Imaging and Analysis of Large Space Geodetic Data Sets for Monitoring, Research, and Response

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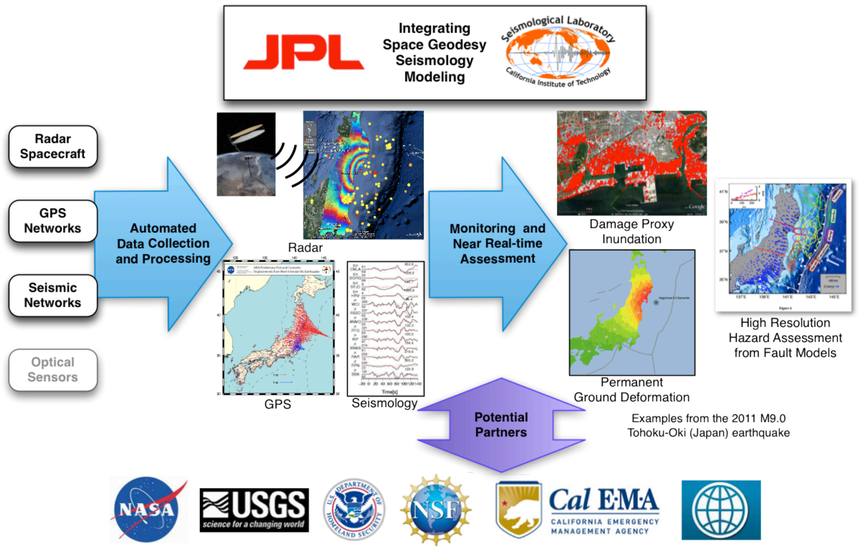
Abstract

Advanced Rapid Imaging and Analysis (ARIA) is a JPL/Caltech coordinated effort to automate geodetic imaging capabilities for monitoring, research, and hazard response. Initial development is focused on earthquake response and volcanic monitoring. Over the past decade, space-based geodetic measurements such as InSAR and GPS have provided new assessment capabilities on the size and location of earthquakes following seismic disasters and on volcanic eruptions during magmatic events. Geodetic imaging's unique ability to capture surface deformation in high spatial and temporal resolution allow us to resolve the fault geometry and distribution of slip associated with any given earthquake in correspondingly high spatial & temporal detail. In addition, remote sensing with radar provides change detection and damage assessment capabilities for earthquakes, floods and other disasters that can image even at night or through clouds. These data sets are still essentially hand-crafted, and thus are not generated rapidly and reliably enough for informing decision-making agencies and the public following an earthquake.

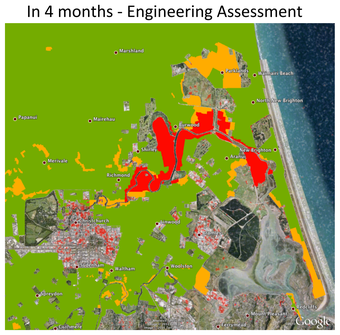
We are building an end-to-end prototype geodetic imaging data system that would form the foundation for an envisioned operational hazard response center integrating InSAR, GPS, seismology, and modeling to deliver monitoring, actionable science, and situational awareness products. This prototype exploits state-of-the-art analysis algorithms from technologists and scientists. These algorithms enable the quick delivery of data products from large data sets, which fuel the development of next generation modeling and interpretation techniques. We are collaborating with USGS scientists in both the earthquake and volcano science program for our initial data product infusion.

We present our progress to date on development of prototype data system, demonstration data products, and example responses such as generating data products for the 2011 M9.0 Tohoku-oki, M6.3 Christchurch earthquakes, the 2011 M7.1 Van earthquake, several simulated earthquake response exercises, the recent Brawley seismic swarm, and M7.6 Costa Rica earthquake.



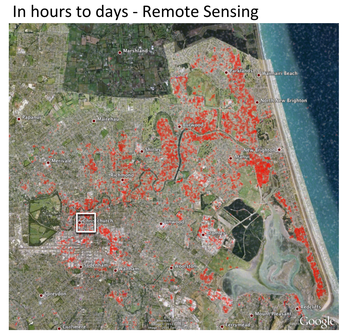
Geodetic Imaging for Hazard Assessment and Situational Awareness

In 4 months - Engineering Assessment

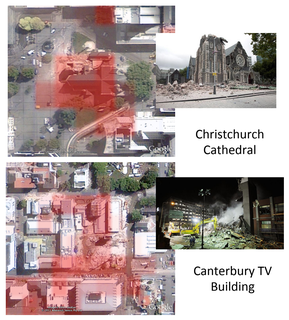


Re-zoning map indicating where repair and rebuilding will be allowed. This map is the product of many man-hours of effort to assess structures and the land that they were built on.

