CzechGlobe
GLOBAL CHANGE
RESEARCH INSTITUTE CAS

Tomáš Hanousek

Rekonstrukce lesa pomocí metod DPZ

12/03/2025

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Kdo jsem

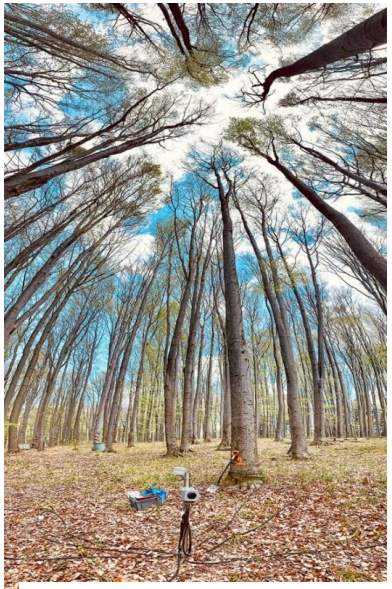
- Absolvent bc. i mgr. oboru kartografie
- Aktuálně ve třetím ročníku Ph.D., zaměření DPZ
- Zaměstnaný na CzechGlobe (Ústav výzkumu globální změny AVČR) – spolupráce v rámci doktorského studia
- Vedoucí doc. Pokorná (bc. a mgr. u doktorky Tajovské)
- Původní zaměření na znečištění vody, teď rekonstruování lesa

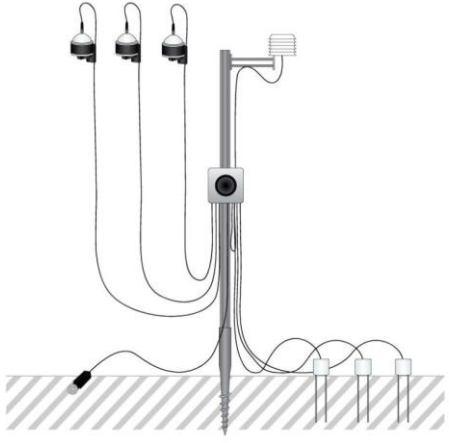
CzechGlobe

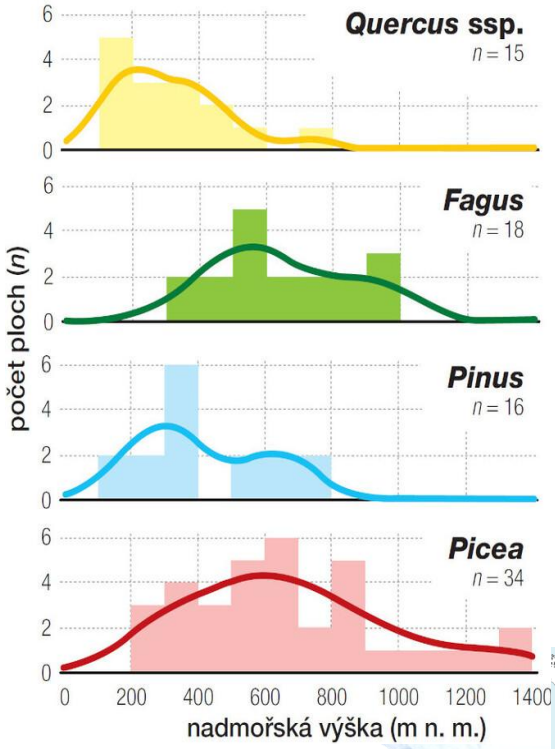
Ústav výzkumu globální změny Akademie věd České republiky – CzechGlobe je veřejná výzkumná instituce, evropské centrum excelence, zabývající se příčinami a dopady **globální změny**, tedy závažného aktuálního problému lidstva, jejímž jedním z hlavních aspektů je **klimatická změna**.

