Notice of the Final Oral Examination
for the Degree of Master of Science

of

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BSc (University of Victoria, 2018)

“Geodetic Methods of Mapping Earthquake-Induced Ground Deformation and Building Damage”

School of Earth and Ocean Sciences

Friday, June 26, 2020
10:00 A.M.
Remote Defence

Supervisory Committee:
Dr. Edwin Nissen, School of Earth and Ocean Sciences, University of Victoria (Supervisor)
Dr. Lucinda Leonard, School of Earth and Ocean Sciences, UVic (Member)
Dr. Tuna Onur, Department of Civil Engineering, UVic (Outside Member)

External Examiner:
Dr. Andrea Donnellan, Jet Propulsion Laboratory, California Institute of Technology

Chair of Oral Examination:
Dr. Mauricio Garcia-Barrera, Department of Psychology, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies
Abstract

We use temporal lidar and radar to reveal fault rupture kinematics and to test a method of mapping earthquake-induced structural damage. Using pre- and post-event data, these applications of remote technology offer unique perspectives of earthquake effects. Lidar point clouds can produce high resolution, three dimensional terrain maps so subtle landscape shifts can be discerned through temporal analysis, providing detailed imagery of co-seismic ground displacement and faulting. All weather radar systems record back-scattered signal amplitude and phase. Pre- and post-event comparisons of phase can illuminate co-seismic structural damage using an oblique look angle, most sensitive to changes in building heights. Extracted information from these geodetic methods may be used to inform decisions on future earthquake modeling and emergency response.

In the first major section of this thesis, we calculate co-seismic 3D ground deformation produced by the Papatea fault using differential lidar. We demonstrate that this fault - a key element within the 2016 $M_w$ 7.8 Kaikoura earthquake - has a distinctly non-planar geometry, far exceeded typical co-seismic slip-to-length ratios, and defied Andersonian mechanics by slipping vertically at steep angles. Its surface deformation is poorly reproduced by elastic dislocation models, suggesting the Papatea fault did not release stored strain energy as typically assumed, perhaps explaining its seismic quiescence in back-projections. Instead, it slipped in response to neighboring fault movements, creating a localized space problem, accounting for its anelastic deformation field. Thus, modeling complex, multiple-fault earthquakes as slip on planar faults embedded in an elastic medium may not always be appropriate. For the second major part of this thesis, we compare mean values of interferometric synthetic aperture radar (InSAR) coherence change across four case studies of earthquake induced building damage. These include the 2016 Amatrice earthquake, the 2017 Puebla {Morelos earthquake, the 2017 Sarpol-e-Zahab earthquake, and the 2018 Anchorage earthquake. We examine the influences of environmental and urban characteristics on co-seismic coherence change using Sentinel-1 imagery and compare the outcomes of various
damage levels. We do not find consistent values of mean coherence change to distinguish levels of damage across the case studies, indicating coherence change values for vary with location, environment, and damage pattern. However, this method of damage mapping shows potential as a useful tool in earthquake emergency response, capable of quickly identifying localized areas of high damage in areas with low snow and vegetation cover. Given the large spatial coverage and relatively quick, low cost acquisition of SAR imagery, this method could provide damage estimates for unsafe or remote regions or for areas unable to self-report damage.