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Anomalous Surface Deformation Associated With the December 22, 2003, San Simeon Earthquake – From RADARSAT-1 Interferometry

By Charles Wicks, U.S. Geological Survey (USGS)

On December 22, 2003, a magnitude (M_w) 6.5 earthquake struck the central California coast in a sparsely populated area NE of San Simeon, California (insert, Figure 1). In the city of Paso Robles (population ~28,000), about 39-km ESE of the epicenter, the two deaths caused by the earthquake occurred in the collapse of a building. The maximum building damage sustained during the earthquake was in city center. To gain insight into the cause of the damage focused on Paso Robles, I used RADARSAT-1 images, made available through the Alaska Satellite Facility (ASF), to study earthquake-related surface deformation in the area.

Satellite InSAR has proven to be very useful in the study of large-scale deformation features, tens of kilometers in extent, but it is also useful in studying small, kilometer scale deformation features. The interferogram in Figure 1 shows the range change between two ascending ST2 mode RADARSAT-1 images with 48 days of separation. The interferogram is unfortunately mostly incoherent in the area of the earthquake epicenter. However, the interferogram does show two areas of apparent subsidence related to the earthquake. One area in Templeton, California, about 8-km south of Paso Robles, coincides with the highest measurement of peak ground acceleration where the measured subsidence is most likely the result of an earthquake induced compaction event. Here, I will concentrate on the other, more interesting area of subsidence in Paso Robles.

The area of subsidence in Paso Robles (Figure 1) is bounded on the NE by a steep NW trending gradient that corresponds with (and parallels) the trend of four new hot springs that formed immediately after the San Simeon earthquake. The steep deformation gradient also corresponds to the area of maximum damage and to the location of the two earthquake-related deaths. Wang, et al. (Geophys. Res. Lett., 2004), showed that streamflow increased in the Salinas River at Paso Robles within minutes after the earthquake. Wang, et al., theorized that the increased streamflow in the Salinas River and formation of the new hot springs, resulting from the earthquake, induced breach of a ~100-m deep seal above a pressurized hydrothermal reservoir. In their scenario fluid from the reservoir exited through the breach and immediately pressurized the overlying fracture zone with fluid that subsequently flowed into the Salinas River. Stream flow measurements indicate that

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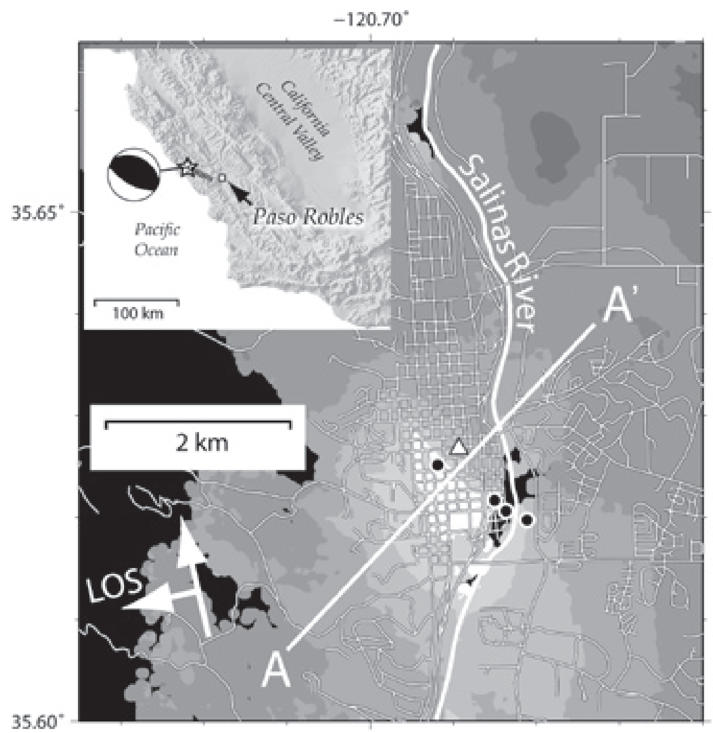

