Intensity signal in discrete-return LiDAR – Uses for it in vegetation RS

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What is a DR LiDAR system, essentially?

-TX Photons out (Medium).. Back-scattering.. (Medium).. Photons in (RX) ranging

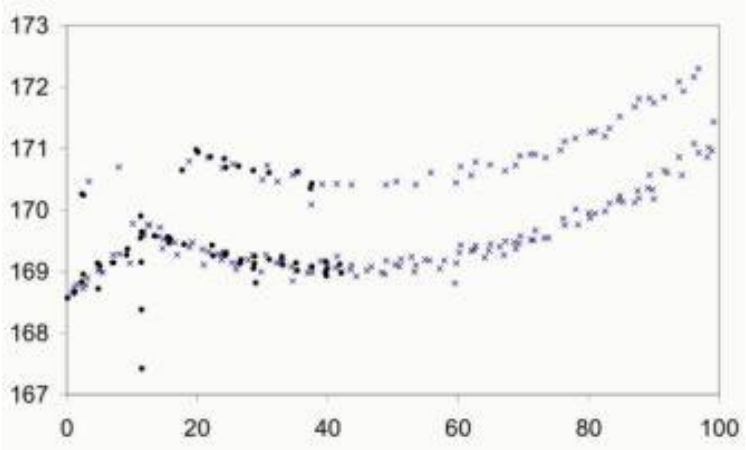
- Outgoing energy: λ, nanosecs, fluctuations, waveform, spreads, attenuates with **R**
- Incident at-target energy (photons/m2/sec)
- Backscattering event: type "surface" or "volumetric": reflectance (target wetness), spectral mixing, in footprint / depth > in volume > returning waveform, photons(t)
- Medium: 2-way transmission losses, sometimes dramatic (fog, clouds)
- RX: Aperture, Gain / amplification, fixed/varying, sampling rate, convolution / correlator (1-4 ranges),

OK, OK, but what is intensity?

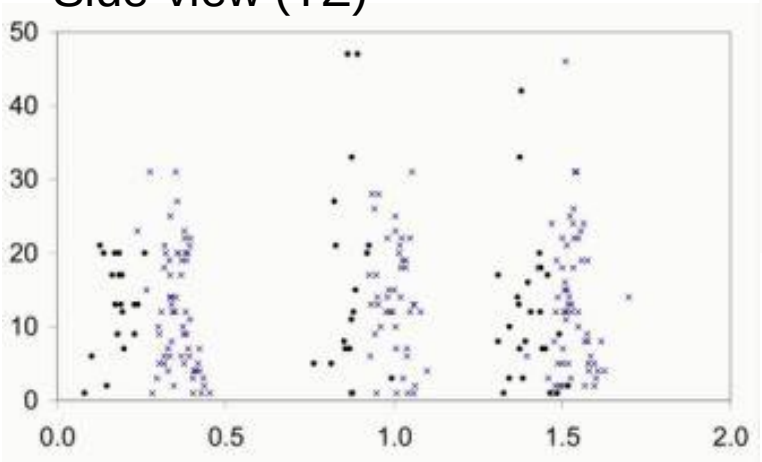
It is believed to correspond to waveform amplitude for the reflection associated with the range (and XYZ data). It is just a DN, and if measured with a linear system, it can possibly be used for reflectance measurements of well-defined surfaces.

A waveform system differs only in the waveform sampling phase. Ranging is not attempted but the backescattered photon-flux is measured at a high frequency.

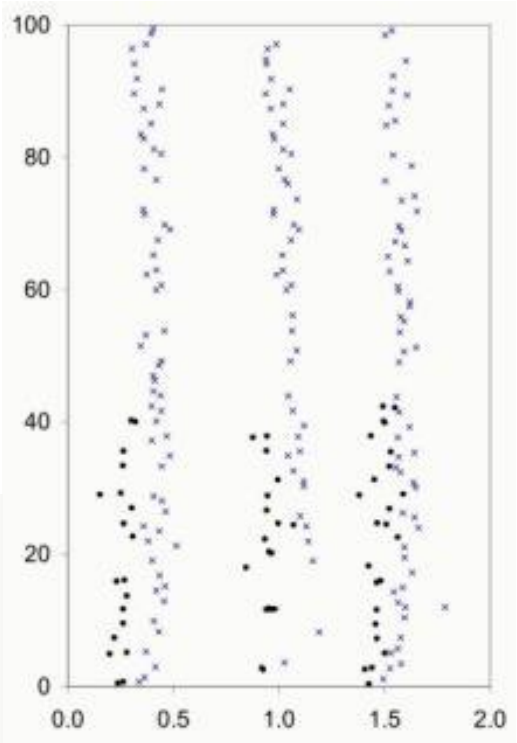
Intensity and target reflectance – Power line ex.



