# The South China Sea Monsoon Experiment (SCSMEX) Implementation Plan

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ABSTRACT

The South China Sea monsoon is not only a main component of Asian monsoon system, but also plays an important role in the weather and climate over the surrounding areas and the globe. However, because of the insufficient observation data, it is self evident that the large-scale field experiment over SCS is very important to deepen understanding East Asian monsoon. In this paper, the composite experiment, modelling and data assimilation, especially the atmospheric observation, oceanic observation, air-sea interface observational network as well as satellite observation are introduced in detail.

**Key words**: SCSMEX, Implementation, Plan

## I. INTRODUCTION

It is well known that the South China Sea monsoon is not only a main component of Asian monsoon system, but also plays an important role in the weather and climate over the surrounding areas and the globe. However, the dearth of observation in the South China Sea is one of the main obstacles for the studies of related physical processes. The current observation network is far from enough to research of many scientific problems. Scientific problems about SCS monsoon, e.g., the onset of summer monsoon, the local and moving disturbance effects, large-scale moisture transport and rainbelt movement and the air-sea interaction over the South China Sea, have not been solved because of the dearth of observation data.

The moisture source needed for the persistent development of East Asian monsoon is basically provided in SCS. However, because of the insufficient observation data, the monsoon moisture source over East Asia, especially over SCS and its southern part, is still not known clearly. Hence a liable observation network needs to be established over SCS and its neighboring areas to study the different downstream effects in monsoon onset and monsoon surge period on the development of streamline flow of the SCS monsoon. The effects of different moisture sources on East Asian monsoon can be studied thereby.

In addition, the frequently observed weather system is mid-level tropospheric cyclone (MTC) and monsoon depression (MD). The MTC over SCS is often accompanied with large-scale precipitation. Although we have already had some understandings of MTC, many aspects are still not well known, including its structure, dynamic features, its dependence on the large-scale system and the vertical distribution of convective heating reesulting from diurnal variation, sensible heat, latent heat and radiation. Moreover some viewpoints and theories about the mechanism of successive outburst of monsoon have been put forward, e.g.,

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the effects of sea surface temperature, tropical forcing, the triggering action of mid-latitudes and differential heating, but it is still a puzzle which mechanism is the most important. The final solution of these problems depends on the implementation of observation experiment.

Furthermore, sea-air interaction may determine the onset of SCS monsoon. Which physical processes determine the seasonal variation of SCS sea surface temperature and surface fluxes? Why does the warm SST persist after the monsoon onset? What are the important effects of this persistent warming on monsoon circulation via sea-air interaction? What is the feedback of monsoon circulation to SST? What is the interaction in the complicated feedback processes related to cloud, radiation forcing, evaporation cooling, sea water mixing and advection?

Briefly, in order to solve the problems above mentioned, we need new upper-air, surface and ocean observation data to provide answers to the problems of monsoon over SCS and East Asia. This is the main scientific motivation of SCSMEX. Thus, it is self evident that the large-scale field experiment over SCS is very important to deepen the understanding of East Asian monsoon.

In summary, the main aim of SCSMEX is: the especial observation data from field experiment of summer monsoon over SCS and its neighboring areas and related history data are to be used to study systematically the main features of atmosphere and ocean in monsoon onset and activity over SCS and its neighboring areas, to develop the understanding of East Asian monsoon mechanism and variation, and eventually to increase our forecasting capability of monsoon.

## II. COMPOSITE EXPERIMENT DESIGN OF SCSMEX

Climatologically, SCS is the region where the monsoon precipitation takes place earliest in the whole Asian monsoon system. The establishment of convection over SCS and its neighboring areas in mid-May indicates the onset of Asian summer monsoon. Thereafter the onset process propagates to the west boundary of Indian Ocean westward. In mid-June the onset of monsoon jumps to the middle and lower reaches of the Yangtze River and Meiyu begins. Thus the SCS monsoon can be regarded as the original source of Asian monsoon. From an oceanographic standpoint, SCS has the largest tropical semi-close sea area. Since its eastern and southern boundary opens, there must be large amount of sea water exchange occurring between the western Pacific Ocean, the East China Sea and the Indian Ocean. The degree of sea water exchange determines the coupling between SCS and main tropical ocean and can play an important role in interannual climate variation. Thus, SCSMEX will be paid more attention on the onset of large-scale monsoon circulation system and convection system over SCS, as well as the interannual variation of their coupling with sea-air coupled system.

Taking account into these facts, the planned SCSMEX area will be selected within 30°N-10°S, 95°E-130°E, shown as the small region in Fig. 1. The larger region in this figure is large-scale research area where the routine observation data will be collected.

SCSMEX will be divided into three phases, i.e., pilot study stage, field experiment phase and numerical simulation and data assimilation phase. They will be discussed in following three sections in detail.

