Using SAR and GPS (and Optical) for Hazard Management and Response: Progress and Examples from the Advanced Rapid Imaging and Analysis (ARIA) Project

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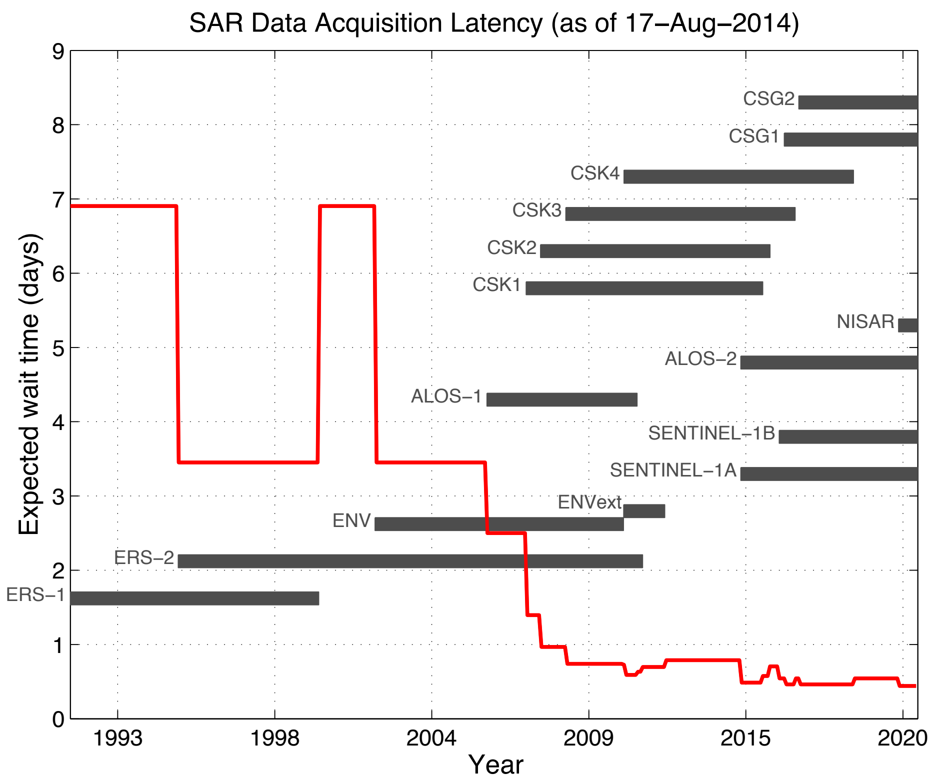
SAR Data Acquisition Latency



- Expected wait time until the first SAR satellite to visit after an event
- Ascending + Descending orbit
- Right-looking mode only
- Latitude : N38° (San Francisco)

Anywhere on Earth, a radar satellite passes overhead at least once per day.

Advanced Rapid Imaging and Analysis (ARIA): An Overview

ARIA JPL-Caltech

JPL

Integrating
Space Geodesy
Seismology
Modeling

Seismological Laboratory
California Institute of Technology

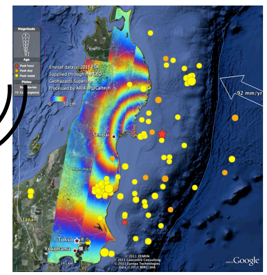
Radar Sensors

GPS Networks

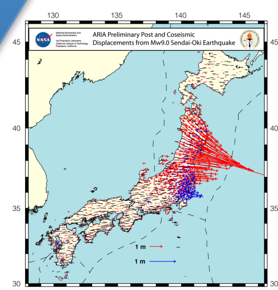
Seismic Networks

Optical Sensors

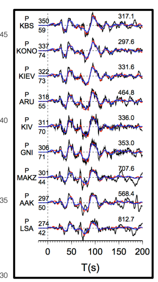
Automated Data Collection & Processing



Radar

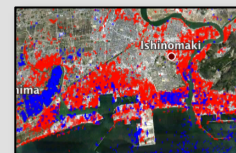


GPS

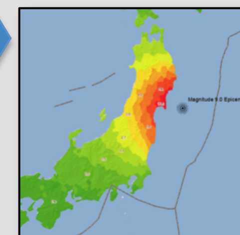


Seismology

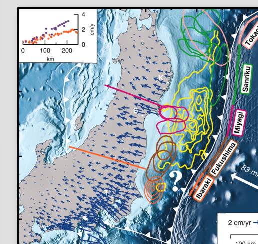
Monitoring & Near Real-Time Assessment



Building Damage & Inundation



Permanent Ground Deformation



High-Resolution Hazard Assessment from Fault Models

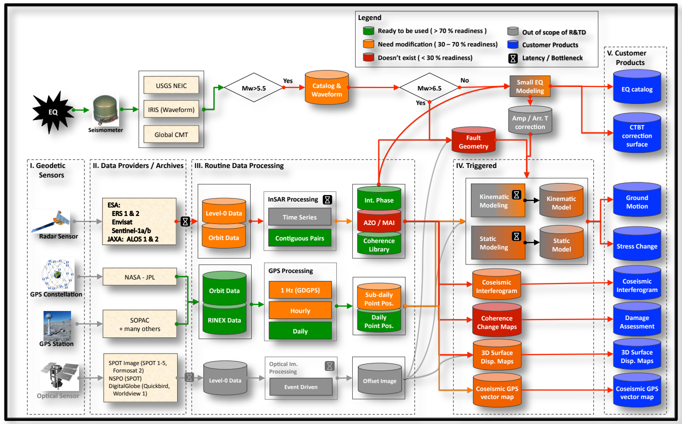
Examples from the 2011 M9.0 Tohoku-Oki (Japan) earthquake

Potential Partners

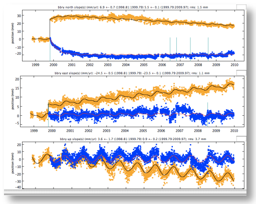
The Challenge of Leveraging Remote Sensing for Disaster Response

Automated data systems are required to analyze large quantities of data from the international constellation of SAR/optical satellites and rapidly expanding GPS networks.

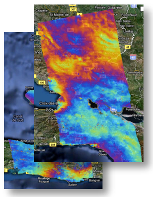
Going from Artisan to Automation: Use system engineering approach to translate specialized data analysis into operational capability.



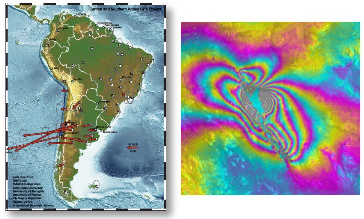
ARIA aims to demonstrate/operationalize response to hazards with standardized set of data products for **decision** & **policy makers** as well as for **discipline scientists**.



