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

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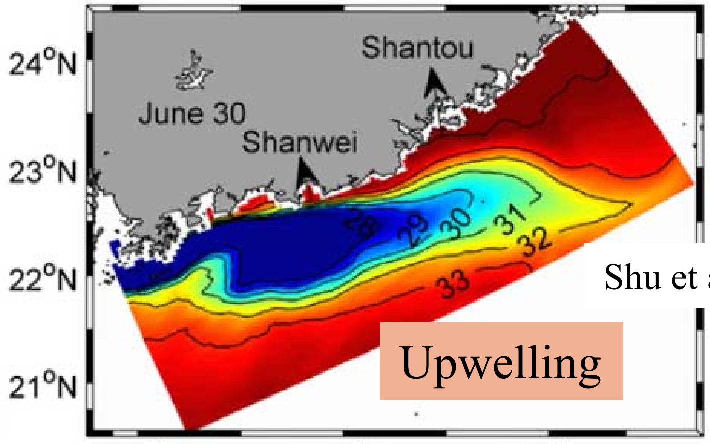
Regional observations in other basins

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

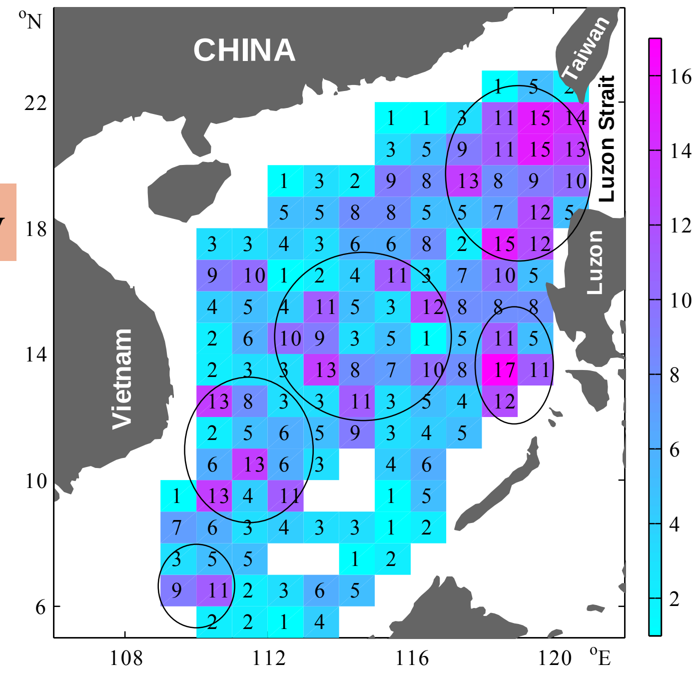
The 8-year (1990–1997) World Ocean Circulation
The Global Ocean Observing System (GOOS)
The Tropical Atmosphere Ocean/Triangle trans-Ocean Buoy Network (TAO/TRITON)
…….

Scientific background

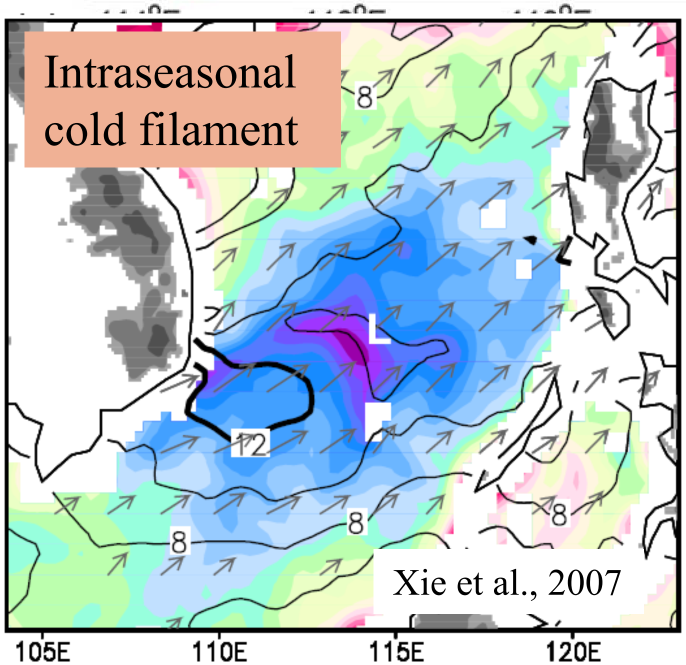


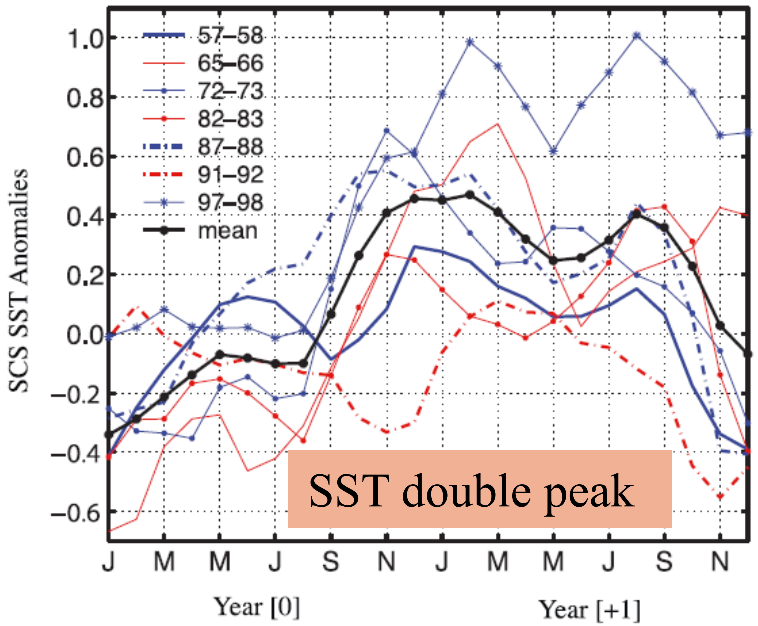
Shu et al., 2011

Eddy



Chen et al., 2011



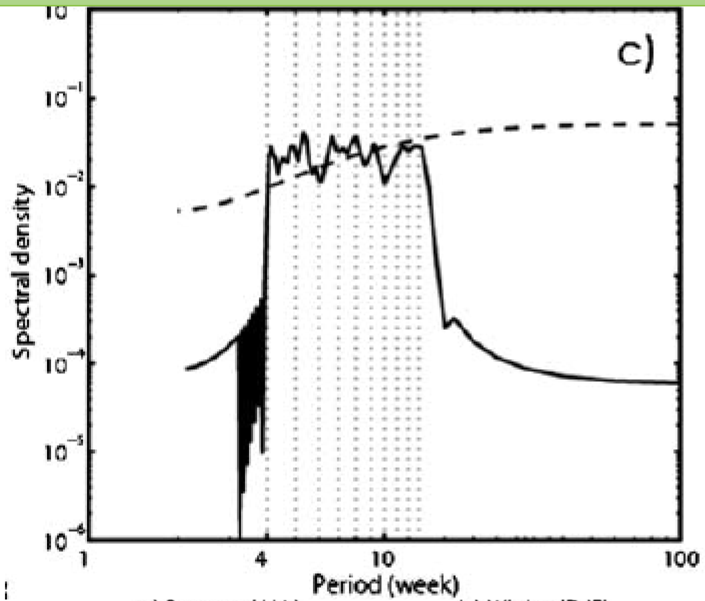


Interannual variability of SST is mostly related to ENSO.
SST double peak

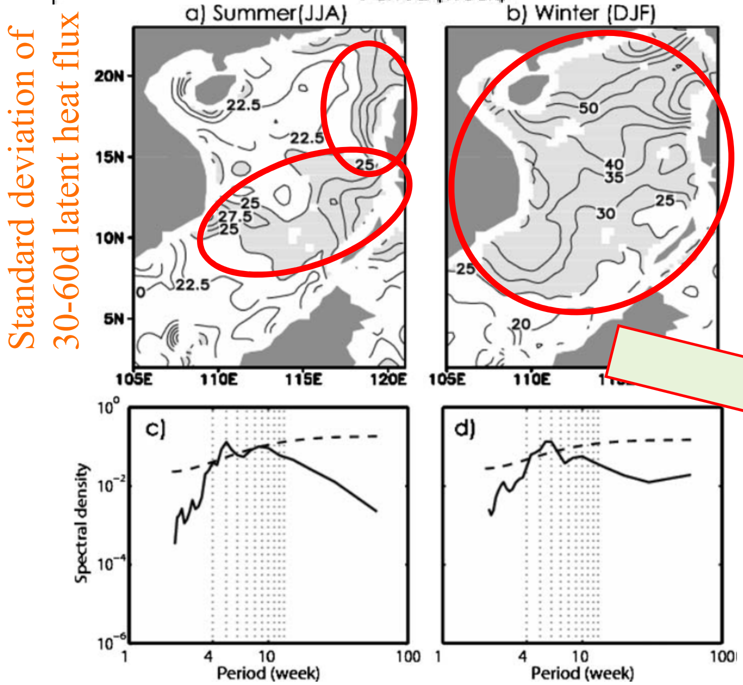
Wang et al., 2006

The air-sea interaction in the SCS is strongly related with Asian monsoon ……

Intraseasonal variability of latent-heat flux in the SCS



Intraseasonal latent heat flux has two spectral peaks around 28–35 and 49–56 days

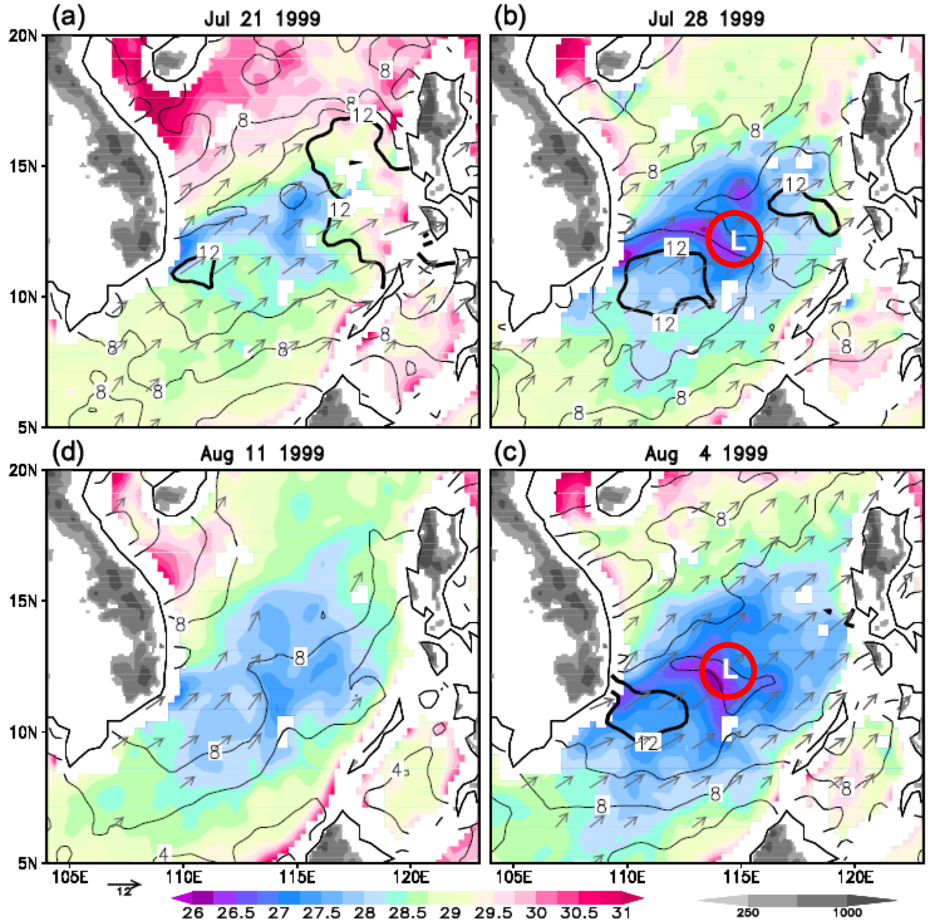


The intra-seasonal latent-heat flux variations in summer are remarkably different from those in winter.

