Balanced and unbalanced aspects of tropical cyclone intensification

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Abstract: We investigate the extent to which the azimuthally-averaged fields from a three-dimensional, nonhydrostatic, tropical cyclone model can be captured by axisymmetric balance theory. The secondary (overturning) circulation and balanced tendency for the primary circulation are obtained by solving a general form of the Sawyer-Eliassen equation with the diabatic heating, eddy heat fluxes and tangential momentum sources (eddy momentum fluxes, boundary-layer friction and subgrid-scale diffusion) diagnosed from the model. The occurrence of regions of weak symmetric instability at low levels and in the upper-tropospheric outflow layer requires a regularization procedure so that the Sawyer-Eliassen equation remains elliptic. The balanced calculations presented capture a major fraction of the azimuthally-averaged secondary circulation of the three-dimensional simulation except in the boundary layer, where the balanced assumption breaks down and where there is an inward agradient force. In particular, the balance theory is shown to significantly underestimate the low-level radial inflow and therefore the maximum azimuthal-mean tangential wind tendency. In the balance theory, the diabatic forcing associated with the eyewall convection accounts for a large fraction of the secondary circulation. The findings herein underscore both the utility of axisymmetric balance theory and also its limitations in describing the axisymmetric intensification physics of a tropical cyclone vortex. Copyright © 2009 Royal Meteorological Society.

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