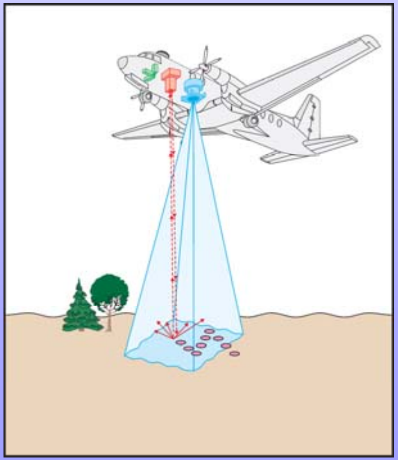
New Features of Airborne Lidar Data Processing in DTM Generating, Forest Inventory and Civil Engineering Works

Evgeny Medvedev,

Altex Geomatica, Moscow, Russia



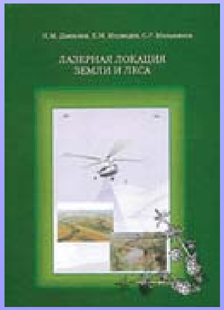
“Innovative Technologies for an Efficient Geospatial Management of Earth Resources”,
23-30 July 2009, Listvyanka, Russian Federation

Contents:

- About Altex Geomatica
- 12 years experience of lidar use in Russia and globally
- Innovative lidar data processing: DTM generating, Forestry inspections, civil engineering
- Some conclusion

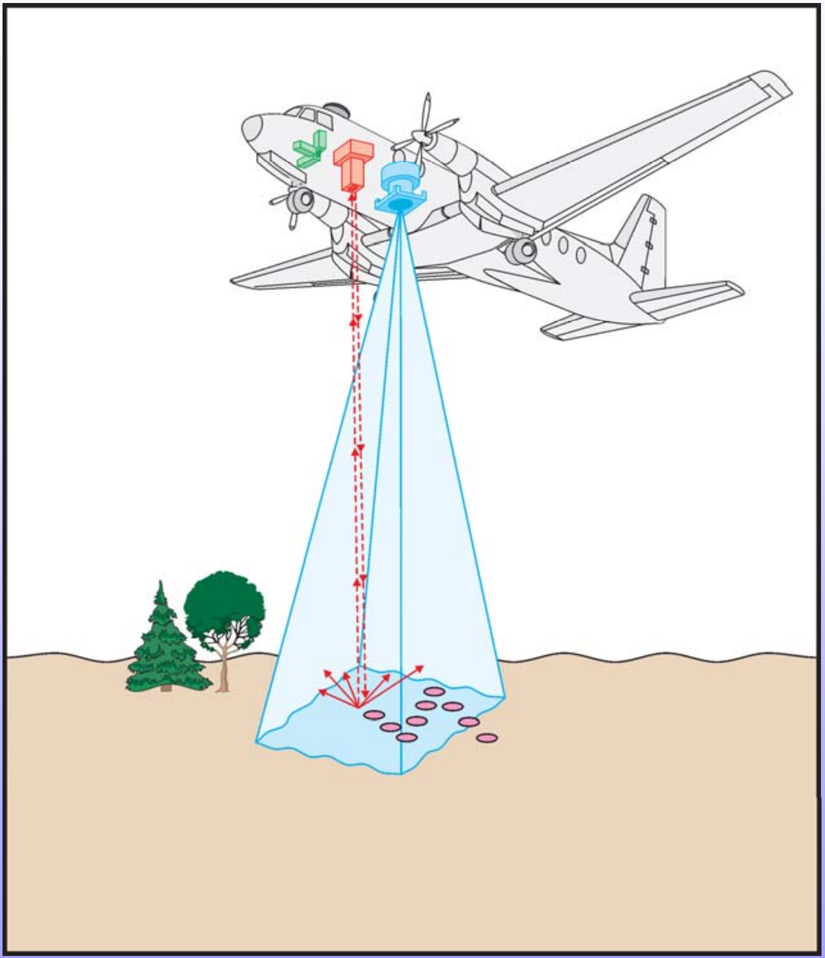
About Altex Geomatica

- 12 years experience in Lidar technology
- Leading Russian company in SW development for Lidar power lines data processing
- Altex's products for power lines are in fact the technological industry standard & also rail roads (soon)
- Supports National Standardization & Certification for lidars, cameras and other products
- Educational programs:



About current situation in Russia and countries of the former SU

- More Liders "per head" than in any other countries (except for Japan and US)
- Optech dominates: **14 ALTMs** against 4 ALS, 2 Lite Mapper, 1 Reigl Airborne
- About 25% of Airborne Lidars are used for Power Lines survey
- None for Forest Inventory at all (?!)
- Extremely intensive use for topographical mapping under "Lidar + Large format Digital camera" mode

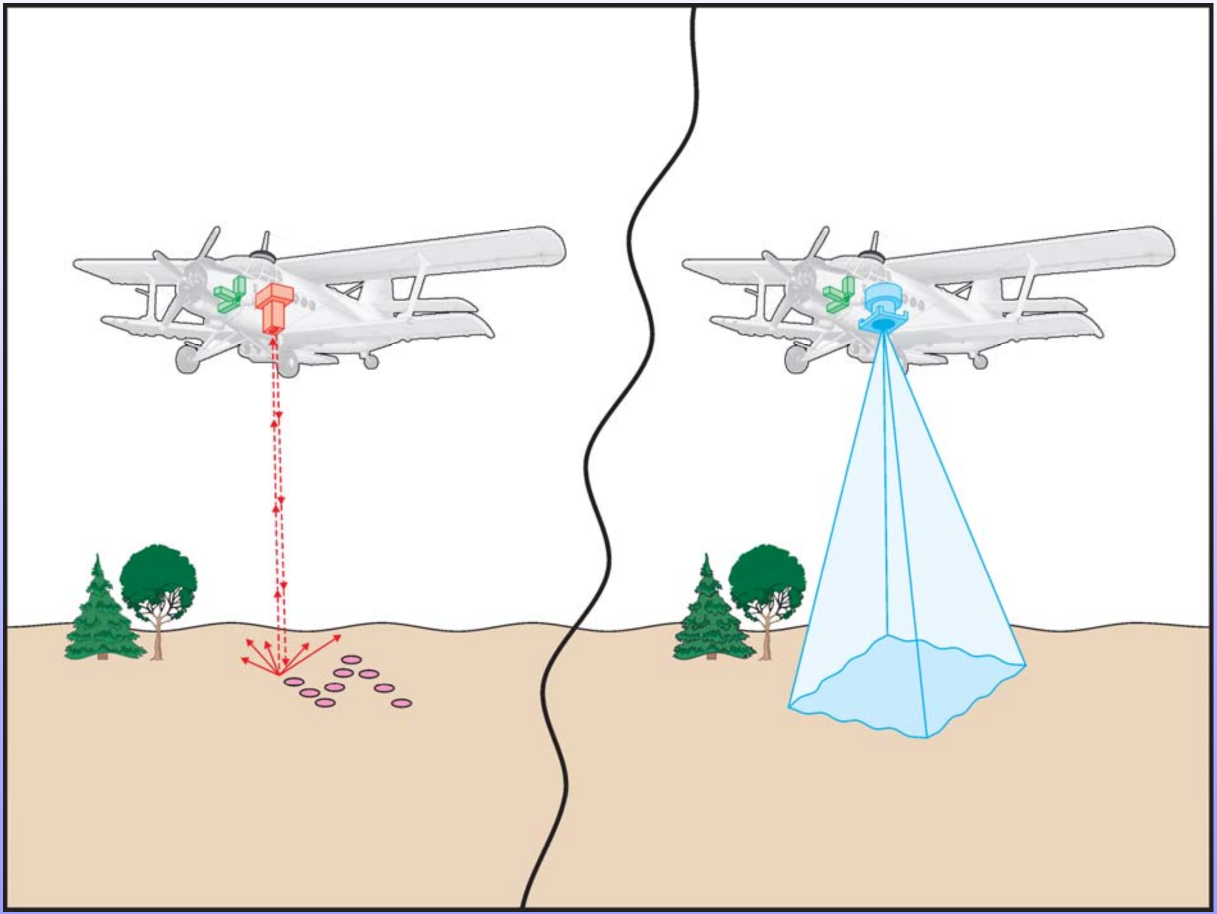


“Lidar + Large format Digital camera” method of topographical mapping

🡐 Parallel mode

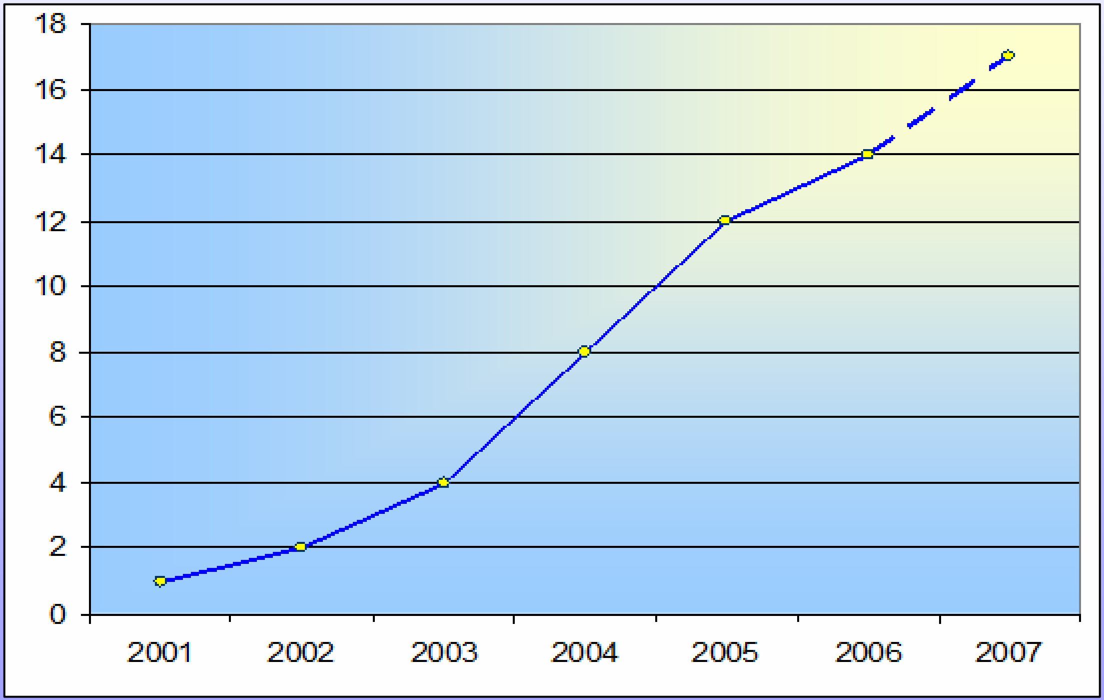
“Lidar + Large format Digital camera” method of topographical mapping

