E-DECIDER: Experience Developing Earthquake Disaster Decision Support and Response Tools

Margaret Glasscoe, Andrea Donnellan, Timothy Stough, Jay Parker, Michael Burl, Robert Granat

Jet Propulsion Laboratory, California Institute of Technology

Marlon Pierce, Jun Wang, Yu Ma

Indiana University

John Rundle, Mark Yoder

University of California, Davis

Gerald W. Bawden

United States Geological Survey

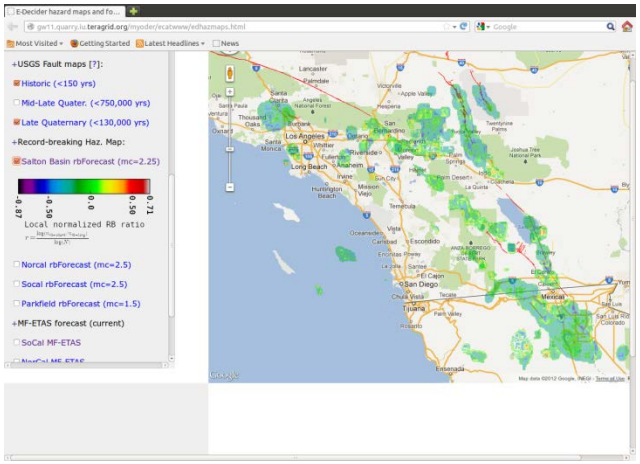
Seth Gorelik

University of California, Santa Barbara

Margaret.T.Glasscoe@jpl.nasa.gov

What is E-DECIDER?

- E-DECIDER = Earthquake Data Enhanced Cyber-Infrastructure for Disaster Evaluation and Response
- Provide decision support for earthquake disaster management and response utilizing remote sensing data and NASA modeling software
- Deliver web-based infrastructure designed for ease-of-use by decision makers, including:
  - Rapid and readily accessible remote sensing and derived data products both pre- and post- earthquake
  - Standards-compliant map data products
  - Deformation modeling and earthquake forecasting results
- Provide both long-term planning information for disaster management decision makers as well as short-term information following earthquake events, such as identifying areas where the greatest deformation and damage has occurred and emergency services may need to be focused

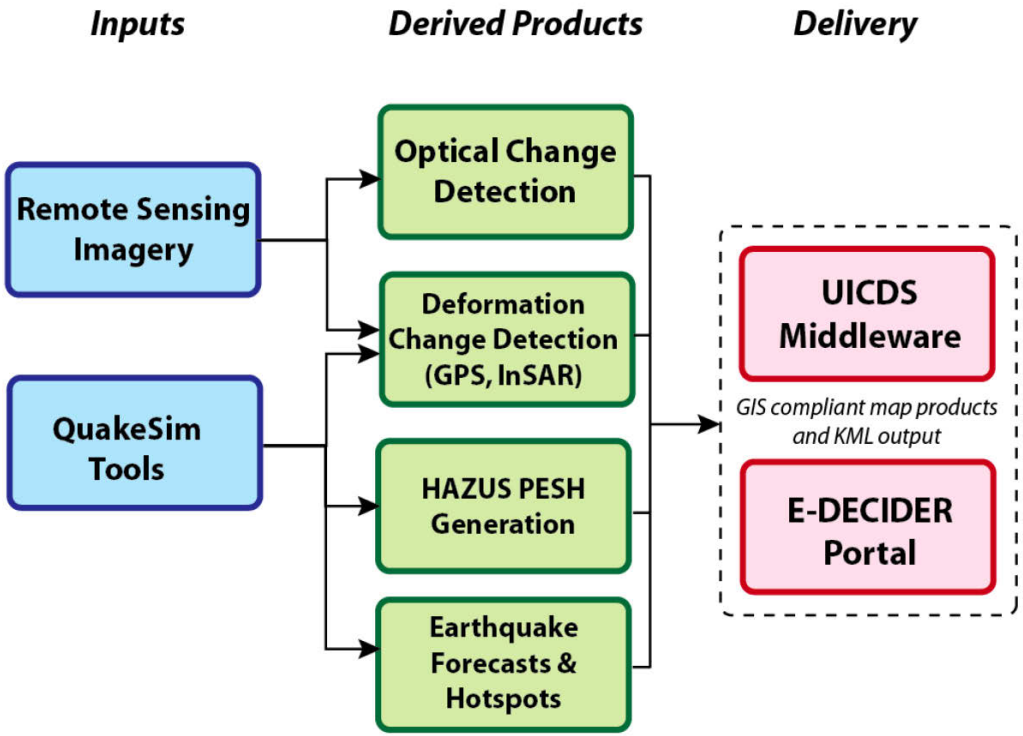


Earthquake forecast tool

What is E-DECIDER? (2)

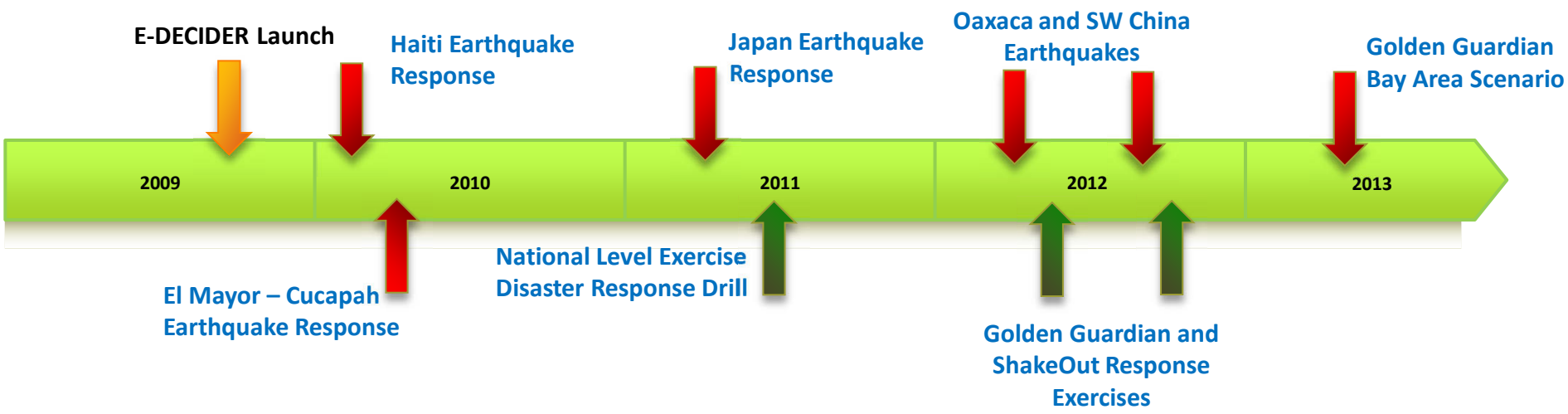
Goals

- E-DECIDER Project Goals: Transform and Distribute NASA Earth Science Data in support of Earthquake Mitigation and Response
- Facilitate coordination of decision support for earthquake disaster response
  - Analysis
  - Distribution of products
  - Identify standards
    - Data formats
    - Distribution methodologies
    - These need to compatible with the state of the art IT infrastructure
  - How to produce results that have immediate utility for disaster response?



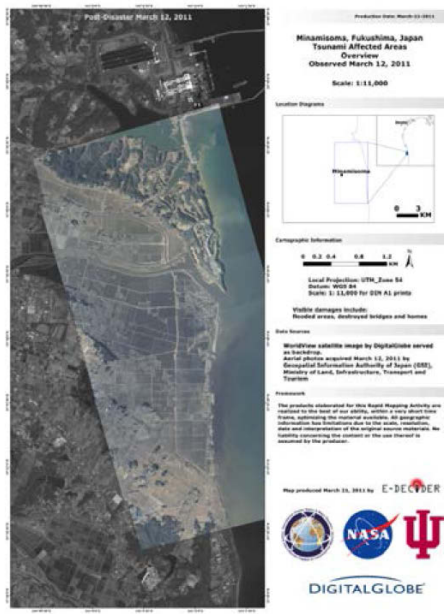
Response to earthquakes and participation in exercises

