Source Models of a Mw 8.6 Hikurangi Megathrust Earthquake

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Introduction

Purpose:

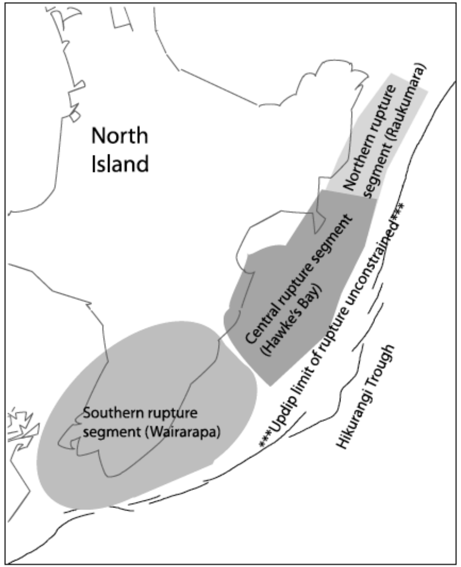
To investigate the sensitivity in ground motions to source model parameters, to aid in the development of source models for future QuakeCore 3D simulations of megathrust earthquakes (e.g. Bradley, 2018).

(not a validation)

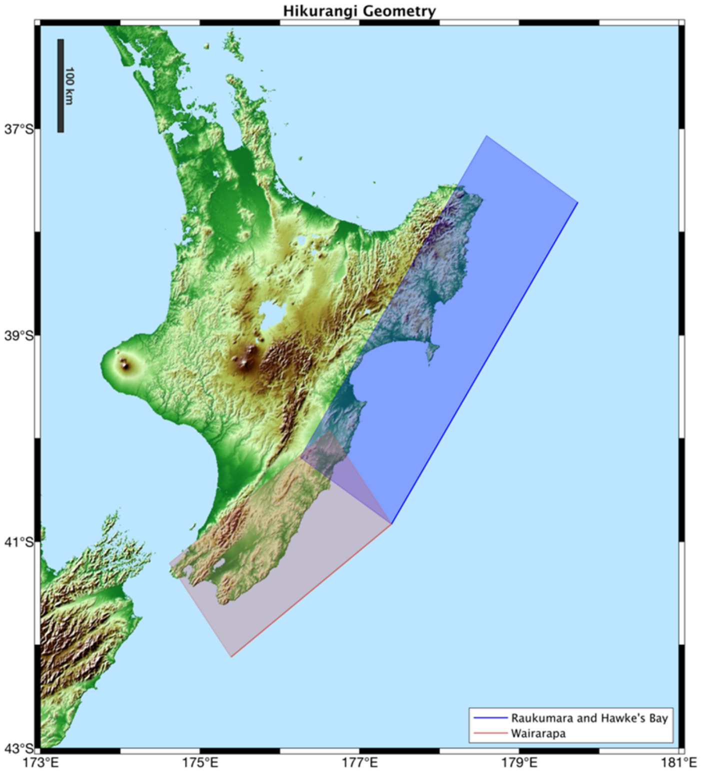
Approach:

- Develop a suite of multi-segment M8.6 rupture models of a Hikurangi megathrust event
- Use the Graves and Pitarka - Irikura method hybrid (Pitarka et al., 2018; GP-IM) for developing the kinematic source models
    - This method combines the Irikura and Miyake (2011) asperity-based kinematic rupture generator with the Graves and Pitarka (2015) rupture generation methods for stochastic spatial variability and background slip in shallow crustal earthquakes
- Use the Graves and Pitarka (2015) method for the ground motion simulations (SCEC BBP v17.3)

Hikurangi Fault Geometry



Schematic from Wallace et al., (2009) showing rupture regions for possible subduction events

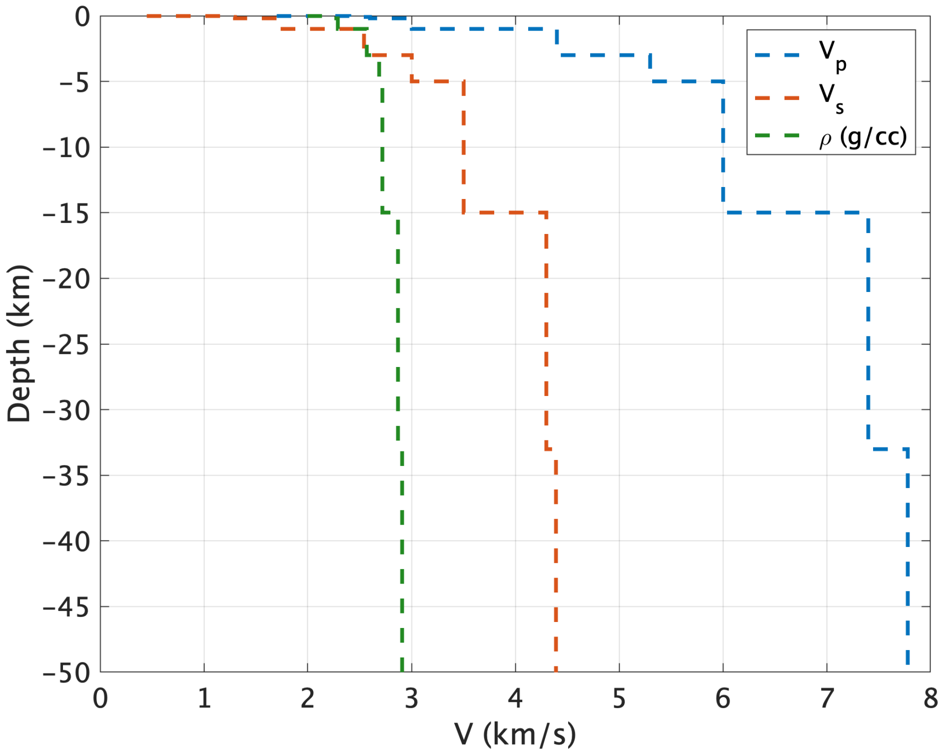


Geometry of the scenario used

Rupture Scenario from Stirling et al., (2012)	Dip Angle (deg)	Depth to Top of Rupture (km)	Length (km)	Strike (deg)	Characteristic Mw
Northern (Raukumara)	8.5	5	200	209.5	8.3
Central (Hawke's Bay)	8.5	5	200	209.5	8.3
Southern (Wairarapa)	10	5	224	224.7	8.4
Combined	9.0	5	624	Varies by segment	~9.0

Seismic Velocity Model

– Eberhart-Phillips et al. (2010) modified in shallow layers to have Vs30 = 500 m/s



Method for Kinematic Rupture Modeling

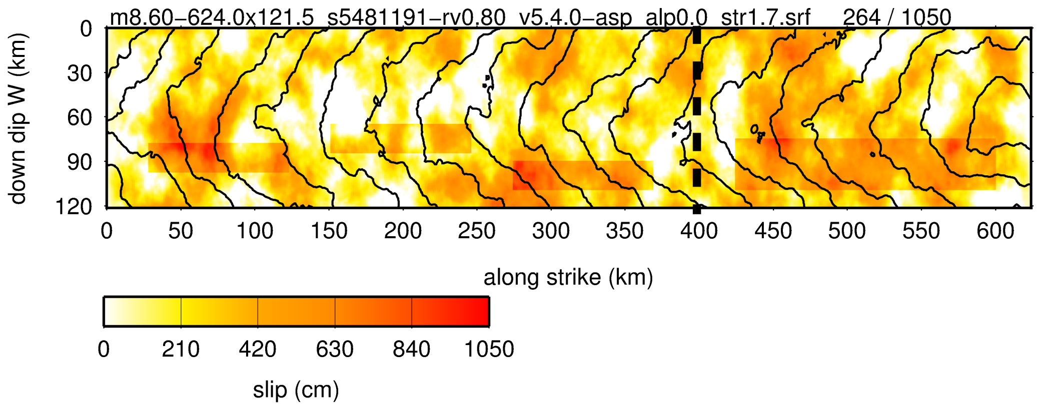
- Pitarka (2018) combined the Irikura and Miyake (2011) asperity-based kinematic rupture method with the Graves and Pitarka (2015) method for stochastic spatial variability and background slip in shallow crustal earthquakes. (GP-IM code version 5.4.0-asp)

