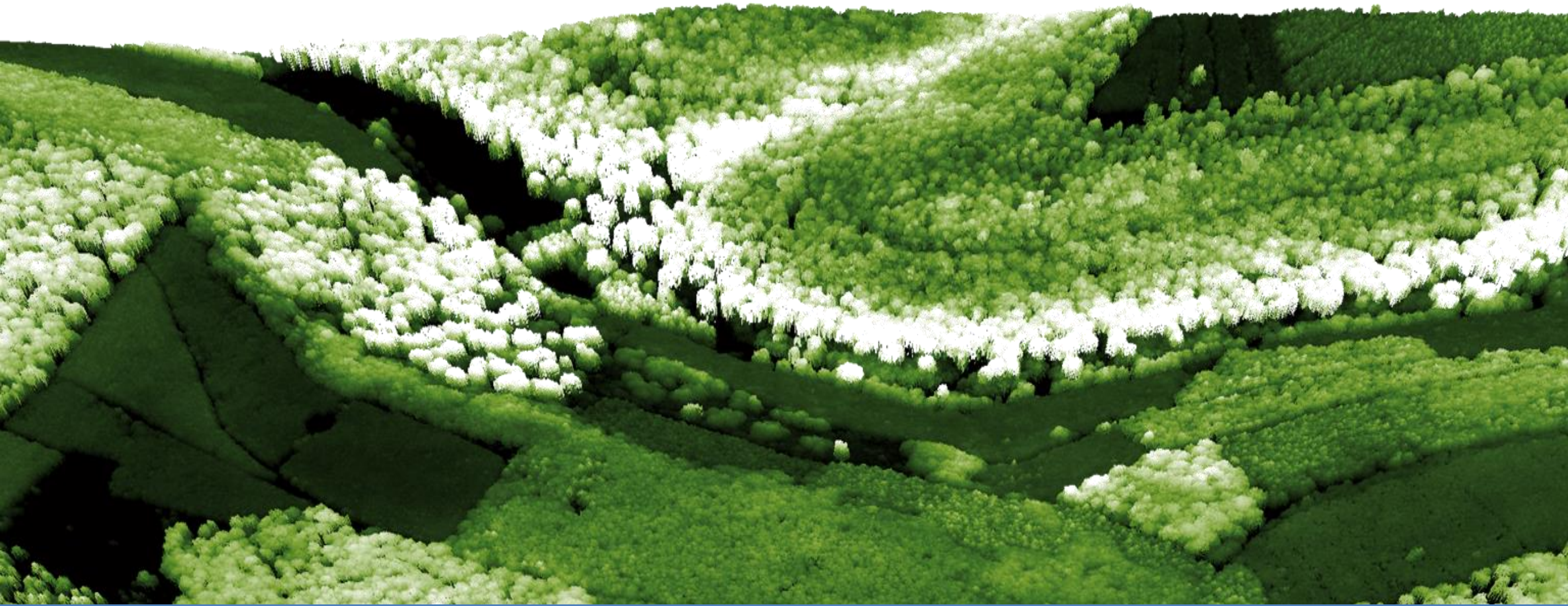

Derivation of Structural Forest Parameters from the Fusion of Airborne Hyperspectral and Laserscanning Data

International Workshop
3D Vegetation Mapping using Advanced Remote Sensing - Implications for Seamless Modeling of Terrestrial Ecosystems

24 – 26 September 2014, St.Oswald, Germany

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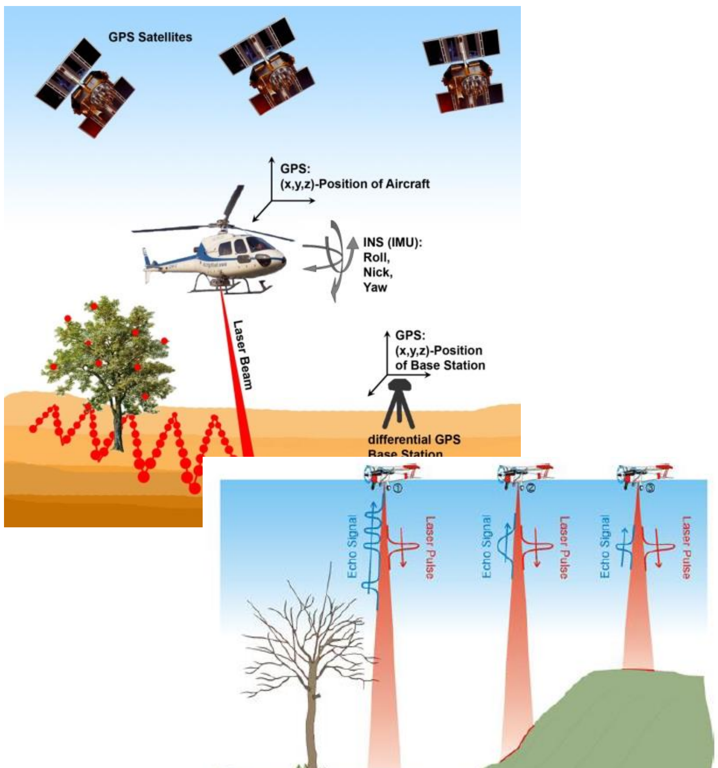
Airborne Laser Scanning & Imaging Spectroscopy

Airborne Laser Scanning

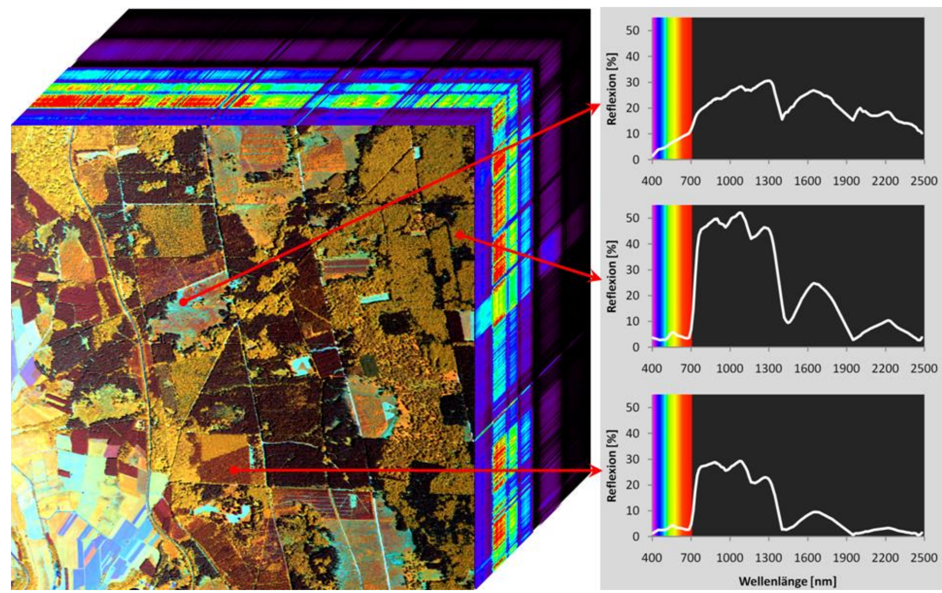
- Active Remote Sensing technique that measures three-dimensional structure



