Intraseasonal Transitions of the Wintertime Pacific Jet Stream

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INTRODUCTION AND MOTIVATION

The wintertime Pacific jet stream is characterized by two leading modes of variability (Athanasiadis et al., 2010; Jaffe et al., 2011)

- Leading mode is an **extension** or **retraction** of the jet exit region 160°E to 120°W.
- Next leading mode is a **meridional shift** of the exit region in which the latitude of the jet axis can vary by 20°.

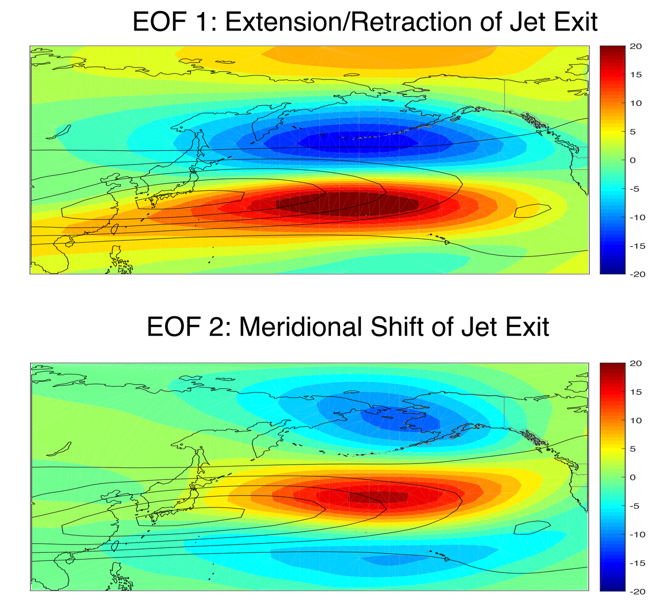


Fig. 1: EOF pattern of the 250-hPa zonal wind over the North Pacific. Perturbations are shaded (ms^{-1}; colorbar). Mean zonal wind over the 71 cold seasons is contoured in black every 10 ms^{-1} beginning with 60 ms^{-1}. (top) EOF1 (bottom) EOF2.

Leading modes associated with basin-scale anomalies in the Pacific have substantial impact on synoptic-scale structure and downstream sensible weather (e.g. Griffin and Martin, 2017; Jaffe et al., 2011; Otkin and Martin, 2004).

- Jaffe et al. (2011) examined 19 cold season jet retractions and found that an increase in storms occurred downstream and poleward of the jet 10 days before retraction events. Over the 10 days surrounding each event, both the 500-hPa geopotential height and sea level pressure (SLP) anomalies switched polarity from negative to positive in the north Pacific.
- Winters et al. (2019) has shown that the mode of the north Pacific jet has an apparent impact on medium-range forecast skill over North America.
  - Greatest skill occurred in conjunction with an **extended** or **poleward** deflected jet
  - Worst skill occurred in conjunction with a **retracted** or **equatorward** shifted jet.

