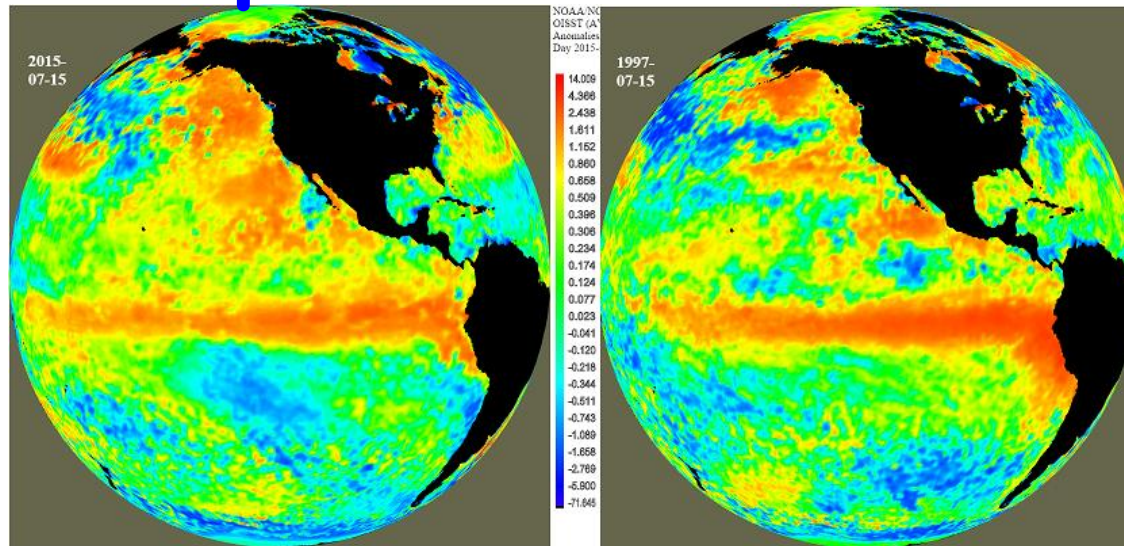


Implication of a new North Pacific climate paradigm on the 2015 El Niño and ENSO prediction



Yu-heng Tseng

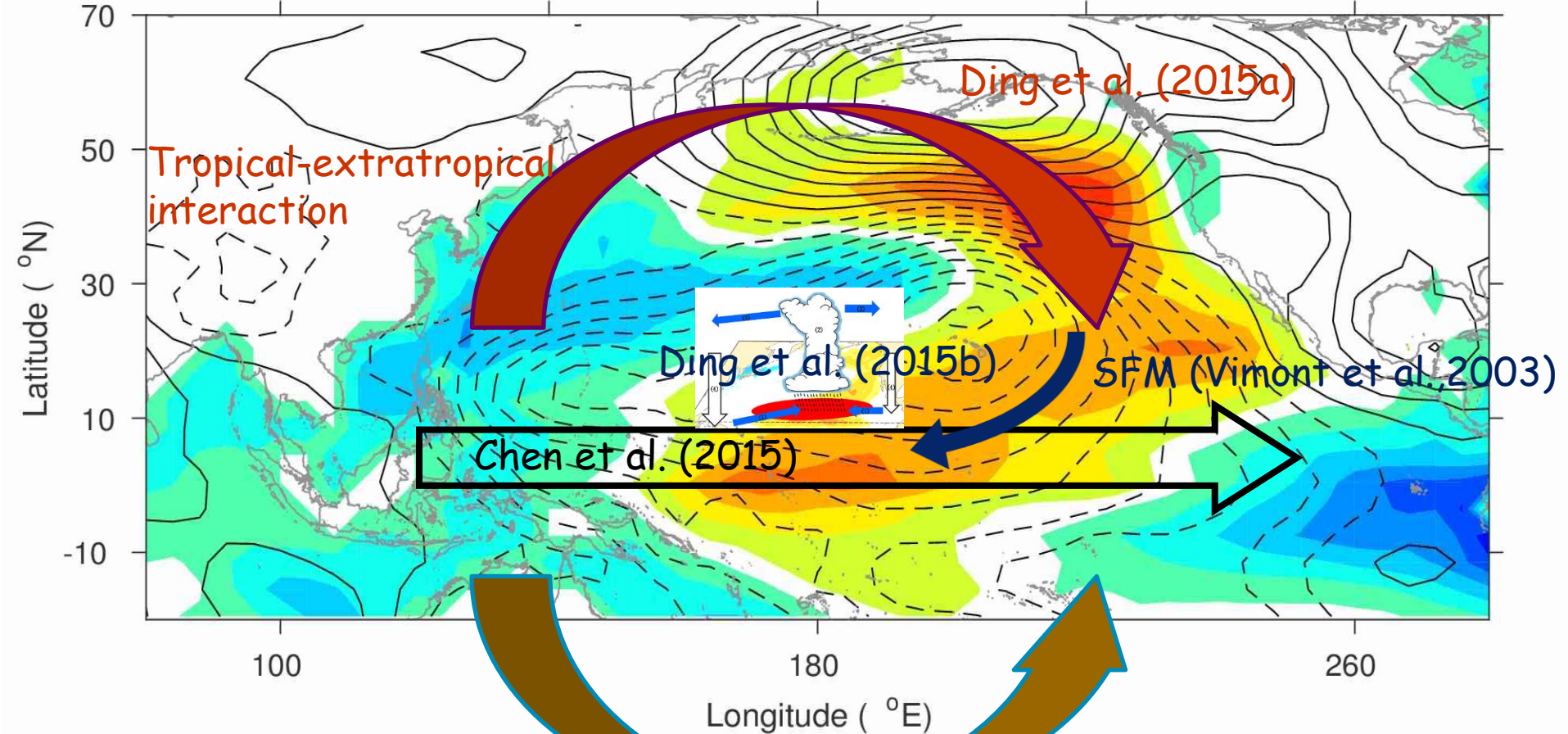
Climate and Global Dynamics Laboratory
National Center for Atmospheric Research, USA

Acknowledgments: Ruiqiang Ding, Zeng-Zhen Hu, Han-ching Chen Jiangping Li, Xiaomeng Huang, Art Miller
NSF EASM-3: Collaborative Research: Quantifying Predictability Limits, Uncertainties, Mechanisms, and Regional Impacts of Pacific Decadal Climate Variability

OUTLINES

- Reviews of the proposed North Pacific climate paradigm
 - Pacific Subtropical Cell and tropical variability
 - Interannual variability in Pacific
 - Extratropical impacts on the ENSO
- Implication on the **2015 El Niño**
- Implication on the **ENSO prediction**
- Conclusions and future work

New North Pacific climate paradigm



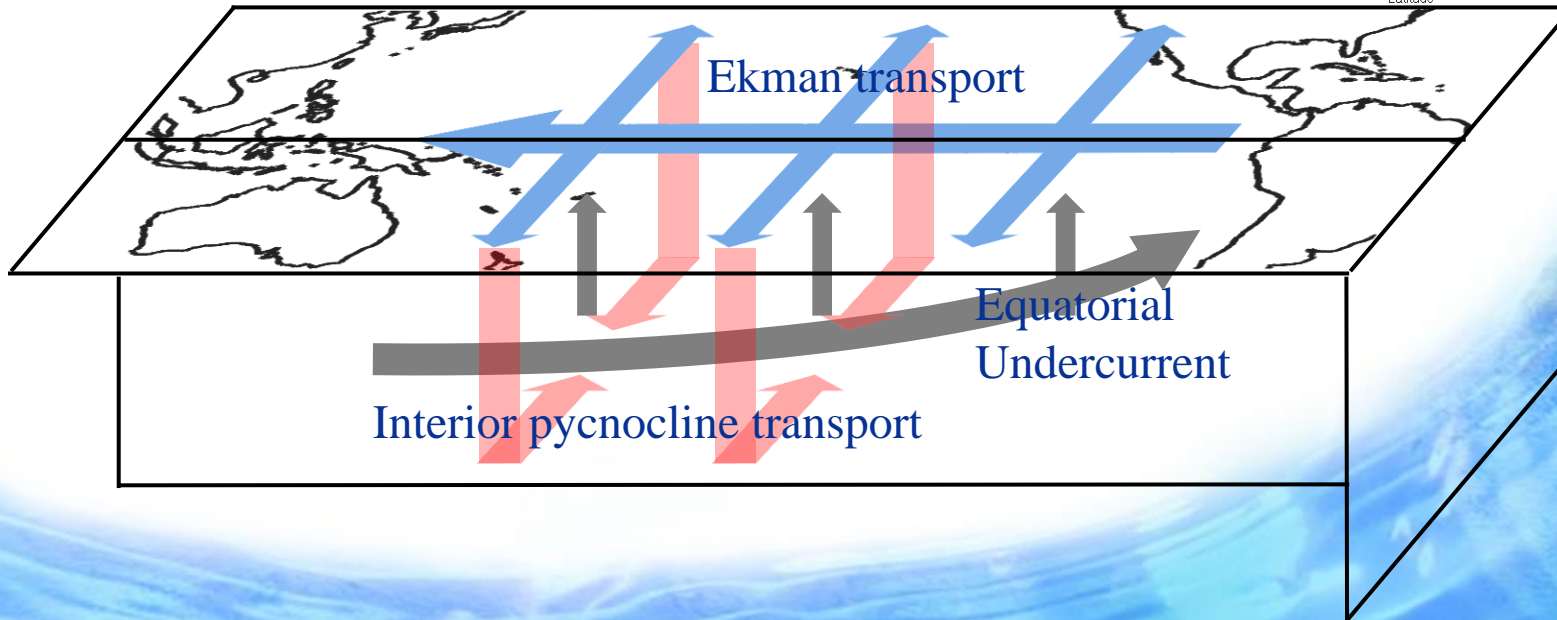
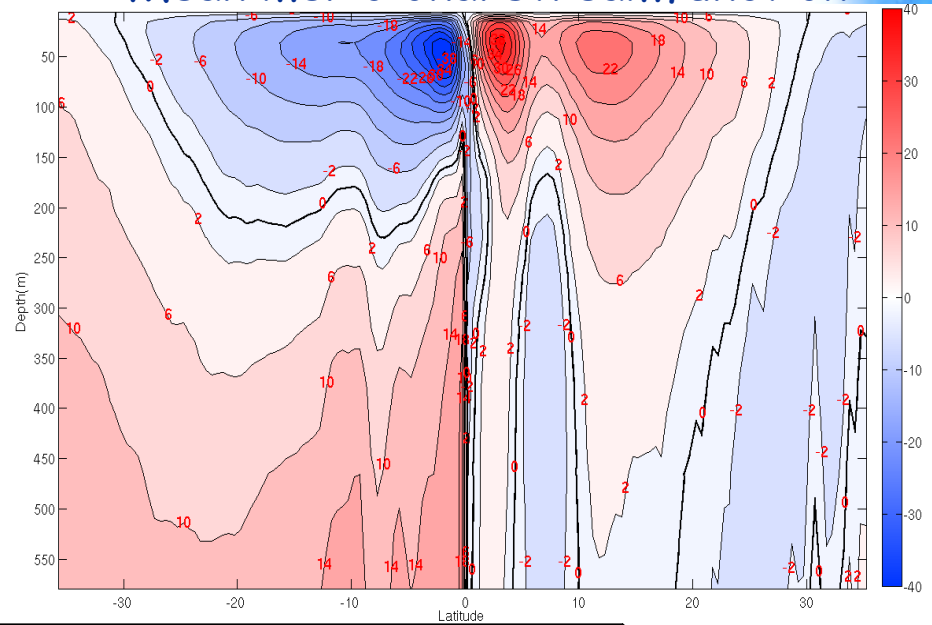
Tropical-extratropical interaction

Ding et al. (2015c); Ding et al. (2016), Zhang et al. (2014a,b)

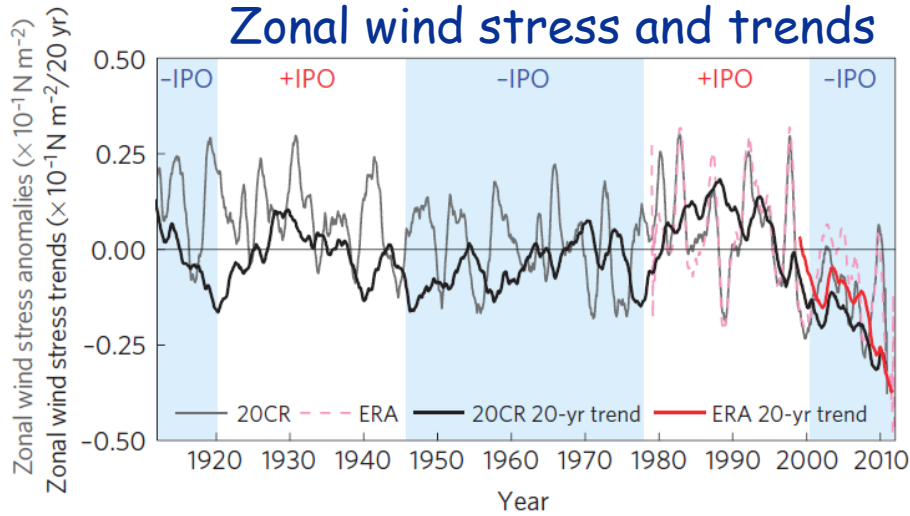
Subtropical Cells (STCs)

shallow meridional overturning circulations

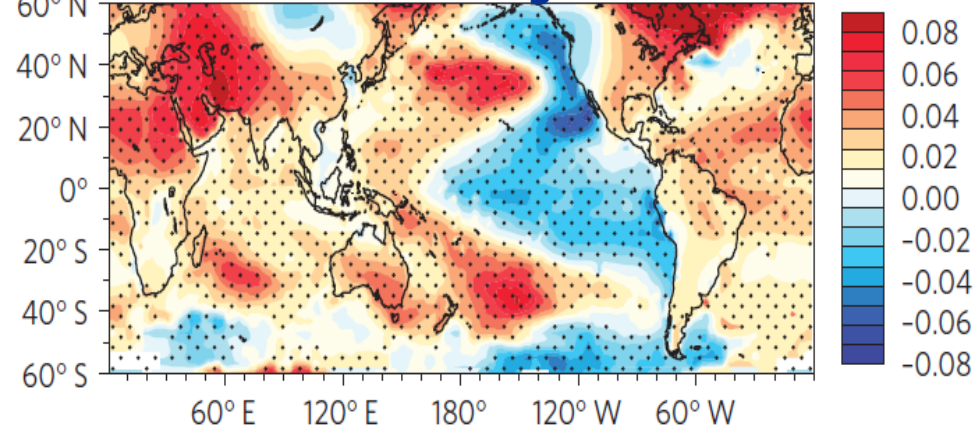
Mean meridional streamfunction



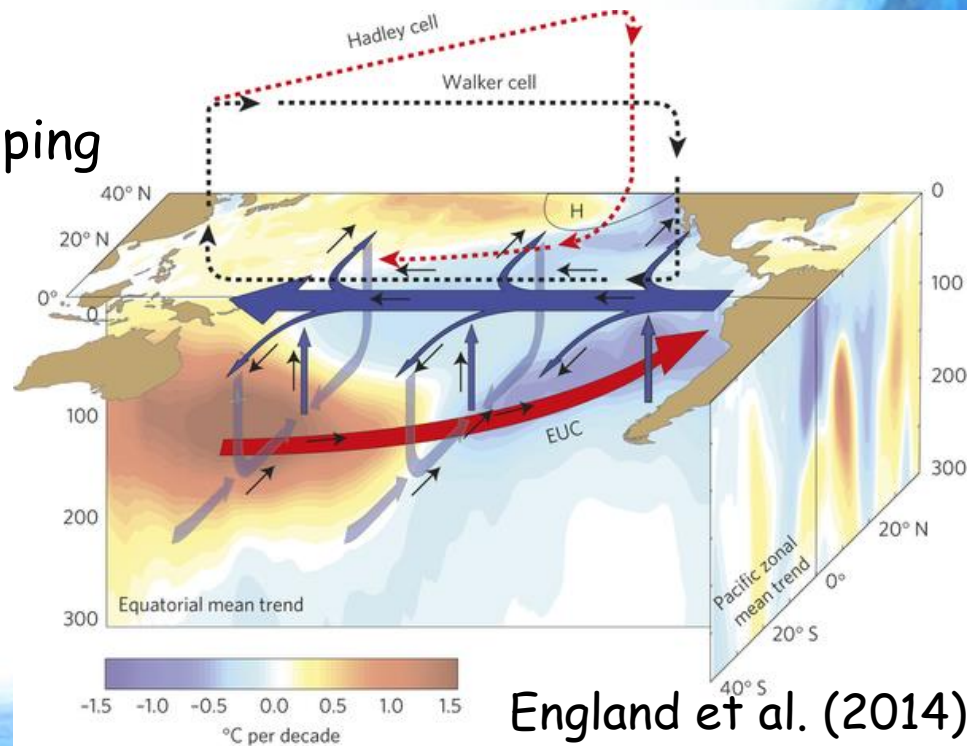
Zonal wind stress and trends



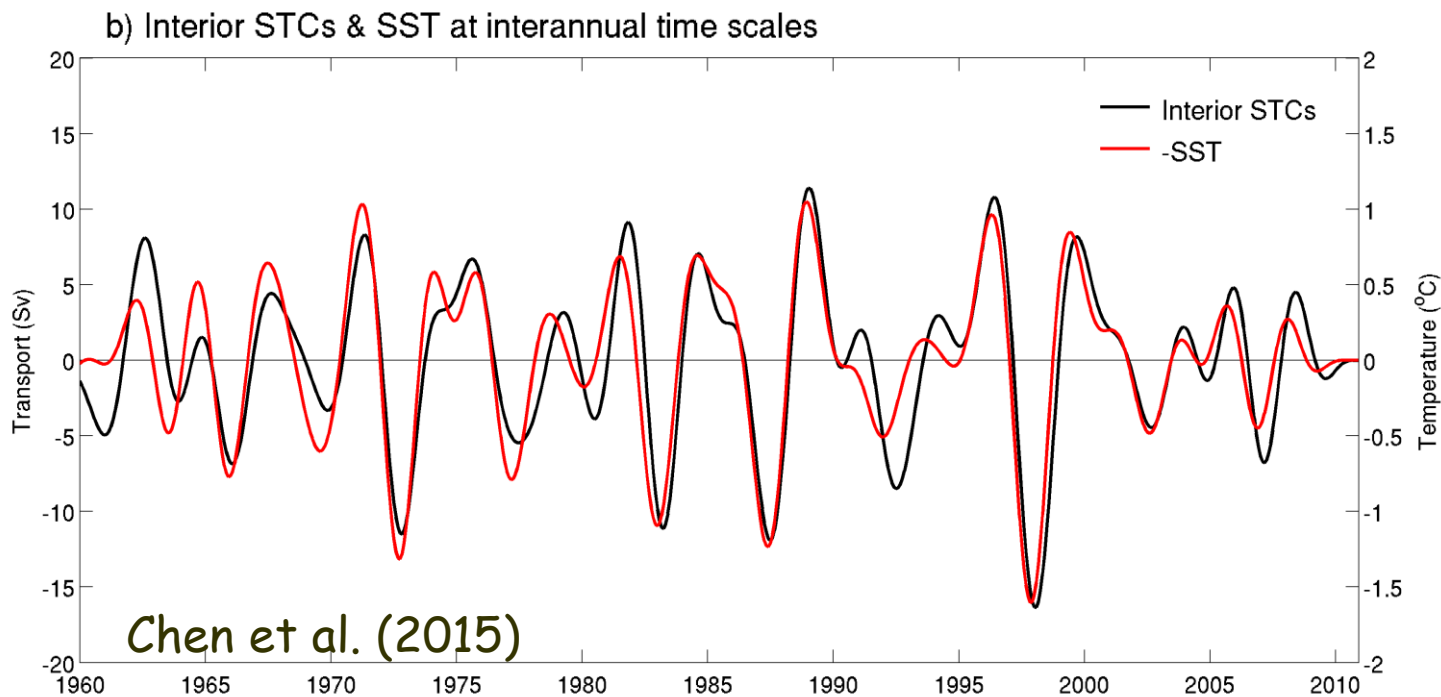
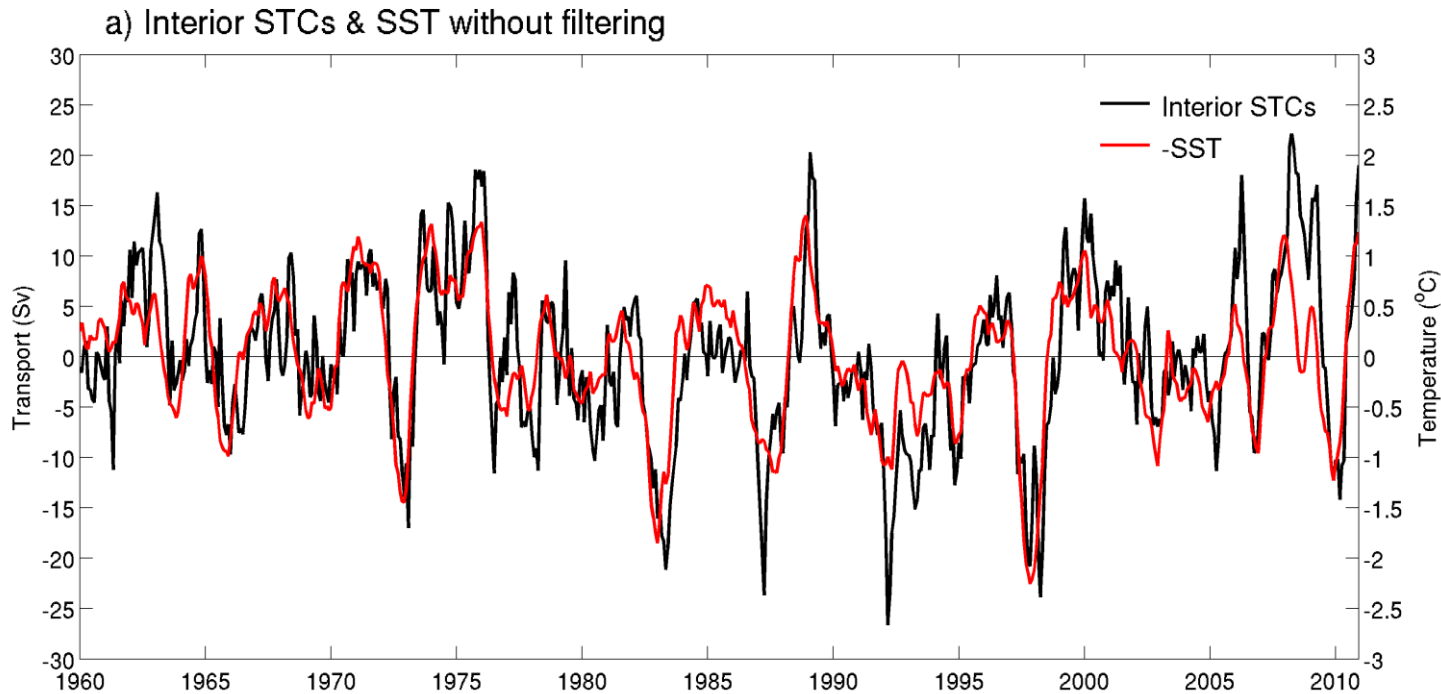
SAT trend Trend during 1992-2011