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

Zeng, Wang et al. (2009) TAC

Intraseasonal variability of cold filament off Vietnam coast in the SCS

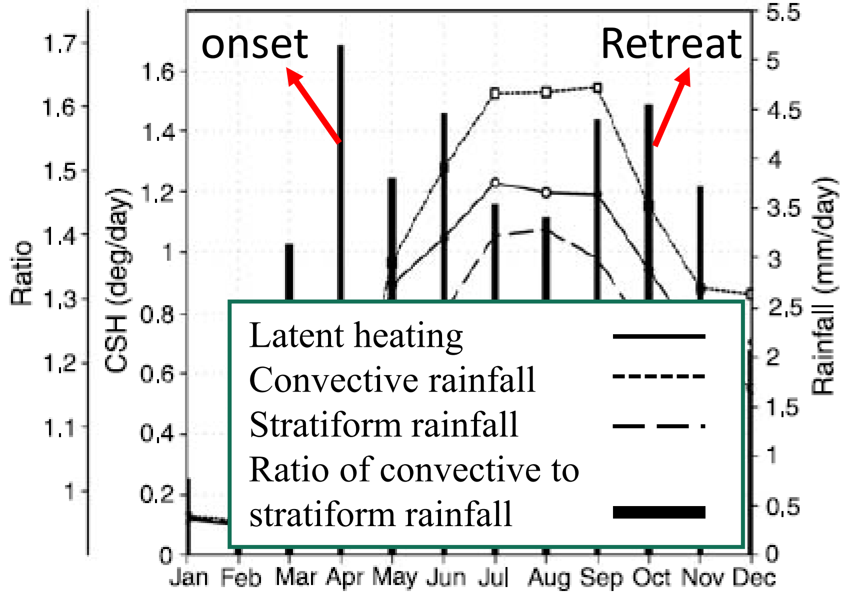


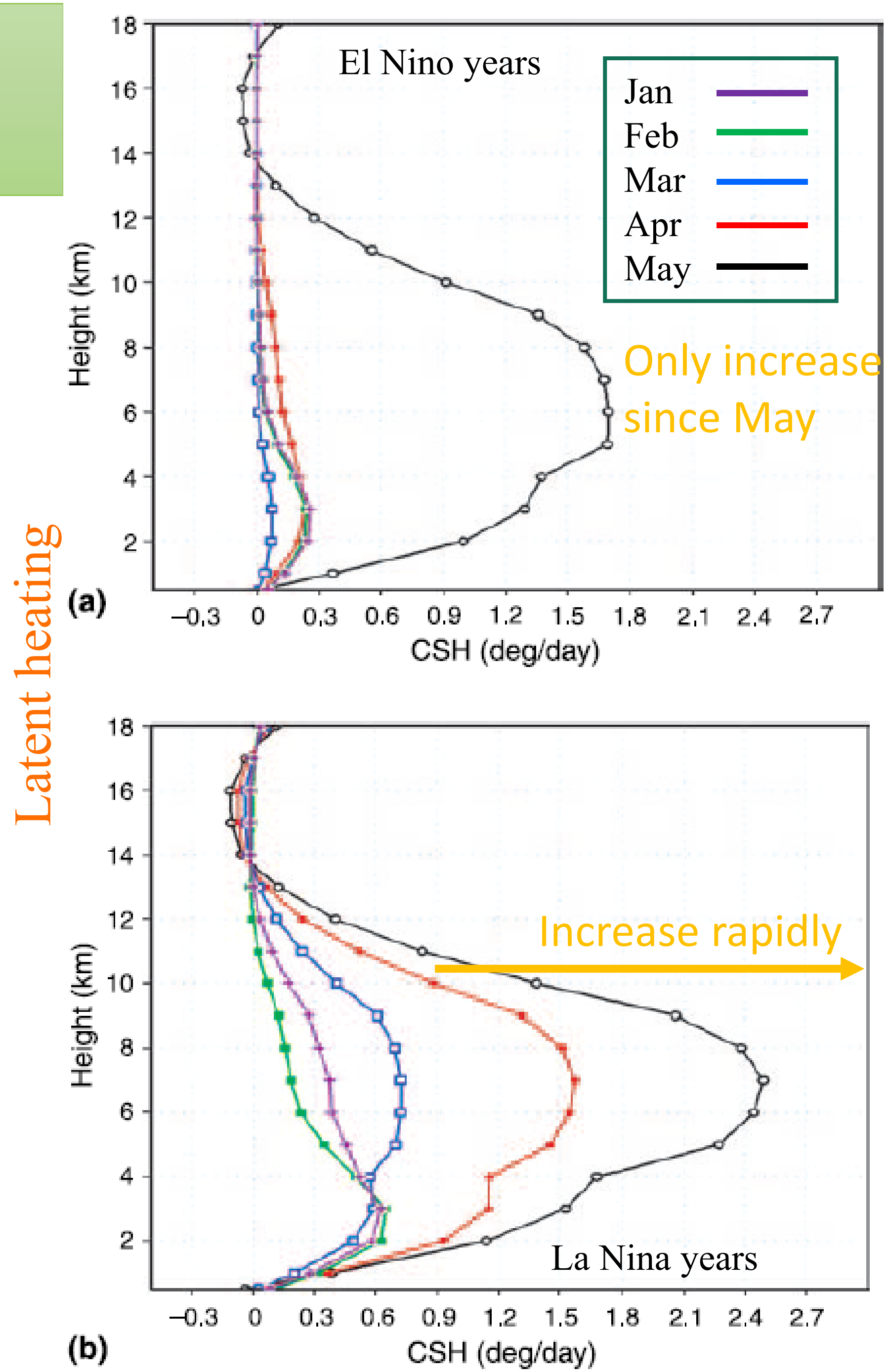
The intraseasonal cold filaments tend to reduce the local wind speed and precipitation due to increased static stability in the near-surface atmosphere, indicating the existence of an ocean–atmosphere feedback

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.

Xie et al. (2007) JGR-Oceans; Wang et al. (2002), CSB

Convective and stratiform rainfall and heating associated with the summer monsoon over the South China Sea (TRMM-based observation)

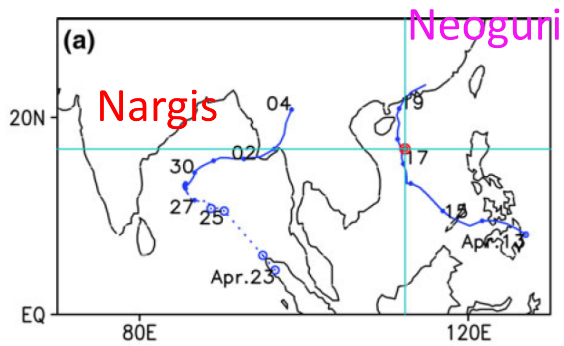




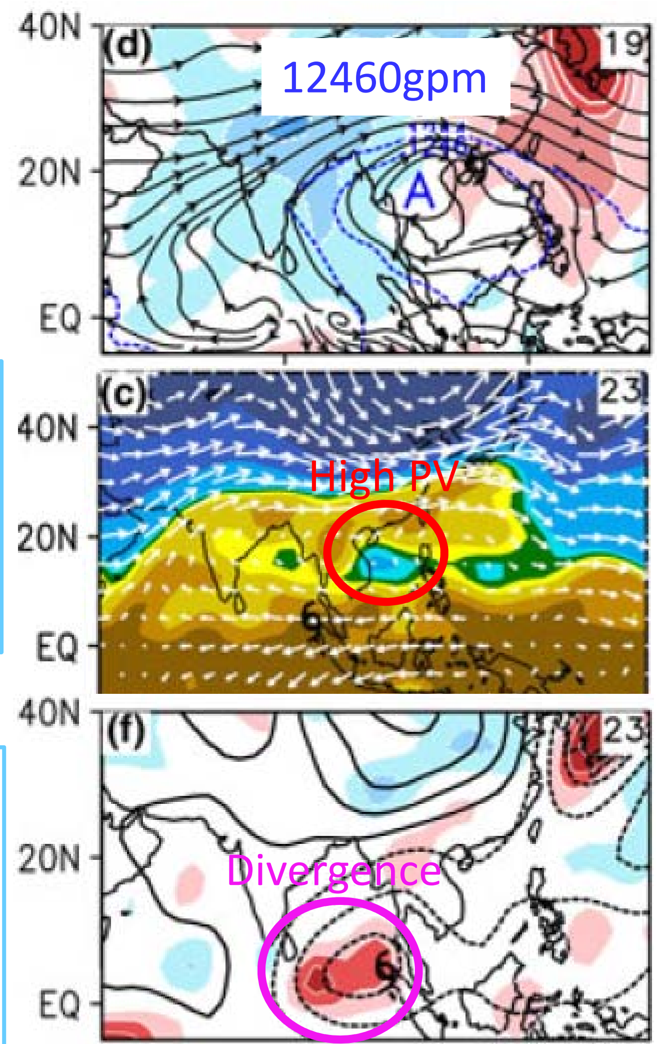
Latent heating and the ration of convective to stratiform rainfall can characterize the seasonal march of the SCS summer monsoon

Li, Wang et al. (2009) TAC

Impact of tropical cyclone development on the instability of South Asian High and the summer monsoon onset over Bay of Bengal



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.

A strong upper tropospheric divergence on the southwest of the SAH also shifts westward

Wu, Wang et al. (2013) Clim Dyn.

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.

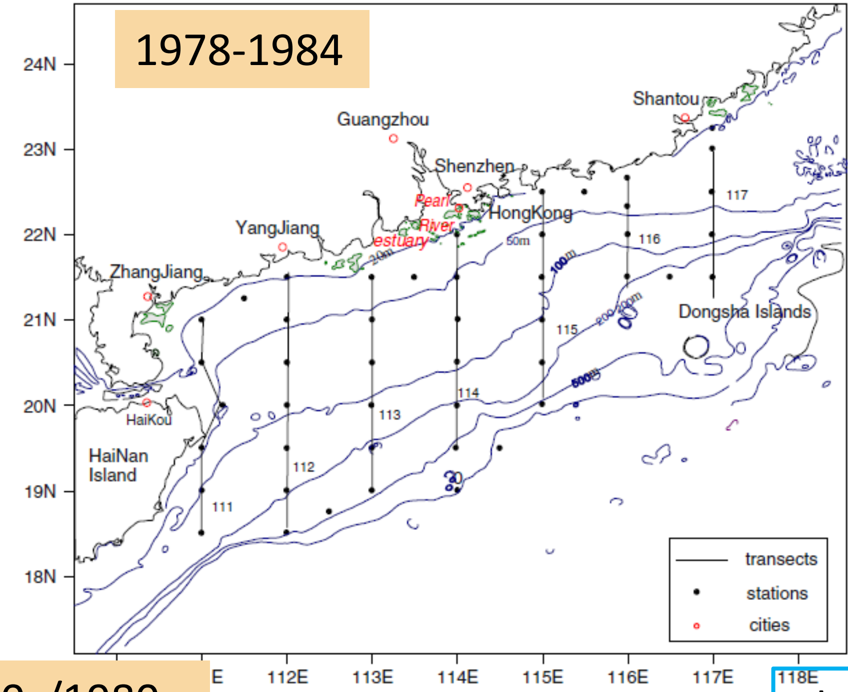
Earlier Observations

Little mapping

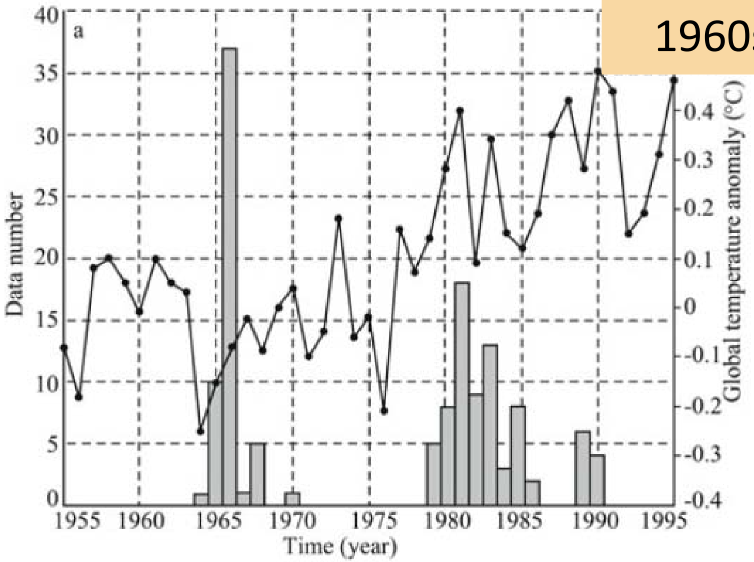
During 1978-1984, observation mainly focus on the costal shelf for the studies of Pearl River plume

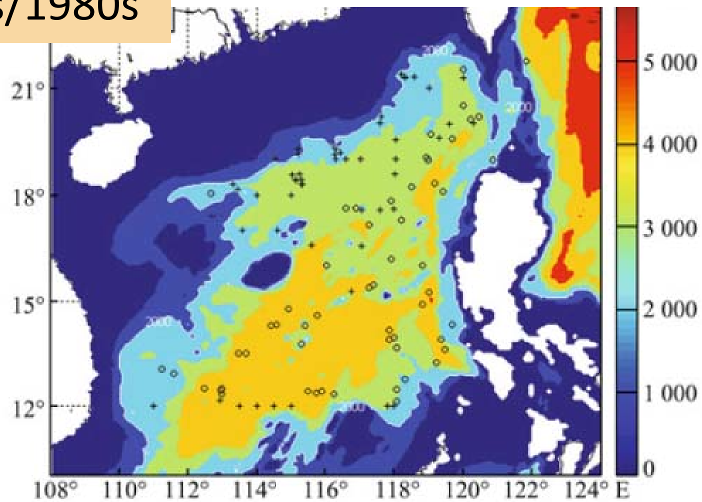
(Ou et al. 2009)

1978-1984



1960s/1980s





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

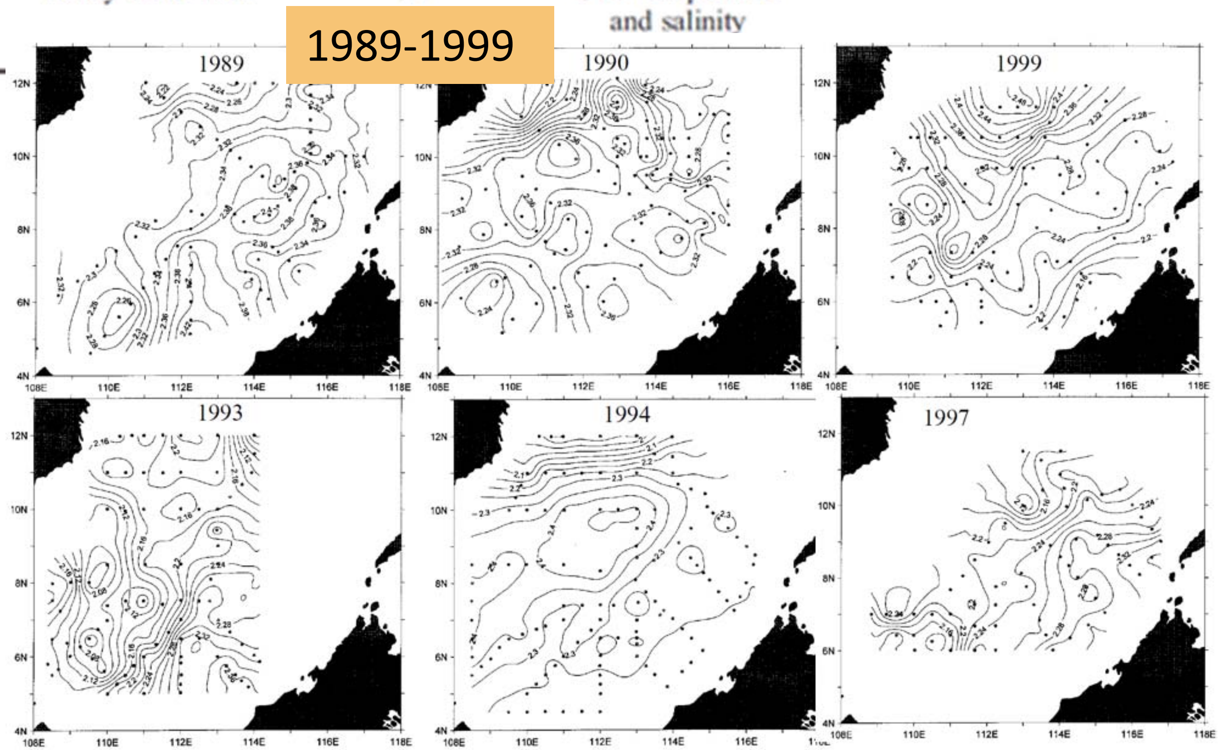
(Liu et al. 2012)

Earlier Observations

Table R1 List of Six Oceanographic Cruises of the Southern SCS by *R/V Shiyan 3*

Survey Cruise	Start Date	End Date	Surveyed Area in Southern SCS	Number of Stations	Parameters Measured
Dec. 1989	Dec. 8	Dec. 30	middle and east	86	CTD temperature and salinity
May–June 1990	May 14	June 28	entire area	90	CTD temperature and salinity
Dec. 1993	Dec. 1	Dec. 20	middle and west	80	CTD temperature and salinity
Sept. 1994	Sept. 10	Oct. 1	entire area	116	CTD temperature and salinity
Nov. 1997	Nov. 7	Nov. 24	middle and east	61	CTD temperature and salinity ADCP current
July 1999	July 1	July 30	nearly entire area	90	CTD temperature and salinity

Most of these earlier observations only have CTD measurements.

