

Some comments on my program NGA08_GM_TMR.

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NGA08_GM_TMR evaluates four of the five PEER NGA ground-motion prediction equations (GMPEs) (not evaluated is Idriss's GMPE, because it does not include site response). The core of the computations uses Fortran code written by Ken Campbell; I have changed the input/output. The program uses a control file to specify the values of the input variables, including the magnitude, distance, and period. This is a more general way of generating output for plotting than special purpose programs that evaluate the GMPEs vs. distance or vs. magnitude. I find that a spreadsheet (nga08_gm_tmr_prepare_ctl.xls is provided) is useful in building the control file, as is a text editor that allows block operations (I use TextPad, available from <http://www.textpad.com/>). Here is a portion of a sample control file (from nga08_gm_tmr_zips.zip, which also contains the output file for this control file):

```
! Control file for program nga08_gm_tmr.for
! Revision of program involving a change in the control file on this date:
    09/09/10
!Header to add to output file (no "!" at beginning;
! "[blank]" means that no header is printed!)
[blank]
!name of path in which these coefficient files are stored:
!
!           AS08_COEFS.TXT
!           BA08_COEFS.TXT
!           CB08_COEFS.TXT
!           CY08_COEFS.TXT
! ** DO NOT FORGET CLOSING "\" IN PATH **
    C:\gm_predictions\nga08_files\
!name of path in which these coefficient files for rjb2rrup are stored:
!
!           rjb2rrup_gen_m_5_6.75.txt
!           rjb2rrup_gen_m_6.75_7.5.txt
!           rjb2rrup_shd_m_5_6.75.txt
!           rjb2rrup_shd_m_6.75_7.5.txt
!           rjb2rrup_ss_m_5_6.75.txt
!           rjb2rrup_ss_m_6.75_7.5.txt
! ** DO NOT FORGET CLOSING "\" IN PATH **
    C:\gm_predictions\nga08_files\
!name of output file:
    hanging_wall_example_m7_vs30_760.out
!   foot_wall_example_m7_vs30_760.out
!   ab10_fig07_example_m4_t0.3_1.0_vs_r.out
!PSA, PGA values in cm/s/s (gals)? (Y,N):
! Note: N = units in g:
    Y
! available periods for BA08:  -1.0 0.0 0.01 0.02 0.03 0.05 0.075 0.1 0.15 0.2
0.25 0.3 0.4 0.5 0.75 1 1.5 2 3 4 5 7.5 10
! force the program to derive Ztor from RHyp and Wells and Coppersmith W by
setting Ztor<0.0
! If dip < 0, the program uses generic values of 90 for SS, 55 for N, 40 for r
(after CY08)
! abs(rake) > 180.0 will result in motion for an undefined fault type for BA08
and null values for the other GMPEs
```

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! Note: Fhw=1 for hw; Rjb, Rrup, Rx, Zhyp, Ztor in km; Vs30 in m/s; Zsed1.0,
Zsed2.5 in m (CB use km for Zsed2.5, but the NGA flatfile uses m).
!
! Undefined values (values will be assigned, unless pairs of values are
! inconsistent, as noted below):
!           Fhw < 0;
!           abs(az)>180;
!           rrup<0;
!           zhyp<0;
!           dip<0; w<0;
!           ztor<0;
!           Zsed1p0as08<0;
!           Zsed2p5<0
!
! Inconsistent values (program will stop):
!           Fhw < 0.0 .and. abs(az) > 180.0;
!           Fhw == 0.0 .and. 0<=az<=180;
!           Fhw == 1.0 .and. -180<az<0
!
!           Rx is computed from provided information, rather than being an input
parameter.
!
! Minimum required input parameters:
!
!           T
!           M
!           Rjb
!           Fhw or az
!           rake (0.0, 90.0, -90.0 for SS, RS, NS)
!           Vs30
!
!hanging wall example
!T      M      Fhw      Az  Rjb(km) Rrup(km) Zhyp(km) rake Dip W(km) Ztor(km)
V30(m/s) Zsed1p0(m) Zsed2p5(m) as(1=aftershock)
0.010  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.020  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.022  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.025  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.029  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.030  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.032  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.035  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.036  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.040  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.042  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.044  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.045  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0
0.046  7      +1      +90  0      -1      5.00  90    -1    -1    -1    760
      -1.0  -1.0  0

```

```

0.048 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.050 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.055 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.060 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.065 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.067 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.070 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.075 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.080 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.085 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.090 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.095 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.100 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
0.110 7      +1      +90    0      -1      5.00  90      -1      -1      -1      760
      -1.0    -1.0    0
Stop

```

Unfortunately, the input lines are wrapped in the above segment---see the actual control file for the unwrapped version (and ignore everything below the “Stop” line in the control file). The meaning of some of the input is discussed below, when describing the sample input and output.