- =>Increased trade wind
- =>Strengthened STG and Ekman pumping
- =>Spin-up STC
- =>Enhanced EUC
- =>Increased equatorial upwelling
- =>Negative SSTA (warming hiatus)

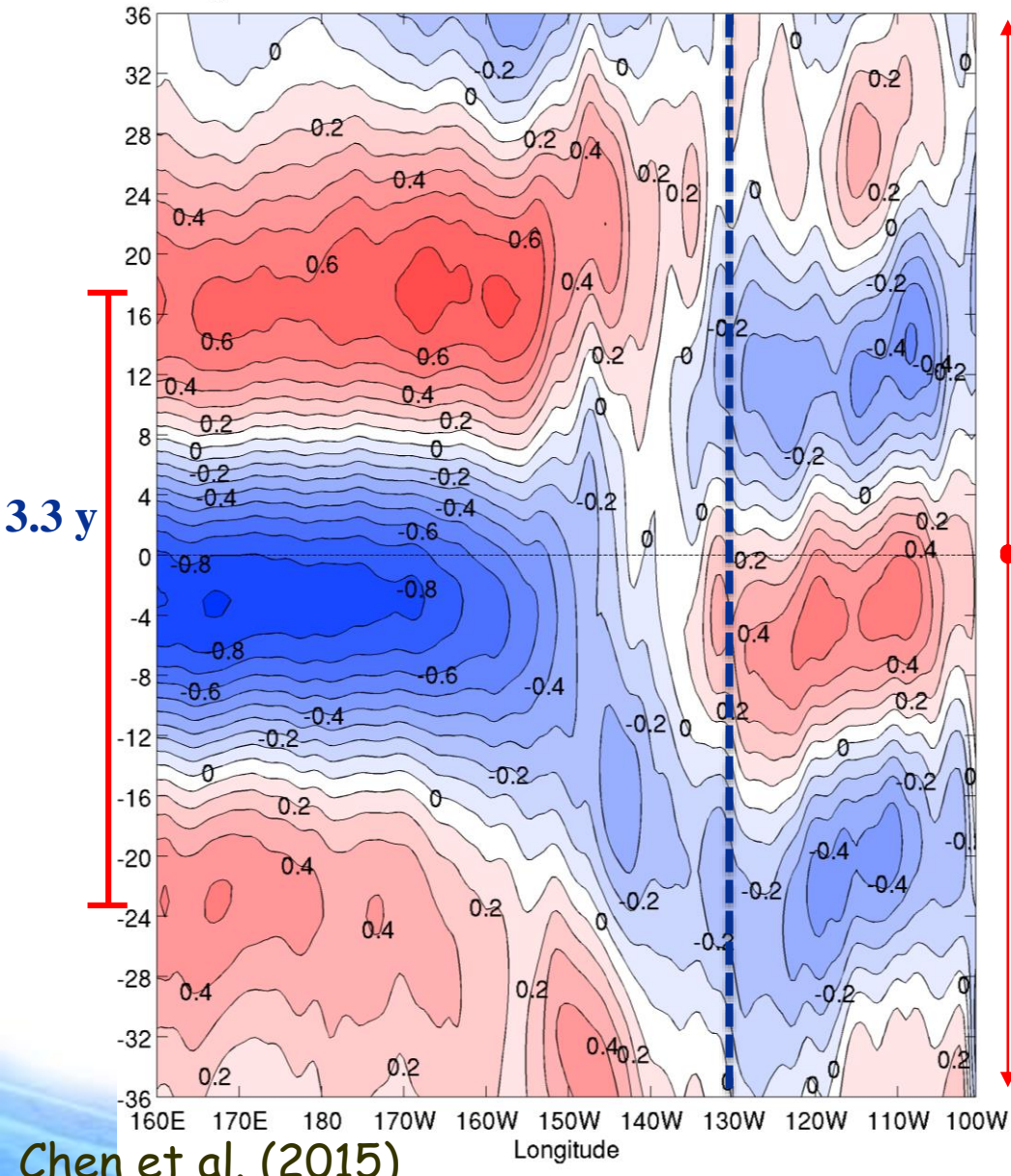


England et al. (2014)



SST and STCs lag-correlation

Lag-correlation at interannual time scale

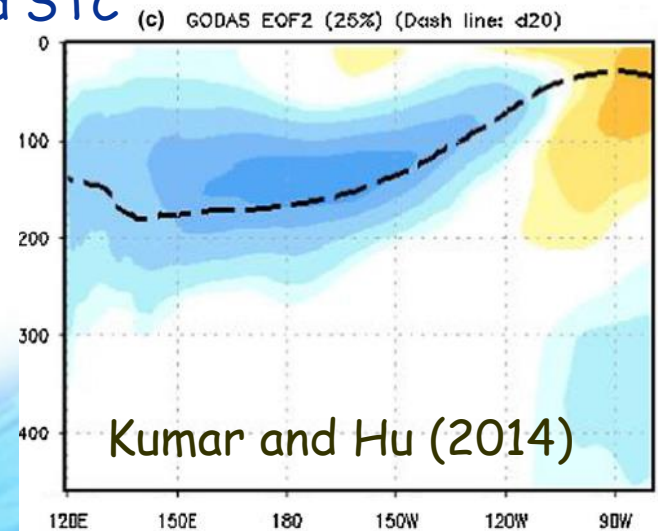


SST: 180°-90°W, 9°S-9°N

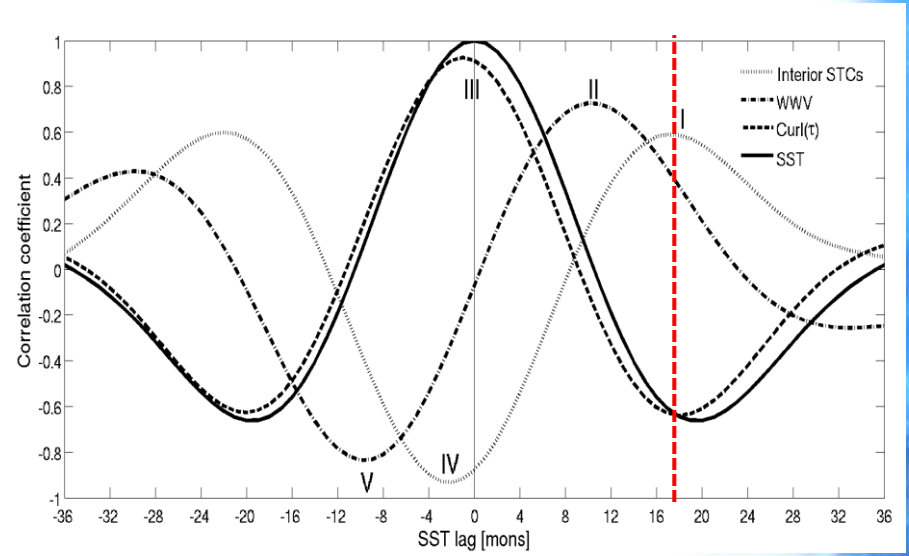
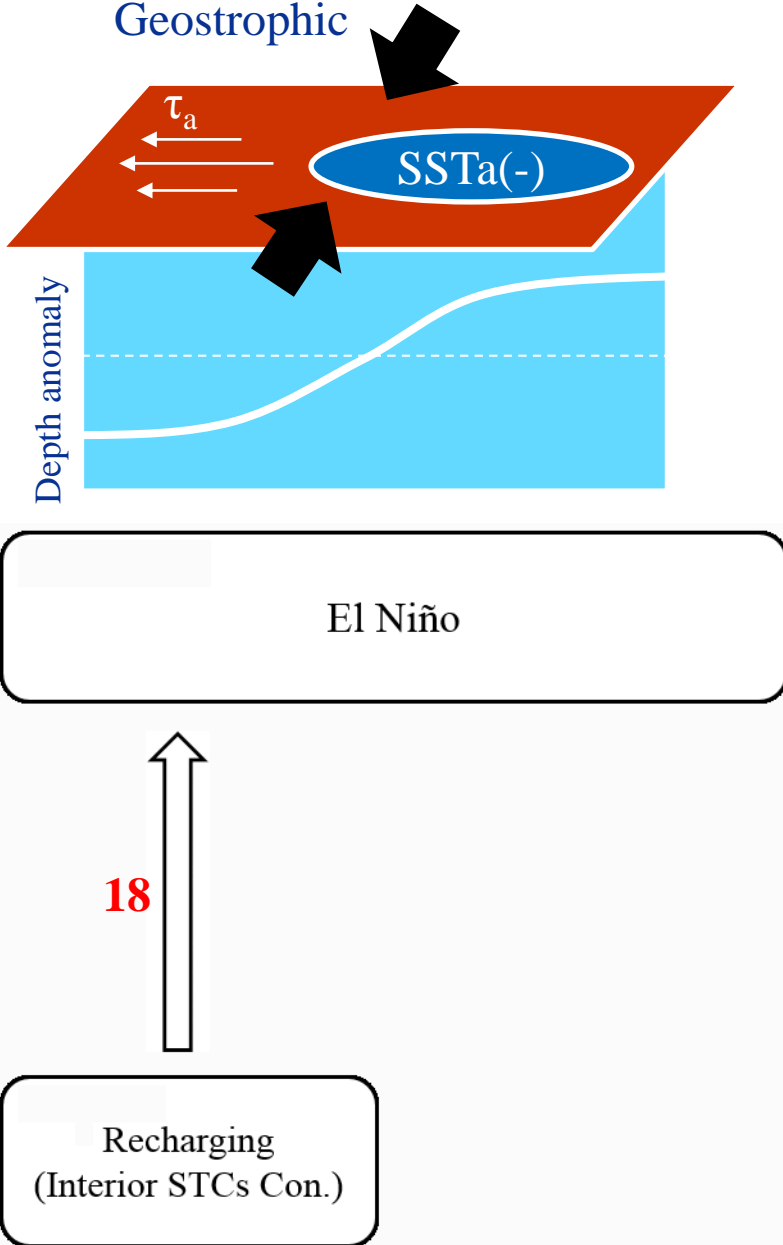
SST lag STC

$$STC(L) = \int_{100^{\circ}W}^L \int_{26\sigma_{\theta}}^{50m} v \, dz \, dx$$

SST lead STC

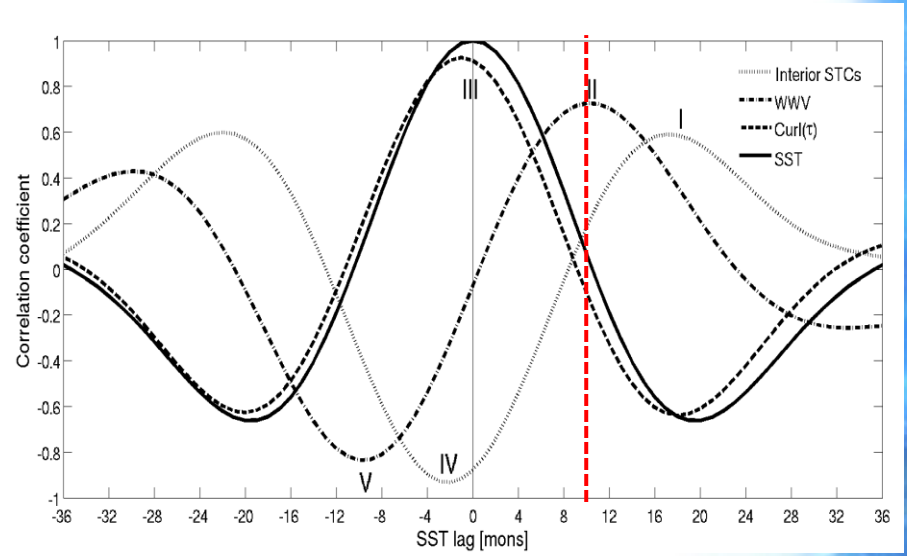
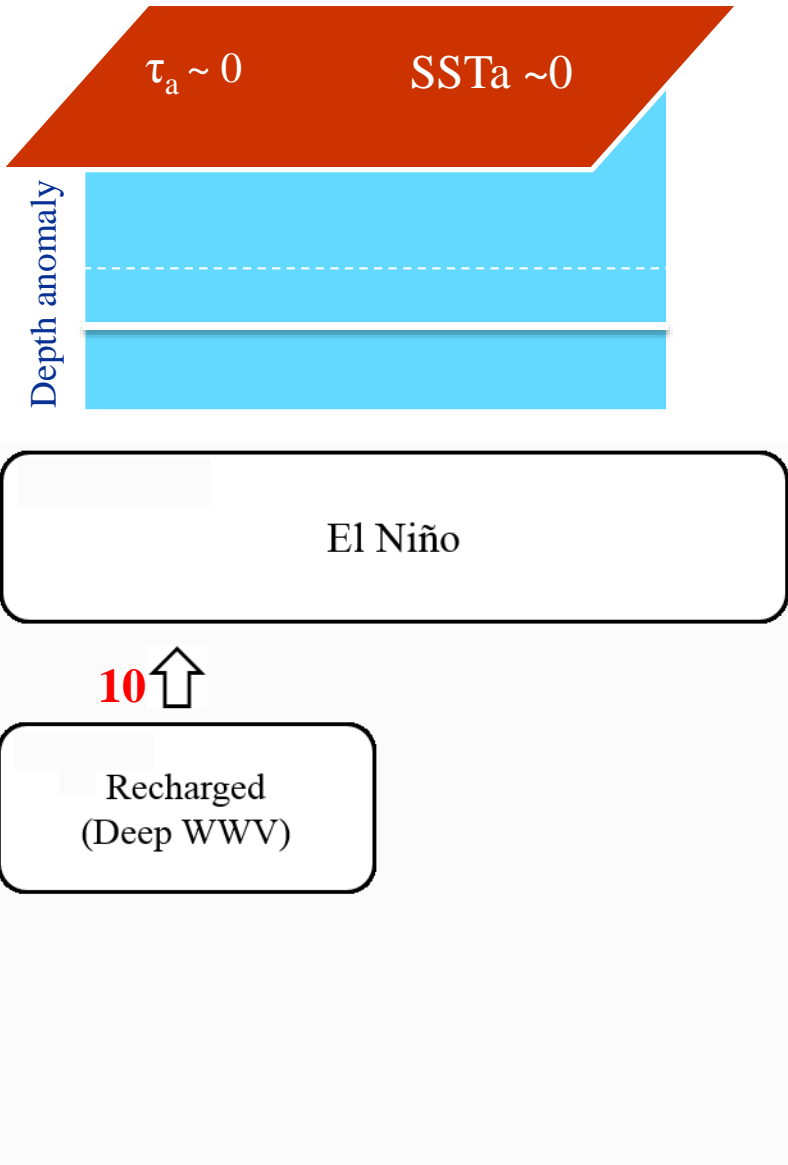


Geostrophic



SST lead

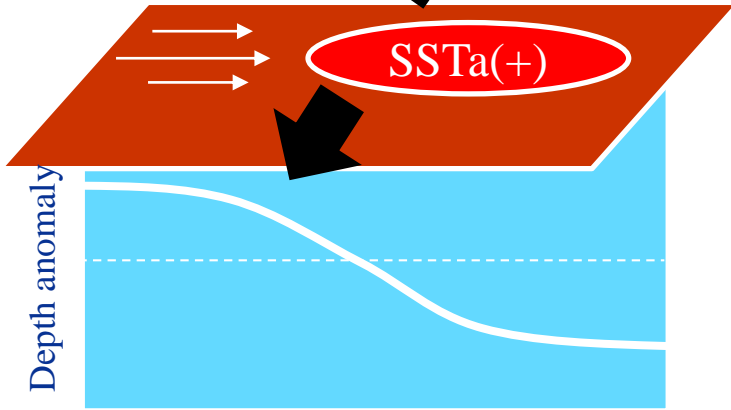
18
SST lag



SST lead

10
SST lag

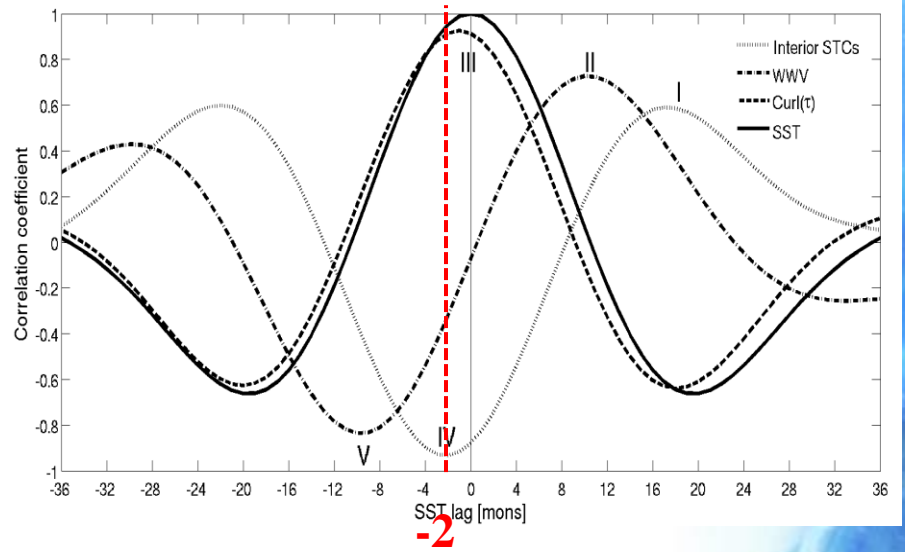
Geostrophic



El Niño

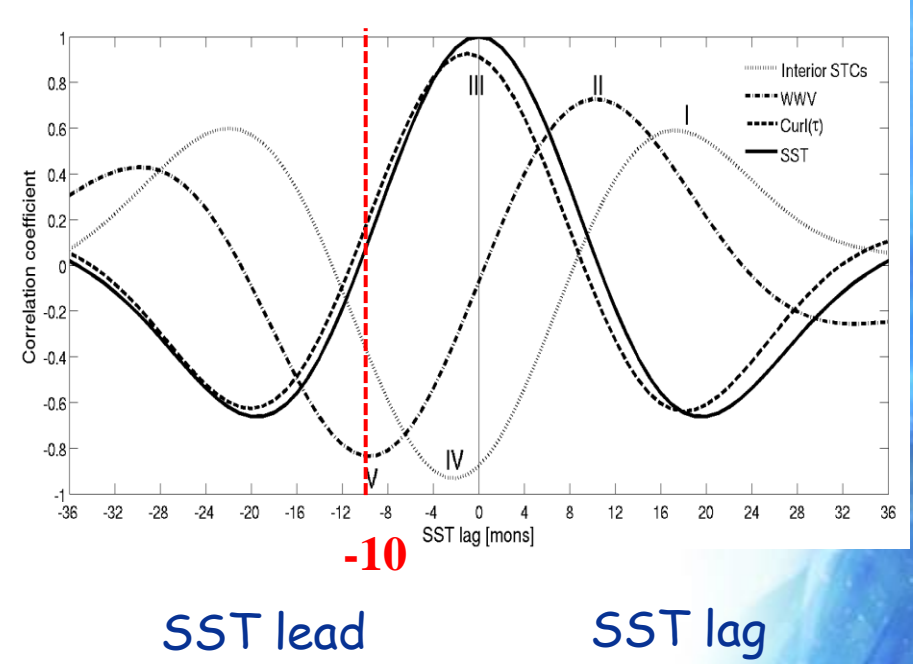
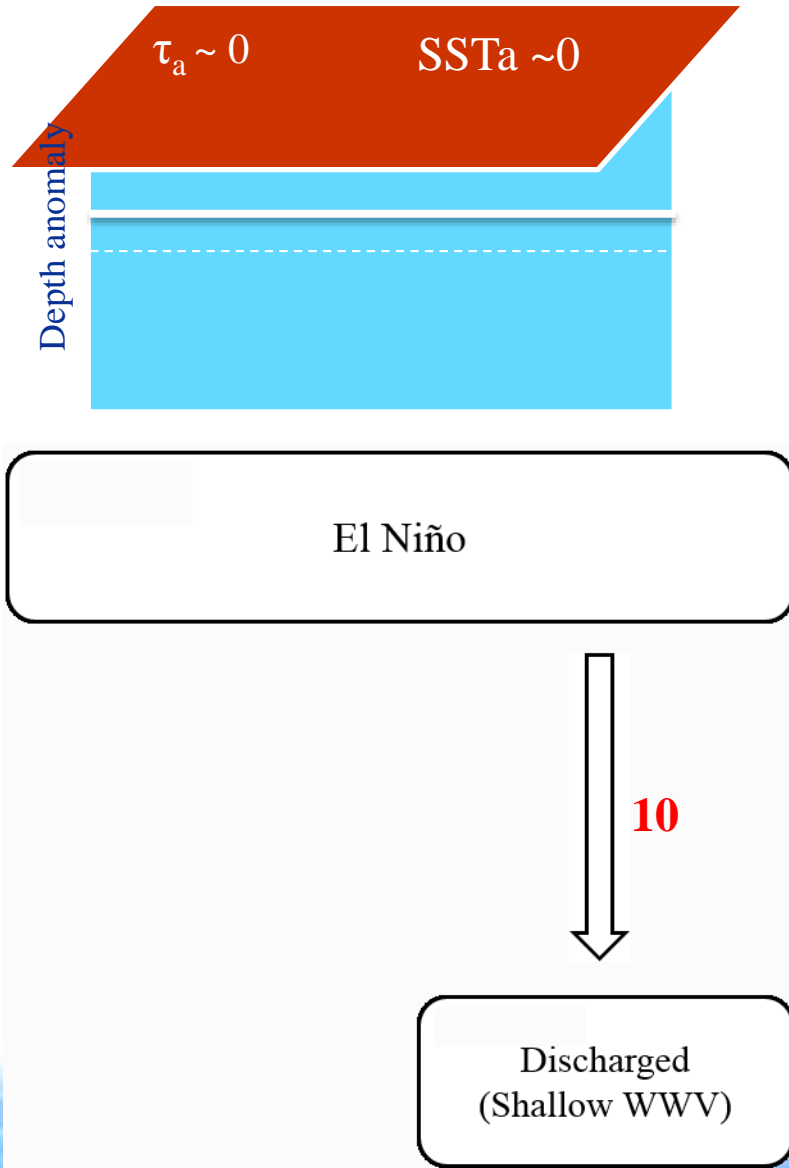