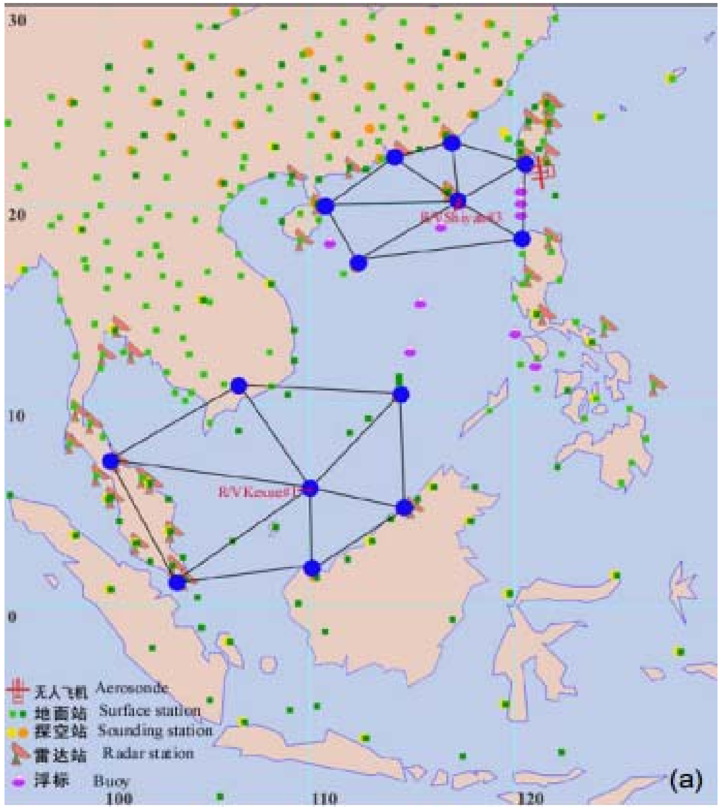


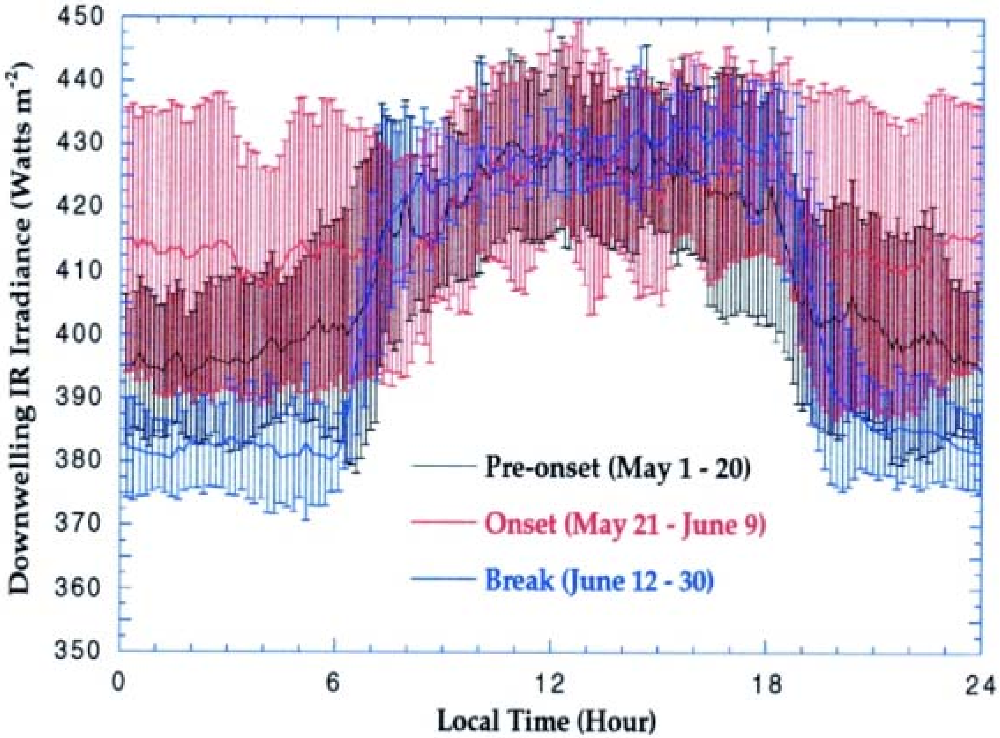
During 1989-1999, several cruises were made in the southern South China Sea

(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





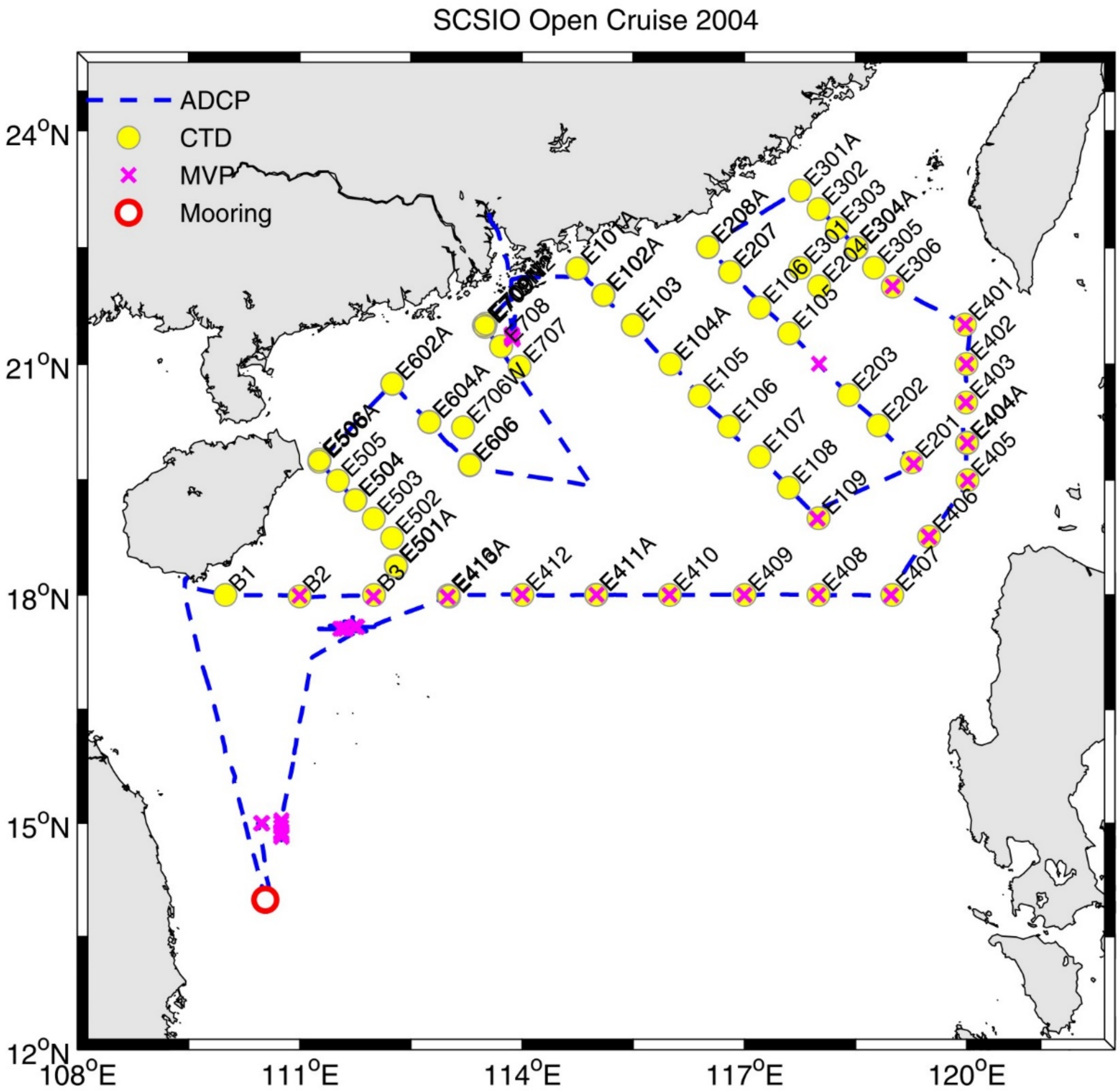
The SCS observational network is designed to

- ✓ 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.

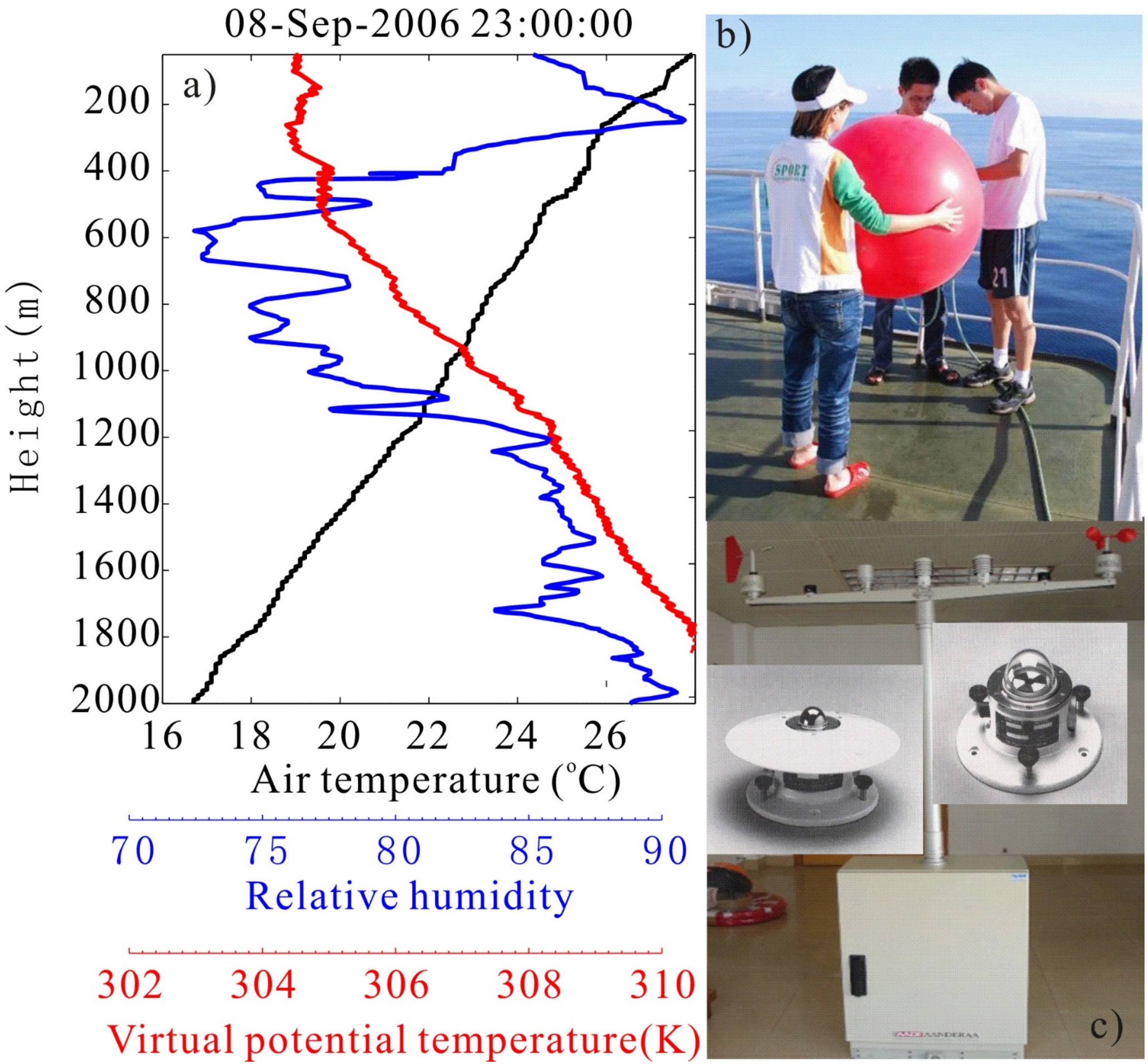
In 2004, the SCS Institute of Oceanology (SCSIO) conducted a cruise in the northern SCS (18–23N, 110–120E) during late summer (August–September)



8 transects were carefully designed based on research interests and important scientific issues.

