PICES Annual Meeting

To initiate seasonal prediction for PICES FUTURE

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Key point:

Through including the small scale surface wave in climate model, the seasonal prediction ability can be much improved based on 21 years hindcast validation (21X12=252 prediction cases).

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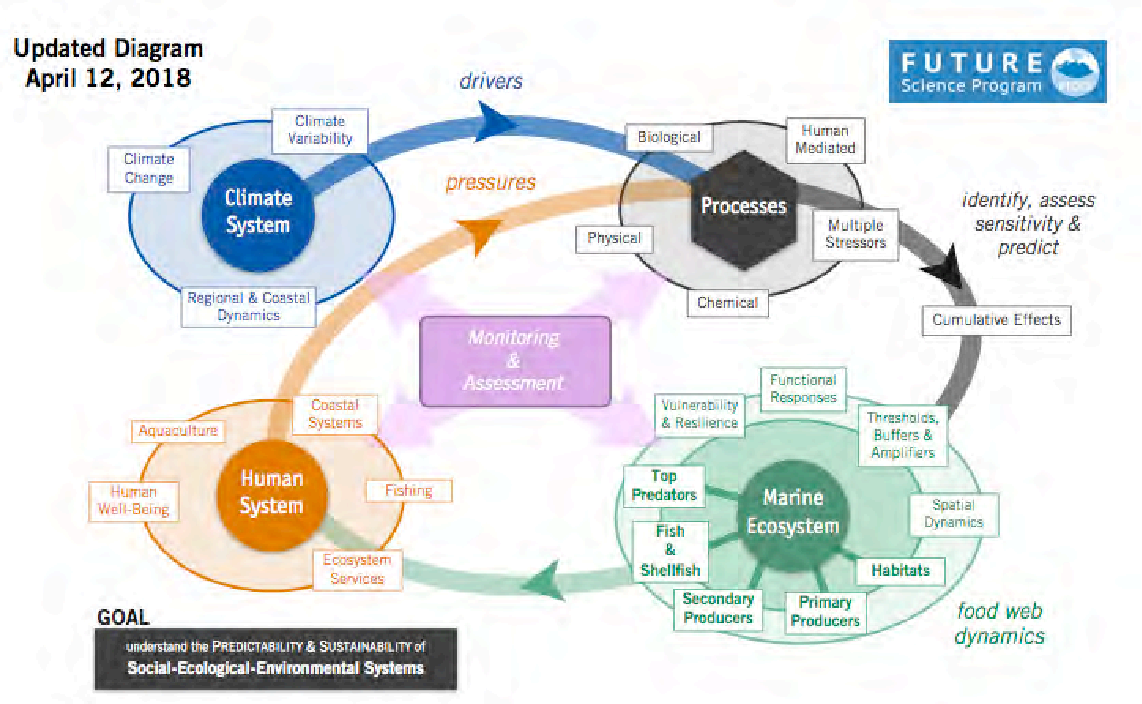
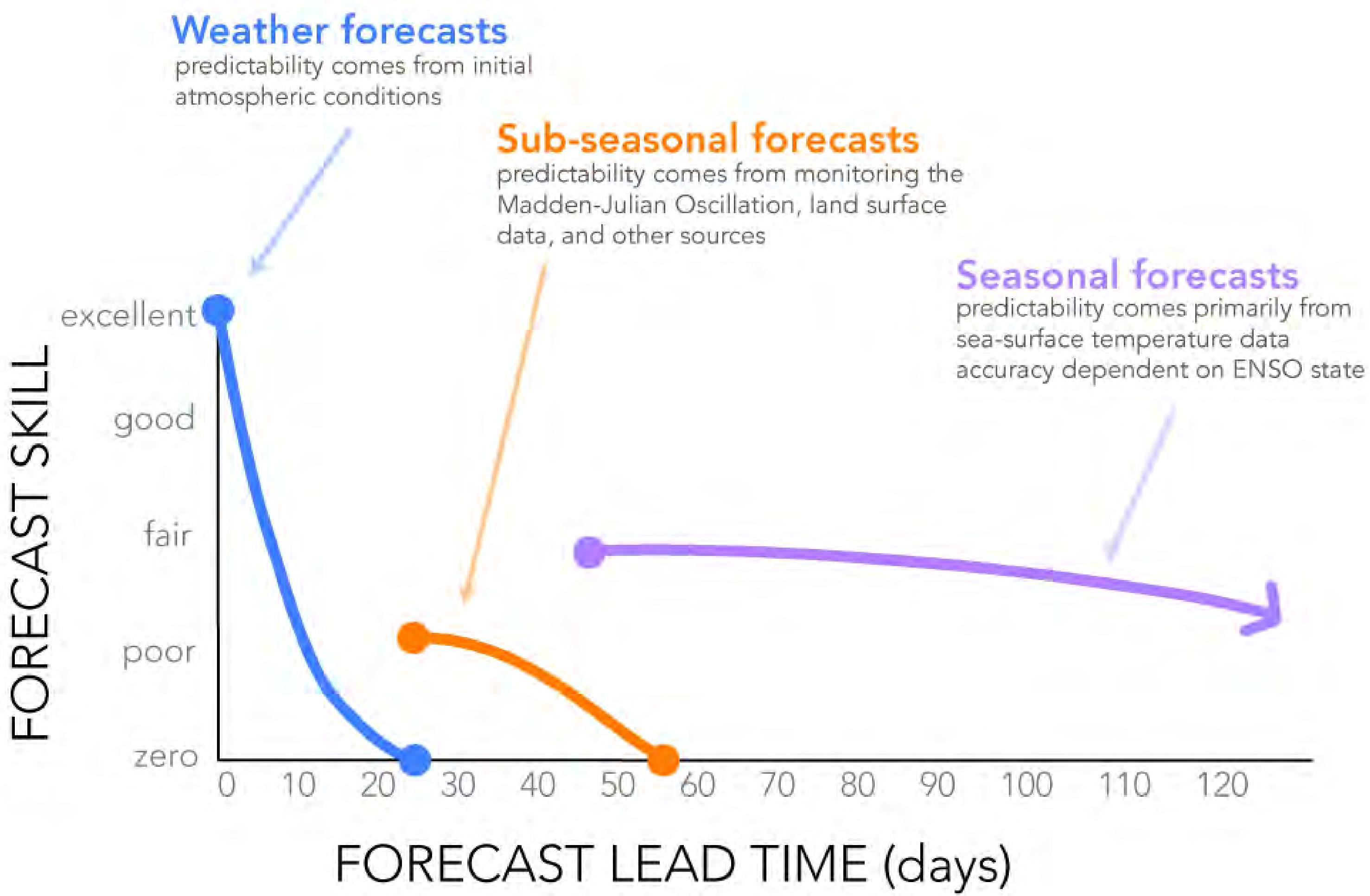
FUTURE: Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems. 10 years Programm from 2009

