Surface deformation in the Western Salton Trough as observed by InSAR

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Summary

Data from 33 ERS-1 and ERS-2 interferograms (track 356, frame 2943) covering the Western Salton Trough and spanning a time period from 1992 to 2000 were analyzed in order to distinguish possible tectonic movement from subsidence due to groundwater withdrawal. Several areas of apparent deformation were observed: along the Superstition Hills/Elmore Ranch faults, near the southern end of the Coyote Creek segment of the San Jacinto fault, in the Borrego Valley, and near the northwest shore of Salton Sea. Faults in the area are known barriers to groundwater flow. Comparison with well draw-down data and surface geology suggests that the deformation signals near the Coyote Creek, Borrego Valley, and Salton Sea area are primarily due to groundwater extraction. The deformation along the Superstition Hills/Elmore Ranch fault appears to be partially tectonic in origin as the amplitude of deformation matches closely with slip data 1987 Superstition Hill/Elmore Ranch earthquake and is consistent with creep meter records.

Work accomplished We examined surface deformation as observed by InSAR in the Salton Trough west of the Salton Sea (Figure 1). The area is characterized by high levels of seismicity as well as faults with known creep events (e.g. Bilham, 2004). Previous work has also shown areas of subsidence due to groundwater removal (Mellors and Bosivert, 2003). In this work we compare observations of deformation recorded by InSAR with known slip as well as ground water withdrawal to assess the impact of ground water related effects on the measurement of tectonic movement. InSAR processing and stacking was largely conducted by R. Mellors with detailed analysis and comparison with geology by A. Vanzandt, an undergraduate at San Diego State (and also 2004 SCEC summer intern although funded by R. Mellors).

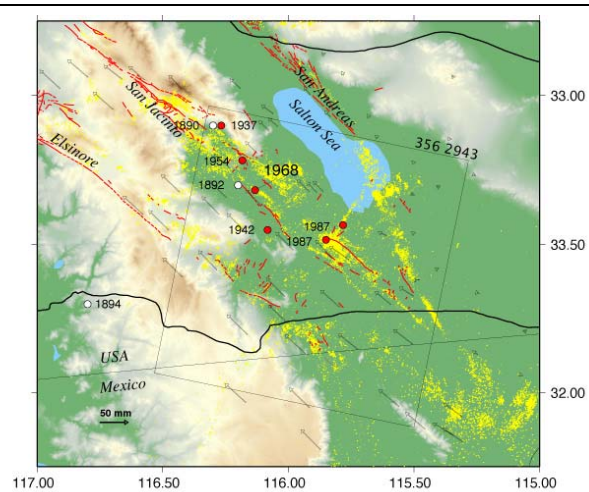

Figure 1. A shaded elevation map of the region covered by satellite radar marked with a box. Known fault traces are red with seismicity (from 1985-2000) in yellow (Magistrale, 2001). Red circles denote the epicenters of large earthquakes with magnitude greater than 6, and white circles are less reliable historical locations. Arrows mark GPS derived crustal velocity vectors with respect to North America (SCEC Crustal Velocity map, 2004)

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*InSAR processing and stacked interferograms***.** We used a set of data from the SCEC-supported WINSAR archive to create 33 interferograms within the time period 1992-2001. These were stacked to produce an high-quality interferogram. The ROI_PAC processing software and SRTM topography were used, along with precise (DELFT) orbits. As no ascending data was available, only descending data was used, which makes it impossible to distinguish vertical from horizontal motion.

