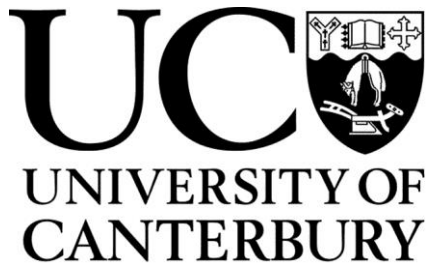# Explicit Modeling of Nonlinear Site Effects in Physics-Based Ground Motion Simulations of the 2010-2011 Canterbury Earthquake Sequence

Chris de la Torre
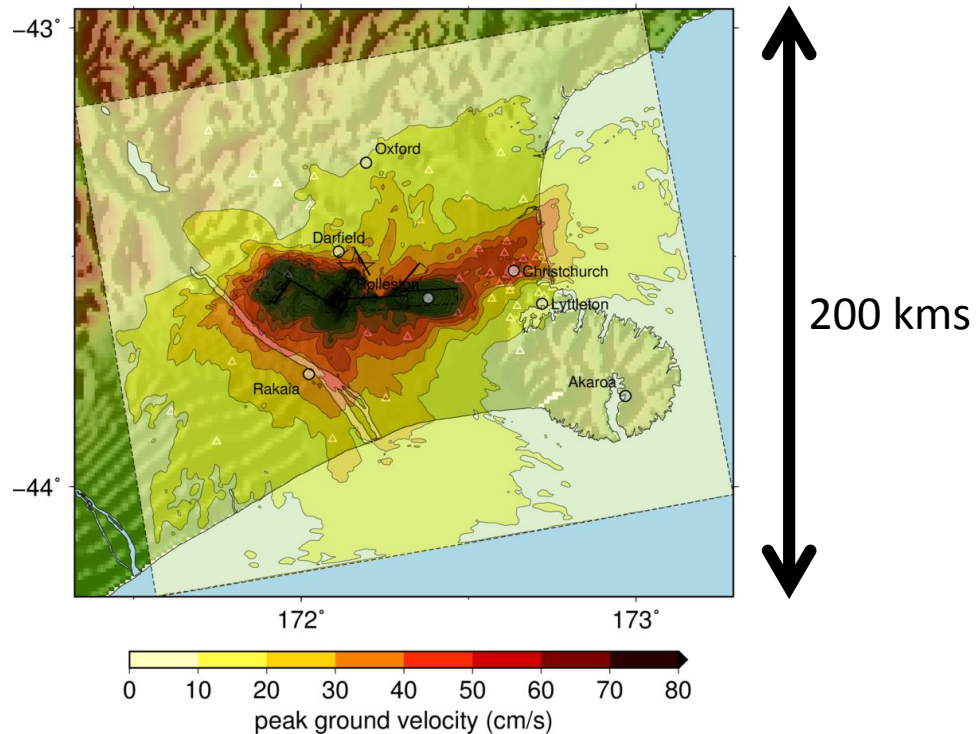
Supervisor:

Brendon Bradley

UNIVERSITY OF CANTERBURY

QuakeCoRE

NZ Centre for Earthquake Resilience

Site Effects in Ground Motion Simulation

Simulations Models
- Regional Scale (100s kms)
- $V_{S,min}$ = 500 – 1000 m/s
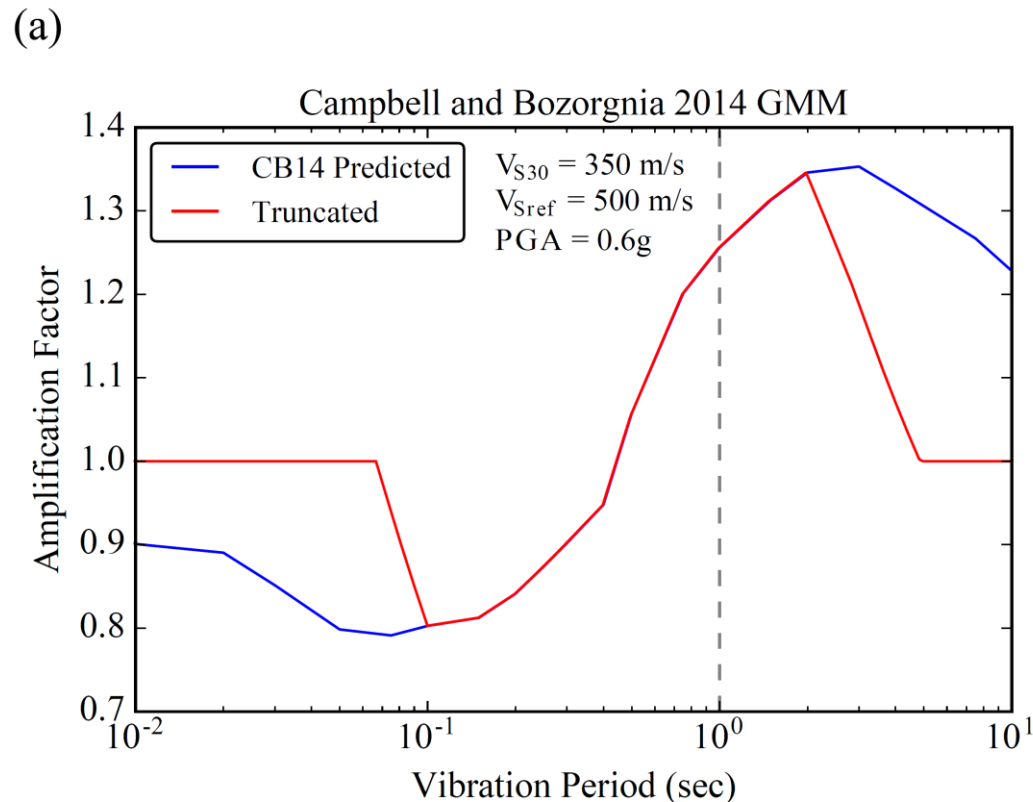- Grid spacing 100 – 400 m

Site Effects
- Local Scale (meters)
- V_S ground surface < 500 m/s
- Grid spacing < 1 m

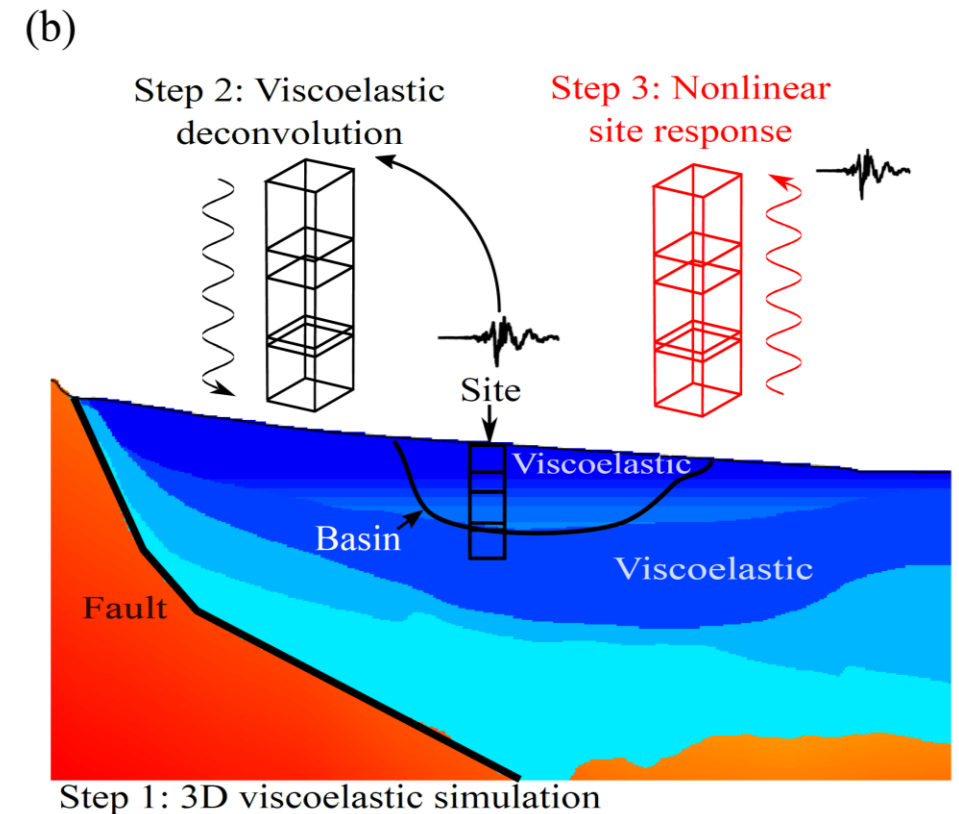
200 kms

5 m

Methods for Modeling Site Effects

Standard of Practice:
- Empirical V_{S30}-based site response
- Site amplification from GMM

