Impacts of Compound Teleconnections on Extratropical Cyclone Characteristics

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1. INTRODUCTION

Extratropical cyclones (ETCs) are high-impact weather systems associated with fronts, heavy precipitation, severe local storms, and strong winds over mid-latitudes. For example, in October of this year, two intense ETCs from North Pacific hit the west coast and east coast in short succession, producing extreme impacts from wind and floods. Recently, a large body of research has focused on the influence of global warming on ETCs. However, there is also uncertainty in how natural variability affects ETC activity, which motivates this research.

Research questions:

a. How do the characteristics of ETCs change during individual and compound (>1) teleconnections during boreal spring (MAM), fall (SON), and winter (DJF)?
b. What are the impacts on ETC-related precipitation, moisture and dynamics under different modes?

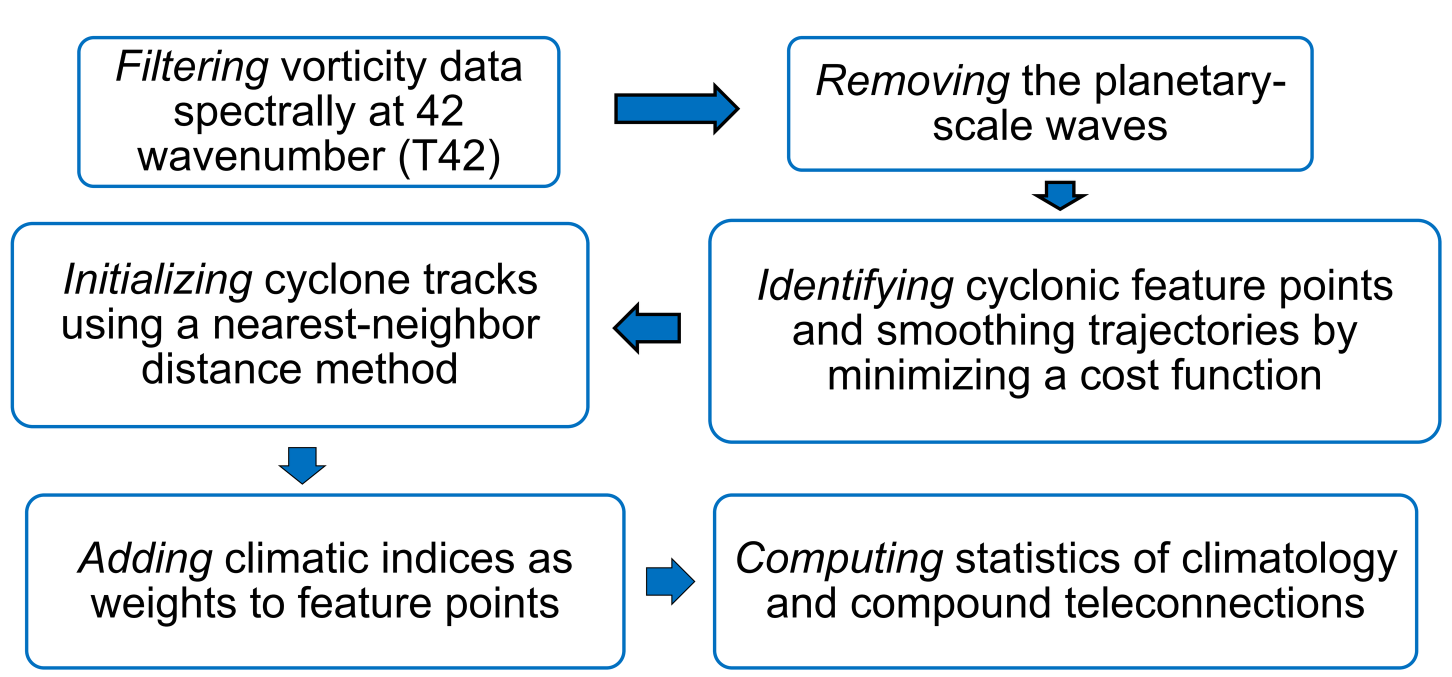
2. DATA & METHODS

NOAA20CR v3 (First 8 ensemble)**:** 3-hour zonal and meridional wind speed at 850 hPa, detrend precipitable water and wind speed at 10m
ERA5: Accumulated 3-hour total precipitation, large scale rain rate from hourly data
Climatic indices:

