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Projected sea level changes in China marginal seas based on dynamical downscaling

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I. Motivation

Global Climate Models (GCMs) produce important scientific insights into the dynamics and evolution of the climate system.

Shortages:

Raw GCMs output is not always adequate to address the regional questions of interest to stakeholders:

- Coarse spatial scale (horizontally and vertically)
- Biases relative to observational data
- Large computation cost

Solution:

Downscaling methods

- **Statistical downscaling:** Transform climate model outputs to statistically refined products based on statistics-based techniques
- **Dynamical downscaling:** the use of high-resolution regional simulations to dynamically translate the effects of large-scale climate processes to regional or local scales of interest.

e.g., Sea level projections (Zhang et al., 2017) for Australian region, Climate changes for Gulf of Mexico (Liu et al., 2012; Liu et al., 2015), the North Sea (Ådlandsvik and Bentsen, 2007; Ådlandsvik, 2008), California (Li et al., 2012; Li et al., 2014)

I. Motivation

Regional Ocean Modeling System (ROMS)

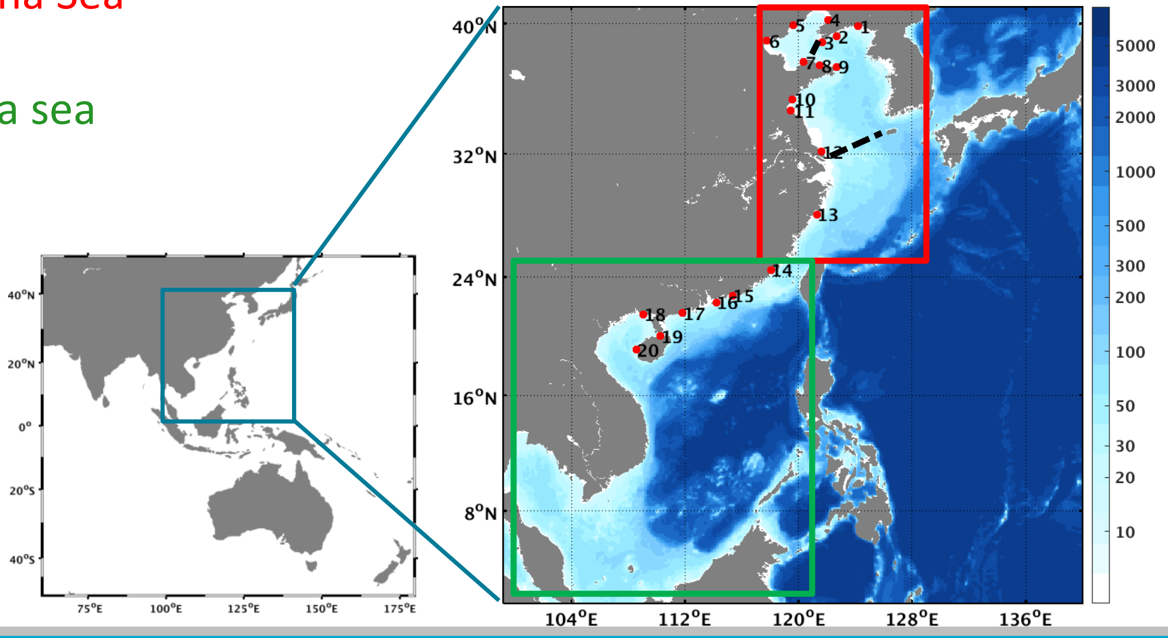
-- a free-surface, primitive-equation, terrain-following sigma vertical coordinate oceanic model

(Shchepetkin and WcWilliams, 2003, 2008)

East China marginal seas

- Bohai Sea (18m)
- Yellow Sea (44m)
- East China Sea

South China sea



The broad and shallow continental shelf

Horizontally:

Coarse resolution **GCMs** (typical 100km)

-> high resolution **ROMS** (~8 km)

Vertically:

Z coordinate **GCMs**

-> sigma coordinate **ROMS** (5m to 5500m)

II. Model Configuration

Spatial Resolution: 1/12° (~8km)

Vertical: 30 layers (s-coordinate)

Boundary condition:

- To exclude the sea level fluctuation caused by net water volume changes, the net water volume flux (i.e., open boundaries + river runoff) is balanced at each model time step to keep **the regional mean sea level as zero.**
- **Clamped condition** for 2D volume flux and tracers (T/S)
- **Radiation condition** for 3D momentum

Sponge layers (2° from the boundary):

- the viscosity and diffusivity are increased from the interior to the boundaries and the nudging strength is increased from 200 days to 5 days.

