Push-broom Laser Altimeter Demonstration for Space-based Cryospheric Topographic and Surface Property Mapping

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Slope Imaging Multi-polarization Photon-counting Lidar (SIMPL)

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Slope Imaging Multi-polarization Photon-counting Lidar

An advanced-technology airborne laser altimeter developed through NASA's ESTO Instrument Incubator Program

A technology and remote sensing pathfinder for next-generation, high-efficiency, spaceflight laser altimeters

Simultaneously measures surface topography, roughness and slope as well as scattering properties to differentiate surface types

Developed with a focus on
- *ice sheet elevation and its change*
- *sea ice thickness and its change*
- *icy moon surface processes*

Objectives

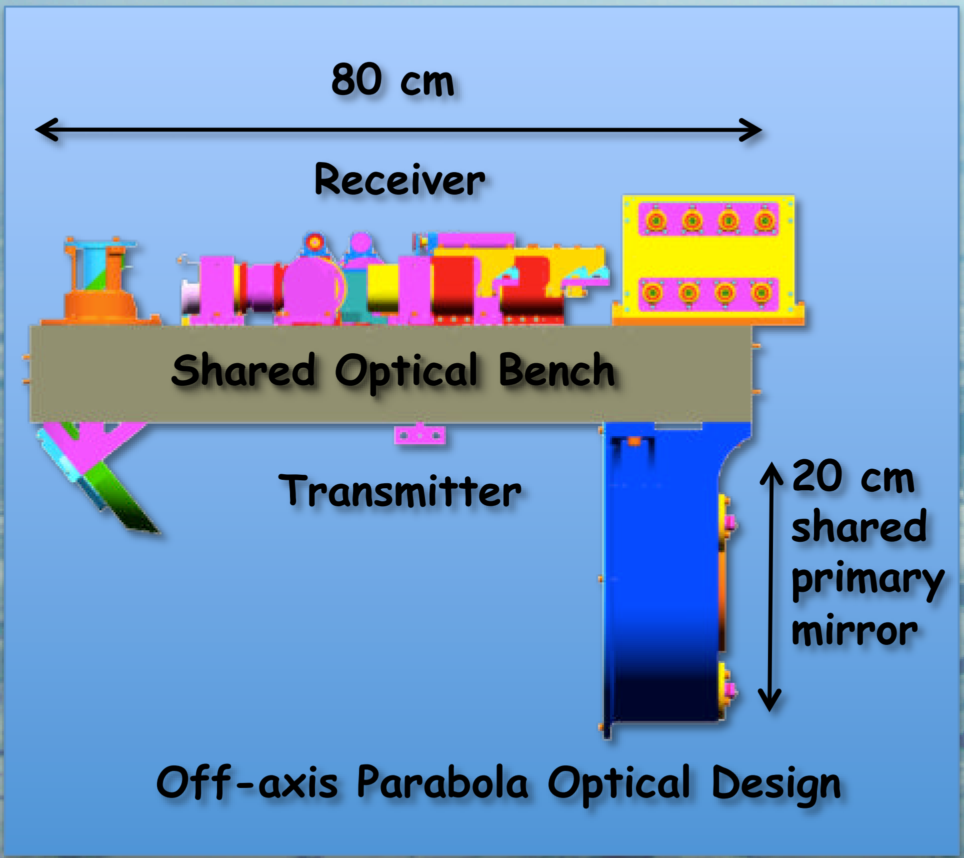
Evaluate efficiencies of high rep-rate, low pulse energy, single photon ranging as compared to traditional low rep-rate, high pulse energy, analog ranging

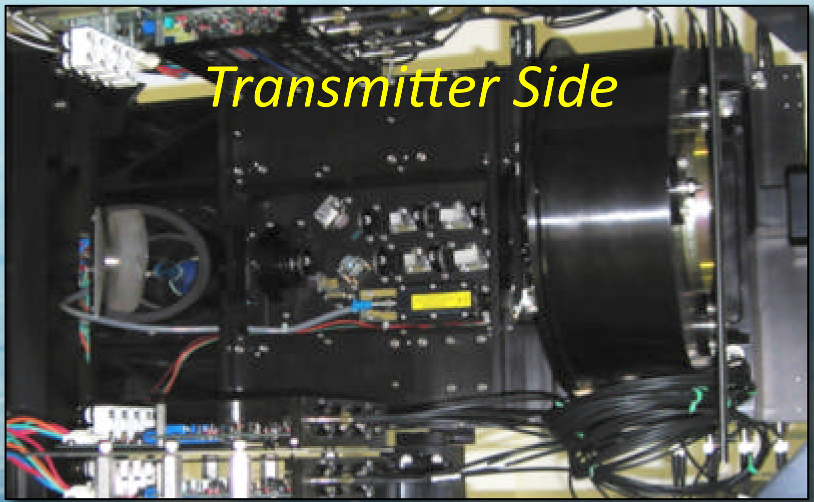
Compare measurement performance and derived surface information at 1064 nm and 532 nm

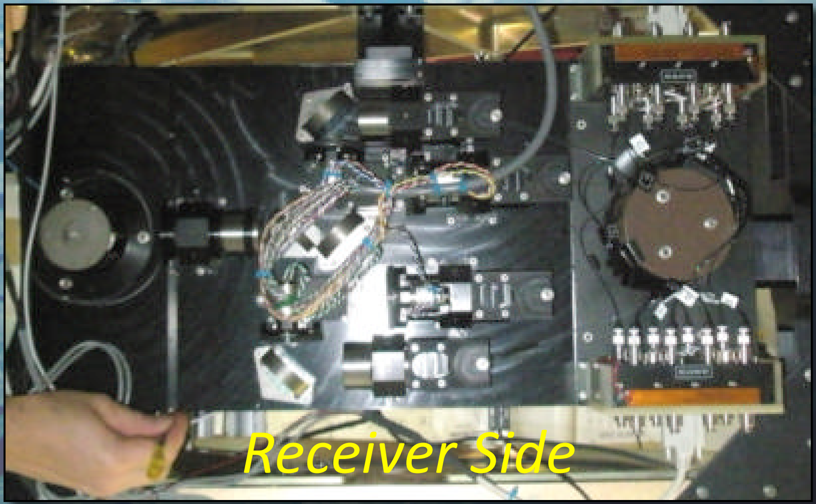
Assess utility of multiple scattering depolarization measurement to differentiate surface types