## III. THE PILOT STUDY PHASE

The pilot study phase of SCSMEX will be 1996-1997. During this stage the pre-arrangement of observation platform will be conducted and the feasibility of observation program will be tested by diagnosis and numerical simulation methods. The main aims of this phase are to:

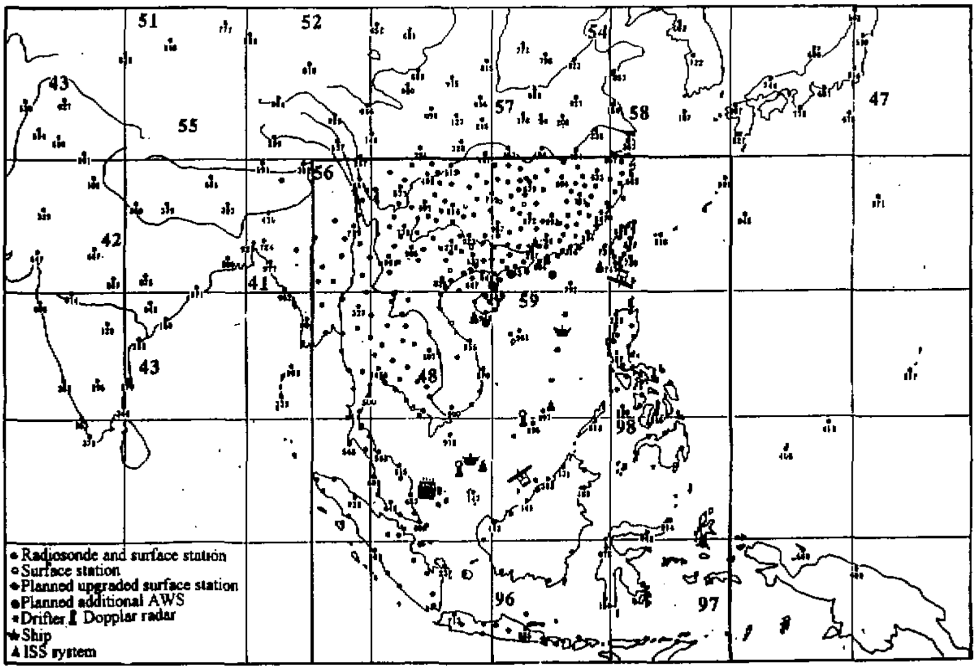


Fig. 1. SCSMEX Observational Network.

(1) Conduct observational studies to document the climatology of SCS wind, temperature and moisture fields from mid–spring to summer based on existing operational observation stations and satellite observations; conduct the climatological analyses of its onset and intensive period; study the condition of SCS onset and conduct the experimental medium– and long–range forecast of monsoon onset.

(2) Carry out preliminary diagnostic studies using new platforms that are scheduled for implementation during 1996–1997 in conjunction with data available from PRC through existing bilateral agreement.

(3) Test the reasonability and scientific level of observation programs, including the international coordination of all kinds of observation platform and the data communication, collection and processing programs.

(4) Provide continuous enhanced monitoring at selected sites over the SCS, test and debug the operations of newly installed or enhanced stations or platforms.

(5) Conduct the development studies of four–dimensional assimilation system using low–latitude data before 1997, especially the TOGA–COARE data set.

At the pilot phase China will launch FY–2 geostationary satellite which will fix at equatorial 105°E. Nansha upper–air sounding station will be upgraded(10.5°N, 115°E). These two new observation platforms will firstly provide the direct observation data over the central South China Sea and can be able to modify the wind field analysis to a great extent especially at the heights of cloud top (250 hPa) and cloud base (900 hPa).

## IV. THE FIELD EXPERIMENT PHASE

The field experiment of SCSMEX covers the period from April 15 to August 31 1998, including enhanced monitoring(EM) and intensive observation(IOP). During the field experiment phase, large amount of atmospheric and oceanic platforms and satellite remote sensing will be used to conduct special observation. Two IOPs are planned: first 10 days of May to the last 10 days of May, and early June to mid-June. The first IOP will last approximately fifteen days to monitor the monsoon variation around the onset of the summer monsoon over SCS. The other IOP will last also fifteen days to monitor the atmospheric and oceanic conditions over the SCS during the intensive stage of East Asian monsoon. The SCSMEX will be coordinated with HUBEX of GAME, TIPEX and TRMM. The observation of these experiments will supplement to each other.

The field experiment will consist of atmospheric observation, oceanic observation, sea–air interface observation and satellite observation.

### 1. *Atmospheric Observation*

The main aim of atmospheric observation is to

- Describe the features of large–scale circulation and thermal field over SCS and its seasonal variation, including detailed surface wind field, temperature and their relation with planetary scale atmosphere, along with the relation between SCS monsoon and El Nino.
- Determine the thermal difference between SCS and its neighboring areas, heat source and sink around SCS, different large–scale heating and its effects on the abrupt outburst of SCS monsoon.
- Determine the effects of early monsoon convection (April to May) and multi–scale processes on the abrupt movement and the following variation of East Asian monsoon, in conjunction with the mechanism and structure of the sudden onset of monsoon.
- Describe the relation among heat, moisture and momentum fluxes at the sea–air interface; clarify the connection between atmospheric phenomenon over SCS and the conversion of dynamics and thermodynamics of the upper level ocean structure.
- Describe the physical processes within the response of SCS to monsoon forcing and the physical features of sea–air interaction.
- Apply the above research results to improve the capability of regional and global models in simulation and prediction of the monsoon onset over Southeast Asia and South China.

