Dynamic site characterisation of the Waikato basin using passive and active surface wave methods

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Summary

Recent earthquakes in New Zealand highlighted the lack of quantitative data required to accurately model local site effects within New Zealand's sedimentary basins. The aim of this project is to characterise the shear wave velocity (Vs) profiles of the Waikato basin (figure 1) using active and passive surface wave methods. This poster presents the preliminary shear wave velocity profiles for two sites, Ruakura and Rotokauri, obtained through the joint inversion of Rayleigh wave dispersion curves and the Rayleigh wave ellipticity peak frequency. Ten more sites are planned for testing in 2020 and the obtained velocity profiles will be used to develop a 3D seismic velocity model of the Waikato basin, which can be used for regional-scale ground motion simulations, seismic response analysis, or liquefaction susceptibility analysis in this region.

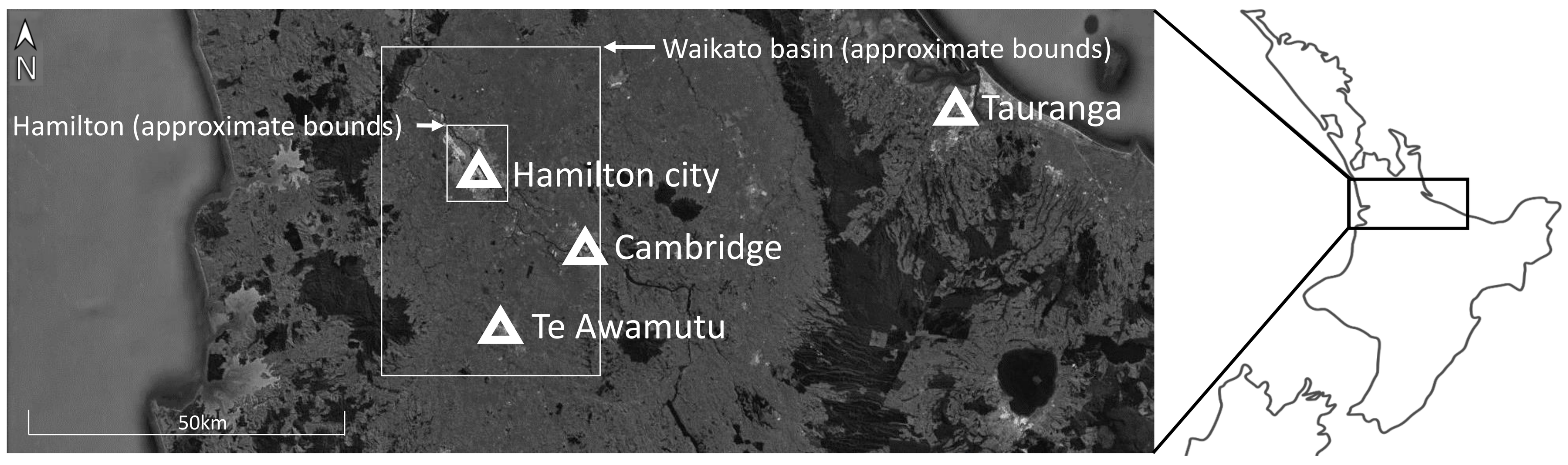

Figure 1. Location of the Waikato basin is defined by the larger rectangle with Hamilton city bounds defined by the smaller rectangle. Place names and a graphic of the North Island are included for clarity

Background

- The ground motion data recorded from the 2018 M6.1 Taumaranui earthquake provided evidence of amplified ground motions in the Waikato basin (figure 2b).
- There is a lack of quantitative site characterisation data required to accurately model the effect of local geology, despite the significance of the regional population, economy, and the critical infrastructure systems.
- The fundamental period of the basin (figure 2a) suggests amplification of long period (2 to 5s) waves. It also suggests that most locations in the Waikato basin will be categorised as class D sites, according to NZS1170.5:2004 (Jeong and Wotherspoon, 2019).
- This project aims to characterise the Waikato basin by using surface wave methods to develop shear wave velocity profiles which will be used to quantitatively model basin response

