Computational Geodynamics Modelling at Utrecht University (2016-2017)

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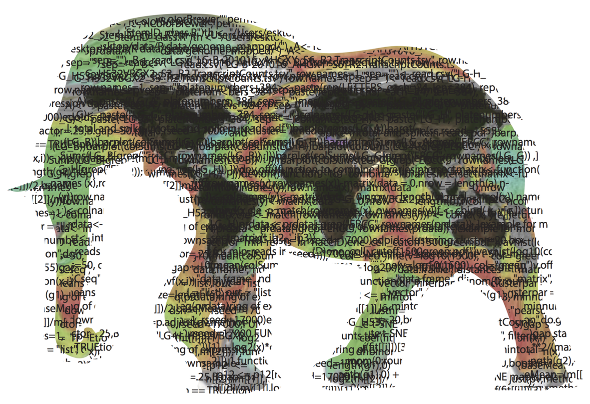
NWO

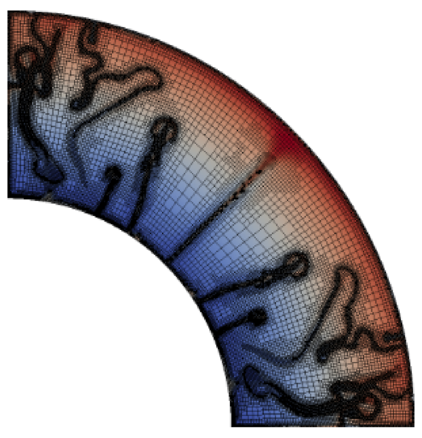
Abstract

The continuous improvement of numerical methods, the widespread availability of geophysical data and the evolution of ever more powerful computers keep pushing the range of numerical modelling applications (from crustal deformation to deep mantle convection, from surface processes to planetology). The Mantle Dynamics group at the Utrecht University makes use of two numerical codes which are tailored to tackle a whole array of problems at different time and length scales. These codes are used by our Master students, Ph.D. students, and post-doctoral researchers alike to investigate the complex interplay between plates and mantle in the Mediterranean region, subduction initiation and evolution, the influence of complex rheologies on subduction processes, or in general, the coupling between surface processes and deep driving processes. They also are ever-evolving research platforms which benefit from a community of users and developers and thus remain state-of-the-art.

1. ELEFANT & ASPECT

Our group uses and develops two thermo-mechanically coupled 2D/3D codes



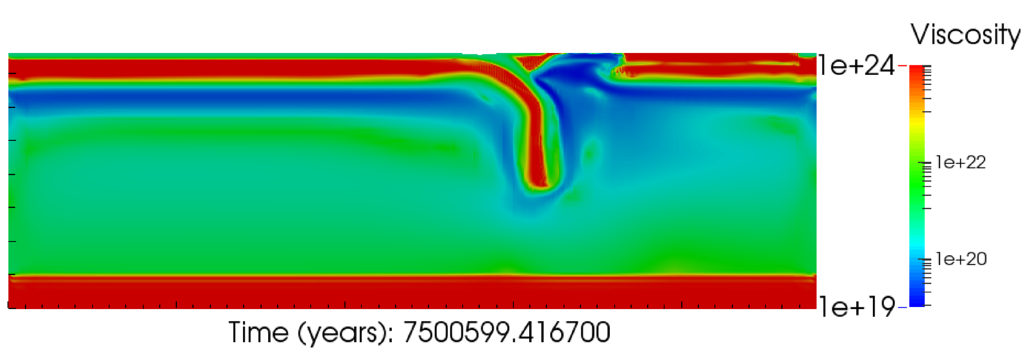


`http://cedricthieulot.net/elefant.html`
`https://aspect.geodynamics.org/`
New Newton solver! POSTER Fraters et al., Thu.
ELEFANT used for teaching TALK Thieulot, Thu. 12pm

