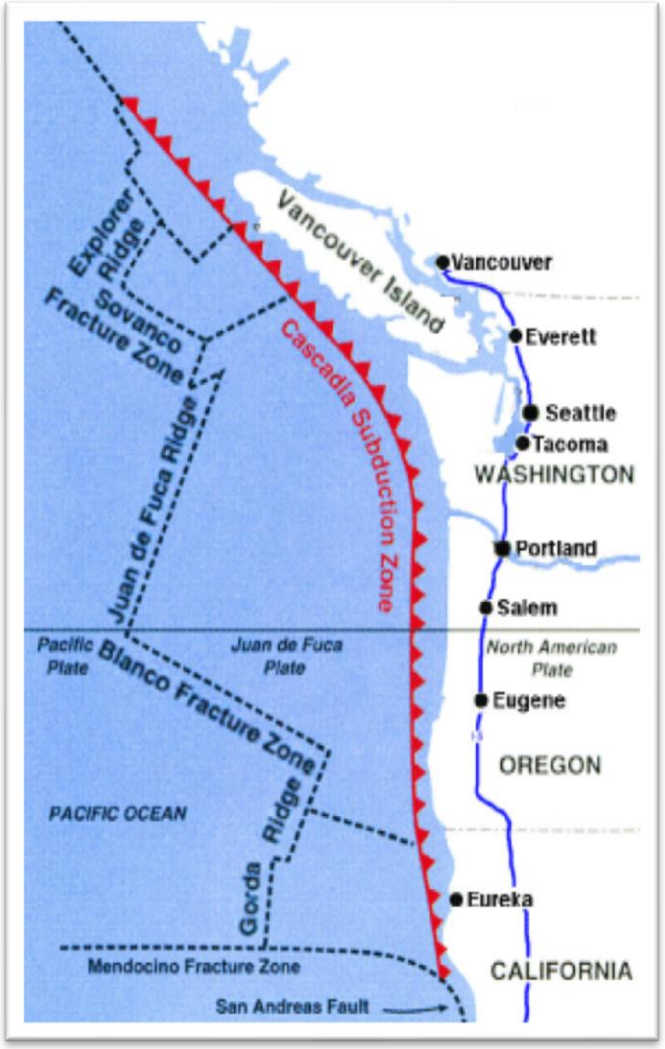
Cascadia Rising 2016 National Level Exercise: Perspectives and Lessons Learned

Maggi Glasscoe
NASA Jet Propulsion Laboratory,
California Institute of Technology
Margaret.T.Glasscoe@jpl.nasa.gov

1. What were the goals and objectives of the exercise (overall and for NASA)
2. What did we do and what did we learn?
3. Where do we go from here?

Exercise Overview

- Cascadia Rising was a FEMA National Level Exercise held 7-10 June 2016
- The scenario included a M 9.0 earthquake resulting in the complete rupture of 700-mile Cascadia Subduction Zone that triggered a tsunami and multiple aftershocks
- Expected shaking duration for over four minutes and affected areas encompassed 140,000 square miles directly impacting the states of Oregon and Washington, the Canadian province of British Columbia, and northern California.
- Over 10 million people reside in the impact zone – widespread damage to critical infrastructure and the built environment, thousands of deaths and injuries



Exercise Goals & Objectives

- Exercise Purpose:
  - **Enhance Disaster Response Joint-Operations –** Test the local, state, tribal, and federal government as well as select private sector and non-government organizations' ability to jointly respond to a Cascadia Subduction Zone M9.0 earthquake and tsunami with associated aftershocks along the West Coast of the U.S.
  - **Prepare for a Level-1 Catastrophic Earthquake Disaster –** Link together Emergency Operations Centers (EOCs) throughout the Pacific Northwest to coordinate and mimic all facets of a complex, wide-area, response to a catastrophic disaster.
  - **Exercise the California Earthquake Clearinghouse –** focus on interdependencies of critical infrastructure, information sharing, and coordination for response, recovery, and regional resiliency.

Participating Agencies

- Over 50 counties and numerous cities across three states
- 19 tribes in OR and WA
- Three state EOCs with all state ESF agencies represented
- FEMA Region 10 RRCC with all Federal ESF and Interagency partners represented
- FEMA NRCC with all Federal ESF and Interagency partners represented
- U.S. TRANSCOM and U.S. NORTHCOM linked exercises and other military and USCG commands
- British Columbia and Public Safety Canada
- Private sector, hospitals, utilities, Non-governmental Organizations etc.
- California Earthquake Clearinghouse and partner organizations (EERI, USGS, NASA, San Jose Water Company, Humboldt County OES, San Diego Law Enforcement Coordination Center, California Department of Fish and Wildlife, Office of Spill Prevention and Response, California Department of Public Health, EF-8, California Environmental Protection Agency, EF-10, Bay Area Center for Regional Disaster Resilience, California Independent System Operator (Cal ISO), Single Automated Business Exchange for Reporting (SABER), California Office of Emergency Services, FEMA Region 9, FEMA Region 10, Cascadia Region Earthquake Working Group, City of Walnut Creek, California National Guard, State of Washington, Central U. S. Earthquake Consortium, Association of Engineering Geologists - Inland Empire, Inland Geological Society, Caltrans

NASA Goals & Objectives

Cascadia Rising 2016 represented an opportunity for NASA to provide relevant data products that assisted in the evaluation of earthquake and tsunami-induced damage and inform decision-making process and resource deployment.

The goal for NASA was to derive value, including:

