Residual Analysis and Non-Ergodic Adjustments to Ground Motion Models for the Wellington Region

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DT1 Ground Motion meeting

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Residual Analysis for the Wellington Region

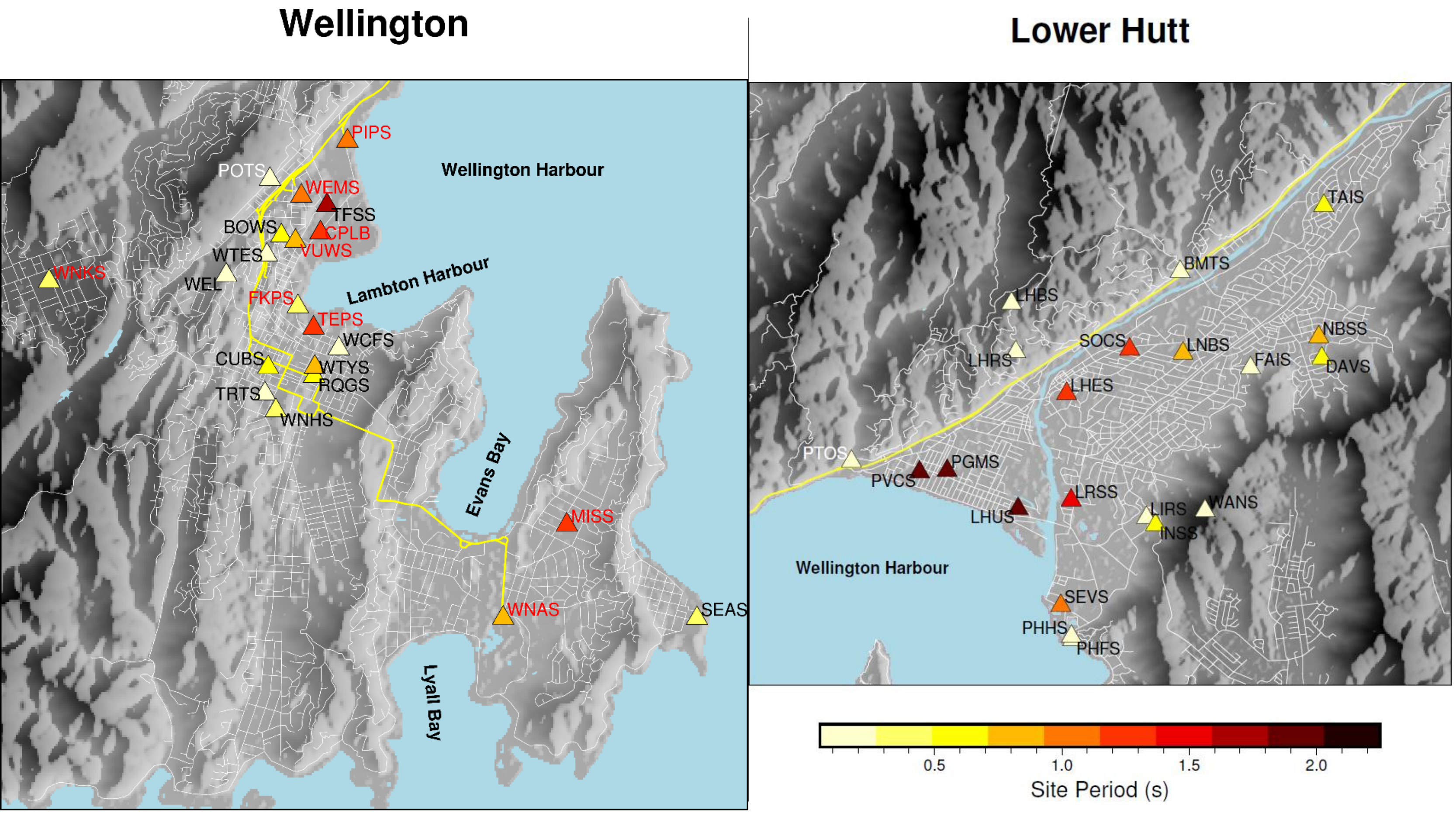
Over-arching Question:

- Do the ground motion models (GMMs) used in the NSHM appropriately capture the amplification from the Wellington basin?

Objectives:

- Rigorously inspect prediction residuals from all GMMs used in NSHM.
- Develop a model for an adjustment factor to capture the full basin amplification.
- Explore details of the adjustment factor:
  - What areas/sites require adjustment?
  - Amplitude and shape (i.e., period-dependence) of adjustment factors.
  - Implementation into GMMs and NSHM.

