

12.3 - Evaluation of Eddy Diffusion Adjustments on Improving Hurricane Simulations in Weather Forecasting Models



Wednesday, January 31, 2024



4:45 PM - 5:00 PM



342 (The Baltimore Convention Center)

Abstract

Rotation in hurricane flows can highly affect the dynamics and structure of hurricane boundary layers (HBLs). Recent studies (Momen et al. 2021) showed that there is a significant distinction between turbulence characteristics in hurricane and regular atmospheric boundary layers due to the strong rotational effects of hurricane flows. Despite these unique features of HBLs, the current planetary boundary layer (PBL) and turbulence schemes in numerical weather prediction (NWP) models are neither specifically designed nor comprehensively tested for major hurricane flows. In this talk, we will address this knowledge gap by characterizing the role of horizontal and vertical eddy diffusion under different PBL schemes in simulated hurricane intensity, size, and track.

To this end, the results of multiple simulated hurricane cases will be presented using the Weather Research and Forecasting (WRF) model. The impacts of changing the grid resolution, horizontal turbulence, PBL scheme, vertical eddy diffusivity, and PBL height on hurricane dynamics and accuracy will be characterized. The results indicate that the current turbulence and PBL schemes in WRF are overly diffusive for simulating major hurricanes (Romdhani et al. 2022; Li et al. 2023) primarily since they do not account for turbulence suppression effects in rotating hurricane flows.

We will also show new suites of simulations in which the default horizontal and vertical diffusion in WRF are modulated to determine the impacts of eddy diffusion changes on hurricane dynamics. The results indicate that reducing the default vertical diffusion depth and magnitude led to ~38% and ~24% improvements, on average, in hurricane intensity forecasts compared to the default models in the considered cases (Matak and Momen 2023). Moreover, by decreasing the default horizontal mixing length, we managed to decrease the intensity errors on average between ~8-23% in the WRF's default models for both low and high resolutions. Figure A displays an example of the simulations in which our new adjustment of the vertical diffusion (reduced diffusion, blue line) agrees better with the observed data (black line) compared to the default WRF results (gray line). The figure also depicts wind speed contours that how this change in vertical diffusion can

remarkably influence the structure, size, and intensity of hurricane simulations. The results of this study provide notable insights into the role of turbulent fluxes in simulated hurricanes that can be useful to advance the turbulence and PBL parameterizations of NWP models for accurate tropical cyclone forecasts.

References:

Li M, Zhang JA, Matak L, Momen M (2023) The impacts of adjusting momentum roughness length on strong and weak hurricanes forecasts: a comprehensive analysis of weather simulations and observations. *Mon Weather Rev*. <https://doi.org/10.1175/MWR-D-22-0191.1>

Matak L, Momen M (2023) The role of vertical diffusion parameterizations in the dynamics and accuracy of simulated intensifying hurricanes. *Boundary Layer Meteorology*. <https://doi.org/10.1007/s10546-023-00818-w>

Momen M, Parlange MB, Giometto MG (2021) Scrambling and reorientation of classical boundary layer turbulence in hurricane winds. *Geophys Res Lett* 48: <https://doi.org/10.1029/2020GL091695>

Romdhani O, Zhang JA, Momen M (2022) Characterizing the impacts of turbulence closures on real hurricane forecasts: A comprehensive joint assessment of grid resolution, horizontal turbulence models, and horizontal mixing length. *J Adv Model Earth Syst*. <https://doi.org/10.1029/2021MS002796>

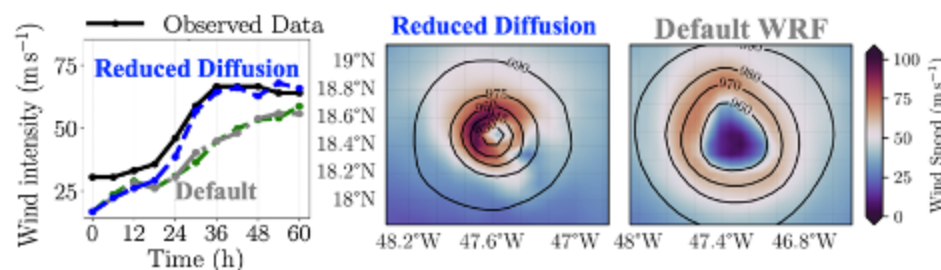


Fig. A. Hurricane Igor simulation using WRF-ARW. The new adjusted diffusion scheme (blue) better captures the best-observed data (black line) compared to the default (gray) WRF simulation. The figure is adopted from Matak & Momen (2023).

Co-Authors



Mostafa Momen (Presenter)

Univ. of Houston
Houston, TX
USA



Leo Matak

Univ. of Houston
Houston, TX
USA