NEW HANGING WALL MODEL

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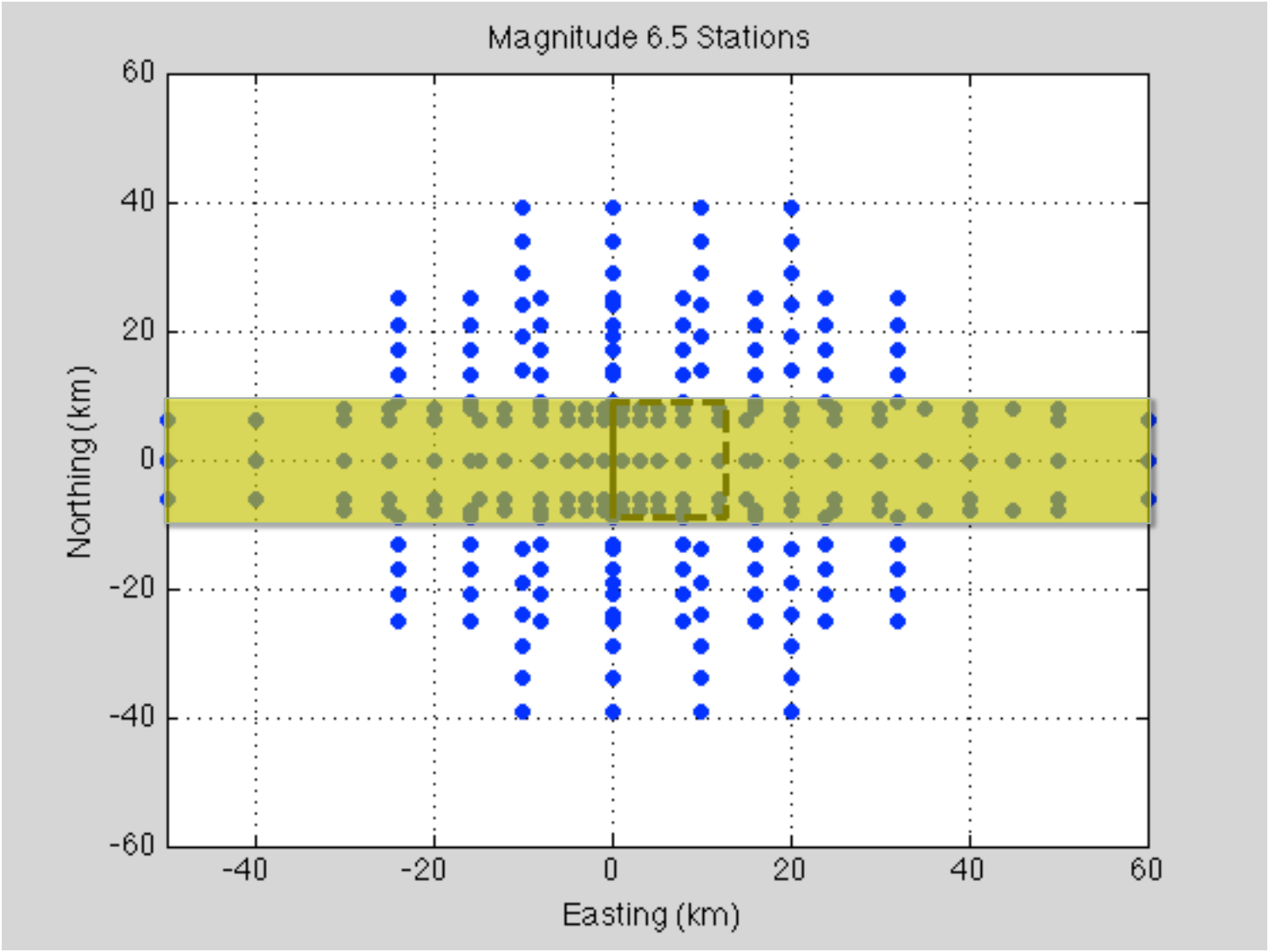
PEER

Geosyntec consultants

Hanging Wall - Empirical Data

- Limited events with both Footwall and Hanging Wall stations
- Source to Site angle of ~ +/- 90°


Magnitude 6.5 Stations
Northing (km)
Easting (km)
60
40
20
0
-20
-40
-60
-40
-20
0
20
40
60

Hanging Wall - Empirical Data

- Limited events with both Footwall and Hanging Wall stations
- Source to Site angle of ~ +/- 90°
- Events meeting criteria:
  - Northridge
  - Chi-Chi
  - Niigata
  - Wenchuan
  - Iwate
  - Loma Prieta
  - L'Aquila

