Department of Atmospheric Sciences
M.S. Defense Announcement

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The Roles of Barotropic Instability and Beta Effect in the Evolution of Tropical Cyclone Eyewall

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You are invited to a Zoom meeting.
When: March 30, 2021 at 2:00PM HST

Register in advance for this meeting:
https://hawaii.zoom.us/meeting/register/tJMtduyvrTsjHNdpNwtEY4M-OQZeJj6IzXIl

After registering, you will receive a confirmation email containing information about joining the meeting.

Abstract:

Due to the diabatic heating by convection in the eyewall, there always exists an annular region of high potential vorticity (PV) around the eye of relatively low PV in a strong tropical cyclone (TC). Such a PV ring structure is barotropically unstable and thus can encourage the exponentially growing PV waves. In this study, the barotropic instability of the nonlinear evolutions of three TC-like vortices that have their PV rings with different degrees of hollowness but have the same total PV values integrated across the whole domain are simulated on a constant-f plane first, using an unforced, inviscid shallow-water-equation model. Results show that perturbations across the hollower PV ring will experience a more rapid growth, result in higher-wavenumber vortex Rossby waves (VRWs), and is more likely to form a quasi-steady asymmetric structure in the end, which generally confirms the conclusions of Schubert et al. (1999) and verifies the generalization of their work to the weakly divergent situation. We also find that the polygonal eyewall structure can be contributed by a combination of VRWs with different amplitudes, and the wave-wave interaction can make the eyewall evolution even more complicated.

Further, the same set of PV rings has been modeled on a varying-f plane (namely, on a beta-plane). As well studied previously, a pair of counter-rotating mesoscale vortices called beta gyres would develop due to differential PV advection. The ventilation flow between the two gyres advects the parent TC vortex northwestward in the Northern Hemisphere. The superposition of such a pair of gyres onto the VRWs resulting from the barotropic instability makes the eyewall structure more asymmetric. Particularly, the southeasterly ventilation flow related to the beta gyres combined with the asymmetric winds associated with VRWs can lead to strong local winds that can exceed the basic-flow by more than 20% in the northeastern quadrant of the TC vortex. In addition to the beta gyres, the beta effect can also induce eddy motions in the inner core region. It is shown that the beta effect can lead to the generation of irregularly occurring WN-1 disturbances. Although the physical cause for such disturbances remains to be figured out, its influence on the interaction of mesovortices is obvious. By reducing the stability of quasi-steady asymmetry in hollow PV-ring vortex, the beta effect can result in an earlier merging and axisymmetrization process among mesovortices and thus the strengthening of the TC-like vortex.