[simula . research laboratory]

Lithospheric Modelling
Research Directions at Simula

Stuart R. Clark and Are Magnus Bruaset
Simula Research Laboratory
Snarøya, Oslo, Norway

Subduction Models

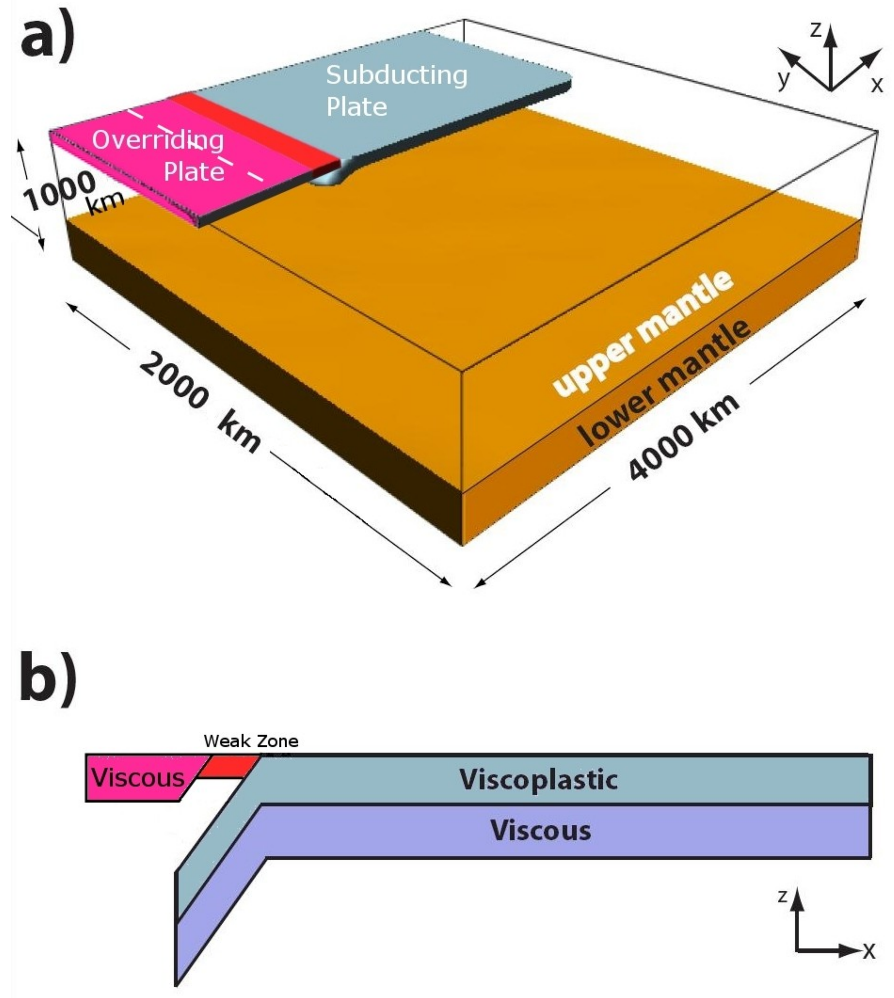


Fig. 1 (above). Initial model setup, showing the overriding plate in pink, the weak zone in red and the subducting plate in grey-blue (visco-plastic top layer) and purple (viscous lower layer). (a) 3D representation of the setup showing the region of computation. The upper mantle is transparent and goes to 670 km depth, while the lower mantle is only included until 1000km depth and is displayed in orange. The dashed line indicates the location of the ridge included in some models. (b) A cross-sectional representation of the two plates and island arc (weak zone).

Subduction Zone Modelling

- Density-driven (isothermal) model: $-\nabla p + \nabla\left(\eta\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right) + \Delta\rho g\hat{z} = 0$
- Brittle subducting plate rheology, following Byerlee's Law: $\tau_y = \tau_o + \mu_o g\rho z$
- A weak interface between plates
- An overriding plate