Source: Hug et al. 2004

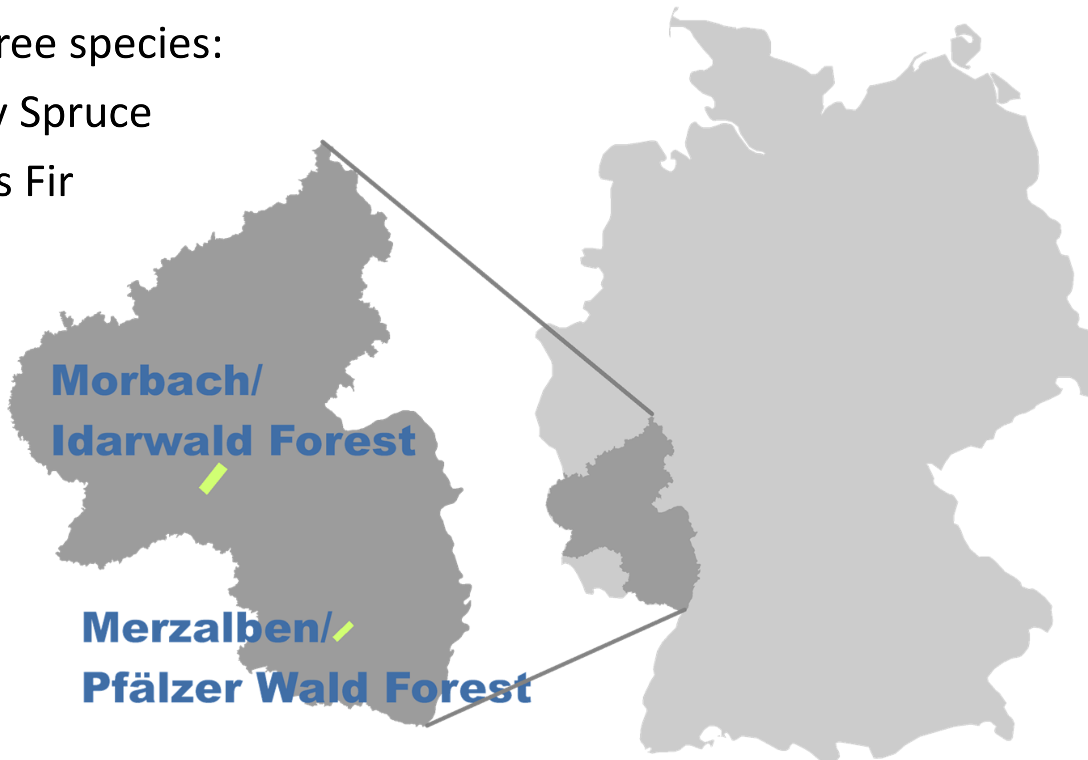
Imaging Spectroscopy

- Also known as Hyperspectral Remote Sensing
- A full reflectance spectrum is measured in each pixel of the image
- Passive technique that measures the surface



Areas of study

- Idarwald forest near Morbach
- Pfälzerwald forest near Kaiserslautern
- Managed forests
- Dominant tree species:
  - Norway Spruce
  - Douglas Fir
  - Beech
  - Oak



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Datasets

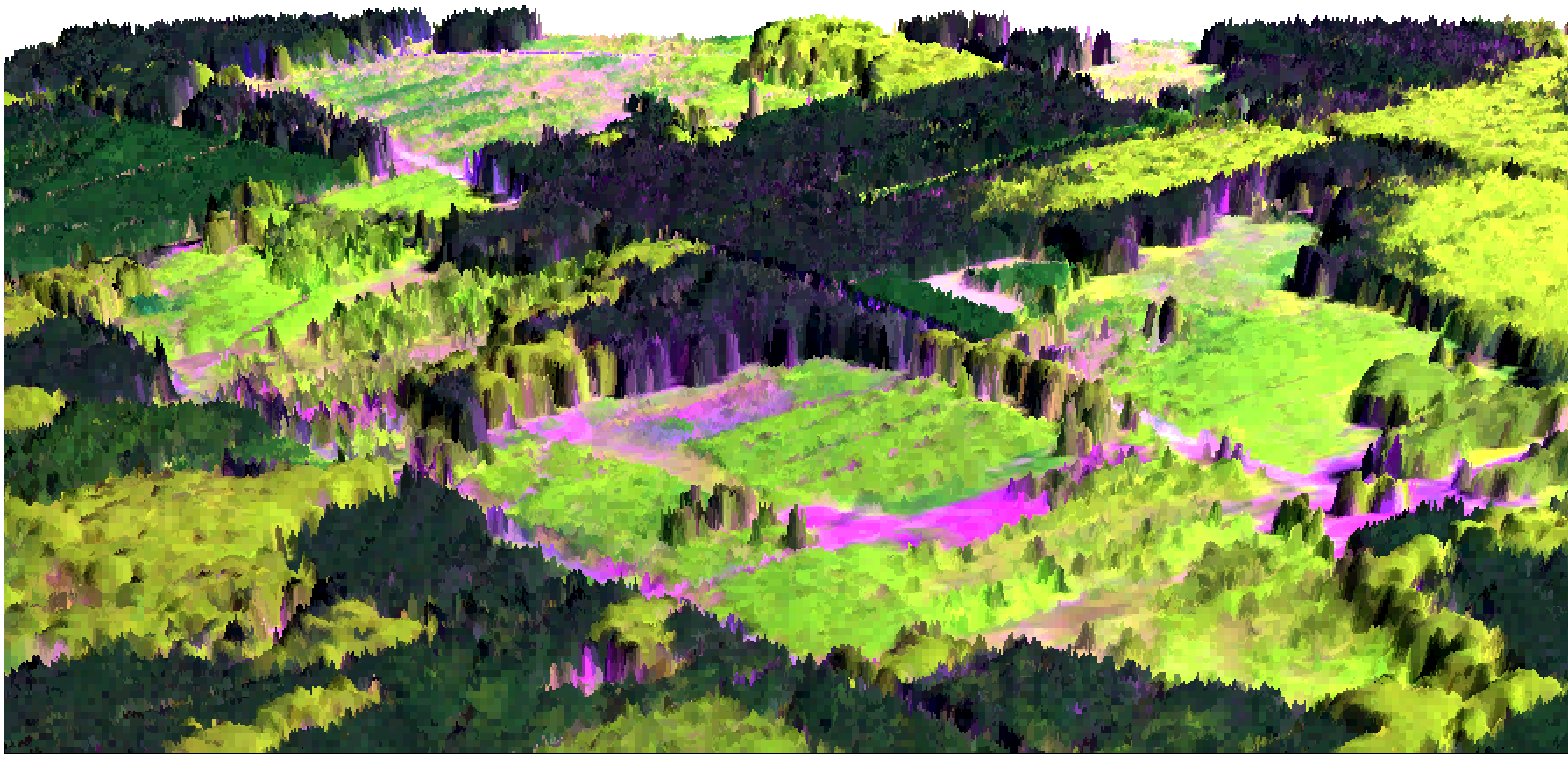
	Idarwald	Pfälzerwald
Imaging Spectroscopy Data (125 bands, 420-2450 nm, 5m GSD)	*HyMap:* **2003**	*HyMap*: **2009**
Waveform Laserscanning Data	Riegl LiteMapper 5600: **2005**	Optech ALTM 3100: **2009**


Riegl LiteMapper 5600

Hyvista HyMap
Hyperspectral Mapper

Combination of image and ALS data

One way of combining passive image data and ALS data is to project the image data on a Lidar-generated height model



