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FDML
FOREST DYNAMICS
MAPPING LABORATORY

RECONSTRUCTING FOREST CANOPY HEIGHT USING STEREO-IKONOS PANCHROMATIC IMAGES AND A LIDAR DTM

Benoît St-Onge

Yong Hu

Cédric Véga

Department of Geography

University of Quebec at Montreal, Canada

February 2006

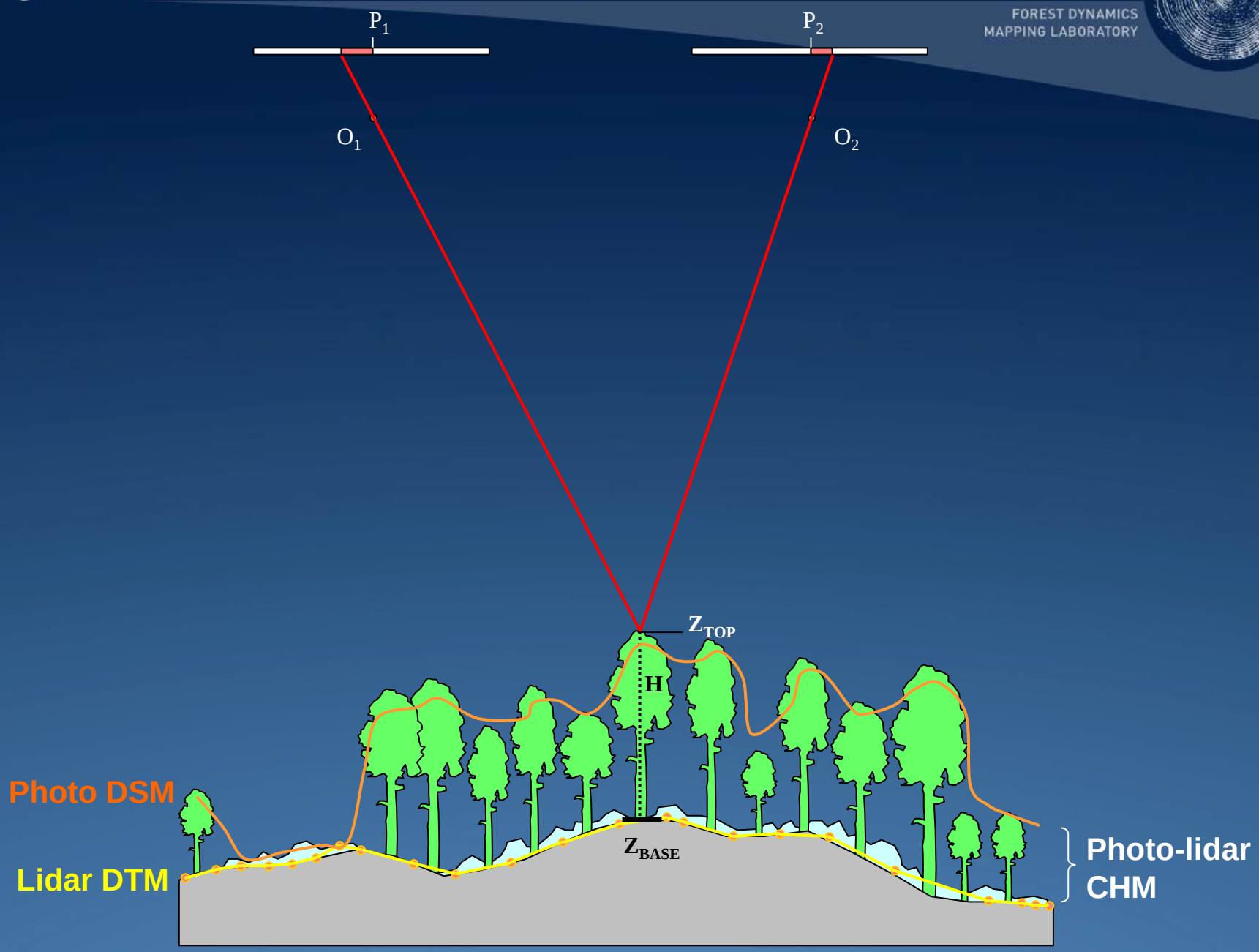
Problem statement

- Regularly updating the data on forest structural attributes is a key aspect of inventory and monitoring systems
- It is however still cost prohibitive to acquire large area lidar datasets on a regular basis.
- Cheaper alternatives should be explored.

