CHINA'S FOUR MAJOR METEOROLOGICAL SCIENTIFIC EXPERIMENTS

Ma Henian (马鹤年) and *Tang Xu* (汤 绪)

China Meteorological Administration, Beijing 100081

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ABSTRACT

China lies in East-Asian monsoon region, which is one of the well-known active monsoon zones around the world. Monsoon anomaly results in frequent natural disasters, such as drought, torrential rain and flood. In 1998, joint intensified observations for 4 major meteorological scientific experiments have been carried out over Chinese major monsoon affected areas. A number of valuable data have been obtained and some observational facts have come out after initial analysis. The present paper is to give an introduction to the 4 major meteorological scientific experiments conducted in 1998 in China, including its origin and scientific goals, implementation and planning, equipment and progress, and initial findings from the important observational facts. It aims to provide a comprehensive report on the progress of the above experiments for those who are interested in.

Key words: South China Sea monsoon, Qinghai-Xizang (Tibetan) Plateau, Haihe River Basin, South China Area, meteorological experiment

I. INTRODUCTION

China lies in East-Asian monsoon region, which is one of the well-known active monsoon zones around the world. In China, frequent occurrence of natural disasters such as drought, torrential rain and flood causes serious damages to its national economy, property and people's life. In 1997 and 1998, China respectively witnessed extreme drought and flood. In particular in the summer of 1998, affected by El Nino and anomalous plateau perpetual snow, the atmospheric circulation is abnormal. The torrential rain systems frequently stayed both on the spatial and temporal scale over the Changjiang River Basin for long periods, and the Songhua River and Nenjiang River Basins, which gave rise to extreme floods. For this reason, it is a principal task for atmospheric science community to reinforce the study on the cause of formation of flood and drought in order to improve the capability of prediction.

II. ORIGIN OF THE FOUR MAJOR METEOROLOGICAL SCIENTIFIC EXPERIMENTS AND ITS SCIENTIC GOALS

1. *The Initialization and Implementation of the Experiments Are Aattributed to ever-Thorough Research on Atmospheric Science at Home and Aabroad*

(1) *South China Sea monsoon experiment (SCSMEX for short)*

Though over the two decades many large-scale scientific experiments related to monsoon have been conducted in the world, these experiments focus on India-Arabian Ocean and West and Mid Pacific at spatial scale and on the two extreme seasons (June—August and December—February) at time scale. Few of them pay attention to other monsoon regions and the changes of transitional seasons (April—May). In fact, the monsoon in the East-Asia region which neighbors in India and its adjacent sea area is very active, however, the answer to its outbreak and maintenance remains unknown. In this connection, the tenth Joint Working Session on the Sino-American Atmospheric Cooperation decided to sponsor the South China Sea Monsoon Experiment. Later on, based upon the consultation between the two sides, more countries such as Australia, Japan, the countries from ASEAN (Association of Southeast Asian Nations) gradually joined in it. In 1995, the scientific report on the South China Sea monsoon experiment was drafted out. In 1996, the project proposal "research on South China Sea experiment" which was used to apply for the National Climbing Project on Basic Science was formally submitted after deliberations and consultations. In October the same year, State Science and Technology Commission (the former of the State Science and Technology Ministry) officially approved the proposed project, under which China Meteorological Administration (CMA) served as the sponsoring body. Research Prof. Ding Yihui, Director-General of National Climate Center and Research Prof. Li Chongyin from Chinese Academy of Sciences were appointed as the chief scientists.