Consecutive mode ↓



Russian Federation, Airborne Lidars

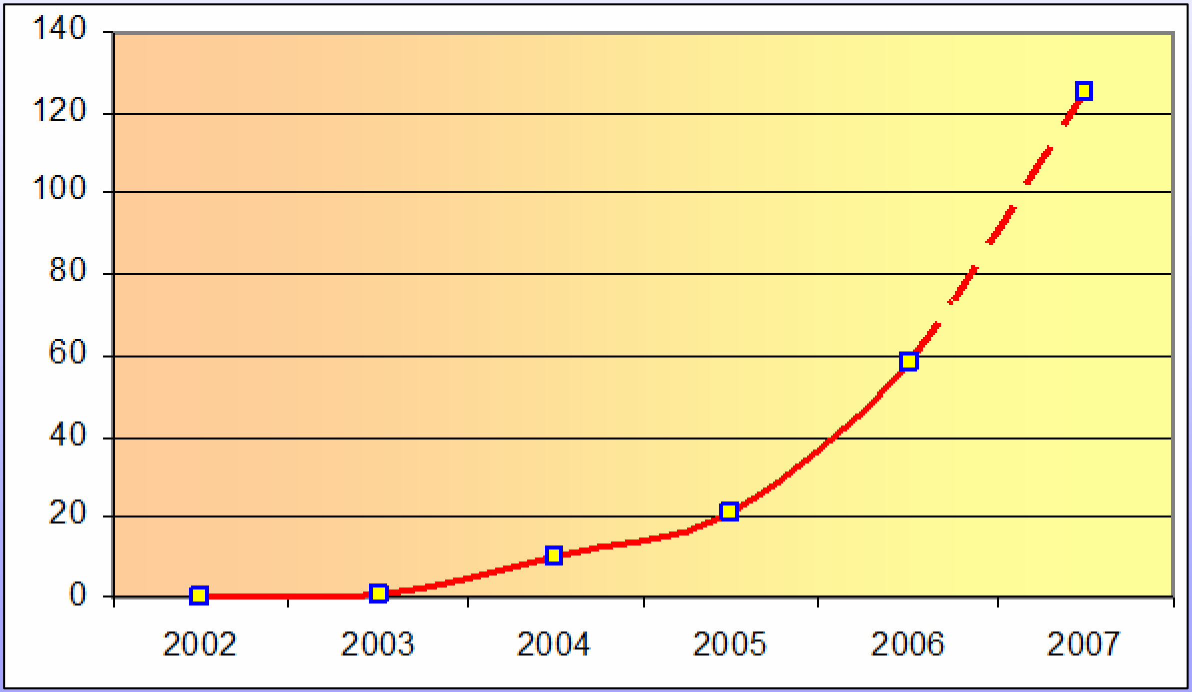
--- **21**



2009

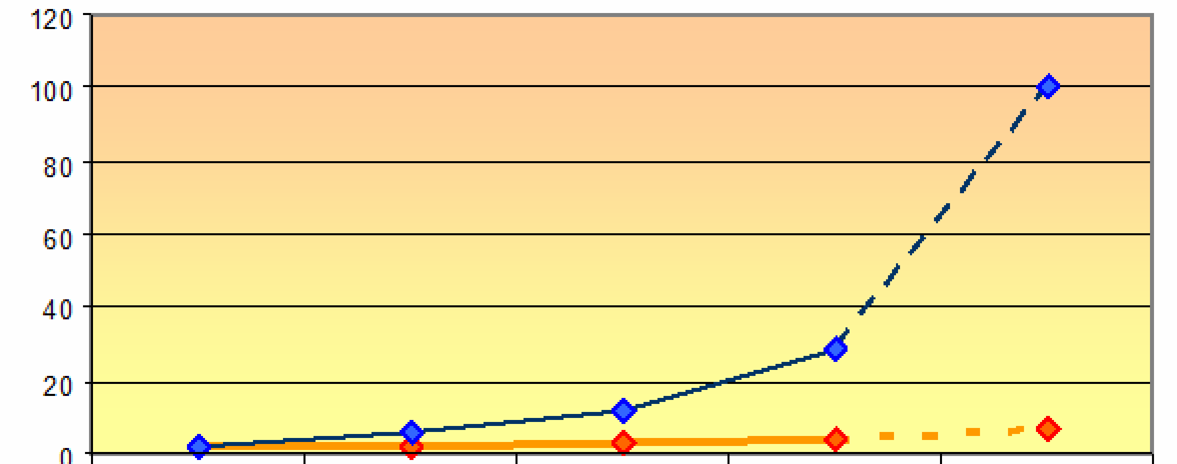
Russian Federation, Airborne Lidar Mapping Market, Mln. USD

-- **170**



2008

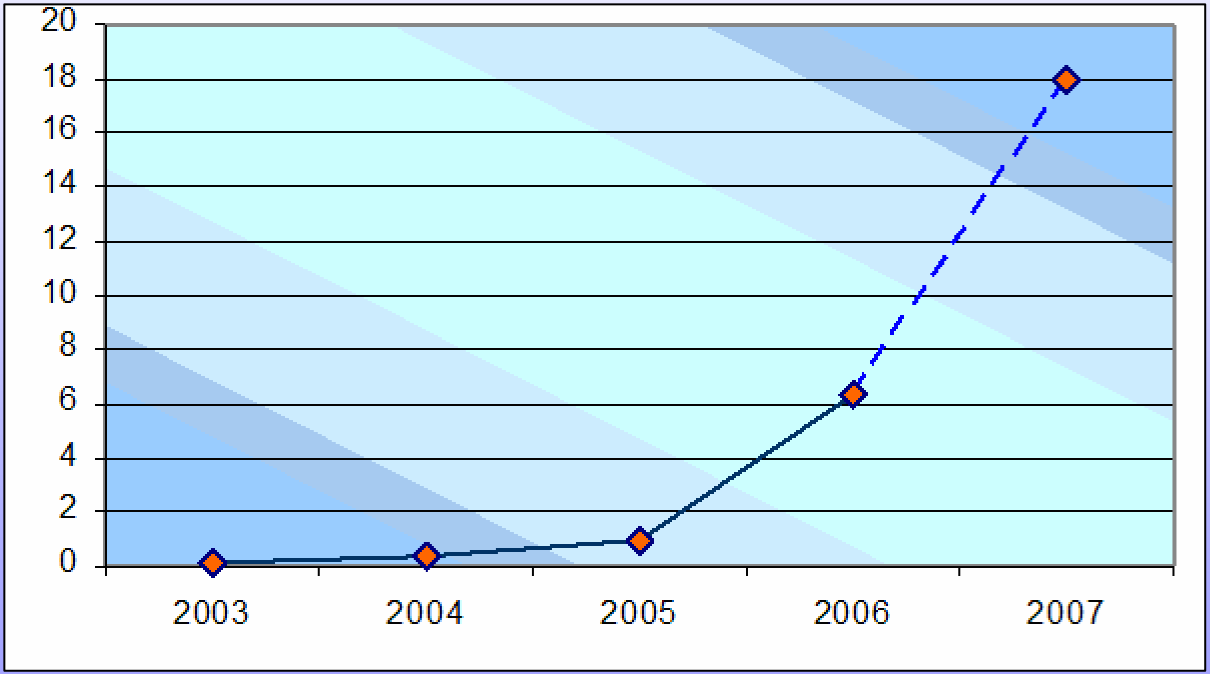
Russian Federation, Digital Topographical Cameras



	2003	2004	2005	2006	2007	2009
LARGE FORMAT	2	2	3	4	7	**14**
MEDIUM FORMAT	2	6	12	29	100	**too many**

Russian Federation, Digital (& Analog) Topographical Aerial Photography Market, Mln. USD

-- **50**



2008

The present situation. Psychological aspects:

- Radical (positive) mentality changes: now everyone regards lidars as aerial geodetic technology
- Many practical companies apply aerial lidars “voluntarily”
- Multi-level market on lidar data collecting and processing has been formed in Russia.
- A number of Universities train students in lidar technology.
- A lot of positive changes in creating national standards on lidar survey
- New lidar products (Mobile mappers) are perceived much more loyally.

The present situation. Technological aspects:

⚐ Great increase of productivity (PRR, multypulse mode, ….) which results in:

- Principally new algorithms of lidar data processing;
- Users now prefer complete dense lidar survey;

Unmanned platforms: Optech Orion or AHAB DragonEye

- Areal lidar data accuracy is so high now, it allows to avoid classical photogrammetrical works at all

Some intermediate conclusions

- Russia is the Great Lidar Power
- Goes mainly extensive way (unfortunately)
- Optech & Leica are still the most respectable Lidar Manufacturer

Airborne Lidars in Forestry:

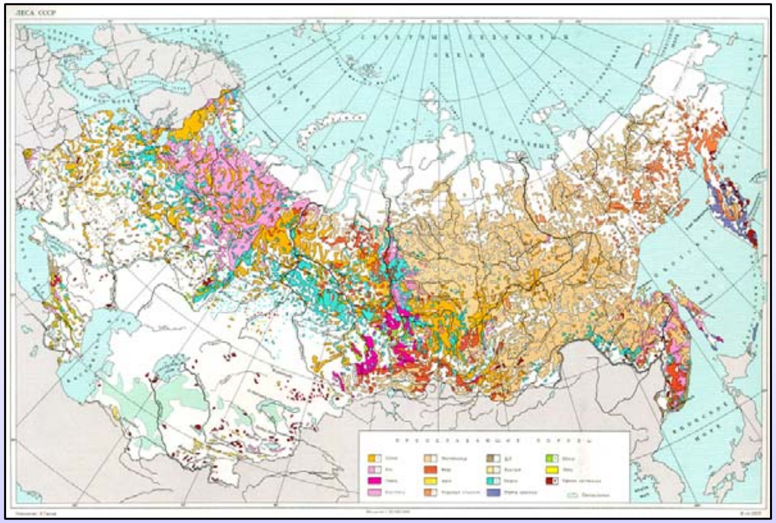
- “Traditional” approach: Forest Inventory and Biomass Assessment by Lidar data statistical analysis
- Innovative approach: feature extraction, object recognition, …

Problem

- In Russia until the present target system for inventory of forest fund by the criteria of carbon pools and flows *is not developed*

- Current methods of forest carbon assessment based on integral phytomass parameters, timber stock and conversion coefficients *not satisfy* relevant accuracy and efficiency requirements

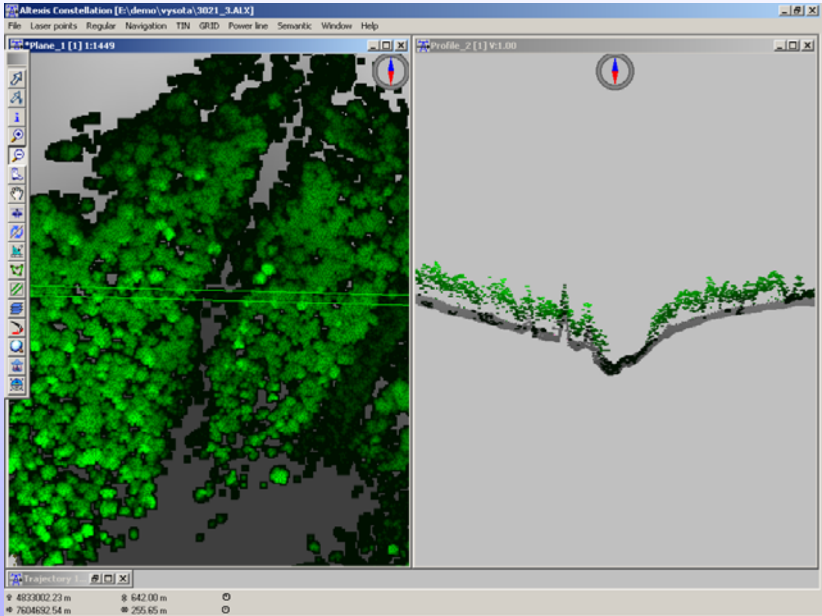
- In this context discussion of global biosphere role of Russian forests, sequestration of atmosphere $C\text{-}CO_2$, the Kyoto Protocol and the other questions is turned to level of *rhetoric*

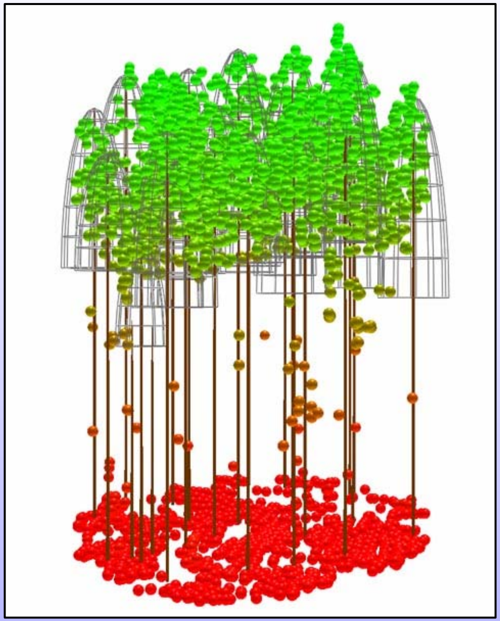


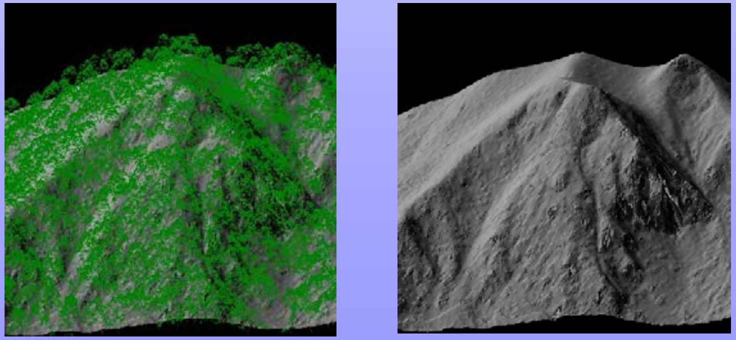
At the same time … ,

Laser terrain mapping and digital aerial- and space photography which one is important constituent part of the newest methods and technologies of geoinformatics and digital photogrammetry
by *accuracy* parameters and *cost efficiency* is superior than other known remote sensing methods for reliable terrain and forest cover measurements