Combining lidar and photogrammetry

We have recently shown that combining a lidar DTM and photogrammetric measurements performed on aerial photos allows us to:

- measure individual tree heights manually with great accuracy,
- map canopy surface height automatically with a fair accuracy.


P1
P2
O1
O2
ZTOP
H
ZBASE
Photo DSM
Lidar DTM
Photo-lidar
CHM

Photogrammetric potential of Ikonos images

- A single Ikonos stereo-pair covers a large area in one piece (approx. 110 km^2)
- It has been reported that orthorecitfied Ikonos images can have a high accuracy (error < 1m).
- Ikonos 3D measurements can also be very accurate.
- There is therefore a strong potential for combining an Ikonos stereo-model and a lidar DTM to measure tree or canopy height.

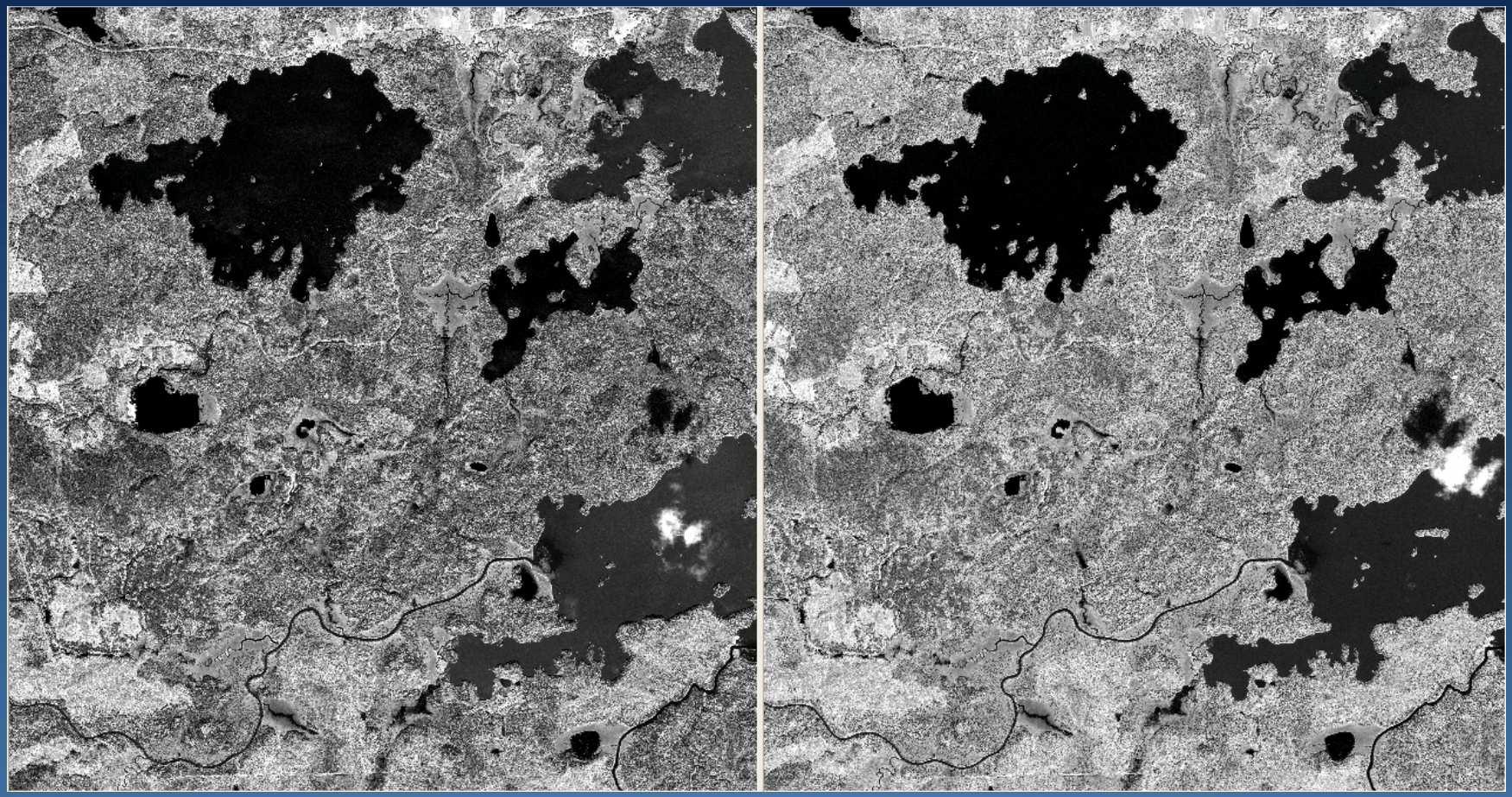
Objectives

- Assess the accuracy of:
  - the Ikonos-lidar coregistration
  - manual Ikonos-lidar individual tree height measurements
  - surface reconstruction based on stereo-matching of Ikonos images
  - average dominant height estimates within 20 m x 20 m plots derived from an Ikonos-lidar CHM

Ikonos stereo-pair (5 September 2003)

Southern boreal mixed forest, Quebec, Canada

Epipolar-resampled Ikonos Reference level



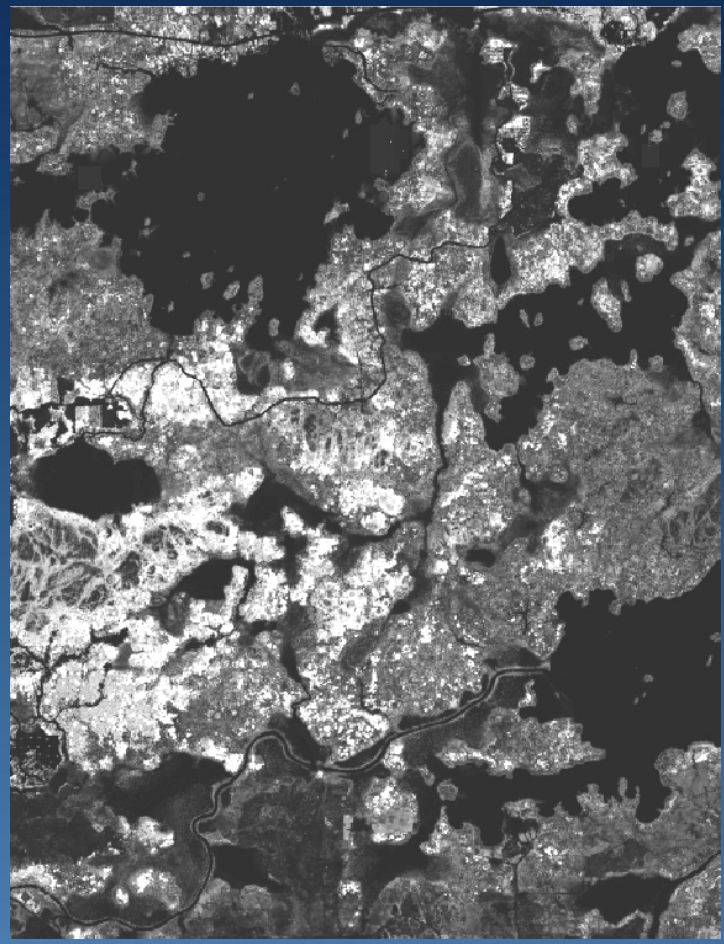
10.3 km

B:H = 0.8

Lidar data (14-16 August 2003)

Part of CHM shown

