Final Report

E-DECIDER

2011 End User Workshop

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Jet Propulsion Laboratory,
California Institute of Technology
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Introduction

Earthquake Data Enhanced Cyber-Infrastructure for Disaster Evaluation and Response (E-DECIDER) is a project funded by the NASA Applied Sciences Program with the goal of integrating Earth science data and information for disaster forecasting, mitigation and response, specifically for earthquakes and post-disaster response and recovery. It will also contribute to providing hazard and disaster information when and where it is needed and recognizing vulnerability of interdependent critical infrastructure.

The E-DECIDER project is developing web-based decision-making capabilities utilizing NASA remote sensing data and modeling tools to provide decision support for earthquake disaster management and response utilizing a web-service architecture. The final system will include a set of web services that deliver data and derived data products to decision-makers in a flexible, extensible, and easy to use interface that can be readily maintained.

The goal of this 2011 End User Workshop is to bring together professionals in disaster response and emergency management with scientists and remote sensing experts to determine the most useful data products and delivery methods in support of decision-making and response both pre- and post-earthquake.

Motivating Scenarios

This section describes a few motivating scenarios in which we have summarized the user needs, current process, and areas for improvement. These scenarios were developed through the breakout sessions and are intended to be illustrative and not exhaustive.

Scenario 1: Infrastructure Operator, Bureau of Reclamation

Infrastructure operators have large GIS holdings that map out their systems. These can be used in combination with georeferenced data products to draw attention to potential damage or danger following an earthquake.

Current Process

The Bureau of Reclamation operates a number of dams, reservoirs, and conveyances in the California Central Valley. In the event of an earthquake, their current, stand alone, GIS system takes a magnitude and epicenter and produces a call list of dams to check up on.

Areas for Improvement

There are many possibilities for improving the current system. These fall into three categories: automation, modeling, and improved infrastructure integration. Automation of the process would allow the alerts and event information from the USGS to kickoff processing in the system. This information would include parameters that allow modeling of the event that takes into account known faults and geology. The resulting model runs would be more accurate in predicting the forces experienced by infrastructure on the ground. In order for the higher quality model data to be useful, more detailed infrastructure information is needed. The resulting system would provide more extensive and targeted information to operators. This would ultimate save time and better focus response and recovery efforts.

Scenario 2: Synoptic Information for Operations

The first need after an earthquake or other wide scale disaster is to establish a coherent picture of the disaster scope at the Regional or State Operations Center (ReOC or SOC). After the initial scope is established, the Operations Centers must maintain situational awareness as they plan response and mitigation efforts.

Current Process

Current processes focus on paper maps and the aggregation of verbal reports. Images from commanded over-flights and some small amount for commercial satellite imagery are used for situational awareness.

Areas for Improvement

There is a need for a one-stop-shop or aggregator for NASA remote sensing products. It is difficult to find particular data for a given disaster scope and Operations Center personnel do not have time or bandwidth to scour the Internet for data.

Scenario 3: Maps and Information in the Field

Geologists, infrastructure operators, and other responders who deploy into the field require up to date situational information about damage, ground deformation, potential inundation, and other secondary hazards. This information must be delivered in a timely way and updated as needed.

Current Process

Responders or workers in the field following an earthquake work off of printed maps and use hand held GPS to navigate and locate points of interest. These maps are, of course, static and cannot reflect new information data products or the inputs of others on the ground.

Areas for Improvement

Given the ubiquity of mobile computing platforms and mobile networks, information products and be delivered directly to those on the ground. In the event of a significant earthquake that causes widespread damage, the availability of bandwidth will vary significantly. Mobile information products must be available at a variety of detail levels from low-bandwidth summaries to highly detailed maps. Delivery of this information should be tailored to the consumer and connectivity situation.

Scenario 4: Real Time Forecast Maps of Likely Aftershock Locations

Emergency responders need to have some idea where major aftershocks are likely to occur in real time, so that rescue and response efforts can be prioritized in real time. Partially collapsed or weakened buildings need to be evacuated if lives are to be saved and injuries prevented. It would be very helpful to know which buildings are most at risk from near-future events.

Of particular interest is the development of criteria to estimate the probability of larger magnitude aftershocks, that is to say, what is the probability that a particular earthquake was a foreshock to a larger event. Following an earthquake, regions that are determined to be at risk of a larger magnitude event (aka, after a $m=5$ earthquake near a region showing significant $m=7$ hazard) would be watched very closely and would initiate cautionary measures.

Current Process

At the moment there is no real time aftershock forecast available, so responders target buildings and rescue operations based on accessibility, real-time calls for assistance, or other real-time information. In addition, the public and bystanders often play an important role in helping to evacuate injured citizens, relaying information about damaged structures, and other critical data needed for rapid action.

Areas for Improvement

Existing, ETAS based, aftershock seismicity models, properly implemented and delivered to the field in a timely fashion, show promise for emergency response applications. Real time computation of likely aftershock locations can play an important new role in helping to organize rescue efforts and emergency response. These maps would presumably be computed on the back end server, then relayed via mobile apps to responders in the field and to those organizing the response efforts. Technology developed for scenario #3 would be important and useful. However, there also needs to be development of rapid forecast computations involving downloading real time earthquake data, combined with previous catalog data, and rapid computation of forecast locations.

