13D.2 QUANTITATIVE MEASUREMENTS OF EXTRATROPICAL TRANSITION IN THE ATLANTIC BASIN

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1. Introduction

Tropical cyclones that undergo extratropical transition (ET) in the Atlantic Ocean basin can have a significant impact on life and industry on the eastern coast of North America and the western basin of the Atlantic. ET involves the evolution of a warm-core, vertically stacked, and quasi-equivalent barotropic cyclone into a cold-core, titled, baroclinic cyclone can take between twelve hours to more than several days, depending upon the relation between the synoptic scale pattern and the tropical cyclone. In order to diagnose which tropical cyclones will complete an ET, it is necessary to examine the dynamics of the large-scale environment.

This goal of this paper is to present several dynamical measures originally developed by Sutcliffe from a mid-latitude perspective that will help diagnose whether a tropical cyclone is a candidate for ET or dissipation in the mid-latitudes. These measures include thermal vorticity and the gradient of thermal vorticity (1000 - 200 hPa layer), as well as the absolute vorticity advection by the thermal wind between 1000 hPa and 200 hPa. Composite cases are presented comparing the differences between hurricanes that undergo a strong and robust transition versus tropical cyclones that decay before transitioning into extratropical cyclones.

2. Data and Methodology

The dataset used to compute all variables presented in this paper is from the NCEP/NCAR Reanalysis Dataset (Kalnay et al. 1996, Kistler et al. 2001). Although the NCEP/NCAR Reanalysis is rather coarse in resolution (2.5° x 2.5°) to determine small-scale structures of tropical cyclones, it is well suited for analysis continuity between 1948-2000, as well as diagnosing synoptic scale variables like thermal vorticity and the advection of thermal vorticity by the thermal wind. Absolute vorticity for this calculation is averaged between 700 hPa to 400 hPa. If best track data is not available for the cyclone, the 850 hPa absolute vorticity maximum was used as a surrogate for cyclone position.

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Tropical cyclones were analyzed and composited using the Generalized Meteorological Analysis Package (GEMPAK).

Thermal vorticity is a valuable tool to measure the thermal structure (warm or cold-core) of the cyclone. The gradient of tropospheric-deep thermal vorticity with respect to storm location allows insight into the interaction of the cyclone with baroclinic zones of varying intensity based on the value of the gradient. The advection of mid-level absolute vorticity by the tropospheric-deep thermal wind measures the forcing for large-scale ascent, based upon Sutcliffe theory. As tropical cyclones move into the mid-latitudes and undergo ET, a positive/negative couplet of this advection variable becomes readily apparent. The difference between the maximum and minimum value of this variable is coined the advection couplet, and is measured anywhere in a 500 km radius from the storm center.

3. Results and Discussion

Table 1 shows the tropical cyclones used in the strong transition and non-transition composite cases, primarily designated by National Hurricane Center best track analyses.

Table 1 - Storms Used in Composite Cases

Strong Transition		Non Transition Cases	
H Hazel	1954	H Gert	1981
H Agnes	1972	H Chantal	1983
H Eloise	1975	H Bob	1985
H David	1979	H Elena	1985
H Frederic	1979	H Bonnie	1986
H Hugo	1989	H Gilbert	1988
H Bob	1991	H Jerry	1989
H Bertha	1996	H Emily	1993
H Fran	1996	H Harvey	1993
H Floyd	1999	H Erin	1995
H Irene	1999	H Dennis	1999
H Michael	2000		

Figures 1 and 2 show a time series of the three variables used to diagnose transition, where 1 represents the strong transition cases, and 2 shows the non-transition cases. The three variables have also been calculated for thirteen memorable East Coast mid-latitude cyclones, whose average values are plotted as straight lines. These values are used as representative of robust extratropical cyclones, and therefore are used as indicators that transition has occurred. Comparing Figs. 1 and 2, it can be seen that for the strong transitioning cases, the composite tropical cyclone values exceed the mean mid-latitude values for all three variables. The gradient of thermal vorticity and advection couplet exceed the extratropical values at the time of National Hurricane Center (NHC) designated extratropical transition. The thermal vorticity value reaches a minimum at NHC transition time, and exceeds the mid-latitude value approximately 36 hours after transition time. Even before NHC designated transition, values of the gradient of thermal vorticity as well as the advection couplet increased from tropical values approximately 24 hours before designated transition. Therefore, the entire transition period for these 13 storms is considered to be a 60-hour period, in which the tropical cyclone evolves into an extratropical cyclone.

In comparison, the non-transition composite in Figure 2 shows that none of the three variables used to define ET achieve values show a robust change from tropical to extratropical values over the time period used. For this composite, time equals zero when the tropical cyclone decreases in intensity to a tropical depression. The advection couplet fails to develop, indicative of a dying cyclone with little or no forcing for ascent. There is no marked change in the thermal vorticity of the storm over this period, while the gradient of thermal vorticity fails to achieve the values found in mid-latitude East Coast cyclones.

4. Acknowledgements

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5. References

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6. Figures

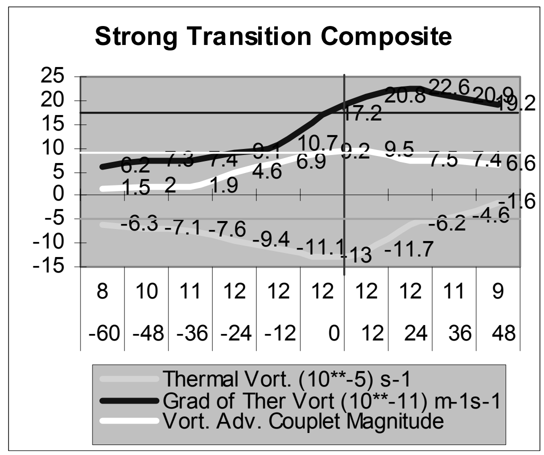

Figure 1 Strong transition composite cases. Y-axis labeled with number of cases at time period, defined as before/after NHC designated transition.

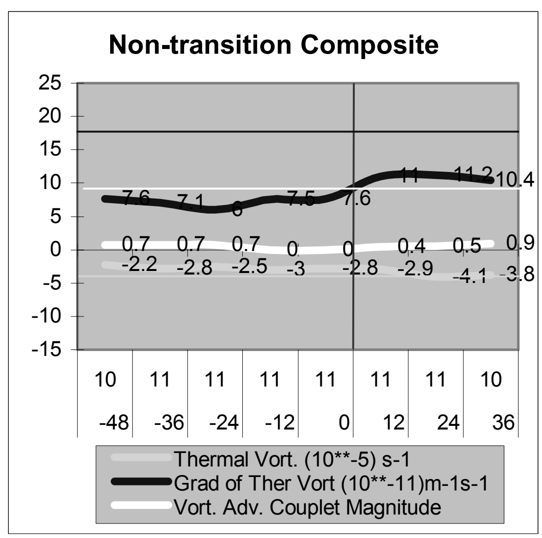

Figure 2 Non-transition composite cases. Y-axis labeled with number of cases at time period, defined as before/after NHC designated transition.