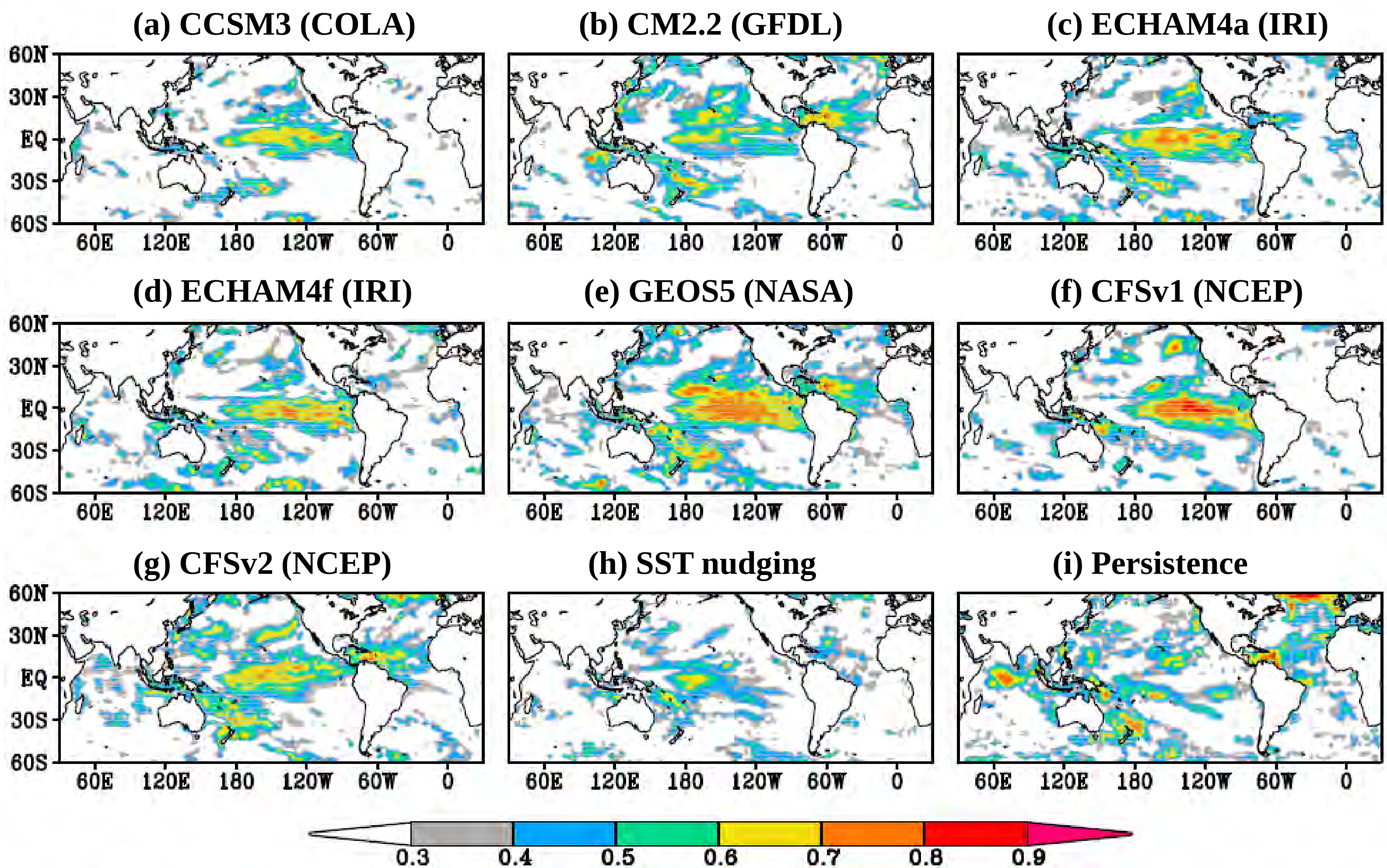


GOAL: Understand the Predictability and Sustainability of the Social-Ecological-Environmental System.


Weather forecasts
predictability comes from initial atmospheric conditions
Sub-seasonal forecasts
predictability comes from monitoring the Madden-Julian Oscillation, land surface data, and other sources
Seasonal forecasts
predictability comes primarily from sea-surface temperature data
accuracy dependent on ENSO state
excellent
good
fair
poor
zero
FORECAST SKILL
0 10 20 30 40 50 60 70 80 90 100 110 120
FORECAST LEAD TIME (days)

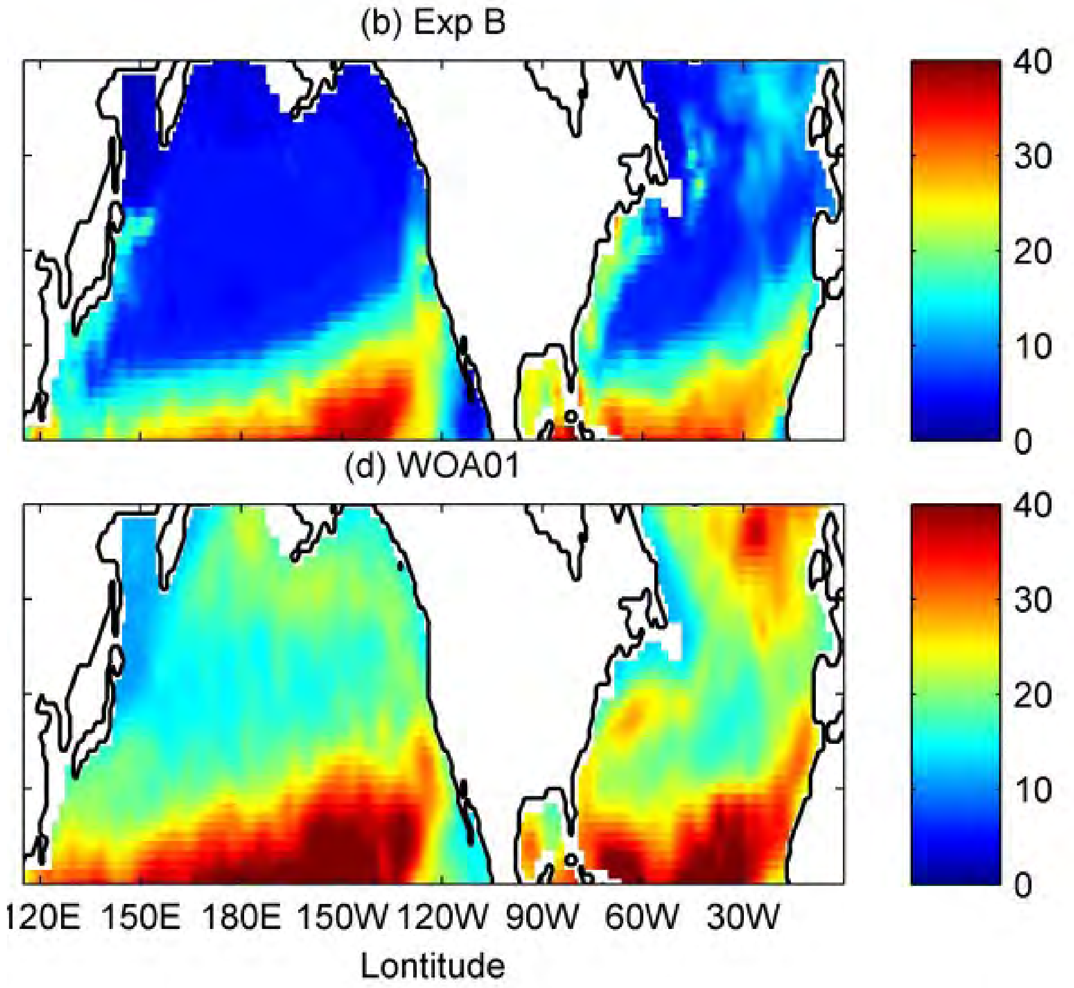
Status of climate model: quite low in PICES area

Distribution of SST prediction skill (6-mon-lead)



(Li and Ding, 2012, Mon. Weather. Rev.)

Ocean plays key role in seasonal prediction, however,



Modeled MLD

Observed MLD

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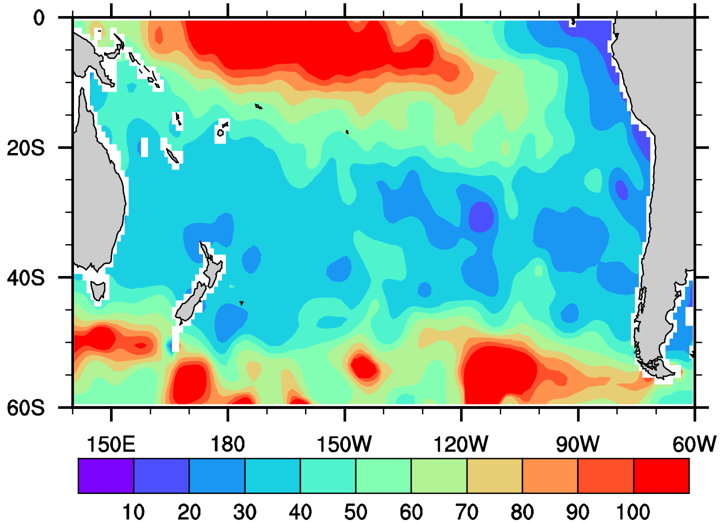
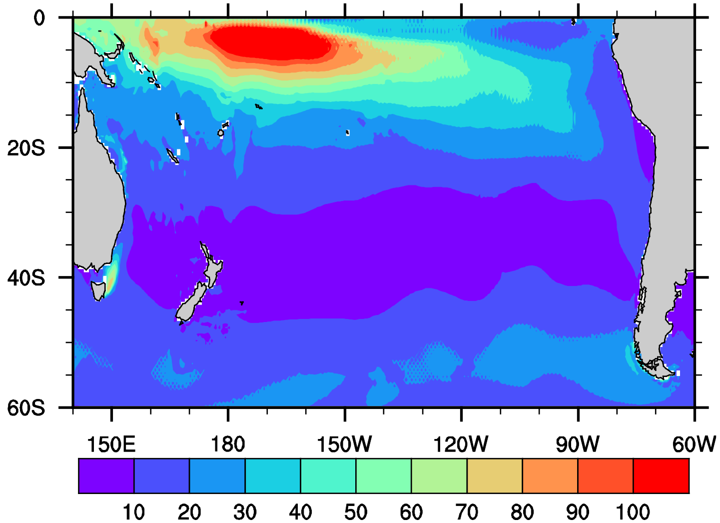
Long-standing challenges for stand alone OGCM models:
Simulated SST is overheating in summertime, and mixed layer depth is too shallow (Martin 1985; Kantha 1994; Ezer 2000; Mellor 2003; Qiao etal, 2016).





