
The Role of Turbulence and Roughness Length Parameterizations in Improving Major Hurricane Simulations in Weather Forecasting Models

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Recent studies have shown that climate change and global warming considerably increase the risks of hurricane winds, floods, and storm surges in coastal communities. Turbulent processes in Hurricane Boundary Layers (HBLs) play a major role in hurricane dynamics and intensification. Most of the existing turbulence parameterizations in the current numerical weather prediction (NWP) models rely on the Planetary Boundary Layer (PBL) schemes. Previous studies (Zhang 2010; Momen et al. 2021) showed that there is a significant distinction between turbulence characteristics in HBLs and regular atmospheric boundary layers (ABLs) due to the strong rotational effects of hurricane flows. Nevertheless, such differences are not considered in the current schemes of NWPs, and they are primarily designed and tested for regular ABLs.

In this talk, we aim to bridge this knowledge gap by conducting new hurricane simulations using Weather Research and Forecasting (WRF) model as well as large-eddy simulations. We investigate the role of the PBL parameterizations and momentum roughness length in multiple hurricanes by probing the parameter space of the problem. Our simulations have shown that the most widely used WRF PBL schemes do not capture the hurricane intensification properly and underestimate their intensity.

We will present that decreasing the roughness length close to the values of observational estimates and theoretical hurricane intensity models in high wind regimes ($\gtrsim 45 \text{ m s}^{-1}$) led to significant improvements in the intensity forecasts of strong hurricanes. Furthermore, by decreasing the existing vertical diffusion values, on average more than 20% improvements in hurricane intensity forecasts were obtained compared to the default runs. Our results provide new insights into the role of turbulence parameterizations in hurricane dynamics and can be employed to improve the accuracy of real hurricane forecasts. The implications of these results and improvements for coastal resiliency and fluid-structure interactions will also be discussed.