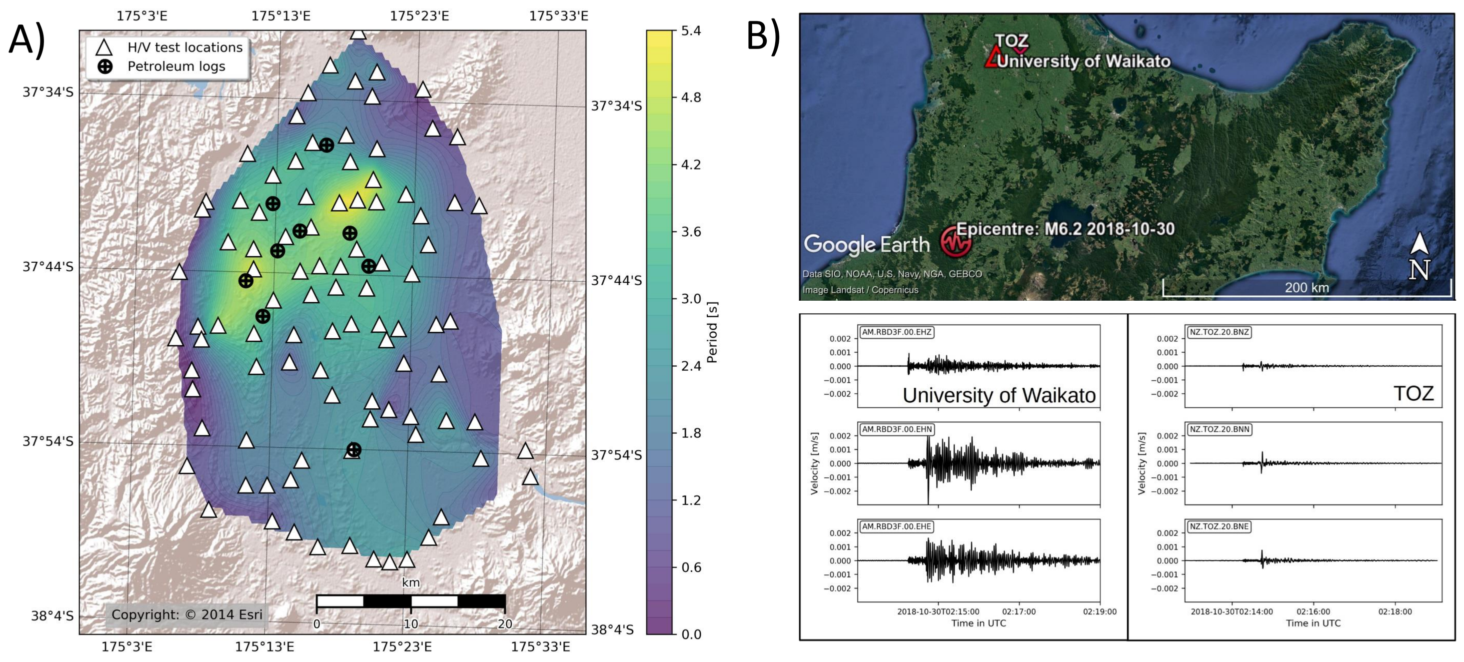

Figure 2. a) Fundamental site period map of the Waikato basin which shows the longer fundamental periods in yellow and shorter periods in purple (b) Comparison of ground motion recorded in Hamilton (UoW and HBHS; soft sites) and Morrinsville (TOZ; a rock site)

Surface Wave Methodology

Two field methods are used; Microtremor Array Measurements (MAM) which involves the deployment of two-dimensional seismometer arrays to record ambient vibrations (figure 3) and Multichannel Analysis of Surface Waves (MASW) which involves the deployment of linear arrays of geophones to record the surface waves generated by a sledge hammer (figure 3).

