A Vs30 map for New Zealand based on geology, topographic slope and direct measurements

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Motivation
Vs30 (the time-averaged shear wave velocity in the uppermost 30 metres of a given location) is an important engineering parameter used in research and practice. Vs30 is not straightforward or inexpensive to measure directly. Mapping Vs30 as a continuous quantity falls within the realm of geostatistical problems – where a limited set of observations in limited locations are used to attempt to understand the quantity elsewhere. These observation points are often geographically and geologically clustered, viz.: more measurements are collected in the built environment (in or near cities and towns), and cities & towns are often located in places with specific geologic characteristics (such as near alluvial deposits and water sources, for their ease of construction and transportation, among other considerations).

This study represents a second proxy Vs30 mapping (Figure 1) for New Zealand after Perrin et al. (2015). Similar work has been carried out for other regions, e.g. North America. Most approaches to Vs30 mapping share some common characteristics: using a limited set of observed Vs30 values for a region, and finding correlations with readily available proxy data (geology & topography) to constrain estimated values of Vs30. This work aims to add to the knowledge of Vs30 mapping for New Zealand including, e.g., interpolation to resolve local discrepancies with available data (Figure 2) and developing a continuous estimate of model uncertainty. The resulting Vs30 and uncertainty maps will be valuable as a first-order resource for classifying uncharacterised sites, and as inputs to ground motion simulation research.

Figure 1: New Zealand Vs30 map with measurements. (Inset box shows Figure 2 region)
Left: geology only model (with Bayesian updating).
Right: Hybrid (slope-dependent) model with interpolation via Worden et al. MVN (multivariate normal) method.

Methodology

We employ a rigorous statistical methodology that expands on similar work in a few important ways. Because Vs30 data is geologically clustered (Figure 3), we take a Bayesian approach to estimating log-mean Vs30 and standard deviation for various geology subgroups. Bayesian priors are borrowed directly from another study (Ahdi, 2017; Alaska). The Bayesian updating allows reasonable Vs30 estimates to be applied for geology that is underrepresented in the NZ data. A “hybrid” map is then generated by applying corrections based on the correlation between topographic slope and Vs30 (Figure 4). A pointwise comparison of geology-based model estimates between this work and Perrin et al. is presented in Figure 5.

The Vs30 estimate map uses a geostatistical interpolation scheme (Worden et al., in review) that offers some advantages over the conventional regression kriging approach. The method is computationally intensive for continuous mapping but has the significant advantages of (a) directly accounting for subgroup standard deviation and (b) allowing for “fuzzy” measurements and/or estimates. Judgment-based assumptions of the precision of measurements are used to represent epistemic uncertainty, allowing the interpolation to constrain the model locally without introducing abrupt “spikes and dips” in the mean, and without conveying a misleadingly low standard deviation in the vicinity of imprecise data.

Figure 3: Vs30 measurements from Kaiser et al., grouped by the geology classifications of Ahdi. Coloration indicates the Kaiser et al. assessment of data quality (Q1, red: highest quality ranking). The high data density is characterized by lower quality data or estimates (some based on previous mapping work by Perrin et al.). Some geology groups are sparsely populated.

Figure 5: For points in the Kaiser dataset, Vs30 values (vertical axis) and minimum & maximum values from Perrin et al. map are compared. Color indicates quality ranking (Q1 = best). (Note that some Q3 Kaiser values are based on Perrin et al.)