Ocean observation to increase predictability in climate change adaptation: status of scientific studies and challenges in Asia and Pacific

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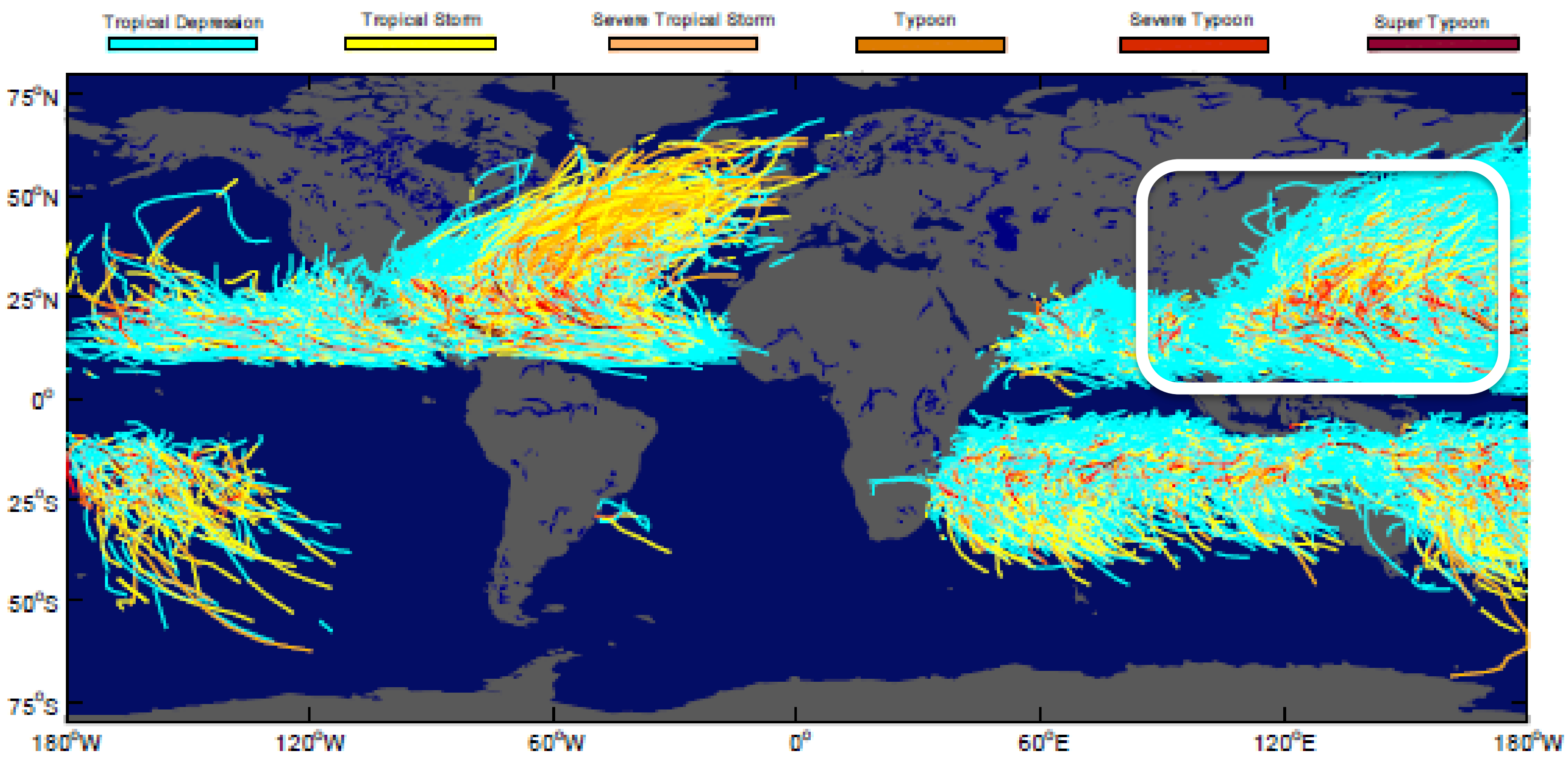
Outline

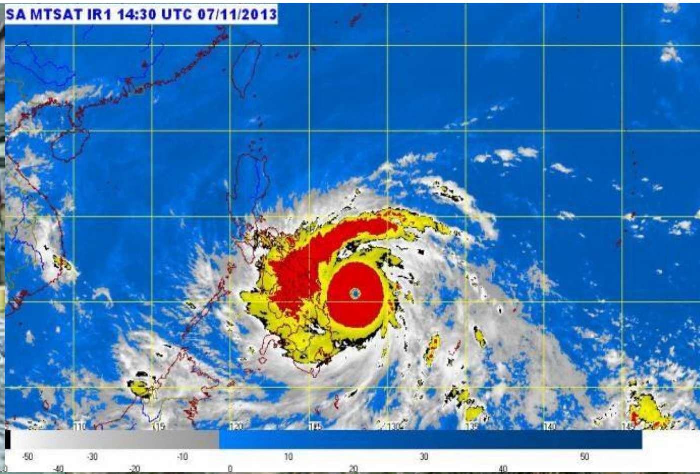
1. Where are we
2. Development of advanced models
3. Joint observation and DA
4. Summary

1. Where are we?

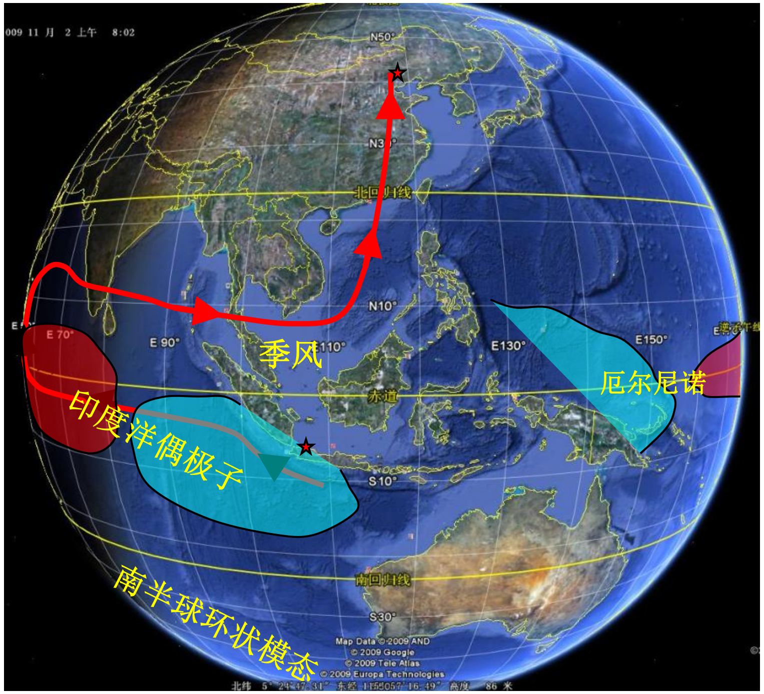
(1) Attacked by marine hazards such as Typhoon frequently

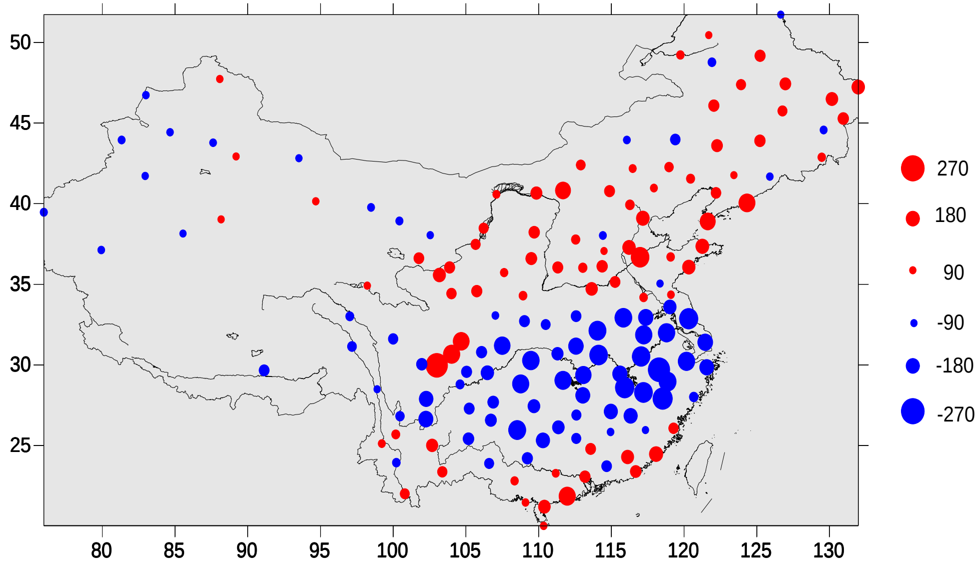


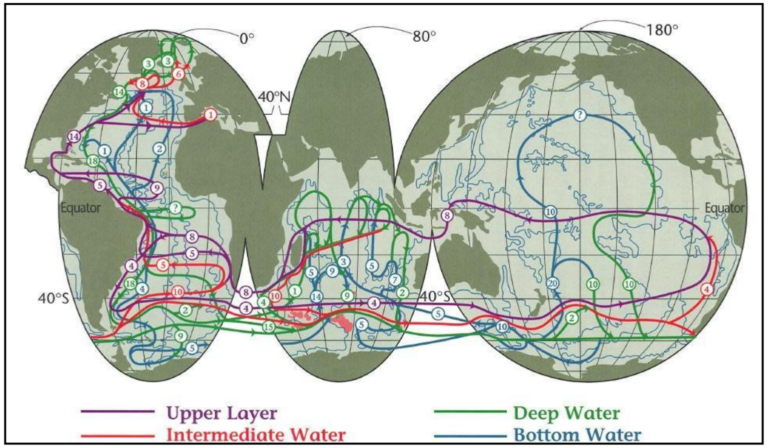
- Haiyan attached the Philippines in Nov 2013, with 6201 dead and 11.8M affected



➢ The relationship with Asian Monsoon

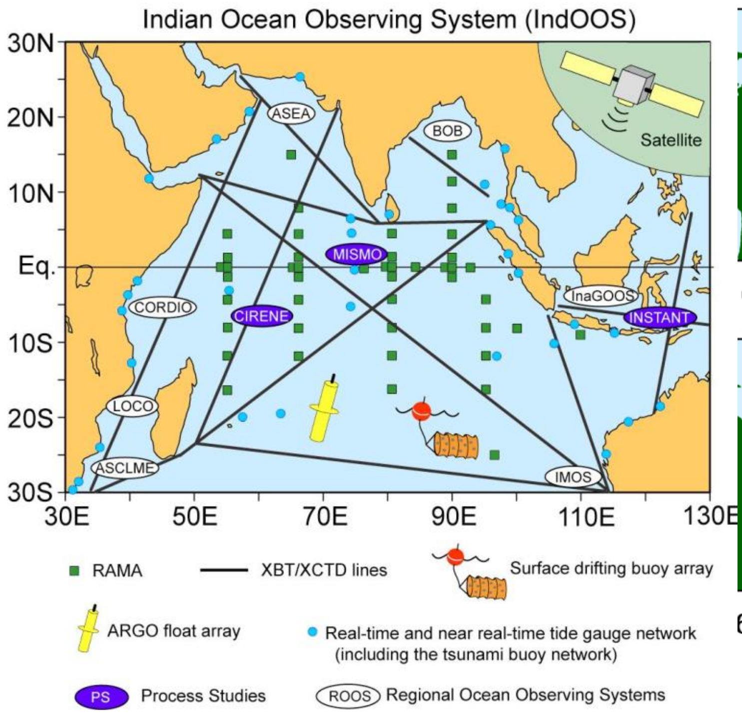


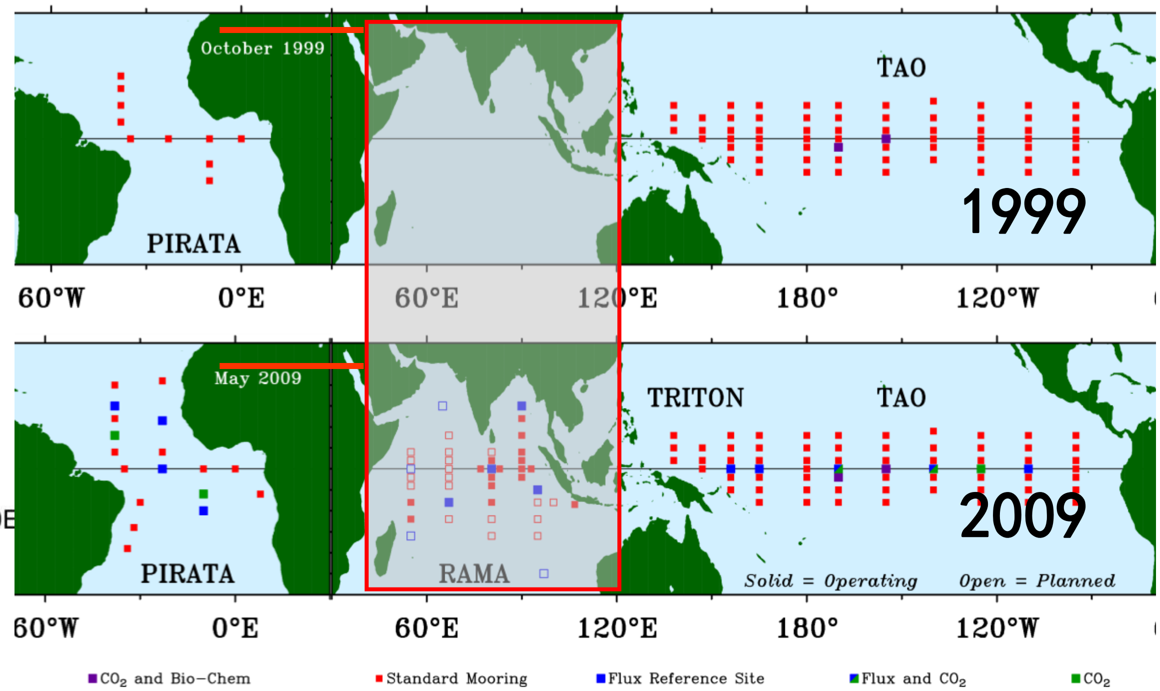




✓ Stong monsoon: More rain in south and north China, while less rain along Changjiang River

