To improve climate prediction ability based on new scientific breakthroughs

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Clean Ocean

Predicted Ocean

Health Ocean

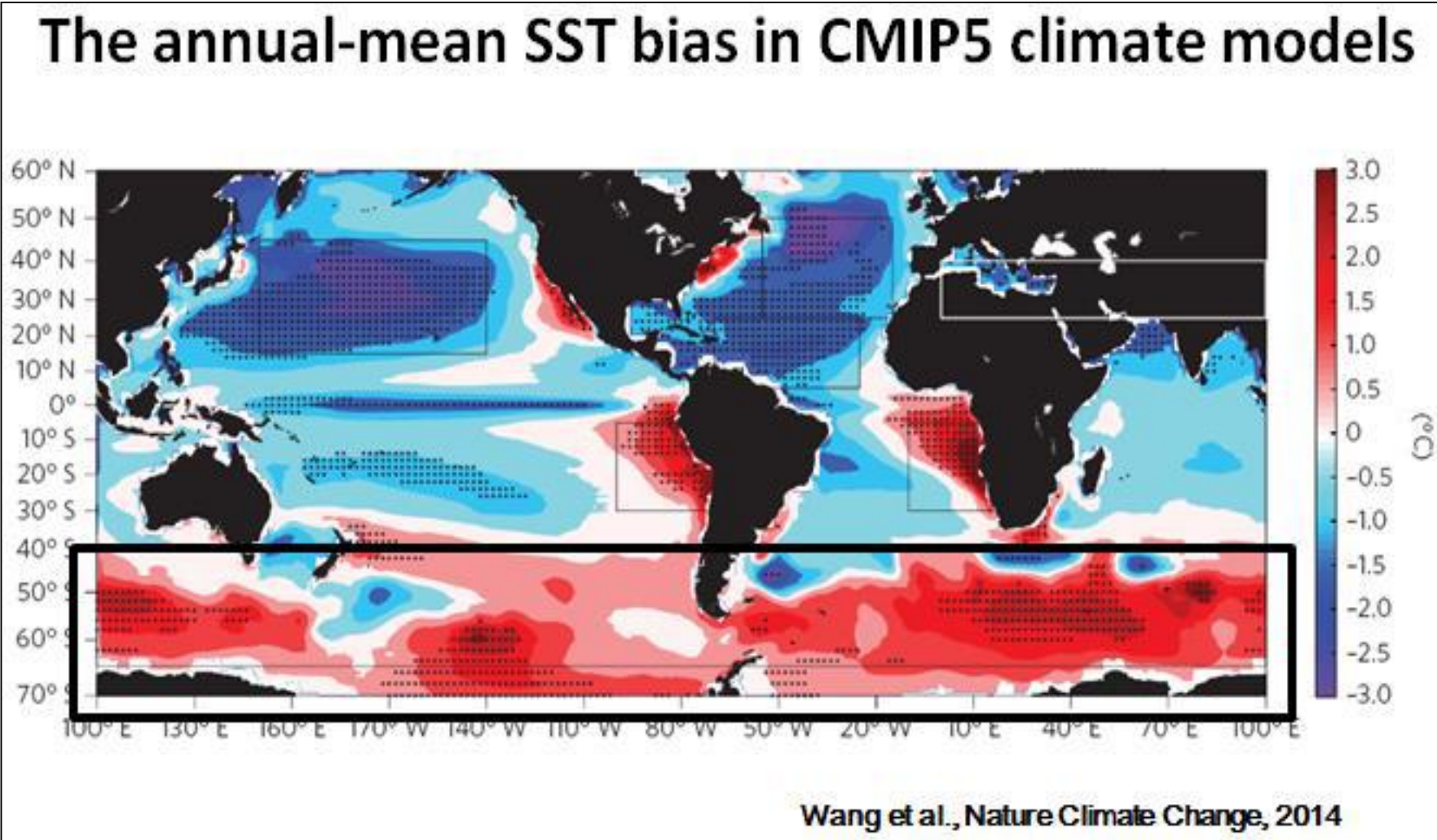UN Decade of Ocean Science for sustainable development (2021-2030)
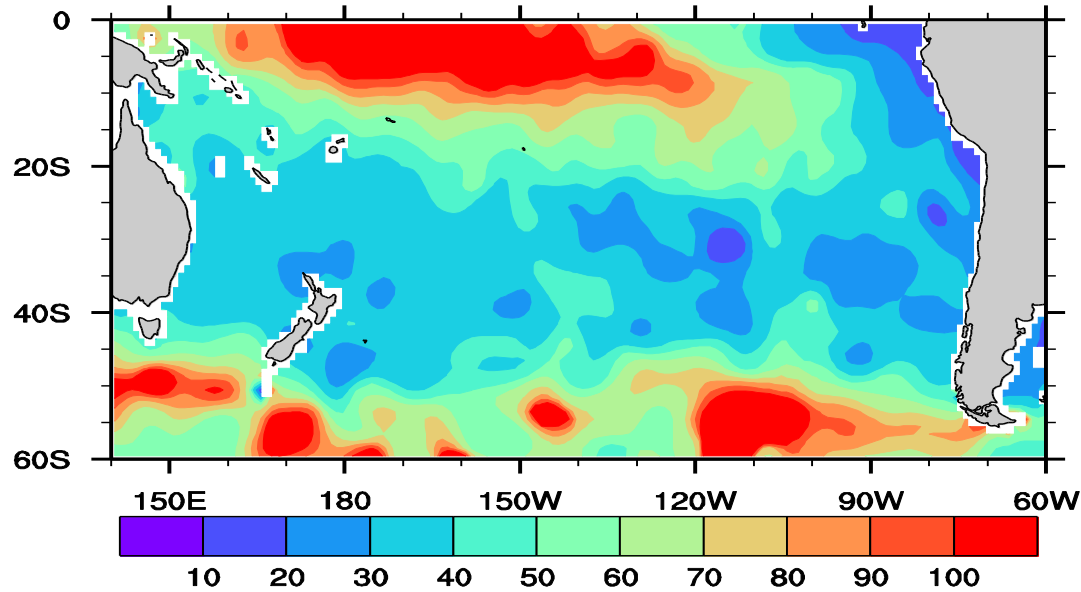
Inspiring & Engaging Ocean
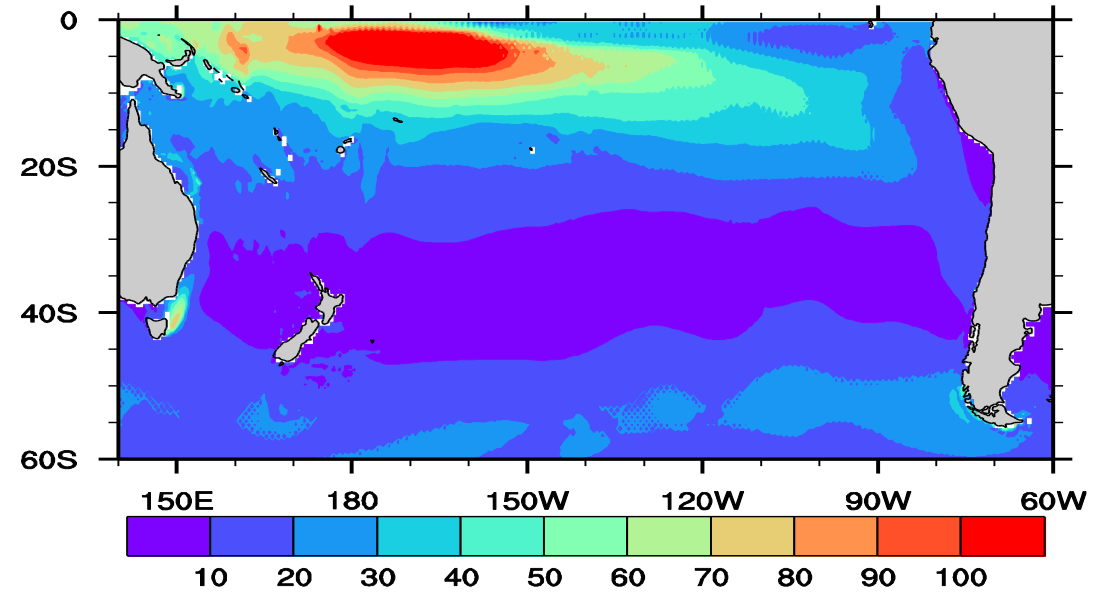
Safe Ocean

