

ARS Online 2.0: Discussion of new features and updated source data

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Purpose

This report describes several enhancements to ARS Online that were executed in a single update referred to as ARS Online 2.0. These enhancements addressed the following needs:

- Implementation of a real-time deterministic spectrum calculation instead of reliance on precalculated results.
- Modification of the probabilistic spectrum calculation to be closely consistent (within 4%) with USGS hazard spectra over a broad spectrum of V_{S30} values.
- Update of earthquake source data to be consistent with recent USGS and CGS source models.
- Addition of administrative tools for website management and simplified uploading of earthquake source and hazard data.
- Improved user interface with regard to the presentation of results for multiple faults.

These needs, underlying issues, and the corresponding modifications to ARS Online 1.0 will be discussed in the next section. The update of the Caltrans Fault Database is discussed in a separate report by M. Merriam. Please refer to the July, 2009, document in ARS Online Technical References titled, "Caltrans ARS Online Report," for detailed discussion of the ARS Online tool and its application.

Modifications incorporated into ARS Online 2.0

Implementation of a real-time spectrum calculation

ARS Online 1.0, in its original implementation, relied on use of precalculated data for the determination of controlling spectral values for the deterministic spectrum calculation. Controlling values were calculated on a 2 km grid statewide using a separate code and saved to a data file. To determine the controlling spectral values at a given site location, data would be retrieved from the four nearest grid points and interpolation was then used to make the final controlling spectral value determination. There were several motivations for using this approach:

- It allowed the use of an existing code developed for the creation of the Caltrans PGA map. This code was already well validated and its reuse accelerated ARS Online development efforts.
- It minimized the amount of code required for the web application since the application only needed to look up precalculated values and perform a simple interpolation. This not only allowed ARS Online to run faster, but it also allowed for a cleaner division of coding labor since the web developer could focus primarily on the user interface and wasn't burdened by the ground motion calculation.
- Performing a real-time spectrum calculation was challenging since identification of the controlling faults at all periods required consideration of up to a hundred or more faults.

While this approach was successfully employed in the development of ARS Online, it suffered from a couple of important limitations. Since the precalculated spectral values only included values from controlling faults, it was impossible to provide results for other faults that may be of interest. A common complaint from users was the inability to examine spectra resulting from other non-controlling faults.

A second limitation was that while simple interpolation schemes could be employed to achieve "exact" results in the case of single, linear faults, interpolation schemes were less accurate when faults were curved or the site was close to multiple faults. In such cases, source to site distances could be in error by as much as 2 km. This potential for error led to the requirement that ARS Online users perform a hand check of distance measurements.

Rectifying these problems was a major motivation for the development of Version 2.0. A key breakthrough was the development of a reliable and fast routine for identifying potentially controlling faults. While it is easy to identify faults that are close to a site of interest, those faults often don't control the deterministic spectrum at long period. More commonly, long period spectral acceleration is controlled by more distant faults with the potential for large magnitude earthquakes. To account for this possibility, one would have to screen all faults within 150 km of a site. This might correspond to calculating response spectra for as many as 100 or more faults, greatly adding to the required computation time.

To avoid the need to calculate so many response spectra, a distance correction factor was developed that allows *modified distance* to be used as a factor to compare the relative impact of more distant faults. Modified distance is defined according to Equation 1:

$$\textit{modified distance} = R_{rup} * DMF \quad (1)$$

The *distance modification factor* (DMF) is given in Equation 2 and plotted in Figure 1 for three magnitudes.

$$DMF(M_w, R_{rup}) = 1 - \frac{(\text{Min}(\text{Max}(M_w, 6.5), 7.4) - 6.5)}{0.8} \quad (2)$$

$$* \frac{1}{0.8 + (\text{Min}(\text{Max}(R_{rup}, 10), 50) - 10) * 0.005}$$

In the Version 2.0 routine, the 10 faults with the shortest modified distance are combined with the 15 faults with the shortest unmodified distance. Full response spectra are calculated for each of these 25 faults and then sorted by spectral acceleration. Since multiple periods must be considered when sorting the spectral acceleration values, a weighting scheme is employed to determine the final composite ranking. The user can then select whether the top 3, 5, or 10 ranked faults are presented.

