Surface deformation in the Western Salton Trough as observed by InSAR

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Abstract

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 are analyzed in order to distinguish possible tectonic movement from subsidence due to groundwater withdrawal. Several areas of apparent deformation are 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 in Coyote Creek, Borrego Valley, and Salton Sea area are primarily due to groundwater extraction. The deformation along the Superstition Hills/Elmore Ranch fault may be partially tectonic in origin as the amplitude of deformation matches closely with slip data 1987 Superstition Hill/Elmore Ranch earthquake.

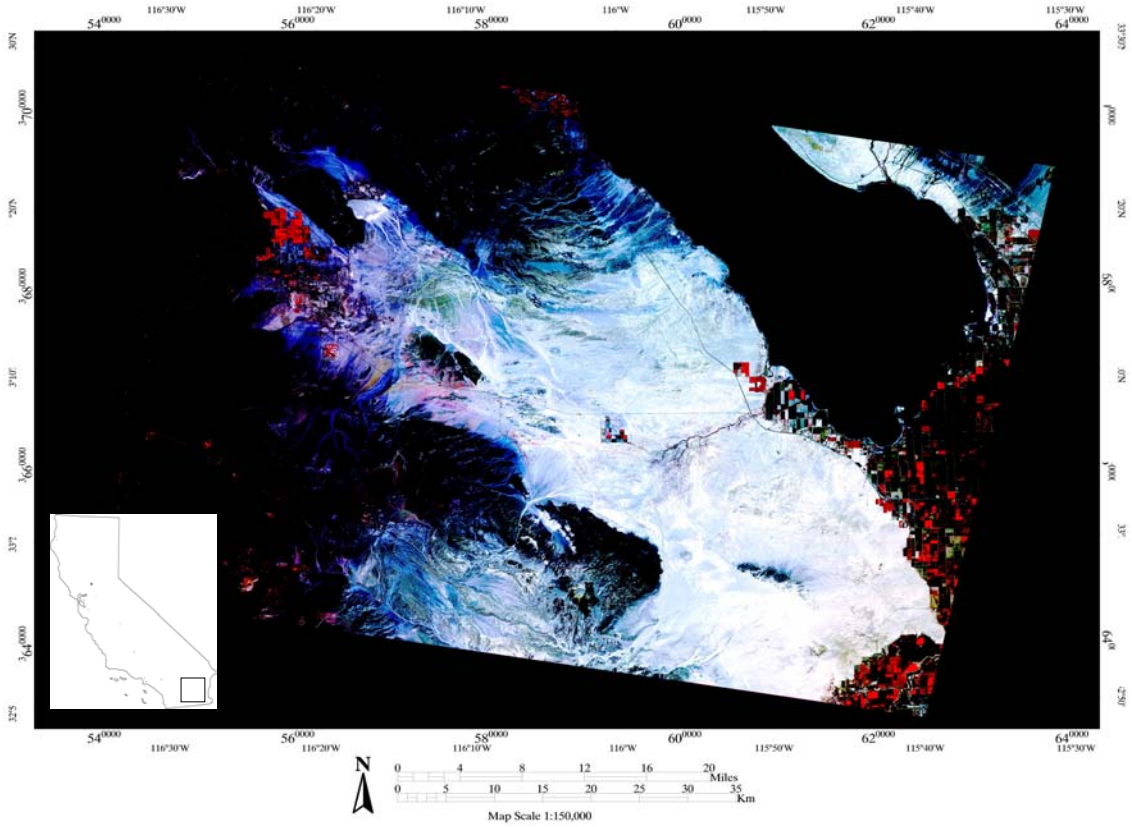


Figure 1. A false-colored, multispectral ASTER image of the area (vegetation appears red). As water supplies for Borrego Springs and Allegretti Farms are almost entirely from groundwater, areas of high vegetation and density are a useful guide to groundwater use.

Introduction: We examine surface deformation as observed by InSAR in the Salton Trough west of the Salton Sea (Figures 1 and 2). 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. 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. Three clear areas of deformation are observed (Figure 3 and 4). The most prominent is centered at a farming area, and is bounded in part on one side by the Coyote Creek branch of the San Jacinto fault. Other areas of deformation occur along the Superstition Hills fault and near the town of Borrego Springs (Figures 5 and 6).

