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The influence of post-perovskite strength on mantle thermo-chemical evolution

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A range of geophysical and mineral physics considerations strongly support the presence of the post-perovskite phase in the lowermost mantle. Recent studies point to the possibility of strong viscosity differences between the perovskite and the post-perovskite phases. The magnitude and sign however of such a viscosity contrast remains debated, with studies supporting the idea of a weaker post-perovskite, while other suggest a stronger post-perovskite is also possible.

We have therefore investigated the influence of post-perovskite strength on Earth's mantle convective dynamics and stirring efficiency, using numerical experiments and simple analytical theory. We show that the viscosity of the post-perovskite phase can have a dramatic influence on mantle convective dynamics: weak post-perovskite enhances the destabilization of the bottom thermal boundary layer, increasing significantly the heat flux. This yields an increase in mantle temperatures that can be predicted using simple energy scalings. This increase in mantle temperature lowers viscosity, and enhances the convective vigor.

The stirring efficiencies measured in our numerical experiments show a significant increase with decreasing the post-perovskite strength. This observed influence is well reproduced by a simple chaotic mixing model.

By coupling this mixing model with a parameterized convection evolution, we find that the presence of weak post-perovskite can increase mantle convective stirring efficiency by at least one order of magnitude.

Our results suggest that the effect of post-perovskite strength on the thermal and chemical evolution of the Earth's mantle must be accounted for when interpreting surface observations such as heat flow data and the geochemical record.