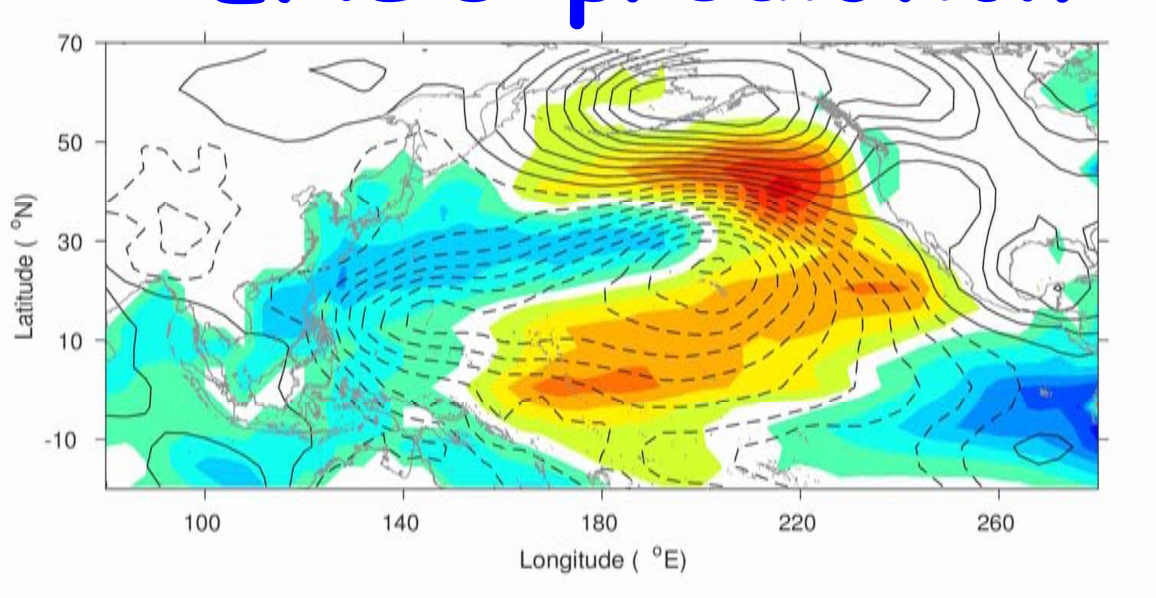
Pacific climate variability and the ENSO prediction



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Acknowledgments: Ruiqiang Ding, Zeng-Zhen Hu, Jiangping Li, Art Miller

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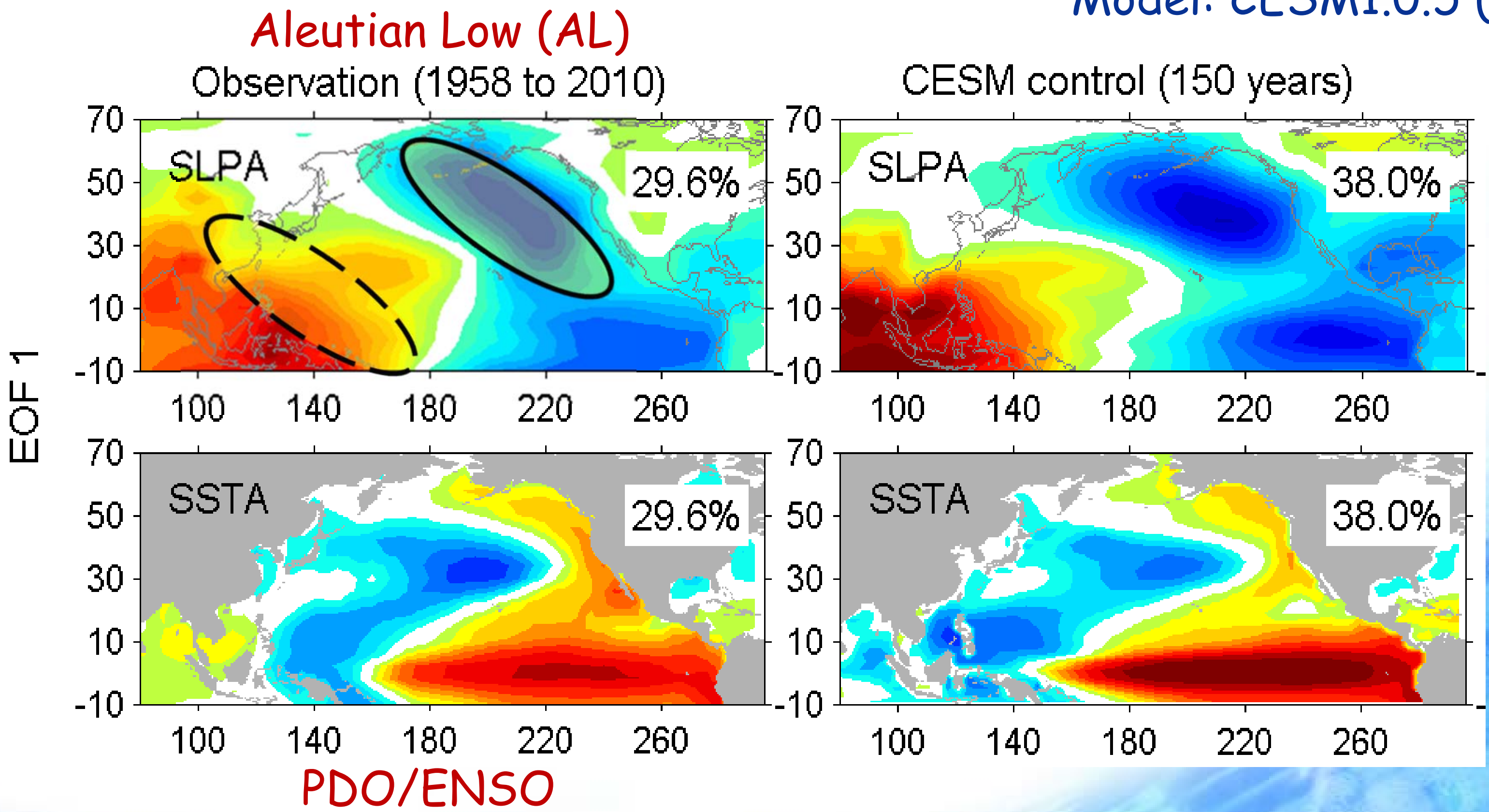
The dominant surface pattern and variability in the North Pacific-1st mode

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

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

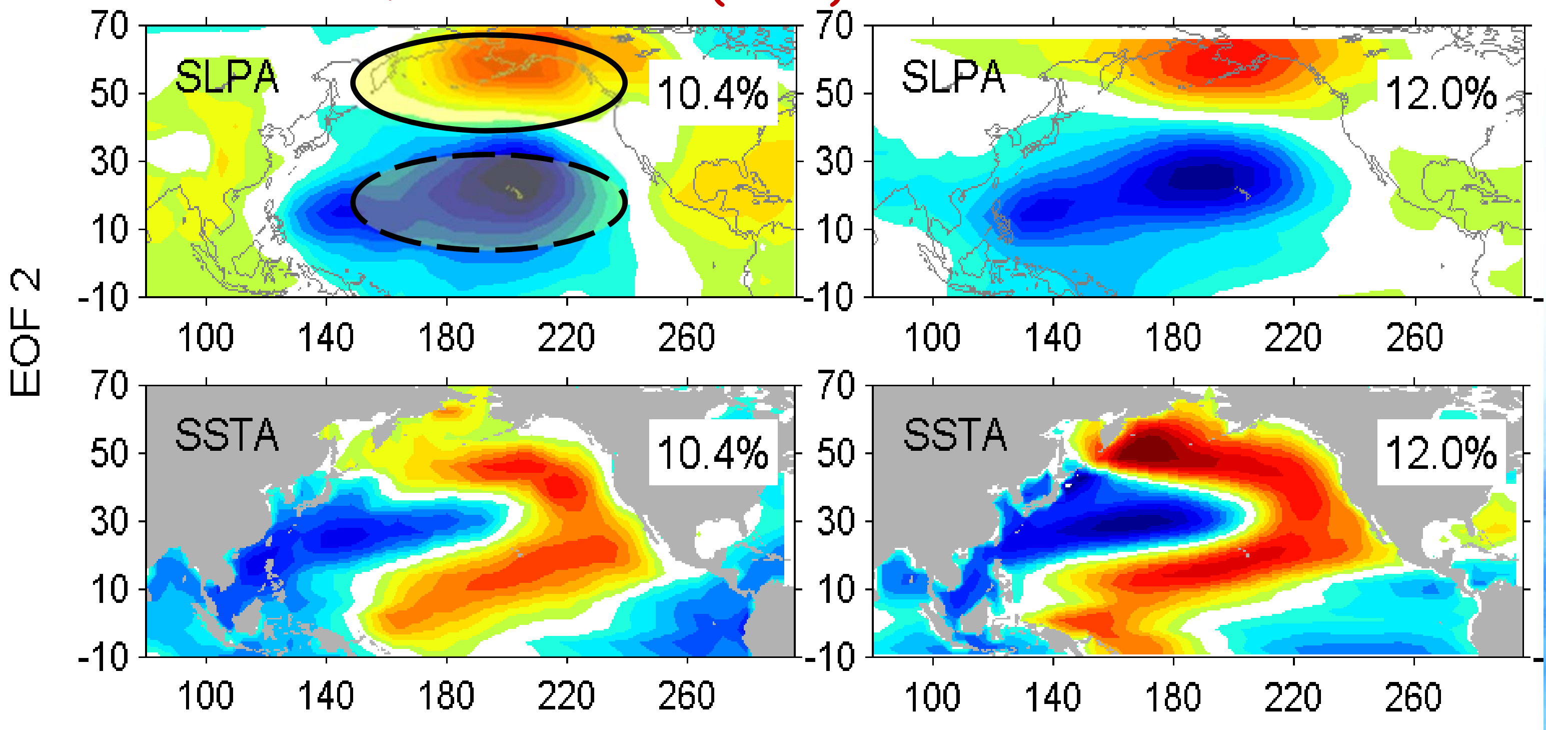


Miller et al. (2017)

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)

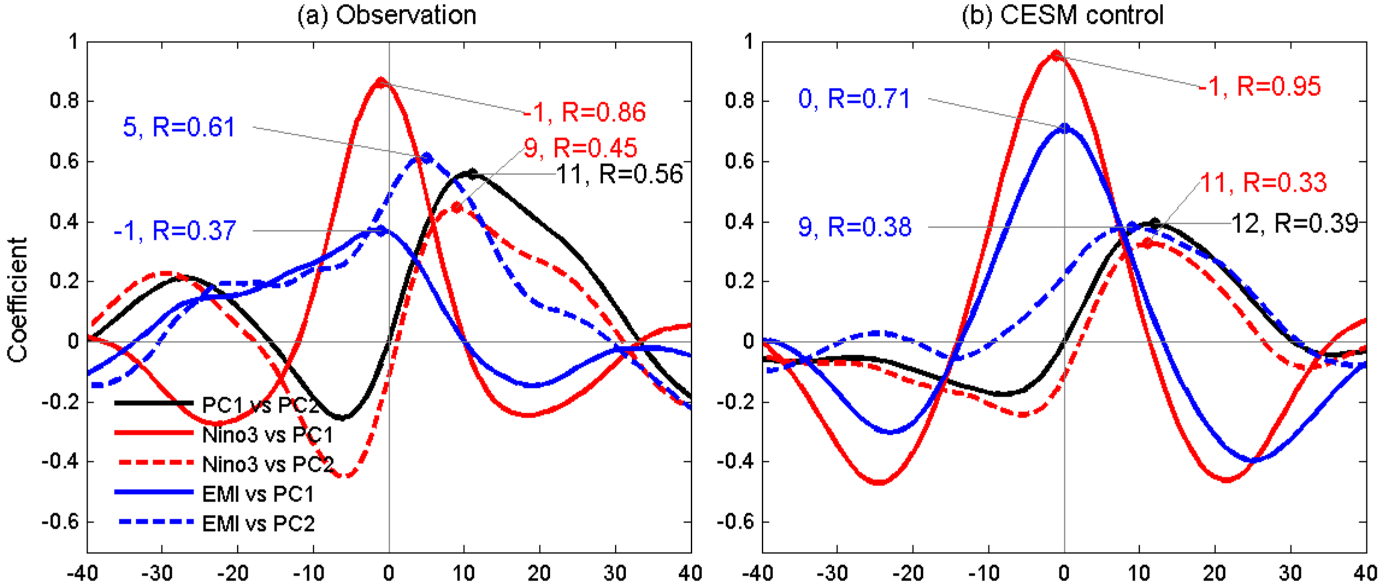


Victoria Mode (VM) or NPGO

Miller et al. (2017)

