

Supporting Information for

Asymmetric Responses of the Western tropical Pacific  
Sea level to El Niño and La Niña

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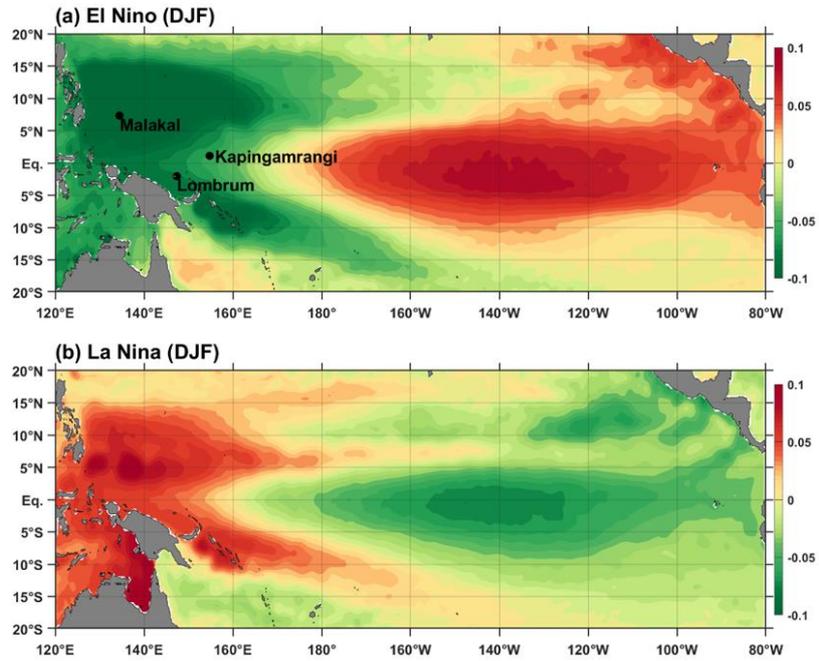
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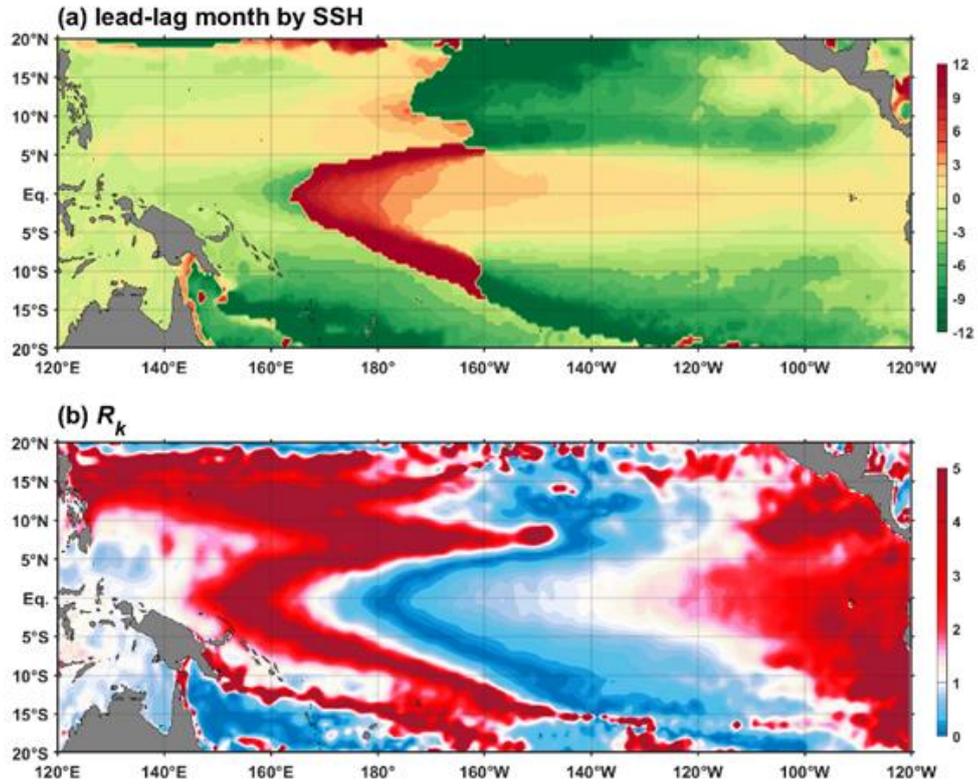
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## **Introduction**