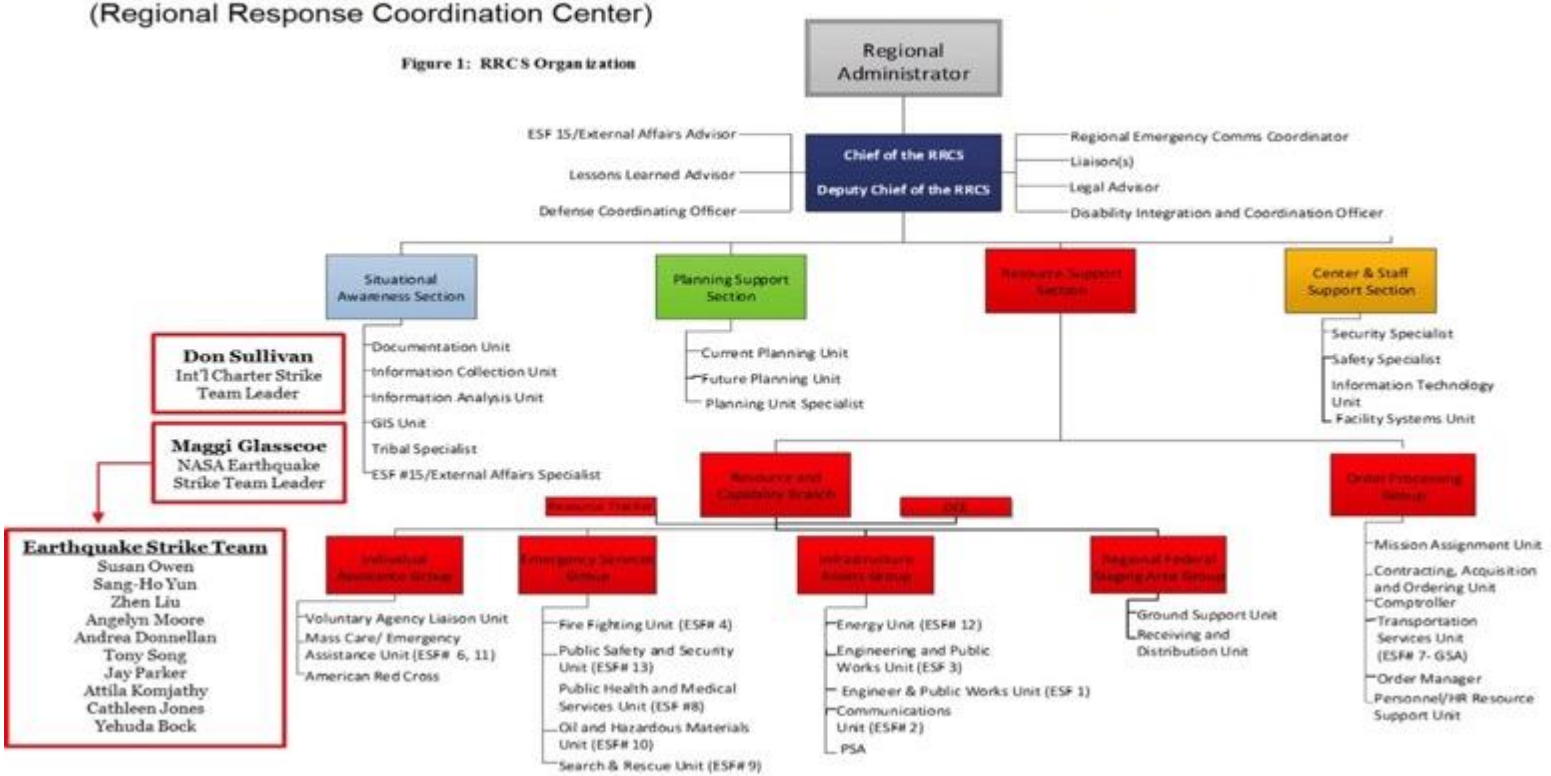
- Participating in a coordinated response amongst a large group of agencies thereby informing stakeholders of NASA capabilities
- Demonstrate NASA disasters data product value and generation/deliverable timeline
- Test and evaluate NASA-JPL earthquake playbook emergency response plan and train appropriate personnel through simulation
- Derive lessons learned to inform priorities for NASA Disasters Applied Science
- Prepare for future disaster responses and exercises and increase overall readiness for real-world emergency response

Reporting Structure

RRCC Reporting Structure, FEMA Region 10

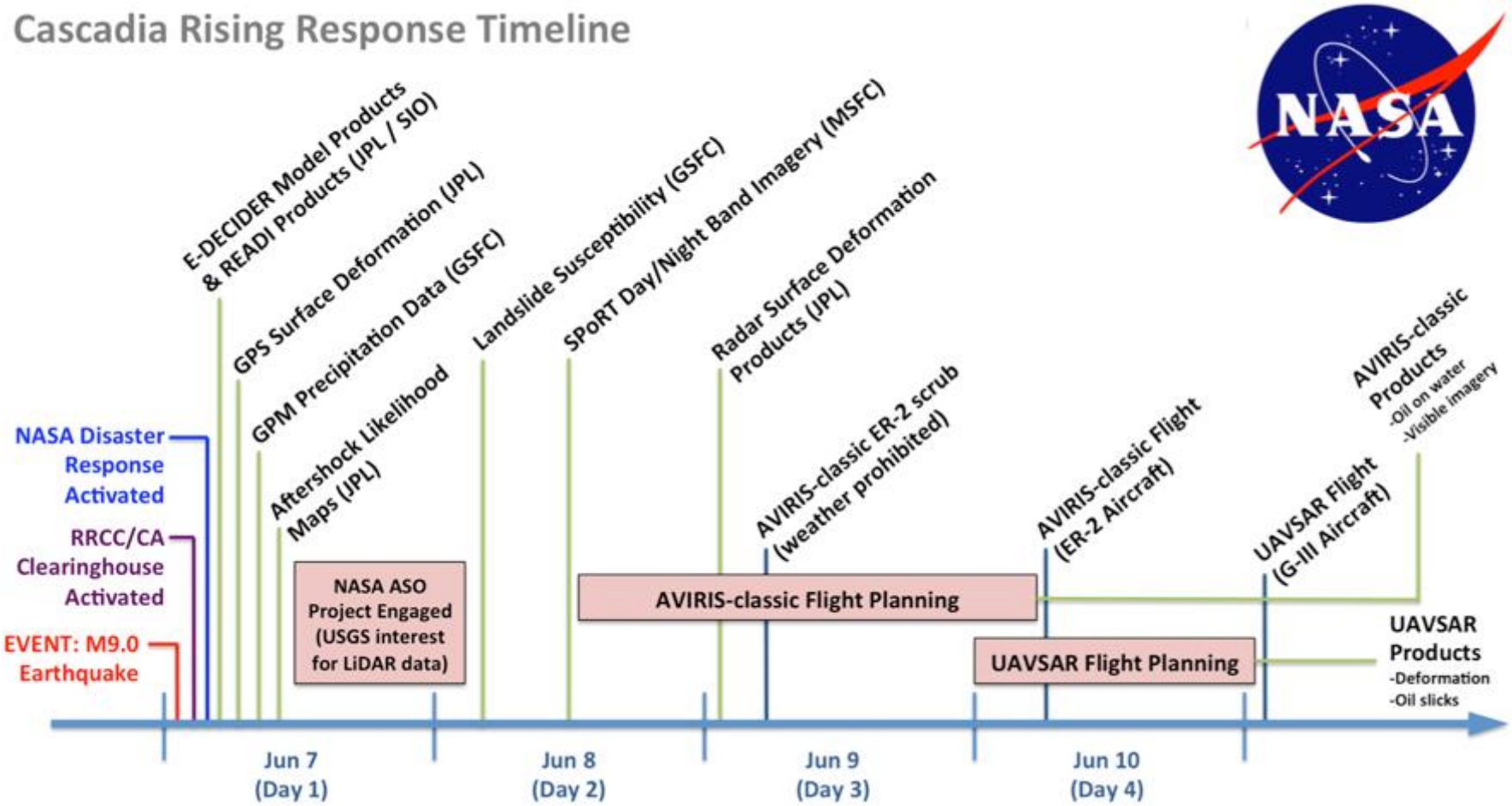
(Regional Response Coordination Center)

