Eastern Mojave Shear Zone/Walker Lane transition

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The transition between the northern part of the Eastern Mojave Shear Zone (EMSZ), south of the Garlock fault, and the region around the Death and Panamint valleys is not currently well measured. Dense profiles of deformation rates have been constructed across separate regions, but the transition of the deformation processes between these regions is poorly understood. The problems we wish to address by densifying the networks in the region between –118.5 and –116 degrees longitude and 34.5 and 35.5 degrees latitude (the region is also amenable to InSAR measurements) are:

(a) Strain accumulation on the Garlock fault. The eastern Garlock fault shows little strain accumulation compared to the geologic estimates of 5-10 mm/yr. One explanation for this difference is that the fault is late in the earthquake cycle and the lower crust has a low viscosity.
(b) This region is likely to be effected by transients from the Landers and Hector Mine earthquakes (and possible future earthquakes in the Eastern Mojave Shear Zone).
(c) Densification in this region should reveal the interactions between the faults of different trends in the region and the mechanism for the transfer of strain between the Imperial Valley region to the south, across the broader deformation zone associated with the EMSZ, to the Walker Lane.
(d) The plate motion normal components show a large amount of scatter. Some parts of this scatter is due to transients from mainly the Landers earthquake, but parts may also arise from the rotations at the ends of truncated faults.

A summary of the existing GPS velocity field south of 38° N is shown in Figure 1. These results are nominally in a North America fixed frame, and are generated from the average of the IGS combined velocity field, the SCEC2 velocity field, version 2 of Bennett and Davis, and our own processing of the data from the Eastern California Shear zone. Each field is rotated to place it on a common datum with all sites within 1 km of each other used to determine the transformation parameters. The velocities of sites within 1 km of each other have been averaged. The RMS difference between the fields is 1 - 2 mm/yr, with the final fit to the North America frame having an RMS difference of 1 mm/yr.

We interpret these velocities using a simple block model that enforces geometric compatibility both on geologic and geodetic time scales. Savage and Buford (1971) suggested that for a system of two blocks, separated by a single infinitely long fault, the total geologic displacement could be represented as the sum of coseismic and interseismic deformation. This argument allowed them to model interseismic surface deformation by subtracting the elastic deformation associated with coseismic ruptures from the block motion velocity field. The block model introduced by Souter (1998) extends this approach, allowing for multiple blocks bounded by finite faults that accommodate both block-boundary-parallel (strike-slip) and block-boundary-normal motions (normal and reverse faults). Interseismic site velocities are obtained by subtracting the elastic effects of virtual backslip on the locked portions of faults from the geologic block velocities. The components of slip on each of the faults are the projections of the relative block motion vector onto the fault plane. This allows for the computation of the elastic deformation associated with the locking of the near surface portion of the fault zone during the interseismic period, assuming that there are negligible variation of interseismic velocities through the seismic cycle. (This is a good assumption if the Elsasser time of the lower crust is 1/3 or more of the average repeat time of earthquakes, but a poor assumption if the lower crust has a lower viscosity [e.g. Savage, 1978, Hager *et al.*, 2000]).

