The topography relaxation model is the same as case 1 from (Crameri et al., 2012) which is used here to validate the free surface implementation. The model setups are shown in Fig 1. It has a 600 km thick mantle, overlain by a 100 km thick lithosphere with a prescribed 7km amplitude cosine topography. The model box is 2800 km × 700 km, caluated by the resolution of 280 × 70 (140 × 35) gridpoints with 9 particles per element.

The maximum topography of this model at time t can be derived analytically (Ramberg, 1967) using the relaxation rate γ and the initial maximum topography :

|  |  |  |
| --- | --- | --- |
|  |  | (X) |

where t = 14.825 ka is the characteristic relaxation time and γ = −0.2139×10−11 s−1 is the characteristic relaxation rate.

The Arbitrary Lagrangian–Eulerian formulation is adapted here to simulate the free surface. In general, the mesh is regridding to fit the free surface with the following three steps (Thieulot, 2011). (1) Advection the free surface: advect the top row mesh points which are the discrete free surface of the domain by the Eulerian velocity, (2) resample free surface resample: use a Clough-Tocher scheme to resample the free surface between x=0 and x=L as the grid points position is fixed at these locations, (3) regrid mesh: solving the Poisson equation to get a uniform distribution of the mesh vertical coordinates, the applied boundary conditions are a Dirichlet constraint and defines that the top is the updated free surface, bottom is the original mesh bottom.