Earthquake Disaster Decision Support and Response Tools

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E-DECIDER

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Earthquake Data Enhanced Cyber-Infrastructure for Disaster Evaluation and Response

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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.

✧ 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.
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.

- 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/](http://www.disasterscharter.org/)
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.
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
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 earthquake events

- Over the lifetime of the project E-DECIDER has produced products for three events:
  - 12 January 2010 M 7.0 Haiti earthquake
  - 4 April 2010 M 7.2 Baja earthquake
  - 11 March 2011 M 9.0 Tohoku-oki earthquake

- Each event presented its 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.
  - Baja: Good satellite coverage, UAVSAR could not fly over international borders.
  - Japan: despite being one of the most well-instrumented regions, critical data could be difficult to obtain; latency on radar data
First real response opportunity for E-DECIDER was the 11 March 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
Change detection with MODIS

MODIS Aqua 721 250m resolution
February 23, 2011

March 13, 2011

Production Date: March 16, 2011
Japan - Northeast Coast of Honshu
Tsunami Inundation
OverMap
Observed inundation extent as of March 13, 2011
Scale: 1:500,000

Location Diagrams

Legend
Inundation Area

Interpretation
On March 11, 2011, an earthquake with a magnitude of 9.0 hits northeast Japan. Numerous roads and towns along the northeast coast of Honshu have been inundated and destroyed by a tsunami triggered by the earthquake.

The map shows the overview of tsunami inundation extent, which was derived from MODIS Aqua images (250 m spatial resolution) acquired on February 23, 2011 and March 13, 2011. The image from March 13 also serves as backdrop.

Cartographic Information
Local projection: UTM Zone 54N, Datum: WGS 1984
Geographic projection: Lat/Lon (DMS), Datum: WGS 84
Scale: 1:500,000 for ODM A1 points

Data Sources
MODIS Rapid Response System
MODIS Aqua images
Acquired February 23, 2011 and March 13, 2011
Website: http://rapidfire.sci.gsfc.nasa.gov/

Framework
The products elaborated for this Rapid Mapping Activity are realized to the best of our ability, within a very short time frame, optimising 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 16, 2011 by
Change detection with LandSat

Red/cyan change detection of LandSat 7 pair of the Minamisoma, Fukushima area. Red areas along coastline and red tinged areas indicate possible inundation.
Tsunami inundation extent with high resolution images from the International Charter
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

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

Scale: 1:2,500

Cartographic Information

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
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Map produced March 19, 2011 by E-DECIDER
E-DECIDER Approach

**Inputs**

- Remote Sensing Imagery
- QuakeSim Tools

**Derived Products**

- Optical Change Detection
- Deformation Change Detection (GPS, InSAR)
- HAZUS PESH Generation
- Earthquake Forecasts & Hotspots

**Delivery**

- UICDS Middleware
  - GIS compliant map products and KML output
- E-DECIDER Portal

Additional Tools:
- RSS Disloc, Simplex, GeoServer, LOS tools, HAZUS Gadget
Data Availability Timeline

✧ Earthquake + 0 – 1 hours
  Modeled results based on location, magnitude, and likely faults
    ✧ Modeled Displacement Maps
    ✧ PESH inputs for the HAZUS-MH model
    ✧ HAZUS Total Loss Maps

✧ Earthquake + 3 hours – 1 day
  Optical, more accurate GPS data and better estimates of the fault rupture become available
    ✧ Surface Displacement Maps with Slope Change
    ✧ Improved PESH inputs using new fault rupture estimates

✧ Earthquake + 1 – 7 days
  InSAR data becomes available to compute further improved fault models and surface displacement as well as change detection
    ✧ InSAR based damage assessment
Lessons learned from other response exercises

✧ E-DECIDER has provided products for both the Haiti and Baja earthquakes and the 2011 National Level Exercise (New Madrid event scenario)

✧ 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
Lessons learned from other response exercises (2)

✧ 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

✧ Participation in the National Level Exercise for the New Madrid Scenario
  
  ▪ 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)
Comparison of SPOT5 dual-image displacement (east component, color image) with modeled surface displacement from E-DECIDER dislocation model, in the region of the 2010 Haiti earthquake epicenter (west of Port-au-Prince). This 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.
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
Critical Infrastructure exposure to Baja 7.2 Earthquake
From ground deformation to decision support

- Earthquake models, InSAR and GPS networks all inform ground deformation
- Deformation can be represented with interferograms or vectors
- These representations are not familiar to or easily interpreted by decision-makers
- A decision support information product must draw attention to areas where damage has or is likely to occur
Slope/tilt and magnitude gradient

- Infrastructure to convey water (supply, runoff, and sewer) depend on slope to ensure flow and even small changes can impact the system.

- Gas distribution, power, and telecommunication systems can be damaged by the ground rupturing, stretching, or compressing (magnitude gradient).

- Producing slope and magnitude gradient products in GIS ready forms is needed for infrastructure operator response.
Model outputs from Disloc are processed using Sobel operators to extract slope change/tilt and magnitude gradient.

The resulting values are stored as GIS products.

Infrastructure owners can use these products in conjunction with their own GIS inventories to identify areas of likely damage.
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 or 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
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)
  - 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?