Figure 1: RRCS Organization

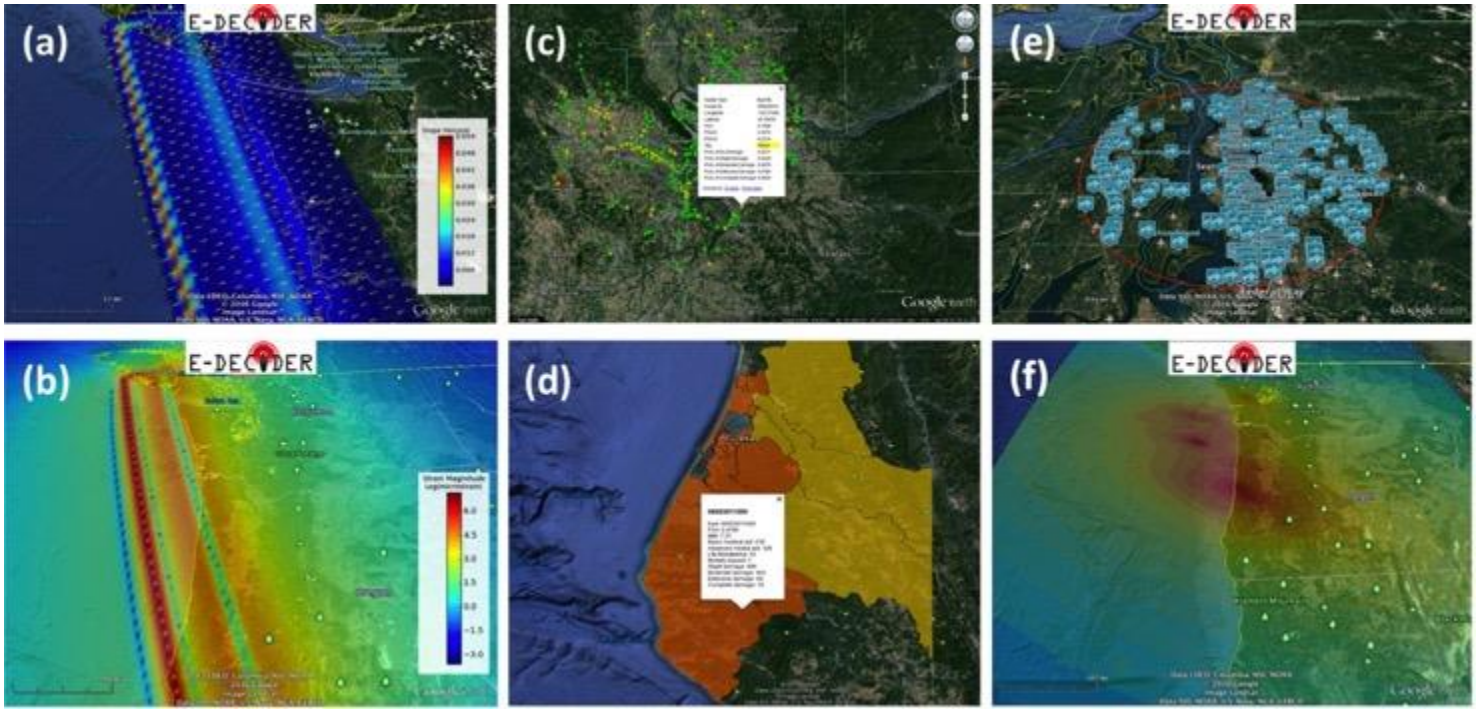


FEMA Cascadia Rising Exercise Support

Exercise Timeline & Product Delivery



Example Products: E-DECIDER



a) **Tilt / Vertical Change Percent Maps** generated from Disloc surface deformation modeling code and iteratively refined using geodetic data from GPS model solutions. These data can be paired with infrastructure layers to assess where damage has likely occurred. Product latency is 0-1 hours and typically delivered in KMZ format.

b) **Strain Magnitude Maps** are generated from Disloc surface deformation modeling code and iteratively refined using geodetic data from GPS model solutions. Deformation strain magnitude can identify locations of potential fault surface rupture as well as locations where infrastructure may be dangerously stressed – maps can be paired with infrastructure data layers to assess where likely damage has occurred. Product generation latency is 0-1 hours and typically delivered in KMZ format.

c) **Critical Facilities Damage Esitmates** convey the suspected impact severity to facilities (facilities layer obtained from “Infrastructure Database Service”). These impacts are modeled using the HAZUS methodology and USGS ground motion shakemaps. Damage estimates are conveyed by modeled impact in where RED is high chance of damage and GREEN is low impact to facility.

d) **InLET (Internet-based Loss Estimation Tool)** is a web-based loss estimation platform that was built to assist response agencies after a catastrophic event. The system monitors USGS shakemap releases and triggers analysis following a new event. These products are delivered as KML products based on model results.

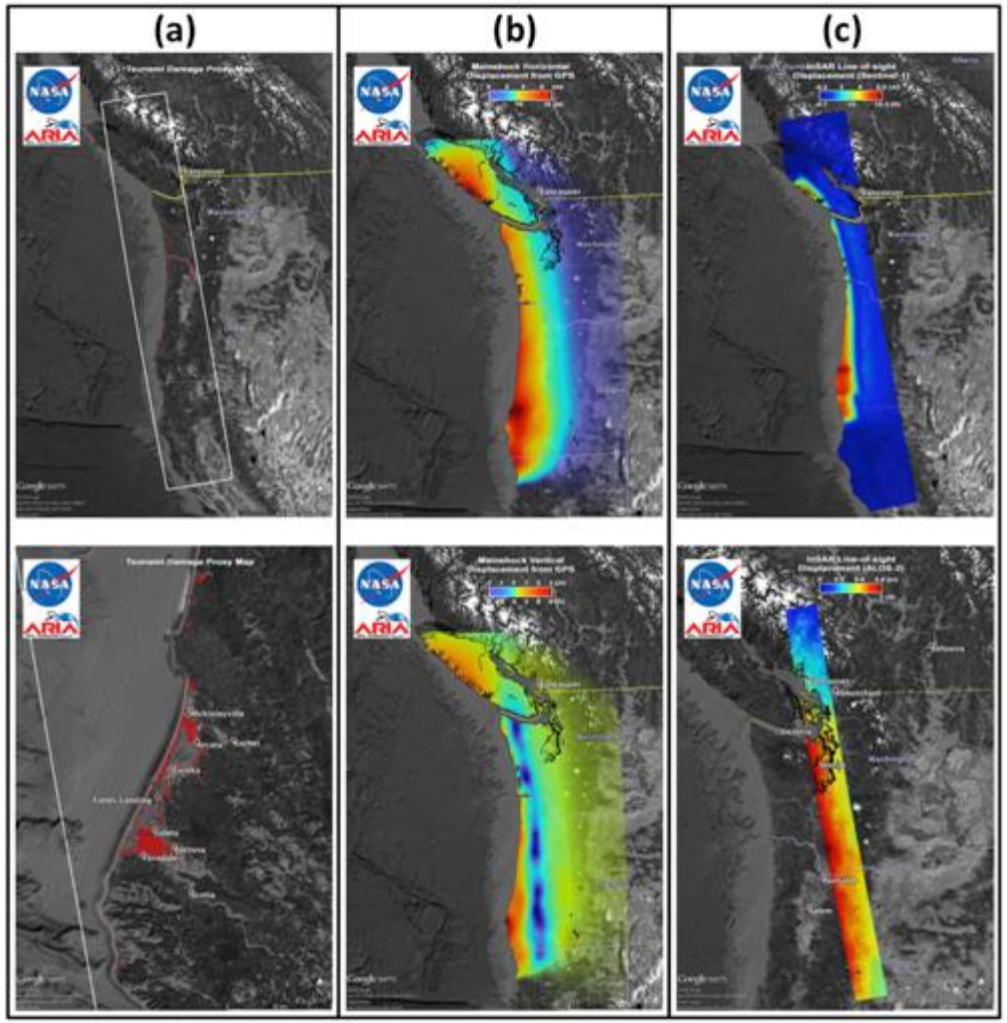
e) **Infrastructure Database Service** provides locations of critical assets that have been exposed to damage after an earthquake. This merges existing databases (e.g. FEMA HAZUS-MH data) into an OGC-compatible KML product that delivers ~30 HAZUS-MH layers for a specified AOI (radius).