Side-view (YZ)

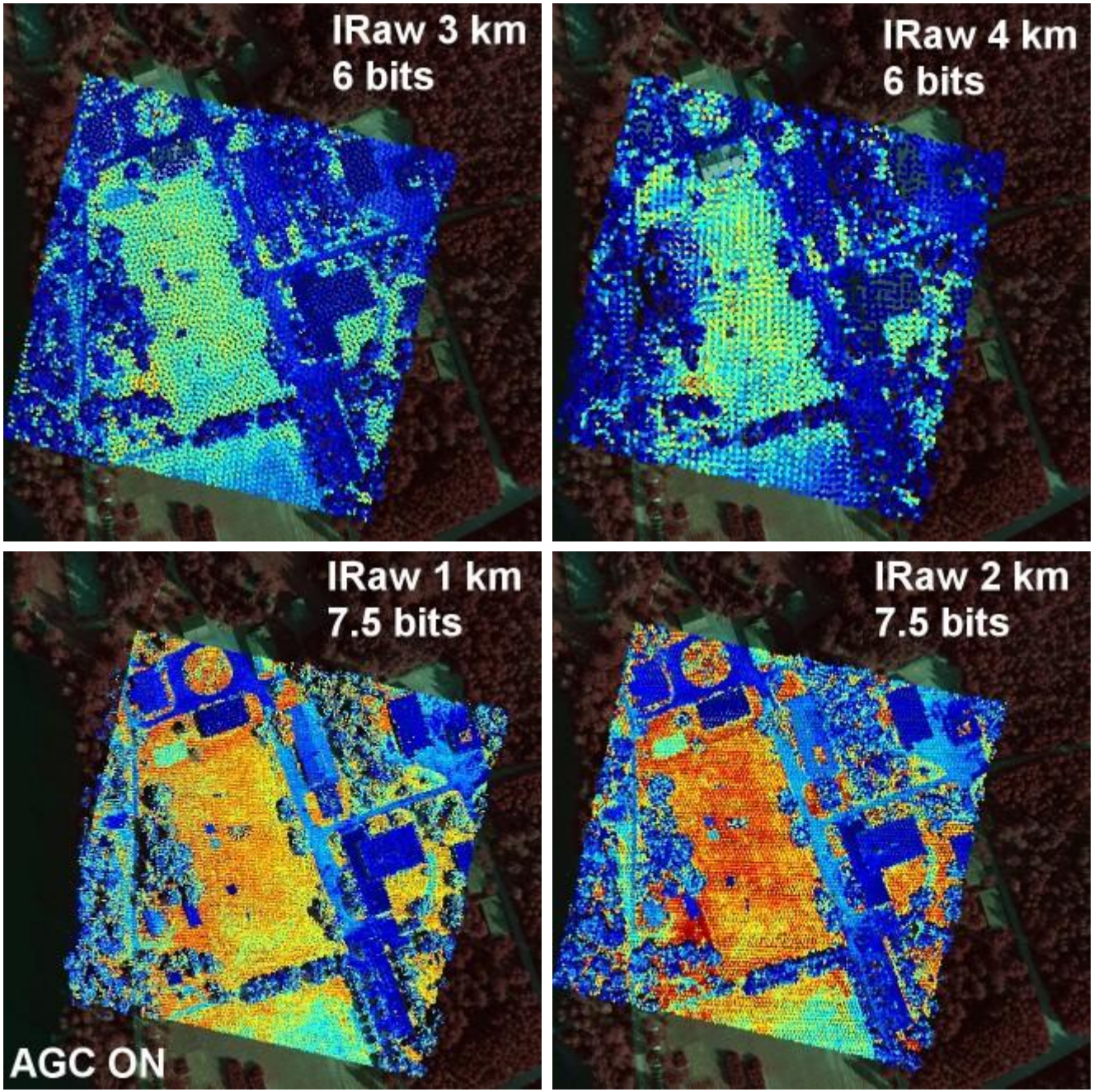


Squirrel-eye view (intensity)



Bird-eye view (XY)

=> For badly defined and small objects, intensity is noisy. Branches in trees are such objects.



