What single-corner-frequency (SCF) stress parameter is consistent with the Atkinson and Silva (2000) (AS00) source model?

Notes by David M. Boore

AS00 say 80 bars ("The equivalent point-source spectrum is characterized by a high-frequency level that corresponds to a Brune point source model with a stress drop of 80 bars"), but my runs suggest 88 bars. I used the stochastic model parameters used by AS00. I ran SCF models as well as my generalization of the two corner model (Boore, 2013; the results here are an example of the use of the generalized 2-corner model—I will eventually submit a paper for publication on the model with some illustrations of its use). Here is a sample params file, in this case for an additive generalized 2-corner model, with the dependence of f_a and ε on **M** being that used in AS00. The parameters below are for a stress parameter $\Delta\sigma$ of 88 bars, but a whole suite of $\Delta\sigma$ was used in the simulations. :

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!Revision of program involving a change in the parameter file on this date:
   03/24/13
!Title:
  additive 2-corner_Raoof path
!rho, beta, prtitn, radpat, fs:
    2.8 3.5 0.707 0.55 2.0
!spectral shape: source number, pf_a, pd_a, pf_b, pd_b
! where source number means:
!  1 = 1-corner (S = 1/(1+(f/fc)**pf_a)**pd_a)
!  2 = Joyner (BSSA 74, 1167--1188)
!  3 = Atkinson (BSSA 83, 1778--1798; see also Atkinson & Boore, BSSA 85,
!      17--30)
!  4 = Atkinson & Silva (BSSA 87, 97--113)
!  5 = Haddon 1996 (approximate spectra in Fig. 10 of
!          Haddon's paper in BSSA 86, 1300--1313;
!          see also Atkinson & Boore, BSSA 88, 917--934)
!  6 = AB98-California (Atkinson & Boore BSSA 88, 917--934)
!  7 = Boatwright & Choy (this is the functional form used by
!                        Boore & Atkinson, BSSA 79, 1736--1761, p. 1761)
!  8 = Joyner (his ENA two-corner model, done for the SSHAC elicitation
!      workshop)
!  9 = Atkinson & Silva (BSSA 90, 255--274)
! 10 = Atkinson (2005 model),
! 11 = Generalized multiplicative two-corner model
!      (S = [1/(1+(f/fa)**pf_a)**pd_a]*[1/(1+(f/fb)**pf_b)**pd_b])
! 12 = Generalized additive two-corner model
!      (S = (1-eps)/(1+(f/fa)**pf_a)**pd_a] + eps/(1+(f/fb)**pf_b)**pd_b)
!          NOTE: if M<M for eps = 1.0, the program uses eps = 1, and the
source spectrum only depends
!          on fb, which is equal to the corner frequency of the single-corner
source model.
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!          One warning: the source duration is given by a weighted average of
1/fa and 1/fb, as
!          specified below.   For eps = 1.0 fa will be set equal to fc (the
corner frequency for the
!          single-corner frequency with the specified stress parameter).
This will probably result in a
!          a discontinuity in fa for eps = 1.0 and for eps slightly larger
than 1.0.  This may affect the
!          computation of duration.  Note that if the weights of 0.5 and 0.0
for 1/fa and 1/fb used by Atkinson and Boore (1995)
!          and Atkinson and Silva (2000) are specified, then the source
duration for M smaller than the M for eps = 1.0
!          will be 0.5/fa, whereas it more logically should be 1/fc = 1/fa.
This is a general problem with
!          the source duration of the two-corner model if the AB95 and AS00
weights are used.  Because
!          M for eps =1.0 is usually small, the inconsistency will probably
only arise for small magnitudes,
!          for which the source duration will be small compared to the path
duration.  But the
!          way to avoid an inconsistency in the source duration is to use
weights of 0.5 and 0.5 for 1/fa and 1/fb, respectively.
!          For large M, fb will usually be much larger than fa, and the
!          source duration will be dominated by 0.5/fa.   For this reason, I
am revising my recommendations
!          for the source duration weights below.