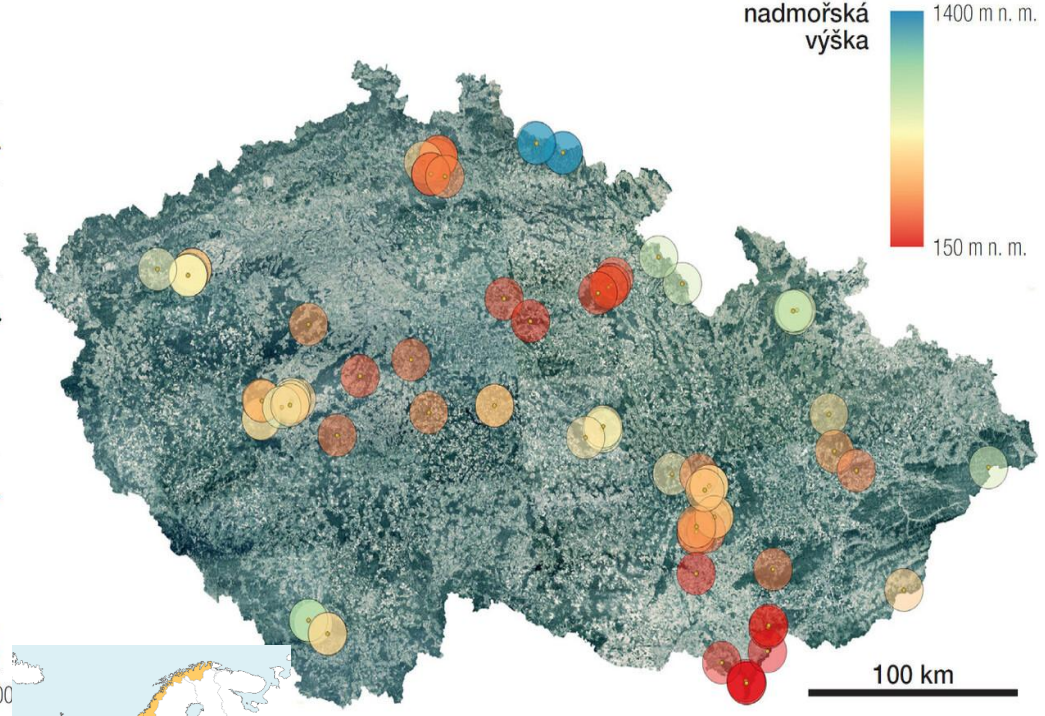
CzechGlobe prostorově distribuovaná výzkumná infrastruktura