(2) Observation

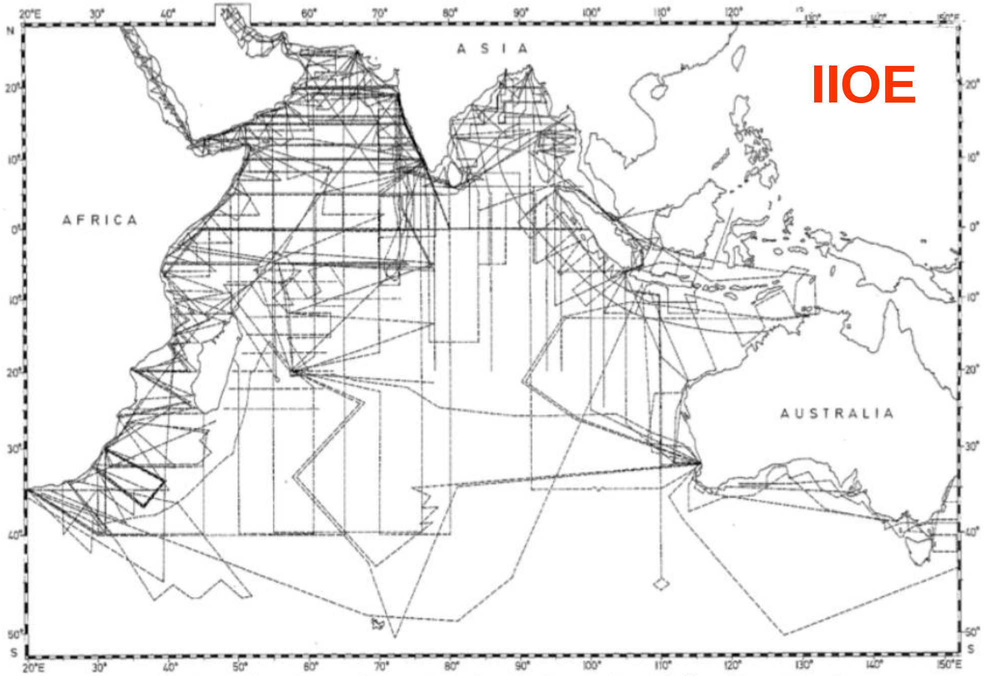




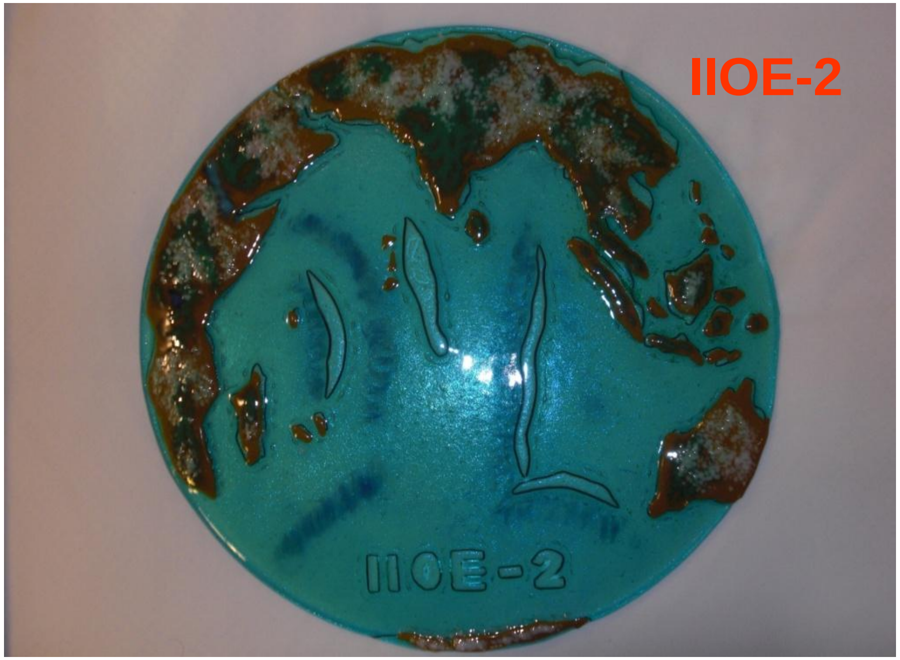
United Nations
Educational, Scientific and
Cultural Organization

➢Planning for the Indian Ocean Expedition 50th Anniversary

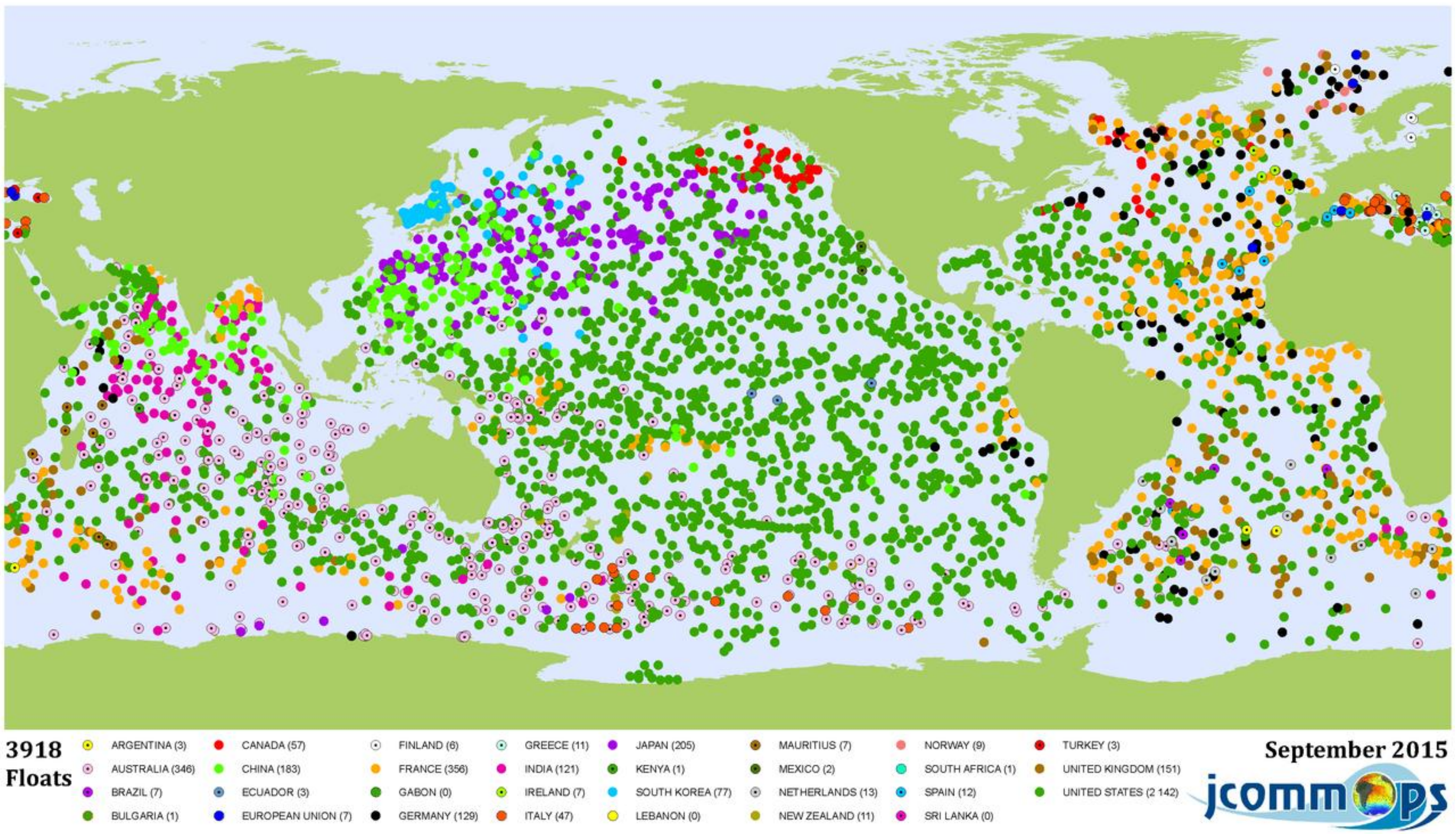
Initiative (IIOE–2, 2015-2020)



Cruise tracks of research vessels during the International Indian Ocean Expedition. Based on information from the Office of Oceanography, UNESCO, Paris

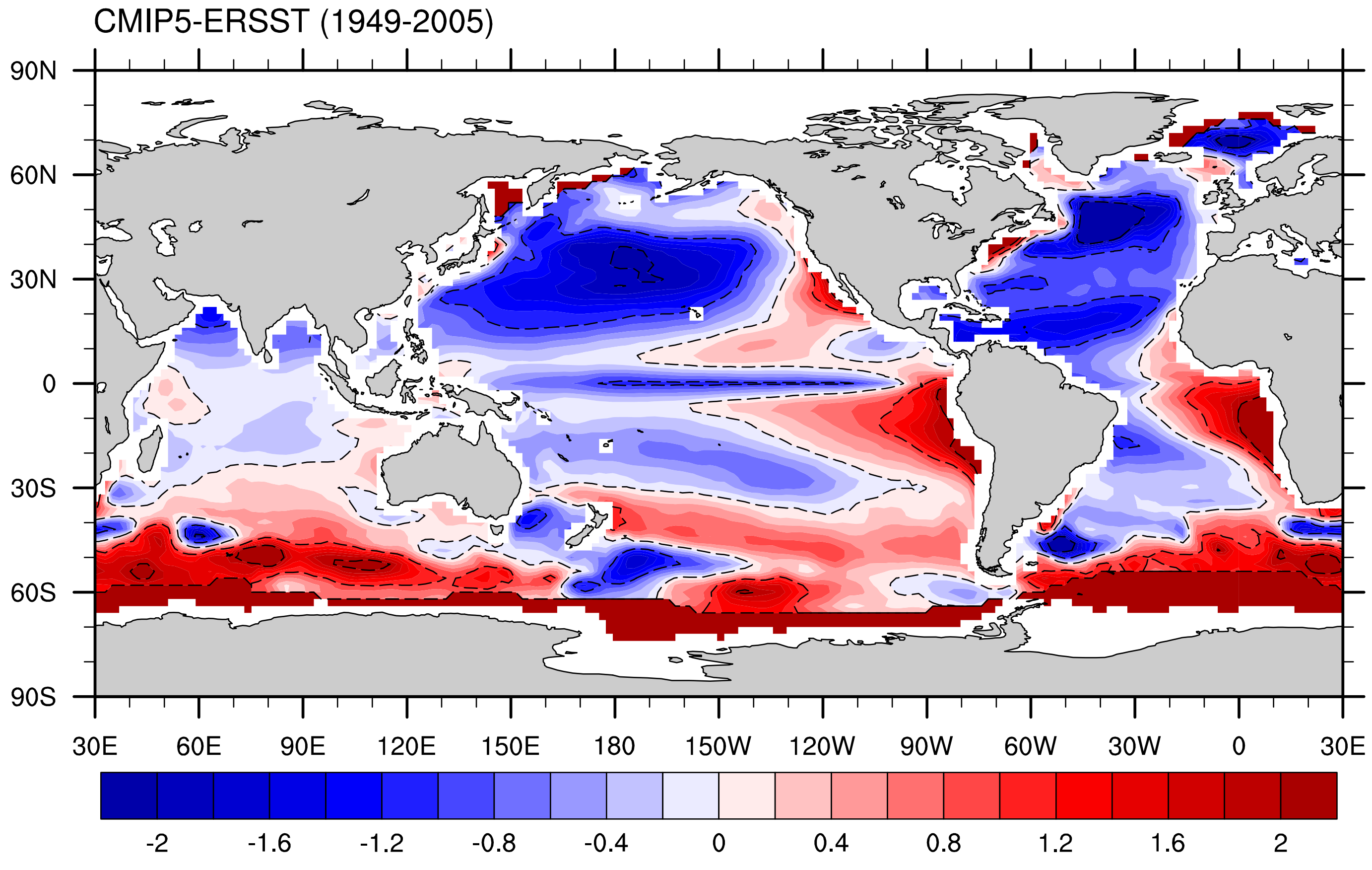


ARGO

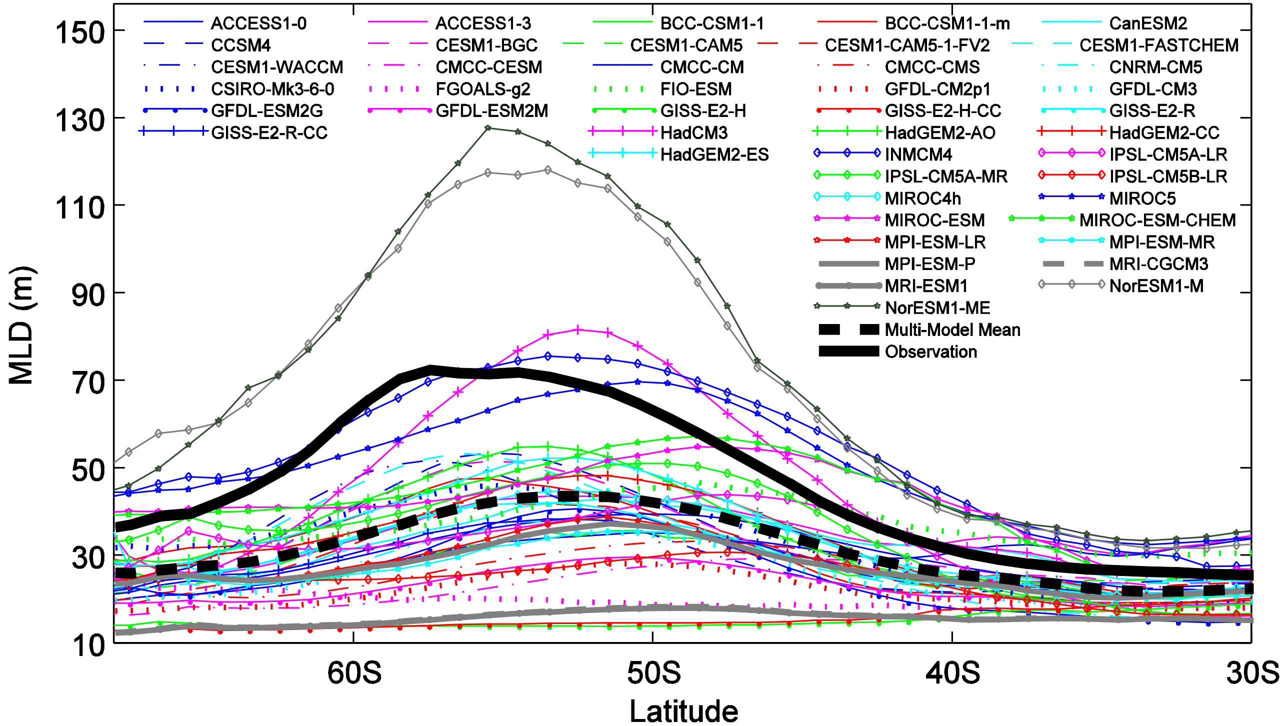


However, ocean monitoring network for marine hazards and climate change is still urgently needed.

