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Testing mantle dynamics models beneath the southeastern North America passive continental margin

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A variety of models for mantle flow beneath southeastern North America have been proposed, including those that invoke westward-driven return flow from the sinking Farallon slab, small-scale convective downwelling at the edge of the continental root, or the upwards advective transport of volatiles from the deep slab through the upper mantle. However, due to the paucity of seismic stations located in the eastern United States, constraints on the character of the mantle flow beneath this passive margin are very sparse. A recent temporary deployment of 9 broadband stations (the Test Experiment for Eastern North America, or TEENA) provides new data along a transect from coastal North Carolina across Virginia and West Virginia stretching into Ohio. We use shear wave splitting observations and receiver function analysis at permanent broadband seismic stations in the southeastern US and stations of the TEENA array to test several proposed mantle flow geometries beneath the passive margin. Near the coast, permanent broadband stations exhibit well-resolved null (no splitting) behavior for SKS phases over a range of backazimuths, consistent with either isotropic upper mantle or with a vertical axis of anisotropic symmetry, which would be expected for vertical mantle flow. Further inland we identify significant shear wave splitting with mainly NE-SW fast directions, consistent with asthenospheric shear due to absolute plate motion (APM), lithospheric anisotropy aligned with Appalachian tectonic structure, or a combination of these. P-to-S receiver functions at three of the permanent stations examined resolved unambiguous conversions from the base of the upper mantle. Arrivals from the 410-km velocity discontinuity are generally consistent with the predictions of the Preliminary Reference Earth Model (PREM). We find that the 410-km discontinuity conversion arrives $\sim$0.7 sec early at a station in northern West Virginia compared to the corresponding arrival at a station in coastal South Carolina. We observe striking variations in the crustal response of the receiver functions with respect to azimuth, related to the strong variation in near-surface structure across the region. In addition to permanent stations, approximately 6 months worth of data from the TEENA array were examined for evidence of SKS splitting. Preliminary splitting measurements agree very well with the results from the permanent stations: stations located closer to the coast are dominated by null measurements, while inland stations exhibit generally NE-SW fast directions. Our results are relevant for testing different models for mantle dynamics beneath the southeastern US and support a model in which mantle flow is primarily vertical (either upwelling or downwelling) beneath the southeastern edge of the North American continent, in contrast to the likely horizontal, APM-driven flow beneath the continental interior. This work demonstrates that the mantle flow field beneath the North American passive margin may be more complex than previously thought and highlights the likely importance of vertical mantle flow.