Our Approach:
- Explicit modeling of site effects
- Wave propagation site response

(a)

Campbell and Bozorgnia 2014 GMM

$V_{S30} = 350$ m/s
$V_{Sref} = 500$ m/s
PGA = 0.6g

CB14 Predicted
Truncated

Amplification Factor

Vibration Period (sec)

(b)

Step 2: Viscoelastic deconvolution

Step 3: Nonlinear site response

Site

Viscoelastic

Basin

Viscoelastic

Fault

Step 1: 3D viscoelastic simulation

# Wave Propagation Site Response Methodology

- Deconvolve with frequency domain solution
  - From $V_{S,ref}$ to stiff soil/rock
  - Riccarton gravel: $V_S = 400 - 600$ m/s
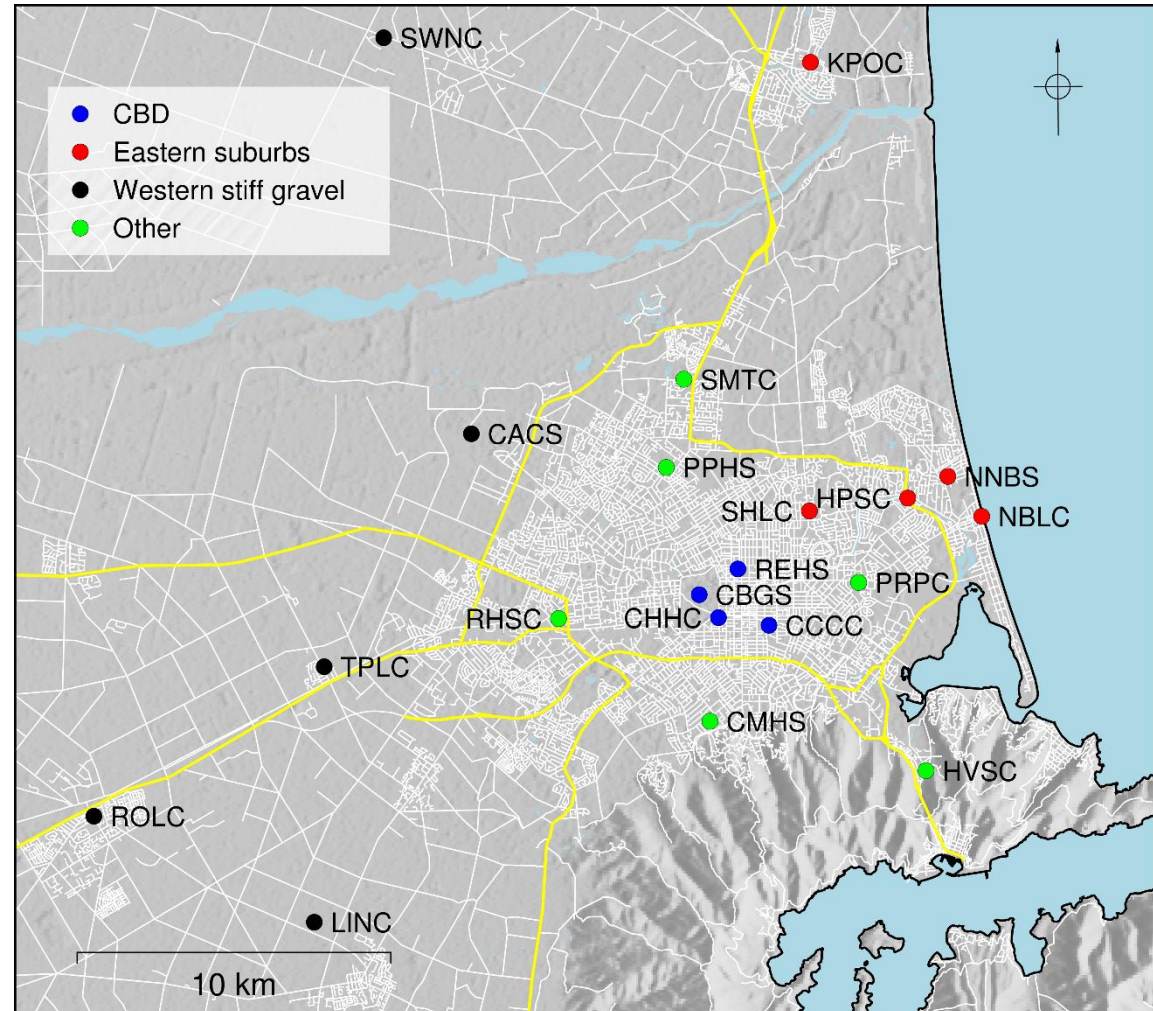
- OpenSees FE Code

- PDMY Constitutive Model
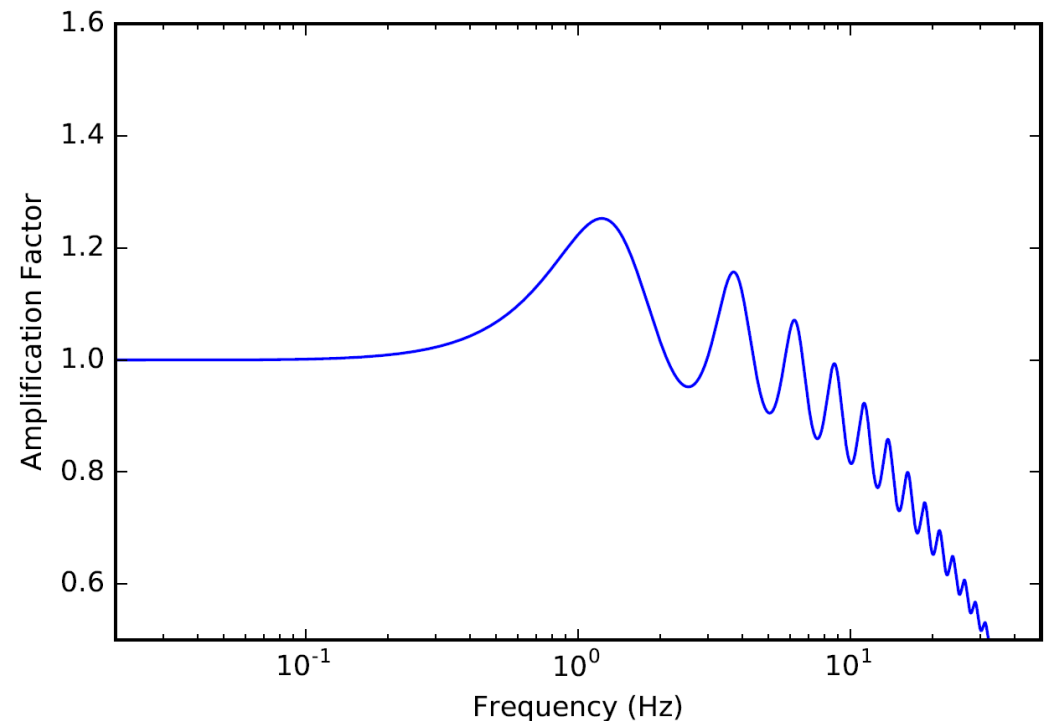
Sites and Earthquakes Considered

