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Compressibility effects in the Earth's core convection

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Boussinesq approximation (BA) is the most widely used simplification of the equations governing buoyancy driven fluids. Although density variations are the very essence of buoyancy, they are neglected everywhere except in so far as they modify the action of gravity. It allows to model convection with the minimum of complexity. The motivations of BA were thus purely pragmatical (to do the calculus as simple as possible) and less attention has been devoted to the physical consequences of such simplifications. It is well known that BA performs well in laboratory conditions and is less satisfactorily for large containers of, say, planetary size. In spite of this, it has been widely used for the modeling of convection and hydromagnetic dynamo in the Earth's core. In the present contribution we assess critically the applicability of BA, especially with respect to the convection in planetary interiors.
Besides the above mentioned direct effect on fluid momentum and continuity equations, Boussinesq Approximation has indirect thermodynamic effects that limit its applicability. It is shown that BA can be applied only if Carnot efficiency is small, D « 1. It is closely related to the fact that kinetic energy is negligible in comparison with the internal (heat) energy. Convection in BA appears suddenly in the whole container when the heat flux across the container achieves a critical value (onset). We show that BA is consonant not only with the convection in laboratory conditions but also in much larger basins like the oceans.On the other hand, the Carnot efficiency in the Earth's core is not small, D is about 1/4, and the internal and kinetic and magnetic energies are comparable. Such compressible convection appears first in a thin shell at the Inner Core Boundary and its area gradually increases with increasing of value of superadiabatic heat flow. We further discuss a new Incompressible approach (Geophys. Astrophys. Fluid Dynam., 104, 65-83 (2010)) that allow to overcome these drawbacks.