Geophysical Research Abstracts
Vol. 16, EGU2014-15852, 2014
EGU General Assembly 2014

The Structure and Dynamics of Coherent Vortices in the Eyewall Boundary Layer of Tropical Cyclones.

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The boundary layer within the eyewall of intense tropical cyclones has been shown to be both highly turbulent and to contain coherent small-scale (of order 1 km) vortices. Dropsonde observations have indicated that extreme updrafts of 10-25 m/s can occur in the lowest 2 km, sometimes as low as a few hundred meters above the sea surface. These updrafts are often collocated with or found very nearby to local extrema in horizontal wind speed, which sometimes exceed 100 m/s. A previous numerical study of Hurricane Isabel investigated updrafts that appeared to be analogous to those seen in the dropsondes, and it was shown that these updrafts were associated with coherent vortices, were confined to low-levels, and were not forced by buoyancy. A significant limitation of this previous work is that the vortices/updrafts were only marginally resolved.

Here, the CM1 model is used to simulate intense tropical cyclones in an idealized framework, with horizontal grid spacing as fine as ~30 meters. At this grid spacing, the scales of the vortices (~500-1500 m) are clearly well resolved. By examining individual features and compositing over many updrafts, we find that there is a consistent structure and relationship between vorticity, vertical velocity, and near surface windspeeds. We quantitatively show that buoyancy is not responsible for the acceleration of strong boundary layer updrafts. Instead, the updrafts are forced by dynamical pressure gradients associated with strong gradients in the velocity fields.

It is currently unknown whether dropsonde observations represent quasi-vertical profiles through the features, or if instead the sondes are horizontally advected through the features. Simulated dropsonde trajectories are used to answer this question, and to aid in the interpretation of the observed kinematic and thermodynamic profiles. In observations, these extreme updrafts are almost exclusively found in Category 4 and 5 hurricanes. We conduct simulations at varying intensity to investigate whether or not similar features exist in weaker storms. Finally, observations indicate that nearly all extreme updrafts are found in the left-of-shear semicircle. We conduct additional simulations with varying amounts of shear in order to better understand the mechanisms by which shear controls the spatial distribution of these features.