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Large-eddy simulation of instabilities in and above a hurricane boundary layer

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A large-eddy simulation (LES) model is used to explore what instabilities occur and what structures are induced in a hurricane boundary layer (HBL) 100 and 40 km away from the center of the hurricane. The LES results are examined through turbulent statistics and proper orthogonal decomposition (POD) analysis, which is also called empirical orthogonal function analysis. The POD analysis and budgets of turbulent kinetic energy (TKE) demonstrate that an inflection-point instability occurs and horizontal roll vortices with wavelengths of 1.4-3.0 km are induced in the HBL. Also the latter and horizontal distributions of velocity fluctuations show the presence of streaks at intervals of several hundred meters near the ground surface, which are more likely related to small-scale damage often observed after hurricane landfalls. Moreover, in the case of the distance of 40 km from the hurricane center, anticyclonic vortices emerge above the HBL and continue to develop. The horizontal distributions of velocity fluctuations and budgets of TKE suggest the occurrence of a centrifugal instability, although it needs to be confirmed through observations whether such anticyclonic vortices are substantial.

Keywords: large-eddy simulation, horizontal roll vortices, streaks, inflection-point instability, centrifugal instability