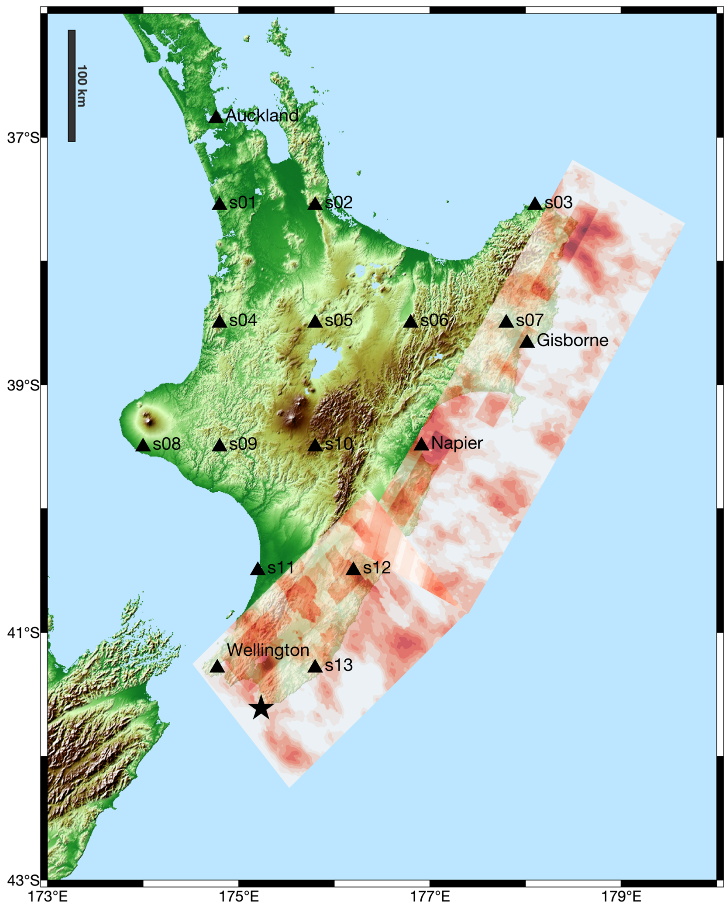
- Adaptations to this method for use with subduction earthquakes:
  - the Skarlatoudis et al. (2016) scaling for the corner spatial wavenumbers in the along strike and down-dip directions for great interface subduction earthquakes. This introduces smoother background slip.

  - Modified perturbations to the rupture times for large earthquakes to make them smoother based on Wirth et al. (2017), and modified the parameters that control average rupture speed and rise time.

- Relationships between seismic moment, rupture area, asperity area, and stress parameters were based on Murotani et al. (2008), Tajima et al. (2013), Miyake (2018) and Skarlatoudis et al. (2016).

Reference Case Rupture Model





- Unilateral rupture with propagation towards the northeast
- Four asperities located in the lower half of the rupture planes
    - Three are ~**M**7 and one is ~**M**7.5
- Maximum slip = 10.5 m, Average slip = 2.6 m
- Asperity strength (ratio of asperity peak slip to total rupture average slip) of 1.7

Method for Kinematic Rupture Modeling

Source parameters fixed in this study	Source parameters modified in sensitivity analyses
• Seismic velocity model • Total seismic moment • Rupture geometry (L, W, depth, strike, location) • Number of asperities • Area of asperities • Corner wavenumbers • Rupture speed and rise time modifications • HF parameters (stress parameter, kappa, Q model form - default GP values for the WUS)	• Relative "strength" of asperities • Hypocenter location • Random slip distributions • Depth of asperities

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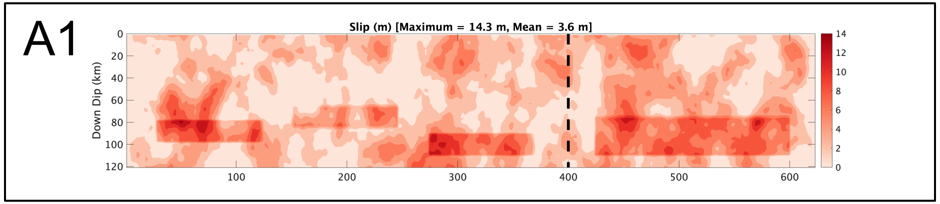
Rupture Model Sensitivities

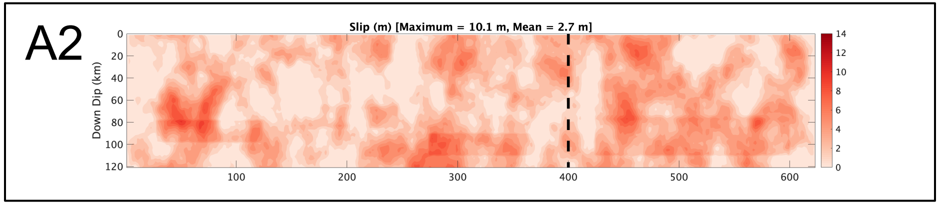
Asperity Strength:
- (A1) 2.1
- (A2) 1.4
- (Ref.) 1.7

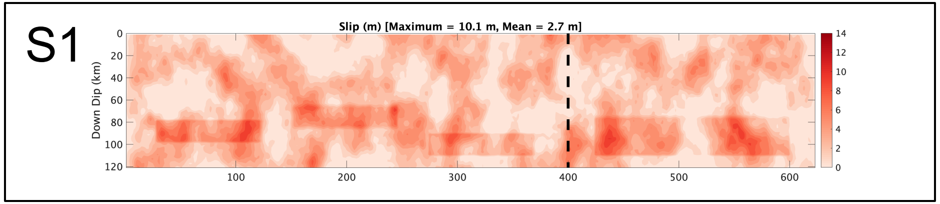
Hypocenter Location:
- (H1) Northern
- (H2) Central
- (Ref.) Southern

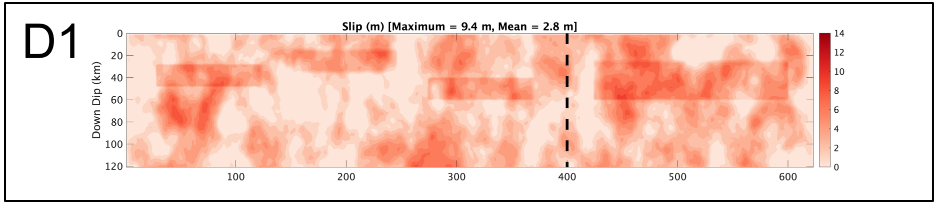
Slip Distribution
- Three randomized sets: S1, S2, Ref.