Figure 1. The insert figure shows the regional setting of the earthquake and the Paso Robles study area. The moment tensor for the earthquake from the Harvard catalog is shown. The star shows the epicenter and the dash line shows the approximate rupture length and orientation. The interferogram is from two ascending ST2 RADARSAT-1 scenes acquired on December 3, 2003 and January 20, 2004. The line-of-sight direction to the satellite is the arrow labeled "LOS," about 29 degrees from vertical and the satellite track is the NNW directed arrow. Streets and roads in and around Paso Robles are shown as white on black lines, and the Salinas River is the labeled bold white line. The black-filled white circles mark the locations of new hot springs formed by the earthquake (from Wang, et al., Geophys. Res. Lett., 2004). The triangle shows the location of the approximate area of maximum building damage. Areas with no data in the interferogram are filled with black. The white line labeled A-A' shows the location of the cross-section shown in Figure 2 – the mapping from gray tone to range change in the interferogram can be inferred from the cross-section.

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the majority of the hydrothermal fluid was expulsed in the first few hours after the earthquake, followed by a much lower rate of extended fluid expulsion. The area of subsidence in Figure 1 most likely represents the extent of the hydrothermal reservoir that served as a source for the increased streamflow.

ERS-2 images acquired 35 days apart after the earthquake (December 31, 2003 to February 2, 2004) also show the subsidence area, but with a peak amplitude of about 15 mm of subsidence. This observation agrees with the lower fluid expulsion rate inferred from the streamflow measurements shown by Wang, et al. In contrast, the area of subsidence in Templeton does not show signs of subsidence in this postseismic interferogram consistent with a compaction origin.

It is probably not a coincidence that the earthquake damage was at a maximum in structures located on the steep NE flank of the subsidence feature where the fluid saturated hydrothermal reservoir apparently truncates sharply. We are investigating further the nature of this subsidence and the sharp boundary with inteferograms from other scenes and numerical modeling of the deformation field.

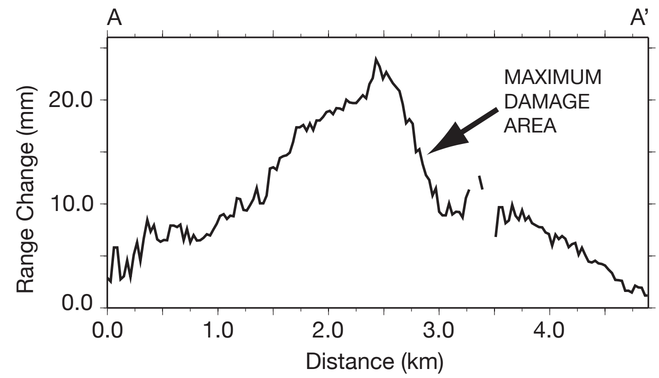


Figure 2. A cross-section of the interferogram in Figure 1 from A to A'. The area of maximum damage is shown.

Summer SAR Class

By David Lokken and Vicky Wolf

This summer's SAR class, held June 19-23, attracted 10 students, ranging from employees of ASF User Services Office to researchers and graduate students from as far away as Michigan and New Mexico. The class ran the full gamut of experience, from beginners to veteran SAR users.

The class started with an introduction to SAR and SAR phenomenology by Richard Carande, President of Neva Ridge Technologies. Carande, formerly of Vexcel Corporation and Jet Propulsion Laboratory, has over 20 years experience with SAR data. The lecture included an overview of the development of radar imaging, types of SAR systems and their applications, and the equations for range and azimuth resolution. He wrapped up the lecture with a discussion about interferometry and speckle.

The class took a break from the classroom, when Phil Utley, a 7-year veteran of ASF's Data Quality group, led them on a 4-km walk along the University of Alaska Fairbanks trails to visit a corner reflector. The 2-m wide metal, three-sided corner is used to calibrate SAR data.

