Further progress on understanding the dynamics of tropical cyclone evolution

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Abstract

In this talk I will summarize a conceptual model for the evolution of tropical cyclones that Professor Michael Montgomery and I are continuing to develop. In particular, in will describe recent insights that we have obtained since the IWTRC meeting in November 2024. The conceptual model, referred to as the "rotating-convection paradigm" [1], is an extension of the classical paradigm for tropical cyclone intensification developed half a century ago by Vic Ooyama, Hugh Willoughby, Lloyd Shapiro, Wayne Schubert and collaborators [2] and has utility in understanding all phases of the tropical cyclone life cycle. The main ingredients are: the collective effect of a region of deep convection to produce a system-scale deep overturning circulation with inflow towards some axis of rotation in the lower troposphere and outflow in the upper troposphere; a shallow frictional boundary layer that, alone, would induce a shallow overturning circulation with inflow near the surface and outflow above the inflow layer; and wind-speed dependent surface moisture fluxes which serve to maintain deep convective instability on the system time scale.

Vortex intensification occurs under conditions where the inflow in the lower troposphere induced by deep convection is strong and persistent enough to reverse the persistent outflow induced by the boundary layer. In that case, intensification ensues as cyclonic absolute vorticity is drawn inwards above the frictional boundary layer. By Stokes' theorem, the concentration of cyclonic absolute vorticity within horizontal circuits at any radius where there is mean inflow is equivalent to an increase in the tangential velocity about that circuit. One may view the foregoing conditions approximately in terms of a metric characterizing the ability of deep convection within a given radius to ventilate air at the rate at which it is converging in the boundary layer at that radius. An added subtlety in the spin up process is the so-called boundary-layer spin-up enhancement mechanism [3] allowing the maximum tangential wind speed to develop within (sic) the frictional boundary layer.

In my talk, I will discuss a recent generalization of the rotating-convection paradigm showing how the foregoing ideas can be applied to understand the translating vortex problem in which the asymmetry in Earth-relative surface stress leads to asymmetries in inner-core deep convection.

[1} R. K. Smith and M. T. Montgomery, *Tropical cyclones: Observations and basic processes*, Elsevier, (2023), Chapter 11.
[2} Ibid, Section 8.2.
[3] Ibid., Section 6.6.