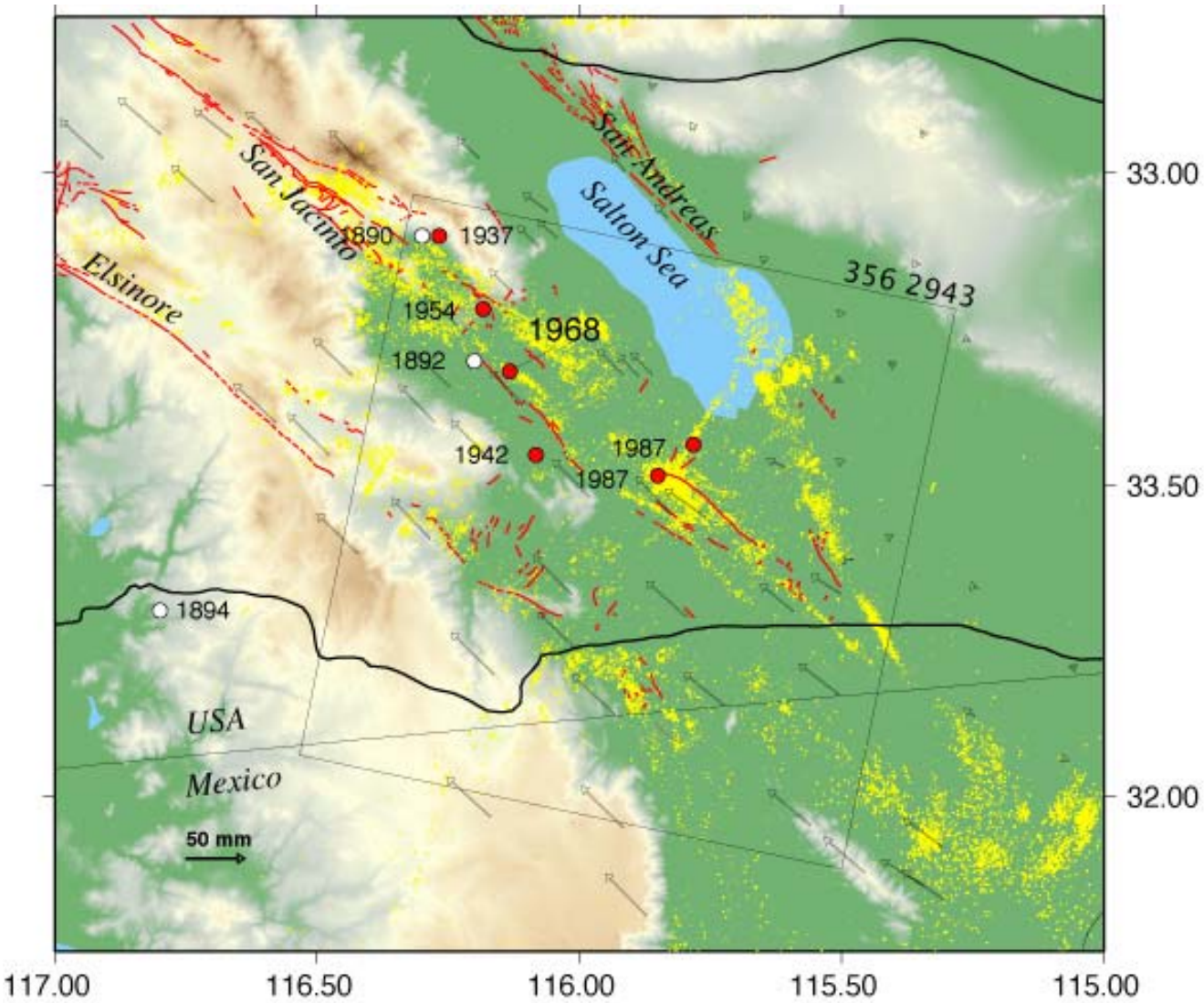
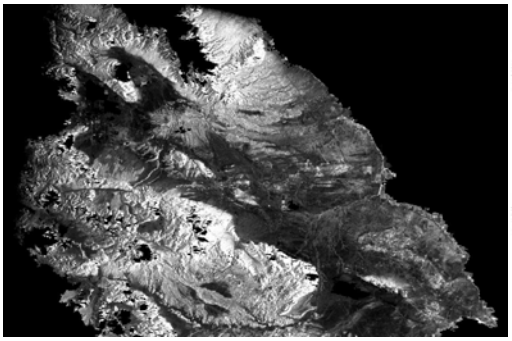


