HIGH-RESOLUTION DIGITAL SURFACE MODELS OF THE 2016 Mw7.8 KAIKOURA EARTHQUAKE, NEW ZEALAND

Allocation: NSF PRAC/240 Knh
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EXECUTIVE SUMMARY

The 4D evolution of topography is critical for understanding faulting and landslide processes and the linkages between the two. For major events that deform and erode landscapes, such as earthquakes, we lack data at an event scale for understanding such processes because of the prohibitive cost of repeat land and airborne surveys, and because pre-event data is usually lacking. However, recent advances in high-performance computing coupled with stereo-satellite imagery collection allow the opportunity to provide regional-scale, high-resolution topographic time-series.

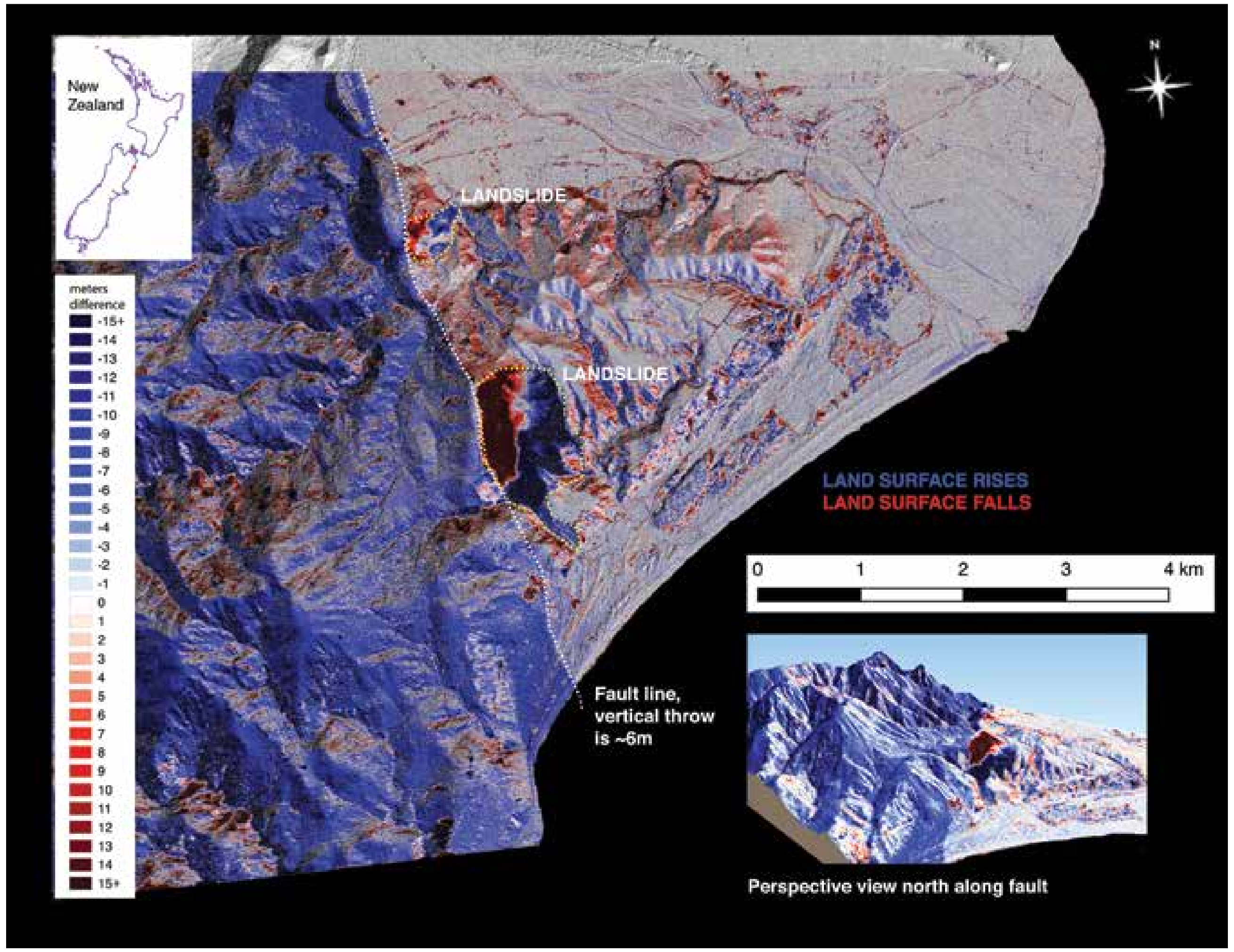

Figure 1: Elevation change from differenced digital surface models of the area near Waipapa Bay, northeastern South Island, New Zealand. Red regions—elevation drop in response to the earthquake. Blue regions—elevation gain. Landslides (yellow dots) are prominent. Satellite measurements of landslide volumes are identical to those made using UAV (unmanned aerial vehicle).

The November 14, 2016, Mw7.8 Kaikoura, New Zealand, event represents the first opportunity to execute such efforts for a regional scale, large-magnitude earthquake because a data for a large area of New Zealand were collected with stereo satellite imagery following the 2011 Christchurch earthquakes.

RESEARCH CHALLENGE

Regional assessment of landsliding and infrastructure damage in the aftermath of large earthquakes is a broad societal problem involving loss of life and property. Because hazard assessment is limited by access and resources in the immediate aftermath of an earthquake, satellite-based photogrammetry methods using high-resolution imagery and high-performance computing potentially provide an avenue to rapidly assess land surface changes and infrastructure damage in a cost-effective and time-sensitive manner.

Whereas commonly used radar-based methods rely on coherent ground deformation for constraints on finite fault slip models, these techniques break down where there is surface disruption, such as surface faulting, landsliding, and infrastructure damage. New methods using photogrammetry techniques take advantage of in-line stereo imagery capture of high-resolution (0.5 m Ground Sampling Distance) Worldview™ satellite data. Digital surface models derived from these data provide valuable information for quantitative assessment of surface change. Immediate collection preserved these data in the most pristine form, and regional assessment provides a synoptic view not provided by typical post-event land- or airborne-based surveys. The third and fourth dimension provided by satellite-derived surface models will significantly advance auto-recognition algorithms by combining image analysis with 3D surface data.