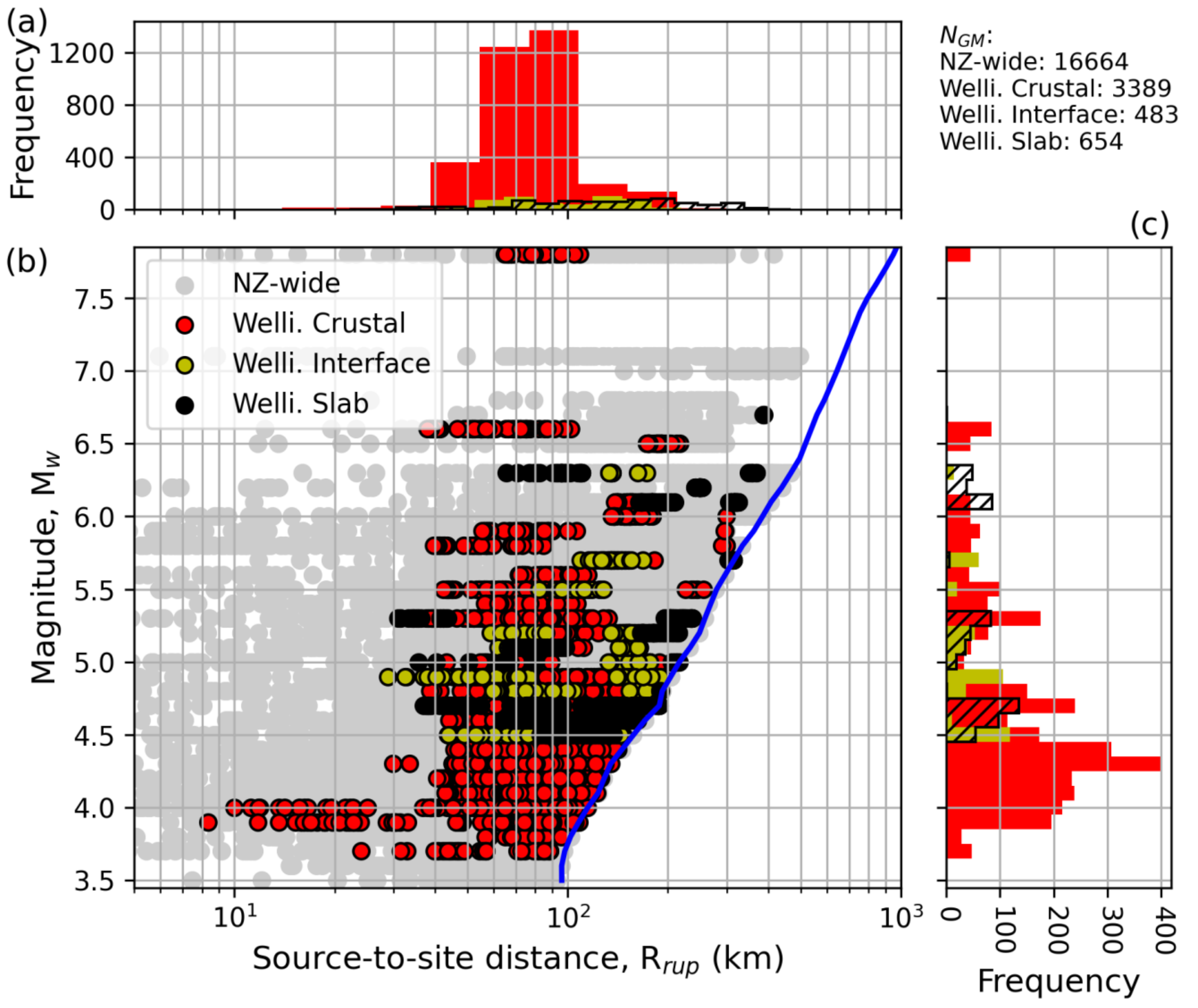
Wellington Basins and Sites Considered



- Wellington CBD
- Lower Hutt
- Surrounding valleys
- 4 sub-basins
- 4 valleys
- 60 stations

Ground Motion Database

- Predictions using all NSHM GMMs and "full" NZ-wide database
  - 16,664 GMs
  - Residual analysis performed on full database
- Only inspecting residuals for the Wellington region:
  - 60 sites: V_{S30} at each SMS
  - 3,389 crustal GMs
  - 483 interface GMs
  - 654 slab GMs
  - Mostly weak "linear" motions



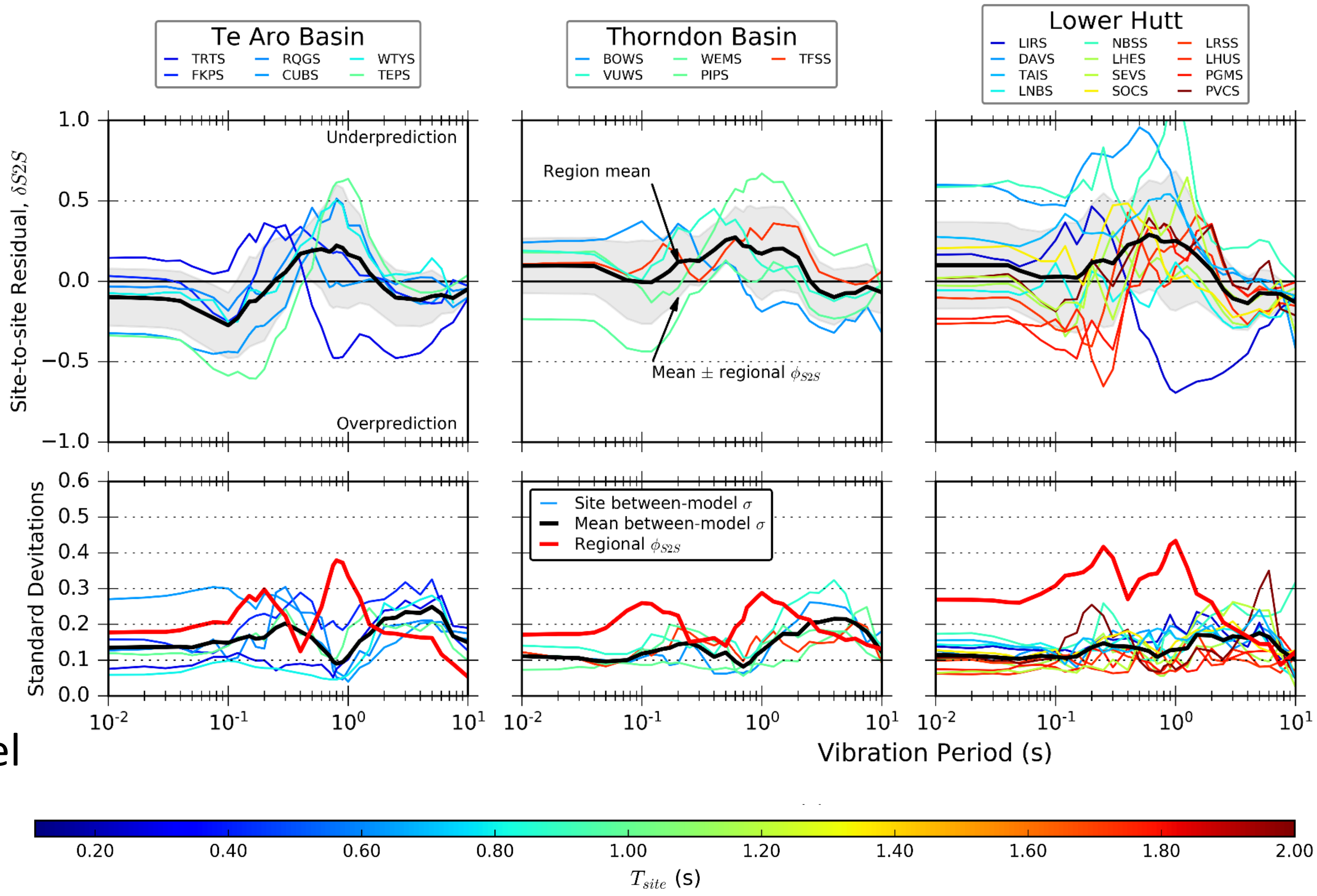
GMMs Considered and Weighting

- Considered only models used in NSHM with the same weights
  - Crustal: NZ-specific, and NGA-West2
  - Interface: NZ-specific, and NGA-Sub (Global)
  - Slab: NZ-specific, and NGA-Sub (Global)
- Equal weight given to crustal, interface and slab

Model ID	Tectonic Type	Weight
A22	Crustal	0.28
S22	Crustal	0.39
ASK14	Crustal	0.066
CY14	Crustal	0.066
CB14	Crustal	0.066
BSSA14	Crustal	0.066
Br13	Crustal	0.066
A22	Interface	0.27
AG20	Interface	0.25
K20	Interface	0.24
P20	Interface	0.24
A22	Slab	0.28
AG20	Slab	0.25
K20	Slab	0.24
P20	Slab	0.23