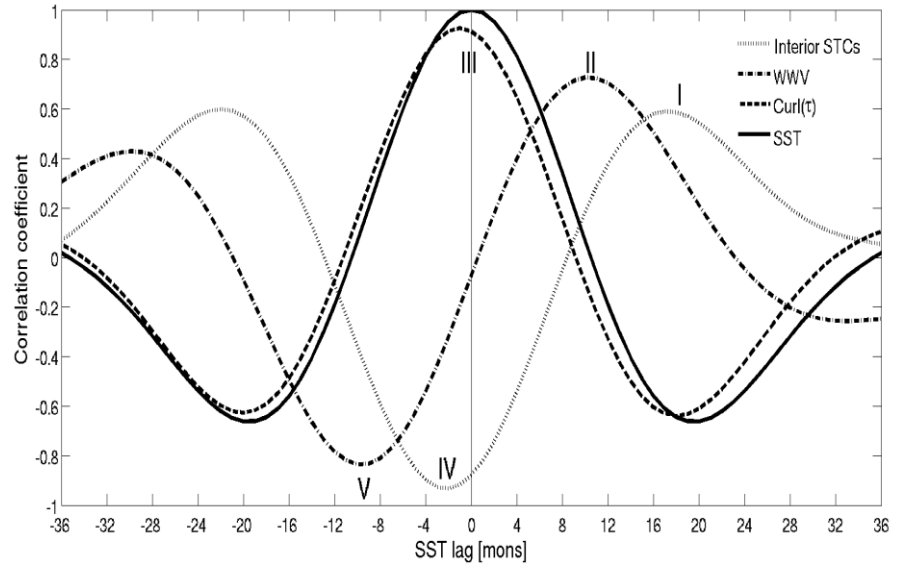
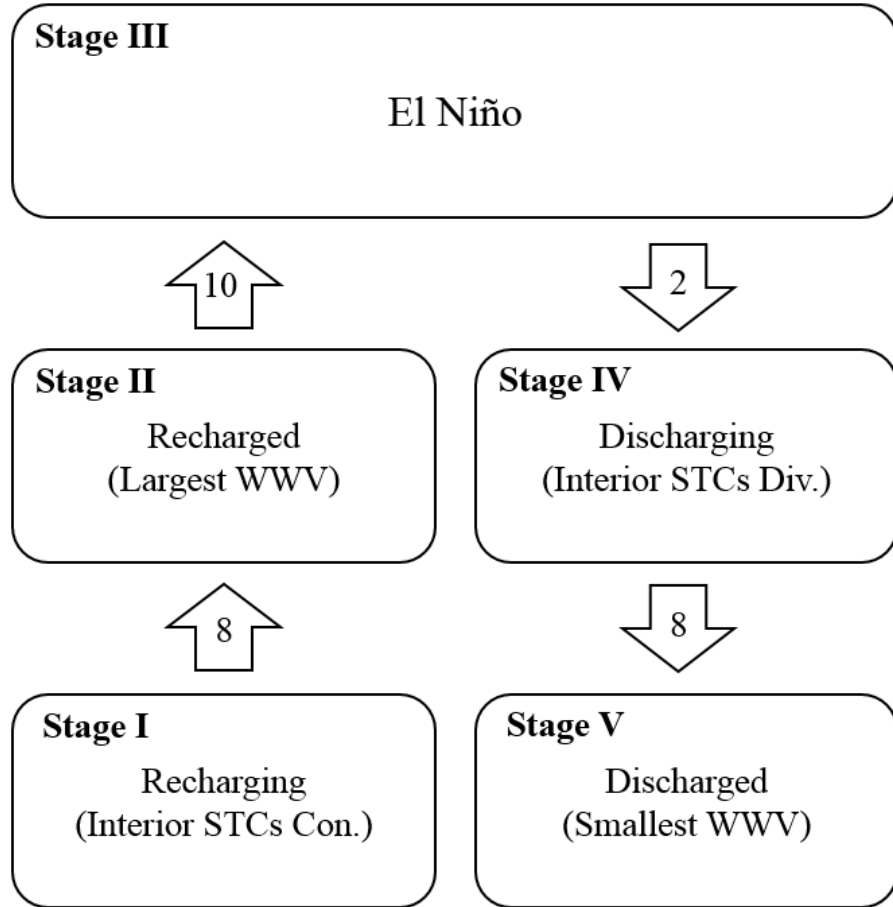
Discharging
(Interior STCs Div.)



SST lead

SST lag





The corresponding timescales for the completed process (from a recharging stage to a discharged stage) are 8, 10, 2 and 8 months, respectively.

Questions:

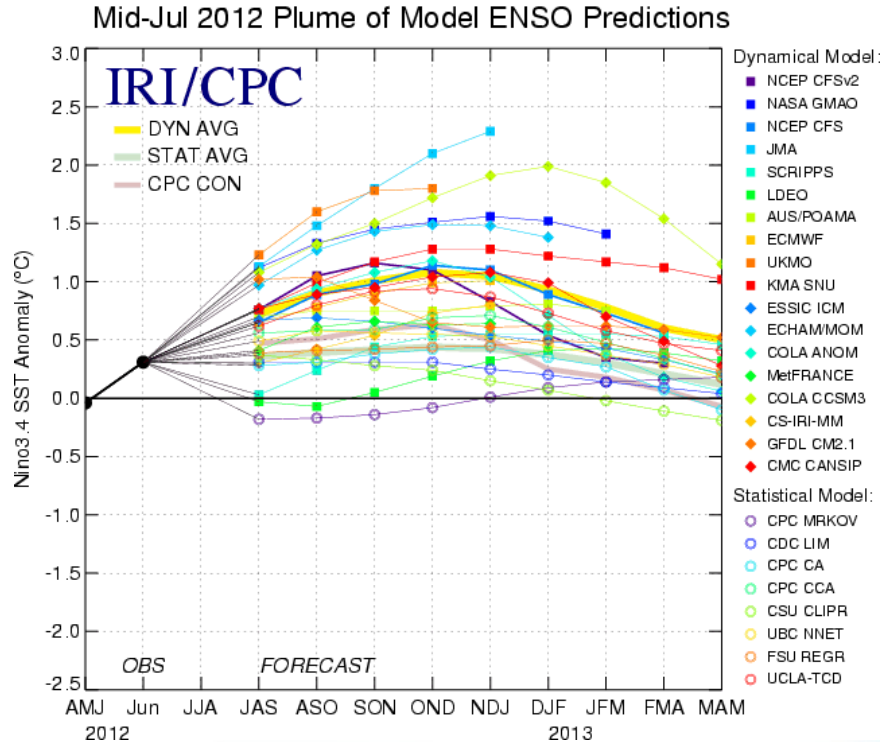
- Is this the whole story?
- Why do we still have the spring barrier and why the current models give the false alarm in 2012?



WWV and STC tell us **ONLY** the interannual variability

Questions:

- Is this the whole story?
- Why do we still have the spring barrier and why the current models give the false alarm in 2012?

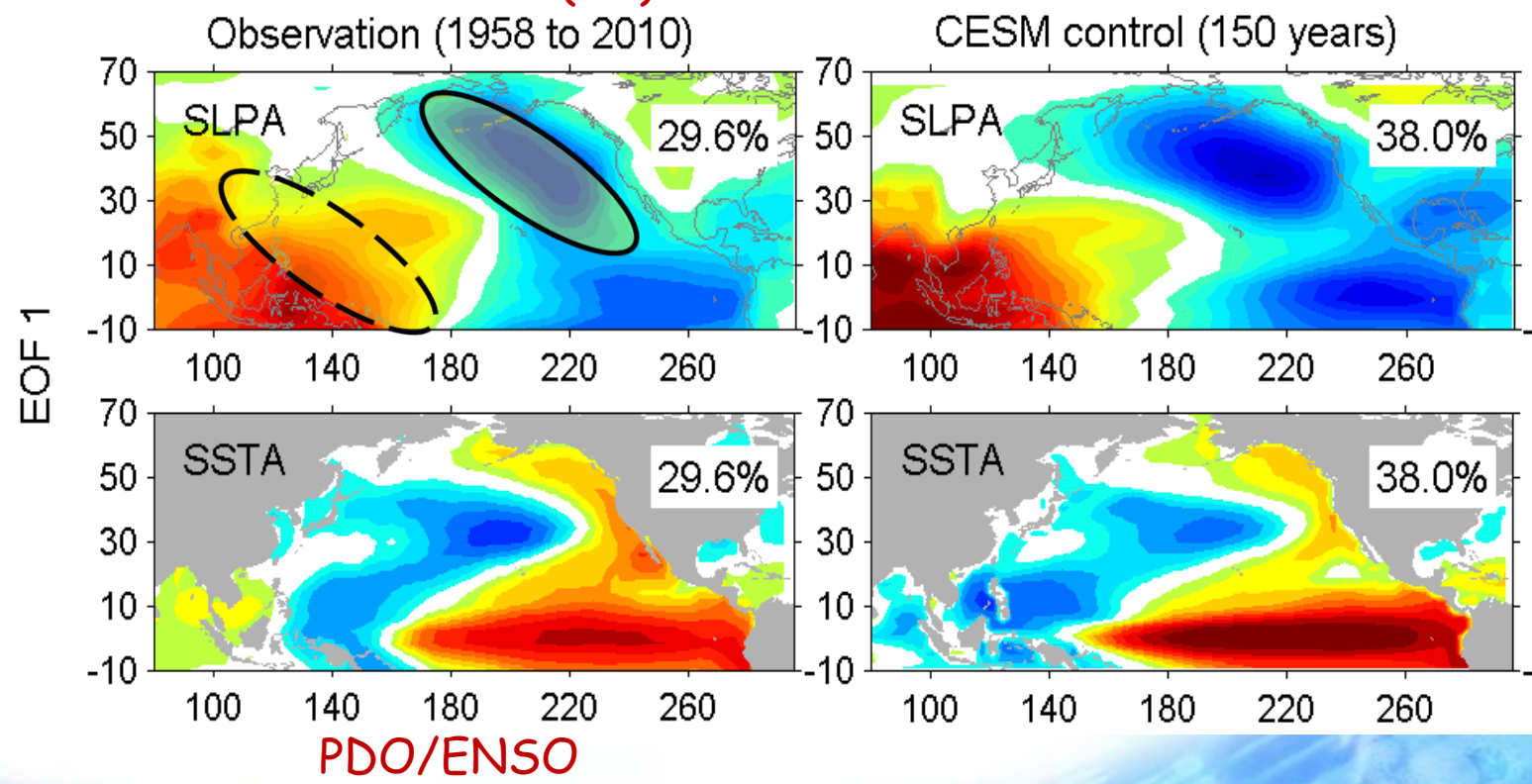


The dominant surface pattern and variability in the North Pacific - 1st mode

The covariability mode of SLP and SST anomalies from the CEOF1 analysis

Obs: NCEP reanalysis, ERSST (1958-2010),
Model: CESM1.0.5 (150 yr)

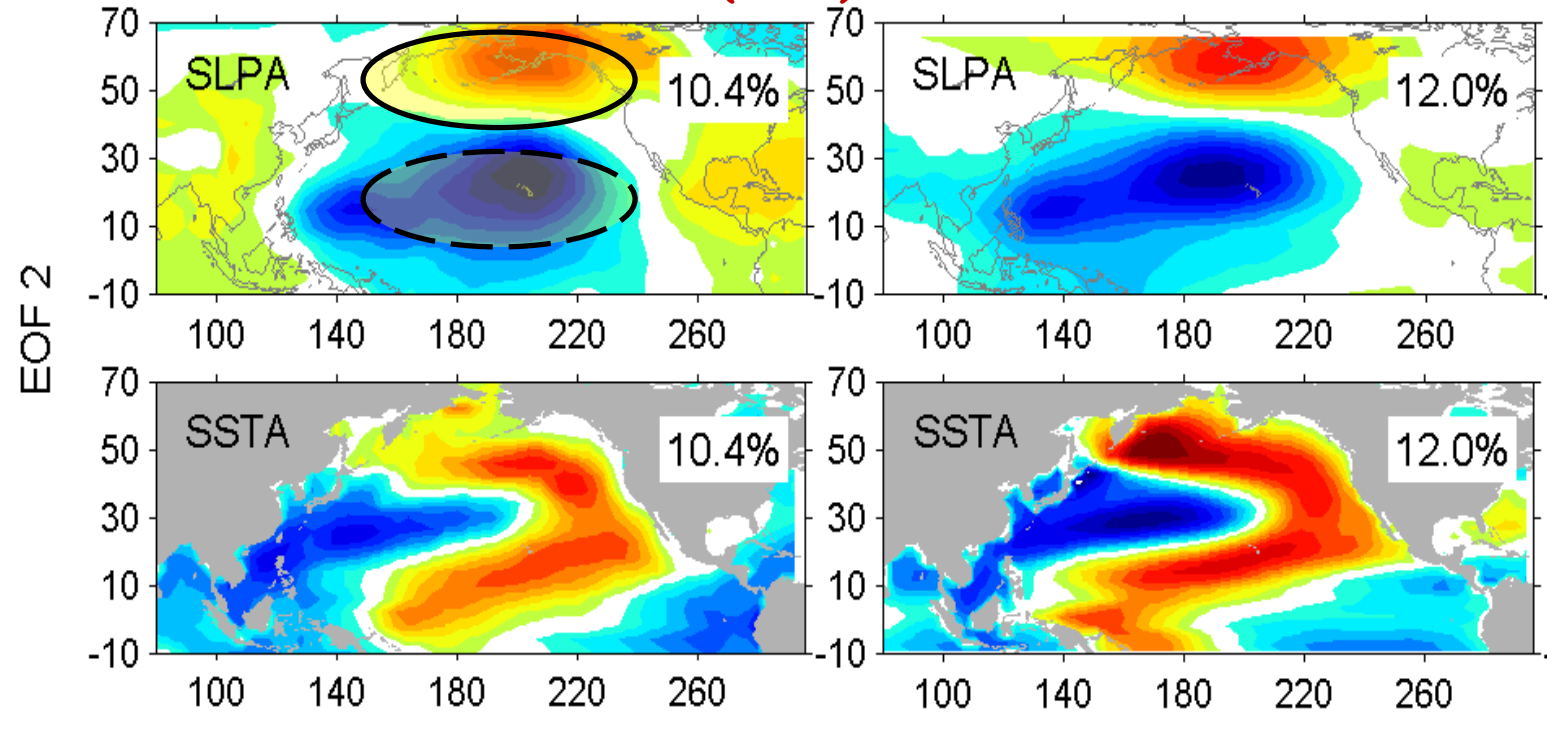
Aleutian Low (AL)



The dominant surface pattern and variability in the North Pacific - 2nd mode

The covariability mode of SLP and SST anomalies from the CEOF2 analysis

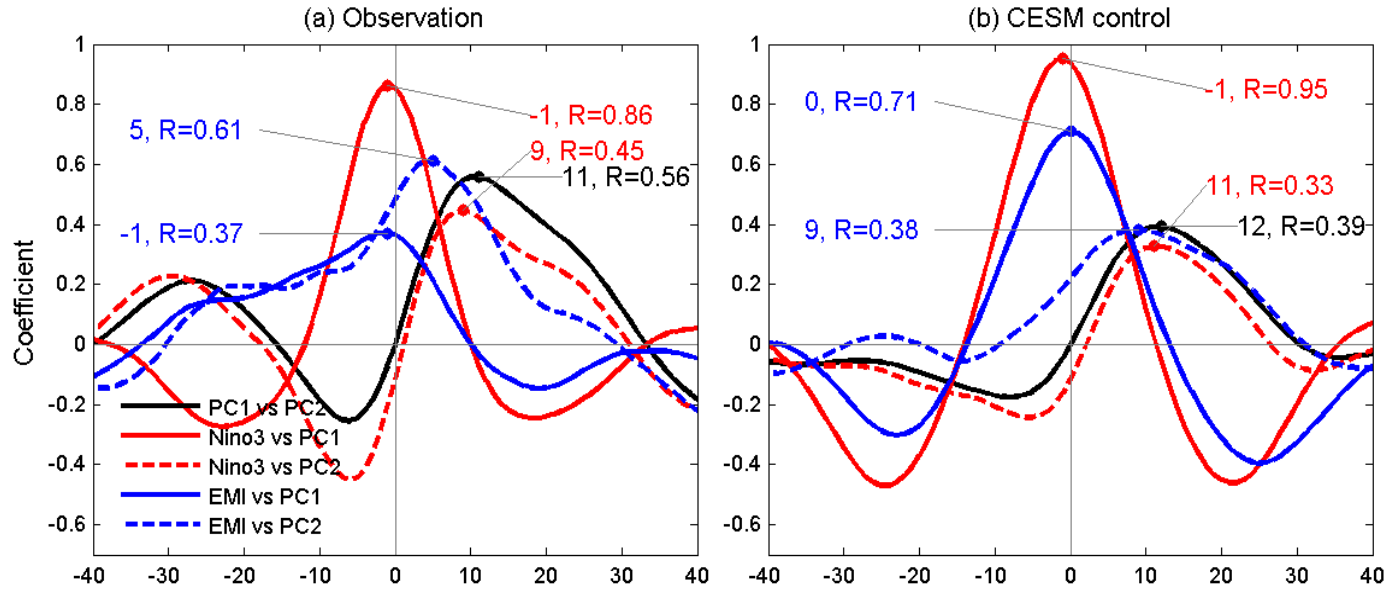
North Pacific Oscillation (NPO)



Victoria Mode (VM) or NPGO

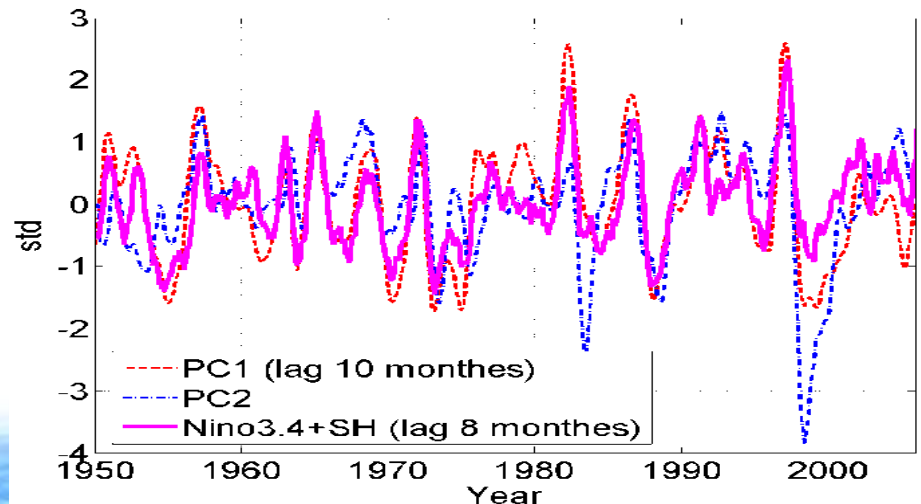
Links between the two dominant CEOF modes

Lag-correlation between Niño3 (and EMI index) and PC1/PC2 of the CEOF



- PC1 is essentially ENSO
- PC2 leads PC1/Niño3 by 9-11 months
- PC2 leads EMI by 5 months

