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INFLUENCE OF MIDLATITUDE CIRCULATION CHARACTERISTICS ON EXTRATROPICAL TRANSITION IN THE SOUTHWEST PACIFIC OCEAN

Mark Sinclair[1], Embry-Riddle Aeronautical University, Prescott, AZ

1. INTRODUCTION

Tropical cyclones (TCs) that undergo extratropical transition (ET) exhibit various structure changes in response to falling SSTs and increasing baroclinity as they enter the midlatitude westerlies. Previous Southern Hemisphere (SH) studies have examined climatological aspects of ET behavior (e.g., Sinclair 2002) and looked in more detail at a few individual cases but there has yet to be a systematic attempt to establish how and why SH ET events vary from case to case. There is much observational and theoretical evidence that distinct synoptic-scale flow patterns lead to fundamentally different modes of midlatitude cyclone evolution. In addition, several Northern Hemisphere studies have suggested that the nature of the midlatitude circulation into which the TC moves largely dictates the structure, motion and intensity changes that occur during ET (Harr et al. 2000; Harr and Elsberry 2000). Following Harr et al. (2000), empirical orthogonal function (EOF) analysis is used here to identify characteristic circulation patterns over the southwest Pacific basin during ET and determine how storms evolve in each. A second component of this study identifies preferred synoptic signatures associated with extratropical regeneration.

2. CHARACTERISTIC PATTERNS NEAR 30°S

It is common to use EOF analysis to identify the variety and importance of synoptic types for a particular region. Here, we follow Harr et al. (2000) and Klein et al. (2000) and use EOF analysis to identify characteristic midlatitude circulation patterns accompanying ET near 30°S. EOFs were derived from the temporal covariance matrices constructed from 52 cases of ET in the southwest Pacific basin during 1970 to 1997. Track information is from an archive developed by the New Zealand Meteorological Service (now called MetService) while gridded analyses are from the 2.5 x 2.5 degree NCEP/NCAR reanalysis dataset. Geopotential heights at 500 hPa were first interpolated onto a moveable 31 x 31 Lambert conformal domain of size 3330 km x 3330 km centered on the minimum 1000 hPa geostrophic vorticity using bicubic splines. The EOF analysis was performed on the set of 52 fields extracted at the time when each storm was closest to 30°S. The temporal coefficients, or principal components (PCs) for each spatial eigenvector pattern were then used to produce high and low composites of various fields by averaging cases having PC amplitude more than one standard deviation above and below the temporal mean. Varimax rotation of the leading 10 PCs was employed to isolate, as far as possible, single or dipole anomaly centers whose synoptic interpretation would be simplified.

The first eigenvector pattern (Fig. 1) explaining 46% of the storm-to-storm variance represents variations in the strength of the westerlies in which the TC is embedded. Positive (negative) excursions of PC-1 represent high (low) 500 hPa heights to the south and are called *high south* and *low south* patterns respectively. As would be expected, this PC is highly correlated with the u-component of storm translation (r = -0.76) and with overall translation speed (r = -0.60) but with no significant correlation with storm intensity as measured by central 850 hPa vorticity. Tracks for the 9 high south TCs are mostly meridional whereas the 7 low south cases featured more zonal motion at speeds nearly double those of the high south storms.

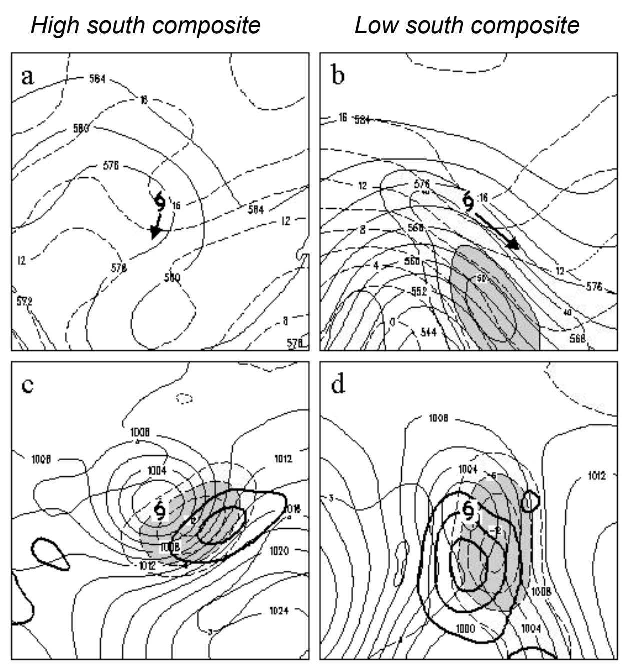

Figure. 1. (a-b) 500 hPa heights (solid, every 4 dam), 850 hPa temps (dashed, every 2°C) and 250 hPa isotachs (thin, > 35 & 45 ms^{-1} shaded), for high (a) and low (b) composites. (c-d) MSL pressure (solid, 2 hPa), vertical p-velocity (3 hPa hr^{-1}, ascent shaded), and positive contours of 850 hPa frontogenesis (thick, solid). Average TC motion is shown by the arrow.