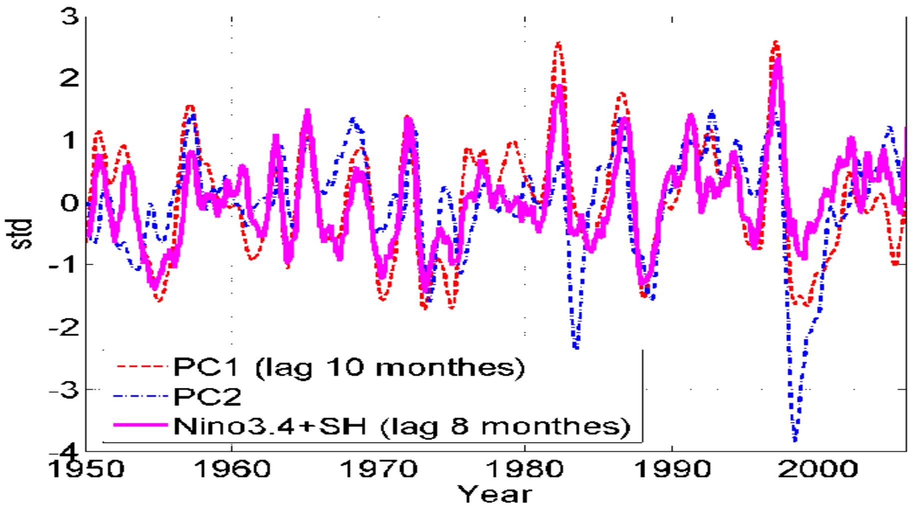
Links between the two dominant CEOF modes

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



- PC1 is essentially ENSO
- PC2 leads PC1/Nino3 by 9-11 months
- PC2 leads EMI by 5 months

PC2 (NPO/VM): important ENSO precursor



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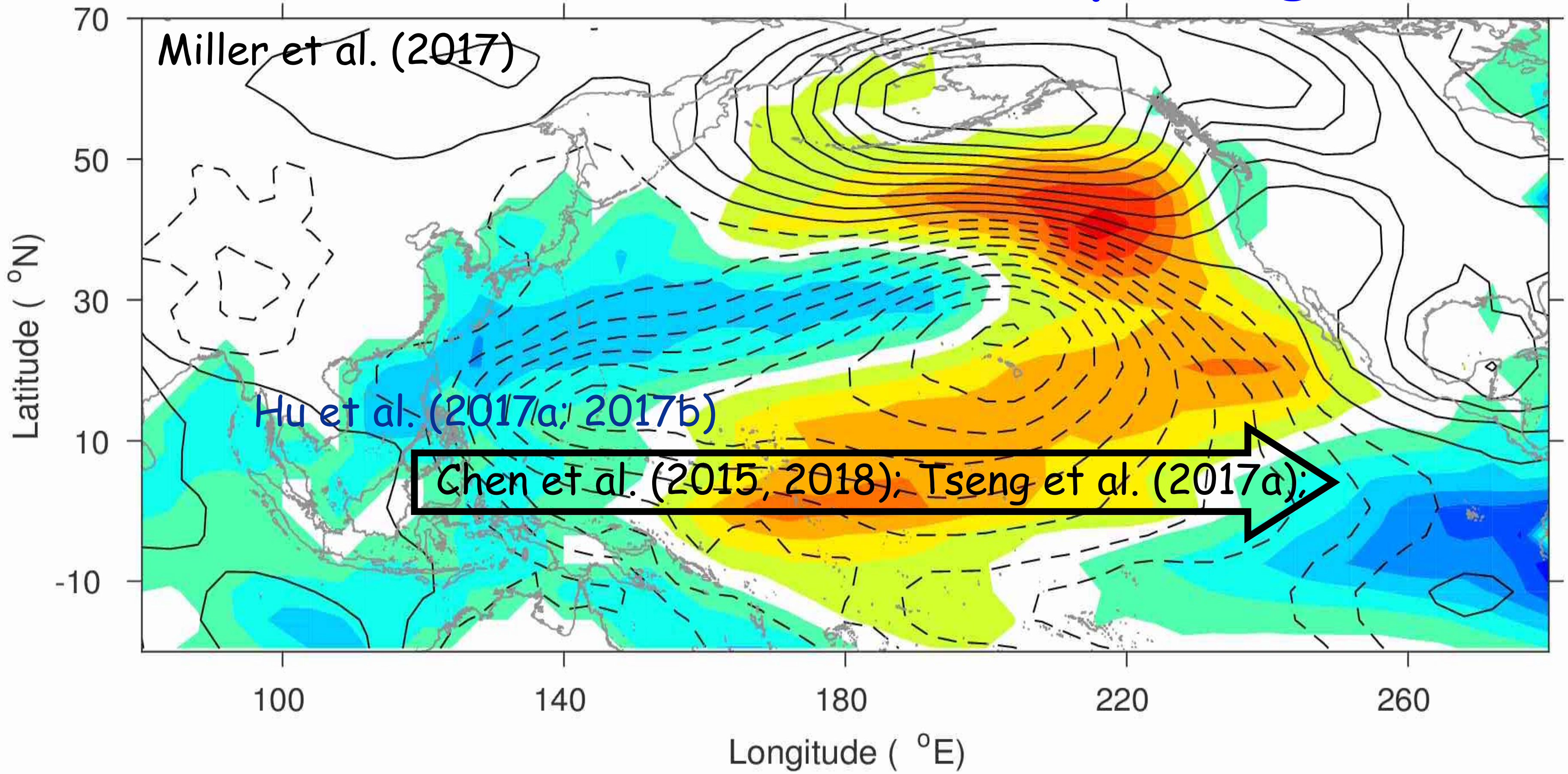
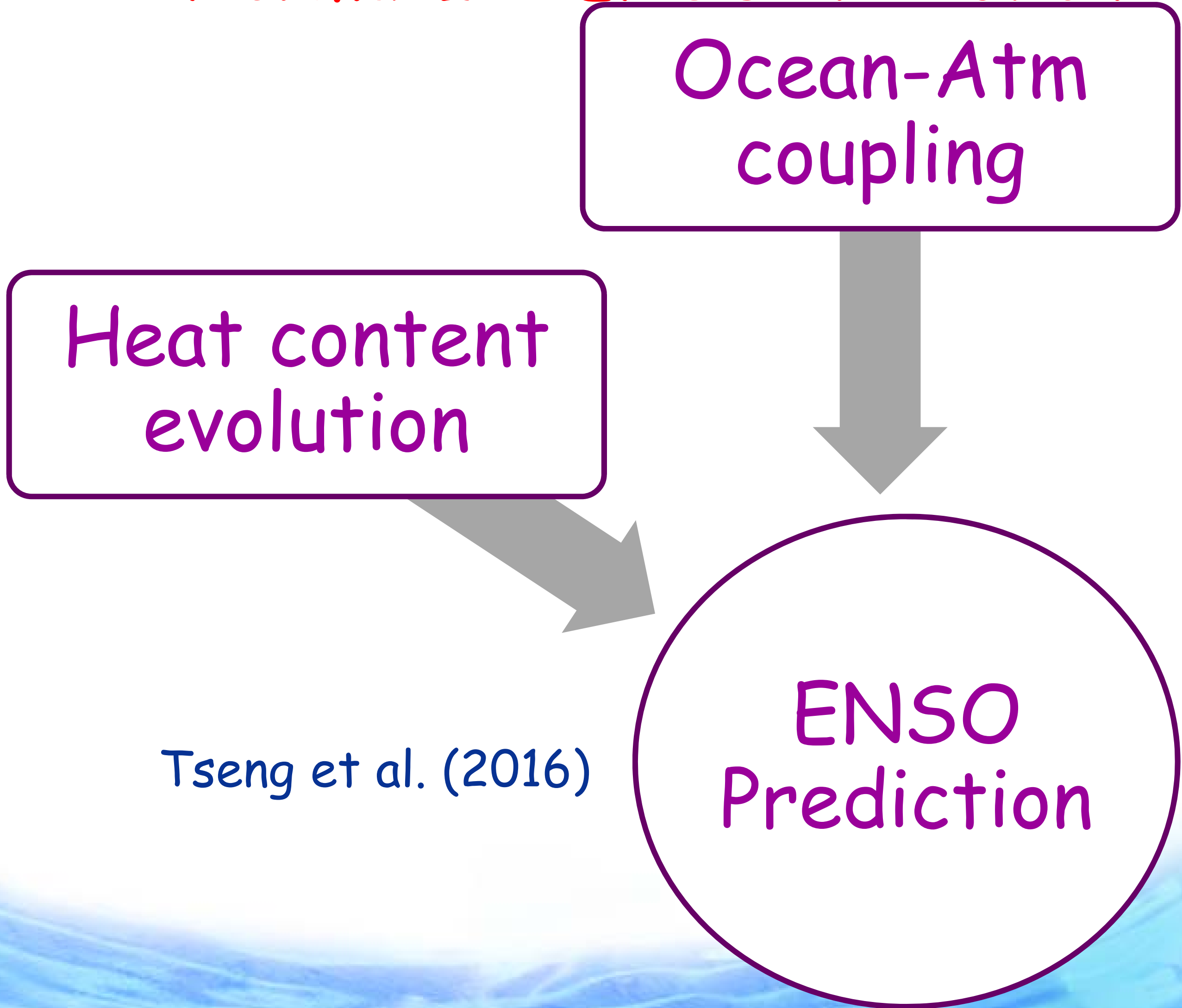


A modified statistical model

Normalized ENSO Prediction Index (nEPI)



Tseng et al. (2016)

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Simple ENSO prediction scheme

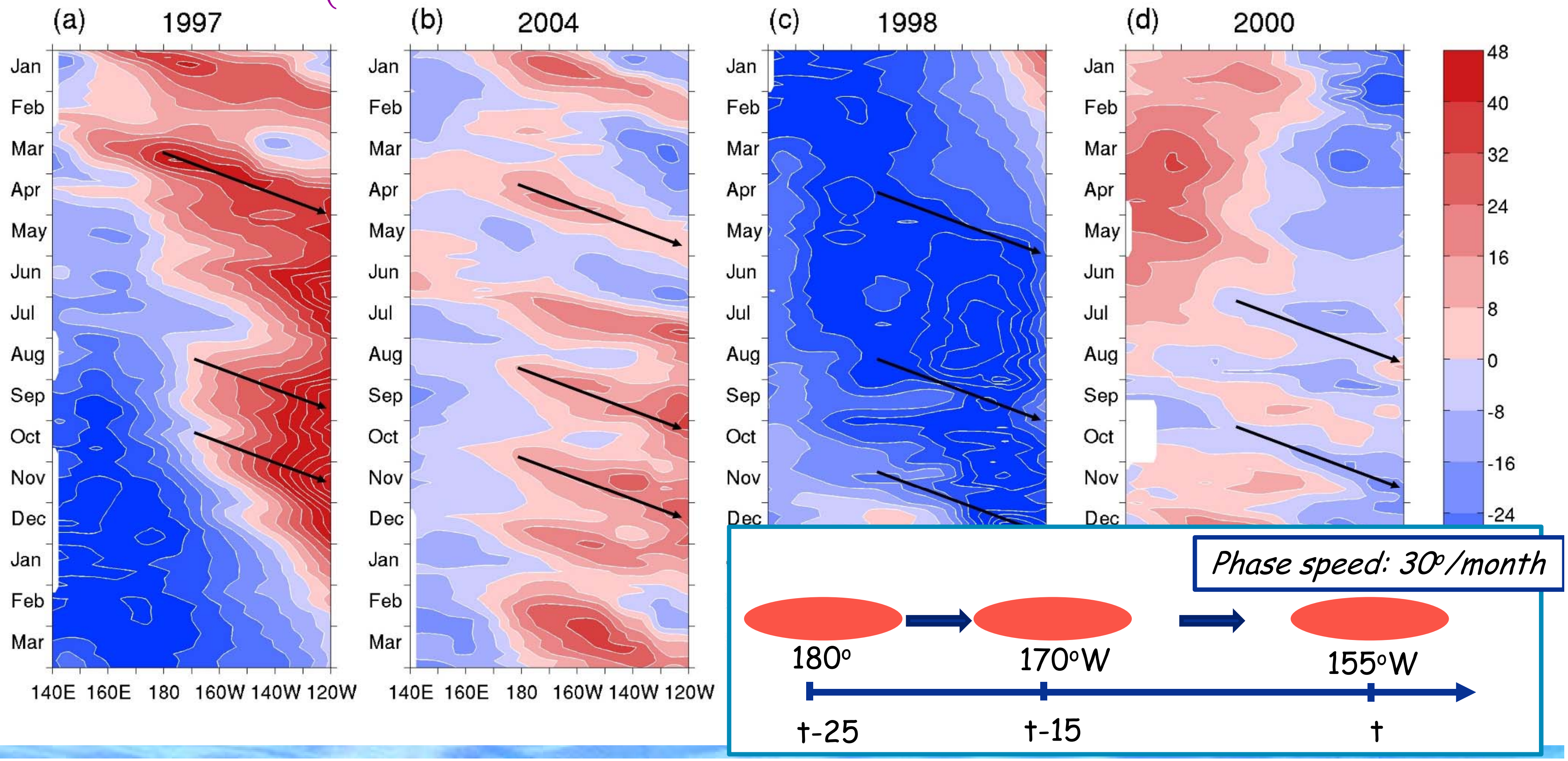
(Tseng et al. , 2017a)