Figure 2. A shaded elevation map of the region covered by satellite radar marked with a box. Known fault traces are red with seismicity (from 1985-2000) in yellow (Magistrale, 2001). Red circles denote the epicenters of large earthquakes with magnitude greater than 6, and white circles are less reliable historical locations. Arrows mark GPS derived crustal velocity vectors with respect to North America (SCEC Crustal Velocity map, downloaded 2003.

InSAR processing and stacked interferograms



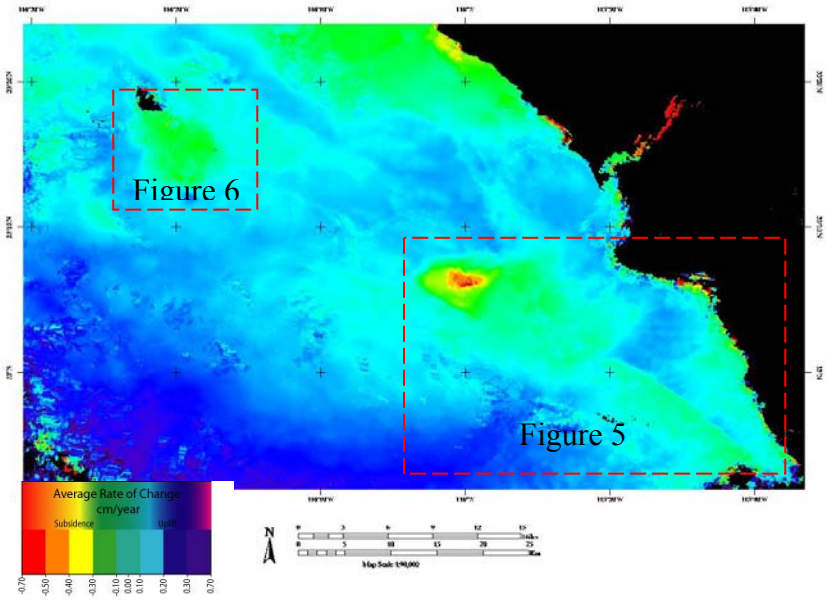


Figure 3. (above) Am amplitude image of the area. Note areas of high topography and the coast of the Salton Sea. (right). Stacked (1992-2000) phase image of the same area. Patches of yellow and green are areas of subsidence or horizontal motion. The dark blue at the lower left may be due to a artificial planar trend related to orbital errors (we have not removed a planar trend from the data).