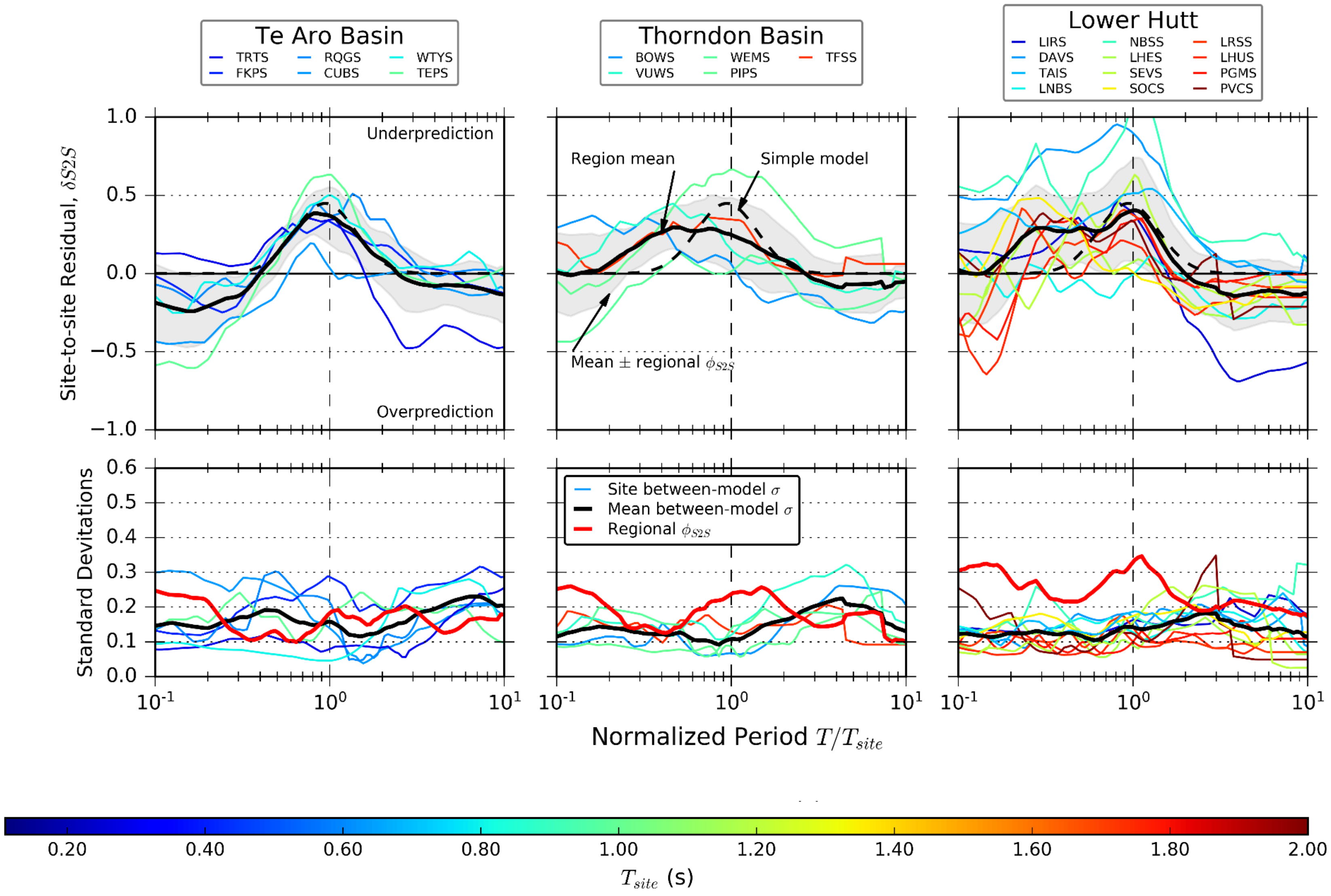
Site-to-Site Residuals: Wellington Basins

- Site-to-site residuals
- Average remaining part not captured by V_{S30} site response model
- Underprediction at T=0.3-2 s
- Variability between sites even within sub-regions
- Highest variability around peak residual
- Relatively small model-to-model variability



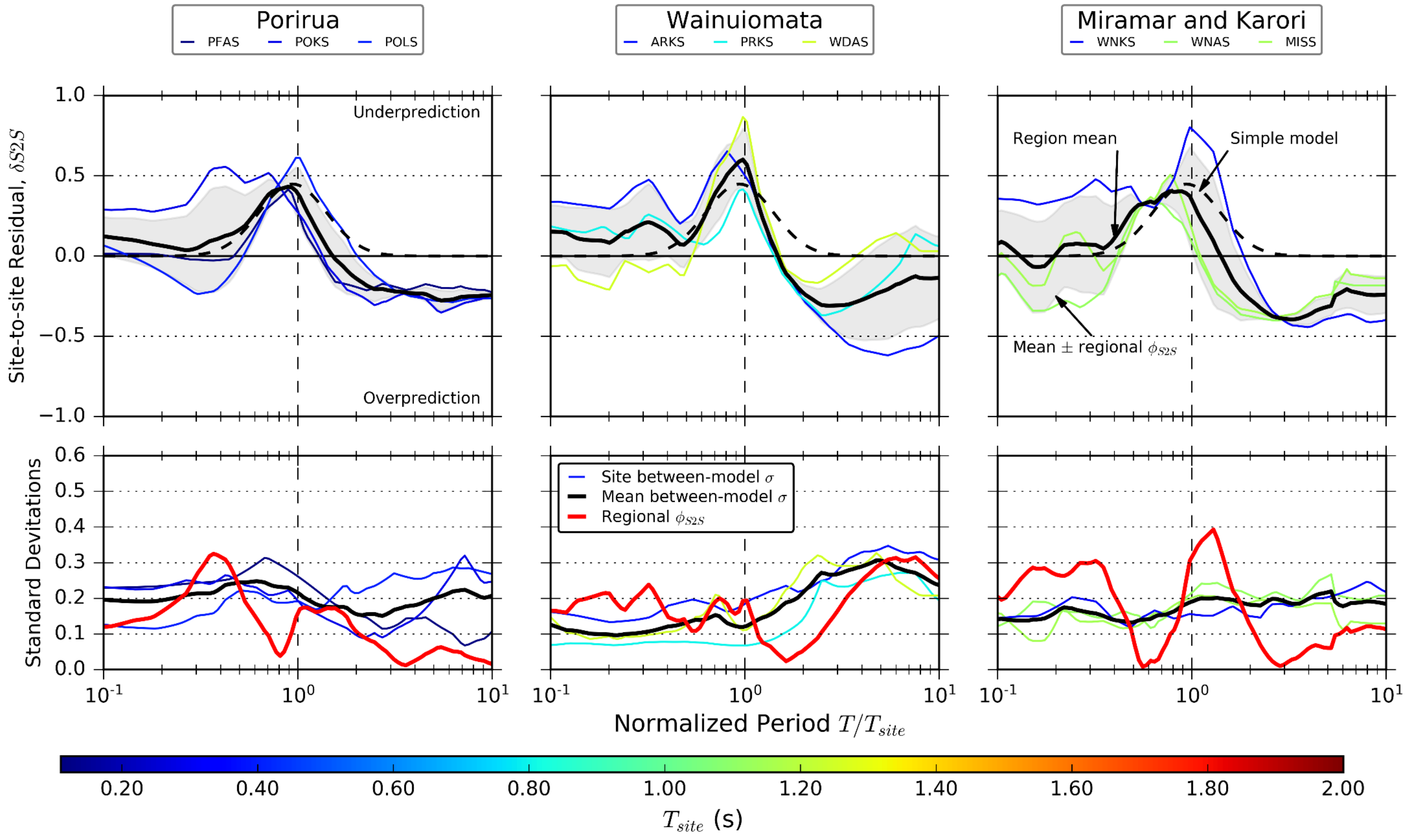
Normalisation by Site Period (T_{site})