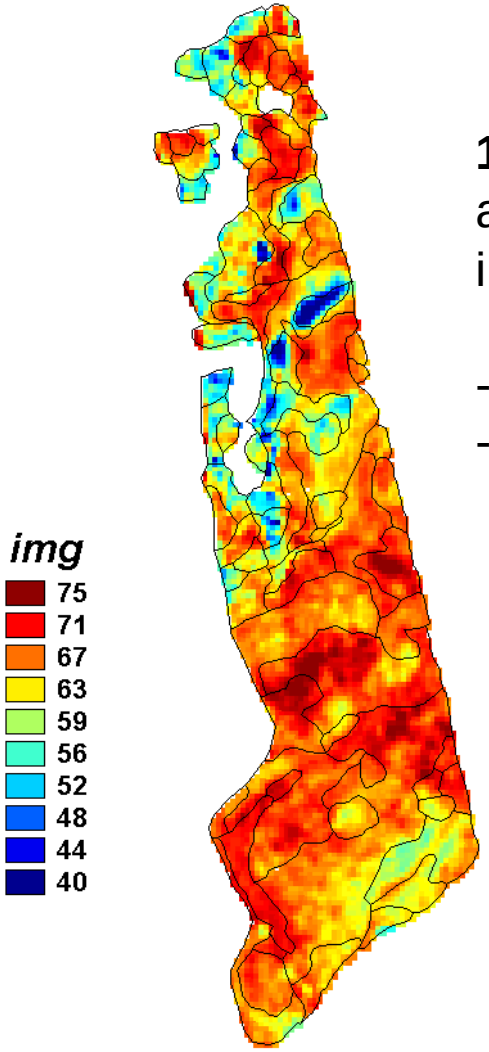
Incresing R, the SNR weakens

Spectral mixing increases

Sampling densities reduce

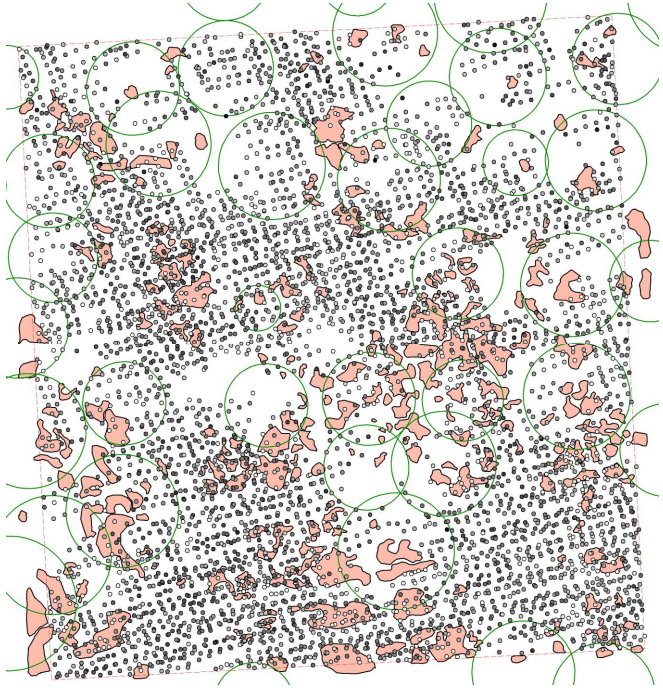
How to exploit the intensity data in DR LiDAR?

Some samples from recent research by Korpela et al.



1) Where's wet? Example shows how flark fens and wet hollows in Lakkasuo, Orivesi had a low intensity.

- Use first-return data only (transmission losses)
- Normalize for R; $I_{norm} = (R/Rref)^{a} \cdot I_{obs}$



1.1) Where's lichen? Example shows LiDAR hits with intensity and Lichen maps in 30x30-m area.

How to exploit the intensity data in DR LiDAR?

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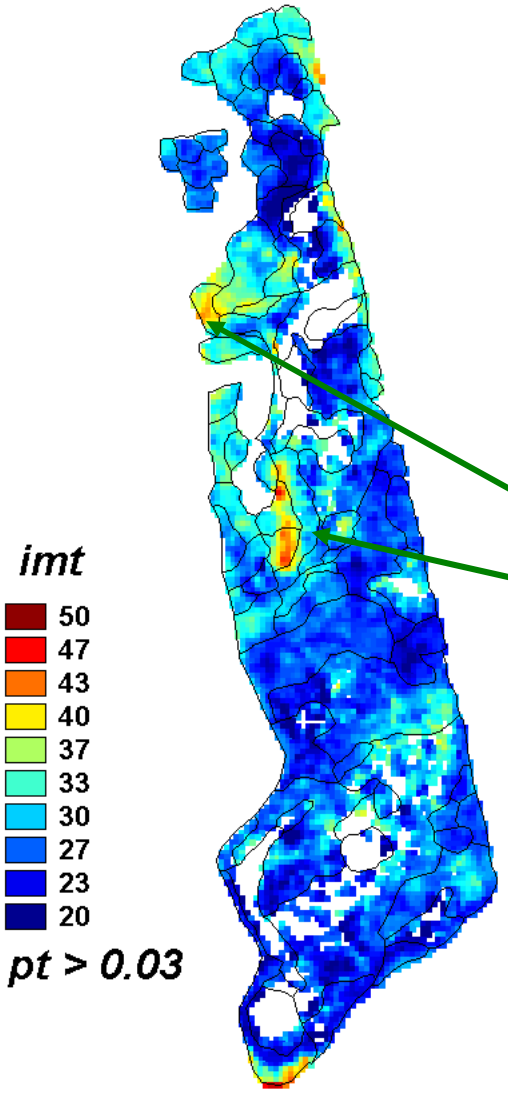