The atmospheric observation of SCSMEX will consist of such observation platforms as upper–air sounding, integrated sounding system(ISS), surface meteorological observation, ship–based and land–based radar, buoy array, unmaned aircraft (aerosonde) and satellite remote sensing et al. The main observation elements are: wind, temperature, moisture, precipitation, cloud amount (convection), pressure, surface radiation, flux and sea surface temperature et al. (see Table 1). The observation of these elements is to meet the need of analyzing basic observation fields over monsoon region and calculating the heating profile, apparent heat source and moisture sink (Q1 and Q2), moist static energy (QE), moisture convergence / divergence, latent heat and sensible heat flux, and other thermodynamical quantities, in order to reveal the temporal and spatial distribution of dynamic and thermal processes in large–scale monitoring region and to describe the relation between multi–scale motions and large–scale circulation in the SCSMEX area.

**Table 1.** An Overview of the Atmospheric Observation System

| Observation element | Observation platform | Observational phenomenon (processes) |
|---|---|---|
| upper-level meteorological elements (geopotential height, temperature, pressure, moisture and wind, et al.) | radiosonde system, ISS, satellite remote sensing, ship, island and autonomous aircraft | tropical rotational and divergent wind, tropospheric middle-level cyclone, moisture and energy cycle |
| precipitation | satellite remote sensing, precipitation station, radar, buoy | precipitation distribution pattern, differential heating |
| surface meteorological elements | surface station, drifting or mooring buoy, ship and island | El Nino, intraseasonal oscillation and monsoon low depression |
| cloud and convection | radar, satellite, ISS and observation array formed by ships | convective heating, moisture and energy cycle |
| sea surface wind / wind stress | coastal and island routine observation station, special station, mooring buoy and satellite remote sensing | seasonal variability, air-sea interaction and low frequency anomaly of wind field |
| radiation (long-wave and short wave) | surface station and satellite remote sensing | sea surface heat balance and sea-air interaction |
| sea surface flux (momentum, sensible heat and latent heat) | iron tower, island station and ship | sea-air interaction, El Nino |
| sea surface temperature (at the height of 10 m) | buoy array, satellite remote sensing, island station and ship | pattern of sea surface temperature, sea-air interaction and El Nino |

(1) Upper-air Sounding Network

Seventy-five upper-air stations, four research ships, three to five aerosondes and four autonomous Integrated Sounding Systems (ISS) are planned to participate in the atmospheric sounding in the enhanced monitoring areas (see Fig. 1), among which the current eighteen routine observation stations along the Chinese coastal area of South China Sea will upgrade their observation to four times a day from twice a day during the intensive observation period. One new temporary sounding stations (Yongshujiao and Taipingdao) will be installed in the Nansha area (for detail see Table 3.1). ISSs are to be installed near Hengchun or Kenxi at the south tip of Taiwan, Hainan Island along with observation ships or islands. Two fixed-point observation ships will also conduct sounding observation. The above-mentioned kinds of station and observation platform will form dense atmospheric sounding network during the SCSMEX enhanced and intensive observation period to provide a full upper-air sounding data over the South China Sea together with the northern and southern inner sounding arrays (ISA).

(2) Surface Observation Network

The routine surface stations are located in the upper-air observation stations, national basic stations and reference stations. Within the experimental area 407 surface stations will participate in the surface observation. The observation will be conducted eight times a day during the intensive observation period when 41 reference stations (24 times a day), 14 upgraded stations (24 times a day from 4 or 8 times) in south mainland China, three reference stations and 4 upgraded stations in Taiwan, and totally 33 reference stations and 13 upgraded stations in the surrounding countries will participate in the SCSMEX intensive observation. Four research ships, mooring buoys and three ATLAS mooring buoys will provide sea surface meteorological data (Fig.1). Meanwhile, observation data from the other surface stations and commercial ship observation data crossing the South China Sea received by the GTS at National Meteorological Center will be included in the surface data bank to supplement the insufficient data in some regions. Additionally, several surface automatic weather stations (AWS) will be installed to observe continuously temperature, pressure, moisture and wind, et al.

(3) Radar Observation Network

Land–based and ship–based Doppler radar will provide the information about the propagation and variation of organized convection during the IOP, which can be used for the estimation of momentum flux and vertical distribution of latent heat, the discrimination of convective precipitation and stratus precipitation. It will also provide the important information about the land conditions for the TRMM satellite. A TOGA Doppler radar system is planned to be mounted on Shiyan#3 and another Australian Doppler radar is planned to be installed on Yongshujiao. Additionally during IOP, the routine meteorological radars (40) in coastal area of South China and surrounding countries and the four meteorological radars in plan (Gaoxiong, Dongsha, Ranai, Puerto Princesa, Fig. 4.1) will also provide the supplemental precipitation observation over the islands and coastal areas in the experiment area. During IOP large quantities of optical and tilting bucket raingauges will be installed on ships to provide precipitation amount over the South China Sea along with TRMM.

