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CitcomSVE: A Three-dimensional Finite Element Software Package for Modeling Planetary Mantle's Viscoelastic Deformation in Response to Surface and Tidal Loads

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This article presents a comprehensive benchmark study for the newly updated and publicly available finite element code CitcomSVE for modeling dynamic deformation of a viscoelastic and incompressible planetary mantle in response to surface and tidal loading. A complete description of CitcomSVE's finite element formulation including calculations of the sea-level change, polar wander, apparent center of mass motion, and removal of mantle net rotation is presented. The 3-D displacements and displacement rates and the gravitational potential anomalies are solved with CitcomSVE for three benchmark problems using different spatial and temporal resolutions: 1) surface loading of single harmonics, 2) degree-2 tidal loading, and 3) the ICE-6G GIA model. The solutions are compared with semi-analytical solutions for error analyses. The benchmark calculations demonstrate the accuracy and efficiency of CitcomSVE. For example, for a typical ICE-6G GIA calculation with a 122-ky glaciation-deglaciation history, time increment of 100 years, and ~50 km (or ~0.5 degree) surface horizontal resolution, it takes ~4.5 hours on CPU 96 cores to complete with about 1% and 5% errors for displacements and displacement rates, respectively. Error analyses shows that CitcomSVE achieves a second order accuracy, but the errors are insensitive to temporal resolution. CitcomSVE achieves the parallel computation efficiency >75% for using up to 6,144 CPU cores on a parallel supercomputer. With its accuracy, computing efficiency and its open-source public availability, CitcomSVE is a powerful tool for modeling viscoelastic deformation of a planetary mantle in response to surface and tidal loading problems.