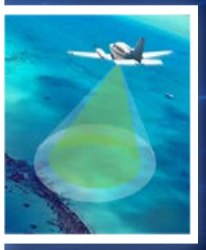
TELEDYNE OPTECH
Everywhereyoulook™

The Optech Titan: A Multi-Spectral Lidar for Multiple Applications



Paul LaRocque, Brent Smith
Teledyne Optech

Ahmed Shaker
Ryerson University, Toronto

JALBTCX Workshop June 2015

Accuracy & Productivity Matter

Optech Titan - One Sensor, Many Applications

Multi-spectral sensor configuration

New application opportunities (eg. vegetation/target discrimination, simultaneous topo/bathy, etc.)

Increased classification accuracy

Day/night operation

Discrete and waveform record options

- Seamless land/water transitions are now possible using much more efficient discrete measurement methods, instead of full waveform capture (full waveform record optionally available)

Same 300 kHz PRF for each of 3 laser channels (900khz total)

- High resolution bathy channel
- High sampling rates for IR channels enable high resolution topo data sets

Embedded Passive Imaging Options

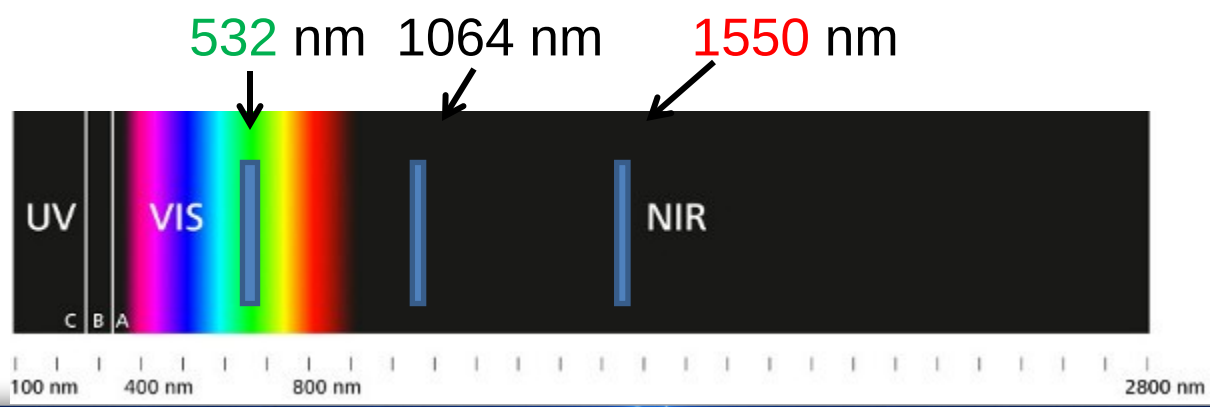
- Capable of supporting any one of the CS-Series camera solutions (80 MP RGB/CIR; 29 MP RGB/CIR/NIR; thermal; 3-5 band multispectral

Three Wavelength Titan

Similar platform as two channel Pegasus HA500

Added two more wavelengths and one more beam

Compatible with 16“ GSM



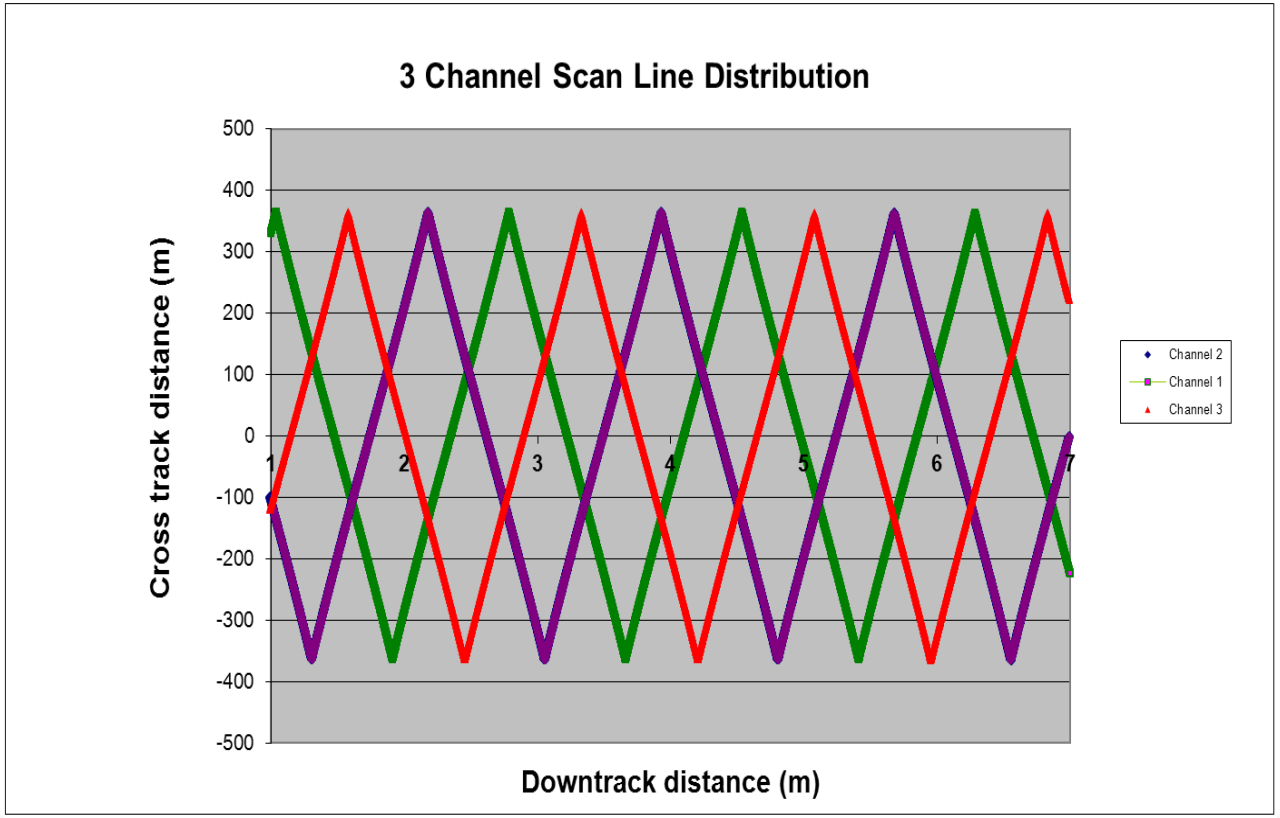
Titan - Scan Pattern MW900

Forward angle separation = 3.5° (~ 60 mrad)

1064 nm (0°) **532 nm (7°)**

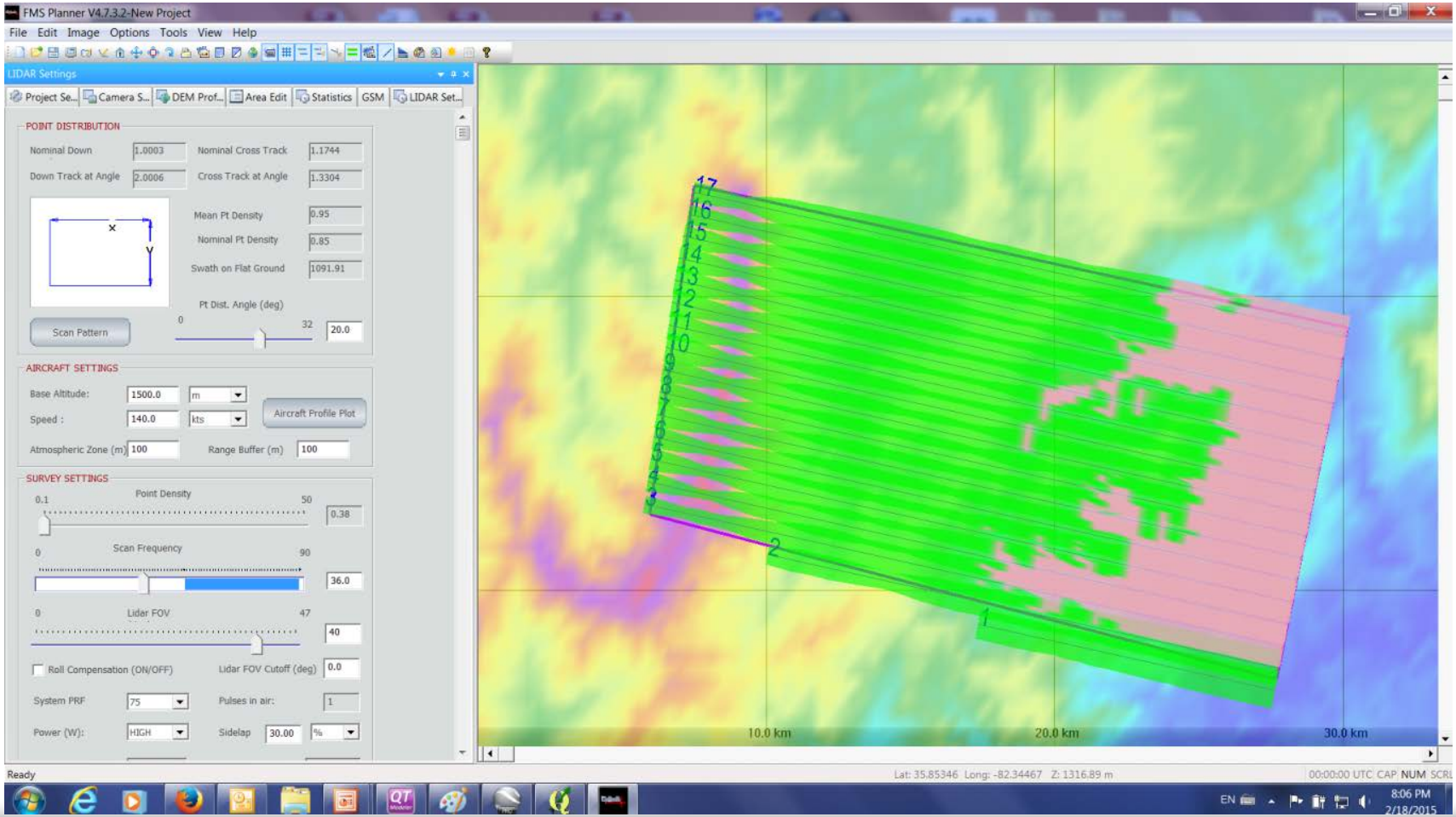
1550 nm (3.5°)

Flight Direction



Titan Workflow – Mission Planning

- Simple seamless mission planning
- Import DEM's, shape files, kml's
- Automatic identification of problem areas

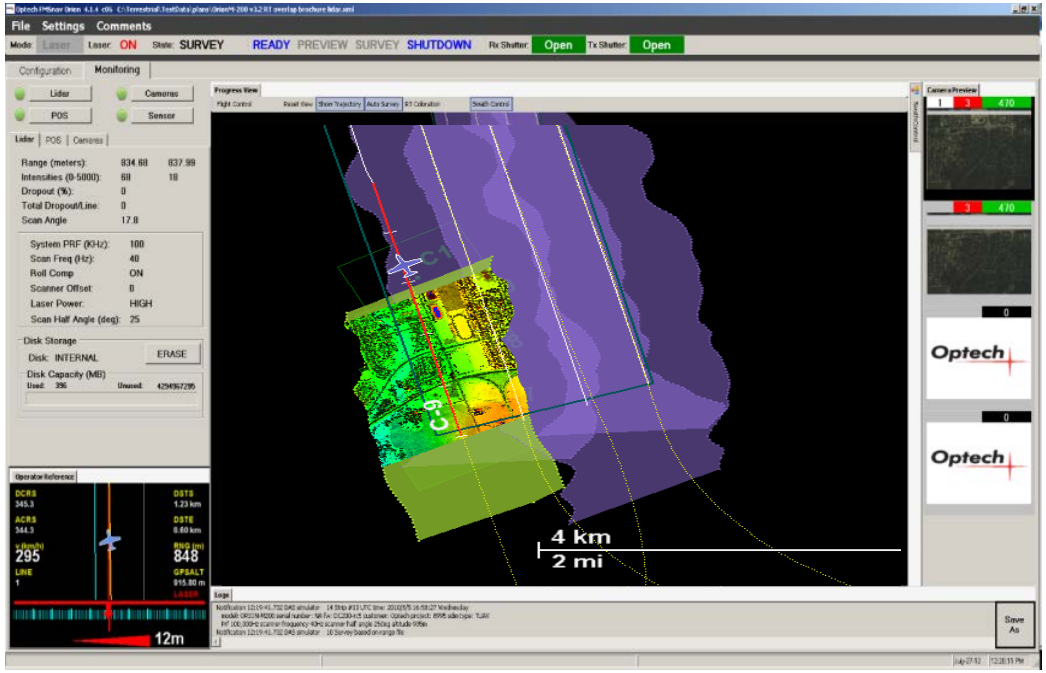


Titan - Operations

Titan uses same lidar workflows common with all other Optech airborne sensors

Optech FMS-NAV

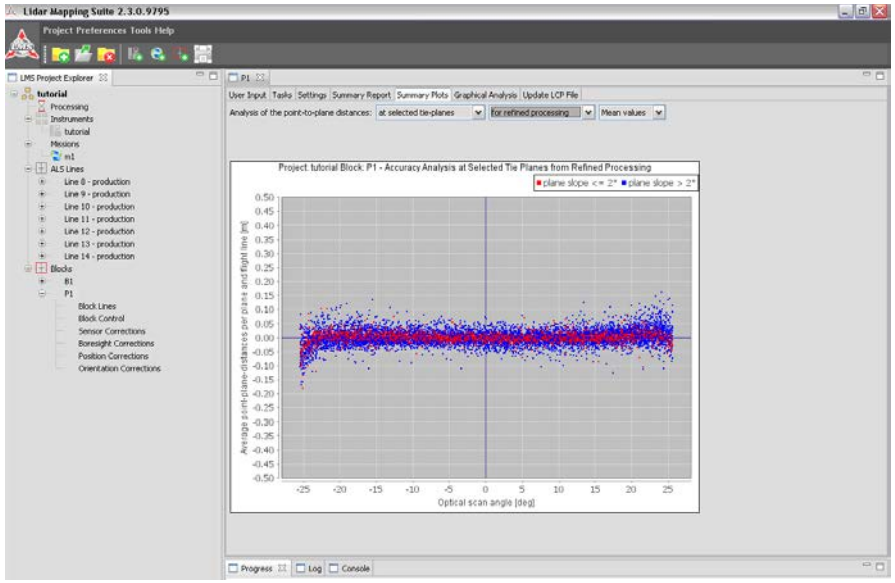
- Optech FMS is a fully-featured mission planning, navigation and sensor control application
- Leverage Titan's realtime sensor protocol for in-air XYZI, QA and true coverage verification
- Monitor Titan's independent lidar channels, waveform feedback and camera thumbnails and histograms while in-flight