- ALTM2050 at 1 000 m AGL
- First returns: 3 hits/m^2
- Ground classified last returns: 0.2 hits/ m2
- Total area: approx. 200 km^2
- The interpolated first returns were filtered using a modified median filter



Reference field data

- Height measurement of 211 individual trees.
- Average height of co-dominant trees measured by averaging 3 to 16 tree heights per 400 m^2 plots

Coregistration of the Ikonos stereo-model and the lidar dataset

- Control points were found based on visual analysis of the Ikonos images and the lidar DSM.
- Shifts in line and sample directions detected in these features were used to update the *LineOffset* and *SampOffset* parameters in the RPC file of the Ikonos image

	Original RPCs			Refined RPCs		
	X	*Y*	*Z*	*X*	*Y*	*Z*
Mean	-11.79	10.39	-1.26	0.02	-0.05	0.07
RMSE	11.81	10.43	1.30	0.57	0.60	0.36

Individual tree height: method

- Only 112 trees out of the 211 measured in the field could be identified unambiguously on both Ikonos images.
- 13 trees were used to train the interpreter to identify the conjugate points corresponding to tree tops by comparing his height estimates to reference field heights.
- The height of the remaining 99 trees was measured using the combination of Ikonos conjugate points and lidar DTM.
- These Ikonos-lidar heights were compared to the reference heights.

