Rapid Post-Earthquake Information and Assessment Tools From the U.S. Geological Survey National Earthquake Information Center

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ABSTRACT

A suite of post-earthquake information products and assessment tools are produced and distributed by the U.S. Geological Survey (USGS) National Earthquake Information Center (NEIC). These products range from the rapid determination of earthquake magnitude and location to tools that provide situational awareness following earthquake catastrophes. The NEIC distributes earthquake location, magnitude, and supporting information through many sources including, text message, pager, and the Internet (e-mail, web-pages and RSS feeds). To aid in the rapid determination of an earthquake's impact, the NEIC has developed tools to 1) map the observed shaking intensity reported from the region affected by the earthquake (Community Internet Intensity Maps), and 2) quantify the number of people exposed to severe shaking (Prompt Assessment of Global Earthquakes for Response).

Keywords

Earthquakes, earthquake information, earthquake impact assessment.

INTRODUCTION

The US Geological Survey (USGS) National Earthquake Information Center (NEIC) provides rapid earthquake information on felt earthquakes in the U.S. and significant earthquakes worldwide to emergency response organizations, federal and state government agencies, the national and international scientific communities, news media, and the general public. The NEIC and its predecessors in the US Departments of the Interior and Commerce have been providing this information for the past 81 years. It is continually improving the quality, reliability, and timeliness of its products. Major recent improvements at the NEIC include 24X7 in-house staffing and a new system to detect and locate earthquakes. Over the past year, response times for significant global earthquakes have improved from about 2 hours to about 20 minutes.

The NEIC is a part of the larger Advanced National Seismic System (ANSS), a partnership between academic, governmental, industrial research institutions and seismic networks. In this paper, we focus on ANSS response oriented products produced in partnership with the NEIC. However, the reader is strongly encouraged to visit the ANSS website (http://earthquake.usgs.gov/anss/) for information on other useful earthquake products not covered here.

DISTRIBUTION OF EARTHQUAKE INFORMATION

Web-based content

The vast majority of NEIC's earthquake information is distributed through the USGS Earthquake Hazards Program webpages (http://earthquake.usgs.gov). The number of visits to the website after a significant earthquake can be enormous. In the week following the 2004 Sumatra earthquake and tsunami, 75 million webpage hits were recorded. The USGS earthquake pages contain the fundamental earthquake parameters of origin-time, location, and magnitude along with supporting maps and educational products. Additionally, a number of new information tools and applications are now available. A few of these tools are discussed in this paper, but since these and other applications are constantly changing and improving rapidly, please see the more up-to-date information at http://earthquake.usgs.gov.

The USGS web pages have recently been completely redesigned from the ground up, taking advantage of and implementing the latest Web tools, including database-driven (PHP/MySQL) content and construction which facilitates archival and search capabilities. Cascading Style Sheets (CSS) and Server Side Includes (SSI) allow for dynamic construction of pages and regional variations, yet preserve a level of uniformity and simplify maintenance. We emphasize Web-based delivery because it allows a suitable portal for map-based information and provides widespread access, redundancy, and bandwidth in the post-earthquake environment. To this end, the ANSS has multiple mirrored servers in geographically distributed locations and we commercially contract for the guaranteed bandwidth necessary for post-earthquake information needs.

For most users, the seismicity maps on the main entry page provide the starting point for earthquake information. Users typically select a specific region and "drill down" to more detailed maps and summary information about specific earthquakes. The *Recent Earthquakes* Web pages (http://earthquake.usgs.gov/recenteqs) provide general background as well as direct links to additional information and products. Maps of current earthquakes are available for the U.S. and the world; these pages are automatically updated by the regional network determining the location and magnitude, or the USGS as new events are located.

For earthquakes that are strongly felt, or that result in damage and casualties, we automatically create a special earthquake report. A link to that report appears on the front page of the USGS Earthquake Hazards Program homepage (http://earthquake.usgs.gov). The Earthquake News & Highlights section includes links to products that include consistent but customizable content, including geographical and tectonic summary maps of the region, aftershock probabilities and maps, earthquake fault models, hazard maps, and links to news and other event-specific information. Informative background summaries that put the event into a regional tectonic framework—called *Rapid Tectonic Summaries*—are now produced automatically in many areas of the country and the world.