f) **Aftershock Likelihood forecasts** provides a forecasting method that can be calculated quickly and updated regularly during a response with minimal user input. Forecasts are generated in KMZ output that are easily interpreted (areas of higher likelihood in warmer colors, lower likelihood in cooler colors).

NASA

CASCADIA RISING

Example Products: ARIA



(http://aria.jpl.nasa.gov)

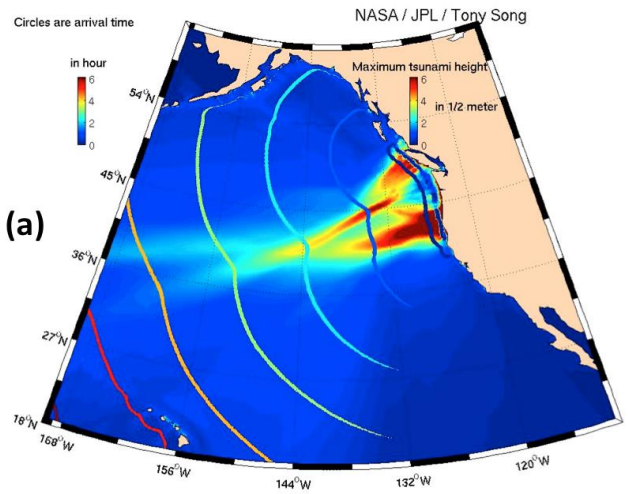
a) **ARIA Damage Proxy Maps (DPM)** show estimates from satellite radar data of where an earthquake has caused significant damage. Red color indicates regions that have been disrupted, where darker red indicates greater change. When combined with building maps, the damage proxy map can be used to identify structures that have been damaged by the earthquake as well as scale of damage over large regions. Maps are derived from Interferometric Synthetic Aperture Radar (InSAR) observations using Sentinel-1A and ALOS-2 satellites.

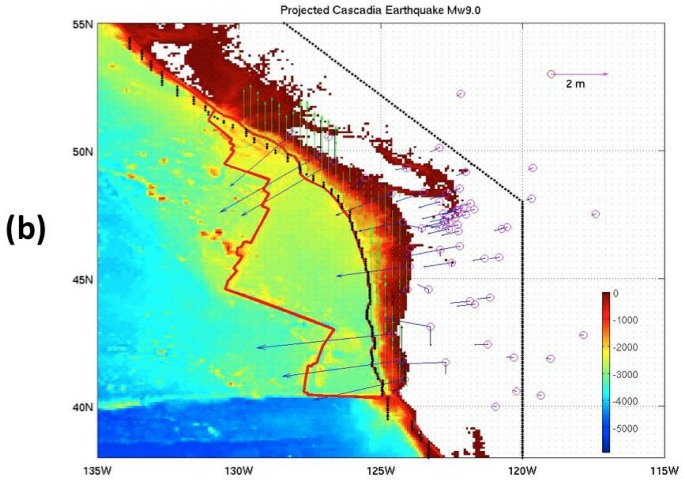
b) **ARIA Ground Displacement Maps** show permanent horizontal and vertical movement caused by the earthquake. The movement shown is relative to the land's geographical coordinates before the earthquake. The maps are based on interpolated measurements from available Plate Boundary Observatory Continuous GPS stations near the earthquake and are not based on models. These maps can be useful for identifying areas that have been impacted by an earthquake. Initial maps are available within minutes after the earthquake with updates after a few hours.

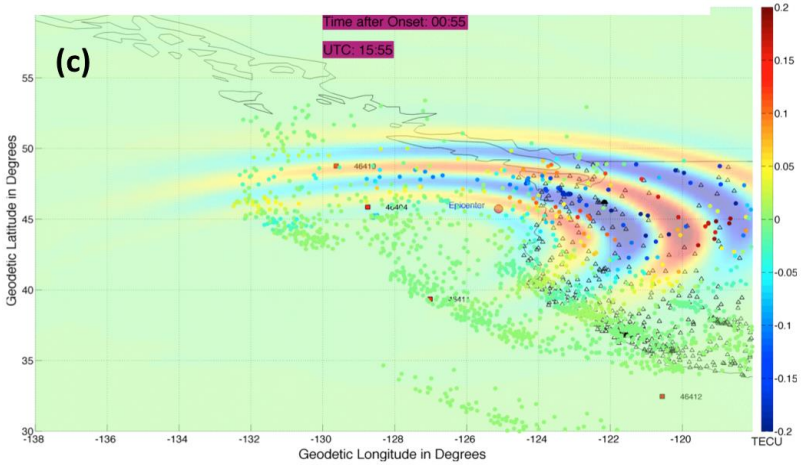
c) **ARIA Detailed Ground Deformation Maps** show permanent ground deformation caused by the earthquake. Movement shown is relative to the land's geographical coordinates before the earthquake. The maps are based on Interferometric Synthetic Aperture Radar (InSAR) observations made with radar sensors mounted on earth-orbiting satellites.

NOTE: Data products derived from satellite radar datasets (a, c) are not impacted by cloud cover and can be acquired during day or night. Maps are available between within a day to several days after the earthquake, depending on the availability of earliest post-earthquake radar observations.

