Toward a mesoscale marine hydrological and meteorological observation network in the South China Sea

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Regional observations in other basins

The Bay of Bengal Monsoon Experiment
The Arabian Sea Monsoon Experiment
The Joint Air–Sea Monsoon Experiment
The Surface Ocean Lower Atmosphere Study
The Coupled Boundary Layers and Air-Sea Transfer program

Large scale air-sea observations

The 8-year (1990–1997) World Ocean Circulation
The Global Ocean Observing System (GOOS)
The Tropical Atmosphere Ocean/Triangle trans-Ocean Buoy Network (TAO/TRITON)
Scientific background

Shu et al., 2011

Interannual variability of SST is mostly related to ENSO.

SST double peak

Wang et al., 2006

The air-sea interaction in the SCS is strongly related with Asian monsoon ......
Intraseasonal latent heat flux has two spectral peaks around 28–35 and 49–56 days.

The intra-seasonal latent-heat flux variations in summer are remarkably different from those in winter.

- Intraseasonal latent-heat flux fluctuations are closely related to monsoon.
- Correlated to southwesterly winds in summer, and primarily associated with northeasterly winds and $Q_a$ in winter.

Zeng, Wang et al. (2009) TAC
Intraseasonal variations of strong upwelling along the south coast of Vietnam, and a cold filament that stretches eastward at about 12N from the coast during June–September each in response to the intraseasonal variations of Asian summer monsoon.

The intraseasonal cold filaments tend to reduce the local wind speed and precipitation due to increased static stability in the near-surface atmosphere, indicating the existence of an ocean–atmosphere feedback.
Convective and stratiform rainfall and heating associated with the summer monsoon over the South China Sea (TRMM-based observation).

Latent heating and the ratio of convective to stratiform rainfall can characterize the seasonal march of the SCS summer monsoon.

Li, Wang et al. (2009) TAC
Strong latent heating related with Neoguri can enhance the development of the SAH aloft and generate zonal asymmetric PV forcing, with positive vorticity advection to its east and negative advection to its west.

Following the decay of Neoguri, this asymmetric forcing leads to instability development of the SAH, presenting as a slowly westward propagating Rossby wave accompanied by a westward shift of the high Potential vorticity advection.

As the main moisture source of the SCS summer monsoon, as well as being a region with high frequency of mesoscale eddies and severe weather systems, e.g. tropical cyclones, storm surges…….

The SCS imposes a profound impact on the weather and climate change of the surrounding landmass. Thus, there are significant potential benefits to an improved understanding of the regional circulation and air–sea interactions taking place in the SCS.

However, progress is hindered by a lack of three dimensional mesoscale observations of the key dynamic processes in both atmosphere and ocean over the SCS.
Earlier Observations

Little mapping
During 1978-1984, observation mainly focus on the costal shelf for the studies of Pearl River plume

(Ou et al. 2009)

There are some deep cast data in the northern South China Sea during 1960s and early 1980s, most of which reached 2000m depth or deeper

(Liu et al. 2012)
During 1989-1999, several cruises were made in the southern South China Sea (Fang et al. 2012)

Most of these earlier observations only have CTD measurements.

(Fang et al. 2012)
Earlier Observations

IOP: The SCS Monsoon Experiment (SCSMEX), conducted between 1996 and 2001 with a field phase from 1 May to 3 August 1998, was a major international field experiment set up to study the physical processes involved in the onset, maintenance, and variability of the SCS summer monsoon.
The SCS observational network is designed to

✓ Provide *simultaneous* atmospheric and oceanic observations, which is essential for air–sea coupling studies, particularly on the synoptic timescale.

✓ Provide *vertical profiles* of oceanic and atmospheric variables, which can then be used to study the baroclinic structures of the atmospheric and oceanic circulation in the SCS.

✓ Provide data that can be used to *evaluate* satellite observations and to assess/calibrate model outputs.
In 2004, the SCS Institute of Oceanology (SCSIO) conducted a cruise in the northern SCS (18–23N, 110–120E) during late summer (August–September).

8 transects were carefully designed based on research interests and important scientific issues.
Since 2006, the SCSIO open cruise has carried a radiometer and conducted GPS sounding. GPS sounding balloons are launched regularly during each cruise to obtain vertical profiles of wind, air temperature and humidity.
Fixed multi-function observation platforms in the ocean complement cruise observations by providing long-term and continuous real-time data.

ADCP, surface buoy, AWS at Xisha station
The 20 m Xisha Island air–sea boundary flux tower located 97 m offshore of Yongxing Island (16.84N, 112.33E), has been in operation since 2013.

