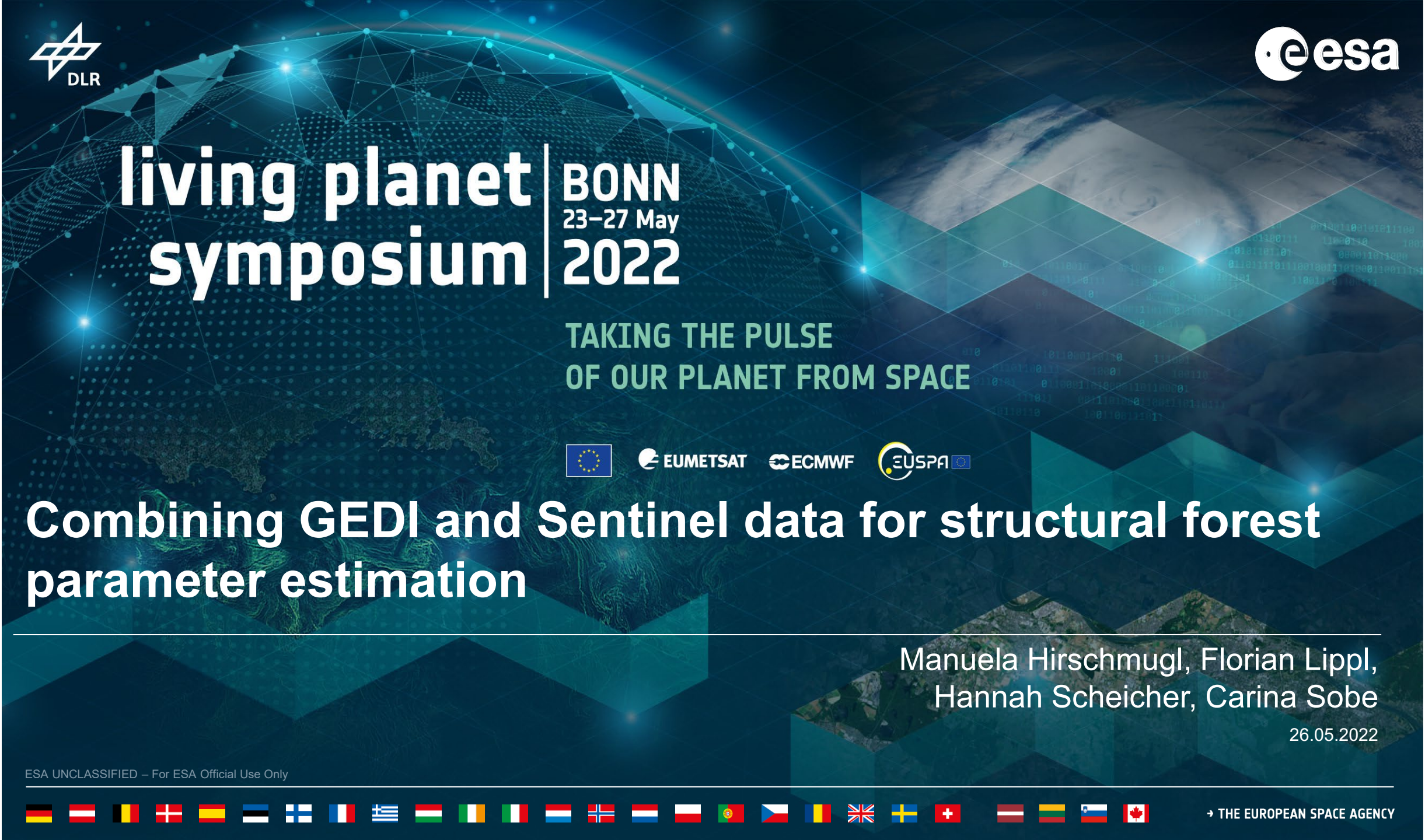

Combining GEDI and Sentinel data for structural forest parameter estimation

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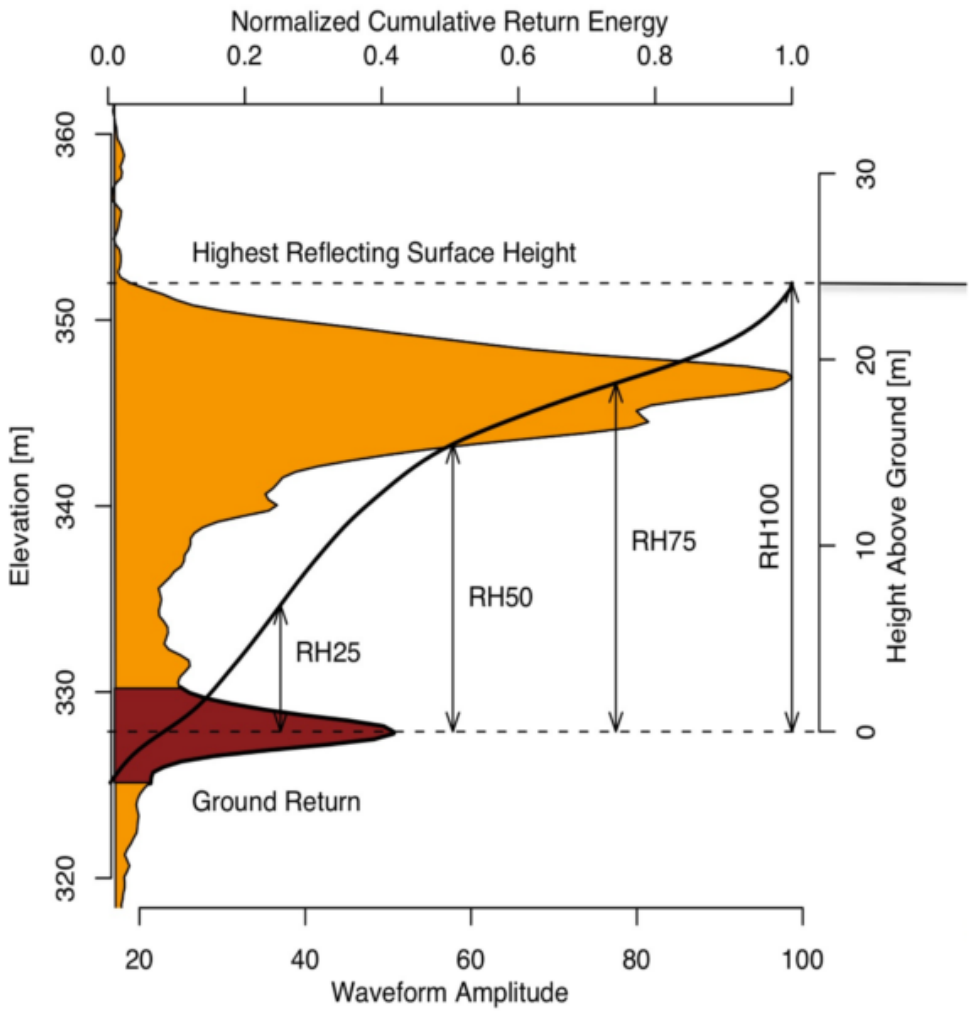
Hannah Scheicher, Carina Sobe

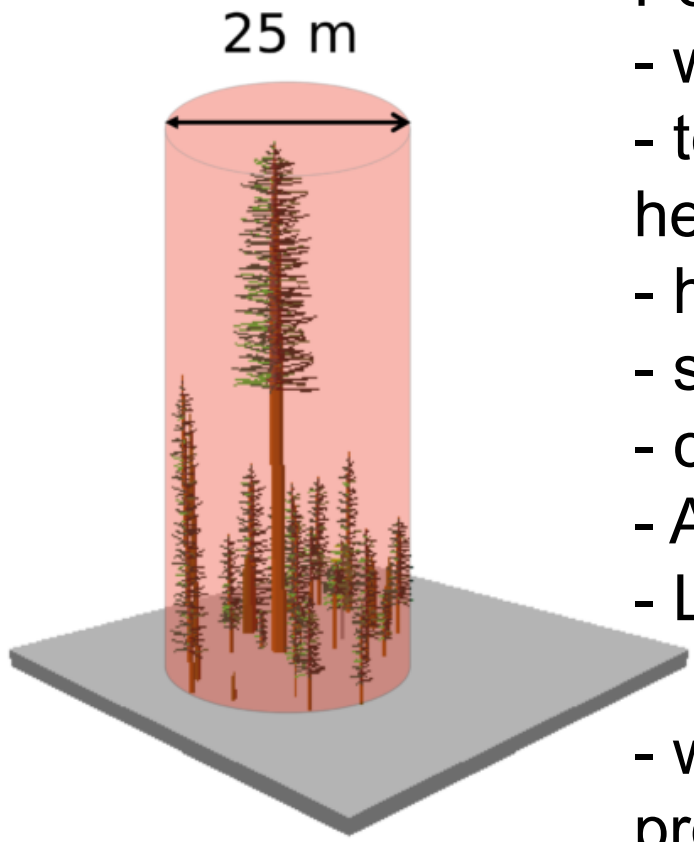
26.05.2022

Overall aims of the project

1. *To assess the quality of GEDI data for difficult terrain & near-natural forests in Austria*
2. *To generate so-far not available forest attribute maps – forest structural parameters*
3. *To evaluate the mutual benefit of combining GEDI data with Sentinel-1 and Sentinel-2 data sets for forest monitoring purposes*

Quick intro to GEDI





Space-based Lidar (ISS)
Point-wise information
- waveform
- terrain & canopy heights
- height metrics
- structure indices (FHD)
- canopy cover fraction
- AGB
- LAI