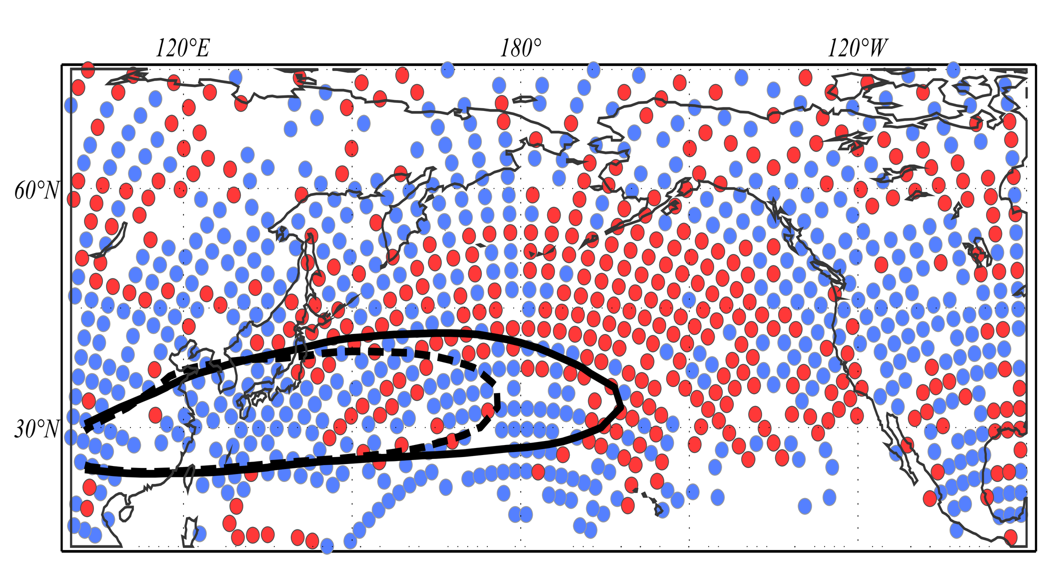


Fig. 2: Fig 10 from Jaffe et al. (2011): Storm track density difference during a composited jet retraction event. Red (blue) circles illustrate a higher density in storm activity before (after) the jet retraction. The solid (dashed) contour is the 300-hPa zonal wind 40 ms^{-1} isotach before (after) the composited jet retraction event.

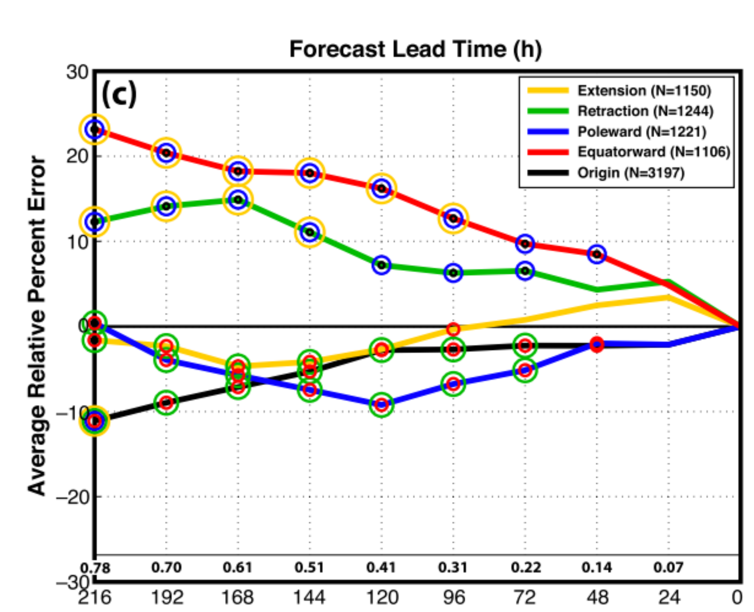


Fig. 3: Fig. 8c from Winters et al. (2019): Average percent distance error of GEFS ensemble mean jet regime forecasts. Positive (negative) errors are errors correspond to errors greater (less than) the average cool season average.

RESEARCH QUESTION

Are there preferred transitions between modes of wintertime Pacific jet variability?

METHODS

Data

- Daily 250-hPa zonal winds from the NCEP/NCAR Reanalysis (U_{250}; Kalnay et al., 1996) available at a 2.5°x 2.5° horizontal resolution daily.
- 71 seasons (1948/49-2018/19) in which a cold season is defined as November 1 through March 31 (NDJFM).
- Spatial domain 100°E to 120°W and 10° to 80°N

EOF Analysis

- Represent state of Pacific jet as a point in 2D phase space
- X-axis : retraction/extension
- Y-axis: poleward/equatorward deflection

Self Organizing Maps (SOM)

- Organize U_{250} dataset into a two-dimensional array of patterns
- Iterative process
  - Begins with set of generalized patterns from input data
  - Input used to train SOM map
- User-determined grid size
  - Aim to minimize root mean square error (RMSE) without dividing patterns based on noise differences

SOM Grid Size	Mean Root Mean Square Error
2x2	403
3x3	385
3x4	378
4x4	373
5x4	368
5x5	364

Table 1: RMS error averaged over all nodes within the SOM grid for various grid sizes.

