Evolution of the 1999 Hector Mine Earthquake surface rupture: a decadal view

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We report on the first ever decadal scale repetition of a high density 3D aerial laser scan covering practically all of a large earthquake surface rupture. The scan was acquired by the National Center for Airborne Laser Mapping (NCALM) on May 27, 2012 along a 50 km stretch of the surface rupture of the October 16, 1999 Mw 7.1 Hector Mine Earthquake. This new scan averages 1100 m total width, overlapping with and significantly increasing the breadth of a previous LiDAR scan acquired on April 19, 2000 by the USGS and Aerotech, LLC. Together, the two datasets comprise a 4D (12 year) snapshot of the post-event landscape evolution of a well-defined fault scarp and its immediate environs as well as a test case for characterization of the interplay between landscape evolution through human timescales and offset measurements made on geomorphic features visible in LiDAR derived DEMs. We investigate a 2 km long focus zone of the Lavic Lake fault where it cuts through Neogene volcanic rocks in the Bullion Mountains, a sparsely vegetated area which contains both the maximum horizontal offset measurements from field study and April 2000 LiDAR DEMs and the highest density of April 2000 LiDAR DEM offset measurements. After gridding both the 2000 and 2012 point cloud data for this zone into exactly congruent 0.5 m resolution DEMs we directly subtracted the two raster DEMs. This new raster elucidates specific and quantifiable areas of erosion and aggradation and shows that no measurable post-seismic slip has occurred within the focus zone during the interscan period. Within the focus zone, 28 offset measurements were made previously using the Ladicaoz matlab script by others at the USGS and Caltech. We revisit these 28 measurement locations and find that in roughly half of the locations the same geomorphic features used to measure offset in the April 2000 data are clearly identifiable in the 2012 data. Re-investigating the locations of the three largest offsets made in the April 2000 dataset (over 600cm), we find that each is complicated by the geomorphology of its specific locale. One is at a stream bifurcation point, one is on a stream bend that potentially existed pre-earthquake, and one is located on a slope with minimal along strike relief. High resolution pre-event aerial photography and field investigation of the specific locales is needed to confirm the validity of these large offset measurements.

