PhD Scholarships and Postdoctoral Fellowships in Ground Motion Simulation, Validation, and Applications

Overview: Two PhD scholarships and two postdoctoral fellowships are available for multiple topics associated with earthquake-induced ground-motion and site response prediction utilizing simulation-based methods. The overarching aim in all specific project instances is to advance understanding of ground-motion phenomena and predictive ability through hybrid broadband simulations. In some instances this is directly through the use of simulations for seismic hazard analysis, and in other instances through the use of simulations to constrain empirical ground-motion models for parameter combinations that observational data are deficient. The projects are based at the University of Canterbury in Christchurch, New Zealand, but PhD students will also interact with national and international collaborators.

Specific topics: Any of the following topics are currently available:

1. *Toward fully non-ergodic considerations in ground-motion simulation:* Simulations have inherent event-, region- and site-specific representations that do not make the ergodic assumption conventionally employed in many empirical ground-motion models, the most obvious being a 3D velocity/crustal model. However, many parameters and sub-models within simulations currently use coefficients that are constant over a broad geographical region, examples include Brune stress parameter, anelastic attenuation dependence on shear-wave velocity, and shallow site response dependence on 30-m-averaged shear wave velocity. This project is intended to progress toward all key model parameters and sub-models having non-constant regional variation. Observational data from earthquakes in New Zealand will be used to develop regionally-varying models, as well as performing validation to iteratively address trade-offs that can exist between prediction residuals and different model components. Supervisors: Brendon Bradley, University of Canterbury; Peter Stafford, Imperial College.
2. *Creating a physics-based understanding of the spatial correlation of earthquake-induced ground motions in regions of complex geology:* Existing spatial correlation modelling has been principally empirical in nature, based on observations of historical earthquakes globally. The overall objective of this research is to advance our fundamental understanding of the salient physics of spatial correlations in earthquake-induced ground-motions through analysis of a large NZ ground motion dataset with advanced geostatistical and ground motion modelling methods. The analysis methods will form a validation framework that will enable consideration of additional spatial information that was previously not possible with conventional analysis methods. In particular, the physics-based ground motion simulation method employed will allow direct association between observed spatial correlation trends and fundamental earthquake fault rupture, seismic

wave propagation, and near-surface site effects. Supervisors: Robin Lee, Brendon Bradley, University of Canterbury; Jack Baker, Stanford University.

3. *Validation of 3D ground-motion simulations at high frequencies:* There is increasing emphasis on pushing the upper frequency limit of 3D ground-motion above 1Hz to cover the full range of engineering interest (10+ Hz). This requires consideration of many phenomena that can be overlooked for frequencies ≤1Hz, including: topography, frequency-dependent Q, small-scale velocity heterogeneties, plasticity, among others. While much emphasis has been placed on the computational inclusion of such phenomena in wave propagation simulations, little to no attention has currently been given to quantifying the improvement (if any) in the prediction of the resulting simulations against observations, and thus where further research is principally needed. This research will seek to answer that question using a large database of observed crustal and subduction earthquakes in New Zealand. Supervisors: Brendon Bradley, Robin Lee, University of Canterbury.
4. *Seismic hazard analysis using simulated ground motions:* There remain several hurdles to routinely adopt hybrid broadband simulated ground motions in probabilistic seismic hazard analysis, and this project will seek to address one or more of: explicit uncertainty incorporation, source models that consider non-characteristic ruptures (that result in several orders of magnitude more rupture realizations), forward or reciprocal calculations, and how to weight simulation-based models in a logic tree along with conventional empirical ground-motion models. Supervisors: Brendon Bradley, University of Canterbury (UC).
5. *Development of region-specific sedimentary basin models:* This project will involve the collection, collation, and analysis of field geophysical and geotechnical data (e.g., MASW, MAM, HVSR, CPT) to develop and/or refine basin models for various geographic regions in New Zealand. The relative performance of models will be based on validation of ground-motion simulations against ground motion observations, and New Zealand-wide models of Z1.0 and Z2.5 will be developed, as well as examining the region-specific dependence of these parameters on Vs30. Particular attention will be given to the use of advanced statistical and machine learning methods to synthesise different data types and spatial clustering. Supervisors: Brendon Bradley, Robin Lee, University of Canterbury (UC).
6. *Coupling explicit site response analysis with ground-motion simulations:* This project will examine the application and validation of near-surface site response analysis approaches that can be coupled with regional ground-motion simulations. Building on recent work that has focused on total stress 1D site response analyses, this work will extend to focus on 2D/3D methods and/or effective stress formulations, and validation of case histories from historical New Zealand earthquakes and instrumentally-observed ground motions. Supervisors: Brendon Bradley, University of Canterbury (UC); Adrian-Rodriguez-Marek, Virgina Tech.
7. *Use of ground-motion simulations to constrain empirical model functional forms:* Due to lack of constraint from observations alone, simulations have been previously used for phenomena such as magnitude scaling, nonlinear site response, hanging-wall, directivity effects, among others. This project will use 3D ground-motion simulations to advance the functional form of empirical ground motion models. Primary attention will be given to non-ergodic regional-variations in 3D path (geometric spreading and anelastic attenuation) and linear site response effects. Supervisors: Brendon Bradley, University of Canterbury (UC); Peter Stafford, Imperial College; Adrian-Rodriguez-Marek, Virgina Tech.

Further information: on research in these fields at the University of Canterbury can be found at: https://sites.google.com/site/brendonabradley/

Relevant background: Applicants should have a background in Civil Engineering, Geophysics, or related disciplines. High competency in data analysis, numerical modelling, and programming is desired.

PhD Scholarship Details: This scholarship includes a $35,000 NZD/year stipend (tax-free) and all university tuition and fees for the three-year duration of the PhD project.

Postdoctoral Fellowship Tenure and Salary Details: The position is for an initial tenure of two years. Salaries are in the range of $85,000-95,000 depending on past experience.

Application Details: If interested in applying, please contact brendon.bradley@canterbury.ac.nz with the email title "PhD Scholarship/Postdoctoral fellowship in ground-motion simulation, validation, and applications" and attach the following documents: (1) CV; (2) cover letter; and (3) any digital copies of journal/conference papers and/or theses you have authored. Applications close 30 November 2023, but will be reviewed as they are submitted. The projects are expected to start in the first half of 2024, though a delayed start maybe possible depending on individual circumstances.