



# Enhancing the ENSO Predictability beyond the Spring Barrier

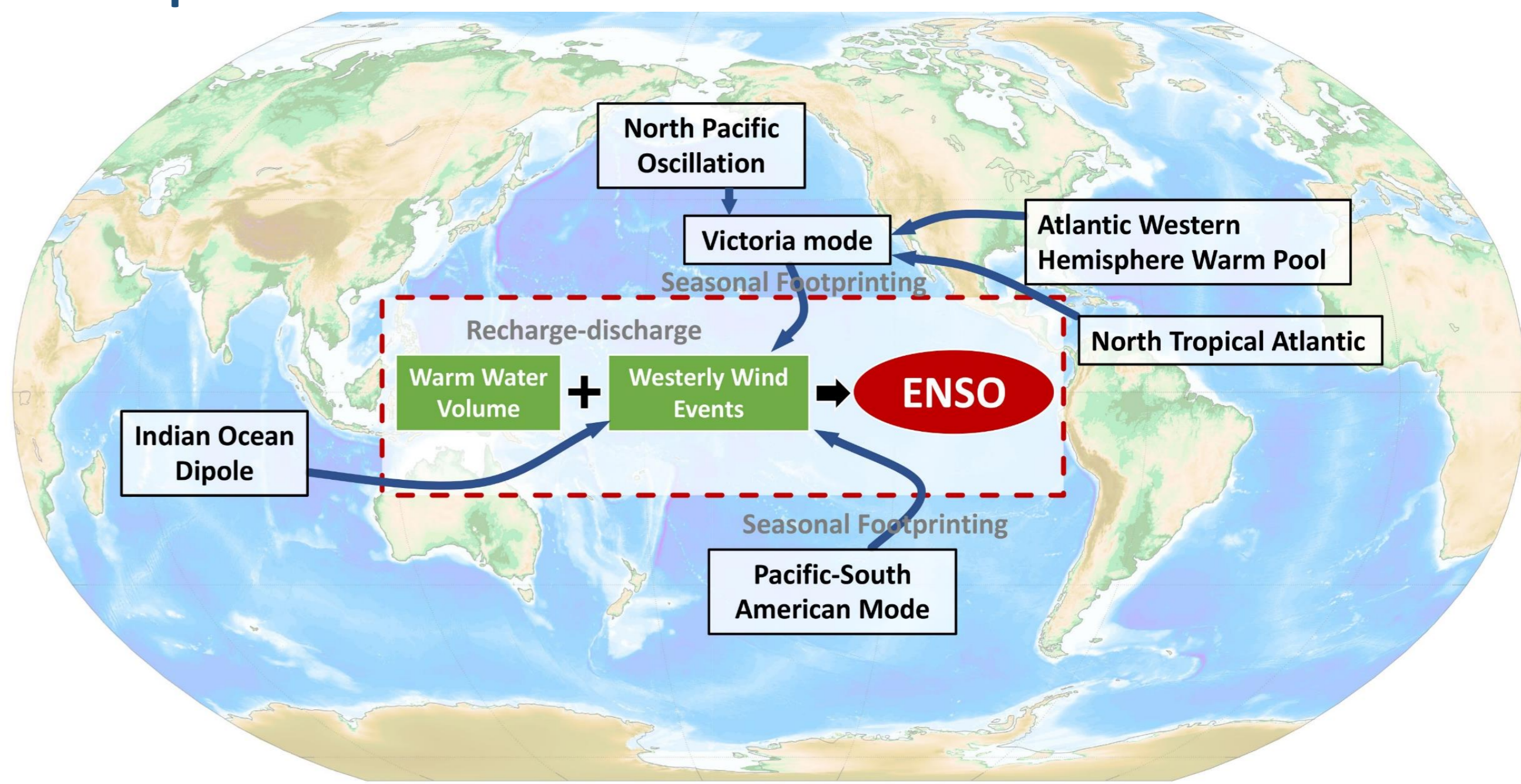
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## Abstract

El Niño-Southern Oscillation (ENSO) shows the dominant interannual-intedecadal variability in the tropical Pacific and substantial efforts have been dedicated to predicting its occurrence and variability because of its extensive global impacts. However, ENSO predictability has been reduced in the 21<sup>st</sup> century. The impact of extratropical atmosphere on the tropics has intensified during the past 2 decades, making the ENSO more complicated and harder to predict. Here, by combining tropical preconditions/ocean-atmosphere interaction with extratropical precursors, we provide a novel approach to noticeably increase the ENSO prediction skill beyond the spring predictability barrier. The success of increasing the prediction skill results mainly from the longer lead-time of the extratropical-tropical ocean-to-atmosphere interaction processes, especially for the first 2 decades of the 21<sup>st</sup> century.

## ENSO predictor



## ENSO prediction model

$$EPM(t + \varphi) = \frac{\sigma_o(m)}{\sigma_p(m)} [\beta_1 EP_{WWV}(t) + \beta_2 EP_{OA}(t) + \beta_3 EP_{EX}(t)]$$