- Seasonal mean of normalized **NINO 3.4 index**:
  - El Nino (> +0.5); La Nina (< -0.5)
- Seasonal mean of normalized **PNA index**:
  - PNA + (> +0.5); PNA - (< -0.5)
- 9-year running mean of **PDO index**:
  - PDO + (> 0.); PDO - (< 0.)

ETC detection: TRACK algorithm (Hodges, 1994; 2002) is applied to identity ETCs using 850-hPa relative vorticity (>= 24-h, >= 1000 km)

Processes of ETC detection



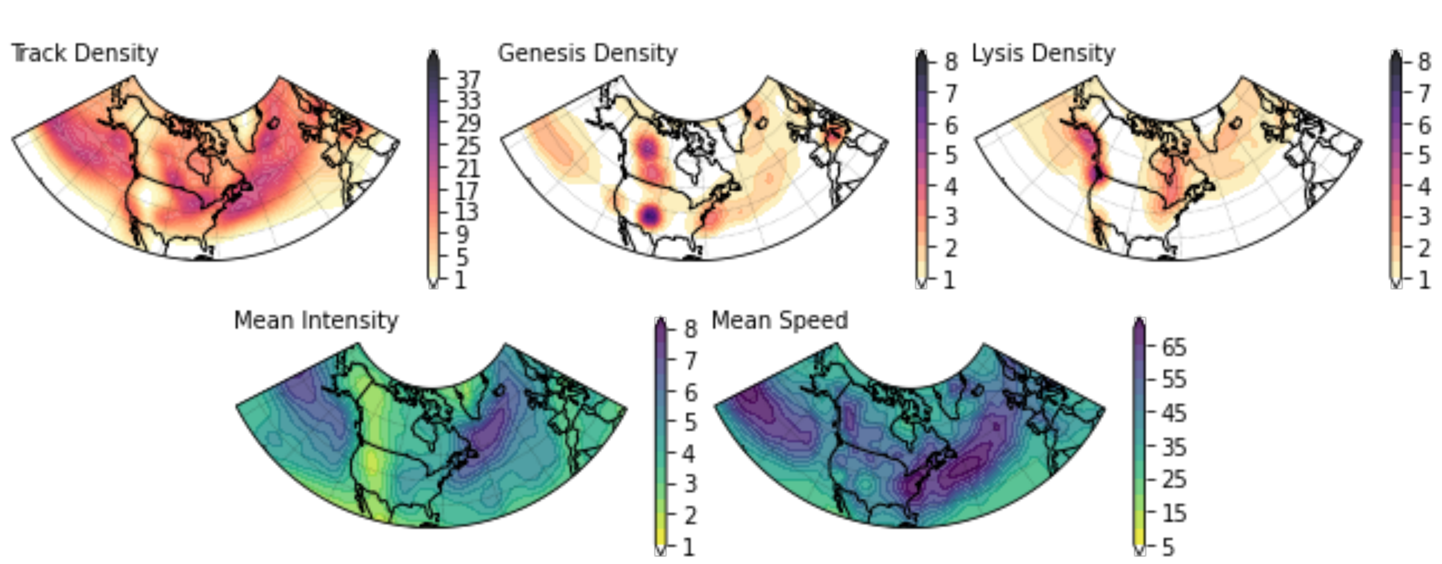


Fig 1: **Climatology** of track density, genesis density, lysis density, mean intensity ($10^{-5}\ s^{-1}$), and mean translation speed (km/hr) during DJF (1950-2014). Unit of density is $per\ unit\ area\ per\ month$. Unit area is a spherical cap of 5°, about $10^6\ km^2$.