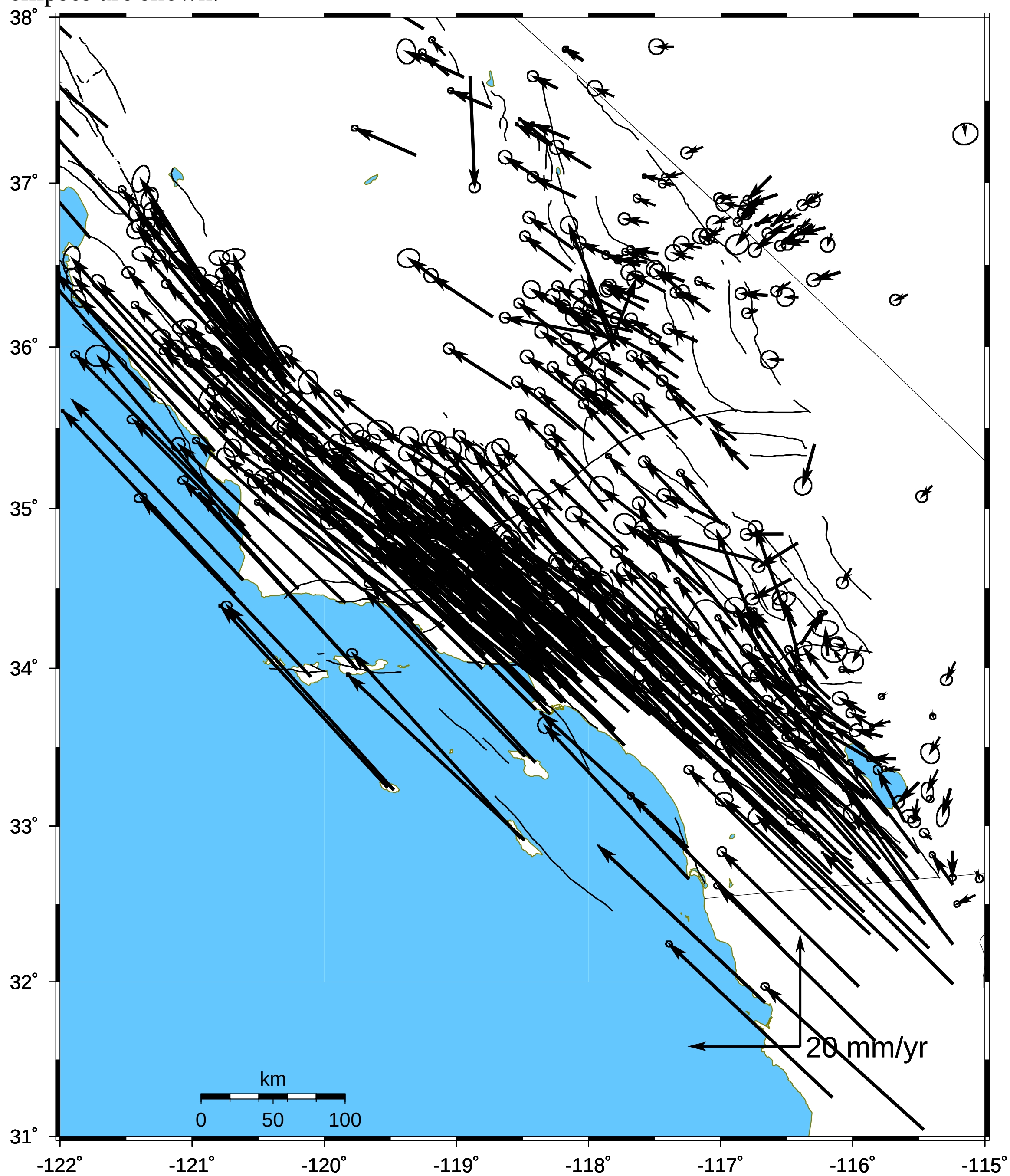
We use block velocities as model parameters and determine fault slip rates as a consequence of these motions. Our model implicitly enforces a path integral constraint on both the secular and geologic velocity fields, ensuring that the relative velocity between any two points is not a function of the path connecting these two points. Since elastic strain accumulation is responsible for the change in internal deformation of blocks as seen in the geodetic data, we account for it using elastic dislocation theory (Okada, 1985), which allows us to analytically model the surface deformation due to an arbitrarily oriented dislocation in a Cartesian elastic half space. (Similar closed form results are not known for spherical bodies. In order to make use of this formulation we project the curved surface of our study area onto a plane using the Lambert conic conformal projection .)

