Single tree remote sensing, STRS using airborne images and LiDAR data

LECTURE 3 & LAB 2
A LOOK AT RADIOMETRIC ISSUES

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CONTENTS

What are we actually measuring

- with camera?
- with LiDAR (DR/FW)

OK, but what are we interested in, i.e. what would we like to measure?

Image chain – chopping it into meaningful pieces

- weak links and bottlenecks

OBJECTIVE of LECTURE 3 AND LAB 2

To learn that there is much unused potential in the radiometric signal, to be used in STRS or STRS++.

What are we actually measuring, with camera and LiDAR?

Some claims with personal flavor.

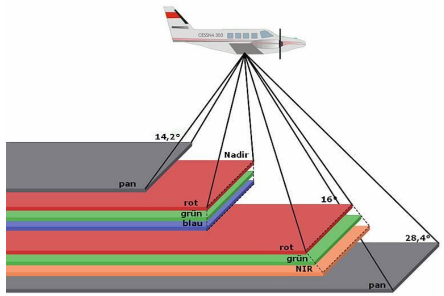
1. Aerial cameras and LiDAR systems are not built having foresters in mind

   - PAN-sharpening is OK for topographic mapping
   - True RGB colors or a color-space for automatic classifications
   - Registering the LAST echo for terrain; tuning the system for solid opaque objects (canopy is see-thru like)

2. We do not have control over the radiometric issues, because they are much more complex than geometry, and vendors even do not know what their devices are capable of.

3. Absolute radiometric calibration of images is finally at our hands; thanks to digital sensors, we can start to treat the DN-values as reflectance data.

IDEAL SENSORS?



If I were to decide; how imaging is carried out:

CAMERA:

-camera; optimized for radiometric (spectral detection) of trees; with 6-7 line CCDs, one for each 30-nm band, looking forward, nadir, backward; thus giving 3 x (6 or 7) images per target.
- optimization with spectrophotometer data (BDRF at different scales)
- 20-30 cm real resolution, all bands
- absolute calibration (measurements of at-sensor irradiance), STABLE
- flown to give 6 views of the target
- high dynamic range, 16-bits

LiDAR:

- Discrete-return system with FW-features, measures the range; echo amplitude, width etc. for 1–N returns.
- measurement of outgoing energy / waveform
- One very narrow beam to measure reflectance (900-1100 nm?)
- One less narrow beam to measure target geometry (500-1500 nm?)

IDEAL SENSORS – what do we want to measure?

CAMERA:

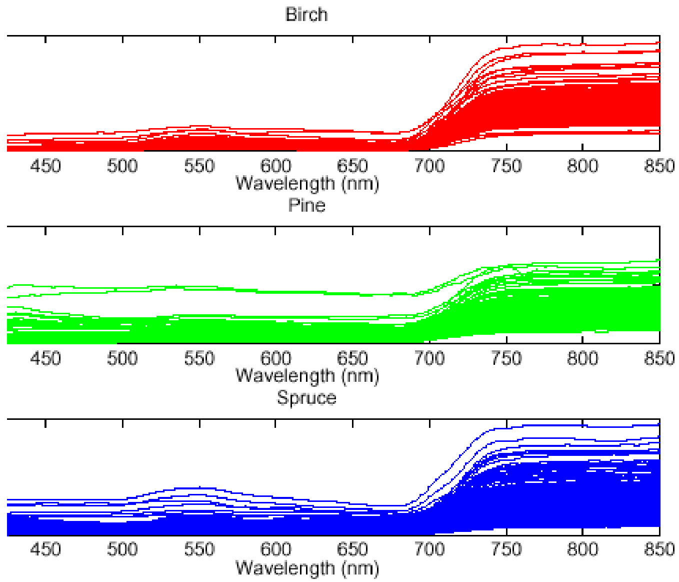
Spectral classification: optimal selection of bands with respect to classification of targets from the background and between classes.

Texture measures: requires very high spatial resolution; < 20 cm; here multi-spectral data is maybe not so important.

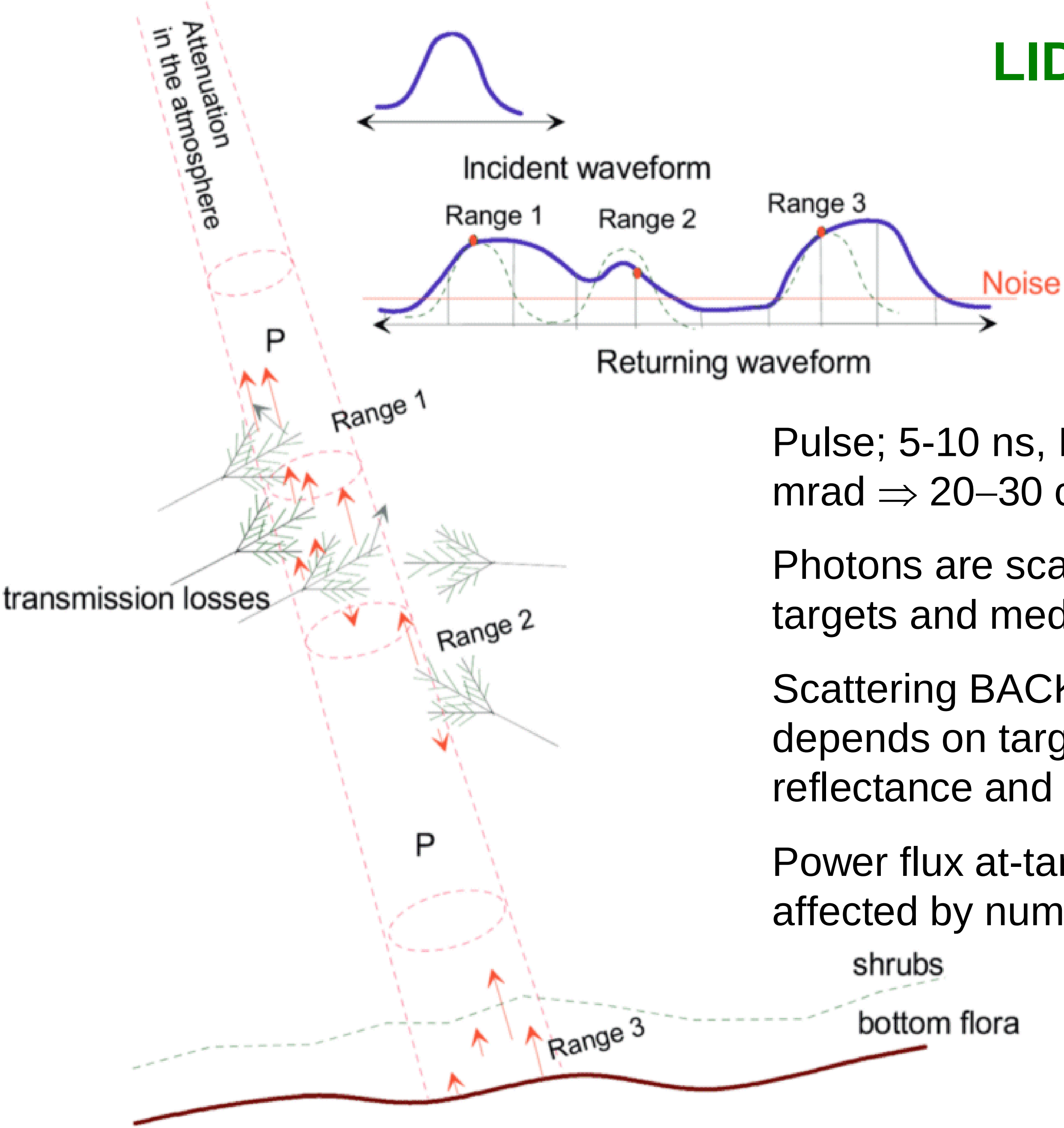
The conversion of DN-values into at-sensor irradiances is followed by their transformation into target-reflectance (0-1). This requires knowledge of the atmosphere (at-target radiances, target-camera trans-mission losses).

