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On the Dynamics of Hurricane Secondary Eyewall Formation

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Despite the fact that asymmetries in hurricanes, such as spiral rainbands, polygonal eyewalls and mesovortices, have long been observed in radar imagery, many aspects of their dynamics still remain unsolved, particularly in the formation of the secondary eyewall. The underlying associated dynamical processes need to be better understood to advance the science of hurricane intensity forecasting. To fill this gap, a simple 2D barotropic "dry" model and the high-resolution PSU-NCAR non-hydrostatic mesoscale model (MM5) are used to study hurricane asymmetries. The Empirical Mormal Modes (ENM) and the newly developed Space-Time Empirical Normal Modes (ST-ENM) techniques, together with the Eliassen-Palm (EP) flux calculations, are used to isolate wave modes from the model datasets to investigate their impact on the changes in the structure and intensity of the simulated hurricanes.

From the ENM diagnostics of the 2D simulations, it is shown that when asymmetric disturbances are placed outside a strong vortex ring with a large vorticity skirt they relax to form concentric rings of enhanced vorticity that contain a secondary wind maximum.

The role of internal dynamics on Concentric Eyewall Genesis (CEG) is further evaluated using the full physics MM5 simulation. The leading modes of the ST-ENM diagnostics exhibit mainly characteristics of vortex Rossby waves (VRWs) and their contribution to the EP flux divergence induced two regions of maximum tangential wind acceleration; one inside the primary eyewall which accounts for eyewall contraction and the other outside the primary eyewall which explains the development of the secondary eyewall. A signal of maximum eddy angular momentum propagating outwards to the critical radius of the mode suggests a redistribution of angular momentum and potential vorticity re-arrangement around that area.

The fact that the critical radius for some of the leading modes is close to the location where the secondary eyewall eventually develops, for the "dry" and the full-physics experiments, suggests that a wave-mean flow interaction mechanism may be suitable to explain important dynamical aspects of the CEG.

The implication of these results on the ability of actual GCM and NWP forecasting systems to represent adequately hurricane intensity is briefly discussed.