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Libration-driven zonal flows in planetary fluid cores

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The flow in a rotating axisymmetric container, driven by time harmonic oscillations of the rotation rate called longitudinal librations, is investigated. Using theoretical analysis as well as laboratory experiments and axisymmetric numerical simulations, we investigate the steady zonal flow that systematically appears in the bulk fluid due to viscous non-linear interactions in the Ekman layer. Our study follows the first analysis by Busse (2010), developed for a spherical container in the limit of small libration frequency - rotation rate ratio w«1, and large libration frequency - spin-up time product. Using PIV measurements and axisymmetric numerical simulations, we confirm quantitatively the main features of Busse's analytical solution (Sauret et al. 2010): the zonal flow takes the form of a retrograde solid body rotation in the fluid interior, which does not depend on the libration frequency nor on the Ekman number, and which varies as the square of the amplitude of excitation. We then extend the weakly nonlinear theory to the limit w>2, where no inertial wave forcing, hence no critical latitude take place. We conclude that a zonal flow still exists, independent of the Ekman number and scaling as the square of the amplitude of excitation, but we also show that this zonal flow can be either retrograde or prograde depending on the libration frequency and on the considered point in the container. A systematic numerical study confirms qualitatively and quantitatively these features in the case of a sphere. Then, these results are numerically extended to more geophysically relevant cases, e.g. for a spheroidal container or by taking into account the composition of several frequencies of libration.

References:
F.H. Busse 2010 Mean zonal flows generated by librations of a rotating spherical cavity. J. Fluid Mech. 650, 505-512.
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