2nd International Symposium, Yeosu, Korea

Bio-physical interaction in the tropical Pacific

ENSO  **Phytoplankton**

Jong-Yeon Park

Jong-Seong Kug

Young-Gyu Park

Korea Ocean Research & Development Institute (KORDI)

Data & Model description

➢ Observational Data

- **Chlorophyll** (measure of upper-ocean phytoplankton)
  : Sea-viewing Wide Field-of-view Sensor (SeaWiFS) : SEP1997~ DEC2007
  : Moderate Resolution Imaging Spectroradiometer (MODIS) : JAN2008~ DEC2009

➢ Model

- **MOM4p1-TOPAZ** : global ocean + ice + biogeochemistry model
- TOPAZ (Tracers in the Ocean with Allometric Zooplankton)
  : Considers 25 tracers (3 phytoplankton groups, organic matter, C, N, P, Si, ...,)
- Forced experiment (1951- 2010)

Realistic Boundary forcing	Climatological forcing
Surface Wind (6hr)	Longwave flux, Specific humidity, Surface temp., Shortwave flux,

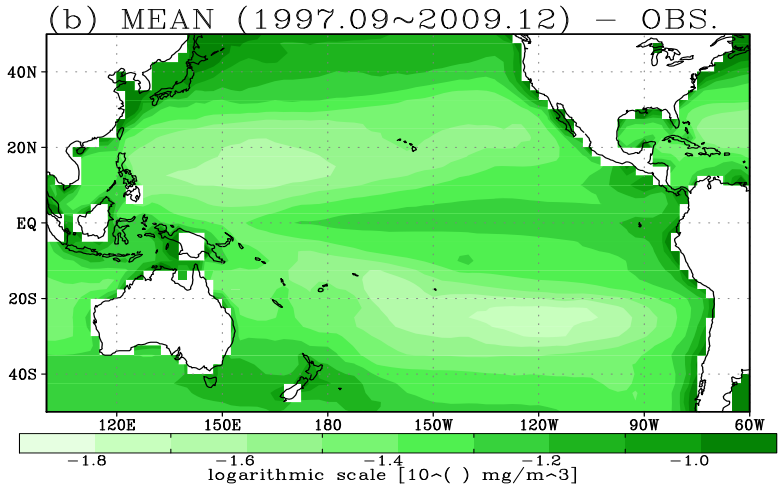
- Shortwave penetration (Manizza et al., 2005)

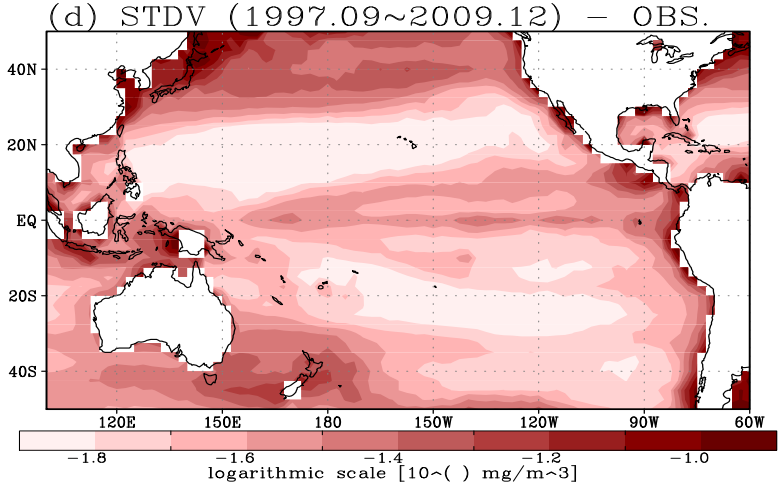
: $I(z) = I(0) * (F_{red} * \exp(-k_{red} z) + F_{blue} * \exp(-k_{blue} z) + F_{IR} * \exp(-k_{IR} z))$

[Attenuation coeff. : $k_{(\lambda)} = k_{sw(\lambda)\_pure} + \chi_{(\lambda)} \cdot Chl^{a(\lambda)}$]

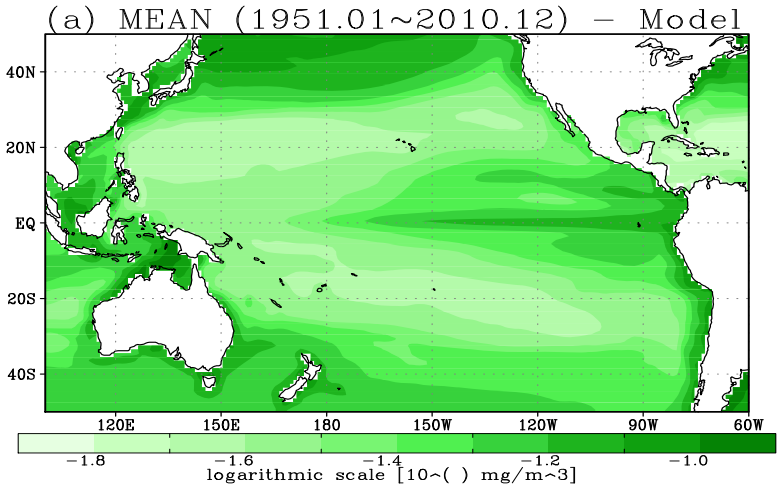
Model Performance

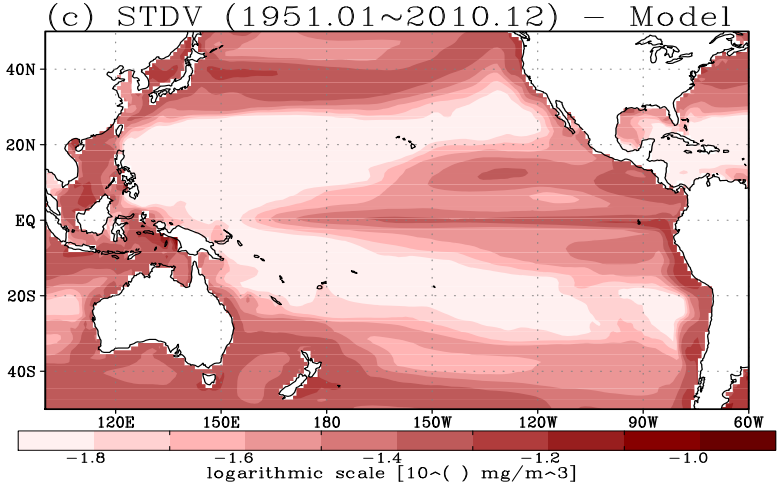
Obs. (SeaWiFS+MODIS)



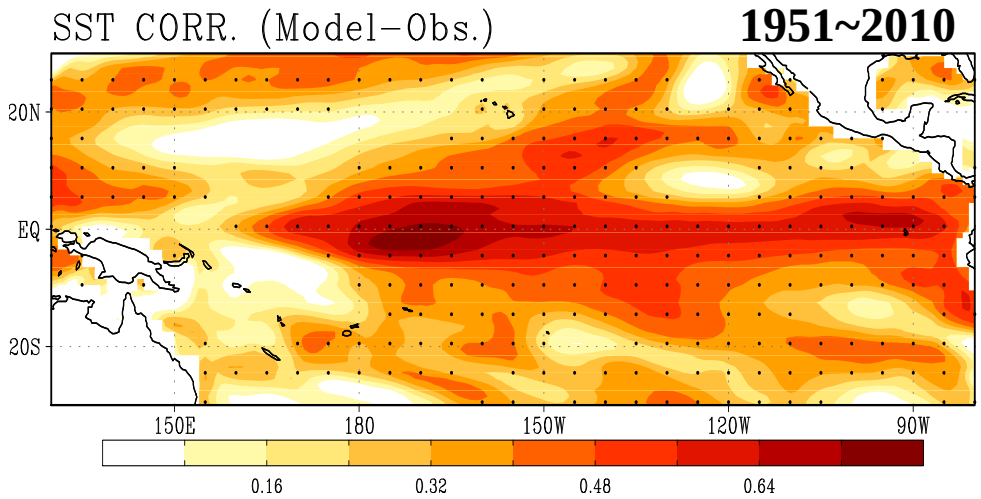


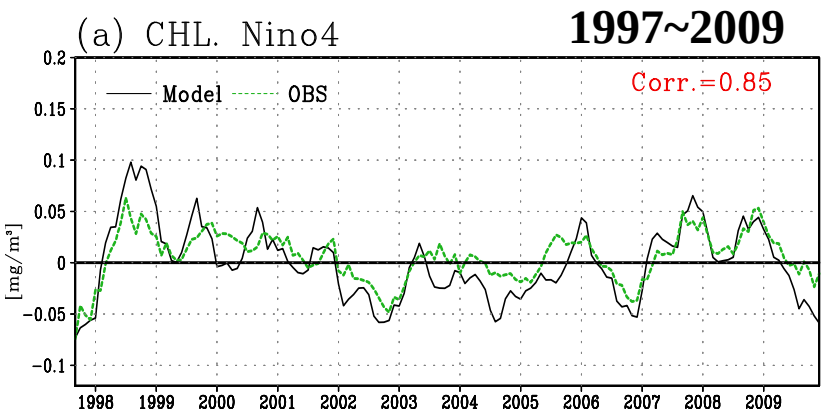
Model

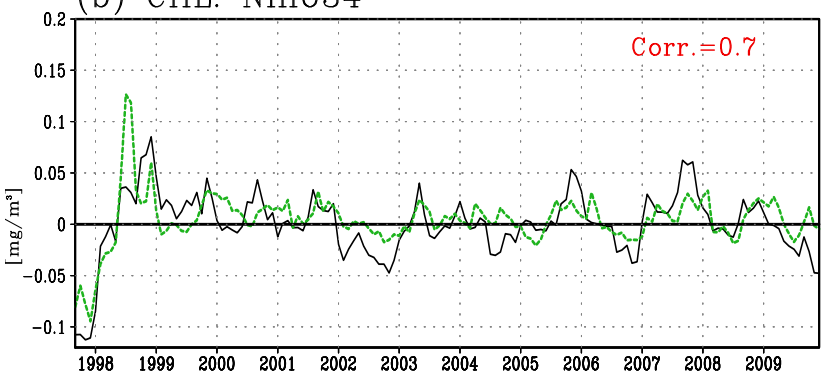


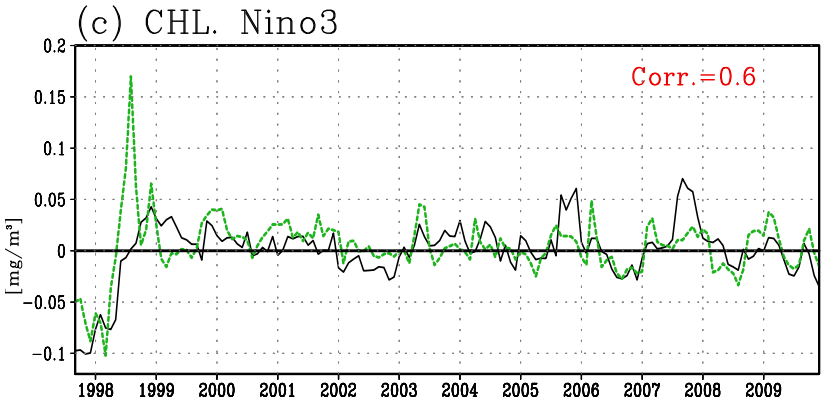


Model Performance



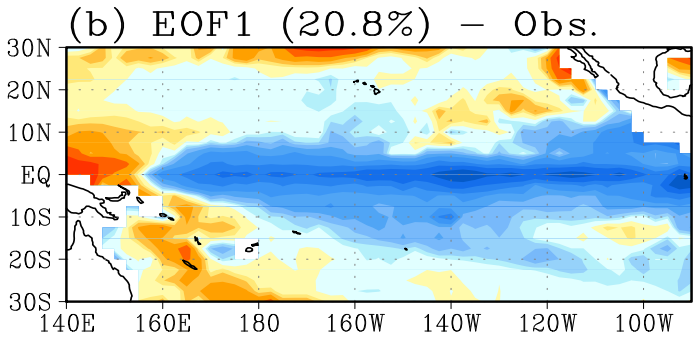


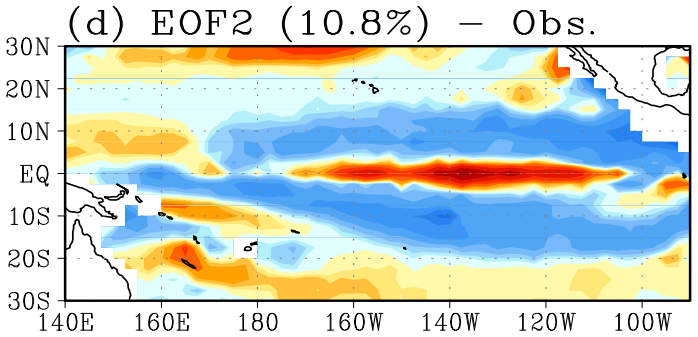


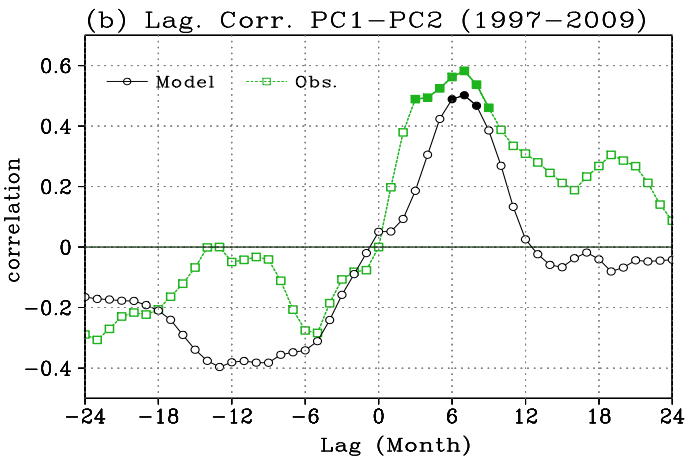


ENSO-related variability

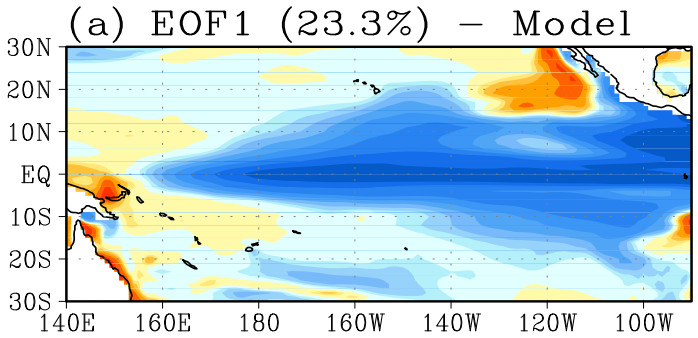
Obs. (1997~2009)