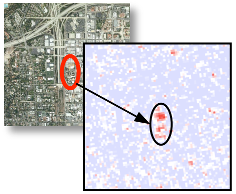
Temporal Records of Ground Deformation



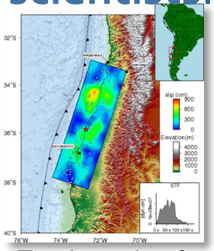
Spatial Maps of Ground Deformation



Earthquake and Eruption Related Ground Deformation



Coseismic & Eruption Damage

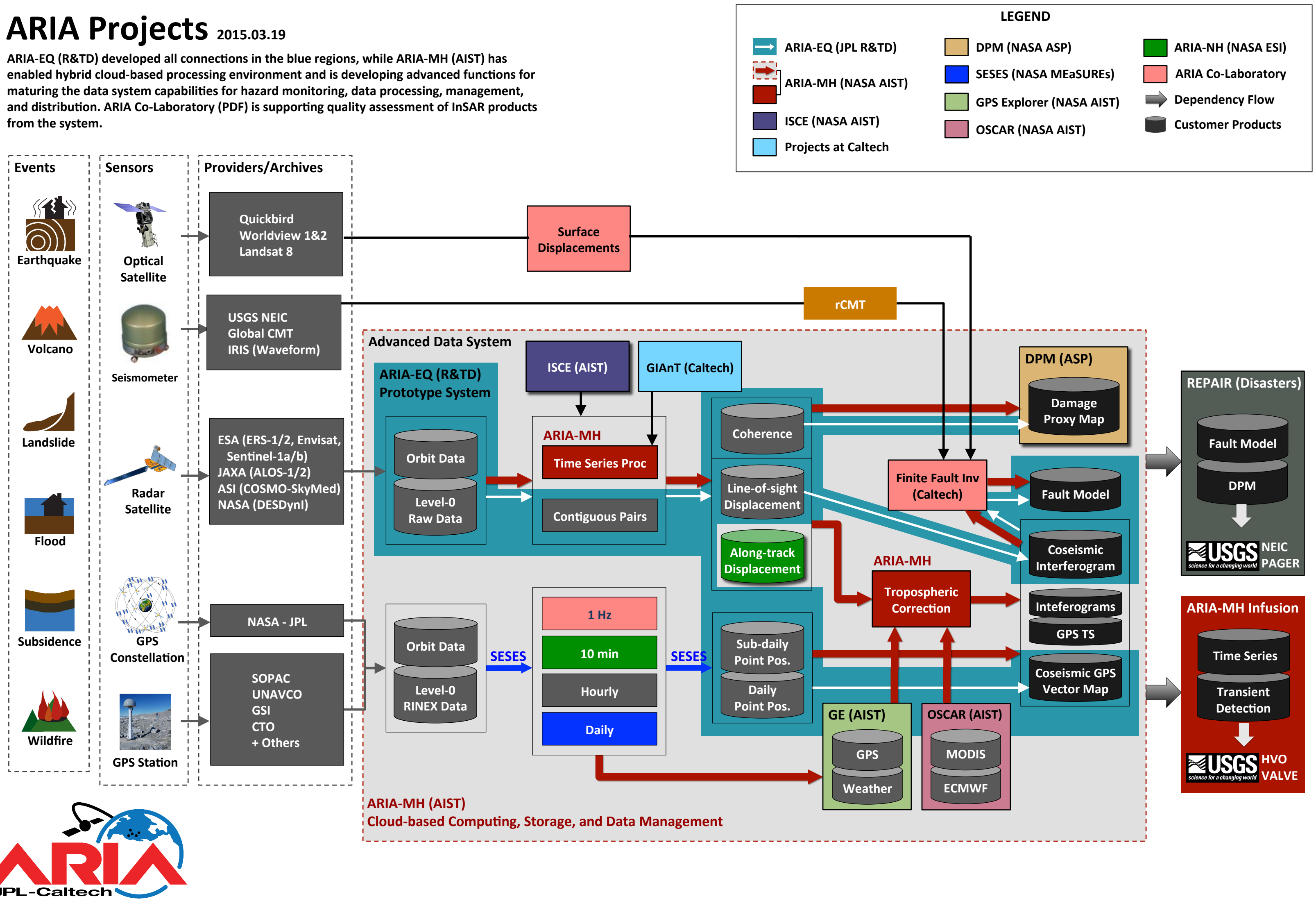


Earthquake & Volcano Models

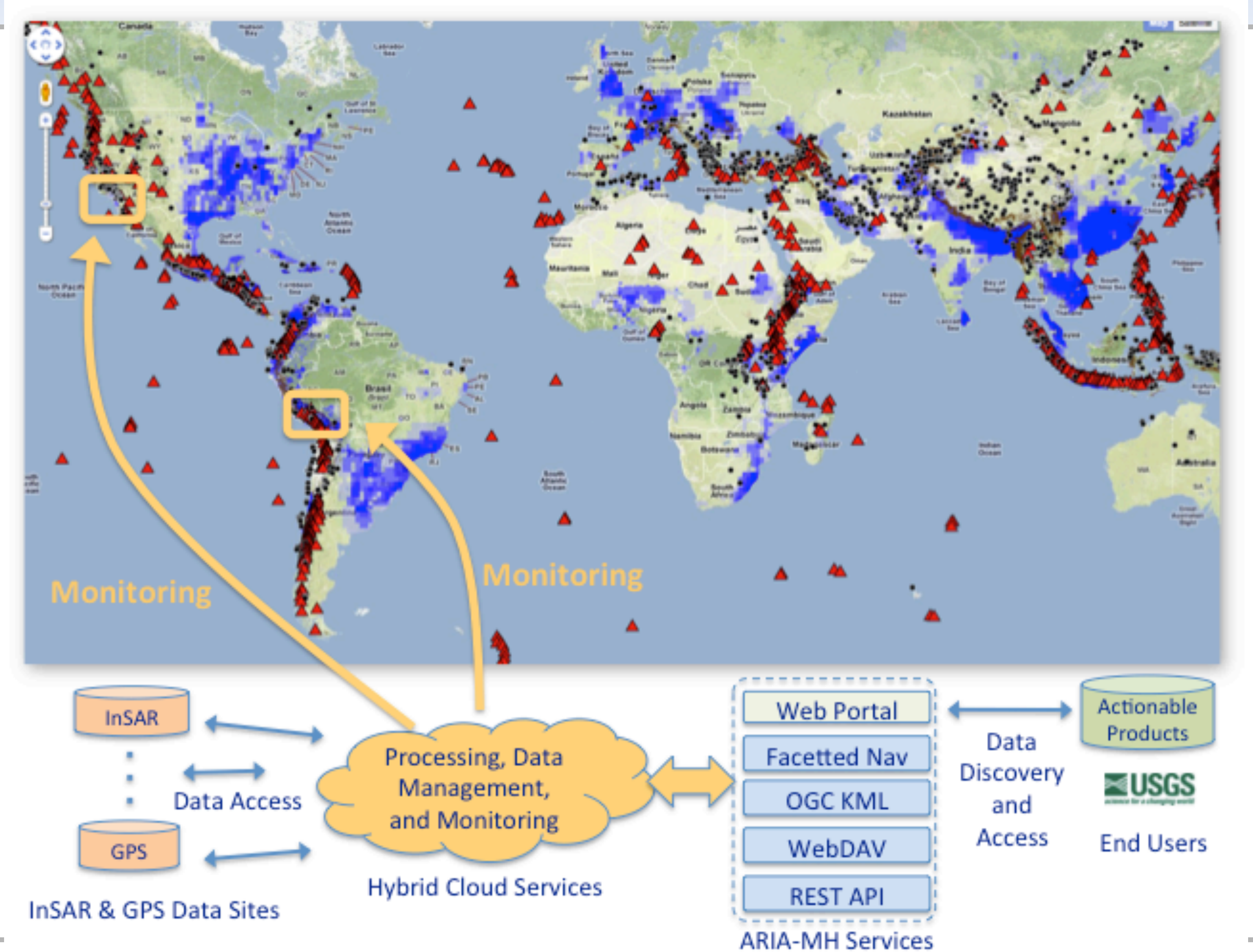
A *sensor-neutral* integrated data analysis system

ARIA Projects 2015.03.19

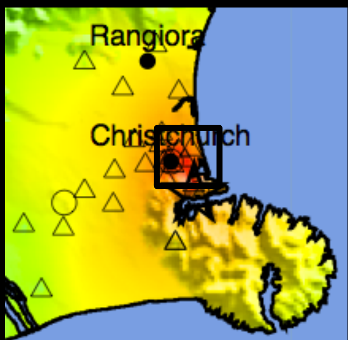
ARIA-EQ (R&TD) developed all connections in the blue regions, while ARIA-MH (AIST) has enabled hybrid cloud-based processing environment and is developing advanced functions for maturing the data system capabilities for hazard monitoring, data processing, management, and distribution. ARIA Co-Laboratory (PDF) is supporting quality assessment of InSAR products from the system.



Infrastructure needed for Monitoring and Disaster Response



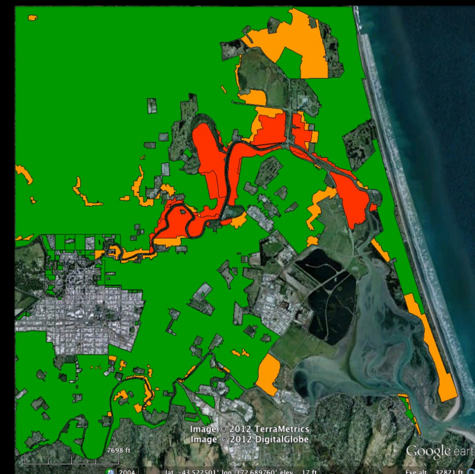
ARIA's Damage Proxy Map & Ground Observations Timeline