Earthquake Notification Tools

Not all user needs are met using web page based delivery. Generally, people access the information on our website after learning about the quake on the news or actually being shaken by it. For many users, such as emergency responders, this is inadequate because they need to hear as quickly as possible of a potential catastrophe. To satisfy this need, the USGS distributes earthquake alerts from all ANSS participating seismic networks automatically in near real-time via text messages for email, cell phones, and pagers. These alerts are delivered in several formats including Common Alert Protocol (CAP).

Customized earthquake alerts are delivered by the USGS through a new service called the "Earthquake Notification Service" (ENS). Formerly, earthquake notification for earthquakes in the U.S. and world was made via email *List Servers*, which limited the range of possible notifications to simple pre-assigned regions and magnitude thresholds. Users who signed up to get *any* notifications, got *all* notifications, many of which were not of interest to the user.

To accommodate a variety of user needs, this has changed. ENS allows simple Web-based customization of the range of conditions under which automatic notification occurs (e.g., location, magnitude threshold, time of day, etc.). This system simply requires a fast database query for associating specific users with more detailed notification conditions each time an earthquake occurs. Only those users whose specific notification conditions are satisfied are alerted. For example, one could get alerts for earthquakes in a particular State, region, or country with any user-defined magnitude threshold. Separate day and nighttime thresholds can be set. Importantly, USGS also provides "aftershock filtering", which temporarily increases local alerting levels to a reasonable level after a mainshock, allowing users to see important events rather than getting overwhelmed with the myriad of small aftershocks.

Earthquake information is also being delivered through Really Simple Syndication (RSS). RSS delivery was pioneered by news services, Weblogs, and other online information services to send rapidly developing content to subscribers. After subscribing to an RSS feed, users can be notified when new content is available without having to manually visit the Web site. Typically, syndication services send out a headline or summary text with a link to the full story. The USGS basic earthquake RSS feed contains the magnitude, location, date/time, and a link to the full USGS report for each event. This content supports the Common Alert Protocol (CAP), a protocol supported and required by the Department of Homeland Security (DHS) for Government alert providers.

TOOLS FOR POST-EARTHQUAKE IMPACT ASSESSMENT

Community Internet Intensity Maps "did you feel it"

The USGS Community Internet Intensity Map, popularly referred to as "Did You Feel It?" (DYFI?) is an automatic Web-based system for rapidly generating seismic intensity maps based on shaking and damage reports collected from Internet users immediately following earthquakes (Wald, Quitoriano, and Dewey, 2005). These rapidly-produced intensity maps provide a rapid assessment of the extent of shaking and damage. For regions with sparse seismic station coverage these maps provide a stand-in for instrumentally derived maps of shaking. To date, we have received over ½ million individual entries in the US, and typically, well-felt earthquakes receive thousands to tens of thousands of reports. This density of reporting is unprecedented in macroseismic intensity collection, and provides for robust maps rather quickly (tens of minutes) after significant events. Entries often come in at a rate of several *per second* (up to about 10,000 *per hour*!) in the hour immediately following a widely felt event in a populated region. DYFI? is a unique opportunity for citizen-science; It is a two-way street for information, since citizens coming to the USGS for information become data providers themselves by contributing valuable observations that benefit the USGS as well as the observers and their local communities. DYFI? also provides an important human perspective on earthquakes, providing documentation of the way people behave and respond, and how they perceive risk (e.g., Celsi, Wolfinbarger, and Wald, 2006).

Until recently, the automatic mapping capability has been restricted to the United States and U.S. territories and commonwealths; intensity observations for U.S. regions are grouped, averaged, and plotted according to ZIP-code regions. We are now also using our system for international macroseismic data collection (Figure 1). For global maps, rather than ZIP code-based mapping (no ZIP code equivalent is uniformly available worldwide), we assign and color-code intensities to individual cities, averaging all responses within each reporting city. To date, felt reports have been received from over 156 countries after less than one year of operation, providing a total of over 14,000 individual responses in 2,400 cities (outside the U.S.). The worldwide DYFI? responses rapidly confirm earthquake occurrence and give a quick indication of the extent and the nature of shaking effects. Finally, these intensity data are also now automatically used as constraints in our global ShakeMap system, which, in turn, is the basic hazard input into our prototype Prompt Assessment of Global Earthquakes for Response (PAGER) system (see below).

