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Finite difference and Marker-in-Cell method: grid convergence and free surface stabilisation

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We studied the accuracy of the finite difference (FD) & Marker-In-Cell technique of Gerya and Yuen (2003) for the discretisation of Stokes equations in two dimensions. This method is popular for studying geodynamic processes that often include various material phases with differing rheological properties. A large number of applied studies have demonstrated the versatility of this method for problems involving large viscous deformations. The principal reason why the method is flexible is the use of an interpolation technique to capture fluid properties at a subgrid level. Given the geodynamic applications, the flow discretisation is required to be robust when the domain contains large and sharp spatial variations in viscosity. In this study, we measure the robustness of the spatial discretisation by computing the discretisation error and analysing the convergence rate of the velocity and pressure fields. We examine the convergence properties of the traditional staggered grid discretisation and show that introducing an interpolated viscosity constructed from the markers does not modify the convergence behaviour. As shown by Kaus (2010), the modelling of free surface geodynamic problems may lead to spurious instabilities at material interfaces. Following their approach, we introduce a strong form of the stabilisation algorithm which is suitable for finite difference methods. We show that the inclusion of stabilisation does not alter the convergence rate of the FD method when applied to models which do not possess a free surface. We also demonstrate that the stabilisation algorithm suppresses spurious free surface oscillations in Rayleigh-Taylor instability models with a free surface.

Gerya, T. V., Yuen, D. A., 2003. Characteristics-based marker method with conservative finite-difference schemes for modeling geological flows with strongly variable transport properties. Physics of the Earth and Planetary Interiors 140 (4), 293-318.

Kaus B.J.P, Mühlhaus H., May D.A., 2010. A stabilization algorithm for geodynamic numerical simulations with a free surface. Physics of the Earth and Planetary Interiors 181, 12-20.