Hanging Wall Simulations - Graves 2012

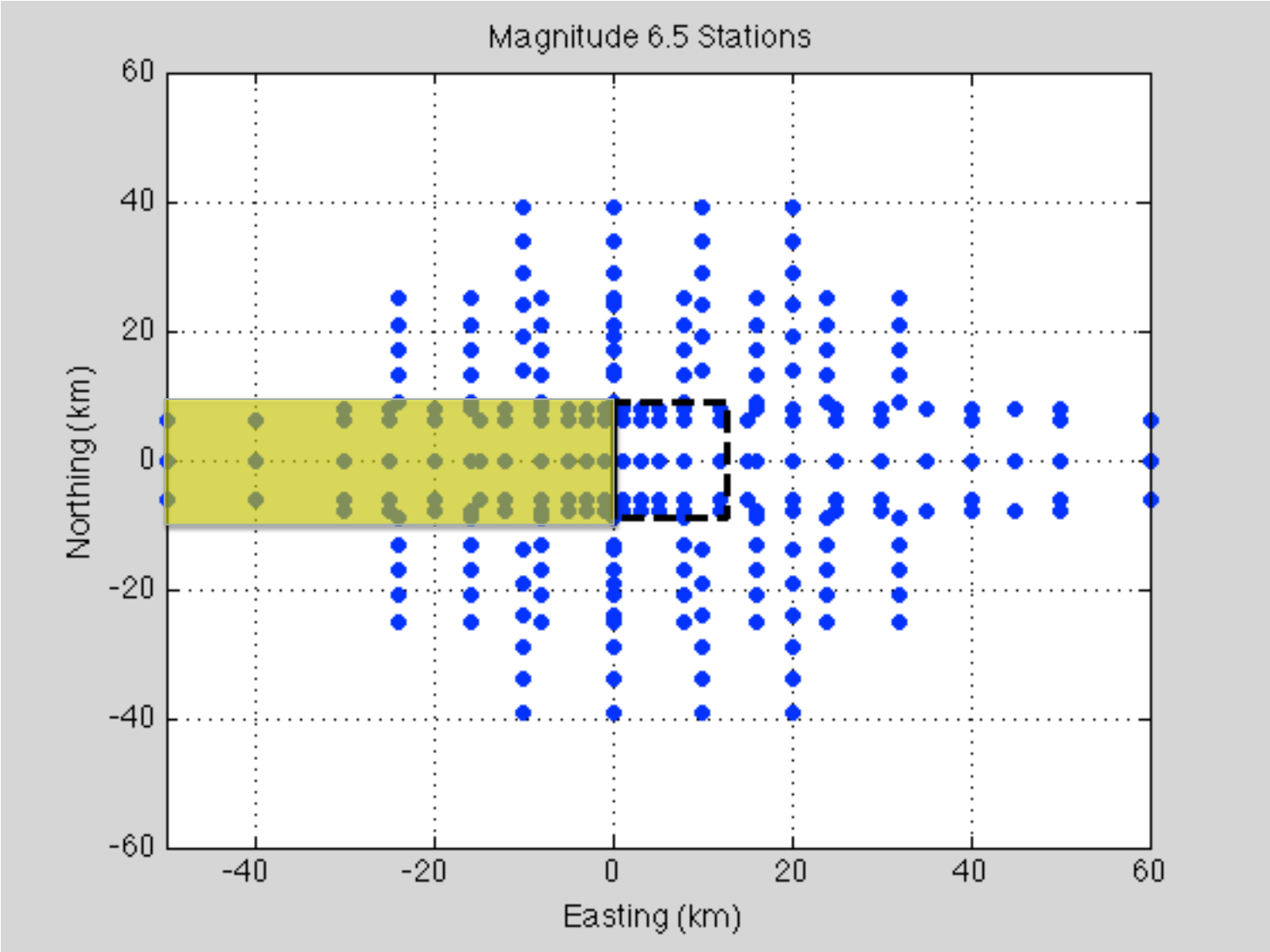
- 34 Reverse fault cases:
  - Surface Faulting
    - 5 Magnitudes (6, 6.5, 7, 7.5,7.8)
    - 5 Dips (20, 30, 45, 60, 70)
  - Buried Ruptures
    - 1 Depth to Top of Rupture (5km)
    - 2 Magnitudes (6, 6.5)
    - 4 Dips (20, 30, 45, 60)
  - Width and Length of faults varied for Mag7 & Mag7.5
  - All simulations have a V_{s30} of 865 m/s

2012 Simulation Scenarios

Magnitude	Area (km^2)	Width (km)	Length (km)	Dip	TOR (km)
6	100	10	10	20	0
6	100	10	10	30	0
6	100	10	10	45	0
6	100	10	10	60	0
6	100	10	10	70	0
6.5	324	18	18	20	0
6.5	324	18	18	30	0
6.5	324	18	18	45	0
6.5	324	18	18	60	0
6.5	324	18	18	70	0
7	1000	25	40	20	0
7	1000	25	40	30	0
7	1012	23	44	45	0
7	1000	25	40	45	0
7	1000	20	50	60	0
7	1000	25	40	60	0
7	1000	25	40	70	0
7.5	3200	32	100	20	0
7.5	3200	32	100	30	0
7.5	3150	25	126	45	0
7.5	3200	32	100	45	0
7.5	3000	20	150	60	0
7.5	3200	32	100	60	0
7.5	3200	32	100	70	0
7.8	4500	25	180	45	0
7.8	4500	20	200	60	0
6	100	10	10	20	5
6	100	10	10	30	5
6	100	10	10	45	5
6	100	10	10	60	5
6.5	324	18	18	20	5
6.5	324	18	18	30	5
6.5	324	18	18	45	5
6.5	324	18	18	60	5

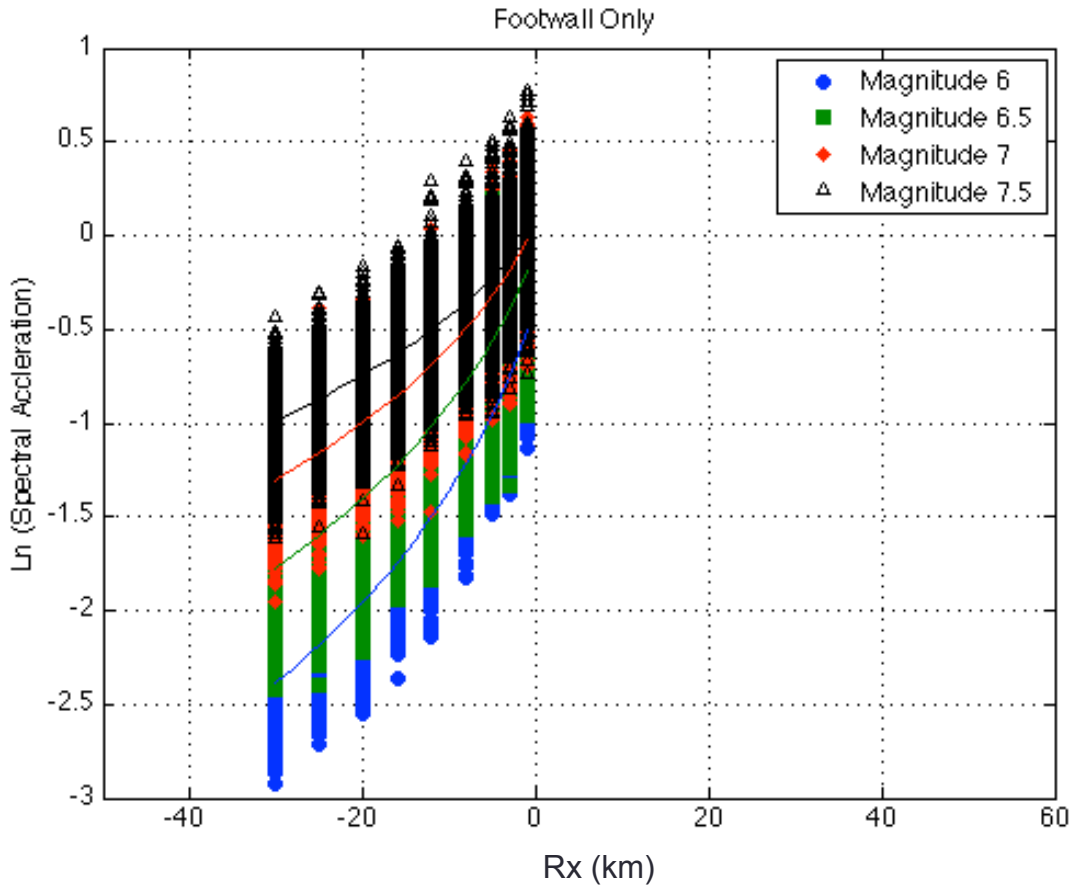
Regress on Footwall only

Rx dist used.



