EGU24-19141, updated on 18 Mar 2025
https://doi.org/10.5194/egusphere-egu24-19141
EGU General Assembly 2024

FastIsostasy - An accelerated regional GIA model for coupled ice-sheet/solid-Earth simulations with laterally-variable solid-Earth structures

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The vast majority of ice-sheet modelling studies rely on simplified representations of the Glacial Isostatic Adjustment (GIA), which, among other limitations, do not account for lateral variations of the lithospheric thickness and upper-mantle viscosity. In studies using 3D GIA models, this has however been shown to have major impacts on the dynamics of marine-based sectors of Antarctica, which are likely to be the greatest contributors to sea-level rise in the coming centuries. This gap in comprehensiveness is explained by the fact that 3D GIA models are computationally expensive, seldomly open-source and require the implementation of an iterative coupling scheme to converge with the history of the ice-sheet model. To close this gap between "best" and "tractable" GIA models, we here propose FastIsostasy, a regional GIA model capturing lateral variations of the lithospheric thickness and mantle viscosity. By means of Fast-Fourier transforms and a hybrid collocation scheme to solve its underlying partial differential equation, FastIsostasy can simulate 100,000 years of high-resolution bedrock displacement in only minutes of single-CPU computation, including the changes in sea-surface height due to mass redistribution. Despite its 2D grid, FastIsostasy parametrises the depth-dependent viscosity in a physically meaningful way and therefore represents the depth dimension to a certain extent. FastIsostasy is here benchmarked against analytical, 1D and 3D GIA solutions and shows very good agreement with them. It is fully open-source, documented with many examples and provides a straight-forward interface for coupling to an ice-sheet model. The model is benchmarked here based on its implementation in Julia, while a Fortran version is also provided to allow for compatibility with most existing ice-sheet models. The Julia version provides additional features, including a vast library of time-stepping methods and GPU support.