LIDAR:

Backscatter-surge is invariant to BDRF!
The photon count at-sensor ~*f*(losses, reflectance, geometry, silhouette area)
The photos are however, pretty well in our control!!



(Reduction on tree species classification accuracy from 5-nm band data to 5-channel aerial camera is low; differences between SO are marginal)



LIDAR

Pulse; 5-10 ns, NIR; divergence 0.2–0.3 mrad ⇒ 20–30 cm (# % of energy)

Photons are scattered or absorbed. By targets and medium.

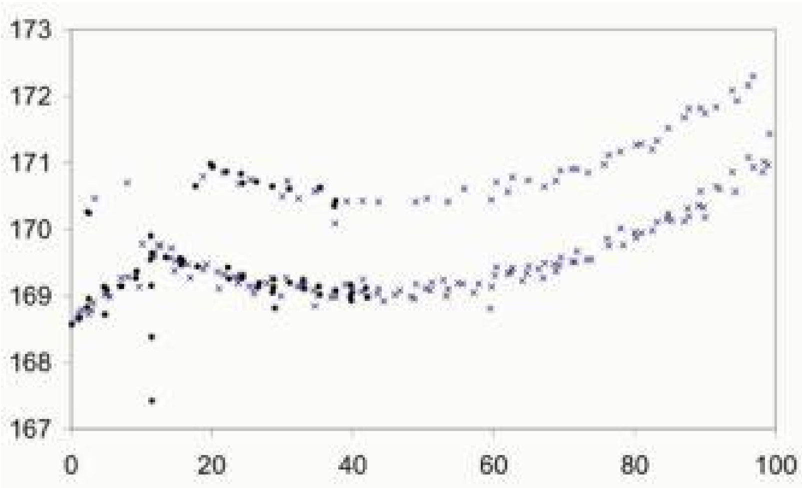
Scattering BACK towards sensor depends on target ”silhoutette area”, reflectance and geometry.

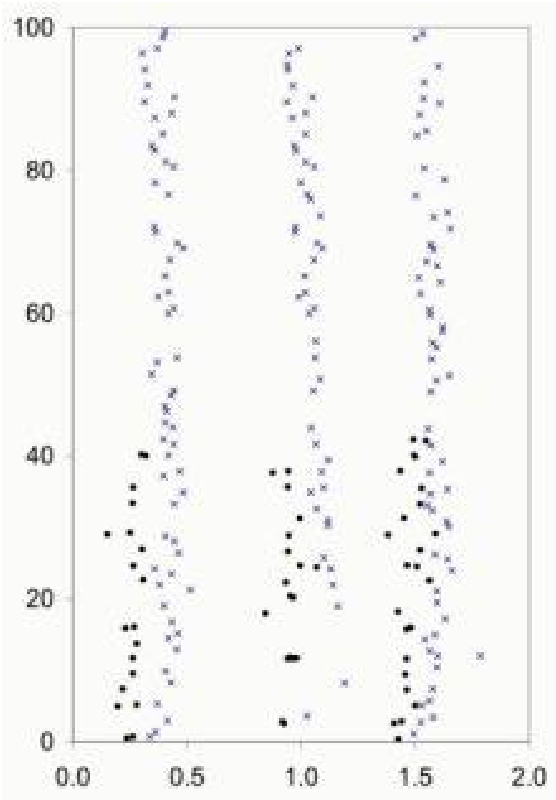
Power flux at-target and at-sensor are affected by numerous factors.

LIDAR

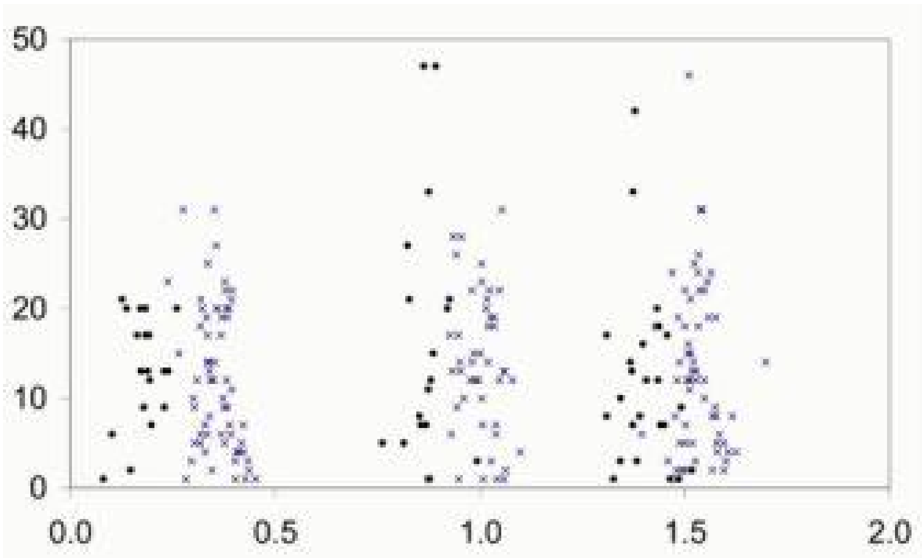
3-cable power line example

Z (sideview)



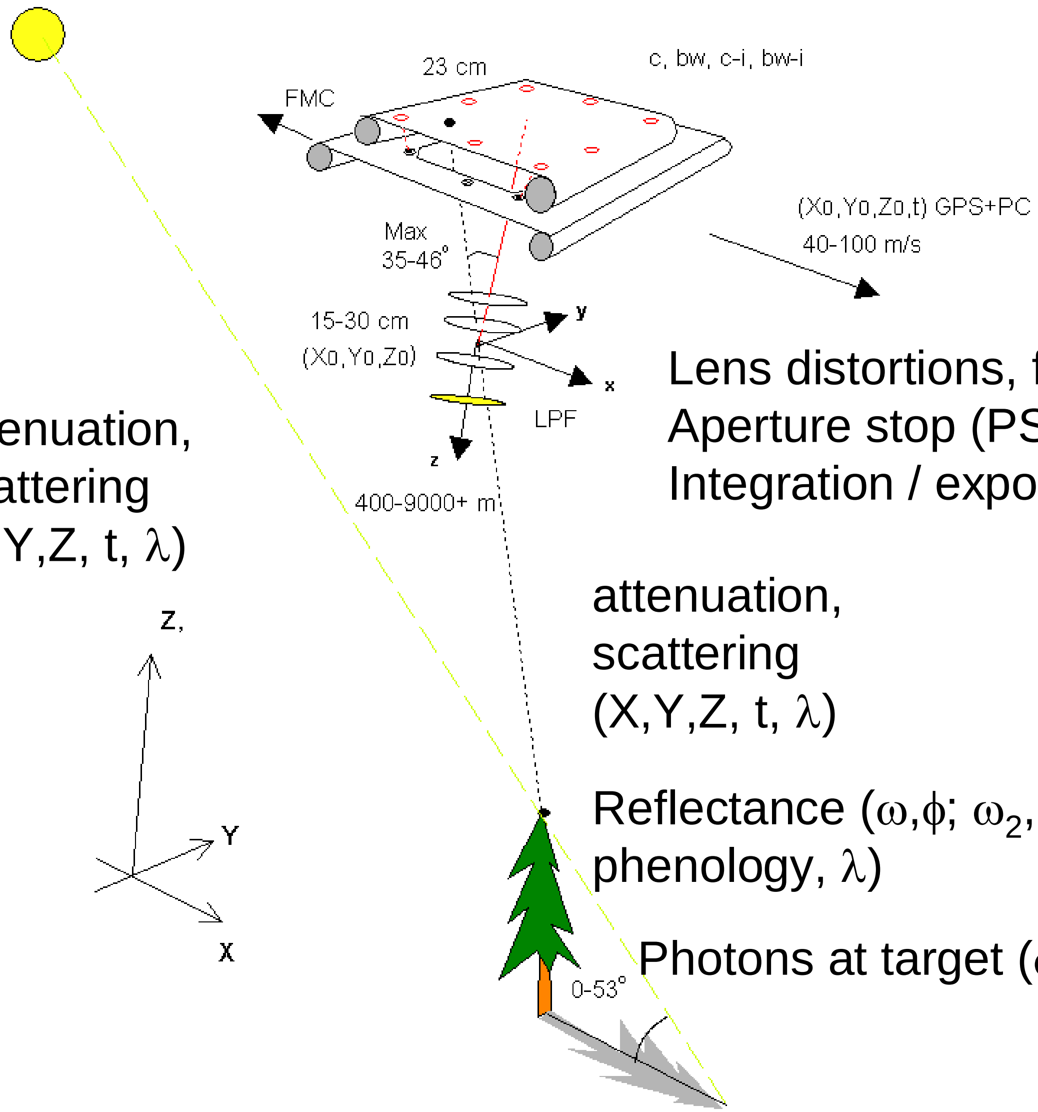


XY (top-view)



intensity (end-view)

