THE SLOPE IMAGING MULTI-POLARIZATION PHOTON-COUNTING LIDAR: DEVELOPMENT AND PERFORMANCE RESULTS

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1. INTRODUCTION

The Swath Imaging Multi-polarization Photon-counting Lidar (SIMPL) is an airborne prototype in development to demonstrate laser altimetry measurement methods and components that enable efficient, high-resolution, swath mapping of topography and surface properties from space. The instrument was developed through the NASA Earth Science Technology Office Instrument Incubator Program with a focus on cryopshere remote sensing. SIMPL incorporates beam splitting, micropulse single-photon ranging and polarimetry technologies at green (532 nm) and near-infrared (NIR, 1064 nm) wavelengths in order to achieve simultaneous sampling of surface elevation, slope, roughness and scattering properties, the latter used to differentiate surface types.

2. METHODOLOGY

Prior work has demonstrated photon counting laser altimetry at green wavelengths using Photomultiplier Tube (PMT) detectors, including the Multikilohertz Photon-Counting Microlaser Altimeter (MMLA) development conducted in an earlier IIP project [1]. In addition earlier work using the Airborne Laser Polarization Sensor (ALPS), a non-range resolved instrument, documented that laser depolarization at 355, 532 and 1064 nm differentiates needle-leaf and broad-leaf vegetation based on differences in their wavelength-dependent scattering properties [2]. SIMPL demonstrates polarization-sensitive photon-counting laser altimetry at both NIR (1064 nm) and green (532 nm) wavelengths employing Single Photon Counting Modules (SPCM), the only mature detector capable of time-resolved single photon detection at both wavelengths. By operating at both wavelengths depolarization ratio data in the visible and NIR enable differentiation of surface types. The depolarization ratio is sensitive to the proportions of specular reflection and surface and volume scattering, and is a function of wavelength. SIMPL's measurement capabilities provide information about surface elevation, roughness, slope and type of ice sheet surfaces and sea ice, including their melt state.

3. INSTRUMENTATION

The SIMPL instrument consists of a multi-beam laser transmitter and receiver mounted on opposite sides of a thermally stable optical bench and sharing a common 20 cm aperture primary mirror (Figure 1). The laser transmitter is a 1 nsec pulse width, 11 kHz, 1064 nm microchip laser, frequency doubled to 532 nm. The two colors are split into four plane-polarized beams using birefringent calcite crystal in order to maintain co-alignment of the colors. The 16 channel receiver splits the received energy for each beam into the two colors and each color is split into energy parallel and perpendicular to the transmit polarization plane, thereby providing the measure of backscatter depolarization. The solar background count rate is controlled by spatial filtering using a pinhole array and by spectral filtering using temperature-controlled narrow bandwidth filters. The receiver is fiber coupled to 16 Single Photon Counting Modules (SPCMs). To avoid range biases due to the long dead time of these detectors the probability of detection per laser fire on each channel is controlled to be below 30%, using mechanical irises and flight altitude. Event timers with 0.1 nsec resolution in combination the narrow transmit pulse yields single photon ranging precision of 8 cm. The high speed, high throughput data system is capable of recording 22 million time-tagged photon detection events per second. At typical aircraft flight speeds, each of the 16 channels acquires a single photon range every 5 to 15 cm along the four profiles providing a highly sampled measure of surface roughness. The nominal flight altitude is 4 km yielding 8 m spacing between the four beam profiles, providing a measure of surface slope at 8 m length scales.

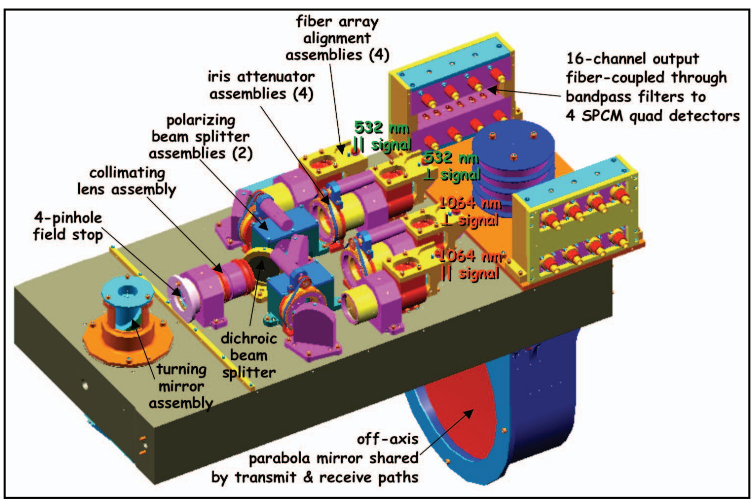

Figure 1. Mechanical schematic of the SIMPL optical bench and receiver-side components.