3-D reconstruction and modeling of a tree stand structure and a separate trees

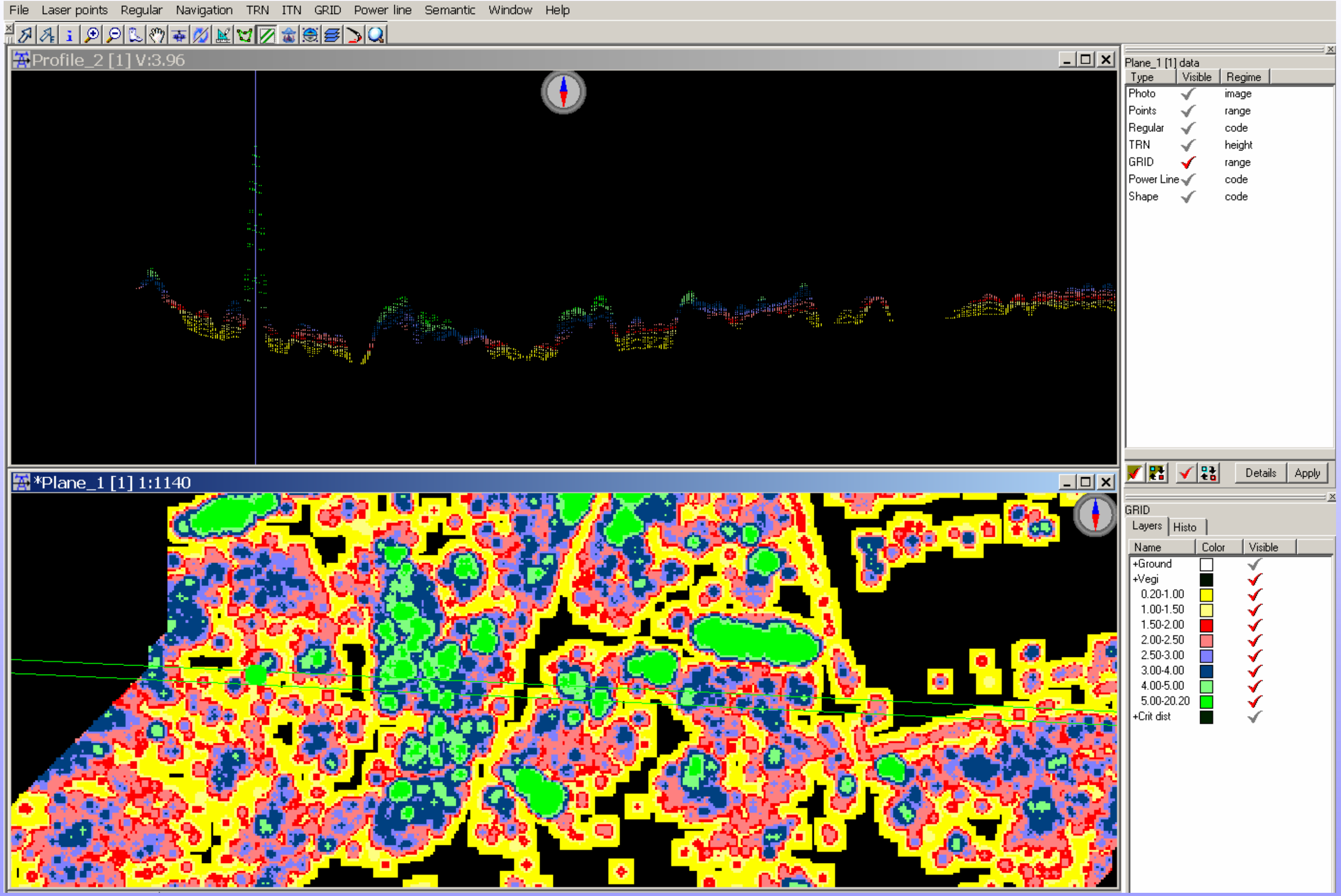






A Possibility for Topography Detection
Under Forest Canopy

Tree height distribution map development using ALTEX software

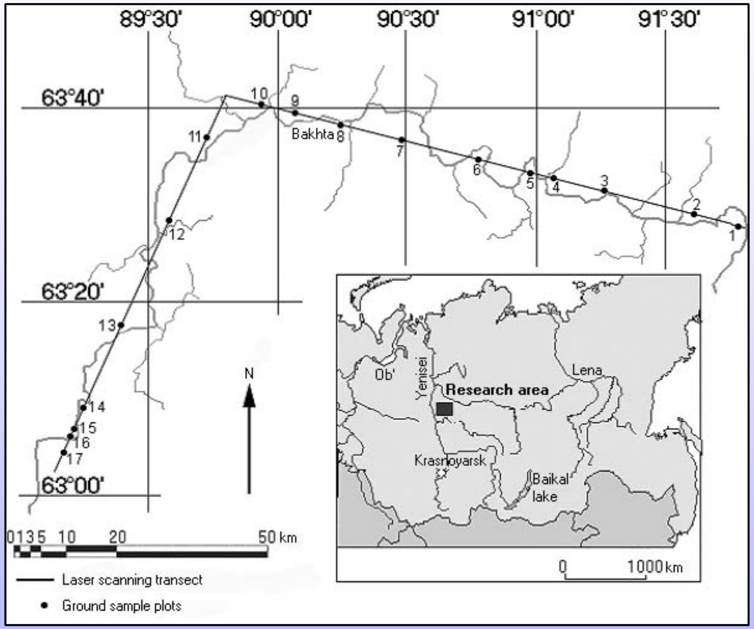


Plane_1 [1] data

Type	Visible	Regime
Photo	✓	image
Points	✓	range
Regular	✓	code
TRN	✓	height
GRID	✓	range
Power Line	✓	code
Shape	✓	code

GRID

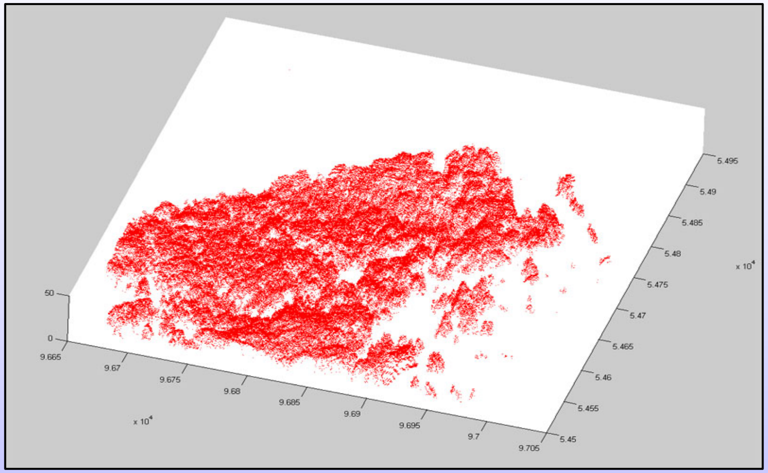
Name	Color	Visible
+Ground	☐	✓
+Vegi	■	✓
0.20-1.00	🟨	✓
1.00-1.50	🟨	✓
1.50-2.00	🟥	✓
2.00-2.50	🟥	✓
2.50-3.00	🟦	✓
3.00-4.00	🟦	✓
4.00-5.00	🟩	✓
5.00-20.20	🟩	✓
+Crit dist	■	✓



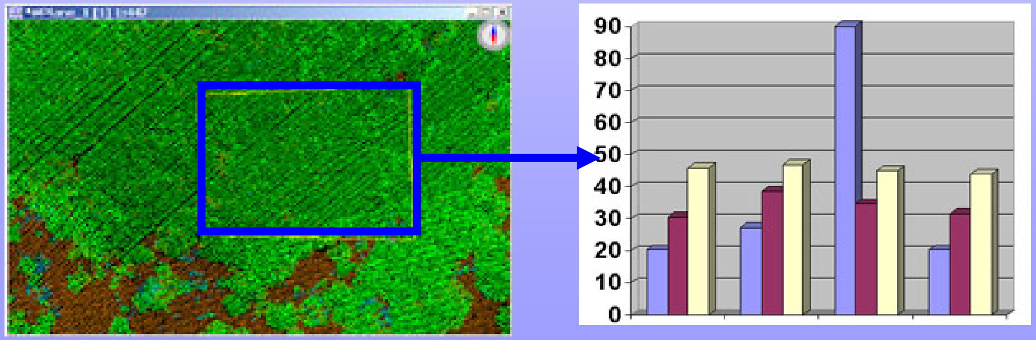
Dominating tree stand types represented by pure larch and mixed larch-spruce-cedar forests within laser scanning transect in Central Siberia
(Bakhta river basin, 63°30′N 89°40′E)

Research site region and distribution of sample plots within laser scanning transect in Central Siberia

