V2.4 HURRICANE IAN INTENSIFICATION ON THE WEST FLORIDA SHELF

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1. Introduction

Rapid intensification (RI) in tropical cyclones is difficult for forecasters, with most instances of RI resulting in the model either getting the intensity wrong and the track right or the intensity right and the track wrong (Bhatia et al., 2022). Papers have attempted to describe conditions that favor RI, but many cyclones still undergo RI despite being in conditions considered “atypical”, or unfavorable.
An atypical case is Hurricane Ian (2022), which underwent RI while already a Category 3 (Saffir-Simpson scale) storm. The purpose of this study is to explain the RI in this storm.

2. Ian’s Evolution

Hurricane Ian entered the warm shallow waters of the West Florida Shelf after already undergoing one RI cycle prior to making landfall over Cuba. In an environment with high environmental shear and low moisture, Ian still experienced a second RI cycle. The winds increased by ~20 m s^{-1} while the central pressure decreased by ~10 mb. During this period, the storm experienced a decrease in atmospheric moisture.

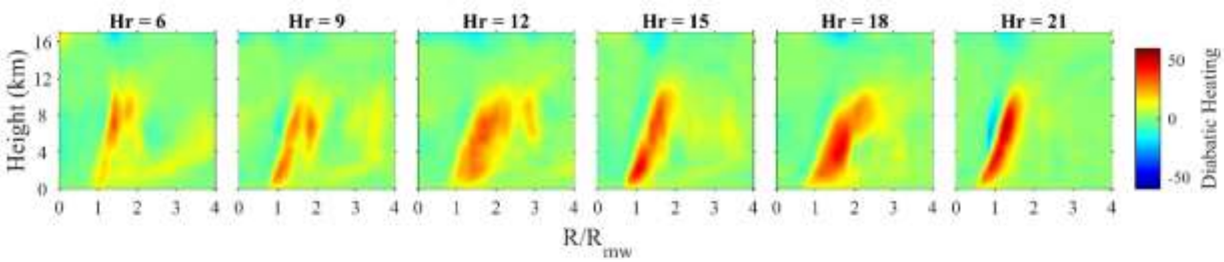

Figure 1: Diabatic Heating in Hurricane Ian

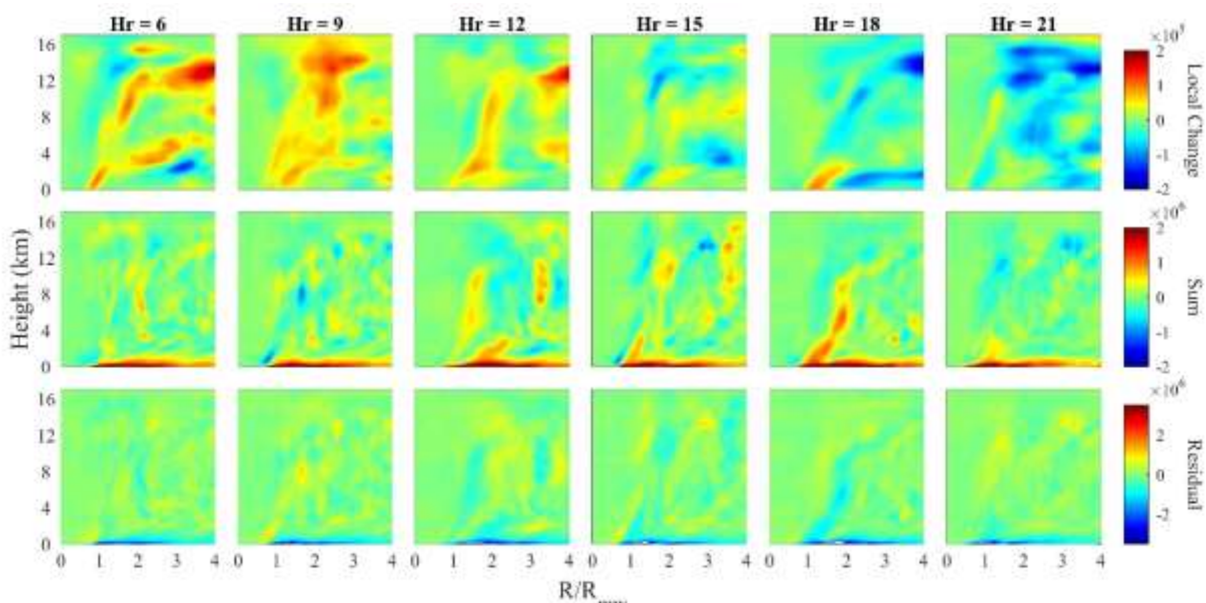

Figure 2: Local change, sum of the eddy and advection terms, and residuals of the absolute angular momentum budget for Hurricane Ian

