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Numerical and experimental study of inertia-gravity waves in the differentially heated rotating annulus

Costanza Rodda (1), Ion Dan Borcia (1), Steffen Hien (2), Ulrich Achatz (2), Patrice Le Gal (3), and Uwe Harlander (1)

(1) Brandenburg University of Technology (BTU) Cottbus-Senftenberg, Department of Aerodynamics and Fluid Mechanics, Cottbus, Germany (rodda@b-tu.de), (2) Institute for Atmospheric and Environmental Sciences, Goethe-University (GUF), Frankfurt am Main, Germany, (3) Aix Marseille Univ, CNRS, Centrale Marseille, IRPHE, Marseille, France

The occurrence and source mechanism of inertia-gravity waves (IGWs) are studied in the differentially heated rotating annulus via laboratory experiments (BTU) and numerical simulations (GUF). Two differentially heated rotating annulus experiments are used for this purpose at the BTU laboratories. The first is a modified version of the classical baroclinic experiment in which a juxtaposition of convective and motionless stratified layers can be created by introducing a vertical salt stratification. The thermal convective motions are suppressed in a central region at mid depth of the rotating tank, therefore baroclinic waves can only build up in thin layers located at the top and bottom, where the salt stratification is weakest. This new experimental setup, coined "barostrat instability", allows to study the exchange of momentum and energy between the layers, especially by the propagation of IGWs. Moreover, in contrast to the classical tank without salt stratification we have layers with $N/f > 1$. A ratio larger than unity implies that the IGW propagation in the experiment is expected to be qualitatively similar to the atmospheric case. Interestingly, we found local IGW packets along the jets in the surface and bottom layers where the local Rossby number is larger than 1, suggesting spontaneous imbalance as generating mechanism [1], and not boundary layer instability [2].

Theoretical considerations and numerical simulations have led to the identification of an annulus configuration, much wider and shallower, with a much larger temperature difference between the inner and outer cylinder walls, which is more atmosphere-like since it shows an N / f >1 even without the vertical salt stratification. Flow regime stability has been tested for this new differentially heated rotating annulus and compared with findings from the small tank. In view of the different geometries of the two experimental systems, their correspondence was excellent with respect to the large-scale. Moreover, direct numerical simulations were performed (GUF) for this atmosphere-like configuration of the experiment and possible regions of IGW activity were characterised by a Hilbert-transform algorithm. The simulations show a clear baroclinic wave structure exhibiting a realistic jet-front system superimposed by small-scale structures which are associated with IGWs occurring in wave packets [3]. The comparison of observations from a corresponding big tank experiment with numerical simulation shows that for both cases (as we already observed in the barostrat experiment), small scale wave packets are clearly correlated with an increased local Rossby number.

References

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