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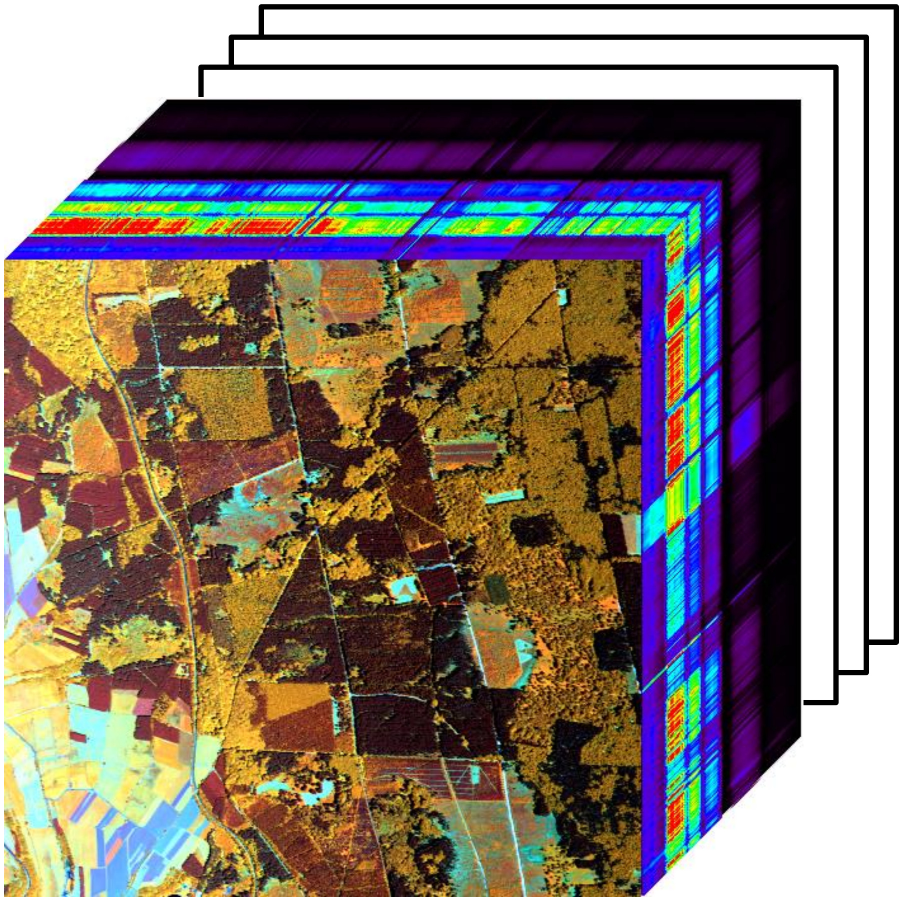
Combination of image and ALS data



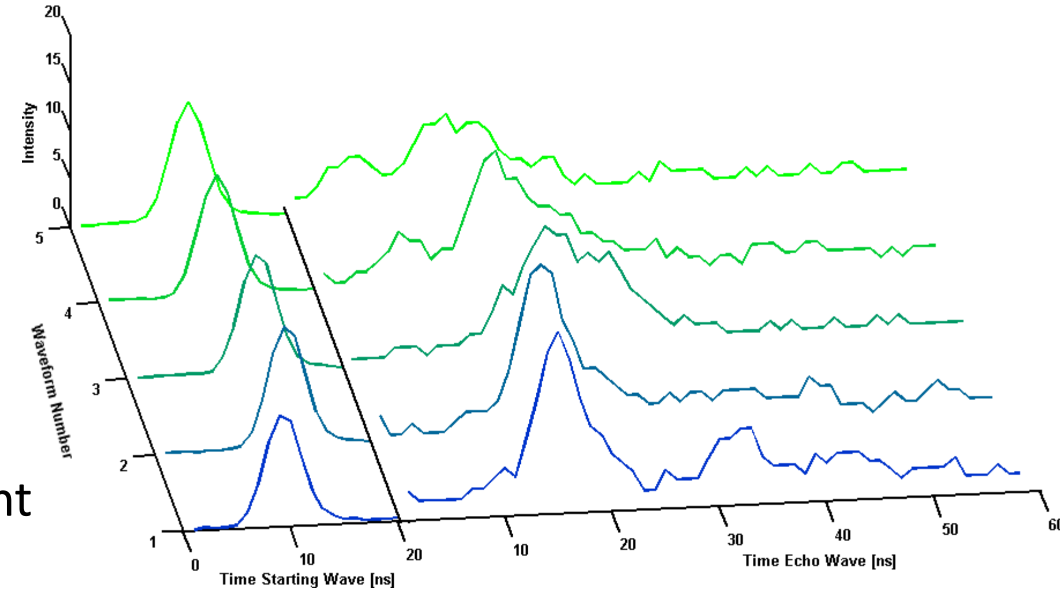
Another possibility is to add LiDAR-derived products like tree height or crown base height or percentile height bands.

But we wanted to use the full waveform data, not just a collection of bands.

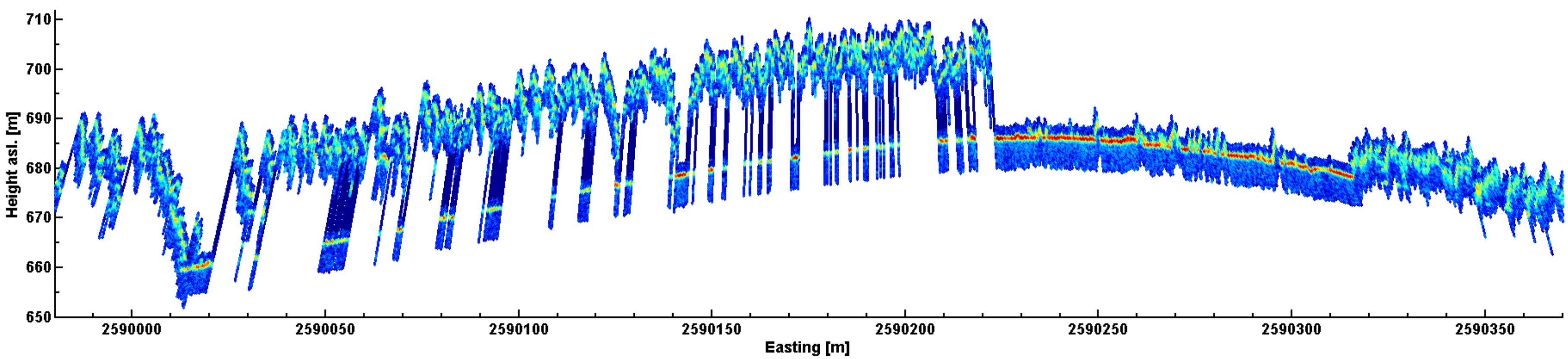
Full Waveform Data

The LiDAR sensors record the full waveforms of the echoes:

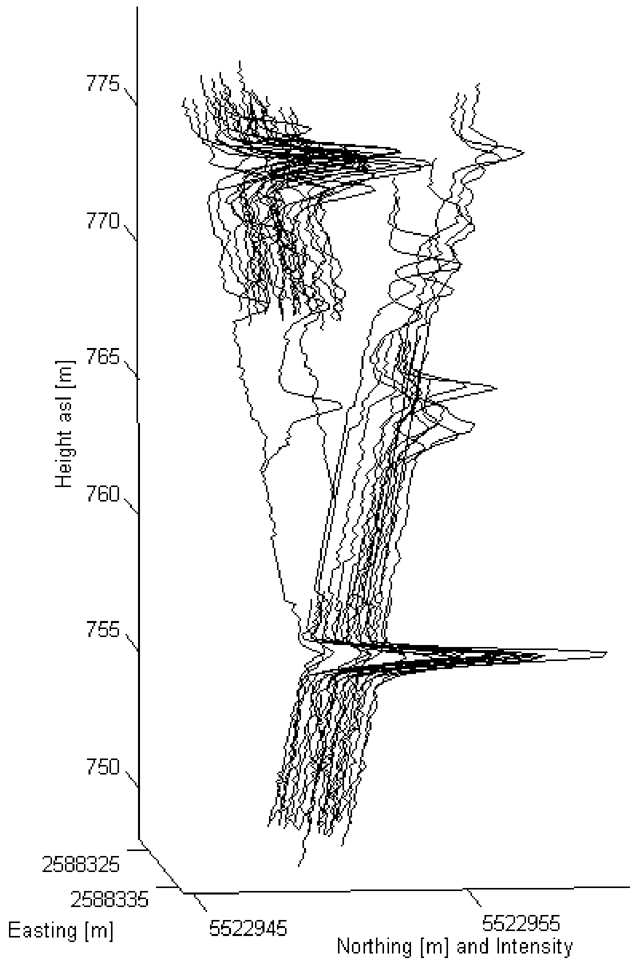
We get a vertical intensity profile for each laser pulse.



