Extratropical Forcing of Kelvin Waves and Short-lived Eastward Disturbances in the Pacific basin

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1. Introduction

Convectively coupled Kelvin waves are eastward-propagating tropical disturbances that play an important role in the overall convective activity in the Intertropical Convergence Zone (ITCZ), especially during spring and summer as suggested by the wavenumber-frequency spectra from brightness temperature (Tb) in Fig. 1.

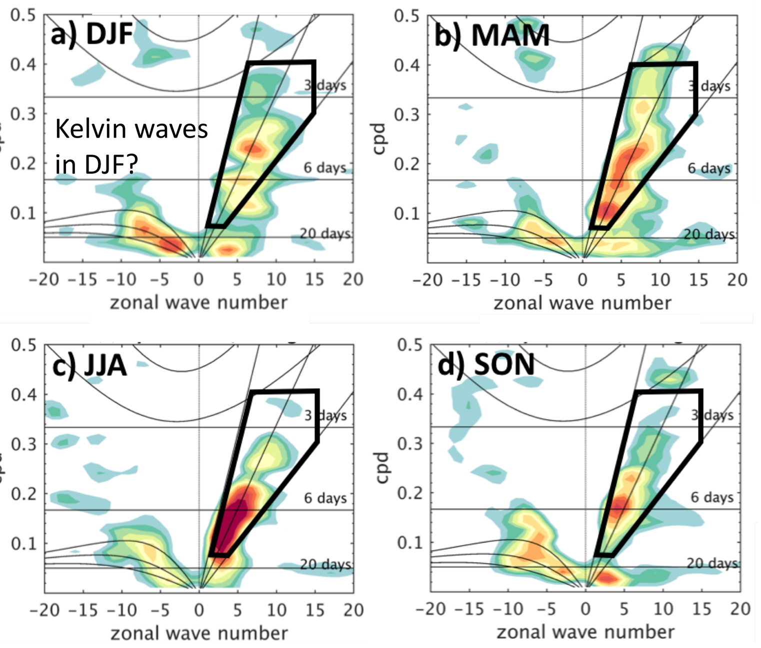


Fig. 1 Tb wavenumber spectrum from 15°S to 15°N, 140°E to 60°W.

2. Data and Methods

This study characterizes the extratropical mechanisms that force Kelvin waves and other westerly disturbances in the tropical Pacific using daily Tb and wind fields and geopotential hgt from MERRA2 reanalysis for 1984 to 2017. We also used precipitation from TRMM 3B42 for 1998 to 2015.

Fourier-filtering (Wheeler and Kiladis 1999) and empirical orthogonal functions (EOF) are used to isolate eastward moving disturbances including Kelvin waves. Regressions of 2.5-17 day band-pass Tb against wind fields are calculated in order to characterize the associated extratropical mechanisms and evolution at different lags by day.

We also calculated E-vectors from 2-20-day band pass wind fields at 200 hPa.

4. Extratropical forcing during boreal spring and summer

4.1 2-17-day band-pass Tb standard deviation

During spring and summer, 2-17 day band-pass Tb std is maximum at 5°N and 8°N, respectively (Figs. 4a,b). E-vectors are large in the NH (SH) during spring (summer). Figs. 4c,d show EOF 1 of Tb in spring and summer with 14.8% and 20.3% variance explained respectively.