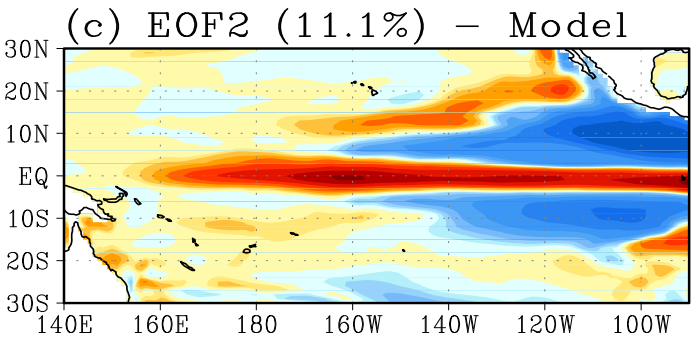


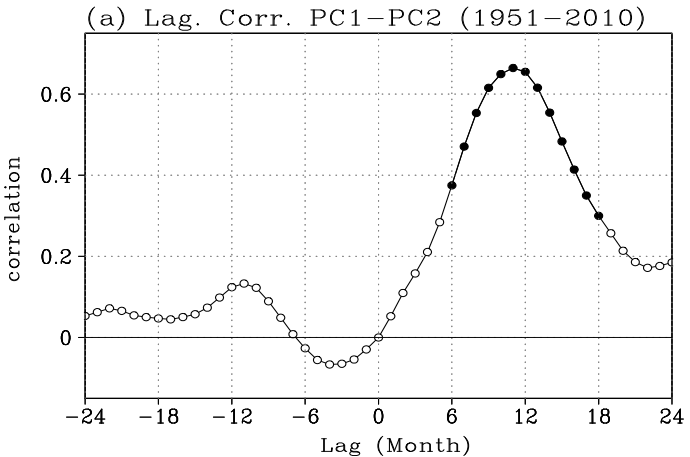




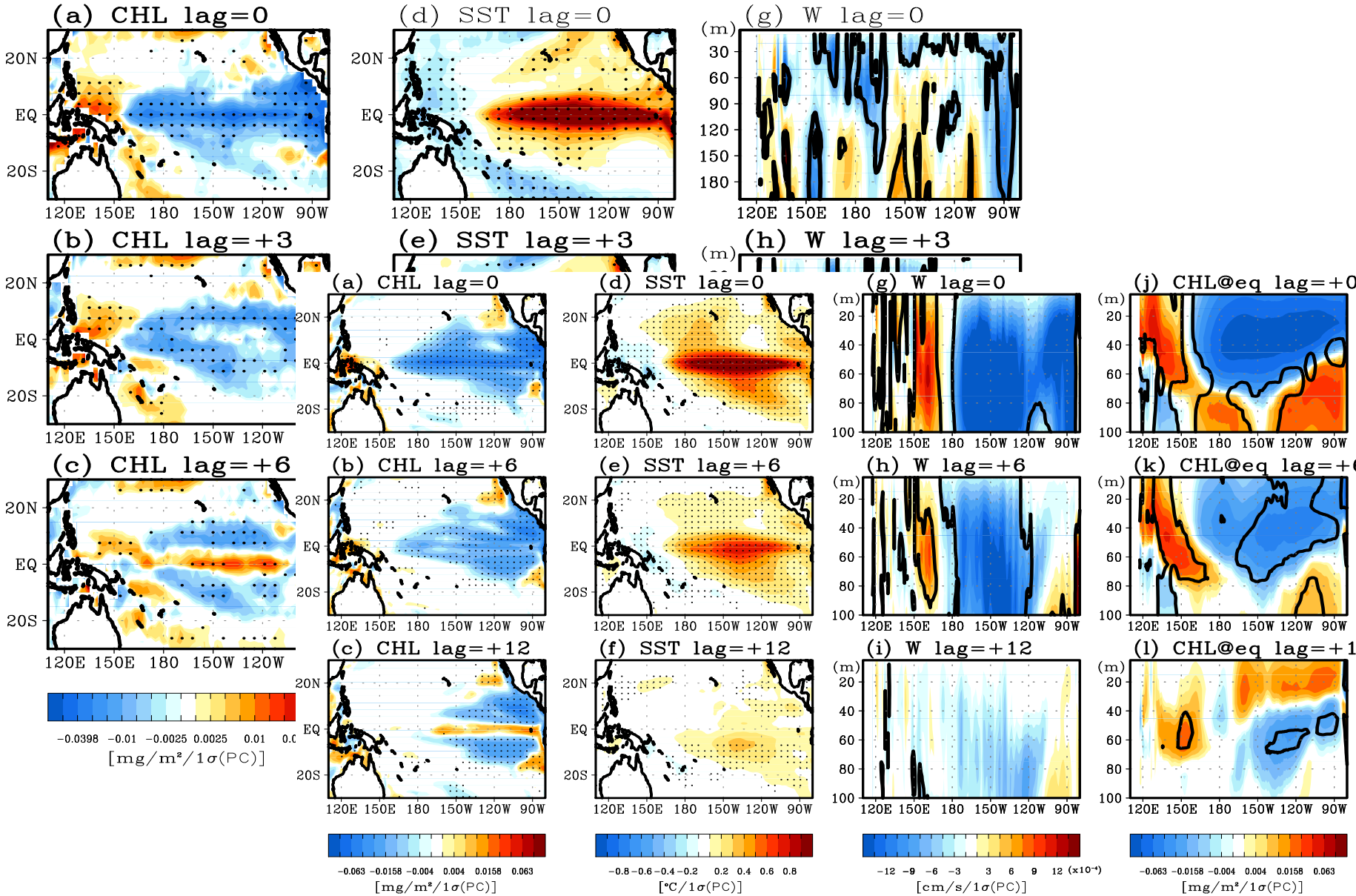
Model (1951~2010)







ENSO-related variability



Biological Feedback

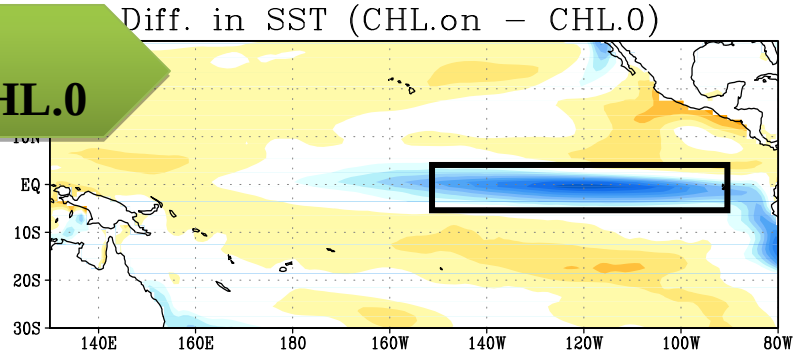
- Experimental Design

Mom4p1
(Hindcast run: 1951-2010)

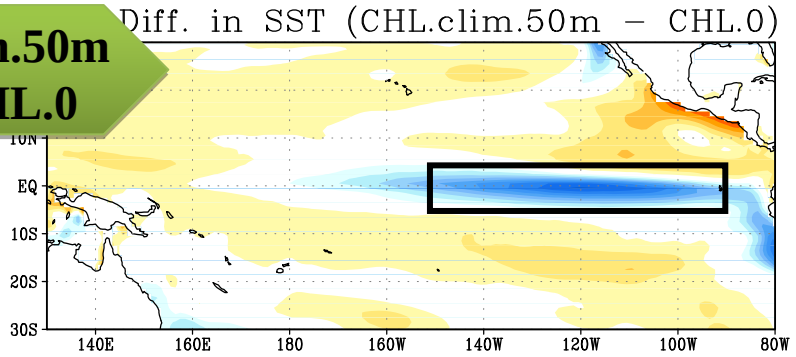
Exp. 1	Exp. 2	Exp. 3, 4, 5, 6
CHL_on	CHL_0	CHL_clim (sfc, ~30m, ~50m, ~100m) Higher CHL climatology !
TOPAZ_ON	TOPAZ_off (Zero CHL)	TOPAZ_off (climatol. CHL)

Biological Feedback - Mean

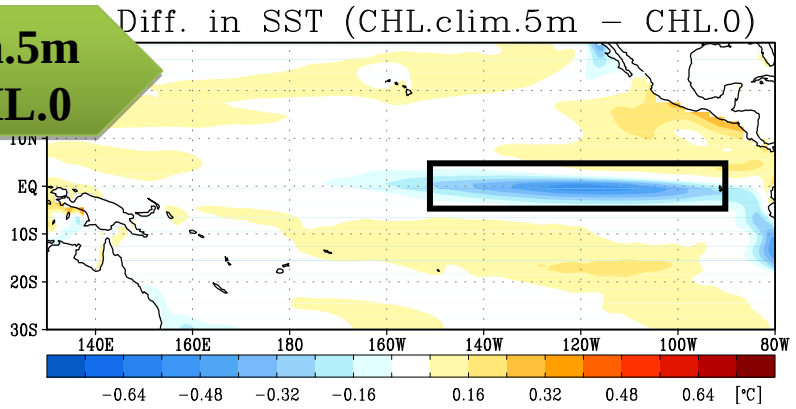
CHL.on – CHL.0

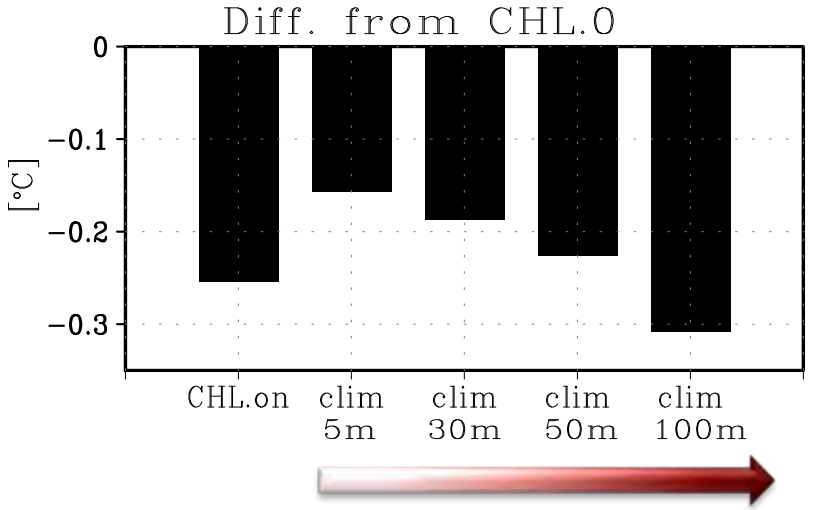


CHL.clim.50m – CHL.0



CHL.clim.5m – CHL.0

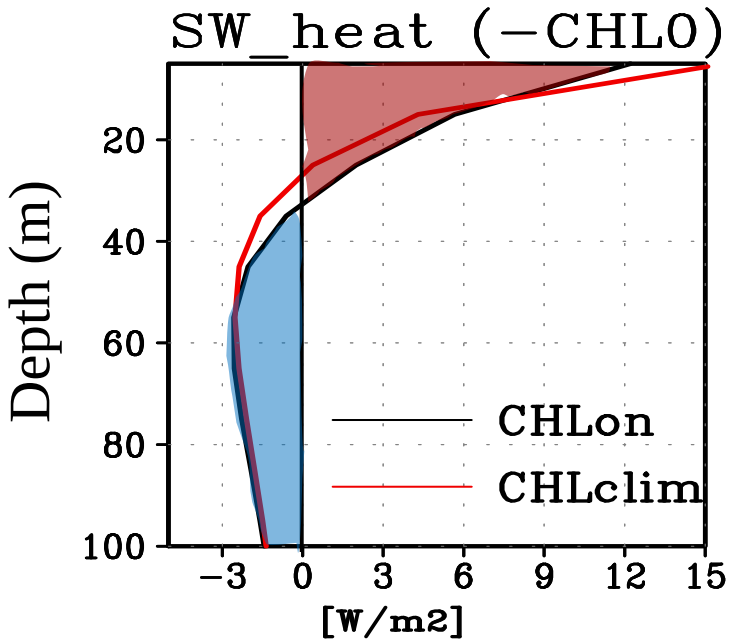


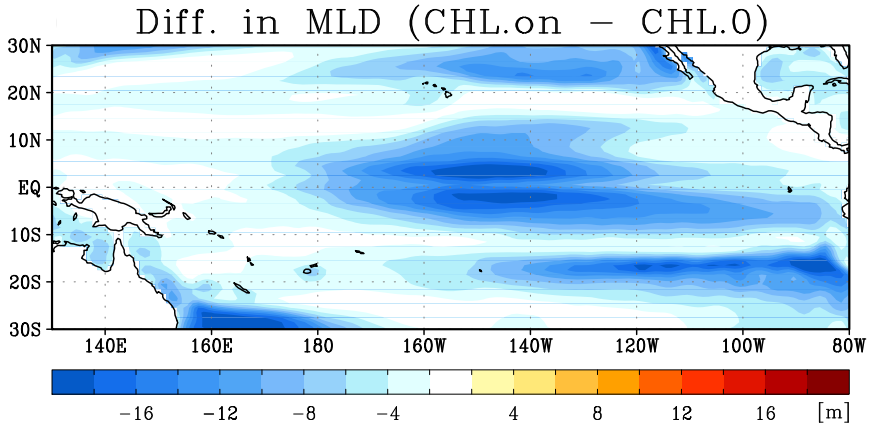


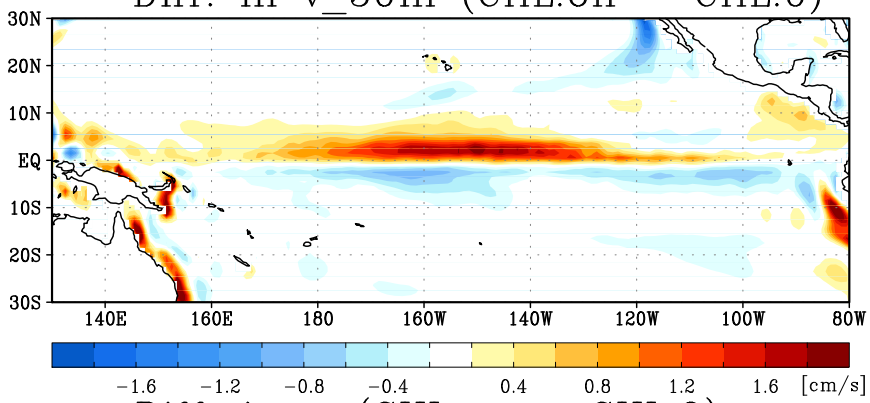
Higher CHL climatology !