2) Where are the broadleaved trees and alders in particular? Example shows how Betulaceae trees in Lakkasuo, Orivesi had highest intensity.

- Use first-return data only (transmission losses)
- Normalize for R; $I_{norm} = (R/Rref)^{a} \cdot I_{obs}$
- Filter with H and I_{norm}

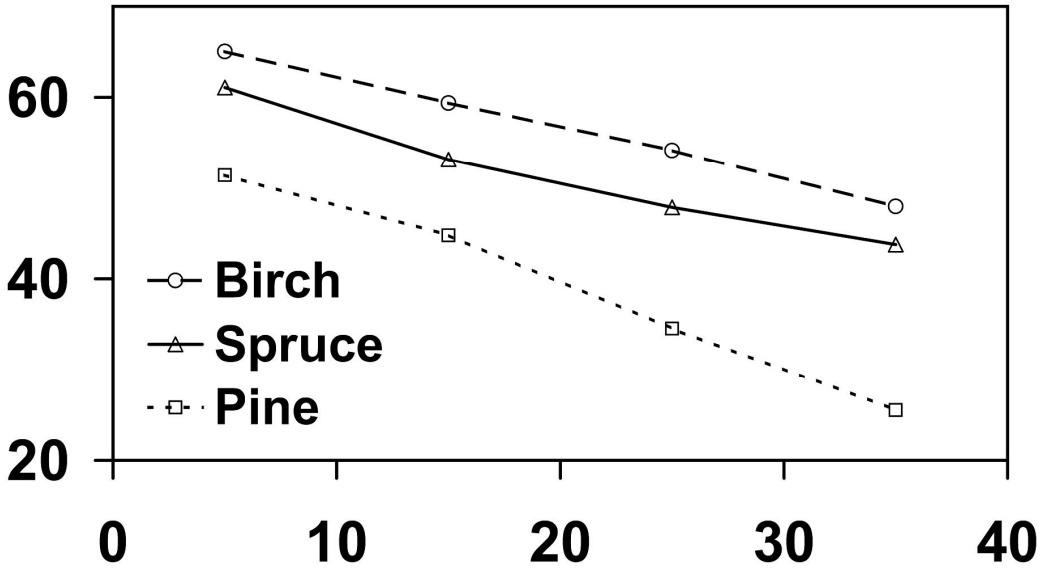
BETULACEAE in Lakkasuo

How to exploit the intensity data in DR LiDAR?

Some samples from recent research by Korpela et al.

3) What is the tree species?

- Separate only, first-of-many, and other echoes
  Use first-or-only
- Extract returns for each tree and divide them
  according to height layers > distributions (metrics)
- Estimate the absolute and relative size of each tree
- Plug all these in a machine learning algorithm



Vegetation intensity is affected by TARGET:

- silhouette area
- reflectance
- geometry

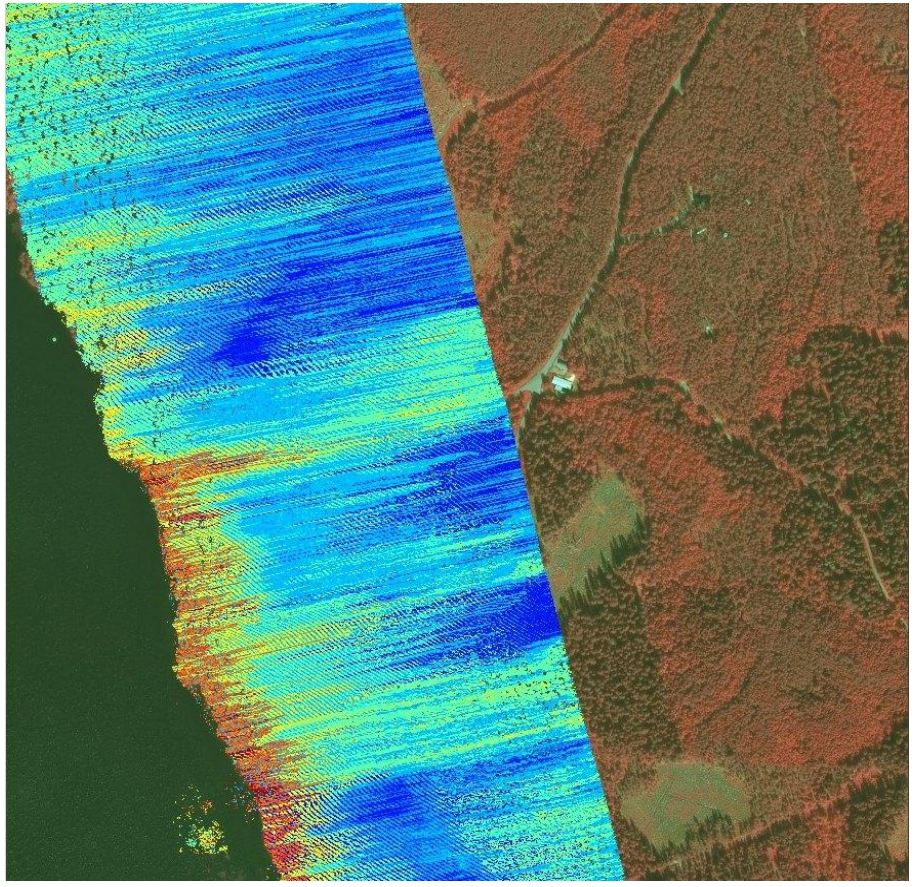
> High for spp?
> Low for spp?

How to exploit the intensity data in DR LiDAR?

Some samples from recent research by Korpela et al.

3) What is the tree species?

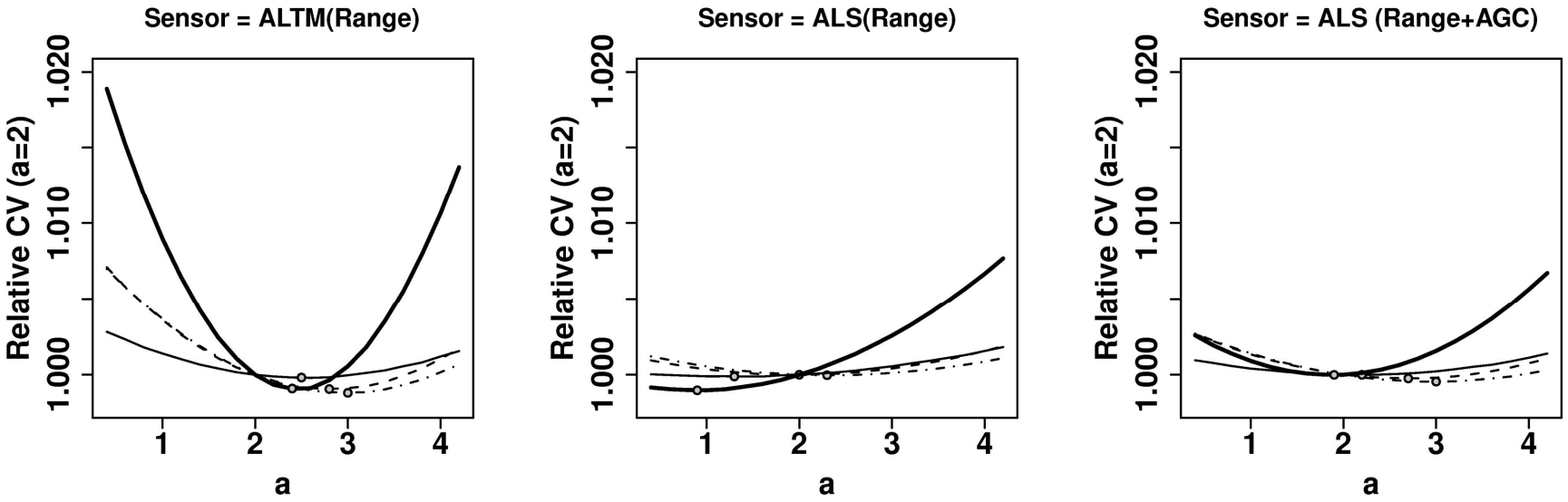
- Normalize for the **R**
- If using als50/als60; normalize for the **AGC**



