P1H.3 FORECAST DIAGNOSTICS TO IMPROVE TROPICAL WAVE FORECASTING AT WFO SAN JUAN

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1. INTRODUCTION

Tropical waves are the primary weather modulator for Puerto Rico during the convective months from June through October. A tropical wave passage across Puerto Rico often results in heavy rainfall which is accompanied by strong gusty winds across the San Juan forecast area. The rainfall and gusty winds create hazards for the marine and aviation communities as well as the residents on the local islands. The impact of tropical waves on the local forecast area makes it necessary for the National Weather Service (NWS) Forecast Office in San Juan to accurately track tropical waves. By NWS definition, a tropical wave is a trough or cyclonic curvature maximum in the trade wind easterlies. These features have several sources; and are primarily of African origin, but can also originate from upper tropospheric trough reflections, or even the midlatitudes. At times, these features can be subtle and difficult to discern via satellite or traditional wave tracking methods, especially when the features are weak or lack active deep convection. These subtle features pose a challenge to the forecasters in San Juan, and can result in significant forecasting errors due to these systems triggering deep convection as they propagate across the island.

Recent diagnostic tools, developed at the University at Albany, in collaboration with the UK Met Office, provide an objective method to identify synoptic scale tropical waves in gridded data sets using the 700 hPa wind field (Berry et al. 2007). The diagnostics have been used the past few convective seasons at the San Juan forecast office. This study will evaluate the performance of the diagnostics in a complex synoptic case from June 2007, where a weakened midlatitude trough migrated into the tropics and moved across Puerto Rico, producing large rainfall totals.

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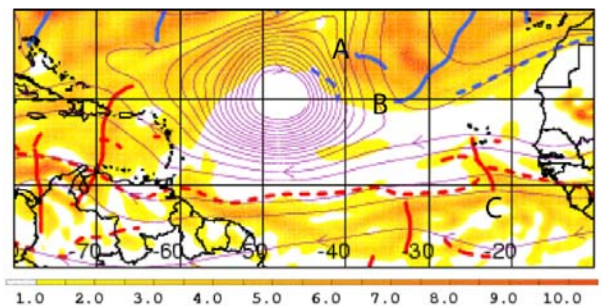

Fig. 1. 700 hPa troughs and potential vorticity (shaded) for 00Z June 20. Eastward moving troughs are in blue, and westward moving troughs are in red. The thin lines are streamlines. The thick dashed lines are jet axes at 700 hPa. Line A is the short wave trough. Line B is the axis of the broad trough. Line C is the AEW.

2. DATA AND METHODS

The objective diagnostic technique developed to track tropical waves is discussed in Berry et al. (2007). This technique uses the wind field output from a numerical weather prediction model to determine the trough axis of a tropical wave. The vorticity is separated into its curvature and shear components. The trough line for a wave is defined as the point where the advection of curvature vorticity is equal to zero in a region where curvature vorticity is positive. The jet axis is defined as the point where shear vorticity is equal to zero where there is a wind speed maxima. The diagnostics are calculated using the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) analysis with a .5

degree resolution. Time height cross sections were created at the Tropical Analysis and Forecasting Branch of the Tropical Prediction Center using the 12Z and 00Z soundings taken at San Juan, Puerto Rico. The cross sections were used to determine a tropical wave passage across the island. It is often observed (e.g. Riehl, 1954) that when a tropical wave passes a point, the winds ahead of the trough axis will prevail from the northeast, and will veer to the east then southeast with the passage of the trough axis.

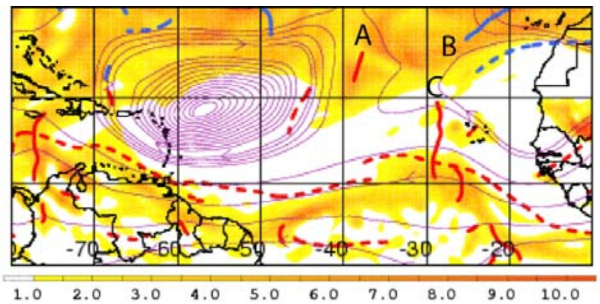

Fig. 2. Same as figure 1, except for 00Z June 21.