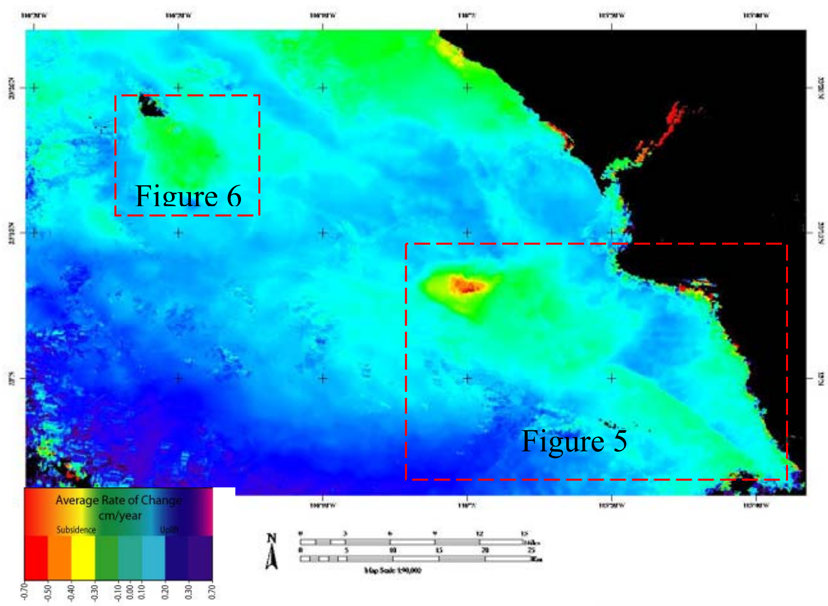


Figure 2. Stacked (1992 - 2000) phase image of the study area. Patches of yellow and green are areas of subsidence or horizontal motion. The dark blue at the lower left may be due to a planar trend related to orbital errors (we have not removed a planar trend from the data).

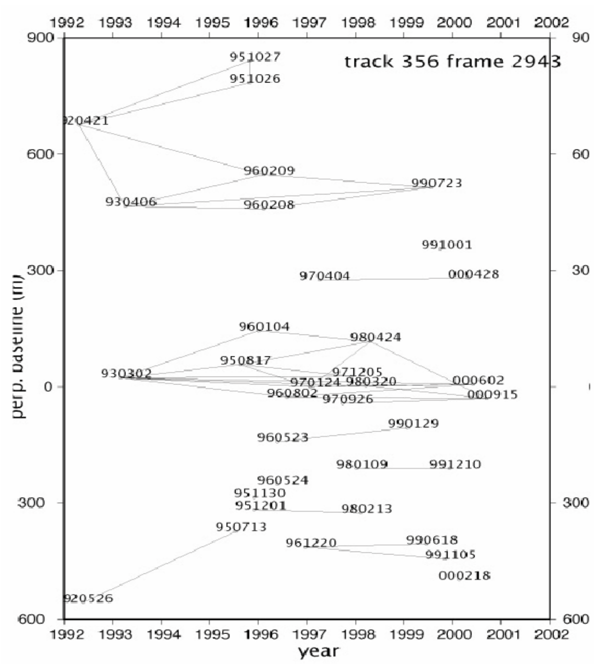


Figure 3. (Right) Baseline plot (perpendicular baseline versus time) of the data used in this study. 33 interferograms are generated from a set of ERS-1 and ERS-2 descending data spanning the time period 1992-2000. The ROI_PAC software is used, along with Delft orbits and the SRTM DEM. The interferogram shown here is a stack of the 33 individual ones divided by the total time so that the scale is the average range change per year. Note that the use of descending data makes it impossible to distinguish vertical from horizontal data, although the measurement is most sensitive to vertical motion.

Superstition Hills fault/Allegretti farms. A broad area of deformation is observed extending from the Superstition Hills fault area up to the Coyote Creek fault. Previous investigation has revealed that the deformation near the Coyote Creek fault is due to groundwater withdrawal from Allegretti farms and is bounded by a previously unmapped section of the Coyote Creek fault and the extra fault. We are now attempting to distinguish the exact boundary between Allegretti Farms deformation and the Coyote Creek. A first approach was to compare the slip during the 1987 Superstition Hills/Elmore Ranch earthquake with the observed slip distribution. Preliminary modeling also matches the deformation near the Elmore Ranch and Superstition Hills area.