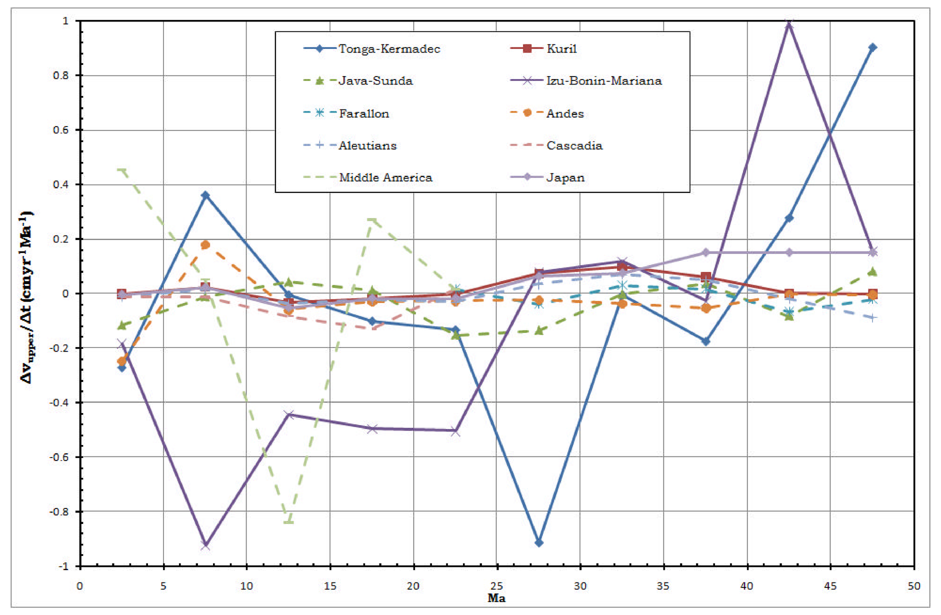


Fig. 2 (above). Changes in average overriding plate velocity at the trench for major subduction zones since the Early Eocene (Clark et al., 2008). Dashed lines indicating subduction zones without back-arc basins, solid lines are those with. Explaining these velocity variations in terms of far-field forces, interaction between the overriding and subducting plates and mantle traction remains a challenge.

