Alaska Satellite Facility
News & Notes
Summer 2013, volume 9:2

ALOS PALSAR Reveals Volcanoes Sink After Large Earthquakes

by Matt Pritchard, Cornell University

Large earthquakes are known to trigger volcanic activity at volcanoes hundreds of km from their epicenters, but interferometric synthetic aperture radar (InSAR) data from Japan's Advanced Land Observing Satellite (ALOS) Phased Array L-Band SAR (PALSAR) have revealed a new phenomenon—enhanced subsidence at some, but not all, volcanoes near two large earthquakes in Chile and Japan. The findings come from two unrelated research teams at Cornell University and Kyoto University.

Five volcanic areas were observed to subside up to 15 cm after the 2010 Maule, Chile, and 2011 Tohoku-Oki earthquakes, magnitudes 8.8 and 9.0 respectively. In both South America and Japan, the size and shape of the deformation zones are similar: All are oriented approximately north–south and measure 15-30 km long and 10-15 km wide (Figures 1-3). The South American volcanoes are Caldera del Atuel in Argentina and Tinguiririca, Calabozos Caldera, Cerro Azul, and Nevados de Chillán, all in Chile. The Japanese volcanoes are Mt. Akitakoma, Mt. Kurikoma, Mt. Zao, Mt. Azuma, and Mt. Nasu.

ALOS PALSAR data were critical for observing the volcano subsidence in both Japan and South America. Sufficient SAR data from other satellites were not acquired at all of the volcanoes, and the available data have low coherence because of the vegetated terrain in both areas. While Japan's dense GPS network confirmed the enhanced subsidence at a few of the volcanoes, the network was still not robust enough to determine the extent of the subsidence and its relation to the volcanoes. However, the GPS data are critical in showing that deformation took less than 24 hours to reach a maximum, indicating a predominantly elastic response.

Several possible mechanisms could cause the deformation, and future work will focus on understanding which are involved. Some deformation mechanisms can be ruled out because the dense seismic sensing network in Japan recorded intensified seismic activity at only one of the deforming volcanoes (Mt. Akitakoma) and no change in gas emissions. Because of the similarities in the patterns and amount of deformation after the two earthquakes, the mechanism of deformation is probably similar. For the Japanese volcanoes, enhanced subsidence of the volcanic regions because of a mechanically weak magma chamber is suggested by the authors of that study.

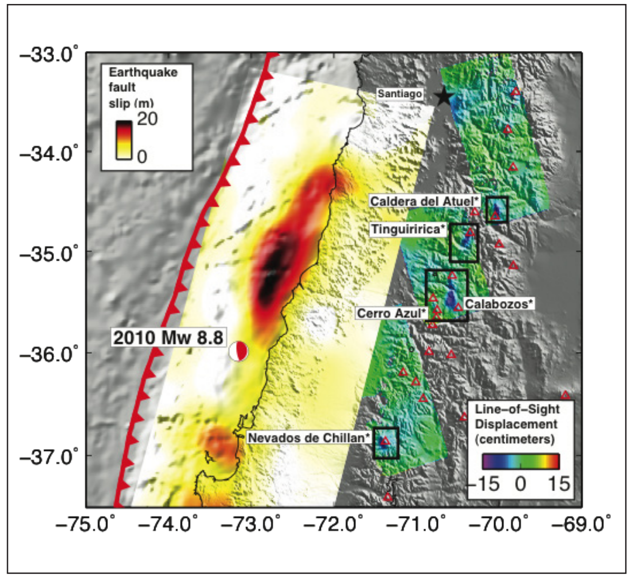


Figure 1: Map of southern Chile and Argentina showing the location of earthquake fault slip from the Maule, Chile, earthquake in 2010 (Mw 8.8) and images from satellite radar of ground subsidence (up to 15 cm) at five volcanoes triggered by the earthquake (see closer look in Figure 2). The deforming volcanoes are labeled. The radar data are from the Japanese Space Agency, and the model of the earthquake slip is from Lorito and others (2011). Ground deformation from the earthquake has been removed from interferograms shown in this and subsequent figures.

