Geophysical Research Abstracts
Vol. 13, EGU2011-418, 2011
EGU General Assembly 2011

Numerical study of tides driven flows in planetary cores and subsurface oceans

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The elliptical (or tidal) instability comes from a parametric resonance and takes place in any rotating fluid whose streamlines are (only slightly) elliptically deformed [1]. Fluid flows in planetary liquid cores and subsurface oceans, elliptically deformed by tidal effects, are thus very likely to exhibit this instability. Our group has been working theoretically and experimentally on this subject for roughly 5 years because of the possible important consequences of this instability in natural systems [e.g. 2]. However, laboratory setups or theoretical results are far from taking into account the complexity of the other phenomena occuring in planets, thus questioning the relevancy of elliptical instability in a geophysical context. We present here the first numerical results towards a more complete modelling of the instability in a geophysical context. So far, the numerical simulations of stellar or planetary flows have been mostly performed using spectral methods for spherical or spheroidal geometries, which facilitate and accelerate the computations but also prevents any elliptical instability. On the contrary, we use here the finite elements method to compute the flow in a triaxial ellipsoid. First, the dependency of the growth rate of the elliptical instability as a function of the oblateness is computed [3]. Classical results of mode selection are recovered. Then, a systematic quantification of the dissipated power by viscosity due to the unstable flow is obtained [3]. Second, the interaction of the elliptical instability with thermal effects reveals striking features such as the enhancement of the growth rate by a thermal stratification [4]. Another important point is the destruction of the Busse columns by the elliptical instability. Finally, magnetohydrodynamics computations are presented, showing the influence of an imposed magnetic field on the development of the tidal instability and the possibility of a dynamo process generated by tides alone. Specific planetary applications are envisaged for selected bodies of our solar system, i.e. Io, where the tidal instability could be responsible for about 10% of the magnetic fluctuations measured by the Galileo probe, and the early Earth, where the tidal instability could be responsible for the initial thermal evolution of the core as well as for the initial dynamo process.

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[4] Cebron D., Maubert P., Le Bars M., 2010, Geophysical Journal International 182, p. 1311-1318.