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Testing tomography-based plate reconstructions from a paired, inverse-forward closed-loop experiment in a mantle circulation model

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Global plate reconstructions that constrain the surface plate motions provide crucial boundary conditions for mantle circulation models. Earth-like plate kinematics could reduce the impact of the uncertain mantle initial conditions and generate slab structures in the mantle that are comparable with seismic tomographies. However, due to the subduction of the oceanic plates, uncertainty increases in global plate reconstruction over time. Here, we utilize a novel slab unfolding technique to retrodeform mantle slabs imaged in the MITP08 seismic topography back to the pre-subduction states at Earth's surface. Such a technique provides additional constraints on plate reconstructions, especially in regions dominated by intra-oceanic subductions, such as Southeast Asia.

Our reconstruction shows a significant trench retreat along Southeast Asia and Northern Australia between 90 and 65 Ma that opened a gigantic, >3,000 km wide backarc basin. This basin, named the East Asian Sea plate, was later consumed by the west-moving Philippine Sea plate and North-moving Australian plate in the Cenozoic. We then embed our reconstruction in a mantle circulation model, TERRA, testing the fidelity of the reconstruction in a closed-loop experiment.

We found that fragmented, sub-horizontal East Asian Sea slabs can be reproduced in the mantle circulation model. These slabs lying underneath the current Philippine Sea plate and northern Australia are similar to the MITP08 tomography on which the reconstruction is built. Moreover, these slabs at 800-1000 km depths result in a more negative dynamic topography on the present Philippine Sea plates comparable with the observed residual topography. On the contrary, the traditional, Andean-style reconstruction can only produce positive dynamic topography. Other Mesozoic, intra-oceanic subductions in NE Asia and western North America embedded in our reconstruction also produce negative, yet smaller magnitude, dynamic topography, possibly due to the older subduction history and deeper slabs. We conclude the negative dynamic topography within the present Pacific plate is the result of ancient intra-oceanic subductions.