Individual tree height: results

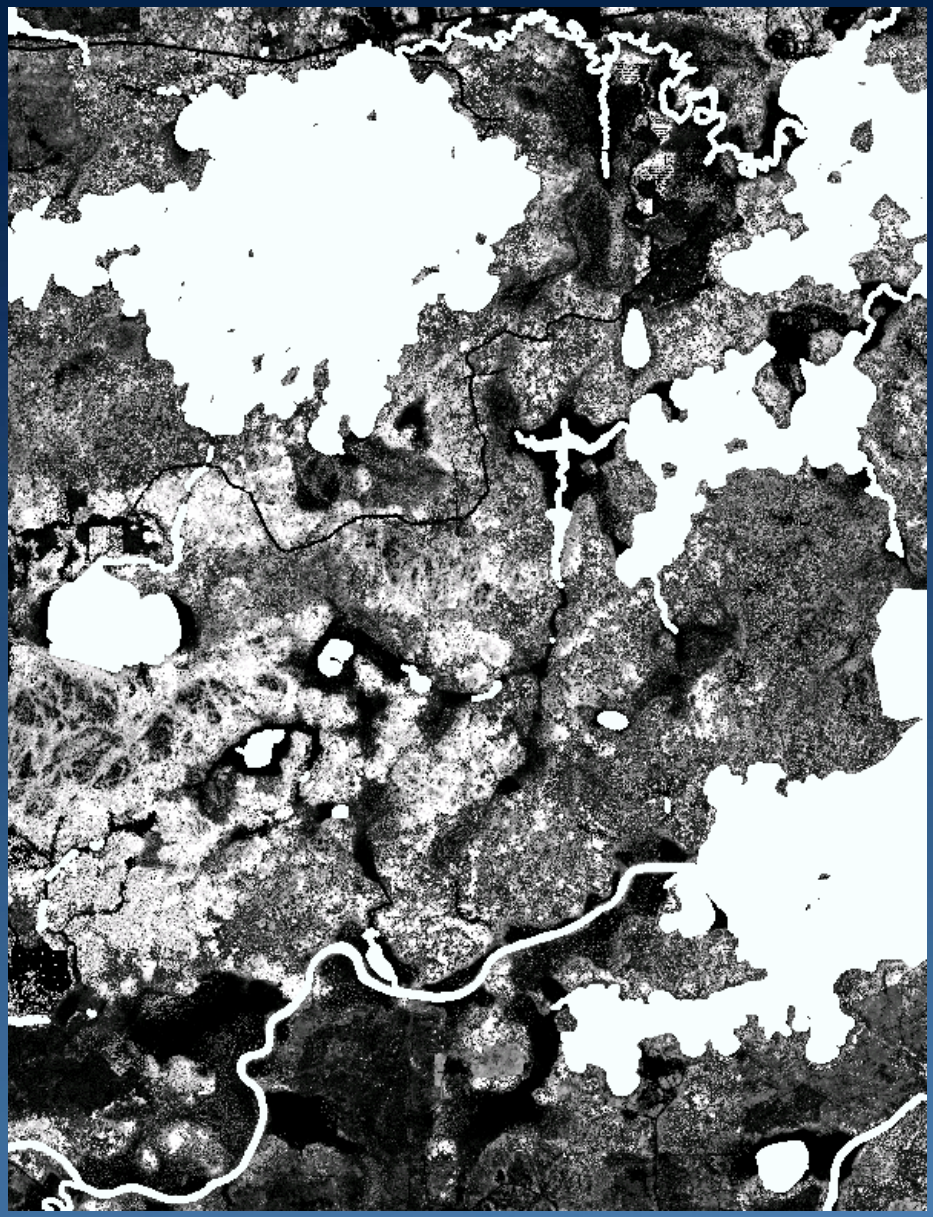
	Ikonos vs. Field	Lidar vs. Field	Lidar vs. field (outlier removed)
Mean	-2.58	-2.03	-1.84
RMSE	3.10	3.31	2.77
R^2	0.87	0.75	0.84

- The -2.58 bias is consistent with that of medium scale photography (e.g. 1 : 40 000).
- When this bias is removed, the Ikonos-lidar RMSE drops to 1.72 m.
- It should be remembered that the field measurements also contain errors.

