4C.3 INFLUENCE OF ENVIRONMENTAL WATER VAPOR ON TROPICAL CYCLONE GENESIS

Derek Ortt* and K. Smith

ImpactWeather, Inc. Houston, TX

1. Introduction

The impact on tropical cyclone (TC) intensity due to interaction with the large-scale environment has been well documented. Initial studies focused on the sea surface temperature (Riehl 1948) and vertical wind shear (e.g. Gray 1968, DeMaria 1996). More recent studies have focused on the impact of environmental water vapor (WV) on TC intensity (e.g. Kimball 2005, Ortt 2007). Ortt (2007) provided a statistical evaluation of the impact of water vapor on TC intensity. It was determined the intensifying TCs are located in environments that are more moist than those remaining steady or weakening. However, Ortt (2007) did not address how WV can affect TC genesis. Forecasting TC genesis is of vital importance. Many interests, both offshore and onshore, require several days of lead time to make appropriate storm preparations. Failing to make an accurate genesis forecast several days in advance can lead to these interests only having 24 hours to prepare for a potential hurricane, as was the case with Humberto in 2007 (Blake 2007) in Texas and Tomas in 2010 in the Windward Islands (Pasch and Kimberlain 2011).

This study will extend Ortt 2007 to include the genesis phase. Using data from the Special Sensor Microwave Imager (SSM/I) and TRMM Tropical Microwave Imager (TMI) satellites, the study seeks to determine statistically the influence of environmental water vapor on TC genesis. The working hypothesis for this study is that TCs that develop will be located within environments that are more moist than those that do not develop. Pennington (2003) did address some of this topic and found that developing tropical waves are located within environments that are more moist than the climatology. However, that study primarily focused on tropical waves. In addition, the horizontal resolution of the data was 1 degree, which limited the ability to evaluate the interaction between the TC and the environment. Dry air intrusions would not be able to be captured by data that coarse.

The data used in the study will be of a higher resolution to capture these processes. In addition, it is not limited to tropical waves. Instead, all disturbances, including thunderstorm complexes that move from the United States into the Gulf of Mexico as well as nontropical areas of low pressure that may transition into a TC will be included in this study.

2. Data and Method

The data used for the study primarily consists of TPW data from the SSM/I F15 satellite and from the TMI satellites. The SSM/I data has a resolution of 25 km, while the TMI data has a resolution of 5 km. The data was acquired from Remote Sensing Systems (REMSS) and has been interpolated by REMSS to a resolution of .25 degree.

Since this study evaluates the pregenesis phase, the positions of the disturbances cannot be taken from HURDAT. Instead, we have used the positions provided in the ImpactWeather products. These products include a Daily Briefing delivered at 1200 UTC every morning as well as tropical disturbance statements that are issued on significant disturbances. These disturbance statements are issued at various times of the day. The positions of the disturbance are derived from linear interpolation from the two nearest ImpactWeather positions to the time of the SSM/I or TMI pass.

The study used data from the 2010 and

Corresponding author address: Derek Ortt, ImpactWeather, Inc., 12650 N. Featherwood Dr., Suite 140, Houston, TX 77034; email: dortt@impactweather.com.

2011 Atlantic hurricane seasons from May 15 through November 30. Disturbances that occurred outside of this time period were disregarded for this study. The spatial domain used for the study was the entire Atlantic Basin, south of 30N. A second subdomain that was evaluated only included disturbances south of 25N. Passes were excluded if there was less than 65 percent data coverage. Tables 1 and 2 provide the number of SSM/I and TMI passes available for the study south of 30N and south of 25N.

	30N	25N
0-800km	**20** **272**	**18** **257**
0-500km	**30** **385**	**26** **365**
0-300km	**45** **462**	**40** **435**

Table 1: Number of SSM/I passes south of 30N and south of 25N used in this study for both developing (black) and nondeveloping (red) disturbances.

	30N	25N
0-800km	**18** **200**	**12** **171**
0-500km	**31** **373**	**23** **337**
0-300km	**40** **465**	**31** **425**

Table 2: Number of TMI passes south of 30N and south of 25N used in this study for both developing (black) and nondeveloping (red) disturbances.

The disturbances were separated into two groups. The first consisted of those that developed into a TC within 48 hours of the pass and the other that did not. Disturbances that developed into a subtropical cyclone within 48 hours of the pass were excluded from the study. The mean TPW was then calculated for each of the following areas: within 0-300km of the center, within 0-500km, and within 0-800km. This is a bit different than Ortt (2007) in that that study used an annulus of 200-600km from the center. The reason this study chose to include the area close to the center is that many disturbances do not have deep convection near the center, or even a center at all. In addition, there is much greater uncertainty as to where the center is located or if there even is a center. Thus, it is not anticipated that by including the area within 200-600km of the center will not contaminate the WV results with the signal from deep convection. Composite mean values, as well as the frequency distributions, were then calculated for developing and nondeveloping disturbances for both the SSM/I and TMI data. Both data sets were not combined into a single data set due to possible differences in TPW values retrieved by the two different satellites. The statistical significance of the results will then be evaluated using the Kolmogorov - Smirnov (KS) test.