Assigning unspecified variables

Note that values of -1 have been specified for some of the input variables. In many applications some or all of these variables will not be known or easy to estimate. For the convenience of the user, the program assigns values to these missing variables. A complete discussion of the algorithms used to assign the variables is given in Kaklamanos et al. (2010). In addition, see the control file and the discussion of the sample cases (given below) for some details.

Note added 3/16/2012: For depth to bedrock, the various developers say this:

AS08:

SOIL DEPTH EFFECTS The ground-motion model includes the depth to $V_s=1.0$ km/ s $Z_{1.0}$ based on the analytical site response models. If this depth is not known, then the median $Z_{1.0}$ should be used based on Eq. 8 [I think this is a typo; it should be Eq. 17]. The standard deviation was derived without $Z_{1.0}$. Therefore, the standard deviation is applicable to the case in which $Z_{1.0}$

is not known. The intra-event standard deviation could be reduced if the $Z_{1.0}$ is known. At this time, we recommend using the standard deviations as listed in Table 4 until improved $Z_{1.0}$ values are available for the strong-motion sites.

$$\ln(\dot{Z}_{1.0}(V_{S30})) = \begin{cases} 6.745 & \text{for } V_{S30} < 180 \text{ m/s} \\ 6.745 - 1.35 \ln\left(\frac{V_{S30}}{180}\right) & \text{for } 180 \leq V_{S30} \leq 500 \text{ m/s} \\ 5.394 - 4.48 \ln\left(\frac{V_{S30}}{500}\right) & \text{for } V_{S30} > 500 \text{ m/s} \end{cases} \quad (17)$$

Interpolation of spectral values for periods not corresponding to the tabulated coefficients

The program uses straight-line interpolation of $\ln PSA$ vs. $\ln T$. Here are two graphs showing a comparison of the PSA and sigma values from an older version of NGA_GM_TMR (for which the periods were required to be the tabulated periods) and given in the distributed version of the program. These graphs confirm that the interpolation is being done correctly.

CB07 (PEER report):

6.3.5 Sediment Depth

If the depth to the 2.5 km/s velocity horizon is unknown, it can be estimated from one of the other sediment depth parameters, if known, using the following relationships developed using data from the PEER database:

$$Z_{2.5} = 0.519 + 3.595 Z_{1.0}; \quad \sigma_z = 0.711 \quad (6.3)$$

$$Z_{2.5} = 0.636 + 1.549 Z_{1.5}; \quad \sigma_z = 0.864 \quad (6.4)$$

where all depths are in kilometers.

However, if none of these depths are known, sediment depth is the only parameter that could possibly be assigned a default value unless it is known or expected that it is either less than 1.0 km or greater than 3.0 km. If sediment depth effects are not expected to be important, V_{S30} alone can serve as a reasonable representative of both shallow and deep site response, and $Z_{2.5}$ can be set to a default value of 2 km (actually any value between 1 and 3 km). If sediment depth effects are expected to be important, then reasonable alternative values for $Z_{2.5}$ and their associated weights should be used to evaluate this parameter.

