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Sea Level Change due to Time-Dependent Long-Wavelength Dynamic Topography Inferred from Plate Tectonic Reconstructions

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Earth's surface is deflected vertically by stresses associated with convective mantle flow. Although dynamic topography is important for both sea level change and continental uplift and subsidence, the time history of dynamic topography is difficult to constrain because the time-dependence of mantle flow is not known. However, the motions of the tectonic plates contain information about the mantle flow patterns that drive them. In particular, we show that the longest wavelengths of mantle flow are tightly linked to the dipole and quadrupole moments (harmonic degrees 1 and 2) of plate motions. This coupling allows us to infer patterns of long-wavelength mantle flow, and the associated dynamic topography, from tectonic plate motions. After calibrating this linkage using models of present-day mantle flow, we can use reconstructions of global plate motions to infer the basic patterns of long-wavelength dynamic topography back to 250 Ma. We find relatively stable dynamic uplift persists above large-scale mantle upwelling beneath Africa and the Central Pacific. Regions of major downwelling encircled the periphery of these stable upwellings, alternating between primarily east-west and north-south orientations. The amplitude of long-wavelength dynamic topography was likely largest in the Cretaceous, when global plate motions were fastest. Continental motions over this time-evolving dynamic topography predict patterns of continental uplift and subsidence that are confirmed by geological observations of continental surfaces relative to sea level. Net uplift or subsidence of the global seafloor can also induce eustatic sea level changes. We infer that dispersal of the Pangean supercontinent away from stable upwelling beneath Africa may have exposed the seafloor to an increasingly larger area of growing positive dynamic topography during the Mesozoic. This net uplift of the seafloor caused $\sim$60 m of sea level rise during the Triassic and Jurassic, ceasing in the Cenozoic once continents fully override degree-2 downwellings. These sea level changes represent a significant component of the estimated $\sim$200 m of sea level variations during the Phanerozoic, which exhibit a similar temporal pattern.