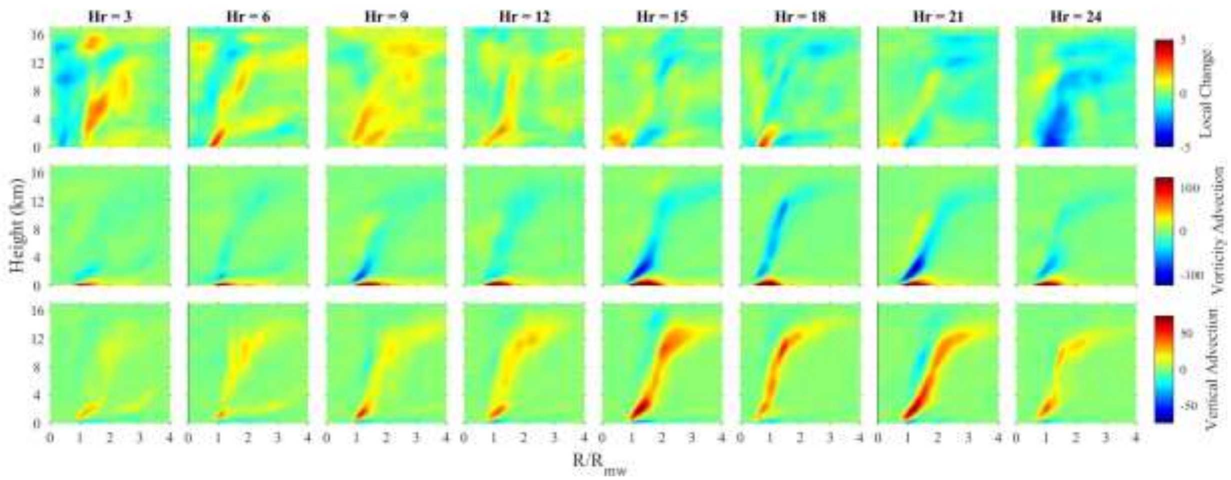

Figure 3: Local change, vorticity advection, and vertical advection terms for the gradient wind balance

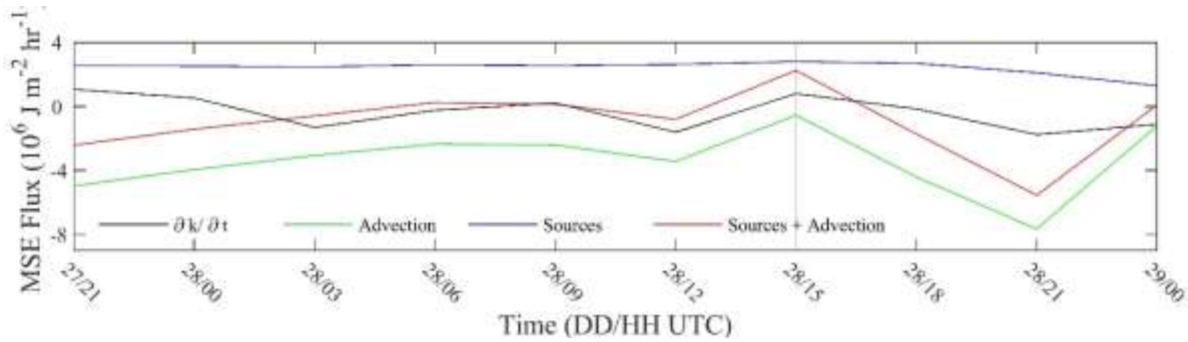

Figure 4: Local change, advection, source, and total balance terms of the MSE budget

3. Methods

The Hurricane Weather Research and Forecast (HWRF) simulation of Ian was chosen for this analysis due to hits higher resolution and accurate representation of Ian's intensity despite the track being less accurate than the North American Mesoscale Model. This model is also coupled to the Princeton Ocean Model for air-sea interactions.

