WCRP Conference, Denver

Phytoplankton variability and its biological feedback in the equatorial Pacific

(Observation and Model)

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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
  : Regridding - 9km x 9km ➔ 2.5 x 2.5 degree

➢ Model

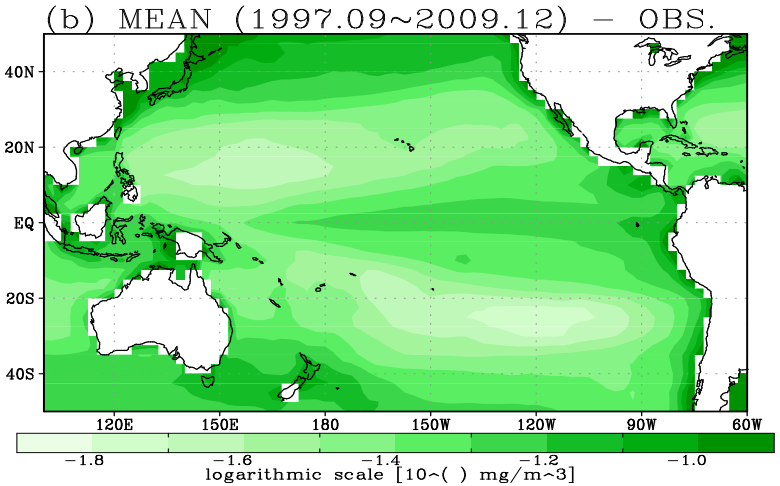
- **MOM4p1-TOPAZ** : global ocean + ice + biogeochemistry model
- TOPAZ (Tracers in the Ocean with Allometric Zooplankton)
  : Considers 25 tracers (3 phytoplankton groups, organic matter, heterotrophic biomas s, C, N, P, Si, ...,)
- Forced experiment (1951- 2010)

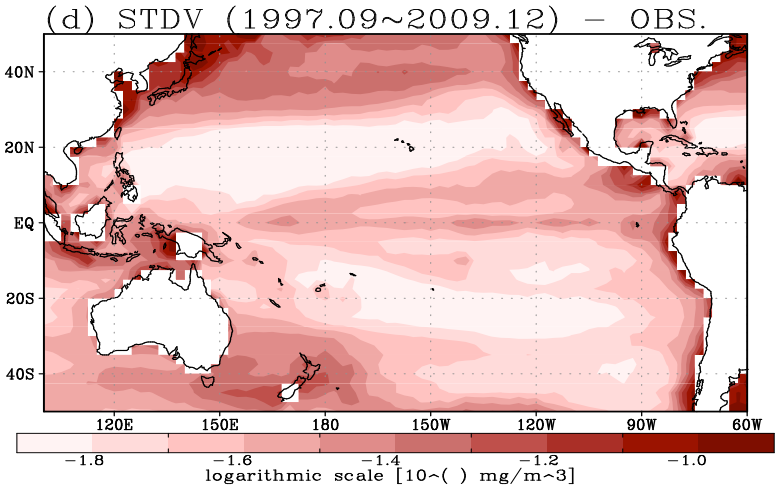
Realistic Boundary forcing	Climatological forcing
Surface Wind (6hr)	Longwave flux, Specific humidity, Surface temp., Shortwave flux,

➢ **Ocean surface albedo / surface net sh** Shortwave penetration (Manizza et al., 200

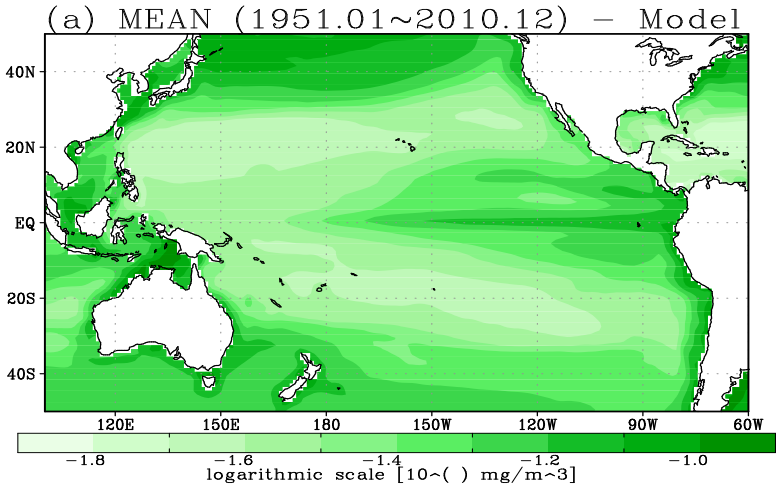
Model Performance

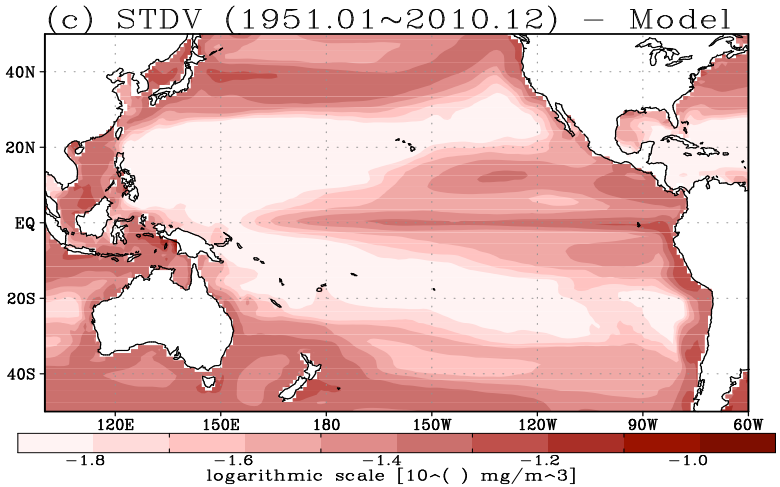
Obs. (SeaWiFS+MODIS)