CY08:

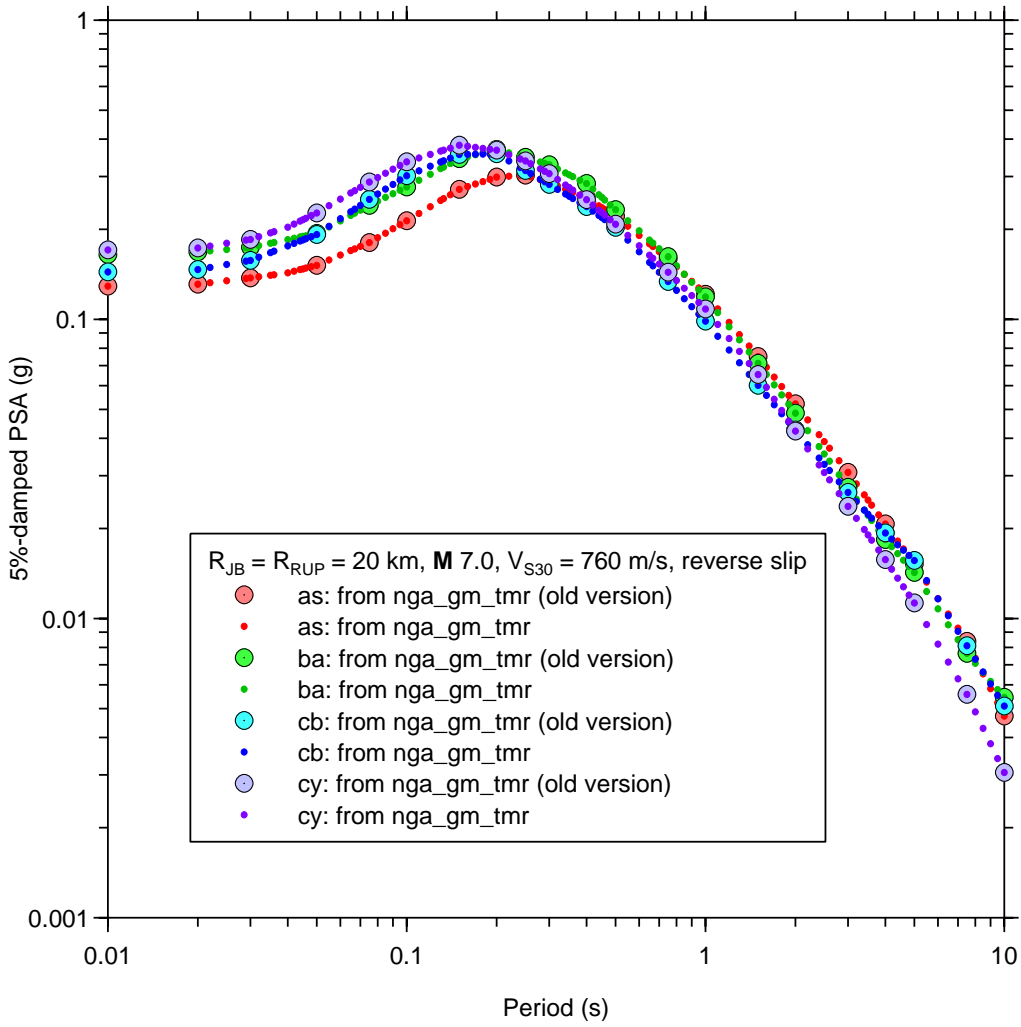
The ground motion model presented here is sensitive to the value of sediment depth, $Z_{1.0}$, for the site. We have used data from the SCEC-3D Version 4 model for southern California and users should use this version to estimate values of $Z_{1.0}$ at sites in southern California. For general application, we recommend that the user estimate $Z_{1.0}$ from Equation 1 unless there is site-specific data to provide a better estimate (e.g., a site velocity profile). Note also that large values of $Z_{1.0}$ may produce numerical overflow of the *cosh* function in some compilers and the user may need to determine the appropriate limits in implementing our model in computer programs.

The thickness of the near-surface sediments is represented in our model by the depth to a shear wave velocity of 1.0 km/s, $Z_{1.0}$. These data are available in the PEER-NGA database for sites within the Southern California Earthquake Center 3-D basin model (Magistrale et al. 2000), for sites in the USGS velocity model for the San Francisco Bay area (Boatwright