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A possible three-dimensional mechanism for oscillating wobbles in tropical cyclone-like vortices with concentric eyewalls

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It is known that concentric eyewalls can influence tropical cyclone (TC) intensity. However, they can also influence their tracks. Observations indicate that TCs with concentric eyewalls are often accompanied by wobbling of the inner eyewall, a motion which gives rise to cycloidal tracks. Currently, there is no general consensus of what might constitute the dominant triggering mechanism.

In this paper, we revisit the fundamentals. The control case constitutes of a TC with symmetric concentric eyewalls embedded in a quiescent environment. Two sets of experiments are conducted, using a two-dimensional nonlinear model and a three-dimensional nonlinear model. It is found that when the system is two-dimensional no wobbling of the inner eyewall is triggered. On the other hand, when the third dimension is introduced an amplifying wobble is evident. This result contradicts the previous suggestion that wobbles occur only in asymmetric concentric eyewalls. It also contradicts the suggestion that environmental wind shear can be the main trigger.

Examination of the dynamics along with complemental linear eigenmode analysis revealed the triggering mechanism to be the excitation of a three-dimensional exponentially growing azimuthal wavenumber-1 instability. This instability is induced by the coupling and growth of two baroclinic vortex Rossby waves across the moat region. Additional sensitivity analysis where vortex shape parameters, perturbation vertical lengthscale, and Rossby number are modified revealed that this instability can be systematically the most excited. The growth rates are shown to peak for perturbations characterized by realistic vertical lenghtscales suggesting that this mechanism can be potentially relevant to actual TCs.