(2) *Second Qinghai-Xizang (Tibetan) Plateau scientific experiment*

China once organized the first Tibetan Plateau scientific experiment in 1979. The experiment has played important and positive role in the research on the impact of plateau surface layer's heat balance and plateau low pressure vortex on the precipitation in east part of China and the impact of plateau thermodynamic and dynamic activities on atmospheric circulation and climate. Nevertheless, due to the limit of condition and means of observation, the observation for and research on some important plateau physical processes were not adequate. For instance, with little knowledge of the characteristics of the boundary layer's structure, the structure of convective clouds and the plateau atmospheric radiation, it is much difficult to improve the part of atmospheric circulation numerical model involving the impact of plateau physics. It has become one of the most serious weaknesses in numerical prediction and greatly prevents the improvement of the capacity in climate prediction and severe weather forecasting. Consequently, CMA in 1992 initiated a proposal to conduct the second Tibetan Plateau Scientific Experiment, which was positively responded and supported by bodies concerned. In June 1993, after careful

review and deliberation by scientists, the project entitled "The observations and theoretical research on the physical process over Tibetan Plateau and its impact on global climate change and disastrous weather in China" (TIPEX for short) was applied for National Key Project on Fundamental Research. In May 1994, State Technology and Science Commission officially approved the proposed project, under which CMA acted as the sponsor and Chinese Academy of Sciences co-sponsor. The chief scientists are Academician Tao Shiyan from Institute of Atmospheric Physics, Chinese Academy of Sciences and Research Prof. Chen Lianshou from Chinese Academy of Meteorological Sciences.

(3) *Experiment and research on the torrential rain across the Taiwan Straits and its adjacent areas (HUAMEX for short)*

The sides of Taiwan Straits and its adjacent areas belong to important developed economic zones. In the area, the primary meteorological disasters are the pre-flood season torrential rains (May and June) generated from mesoscale weather process and torrential rain caused by typhoon (July and August). Research on mesoscale torrential rain requires more dense observational data on spatial and temporal scale. The unique geographical characteristic along with the relatively dense mesoscale monitoring network in this area constitutes a good place for field experiment, the meteorologists across the Straits in April 1994 began to negotiate the joint research on mesoscale torrential rain experiment. With the efforts of the meteorologists across the Straits and many workshops and meetings for experiment plan drafting, the early 1996 saw the duly completed project proposal entitled "The Experiment and Research on the Torrential Rain Across the Taiwan Straits and Its Adjacent Areas". The initiative aroused the favorable response and support of the meteorological services and universities over Taiwan, Hong Kong and Macau. In October 1996, State Science and Technology Commission approved it as a supporting project of the National Ninth Five-Year Climbing Poject. Under the project, CMA is the sponsor, and Academician Zhou Xiuji from Chinese Academy of Meteorological Sciences the chief scientist.

(4) *The energy and water cycle experiment of the Huaihe River Basin (HUBEX for short)*

It is well known that in the early summer the precipitation in the East Asia closely relates to the Meiyu front on the north of the subtropical high. The torrential rain resulting from the disturbance of the Meiyu frontal mesoscale system usually causes serious floods and mudflows in the mountainous area, which directly influences the regional and local hydrological process. Study shows that the movement of Meiyu front is greatly influenced by the Asian monsoon, cold air from mid-latitude and subtropical high. In particular, the water vapor bands from the southeast monsoon and the southeast airflow of subtropical high send water vapor to the front, which supports the precipitation process. The front system plays an important role in the transportation of the energy and water vapor. In addition, the mesoscale cloud system is closely linked with the hydrological process of the land surface. However, most of the models at present can not be well qualified to simulate the system and forecast the relative precipitation. This is

mainly due to the lack of understanding of the small- and mesoscale system in the East-Asia Meiyu front and the relationship between the above-mentioned system and the Asian monsoon. Therefore, in order to better understand the energy and water cycle process of the multi-scale cloud systems in the Meiyu front and the interaction between the systems and hydrological process of the land surface, it is necessary to carry out the observational experiment in the Huaihe River Reaches, which is located in the subtropical high pressure zone and temperate zone, and boasts the developed hydrological system. In 1991, the scientists from China and Japan initiated to establish the Committee on GAME/HUBEX and made a proposal on the joint observation and scientific research, which made the experiment be an integrated and important part of the GEWEX. In January 1996 the proposal "The experiment on the energy and water cycle in Huaihe River Basin" was submitted to the National Natural Science Foundation of China and was approved as a key project in January 1997. Perking University is the sponsor and Academician Zhao Bolin the chief scientist.

