
A laboratory dry model of cyclone eye formation

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Abstract

One of the most recognizable features of tropical cyclones is the eye, a central region characterized by subsiding flow, the absence of clouds, and reduced azimuthal velocity relative to the surrounding vortex. Despite its clear visual signature, the dynamical mechanisms responsible for eye formation remain debated. Atmospheric dynamics indeed involve many coupled physical processes - stratification, rotation, moist convection, latent heat release, multiphase effects, turbulence, ... - making it difficult to disentangle their respective roles. Motivated by the laminar, axisymmetric numerical study of Oruba et al. (1), we investigate cyclone eye formation using a minimal-ingredient approach that deliberately excludes humidity effects. The objective is to identify the essential dynamical conditions required for eye formation before introducing additional complexity. We present a laboratory experiment conducted in air, consisting of a rotating cylindrical tank heated from below at a constant heat flux and maintained at constant temperature along the sidewall. Flow diagnostics combine temperature measurements and particle image velocimetry (PIV), performed in both horizontal and vertical cross-sections. By systematically varying the control parameters - heating and rotation rate, quantified by the Rayleigh and Ekman numbers - we identify regimes with and without eye formation.

The experiments reveal a dual role of rotation: it is required to establish a Hadley-type convective circulation and enable eye formation, while excessive rotation suppresses the cyclone and leads to a predominantly geostrophic flow. We further show that the physical mechanism proposed by Oruba et al. (1) - namely, the stripping of negative azimuthal vorticity from the bottom boundary layer and its advection toward the eyewall, with the eye emerging as a passive response to eyewall formation via cross-stream diffusion - is experimentally confirmed in fully turbulent regimes.

(1) Oruba, L., Davidson, P. A., & Dormy, E. (2017). Eye formation in rotating convection. *Journal of Fluid Mechanics*, *812*, 890-904.

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