University of Zurich[UZH]

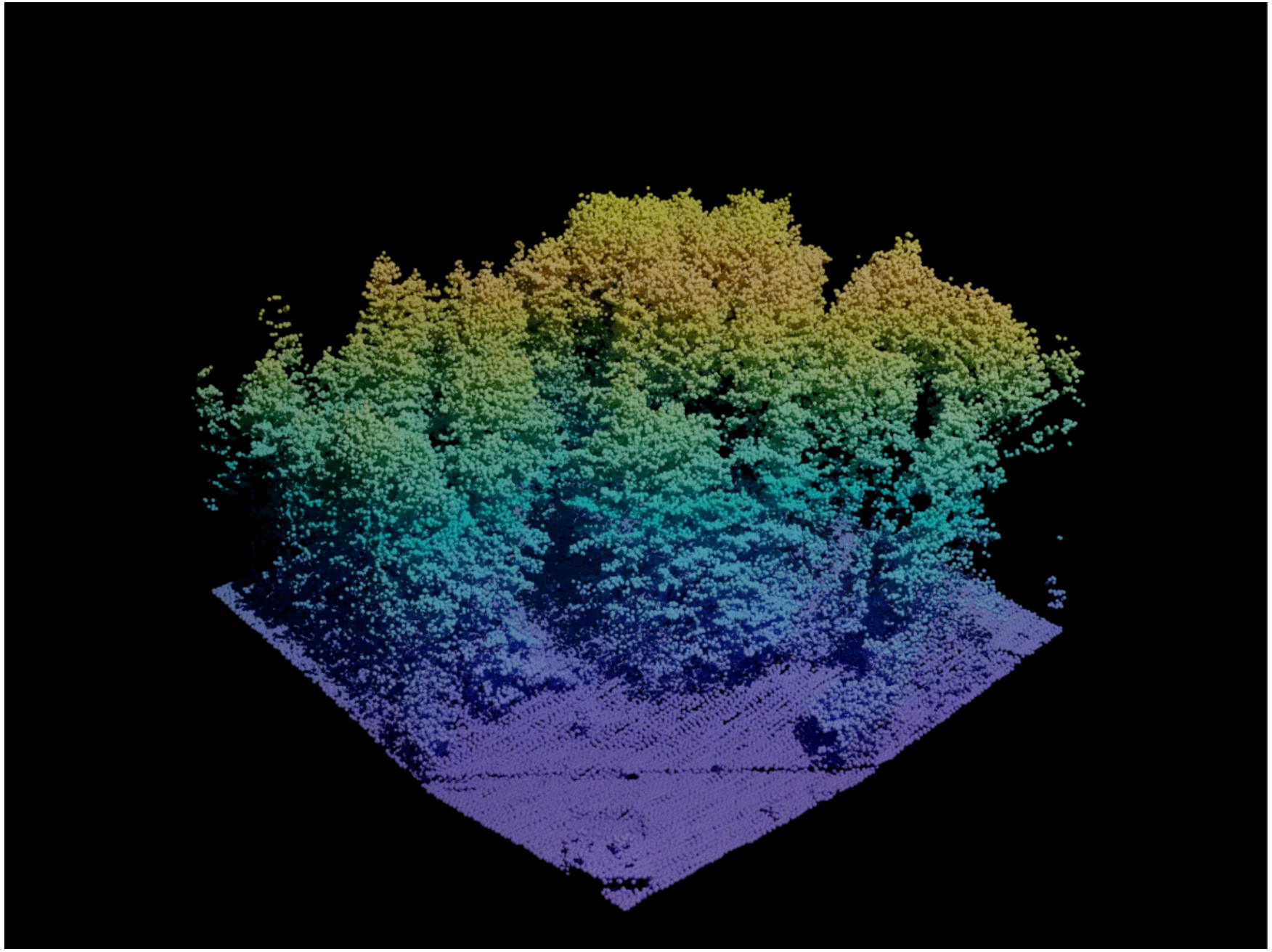
Department of Geography

RSL measurements | products | policy

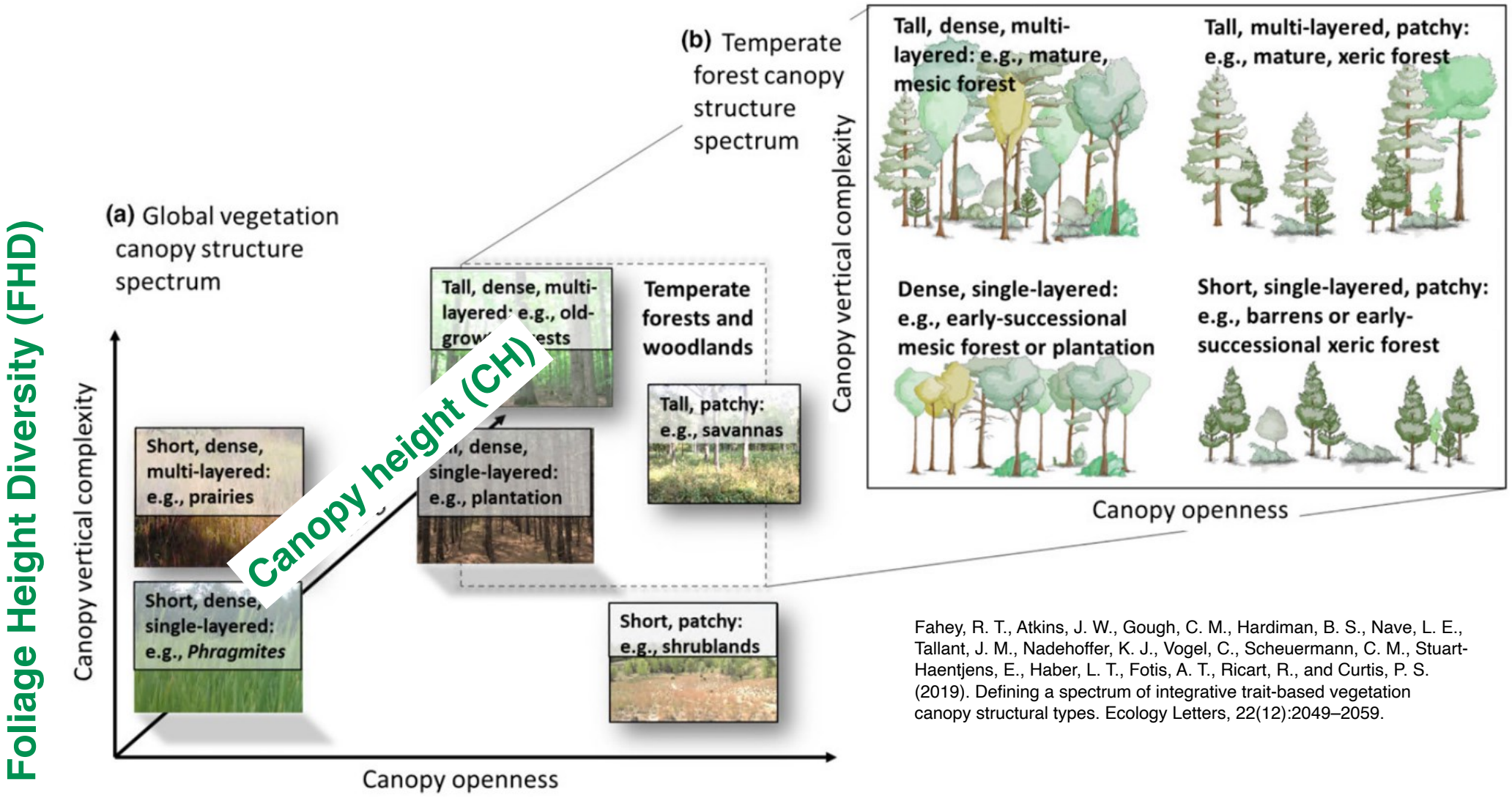
4D point clouds – towards physically-based monitoring across scales