Shakemap released by USGS NEIC

DPM from radar data

Radar data acquired by ALOS satellite



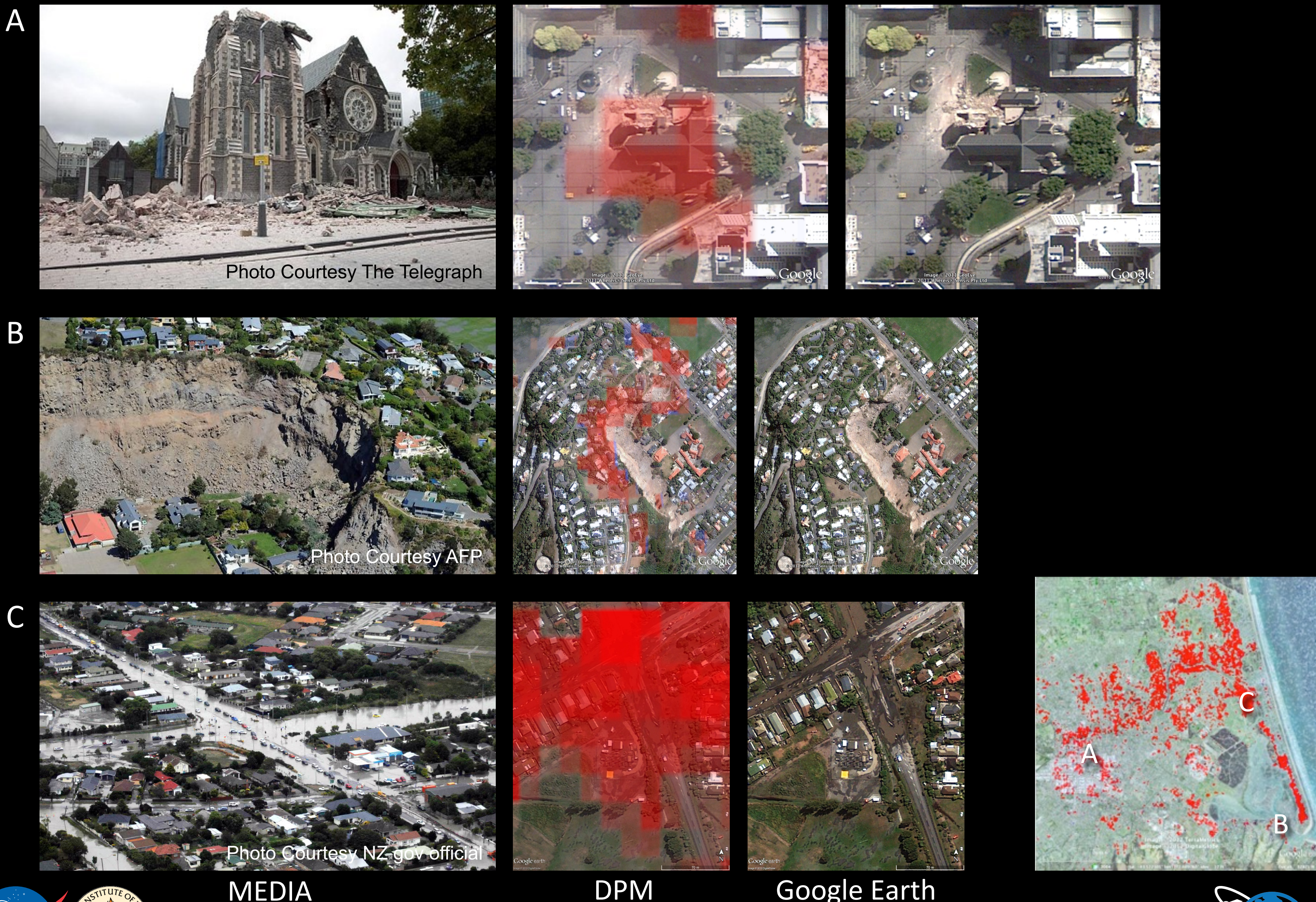
Official damage map released based on ground observations

Official damage map updated based on ground observations

2011 Feb Mar Apr May Jun Jul Aug Sep Oct

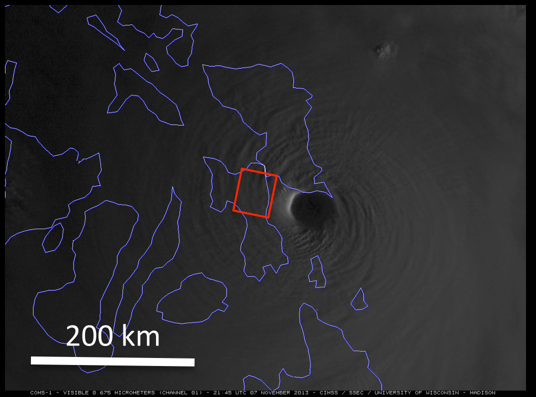
M6.3 Christchurch Earthquake

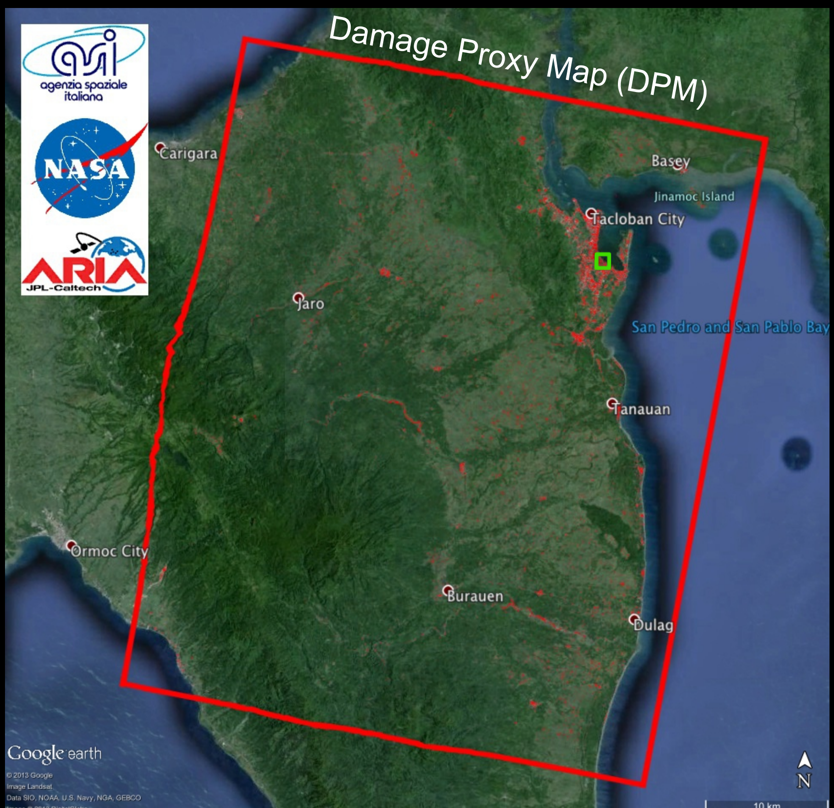
- **185 people killed**
- **> 1000 buildings destroyed**
- **Over US $30 billion damage**


A
Photo Courtesy The Telegraph
B
Photo Courtesy AFP
C
Photo Courtesy NZ gov official
C
A
B
MEDIA
DPM
Google Earth

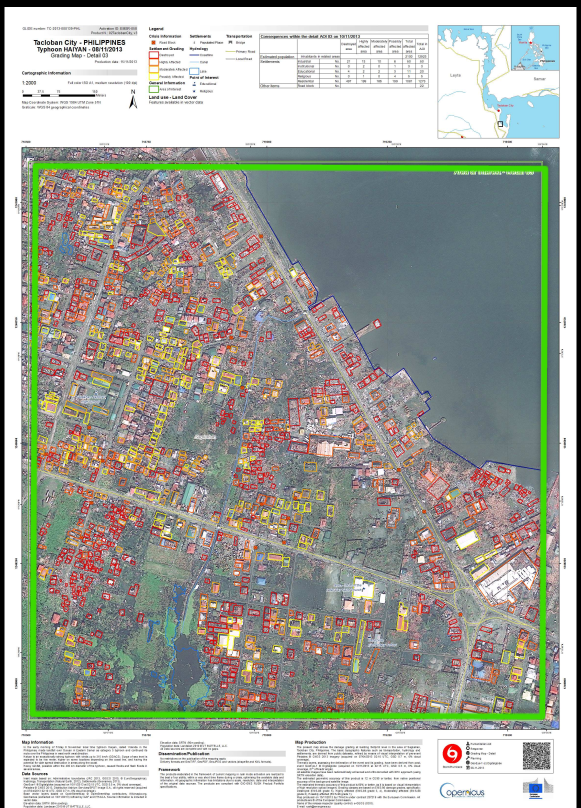
Super Typhoon Haiyan Damage in Tacloban, Philippines Imaged with COSMO-SkyMed

- 2013-11-08 00:00 (UTC): Haiyan hit Philippines
- 2013-11-11 (Day 3): COSMO-SkyMed (X-band) data acquired
- 2013-11-11 (Day 3): Damage Proxy Map produced by ARIA





