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Traditional or Reversed Funnel Shape in a Tornado-Like Vortex

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Extended Abstract

In this work we study numerically the development of traditional and reversed funnel-shaped vortices in a rotating cylinder in the presence of horizontal thermal gradients at both, bottom and top, which are heated and cooled respectively.

Field observations show the formation of traditional funnel-shaped and reversed funnel-shaped vortices in tornadogenesis. It is questionless the relevance of horizontal and vertical thermal gradients on the formation and evolution of those and other atmospheric vortices. Studies show the development of bottom-up vortices when exists a horizontal temperature gradient at the bottom [1,2], and the situation of a cold pool aloft is found in the context of cold air funnels and tornadoes [3].

In previous works, we have studied the development of dust devil-like vortices in cylindrical configurations localized heated at the bottom with and without rotation [4,5], and top-down vortices in a cylindrical setting cooled on the top [6]. Now we want to study the interaction of both thermal conditions, a cold pool of air at the top together with a hot air pocket at the bottom, and the role that they have on the type of funnel developed.

We restrict to the axisymmetric regime, and for the computations, the time-dependent governing equations have been solved by direct numerical simulation using a second-order time-splitting method which is described and tested in detail in [5]. For the spatial discretization, a pseudo-spectral method is used, with Chebyshev collocation in the radial and vertical directions, and Fourier expansion in the azimuthal coordinate.

If cooling at the top is more localized than heating at the bottom, a traditional funnel-shaped tornado like vortex with an inner downdraft is developed, for a Rayleigh number sufficiently high. On the contrary, if heating at the bottom is more localized, a reversed funnel-shaped vortex develops with an inner updraft in the central part. We also perform a force balance analysis to give a physical insight on the phenomena. The results evidence the relevance of the thermal conditions on the vortical structures developed and they may contribute to the understanding of the formation, evolution, and shape of atmospheric vortices such as tornadoes.

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