Productive Ocean

Accessible Ocean

Ground challenge for climate models for several decades:
Huge SST biases for the global ocean

The annual-mean SST bias in CMIP5 climate models

Wang et al., Nature Climate Change, 2014

(1) Simulation error in upper ocean: The simulated MLD is too shallow in summer for half century

MLD from observation

MLD from ocean model
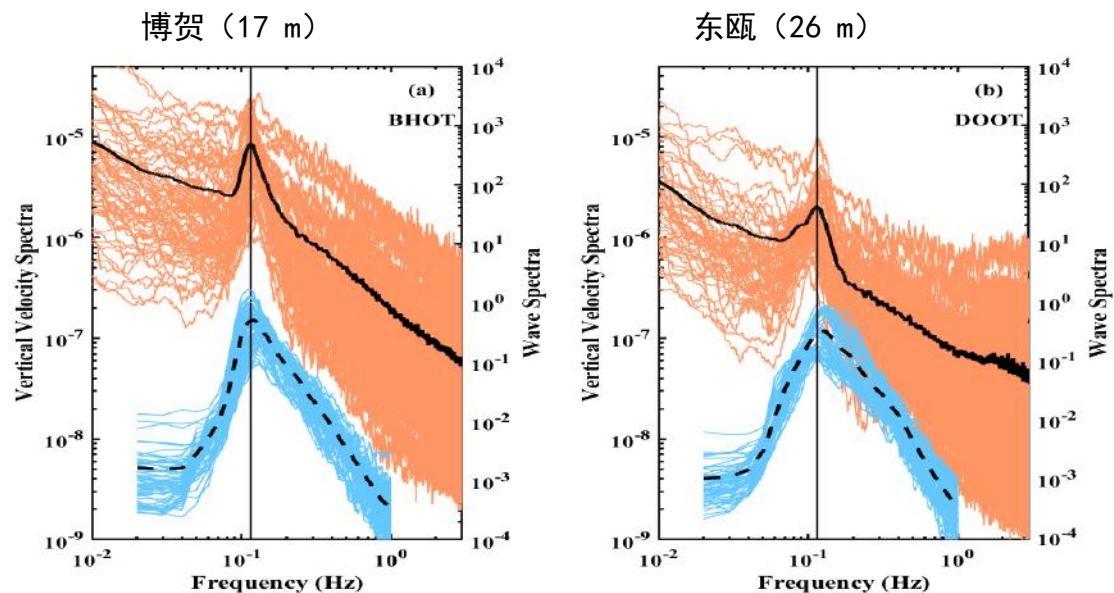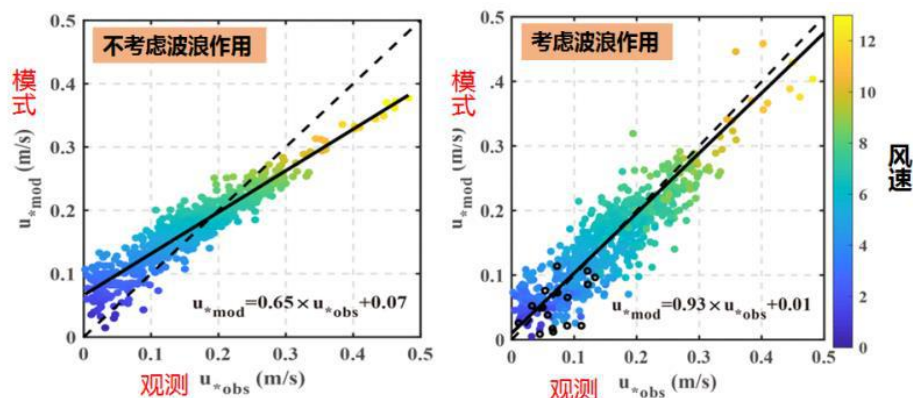
(2) Air-sea momentum flux is incorrect

风应力方向与风速及波浪的关系

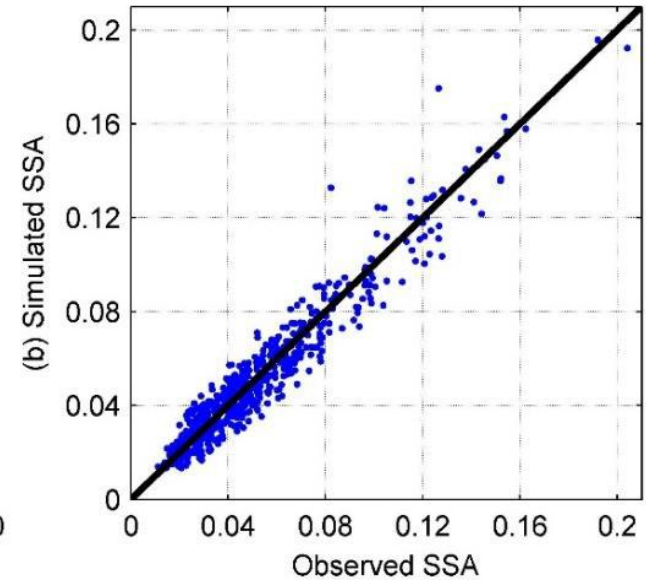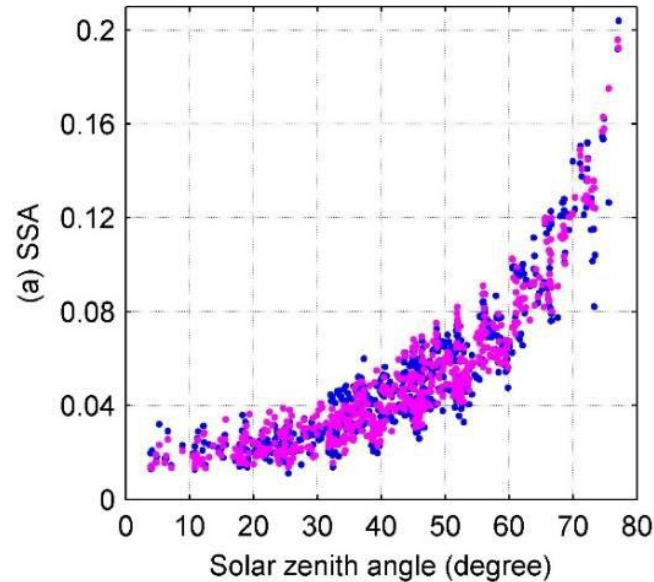博贺（17 m）　　　　　　东瓯（26 m）
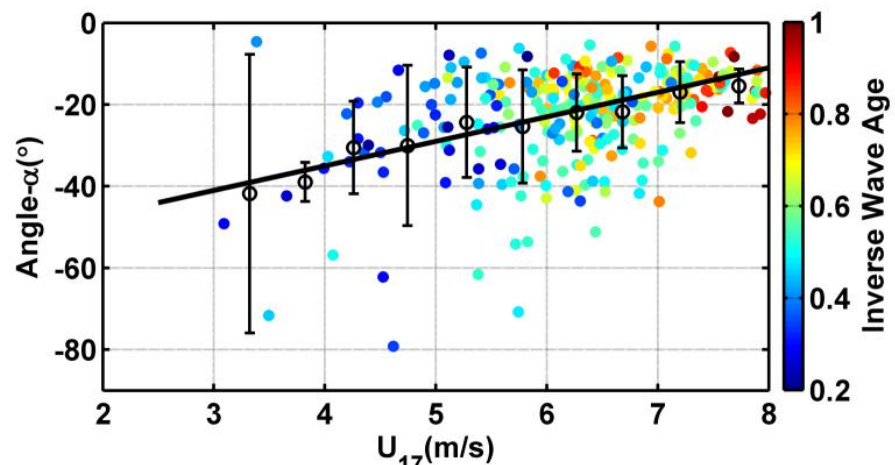
湍流速度谱（红线）