3. RESULTS FOR ICE COVERED LAKE ERIE

SIMPLwas flown aboard the Glenn Research Center Lear-25 acquiring data over ice-covered Lake Erie in February, 2009. Observed in simultaneously acquired digital video frames, the ice cover appears to be a heterogeneous amalgamation of ice types, thicknesses and ages. The lake ice is covered by snow in places and contains numerous open water leads that enable measurement of the ice height relative to the water surface (i.e., freeboard used in estimation of ice thickness). Instrument performance was characterized by analyzing data from targets with variably surface roughness, reflectance and depolarization (Figure 2). The detected photons reflected from the surface form a "point cloud". The density and height dispersion of the point cloud are a measure of surface reflectance and roughness (Figure 3). The depolarization ratio differentiates open water, young clear ice, older granular ice and snow cover (Figure 4). The four parallel profiles spaced apart by 8 m exhibit highly correlated depolarization ratios demonstrating that the measurement is reproducible within distinct lake ice types.

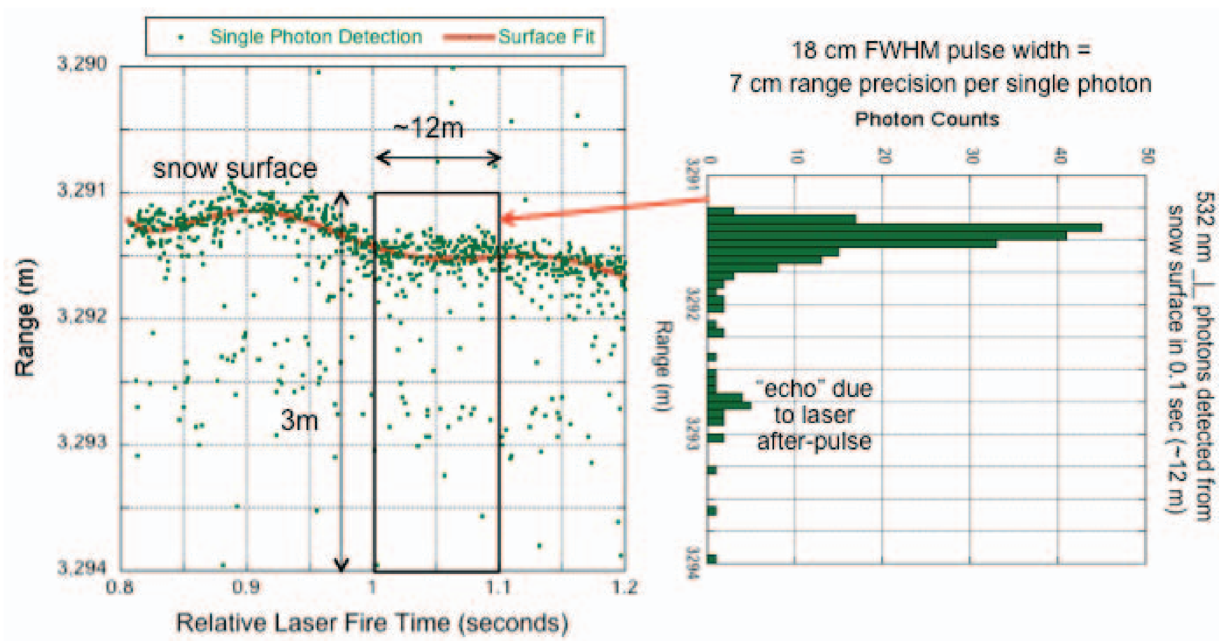

Figure 2. Performance analysis using a smooth, flat snow surface showing the single photon point cloud (left) and a range histogram (right) that recreates the transmit pulse wavefom.