CAMERA



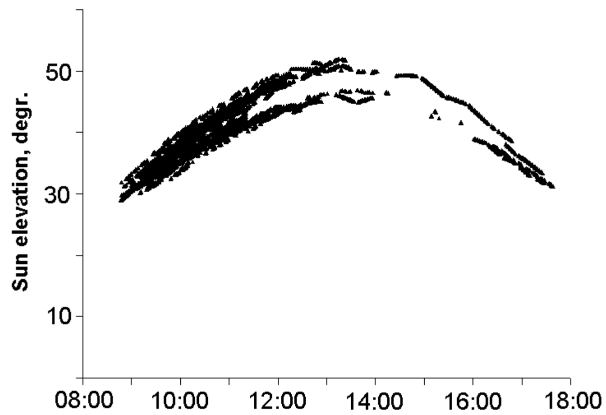
Lens distortions, filter responses
Aperture stop (PSF, MTF)
Integration / exposure time

attenuation,
scattering
(X,Y,Z, t, λ)

attenuation,
scattering
(X,Y,Z, t, λ)

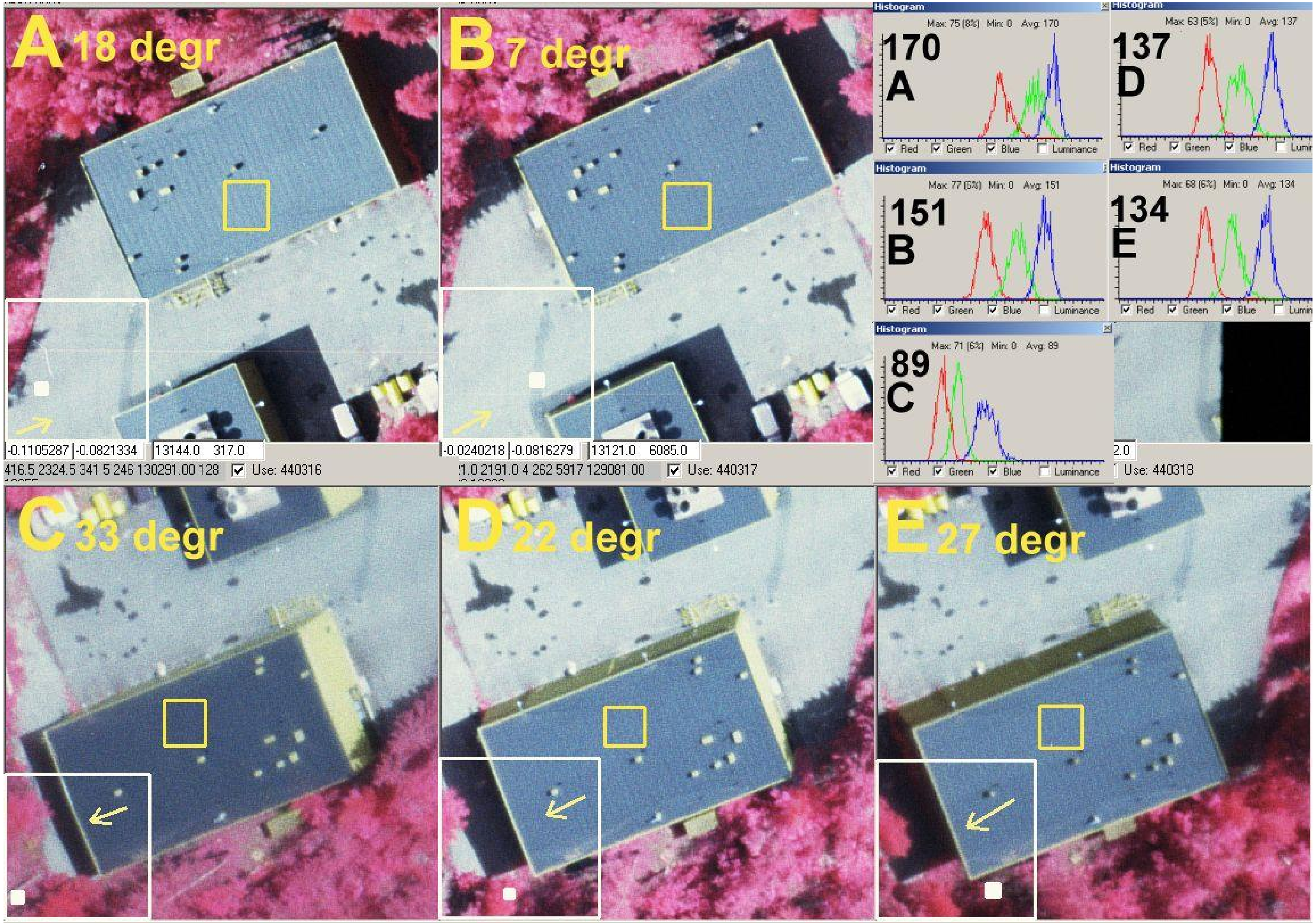
Reflectance (ω,ϕ; $\omega_2,\phi_2,$
phenology, λ)

Photons at target (ω, ϕ, λ)



⇒ It is not easy to control the photons, and infer from the the DN-values

Bitumen in CIR film; inside 5 mins



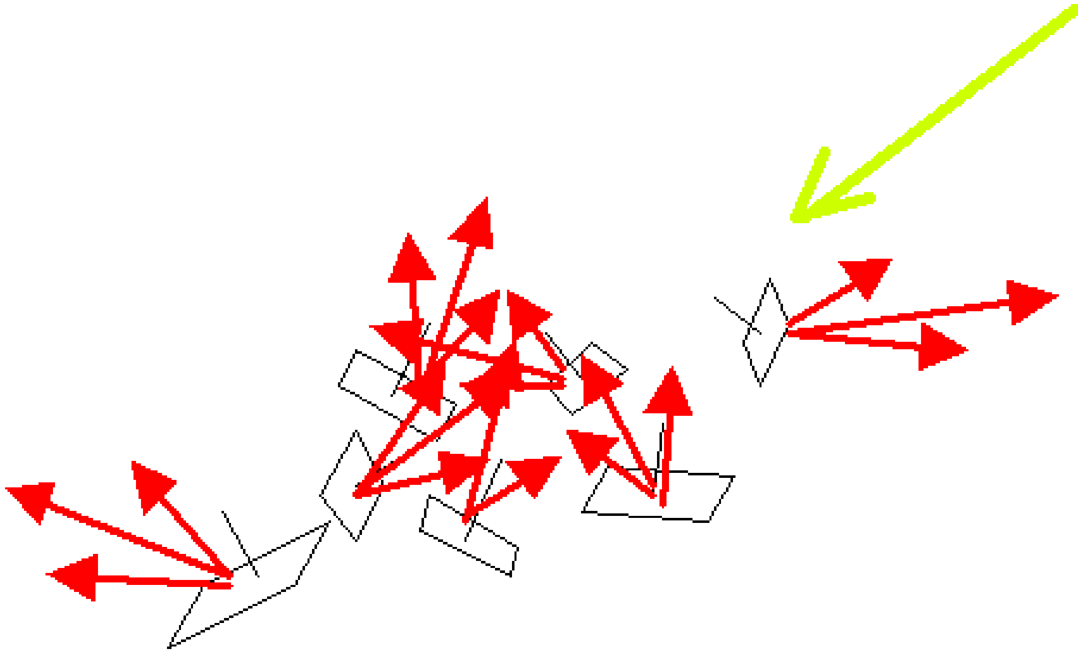
RADIOMETRY – through empirical LBD or theoretical, even model-based approach?