(3) Climate models of CMIP5: Double ITCZ and SST

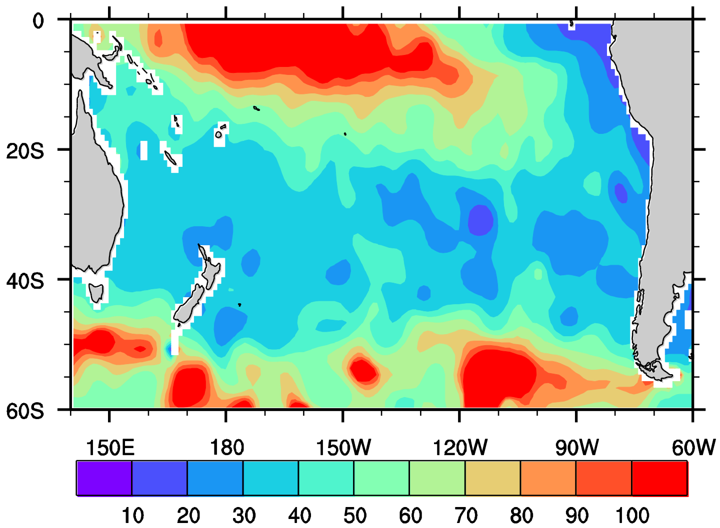


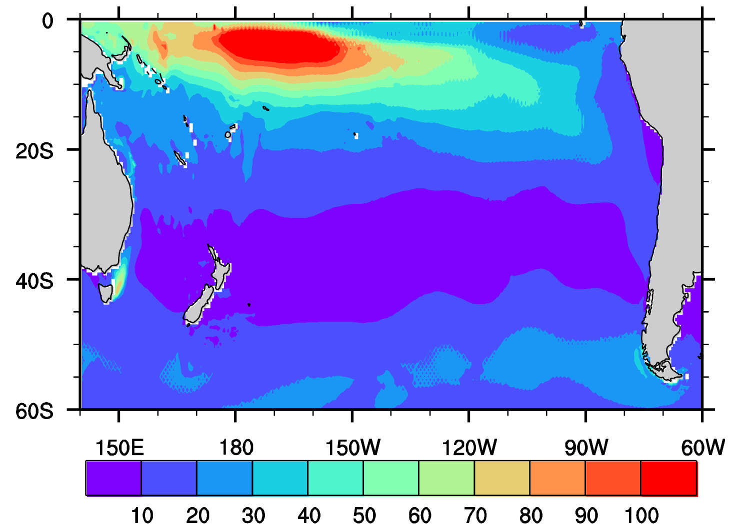
MLD in CMIP5 models



Huang et al, 2014, JGR

MLD in OGCM

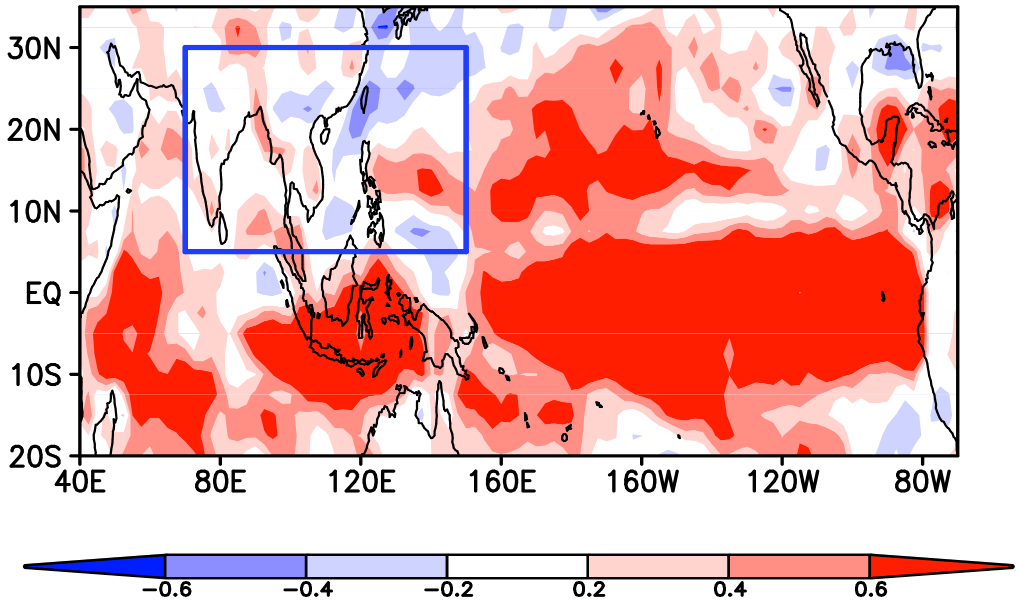




✓ Observation

✓ Model from POM

➢ For Asian Monsoon area



✓ Prediction skills of 5 AGCMs

（Wang et al, 2004）

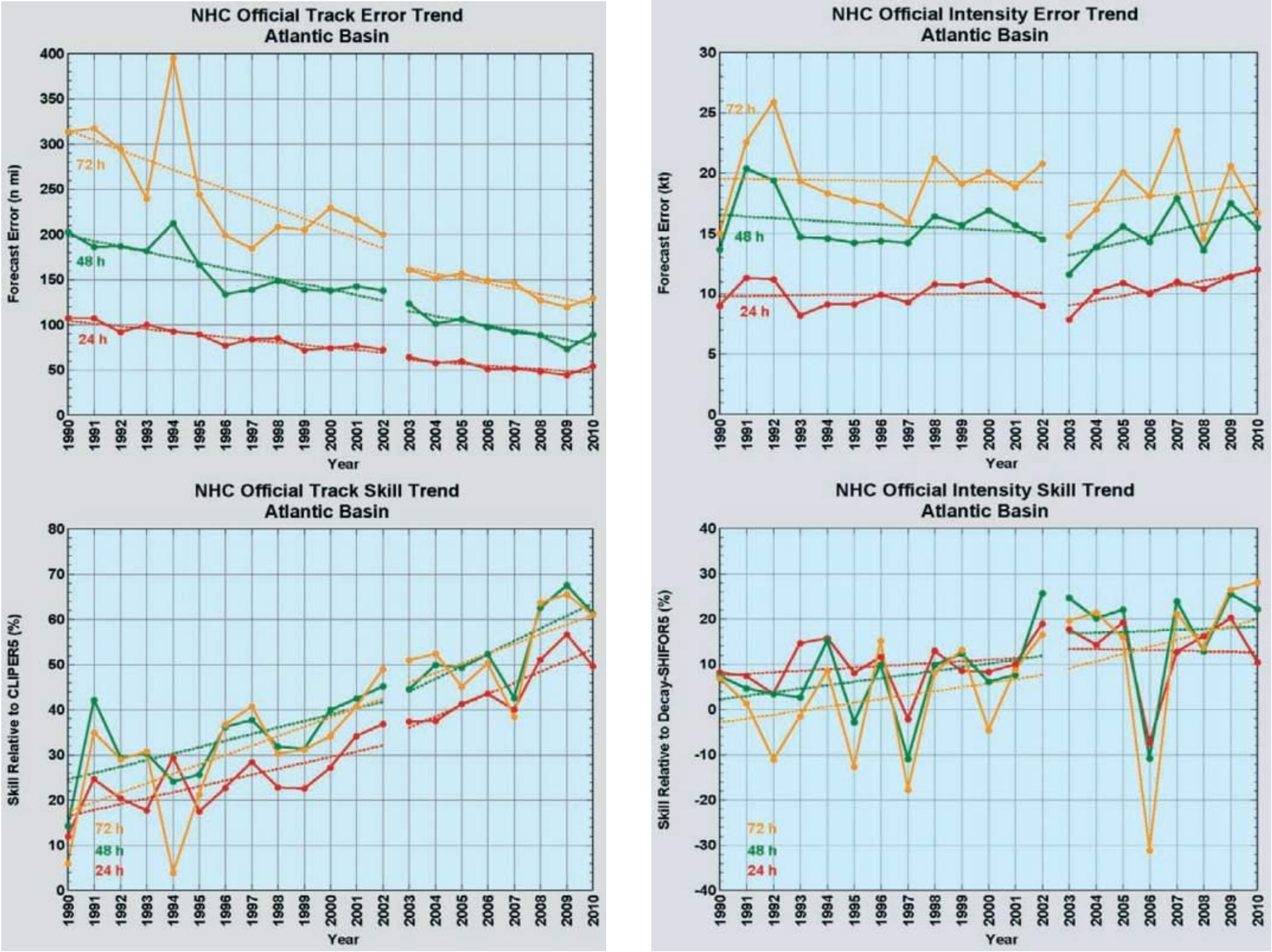
25 CMIP5 models

- Rainfall
- Too late for Monsoon onset
- Asian summer monsoon too weak while northwest Pacific monsoon too strong

Sperber et al,2012, CD

➤ Typhoon/Hurrican

Rappaport et al, 2012, BAMS



2. Development of advanced numerical models

(1) Theory of surface wave-induced mixing

$$B_V = \alpha \iint_{\vec{k}} E\left(\vec{k}\right) \exp\left\{2kz\right\} d\vec{k} \, \frac{\partial}{\partial z} \left(\iint_{\vec{k}} \omega^2 E\left(\vec{k}\right) \exp\left\{2kz\right\} d\vec{k} \right)^{1/2}$$

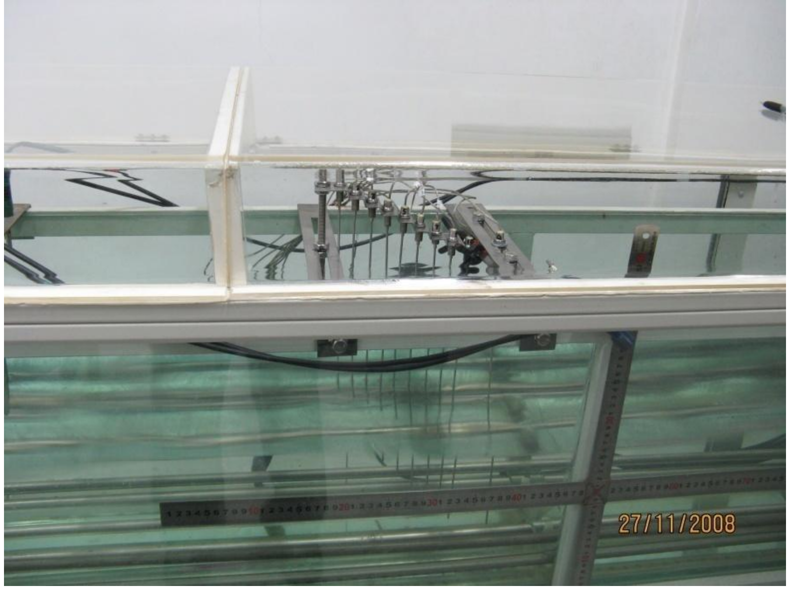
E(K) is the wave number spectrum which can be calculated from a wave numerical model. It will change with (x, y, t), so Bv is the function of (x, y, z, t). **Qiao et al, 2004, 2010, 2015**

If we regard surface wave as a monochramatic wave,

$$B_v = \alpha A^3 k \omega \, e^{(-3kz)} = \alpha A \, u_s \, e^{(-3kz)} \, ,$$

Stokes Drift

Bv is wave motion related vertical mixing instead of wave breaking.

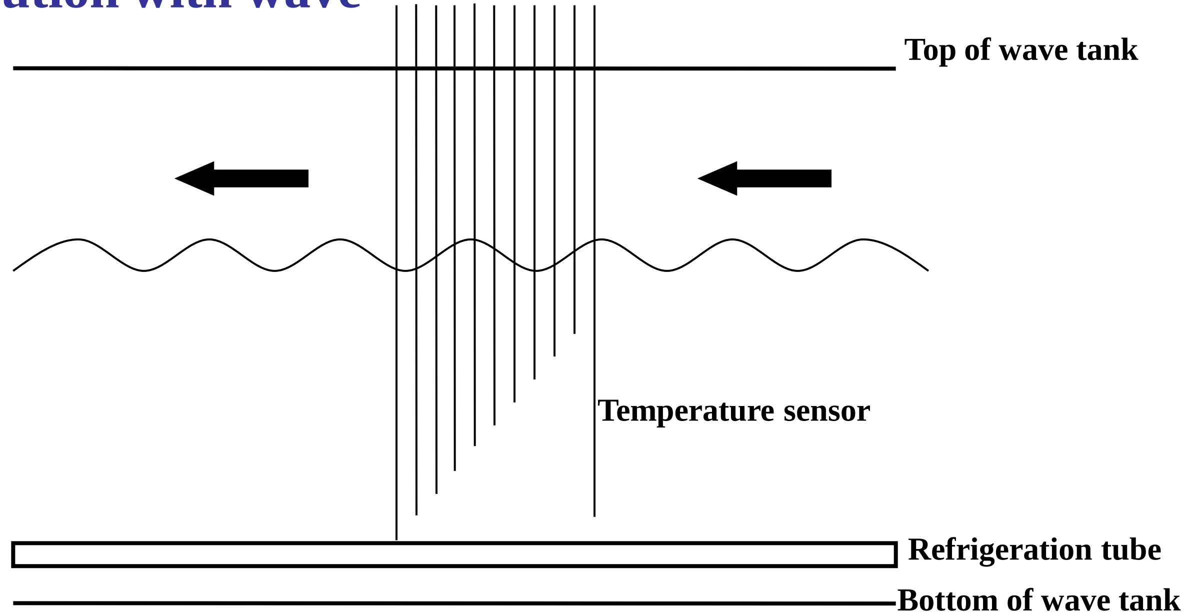


Laboratory experiments:

Wave tank: 5m in length with height of 0.4m and width of 0.2m. To generate temperature gradient through bottom cooling of refrigeration tubes, and temperature sensors are self-recorded with sampling frequency of 1Hz.