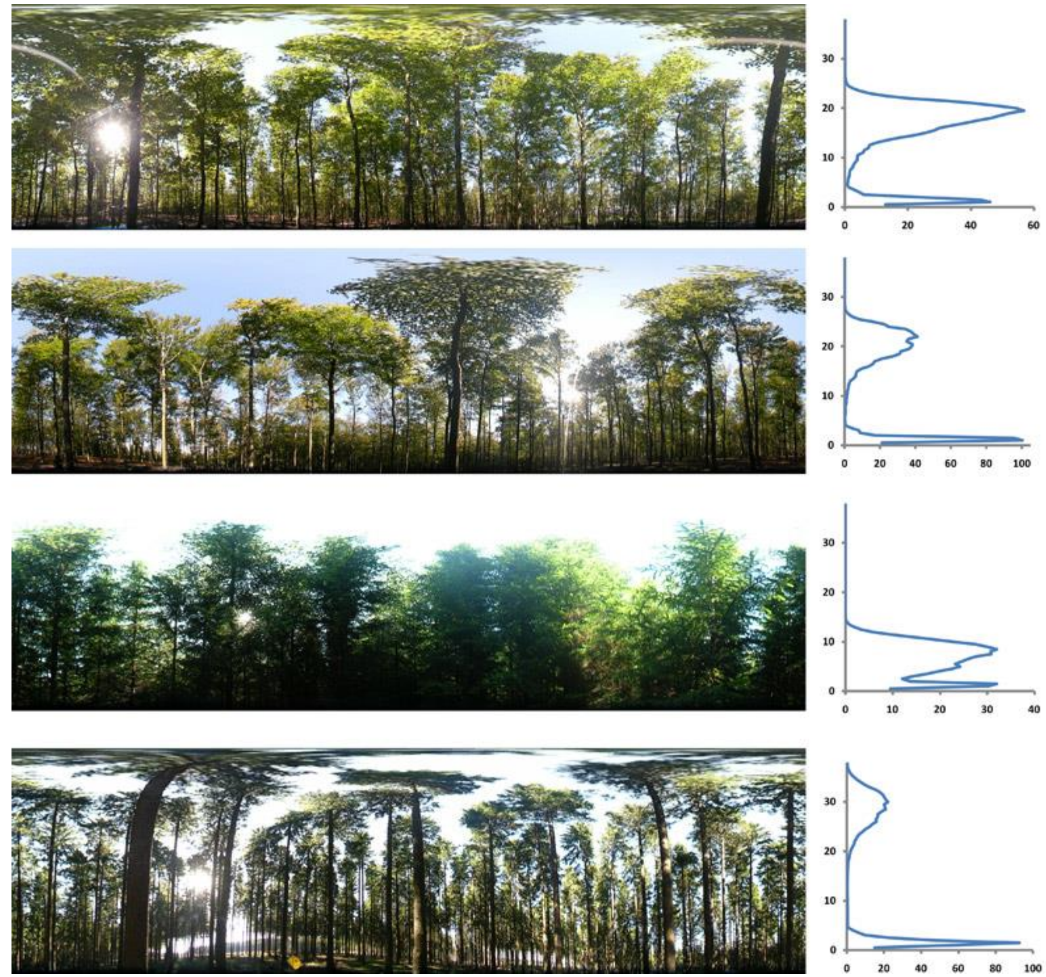
→ Full waveform, small footprint airborne Laser scanning data



From Waveforms to Voxels



All waves that converge on a small area.