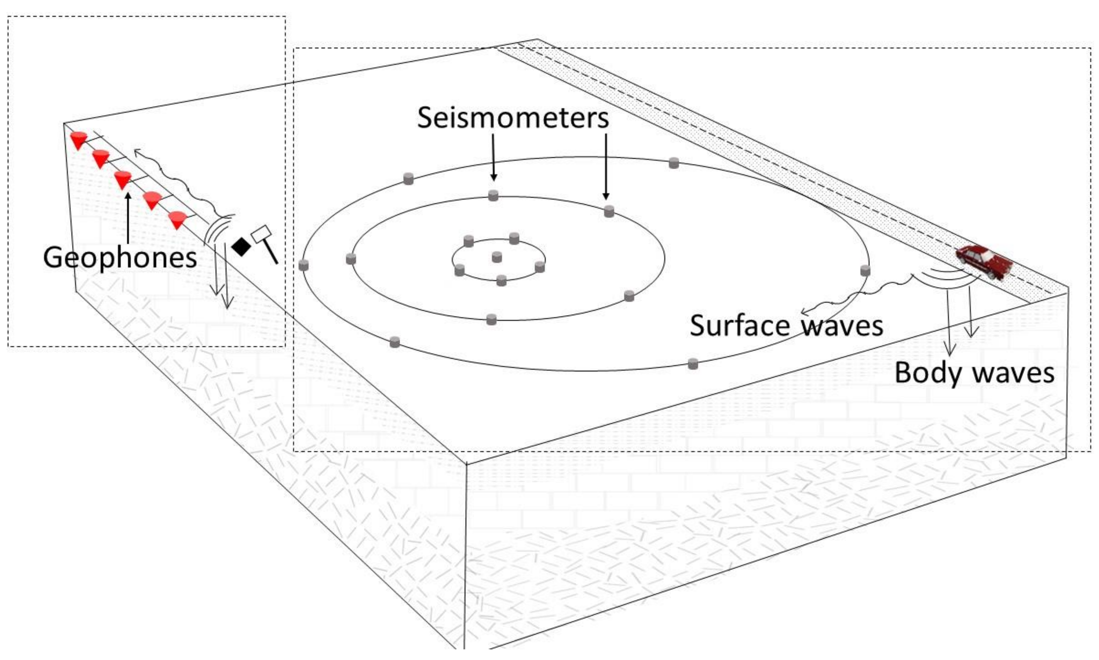

Figure 3. A schematic of the field testing setup for Microtremor Array Measurement (MAM) and Multichannel Analysis of Surface Waves (MASW). The geometry and number of arrays can vary depending on the site.

The obtained data are processed into a dispersion curves (DC) which describe surface wave propagation speed as a function of frequency (or wavelength). DCs are inverted using software packages to develop a suite of shear wave velocity profiles.

For the preliminary results in this poster, the layering ratio method (Cox & Teague, 2016) was combined with a best fit dispersion curve and an H/V derived fundamental ellipticity peak for the inversion. No a priori information was used, however, this will be used in the final results.

Preliminary Shear Wave Velocity Profiles

The locations of test sites (Ruakura and Rotokauri) within the Waikato basin is depicted in figure 4. The shear wave velocity profiles, the dispersion curves and the Rayleigh wave ellipticity curves from the Ruakura site are displayed in figure 5. Shear wave velocity (Vs) ranged from 170-190m/s in the upper 20m, which as per NZS1170.5:2004, classifies this site as site class D. However, it should be noted that these results are preliminary and are subject to change. As per figure 5a the shear wave velocity increases with depth representing the increasing geologic unit thickness and density. Bedrock depth can be inferred from the large impedance contrast in the Vs profiles, which ranges from 450m to 700m with a shear wave velocity of 1500-2600m/s.

