Geodynamics modelling at the Universiteit Utrecht

Introduction

Understanding the coupling between lithospheric/crustal dynamics and mantle processes, studying the Earth or Mars, or unraveling the spatial and temporal complexity of the mediterranean subduction by means of numerical modelling requires versatile and efficient codes.

The Mantle Dynamics group of the Utrecht University use a variety of numerical codes taylored to address the research questions being investigated. Some are commercial (e.g. SEPRAN), some are open source (ASPECT), some are used in collaboration with other universities (TERRA, PARODY-JA), and some have been developed in Utrecht in the past three years (ELEFANT). Our codes are state-of-the-art in terms of numerical algorithm, parallelisation, and the nonlinear physics that is modelled. We hereby briefly showcase results of ongoing work obtained with these tools.

NAC Conference contributions:

- C. **Blom**, Numerical modelling of the effect of mantle phase transitions on lithospheric and crustal processes
- L. **Cornelis**, The influence of elasticity in the lithosphere on subduction evolution, a numerical study
- M. **Chertova**, Mantle flow influence on the evolution of subduction systems, poster.
- M. **Drummond**, The effect of giant impactors on the magnetic field energy of an early Martian dynamo
- M. **Fraters**, Toward coupling deep driving processes to surface evolution in the Caribbean region
- A. **Glerum**, 3D instantaneous dynamics modeling of present-day Aegean subduction
- G. **Harms**, Numerical modelling of salt diapirism during thin-skinned extension
- A. **Lavecchia**, Lithosphere erosion and breakup due to the interaction between extension and plume upwelling
- A. **Plunder**, Subduction obliquity as a prime indicator for geotherm in subduction zone
- C. **Thieulot**, this poster.

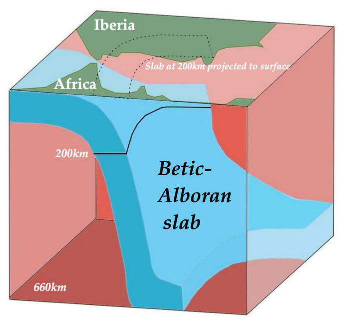
SEPRAN

3-D numerical modelling of subduction evolution of the western Mediterranean region

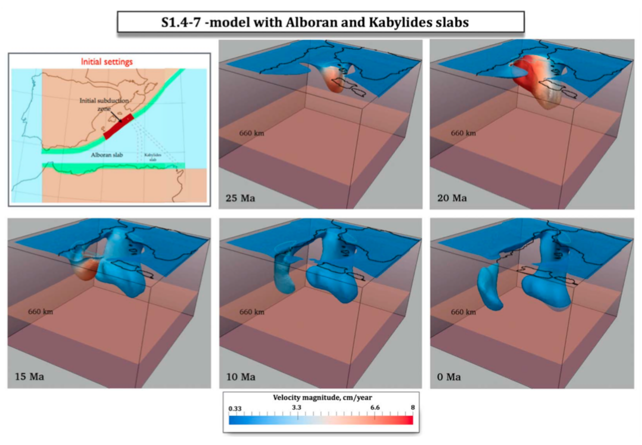
The extended SEPRAN code allows for 3D numerical modelling of the evolution of natural subduction zones. We have implemented and tested this code for the evolution of the western Mediterranean region. At present, two investigations have been performed based on the initial geometrical and numerical settings for this region:

- Modelling of the evolution of the western Mediterranean region based on different tectonic reconstruction scenarios and their initial subduction zone settings. From a wide range of experiments we have concluded that only one proposed reconstruction scenario is successful in predicting present day mantle structure of the region and matches first-order temporal constraints on slab evolution.

-The role of global plate tectonic for the modelling of natural subduction zone. Four different absolute plate motion frames were tested. All motion frames results in distinctly different 3D subduction evolution showing a critical sensitivity of slab morphology evolution on absolute plate motions adopted.



cartoon interpretation of the RGB-slab following Spakman and Wortel 2004.