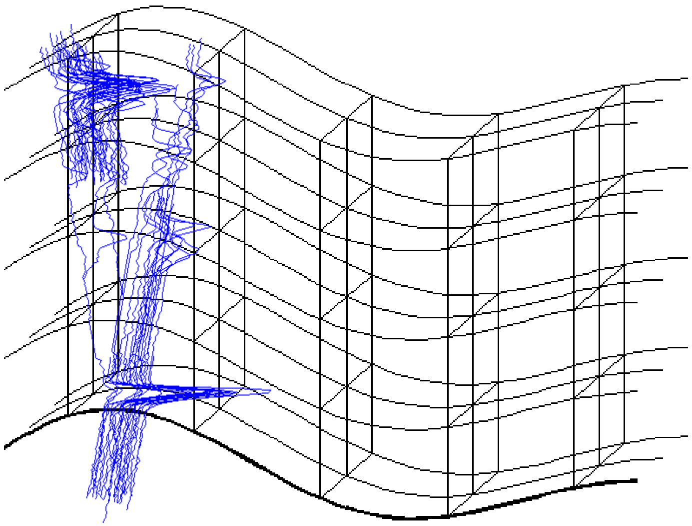
Mean waveforms in different stand types

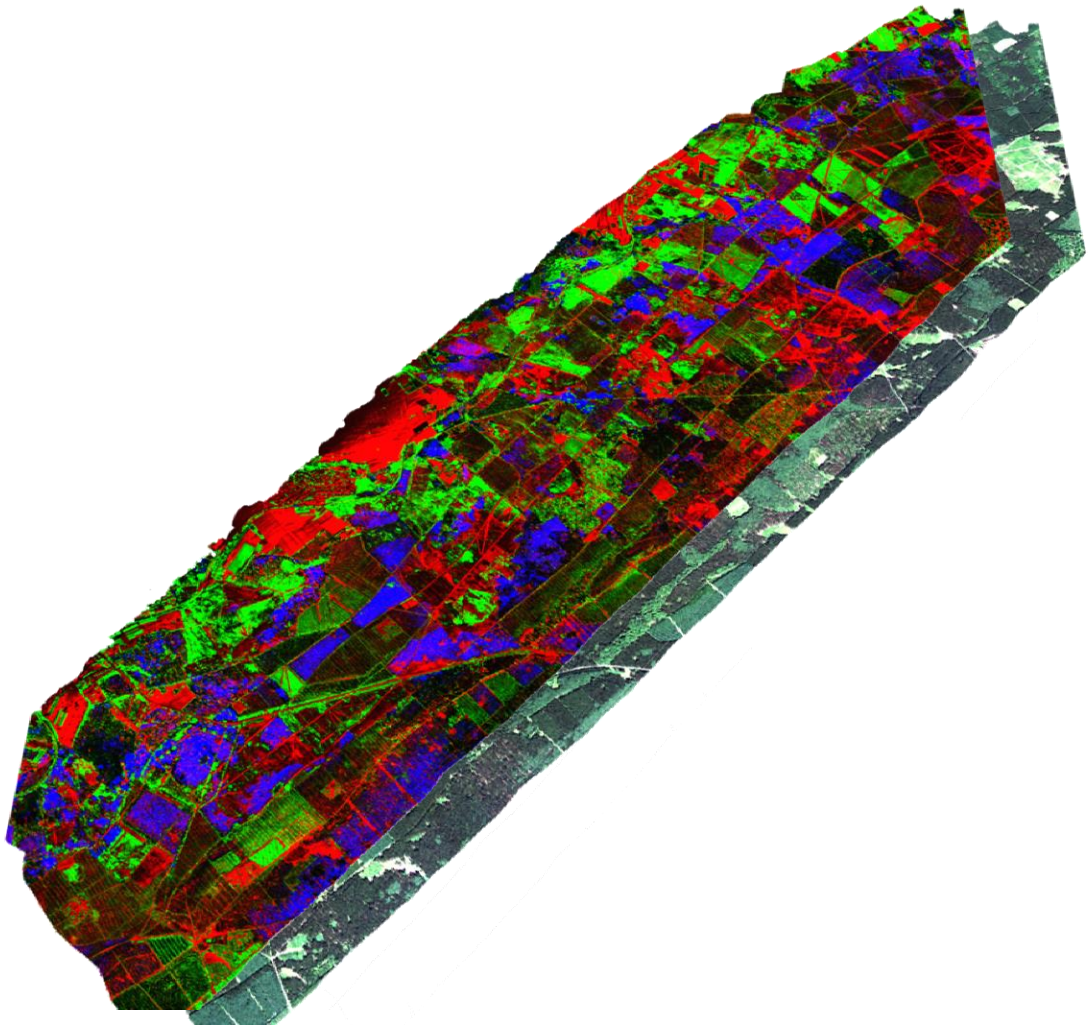
From Waveforms to Voxels

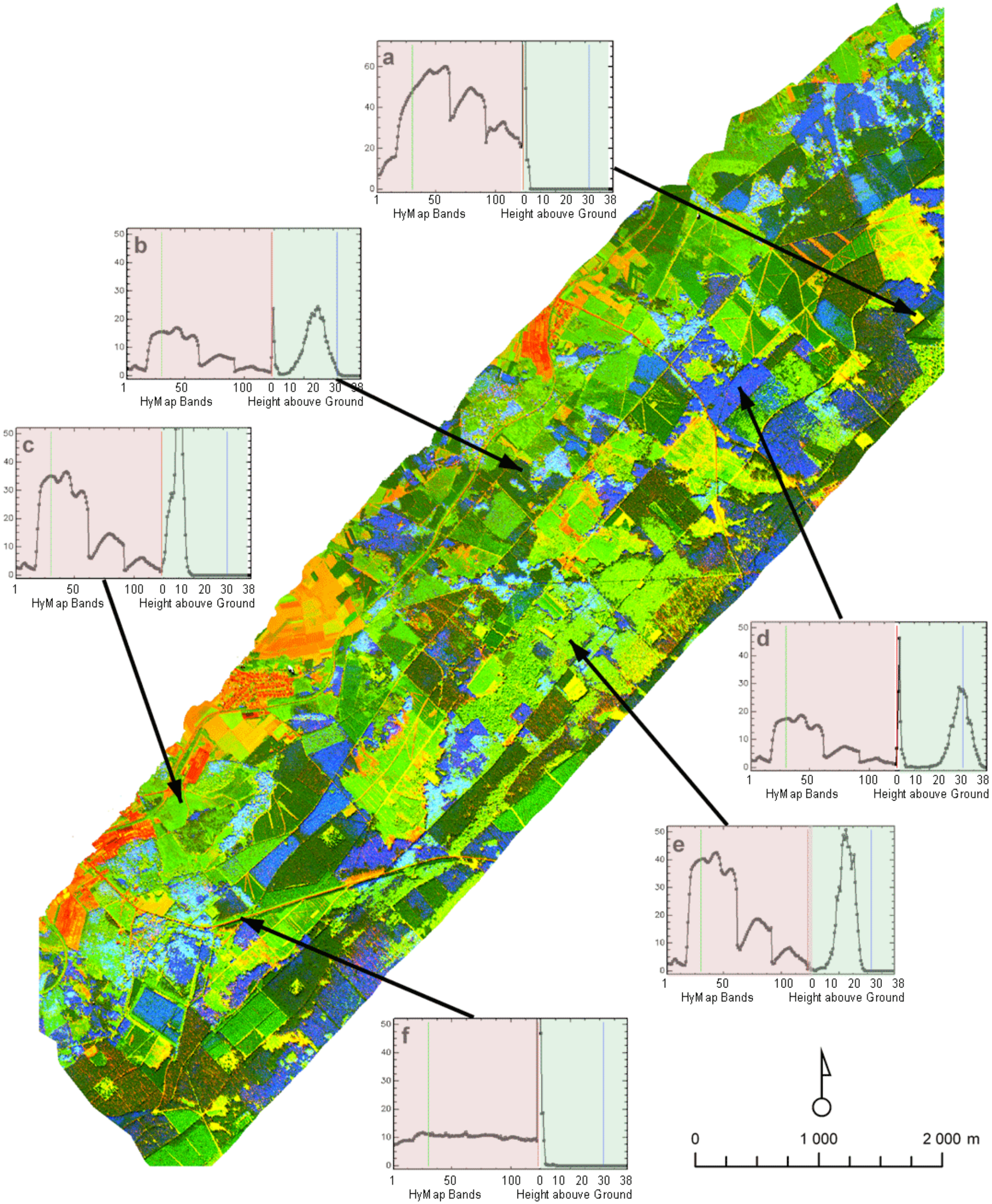
A mesh of Voxels atop each HyMap pixel was defined.

Each Voxel is 5 m × 5 m × 0.5 m

The Voxels get filled with the mean Lidar Intensity





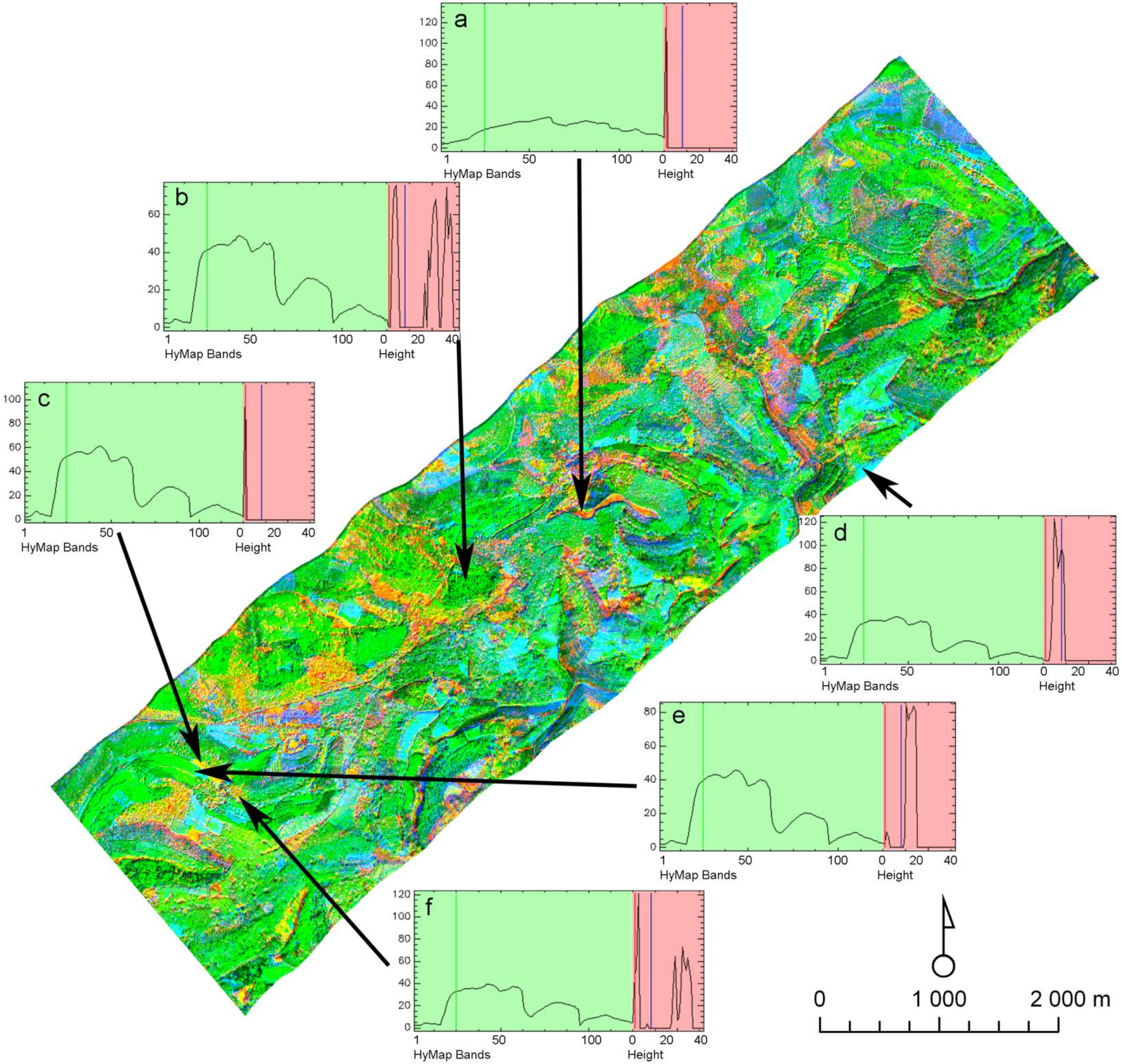


Idarwald Forest

122 Hymap bands combined with 76 fullwave LiDAR bands.

Combined spectra show reflectance properties and stand structure.

