Investigation of Regional Quality Factors from a New Zealand-wide Velocity Model

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1. Background and Objective

This poster presents an investigation of regional quality factors from a New Zealand-wide velocity model recently developed by Eberhart-Phillips et al. (2015). In earthquake-induced ground motions, attenuation exists in two components, geometric spreading and anelastic attenuation. Anelastic attenuation occurs due to friction related to material and fabric properties of the medium where the waves propagate. The quality factor, Q, is related to the level of viscoelastic damping the medium provides, as a simplified means to represent this intrinsic attenuation.

In conventional ground motion simulations, 3D models are typically utilised for P- and S-wave velocities (V_P and V_S), and density, but anelastic attenuation is generally obtained from correlations with V_S (Olsen et al. 2008, Graves and Pitarka 2010, Taborda et al. 2014). Eberhart-Phillips et al. (2015) merges, through inversion, several individual regional P-wave quality factor (Q_P) studies, shown in Figure 1, into a single nation-wide model. With this model, there is an opportunity to investigate the regional Q_P–V_S trends in New Zealand (NZ) and compare them with empirical correlations which have been utilized in past physics-based ground motion simulations to determine their practicality for NZ applications.

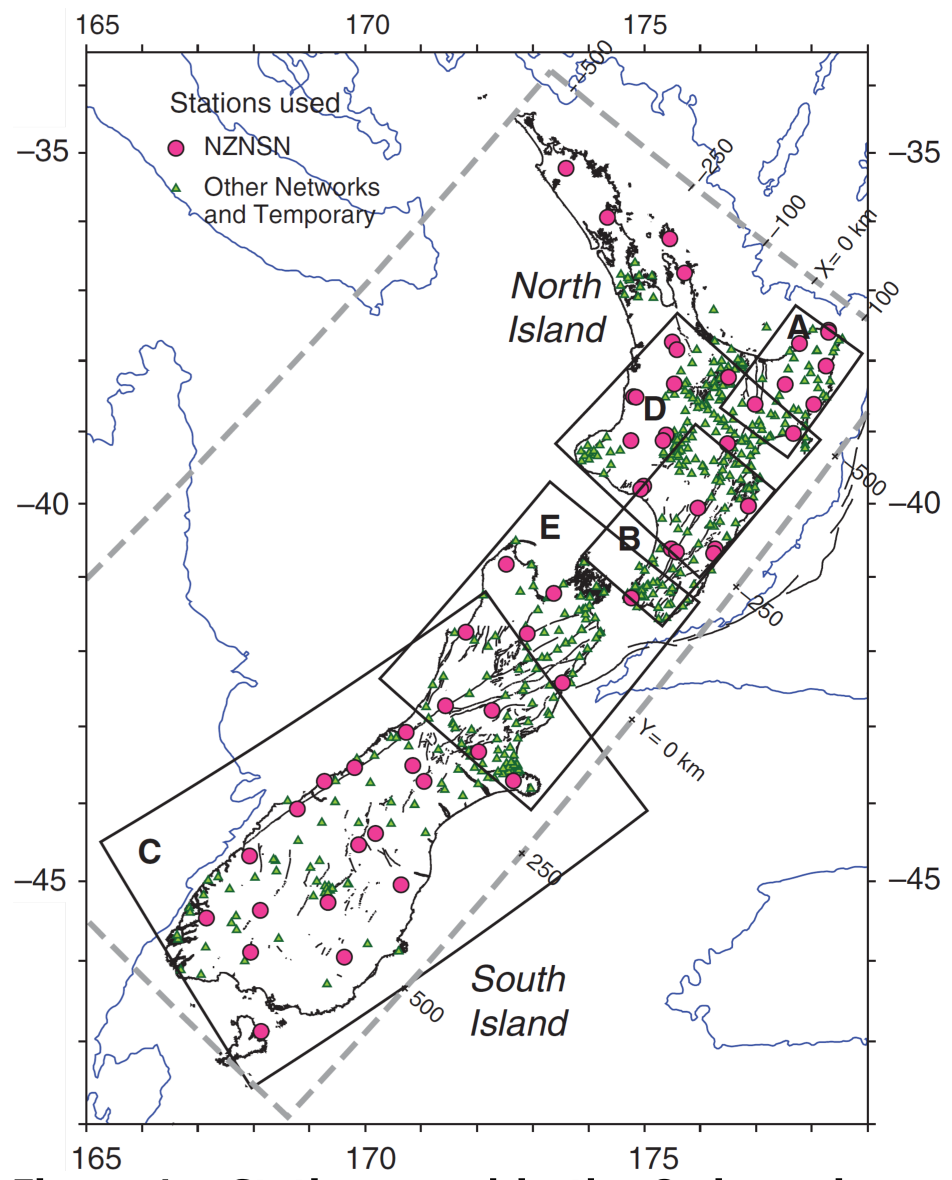