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

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

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

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



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	
	GODAS	1981-2010	0.68 (0.65)		0.73	
eight-month	TAO	1994-2015	0.57	0.49	0.82	0.87
	GODAS	1980-2015	0.58		0.79	

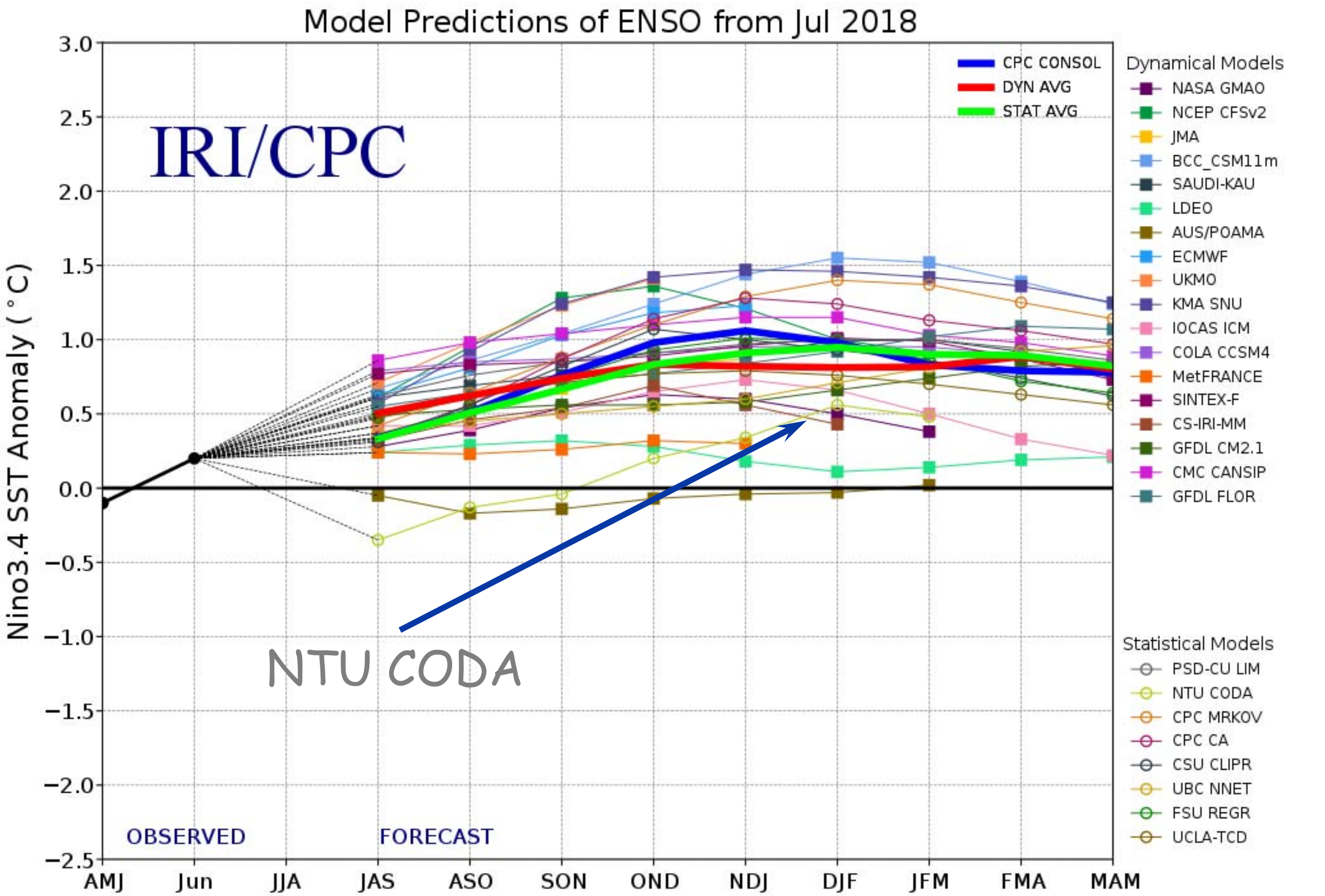
Percent correct of six-month ENSO forecast

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

IRI ENSO plume prediction in July



https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/

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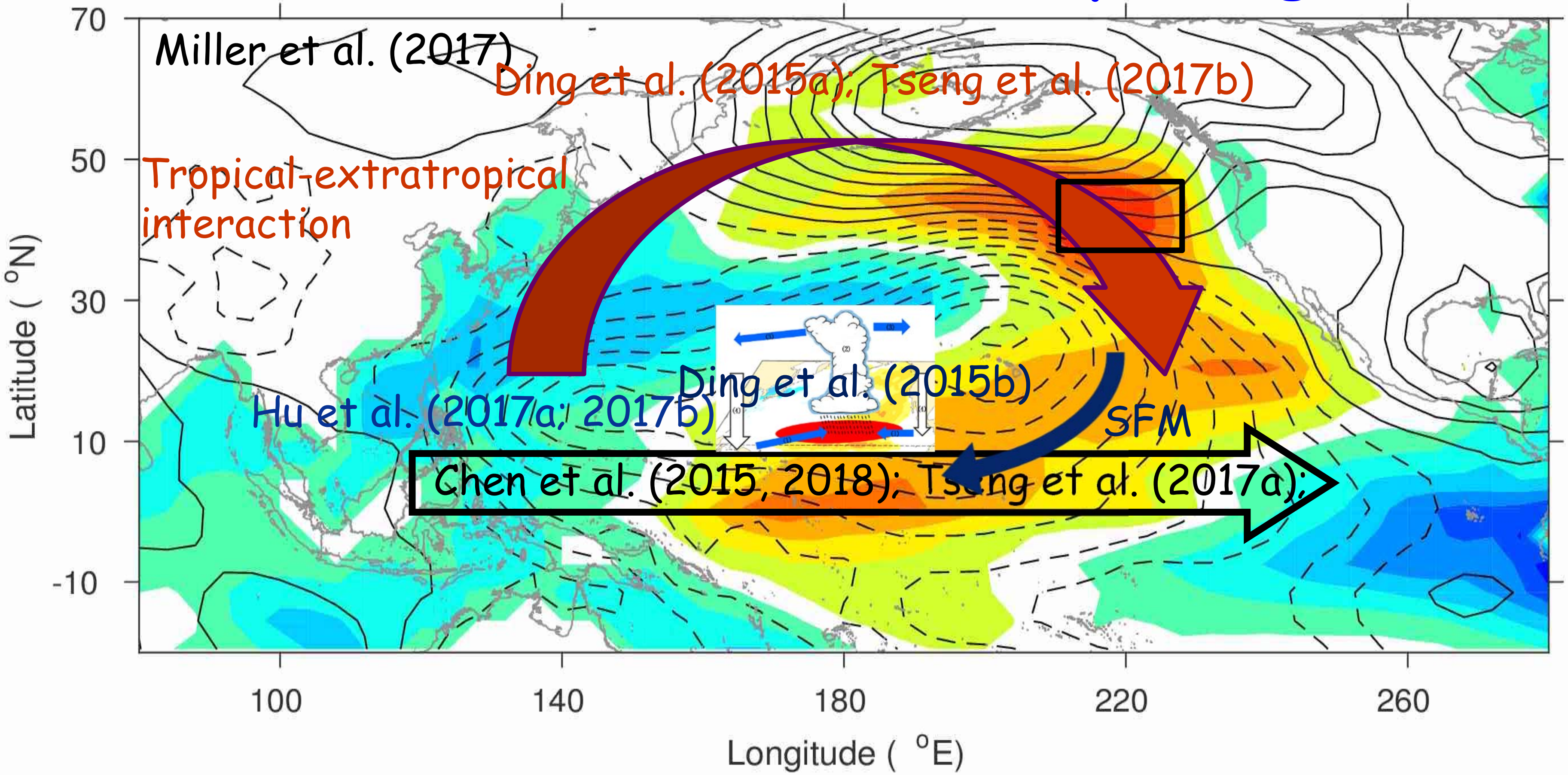
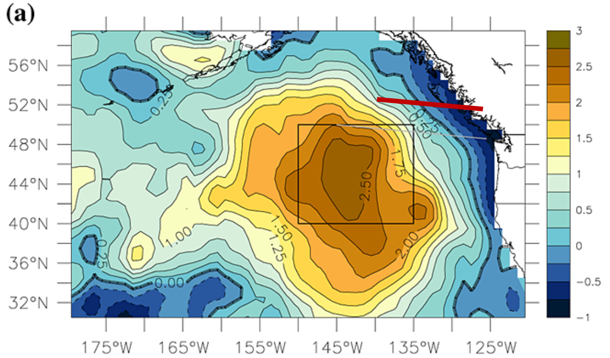


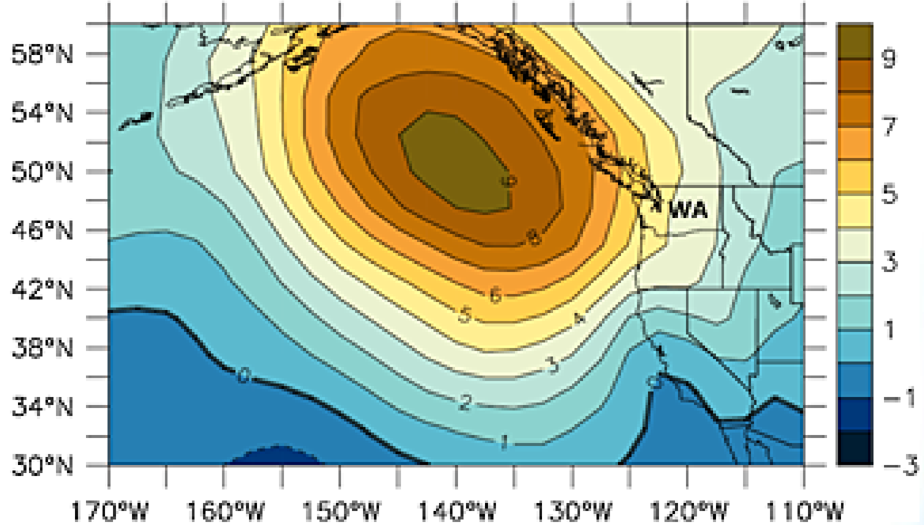
Warm Blob in the Northeastern Pacific after late 2013

(a)