Example Products: Tsunami Modeling



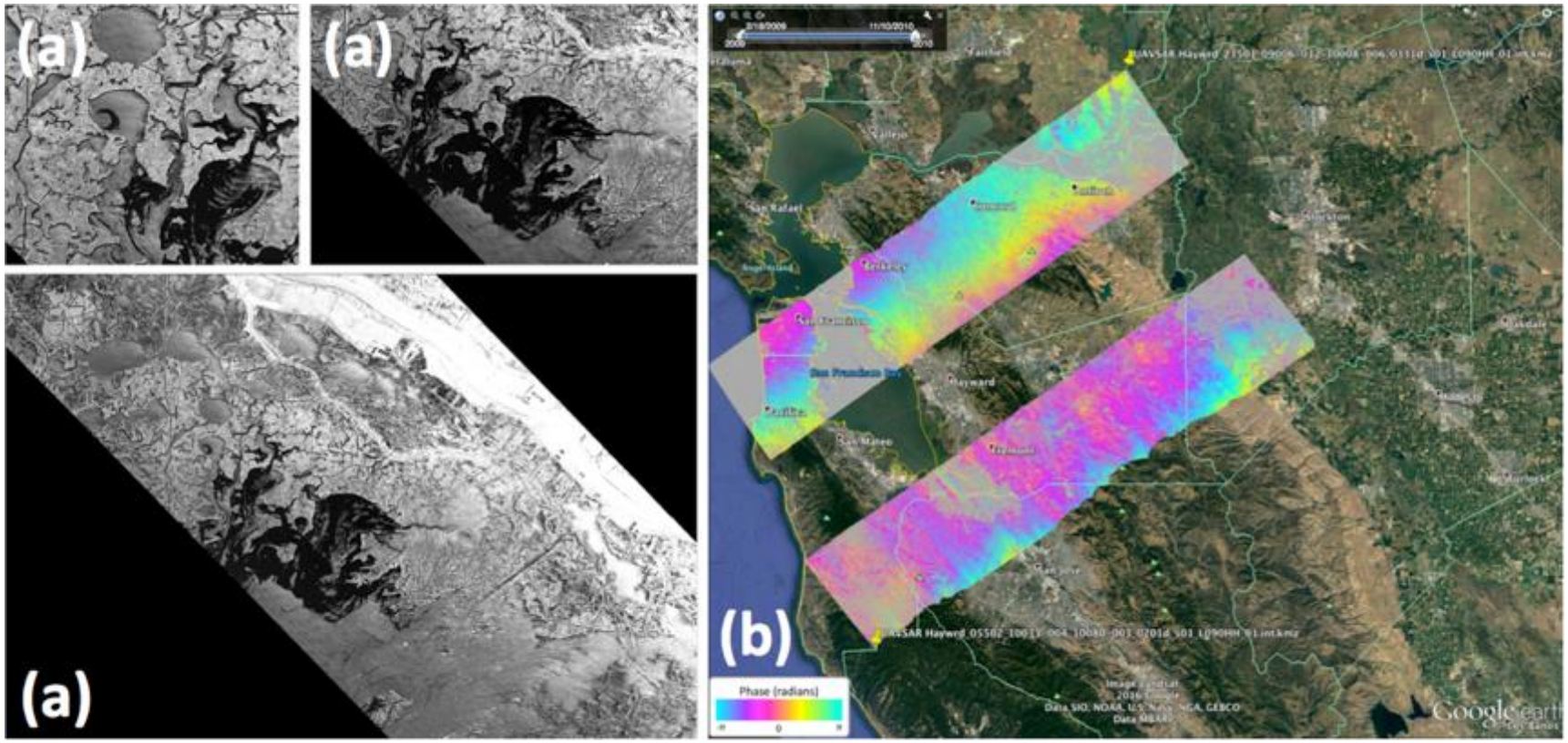




- JPL Tsunami arrival times (courtesy T. Song)
- JPL Tsunami source location model (courtesy T. Song)
- Total Ionospheric Electron (TEC) disturbances generated for the Cascadia Rising exercise. This method can provide tsunami early warning products based on GPS observations of ionospheric total electron content (TEC) disturbances generated by tsunami waves. As the TEC perturbations propagate towards the shores more GPS satellites at higher elevation angles join in tracking these TEC signatures, thereby reducing the error bars associated with the arrival time of tsunamis.

The GPS ionosphere-based tsunami arrival times and associated uncertainties are expected to constrain Dr. Tony Song's (JPL) tsunami wave height predictions.

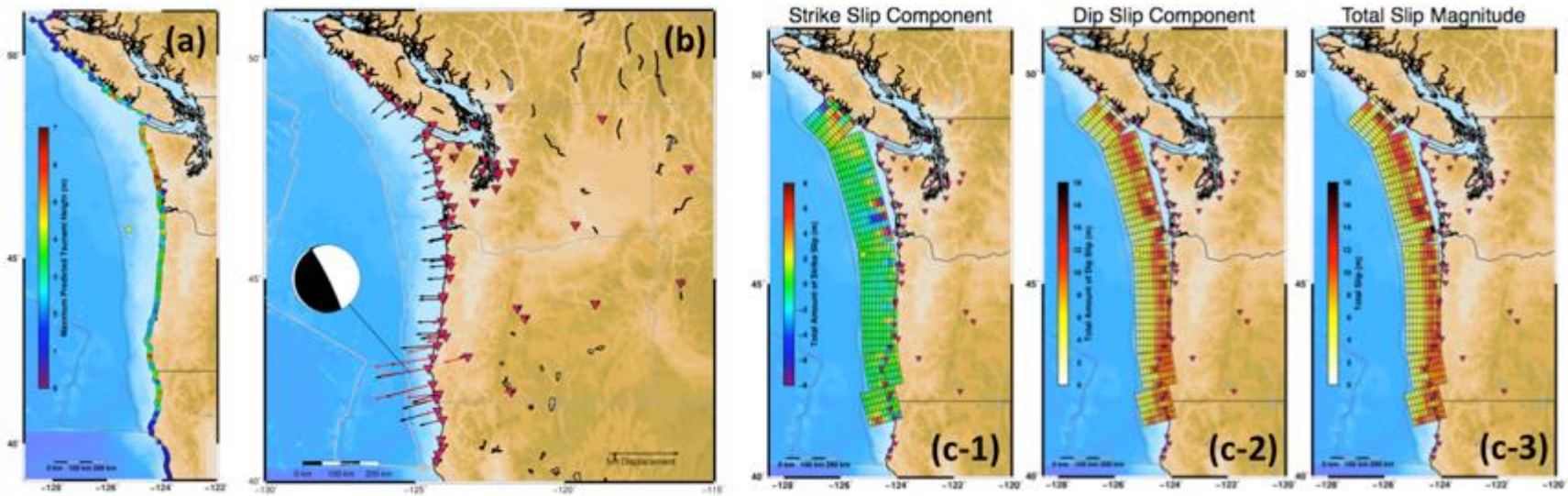
Example Products: UAVSAR



JPL UAVSAR Data Products (courtesy Cathleen Jones, http://uavsar.jpl.nasa.gov):

a) UAVSAR data product examples showing detection of oil on water from the Deepwater Horizon oil spill.
b) UAVSAR interferograms showing maps of surface deformation for the Hayward Fault.