(1) Temperature evolution in natural condition

(2) Temperature evolution with wave

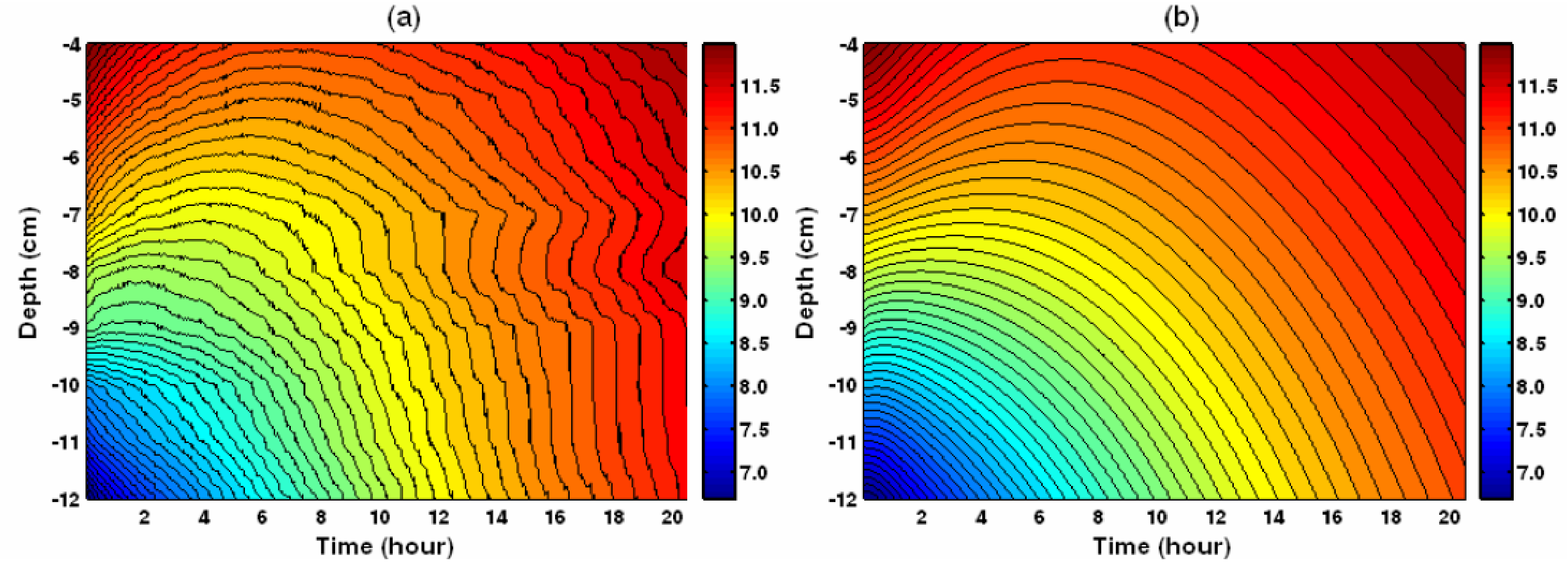


Dai and Qiao et al, JPO, 2010

Experiment results without and with waves

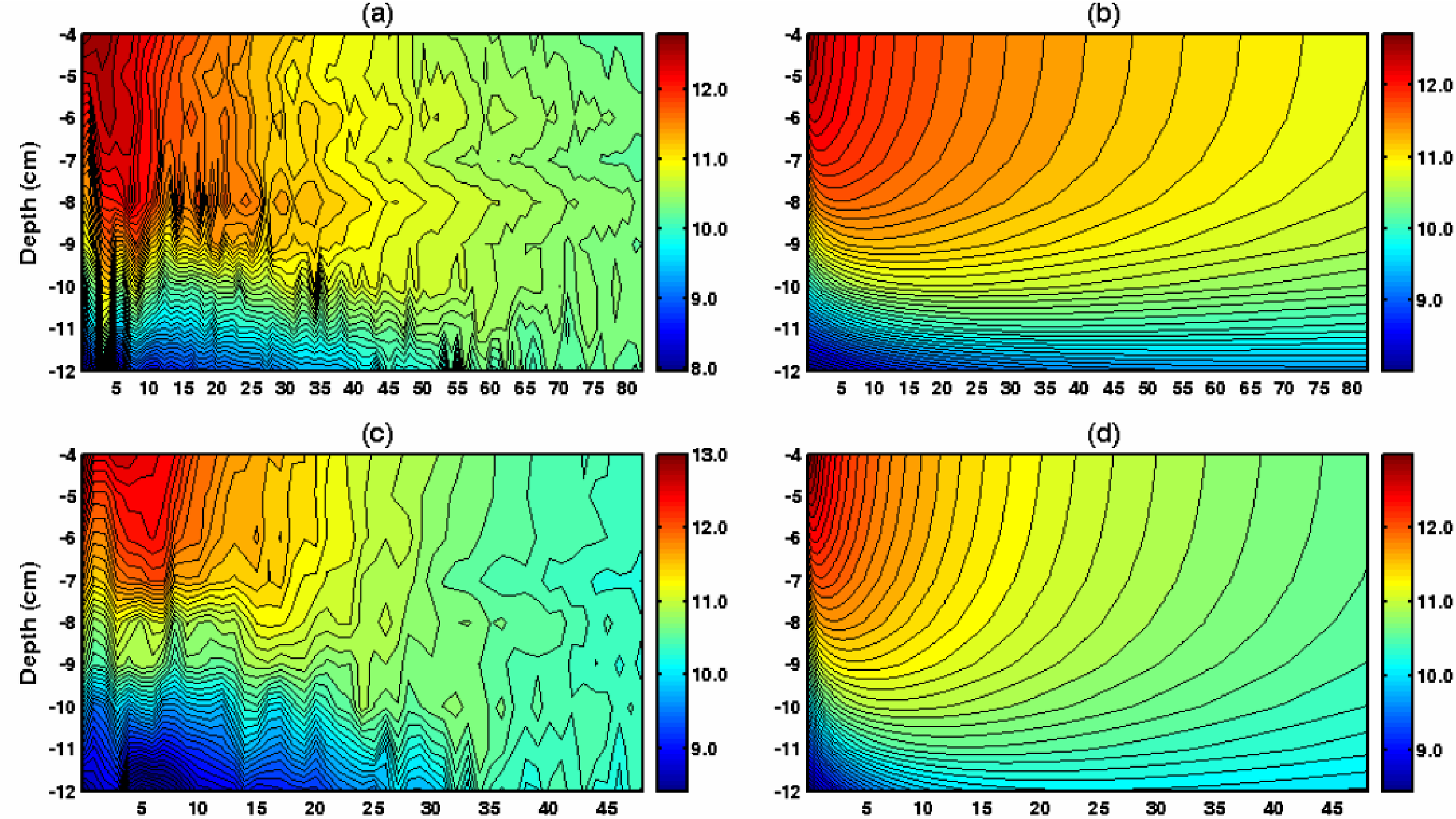
$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(k_z \frac{\partial T}{\partial z} \right)$$

kz=k0+Bv



Evolution of water temperature without waves.
(a) Observation; (b) simulation.

Simulation results with waves



Evolution of water temperature with waves. Left: observation; right: simulation; (a,b) 1.0cm, 30cm; (c,d) 1.0cm, 52cm;

(2) Improvement of ocean models

3-D coastal circulation model **(Special Issue on JGR, 2006 at [http://www.agu.org/journals/ ss/CHINASEAS1/](http://www.agu.org/journals/ss/CHINASEAS1/))**

We apply Bv into:

