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Inertial wave beams and inertial wave modes in a rotating cylinder with time-modulated rotation rate

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Inertial gravity waves play an crucial role in atmospheres, oceans, and the fluid inside of planets and moons. In the atmosphere, the effect of rotation is neglected for small wavelength and the waves bear the character of internal gravity waves. For long waves, the hydrostatic assumption is made which in turn makes the atmosphere inelastic with respect to inertial motion. In contrast, in the Earth's interior, pure inertial waves are considered as an important fundamental part of the motion. Moreover, as the deep ocean is nearly homogeneous, there the inertial gravity waves bear the character of inertial waves. Excited at the oceans surface mainly due to weather systems the waves can propagate downward and influence the deep oceans motion. In the light of the aforesaid it is important to understand better fundamental inertial wave dynamics.

We investigate inertial wave modes by experimental and numerical methods. Inertial modes are excited in a fluid filled rotating annulus by modulating the rotation rate of the outer cylinder and the upper and lower lids. This forcing leads to inertial wave beams emitted from the corner regions of the annulus due to periodic motions in the boundary layers (Klein et al., 2013). When the forcing frequency matches with the eigenfrequency of the rotating annulus the beam pattern amplitude is increasing, the beams broaden and mode structures can be observed (Borcia et al., 2013a). The eigenmodes are compared with analytical solutions of the corresponding inviscid problem (Borcia et al, 2013b). In particular for the pressure field a good agreement can be found. However, shear layers related to the excited wave beams are present for all frequencies. This becomes obvious in particular in the experimental visualizations that are done by using Kalliroscope particles, highlighting relative motion in the fluid. Comparing the eigenfrequencies we find that relative to the analytical frequencies, the experimental and numerical ones show a small shift towards higher frequencies. This frequency shift is due to the reduction of the effective resonance volume that results from the existence of a Stokes boundary layer at the outer librating wall. Due to the symmetry of the forcing not all possible modes can be excited. It is shown that only symmetric modes with respect to the rotation axis exist. From a fundamental perspective, the study might help to understand better inertial mode excitation in librating planets and moons where inertial waves are emitted from critical points on the inner or outer spherical boundary.

Recently, Zhang et al. (2013) pointed out the resonance should not occur in symmetric librating bodies without precession. We will discuss how this assumption depends on the boundary conditions. It might turn out that even when the projection of the Euler (or Poincare) force on the modes is zero, the projection of the excited wave beams on the modes is non-zero.

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