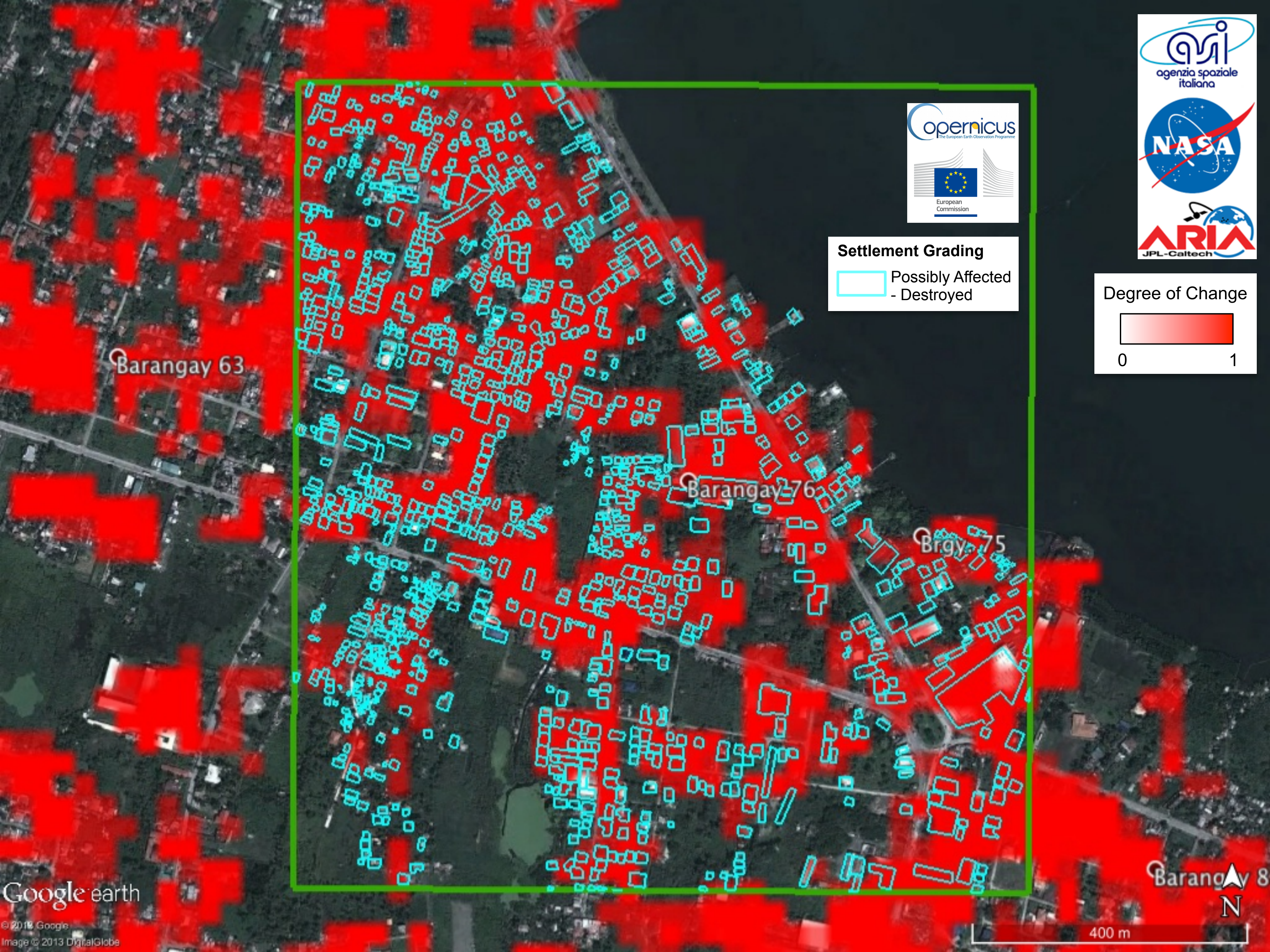
COSMO-SkyMed © ASI (acquired on 2013/08/15, 2013/08/19, 2013/11/11)



Settlement Grading

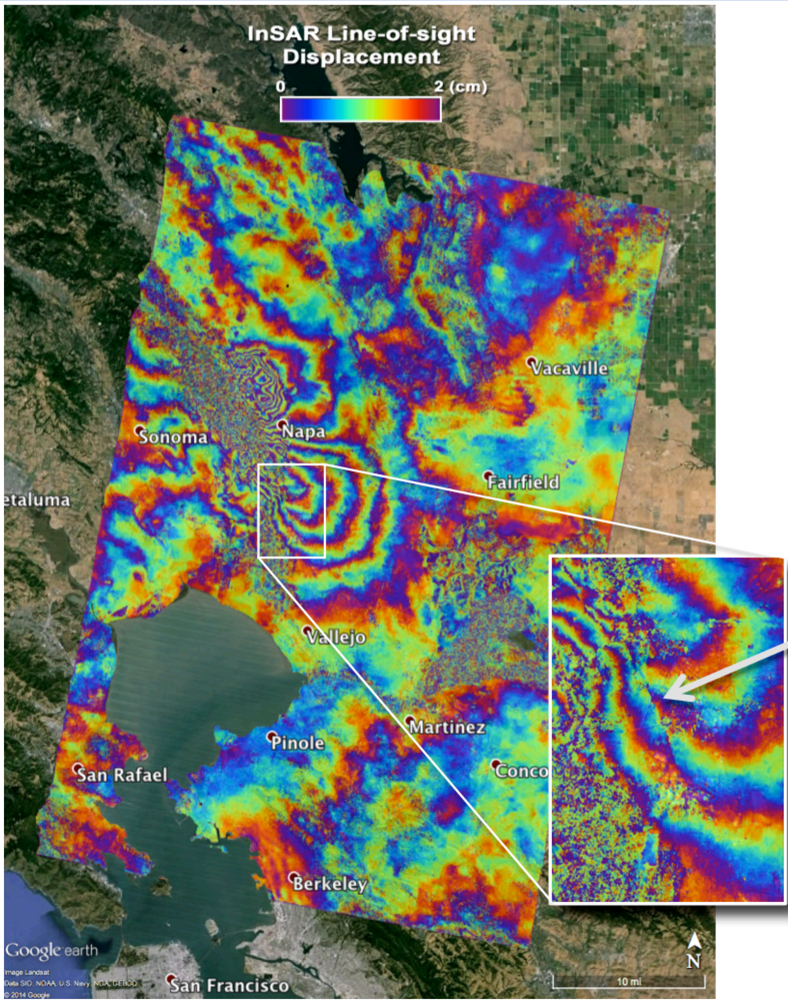
- Destroyed
- Highly Affected
- Moderately Affected
- Possibly Affected

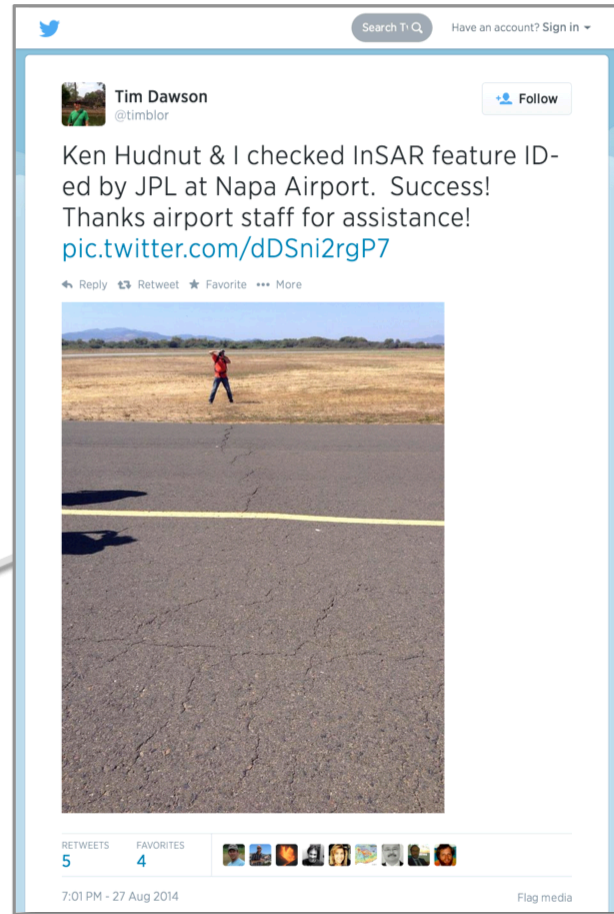
Damage grade polygons derived by Copernicus Emergency Management Service from visual interpretation of pre-event (Pleiades © CNES 2013/04/07) and post-event (GeoEye-1 © Digitalglobe 2013/11/10) optical images



Settlement Grading
Possibly Affected - Destroyed
Degree of Change
0
1
Barangay 63
Barangay 76
Brgy. 75
Barangay 8
N
400 m
Google earth
© 2013 Google
Image © 2013 DigitalGlobe
opernicus
European Commission
agenzia spaziale italiana
NASA
ARIA
JPL-Caltech