Asperity Depth
- (D1) shallow
- (Ref.) deep

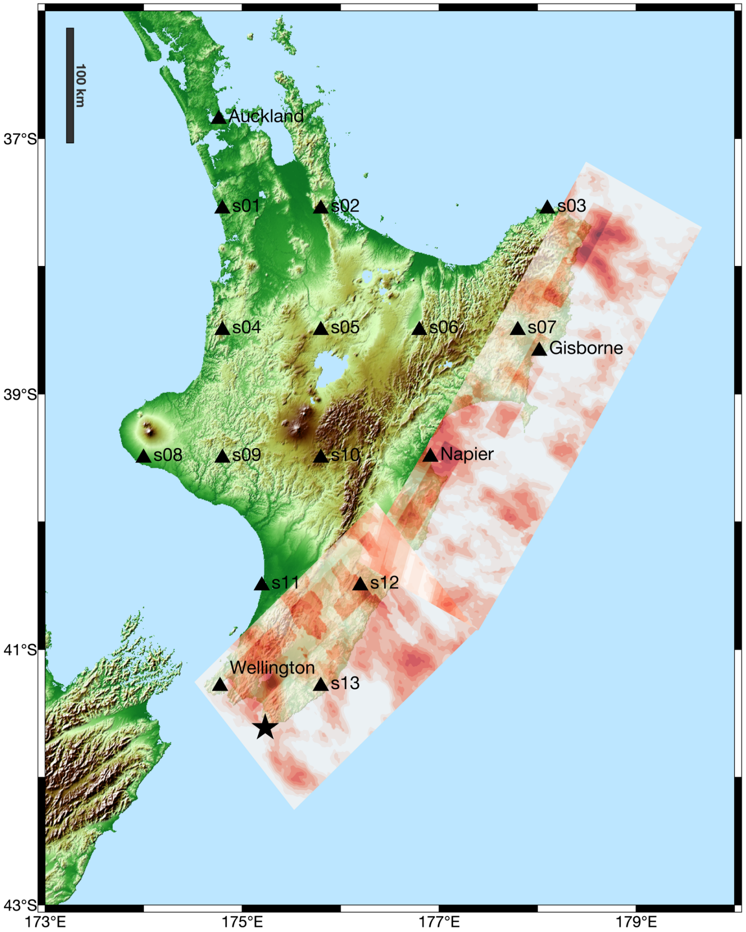


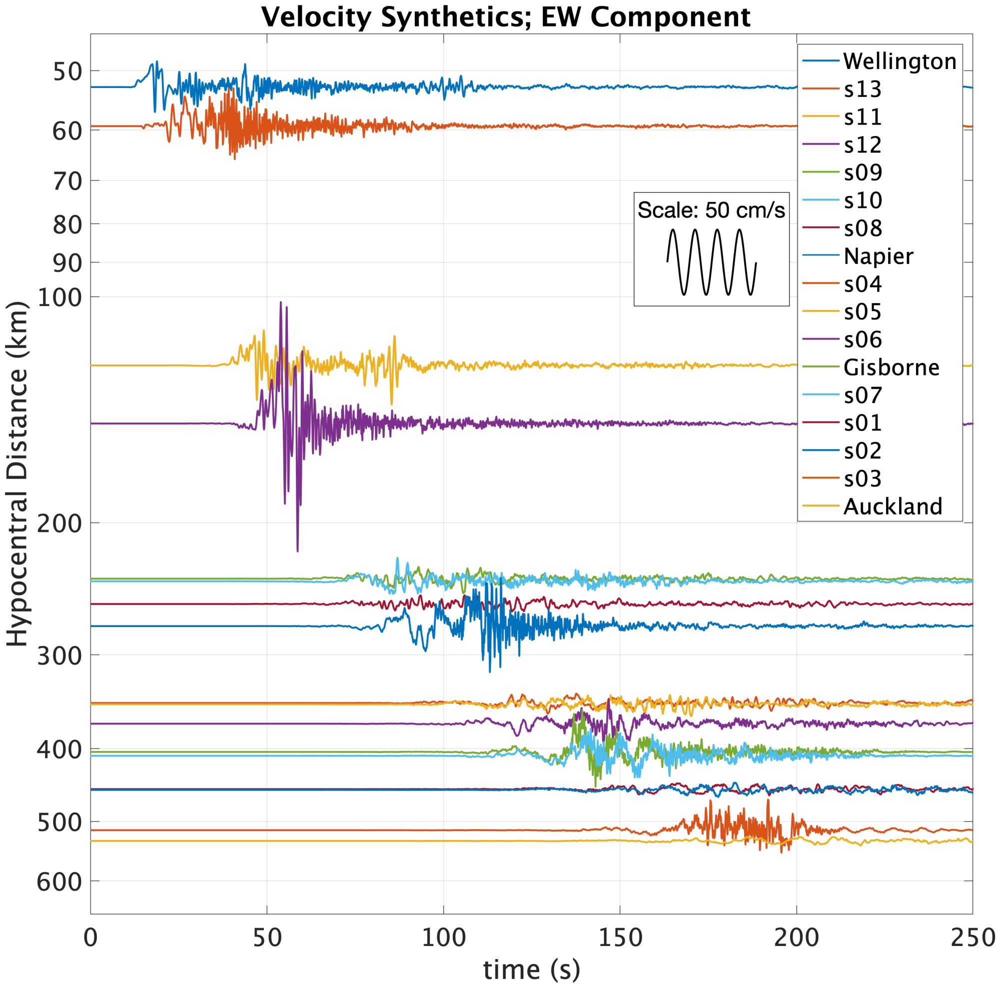






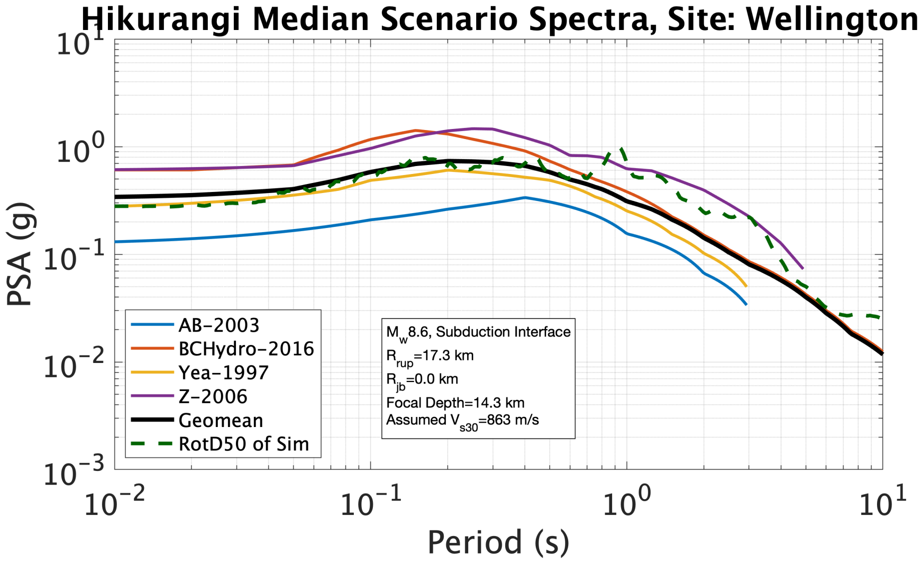
Reference Case Results

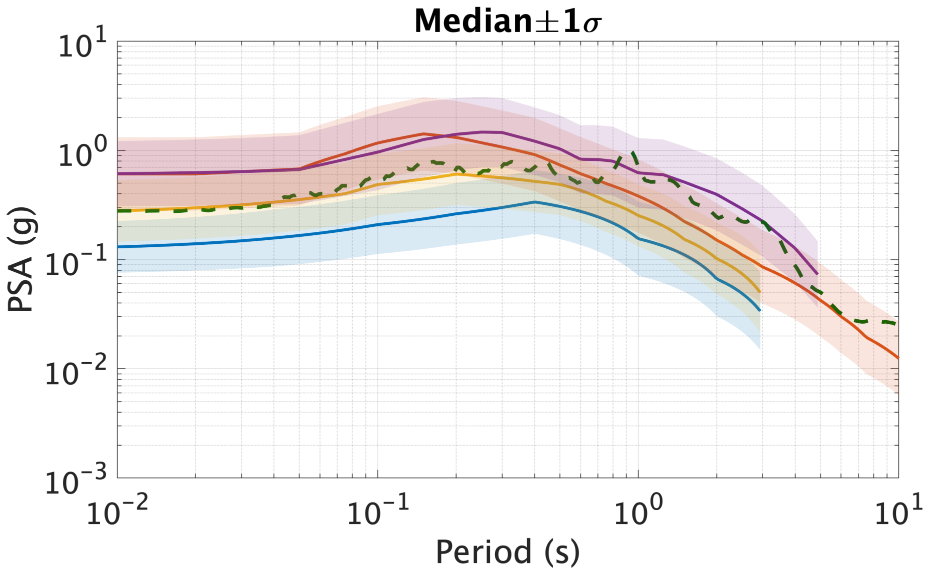




Reference Case Results: city of Wellington

Note: The simulations are for rock site conditions (which do not reflect the conditions at Wellington) in order to isolate the source effects in sensitivity studies.