- X-axis normalised by T_{site}
- Consistently underpredicting at T_{site}
- Reduction in regional φ_{S2S}
- Complex behaviour at “basin-edge” sites
- Double peak in Lower Hutt



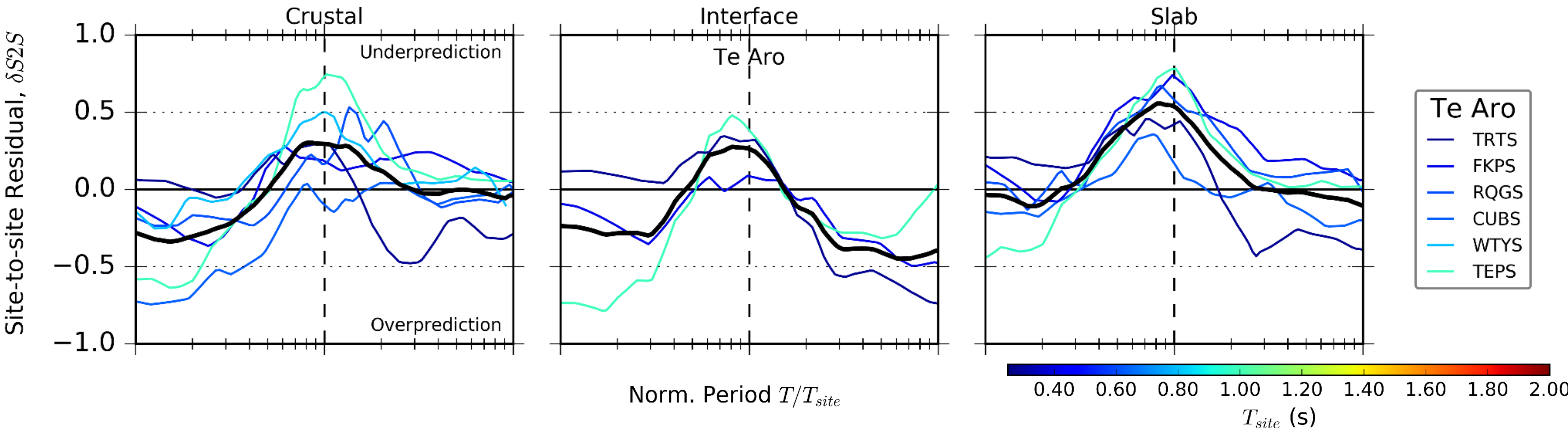
Wellington Valley Sites (Small Basins)

- X-axis normalised by T_{site}
- Well-represented by the "simple model"



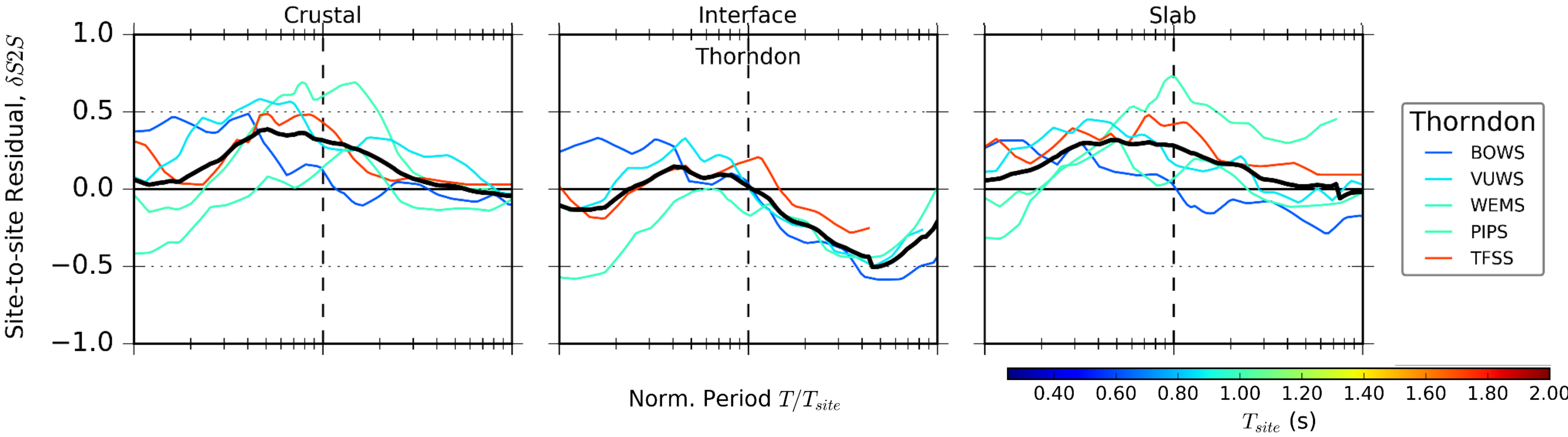
Stability Across Tectonic Type (Te Aro)

- Reasonable agreement between models: especially Crustal and Slab
- Interface slightly lower (less underprediction) on average
- Are the differences physical? Or database dependent (less events for subduction)?
  - Some path and source effects may be mapped into δS2S



