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The effect of elastic compressibility in geodynamic models using a benchmark of a sinking cylinder in a bounded medium

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Although it is commonly accepted that the Earth is compressible, in most numerical models this is neglected. To test the effect of the elastic compressibility, a numerical model is set up in which the gravity driven motion of a rigid cylinder is examined. The surrounding fluid is homogeneous and bounded with no-slip conditions. In fluid dynamics, this is a well-defined benchmark, for which an analytical solution exists in the case of a purely viscous incompressible fluid. As expected, our models converge towards the analytical terminal velocity for an increasing Poisson ratio (i.e. towards incompressibility)

For an Earth-like Poisson ratio (ν=0.3), the results differ significantly compared to the solution of an incompressible fluid: the terminal velocity of the cylinder is increased by 40%. Furthermore, the cylinder sets a much larger portion of the fluid in front of it in motion. Above the cylinder, the behaviour is quite similar to that of incompressible fluids. Confinement of the walls increases the volumetric changes of the fluid and causes further deviations from the analytical steady state solution.

Thus, elastic compressibility can have a significant effect on the fluid flow and by assuming an incompressible medium, this can lead to an oversimplification in numerical models.