### Tropic dynamics

$EP_{WWV}$ : Propagation of WWV in the central Pacific

$EP_{OA}$ : Ocean-atmosphere feedback

### Extratropical teleconnection

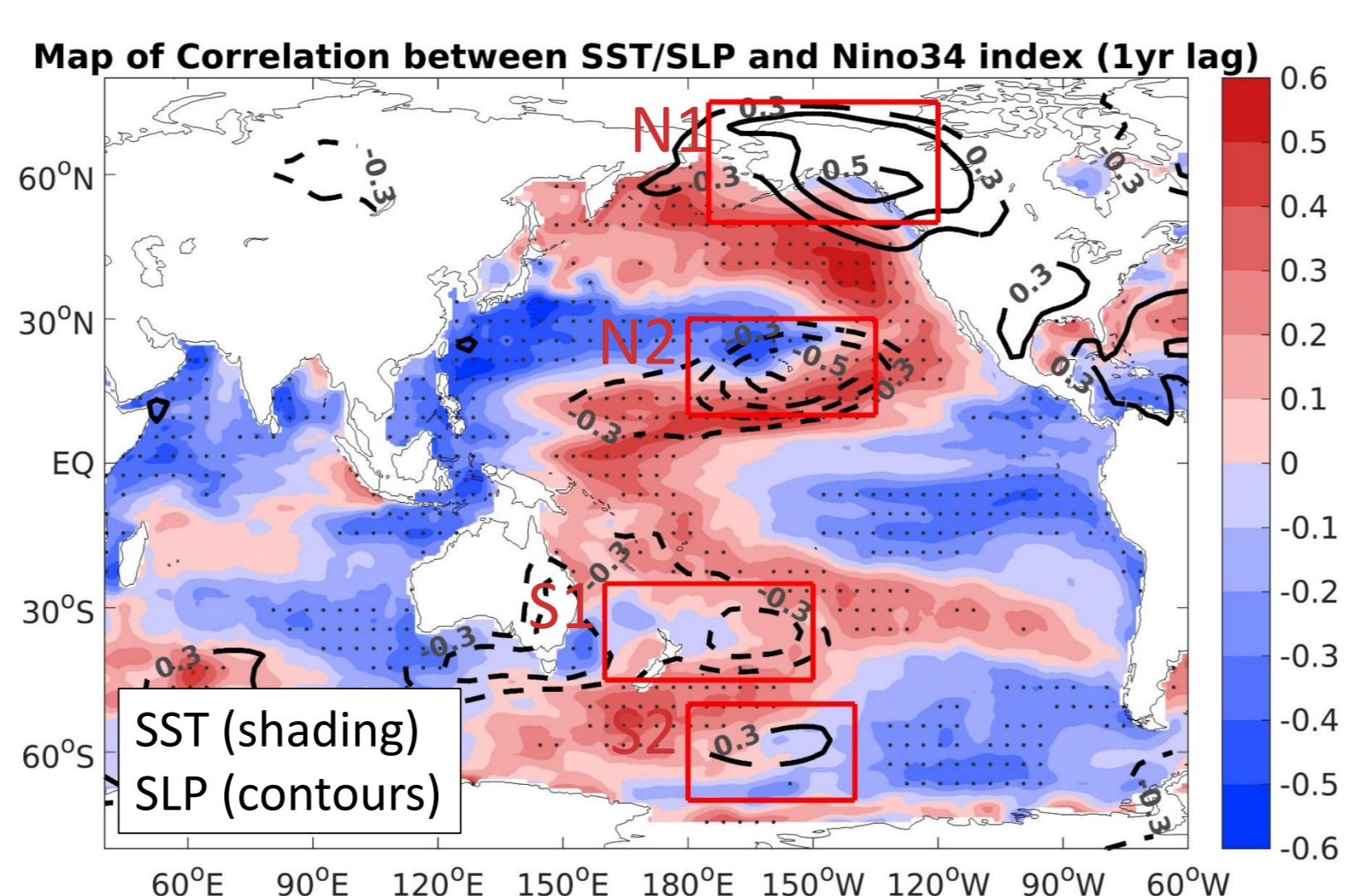
$EP_{EX}$ : Extratropical atmosphere forcing

Tseng, Y.-H., Z.-Z. Hu, R.-Q. Ding, H.-C. Chen, 2017:

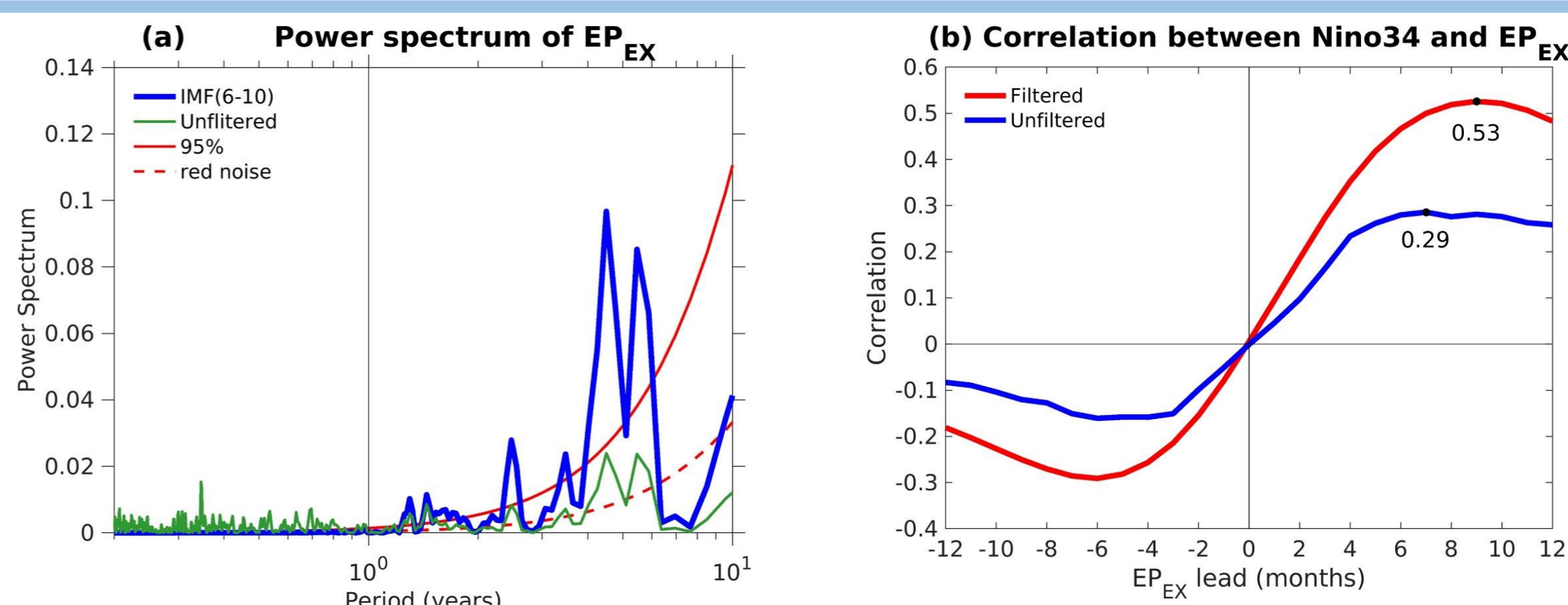
An ENSO prediction approach based on ocean conditions and ocean-atmosphere coupling. *Clim. Dyn.*  
DOI: <https://doi.org/10.1007/s00382-016-3188-2>.