Among the four experiments, the priority of the HUAMX is on the mesoscale weather system, and the other three are on the fields of climate. From the point of the atmospheric science, the four experiments are actually inter-linked. SCSMEX and TIPEX provide a large-size background field for HUAMEX and HUBEX, while the latter two are intended to study on the effect of mesoscale system of Meiyu front and on the interaction of multi-scale systems. In order to bring their benefits as a whole into play, proposed by CMA and with the approval of the principal scientists, it was decided to conduct the concerted intensified observations and share the related observational data in order that the four major experiments become an organic whole in time and space and the data obtained could play a more important role in the future scientific research. We therefore refer them as the "Four Major Meteorological Scientific Experiments" (4-Experiments for short).

2. *Scientific Goals and Priority of* 4-*Experiments*

In general, it can be summarized as the following three points.

(1) Large quantity of the first hand new and dense data will be collected through the organization of the large-scale field observational experiments by the use of a large number of advanced high tech instruments and equipment.

(2) New facts will be discovered and the laws governing the atmospheric motions will be brought to light on the basis of data analysis and numerical modeling. Concretely speaking, the research will be mainly in the following four areas:

- The impact of Tibetan Plateau on the global climate, especially on the Asian monsoon and the severe weather in China.
- The revelation of the mechanism and laws of the summer monsoon activities in the South China Sea and the research on its interactions with the East-Asian and global atmospheric circulation and its impact on the drought and flood in China.
- The research on the energy and hydrological process on multi-scale rain system in Meiyu season and the development of climate modeling.
- The monitoring of the mesoscale structure and its evolution of the frontal torrential rains in South China and the landing typhoon systems to find out the laws governing the

generation and development of the mesoscale meteorological system.

(3) Global, regional and mesoscale meteorological modeling will be improved through comprehensive studies and new forecast concept will be proposed so as to enhance our capabilities of predicting global change and severe weather and climate in China.

III. THE ORIGANIZATION AND CHARACTERISTICS OF 4-EXPERIMENTS

1. *Great Scale*

The 4-Experiments are the largest comprehensive atmospheric-oceanic-hydrological experiment that is conducted primarily by China in its history. During the period of the experiments, 107 upper-air stations involved the intensified observation of 4 times per day. 528 surface stations carried out the observations of 24 times per day. 27 weather radars were employed to real time monitoring, and 7 vessels participated in the fixed-point observation and cruising observation. According to general statistics, more than 6000 scientific personnel attended the experiments. Among them, there are 5 academicians, over 600 scientific research personnel. The young scientific research personnel account for half.

2. *Extensive Observational Scope*

The observations cover the area extending to the Indonesian coast south of the equator in the south, the Huanghe River Reaches about 40°N in the north, the Tibetan Plateau and the adjacent India Sub-continent in the west and the Pacific Ocean in the east. It almost covers all the provinces, South China Sea area and some areas of Southeast Asia (see Fig. 1).

3. *Large Number of Participating Countries and Regions*

Chinese atmospheric community is the main body of the large-size regional joint experiment, and scientists from mainland paid a lot of efforts to the experiments. In the meantime, the scientists from Taiwan, Hong Kong and Macau were active in the experiment. In addition, scientists from USA, Australia, Japan, Republic of Korea, Vietnam, Malaysia, Philippine, Indonesia, Thailand, Singapore and Brunei also attended the experiment.