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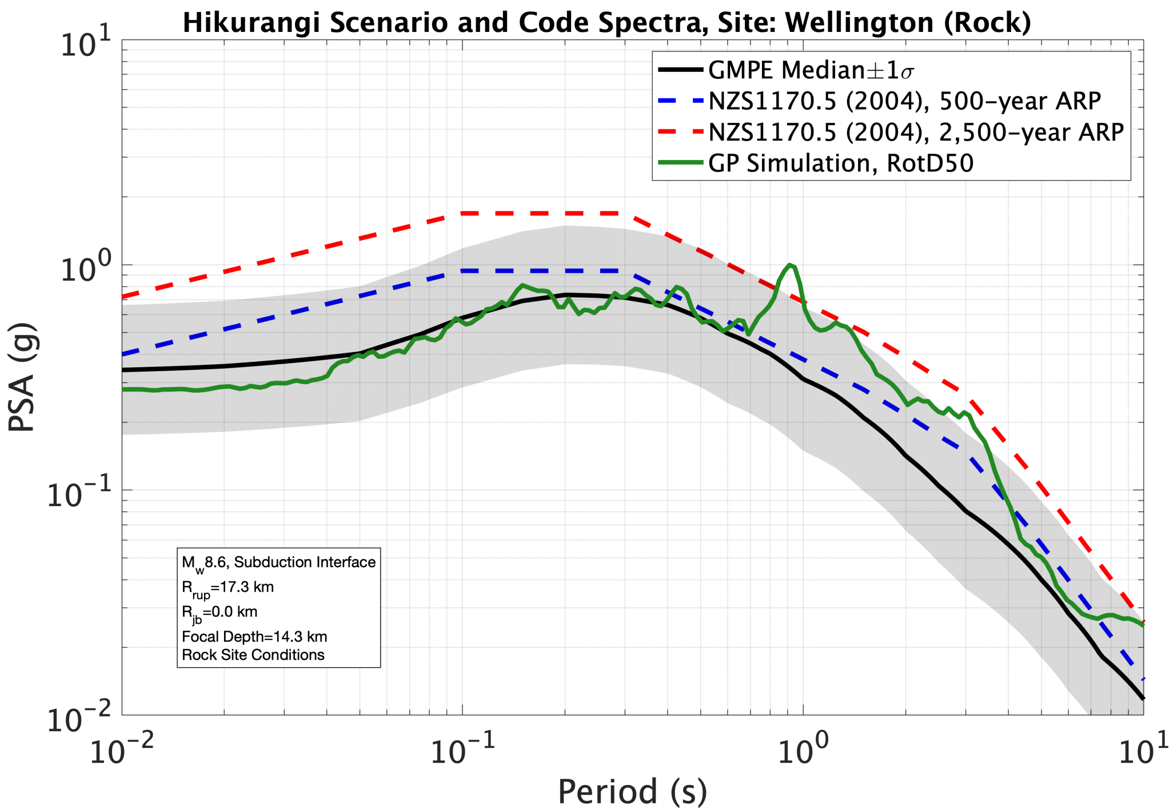

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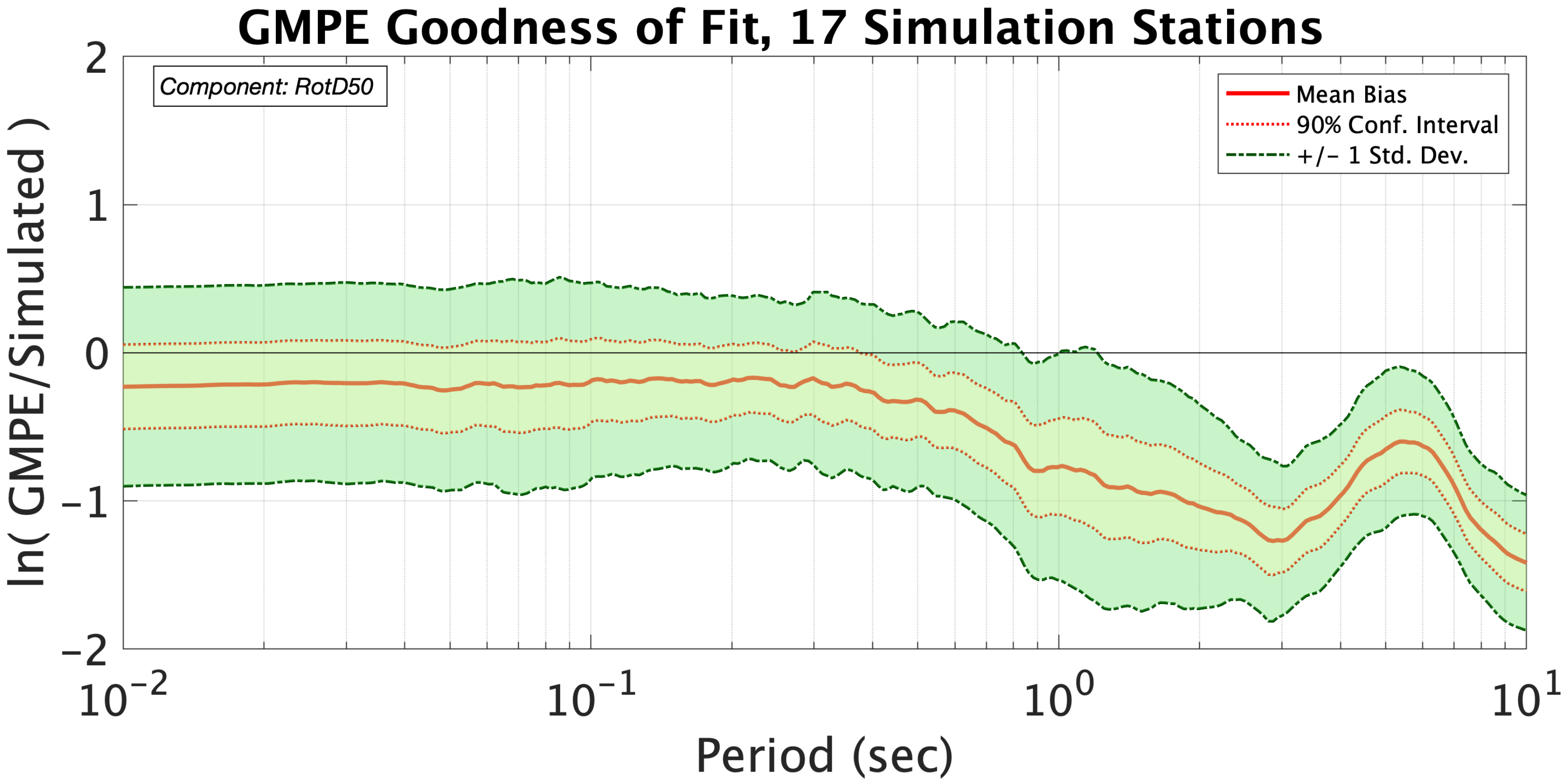
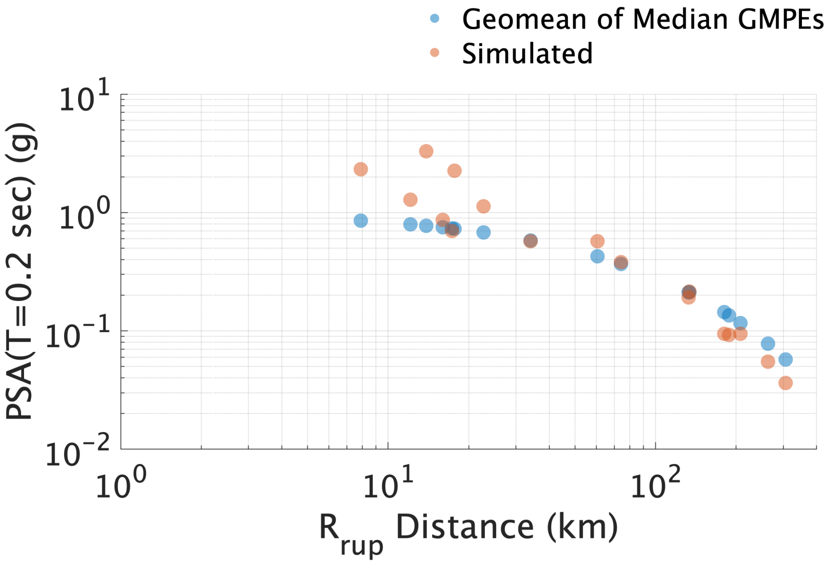
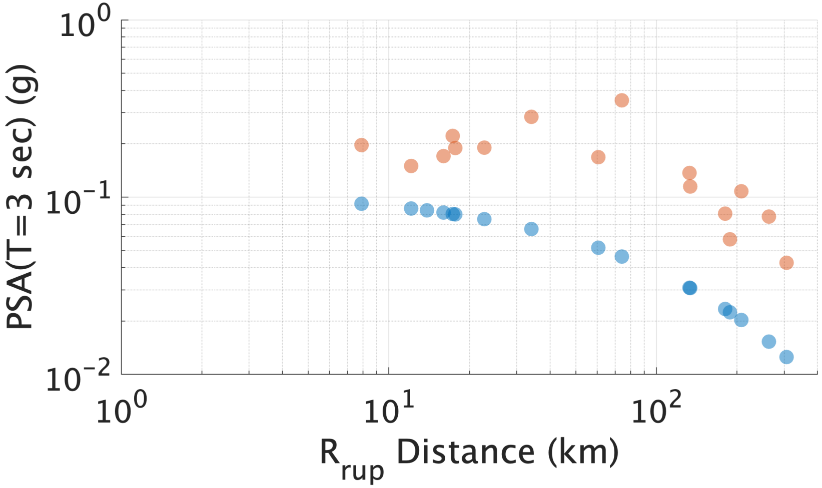