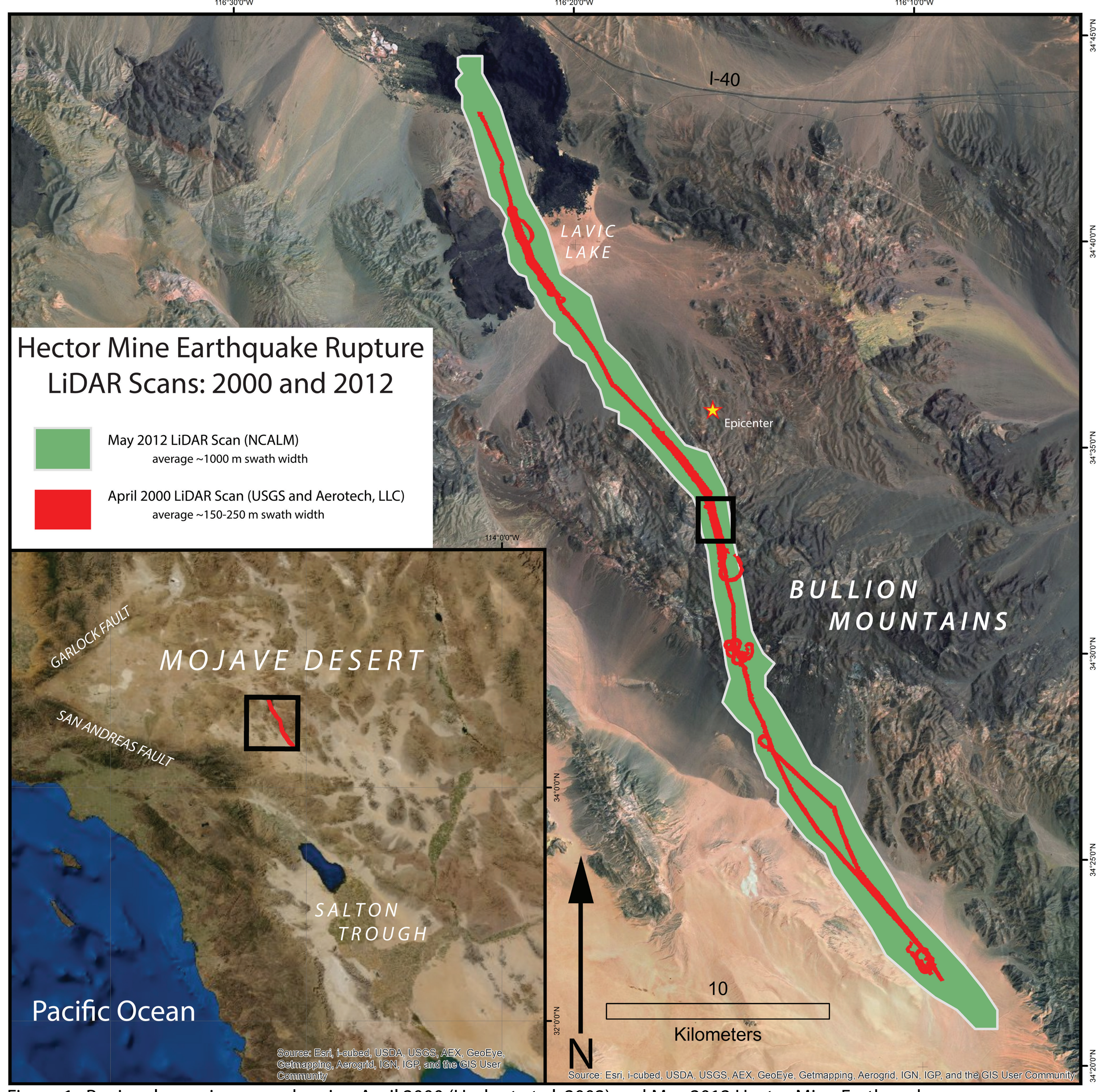

Figure 1. Regional overview map showing April 2000 (Hudnut et al, 2002) and May 2012 Hector Mine Earthquake surface rupture LiDAR scans. Smaller inset shows extent of 2 km focus zone (Figs 2, 4, and 5).

Key Points

- No offset (>~13 cm resolution) is measurable along the Hector Mine rupture during the 12 year interscan period
- Quantifiable erosion and aggradation in washes
- Identical offset geomorphic features are present and measurable in both data sets