Napa Earthquake Response



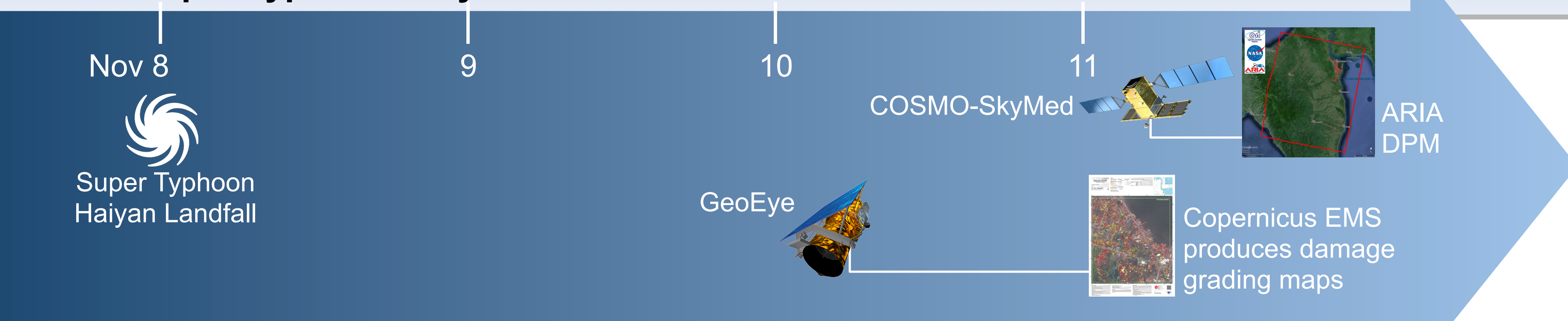


Processed by ARIA team at JPL-Caltech in collaboration with the Italian Space Agency (ASI) and University of Basilicata. Original COSMO-SkyMed Data © ASI 2014

- CSK and GPS products used by USGS/NEIC for fault modeling.
- CSK interferograms/decorrelation used to identify surface fault rupture.

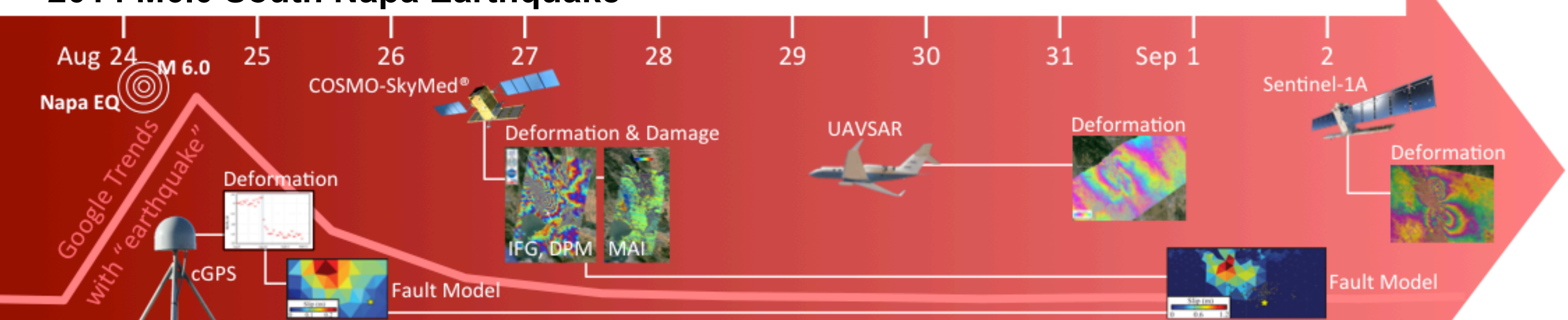
Response Timeline

2013 Super Typhoon Haiyan



Damage Proxy Map (DPM) delivered to

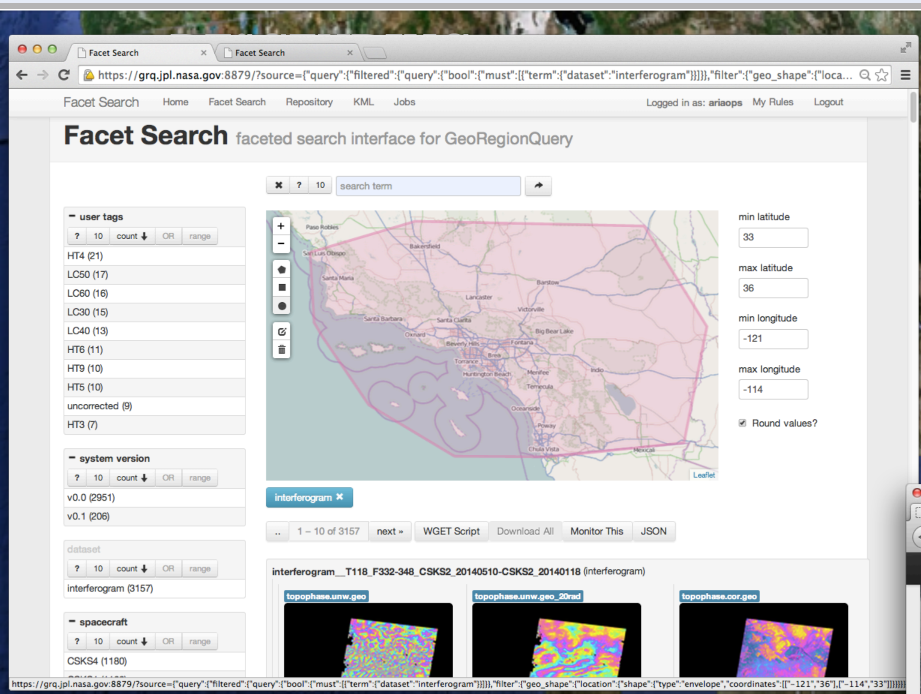
2014 M6.0 South Napa Earthquake



Interferogram delivered to USGS and CGS and other scientists and responders

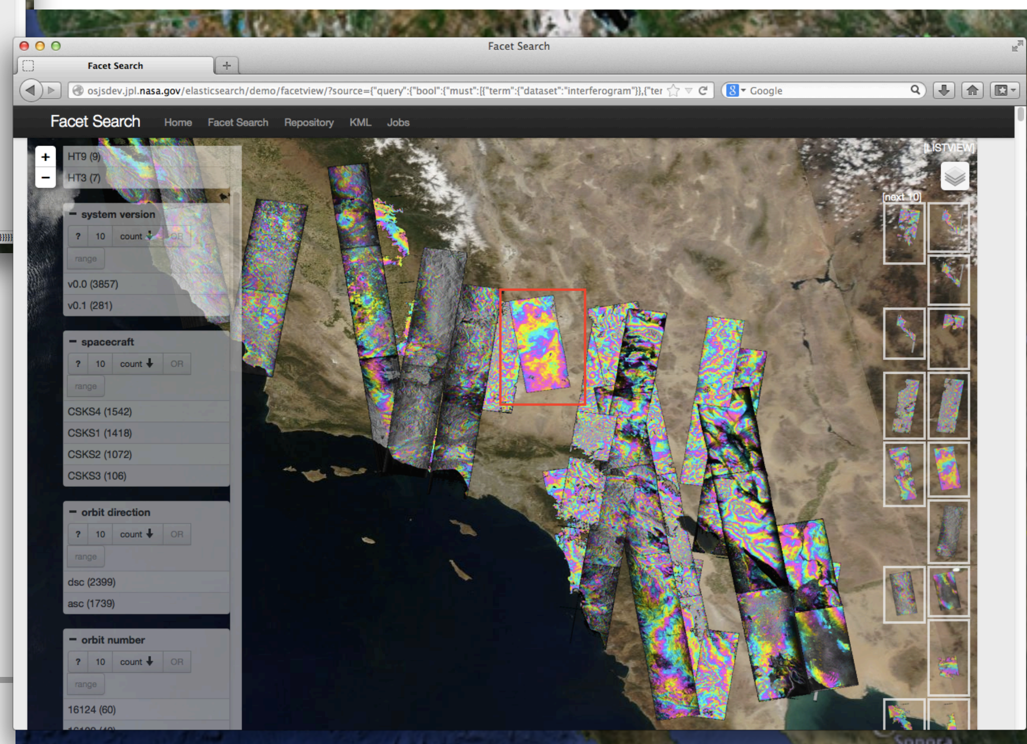
→ 4 peer-reviewed journal articles and 1 USGS report published as of 23 Mar 2015

