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A finite element approach to modelling Glacial Isostatic Adjustment on three-dimensional compressible earth models

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A new finite element method called FEMIBSF is presented that is capable of modelling Glacial Isostatic Adjustment (GIA) on compressible earth models with three-dimensional (3D) structures. This method takes advantage of the classical finite element techniques to calculate the deformational and gravitational responses to the driving forces of GIA (including body forces and pressures on Earth's surface and core-mantle boundary, namely CMB). Following Wu (2004) and Wong & Wu (2019), we implement the GIA driving forces in the commercial finite element software Abaqus and solve the equation of motion in an iterative manner. Different from those two studies, all formulations and calculations in this study are not associated with spherical harmonics but are performed in the spatial domain. Due to this, FEMIBSF is free from expanding the load, displacement, and potential into spherical harmonics with the short-wavelength components (of high degree and order) neglected. We compare the loading Love numbers (LLNs) generated by FEMIBSF with their analytical solutions for homogeneous models and numerical solutions for layered models calculated by the normal-mode approach/code, ICEAGE (Kaufmann, 2004), the iterative body force approach/code, IBF (Wong & Wu, 2019) and the spectral-finite element approach/code, VILMA-C (Martinec, 2000; Tanaka et al., 2011). We find that FEMIBSF agrees well with analytical and numerical LLN results of these codes. In addition, we show how to compute the degree-1 deformation directly in the spatial domain with the finite element approach and how to implement it in a GIA model using Abaqus. Finally, we demonstrate that the CMB pressure related to the gravitational potential change in the fluid core only influences the long-wavelength surface displacement and potential such as the degree-2 component.

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