et al. 2004), for sites in the Eel River basin (Graves 1994), and for sites where measured velocities reach this velocity horizon. Note that in our study we updated the $Z_{1.0}$ values from SCEC-3D Version 2 to those from Version 4. For the remaining sites $Z_{1.0}$ was estimated through the following correlation with V_{S30} developed from the data in the PEER-NGA database:

$$\ln(Z_{1.0}) = 28.5 - \frac{3.82}{8} \ln(V_{S30}^8 + 378.7^8) \quad (1)$$

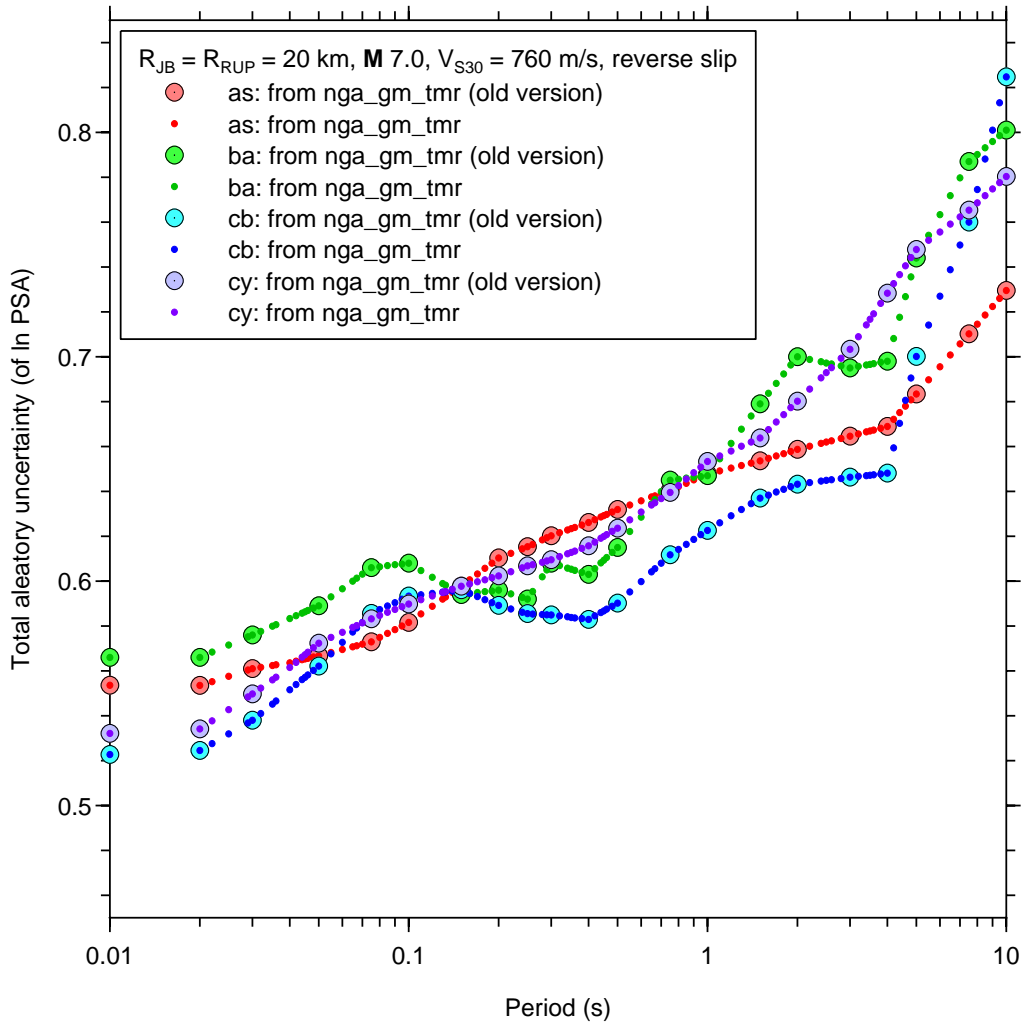
Interpolation of spectral values for periods not corresponding to the tabulated coefficients

The program uses straight-line interpolation of $\ln PSA$ vs. $\ln T$. Here are two graphs showing a comparison of the PSA and sigma values from an older version of NGA_GM_TMR (for which the periods were required to be the tabulated periods) and given in the distributed version of the program. These graphs confirm that the interpolation is being done correctly.



File: C:\gm_predictions\check_nga_psa_vs_interpolated_periods_m_7_r_20_vs_760.out.draw; Date: 2010-01-13; Time: 12:38:4

Figure 1.