3. RESULTS (All Examples for Boreal Winter – DJF)

Correlation and Empirical Orthogonal Function (EOF) analyses are applied to examine how the ETCs activity changes during **individual modes of internal variability**.

- The correlation maps of track density with PNA and ENSO shows that during the positive phase, the Pacific storm track shifts eastward while ETC genesis regions along the US west coast shift equatorward.
- Possible reasons could be the impacts on jet stream position as well as the meridional moisture transport.
- The correlation with PDO (decadal variability) is weaker than PNA and ENSO but shows impacts on Atlantic storm track and Europe.
- The Rotated EOF patterns are similar to the correlation maps of PNA and ENSO (EOF2) and PDO (EOF1).

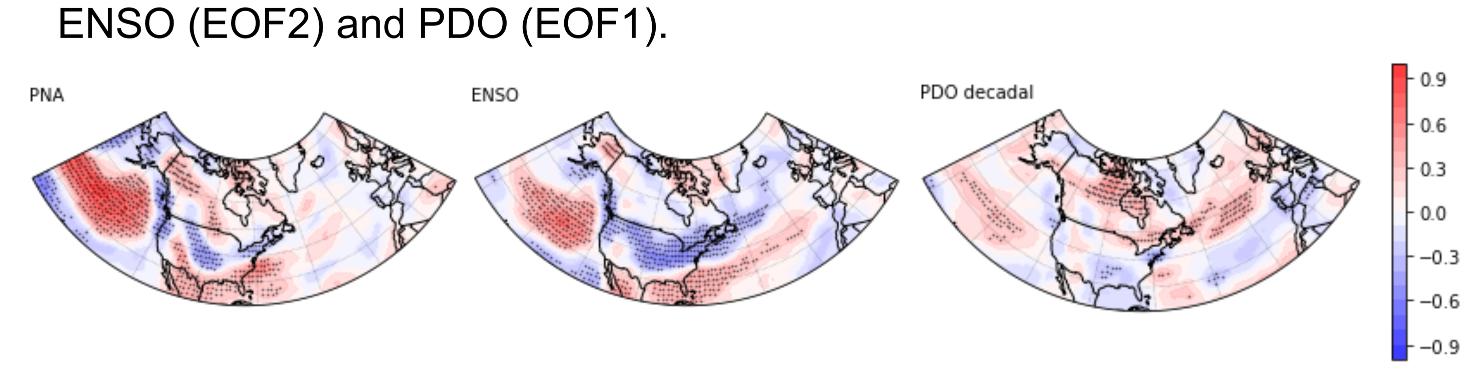


Fig 2: **Correlation maps** between track density and climatic indices (PNA, NINO 3.4, and 9-year running mean PDO) in DJF (1950 - 2014).

