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Integrating lithospheric deformation and plate tectonic models: The evolution of South Atlantic conjugate margins revisited

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Continental lithospheric deformation and plate tectonic models have classically not been integrated quantitatively and systematically to construct regional tectonic frameworks, although this can provide robust and powerful constraints for the spatio-temporal evolution of tectonically complex regions such as passive margins. Reasons for the apparent disconnect between the two domains are manifold: continental crust lacks the relatively simple features of oceanic crust such as oceanic fracture zones acting as flow lines or isochrons which can be easily derived from magnetic anomalies, both allowing to devise robust quantified models of relative motions between lithospheric plates. Furthermore, the massive differences in scale between structural geology and plate kinematic models, as well as the lack of an information model and software, which allow to assimilate and visualise the models easily, complicates such an integrated approach.

We have analysed an extensive dataset for the Brazilian and West African margins encompassing seismic, gravity and magnetic data in conjunction with published data related to intracontinental deformation in Africa and South America. Using the open-source plate reconstruction software GPlates as information hub, we have been able to assimilate and model the time-dependent evolution of the South Atlantic rift basin and associated lithospheric deformation from pre-breakup to early seafloor spreading. Our new model for the formation of the South Atlantic rift basin combines isostatically restored margin cross sections, time-dependent information on crustal deformation and forward modelling of passive margin evolution within a global self-consistent plate rotation framework. The model drastically simplifies the pre-breakup evolution of the South Atlantic rift basin yet explains most lithospheric deformation events related to the South Atlantic breakup. We find that changing kinematic boundary conditions during rifting are ultimately responsible for the evolution and architecture of the conjugate passive margins in the South Atlantic and can explain features like the extensive Pre-Salt sag basins on the West African and Brazilian margins, different stages of continental crustal stretching, as well as the segmentation of both margins, within a self-consistent plate kinematic framework. Our methodology of coupling observations of spatio-temporal patterns of lithospheric deformation with global scale plate tectonic models offers a new, powerful way of converging to robust regional tectonic models and link plate-scale kinematics to lithospheric deformation modelling.