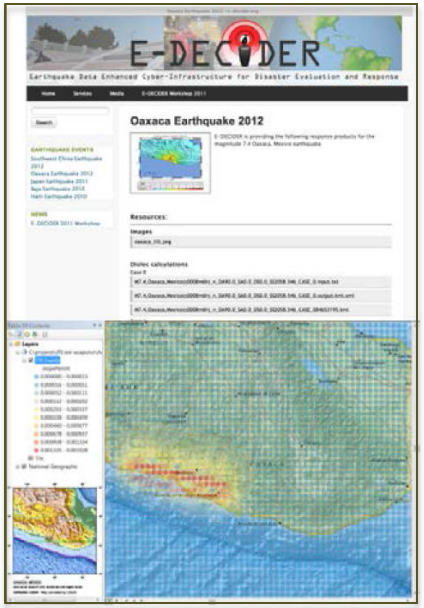
- Over the lifetime of the project E-DECIDER has produced results for a number of events and exercises:
  - 12 January 2010 M 7.0 Haiti earthquake
  - 4 April 2010 M 7.2 El Mayor-Cucapah earthquake
  - 11 March 2011 M 9.0 Tohoku-oki earthquake
  - June 2011 National Level Exercise Disaster Response Drill
  - 20 March 2012 M 7.4 Oaxaca Mexico earthquake
  - May 2012 California Golden Guardian Response Exercise
  - 7 September 2012 M 5.6 Southwest China earthquake
  - October 2012 ShakeOut Exercise



Response to earthquake events (2)

- Two of the events involved the invocation of the International Charter and had their own unique challenges:
  - Haiti: not a very well-instrumented region, and there were no radar data readily available; most easily accessible remote sensing data were optical imagery; limited interferometry, even though UAVSAR was flown after event.
  - Japan: despite being one of the most well-instrumented regions, critical data could be difficult to obtain; latency on radar data

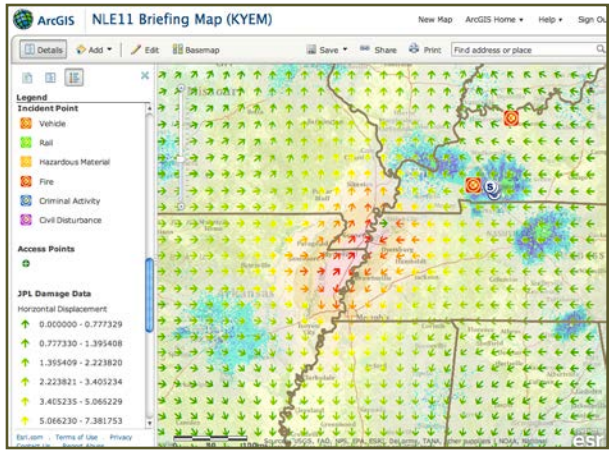




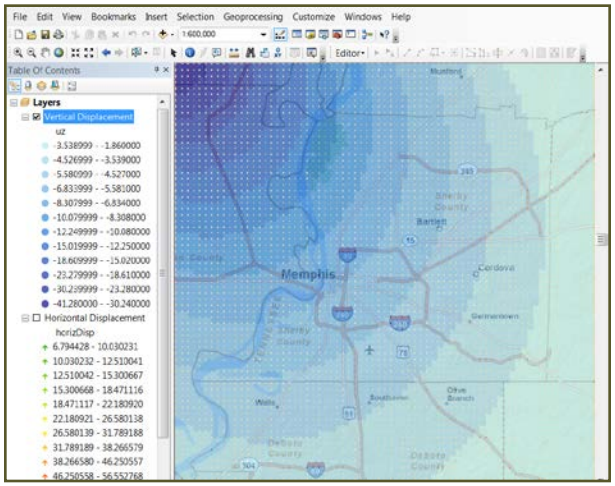
Minamisoma, Fukushima Japan tsunami affected area (left) and example webpage (right) showing E-DECIDER results for Oaxaca Mexico earthquake.

Participation in large-scale response exercises

- E-DECIDER has also provided products for the 2011 National Level Exercise (New Madrid event scenario), the 2012 California Golden Guardian Exercise, and will provide products for the 2012 California Earthquake Clearinghouse ShakeOut Exercise
- Participation in the National Level Exercise for the New Madrid Scenario revealed:
  - Both short (0-3 day) and long (1-3 week) time scale layers are needed
  - For products with a very specific audience, data delivery should be direct
  - Updated data products should show significant changes
  - Products should be delivered to the web in easy to use packages (e.g. KML, GeoRSS feeds)
- Participation in the Golden Guardian Exercise has allowed us to test our products in an operational environment and obtain feedback on some of the requirements of EOCs. Further work will be required for direct delivery to responders.
  - Interferograms (modeled and UAVSAR) have been requested by EOCs



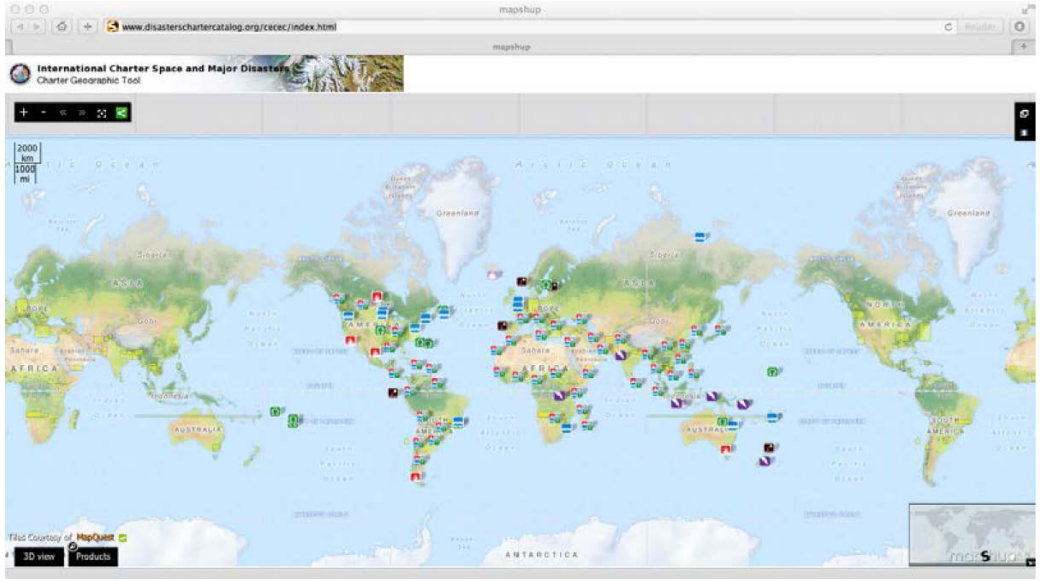
GIS outputs of deformation vectors from central US scenario for NLE.



GIS outputs of vertical change or tilt from central US scenario for NLE.

What is the International Charter?

- The International Charter
  - Aims to provide a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through Authorized Users.



International Charter tool illustrating activations and disaster types.

  - Provides resources to support the provisions through member agencies in order to mitigate the effects of disasters on human life and property.
  - Was initiated following the UNISPACE III conference held in Vienna Austria in July 1999 by The European and French space agencies (ESA and CNES) with the Canadian Space Agency (CSA) signing the Charter on 20 October 2000.

- **http://www.disasterscharter.org/**

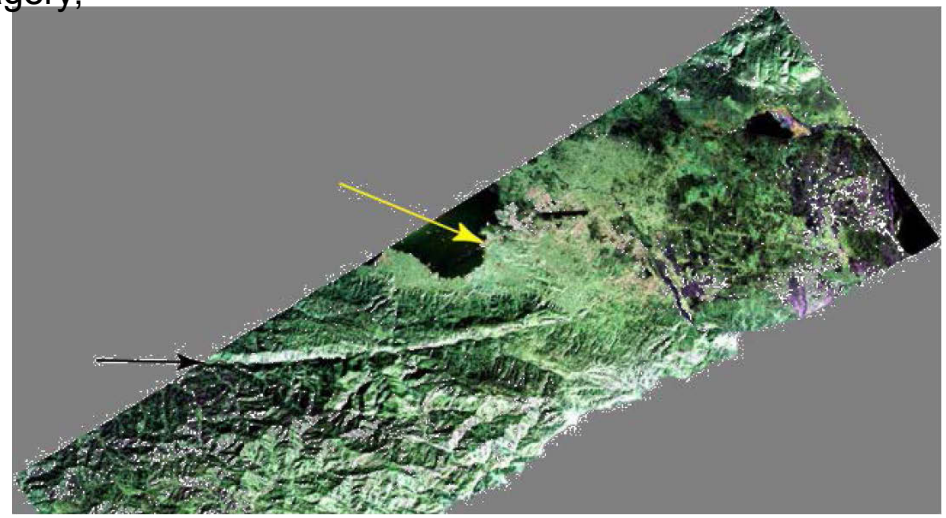
What is the International Charter? (2)

- The following agencies subsequently joined the Charter as members:
  - National Institute For Space Research - Brazilian Institute (INPE, November 2011)
  - Korea Aerospace Research Institute (KARI, July 2011)
  - German Aerospace Center (DLR, October 2011)
  - China National Space Administration (CNSA, May 2007)
  - BNSC/DMCii (November 2005)
  - Japan Aerospace Exploration Agency (JAXA, February, 2005)
  - United States Geological Survey (USGS) as part of the U.S. team (2005)
  - Argentine Space Agency (CONAE, July 2003)
  - National Oceanic and Atmospheric Administration (NOAA)
  - Indian Space Research Organization (ISRO) (September 2001)
- The International Charter was declared formally operational on November 1, 2000.