- Good theoretical, physically-based models exist that help understanding the signal measured in the image or by LiDAR
- Basic data is still needed for example to build a good LiDAR simulator
- Empirical (inductive) approach and theoretical modeling can go hand-in-hand

CAMERAS – some empirical LBD-research results

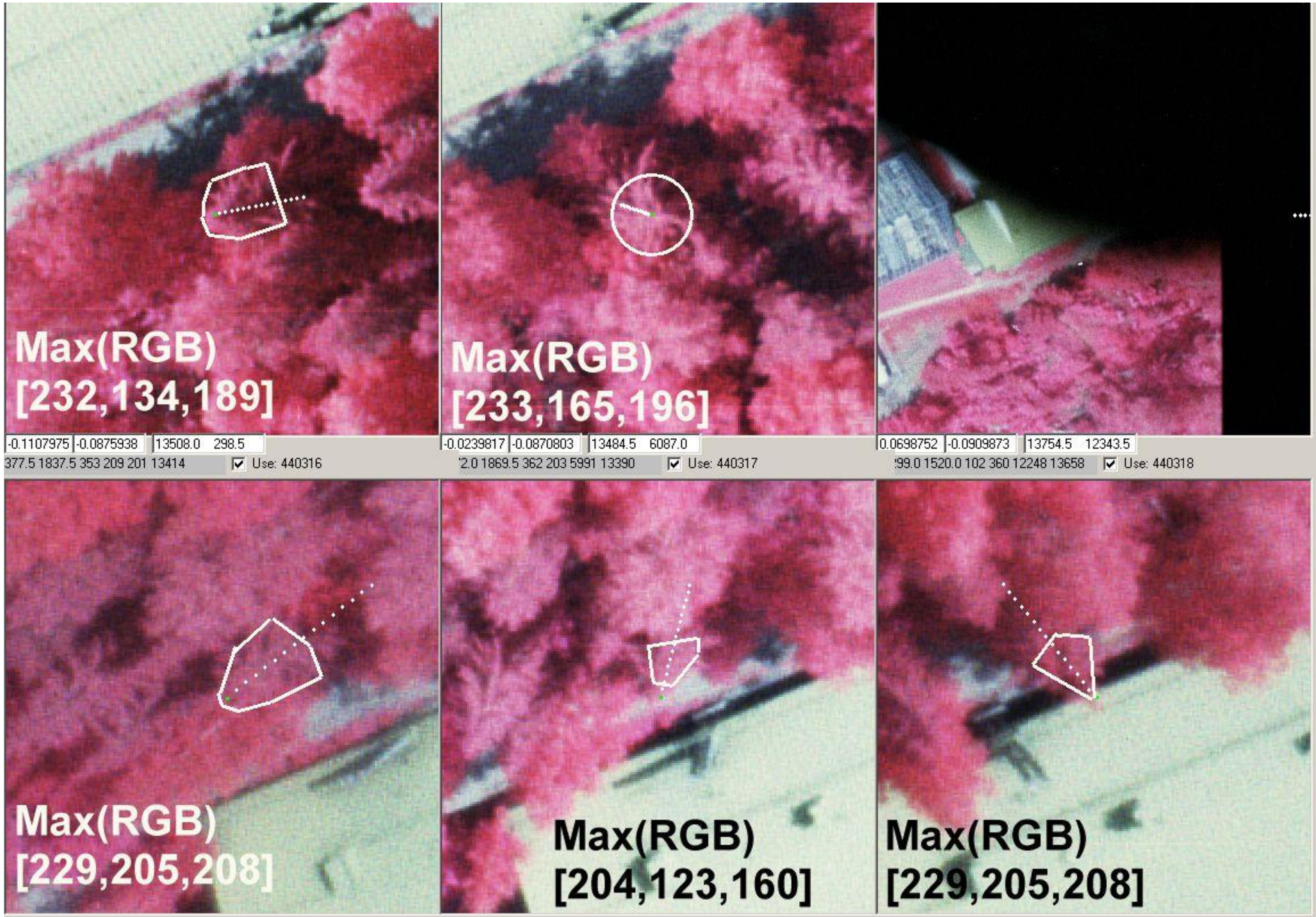
2005 Max BRIGHTNESS is invariant to angles -thesis

Any particular spot in the crown under direct light that gives invariant spectral values; not affected greatly by the viewing/sun angles?



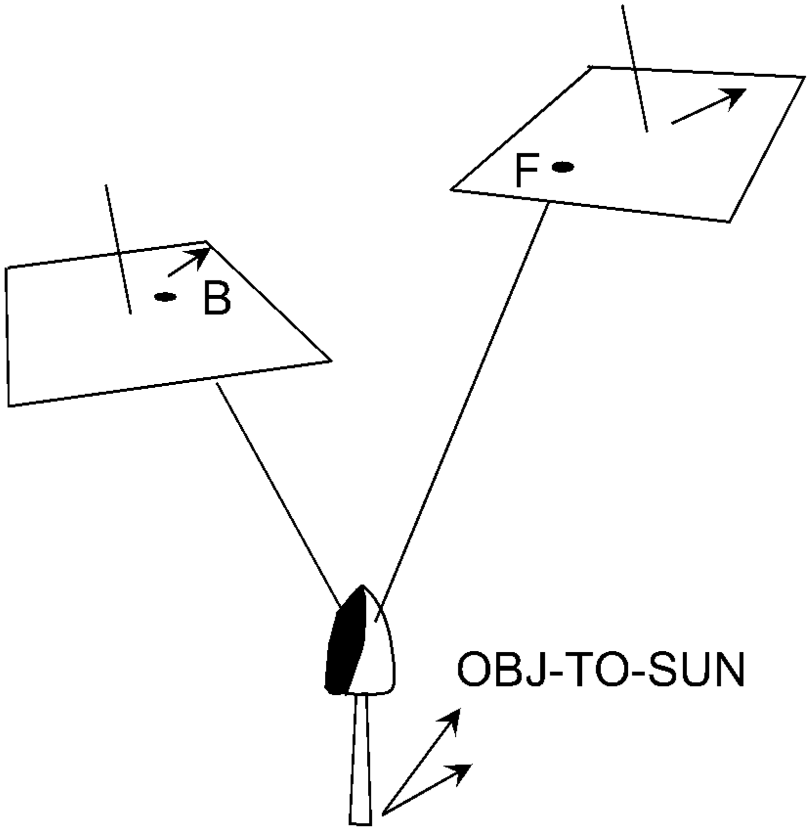
CAMERAS – some empirical LBD-research results

Max BRIGHTNESS is invariant to angles -thesis



CAMERAS – some empirical LBD-research results

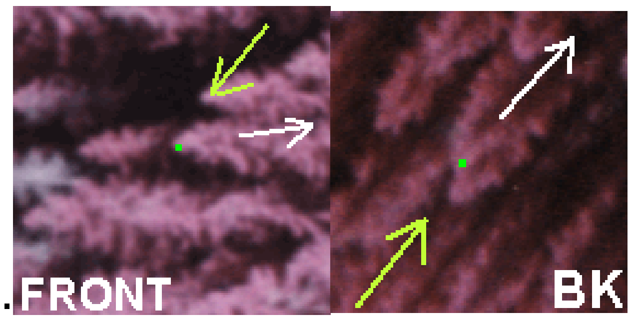
Treat BDRF as your friend –thesis (2004, 2008–)



A BDRF-correction in an image is doomed to fail unless all targets have the same relative BDRF-pattern.