Figure 1: Stations used in the Q_P inversions and areas of individual Q_P studies: (A) Northeastern North Island (Eberhart-Phillips and Chadwick 2002); (B) Southern North Island (Eberhart-Phillips et al. 2005); (C) Central–southern South Island (Eberhart-Phillips et al. 2008); (D) Central North Island (Eberhart-Phillips et al. 2008); and (E) Northern South Island (Eberhart-Phillips et al. 2014). (After Eberhart-Phillips et al. 2015)

2. Scope of Investigated Regions

Fifteen geographically- or seismically-significant regions across NZ were investigated to determine regional Q_P–V_S trends. The location and scope of the considered regions are shown in Figure 2 which also illustrates the variable spatial resolution of the Eberhart-Phillips et al. (2015) model. The relevance of the regions are listed below:

- Auckland, Wellington, Canterbury and Otago are the four major high-population urban provinces. The Canterbury and Auckland regions have the highest and lowest spatial resolution, respectively, as a result of their inversion constraint and coverage of regional studies.
- Napier, Palmerston North, Nelson, Blenheim, West Coast, Kaikoura, Queenstown, Timaru/Oamaru, and Invercargill are lesser populated cities, towns or regions.
- The Fox and Franz Josef Glacier region, and Taupo Volcanic Zone are areas which have previously exhibited seismic activity or potential.

The depths considered in this study are limited to 50km below sea level for two reasons:
(1) Earthquakes generally occur in the upper crust of the Earth structure; and (2) The upper crust has the most significant effect on seismic wave attenuation.