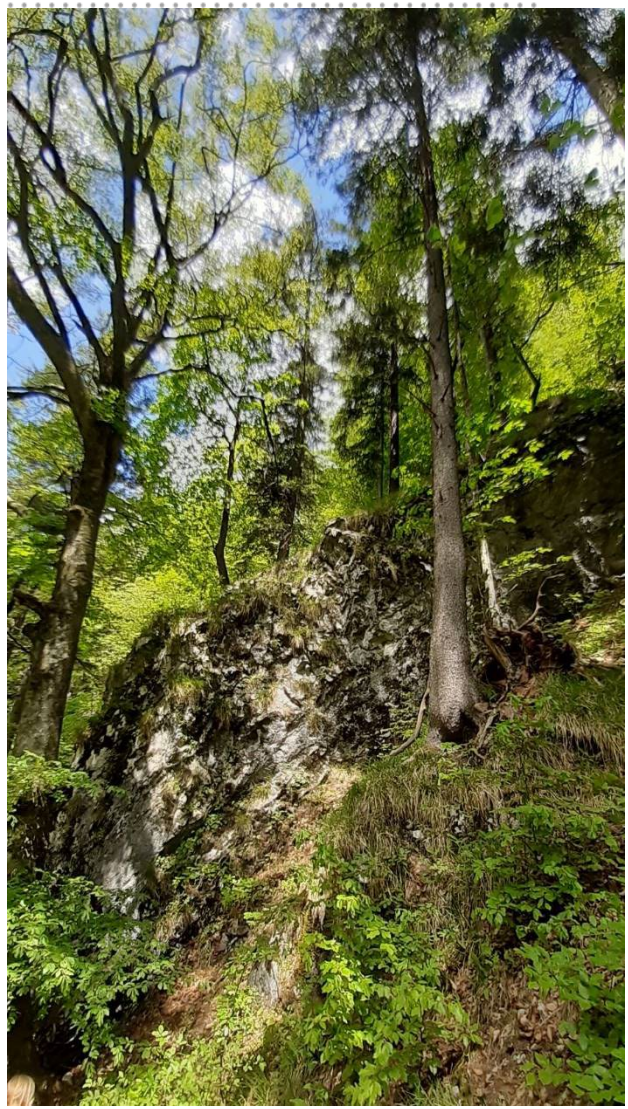
- wall-to-wall gridded products

1 - Usability and quality of GEDI data under difficult conditions

- NP Kalkalpen and NP Gesäuse (eLTER Site) – mountainous terrain, steep slopes, near natural forest → perfect conditions
  (= the remote senser's worst nightmare)
- ALS data acquired 2018

Data filters applied (GEDI plots used):

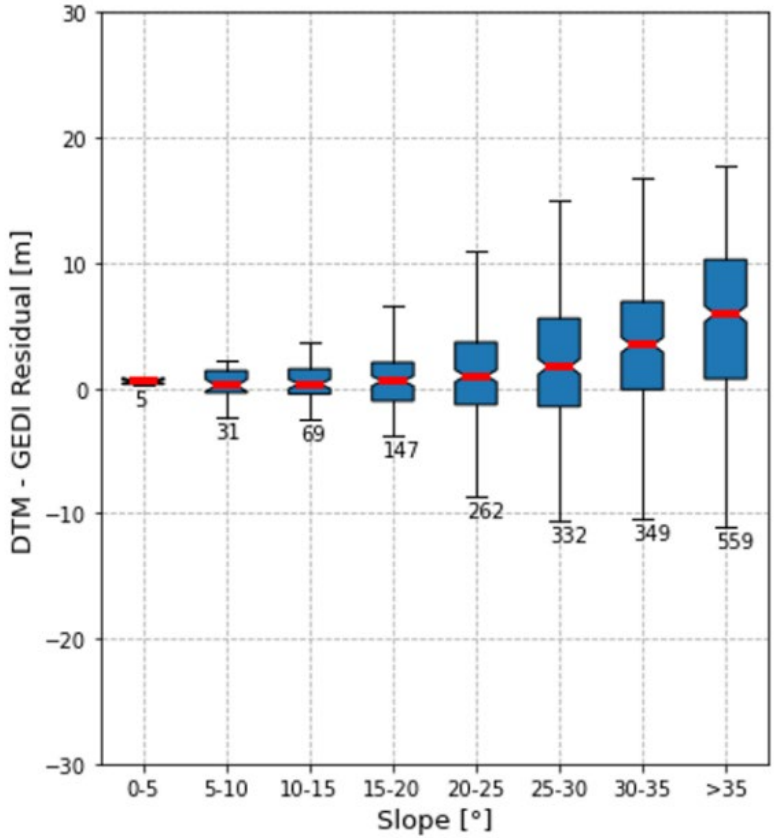
- Quality flag = 1
- Degrade flag = 0
- No changes between 2018 & 2020
- No winter observations (deciduous)
  (only plots from June – October 2019 & 2020)