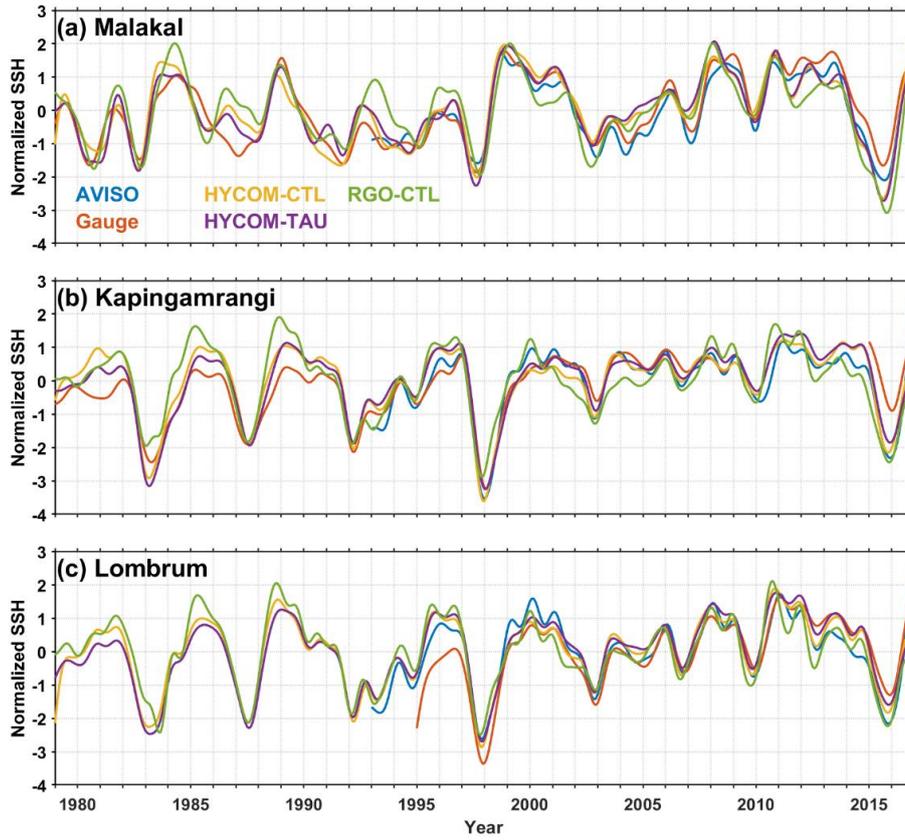
Seven figures and one table are uploaded as supporting information. **Figure S1** shows composites of sea level anomalies (SLAs) from AVISO for the mature phases of El Niño and La Niña conditions. **Figure S2** shows the lead-lag months of SLAs and Niño-3.4 index and Ratio of the synchronous-regressed coefficients  $k_{\text{Niño}}$  and  $k_{\text{Niña}}$ . **Figure 3** shows the time series of the normalized SLAs at three tidal gauge station from different datasets. **Figure S4** shows the distributions of the 1<sup>st</sup> SVD mode for the sea surface temperature and wind stress of different condition during 1979-2016. **Table S1** shows the model experiments descriptions of HYCOM and 1.5-layer RGO. **Figure S5** shows the time-longitude plots of normalized ULT anomaly from RGO-CTL, EXP1, and SVD2. **Figure S6** shows  $R_k$  produced by SVD2, SVDD5, and SVD10. **Figure S7** shows  $R_k$  produced by EXP3.