3. Results

Figure 1 shows the composite mean SSM/I TPW for developing and nondeveloping disturbances south of 30N. For all three radii, developing disturbances on average are within a more moist environment than nondeveloping disturbances. The greatest difference is close to the center. Within 300km of the center, developing disturbances have on average nearly 2.8mm more TPW than nondeveloping ones, or about 5 percent more. The differences are greater when only considering disturbances south of 25N as shown in figure 2. Here, developing disturbances have more than 3mm more of TPW within 300km of the center than nondeveloping disturbances. A reason why the differences may be greater south of 25N is that south of 25N there are fewer nontropical systems that transition into TCs. The transitioning nontropical systems typically are located within dry environments and form through baroclinic forcing, not through the release of latent heat as do many systems in the deep tropics.

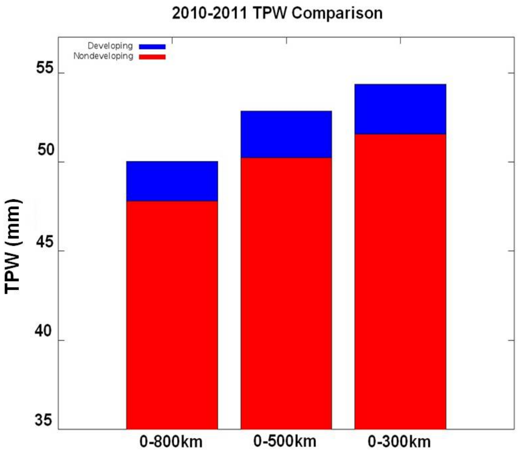

Figure 1: Composite mean SSM/I TPW for developing (blue) and non developing (red) Atlantic disturbances from 2010-2011 south of 30N.

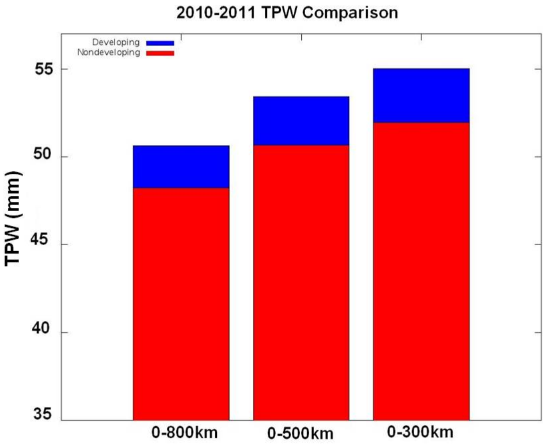

Figure 2: Composite mean SSM/I TPW for developing (blue) and non developing (red) Atlantic disturbances from 2010-2011 south of 25N.

To look closer at the differences between developing and nondeveloping disturbances, the frequency diagrams of TPW were generated. The frequency diagram of TPW within 300km of the center for developing and non developing disturbances is show in in figure 3.

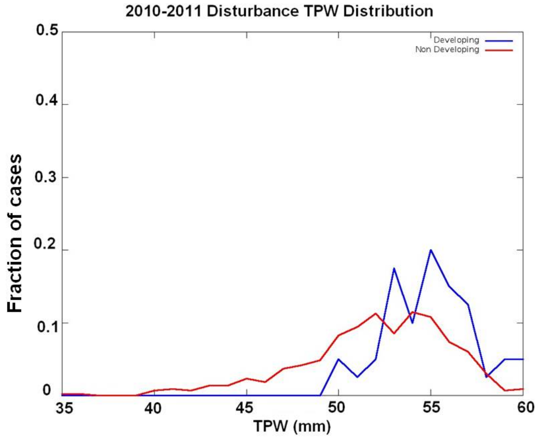

Figure 3: Frequency diagram of SSM/I TPW for developing (blue) and non developing (red) Atlantic disturbances from 2010-2011.

The frequency diagrams indicate different TPW environments for developing and non developing disturbances. Development did not occur when the mean TPW was less than ~49mm, while some nondeveloping disturbances had TPW values less than 40mm. Development into a TC occurred most frequently when the TPW was greater than 52mm. Results from the K-S test indicate that the differences between developing and nondeveloping disturbances are significant to the 99 percent confidence level.

The results from the TMI data confirmed the SSM/I results. The TMI data showed that developing disturbances have more TPW on average than nondeveloping ones. In addition, the signal is strongest within 300km of the center and south of 25N. The composite mean for developing disturbances is about 2.6 mm above nondeveloping disturbances. This is the same order of magnitude for the SSM/I data. However, the absolute values of the composite means for developing and non developing disturbances are about 1 mm greater in the TMI data.