海浪频谱（蓝线）

波浪对风应力的影响

Chen et al., 2018, JGR; 2019, JPO
Chen et al., 2020, JGR, GRL

(3) Air-sea heat flux is incorrect

Albedo and surface wave-induced sea-spray

$$\alpha_{clear} = \frac{0.041}{\mu^{4/3}+0.083} + 0.0025w - 0.005e_0 - 0.015, \quad \beta \geq 0.55$$

Huang et al., JGR-Oceans, 2019
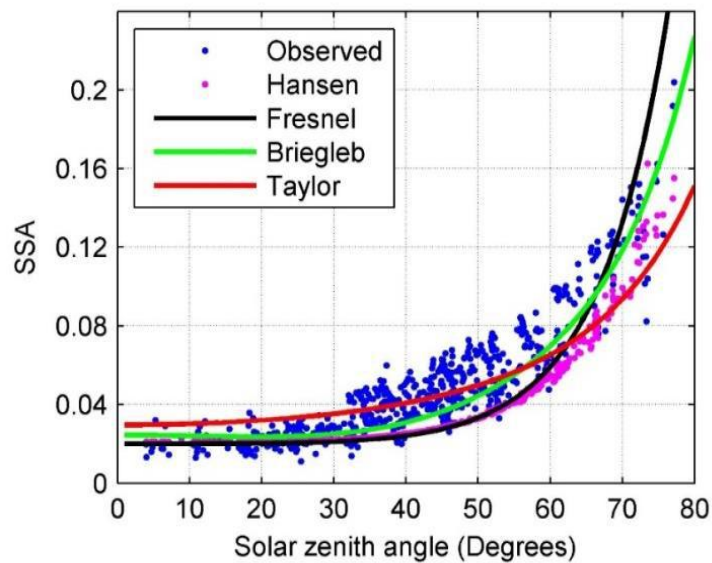
Bv theory was established: MLD in summer (Qiao et al, OD, 2010)

MLD of the Southern Pacific in Feb.
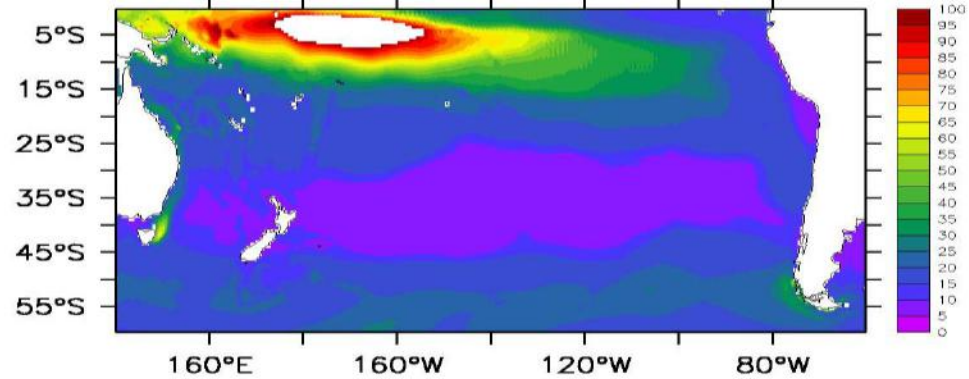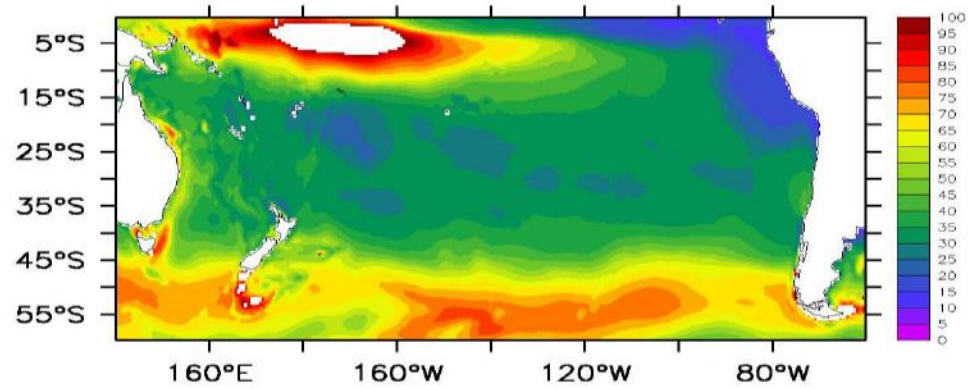
MLD of the Northern Atlantic in Aug.
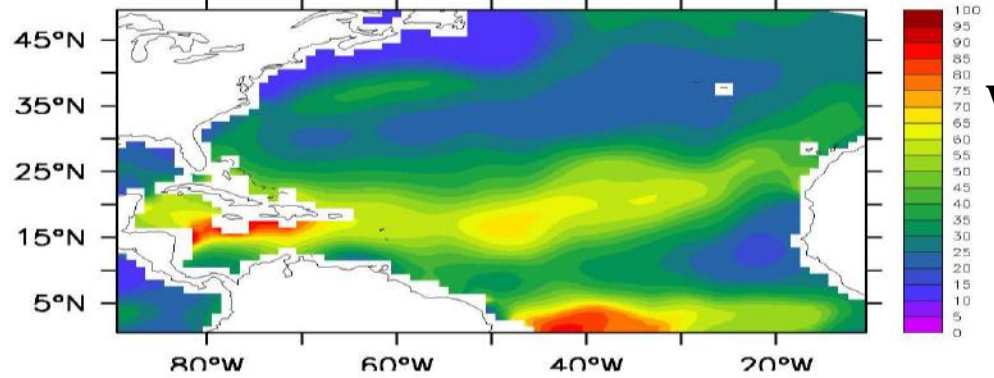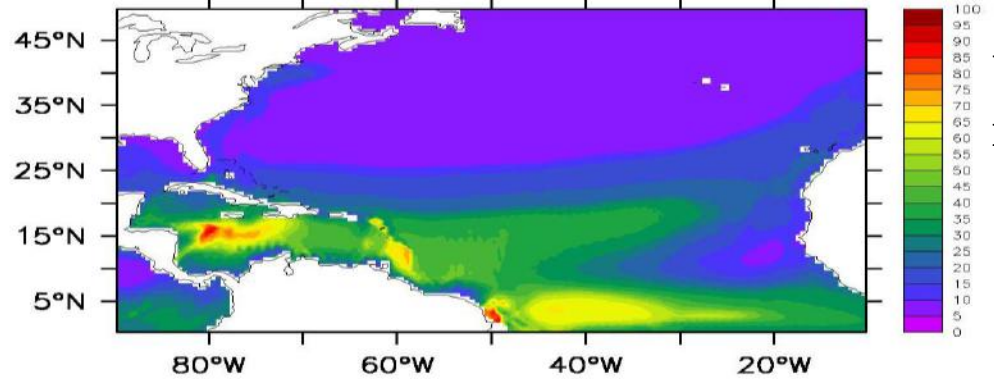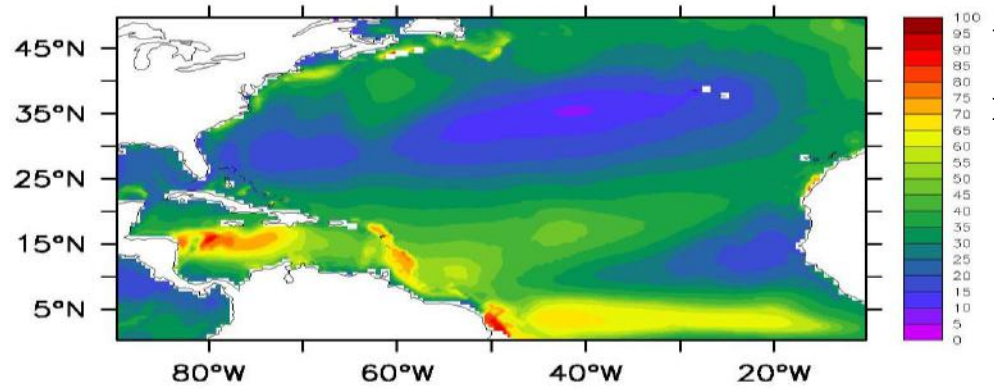
With wave-induce mixing