Automatic *Dendrometer* network

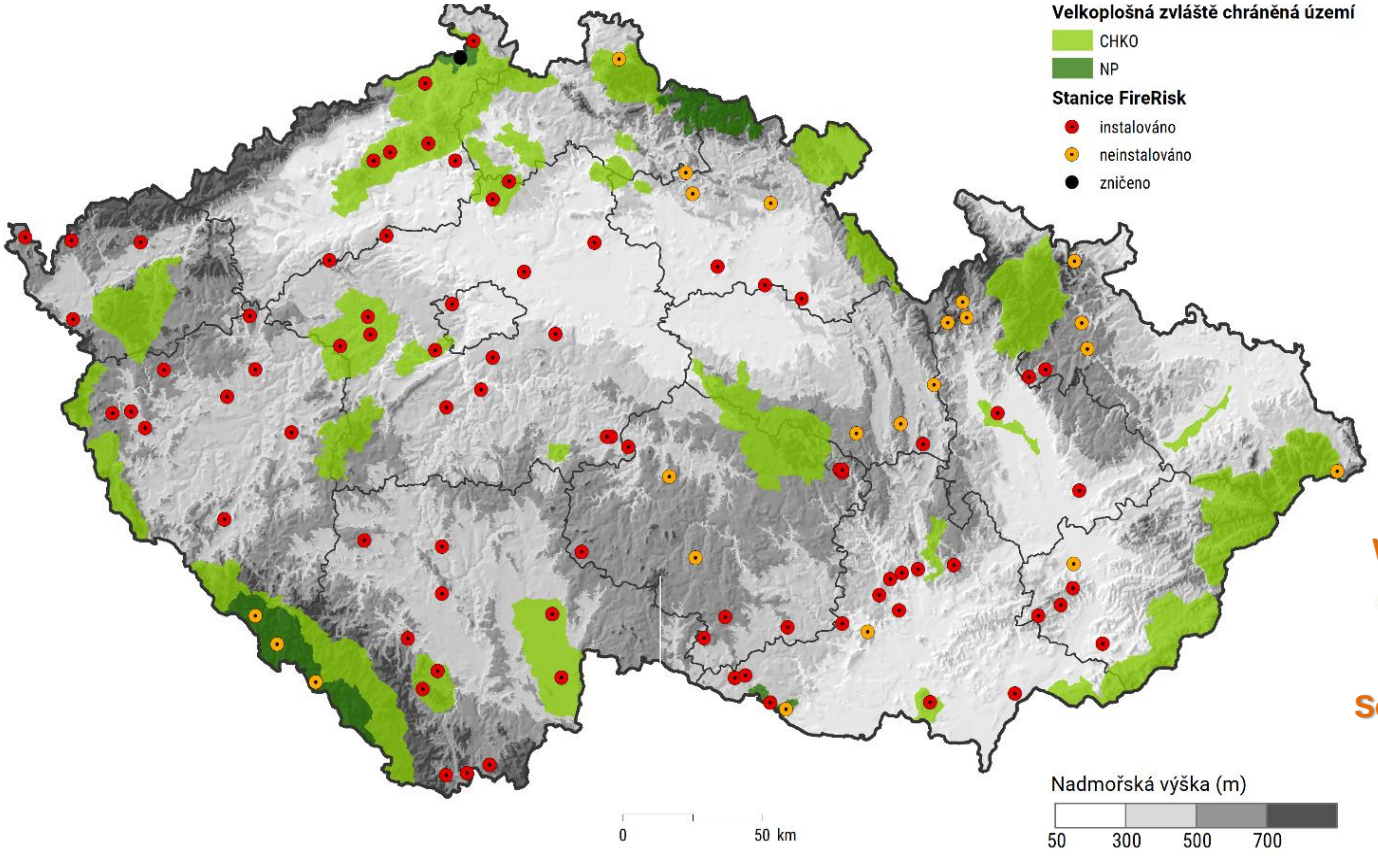


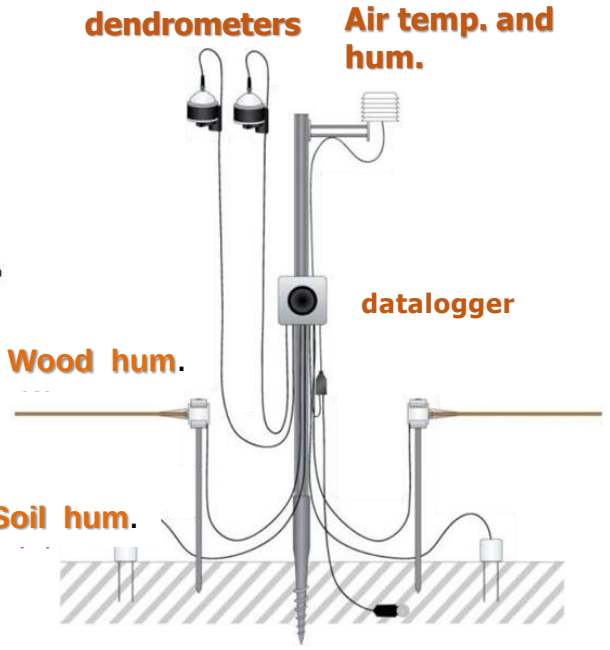




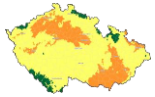


FireRisk – network of monitoring stations

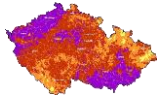




Air temp.



Air hum.



Wind

Letecký dálkový průzkum na CzechGlobe

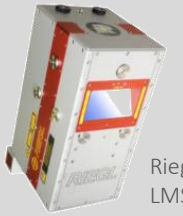
EUFAR
European Facility for Airborne Research