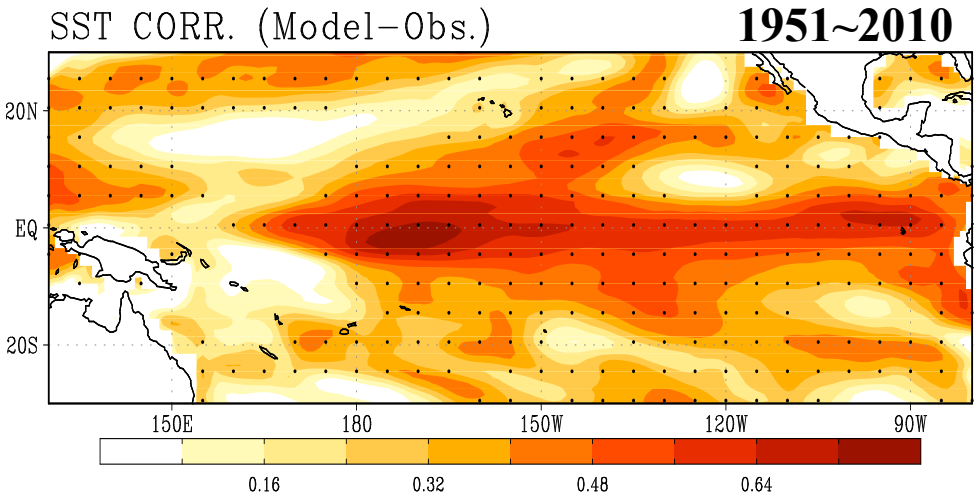


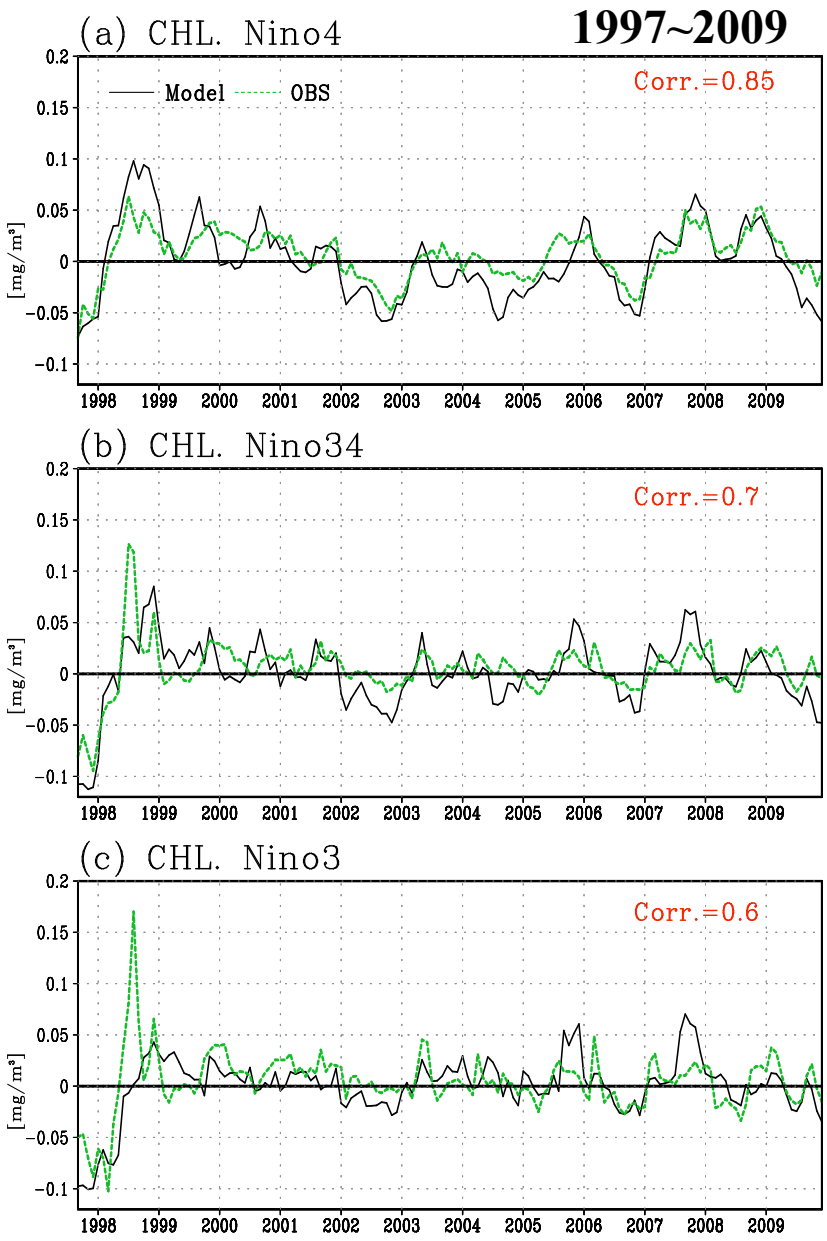
Model





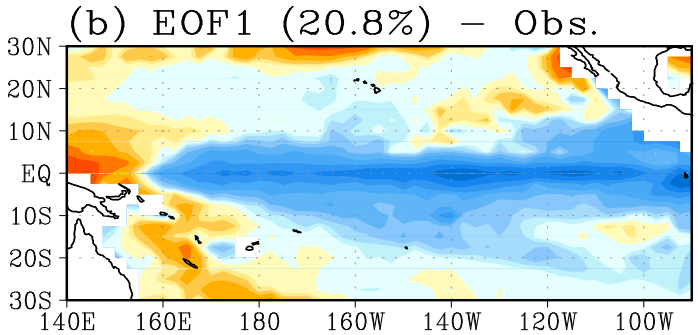
Model Performance

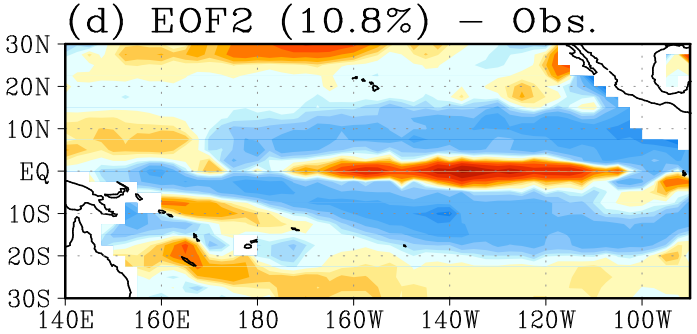


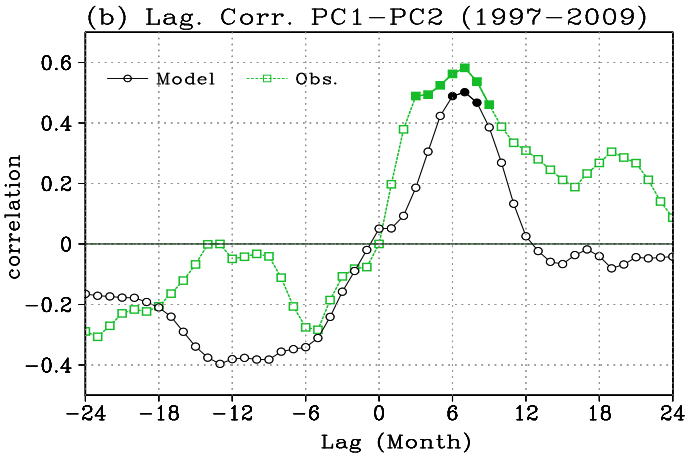


ENSO-related variability

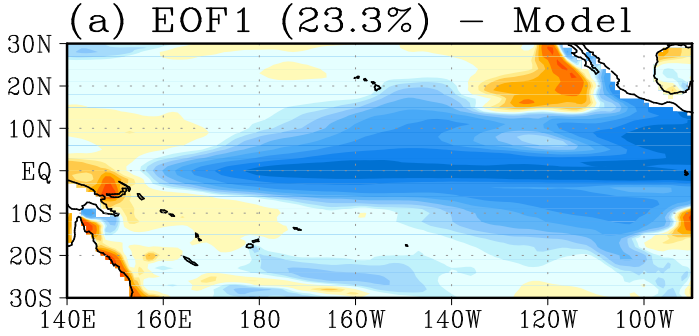
Obs. (1997~2009)

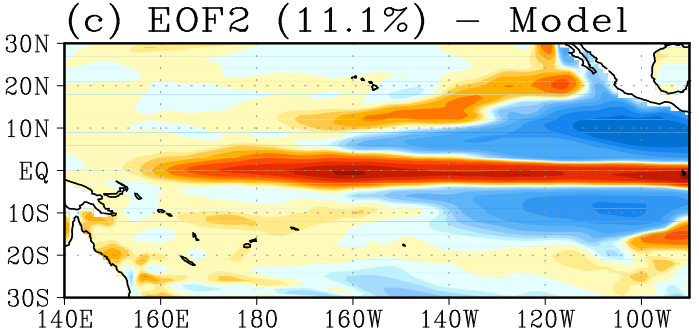


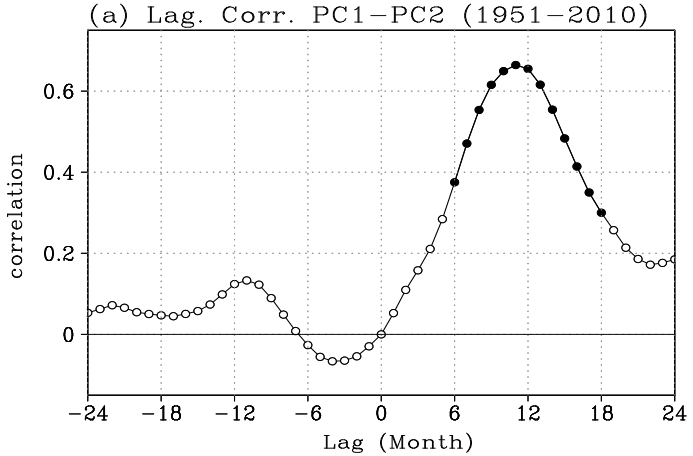


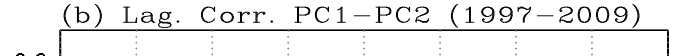


Model (1951~2010)

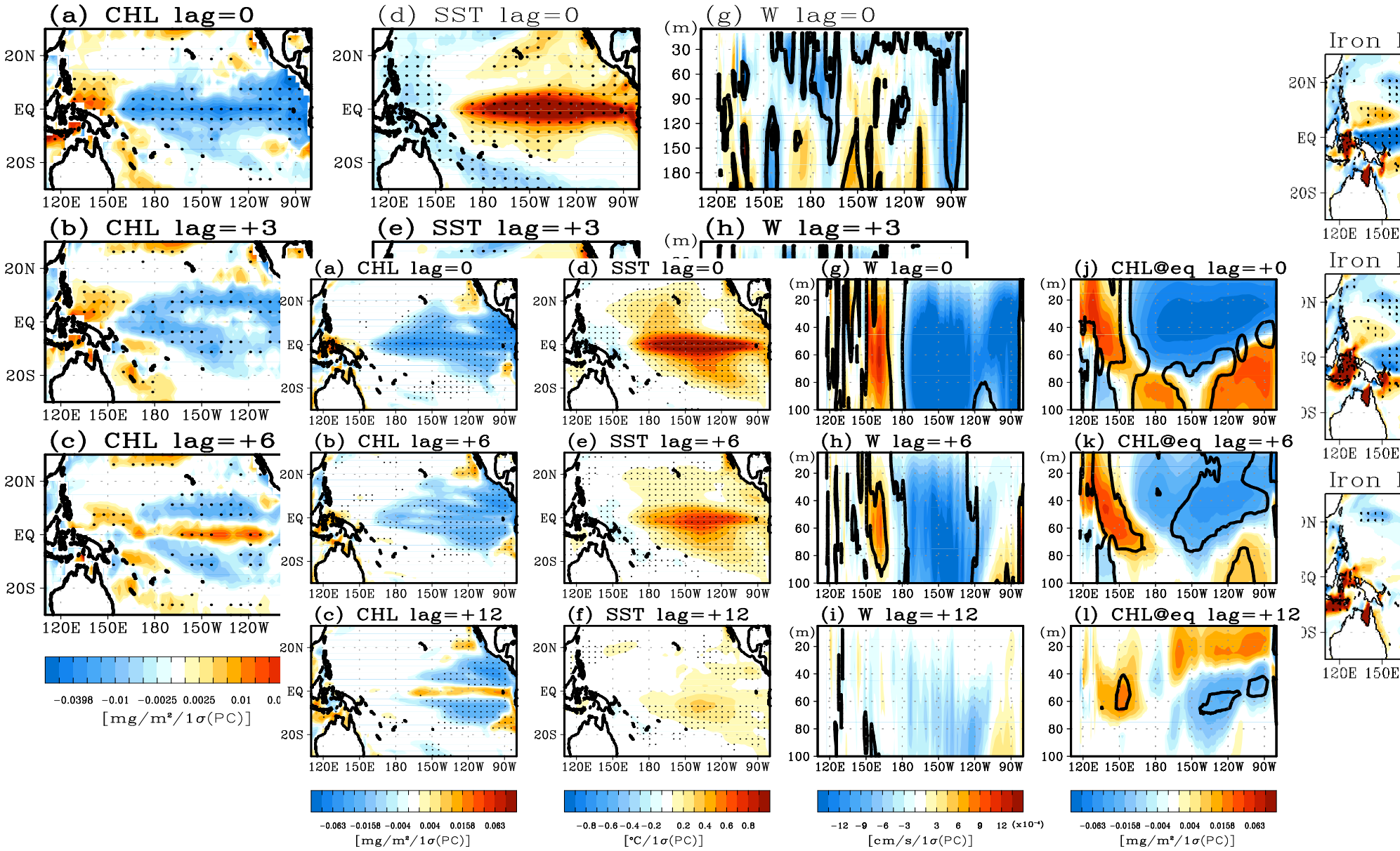








ENSO-related variability



Biological Feedback

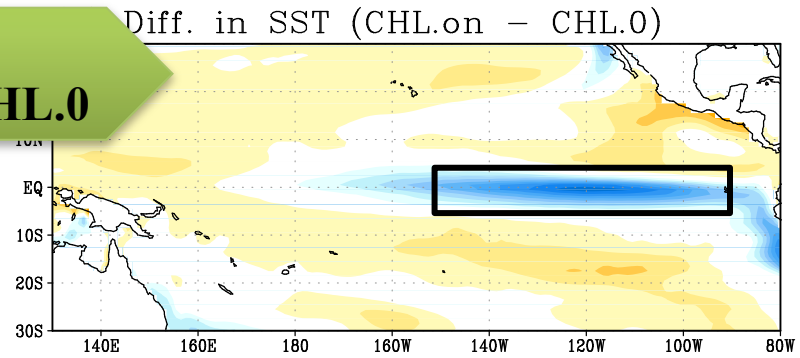
- Experimental Design

Mom4p1
(Hindcast run: 1951-2010)

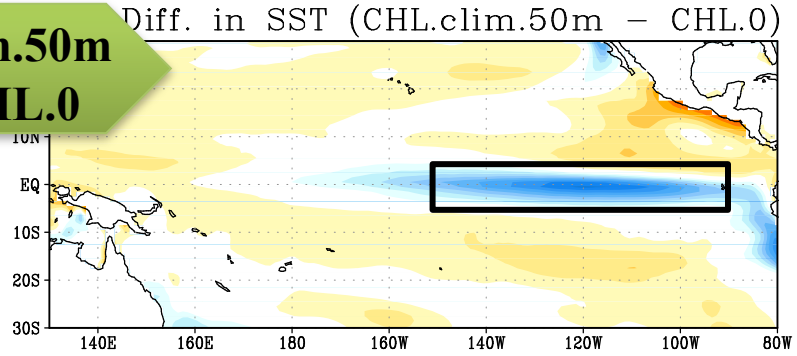
Exp. 1	Exp. 2	Exp. 3, 4, 5, 6
CHL_on	CHL_0	CHL_clim (sfc, ~30m, ~50m, ~100m) Higher CHL climatology !
TOPAZ_ON	TOPAZ_off (Zero CHL)	TOPAZ_off (climatol. CHL)