## Extratropical ENSO precursors index

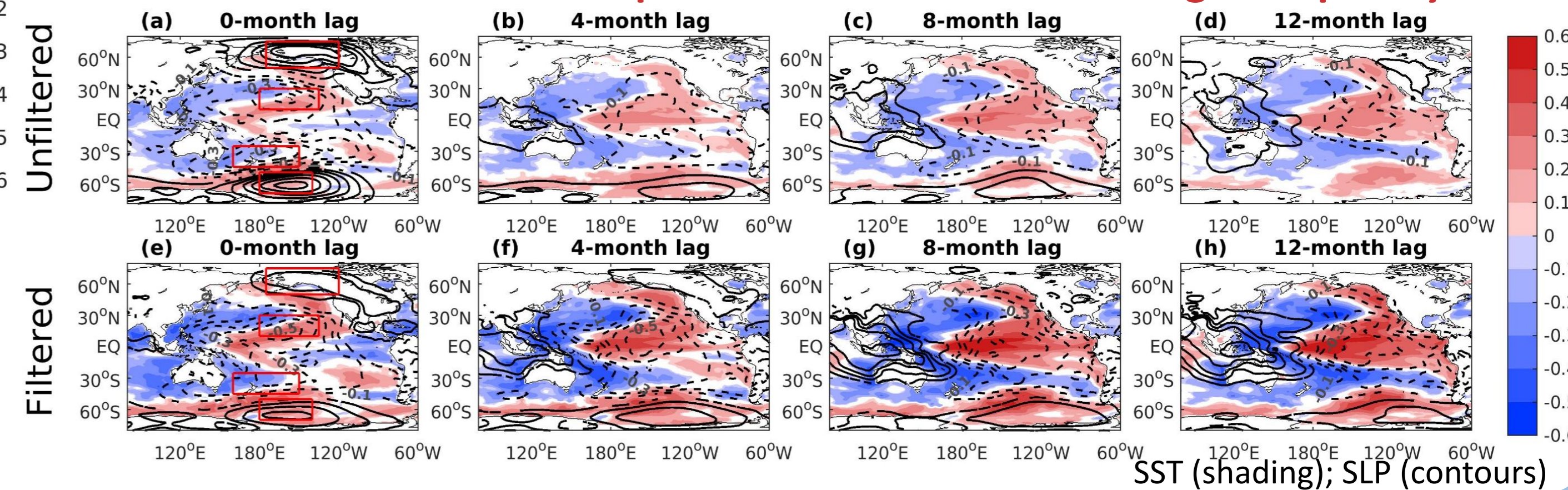
$$EP_{EX} = (SLPA_{N1} - SLPA_{N2}) + (SLPA_{S2} - SLPA_{S1})$$



A potential of the extratropics to enhance the predictability of ENSO

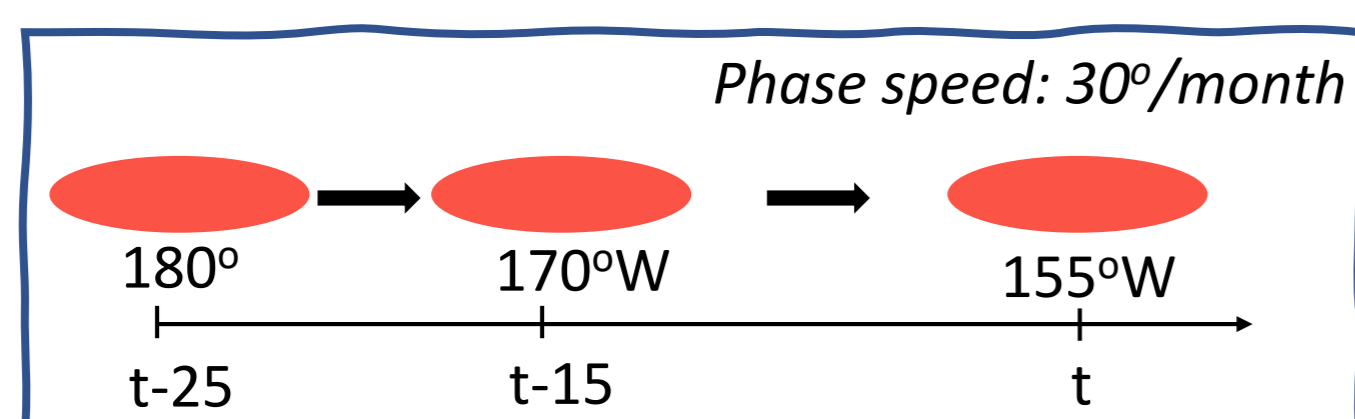
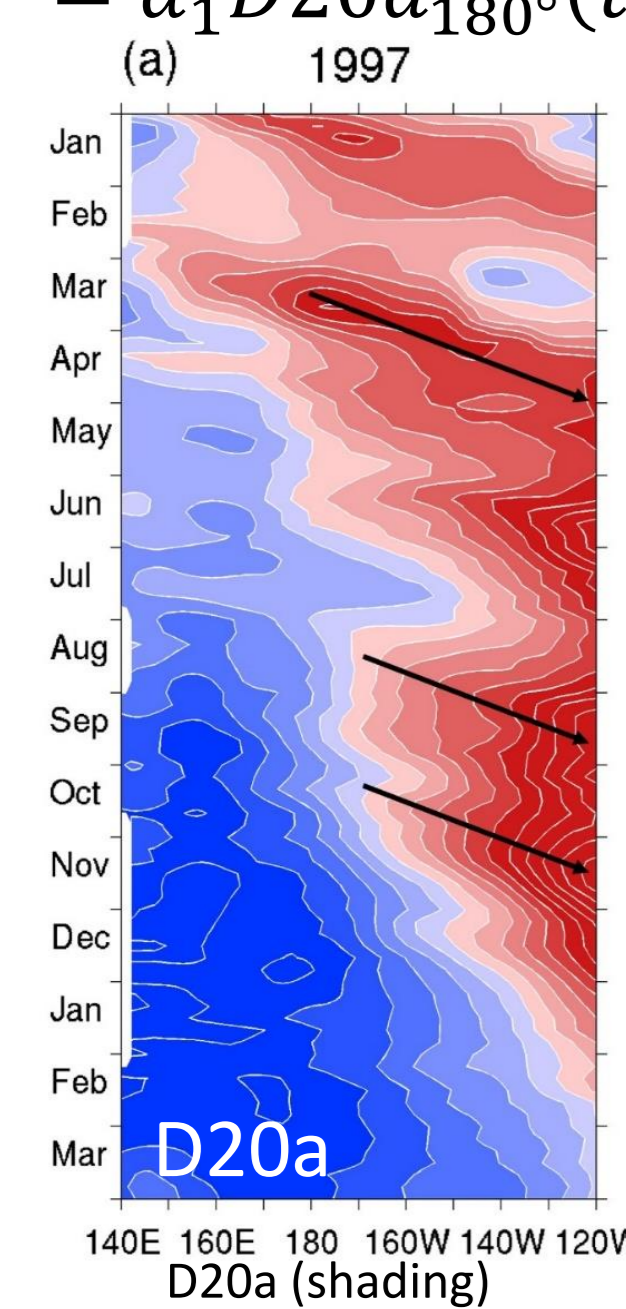