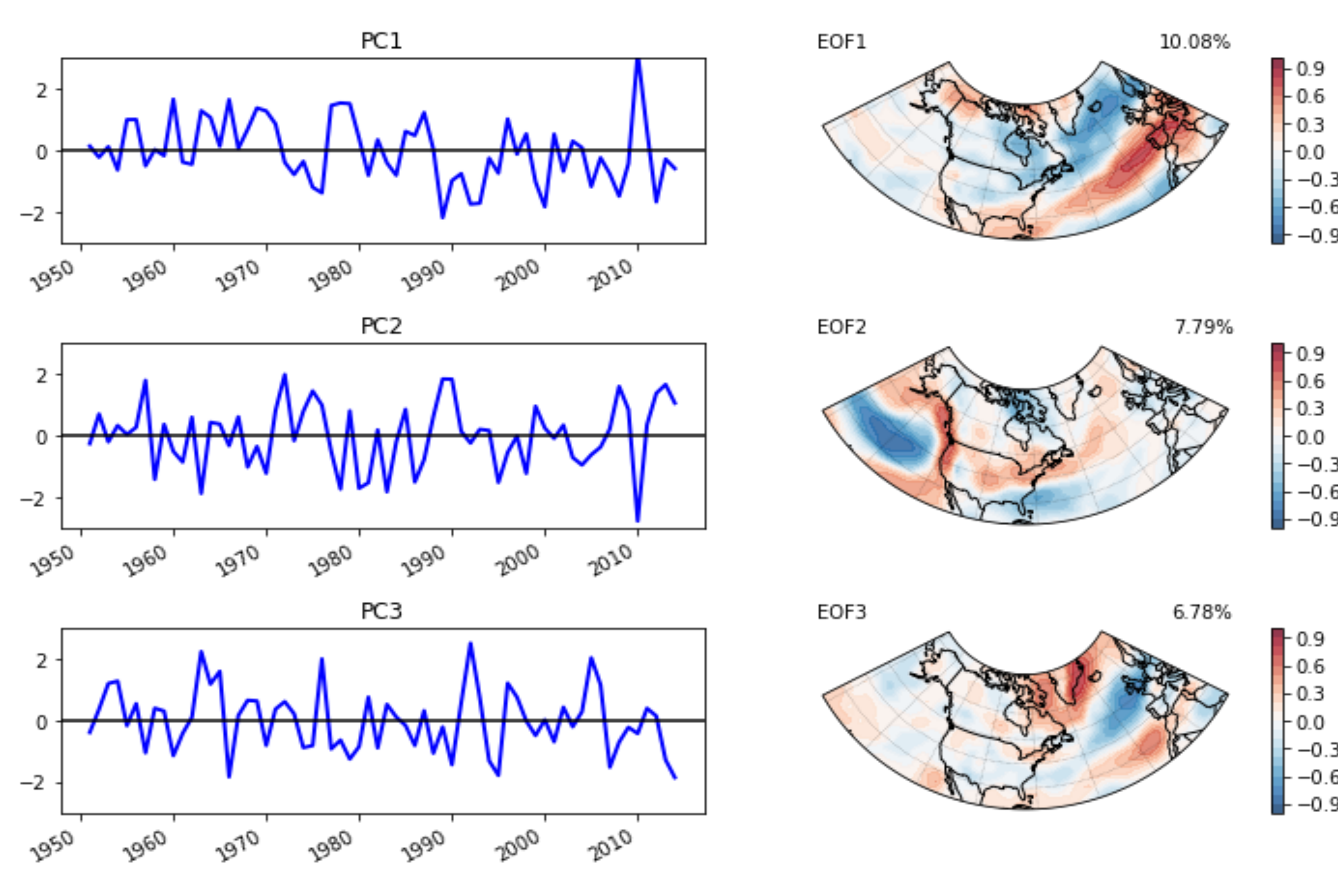


Fig 3: Top 3 spatial modes associated with explained variances and time series of principal components from Rotated EOF analysis by rotating the first 5 loadings from EOF methods of track density in DJF.

Note: **PC1** is statistically correlated with ***NINO34*** index (***0.27***) and with 9-year running average ***PDO*** index ***(-0.24)***. **PC2** is statistically correlated with ***PNA*** and ***NINO 34*** indices (***-0.54*** and ***-0.55*** respectively; also, with seasonal mean PDO index). The correlation coefficients of **PC3** with these indices are insignificant at the 5% level.

Composite analysis is used to examine the changes of ETC activity in different **compound teleconnection categories** (combinations of PNA & PDO and ENSO & PDO).

- Patterns of the positive (negative) PNA with either positive or negative PDO are quite similar;
- Two in-phases of ENSO & PDO have opposite impacts on ETCs, especially over Pacific and US.