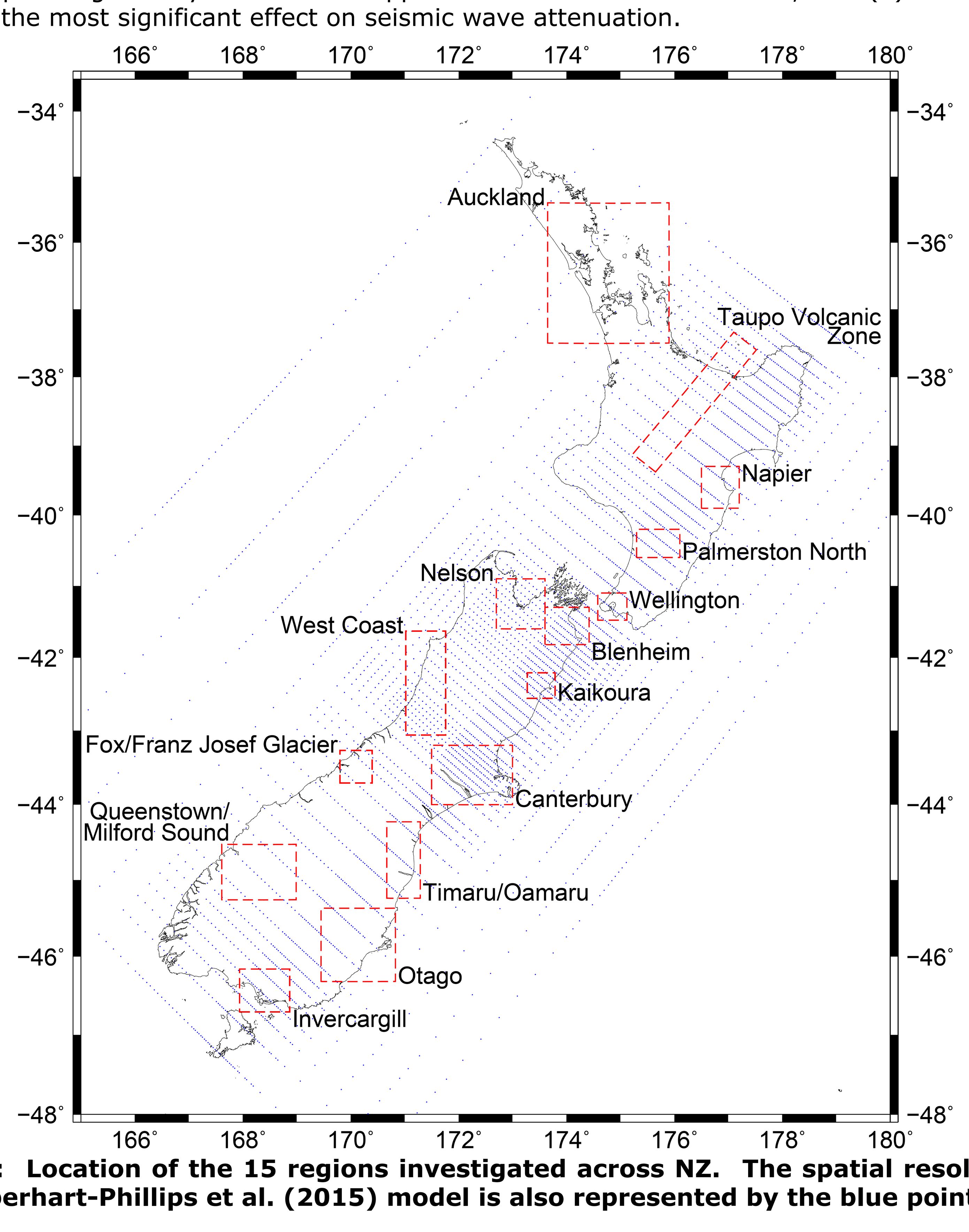

Figure 2: Location of the 15 regions investigated across NZ. The spatial resolution of the Eberhart-Phillips et al. (2015) model is also represented by the blue points.

3. Regional P-wave Quality Factors

The Q_P and V_S data from the Eberhart-Phillips et al. (2015) model are plotted with their moving average and 90% confidence interval for each region, although only the Canterbury region and Taupo Volcanic Zone (TVZ) are presented here. The Graves and Pitarka (2010) correlation, Q_P=100V_S, currently utilised in the Canterbury ground motion simulations (Razafindrakoto et al. 2016) is also plotted for comparison.

Figure 3a and 3b illustrate the Q_P-V_S data from the seismically active Canterbury region, the second highest populated province in NZ, and the volcanically active TVZ, respectively:

- The moving average of the Canterbury region data fits the correlation well for V_S≤3.25km/s (12km depth).
- At V_S>3.25km/s, the Q_P of the Canterbury region increases at a larger rate. However, the shallow crust area (top 10km) is most important for strong motion attenuation as attenuation (1/Q_P) is greatest at shallow depths.
- The TVZ consists of volcanic rock which may be highly fractured at shallow depths and is also affected by high thermal activity. This suggests that the attenuation in the area should be relatively high.
- The Q_P for the TVZ is low at all V_S relative to the other investigated regions. In particular, the moving average deviates far below the Graves and Pitarka (2010) correlation at V_S <3.5km/s.

