



## USGS SHAKEMAP: AN UPDATE AND STATUS REPORT

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The U.S. Geological Survey's (USGS) ShakeMap system has been under development for more than a decade. What started as a practical means of visualizing earthquake ground motions has become an indispensable tool for emergency response, planning, loss-modeling, and public information. Over the years, we have greatly broadened the range of products ShakeMap creates and distributes, improved the quality of the ground motion interpolation, and developed formal uncertainties for all ground-motion parameters. As it has evolved, ShakeMap has become a standard post-earthquake information tool for the U.S. Advanced National Seismic System as well as for the USGS's analysis and reporting of global earthquakes through the National Earthquake Information Center. ShakeMap provides the fundamental inputs to the USGS's earthquake response tool – ShakeCast – and its signature post-earthquake loss-modeling tool, PAGER (Prompt Assessment of Global Earthquakes for Response). ShakeMap has also found broad acceptance within the international community, with systems deployed in Europe, Asia, South and Central America, the Pacific, and other regions.

In this presentation, we will discuss some of our more recent development work. We discuss new technical capabilities, new products, and some current directions of our development efforts.

Among the recent software developments in ShakeMap, we highlight:

1. The addition of new modules for Ground Motion Prediction Equations (GMPEs), Ground Motion/Intensity Conversion Equations (GMICEs), and Intensity Prediction Equations (IPEs). Among them:
  - a. **GMPEs:** ASB13 (Akkar et al., 2013), for Europe and the Middle East; Garcia05 (Garcia et al., 2005), for Mexico.
  - b. **GMICEs:** DC11\_CA, for California, and DC11\_ENA, for Eastern North America (Dangkua and Cramer, 2011); Caprio14, global (Caprio et al., submitted).
  - c. **IPEs:** TA12 (Allen et al., 2012); an update to AW07 (Atkinson and Wald, 2007), using a referenced empirical approach.
2. The systematic use of empirically derived conversions from various measures of horizontal motion (random component, arithmetic mean, geometric mean, etc.), and their uncertainties, to maximum component, via the relations of Beyer and Bommer (2006).
3. Progress on our ongoing efforts to internationalize ShakeMap:
  - a. Customizable date/time stamps, and flexible handling of time zones.
  - b. Configurable XML encoding of station lists.
  - c. Removal of text strings for maps and web pages into configurable files.
4. The symbols representing seismic stations on maps of peak ground motion and pseudo-spectral acceleration may now be color coded to intensity (derived by the operative GMICE from the stations' ground motion observations). See Figure 1, for example.

The macroseismic and seismic station color-coding (enumerated above) turns out to be particularly useful. Previously, ShakeMap station codes were color-keyed by the contributing seismic network. Now, based on the work of Worden et al. (2010), the symbology and color-coding for

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macroseismic observations and seismic station (circles and triangles, respectively) can be segregated and keyed to the correlative intensity color as provided by the GMICE employed for that ShakeMap (as configured and labeled beneath the scale bar). Figure 1 shows an example of employing both data sources. Because macroseismic data (circles) provide important constraints not only for near real time events but also for historical events, it is important to delineate these contributions so as to not confuse them with strong motion station data (triangles). Note that each datum type is weighted differently depending on which ground-motion measure is being interpolated (Worden et al., 2010).

The latest versions of ShakeMap also produce a variety of new products that are useful for emergency response, GIS, web mapping, loss modeling, and public information, including:

1. Grids of uncertainty values are available for all mapped ground motion parameters, including macroseismic intensity.
2. New contour files and formats have been added to the ShakeMap outputs:
  - a. Contours of intensity (MMI) have been added to those of other ground motion parameters.
  - b. All contours are now available in text, KML, and GeoJSON formats.
3. Ground motion parameters are available in ESRI raster (.fit) format.
4. The KML output (see Figure 2) has been enhanced in a number of ways:
  - a. Contours are available for all ground motion parameters (Figure 2)
  - b. The intensity overlay can be adjusted from fully opaque to fully transparent.
  - c. The ShakeMap legend and user organization’s logo are now configurable.
  - d. The nesting of the products has been flattened for easier incorporation of the Google Earth™ KMZ files into other products.
  - e. Seismic stations (and intensity observations) are now colored according to the observed intensity and the operative intensity scale legend (see Figure 1).