- Lowest water temperature is set as -1.5 ℃

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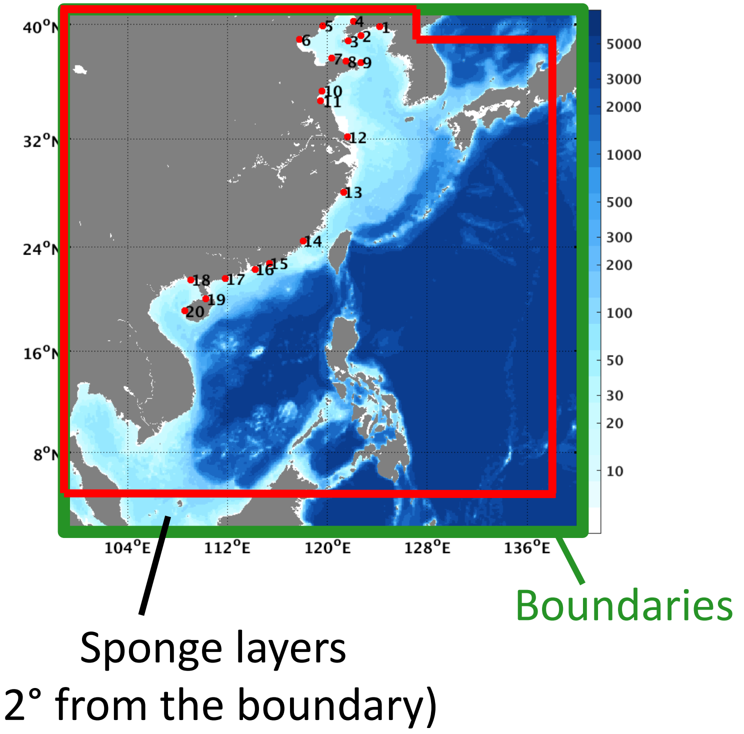

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III. Historical Experiment

No.	Experiment name	Boundary condition	Surface forcing	Simulation Period
1	Historical Experiment	5-day BRAN (Oke et al., 2013)	6-hour ERAI (Dee et al., 2011)	1994-2015 (22 years)

- Climatological monthly SSS from BRAN is used to surface **salinity relaxation** (30 days)
- **Runoff**: climatological monthly transports of Yangtze River (salinity: 5 psu; temperature is consistent with surrounding water)

Initial condition:

- Spin-up experiment: T/S and u/v fields from 01/01/1994 of **BRAN** forced by ERAI and BRAN of 1994 repeatedly
- The first day state of the 6th year is used as initial condition when the model is quasi-stable

<u>The model validation of sea level, temperature and ocean current indicates that this regional model reproduces historical ocean states reasonably well at different spatiotemporal scales.</u>

IV. Dynamical Downscaling

No.	Experiment name	Boundary condition	Surface forcing	Simulation Period
1	Historical Experiment	BRAN	ERAI	1994-2015 (22 years)
2	Future Experiments (8 times)	BRAN + ΔF_O	ERAI + ΔF_A	2079-2100 (22 years)

Step1: Climate change signal ΔF (mean + seasonal)

= ACCESS1.0 future (RCP8.5) monthly climatology (2079-2100)

– ACCESS1.0 historical monthly climatology (1980-2005)

Step2: Future Experiment forcing = Historical Experiment forcing + ΔF

Step3: The results forced by Future Experiments forcing

Step4: Downscaled result = Future Experiment - Historical Experiment

Totally 8 CMIP5 models are downscaled (ACCESS1.0, CanESM2, CMCC-CM, CMCC-CMS, GISS-E2-R, HadGEM2-CC, MRI-CGCM3, MPI-ESM-MR) => Dynamical Downscaling Ensemble

