Development of a 3D Canterbury Seismic Velocity Model

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1. Background and Objective

This poster presents the ongoing development of a 3D Canterbury seismic velocity model which will be used in physics-based hybrid broadband ground motion simulation of the 2010-2011 Canterbury earthquakes. Velocity models must sufficiently represent critical aspects of the crustal structure over multiple length scales which will influence the results of the simulations. As a result, numerous sources of data are utilized in order to provide adequate resolution where necessary.

The Canterbury region has a unique and complex geology which likely has a significant impact on strong ground motions, in particular the deep and loose deposits of the Canterbury basin. The Canterbury basin has several implications on seismic wave phenomena such as long period ground motion amplification and wave guide effects. Using a realistic 3D seismic velocity model in physics-based ground motion simulation will implicitly account for such effects and the resultant simulated ground motions can be studied to gain a fundamental understanding of the salient ground motion phenomena which occurred during the Canterbury earthquakes, and the potential for repeat occurrences in the Canterbury region.

Figure 1 shows the current model domain as a rectangular area between Lat=[-43.2˚,-44.0˚], and Lon=[171.5˚,173.0˚]. This essentially spans the area between the foot of the Southern Alps in the North West to Banks Peninsula in the East. Currently the model extends to a depth of 50km below sea level.

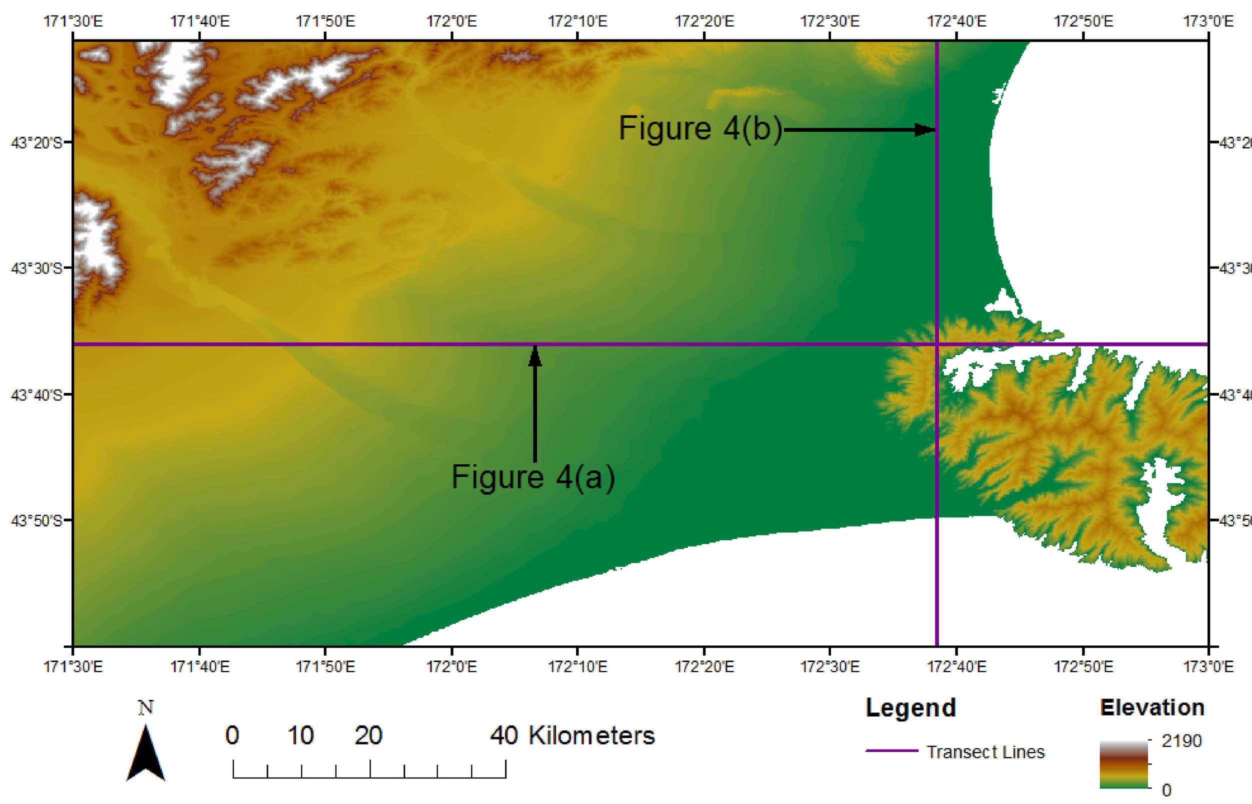

Figure 1: Model domain of the Canterbury velocity model showing transect lines for the cross sections in Figure 4.

2. Experimental Data

The development of a Canterbury seismic velocity model requires collection of numerous sources of data to adequately constrain the desired domain at length scales required to propagate reasonably high frequency ground motions. Although there have been some simplified studies on the geologic and velocity structure of Canterbury in the past, there is also now an abundance of high quality data from both recent and ongoing studies as a result of the 2010-2011 Canterbury earthquake sequence. The different experimental data and their application within the velocity model are listed below:

- 3D seismic tomography data (Eberhart-Phillips et al. 2010) will be utilized for the deeper parts of the velocity model, roughly between 2.5km to 50km. The data is provided as a 3D grid of P-wave and S-wave velocities, and density values.
- Onshore and offshore seismic reflection lines (Barnes et al. 2011; Pettinga et al. 2013) will be used to constrain the velocity model in the intermediate depths, roughly between 500m and 2.5km. An example seismic reflection line is shown in Figure 2 (a) which shows a vertical plane of P-wave velocities and also significant geologic horizons.
- Shear wave velocity profiles produced from forward modeling of passive and active surface wave testing (Cox et al. 2013) will be used to constrain part of the near surface velocities from the ground surface to depths of up to 1.5km. Figure 2(b) shows 10 examples of shear wave profiles at different sites produced from testing carried out in early 2013.
- Standard penetration test, cone penetration test and shear wave velocity data (CGD, 2013) will also be used to constrain the near surface velocities, and also enable the determination of nonlinear constitutive model soil parameters.