IDEA: try to measure the BDRF and induce species from that!

⇒ Lots of views per target; note that nowadays film-is-free, is it?



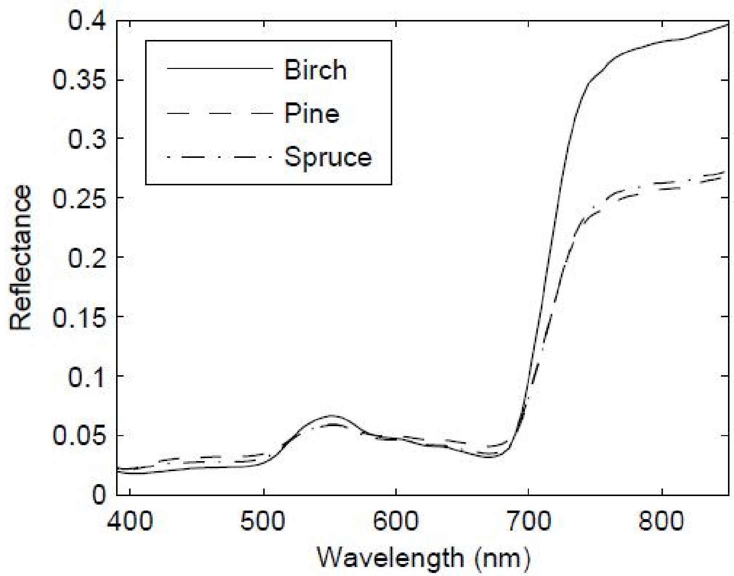
Korpela 2004; sample crowns from the shaded side.

CAMERAS – some empirical LBD-research results

Is target reflectance affected by morphology / physiology?

CAMERAS – some empirical LBD-research results

Simulated Multispectral Imagery for Tree Species Classification Using Support Vector Machines
Ville Heikkinen et al. 2009



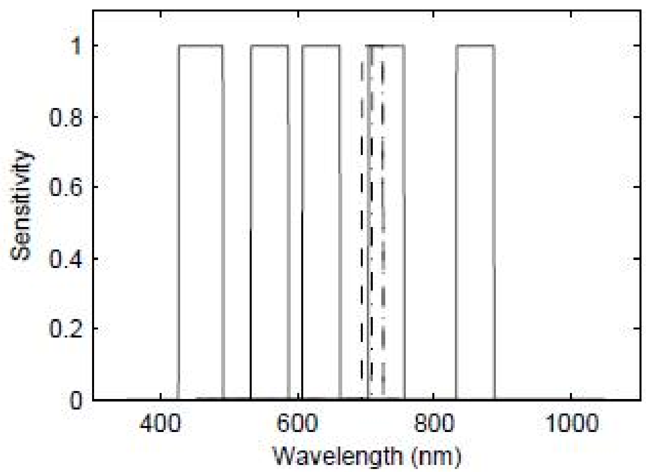
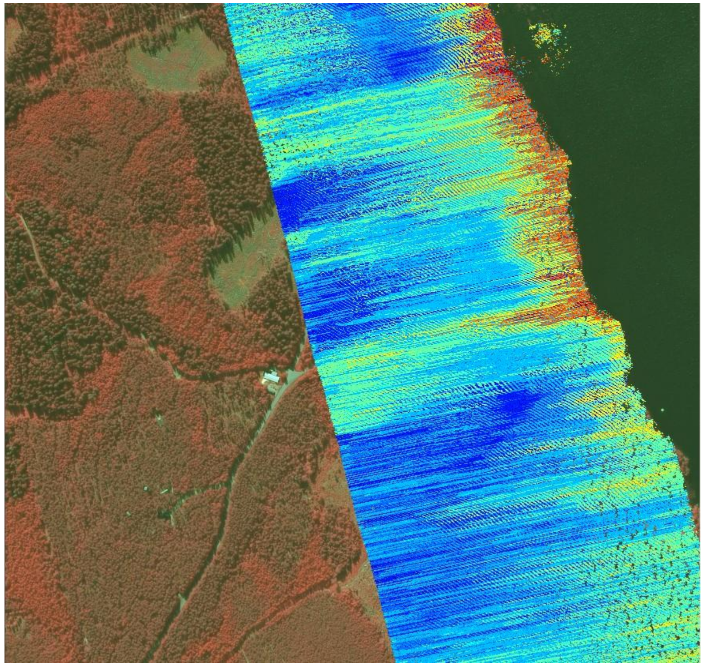


Fig. 3. The Leica system with an additional band (NIR1) in the 705-755 nm waveband (solid), an additional band in the 710-725 nm waveband (dash-dotted) and an additional band in the 695-725 nm waveband (dashed).

Study reflectance of targets; properly – derive the optimal sensor by means of simulation.

LIDAR – some empirical LBD-research results

- First we thought that LiDAR is only about the XYZ-points (and pulses)
- Intensity was noisy; just an excess value
- With research in FW-LiDAR; we started to understand intensity in DR-LiDARs:
  - we believe, that it is a measure of backscatter amplitude
  - we believe, that it is insensitive to echo width (duration)
  - it is affected by many factors; some of which depend on the scatterers in the canopy.

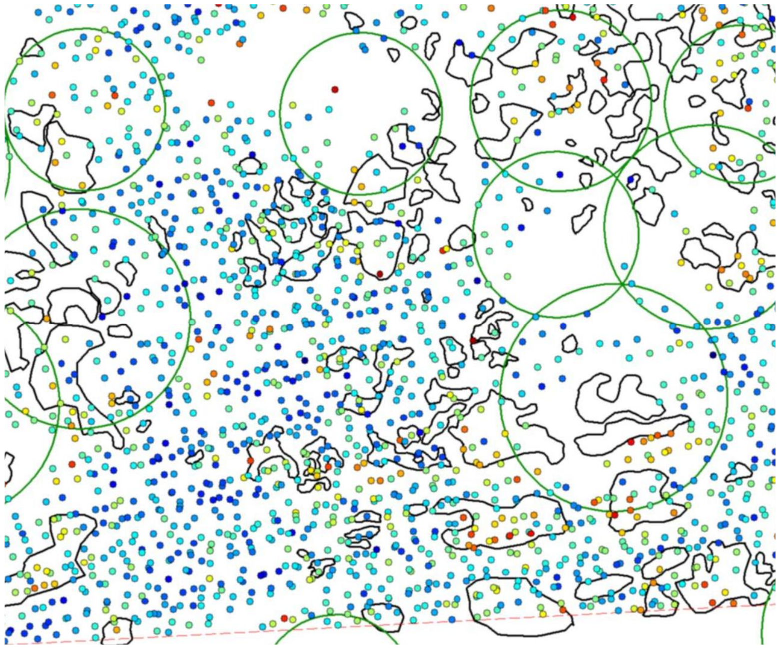


One factor is AGC

LIDAR – some empirical LBD-research results

I started with simple binary classification task; ground lichens;
In laboratory; high backscatter surge (Kaasalainen 2005),
suggesting that lichen mapping s.b. possible.