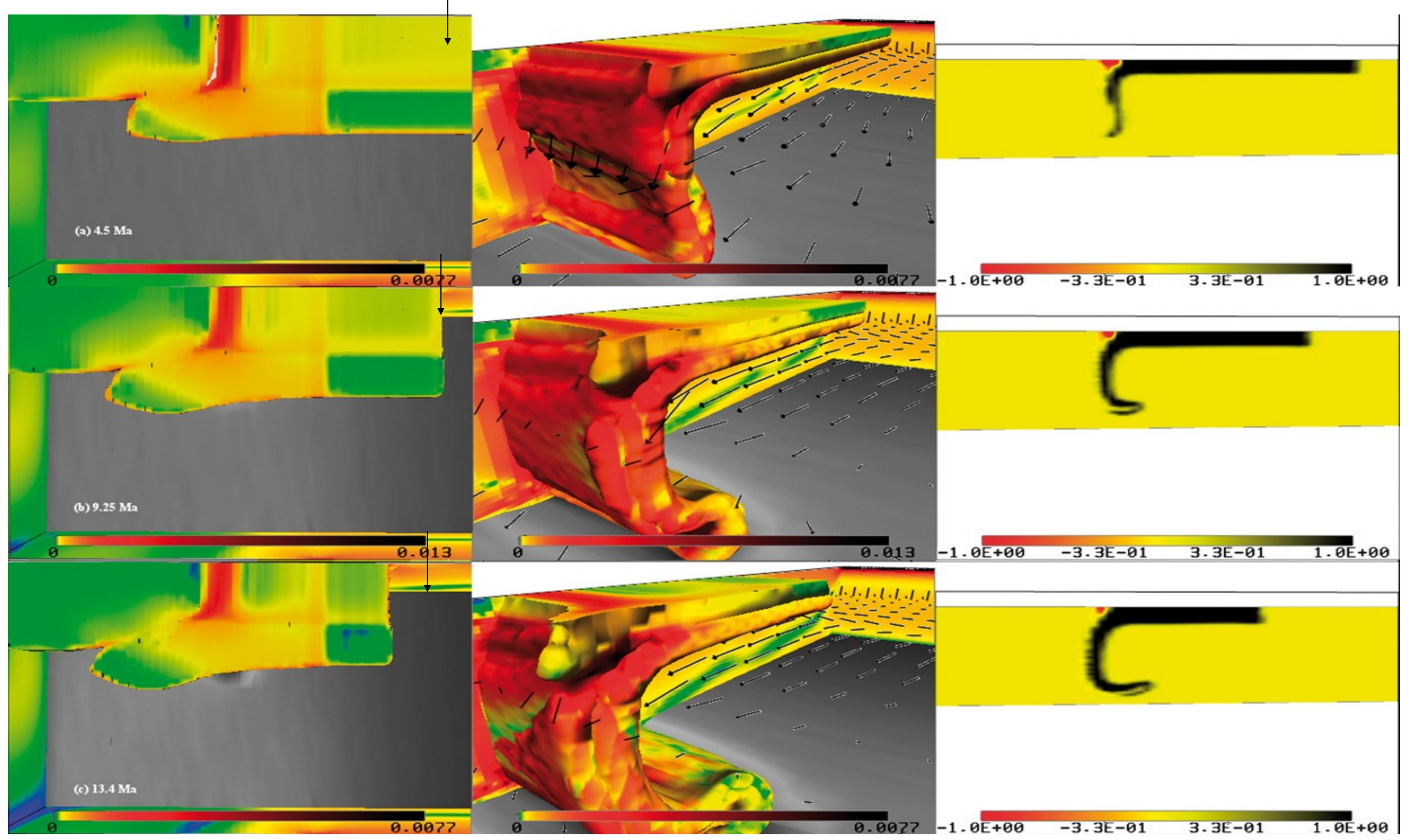


Fig. 3 (above). The left frame is the dimensionless strain rate seen from above, including a view of the side plate which is removed for clarity in the other plots. The dashed line in the left and centre frames shows the location of the axis of symmetry. The centre of the trench is marked with a dot labelled C in the centre view. The centre viewport is a perspective view of the dimensionless strain rate, looking only at the subducting plate. Velocity vectors show direction of flow at 200 km depth. The right frame is a view of the cross-section through the middle of the plate (at the boundary of the computational domain) of the dimensionless buoyancy of the subducting plate and the weak zone only (overriding plate removed). The transition zone at 670 km is shown as grey in the left and centre windows and in white in the right cross-section. Figure is from Clark et al., 2008.

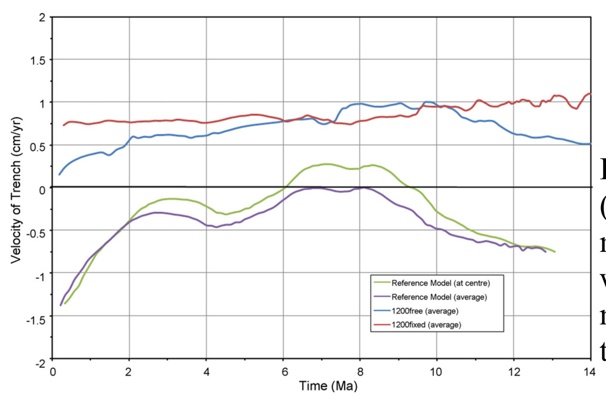


Fig. 4 (left). Trench motion for three models, one with the subducting plate's tail free (blue), fixed (red) and pushed (green: centre, purple average), which corresponds to the model shown in Fig. 3. A model with a pushed edge, such as is found in the Pacific plate with a ridge-push force as the boundary force, replicates some of the episodicity found in nature, with overriding plate motion varying between ±0.5 cm/yr. As the centre of the trench first advances (a), then retreats (b), then advances again (c).