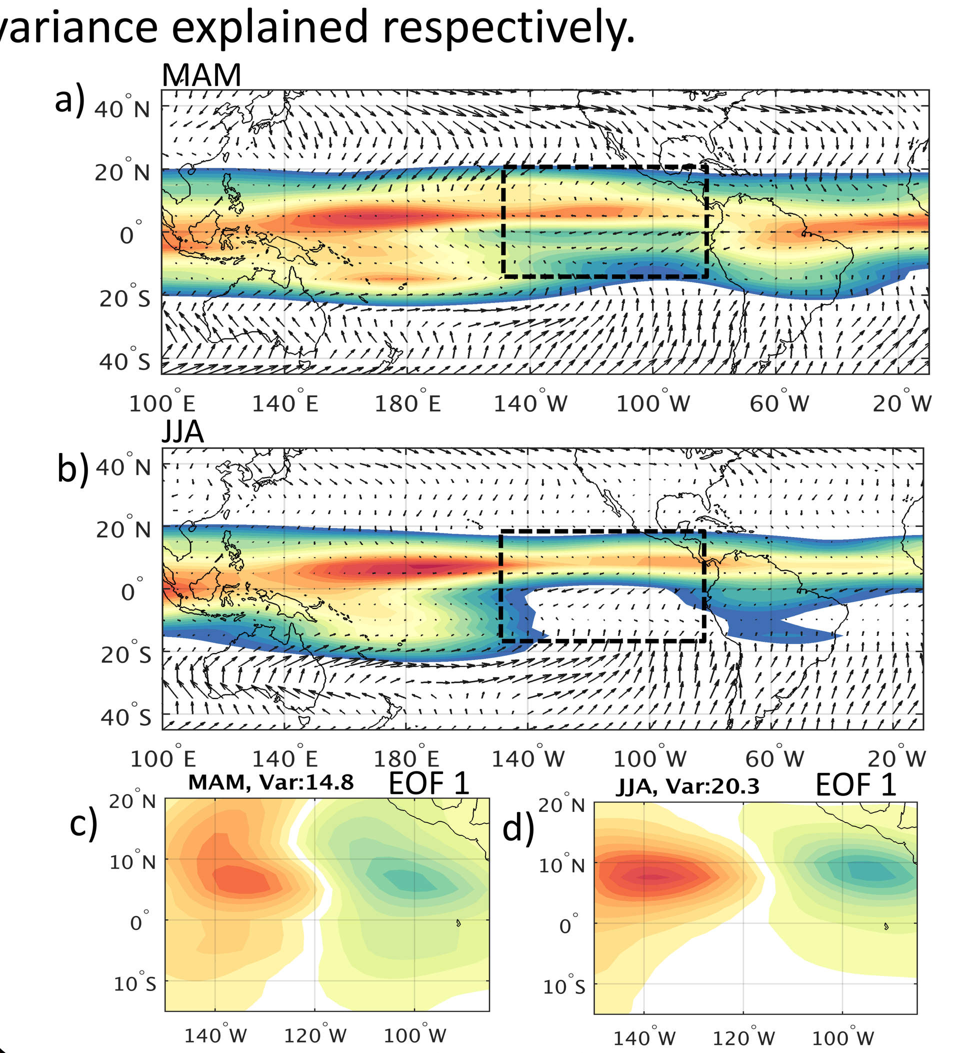


Fig. 4: Same as fig. 2 but for spring, summer

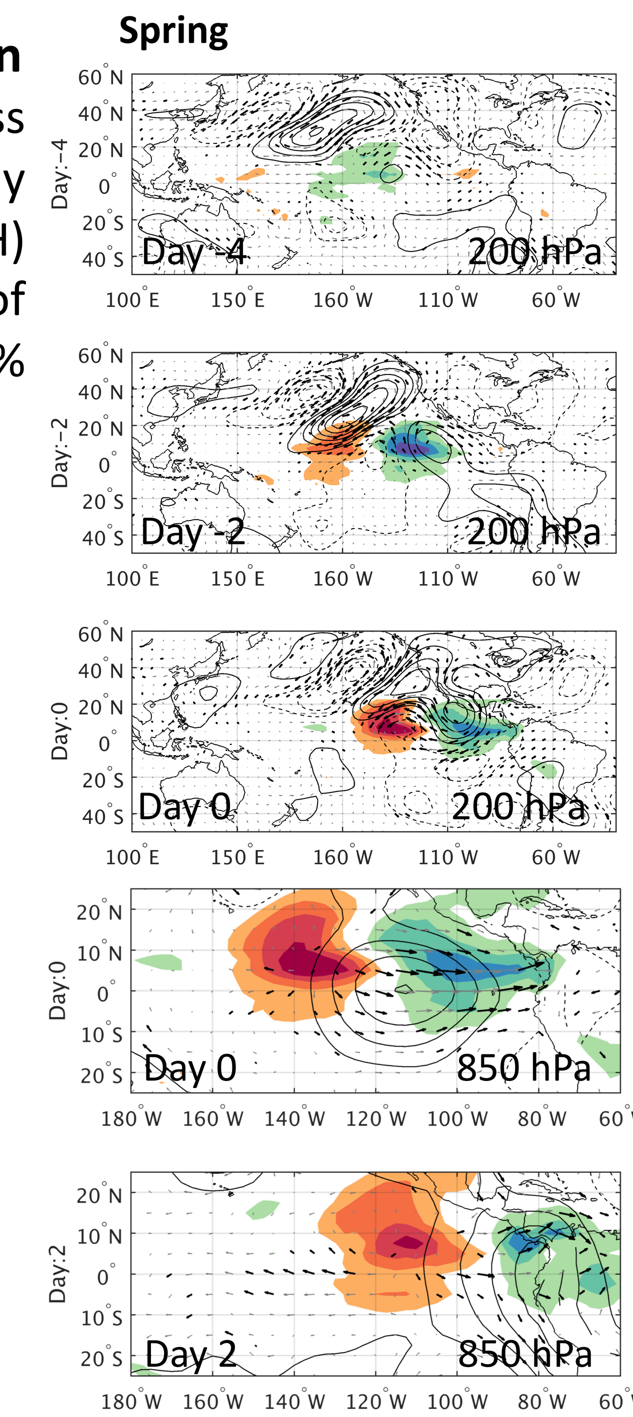


Fig. 5: Same as Fig. 3 but for Spring

4.2 Extratropical forcing mechanism

a) Spring

Extratropical Rossby disturbances from the northwest Pacific propagate into the tropics (Fig. 5, 200hPa) and intensify Kelvin waves in the East Pacific (Fig. 5, 850 hPa), mainly at 5°N but as far south as the Equator if the cold tongue is muted and replaced by warm water (not shown). The dynamic field at 850 hPa and the vertical across section of zonal wind are consistent with the linear theory of Kelvin waves, in contrast to winter.

b) Summer

During boreal summer, extratropical Rossby disturbances propagating from the southeast Pacific (Fig. 6, 200 hPa) appear linked to the initiation of Kelvin waves in the East Pacific, similar to Straub and Kiladis (2003). This Rossby wave pattern is also seen using composites (not shown). Similarly, the dynamic fields and vertical across sections are consistent with the linear theory of Kelvin waves.