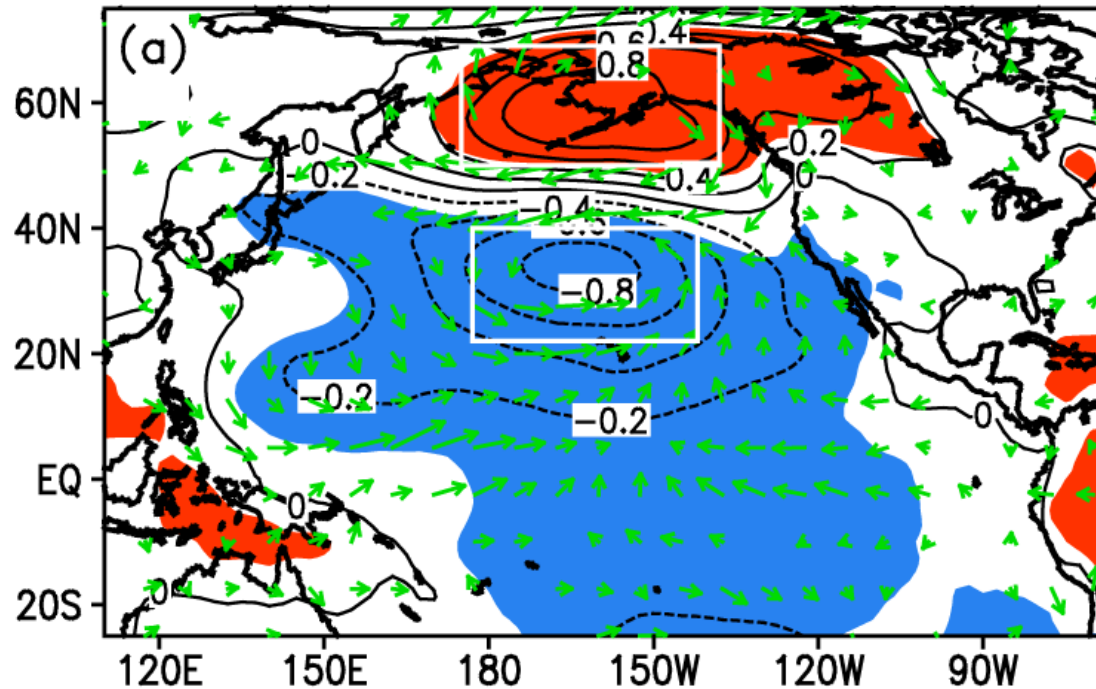
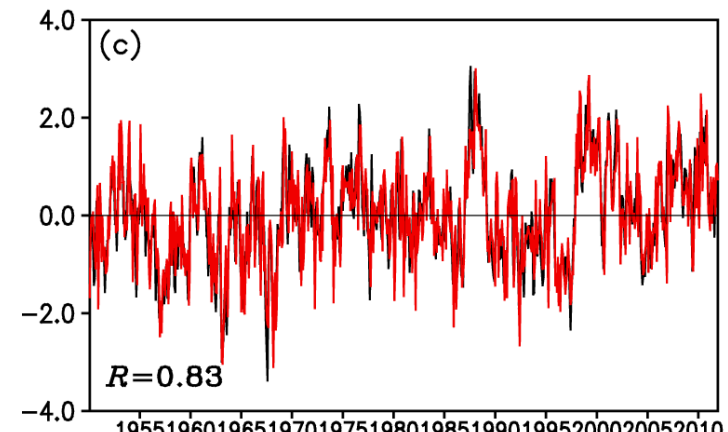
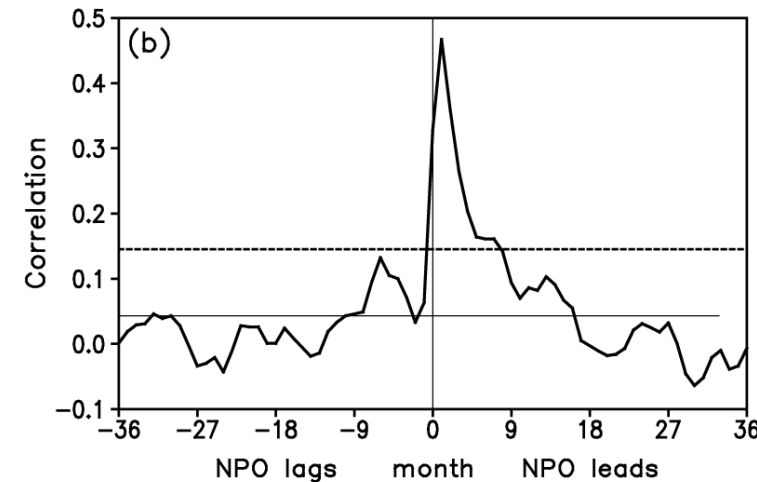
PC2 (NPO/VM): important ENSO precursor



Pacific SLP and surface wind anomalies regressed on the VM

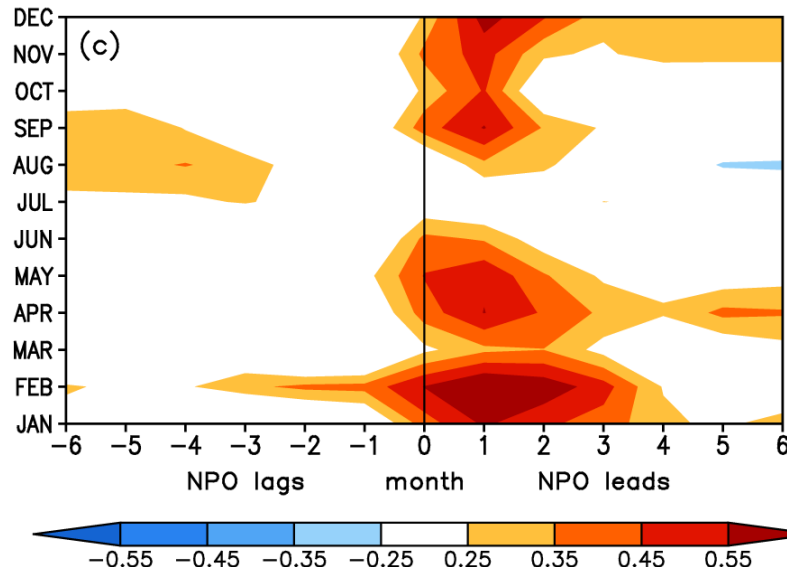
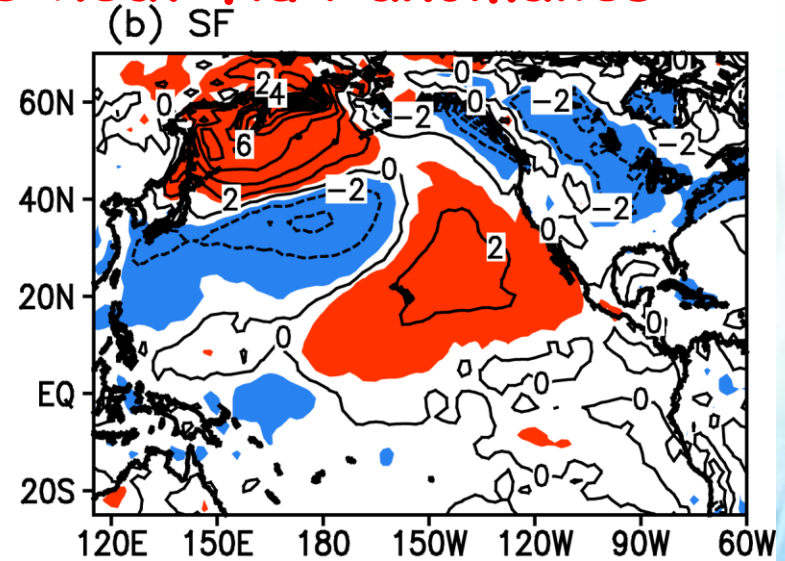
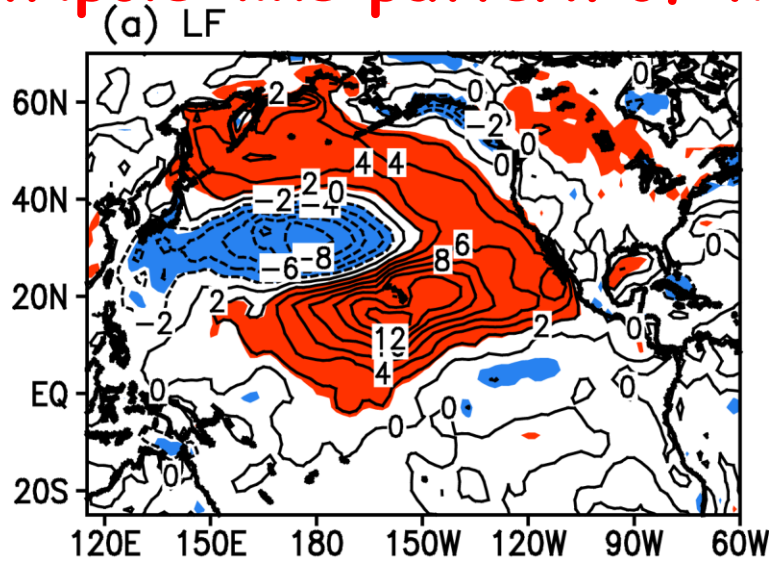
1 Reconstructing VM using NPO (AR1):

$$VM_{t+1} = \alpha NPO_t + \beta VM_t + \eta_t$$



A significant fraction (~69%) of the VM variability can be interpreted as the integrated response of the ocean to atmospheric forcing.

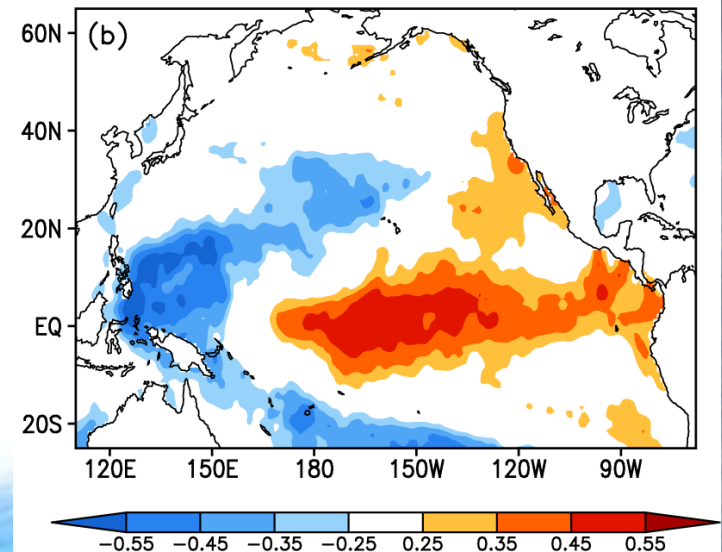
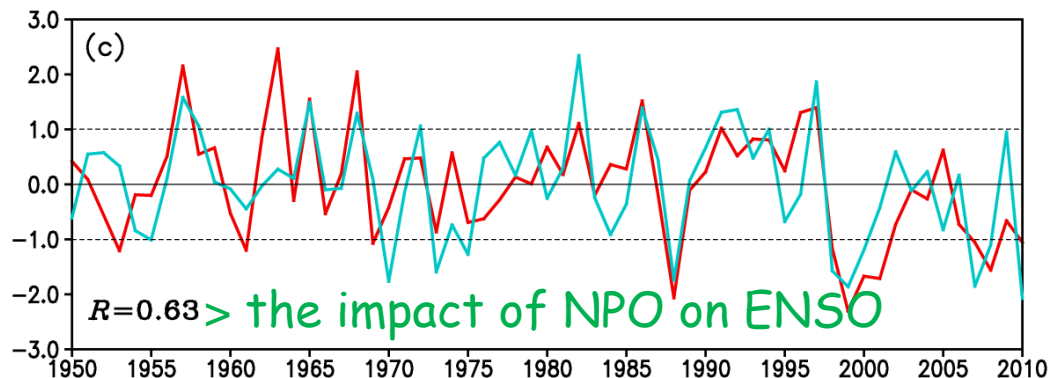
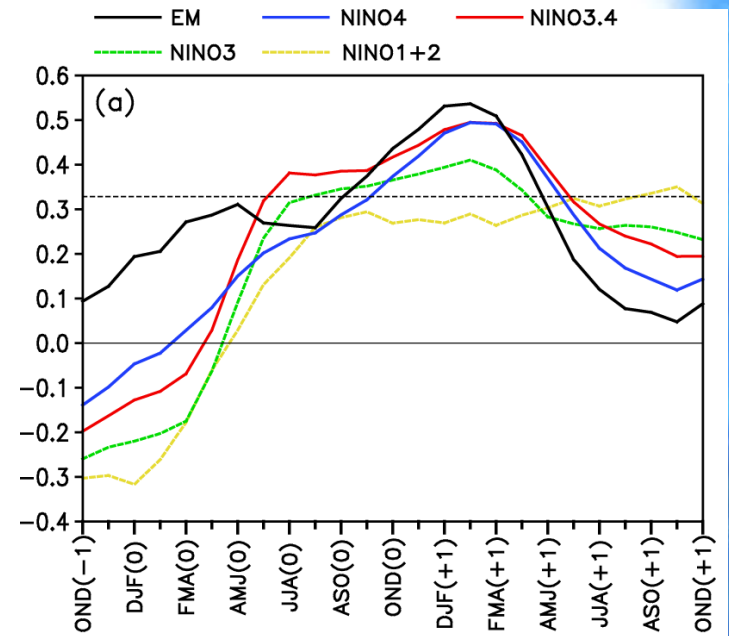
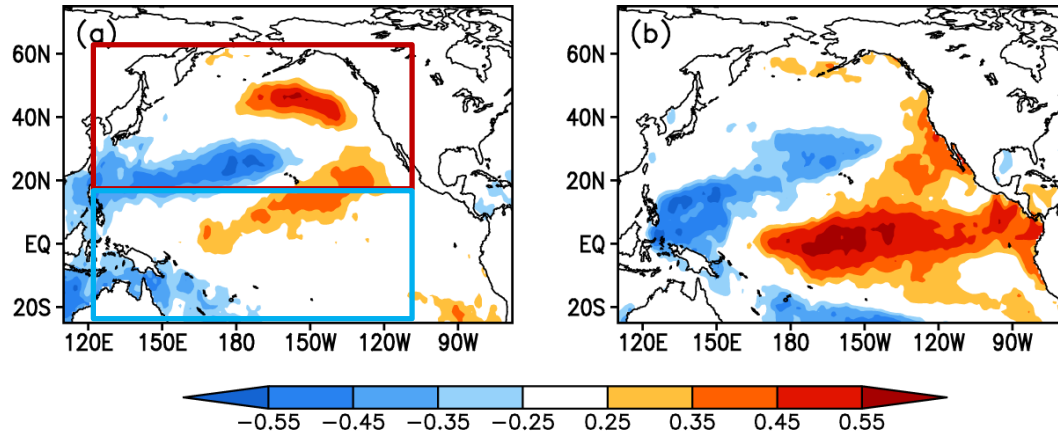
Surface wind anomalies associated with the NPO force a tripole-like pattern of the heat flux anomalies



VM lags NPO by 1~2 months
 NPO [DJF] → VM [FMA]
 Impact on VM is confined in winter

Linking between VM and ENSO

MCA mode for the FMA(0) North Pacific SSTA field and the following JFM(+1) tropical Pacific SSTA field



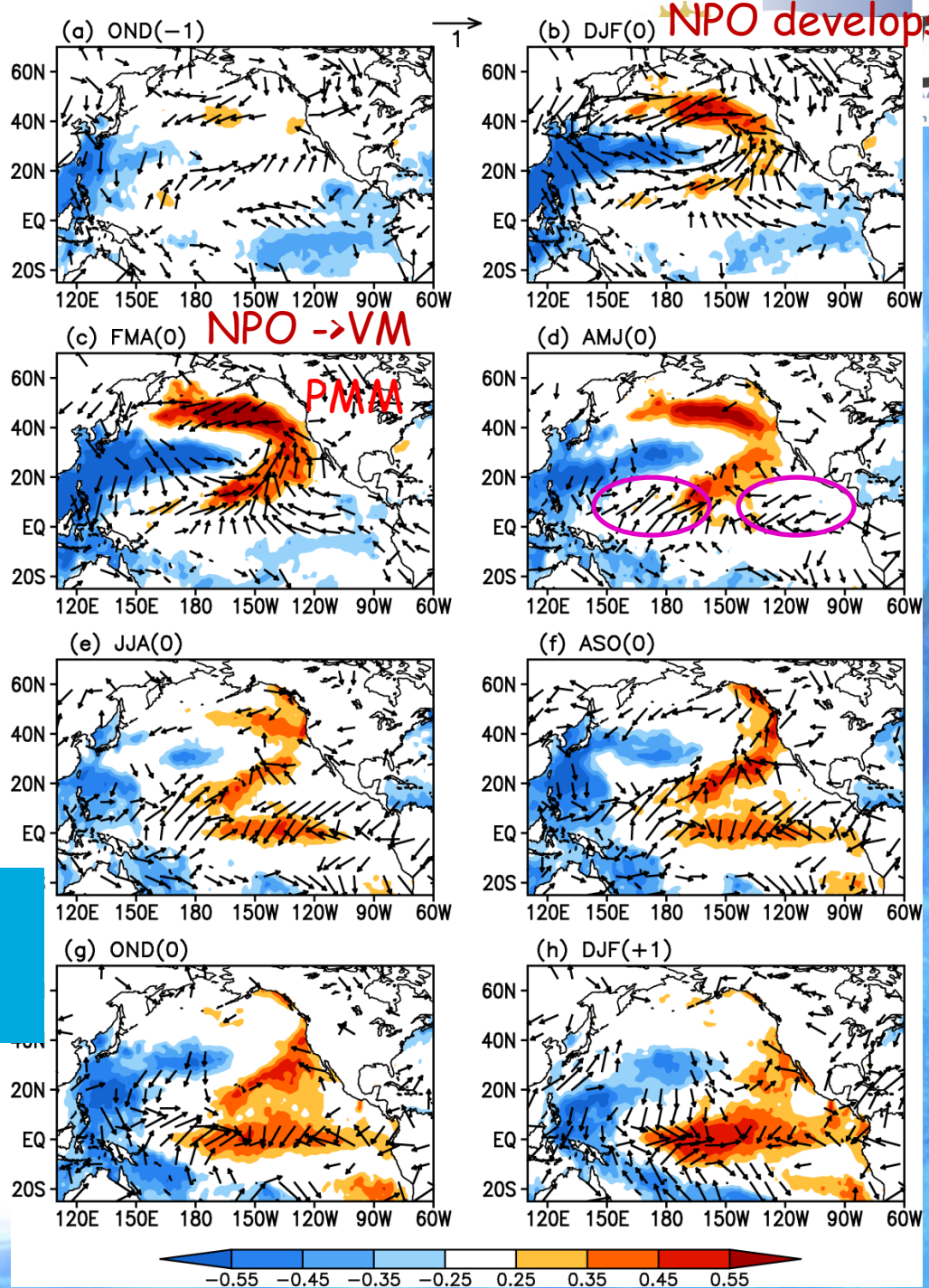
How VM affects ENSO?