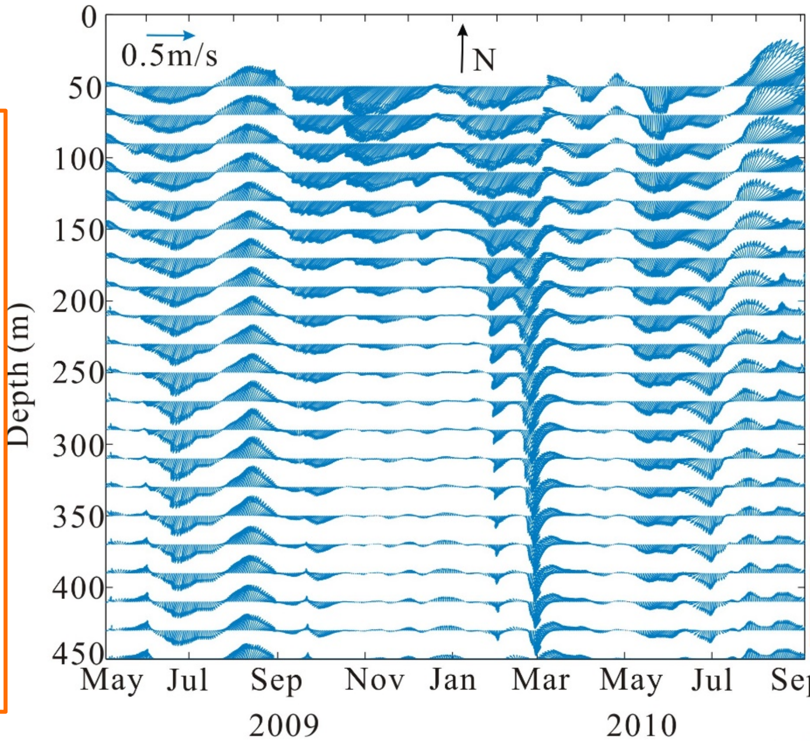
Since 2006, the SCSIO open cruise has carried a radiometer and conducted GPS sounding.

GPS sounding balloons are launched regularly during each cruise to obtain vertical profiles of wind, air temperature and humidity.

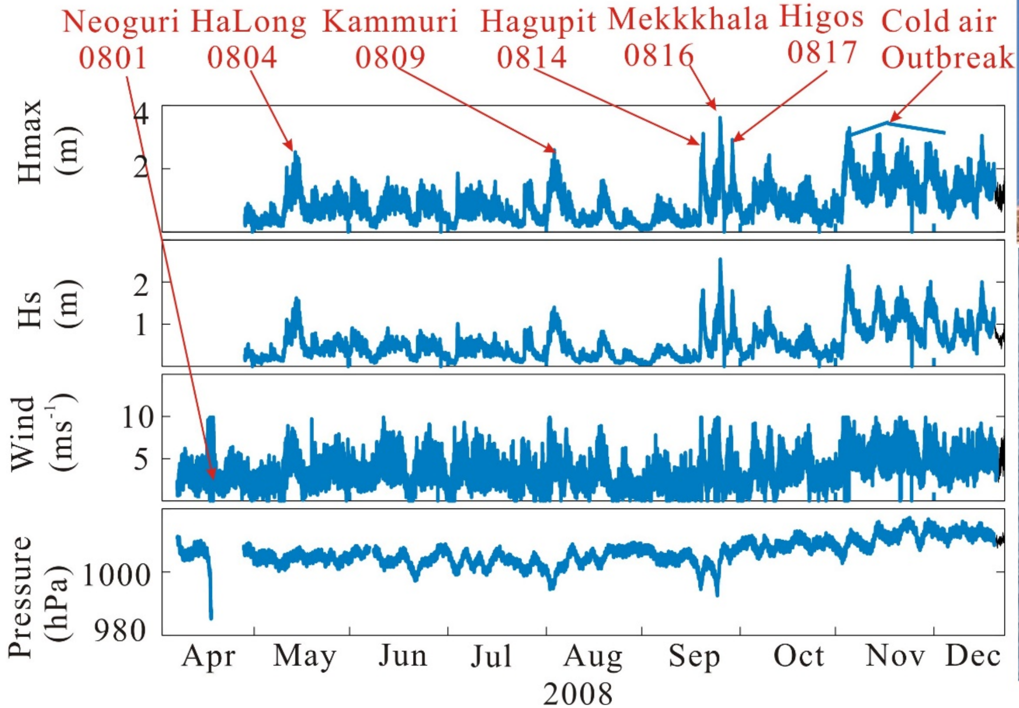


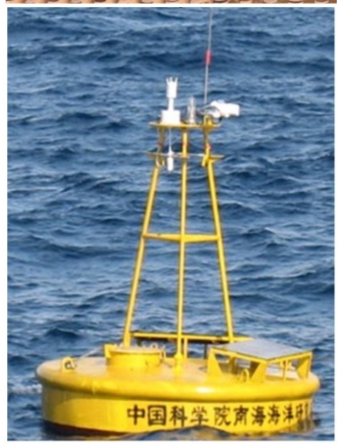
GPS sounding
AWS (including longwave and showave radiometer)

Fixed multi-function observation platforms in the ocean complement cruise observations by providing long-term and continuous real-time data.

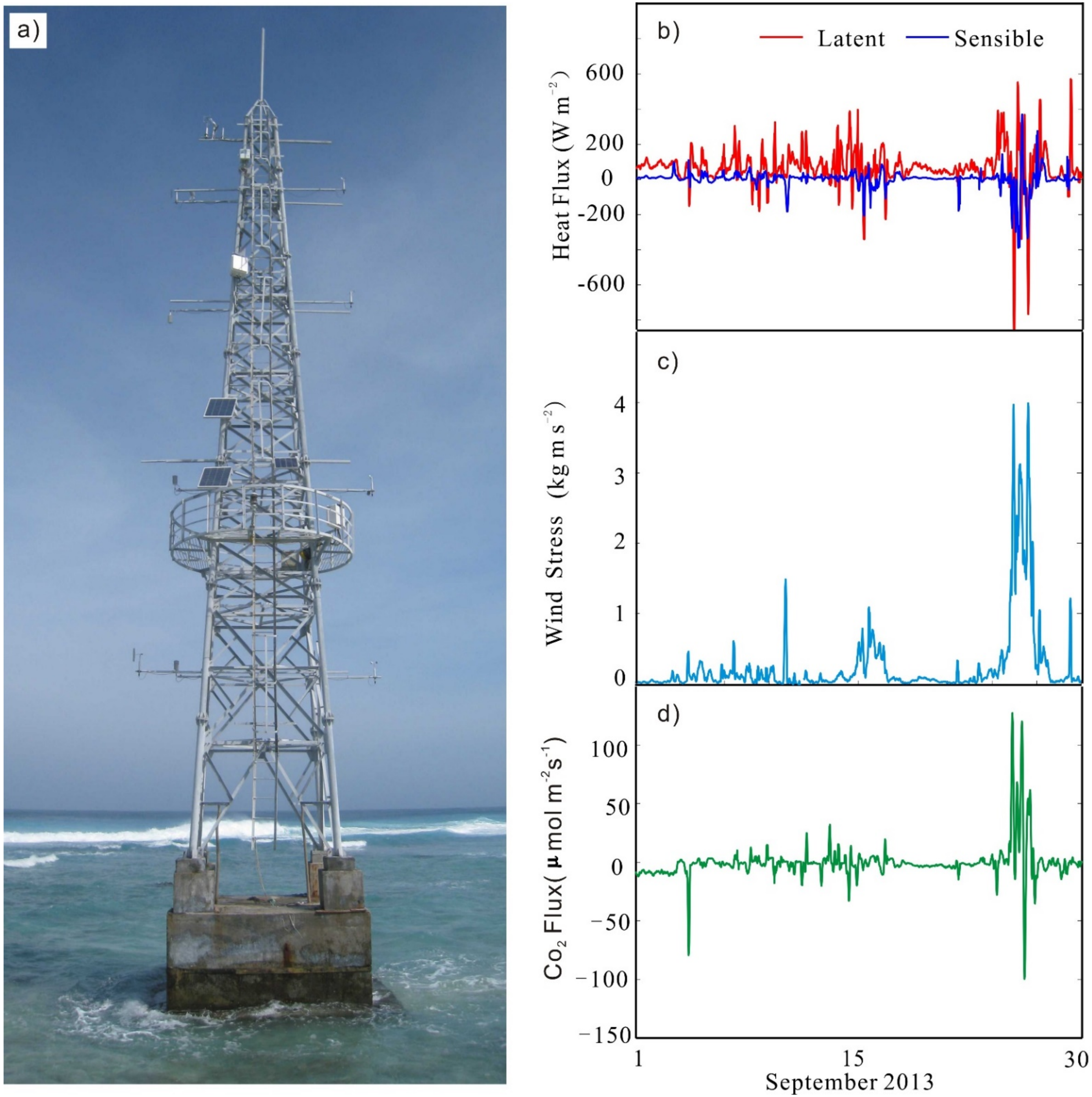


ADCP, surface buoy, AWS at Xisha station

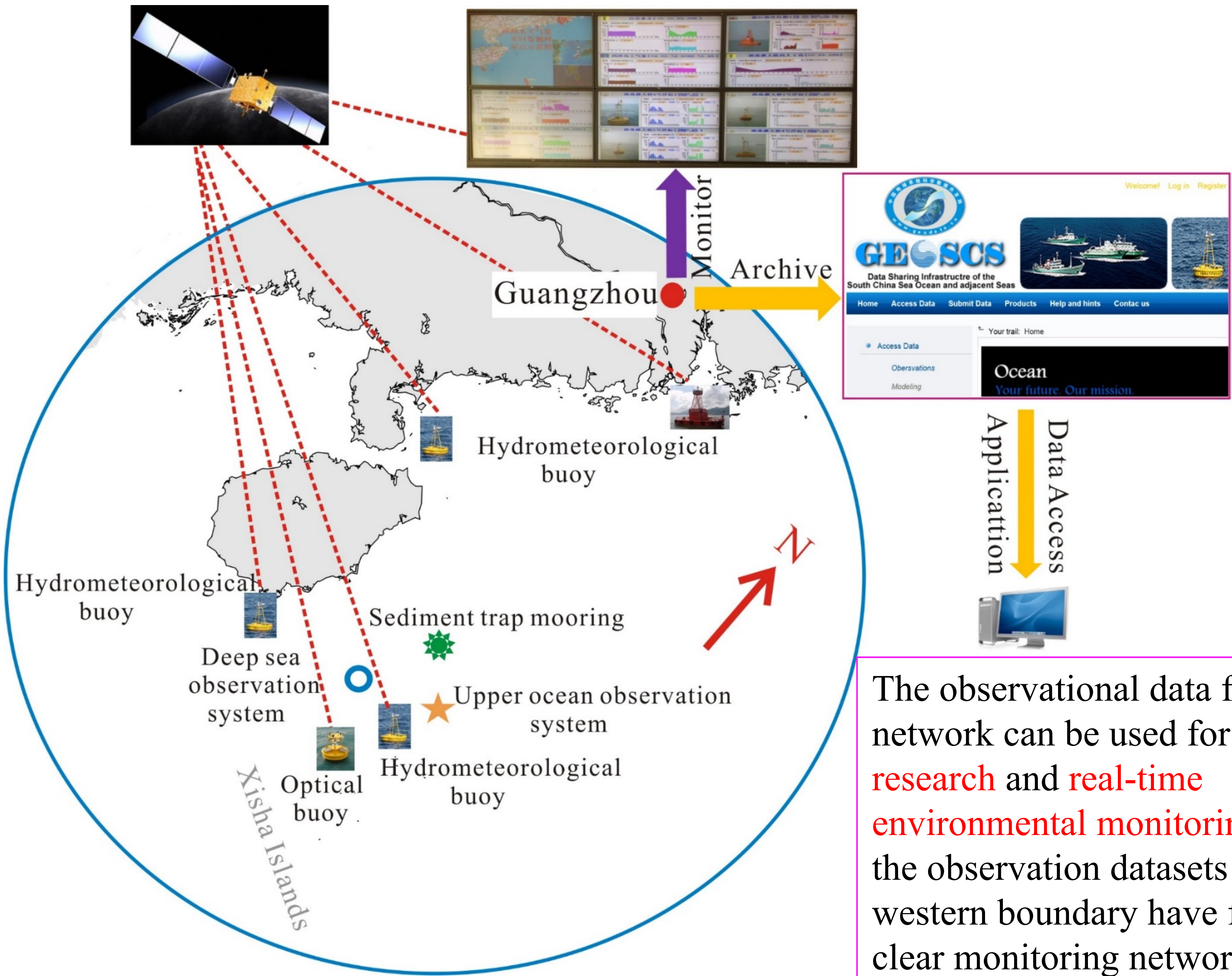




The 20 m Xisha Island air–sea boundary flux tower located 97 m offshore of Yongxing Island (16.84N, 112.33E), has been in operation since 2013.