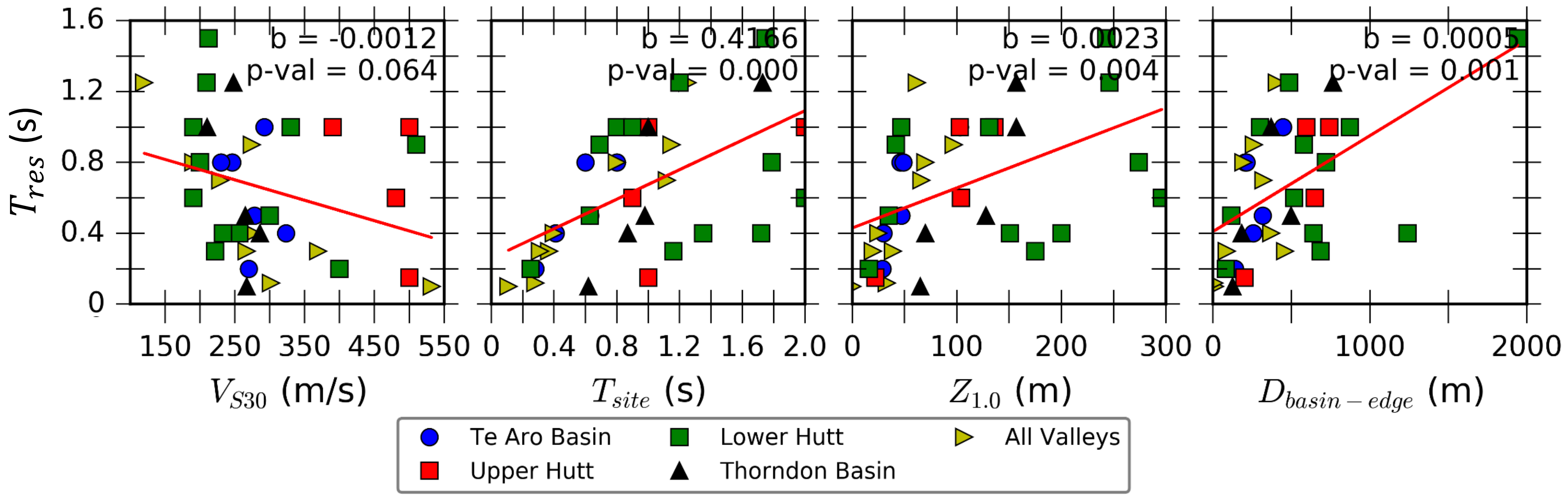
Stability Across Tectonic Type (Thorndon)

- Reasonable agreement between models: especially Crustal and Slab
- Interface slightly lower (less underprediction) on average
- Are the differences physical? Or database dependent (less events for subduction)?
  - Some path and source effects may be mapped into δS2S



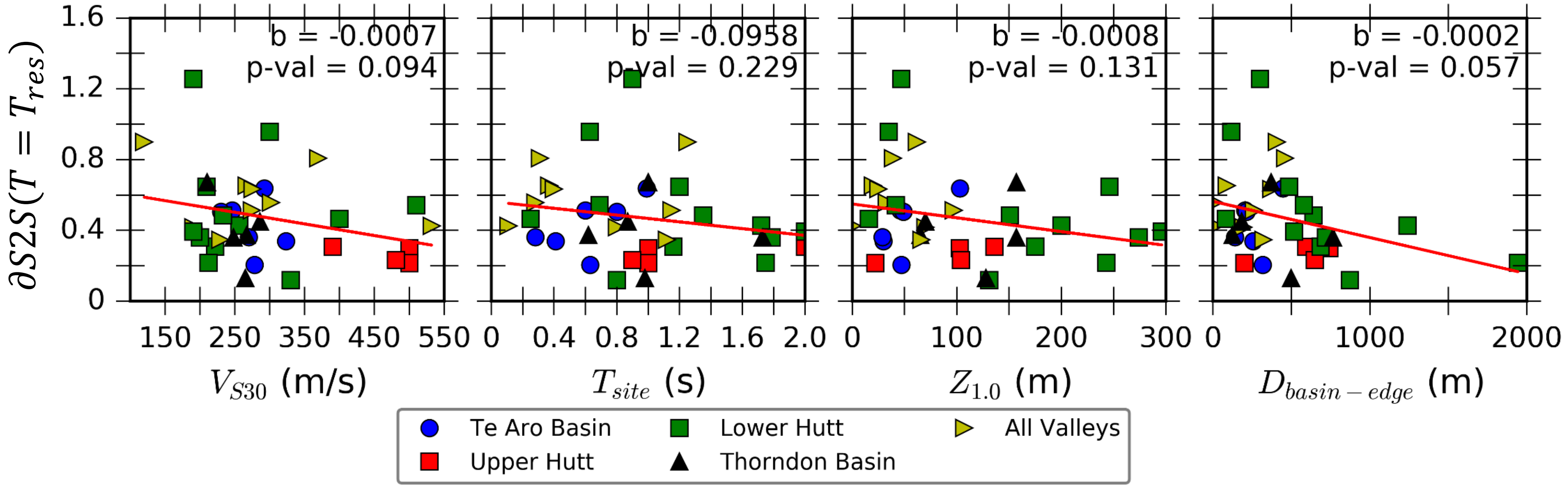
Dependence of Residuals (T_{res}) on Site Parameters

- T_{res} = Period at which peak residual occurs
- Four site parameters: V_{S30}, T_{site}, $Z_{1.0}$, and $D_{basin\text{-}edge}$
- No dependence on V_{S30} (parameter already included in site effects model)
- Relatively good correlation with: (1st) T_{site}, (2nd) $D_{basin\text{-}edge}$, (3rd) $Z_{1.0}$