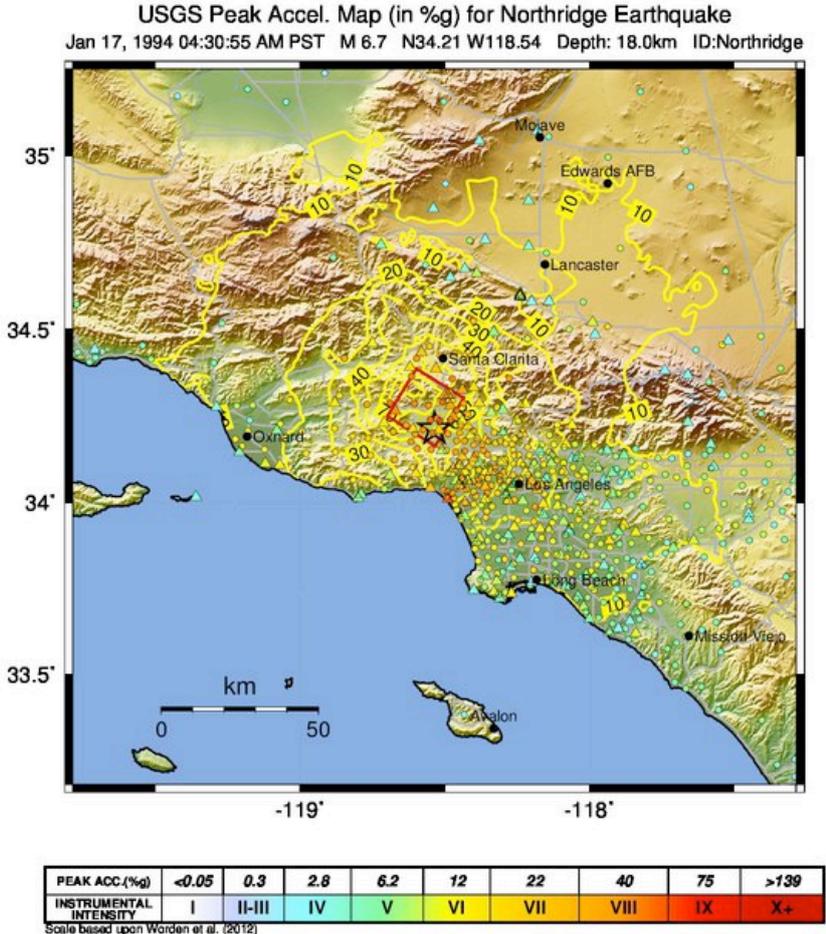


Figure 1. ShakeMap peak ground velocity map for the January 17, 1994 Northridge, California earthquake, showing intensity-colored seismic stations (triangles) and MMI observations (circles).

Finally, we will provide a glimpse of our current areas of development, including:

1. New, modernized ShakeMap web pages.
2. Incorporation of a new model of spatial correlation for intensity based on Worden et al. (in prep.)
3. A new, empirically derived model of site amplifications for intensity (Worden et al., in prep.)

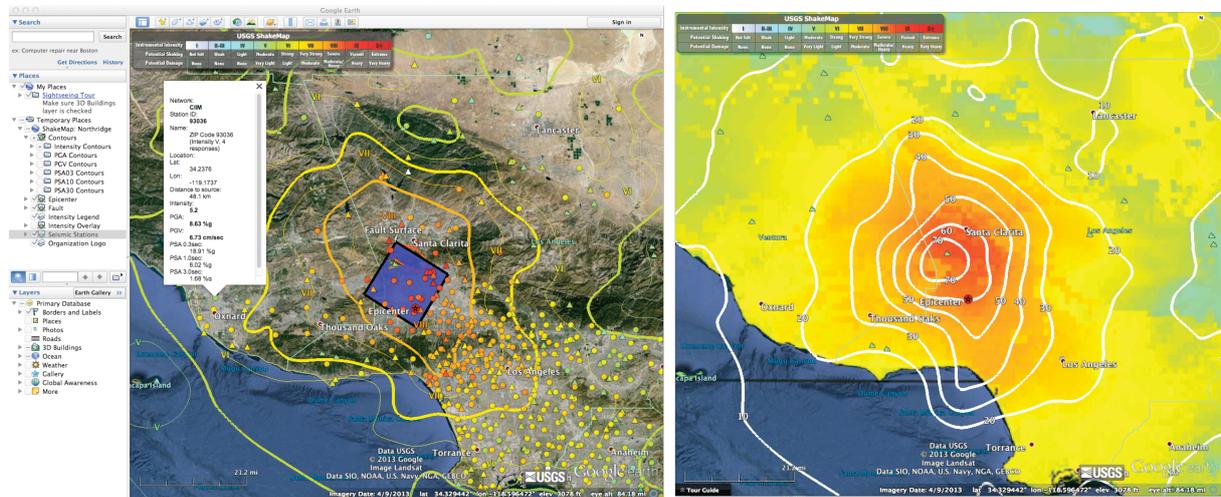


Figure 2. Google Earth™ images of ShakeMap KML for the January 17, 1994 Northridge, California earthquake. Left: Contours of MMI, the fault surface (blue square), seismic stations (triangles), and MMI observations (circles; observations from “Did You Feel It?”). Right: MMI overlay with contours of peak ground acceleration (PGA).

## ACKNOWLEDGEMENTS

Any mention of trade names or commercial products does not constitute their endorsement by the U.S. Government.

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