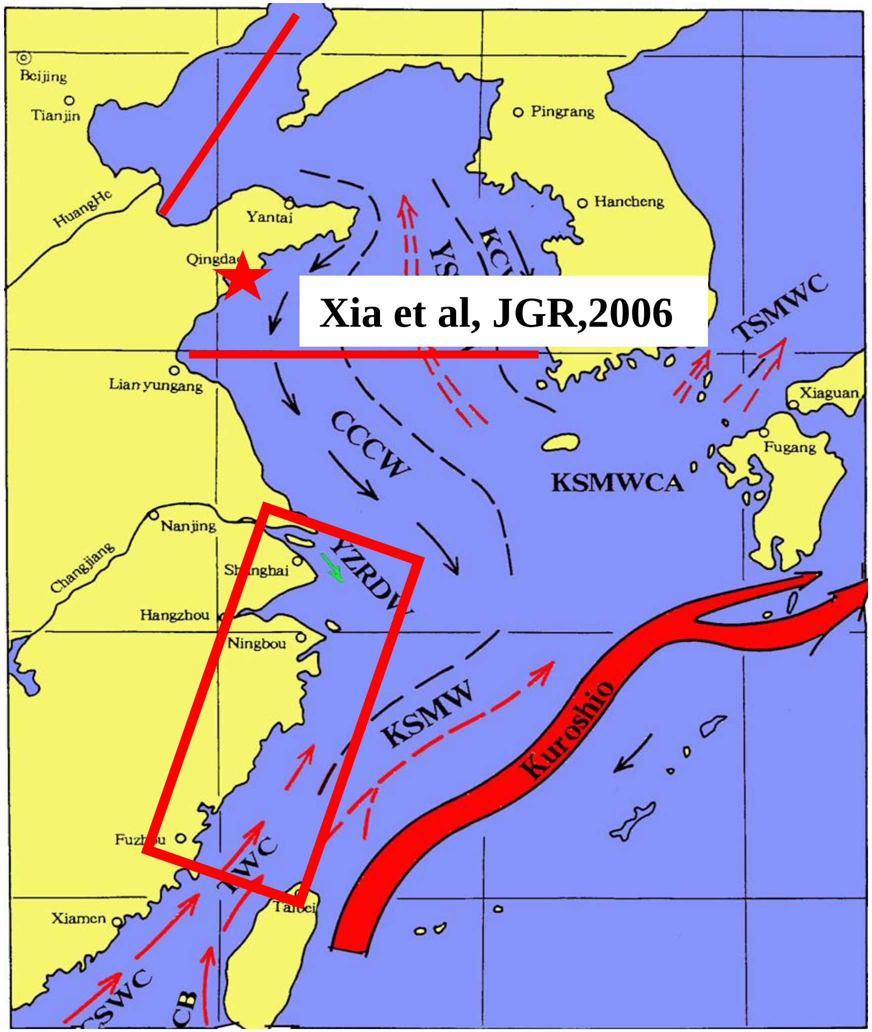
Bohai Sea

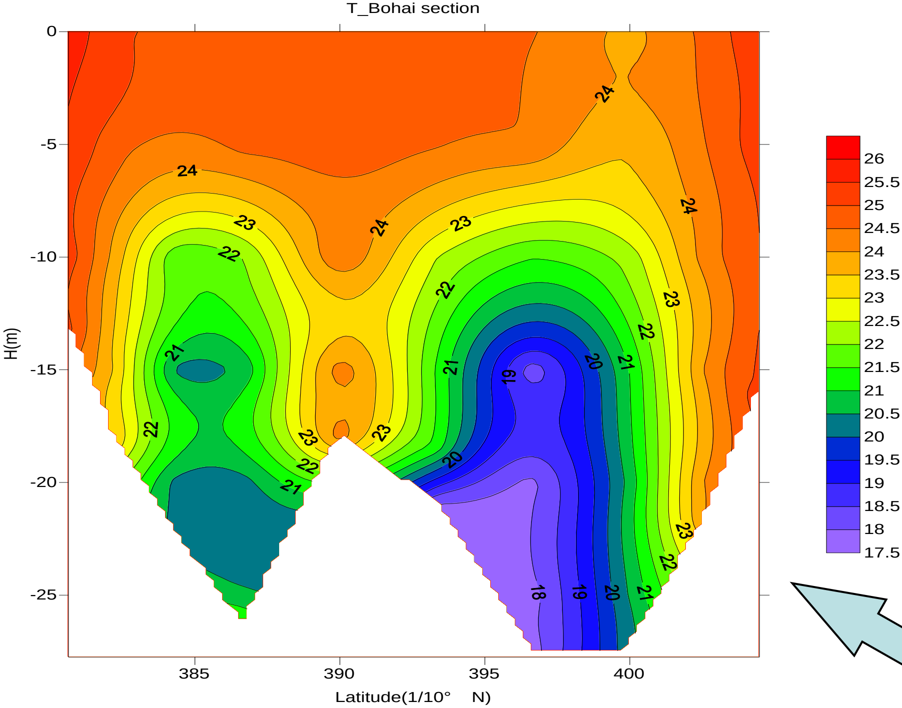
Yellow Sea

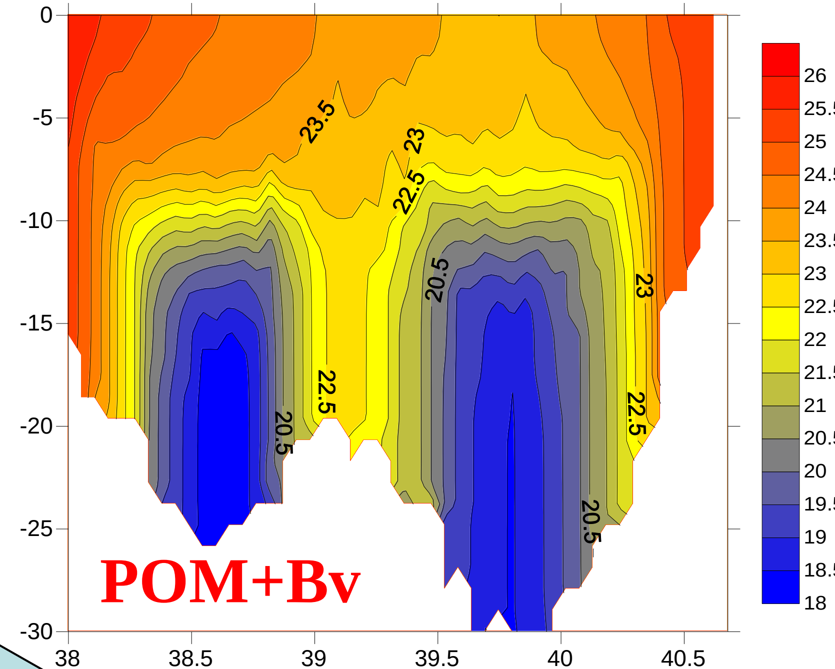
East China Sea

And

South China Sea

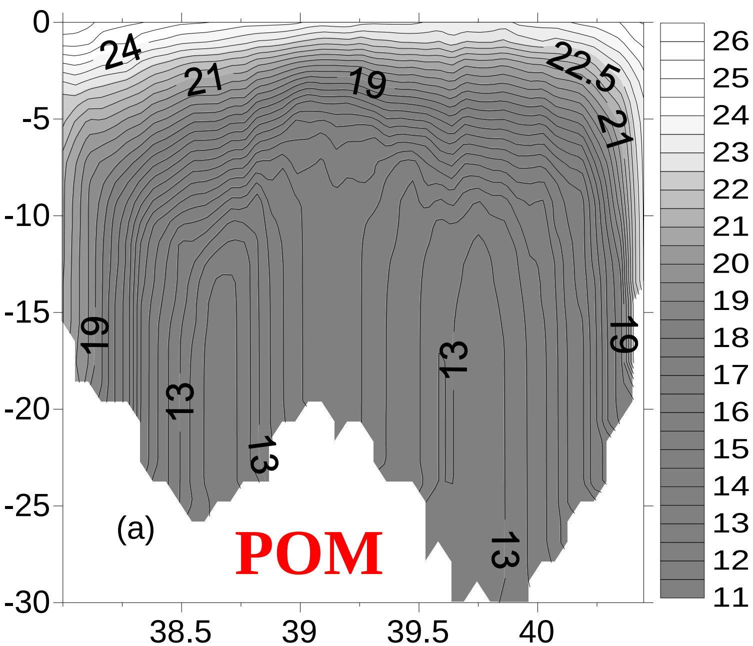


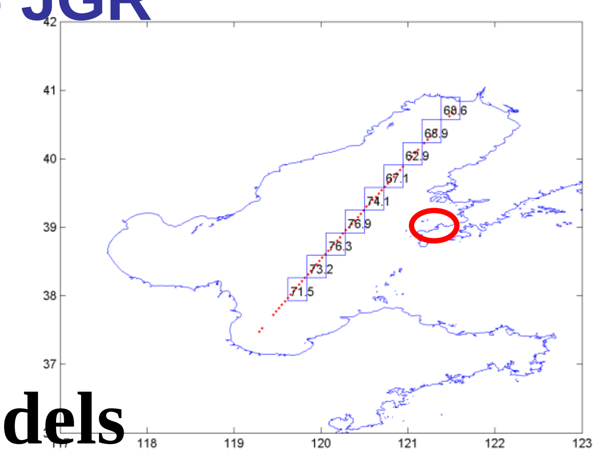




Observation in summer

Lin et al, 2006 JGR

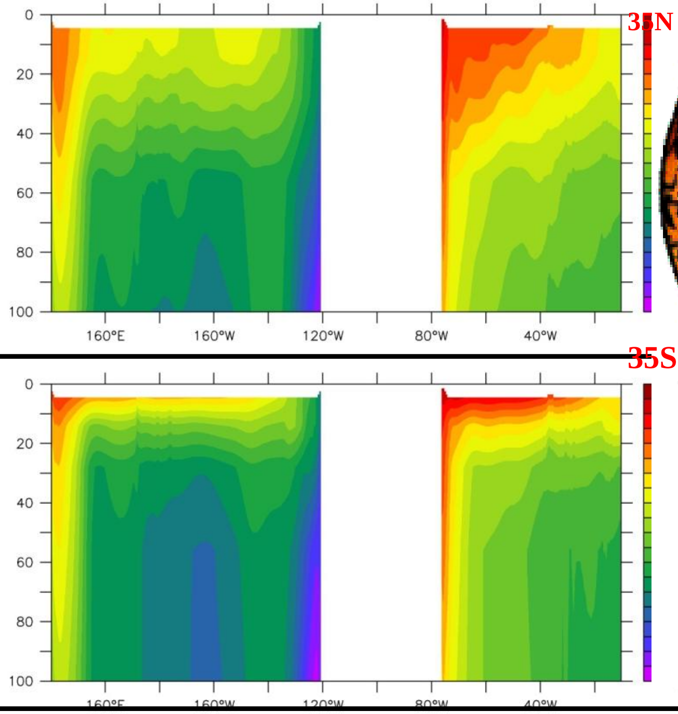


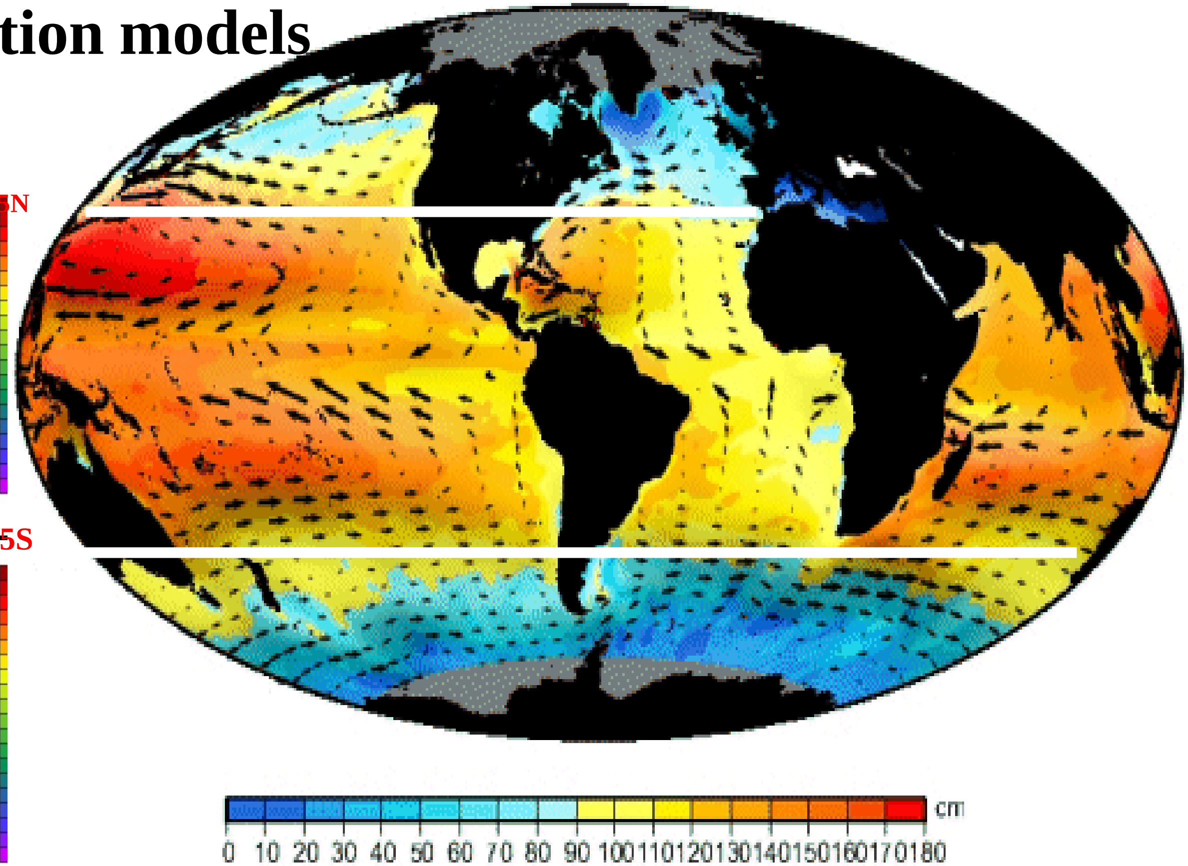


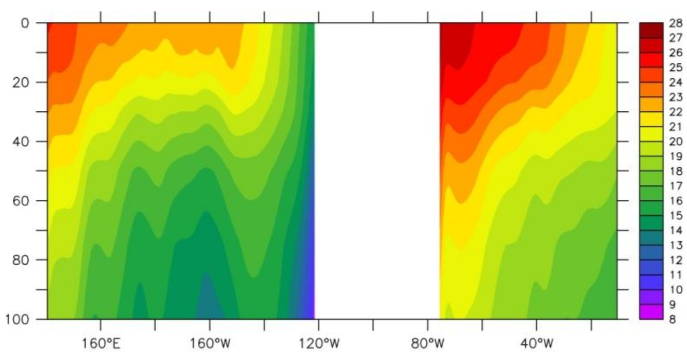
3-D coastal models

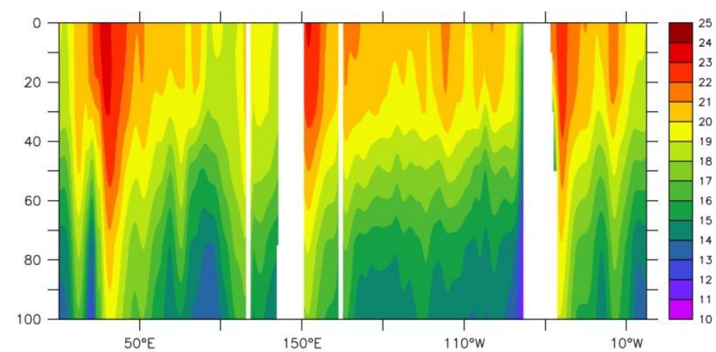
3-D global ocean circulation models

Pacific **Atlantic**





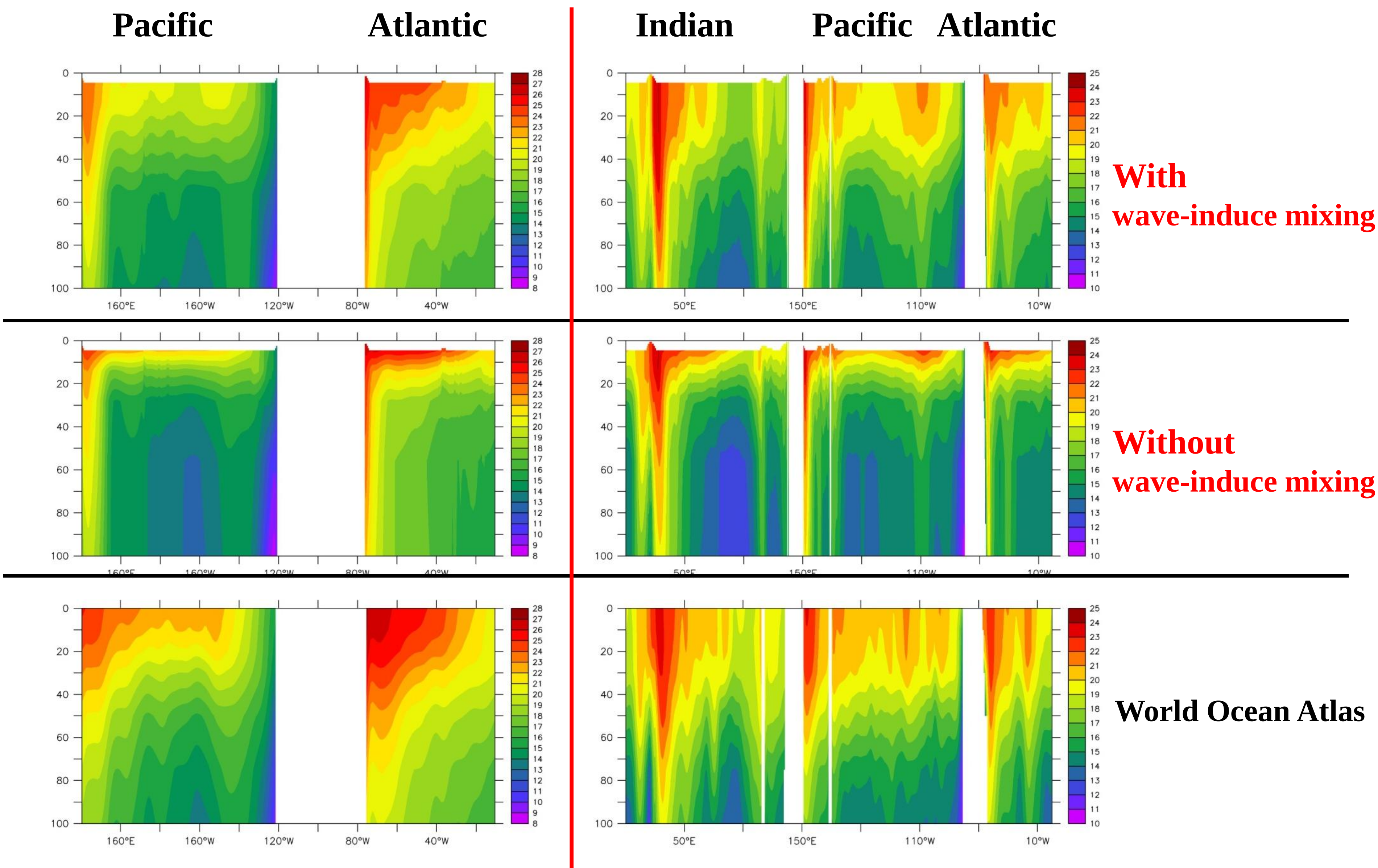




World Ocean Atlas

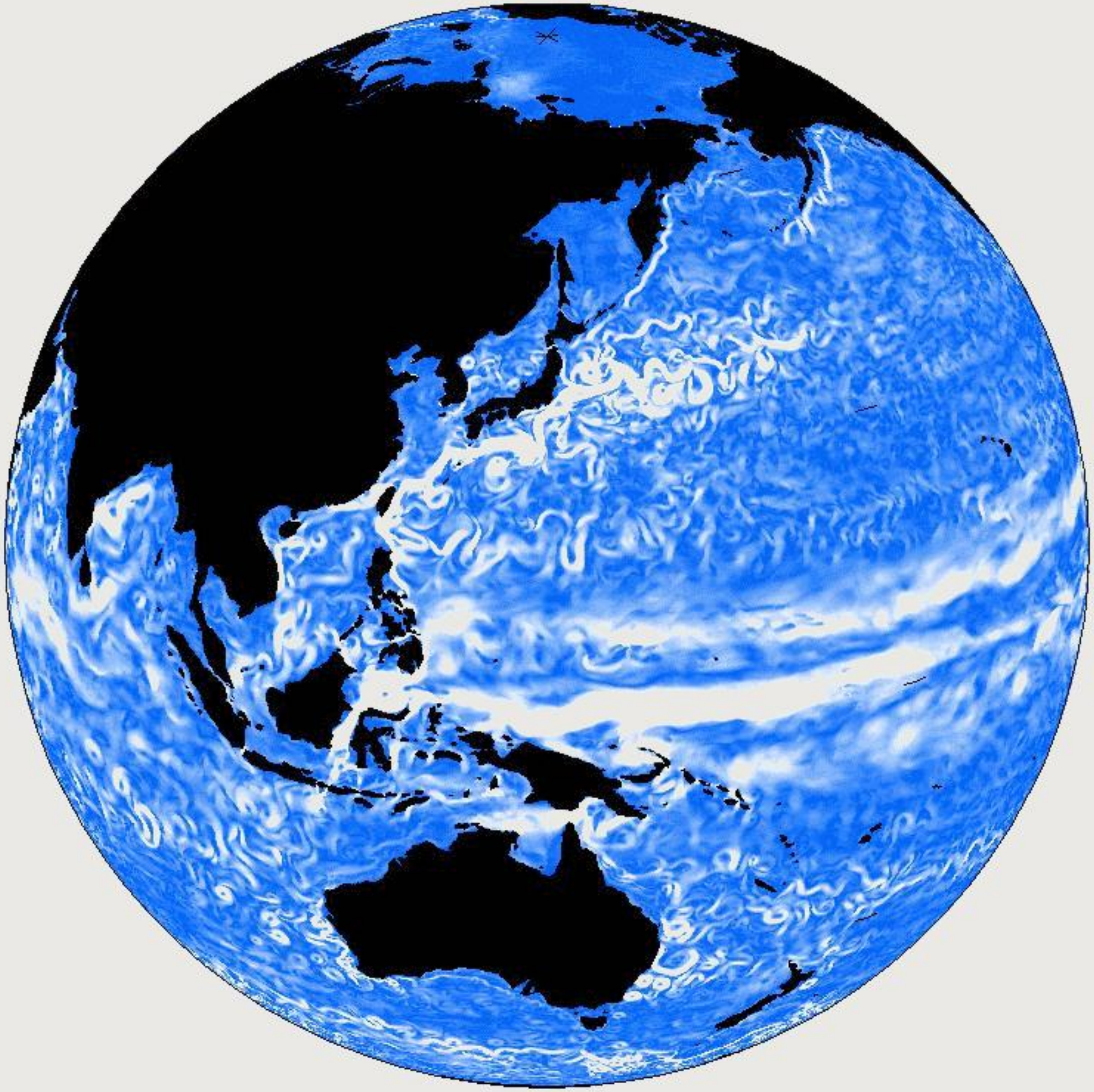
Along 35N transect in Aug. **Along 35S transect in Feb.**

Vertical Temperature Distributions



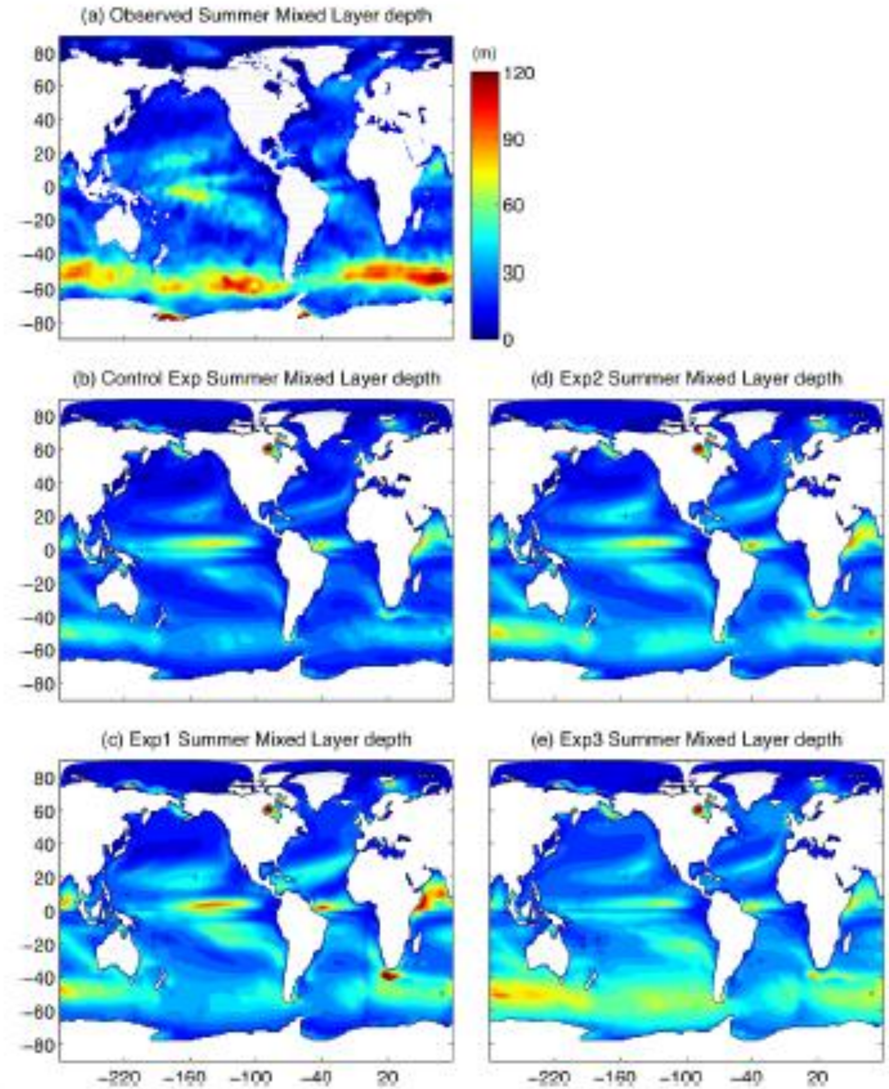
Along 35N transect in Aug.

Along 35S transect in Feb.



