The Role of Nonlinear Energy Advection in Forming Asymmetric Structure of ENSO Teleconnections over the North Pacific and North America

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Introduction

- During the boreal winter, the ENSO-induced Pacific-North American (PNA) teleconnection pattern exhibits a westward shift in its position during La Niña events compared to El Niño events, resulting in notable and distinct climate impacts.
- From an energy diagnostic perspective, the exit region of the Pacific subtropical jet stream facilitates the conversion of mean kinetic energy into eddy kinetic energy, thereby playing a role in anchoring the position of the PNA pattern. This mechanism, however, does not elucidate the zonal asymmetry during different ENSO phases.
- This study employs a comprehensive kinetic energy diagnostic approach to gain insights into this asymmetric structure and underscore the role of nonlinear energy advection.

Methods

Eddy Kinetic energy tendency equation:

$$\frac{\partial EKE}{\partial t} = \underbrace{-\left[u'^2\frac{\partial \bar{u}}{\partial x} + u'v'\left(\frac{\partial \bar{u}}{\partial y}+\frac{\partial \bar{u}}{\partial x}\right) + v'^2\frac{\partial \bar{v}}{\partial y} + u'\omega'\frac{\partial \bar{u}'}{\partial p} + v'\omega'\frac{\partial \bar{v}}{\partial p}\right]}_{KI}$$
$$\underbrace{-(u'+\bar{u})\left(\frac{\partial EKE}{\partial x}\right) - (v'+\bar{v})\left(\frac{\partial EKE}{\partial y}\right) + (\omega'+\bar{\omega})\left(\frac{\partial EKE}{\partial P}\right)}_{KA}$$
$$\underbrace{-\frac{R}{P}\omega'T'}_{KP} \underbrace{-u'\frac{\partial \Phi'}{\partial x} - v'\frac{\partial \Phi'}{\partial y} - \omega'\frac{\partial \Phi'}{\partial P}}_{KZ}$$

Model experiments:

Idealized SSTA with symmetric SSTA by ECHAM5.3.2

EN_SYM_EN: Forced by El Nino-like SSTA

LN_SYM_SST: Forced by La Nina-like SSTA

LBM experiments

LBM_EXP1: Forced by El Nino-like heating source

LBM_EXP2: As LBM_EXP1, but increased the background zonal wind by 1m/s

Results

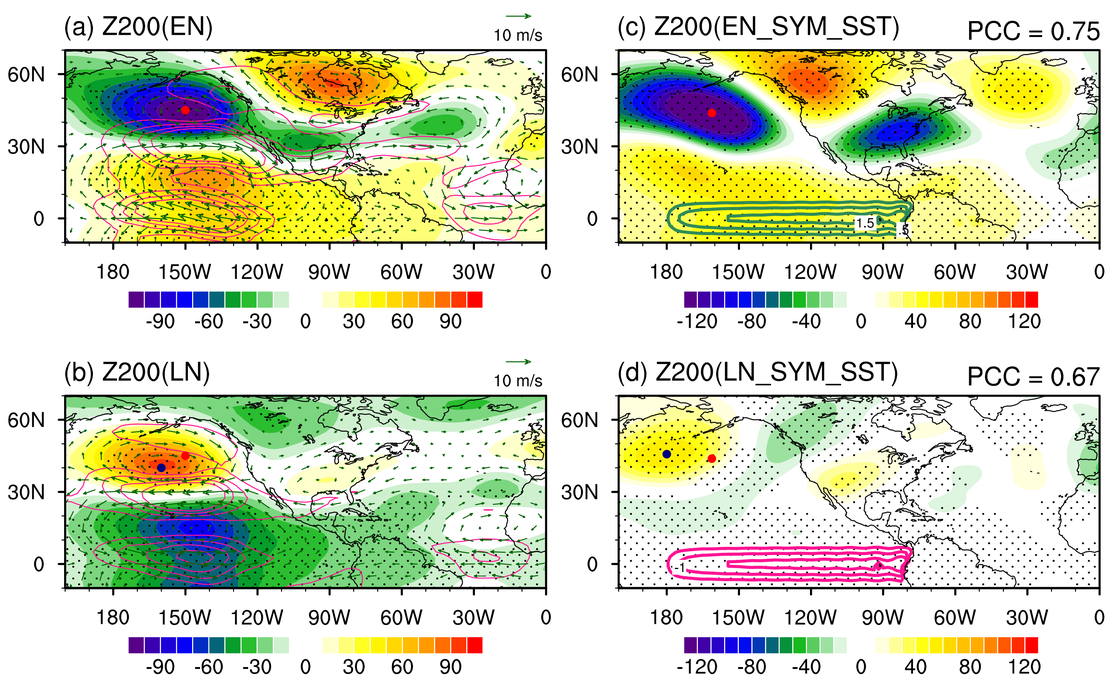

Figure 1 DJF composite 200-hPa geopotential height (shading; m), winds (vectors; 10 m/s), and eddy kinetic energy (contour lines with interval of 10 m^2/s^2) anomalies during EN (a) and LN (b) in NCEP2. DJF anomalous 200-hPa geopotential height (shading; m) and SST (contour lines; K) in (c) EN_SYM_SST and (d) LN_SYM_SST experiments, respectively.