2. MSc projects

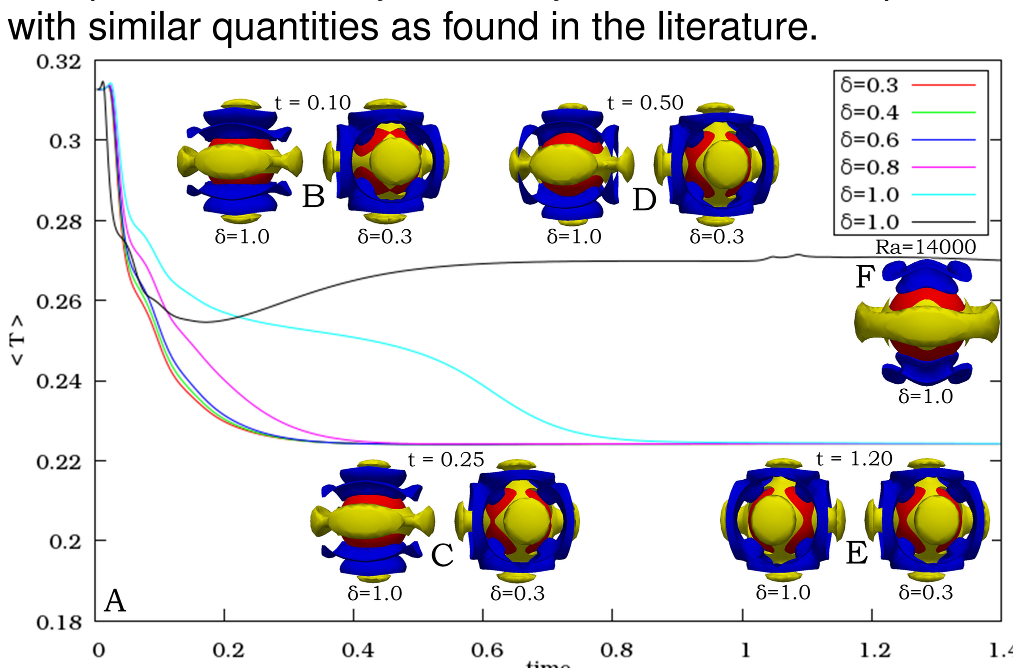
2.1 Modelling of overriding plate deformation and slab rollback in the Mediterranean, L. Schuurmans

Luuk investigates the controlling factors on the opening of the Liguro-Provencal Basin and the Tyrrhenian Basin as well as of the Aegean basin with 2D numerical modelling of a central transect through the two backarc regions with ASPECT.
POSTER Schuurmans et al., Thu.



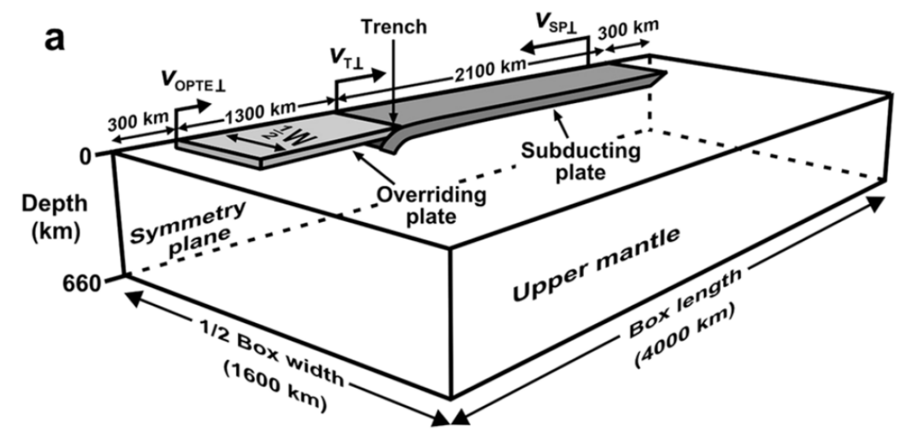
2.2 Implementing and benchmarking spherical harmonics on a three-dimensional spherical shell model. E. van der Wiel

