18C.2

EXTREME RAINFALL AND INTENSIFICATION MECHANISMS IN HURRICANE FIONA (2022)

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1. INTRODUCTION

In a warming and changing future climate, tropical cyclone (TC) hazards, such as extreme precipitation, will be enhanced due to the expected increase of favorable conditions (Keellings and Hernández Ayala 2019; Klotzbach et al. 2022). Record breaking extreme precipitation and frequency of these events are expected to threaten vulnerable communities, increasing the risk of landslides, flooding, and fatalities. Past TC rainfall studies have been focused on terrain-induced and vertical wind shear enhanced events (Franklin et al. 2005; Cheung et al. 2018; Bohem and Bell 2021). Our case study will encompass an overview of the lifting mechanisms affecting Hurricane Fiona's intensification and precipitation enhancement post landfall as it interacted with moderate vertical wind shear (VWS).

Hurricane Fiona was a long-lived and powerful TC in 2022 that caused substantial damage in the Caribbean and Nova Scotia. Hurricane Fiona approached Puerto Rico during the morning of September 18th and caused devastating flooding over the island as an intensifying category 1 hurricane. The event ranks fourth in tropical cyclone (TC) rainfall total records over a 24-hour period in Puerto Rico (Ramos Scharrón et al. 2023) with rainfall totals in the southern areas surpassing 823 mm. We hypothesize that the large rainfall totals can be attributed to a persistent rainband that was visible in both radar and satellite data. Similar rainbands have been the focus of studies in other TC prone regions such as Taiwan and Japan. These studies have found that TC tail rainbands are enhanced by the monsoonal flow effects that can alter track, wind strength, and residence time over islands, in addition to orographic lifting (Wu et al 2011; Xu et al. 2012).

We hypothesize that enhanced potential vorticity displaced from the inner core by vertical wind shear was a primary contributor of the heavy rainfall production, resulting in both isentropic uplift and boundary layer convergence in the down shear tail rainband. Additional enhancements of the rainfall occurred over Puerto Rico's high terrain by orographic effects (Hossanah et al. 2020).

2. METHODOLOGY

To analyze the rainfall mechanisms, we use the Hurricane Analysis and Forecast System (HAFS-B) model in concert with observations from the Puerto Rico NEXRAD radar data and aircraft data collected as part of the joint Office of Naval Research Tropical Cyclone Rapid Intensification (TCRI) Departmental Research Initiative and the NOAA Advancing the Prediction of Hurricanes Experiment (APHEX).

3. RESULTS

A rainfall accumulation verification of the HAFS-B forecast is first conducted, indicating that the rainfall rates over Puerto Rico were reasonably well-simulated but were displaced over the ocean due in part to track differences from the real storm. Figure 1 shows Hurricane Fiona's NEXRAD's TJUA 48 hr rainfall accumulation used for verification. The results shown on Figure 2 accurately represent the simulated significant precipitation the southern part of the island experienced. Preliminary findings support the hypothesis that heavy rainfall is associated with interactions between enhanced potential vorticity and moist southerly flow in the down shear rainbands. Strong vertical motions and rainfall continued even after the eyewall was located well to the northwest of the island 24 hours after landfall in Puerto Rico. Figure 3 shows a decrease in pressure along the 305 K isentropic surface from south to north associated with upward isentropic vertical motions, consistent with our hypothesis. The decreasing isentropic pressure is associated with a meridional temperature gradient, believe to be due in part to evaporative cooling associated with the rainfall to the north of Puerto Rico and off the southern coast. A secondary maximum in upward motion is also likely associated with orographic lifting. The physical mechanisms producing the extreme rainfall and the relationship to the concurrent intensification of Fiona in the presence of moderate VWS will be discussed at the conference.

4. CONCLUSIONS

This case study acknowledges unanswered questions and fills literature gaps on extreme precipitation from TC tail rainbands. A structure analysis prior and post landfall is possible using both modeling and observational data. We found that intensification over waters is a result of isentropic lifting while orographic lifting enhances precipitation over land. In addition, potential vorticity is found where we have strong vertical motions, resulting in rainfall intensification. Simulations in this study aid in understanding the dynamical mechanisms of the tail rainband while observational data confirm these findings.

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mendations expressed in this material are those of the authors(s) and do not necessarily reflect the views of the National Science Foundation.

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6. FIGURES

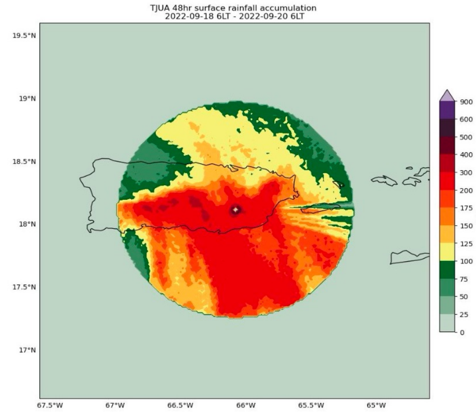

FIG. 1. NEXRAD Level 2 TJUA 48 hr rainfall accumulation plot from 09/18/22 at 6:00 AM local time to 09/20/22 6:00 AM local time.

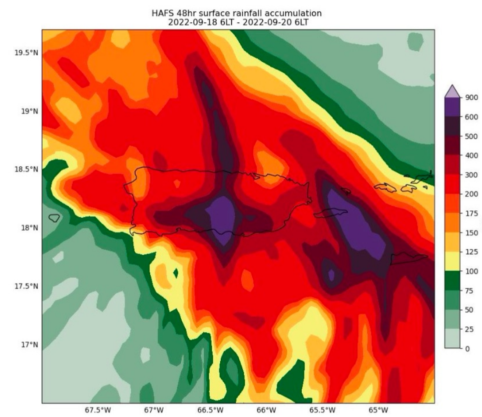

FIG. 2. HAFS-B (parent domain) 48 hr rainfall accumulation plot from 09/18/22 at 6:00 AM local time to 09/20/22 6:00 AM local time.

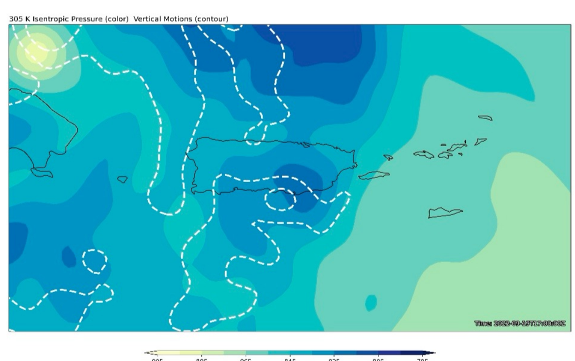

FIG. 3. Isentropic analysis at a 305K potential temperature level. Colored contours indicate pressure at the same isentropic level (305K). More intense colors indicate a lower isentropic pressure. Dashed line closed contours indicate vertical motions less than -1 Pa/s (upwards).