Directivity models produced for the Next Generation Attenuation-West 2 (NGA-West 2) project

Authors:

Rowshandel

Shahi and Baker

Somerville and Bayless

Spudich and Chiou

Watson-Lamprey

Physics/Principles of Directivity

- Caused by motion of the rupture front, causing amplitude increase and time contraction in forward direction.
- Ground motions are largest where the SH radiation pattern lobe (maximum in the direction of slip) aligns with the direction of rupture propagation and the site
- Directivity is stronger when the distance the rupture front travels is longer
- All sites experience some form of directivity.
- A correlated but separate phenomena is ground motion polarization, related to source radiation pattern.

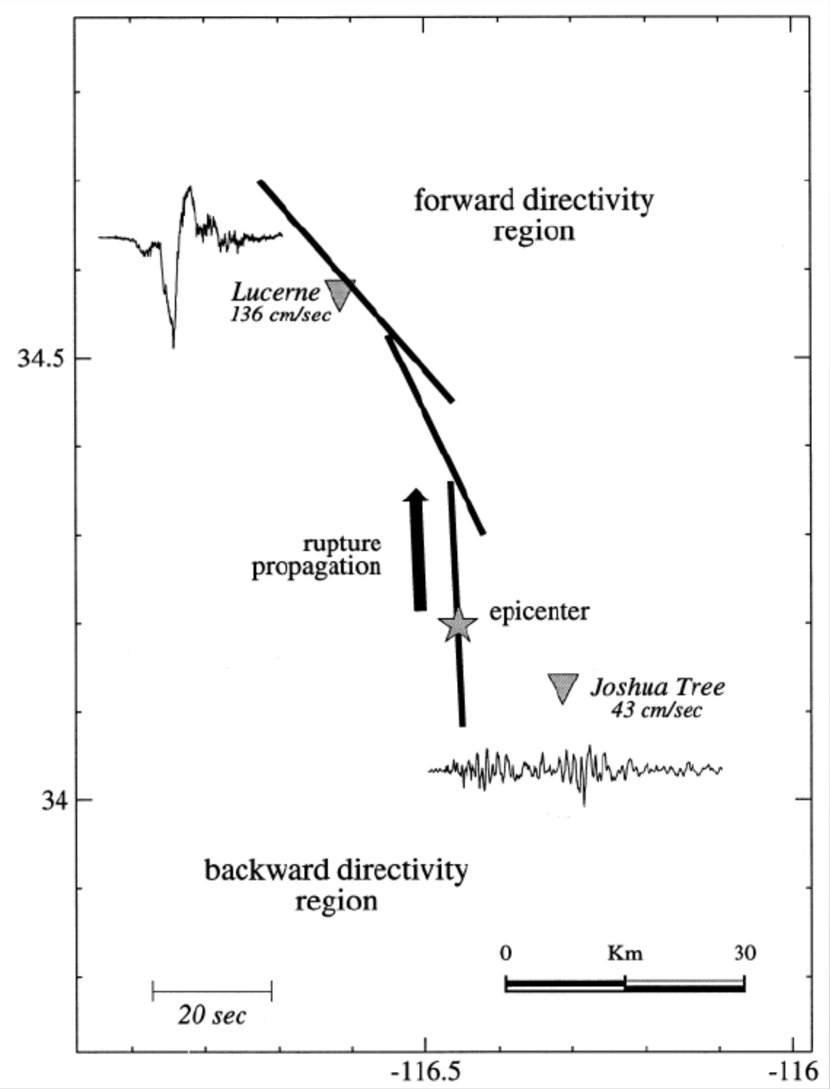


Illustration of directivity observed in the 1992 Landers earthquake. From Somerville et al. 1997

Goals of Directivity Working Group

- To develop directivity models which NGA-W2 developers can choose to include in their regressions, so that the directivity model is included *ab initio* in the resulting ground motion prediction equations, instead of after-the-fact corrections.

- Preliminary directivity models have been developed by most or all modelers based on sets of ground motion intra-event residuals, typically with respect to the NGA 2008 GMPEs

- To develop updated/new directivity models using a more current and expansive record set than previous versions

Brief Summary of the 5 Directivity Models

1) **Bayless & Somerville (bs12):**
   Update to the Somerville et al. (1997) model.
   Predictor based on fault-site geometry, magnitude. Broadband model.
2) **Rowshandel (row12):**
   Update to the Rowshandel (2010) model.
   Predictor computed based on the direction of rupture or the direction of slip, and is only dependent on the geometry of the fault and the location of the site. Broadband model.
3) **Shahi and Baker (sha12):**
   Update to the Shahi and Baker (2011) pulse probability model.
   Model uniquely simulates the probability of occurrence and the characteristics of a directivity pulse at a site. Coefficients independent of period. Narrowband model.
4) **Spudich and Chiou (sc3b):**
   Update to Spudich and Chiou (2008) model.
   Parameter IDP as defined in Spudich and Chiou (2008). Coefficients estimated by joint regression of combined data from all spectral periods Narrowband model.
5) **Watson-Lamprey:**
   New model.
   Theory is that most of the directivity amplification comes from the SH pulse, for which the radiation pattern (as seen at the site) is largest when rupture is near the hypocenter. Has narrowband characteristics.