An EEMD filter is performed to remove the high-frequency



## WWV propagation

$$EP_{WWV}(t) = \alpha_1 D20a_{180^\circ}(t - 5 \text{ pentads}) + \alpha_2 D20a_{170^\circ W}(t - 3 \text{ pentads}) + \alpha_3 D20a_{155^\circ W}(t)$$



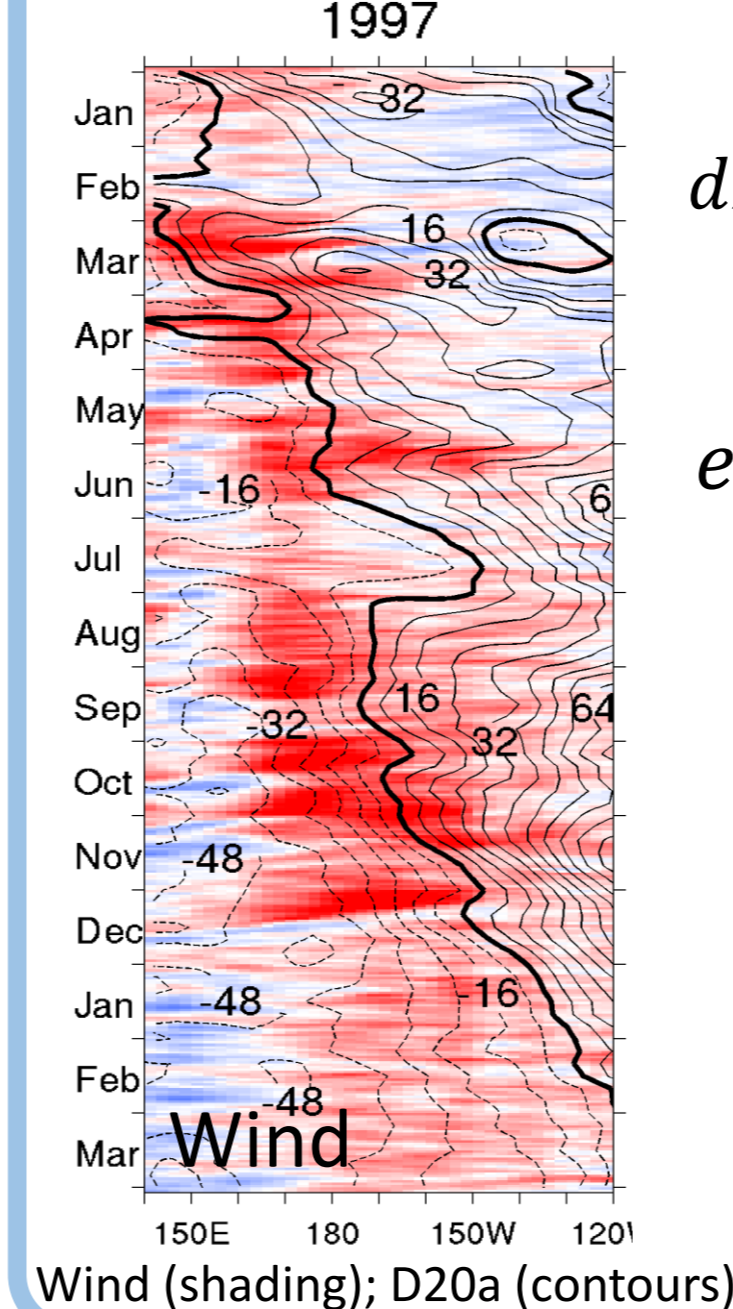
$\alpha_1 - \alpha_3$ : weighting coefficient

An evident thermocline anomaly deepening (or shoaling) toward the east over time, indicating the ocean heat content anomalies propagating eastward along the equator in the El Niño (or La Niña).