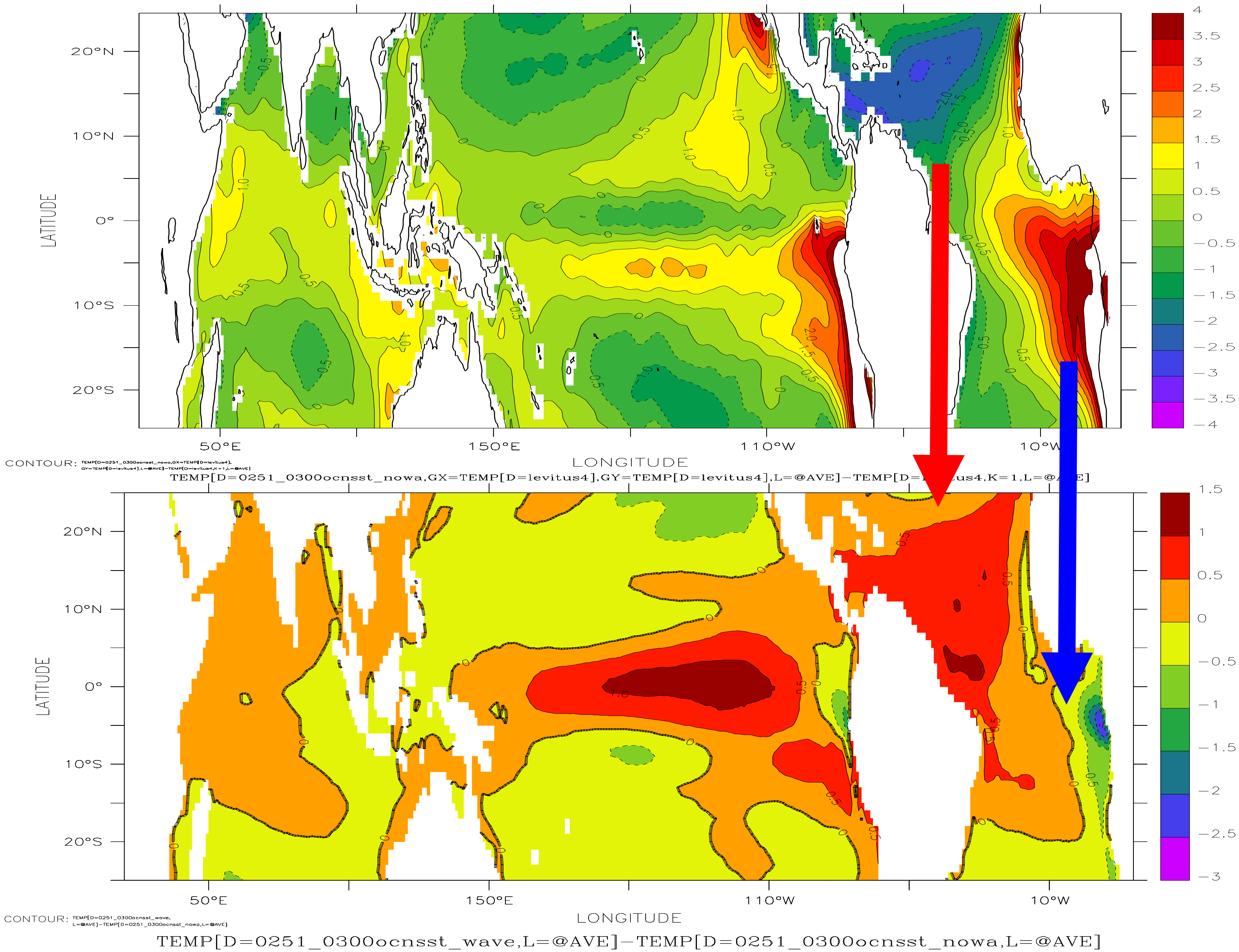
FIO wave-tide-circulation coupled model 0.1X0.1

(3) Improvement of climate models



Summertime oceanic mixed layers are biased shallow in both the GFDL and NCAR climate models (Bates et al. 2012; Dunne et al. 2012, 2013). This scheme (Qiao et al., 2004) has most impact in our simulations on deepening the summertime mixed layers, yet it has minimal impact on wintertime mixed layers.

Yalin Fan, and Stephen M. Griffies, 2014, JC (Fig 3)



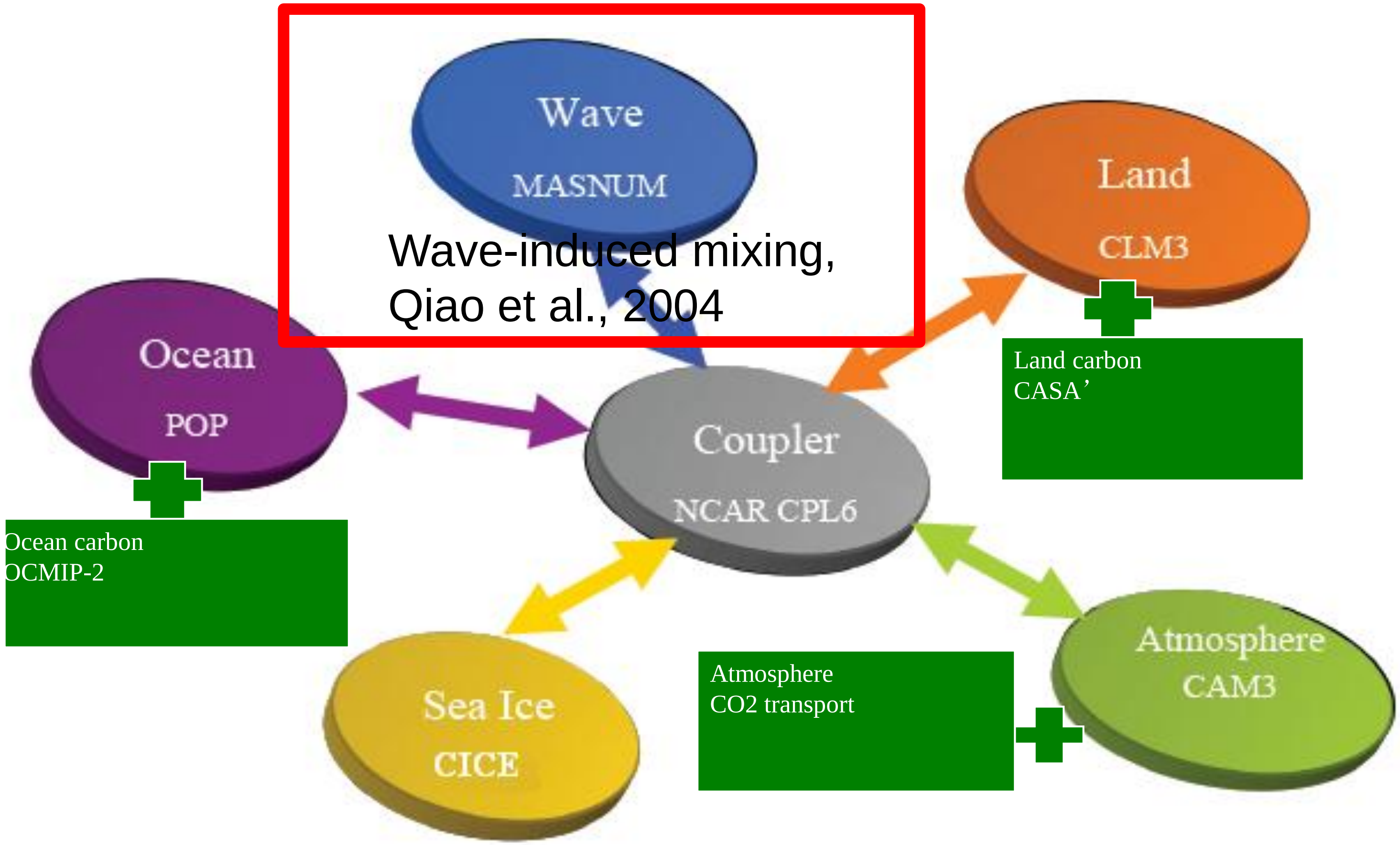
50a averaged SST (251-300a).

Up: Exp1-Levitus, Down: Exp2-Exp1

Exp1: CCSM3 without Bv

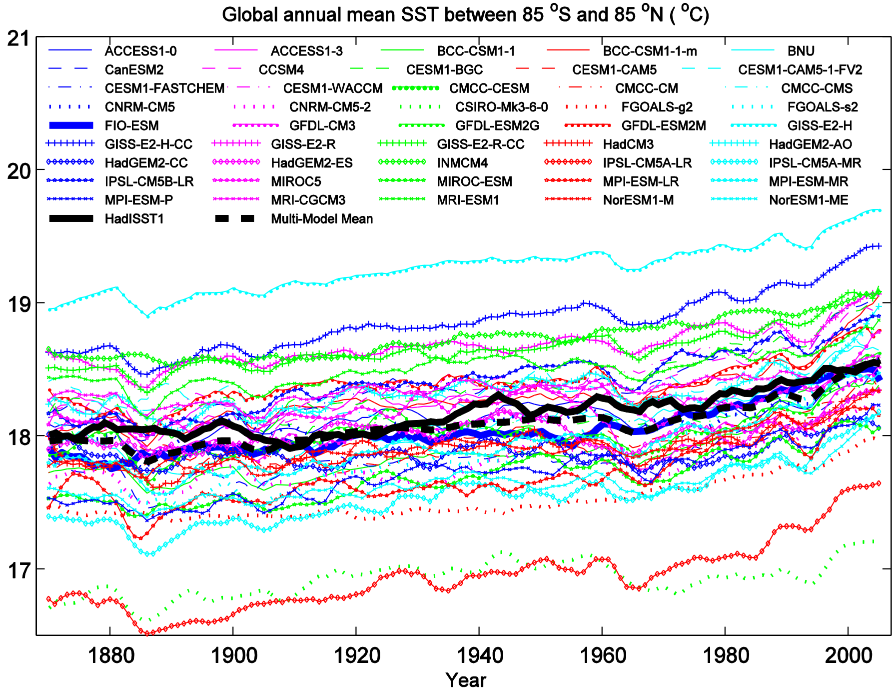
Exp2: with Bv

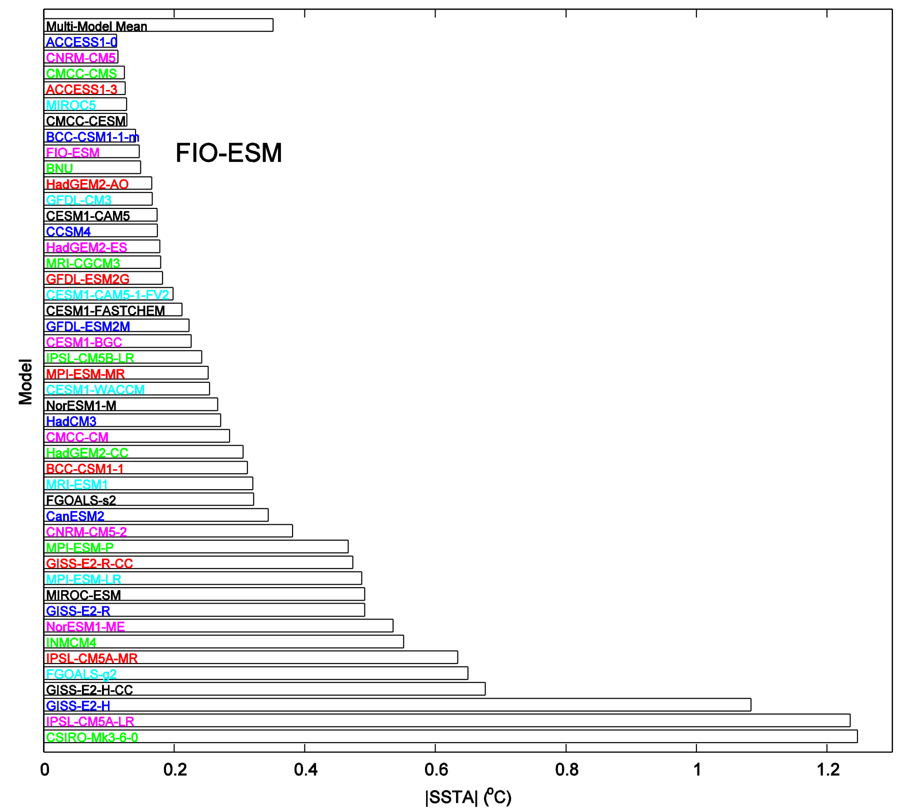
FIO-ESM for CMIP5



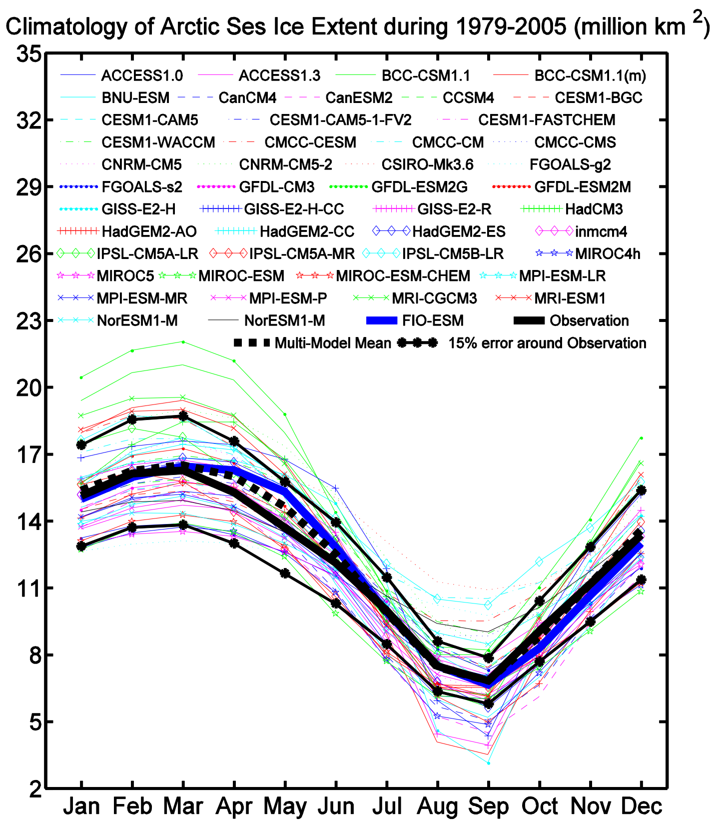
Framework of FIO-ESM version1.0

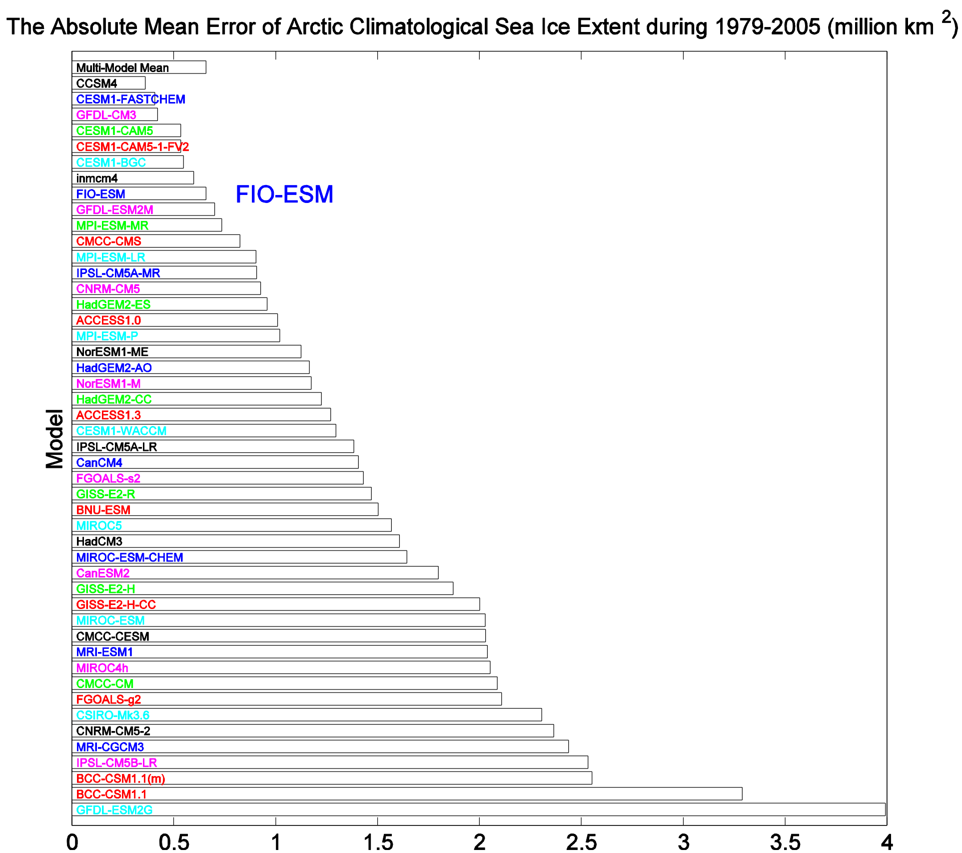
SST absolute mean errors for 45 CMIP5 models