In Cartesian space the velocity of a point p, on an undeformed block b, can be represented a rotation of the block about some point, $\mathbf{v}_p = \omega_b \times (\mathbf{x}_p - \mathbf{x}_\omega) = \mathbf{v}_o + \omega_b \times \mathbf{x}_p$, where $\mathbf{x}_p$ gives the coordinates of the point p, $\mathbf{x}_\omega$ gives the coordinates of the rotation axis, ω_b is the block rotation vector, and $\mathbf{v}_o$ is the origin translation vector. For the motion of some block in two dimensions we have three degrees of freedom. For a collection of points on several blocks we have a linear system of equations that can be solved for the block motion parameters $\mathbf{v}_o$ and ω_b. The strain accumulation due to a locked fault bounding two blocks affects not only those two blocks, but propagates across all block boundaries. To calculate this requires knowledge of the various components of slip on a fault plane. In the context of a block model, slip rates are the projection of relative block motions onto the fault plane geometry. We still have a linear system of equations, $(\mathbf{A} - \mathbf{GD})\mathbf{b} = \mathbf{v}$, for the deformed block case. Here **A** is a block assignment matrix, **G** relates block motions to components of slip on the bounding fault plans, **D** gives the partial derivatives of the elastic dislocation equations, **b** is a vector of block motion parameters and **v** is a vector of the predicted velocities. As block motions are not, in general, known we seek to estimate them by minimizing the weighted, correlated, squared residuals (χ^2) by differentiation, $\partial_{\mathbf{b}}\mathbf{r}(\mathbf{b})\mathbf{C}^{-1}\mathbf{r}(\mathbf{b}) = 0$, where **r** is the residual velocity vector and **C** is the partial data covariance matrix.

Figure 2 shows the residual velocities for the EMSZ/southern Walker Lane region, obtained by subtracting the predicted velocities for our model from the observed velocities shown in Fig. 1. The predicted rates of motion on the fault segments are shown in Table 1. Note that the Garlock fault in the region to the east of its intersections with the Airport Lake fault has remarkably little (< 1 mm/yr) left-lateral motion inferred, compared to the geologic estimate (McGill, 1993) of 5 - 10 mm/yr. Such a lack of strain accumulation may be the result of a low viscosity lower crust in this region

Unfortunately, this region, as well as that to the east of the Goldstone Lake fault and in the Avawatz Mountains has rather sparse GPS coverage compared to the region to the north. This lack of coverage is particularly problematic in the region east of GL where NW-SE shear may be accompanied by rotation of blocks trending E-W (Dokka et al, 1990). Access to most of this area (Fort Irwin) is restricted by the military, but we expect that it should be possible to find enough secure sites to densify this region.

Figure 1: Velocity field in Southern California for all sites with velocity uncertainties of less than 2 mm/yr. The brown sets of parallel lines show the regions used to construct the North, Mid and South profiles shown in Figures 2-4. The anomalous velocities in the –117.5 longitude, 36 degree latitude are in a geothermal field. 50% confidence error ellipses are shown.



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Velocities relative to NONE   Input file : iwsepy.nafd.vel

Figure 2. Residuals of velocities shown in Figure 1 to the block model shown in Table 1.