Corr. maps of the FMA(0)-averaged VMI with averaged SST and surface wind anomalies

Previous proposed mechanisms

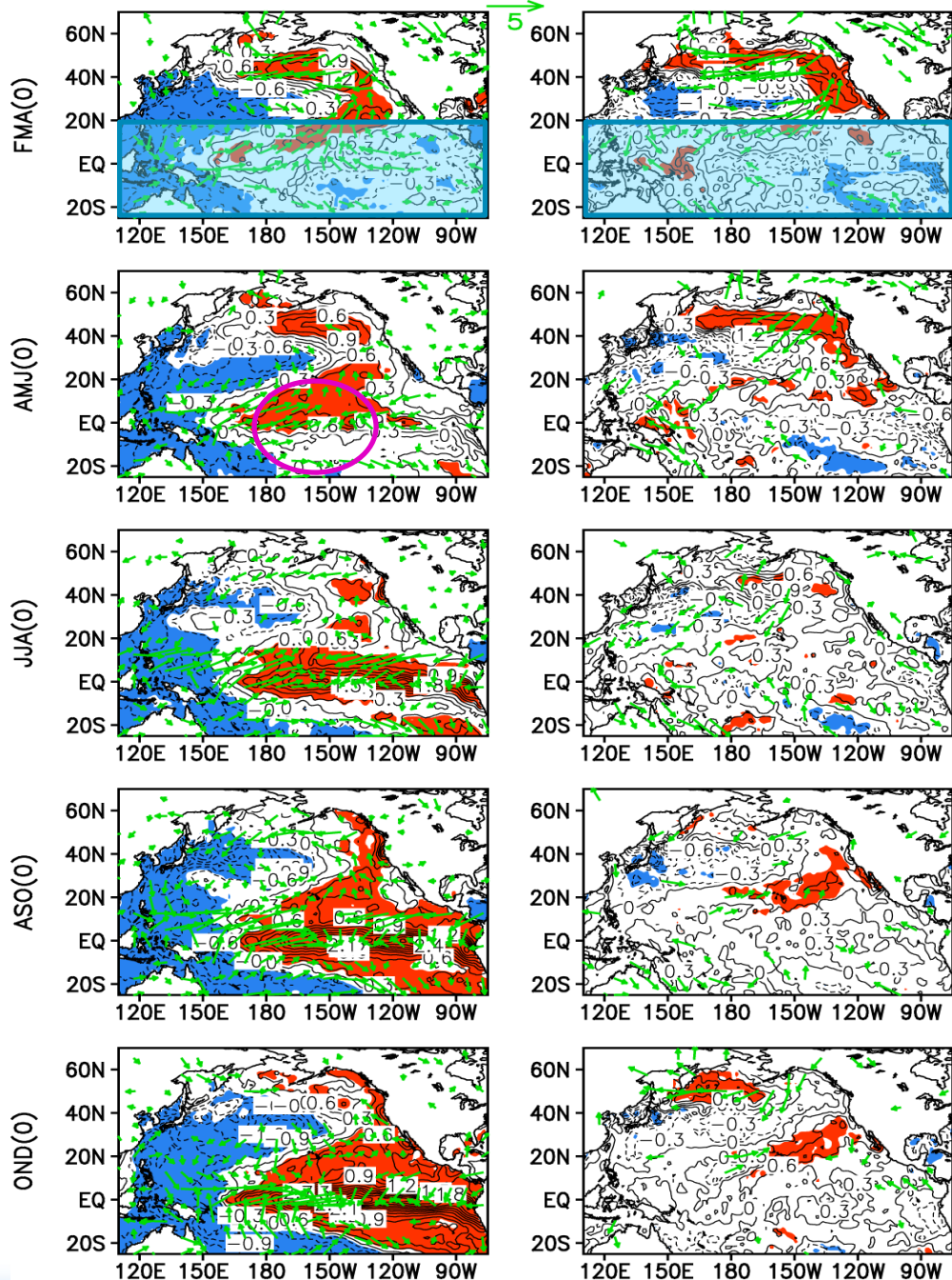
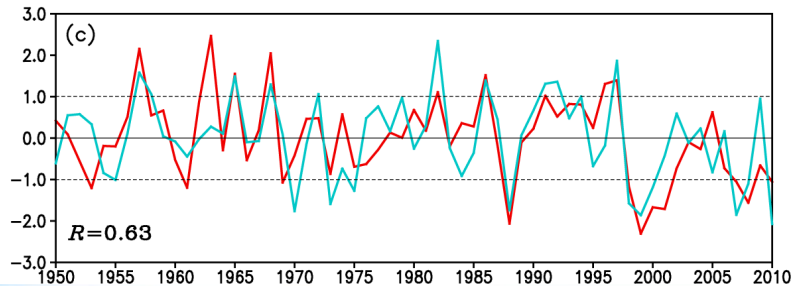
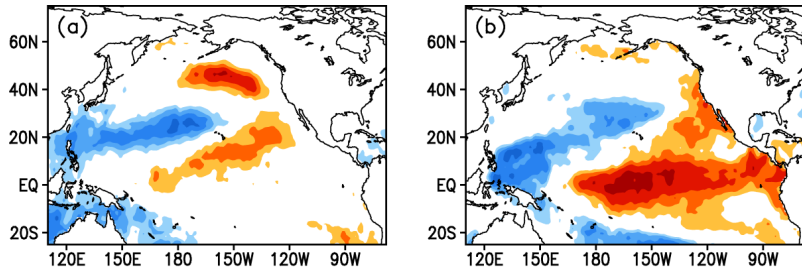
- 1) SFM
- 2) PMM
- 3) TWC

Zonal tropical SST grad increases
 -> WWB
 -> Bjerknes feedback



Why cannot some VM excite ENSO?

Composite diff. of the 3-month averaged SST and surface wind anomalies between VM followed by ENSO (14) and VM not followed by ENSO (6).

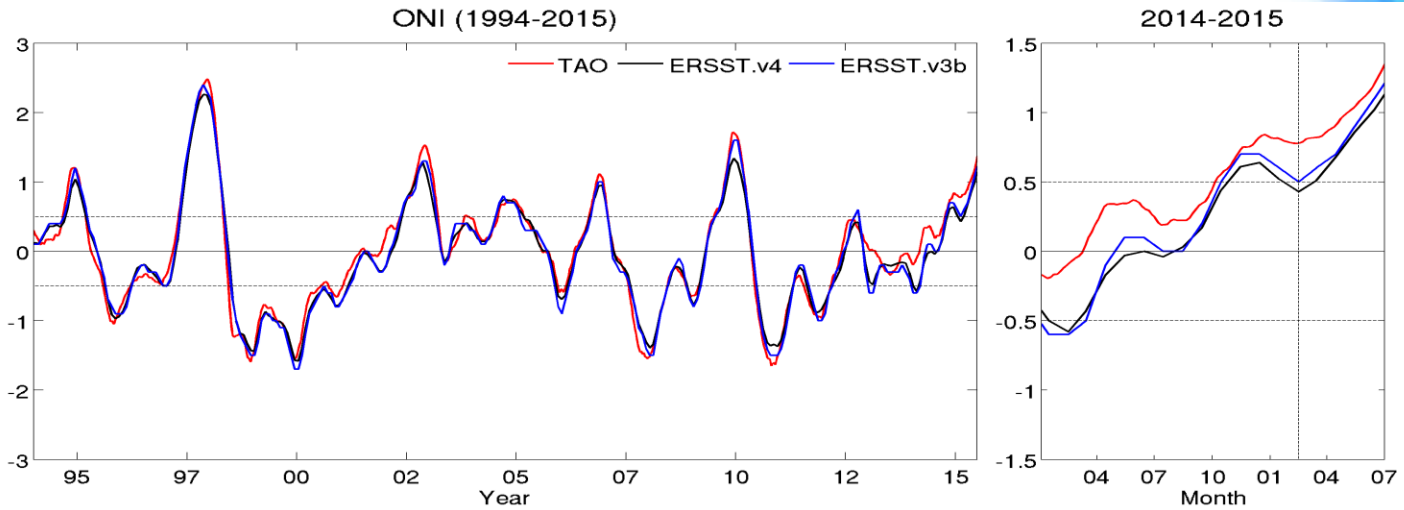


VM->ENSO

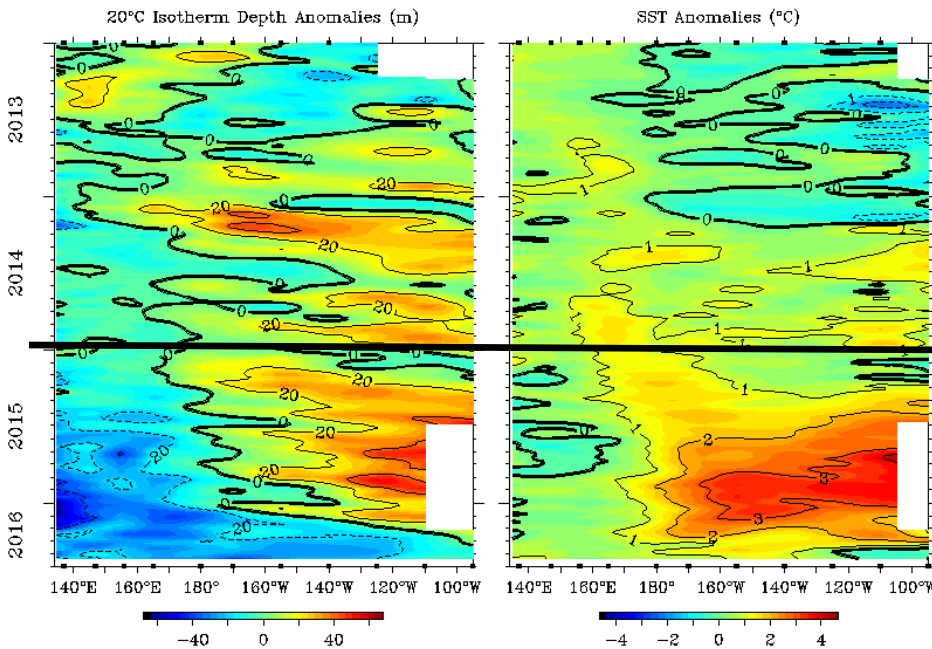
VM only

Implication on the 2015 El Niño

Nino3.4 SSTa



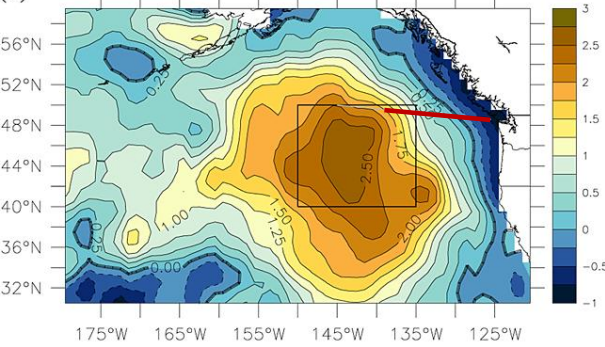
Five-Day 20°C Isother:



Define 2015 El Niño as a long El Niño started from the end of 2014

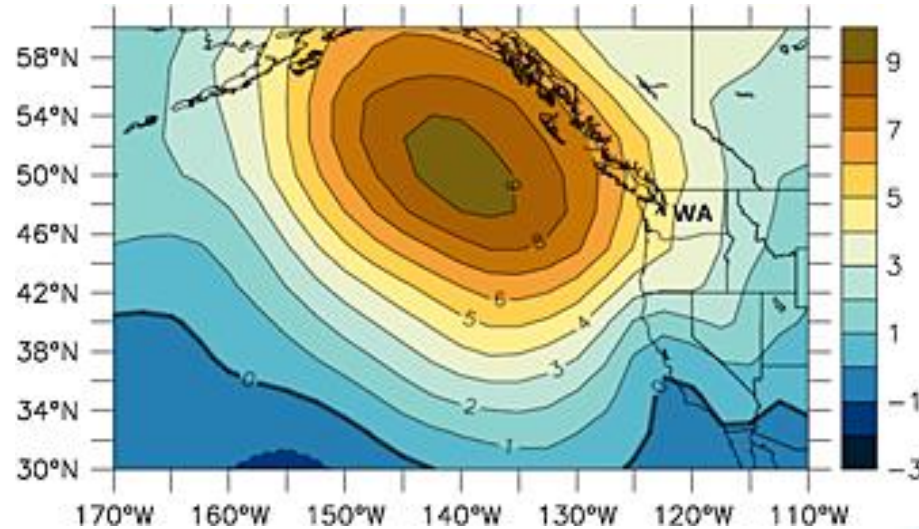
Warm Blob in the Northeastern Pacific after late 2013

(a)

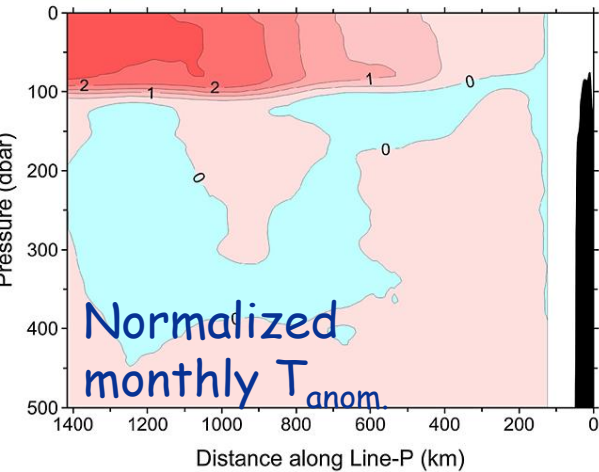


SSTa (°C) in NE Pacific Ocean for Feb. 2014

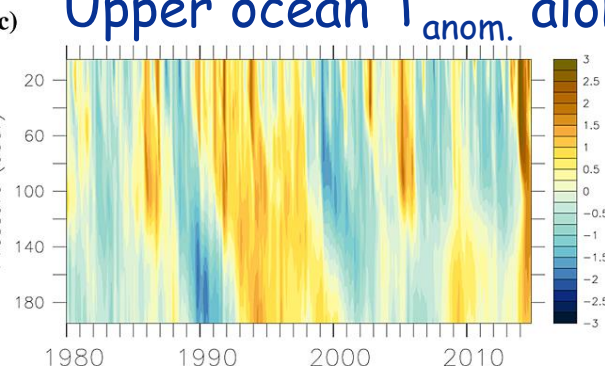
Mean SLPa (hPa) in the NE Pacific Ocean for 2013/10-2014/1



(b)

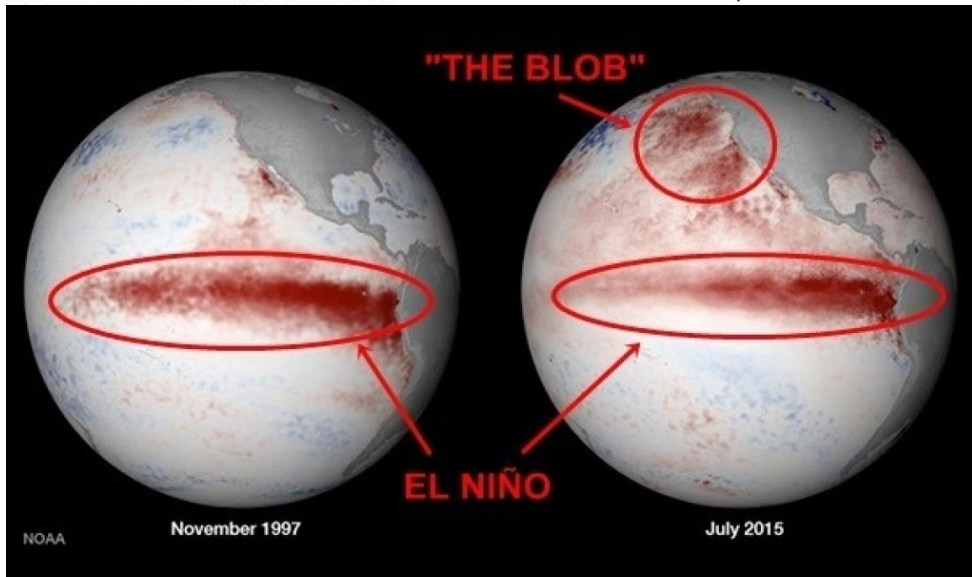


Upper ocean T_{anom} . along "Line P"



Great impacts on the ocean ecosystem and U.S. climate

Bond et al. (2015)



Record El Niño brought more rain to L.A.



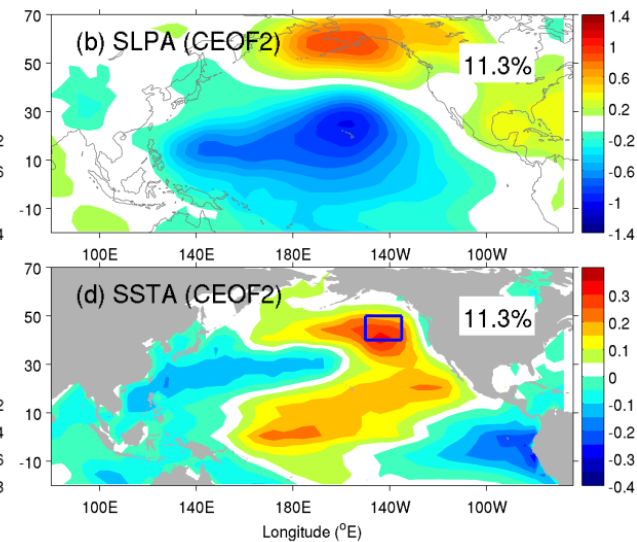
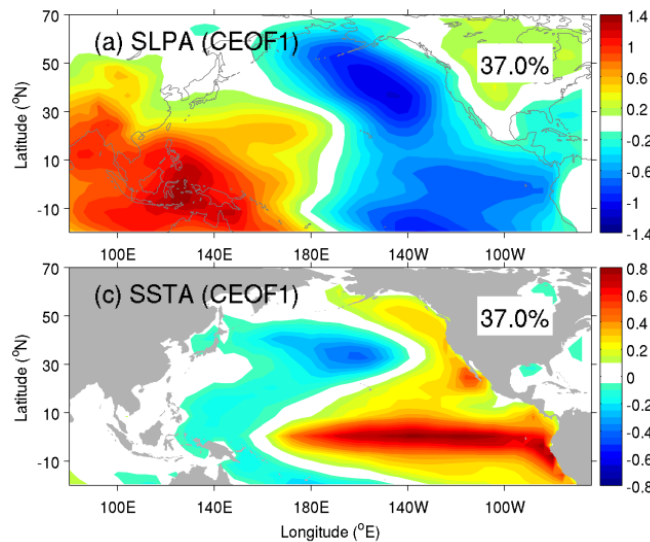
Source: NOAA Climate Prediction Center

@latimesgraphics

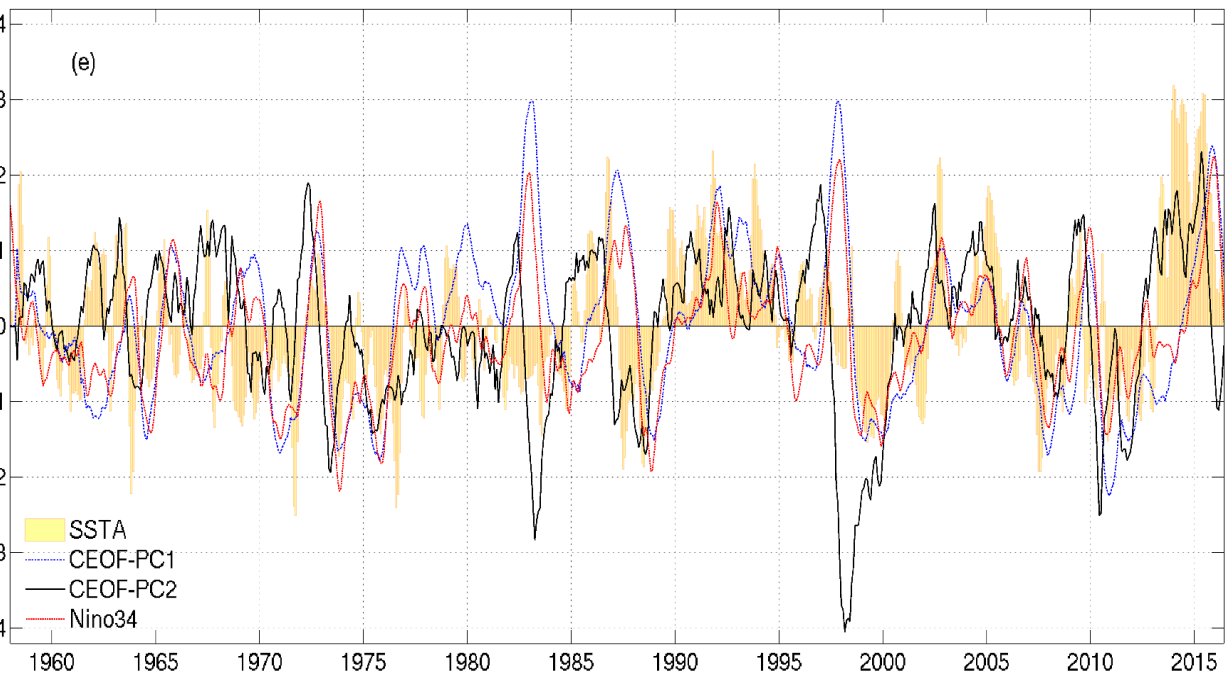
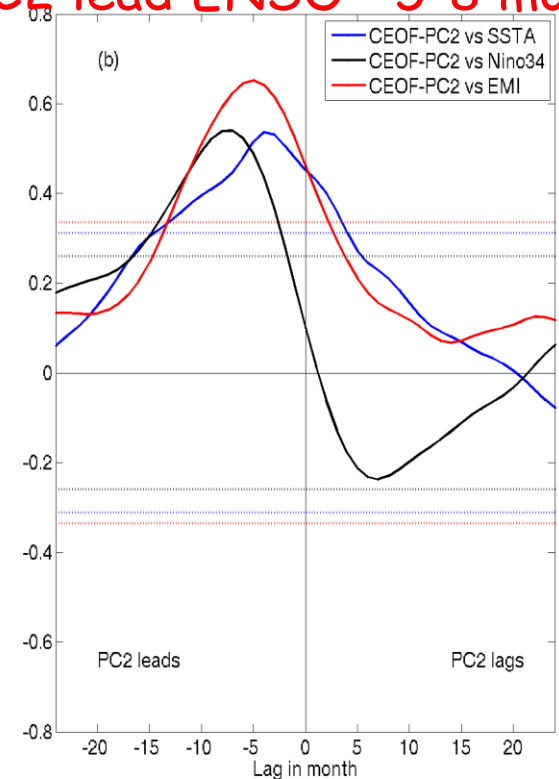


