaged for 1950-1979. Unit: mm.

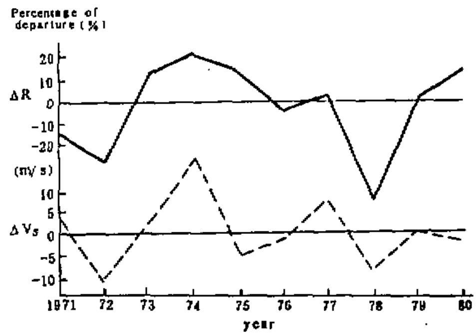

Fig. 8. The relationship between the interannual variability of the precipitation anomalies (ΔR) for June and July over middle and lower reaches of the Yangtze River, and anomalies of the south wind for April and May (ΔV_s) in the South China Sea and Southeast Asia.

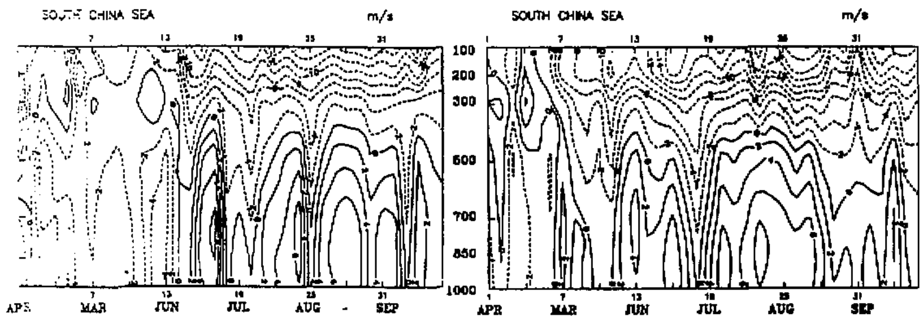

Fig. 9. Height–time cross–sections of the zonal wind averaged over the South China Sea region (10°–20°N, 105°–120°E) for April–September for 1991 (left panel) and 1994 (right panel). Abscissa is the pentad. The interval is 1 m / s.

episodes of heavy rainfall.

3. *Major Problems for the Recent Monsoon Research*

Recent monsoon research is focused on the following nine aspects:

(1) Heat source and sink in East Asia and their thermal and dynamic effects on the East Asian monsoon,

(2) The thermal and dynamic effects of the Tibetan plateau on the Asian monsoon,

(3) Intraseasonal low–frequency oscillations in the East Asian monsoon region,

(4) Interannual variability of the monsoon and its effect on droughts / floods,

(5) Air–sea interaction in the monsoon and its relationship to ENSO events,

(6) Formation and activity characters of monsoon rainfalls (for example, Meiyu rain),

(7) The winter monsoon and cold surge,

(8) Role of the East Asian monsoon in the seasonal change in the general circulation in East Asia,

(9) Medium–and long–term prediction of the monsoon and their socio–economic implication.

III. THE EAST ASIAN MONSOON-RELATED SCIENTIFIC EXPERIMENTS AND RESEARCH PROJECTS

In order to make new breakthrough in the study of the East Asian monsoon, it is necessary to enhance the field experiments, and in–depth and systematic research on the East Asian monsoon. Scientifically, the monsoon scientific experiments in East Asia are quite crucial for making this new breakthrough. Previous monsoon experiments are mainly confined in the Indian and the Australian regions. In the East Asian region, no monsoon experiments have been undertaken so far. Due to lacking in the necessary data, many problems cannot be studied and solved. The Chinese scientists have realized the importance of this problem. With much efforts for recent years and extensive international cooperation, four East Asian monsoon–related scientific plans of field experiments and research have been formulated, i.e., the science plan of the South China Sea Monsoon Experiment (SCSMEX), the science plan of energy and water cycle experiment and research in the East Asian monsoon region (GAME / HUBEX), the China–Japan Cooperative Program on the Asian Monsoon Mechanism, and the Second Meteorological Experiment over the Tibetan Plateau (TIPEX). A brief description of these three plans is given below.