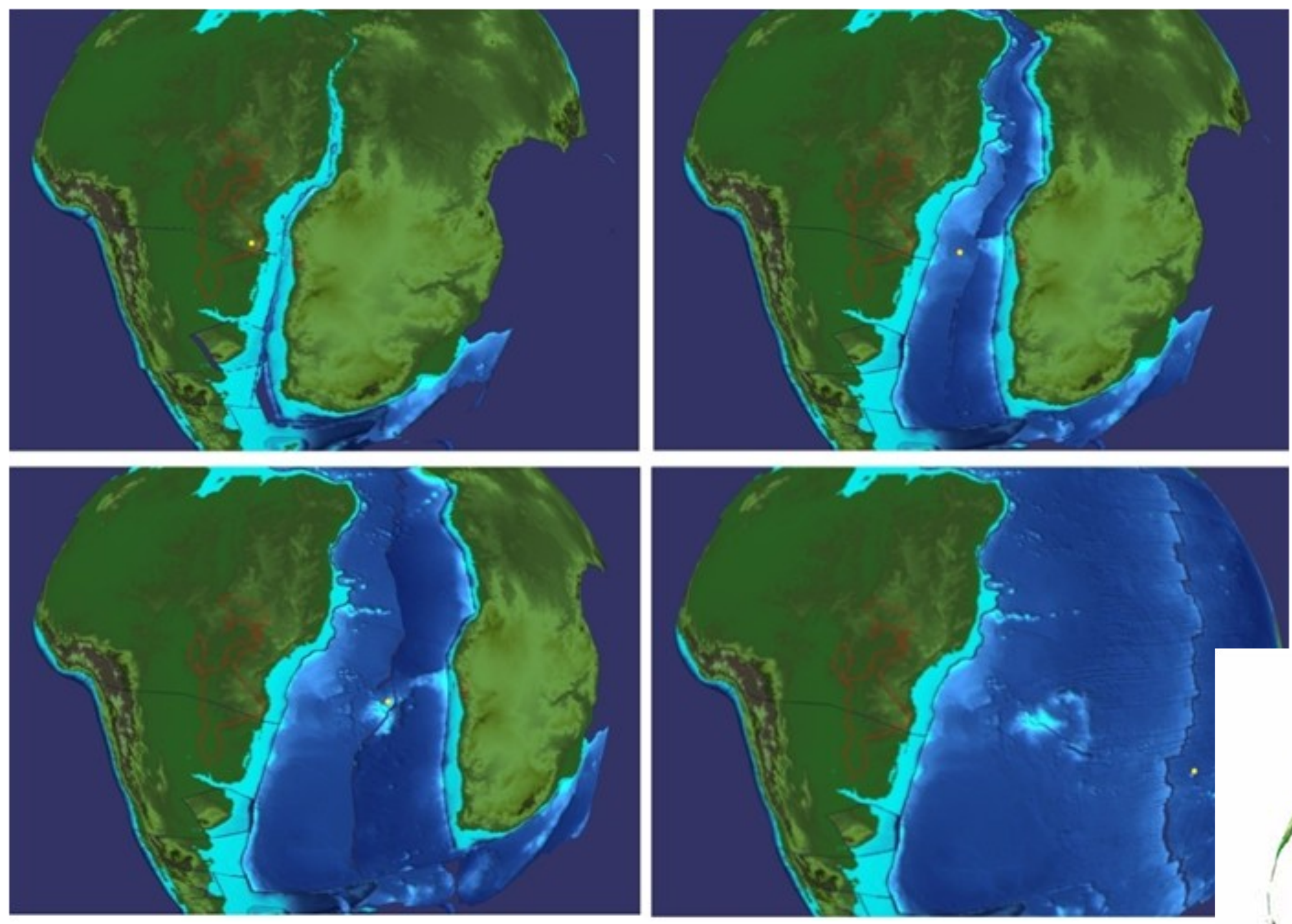
Scientific Computing at Simula

Scientific computing at Simula falls into three main categories: numerical methods; development of generic software tools; and applications to problems in science and technology.

The Computational Geosciences Project at Simula carries out fundamental research and geoscience-related software development with a focus on industry-collaboration.

We are recruiting geophysicists at PhD and postdoc levels! See www.simula.no/jobs

Visualising Geophysical Data



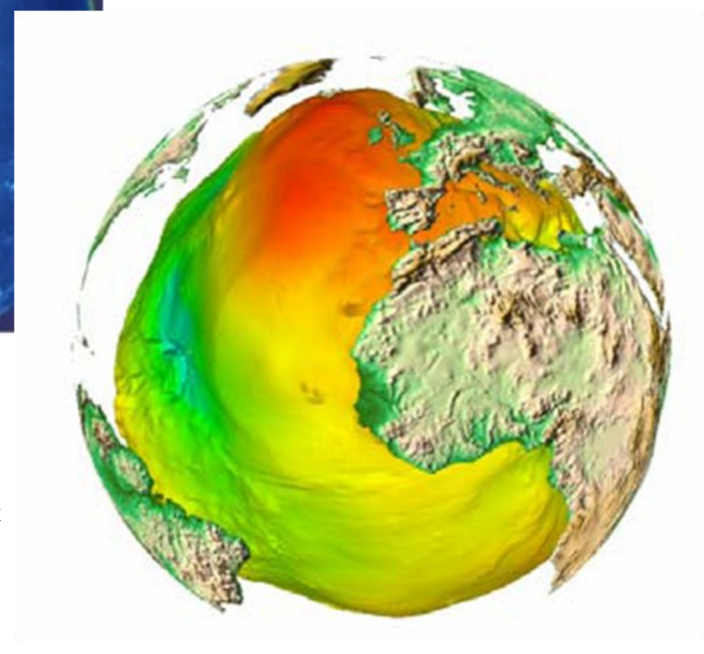


Fig. 5. *4D Lithosphere Model* is a software for the interactive manipulation of grid based data, including performing plate reconstructions, grid overlays, and grid-based calculations. Using the *4D Lithosphere Model* to interactively display, reconstruct and perform grid-based calculations is a key feature of geodynamics at Simula. **a) (above).** Reconstructed present-day bathymetry and topography masked by the age-grid of Muller et al. (2008). **b) (right)** Geoid overlain by topography displayed using 4DLM