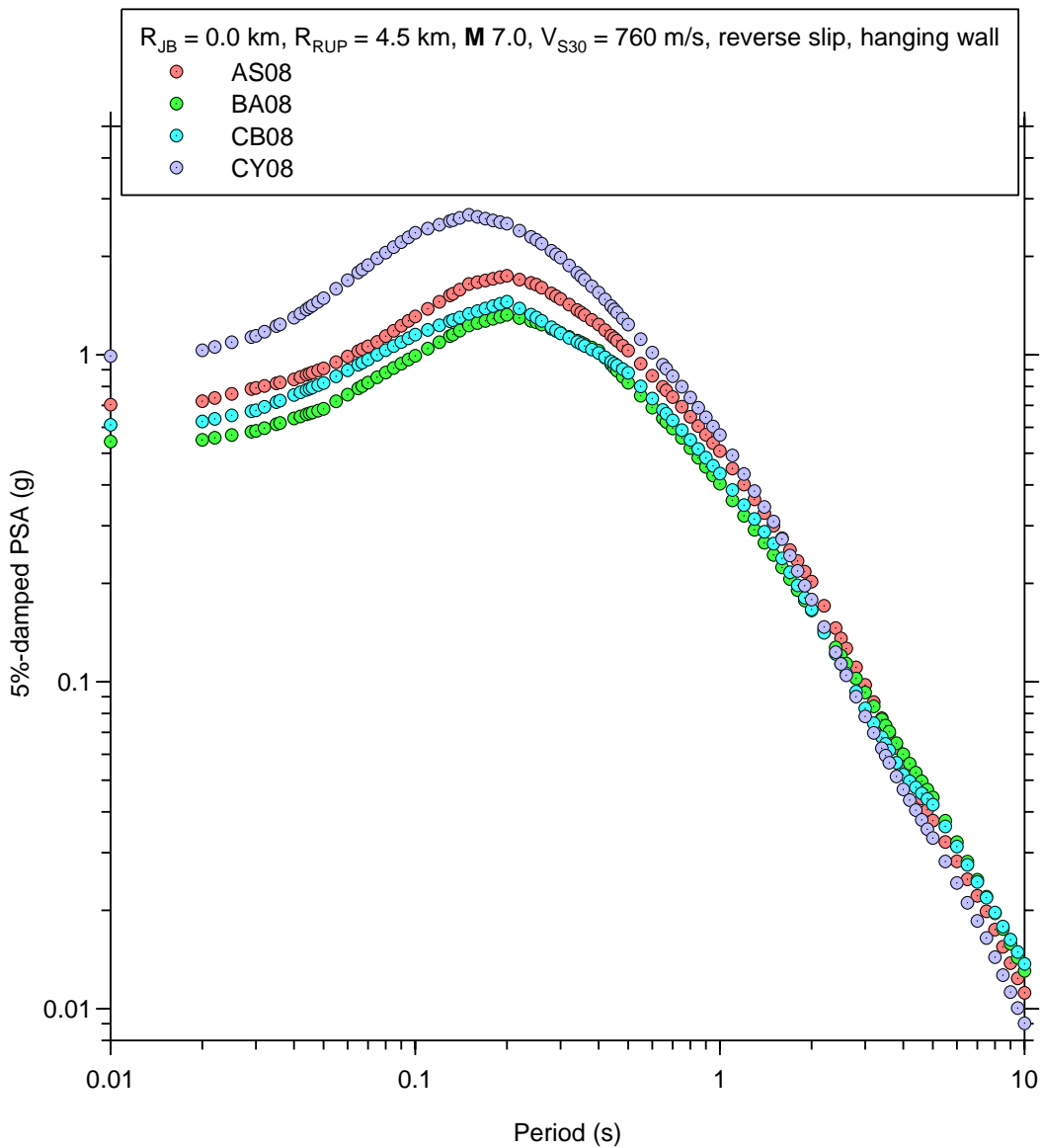
File: C:\gm_predictions\check_nga_sigma_vs_interpolated_periods_m_7_r_20_vs_760.out.draw; Date: 2010-01-13; Time: 12:39;

Figure 2.