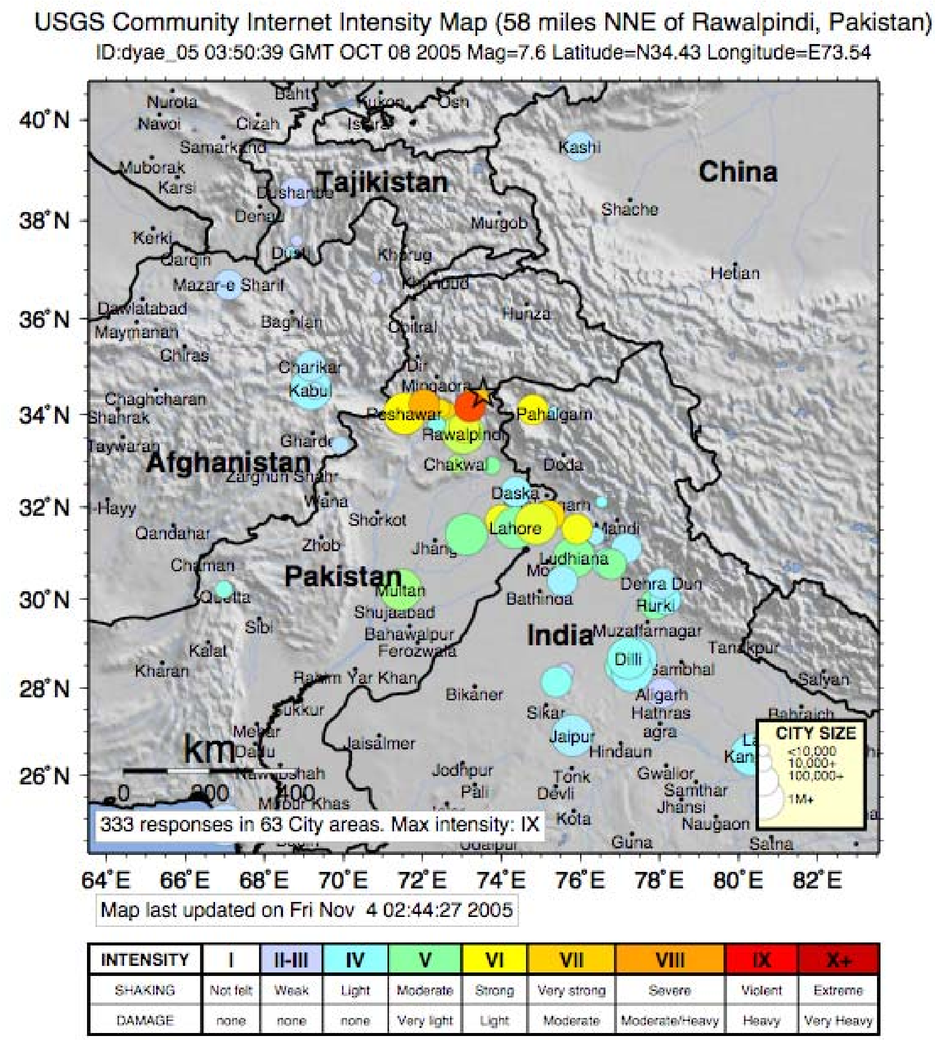


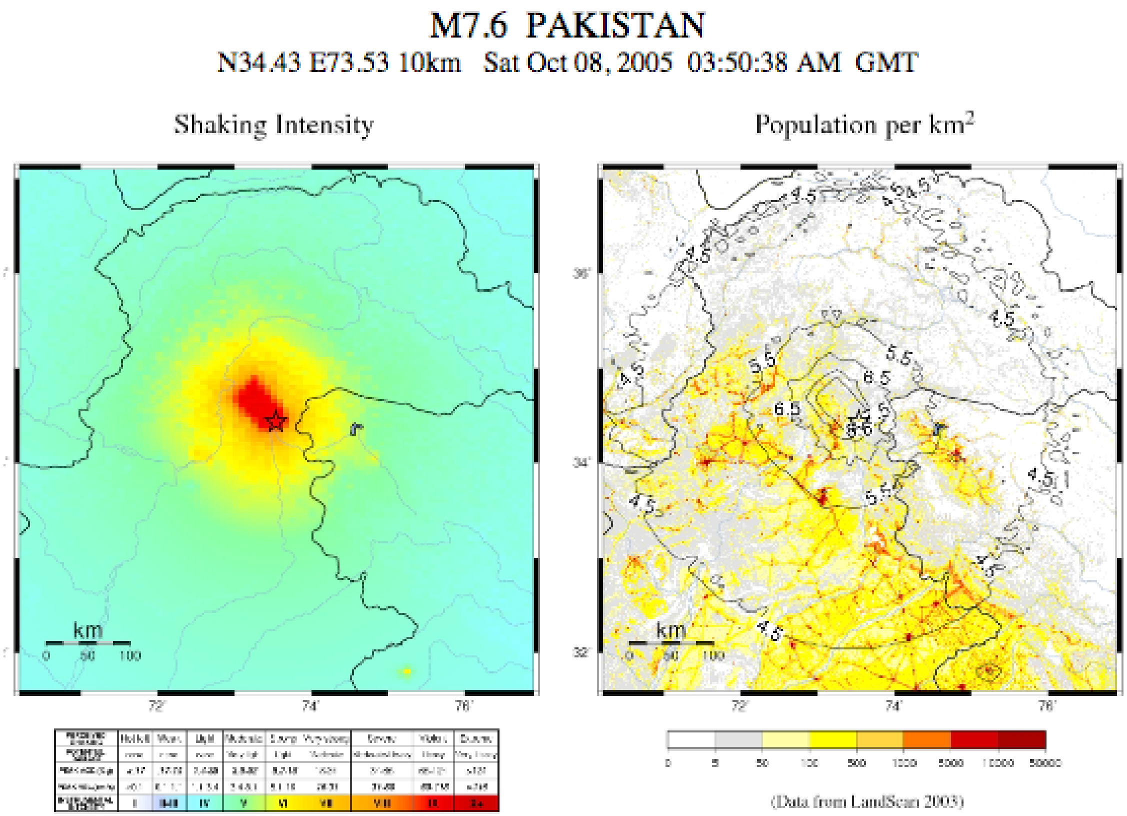
Figure 1. Sample DYFI? report for the October 8, 2005 M7.6 Pakistan earthquake, summarizing the estimated shaking intensity. The average shaking level reported for a city is indicated by color and the size of the symbol is propotional to the citie's population.

Prompt Assessment of Global Earthquakes for Response (PAGER).

The USGS NEIC is developing an automated system to estimate overall impact immediately following global earthquakes. The system called Prompt Assessment of Global Earthquakes for Response (PAGER), will provide important information to help emergency relief organizations, government agencies, and the media plan their response to earthquake disasters through alarms via pager, mobile phone, and e-mail (Earle and Wald, 2005). Other agencies are running and developing near realtime systems to estimate earthquake impact including: the World Agency Of Planetary Monitoring and Earthquake Risk Reduction (WAPMERR) (Wyss, 2004), The Russian

Ministry of Civil Defense, Emergencies, and the Elimination of the Consequences of Natural Disasters (EMERCOM) (Shakhramanjyan, et al., 2001), and the Joint Research Center of the European Commission (http://dma.jrc.it/Services/DSS/Earthquakes/earthquakes.asp).

Currently, the alarms report an estimate of the number of people exposed to varying levels of shaking (Figure 2) . Planned enhancements will provide both estimates of the likely range of casualties and losses as well as a measure of confidence in the system's impact assessment. Associated maps, including shaking distribution, population density, and susceptibility to landslides will be posted on the Internet and distributed as "Portable Document Format" (PDF) e-mail attachments.