[1] *Corresponding author*: Mark R. Sinclair, Embry-Riddle Aeronautical University, 3200 Willow Creek Road, Prescott AZ 86301; email: Mark.Sinclair@erau.edu

The high south composites (Figs. 1a,c) are similar to the “cradled” classification of Foley and Hanstrum (1994), where the TC is cradled in a surface high to the southeast (their Fig. 5a). It features steady poleward movement into a region of environmental easterly flow. Ascent occurs within a warm frontogenetical zone southeast of the center. The low south composite (Fig. 1b) features a vigorous 500 hPa trough to the south, with the TC moving rapidly southeast. The surface center is located beneath the equatorward entrance region of a strong upper jet with a meridionally oriented band of baroclinity, cold frontogenesis and ascent beneath. The low appears to be in the process of becoming absorbed into the trough to the south, making this synoptic signature similar to the “captured” classification of Foley and Hanstrum (1994).

The eigenvector pattern for rotated EOF2 (not shown) represents 12% of the intercase variance and features a dipolar pattern, with out of phase centers of action southwest and southeast of the surface low center, analogous to the northeast and northwest patterns of Klein et al. (2000) and Harr et al. (2000). High composites exhibit a 500 hPa ridge southwest of the center and a trough to the southeast (*southeast* pattern) while low composites have a trough to the southwest and ridging to the southeast *(southwest* pattern). Cyclones moving into the southeast pattern are located beneath the equatorward entrance region of an upper jet and undergo considerable intensification. Those associated with the southwest pattern weaken after passing 30°S and have no upper jet.

3. SIGNATURES OF REDEVELOPMENT

To identify synoptic signatures favoring extratropical regeneration, the EOF analysis was repeated for the time(s) when central 850-hPa vorticity fell by more than 2 x 10^{-5} s^{-1} over a 24 h period in the region poleward of 25°S. This criterion was a tradeoff between identifying events that were clearly reintensifying and achieving a large enough event count for statistical analysis. Some of the 52 storms decayed monotonically in middle latitudes so were not candidates for regeneration. However, others had one or more pulses of redevelopment south of 25°S, so were counted as above. A total of 43 periods of cyclonic central vorticity tendency were found. EOF analysis was performed to identify preferred synoptic signatures favoring extratropical redevelopment.

The first EOF explained 61% of the variability, suggesting that most regeneration episodes fitted into the two main synoptic types corresponding to opposite swings of the associated temporal coefficient (PC). High composites feature a cutoff low at 500 hPa, strong warm fronts and frontogenesis beneath the equatorward entrance region of a downstream upper jet (Figs. 2a,c). Previous studies have demonstrated a synergy between low-level frontogenesis and the upper jet, which moves poleward with the cyclone. Low composites (Figs. 2b,d) feature the surface low beneath the poleward exit region of an upper jet. Thermal and frontogenesis fields suggest a structure similar to that of the Norwegian cyclone model, with separate cold and warm fronts and a narrow warm sector.

High composite Low composite

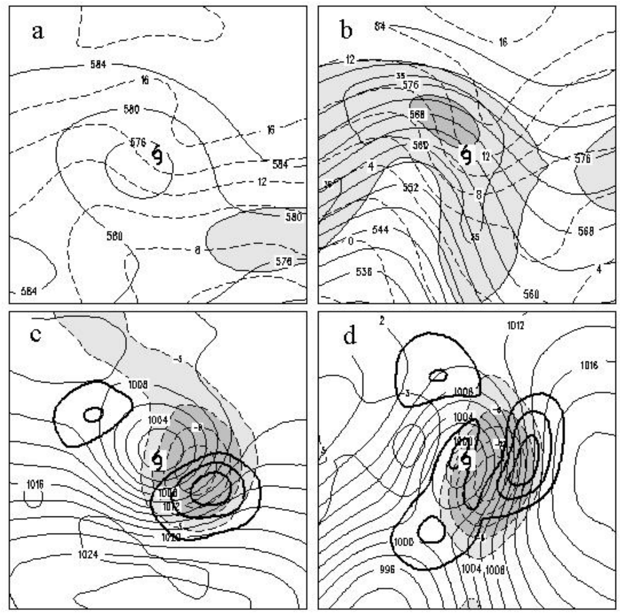

Figure 2. As in Fig. 1 except for redeveloping storms.

4. SUMMARY AND CONCLUSIONS

This study has used EOF analysis to objectively identify characteristic synoptic patterns accompanying ET. Results are similar to “cradled” and “captured” classifications obtained manually by Foley and Hanstrum (1994) for ET events near western Australia. Redeveloping storms feature favorable coupling with the divergence quadrant of an upper jet.

5. REFERENCES

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