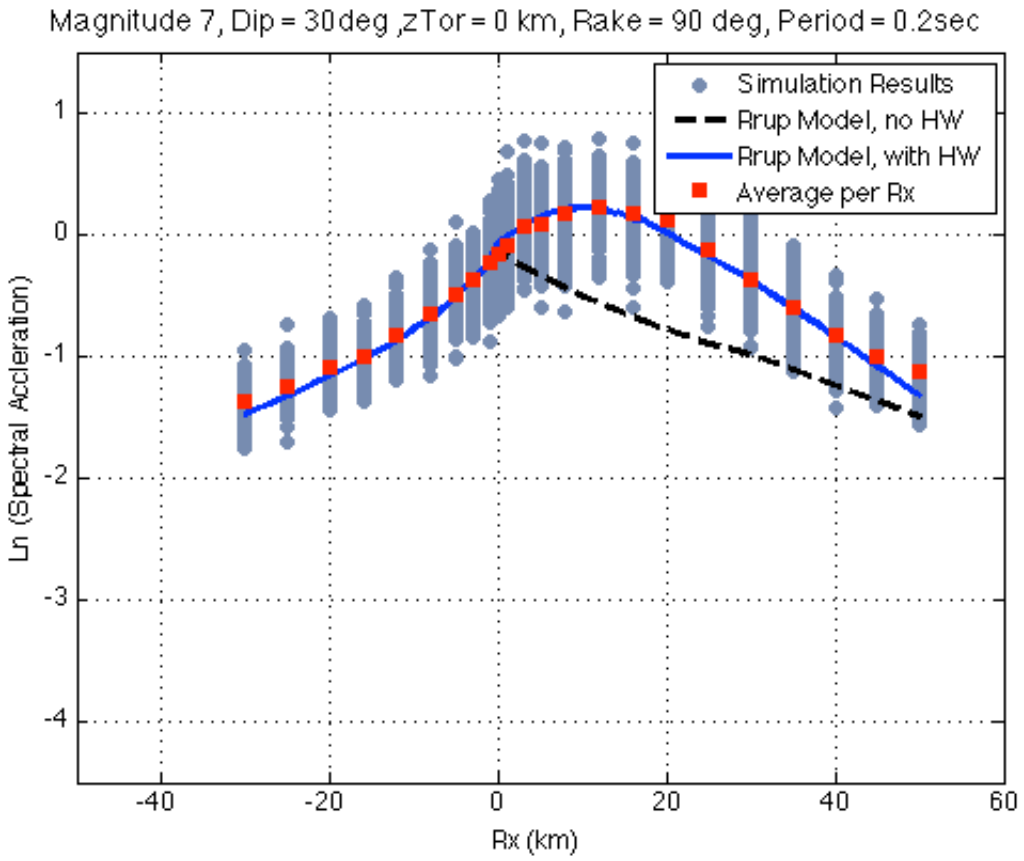
Regress on Footwall only
Rx dist used.

$$\ln(y) = b1 + (b2+b3*(M-6))*(\ln((R)+b4)) + b5*(M-6) + b6*(M-6)^2 + b7*(R) + f_{dip}(\delta) + f_{ZTORFW}(ZTOR, \delta, M)$$



Hanging Wall Model Development

- Apply Footwall Regression to Hanging Wall
- Find median ln(spectral acceleration) per Rx
- Develop nonparametric model for Hanging Wall



Hanging Wall Model

$$\ln(y) = b1 + (b2+b3*(M-6))*(\ln((Rrup)+b4)) + b5*(M-6) + b6*(M-6)^2 + b7*(Rrup)$$
$$+ f_{dip}(\delta) + f_{ZTORFW}(ZTOR, \delta, M) + f_{hw}(M, \delta, W, ZTOR, Rx, Ry, L)$$

Event Terms for footwall regression:

$$f_{dip}(\delta) = d_1*(90-\delta)^2+d_2*(90-\delta)+d_3$$

$$f_{ZTORFW}(ZTOR, \delta, M) = (z_{ft1}*(90-\delta)+z_{ft2})+(z_{ft3}*(M-6))$$

Hanging Wall Model

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Hanging Wall Function:

$$f_{hw}(M, \delta, W, ZTOR, Rx, Ry, L) = a_1\, T_1(\delta)\, T_2(M)\, T_3(Rx, W, \delta, M)\, T_4(ZTOR) T_5(Rx, Ry, L)$$

Hanging Wall Model

$$\ln(y) = b1 + (b2+b3*(M-6))*(\ln((Rrup)+b4)) + b5*(M-6) + b6*(M-6)^2 + b7*(Rrup)$$
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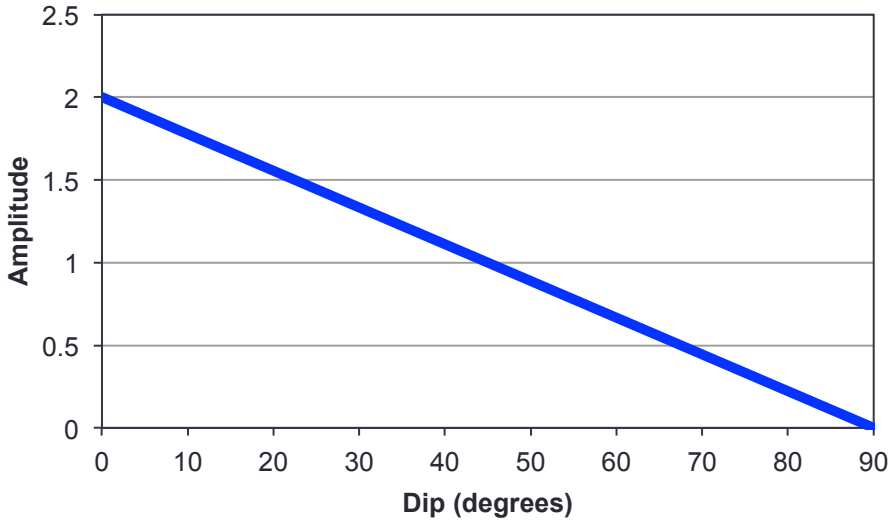
$$f_{hw}(M, \delta, W, ZTOR, Rx, Ry, L) = a_1 T_1(\delta) T_2(M) T_3(Rx, W, \delta, M) T_4(ZTOR) T_5(Rx,Ry,L)$$