Reference Case Results

0.2 sec



3 sec



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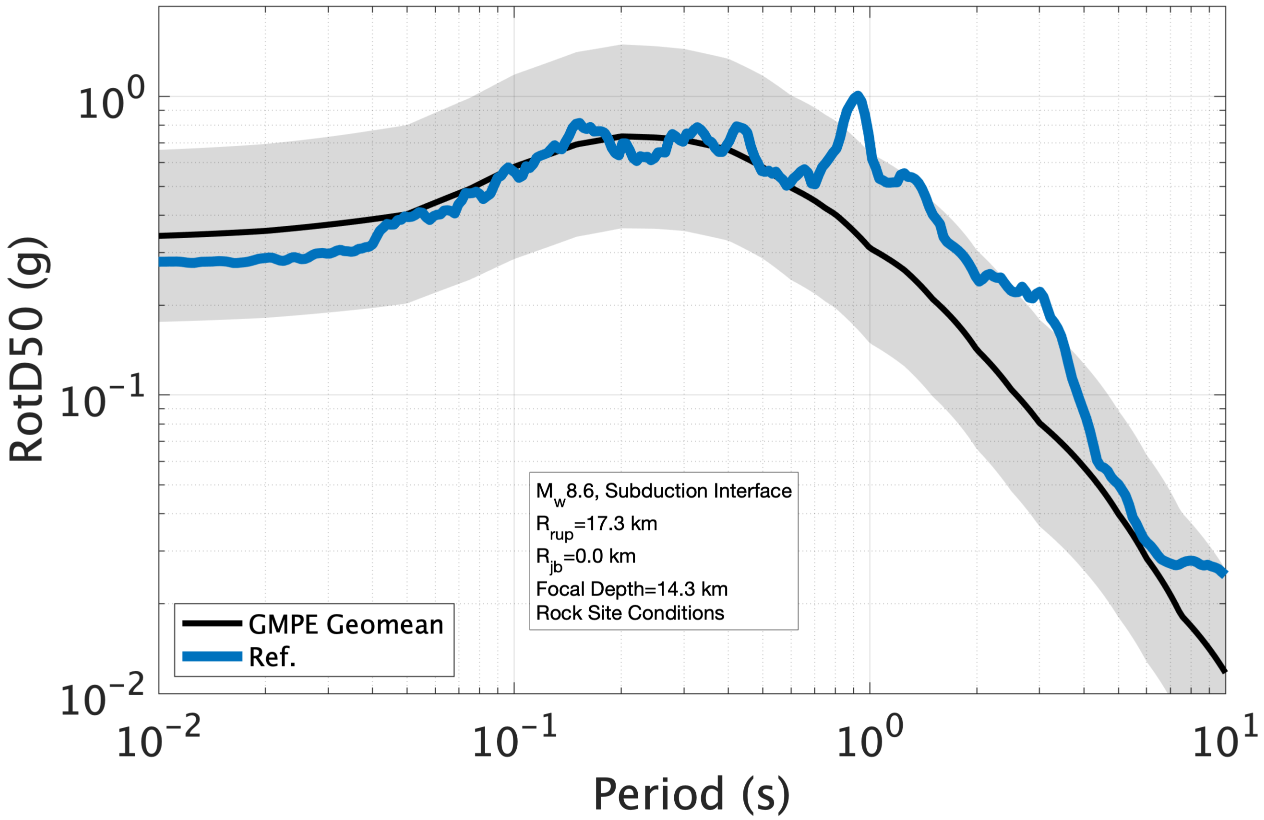
Sensitivity of Results: Wellington



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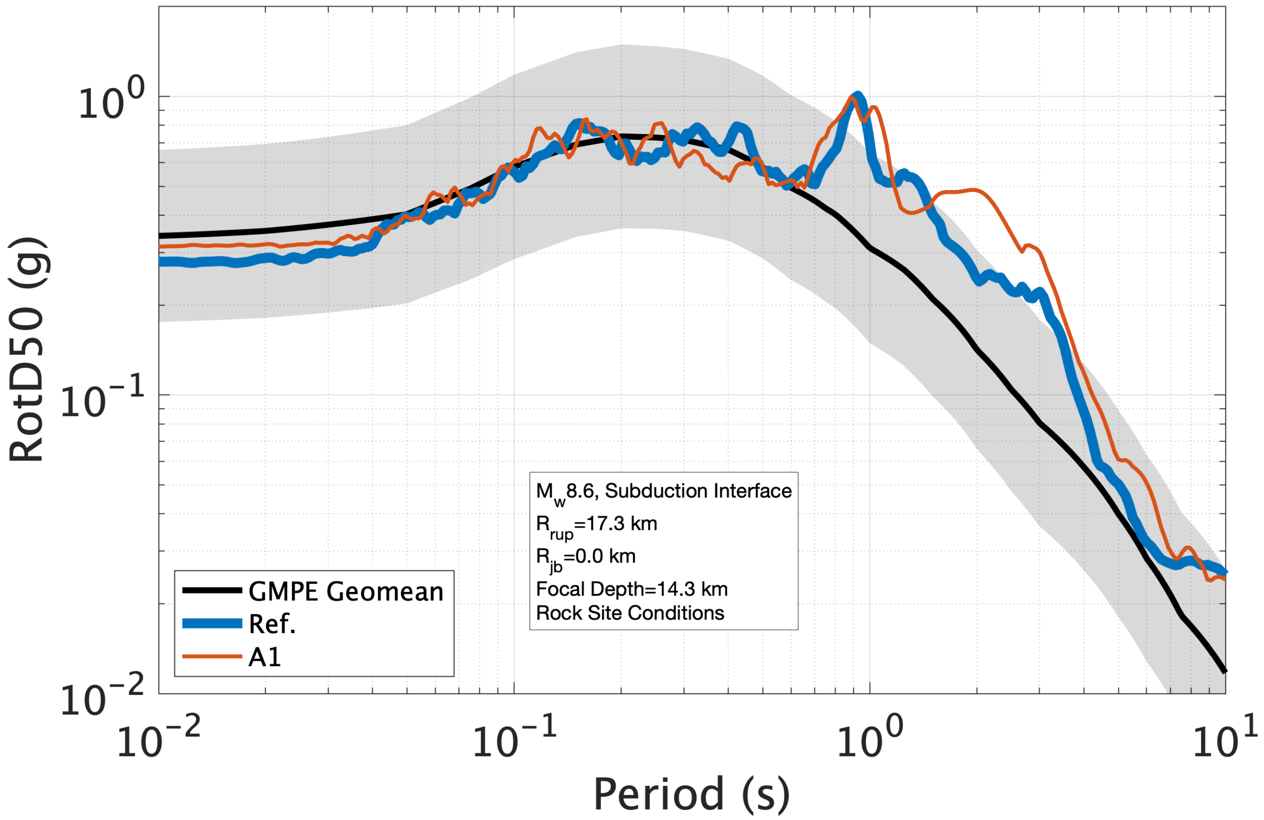