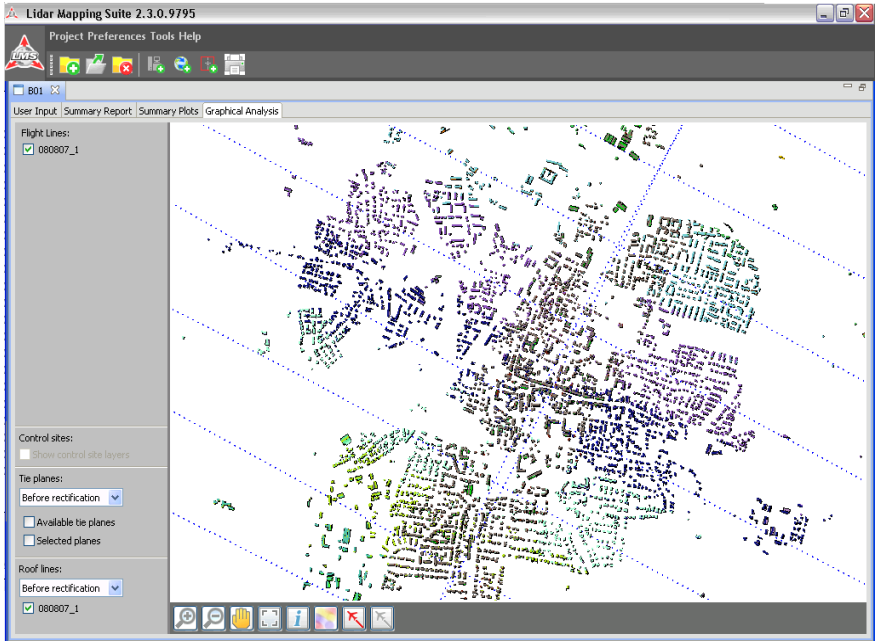


Titan – Workflow – Data Processing

Optech LMS

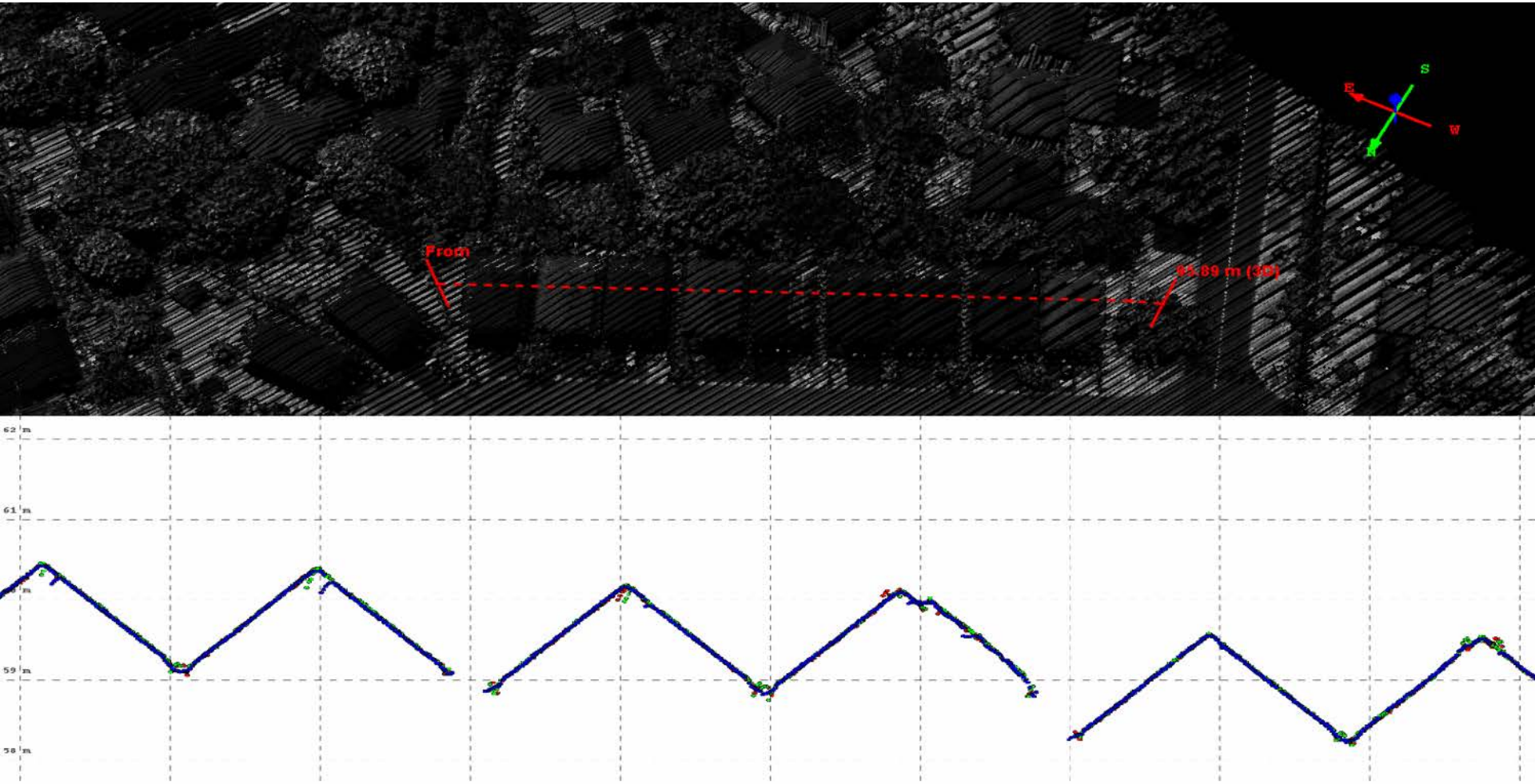
- Fully automatic sensor calibration
- Quantified lidar point accuracies and reporting metrics
- Camera boresight
- Coordinate conversion
- LAS outputs





LMS Processing

All channels automatically aligned



Titan - Accuracy

Absolute Vertical Accuracy Analysis

The vertical accuracy of the system was confirmed using a hard, flat surface with unobstructed ground control points over 2047 points surveyed on the Oshawa Airport runway. The system was flown over the area on date: October 2nd 2014.

Altitude:
900 – 1200 m

Mean Difference:
1 cm or less for all channels

Standard Deviation:
all less than 2 cm

Flight day (yy/mm/dd)	Flight Altitude (m AGL)	PRF (kHz)	FOV (± degree)	Scan Freq. (Hz)	Mean Difference from GCPs (m)	Std Dev. (m)	RMS (m)	Channel
2014/10/2	*901*	*200*	*25*	*32*	*0.0062*	*0.0131*	*0.0145*	*1*
	901	*200*	*25*	*32*	*0.0028*	*0.0136*	*0.0139*	*2*
	901	*200*	*25*	*32*	*0.0002*	*0.0125*	*0.0125*	*3*
	1098	*200*	*25*	*32*	*0.0064*	*0.0166*	*0.0177*	*1*
	1098	*200*	*25*	*32*	*0.0064*	*0.0166*	*0.0177*	*2*
	1098	*200*	*25*	*32*	*0.0060*	*0.0195*	*0.0204*	*3*
	1208	*200*	*25*	*32*	*0.0111*	*0.0137*	*0.0176*	*1*
	1208	*200*	*25*	*32*	*0.0041*	*0.0135*	*0.0141*	*2*
	1208	*200*	*25*	*32*	*0.0044*	*0.0177*	*0.0182*	*3*

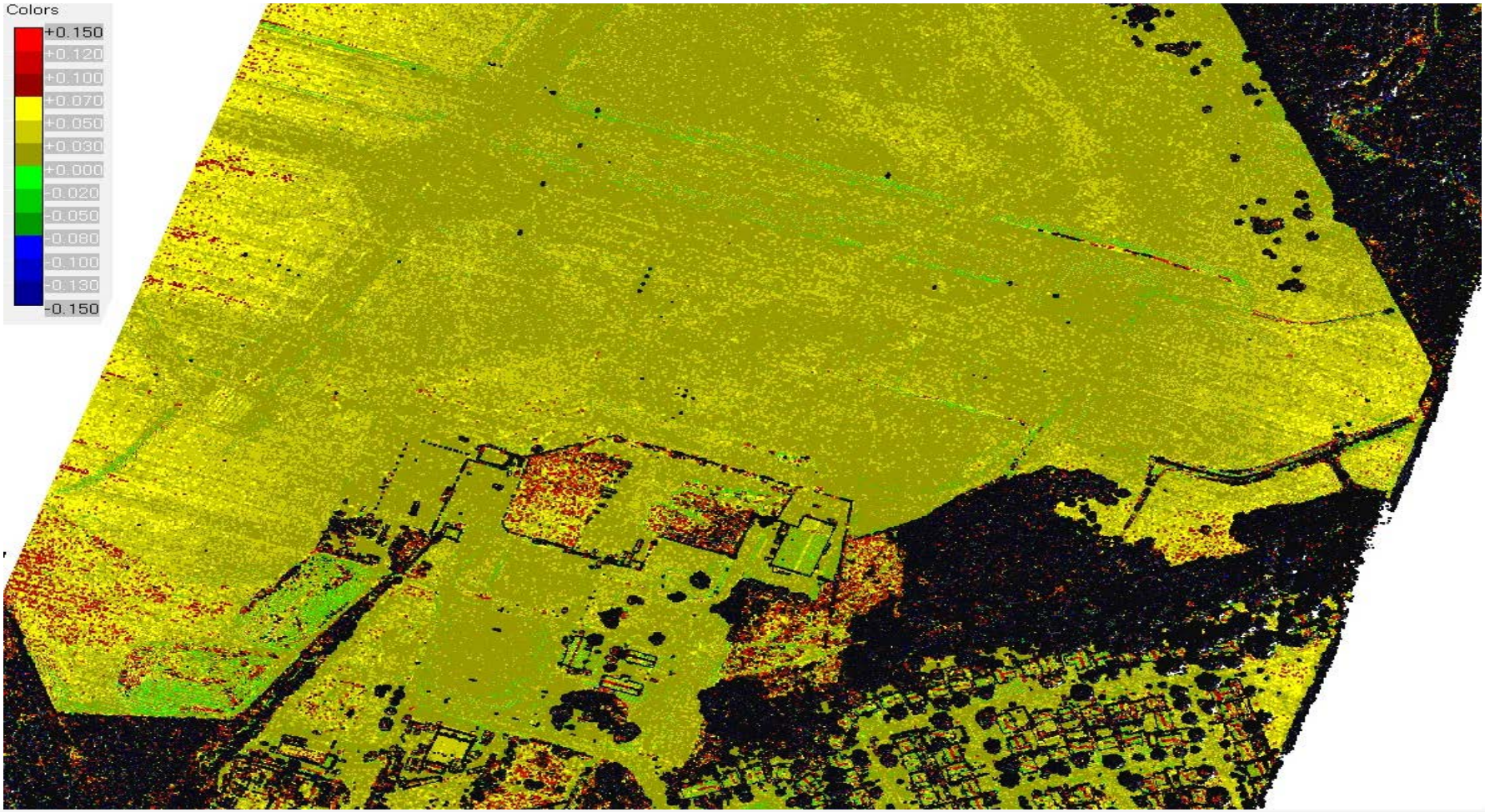
Accuracy Verification - Roof Line Analysis

The roof line analysis compares roof lines in the overlapping areas of flight lines. For a pair of roof lines, it computes the shortest vector between them at the center point of one of the lines. The table presents a summary for all roof lines comparisons. **The RMS horizontal distance of 0.131cm is below our horizontal specification** of (1/7500 x 1000m AGL) = 13.3cm. LMS professional treats roof line from all 3 channels as one instrument, the table below shows results from all channels.

	Mean	RMS	Minimum	Maximum
Delta East (m)	-0.010	0.102	-0.679	0.854
Delta North (m)	0.007	0.082	-0.556	0.824
Delta Height (m)	-0.005	0.030	-0.496	0.169
Horizontal Distance	0.017	**0.131**	-0.909	0.864
Difference of Azimuth (deg)	0.000	0.242	-0.995	0.995
Difference of Slope (deg)	0.011	0.093	-0.538	0.654