Response to the Haiti Earthquake

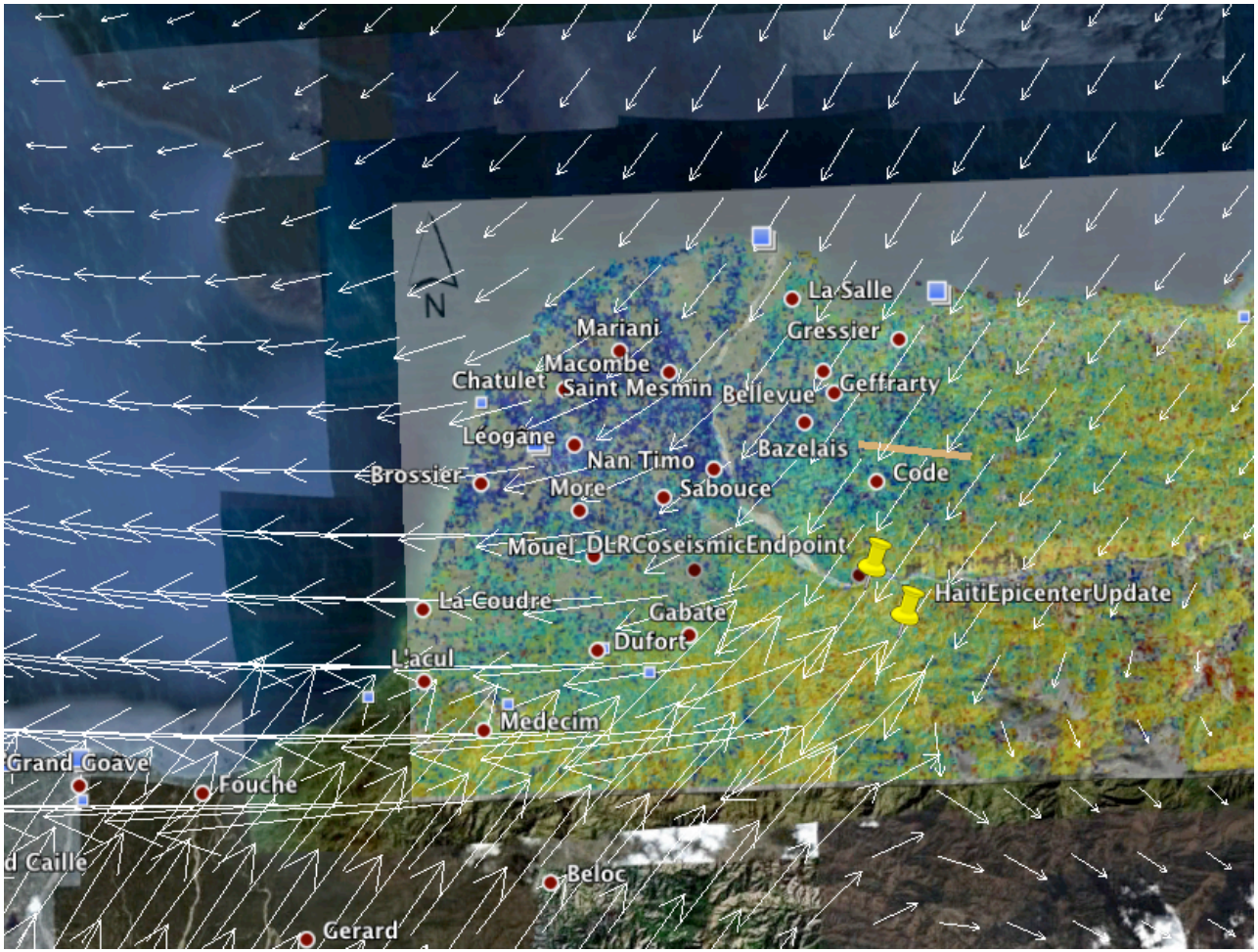
- Our first experience with an earthquake disaster response scenario involved the 12 January 2010 M 7.0 Haiti earthquake
  - Complicated from a response and scientific standpoint as this was not a very well-instrumented region, and there was no radar data readily available
  - Most easily accessible remote sensing data was optical imagery, mostly from commercial satellites tasked through the International Charter
  - NASA's UAVSAR was flown over the affected area, but since there was no pre-earthquake acquisition, there was limited use for interferometry and other change detection methods
- E-DECIDER produced:
  - Preliminary deformation results overlain on optical imagery
  - Facilitated contact of US International Charter representative with JPL UAVSAR team for targeted post-earthquake acquisition

False-color composite image of the Port-au-Prince, Haiti region, taken Jan. 27, 2010 by NASA's UAVSAR airborne radar. The city is denoted by the yellow arrow; the black arrow points to the fault responsible for the Jan. 12 earthquake. Image credit: NASA/JPL



UAVSAR image of Haiti.

Deformation map overlain on SPOT image for Haiti earthquake

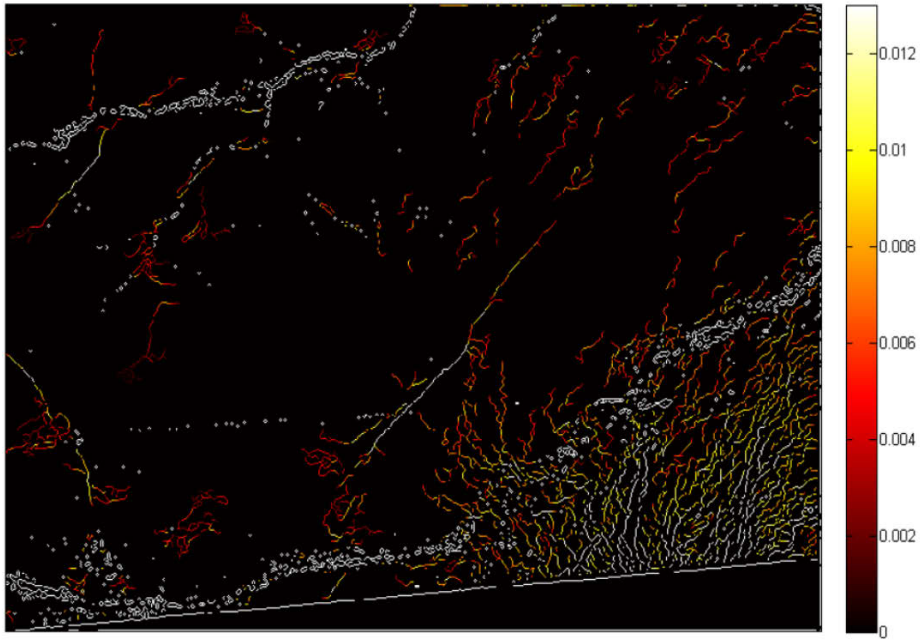


SPOT image with modeled deformation vectors overlain.

- A preliminary result produced for the Haiti earthquake was a comparison of optical change with an E-DECIDER modeled surface displacement.
  - SPOT5 dual-image displacement (east component, color image)
  - Compared with Disloc model of the region of the 2010 Haiti earthquake epicenter (west of Port- au-Prince).
  - Map overlay of image layers is carried out in Google Earth.
  - Correlation of SPOT images processed by CEA, images courtesy of CNES and International Charter on Space and Major Disasters.