Forest stands with nearly identical reflectance spectra can be discriminated (b-d and c-e).



Pfälzerwald Forest:

125 HyMap bands combined with 40 LiDAR waveform bands

(1 m vertical resolution)

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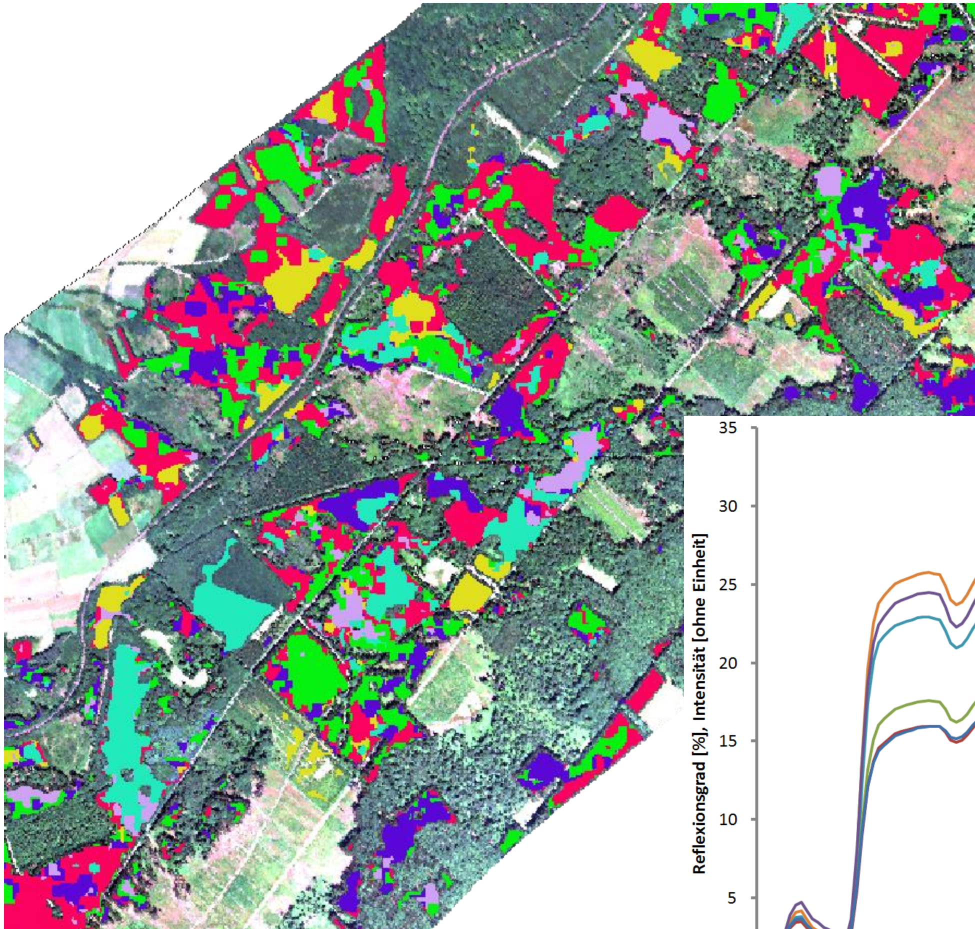
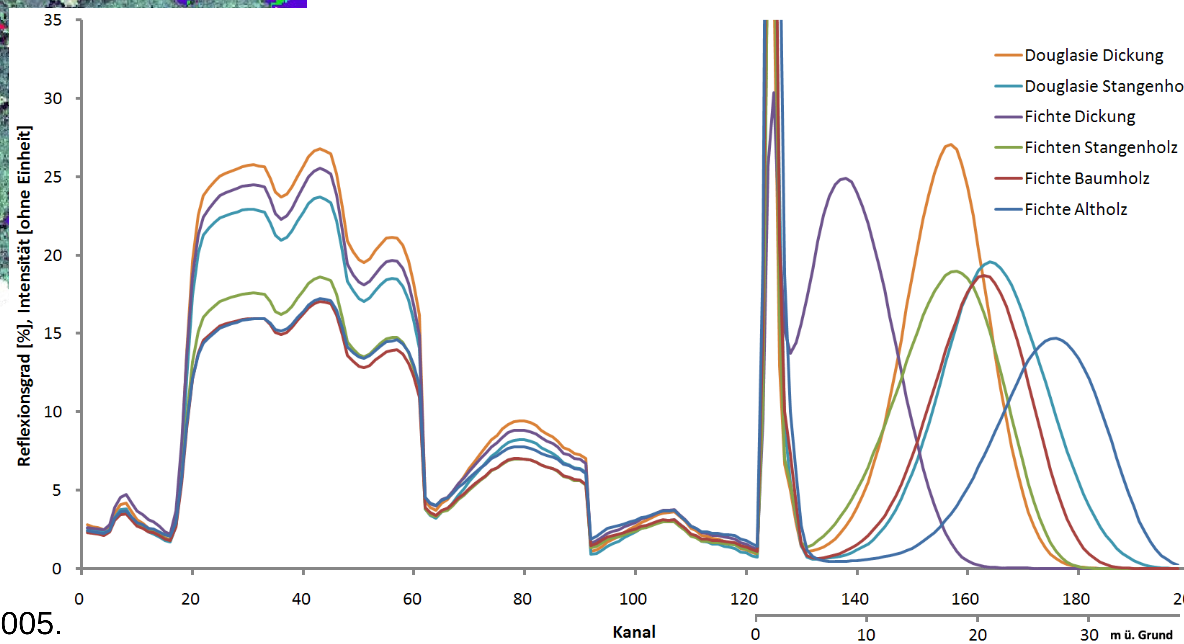
Applications: Classification

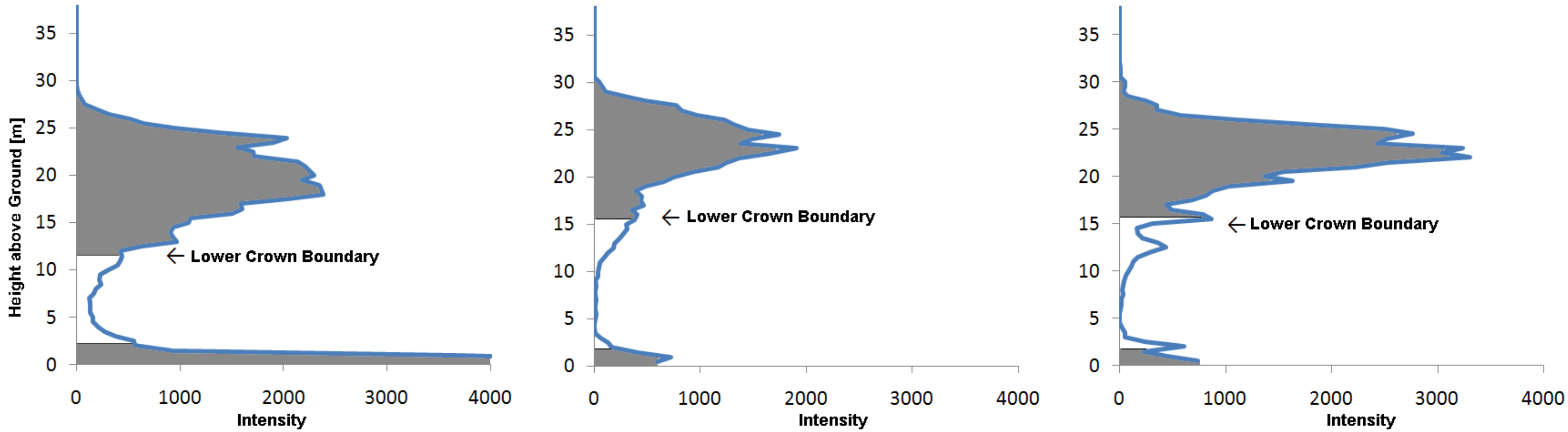


A better discrimination between similar classes (coniferous trees):
4 age classes of Norway spruce
2 age classes of Douglas fir

