NASA's E-DECIDER Platform plays a crucial role in responding to the devastating M7.8 Nepal Earthquake

The 25 April 2015 M7.8 Gorkha Nepal earthquake was one of the first global disasters for which NASA responded with an agency-wide effort that included multiple NASA centers, as well as academic, commercial, and other government agency partners. This disaster provided an opportunity for NASA and its partners to gain a number of valuable insights, and as part of this effort, the E-DECIDER team contributed a number of actionable products, provided leadership in the Damage and Vulnerability Maps Subgroup, and facilitated coordination between NASA subgroups and end-user partners.

E-DECIDER products

The E-DECIDER team, as participants of the Damage and Vulnerability Maps Subgroup, mobilized to produce a number of products in the days and weeks following the Gorkha earthquake. The team generated building exposure maps that helped to identify affected populations and provide a key database for damage and casualty calculations; damage maps that were used for estimating building rebuilding costs for World Bank and shelter needs; casualty maps that were used to estimate response needs for hospitalization and medical supplies; and aftershock forecasts estimating future hazard potential after the main shock, which are useful in quantifying the future damage and risk from the main event.

Damage, vulnerability, fatality, and rebuilding cost estimates

As part of the joint NASA/JPL response, ImageCat produced the following products in response to the Nepal Earthquake: 1) building damage maps that estimated the number of buildings by damage state/class (slight, moderate, extensive and complete); 2) number of fatalities based on the percentage of collapsed/destroyed structures; 3) number of displaced persons (estimated as the number of people living in structures that were extensively damaged or destroyed) that were not fatally injured; and 4) rebuilding costs estimated from number of buildings in each damage state/class, the average building size, and the average building cost per square meter for each building type. These estimates were provided in ranges on a 500 square meter grid. The estimated totals were:

- Extensively damaged or destroyed buildings: 225,000 to 450,000
- Fatalities: 9,000 to 22,000, with a mean estimate of 16,000.
- The total number of displaced persons: between 1 and 2 million.
- Rebuilding costs from building damage only (i.e., no infrastructure repairs are considered): between 2 and 3 billion USD.

> "The products that were produced by the joint ImageCat and NASA/JPL team, including the estimates of rebuilding costs, were helpful in scoping the magnitude of the disaster in the days following the earthquake and in setting up the Post Disaster Needs Assessment."
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> *Alana Simpson, World Bank*

This information was delivered to the World Bank on 20 May 2015, a little more than a month before the Government of Nepal released its Post Disaster Needs Assessment – see http://reliefweb.int/report/nepal/nepal-earthquake-2015-post-disaster-needs-assessment-executive-summary. This was one of the several loss products used by the World Bank to estimate rebuilding costs for Nepal from this devastating earthquake.

Aftershock forecasts

Recent efforts to mitigate losses, in both lives and property, have focused on *triggered* hazards due to earthquake disasters. In addition to more commonly recognized triggered hazards such as tsunami and landslides, aftershocks can contribute significant hazard in post-seismic environments. In recent years, aftershock forecasts (provided by a joint NASA, JPL, UC Davis, and ImageCat collaboration) have been provided for several simulated and real earthquake response scenarios, including the 2014 M6 Napa CA and 2015 M7.8 Gorkha Nepal events. Following the response to the Gorkha earthquake, in which an aftershock forecast provided on 7 May accurately predicted the locations of the large M7.3 and M6.3 aftershocks that occurred on 12 May, many groups in the disaster response community discussed 1) expanding the role of aftershock forecasts in earthquake disaster response scenarios, and 2) extending this tool by convolving it with ground motion prediction equations (GMPE) and other data sets. Of particular interest have been discussions of incorporating aftershock forecasts combined with topographical and geo-spatial infrastructure data sets to model and forecast landslide hazard.