Felix Morsdorf, Charis Gretler, Daniel Kükenbrink, Meinrad Abegg, Aline Bornand & Nicole Manser

Promise of the point cloud …



Global Spectrum of Canopy Structure

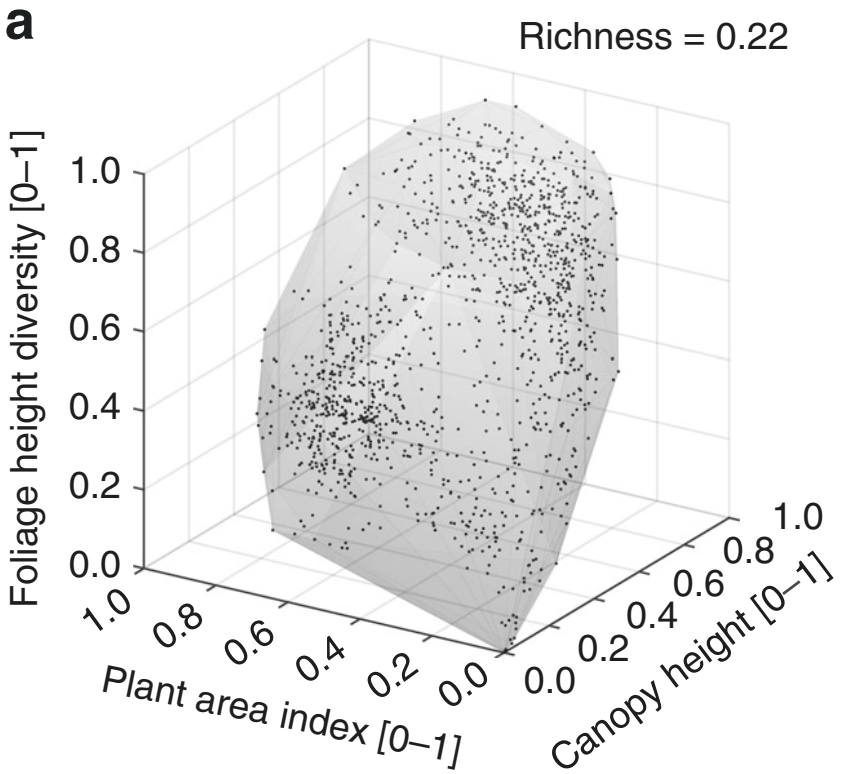


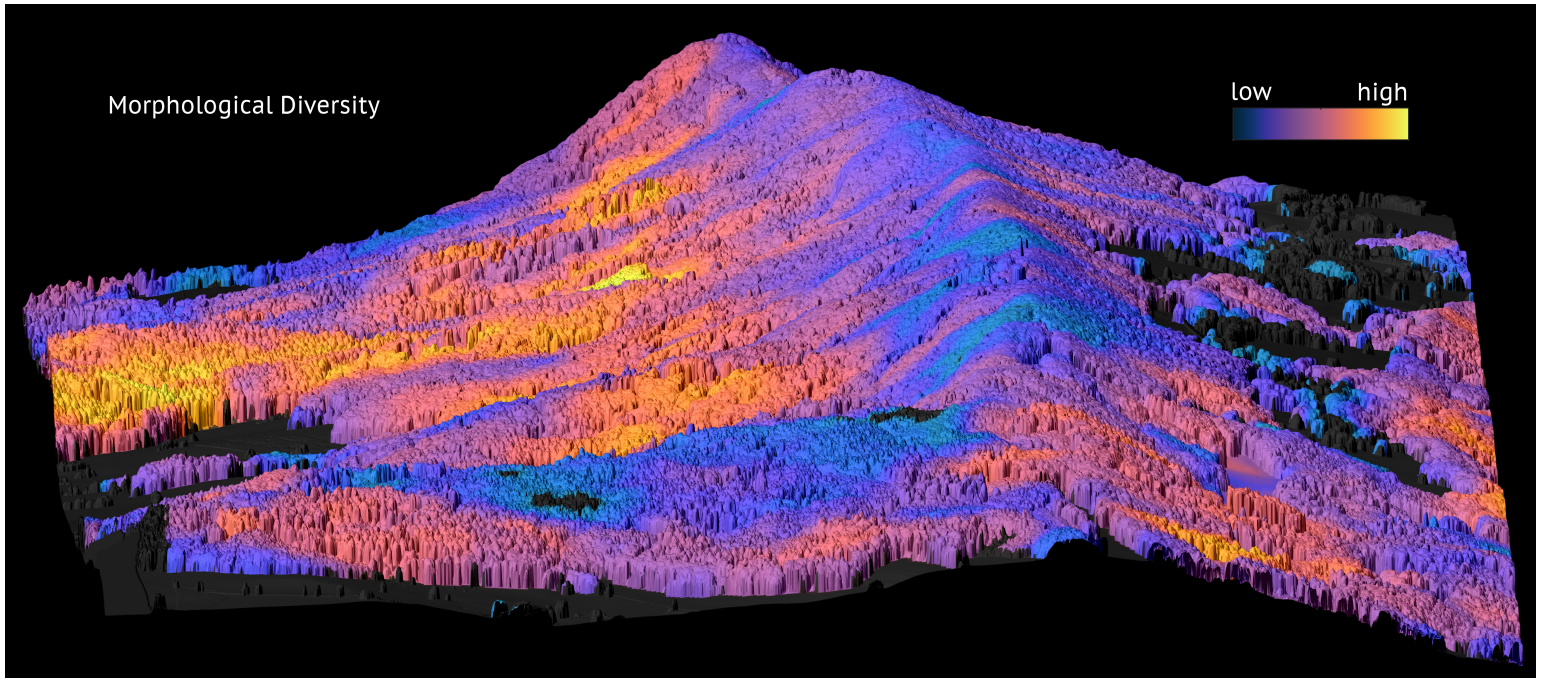
Fahey, R. T., Atkins, J. W., Gough, C. M., Hardiman, B. S., Nave, L. E., Tallant, J. M., Nadehoffer, K. J., Vogel, C., Scheuermann, C. M., Stuart-Haentjens, E., Haber, L. T., Fotis, A. T., Ricart, R., and Curtis, P. S. (2019). Defining a spectrum of integrative trait-based vegetation canopy structural types. Ecology Letters, 22(12):2049–2059.

