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New constraints on the Hawaiian swell origin using wavelet analysis of the geoid to topography ratio

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Analyzing the formation of hotspot swells, including the shallowness around the Hawaiian Islands, is critical for understanding the origin of intraplate volcanism and the underlying geodynamical processes. Two main hypotheses for the origin of this swell are generally considered: thermal lithospheric thinning, and dynamical support by a convective ascending plume. A major goal of these models is to quantitatively explain the two important characteristics of the Hawaiian swell: its topography and the corresponding geoid anomaly. In simple models of isostatic compensation, the geoid-to-topography ratio (GTR) is linearly related to the depth of the compensating mass; therefore it is often considered as a fundamental parameter to assess swell support mechanisms. According to previous work, the observed GTR has been reported to range from 4 to 5 m/km. The corresponding apparent compensation depth is about 45 km, which is shallower than predicted by the dynamic support model. However, analysis of the data processing methods shows that the applied bandpass filters to retain only characteristic wavelengths of the swell topography and geoid, cannot completely remove the signal due to loading of the volcanic edifices and related lithospheric flexure. In order to resolve these issues, we apply a continuous wavelet transform, which allows us to retrieve lateral variations of the GTR at each spatial scale. A series of synthetic tests based on different geodynamic models clearly indicates that by efficiently filtering the unwanted contributions, our approach is able to estimate the proper GTR of the Hawaiian swell. A high GTR of 8 m/km is recovered on the current hotspot location. Therefore, for the first time, the recovered GTR agrees with realistic geodynamic models of the Hawaiian plume. Accordingly, the thermal rejuvenation model can be ruled out by our analysis. Instead, the swell as a whole is shown to be mainly supported dynamically by the uprising Hawaiian plume. Furthermore, we find that the depth of the compensating mass decays by 20 km over a distance of 500 km from Hawaii to Kauai. Thus, a second mechanism has to be invoked to fully explain the Hawaiian swell formation. One of our synthetic tests including small-scale convection in the center of the plume pancake is able to recover the rate of this decay, but not its full spectral characteristics. Nevertheless, in agreement with seismic evidence for lithospheric thinning along the Hawaiian chain, we propose that additional small-scale convection on the flanks of the pancake can resolve this discrepancy.