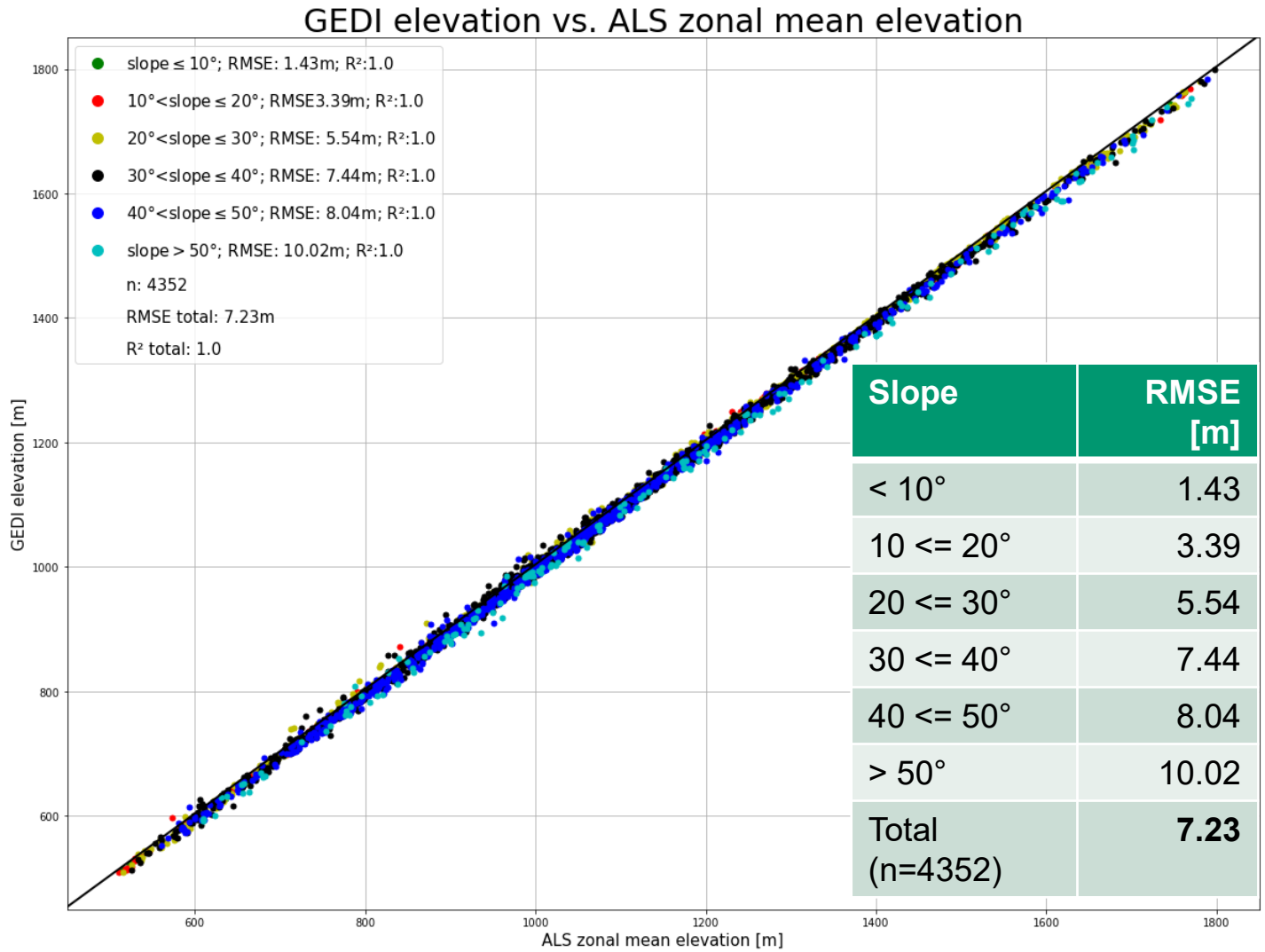


1 - Usability and quality of GEDI data under difficult conditions

1.1. – terrain height

- Dependence on slope

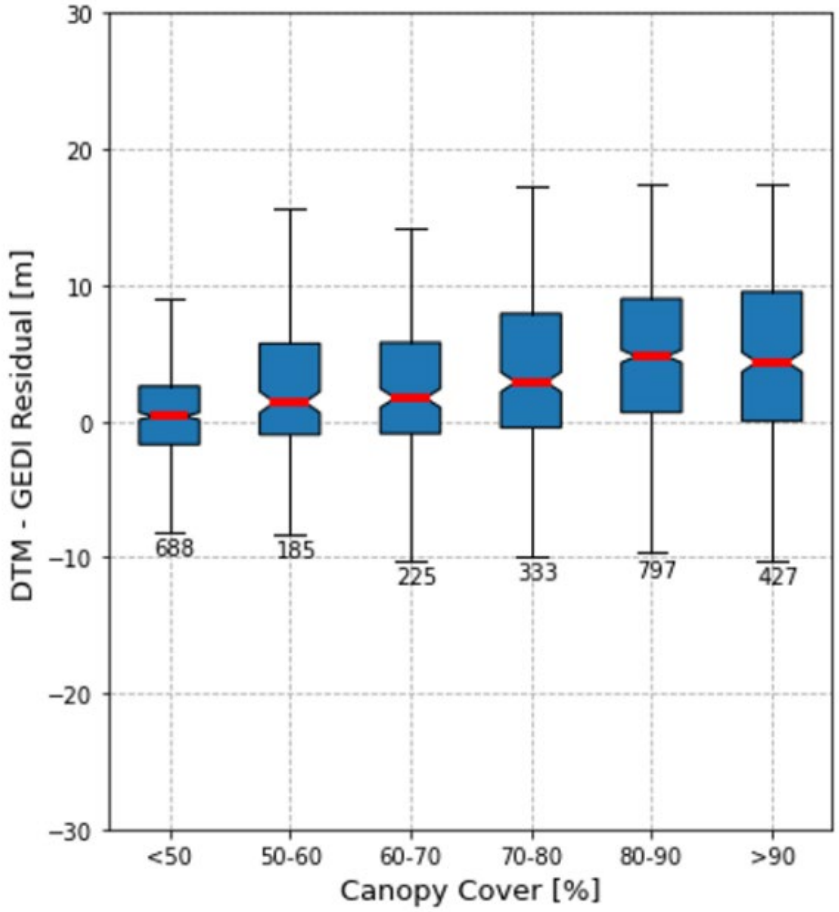


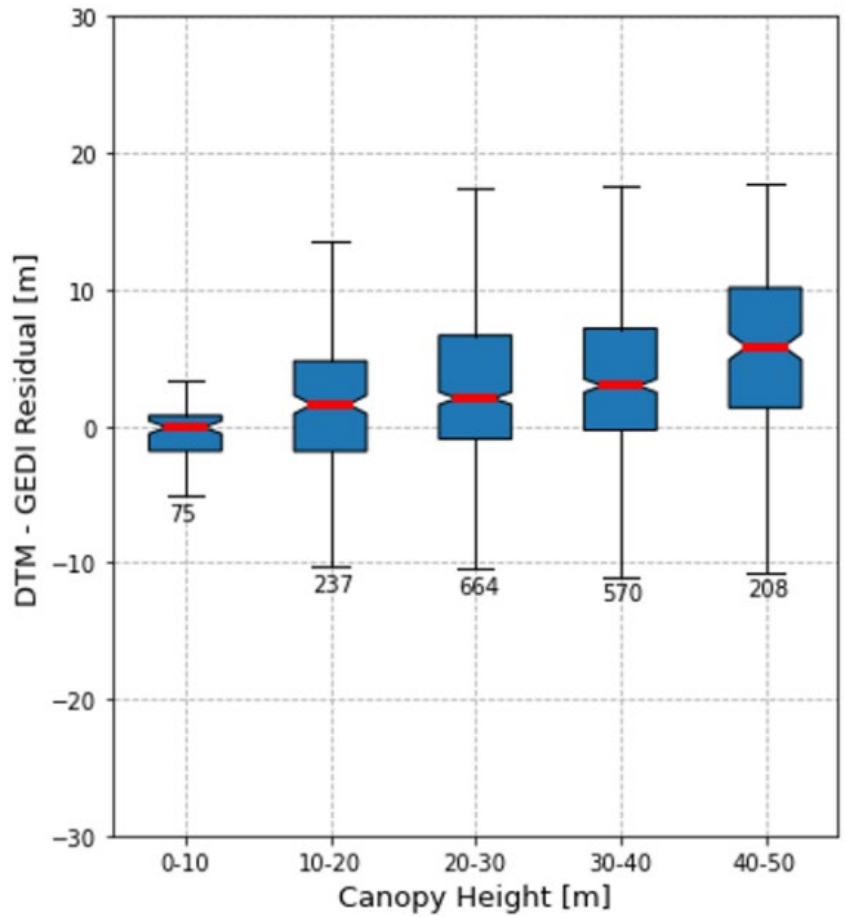


Slope	RMSE [m]
< 10°	1.43
10 <= 20°	3.39
20 <= 30°	5.54
30 <= 40°	7.44
40 <= 50°	8.04
> 50°	10.02
Total (n=4352)	**7.23**

1 - Usability and quality of GEDI data under difficult conditions
1.1. – terrain height

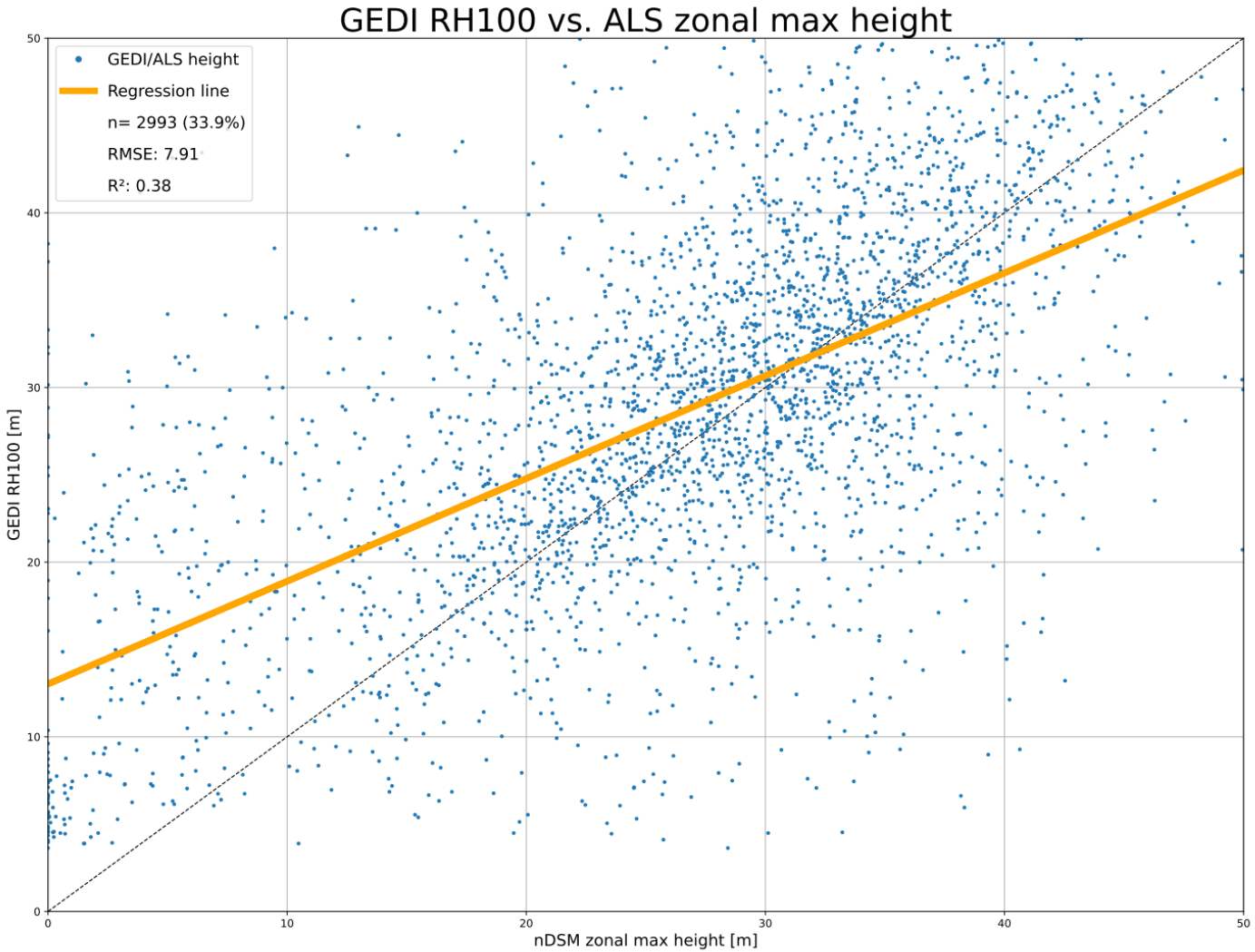
- Dependence on canopy cover and canopy height





1 - usability and quality of GEDI data under difficult conditions

1.2. – canopy height



GEDI
overestimates small trees
and
underestimates large trees

→ Dependence on slope again?

→ Dependance of canopy cover as well?

1 - Usability and quality of GEDI data under difficult conditions

1.2. – canopy height

coverage	0% – 100%	
statistics	RMSE $[m]$	R^2
slope $< 90°$	7.38	0.43
slope $< 50°$	7.25	0.45
slope $< 35°$	6.82	0.50
slope $< 20°$	6.12	0.63

Summary canopy height:

- for small trees overestimated, for large trees underestimated, RMSE ~ 7 m
- for steep slopes less accurate
- for open forests less accurate

>> generally in line with previous findings, but slightly lower R^2s
(Adam et al., 2020; Liu et al., 2021, Urbazaev et al., 2021, Potapov et al., 2021: RMSE 7.2/R^2 0.7)

3 – New Forest Parameters
Structure/Layers

- Foliage height diversity (FHD)

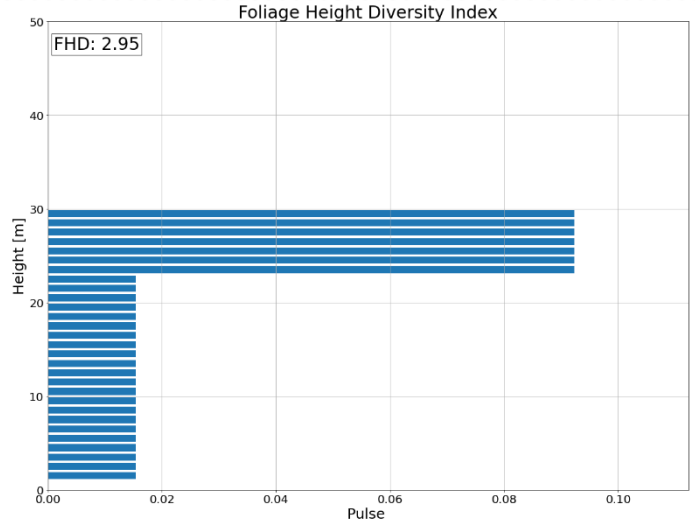
- MacArthur 1961: "The more equal the proportion of vegetation coverage at every height, the higher the FHD value"
- Rishmawi et al. 2021: "Foliage height diversity is a canopy structural index that describes the vertical heterogeneity of foliage profile"
  "Finally, the GEDI-derived FHD is calculated from the PAI vertical profile and is a measure of the complexity of canopy structure with higher FHD values often associated with multiple canopy layers"