Rainfall data were obtained from the United States Geological Survey (USGS), using roughly 130 rain gauges set up across Puerto Rico. These gauges were used to determine rainfall distribution across the island. The data includes the 24 hour time period from 8 AM AST June 24 through 8 AM AST June 25. Even though the precipitation data runs through the morning of June 25, radar analysis indicates that the rainfall occurred on June 24, when the synoptic feature moved across Puerto Rico.

3. RESULTS

On June 20 at 00Z, 700 hPa streamline analysis indicates a broad trough across the eastern Atlantic (line B) (Fig 1). Forecast diagnostics indicate a shortwave trough extends from 23N 35W to 25N 40W (line A) at 700 hPa, moving eastward. A reflection of this mid-tropospheric trough is noted as a weak low pressure center in the surface analysis (not shown). In the figure, there is an African easterly wave (AEW) at 22W (line C), which will follow behind the shortwave trough across the Atlantic. The broad trough across the eastern Atlantic and surface low weakened by 00Z June 21, while the shortwave trough remained and extended from 24N 37W to 22N 39W (line A) (Fig. 2). Note that it has started to move westward. The AEW was located near 29W (line C). From here forward, these features will be referred to as trough and AEW, respectively. By 12Z June 21, the trough was firmly embedded in the easterly flow, ahead of the AEW (not shown). The distance between the features was roughly 10 degrees longitude when the trough first moved into the tradewinds, and then decreased to 5 degrees longitude as the trough reached 50W. This distance of separation will move it past a point roughly 24 hours apart from one another.

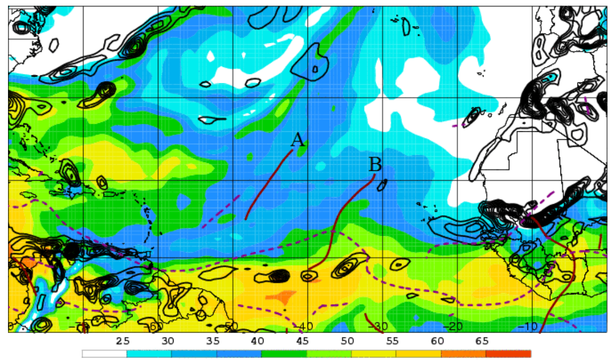

Fig. 3. 700 hPa troughs and precipitable water (in mm) for 00Z June 22. Line A is the trough and line B is the AEW. The dashed line is the jet axis.

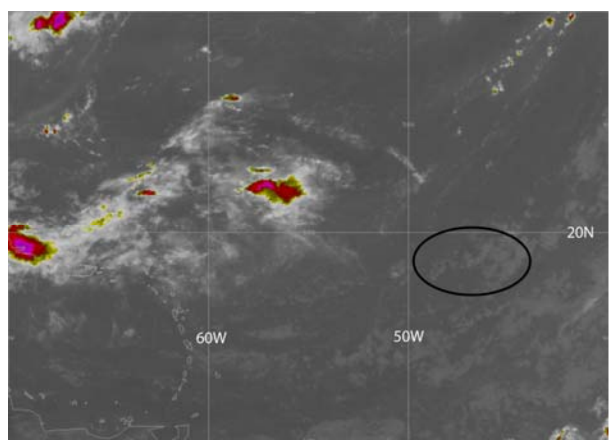

Fig. 4. IR satellite at 00Z June 22. Circled cloud mass is due to the trough at 700 hPa.

Deep convection was limited as the trough was in a dry air environment near 46 W at 00Z on June 22 (line A) (Fig. 3). However, a cloud mass associated with this feature was evident in a still IR image (Fig. 4). A Hovmoller diagram of IR satellite and the forecast diagnostics (not shown) confirm that the cloud mass was associated with the trough. This cloud mass was subtle at times, but was persistent as it tracked across the Atlantic waters. The diagnostics helped track this feature when the cloud mass was not as evident. The trough moved into a moist environment as it approached Puerto Rico at 12Z on June 24 (line A) (Fig. 5), while convective activity started to increase and became more evident on satellite imagery (Fig. 6).