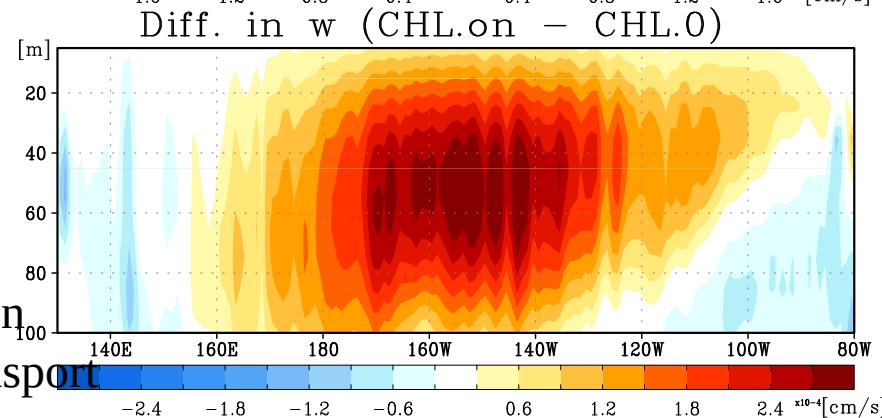
Biological Feedback - Mean

- **Mean Difference**
  : "CHL_on" - "CHL_0"









$$f \cdot [v]_{mix} = \int_{MLD}^{sfc} -\frac{1}{\rho_0}\frac{\partial p}{\partial x}\,dz + \frac{\tau_x}{\rho_0}$$

Merdional transport

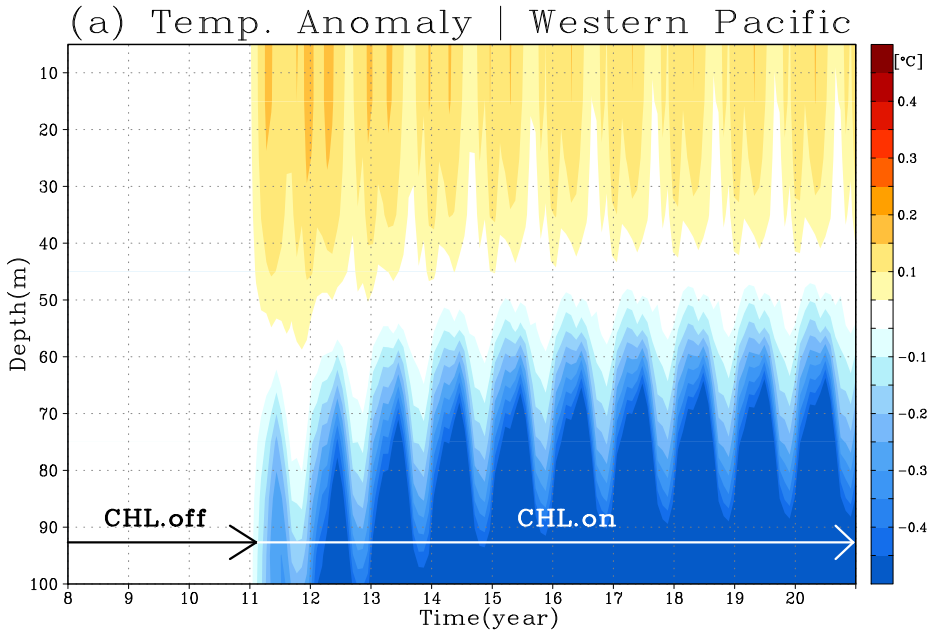
Geostrophic balanced flow

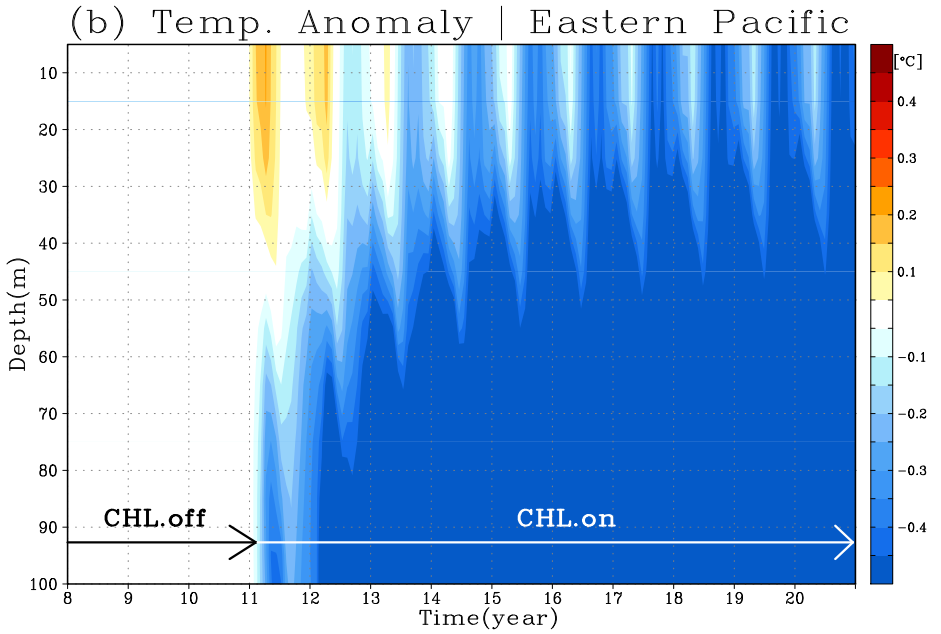
Wind-driven Ekman transport

Biological Feedback

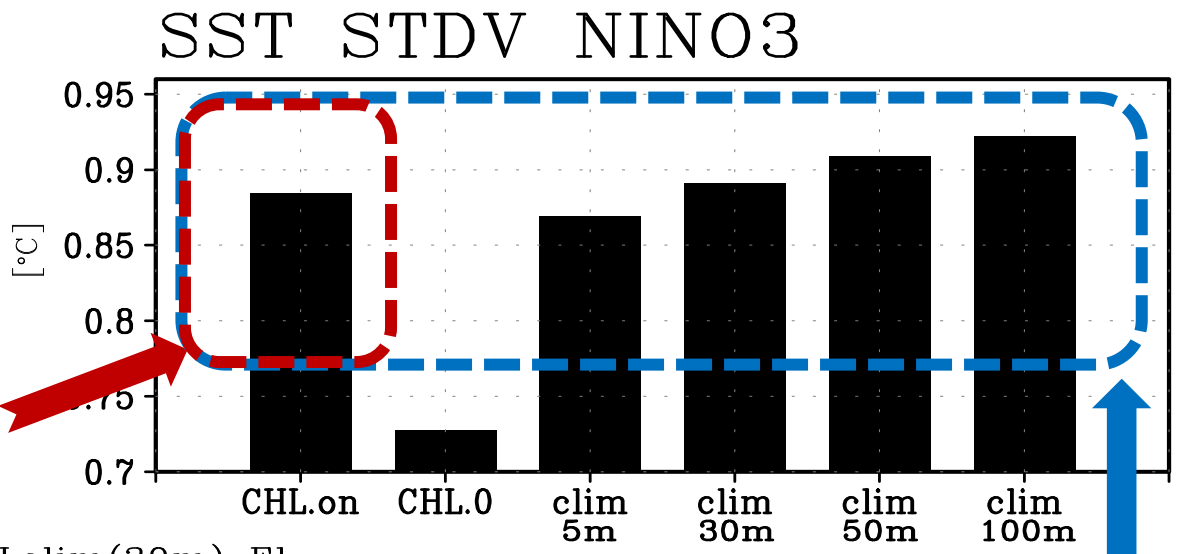
- **Test experiment**

  : "CHL.off" followed by "CHL.on"

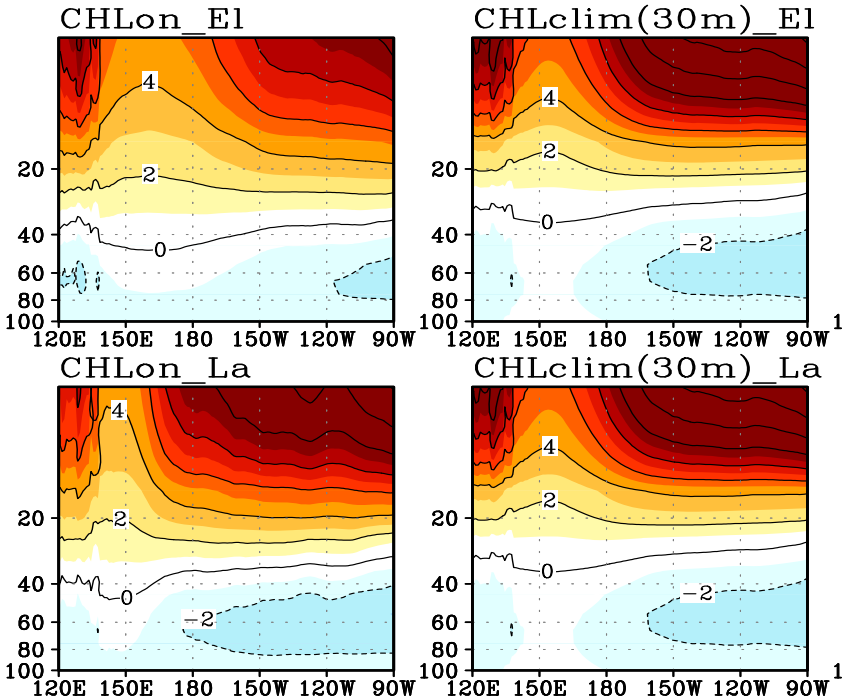




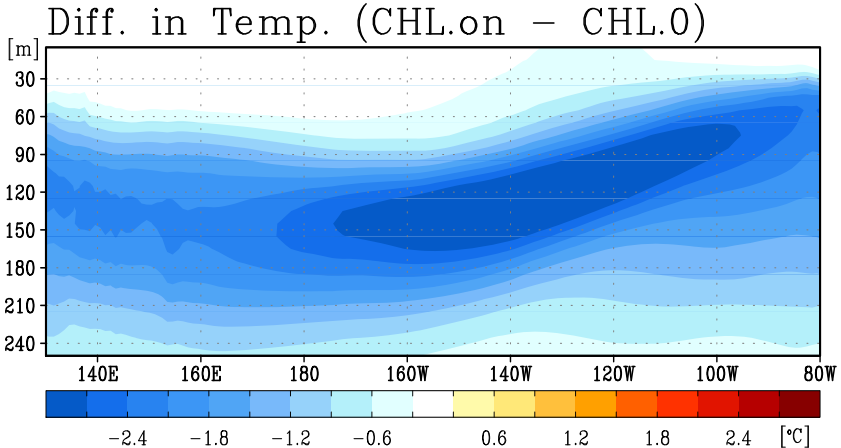
Biological Feedback - STDV



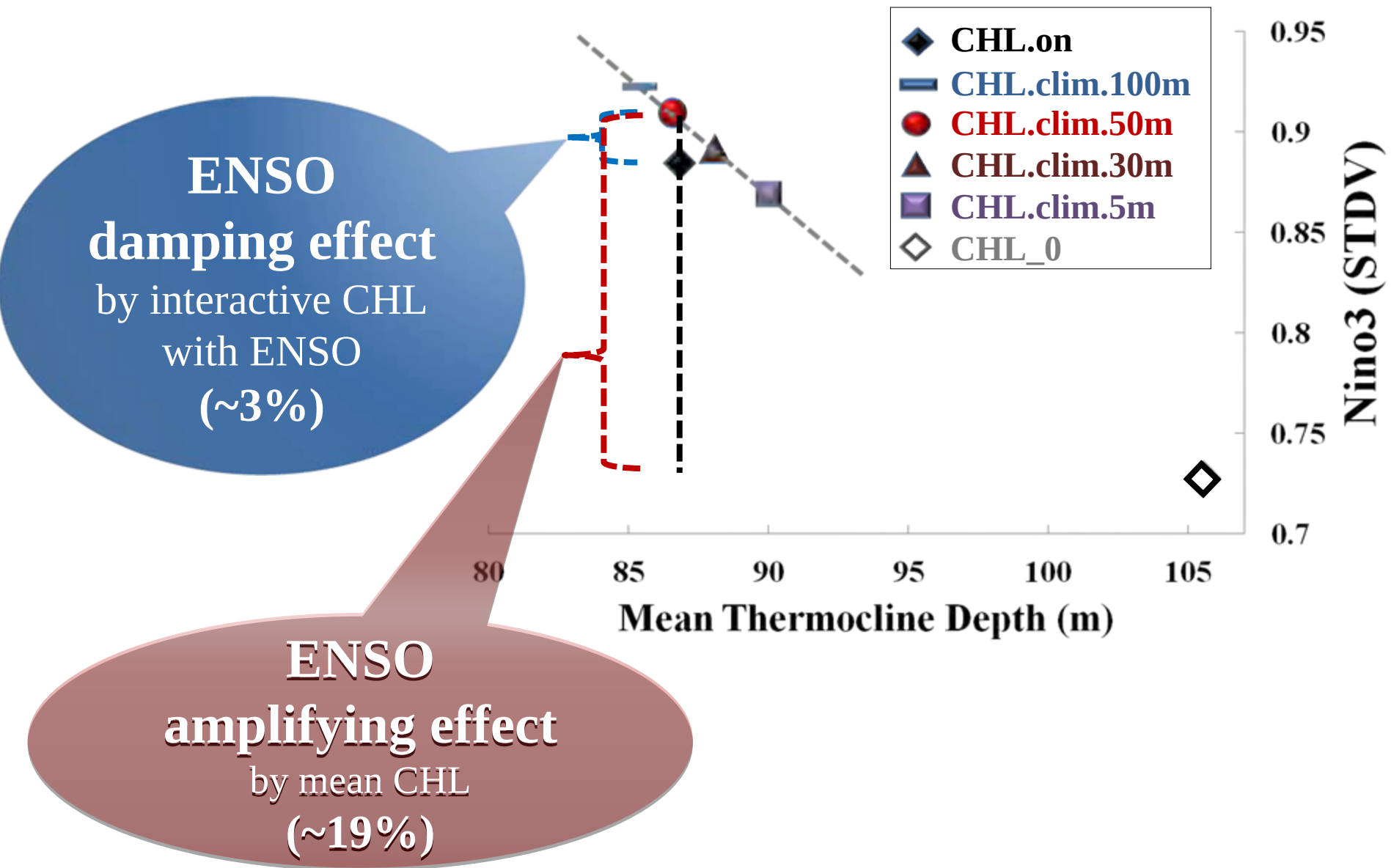
"ENSO damping effect by Interactive CHL "