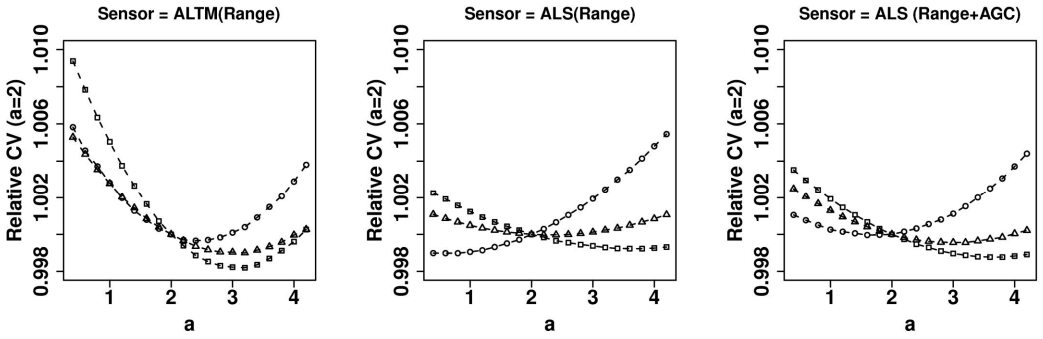
What is the range normalization coefficient / factor?

$I = (R/Rref)^a \cdot I_{Raw}$

Theory says *a* is “from 2…4”.

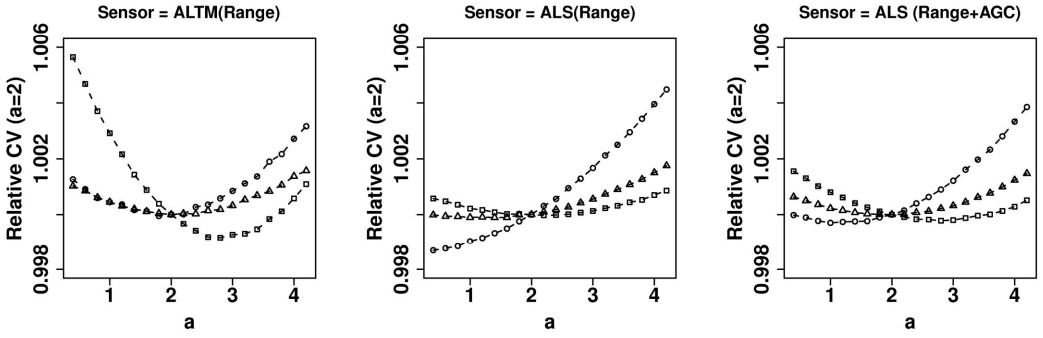


Optimal a depends on echo type.