We can use this signature to predict ENSO

## Ocean-atmosphere coupling

$$EP_{OA}(t) = \text{sign}(\text{event}(t, w_x)) \cdot dH(t, EP_{WWV})$$



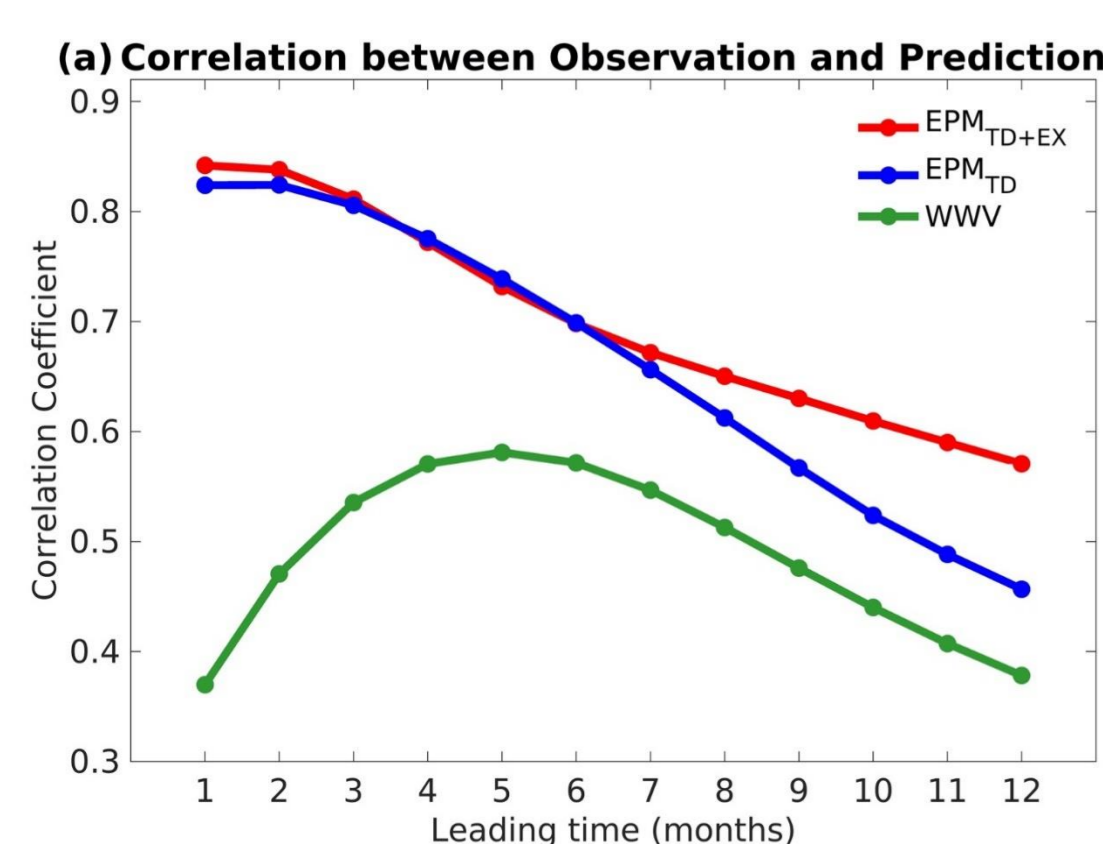
$$dH(t, EP_{WWV}) = \begin{cases} \frac{|EP_{WWV}(t) - EP_{WWV}(t-5)| + |EP_{WWV}(t-5) - EP_{WWV}(t-10)|}{2}, & 5 \text{ pentads} \leq \text{event}(t, w_x) \\ 0, & \text{event}(t, w_x) < 5 \text{ pentads} \end{cases}$$

$$\text{event}(t, w_x) = \begin{cases} \text{positive } w_x \text{ in } [t - 10 \text{ pentads}, t] \\ \text{negative } w_x \text{ in } [t - 10 \text{ pentads}, t] \end{cases}$$

Assume  $EP_{OA}(t)$  is active only when the  $EP_{WWV}$  changes dramatically and the same sign wind events last for more than 5 pentads (25 days) during a continuous period of 10 pentads (50 days), representing the consistent westerly or easterly anomalies.

The eastward propagating waves can be excited by the westerly wind events

## EPM and hindcast skill in different prediction lead time



### WWV

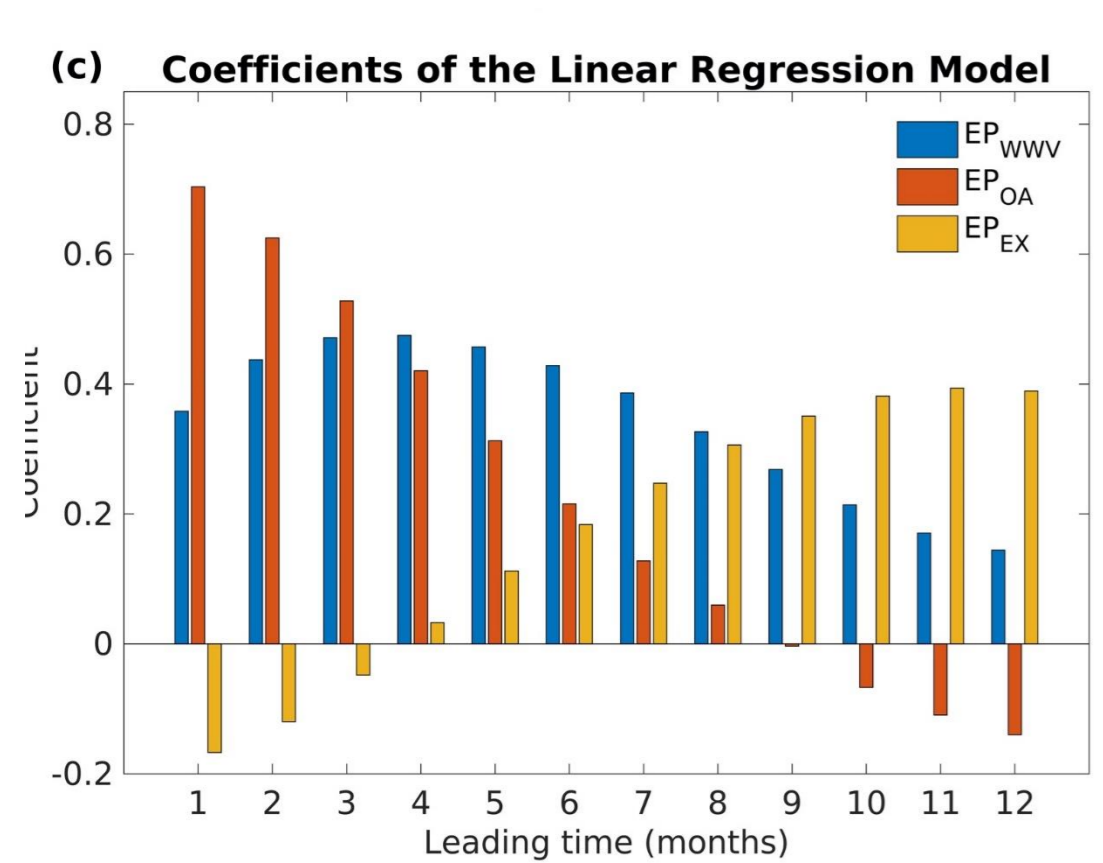
Best hindcast skill appeared in the 5-month lead.