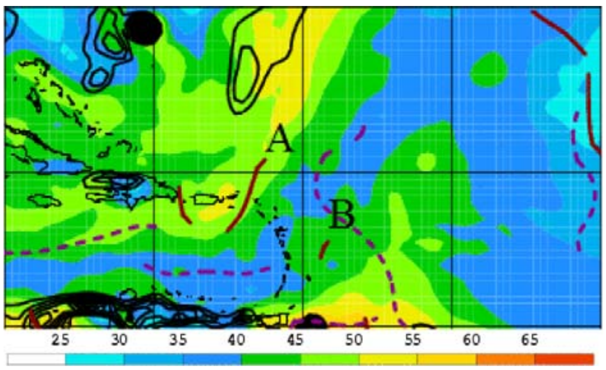

Fig. 5. Same as figure 3, except for 12Z June 24.

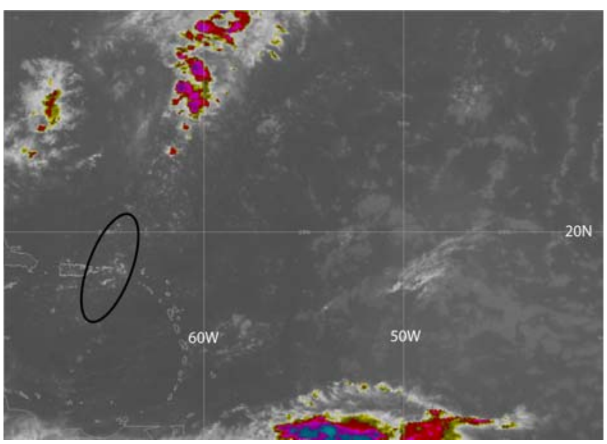

Fig. 6. IR satellite at 11Z June 24. Circled cloud mass is associated with the trough at 700 hPa.

A Hovmoller diagram was made using GFS analysis data to evaluate curvature vorticity along latitude bands at 700 hPa. The Hovmoller diagrams indicate that the vorticity maximum associated with the trough moved across Puerto Rico on June 24, while the second vorticity maximum, associated with the AEW, moved across Puerto Rico on June 25 (Figs. 7, 8). Closer examination of the latitude bands of 10-20N and 15-25N reveal that the vorticity associated with the AEW remained south of Puerto Rico until it approached the island. These bands were chosen since they both include the latitude of Puerto Rico (18N, 66W), while one includes the deep tropics, and the other the subtropics. If the trough and AEW were both present in the latitude bands, two positive vorticity maxima will be evident. On the latitude band of 10-20 N, two vorticity centers are discernible (Fig. 7), while only one vorticity center is evident on the latitude band of 15-25 N (Fig. 8). This implies that the vorticity associated with the AEW did not extend much past 15N until it approached Puerto Rico.

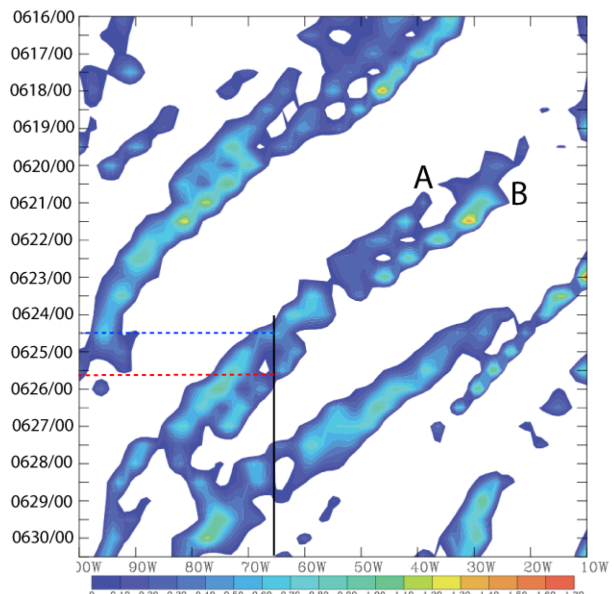

Fig. 7. GFS 700 hPa curvature vorticity for the latitude band 10–20N. "A" is the vorticity maximum associated with the trough. "B" is the vorticity maximum associated with the AEW. Solid vertical line is the longitude of Puerto Rico. Blue dashed line is the passage of the vorticity maximum associated with the trough. Red dashed line is the passage of the vorticity maximum associated with the AEW.