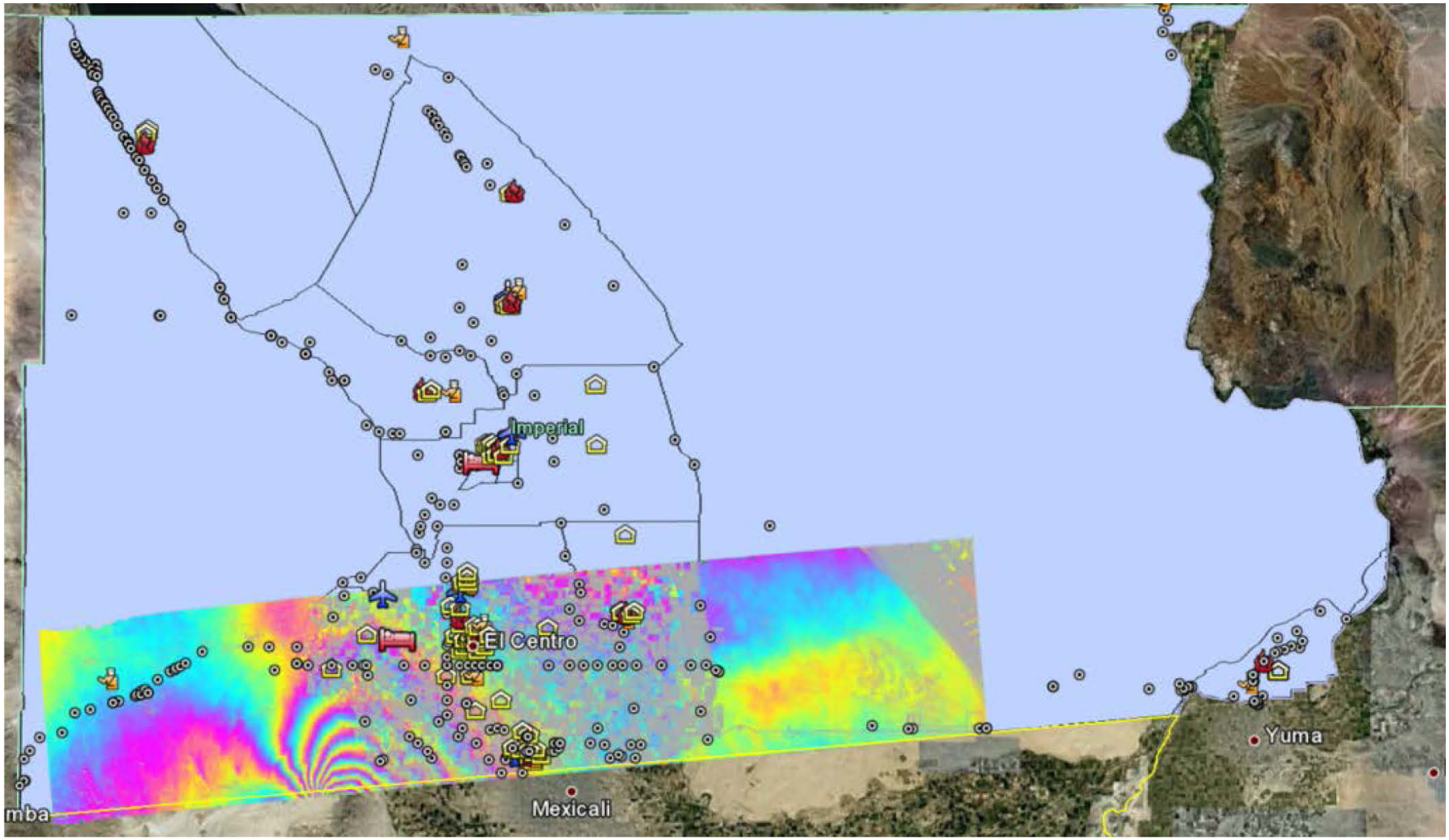
El Mayor-Cucapah Earthquake Response

- Our next real earthquake was the 4 April 2010 M 7.2 Baja earthquake
  - UAVSAR coverage of this area both prior to the earthquake and quickly following it
  - Also good satellite radar coverage of the area affected by the quake
  - Luckily, this earthquake was in a relatively low population density area, so damage was minimal and the disaster response need wasn't as critical
- E-DECIDER produced:
  - Overlays of critical infrastructure using HAZUS from PESH files generated from OpenSHA
  - Fault edge detection using an algorithm originally developed in Matlab but later translated to python
  - Initial optical change detection



Edge detection of features in Yuha fault region in Baja California

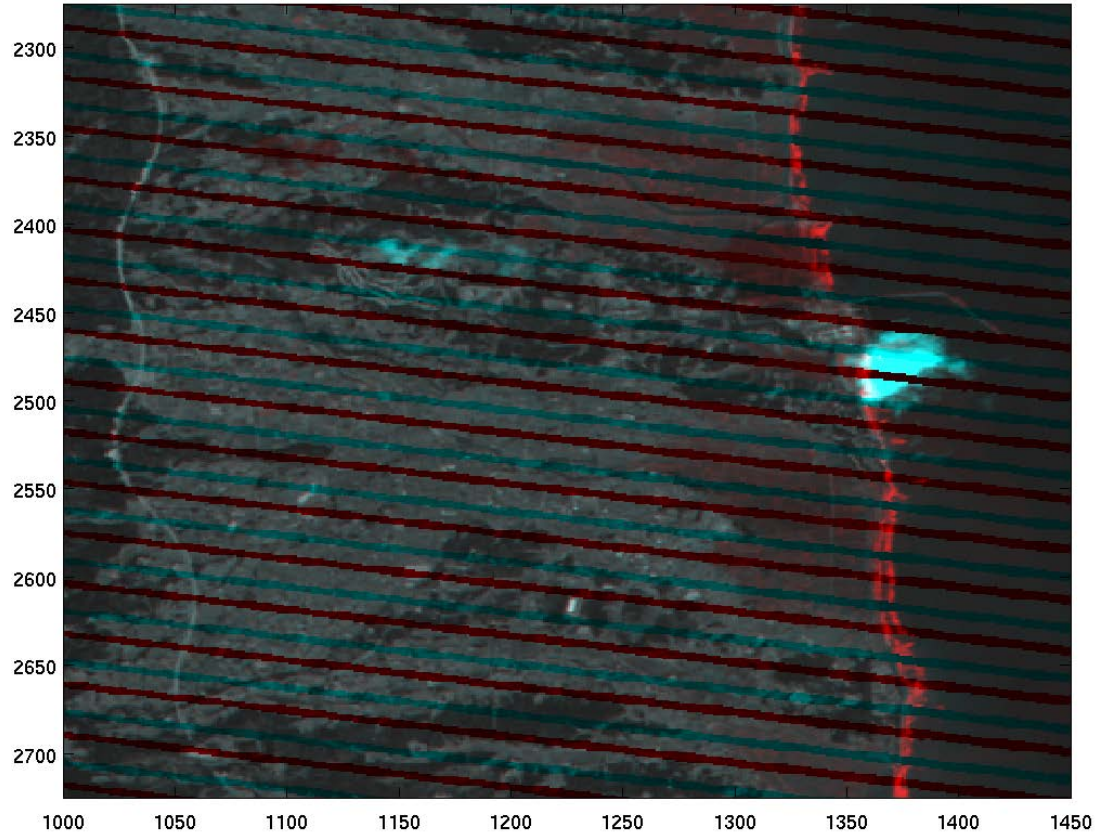
HAZUS model output overlain on UAVSAR image of El Mayor-Cucapah earthquake deformation



Critical Infrastructure exposure to El Mayor-Cucapah 7.2 Earthquake

Tohoku-oki earthquake response

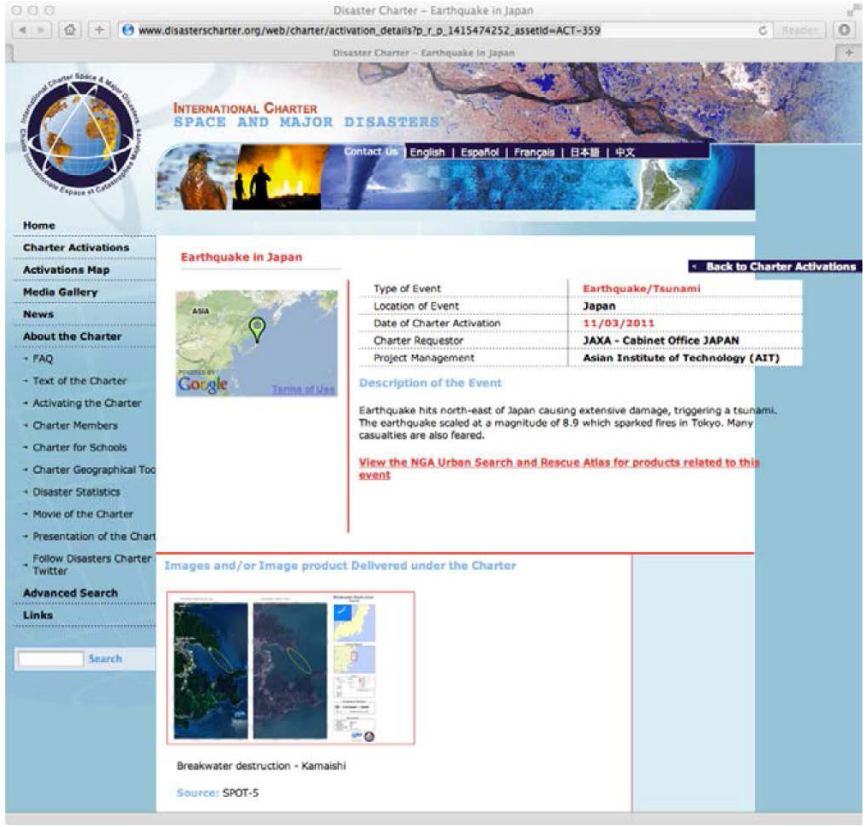
- First official use of E-DECIDER results: th 2011 M 9.0 Tohoku-oki earthquake
- This was similar to the Haiti earthquake in that the disaster response need was urgent and radar data were not readily available
- Optical satellite imagery were the primary data available for disaster response through the International Charter.
  - Hyperspectral data were also available (e.g. MODIS, LandSat)
- Despite Japan being one of the most well-instrumented regions in the world, useful disaster response data was still difficult to obtain



Red/cyan change detection of LandSat 7 pair of the Minamisoma, Fukushima area. Red areas along coastline and red tinged areas indicate possible inundation.