Day two started with Carande discussing radar fundamentals, including range and resolution, and the basics of SAR processing. During the afternoon lab, every student tried to create a SAR sensor using Carande's spreadsheet illustrating the trade-offs involved in designing a satellite-based SAR system, including parameters such as power requirements, peak power, and frequency.

On day three, Dr. Rudi Gens of ASF lectured about geocoding and map projections. During the lab, the class got hands-on practice processing data with the ASF SAR Training Processor (STP), a software program that allows the user to see the results of each of the many intermediate steps that are required to turn raw data into a final product. The training processor is available from ASF via the web at http://www.asf.alaska.edu/softwaretools/.

On day four, the class learned about topics like image filtering and terrain correction and applications of SAR data. UAF researcher, Dr. Matt Nolan, discussed some of his recent work using SAR data, including imaging methane bubbles in lake ice. According to Nolan, SAR's real power is in revealing change.

Day five, the final day, continued the SAR applications topic with talks by Dr. Martin Jeffries and Dr. Claude Duguay, both research professors with the UAF Geophysical Institute (GI), on interpreting SAR images of snow and ice cover. In the afternoon, the class divided into pairs, and worked on interpreting data and applying the knowledge gained in the preceding days. Each pair presented their conclusions to the rest of the class. All walked away with a greater understanding of SAR systems and data.

NASA Recognizes Data Center Excellence

By Nettie La Belle-Hamer

NASA's Earth Sciences Data and Information System Project manages the Earth Observing System Data and Information System (EOSDIS) through contracts with data centers located at Goddard, JPL, Langley, Marshall, The Department of Energy, USGS, Columbia University, University of Alaska Fairbanks Geophysical Institute, and the University of Colorado. EOSDIS systems manage over 4 petabytes of data and were collectively accessed by over 200,000 distinct users last year. The data centers distributed more than 37 million earth science data products during 2004.

In 2004 and 2005, NASA contracted with an independent agency to assess the quality of its EOSDIS data centers. The American Customer Satisfaction Index (ACSI) survey results validate what we have known for a long time, that the EOSDIS data centers provide excellent customer support. Despite dwindling budgets, reduced staff, a steady increase of customers, and a steady increase in products distributed, they continue to find more ways to provide excellent service as evidenced by ACSI results and the many complimentary messages from our user community.

The data centers serve a diverse customer community, ranging from educators (K-12) to researchers, spanning the breadth of all earth science disciplines. The data centers provide unparalleled customer support including, but not limited to, generating special products for users, providing expert assistance in helping users to quickly and easily locate and order data, helping users understand and use the data, and creating new tools to address users' constantly changing needs. ASF personnel maintain close ties to the user community by proactively offering hands-on training such as the SAR course described in this issue, and participating in targeted earth science conferences.

To recognize the efforts and the resulting excellence of the data centers, NASA presented the Group Achievement Award to the EOSDIS Data Centers Customer Support Team. The ASF data center staff received their award from Jeanne Behnke and Medora Macie on August 29, 2006, during their visit to the facility.

ASF Provides Scientific and Technical Support for Education and Outreach

By Anupma Prakash, Associate Professor – Remote Sensing Geophysics, UAF

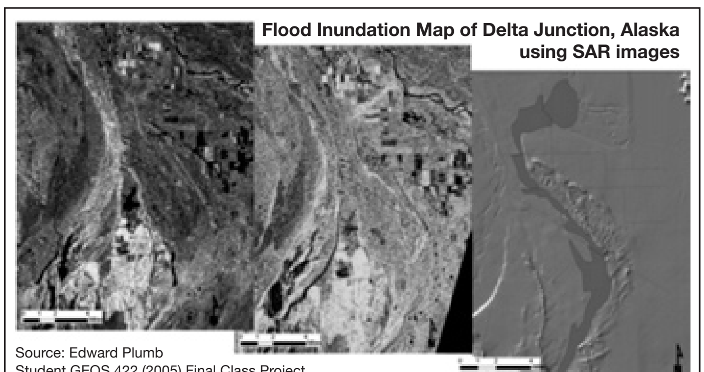
Undergraduate and graduate students getting specialized education in the field of remote sensing at UAF have an upper hand to their peers at other universities. Little are they aware of the fact that they work in one of the most data-rich environments in the circum-Pacific north.