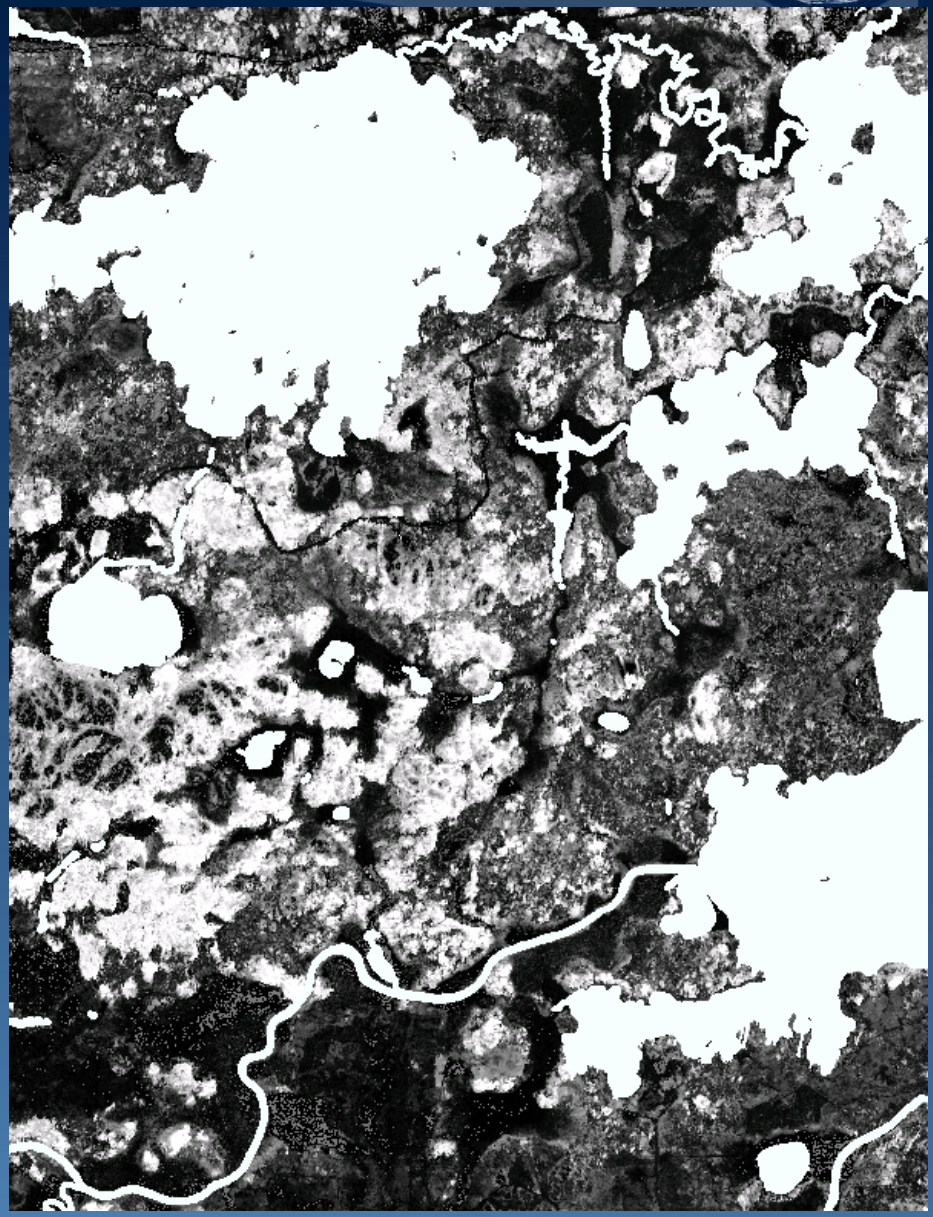
Creating an IKONOS-lidar CHM

- PCI OrthoEngine was used to compute an Ikonos DSM by stereo-matching based on the refined RPCs.
- Water bodies, clouds, and cloud shadows were masked.
- The surface was compared to the lidar DSM for 3 different types:
  - bare areas (CHM < 0.5 m)
  - regeneration areas (0.5 <= CHM <= 5 m)
  - forested areas (CHM > 0.5 m).