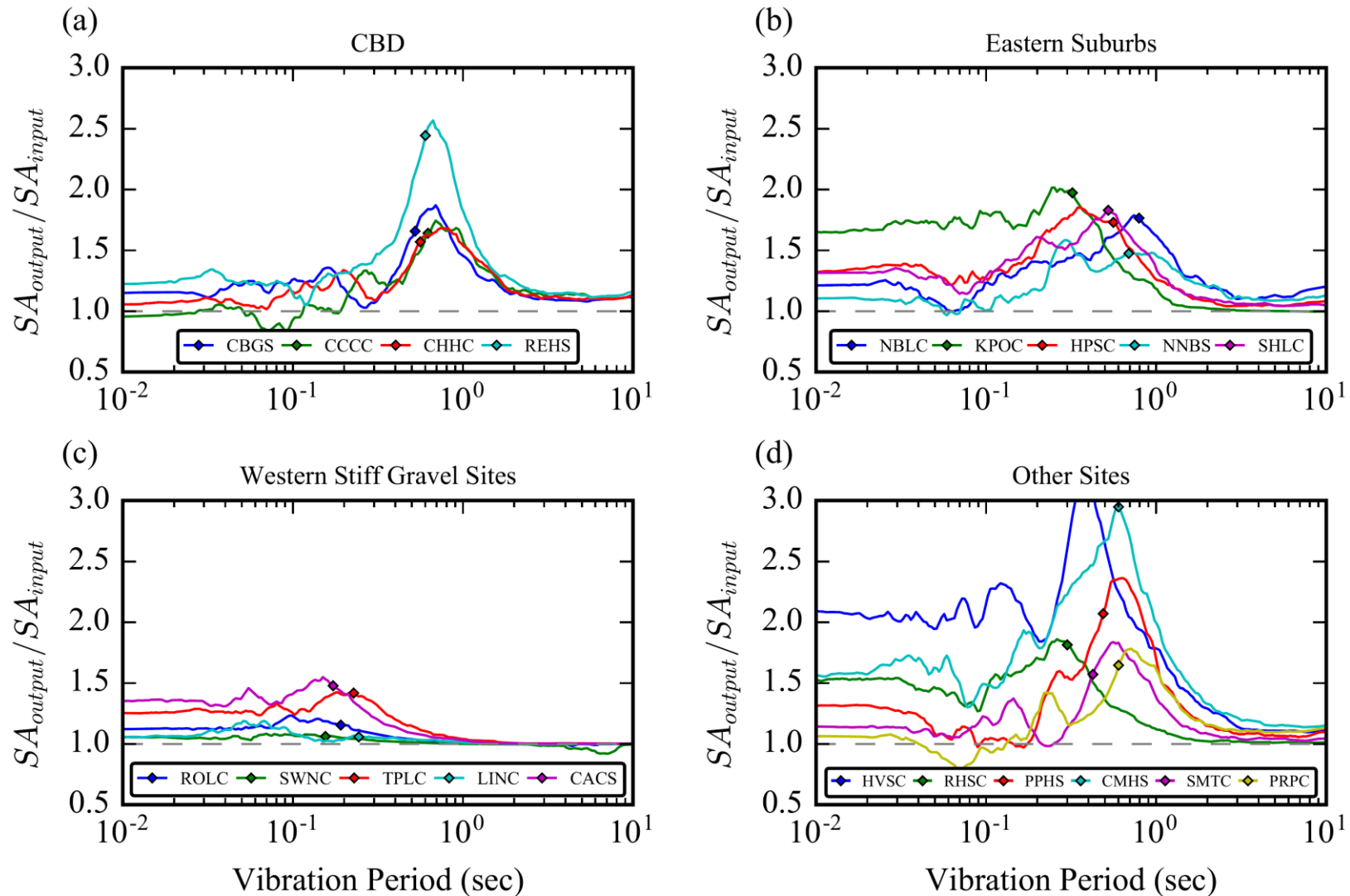| Event Date	M_W	Event ID
4 September 2010	7.1	1
19 October 2010	4.8	2
26 December 2010	4.7	3
22 February 2011	6.2	4
16 April 2011	5.0	5
13 June 2011 (1:01 p.m.)	5.3	6
13 June 2011 (2:20 p.m.)	6.0	7
21 June 2011	5.2	8
23 December 2011 (12:58 p.m.)	5.8	9
23 December 2011 (2:18 p.m.)	5.9	10
14 February 2016	5.8	11
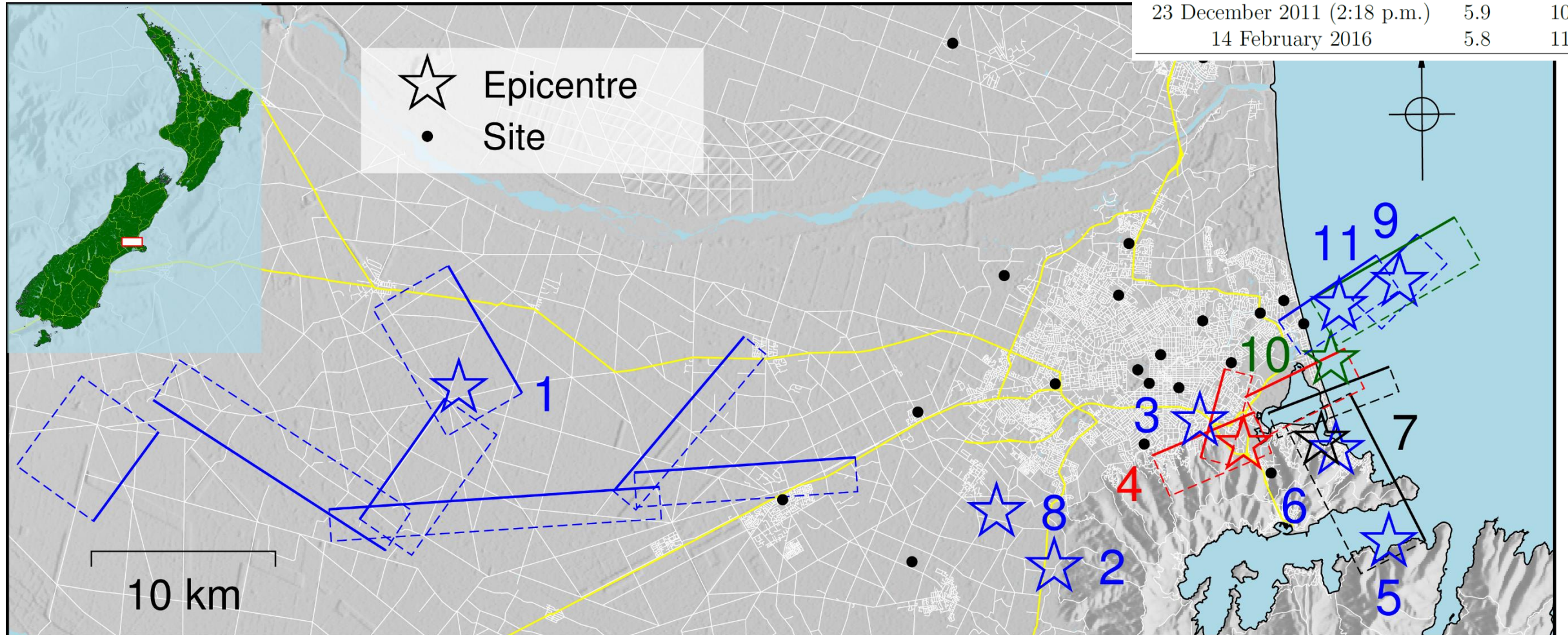
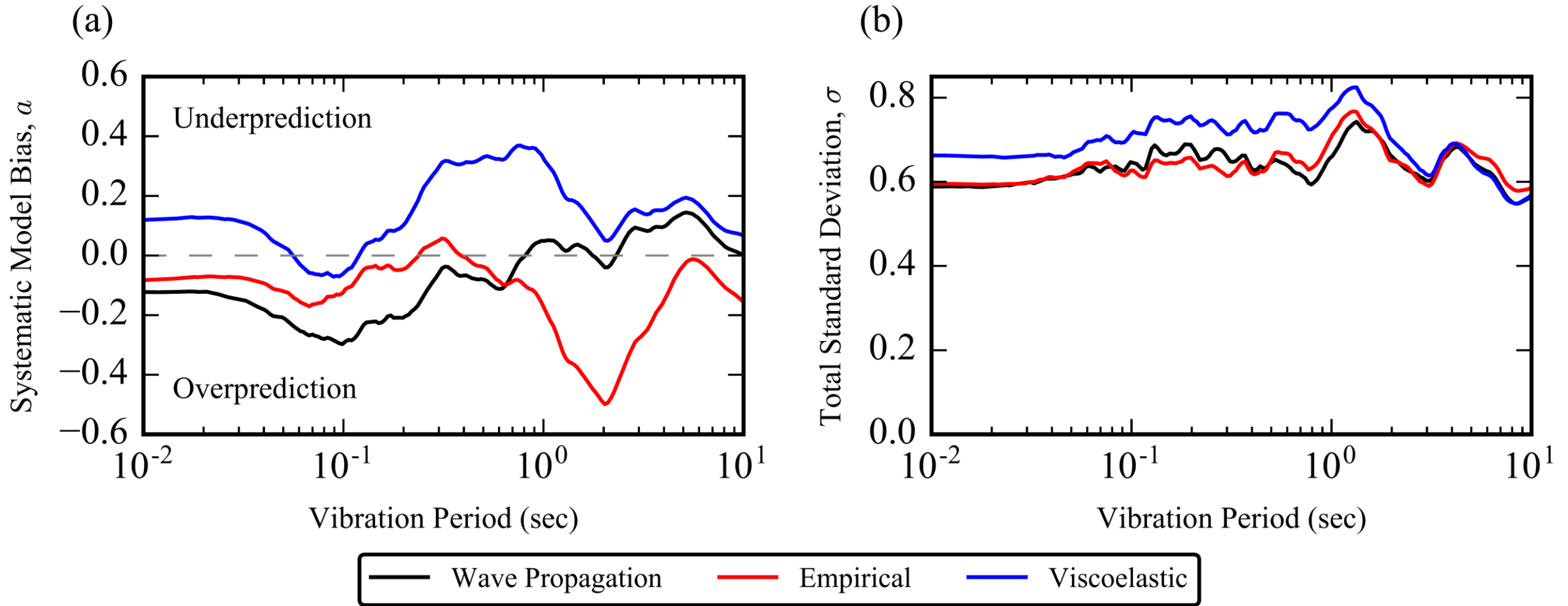# Christchurch Strong Motion Stations

