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Rapid South Atlantic spreading changes and coeval vertical motion in surrounding continents: evidence for temporal changes of pressure-driven upper mantle flow

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The South Atlantic region is characterised by three observations: (1) a topographic gradient across the basin, with Africa being elevated relative to South America, maintained by non-isostatic forcing, evidenced by significant residual basement depth anomalies in the oceanic realm, (2) a bimodal spreading history with fast spreading rates in Late Cretaceous and Eo-Oligocene, and (3) episodic regional uplift events in the adjacent continents concentrated in Late Cretaceous and Oligocene, evidenced by apatite fission track data, lowstand sedimentary wedges, passive margin uplift, and successive phases of planation surfaces. Here we show that these observations are linked by dynamic processes within Earth's mantle, and that they provide powerful geodynamic constraints on plate driving forces and the regional style of mantle convection. The topographic gradient of the region in excess of 1 km implies westward, pressure-driven (Poiseuille) mantle flow beneath the basin, whereas the spreading rate changes, on order 15 million years, require significant decoupling of regional plate motion from the large scale mantle buoyancy distribution, through a mechanically weak asthenosphere. While Andean topographic growth in late Miocene can account for the recent reduction in South Atlantic spreading velocity, likely due to increased plate boundary forcing associated with the newly elevated topography, we show here with torque balance models that the prominent late Cretaceous/Tertiary South Atlantic spreading variations necessitate an unsteady flow component in the asthenosphere beneath the South Atlantic region, because changes in Andean paleoelevation at the time, inferred from a variety of geologic indicators, are too small to explain the South American plate motion change. The magnitude of pressure-induced mantle flow velocities compares well with those required from independent considerations to affect South American plate motion through basal shear. The predictions from our models for temporal changes in regional topography, due to temporal changes in mantle pressure gradients, agree with a broad range of geologic and geophysical observations, including episodes of passive margin uplift, regional basin reactivation and magmatic activity.