(4) Aircraft Sounding

Three to five aerosondes will be scheduled to conduct routine upper–air observation over South China Sea. During IOP they will fly continuously to monitor the condition change before and during the onset of monsoon, as well as the continuous variation of monsoon rainbelt. The sounding observation crossing the SCS from northeast to southwest at the boundary layer of one kilometer and in the fixed points in SCS at the height lower than five kilometer will be possible.

(5) ISS Integrated Sounding System

In addition to the two wind profilers of Hongkong observatory, four additional ISSs will be used. The ISSs consist of UHF wind profiler, OMEGA sounding carried by balloon, RASS system for thermal profile sounding and surface meteorological observation. They will be installed around Hengchun or Kending at the south end of Taiwan Hainan Island and a research ship to monitor the abrupt onset of SCS monsoon and provide the observation data, such as moisture convergence and precipitation time series, together with satellite and radar sounding network.

(6) Cloud and Radiation Observation System

The radiation observation mainly will be focused on observation of the components of radiation balance, including the observation of total radiation, reflected radiation, upward and downward surface long–wave radiation. Currently research on the effects of surface radiation flux, thermal vertical profile and the interaction of multi–scale aspects of cloud and radiation is still lacking. SCSMEX will enhance the observation of these aspects during the observation period. There will be 25 routine radiation observation stations along the coastal South China and 28 radiation stations in surrounding countries and regions. Xisha will be one of the important radiation observation stations, where the sunphotometer and lidar observation is being planned to be added in addition to the routine radiation observation. If it is possible, the solar spectral radiation and long–wave observation in island stations, some coastal stations and on ship are recommended to increase. Moreover, the satellite data from geostationary satellite and other satellites will be fully used to derive the information of cloud and earth radiation to enhance the surface observation of cloud amount, height and form.

2. *Oceanic Observation*

The objectives of the oceanic observation are:

- To describe and document the space–time evolution of the basic oceanic flow patterns and thermohaline structures associated with the SCS monsoon, particularly, the space–time structure of sea–surface temperature (SST) and sea–surface salinity (SSS) in the SCS;
- To determine the processes which contribute to SST and SSS variability on time scale of days to months to years in SCS;
- To determine how the upper oceanic current and temperatures in the SCS respond to the monsoon wind forcing and what the important feedback mechanisms are;
- To determine how mixing of heat, salt, and momentum occurs in the SCS;
- To determine the physical nature of the air–sea interaction over the SCS and the variability of the net mass, heat, and salt flux into the SCS.

*(i) Intensive Observation*

The space–time structures of SST and SSS, and the physical processes that determine them, are the principal focus of the oceanographic component during IOP. Observation will be divided into three spatial scales: (1) large–scale (zonal and meridional scales of 1000 km and 200 km); (2) intermediate–scale (spatial scale of 25 km to 200 km); and (3) small–scale (spatial scale less than 1 km to 25 km).

The oceanic observational platforms being considered for SCSMEX include islands, shipboard measurements, drifters, mooring and buoys(see Table 2). During the IOPs, four shipboard measurements will be separately located. There are two options which may be considered(see Fig. 2). The research vessels should be equipped with instruments for the upper ocean temperature, salinity, velocity, and surface flux measurements. During the IOPs, all the above oceanic measurements will be coordinated with atmospheric measurements in order to understand the SCS upper oceanic variation and its interaction to monsoon before and after the abrupt transition of monsoon.

(1) Thermohaline Structure and Turbulence Measurement

To obtain the most effective time series for thermohaline structure and turbulence measurement, the R / V ships will profile continuously within a few miles of one of the central moorings. Profiling CTD and ADCP will measure temperature, electrical conductivity, thermohaline fine–structure, and velocity fine–structure. These data will be used to estimate the buoyancy frequency, vertical scale of turbulent overturning, the diffusive dissipation rate for temperature fluctuations, and the viscosity. To measure vertical shear, the ship will also profile continuously with a 150 kHz or 300 kHz high–resolution ADCP. It should obtain good data to at least 300 m, which will be the maximum depth for the thermocline and the subsurface salinity maximum. The R / V ships should be equipped to measure meteorological fluxes in the lower boundary layer of the atmosphere.

**Table 2.** Outline of Oceanic Observational System

| Observational Elements | Observational Device(System) | Observational Phenomenon (Process) |
|---|---|---|
| Sea surface height | tidegage station, moored temperature sensors, shipboard measurements, ATLAS moored array | thermocline variation, sea surface relief, surface ocean current, wind forcing response and baroclinic process |
| sub–surface sea temperature | drifter array, satellite remote sensor, XBTs | SST distribution type, cold–heat source variation in the ocean |
| sea salinity | oceanographic vessel, XTBs, CTD | density variation in sea water, stratified level and upwelling |
| sea current speed for sea surface and sub–surface | drifter, ADCP, moored current–meter | sea surface and sub–surface sea current motion |
| SST | ship observation, drifter, satellite remote sensor, CTD | abnormal events of sea current, upwelling |

