DESDYNI LIDAR FOR SOLID EARTH APPLICATIONS

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1. INTRODUCTION

Although the primary objective of the DESDynI-Lidar is recovery of the vegetation structure for estimation of above ground biomass and for ecosystem health, the moderate footprint, contiguous multi-beam data[1] (25 m footprints) will provide important new information on surface topography and topographic change. Over the last decade we have conducted a number of studies that support the rationale for the simulations reported here. For example, prior to the launch of the Ice, Cloud and land Elevation laser altimetry satellite (ICESat, single laser beam with 55-80 m footprint), we used NASA's Airborne Topographic Mapper[2] (ATM) to estimate how effective ICESat would be in recovering ice elevation change over the rapidly retreating Jakobshavn Glacier. These simulations enabled us to identify an approach to successfully use ICESat plus InSAR derived DEMs for ice elevation change on mountain glaciers[3,4]. Also, we have used repeat Laser Vegetation Imaging Sensor (LVIS) measurements with full-waveform, 20-m contiguous footprints, to quantify pyroclastic and lava flow of a stratovolcano in Costa Rica[5]. In another study, near Barrow, Alaska, we introduced high quality ICESat derived positions into processing of ERS-1/2 data to improve the vertical resolution of the InSAR derived digital elevation models (DEM) by a factor of three[6]. An extension of this approach to fuse moderate resolution multi-beam Lidar into processing of L-band derived data for derivation of DEMs for a wider range of topographic slope and roughness could be especially useful outside SRTM coverage. In this paper, we focus on the results of simulation studies of the multi-beam Lidar instrument performance over active faults and folds and marine terraces and for recovery of coseismic slip parameters following a seismic event in southern, coastal Alaska.

2. APPROACH

In our performance studies we used Lidar data National Center for Airborne Laser Mapping lidar (NCALM) and ATM acquisitions. NCALM data provides the user community with point cloud Lidar returns and bald Earth images with 1 m postings and ~0.10-0.15 vertical accuracy. By accounting for sensor characteristics such as footprint size and the temporal and spatial distribution of laser energy, in an earlier study we generated

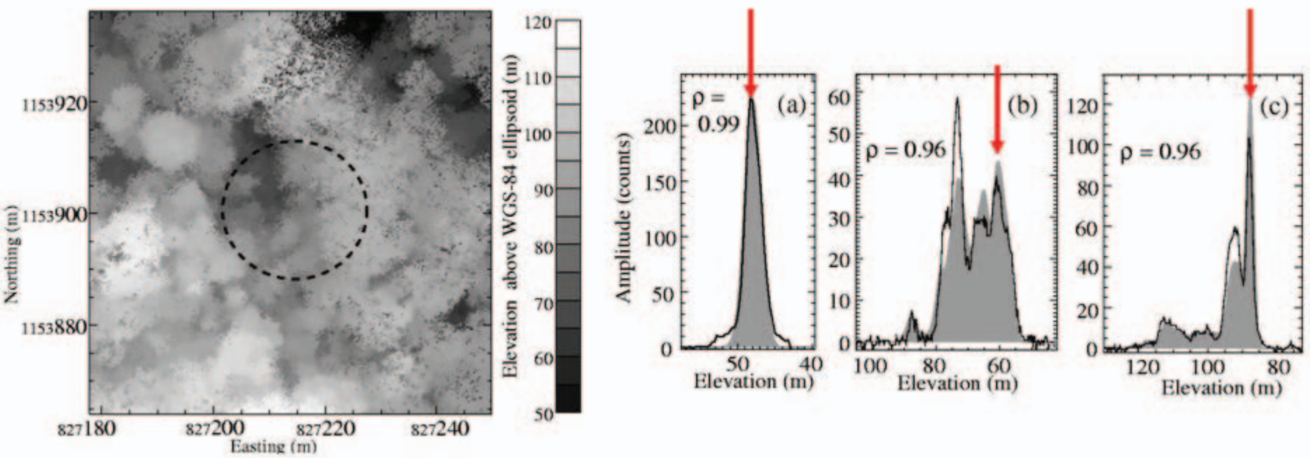

Figure 1. Elevations of a region (left) used to simulate lidar waveforms[7] {(a)-sloped but unvegetated, (b-c) vegetated terrain}. The red arrow indicates ground return. High resolution aircraft lidar point cloud data can be combined to simulate waveform data from a moderate footprint lidar sensor. Using waveform interpretation methods we will extract DESDynI-Lidar like ground elevations and assess their usefulness for characterizing various tectonic landforms and fault offset.

pseudo DESDynI waveforms with high correlation (Figure 1, a-c)[7]. For assessing topographic change such as fault slip in a major earthquake, we used Lidar point cloud data to generate a DESDynI like waveforms and a modified post-earthquake waveform and then compared products derived from the waveforms. Also, NCALM and ATM data were used to simulate centroid elevations across fold and fault structures. Some of these structures are masked by southern Alaska glaciers.