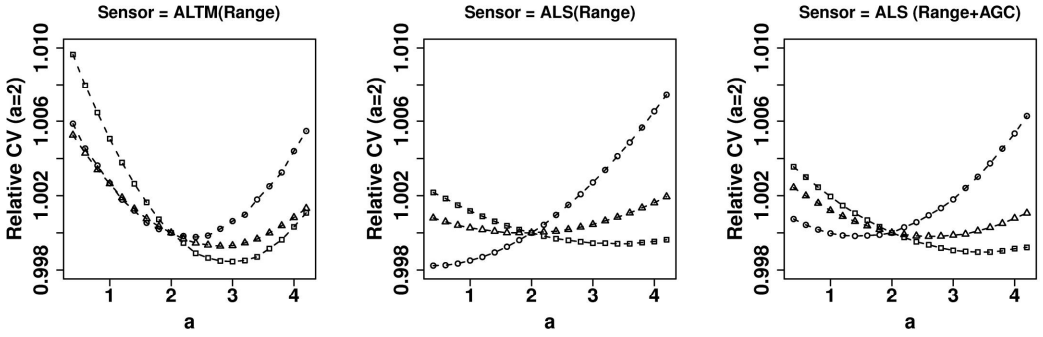


All

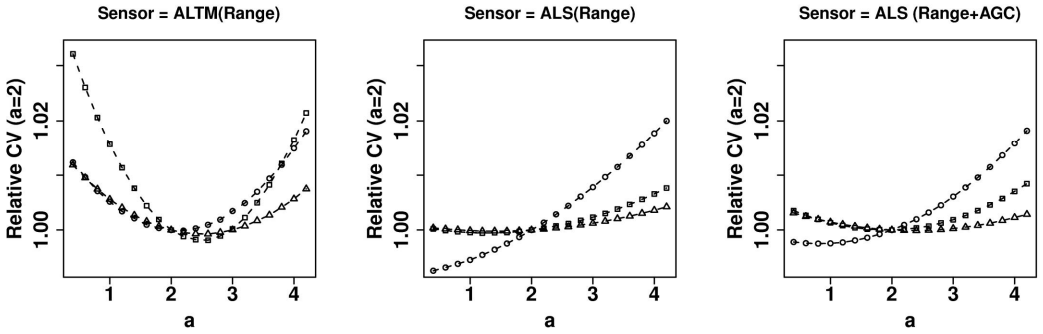
Pine>Spruce>Birch



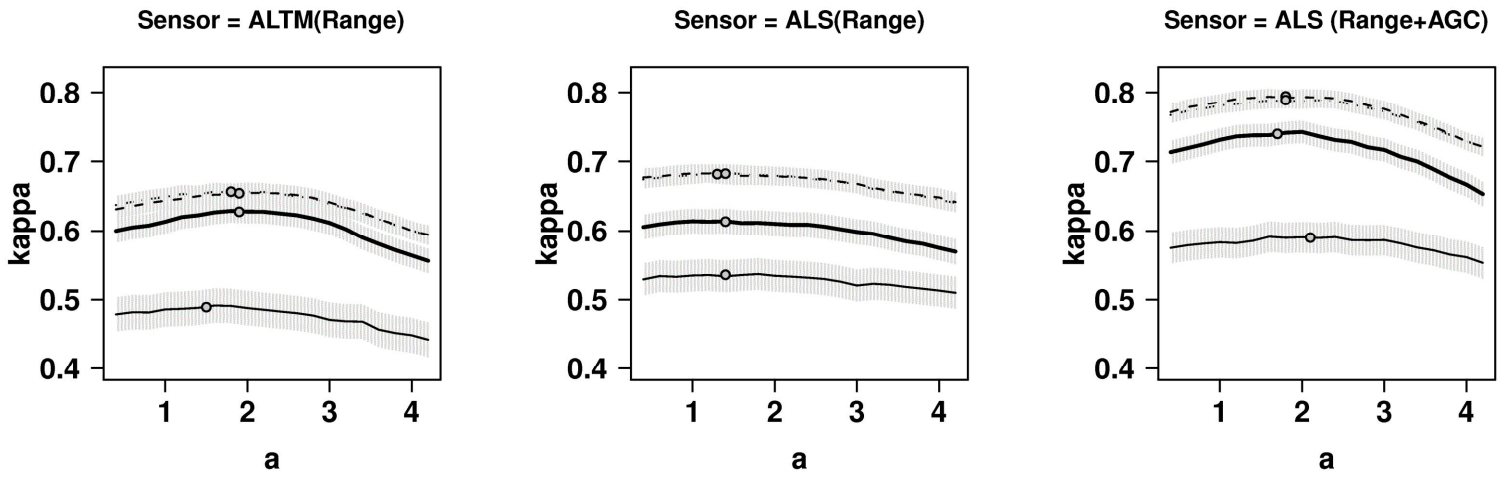
First



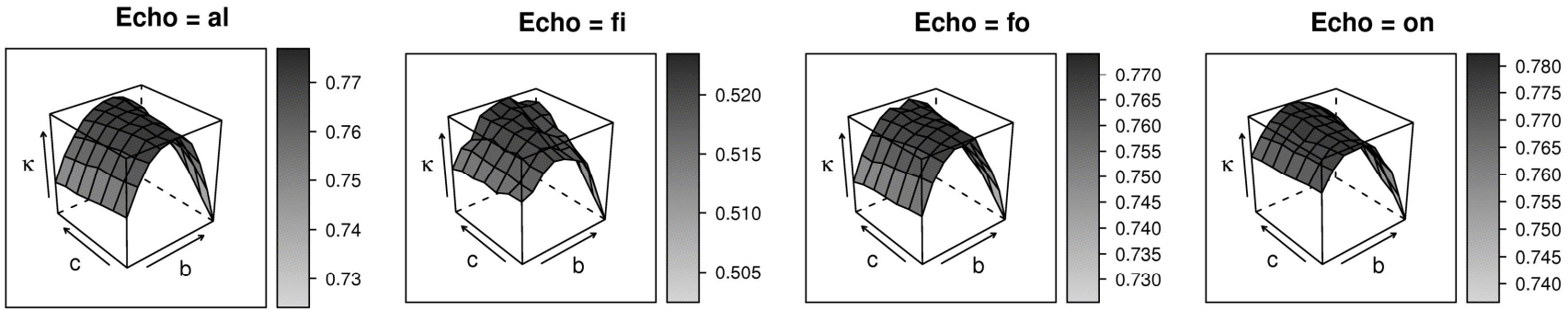
First-or-only



Only



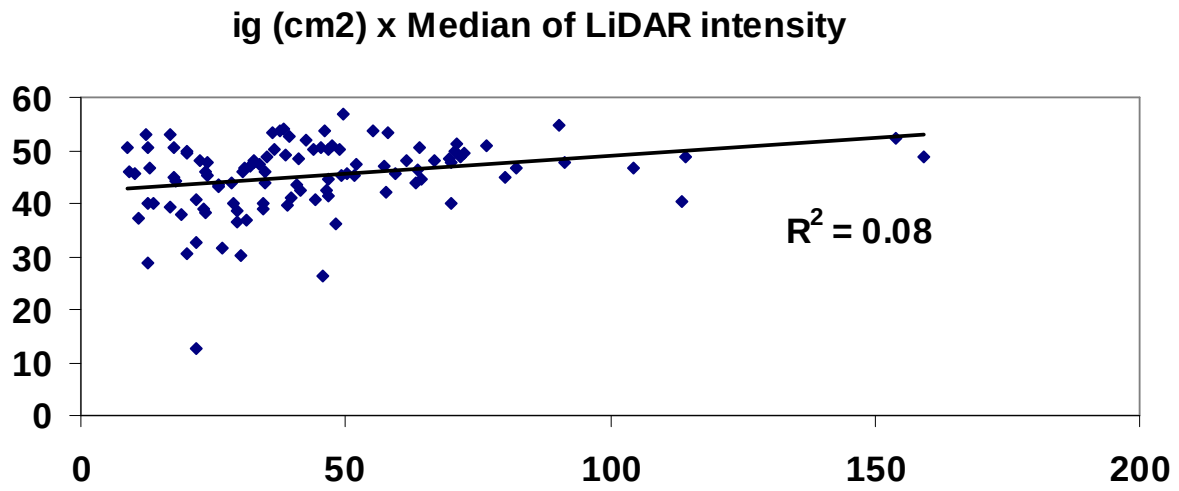
Optimal a in classification is different from the physical optimum

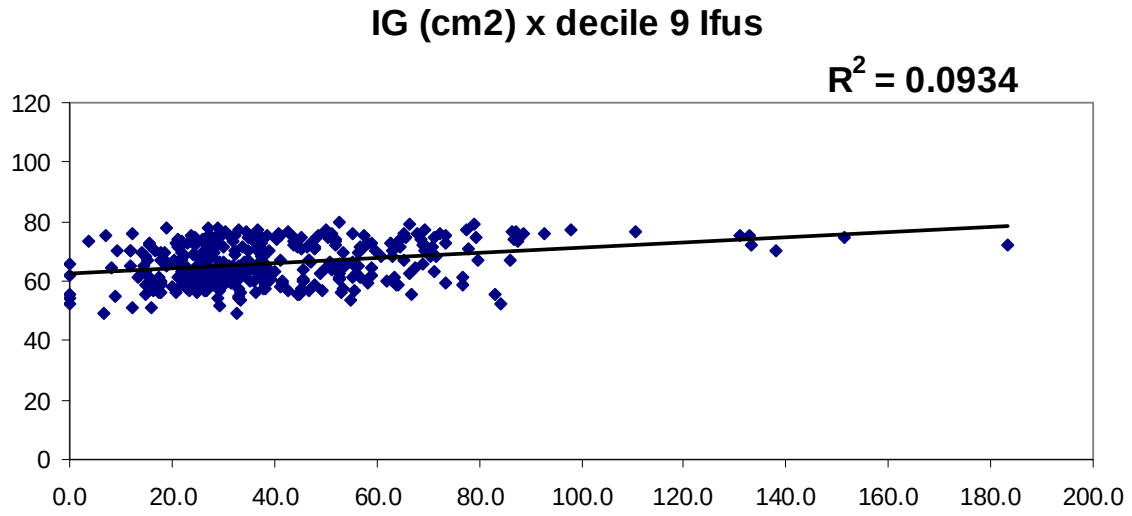


AGC optimization in als50-ii / als60 sensor (two parameters)

What else is “intensity measuring” in a tree

If intensity measures silhouette area, could it be used for estimating per-tree foliage?





Conclusions

Intensity measures silhouette area, geometry and reflectance of vegetation; simultaneously

In FW-data, we have, in addition to amplitude, also the width and symmetry of the echo to characterize the pulse-vegetation interaction. We can expect to have these in future DR-systems.

Normalizing for the R (altm-sensors) and RX-settings (als#0 sensors) is important, a gain of 2-8% was achieved in sp-detection accuracy (80->90%). Some sensors have built-in R-correction with a=?

Intensity is noisy, thus we need a lot of pulses per target, and a good target delineation (segmentation).

To use intensity in area-based forest inventory? LAI -> quantitative timber statistics? SP-proportions – I doubt (“non-bijective dependencies”).