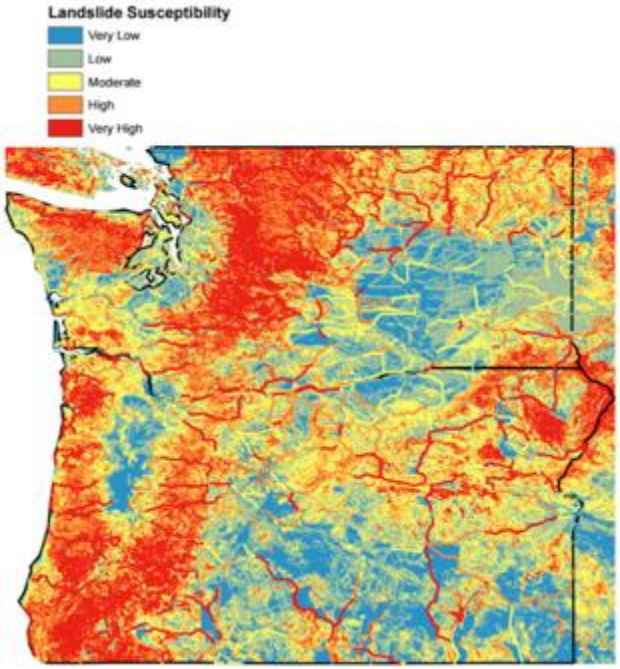
Example Products: READI Rapid GPS



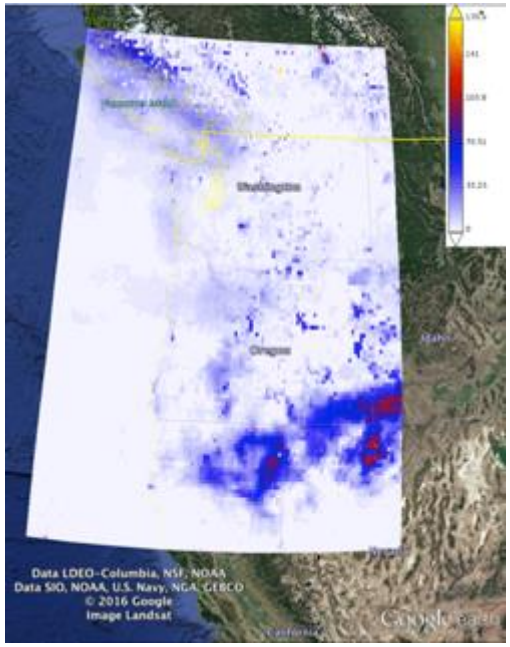
SIO READI Data Products (courtesy Yehuda Bock, http://geodemo-c.ucsd.edu/gridsphere/gridsphere?cid=Cascadia+Rising):

(a) Predicted Tsunami maximum height (not runup) along the westernmost Cascadia coastline for the Cascadia Rising 2016 exercise. The tsunami model uses a static seafloor deformation model as input. The seafloor deformation is computed form the result of the static slip finite fault inversion, which used synthetic GPS data generated for the scenario earthquake.
(b) Rapid Centroid Moment Tensor Solution is created using the coseismic offsets measured by GNSS. Observed coseismic offsets in black, synthetic fits in red. Method detailed in *Melgar et al. (2012) Real-time centroid moment tensor determination for large earthquakes from local and regional displacement records. GJI 188, 703-718.*
(c) Static slip fault inversion maps for Cascadia Rising 2016 scenario. Fault inversion uses synthetic GPS data for the stations shown by the magenta triangles:
c-1: amount of strike slip on each subfault, where positive values indicate northward motion.
c-2: Amount of dip slip on each subfault, where positive values indicate trenchward (Western) motion.
c-3: Total slip magnitude (note that the strike slip component map uses a different color scale than the dip slip and total slip maps). The mean total slip on the subfaults is 7.2m. The READI team does not consider slip variations occurring on intervals smaller than 4 subfaults to be reliably resolved.

Example Products: Landslide & Rainfall Data

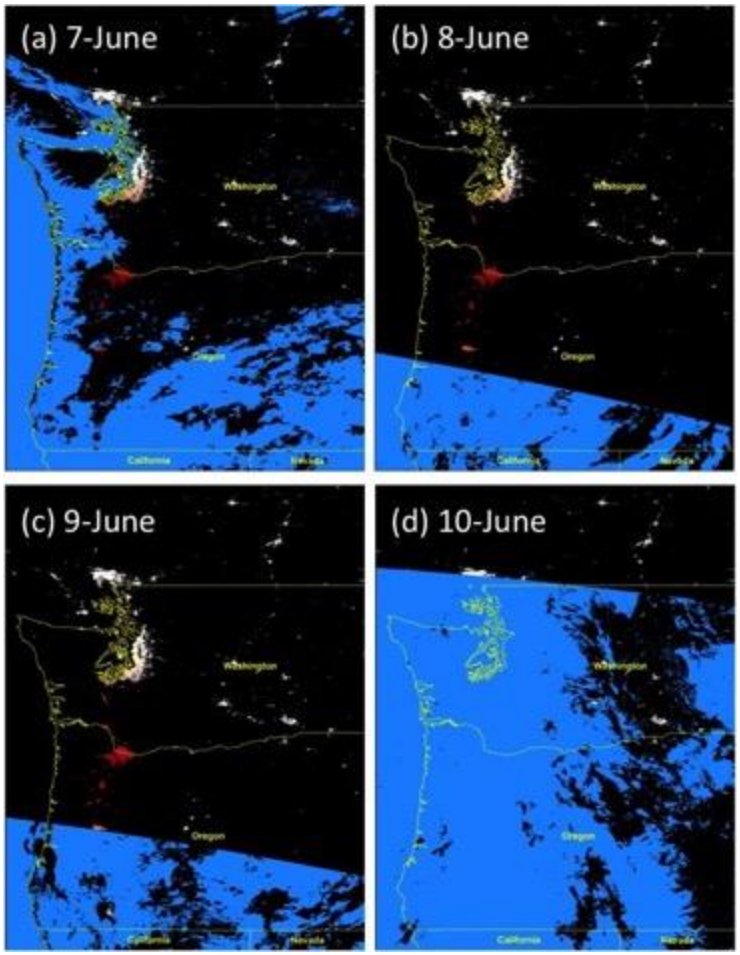


GSFC product providing information on where main road networks intersect areas of high landslide susceptibility (landslide susceptibility from low to high). The product was generated using global road network dataset from CIESIN road networks (global roads dataset from CIESIN). This analysis suggests roads that could be impacted by landslides (either from seismic triggering or subsequent rainfall triggering). Data provided from GSFC in ARC-GIS format (.mpk).