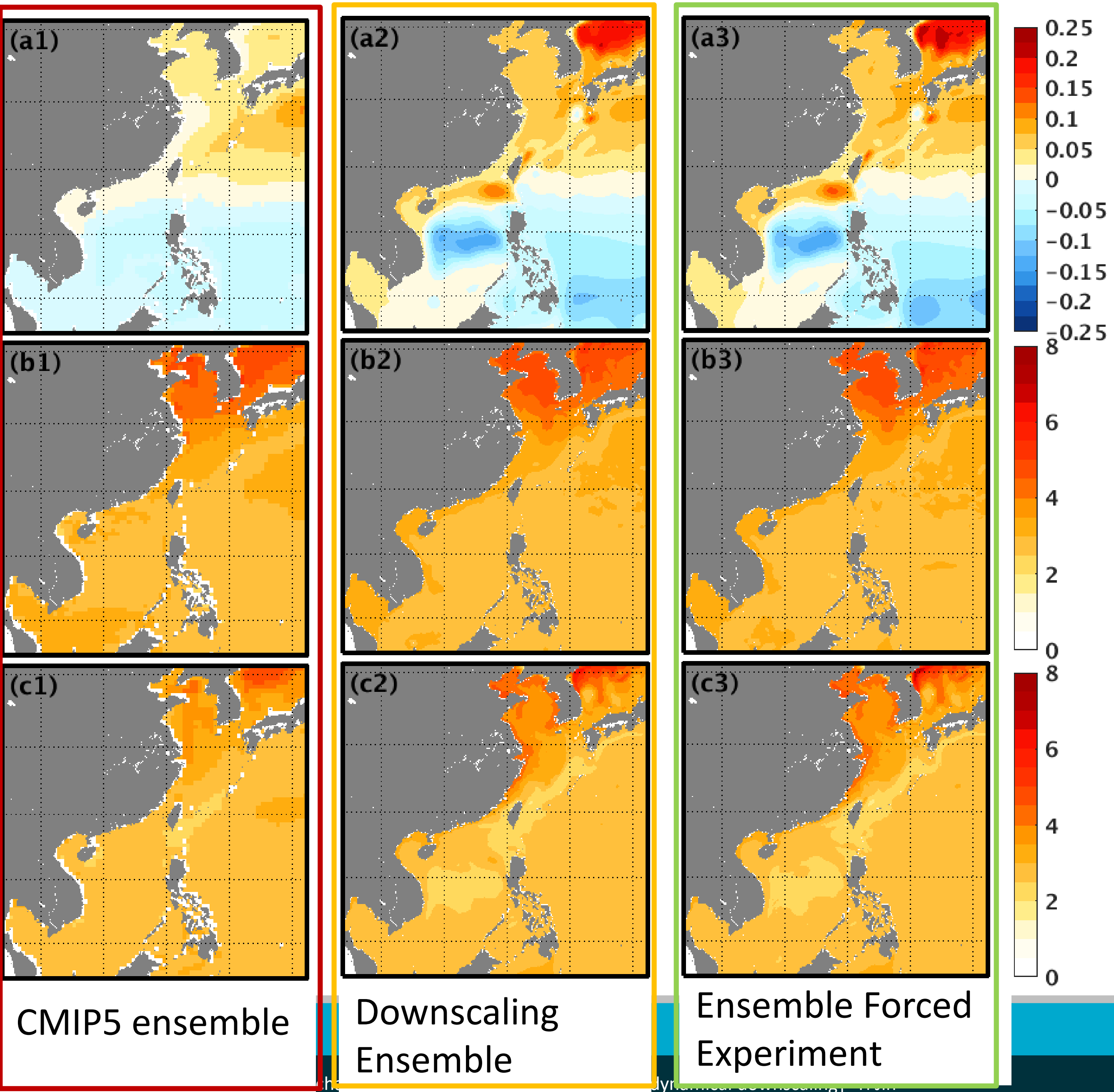
V. Ensemble-forced Experiment

No.	Experiment name	Boundary condition	Surface forcing	Simulation Period
1	Historical Experiment	BRAN	ERAI	1994-2015 (22 years)
2	Future Experiments (8 times)	BRAN + ΔF_O	ERAI + ΔF_A	2079-2100 (22 years)
3	Ensemble-forced Experiment	BRAN + $\overline{\Delta F_O}$	ERAI + $\overline{\Delta F_A}$	2079-2100 (22 years)

$$\overline{\Delta F} = \text{mean}(\Delta F_1 + \Delta F_2 + \cdots + \Delta F_8)$$

