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A New Approach to the Energetics of Hurricane Intensification

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Forecasting hurricane intensity has remained a challenging task despite the improvements in observations and numerical models over the past few decades. One way to explore vortex intensification is to simplify the problem by making certain assumptions and use an analytic approach. One notable example is Kerry Emanuel's Maximum Potential Intensity (MPI) theory which predicts a theoretical upper bound on the vortex's intensity by assuming the maximum wind speed is set by the energy available from the Carnot Cycle. Meanwhile, the use of high resolution numerical models to study hurricanes has become increasingly popular in the last decade. As model grid spacing increases towards 1 km, the vortex is simulated more accurately and in some cases the modelled intensity may exceed the theoretical maximum predicted by the MPI theory. Such discrepancy suggests there are limitations in current intensification theories which could be attributed to the lack of understanding of hurricane dynamics.

Here we study hurricane intensification dynamics using the Available Potential Energy (APE) framework, which is more rigorous than the Carnot heat engine framework adopted in the MPI theory. Diagnostics of APE generation and dissipation are developed and applied to a modified version of the 2-D axisymmetric hurricane model developed by Emanuel and Rotunno which simulates the evolution of a pre-existing vortex. The governing equations of this model are essentially the same as those used in developing the MPI theory. First we define a relatively simple expression for the local APE budget in a moist atmosphere. By considering effects such as external heating and phase change in the 2-D model, we can determine when diabatic processes act as sources or sinks of APE in the vortex. Eventually we can compute the APE budget by considering the conversion of APE into kinetic energy and its dissipation in the 2-D model. The computation of APE also requires knowledge of a hypothetical 'reference' state and its computation using the parcel sorting method can be
computationally expensive. In this study we show that the background atmospheric sounding used to initialise the 2-D model can be adopted as the reference state when calculating the APE and eliminating the need for parcel sorting. This work will provide new insight into the dynamics of hurricane intensification.