"ENSO amplifying effect by shaoled thermocline depth"



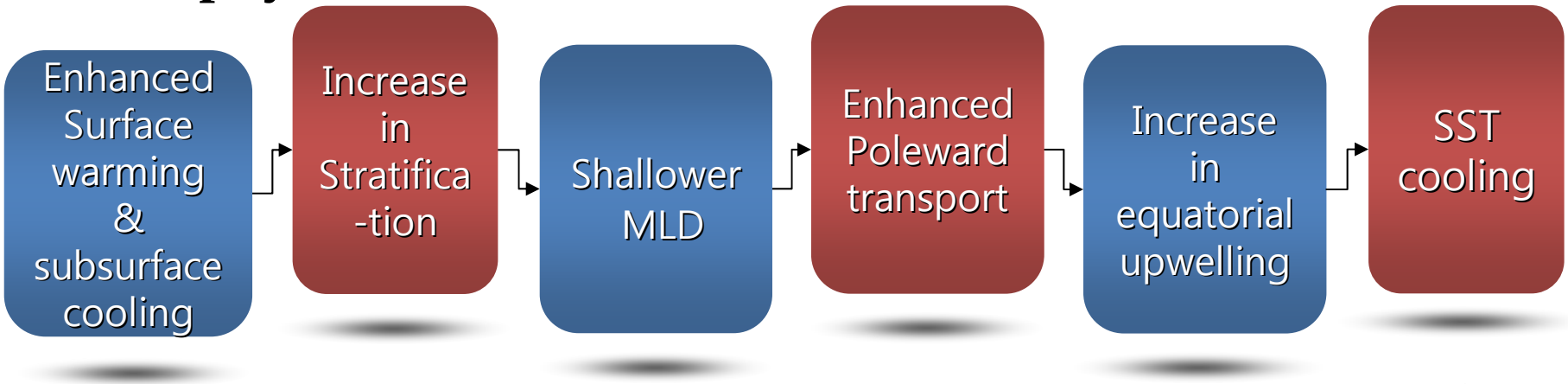
Biological Feedback - STDV



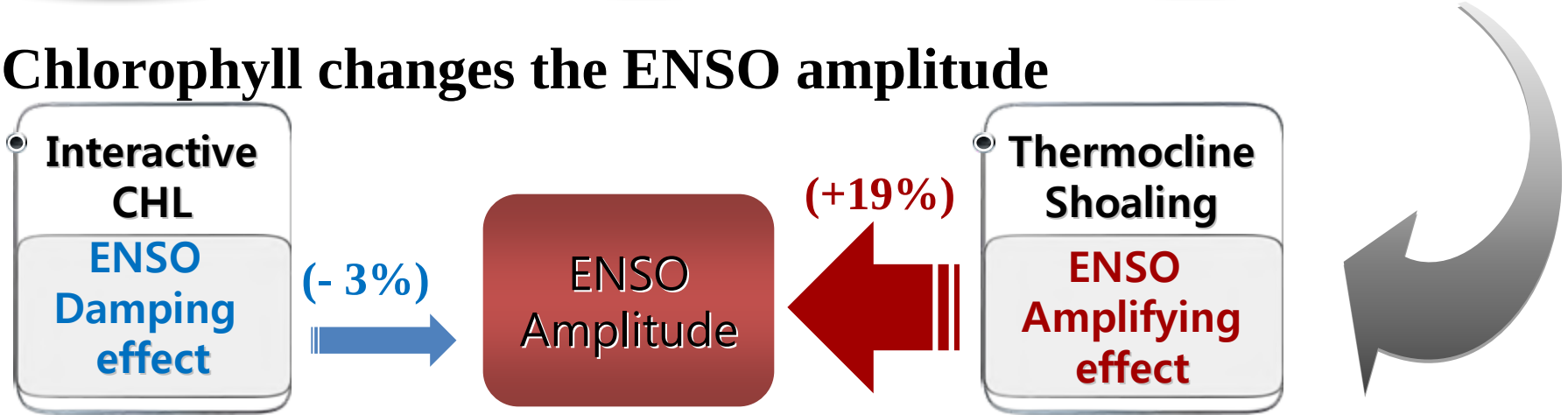
Summary

- **Major modes of chlorophyll** are associated with the **mature phase** and the **transition phase of El-Niño. ➔ Confirmed by Model!**

- **Chlorophyll modifies the mean state**

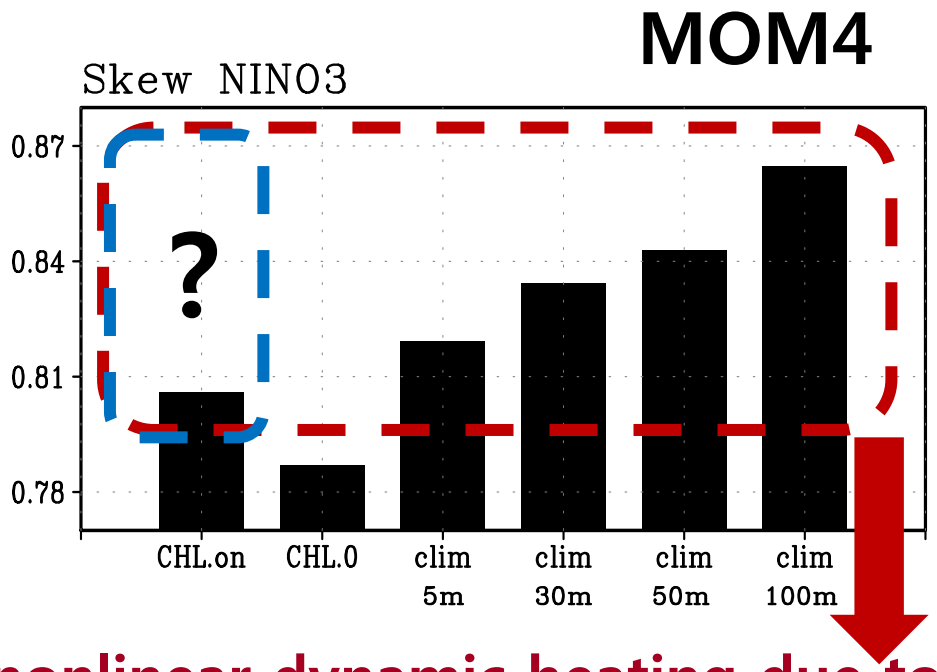


- **Chlorophyll changes the ENSO amplitude**

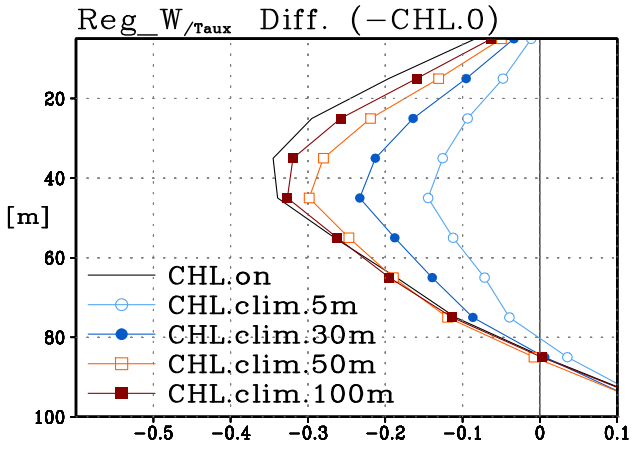


Thank you.

CHL impact on ENSO skewness



"Intensified nonlinear dynamic heating due to more sensitive upwelling response to the same wind"



Biologically-induced shallower MLD

$$\left(-w' \frac{\partial T'}{\partial z}\right) : + \rightarrow +$$

Model experiments

MOM4p1-TOPAZ

Ocean + Biogeochem.

CHL_on	**Simulated** Chlorophyll
CHL_0	**Prescribed** **Zero** Chlorophyll
CHL_clim	**Prescribed** **Climatological** Chlorophyll **(30m)**

Forced experiment by surface wind (1951- 2010)

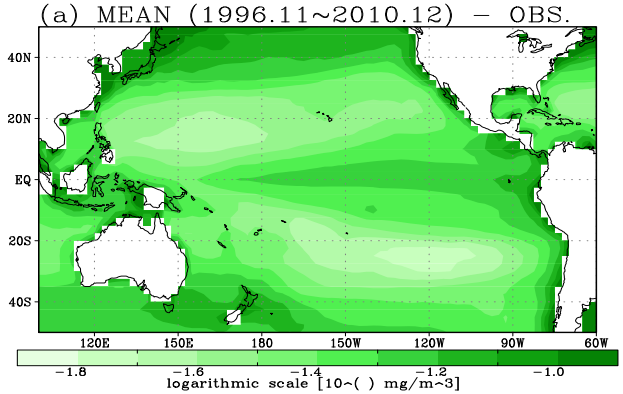
CM2.1-TOPAZ

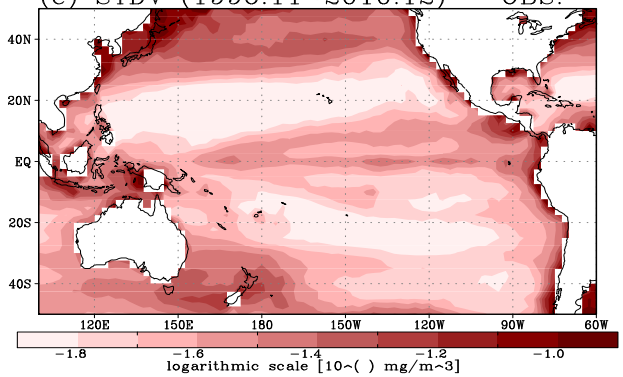
Ocean + Atmos. + Biogeochem.

CHL_on	**Simulated** Chlorophyll
CHL_0	**Prescribed** **Zero** Chlorophyll
CHL_clim	**Prescribed** **Climatological** Chlorophyll **(30m**

