Bullen's parameter as a seismic observable for spin crossovers in the lower mantle

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Elastic anomalies produced by the spin crossover in ferropericlase have been documented by both first principles calculations and high pressure-temperature experiments. The predicted signature of this spin crossover in the lower mantle is, however, subtle and difficult to geophysically observe within the mantle. Indeed, global seismic anomalies associated with spin transitions have not yet been recognized in seismologic studies of the deep mantle. A sensitive seismic parameter is needed to determine the presence and amplitude of such a spin crossover signature. As a measure of density changes that deviate from those associated with an adiabatic density profile, Bullen's parameter is a likely candidate for a seismic probe of spin transitions. The effects of spin crossovers on Bullen's parameter, η, are assessed here for a range of compositions, thermal profiles, and lateral variations in temperature within the lower mantle. Velocity anomalies associated with the spin crossover in ferropericlase span a depth range near 1,000 km for typical mantle temperatures. Positive excursions of Bullen's parameter with a maximum amplitude of ~0.03 are calculated to be present over a broad depth range within the mid-to-deep lower mantle: these are largest for peridotitic and harzburgitic compositions. These excursions are highest amplitude for model lower mantles with large lateral thermal variations, and with cold downwellings having longer lateral length-scales relative to hot upwellings. We conclude that predicted deviations in Bullen's parameter due to the spin crossover in ferropericlase for geophysically relevant compositions may be sufficiently large to resolve in accurate seismic inversions of this parameter, and could shed light on both the lateral variations in temperature at depth within the lower mantle, and the amount of ferropericlase at depth. Thus, accurate observational constraints on Bullen's parameter could provide insights into both the bulk composition of the lower mantle and on the planform of deep mantle convection.