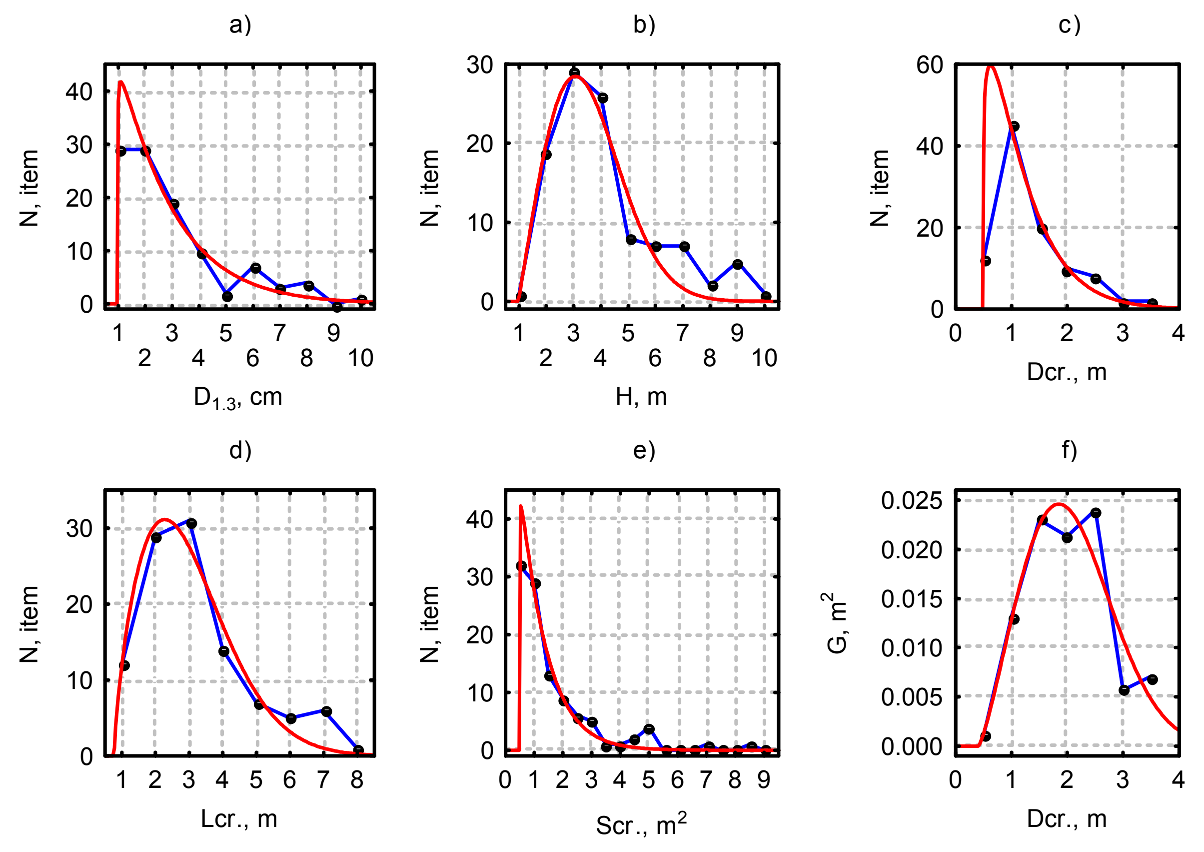
Tree canopy detection and modeling



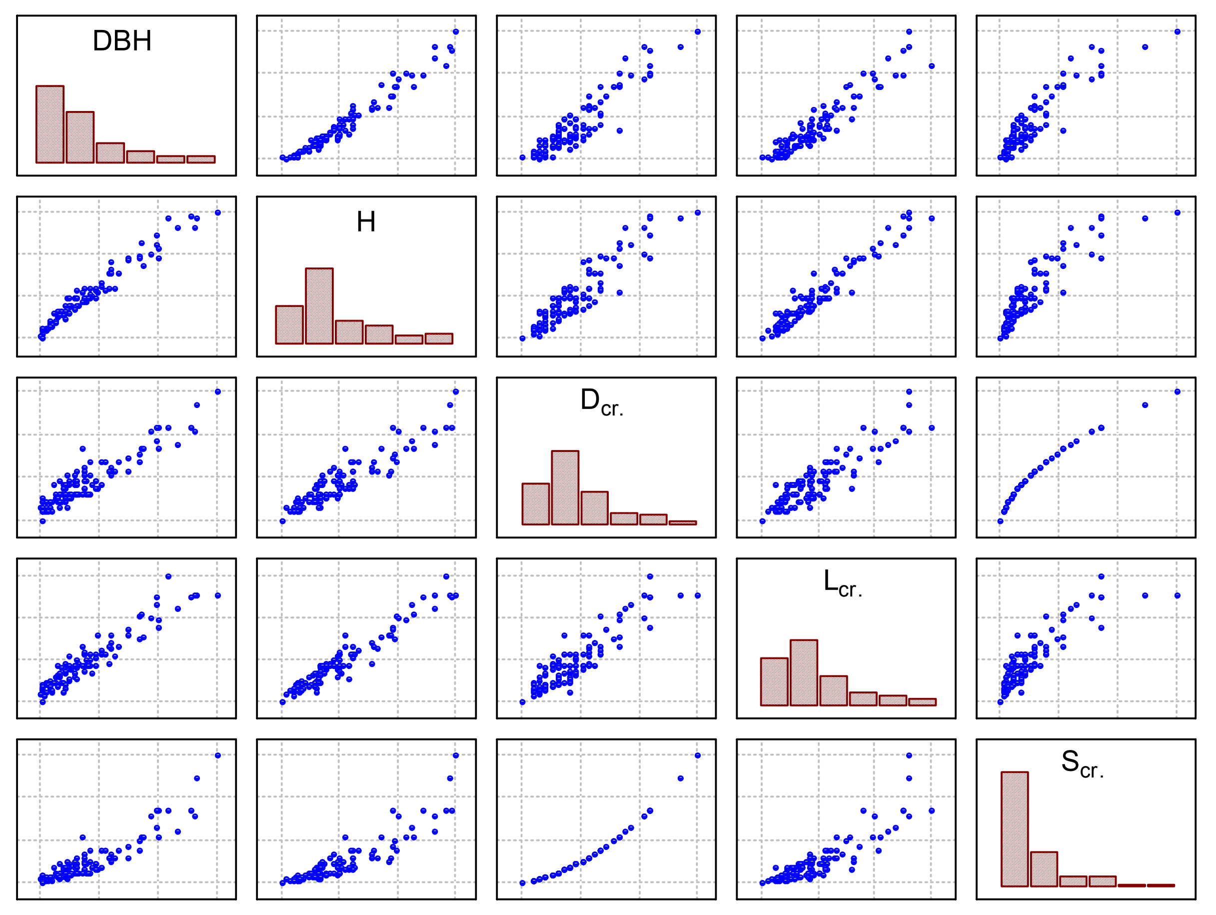
$$Canopy(x,y) = DSM(x,y) - DTM(x,y)$$



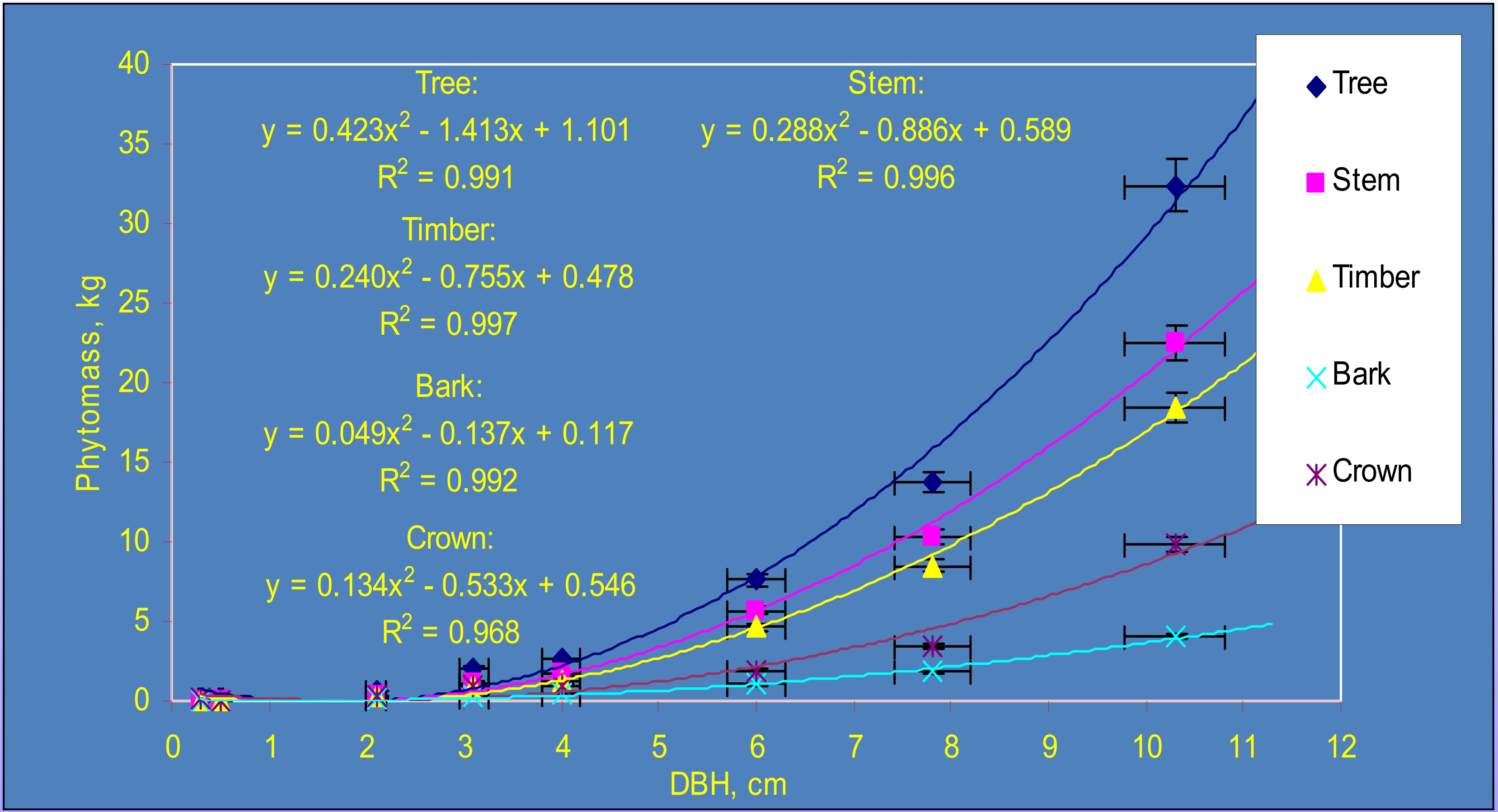
Empirical distribution lines for larch trees by morphometric indices of stems and crowns and approximated by Weibull distribution: a) - DBH, b) - H, c) – Dcr, d) - Lcr., e) - Scr., f) - G *f*(Dcr.)

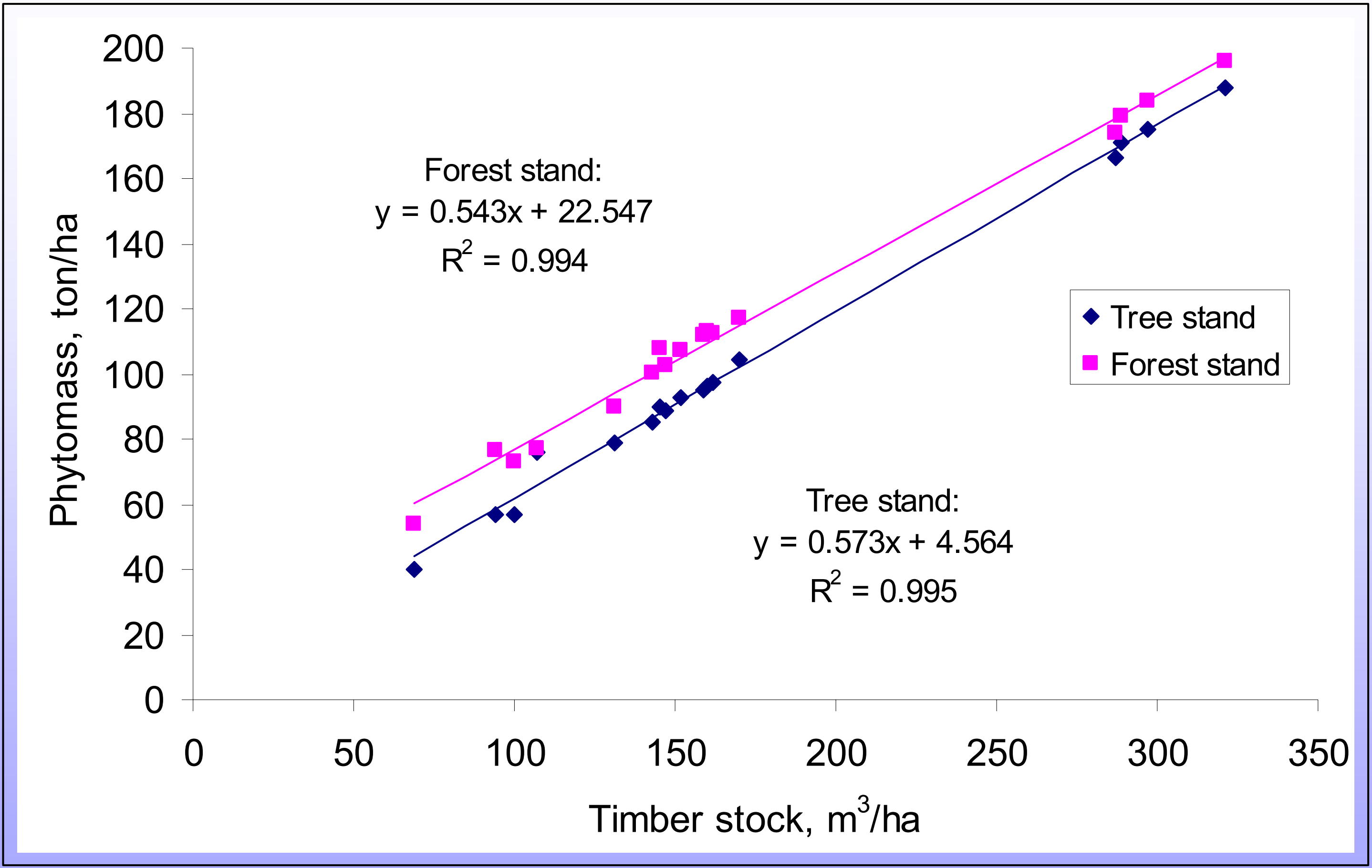


Overlap matrix for distribution histogram and correlated scattering of the main morphometric indices of larch stand (Central Siberia)



Aboveground phytomass/DBH correlation by fractions for sample larch trees (Central Siberia)





Aboveground phytomass/timber stock correlation of “Forest” and “Tree” stands within laser scanning profile at Bakhta river basin in Central Siberia (Krasnoyarsk territory)

The regression method provides high accuracy of stand biomass interpretation when processing a laser profiling data

In each specific case *basic reference data and regularities* of forest stand should be studied defining correlation between DBH, height, crown diameter, stem volume and tree biomass, which constitutes about *87-99%* of the stand biomass variability

Measuring and registration of forest inventory and morphometric sample plots by laser dendrometer Laser Ace 300, integrated with field computer Psion and DGPS Trimble ProXR tree parameters at

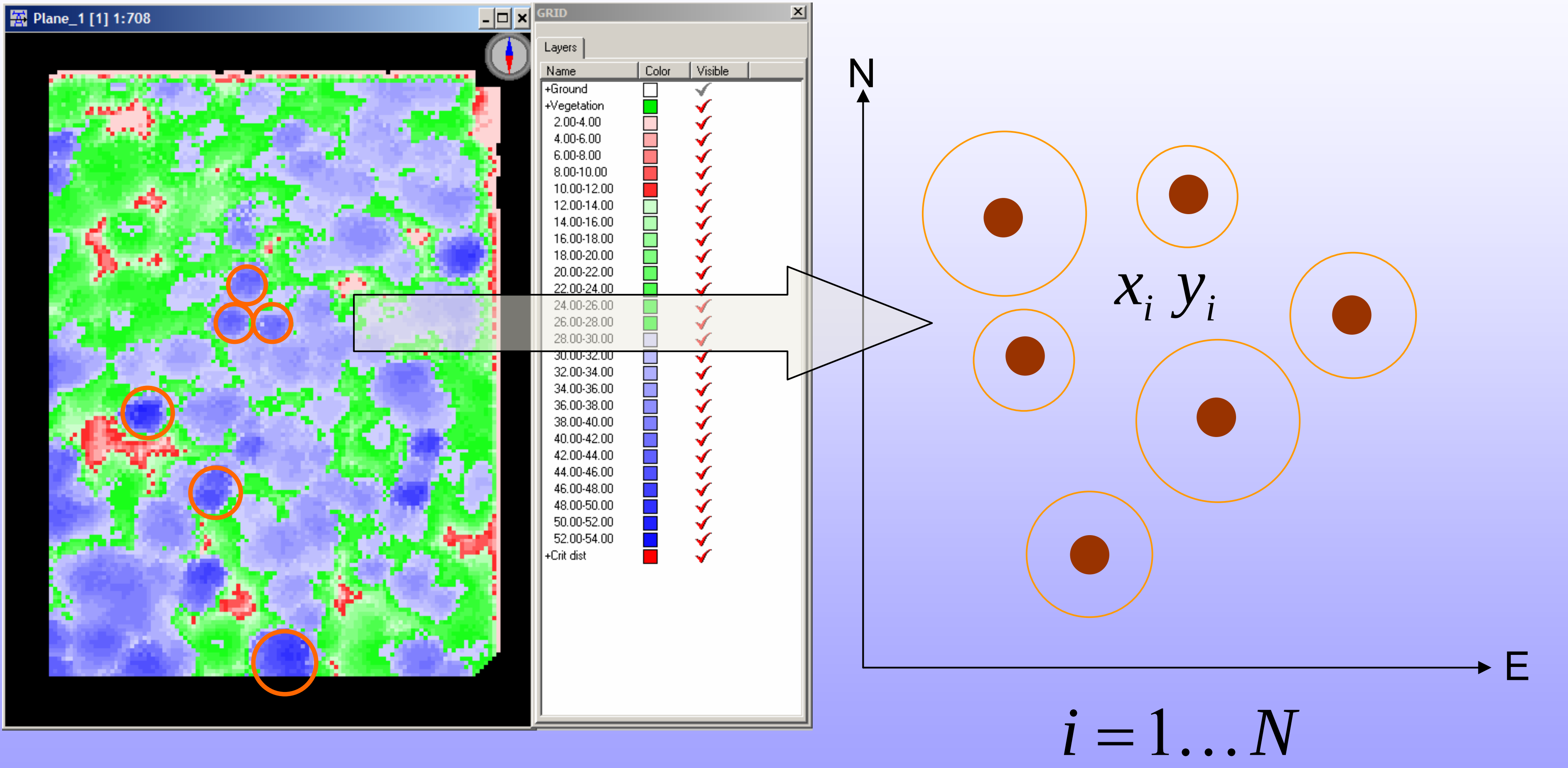
Cost efficiency of laser forest inventory by the aggregative indices (for 1 mln ha, IIIrd grade of forest inventory)

