Hotspot swells and the lifespan of volcanic ocean islands

Kimberly Huppert1, J. Taylor Perron2, and Leigh Royden2
1GFZ Potsdam, Potsdam, DE (khuppert@gfz-potsdam.de)
2Massachusetts Institute of Technology, Cambridge, MA, USA

The seafloor surrounding ocean hotspots is typically 0.5 - 2 km shallower than expected for its age over areas hundreds to >1000 km wide, but the processes generating these bathymetric swells are uncertain. Two end-member models have been proposed to explain swell uplift. The first model, lithospheric thinning, posits that reheating of the lithosphere causes the seafloor to uplift due to the isostatic effect of replacing colder, denser lithosphere with hotter, less dense upper mantle. The second model, dynamic uplift, proposes that swells are supported by upward flow of ascending mantle plumes and/or hot, buoyant plume material ponded beneath the swell lithosphere. If swells are dominantly produced by lithospheric thinning, the resulting thermal subsidence should approximately mimic the subsidence of young ocean lithosphere. This places an upper bound on the rate of seafloor and island subsidence following swell uplift, since conductive cooling of the lithosphere is a gradual process. On the other hand, if swell topography is dominantly produced by dynamic uplift, then seafloor subsidence depends primarily on how rapidly plate motion carries the seafloor off the swell and the spatial extent of the swell.

Because these two models predict different patterns of seafloor and island subsidence, swell morphology and the geologic record of island drowning may reveal which of these mechanisms dominates the process of swell uplift. To test this, we isolated regional swell bathymetry at 14 ocean hotspots. Considering the end-member case of lithospheric thinning, we modeled the thermal evolution of the lithosphere at each hotspot following swell uplift, and we compared the resulting thermal subsidence to observed swell subsidence. We also estimated island residence times atop swell bathymetry (swell length/plate velocity), and we compared this residence time to the age at which islands typically drown in each hotspot island chain. We found that observed swell subsidence significantly outpaces thermal subsidence. Moreover, island drowning ages match swell residence times, suggesting that islands and the seafloor subside as tectonic plate motion transports them past mantle sources of swell uplift. This correspondence argues strongly for dynamic uplift of the lithosphere at ocean hotspots. Our results also explain global variations in island lifespan on fast- and slow-moving tectonic plates (e.g. drowned islands in the Galápagos <4 million years (Ma) old versus islands >20 Ma above sea level in the Canary Islands), which profoundly influence island topography, biodiversity, and climate.