12^{th} International Workshop on Modeling of Mantle Convection
and Lithospheric Dynamics

August 20^{th} to 25^{th} 2011, Döllnsee Germany

Subduction History Models for Dynamically Consistent Reconstructions

Leonardo Quevedo[1], Gabriele Morra[2,1], R. Dietmar Müller[1]
[1] *EarthByte Group, School of Geosciences, University of Sydney, Sydney, Australia*
[2] *School of Earth and Environmental Sciences, Seoul National University, Seoul, South Korea*
Leonardo.Quevedo@sydney.edu.au

Given the wealth and complexity of current plate reconstructions, a simple yet general methodology to compare them in relation to their global scale predicted geodynamics could be of great help revising them to improve their fit with the present structure of the mantle and with geological observations. The main drivers of large-scale mantle flow and plate tectonics are considered to be the pull and suction forces associated to cold material sinking into the mantle [1]. As the geometry and the density contrast of subducting slabs are the primary factors determining such force, tectonic dynamics and mantle flow has been inferred with reasonable accuracy from the history of subduction based on kinematic reconstructions. The resulting dynamics predicted from a simple subduction history model of the lithosphere could provide such an effective quality metric for reconstructions, and serve as a guide on the exploration of mantle flow itself.

We present a new methodology to build global subduction history models from plate reconstructions and infer a global estimation of their associated geodynamic behavior. The shape of mantle density heterogeneities is built by assuming that slabs sink in the upper mantle with a speed related to the convergence rate between subducting and overriding plates and move tangentially on the globe following the absolute Euler rotation of the subducting plate. Lithospheric thickness is derived from oceanic age using the GDH1 thermal model [2].

We show that the resulting subduction history model where slabs are advected into the mantle according to the absolute and relative plate motions given by the reference [3], provide a better fit with the present day slab dips observed in mantle tomography than with instantaneous kinematic quantities like present convergence rate on the same model.

By assuming a simple rheological model of the lithosphere, we used the Boundary Element Method-based software BEMEarth [4] to infer the global pattern of mantle flow. Predicted plate motion orientations for varying rheologies and mantle structures at the present day and mid-Cretaceous [5] were compared with the kinematic model, and found to be an indicator of the physical consistency of kinematic reconstructions.

The predicted motion of the Farallon plate during the Early Cretaceous, was selected as an example case in which the predicted motion was found to be more consistent with the regional geology of the Western North American Cordillera system than the instantaneous motion suggested by a reconstruction at 125 Ma based on sparse hotspot track data on the Pacific Plate. This suggests that a methodology based on forward geodynamic modeling could be used to predict absolute plate motions in reconstructions when observations constraining them are insufficient.

References

[1] Conrad, C. P., Lithgow-Bertelloni, C., October 2002. How mantle slabs drive plate tectonics. Science 298 (5591), 207–209. http://www.jstor.org/stable/3832732

[2] Stein, C. A., Stein, S., 09 1992. A model for the global variation in oceanic depth and heat flow with lithospheric age. Nature 359 (6391), 123–129. http://dx.doi.org/10.1038/359123a0

[3] Seton, M., Müller, R. D., Zahirovic, S., Gaina, C., Torsvik, T., Shephard, G., Talsma, A., Gurnis, M., Turner, M., 2011. Global continental and ocean basin reconstructions since 200 ma, in review.

[4] Morra, G., Chatelain, P., Tackley, P., Koumoutsakos, P., 2007. Large scale three- dimensional boundary element simulation of subduction. In: Shi, Y., van Albada, G. D., Dongarra, J., Sloot, P. M. (Eds.), Computational Science – ICCS 2007 7th International Conference, Beijing, China, May 27 - 30, 2007, Proceedings, Part III. No. 4489 in Lecture Notes in Computer Science. Springer, pp. 1122–1129.

[5] Morra, G., Quevedo, L., Müller, R. D., 2011. Spherical dynamic models of top-down tectonics, in preparation.

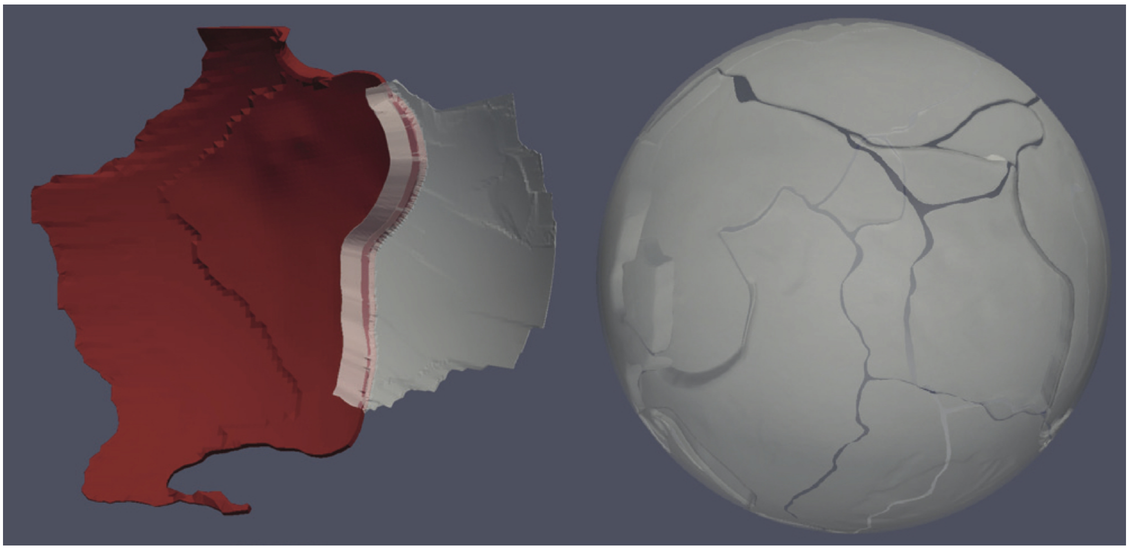

Figure 1: Right: A global lithospheric model of the present day tectonic setup with inferred oceanic thickness. Left: Detail of subduction of Nazca beneath South America (red).

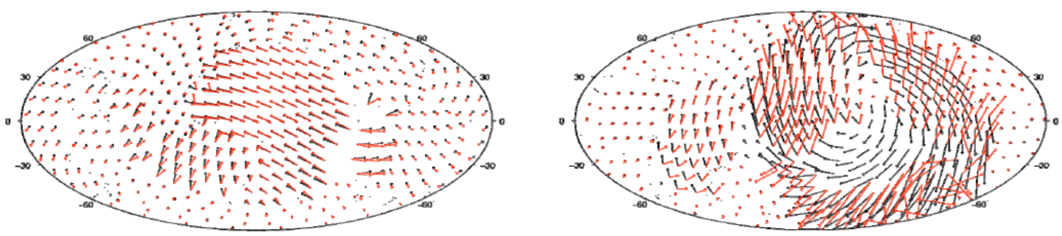

Figure 2: Predicted (red) vs observed (black) global kinematics for the present (left) and 125Ma (right).