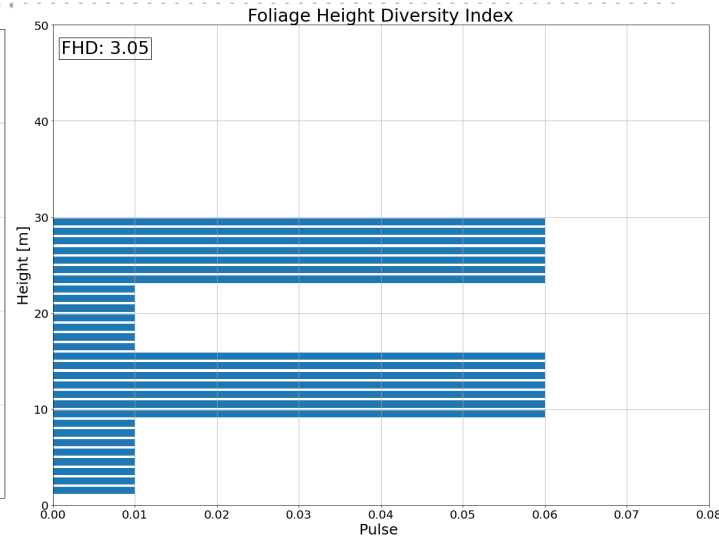
$$\mathrm{FHD} = -\sum_i p_i * ln(p_i)$$

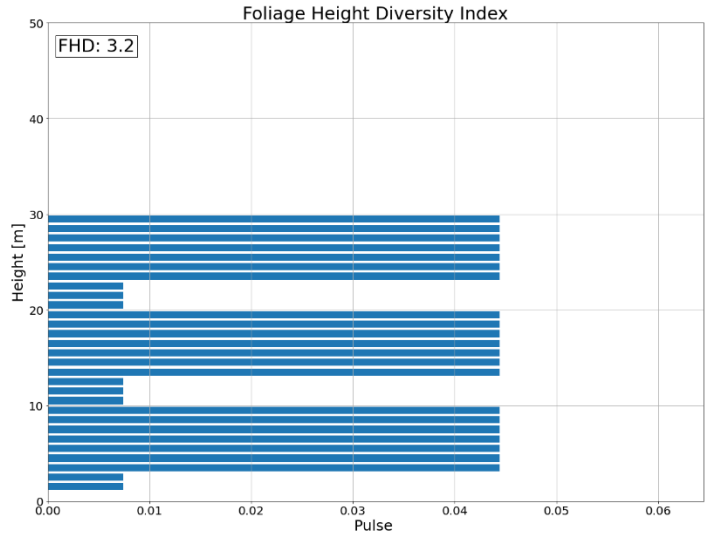
p_i ... vertical PAI profile in the ith layer, summed over the number of layers

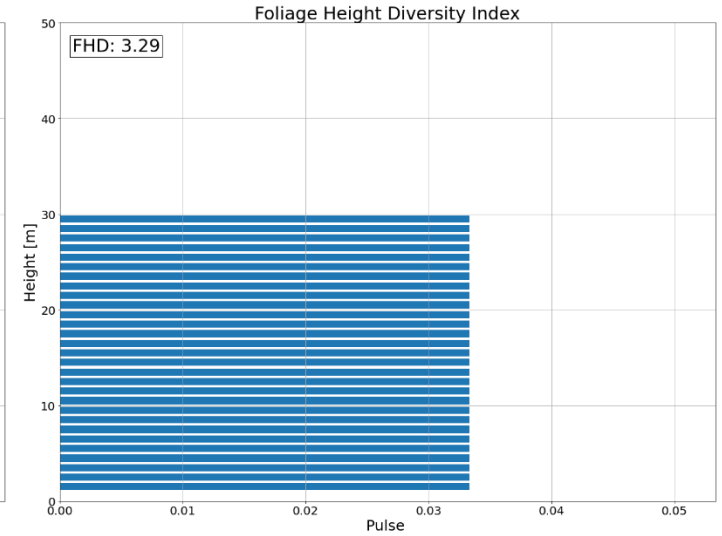
3 – New Forest Parameters
Structure/Layers

- Is FHD describing vertical structure or no. of layers?
  Or do we need to generate another indicator from GEDI?
- Theoretical examples >>





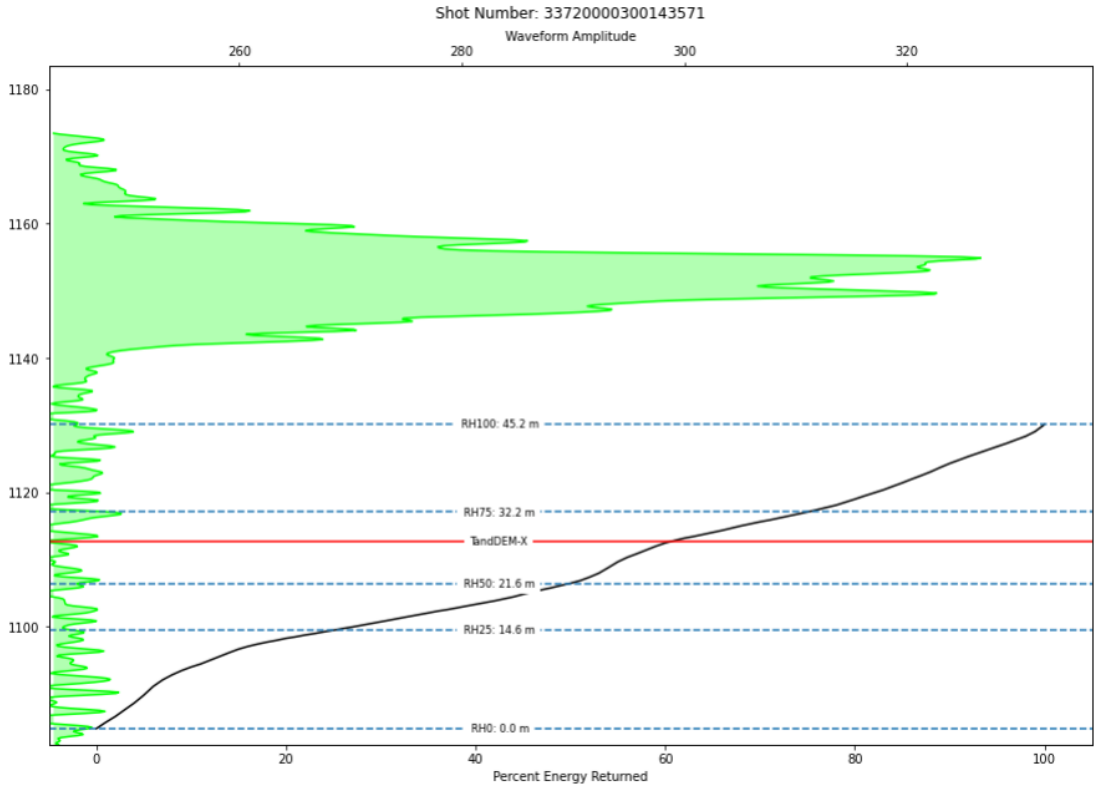




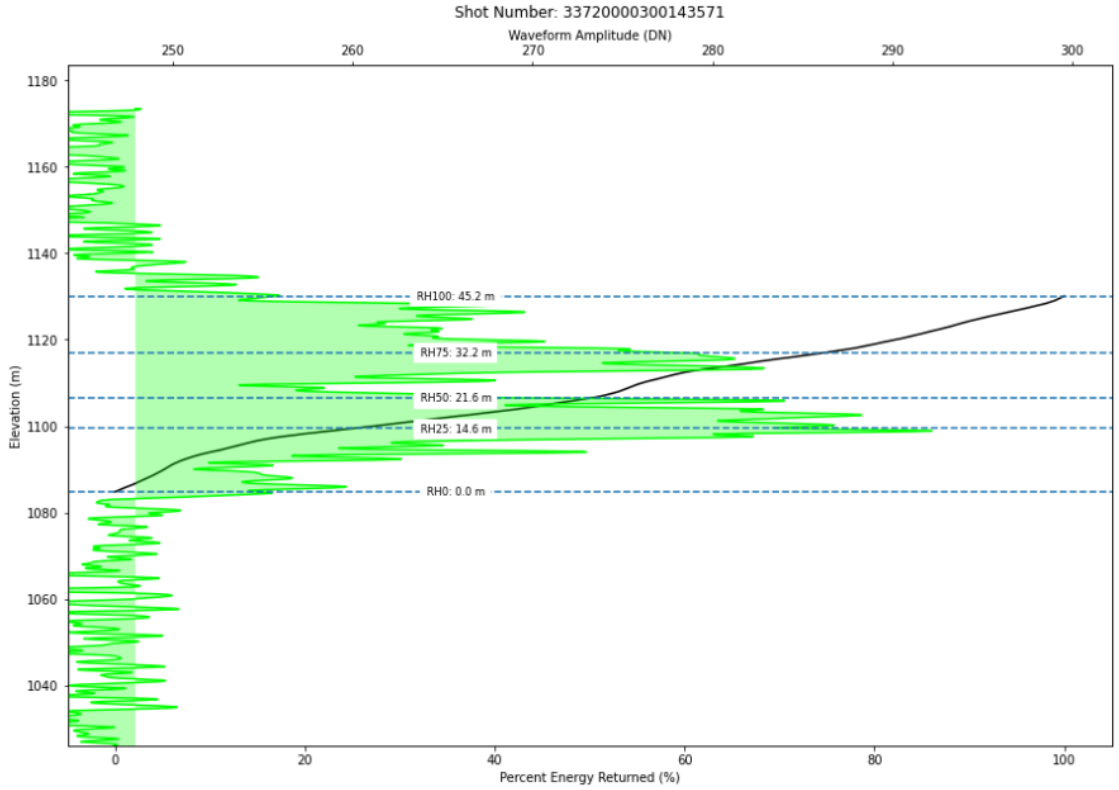
3 – New Forest Parameters
Structure/Layers