! pf_a, pd_a, pf_b, pd_a are used for source numbers 1, 11, and 12, usually
! subject to these constraints for an omega-squared spectrum:
! source 1: pf_a*pd_a = 2
! source 11: pf_a*pd_a + pf_b*pd_b = 2
! source 12: pf_a*pd_a = pf_b*pd_b = 2
! The usual single-corner frequency model uses
! pf_a=2.0,pd_a=1.0; the Butterworth filter shape is given by
! pf_a=4.0,pd_a=0.5.  pf_b and pd_b are only used by sources 11 and 12, but
dummy
! values must be included for all sources.
!      1 2.0 1.0 0.0 0.0
    12 2.0 1.0 2.0 1.0
!spectral scaling:
! stressc, dlsdm, fbdfa, amagc, c1_fa, c2_fa, amagc4fa,  c1_eps, c2_eps,
amagc4eps
!   stress=stressc*10.0**(dlsdm*(amag-amagc))
!   fbdfa, amagc for Joyner model, usually 4.0, 7.0)
!   c1_fa, c2_fa, amagc4fa:  the coefficients relating log fa to M in
!     sources 11 and 12, as given by the equation log fa = c1_fa + c2_fa*(M-
amagc4fa).
!   c1_eps, c2_eps, amagc4eps:  the coefficients relating log eps to M in
!     source 12, as given by the equation log eps = c1_eps + c2_eps*(M-
amagc4eps).
!   fb for sources 11 and 12 are given such that the high-frequency spectral
level
!   equals that for a single corner frequency model with a stress parameter
!   given by stress=stressc*10.0**(dlsdm*(amag-amagc).
!   See Tables 2 and 3 in Boore (2003) for various source descriptions
!   (Note: the parameters in the line below are not used for most of the
!   sources, for which the spectrum is determined by fixed relations between
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!   corner frequency and seismic moment, but placeholders are still needed)
! For convenience for those using source 12, here are some of the
coefficients for
! fa and eps from Table 3 in Boore (2003):
!                      Model        c1_fa  c2_fa amagc4fa c1_eps  c2_eps
amagc4eps
!  Atkinson and Boore (1995) M>=4.0 2.410 -0.533      0.0   2.520 -0.637
0.0
!                            M< 4.0 2.678 -0.500      0.0   0.000  0.000
0.0
!  Atkinson and Silva (2000) M>=2.4 2.181 -0.496      0.0   0.605 -0.255
0.0
!                            M< 2.4 1.431 -0.500     -2.4   0.000  0.000
0.0
   88.0 0.0 4.0 7.0  2.181 -0.496      0.0   0.605 -0.255       0.0
!iflag_f_ff, c1, c2, c3 (0 0.0 0.0 if not used)
!  If iflag_f_ff = 1:
!    modified distance: rmod = sqrt(r^2 + f_ff^2))
!  If iflag_f_ff = 2:
!    modified distance: rmod =  r + f_ff
!  where log10(f_ff) = c1 + c2*amag
!  Use rmod in the calculations
!  Published finite-fault factors
!  Author                    meaning of r  iflag_f_ff    c1     c2
!  Atkinson and Silva (2000)     r_rup           1     -0.05    0.15
!  Toro (2002)                   r_rup           2     -1.0506  0.2606
!  Atkinson and Boore (2003)     r_rup           1     -2.1403  0.507
  1 -0.05 0.15
!   0  0.0 0.0
!Geometrical spreading option:
!  0 = use standard hinged line segments
! >0 = frequency-dependent spreading:
!  1 = Gail Atkinson's November 2011 proposed spreading for eastern North
America (ENA),
!      with Q=500f^0.5, which must be specified below).
!  2 = Dave Boore's trial spreading #1 for ENA).
!  3 = Gail Atkinson's Sept, 2012 report "nga-e-r12_AttenShape.pdf". For this
!      model, Q = 680f^0.33, and this must be specified below.
