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Role of rheology in reconstructing slab morphology in global mantle models

Léa Bello (1), Nicolas Coltice (1,2), Paul Tackley (3), and Dietmar Müller (4)

(1) Laboratoire de Géologie de Lyon, CNRS - UCBL- ENS Lyon, France (lea.bello@ens-lyon.org), (2) Institut Universitaire de France, Paris, France (coltice@univ-lyon1.fr), (3) Institut für geophysik, ETH Zurich, Swizerland, (paul.tackley@erdw.ethz.ch), (4) Earth Byte, The University of Sydney, Australia (dietmar.muller@sydney.edu.au)

Reconstructing the 3D structure of the Earth's mantle has been a challenge for geodynamicists for about 40 years. Although numerical models and computational capabilities have incredibly progressed, parameterizations used for modeling convection forced by plate motions are far from being Earth-like. Among the set of parameters, rheology is fundamental because it defines in a non-linear way the dynamics of slabs and plumes, and the organization of the lithosphere. Previous studies have employed diverse viscosity laws, most of them being temperature and depth dependent with relatively small viscosity contrasts.

In this study, we evaluate the role of the temperature dependence of viscosity (variations up to 6 orders of magnitude) on reconstructing slab evolution in 3D spherical models of convection driven by plate history models. We also investigate the importance of pseudo-plasticity in such models. We show that strong temperature dependence of viscosity combined with pseudo-plasticity produce laterally and vertically continuous slabs, and flat subduction where trench retreat is fast (North, Central and South America). Moreover, pseudo-plasticity allows a consistent coupling between imposed plate motions and global convection, which is not possible with temperature-dependent viscosity only. However, even our most sophisticated model is not able to reproduce unambiguously stagnant slabs probably because of the simplicity of material properties we use here. The differences between models employing different viscosity laws are very large, larger than the differences between two models with the same rheology but using two different plate reconstructions or initial conditions.