4. *Advanced Equipment*

In the experiment, the advanced equipment constitutes a three-dimensional intensified observational system, namely a land-sea-air integrated observational field. According to the general statistics by experts, the observational data of the 4-Experiments reach 40—50 GB. The equipment includes the following:

- Meteorological satellite: FY-2, TRMM, GMS, NOAA;
- Radar: Doppler weather radar, digital weather radar, wind-profiler, ISS system
- Aerosonde, ISS system, GPS sounding system;
- Boundary-layer observing instruments, meteorological gradient instrumentation tower and automatic weather station;

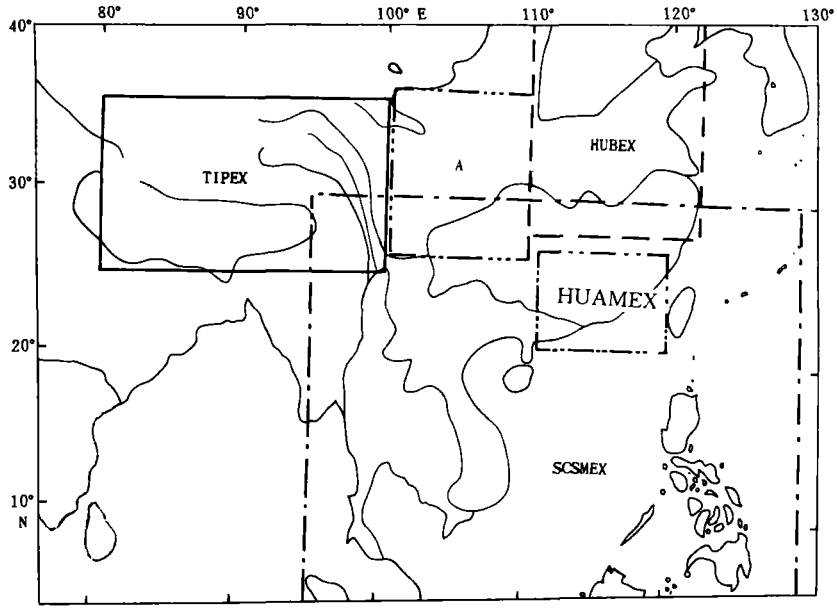

Fig. 1. Observational scope for 4-Experiments.

• Ocean observing instrument: large-scale buoy, airborne XBT (expendable bathythermograph).

5. *Reflection of the cross-Disciplinary and Comprehensive Nature of Fundamental Research*

Aiming at the studies of the monsoon activities and the severe weather and climate that are associated with them, the 4-Experiments will not only study the laws of the atmospheric motions but also the interactions between the land and the atmosphere, especially the interactions between the Tibetan Plateau with an average height of more than 4000 m above sea level and the atmosphere, the interactions between the ocean and the atmosphere (especially between the South China Sea and the atmosphere) as well as the interactions of the ocean-land-atmosphere. The studies involve the land-surface process, hydrological process, ocean circulation, and the exchange between energy and water.

6. *Bringing about* 4 *Separate IOPs (Intensive Observational Period) for the Experiments as One*

After careful consideration by experts and with the coordination and organization of the State Science and Technology Ministry, the China Meteorological Administration and other agencies, it was decided to conduct the joint intensified observations during the period from early May to late August 1998. In fact, the coordination of the four major experiments, in particular the coordination of the observations is a very tough task. In this connection, Administrator of CMA takes charge of the general coordinator for the experiments so as to reinforce the coordination. In addition to coordination meeting of the four major experiments, the coordination meetings for the Directors-General and Directors of the Operational Division from the provincial weather services concerned were held many

times. Furthermore, careful coordination on many aspects such as transportation, maintenance and standardization of the equipment, allocation of the human resources, the decision on the data-sharing, data format and disseminating in order to ensure the success of the experiment.

7. *Great Contribution to Global Atmospheric Research*

The four major experiments together with other regional experiments (such as GAME) constitute a large inter-linked and research program on atmospheric science. It is a part of the recent international atmospheric scientific research experiments. Due to the contribution of China to the international atmospheric science, the Panel on GEWEX agreed to hold the Third International Conference on GEWEX in 1999 in China.