Biological Feedback - Mean

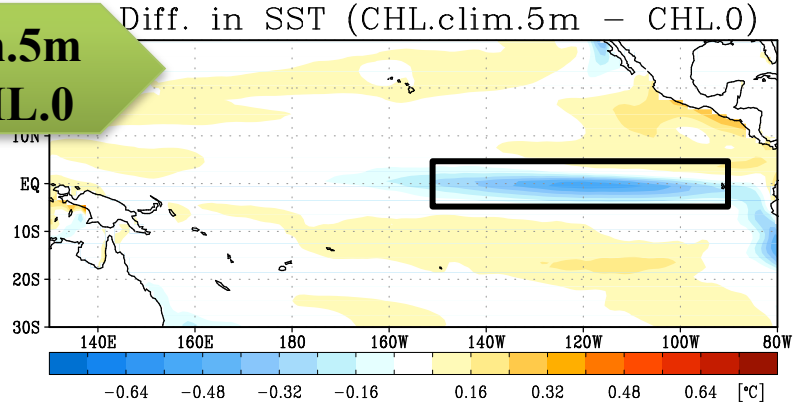
CHL.on – CHL.0

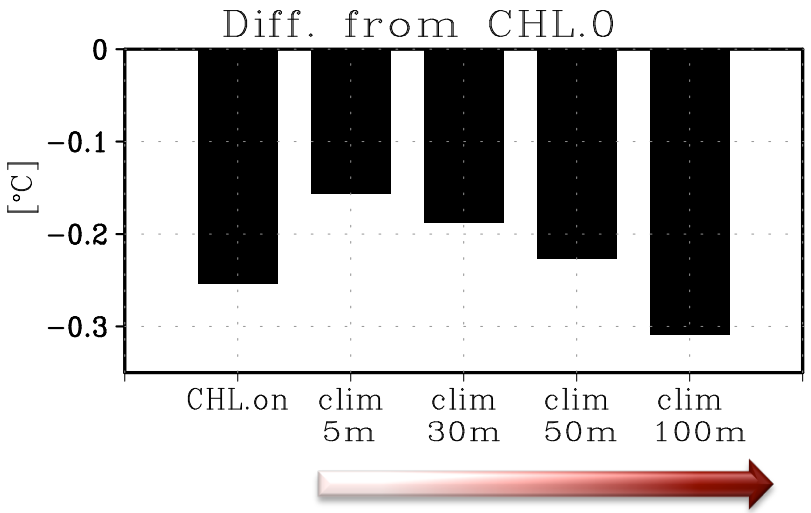


CHL.clim.50m – CHL.0



CHL.clim.5m – CHL.0



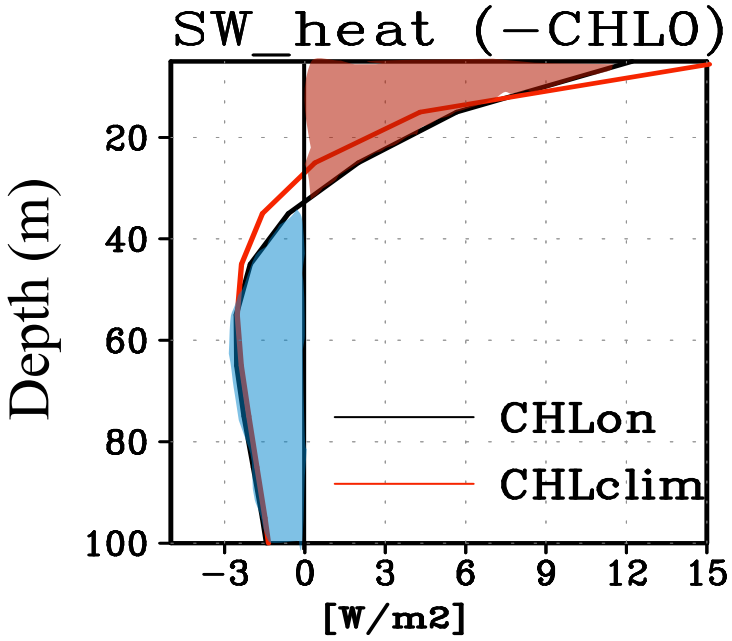


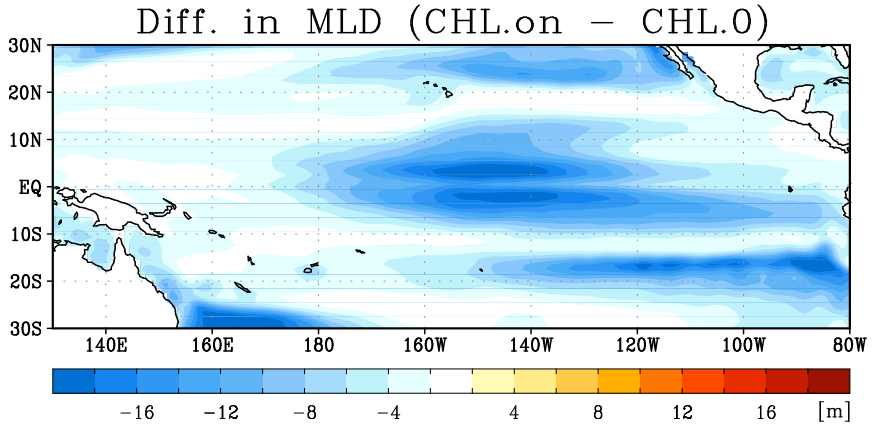
Higher CHL climatology !