Provide guidance for future spaceflight laser altimeter instrumentation

SIMPL Transceiver







SIMPL Subsystems

Micropulse Laser Transmitter

11 kHz, 1 nsec pulse width, microchip laser

1064 nm + frequency doubling to 532 nm

Split into 4 plane-polarized beams

Several mW output power / beam / color

Sixteen-channel, Photon Counting Receiver

Four beams, 2 colors, || and _|_ polarizations

Small FOV and narrow-band spectral filtering

  To reduce solar background noise

Fiber-coupled detectors

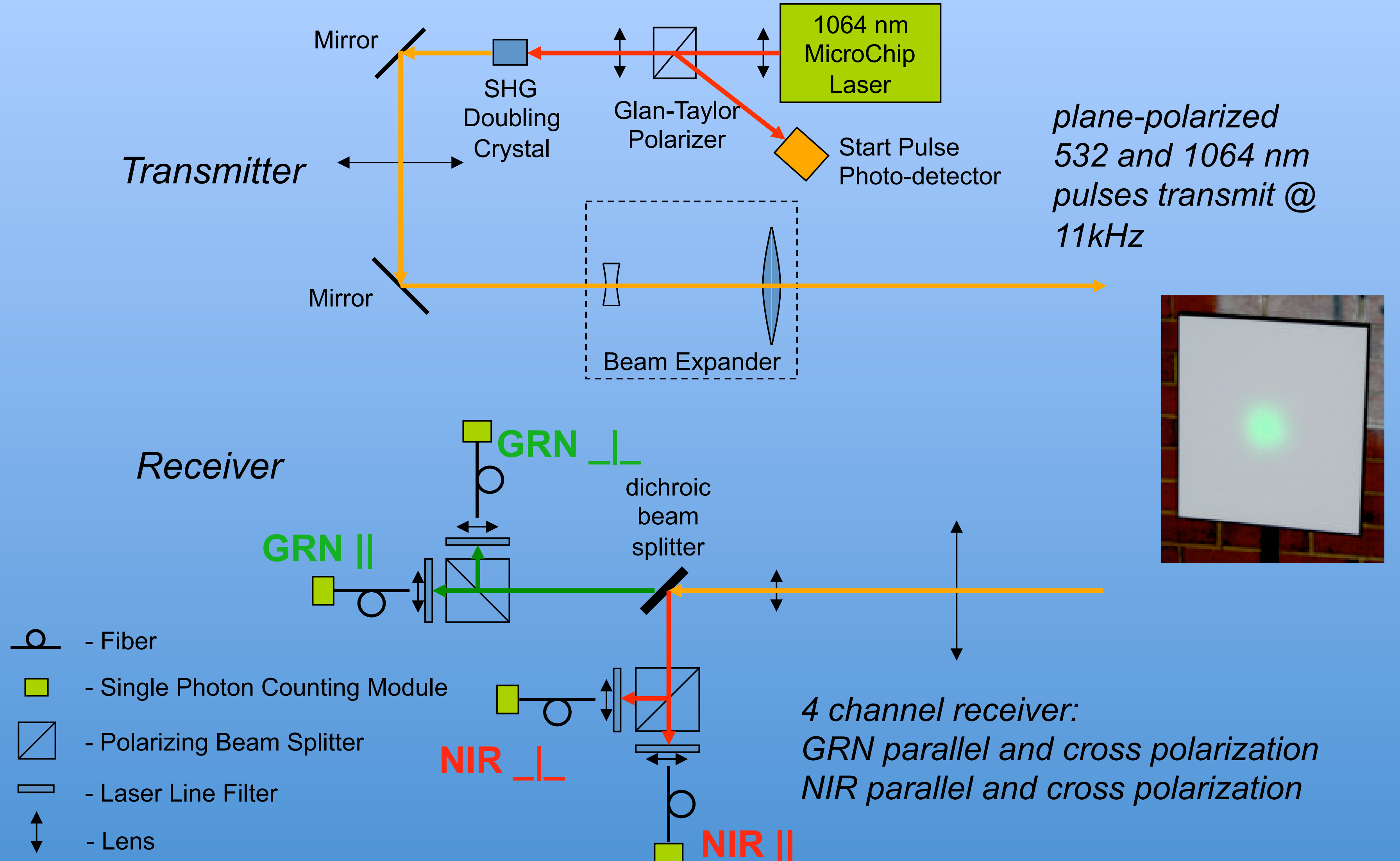
  Single Photon Counting Modules

High Precision, High Throughput Data System

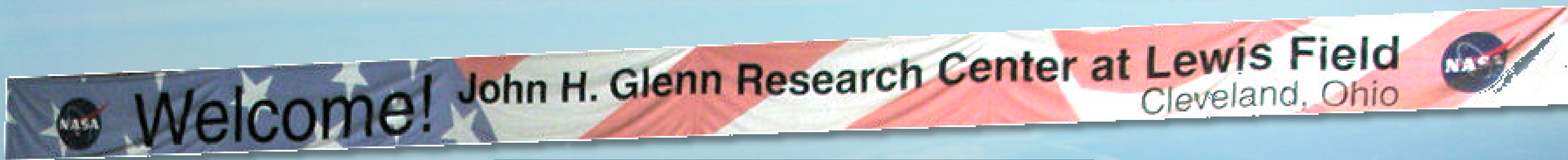
Four event timer cards with 100 psec resolution

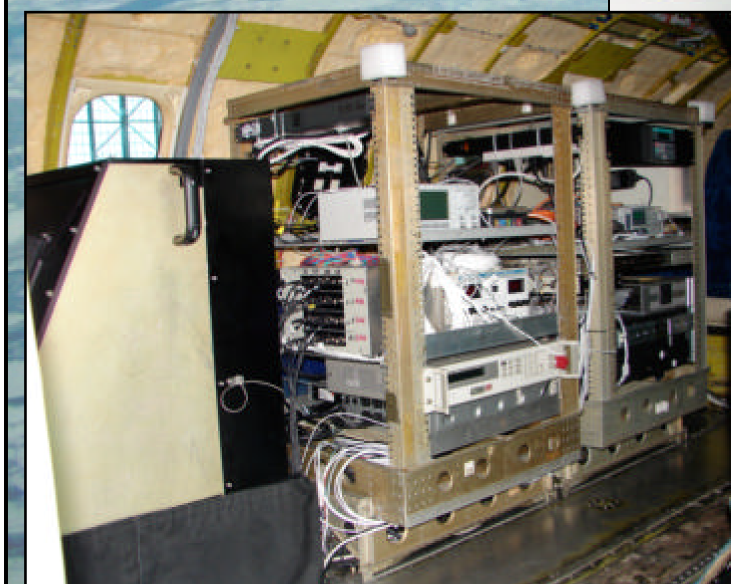
Up to 22 million photon detections per sec