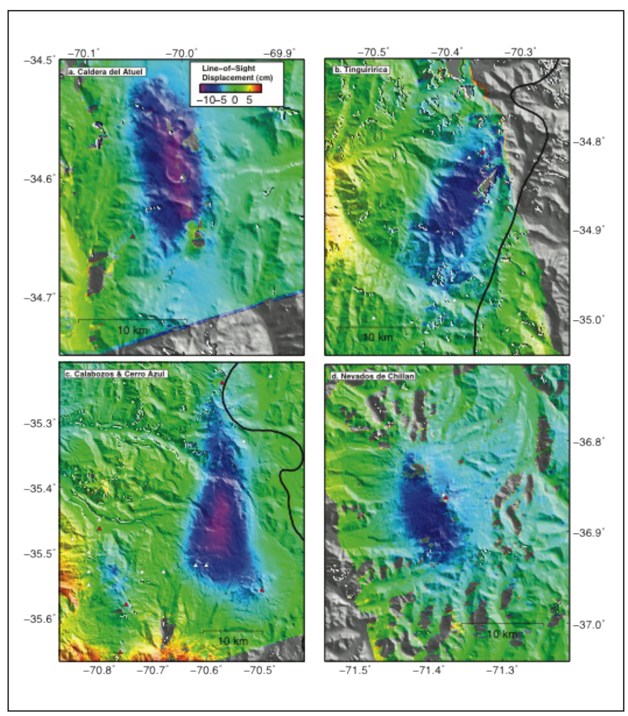


Figure 2: Closer look at ground subsidence at the five volcanoes shown in Figure 1.

Continued on page 2

Continued from front page

In South America, the authors of that study propose that co-seismic shaking and the opening of fractures could have released hydrothermal fluids that then caused enhanced subsidence, partially explaining observed increases in stream flow.

It is not understood why some volcanoes in the rupture zone subsided but others did not. For example, the geothermally active Laguna del Maule, which is currently one of the fastest deforming volcanoes (>20 cm/yr) without a recent eruption had no coseismic deformation; nor did the deformation rate change between March 2010 and January 2011 (the date of the last acquired ALOS PALSAR data in this region). One possible explanation for the lack of deformation at Laguna del Maule is that the earthquake slip was at a minimum near the Laguna del Maule system (Figure 1).

Additional discoveries using ALOS-1 data from 2006-2011 will be enabled by the more than 1,000,000 scenes that will be part of the PALSAR datapool in early 2014, including all data for the Americas and selected locations around the world. These data are available to U.S.-based members of the Western North America InSAR Consortium (WInSAR) once they sign a data use agreement. More data from around the world can be added to the ASF DAAC datapool through a simple proposal process. Please contact uso@asf.alaska.edu for details.

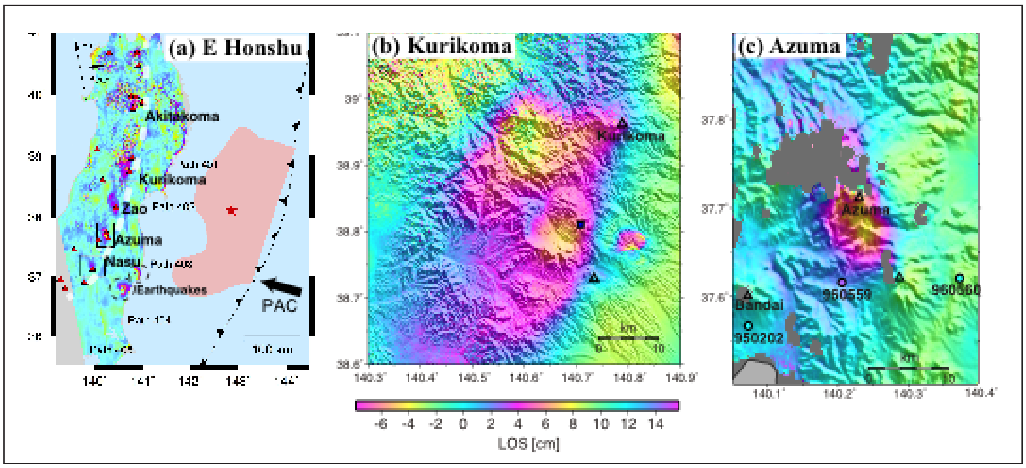


Figure 3: Reference map and interferograms showing subsidence of five volcanic regions in Japan triggered by the 2011 Tohoku-Oki (Mw 9.0) earthquake, with a closer look at two of the areas. The small numbered circles indicate GPS stations that recorded the ground deformation. Courtesy Takada and Fukushima (2013).

Insights on Southwest Sinkholes Through InSAR

by Brian Conway, Arizona Department of Water Resources

At a recent conference on sinkholes, the Arizona Department of Water Resources (ADWR) presented a paper[1] summarizing new findings on land subsidence in the Holbrook Basin, Arizona, detected through interferometric synthetic aperture radar (InSAR). In addition, ADWR drew upon its familiarity with InSAR to share with other attendees the results of on-the-spot downloading of data and InSAR processing and analysis. The conference was the 13th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, more commonly called the "Sinkhole Conference," held in May of 2013 in Carlsbad, New Mexico.

