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Influence of Large Low Shear Velocity Provinces in the lower mantle on the geoid

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The influence of the two near-equatorial, antipodal Large Low Shear Velocity Provinces (LLSVPs) in the lower mantle on global mantle dynamics is a topic of major interest in geodynamics. It was found in seismic studies that LLSVPs exhibit excess density with respect to the surrounding mantle which means that they are not thermal superplumes, as previously thought, but instead constitute large domes of dense material residing at the base of the mantle. This has important implications for the overall convection style of the Earth's interior. It also changes the interpretation of the strong spatial correlation between LLSVPs and observed positive geoid anomalies. If the anomalies were hot superplumes, they would drive a rising flow in the mantle and thus cause positive geoid anomalies due to dynamic topography of the surface. Yet, since the anomalies were found to exhibit excess density, such flow is expected to be much weaker and the associated geoid anomalies would be smaller than for superplumes. Instead, the excess density itself contributes to the positive geoid signal above LLSVPs. Even though density anomalies in the lower mantle are in general expected to have a relatively small influence on the geoid due to their great distance from the surface, large volumes with wide lateral extent, as is the case for LLSVPs, could still produce a strong geoid signal and be responsible for the observed positive geoid anomalies. Since both density excess of the anomalies and dynamic effects (resulting in dynamic topography) have an influence on the geoid signal, we investigated both effects on the geoid in fully dynamic mantle convection models with Cartesian and spherical axisymmetric geometries. In general, we found that for increasing chemical/thermal density contribution the geoid signal above the LLSVPs decreases, but remains significant.

Whereas steady-state was reached in the Cartesian simulations up to $Ra=10^6$, spherical axisymmetric simulations remained in a long-term time-dependent regime for $Ra=10^5$ and 10^6. For some spherical axisymmetric simulations, we found long-term existence of dense anomalies compatible with LLSVPs as observed inside Earth, even for relatively high Rayleigh numbers. We developed a new technique that enables us to quantitatively analyze the geoid signal above these anomalies in time-dependent simulations. A comparison of the thus obtained global geoid with the observed one delivered a relatively good fit.