- Sidestep: when working with L1B (waveform) → do not use the spatial subsetting option → data deteriorated --> GEDI DAAC team is working on it

with spatial subsetting > z-offset



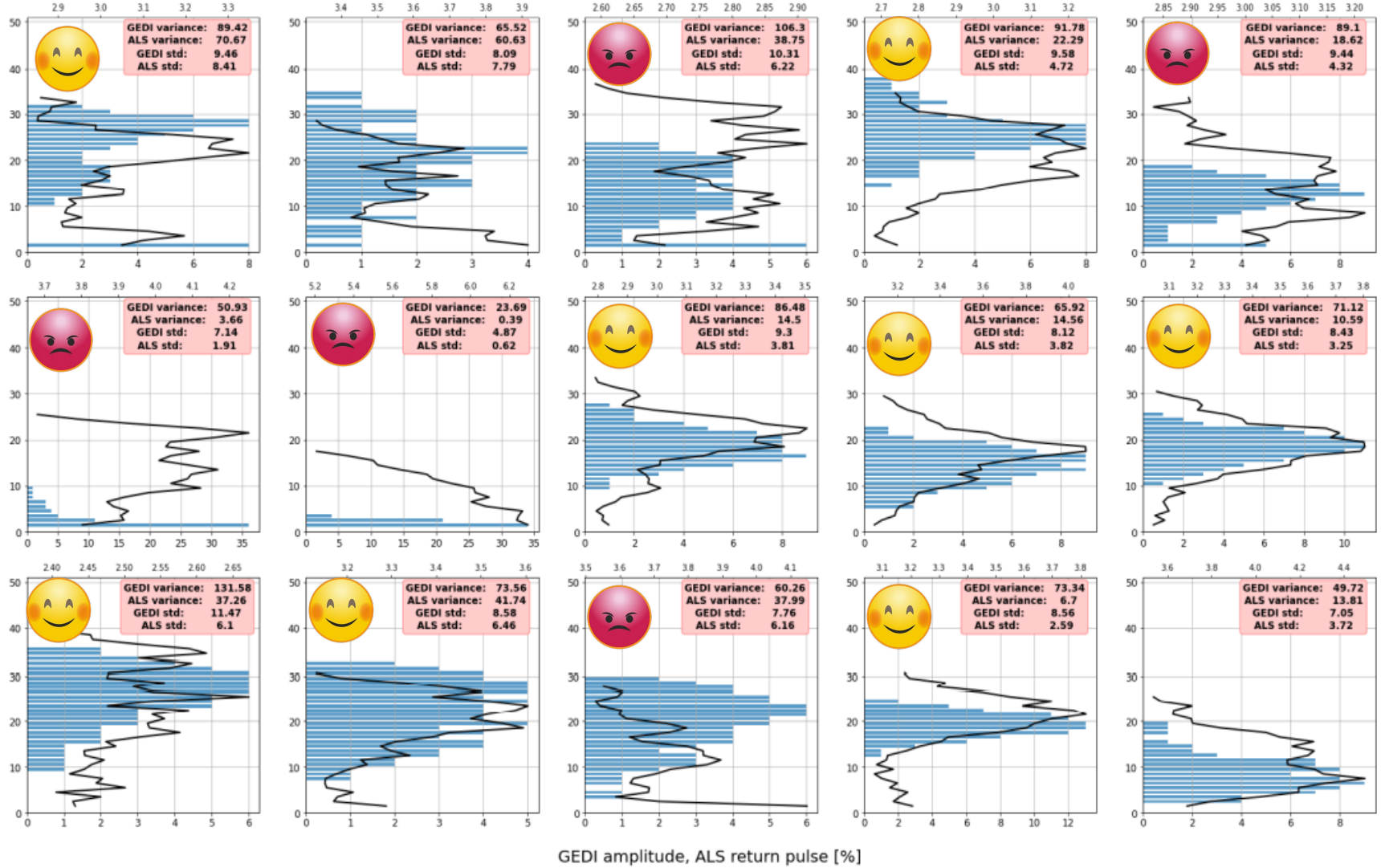
without spatial subsetting > L1B & L2A data fit



3 – New Forest Parameters

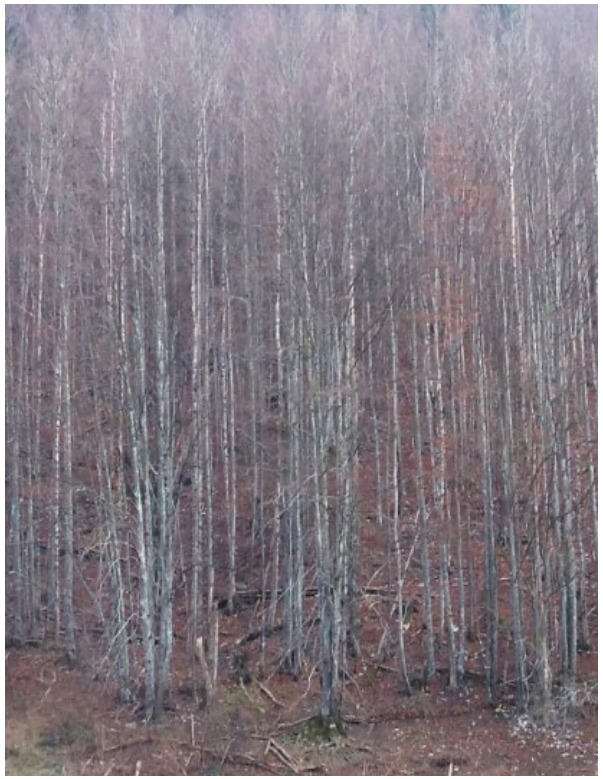
Structure/Layers

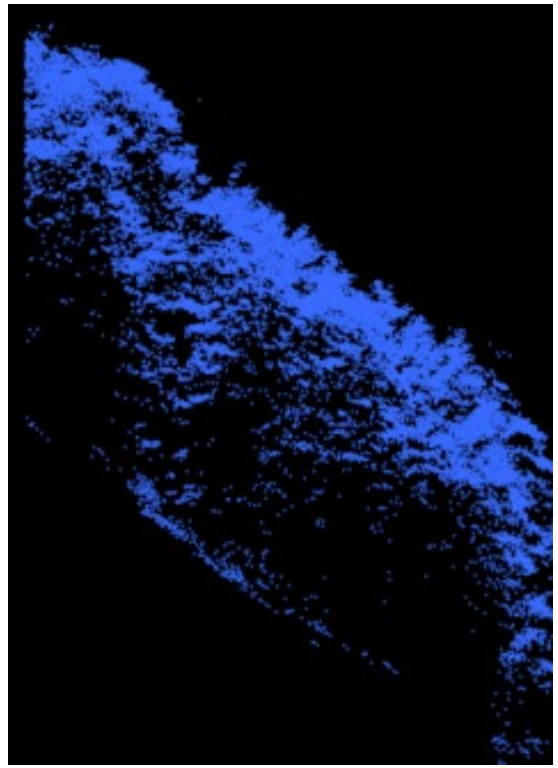
- Comparison ALS - GEDI waveforms:
  - GEDI
  - ALS
- And what does that reflect?
- Need for real reference!