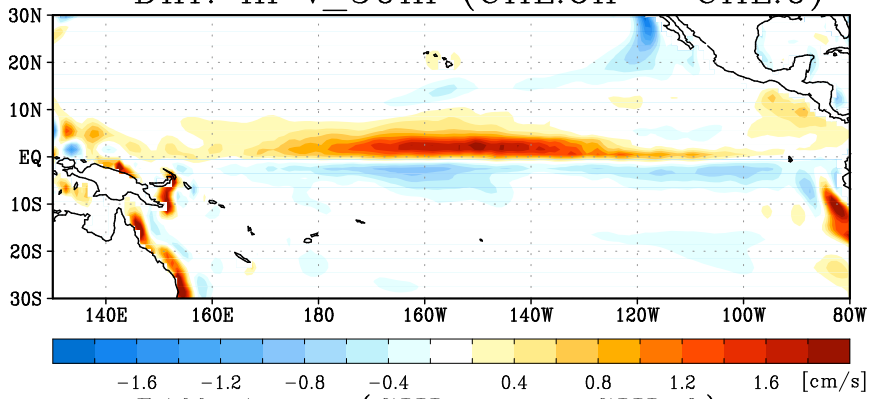
Biological Feedback - Mean

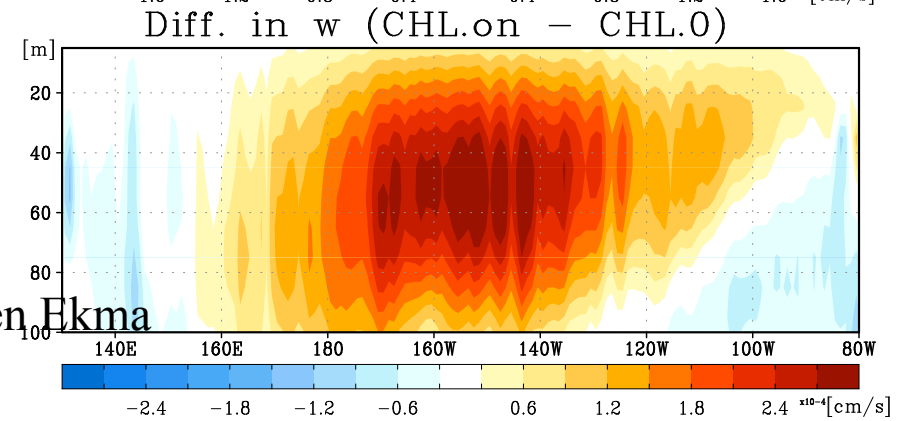
➢ **Mean Difference**

: "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

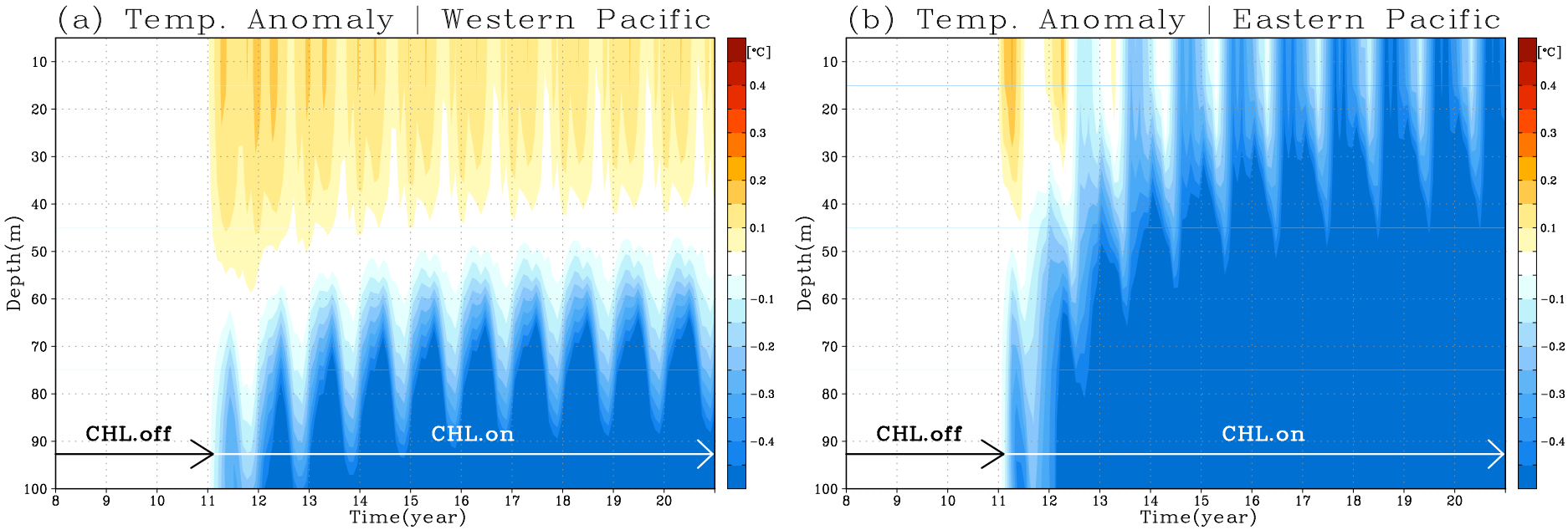
Geostrophic balanced flow

Wind-driven Ekman transport

Biological Feedback

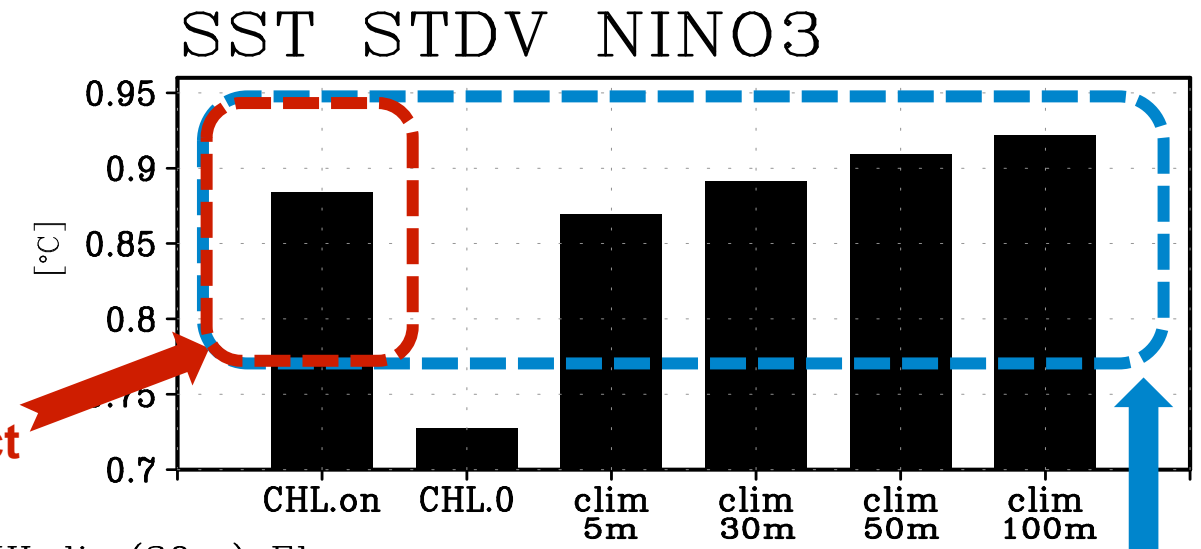
➢ **Test experiment**

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

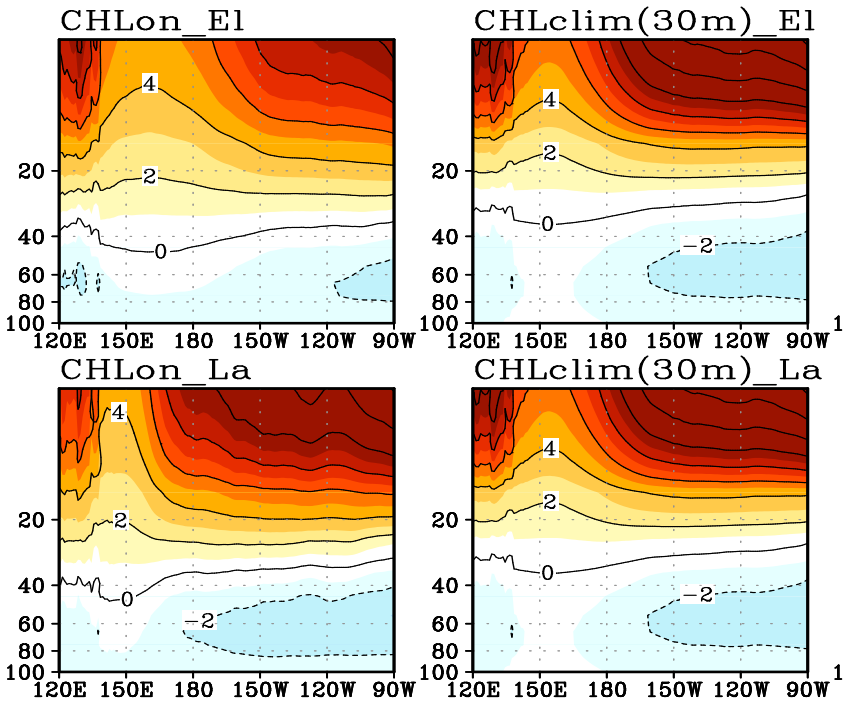


nino3 MLD

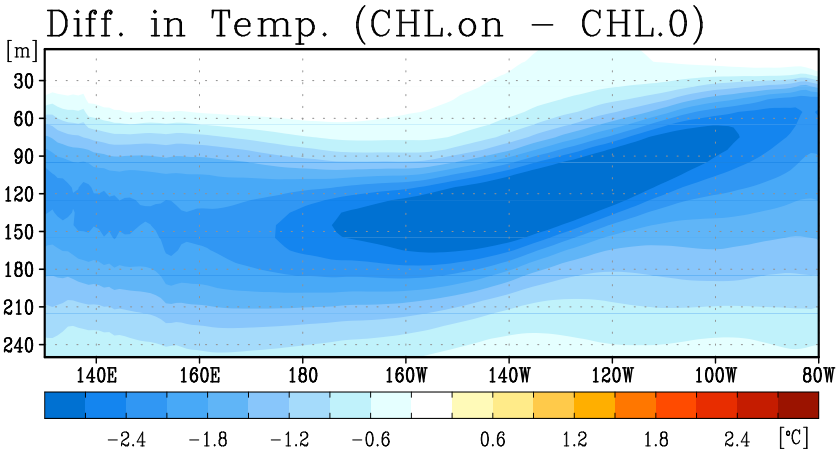
Biological Feedback - STDV



"ENSO damping effect by **Interactive CHL** "

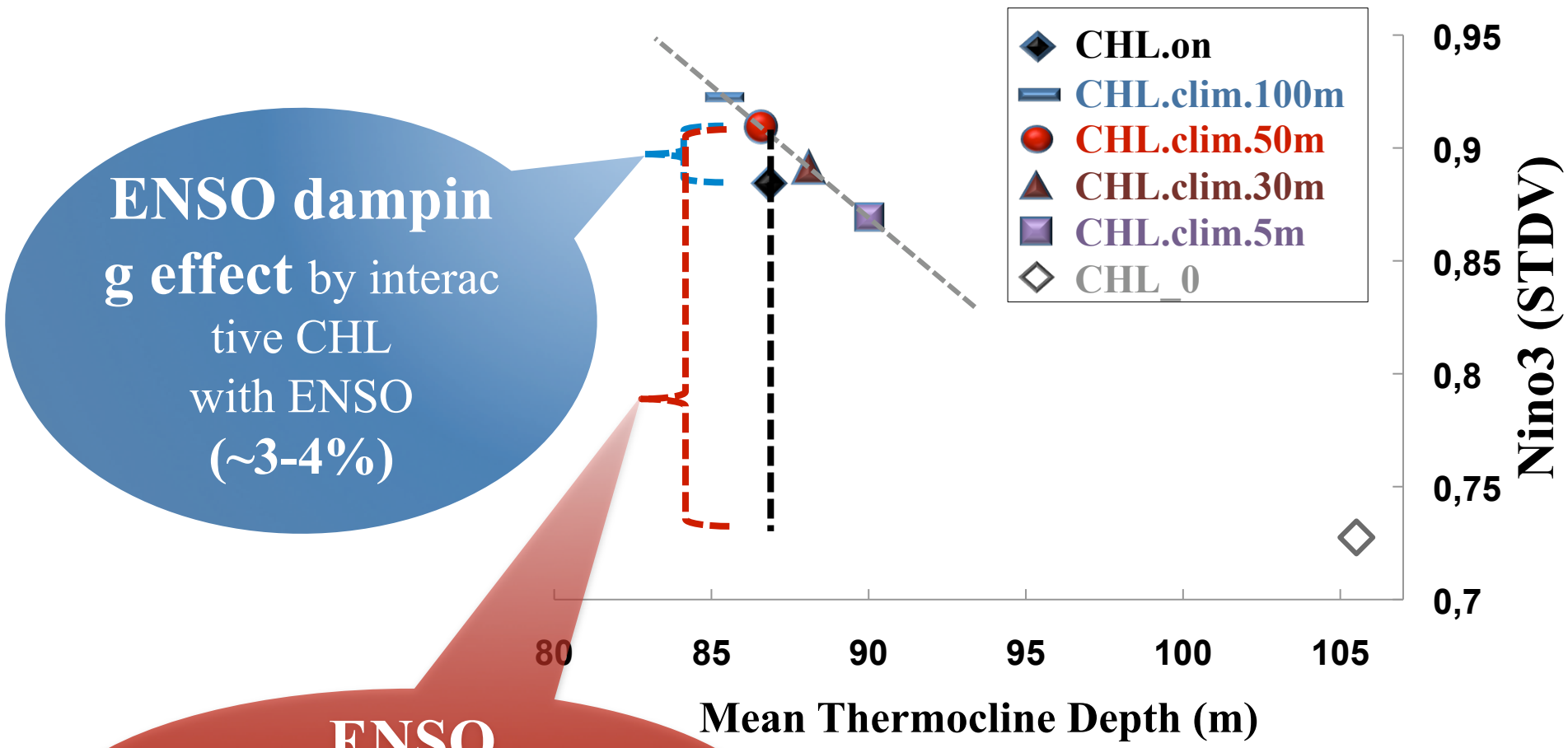


"ENSO amplifying effect by **shoaled thermocline depth**"



no34_histogram

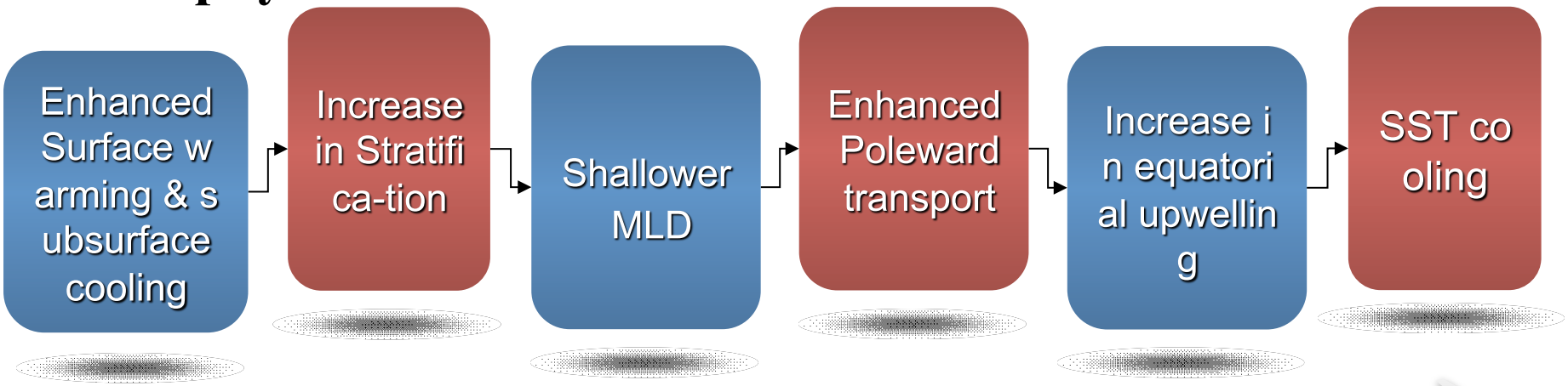
Biological Feedback - STDV



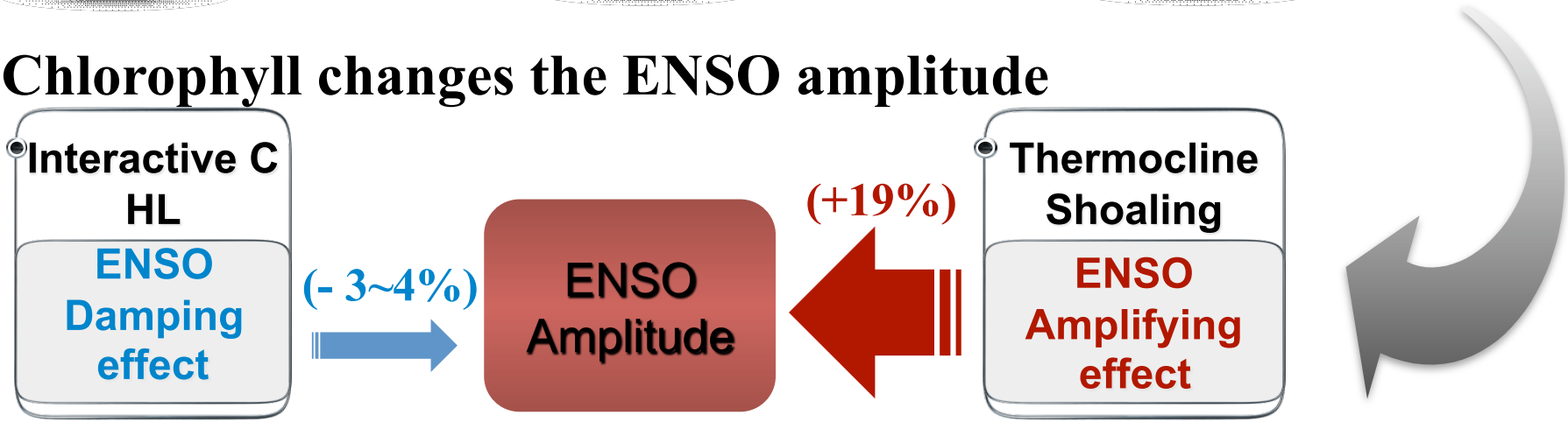
Summary

- **Major modes of chlorophyll** are associated with the **mature phase** and the **transition phase of El-Niño.**