SIMPL 1-Beam Schematic

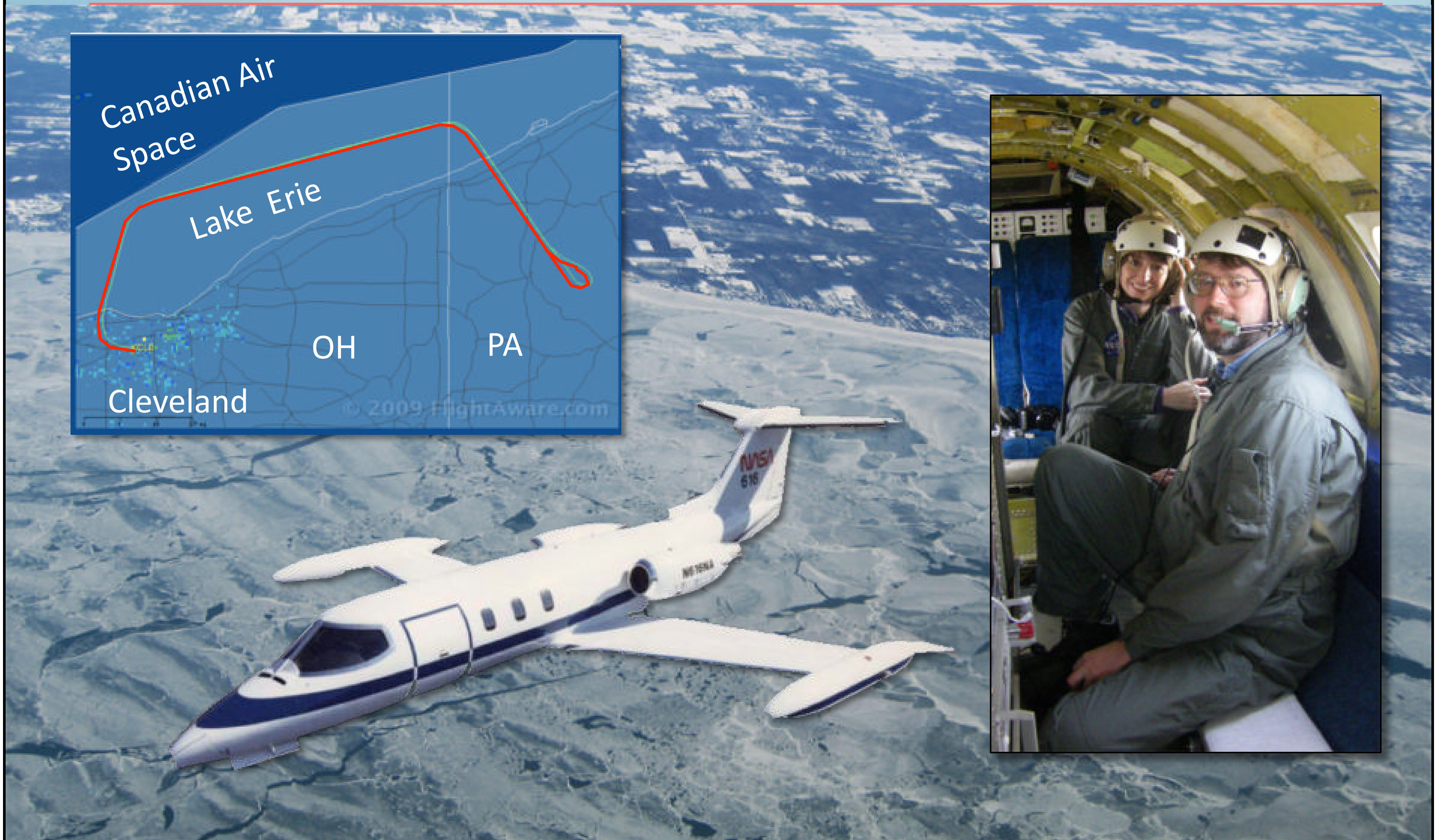


SIMPL Installed in GRC Lear-25

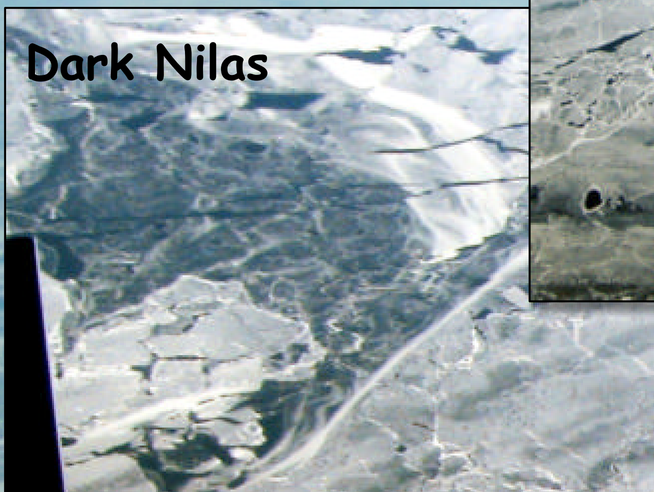


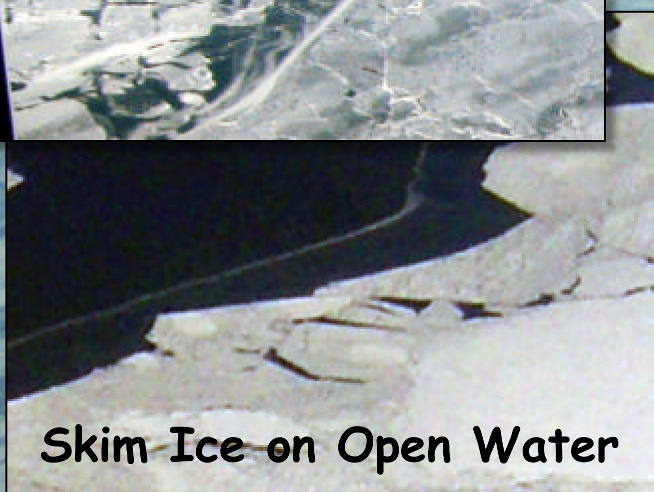


Flight Over Lake Erie Ice Cover



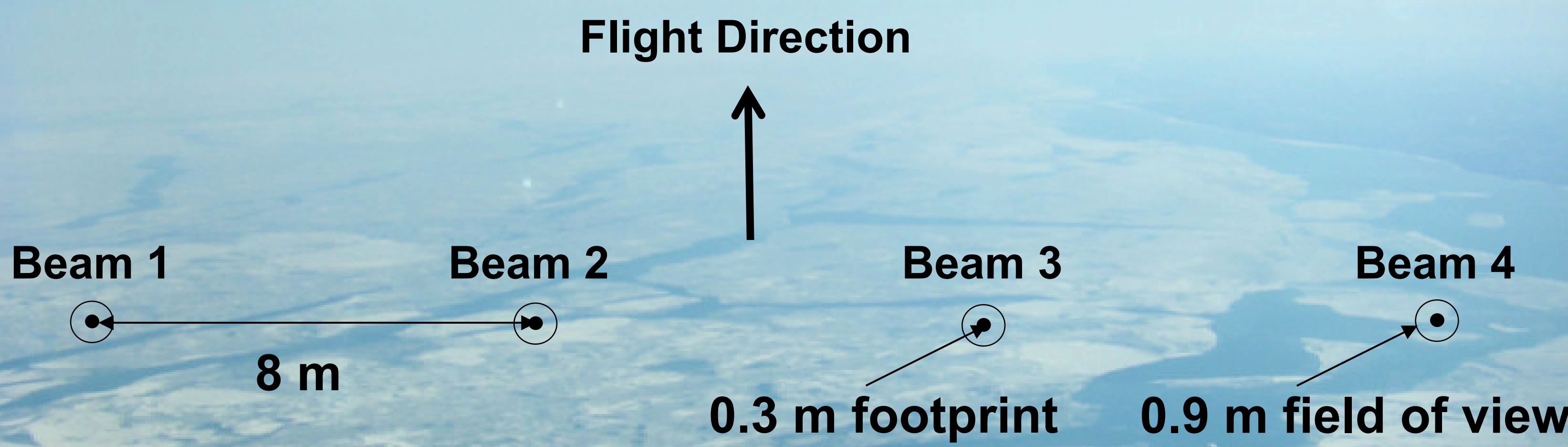
Lake Erie Ice Cover Evolution





Ice thickness derived from freeboard; height difference between water and ice surface

