**Auxiliary material for**

**The Mw 6.5 Offshore Northern California Earthquake of January 10, 2010：ordinary stress drop on a high strength fault**

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**Introduction**

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**Sparse Regularization Inversion**

The regularized inversion problem we solve is called a Lasso problem: minimize $|\left|Ax-b\right||\_{2}$ subject to $|\left|x\right||\_{1}\leq τ$, where *A* is the Green’s function, *b* is data, *x* is the slip model, $τ$ controls the sparse of the slip model. The specific value of $τ$ depends on the unit/value of *x*. We used the matlab software package SGPL1 to solve the Lasso problem. SGPL1 is a solver for large-scale sparse reconstruction (<http://www.cs.ubc.ca/~mpf/spgl1/>) [*Van den Berg and Friedlander*, 2008]. It was also used by *Evans and Meade* [2012].

We have performed a number of inversion tests with both synthetic and real data while varying $τ$ and the dependence of grid size on depth. The summaries are:

* As $τ$ decreases, the slip model will become more sparse (less non-zeros), the misfit will increase, and the seismic moment will decrease but still result in around *Mw* 6.5
* The grid size needs to increase with depth, otherwise the non-zero slip patches will tend to concentrate at shallow depths where we have little resolution. It is generally desirable to implement this in geodetic inversions due to the decreasing sensitivity of the data with fault depth [*Barnhart and Lohman*, 2010].
* The sparse method will result in estimates of negative slip when $τ$ is too large, as was shown in *Evans and Meade* [2012]. Choosing $τ$ by cross-validation results in slip distributions that only have positive values in our resolution tests. Thus, we think it is an appropriate way to implement this particular regularization.

We used a cross-validation method to find the best $τ$. The procedure follows *Murray et al.*, [2005]. Based on the results of our resolution tests, we use a grid size of 2x2 km at shallow depth and increases with depth at a rate of 1.2 for the sparse regularization.

**References**

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Evans, E. L., and B. J. Meade (2012), Geodetic imaging of coseismic slip and postseismic afterslip: Sparsity promoting methods applied to the great Tohoku earthquake, *Geophys. Res. Lett.,* 39, L11314, doi:10.1029/2012GL051990.

**Figure S1.** Examples of the Network Strain Filter output of PBO station P158. (Top) East component. (Bottom) North component. Blue dots are GPS data with the secular velocity and reference frame terms removed. Different solid lines represent terms of Network Strain Filter, labeled in the legend. The flat transient terms are an indicator of the small amount of post-seismic slip required by the data.

**Figure S2.** Evolution of hyper-parameter $α$ in the forward run of the NSF for runs with different values of $λ$, which controls the spatial smoothness of the transient deformation field. Smaller $λ$ results in smoother transients. An increase of $α$ is the best indicator of the existence of transient. The NSF is initialed with an extremely smooth but highly uncertain prior and the estimate of alpha increases, as information from the dataset is incorporated. In all three runs the value of $α$ levels out at a relatively smooth level and does not show a spike at the time of the earthquake. The lack of a significant change in $α$ after the 2010 earthquake implies a lack of any significant post-seismic (transient) slip on the fault [e.g. *McGuire and Segall*, 2003].

**Figure S3.** Cross validation for L2 norm inversion with different $α$, which is a non-negative scalar in $|\left|Gm-d\right||\_{2}+α|\left|m\right||\_{2}$. The fault is 50 km long and 30 km wide. The cell size is 2 x 2 km.

**Figure S4.** Examples of slip models with different $α$. The values of $α$, misfit and *Mw* are shown above the slip models. The larger $α$, the smoother the slip model is and the larger misfit.

**Figure S5.** Cross validation for Sparse Regularized inversion with different values of $τ$, which is a non-negative scalar that controls the sparse of the solution of $min|\left|Gm-d\right||\_{2}$ subject to $|\left|m\right||\_{1}\leq τ$. The fault model is 50 km long and 30 km wide. The cell size is 2 x 2 km for the top row then increase with depth at a rate of 1.2.

**Figure S6.** Examples of slip models based on the sparse regularization method with different Tau. As Tau increased, there will be more non-zero slip patches in the slip model and the misfit will decrease.

**Figure S7.** Co-seismic slip and the static stress change for Model L2 in Figure 2 and S4. Static stress change was calculated based on [*Ripperger and Mai*, 2004]. The co-seismic stress perturbation on the beneath shear zone is about 0.5 – 1 MPa at 25-30 km depth.

**Figure S8.** Co-seismic slip and the static stress drop for the sparse model in Figure 2 and S6. Static stress change was calculated based on [*Ripperger and Mai*, 2004]. The co-seismic stress perturbation on the beneath shear zone is about 5-10 MPa at 25-30 km depth.

**Figure 9.** Resolution test. Synthetic data was generated using the same code for calculating Green’s function. Same procedure was used to recover the synthetic slip. (left) Source model 1 and the recovered slip models with two inversion methods. (right) Source model 2 and the recovered slip models with two inversion methods.