1. *SCSMEX*

SCSMEX is a plan of the monsoon scientific experiment initiated and organized by Chinese and US scientists, and actively supported by the surrounding countries and regions. The goal of SCSMEX is to provide better understanding of the principal processes responsible for the onset and maintenance of the monsoon over Southeast Asia and the southern China leading to improved predictions.

. To attain this goal, the following specific scientific objectives are identified:

(1) To describe and document the 4–dimensional evolution of the large scale circulation and thermodynamic fields in the atmosphere and ocean associated with the South China Sea monsoon.

(2) To identify the influence of heating contrasts between the South China Sea and surrounding regions and the role of early monsoon (April–May) convection and air–sea interaction in the abrupt monsoon transition and subsequent evolution of the East Asian monsoon.

(3) To delineate the mechanisms of genesis, maintenance and interaction among mesoscale, synoptic scale and low frequency variabilities over the South China Sea and vicinity.

(4) To improve the understanding of the impact of the Asian monsoon on the energy and water cycles of the tropical ocean–atmosphere–land system.

(5) To improve the capability of numerical predition and simulations in East Asian region.

In order to achieve the objectives of SCSMEX, three components are necessary:

(6) A pilot study component, including diagnostic and modelling studies, and testing of observation strategies.

(7) A field experiment component, including enhanced monitoring and intensive observation periods (IOP).

(8) A modelling component, covering a wide ranges of scales from process oriented modelling to four dimensional data assimilation.

These three components will form the pillars of SCSMEX. The pilot phase will focus on diagnostic and modelling studies, including testing of observational platforms, that will provide the scientific guidance for the design of the field experiment. The field experiment will include an enhanced monitoring phase for an extending period covering the early onset to the mature phase of the East Asian summer monsoon. Embedded in the enhanced monitoring phase which includes upgrading upper air observations are IOPs when special platforms will be deployed to the experiment site for intensive observations. The modelling component is essential in providing the understanding and interpretation of observations. In particular, the 4–D assimilation effort will blend observations with model–based physics to provide dynamically consistent description of the entire coupled system.

The observation network of SCSMEX will consist of, but not be restricted to the following platforms: upper air sounding, aerosondes, Integrated Sounding Systems (ISS), surface meteorological observations, planetary boundary layer observations, ship-based and land-based radar, oceanic surface and subsurface observations from ships, TOGA-TAO arrays and satellite observations. An aircraft component is not considered as a priority platform. However, in the overall design of the experiments to achieve the scientific objectives, an aircraft component can be included, if deemed essential (Figure 10).

The full field experiment phase will take place in 1998, covering April 15 to August 31 of the year. Two intensive observation periods (IOPs) are planned the year: early to middle of May, and early and middle of June. The first IOP will last approximately 15 days to monitor the onset of the summer monsoon over the SCS. The second IOP will last approximately 15 days to monitor the atmospheric conditions over the SCS after the abrupt changes of the East Asian monsoon rainfall regimes as the Meiyu rain belt jumps northward. In 1998, the field phase including the IOPs will coincide with TRMM, which is expected to have been launched and fully operating, to obtain broad rainfall coverage over the SCS region.

2. *GAME / HUBEX*

The GAME / HUBEX is a China-Japan cooperative scientific experiment and research plan to be undertaken in the East Asian monsoon region under international GEWEX programme.

The goal of GAME / HUBEX is to understand the energy and hydrological processes of multi-scale precipitating systems, especially during Meiyu period, to develop meteorological and hydrological numerical model and data assimilation system, and to improve the ability of climate simulation and short-term climate prediction. The specific objectives are:

(1) To establish the regional data base by intensive meteorological and hydrological observations as well as radar and satellite observations (Figure 11).

(2) To carry out four-dimensional data assimilation analysis from all kinds of data sources derived in the experiment, to develop four-dimensional data assimilation scheme and to provide the more accurate initial field for climate model and regional meteorological / hydrological coupled model as well as the suitable data sets for climate diagnosis.

