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Sources of mantle plume lateral motions in whole-mantle convection models with plate-like tectonics

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Mantle plumes have been widely used as a fixed reference frame in order to reconstruct the past motions of tectonic plates (e.g. Müller et al, 1993). However, some paleomagnetic and geochronological observations suggest that substantial relative motions between hotspots or clusters of hotspots can occur (e.g. Molnar and Stock, 1987, Tarduno et al., 2003, Konrad et al., 2018). Mechanisms explaining such lateral motions of mantle plumes remain debated and include: plume deflection by mantle wind (Steinberger and O'Connell, 2000), plume capture by a spreading ridge (Tarduno et al., 2009), or plume push by a slab (Hassan et al., 2016).

The aims of this study are to quantify the properties and relative motions of mantle plumes and to identify the sources of their lateral drift in a set of 3D-spherical models of mantle convection self-generating tectonic-like behaviour. In these models, fully-dynamic mantle plumes emerge and drift due to interactions within the convective system. We investigate the role of mantle and lithosphere dynamics on the behaviour of mantle plumes by varying the lithospheric yield stress, the depth-dependence of thermal expansivity and the presence of dense thermochemical provinces above the core-mantle boundary across a series of model cases.

All models feature surface topography, plate-size distribution and surface heat flow comparable to Earth. Model plumes are consistent with the temperature, buoyancy flux, heat flux, lifetime and pulses of activity of plumes inferred from geological and geophysical observations. Model plumes are almost insensitive to mantle wind and ascend quasi-vertically. 90% of model plumes move relatively to each other at speeds slower than 2 cm/yr, driven by slow entrainment by ambient lower mantle flow. 10% of model plumes drift at speeds between 2 and 15 cm/yr due to lateral pressure gradients at their base, induced by lower mantle slab push or the proximity of another plume conduit leading to plume merging.

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