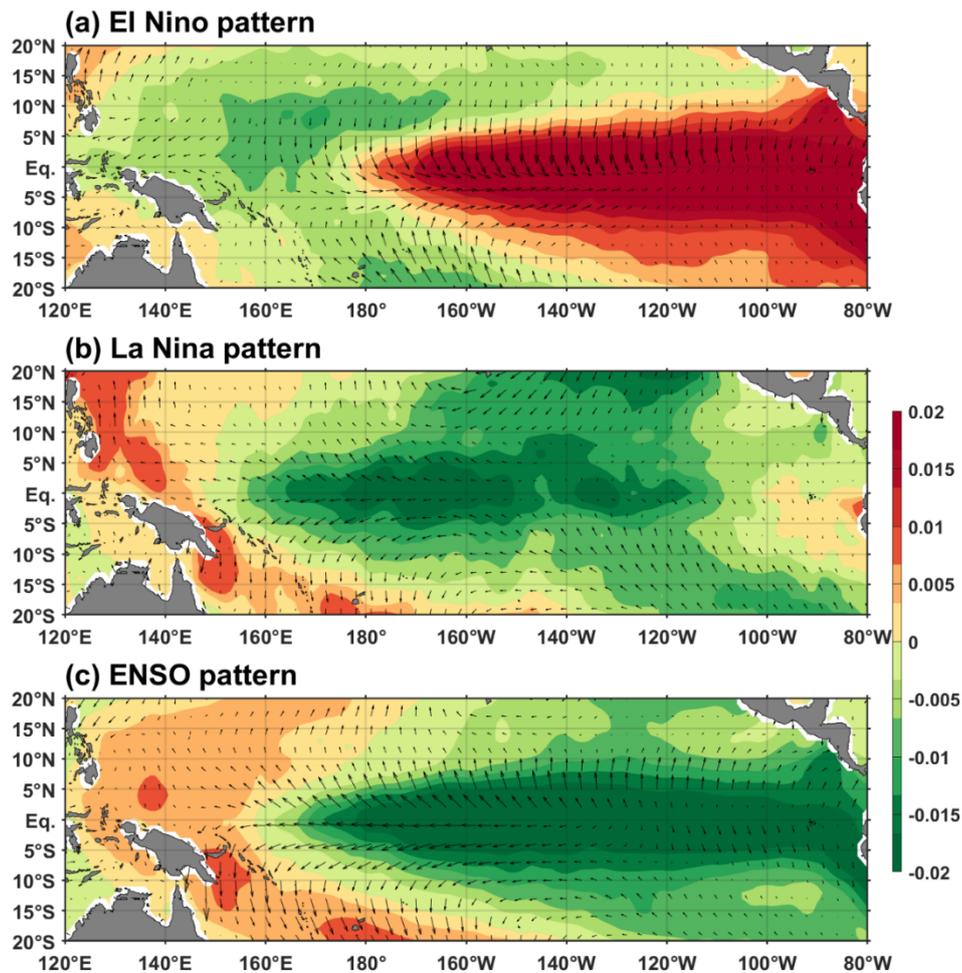
**Figure S1.** Composites of sea level anomalies (SLAs, m) from AVISO for the mature phases (December, January, and February, DJF) of (a) El Niño and (b) La Niña conditions during 1993-2016. The black dots at (7.33°N, 134.47°E), (1.1°N, 154.78°E) and (2.04°S, 147.47°E) indicate the Malakal, Kapingamrangi, and Lombrum tidal gauge stations.



**Figure S2.** (a) The lead-lag months of SLAs and Niño-3.4 index. (b) Ratio of  $k_{\text{Niño}}$  to  $k_{\text{Niña}}$ , i.e.,  $R_k = k_{\text{Niño}}/k_{\text{Niña}}$ .  $k_{\text{Niño}}$  and  $k_{\text{Niña}}$  are the synchronous regression coefficients of SLAs during El Niño (Niño-3.4 > 0) and La Niña (Niño-3.4 < 0) condition onto the normalized Niño-3.4 index, respectively. SLA data are derived from AVISO sea level product of 1993-2016.