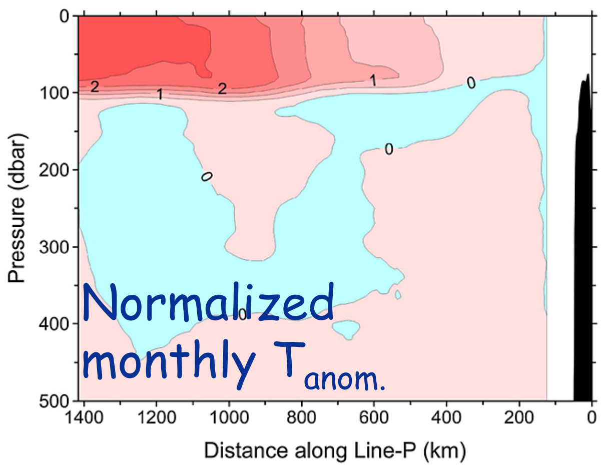


SSTa (°C) in NE Pacific Ocean for Feb. 2014

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

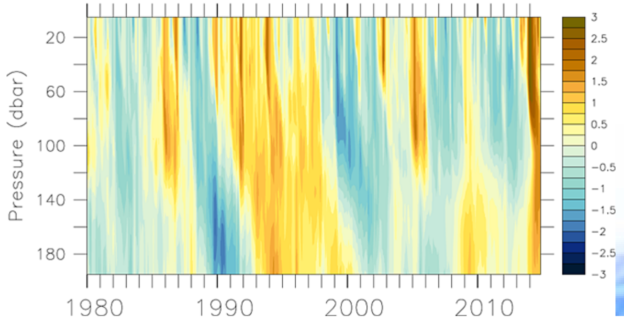


(b)



Normalized monthly $T_{anom.}$

(c) Upper ocean $T_{anom.}$ along "Line P"

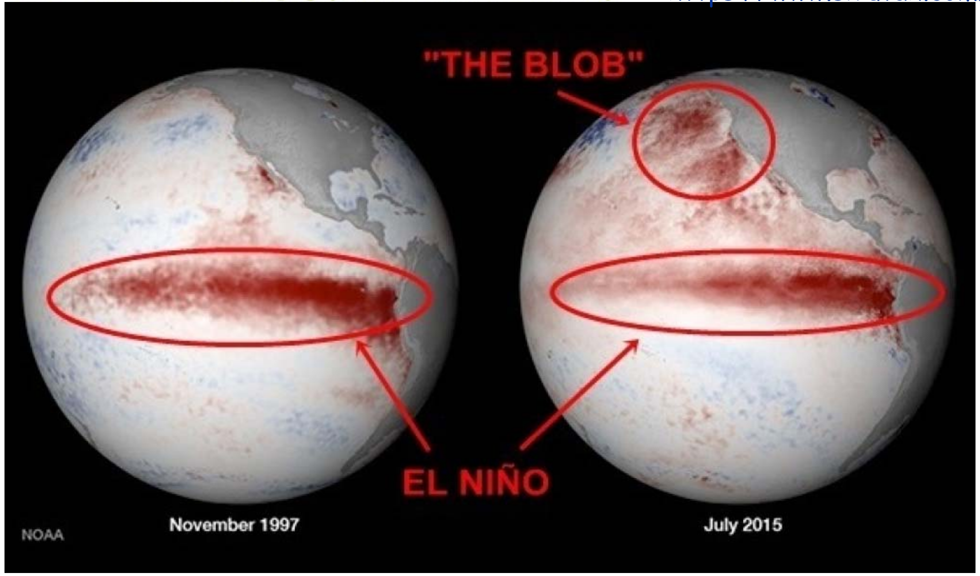


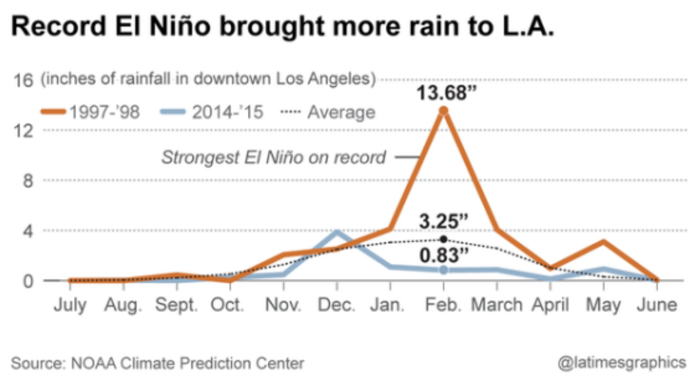
Bond et al. (2015)

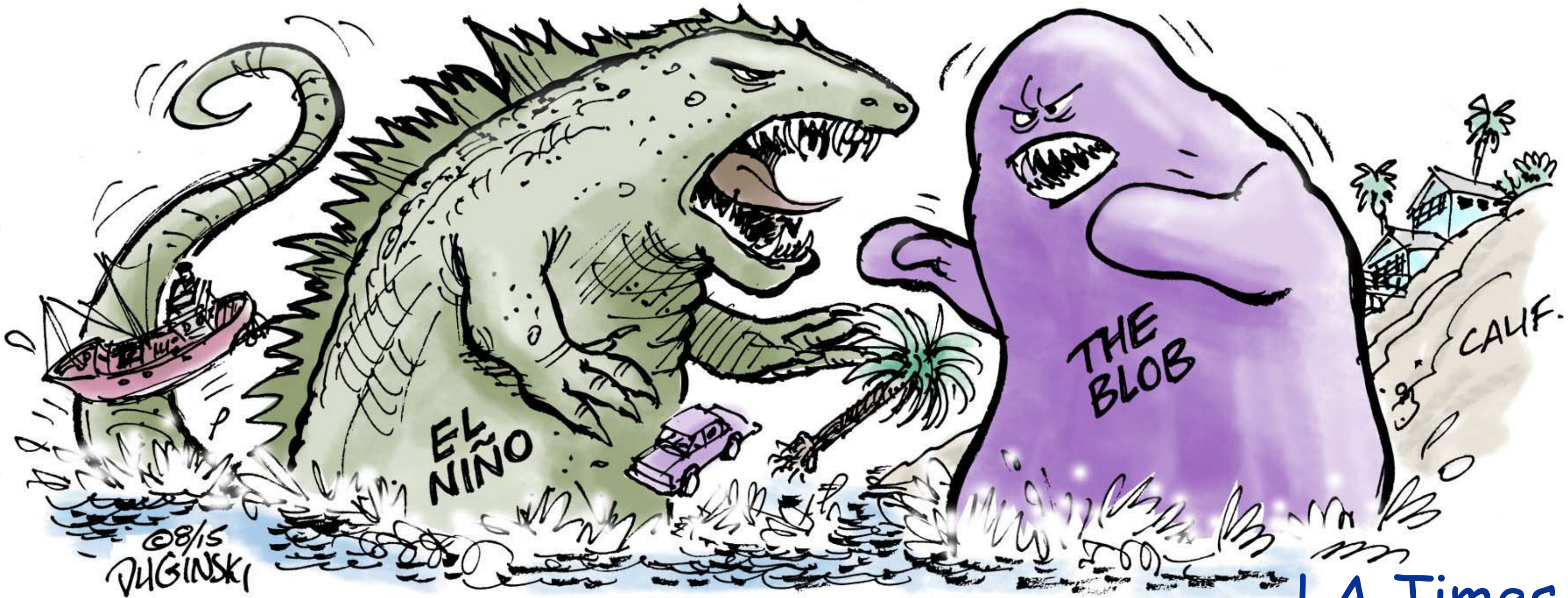
<u>Great impacts on the ocean ecosystem and U.S. climate</u>

Ski Utah

https://www.skiutah.com/blog/authors/yeti/el-ni-o-vs-the-blob







LA Times

http://www.latimes.com/local/lanow/la-me-ln-godzilla-el-nino-winter-california-20150821-htmlstory.html

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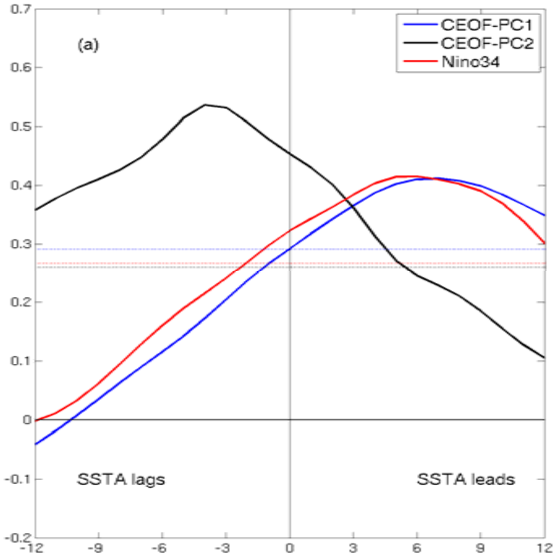
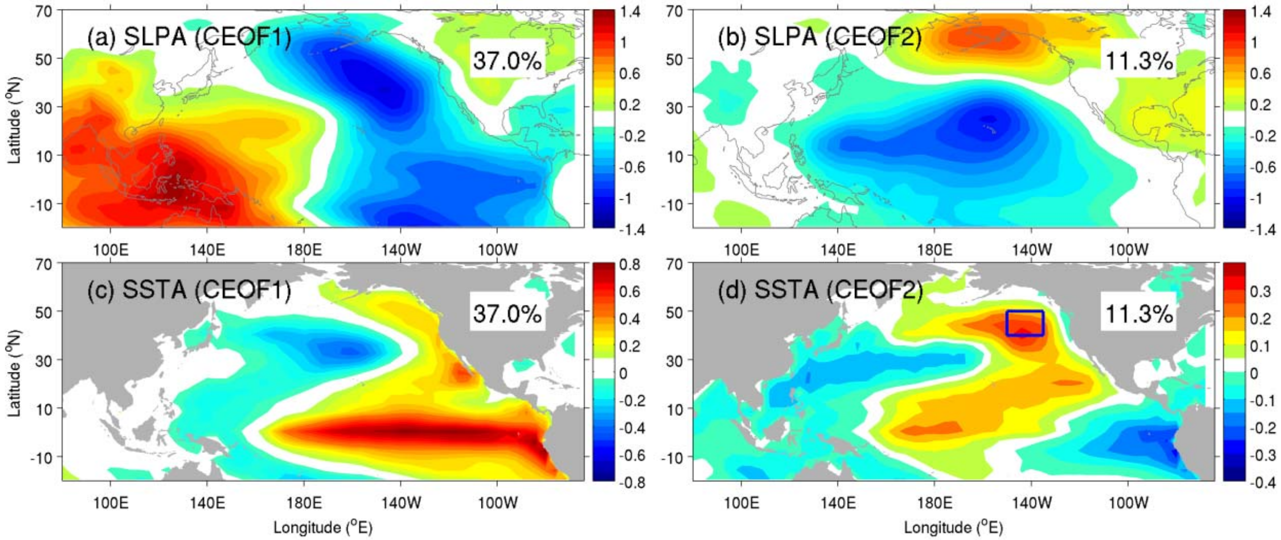
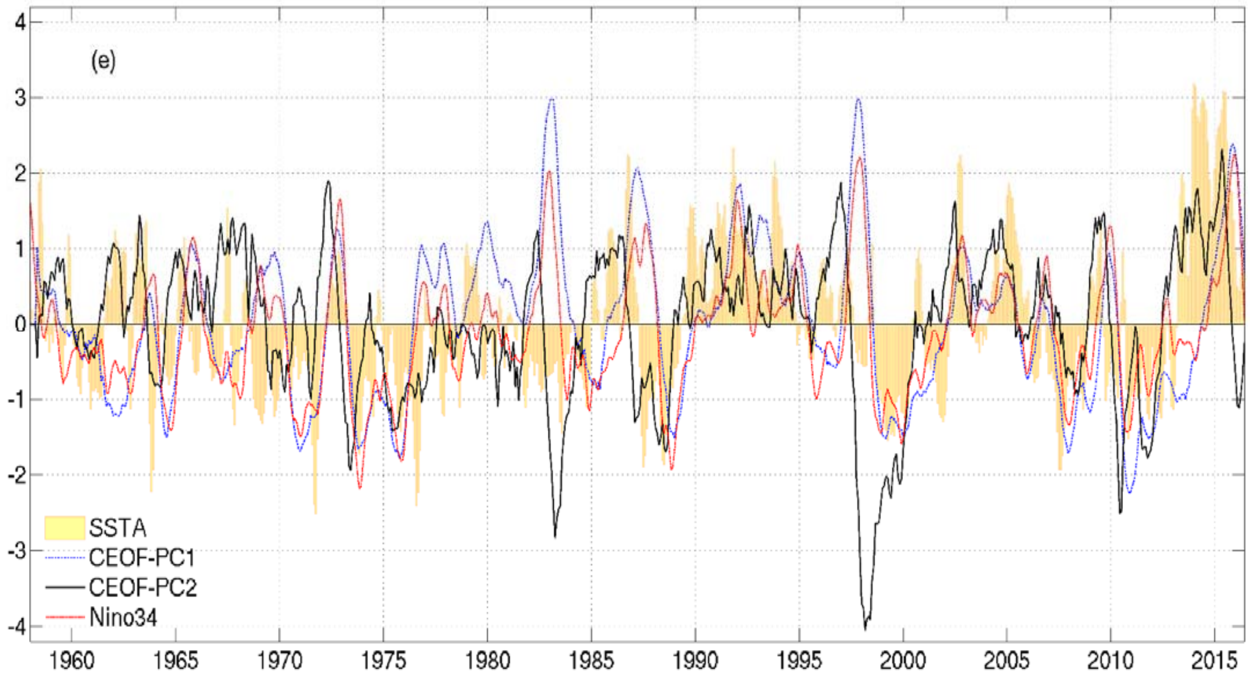
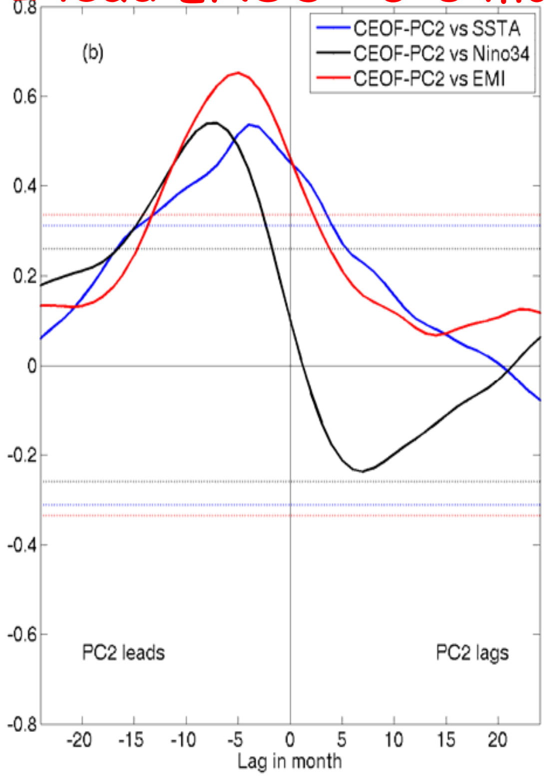
SSTa lag PC2 ~2-4 mon