Mapping the functional richness of forests structural parameters

- Functional richness is computed as convex hull of pixels in 3d feature space spanned by the parameter values
- Functional richness shows strong spatial patterns potentially linked to abiotic and biotic drivers
- SNF Project “BEF Lägern” (PI Kurt Bollmann, RS PhD Nicole Manser) will study these patterns and their linkage with in-situ diversity across trophic levels in more detail

F. D. Schneider, F. Morsdorf, B. Schmid, O. L. Petchey, A. Hueni, D. S. Schimel, and M. E. Schaepman, “Mapping functional diversity from remotely sensed morphological and physiological forest traits,” *Nature Communications*, vol. 8, no. 1, p. 1441, **2017**.

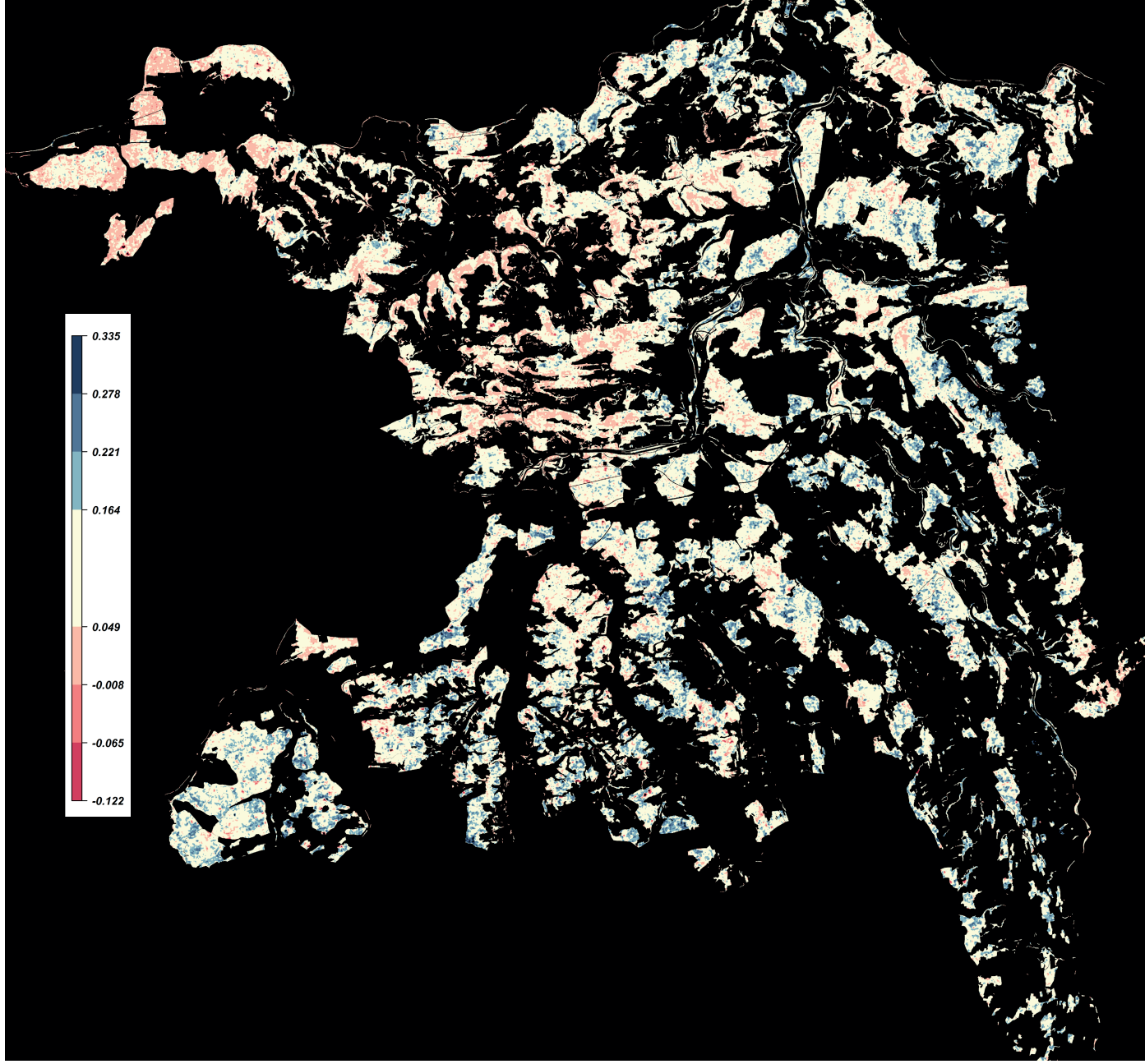




Monitoring Structural Richness 2014 - 2019

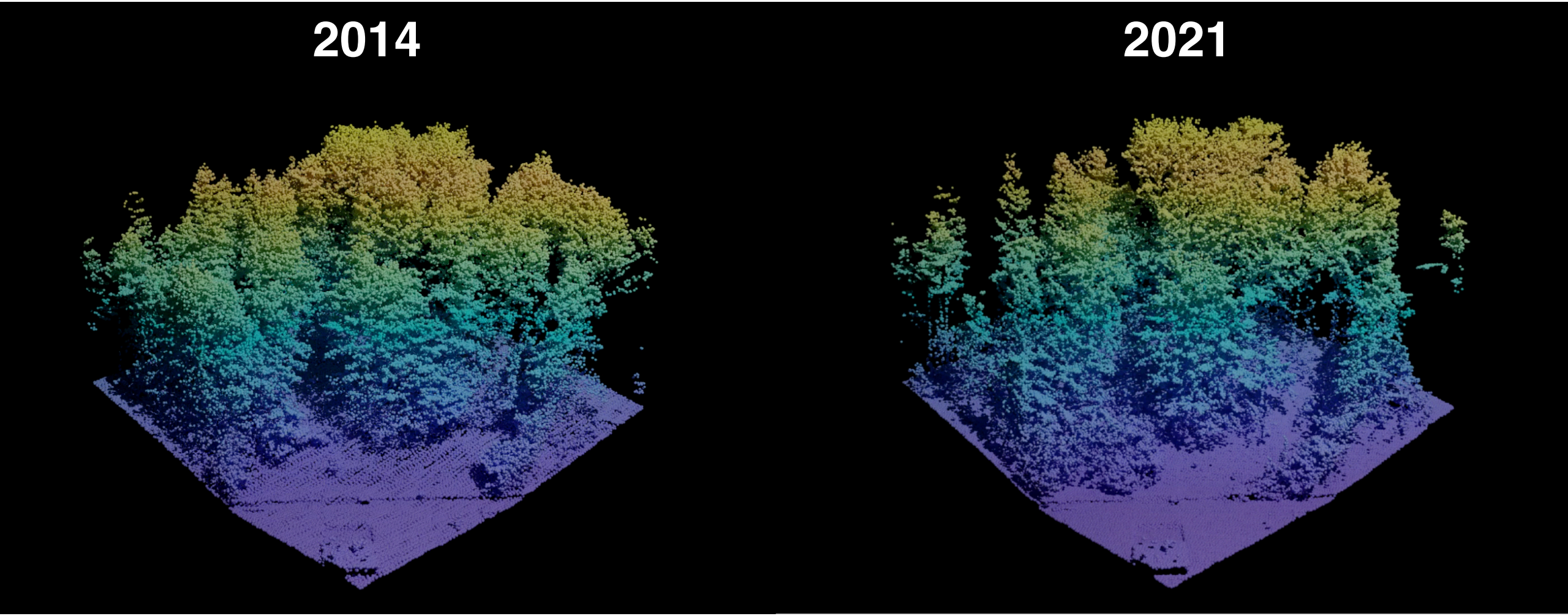
- ALS is operational in many European countries
  - this includes CH, many multi-temporal datasets at cantonal and national level
- Difference in structural richness for the whole forested area of the Kanton of Aargau (1400km2)
- However, *some* differences might be attributed to sensor and survey configurations changes…