The aftershock forecasts provided during the Nepal response were based on a novel ETAS formulation, developed as part of the E-DECIDER project that requires minimal parameterization or user input. ETAS forecasts, using this formulation, are published electronically for northern California, southern California, and the Cascadia region on an automated 24-hour cycle. In response to disasters such as the 2014 Napa and 2015 Nepal events, customized forecast forecasts, for the relevant geo-spatial extents and catalog lengths, are produced in a semi-automated fashion and provided to responders in KML, image, and simple raw data formats. Forecasts are distributed by email and via various modern data sharing technologies including Google Apps and DropBox.

> "In the days and weeks following the April 2015 Nepal earthquake, volumes of geospatial data were generated to assist with the recovery and rebuilding operations. The Damage and Vulnerability Maps Subgroup provided USAID's Office of Foreign Disaster Assistance and GeoCenter a forum to understand unique analytical products related to damage estimates and induced hazards. The Subgroup communicated updates to the products, limitations of the analysis and provided an information exchange on which organizations could benefit most from this work. The work and collaboration originating from this group has the potential to inform longer term disaster and resilience planning as the various participating agencies continue to integrate geospatial analysis into their disaster response and recovery efforts."
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> *Michael Crino*
> *GeoCenter Deputy Dir., USAID*

ETAS forecasts can be enhanced and extended by convolving them with GMPE and geospatial data sets. Landslide hazard, for example, can be measured by combing ETAS, GMPE, and topographical data sets – highlighting regions that are steep and where strong ground motions are expected. Access to these data can be improved by integrating ETAS with web-based infrastructure that include data service APIs and data convolution tools. An improved version of the current ETAS code, currently under development, will facilitate regular global aftershock (ETAS) forecasts and can be easily integrated into such a universal disaster response cyber-infrastructure.

End-user engagement

Following the M7.8 25 April Gorkha earthquake in Nepal, the NASA JPL and ImageCat team were contracted to develop and launch the Disaster Viewer Platform, which addressed a major challenge that had emerged for UNICEF after the earthquake – an overwhelming amount of data and imagery generated about the event. A work plan was developed within the first week of the effort that was focused on the immediate priorities of UNICEF and their response efforts. By working with UNICEF Nepal's Chief of Social and Economic Policy, the project team identified program areas to target for publishing data and maps through the Disaster Viewer Platform. For UNICEF, data that helped to assess impact on children and their vulnerability, locating displaced population, or provided information about migrating population were all critical information that were valuable for operations. A key task in the engagement with UNICEF was to identify information already available to various groups within UNICEF that could be merged with products developed from our team's effort. For example, available information on school and hospital data at the Village Development Committees (VDC) levels, were used to estimate damage to such facilities and calculate accessibility factors. UNICEF's demographic definition of children was used to estimate the proportion of children population affected due to ground shaking and landslides including the likely spatial distribution of such impacted children.

The engagement process involved close coordination and regular meetings with the UNICEF Nepal Task Lead and his team to discuss task progress and provide updates. The project team monitored each task closely and worked with UNICEF Nepal Task Lead to ensure the deliverables (portal and published information) met the criteria of acceptance for UNICEF. Our team solicited input to effectively vet and select data for use in the UNICEF Disaster Viewer.

> "NASA/JPL and the ImageCat team provided the UNICEF Nepal Social Policy and Economic Analyses (SPEA) Unit with useful and timely loss estimation and damage products that captured the impact on children and critical infrastructure after the Nepal earthquake. SPEA, NASA JPL, and ImageCat collaboration helped to effectively filter tremendous amounts of data and imagery that become available after the earthquake and put them in context for post-event analysis and decision making by UNICEF."
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> Amjad Rabi, UNICEF Nepal Country Office Social Policy Chief (April 2015)

We received feedback on organizing the data under the UNICEF priority areas on the disaster portal. For several days and weeks following the disaster, our team monitored major data initiatives to filter the most useful information and process various data layers to publish on the Disaster Viewer. This process resulted in organizing the data under four priority areas as identified by UNICEF Nepal personnel for this event: 1) Children and Risk, 2) Schools and Healthcare Facilities, 3) Shelter and Displaced Population, and 4) Rebuilding and Recovery.