To support the GFS analysis in depicting two closely spaced synoptic features, upper air soundings from San Juan were examined (Fig. 9). The 700 hPa winds at 00Z on June 24 were from the northeast, then veered to the east northeast at 12Z in response to the trough. By 00Z on June 25, the winds backed to the northeast ahead of the AEW, then veered to the southeast with its passage by 00Z on June 26. So, the upper air data indicate that there were in fact two features, separated by roughly 24 hours, which moved across Puerto Rico.

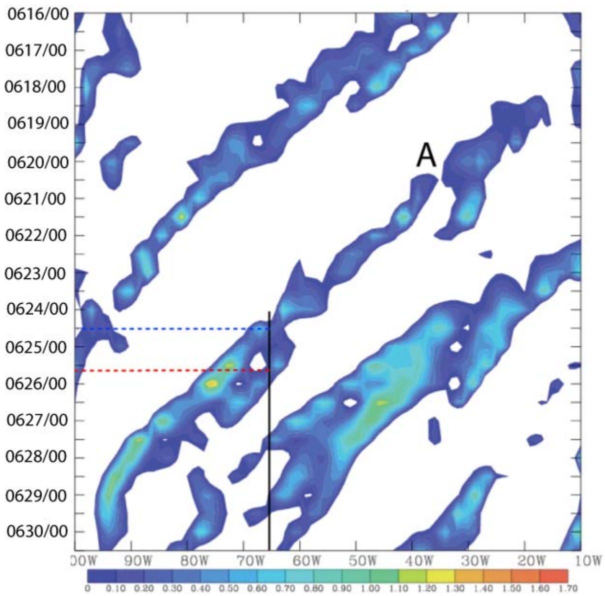

Fig. 8. Same as for figure 6, except for the latitude band 15–25N. “A” is the vorticity maximum associated with the trough.

In response to these features, broad surface cyclonic flow moved across Puerto Rico. Northeasterly surface winds ahead of this feature prevailed on June 24 at 00Z, and veered to the east northeast by 12Z, and eventually the east southeast by June 25 at 00Z. The near surface winds interacting with the islands topography affected the rainfall distribution across Puerto Rico. The precipitation distribution (Fig. 10) implies that east to east southeast surface winds prevailed during the peak heating and diurnal convection on June 24. The San Juan vicinity received over 6 inches of rain on this day. San Juan is a favored location for rainfall under east southeast wind flow as convective cloud lines (streamers) form downstream of El Yunque as a result of air splitting then converging around the 1075 m tall mountain. When the wind is from the east southeast, the streamers will be oriented where they will affect the San Juan area. Another area which received over 6 inches of rainfall was the western interior, where rainfall would also be favored with this wind direction. The third area of peak rainfall, where over 6 inches of rain fell, was just upstream of Cerro de Punta, which is the highest mountain peak in Puerto Rico (1338 m). While this is not typically a favored location for precipitation maxima with this wind direction, it is possible that this mountain peak provided a focus for orographic enhancement on this day.

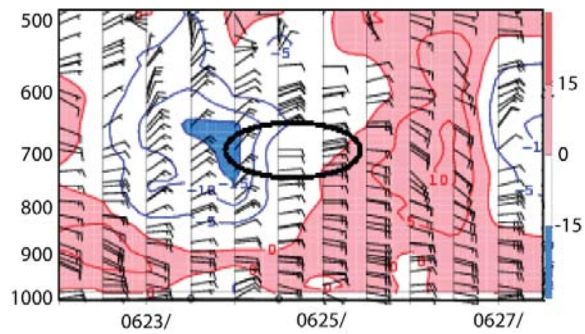

Fig. 9. Upper air winds for San Juan, Puerto Rico. Shading is the v-component of the wind. Circled area is 700 hPa winds during the passage of the trough and AEW. (image courtesy of Tropical Prediction Center).