RESULTS

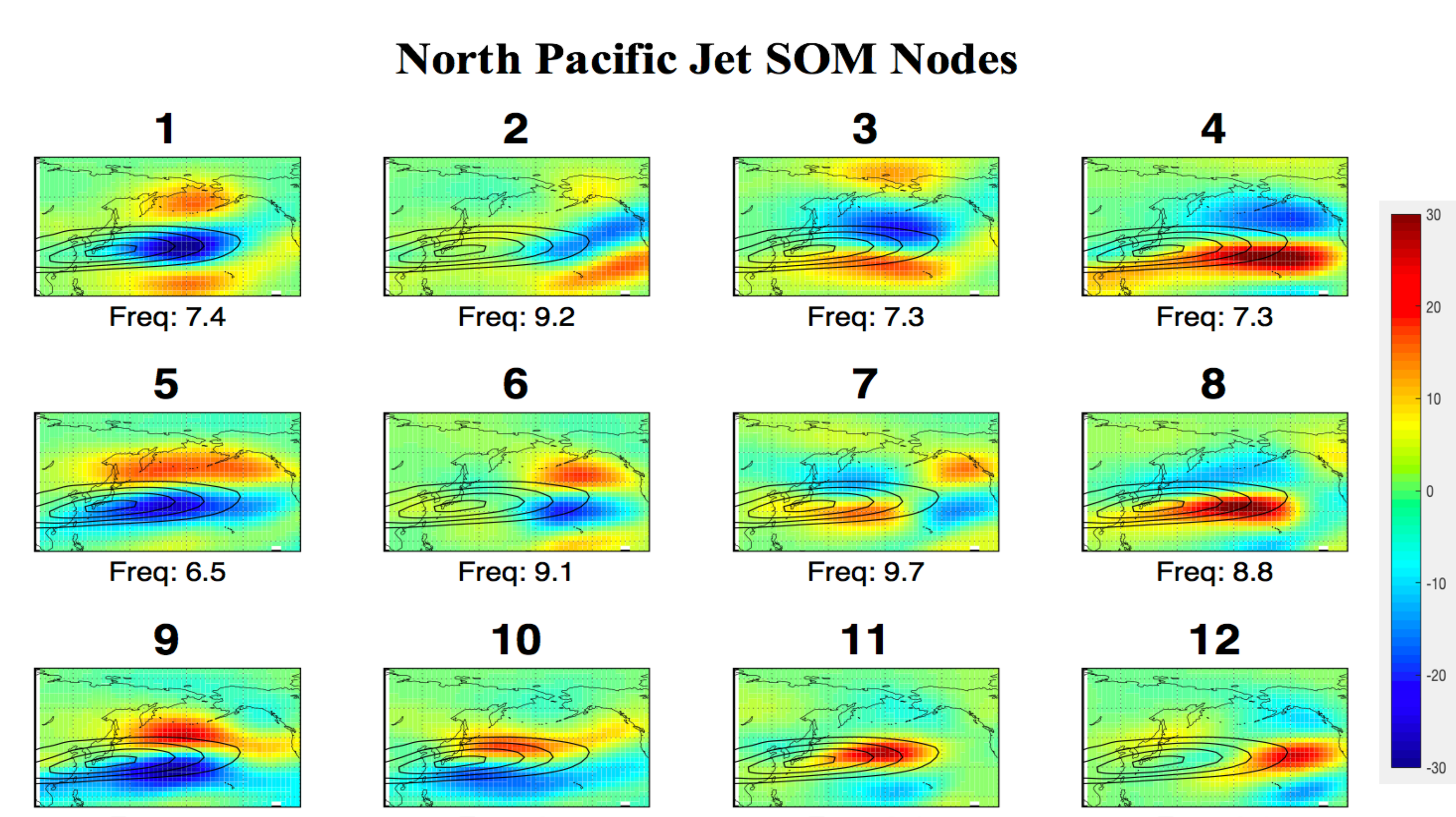


Fig. 4 : SOM grid of 12 most recurring patterns of the wintertime Pacific basin 250-hPa zonal wind. Anomalies of the 250-hPa isotachs are shaded (ms^{-1}; colorbar). Mean zonal wind over the 71 cold seasons is contoured in black every 10 ms^{-1} beginning at 30 ms^{-1}. Below each node is the associated frequency of occurrence (in %) relative to all other nodes.

SOM map of the 12 most common jet configurations

- Jet anomalies capture both EOF1/EOF2 patterns as well as combinations of the two EOF patterns
- SOM patterns furthest apart are most dissimilar