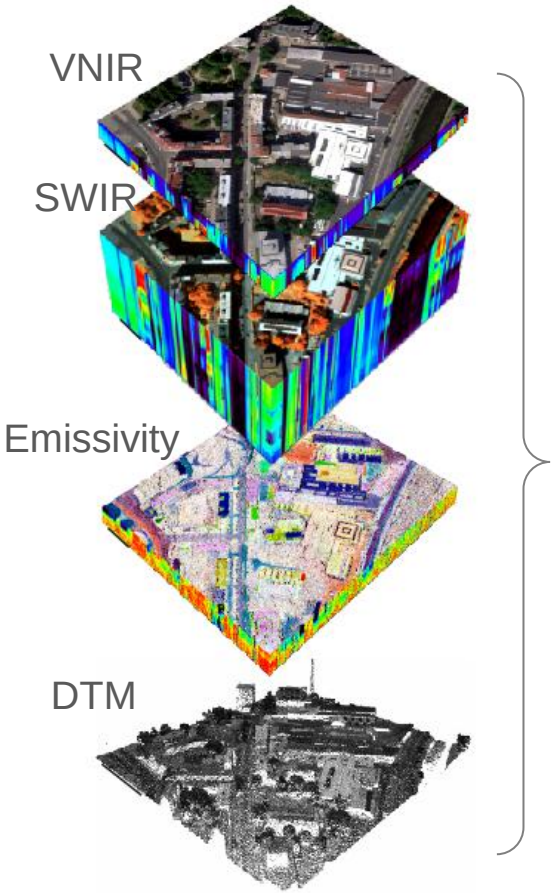
Flying laboratory of imaging systems

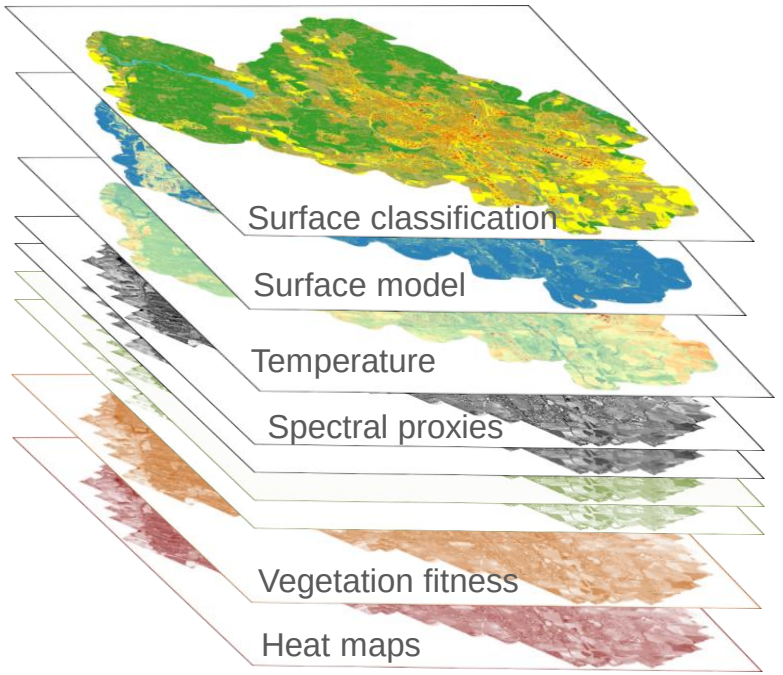
VNIR-SWIR imaging spectroscopy

Thermal imaging spectroscopy

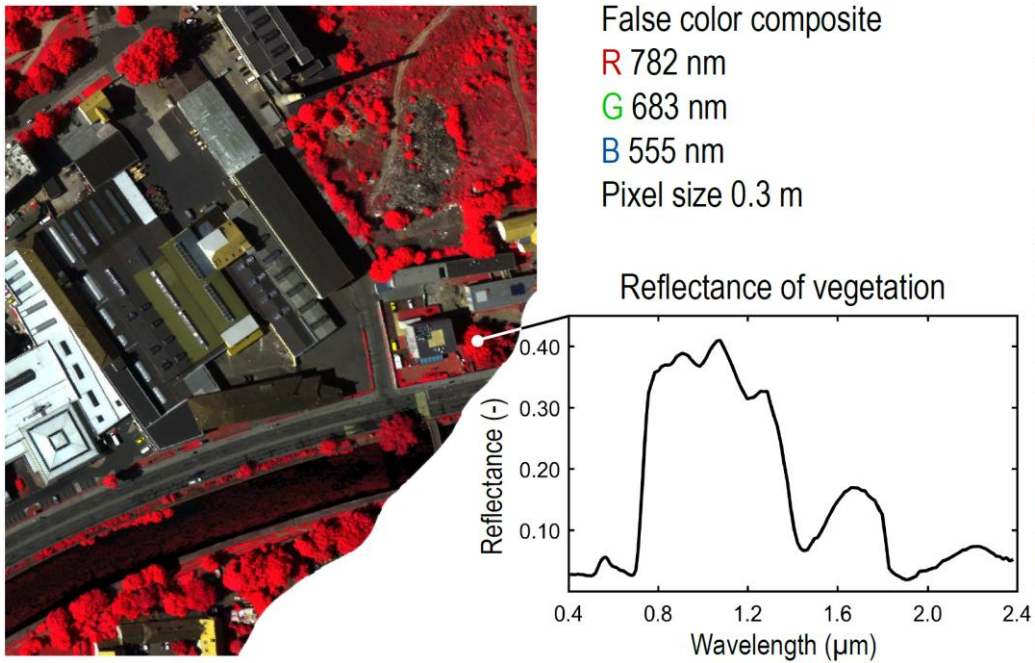
Laser scanning