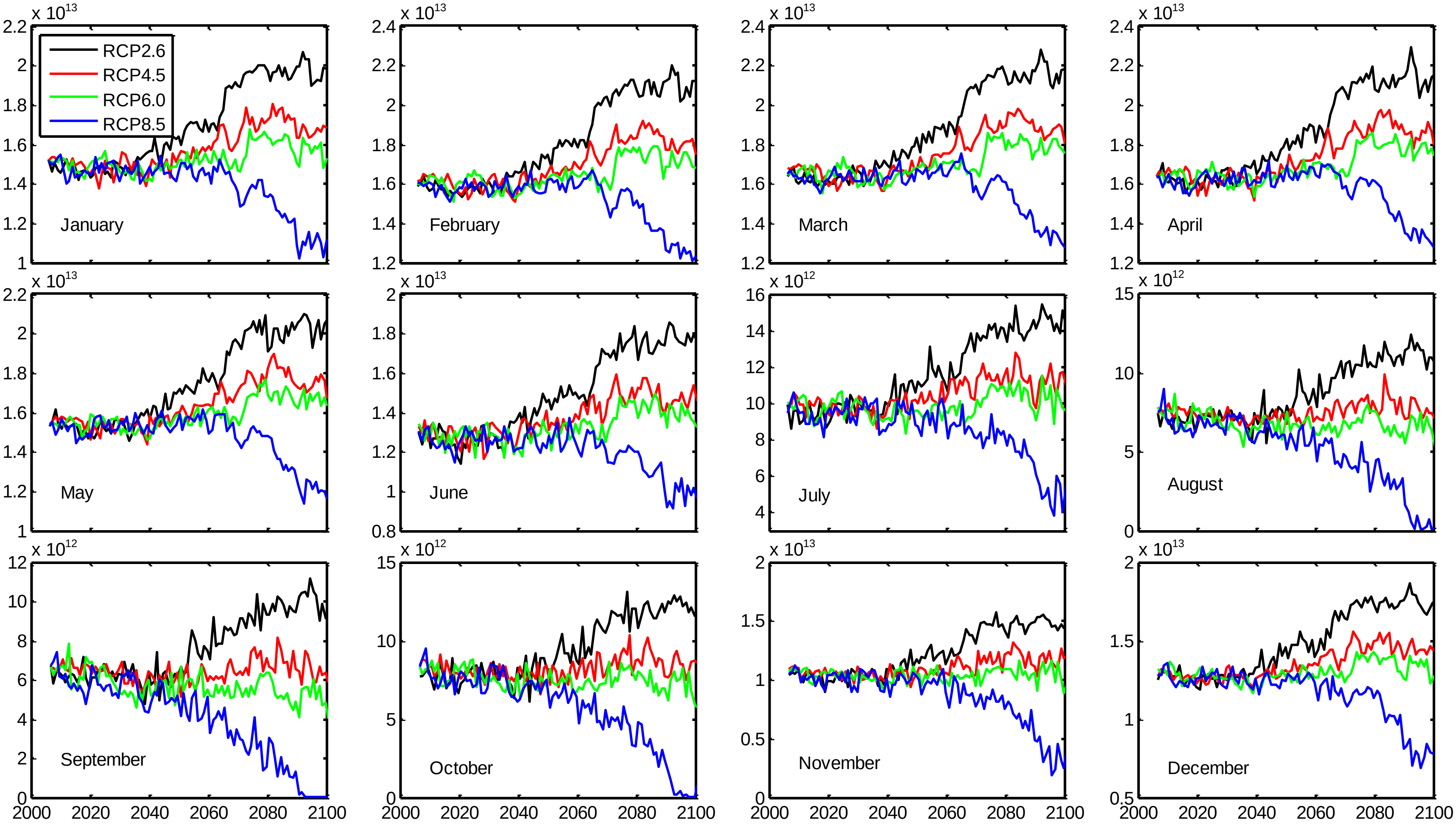




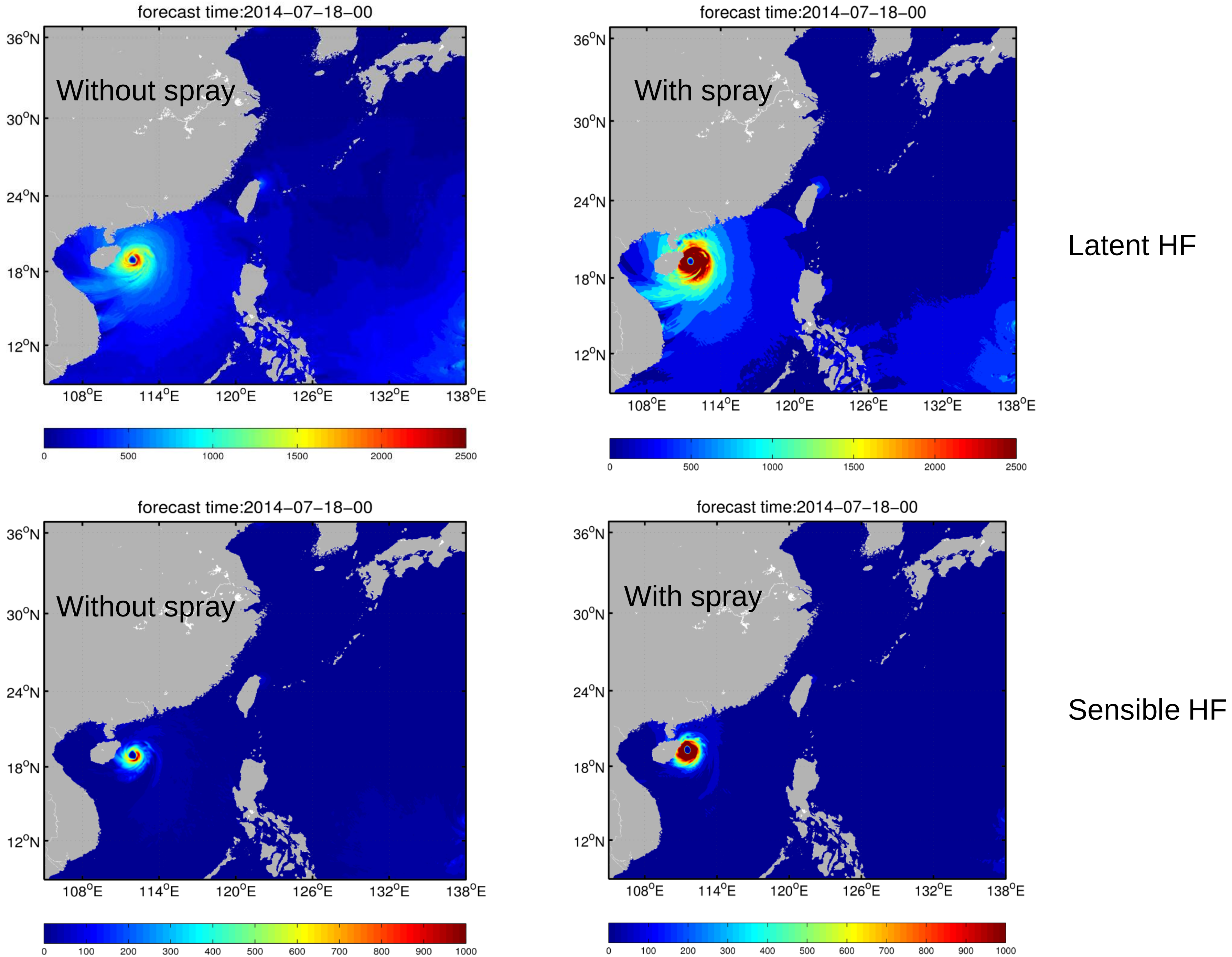
Sea ice annual cycle in Arctic

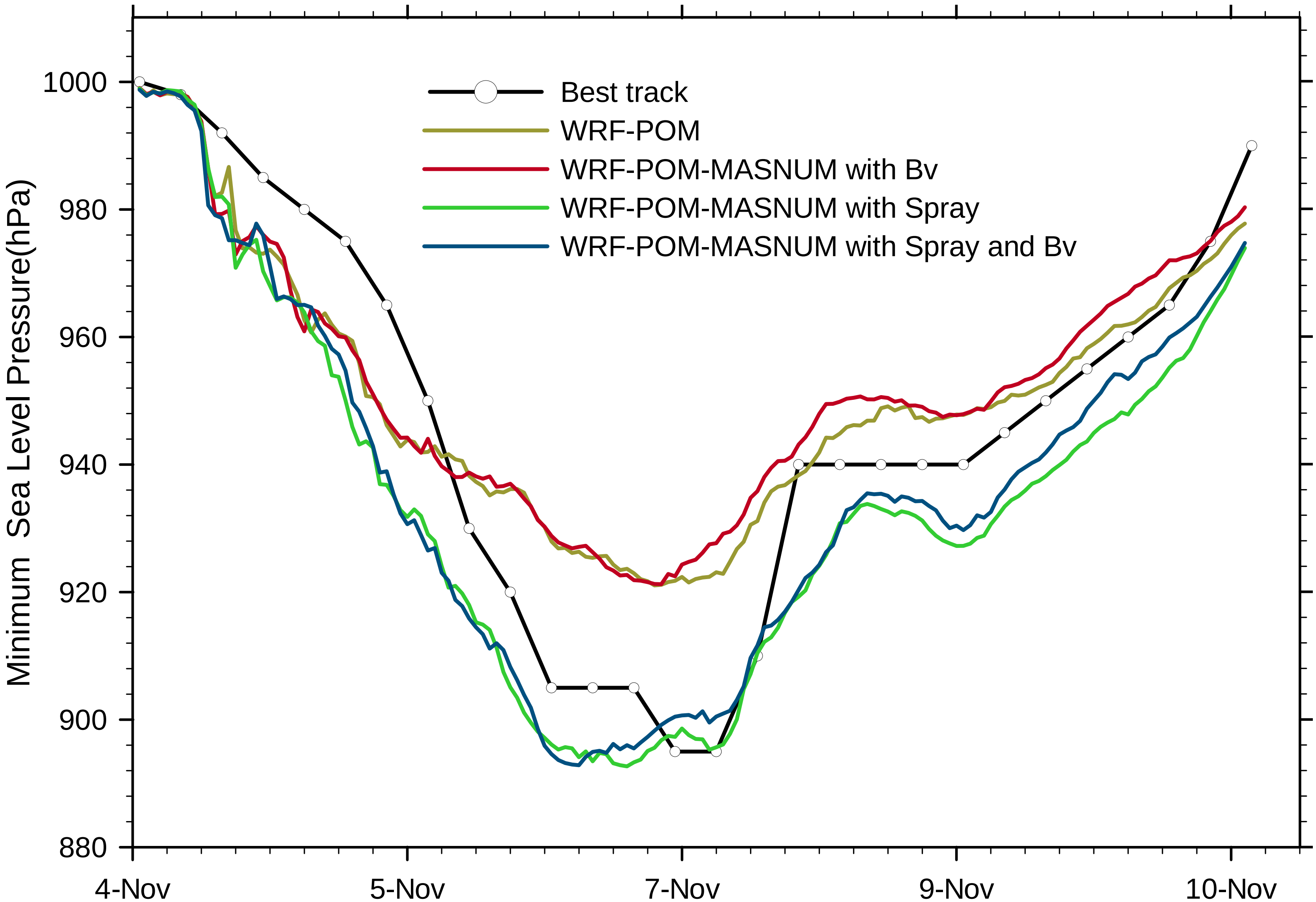






Time series of Arctic sea ice extent from RCP run. **Unit: m^2**


forecast time:2014−07−18−00
Without spray
With spray
Latent HF
Sensible HF
36°N
30°N
24°N
18°N
12°N
108°E
114°E
120°E
126°E
132°E
138°E
0
500
1000
1500
2000
2500
100
200
300
400
600
700
800
900



Best track
WRF-POM
WRF-POM-MASNUM with Bv
WRF-POM-MASNUM with Spray
WRF-POM-MASNUM with Spray and Bv
Minimum Sea Level Pressure(hPa)
1000
980
960
940
920
900
880
4-Nov
5-Nov
7-Nov
9-Nov
10-Nov