	2014	2019
Altitude	600	1250
Scan Angle	±15	±30
PRF	300	1000
Beam Divergence	0.5	0.3
Point Density	16	30

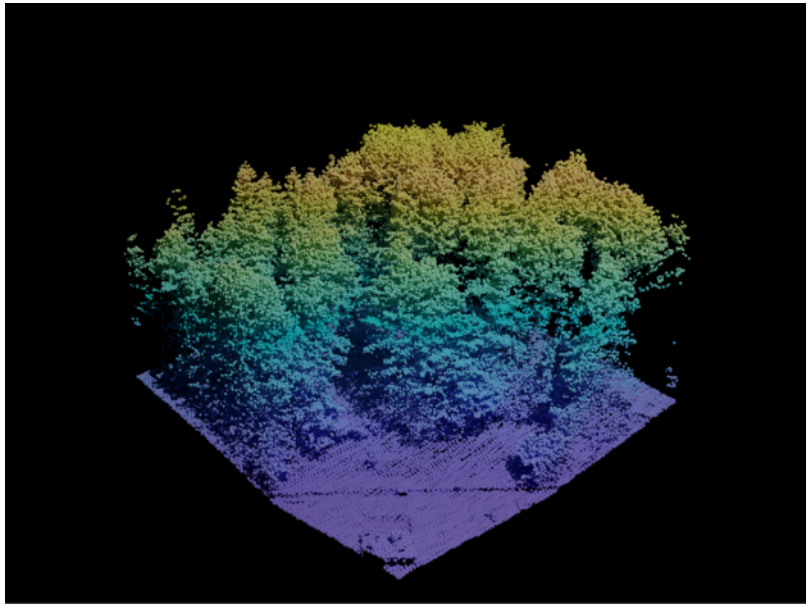


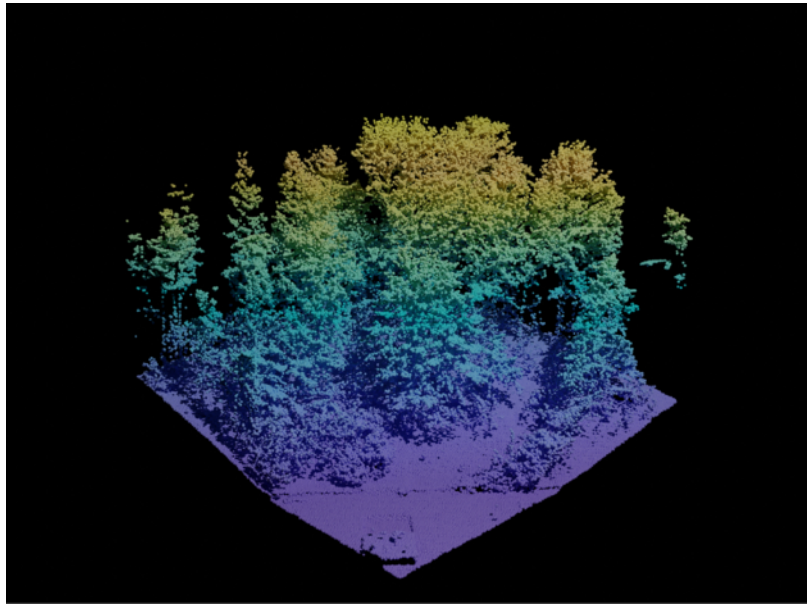
Mapping change of functional forest traits and diversity using airborne laser scanning in the canton Aargau 2014-2019, Charis Gretler, MSc Thesis, University of Zürich, 2022

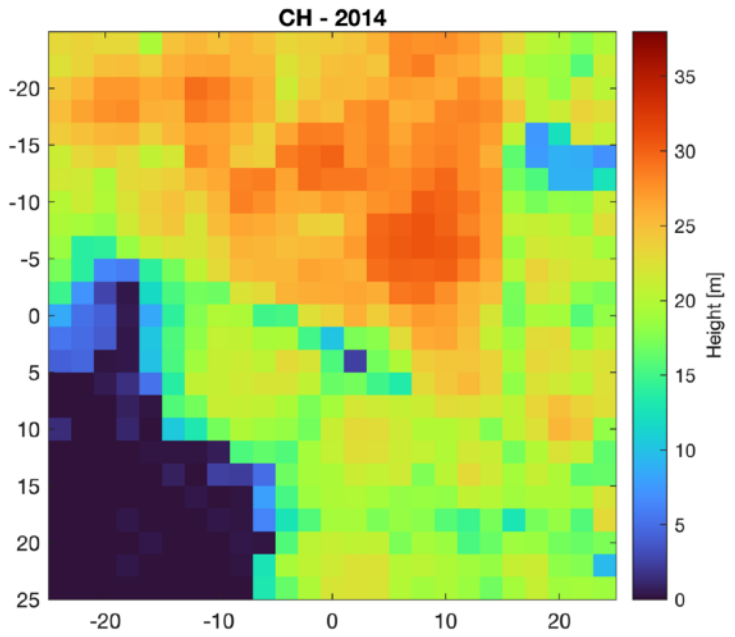
Towards monitoring - change between point clouds