LA Times

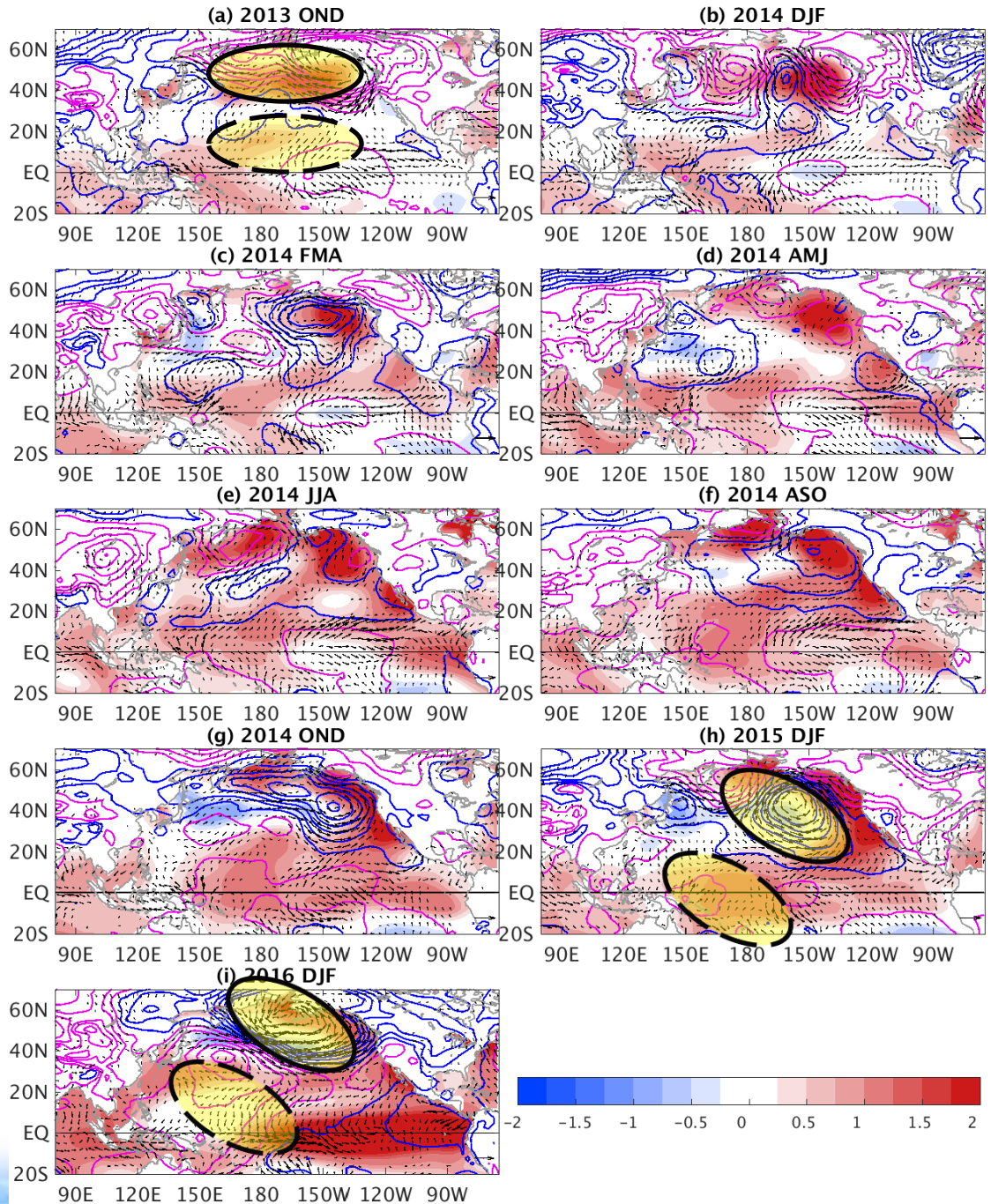
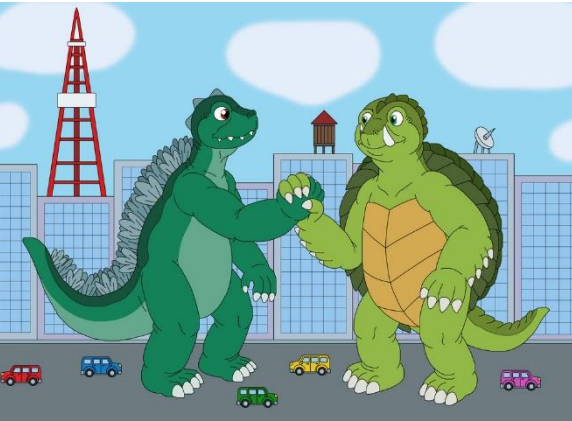
SSTa lag PC2 ~2-4 mon



PC2 lead ENSO ~5-8 mon



3-mon-averaged
SST (shaded),
SLP (contours) and
surface wind anomalies
in 2014.



Warm Blob and El Niño
are related!

Can we enhance our ENSO prediction skills?



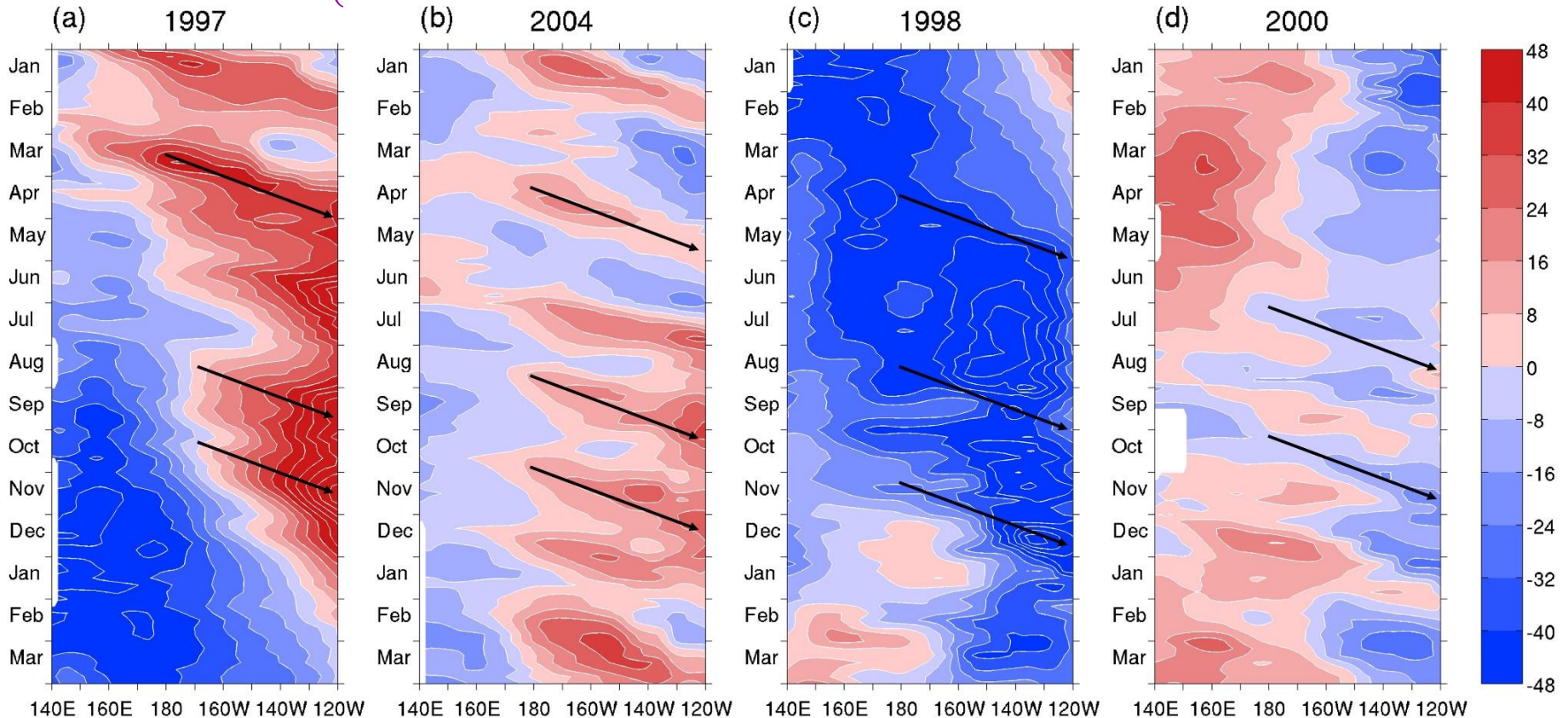
$$nEPI(t) = \alpha nEPI_{WWV}(t) + \beta nEPI_{O-A}(t)$$

(Tseng et al. , 2016)

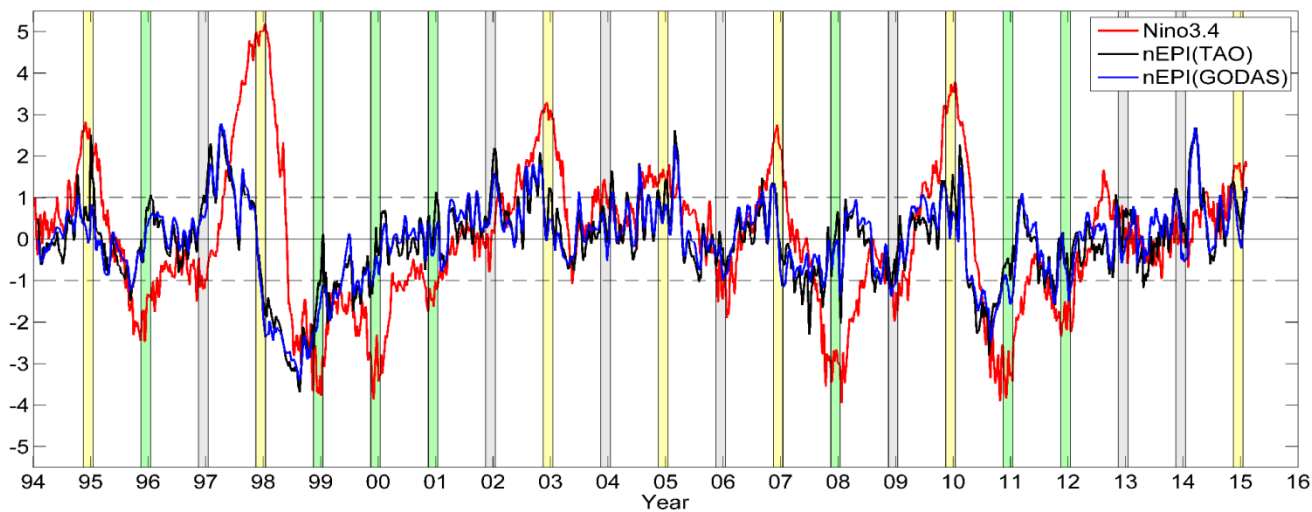
$$nEPI_{WWV}(t) = \alpha_1 D20a_{180^\circ}(t-25) + \alpha_2 D20a_{170^\circ W}(t-15) + \alpha_3 D20a_{155^\circ W}(t)$$

$$nEPI_{O-A}(t, nEPI_{WWV}, w_x) = \text{sign}(\text{event}(t, w_x)) \cdot dH(t, nEPI_{wwv}) \quad \text{event}(t, w_x) = \begin{cases} \text{positive } w_x & \text{in } [t - 50, t] \\ \text{negative } w_x & \text{in } [t - 50, t] \end{cases}$$

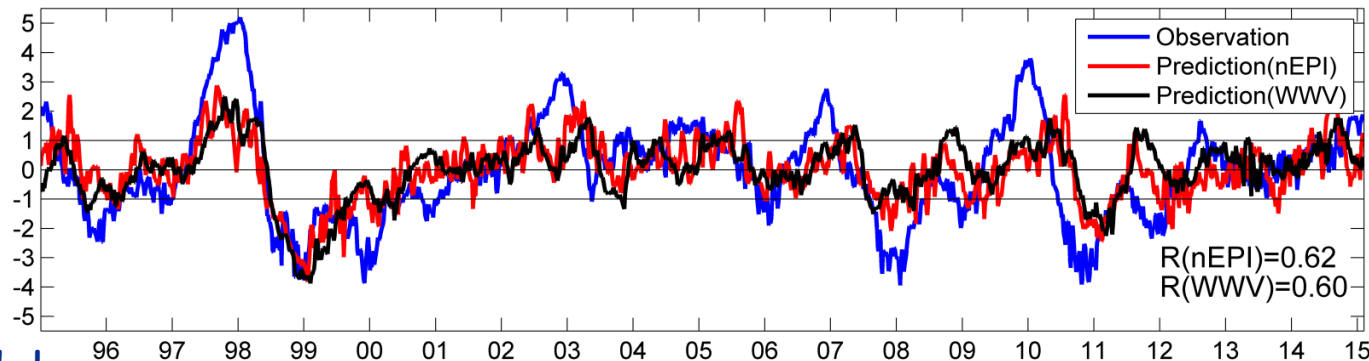
$$dH(t, nEPI_{wwv}) = \begin{cases} \frac{[||nEPI_{wwv}(t) - nEPI_{wwv}(t-5)|| + ||nEPI_{wwv}(t-5) - nEPI_{wwv}(t-10)||]}{2}, & 1/2 \leq P(\text{event}(t, w_x)) \\ 0, & P(\text{event}(t, w_x)) < 1/2 \end{cases}$$



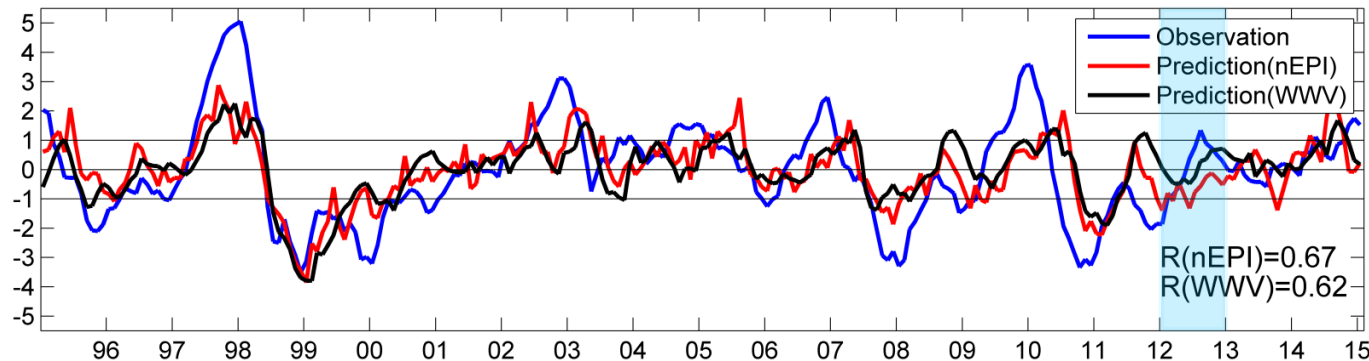
1994-2015 Nino3.4 and nEPI



(a) TAO (1994-2015) with 5-days data



(b) TAO (1994-2015) with monthly data



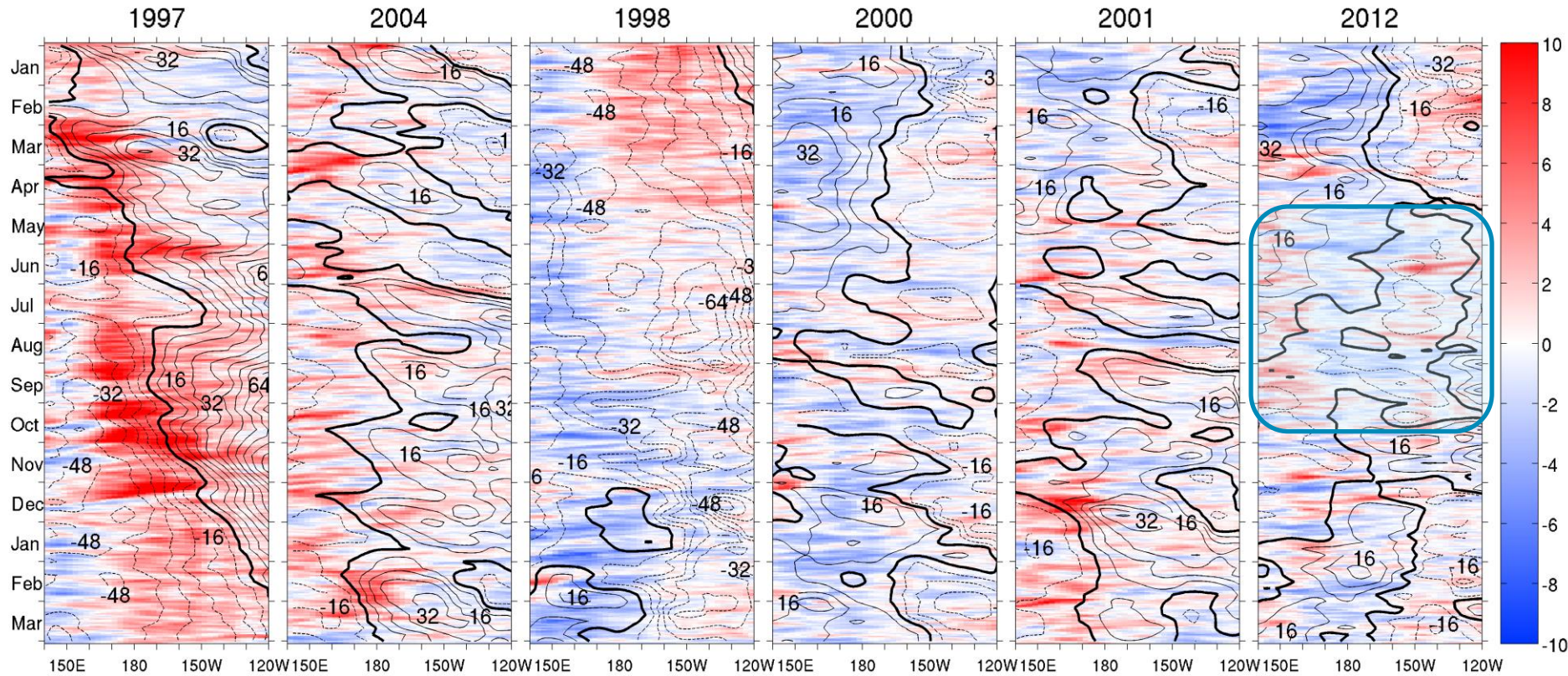
Linear regression model
-6month lead time

Hovmöller diagram of D20a and zonal wind anomaly (2°S-2°N)

El Niños
strong weak

La Niñas
strong weak

Neutral years



Hindcast skills

Multi-model ensemble mean skill
(Barnston et al., 2012)

| Lead time | Data source | Year | Correlation | | Normalized RMSEs | |
|-------------|-------------|-----------|-------------|------|------------------|------|
| | | | nEPI | WWV | nEPI | WWV |
| four-month | TAO | 1994-2015 | 0.75 | 0.70 | 0.66 | 0.72 |
| six-month | TAO | 1994-2015 | 0.67 | 0.62 | 0.75 | 0.78 |
| | TAO | 2002-2011 | 0.59 (0.42) | | 0.81 | |
| | GODAS | 1980-2015 | 0.64 | | 0.77 | |
| eight-month | GODAS | 1981-2010 | 0.68 (0.65) | | 0.73 | |
| | TAO | 1994-2015 | 0.57 | 0.49 | 0.82 | 0.87 |
| | GODAS | 1980-2015 | 0.58 | | 0.79 | |

Percent correct of six-month ENSO forecast

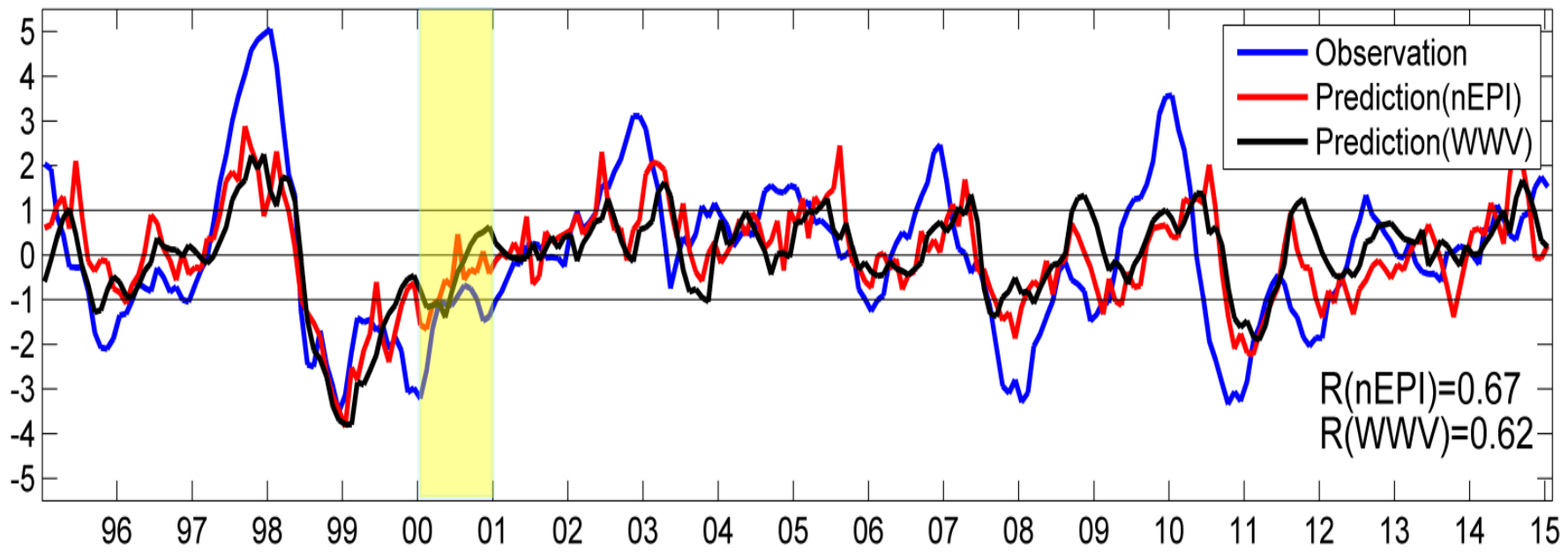
| ENSO index threshold | Percent correct 1994-2015 (TAO) | Percent correct 1980-2015 (GODAS) |
|---------------------------------------|------------------------------------|--------------------------------------|
| + Niño3.4 index | 100% (67%) | 68% |
| - Niño3.4 index | 83% (75%) | 87% |
| upper tercile Niño3.4 index (El Niño) | 86% (57%) | 73% |
| lower tercile Niño3.4 index (La Niña) | 86% (71%) | 82% |