(2) Moored Array

The moored array (3 ATLAS drifters to be planned) in the IOPs is collocated with the intensive flux array in the atmosphere, centered near the middle point between the Dongsha Island and the Yongshujiao. The concentration of moorings is under the atmospheric region which will have the highest resolution in space and time of air–sea flux information. This is needed to assess the response of the upper ocean to strong buoyancy forcing, including the modulation of turbulent mixing by variation in the relative strengths of mechanical and buoyancy forcing. The IOPs moored array is designed to observe responses at scale which provide a context for direct observation of mixing during the IOPs. On these intermediate scales, we expect to resolve frontal variability and response to mesoscale atmospheric disturbances such as individual members of cloud superclusters over the SCS. Vertical advection in response to both local and remote equatorial–wave forcing can be estimated on these scales. The intermediate–scale moored array is sited within the region of potential dual–Doppler radar coverage in the IFA. If ship–based dual–Doppler measurements are successful, they will occur in two areas about 100 squared km square. Within one of these region, a nested array of moored elements will be deployed, each separated by 25 km. Most of the mixing measurements in SCSMEX will be in the immediate vicinity of the most finely separated moored array elements.

(3) Shipboard Surveys

During the IOPs, shipboard survey with 2 vessels (see Fig. 2) will be conducted to obtain

Option-A

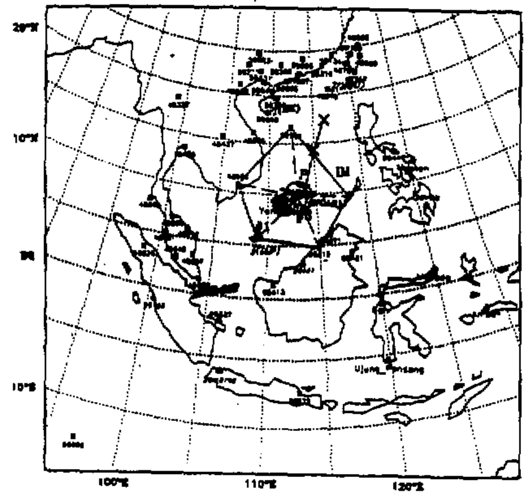

Fig. 2(a). Tentative upper air sounding network for SCSMEX showing locations of stations for Category 1(■), Category 2 (●) and Category 3(▲). Approximate locations of ships ( ) and the FY-2 Geostationary satellite ( ) are also included. I: ISS, O: TOGA RADAR, ●: BMRC RADAR, P: NCAR profiler, X: ATLAS mooring, IM: IMET Buoy.

Option-B

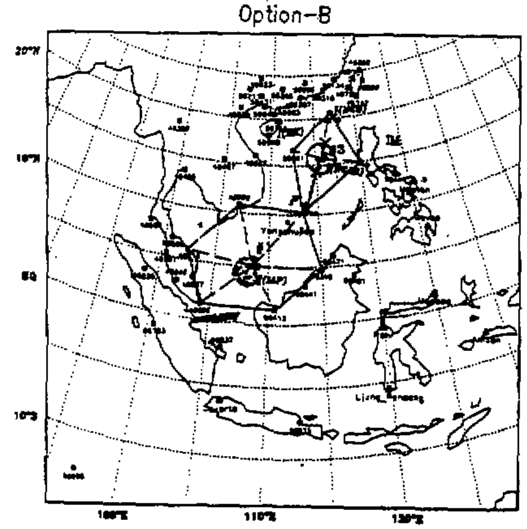

Fig. 2(b). Tentative upper air sounding network for SCSMEX showing locations of stations for Category 1(■), Category 2 (●), and Category 3(▲). Approximate locations of ships ( ) and the FY-2 Geostationary satellite ( ) are also included. I: ISS, O: TOGA RADAR, ●: BMRC RADAR, P: NCAR profiler, X: ATLAS mooring, IM: IMET Buoy.

time series temperature, salinity and horizontal velocity in the upper layer. The thus obtained data will be used to determine the spatial structure, statistical variability and temporal evolution of these fields. The data will also be used, together with the mooring data, to construct near–synoptic maps of the IOP. The survey data will provide spatial resolution on scales of an order of magnitude smaller than the minimum moored array element separation, and will provide spatial coverage at enhanced resolution on scale intermediate between the IOPs array and the enhanced monitoring array. Thus the ship survey will provide the high spatial resolution data needed to describe the horizontal gradient of these properties on a variety of scales. One survey ship is needed to cover as rapidly as possible the horizontal scales between about 1 and 25 km around the CTD profiling ship, measuring temperature, salinity, and horizontal velocity in the upper layer, and meteorological fluxes in the lower boundary of the atmospere.

The butterfly array is designed as an example of a possible survey pattern. The central cross of the butterfly pattern should be lined up with the central cross of the IOPs moorings. Ship track should be at least 2 km from moorings. The survey patterns need to include enclosed domains for calculating budgets and for modelling temporal changes of temperature and salinity along streamlines.

(4) Oceanic Cruising cross Observation

Three–time cruising cross observation should be required before and during the abrupt transition of monsoon and during the mature phase of monsoon in order to understand how the upper ocean current and temperatures in the SCS respond to the monsoon wind forcing. The combination of cruising and shipboard surveys could pledge to discriminate the upper oceanic response to monsoon forcing in different spatial–temporal scale and the evolution process between the relationship of upper ocean and monsoon.