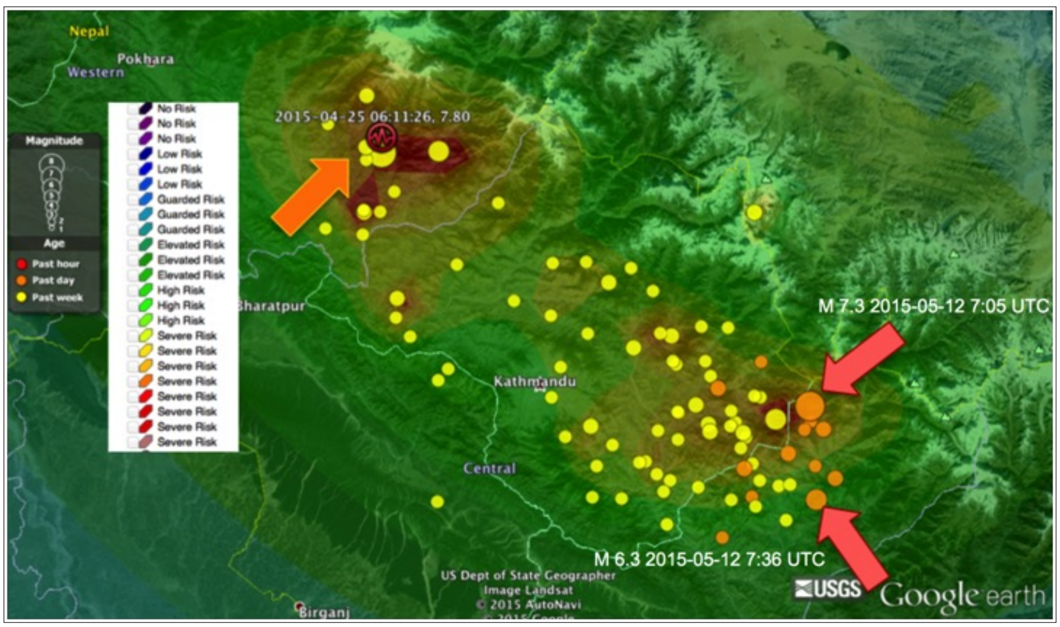
At the end of our project, we met with the UN Innovation Unit leader (UN Headquarters NY) to solicit feedback on the use of the open technologies and data to support the UNICEF efforts. The UN Innovation Unit provides support by connecting emerging technologies with needs of various UN organizations. Our activities were highlighted as one of the key components of the overall response efforts, particularly the mapping of damage and impacts to building and children. This resulted in further discussions, information sharing, and exchanging ideas with U-report activities, a major initiative for UNICEF for crowd-sourced reporting of social issues.

We also met with and presented our work to the UN Head of Policy Planning (UN Headquarters New York). One of the key tasks of the Policy Planning Head is to scan for innovative mapping technologies and promoting the use with UN organizations. One of the working papers from the NASA JPL activities was covered in an internal "reading list" under the "map of the week" section and was downloaded over 3,000 times.

FUTURE PLANS – Our Priorities

The E-DECIDER team remains engaged with our end-user partners and committed to supporting their disaster response and decision making efforts. Our priorities include:

1. Developing a sustainable plan to support on-going platform capability enhancements.
2. Pursuing international partnerships to support global disaster decision making.
3. Continuing to foster and support established partnerships with local, state, and federal agencies for disaster decision making.
4. Establishing a more systematic framework of integrating earthquake and other hazard monitoring, aftershock forecasts, damage estimation, remote sensing-based change detection, and a cloud-based GIS gateway, which would better support the stakeholder's disaster response and recovery efforts as earthquakes or other disasters unfold in real time.



The 25 April Gorkha earthquake mainshock is highlighted by the orange arrow. The 12 May aftershocks, east of Kathmandu, are highlighted by the two red arrows. Note that each falls in areas of increased aftershock risk in the 7 May ETAS forecast.

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