$$T_1(\delta) = (90-\delta)/45 \qquad \text{for } \delta \leq 90°$$

Dip Taper: $T_1(\delta)$



Hanging Wall Model

$$\ln(y) = b1 + (b2+b3*(M-6))*(\ln((Rrup)+b4)) + b5*(M-6) + b6*(M-6)^2 + b7*(Rrup)$$
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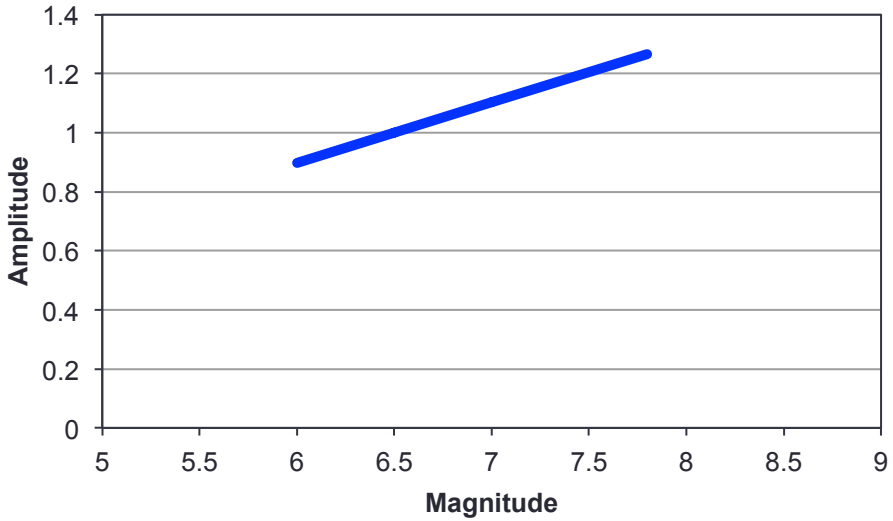
Hanging Wall Function:

$$f_{hw}(M, \delta, W, ZTOR, Rx, Ry, L) = a_1 T_1(\delta) T_2(M) T_3(Rx, W, \delta, M) T_4(ZTOR) T_5(Rx,Ry,L)$$

$$T_2(M) = 1 + a_2 (M-6.5)$$

Note: The minimum simulation magnitude is M6 and the maximum is M7.8. Extrapolation below the minimum and above the maximum for the T_2 term should be done at the discretion of the developer.

Magnitude Taper: $T_2(M)$



Hanging Wall Model

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Hanging Wall Function:

$$f_{hw}(M, \delta, W, ZTOR, Rx, Ry, L) = a_1\, T_1(\delta)\, T_2(M)\, T_3(Rx, W, \delta, M)\, T_4(ZTOR)\, T_5(Rx,Ry,L)$$

$$T_3(Rx, W, \delta, M) = \begin{cases} 0 & \text{for } Rx < 0 \\ f1 & \text{for } Rx \le R1 \\ f2 & \text{for } Rx > R1 \ \&\ Rx \le R2 \\ f3 & \text{for } Rx > R2 \end{cases}$$