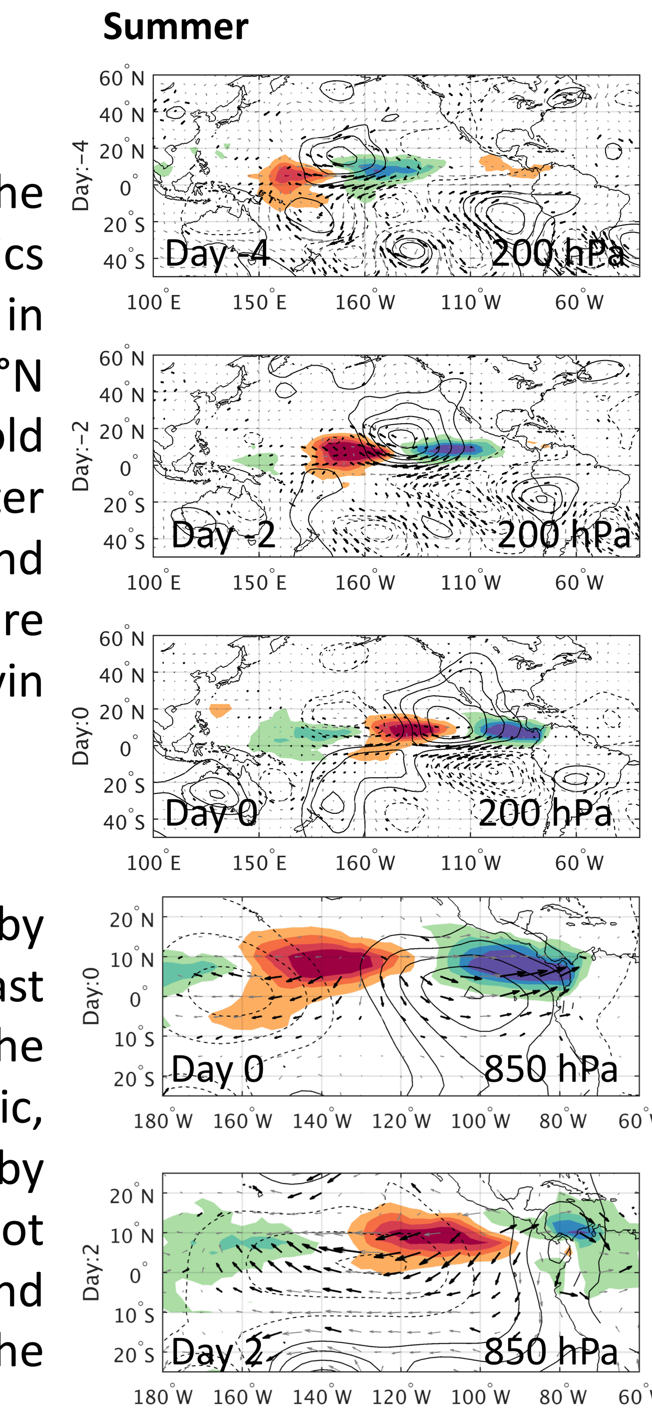
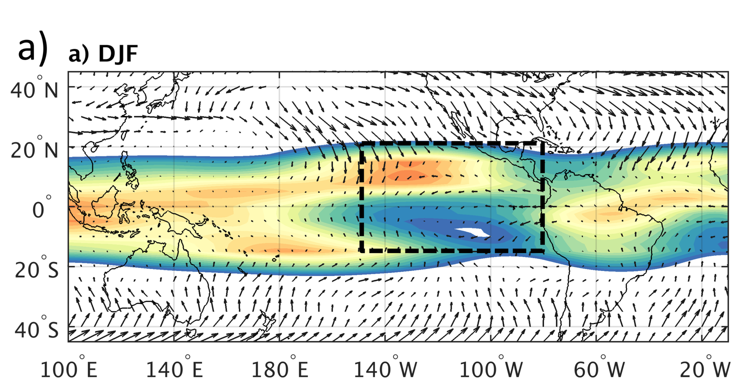


Fig. 6: Same as Fig. 3 but for Summer

3. Extratropical forcing during boreal winter



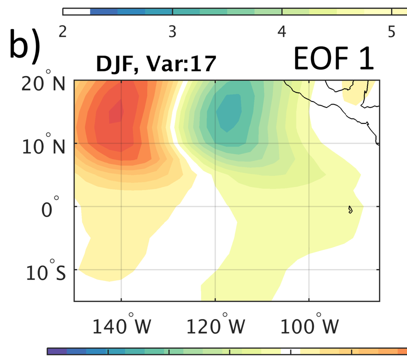


Fig. 2: a) Tb band-pass standard deviation in K and mean E-vectors, b) EOF1 map in the East Pacific during Dec-Jan-Feb.

3.1 2-17-day band-pass Tb standard deviation

During winter, Tb std in the East Pacific is maximum at 130°W ITCZ around 10°N and 15°N (Fig. 2a). The strong E-vectors in this region suggest that extratropical perturbations play an important role in Kelvin-band convection over the tropics. Fig. 2b shows the EOF 1 of Kelvin Tb with 17% variance explained.

3.2 Extratropical forcing mechanism

Extratropical Rossby disturbances from the northwest Pacific propagate into the tropics (Fig. 3, 200 hPa) and produce westerly disturbances in the East Pacific centered at 15 °N (Fig. 4, 850 hPa) by advecting vorticity (Kiladis 1998). The convection is centered at 15°N, and the 850 hPa geopotential and wind structures do not suggest a Kelvin wave structure based on the linear theory of Kelvin waves, therefore, this structure will be called short-lived eastward disturbances.