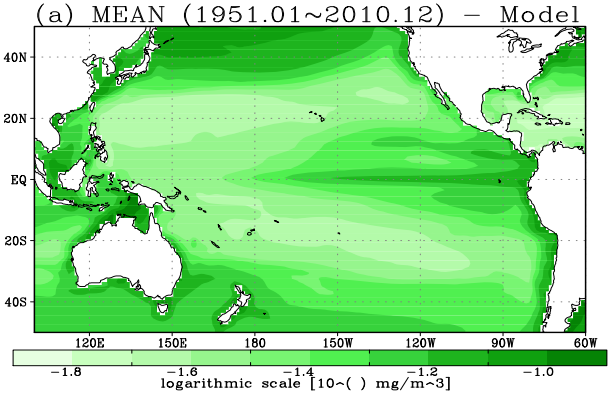
Model Performance

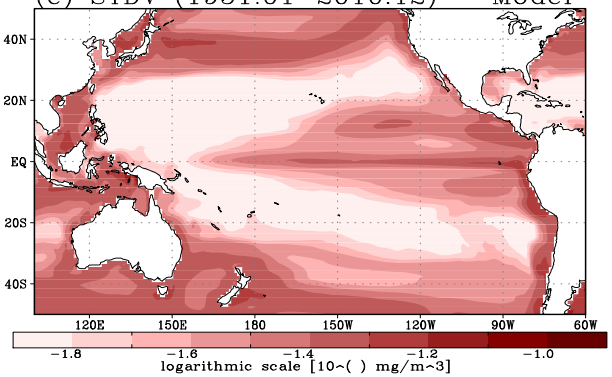
OBS



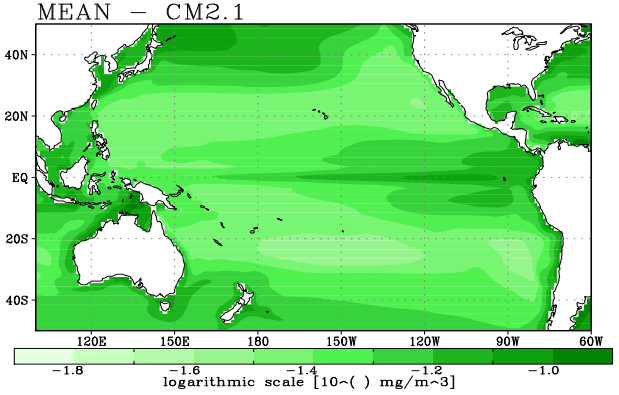


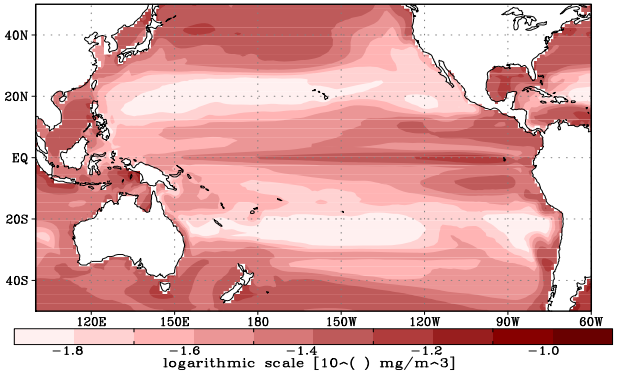
MOM4





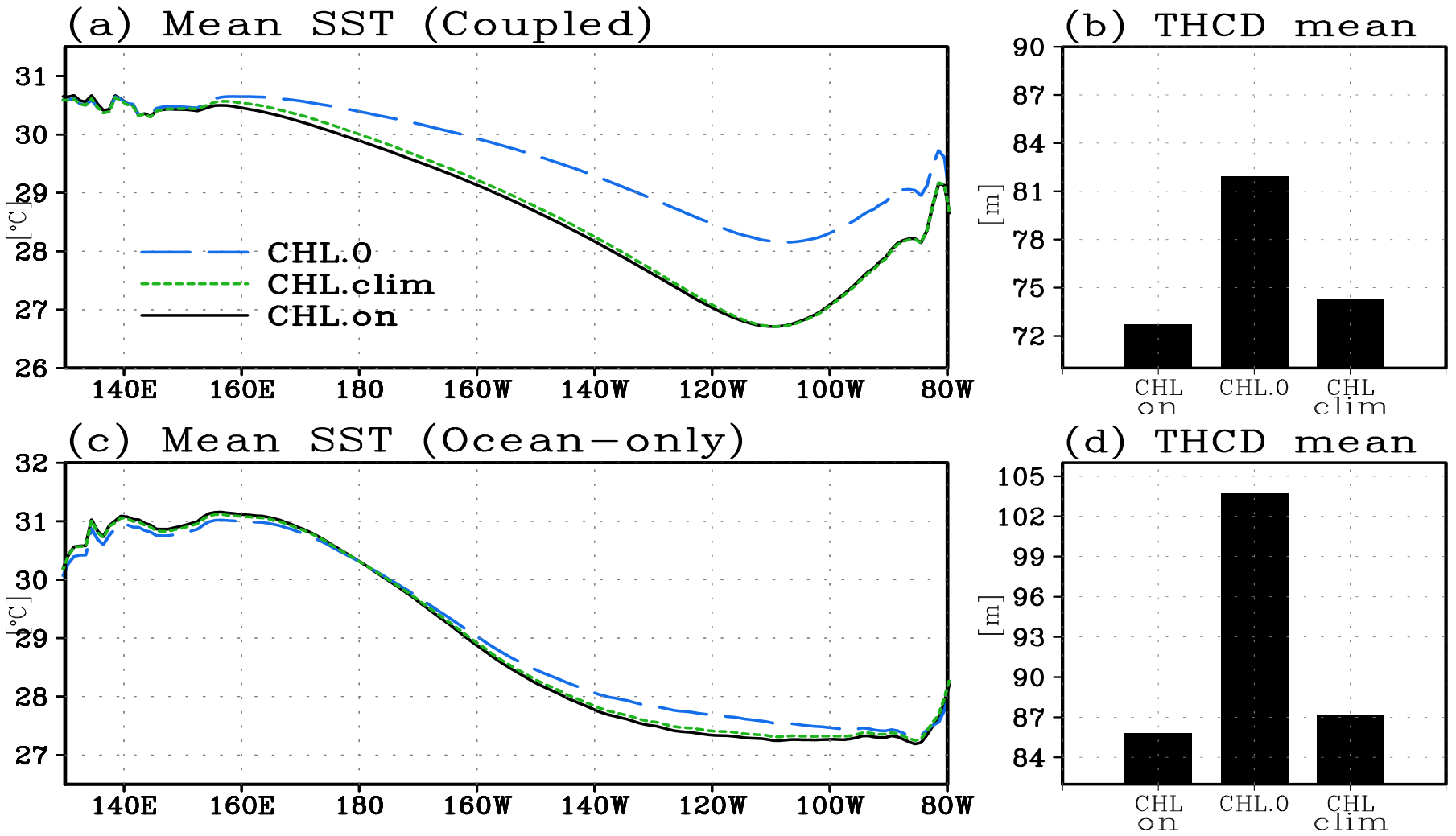
CM2.1





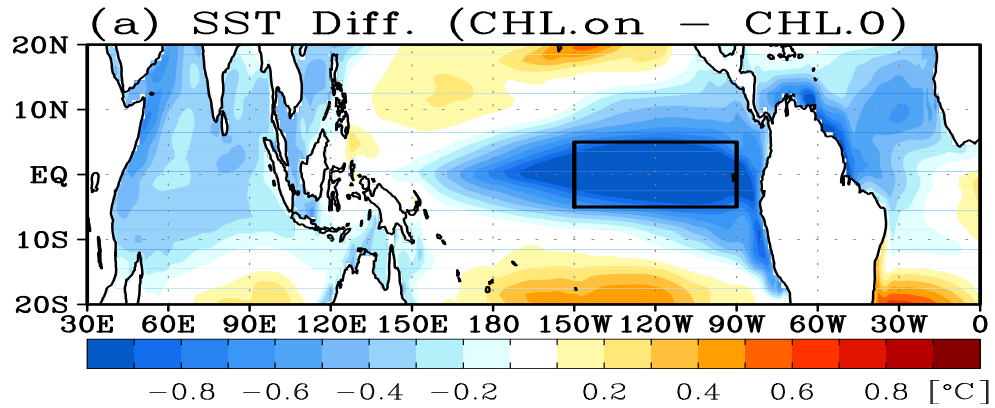
Sea-viewing Wide Field-of-view Sensor (SeaWiFS) : SEP1997~ DEC2007

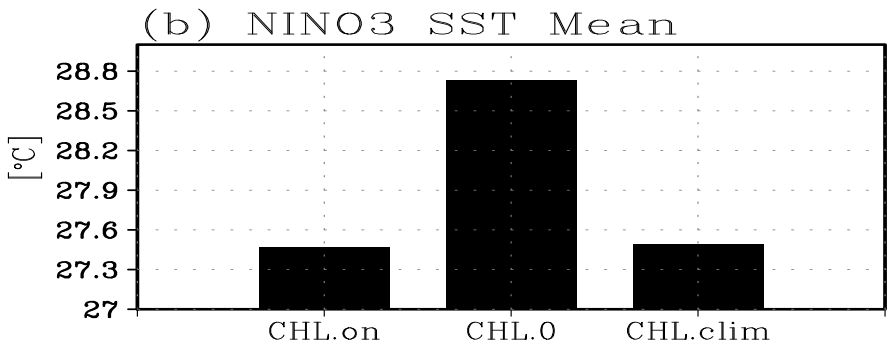
Moderate Resolution Imaging Spectroradiometer (MODIS) : JAN2008~ DEC2010

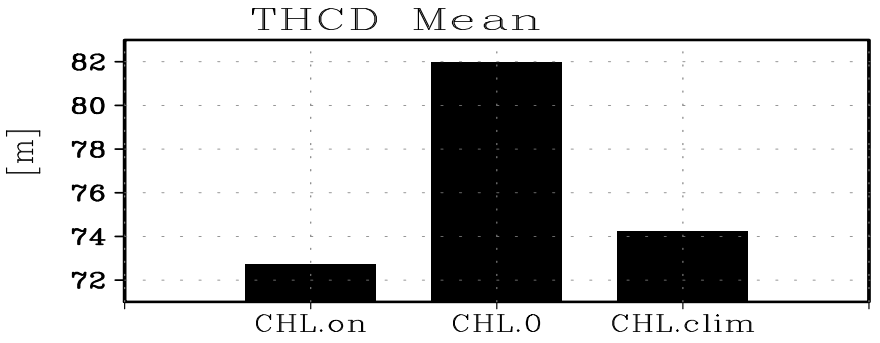

(a) Mean SST (Coupled)
[°C]
31
30
29
28
27
26
CHL.0
CHL.clim
CHL.on
140E
160E
180
160W
140W
120W
100W
80W
(b) THCD mean
[m]
90
87
84
81
78
75
72
CHL on
CHL.0
CHL clim
(c) Mean SST (Ocean−only)
[°C]
32
31
30
29
28
27
140E
160E
180
160W
140W
120W
100W
80W
(d) THCD mean
[m]
105
102
99
96
93
90
87
84
CHL on
CHL.0
CHL clim