Examples of input and output:

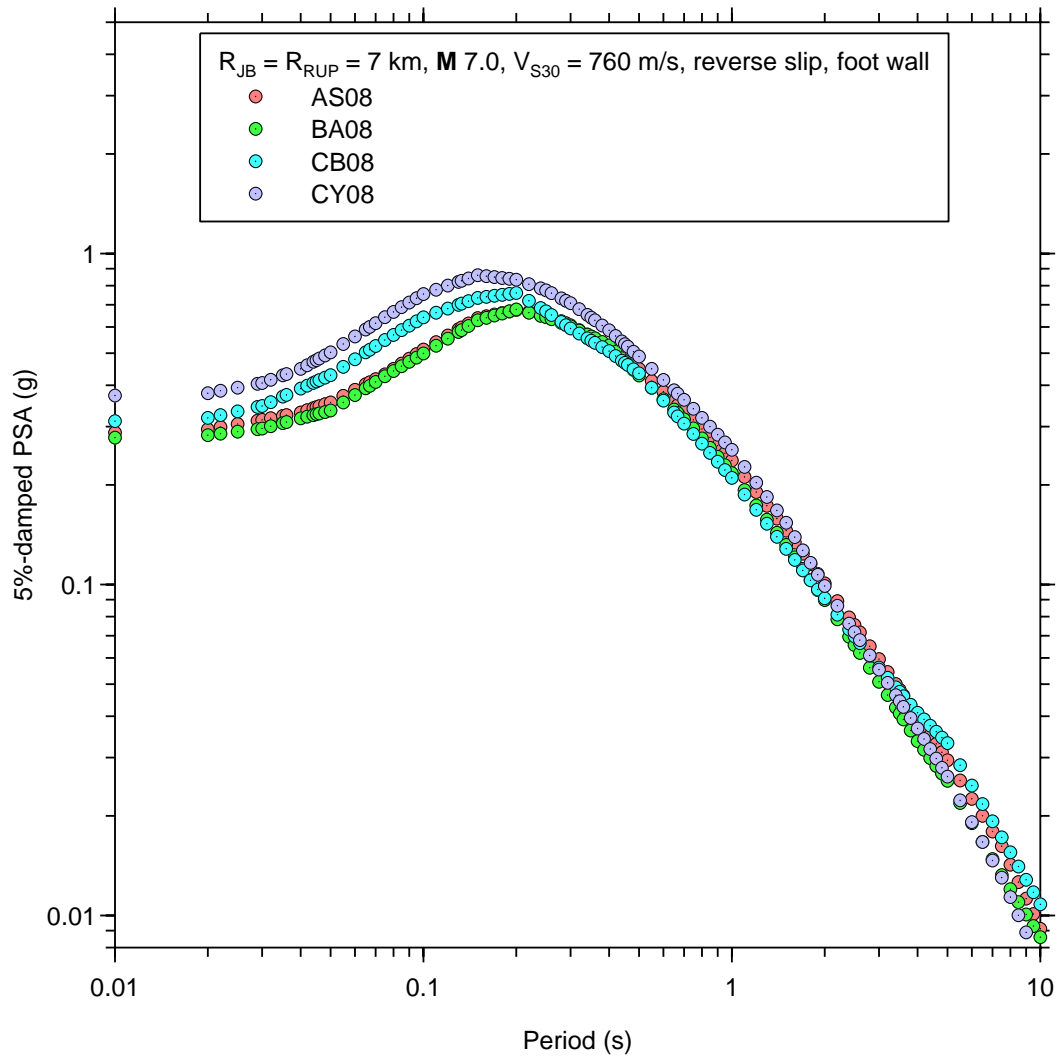
The distribution zip file contains sample input (`nga_gm_tmr.ct1`) and output (`hanging_wall_example_m7_vs30_760.out` and `foot_wall_example_m7_vs30_760.out`). A portion of the input file is given above. Two cases are considered for $M 7$: a site on the hanging wall (over a dipping reverse fault) and on the foot wall at a distance corresponding to the distance from the surface projection of the fault to the site over the hanging wall. The fault has a rake of 90° and a hypocentral depth of 5 km. Because fault dip was not specified, a generic dip of 40° was assigned by the program. In addition, the fault width was not specified but was assigned using the Wells and Coppersmith (1994) empirical relations. The vertical distance from the surface to the top of the rupture surface (Z_{TOR}) was not specified, but was calculated using the fault width and the hypocentral depth. With the fault type and

geometry determined, the next task is to specify the site location at which the GMPEs will be evaluated. The hanging wall case was specified first, with $R_{jb} = 0.0$ km but without specifying R_{rup} . An azimuth of 90° was specified (along a line normal to the strike of the fault). In this case the program assumes that the site is in the middle of the surface projection of the fault and calculates R_{rup} and R_x . See the sample program output file for the values assigned by the program. Once the hanging wall case was run, the foot wall case was run, using R_{jb} from the hanging wall case. Here are plots of PSA and the total standard deviations for the two cases.