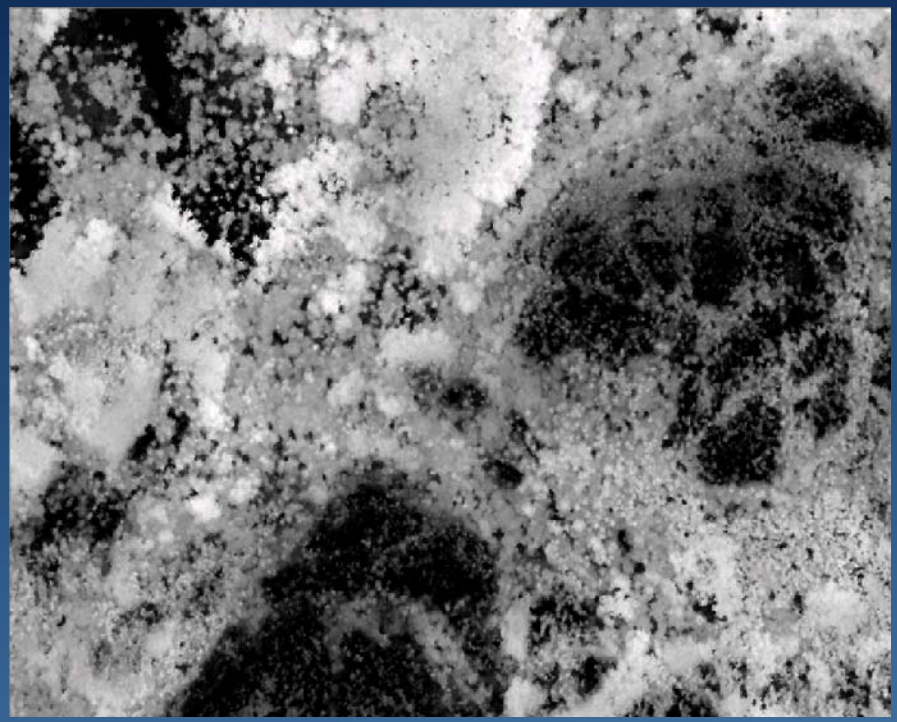
Ikonos-lidar CHM



Lidar-only CHM

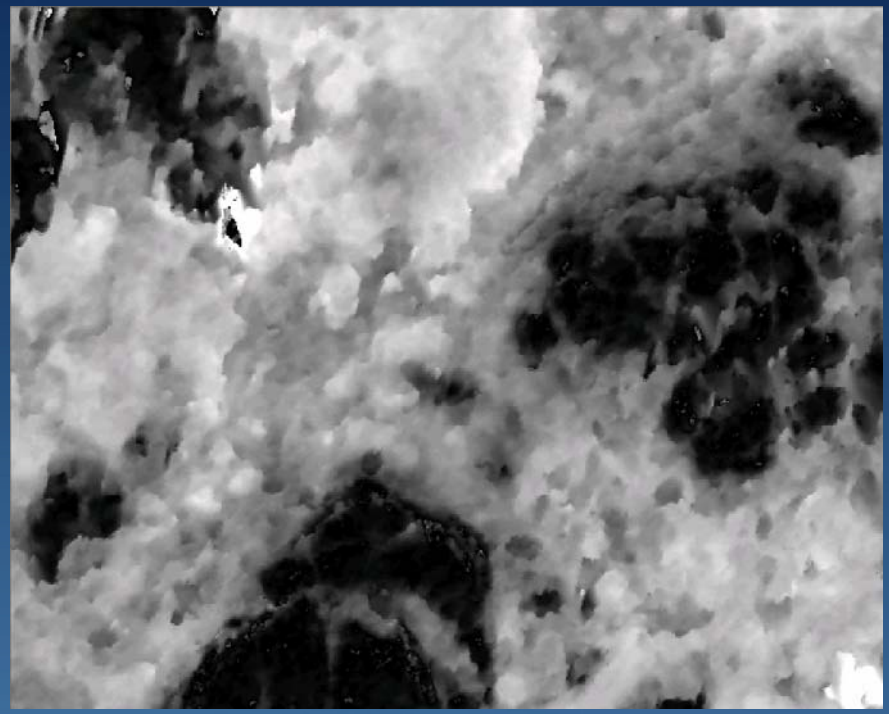


Ikonos-lidar CHM



750 m

Lidar-only CHM



750 m

Quantitative comparison of the lidar and Ikonos DSMs: elevation differences

	Bare	Regeneration	Forested
Mean (bias)	0.74	0.93	-0.38
Mean absolute	0.87	1.78	3.06
RMSE	1.23	2.62	4.24

Plot wise comparison between field and Ikonos-lidar percentiles

- For 43 plots measuring 20 m x 20 m, we have extracted from the Ikonos-lidar CHM the following statistics :
  - mean, height at percentiles 0, 50, 75, 90, 95, 99, 100.
- These values were regressed against the field values for mean co-dominant height.

Coefficient of determination (R^2) between Ikonos-lidar plot percentiles and field heights

	mean	0th	50th	75th	90th	95th	99th	100th
Ikonos-lidar	0.42	0.29	0.39	0.48	0.50	0.52	0.52	**0.53**
Ikonos-lidar minus 5 outliers	0.72	0.45	0.68	0.82	0.85	0.88	0.90	**0.91**
Lidar only minus 5 outliers	0.86	0.21	0.89	0.93	0.94	0.94	**0.95**	0.93

- The standard error of the estimate for the best Ikonos-lidar regression (R^2 = 0.91) is 2.08 m.

Comparing lidar and Ikonos-lidar plot statistics over the entire overlap area

- "Virtual" 20 m x 20 m were extracted from both CHMs at 100 m intervals, yielding 4803 plots.
- The following statistics were extracted from both the lidar and the corresponding Ikonos-lidar CHMs :
  - mean, height at percentiles 0, 50, 75, 90, 95, 99, 100.
- R^2 were calculated by regressing the Ikonos-lidar statistics againts the corresponding lidar statistics

Coefficient of determination between the lidar and Ikonos-lidar statistics for 4803 plots