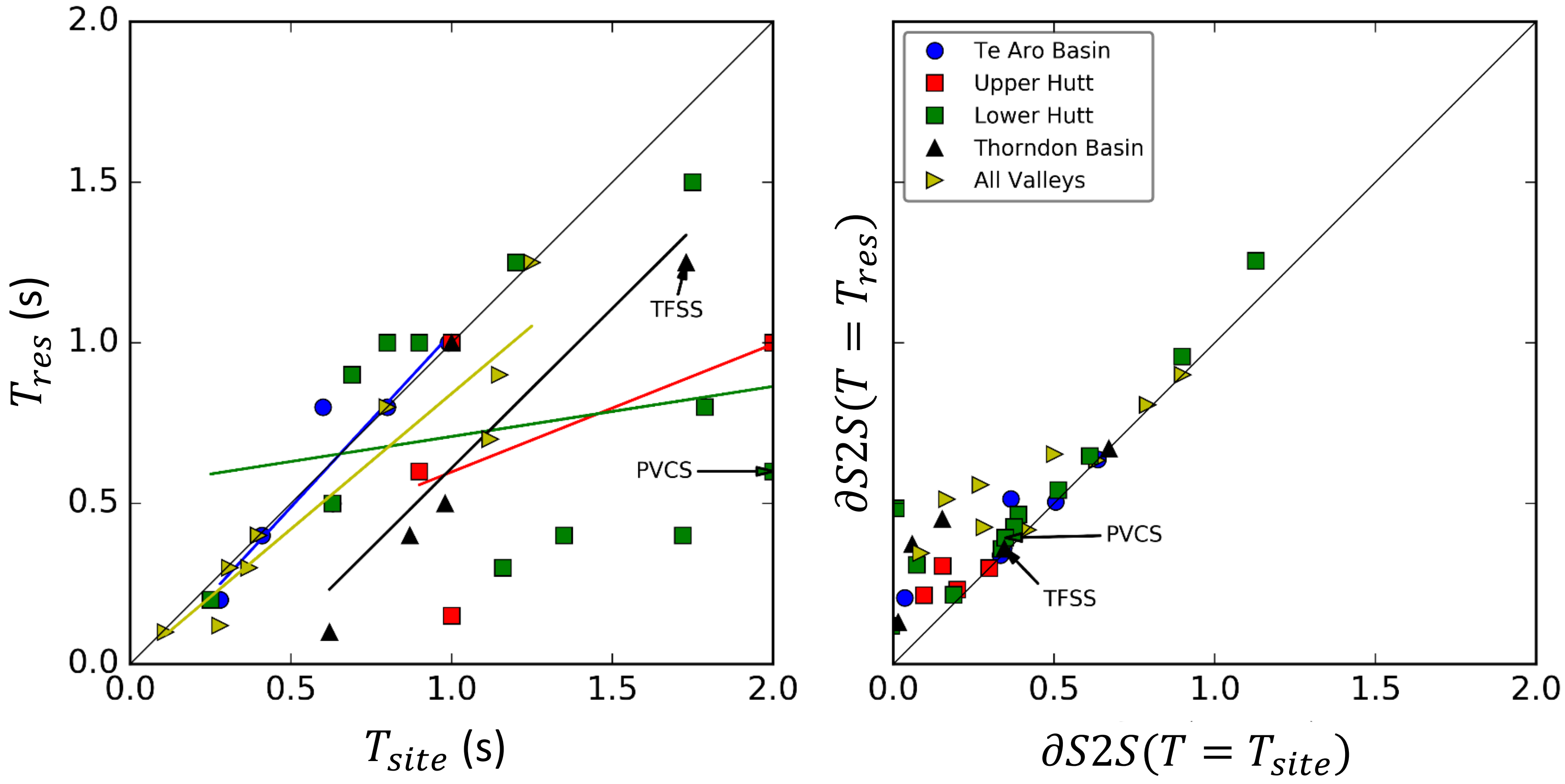
Dependence of Residuals [δS2S(T_{res})] on Site Parameters

- δS2S(T = T_{res}) = Maximum value of residual (i.e., at T_{res})
- Four site parameters: V_{S30}, T_{site}, $Z_{1.0}$, and $D_{basin\text{-}edge}$
- Essentially no correlation with any of the site parameters
- Challenge for "site-specific" scaling of amplitude of adjustment factors
  - Average value ~0.5 in log space (~1.65 in linear space)

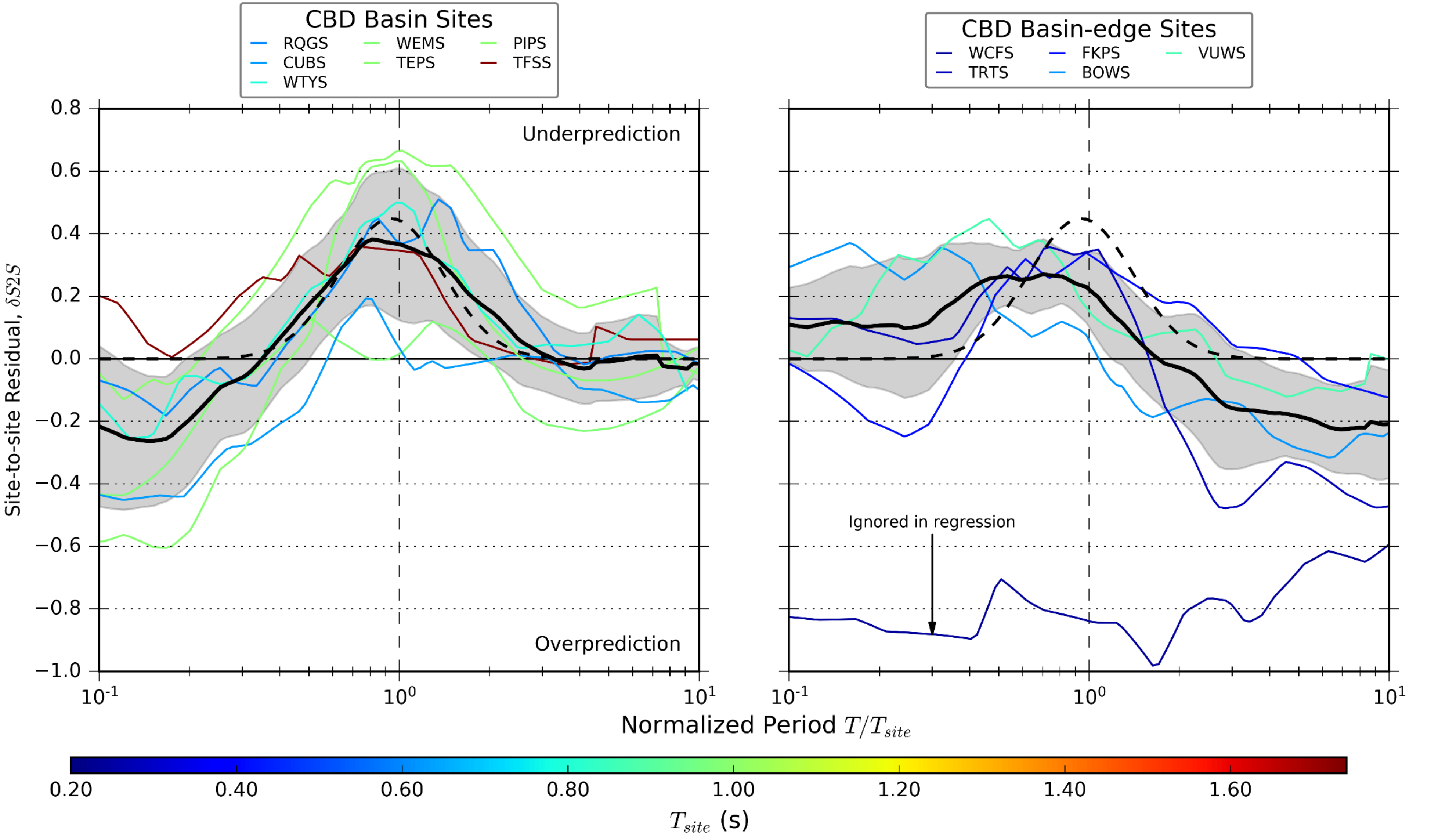


Is T_{site} a Good Parameter for Scaling the Adjustment?

- Excellent correlation for Te Aro and smaller valleys
- Thorndon → BOWS and VUWS: complex basin-edge behaviour. (WEMS?)
- Lower Hutt → Double peak. It's better than it looks (e.g., PVCS still large residual at T_{site}).