Titan Accuracy

Separation Between Channels less than 3cm



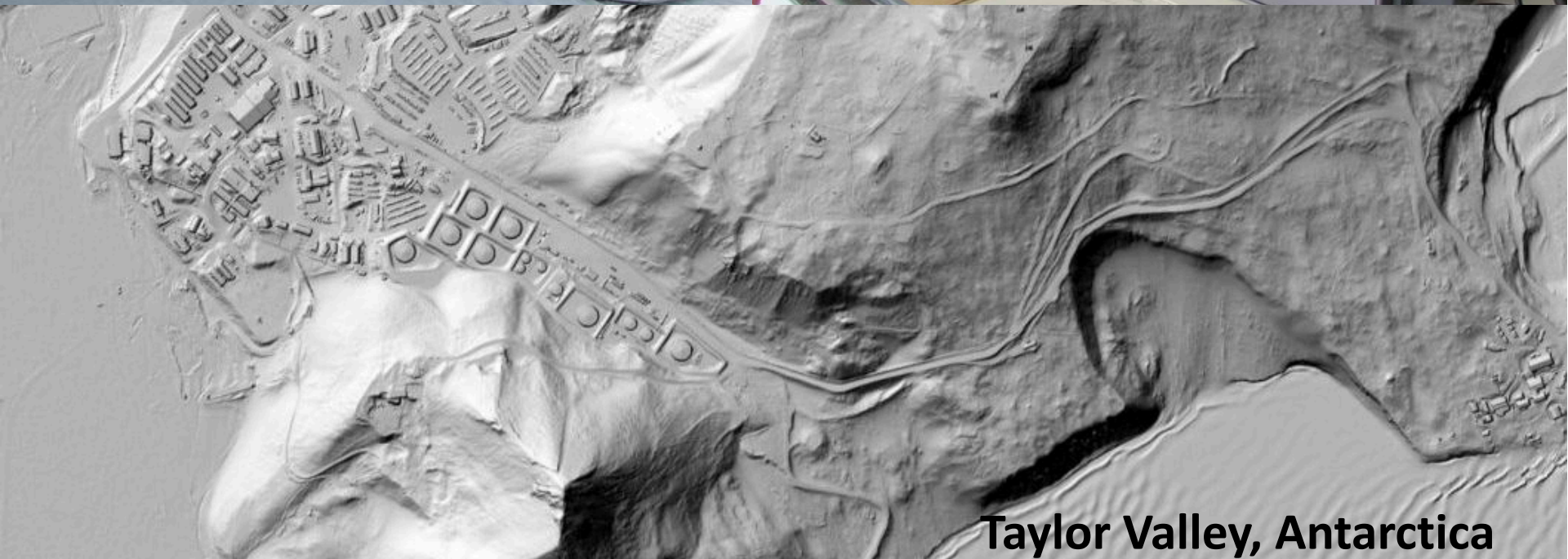
Titan 1 NCALM

Antarctic Expedition

2014/2015

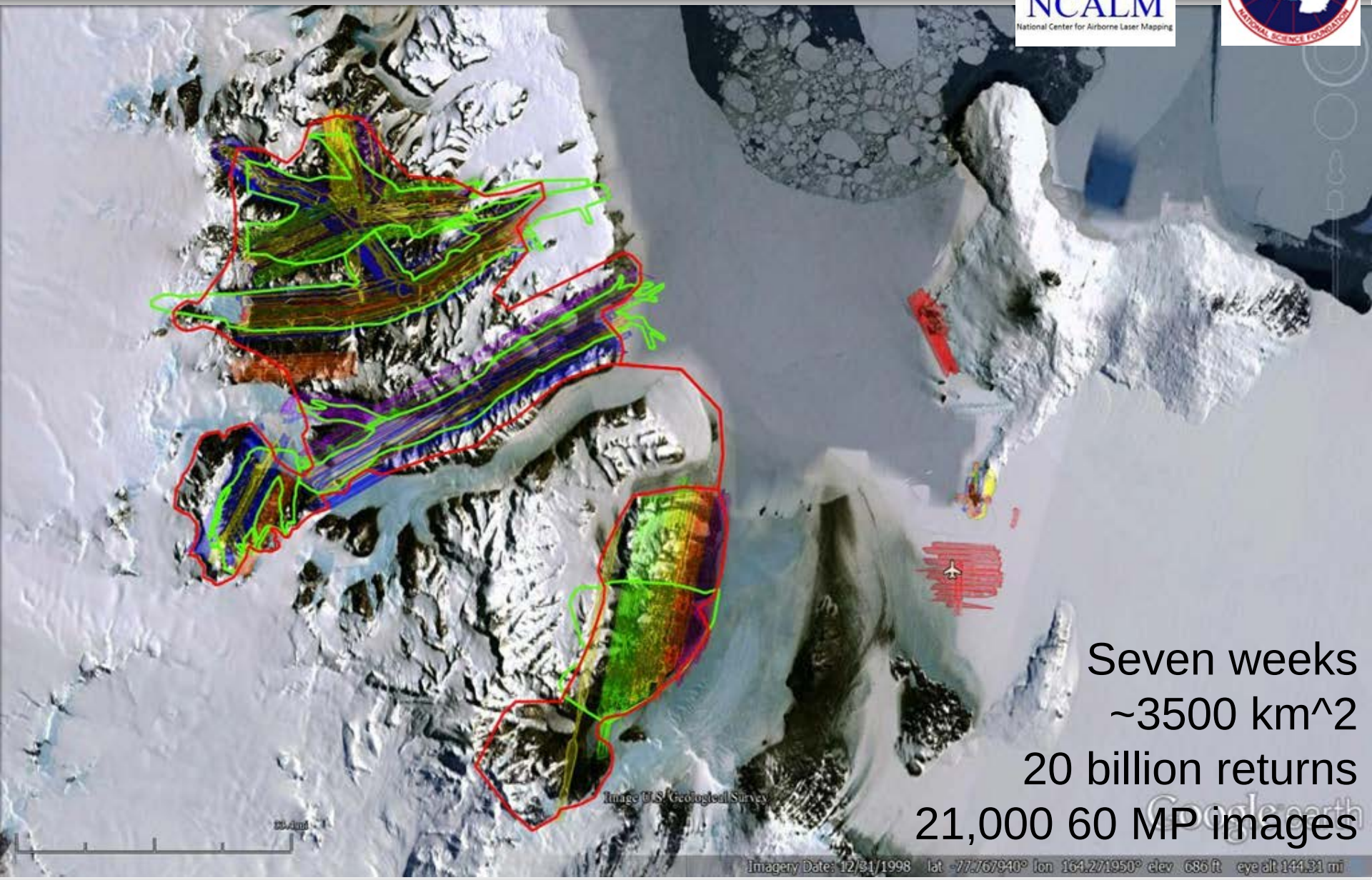
- Titan installation in a Twin Otter

Titan 1 NCALM



Taylor Valley, Antarctica

NCALM 2014-15 LIDAR SURVEY COVERAGE



Seven weeks
~3500 km^2
20 billion returns
21,000 60 MP images

Optech TITAN:

Shallow Water Bathymetry

Titan – Applications Shallow Water Bathymetry

- The seven degree forward tilt of the green beam is optimized for performance in shallow water mapping
- The addition of the IR channels significantly aids land/water discrimination necessary for corrected range measures in the attenuated water column
- Full coverage through the surf zone is attained without having to store bulky waveform data
- The laser in Titan does not lose its peak power with increasing PRF. This means the depth performance stays the same from 50 kHz to 300 kHz.
- Effective water depth penetration of over 15m possible in coastal waters, with even greater depths from averaging of very high point density

Titan – Tobermory Survey

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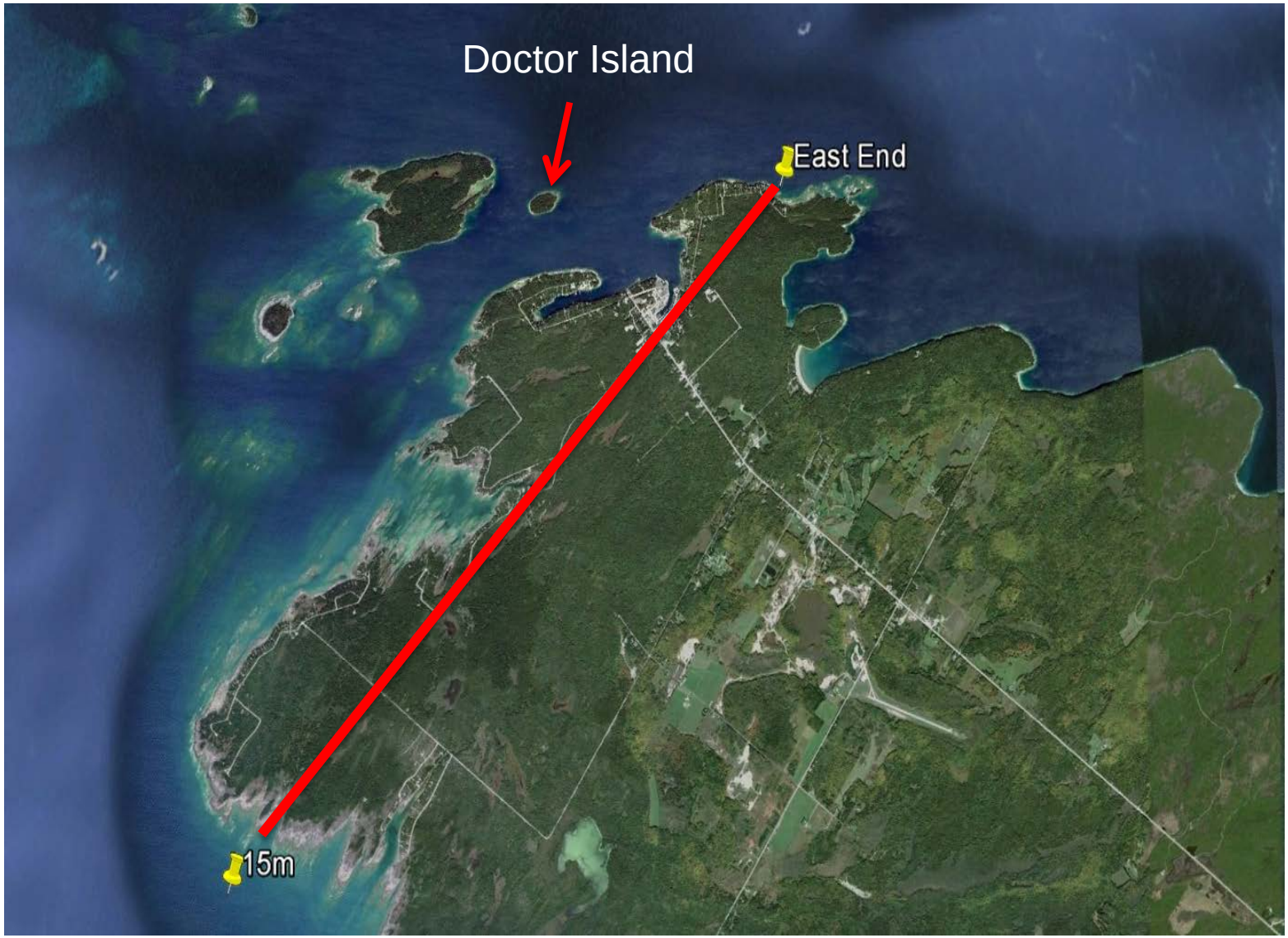
Titan – Tobermory Survey



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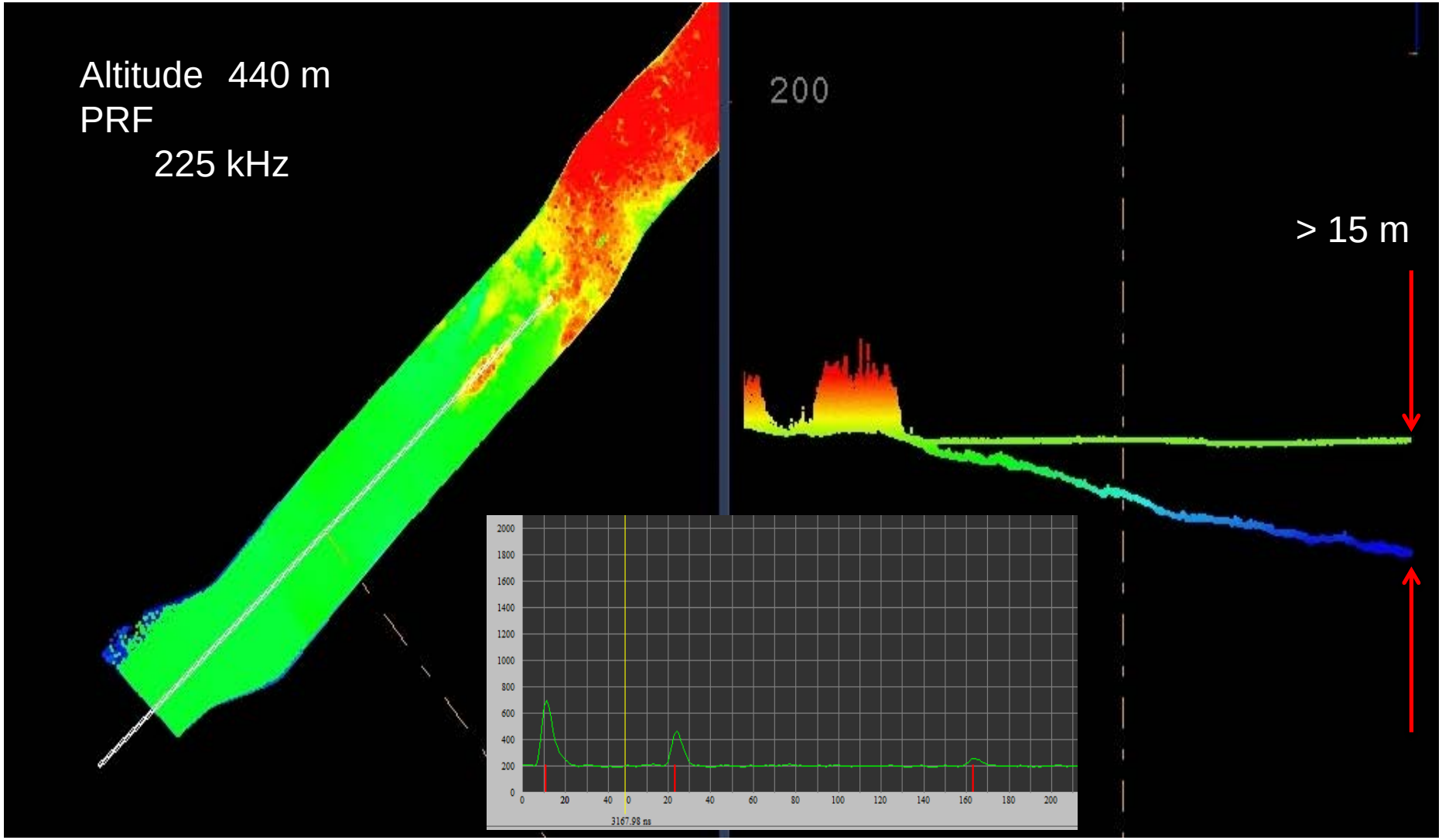
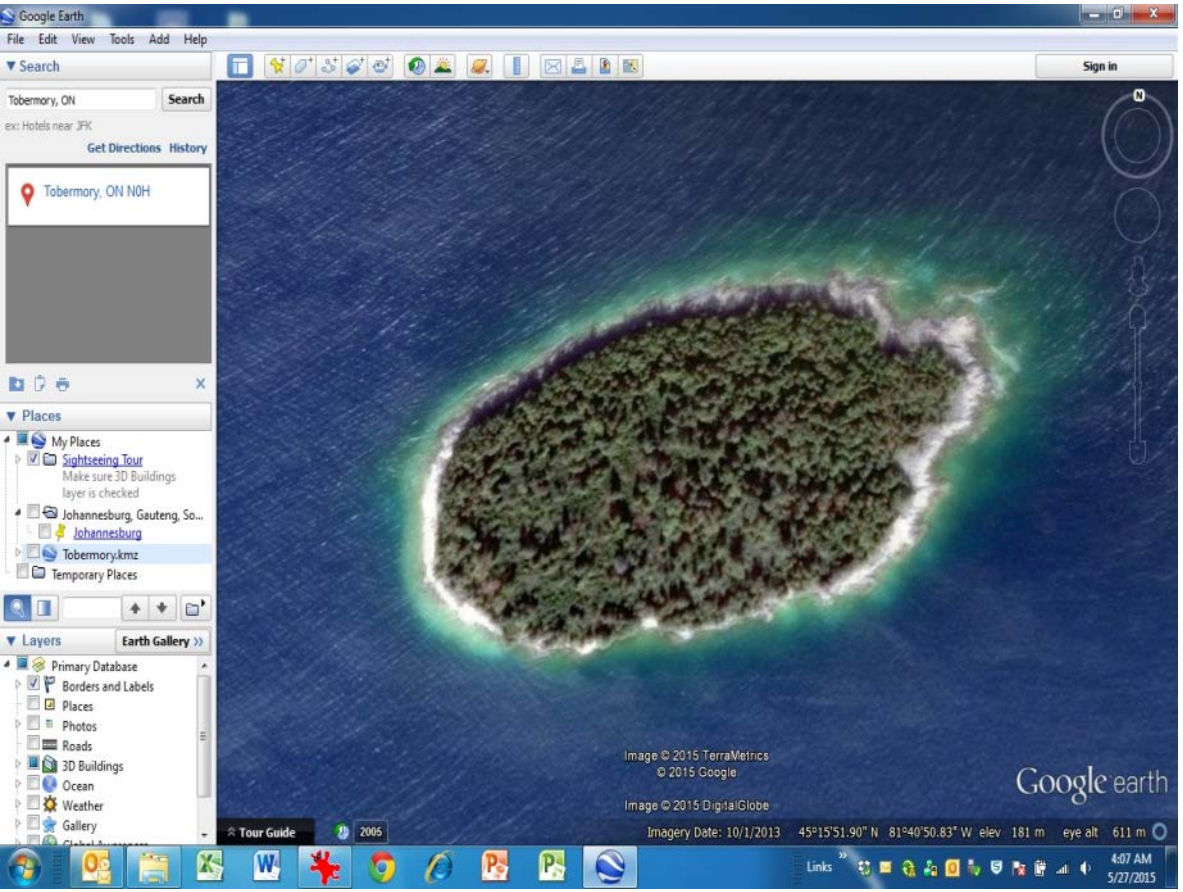
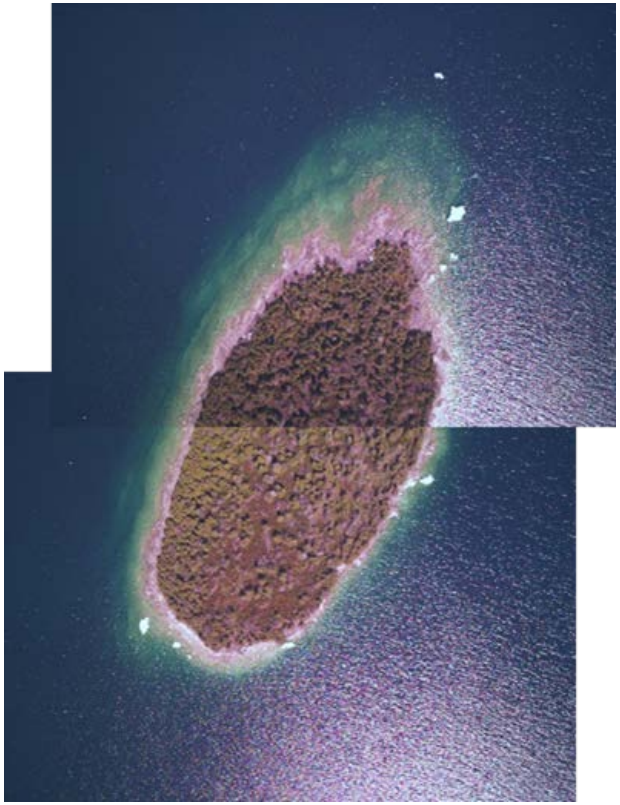
Titan – Water depth profile in Lake Huron