### EPM<sub>TD</sub>

Hindcast skill increases for all lead times, especially for 1- to 6-month.

### EPM<sub>TD+EX</sub>

Hindcast skill further increases with 6- to 10-month leads.



### For 1- to 3-month leads

Hindcast skill is mainly contributed by the ocean-atmosphere coupled feedback.

### For 4- to 7-month leads

Eastward-propagating WWV becomes a main ENSO predictor.

### For 8- to 10-month leads

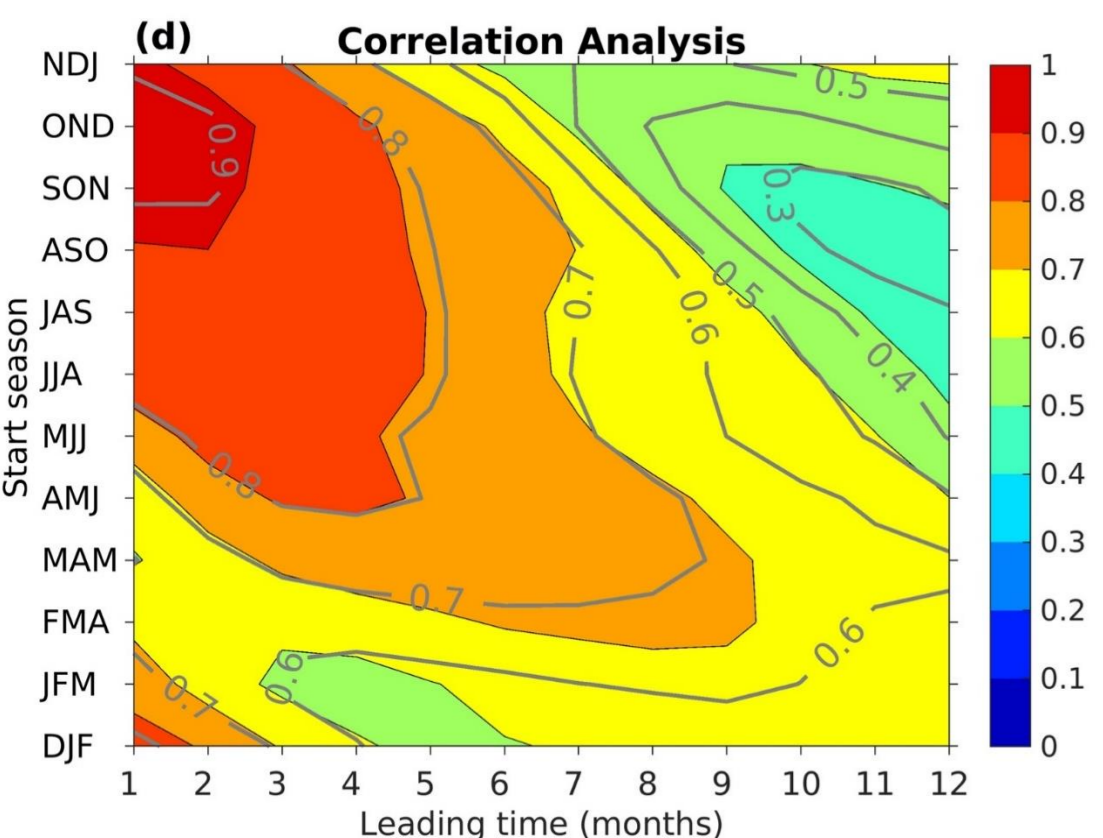
Extratropical precursor has the largest contribution.