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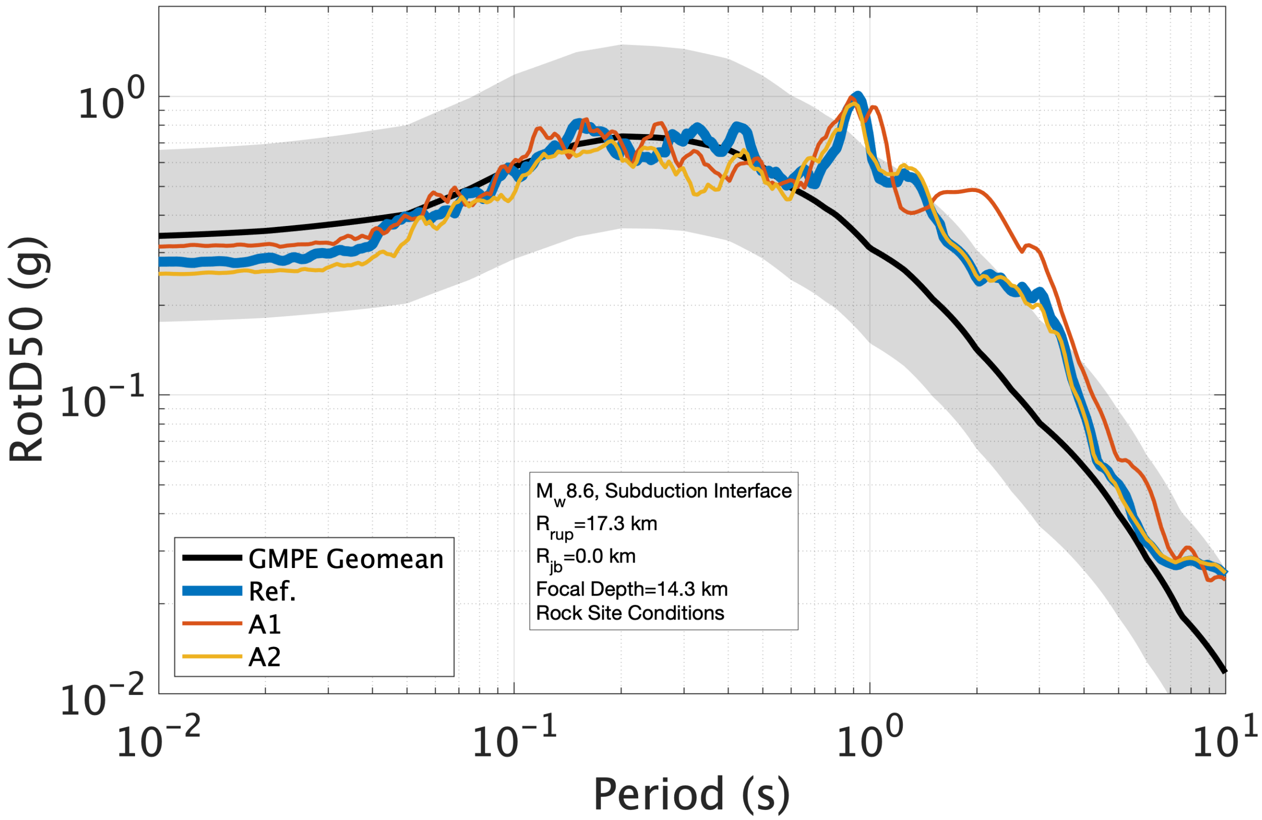

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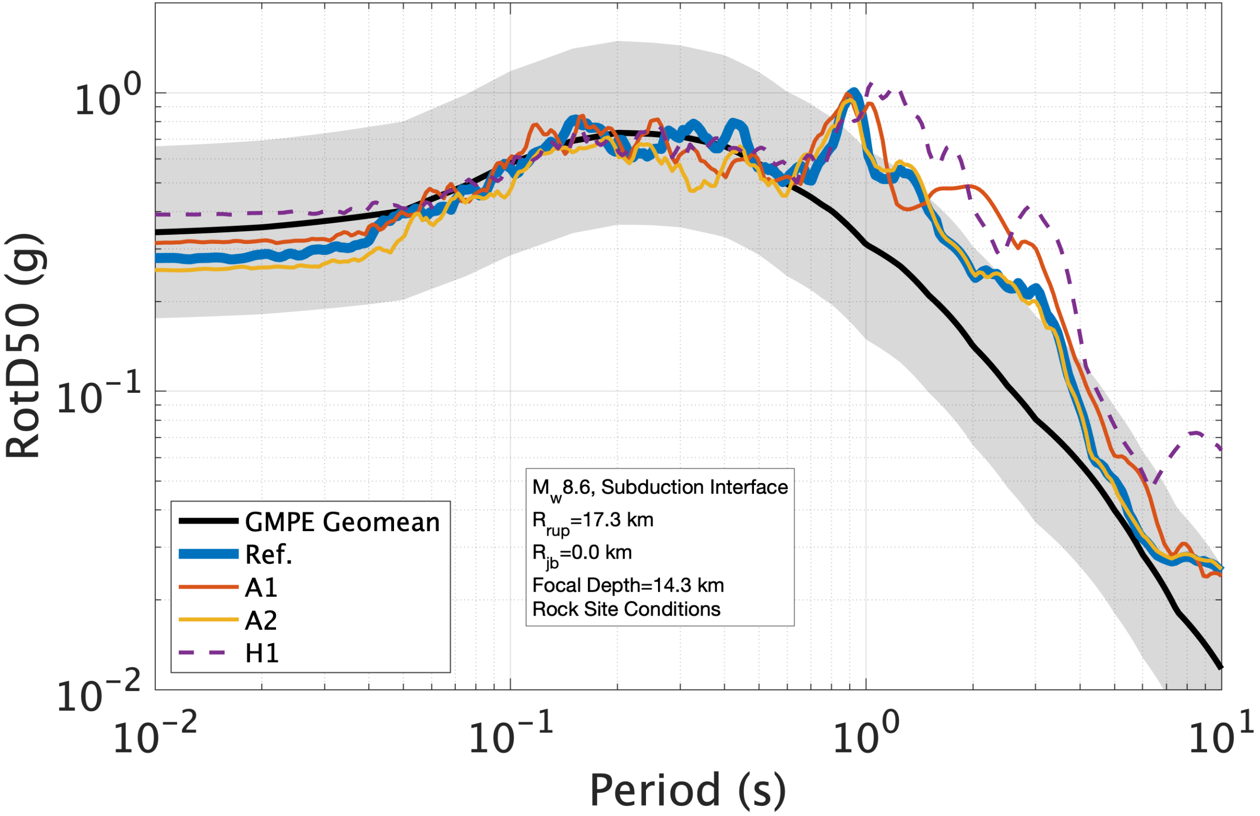

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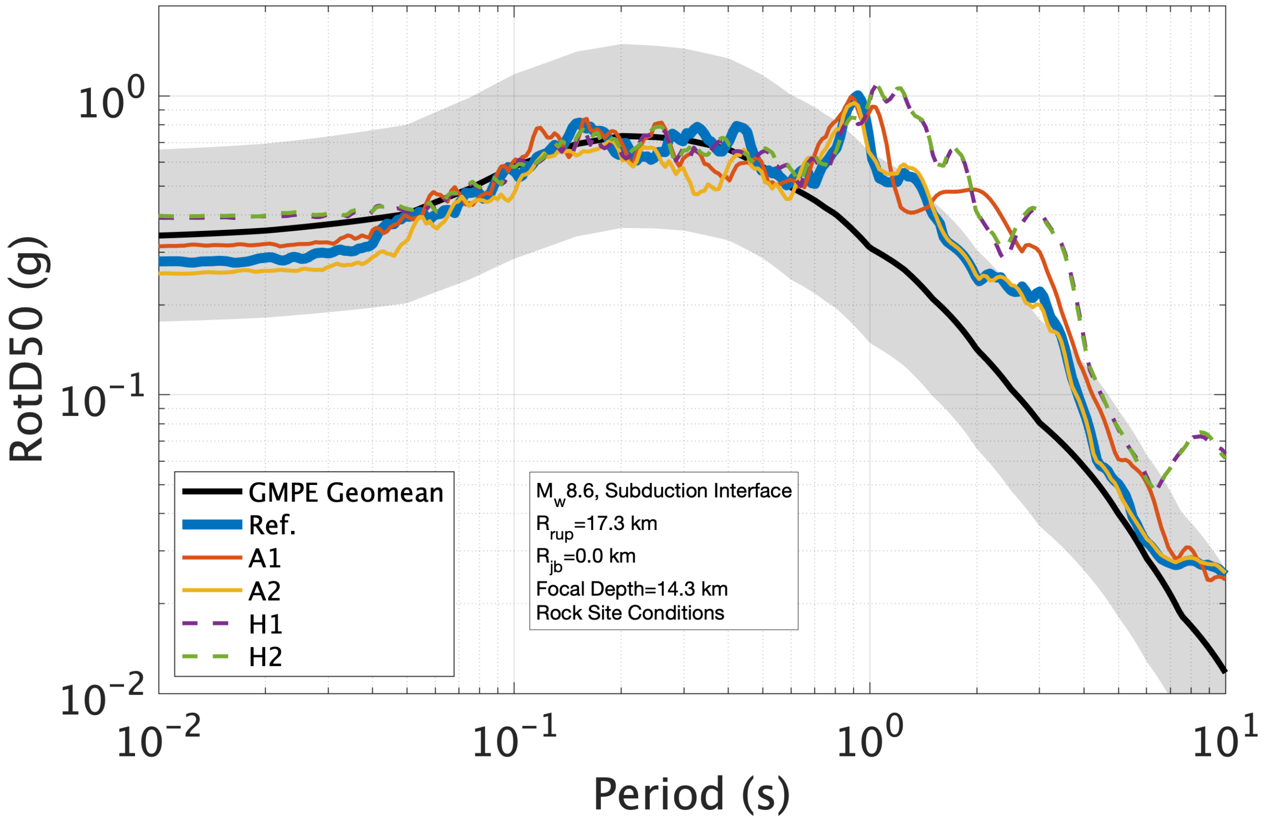