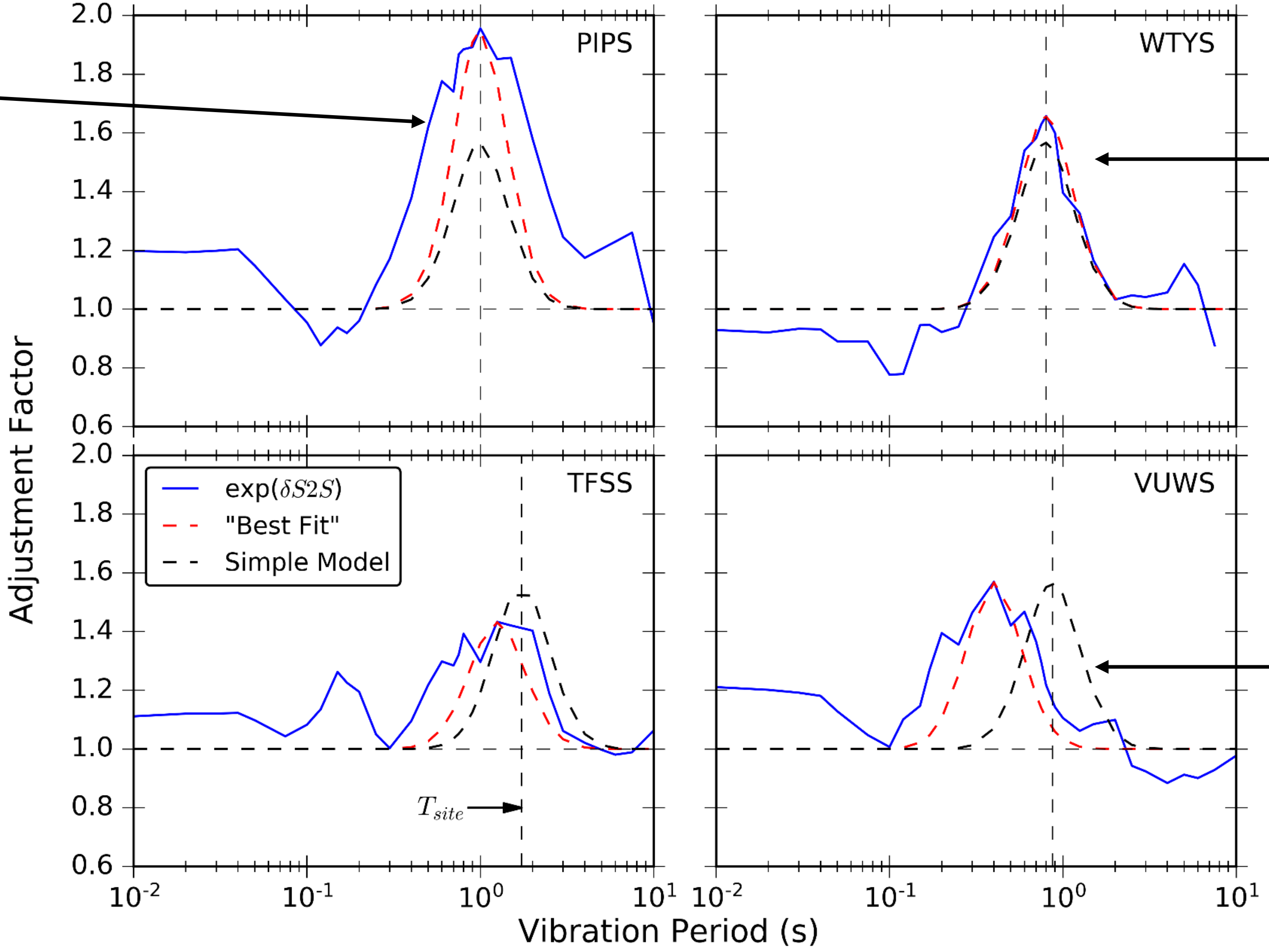


How should the Adjustment Factor Look for CBD?



