2009 SCEC Progress Report

Restoration of fault slip from lidar point-clouds and testing slip-rate discrepancy in the eastern California shear zone

Principal Investigator: Dr. Michael Oskin, UC Davis Geology
Co-Principal Investigator: Dr. Eric Cowgill, UC Davis Geology
Co-Principal Investigator: Dr. Oliver Kreylos, UC Davis Computer Science

High-resolution lidar data sets present an immense, largely untapped archive of information useful for understanding fault system behavior. In arid settings, such as southern California, the most recent slip events are often well preserved in the landscape, even after several hundred to thousands of years of modification by surface processes (e.g. Oskin et al., 2007). Thus it is possible to vastly expand knowledge of the extent and magnitude of past earthquake ruptures through systematic measurement of small-scale offsets illuminated by this new topography. This data in turn is valuable for understanding rupture scaling relationships used in hazard models, relating rupture patterns to longer-term fault slip, and testing how ruptures respond to fault-zone complexity and fault interaction.

For 2009 we proposed to develop, test, apply, and deploy a new tool to explore and quantify fault offsets using full, 3-D point cloud data. This tool is based on the open-source LidarViewer software (Kreylos et al., 2006), developed at UC Davis KeckCAVES, to enable rapid identification and quantitative measurement of fault offsets from raw lidar point cloud data. We also proposed to use this tool to test alternative hypotheses for the origin of geologic-geodetic slip-rate discrepancy in the eastern California shear zone (ECSZ) using fault slip-per-event measurements gleaned from newly acquired Earthscope lidar data and to conduct a comparison study to Zielke et al. (2010) on offset features in the Carrizo plain, benchmarked against ultra-high resolution ground-based lidar scans.

We have recently completed development of a functional cross-correlation tool in LidarViewer (Figure 1). Two different swaths of data (referred to as the shorter 'key' and longer 'target') are selected on opposite sides of the fault. Three additional swaths of data are used to define the fault trace and the projection of features onto that trace. A typical target, as illustrated, would be an offset channel projected to the fault trace along the channel axis. Data are compared via a cross-correlation function that computes the covariance of the key and target at a range of offset values. The best fit is defined by the offset that explains the greatest amount of covariance. For very well defined features, such as channels on the Carrizo Plain, up to 95% of the covariance is matched across the fault. This covariance technique gives both a quantitative estimate of displacement as well as a formal mechanism to compare the quality of offset sites through their relative covariance values.

In April of 2010 we re-directed our field efforts from surveys of the Carrizo plain to instead survey the fault rupture from the Baja California earthquake. These data (Figure 2) provide a stunning view of a fresh surface rupture at a sufficient resolution to resolve fine scale fault texture, distributed deformation, and warping of the ground surface. Now that the cross-correlation tool has reached maturity, we will use it to analyze the combined Baja California ground-based and airborne lidar data set (airborne lidar has been awarded funding from NSF and should be acquired by the summer). These results, in addition to analysis the Earthscope lidar data from the eastern California shear zone, will be presented at the 2010 SCEC annual meeting.

Kreylos, O., Bawden, G.W., Bernardin, T., Billen, M.I., Cowgill, E.S., Gold, R.D., Hamann, B., Jadamec, M., Kellogg, L.H., Staadt, O.G. and Sumner, D.Y. (2006), Enabling scientific workflows in virtual reality, in: Hong Wong, K., Baciu, G. and Bao, H., eds., Proceedings of ACM SIGGRAPH International Conference on Virtual Reality Continuum and Its Applications 2006 (VRCIA 2006), ACM Press, New York, New York, pp. 155-162.

Oskin, M., Le, K., and Strane, M., (2007a), Quantifying active faulting in arid environments in with high-resolution topography, Geophysical Research Letters, doi:10.1029/2007GL031295.

Zielke, O., Arrowsmith, R., Ludwig, L., and Akciz, S. (2010): Slip in the 1857 and Earlier Large Earthquakes Along the Carrizo Plain, San Andreas Fault. Science vol. 327 (5969) pp. 1119-1122.

