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The role of environmental inertial stability in tropical cyclone intensification

E. Rappin, M. Morgan and G. Tripoli

Department of Atmospheric and Oceanic Sciences

University of Wisconsin – Madison

Madison, Wisconsin (edrappin@aos.wisc.edu)

Rapid intensity fluctuations of tropical cyclones (TC's) remain one of the great mysteries of tropical meteorology. TC's in nature often fail to obtain the theoretical maximum potential intensity (MPI) while idealized simulations of TC's in ambient environments never fail to obtain MPI. One key difference between TC's in nature and an isolated TC in an idealized model simulation is the influence of an environmental flow field, suggesting that environmental flows act to inhibit growth to MPI. An understanding of synoptic scale conditions that are favorable for intensification to MPI would increase insight into the intensification change problem.

The energy supplied to the TC by the air sea interaction is used to spin up the primary circulation, spin up the eye, and expand the outflow anticyclone against the ambient environment, several of the energy sinks of the system. By minimizing the energy expenditure for one of these sinks, more energy should be available for the other sinks. This study looks at how environmental resistance to TC outflow impacts the magnitude of a TC energy sink and its impact on storm intensification. Observational and theoretical studies have found that TC's that are able to ventilate outflow in jets far from the storm core are associated with storms that obtain MPI. Such observations suggest that regions of small inertial stability in the TC environment may be important in the development of asymmetric outflow jets and a minimization of the outflow energy sink. The work presented here represents a shift from the more conventional viewpoint that energy is supplied to the TC by cyclonic eddy angular momentum transports or potential vorticity superposition. Alternatively, the outflow environment should be considered as an energy drain and that environments characterized by certain low inertial stability

distributions are most favorable for intensification to MPI.

Using the University of Wisconsin - Nonhydrostatic Modeling System two sets of experiments were performed. The first set of experiments were designed to explore the impact of a symmetric, outflow layer, environmental inertial stability distribution on tropical cyclone intensification by varying the Coriolis parameter. It was found that a low latitude simulation obtained MPI 35% quicker than a high latitude simulation. The energy drain in the outflow layer was determined to be approximately 10-15% percent of the net energy input for the high latitude simulation and roughly 1% of the net energy input for the low latitude simulation. An analogy is made between the spin-up of the eye by turbulent momentum fluxes from the eyewall and the spin-down of the ambient cyclonic environment by the TC outflow. The large kinetic energies (manifested as a strong, symmetric, anticyclonic jet) generated in the higher latitude simulations, due to the dominance of rotation over divergence implied by the relatively small Rossby radius, act to spin down the comparatively strong ambient cyclonic rotation by turbulent fluxes of momentum. Conversely, little resistance to outflow expansion occurs in the lower latitude simulation as the large Rossby radius allows for divergent motions to dominate at larger radii then the high latitude simulation.

The second set of experiments were designed to test the impact of an asymmetric distribution of outflow layer environmental inertial stability on TC intensification. A series of idealized simulations using a jet of variable strength located north of the TC center were performed to test the hypothesis. Initial intensification rates were a function of the jet strength with the strongest jet simulations showing the smallest intensification rates due to the larger shear values. After initial development, once the TC vortex was more resilient to the effects of weak shear, intensification rates were a function of the inertial (in)stability. The stronger jets, yielding the smallest inertial stabilities, produced the most rapid intensifications. The presence of the jet provides a path of least resistance for TC outflow. It is shown that a large fraction of the TC outflow is ventilated in the direction where both the radial angular momentum (PV) gradient is minimized across the outflow-environment boundary and the work done to expand outflow is minimized.