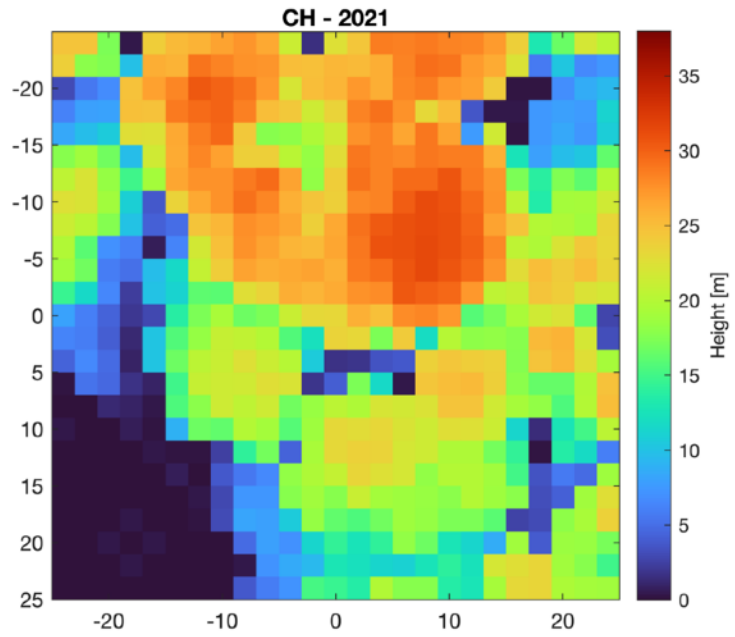


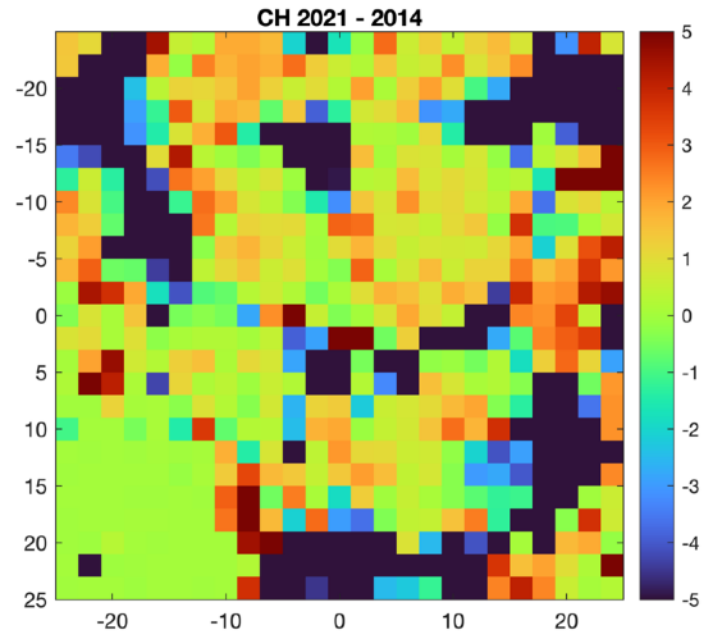
Change between point clouds - 2014 to 2021 (both leaf-off)











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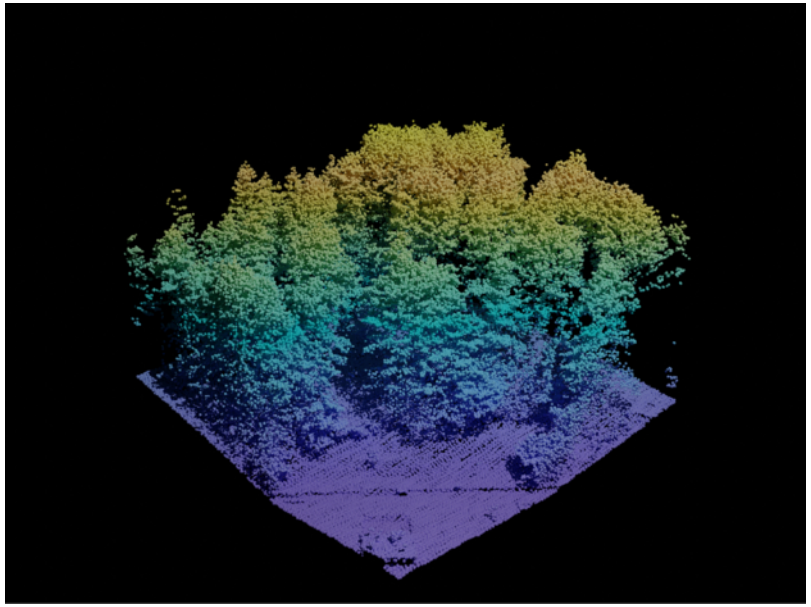
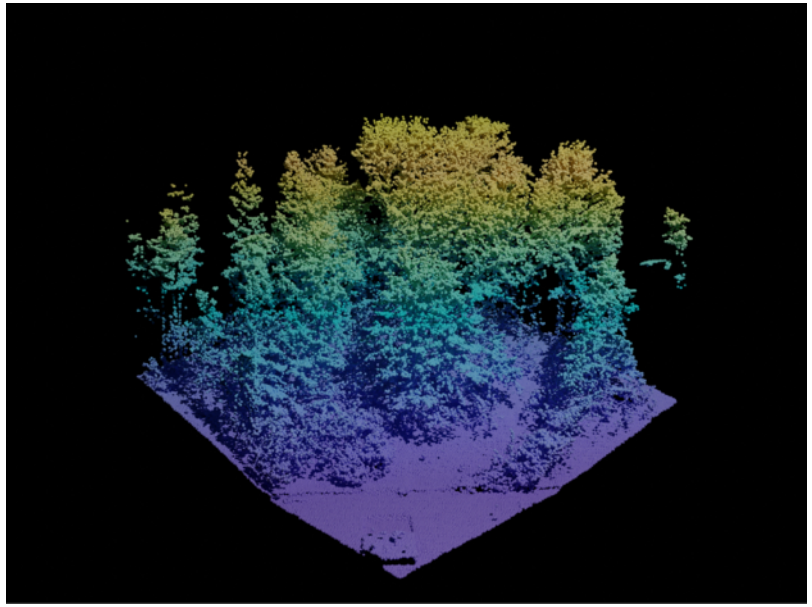
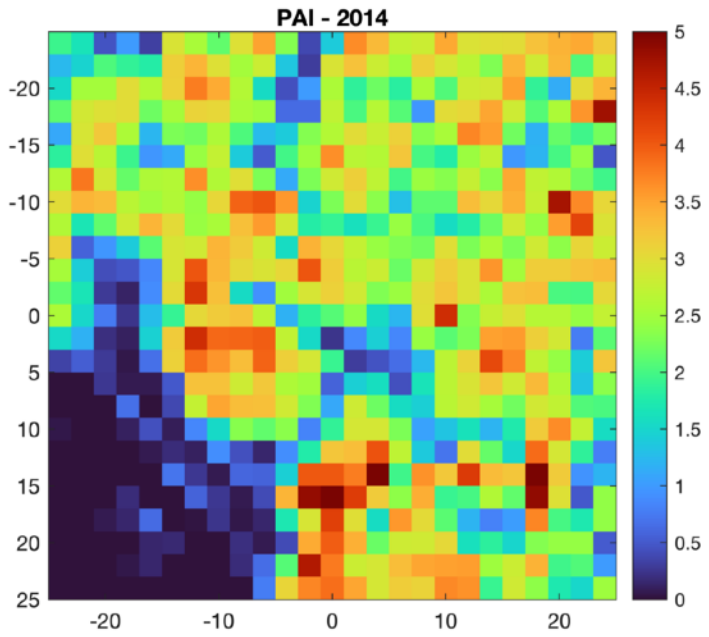
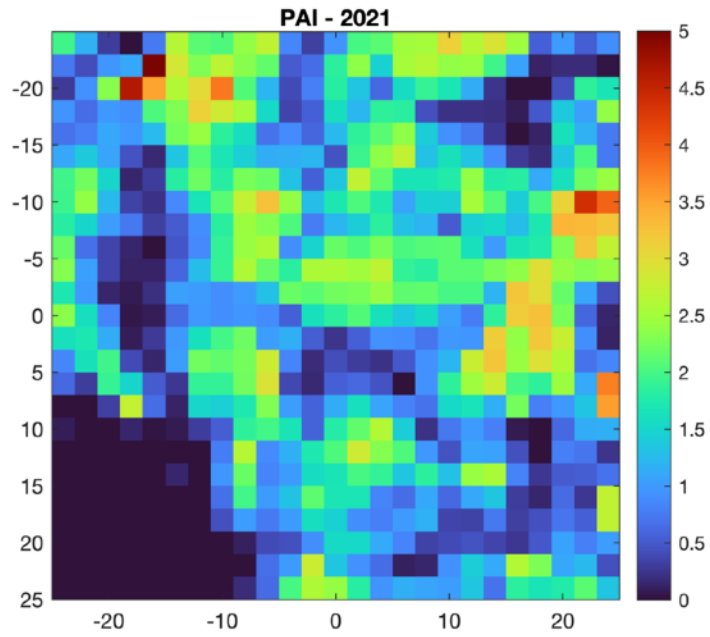
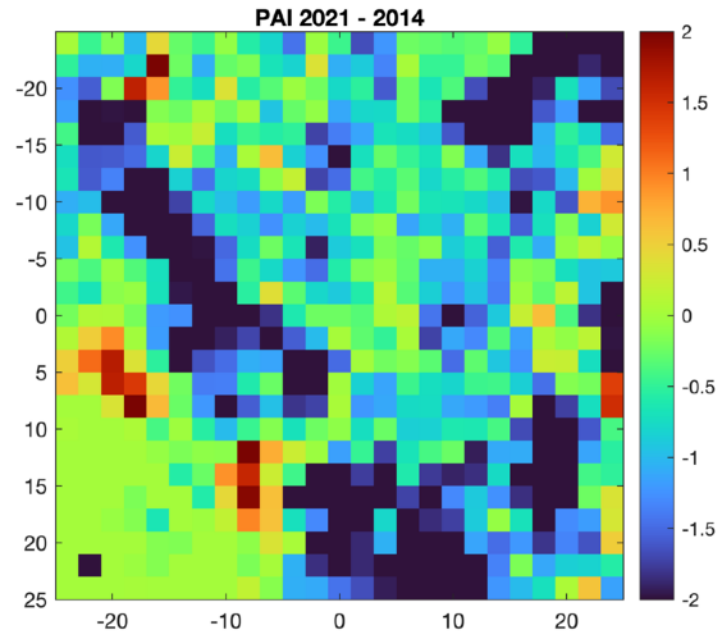