   0
!Parameters for the DMB gsprd:
!     r1_dmb_gsprd, pgsprd_r_le_r1_lf, pgsprd_r_le_r1_hf, pgsprd_r_gt_r1,
!     ft1_dmb_gsprd, ft2_dmb_gsprd
! (Placeholders are needed, but not used, even if the geometrical spreading
option
! is not for Dave Boore's spreading function
  60.0 -1.1 -1.3 -0.5 1.0 3.2   ! this corresponds to 1/r^1.1 for f<=1 Hz and
1/r^1.3 for f>=3.2 Hz, for r< 60 km and 1/r^0.5 for all f beyond 60 km.
!gsprd: r_ref, nsegs, (rlow(i), a_s, b_s, m_s(i)) (Usually set
! r_ref = 1.0 km)
! *** NOTE: these lines are needed even if option 1 is chosen above---and
! there must be nsegs lines following the "nseg" specification, even if the
! geometrical spreading is not used because option 1 has been chosen.
    1.0
    2
      1.0 -1.0 0.0 6.5
     40.0 -0.5 0.0 6.5
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!q: fr1, Qr1, s1, ft1, ft2, fr2, qr2, s2, c_q
    1.0 180 0.45 1.0 1.0 1.0 180 0.45 3.5
!source duration: weights of 1/fa, 1/fb
! Previous to 03/25/13, I recommended that the weights for source 1 be 1.0
0.0, and
! for the Atkinson and colleagues 2-corner sources be 0.5 0.0.  But since
dursource is always computed as w_fa/fa + w_fb/fb, and because
! fb is set equal to fa for source 1, even though fb is not used in
spect_shape, using weights of 0.5 and 0.5
! for source 1 will give the same answer as the previously recommended 1.0
0.0 weights.  The advantage
! to using weights of 0.5 0.5 is that they are the same as I am now
recommending for the Atkinson and colleagues (and perhaps
! all) 2-corner models, for reasons discussed in the spectral shape, source
12
! section above.  This is not what is used by Atkinson and colleagues; they
use 0.5 0.0 for the weights
! (Atkinson and Boore (1995, p. 20) and Atkinson and Silva (2000, p. 259)).
    0.5 0.5
!path duration: nknots, (rdur(i), dur(i), slope of last segment)
    1
      0.0 0.0
    0.05
!crustal amplification, from the source to the site (note that this can
include
! local site amplification): namps, (famp(i), amp(i))
    11
    0.01          1.00
    0.09          1.10
    0.16          1.18
    0.51          1.42
    0.84          1.58
    1.25          1.74
    2.26          2.06
    3.17          2.25
    6.05          2.58
    16.6          3.13
    61.2          4.00
!site diminution parameters: fmax, kappa, dkappadmag, amagkref
! (NOTE: fmax=0.0 or kappa=0.0 => fmax or kappa are not used.  I included
this
!  to prevent the inadvertent use of both fmax and kappa to control the
diminution
!  of high-frequency motion (it would be very unusual to use both parameters
!  together.  Also note that if do not want to use kappa, dkappadmag must
also
!  be set to 0.0).
