Geophysical Research Abstracts, Vol. 8, 03141, 2006
SRef-ID: 1607-7962/gra/EGU06-A-03141

Direct numerical simulation of the Plumb-McEwan laboratory analogue of the QBO

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The laboratory experiment of Plumb and McEwan demonstrates the principal mechanism of periodically reversing winds observed in the stratosphere — the quasi-biennial oscillation (QBO). However,despite numerous studies, some aspects of the QBO and the connection to its laboratory analogue remain unclear. Incorporating the rapidly undulating boundaries of the laboratory experiment into the numerical algorithm, via time-dependent curvilinear coordinates, allows to reproduce the experimental setup, while minimizing numerical uncertainties. Results are presented of the first direct numerical simulation of the phenomena that lead to the zonal mean flow reversal in the laboratory analogue. We attempt to bridge the gap between theoretical understanding of laboratory-scale, internal gravity wave processes and the complexity of global-scale circulations. A detailed study is presented of the parametric and numerical sensitivities of the oscillation. Based on our results, we confirm a number of sensitivities, addressed in earlier studies with simplified models. We discuss the analogy of radiative damping in the atmosphere and the role of molecular viscosity in the zonally-varying laboratory flow, emphasizing the dominant role of wave-wave and wave mean flow interactions in the latter, and in particular the retroaction of the induced mean flow on the waves. The findings elevate the importance of the laboratory setup for its potentially fundamental similarity to the atmosphere. Implications are discussed for the theory and numerical realizability of equatorial zonal mean zonal flow oscillations. The study corroborates the dependence of global-scale motions on small-scale wave-driven fluctuations, while being independent of parametrized or approximated means of forcing and wave dissipation.