SIMPL's 4 Beams at 3.7 km Altitude



<u>Each Beam Has Four Channels</u>

532 nm parallel polarization: ||

532 nm perpendicular polarization: _|_

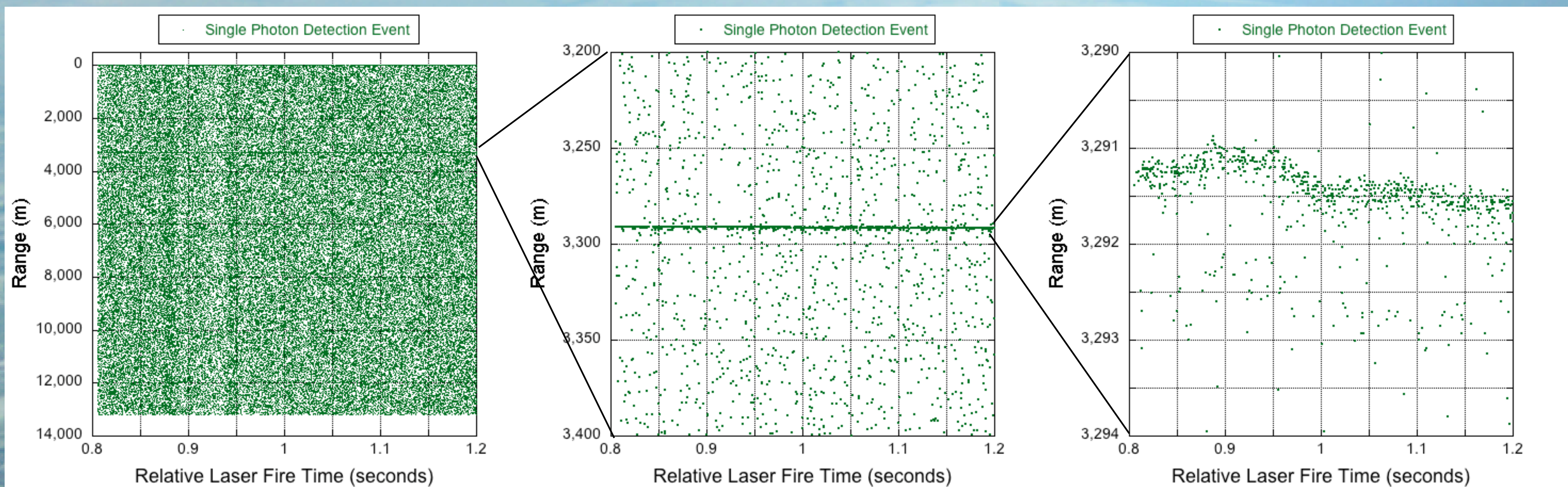
1064 nm parallel polarization: ||

1064 nm perpendicular polarization: _|_

Single Photon "Point Cloud" from Snow

One of 16 channels: Beam 4, 532 nm, perpendicular polarization

0.4 sec ~ 40 m

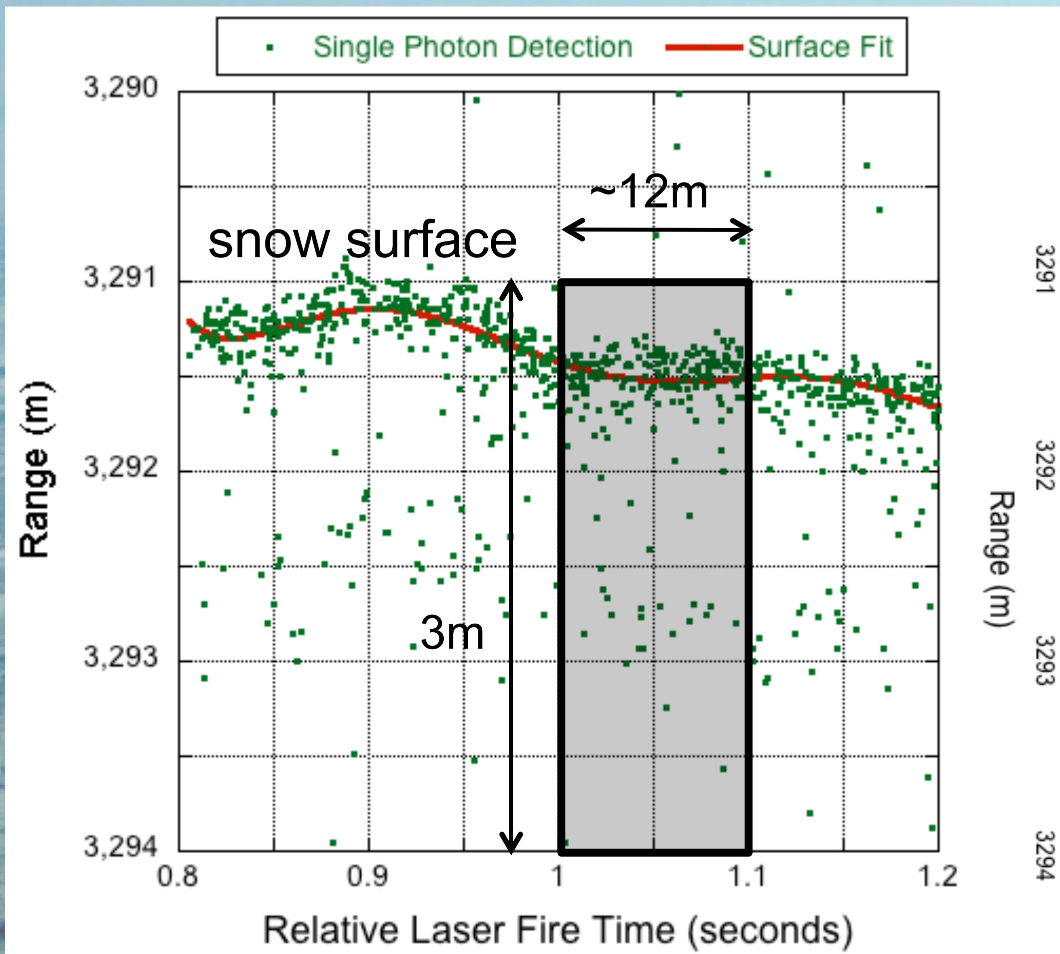


13 km range window
~ 90,000 detected photons
in 0.4 sec

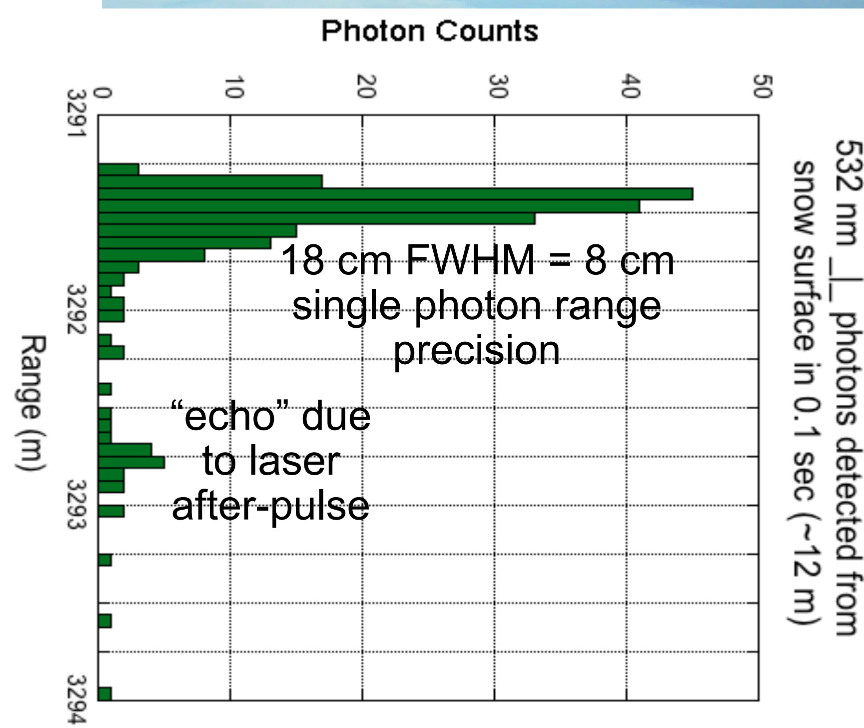
Correlated surface returns
and random solar
background noise

790 single photon returns
from snow surface
(0.9% of all returns)