Traditional technologies			Laser forest inventory	
Kind of works	Cost, thousand Rubles			
	On-ground forest inventory	On-ground forest inventory and aerial photo-interpretation	Kind of works	Cost, thousand Rubles
Aerial photography	7500	2500	Digital aerial photo- and videography with data processing	585
Spade-works	175	175	Remuneration of labour	342
Field-works	9500	1800	Other operating costs	200
Office studies	1500	1500	Overhead expenses	1127
Total:	18675	5975		2254
Calculated to 1 ha, Rubles	18.7	6.0		5,0

Some intermediate conclusions:

- The method of aerial laser scanning integrated with digital aerial- and space photography is highly prospective for stand's measuring, analysis and modeling of forest cover structure, forest inventory and strategical ecological monitoring of boreal forests
- The method makes it possible to conduct forest inventory using remote sensing techniques with high efficiency and minimal on-ground works and allow to meet the conditions of the Kyoto protocol on accuracy and reliability of carbon flows' evaluation in forest ecosystems
- The mostly principal and critical point is declining of the laser scanning labor costs comparably to classic aerial survey methods it is *cheaper* and *more effective* at about *three times*

DSM local maximums – to detect probable stem position



Plane_1 [1] 1:708

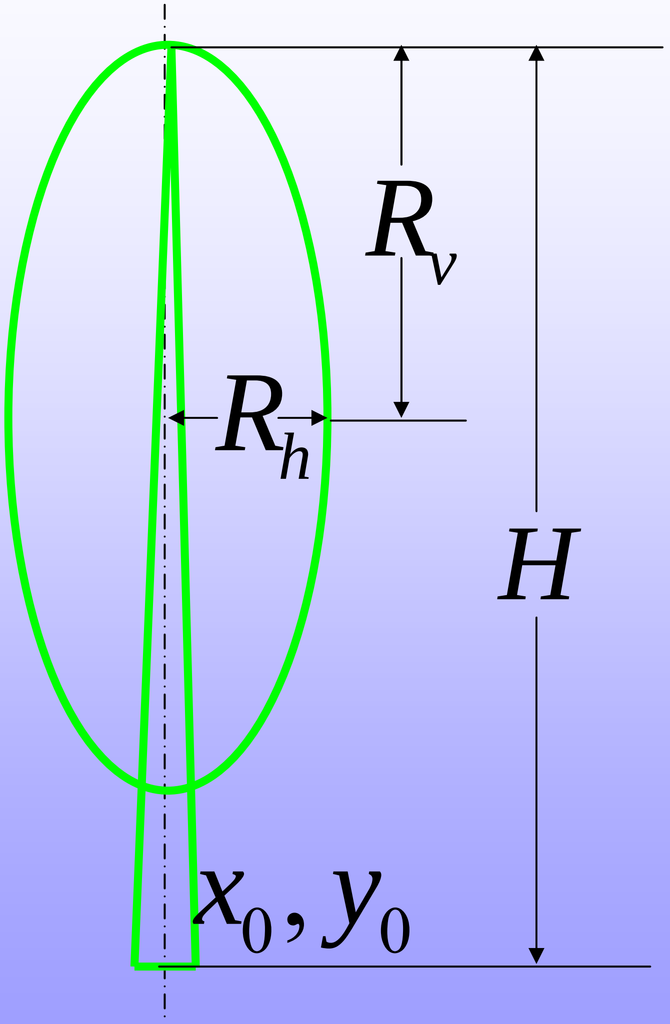
GRID

Layers

Name	Color	Visible
+Ground	⬜	✓
+Vegetation	🟩	✓
2.00-4.00	🟥	✓
4.00-6.00	🟥	✓
6.00-8.00	🟥	✓
8.00-10.00	🟥	✓
10.00-12.00	🟥	✓
12.00-14.00	🟩	✓
14.00-16.00	🟩	✓
16.00-18.00	🟩	✓
18.00-20.00	🟩	✓
20.00-22.00	🟩	✓
22.00-24.00	🟩	✓
24.00-26.00	🟩	✓
26.00-28.00	🟩	✓
28.00-30.00	🟦	✓
30.00-32.00	🟦	✓
32.00-34.00	🟦	✓
34.00-36.00	🟦	✓
36.00-38.00	🟦	✓
38.00-40.00	🟦	✓
40.00-42.00	🟦	✓
42.00-44.00	🟦	✓
44.00-46.00	🟦	✓
46.00-48.00	🟦	✓
48.00-50.00	🟦	✓
50.00-52.00	🟦	✓
52.00-54.00	🟦	✓
+Crit dist	🟥	✓

$$i = 1 \ldots N$$

Crown modeling

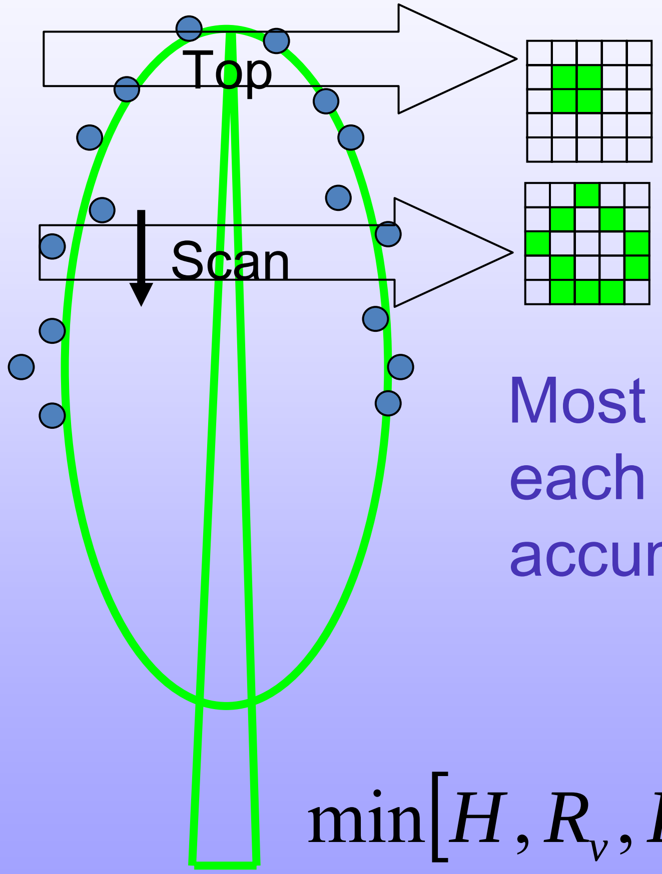


- Crown model

$$Z(x,y) = H - R_v + R_v\sqrt{\left(1 - \frac{x^2 + y^2}{R_h^2}\right)}$$

- Stem height and crown dimensions are essential

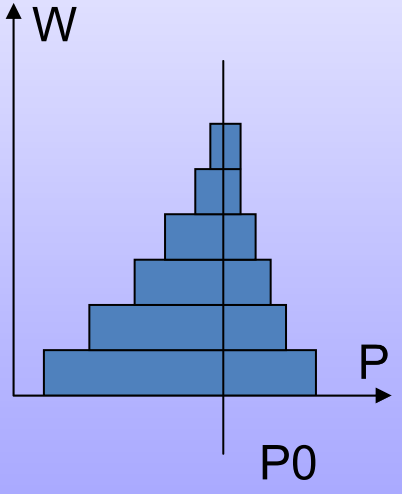
Maximum probability methods with accumulation