RESULTS

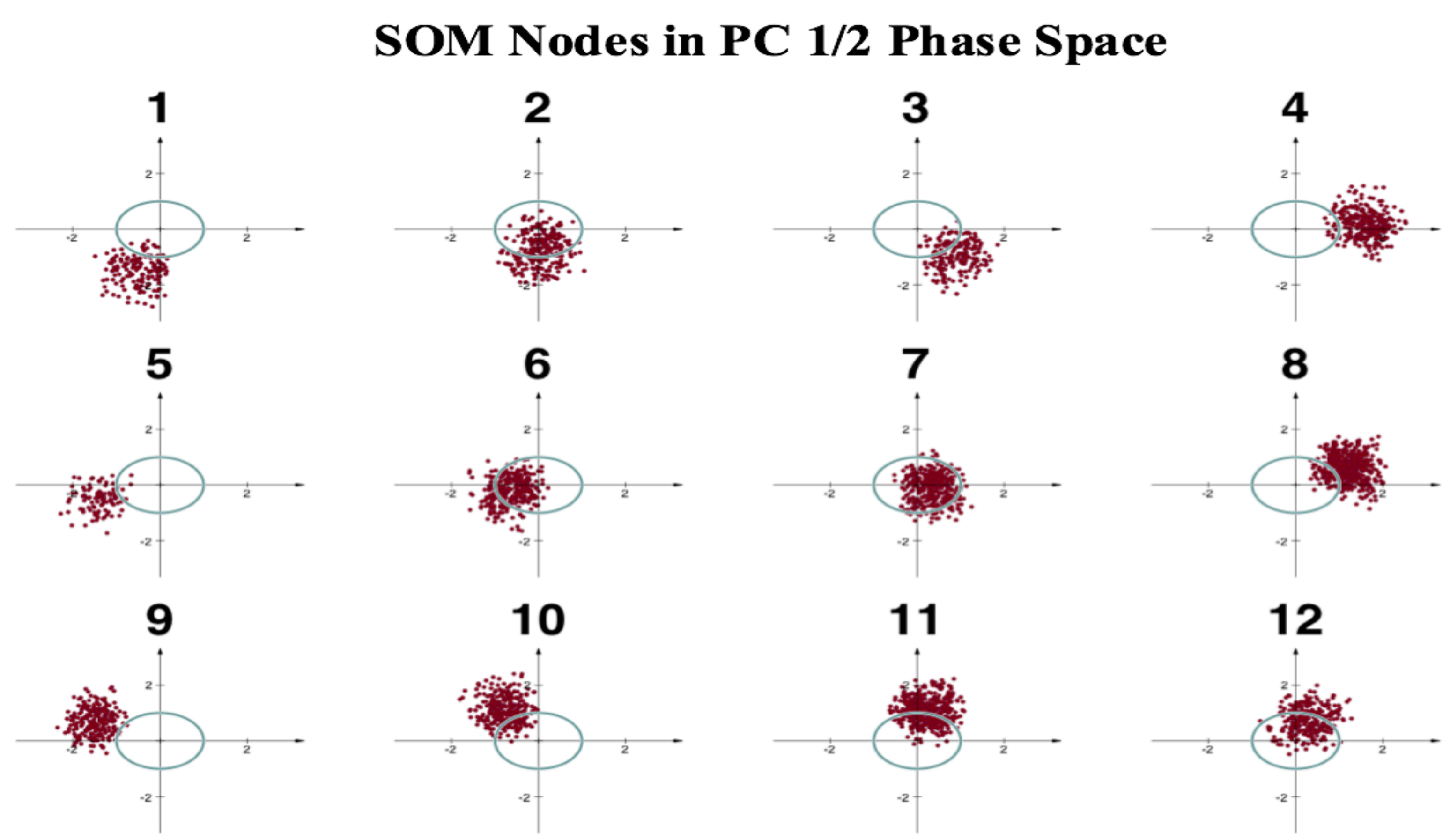


Fig. 5: State of the daily Pacific jet (maroon circles) in the 2D phase space of the leading 250-hPa zonal wind PCs for every day comprising each of the 12 SOM nodes within the 71 cold seasons (1948/49-2018/19). Blue circles represent the 2 and 4 contours of magnitude in the EOF/PC phase space.

SOM Nodes in EOF Phase Space

- Days with a low degree of dissimilarity (RMSE within 1σ of the node's mean) show clustering in specific quadrants of phase space
  - Nodes 4 and 8 cluster along the positive *x*-axis (jet extension)
  - Nodes 5 and 9 cluster along the negative *x*-axis (jet retraction).
  - Nodes 1, 2, and 3 illustrate equatorward deflections
  - Nodes 9-12 illustrate poleward deflections