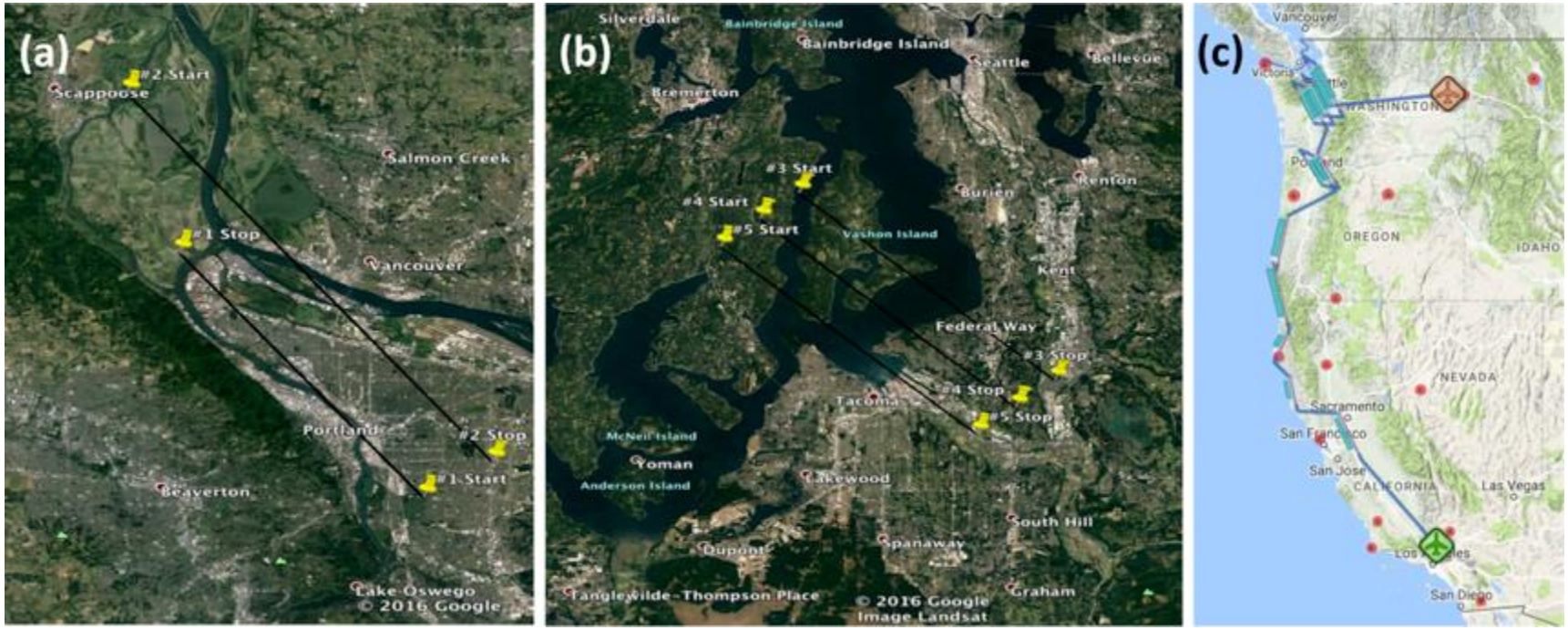
GPM IMERG product showing the 7-day rainfall accumulation over Washington and Oregon. This reveals very little rainfall accumulation on the Washington and Oregon Coasts over the past 7-days of rainfall. There are higher totals in southeastern Oregon. Data delivered from GSFC in KML format. Other examples of GPM products can be accessed: http://www.gpm.nasa.gov

Example Products: Power Outage



Simulated power outage product that can be used in real-time data acquired by the VIIRS/Day-Night Band (DNB). These products were of particular interest to DOE as they provided capability to assess power outages. These is potential for active fire detection, which was not injected into these simulated analyses. Simulated outage detection images were also generated for 11-14 June 2016 (Images courtesy: MSFC, http://weather.msfc.nasa.gov/sport/

Example Products: Mock Airborne Flight Plans



Mock flight plans for deployment from Palmdale, CA, of the NASA ER-2 (AVIRIS-classic) and the NASA G-III (UAVSAR):

ER-2 / AVIRIS-classic flight plan: Flight authorization for 10-June obtained from FAA Cascadia Rising POC. David Green authorized AVIRIS flights on 9-June (1530 deadline for GO). 8-hour flight round trip from Palmdale, CA, scheduled for 10-June planned (0730 Takeoff, 1530 landing).

2 flight lines for data acquisition with AVIRIS-classic targeted Portland, OR, at FL280 (28,000 feet MSL).

ER-2 flight lines for data acquisition with AVIRIS-classic. Coverage targeted 3 lines over the Tacoma oil spill at FL280 (28,000 feet MSL).
G-III / UAVSAR flight plan: http://uavsar.jpl.nasa.gov/cgi-bin/report.pl?planID=cjones_0077#summary

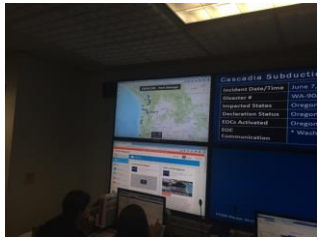
UAVSAR flight plan developed drafted by Cathleen Jones for Saturday 11-June. Airport for refueling, Fairchild Air Force Base (KSKA), was confirmed as viable by FAA POC Gregory Moore. Flight authorization was requested on the last day of the exercise (10-June) for departure 11-June. Flights targeted coastal areas to look at inundation and damage from Tsunami, the Portland area, and the Tacoma oil spill.

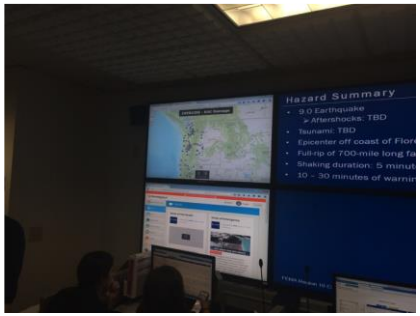
Situational Reports from FEMA RRCC



Pictures from RRCC received on Tuesday 7-June at 10:44am (Exercise Day 1).
"NASA Coordination with USGS and NOAA"


Pictures from RRCC received on Tuesday 7-June at 11:15am (Exercise Day 1).
"Situation Here"





Pictures from RRCC received on Tuesday 7-June at 12:24pm (Exercise Day 1).
"EOC Damage Map Confirmation Request"

State of California Partnership

About the California Earthquake Clearinghouse…

- Facilitates field investigations by earth scientists, engineers and social scientists, who converge on the disaster site
- Assists researchers in accessing perishable data through coordination with emergency management organizations and law enforcement
- Provides a forum for sharing information via meetings at a physical location (field office) and through our new virtual Clearinghouse
- Tracks fieldwork progress and minimize duplication of effort; organize data and imagery collected via various technologies and applications and synthesize information for response agencies