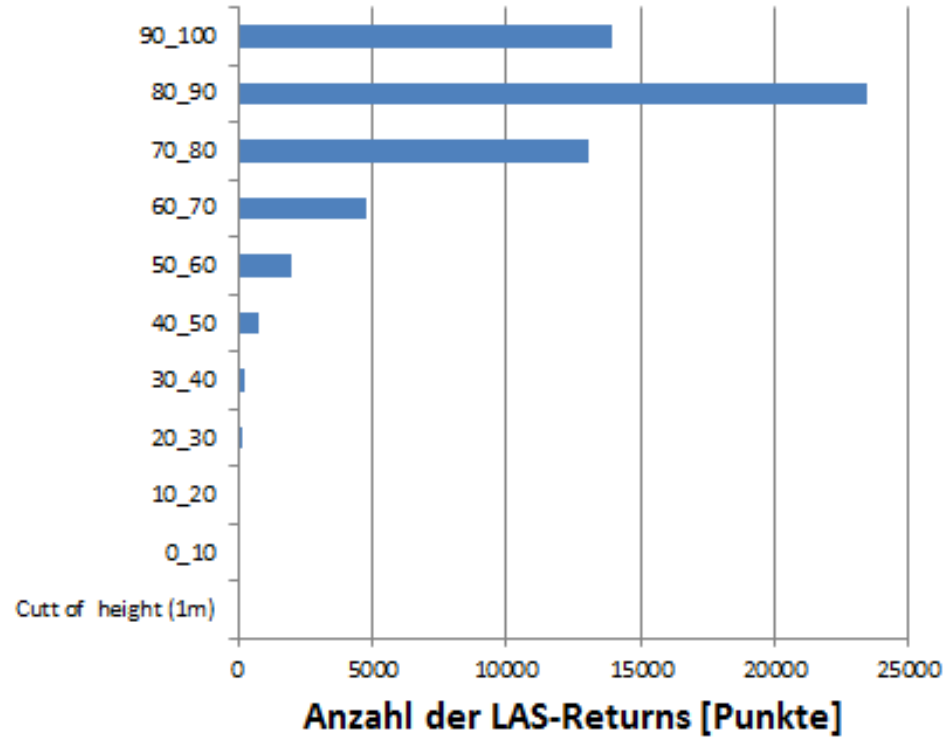


3 – New Forest Parameters
Structure/Layers

- One layer, low vertical structure

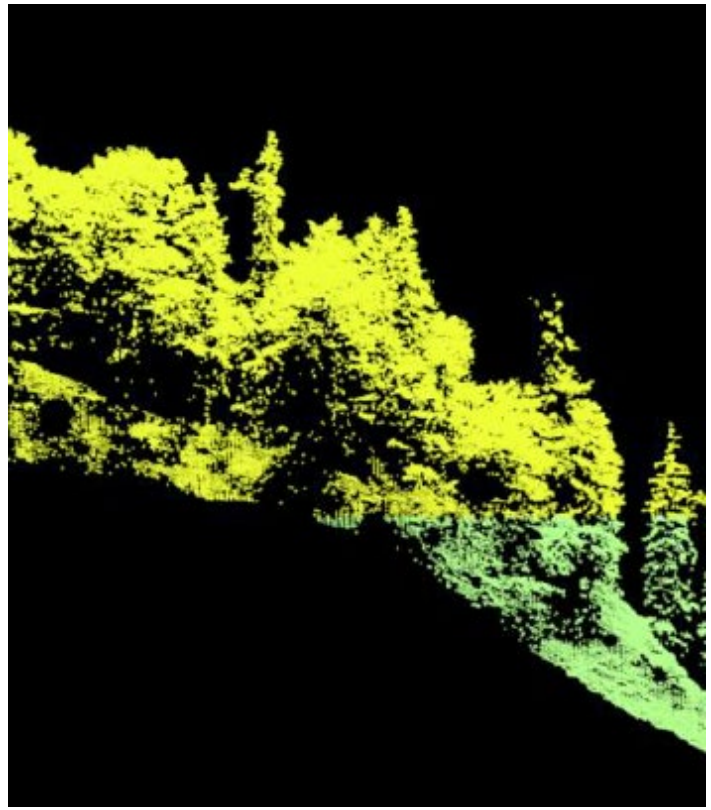


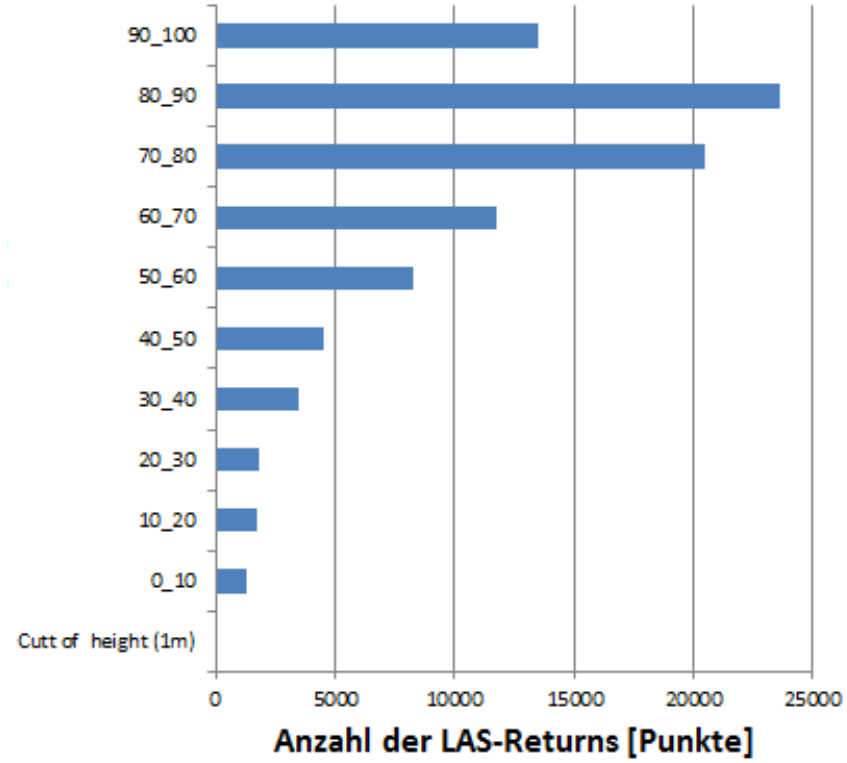




3 – New Forest Parameters
Structure/Layers

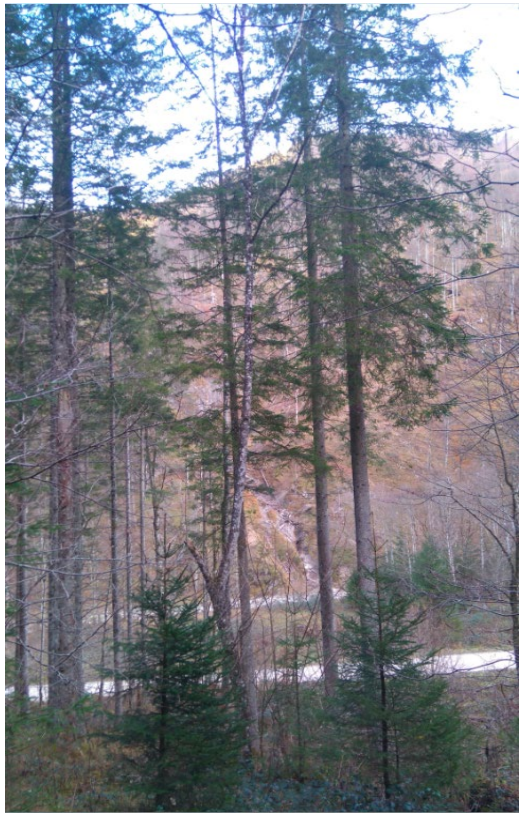
- One layer, medium vertical structure

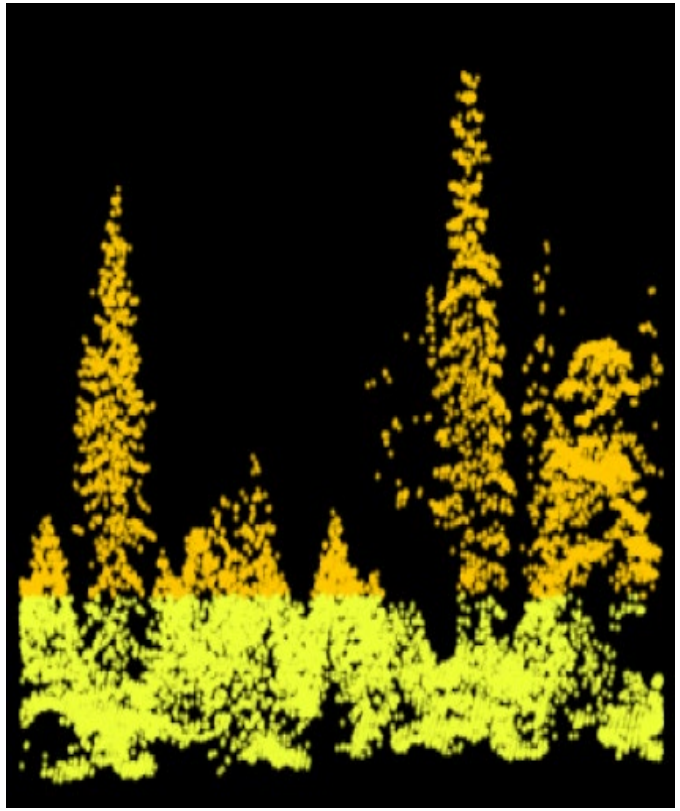


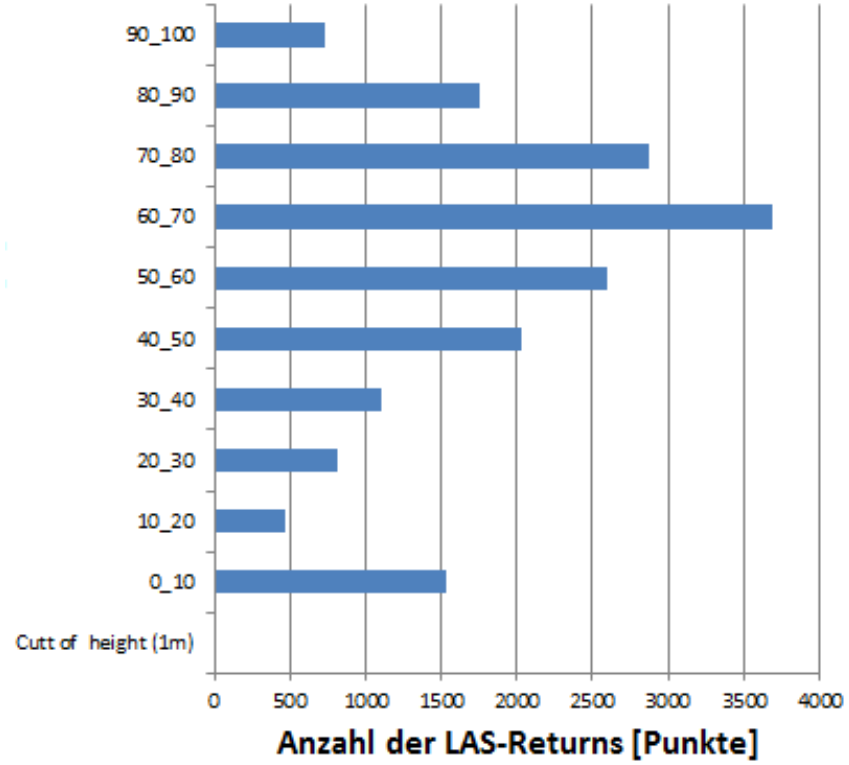


3 – New Forest Parameters
Structure/Layers

- Multi-layered, high vertical structure

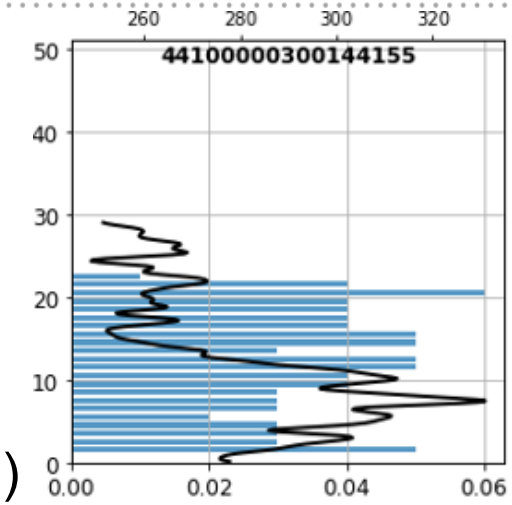


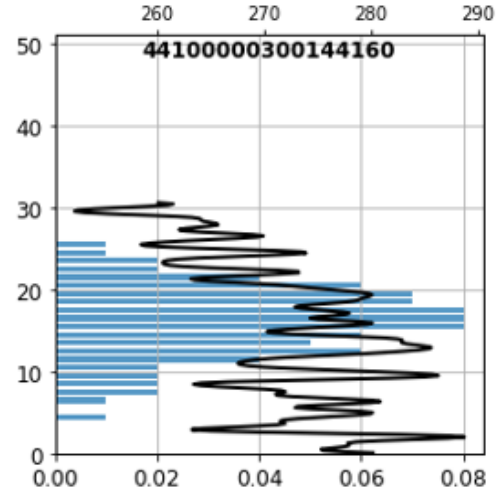




3 – New Forest Parameters
Structure/Layers

Visual interpretation of GEDI & ALS waveforms in **428 GEDI shots**





Two attributes

- Number of layers (single, double, multi-layered)
- Vertical Structure (low, medium, high)