$$x_i\ y_i\ i=1\ldots n$$

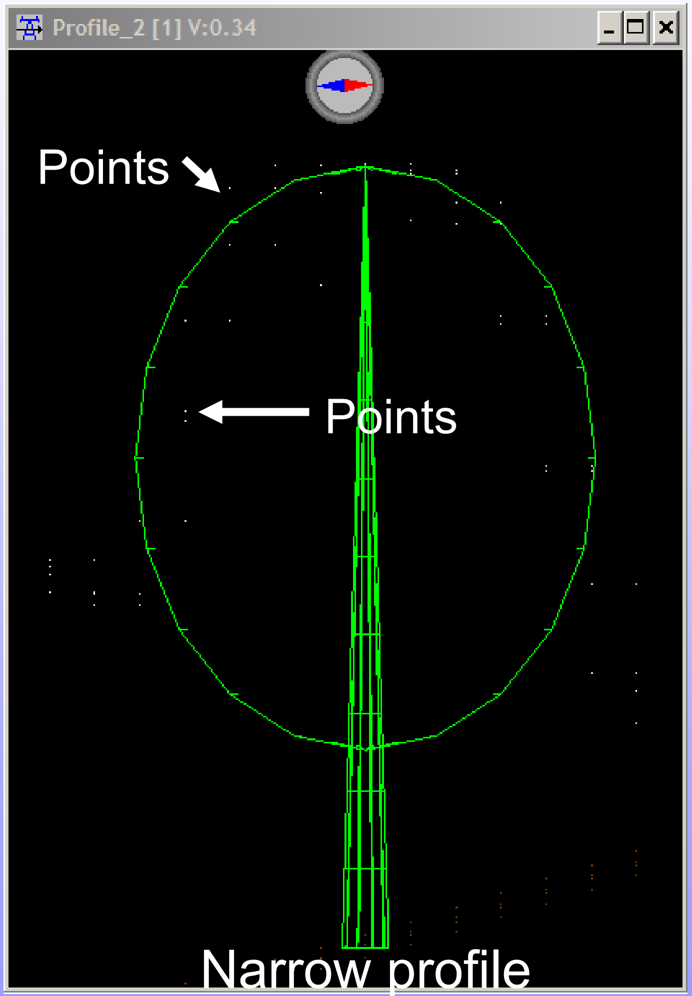
$$z_i\ x_i\ y_i\ i=1+n\ldots N$$

Most probable parameters for each scan are estimated and accumulated

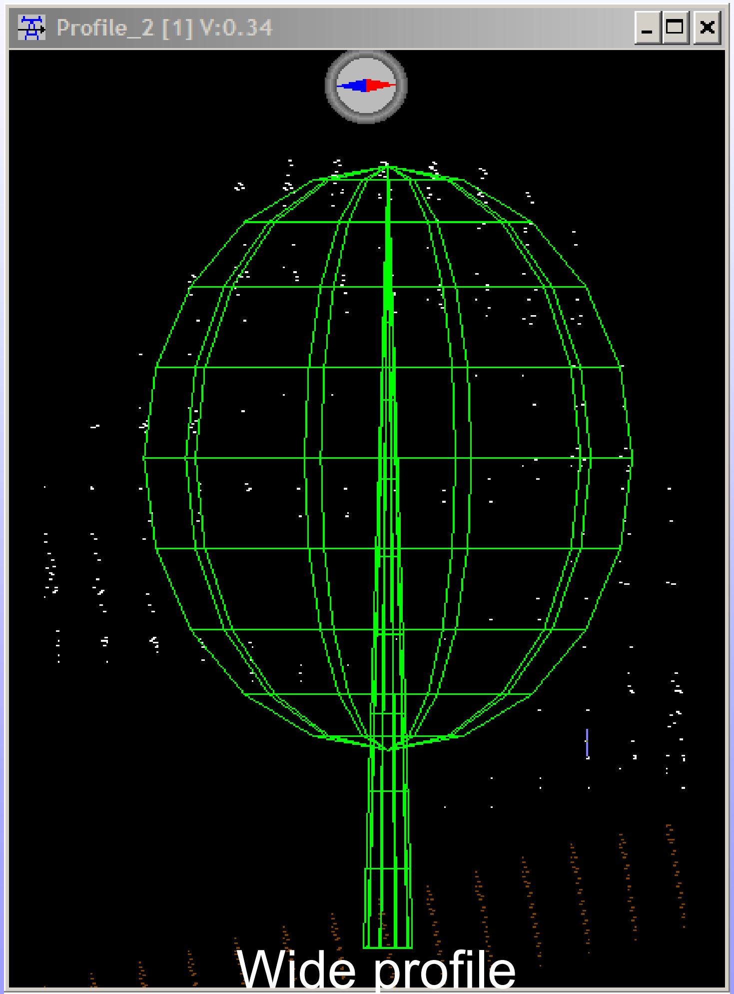


$$\min[H,R_v,R_h,x_0,y_o]\sum_i \left|Z(x_i,y_i)-z_i\right|$$

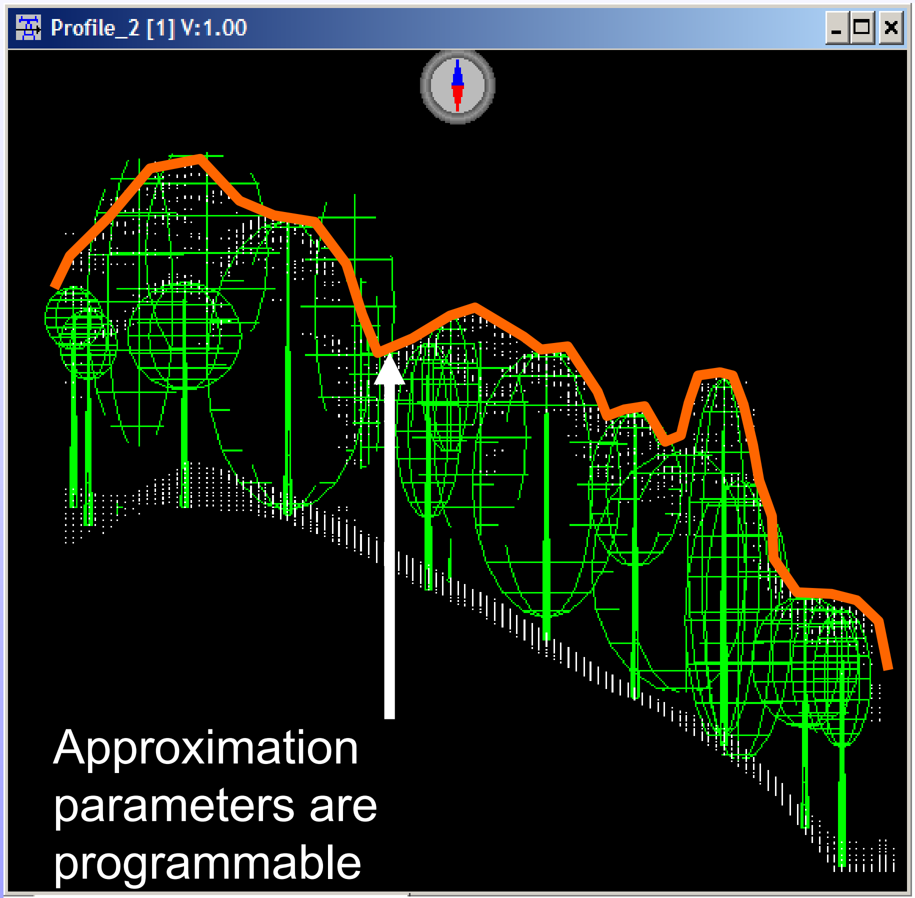
Single model



Profiling



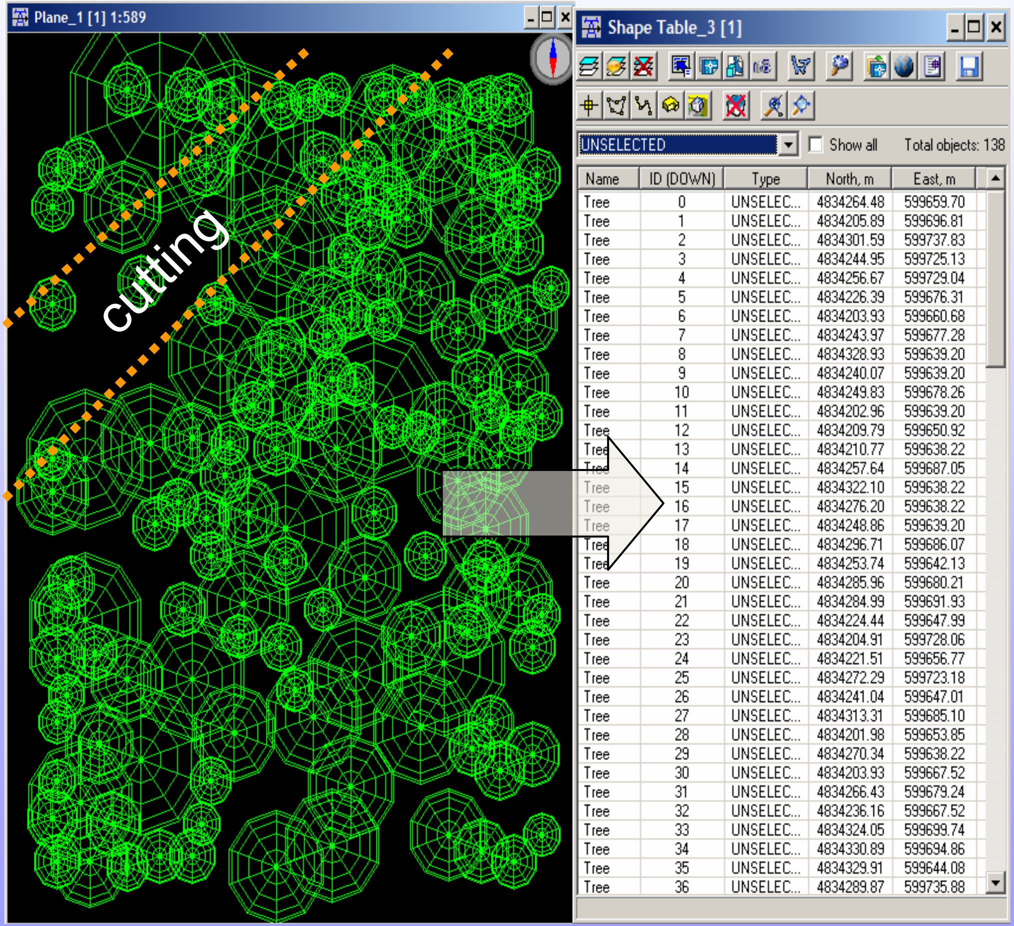
Canopy model: profile



Approximation parameters are programmable

Multiple model provide practically continuous coverage

Canopy model: objects

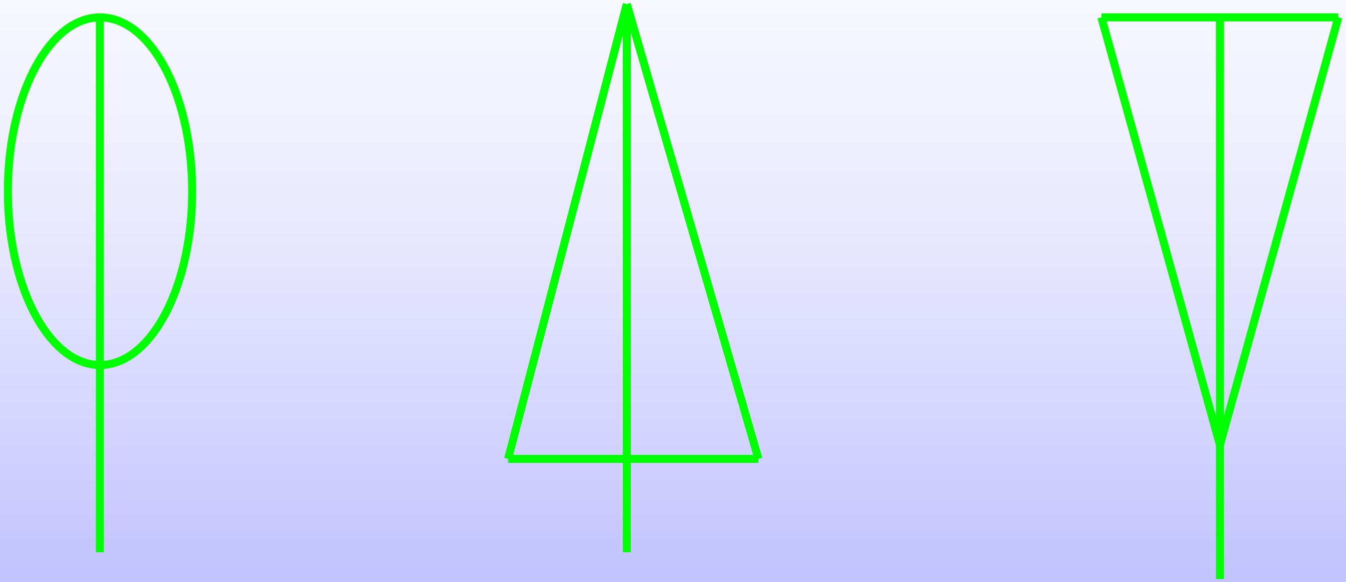


UNSELECTED ☐ Show all Total objects: 138

Name	ID (DOWN)	Type	North, m	East, m
Tree	0	UNSELEC...	4834264.48	599659.70
Tree	1	UNSELEC...	4834205.89	599696.81
Tree	2	UNSELEC...	4834301.59	599737.83
Tree	3	UNSELEC...	4834244.95	599725.13
Tree	4	UNSELEC...	4834256.67	599729.04
Tree	5	UNSELEC...	4834226.39	599676.31
Tree	6	UNSELEC...	4834203.93	599660.68
Tree	7	UNSELEC...	4834243.97	599677.28
Tree	8	UNSELEC...	4834328.93	599639.20
Tree	9	UNSELEC...	4834240.07	599639.20
Tree	10	UNSELEC...	4834249.83	599678.26
Tree	11	UNSELEC...	4834202.96	599639.20
Tree	12	UNSELEC...	4834209.79	599650.92
Tree	13	UNSELEC...	4834210.77	599638.22
Tree	14	UNSELEC...	4834257.64	599687.05
Tree	15	UNSELEC...	4834322.10	599638.22
Tree	16	UNSELEC...	4834276.20	599638.22
Tree	17	UNSELEC...	4834248.86	599639.20
Tree	18	UNSELEC...	4834296.71	599686.07
Tree	19	UNSELEC...	4834253.74	599642.13
Tree	20	UNSELEC...	4834285.96	599680.21
Tree	21	UNSELEC...	4834284.99	599691.93
Tree	22	UNSELEC...	4834224.44	599647.99
Tree	23	UNSELEC...	4834204.91	599728.06
Tree	24	UNSELEC...	4834221.51	599656.77
Tree	25	UNSELEC...	4834272.29	599723.18
Tree	26	UNSELEC...	4834241.04	599647.01
Tree	27	UNSELEC...	4834313.31	599685.10
Tree	28	UNSELEC...	4834201.98	599653.85
Tree	29	UNSELEC...	4834270.34	599638.22
Tree	30	UNSELEC...	4834203.93	599667.52
Tree	31	UNSELEC...	4834266.43	599679.24
Tree	32	UNSELEC...	4834236.16	599667.52
Tree	33	UNSELEC...	4834324.05	599699.74
Tree	34	UNSELEC...	4834330.89	599694.86
Tree	35	UNSELEC...	4834329.91	599644.08
Tree	36	UNSELEC...	4834289.87	599735.88

Vector model consists of separate trees and other morphological objects with geometrical characteristics, which could be quantitatively estimated