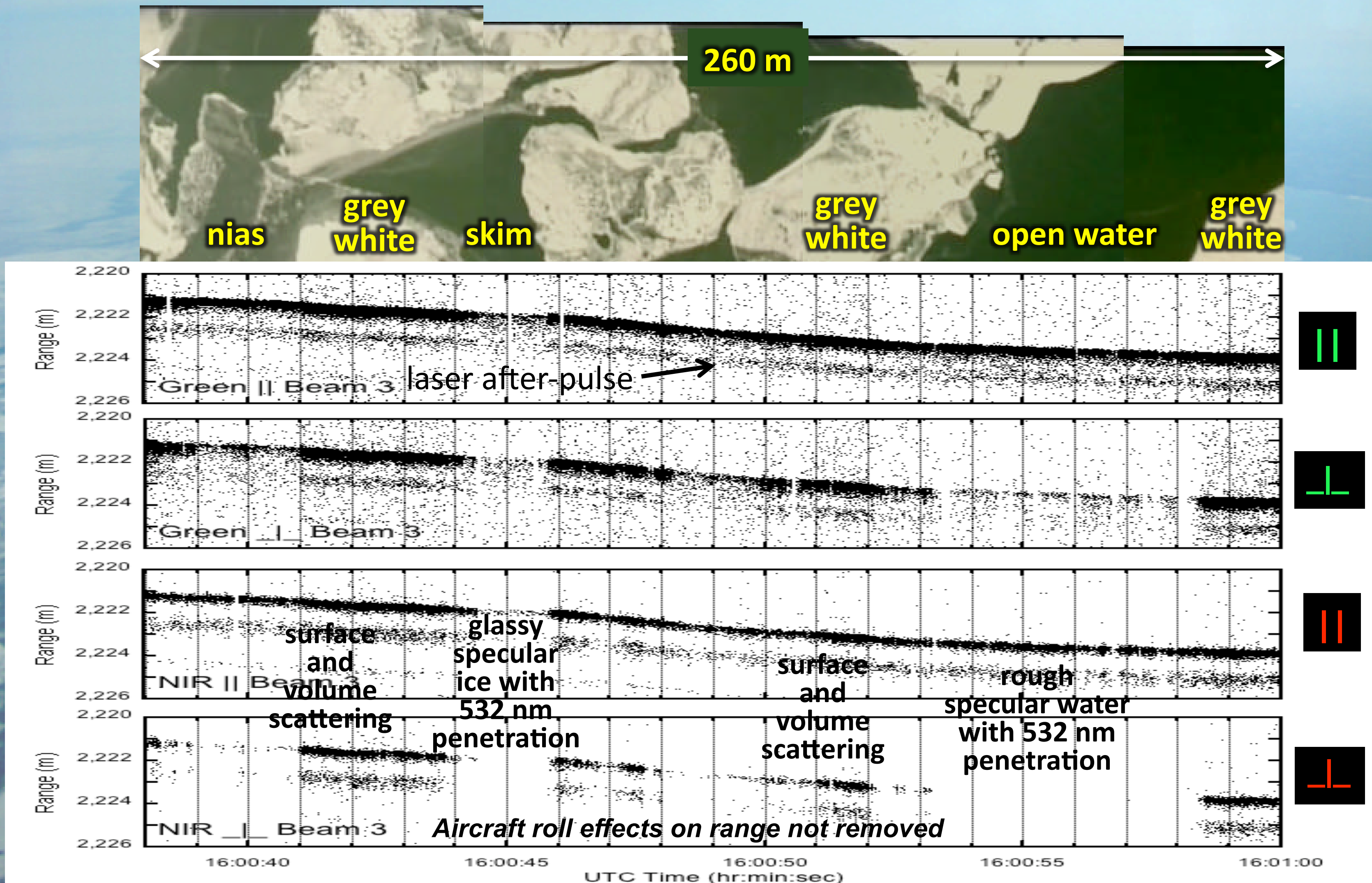
Range Histogram: Distance to Target



Histogram of single photon ranges acquired in 0.1 sec

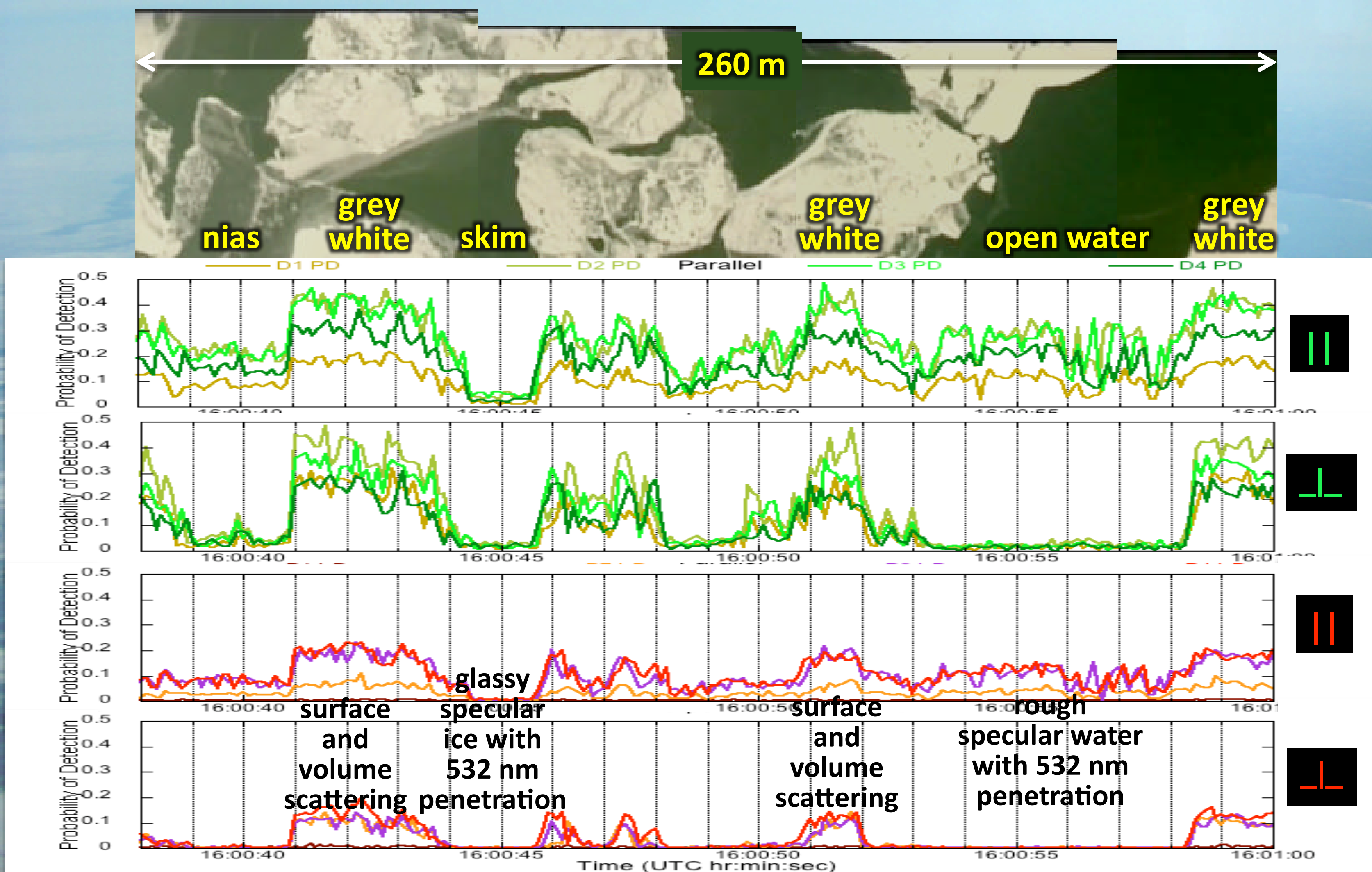


Ice Cover Point Cloud Profiles
Single Photon Ranges



David Harding, NASA ESTO Earth Science Technology Forum, July 22-24, 2010

Probability of Detection Profiles
Surface Returns / Laser Fires



Scattering Properties
Wavelength and Polarization Dependent

Depolarization Ratio: _|_ / ||

received photons with vibration plane perpendicular to transmit plane
―――――――――――――――――――――――――――
received photons with vibration plane parallel to transmit plane

Specular single-scatter reflection consists of only || light (ratio = 0)

Water surface and glassy ice

Water return strength correlated with roughening caused by wind

_|_ reflectance increases due to multiple scattering caused by:

Surface roughness and volume scattering in ice, snow and water

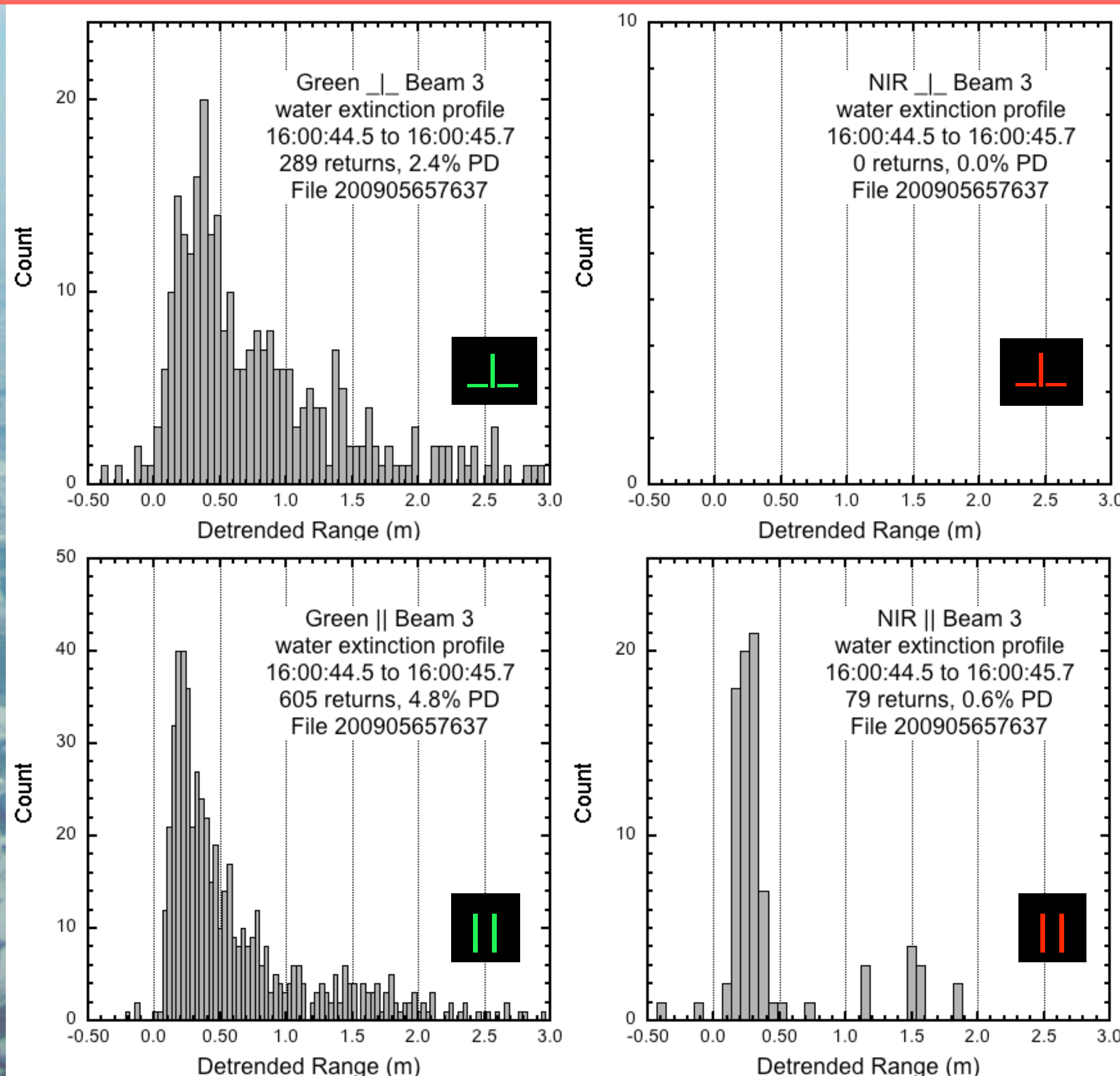
532 nm penetration into water results in volume scattering