Doctor Island, Tobermory

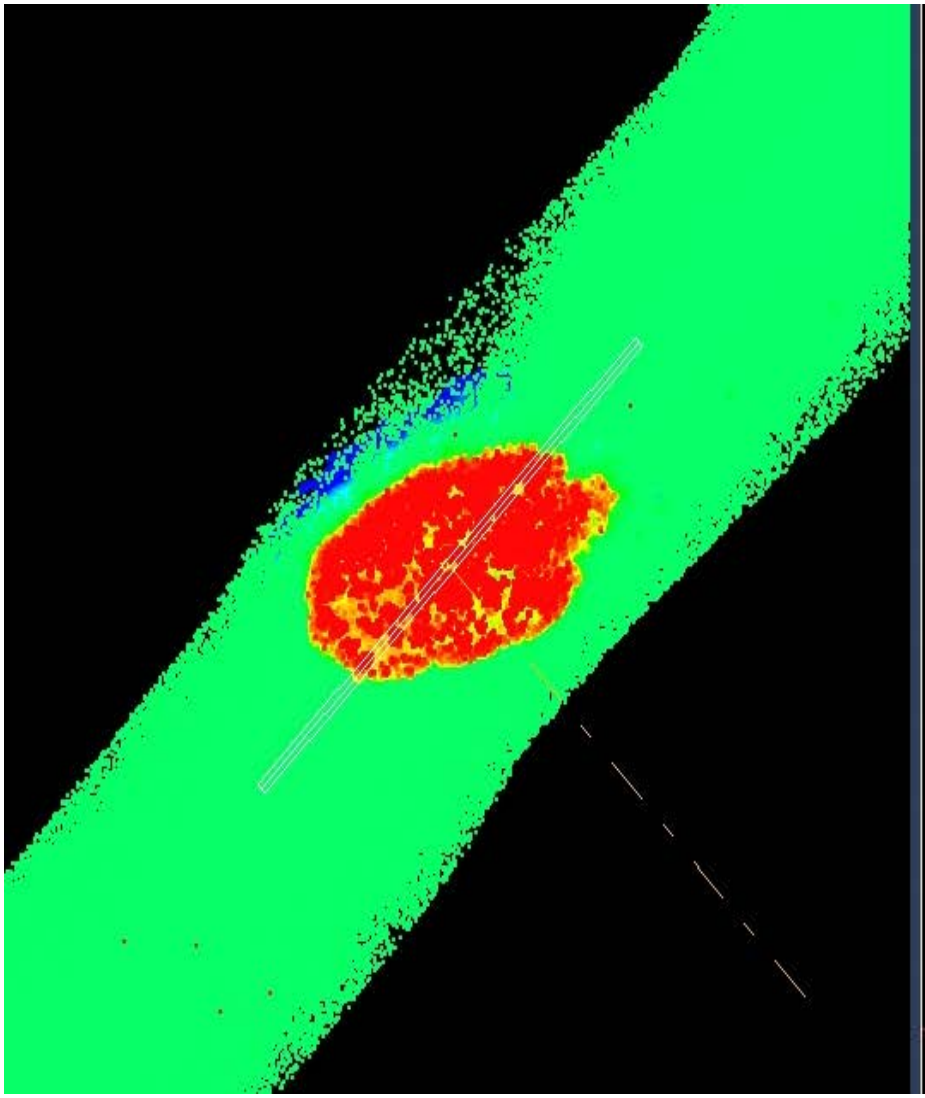


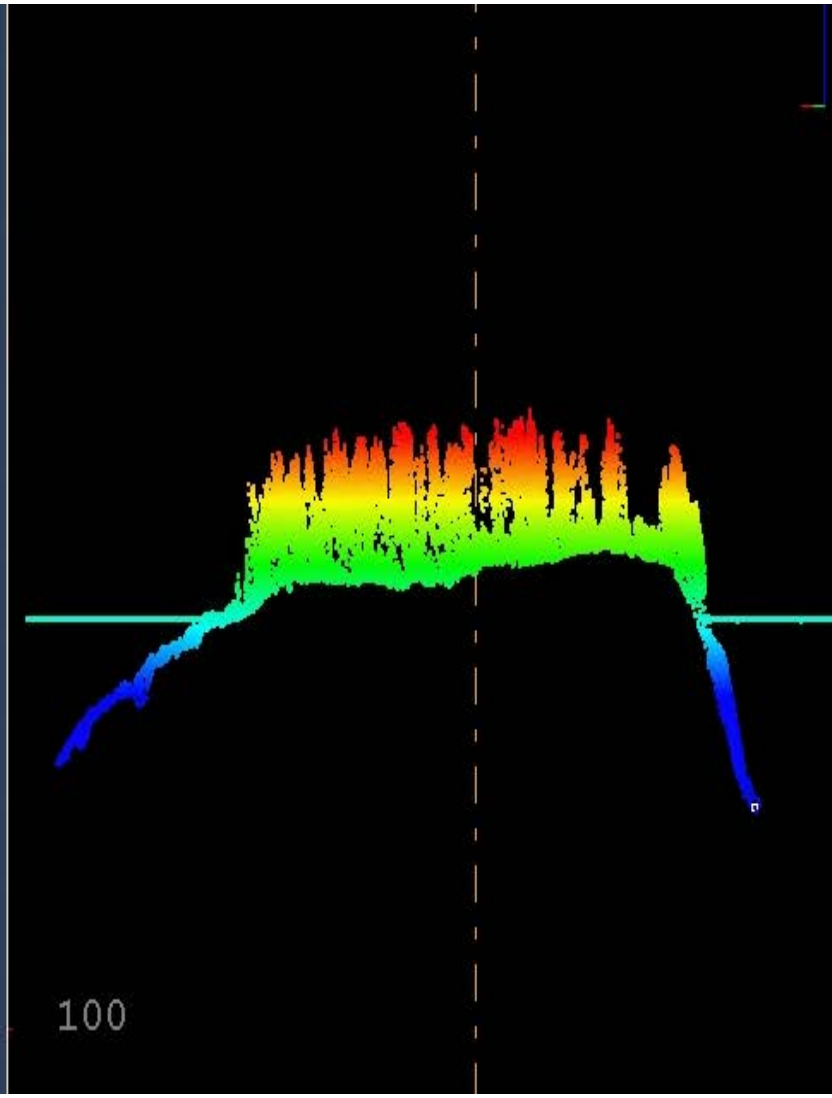
Google Earth



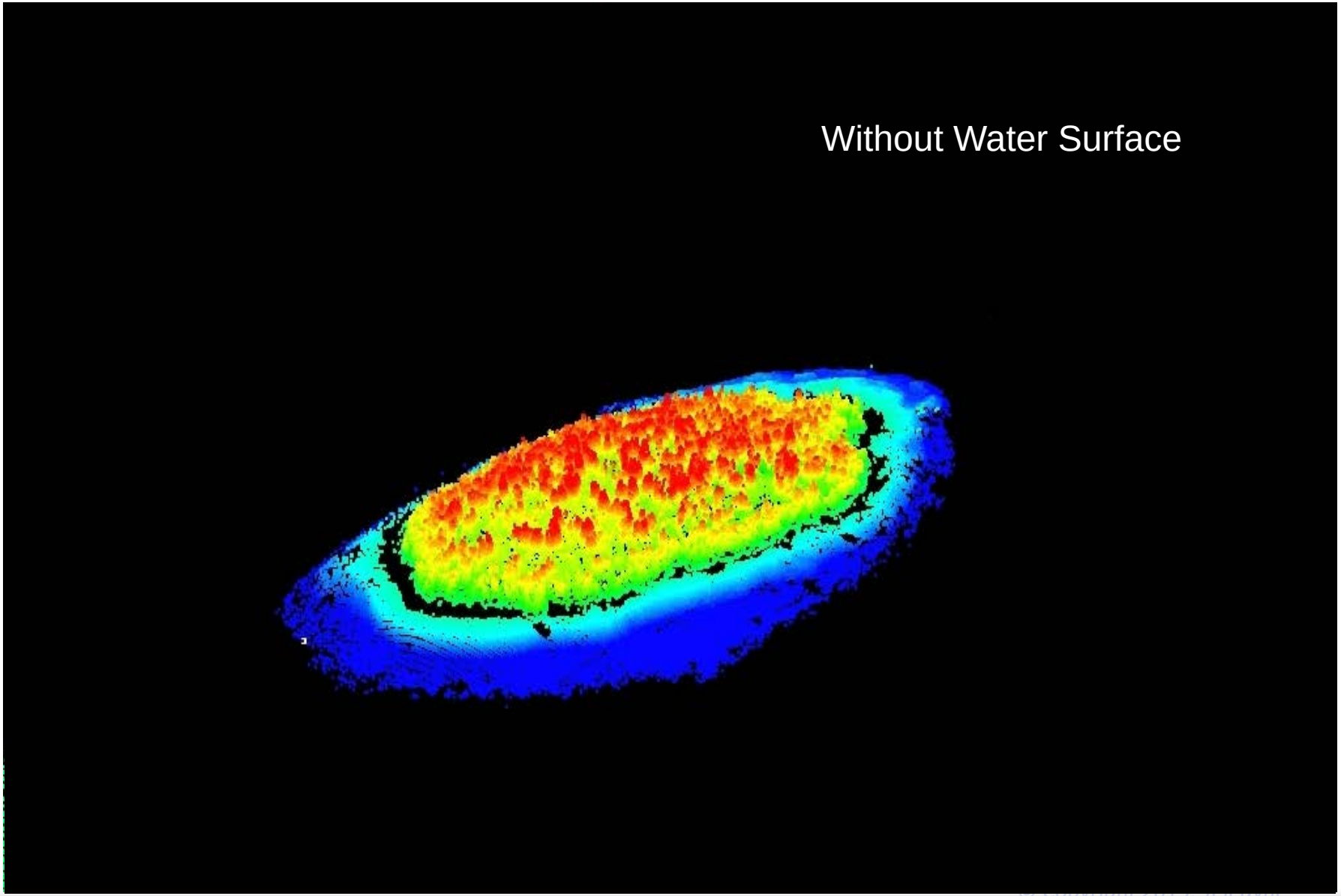
Thumbnails from CS10000 camera

Doctor Island, Tobermory





Doctor Island, Tobermory



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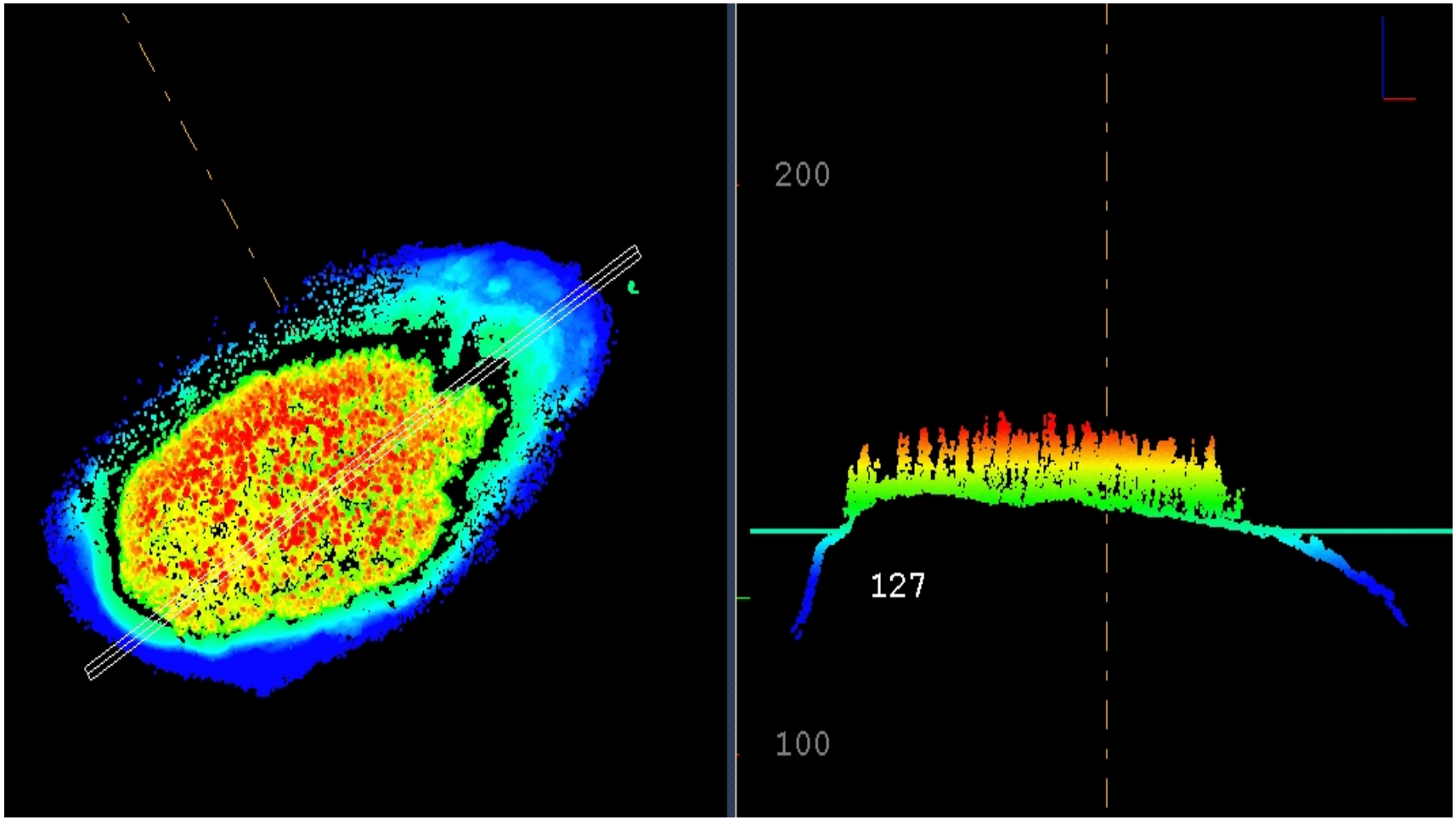
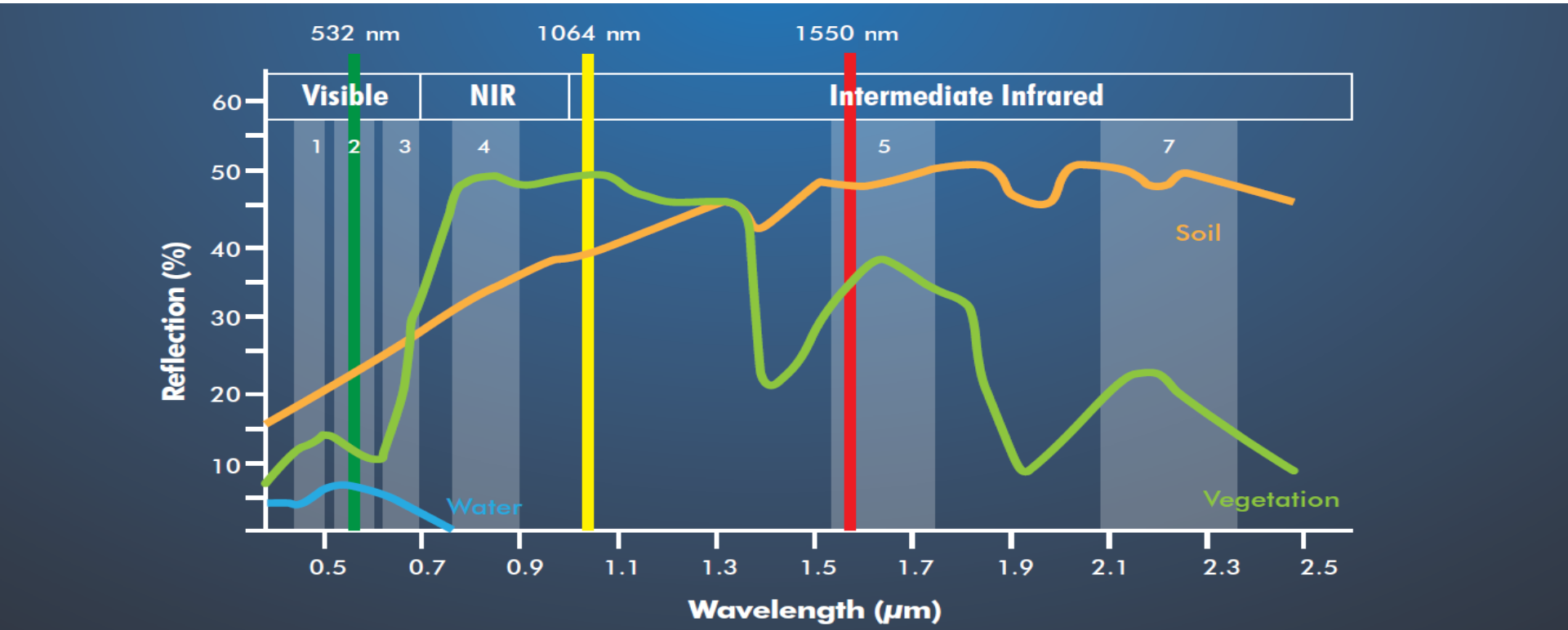
Doctor Island, Tobermory



14 m depths achieved around the island
Note: results are discrete data only – no waveforms

Titan – Wavelength Sensitivities

- Vegetation is strongly reflective in NIR, and slightly so in visible green spectrum
- Vegetation can be easily distinguished from soil and water (i.e. vegetation versus non-vegetation)
- Water is best penetrated using green wavelengths



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1550 nm

Corrected Intensity image from Channel 1 (1550 nm)

Soil is reflective in intermediate IR

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1064 nm

Corrected Intensity image from Channel 2 (1064 nm)

Vegetation is strongly reflective of NIR

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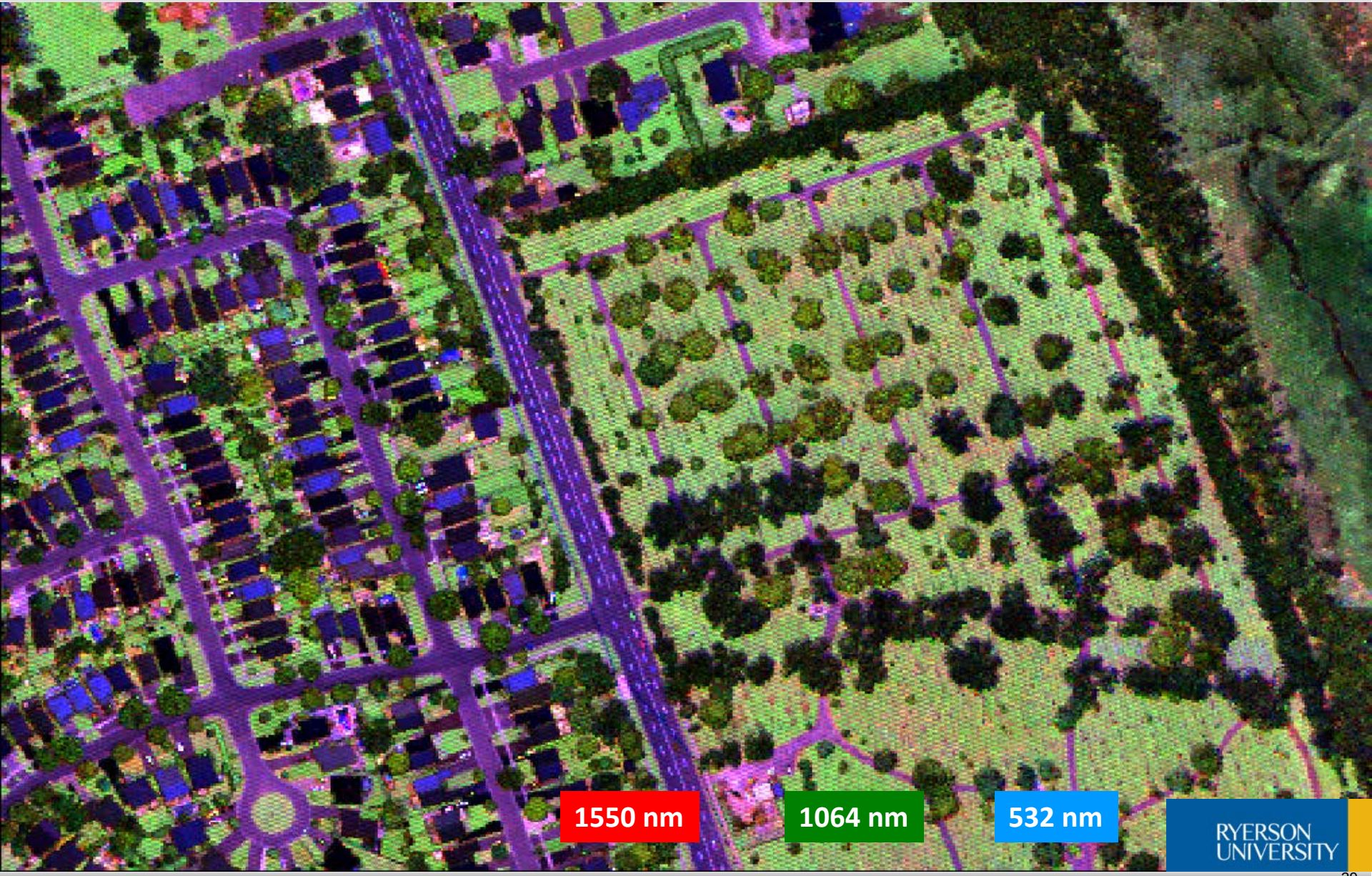
532 nm

Corrected Intensity image from Channel 3 (532 nm)

Vegetation is poorly reflected in the green and appears darker

False Color IR – Lidar intensity only