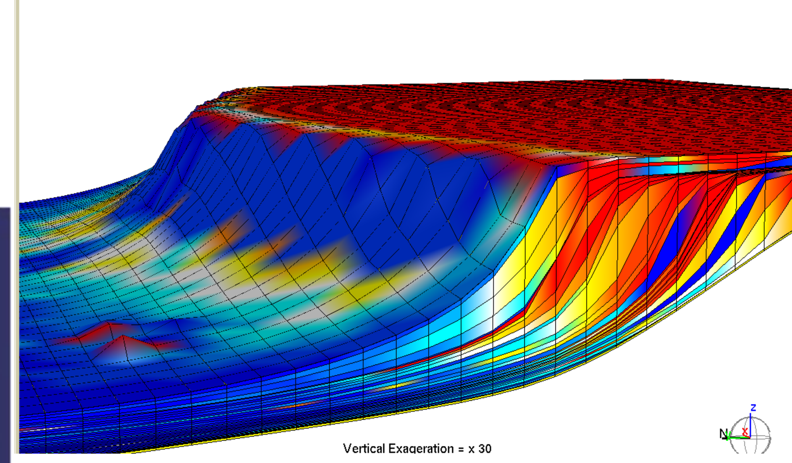


Fig. 6 (above). Pro-grading delta, showing sand fraction (red high, blue low) from DIONISOS, a sediment transport program, which handles gravity and wave diffusion as well as long-range transport and tectonic uplift or subsidence.