PC2 lead ENSO ~5-8 mon





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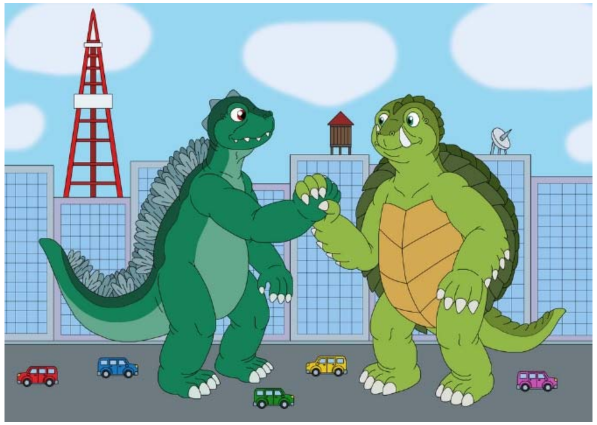
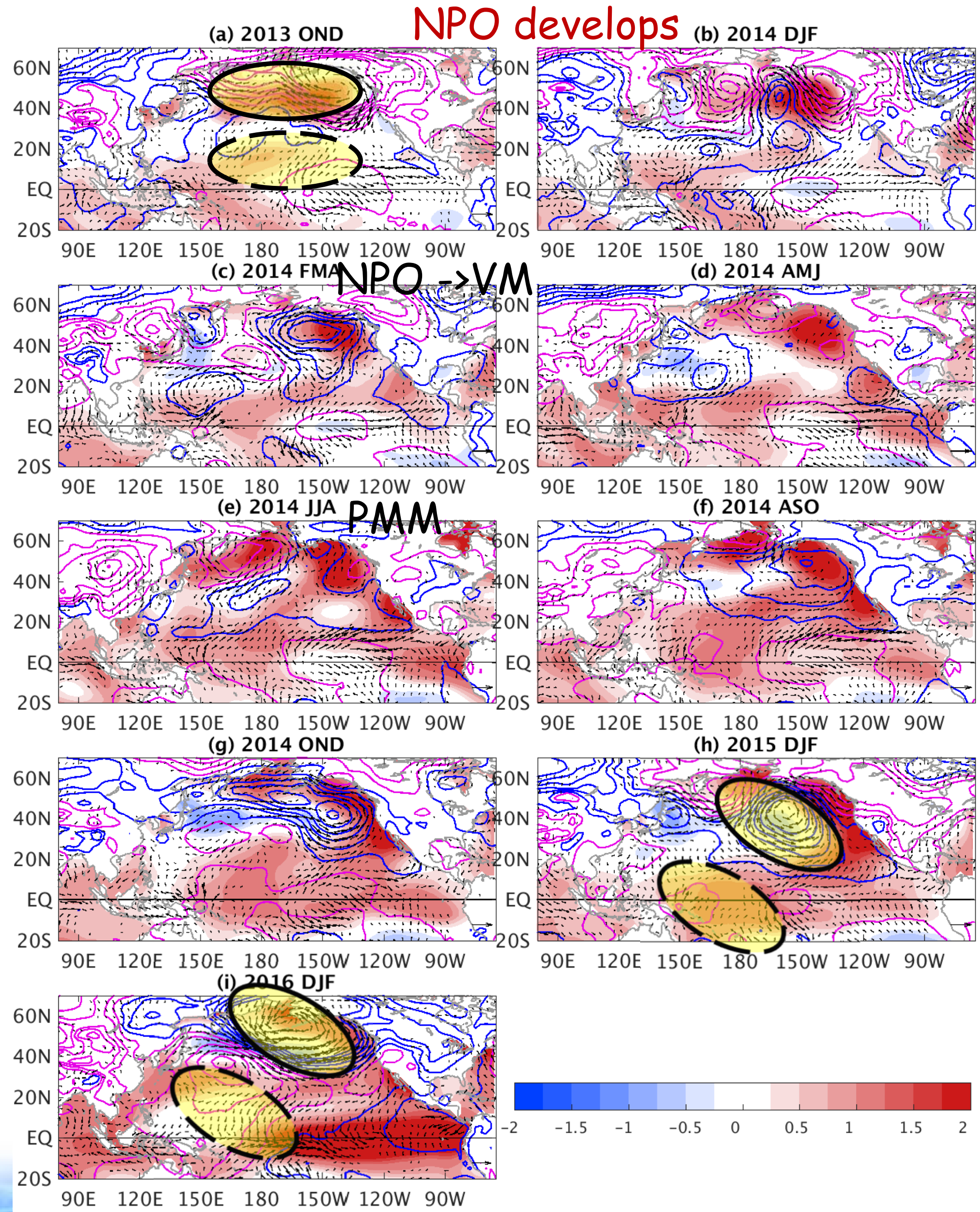
3-mon-averaged
SST (shaded),
SLP (contours) and
surface wind anomalies
in 2014.





Warm Blob and El Niño
are related!

Medium to strong ENSO events (bold: the SSTa in the Blob region >1std preceding the ENSO)	
El Niño	**1965/66, 1972/73,** 1982/83, **1986/87, 1987/88, 1991/92,** 1997/98, **2002/03, 2009/10, 2015/16**
La Niña	**1970/71, 1973/74, 1975/76,** 1988/89, **1998/99. 1999/00, 2007/08, 2010/11**

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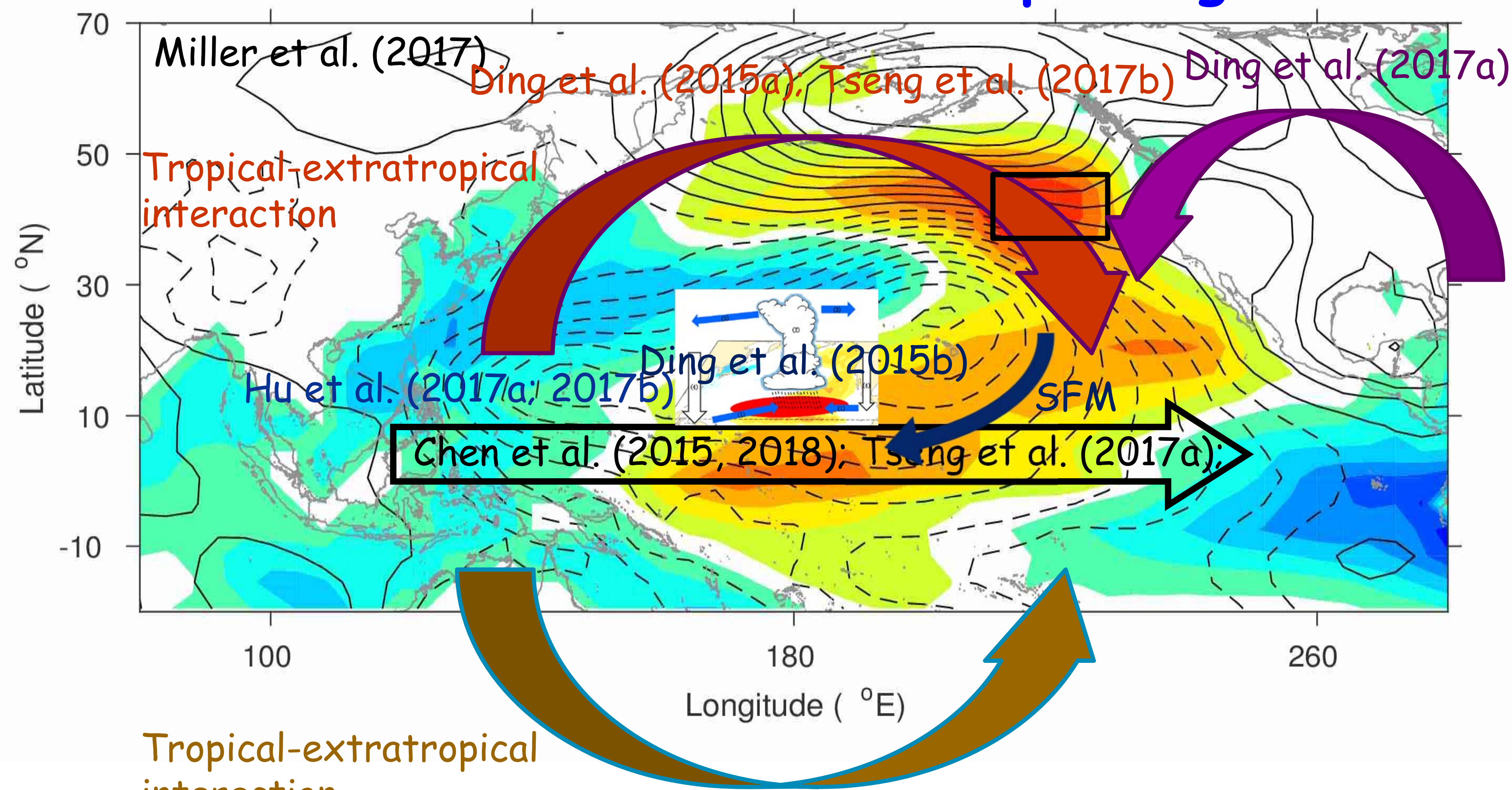
New North Pacific climate paradigm



Tropical-extratropical interaction

Ding et al. (2015c); Ding et al. (2016)