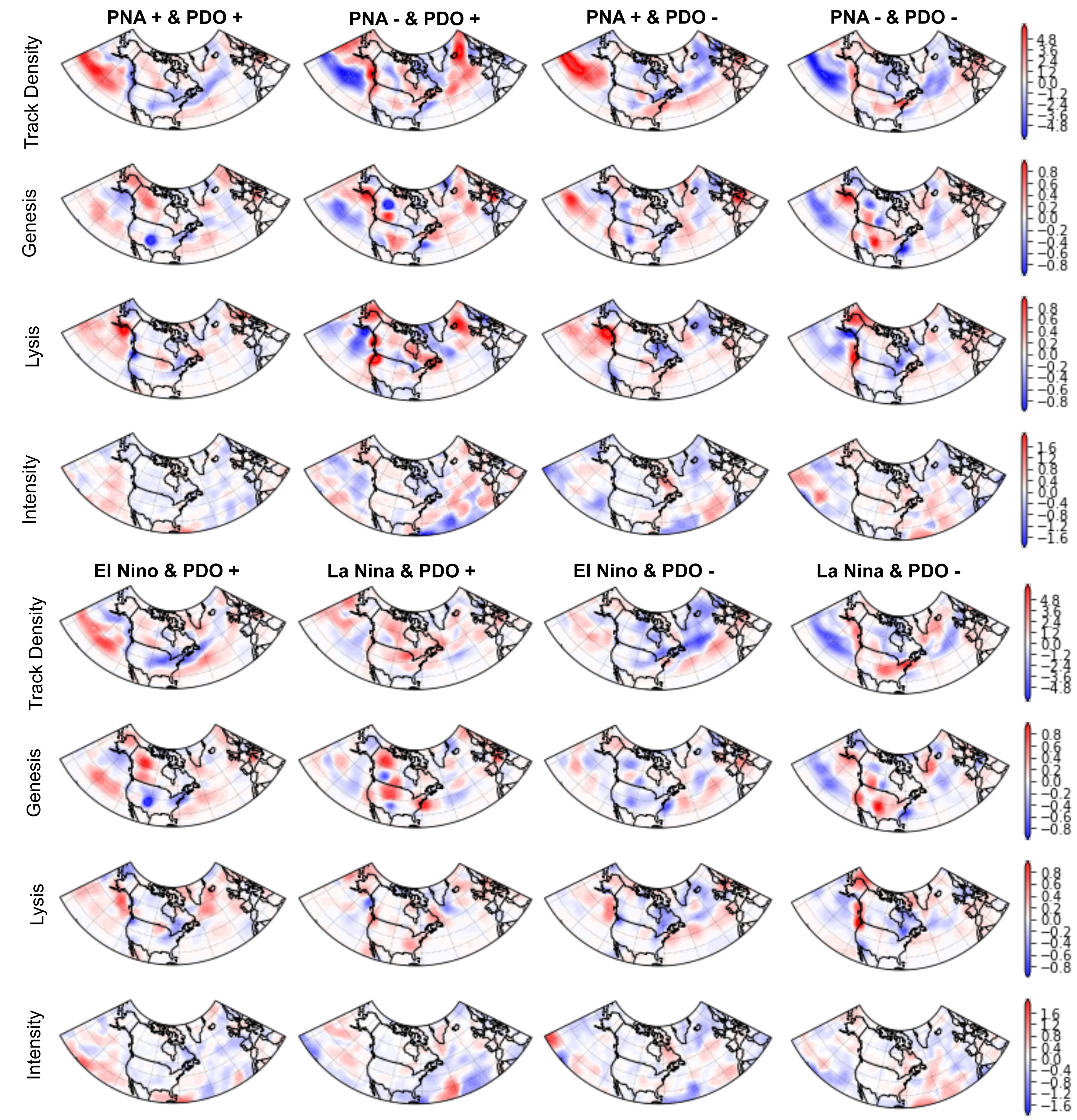


Fig 4: Differences in ETCs characteristics from climatology in compound teleconnections in DJF.