1064 nm completely absorbed in water so no volume scattering

Scattering from Skim Ice Covered Water

Multiple scattering in water column

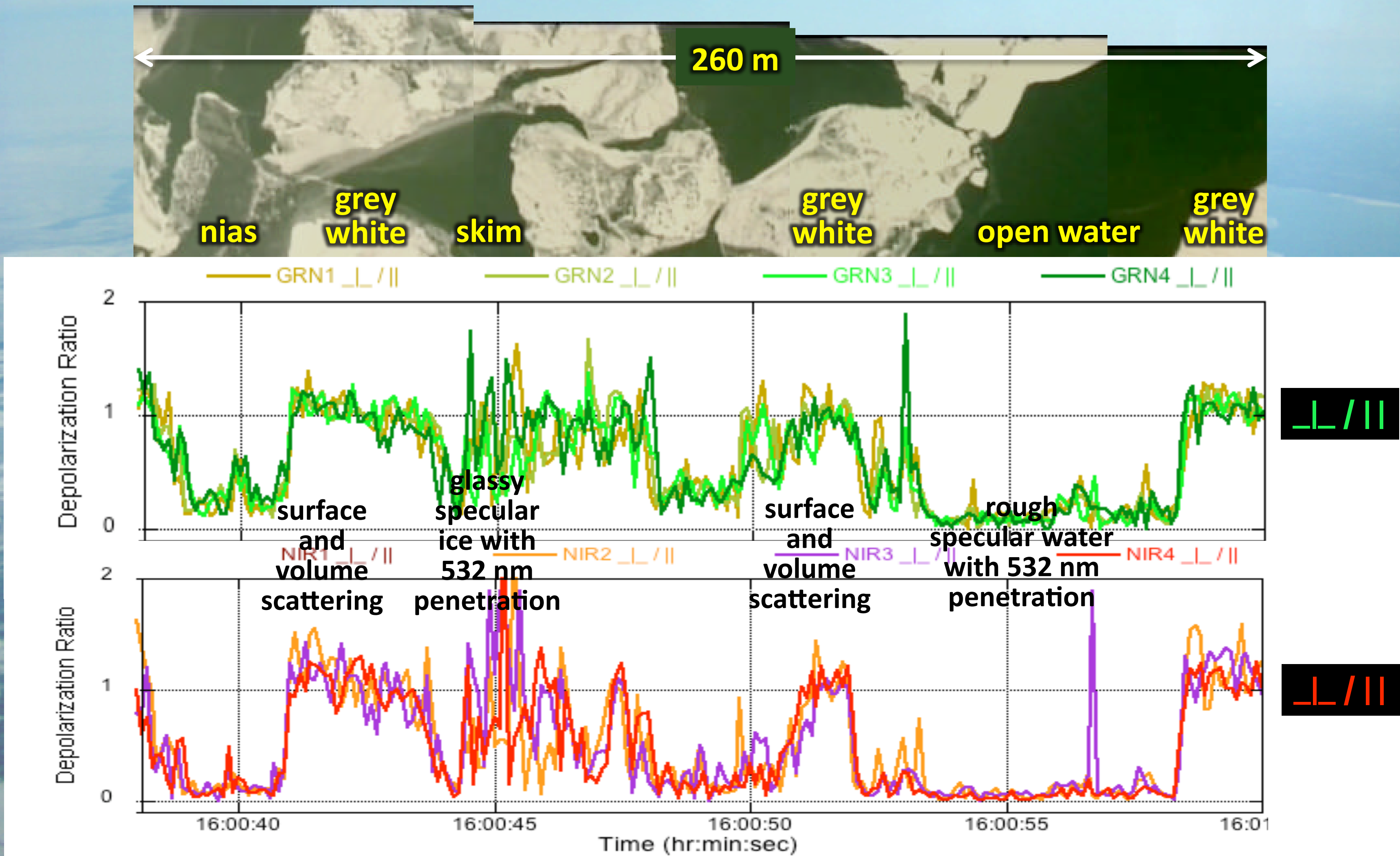
Single scattering in water column



No specular reflection nor water column scattering

Ice surface specular reflection

Depolarization Ratio Profiles

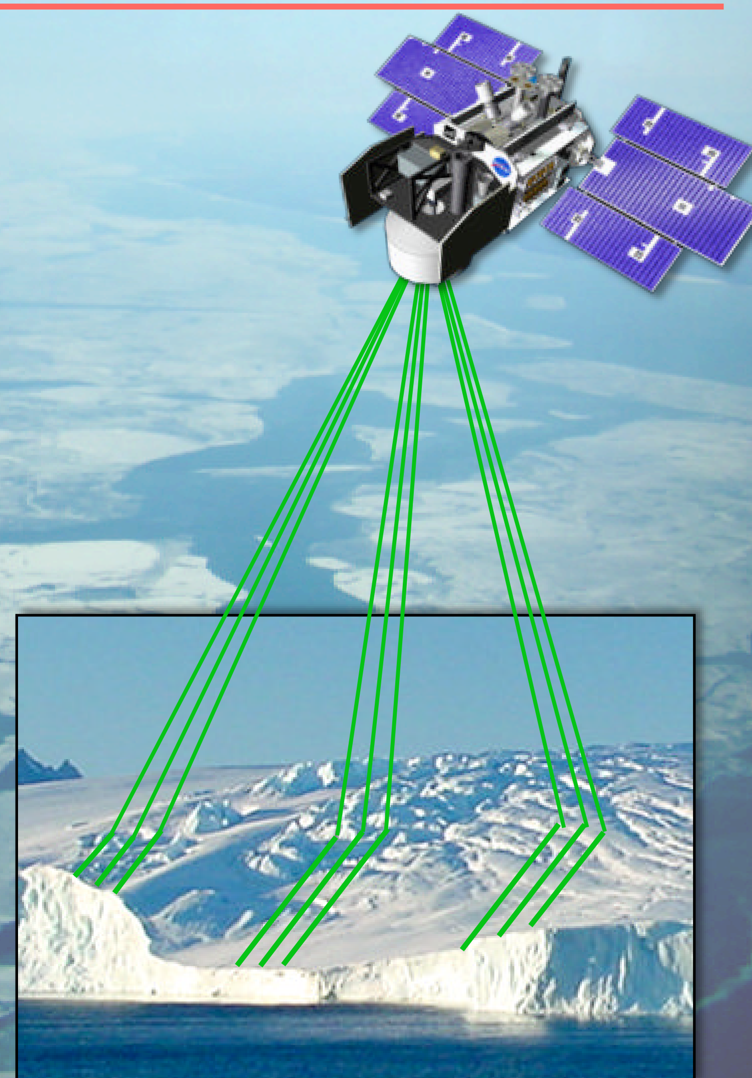


ATLAS Instrument on ICESat-2
532 nm Micropulse Single-photon Ranging

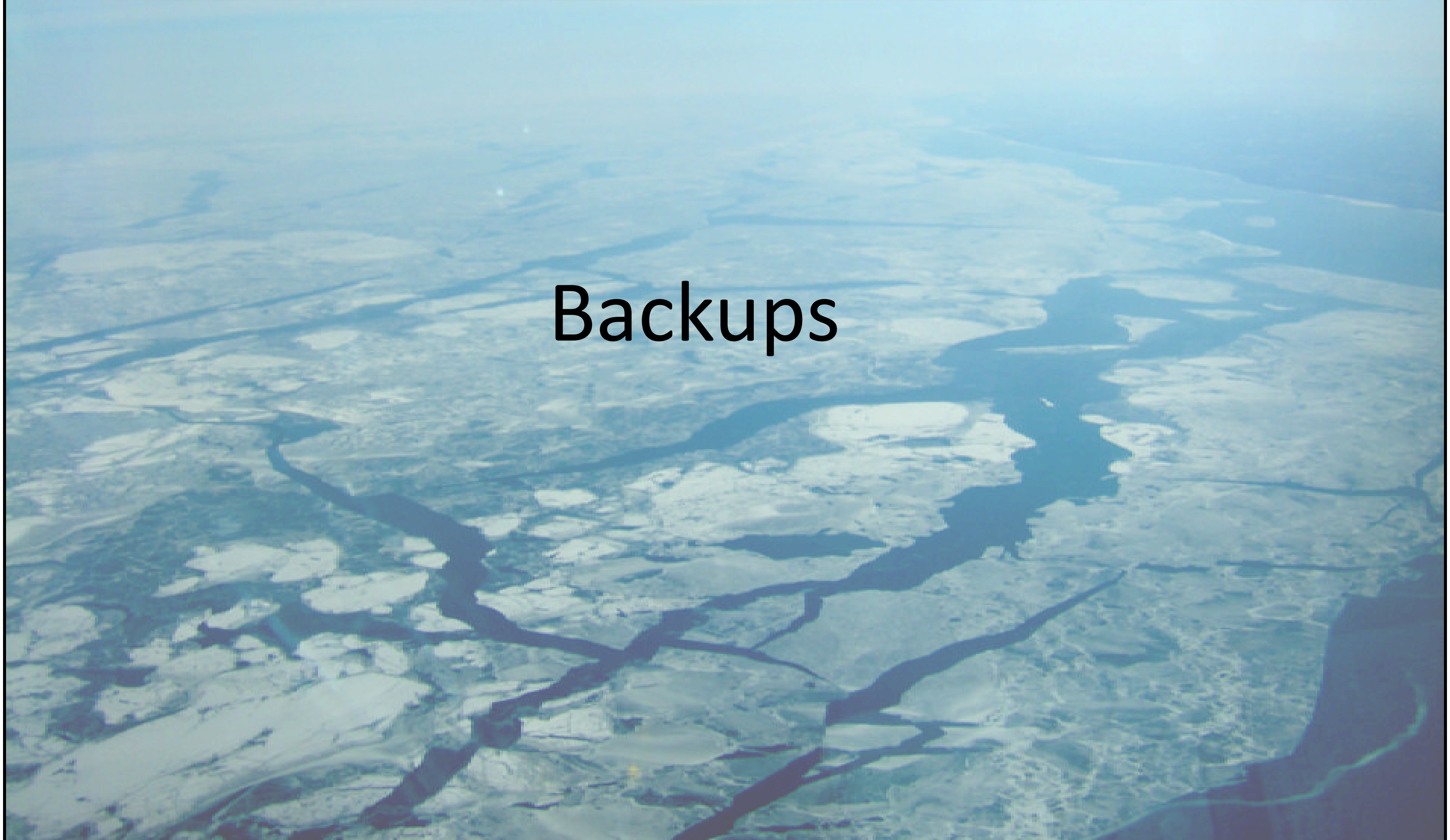
Follow on to ICESat with 2015 launch

Cryosphere and Ecosystem Objectives:
- ***Ice sheet elevation and its change***
- ***Sea ice thickness and its change***
- ***Forest canopy height***

Employs methods used in SIMPL:
- ***Micropulse laser transmitter***
- ***1064 nm frequency doubling to 532 nm***
- ***Transmit beam splitting***
- ***Small detector fields of view***
- ***Fiber coupled detectors***
- ***Single photon ranging @ 532 nm***
  - ***Depolarization not in current plan***



Backups



Four-beam Transmitter