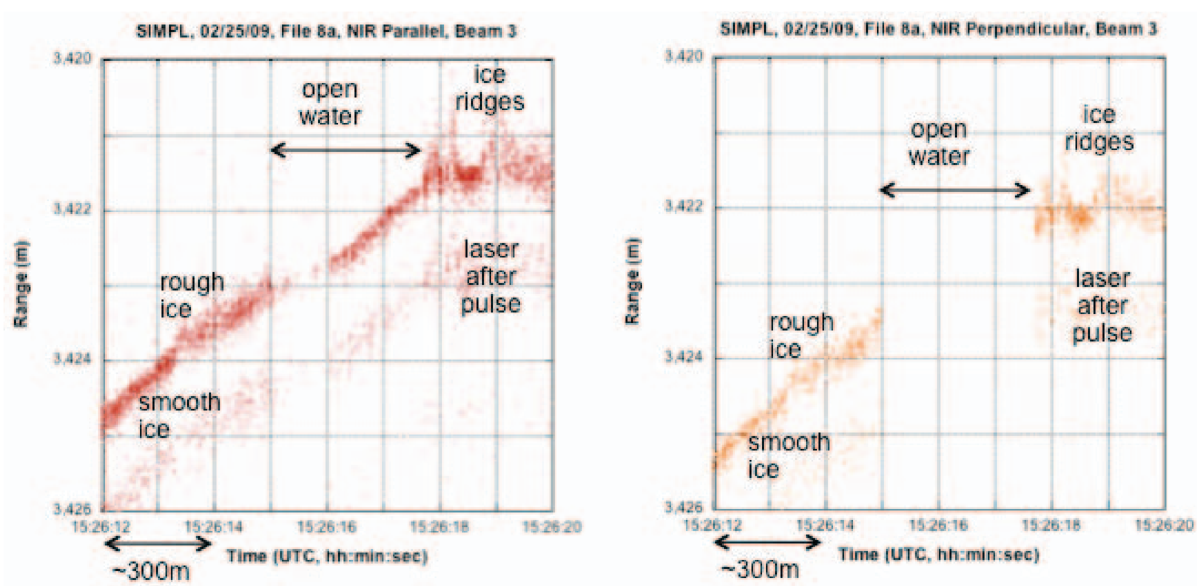

Figure 3. Near-infrared parallel (left) and perpendicular (right) polarizations from a profile across Lake Erie ice cover showing varying surface roughness and depolarization. The absence of perpendicular return energy uniquely identifies liquid water in open leads. The lake surface is slopped because aircraft roll effects have not been removed.

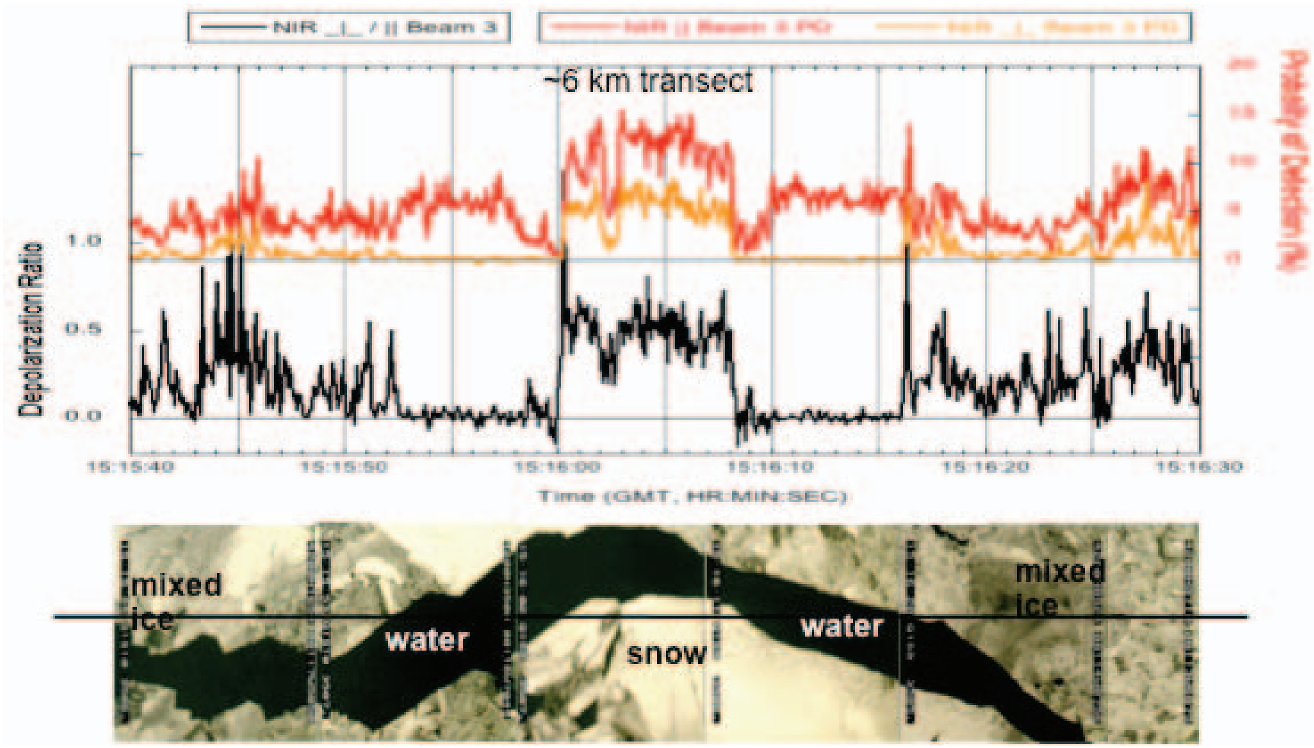

Figure 4. Parallel and perpendicular received energies and the derived depolarization ratio differentiate areas of ice, snow covered ice and open water leads.

4. REFERENCES

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