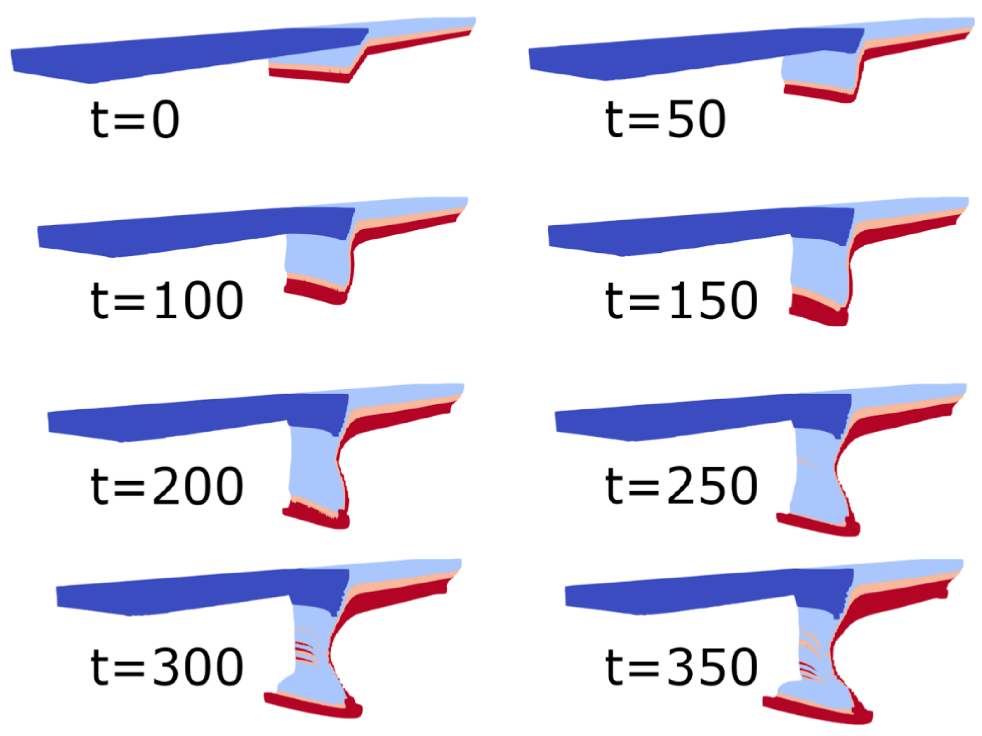
Erik has carried out 3D Rayleigh-Bénard convection benchmark of cubic, tetrahedral and axisymmetric convection patterns in a spherical shell and showed that *ELEFANT* is able to reproduce a variety of steady-state convection patterns with similar quantities as found in the literature.



2.3 Performance optimization of solving methods in ELEFANT, J. Mos

Job has coupled PETSc (a suite of data structures and routines for the scalable (parallel) solution of scientific applications modeled by partial differential equations) with the ELEFANT code as a first step towards performance optimisation. He has found that in most cases an AMG preconditioner is best suited for the so-call inner solves.