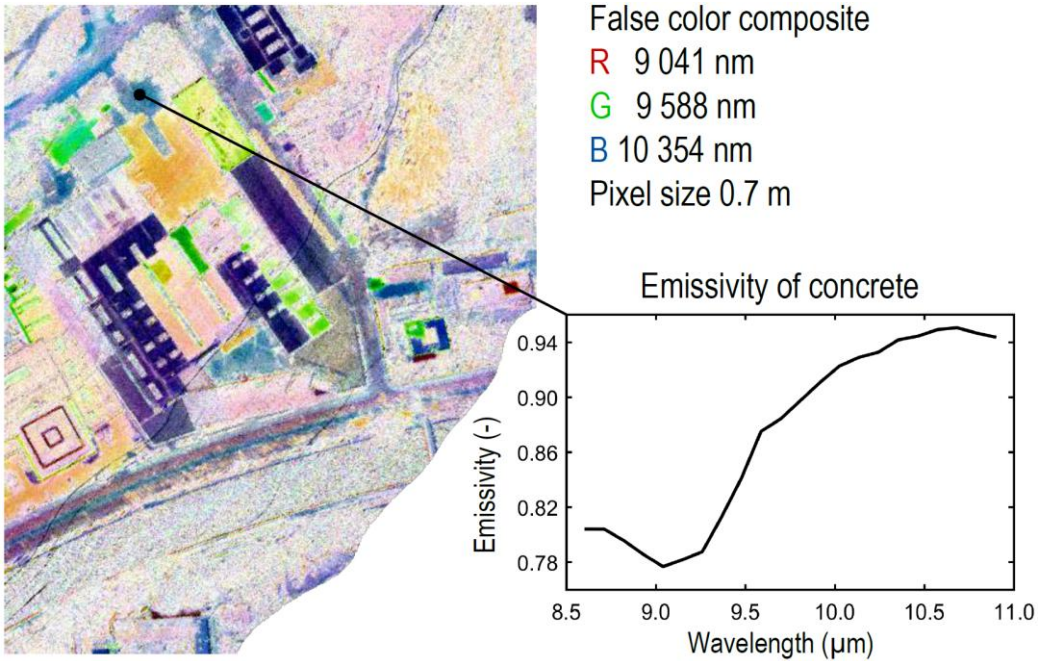




Zpracování hyperspektrálních dat – standardní výstupy



VNIR,SWIR – odrazivost

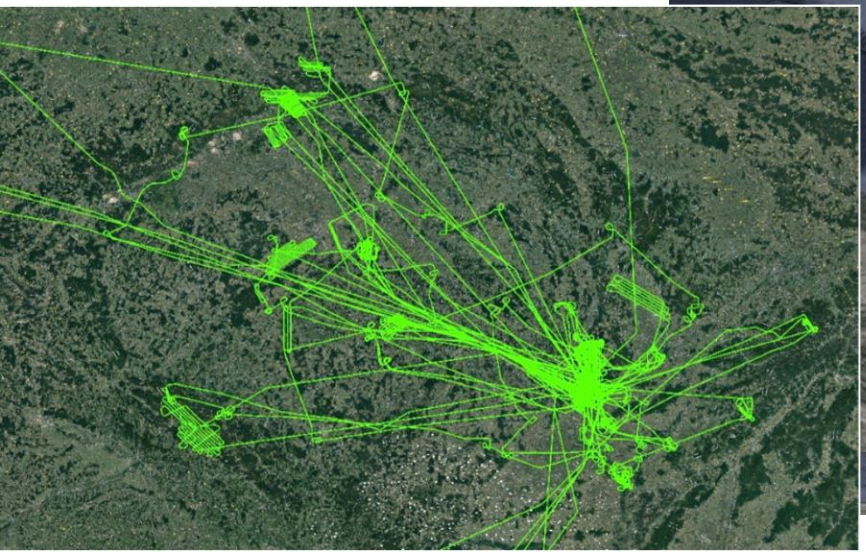


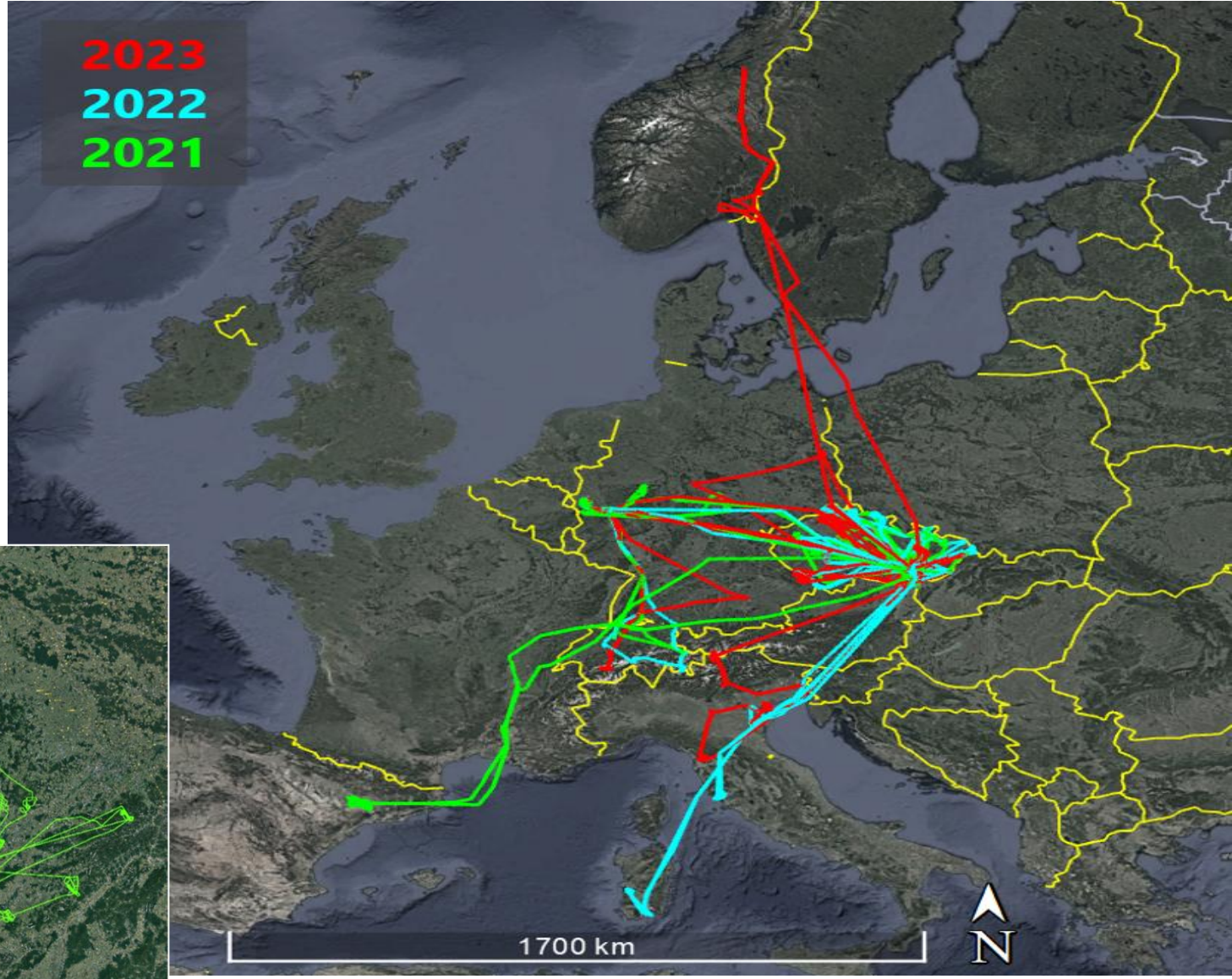
LWIR – povrchová teplota
– emisivita

Letecké kampaně

Letecká laboratoř CzechGlobe uskutečnila v roce 2024 **více jak 60 letů**, zejména pro účely projektů SustES a CzeCOS. K nejzajímavějším patřily kampaně prováděné ve spolupráci s CNR, za účelem kalibrace Italského hyperspektrálního satelitu PRISMA.

