1. Summary

Evolution of the subducting slab has been widely investigated in the past two decades by means of numerical and laboratory modeling, including analysis of the factors controlling its behavior. However, until recently, relatively little attention has been paid to the influence of the mantle flow. While for large subduction zones, due to the high slab buoyancy force, this effect might be small, mantle flow might be the primary factor controlling the evolution of a regional subduction zone.

Here we investigate the impact of prescribed mantle flow on the evolution of both generic (Fig. 2) and real Earth (Fig. 3) subduction models by means of 3D thermo-mechanical numerical modeling. We implement two types of generic models. The first includes only a single subducting plate. The second has a subducting, overriding and two side plates. For the generic setup we test arbitrary mantle flow prescribed on one of the four side boundaries or for the combination of two boundaries.

To test the mantle flow influence on the dynamics of real Earth subduction zone we adopt the numerical model from Chertova et al. (2014) for the evolution of the western Mediterranean subduction since 35 Ma. This model was tested with time-dependent estimates of the actual mantle flow in the region based on Steinberger (2015) given for every 1 My. Our models demonstrate that for the western-Mediterranean subduction, the surrounding mantle flow is of second-order compared to the slab buoyancy in controlling the dynamics of the subducting slab. Introducing mantle flow on the side boundaries might, however, improve the fit between the modeled and the real slab imaged by tomography, although this may also trade-off with varying rheological parameters of the lithosphere and mantle.

2. Experimental settings. Generic models.

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3. Models with single subducting plate

Comparison between models with eastern, western, and frontal inflows of 3 cm/yr prescribed on two sides and the reference model (transparent red). The speed of subducting plate for models is 3 cm/yr. For the reference model below the lithosphere side boundaries are open except the western boundary which has free slip BC.

4. Experiments with 4 plates

We perform models with eastern, western and frontal inflow of 3 cm/yr and investigate their evolution in comparison with the reference model (transparent blue). The speed of subducting plate is 1.5 cm/yr for the reference model all side boundaries are open.

5. Model setup for the western Mediterranean region.

We use the initial model geometry and rheological settings from our recent experiments on modeling of the western Mediterranean subduction system (Chertova et al., 2015). In Fig. 5, we show the example of prescribed mantle flow based on Steinberger, 2015. The mantle flow was subsequently changed each 1 My.


The subduction process in models with prescribed mantle flow on southwest (Fig. 7) and northeast (Fig. 8) domain sides demonstrates evolution similar to the reference model (Fig. 8).

7. Mantle flow influence.

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8. Conclusions

- For the single plate generic models, mantle flow might significantly change the shape of the slab. Prescribing trench-perpendicular mantle flow leads to an initiation of spontaneous subduction on the slab sides due to the absence of side plates (Fig. 10).
- For models, which include overriding and side plate, the prescribed mantle flow influences the evolution of subduction process to a lesser extent than for the model with single plate (Fig. 2).
- Trench-parallel mantle flow has an impact on the evolution of the subduction zone only in the case of a short subducting slab; for the well developed subduction zone slab buoyancy controls subduction dynamics.
- For the model of the western Mediterranean subduction zone tomography derived (Steinberger, 2014) mantle flow on sides of the modeling domain does not significantly disturb the subduction process (Fig. 8); however, it decreases the amount of tearing under the Iberian margin and drags Kabydias slab to the north which provides better fit with tomographical constraints.

References

2. Chertova, M.V., W.Spakman, T. Geenen, A.P. van den Berg, D.J.J. von H Builtbergen (2014), Underplating tectonic reconstructions of the western Iberia plate with dynamic slab evolution from 3-D numerical modeling, JGR.