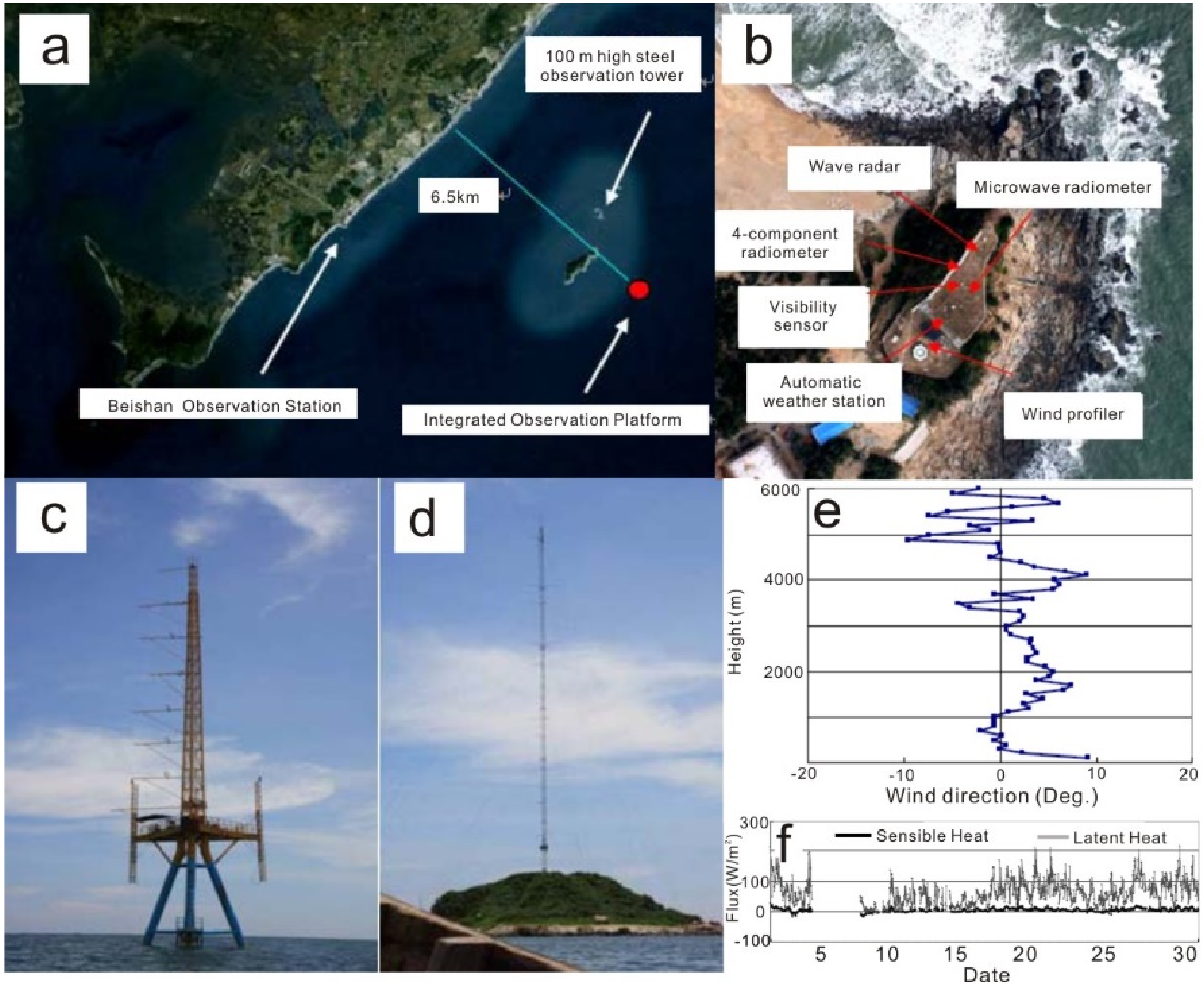


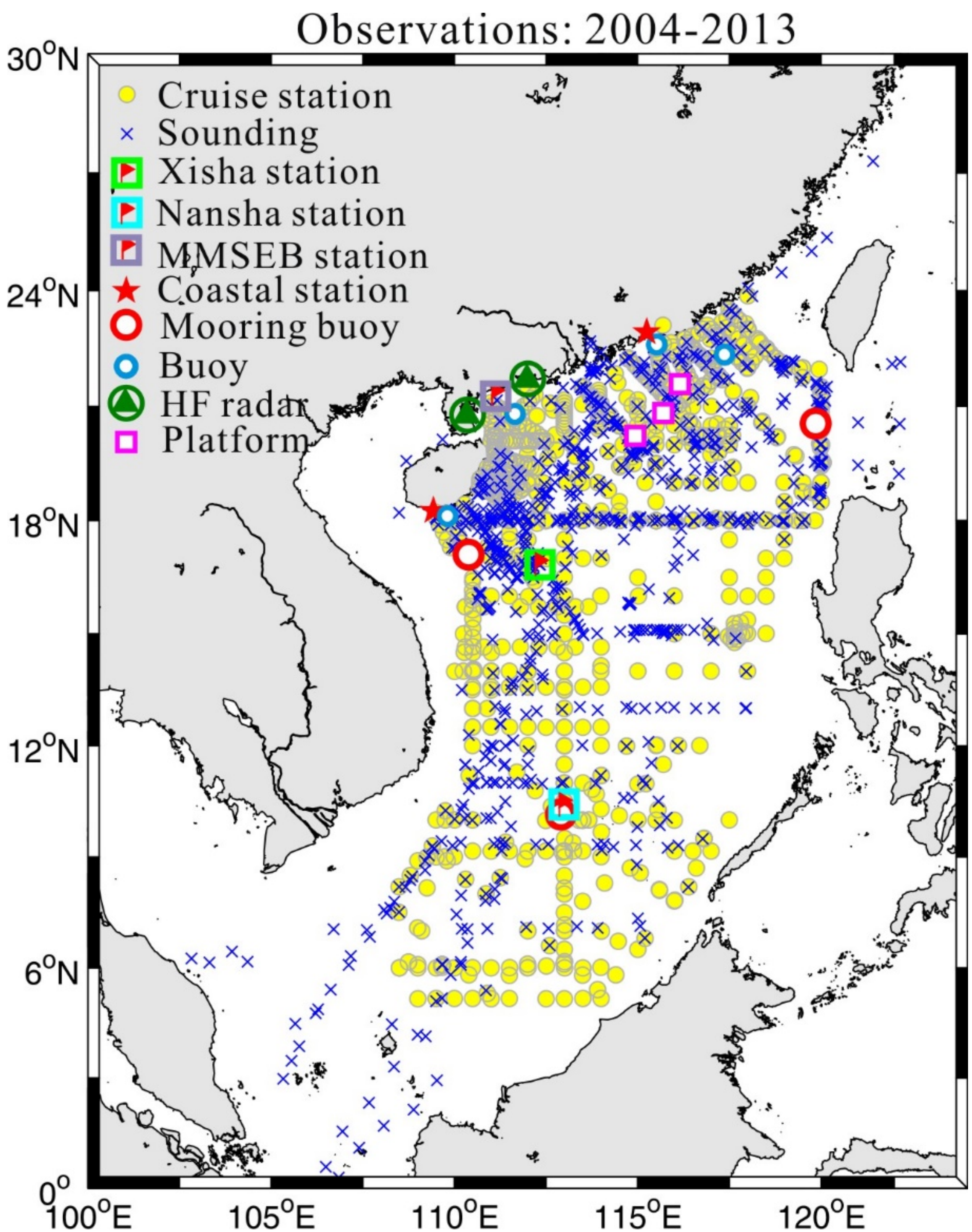
The tower is equipped for gradient and eddy covariance observations for the measurement of air–sea boundary fluxes



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

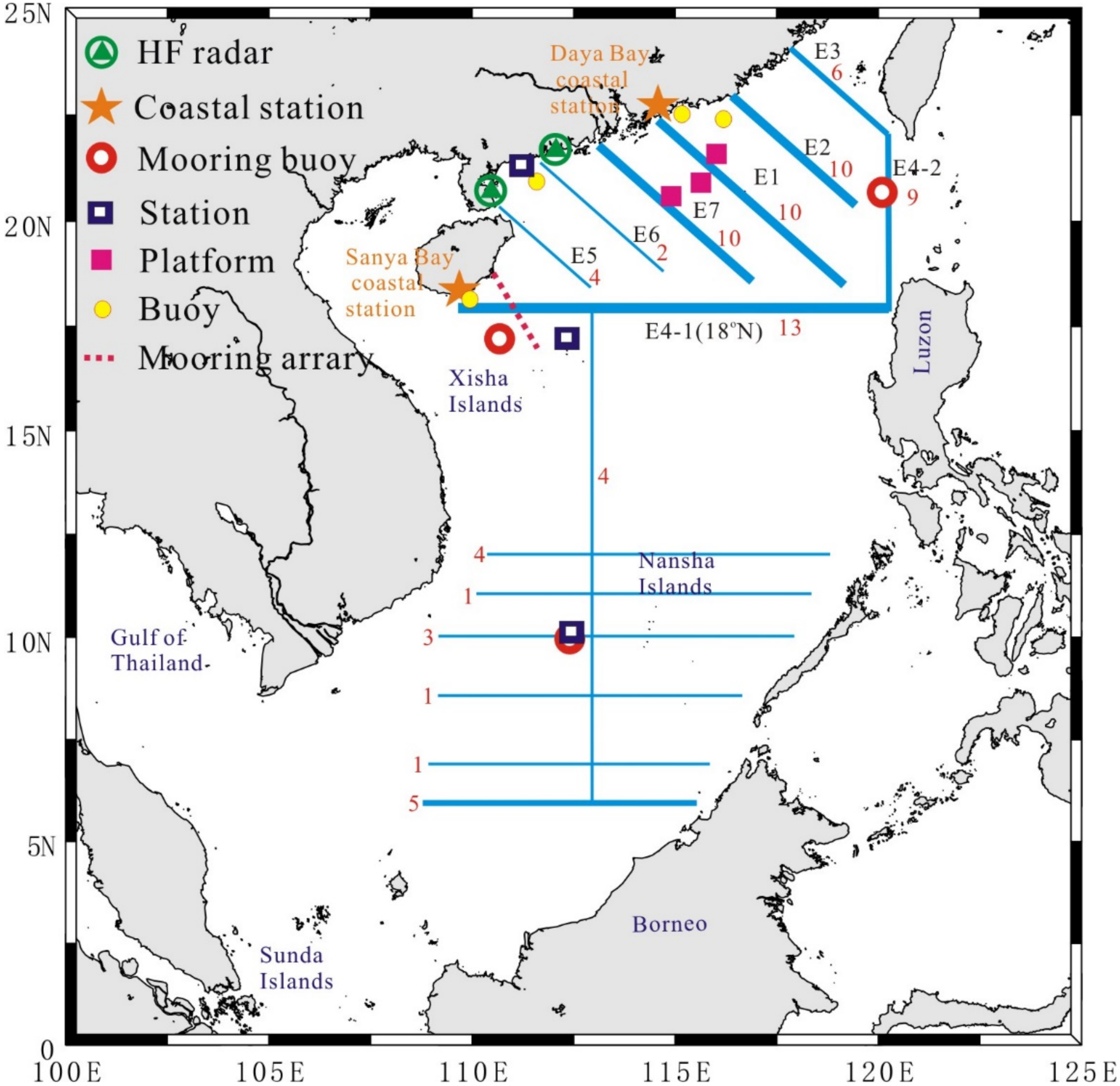



Observations: 2004-2013
Cruise station
Sounding
Xisha station
Nansha station
MMSEB station
Coastal station
Mooring buoy
Buoy
HF radar
Platform
30°N
24°N
18°N
12°N
6°N
0°
100°E
105°E
110°E
115°E
120°E

Station or Cruise		Latitude	Lon
Buoys and stations	Sanya Bay buoy	18.21°N	109
	Shanwei buoy	22.60°N	115
	Maoming buoy	20.73°N	111
	Shantou buoy	22.31°N	117
	Xisha mooring buoy	17.1°N	110
	Nansha mooring buoy	9.78°N	112
	Luzon mooring buoy	20.55N	11
Observation stations including AWSs, flux tower, and platforms	Xisha Station	16.83°N	112
	Nansha Station	9.78°N	112
	Liuhua Platform	20.82°N	11
	Panyu Platform	20.23°N	114
	LeFeng Platform	21.58°N	116
	MMSEB station	21.46 °N	111

Station or Cruise	Latitude	Longitude	Deployment Period	Organized by
Open cruise 2004	14.39°–22.19°N	109.48°–119.45°E	17 Sep–04Oct 2004	SCSIO
Open cruise 2005	13.38°–22.24°N	109.48°–119.61°E	05–22 Sep 2005	SCSIO
Open cruise 2006	17.98°–22.25°N	109.47°–120.01°E	09–28Sep 2006	SCSIO
MEL cruise 2006	10.50°–22.15°N	110.20°–119.00°E	26 Nov–16Dec 2006	Xiamen University
SSCS cruise 2007	5.38°–20.87°N	108.49°–117.98°E	15May–20Jun 2007	SCSIO
Open cruise 2007	17.95°–23.39°N	110.06°–120.03°E	13–27 Aug 2007	SCSIO
Cruise 200709	18.01°–25.01°N	111.13°–119.75°E	24–29 Sep 2007	SCSIO
Cruise 200803	18.89°–22.70°N	112.64°–113.85°E	16–20 Mar 2008	SCSIO
SCOPE cruise 2008	20.27°–23.53°N	114.07°–117.96°E	29Jun–14Jul 2008	Five institutes*
Open cruise 2008	17.01°–22.41°N	109.50°–119.98°E	16 Aug–04Sep 2008	SCSIO
SSCS Cruise 2009	6°–18°N	108°–119.5°E	28Apr–20Jun 2009	SCSIO
MPKI Cruise 2009	18.21°–33.72°N	109.49°–122.55°E	09Jun–05Jul 2009	Institute of Oceanography of the CAS
ROSE cruise 2009	9.19°–19.55°N	110.31°–117.96°E	19Jun–30Jun 2009	First Institute of Oceanography of the SOA
Open cruise 2009	15.77°–22.57°N	109.55°–120.09°E	1–19 Sep 2009	SCSIO
NSFC cruise 2010	8°–23°N	110°–120°E	24 Apr–25 May 2010	SCSIO
Xisha cruise 2010	16.5°–19°N	110.5°–113.2°E	10–14Aug 2010	SCSIO
Open cruise 2010	18°–22°N	110°–120°E	31Aug–23Sep 2010	SCSIO
Open cruise 2010	16.93°–23.05°N	110.30°–120.01°E	02–20Sep 2010	SCSIO
ROSE cruise 2010	7.06°–19.00°N	109.95°–117.95°E	26Oct–11Nov 2010	First Institute of Oceanography of the SOA
SSCS cruise 2010	6°–18°N	108°–120.11°E	27Oct–20Nov 2010	SCSIO
Xisha Cruise 2011	16.47°–18.39°N	109.56°–111.74°E	2–5Jun 2011	SCSIO
Open cruise 2011	16.97°–22.32°N	109.44°–120.02°E	21Aug–10Sep 2011	SCSIO
SSCS cruise 2011	6°–18°N	105.5°–114°E	28Nov 2011– 12Jan2012	SCSIO
Xisha cruise 2012	15.64°–17.74°N	110.04°–112.33°E	15–25 May 2012	SCSIO
SSCS cruise 2012	6°–22°N	108°–119°E	Aug 6–Sep 12 2012	SCSIO
NSFC open Cruise 2012	14°–22°N	110°–119°E	2 6Sep–29 Oct 2010	SCSIO
Open cruise 2012	17.27°–21.93°N	108.49°–113.74°E	13–22 Dec 2012	SCSIO
Xisha Cruise 2013	14.96°–18.41°N	110.79°–116.54°E	14–26 Aug 2013	SCSIO
NSFC open cruise 2013	9.8°–21.3°N	110.3°–114°E	05 Aug–06 Sep 2013	SCSIO
NSFC open cruise 2013	14.1°–23°N	110.3°–118°E	24 Sep–24 Oct 2013	SCSIO