$R1(W, \delta) = W * \cos(\delta)$

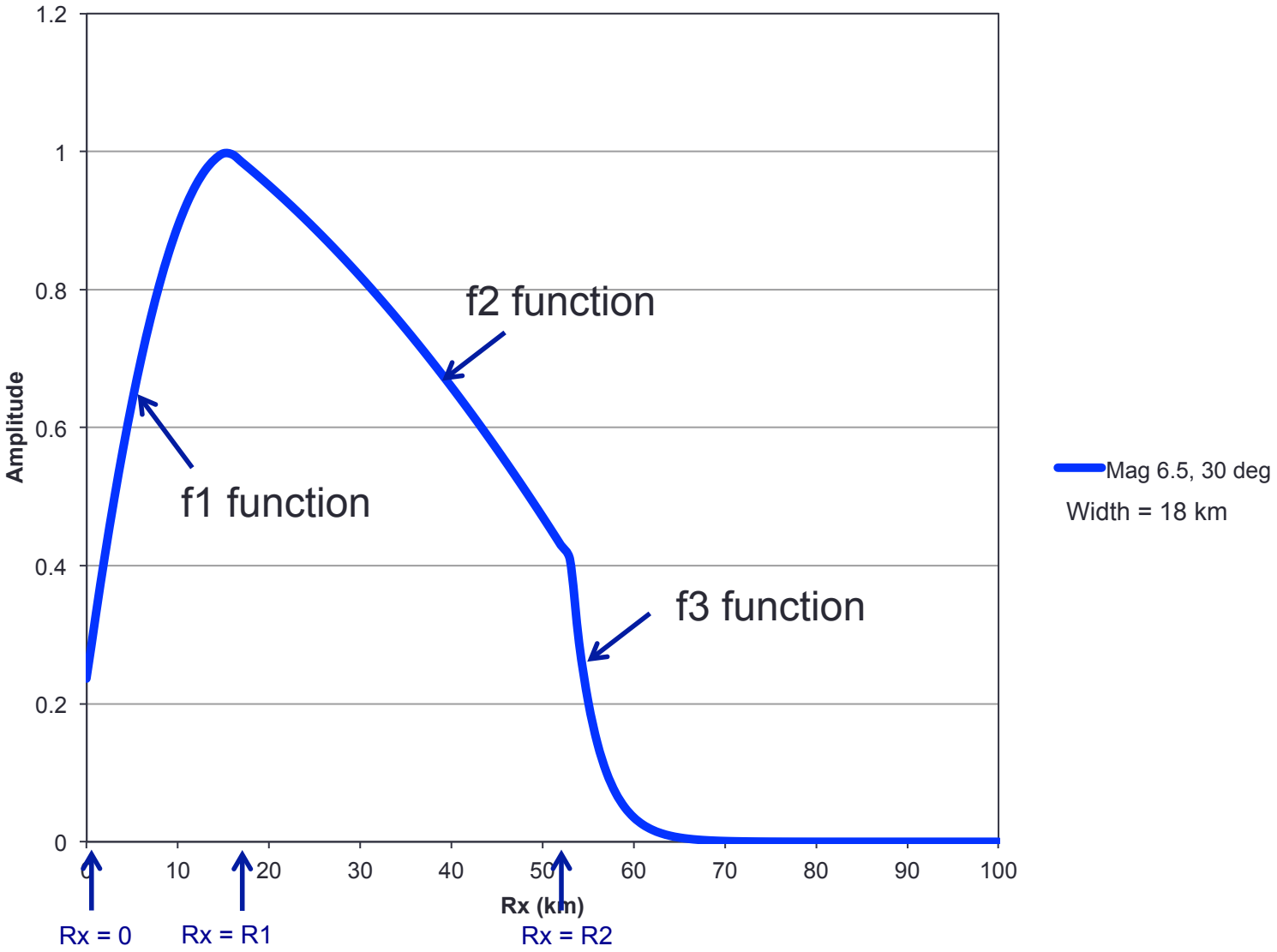
$R2(M) = 62*(M)-350$

$f1(Rx) = h_1 + h_2(Rx/R1) + h_3(Rx/R1)^2$

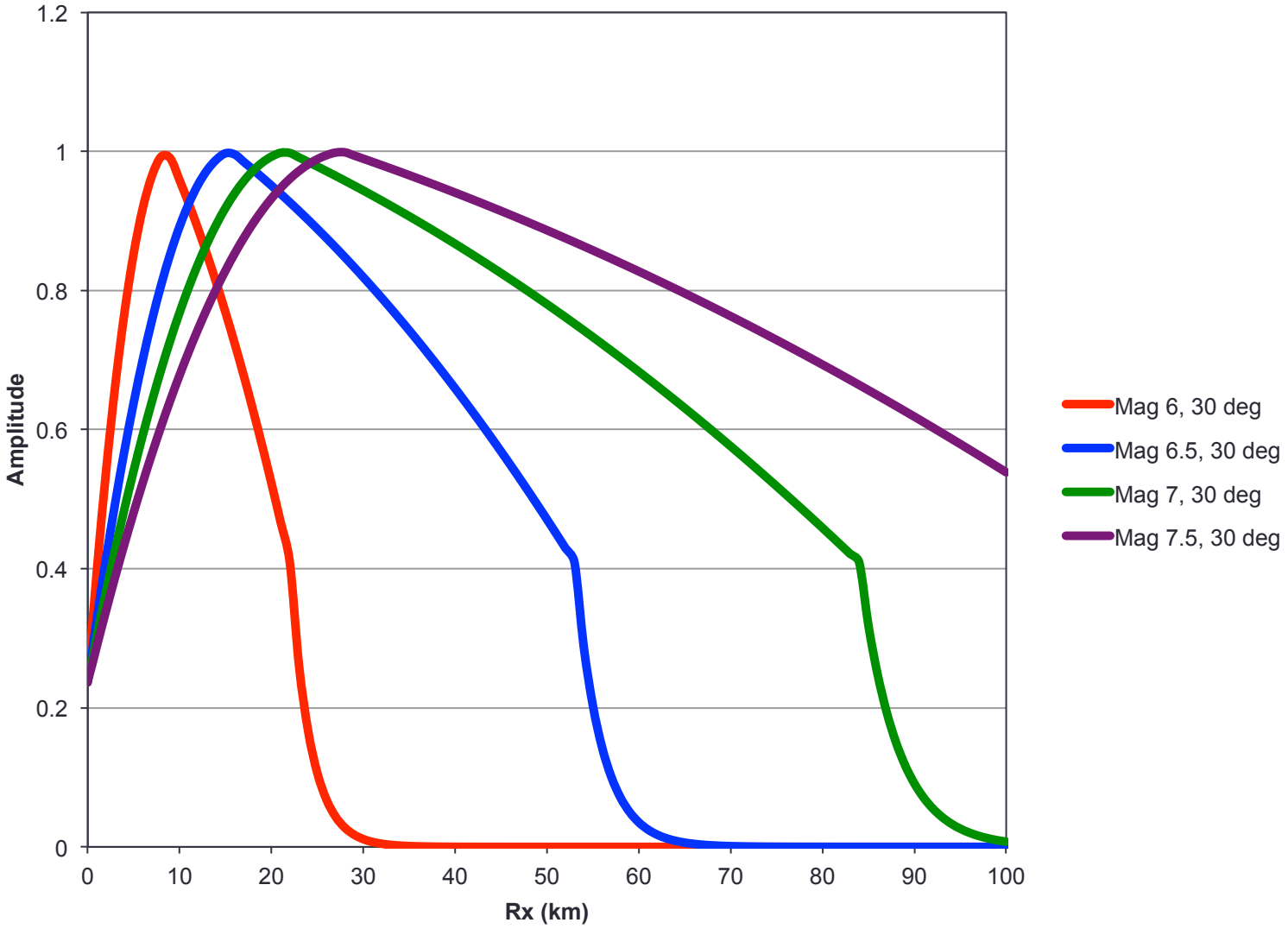
$f2(Rx) = h_4 + h_5((Rx-R1)/(R2-R1)) + h_6((Rx-R1)/(R2-R1))^2$

$f3(Rx, M) = (h_4 + h_5 + h_6) * e^{(-(Rx-R2)*\gamma)}$ where $\gamma = -0.2(M) + 1.65$

Distance Taper: $T_3(Rx, W, \delta, M)$



Distance Taper: T_3(Rx, W, δ, M)



Hanging Wall Model

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Hanging Wall Function:

$$f_{hw}(M, \delta, W, ZTOR, Rx, Ry, L) = a_1 T_1(\delta) T_2(M) T_3(Rx, W, \delta, M) T_4(ZTOR) T_5(Rx,Ry,L)$$

$T_4(ZTOR)$ Only two points were modeled in the 2012 simulation series…0 km depth and 5 km depth. It is not known if there is a linear interpolation between the two, nor is it known what the amplitude will be greater than 5 km.

However, at **ZTOR = 5km, the amplitude is reduced by 30%** when compared to a surface rupture.