IV. RESEARCH PROGRAM AND PROGRESS OF THE EXPERIMENS

1. *Tibetan Plateau Scientific Experiment (TIPEX)*

According to the overall design, a cross section shaped observational network extending to the four directions with Nagqu as the center was established in the Tibetan Autonomous Region. Three observational bases were set up in Gerze, Damxung and Qamdo in the west, central and east part of the region respectively to monitor land-atmospheric processes. During the intensified observational period (IOP) from May to August 1998, special observational programs were implemented. The scope of the experiment involves Tibet, Qinghai and Sichuan. 11 upper-air sounding stations (6—8 observations per day) and 12 surface stations (8—24 observations per day) participated in the experiment. For the first time in the west of the plateau were established two sounding stations in Gerze and Shiquanhe. The chosen observation stations and established bases represented the North-South and West-East sections, geographical difference and the situation of underlying surface over the plateau.

A series of advanced instruments and facilities, such as the fluxplate optical hyetograph, automatic temperature, humidity and wind acquisition system, Bowen ratio temperature and humidity measuring equipment, ultra-sonic anemometer thermometer, fluctuating thermometer, fluctuating hygronom, Doppler weather radar, captive balloon sounding system, long and short-wave radiation system, infrared water-vapor and CO_2 measuring system, and aerosol observing equipment have been used. There are all together five research topics, including the physical processes over the plateau and its parameterization, the impact of Tibetan Plateau on the global atmospheric circulation, the thermodynamic processes and hydrological cycle of the plateau and their impact on the monsoon circulation in Asia, the impact of the plateau physical processes on global climate change, and the impact of the plateau physical processes on the severe weather and climate.

To date, planned intensified conventional surface and upper-air observations (May—October) and the surface layer observations undertaken by three surface layer observation bases have been completed. The valuable data of the atmosphere and the cross-section shaped (see Fig. 2) land-atmosphere physical process are available now. Under the Sino-

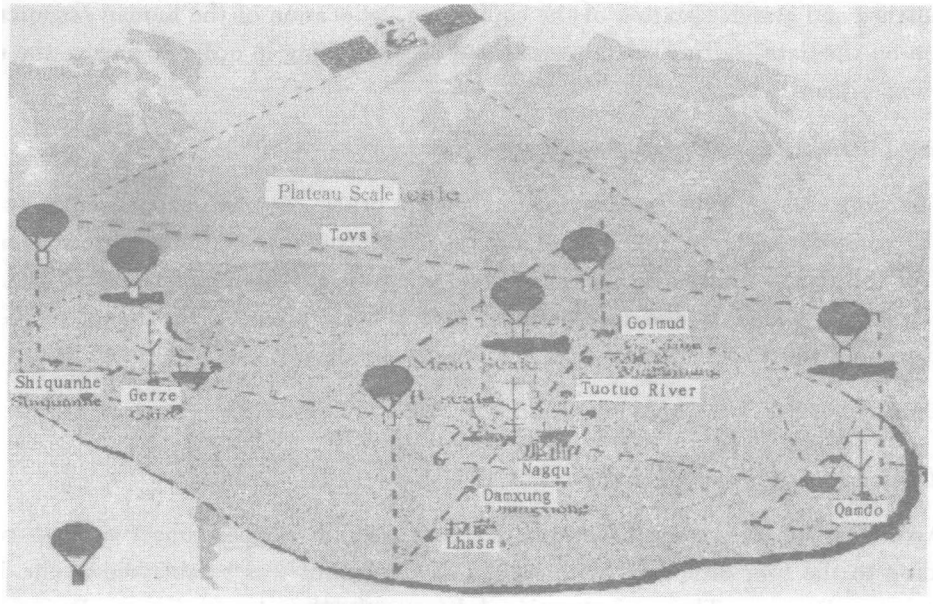

Fig. 2. Illustration for the north-south and east-west sections of the TIPEX.

