15A.2 SIGNS OF RAPID INTENSIFICATION AS DEPICTED IN THE MICROWAVE IMAGERY

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1. INTRODUCTION

For the tropical cyclone (TC) forecaster, forecasting intensity (maximum sustained winds in the TC core) remains one of the most difficult aspects of the TC warning process. While forecast position errors have almost halved in the past 20 years, little improvement has been shown in forecasting intensity changes, especially for periods of rapid intensification. Operational forecasters have many empirical methods to determine whether a particular storm will intensify rapidly (such as the depth of warm sea surface temperatures (SST) and minimal environmental vertical shear); however, these methods are often more reliable for determining whether the TC will intensify at all, rather than provide any special insight towards a specific intensification rate. Methods that forecasters use to forecast TC movement, don't seem to work well with the intensification process. Numerical Weather Prediction (NWP) models that have shown such amazing improvements in TC movement, have yet to excel in intensification change. Besides from the smaller scale of interaction and the requirement for a greater density of data necessary for model initialization, the physical processes at the convective scale are still not completely understood. This paper looks at patterns, primarily seen in the satellite-based microwave data at both 85 and 37 GHz to help distinguish changes in convective banding which are similar to those shown in the Dvorak TC intensification technique (Dvorak 1975, 1984). In addition, scatterometer data are also examined to see whether any distinguishing surface wind features can be observed in the time period prior to the onset of rapid intensification. Finally, findings are compared for those TCs that begin rapid intensification at an early stage of development (34kt) versus those that intensify later on while at a more mature stage (55kt to 90kt).

2. INTENSIFICATION RATE AND WHAT IS RAPID INTENSIFICATION.

During an earlier study for rapidly intensifying TCs in the western North Pacific between 1975 and 2001, the second author looked at environmental wind flow characteristics via EOF compositing techniques to distinguish varying intensification rates for all TCs starting at the same intensity, 35kt (Ventham and Wang, 2007). In this study, they were able to distinguish the importance of the 200mb flow pattern prior to both rapid intensification, RI (defined as in increase in winds of 30kt in 24hr) and very rapid intensification, VRI (40kt in 24hr). For TCs with VRI, the importance of enhanced convergence at 850mb was also noted. The author's definition for RI was similar to that of Kaplan and DeMaria (2003) of 30kt in 24hr; however, they also surmised that RI at a starting intensity or 35kt would be probably different than one starting at 55 or 90 kt.

This is best illustrated by the two graphs shown in Fig 1 and 2 that compare typical and rapid intensification rates with the Dvorak rates of intensification. For over 30 years, the standard Dvorak intensification rate of one (1) T# per day has been used by the global TC forecasting agencies to predict typical rates of intensifications. If conditions stated in the technique appeared to be favorable (such weakening vertical shear or a proximity to a favorable upper trough), a intensification rate of 1.5 T# /24hr could be assumed. Typically this forecast rate could not be exceeded, however, during the analysis phase, if a TC appeared to really have rapidly developed, it could be assessed up to 1 T# higher (or 2.5T/24hr). For most of the world's ocean basins where aircraft reconnaissance did not exist, these assessments would become part of the TC best track data base. In the Atlantic, where aircraft reconnaissance is available, these constraints seem to fit the data reasonably.

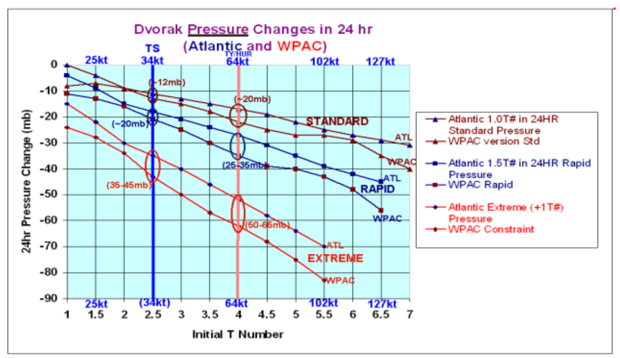

Fig. 1. 24 hr Pressure changes using the standards for Atlantic and W. Pacific ocean basins for pressure versus wind and T#. The three groups of curves represent, the standard, rapid, at 'constraint' rate of intensification.

