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Neotectonic Rates of Motion Between Hotspots

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Hotspots, sites of mid-plate or excessive volcanism, overlie plumes of hot rock that rise in the solid state from Earth's deep mantle. Estimated rates of lateral hotspot motion since Late Cretaceous time have been as low as ≈3 mm/yr to as high as ≈80 mm/yr. We focus on geologically current (i.e., neotectonic) motions because the precision and accuracy of relative plate motions in the MORVEL set of relative plate angular velocities (DeMets et al., 2010) are an order of magnitude greater than plate motion estimated for earlier time intervals. Prior efforts to estimate neotectonic relative motion between hotspots from trends of hotspot tracks found no significant difference from zero motion (i.e., they are consistent with fixed hotspots) and no useful upper bound on the rate of motion (e.g., Minster et al., 1974; Gripp & Gordon, 1990, 2002).

Our recent analysis builds on methods to objectively estimate the uncertainty of hotspot trends. We use the uncertainties estimated by Gripp & Gordon (2002) and by Wang et al. (2019a) for the hotspot trend data set of Morgan & Morgan (2007). The objectively estimated uncertainties tend to be larger than those assigned by Morgan & Morgan (2007), especially for slow moving plates. In a global inversion of the observed trends, a chisquare test indicates that the trends and adopted uncertainties are consistent with fixed hotspots (p=0.08; p < 0.05 would indicate significance). When we conduct a twotier analysis, however, the motion between groups of hot spots is significant. The groupmeans of trendperpendicular component of velocity range in nominal magnitude from 0 to 6 mm/a with a median of ≈3 mm/a. Wang et al. (2019b) applied these data and uncertainties to investigate how well the hotspot motion predicted by Doubrovine et al (2012) in their Global Moving Hotspot Reference (GMHRF) fit the observations. Surprisingly the GMHRF fits the observed trends much worse than they are fit assuming fixed hotspots.

The key to our newest analysis, which attains far higher resolution than before, is the novel use of Monte Carlo inversion to find directions and rates of hotspot motion that misfit the observed trends by angles consistent with the uncertainties in the trends. We obtained one million pseudorandom realizations of the direction of motion of each of 53 hotspots and inverted for the rate of hotspot motion that best fits the observed hotspot trend data. We examined speeds ranging from 0 to 15 mm/yr in increments of 1 mm/yr. For 60% of the realizations the best-fitting hotspot speed is 0 mm/yr, i.e., no motion between hotspots. Forty per cent of the realizations are fit better with some motion between hotspots with merely 2% of the realizations being fit acceptably close to the misfit expected given the size of the uncertainties. No realizations gave an acceptable fit with motion less than 2 mm/yr or with motion exceeding 8 mm/yr; the 95% confidence interval is 2–4 mm/yr, significantly different from zero, but low enough to strongly support the use of the fixed hotspot approximation.