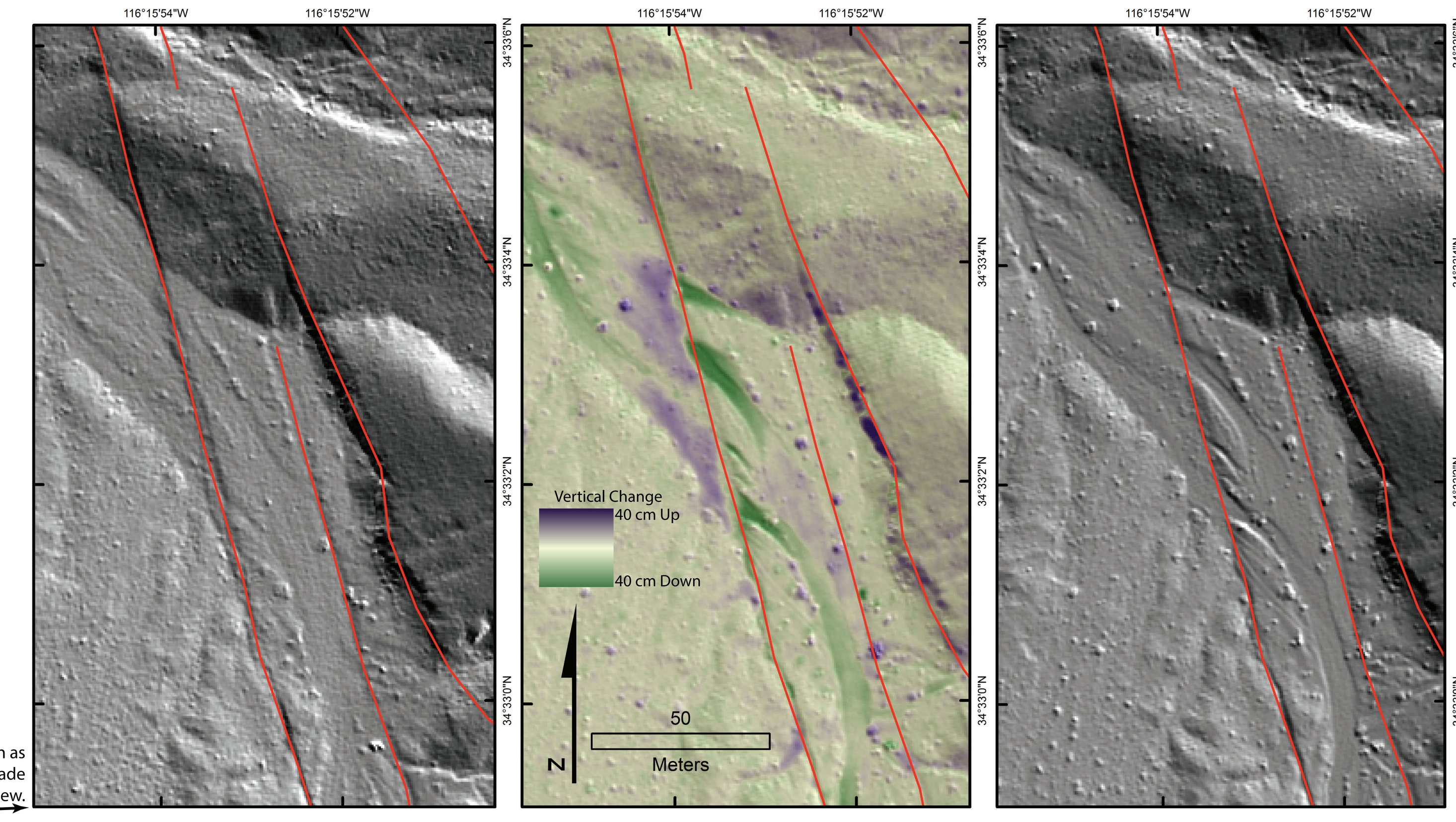

Figure 3. Inset region (from Figure 2, black box) demonstrating fault scarp erosion shown as difference raster (center) and hillshade of the 2000 LiDAR data (left) and 2012 (right). Hillshade parameters are azimuth 45°, sun angle 30°. Fault line is taken from Chen et al, in review.