Since 2005, ADWR has identified more than 25 Arizona land subsidence features through the use of archived and regularly collected InSAR data. These features, most of which are located in south-central and southern Arizona, are a result of compaction from excessive historical groundwater withdrawal, and they collectively cover an area greater than 3,600 km^2.

One particular area of interest has been the Holbrook Sinks, located in northeastern Arizona, south of the town of Holbrook. Many of the basin's more than 400 sinkholes, formed by the dissolution of large underlying salt deposits, are 50 m to 100 m across by 10 m to 25 m deep. ADWR collected, processed, and analyzed archived ALOS-1 data from the Alaska Satellite Facility Distributed Active Archive Center (ASF DAAC), with two main goals: to determine if the existing sinkholes were subsiding and to develop a baseline for any existing land subsidence around the Petrified Forest National Park before the development of planned potash mines in that area.

The ALOS-1 data confirmed that existing sinks were not subsiding, and the data also identified two previously unknown sinkholes within the Holbrook Sinks area. A subsequent field investigation verified that area around the sinkholes identified with the ALOS-1 InSAR data is active with depressions and expansion cracks (Figure 4).

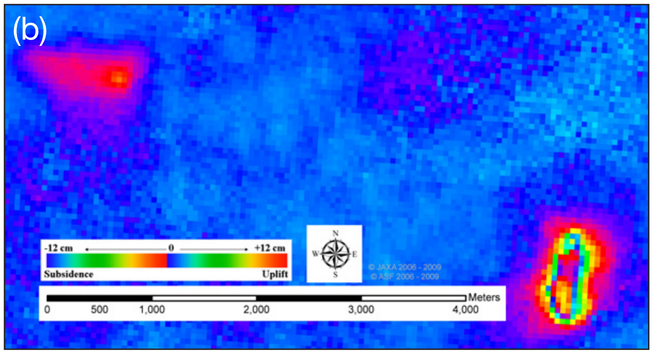


Figure 4: (a) Field-verified expansion crack in Holbrook Sinks. (b) Recently identified Holbrook Sinks using ALOS-1inSAR data from 12/06/2006 to 12/14/2009.

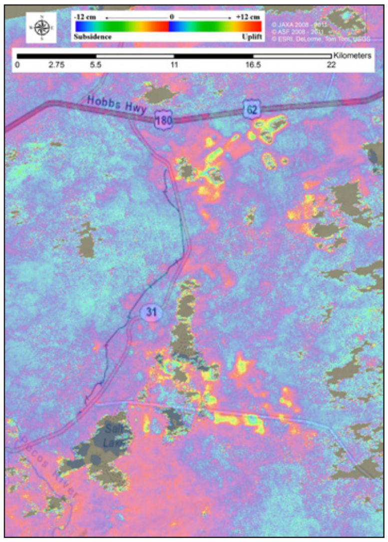


Figure 5: (right) Land subsidence from potash mining, SE N.M., ALOS-1 InSAR data from 05/21/2008 to 03/16/2011.

ADWR presented these findings at the May 2013 "Sinkhole Conference." Very few people at the conference had used InSAR data (or even heard of the technology) to examine sinkholes and land subsidence features in the Carlsbad area—despite the fact that around this area, as well as in southeast New Mexico and southwest Texas, significant oil and gas production, potash mining, brine well extraction, and karst dissolution have resulted in numerous sinkholes and land subsidence areas. In northeastern Arizona, a number of mines are expected to mine the potash deposit in the next decade. The mining may result in significant land subsidence, which may produce effects similar to those seen in parts of New Mexico and Texas.

During the conference, ADWR downloaded and processed ALOS-1 data from ASF to research the area around Carlsbad where potash mining has been ongoing and where sinkholes have opened up in the past 30 years. ADWR then compared the karst features of New Mexico and Arizona with their InSAR signatures, as well as how land subsidence associated with potash mining in New Mexico may be used to monitor and better understand the potential for future potash-mining-related land subsidence in northeast Arizona.

The ALOS-1 data of southeast New Mexico and southwest Texas yielded very interesting results. There has been significant land subsidence in the potash mining district to the east of Carlsbad, New Mexico: as much as 25 cm of land subsidence from 05/21/2008 to 03/16/2011 (Figure 5). Three sinkholes that opened up at various times over the past 30 years (Figure 6) exhibit land subsidence from 05/21/2008 to 11/27/2010 as high as 12 cm (Jal sinkhole, 1998), 15 cm (Wink 1 sinkhole, 1980), and 27 cm (Wink 2 sinkhole, 2002).