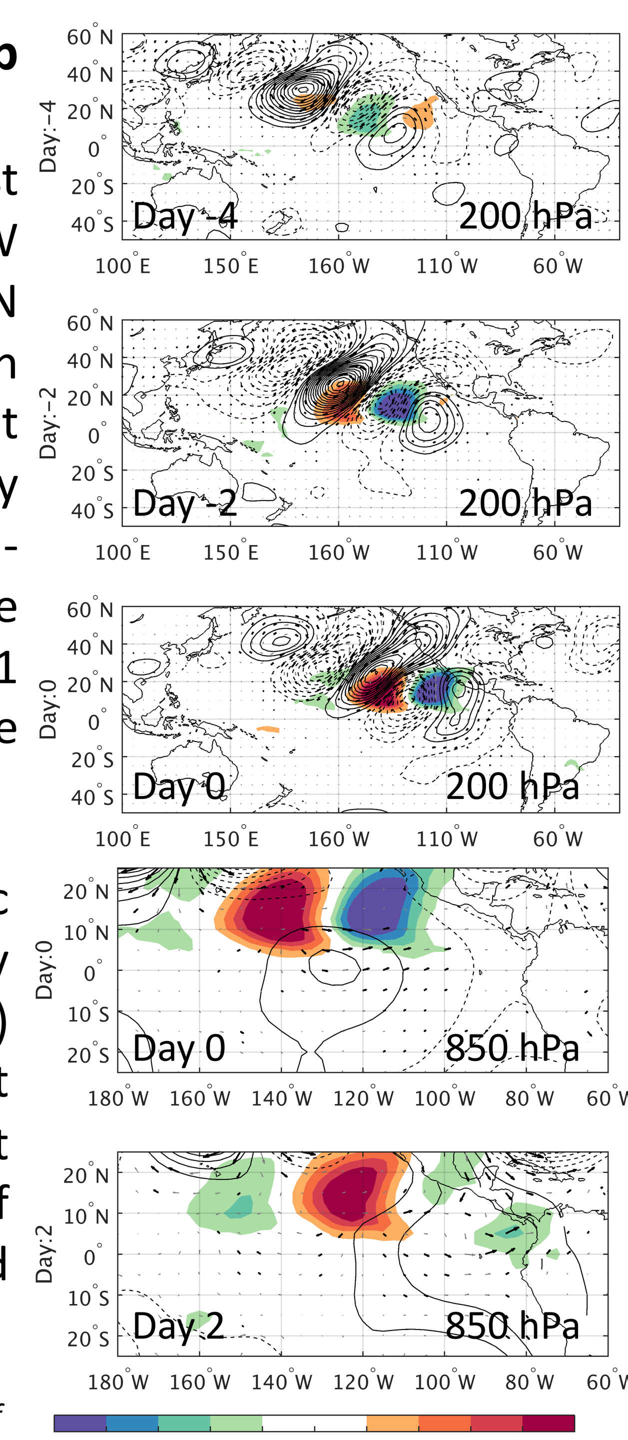


Fig. 3: Regressions of winds and streamfunction at 200 hPa and 850 hPa, and Tb against PC1. Regresssions of zonal wind at different levels and lag days. Positive (negative) values of streamfunction in solid (dotted) contours. Bold wind vector show significance values at 95%.

5. Interannual Variability

5.1 El Nino events

Strong convection over the Pacific basin is associated with warm SST and large E-vectors in the NH during El Niño years (1987, 1992, 1998, 2010, 2016) in DJF (Fig 7a). This result is consistent with correlations between Tb and E-vectors (Fig 7b).