Shear Wave Velocity Profiles
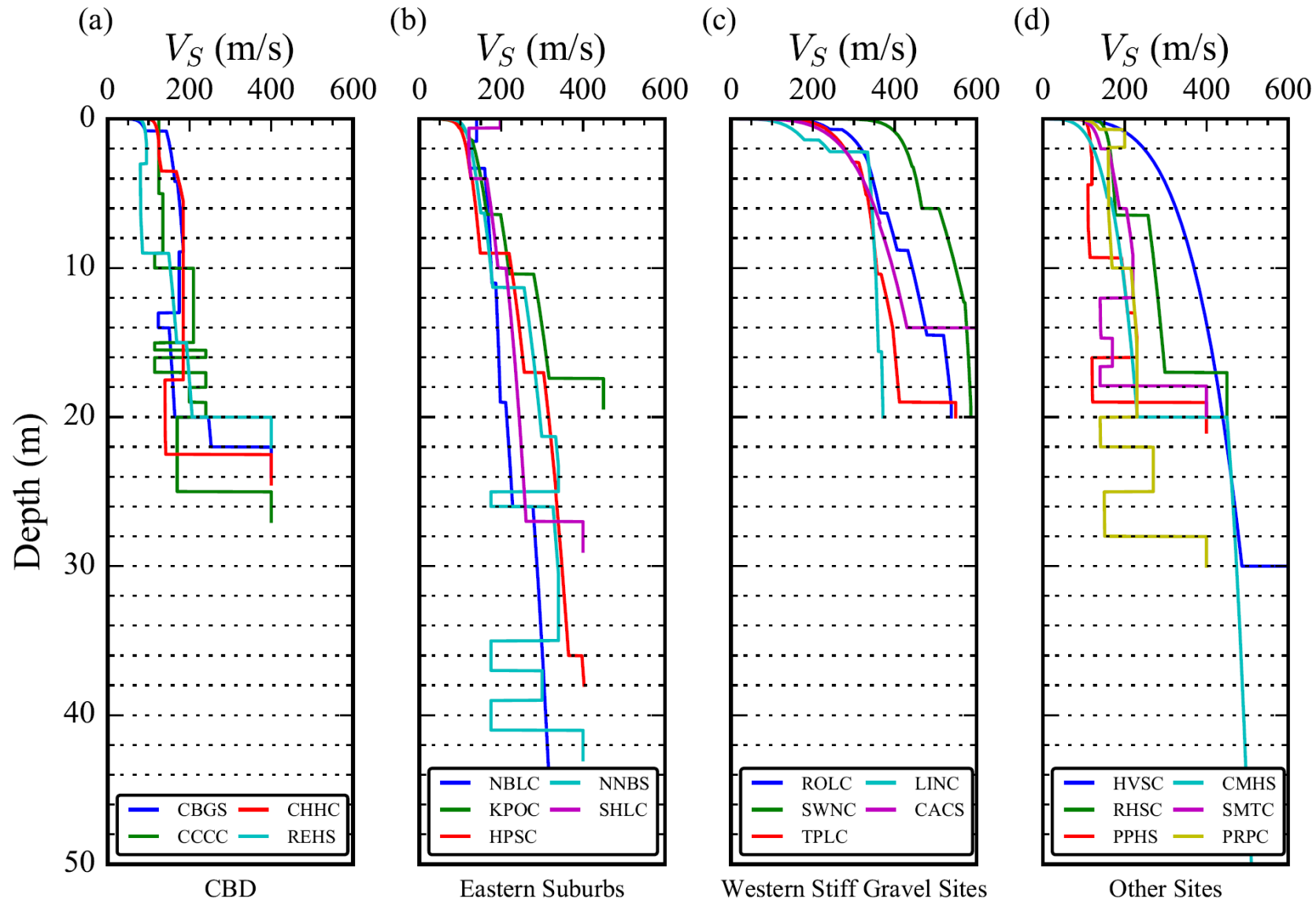
Site Response Characteristics