mean	0th	50th	75th	90th	95th	99th	100th
0.87	0.38	0.85	0.85	0.83	0.79	0.72	0.66

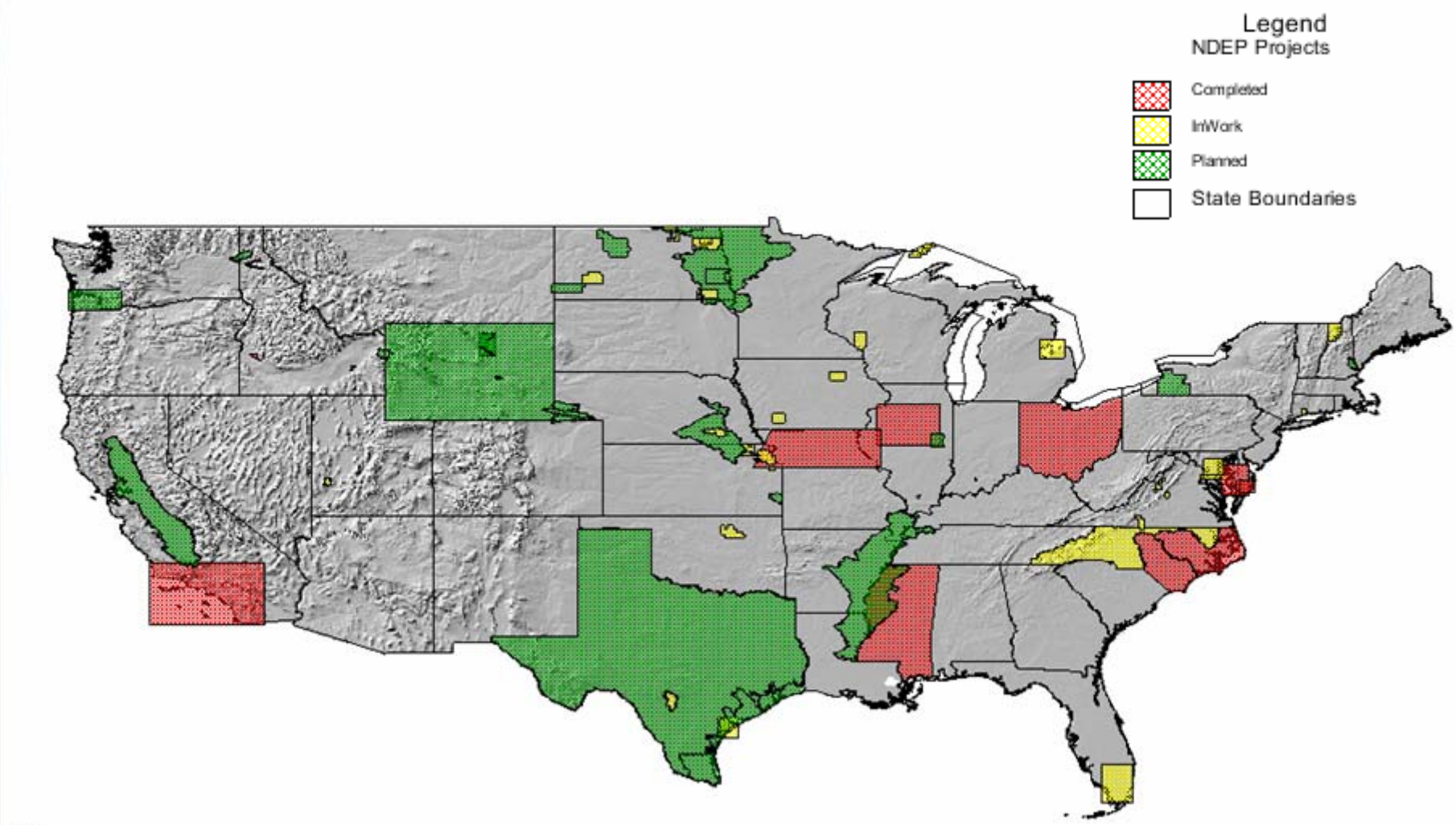
- The standard error of the estimate for the strongest relation (mean) was 1.90 m.

Conclusions

- An Ikonos stereo-model can be registered to a lidar DTM with a sub-meter accuracy.
- The height of well defined individual trees can be manually estimated from the Ikonos stereo-model and the lidar DTM with an RMSE of approximately 1.7 m once the 2.6 m downward bias is corrected.
- The average co-dominant plot height can be estimated with a standard error of estimate of approximately 2 m where no matching blunder occurred.
- The effect of localized matching blunders is minor as reflected by the fact that the mean lidar height within 4803 plots could be predicted based on the Ikonos-lidar CHM with a standard error of estimate of 1.9 m.

National Digital Elevation Program

Project Tracking



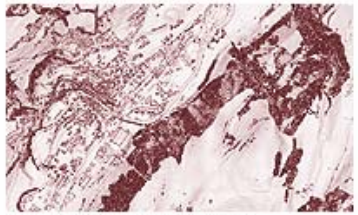
swisstopo web site for lidar data distribution

Height model for highest demands

- height model of the earth's surface with (DOM) or without (DTM-AV) vegetation and buildings
- based on highly accurate laser observations
- for high-precision modelling of the earth's surface below 2000 m

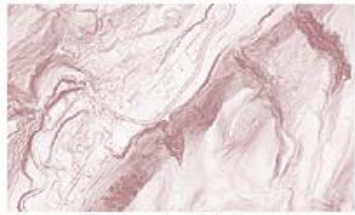
Height models

DOM oblique shading



- represents the earth's surface
- surface with vegetation and buildings

DTM-AV oblique shading



- represents the topography of the earth's surface
- surface without vegetation and buildings

Formats

DOM	DTM-AV	Accuracy
INTERLIS-1 ASCII x y z	ASCII x y z	DOM in open terrain: ±0.5 m 1σ in terrain with vegetation: ±1.5 m 1σ DTM-AV ±0.5 m σ

Perimeter / Production status

DOM

DTM-AV

Test data

Different data sets for downloading and testing.

Information

Flyer (753K)

Price list (181K)

Distribution

Directly online or via geodata@swisstopo.ch.

Acknowledgments

- National Science & Engineering Research Council of Canada
- BIOCAP Foundation
- LaserMap Image Plus / Pierre Bélanger