Geophysical Research Abstracts, Vol. 9, 03417, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-03417

Direct Numerical Simulation of the transition from baroclinic to centrifugal convection

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Direct numerical simulations of flow of air in a rotating baroclinic annulus is presented. Following an earlier study which delineated the transition from the basic flow to regular and chaotic behaviour, this study extends into a flow regime where the regular large-scale flow structure changes from that of a classical baroclinic wave to a flow pattern with a largely barotropic vertical structure and increasingly narrow radial jets of plumes.

It was found that the transition occurred over a very narrow range of rotation rate of the system, consistent with a criterion that the ratio of the local centrifugal acceleration to gravity, $r\Omega^2/g$, was unity within the fluid domain. A conclusion drawn is that the flow at rotation rates above the transition should be seen as the rotational equivalent of Rayleigh-B'enard convection driven by centrifugal buoyancy.

On further increase of the rotation rate, the steady convection cells developed small-scale fluctuations, which seemed to be immediately disordered. The structure of those fluctuations was reminiscent of Structural Vacillation as observed in the liquid-filled baroclinic annulus. The results from the simulations at high rotation rate are consistent with Structural Vacillation observed in the laboratory. While the large scale of the flow persists, the flow does show noticeable irregular fluctuations at small scales. The analysis presented uses spectral techniques as well as EOF analysis and the calculation of Lyapunov exponents.