Robustness under emergency response conditions is also a consideration. In the event of a significant earthquake that causes widespread damage, the availability of bandwidth, and other information technology resources, will vary significantly. Mobile information products must be available at a variety of detail levels from low-bandwidth summaries to highly detailed maps. Delivery of this information should be tailored to the consumer and connectivity situation.

Clearly, further development of ETAS based and other seismic forecasting methods will improve the availability of useful information to disaster response planners and emergency responders. The models currently being developed under this project show promise to significantly improve our capabilities with respect to the objectives outlined in this scenario.

Scenario 5: Enhanced, Integrated Geospatial Information Services

A common need identified by many agencies at the workshop was for enhanced, integrated GIS services. Important capabilities include

- The availability of HAZUS-MH information as online layers in standard formats;
- The ability to integrate multiple GIS sources into a single service;
- GIS capabilities that were equally compatible with online tools (particularly tablets and smart phones) and desktop tools.
- The ability to collect and share user input.
- The ability of the online services to grow elastically to accommodate peak usage following an emergency.

Current Process

Currently these tools are not available. However, the basic capabilities are can be built using open source, Open Geospatial Consortium compliant software.

Areas of Improvement

IU members of the E-DECIDER team are working to address the bulleted list above, basing their GIS capabilities on open source GeoServer software. Currently available layers include UAVSAR imagery, UCERF 2.0 and CGS 1996 and 2002 earthquake fault catalogs, and imported HAZUS-MH layers. The IU team has made a proof of concept demonstration for integrating third party GIS services into the E-DECIDER GeoServer instance through OGC-compatible proxying. Finally, the IU team has extensively evaluated libraries and tools for building mobile application interfaces to its GeoServer instance using both Apple iPhone/iPad and Android-compatible devices.

Determining specific capability and operations requirements is the major area of improvement at this point. This will allow E-DECIDER developers to transform current proof-of-concept tools into production services.

Other areas of improvement include the integration of more tools and their outputs into the E-DECIDER GeoServer. These include providing the ability of earthquake researchers to publish their simulation results into GeoServer for sharing and to integrate GIS capabilities with image analysis tools.

Scenario 6: Post-earthquake deformation products

From the time of an earthquake disaster into the recovery phase regional and civic agencies must perform extensive inspection and maintenance of physical infrastructure, including water lines, gas lines, sewer lines, bridges, and dams. Some are sensitive to ground tilt, such as sewage. An overlapping set is vulnerable to strain (stretching and shearing), such as ceramic pipelines. A rapid model of the earthquake rupture can provide estimated maps of tilt and strain, enabling inspections to proceed in a rational priority order.

Current Process

Current estimates of vulnerabilities are based on seismic reports of earthquake epicenter and magnitude, any recordings of shaking, and the slow accumulation of clues in the field. Long-term tilt and strain are based on the slow process of taking surveys of the area. Maps of deformation-based vulnerability are not integrated with enhanced geospatial information services.

Areas of Improvement

When there is sufficient geodetic coverage near an urban earthquake disaster (as there is in much of California), the sudden deformation at geodetic stations (usually available within 36 hours and becoming more rapid over time) can be reliably inverted for a simple fault slip model using the QuakeSim Simplex tool. Such a model provides an immediate dense surface map of deformation, including maps of tilt and shear. Integration with GIS tools and resources provides a means for generating a priority inspection list for city and regional infrastructure, which is particularly vital for extended structures such as aqueducts, gas pipelines, bridges and sewage systems. Such a system can easily update the deformation tilt, and strain products as they change due to aftershocks and continuing fault slip, providing updates on the inspection and maintenance priorities.

Challenges in Current Processes

The current processes fall short in three main areas with respect to information products: availability, accessibility, and interpretability. Currently, obtaining synoptic data (optical, thermal, or radar) is difficult when your primary option is the use of aircraft. In many cases, the usefulness of static paper maps is limited by the lack of the ability to zoom, focus attention on current location, and show up to date situational awareness. In some cases, computer models like HAZUS runs based on initial shake-map can help in focusing attention on likely trouble spots. However, these simplistic models may encourage too much or improperly focused inspections of infrastructure. In addition, although these models are updated as more information is available, responders and emergency managers may not realize that updated model runs are available. In some cases, remote sensing data may be available, but emergency managers have difficulty finding, interpreting, and using them. The difficulty in using remote sensing data are due both to lack of familiarity as well as the fact the data is tailored to a specific scientific purpose which limits its usability.

Although there are methods for producing detailed hazard maps in the wake of a major earthquake, they are computationally intensive to produce. In particular, for real-time, user-defined applications (i.e. user defined spatial, temporal, and magnitude extents), detailed ETAS (and other) maps are impractical for single-processor back-end/web or mobile UI front-end applications. Smaller maps may be practical for real-time applications. A comprehensive solution will require defining a set of both user requirement and technical specifications.