(5) Drifting Buoys

Additional drifting–buoy deployments may be required during the IOPs to keep the population of drifters sufficiently dense within the IFA. Additional drifters, specifically serving the requirements of the IOP, should be buoyed at a depth of 5 m to augment the very sparse direct current measurements planned for the upper 10 meters. Time–series drifter deployments could be from either the survey ships or the stationary sounding ships. The combined mooring and drifter measurements are meant to provide a context of horizontal and vertical advective changes in upper–ocean properties within which mixing studies can be interpreted.

(6) Ancillary Observations

In addition to making measurements as part of the large–scale atmospheric array, the fine–structure ship(s) will also have a suite of sensors for near–surface measurements of the turbulent fluxes of moisture, sensible heat, and stress; of solar and infrared radiative fluxes; of precipitation; and of standard bulk parameters.

*(ii) Enhanced Monitoring Array (EMA)*

The Enhanced Monitoring Array (EMA) is intended to describe not only ocean response to large–scale meteorological forcing events but also, in combination with model data assimilation, the net lateral transports of mass, heat, and salt into the SCSMEX domain. These measurements will provide a context for understanding observations on intermediate scales. The planned elements of the oceanographic component of the EMA are:

- An enhanced version of the TOGA-TAO moored array;
- A regionally enhanced drifter array
- Enhanced R / V observation; and
- Satellite altimeter-scatterometry measurements

These elements of the EMA will be in place over the one-year period preceding (1997) and following (1999) the IOP.

3. *Air-sea Interface Observation*

Observations of the flux components on the air-sea interface are crucial for understanding the physical and thermodynamical exchange processes on the interface and air-sea flux exchanges over the open regions in the eastern and southern SCS, exploring the overall influence of the wind structures during SCS monsoon onset, development and decay stage on the air-sea exchanges of heat, moisture, radiation and momentum, and improving the empirical net surface heat flux estimation formulas suitable for the SCS region. The air-sea interface observation platforms being considered mainly include the shipboard measurement, buoys and moorings, satellite sensors and meteorological tower gradient observations.

(1) Shipboard Measurement

During the IOP, 4 vessels will be provided to form a polygon array to carry out shipboard observations. The observational instruments include radiometer (short and long wave), ocean temperature measurement instrument, humidometer, barometer, Doppler radar, tethered balloon, ultrasonic anemometer, optical raingauges and evaporation pans. At least one vessel should be equipped with direct flux measuring instrument (eddy correlation techniques). Oceanic cruises should be conducted prior to and after the IOPs to examine the air-sea flux exchange processes and response of the SCS upper ocean to wind forcing. During the IOP, observations of radiation, ocean temperature, wind velocity, humidity and pressure are carried out at least 8 times each day and during the enhanced observation period hourly obsevations will be carried out.

(2) Buoys and Moorings

Tethered spar buoys will be deployed from the research vessel, located near the center of the IOP area to measure the bulk temperature of the ocean, and surface wind speed, air temperature and humidity profile in the first six meters of the atmospheric boundary layer. The spar buoys will be equipped with five temperature and humidity sensors, utilizing thin polymer film techniques to achieve high accuracy and fast response. These will be positioned at various heights to obtain good spatial resolution in the first few meters of the surface layer where humidity declines rapidly. A wind monitor will also be needed on the buoy to measure the wind direction and speed.

The ATLAS (Automatic Temperature Line Acquisition System) Moorings are developed by Pacific Marine Environmental Laboratory (PMEL) for long term monitoring of surface meteorology and upper ocean temperature. Raingauges will be mounted on the moorings and coordinated with land-based and ship-based radar measurements. The ATLAS moorings will provide through ARGOS, real time data which could be used to determine the scale of surface wind and upper ocean variability in the SCS and to allow estimation of one-dimensional water and energy budget over the mooring sites. It is possible that three ATLAS moorings will be installed in the cross-section from Dongsha to Nansha (see Fig. 1).

(3) Satellite Sensors

Satellite microwave scatterometer can measure the surface wind vectors. There is potential for three scatterometers flying at the same time at the onset of SCSMEX and two sensors for most of SCSMEX, providing unprecedented coverage of ocean surface wind vector. Furthermore, the Special Sensor Microwave Imager (SSMI) on operational spacecraft of the Defense Meteorological Space Program (DMSP) will provide global wind speed. The SSMI wind speed can be converted into wind vectors with variational techniques in combination with other available data. Atmospheric water vapor could be derived with good accuracy from SSMI and SSMT2 on DMSP. The surface wind speed and atmospheric water vapor from SSMI can be combined with sea surface temperature from the Advanced Very High Resolution Radiometer (AVHRR) to compute surface evaporation and latent heat flux over the SCS region.