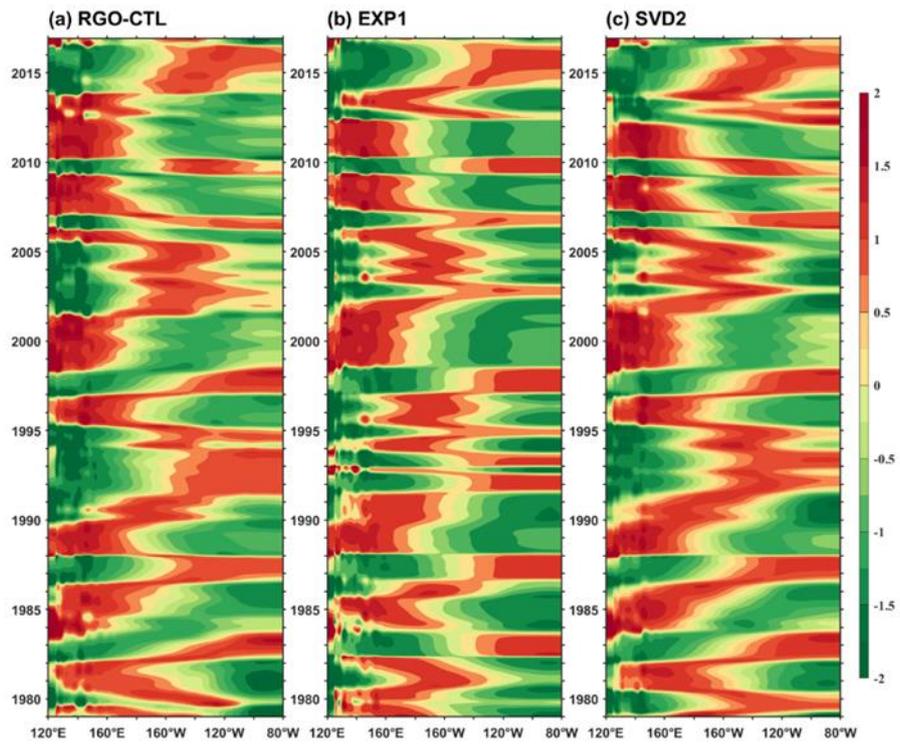
**Figure S3.** Time series of the normalized SLAs at (a) Malakal, (b) Kapingamrangi, (c) Lombrum from AVISO, tidal gauge, HYCOM-CTL, HYCOM-TAU and RGO-CTL. All the time series are 13-month low-passed filtered and normalized by the standard deviation. The normalized upper-layer thickness (ULT) anomaly in RGO-CTL represents SSH anomalies to compare with other datasets.



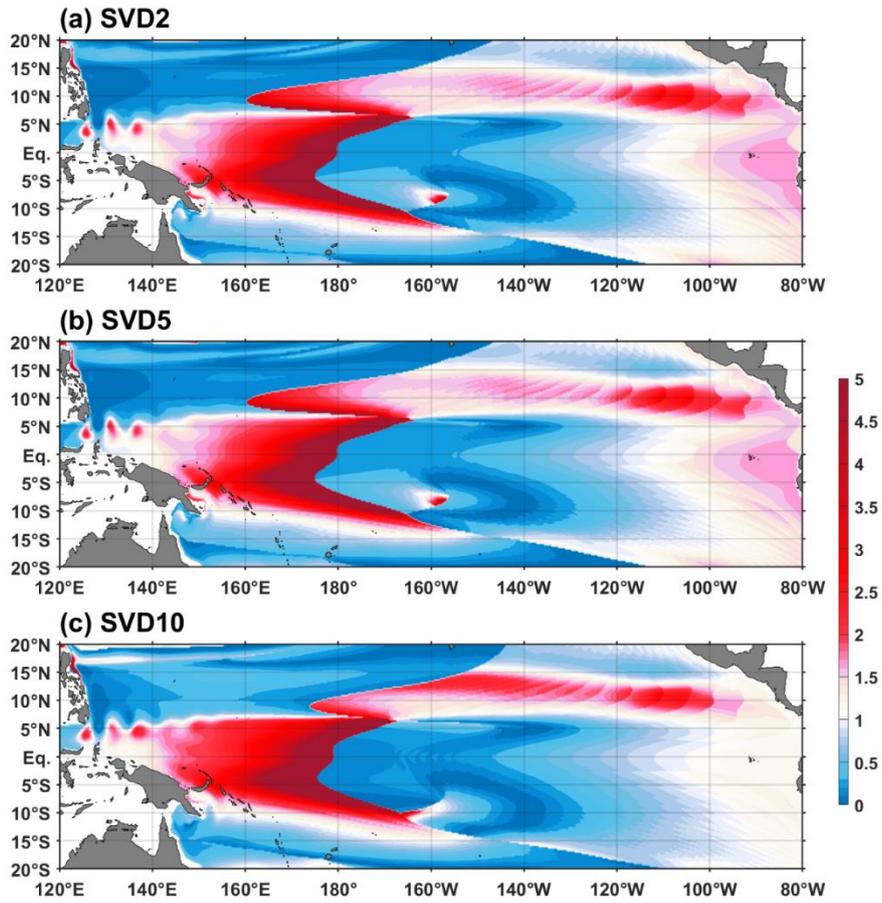
**Figure S4.** (a) Distributions of the 1<sup>st</sup> SVD mode for the sea surface temperature (SST; color shading) and wind stress (vector) of El Niño condition during 1979-2016. (b) and (c) are the same as (a), but for La Niña condition and ENSO condition, respectively. ENSO condition does not distinguish El Niño and La Niña conditions.