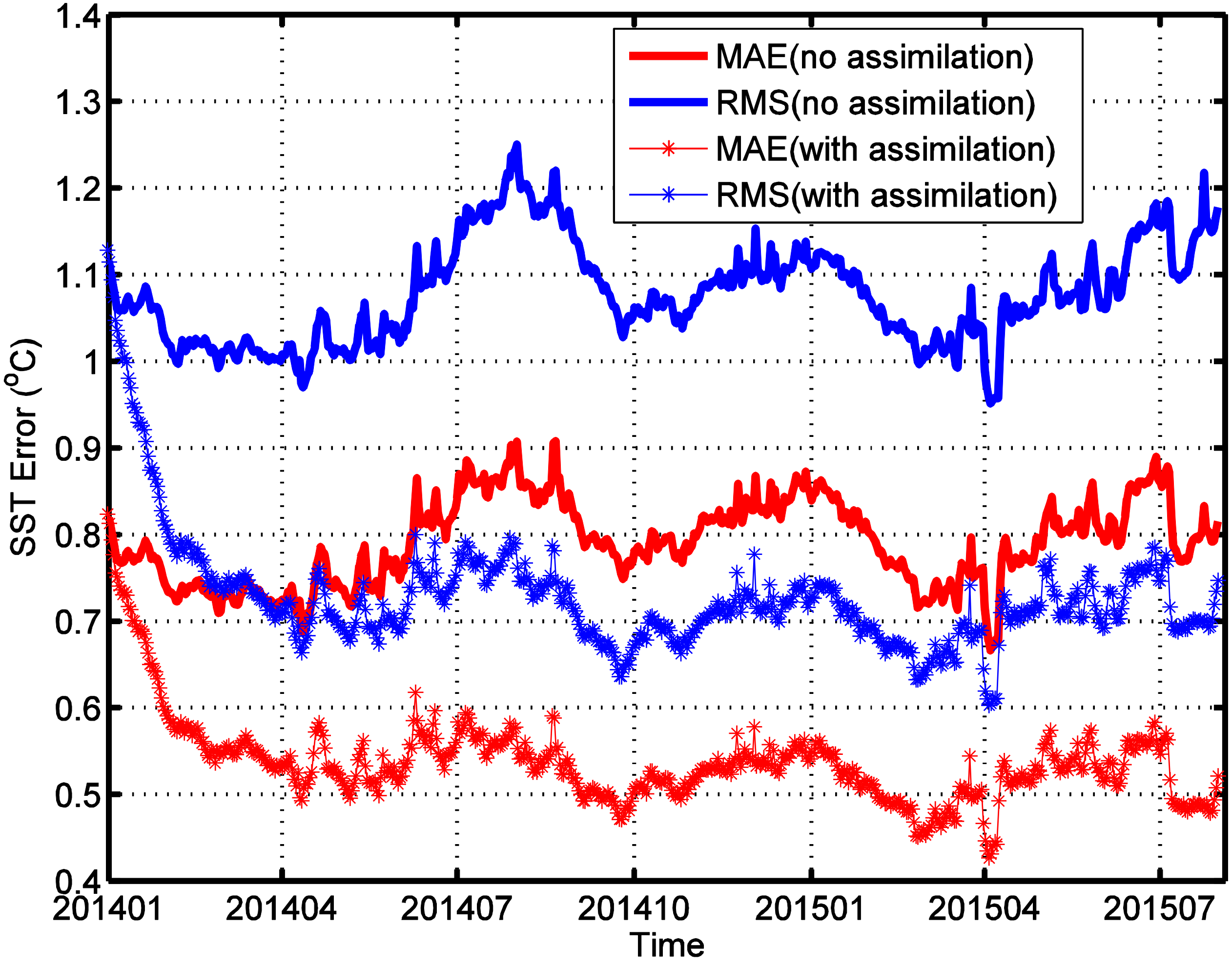
3. Joint observation and DA

DA

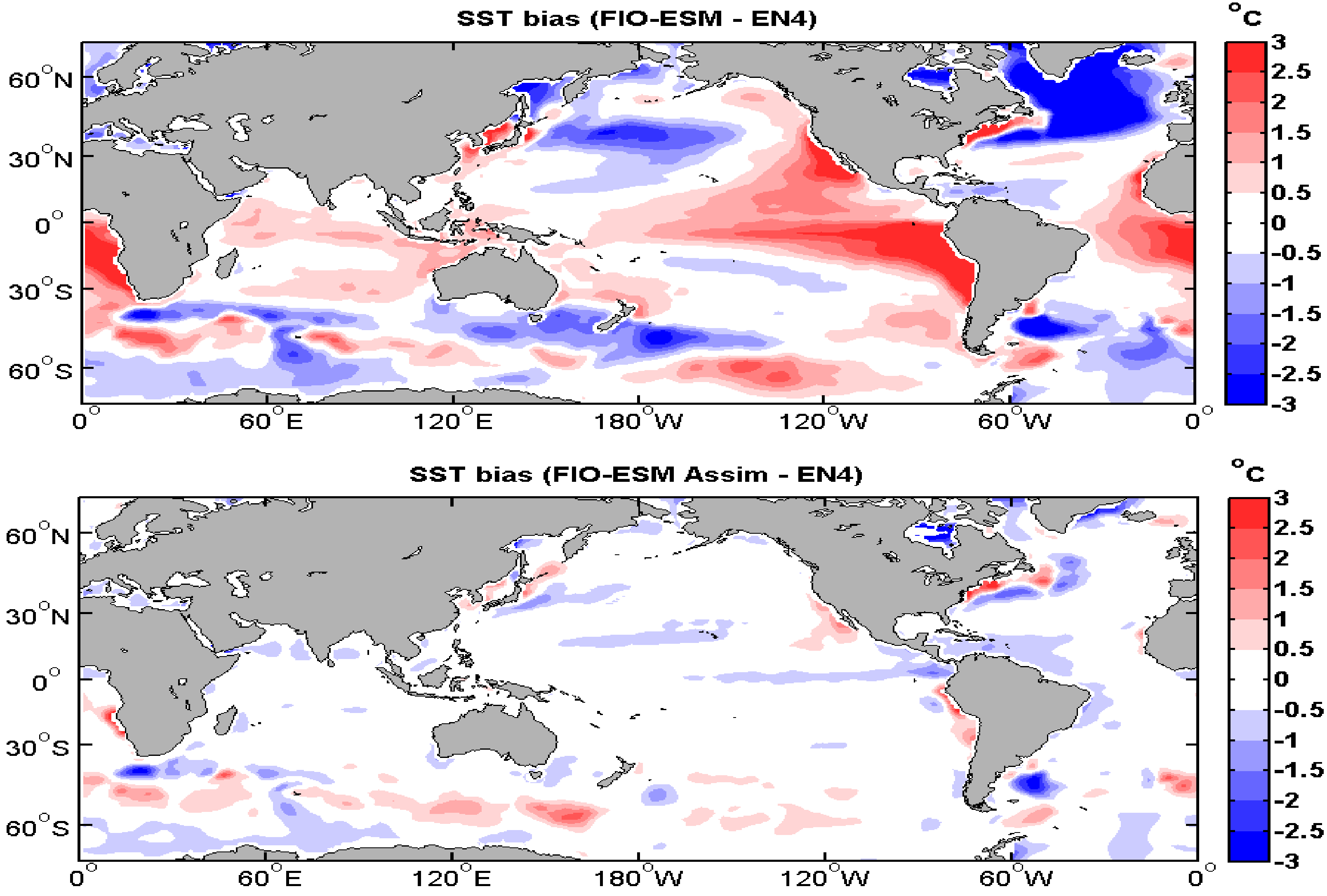
SST, SLA, Argo

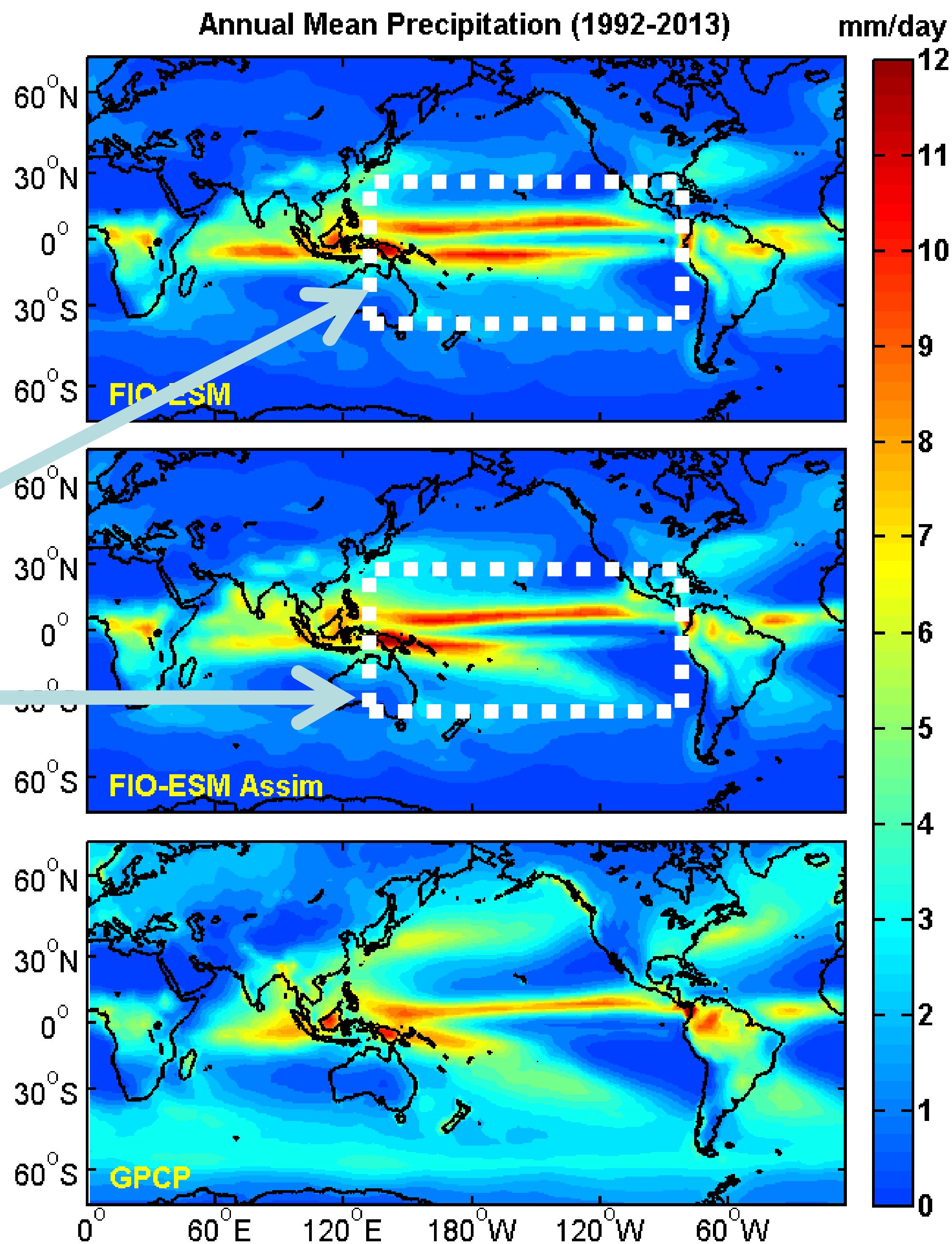
RMS

AME



DA of FIO-ESM (1992-2014)

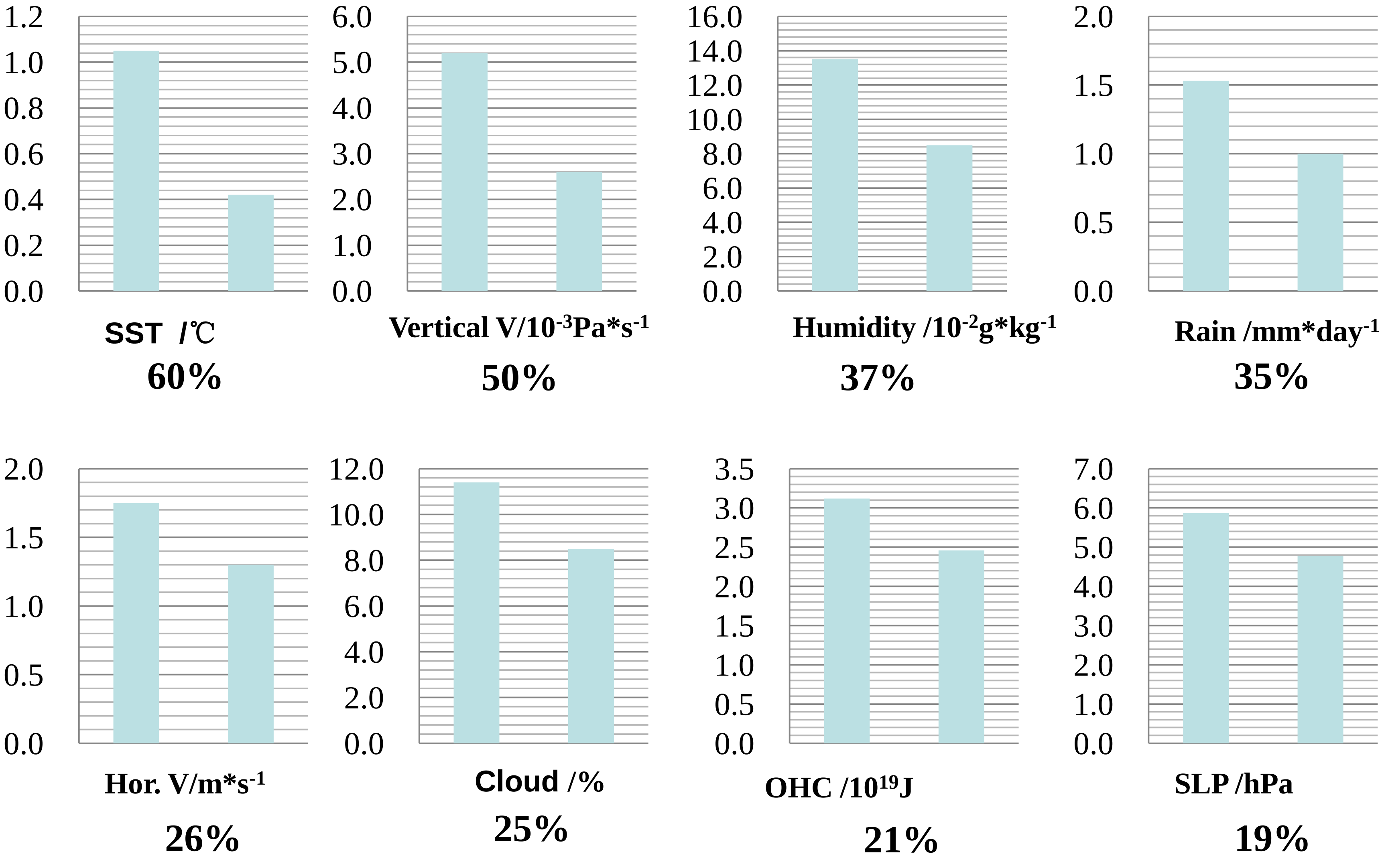




Double ITCZ

GPCP

RMS errors with and without DA



United Nations Educational, Scientific and Cultural Organization

IOC Sub-Commission for the Western Pacific (WESTPAC)

(3) IPOVAI 2015-2020

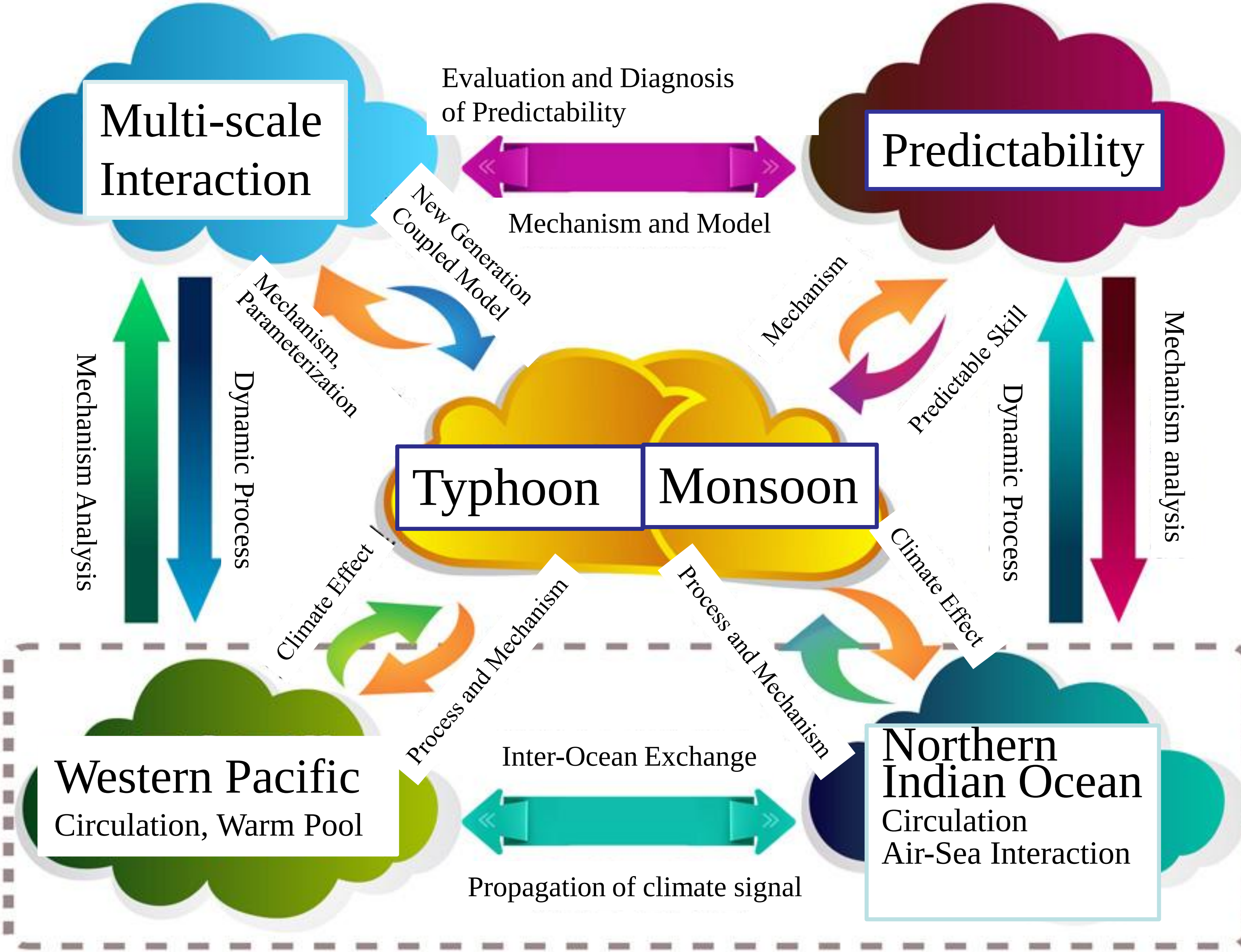
Indo-Pacific Ocean Environment Variation and Air-sea Interaction

IPOVAI Project Proposal

Dr. Prof. Fangli Qiao

First Institute of Oceanography, SOA, China

11-13 May 2015 , Phuket, Thailand



Multi-scale Interaction
Evaluation and Diagnosis of Predictability
Predictability
Mechanism and Model
New Generation Coupled Model
Mechanism, Parameterization
Mechanism
Predictable Skill
Mechanism Analysis
Dynamic Process
Dynamic Process
Mechanism analysis
Typhoon
Monsoon
Climate Effect
Process and Mechanism
Process and Mechanism
Climate Effect
Western Pacific
Circulation, Warm Pool
Inter-Ocean Exchange
Propagation of climate signal
Northern Indian Ocean
Circulation
Air-Sea Interaction

4. Summary

- We have identified the key role of surface wave in ocean and climate models, and coupled models with surface wave have been successfully developed. We would like to share the knowledge;
- No one nation can afford ocean observations. We need joint efforts, "**Indo-Pacific Ocean Environment Variation and Air-sea Interaction**" (IPOVAI) is open and welcome participants.


Thanks for your attention