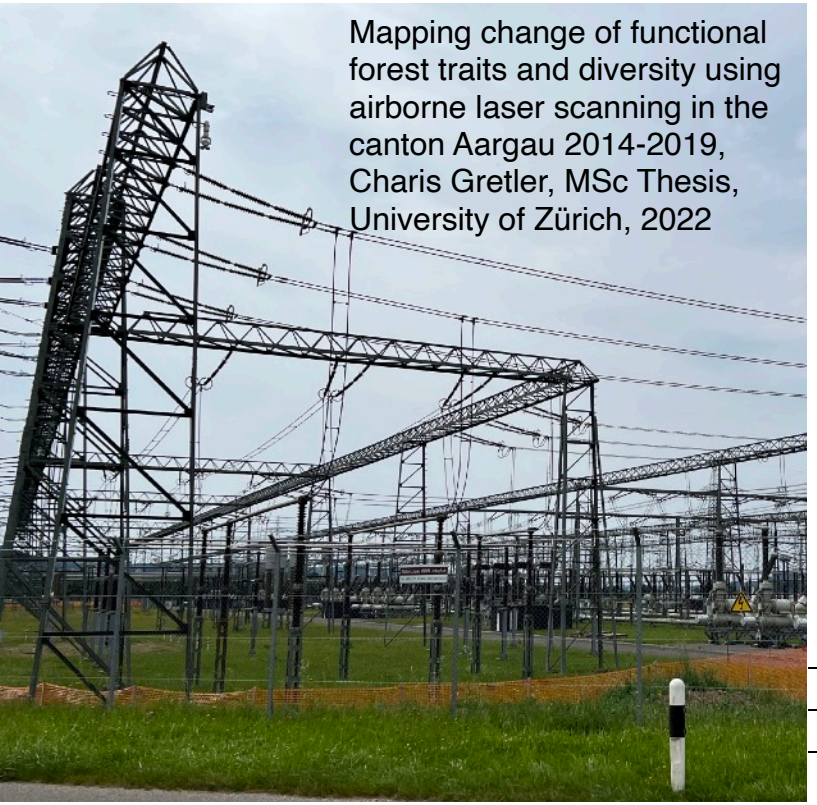






“Persistent scatterer?” - Swissgrid Substation (Kt. AG)

- Surface power switching installations of Swissgrid in Laufenburg are a complex 3d structure that did not change between 2014 and 2019
  - Canopy height (max and percentiles) do not change much (0.1 m)
  - Foliage height diversity is quite robust as well
  - PAI changes dramatically between the two acquisitions



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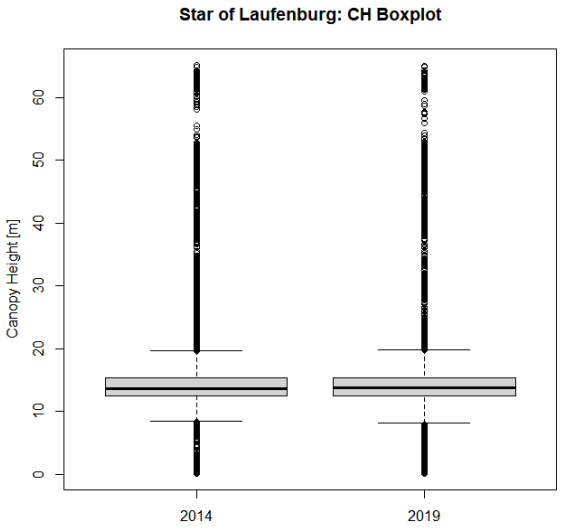
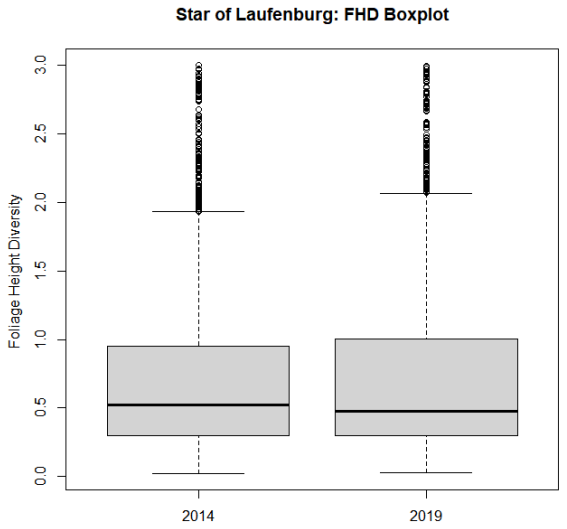
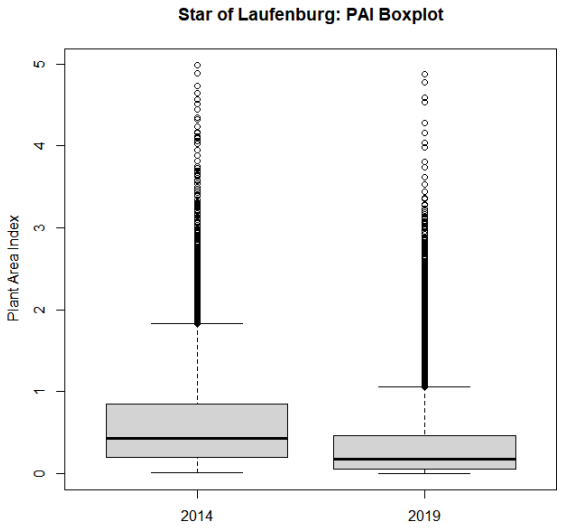