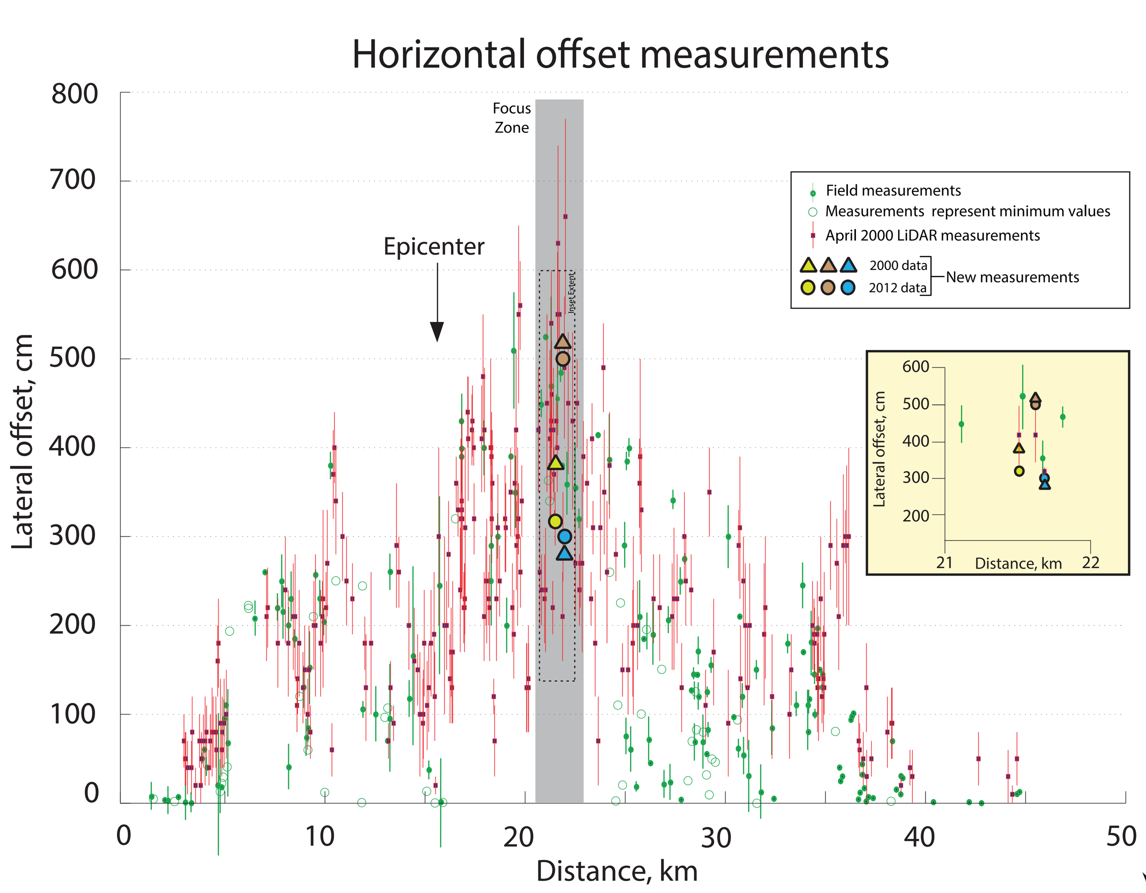

Figure 5. Horizontal displacement vs along-strike distance. Field measurements are shown in green (Treiman et al, 2002). LiDAR measurements done by other workers are shown in red (Chen et al, in review). Colored circles and triangles represent new offset measurements (this study) made on the exact same geomorphic features in both DEMs. Inset chart shows these three measurements and proximal LiDAR and field measurements made by others (Treiman et al, 2002; Chen et al, in review). Gray shade is focus zone (Figs. 1, 2, 4).