Common Themes and Relevant Technologies

In addition to the themes of availability, accessibility, and interpretability mentioned above, mobility of data access was important. Many instruments collect both optical and thermal data are very important. This data needs to be collected in advance by cooperating agencies. Real time maps and data display will be critical to enabling many of the technologies described above, combined with twitter-like feeds of photos and real time information.

E-DECIDER can produce data products based on simulated as well as actual events; it is important to separate preparedness products from response products clearly. However, these simulated products allow us to meet the need of *creating consistent products in order to encourage use by emergency managers*. ***Products must be accurate, known, trusted, familiar, stable, and standard.***

Mobile solutions are needed to support those on the ground. However, in an emergency situation, the availability of bandwidth varies dramatically from excellent coverage to zero. Product development needs to keep in mind this spectrum in order to create static and low bandwidth products in addition to high-resolution frequent updated projects.

Vision

E-DECIDER will deliver earthquake scenario and response products and web services through our website at http://e-decider.org and engage end users through earthquake preparedness exercises like the Great ShakeOut and Golden Guardian. We will also host additional end user workshops to assess our product offerings.

We envision that E-DECIDER will embody an end-to-end process where the announcement of an earthquake event triggers a suite of tools that generate the following products:

- Fault Model
- Ground Deformation Simulation
- Tilt and Gradient Maps

- Aftershock Forecasts
- HAZUS Model Inputs Based on the Event
- Optical and InSAR Based Change Detection Products

These products will be produce following the event and will be updated as new information and data becomes available. These data products will be distributed via three main channels. First, all products will be posted to the E-DECIDER web portal. Products will also be available via the mobile web application. Finally, products will be announced via the UICDS middleware for emergency management.

These distribution methods will provide a synoptic overview of the hazards and damage caused by the event. All products will be available as GIS layers to allow end-users to analyze them with their preferred tools. These layers will also be downloadable as KML snapshots so that they can be used in an offline mode. Products distributed via UICDS are available for experts to annotate in order to focus the attention of responders or recovery personnel.

Conclusions and Recommendations

Scientists and engineers must continually improve visualization and value added information products to have immediate utility for emergency management, disaster response, and recovery. In addition to improving products in cooperation with end users, data providers must share their products in a consistent format via easily accessible channels (web portal, UICDS, etc.)

There were a number of issues revealed both in data availability and the data product quality. Data availability suffers from a number of known issues. Most data products have high latencies. This is due to a number of factors including commanding satellite data acquisition, waiting for downlink of data, processing of initial data products, creation of information products for response, and, finally, delivery of the information products to the end user. These factors need to be addressed and mitigated, but it is important to manage expectations. In addition, data can be difficult to find, there is limited support for search over all NASA imagery based on acquisition time and location, there is no central location in which to find data, and many data sources are restricted access. Data quality is impacted by the lack of a standardized geo-referencing and registration across data providers, the lack of automated data quality filters, and the use of lossy compression algorithms such as JPEG. The development of a centralized system to automatically deliver relevant data is key to solving data accessibility and quality issues.

There is a need for better access and support for the use of mobile devices. Products developed for emergency management and response should be available on mobile devices. Responding to natural disasters requires mobility; however, many mobile applications are dependent on high-bandwidth connections. Information product providers need to deliver data in mobile packages and on mobile devices with apps that support a variety of bandwidth environments. The use of Twitter, RSS, or UICDS feeds would allow low bandwidth notification of the availability of new data.

This workshop embodies a community call to action. While there are clear applications for Earth science and remote sensing data in earthquake emergency response, there are a number of issues that the community can address improve the use of this resource. Within NASA and other agencies that provide data products, we need better coordination of both analysis efforts and the distribution of data products that cover regions affected by earthquakes or other natural disasters. A crucial part of this coordination is an agreement on standards for data products and distribution methods that are compatible with the state of the art technologies employed by emergency managers, responders, and recovery personnel.

Appendix A – Attendees

Invitee	Affiliation
Bob Anderson	Alfred E. Alquist Seismic Safety Commission
Mark Gallo	INCOSE Los Angeles
Shubharoop Ghosh	Image Cat, Inc.
Swapan Nag	Nag, Inc.
Chuck Real	California Geological Survey
Anne Rosinski	California Earthquake Clearinghouse
Shirley Tseng	Tseng, LLC
Matthew Vaughan	Nag, Inc.
Mary D Williams	USBR
Thomas Heinzer	USBR
Ken Hudnut	USGS
Gerald Bawden	USGS
Marlon Pierce	Indiana University
Michael Sachs	UCD
John Rundle	UCD
Yehuda Bock	UCSD
Lucien Cox	NASA
Sue Owen	JPL
Sang-Ho Yun	JPL
Jay Parker	JPL
Karen Yuen	JPL
Scott Hensley	JPL
Mike Burl	JPL
Andrea Donnellan	JPL
Tim Stough	JPL
Maggi Glasscoe	JPL