Examples of the Adjustment Factor

Thorndon deeper reclaimed sites



“Well-behaved” Te Aro sites

Complex “basin-edge” sites

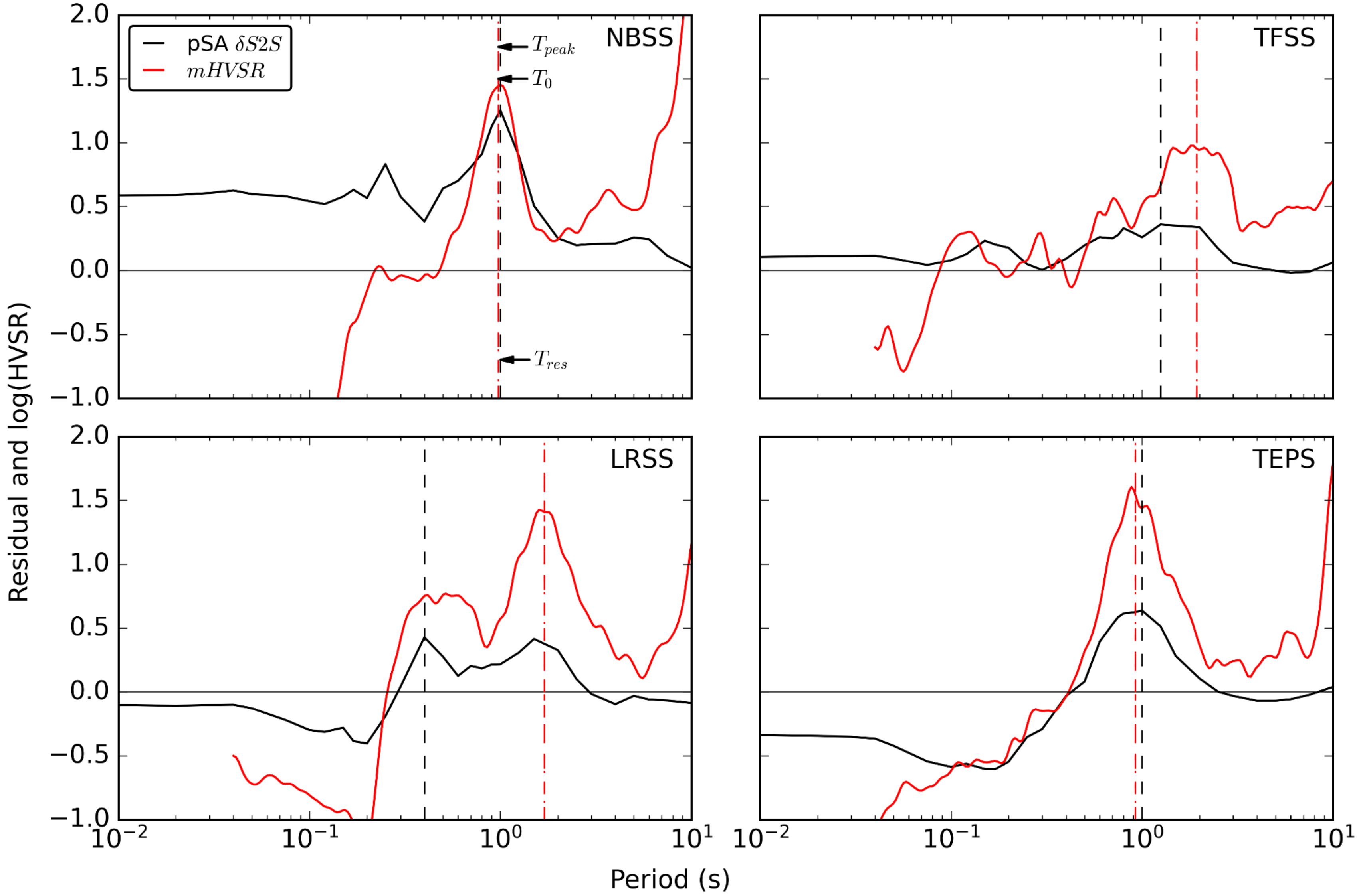
From mHVSR to Site Response

mHVSR captures general features of site response:

- Large peaks in residuals (under-prediction)
- Double peaks
- Broad peaks

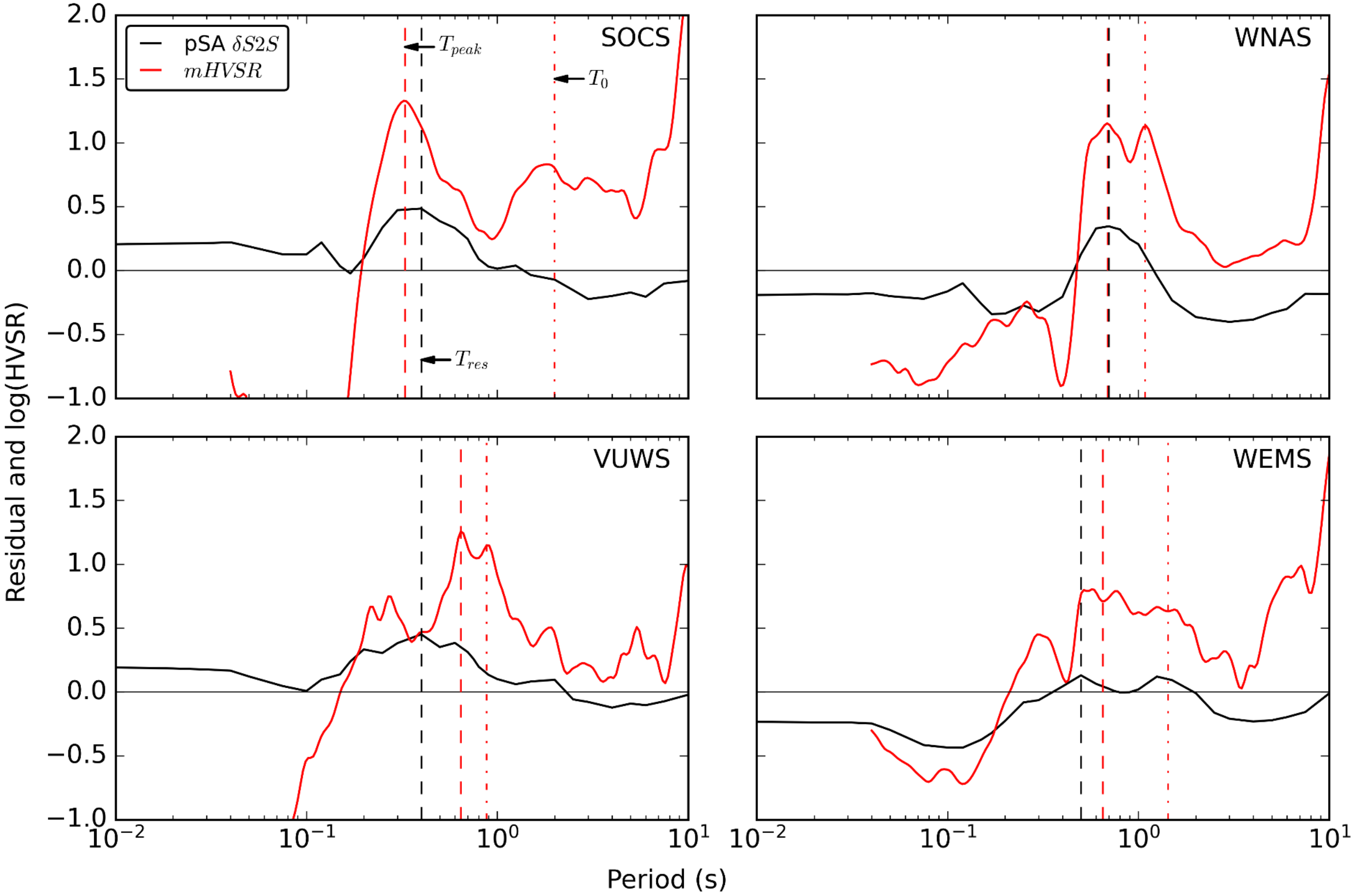
mHVSR metrics:

- T_0: Lowes freq. peak
- T_{peak}: Highest amp. peak
- Full mean curve



T_0 or T_{peak} from mHVSR?

- At several sites, T_{peak} is a better predictor than T_0
- Often some amount of observed site amplification at or around T_{peak}



Conclusions

- Systematic underprediction at most basin and valley sites:
  - Especially pronounced at T = 0.5-2 sec
  - Peak residual (i.e., the largest underprediction) typically at or close to T_{site}
- T_{site} is a good candidate for an input parameter of the adjustment factor
  - T_0 and T_{peak} from mHVSR
  - mHVSR full curve likely contains more information
  - $D_{basin\text{-}edge}$ and $Z_{1.0}$ also correlated residual metrics.
- "Site-specific" amplitude of the adjustment factor might be challenging
  - Adjustment factor of ~1.6 at T_{site} fits data on average

Next Steps

- Revisit T_{site} picks to understand why for certain sites $T_{res} \neq T_{site}$
- Investigate the correlation between residual peak amplitude and mHVSR peak amplitude.
  - Do sites with a higher mHVSR amplitude have a larger underprediction at T_{site}?
- “Finalise” and test “simple” adjustment factor for CBD area:
  - Dependent on T_{site}?
  - Modify GMMs on OpenQuake → rerun predictions → rerun residuals → compare residuals
- Create maps of adjustment factor:
  - Option 1: Provide T_{site} maps and equation for adjustment factor
  - Option 2: Produce maps of adjustment factor (Lat Lon → T_{site} → adjustment factor)
- Collect mHVSR at more SMS