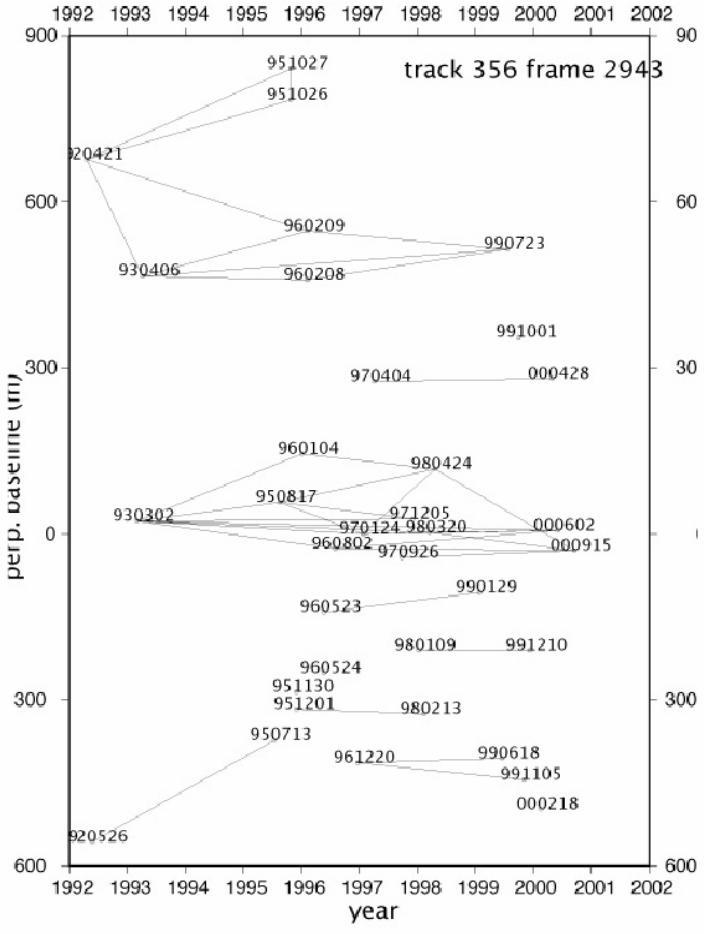


Figure 4. (Right) Baseline plot (perpendicular baseline versus time) of the data used in this study. 33 interferograms are generated from a set of ERS-1 and ERS-2 descending data spanning the time period 1992-2000. The ROI_PAC software is used, along with Delft orbits and the SRTM DEM. The interferogram 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.