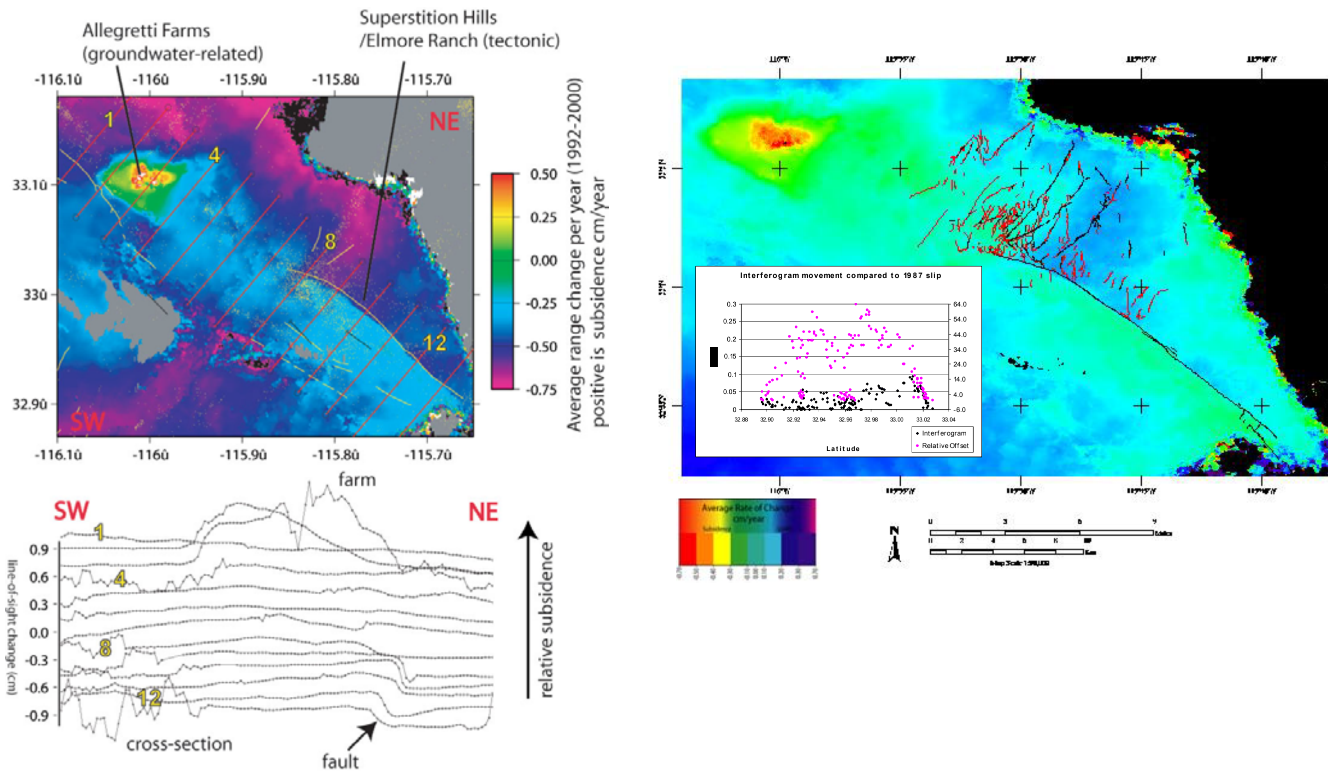
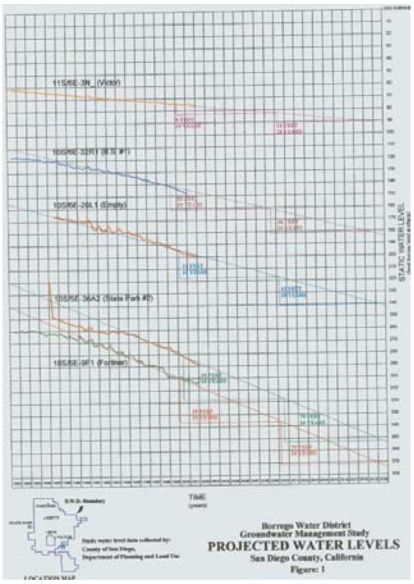
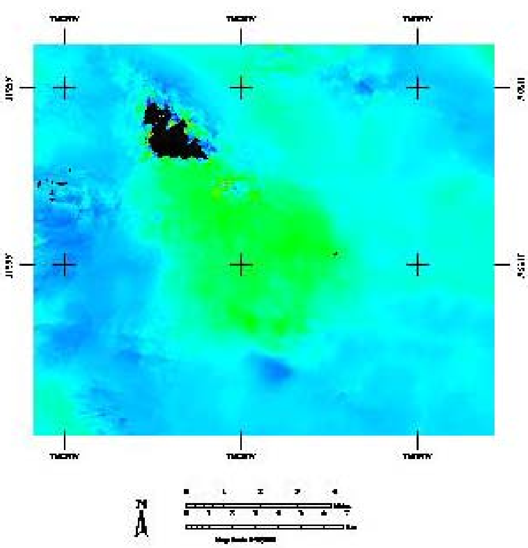


Figure 4 (top) A close-up of the Superstition Hills fault with Quaternary faults (red) and surface rupture (black) from the 1987 Superstition Hills/ Elmore Ranch Earthquake marked (Sharp et all, 1989). (bottom left) A detrended version of the interferogram with cross-sections of the range change shown. Yellow dots indicate seismicity (Magistrale, 2001). (lower left) A comparison of the measured range change from the interferogram with measured surface slip along the Superstition Hills fault following the 1987 event. The fault data matched trends found on the interferogram.