The CaliMap Project: An ASI/ARIA Collaboration



Demonstration

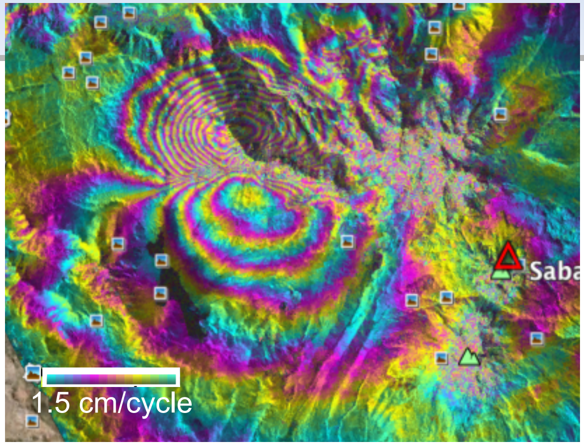
- 16 day repeat coverage (ASC/DSC)
- For a given location, data collected ~1/week
- ARIA system downloading, processing InSAR data automatically, continuously



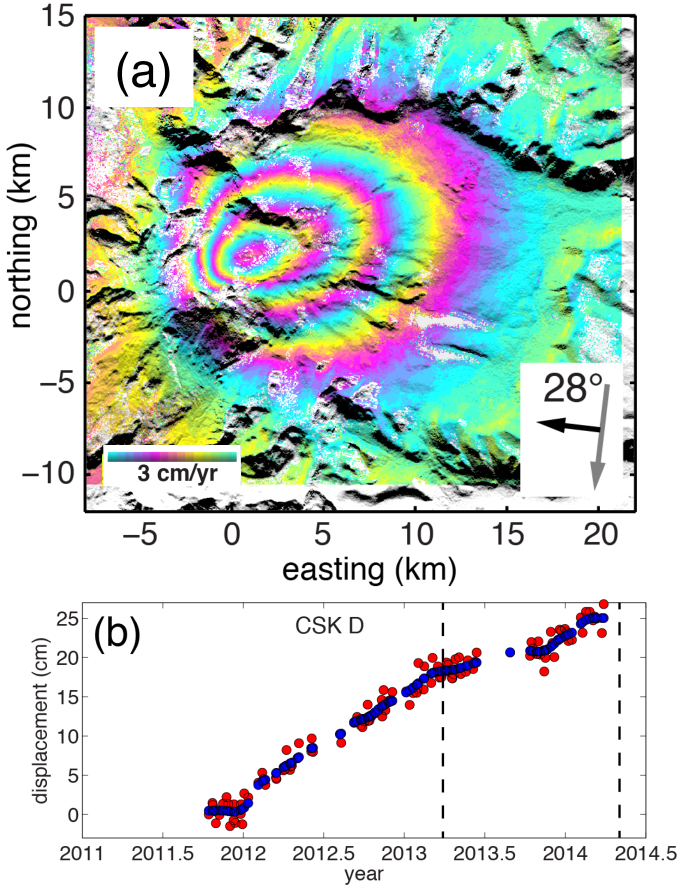
- Enables testing/refining of ARIA hybrid science data system & faceted search
- Driving development of automating InSAR quality assessment
- Becoming sensor neutral (CSK/TSX/Sentinel/ALOS2/ERS/Envisat/…)

Volcanic Hazard Monitoring

Sabancaya Volcano, S. Peru: July 2013 M 6.0 earthquake

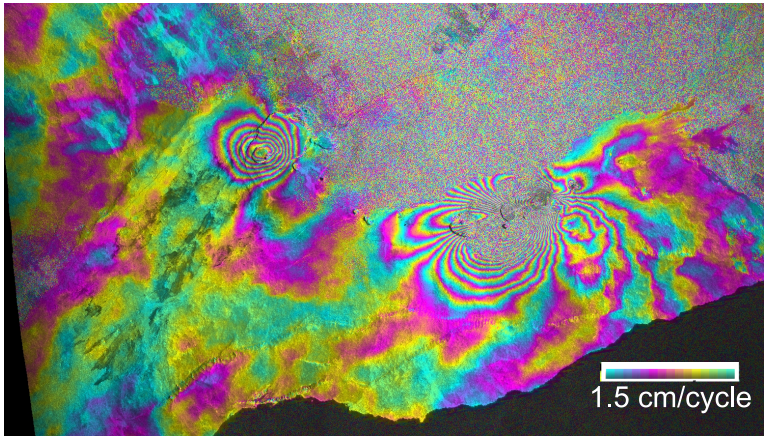


Copahue Volcano inflation



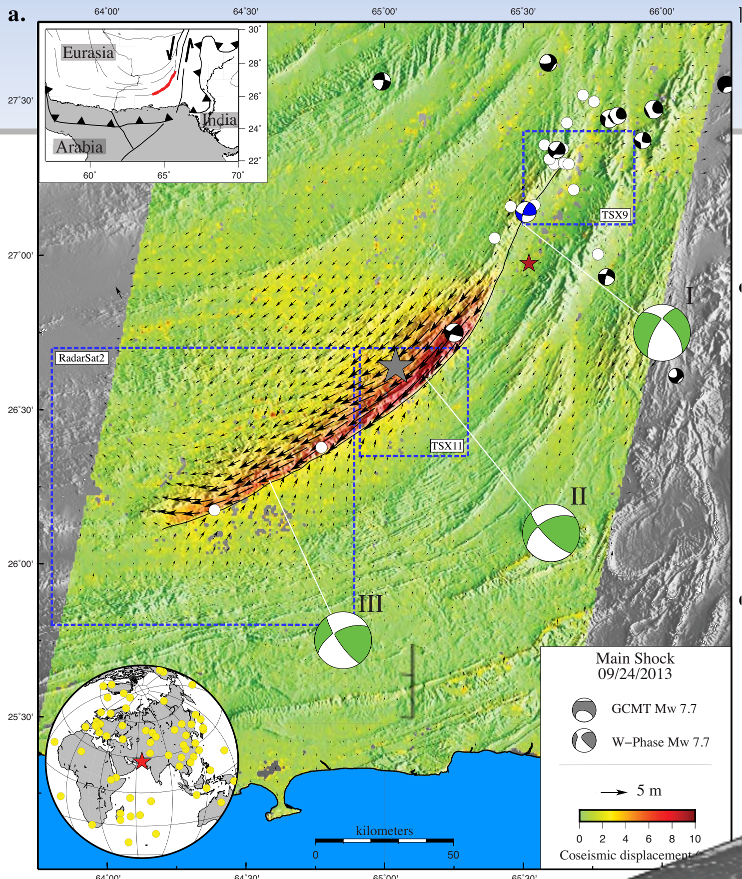
InSAR time series

Kilauea Volcano, Hawaii: summit subsidence and dike intrusion. First time InSAR data used at low-latency during an ongoing fissure eruption