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


HF radar
Coastal station
Mooring buoy
Station
Platform
Buoy
Mooring arrary
Daya Bay coastal station
Sanya Bay coastal station
E3 6
E2 10
E1 10
E4-2 9
E7 10
E6 2
E5 4
E4-1(18°N) 13
Xisha Islands
Luzon
4
Nansha Islands
4
1
3
1
1
5
Gulf of Thailand
Borneo
Sunda Islands
25N
20N
15N
10N
5N
0
100E
105E
110E
115E
120E
125E

Observations have been used in several scientific issues

Regional circulation in the SCS since the 1990s

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

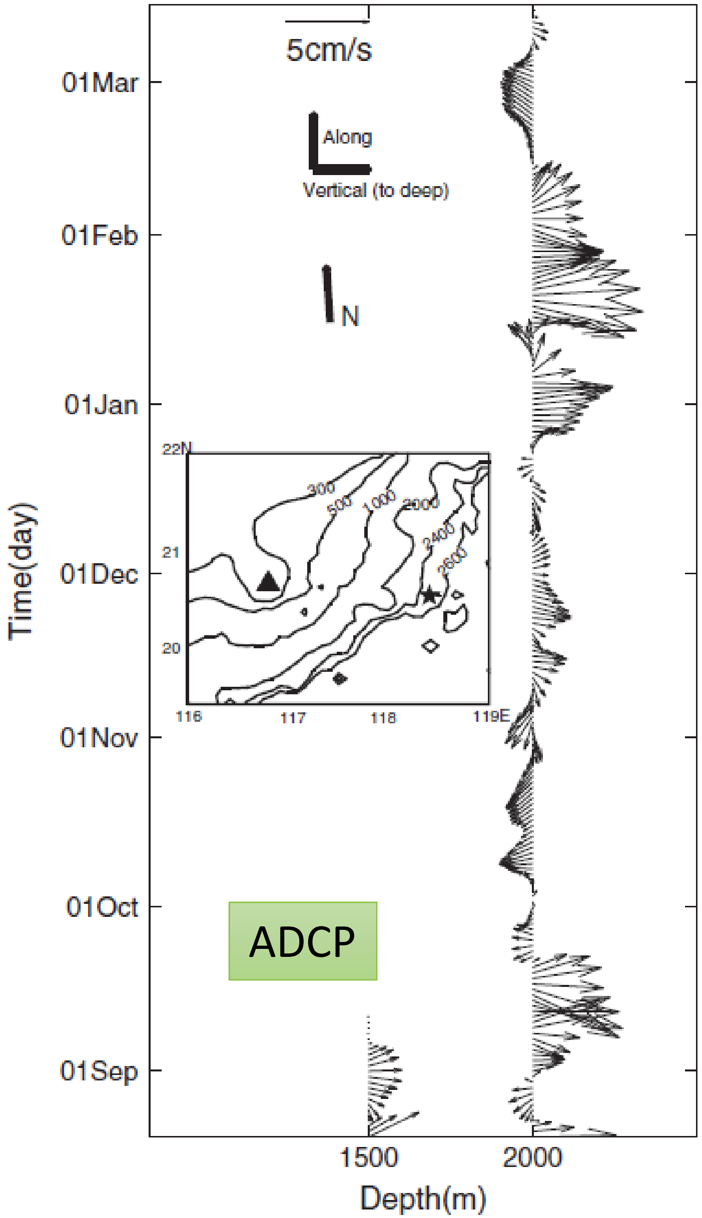
Processes in the MABL

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

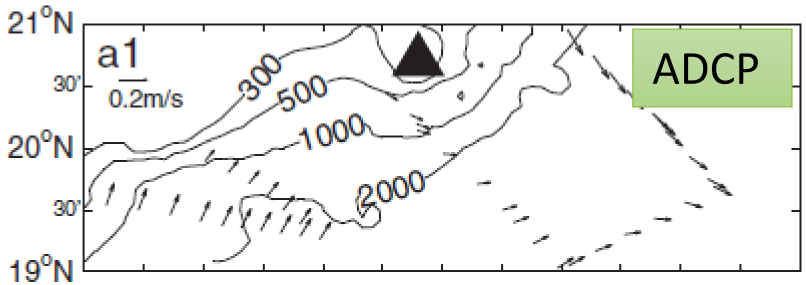
Atmospheric disturbance and tropical cyclones

- Synoptic perturbations and their interannual variability
- Air-sea interactions during tropical cyclone passages

Scientific applications

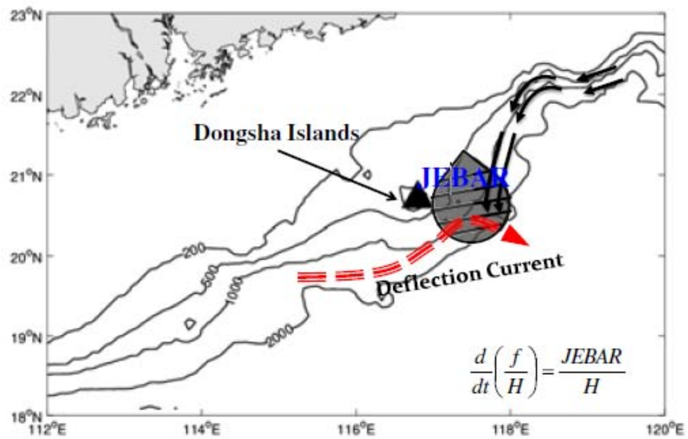


The deflection of the SCS warm current



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.

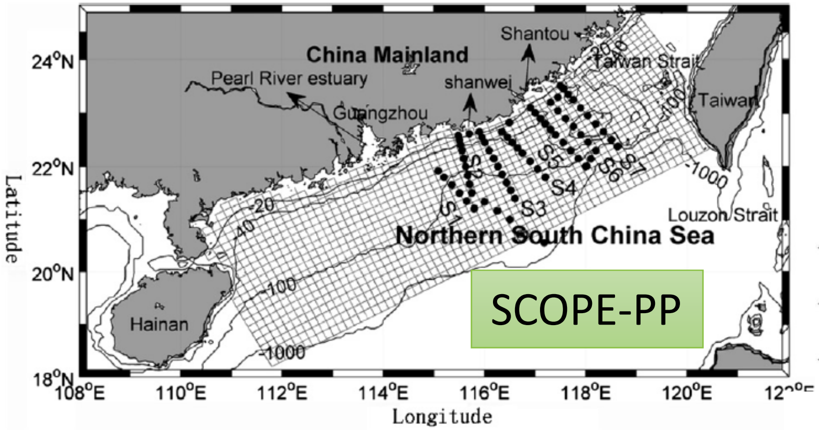
ADCP and CTD confirmed the deflection. Combining the observations and model simulation, it is found that JEBAR plays an important role in the deflection



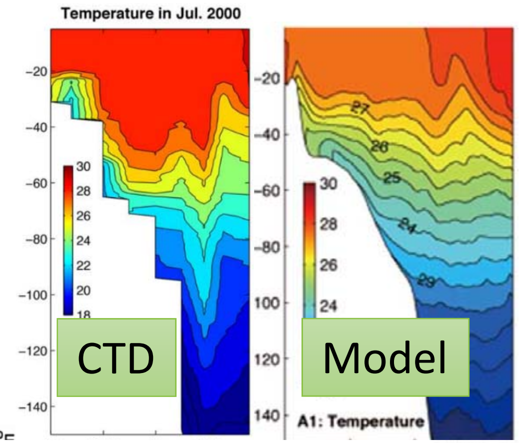
Wang et al. (2013) JGR

Scientific applications

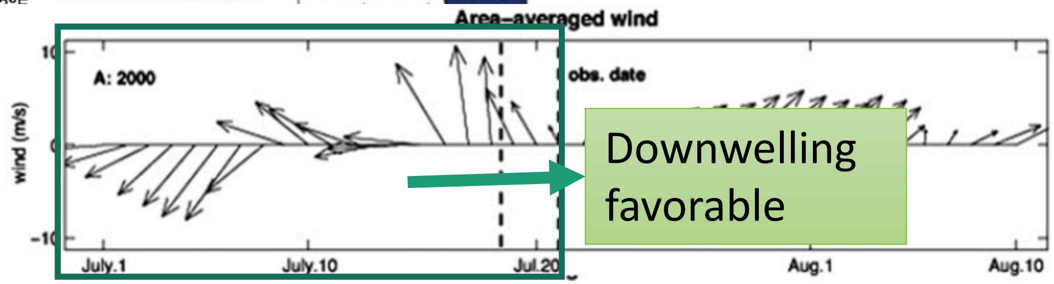
Upwelling in the northern SCS

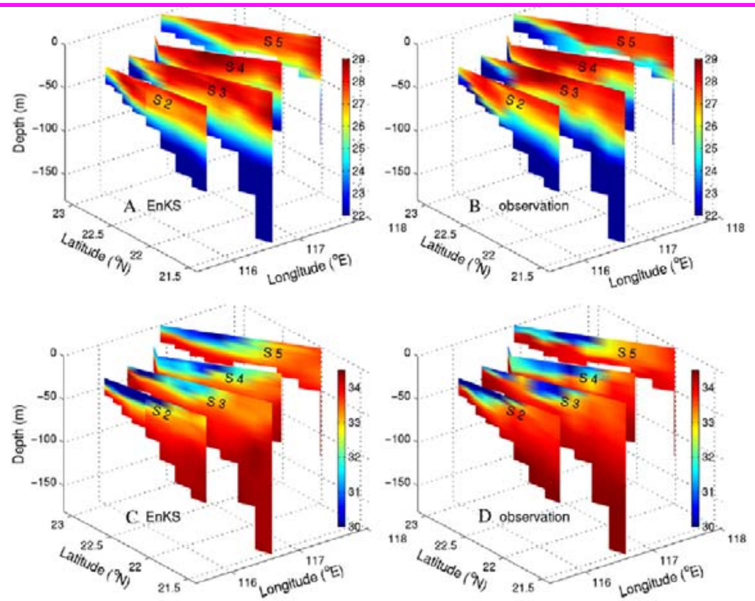


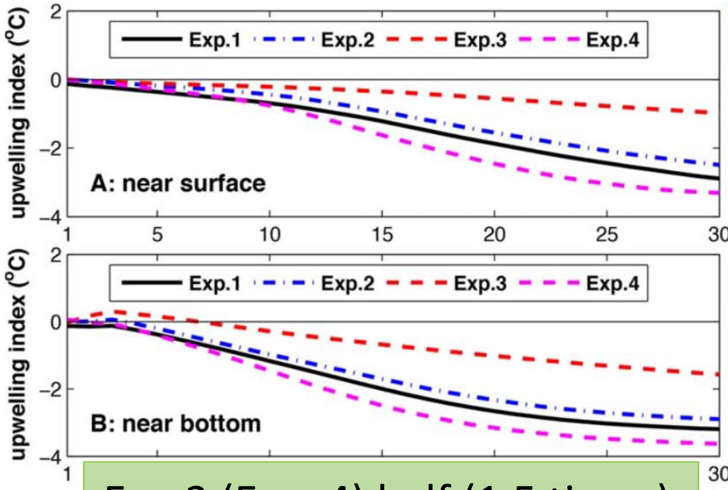
Assimilating CTD measurements obtained from SCOPE (2008) into a regional ocean model



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.







