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A free surface method for Eulerian finite difference geodynamic codes

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In geodynamic simulations, the surface of the Earth is generally represented by a free surface. Whereas some methods offer natural free surface boundary (e. g. Lagrangian Finite Elements), the implementation of a free surface is not trivial in Eulerian finite difference codes. Therefore, the so-called "sticky air" method is often employed. This method is straightforward to implement but suffers from a number of drawbacks. Alternatively a Eulerian discretisation of the free surface is here proposed. The free surface boundary condition is applied on the staggered grid and the resulting free surface is advected using a set of marker points. Numerical tests show that this free surface representation is convergent and offers first order spatial accuracy. Classical community benchmarks test were successfully reproduced and a number of real-life applications (large strain, thermo-mechanical, visco-elasto-plastic models) are presented. Moreover, we show the benefits of this method when an iterative Stokes solvers is employed. This free surface representation is hence a promising tool for three-dimensional numerical simulations.