Background

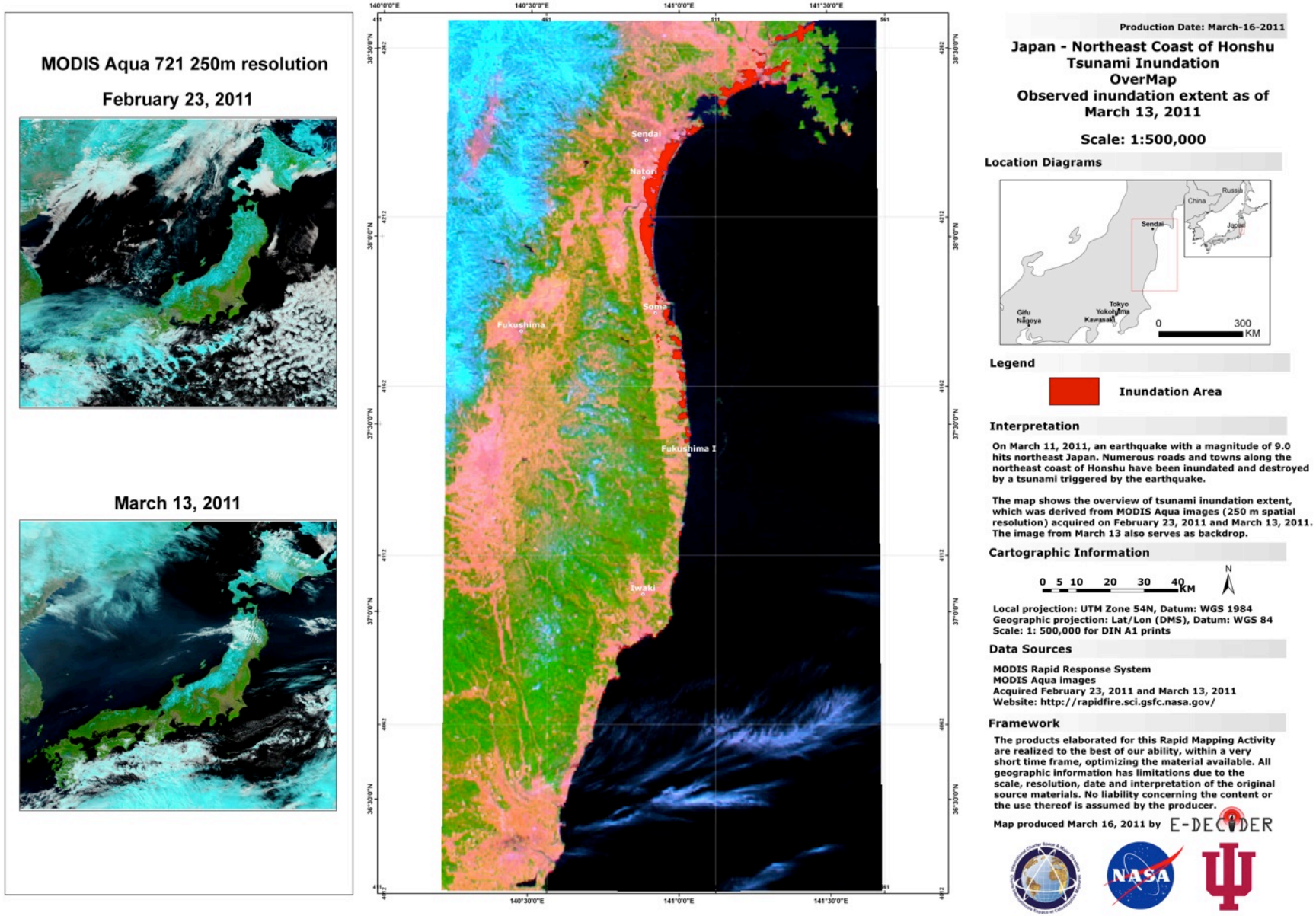
- The International Charter was activated to provide remote sensing response information for the Tohoku-oki event on 11 March 2011
- The E-DECIDER team worked with USGS representatives for the International Charter in order to:
  - Provide response products to the Japanese government in order to assess damage from the tsunami and earthquake.
  - Provide georeferenced maps of target areas identified by the Japanese International Charter representative showing before and after high resolution optical images, including those of the Fukushima nuclear reactor.



http://www.disasterscharter.org/web/charter/activation_details?p_r_p_1415474252_assetId=ACT-359

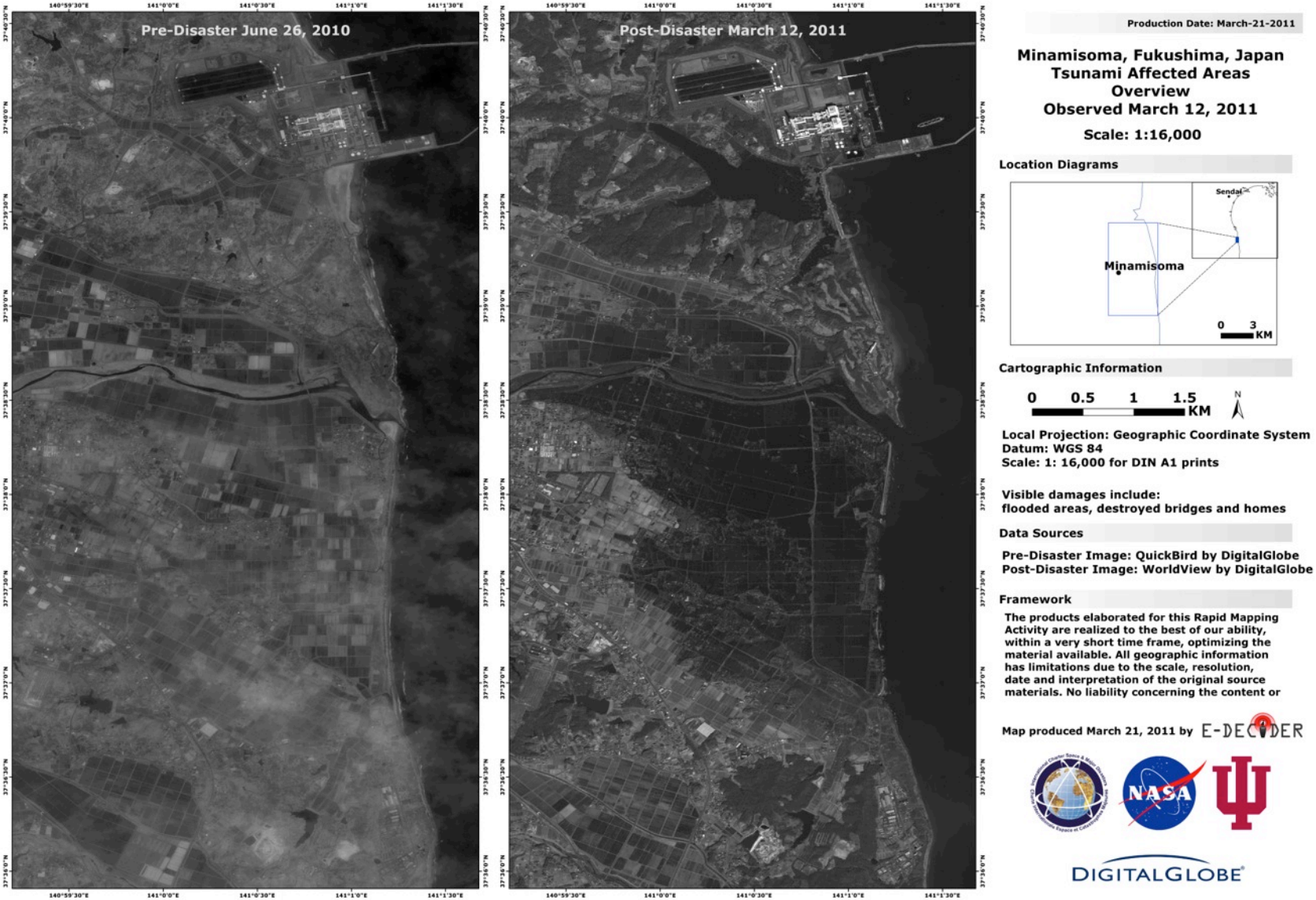
E-DECIDER delivered initial change detection results within a few days and image pair maps within a week, alongside other teams working with the US International Charter representatives

