1.1 - Enhancing Real Hurricane Forecasts by Rotation-based Adjustments of Vertical Diffusion Parameterizations in the Planetary Boundary Layer

Monday, January 13, 2025

8:30 AM - 8:45 AM

221 (New Orleans Ernest N. Morial Convention Center)

Abstract

Forecasting hurricanes is critically important for mitigating their devastating impacts caused by wind damage, storm surges, and flooding. Despite remarkable advancements in numerical weather prediction (NWP) models, such as the Weather Research and Forecasting (WRF) model, accurate hurricane forecasts remain challenging likely due to inaccurate physical parameterizations of complex dynamics of these storms. One major issue of these models is related to their Planetary Boundary Layer (PBL) schemes, which are not typically designed for hurricane flows with strong rotation. Previous studies have shown that the existing PBL schemes of hurricane simulations are often overly dissipative, leading to underestimations of the storm intensity (Matak and Momen 2023; Romdhani et al. 2022). Our recent research (Khondaker and Momen 2024) demonstrated that reducing diffusion in these models improved the hurricane's intensity and size forecasts by more than ~30% on average in four considered major hurricanes. This reduced diffusion is due to the strong rotational nature of hurricanes, which suppresses turbulence and produces smaller eddies compared to regular PBLs (Momen et al. 2021). While prior studies showed that decreasing the vertical diffusion significantly improves major hurricane intensity forecasts, they mostly relied on simplified and often invariable adjustments of vertical diffusion such as multiplying it by a constant coefficient. The objective of this study is to address this issue by introducing a rotation-based variable adjustment of diffusion to account for the strong rotational nature of tropical cyclone (TC) dynamics.

To this end, we will present multiple real strong and weak hurricane simulations using the Advanced Research WRF (ARW) model in the US. We modified the vertical eddy diffusivity based on the relative vorticity to accommodate the rotational dynamics of TCs in PBL schemes. While the default model significantly underpredicts hurricane intensity, our new adjustments outperform the default schemes for these strong hurricanes (see, e.g., attached fig. a), with notable improvements in track and minimum sea level pressure accuracy. This modification also remarkably increases the inflow in hurricanes compared to default models and leads to the intensification of the TC vortex (see, e.g., attached fig.

b,c). Our newly adjusted model matched more closely with dropsonde, and satellite observations compared to the default WRF's PBL schemes. These modifications to the PBL schemes make them more physics-based adjustments compared to previous treatments, offering valuable insights for improving hurricane forecasts in NWP models.

References

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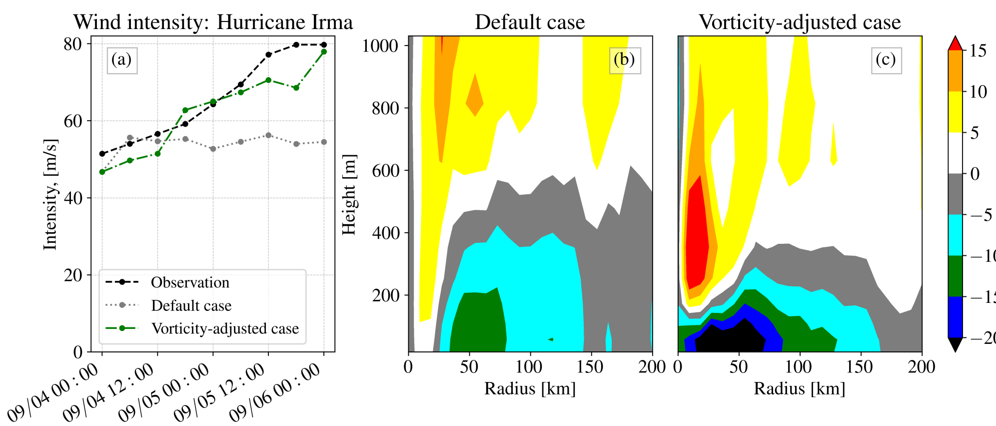

Fig. (a) Wind intensity of Hurricane Irma, (b-c) Azimuthally averaged radial wind profile for Hurricane Irma at 0000 UTC 06 September 2017 for (b) Default and (c) Vorticity-adjusted case

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