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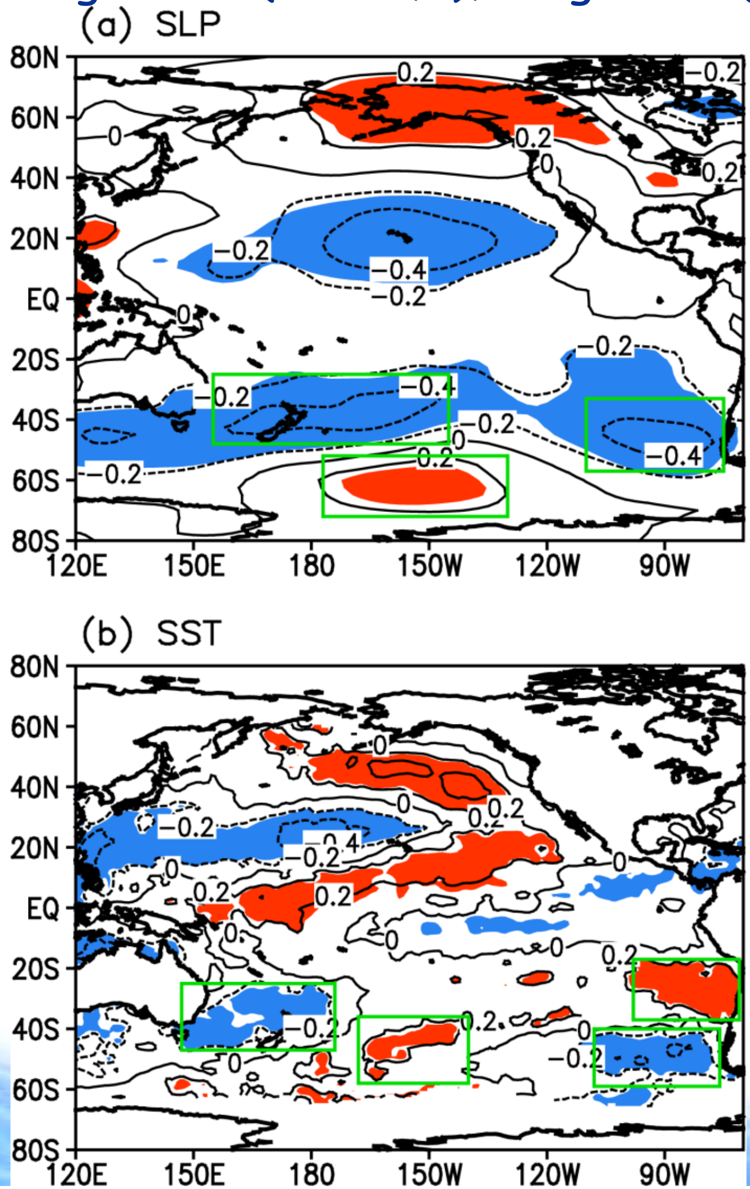
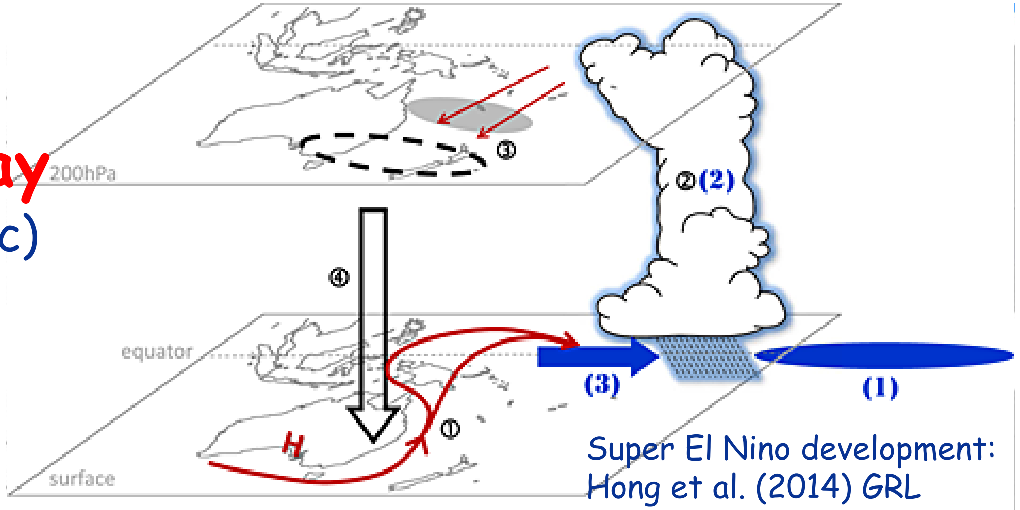
Southern hemisphere pathway

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





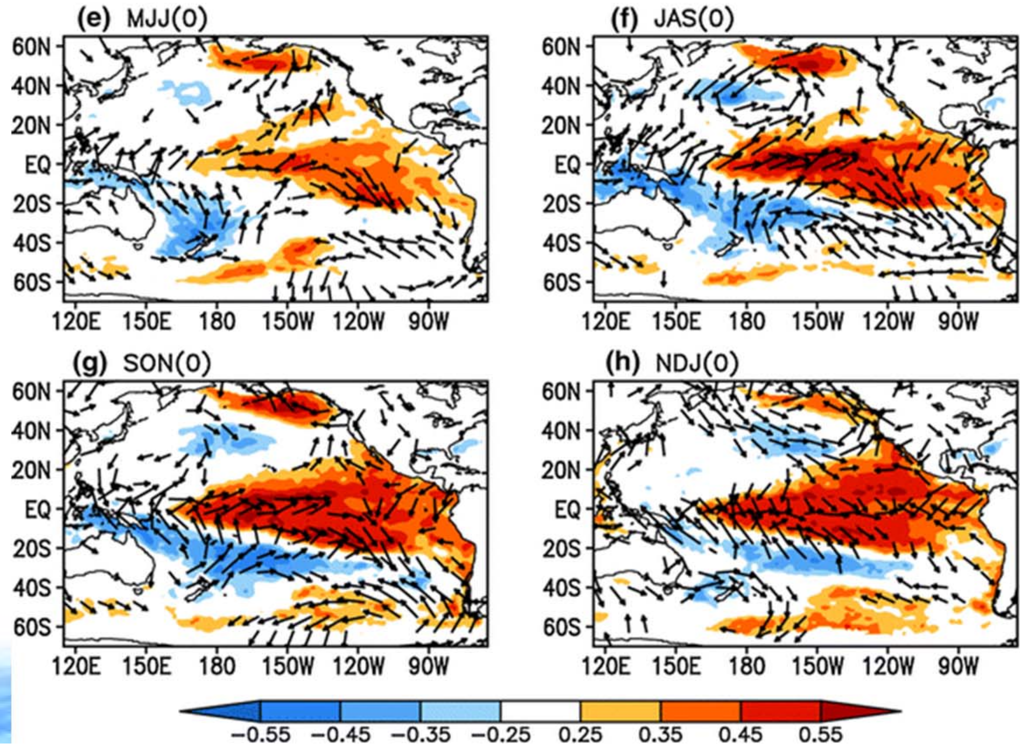
Super El Nino development: Hong et al. (2014) GRL

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



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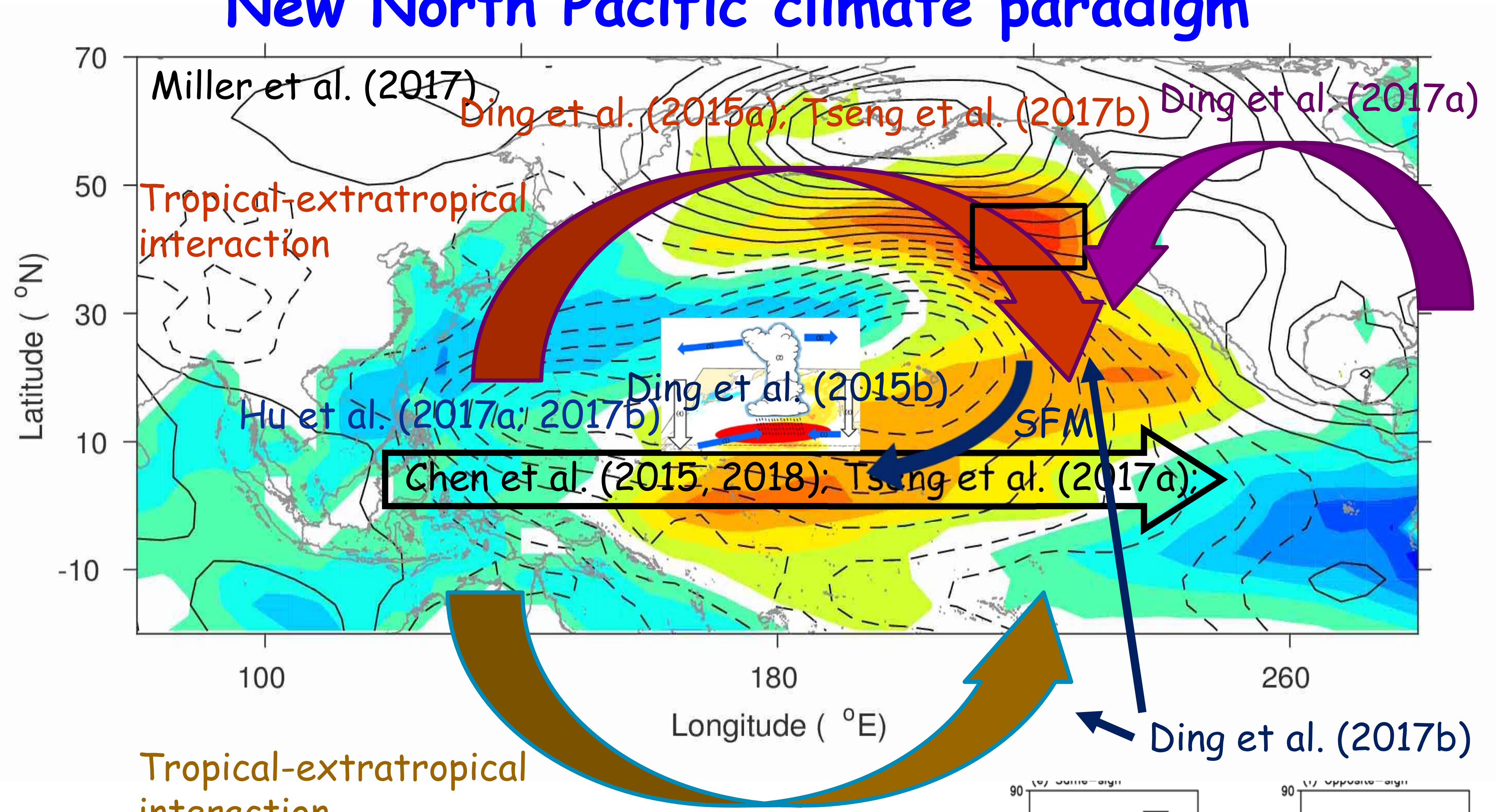
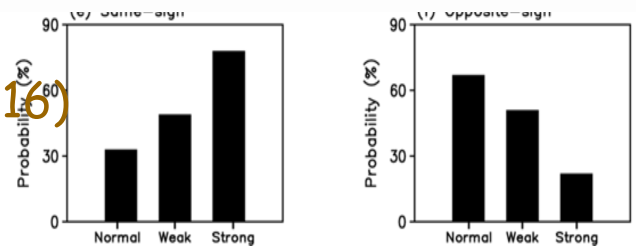
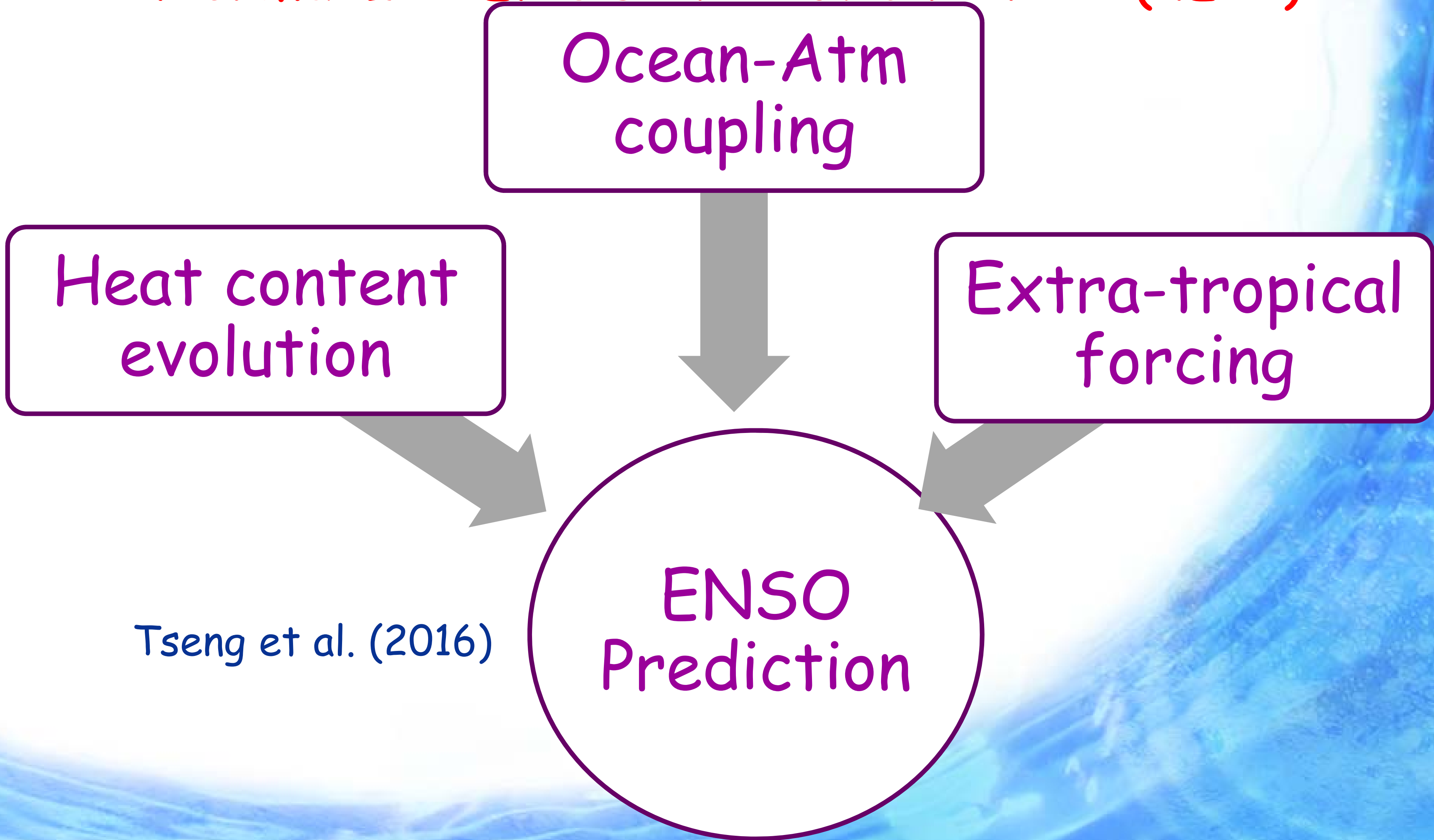