Natural Color Composite - Lidar intensity only



Initial Raster Results

Maximizing the benefit of using lidar data for land cover information extraction

Take advantage of existing image classification algorithms to achieve accurate Land-Cover classification based on Lidar data (Range and intensity data).

Explore the use of Titan multi-spectral Lidar data for land cover classification and information extraction

Dr. Ahmed Shaker AbdElrahman

Associate Professor, Ryerson University, Toronto, Canada

Study Area

- The collection area was a suburban area north of the City of Oshawa, ON, Canada.
- Altitude of 500 m; 600 kHz; density was 36 pts/m^2
- The study area was a subset of the collection area, about 550 m x 380 m
- The study area contained various types of Land Cover classes including buildings, parking areas, sidewalks, roads, bare soil, grass, and trees.

Imagery ©2014 Google, Map data ©2014 Google

Results and Analysis

Image Classification:

- Maximum likelihood classifier is used to classify the intensity data of:
  1) each channel separately. and
  2) all combined.
  3) a DSM band is used with combined three intensity bands.

- 200 random checkpoints distributed overall the study area were used for classification assessment.

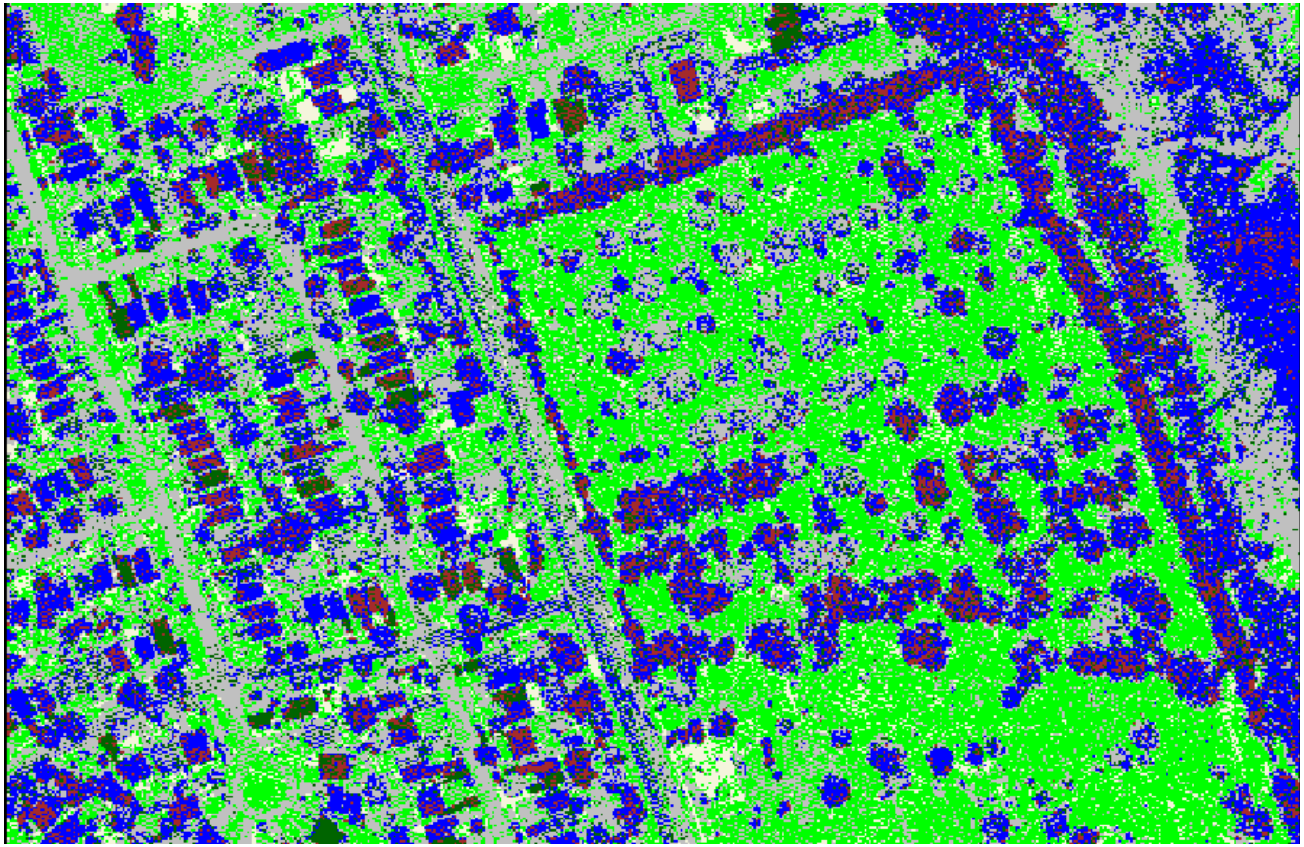
- The images were classified to **six classes**:

  - Buildings (Brown color)
  - Trees (Dark Green color)
  - Roads (Gray color)
  - Grass (green color)
  - Soil (Beige color)
  - Water (Blue color)

Class	Color
Buildings	
Trees	
Roads	
Grass	
Soil	
Water	

Results and Analysis

Classification results of Channel 1 (1550 nm) intensity data

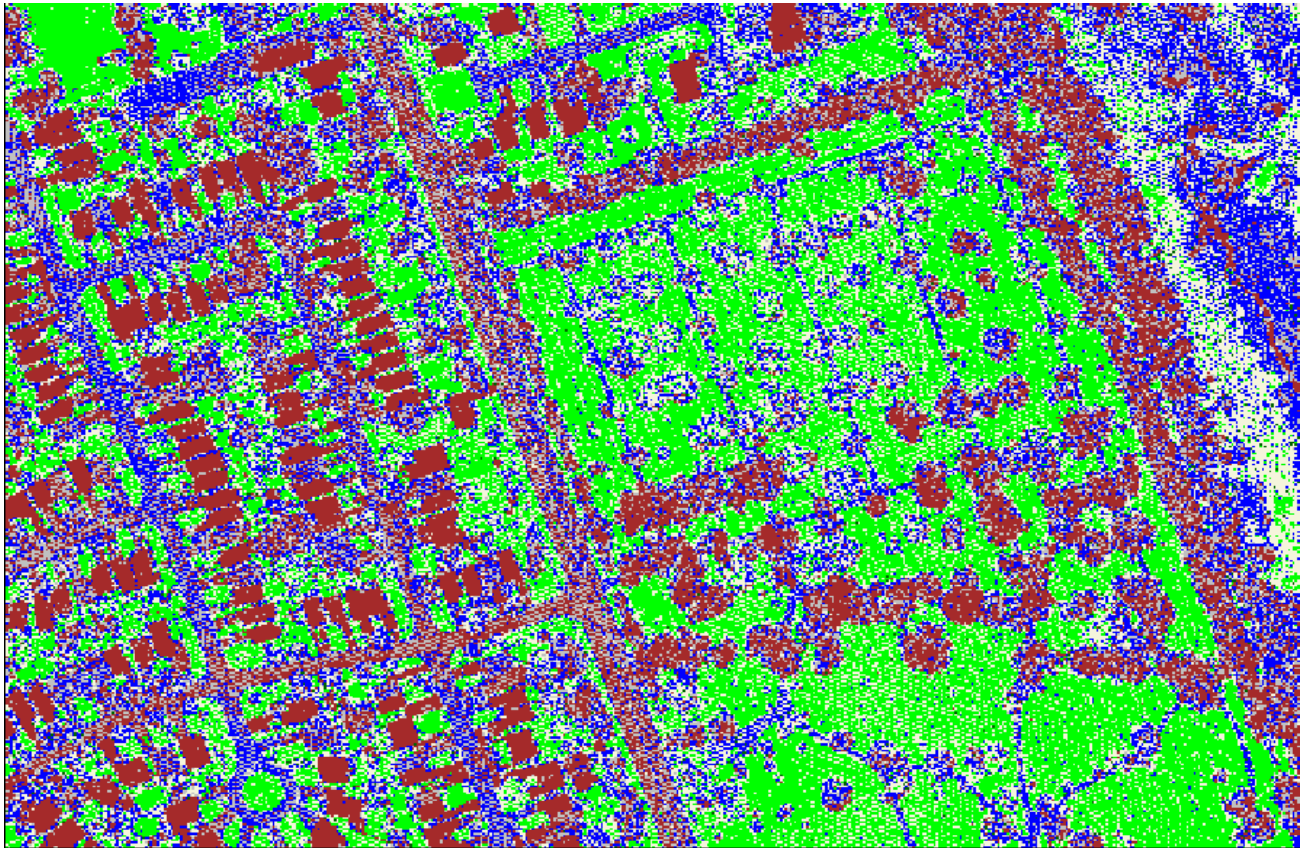


Buildings	
Trees	
Roads	
Grass	
Soil	
Water	

Overall classification accuracy = **38 %**

Results and Analysis

Classification results of Channel 2 (1064 nm) intensity data

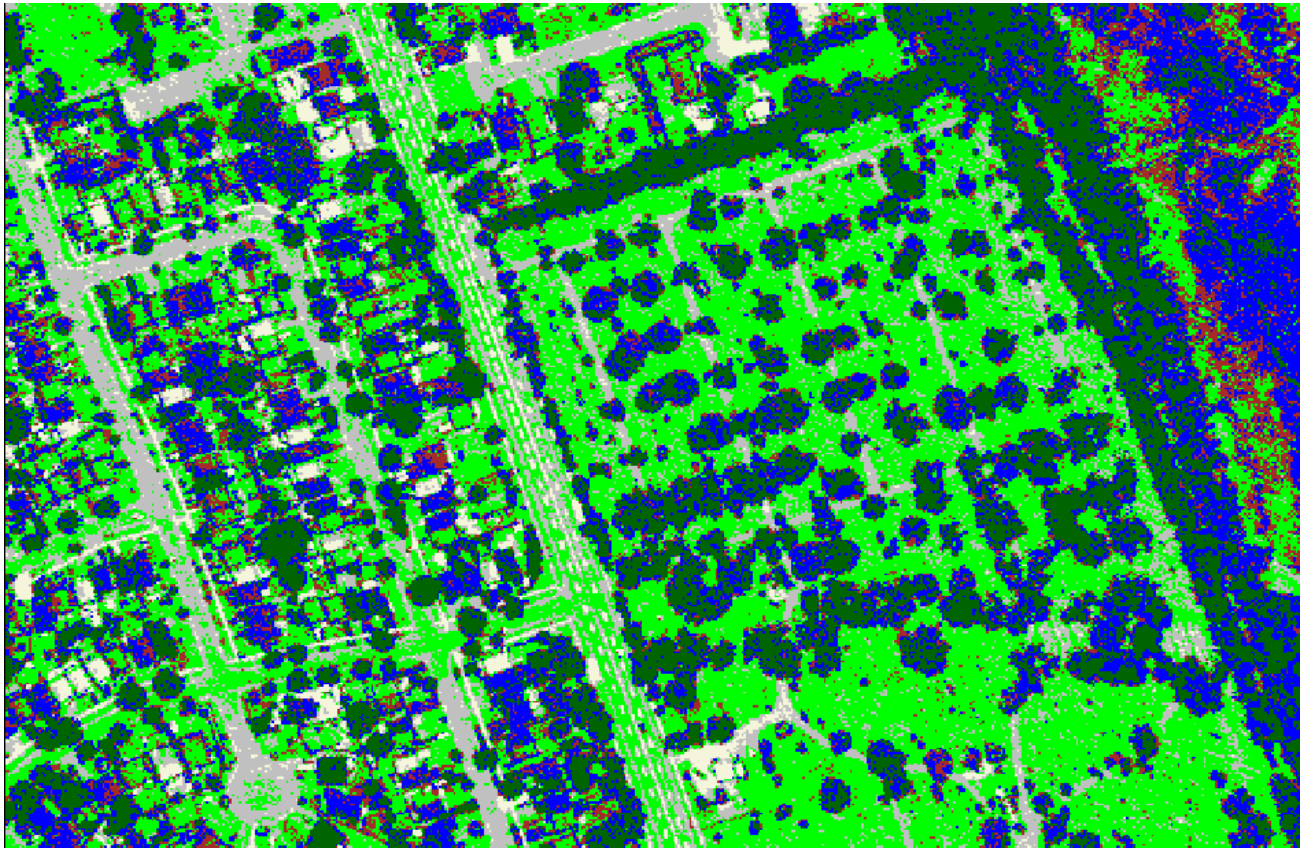


Buildings	
Trees	
Roads	
Grass	
Soil	
Water	

Overall classification accuracy = **46 %**

Results and Analysis

Classification results of Channel 3 (532 nm) intensity data



Buildings	
Trees	
Roads	
Grass	
Soil	
Water	

Overall classification accuracy = **52.5** %

Results and Analysis

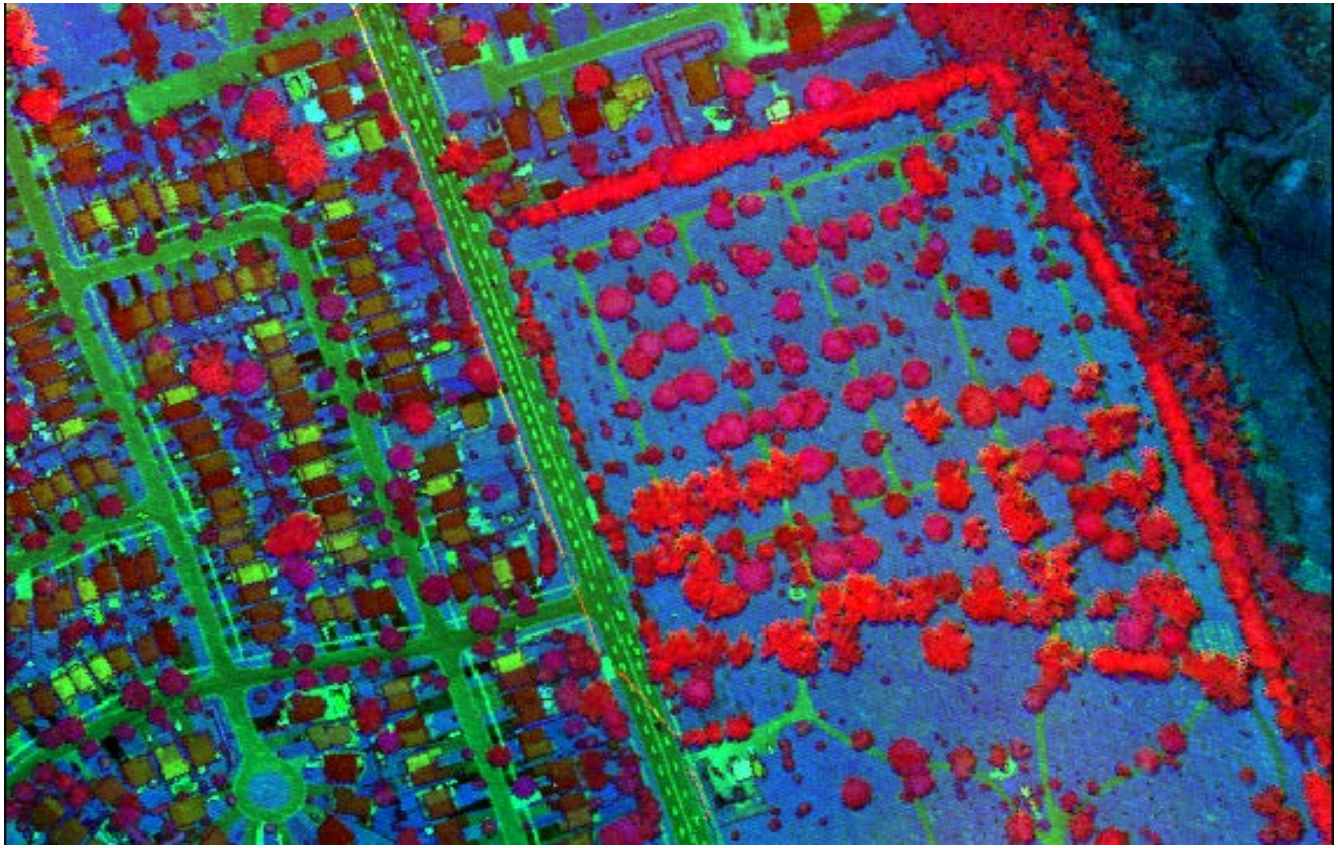
Combined classification results of Channels 1,2 and 3 (1550/1064/532 nm) intensity data

Buildings	
Trees	
Roads	
Grass	
Soil	
Water	

Overall classification accuracy = **69** %

Results and Analysis

To improve the classification results, a Digital Surface Model (DSM) is added as an additional band to the combined intensity bands used previously.



Bands displayed: DSM in Red, 1550 nm Green, 1064 nm Blue

Results and Analysis

Combined classification results of Channels 1,2 and 3 (1550/1064/532 nm) intensity data + DSM

Buildings	
Trees	
Roads	
Grass	
Soil	
Water	

Overall classification accuracy = **78** %

Initial Raster Results

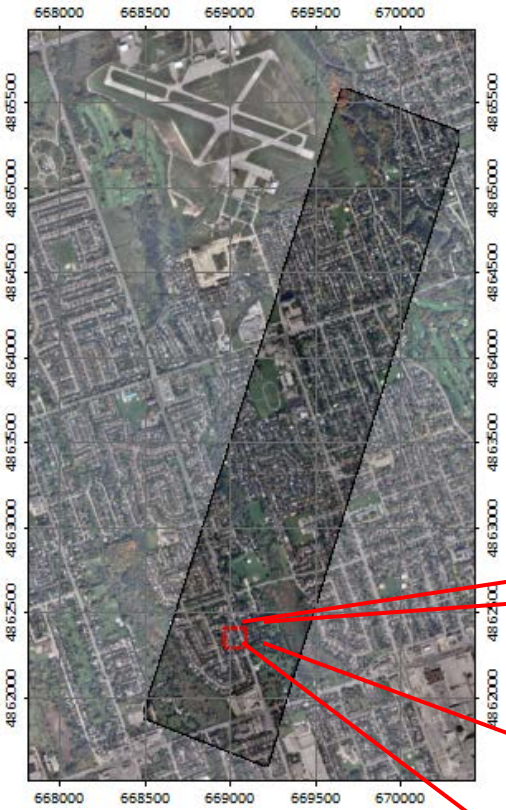
Summary of the Raster Classification Results Using Multi-Spectral Lidar Data (Accuracy assessment using 200 checkpoints)

Lidar Data (Band) Combination	Overall Accuracy (%)
1 Band (1550 nm)	38
1 Band (1064 nm)	46
1 Band (532 nm)	52
3 Bands (1550 nm & 1064 nm & 532 nm)	69
3 Bands (1550 nm & 1064 nm & 532 nm) + DSM	78