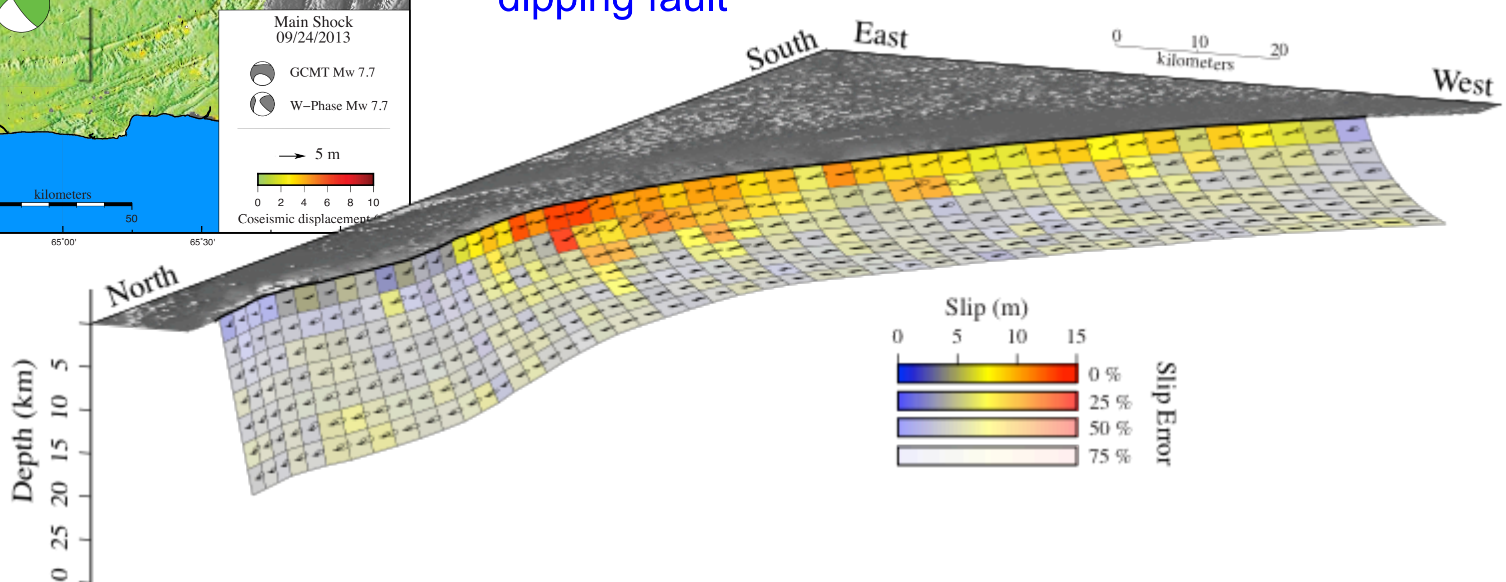


Lundgren, Milillo and others

9/24/2013 Mw 7.7 Pakistan EQ

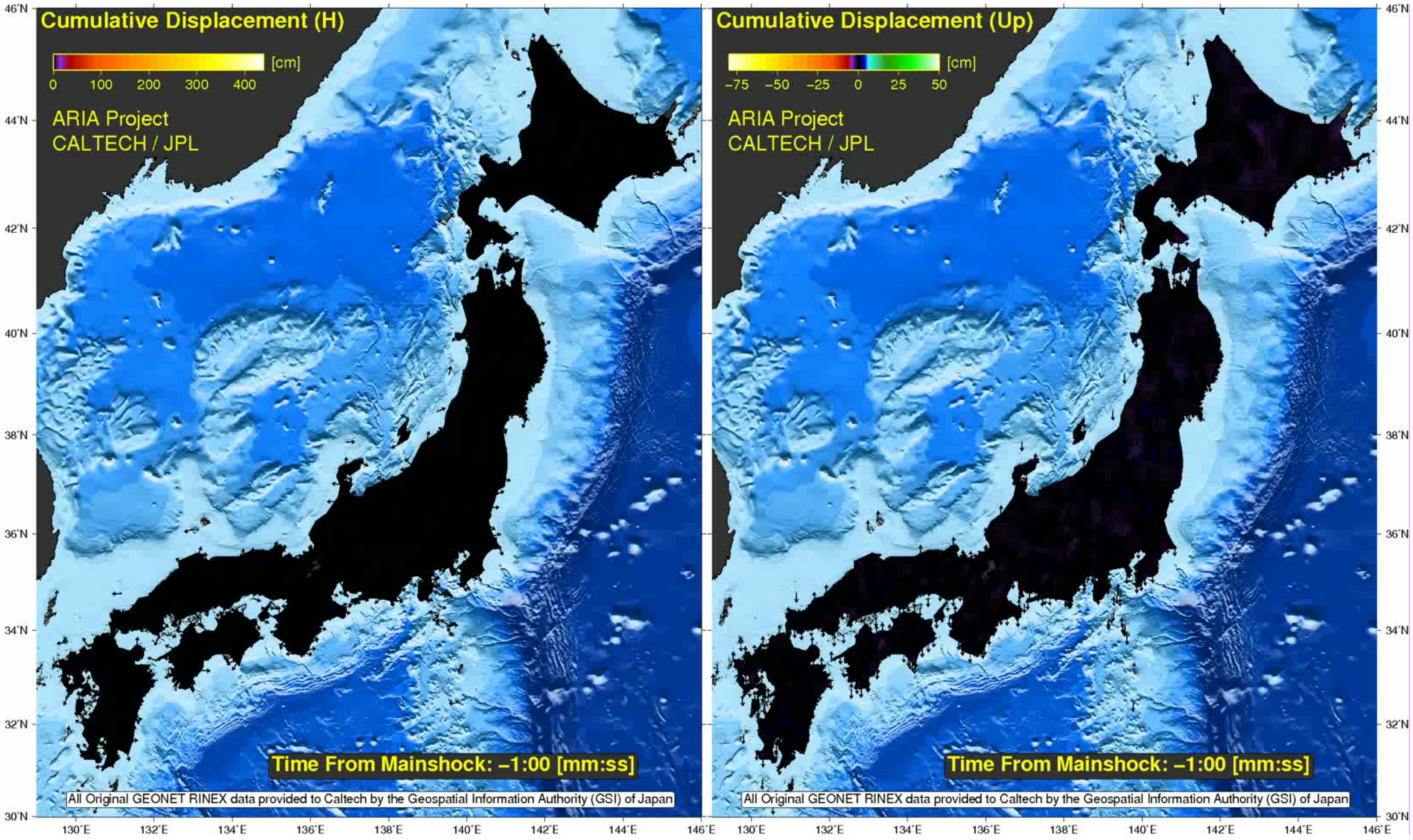


- Surface deformation
  - Cross-correlation of **Landsat 8** images.
  - Radarsat-2 and TerraSAR-X
- Bayesian estimates of subsurface fault slip
  - Fully exploits HPC resources
  - 12 billion models evaluated
  - ~3 hours wall-clock time
- Variable fault geometry consistent with local geology
- First observation of large strike slip motion on a strongly dipping fault

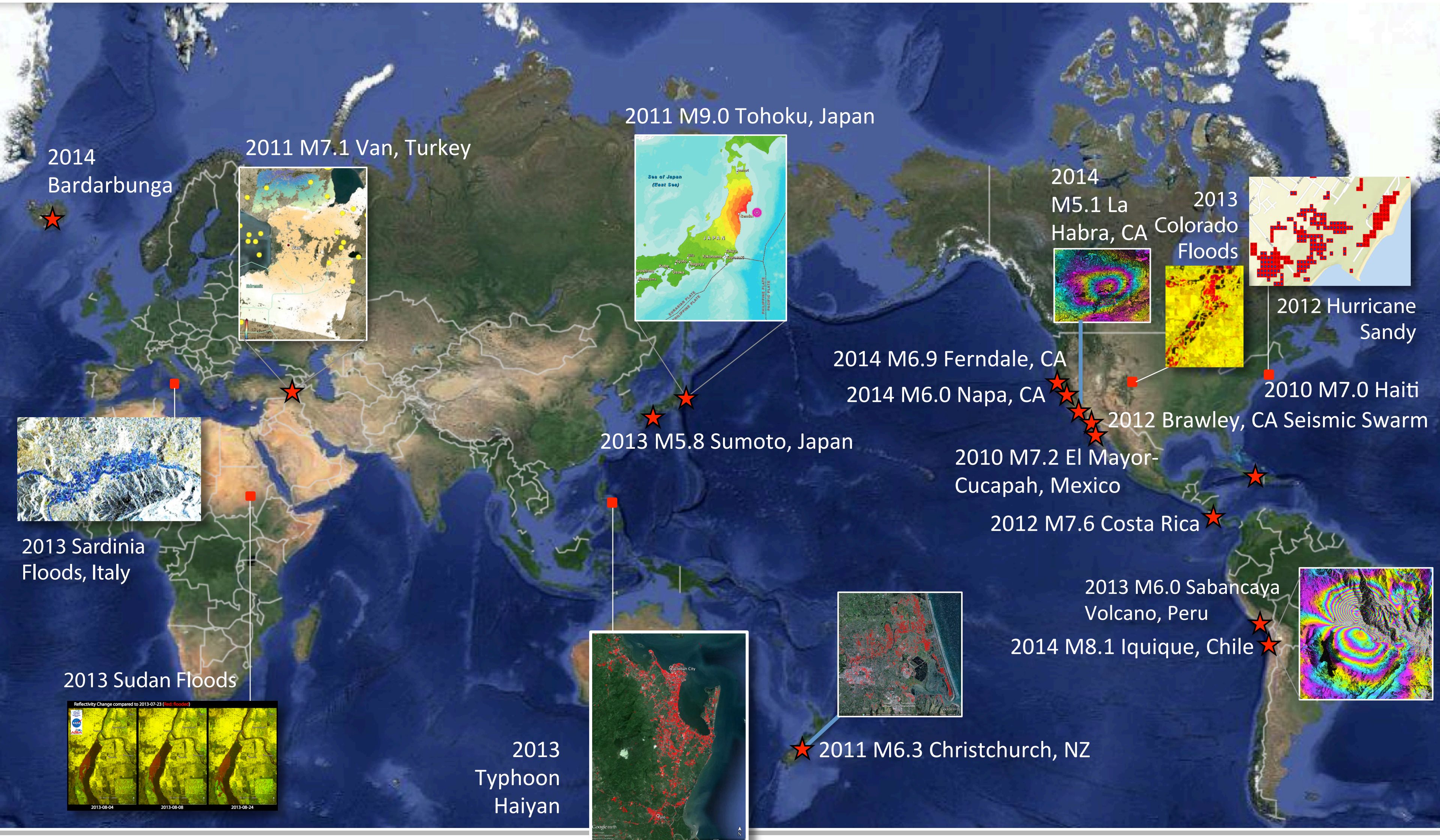


Avouac et al., 2013; *Jolivet et al.*, 2013

Rapid High rate GPS analysis
2011 Mw 9.0 Tohoku-Oki (Japan)