A modified statistical model

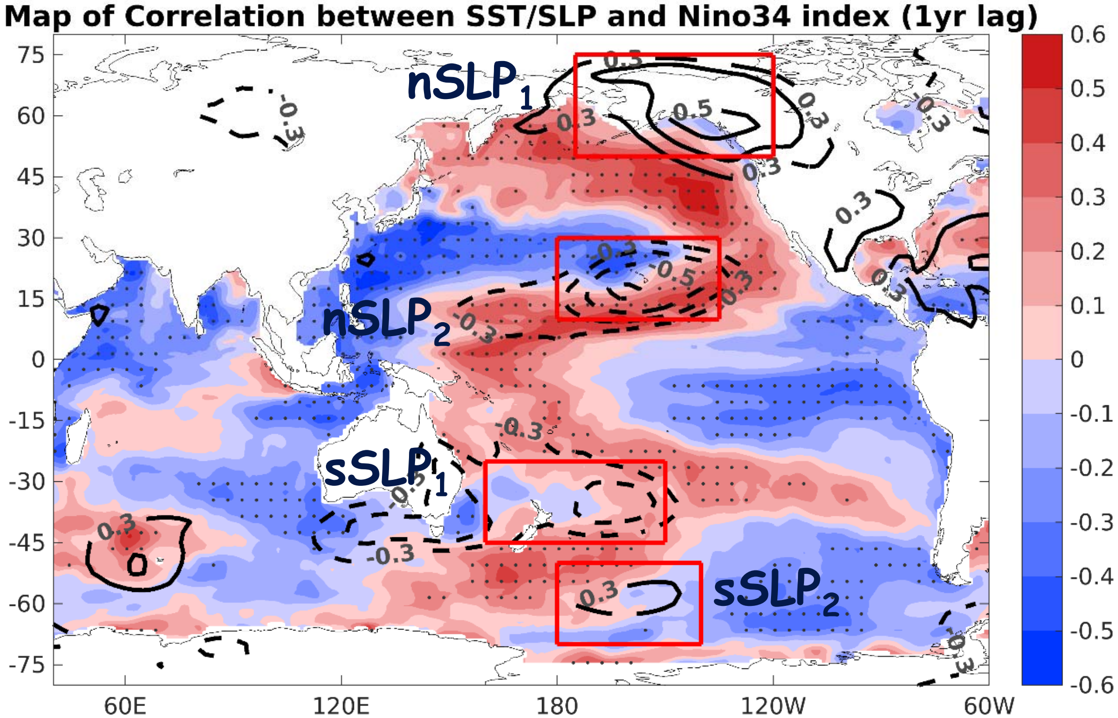
Normalized ENSO Prediction Index (nEPI)

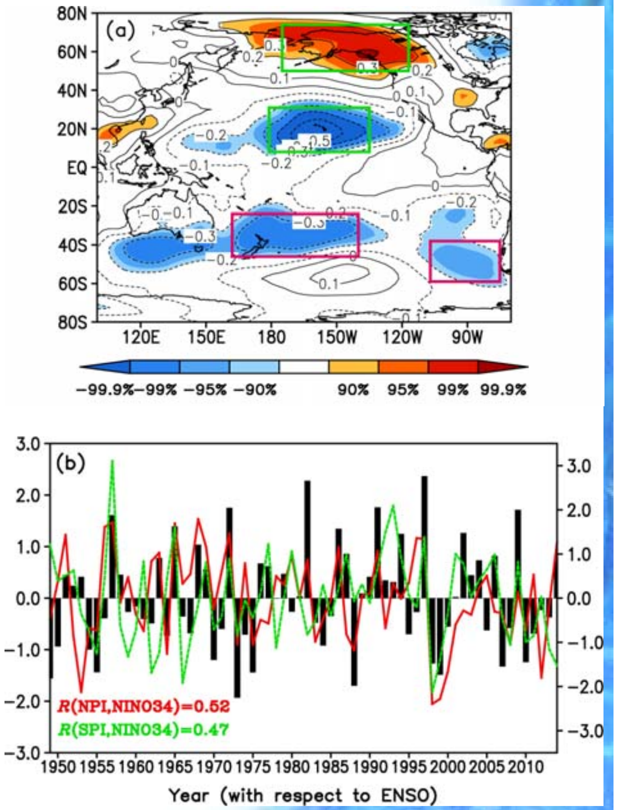


Tseng et al. (2016)

Extra-tropical forcing

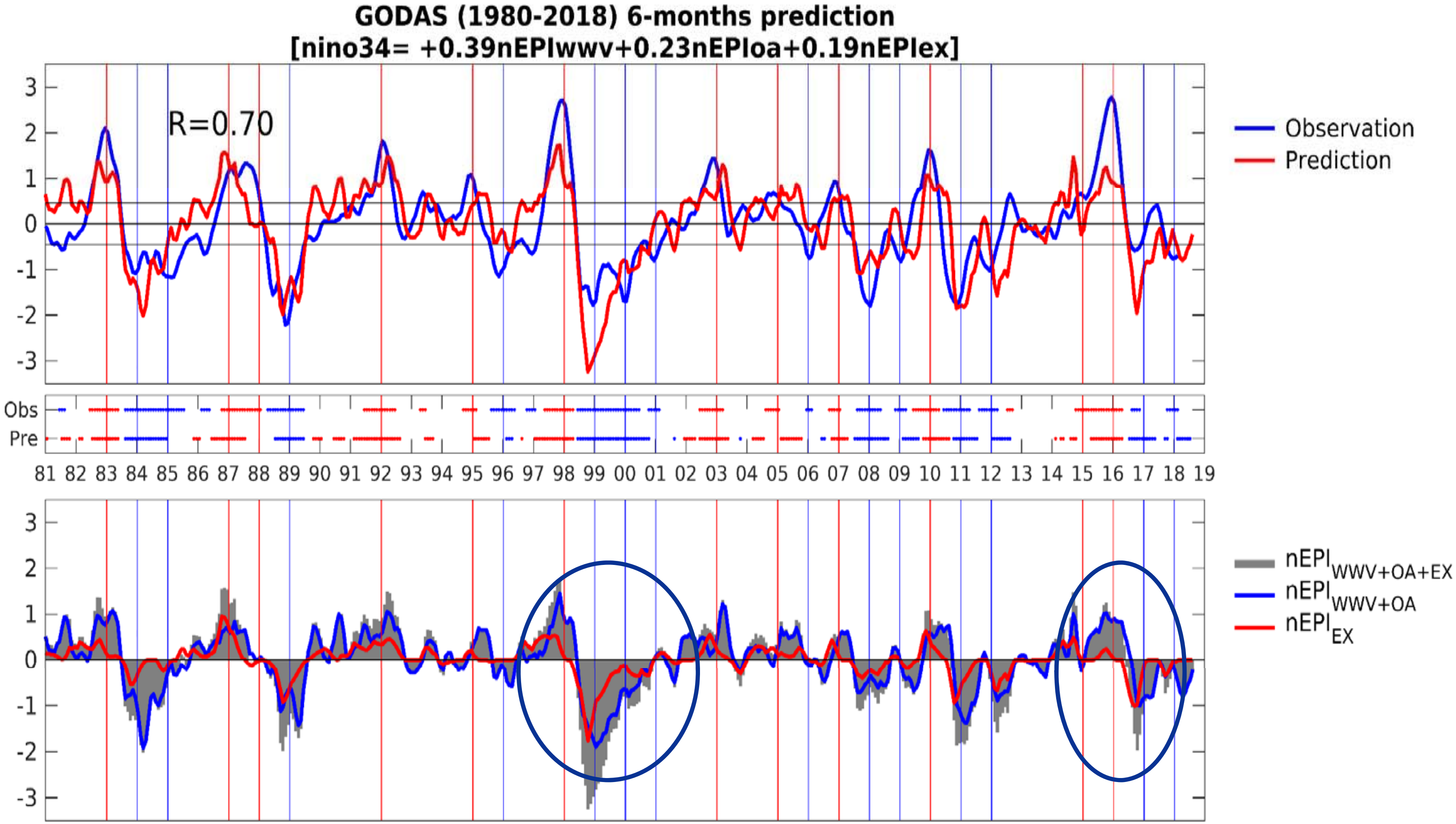
$$nEPI_{EX} = -[(-nSLP_1 + nSLP_2) + (sSLP_1 + sSLP_2)]$$





Ding et al. (2016)

The boreal winter subtropical and extratropical SLPa over both the North/South Pacific are significantly related to the ENSO state in the following boreal winter



Extratropical forcing dominates WWV dominates

1981-2010 Multi-model ensemble mean skill: 0.65 6-month lead

Hindcast skills (1980-2018)

