Comment on egusphere-2022-1172
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In this paper, a mantle convection simulation is used to compute true polar wander (tpw) and the resulting heat flux pattern at the core-mantle boundary. I think the main shortcoming of the paper is that the computed geoid (at least when compared to the present-day geoid) has much too large amplitude and is therefore probably very unrealistic. Since tpw depends on the geoid, the true polar wander in relation to the motion of mantle density anomalies is probably likewise unrealistic.

As the authors note, the geoid is caused by both internal mantle density anomalies and deflection of the surface and core-mantle-boundary. In reality, these contributions largely compensate each other, and the remaining geoid is rather small (amplitude of about 100 m), whereas in their model it appears that they don't nearly as closely compensate each other, hence the computed geoid has much large amplitude of several km. In particular I find the km-scale geoid anomalies associated with continents unrealistic. The continent-ocean topography is largely compensated at the Moho, hence this contribution to topography due to crustal thickness variations (correlated with continental distribution) should be only a few meters.

Depending on mantle viscosity structure and depth of the anomaly, either the internal density anomalies or the boundary deflection can be dominant. Previous work has shown that, in order to achieve a good fit to the geoid, a strong increase of viscosity with depth is required, which then causes that high-density slabs in the upper mantle cause a positive geoid, whereas, at the largest scales, they cause a negative geoid in the lower mantle, and it is the other way round for low-density materials at a similar scale. In particular, LLSVPs are associated with geoid highs. In contrast, the computed relation is very different in the model presented here, with piles (corresponding to LLSVPs) being associated with low geoid, and slabs always with high geoid. In the Earth, the LLSVPs remained at equatorial positions (at least for the past 200-300 Myrs); subduction zones (such as in the west and east of the Pacific) tend to also be near the equator, whereas regions where slabs have sunk to the lower mantle (such as the Phoenix plate, close to Antarctica) tend to be in polar regions. In contrast, in their model, slabs and continents tend to get shifted to the equation by tpw, whereas piles get shifted to the poles. That is
why it doesn't matter that, as they write, tpw only depends on the geoid pattern (not amplitude) because this pattern, in relation to subduction history and continent location, is probably also wrong. Accordingly, the association with core heat flow pattern is likely also wrong: In their model, they obtain positive heat flux anomalies near the equator, whereas in the Earth, piles / LLSVPs which are associated with negative heat flow anomalies tend to remain near the equator.

Of course, the geoid is only known for present-day, and in the past, the mantle viscosity structure, and hence the relation of geoid and density anomalies, could also have been very different. But at least there are indications, that for the past 200-300 Myrs the LLSVPs (which the piles in their model are meant to correspond to) have remained in equatorial positions, therefore likely have corresponded to geoid highs. Although theoretically possible, there is no indication that their model is realistic for any time in the past. Hence, it is most likely that this is just a numerical exercise with probably no relevance to the real Earth and thus no scientific value.

However, I also think that the flaws in the paper are relatively easy to fix by changing the radial mantle viscosity structure, and in general, the paper is quite well-written already. At the moment, mantle viscosity, especially its depth- and temperature dependence, is not even explained, and I think it should be. I would therefore suggest that a resubmission is encouraged, once the authors have managed to obtain a more realistic geoid amplitude, and more realistic relations to slabs (positive geoid contribution in the lower mantle, negative in lower mantle), piles (positive) and continents (much lower-amplitude positive).