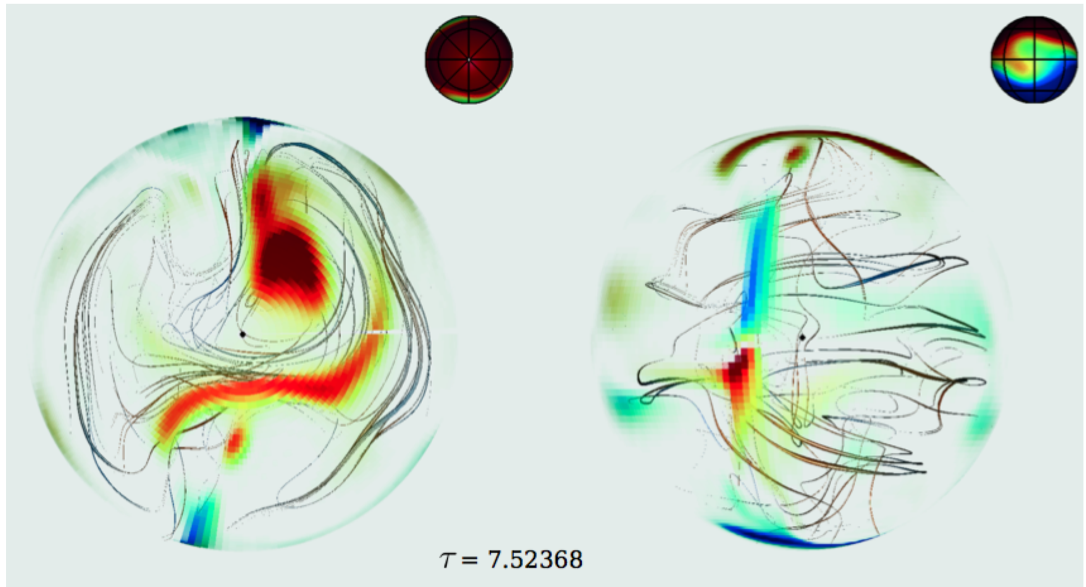


Evolution of subduction model from Chertova et al., JGR, 2014.

Chertova et al., NAC poster

PARODY-JA

We investigate the influence of giant impacts on the early Martian dynamo using the numerical dynamo modelling code PARODY-JA. We hypothesize that the input heat from a giant impact will decrease the total heat flux at the CMB through mantle heating, leading to a decrease in the Rayleigh number of the core.