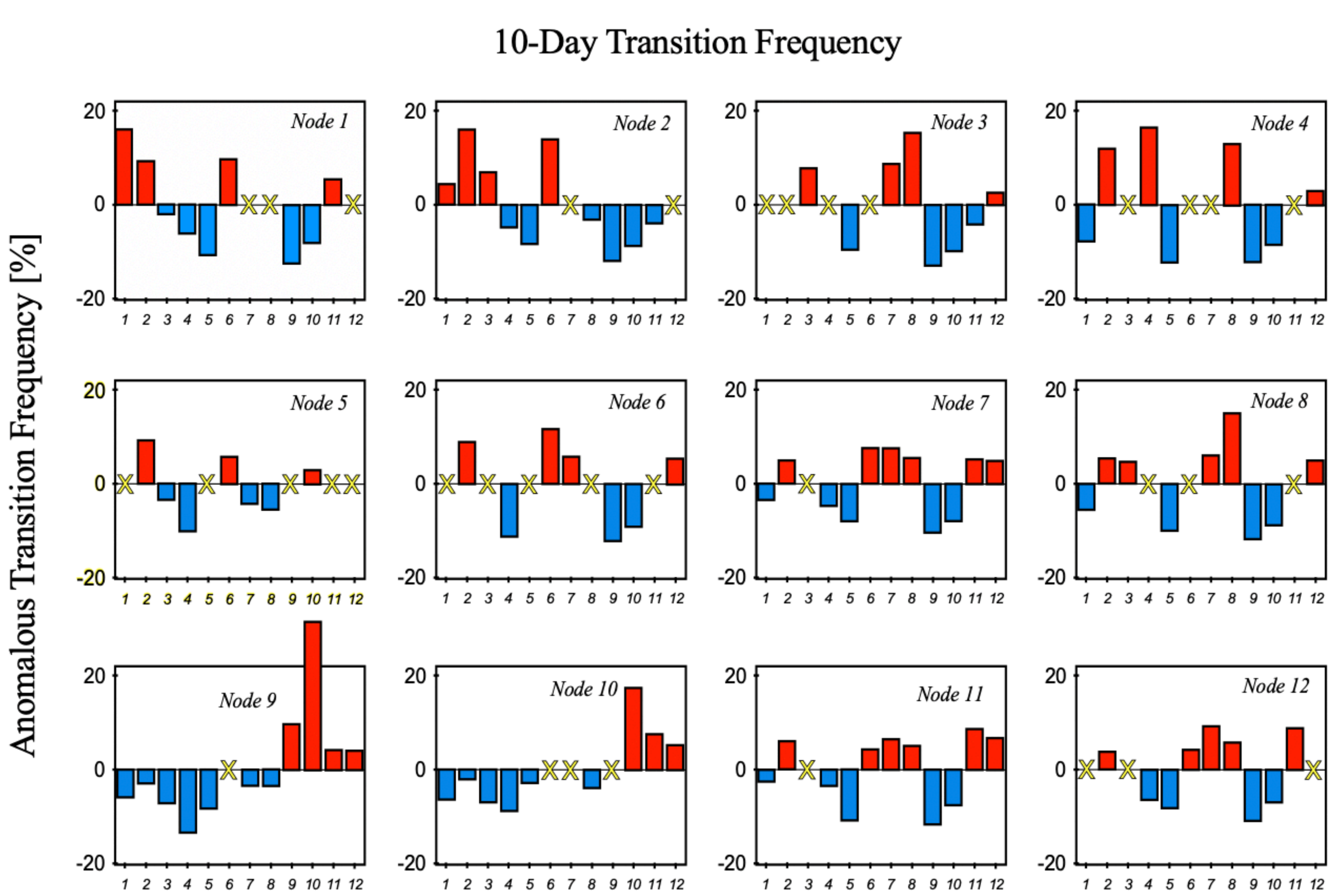