### Spring predictability barrier

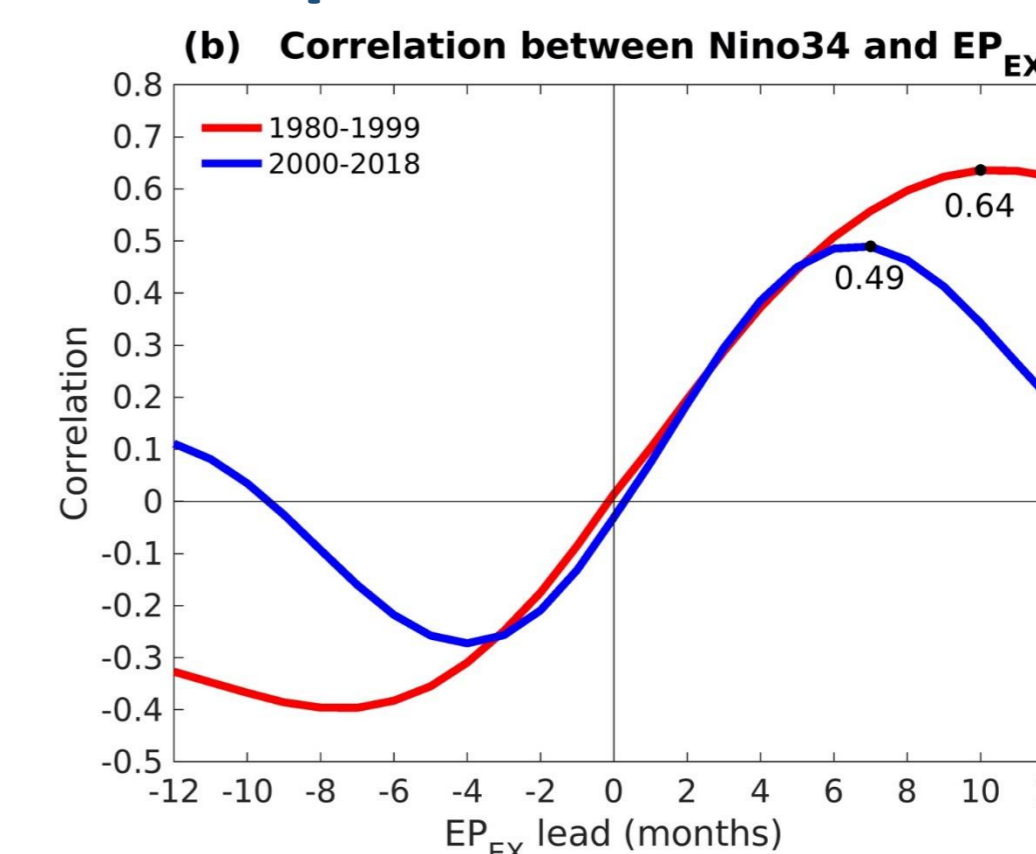
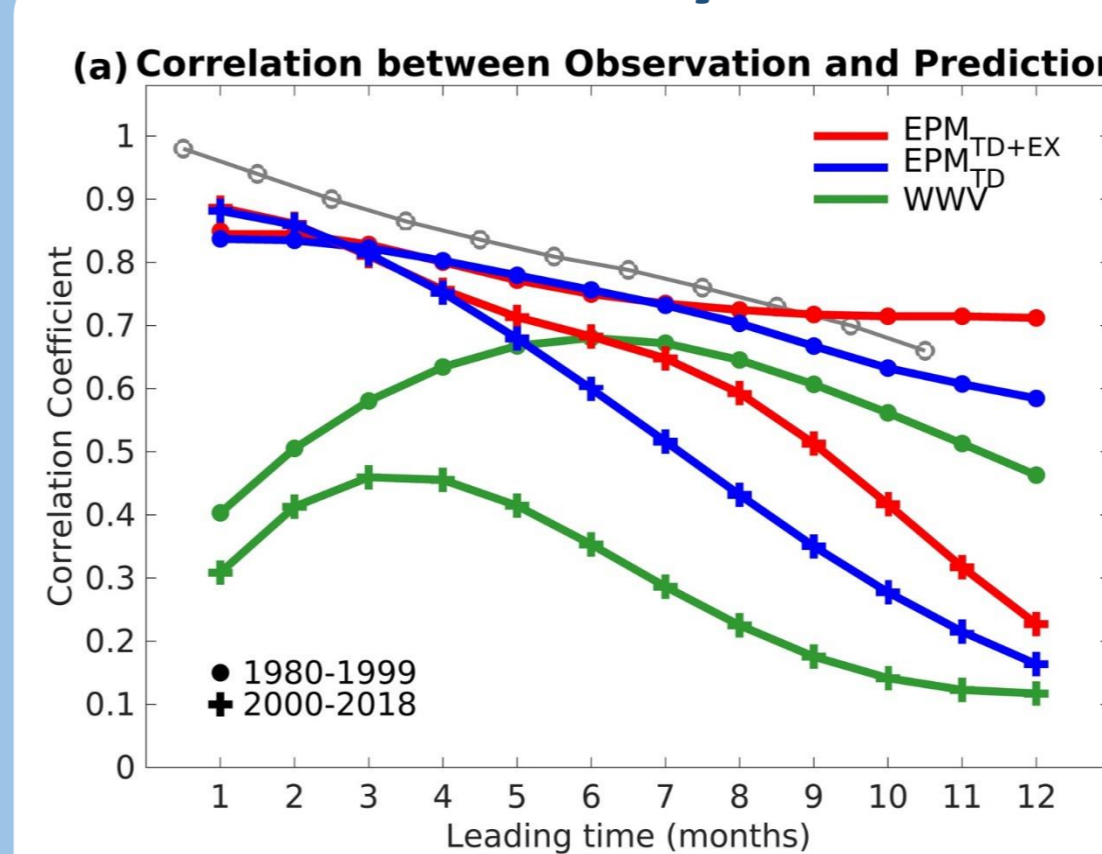
Prediction starting from boreal spring (MAM) had the lowest correlation, while that starting in boreal summer (JJA) tended to have the greatest hindcast skills.

### Reduce the long-lasting concern of SPB

$EPM_{TD+EX}$  (shading) showed a higher correlation than  $EPM_{TD}$  (contours) when the prediction started in MAM and the lead time was longer than 7-month.