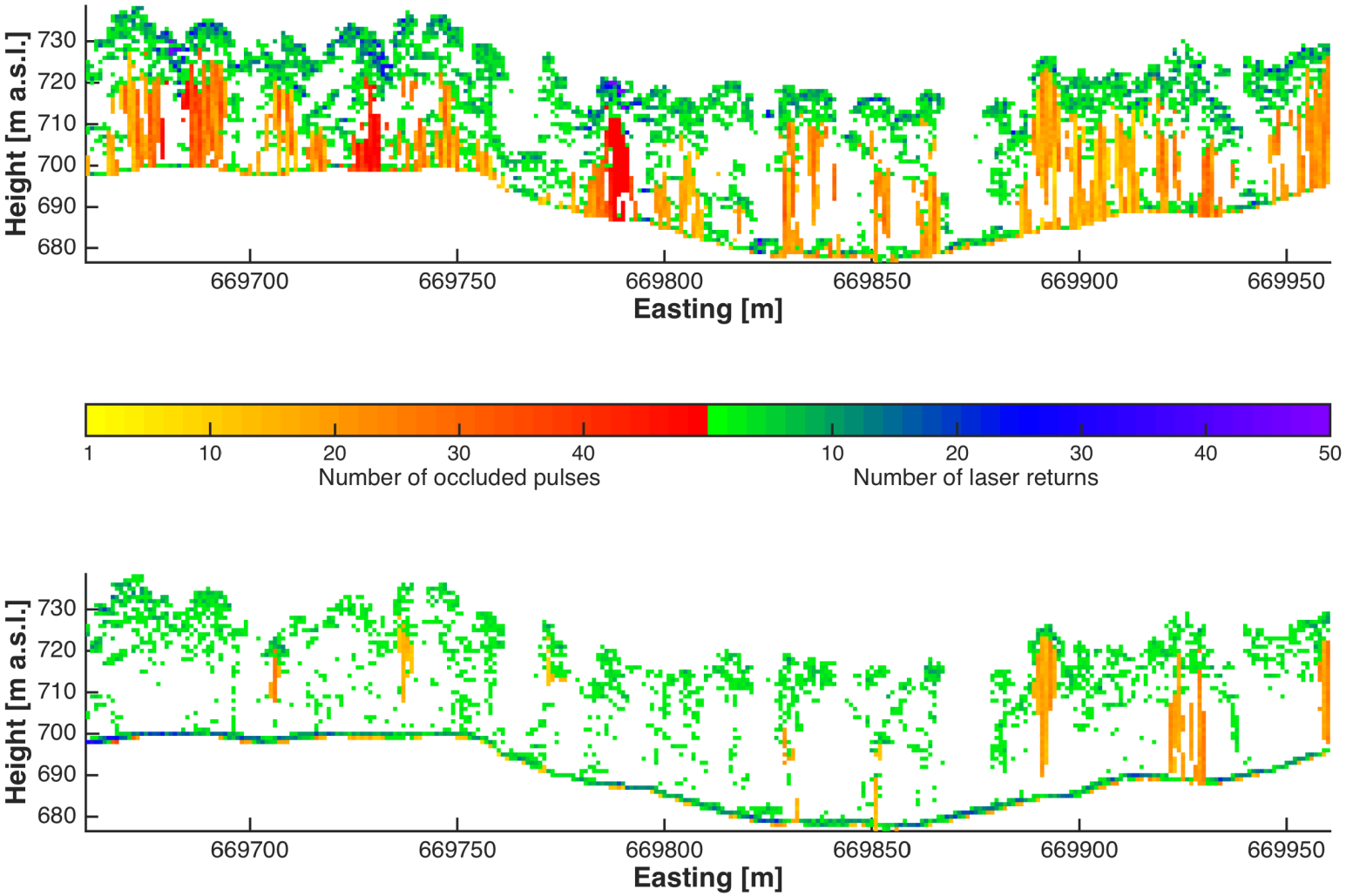




	CH		FHD		PAI	
	2014	*2019*	*2014*	*2019*	*2014*	*2019*
25th percentile	12.6	12.5	0.297	0.299	0.1983	0.0543
50th percentile	13.7	13.8	0.52	0.481	0.428	0.168
75th percentile	15.4	15.4	0.951	1.012	0.85	0.458

Ray-tracing of ALS returns for occlusion mapping

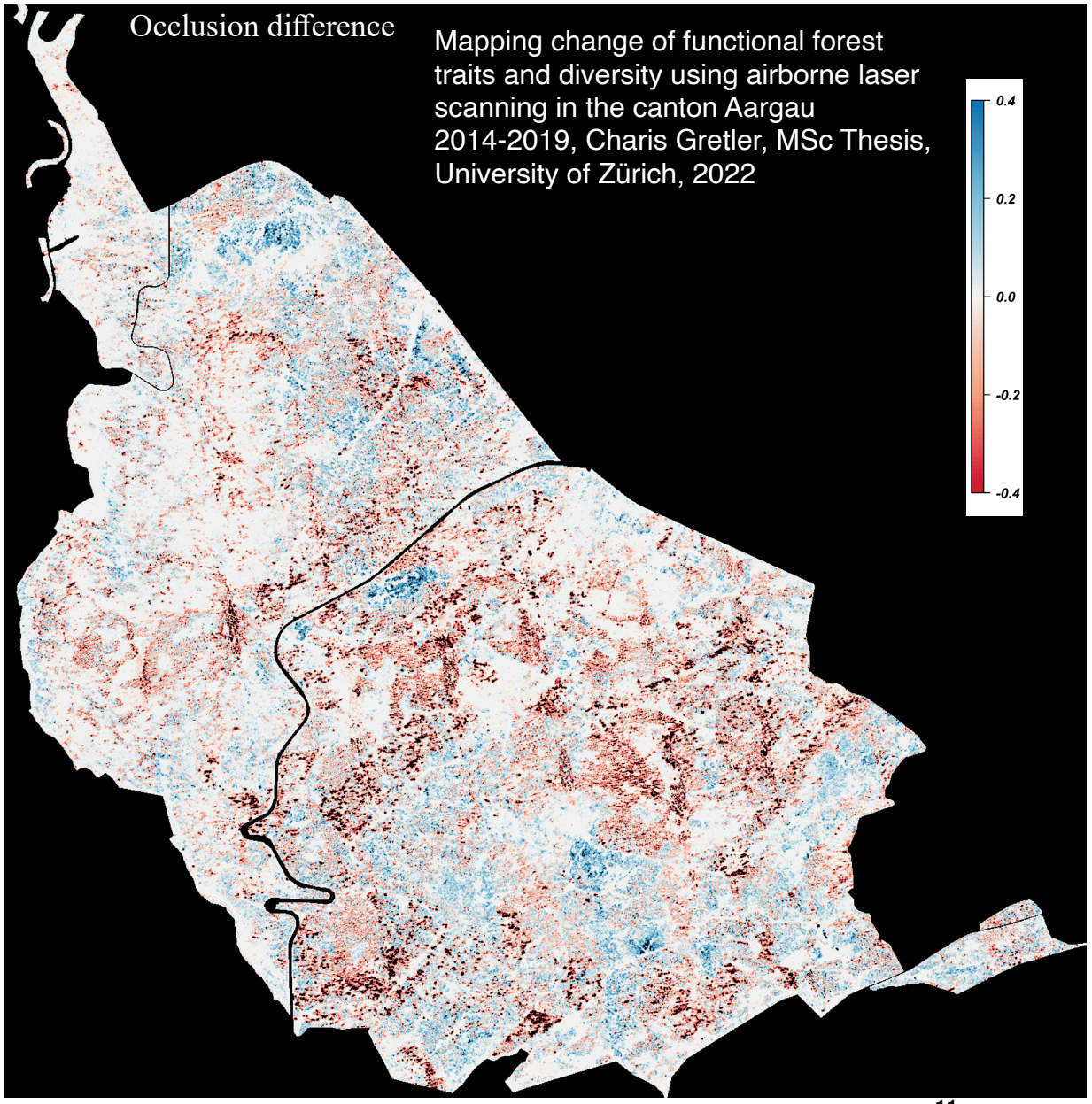
- For each ALS pulse, we can trace its path through the 3d space.
- Voxel grid is populated with number of echo or number of occlusions.
- Now we know the unknown and can exclude voxel with different state in occlusion from change detection
- Leaf-off data might be better suited to detect changes in forest structure …