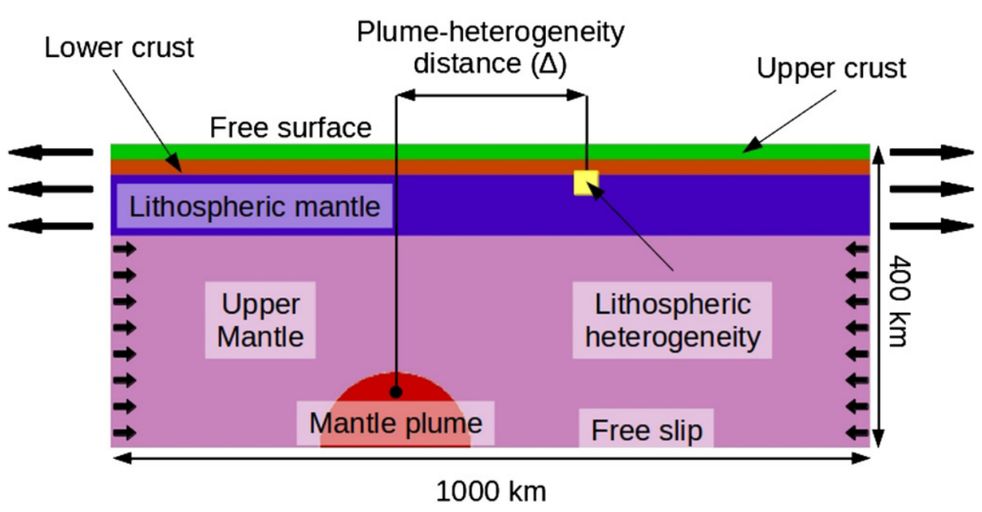


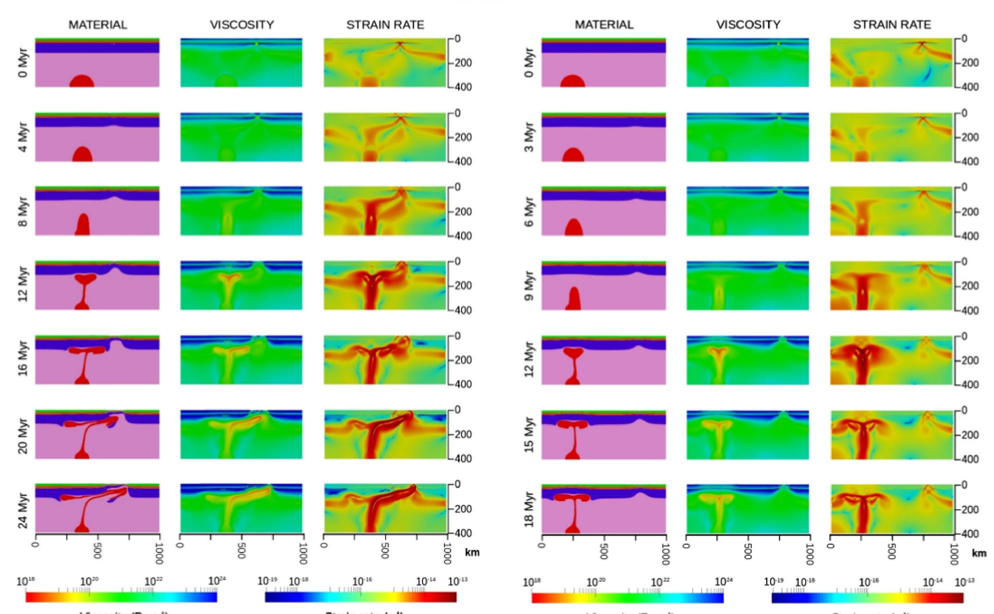


3. Publications

3.1 Lithosphere erosion and continental breakup: Interaction of extension, plume upwelling and melting, Lavecchia et al., 2017

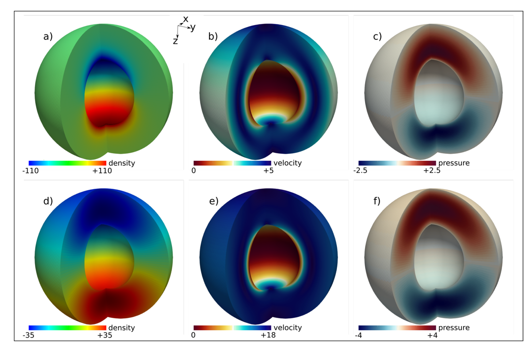
In our 2017 EPSL paper we present the results of thermo-mechanical modelling of extension and breakup of a heterogeneous continental lithosphere, subjected to plume impingement in presence of intraplate stress field. We have incorporated partial melting of the extending lithosphere, underlying upper mantle and plume, caused by pressuretemperature variations during the thermo-mechanical evolution of the conjugate passive margin system. We have focused particularly on the role of melting for the temporal and spatial evolution of passive margin geometry and rift migration.