(a) CBD

(b) Eastern Suburbs

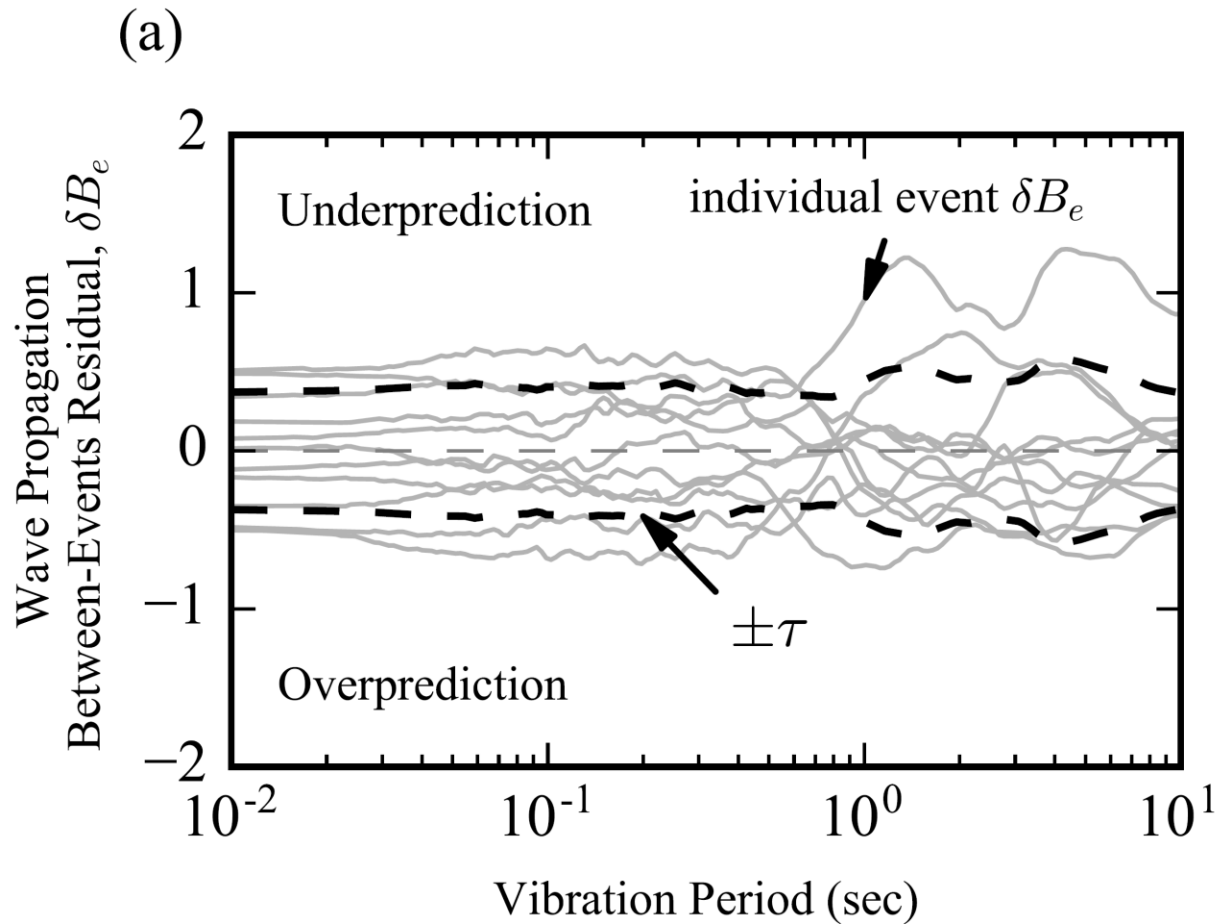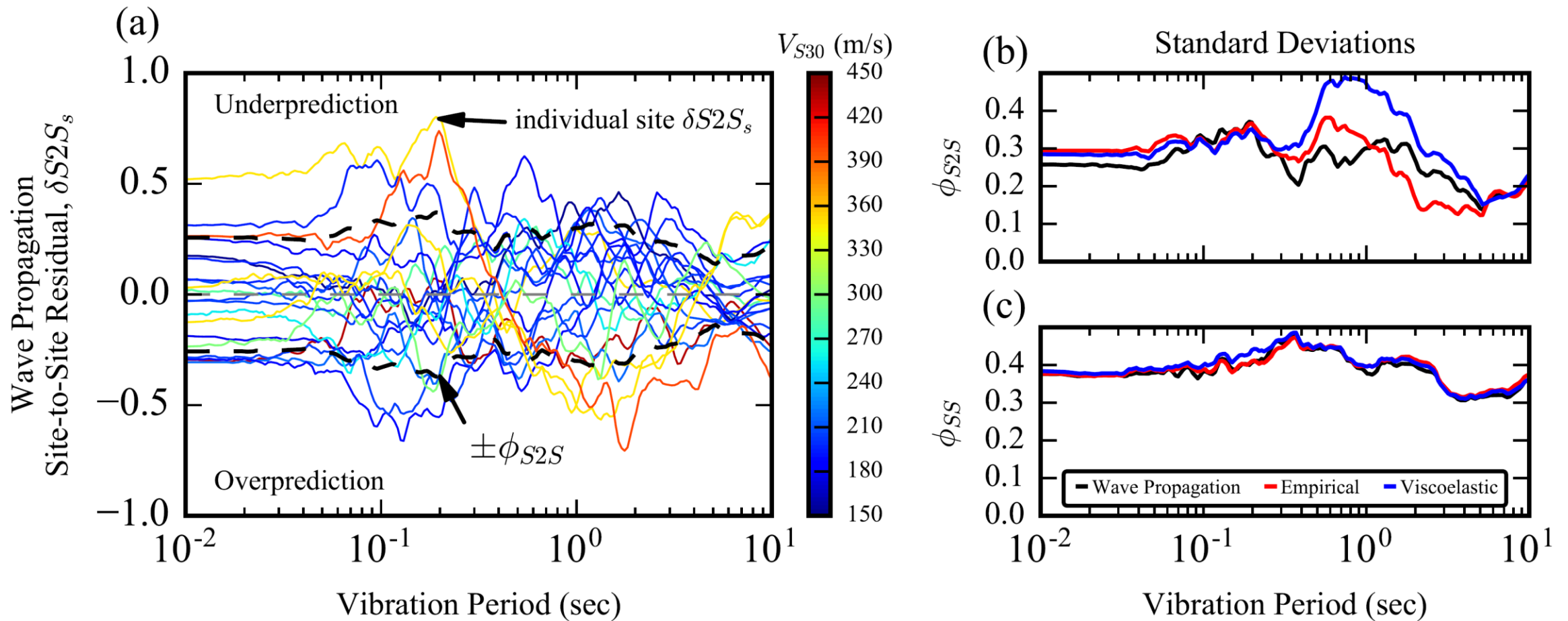(c) Western Stiff Gravel Sites

(d) Other Sites

Total Bias and Uncertainty

(a) Systematic Model Bias, a vs Vibration Period (sec), showing Underprediction and Overprediction regions.