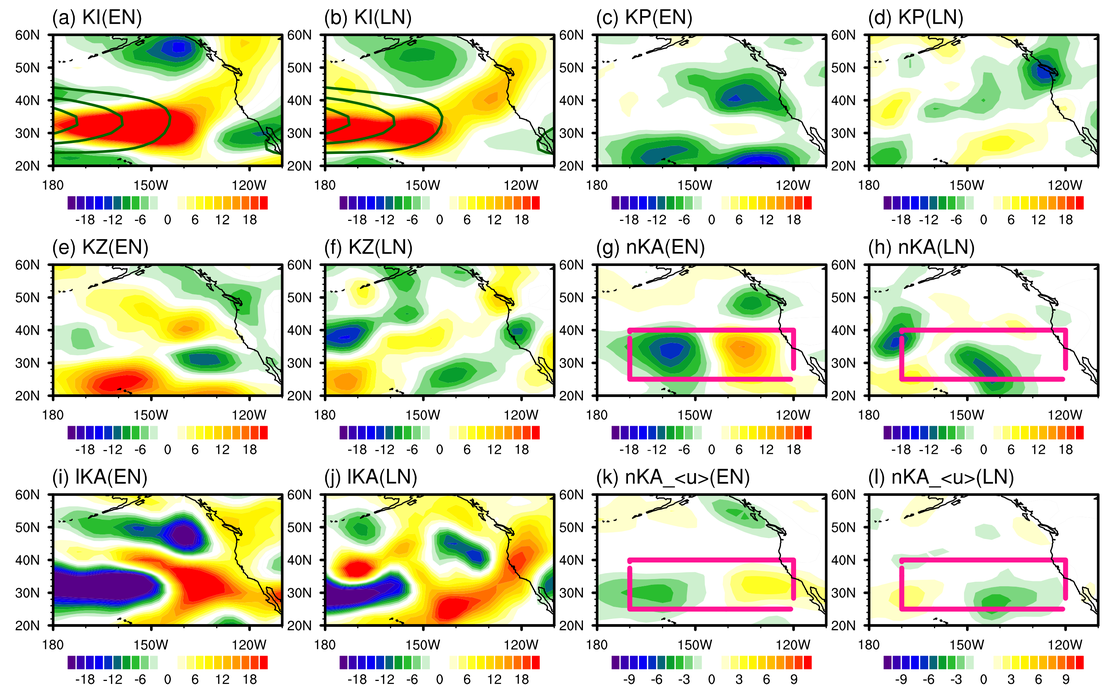

Figure 2 Horizontal distribution of composite (a, b) KI ($m^2\,s^{-3}$), (c, d) KP ($m^2\,s^{-3}$), (e, f) KZ ($m^2\,s^{-3}$), (g, h) nKA ($m^2\,s^{-3}$), (i, j) KZ ($m^2\,s^{-3}$), and (k, l) nKA_$\langle u \rangle$ ($m^2\,s^{-3}$) in (a, c, e, g, i, k) EN and (b, d, f, h, j, l) LN, respectively. The contour lines denote the climatological zonal flow (larger than 30 m/s are shown, with interval of 10 m/s)

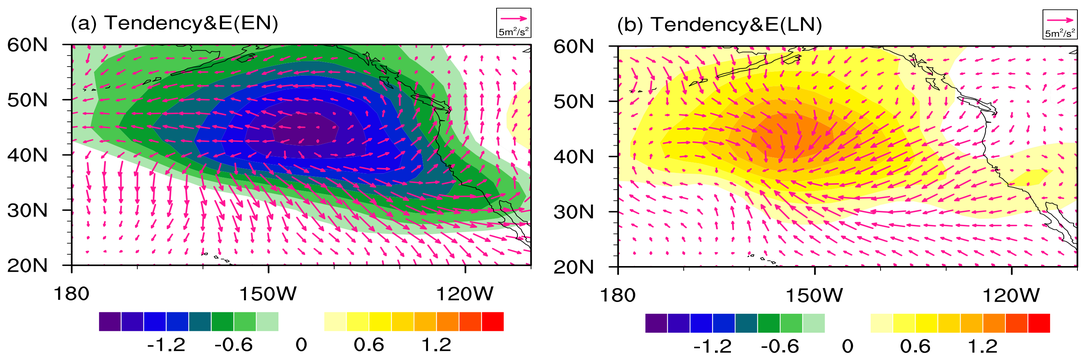

Figure 3 Distributions of composite geopotential height tendency (shading; m/s) and E (vectors; m^2/s^2) in (a) EN and (b) LN.

Conclusions

- Factors other than the spatial pattern and intensity of tropical SST also contribute to the observed asymmetry in the PNA response.
- The zonally symmetric responses to ENSO, specifically the anomalies in zonal mean zonal flow, generate opposing nonlinear energy advection (nKA) patterns by advecting anomalous eddy kinetic energy in the North Pacific, which leads to the shift of the PNA teleconnection pattern.
- Transient eddy activities responded to changes of baroclinicity help maintain the asymmetry through a feedback effect.