✓ Observed MLD ✓ Modeled MLD

Lack of mixing in the upper ocean

As the mixing process is essentially an energy balance problem, waves, as the most energetic motions at the ocean surface, should play a controlling role. Surface wave: 60 TW, Circulation: 4 TW

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

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, GRL, 2004; OD, 2010; RS, 2016

If we regard surface wave as a monochramatic wave,

$$B_v = \alpha A^3 k \omega \, e^{(-3kz)} = \alpha A \, \underbrace{u_s}_{\text{Stokes Drift}} \, e^{(-3kz)} \, ,$$

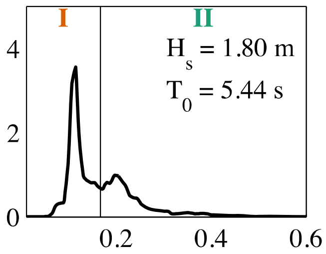
Bv is wave motion related vertical mixing instead of wave breaking.

Blue line
Osborn, 1980

Green line
Terray et al. (1996)

Red line
Huang and Qiao (2010)

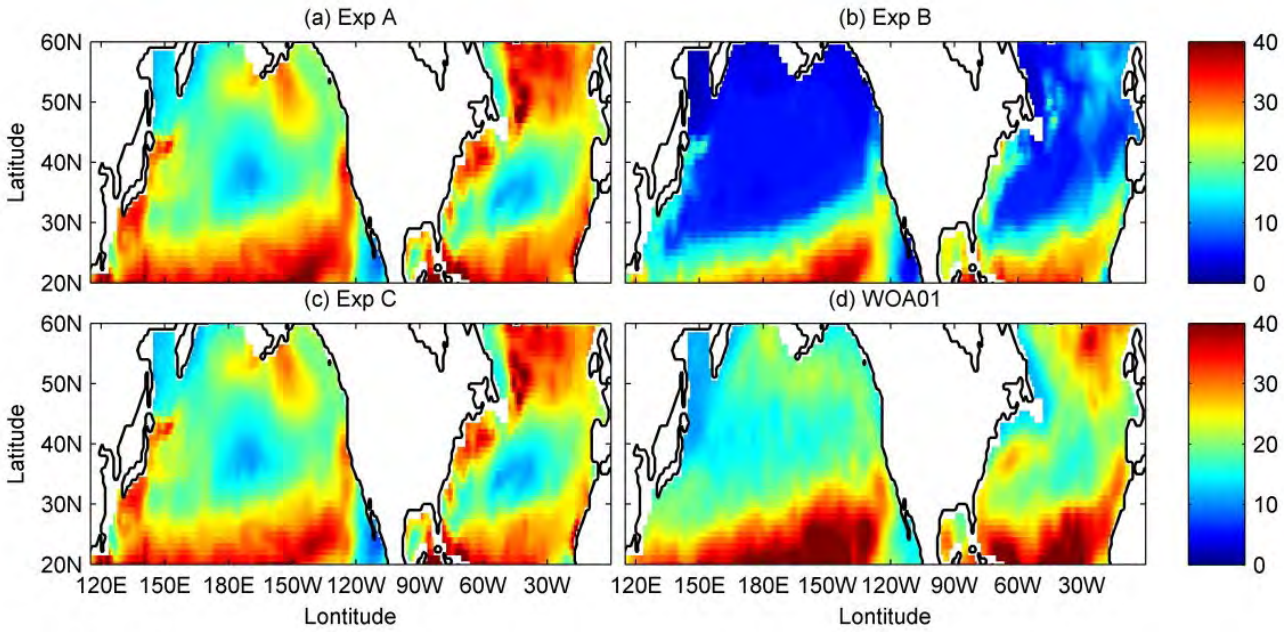
Sutherland et al., 2013, OS



Climatology MLD in August

MY+Bv

Bv only

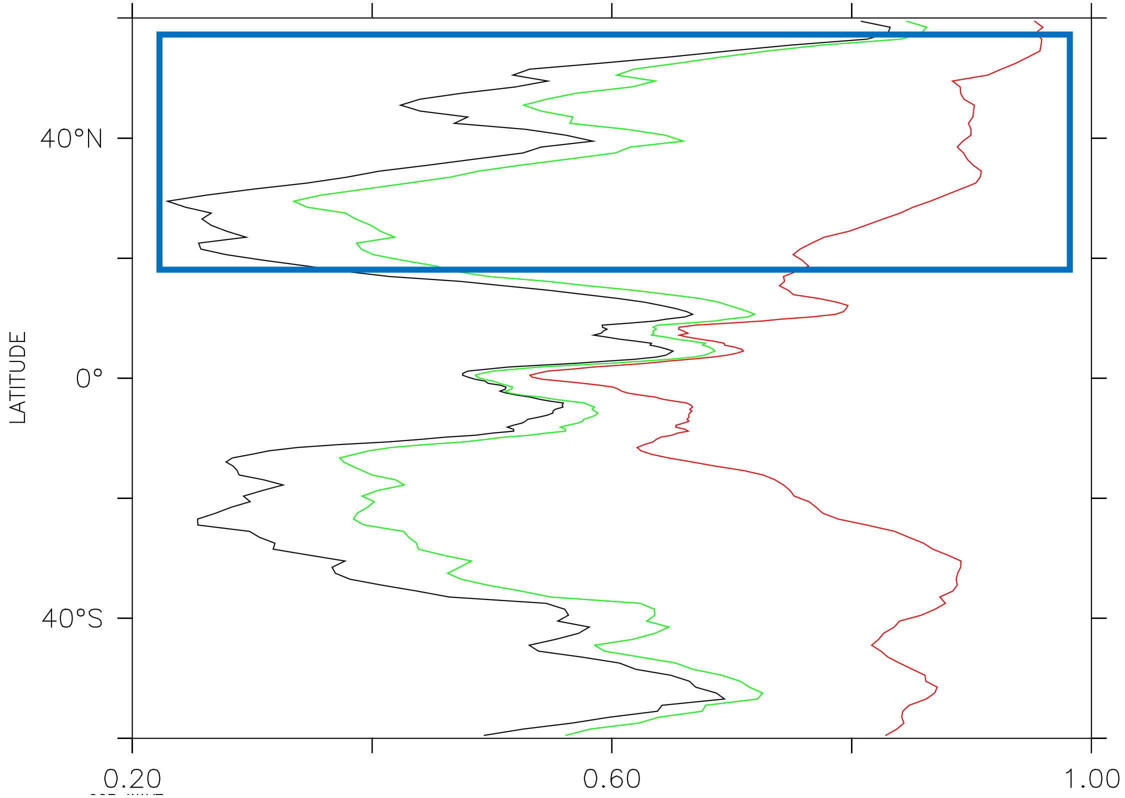


MY

Obs

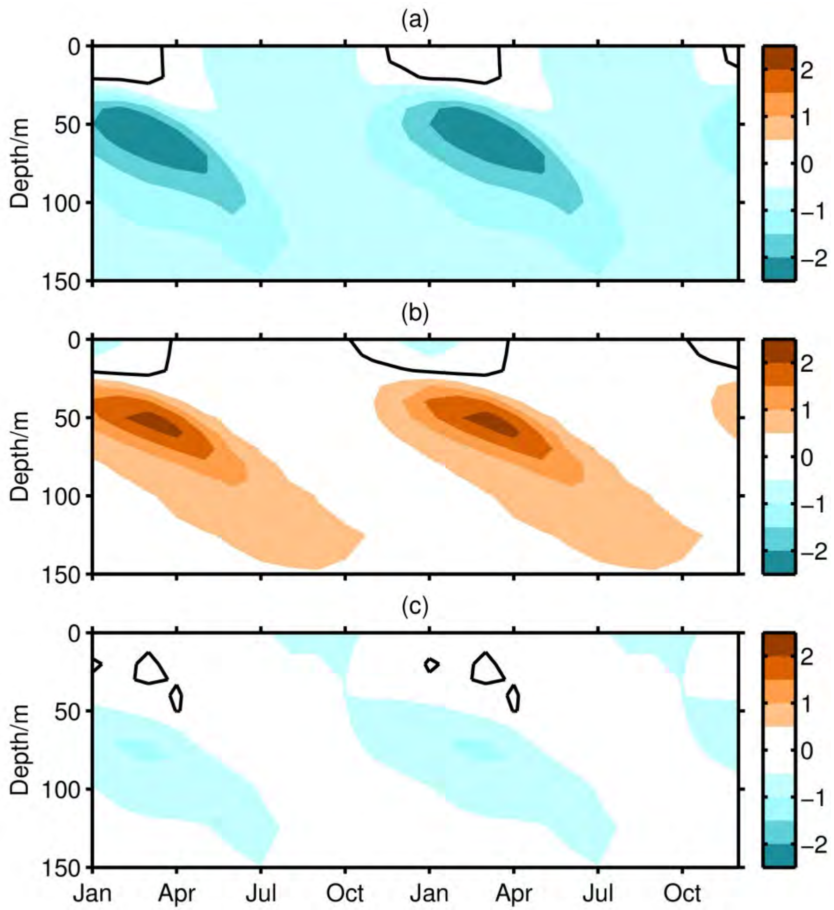
The two lines represent the whole upper ocean: Zonal (x-direction) and upper 100m (z-direction) averaged correlation coefficient (t).