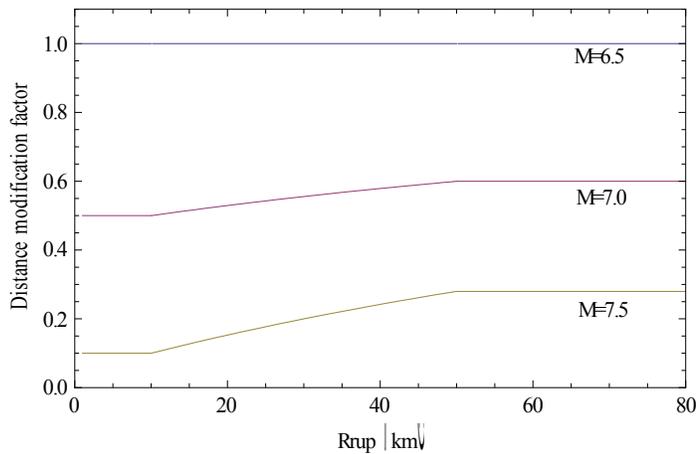


Figure 1: Distance modification factor (DMF) as a function of distance and magnitude

Modification to the Probabilistic Spectrum Calculation

The original implementation of ARS Online 1.0 makes use of 5% in 50 year hazard data provided by the USGS on a 0.05 degree grid. These spectral values (provided at 11 periods) are referenced to a soft rock site condition (i.e. $V_{S30} = 760$ m/s). To obtain spectral values for other site conditions (i.e. other V_{S30} 's) a soil amplification factor is applied to the soft rock referenced value. Shortly before the release of ARS Online 1.0, the USGS modified their online hazard tool so that it provides spectral values for a given hazard level *and* soil condition (parameterized by V_{S30}). These

results are based on a more advanced hazard calculation than the results supplied to Caltrans since the effect of soil amplification is incorporated directly into the hazard calculation. For stiff soil sites, the difference between ARS Online 1.0's approximate method and the more exact USGS procedure is small. However, as soil amplification effects become larger (because of softer soil), the differences become more significant (20% or more). Comparison studies found that for profiles with a V_{S30} of 300 m/s or larger the differences between the two procedures is acceptably small (less than 10%). However, for profiles with V_{S30} 's less than 300 m/s users were required to use the USGS web tool to calculate the probabilistic spectrum.

For ARS Online 2.0, spectral values with a 5% in 50 year annual probability of exceedence have been provided by USGS at a variety of V_{S30} values. This data is then used to interpolate results to any V_{S30} value greater than 150 m/s (the lower limit of ARS Online applicability). Interpolation between V_{S30} values is done based on an average of Campbell-Bozorgnia, Chiou-Youngs, and Boore-Atkinson soil amplification models. Comparison of the ARS Online 2.0 and USGS results show excellent agreement with differences generally less than 3 or 4 percent.

New Administrative Tools

An Administrative Tools feature was added to ARS Online 2.0 to minimize the effort and expertise required to upload fault data as well as modify Technical Reference links, file content, and start-up user message. Fault locations and associated metadata can be easily updated by uploading two Excel spreadsheet files. Probabilistic hazard data can also be updated through the uploading of several spreadsheet files. In the previous version of ARS Online updating fault information required a lengthy process of regenerating controlling spectral values at each grid point. ARS Online 2.0's move to a real-time calculation enabled the simple uploading of data files to implement changes. Figures 2 and 3 below are screen shots of the Administrative Tools interface.