Results and Observations

- An empirical attenuation relation without directivity effect (Sa) can be modified to obtain the spectral acceleration with directivity effects (Sa_{dir}) by the following equation:

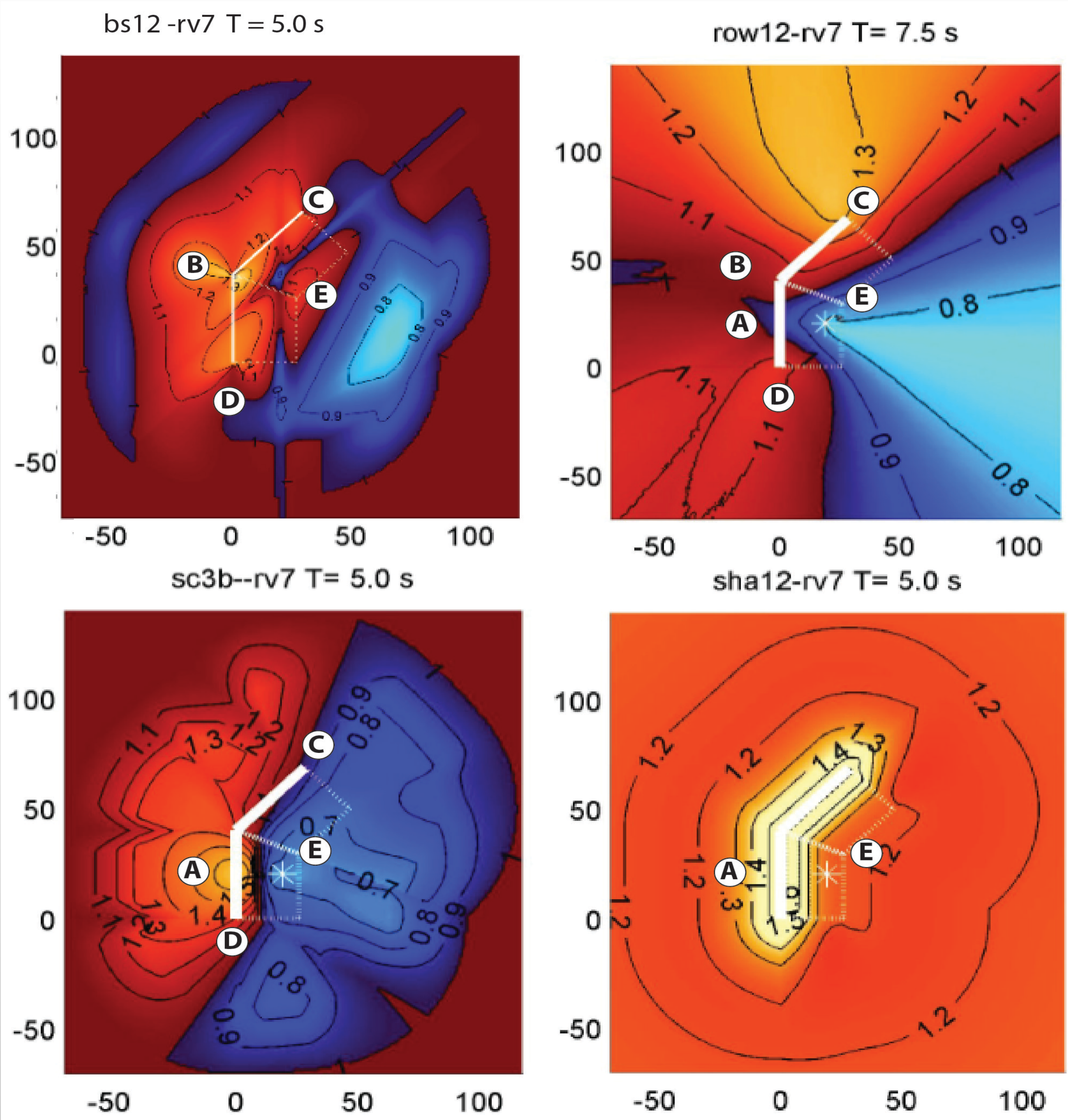
$$\ln(Sa_{dir}) = \ln(Sa) + f_D$$

Where f_D is the directivity effect.

- In the following plots we show the predicted quantity $exp(f_D)$ in which is the ground motion amplification factor. These plots are in map view with the fault plane itself shown in white solid (surface) and dashed (buried) lines.

