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Adjoint modeling of load-tide sensitivity

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Deformations of the solid Earth as a response to ocean tidal loading (OTL) are sensitive to the material properties of Earth's interior across a broad range of spatial and temporal scales. Studying tidal response can provide constraints on the interior structure, which are complementary to seismic tomography and particularly important to explore the interior response to low frequency loads. Although seismic tomography is widely used to constrain the Earth's interior, it is prone to be only slightly sensitive to the density distribution in the interior with an increase of the sensitivity towards the long period signal. Whereas previous research (e.g. Ito & Simons, 2011, Martens et al., 2016) has shown that the tidal surface displacements may be sensitive to elastic properties of the interior to the same extent as to the mass distribution in the lithosphere and the mantle. The latter are of massive interest to all fields of geophysics and especially geodynamics.

We present a numerical approach to simulate the elastic and gravitational responses of the solid Earth that relies on the spectral-element method. Modeling the governing equations in a 3-D Earth using a coupled system of the elastostatic and Poisson's equations enables us to include effects like topography or lateral variations in Earth structure. The adjoint method is a powerful technique to simultaneously compute sensitivity with respect to all material parameters, e.g., density and elastic moduli, by solving an auxiliary linear system. We introduce a recipe for computing adjoint-based sensitivities of the complex-valued amplitude of surface displacement by two simulations for the real and imaginary part of the surface load. Those two simulations are independent under assumption of negligible attenuation.