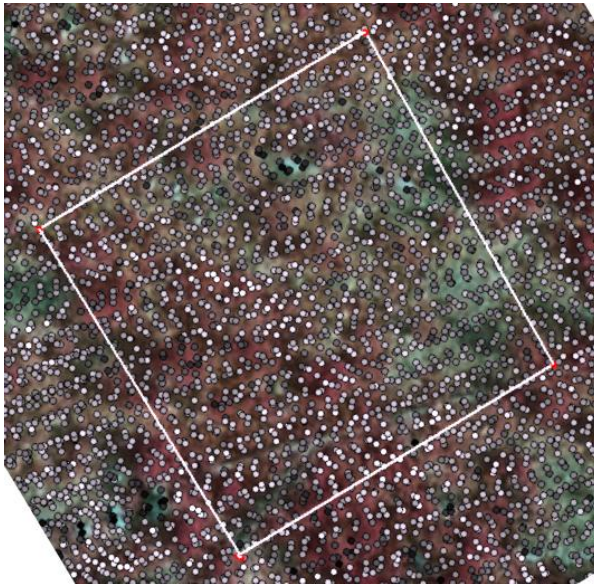
ALS50 – AGC problem and range normalization
ALTM3100 – range normalization



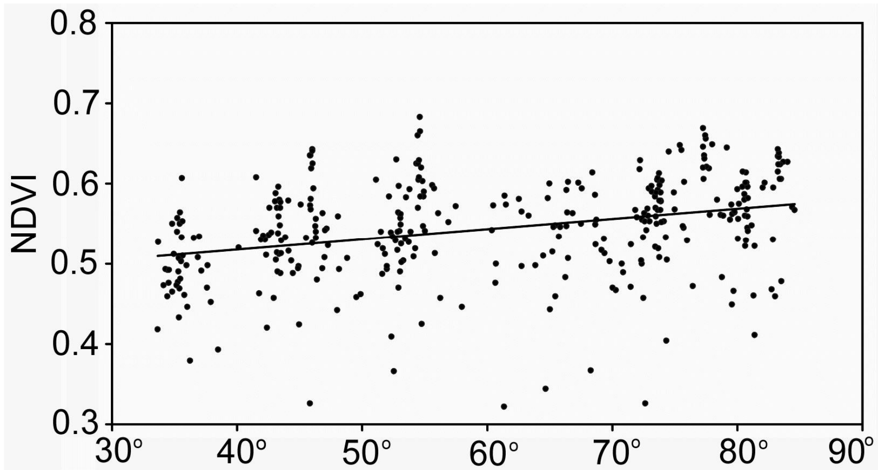
I.S. Korpela / Remote Sensing of Environment 112 (2008) 3891–3897

LIDAR & images – some empirical LBD-research results

Seedling stands; Korpela et al. 2008 Silva Fennica; LIDAR and UltraCAM 1-km data.

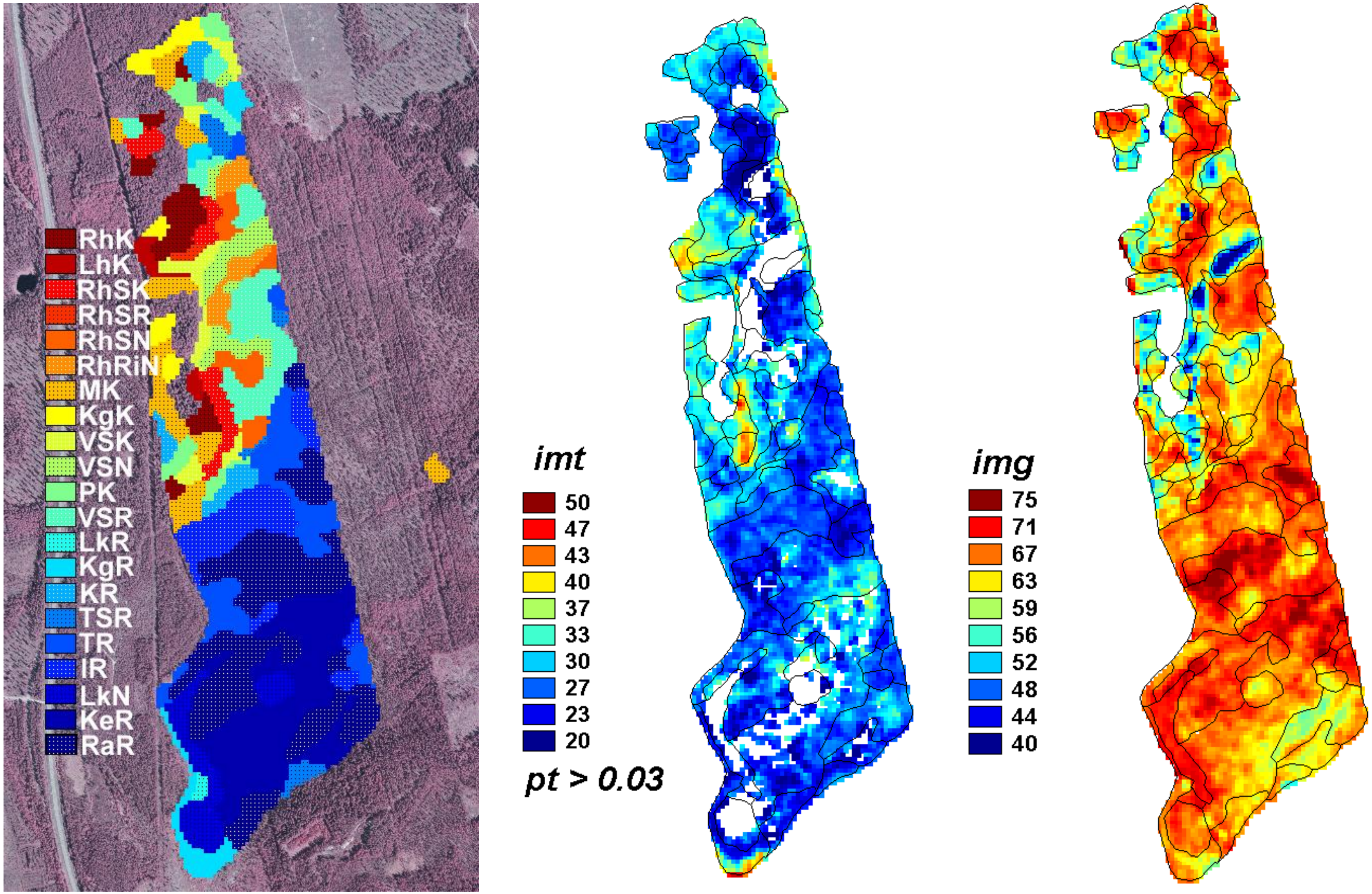


- Tree spp. not easily detected.
- Large-leaved spp. showed high intensity; intensity was not highly correlated with image data.
- BDRF-effects observed
- LiDAR heights were very useful in discriminating between seedlings and competitive vegetation

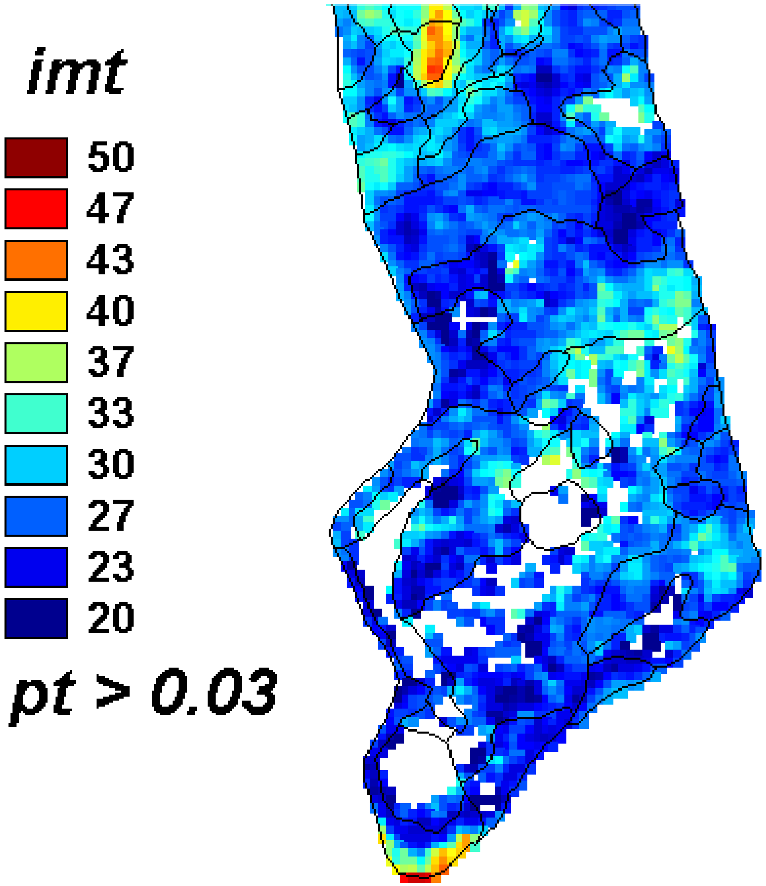


LIDAR – some empirical LBD-research results

Intensity metrics (area-based) in 21-class peatland site type detection; LAKKASUO