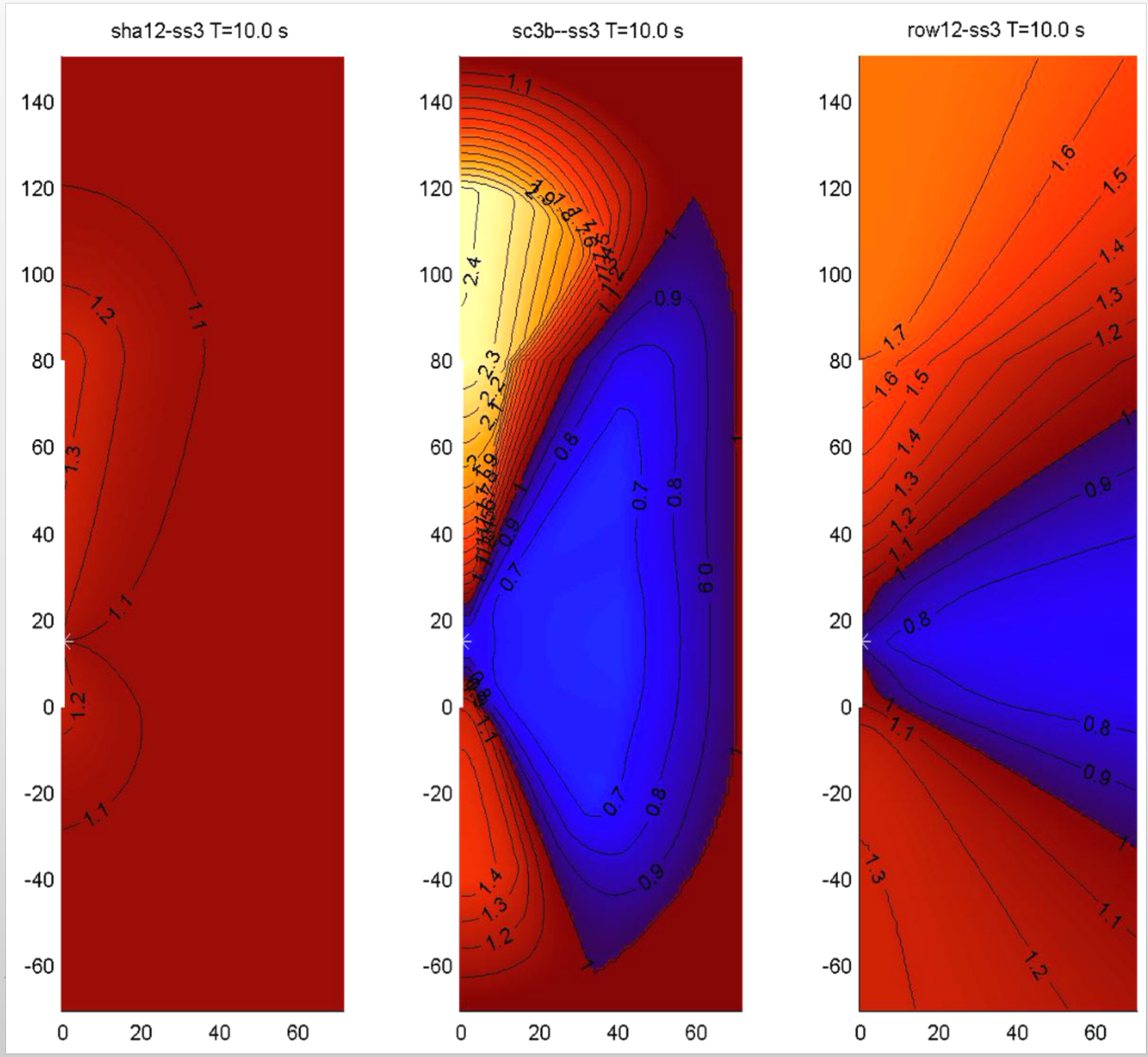
Example: Reverse Scenario

- Comparison of 4 directivity models for a multi-segment reverse fault having a 45° bend
- Observed: for reverse faults, the directivity models have a stronger effect on the predictions than do the data.
- All models except sha12 predict higher motions on the footwall than on the hanging wall.
- At certain points near the fault trace, the models give quite different predictions.



Example: Strike-Slip Scenario

- Comparison of 3 directivity models for a single-segment strike-slip fault, M7.2 (fault is vertical on maps, between 0-80km north, only eastern portion of map shown)
- Observed: models predict fairly similar patterns of directivity; this trend persists over many test rupture geometries
- Relation sha12 (left) keeps the directivity amplification concentrated close to the rupture. sc3b and row12 extend to further distances.



Conclusions

- Five teams derived improved directivity models by making conceptual advances as well as through empirical study of the expanded NGA-West2 data set. **Incorporation to the NGA-West2 GMPE's is in progress**.
- Among the conceptual advances was the adoption by some modelers of '**narrow-band**' directivity models.
- All models chose to **unnormalize fault dimension parameters**, because normalized fault dimensions caused nonphysical scaling of directivity for large magnitude events.
- Comparisons show that the **vertical strike slip rupture geometries are modeled similarly** by each directivity model, and there are many areas of agreement.
- For **reverse faults the predicted motions differ from each other** so much that it would be unwise to use just one directivity model to simulate motions at a specific site.