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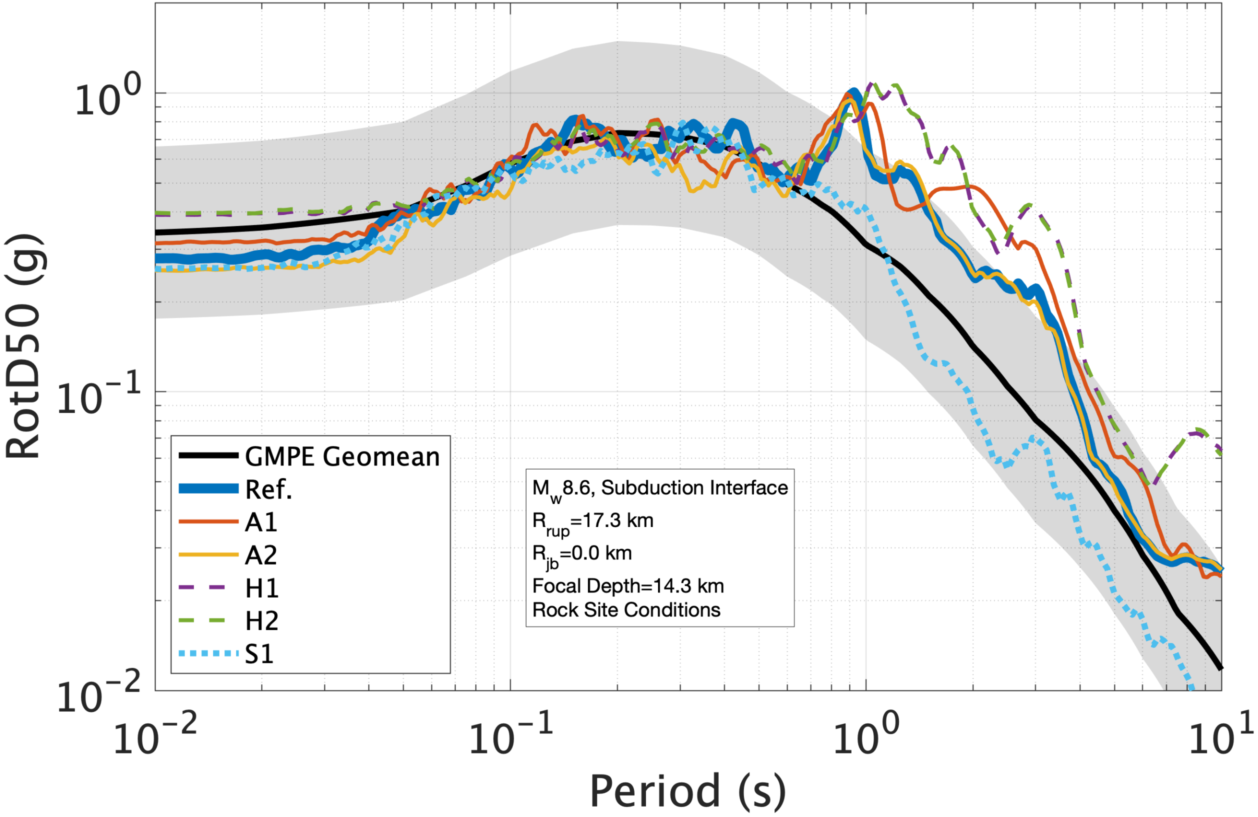

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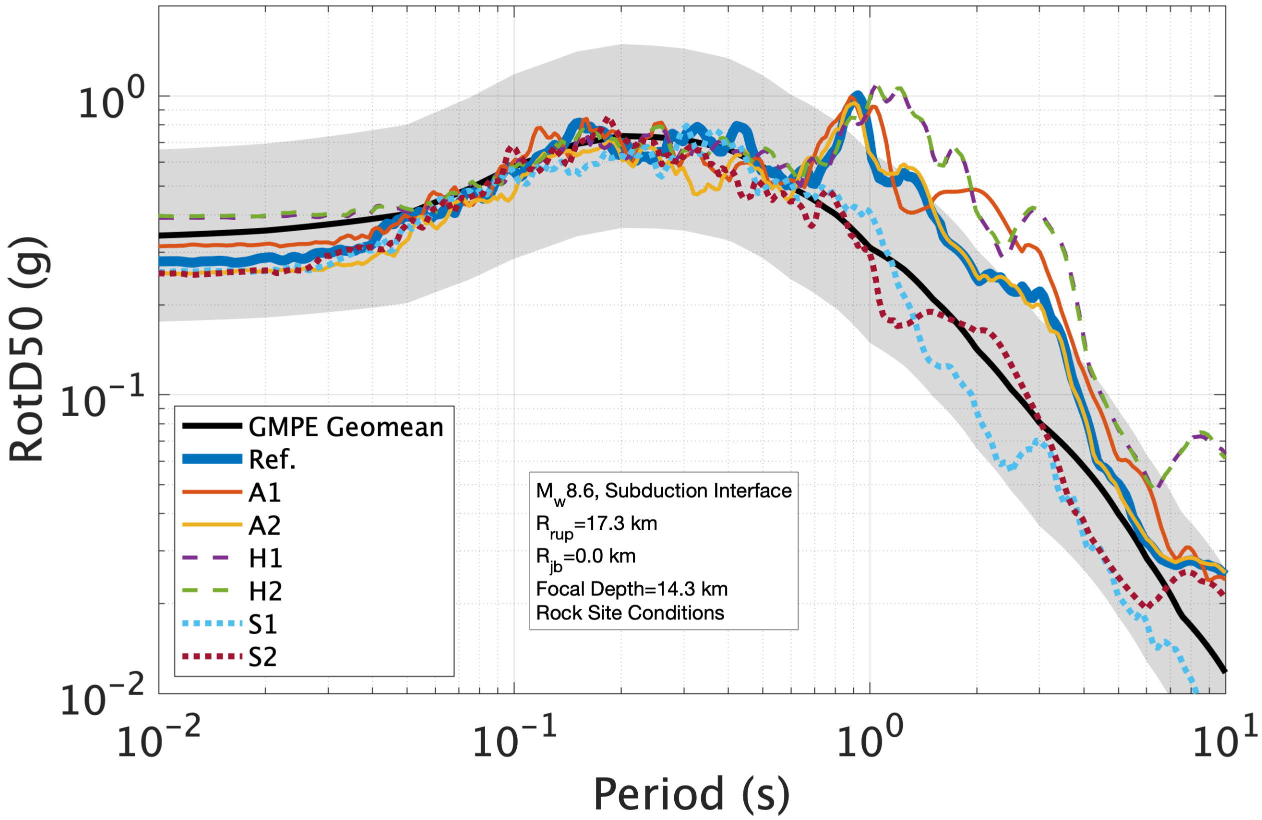