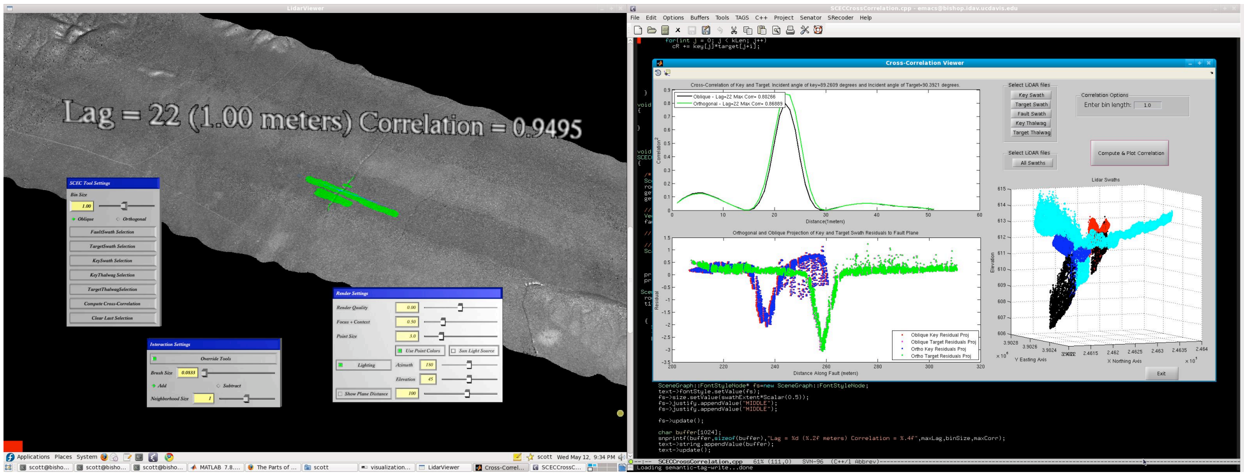

Figure 1. Right: Screen shot of LidarViewer cross-correlation tool showing analysis of channel offset in the Carrizo Plain 'B4' lidar data set. Left: Illustration of cross-correlation results in companion Matlab tool. Upper left plot is the covariance as a function of offset, with peak at best fit. Lower left is a plot of cross-channel point data projected onto the fault trace.

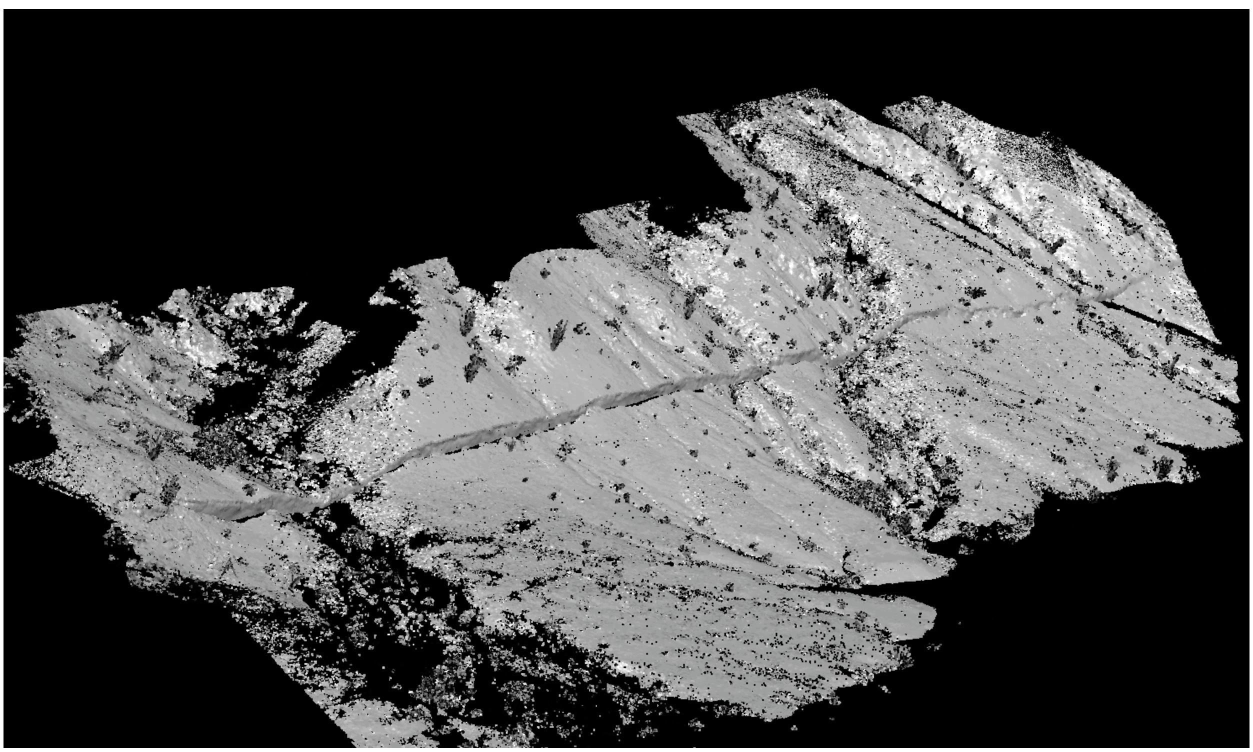

Figure 2. Overview of composite of four ground-based lidar scans of rupture on the Borrego fault produced by 4 April 2010 Sierra Mayor-Cucapah earthquake. Almost four meters of oblique-normal dextral slip occurred on a discrete fault plane at this locality. In total 21 scans at four different localities were collected that sample a variety of rupture styles.