CHL impact on Mean state

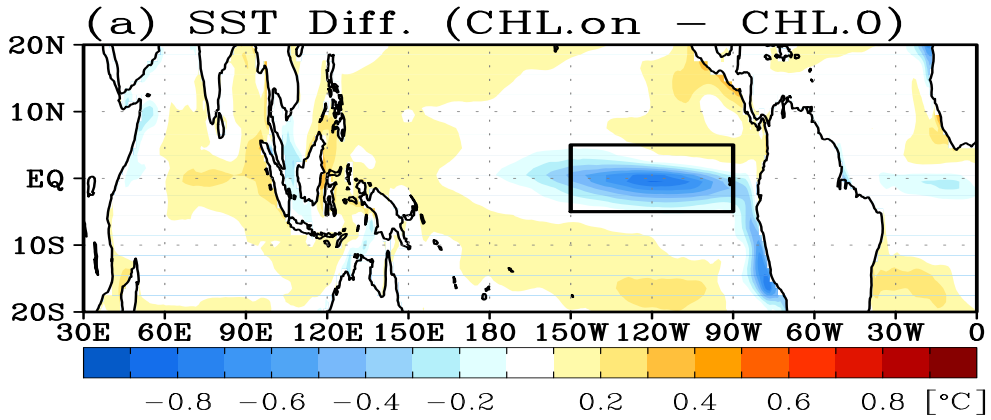
CM2.1

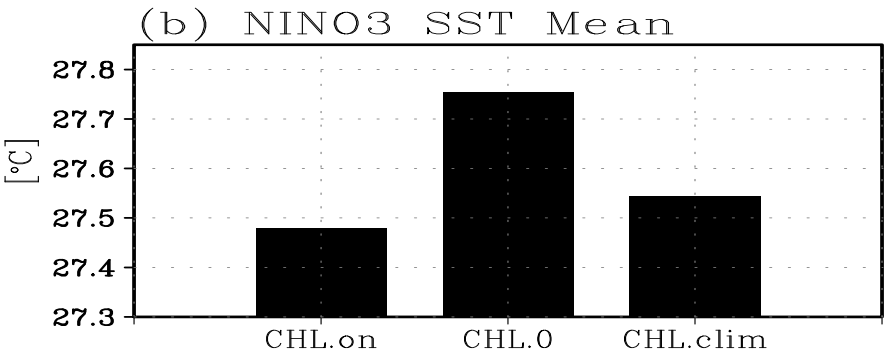




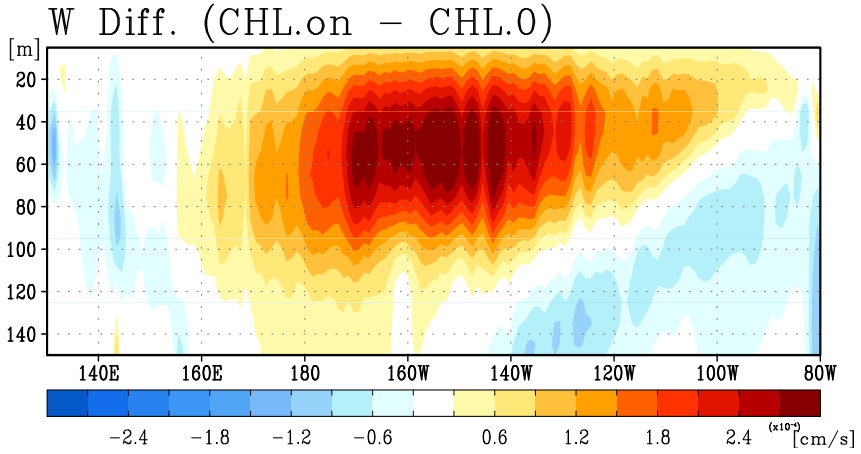


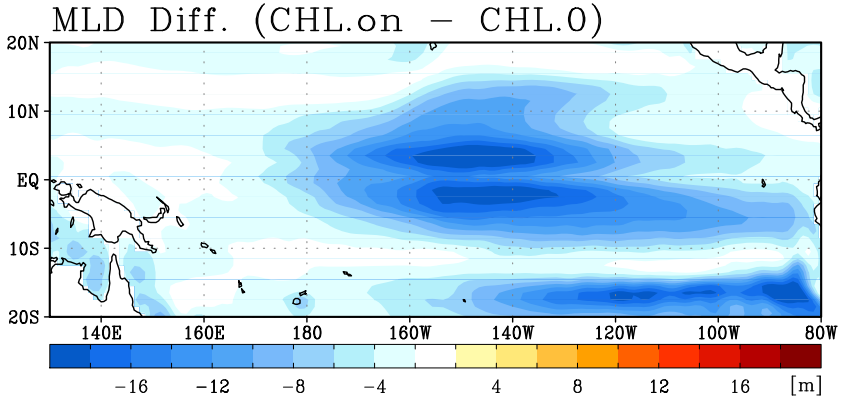
MOM4



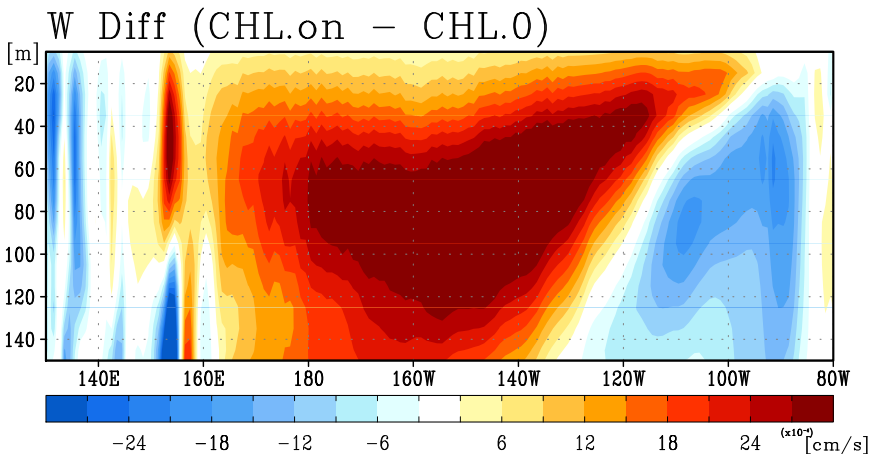


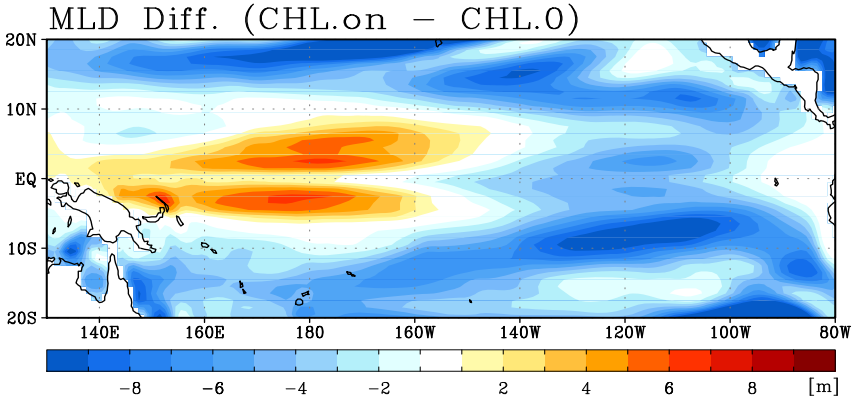
MOM4

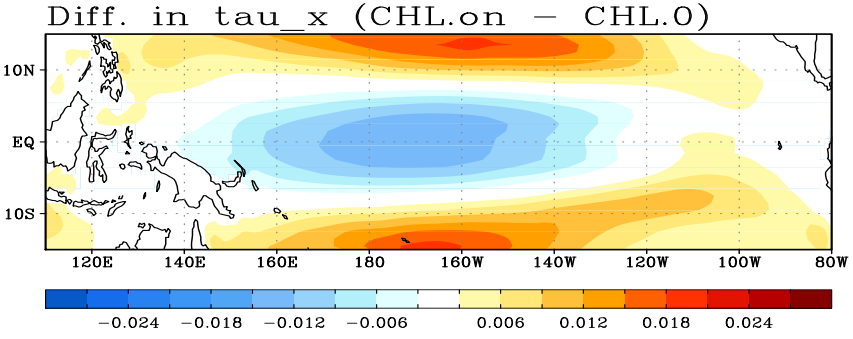

W Diff. (CHL.on – CHL.0)
[m]
20
40
60
80
100
120
140
140E
160E
180
160W
140W
120W
100W
80W
−2.4
−1.8
−1.2
−0.6
0.6
1.2
1.8
2.4
(x10⁻²)
[cm/s]


MLD Diff. (CHL.on – CHL.0)
20N
10N
EQ
10S
20S
140E
160E
180
160W
140W
120W
100W
80W
−16
−12
−8
−4
4
8
12
16
[m]

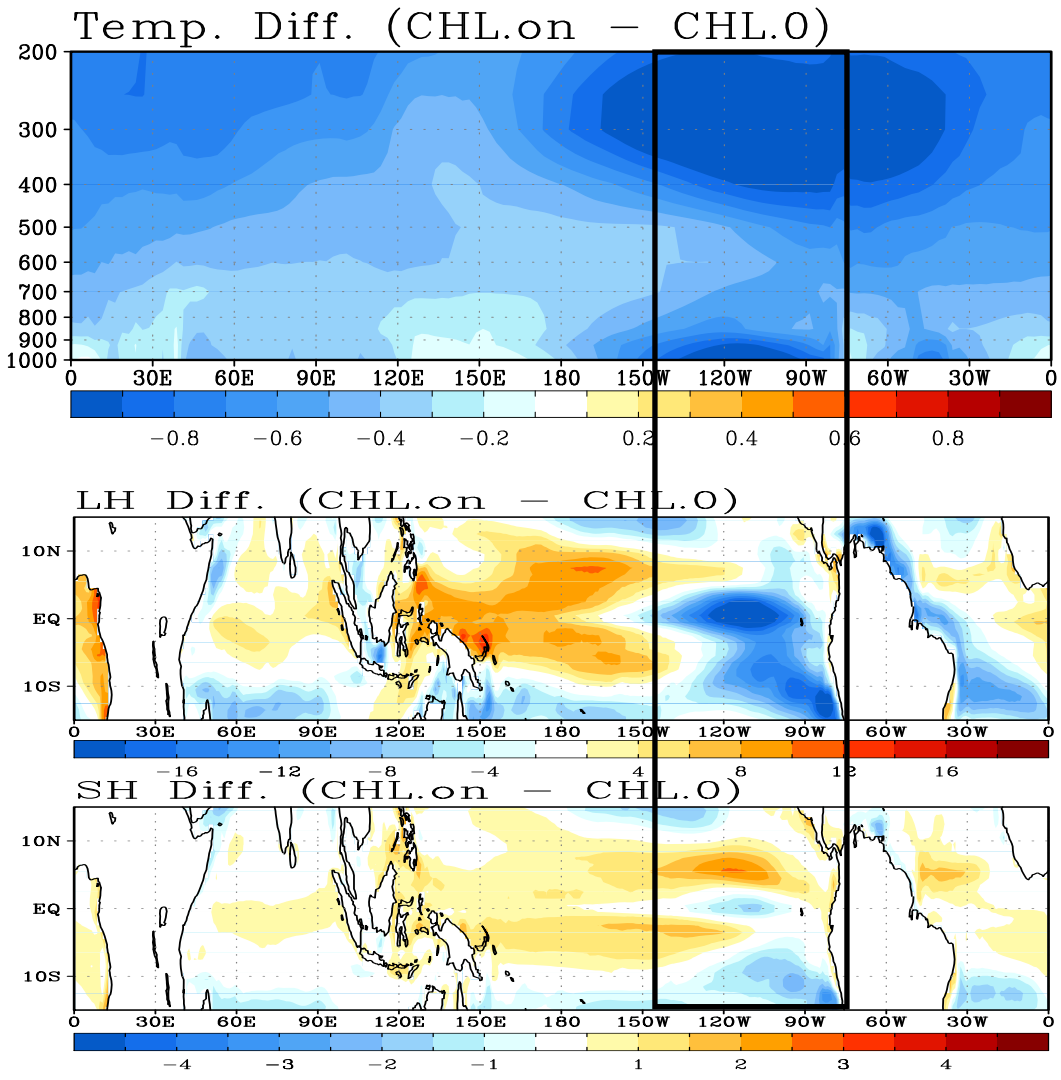
CM2.1


W Diff (CHL.on – CHL.0)
[m]
20
40
60
80
100
120
140
140E
160E
180
160W
140W
120W
100W
80W
−24
−18
−12
−6
6
12
18
24
(x10⁻²)
[cm/s]

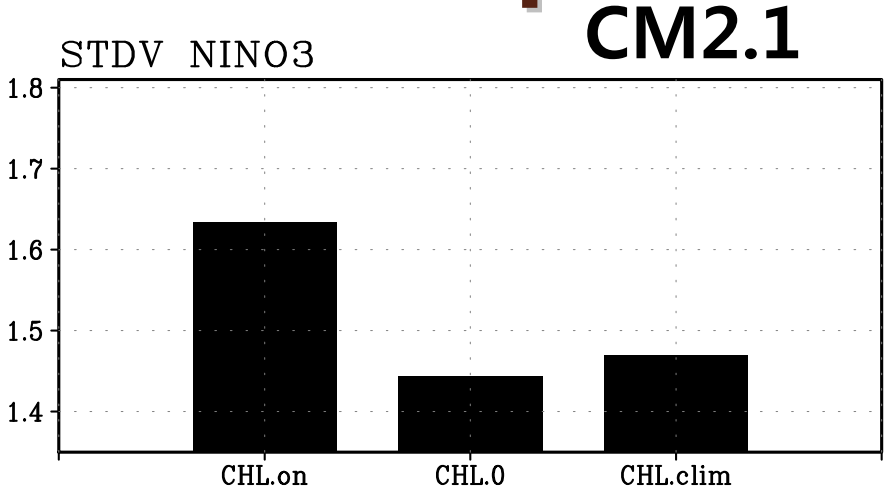

MLD Diff. (CHL.on – CHL.0)
20N
10N
EQ
10S
20S
140E
160E
180
160W
140W
120W
100W
80W
−8
−6
−4
−2
2
4
6
8
[m]

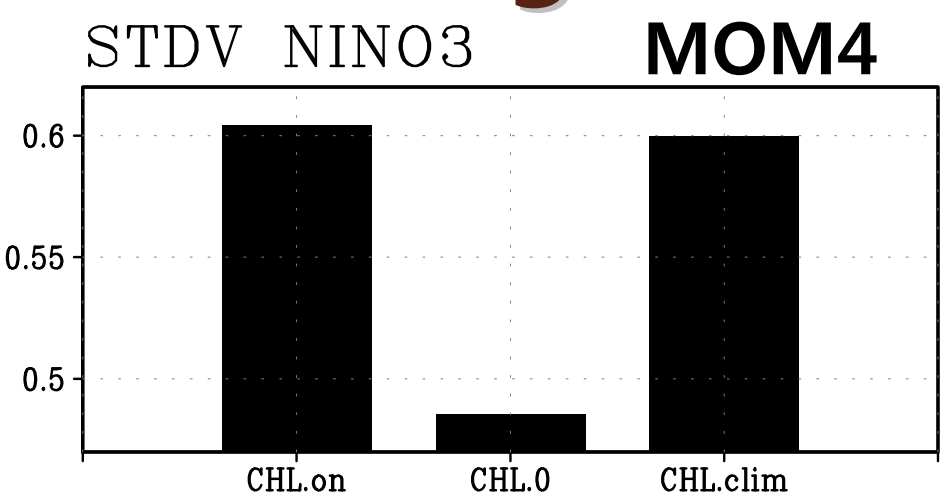

Diff. in tau_x (CHL.on – CHL.0)
10N
EQ
10S
120E
140E
160E
180
160W
140W
120W
100W
80W
−0.024
−0.018
−0.012
−0.006
0.006
0.012
0.018
0.024

CM2.1


Temp. Diff. (CHL.on − CHL.0)
200
300
400
500
600
700
800
900
1000
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
−0.8 −0.6 −0.4 −0.2 0.2 0.4 0.6 0.8
LH Diff. (CHL.on − CHL.0)
10N
EQ
10S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
−16 −12 −8 −4 4 8 12 16
SH Diff. (CHL.on − CHL.0)
10N
EQ
10S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
−4 −3 −2 −1 1 2 3 4