Population exposed to shaking

MMI Intensity	Population
IX	525,000
VIII	827,000
VII	1,550,000

Figure 2. Sample PAGER System report for the October 8, 2005 M7.6 Pakistan earthquake, summarizing the estimated shaking intensity and population distribution and exposure. This update was provided within hours of the earthquake, well before the scope of the disaster.

The basic flow and processing of information through PAGER is straightforward. However, the implementation—the science behind the system, the gathering of the necessary data sets, testing, and calibration—requires significant system development. Conceptually, the PAGER system is best thought of as three parts: 1) Hazard Determination, in short, the distribution and intensity of ground shaking , 2) Loss Estimation, that is, the impact to the area effected by the earthquake, and 3) a Notification System for delivery and use of these hazard and loss estimates. These tools are being developed in an open, collaborative project that will integrate efforts from the external research community investigating source characterization and loss estimation, moving research studies into operational tools.

At the heart of the impact assessment system are the timely and accurate earthquake locations and magnitudes that the USGS has been producing for decades. PAGER uses these earthquake solutions to estimate the distribution of ground shaking for any earthquake, of magnitude 5.5 or larger, using the methodology and software developed for ShakeMap (Wald, Worden, Quitoriano, and Pankow 2005). Initially, a point source approximation (hypocenter and magnitude) is used to constrain region-specific empirical ground motion estimations and site amplification is approximated from the topographic gradient and elevation (Wald, Earle, and Quitoriano, 2004). Additional constraints for these predictive maps come primarily from three important sources, the availability of which varies depending on the region in which the earthquake occurred, as well as time after the earthquake occurrence. These constraints include: (1) additional earthquake source information, particularly fault rupture dimensions, (2) observed macroseismic intensities (provided via the USGS "Did You Feel It?" system, e.g., and (3) observed ground motions available from near-source strong ground motion stations, where and when available.

