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High vigour mantle convection simulations produce upwellings with Earth-like behaviour

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We have undertaken numerical models of mantle convection in spherical geometry at realistic Earth-like vigour - basal Rayleigh number 10ˆ8, internal heating Rayleigh number 10ˆ9. These computational demanding simulations were enabled by a new, validated, extension to the established mantle convection code TERRA which includes a radially variable-level multigrid. The models incorporated a lower mantle with a viscosity 40 times the upper mantle, with free-slip, isothermal boundaries. We discovered strong upwellings extending from the core-mantle boundary to the surface. The upwellings show a broad range of behaviour; some were fixed, others drifted at rates less than the surface velocity, some would die and others were born. This contrasts to earlier free-slip simulations which have shown just single behaviour of upwellings, either very stable upwellings, or sometimes in lower geometry highly time –dependent upwellings.

Assuming that hot-spots are the signature of mantle upwellings on Earth, one observes that they are nearly fixed or have a low velocity relative to each other. They can have a long but finite life span. Therefore in this context our current simulations are much more Earth-like than many previous simulations. They did not require the chemical layering of tank experiments to lower the migration velocity of upwellings, or introduce any major complications to destabilise the ultra-steady plumes of lower Rayleigh number spherical numerical simulations. This points to the requirement to be able to simulate the Earth's mantle at the appropriate Rayleigh number to observe Earth-like behaviour. If the mantle's chemical heterogeneity is limited largely to processes at the two boundaries and have limited dynamical effect, then these simulations support the need to fully investigate isochemical mantle models since they still have much

promise, at least in explaining the dynamics.