Solid Earth Discuss., 4, C384–C387, 2012
www.solid-earth-discuss.net/4/C384/2012/

Solid Earth
Discussions

SED

4, C384–C387, 2012

Interactive
Comment

Interactive comment on "Subduction to the lower mantle – a comparison between geodynamic and tomographic models" *by* B. Steinberger et al.

Anonymous Referee #2

Received and published: 6 September 2012

General evaluation:

This paper evaluates how well geodynamic models can help to understand tomographically imaged seismic structure of the mantle. Updated plate motions, and some dynamic improvements (allowing lateral slab movements and including deep mantle dense chemical piles) improve the fit somewhat over models the authors previously tested. Still only the longest wavelength seismic structure (on scales of a few 1000 km) is reasonably reproduced. The authors nicely document what aspects of the observed (slab) structure are matched and mismatched. And they highlight the question what additional dynamics would be required to substantially improve the match with seismically imaged structure.

The models used build on many years of research by the coauthors. The originally

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

simple Stokes flow calculations have gained a lot more Earth-like characteristics with the Steinberger & Torsvik (2012) modifications where energy equation and chemical density advection were added. The composite tomographic model SMEAN has been investigated in quite a number of previous studies by Becker and coworkers and captures the main resolved characteristics of S tomography. Although P tomography images slabs better, P-wave coverage does not provide much resolution for the rest of mantle structure. The plate motion history is the most recent version of a long-standing comprehensive effort by Torsvik and coworkers. The paper is well written, concise and has good figures. This will most likely be a well-read and referenced paper. I recommend only some minor revisions.

One of the main limitations of the study is that the dynamic models used do not include lateral viscosity variations. This has the effect that slabs are too easily deformed, and upwellings are not narrow and mobile enough. The models also only partially include phase-transition effects that may delay slab flow through the transition zone. Another important limitation is that the correlation with seismic tomography does not account for seismic resolution, which varies with depth, laterally and with wavelength, in a highly non-linear fashion because tomographic models jointly invert different wave types. These limitations are acknowledged by the authors.

Main comments for revision

(1) In the abstract you write that compared to previous models correlation is improved significantly. But is the improvement significant? For the model shown in most of the figures st12dens-2, the averaged correlations <r8> and <r20> are 0.35 and 0.21 compared with 0.30 and 0.21 in Steinberger (2000), and 0.33 and 0.18 for a simple slab sinker model. The difference between the last two is discussed as being not significant and the difference between the first two is. . .The models with the highest correlation values, stdens-7 and slabplume2, present useful tests, but are not reasonable dynamic alternatives. I understand that these averaged correlation values may not represent the best characterization of a match. Still maybe one should conclude that all the

SED

4, C384–C387, 2012

Interactive Comment

updates in the models constitute rather small improvements in terms of fitting global tomographic mantle structure.

(2) The model setup is hard to understand without reading Steinberger and Torsvik. Some more explanation is warranted, starting with a summary of the main model features and limitations (rather than the detailed updates of the subduction model)

(3) Visual comparison with tomography (Fig 4 and 5) is quite tricky because of the very long wavelength character of the tomographic model compared with the dimensions of slabs. This comparison may also not be very representative, because resolution of features with wavelengths less than or close to the minimum wavelength resolved in the tomographic models is especially nonlinear. Visual comparison should be easier with models like those of Li et al. (2008) and Bijwaard et al. (1998) even if their average correlation is worse than with SMEAN, because the focus of the visual comparison is on slabs, which are better resolved in these models. It would be a good addition to show cross sections from for example the Li et al. (2008) in Fig. 5 to strengthen the interpretations of this figure.

(4) In the discussion, lateral viscosity variations are suggested as a possibly important factor to improve the geodynamic-tomographic model match. However not mentioned is that lateral viscosity variations may lead to overestimated sinking velocities as weaker slabs can thicken more and hence sink faster. Thus stronger slabs may sink slower without the need for a higher lower-mantle viscosity.

Small comments for revision

(a) Some discussion of the implementation of phase transition effects would be warranted as the effect of the transition zone is a candidate mechanism for better reconciling tomography and geodynamic models. What aspects are not captured by your approach? Could more complex interaction (and hence more stalling and lateral movement in the transition zone be expected with other (more complete) approaches?

SED

4, C384–C387, 2012

(b) Does conductivity vary with depth as well? How big an effect is neglecting lateral heat diffusion? Can this assumption be justified? How large is basal heat flow and how does it affect CMB temperature?

(c) Would correlation values change if warm low-density anomalies were scaled to larger anomalies than cold high-density anomalies to account for the non-linear seismic sensitivity to temperature?

(d) Section 3.3 gets confusing with the different model types. Possibly a small table explaining st12dens-1, -2, -7 and also assigning a number to the model in panel 6b where no thermochemical piles are included might help. What is the correlation value for the model in panel 6b?

(e) Labeling figure panels as a,b,c etc would further facilitate the discussion.

Interactive comment on Solid Earth Discuss., 4, 851, 2012.

SED

4, C384–C387, 2012