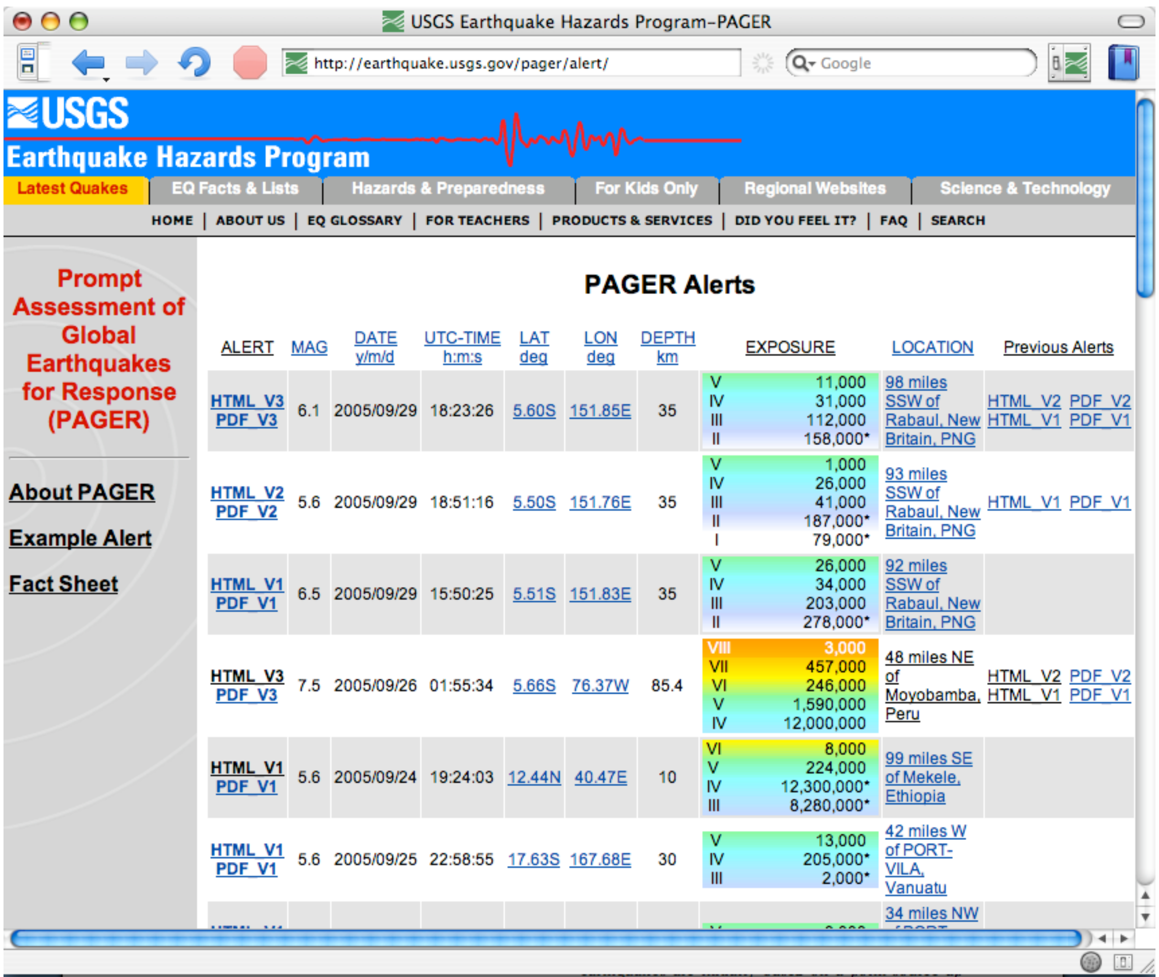


Figure 3. Example of the prototype USGS Prompt Assessment of Global Earthquakes for Response (PAGER) event page, showing recent earthquakes as well as links to short reports.

A prototype of the PAGER system is now operational and example Web pages are shown in Figures 2 and 3. Ongoing development is focused on quantifying both losses and their uncertainties on a global basis. These estimates are expected to be operational by the end of 2006.

SUMMARY

The USGS NEIC and the broader ANSS are offering and developing a wide array of products to help meet our users' needs for earthquake information and alerts. New products are focused on expanded content (webpages), customizable alert delivery (e.g., Earthquake Notification System), and tools to rapidly provide impact estimates for earthquakes worldwide (e.g., DYFI? and PAGER).

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REFERENCES

1. Celsi, R., M. Wolfinbarger, and D. J. Wald (2006). The Effects of Magnitude Anchoring, Earthquake Attenuation Estimation, Measure Complexity, Hubris, and Experience Inflation on Individuals' Perceptions of Felt Earthquake Experience and Perceptions of Earthquake Risk, *Earthquake Spectra* in press.
2. Earle, P. S., and D. J. Wald (2005). Helping Solve a Worldwide Problem— Rapidly Estimating the Impact of an Earthquake, *USGS Fact Sheet* 2005-3026, http://pubs.usgs.gov/fs/2005/3026/
3. Wyss M., Earthquake loss estimates in real-time begin to assist rescue teams, worldwide EOS, 85, 52, 565-567, 2004.
4. Shakhramanjyan,M.A.,G.M.Nigmetov,V.I.Larionov, A.V.Nikolaev,N.I.Frolova,S.P.Sushchev,and A.N.Ugarov (2001), Advanced procedures for risk assessment and management in Russia, Int. J. Risk Assess. Manage.,2(3/4),303–318.
5. Wald, D. J., P. S. Earle, and V. Quitoriano (2004). Topographic Slope as a Proxy for Seismic Site Correction and Amplification, *EOS. Trans. AGU*, 85(47), F1424.
6. Wald, D. J., B. Worden, V. Quitoriano, and K. Pankow (2005). ShakeMap Manual: Users Guide, Technical Manual, and Software Guide, USGS Techniques and Methods 12–A1, 128 pp., http://pubs.usgs.gov/tm/2005/12A01/
7. Wald, D. J., V. Quitoriano, and J.W. Dewey (2005). Did You Feel It?" Goes Global: Testing the USGS Community Internet Intensity Map Procedure for Non-U.S. Earthquakes, *Seism. Res. Lett.,* 76, 231.