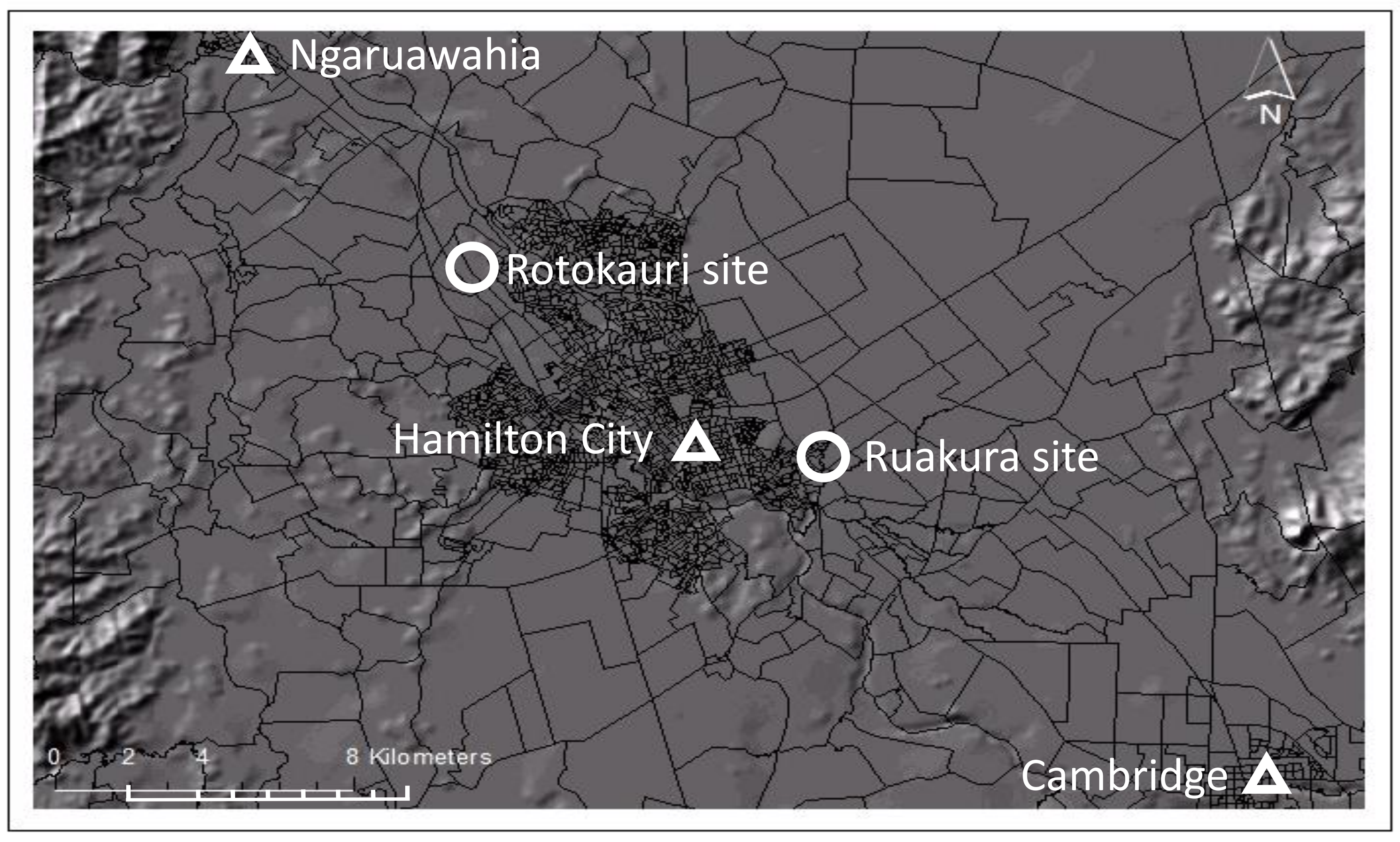

Figure 4. Relief map of Hamilton city and surrounds with testing site locations marked by circles

