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Stress boundary conditions with the staggered grid: a numerical investigation

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In this study, we investigate the numerical properties of the finite-difference method employing dynamic boundary conditions (BC). Stress BC's are gaining popularity in the geodynamic modelling community since the use of a free surface (stress-free BC) is required to model the dynamic evolution of topography. Additionnaly, normal stress BC's might also be used to prescribe known lithospheric rheological models as a dynamic forcing. Under this constraints, boundary velocities are not fixed, they thus vary through time in reaction to stress equilibria within the domain.

Dynamic BC's were implemented on a regular Cartesian mesh using a standart staggered grid discretisation. The numerical properties of the scheme were quantified by means of a convergence study and error analysis. Integrated errors owing to the numerical method were evaluated using analytical and manufactured full flow-field solutions and associated convergence rates were derived.

Finally, we present two lithospheric-scale applications. The first model depicts the topographic evolution of a linear-viscous lithosphere subjected to the rise of a mantle plume, employing a staircase type free surface. The second model shows the pattern of strain localisation in a thermally activated power law crust subjected to normal stress loading.