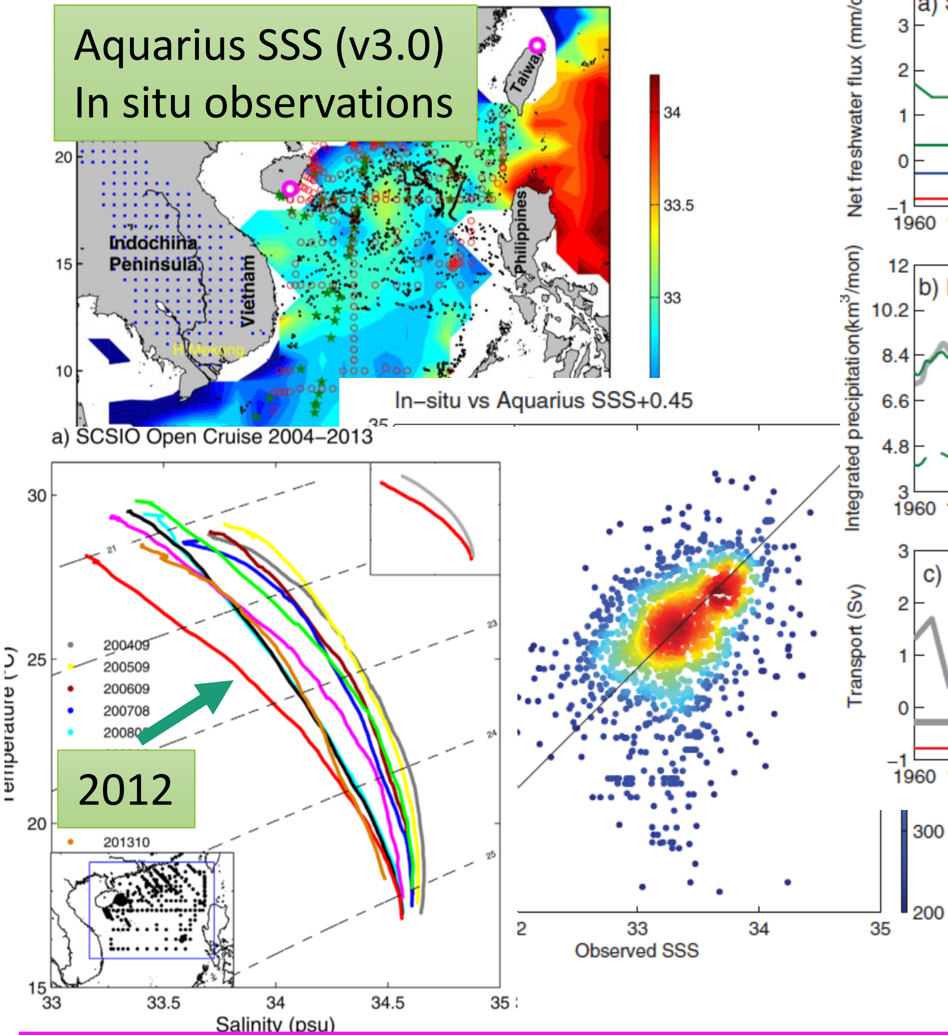
Exp.3 (Exp. 4) half (1.5 times) large-scale current

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

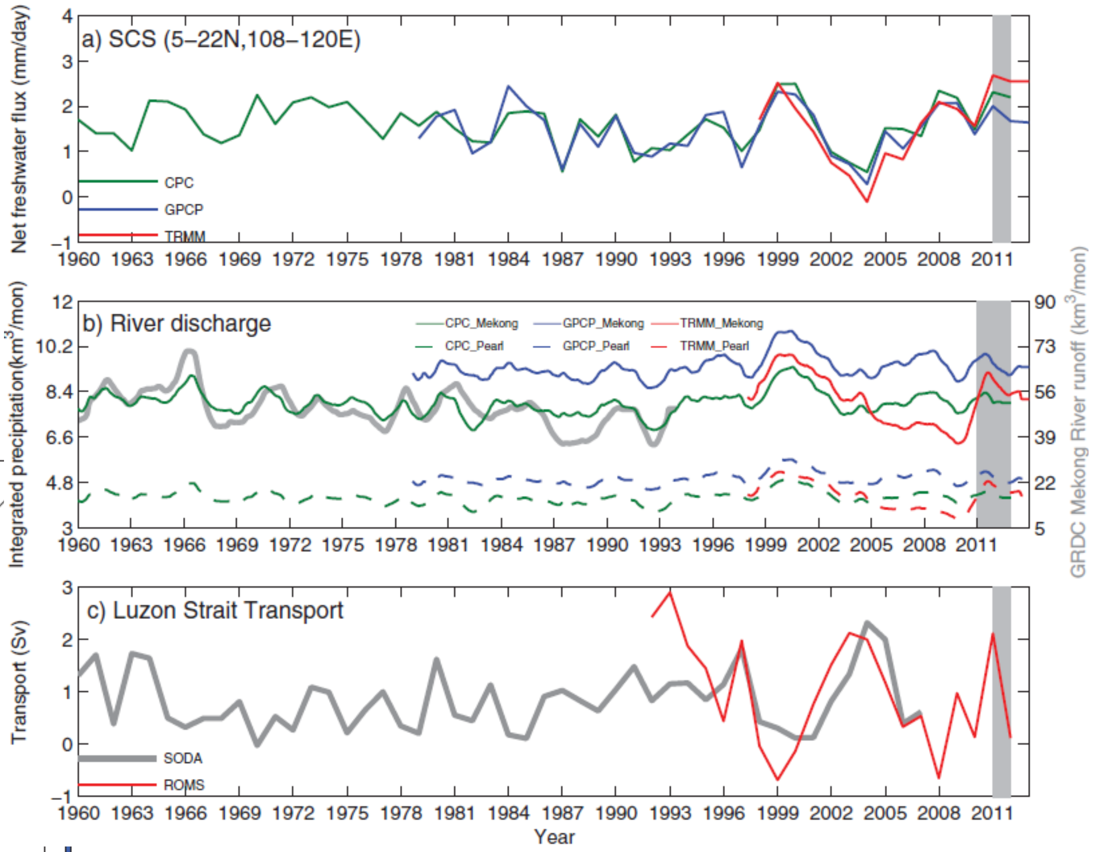
Shu et al. (2011a) CSR; Shu et al. (2011b OM); Wang et al., (2014) JGR

Scientific applications

Aquarius SSS (v3.0)
In situ observations



Freshening of 2012 in the northern SCS



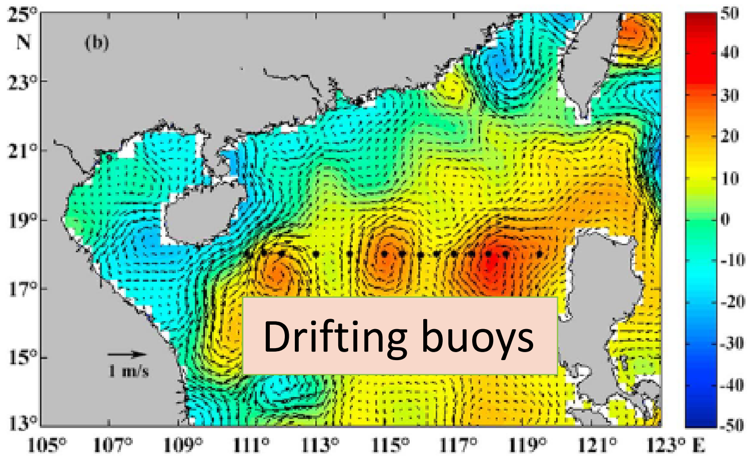
A freshening of up to 0.4 psu in the upper ocean of the northern SCS in 2012 using satellite observations, which were evaluated against in situ observations from the SCS

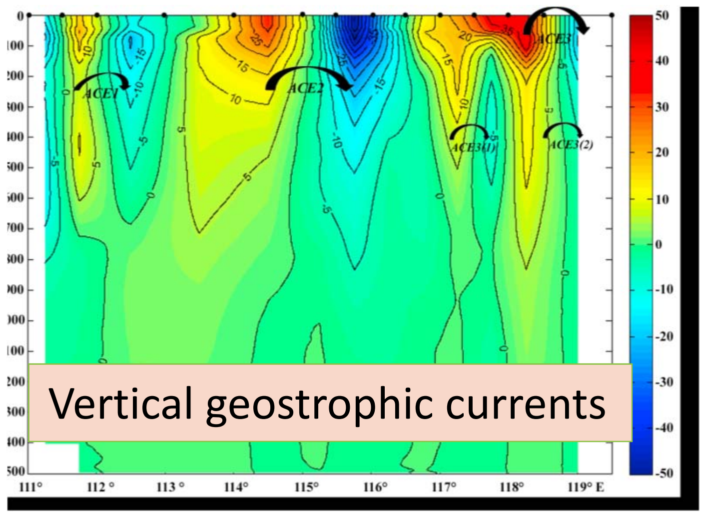
The study suggested that the freshening in 2012 might have been caused by the combined effect of abundant local freshwater flux and limited Kuroshio intrusion.

Zeng et al. (2013) JGR

Scientific application

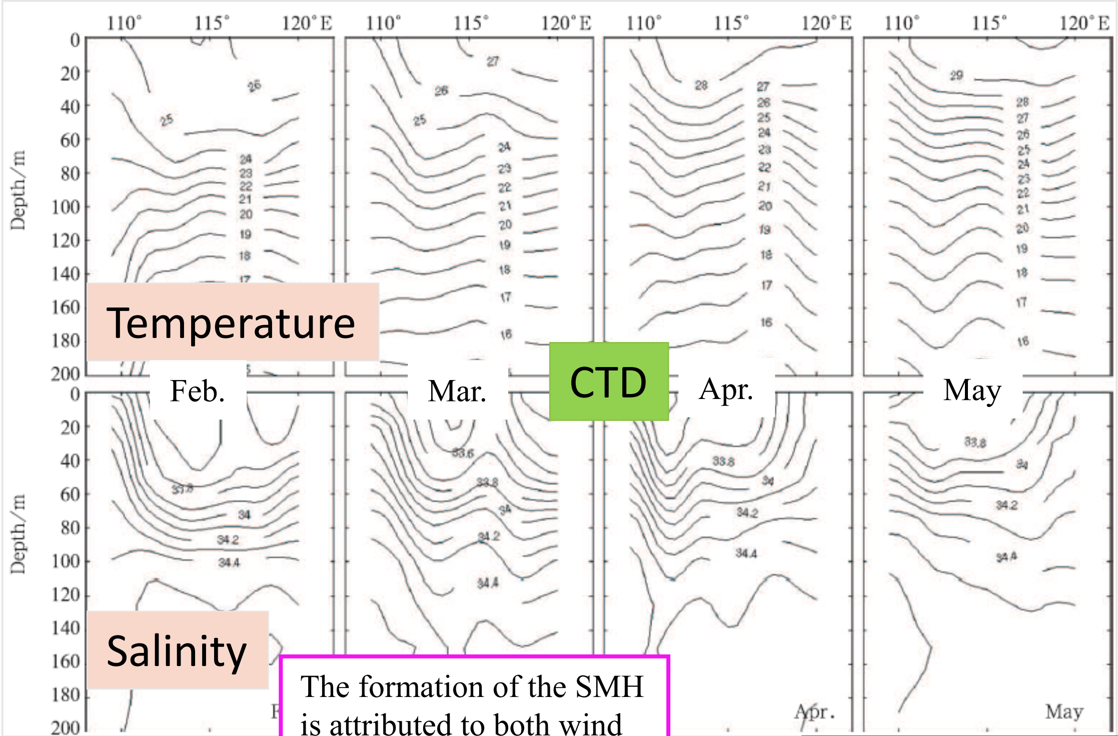
SST perturbations associated with eddies, oceanic fronts

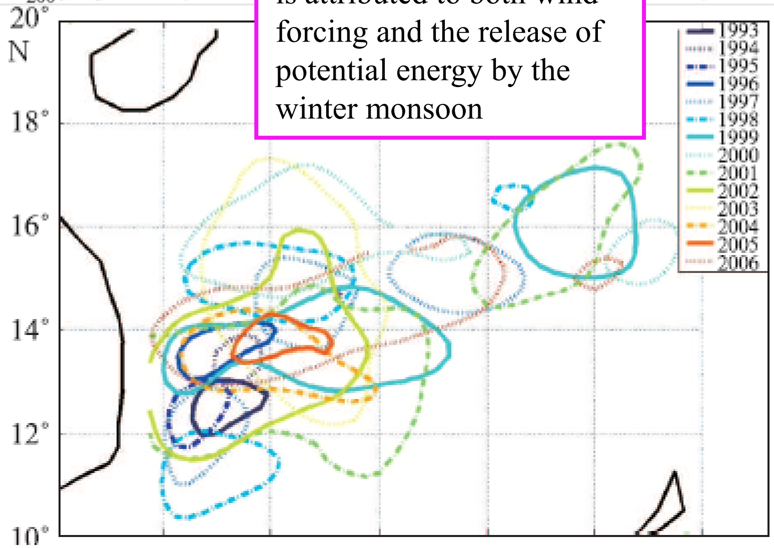




The CTD and ADCP data, as well as those from drifting buoys, successfully captured the vertical structure of the three eddies and their evolutions