- **Chlorophyll modifies the mean state**



- **Chlorophyll changes the ENSO amplitude**

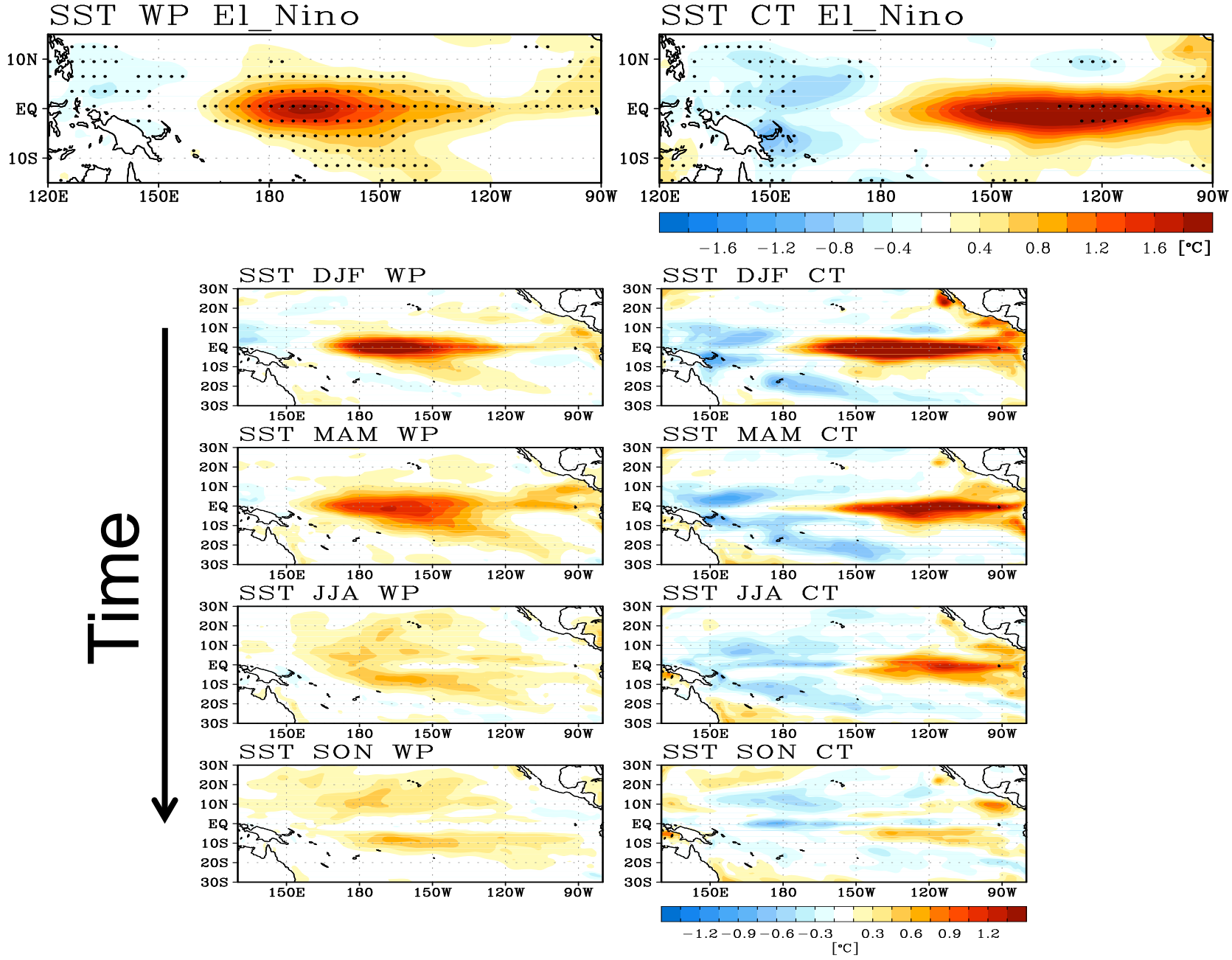


Thank you.

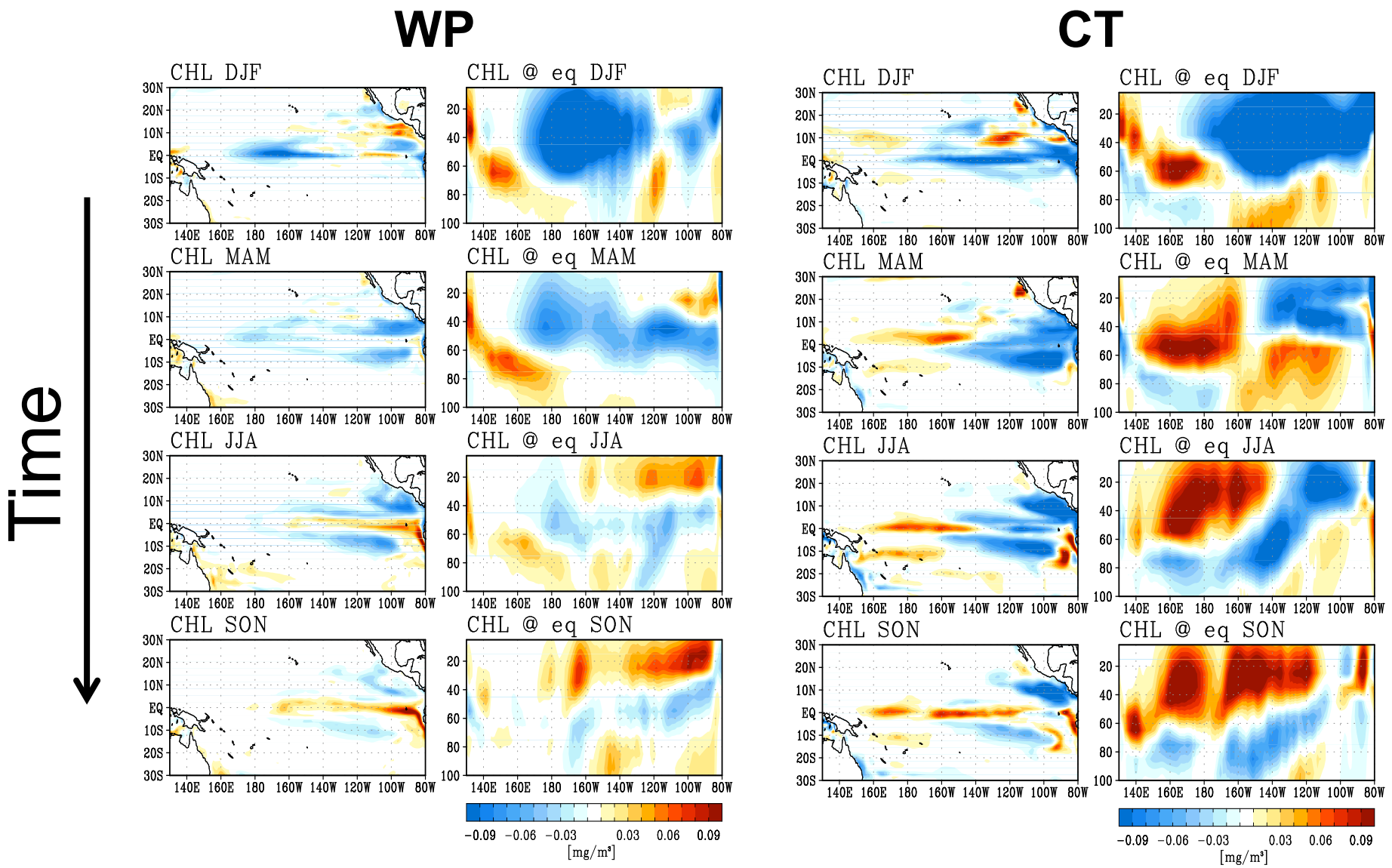
Backup

From Park et al. (2011, JGR)

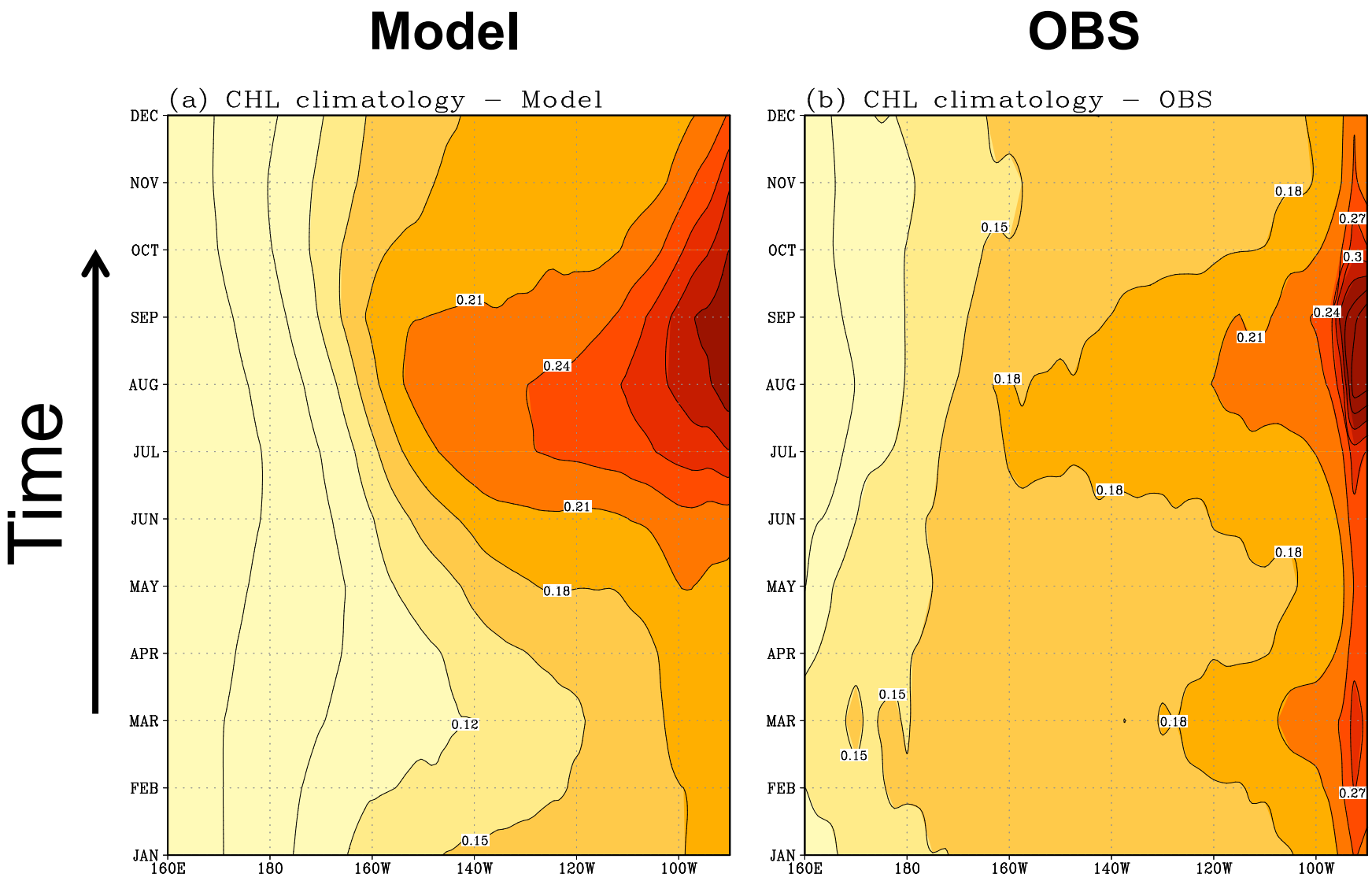
WP vs. CT El Nino



WP vs. CT El Nino



Model Performance



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

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

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)

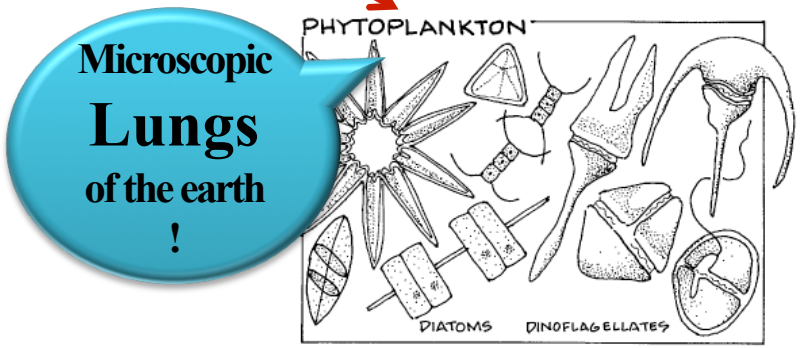
Nonlinear response of ocean biology to the El-Niño and La-Niña.