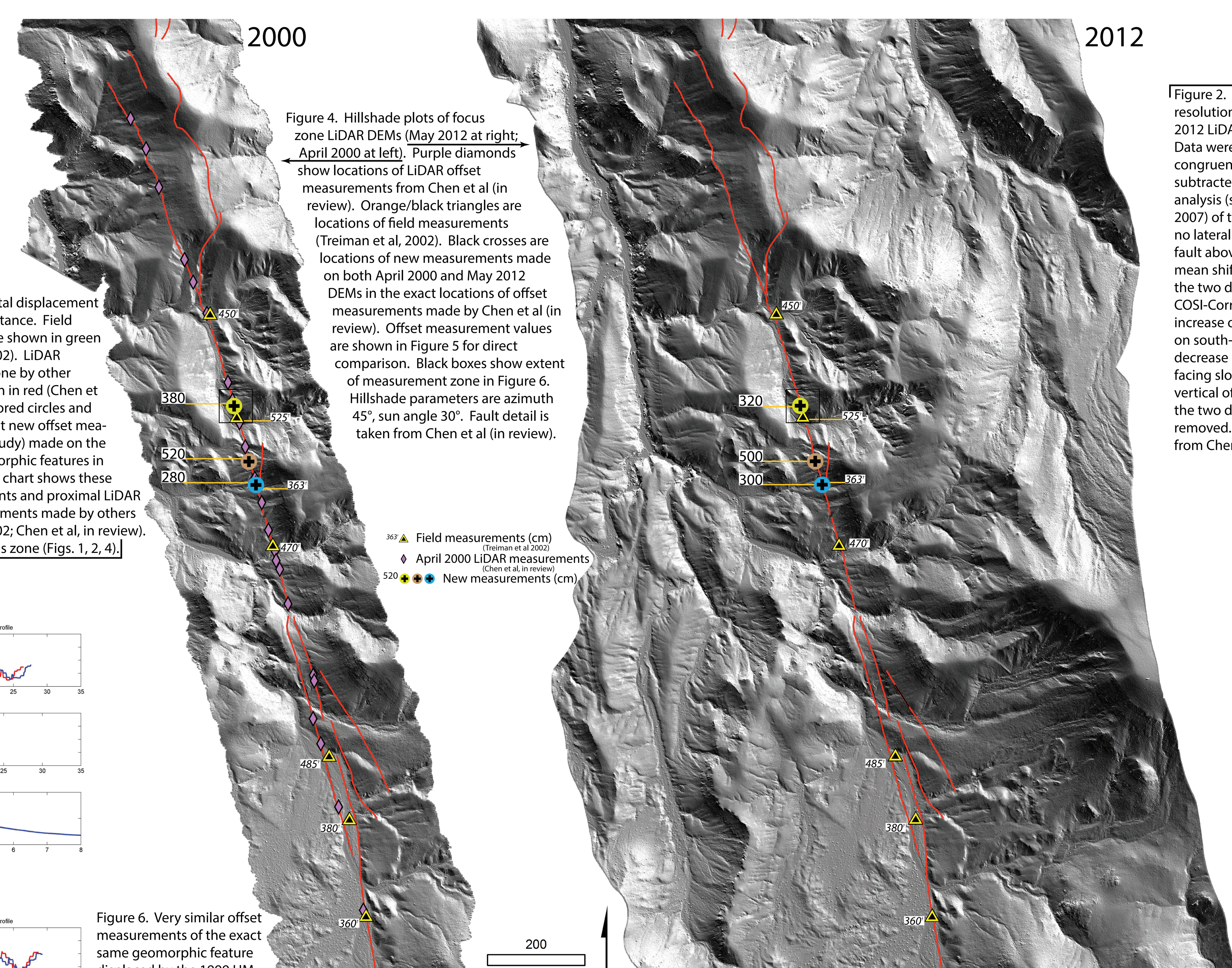

Figure 4. Hillshade plots of focus zone LiDAR DEMs (May 2012 at right; April 2000 at left). Purple diamonds show locations of LiDAR offset measurements from Chen et al (in review). Orange/black triangles are locations of field measurements (Treiman et al, 2002). Black crosses are locations of new measurements made on both April 2000 and May 2012 DEMs in the exact locations of offset measurements made by Chen et al (in review). Offset measurement values are shown in Figure 5 for direct comparison. Black boxes show extent of measurement zone in Figure 6. Hillshade parameters are azimuth 45°, sun angle 30°. Fault detail is taken from Chen et al (in review).

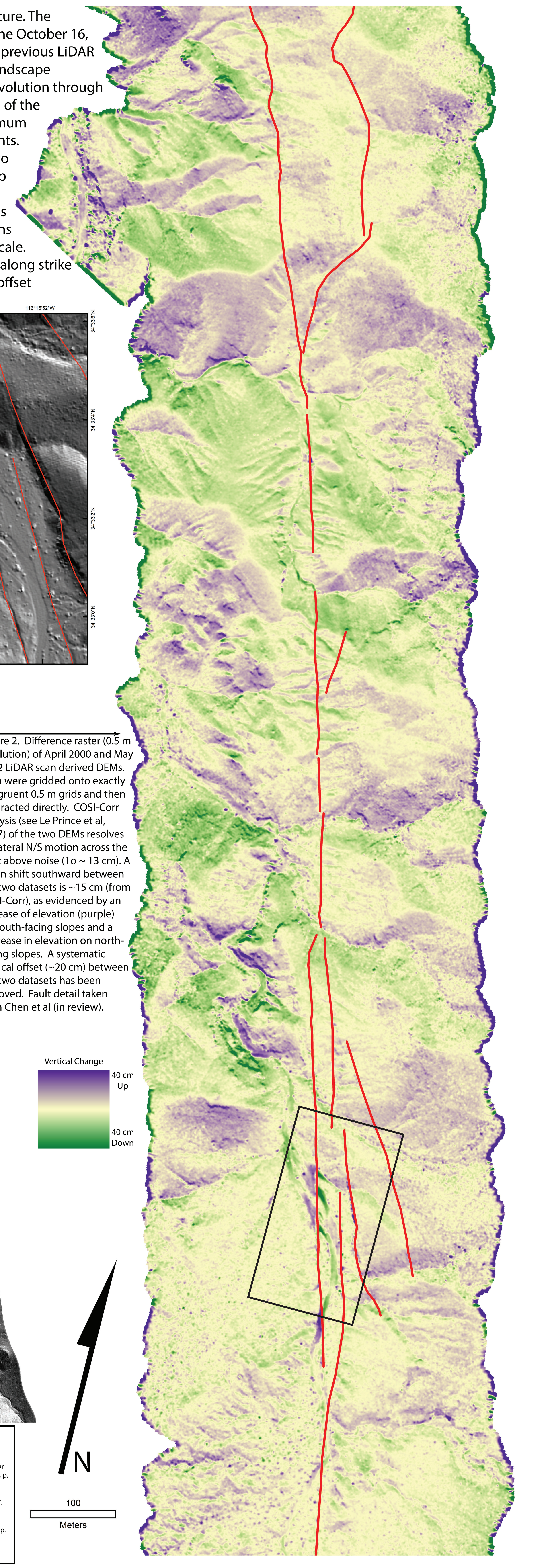

Figure 2. Difference raster (0.5 m resolution) of April 2000 and May 2012 LiDAR scan derived DEMs. Data were gridded onto exactly congruent 0.5 m grids and then subtracted directly. COSI-Corr analysis (see Le Prince et al, 2007) of the two DEMs resolves no lateral N/S motion across the fault above noise (1σ ~ 13 cm). A mean shift southward between the two datasets is ~15 cm (from COSI-Corr), as evidenced by an increase of elevation (purple) on south-facing slopes and a decrease in elevation on north-facing slopes. A systematic vertical offset (~20 cm) between the two datasets has been removed. Fault detail taken from Chen et al (in review).