Clearinghouse does not direct or control activities of participants

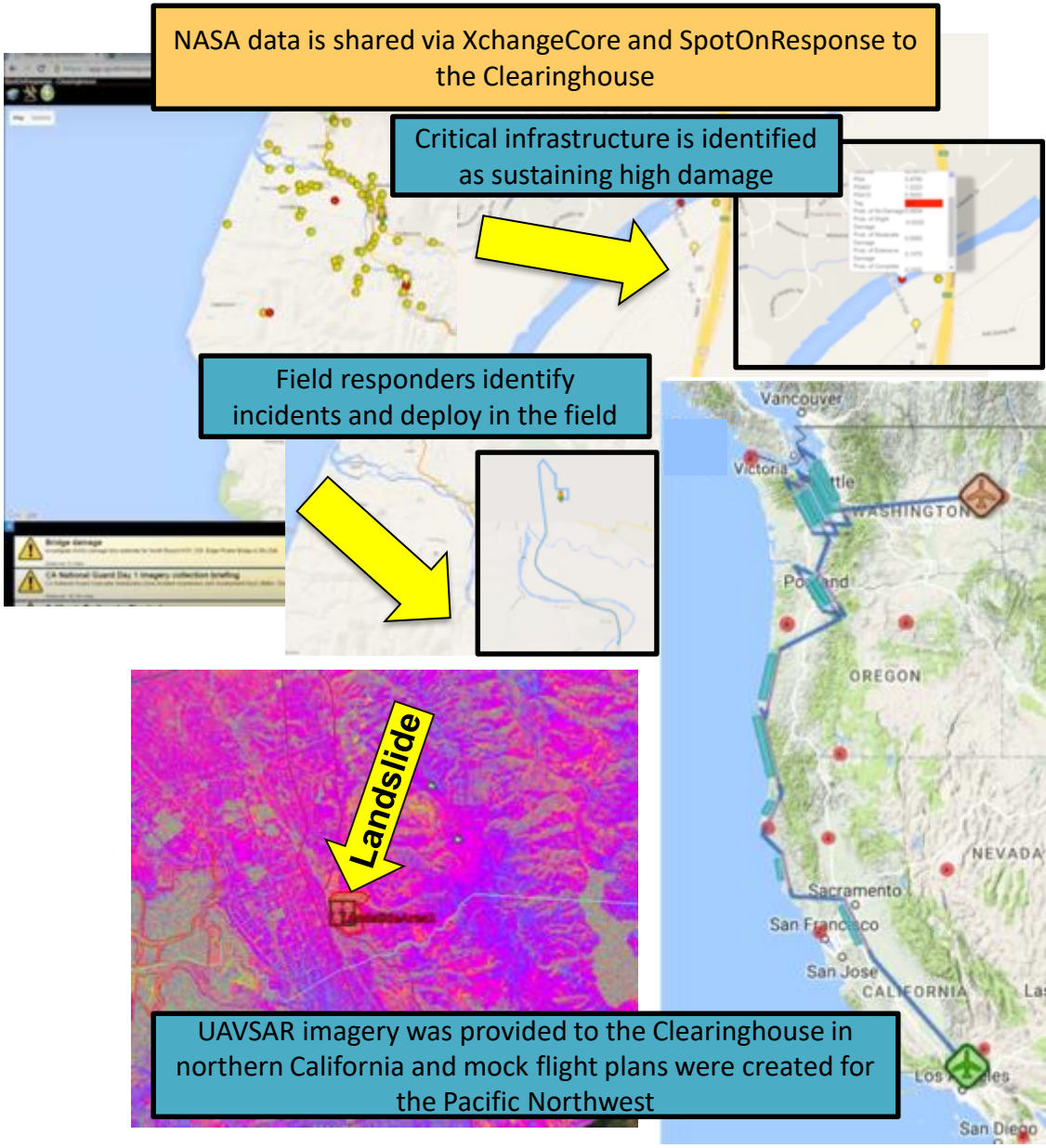
NASA

California Earthquake Clearinghouse

CASCADIA RISING

State of California Partnership

- The California Earthquake Clearinghouse held a parallel exercise focused on interdependencies of critical infrastructure, information sharing, and coordination for response, recovery, and regional resiliency
- NASA participants supported the Clearinghouse through XchangeCore Web Service Data Orchestration and SpotOnResponse



NASA

California Earthquake Clearinghouse

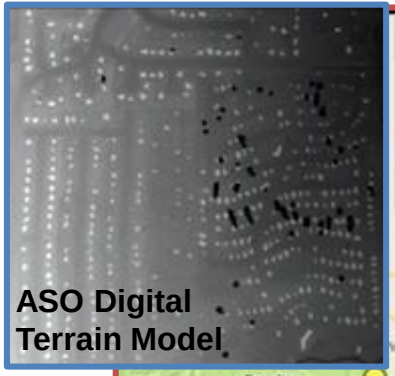
CASCADIA RISING

Where we go from here…

- Incident command is a bottom up structure – we need to build relationships both at programmatic and at the emergency function levels in order to ensure optimal integration of our products
- Better coordination
  - ***Intra***-agency as well as ***inter***-agency
- Focus on data standards and data delivery that are compliant with stakeholder needs
- Capacity building between exercises and disasters that are stakeholder focused
- Establish and ***follow*** protocols

Vigilant Guard 17

- Vigilant Guard 17 was a Full Scale National Guard Exercise hosted by California and Nevada involving a M 6.0 earthquake east of Las Vegas and a M 7.8 earthquake in southern California
- The California Earthquake Clearinghouse, California National Guard, and partners (including NASA) participated from 14-20 November 2016
- NASA provided response products and remote sensing imagery to the Clearinghouse via XchangeCore Web Service Data Orchestration for integration with field response and decision support
- NASA representatives also participated with National Guard imagery analysts at the Joint Operations Center at Beale AFB to provide product integration and analysis support
- NASA provided imagery from Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR), Airborne Snow Observatory (ASO), and AVIRIS (Airborne Visible/Infrared Imaging Spectrometer)

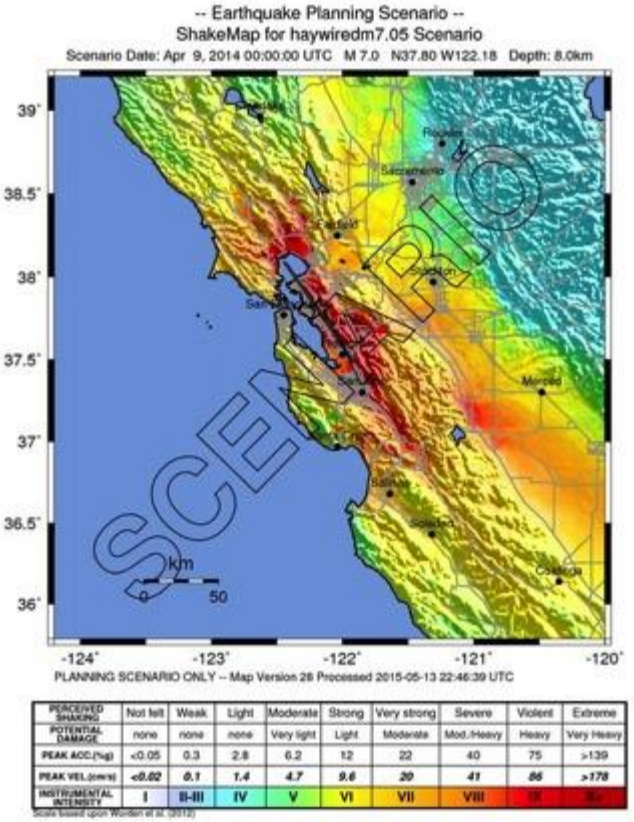


Upcoming Haywired 2017 California Exercise (USGS & Clearinghouse)

Scenario Description

- Earthquake scenario to model and study impacts on the San Francisco Bay area from a Mw 7.05 earthquake on the Hayward fault (planned early 2017)
- Builds upon understanding of the last large earthquake to occur on the Hayward fault in 1868
  - Considers that modern urban infrastructures are made vulnerable by multiple layers of interdependencies between lifelines
  - There is a major reliance on the Internet.
- Also considers impacts from a sequence of aftershocks following the main earthquake

SAFRR - Science Application for Risk Reduction



Time's Up!

- **To conclude:**
  - NASA has participated in a number of exercises and has the opportunity to participate in more
  - This gives us the unique opportunity to both demonstrate capability, evaluate our response process, and improve for future disasters
  - Using lessons learned will aid in shaping our own agency strategy
  - Capacity building during and between exercises and leveraging partnerships (particularly such as our long-standing California State partnership) will allow better understanding of stakeholder needs