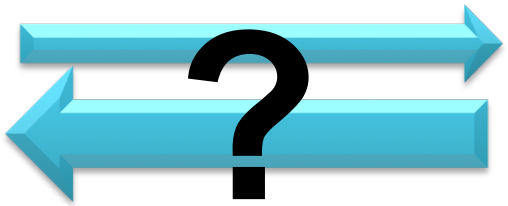
- **Chlorophyll variations** associated with **ENSO** give the **~ 2 W/m^2/1σ_{PC1} shortwave flux feedback** on the equatorial Pacific.

Introduction

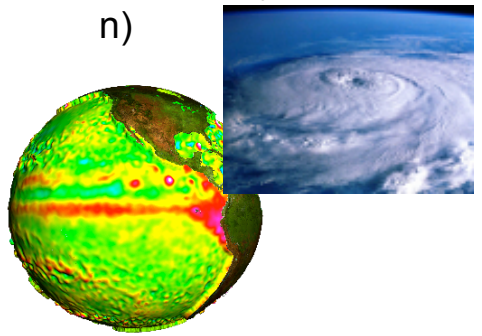
?? To improve climate models

- Cloud physics
- Aerosol radiative forcing
- Surface scheme
- Chemical process
- Glacier dynamics
- **Bio-climate interaction**





Climate system (ENSO, Typhoon)



- **Half of the world's oxygen** is produced via **phytoplankton photosynthesis.** [Field et al., 1998; Behrenfeld et al., 2001]
- The concentration of **phytoplankton** interacts with the **tropical variability**. [Chavez et al., 1999; Timmermann and Jin, 2002; Behrenfeld et al., 2006; Henson et al., 2010]
- Contribution of **typhoon** to annual production is **20~30%** in the SCS. [Lin et al. 2003]
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Data

- **Chlorophyll** (measure of upper-ocean phytoplankton)
  - Sea-viewing Wide Field-of-view Sensor (SeaWiFS) : SEP1997~ DEC2007
  - Moderate Resolution Imaging Spectroradiometer (MODIS) : JAN2008~ DEC2009
  - 9km x 9km ➔ 2.5 x 2.5 degree

- **Ocean surface albedo / surface net shortwave flux**
  - Clouds and the Earth's Radiant Energy System (CERES) : MAR2000~OCT2005
  - International Satellite Cloud Climatology Project (ISCCP) : JULY1983~DEC2007

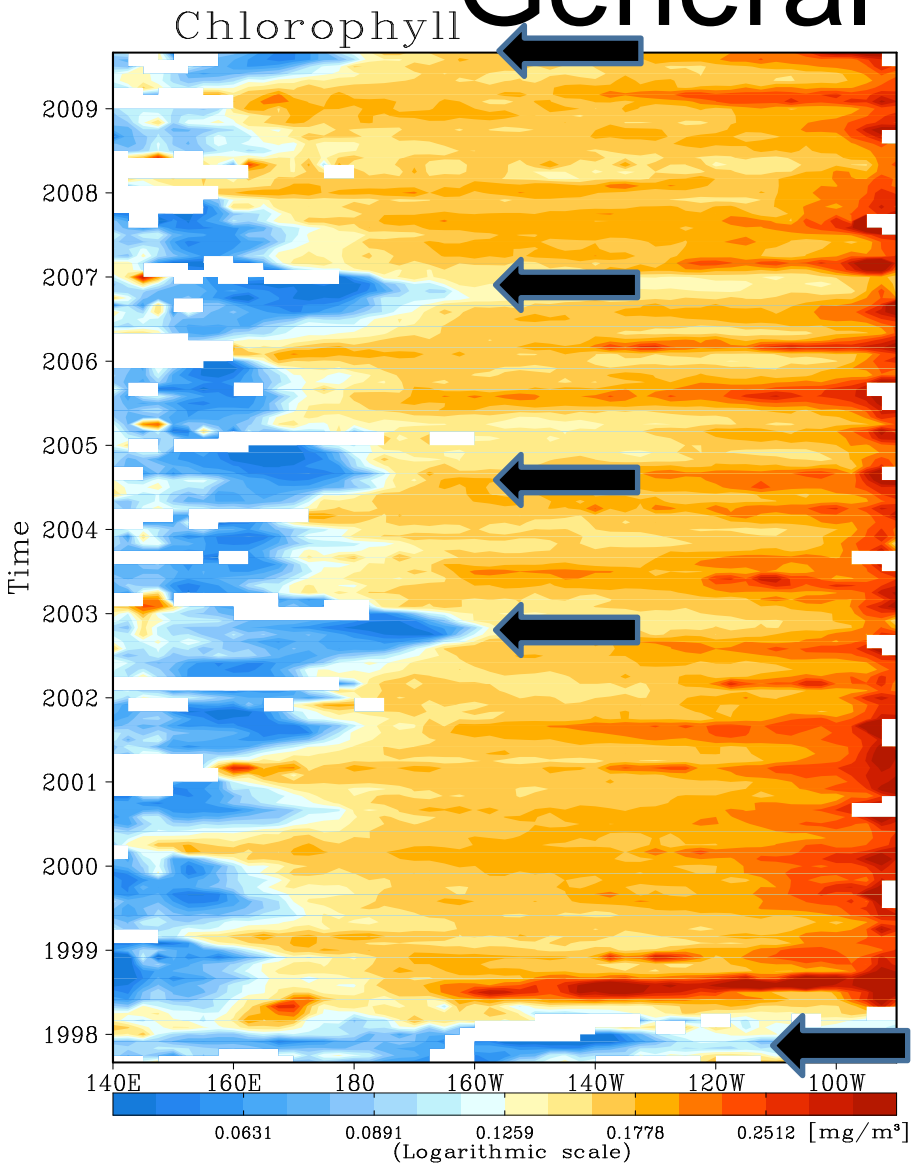
- **Oceanic variables** (vertical velocity)
  - Global Ocean Data Assimilation System (GODAS)

- **Atmospheric variables** (radiation flux, u(v)-momentum flux)
  - NCEP/DOE Reanalysis 2

- **SST:** NOAA Optimum Interpolation (OI) SST V2

- **Precipitation**
  - Climate Prediction Center Merged Analysis of Precipitation (CMAP)

General feature

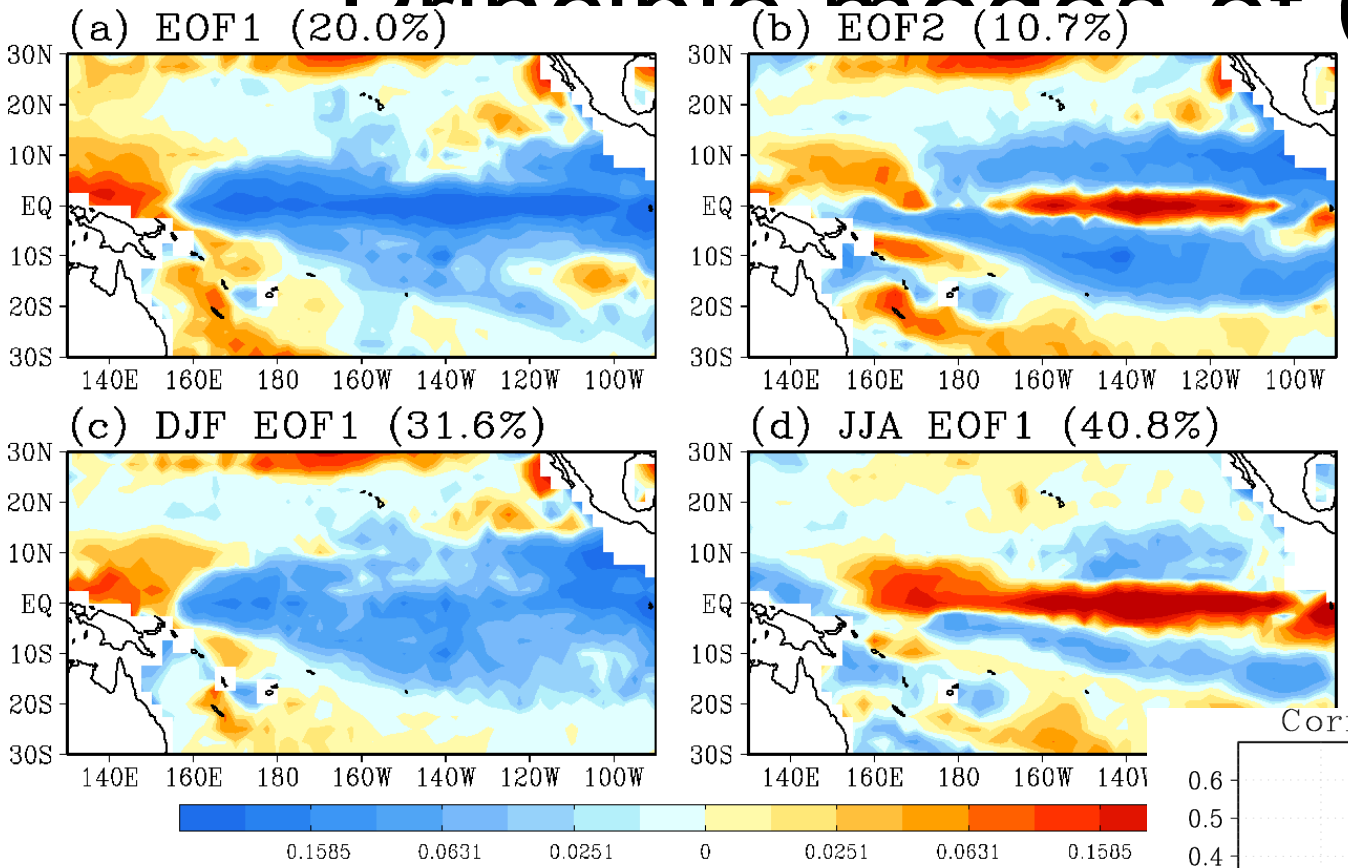


?? Spatio-temporal variability of chlorophyll related to ENSO

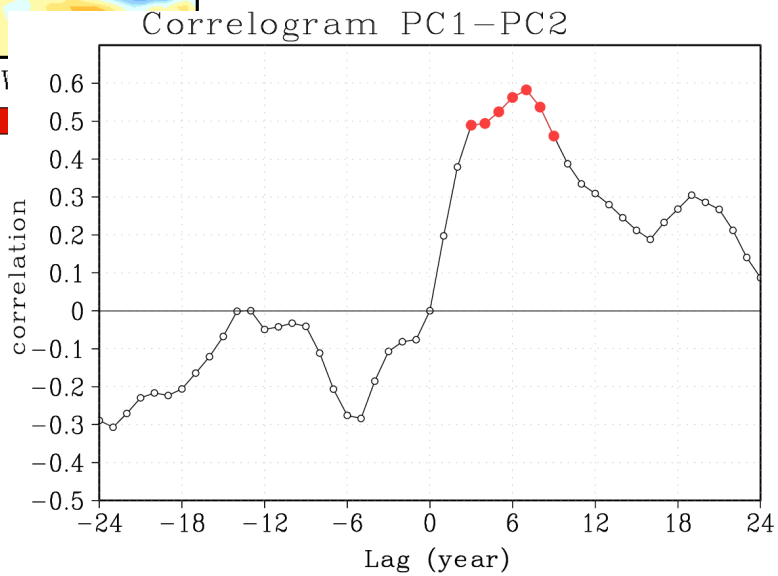
?? Regional differences in the chlorophyll variability