The tower is equipped for gradient and eddy covariance observations for the measurement of air–sea boundary fluxes.
The observational data from the network can be used for both research and real-time environmental monitoring. To date, the observation datasets along the western boundary have formed a clear monitoring network for the coastal area of southern China.
The Marine Meteorological Science Experiment Base at Bohe was jointly established in 2006 by Guangzhou Institute of Tropical and Marine Meteorology and Maoming Meteorological Bureau under the Guangdong Meteorological Service of the China Meteorological Administration.
### Station or Cruise Details

<table>
<thead>
<tr>
<th>Station or Cruise</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Deployment Period</th>
<th>Organized by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open cruise 2006</td>
<td>17.98°–22.23°N</td>
<td>109.47°–120.01°E</td>
<td>09–28 Sep 2006</td>
<td>SCSIO</td>
</tr>
<tr>
<td>MEL cruise 2006</td>
<td>10.50°–22.13°N</td>
<td>110.20°–119.00°E</td>
<td>26 Nov–16 Dec 2006</td>
<td>Xiamen University</td>
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<tr>
<td>Open cruise 2007</td>
<td>17.93°–23.39°N</td>
<td>110.06°–120.03°E</td>
<td>13–27 Aug 2007</td>
<td>SCSIO</td>
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<tr>
<td>Cruise 200706</td>
<td>18.01°–25.01°N</td>
<td>111.13°–119.75°E</td>
<td>24–29 Sep 2007</td>
<td>SCSIO</td>
</tr>
<tr>
<td>Cruise 200803</td>
<td>18.89°–22.70°N</td>
<td>112.64°–113.83°E</td>
<td>16–20 Mar 2008</td>
<td>SCSIO</td>
</tr>
<tr>
<td>SCOPE cruise 2008</td>
<td>20.27°–23.51°N</td>
<td>114.07°–117.96°E</td>
<td>29 Jun–14 Jul 2008</td>
<td>Five Institutes*</td>
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<tr>
<td>Open cruise 2008</td>
<td>17.01°–22.41°N</td>
<td>109.20°–119.98°E</td>
<td>16 Aug–04 Sep 2008</td>
<td>SCSIO</td>
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<tr>
<td>MPFI Cruise 2009</td>
<td>18.21°–33.72°N</td>
<td>109.49°–122.55°E</td>
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<td>Institute of Oceanography of the CAS</td>
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<td>109.55°–120.08°E</td>
<td>1–15 Sep 2009</td>
<td>SCSIO</td>
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<td>NSFC cruise 2010</td>
<td>8°–23°N</td>
<td>110°–120°E</td>
<td>24 Apr–25 May 2010</td>
<td>SCSIO</td>
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<tr>
<td>Xisha cruise 2010</td>
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<td>110.5°–113.2°E</td>
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<td>SCSIO</td>
</tr>
<tr>
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<td>110°–120°E</td>
<td>31 Aug–23 Sep 2010</td>
<td>SCSIO</td>
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<tr>
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<td>SCSIO</td>
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<td>ROSE cruise 2010</td>
<td>7.05°–19.09°N</td>
<td>109.95°–117.95°E</td>
<td>26 Oct–11 Nov 2010</td>
<td>First Institute of Oceanography of the SOA</td>
</tr>
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<tr>
<td>SSSS cruise 2011</td>
<td>6°–18°N</td>
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<td>28 Nov 2011–12 Jan 2012</td>
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<tr>
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<td>108.49°–111.74°E</td>
<td>13–22 Dec 2012</td>
<td>SCSIO</td>
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<tr>
<td>Xisha Cruise 2013</td>
<td>14.96°–18.41°N</td>
<td>110.79°–116.54°E</td>
<td>14–26 Aug 2013</td>
<td>SCSIO</td>
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<tr>
<td>NSFC open cruise 2013</td>
<td>9.8°–21.3°N</td>
<td>110.3°–114°E</td>
<td>05 Aug–06 Sep 2013</td>
<td>SCSIO</td>
</tr>
</tbody>
</table>

- **7 buoys, 3 stations, 3 platforms, 30 cruises including 10 SCSIO open cruises in the northern SCS, 4 Xisha cruises, 5 southern SCS cruises, four NSFC open cruises, and 7 other cruises**
Regional circulation in the SCS since the 1990s

- The formation of SCS warm current
- Upwelling
- Freshening of 2012
- Eddy activities

Processes in the MABL

- SST perturbations associated with eddies, oceanic fronts
- Air–sea boundary fluxes related to monsoon onset and retreat, sea fog
- Atmospheric ducts

Atmospheric disturbance and tropical cyclones

- Synoptic perturbations and their interannual variability
- Air-sea interactions during tropical cyclone passages
The deflection of the SCS warm current

The eastern part of the SCS Warm Current flows eastward along the isobath, and then veers off toward the deep sea while it flows around the Dongsha.