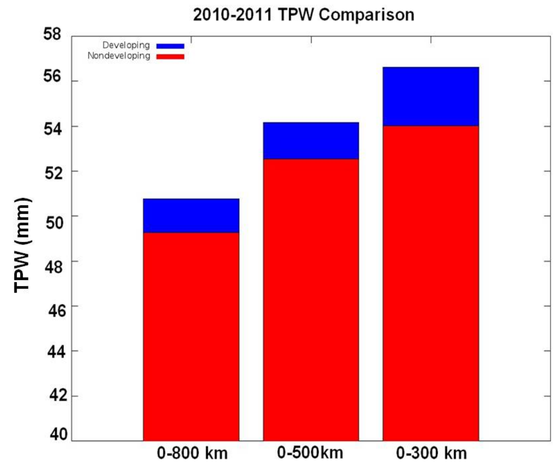

Figure 4: Composite mean TMI TPW for developing (blue) and nondeveloping (red) Atlantic disturbances from 2010-2011 south of 25N.

There are differences in the frequency distributions as shown in figure 5. As was the case with the SSM/I data, there appears to be a minimum amount of TPW required for genesis. In this case, it is ~53mm. There was one case of development when the TPW was ~36mm. This was Hurricane Shary, which formed from a nontropical area of low pressure in late October, 2010. Since there were baroclinic processes involved in its transition, it is not representative of the majority of Atlantic genesis cases. In comparison to the developing disturbances, nondeveloping ones often were in environments when the TPW was below 50mm.

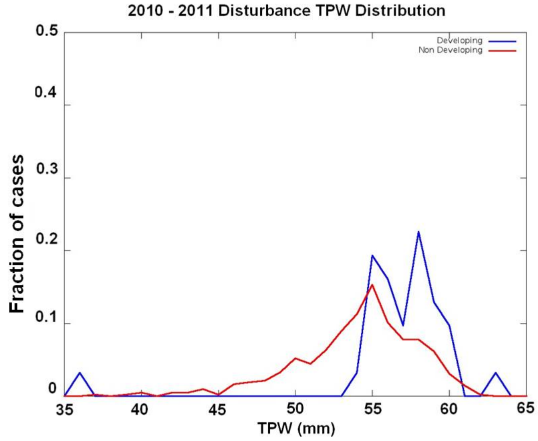

Figure 5: Frequency diagram of TMI TPW for developing (blue) and nondeveloping (red) Atlantic disturbances from 2010-2011.

4. Summary and Discussion

Microwave TPW data has shown that developing disturbances in the Atlantic basin south of 30N on average are located in environments with more WV than nondeveloping disturbances. However, the greatest differences are south of 25N, when most of the tropical transition cases are removed from the data set. These results are what were expected based upon the findings of Ortt (2007) with developed TCs and the fact that a TC derives its energy from the release of latent heat through the condensation of water vapor. The release of latent heat generates warming. The warming breaks the hydrostatic balance, forcing the atmosphere to respond with rising motion in an attempt to restore the balance. The rising motion leads to increased low level convergence, leading to an increase in vorticity. As the vorticity increases, a surface circulation forms, or the existing one intensifies, leading to the formation of a TC. Dry air tends to result in downdrafts, leading to surface divergence. This would act against genesis.

A note of caution needs to be stated about using the results from this study for operational forecasting. While the results are valid for individual satellites, these are not generally applicable for the combined satellite products that are currently in use. This is because difference satellites provide slightly different values of TPW. Since the combined products contain SSM/I, SSM/I S, and TMI data, the exact mean TPW values from those products may indicate a system is more likely to develop when that may not be the case. Instead, if using for operational forecasting, one should only use either the SSM/I satellite or the TMI satellite as a stand-alone product and compare the mean values to the results from this study.

5. Future Work

Future work will expand the study to include other ocean basins, including the western

Pacific, Indian Ocean, and southern Hemisphere. The purpose of this will be to determine whether the signal found in the Atlantic is applicable worldwide. This would provide a benefit for forecasters as it would provide another tool in forecasting TC genesis.

Acknowledgments

The authors are grateful to ImpactWeather for providing the time required to conduct the study. We would also like to thank Remote Sensing Systems for the SSM/I and TMI data. We additionally would like to thank Chris Hebert for some thoughtful comments that improved the study.

References

Blake, E. S., 2007: Tropical cyclone report on Hurricane Humberto. Available online at http://www.nhc.noaa.gov/pdf/TCR-AL092007_Humberto.pdf

DeMaria, M., 1996: The effect of vertical shear on tropical cyclone intensity change. *J. Atmos. Sci.,* **53,** 2076-2088.

Gray, W. M., 1968: Global view of the origin of tropical disturbances and storms. *Mon. Wea. Rev.,* **95,** 669-700.

Kimball, S. K., 2006: A modeling study of hurricane landfall in a dry environment. *Mon. Wea. Rev.,* **134,** 1901-1918.

Ortt, D., 2007: Effects of environmental water vapor on tropical cyclone structure and intensity. Masters Thesis, University of Miami, 91 pp.

Pasch, R. J. and T. B. Kimberlain, 2011: Tropical cyclone report on Hurricane Tomas. Available online at http://www.nhc.noaa.gov/pdf/TCR-AL212010_Tomas.pdf

Penninton, J. T., 2003: Environmental moisture impacts on Atlantic tropical cyclogenesis. Masters Thesis, University of Miami, 105 pp.

Riehl, H., 1948: On the formation of typhoons. *J. Atmos. Sci.,* **5,** 247-265.