The effect of an azimuthal background magnetic field on waves in a stably stratified layer at the top of the Earth's outer core

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We investigated waves in a stably stratified thin layer in a rotating sphere with an imposed magnetic field. This represents the stably stratified outermost Earth's core or the tachocline of the Sun. Recently, many geophysicists focus on the stratification of the outermost outer core evidenced through seismological studies (e.g. Helffrich and Kaneshima, 2010) and an interpretation of the 60-year geomagnetic secular variations with Magnetic-Archimedes-Coriolis (MAC) waves (Buffett, 2014).
Márquez-Artavia et al.(2017) studied the effect of a toroidal magnetic field on shallow water waves over a rotating sphere as the model of this stratified layer. On the other hand, MAC waves are strongly affected by a radial field (e.g. Knezek and Buffett, 2018). We added a non-zero radial magnetic perturbation and magnetic diffusion to Márquez-Artavia et al.(2017)'s equations. Unlike their paper's formulation, we applied velocity potential and stream function for both fluid motion and magnetic perturbation, which is similar to the first method of Longuet-Higgins(1968).
In the non-diffusive case, the dispersion relation obtained with the azimuthal equatorially symmetric field ($B_\phi(\theta) \propto \sin\theta$, where θ is colatitude) is almost the same as Márquez-Artavia et al.(2017)'s result, which includes magneto-inertia gravity (MIG) waves, fast magnetic Rossby waves, slow MC Rossby waves and an unexpected instability. In particular, we replicate the transition of the propagation direcition of zonal wavenumber m=1 slow MC Rossby waves from eastward to westward with increasing Lamb parameter ($\varepsilon = 4\Omega^2 a^2/gh$, where Ω, a, g and h is the rotation rate, the sphere radius, the acceleration of gravity and a equivalent depth, respectively) and Lehnert number ($\alpha = v_A/2\Omega a$, where v_A is Alfvén wave speed). As a consequence, fast magnetic Rossby waves and slow MC Rossby waves interact, and the non-diffusive instability occur.
Next, we are examining the case with an equatorially antisymmetric background field, which is more realistic in the Earth's core. In this case, if the magnetic diffusion is ignored, the continuous spectrums appear owing to Alfvén waves resonance (similar to the continuous spectrums in inviscid shear flow, e.g. Balmforth and Morrison, 1995). To solve this difficulty, our numerical model includes the magnetic diffusion term.

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