El-Niño

Principle modes of CHL



"PC1 leads PC2 by 6 months"

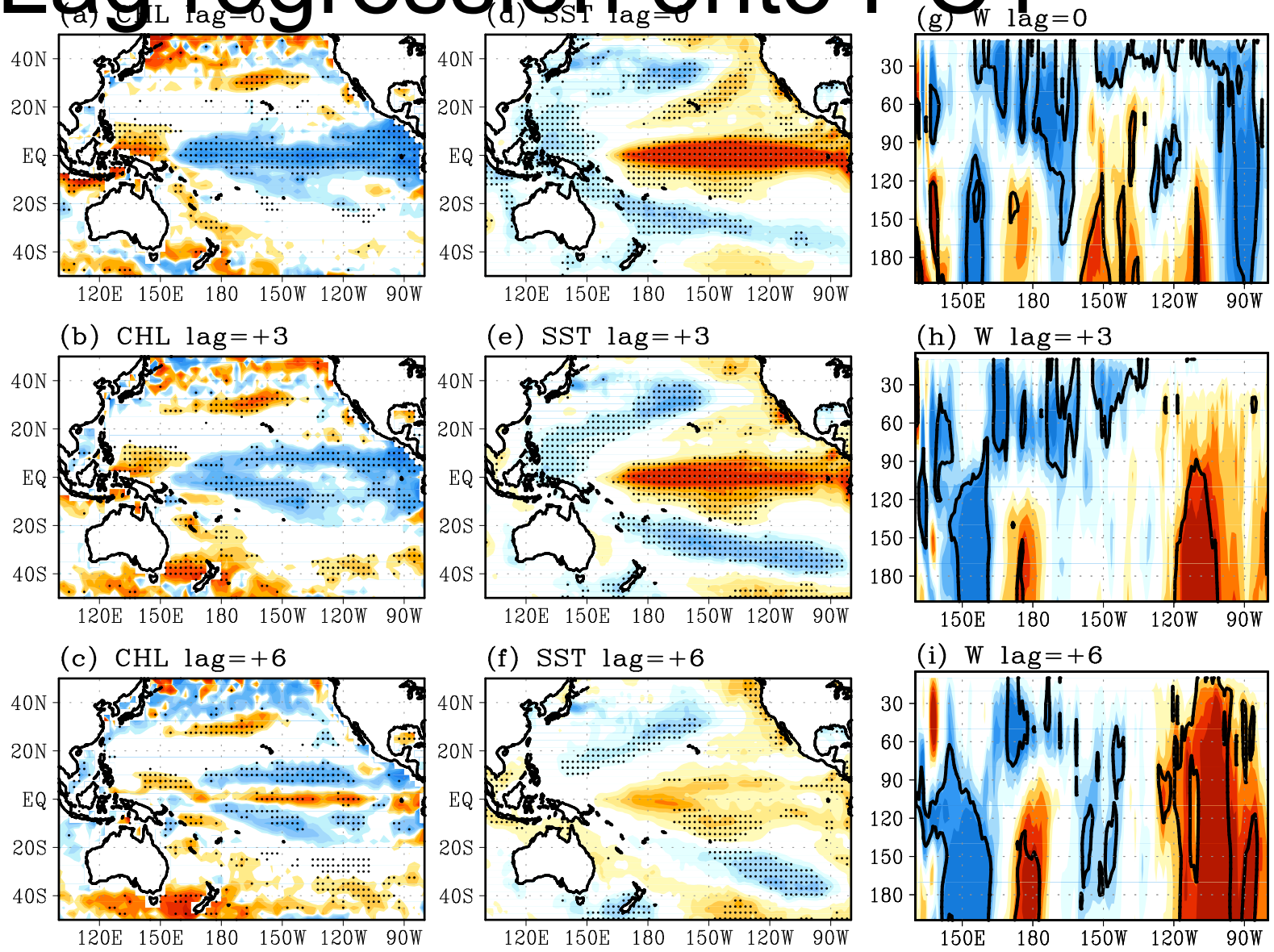


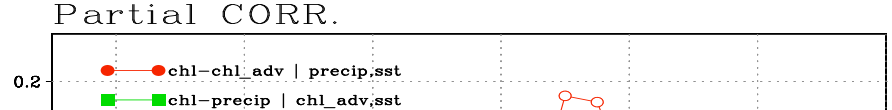
Lag regression onto PC1

Lag=0

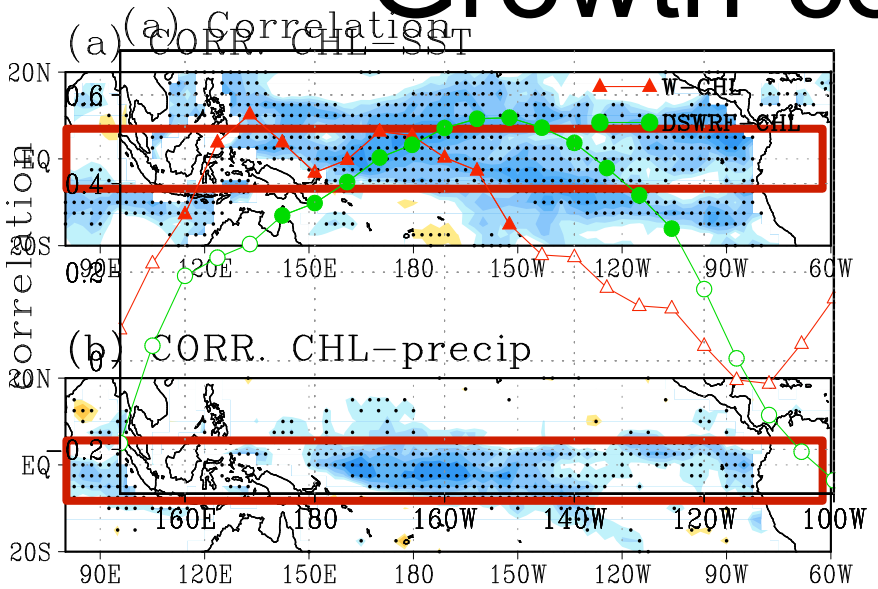
Lag=+3

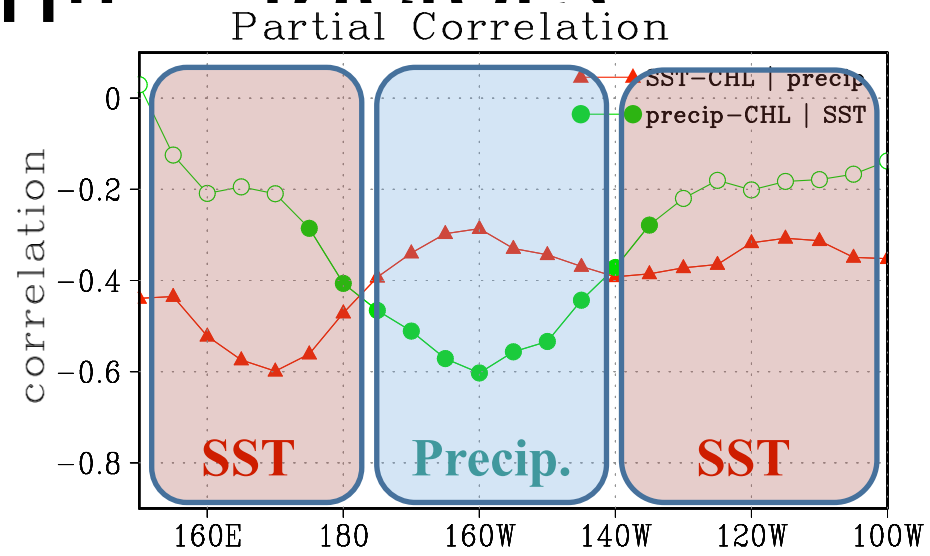
Lag=+6

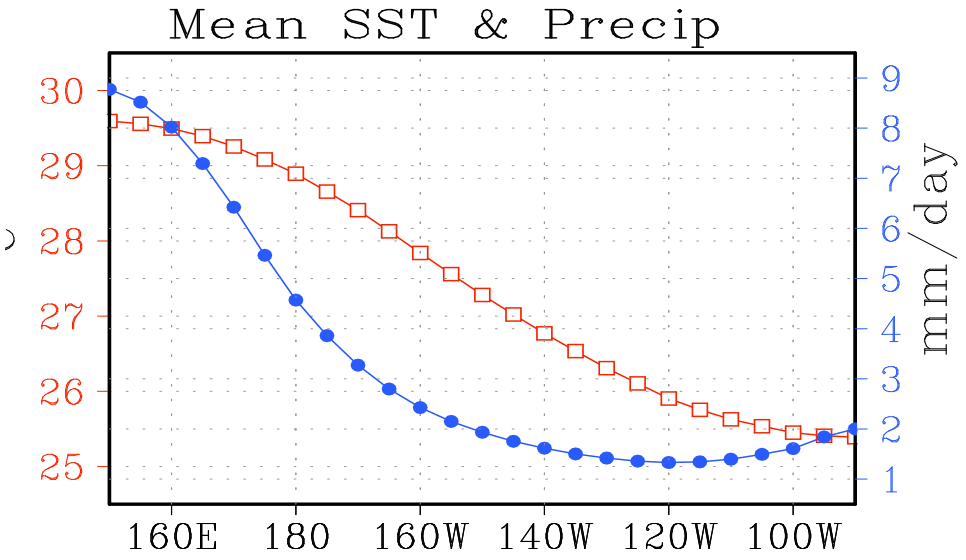




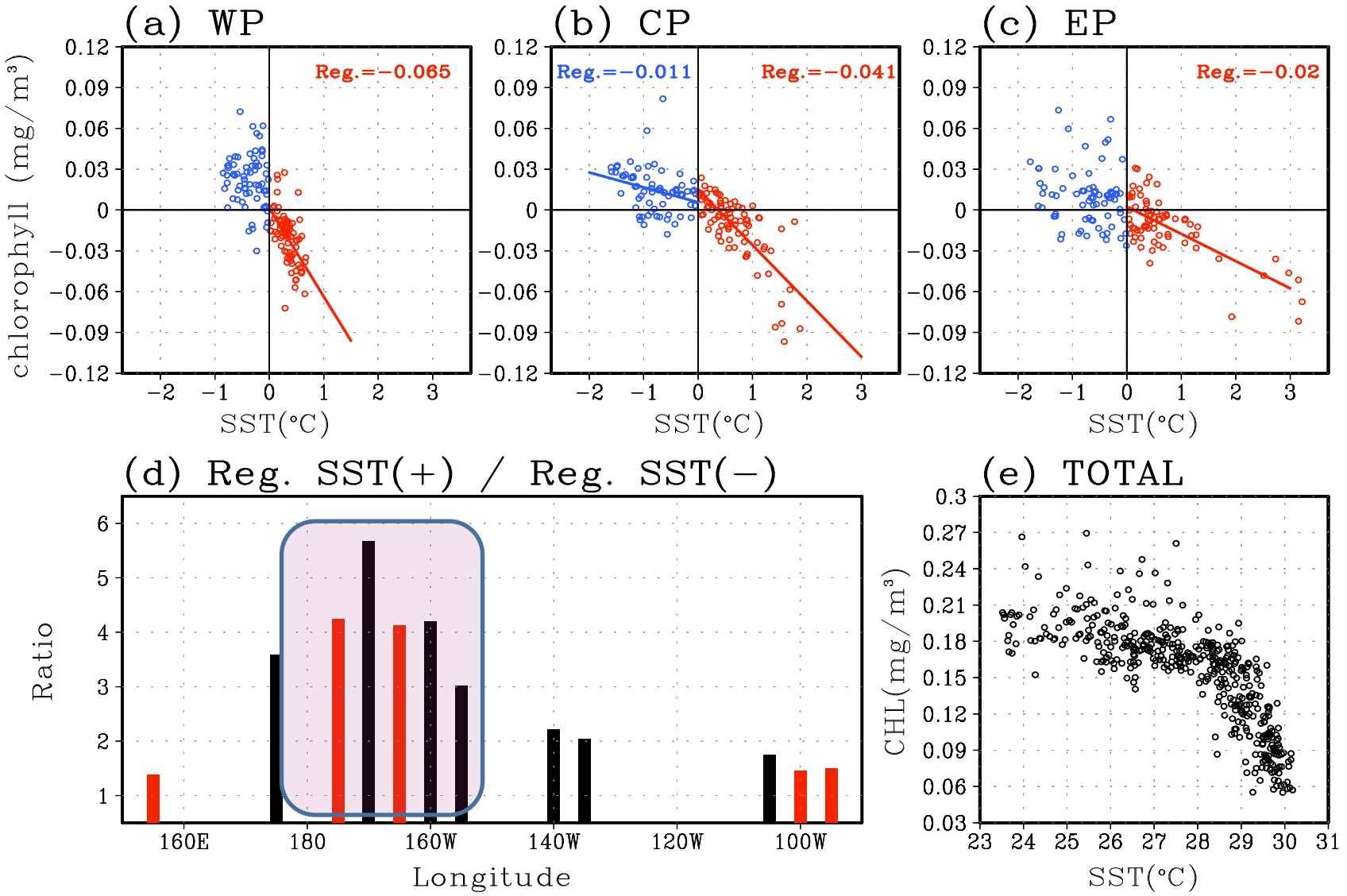
Growth-control factors



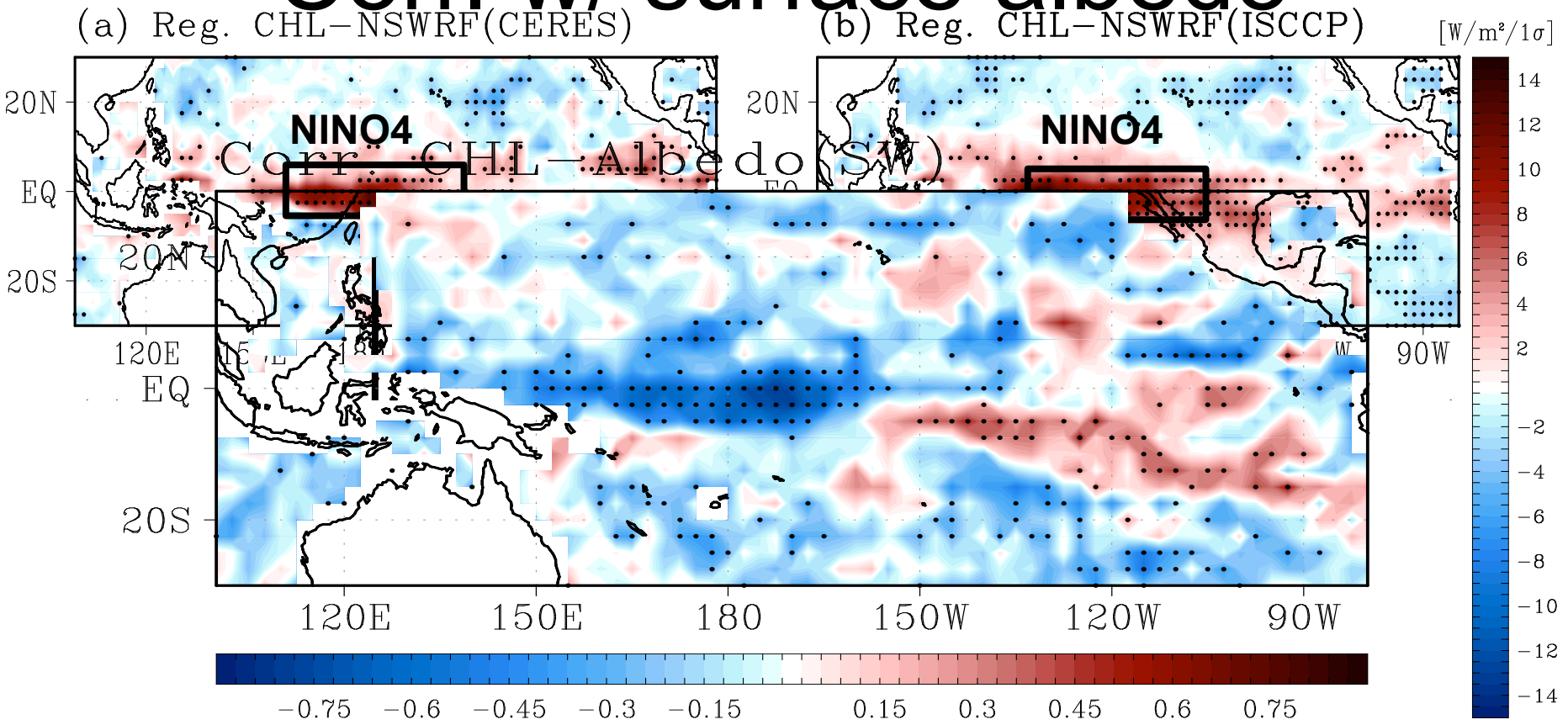




Asymmetric response to ENSO

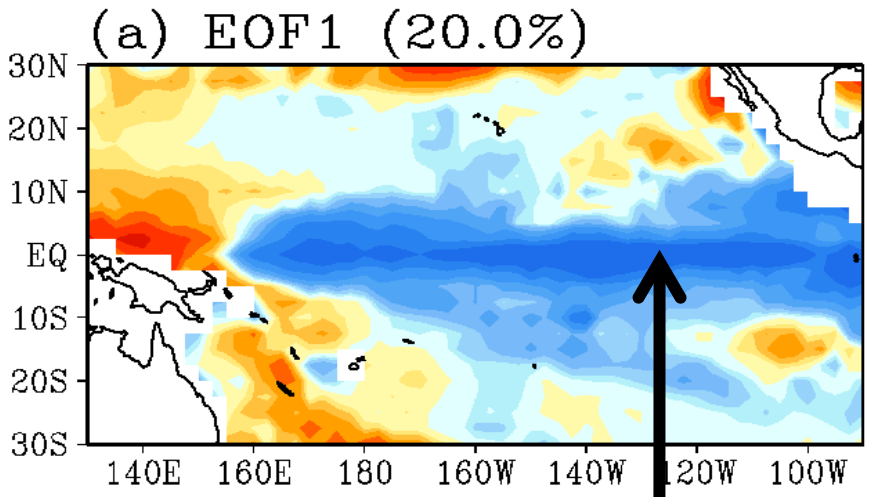


Corr. w/ surface albedo



“Cloud (OLR) effect removed ”

Feedback by ENSO-driven CHL