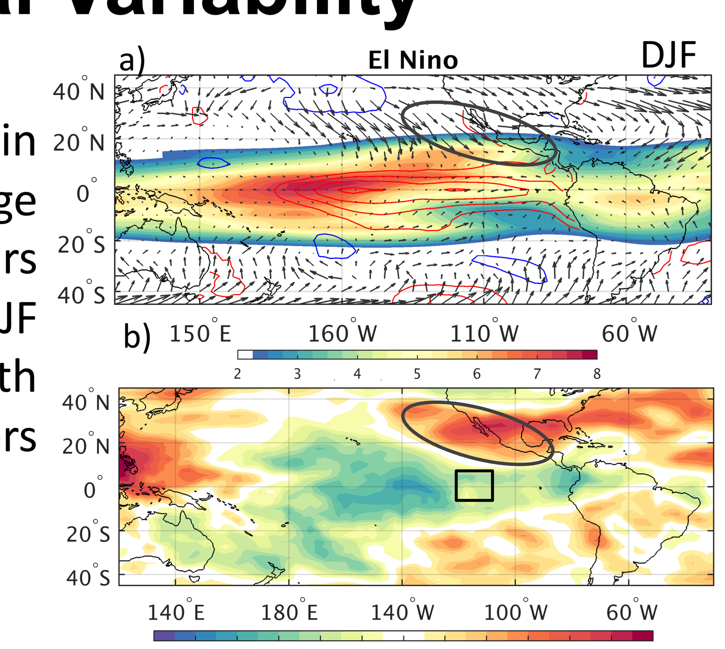


Fig. 7: a) El Niño years composite (1987, 1992, 1998, 2010, 2016). Mean E-vectors, 2-17 day band-pass Tb is shaded, and SST in contours [negative (positive) anomalies in blue (red)]. b) Correlation between Tb (box average) and E-vector amplitude.

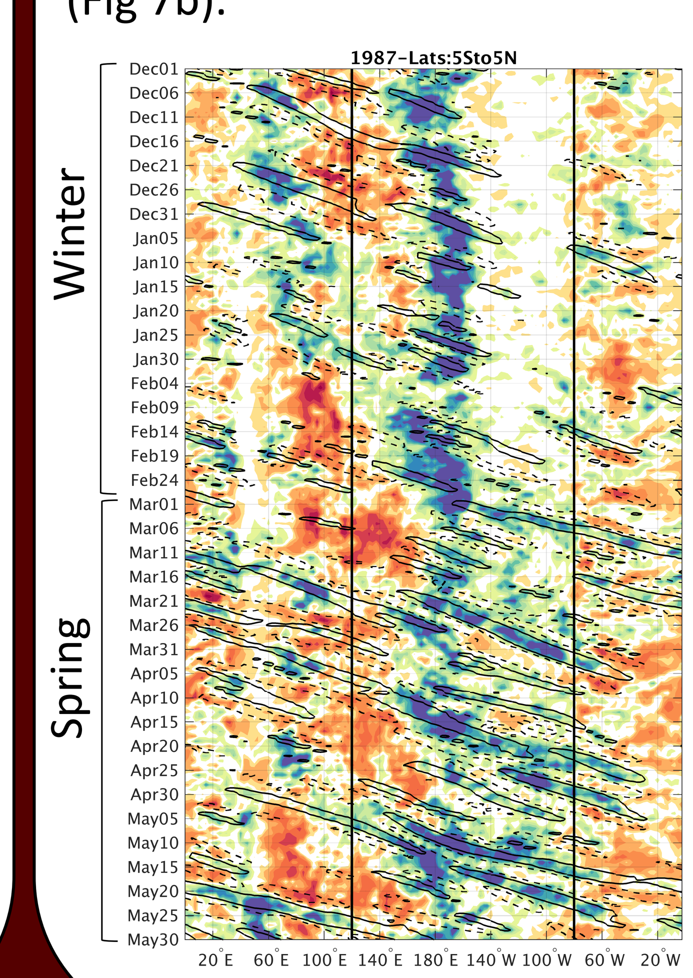


Fig. 8: Hovmüller of Tb from 5°S - 5°N for 1986-87.

5.2 El Nino 1986-87

During winter, strong convection is associated with extratropical disturbances from the NH (Figs. 7,8). Kelvin waves are muted during this season.

However, strong convection observed in spring is associated with Kelvin waves formed in the West Pacific that propagate into the East Pacific (Fig. 8). These Kelvin waves may be forced by extratropical perturbations.

6. Conclusions

- Kelvin-band Tb includes eastward disturbances that may be Kelvin waves in boreal spring and summer or short-lived eastward (non-Kelvin) propagating disturbances in boreal winter.
- In boreal winter, extratropical perturbations can force eastward propagating convective signals over the tropics but with horizontal structure that does not correspond to the linear theory of Kelvin waves.
- Eastward-propagating extratropical waves from both hemispheres can force Kelvin waves. Northern (Southern) hemisphere extratropical disturbances can intensify Kelvin waves during boreal spring (summer).
- During El Niño events, in winter, the strong wave activity in the northeast Pacific can force convection with eastward propagation that does not correspond to Kelvin waves. We do believe that extratropical disturbances cannot initiate Kelvin waves but can enhance existing Kelvin waves (e.g. El Niño 1997-98) similar to spring (section 4).

References

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