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ANALYSIS OF OPERATIONAL MODEL FORECAST TRENDS IN EXTRATROPICAL TRANSITION STORM STRUCTURE

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1. INTRODUCTION

Cyclone structure representation in numerical models is likely different when viewed in terms of model analysis fields versus forecast fields. Model biases can cause cyclone structure to deviate from the analysis in a systematic way, regardless of environmental influences. Similarly, alterations to the initial analysis fields can change the appearance of model forecasts of cyclone structure. Therefore, identifying the effect of these biases and alterations is essential to understanding cyclone structure representation in the models.

The representation of *tropical cyclones* (TCs) in numerical models is a vivid example of differing approaches to deriving model initial conditions. This example is prompted by the poor representation of tropical cyclone structure caused by insufficient resolution (Hart 2003). While some models do not augment the analyzed structure of a TC, others replace the TC vortex with a synthetic (bogus) vortex in the initial fields, altering the representation of the TC structure. The inclusion of such a vortex can dramatically effect the perceived structural evolution of such a system.

In this study, we examine the cyclone structure lifecycle of TCs undergoing *extratropical transition* (ET) in the North Atlantic. Because this subset of cyclones experiences a well-documented change in structure, it is well suited for examining the impacts of model biases and initialization changes in cyclone structure.

2. ANALYSIS METHODOLOGY

Comparing short term (0-36hr) forecasts of cyclone structure to analysis fields is a logical method of examining the effects of a bogus vortex and model biases. Longer term forecasts are excluded because of their likely inclusion of errors in the evolution of the environment surrounding the ET cyclone (especially during the ET process), which may also lead to changes in cyclone structure.

Cyclone Phase Space (CPS; Hart 2003) observations generated using AVN and NOGAPS 1° *analyses* of 19 North Atlantic ET events during 1998-2002 are used to define 7 cyclone structure subgroups by way of cluster analysis (Arnott 2004). CPS representations of the 12, 24, and 36 hr *forecasts* verifying at the analysis times in the original dataset are then computed for each cyclone. The forecasts and analyses are compared for each cluster to determine how model biases and initialization differences may effect the CPS location of that cluster. Unfortunately, a lack of forecast fields for the NOGAPS reduced its forecast dataset to 4 of the 5 years (1999-2002) of the original analysis dataset. Finally, because the AVN initialization of tropical cyclones changed on 6 July 2000 from bogus vortex insertion to vortex relocation (Q. Liu 2003, personal communication), the AVN analysis and forecast data are also partitioned before and after this date to isolate the effects of the bogus.

3. AVN / NOGAPS LIFECYCLE COMPARISON

Figure 1a (1b) shows the mean CPS location ($-V_T^U$ vs. $-V_T^L$) of all cyclones in clusters 1-4 using analysis fields (A) and 12, 24, and 36 hr forecasts from the AVN (NOGAPS) (clusters 5-7 are excluded for brevity). Clusters 1-3 represent increasingly strong TCs while cluster 4 represents TCs undergoing ET (Arnott 2004).

Initially apparent are the different $-V_T^L$ scales for the AVN (fig. 1a) and NOGAPS (fig. 1b), with NOGAPS cyclones featuring systematically higher values of $-V_T^L$. NOGAPS employed bogus vortex insertion during the years analyzed and this appears to enhance the warm core of NOGAPS TCs (Evans and Hart 2003). This discrepancy in mean cluster location is especially pronounced in clusters 2 and 3, suggesting the largest impact of the NOGAPS bogus in these clusters.

AVN forecasts approaching the analysis time for cluster 1 (weak TCs) cyclones are increasingly colder in the lower troposphere (i.e. decreasingly positive $-V_T^L$) (fig. 1a). This suggests that at longer leadtimes, the AVN increasingly overdevelops the low level warm core of incipient tropical lows. In fact, the 36 hr forecast indicates a slightly warm core cyclone while the analysis indicates a slightly cold core cyclone (fig. 1a). No trend is evident for the NOGAPS (fig. 1b).

A lesser degree of warm core overdevelopment in the lower troposphere is evident in the AVN for cluster 2 (moderately strong TCs) cyclones (fig. 1a). The NOGAPS bogus becomes apparent in this cluster with cyclones having the strongest lower (and upper) tropospheric warm core at analysis time. This suggests that while the bogus may be present 36 hrs before the analysis time, it systematically weakens from its initial strength.

The NOGAPS bogus is strongest in cluster 3 (strong TCs) cyclones (fig. 1b), as 36 hr forecasts reveal a ~20% reduction in lower tropospheric warm core strength. AVN cluster 3 cyclones show this same trend, but only in the upper troposphere (fig. 1a). This is likely tied to the fact that the AVN dataset includes years with and without a bogus (see section 4).