Change detection with MODIS



http://e-decider.org/content/japan-earthquake-2011

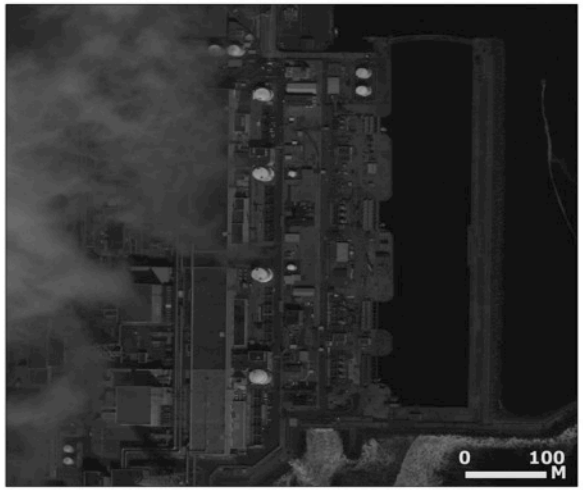
Tsunami inundation extent with high resolution images from the International Charter



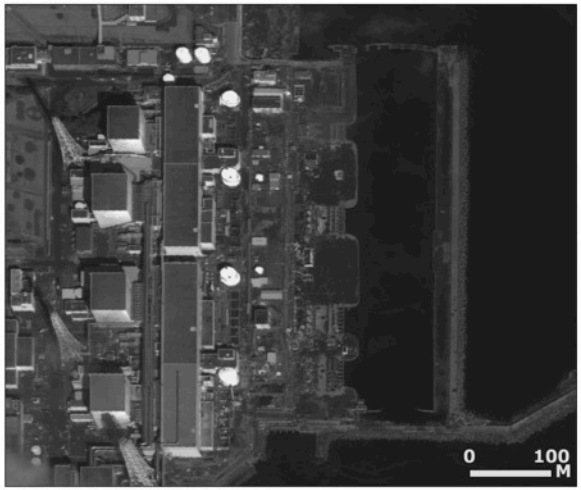
http://e-decider.org/content/japan-earthquake-2011

Tsunami inundation extent with high resolution images from the International Charter

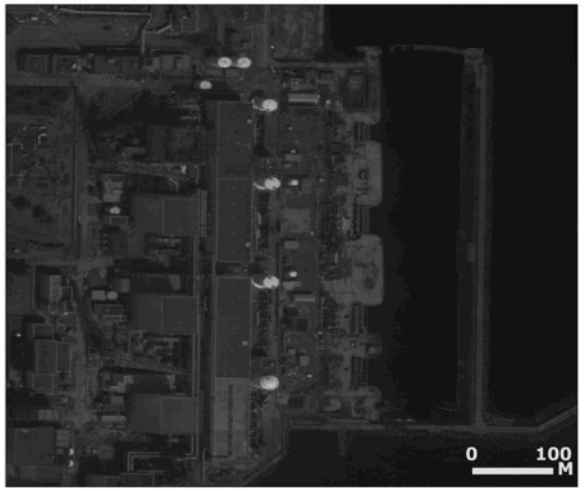
Pre-tsunami: March 26, 2009



Post-tsunami: March 12, 2011



Post-explosion: March 14, 2011



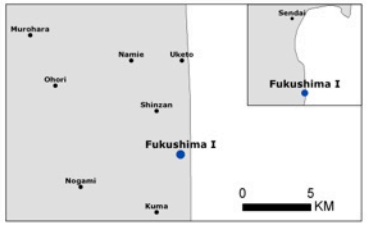
Post-explosion: March 17, 2011

Production Date: March-19-2011

Okuma, Fukushima, Japan
Fukushima I Power Plant
Observed March 17, 2011

Scale: 1:2,500

Location Diagrams



Cartographic Information

0 50 100 200 Meters

N

Local Projection: Geographic Coordinate System
Datum: WGS 84
Scale: 1: 2,500 for DIN A1 prints

Visible damages include:
Fukushima I power plant Unit 1~4

Data Sources

WorldView Images by DigitalGlobe

Framework

The products elaborated for this Rapid Mapping Activity are realized to the best of our ability, within a very short time frame, optimizing the material available. All geographic information has limitations due to the scale, resolution, date and interpretation of the original source materials. No liability concerning the content or the use thereof is assumed by the producer.

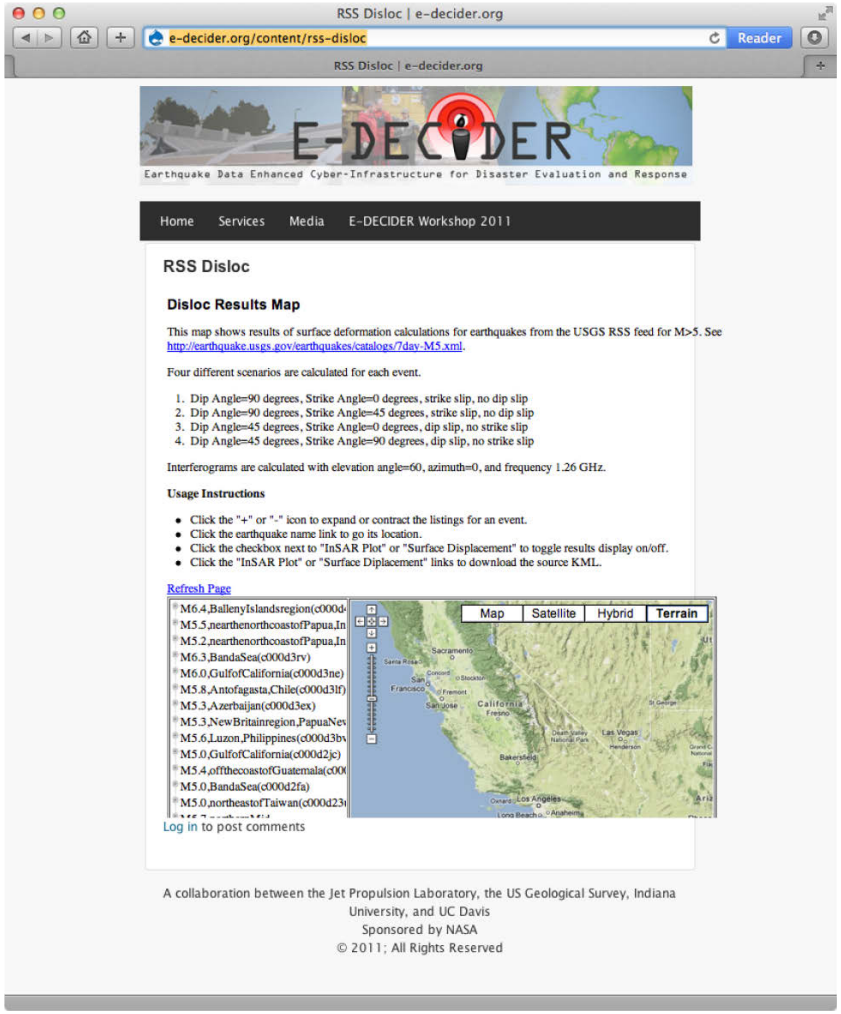
Map produced March 19, 2011 by E-DECIDER