Black, POM2008 without wave effects; Green: with wave breaking (and IW) suggested by Mellor (2004, JPO); Red: with Bv

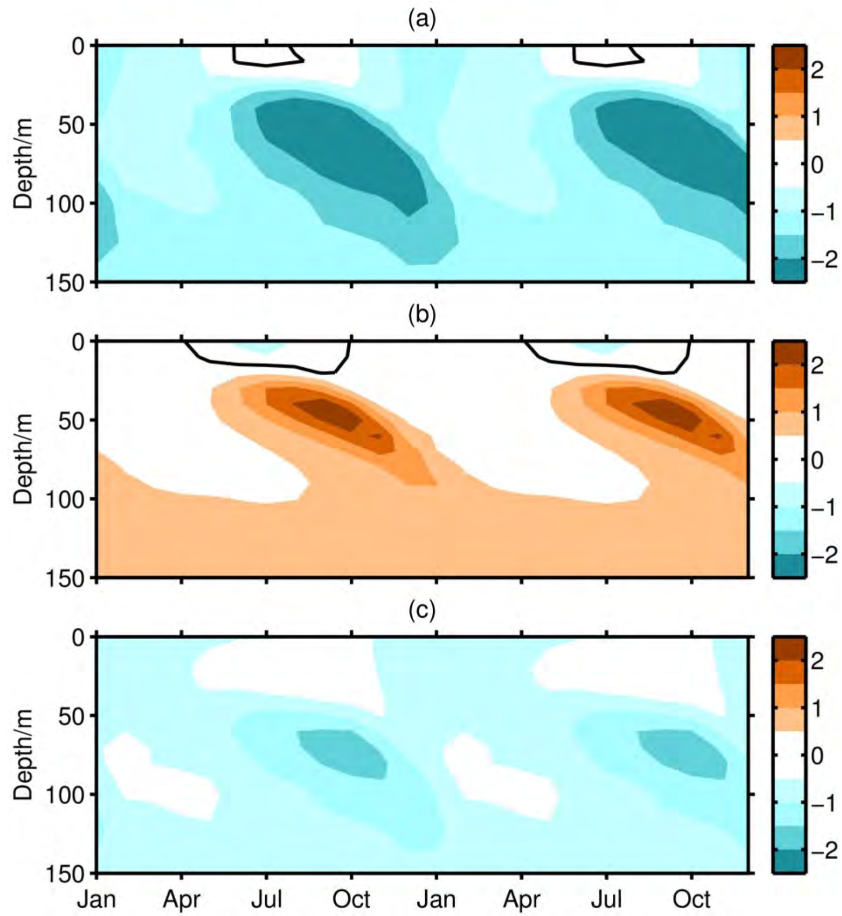


Temperature differences: cooperated with Prof G Lohmann of AWI, Gernany

Temperature Difference of 30S



Temperature Difference of 30N



(a) without Bv - WOA09

(b) with Bv - without Bv

(c) with Bv - WOA09

black line - zero line

(a) without Bv - WOA09

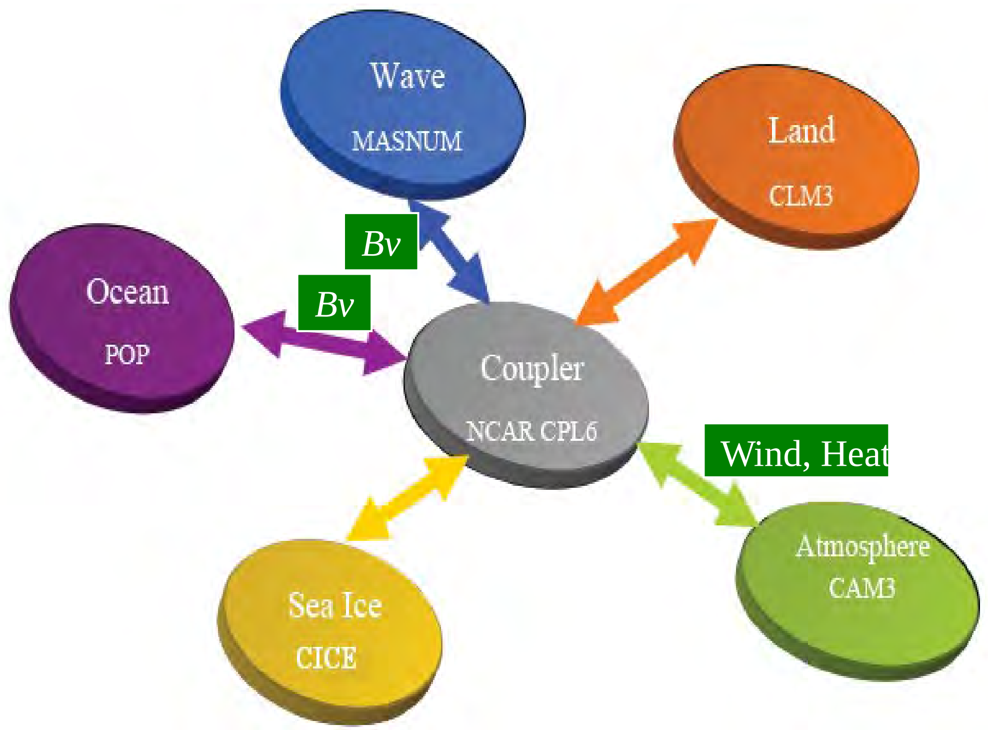
(b) with Bv - without Bv

(c) with Bv - WOA09

black line - zero line

CONTENTS

FIO-ESM First Institute of Oceanography Earth System Model



(Qiao et al., 2013, J. Geophys. Res.)

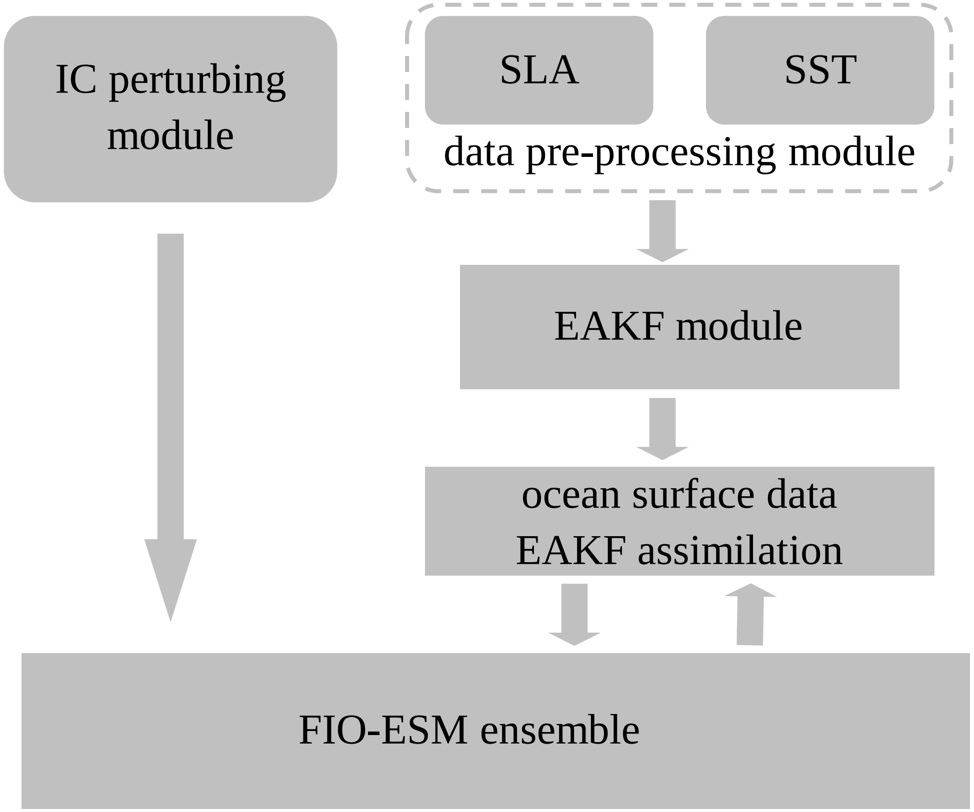
- ATM : CAM3.5 T42, L26
- LND : CLM3 T42
- OCN : POP2 1.1°×0.3~0.5°, L40
- ICE : CICE4 1.1°×0.3~0.5°
- WAV : MASNUM 2°×2°

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

$$K_m = K_{m0} + Bv$$
$$K_h = K_{h0} + Bv$$

DA method

EAKF Ensemble Adjustment Kalman Filter



(Anderson, 2001, Mon. Weather. Rev.)

