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Numerical investigations of plate bending in free subduction

Loïc Fourel[1], Saskia Goes[1], Gabriele Morra[2], Fabio Capitanio[3]
[1]*Department of Earth Science and Engineering, Imperial College of London, UK*
[2]*School of Earth and Environmental Sciences, Seoul National University, South Korea*
[3]*School of Geosciences, Monash University, Australia*
l.fourel@imperial.ac.uk

Plate bending at the trench has been suggested to be a major source of energy dissipation in subduction. Understanding how bending processes control subduction dynamics is therefore critical to estimate the energy available for global mantle convection. Geophysical observations of slab dip angles and radii of curvature from earthquake locations and tomographic images have been used to estimate the amount of energy dissipated via bending in subduction zones, by comparison with bending theory or models. The amount of energy dissipated in bending a slab into an observed geometry depends on slab rheology and subduction velocity. Velocities are well constrained by plate-motion reconstructions. However, estimates of how much of the slab's potential energy is used up in bending range from 10-20% to close to 100%, depending on rheology and the effective strength in bending. Thus we need further understanding of how plate bending dissipation varies with slab parameters. We investigate here how rheology as well as interaction of the slab with a 660 km discontinuity will affect bending.

We carried out finite-element numerical simulations of a free subduction system using a viscoelastic plate. Mantle drag forces are implemented so that they take into account the 3D effects of the flow. An increase of density is used to model the 660 km discontinuity. The rheology, the buoyancy, as well as the dimensions of the down-going plate are varied to characterize bending mechanisms. This wide range of parameters allow us to investigate both retreating and advancing modes of subduction, compatible with regime diagrams derived in other studies. Thin viscous sheet theory shows that the appropriate length scale for bending is the length over which the rate of change of curvature varies significantly (Ribe, 2010). Many previous studies considered the bending length to be proportional to the radius of curvature, but this is only true over part of the range of bending. Our models satisfy the scaling relations established by Ribe (2010), however, we find that the 660 km discontinuity forces bending length to be shorter than predicted by viscous slabs falling in an infinite medium.

References

Neil M. Ribe (2010), Bending mechanics and mode selection in free subduction: a thin-sheet analysis, Geophysical Journal International, 180, Issue 2, 559-576