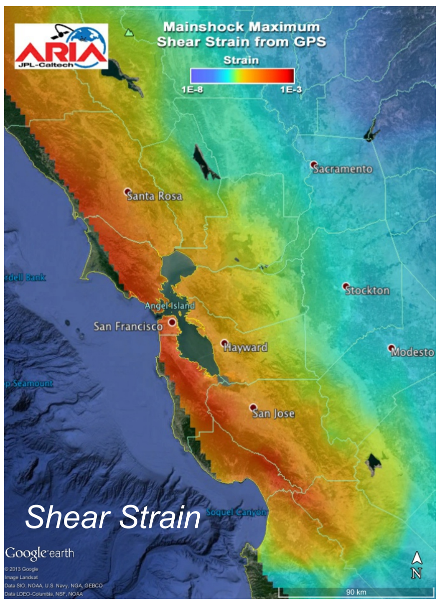
Disasters With Demonstration Response Products



Delivering products to responders: Earthquake simulation exercises

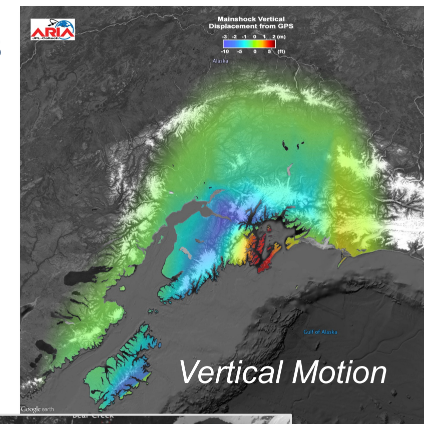
Participation in regular earthquake simulation exercises with state and federal agencies provides opportunities to:

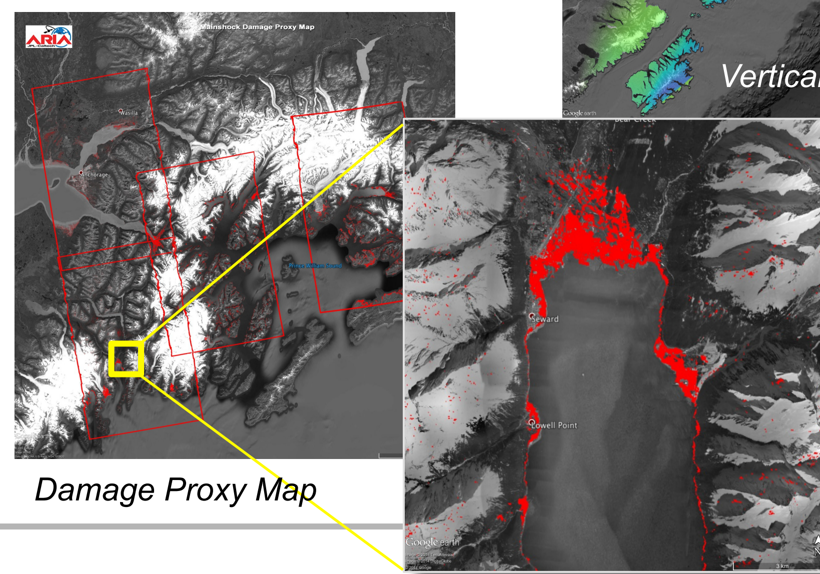
- demonstrate new information products.
- receive feedback on information needs of response agencies.



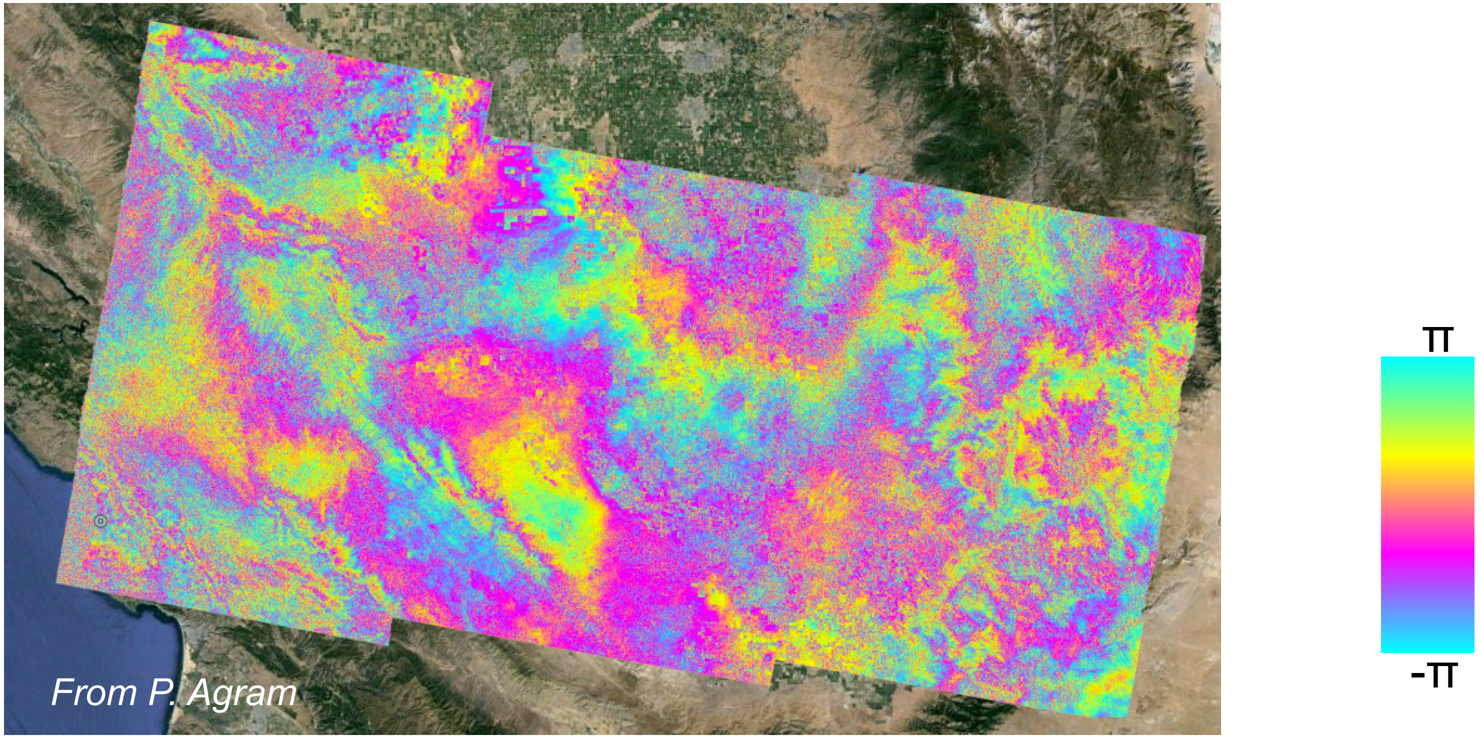
Examples of simulated products for Golden Guardian earthquake exercise based on a repeat of 1906 San Andreas earthquake, using current GPS network and archived ALOS data

Examples of simulated products for FEMA National Level earthquake exercise based on a repeat of 1964 Alaska earthquake, using current GPS network and archived ALOS data





Example: Sentinel 1A (from SLCs)



- 1 slice, 3 swaths, no visible swath boundary
- $\Delta t = 6\ \mu\text{sec}$, B_{temp}=24 days, B_{perp}=240 m
- Geometric coregistration + Spectral Diversity
- No gross azimuth or range timing error corrections applied

Summary

- Space geodesy can provide information on ground displacement, location of fault rupture and damage, improving our estimates of where response & recovery resources are needed.
  - End-to-end automation essential for most useful hazard response
- ARIA is developing an automated *sensor-neutral* geodetic analysis system, using a "hybrid cloud" elastic computing approach
- Must work with decision support end-users to understand what information they need, test data product formats, familiarize end-users before actual disaster.
- Automation supports natural hazard science, in addition to rapid response, and reduces burden on discipline scientists.
- Only real limitation is *free, open & low latency* access to data/archive.