Special Seminar

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Gradient Non-Balance at the Outflow of Tropical Cyclones: Theory, Models and Observations

Hosted by Michael Bell

3 p.m. Monday, Oct. 15
ATS 101

Gradient non-balance is the lack of physical solutions to gradient wind balance for a given pressure map. This flow regime occurs around a *high* when the sum of the outwards pointing centrifugal and pressure gradient forces cannot be balanced by the inward pointing Coriolis force. In this case some of the radial pressure gradient has to act on the radial velocity. Non balance is diagnosed by the geostrophic Rossby number ($Ro_g = v_g / fr$) <-1/4 and is thus more likely for small scale highs, such as may develop above a warm core of TCs. Since, the pressures map at the top of a TC is approximately the hydrostatic sum of the near surface low and the warm core, non-balance may serve as the dynamical process by which the relative position and size of the warm core could play a role in the dynamics of the outflow.

Non balance is found at the top (15km height) of several TCs observed during the TCI and HS3 campaigns as well as in WRF simulations in a variety of setups. Dropsonde data from these observation campaigns are analyzed using a wavenumber decomposition method (Marks and Soukop, 2017) to yield a 3D map of the storm. This reveals compact high-pressure centers at TC top with $Ro_g < -10$.

In simulated storms, similar Ro_g values are found. An analysis non balance through the storm simulation shows that it is accompanied by changes in both maximum wind and radius of maximum wind. Moreover, while idealized (f-plane) storms return to balance within several days, simulations of real-world TCs retain a considerable degree of non-balance throughout the model integration. Comparing mean and maximum values of different simulated storms shows that peak non-balance correlates with either peak intensity or intensification, implying the possible importance of non-balance at upper levels for the near surface winds.

Finally, an idealized, dynamical systems view for non-balance is derived by analyzing the trajectories of Lagrangian parcels given realistic, but time independent, pressure maps. A bifurcation diagram of the possible steady states for a range of initial conditions bolsters the difference between non-balance and imbalance. While imbalance is a deviation from the steady solution as defined by the initial conditions of trajectory, non-balance is the lack of a steady solution due to the shape of the pressure field, and regardless to the details of a trajectory.