*Subsidence at Borrego Springs***.** An area of apparent subsidence (increased range change with time) was observed centered on the town of Borrego Springs. This is an area of known ground water use and decreased water and we conclude that the subsidence is almost certainly due to lowering of ground water. This was of great interest to the local hydrogeologists, and we are currently working with them on this issue. The eastern edge of the subsidence appears to be bound by the Coyote Creek branch of the San Jacinto.





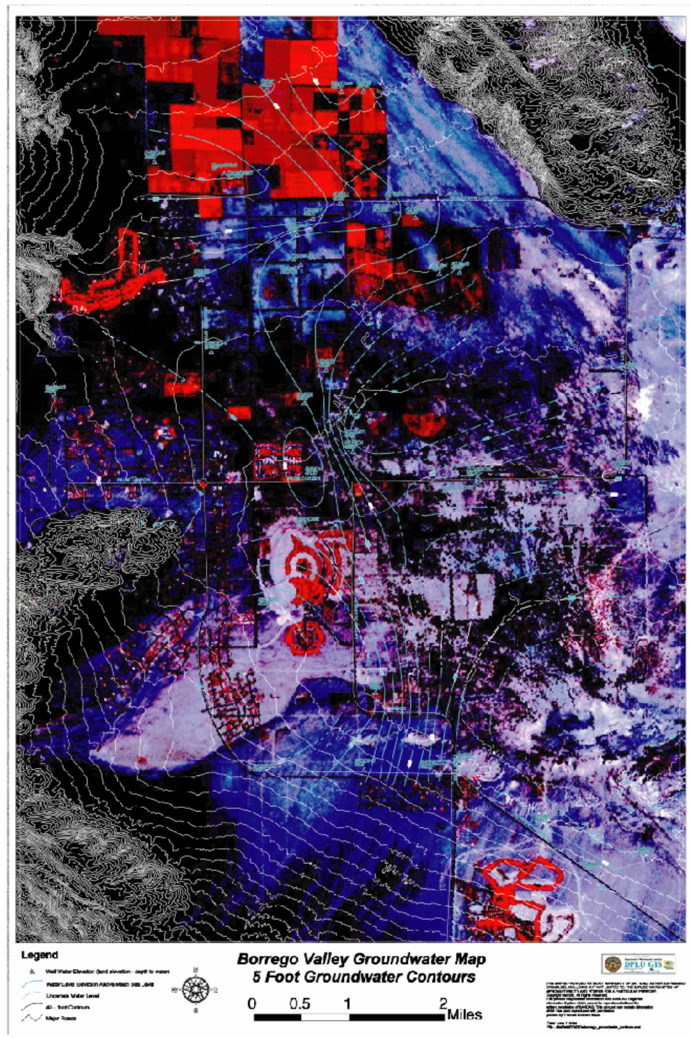


Figure 5. (top left) Water levels at several wells in and around Borrego Springs. (bottom left) Portion of stacked interferogram centered on Borrgeo Springs. Green means subsidence (positive range change) and dark blue uplift. (top right). (bottom right) False-color ASTER image of the Borrego Springs area with current estimated ground water levels shown. The red areas represent vegetation, which require irrigation derived from ground water in this area. The red area at lower right is a golf course which shows a slight uplift. Investigation reveals that the golf course derives their water from wells off the property, which explains the uplift directly under the property.

Conclusions

Subsidence due to groundwater use is occurring at Allegretti Farms and around Borrego Springs. The deformation near the Superstition Hills fault appears to be primarily tectonic, based on known creep measurements and lack of known well use. We are investigating the exact pattern of deformation between the Superstition Hills fault and Allegretti Farms.

Data availability and submission to SCEC

We have been in contact with T. Rockwell regarding the possibility of adding groundwater-related subsidence to the vertical motion map, once a proper format is decided. We have contour intervals available of needed. We have also been in informal contact with SCIGN and Earthscope GPS site installers.

References

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