(b) Total Standard Deviation, σ vs Vibration Period (sec).
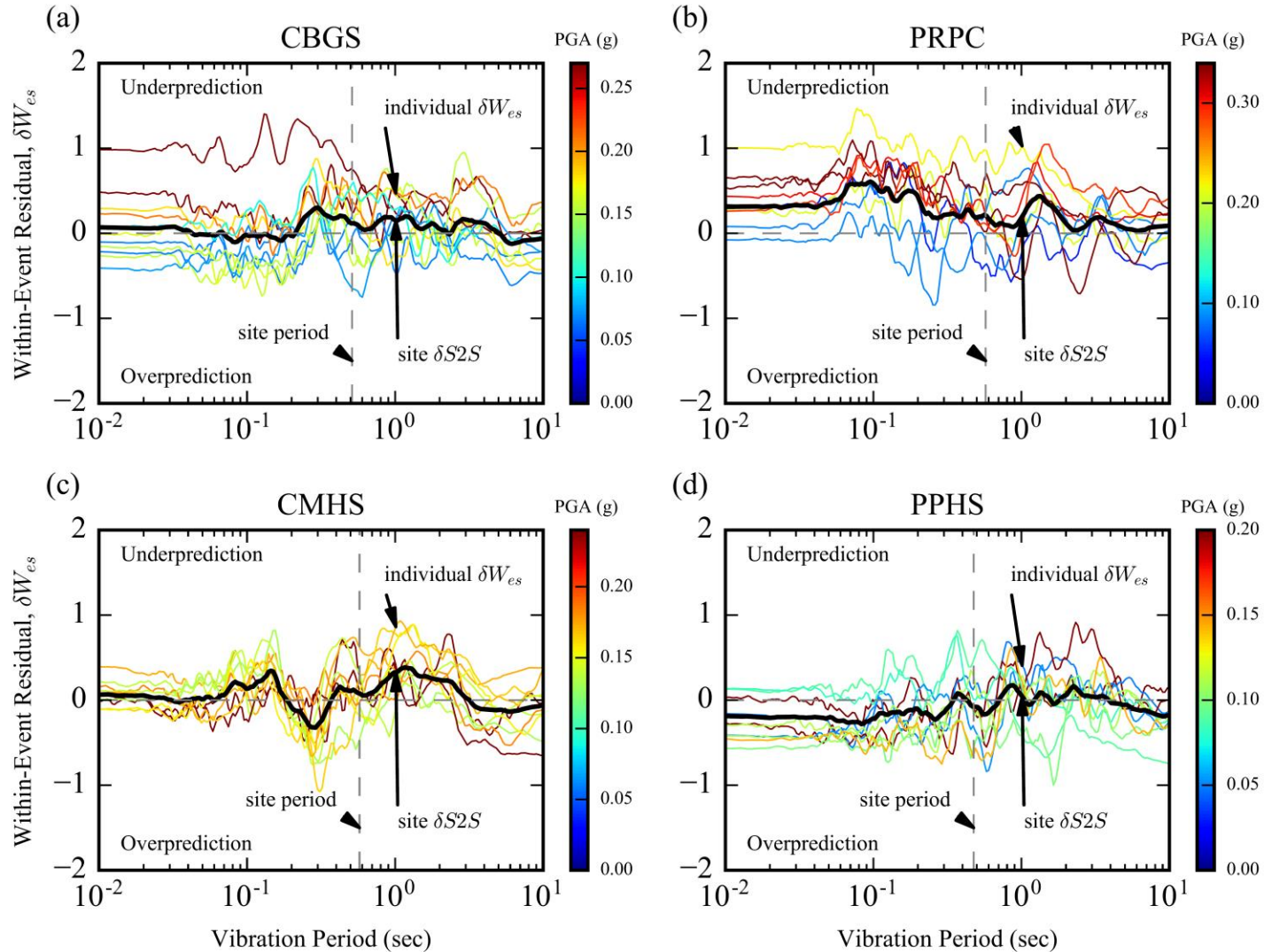
Wave Propagation — Empirical — Viscoelastic