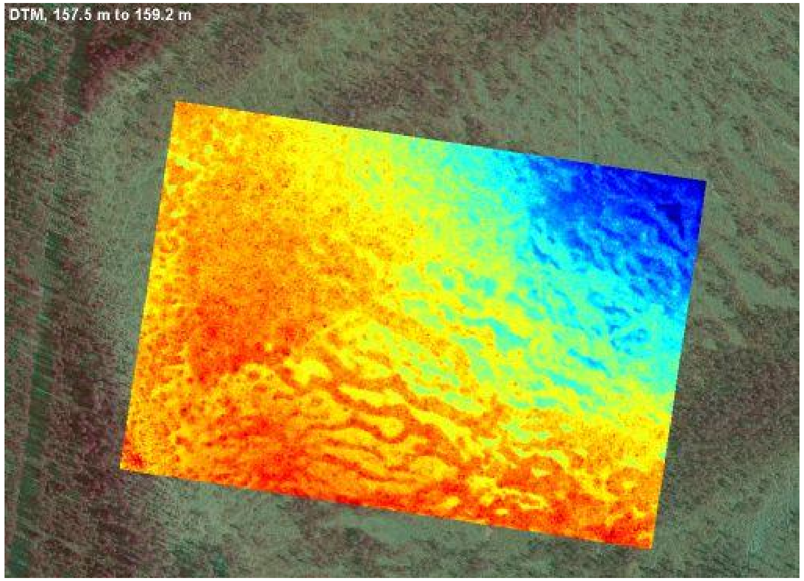


LIDAR – some empirical LBD-research results



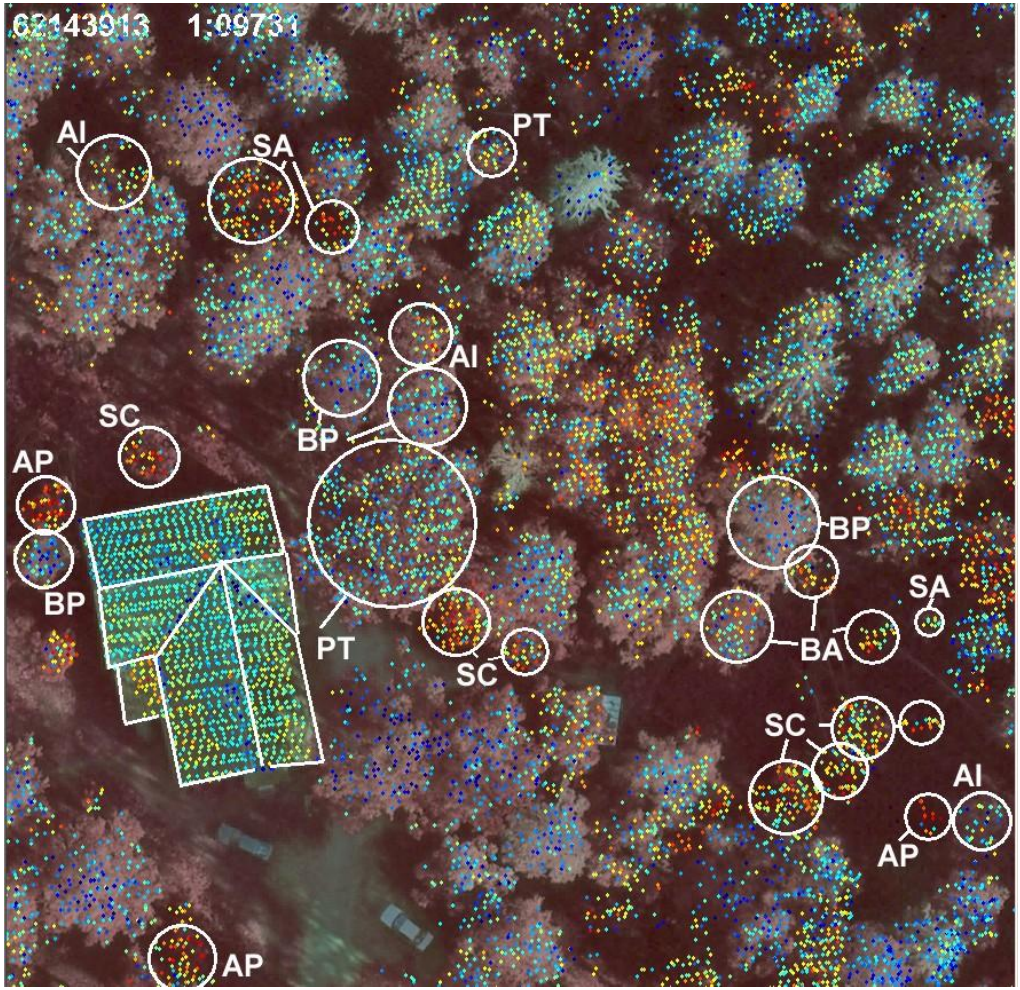
Intensity of pine mires seemed to be correlated with site fertility (0-4 m3/ha/a).

⇒ it seems that needle mass / density or crown architecture affects the intensity data.



<u>LIDAR</u> – some empirical LBD-research results

Trees



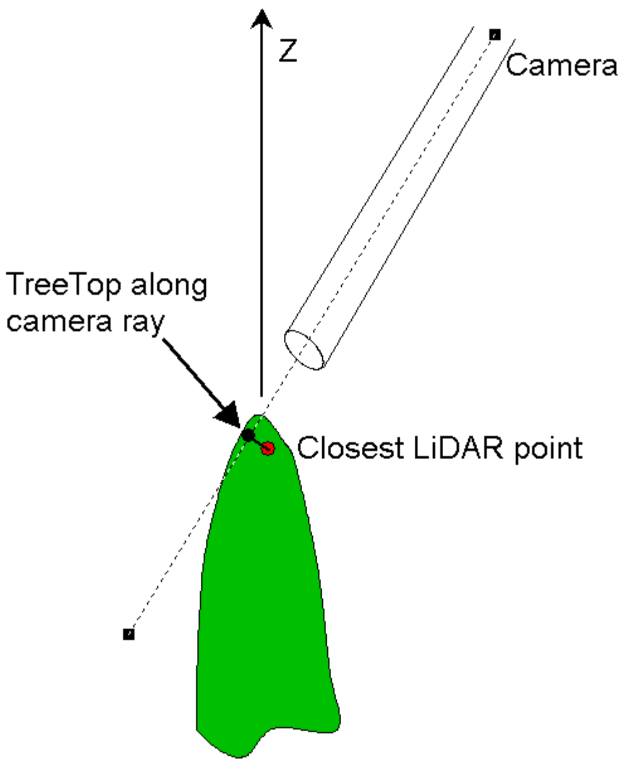
Visualization ⇒
Understanding ⇒
Feature extraction ⇒
SP detection

Intraclass variation ⇒ Plenty of observations ⇒
Preferably “virgin interaction” ⇒
Intensity of first returns ⇒
Study distribution moments

Examine trends/effects due to silviculture, site quality, tree age, vigor, morphology.