## A 21st century shift in the ENSO prediction skill

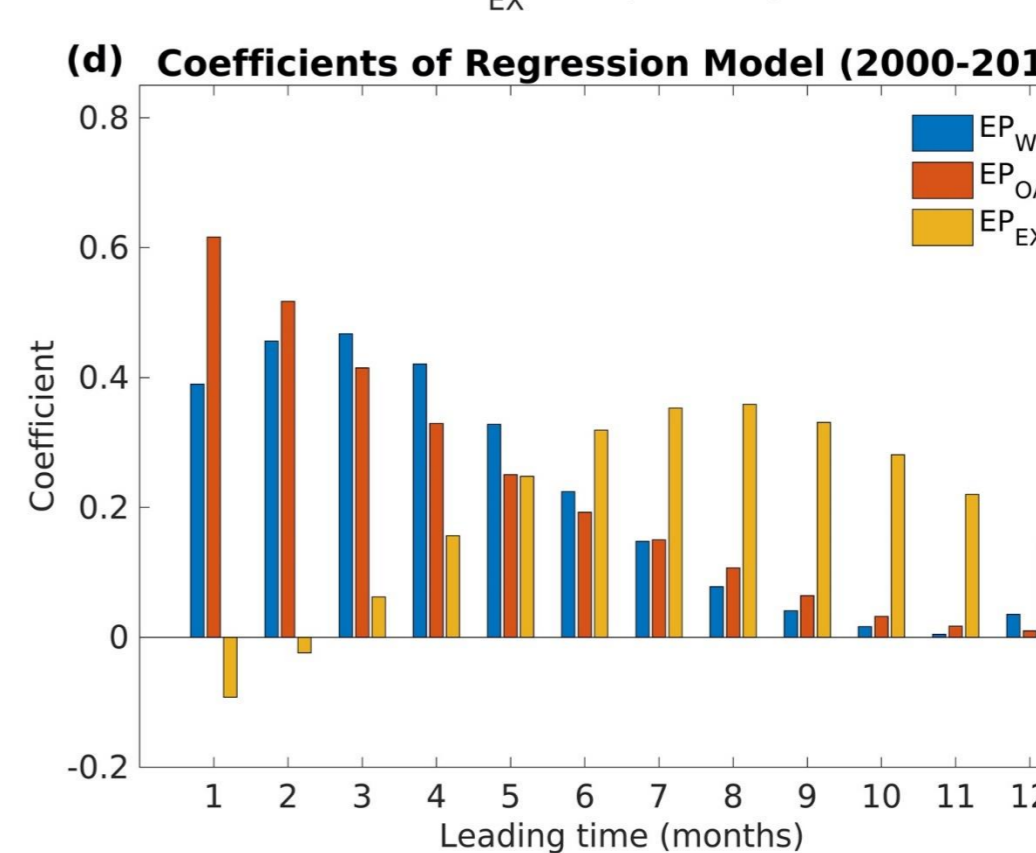
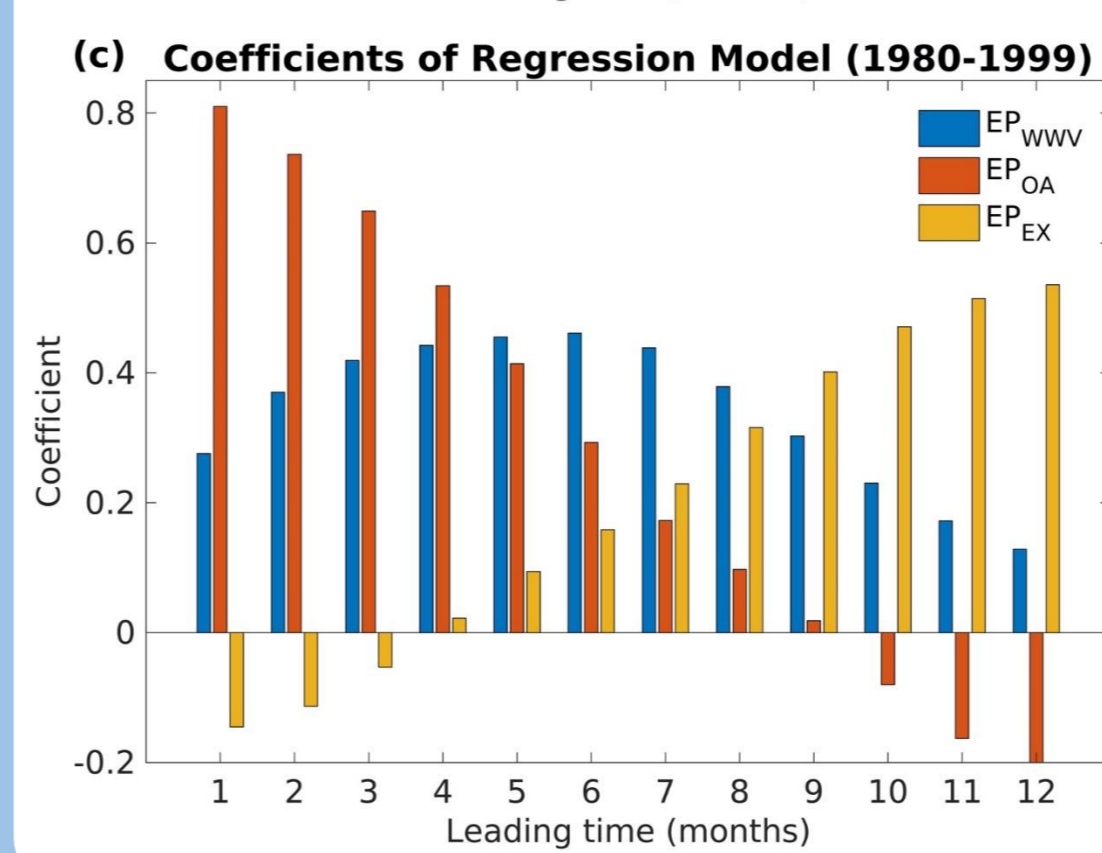


### WWV

WWV lead time changed from 6-9 months to 3-4 months after 2000.

### EPM<sub>TD</sub>

Hindcast skill is much higher during 1980-1999.



### EPM<sub>TD+EX</sub>

Although the hindcast skill was higher before 2000, the improvement in the hindcast skill was greater in 2000-2018 compared with that during 1980-1999.

## Table of hindcast skill

Lead time	Percent correct (%)			False alarm rate (%)			Correlation			RMSE (°C)		
	El Niño (La Niña)			El Niño (La Niña)			EP <sub>TD+EX</sub>	EP <sub>TD</sub>	WWV	EP <sub>TD+EX</sub>	EP <sub>TD</sub>	WWV
Six-month	92 (86)	92 (79)	83 (71)	39 (14)	39 (21)	47 (23)	0.70	0.70	0.57	0.70	0.70	0.84
Eight-month	83 (79)	83 (64)	75 (64)	38 (15)	50 (36)	50 (36)	0.65	0.61	0.51	0.76	0.80	0.90
Ten-month	83 (71)	75 (71)	75 (64)	38 (17)	50 (41)	47 (31)	0.61	0.52	0.44	0.80	0.89	0.96

Chen, H.-C., Y.-H. Tseng, Z.-Z. Hu, R.-Q. Ding, 2019: Enhancing the ENSO Predictability Skill beyond the Spring Barrier. *Scientific Report (in press)*.