The land subsidence associated with the sinkholes in New Mexico and Texas differs from the land subsidence associated with the recently discovered sinkholes that have occurred and are occurring in northeast Arizona.

The Jal and Wink sinks formed due to dissolution caused by a collapsed oil and gas well-casing and a poor seal that acted as a conduit for groundwater to dissolve massive halite (salt) deposits in underlying Permian age evaporite formations. The subsidence associated with the potash mining in New Mexico is a possible glimpse into the future for planned potash mining activity in Arizona and subsequent land subsidence, as the Arizona mining will use techniques similar to those of the New Mexico mine to extract the potash.

In contrast, the two Holbrook sinks recently discovered using the ALOS-1 data are not caused by the dissolution of salt. Rather, they are caused by the natural weathering or other

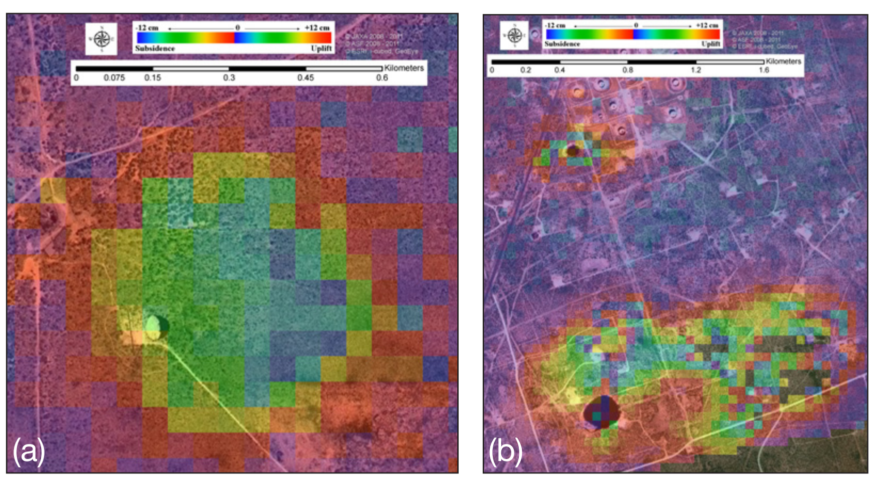


Figure 6: (a) Land subsidence at Jal Sinkhole, SE N.M., ALOS-1 InSAR data from 05/21/2008 to 11/27/2010. (b) Land subsidence at the Wink-1 & 2 sinkholes, SW Texas, ALOS-1 InSAR data from 05/21/2008 to 11/27/2010.

Continued on back page

Alaska Satellite Facility
UAF Geophysical Institute
903 Koyukuk Drive
PO Box 757320
Fairbanks, AK 99775-7320

www.asf.alaska.edu

Please follow us on Facebook and Twitter:

facebook.com/AKSatellite
twitter.com/Ak_Satellite

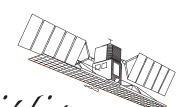
Continued from page 3

disintegration of rock fabric structure of the underlying Coconino formation. Recent InSAR data suggest a different mechanism from those that formed the Jal, Wink, and other Holbrook sinks studied. The two new Holbrook sinks are much larger in area (1 km across), not as deep, and do not have steep vertical side walls.

ASF's resources allowed accessing of the ALOS-1 data library on a moment's notice, resulting in immediate data download, InSAR processing, and analysis that was then shared with other attendees of the conference, whose time was greatly limited. This resulted in valuable conversations and comparisons among land subsidence and sinkholes in Arizona, New Mexico, and Texas. The research project also allowed others to learn about the value of InSAR data and how it might be applied for their own projects inside and outside the region.

[1]Conway B, Cook J., "Monitoring Evaporite Karst Activity and Land Subsidence in the Holbrook Basin, Arizona, using Interferometric Synthetic Aperture Radar (InSAR)": 13th Conference on the Engineering and Environmental Impacts of Karst (2013).

Submissions and Subscriptions



This newsletter provides detailed information about special projects and noteworthy developments, as well as science articles highlighting the use of ASF data.

With the next edition, *ASF News & Notes* will be published only online. It will be available at www.asf.alaska.edu, and readers can receive the newsletter via email by emailing our User Support office at uso@asf.alaska.edu. Back issues are also available on the ASF website.

Submissions to *ASF News & Notes* and suggestions about content are always welcome. If you are interested in contributing materials, please call or send an email to the editor:

Vicky Wolf, ASF User Support

907-474-6166 | uso@asf.alaska.edu

Alaska Satellite Facility Management

Nettie La Belle-Hamer, *ASF Director*
Scott Arko, *ASF Deputy Director*