LIDAR – some empirical LBD-research results

Trees; SP-classification with LiDAR features; Korpela et al. 2009.



	Pine	Spruce	Birch	All
Pine	**4429**	403	165	4997
Spruce	349	**4671**	1003	6023
Birch	100	434	**1379**	1913
All	4878	5508	2547	12933

Table 4. Confusion matrix of k-NN classification. Kappa=0.69.

Instrument	**ALTM3100**	**ALS50-II**
Date	**July 25, 2006**	**July 4, 2007**
Pulse frequency	**100 kHz**	**115.8 kHz**
Scan frequency	**70 Hz**	**52 Hz**
Footprint	**25–28 cm**	**17–18 cm**
Range	**840–950 m**	**770–820 m**
Scan angle	**± 14°**	**± 15°**
Air humidity, 2 m	**48–52%**	**60–75%**
AGC	**-**	**8 bits**

Table 1. Characteristics of the LiDAR datasets.

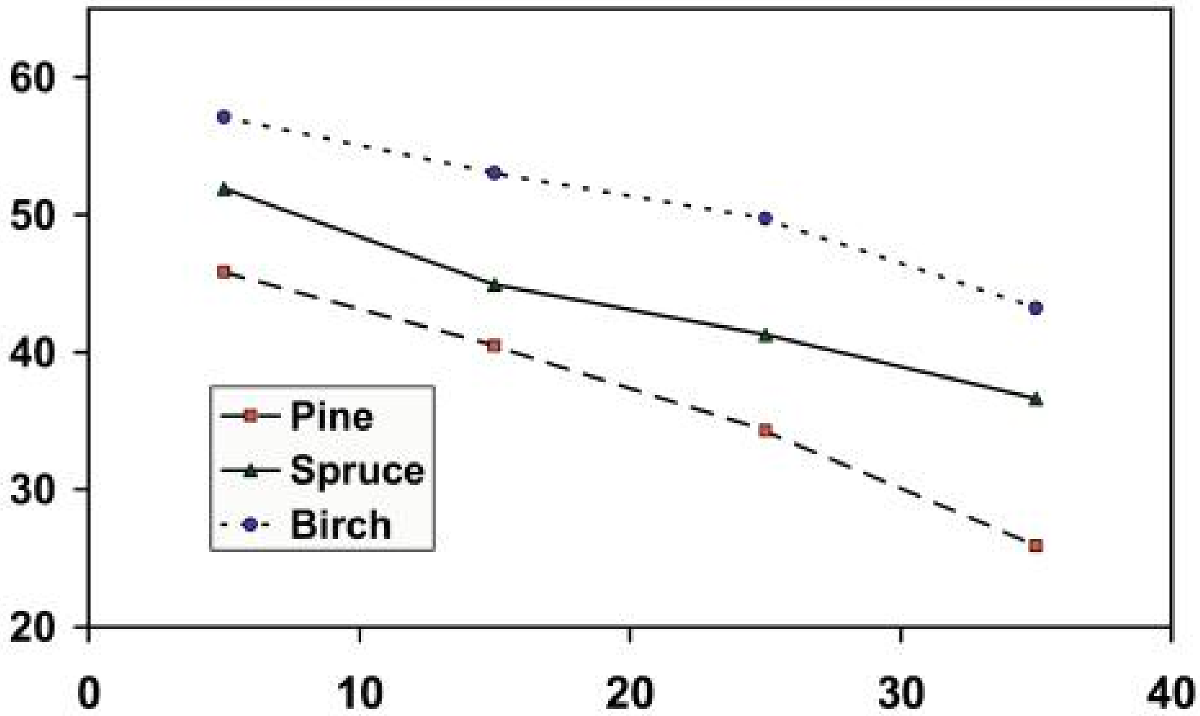
LIDAR – some empirical LBD-research results

Species	n	Mean	SD
Norway Maple	30	72.1	11.0
Goat willow	66	66.5	11.2
Rowan	32	66.0	13.8
Siberian fir	45	64.5	9.2
Small-leaved lime	9	59.5	8.1
Alder	89	57.2	11.1
Siberian larch	17	56.9	9.6
Grey alder	16	53.9	11.0
Douglas fir	2	53.4	3.3
Wych elm	7	52.3	7.3
Cembra pine	9	51.4	5.1
Aspen	64	49.9	11.3
Birch	100	45.3	10.9
Spruce	32	44.3	5.8
Pine	38	43.9	6.3
Contorta pine	2	37.9	4.9

Mean intensity

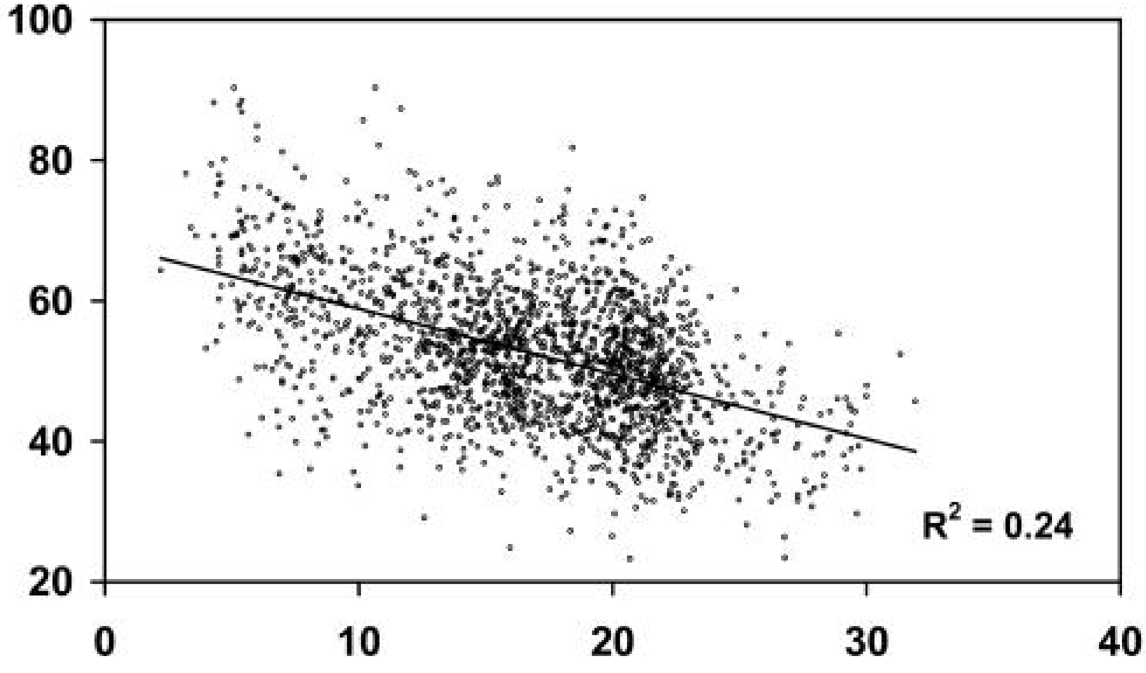
LIDAR – some empirical LBD-research results

Intensity: topmost 40% of the crown.



<u>LIDAR</u> – some empirical LBD-research results

Intensity: young and old birch trees.



Conclusions

In STRS ; it seems that LiDAR carries nearly all the needed information; especially if DR systems are “tuned” to include some FW-flavor.

In Scandinavia; we might still need images for enhanced species detection although the gain from having images if high-density LiDAR exists might be low. If absolute calibration of the images is available; and images can be transferred into reflectance data; the gain from having also images is higher. We are reaching the 95-% species detection accuracy.

There is unused potential in using images for the refinement of LiDAR based crown detection.

LiDAR-vegetation interactions (intensity, FW features, point patterns) are not yet fully known. Focus s.b. put in co-operation with physically-based RS specialists.

STRS can be combined with the area-based approach to help the cost-efficiency of the forest inventory; they should be seen as complementary.