4. IMPACTS - Southeast US

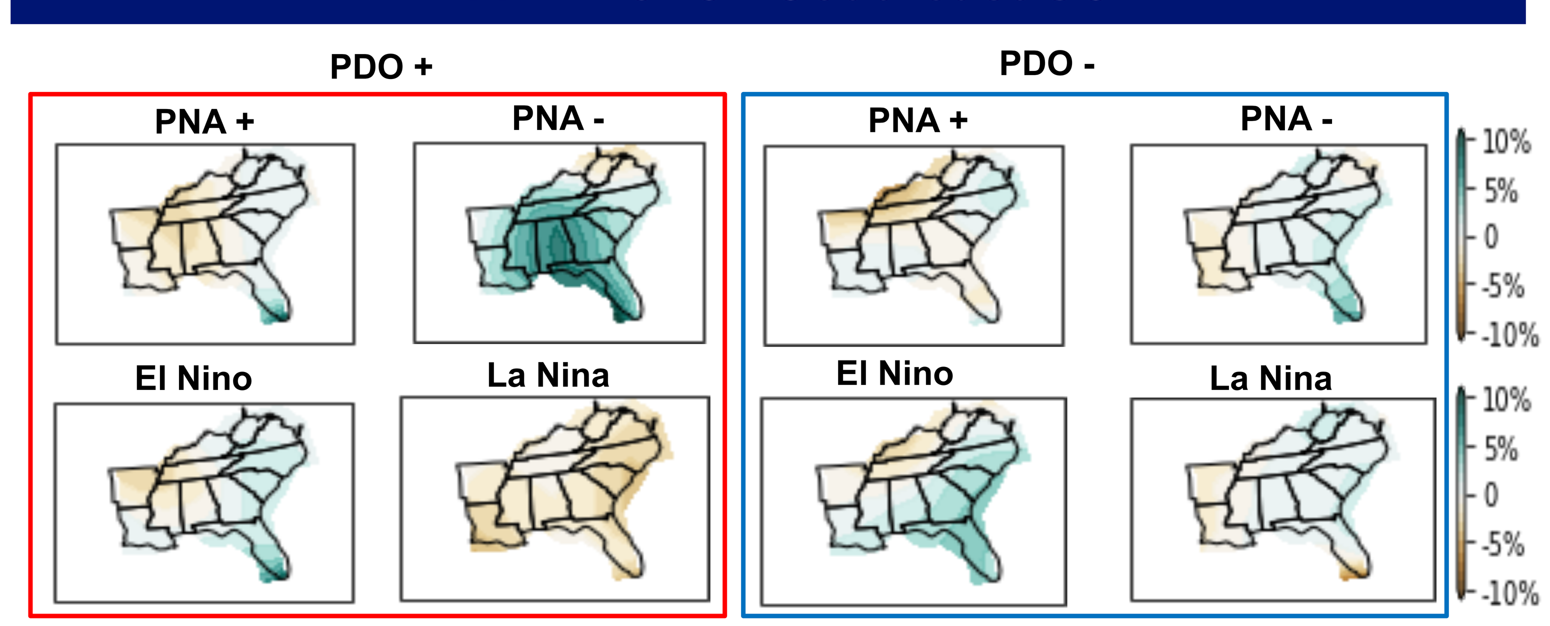


Fig 5: Percentage of ETC-related precipitation changes compared to climatology under different compound teleconnections (subtracting the ETC-related precipitation of climatology from one mode and then dividing by base climatology 1981-2010).

5. CONCLUSIONS

1. Climatology of ETC characteristics in DJF shows agreement with previous studies, except for the magnitude. Possible reasons could be different reanalysis datasets, criteria selected such as minimum moving distance, minimum lifetime and intensity threshold of ETCs defined here.
2. Results from the rotated EOF analysis confirms the correlation results, indicating the notable role of internal variability on ETC activity. PNA and ENSO drive ETC variability over the Pacific and central Great Plains. PDO most notably impacts Atlantic ETCs, especially during PNA - , while also having a decadal modulation on ENSO impacts over Pacific.
3. ETC-related precipitation demonstrate changes under different climate conditions. But it is unclear to what extent natural variability may change the proportion of ETC precipitation that is heavy/extreme, or how much ETCs contribute to intense precipitation over these seasons, which is the subject of ongoing work.

Hodges, K.I., 1994. A general method for tracking analysis and its application to meteorological data. Monthly Weather Review, 122(11), pp.2573-2586.
Hoskins, B.J. and Hodges, K.I., 2002. New perspectives on the Northern Hemisphere winter storm tracks. *Journal of the Atmospheric Sciences*, *59*(6), pp.1041-1061.