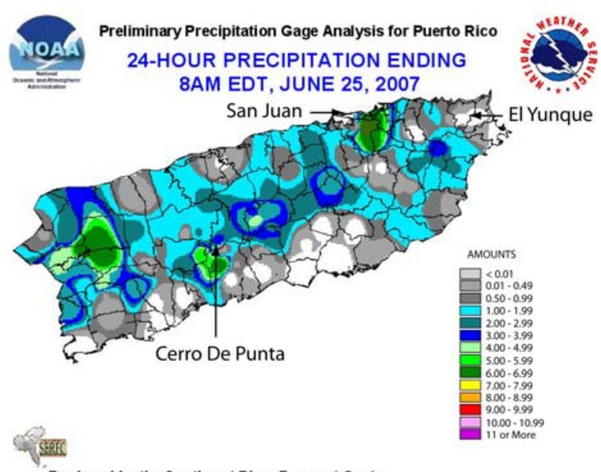

Fig. 10. Precipitation over Puerto Rico from the USGS rain gauges for the 24 hour period ending 8 AM June 25. The locations of San Juan, El Yunque, and Cerro De Punta are noted.

4. CONCLUSION

The new forecast diagnostics were used operationally to determine a complex weather pattern where a trough appears to have initiated in the midlatitudes, and tracked around the periphery of the subtropical high into the tropics ahead of an AEW. The trough helped produce rainfall totals above 6 inches over parts of the island of Puerto Rico. Convection with the trough was limited during much of the track across the Atlantic, as it was situated in a dry environment. On satellite imagery, a subtle region of moisture was evident, and with the help of the diagnostics was able to be coherently tracked. As a result, the trough, and a complex synoptic situation were forecast well at the San Juan forecast office, which was evident in the area forecast discussion (AFD) (Fig. 11).

Tropical wave tracking is often highly subjective and varies between forecasters. This can lead to significant errors in tracking waves when a complex situation arises, or when the feature is very subtle on satellite. The diagnostics have been used at the San Juan forecast office the past few convective seasons, and provide a way to objectively track tropical waves. They have proven useful in determining tropical wave origins and tracks, and this complex situation is just one example where the diagnostics were used to augment more traditional forecasting tools and methods. The use of these diagnostic tools can be recommended to improve the quality of meteorological analyses and forecasts of tropical waves. These tools are available via public domain:

http://www.atmos.albany.edu/student/gareth/plots.html .

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE SAN JUAN PR
629 AM AST SUN JUN 24 2007

.DISCUSSION...A WEAK LOW LEVEL TROUGH WILL MOVE WEST ACROSS THE LOCAL AREA TODAY...BRINGING AN INCREASE IN CLOUDINESS...SHOWERS AND A COUPLE OF THUNDERSTORMS TO THE LOCAL ISLANDS. THIS FEATURE WILL LIFT AWAY FROM THE LOCAL AREA TONIGHT...WITH A BRIEF DRY SLOT AHEAD OF AN APPROACHING TROPICAL WAVE...ENCOMPASSING THE LOCAL ISLANDS EARLY TONIGHT...BEFORE THIS TROPICAL WAVE AND ITS ASSOCIATED MOISTURE SPREAD ACROSS THE LOCAL ISLANDS BEGINNING LATE TONIGHT AND THEN CONTINUING THROUGH LATE MONDAY AFTERNOON/EARLY MONDAY NIGHT.

Fig. 11. Portion of the AFD, written by lead forecaster Brian Seeley, discussing the trough passage followed by the AEW passage.

5. REFERENCES

Berry, G. J., C. Thorncroft, and T. Hewson, 2007: African Easterly Waves during 2004 - analysis using objective techniques *Mon. Wea. Rev.,* **135,**1251-1267.

Riehl, H. 1954: Tropical Meteorology, McGraw Hill, 392pp.