DIGITALGLOBE

http://e-decider.org/content/japan-earthquake-2011

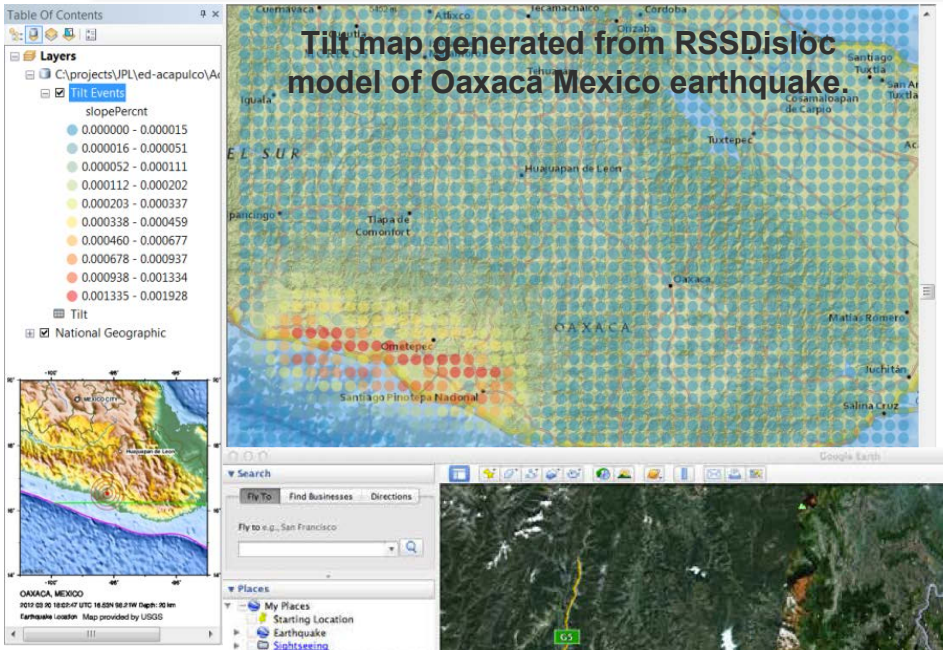
Automatically generated earthquake products

- E-DECIDER delivers automated deformation products through web services in conjunction with QuakeSim
- Forward models are triggered from the USGS earthquake feed and vector displacements, synthetic interferograms, and tilt maps are generated and posted to an RSS feed.
- An automated web service will soon be available on the E-DECIDER website that will make these results available along with an on-demand KML generator that will allow overlay of census and infrastructure data.
- Example results have been posted to the E-DECIDER website.

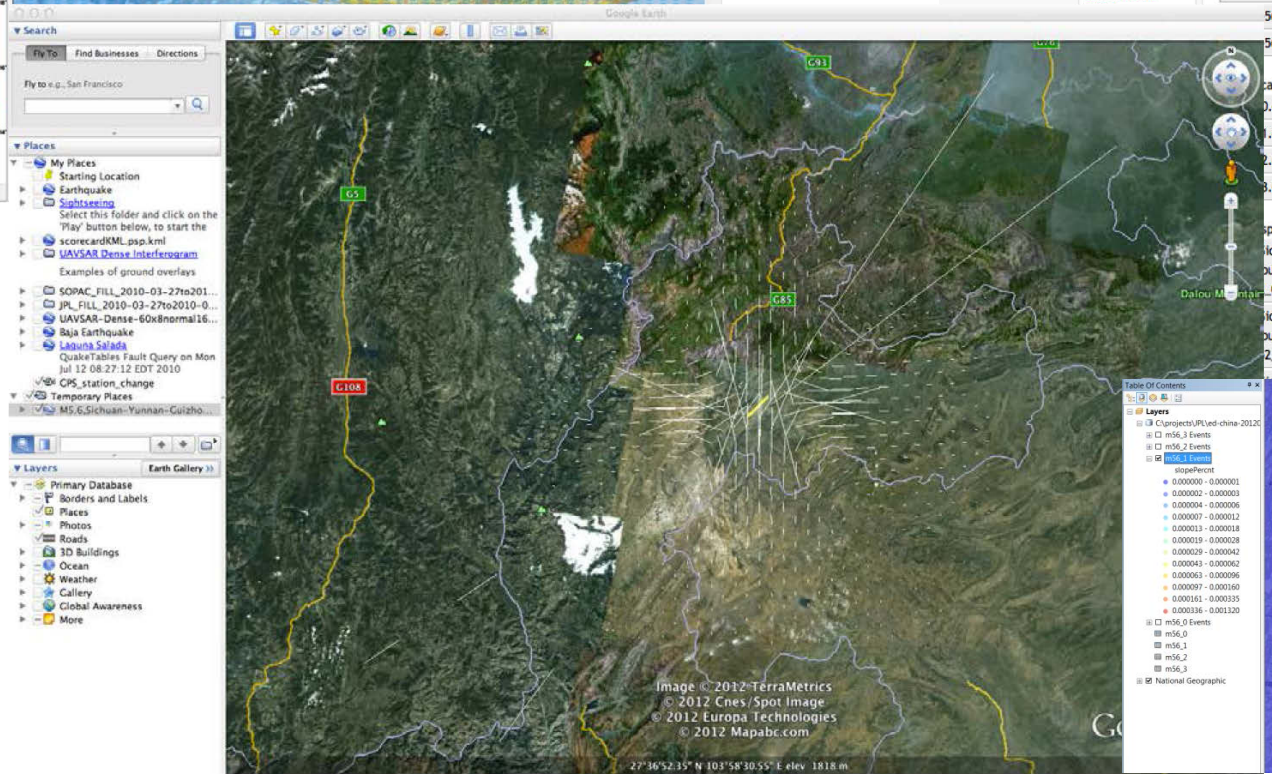


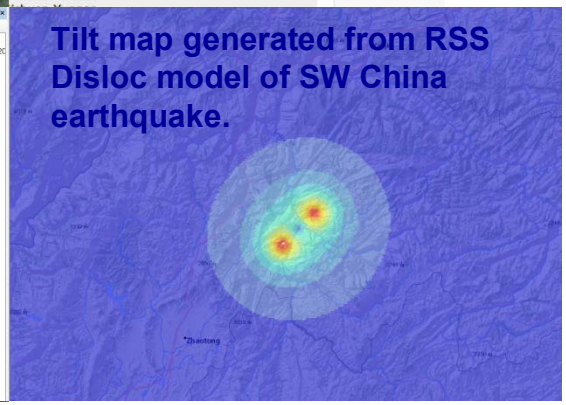
RSSDisloc web service on E-DECIDER webpage