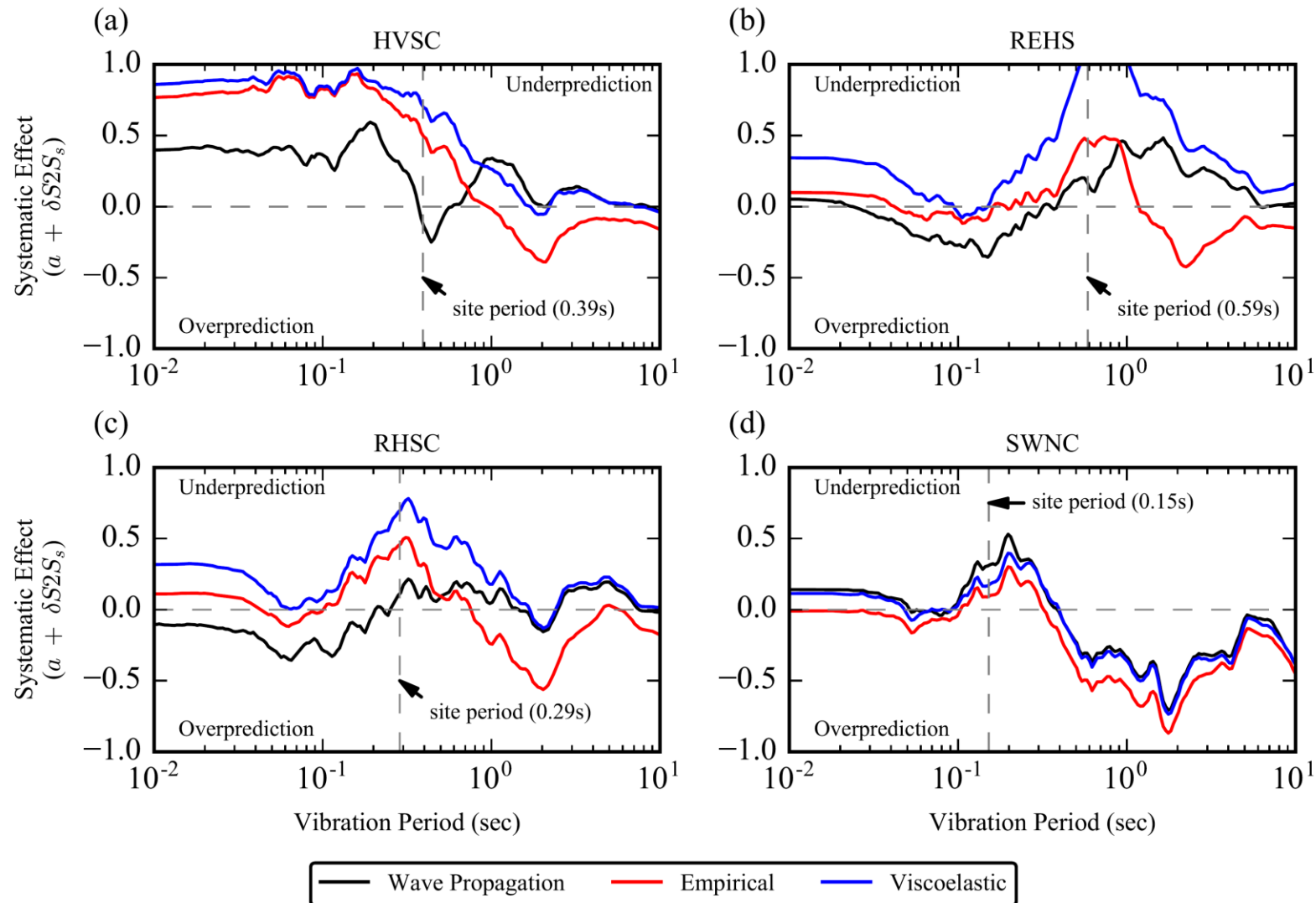
Between-Events Residuals
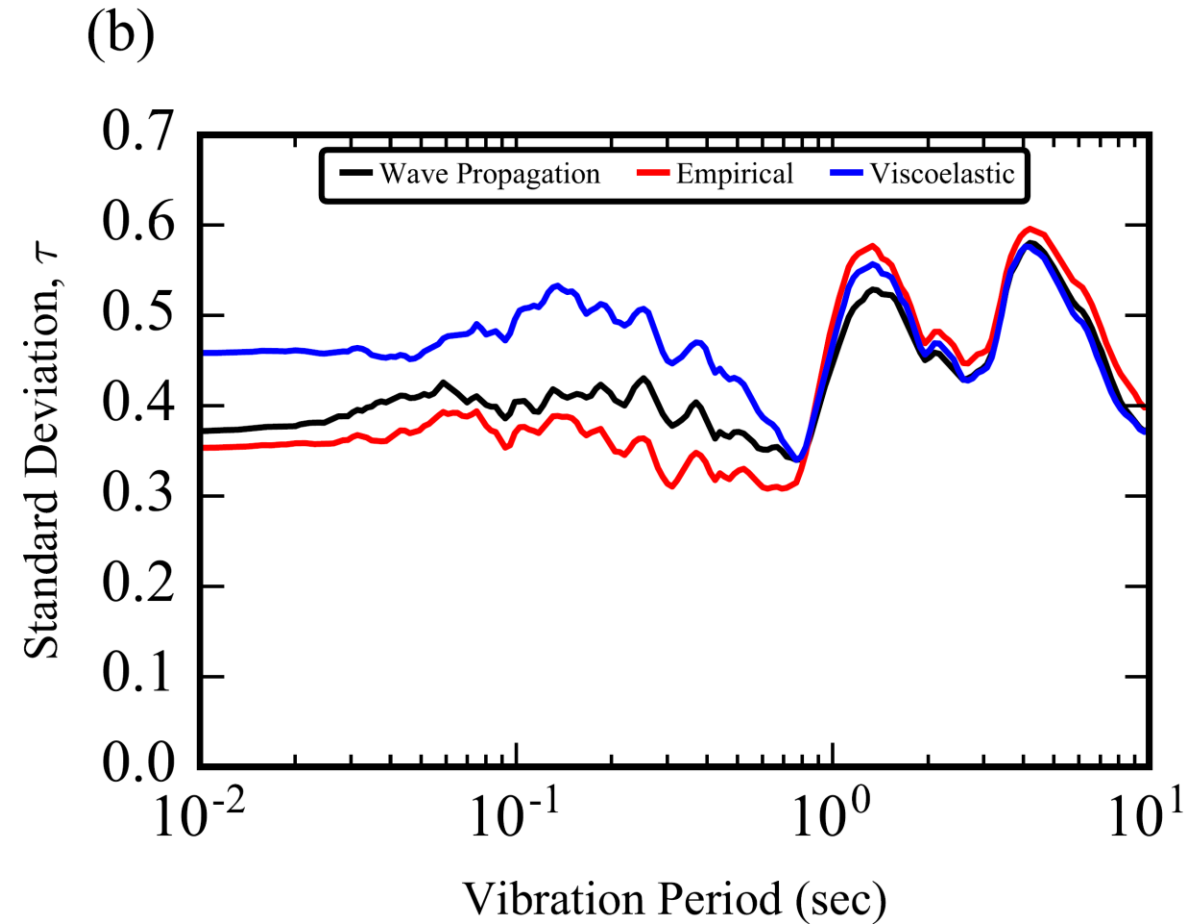
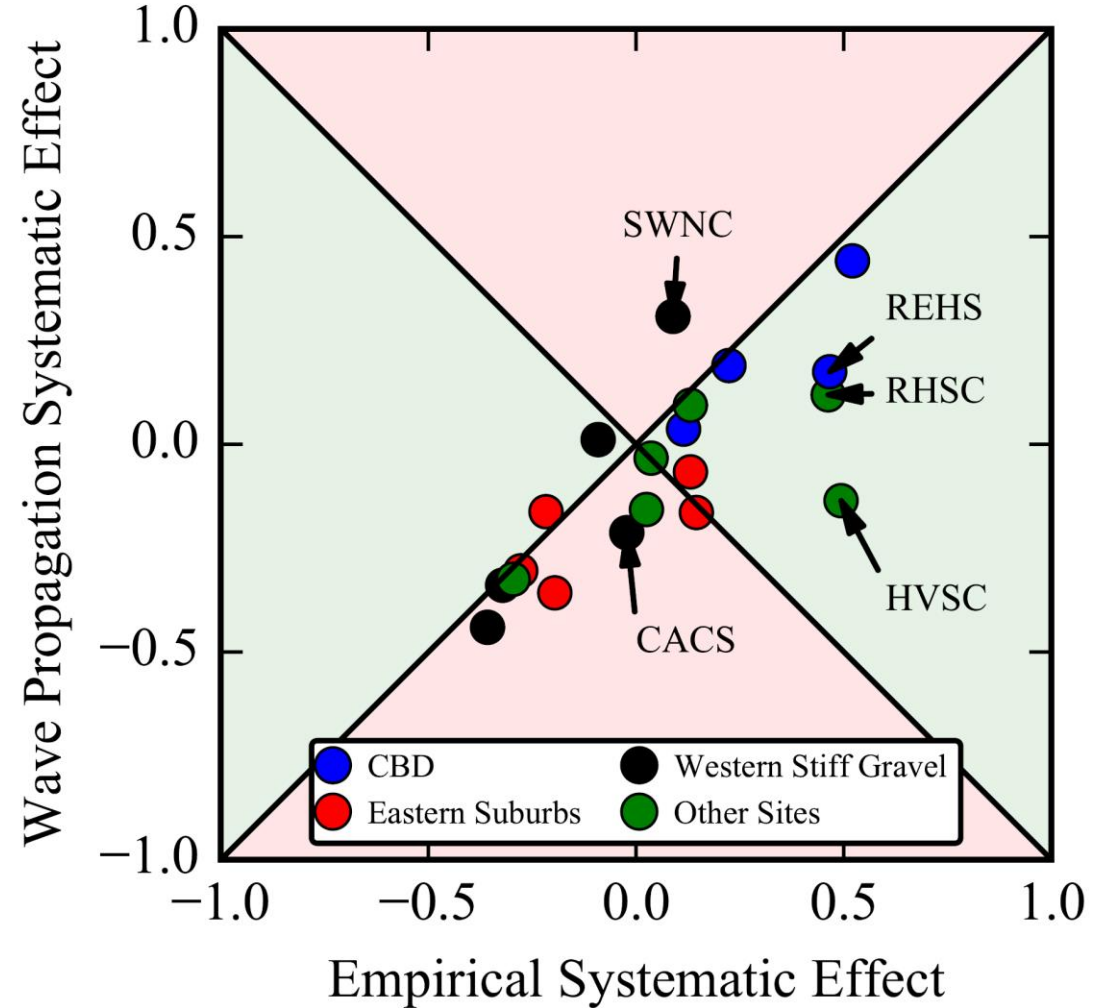# Site-to-Site Residuals