ADCP and CTD confirmed the deflection. Combining the observations and model simulation, it is found that JEBAR plays an important role in the deflection.
Without upwelling favorable wind, the cold near-bottom water climbed up the slope and the subsurface upwelling took place between 20 and 100 m in the NSCS.

Topographically induced upwelling is sensitive to alongshore large-scale currents, which have an important contribution to the upwelling intensity.

Assimilating CTD measurements obtained from SCOPE (2008) into a regional ocean model.
Freshening of 2012 in the northern SCS

The study suggested that the freshening in 2012 might have been caused by the combined effect of abundant local freshwater flux and limited Kuroshio intrusion.

A freshening of up to 0.4 psu in the upper ocean of the northern SCS in 2012 using satellite observations, which were evaluated against in situ observations from the SCS.

Zeng et al. (2013) JGR
Nan et al. (2011) JGR; He et al. (2013) AOS

The CTD and ADCP data, as well as those from drifting buoys, successfully captured the vertical structure of the three eddies and their evolutions.

The formation of the SMH is attributed to both wind forcing and the release of potential energy by the winter monsoon.

Observations confirm the existence of a recurring spring mesoscale eddy with a warm core and low salinity (with interannual variation on location and size.)
In 2010, an extremely large and long-lasting warm eddy was observed in the SCS to be moving northward from the south of the Xisha Islands.

The CTD and XBT obtained during the 2010 warm-eddy cruise were used to explore the eddy’s vertical structure.

A strong El Niño event in 2009/2010 altered the intensity and direction of the summer monsoon, resulting in the disappearance of this pattern and the northward movement of a preexisting warm eddy along the Vietnam coast.

During this northward movement, the western boundary current cascaded energy to the eddy, which led to its continuing growth in both strength and size.

Chu et al. (20114) JGR;
Data from the Xisha flux tower

Both boundary momentum and heat flux exchanges responded strongly to the retreat of monsoon near around 7 September 2013.

Satellite-derived air specific humidity is verified against 1016 high-resolution radiosonde profiles from 1998 to 2012 and the time series from the 26 AWS at Xisha during 2008–2010.

SCSSLH shows the highest spatial resolution and realistic values in the SCS, with an exception along the northern continental shelf. The other five products overestimate the latent heat flux systematically.

Improved estimates of bulk variables based on in situ measurements has contributed the better representation of daily SCSSLH, which further highlights the unique role of high-quality meteorological measurements and atmospheric weather stations in evaluating the air–sea interaction in the SCS.
A total of 52 tropical cyclones passed over the SCS during the period 2008–2011, and 21 of those 52 were found to be less than 400 km away the Xisha Station.

Using the AWS and buoy data from Xisha Stations, studies have shown that atmospheric variables and air–sea interaction during tropical cyclone passages experience significant changes.

Wang et al., 2012
The mesoscale observation network in the SCS consists of both oceanic and meteorological observations during cruises and at stations.

The network was designed based on the characteristics of the regional circulation and air–sea interaction over the SCS.

The observations were mainly concentrated in the dynamically active areas. The oceanic processes in these key regions represent the main dynamic characteristics of the SCS, and their related air–sea interactions have direct impacts upon the economies and human activities of the surrounding countries.

Collecting observations at mesoscale resolution in these key regions (in terms of both horizontal mapping and vertical profiles) is an important approach to investigating regional air–sea coupling in the SCS under current research-funding conditions.
From SCSMEX to YMC
Workgroup of Chinese YMC
Guangzhou, 17 Nov., 2015
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• Qilin Wang: *Guangzhou Institute of Tropical and Marine Meteorology, China Meteorological Administration*

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Planed Observation

- **Maintain** ground-base or island-base air-sea flux tower in Sri Lanka, Xisha Island, Bohe
- **Build** a air-sea flux tower with other institutes or universities in MC
- **Conduct** RV Investigator and buoy deployed in southern South China Sea
- **Apply** grant fund from NSFC and other way
Research Interests

• Circulations associated with ITF and SCSTF
• Air-sea interaction in the South China Sea and its climate impacts
• Upper ocean processes associated with ITF and mixing
• MC and MJO
  MC convection; impacts of MC on MJO; impacts of MC and MJO on regional climate (i.e., equator currents, Australia monsoon, South China Sea summer monsoon)
• Regional model development
Thank you for your attention!

URL: http://lto.scsio.ac.cn/