Oaxaca and Southwest China earthquake products



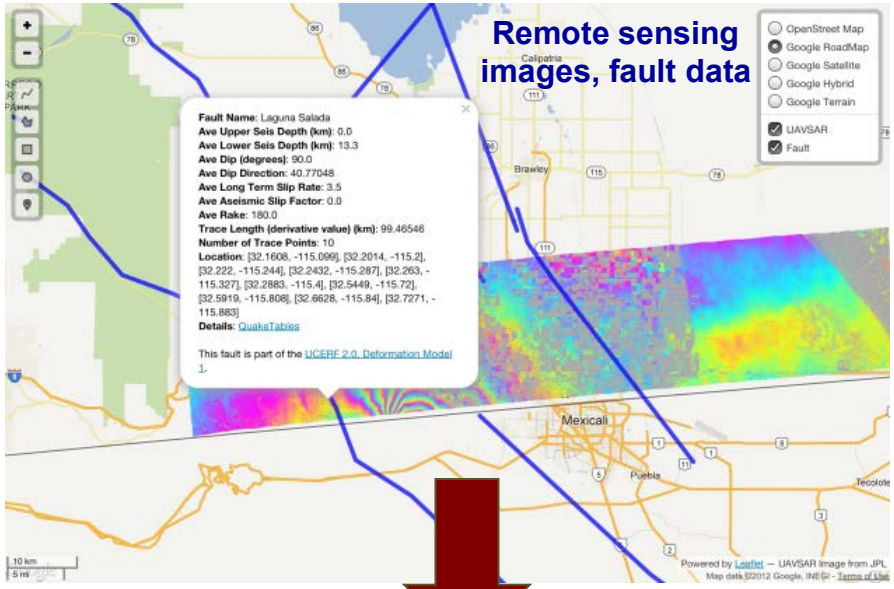
SW China EQ page

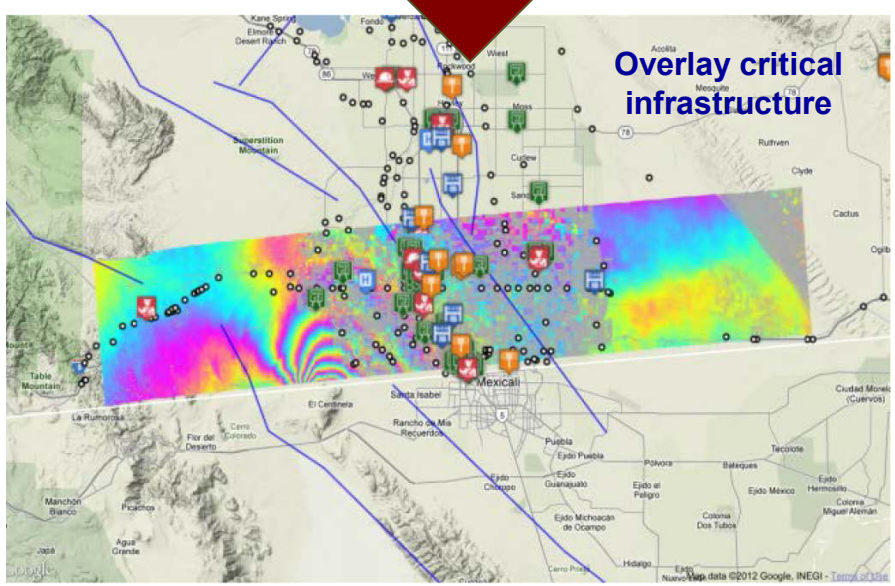




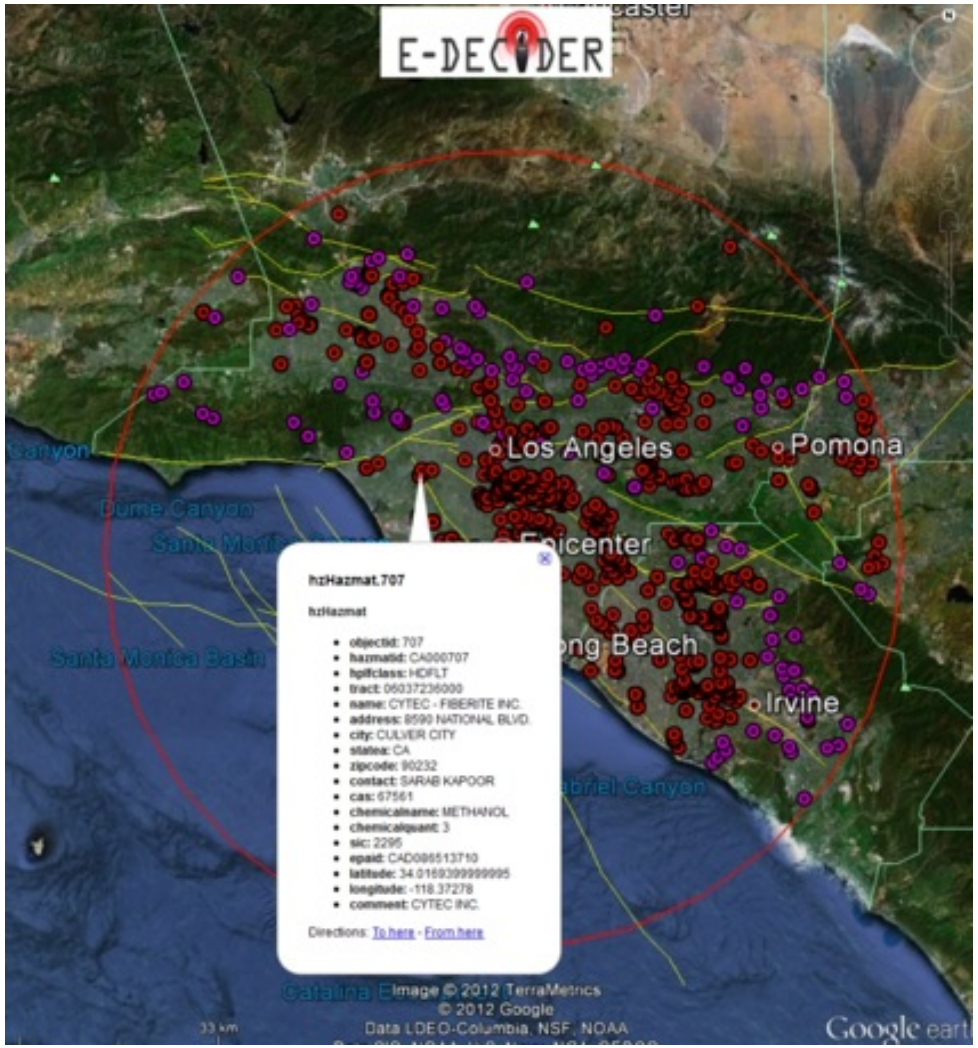
KML output of deformation vectors in Google Earth generated from RSSDisloc model of SW China earthquake.

From science data products to decision support





Earthquake epicenter, critical infrastructure with circles denoting various radii distances



Online on-demand KML generator http://E-DECIDER.org/services/kmlgenerator

Online demonstration mobile interface: http://gf2.ucs.indiana.edu/mobile/mobile.html

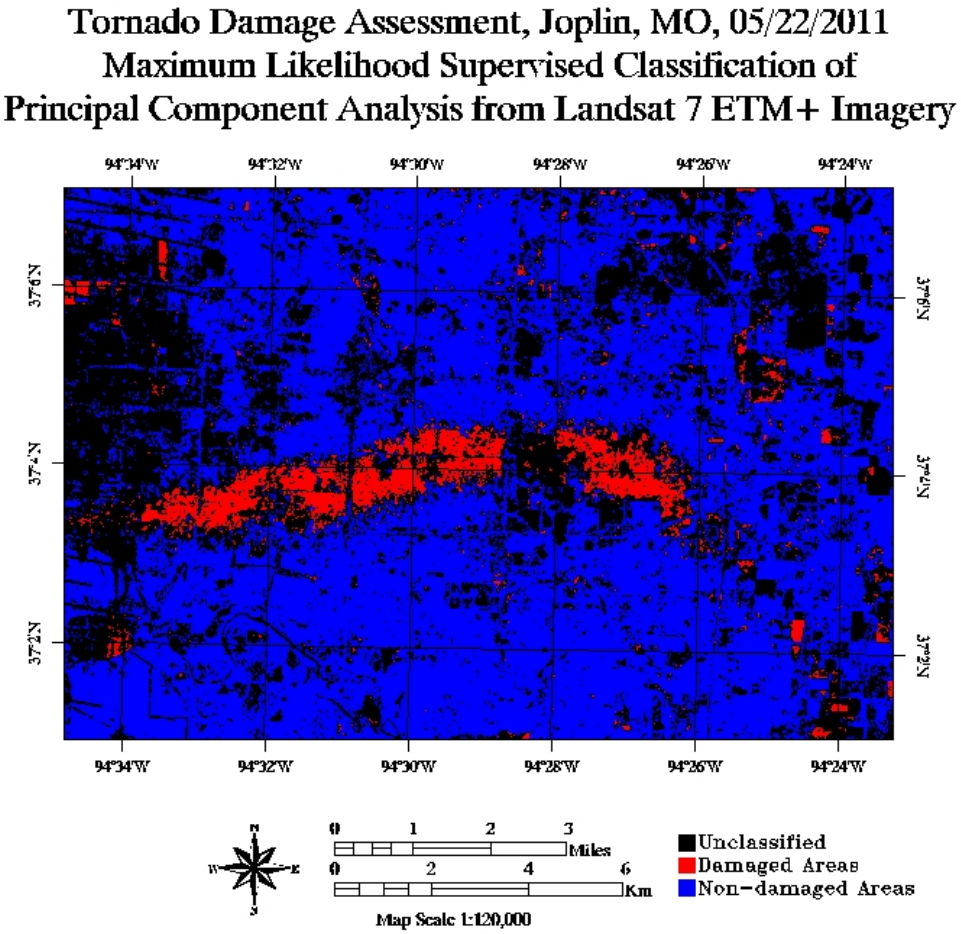
Key requirements for products

- Disaster response operates on a number of timelines
  - Immediate (crucial first minutes to hours following the event) – rapid results to focus initial response efforts
  - Intermediate (hours to days following the event) – continued response, refining initial results and assessments
  - Longer term (weeks to months) – identify areas where repair of infrastructure needs to be addressed

- Must identify where deformation is greatest and likely damage has or is likely to occur
  - This will allow decision makers and responders to focus response efforts
- Format and distribution
  - Standards compliant, georeferenced data products
  - Standards compliant distribution services
- How data is currently represented may not be easily understandable or interpreted by users
  - Must move beyond science products to decision support/response products

Issues revealed

- High latency on most data products
- No good search facility to obtain imagery by time and location
- Limited search capability, but what existed was poor
- No automated or standardized geo-referencing c registration
- No automated data quality filter (for example for clouds)
- Data sources distributed across multiple providers, with no standardized interface
- Some data products were only available in compressed format (i.e. JPEG)
- No automated delivery system
- Many data sources were user restricted, negotiating restrictions takes precious time



Proof of concept change detection methodology to assess damage for tornados. Damage in this image is on the scale of what would be seen from a large earthquake so it can be used as a proxy for expected damage.

Community actions for the future

- Need better coordination
  - Analysis efforts
  - Distribution of high and low level data products
- Agreement on standards
  - Data formats (OGC)
  - Distribution methodologies (FEMA-UICDS, web services, mobile services)
  - These need to compatible with the state of the art IT infrastructure
- Data sharing!
- As scientists, how can we produce results that have immediate utility for disaster response?