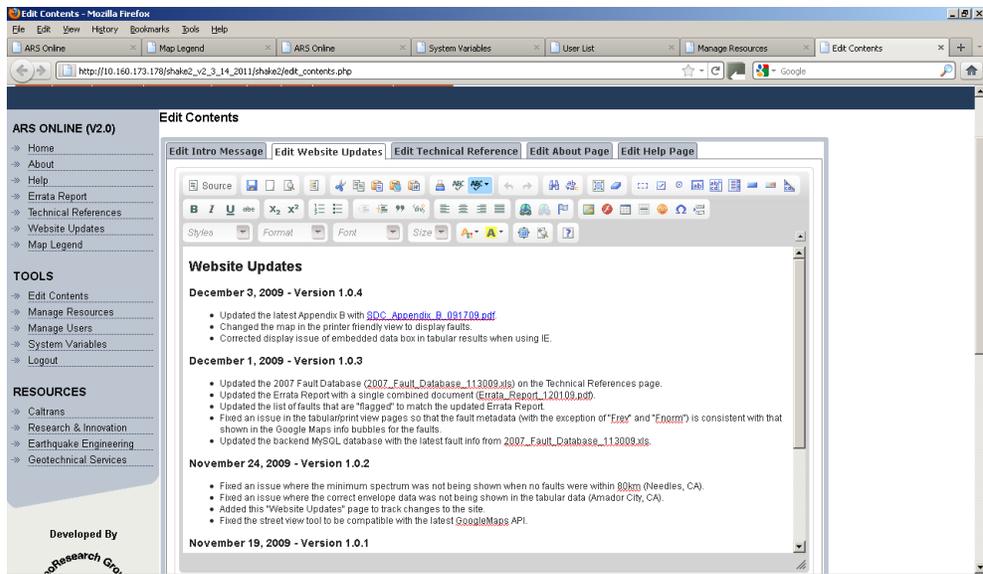


Figure 2: Screen shot of administrative tools used to edit on-screen messages and provide document links.

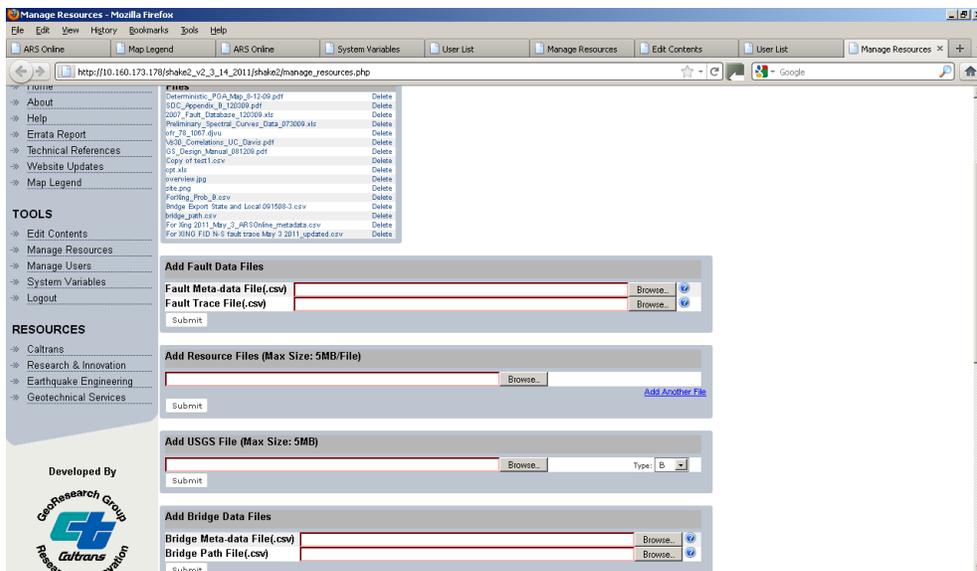


Figure 3: Screenshot of administrative tools used to update fault data and USGS hazard data

Interface Update

ARS Online 2.0 includes a couple of interface enhancements related to the presentation of results for multiple source faults. As shown in Figure 4 the user now has an option to select presentation of up to 10 deterministic spectra. The presented spectra are drawn from a list sorted from highest spectral values to

lowest. Thus, selecting 5 deterministic spectra gives the user the 5 highest deterministic spectra.