Daniel Kükenbrink, Reik Leiterer, Fabian D. Schneider, Michael E. Schaepman and Felix Morsdorf, *Quantification of hidden canopy volume of airborne laser scanning data using a voxel traversal algorithm,* **Remote Sensing of Environment, 2017**

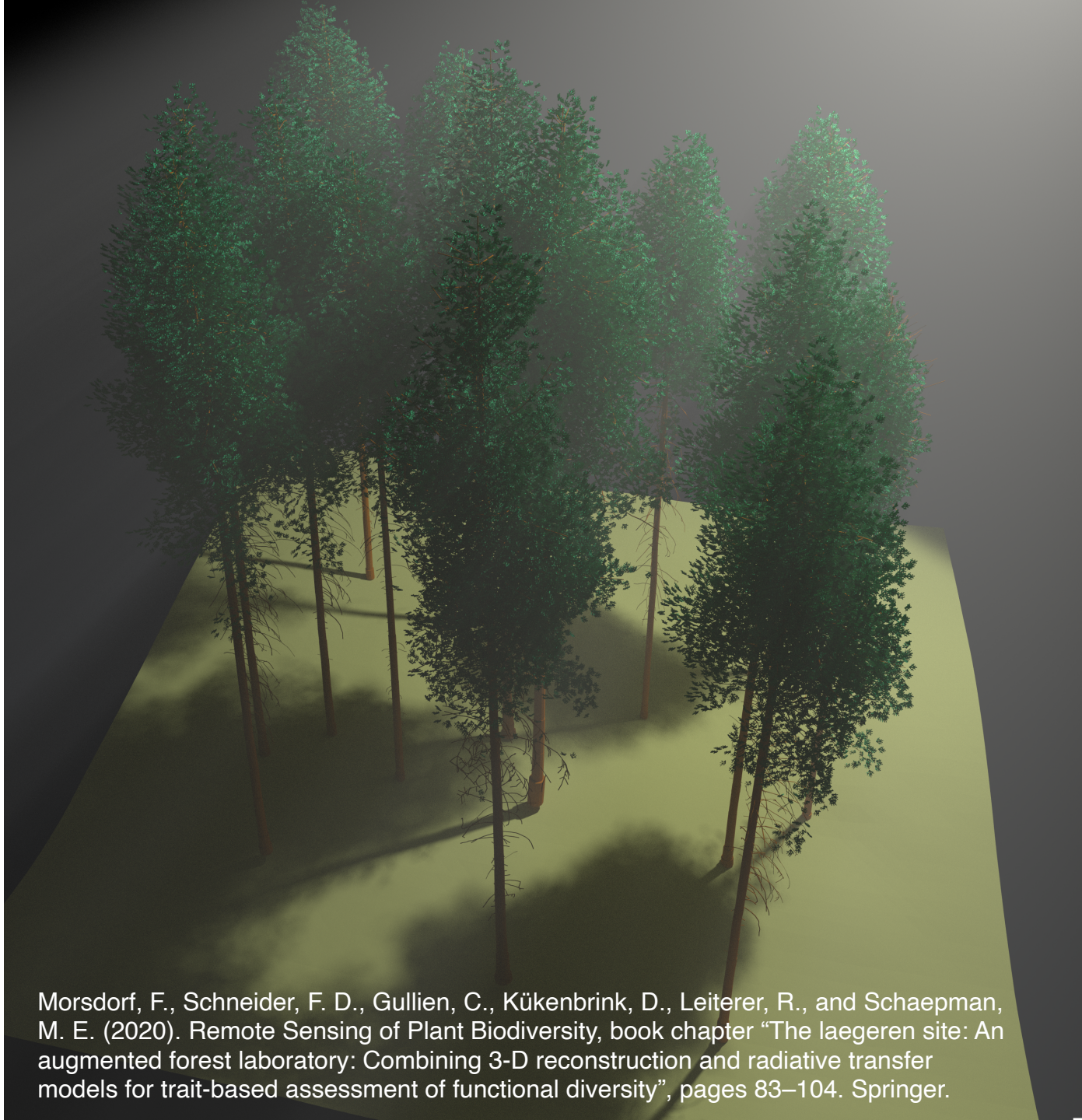
Occlusion difference between 2014 and 2019

- Occlusion mapping informs about areas with large difference in observed volume.
- Change in 3d structure metrics from such areas need to be treated with caution.
- However, occlusion is just one part of the problem, the representation of 3D objects like trees in the point cloud is another.



Summing Up…

- Point clouds of forests contain a wealth of 3d structural information
  - but these are impacted by sensor and survey configurations …
  - … just as any other remote sensing technology!
- Change detection using point clouds needs to consider this for all but the simplest structural metrics (e.g. height)
  - but even then, scale matters.
- Monitoring with complex structure variables needs more work -
  - radiative transfer models will help to increase our understanding of laser pulse - canopy interactions



Morsdorf, F., Schneider, F. D., Gullien, C., Kükenbrink, D., Leiterer, R., and Schaepman, M. E. (2020). Remote Sensing of Plant Biodiversity, book chapter “The laegeren site: An augmented forest laboratory: Combining 3-D reconstruction and radiative transfer models for trait-based assessment of functional diversity”, pages 83–104. Springer.