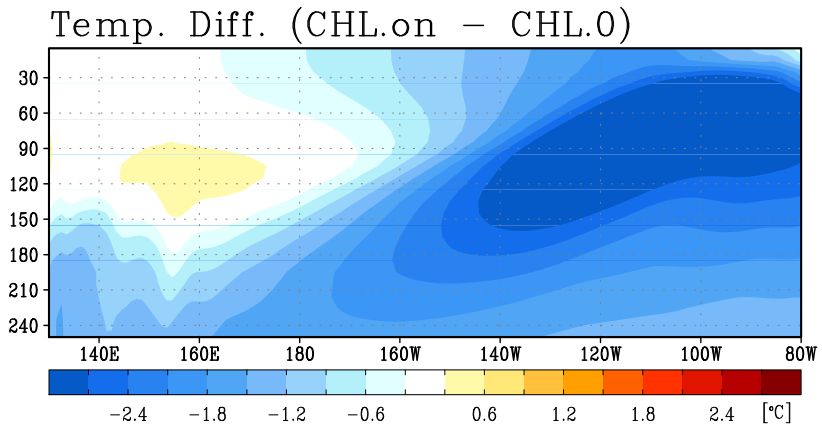
CHL impact on ENSO magnitude

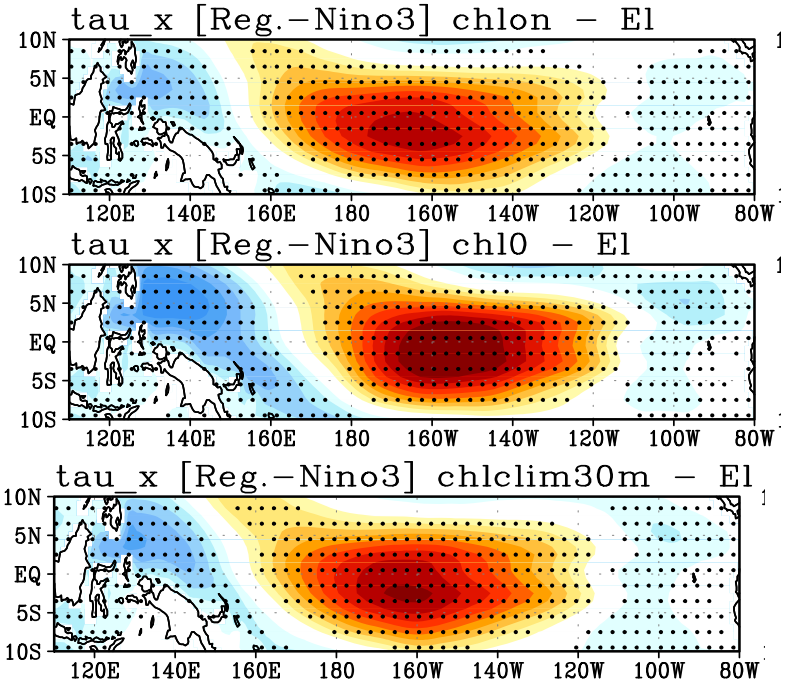




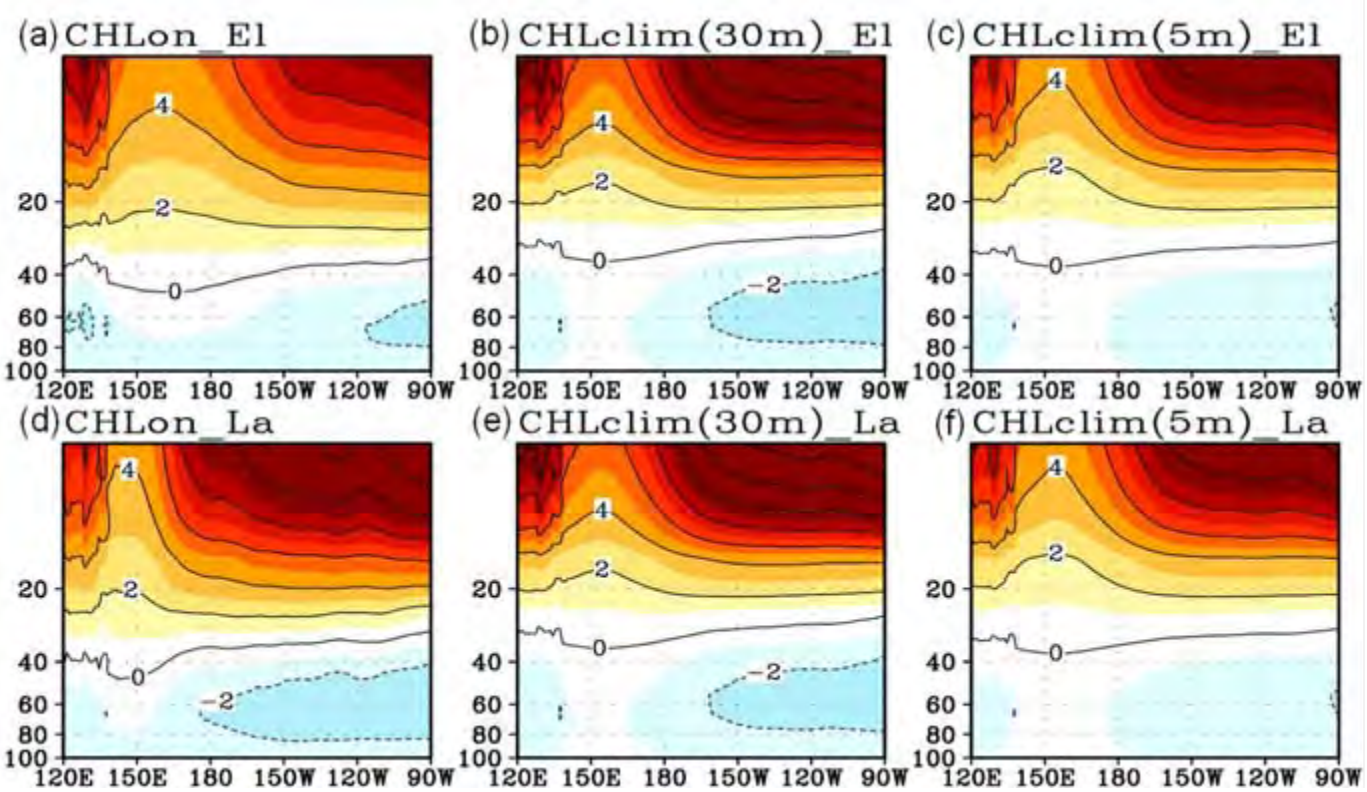
"ENSO damping by reduced atmospherice feedback

"ENSO amplifying effect by shoaled thermocline depth"



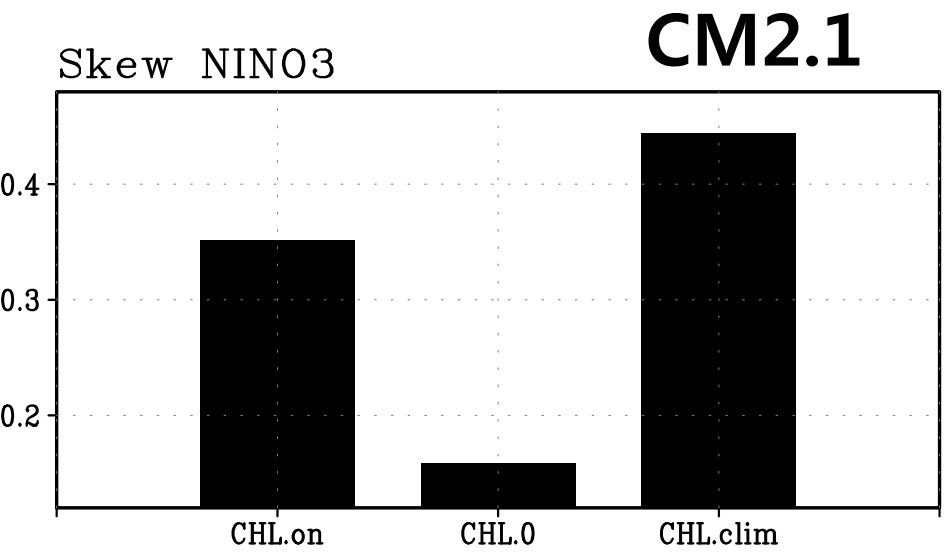


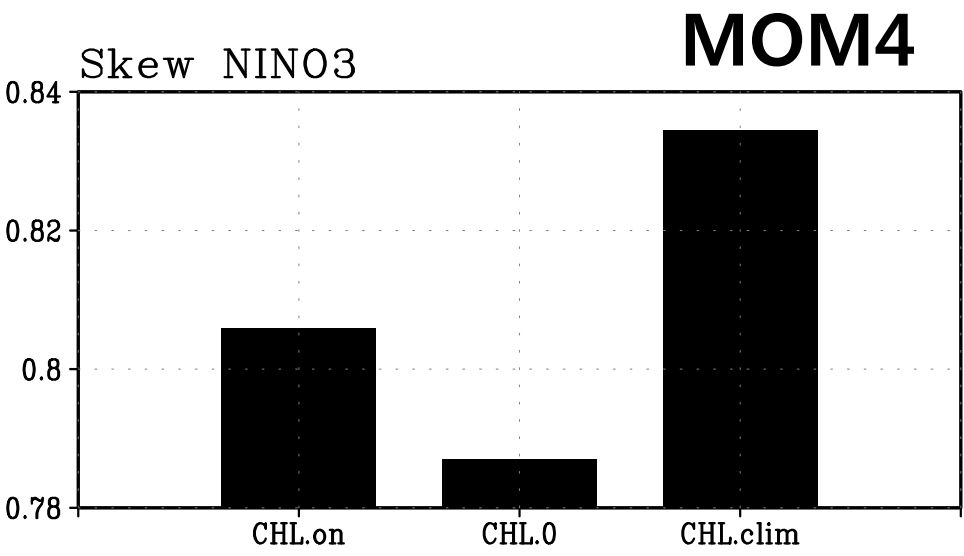
CHL impact on ENSO magnitude



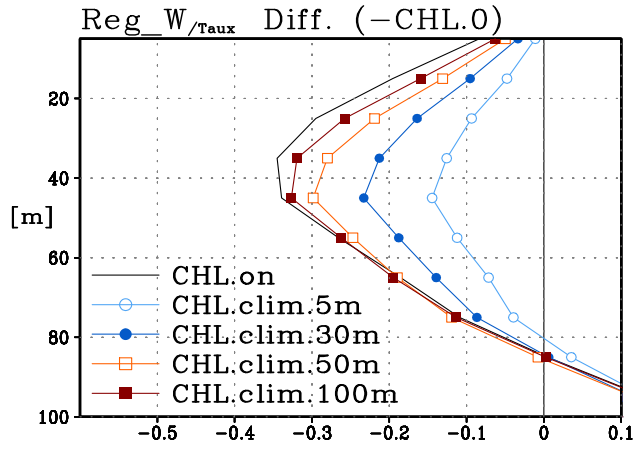
- Shoaling THCD ➔ ENSO ↑
- Cool SST in EP ➔ ENSO ↓
- ~~Direct heating ➔ ENSO ↓~~

CHL impact on ENSO skewness





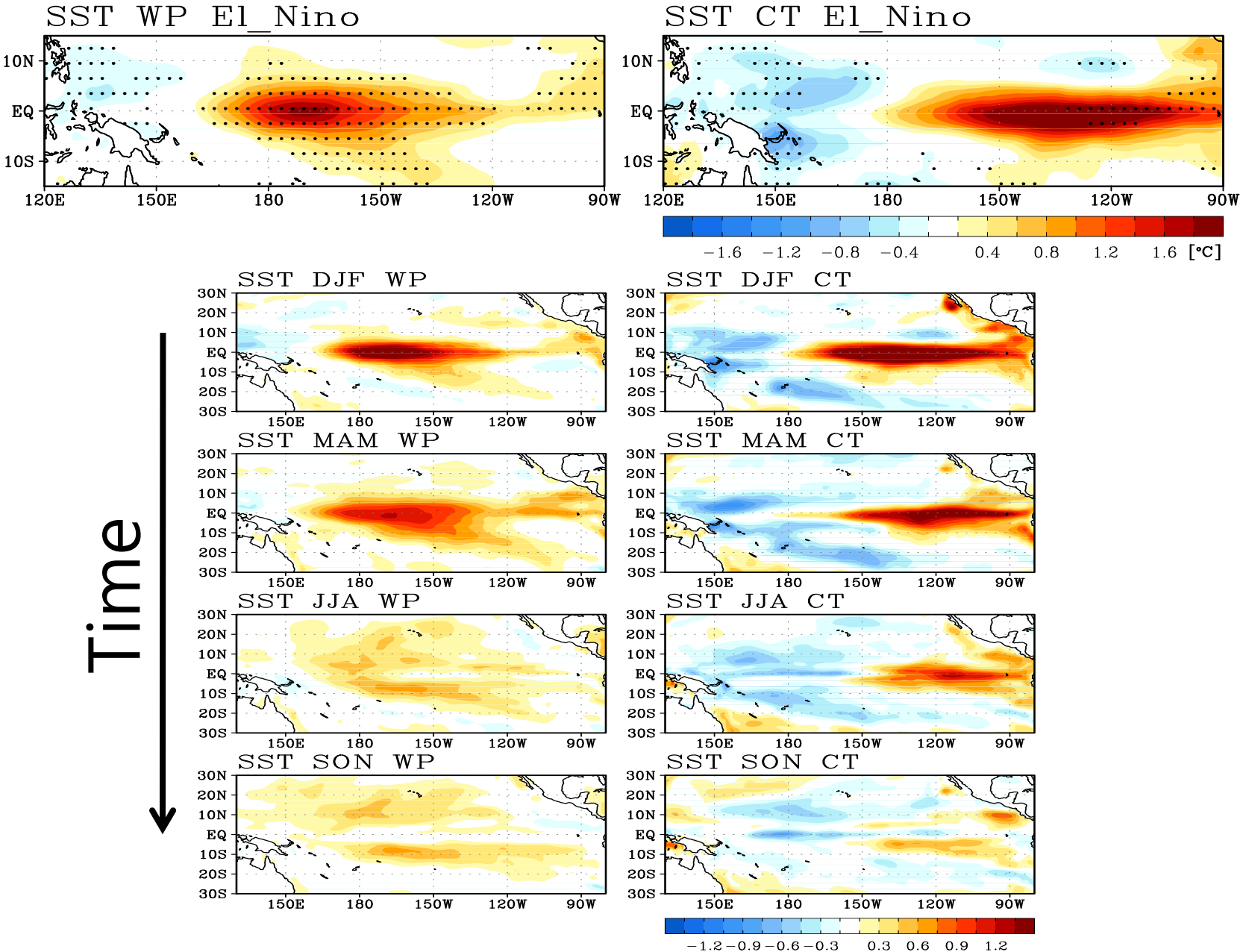
"Intensified nonlinear dynamic heating due to more sensitive upwelling response to the same wind"