Using the Tabular Data command provides the calculated spectral values for each fault in tabular form that can be cut and pasted into report documents. (Figure 5) The user can also select results using a reduced set of spectral periods (19) or use a full set of periods (95) as in ARS Online 1.0.

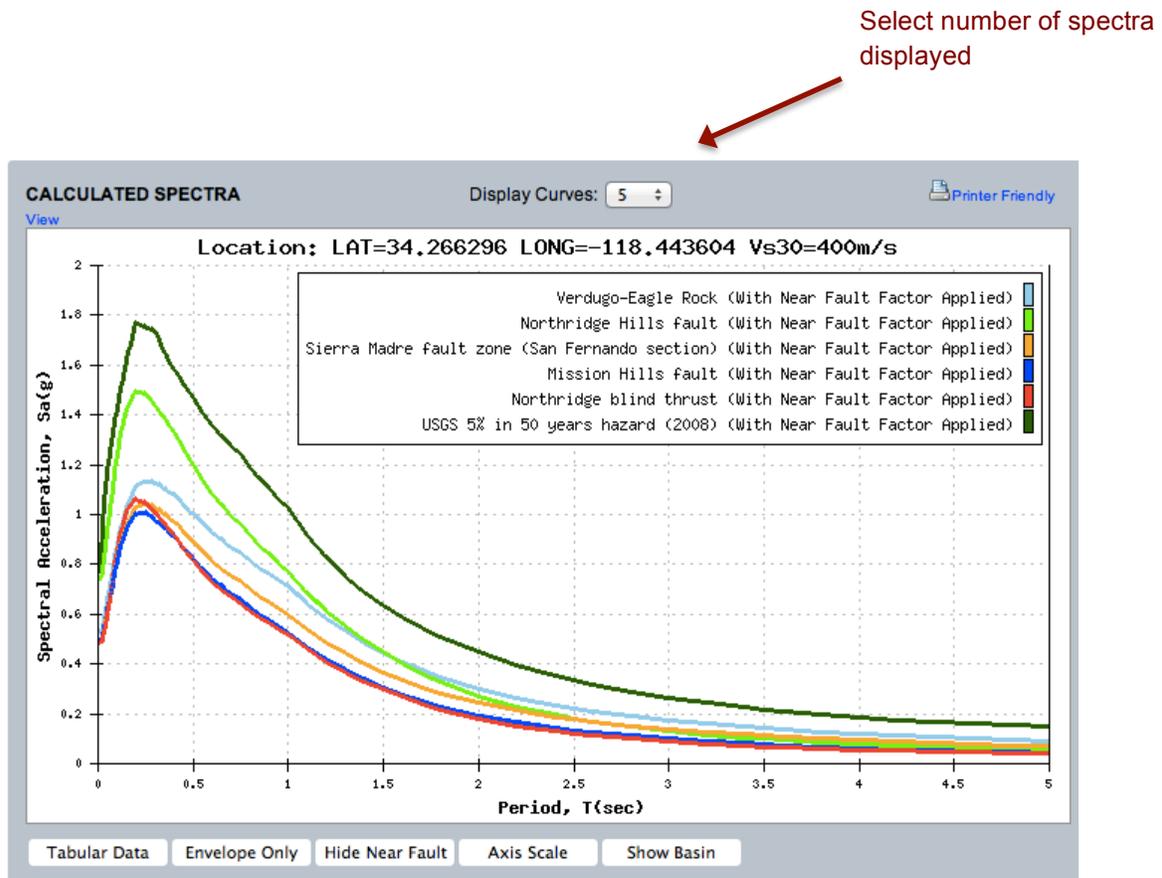
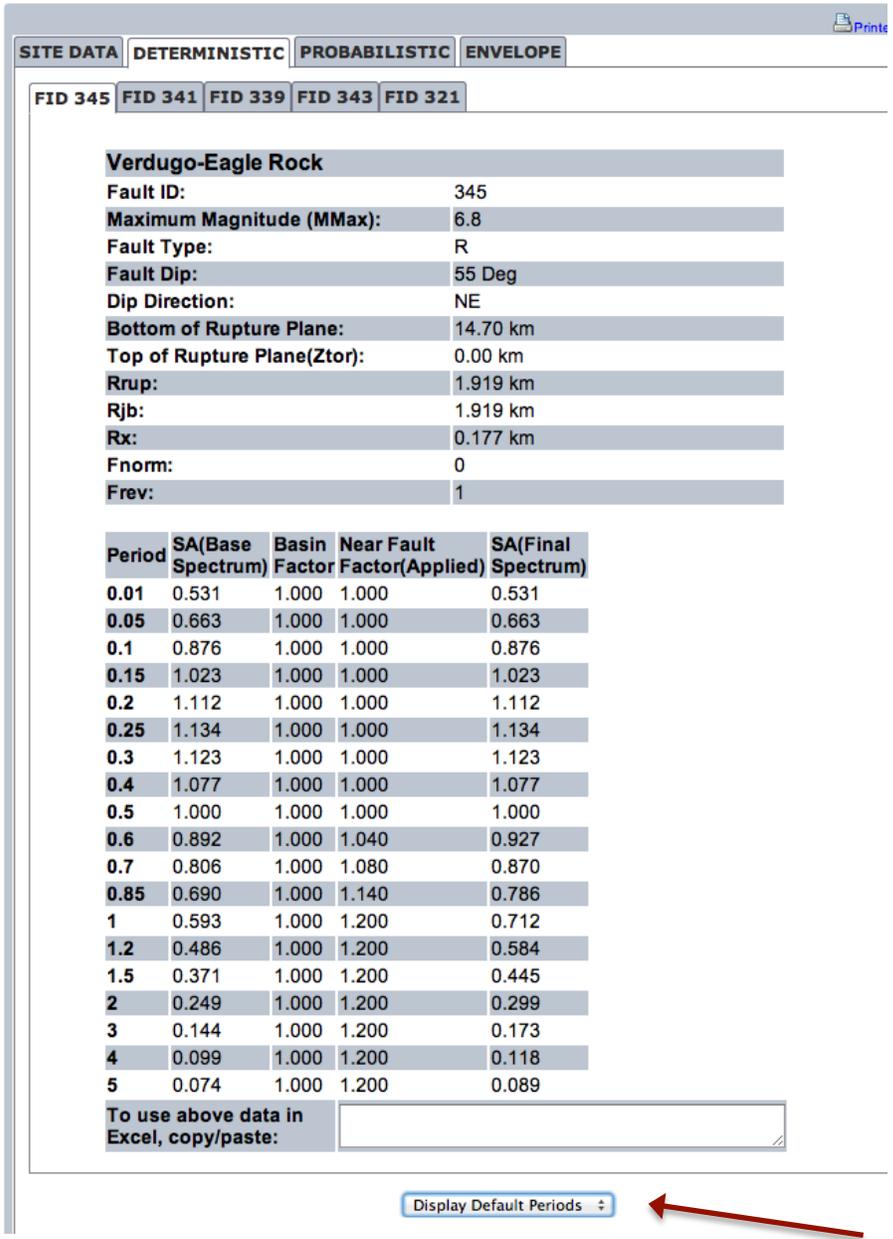


Figure 4: User can now select the number of deterministic spectra displayed (max 10). The spectra are selected in order of highest to lowest.



User can select either 19 or 95 spectral periods

Figure 5: Tabular results are provided for each deterministic spectrum.

Version Convention

Adoption of ARS Online 2.0 will also include use of a new version number convention of the form

$$x.y.zz$$

where x refers to the primary version number, y refers to the secondary version number, and zz refers to the source Caltrans Fault Database number. Primary

version numbers will increase when major modifications are made to the methodology such as updated ground motion prediction equations (GMPE's), availability of updated national hazard maps, changes to SDC, or comprehensive updates to source data. Secondary version numbers will increase when a change is made to the user interface or a bug is fixed. The Caltrans Fault Database number will increase each time a change is made to the source database. All previous versions of source databases will be archived for reference along with the date that the database version was superseded.