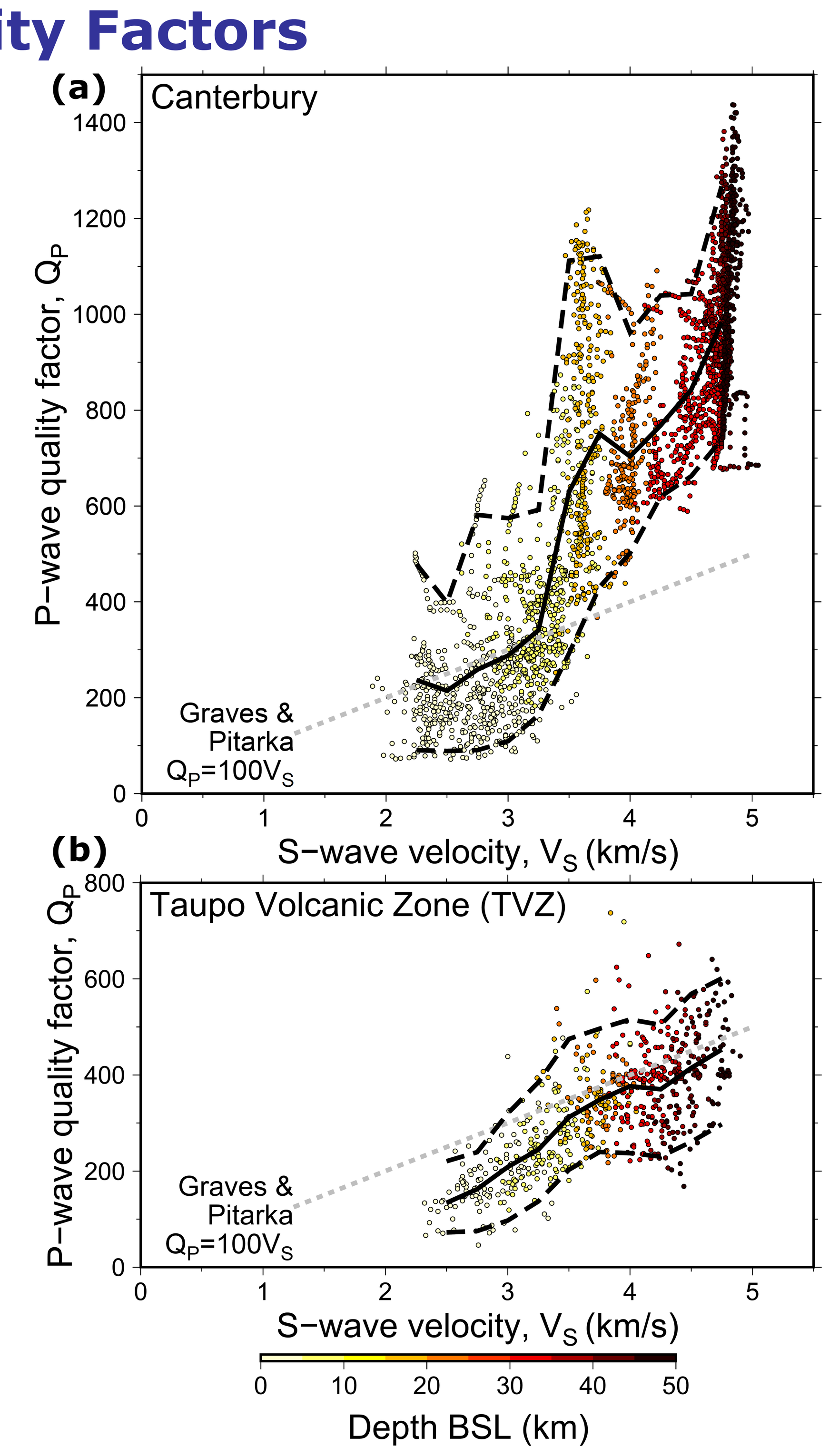

Figure 3: Regional P-wave quality factors from the Eberhart-Phillips et al. (2015) model compared with the Graves and Pitarka (2010) correlation of Q_P=100V_S for the: (a) Canterbury region; and (b) Taupo Volcanic Zone (TVZ).

4. Regional Moving Averages and Correlations

The Q_P-V_S data of each investigated region exhibit different features and trends relating to their geological and seismological setting. Figure 4 illustrates the moving averages of all 15 regions compared against correlations which have been utilized in past physics-based ground motion simulations. The comparison presents the following features and trends:

- The spread of moving averages is smaller at low V_S compared to high V_S.
- The Graves and Pitarka (2010) correlation generally underpredicts Q_P for most regions. Exceptions are the TVZ, Auckland region, and a few other regions at V_S≤3.25km/s (e.g. Canterbury).
- The Aagaard et al. (2008), Brocher et al. (2008), and Taborda et al. (2013) correlations appear to overpredict Q_P for most NZ regions.
- The Brocher et al. (2008) and Taborda et al. (2013) correlations monotonically increase within the V_S values considered while the Aagaard et al. (2008) correlation saturates to a value of Q_P=1000 for V_S≥3.4km/s.
- The Aagaard et al. (2008) correlation appears to model the Timaru/Oamaru region well which roughly saturates to Q_P=900 at around V_S=4km/s.
- The Olsen et al. (2003) correlation fits all the regional moving averages collectively the best and also several individual regions such as the Nelson and West Coast regions.