(3) To understand the evolution and interaction processes of multi-scale precipitating cloud systems, especially during Meiyu period, including radiation process and land surface process, to improve the parameterization scheme of physical processes, and to develop the meteorologial / hydrological coupled model nested in GCM so as to improve the ability of predicting the regional climate and water resource management.

(4) To understand the process of regional energy and water cycle, to assess the impact of large-scale climate variability in the subtropical frontal zone and monsoon variation on it, and to study the sensitivity of flood and drought events to the energy and water cycle in East Asia. The research is also directed to assessing the impact of climate variation upon water resource and ecosystem for providing the scientific advisories for government and concerned departments.

The HUBEX field experiment phase will take place in 1998 and 1999, covering May 15 to August 15 each year. Two intensive observation periods (IOPs) spanning three weeks each period are planned each year. A pilot study for 1-2 years before the full field experiment and a follow-up study after the experiment will be planned. China and Japan will work together to carry out this experiment.

3. *TIPEX*

TIPEX is short for "Observational and Theoretical Study of Physical Processes of the Land–Atmospheric System over the Tibetan Plateau and its Effect on the Globe as well as Disastrous Weather in China". This project, initiated and organized by Chinese scientists, has been implemented since 1994. The scope and goal of TIPEX contain six problems:

(1) Physical process of the land–atmospheric system over the Tibetan plateau and its parameterization schemes

(2) The effect of the physical process of the land–atmospheric system over the Tibetan plateau

(3) The thermodynamic and water cycle processes of the land–atmospheric system over the Tibetan plateau and its interaction with the Asian monsoon circulation

(4) The effect of the physical process of the land–atmospheric system of the Tibetan plateau on global climate change

(5) The effect of the physical process of the land–atmospheric system of the Tibetan plateau on disastrous weather and climate in East Asia

(6) The field experiment of the physical process of the land–atmospheric system of the Tibetan plateau

The item (f) is the basis for the project. The enhanced observation will take place in May–August, 1998.

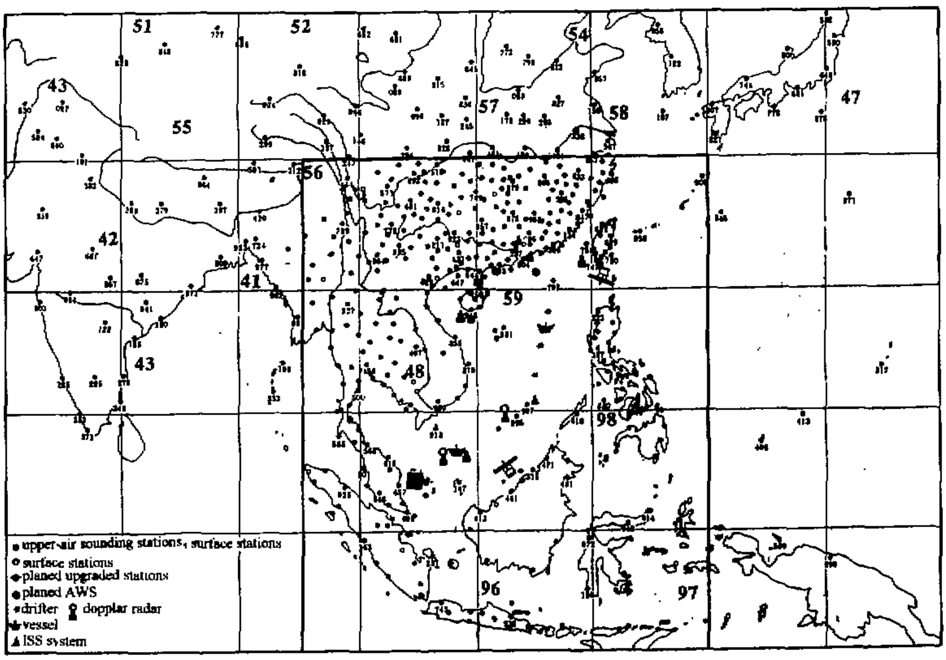

Fig. 10. Observational network for SCSMEX.