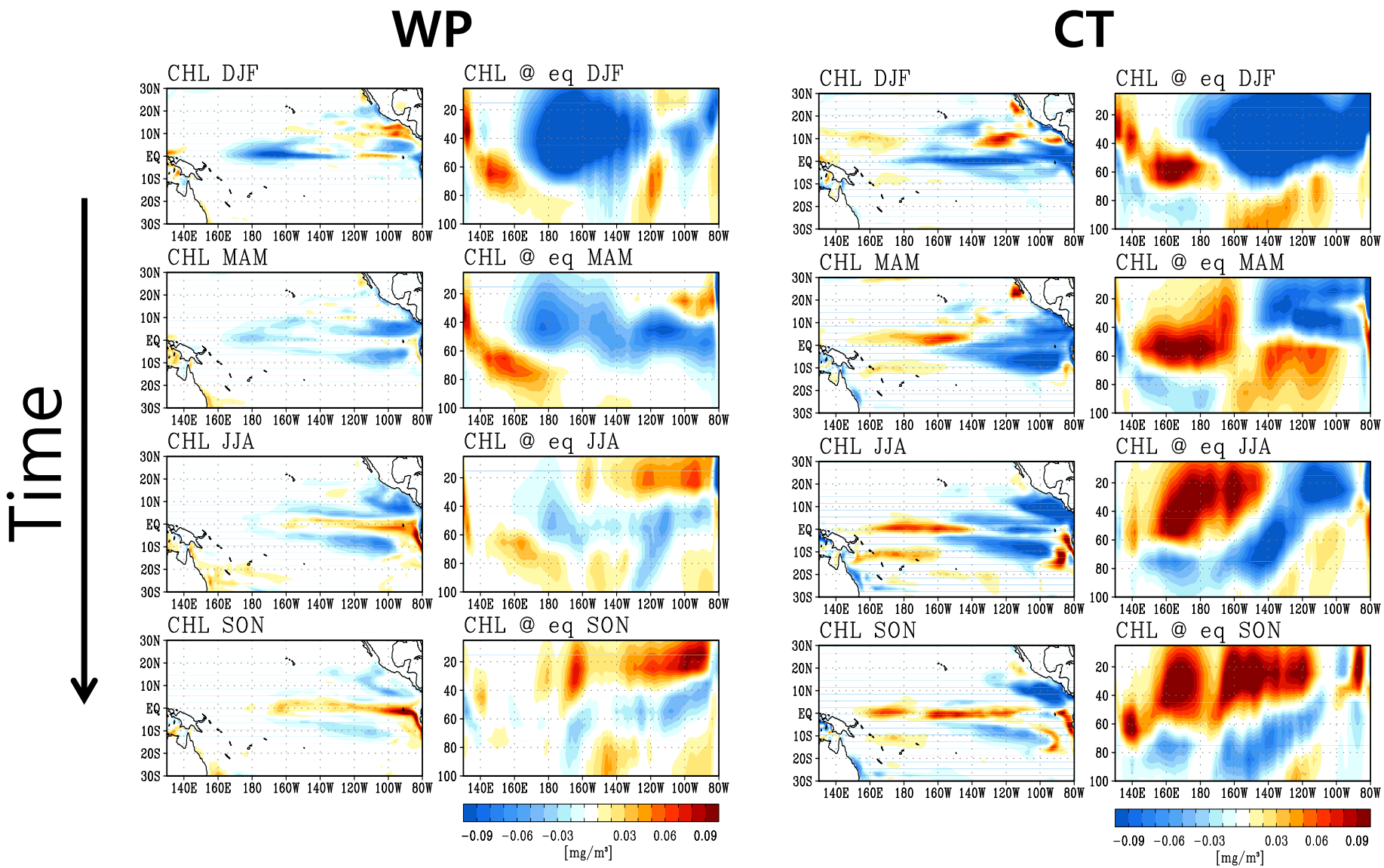
Biologically-induced shallower MLD

$$\left(-w' \frac{\partial T'}{\partial z}\right) : + \rightarrow +$$

WP vs. CT El Nino



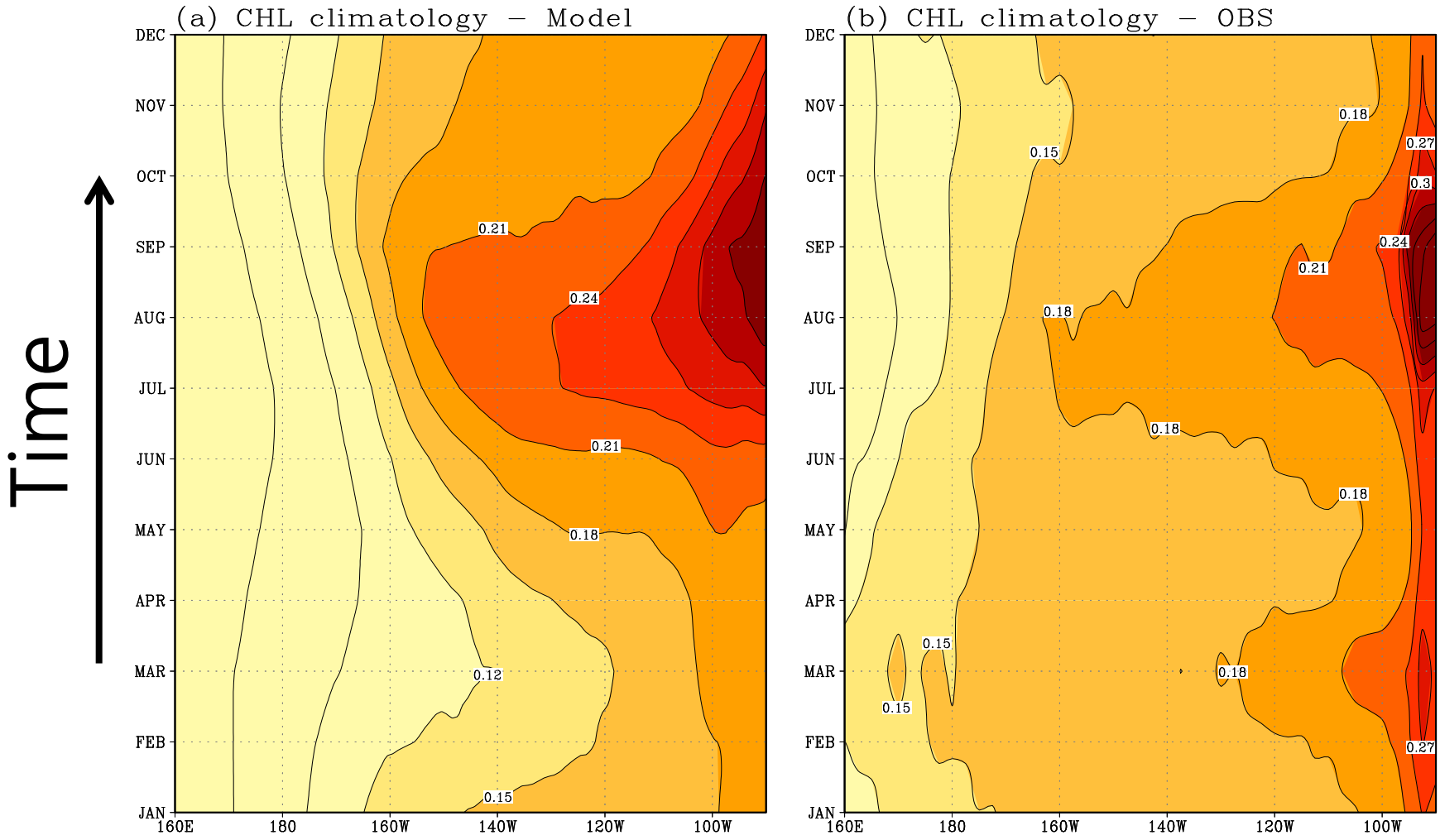
WP vs. CT El Nino



Model Performance

Model

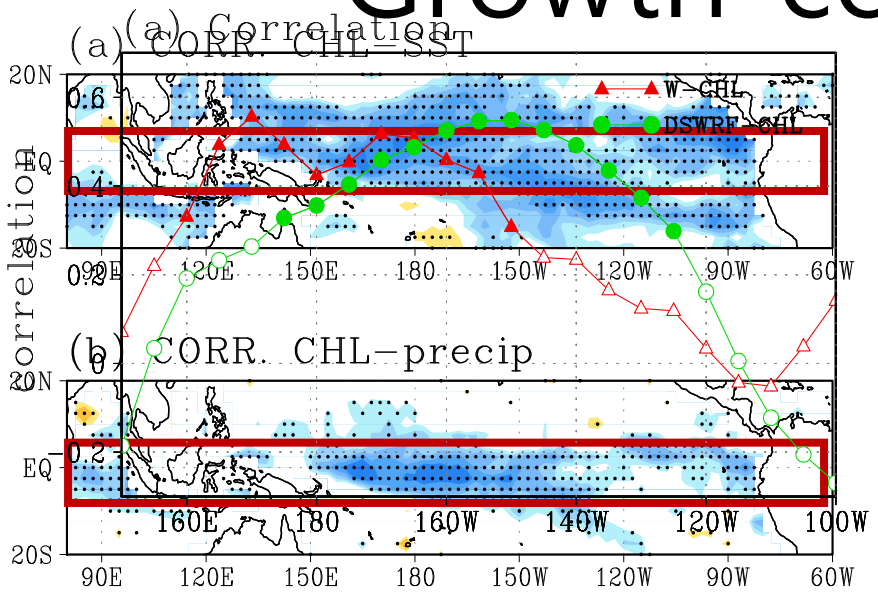
OBS

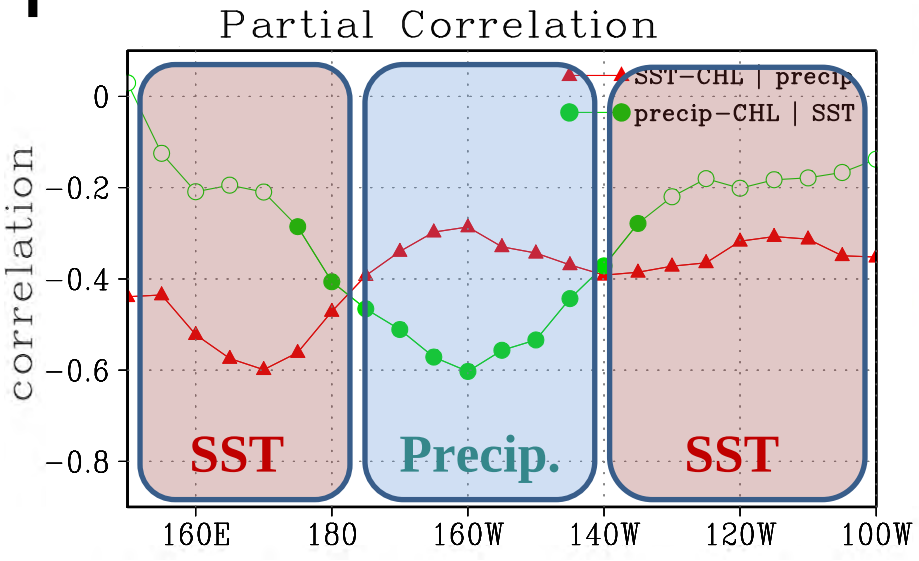


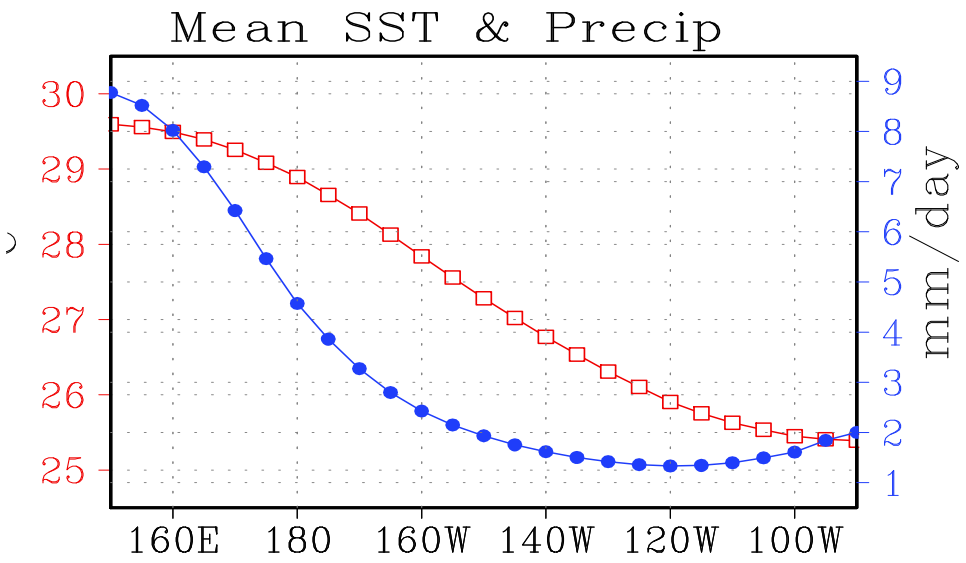
$$\frac{\partial T'_E}{\partial t} = a u'_g + \gamma h'_E - \alpha T$$

$$\frac{\partial h_E}{\partial t} = -r h_E + a \tau_x$$

Growth-control factors

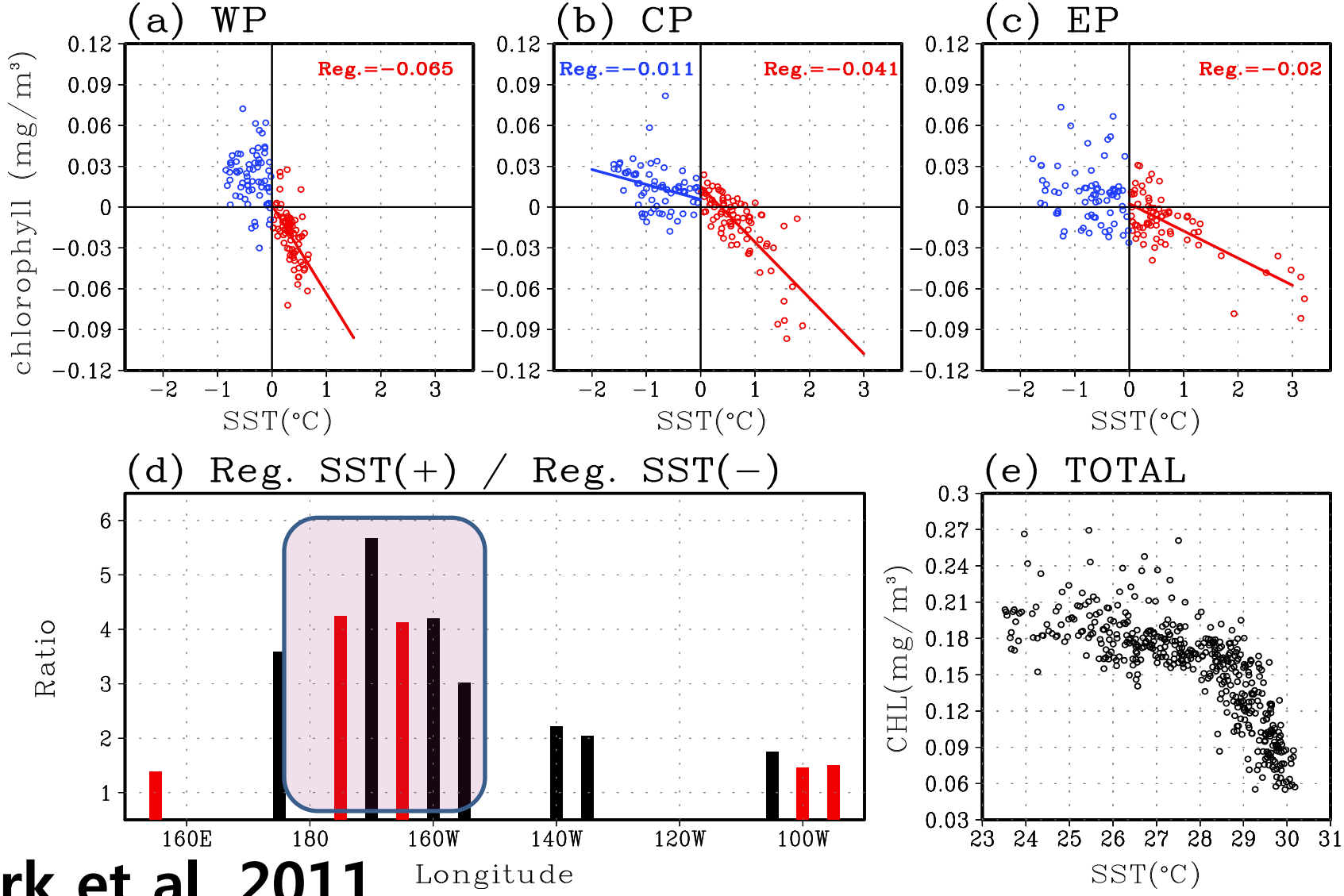






Park et al. 2011

Asymmetric response to ENSO



Park et al. 2011

Summary

- **Biological perturbation** is associated with the **ENSO** in the equatorial region.
- **First two leading modes of chlorophyll** are associated with the **mature phase of El-Niño** during winter **and the decaying phase of El-Niño** during summer**.**
- **Growth-control factors**
  (ocean circulation, mixed-layer dynamics, and incoming shortwave radiation**.)**

Equatorial Pacific		
Western	Central	Eastern
Nutrient (insufficient light)	Solar radiation	Nutrient (sufficient light)

Nonlinear response of ocean biology to the El-Niño and La-Niña.

- **Chlorophyll variations** associated with **ENSO** give the **~ 2 W/m^2/1σ_{PC1} shortwave flux feedback** on the equatorial Pacific.