In hours to days - Remote Sensing

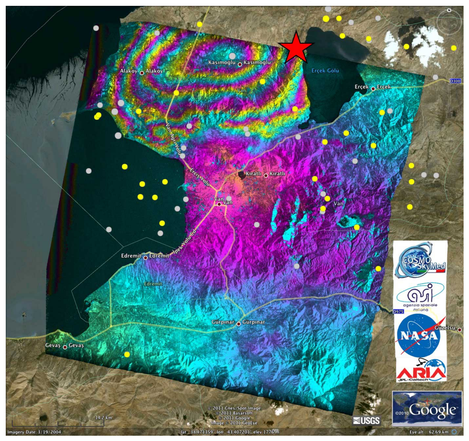


The Damage Proxy Map indicates significant centimeter scale change due to subsidence, inundation, or structure collapse allowing early assessment of the scale of damage.



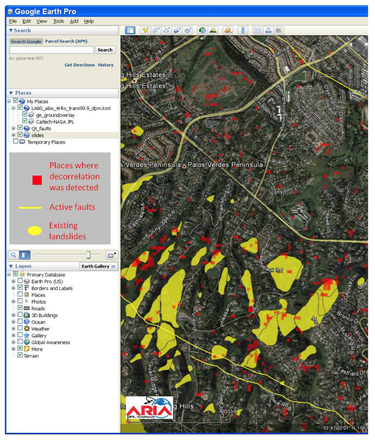
We applied our prototype damage proxy map algorithm to February 2011 M6.3 Christchurch earthquake in New Zealand using ALOS PALSAR data (2010/10/10 - 2011/01/10 - 2011/02/25). A number of detected damage sites, including the ones covered in media, were confirmed with Google earth images provided by GeoEye (figures on right). Three different types of damage - liquefaction, building collapse, and landslide - appear as red pixels.

October 2011 M7.1 Van, Turkey Earthquake



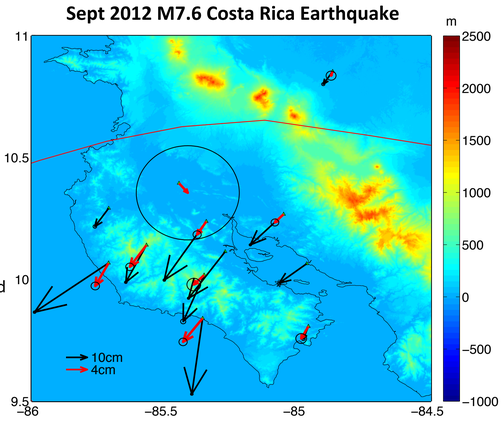
Following the October 23, 2011 earthquake near Van, the ARIA team processed both InSAR and GPS results to understand the spatial extent of the earthquake faulting. To the right is the COSMO-SkyMed interferogram rewrapped with 20 cm color wrap. The red star shows USGS epicenter of mainshock and gray and yellow circles show USGS aftershock locations between Oct. 23 and Nov. 3. The interferogram shows that the main coseismic fault rupture was limited to depths greater than about 8 km, so shallow faults remain a risk for future quakes.

Golden Guardian Exercise



We developed a data sharing tool for use in Golden Guardian 2012 Exercise: the Earthquake Product Annotation Tool. With this tool, annotations are entered into GeoRSS Feed, creating Hazard Focus of Attention Points. The Damage Proxy Map is provided in data formats that can be layered with other maps (e.g., potential landslides as shown in figure to the left).

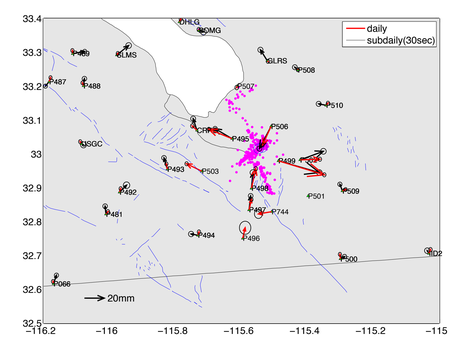
Sept 2012 M7.6 Costa Rica Earthquake



At the request of seismologist Dr. Marino Protti, of Costa Rica Volcanological and Seismological Observatory, (OVSICORI), and U.S. colleagues, we provided coseismic (black vector) and postseismic (red vector) GPS displacements for the Sept 5, 2012 M7.6 earthquake in Costa Rica (figure right). These data provide critical constraints on how much of the subduction zone fault had slipped and understanding whether a larger earthquake is possible.