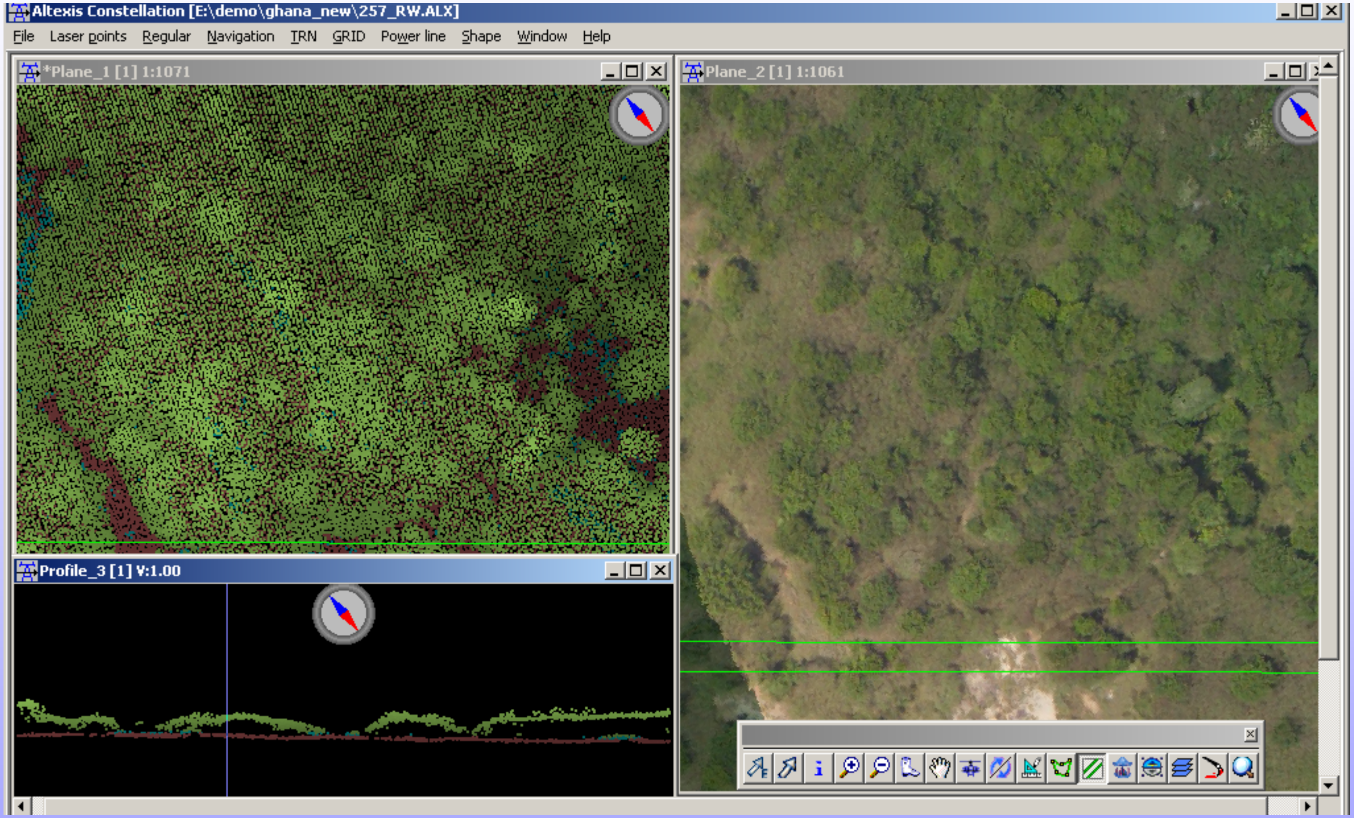
Further development: more models



Coniferous & deciduous models provide more accurate DSM local extremes detection:

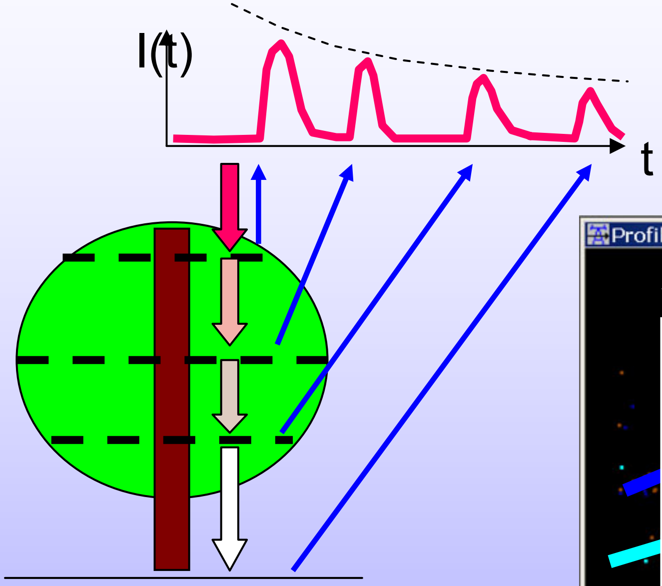
$$\min\left[H, R_v, R_h, x_0, y_o, species\right] \sum_i \left| Z^{species}(x_i, y_i) - z_i \right|$$

Further development: multy sensor data fusion

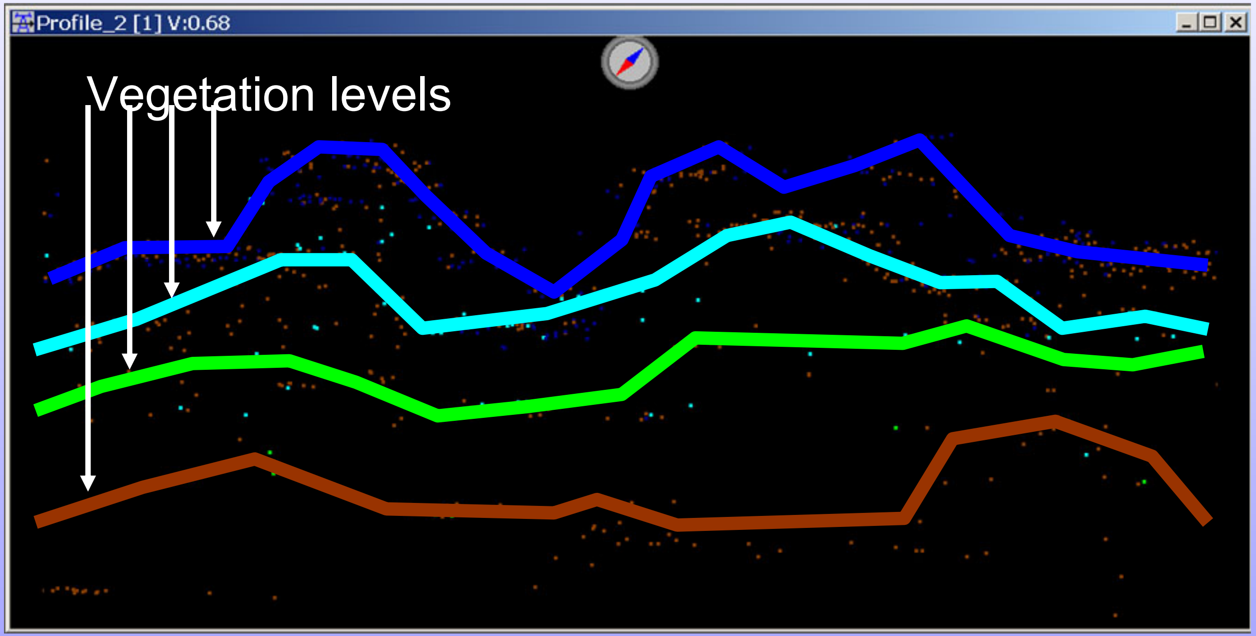


Lidar + Aerial photo give more reliable detection

Multiple response and level detection

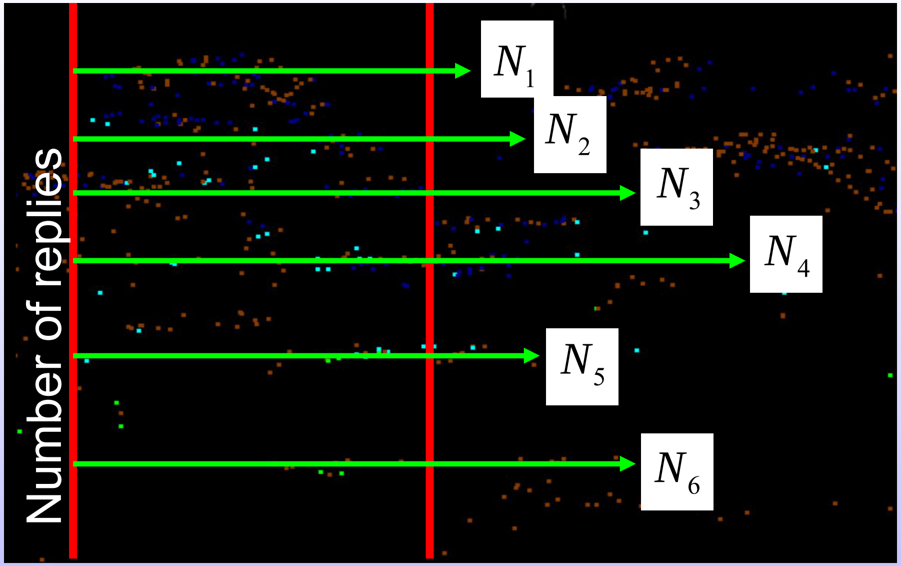


Multiple response feature is extreamly substantial



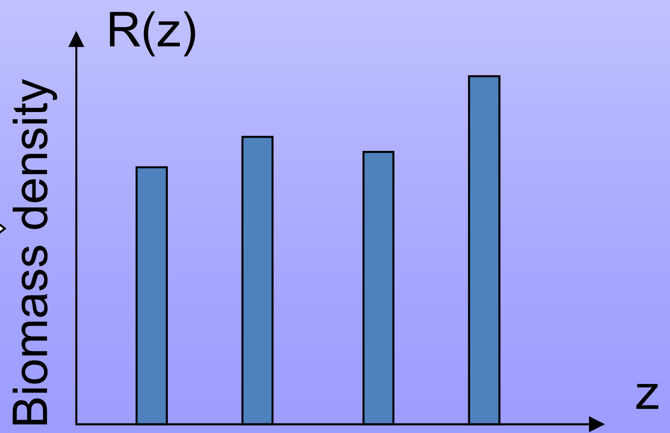
- 1st reflection	●
- 2nd reflection	●
- 3rd reflection	●
-4th reflection	●

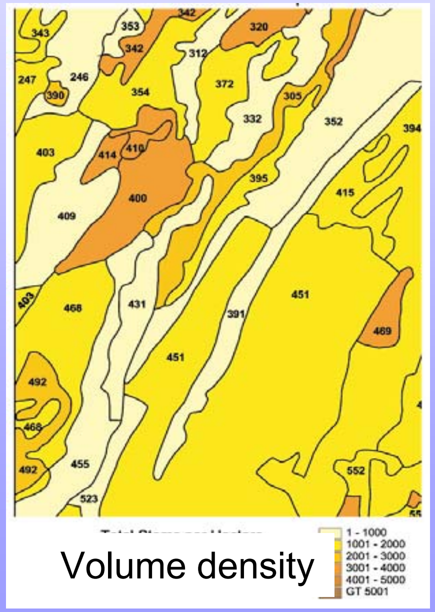
Biomass 3-D distribution



3-D point cloud processing allows to get biomass distribution function

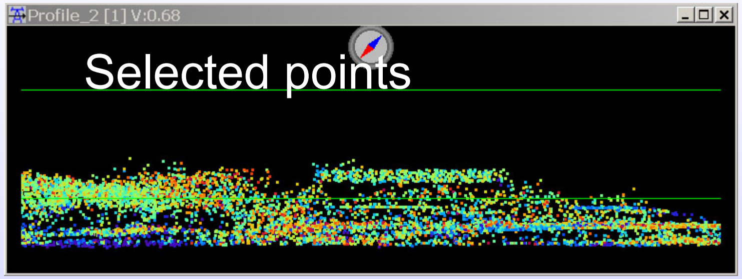
$$\begin{cases} N_1 = k \cdot N \cdot R_1 \\ N_2 = k \cdot (N - N_1) \cdot R_2 \\ \bullet\bullet\bullet \\ N_i = k \cdot (N - \sum\limits_{1}^{i-1} N_i) \cdot R_i \end{cases}$$



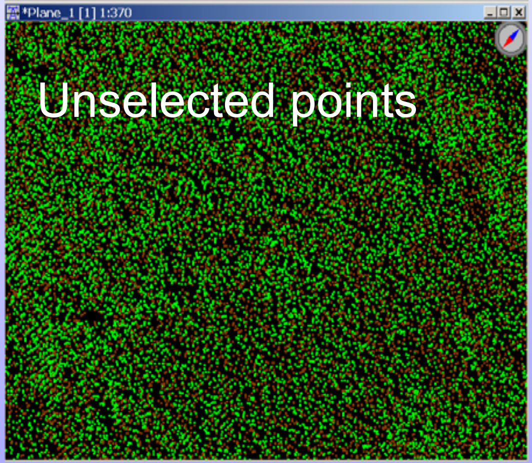


Under canopy object detection

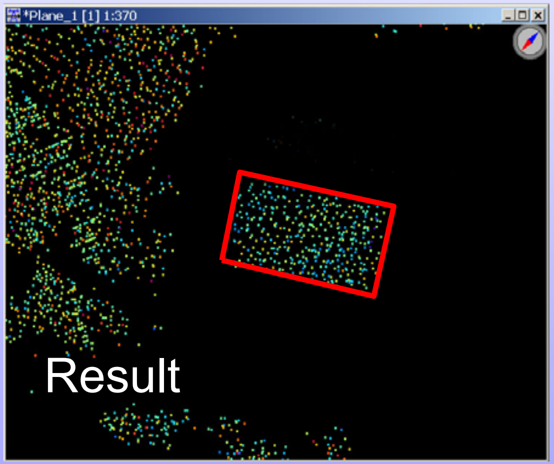
Arial photo



Selected points



Unselected points



Result

Intermediate conclusion:

- Separate tree geopositioning is possible in not to dense forest conditions (Siberia)
- Automated species classification and 3-D biomass distribution are also possible in most cases
- Research must go on!