Without wave-induce mixing

World Ocean Atlas

Bv theory has been adopted by NEMO (Europe), GFDL (USA) and AWI (Germany), and has been tested at different popular OGCMs, such as POM, ROMS, MOM etc.
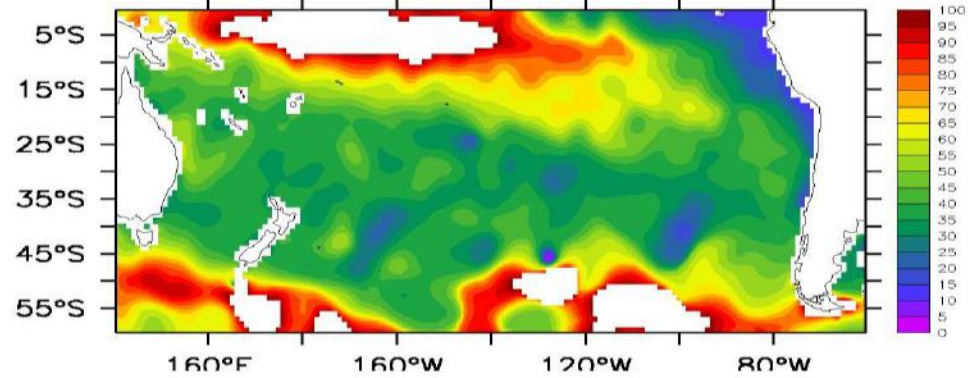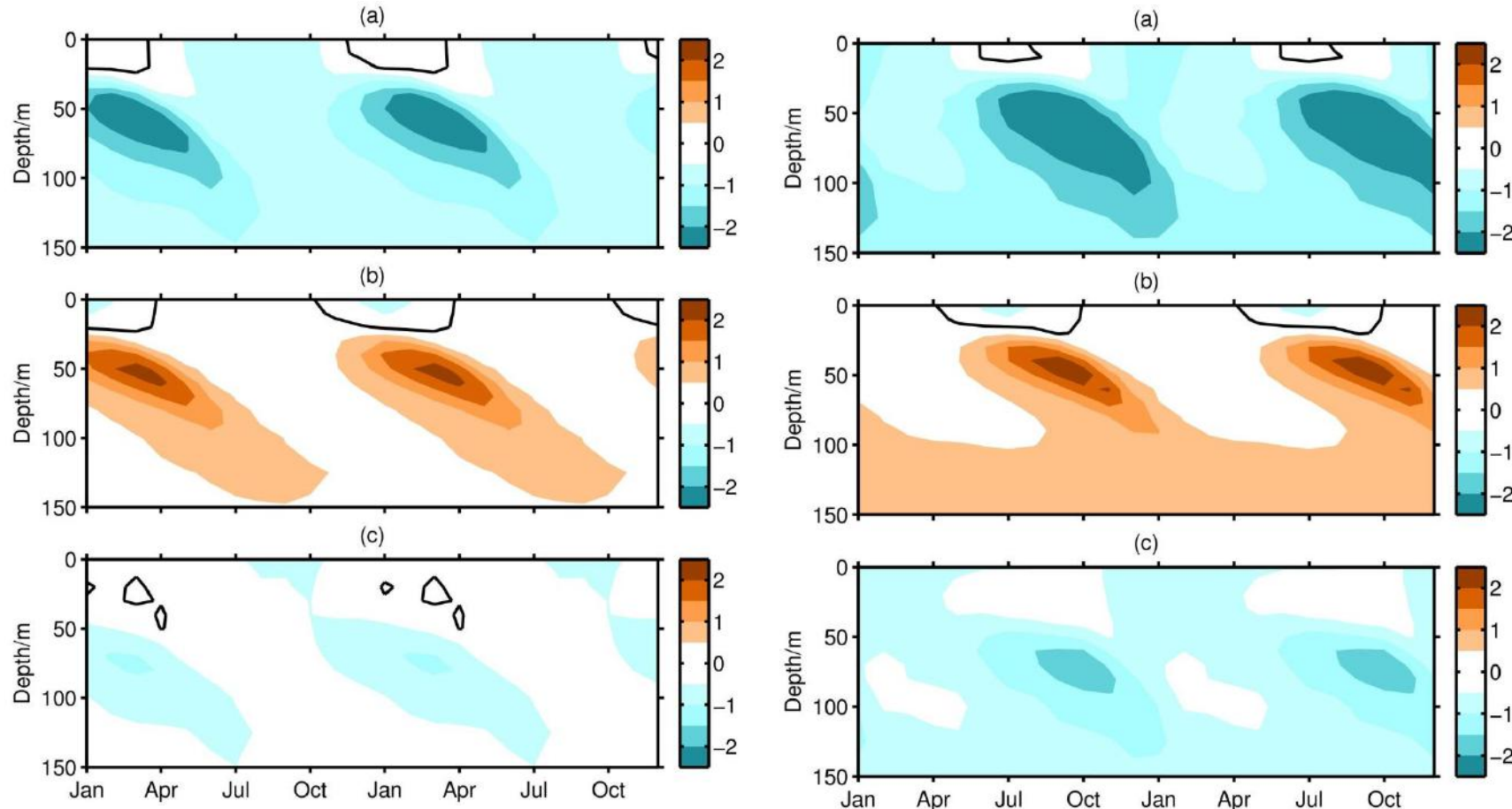

FESOM model improvement of AWI, Germany as an example:
error in the upper ocean was killed by about 90%