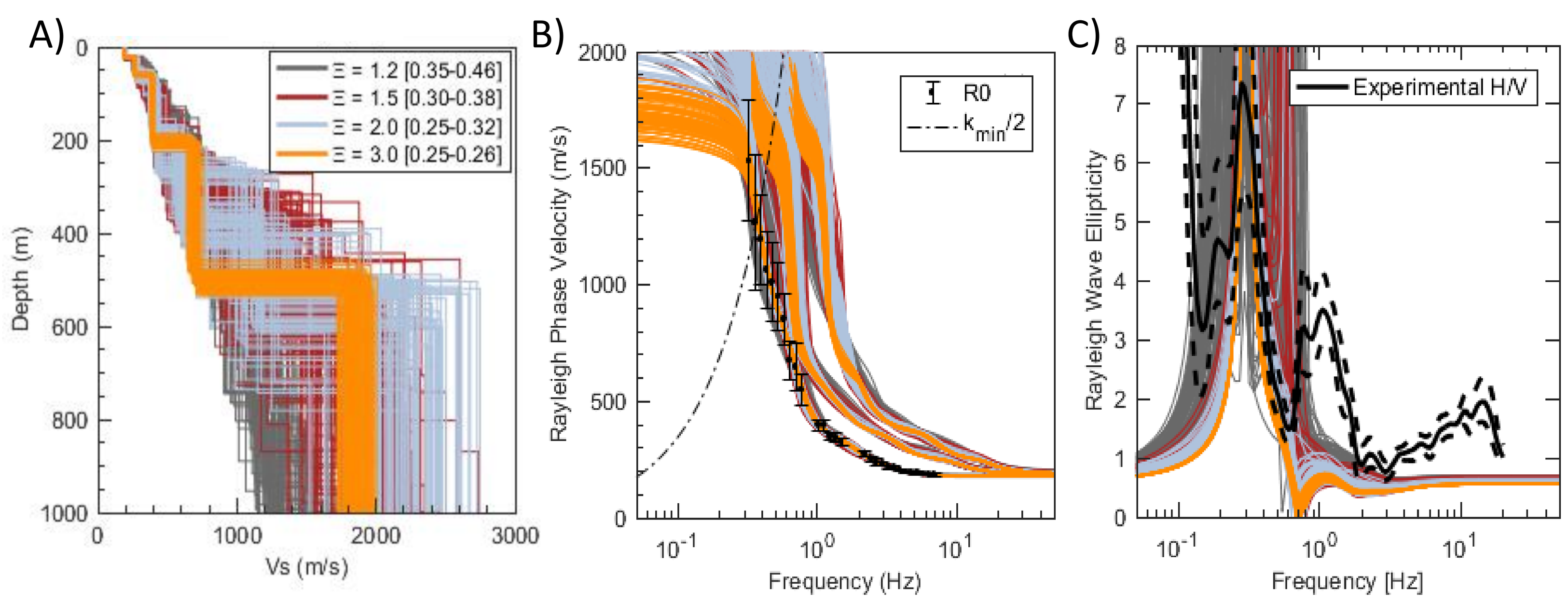

Figure 5. a) Inverted shear wave velocity profiles at Ruakura. Each colour code represents 100 best profiles for each layering ratio b) The dispersion curve used in the inversion c) The Rayleigh wave ellipticity curves compared with the experimental HVSR used in the inversion.

At the Rotokauri site (location in figure 4), the upper 20m has a shear wave velocity range of 100m/s to 155m/s classifying this site as class E as per NZS1170.5:2004. The shear wave velocity profiles, dispersion curve and ellipticity curve are shown in figure 6. Bedrock depth can be inferred from the large impedance contrast in the velocity profiles, which ranges from 1200m to 1600m with a shear wave velocity of 2800-3500m/s.