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



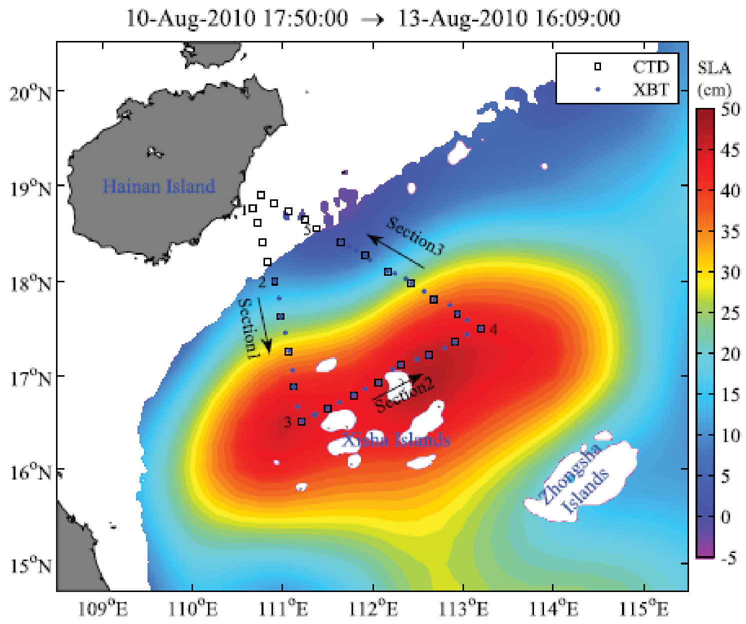


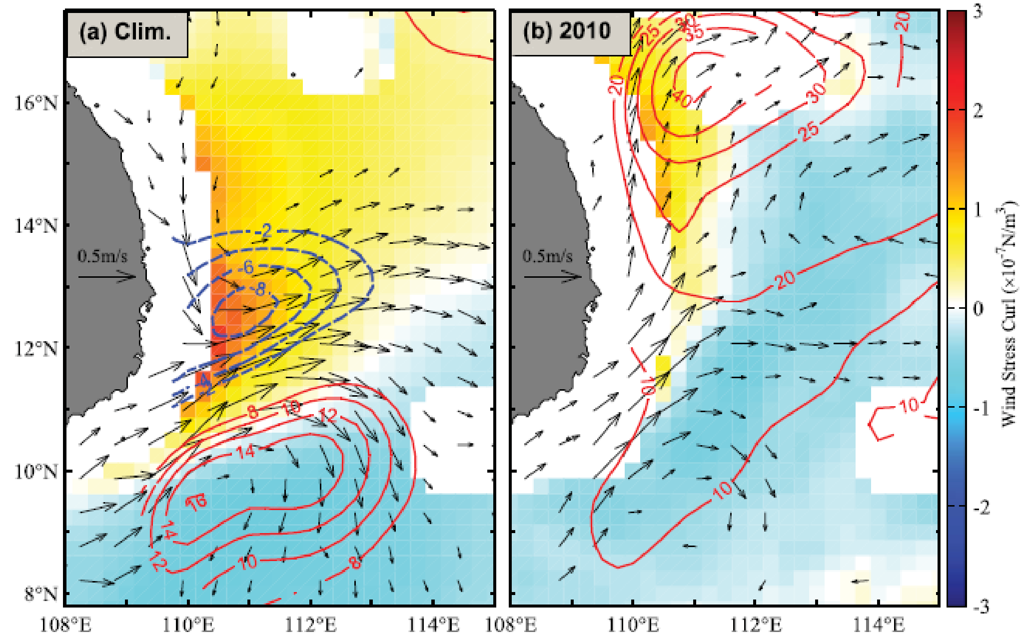
The formation of the SMH is attributed to both wind forcing and the release of potential energy by the winter monsoon

Observations confirms the existence of a recurring spring mesoscale eddy with a warm core and low salinity (with interannual variation on location and size)

Scientific applications

SST perturbations associated with eddies, oceanic fronts





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

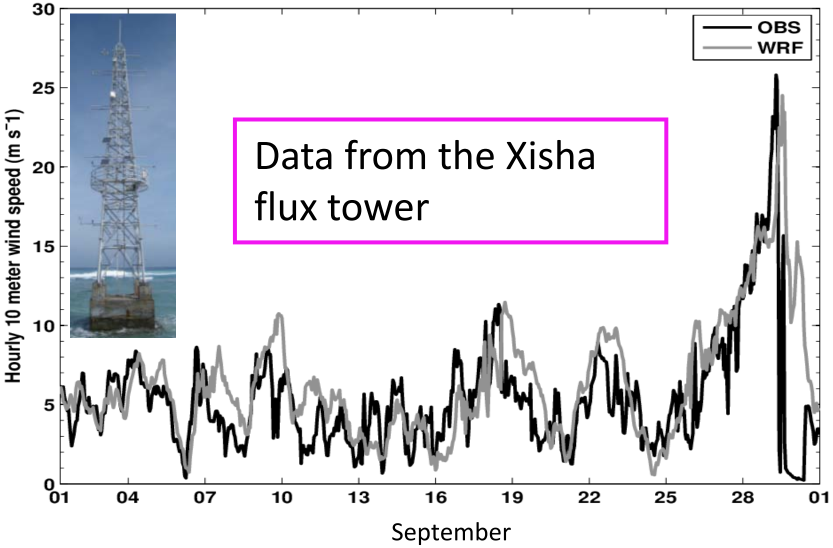
A strong El Niño event in 2009/2010 altered the intensity and direction of the summer monsoon, resulting in the disappearance of this pattern and the northward movement of a preexisting warm eddy along the Vietnam coast.

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

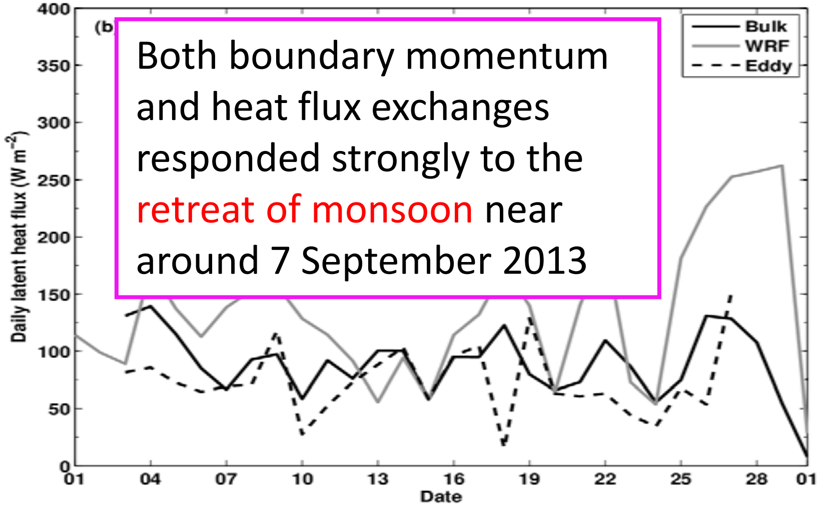
Chu et al. (20114) JGR;

Scientific applications

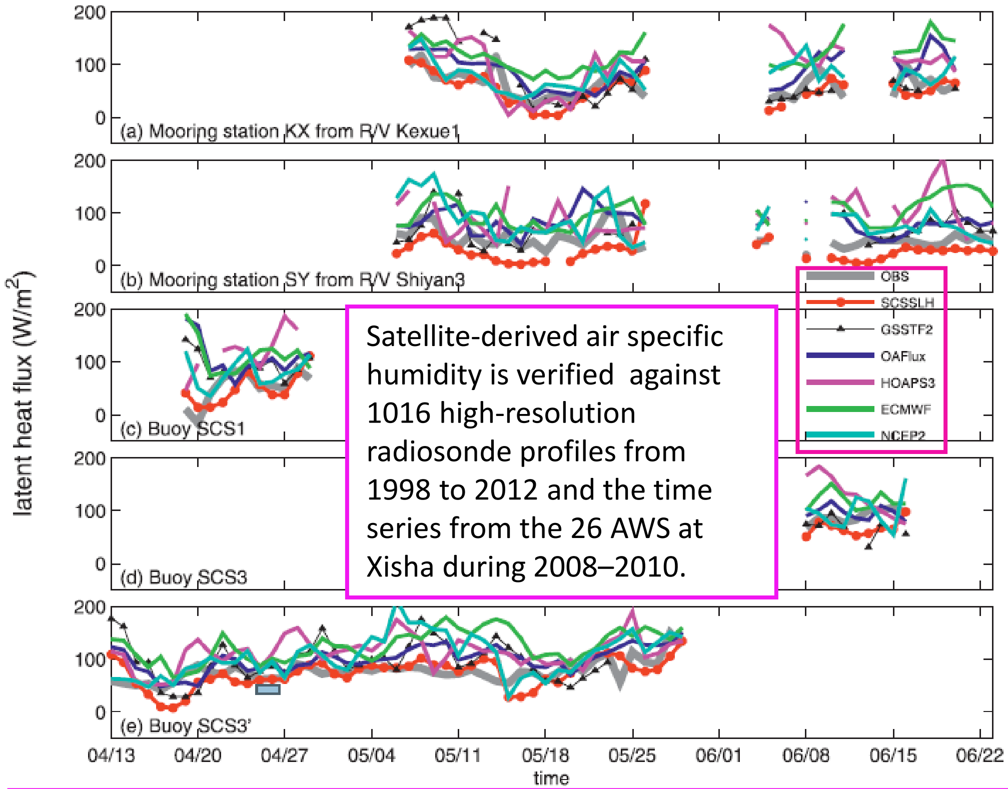
Processes in the MABL



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.

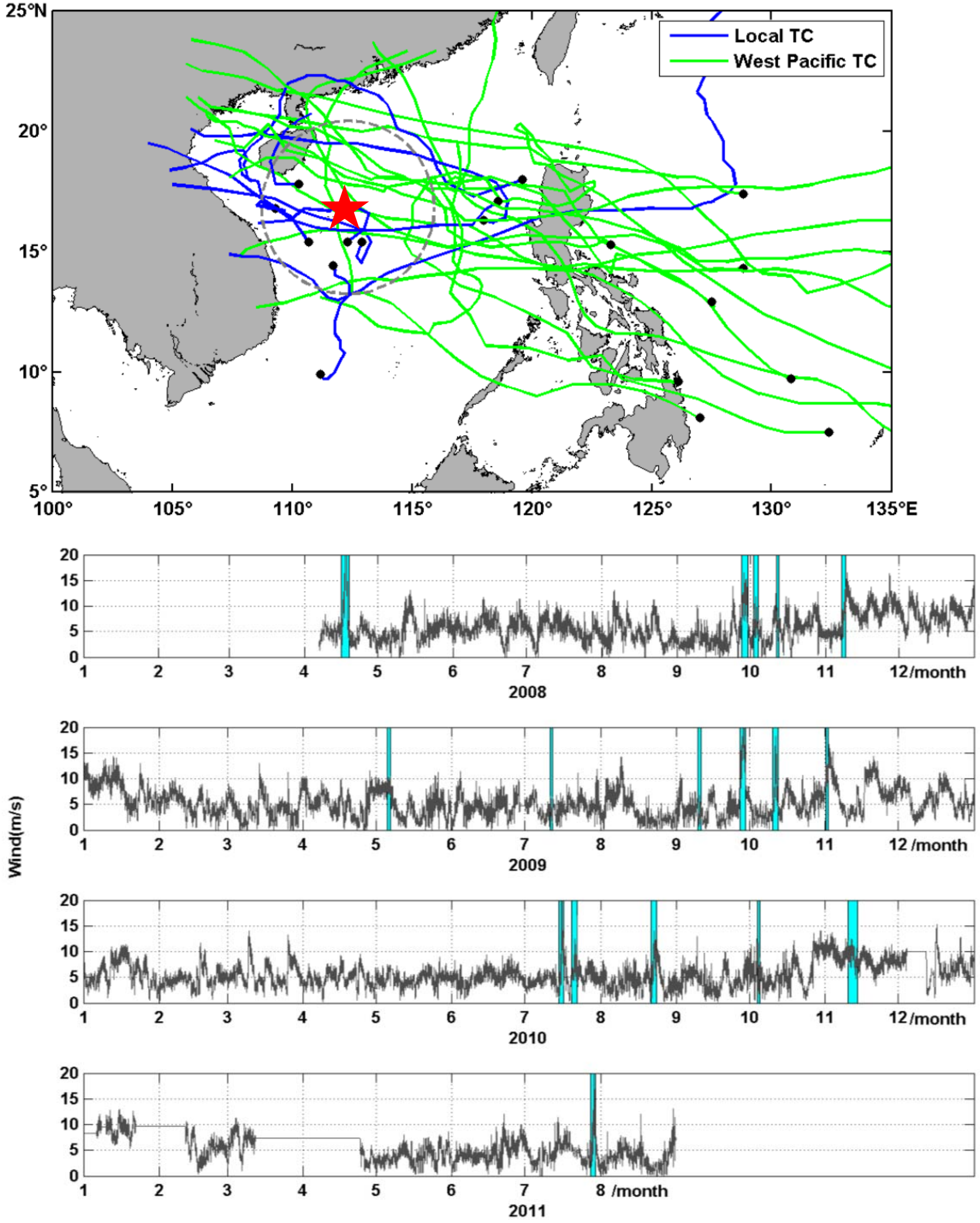
SCSSLH shows the highest spatial resolution and realistic values in the SCS, with an exception along the northern continental shelf.
The other five products overestimate the latent heat flux systematically.

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.

Shi et al. (2014), AHEMS; Wang et al. (2014), JAOT

Scientific applications

Air-sea interactions during tropical cyclone passages



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

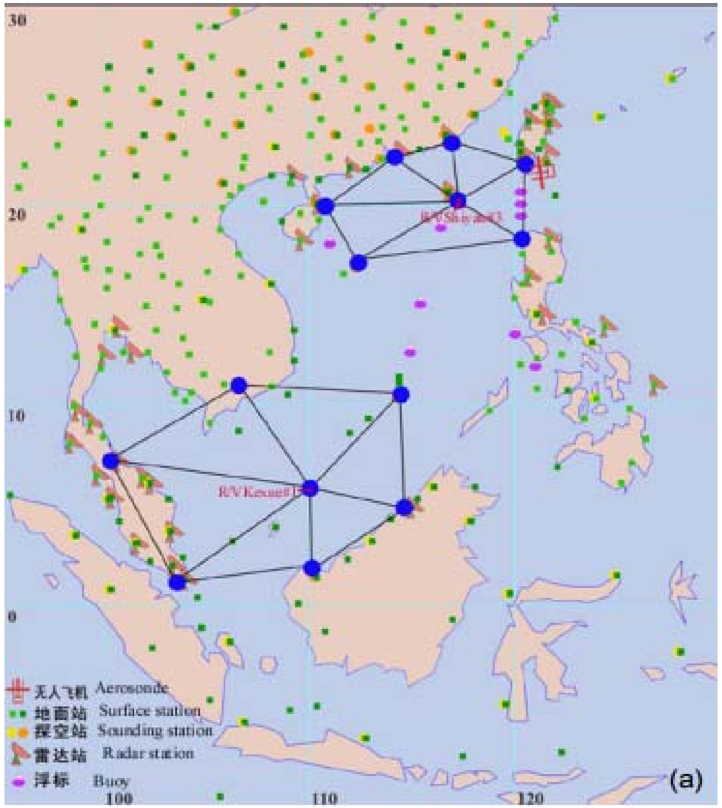
The mesoscale observation network in the SCS consists of both oceanic and meteorological observations during cruises and at stations.

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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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, Austrlia monsoon, South China Sea summer monsoon)

- Regional model development

Thank you for your attention!

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