    0.0 0.04 0.0 6.0
!low-cut filter parameters: fcut, nslope (=4, 8, 12, etc)
    0.04 8
!rv params: zup, eps_int (int acc), amp_cutoff (for fup), osc_crrctn(0=no
correction;
!  1=bj84;2=lp99; 3=bt12 wna; 4=bt12 ena; 5=average of bt12 ena & wna)
    10.0 0.00001  0.001 3
!Name of pars file for Boore-Thompson oscillator correction for WNA:
!  NOTE: If no folder is specified, the program will look for the files in
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!  the folder from which the driver is called)
         \smsim\wna_bt12_trms4osc.pars
!Name of pars file for Boore-Thompson oscillator correction for ENA:
!  NOTE: If no folder is specified, the program will look for the files in
!  the folder from which the driver is called)
         \smsim\ena_bt12_trms4osc.pars
!window params: idxwnd(0=box,1=exp), tapr(<1), eps_w, eta_w, f_tb2te,
f_te_xtnd
    1 0.05 0.2 0.05 2.0 1.0
!timing stuff: dur_fctr, dt, tshift, seed, nsims, iran_type
(0=normal;1=uniform)
    1.3  0.005 20.0 123.0 100 0
```

Here are figures:

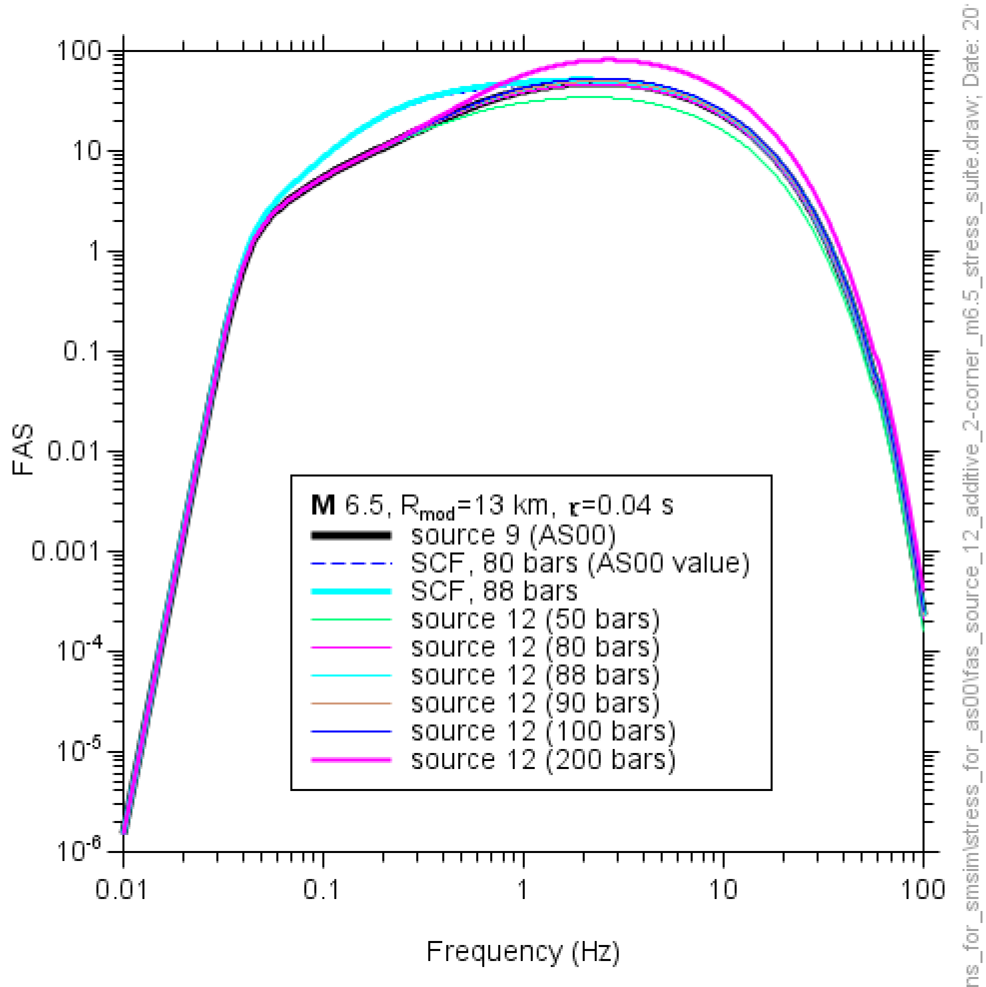

Figure 1. Comparison of FAS from AS00 with SCF and generalized 2-corner models for a suite of stress parameters.

