Forum Reply

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Persistent slip rate discrepancies in the eastern California (USA) shear zone

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We thank John Platt for his interest (his Comment: Platt, 2017) in our paper (Evans et al., 2016) and for bringing our attention to Platt and Becker (2013), which explores the hypothesis that large-scale rotations may contribute to geologic-geodetic slip rate discrepancies on the Garlock fault, Southern California, USA. We agree with his Comment (also stated by Platt and Becker, 2013) that the Garlock fault appears to be nearly invisible to geodetic observations, which is surprising given that the Garlock fault (1) is a continuous morphological feature that is not obviously disrupted by through-going right-lateral eastern California shear zone (ECSZ) faults, and (2) appears have slipped 4–11 mm/yr during the late Holocene (e.g., McGill et al., 2009).

The degree to which wholesale clockwise rotation of the region contributes to the geologic-geodetic discrepancy seems to depend on the differing modeling assumptions in our two approaches. The conceptual model of Platt and Becker (2013) postulates clockwise rotation in a region around the Garlock fault that cancels sinistral shear due to buried slip on the Garlock. The degree to which dextral shear occurs in the Platt and Becker (2013) model is dependent on the applied sphericity correction of 26% of Pacific–North America relative plate motion and is sensitive to this particular choice.

An advantage of our geodetic analysis using block modeling is that it explicitly accounts for the kinematics of intersecting fault sets. Block models divide the crust into microplates that are bounded by faults and estimate block rotations and elastic strain accumulation, constrained by geodetic observations. Fault slip rates are then determined by the relative rotations of adjacent blocks (e.g., Meade and Hager, 2005).

As a demonstration of block model estimation in the presence of wholesale rotation, we generate a synthetic forward velocity field across four blocks separated by a left-lateral east-west–striking fault and a right-lateral north-south–striking fault and superimpose a clockwise rotation (Figs. 1A–1C). We then add noise randomly drawn from a normal distribution with standard deviation 1.5 mm/yr in east and north velocities, and estimate block rotations on a spherical shell. Relative block rotations determine estimated slip rates. In this experiment, the block model does resolve left-lateral slip on the east-west fault (Figs. 1D and 1E) (without added noise, slip rates are recovered exactly).

Another advantage of the block model is that it fits the full surface velocity field in a way that is impossible when considering one-dimensional profiles alone, ensuring that the Garlock study area is kinematically consistent with deformation in the rest of Southern California. In contrast, Platt and Becker (2013) do not consider the deformation that must necessarily occur beyond the boundaries of the small region to which their rotation was applied. In particular, how does the postulated local clockwise rotation transition to dextral shear to the north in the Walker Lane fault or to the south in the central Mojave and southern San Andreas faults?

Consideration of the larger region is especially important in the context of the Platt's assumption that faulting may be represented as simple shear at a local scale. Interseismic strain accumulation only produces simple shear very close to a locked fault (within ~1 locking depth, where the velocity gradient is linear), and the magnitude of simple shear decays with distance from the fault (e.g., Savage and Burford, 1973). Therefore a left-lateral fault in the presence of a clockwise rotation would only be invisible very close to an intersection with a right-lateral fault. Simple shear across the wider region would require many through-going, closely spaced (<15 km) strike slip faults with very similar slip rates. This is exactly the question that we (Evans et al., 2016) address with total variation regularization (TVR): does including many faults improve geologic and geodetic agreement?

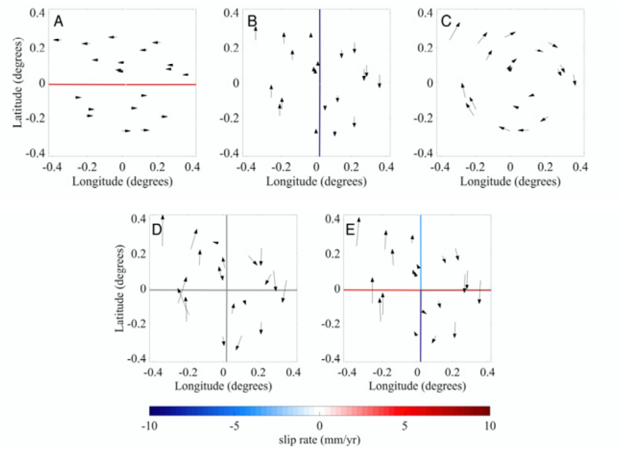

Figure 1. Toy model of slip rate estimation within a block model, in the presence of clockwise rotation. A: Forward velocity field due to relative block motions equivalent to a long-term slip rate of 7 mm/yr on a vertical left-lateral strike-slip fault that is locked from the surface to 15 km depth. B: Forward velocity field due to relative block motions equivalent to a long-term slip rate of 10 mm/yr on a vertical right-lateral strike-slip fault that is locked from the surface to 15 km depth. C: Forward velocity field due to clockwise rotation about an Euler Pole near 0 Long, 0 Lat. D: Combined velocity field (sum of A–C), plus noise. Fault locations shown in gray. E: Estimated strike-slip rates (left-lateral positive), and modeled velocity field.

The TVR strategy applied to the block model in our paper may add additional complications to the block model's ability to resolve left-lateral slip on the Garlock fault (although this would not be a factor in previous geodetic block models). The sparse spatial distribution of geodetic observations, the potential presence of many additional strike slip faults, and the termination of right-lateral ECSZ faults into the Garlock fault may all influence estimated slip rates and limit the ability of the current geodetic data to resolve left-lateral slip on the Garlock fault. However, the experiment described above demonstrates that the Garlock fault, even in the presence of wholesale regional rotation as described in Platt and Becker (2013), is not necessarily invisible in geodetic analysis with a block model.

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