Hanging Wall Model

$$\ln(y) = b1 + (b2+b3*(M-6))*(\ln((Rrup)+b4)) + b5*(M-6) + b6*(M-6)^2 + b7*(Rrup)$$
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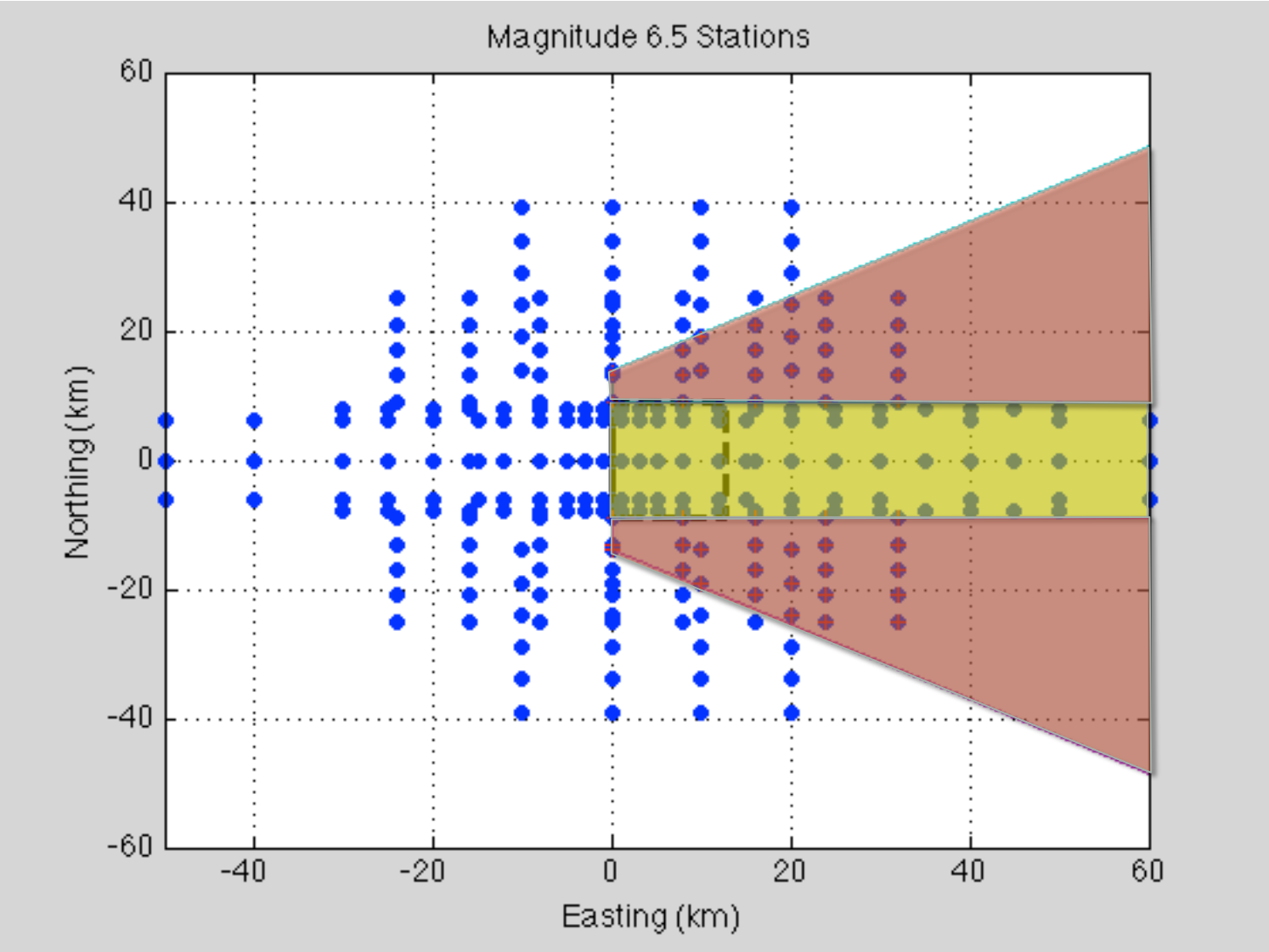
Hanging Wall Function:

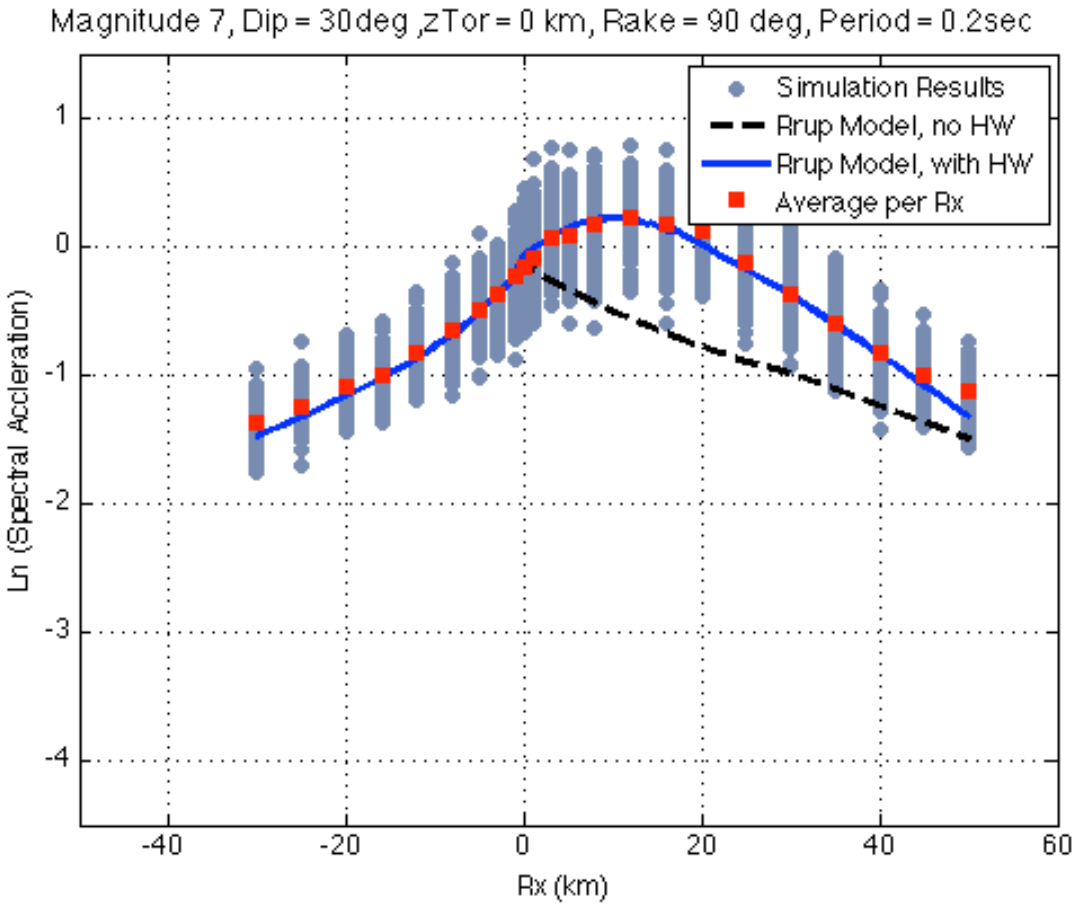
$$f_{hw}(M, \delta, W, ZTOR, Rx, Ry, L) = a_1\, T_1(\delta)\, T_2(M)\, T_3(Rx, W, \delta, M)\, T_4(ZTOR)\, T_5(Rx,Ry,L)$$