Recent Results

2ND Location

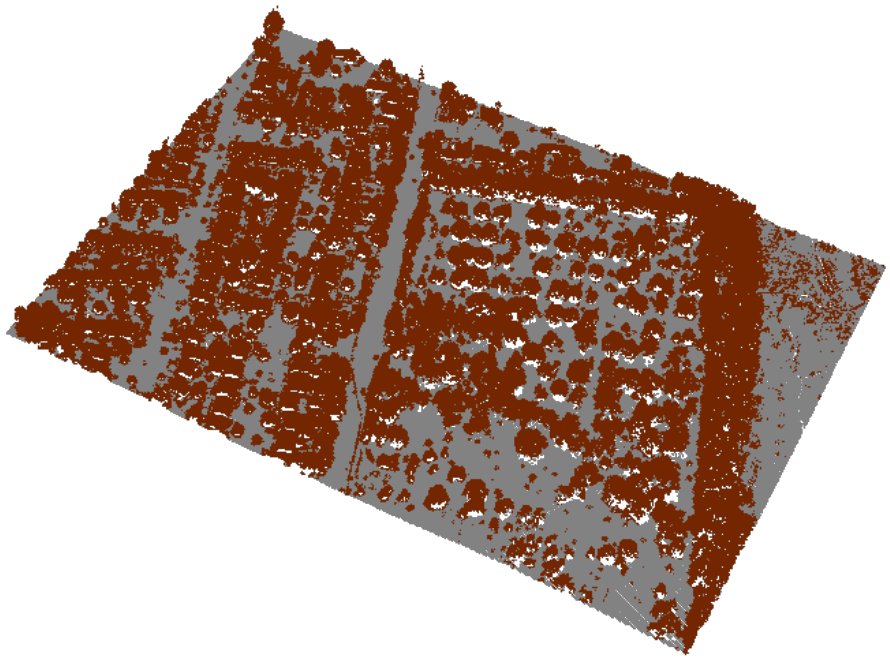
- Flat urban area south of Oshawa Municipal Airport of the city of Oshawa, Ontario, Canada.
- Contains various types of Land Covers



120x120m
50,000 pts

South of Oshawa Municipal Airport

Ground Filtering



Buildings

Trees

Roads

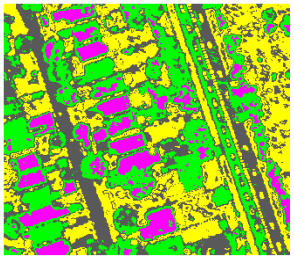
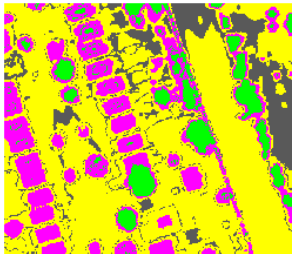
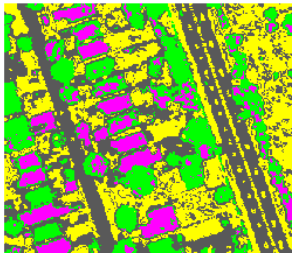
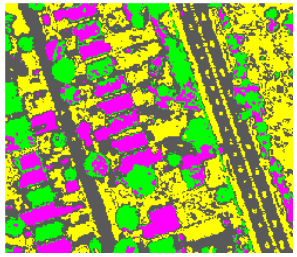
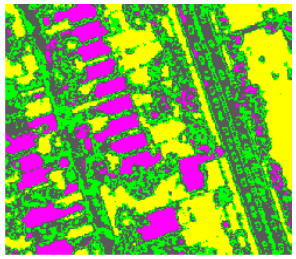
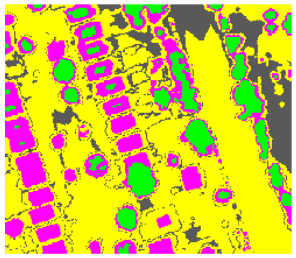
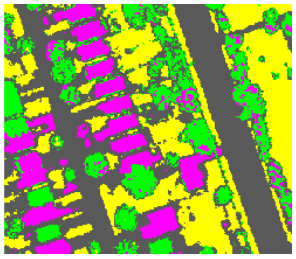
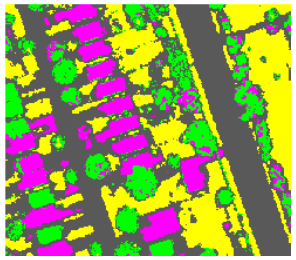
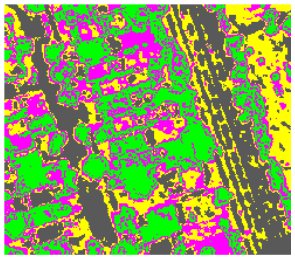
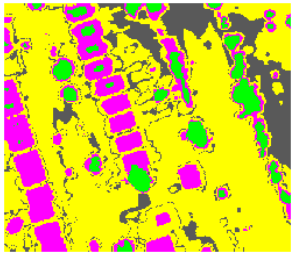
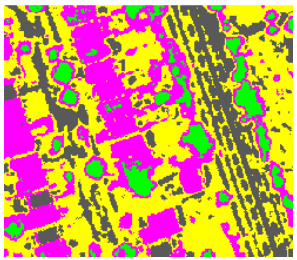
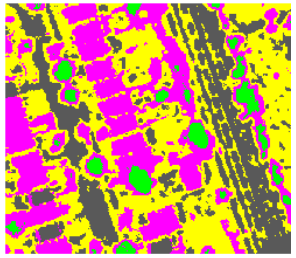
Grass

Non-Ground Points

Ground Points

Classification: Pixel-Based

New Approach: **1) Object Oriented Classification**
2) Use of Normalized DSM

	Intensity Image	DSM	Intensity & DSM	Intensity & NDSM
Channel1				
Channel2				
Channel3				

Classification: Pixel-Based Results

Case	Overall Accuracy %		
	Channel1	Channel2	Channel3
Intensity images	64	73	61
DSM	45	44	46
Intensity and DSM	75	93	78
Intensity and NDSM	76	93	81
Intensity of the three channels in one three-layer image.	91		
Intensity and DSM of the three channels in one six-layer image	94		
Intensity of the three channels and DSM of one channel in one four-layer image.	93		

Titan Data Analysis Approach

- Use the sample Titan dataset from Toronto area
- Use Google Street View to get field reference
- Use tree polygons as analysis units

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”Field” Data Collection

- Analyst ”walked” in Google Street View (c) , identifying tree species for the polygons
- Classes were re-coded to test classification to different species groupings
- Tree polygons that could not be seen or identified from Street View, were excluded

Species Classes
1. Maple(Acer)
2. Oak(Quercus)
3. Poplar(Populus)
4. Pine(Pinus)
5. Spruce(Abies, Picea)
6. Cedar(Juniperus)
7. Other hardwood
8. Other conifers
9. Dead wood

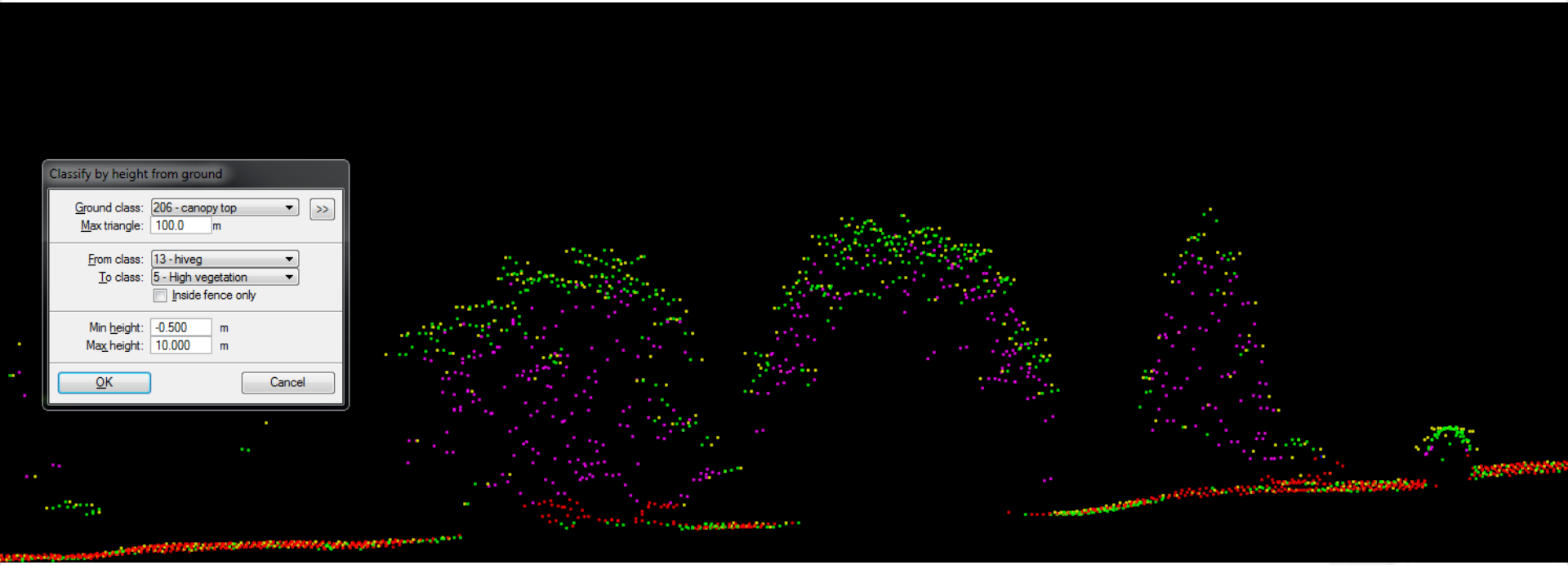
Images Courtesy of Google Street Wiew

Images Courtesy of Google Street Wiew

Processing Outline

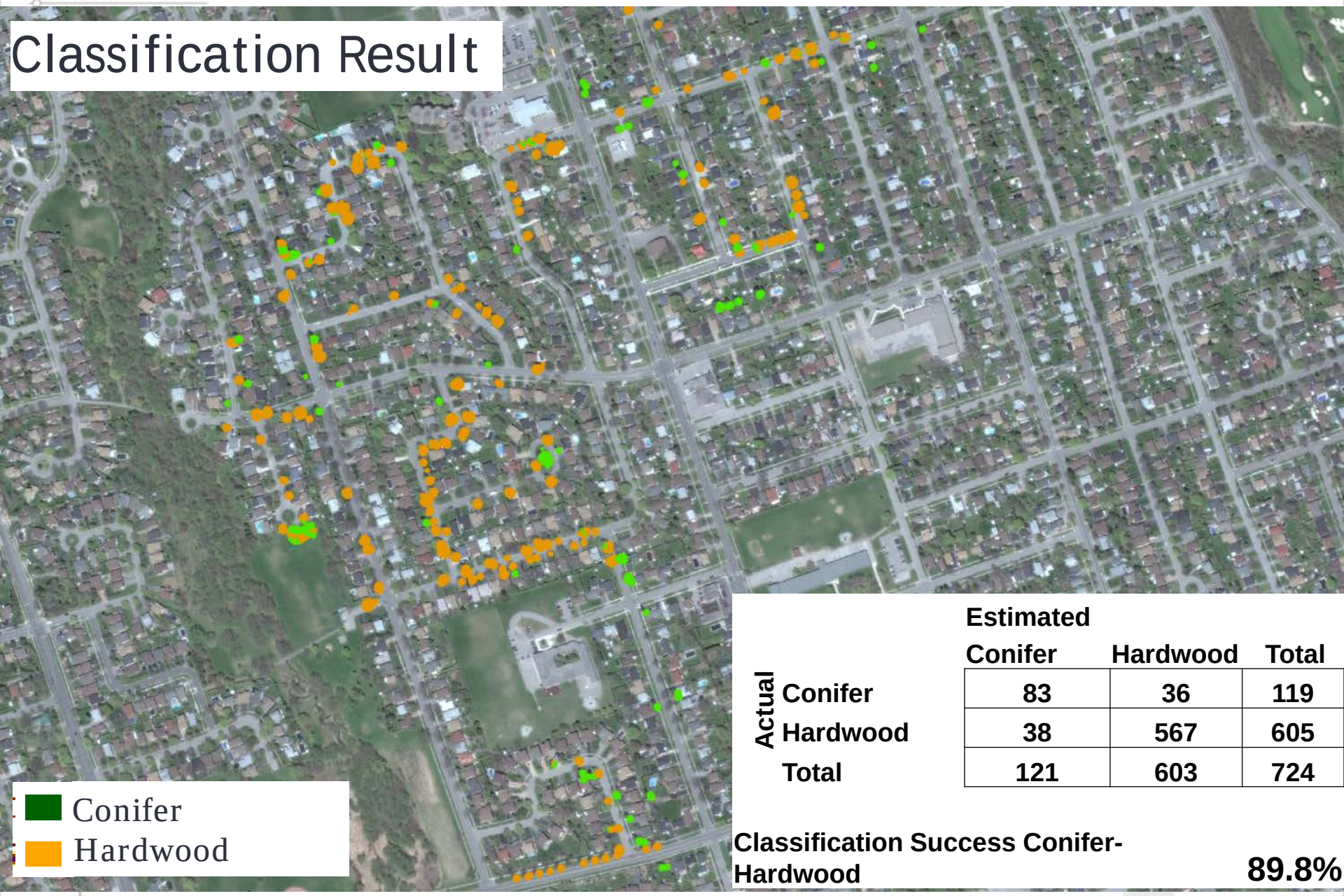
- ArboLiDAR was used for processing
- Polygons were made from all returns. They were attributed with spectral predictors, using spectral information from the top of the canopy only
- Predictors combine band information
- Prediction was done to three different species groupings

