12th International Workshop on Modeling of Mantle Convection
and Lithospheric Dynamics

August 20th to 25th 2011, Döllnsee Germany

Modeling of compositionally buoyant diapers in the mantle wedge using 2-D and 3-D parallel finite element codes written in MATLAB

Jörg Hasenclever[1,3], Jason Phipps Morgan[2], Matthias Hort[1], Lars H. Rüpke[3]
[1] *Institute of Geophysics, University of Hamburg, Hamburg, Germany*
[2] *EAS Dept., Cornell University, Ithaca, USA*
[3] *SFB 574, IFM-Geomar, Kiel, Germany*
joerg.hasenclever@zmaw.de

We present 2-D and 3-D numerical model calculations that focus on the physics of compositionally buoyant diapirs rising within a mantle wedge corner flow. Compositional buoyancy is assumed to arise from slab dehydration during which water-rich volatiles enter the mantle wedge and form a wet, less dense boundary layer on top of the slab. Slab dehydration is prescribed to occur in the 80-180 km deep slab interval, and the water transport is treated as a diffusion-like process. In this study, the mantle's rheology is modeled as being isoviscous for the benefit of easier-to-interpret feedbacks between water migration and buoyant viscous flow of the mantle. We use a simple subduction geometry that does not change during the numerical calculation.

In a large set of 2-D calculations we have identified that five different flow regimes can form (Fig. 1), in which the position, number, and formation time of the diapirs vary as a function of four parameters: subduction angle, subduction rate, water diffusivity (i.e. mobility), and mantle viscosity. Using the same numerical method and numerical resolution we also conducted a suite of 3-D calculations for 16 selected parameter combinations. In 3-D, initial instabilities are in the form of ripples that are aligned parallel to the slab's motion. Some of these ripples turn into cones and eventually form diapirs (Fig. 2). Comparing the 2-D and 3-D results for the same model parameters reveals that the 2-D models can only give limited insights into the inherently 3-D problem of mantle wedge diapirism. While often correctly predicting the position and onset time of the first diapir(s), the 2-D models fail to capture the dynamics of diapir ascent, the interaction of diapirs as well as the formation of secondary diapirs that result from boundary layer perturbations caused by previous diapirs.

Of greatest importance for physically correct results is the numerical resolution in the region where diapirs nucleate, which must be high enough to accurately capture the growth of the thin wet boundary layer on top of the slab and, subsequently, the formation, morphology, and ascent of diapirs. Here 2D models can be very useful to quantify the required resolution, which we find to be about 1km node spacing for quadratic-order velocity elements.

Part of the poster is devoted to the numerical method used to solve the equations describing incompressible Stokes flow. We use a Schur complement formulation that leads to outer iterations calculating the pressure solution within which the velocity solution is updated (inner iterations). Both pressure and velocity parts are solved using conjugate gradient algorithms, which are preconditioned by the inverse-viscosity-scaled pressure mass matrix and a geometrical multigrid algorithm with a Cholesky direct solver on the coarsest multigrid level, respectively. Parallelization is done using Matlab's *Parallel Computing Toolbox*.

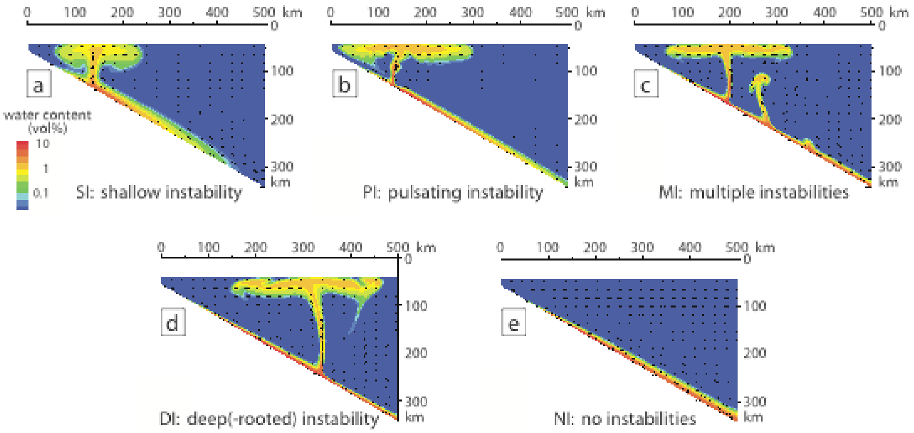

Figure 1: Snapshots of the five regimes that have been identified in 2-D calculations.

