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Benchmark of numerical GIA codes capable of laterally heterogeneous earth structures

Volker Klemann[1], Jacky Austermann[2], Meike Bagge[1], Natasha Barlow[3], Jeffrey Freymueller[4], Pingping Huang[1,5], Erik R. Ivins[6], Andrew Lloyd[7], Zdeněk Martinec[8,9], Glenn Milne[10], Alessio Rovere[11,12], Holger Steffen[13], Rebekka Steffen[13], Wouter van der Wal[14], Maryam Yousefi[15,16], and Shijie Zhong[17]

[1]GFZ German Research Centre for Geosciences, Geodesy 1.3, Potsdam, Germany (volkerk@gfz-potsdam.de, bagge@gfz-potsdam.de, pingping@gfz-potsdam.de)
[2]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, United States (jackya@ldeo.columbia.edu)
[3]Faculty of Environment, School of Earth and Environment, University of Leeds, Leeds, United Kingdom (n.l.m.barlow@leeds.ac.uk)
[4]Department of Earth and Environmental Sciences, Michigan State University, East Lansing, MI, United States (freymuel@msu.edu)
[5]School of Civil Engineering and Geosciences, Newcastle University, Newcastle upon Tyne, United Kingdom
[6]Jet Propulsion Lab, California Institute of Technology, Pasadena, CA, United States (erik.r.ivins@jpl.nasa.gov)
[7]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, United States (andrewl@ldeo.columbia.edu)
[8]Dublin Institute for Advanced Studies,Dublin, Ireland (zdenek@cp.dias.ie)
[9]Department of Geophysics, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic
[10]Department of Earth and Environmental Sciences, University of Ottawa, Ottowa, ON, Canada (gamilne@uottawa.ca)
[11]Ca' Foscari University of Venice, Venice, Italy
[12]MARUM, Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany (arovere@marum.de)
[13]Geodetic Infrastructure, Lantmäteriet, Gävle, Sweden (rebekka.steffen@lm.se, holger.steffen@lm.se)
[14]Delft University of Technology, Faculty of Aerospace Engineering, Delft, The Netherlands (w.vanderwal@tudelft.nl)
[15]Department of Earth and Planetary Sciences, McGill University, Montreal, Quebec, Canada (maryam.yousefi@mcgill.ca)
[16]Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA, United States
[17]Department of Physics, University of Colorado at Boulder, Boulder, CO, United States (shijie.zhong@colorado.edu)

During the last decade there has been an increasing demand to improve models of present-day loading processes and glacial-isostatic adjustment (GIA). This is especially important when modelling the GIA process in tectonically active regions like the Pacific Northwest, Patagonia or West Antarctica. All these regions are underlain by zones of low-viscosity mantle. Although one-dimensional earth models may be sufficient to model local-scale uplift within these regions, modeling of the wider-scale deformation patterns requires consideration of three-dimensional viscosity structure that is consistent with other geophysical and laboratory findings. It is this wider-scale modeling that is necessary for earth-system model applications as well as for the validation or reduction of velocity fields determined by geodetic observation networks based on GNSS, for improving satellite gravimetry, and for present-day sea-level change as paleo sea-level reconstructions.

There are a number of numerical GIA codes in the community, which can consider lateral variations in viscoelastic earth structure, but a proper benchmark focusing on lateral heterogeneity is missing to date. Accordingly, ambiguity remains when interpreting the modelling results. The numerical codes are based on rather different methods to solve the respective field equations applying, e.g., finite elements, finite volumes, finite differences or spectral elements. Aspects like gravity, compressibility and rheology are dealt with differently. In this regard, the set of experiments to be performed has to be agreed on carefully, and we have to accept that not all structural features can be considered in every code.

We present a tentative catalogue of synthetic experiments. These are designed to isolate different aspects of lateral heterogeneity of the Earth's interior and investigate their impact on vertical and horizontal surface displacements, geocenter and polar motion, gravity, sea-level change and stress. The study serves as a follow up of the successful benchmarks of Spada et al. (2011) and Martinec et al. (2018) on 1D earth models and the sea-level equation. The study was initiated by the PALSEA-SERCE Workshop in 2021 (Austermann and Simms, 2022) and benefits from discussions inside different SCAR-INSTANT subcommittees, the IAG Joint Study Group 3.1 “Geodetic, Seismic and Geodynamic Constraints on Glacial Isostatic Adjustment", the IAG Subcommission 3.4 “Cryospheric Deformation" and PALSEA.

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