Japanese Joint Coordination Committee on Plateau Experiment, extensive cooperation among this project, the Sino-Japanese Joint Research on Monsoon and the Japanese GAME projects were carried out. Japan also set up the surface layer observation stations in Amdo and Nagqu and carried out the same surface layer observations in the same period.

2. *The Research Program and Progress of South China Sea Monsoon Experiment*

The program is aimed at studying the large-scale atmospheric and oceanographic circulation related to the South China Sea monsoon and the four dimensional evolution of the thermal dynamic field, the role of monsoon in seasonal changes and in the evolution of the heating field as well as the impact of the early monsoon convection on the air-sea interactions. It also studies the mechanism of the generation and development of the synoptic-scale system and low frequency oscillation changes and their interactions in the South China Sea and the adjacent areas in order to improve monsoon and drought and flood forecast in East Asia. The intensified observations include observations by cruise vessels, meteorological aerosonde, intensified upper air sounding and surface observation, meteorological radar network, boundary layer observing system, and the satellite observing system. Island and sea-surface energy flux observations were conducted on Dongsha and Xisha Islands in South China Sea. Three moored ATLAS buoys and a number of drifting buoys were laid and distributed in the South China Sea by scientists from Taiwan. In addition, the US TOGA Radar and the Australian C-POL Radar network to observe the structure and microphysical characteristics of the convective system in the monsoon region. There is also an integrated sounding system (ISS) and two wind profilers (Hong Kong, China and Singapore) monitoring the evolution of the various main

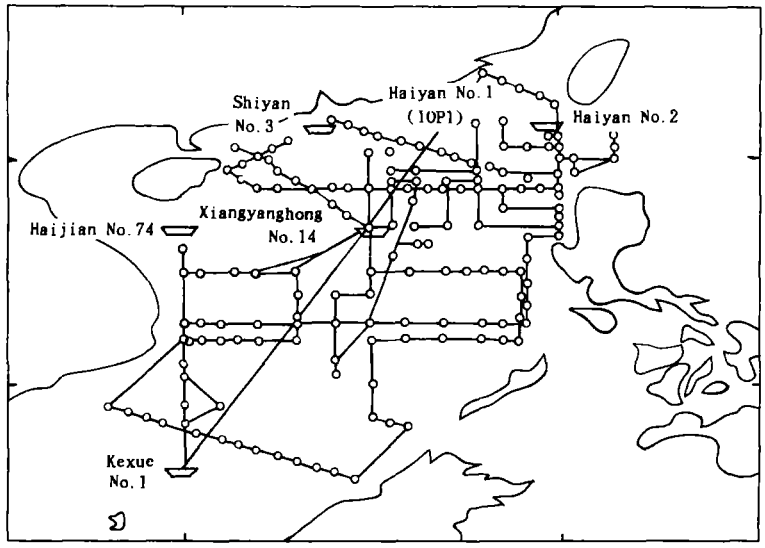

Fig. 3. The sea route of vessels for the SCSMEX.

atmospheric elements. The intensified field observations were accomplished on 25 June, which included two IOPs (5—25 May and 5—25 June). 66 upper-air stations attended the experiment, among those 33 stations carried out the observation of 4 times per day. Between the period of the two IOPs, 11 stations kept implementing the intensified observations. 237 surface stations participated in the experiment, among those 105 carried out 24 observations every day. Owing to the daul Doppler radar array in the north of South China Sea, the outbreak of monsoon and development process of convection were successfully observed. Other special observations were also reached its proposed goals. The observation of flux (Xisha) provides reliable data for the further research on ocean-atmosphere momentum and the exchange between latent heat and sensible heat. In addition, the following observations have been accomplished: aerosonde observations (Taiwan has taken 19 flights over Dongsha, and Mainland 6 flights over Luoding), and oceanic meteorological observation by vessels (see Fig. 3). However, during the IOP, some vessels were hit upon the harassment and some buoys were intentionally damaged, which caused the deficiency in the observational data.