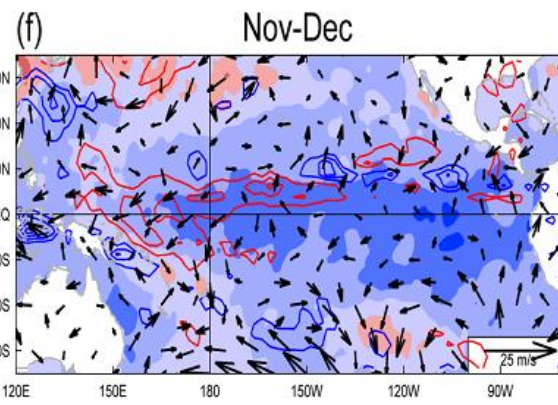
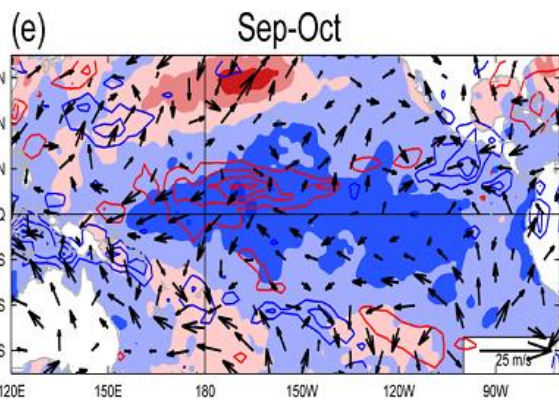
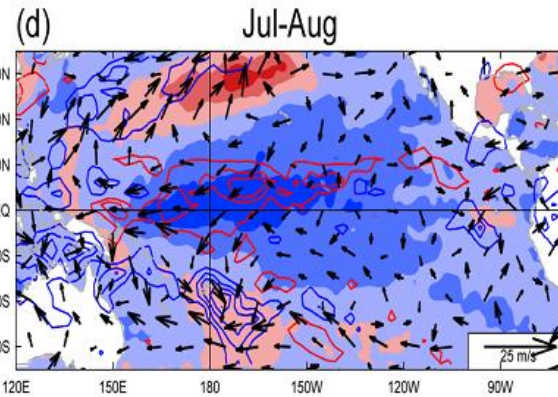
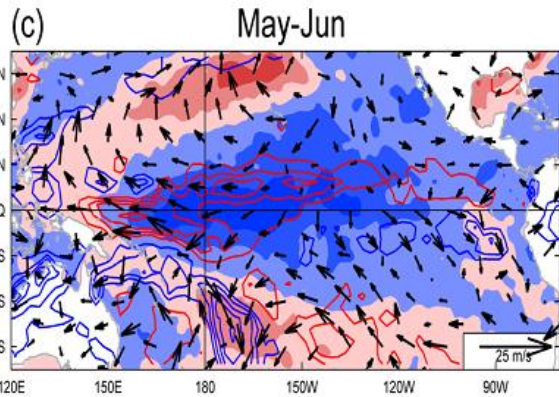
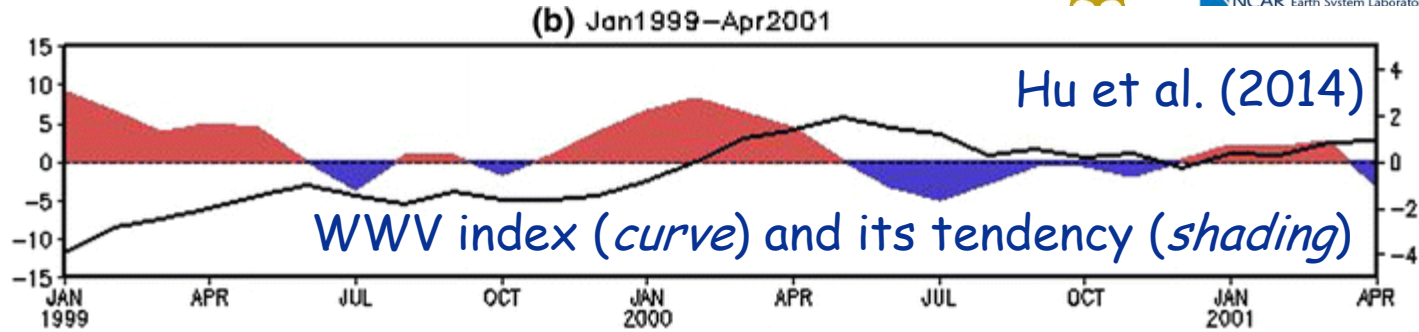
(Larson and Kirtman, 2014)

↑
Using WWV

The only missed event: 2000/01 La Niña

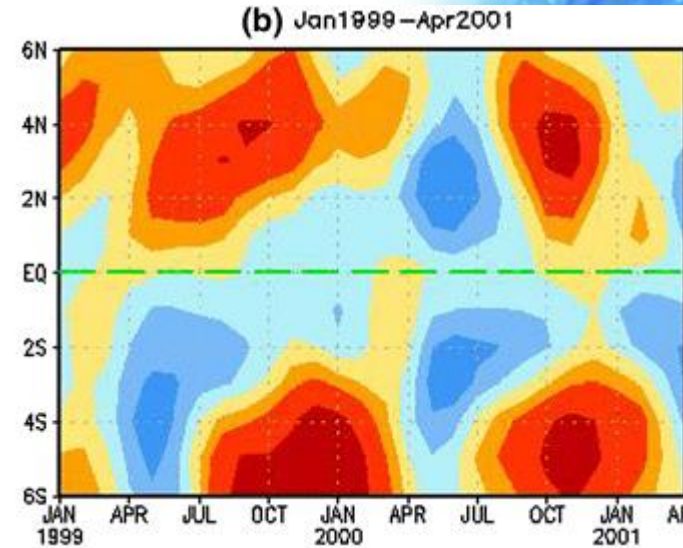
(b) TAO (1994-2015) with monthly data





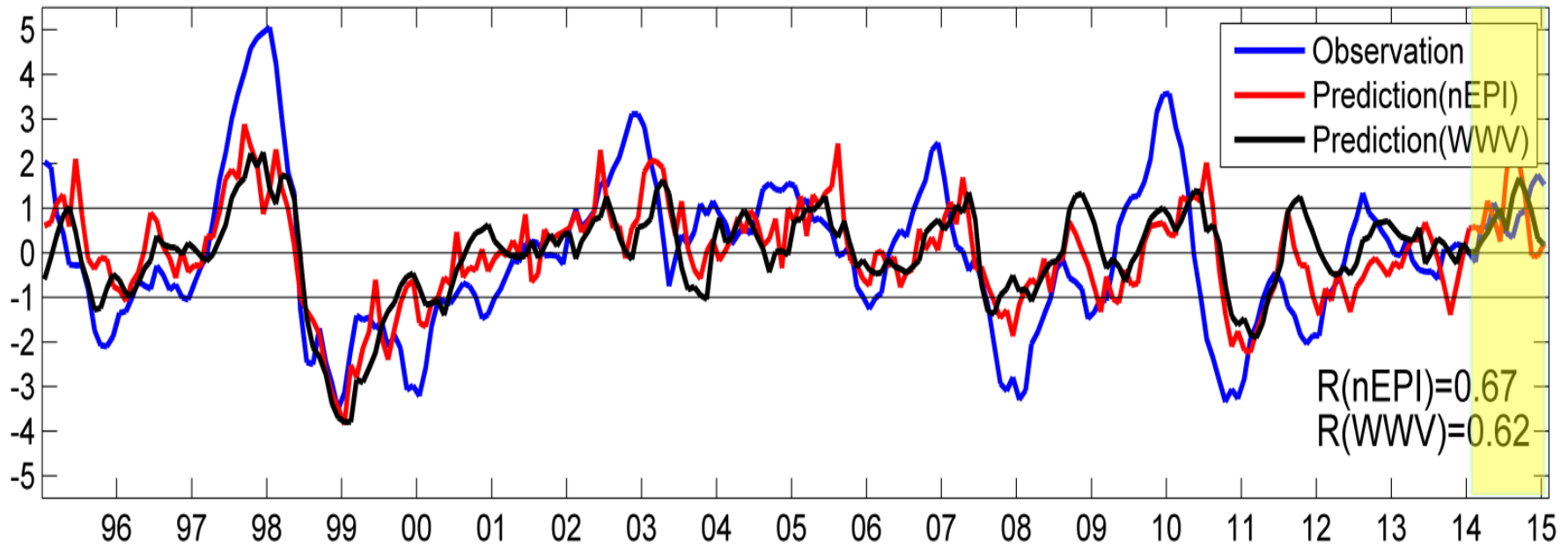
Extensive cold SST in the tropic and subtropics

Meridional temp. advection
5-205 m, 170°-120°W



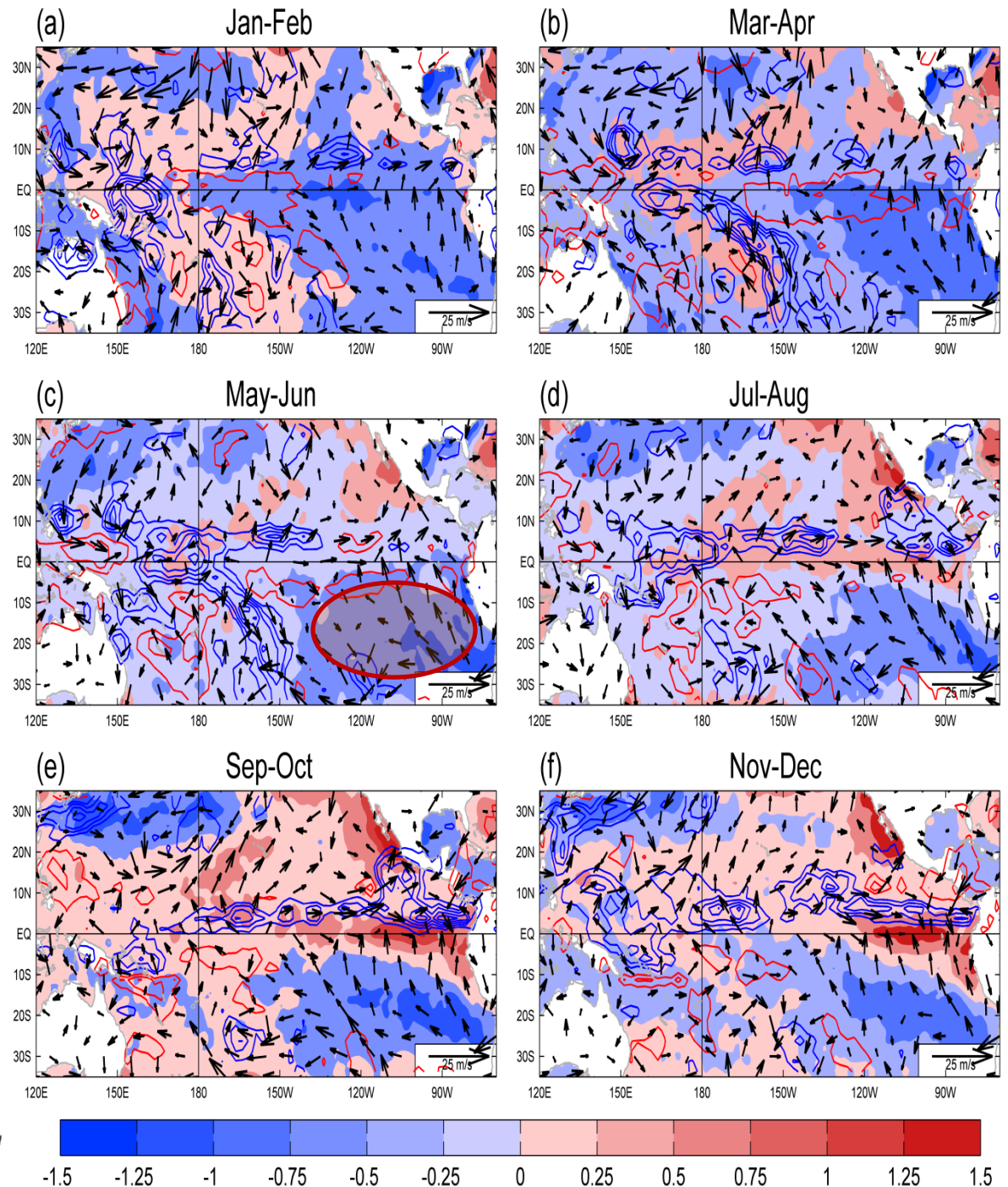
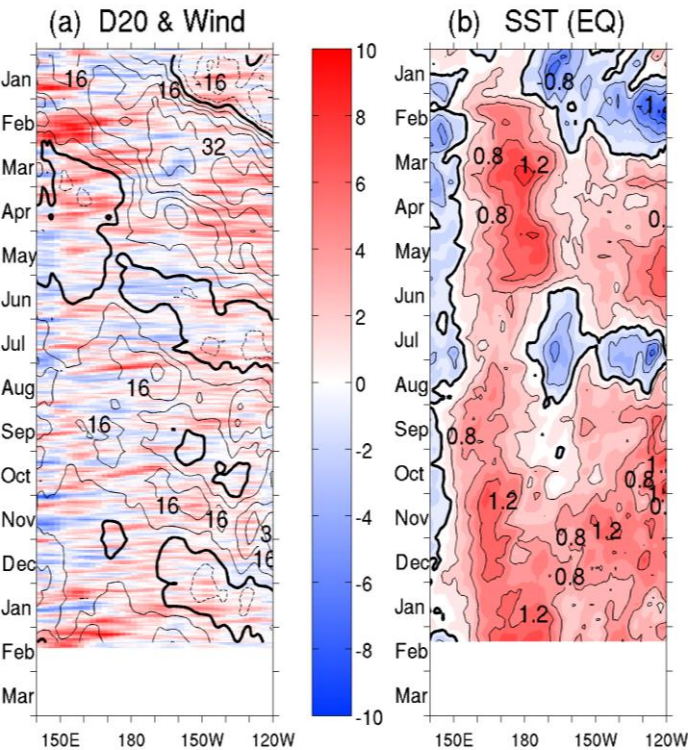
Why 2014/15 boreal winter is a neutral state or weak El Niño (TAO/ERSST.v3b)?

(b) TAO (1994-2015) with monthly data

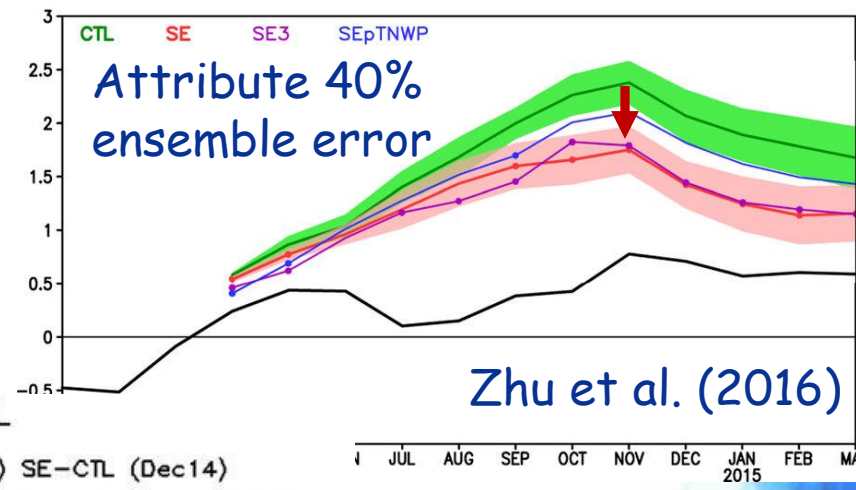


Southern hemisphere Suppression in 2014

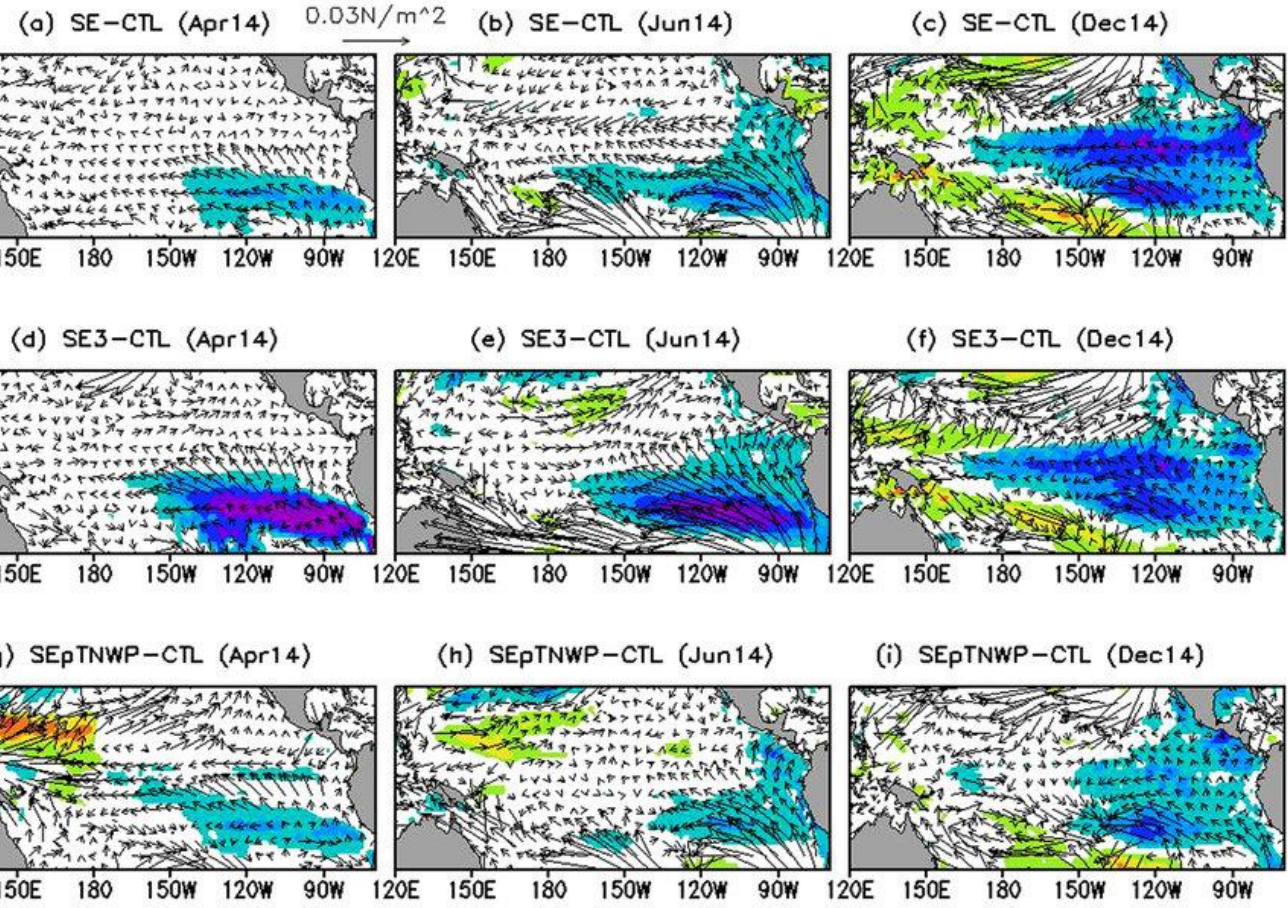
Min et al., 2015; Zhu et al.,
2016; Tseng et al. 2016b