Exp. HIND	Setting
Hindcast period	1993-2013
Ensemble size	10
Lead times (months)	1-6
Arrangement of ensemble members	All first of the month 0000 UTC

Hindcasted SST Results

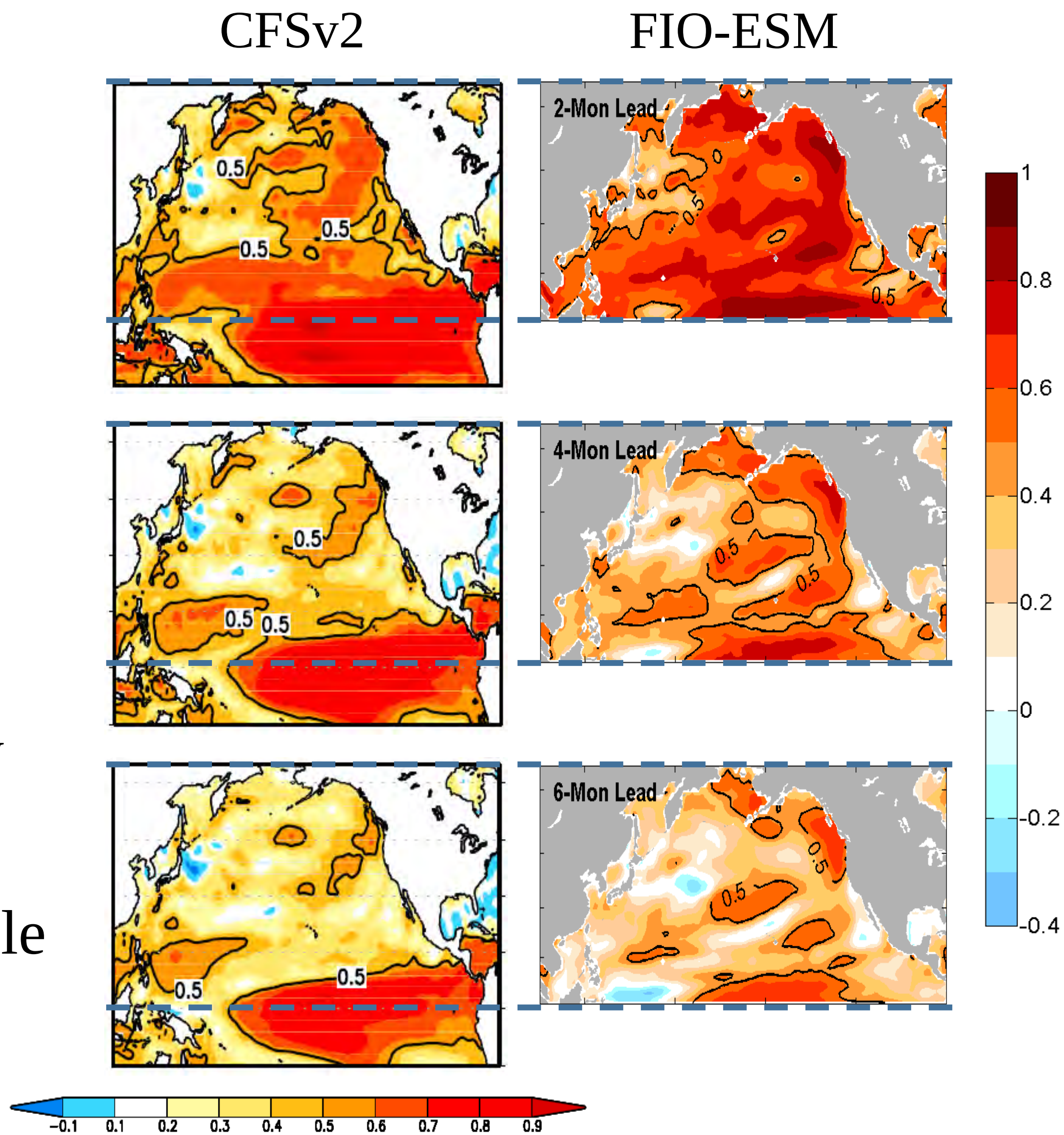
Anomaly correlation coefficient(ACC):

$$ACC_{i,j} = \frac{\mathrm{cov}(F_t, O_t)}{\sigma_F \sigma_O}$$

$\mathrm{cov}(F_t,O_t)$: the covariance of the simulated and observational anomaly

σ : the standard deviation of the variable

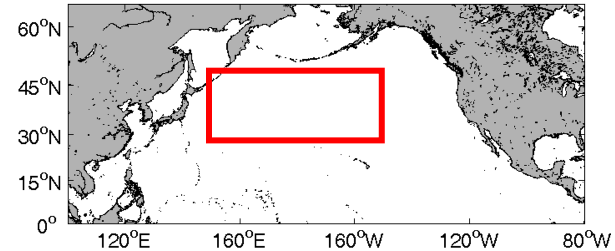
(Hu et al., 2014, J. Climate)



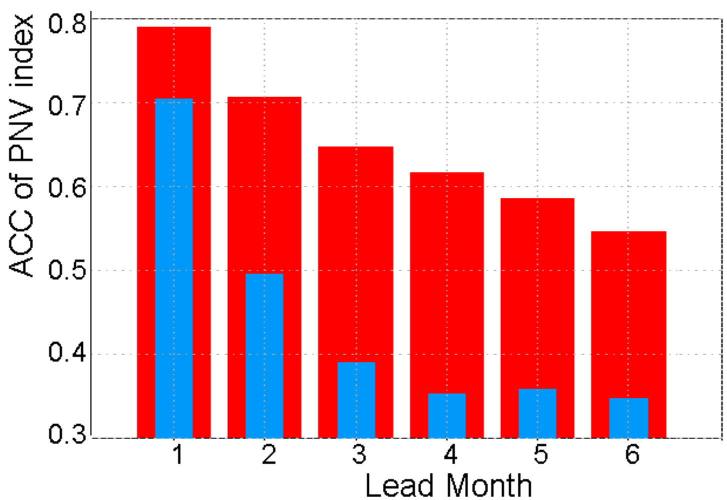
Hindcast Results

NPV: (30°-50°N, 150°-150°W) SSTA

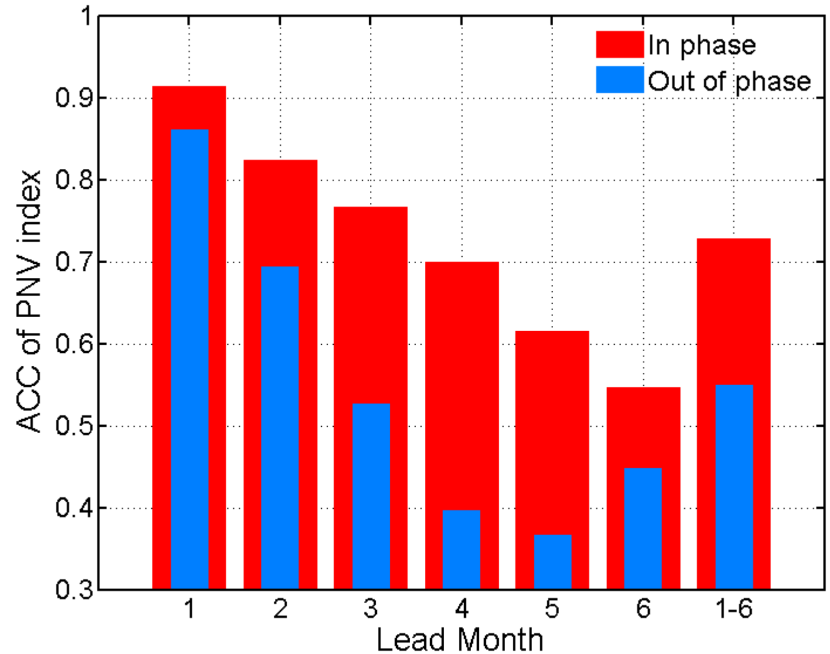
North Pacific Variability (NPV) in or out of phase with ENSO