3. *The Experiment and Research on the Torrential Rain across the Taiwan Straits and Its Adjacent Areas (HUAMEX)*

The experiment aims at studying the laws governing the generation and evolution of the mesoscale torrential rain system and furthering the theoretical research on the mesoscale severe weather system so as to effectively improve the mesoscale numerical weather prediction models and the mesoscale severe weather monitoring through field experiment and the numerical modeling. It is also expected to optimize and develop the mesoscale meteorological operational system (including observations, analysis and prediction) in order to improve the short range torrential rain forecast, mitigate the economic losses and promote the regional economic development. The experiment takes

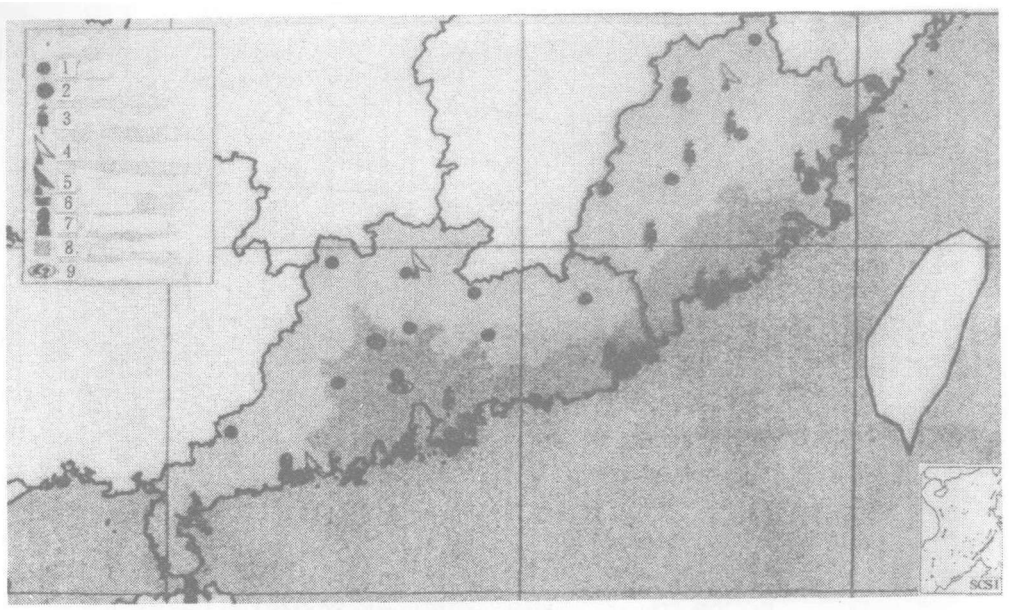

Fig. 4. The IOP area of the HUBEX.

the South China Sea Monsoon Experiment that is being conducted concurrently as the large-scale background field. The intensified observations mainly involve Guangdong, Fujian, Hong Kong and Macau (see Fig. 4). Six upper-air stations (6—8 times/day) and 38 surface stations (8—24 times/day) were involved in atmospheric observation. With respect to specialized observation, 3 Doppler radars, 3 conventional radars, 2 wind profilers, 6 lightning detection systems, and 3 GPS systems were recruited. Through consultation with scientists across the Taiwan Straits, exchanges and cooperation will be carried out in the form of cooperative research on torrential rain cases. It is expected that the experiment will play an active role in promoting the research and operational development in the field of mesoscale meteorological disasters. At present, intensified observations for frontal torrential rain have been smoothly accomplished. From 13 May to 25 June, field intensified observations for 8 torrential rain cases were successfully implemented. In addition, 7 upper-air stations, 24 intensified surface stations, over 300 automatic weather stations and 7 weather radars (including 4 Doppler radars) in Taiwan area were implemented on intensified observation simultaneously for the torrential rain.