Wang et al., 2019, JAMES

a

SST Biases

(b) FIO-ESM v2.0 - Obs   PCC=1.00 RMSE=0.93°C
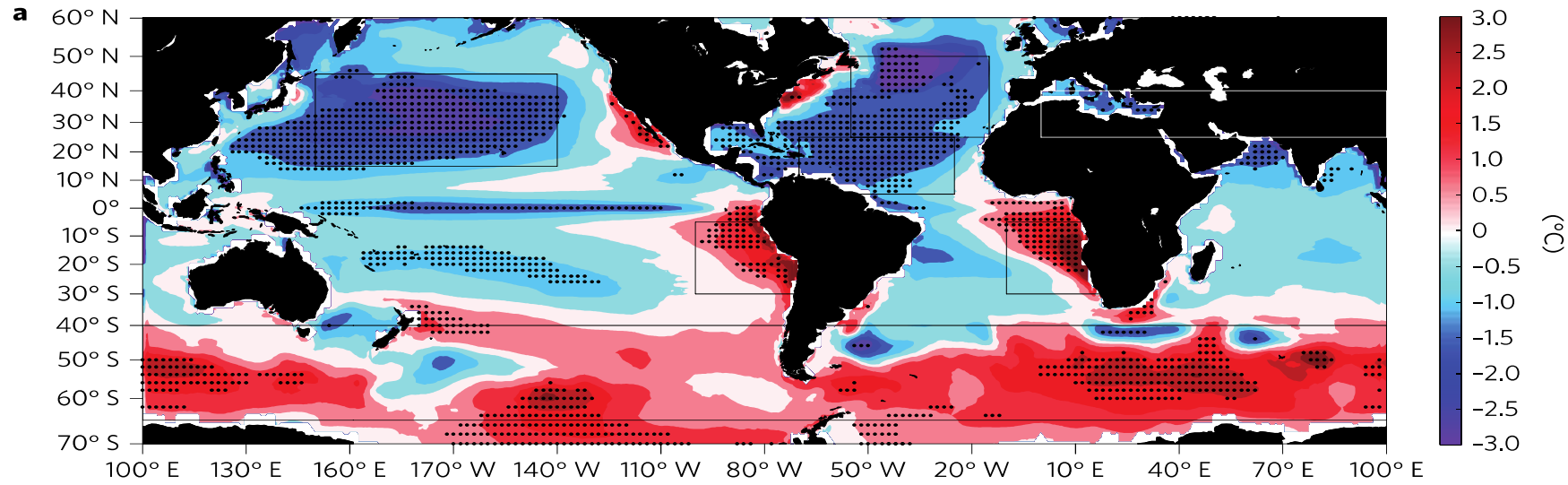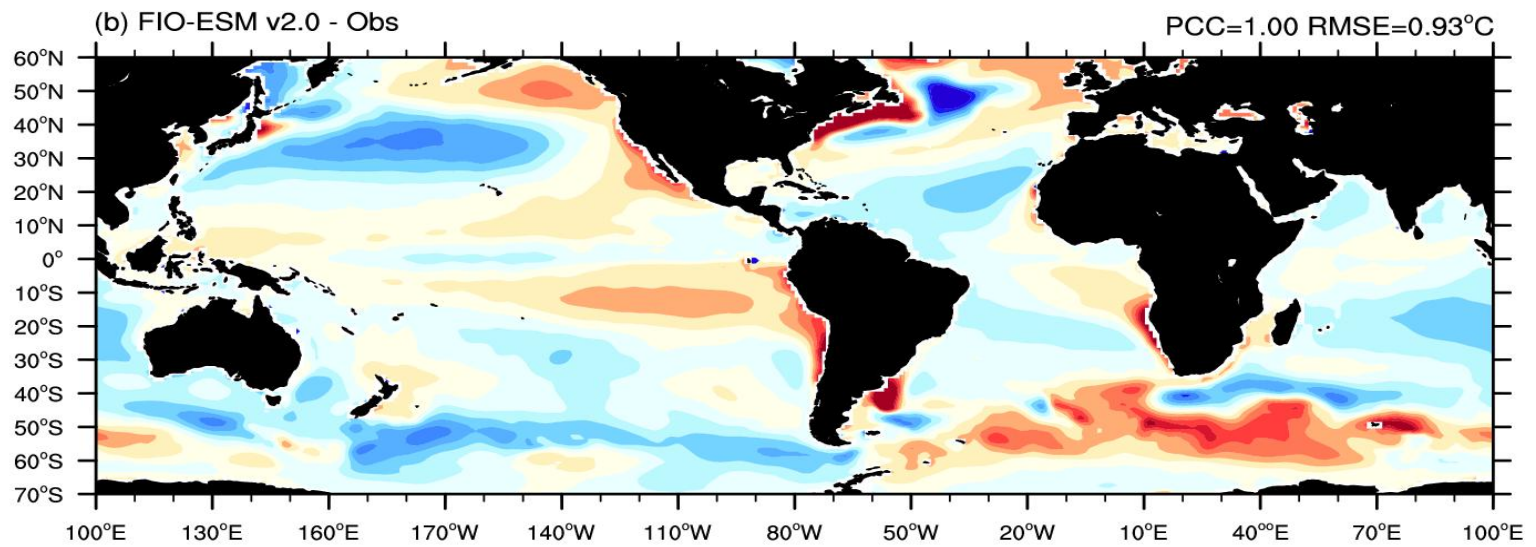
FIO-ESM v2.0
Bv+ sea spray +

Bao et al., 2020, J. Geophys. Res.
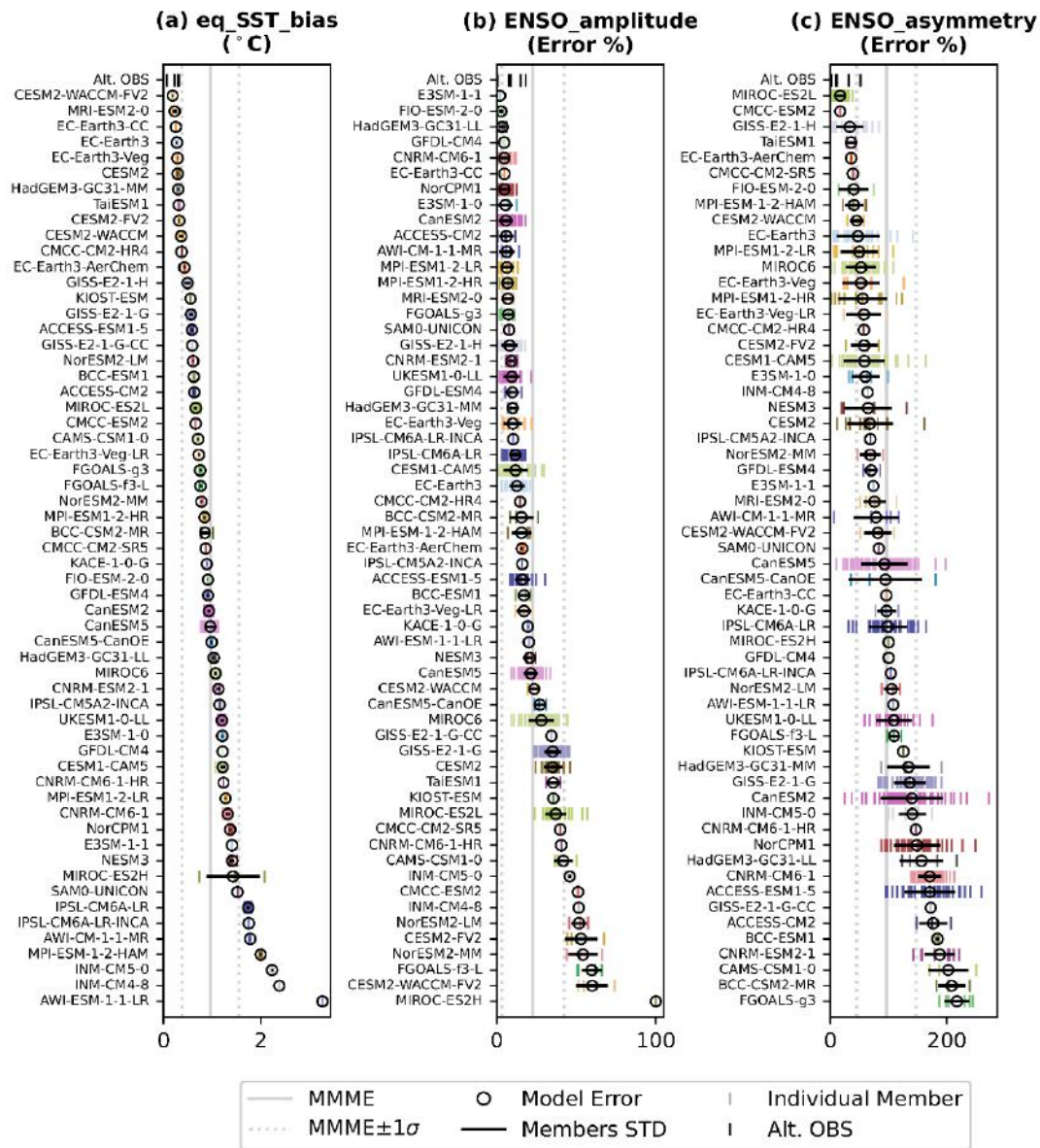
Figure 2. Error metrics calculated for ensemble simulations from the Coupled Model Intercomparison Project (CMIP6) models and large ensembles of CESM1-CAM5 and CanESM2. Lines represent standard deviation of error metrics for individual model ensembles, with circles denoting the average of all members for any given model. Three representative metrics are shown: (a) Equatorial sea surface temperature (SST) Bias, (b) El Niño-Southern Oscillation ENSO Amplitude, and (c) Asymmetry, with results from other metrics in Figure S1 in Supporting Information S1. In each panel, a corresponding unit is given in the subtitle. Models are sorted by their metric values (smaller metric value for better performance). Vertical solid and dotted lines in light gray are for multi-model mean error and its ±1 standard deviation, respectively. Error metrics calculated for alternative observation-based data sets (Alt. OBS) are shown at the top row of each panel.