CFSv2

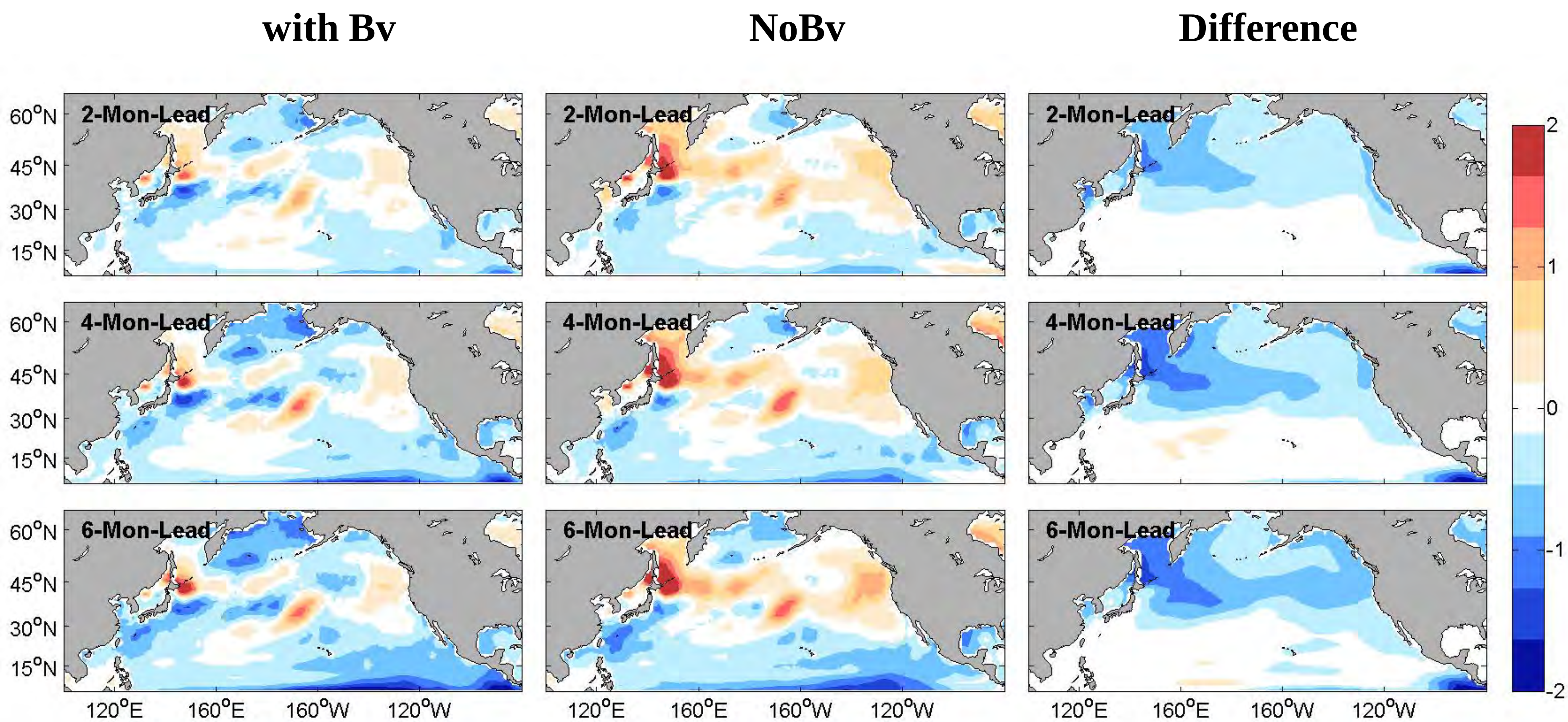


FIO-ESM

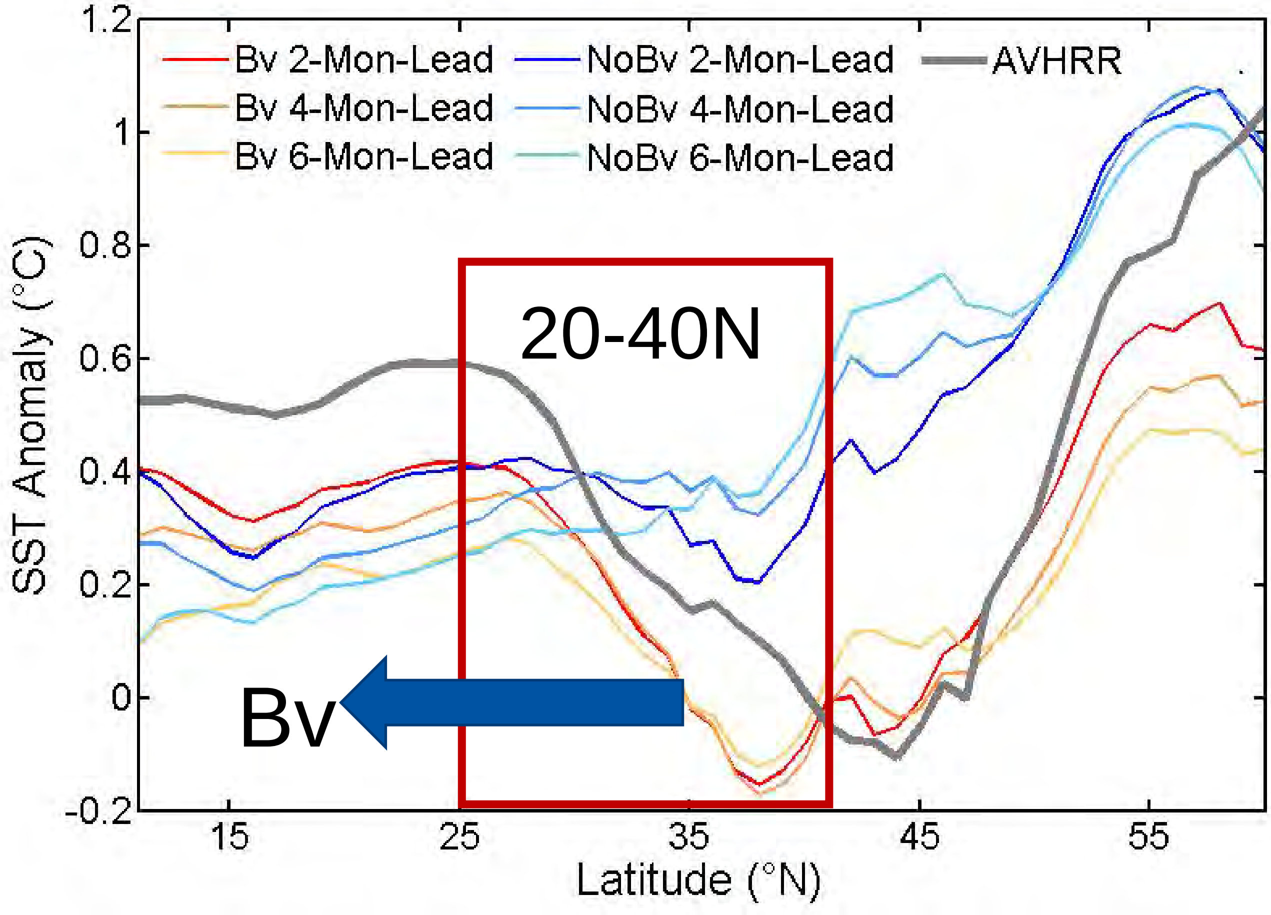


- In phase : ↑ 11.6% ⟶ ENSO teleconnection
- Out of phase : ↑ 23.6% ⟶ local variability

Bv effect: of annual averaged SSTA prediction error (°C)