Drummond et al, NAC poster

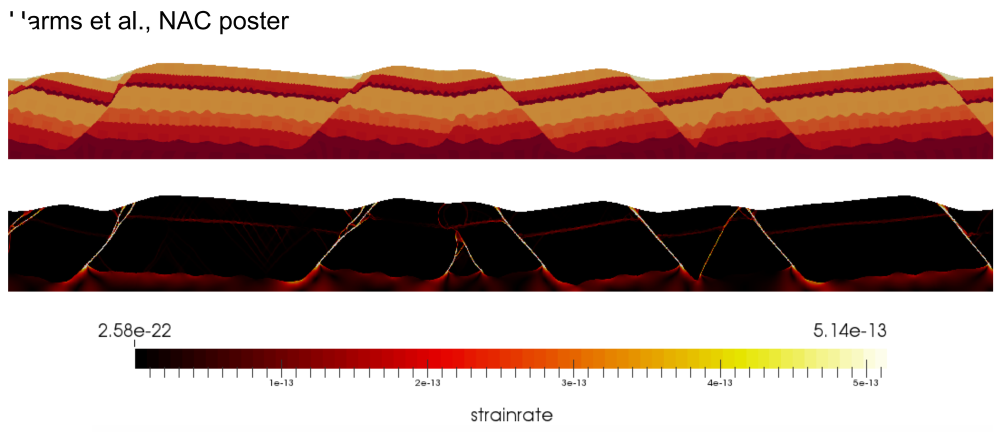
ELEFANT

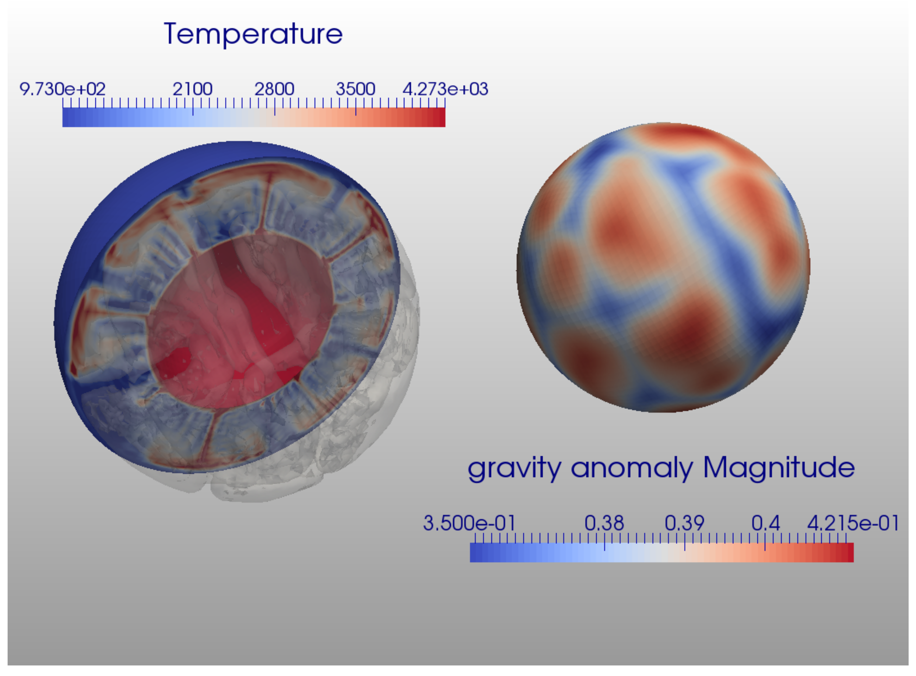
www.cedricthieulot.net

- Finite Element Method code
- Two- and three-dimensions
- Cartesian, cylindrical, spherical geometries
- Incompressible flow
- Thermo-mechanically coupled
- ALE formulation -> large deformation
- Mixed or penalised formulation
- (stabilised) Q1P0 element
- Precond CG or Uzawa outer iterations
- Direct solver (MUMPS) or CG inner solve
- simple diagonal preconditioners
- particle-in-cell material tracking
- Rudimentary surface processes
- Boussinesq & Extended Boussinesq approximation
- Built-in post-processing & visualisation
- viscous-plastic nonlinear rheologies
  (diffusion & dislocation creep, MC yield criterion)
- strain weakening & softening
- passed more than 30 benchmarks

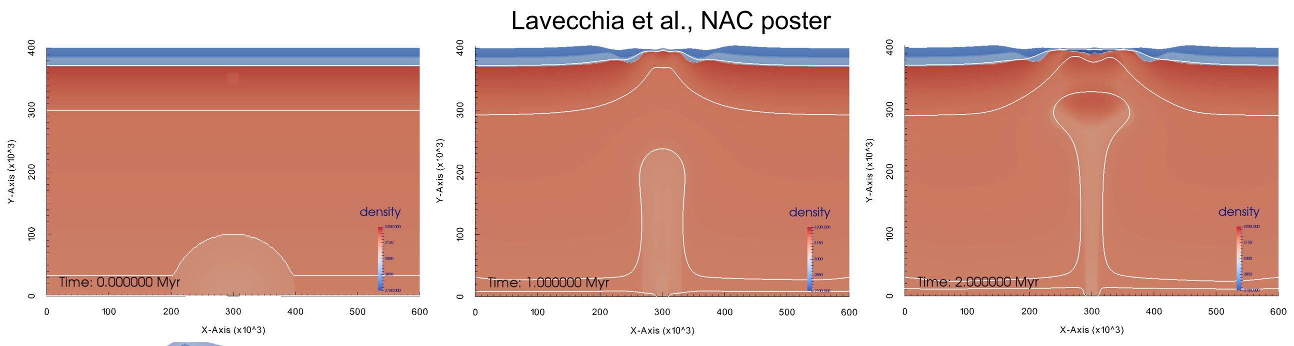
Current work:
- elasticity
- conformal mesh refinement
- Picard/Newton nonlinear iterations
- Melting algorithm