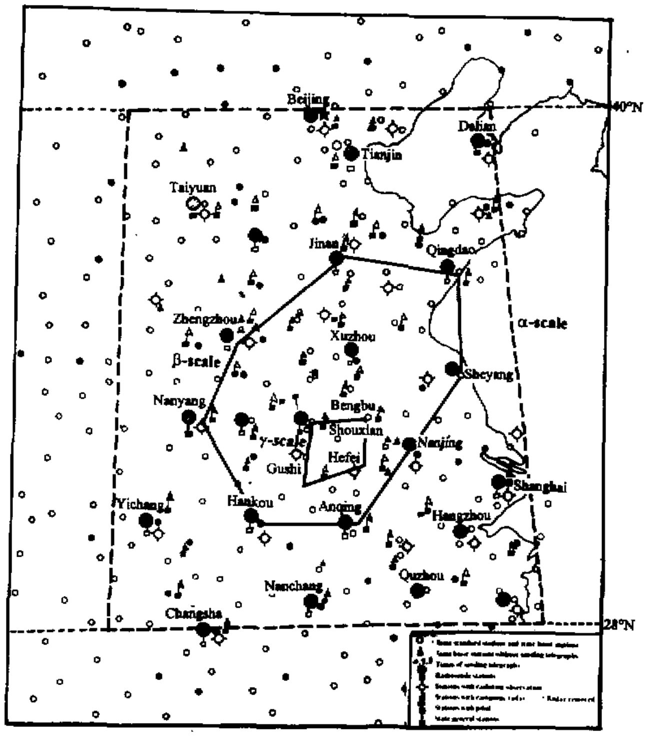

Fig. 11. Observational network of GAME / HUBEX.

4. *China–Japan Cooperative Program on the Asian Monsoon Mechanism*

The China–Japan Cooperative Program on the Asian Monsoon Mechanism is the 10–yr (1989–1999) monsoon study project undertaken jointly by China and Japan. Actually, it started implementing from 1992. The goal of this project is to study the effect of the Tibetan plateau on the Asian monsoon and the impact of the monsoon on the weather and climate over East Asia and the western Pacific by use of observations of heat budget of the land–atmospheric system of the Tibetan plateau and other observations of land surface features. The scope of this project is as follows:

(1) Analysis of interaction between air and land over the Tibetan plateau

(2) Analysis of the environmental conditions affecting the Asian monsoon cycle and variations in ice sheet and snow cover

(3) Study on the relationshop between the monsoon and Meiyu, and the seasonal and interannual variability of the monsoon

(4) The numerical simulation experiments of the monsoon

(5) The water budget of the representative river basins in Asia

According to this project four automatic weather stations (Lhasa, Rikeze, Nagqu and Lingzi) and three snow depth and frozen ground depth stations (Lhasa, Rikezi and Nagqu) were deployed to carry out the observations and measurements of heat budget, snow cover and frozen ground depth. The continuous dataset for two years (from August 1993 to April

1996) has been acquired. The preliminary analysis has shown that these first-hand dataset over the Tibetan plateau is quite important for better understanding of the features of heat source of plateau air-land system and the summer monsoon.

It may be expected that, with the intensive research for the future ten years, a new breakthrough on the problem of the East Asian monsoon will be made. For realization of this breakthrough, a key problem is the extensive collaboration, including the countries at rim of the SCS. During the implementation of above-mentioned ongoing and future four plans, there is a need to coordinate the IOPs in various countries and regions, in order to supplement each other to compose a complete, three-dimensional atmospheric and oceanic observational system. The equipments and instruments should be technically standardized for intercomparison. A data bank should be set up with uniform format. Development of 4-DDA and numerical models should be coordinated to avoid the duplicate work. The scientific achievements should be often exchanged and new problems should be discussed. In order to better facilitate and realize the cooperation, the appropriate scientific organization should be established and the corresponding activities should be carried out, for instance, establishment of regional coordination group for monsoon experiments, and organization of monsoon workshops on the regular basis.

We believe that with the above-described close and extensive cooperation and hard work of scientists, the salient achievements of the reaeach on the East Asian monsoon will be certainly made in the near future.

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