Future Work: Models of Rifting with Sediment Transport

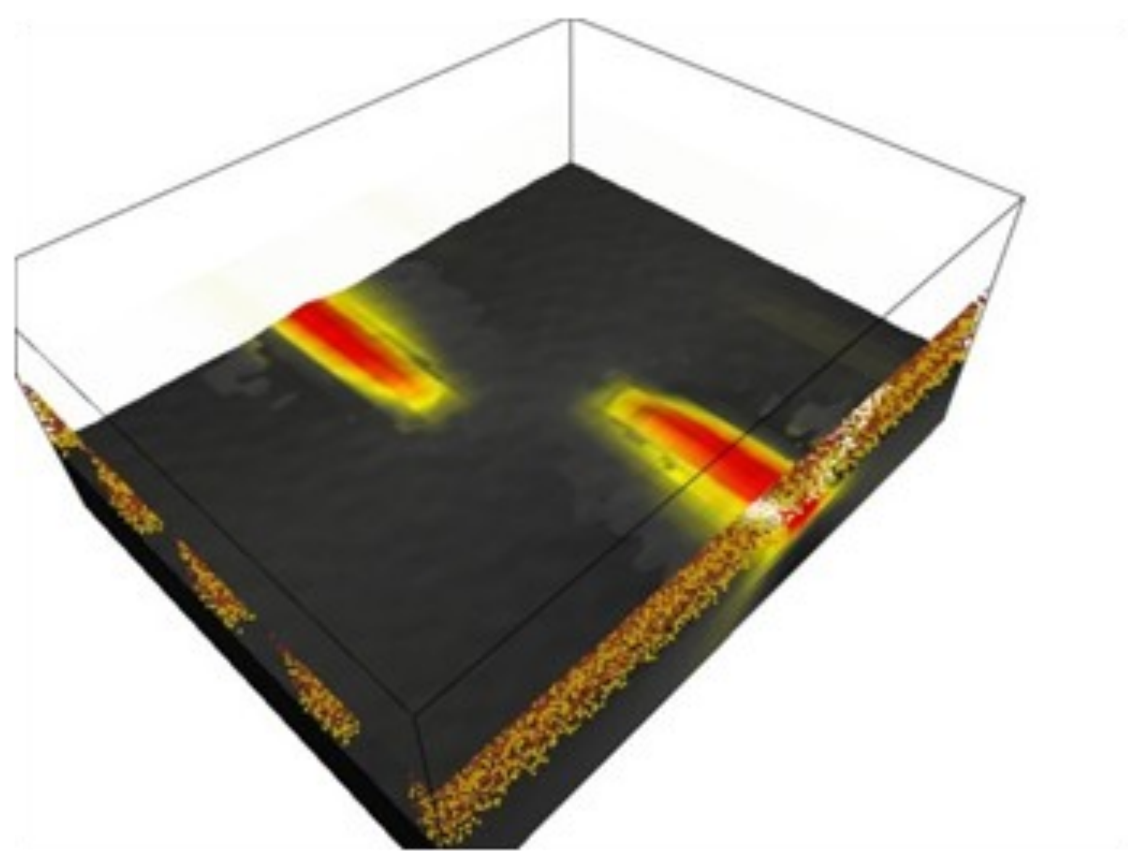


Fig. 7 (above). An Underworld/GALE rift model, with two offset rifts and a free upper boundary layer. Diffusion-based sediment transport can be incorporated directly or more robust sediment transport codes (e.g. DIONISOS) can be used to measure sediment flux.

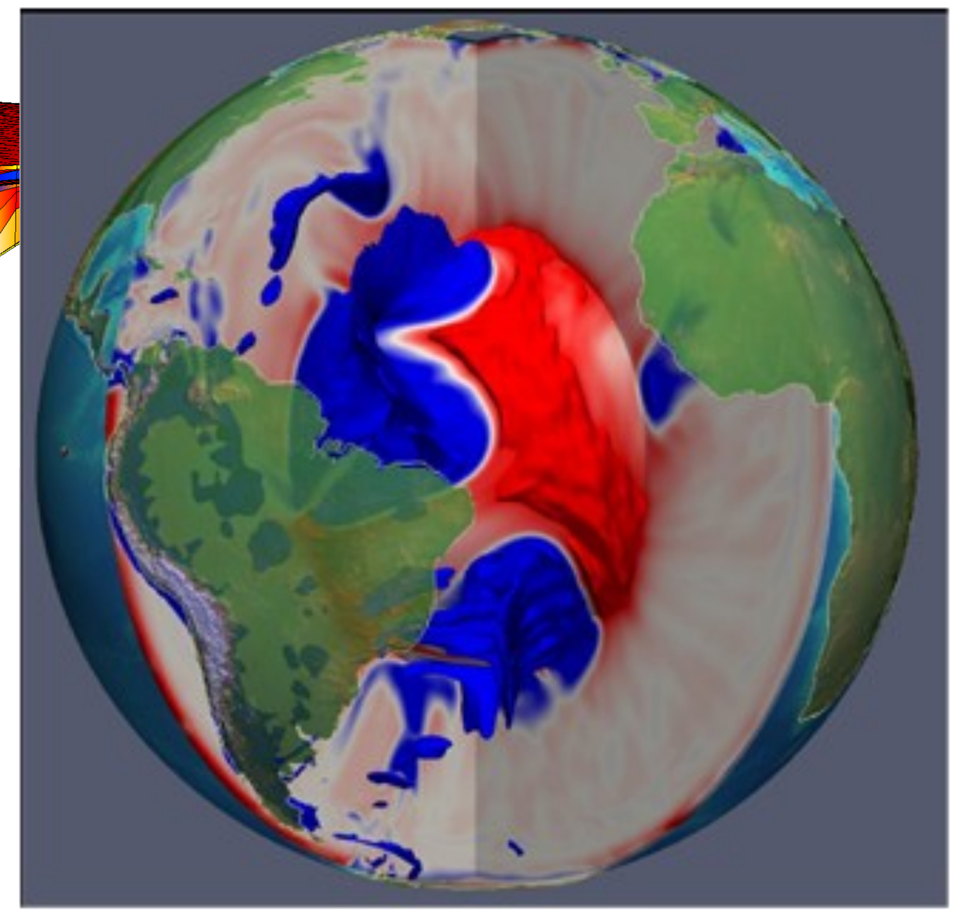


Fig. 8 (above). Generated thermal anomalies from a model with plate histories: blue representing cold anomalies from subducted slabs in the mantle and red representing hot upwellings.

We are collaborating with LMU, Munich, to incorporate Mantle Circulation Models (e.g. Bunge, 2005) Time-dependent mantle circulation from these models will be used as a boundary condition for regional lithospheric models.

Acknowledgement

Simula Research Laboratory works closely with StatoilHydro, our industry partner, by drawing on their expertise, providing software solutions and making basic research industry-relevant. The research outlined here is funded by StatoilHydro.

StatoilHydro