ASF has a large archive of SAR data, the only satellite data that is guaranteed to provide ground information in all weather conditions. Students use data sets of Alaska and neighboring regions to carry out small-term projects in the classroom environment. The data sets are used for a variety of applications that have direct significance to the State of Alaska. This education and training prepares them for careers in research, teaching, and industry.

ASF's support for these educational courses includes providing access to data, user service support to train students on how to order the data, facility tours to demonstrate how data is acquired and processed in near real time in an operational setting, scientific support in the form of guest lectures, and serving as co-mentors for students.

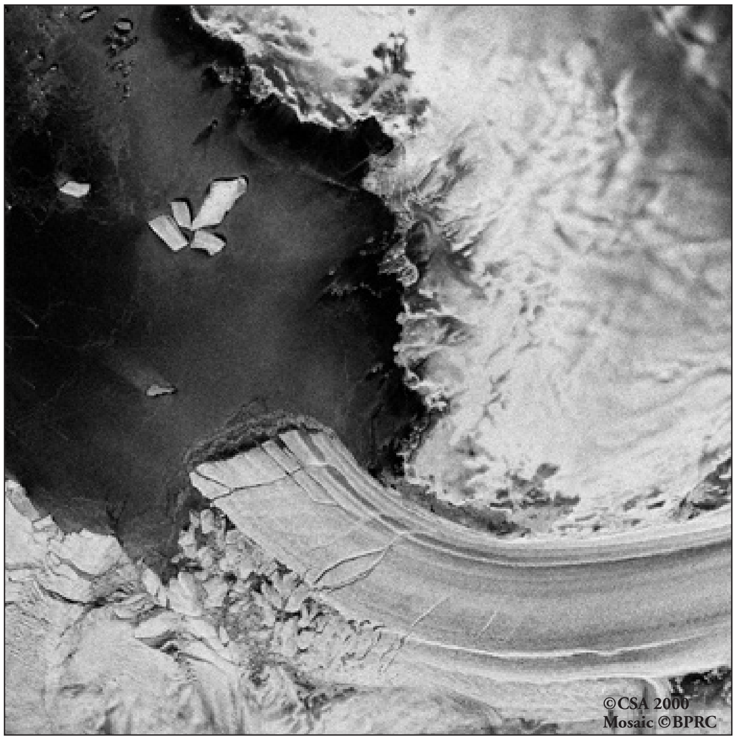
The partnership between ASF and UAF teaching faculty has resulted in motivating many students to pursue careers in earth and space sciences.

The class projects based on the use of SAR data have also been successfully used as training material in selected high schools in the State of Alaska, strengthening UAF's efforts in public outreach. Educational web sites and CD-ROMs on use of SAR data generated with input from ASF personnel are another means of our public outreach. The most recent product in this direction is an educational web story for 4th and 5th grade students conveying concepts of SAR imaging and facts about Alaska.



At UAF the students work in a data-rich environment with unparalleled scientific and technical support.

Visit: www.uaf.edu/asgp/k12/treasure_hunt/



This view of Shirase Glacier, Antarctica is a compilation of RADARSAT-1 fine beam1 images. Shirase Glacier is an outlet glacier for the East Antarctic ice sheet. The data for this mosaic were collected in 2000 as part of the Modified Antarctic Mapping Mission, a part of the RADARSAT Antarctic Mapping Project, to measure velocities of Antarctic glaciers.

Submissions and Subscriptions

This newsletter, published by the Alaska Satellite Facility, was created to provide detailed information about special projects and noteworthy developments, as well as science articles highlighting the use of ASF data.

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