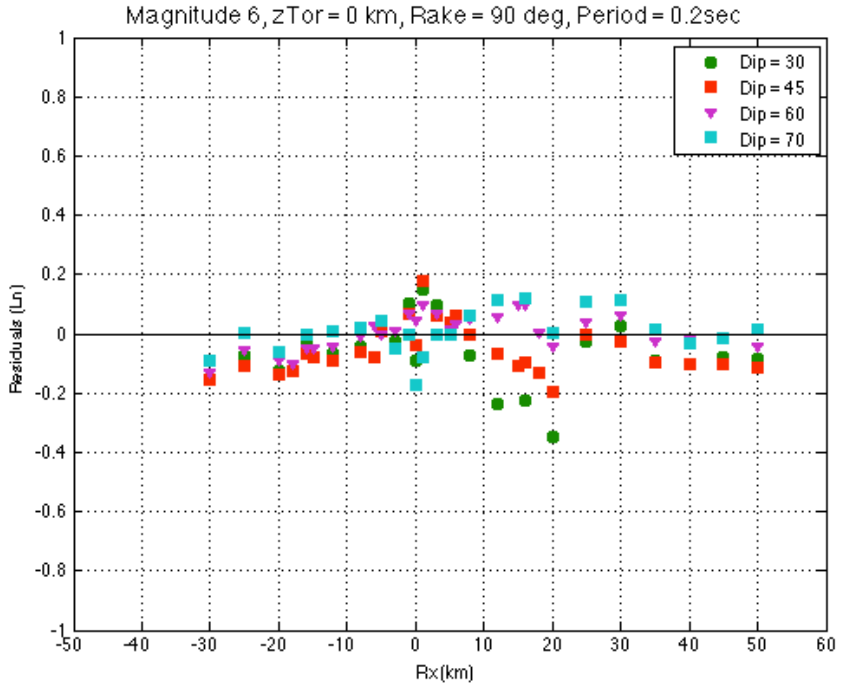
$$T_5(Rx,Ry,L) = \begin{cases} 1 & \text{for } abs(Ry) \le L/2 \\ [(0.577*Rx + 5) - (abs(Ry) - L/2)] / (0.577*Rx + 5) & \text{for } L/2 < abs(Ry) < 0.577*Rx + 5 + L/2 \\ 0 & \text{for } abs(Ry) \ge 0.577*Rx + 5 + L/2 \end{cases}$$

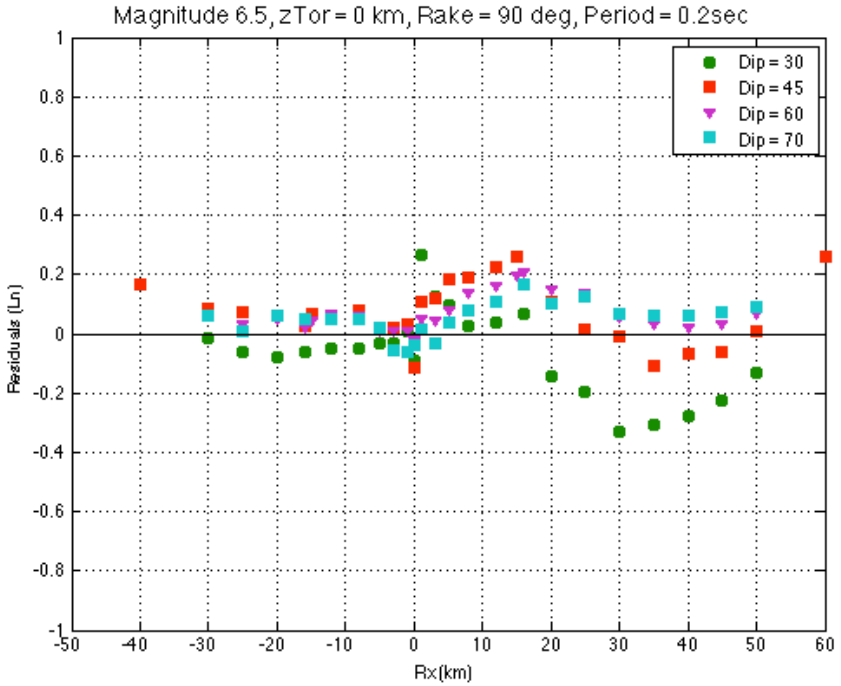
Side Taper: T_5(Rx, Ry, L)