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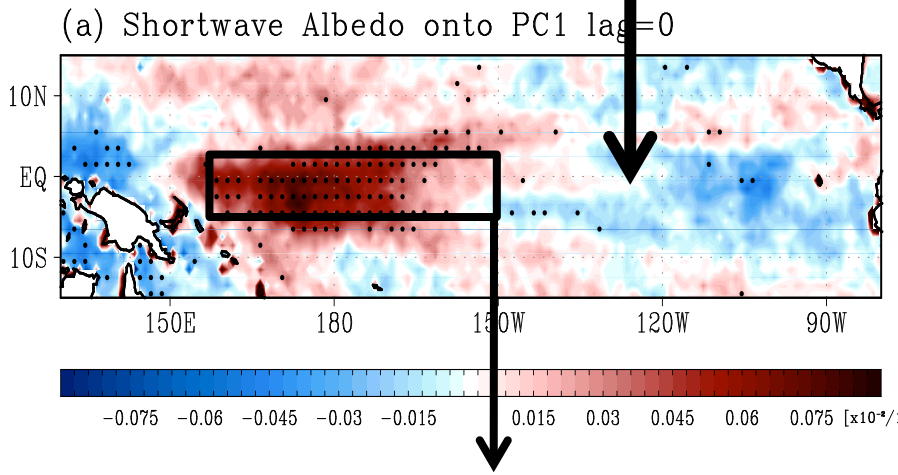
➢ **Physical parameters affecting ocean surface albedo**

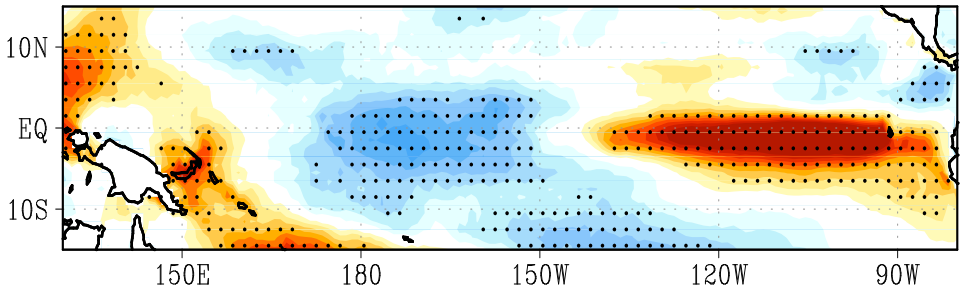
: Chlorophyll

: Solar zenith angle

: Cloud

: Wind speed





Radiant feedback by chlorophyll
: -2 W/m² Cooling effect

Figure 11. Regressed fields of the CERES net shortwave flux at the surface against the PC1 of chlorophyll concentration. Dotted areas denote 9

Variability of equatorial chlorophyll & its biological feedback

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Sang-Wook Yeh

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