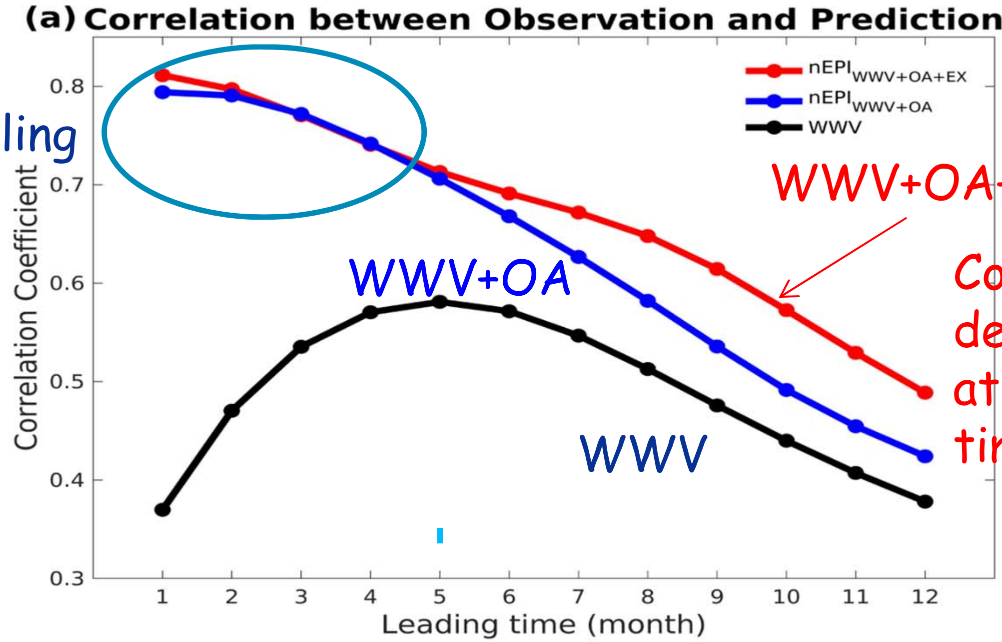
Lead time	Correlation pentad (monthly)		
	nEPI (WWV+OA+EX)	nEPI (WWV+OA)	WWV
Six-month	0.65 (0.71)	0.59 (0.67)	0.55 (0.57)
Eight-month	0.63 (0.67)	0.52 (0.58)	0.48 (0.51)
Ten-month	0.57 (0.60)	0.44 (0.49)	0.41 (0.44)

For $nEPI_{(WWV+OA+EX)}$, Nino 3.4 SSTa hindcast skill based on the linear regression model is generally better in terms of the monthly correlation.

Also, significantly increased for 10-month forecast

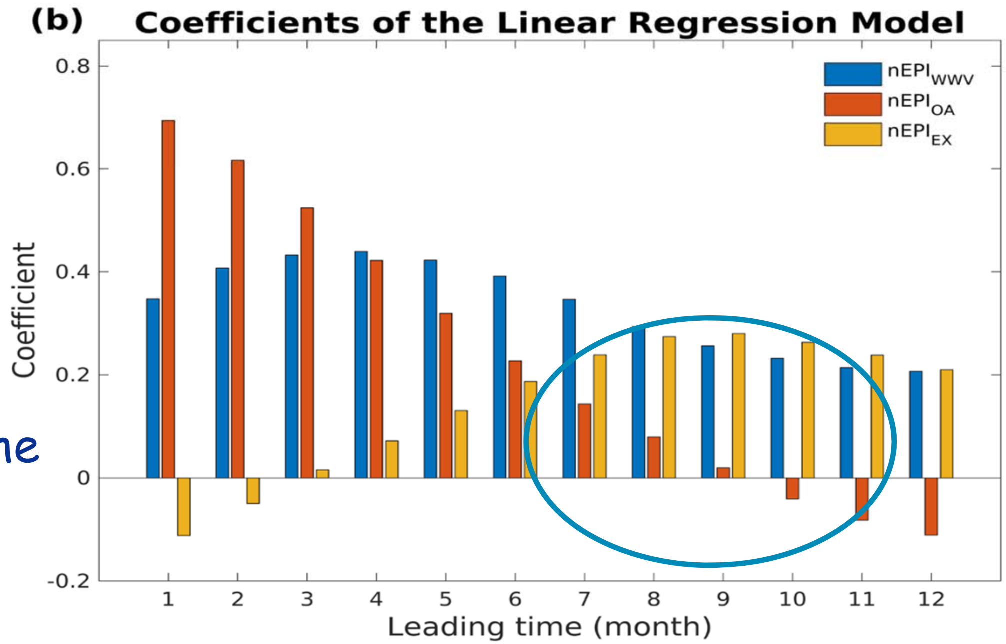
Role of individual terms

Strong O-A coupling



Correlation is not degraded too much at 6-month lead-time or longer

WWV is $\frac{1}{4}$ phase lead

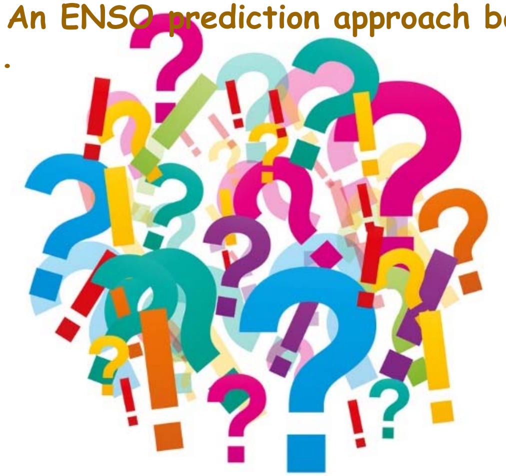


Extratropical forcing weights increase for the longer lead-time

Conclusion

- **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 (precursor of ENSO/PDO)
- **Hindcast skill of SSTa is generally better than the commonly used WWV index and all other prediction models in terms of the monthly correlation**
- **WWV propagation+O-A coupling greatly improves the ENSO prediction skill**
- **6 to 10 months lead time hindcast skill can be even enhanced by further incorporating the extratropical North/South Pacific forcing (Spring barrier may not be an issue)**

- Ding, R., Li, J., Tseng, Y.H., Sun, C. and Zheng F. (2017b), Linking a sea level pressure anomaly dipole over the North America to the central Pacific El Niño, *Clim. Dyn.*. 49, 1321-1339.
- Ding, R., Li, J., Tseng, Y.H., Sun, C. and Xie F. (2017a), Joint impact of North and South Pacific extratropical atmospheric variability on the onset of ENSO events, *J. Geophys. Res.-atmos,* 122, 279-298.
- Ding, R., Tseng, Y.H., Ha, K.J., Lee, J.Y. and Li, J. (2016), Interdecadal change in the lagged relationship between the Pacific-South American pattern and ENSO, *Clim. Dyn.*, 47, 2867-2884.
- Chen, H.C., Sui, C.H., Tseng, Y.H. and Huang, B.H. (2015), An analysis of the linkage of Pacific subtropical cells with the Recharge-Discharge processes in ENSO evolution, *J. Clim.,* 28, 3786-3805.
- Ding, R., Li, J., Tseng, Y.H., Sun, C. and Guo, Y. (2015), The Victoria mode in the North Pacific linking extratropical sea level pressure variations to ENSO, *J. Geophys. Res.,* 120, 27-45.
- Ding, R., Li, J., Tseng, Y.H. and Ruan, C. (2015), Influence of the North Pacific Victoria mode on the Pacific ITCZ summer precipitation, *J. Geophys. Res.*, 120, 964-979.
- Ding, R., Li, J. and Tseng, Y.H. (2015), The impact of south Pacific extratropical forcing on ENSO and comparisons with the North Pacific, *Clim. Dyn.,* 44, 2017-2034.
- Hu, Z.Z., Humar, A., Zhu, J., Huang, B., Tseng, Y.H., Wang, X. (2017a), On the shortening of the lead time of ocean warm water volume to ENSO SST since 2000 *Sci. Rep.*, 7, 4294.
- Hu, Z.Z., Huang, B., Tseng. Y.H., Wang, W., Kumar, A. Zhu, J. and Jha, B. (2017b), Does vertical temperature gradient of the atmosphere matter for El Nino development? *Clim. Dyn.*, 48, 1413-1429.
- Miller, A. J. et al. (2017), Coupled ocean-atmosphere modeling and predictions, *J. Marine Res.*, 75, 361-402.
- Tseng, Y.H., Ding, R. and Huang, X.-M. (2017a), The warm blob in the northeastern Pacific-the bridge leading to the 2015/16 El Niño, *Environ. Res. Lett.*, 12, 054019.
- Tseng, Y.H., Hu, Z.Z., Ding, R. and Chen, H.C. (2017b), An ENSO prediction approach based on ocean conditions and ocean-atmosphere coupling, *Clim. Dyn.* 48, 2025-2044.



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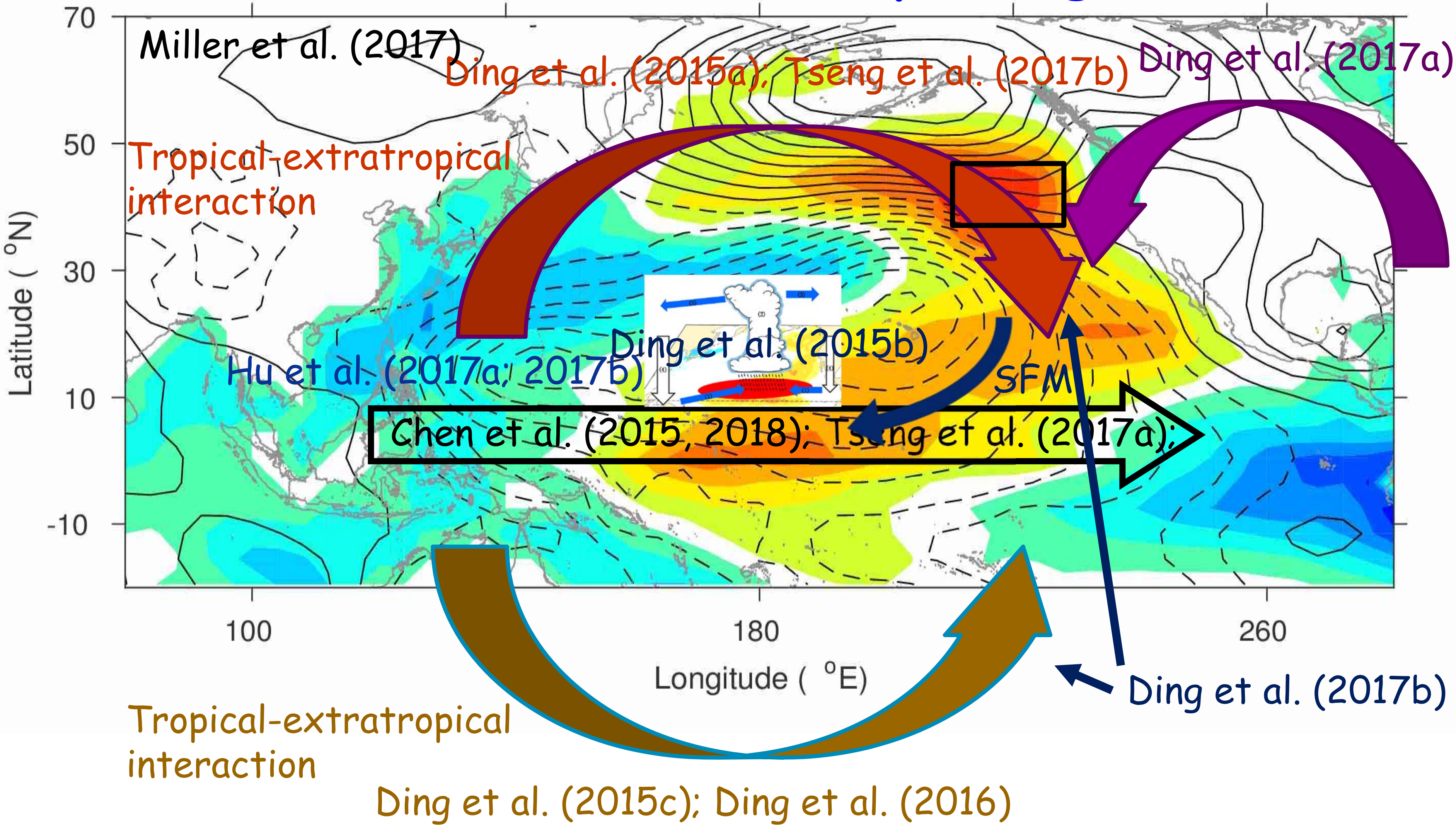

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