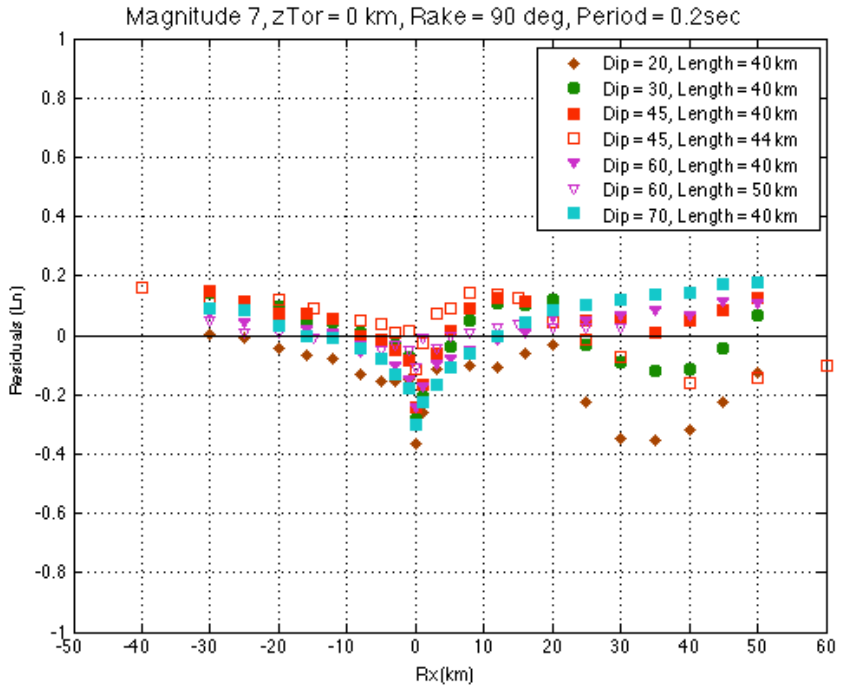


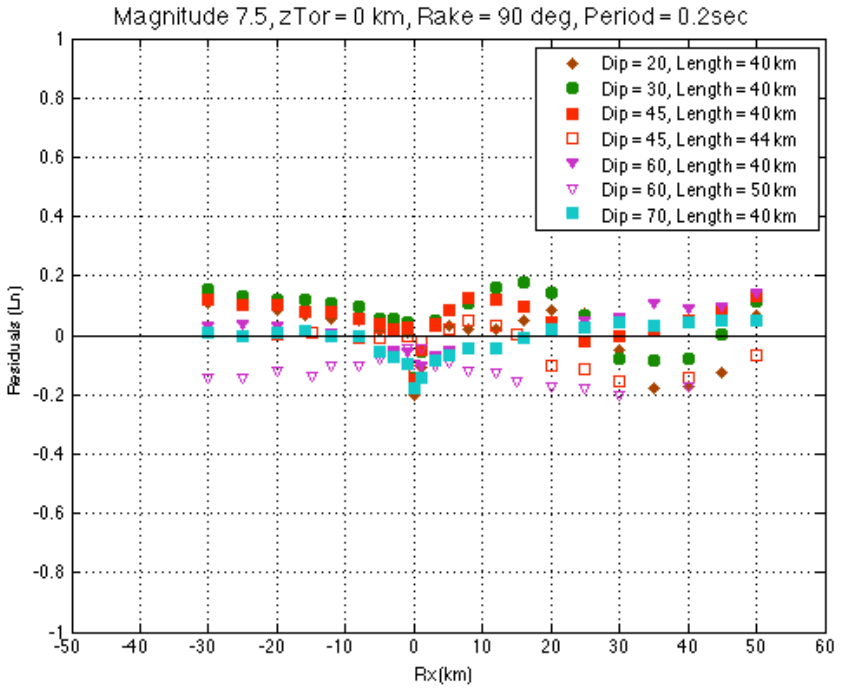
SURFACE RUPTURES



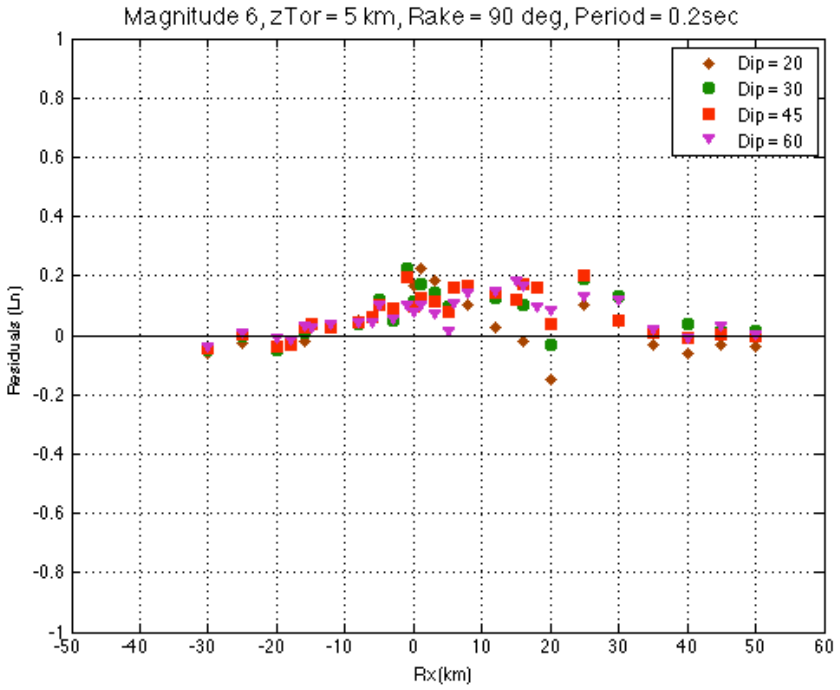

Magnitude 6, zTor = 0 km, Rake = 90 deg, Period = 0.2sec
Dip = 30
Dip = 45
Dip = 60
Dip = 70
Residuals (Ln)
Rx(km)

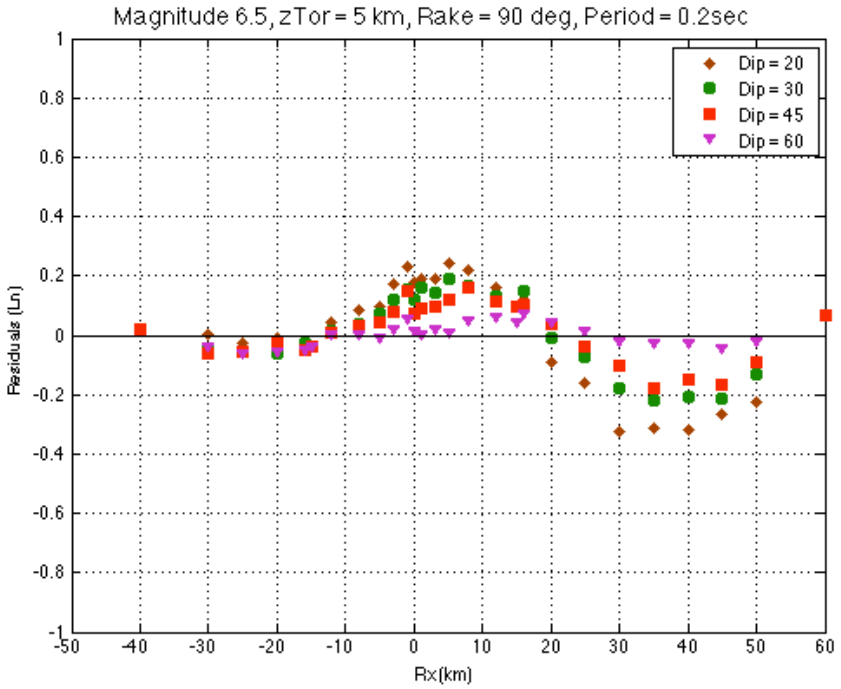

Magnitude 6.5, zTor = 0 km, Rake = 90 deg, Period = 0.2sec
Dip = 30
Dip = 45
Dip = 60
Dip = 70
Residuals (Ln)
Rx(km)


Magnitude 7, zTor = 0 km, Rake = 90 deg, Period = 0.2sec
Dip = 20, Length = 40 km
Dip = 30, Length = 40 km
Dip = 45, Length = 40 km
Dip = 45, Length = 44 km
Dip = 60, Length = 40 km
Dip = 60, Length = 50 km
Dip = 70, Length = 40 km
Residuals (Ln)
Rx(km)


Magnitude 7.5, zTor = 0 km, Rake = 90 deg, Period = 0.2sec
Dip = 20, Length = 40 km
Dip = 30, Length = 40 km
Dip = 45, Length = 40 km
Dip = 45, Length = 44 km
Dip = 60, Length = 40 km
Dip = 60, Length = 50 km
Dip = 70, Length = 40 km
Residuals (Ln)
Rx(km)

BURIED RUPTURES


Magnitude 6, zTor = 5 km, Rake = 90 deg, Period = 0.2sec
Dip = 20
Dip = 30
Dip = 45
Dip = 60
Residuals (Ln)
Rx(km)


Magnitude 6.5, zTor = 5 km, Rake = 90 deg, Period = 0.2sec
Dip = 20
Dip = 30
Dip = 45
Dip = 60
Residuals (Ln)
Rx(km)

QUESTIONS?

Reference:

- Graves, R. (2011). “Broadband Simulation Plan for Analysis of Footwall / Hanging Wall and Rupture Directivity Effects”