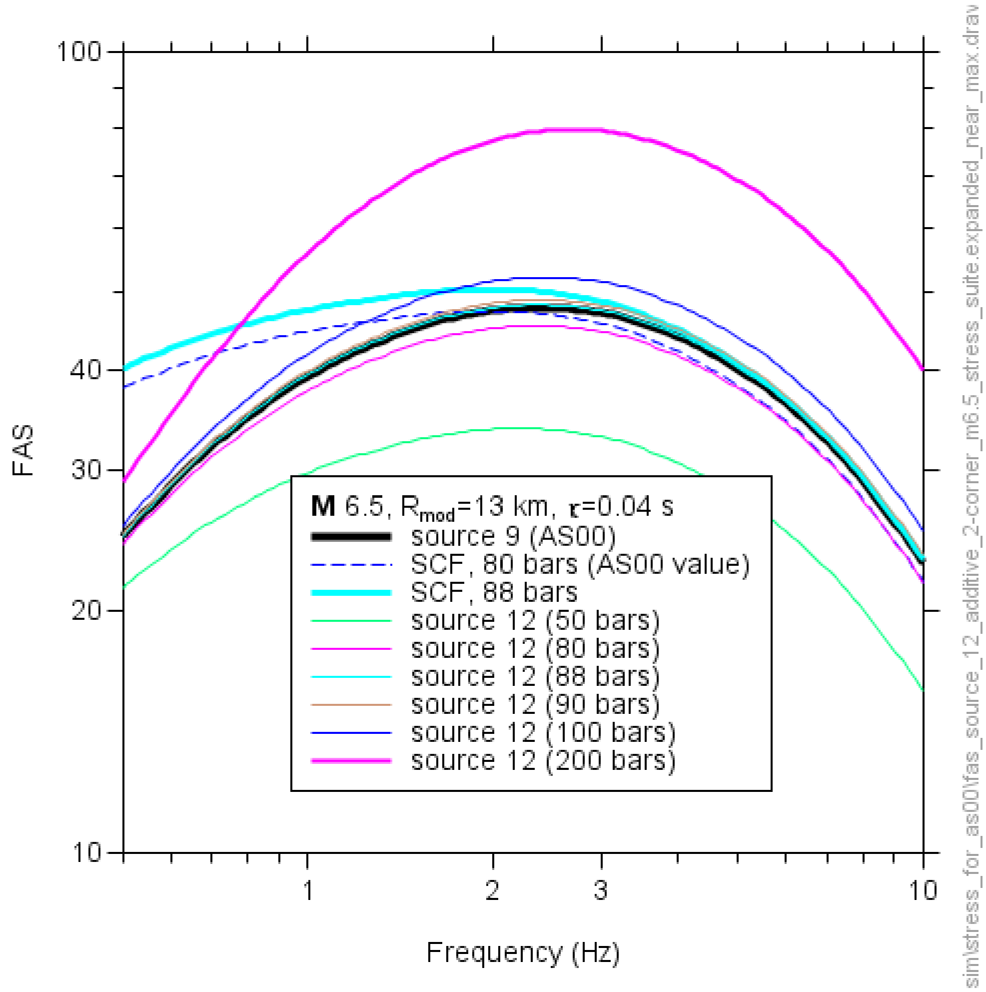

Figure 2. Expanded view of the comparison of FAS.

Both the SCF and the additive generalized (source 12) models with $\Delta\sigma$ of 88 bars are more consistent with the Fourier acceleration spectrum (FAS) from the AS00 model (source 9) than are the FAS for models with 80 bars.

References

Atkinson, G.M. and W. Silva (2000). Stochastic modeling of California ground motions, *Bull. Seismol. Soc. Am.* **90**, 255–274.

Boore, D.M. (2013). Generalization of 2-corner frequency source models used in SMSIM, unpublished notes, available from `www.daveboore.com\daves_notes\smsim_generalization_of_2-corner_frequency_source_models_v04.pdf`