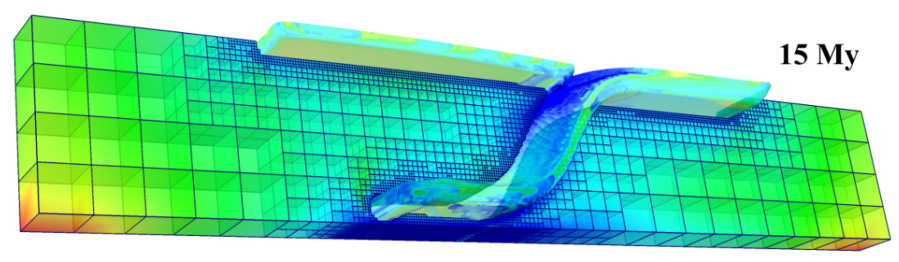
3.2 Analytical solution for viscous incompressible Stokes flow in a spherical shell , Thieulot, 2017

I have published a new family of analytical flow solutions to the incompressible Stokes equation in a spherical shell. The velocity is tangential to both inner and outer boundaries, the viscosity is radial and of the power-law type, and the solution has been designed so that the expressions for velocity, pressure, and body force are simple polynomials and therefore simple to implement in (geodynamics) codes. I have implemented it in ASPECT and ELEFANT and report error convergence rates for velocity and pressure.



3.3 Implementing nonlinear viscoplasticity in ASPECT: benchmarking and applications to 3D subduction modeling , Glerum et al., 2017

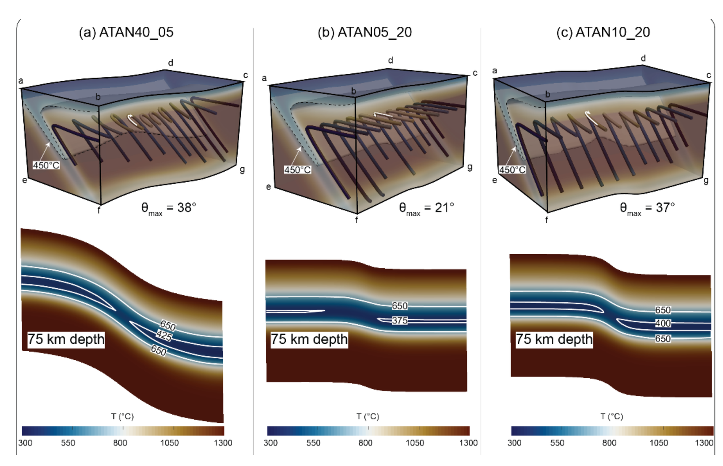
We have have implemented in ASPECT a frictional plasticity criterion that is combined with a viscous diffusion and dislocation creep rheology. We described and validated our implementations of complex, multi-material rheology by reproducing the results of four well-known two-dimensional benchmarks



POSTER Glerum et al., Thu.

3.4 The effect of obliquity on temperature in subduction zones: insights from 3D numerical modeling, Plunder et al., Subm.

We have designed and computed simple thermo-kinematic finite element 3D numerical models. We prescribe the trench geometry by means of a simple mathematical function and compute the mantle flow in the mantle wedge only by solving the equation of mass and momentum conservation. We then solve the energy conservation equation until steady-state is reached. We analyse the results (i) in terms of mantle wedge flow with emphasis on the trench-parallel component and (ii) in terms of temperature along the plate interface by means of maps and depths-temperature path at the interface. We show that the effect of the trench curvature on the geotherm is substantial.



4. NWO-GO Post-doc

Three-dimensional thermal convection in a spherical shell with a free surface. We use an incompressible and isoviscous Rayleigh-Bnard thermal convection benchmark at infinite Prandtl number in a spherical shell to compare the state-of-the-art finite element code ASPECT with the previously benchmarked numerical code CitcomS.
POSTER Jeanniot et al.