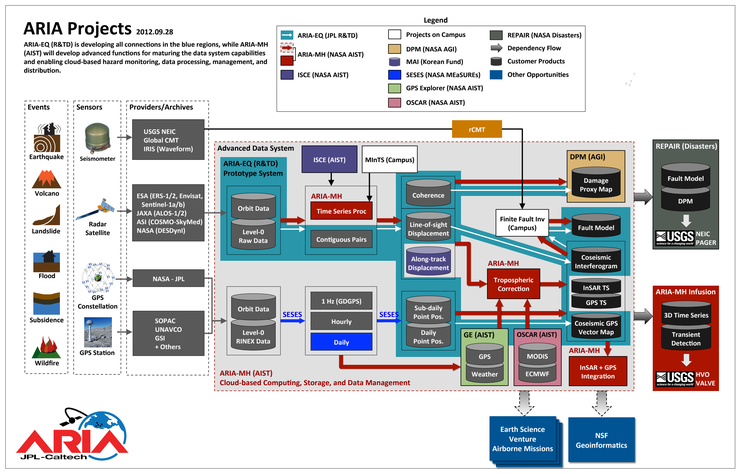
August 2012 Brawley Seismic Swarm

On August 26, 2012 a seismic swarm began in the area known as the Brawley Seismic Zone in southern California. The two largest earthquakes were a M5.3 at 12:31 pm and a M5.5 at 1:57 pm; over thirty events over M3.5 occurred. The ARIA GPS Processing system was automatically getting data from sites available hourly (P499) and generating 30 second point positioning results with JPL's Ultra Rapid Orbits and Clocks (5 min). The earthquake offset was below the noise level for these preliminary results. Monday, August 27, 2012, the ARIA processing system automatically updated the positions for P499 and other sites in the region now available. We posted 30 second PPP time series using JPL's Rapid Orbits and High Rate Clocks (30 sec), and these results showed ~cm level horizontal offsets at P499, P495, P502, P506 (see vector plot to the right).



ARIA Projects 2012.09.28

ARIA-EQ (R&TD) is developing all connections in the blue regions, while ARIA-MH (AIST) will develop advanced functions for maturing the data system capabilities and enabling cloud-based hazard monitoring, data processing, management, and distribution.



The ARIA Project

ARIA-EQ is a 3 year project to develop an earthquake hazards geodetic imaging prototype system that will be capable of producing reliable near real-time earthquake science and assessment products. In the process of developing this data system, we are capturing scientific knowledge into reliable software models to enable automation of geodetic imaging products. The ARIA EQ team is an interdisciplinary group composed of earth scientists, system and software engineers.

The project began in October 2010, and the focus has been on system requirements, architecture design and developing the prototype system for autotmated InSAR processing and GPS earthquake product generation. In addition, we have developed algorithms for using SAR coherence and amplitude change to image damage from an earthquake (as well as other disasters) and enhanced existing GPS software for automated analysis to include sub-daily processing.

In June 2012, we began a NASA funded AIST project to develop hazard monitoring capabilities (e.g. time series for SAR and GPS) and to enable cloud-based computing and data management. In October 2012 we initiated a NASA funded Applied Science Disasters.

The ARIA Data System

The ARIA team designed and documented an architecture for the prototype data system, using a loosely coupled architecture that would allow for scaling-up required for operational implementation and simple upgrading when new algorithms are developed. We have defined architecture layers as well as the event, job and resource management description.

The protocode for InSAR workflow and data management for ALOS data was completed in our first year. In the second year, Envisat and GPS data management workflow were added. We have demonstrated the processing capabilities of the data system, including staging canned radar frame data, having the event manager identify contiguous frames and create jobs.

Over the next year, we will be developing the triggered product generation capability within the data system. Under the NASA-funded AIST, we will also be working on integrating InSAR time series code and cloud computing capabilities (Diagram to the right).