METHODS & CODES

We want to understand how the landscape evolves in time after an earthquake, examining fine-scale land-surface rupture and landslide processes. We do this by making repeat models of the terrain in northeast South Island New Zealand from a series of stereo satellite images collected both before and after the Kaikoura Earthquake. We use the Surface Extraction with TIN-based Search-space Minimization (SETSM) algorithm, developed at The Ohio State University, in a high-performance computing (HPC) workflow that bulk corrects hundreds of raw stereo satellite imagery pairs for image distortions and then performs a photogrammetric analysis. We order the surface model output in time and then use co-registering routines to make sure that the models are then further oriented in the right place in space. With this time series of landscape change we can see the immediate effects of the earthquake, how faults move in three dimensions, and how the landscape adapts to a huge number of mass flow events.

RESULTS & IMPACT

Our project has the potential to transform the way that first responders are provided information about a disaster zone. With rapid, reactive HPC access and processing and an initial pre-event data set for areas of the globe that are likely, or have already been exposed to natural disasters, we have the ability to provide damage maps and cascading hazard monitoring in a space of hours to days. This overview information is critical in the chaotic aftermath of an event. Scientifically, we are able to study the immediate evolution of surface ruptures and landslides and provide information to geo-mechanical modelers whose work informs safety regulations and building codes.

WHY BLUE WATERS

Blue Waters-scale computing was necessary to complete the project in a timeframe useful to coordinate perishable field data collection and provide rapid feedback on the event history. Maps and volume estimates of current slope failures estimated from the surface model will immediately assist New Zealand partners in monitoring and assessing dam hazards and slope reactivation, which will continue to affect the area for months to come. Our code and workflow is optimized for Blue Waters and allowed us to instantly activate the processing chain, which would likely have taken weeks to months on cloud resources.