From Fig 2 of Lee et al (2021, GRL), the ENSO simulation ability of FIO-ESM v2.0 is at the top of all CMIP6 models

Lee, J., Planton, Y. Y., Gleckler, P. J., Sperber, K. R., Guilyardi, E., Wittenberg, A. T., et al. (2021). Robust evaluation of ENSO in climate models: How many ensemble members are needed? Geophysical Research Letters, 48, e2021GL095041. https://doi. org/10.1029/2021GL095041

Flowcharts for FIO-CPS v1.0 and FIO-CPS v2.0

FIO-CPS v1.0

Atmosphere (CAM3) — Exchange data Every 1 h
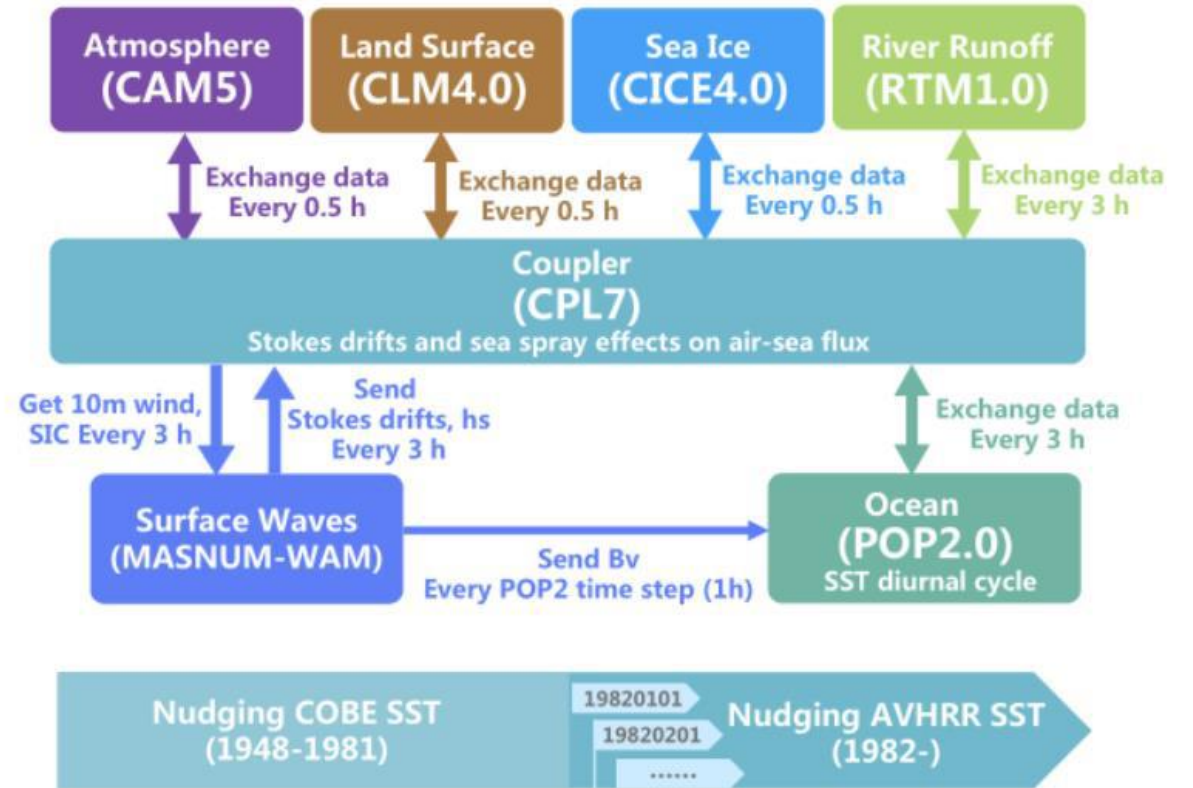Land Surface (CLM3.5) — Exchange data Every 1 h
Sea Ice (CICE4.0) — Exchange data Every 1 h

Coupler (CPL6)

Get 10m wind, SIC Every 6 h
Send wave-induced mixing (Bv) Every 6 h
Exchange data Every 1 d

Surface Waves (MASNUM)
Ocean (POP2.0)

19930101
19930201
......
EAKF AVHRR SST & AVISO SLA (1992-2020)

FIO-CPS v2.0

Atmosphere (CAM5) — Exchange data Every 0.5 h
Land Surface (CLM4.0) — Exchange data Every 0.5 h
Sea Ice (CICE4.0) — Exchange data Every 0.5 h
River Runoff (RTM1.0) — Exchange data Every 3 h

Coupler (CPL7)
Stokes drifts and sea spray effects on air-sea flux

Get 10m wind, SIC Every 3 h
Send Stokes drifts, hs Every 3 h
Exchange data Every 3 h

Surface Waves (MASNUM-WAM)
Send Bv Every POP2 time step (1h)
Ocean (POP2.0) SST diurnal cycle