Results:

	NUMBER OF LAYERS	
	ALS	**GEDI**
Single	338	255
Double	80	119
Multi-layered	10	54

	VERTICAL STRUCTURE	
	ALS	**GEDI**
Low	61	23
Medium	198	250
High	169	155

3 – New Forest Parameters
Structure/Layers

- Interpretation plots GEDI FHD / ALS

Number of layers		GEDI		
		Single	**Double**	**Multi**
ALS	**Single**	**223**	86	29
	Double	30	**32**	18
	Multi-layer	2	1	**7**

Overall compliance ALS-GEDI: 61.21 %

Vertical structure		GEDI		
		Low	**Medium**	**High**
ALS	**Low**	**19**	41	1
	Medium	4	**139**	55
	High	0	70	**99**

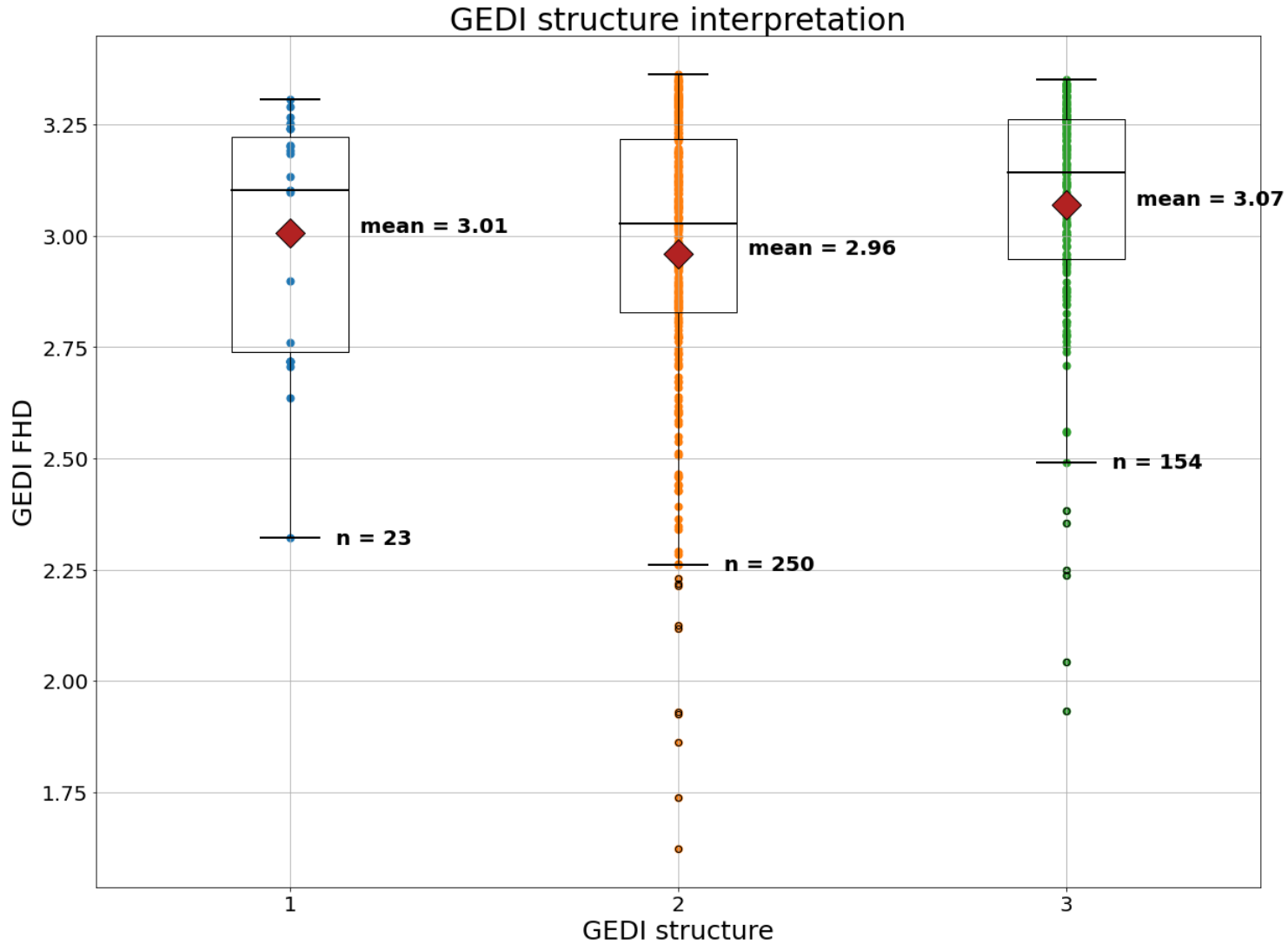
Overall compliance ALS-GEDI: 60.05 %

3 – New Forest Parameters
Structure/Layers

- Comparison of GEDI interpretation with FHD values for vertical structure

		Structure		
		low	medium	high
FHD	1	1	0.5	1
	2	1	1	1
	3	0.35	0.31	1

Table 3: p-value - GEDI structure

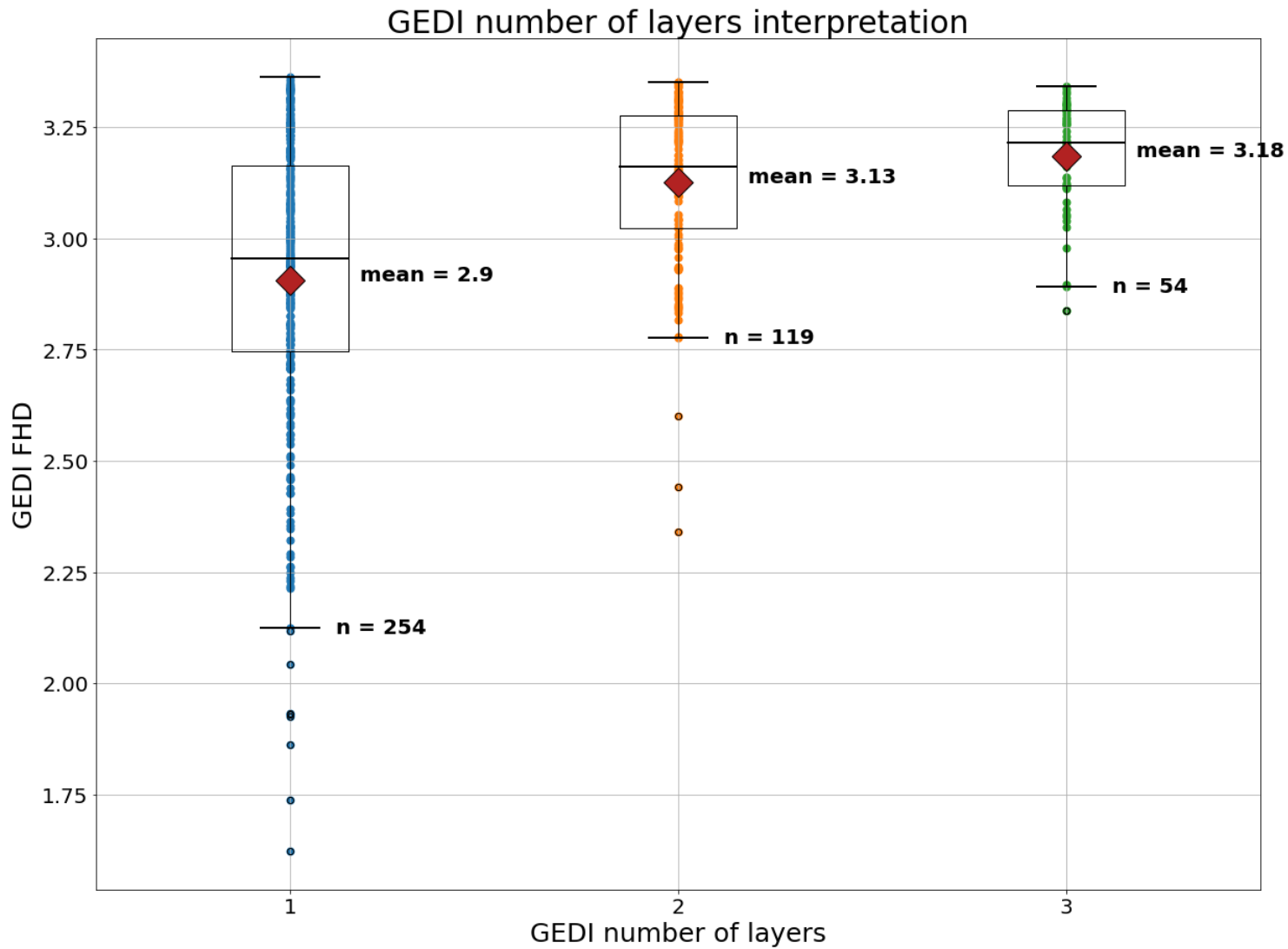


3 – New Forest Parameters
Structure/Layers

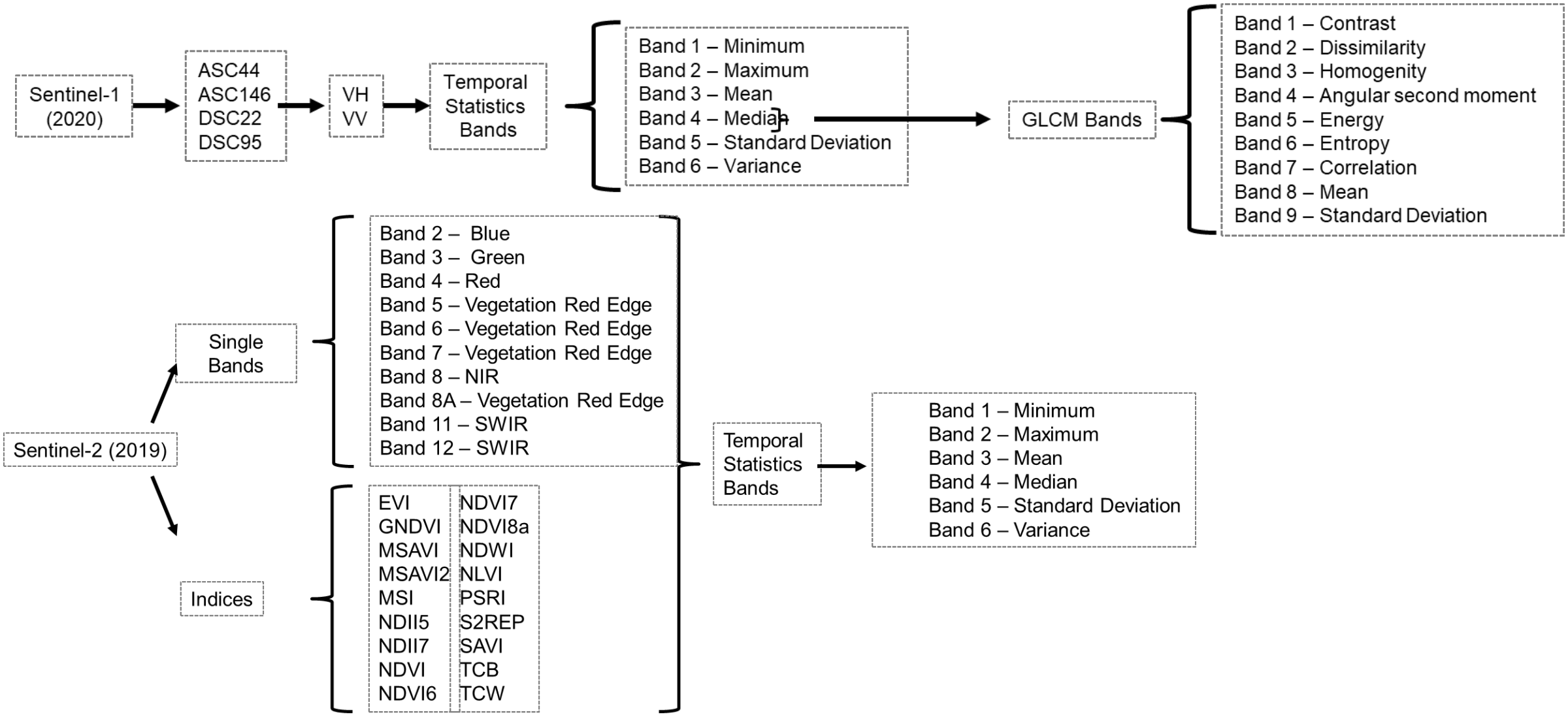
- Comparison of GEDI interpretation with FHD values for number of layers

		Number of layers		
		1	2	3
FHD	1	1	1	1
	2	0.16	1	1
	3	0.11	0.2	1

Table 4: p-value - GEDI number of layers