(4) Meteorological Tower Gradient Observation

Meteorological tower gradient observation is an important tool for atmospheric boundary layer observation, with its advantages being able to get long time series of observational data closer to the land and sea surface. This kind of obervations can measure the momentum, sensible and latent heat fluxes through gradient or correlation techniques by measuring the perturbations of near surface wind, temperature and moisture, and the gradient of their means. Land-based and sea-based gradient observation towers will be installed in coastal area of South China, Xisha, Nansha, Dongsha, Puerto Princesa and Weizhoudao. During the routine observation period and IOP, obervations will be carried out 8 times each day and during the enhanced observation period hourly observations will be carried out.

4. *Satellite Observation*

During the period of SCSMEX, the satellite observation will provide data of wind vector, precipitation, atmospheric water vapor, cloud and convection, radiation and heat fluxes, SST, profile of temperature and humidity, etc.

(1) Wind Vector

The NASA scatterometer is scheduled to be launched in February 1996 on the Japanese ADEOS platform. It is designed to provide surface wind vector, with approximately 50 km resolution, under both cloudy and clear skies every two days.There is potential for two scatterometers flying for most of SCSMEX, providing unprecedented coverage of wind vector. The FY-2 stationary satellite is scheduled to be launched in the later of 1996 or the first half of 1997, which will provide surface wind vector with 50 km resolution and sent to users through GTS. Furthermore, the Special Sensor Microwave Image (SSMI) on operational spacecraft of the Defense Meteorological Space Program (DMSP) will provide global wind speed. The SSMI wind speed can be converted into wind vectors with variational techniques in combination with other available data.

(2) Rain and Atmospheric Water Vapor

The launching of TRMM is scheduled for the end of 1997 or the beginning of 1998. From the package of sensors including TMI (TRMM Microwave Instrument), PR (Precipitation Radar) and VIRS (VIS / IR Sensor), rainfall rate and precipitation profile could be derived. Before TRMM is operational, gross features of rain variability could be estimated from

SSMI and Geostationary satellites. Atmospheric water vapor could be derived with good accuracy from SSMI and SSMT2 on DMSP.

FY−2 will provide water vapor observations twice daily with a resolution of 50 km.

(3) Cloud and Convection

Cloud information could be derived from observations of geostationary satellite such as the GMS operated by Japan and FY−2. The Chinese geostationary satellite Feng−Yun−2 (FY−2), fixed near 0°N,105°E, will provide cloud parameter maps over the SCS 8 times each day with a resolution of 50 km.

The Satellite Cloud Image Composite map (SCIC) of Japanese GMS will be sent to the user 8 times each day. The cloud amount derived from the infrared data of GMS reflects the cloud distribution over the region of 60°N−60°S and 80°E−160°E which covers the whole Intertropical Convergence Zone (ITCZ).

(4) Radiation and Heat Flux

The net heat flux includes four terms, e.g., net short wave radiation, net long wave radiation, latent heat flux and sensible heat flux. The net heat flux is the difference between the shortwave radiation into the ocean and the lost heat of the ocean.The latent heat flux can be calculated with bulk transfer formula. Atmospheric water vapor from SSMI can be combined with sea surface temperature from the Advanced Very High Resolution Radiometer (AVHRR) to compute latent heat flux over the SCS region.

FY−2 will provide OLR 8 times each day with a resolution of 50 km.

(5) Sea Surface Temperature

SST, as a key parameter, is essential to estimate the sea surface fluxes. At present, the products of US Climate Prediction Center (CPC) provide monthly mean $2° \times 2°$( SST data, while the operational satellite can only provide the surface temperature observed through clear sky or crevice in the cloud. FY−2 can provide SST of 50 km resolution twice each day on the extended wide digital image and provide SST of 10 km resolution twice each day over selected regions on the narrow digital image. The resolution of the SST derived from observations of Japanese GMS is $0.5° \times 0.5°$ (in case of clear sky).

(6) Sea Level

Sea level can be derived with satellite remote techniques including altimetry methods . Data from the joint US−French TOPEX−Poseidon mission may provide some preliminary information on the sea level fluctuations in the SCS and surrounding waters.

(7) Air Temperature and Humidity Profiles

The data come from satellite microwave instrument (SSM / T−Space Satellite Microwave / Temperature measurement and SSM / I−Space Satellite Microwave Image). These data can be validated with the data of Integrated Sounding Systems (ISS) and enhanced radiowind stations.

## V. MODELING AND DATA ASSIMILATION COMPONENT

Modeling and data assimilation component will study the physical mechanisms of monsoon with models from regional to global scales based on the observations, and integratively process the observational data from the field experiment through 4−dimensional data assimilations.

1. *Modeling Component*

The modeling program will be designed to provide real time forecasts and carry out experiments to interpret SCSMEX observations using a wide range of models from general circulation models (GCM), regional atmospheric models, regional oceanic models, coupled regional atmosphere–ocean models to cumulus ensemble models (CEM) to study atmospheric and oceanic processes over the SCS from cloud scale to global scale. In situ and satellite data collected from SCSMEX will be used with these models in at least four different ways:

a. Validate model outputs, facilitate the diagnosis and interpretation of observations by designing very anomalous experiments and "suppressed physics" experiments to elucidate the relative importance of certain phenomena and to test hypothesis,

b. Use large–scale observation SCSMEX data to provide boundary condition for mesoscale and / or cumulus ensemble model to study the morphology of organized convection under different large–scale forcing,

c. Explore the medium range predictability of the SCS monsoon, its dependence on initializing procedures and ensemble forecasting techniques and,

d. Conduct 4–dimensional data assimilation of in situ and satellite data for SCSMEX to provide real time forecast fields and research quality datasets for moisture transport, regional and global water and energy budget studies.

