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3D instantaneous dynamics modeling of present-day Aegean subduction

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To study the sensitivity of surface observables to subduction and mantle flow, i.e. the coupling of crustal tectonics and the underlying mantle dynamics, we have developed 3D numerical models of the instantaneous crust-mantle dynamics of the eastern Mediterranean. These models comprise both a realistic crust-lithosphere system and the underlying mantle. The focus for this presentation lies on the regional crustal flow response to the present-day Aegean subduction system.

Our curved model domain measures ∼40°x40°x2900km with the Aegean subduction system taken as the geographic center. Model set-ups are based on geological and geophysical data of the eastern Mediterranean. We first create a 3D synthetic geometry of the crust-lithosphere system in a stand-alone program, including the present-day configuration of the plates in the region and crust and lithosphere thickness variations abstracted from Moho and LAB maps (Faccenna et al., 2014, Carafa et al., 2015). In addition we construct the geometry of the Aegean slab from a seismic tomography model (UU-P07; Amaru, 2007) and earthquake hypocenters (NCEDC, 2014). Geometries are then imported into the finite element code ASPECT (Kronbichler et al., 2012) using specially designed plugins.

The mantle initial temperature conditions can include deviations from an adiabatic profile obtained from conversion of the UU-P07 seismic velocity anomalies to temperature anomalies using a depth-dependent scaling (Karato, 2008). We model compressible mantle flow for which material properties are obtained from thermodynamics P-T lookup-tables (Perple_X, Connolly, 2009) in combination with nonlinear viscoplastic rheology laws. Sublithospheric flow through the lateral model boundaries is left free via open boundary conditions (Chertova et al., 2012), while plate motion is prescribed at the model sides in terms of relative as well as absolute plate motion velocities (e.g. Doubrovine et al., 2012). So far, we used a free-slip surface, but we also intend to experiment with a dynamic free surface. In short, the forcing in our models comprises lateral pressure gradients, mantle buoyancy and forcing related to the prescribed plate motions.

Based on the above initial and boundary conditions, we obtain model predictions of the regional flow field. Focusing on the crust, these represent predictions of the GPS velocity field that we can compare to the actual GPS field (e.g. compilation of Kreemer et al., 2014). Our preliminary models provide a good overall fit to the direction and magnitude of the GPS velocities. Subsequent models will include constructed variations in subduction morphology, slab segmentation, fault zone geometry and boundary conditions, for which a wide range of hypotheses can be found in the literature (e.g. Biryol et al., 2011). Changes in the resulting model predictions either improve or lessen our fit to the GPS velocity field and help determine the controls of mantle dynamics on present-day tectonic deformation in the Aegean region. This enables us to characterize the general sensitivity of surface observables to plate motions, mantle flow and slab dynamics and to further quantify the coupling of crust and mantle dynamics.