Harms et al., NAC poster

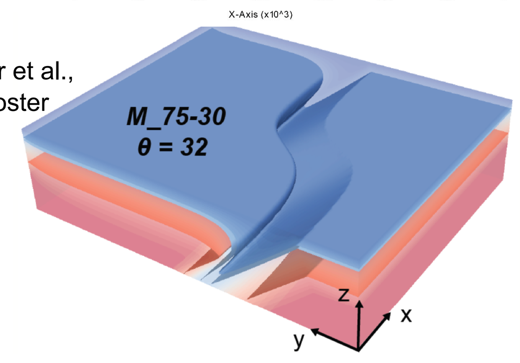


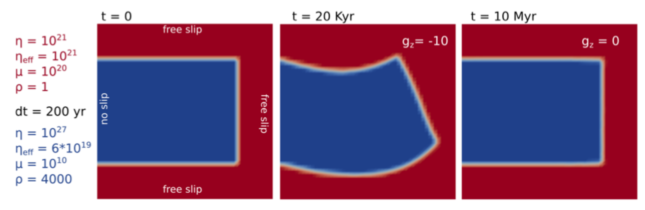


Lavecchia et al., NAC poster

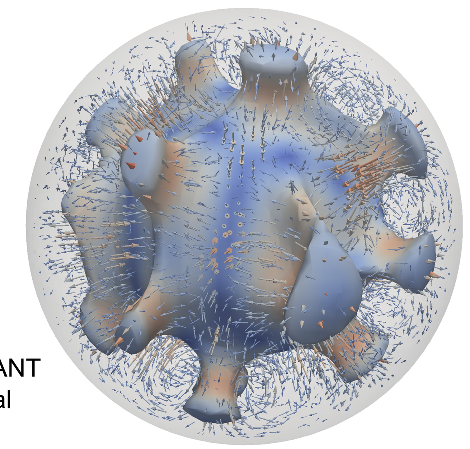


Plunder et al., NAC poster

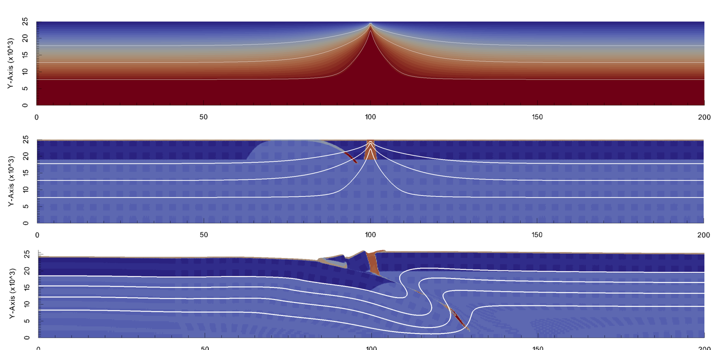




Cornelis et al., NAC poster



ELEFANT manual



subduction initiation at ridge

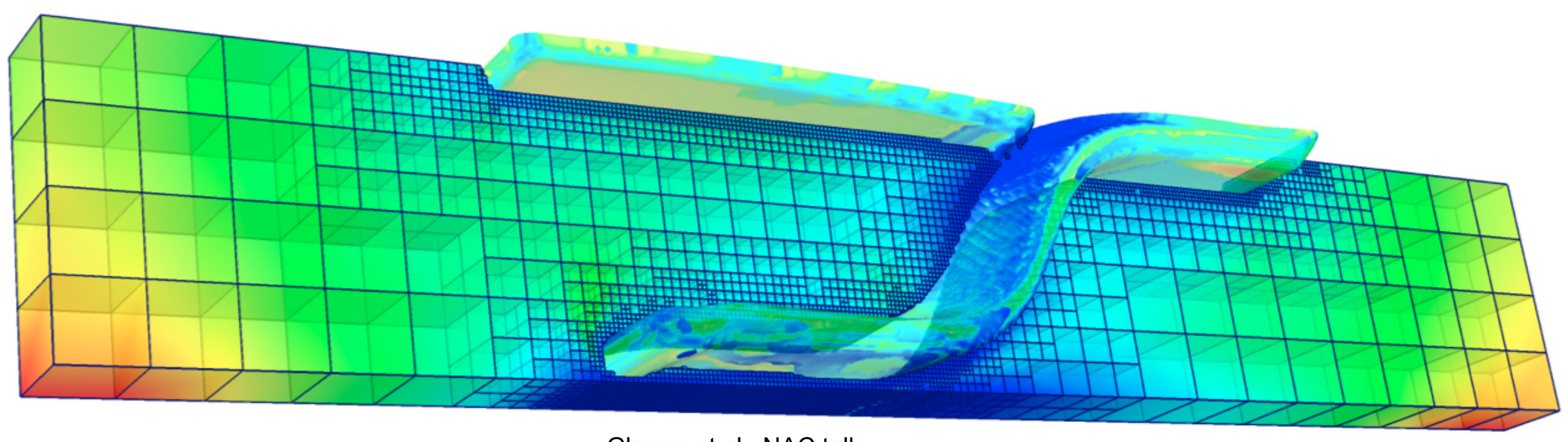
Maffione et al., G[3], 2015

ASPECT

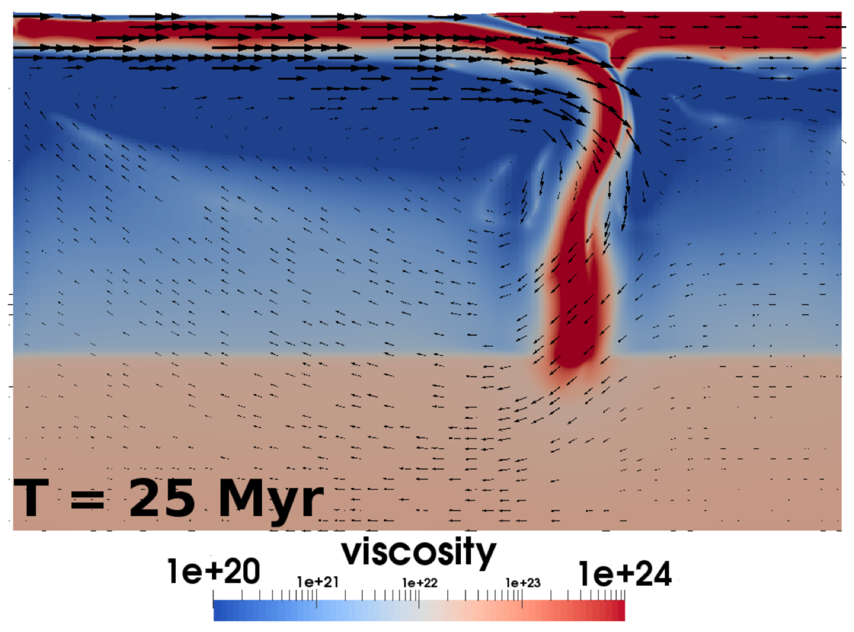
https://aspect.dealii.org/

- Finite Element Method code
- Two- and three-dimensions
- Adaptive mesh refinement
- Cartesian, cylindrical, spherical geometries
- Incompressible & compressible flow
- Thermo-mechanically coupled
- ALE formulation -> large deformation
- Mixed formulation
- Q2Q1 or Q2P1 element
- Trilinos massively parallel iterative solver
- compositional field material tracking
- Built-in post-processing & visualisation
- viscous-plastic nonlinear rheologies
  (diffusion & dislocation creep, MC yield criterion)
- open source code
- passed more than 15 benchmarks
- Melting