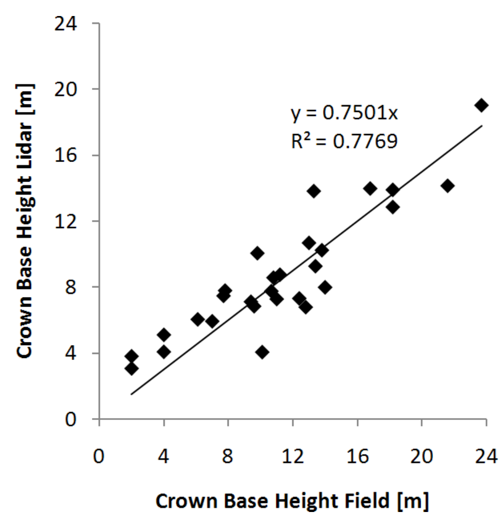


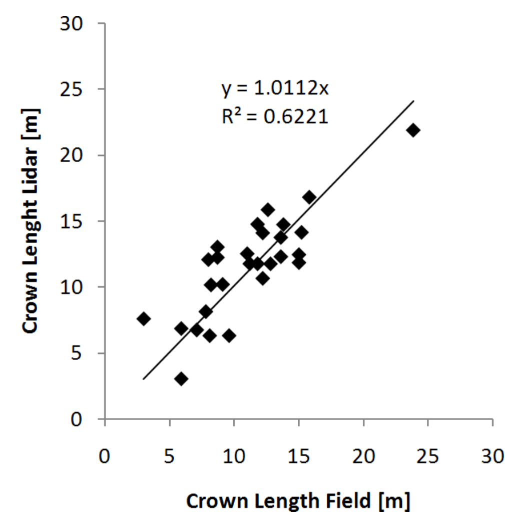
See also Buddenbaum, Schlerf & Hill, IJRS 26, 2005.

Applications: ALS-based estimation of forest structure

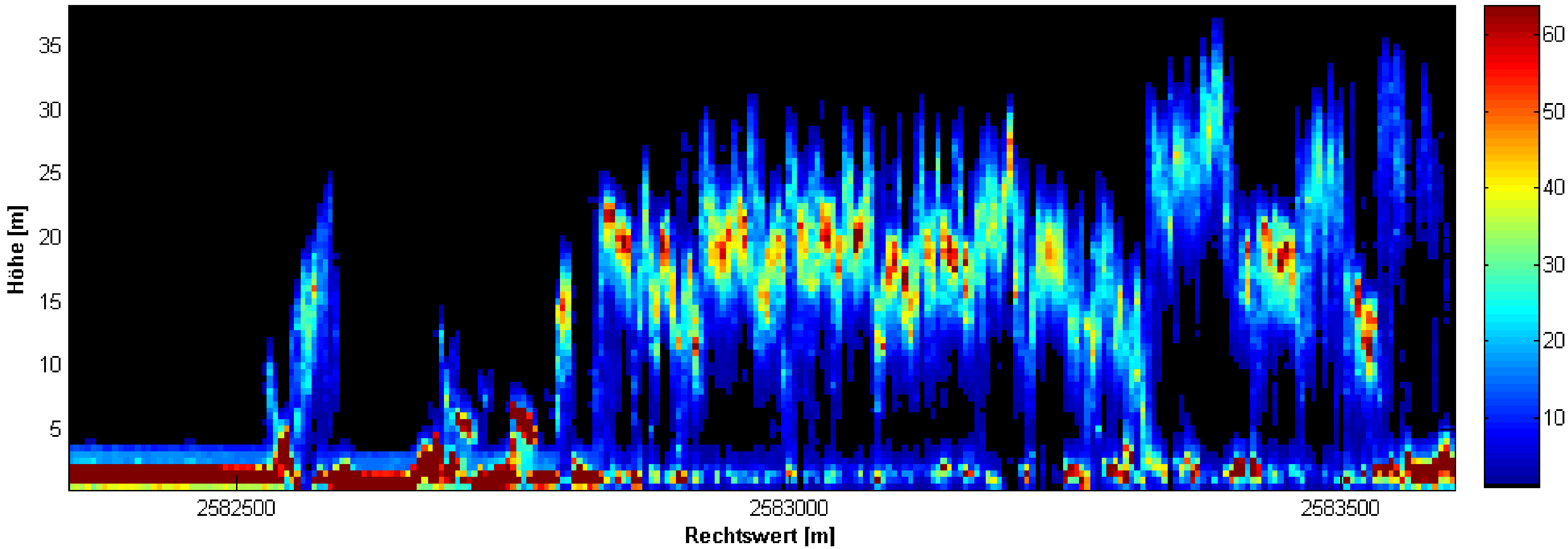


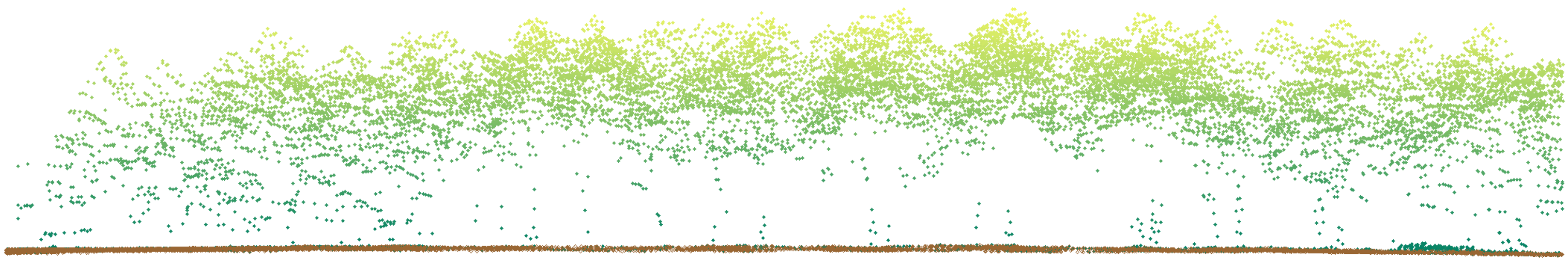
- We can estimate tree height, crown closure and stem density using single-pulse Lidar
- Other structure parameters like crown base height and number of crown layers benefit from full waveform data





