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Numerical modelling of the Earth's free surface with the level set method

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Being able to accurately model the free surface of the Earth is important for nearly all geodynamical problems. Importantly, free surface deformation is coupled to vertical motions and therefore allows for selfconsistent modelling of topography build up. Such modelling allows for additional prediction from numerical models which can be compared to real Earth observations. When using an Eulerian framework, modelling the free surface is not straightforward and the so called "sticky air" approach is often used in which the "air" is modelled as a zero density fluid which has sufficient thickness (∼100km) and a low viscosity compared to the underlying crust-mantle system (∼5 orders of magnitude less, e.g. Crameri et al 2012). Tracers are commonly used to account for the tracking of all materials and interfaces.

We here propose to use the level set method to track the interface between the crust and the air as a simulation of the free surface. The level set method represents a n-dimensional interface by a (n+1)-dimensional function chosen to be zero at the interface and it is mathematically described as a smooth (signed-distance) function. The target interface coincides with the zero-level set and its location can be traced through time by solving the advection equation for the level set function and subsequently locating the zero-level set every time-step. The level set method has several advantages over tracers, namely 1) with the level set method the exact location of the interface is known, 2) the exact distance of every point in the domain to the interface is known and 3) it is computationally less expensive compared to using tracers (particularly in 3-D applications).

We will show results of benchmarks and 3-D numerical subduction models which contain multiple level sets representing the free surface and selected internal surfaces.

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