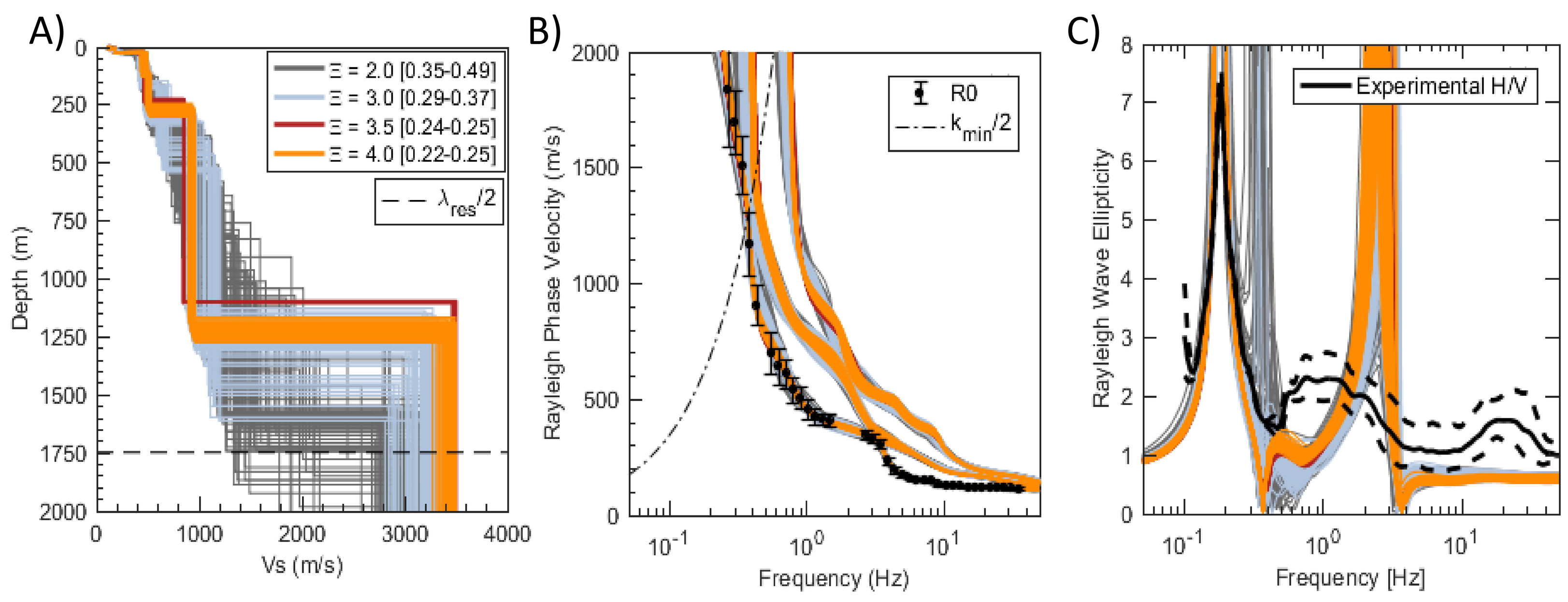

Figure 6. a) Preliminary inverted shear wave velocity profiles at Rotokauri. Array resolution limit lines in black for Rotokauri show the maximum resolvable depth from the surface wave data (approximately ½ kmax or the maximum array diameter used in the testing). Each colour code represents 100 profiles for each layering ratio b) Dispersion curves of inverted profiles and the experimental dispersion curve used in the inversion c) The Rayleigh wave ellipticity curves compared with the experimental HVSR used in the inversion.

Conclusions

This poster presents the preliminary results of the surface wave tests we conducted at two sites in the Waikato basin. The shear wave velocity profiles are obtained by the joint inversion of surface wave dispersion curves and the Rayleigh wave ellipticity peak frequencies. Ten more sites are planned for testing in 2020, with a purpose of developing a 3D velocity model of the Waikato basin which can be used for regional-scale ground motion simulations, seismic response analysis, or liquefaction susceptibility analysis in this region

References

Jeong, S., & Wotherspoon, L. (2019). Development of a Waikato Basin T0 and depth model by the H/V spectral ratio method. *2019 Pacific Conference on Earthquake Engineering*

Cox, B. R., & Teague, D. P. (2016). Layering ratios: A systematic approach to the inversion of subsurface wave data in the absence of a priori information. *Geophysical Journal International*, (207), 422–438. https://doi.org/10.1093/gji/ggw282