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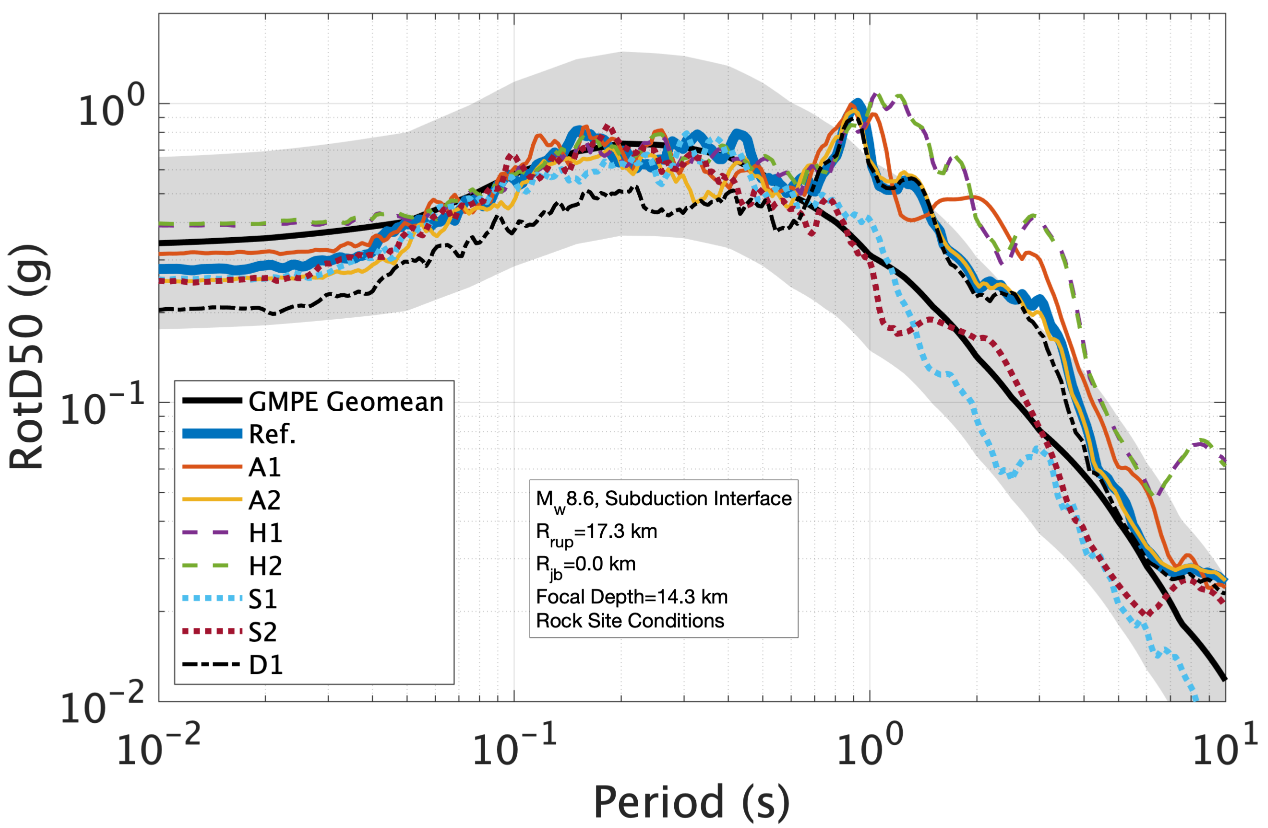

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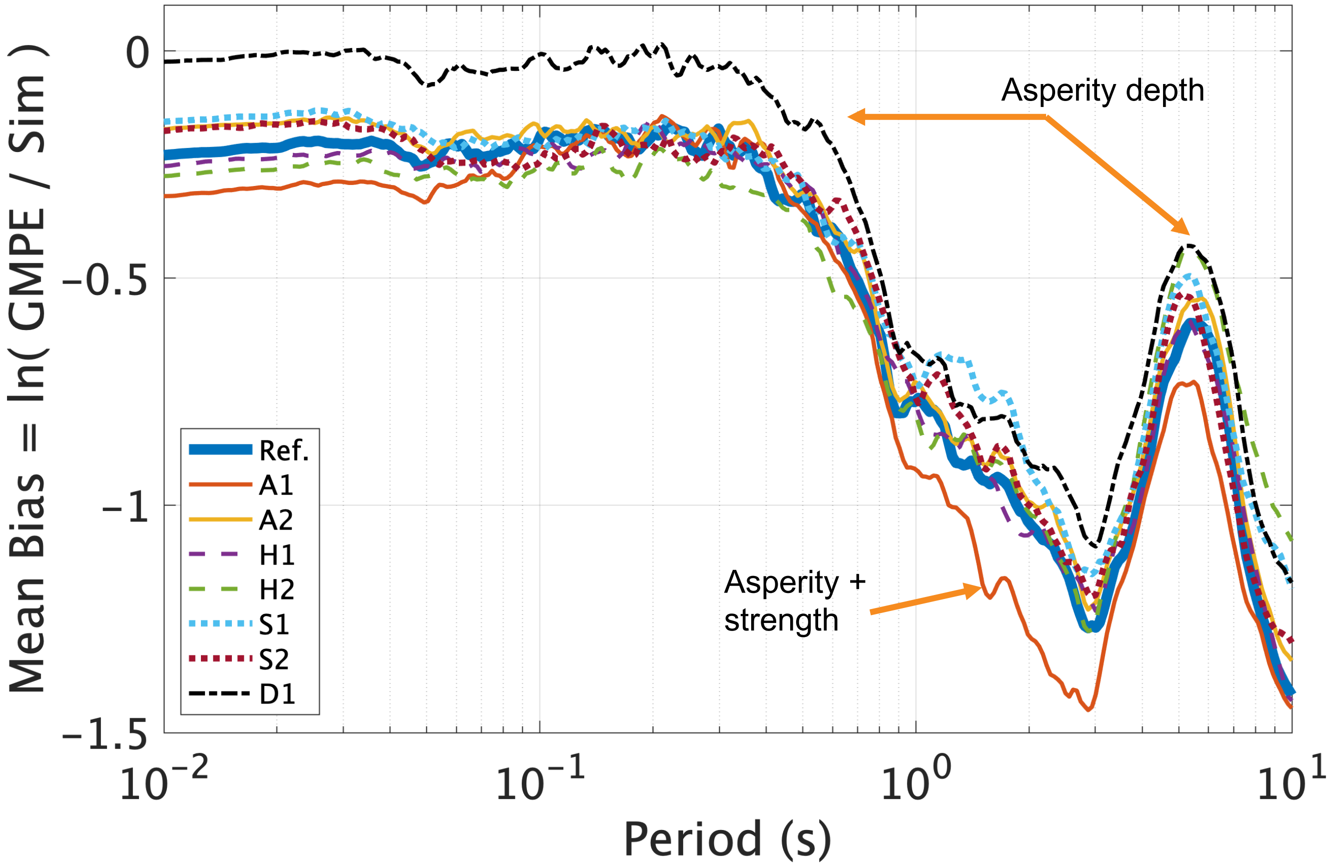
Sensitivity of Results: Mean Bias over all Stations



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Conclusions

Purpose:

To investigate the sensitivity in ground motions to source model parameters.

Conclusions:

- Sensitivity to the randomized background slip is significant (particularly at a given station) and so multiple realizations should be utilized in forward simulations.
- T>1 sec GMs, averaged over all azimuths and distances, are most sensitive to the asperity strength and asperity depth.
- T>1 sec GMs show azimuthal dependence in their sensitivity to hypocenter location, but hypocenter location has a minimal effect on the average bias.
- Reducing the asperity strength ratio from 1.7 to 1.4 has minimal effect on GMs.
- Short period GMs are quite sensitive to the asperity depth.

- The simulations at short periods are remarkably similar to the GMPEs given that no tuning was performed.
- On average, the simulations at long periods are stronger than the median GMPEs (with some variation spatially).
- The megathrust implementation of G&P (2015) should undergo future validations against strong motion recordings.

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