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Strong Correlation Between Stress Orientations and Absolute Plate Motions Constrained by Seismic Anisotropy

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Recently, Kreemer (2009) presented a new absolute plate motion model (GSRM-APM-1) that is based on the alignment between present-day surface motions (mainly from geodesy) and orientations of shear wave (SKS) splitting underneath cratons and oceanic islands. The average data misfit is 19° and 24° degrees for oceanic and cratonic areas, respectively, but the normalized root-mean-square misfits are about equal at 5.4 and 5.2. While this model fits independent hotspot propagation directions very well (<8° on most plates), the global net-rotation of this velocity field is less than half of that implied by HS3-NUVEL-1A. For slow moving plates, antipodal to the Pacific plate (e.g., Eurasia, Africa) the predicted velocities for GSRM-APM-1 and HS3-NUVEL-1A are at very large angles to each other.

In light of the differences between these (as well as others) APM models, we re-evaluate the correlation between various APM models and binned averages of maximum horizontal compression orientations (S-Hmax). When we exclude data near plate boundaries and those in strike-slip and extensional regimes, the average fit with GSRM-APM-1 is 41°. This is a considerable better misfit than when comparing stress orientations with HS3-NUVEL-1A or no-net-rotation velocity directions, particularly since those latter models do not show any systematic or symmetric misfit distribution. The average misfit with GSRM-APM-1 is about 15° that is mainly due to stresses in slowly moving Europe that are oriented systematically counterclockwise from APM. Globally, misfit are highest in oceans. Interestingly, because tectonic activity and orogenesis ultimately result from global plate motion, data in continental plate boundaries zones are fit best, as are S-Hmax orientations in a thrust faulting regime.

Because of the positive global correlation between GSRM-APM-1 and S-Hmax orientations, we used the binned averages and the surface velocity field used by Kreemer (2009) to find the net-rotation that best fits the data. We find the net-rotation pole to be at 55.5°S, 16.6°E at a rate of 0.243°/Ma, whereas GSRM-APM-1 predicts it to be at 57.6°S, 63.2°E at 0.207°/Ma. The global average misfit is 38° degrees, with the deviation from zero being symmetric for both oceanic and continental data, and, as for GSRM-APM-1, we find best fits for continental boundaries and thrust faulting regimes.

The APM model inverted from the stress data is rather sensitive to which data is included and what sampling interval is used for averaging the data. This, together with the fact that the misfit to the stress data is double that to the splitting orientations, suggests that GSRM-APM-1 is a more stable hotspot-independent model than any model that is based on stress. Our results also suggests that GSRM-APM-1 is most likely the most sensible APM model available. In any case, the strong correlation between stress orientations and APM reconfirms the notion that to first order the stress data reflect the same forces that drive the plates.