2. *Data Assimilation Component*

For the success of SCSMEX, it is necessary to establish a complete data collection and management system, e.g., to lay down a series of data management regulations in order to obtain high quality datasets and ensure the obtained routine and special obervational data to be used timely, openly and efficiently by the scientific research communities and scientists of all countries. Also, it is crucial to establish a 4–dimensional data assimilation system in order to lay a sound foundation for the follow–up study. In one word, to realize the objectives of SCSMEX this data management system is essential to every research field.

(1) Data Management

- Make unified observation format, spatial resolution, accuracy requirement and unified quality standard and use unified observation instruments and calibrations;
- Make unified data assimilation standard, including the data products derived or calculated from the database, to ensure the identity of data usage;
- The observational data obtained during IOP should be open and available within fixed time limits (6 months, 18 months, 24 months, 36 months and 60 months) and provide the research communities and scientists of participant countries and regions with their interested data, readable format and quality standard.

(2) Data Classification

- The routine and special observational data obtained in the experiment are classified into three categories, e.g., real–time data, near–real–time data and non–real–time data;
- All the data associated with SCSMEX are classified into four classes, e.g.,

  Class 1: raw data

  Class 2: analysed and specially processed data

  Class 3: uniform data derived from Class 2

Class 4: model output data

(3) SCSMEX Database

Establish a relatively complete, fully checked and compiled, and confirmed SCSMEX database including real-time database, near-real-time database, non-real-time database and final database. These databases will be available to all participant countries, regions and international scientific communities 6 months, 12 months and 18 months after the IOP (see Fig. 3). In addition, some main participant countries should try their best to establish special SCSMEX database (for example, atmospheric circulation and oceanographic data etc.) and collect historical data and objectively analyzed data of atmospheric / oceanographic observations before 1998.

(4) Establishment of Data Centers

Two kinds of data center will be established. The first kind is the national (or regional) SCSMEX data centers aimed at processing observational data of the experiment within the

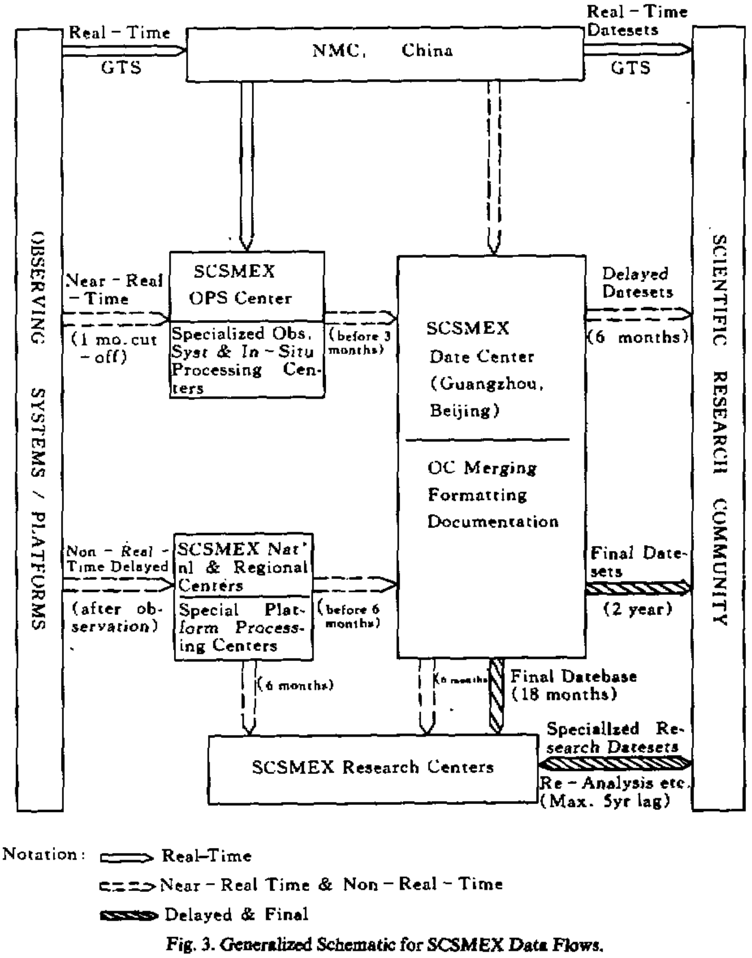


Fig. 3. Generalized Schematic for SCSMEX Data Flows.

areas of the participant countries and organizes and manages the experiment data of their own countries and regions. The second kind is the international SCSMEX data centers in Beijing and Guangzhou whose task is to collect and distribute data, check all the observational data during the SCSMEX and conduct assimilation analysis. Their ultimate task is to assemble and select the data and establish a final and complete international SCSMEX database.

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