Ve spolupráci s německým FZJ byla uskutečněna již tradiční kampaň se senzorem HyPlant, který je leteckým demonstrátorem budoucí družicové mise FLEX. Zpestřením v průběhu kampaně bylo snímání ledovců ve švýcarských Alpách.



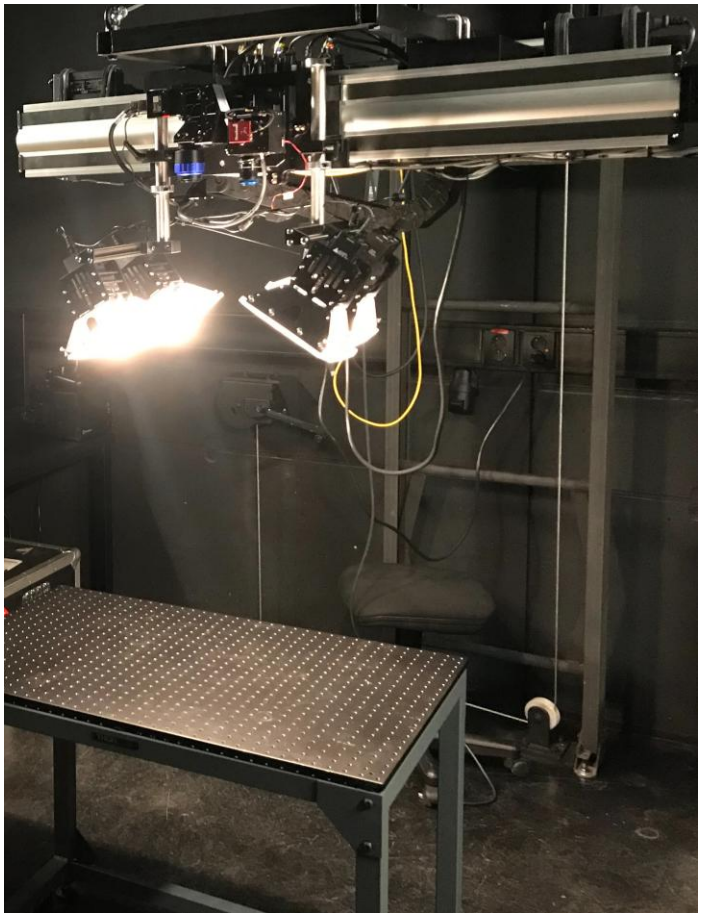


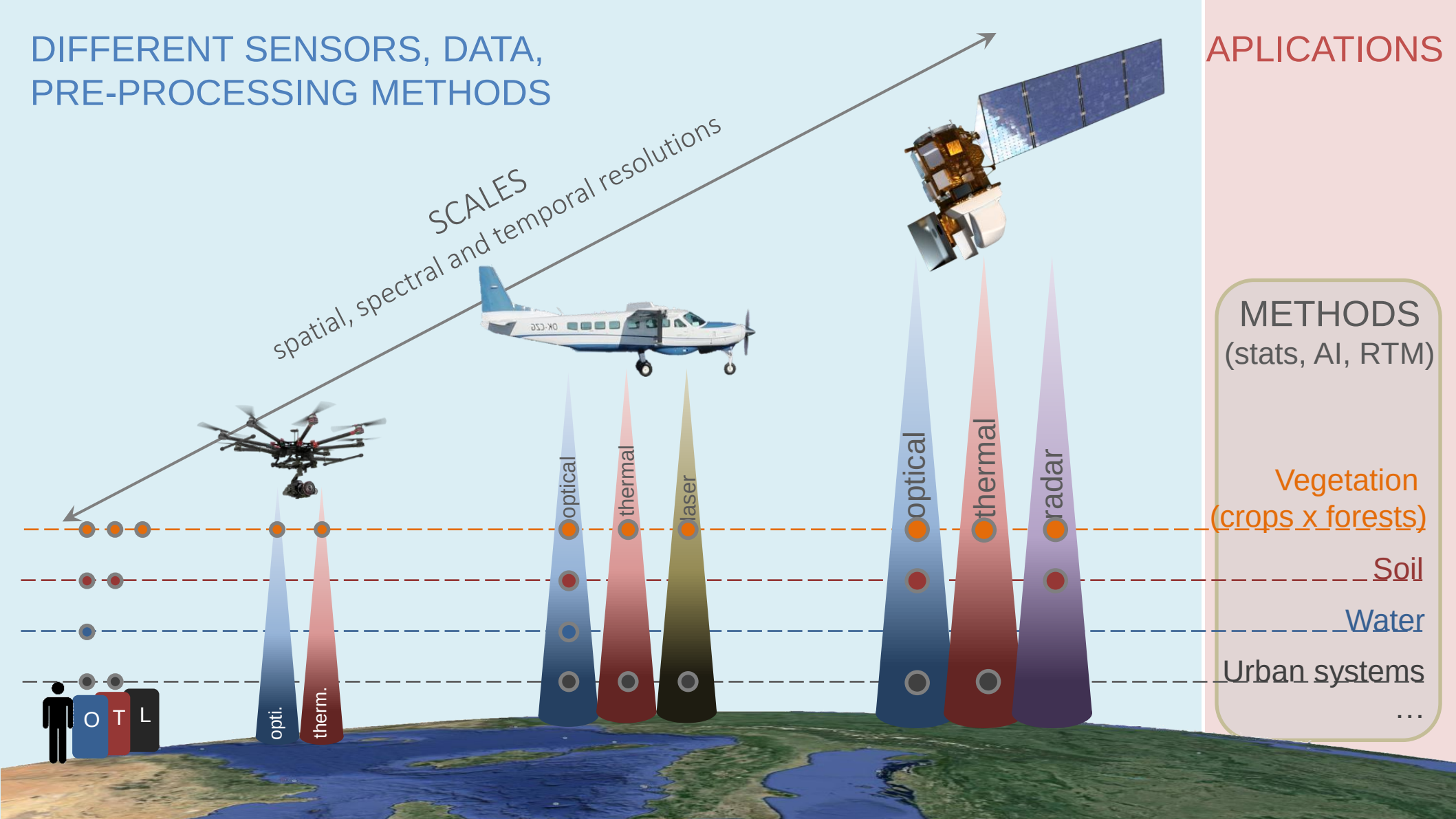
Laboratory – Image Data Acquisition

Core instruments:

- Laboratory Kit provided by headwall Photonics
- Imaging instruments

		
Sensor	**Nano**	**Micro**
Range	VNIR	NIR