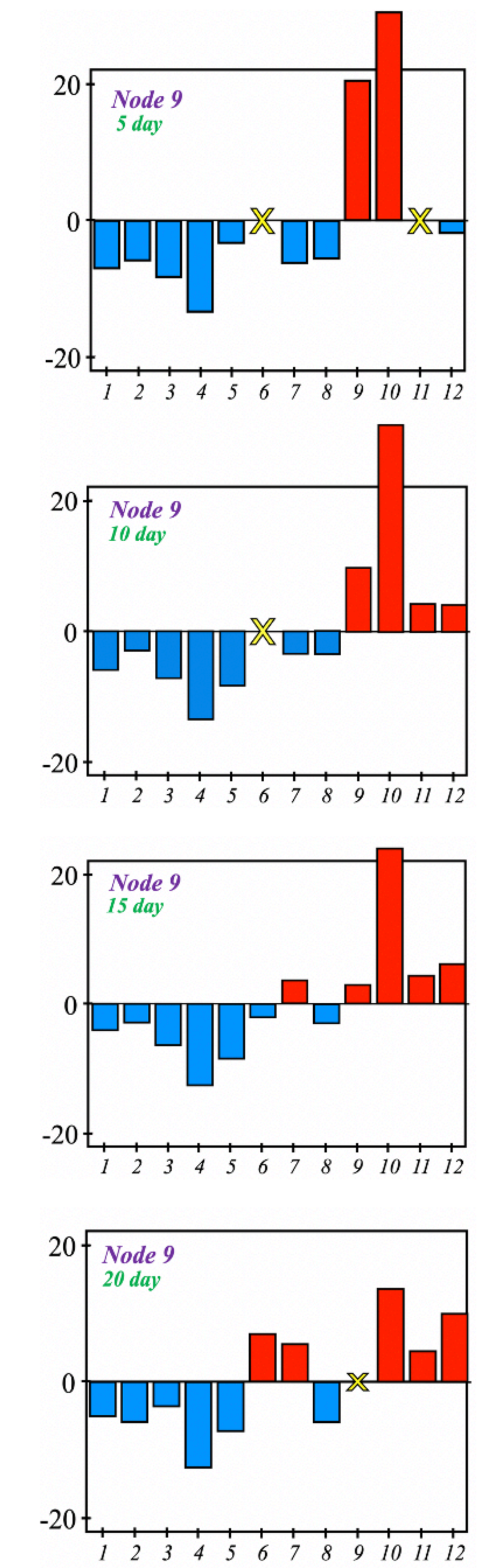