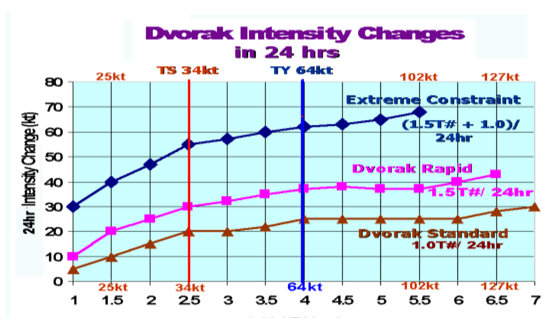

Fig. 2. Dvorak 24hr intensify change for different starting T# for Dvorak standard, rapid, and constraint rates of intensification.

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2. THE DATA.

This study shifts the time period from the earlier study by looking at the WPAC RI between the years from 2000 to 2007. In addition, Atlantic TCs that meet these criteria were also examined; and in this way, satellite-based wind and pressure estimates could be compared to the aircraft measurements, where available. During this time there was a wealth of new satellite-based, polar-orbiting microwave imagery (MI) such as from the TRMM, SSMIS, WindSAT and AMSR-E programs. These data had the added advantage of having higher resolution imagery than the earlier DMSP SSM/I program and could be more easily viewed in both the 85 GHz and 37 Ghz ranges.. In addition, the QuikSCAT scatterometer has been available since 1999 and allows the surface wind field to be closely examined in conjunction with the imagery. As discussed in earlier works, the MI has the ability to see rain and ice particle patterns within the TC rain bands that are normally blocked by mid- to upper- level clouds in the IR and VIS imagery. This gives the ability to more directly deduce at least three physical properties related to TC intensity: vorticity (and the related circulation position); shear; and convective vigor. In addition, interpretation techniques using the 85 GHz and 37 GHz MI have enabled the analyst to distinguish between two vertical levels within the TC: ~85 GHz (for views of the deep convective bands and overall moisture availability) and ~37 GHz (for views of lower rain band activity).

2. EXAMPLES OF MI AS A SUPPLEMENT TO THE DVORAK TECHNIQUE

Besides from having favorable environmental conditions such as warm sea surface temperatures and minimal vertical shear, it seems apparent that the degree of initial convective organization in the developing TC is next most important feature__pre-eyewall features are examined which do not exist in the Dvorak technique. Finally, a comparison is made for any distinctive features that can be observed in the microwave imagery between rapid versus slowly . that are precursors to rapid development (such as the shape of the outflow jet), but little discussion on the character of the convective organization during the crucial upper- tropical storm intensity (~50-55kts) time period when rapid intensification often begins. These features are normally obscured under the central dense overcast (CDO) in the VIS and IR. Patterns, however, exists in the MI that show increased organization and early eye development during this period that can be included into the current IR/VIS technique as signs that the three physical parameters of the TC (vorticity, shear and convective vigor) are quickly improving.

3. RESULTS

Results will be shown during the presentation.

Key findings include:

1) Before a TC can intensify, its low level center must be organized, as depicted by a convective ring around the wind center. The convection is not necessarily deep, as it would normally show up first in the 37Ghz imagery before showing a deeper convective ring in the 85Ghz.

2) All TCs showed evidence of a ‘convective burst’ within the ring, the signal the start of the RI phase. This could sometimes be seen in the enhanced IR imagery, but was more clearly seen in the 85h.

3) In the early stage especially, QuikSCAT often showed a strong low level convergence into the inner convective ring.

4) Many times, the convective burst would occur right after the ending of an environmental inhibiter (such as the weakening of vertical shear or movement away from land.

3. CONCLUSIONS AND FUTURE WORK.

This paper offers some suggestions for where the microwave data can help distinguish the onset of rapid intensification. It is important to distinguish the difference in patterns between those TCs that begin rapidly intensifying at an earlier stage in their development versus those that start later on. Typically, the later stage intensifiers require the abatement of some form of environmental inhibiter such as an increase in vertical shear or the movement away from land. For the earlier stage or rapid intensification, the key feature appears to be the formation of an early ring of developing convection that surrounds the wind center, this looks like a pre-eye wall in the 37 GHz imagery. In both cases, TCs with smaller cores appear to intensify quicker than those with larger cores. In addition, each TC showed signs of one or more convective bursts from within the ring that signaled the start of rapid intensification. In the future, the authors hope to expand the study to other ocean basins and to complete a more thorough analysis of those features that distinguish between normal rates of intensification and those that are rapid, or very rapid.

Acknowledgments. The first author would like to thank Margie Kieper for some of the pre-processing of the Atlantic TC data. The second author also thanks Dr. Bin Wang, Univ of Hawaii at Manoa.

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