Total variation regularization of geodetically and geologically constrained block models for the western United States

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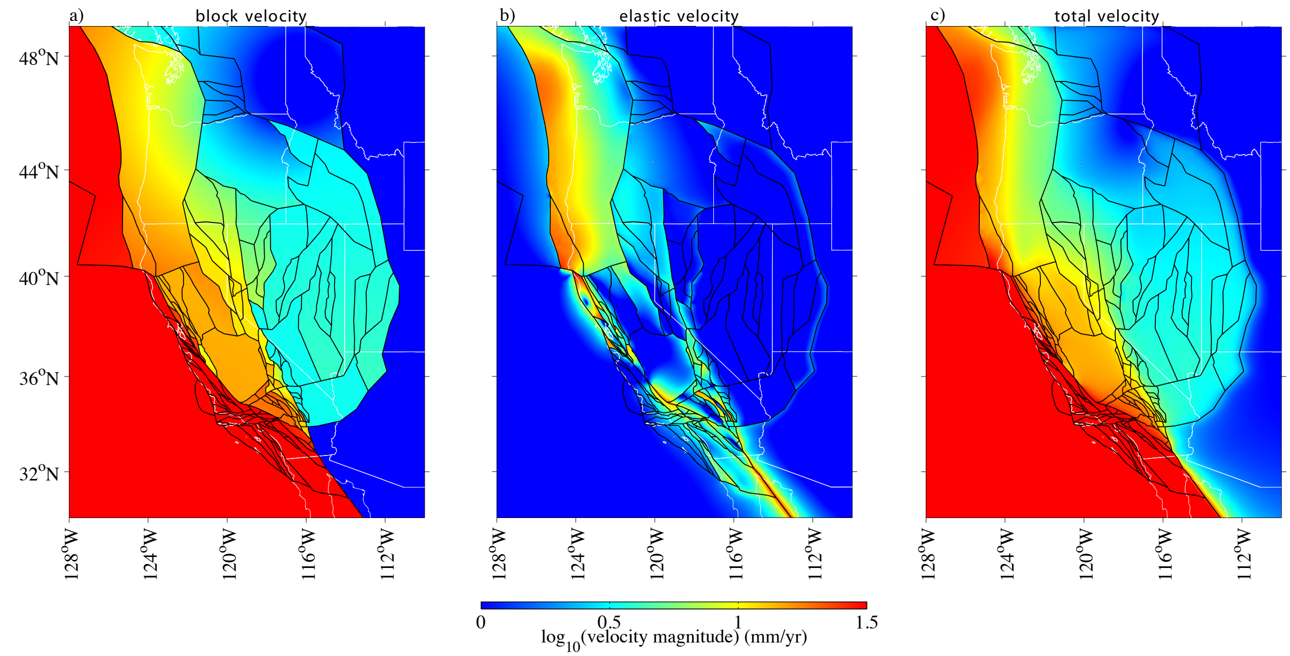
Geodetic observations of interseismic deformation in the Western United States provide constraints on microplate rotations, earthquake cycle processes, and slip partitioning across the Pacific-North America plate boundary. These measurements may be interpreted using block models, in which the upper crust is divided into microplates bounded by faults that accumulate strain in a first-order approximation of earthquake cycle processes. The number and geometry of microplates are typically defined with boundaries representing a limited subset of the large number of potentially seismogenic faults. An alternative approach is to include a large number of potentially active faults bounding a dense array of microplates, and then algorithmically estimate the boundaries at which strain is localized. This approach is possible through the application of a total variation regularization (TVR) optimization algorithm, which simultaneously minimizes the L_2 norm of data residuals and the L_1 norm of the variation in the differential block motions. Applied to three-dimensional spherical block models, the TVR algorithm can be used to reduce the total variation between estimated rotation vectors, effectively grouping microplates that rotate together as larger blocks, and localizing fault slip on the boundaries of these larger block clusters. Here we develop a block model comprised of 137 microplates derived from published fault maps, and apply the TVR algorithm to identify the kinematically most important faults in the western United States. This approach reveals that of the 137 microplates considered, only 30 unique blocks are required to approximate deformation in the western United States at a residual level of <2 mm/yr.



Model decomposition of selected block model: a) velocities due to block rotations, characterized by sharp velocity gradients at block boundaries; b) velocities due to elastic strain accumulation at faults and on the subduction zone; c) forward velocities due to full block model. Block velocity gradients have been smoothed by contribution from elastic strain accumulation. Elastic earthquake cycle elastic effects explain how the apparently smooth deformation field across much of the western United States is well described by slip on only a subset of possible active structures.