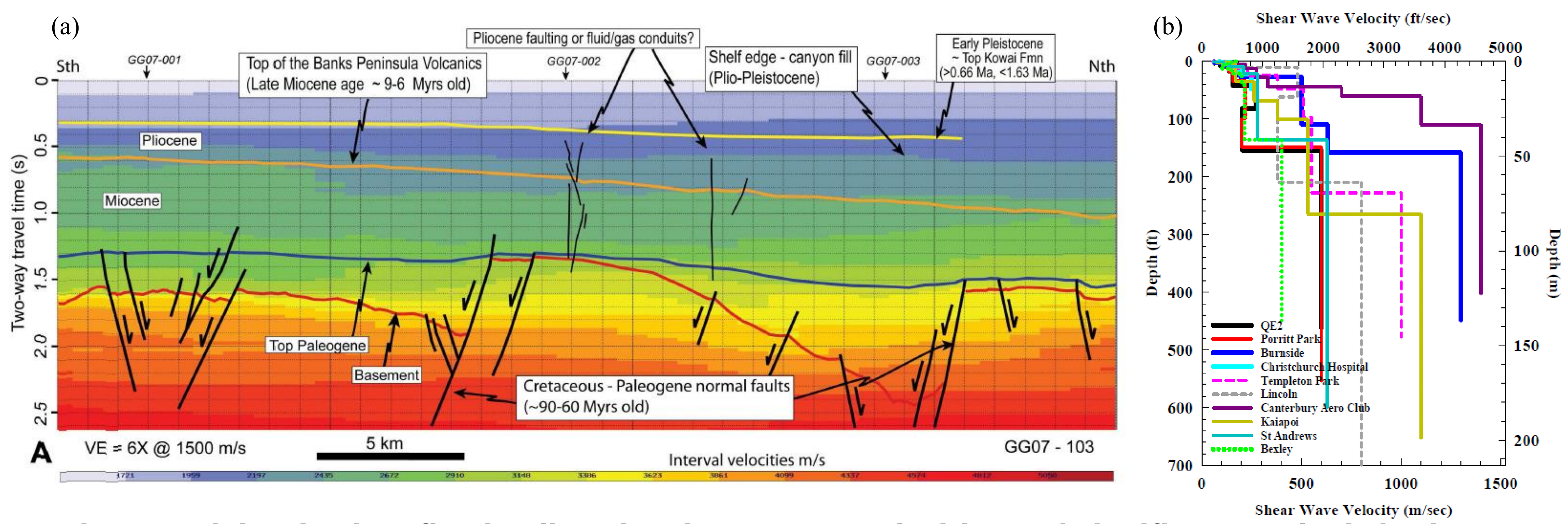

Figure 2: (a) Seismic reflection line showing P-wave velocities and significant geologic horizons (Barnes et al. 2011), and (b) Shear wave profiles at 10 locations (Stokoe et al. 2013).

3. Ground Surface and Geologic Horizon Models

Elevation surfaces are also important in defining a velocity model. The ground surface and significant geologic horizons are used to determine which rules and data sets to utilize for a given point in the velocity model. Several elevation surfaces have been produced thus far and other surfaces are currently being developed, including:

- A ground surface model, as shown in Figure 3(a), has been produced to constrain the upper bounds of the velocity model and was produced by stitching together numerous available digital elevation models (DEM), making use of higher resolution models where possible.