4. *Research Program and Progress of the Energy and Water Cycle Experiment of the Huaihe River Basin*

The research program deals with cloud and radiation and their interactions along the Huaihe River Basin, the land process and the land-air interaction in the Huaihe River Basin, and the relationship between the energy and water cycle along the Huaihe River Basin and the regional climate. There are 16 provinces in the east of China involving in the experiment. The scope of the experiment is divided into the following parts: meso-α scale observation area (1200 km×1500 km); meso-β scale observation area (700 km×500 km); meso-γ scale observational area (140 km×150 km); and a key hydrological observation

area (5930 km^2), which is a relatively closed area representative for the study of the mountain flood. At the same time, an integrated observation base was established in Shouxian, Anhui Province. Meso-β and meso-α scale observation areas are located in the periphery of the meso-γ experimental area which provides convenience for the coordination of the multi-scale researches. The specialized observations mainly include boundary layer tower observing system, surface daul-channel microwave radiometer observations, sophisticated radiation observing system, Bowen ratio and eddy correlation observation, rain drop collector, fluctuating thermohygrometer, portable automatic meteorological observation stations, recording water-stage, soil water level recorder, hydrological and flow observing system and mobile surface flux observing system. The experiment is not only a key project of the National Natural Science Foundation of China, but also a sub-program of the HUBEX/GAME. At present, the experiment has mastered the comparatively strong mesoscale torrential rain processes in the different weather situations, including the front, the flourishing and the end of the Meiyu. It provides valuable data for the study on the process of precipitation, energy and water cycle of mesoscale Meiyu frontal clouds. These data are as follows:

- Surface stations: 150 stations, 10 June —22 July, 24 times per day;
- Upper-air stations: 36 stations, 11 June—23 July, 4 times per day;
- Radar: 4 stations in Jiangsu, 25 May—20 July;
  1 station in Anhui, 25 May—31 July;
  3 Doppler radars 4 June—20 July.

Hydorological observational data are from 1 May to 31 August.

V. INITIAL ANALYSIS RESULTS AND FOLLOW-UP ACTIVITIES OF THE EXPERIMENTS

The outcomes of the initial analysis are as follows:

- Both the intensity and depth of the convention movement in the plateau are beyond our previous knowledge.
- By means of observations, the characteristic and complexity of the structure of plateau atmospheric layer are further discovered.
- By means of conventional observational methodology and instrument, it is found out that the intensity of instant atmospheric radiation is greater than the solar constant in the case of the cumulus congestus.
- Fortunately master the processes which greatly influence the torrential rain processes in China, including the outbreak of China South Sea Experiment, pre-flooding in South China, Meiyu (27 June—4 July) and second Meiyu period (17 July—7 August).
- For the first time, it is found that there are the strong convention systems such as South China Sea tropical squall line and water tornado.
- It is initially come out that the Meiyu torrential rain in Huaihe River Basin is caused by the interaction of multi-scale systems. In particular, the meso-β scale plays an important role.

The follow-up activities for the experiments are:

- Timely collect, sort, archive and analyze the field observational data, and organize specific scientific research.

• Set down and complete the regulation on the data management and exchange to ensure the release and exchange of data in order.

• Organize related academic activities: (a) Organizing the activities on academic exchange, such as International Workshop on Plateau Atmospheric Science and Seminar across Taiwan Straits on Torrential Rain; (b) Assisting World Meteorological Organization (WMO) in the sponsorship of the third International Scientific Conference on Global Energy and Water Cycle Experiment.

• Organize conferences on scientific achievements and experience exchange in four major scientific experiments, summarizing the latest achievements in the four major experiments.

Acknowledgement: The preparation and successful implementation of the four major meteorological experiments contribute to the strong support of the large number of scientists from participating countries and areas. Positive co-operation is the key issue and basis for the success of the experiments. Taking this opportunity, we wish to give our special thanks to the scientists from various fields. With respect to the domestic co-ordination, we would like to express our special appreciation to the State Science and Technology Ministry and the scientists from Chinese Academy of Sciences and from universities for their strong support to the co-ordination and organization work of CMA.