Overall, the comparisons indicate that the Graves and Pitarka (2010) correlation can be appropriately utilised for the current ground motion simulations being undertaken for the Canterbury region. However, provided the large differences which occur in both regional Q_P values and empirical correlations, correlations should not be used without proper validation of their applicability to the specific region of interest.

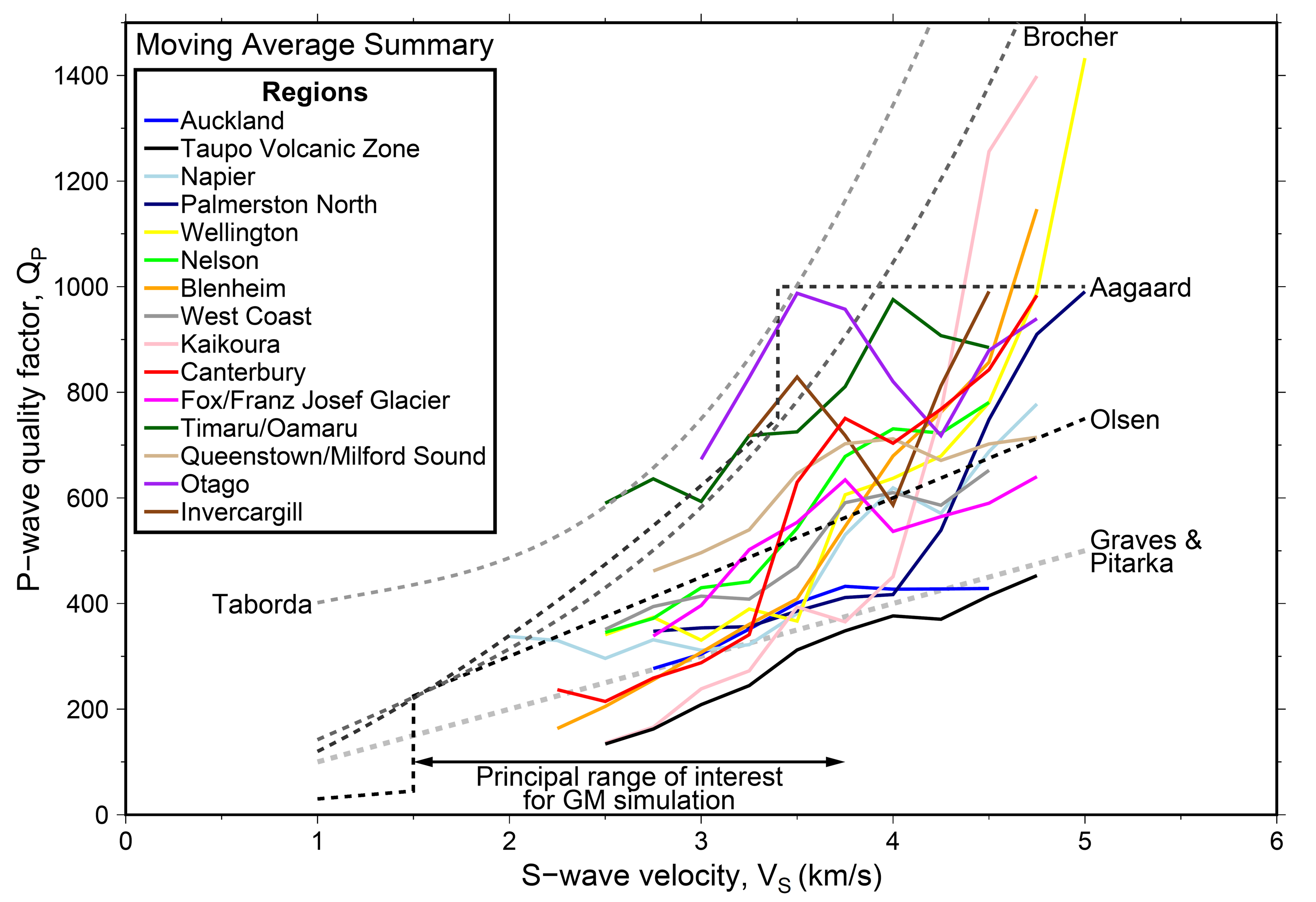

Figure 4: Moving average summary of all 15 regions compared to correlations which have been utilized in past physics-based ground motion simulations.