Title: - A numerical study of subduction zone dynamics using linear viscous to thermo-mechanical model setups including (de)hydration processes.
Author: Matthieu Quinquis.
Department / Institute: Department of Geophysics, Faculty of Mathematics and Physics, Charles University in Prague.
Supervisor of the doctoral thesis: doc. RNDr. Ondřej Čadek, CSc.
Consultant: RNDr. Susanne J.H. Buiter, DrSc.

Abstract:

Subduction zones are complex systems that include different types of material behaviour, several time-scales from short-term earthquakes to long-term mantle flow, and melting and (de)hydration processes. These complexities can be challenging to include in numerical experiments, both from a physics perspective of representing a process in equations, and from a numerical perspective of keeping calculation times reasonable. Numerical models therefore often simplify the system, by, for example, limiting the size of the model domain, reducing viscosity contrasts, using simple boundary conditions, or approximating water and melt migration through the mantle wedge with simplified equations. The aim of this thesis is to show how simplifications in the set-up of a numerical model could affect the mechanical evolution of the modelled subduction system. A first set of experiments shows how the numerical implementation of surface, side and bottom boundary conditions in an experiment on the scale of the upper mantle can determine whether the model slab will evolve through trench advance or trench retreat. The boundary conditions can also control the large-scale geometry of the subducted slab in the upper mantle. In order to allow a first-order appraisal of the effects of model set-up versus the potential effects of numerical software, a set of model set-ups was created that evolve from linear viscous to thermo-mechanical rheologies. These were run by various modellers with different numerical codes. The more simplified the model set-up, the more similar the results of the different codes are. Linear viscous models provide very similar results, within 5% variability in quantitative parameters such as slab tip depth and root-mean-square velocities. Increasing the rheological complexity increases the differences in results, even though the general model evolution remains similar between codes. A last series of experiments shows how the numerical method for implementing the migration of free water affects the spatial distribution of hydrated mantle material in the mantle wedge that results from slab dehydration, The water distribution in turn affects the mechanical evolution of the subduction system. The experiments in this thesis provide a possible starting point for other numerical modellers for their study of subduction zones by providing them with a series of detailed model setups that can be used to test modelling software, obtain a first-order understanding of the effects of slab rheology on subduction evolution, and estimate the level of complexity of water migration mechanisms required in a model simulation.

Keywords: Subduction, Numerical Modeling, Water Migration, Boundary Conditions, Benchmark, Rheology.