Deformation along the Superstition Hill Fault

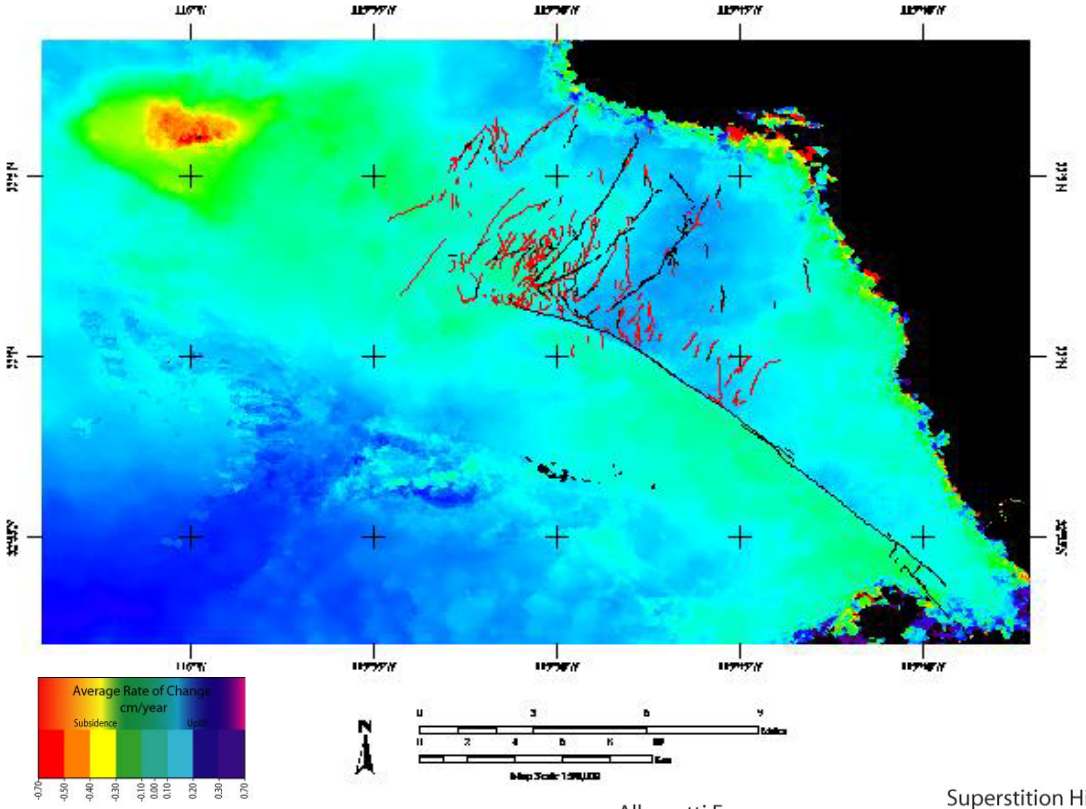
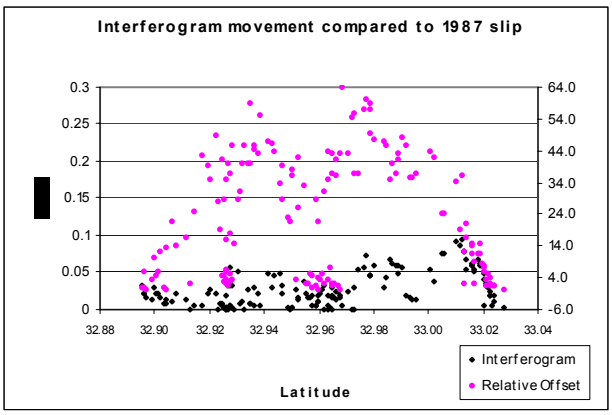
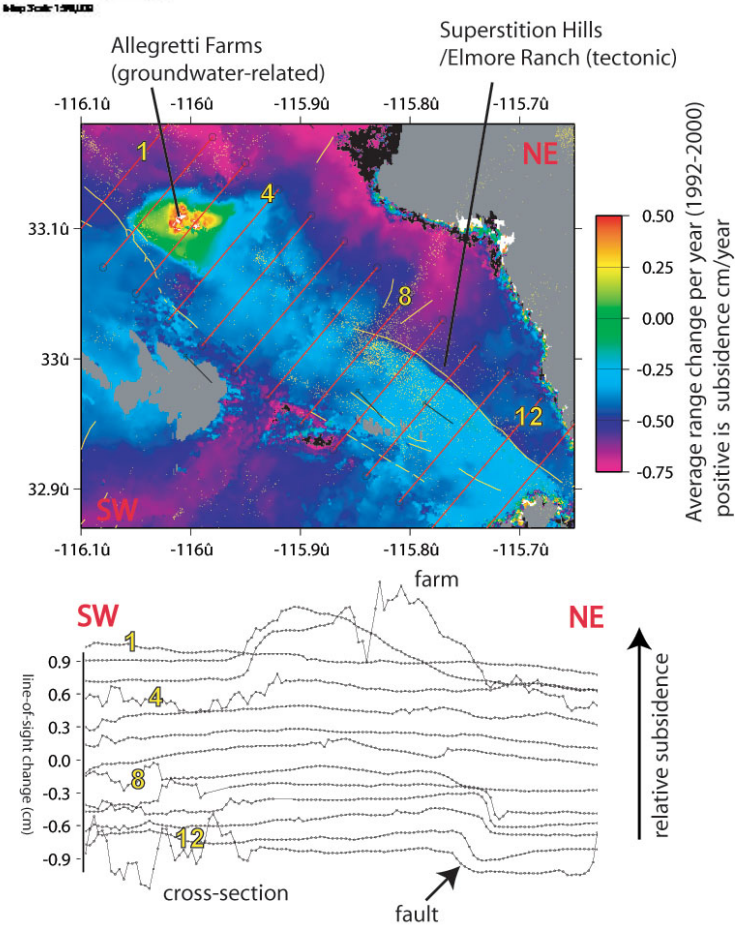
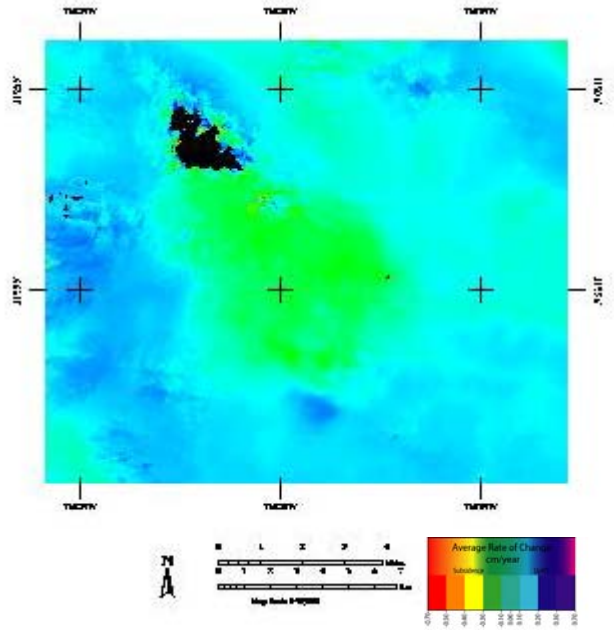