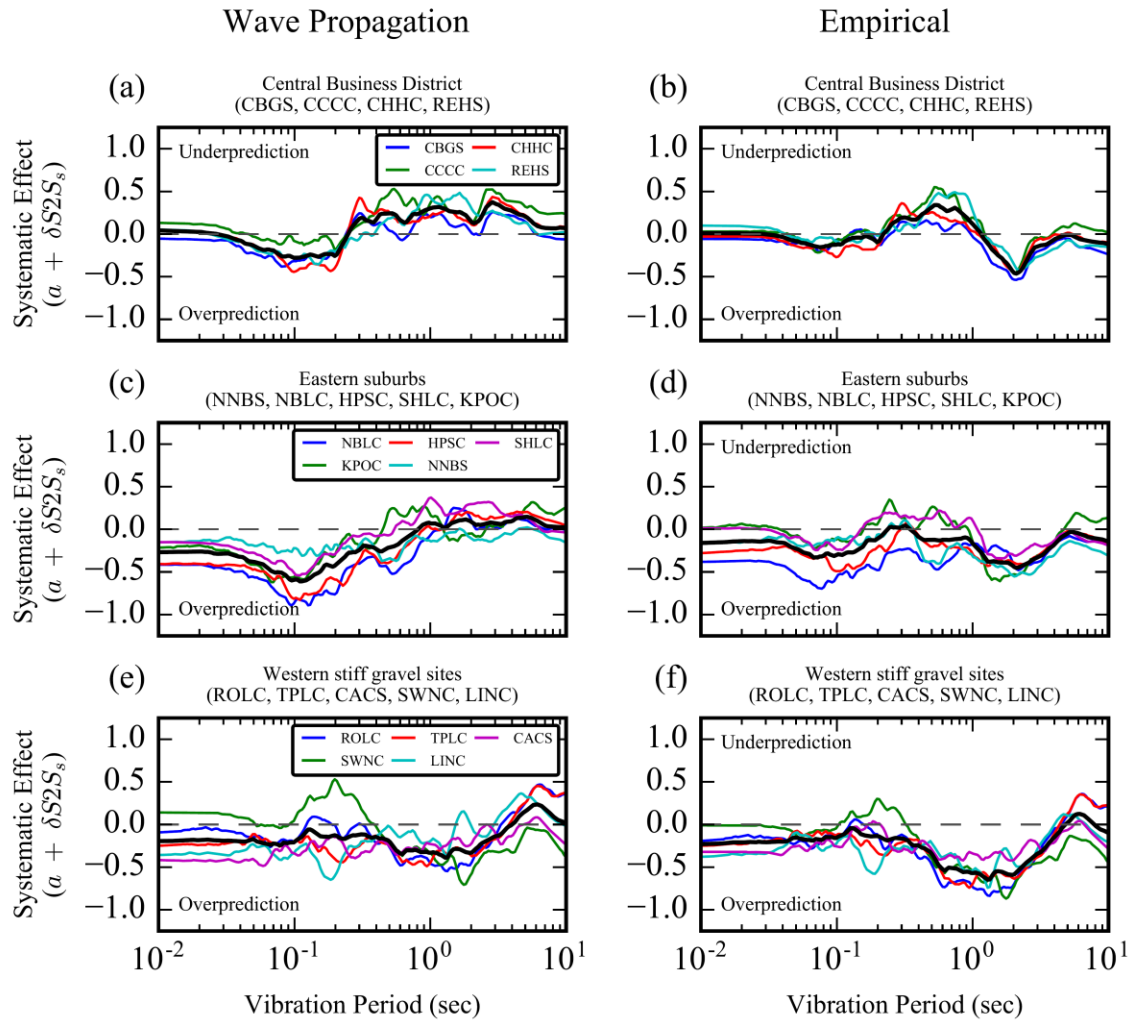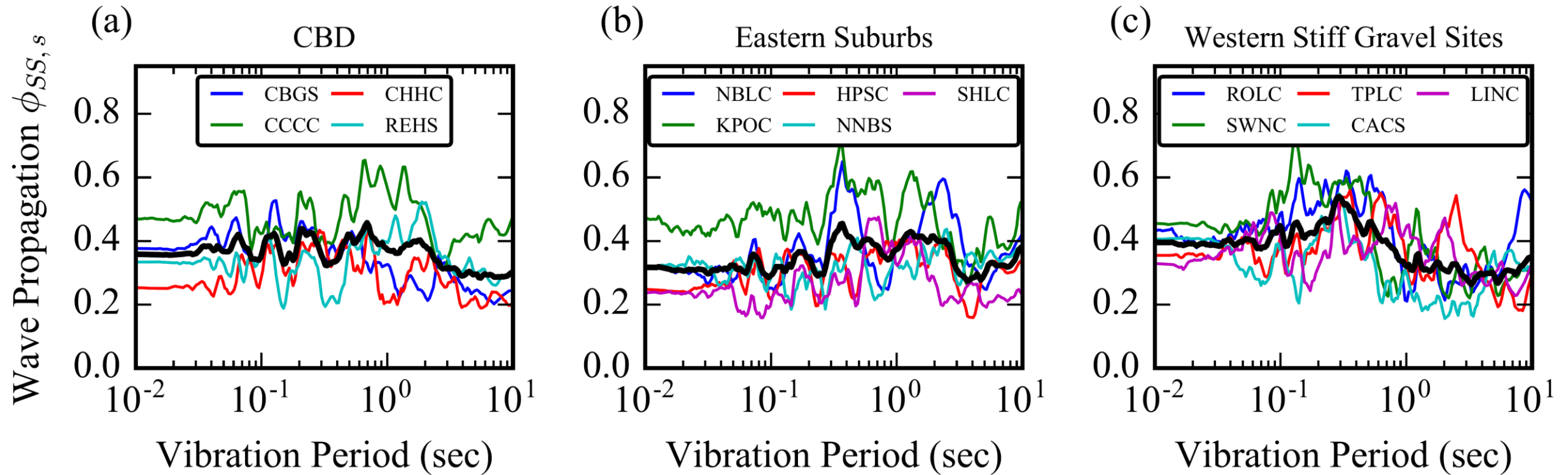# Within-Event Residuals – 4 stations
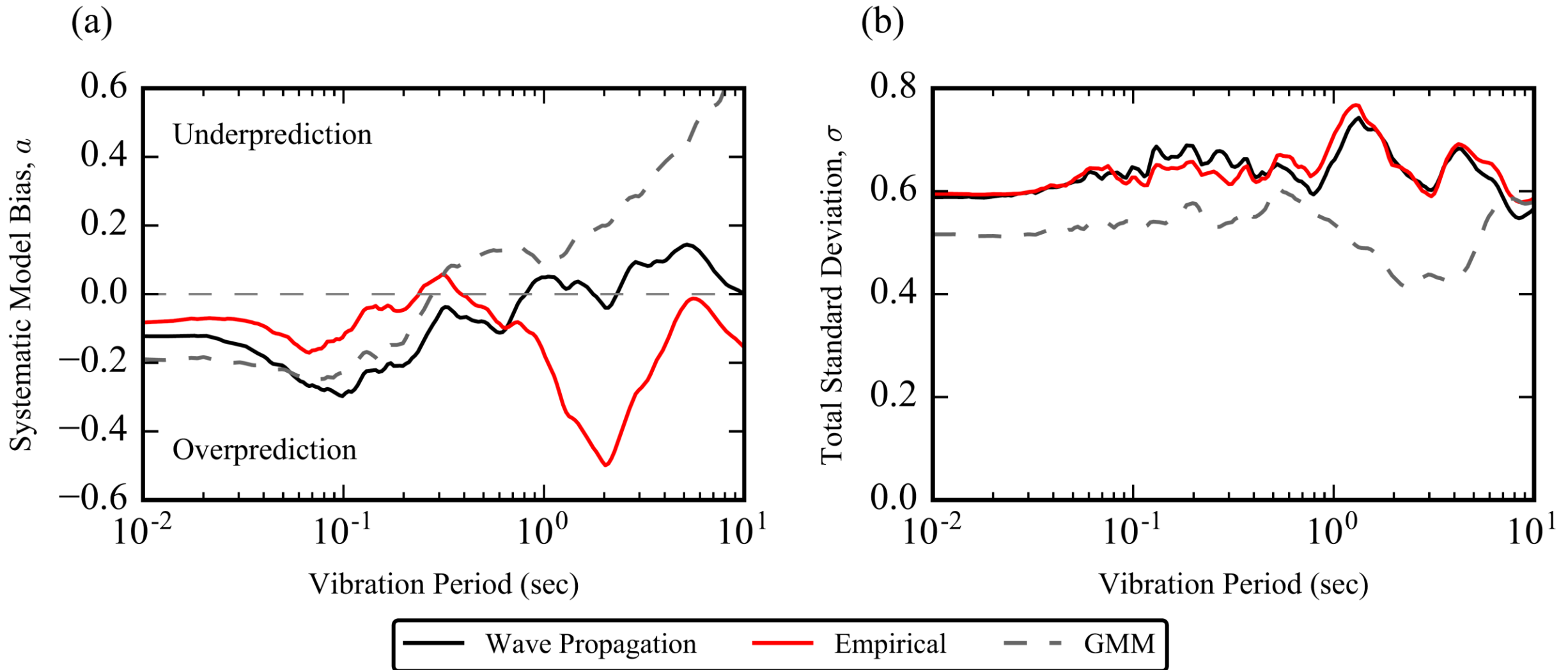
Site Specific Systematic Effect

Systematic Effect – All Sites

Uncertainty in Input Motion

Comparison with Empirical GMM- Bias

Comparison with Empirical GMM- Uncertainty