Applications: Vertical Slices through ALS data





Applications: Horizontal Slices through ALS data

Ground

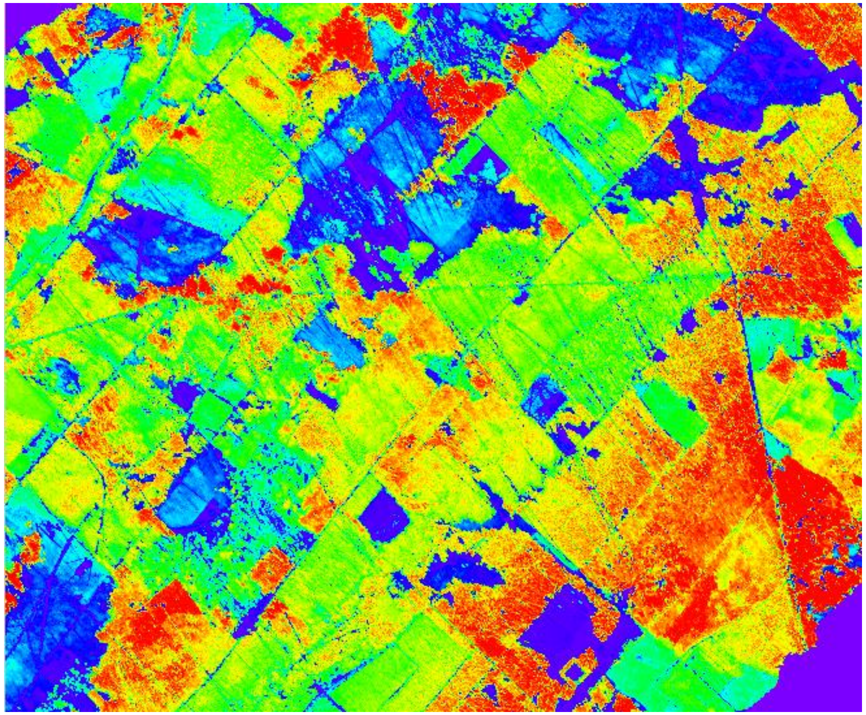
10 m above ground

20 m above ground

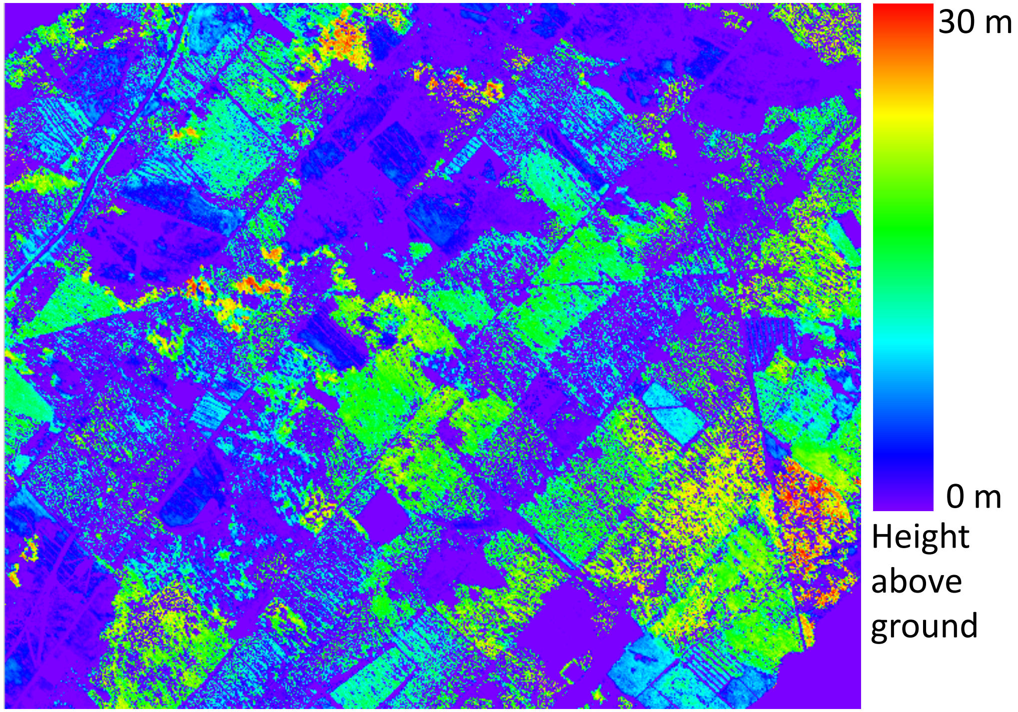
30 m above ground

38 m above ground

Applications: Percentile Images



90th percentile



20th percentile

Lidar percentiles have been used for the estimation of biomass, timber volume etc.

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Conclusions

- Combining IS and ALS data (passive and active remote sensing) increases the dimensionality without adding much redundancy.
- Vertical intensity profiles from several small-footprint waveforms correspond to large-footprint waveforms of the pixel size.
- Valuable as
  - classification input
  - detailed description of the stand
  - physically-based derivation of structural parameters like crown base height and crown length.
- Single waveform profiles are rather noisy, composite waveforms show the vertical crown extent well

Further Reading

- **Torabzadeh, H., Morsdorf, F., & Schaepman, M.E.** (2014):
  Fusion of imaging spectroscopy and airborne laser scanning data for characterization of forest ecosystems – A review.
  ISPRS Journal of Photogrammetry and Remote Sensing, 97, 25-35
- **Buddenbaum, H., Seeling, S., & Hill, J.** (2013):
  Fusion of full-waveform lidar and imaging spectroscopy remote sensing data for the characterization of forest stands.
  International Journal of Remote Sensing, 34, 4511-4524
- **Latifi, H., Fassnacht, F., & Koch, B.** (2012):
  Forest structure modeling with combined airborne hyperspectral and LiDAR data.
  Remote Sensing of Environment, 121, 10-25
- **Anderson, J.E., Plourde, L.C., Martin, M.E., Braswell, B.H., Smith, M.-L., Dubayah, R.O., Hofton, M.A., & Blair, J.B.** (2008):
  Integrating waveform Lidar with hyperspectral imagery for inventory of a northern temperate forest.
  Remote Sensing of Environment, 112, 1856-1870

Thanks for your Attention

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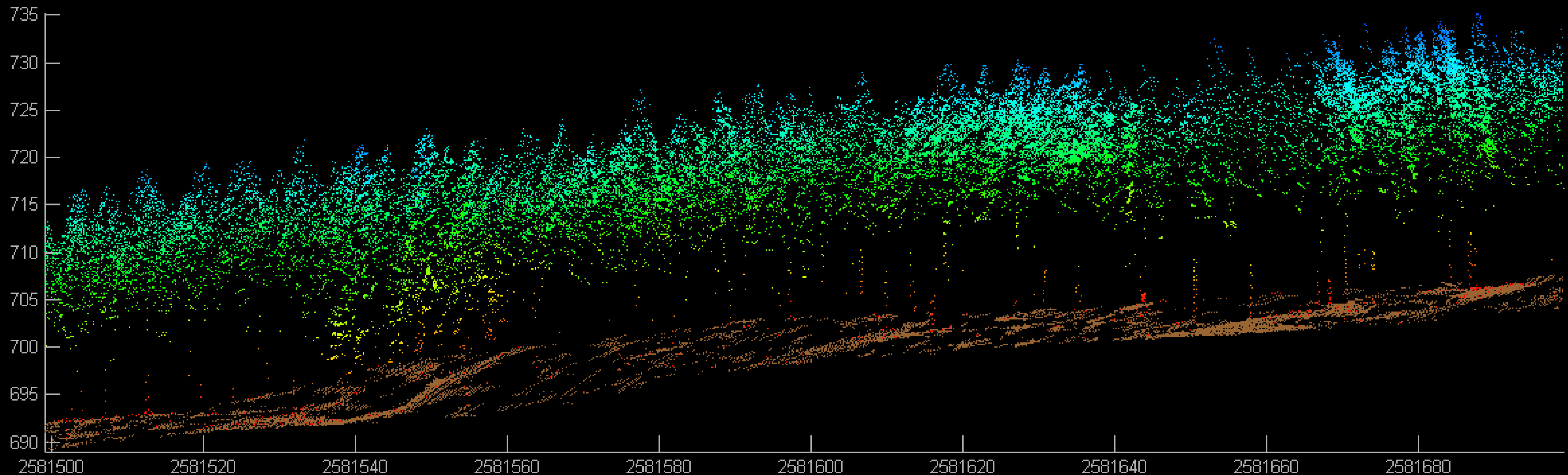
If you are interested in Hyperspectral remote sensing, visit the
9th EARSeL SIG Imaging Spectroscopy workshop
14-16 April 2015, Luxembourg
http://www.earsel2015.com/



Reference:

H. Buddenbaum, S. Seeling & J. Hill (2013): **Fusion of full waveform LiDAR and imaging spectroscopy remote sensing data for the characterization of forest stands.** *International Journal of Remote Sensing*, 34 (13): 4511-4524.

Thanks to funding projects

EnMAP Hyperspectral Imager
Regiowood
ForeStClim
WaReLa