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Resolving the Mantle Heat Transfer Discrepancy by Reassessing Buoyancy Flux Estimates of Upwelling Plumes

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The size and relative importance of mantle plumes is a controversial topic within the geodynamics community. Numerical experiments of mantle convection suggest a wide range of possible behaviours, from minor plumelets through to large scale, whole-mantle upwellings. In terms of observations, recent seismic tomographic models have identified many large, broad plume-like features within the lower mantle. In contrast, existing estimates of buoyancy flux calculated from plume swells have suggested that these upwellings transfer a relatively minor amount of material and heat into the uppermost mantle. Here, we revisit these calculations of buoyancy flux using a global map of plume swells based upon new observations of dynamic topography. Usually, plume flux is calculated from the cross-sectional area of a swell multiplied by either plate velocity or spreading rate. A key assumption is that plume head material flows laterally at or below the velocity of the overriding plate. Published results are dominated by contributions from the Pacific Ocean and suggest that a total of ~ 2 TW of heat is carried by plumes into the uppermost mantle. An alternative approach exploits swell volume scaled by a characteristic decay time, which removes the reliance on plate velocities. The main assumption of this method is that plumes are in quasi-steady state. In this study, we have applied this volumetric approach in a new global analysis. Our results indicate that the Icelandic plume has a buoyancy flux of $\sim 27 \pm 4$ Mg s^{-1} and the Hawaiian plume is $\sim 2.9 \pm 0.6$ Mg s^{-1}. These revised values are consistent with independent geophysical constraints from the North Atlantic Ocean and Hawaii. All magmatic and amagmatic swells have been included, suggesting that the total heat flux carried to the base of the plates is $\sim 10 \pm 2$ TW. This revised value is a five-fold increase compared with previous estimates and provides an improved match to published predictions of basal heat flux across the core-mantle boundary. If this higher estimate is correct, it suggests that upwelling plumes play a much more significant role in the transfer of heat through the Earth's mantle.