**Table S1.** HYbrid Coordinate Ocean Model (HYCOM) and 1.5-layer nonlinear reduced gravity ocean (RGO) Model experiments descriptions.

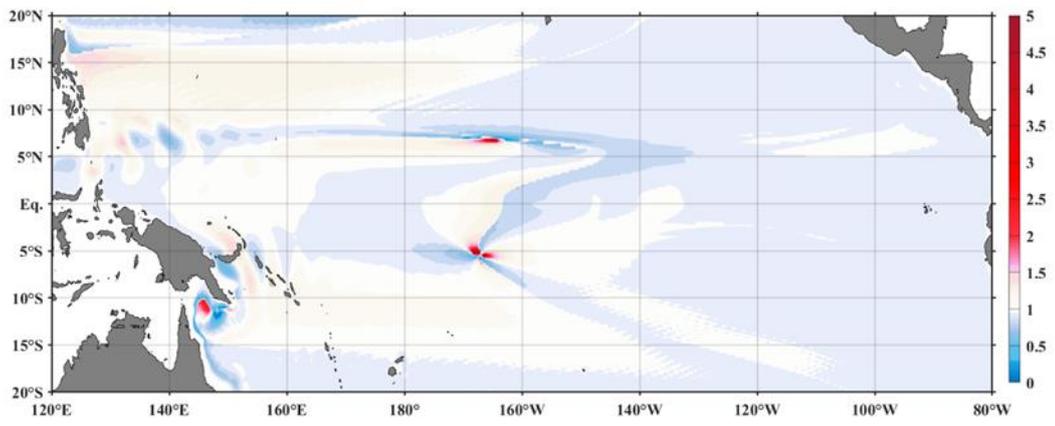
Exp. Name	Forcing
HYCOM-CTL	Daily ERA-Interim atmospheric fields
HYCOM-TAU	Daily ERA-Interim wind stress, but all the other forcing fields are fixed to monthly climatology
RGO-CTL	Monthly ERA-interim wind stress
EXP1	Reconstructed wind stress for El Niño and La Niña phase based on the 1 <sup>st</sup> SVD mode of SST and wind stress
EXP2	Reconstructed wind stress for all the period based on the 1 <sup>st</sup> SVD mode of SST and wind stress
EXP1-TAUX	Same as EXP1, but the meridional wind stress $\tau^y$ is fixed to monthly climatology
EXP2-TAUX	Same as EXP2, but the meridional wind stress $\tau^y$ is fixed to monthly climatology
EXP3	Reconstructed wind stress , $\tau(x, y, t) = V_{\tau}(x, y)T(t)$ $x, y$ and $t$ indicate the zonal, meridional and time grid points, respectively. $V_{\tau}$ is the 1 <sup>st</sup> SVD singular vectors for wind stress. $T(t)$ is the idealized Niño-3.4 index and is a time-varying sinusoidal function with a timescale of 4 years, $\sin(t/4)$ . EXP3 makes use of the 1 <sup>st</sup> mode only and is integrated for 50 years.
SVD2	Same as EXP1, but reconstructed wind stress based on the first two SVD modes
SVD5	Same as EXP1, but reconstructed wind stress based on the first five SVD modes
SVD10	Same as EXP1, but reconstructed wind stress based on the first ten SVD modes



**Figure S5.** Time-longitude plots of normalized ULT anomaly from (a) RGO-CTL, (b) EXP1, and (c) SVD2.



**Figure S6.**  $R_k$  produced by (a) SVD2, (b) SVD5, and (c) SVD10.  $k_{\text{Nino}}$  and  $k_{\text{Nina}}$  are the regression coefficients of ULT anomaly during El Niño (Niño-3.4 > 0) and La Niña (Niño-3.4 < 0) condition onto the normalized Niño-3.4 index, respectively.



**Figure S7.**  $R_k$  produced by EXP3.