3. GEODETIC IMAGING OF SEISMOTECTONIC STRUCTURES IN GLACIATED SOUTHERN ALASKA

The complex plate boundary in southern coastal Alaska provides an excellent setting for testing DESDynI capabilities to recover fundamental parameters of seismotectonic processes. Additionally, we could use recently acquired NCALM and ATM aircraft Lidar data for our waveform simulations. NCALM was acquired over marine terraces west of Icy Bay ("Sullivan data") in southern Alaska in September 2005 as part of the NSF STEEP study (www.ig.utexas.edu/steep). In this acquisition the point cloud data included both the first and last lidar return. The vegetation in this region ranges from dense conifer forest to alpine tundra. The last return has been interpreted as a ground return and a "bald Earth" 1 m DEM has been created. Between Icy Bay and Cape Yakataga there are four marine terraces that range in elevation from approximately 1 m to 50 m elevation located on the southern flank of the Sullivan anticline, and in the footwall of the Sullivan thrust fault[8]. These features trend roughly east-west, an approximately optimum orientation for future roughly N-S DESDynI-Lidar ground tracks. The terraces contain evidence for rapid uplift during large to great magnitude earthquakes[8]. Terrace surfaces are hundreds of meters to over a kilometer in width, partly buried by alluvial fans, and separated by remnant sea cliffs that mark the former shorelines. The Sullivan fault is marked by a prominent escarpment on the mountain above the highest terrace level. The thick coastal forest and brush mask important aspects of the geomorphology on aerial photographs, standard DEM, and C-band synthetic aperture radar images, a problem that is largely overcome by the NCALM Lidar data[9]. We created synthetic waveforms by extracting the NCALM data along the DESDynI-Lidar calculated ground tracks. An advantage of even the medium footprint DESDynI-lidar data over the standard existing 30 m DEM is the ability to see through the vegetation to discern the individual terrace heights, features of the escarpment associated with the Sullivan fault, and to map out the morphology of the Sullivan anticline.

Also in the late summer of 2005, ATM laser swath (~480 m width) data was acquired in coastal, southeastern Alaska and it included data from the Malaspina and Seward glaciers (https://www.atm.wallops.gov). In the lower Seward glacier the glacier surface elevation, along track slope, and within footprint roughness and slope has been used to identify thrust faults beneath the ice and it is being used to interpret ice velocities derived from ALOS PALSAR L-Band InSAR data[9].

4. COSEISMIC SLIP RECOVERY SCENARIO FOR A SOUTHERN ALASKA EARTHQUAKE

As summarized in the DESDynI Science Definition Document, "in areas where the surface is disrupted over the course of a large geophysical event such as coseismic displacement and shaking of the surface, the InSAR-derived surface deformations measurements cannot be made. It is helpful to take advantage of the Lidar to repeat elevation transects over the deformed surface to fill in some area of disruption."[10]. Here we simulated waveforms along DESDynI-Lidar ground tracks before and after the occurrence of a hypothetical large earthquake in the southern coastal Alaska. We used the NCALM aircraft Lidar imagery acquisition described above to simulate the "before" waveforms and we used a perturbed version of a high-resolution DEM to simulate the "after" waveforms. For the future DESDynI -Lidar acquisitions, we will need to target the near-field coseismic deformation region with off-nadir pointing otherwise we will have a limited number of transects over a short-coseismic interval. This study is enabling us to assess the minimum number of transects needed to provide timely, and spatially dense enough, data for estimation of earthquake parameters to calculate associated stress redistribution and triggered slip on nearby faults, inform detailed field studies, and to enable disaster managers to assess damage as discussed in the "Use Case Scenario" for a Seismic Event in California outlined in the Report of the DESDynI Applications Workshop[11].

5. SUMMARY

Since DESDynI-Lidar would penetrate most vegetation, the accurate bald Earth elevation profiles will give new information beyond the standard 30-m DEM. In our southern Alaska study region, the major crustal seismotectonic features are roughly perpendicular to the satellite ground tracks and the accurate elevation profiles will enable process studies of folds, faults, and marine terraces. For a major earthquake with on-land surface disruption, such as a thrust-slip event in southern Alaska, DESDynI-Lidar could provide new and timely near-field vertical static displacements when used in combination with pre-earthquake acquired DEM or with some off-nadir pointing to previous DESDynI-Lidar transects. We have found that these new simulations inform prelaunch strategies for maximizing our ability to expand the range of solid Earth applications for this medium resolution Lidar as part of the DESDynI mission.

6. REFERENCES

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