Current work:
- elasticity
- open boundary conditions
- Picard/Newton nonlinear iterations

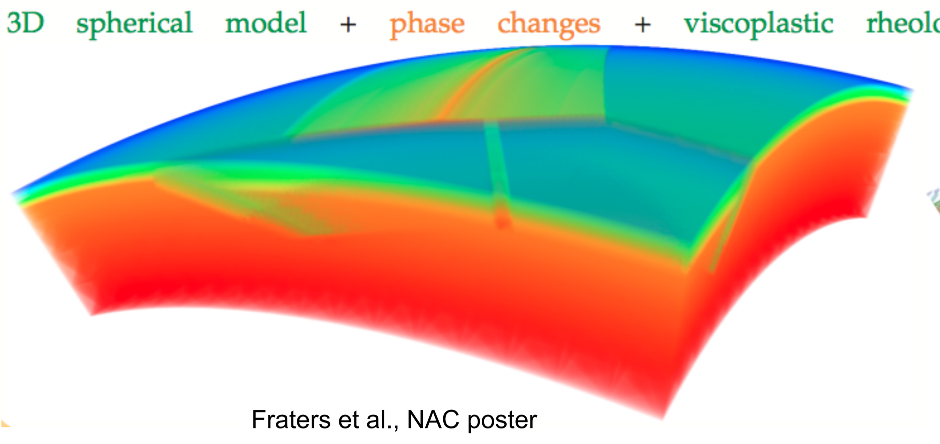


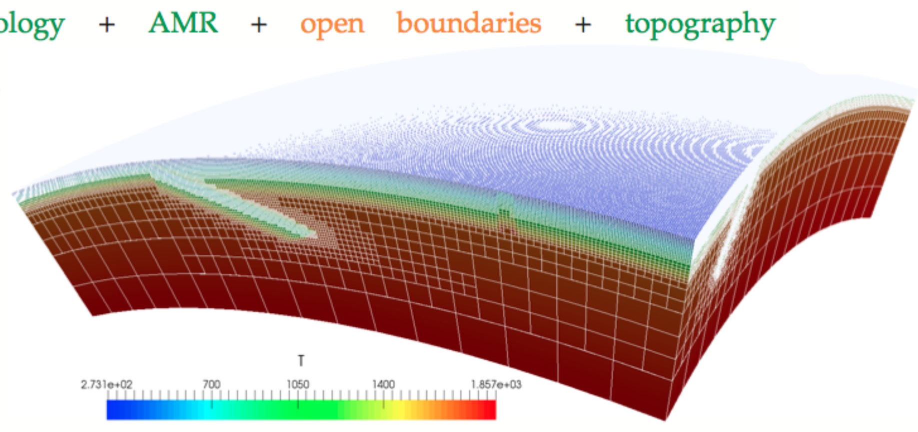
Glerum et al., NAC talk



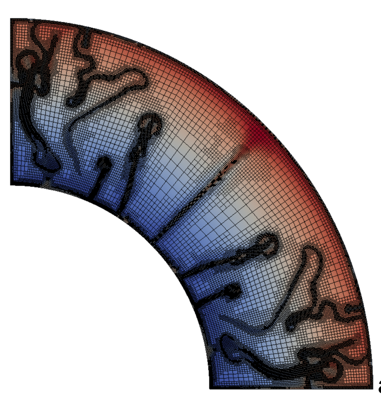
Blom et al, NAC poster

3D spherical model + phase changes + viscoplastic rheology + AMR + open boundaries + topography





Fraters et al., NAC poster



aspect manual