Fig. 6: 10-day anomalous transition probabilities for SOM Nodes 1-12 observed in the NCEP Reanalysis data. Within each subplot, columns 1-12 correspond to the SOM Node into which the transition is observed. Red (blue) columns indicate enhanced (reduced) transition frequency expressed as a percentage-relative to random noise. Only anomalous frequencies of occurrence at the 99% significance level are shown. Yellow X's indicate observed outside of the 99% significance level.

Transition Probabilities

- Statistically significant enhanced and reduced transition probabilities evident in every node
- Nodes depicting a more extended jet (nodes 4, 8) show reduced probability of rapidly transitioning both into and from a retracted jet (nodes 1, 5, 9)
- Extended jet (node 4) has enhanced probabilities of transitioning into poleward shifted jet regimes (nodes 8, 12) in contrast to the reduced probability of transitioning into a retracted regimes (nodes 1, 5, 9)

Node 9 Transitions



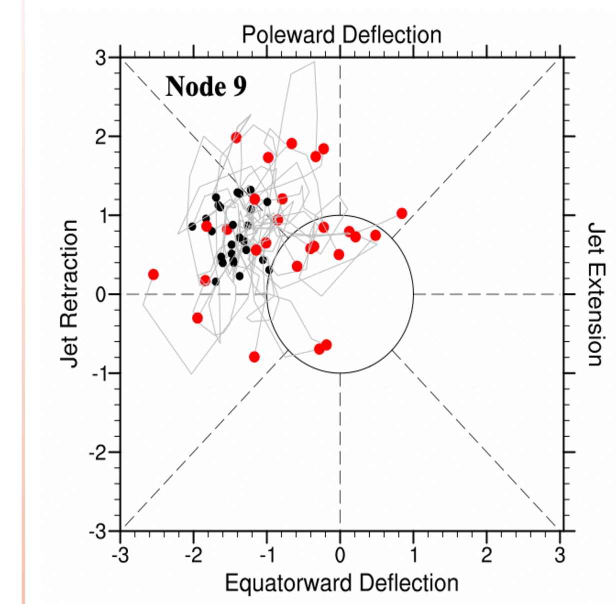


Fig. 8: 10-day forward trajectories for a subset of days within node 9. Subsequent days within node 9 are represented as a single dot following the last day the jet is within that node. Black dots depict days within nodes at day 1. Red dots depict the jet state 10 days later. Grey lines are the trajectories from day 1 to day 10.

Fig. 7: As in Fig. 6 but for anomalous transition probabilities at 5, 10, 15 and 20 days for SOM node 9.

- Node 9, a jet retraction, has low probability of transitioning into a jet extension (nodes 4 or 8) within a 5 to 20-day period
  - Nodes with extended regimes have lower probability of transitioning into strong jet retractions within a 5 to 15-day period
- Phase space trajectories from node 9 show majority of transitions move clockwise through the phase space into nodes 10 and 11

INITIAL CONCLUSIONS

- Analysis of 5, 10, 15, and 20-day transition probabilities show statistically significant transition probabilities exist.
  - Rapid jet retractions from an extended state and vise versa are less probable for time periods less than 15 days
  - Both jet extensions and retractions are more likely to transition meridionally than zonally
- Evidence that MJO impacts some transitions more than others (not shown but available upon request)

ONGOING WORK

Use of Linear Inverse Model to decipher role of tropical processes like MJO and other extratropical processes in modulating Pacific jet transitions

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