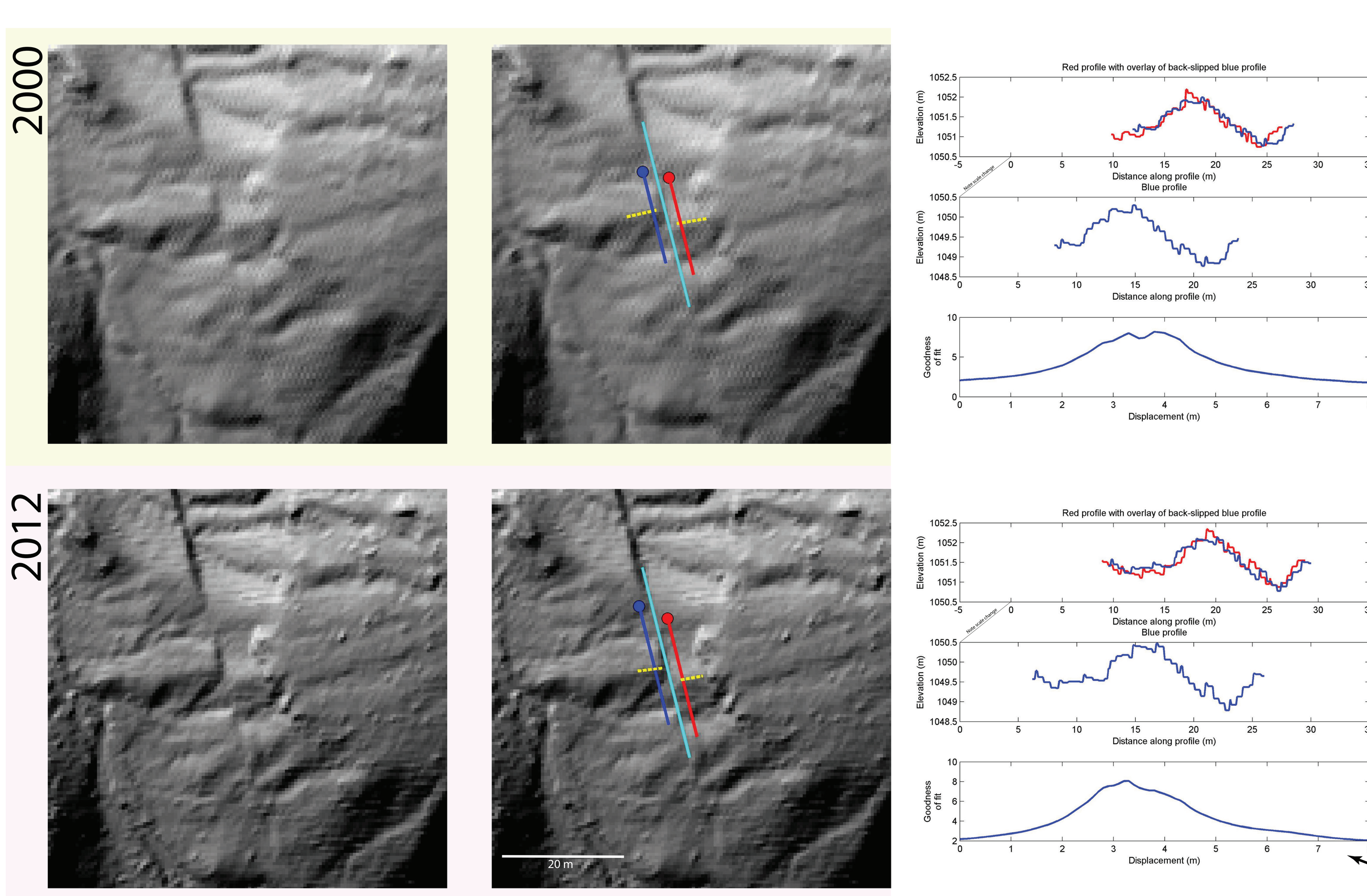

Figure 6. Very similar offset measurements of the exact same geomorphic feature displaced by the 1999 HM earthquake surface rupture made on DEMs derived from aerial LiDAR scans acquired ~12 years apart. April 2000 top, May 2012 bottom. At left are hillshade rasters of measurement zone; at center are fault trace, geomorphic profiles, and feature trends (defined manually) overlain on same hillshade; at right are plots of cross correlated geomorphic profiles and goodness-of-fit plots showing best-fit offset measurement. Analysis done with LaDiCaoz (Zielke and Arrowsmith, 2012)

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