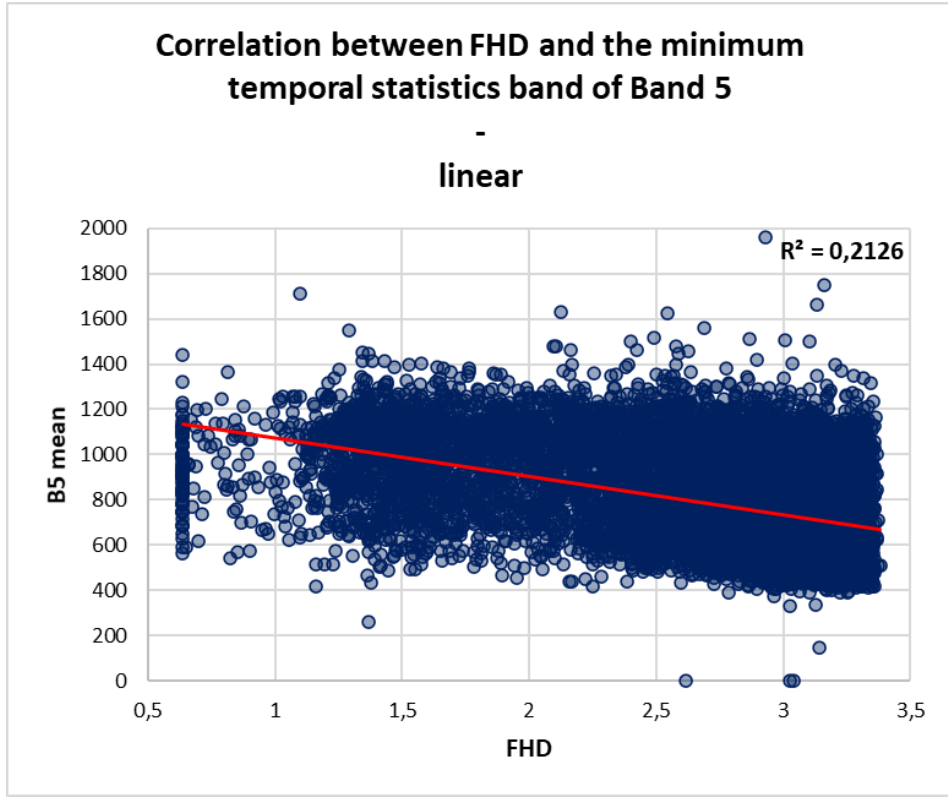


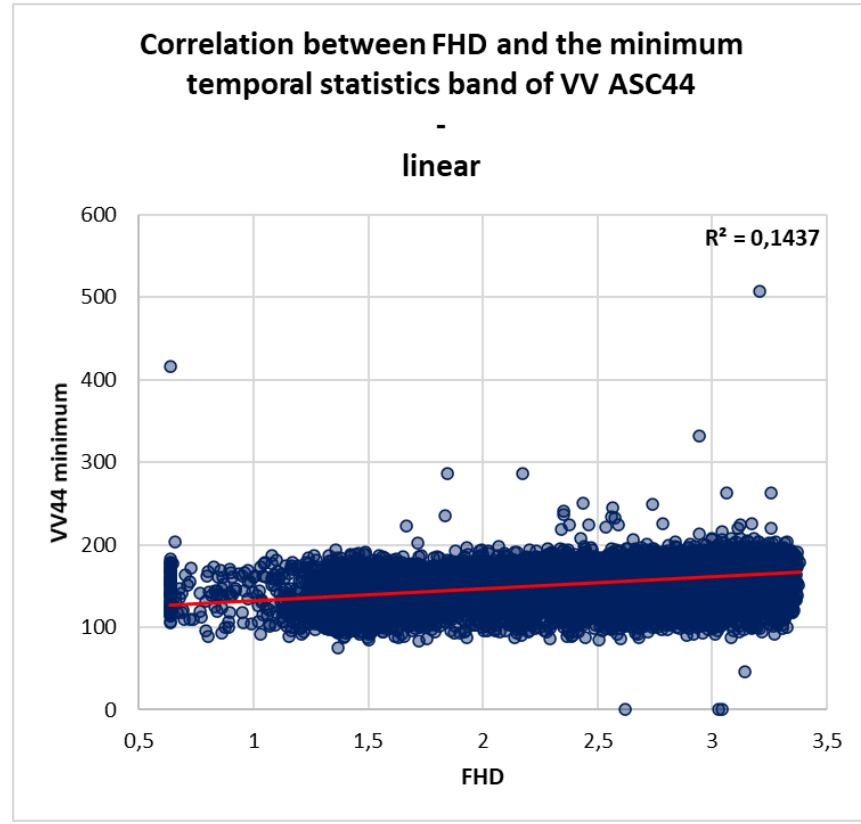
3 - Combining GEDI with Sentinel-1 and -2 Preprocessing



3 - Combining GEDI with Sentinel-1 and -2

- Some examples (only flat areas (< 15°)) - very first results - work ongoing





Conclusions

1. *Steep slopes are a main problem - decreasing accuracy and thus hindering the use of GEDI*
2. *Forest structure is still not fully clear in terms of definition - what do we really want to map?*
3. *No of layers seems to be reflected in FHD values - way to go*
4. *Both S-1 (flat areas only) and S-2 have some explanatory power for FHD*

Next steps

1. *Test slope-adaptive metrics?*
2. *Forest structure definition - discussion with foresters (i.a. at ForestSAT conference in Berlin in August 2022 - call for abstracts open until 31 May!)*
3. *maybe come up with a new structure indicator?*
4. *Better understand differences in waveforms between GEDI and ALS*
5. *Include all S-1 and S-2 input bands in a RF regression estimator for FHD and analyse the results*

Thank you very much for your attention

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