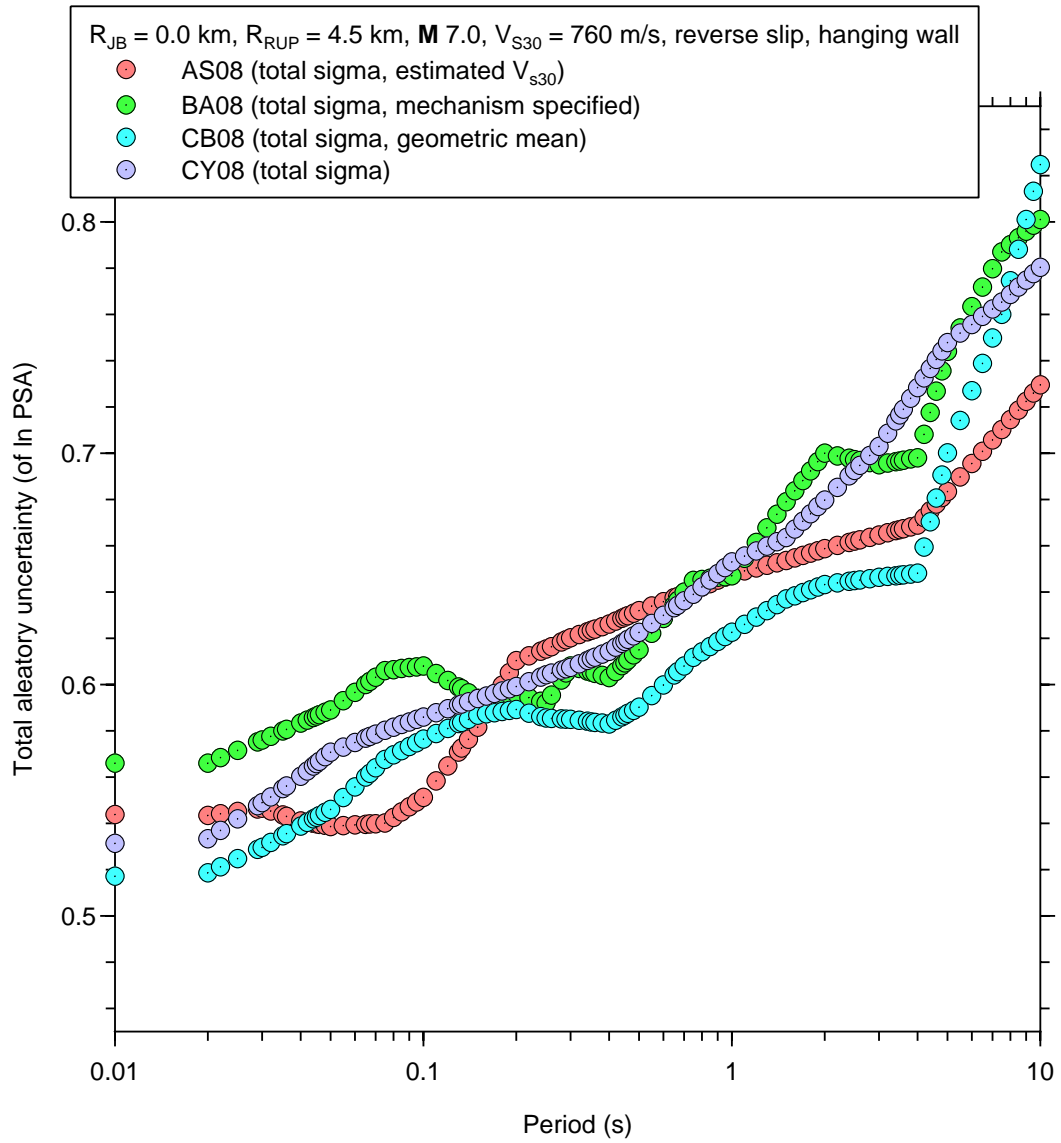
C:\gm_predictions\nga_files\nga_psa_vs_interpolated_periods_m_7_r_20_vs_760.hangingwall.out.draw; Date: 2010-06-02; Time: (

Figure 3.