Impacts of SE Pacific SSTa on the ensemble CFSv2



SST and Taux_Tauy Diff. relative to CTL



SE: obs. cold SSTa in April

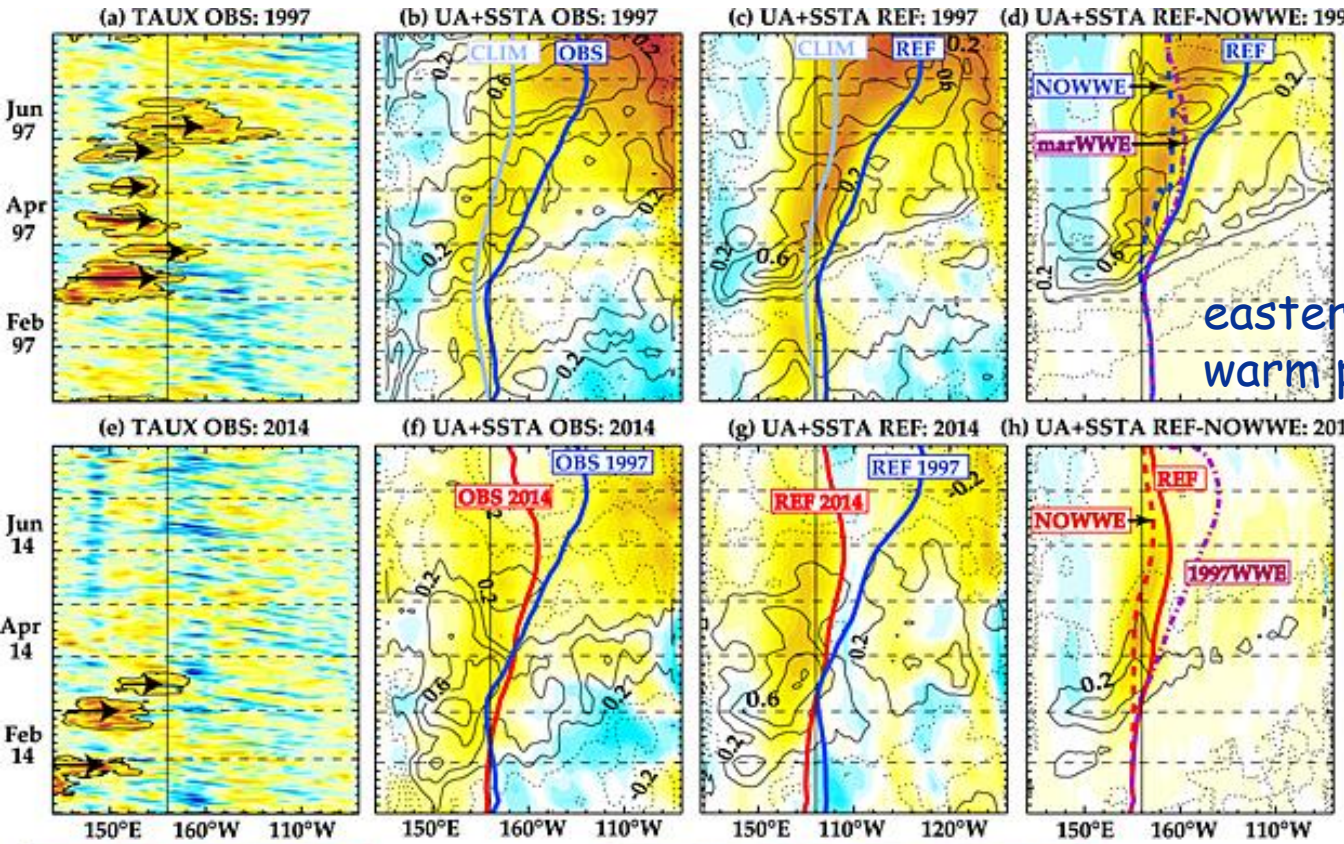
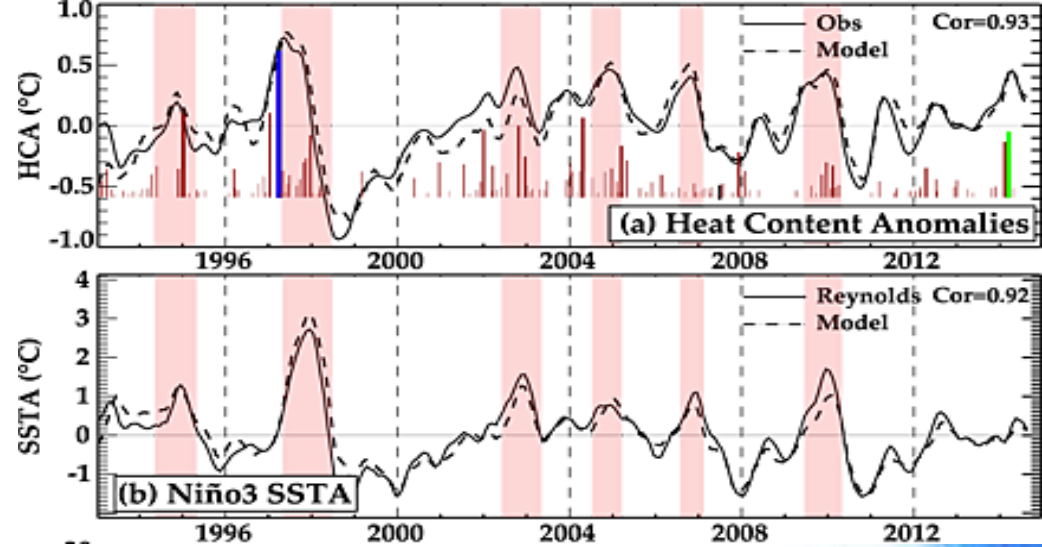
SE3: triple obs. cold SSTa in April

SEpTNWP: obs. cold SSTa in April+ observed wnp warm SSTa

Impacts of WWEs in 2014

NOWWE: no WWEs

1997WWE: all WWEs 1997 added



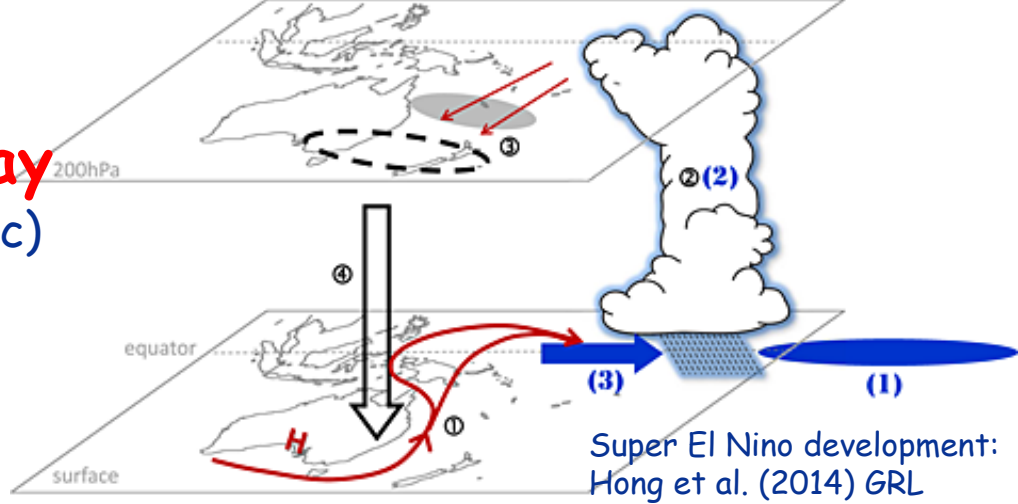
1997

eastern edge of the warm pool (EERP)

2014

Southern hemisphere pathway

Zhang et al. (2014a,b), Ding et al. (2015c)



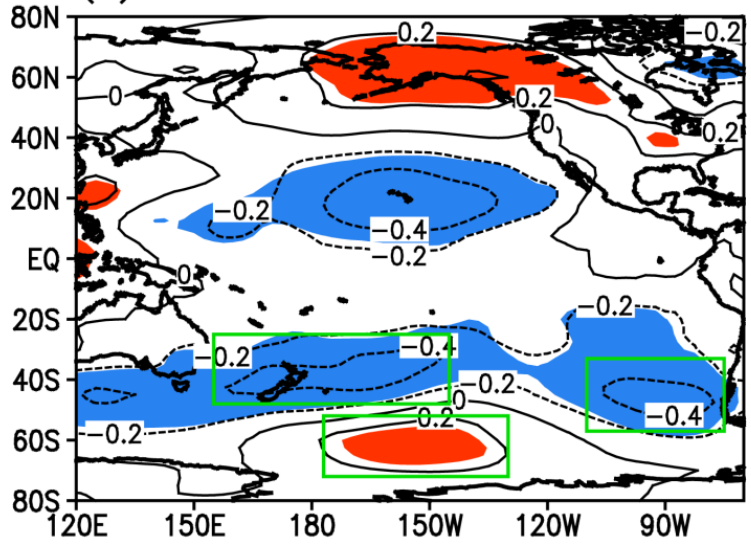
Transverse cell

- ① Australian High, equator-ward flow, additional westerly on the equator
- ② Enhanced deep convection
- ③ Divergent winds (thin arrows), RWS-advection term (gray shades), RWS-stretching term (dashed contour)
- ④ Subsidence

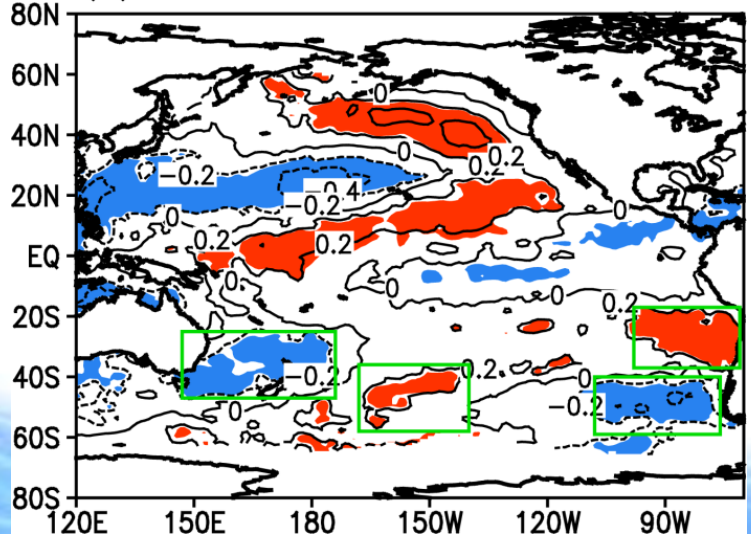
Bjerknes Feedback

- (1) Eastern Pacific SST
- (2) Enhanced deep convection
- (3) Westerly winds

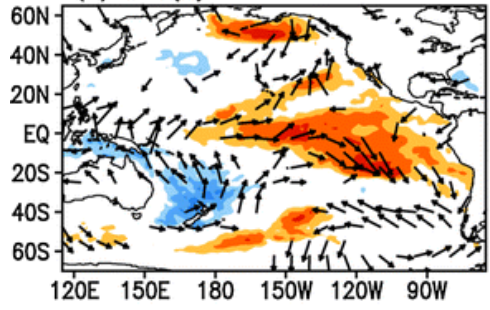
(a) SLP



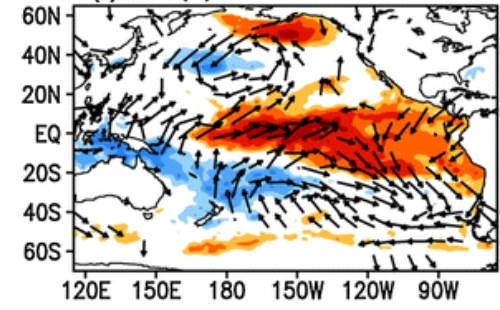
(b) SST



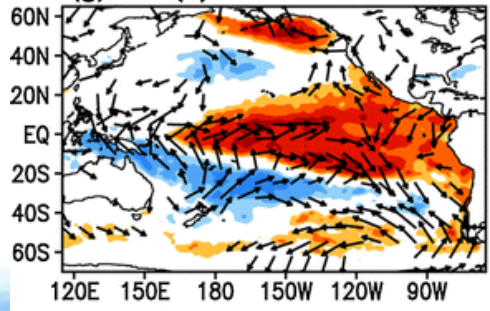
(e) MJJ(O)



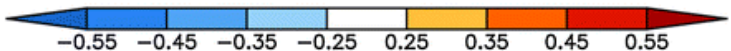
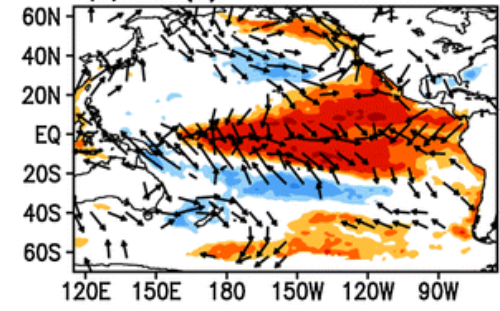
(f) JAS(O)



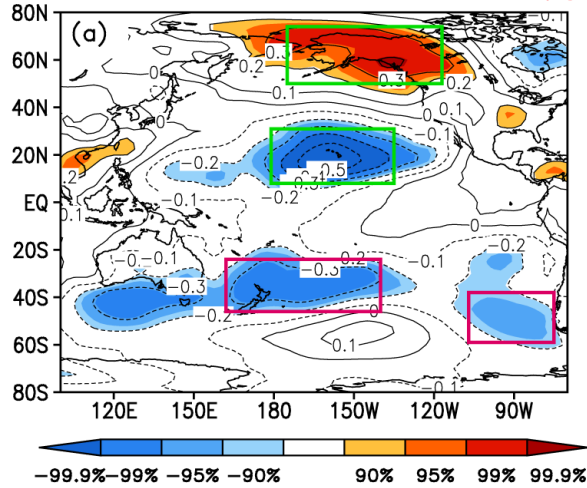
(g) SON(O)



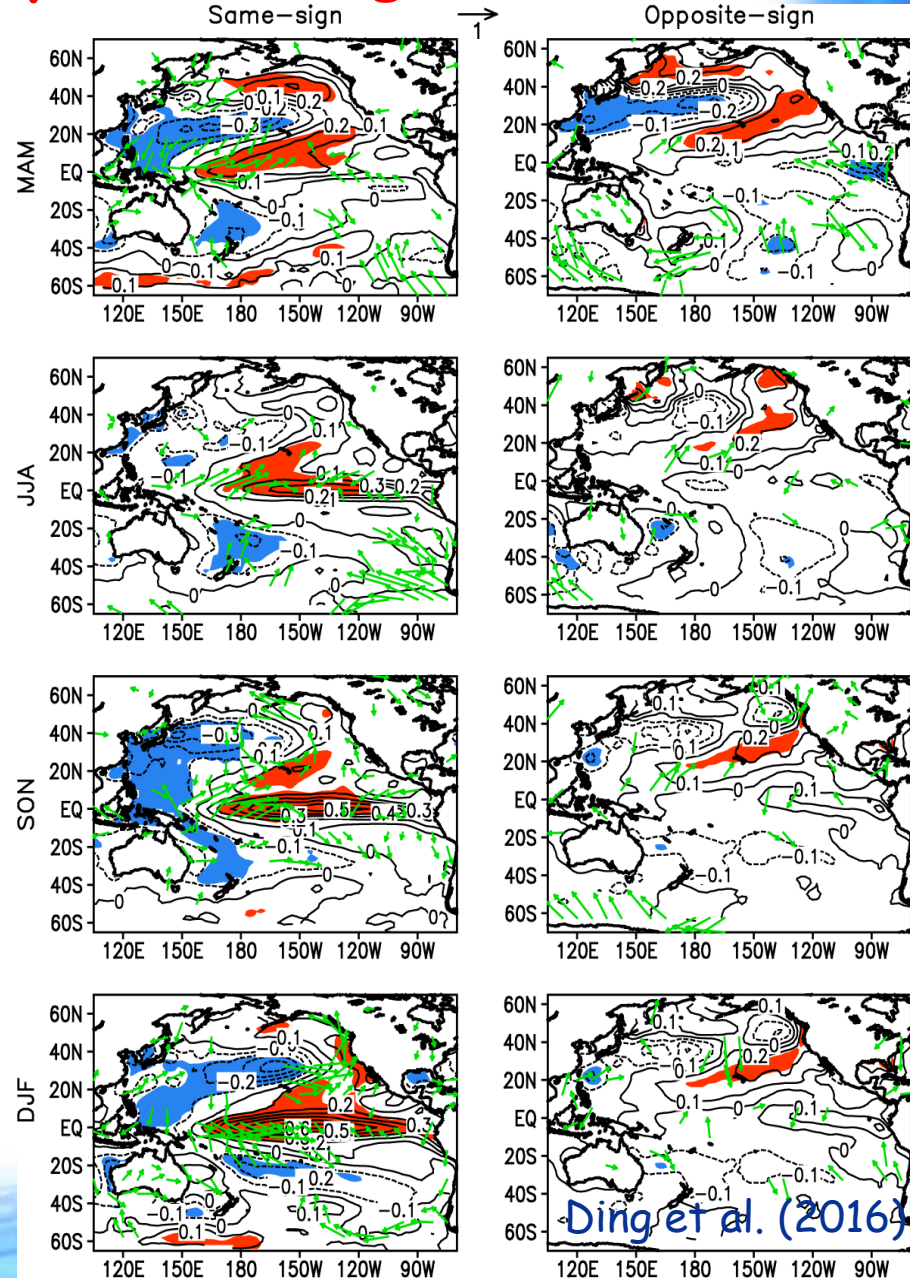
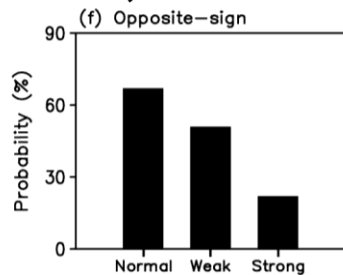
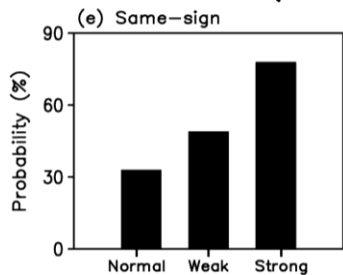
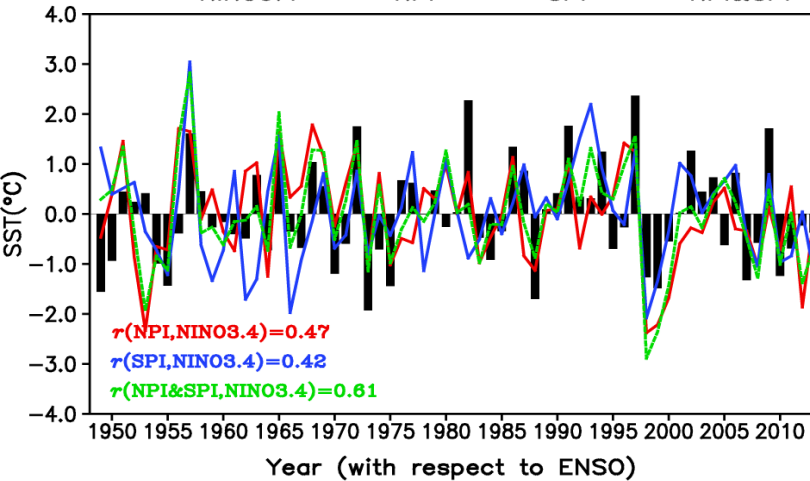
(h) NDJ(O)



Joint impact of North and South Pacific extratropical forcing



█ NINO3.4 █ NPI █ SPI █ NPI&SPI



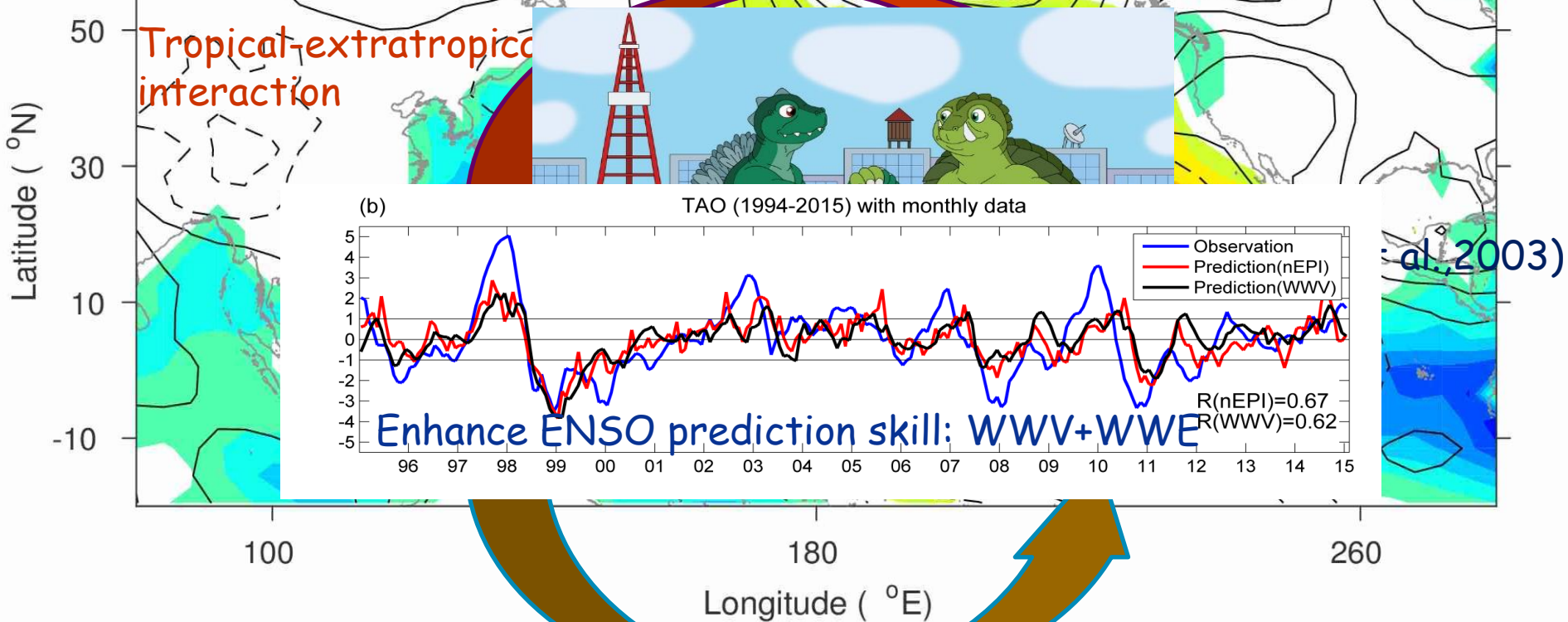
Ding et al. (2016)

Summary

- A modified North Pacific climate paradigm connects and explains the observed ENSO and its precursor
- Two dominant modes of NPCV are linked
 - ENSO/PDO: the zonal variability in tropic and mid-latitude
 - NPO/VM: a footprint of the meridional variability through the tropic-extratropical teleconnection
- VM, forced by NPO, is closely linked to the development of ENSO (ocean bridge)
 - Warm Blob after 2013 is an example leading to 2015 El Niño
- Subtropical SSTa can enhance/suppress the ENSO development (affecting the O-A coupling)
- WWV+O-A interaction can enhance the ENSO predictability

New North Pacific climate paradigm

Warm Blob-the ocean expression of the 2nd O-A mode variability (NPO/VM) Ding et al. (2015a)



Tropical-extratropical interaction

Ding et al. (2015c); Ding et al. (2016), Zhang et al. (2014a,b)

Future work

- Enhance the prediction skill by further including the subtropical SSTa
- How the interannual variation of NPO/WP is modified?
 - Indo-Pacific Warm Pool (O-A interaction from maritime continent, MC)
 - Impacts from the North Atlantic
- How are the STCs connected with the Pacific decadal and multi-decadal Variability? What force the STC variability? Can we enhance the decadal predictability?