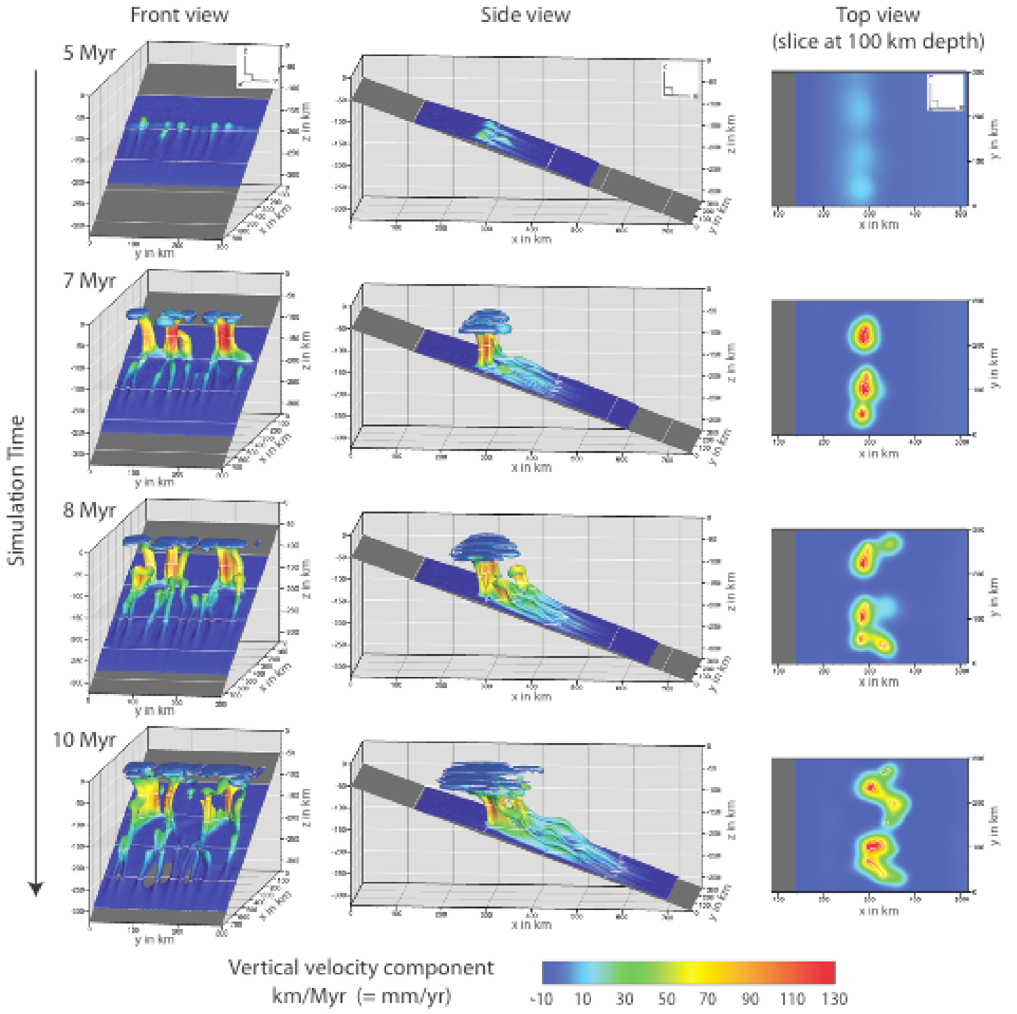

Figure 2: Temporal evolution of a 3-D experiment (subduction angle=20°, subduction rate=60mm/yr, mantle viscosity 10^{19}Pa s, water diffusivity $10^{-7}m^2/s$). Left and mid: dark grey plane is top of slab, colored surface is isosurface for 1% water content, colors show vertical velocity. Right: horizontal slice at 100km depth, white isolines at 1% water content.