- The depth to the base of the Quaternary sediments, as shown in Figure 3(b), has been produced from structural contours and elevations derived from seismic reflection lines (Jongens, 2011). This surface is being continuously updated with incoming new data such as seismic reflection lines and shear wave profiles.
- Another significant geologic horizon which is not yet implemented is the Riccarton Formation, a shallow geologic horizon (depths of 10-40m over the Christchurch urban area) which will strongly influence shallow site response

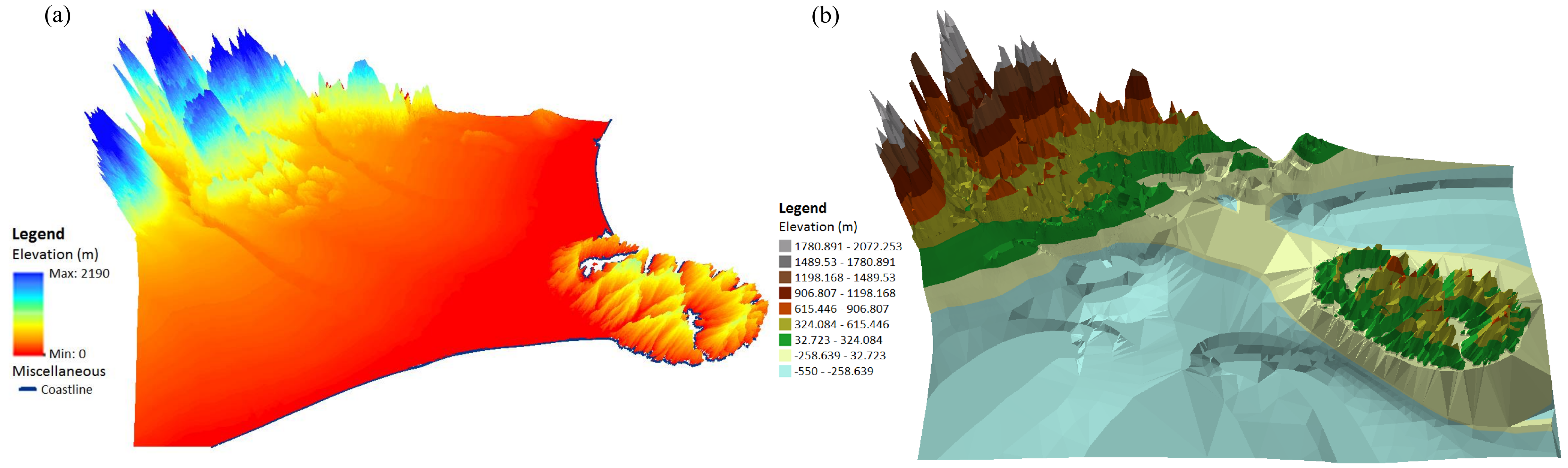

Figure 3: (a) Ground surface model derived from numerous available digital elevation models, and (b) Base of the Quaternary sediments derived from structural contours and seismic reflection line elevations.

