Tropical Cyclone Intensification

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An important subject in tropical meteorology that has kept many scientists busy in the recent years is that of tropical-cyclone intensification. This talk emphasized the role of the frictional boundary layer in an axisymmetric view of the intensification process.

Balanced theory tells us that the air in the lower troposphere converges largely because of the latent heating that is associated with the deep convection in the core (Bui et al. 2009, QJRMS, 135, in press). The convective instability is sustained by enhanced moist entropy fluxes at the surface. The radial velocities are proportional to the maximum radial gradient of the heating rate. Inflow occurs below the level of maximum heating rate and outflow above this level. Except near the surface, where friction is important, converging air parcels conserve their absolute angular momentum and as they move inwards they spin faster.

The inflow is greatly enhanced in the boundary layer, a surface-based layer 500 m to 1 km, because of the action of friction. Friction reduces the tangential wind component, and therefore the centrifugal and Coriolis forces acting on an air parcel, but has little effect on the radial pressure gradient. This reduction leaves a net inward force that accelerates air parcels inwards. As these air parcels converge in the boundary layer, they do not conserve absolute angular momentum, because of the frictional torque. Nevertheless, if they converge quickly enough so that not too much angular momentum is lost, the tangential winds can still increase with decreasing radius. Indeed, the tangential wind speed can increase so much that it can become supergradient. When this happens the radial flow decelerates rapidly and the supergradient winds are carried upwards and outwards, feeding into the eyewall clouds. This means that the spin-up of the inner core is a low level process that is strongly related to the dynamics of the boundary layer. This feature is supported by numerical experiments using a three-dimensional model (Smith et al. 2009, QJRMS, 135, 1321-1335).

Thus, there are two mechanisms that lead to spin up. The first is related to convergence of absolute angular momentum above the boundary layer, which spins up the outer circulation. The second one is related to convergence of absolute angular momentum in the boundary layer, which accounts for the spin-up of the inner core.