Nudging COBE SST (1948-1981)
19820101
19820201
......
Nudging AVHRR SST (1982-)
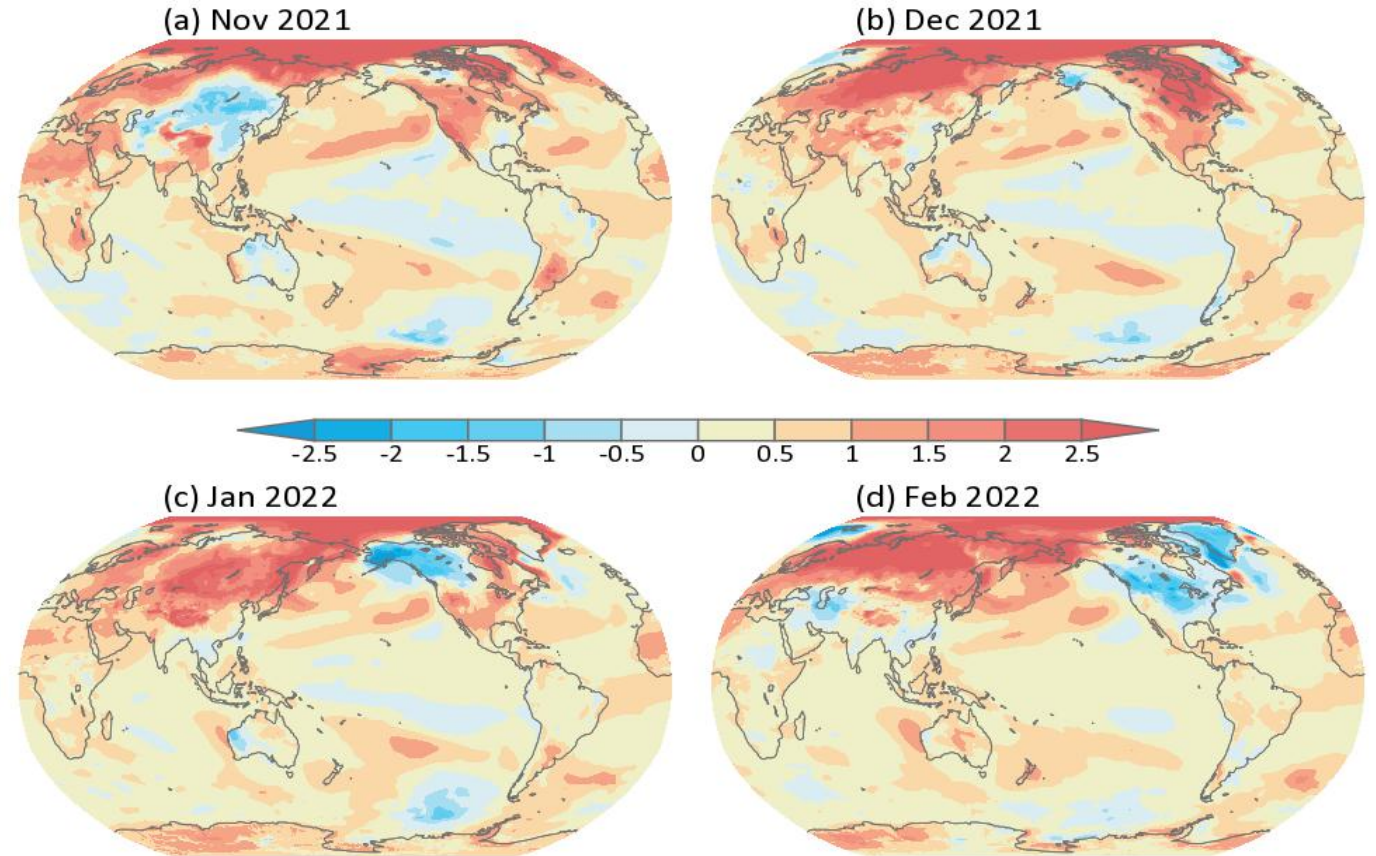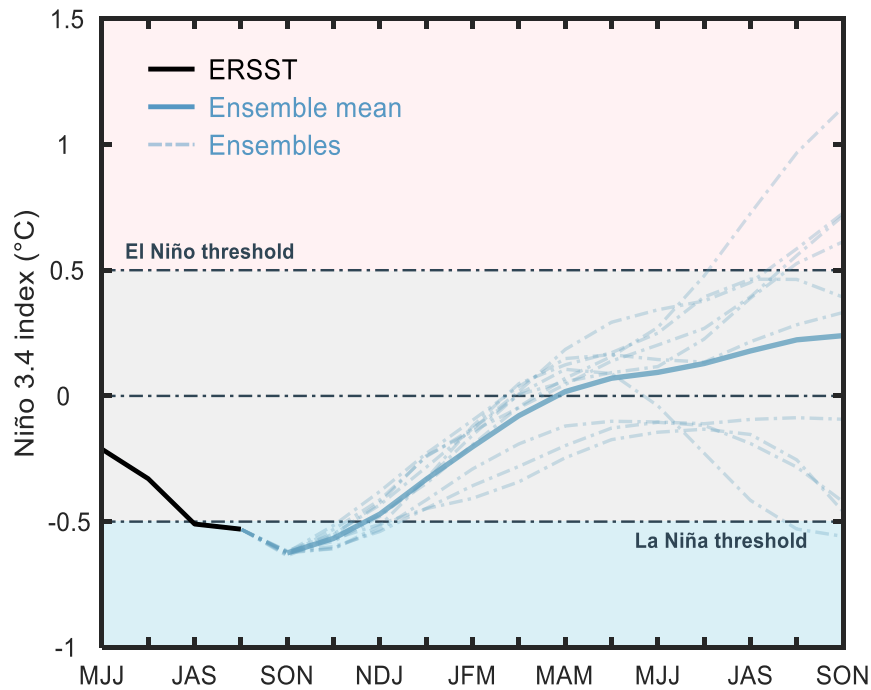
➢ **New physical process**
➢ **Component model is upgraded**
➢ **Resolution and coupling frequency are improved**

- Wave-induced mixing
- Stocks drift (air-sea flux)
- Sea spray (air-sea flux)
- SST diurnal cycle

Climate prediction of Niño 3.4 index and air temperature from FIO-CPS, started from 1ˢᵗ Oct, 2021

(a) Observed Summer Mixed Layer depth

(b) Control Exp Summer Mixed Layer depth

(d) Exp2 Summer Mixed Layer depth

(c) Exp1 Summer Mixed Layer depth

(e) Exp3 Summer Mixed Layer depth

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
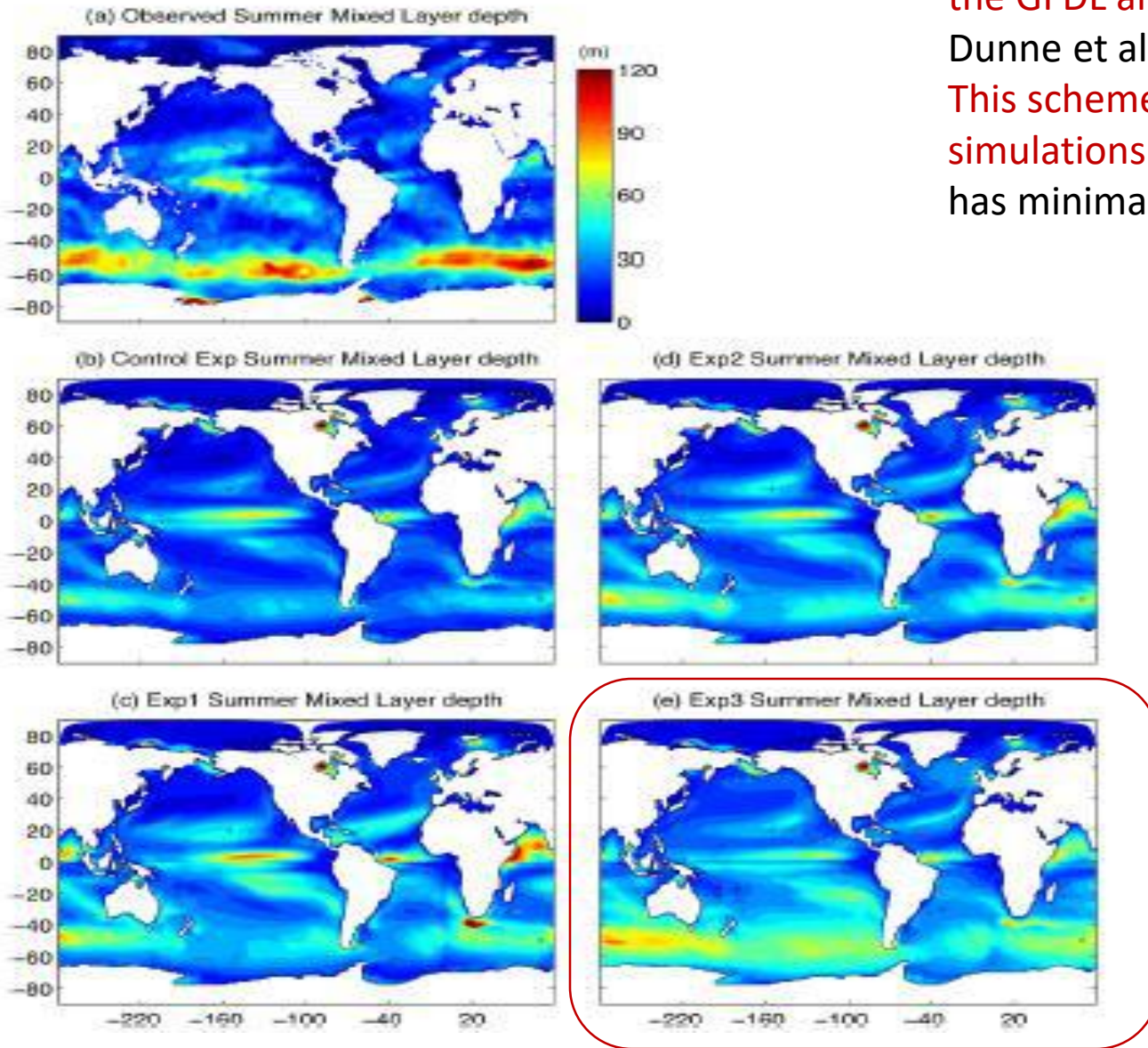
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First RTRC of UNESCO/IOC