Using Top Canopy Points Only



Field Reference

Classification Result

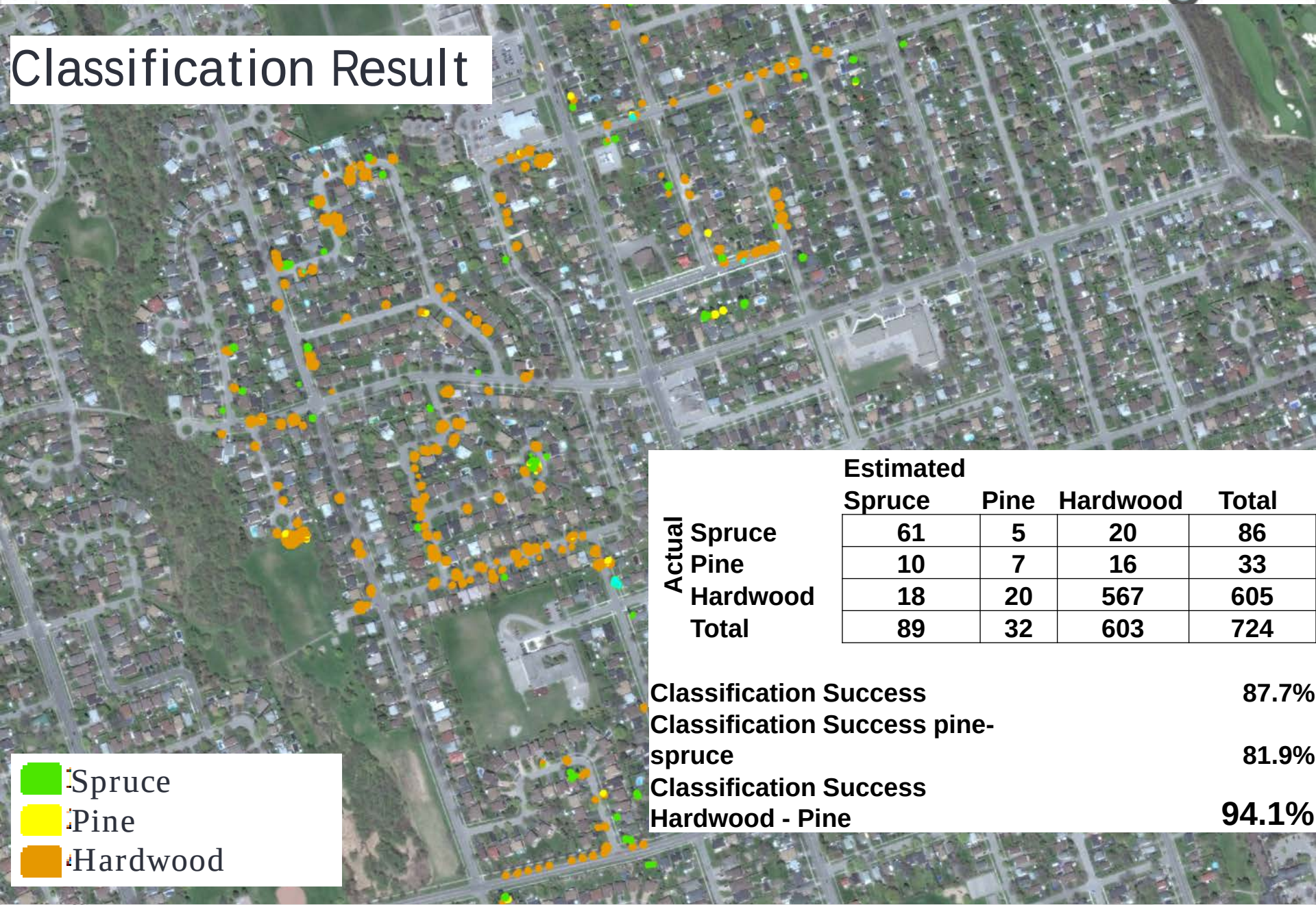


		Estimated		
		Conifer	Hardwood	Total
Actual	Conifer	83	36	119
	Hardwood	38	567	605
	Total	121	603	724

Classification Success Conifer-Hardwood **89.8%**

Field Reference

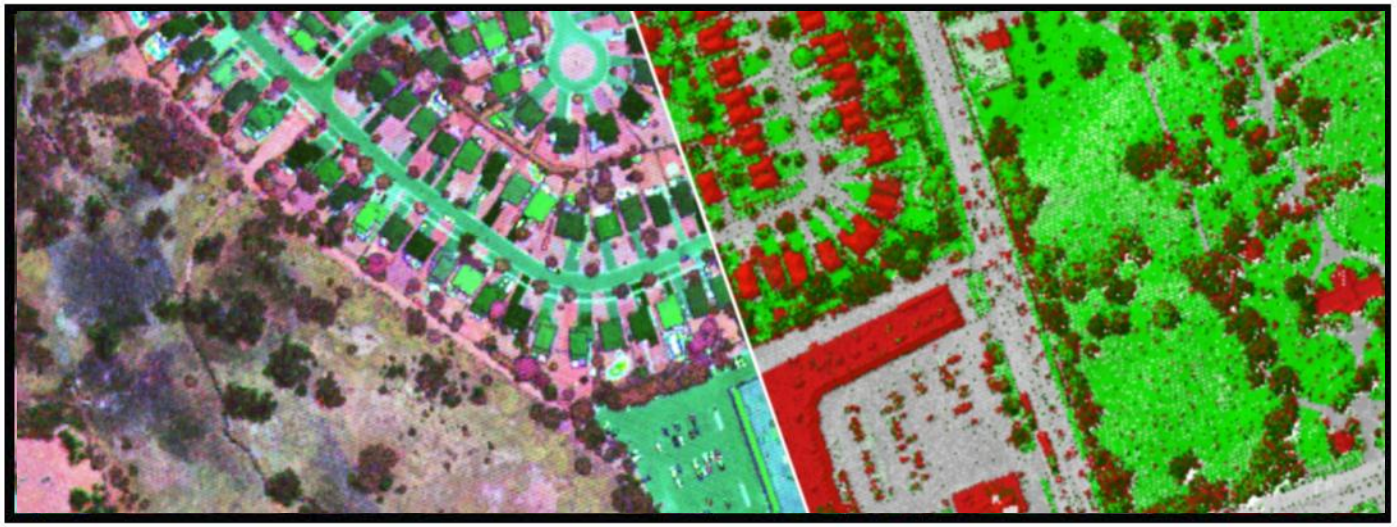
Classification Result



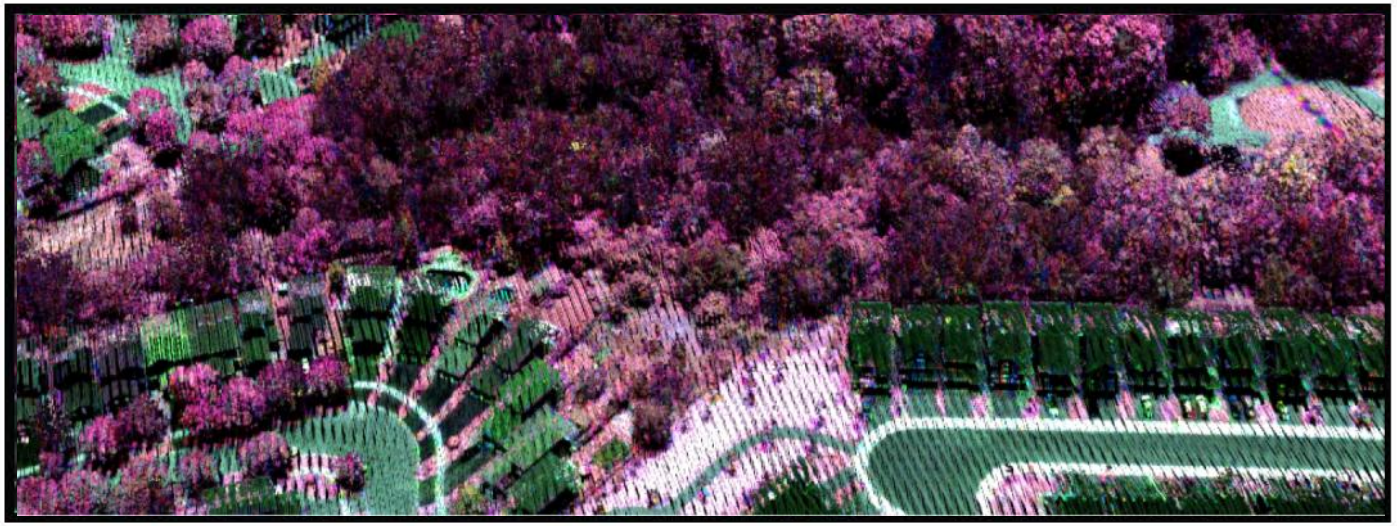
		Estimated			
		Spruce	Pine	Hardwood	Total
Actual	Spruce	61	5	20	86
	Pine	10	7	16	33
	Hardwood	18	20	567	605
	Total	89	32	603	724

Classification Success	87.7%
Classification Success pine-spruce	81.9%
Classification Success Hardwood - Pine	94.1%

Multi-Spectral – Imagine the possibilities



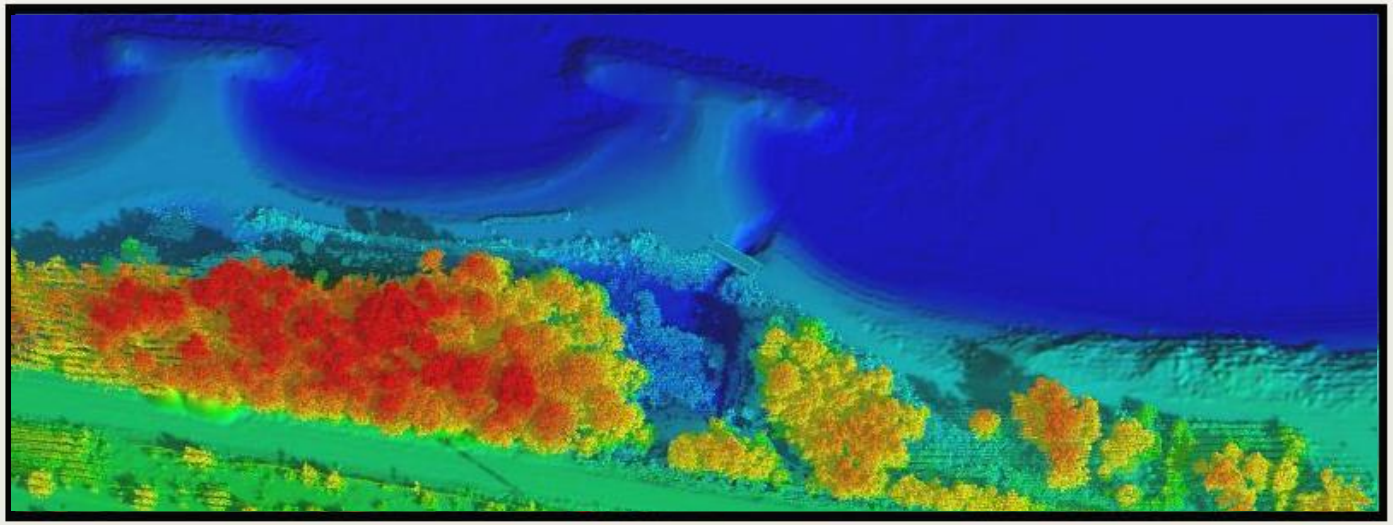
3D land cover classification:
Significantly improve land cover classification accuracies with 3D multispectral intensity analysis



Vegetation mapping:
Map vegetative differences for environmental, forestry and agricultural applications day or night, with high precision and accuracy

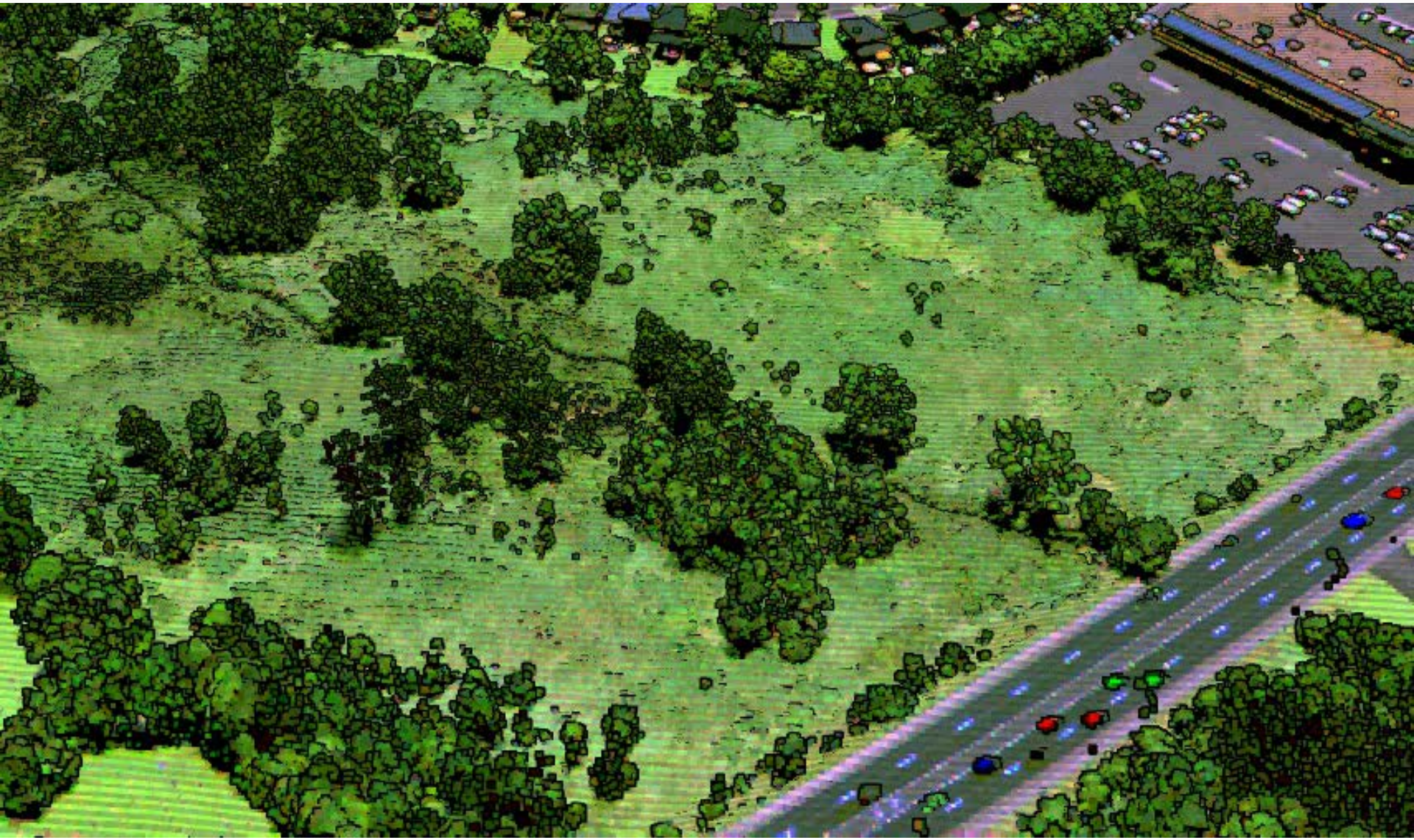
Multi-Spectral – Imagine the possibilities

Shallow-water bathymetry: Collect seamless data sets across the land-water interface with Titan's water-penetrating green channel for clear shallow water bathymetry and surface-detecting NIR channels



Dense topography: Achieve extreme point density and consistent point distribution with Titan's 900 kHz pulse repetition frequency, 210 Hz scanner rate, and gyro-stabilized sensor configuration

Questions?



Video courtesy of Terrasolid