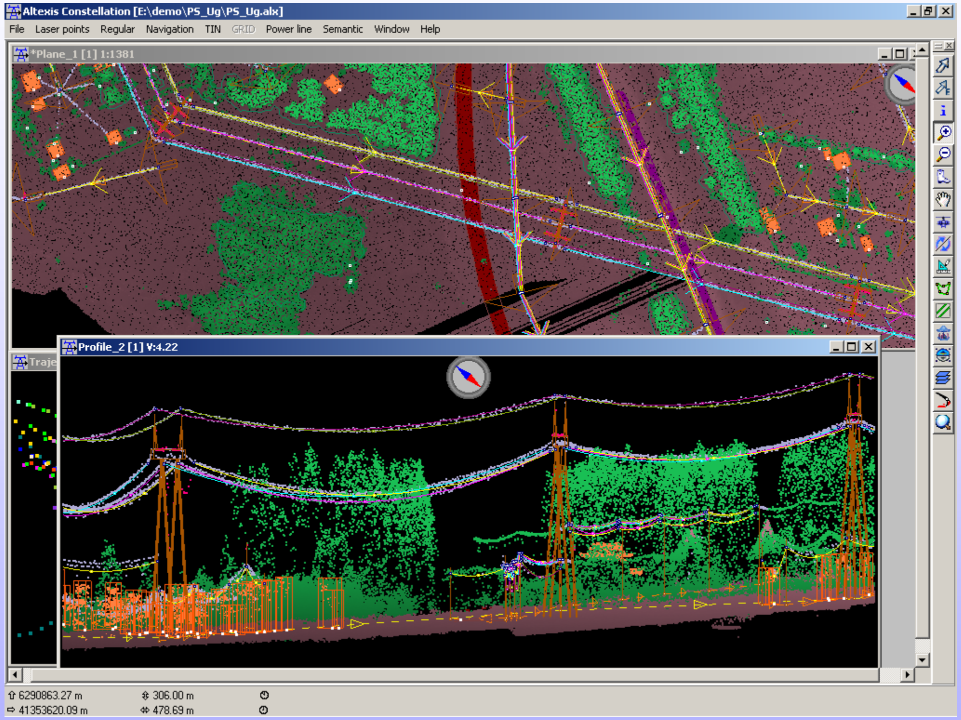
Power Lines Lidar Survey:

Imperative:

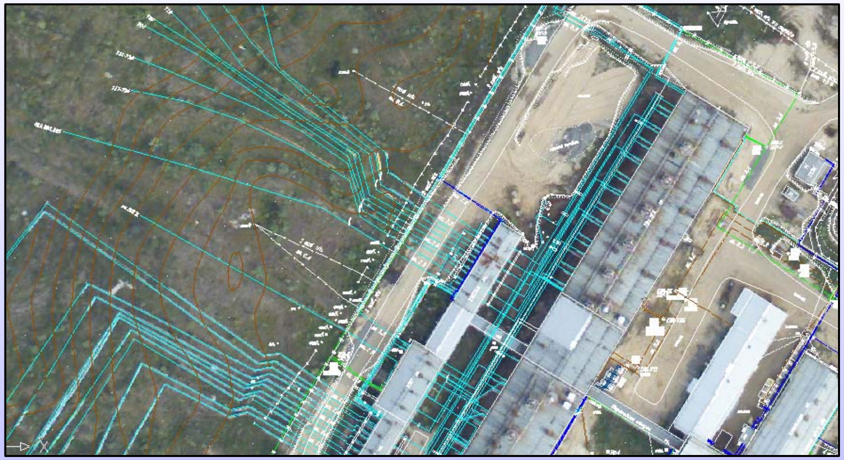
⚐To keep leading position:
  - by exploiting Russian national conservatism (PUE against NEC, IEEE, SIGRE, …)
  - by innovative R&D works

Main goals:

⚐Full automation of wire, cables and other similar 1-D object recognition (done!)
⚐ Insulators, wires break points (derivative break)
⚐ Tower detection, recognition and geopositioning:
  - with a priory defined exact frame model (done!)
  - without (know how to do)



6290863.27 m
306.00 m
41353620.09 m
478.69 m



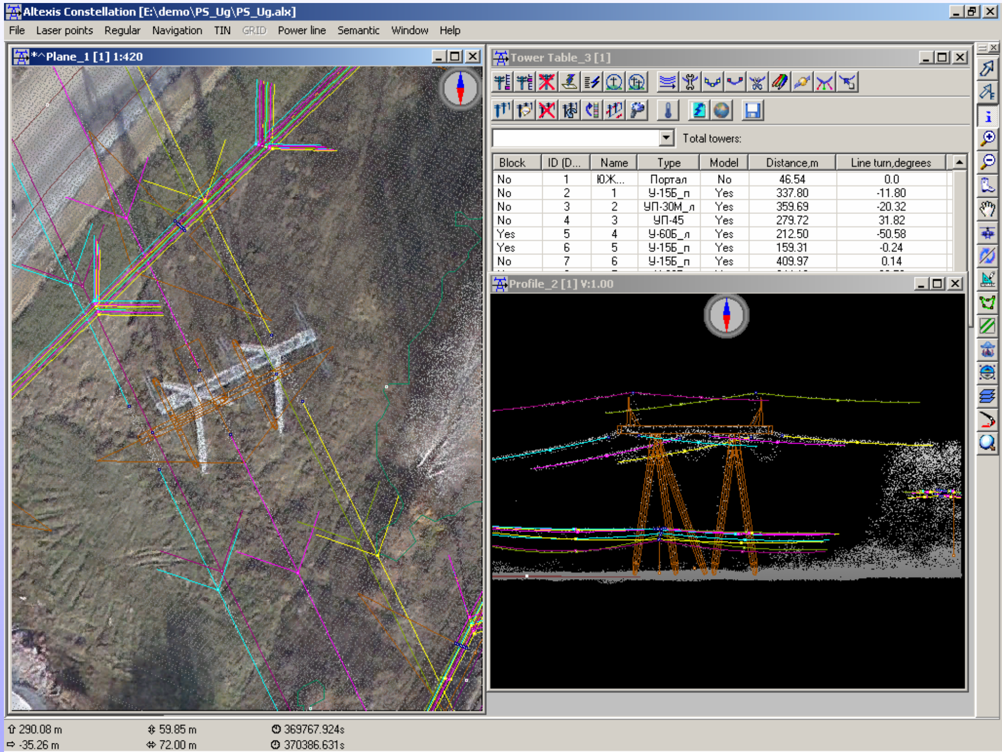
Wires and other similar 1-D object detection in noisy environment

Achievements:

- ”Normal” wire recognition – near 100% probability
- Non-trivial wire models:
  - parabolic
  - catenary
  - arbitrary smooth function with limited number of derivative breaks
- Accuracy: up to 2 cm, RMS for wire positioning

Problems:

- Splitted phase conductors



Block	ID (D...	Name	Type	Model	Distance,m	Line turn,degrees
No	1	ЮЖ...	Портал	No	46.54	0.0
No	2	1	У-15Б_п	Yes	337.80	-11.80
No	3	2	УП-30М_л	Yes	359.69	-20.32
No	4	3	УП-45	Yes	279.72	31.82
Yes	5	4	У-60Б_л	Yes	212.50	-50.58
Yes	6	5	У-15Б_п	Yes	159.31	-0.24
No	7	6	У-15Б_п	Yes	409.97	0.14

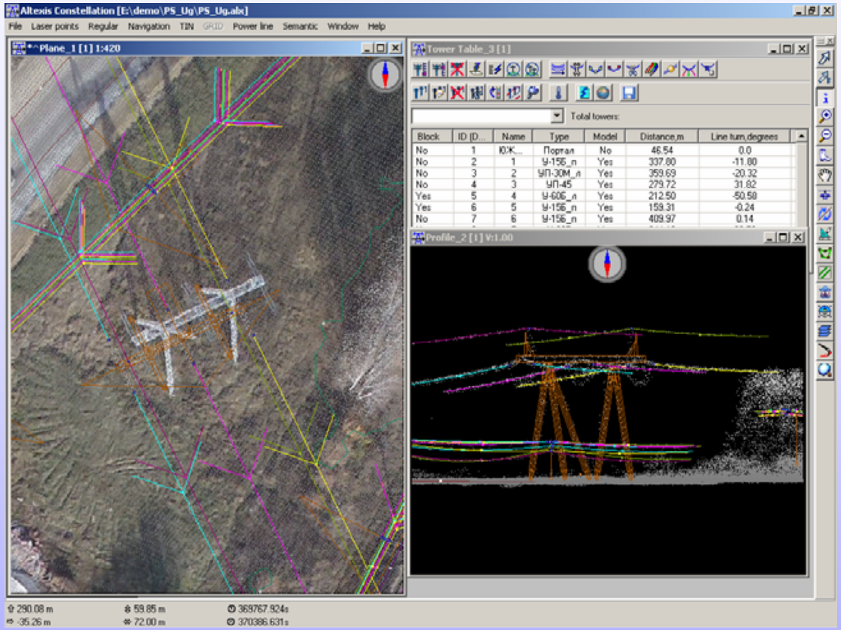
Towers:

Detection, recognition and geopositioning:

- with a priory defined exact frame model
- without it

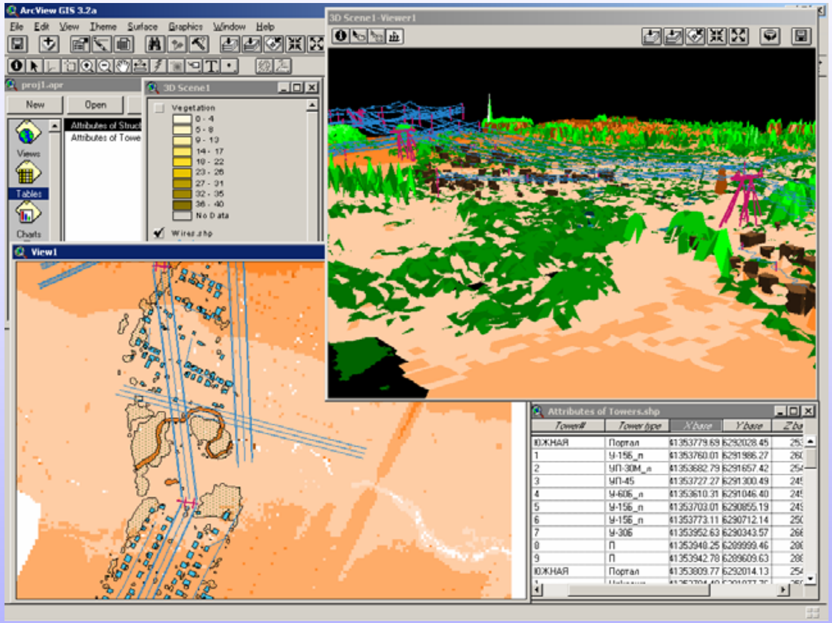
The latter is better since a priory defined exact model does not usually exist

Final Data Representation



Block	ID (D...	Name	Type	Model	Distance,m	Line turn,degrees
No	1	ЮЖ...	Портал	No	46.54	0.0
No	2	1	У-156_п	Yes	337.80	-11.80
No	3	2	УП-30М_л	Yes	359.69	-20.32
No	4	3	УП-45	Yes	279.72	31.82
Yes	5	4	У-606_л	Yes	212.50	-50.58
Yes	6	5	У-156_п	Yes	159.31	-0.24
No	7	6	У-156_п	Yes	409.97	0.14

Altex representation: everything according Russian soul wants



Tower#	Tower type	X base	Y base
ЮЖНАЯ	Портал	41353779.69	6292028.45
1	У-156_п	41353760.01	6291986.27
2	УП-30М_л	41353682.79	6291657.42
3	УП-45	41353727.27	6291300.49
4	У-606_л	41353610.31	6291046.40
5	У-156_п	41353703.01	6290855.19
6	У-156_п	41353773.11	6290712.14
7	У-306	41353952.63	6290343.57
8	П	41353940.25	6289999.46
9	П	41353942.78	6289609.63
ЮЖНАЯ	Портал	41353809.77	6292014.13

Export representation: GIS, CAD, PLS-CADD, …

Intermediate conclusion:

- All remaining problems in Lidar Power Data processing will be overcame shortly
- New problems will appear then

Thank you!

Altex Geomatica

www.altex-gmt.ru