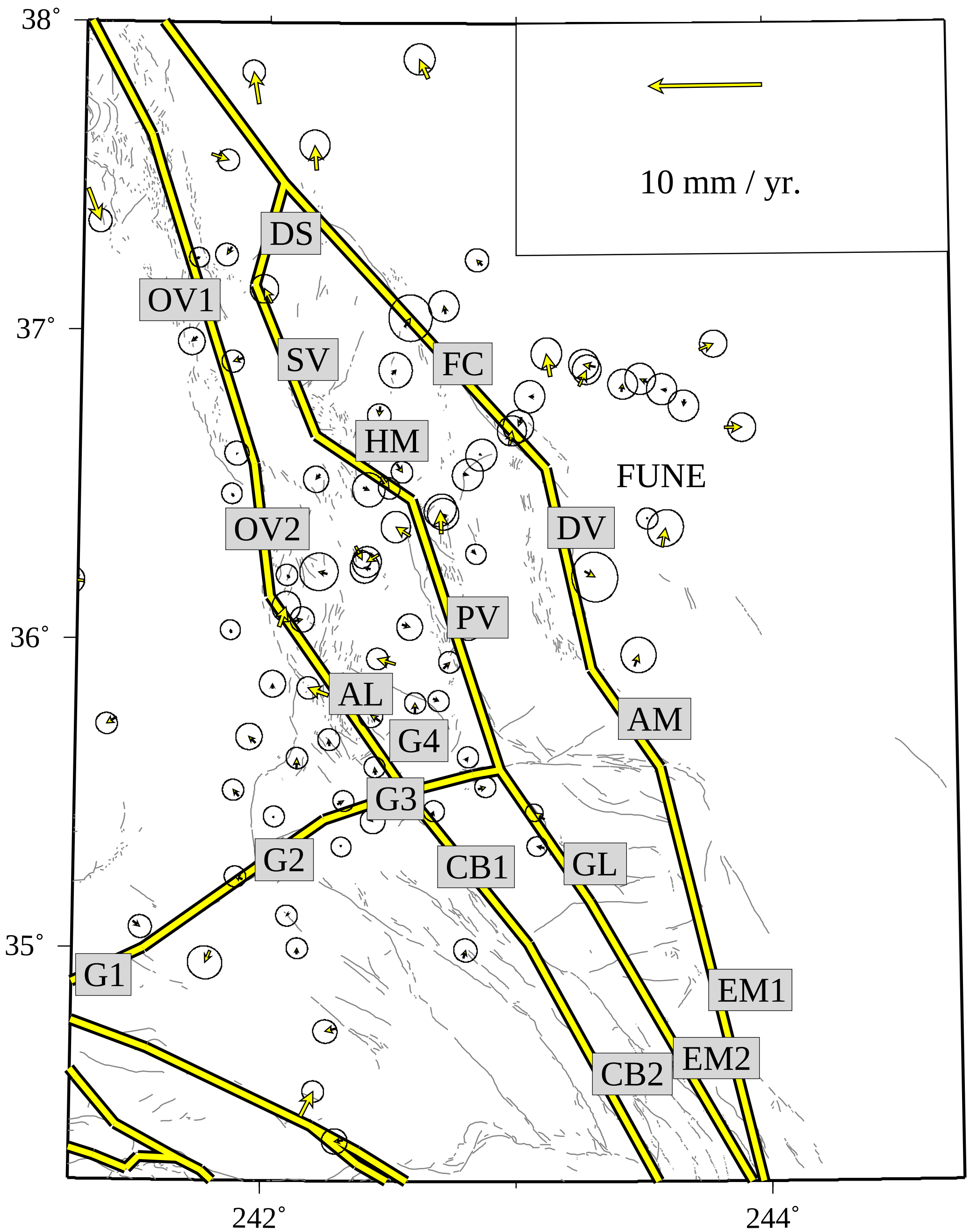

Table 1: Block model parameters used to generate model velocity field for Figure 2.

Fault name	Fault symbol	Strike slip rate[a] (mm/yr)	Fault normal rate[b] (mm/yr)
Garlock	G1	3.5 ± 1.7	6.9 ± 1.7
Garlock	G2	4.5 ± 1.7	2.1 ± 1.7
Garlock	G3	3.8 ± 1.6	2.3 ± 1.6
Garlock	G4	0.6 ± 2.3	3.7 ± 2.1
Owens Valley	OV1	-4.3 ± 1.0	-2.1 ± 1.1
Owens Valley	OV2	-3.9 ± 0.8	-2.8 ± 1.0
Airport Lake	AL	-4.8 ± 1.1	-0.7 ± 1.2
Panamint Valley	PV	-2.6 ± 1.3	-1.8 ± 1.5
Hunter Mountain	HM	-3.2 ± 1.6	0.1 ± 1.5
Saline Valley	SV	-2.7 ± 1.4	-1.7 ± 1.5
Deep Springs Valley	DS	-1.1 ± 1.3	-3.0 ± 1.5
Furnace Creek	FC	-3.3 ± 0.9	1.4 ± 0.9
Death Valley	DV	-3.5 ± 0.7	-0.4 ± 0.8
Avawatz Mountains	AM	-3.4 ± 0.9	1.0 ± 0.9
Calico-Blackwater	CB1	-1.8 ± 3.1	0.2 ± 3.1
Calico-Blackwater	CB2	-1.5 ± 3.0	-3.9 ± 3.1
Goldstone Lake	GL	-6.3 ± 2.7	0.8 ± 2.8
Eastern Mojave	EM1	-3.5 ± 0.7	-0.3 ± 0.9
Eastern Mojave	EM2	-6.3 ± 2.7	0.8 ± 2.8

[a] : negative values indicate right lateral motion

[b] : negative values indicate opening