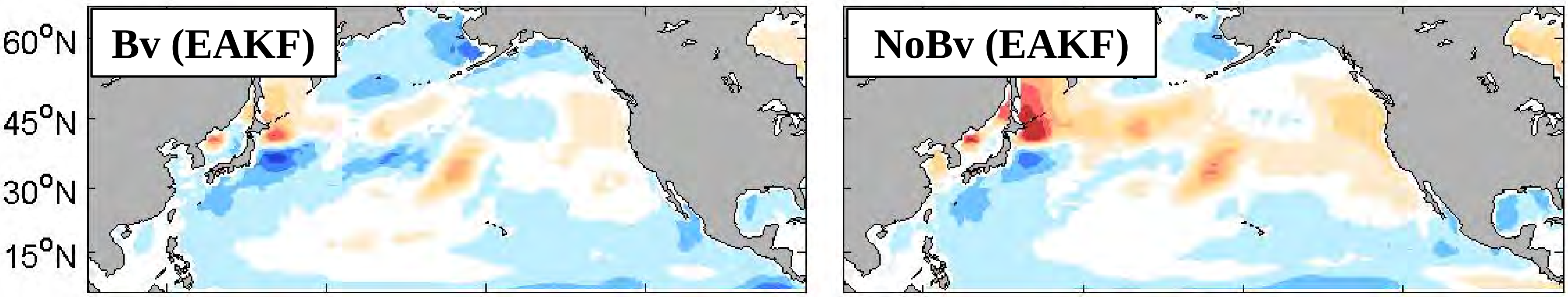


Bv effect: Zonal mean SSTA varies with latitude

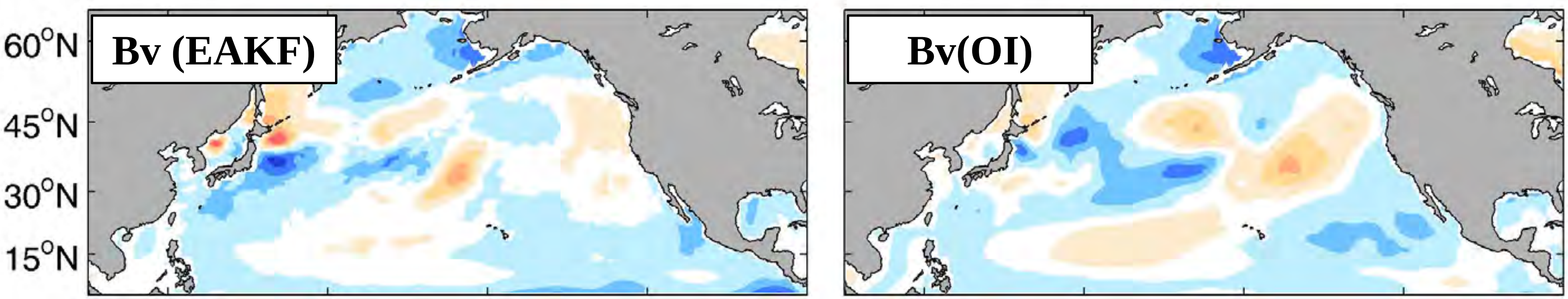


Bv and DA effects cmparison

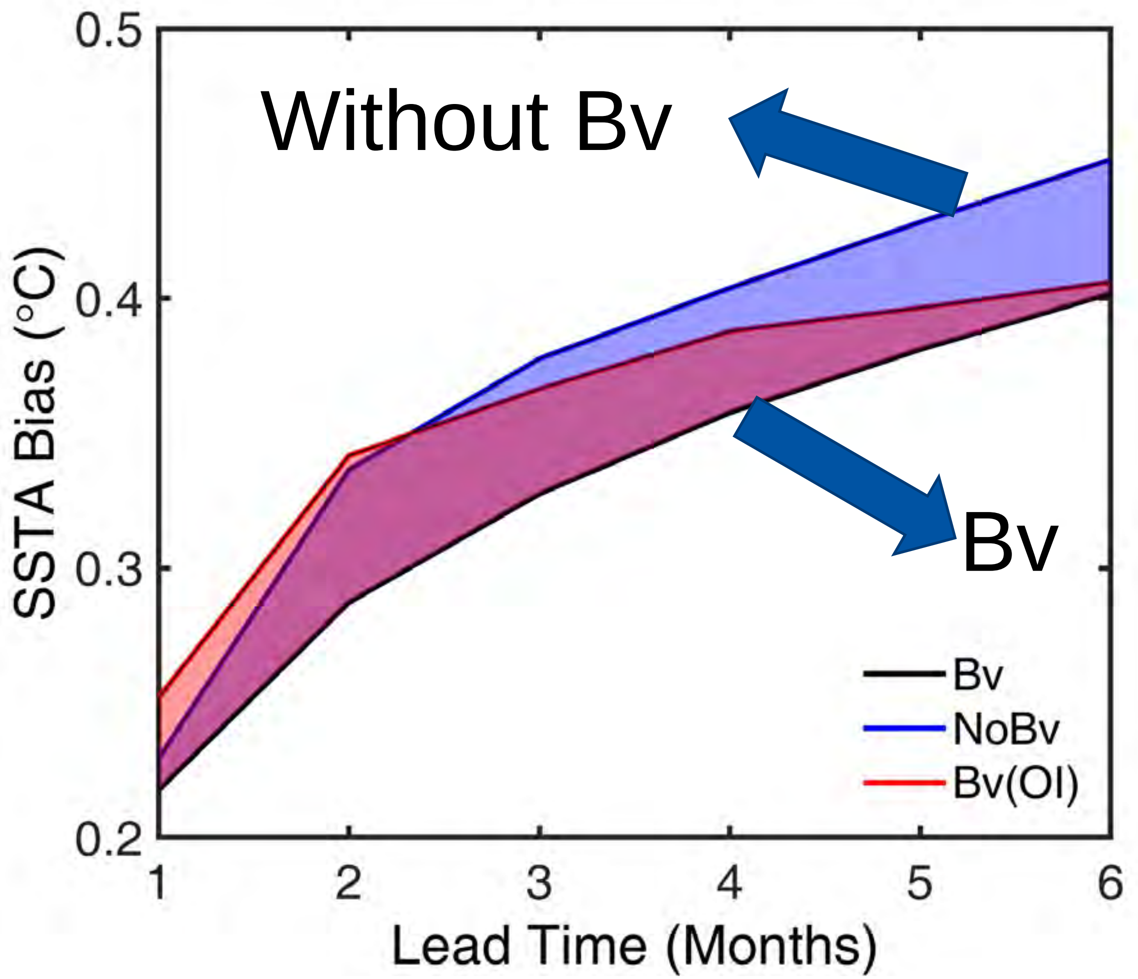
Wave effect



DA effect

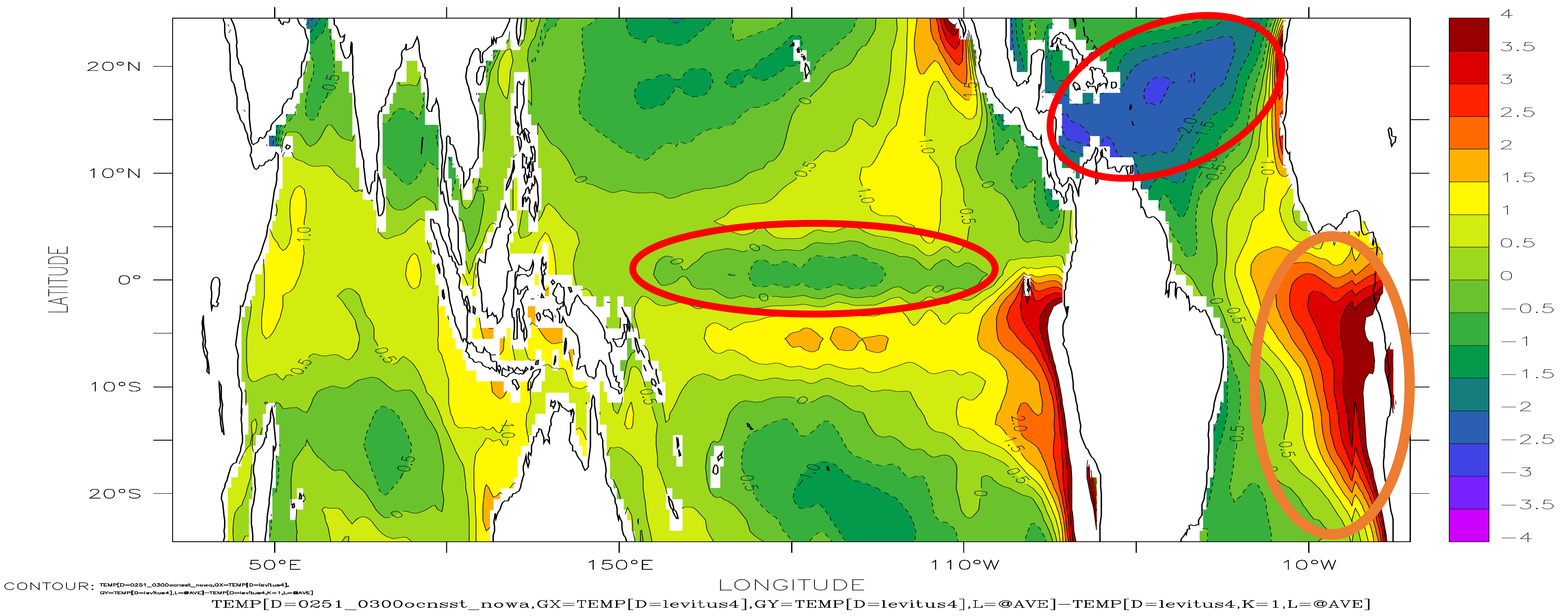


Take 2016 as an example

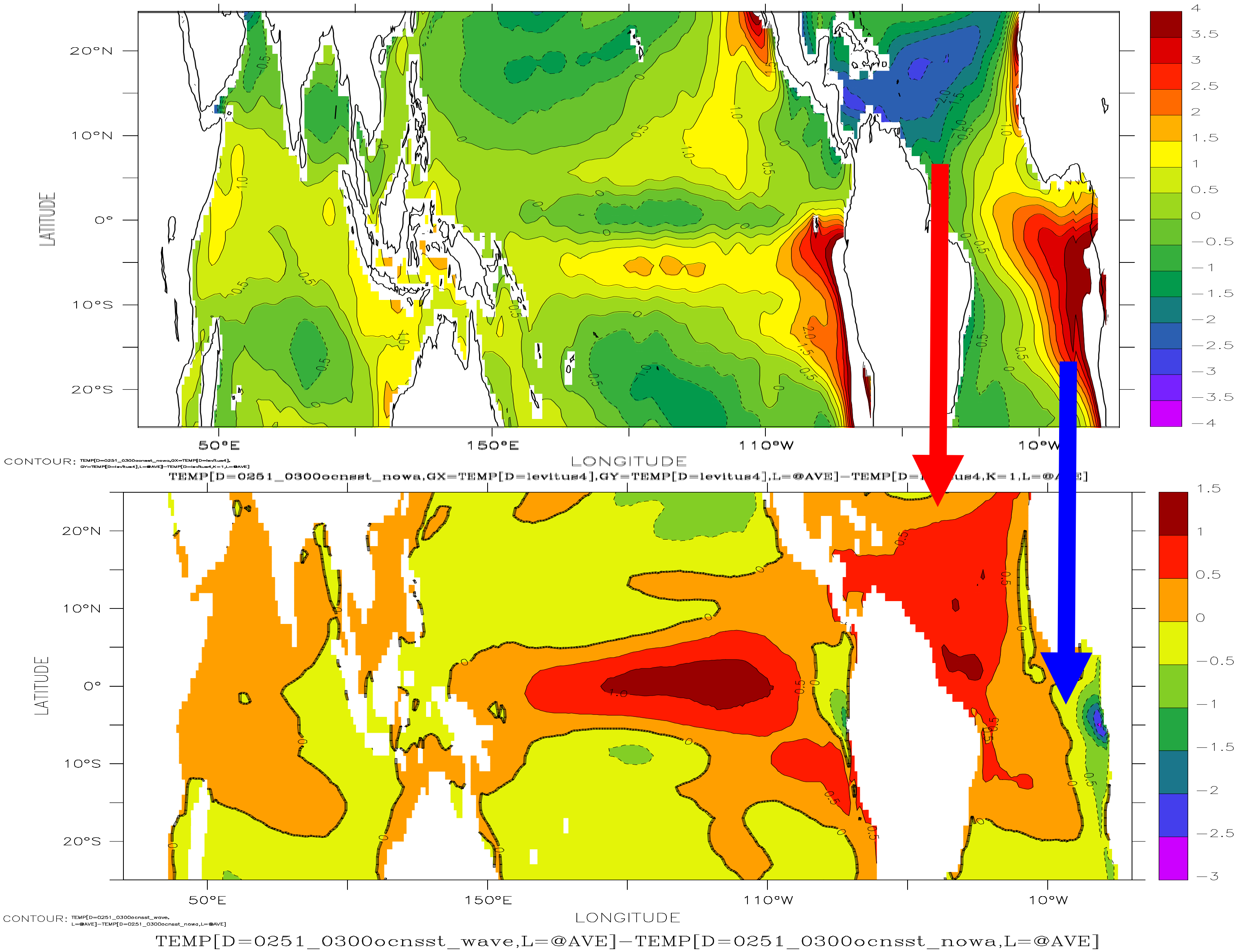


- In phase:FIO-ESM increases 11.6% compared to CFSv2
- In phase: FIO-ESM increases about 10% with to without Bv

Tropical biases: a common problem for all climate models



Song et al, 2012, JGR

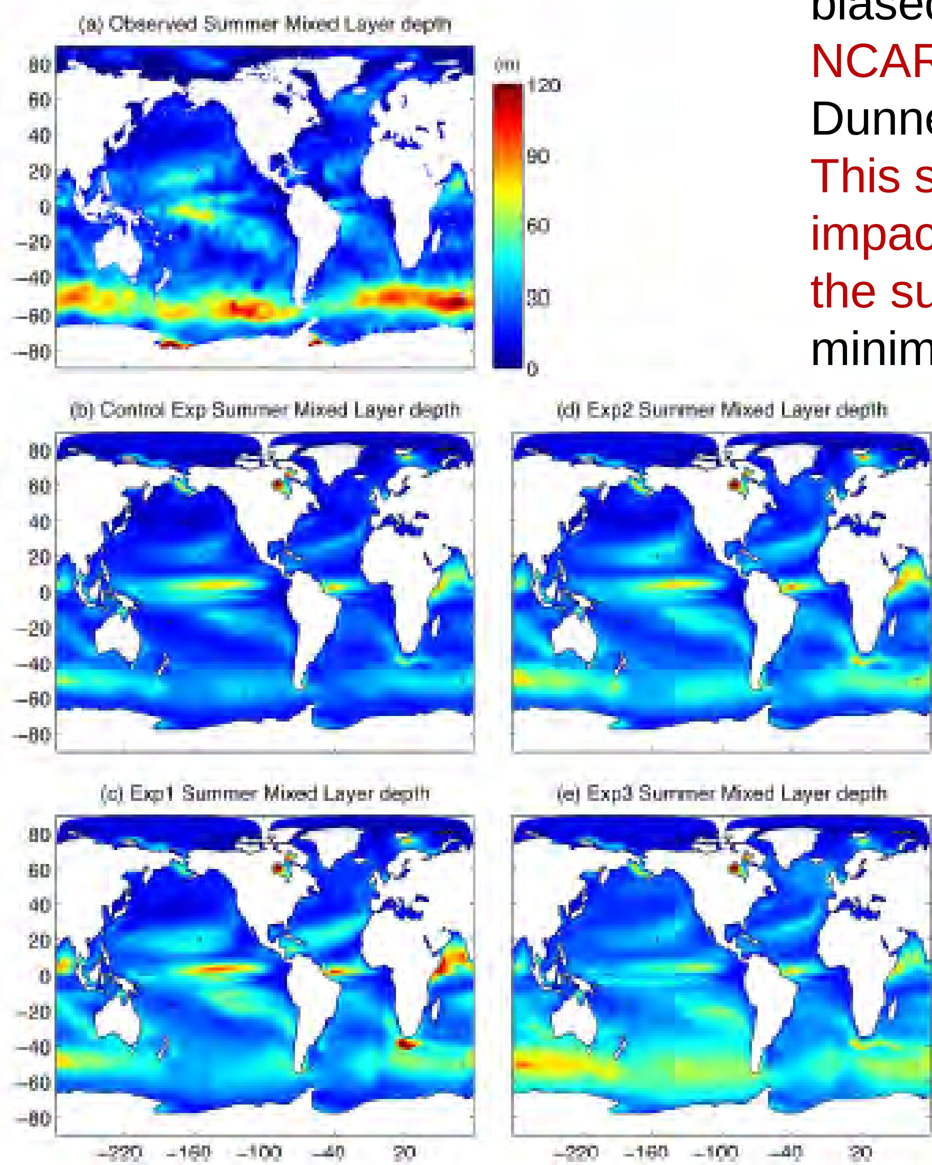


50a averaged SST (251-300a).

Up: Exp1-Levitus, Down: Exp2-Exp1

Exp1: CCSM3 without Bv

Exp2: with Bv



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)

4. Summary

Prediction skill

By including Bv, the climate model of FIO-ESM has good performance in preciting North Pacific SST, especially at mid-latitudes. Prediction skil of FIO-ESM is 17.6% higher than that of CFSv2.

PICES

The PICES has successfully run FUTURE for 10 years. The community has crying demand for accurate seasonal prediction. It should be the time for PICES to start providing operational prediction service.

Thanks