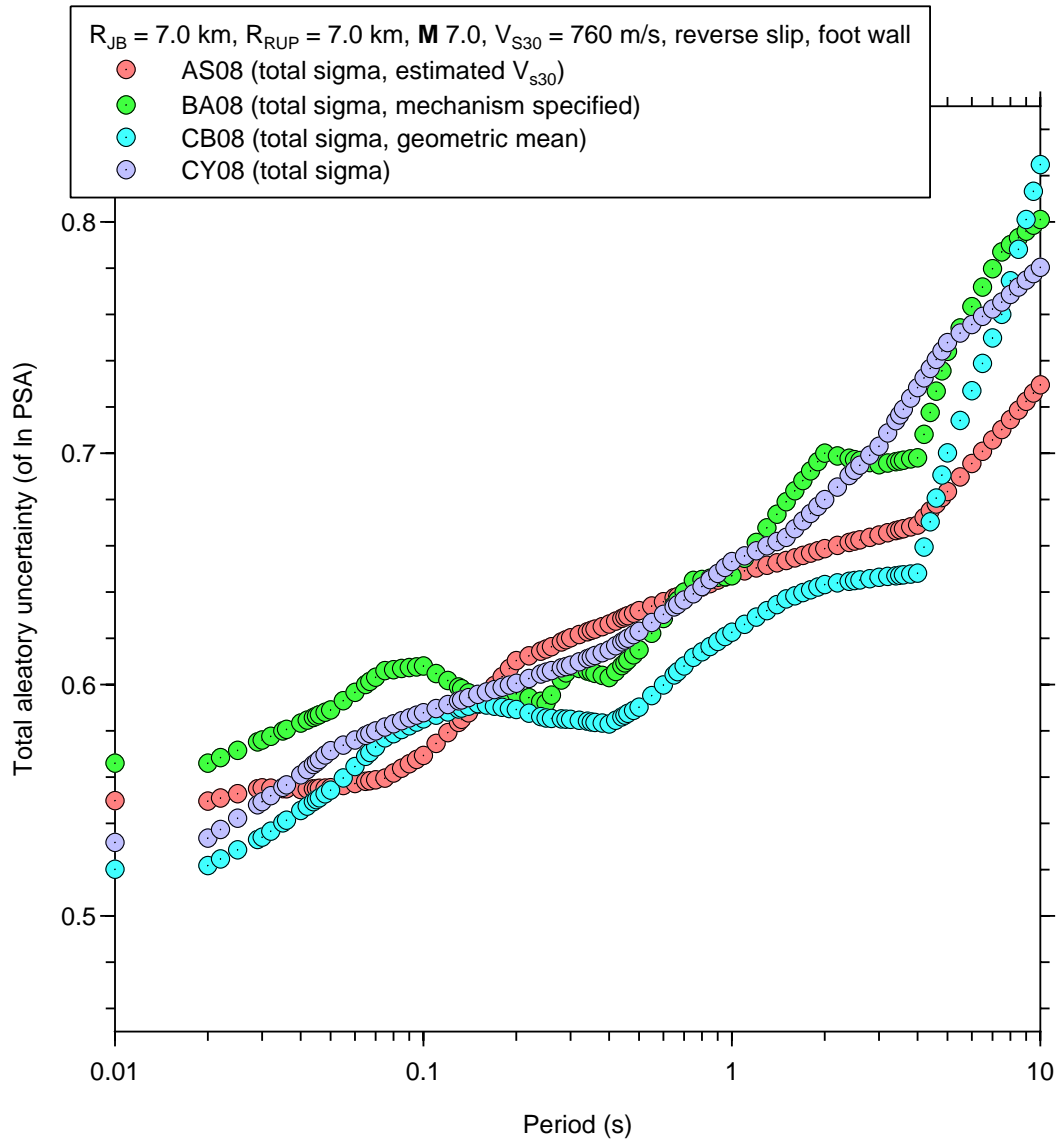
ie: C:\gm_predictions\nga_files\nga_psa_vs_interpolated_periods_m_7_r_20_vs_760.footwall.out.draw; Date: 2010-06-02; Time: 08

Figure 4.



C:\gm_predictions\nga_files\nga_sigma_vs_interpolated_periods_m_7_r_20_vs_760.hangingwall.out.draw; Date: 2010-06-02; Time:

Figure 5.



C:\gm_predictions\nga_files\nga_sigma_vs_interpolated_periods_m_7_r_20_vs_760_footwall.out.draw; Date: 2010-06-02; Time: 1

Figure 6.

References

Kaklamanos, J., D. M. Boore, E. M. Thompson, and K. W. Campbell (2010). Implementation of the Next Generation Attenuation (NGA) ground-motion prediction equations in Fortran and R, *U. S. Geological Survey Open-File Report 2010-xxxx*, (in preparation).

Mai, P. M., P. Spudich, and J. Boatwright (2005). Hypocenter locations in finite-source rupture models, *Bull. Seismol. Soc. Am.* **95**, 965—980. doi: 10.1785/0120040111.

Scherbaum, F., J. Schmedes, and F. Cotton (2004). On the conversion of source-to-site distance measures for extended earthquake source models, *Bull. Seismol. Soc. Am.* **94**, 1053—1069.

Wells, D. L. and K. J. Coppersmith (1994). New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement, *Bull. Seism. Soc. Am.* **84**, 974--1002.