The quantities analyzed here are a mixture of both classic and more recent methods. The absolute angular momentum (AAM, Zhang and Rogers, 2019), gradient wind balance (GWB), diabatic heating, and moist static energy (MSE) are all considered. The GWB has been shown in recent studies to be more accurate in the planetary boundary layer than the AAM (e.g. Smith et al., 2017). The MSE has been recently used in tropical cyclones by Chen et al. (2019). Combined with environmental parameters, these quantities represent the processes that can explain RI in most tropical cyclones.

4. Results

Analysis of the diabatic heating reveals a large and positive heating (Fig.1) in the eyewall of the storm. This is accompanied by an inward advection of AAM (Fig. 2), a signature of the classic spinup mechanism of cyclones. A further comparison using the GWB (Fig. 3) confirms these finds that the momentum is indeed advected, primarily in the planetary boundary layer. A classic spinup explains what physical happened, but what ingredients allowed this to happen?

An analysis of the MSE budget (Fig. 4) reveals that the storm maintained its MSE content throughout the RI period. Advection is taking heat away from the storm, but this is balanced by the source term, which is dominated by latent heating from the surface in particular.

A comparison of the latent heat flux from the ocean alongside the tropical cyclone heat potential (TCHP) reveals the significance of the latent heat term (Fig. 5). The TCHP is small due to the shallow water on the West Florida Shelf (e.g. Potter et al.,

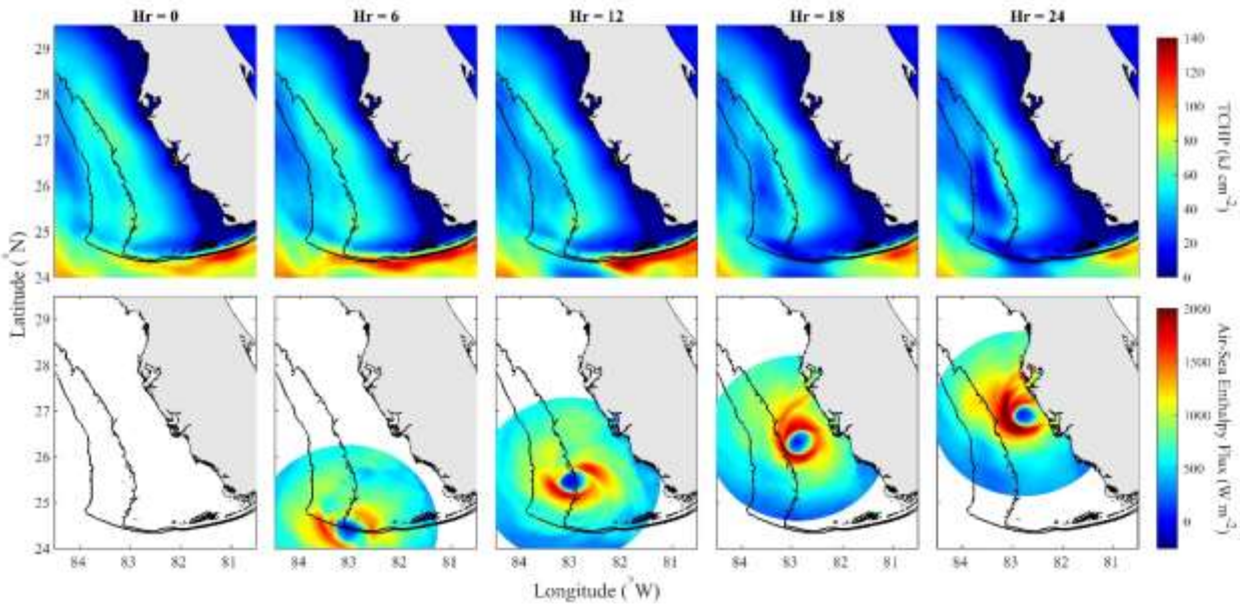

Figure 2: Tropical cyclone heat potential (top) and air-sea enthalpy flux (bottom)

2019), but the latent heat term is almost 2000 W m^{-2} in the eyewall region.

5. Discussion

The RI of Ian took place on the shallow West Florida Shelf despite an unfavorable environment characterized by high shear and decreasing moisture. Analysis of the diabatic heating and both the absolute angular momentum and gradient wind balance reveals that Ian intensified via the classic spin-up mechanism (e.g. Ooyama, 1982). An analysis of the MSE budget shows that the latent heating was large enough to balance the heat lost due to outflow at the top of the storm. A closer look at the latent heating from the surface shows that this quantity was large, especially in the left half of the storm, and this is why it was able to intensify to a Category 5 storm before making landfall in southwest Florida.

References

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