4. Prototype velocity model

A preliminary prototype version of the Canterbury velocity model has been developed. The required inputs are domain boundaries and grid spacing in the x, y and z directions. This allows a 3D mesh of points to be produced at the preferred grid spacing.

Currently, the implemented model contains the DEM and Quaternary surfaces, and 3D seismic tomography data. Basin velocities have been given placeholder values of V_P=1500 m/sec and V_S=400 m/sec. Data from seismic reflection and active and passive surface wave analysis are currently being included, and SPT/CPT and surficial V_S data will be subsequently incorporated. Empirical relations have also been implemented into the velocity model (e.g. to provide V_S and density, where seismic reflection gives only V_P data).

As shown in Figure 4, for example, the model was interrogated via numerous cross sections of constant latitude and constant longitude in order to determine its robustness and validity. The ground surface and basin elevation models (shown as black lines), and velocity patterns were consistent with conventional understanding of the regional geology. Depths to shear wave velocities of 1.0 km/sec and 2.5 km/sec are also provided as the grey lines. Figure 4(a), at a constant latitude value of -43.6˚, explicitly shows the Canterbury foothills on the left and the Port Hills on the right. Figure 4(b), at a constant longitude value of 172.64˚, also shows the Port Hills and crosses through the Christchurch Central Business District.

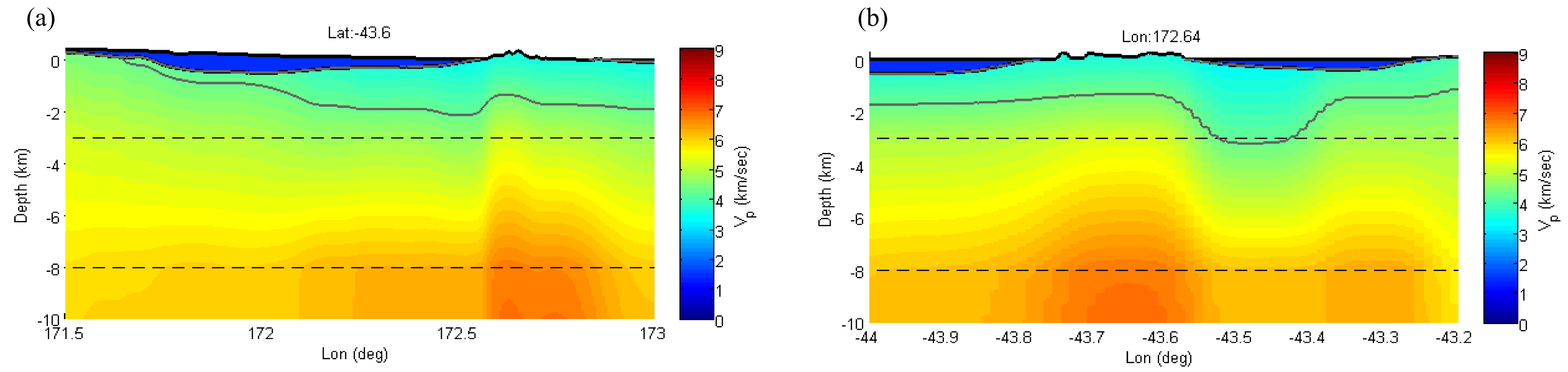

Figure 4: Cross sections of the current version of the Canterbury velocity model to depths of 10km as shown in Figure 1: (a) at a constant latitude value of -43.6˚, and (b) at a constant longitude value of 172.64˚.