- To enhance capacity development of marine science and technology has been the key area of IOC;
- To initiate 'IOC Regional Network of Training and Research Centers (RTRCs) on Marine Science' by WESTPAC in 2008;
- To sign agreement between FIO and IOC at WESTPAC-VIII in Bali, Indonesia on May 11, 2010;
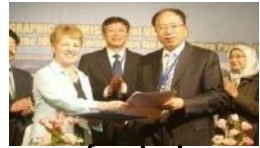- Being officially launched at FIO on June 9, 2011.
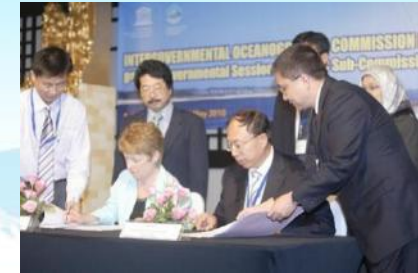
Capacity building

ODC in Qingdao, China
since 2011

**Ceremony for signing agreement
On the establishment of ODC
11 May 2010**

**Ceremony for launch
of ODC in FIO
9 June 2011**

**Ceremony for issuing Prof. Qiao a
certification of the director of ODC
10 May 2012**

**The first training course
on ocean models
Qingdao, China, 10-16 June 2011**

**The second training curse
on ocean dynamics
Qingdao, China, 16-22 July 2012**

**The third training course
on air-sea interaction and modeling
Qingdao, China, 12-23 August 2013**

**The fourth training course
on climate models
Qingdao, China, 03-14 November 2014**

**The fifth training course
on climate change
Qingdao, China, 07-18 September 2015**

**The sixth training course
on ocean dynamics and
multi-scales interaction
Qingdao, China,
05-16 September 2016**

**The seventh training curse
on development of coupled
regional ocean models
Qingdao, China, 12-23 June 2017**

**The eighth training course
on ocean forecast system and
first CLIVAR-FIO summer school
on past, present and future
sea level changes
Qingdao, China,
25 June-7 July 2018**

**The ninth training
Course on climate
dynamics and   air-sea
interactions
Qingdao China, 17-28
June 2019**

2011-2021 Applicants: 1028 from 66 countries; Trainees: 522 from 51 countries.

Distribution of Trainees

Total :
51 countries
522 Trainees
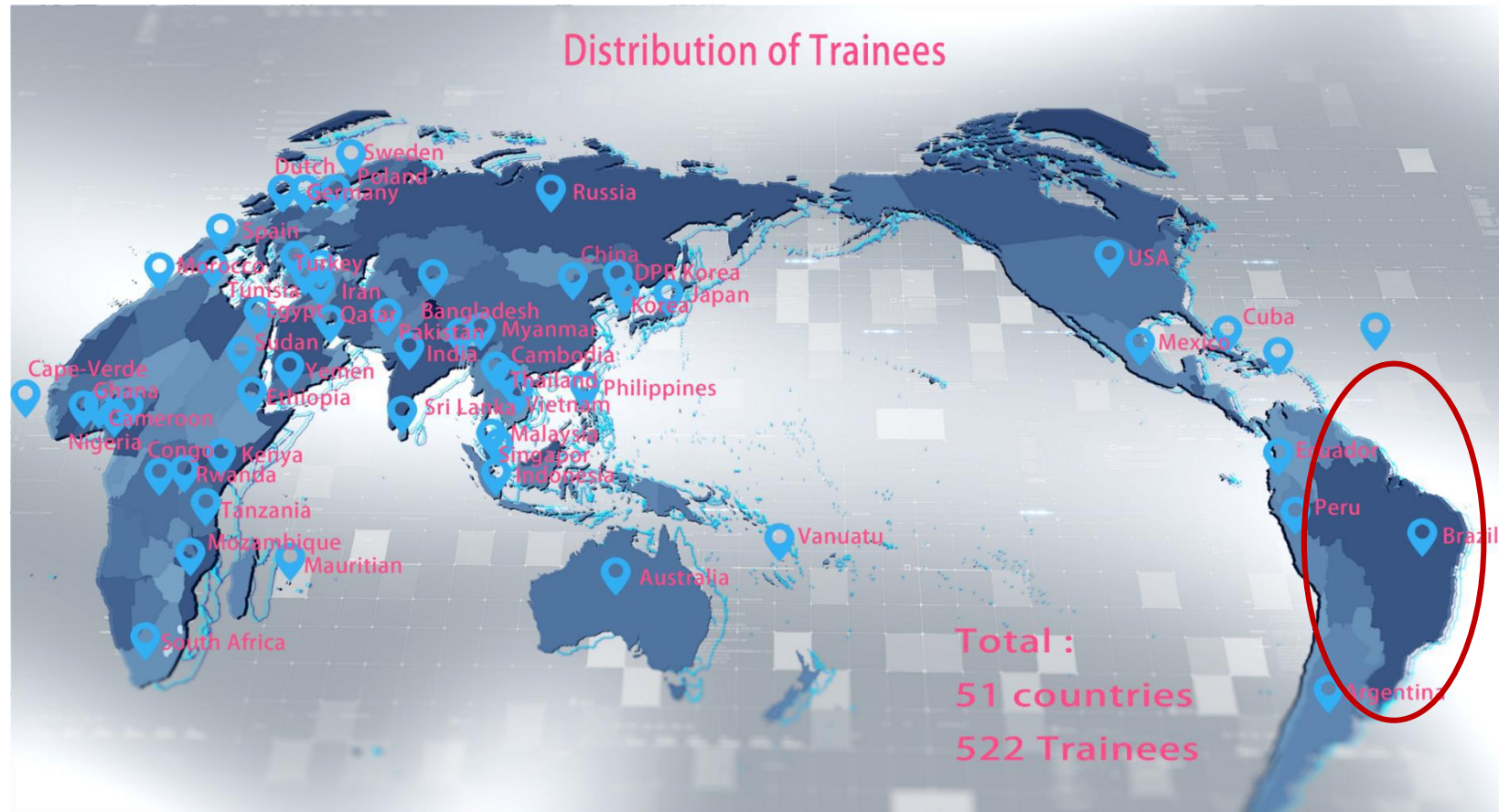
Trainees from Brazil recently: Bruno Ferrero, University of Sao Paulo (2018); Victor Carvalho Cabral, UNESP- São Paulo State University (2019); and Bruno Pereira, University of Sao Paulo Oceanographic Institute (2021)

CONTENTS

Conclusions

❑ Solid scientific base for China-Brazil cooperation: With the scientific breakthroughs on ocean turbulence, we have dramatically improved the forecasting ability of ocean and climate;

❑ Common interests for cooperation: All following Brazil Professors hope to cooperate: Moacyr Cunha de Araujo Filho (UFPE); Fabiano Thompson(UFRJ); Clemente Augusto Souza Tanajura (UFBA); Mauro Cirano (UFRJ) etc.

❑ China-Brazil cooperation proposal: A project "For better simulation and prediction of climate", which can also be a UN Ocean Decade program proposal.

Thank you for your attention

Observing the Ocean, Predicting the climate