Tropical cyclones experiencing ET (cluster 4) have a stronger lower tropospheric warm core at the analysis

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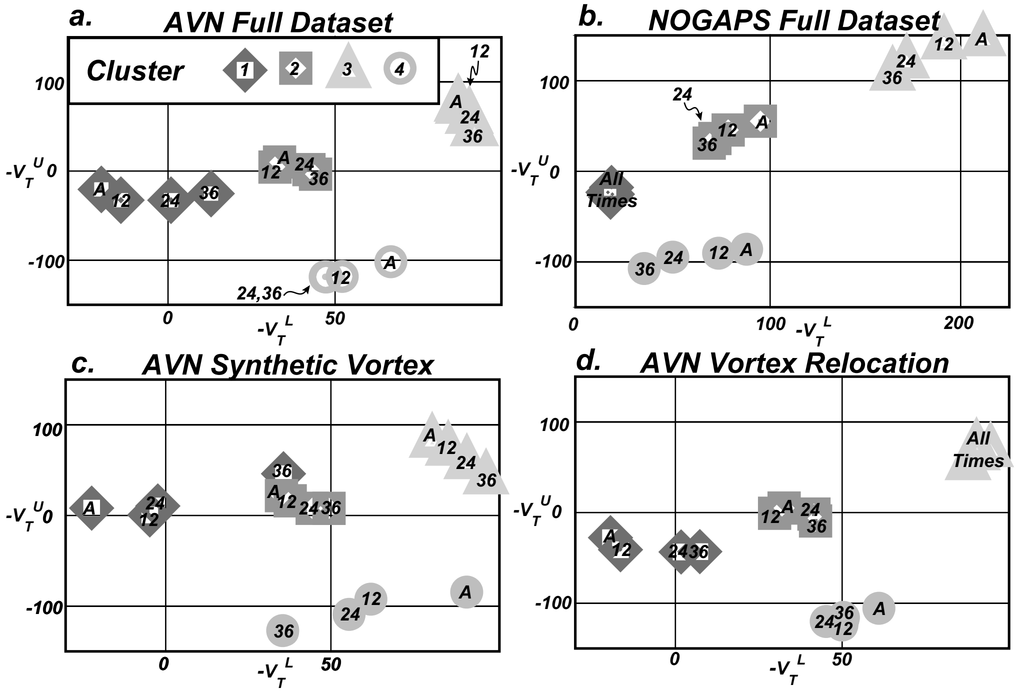

Fig. 1. Mean upper tropospheric ($-V_T^L$) vs. lower tropospheric ($-V_T^U$) warm core strength of cyclones in clusters 1-4 (shape and shading; see legend in a.) at analysis (labeled A), and at 12, 24, and 36 hr forecasts verifying at the analysis time (labeled 12, 24, and 36, respectively). Increasing $-V_T^L$ ($-V_T^U$) indicates a stronger lower (upper) tropospheric warm core. a.) full AVN 1998-2002 dataset, b.) full NOGAPS 1999-2002 dataset, c.) AVN dataset when bogus vortex initialization was employed, and d.) AVN dataset when vortex relocation was employed.

time than at any forecast time in both the AVN (fig. 1a) and especially the NOGAPS (fig. 1b). This indicates that in the NOGAPS TCs undergoing ET are (on average) initialized with a bogus vortex, likely impacting the eventual ET evolution.

4. SYNTHETIC VORTEX IMPACT ON LIFECYCLE

The AVN dataset is further partitioned into synthetic vortex years (fig. 1c) and vortex relocation years (fig. 1d), thus isolating the impact of the AVN bogus. While cluster 1 cyclones tend to have overdeveloped warm cores at all forecast times in both datasets, this trend is increased in the years when the AVN employed a bogus.

Cluster 2 cyclones show this same trend, to a lesser extent, in both datasets. Cluster 3 cyclones, those most likely to be influenced by a bogus, exhibit a striking difference. While the vortex relocation years feature no systematic trend in the warm core strength from analysis to forecast (fig. 1d), the bogussed years show that analyzed cyclones have a stronger (weaker) warm core in the upper (lower) troposphere than cyclones at any forecast hour (fig. 1c).

A markedly stronger warm core is present in the analyzed cluster 4 cyclones (vs forecast) in the bogussed years with a much weaker trend shown in the vortex relocation years. This indicates that when the AVN bogussed, it did so for cyclones experiencing ET, as did the NOGAPS. The fact that the lower tropospheric warm core strength of the 36 hr forecast cyclone is only 40% of that in the analyzed cyclone suggests that the stronger warm core of the bogus may be in error during ET events.

5. CONCLUSIONS AND FUTURE WORK

An inspection of AVN (NOGAPS) analysis and forecast fields from 5 (4) years of ET cyclones suggests that model representation of cyclone structure is impacted both by model biases and by bogus vortex insertion. The AVN appears to systematically overdevelop the lower tropospheric warm core of TCs before ET. Also, the inclusion of a bogus vortex in the NOGAPS causes the warm core of a TC to be strongest at analysis time, where it then weakens. For cyclones undergoing ET, the inclusion of a synthetic vortex delays the transition of the cyclone's warm core structure to cold core and thus likely plays a role in the evolution of ET. Future research is required to quantify this impact and determine when/whether a bogus should be included during ET.

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