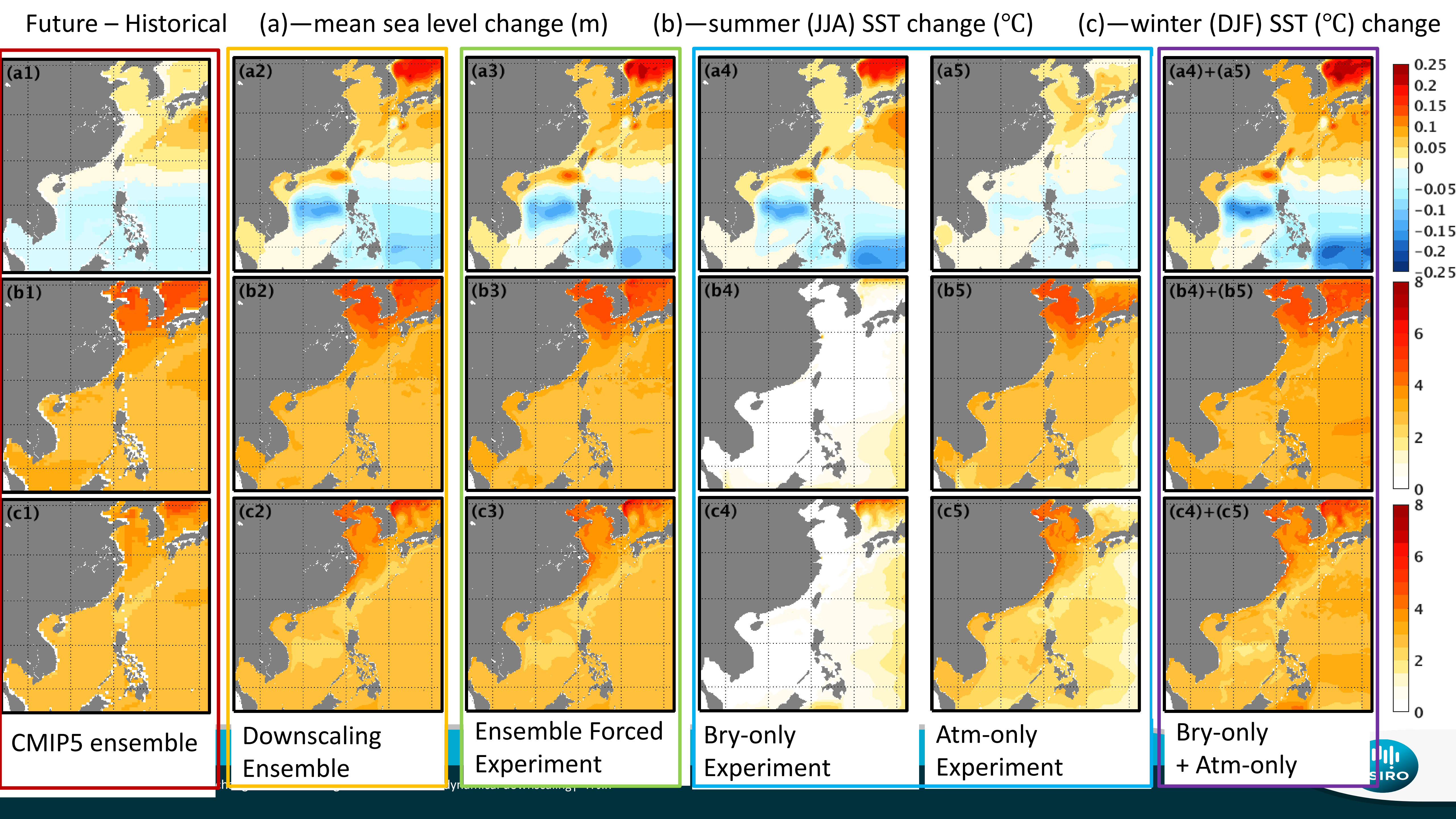
Ensemble mean of these 8 selected GCMs

Future – Historical (a)—mean sea level change (m) (b)—summer (JJA) SST change (°C) (c)—winter (DJF) SST (°C) change



VI. Perturbation Experiments

No.	Experiment name	Boundary condition	Surface forcing	Simulation Period
1	Historical Experiment	BRAN	ERAI	1994-2015 (22 years)
2	Future Experiments	BRAN + ΔF_O	ERAI + ΔF_A	2079-2100 (22 years)
3	Ensemble-forced Experiment	BRAN + $\overline{\Delta F_O}$	ERAI + $\overline{\Delta F_A}$	2079-2100 (22 years)
4	Bry-only Experiment	BRAN + $\overline{\Delta F_O}$	ERAI	22 years
5	Atm-only Experiment	BRAN	ERAI + $\overline{\Delta F_A}$	22 years


Future – Historical
(a)—mean sea level change (m)
(b)—summer (JJA) SST change (°C)
(c)—winter (DJF) SST (°C) change
(a1)
(a2)
(a3)
(a4)
(a5)
(a4)+(a5)
(b1)
(b2)
(b3)
(b4)
(b5)
(b4)+(b5)
(c1)
(c2)
(c3)
(c4)
(c5)
(c4)+(c5)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
8
6
4
2
0
8
6
4
2
0
CMIP5 ensemble
Downscaling Ensemble
Ensemble Forced Experiment
Bry-only Experiment
Atm-only Experiment
Bry-only + Atm-only

VII. On-going

Projected **extreme sea level** changes in China marginal seas based on dynamical downscaling

(the **Generalized extreme value distribution** is used to describe the change of extreme sea level)

$$\Delta F = \Delta F_{mean} + \Delta F_{seasonal} + \Delta F_{non\text{-}seasonal}$$

$$\Delta F_{LF} \qquad \Delta F_{HF}$$

- The extreme sea level changes caused by $\Delta F_{mean} + \Delta F_{seasonal}$
- The extreme sea level changes caused by ΔF_{LF}
- The extreme sea level changes caused by ΔF_{HF}

Thank you

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