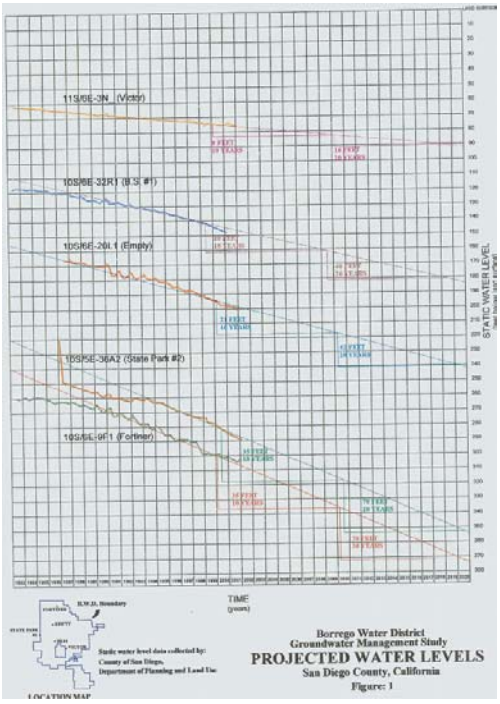
Figure 5 (top) A close-up of the Superstition Hills fault with Quaternary faults (red) and surface rupture (black) from the 1987 Superstition Hills/ Elmore Ranch Earthquake marked (Sharp et all, 1989). (bottom left) A detrended version of the interferogram with cross-sections of the range change shown. 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





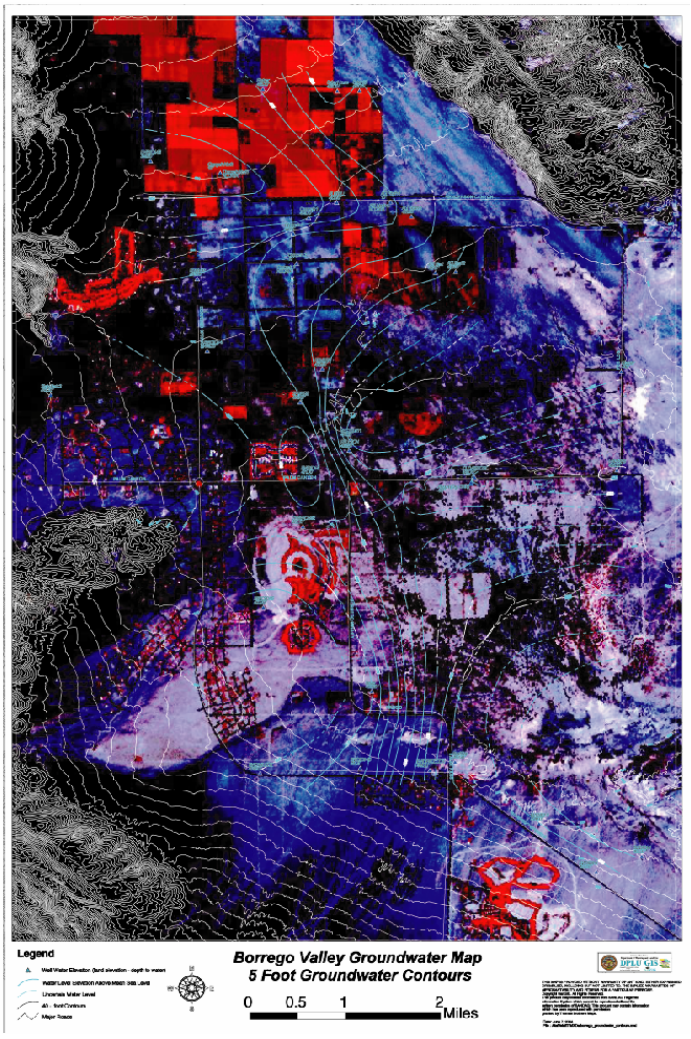


Figure 6. (top left) Portion of stacked interferogram centered on Borrgeo Springs. Green means subsidence (positive range change) and dark blue uplift. (top right). Water level at several wells in the Borrego Springs area. Note that ground water levels are decreasing at all places. (bottom right) False-color 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.

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.

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