Spectral range [nm]	400-1000	900– 1700
Number of spatial pixels	640	320
Max. spectral resolution [nm]	6.0	10.0

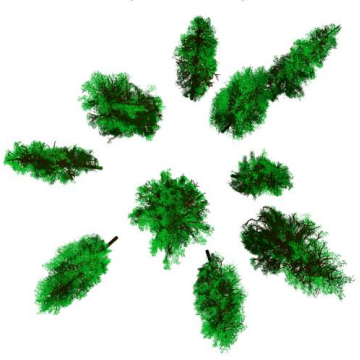


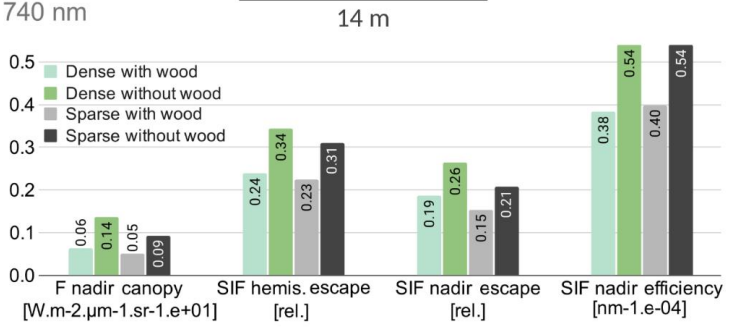

DIFFERENT SENSORS, DATA,
PRE-PROCESSING METHODS
APLICATIONS
SCALES
spatial, spectral and temporal resolutions
METHODS
(stats, AI, RTM)
Vegetation
(crops x forests)
Soil
Water
Urban systems
…
O T L
opti.
therm.
optical
thermal
laser
optical
thermal
radar

3D modelling of forest

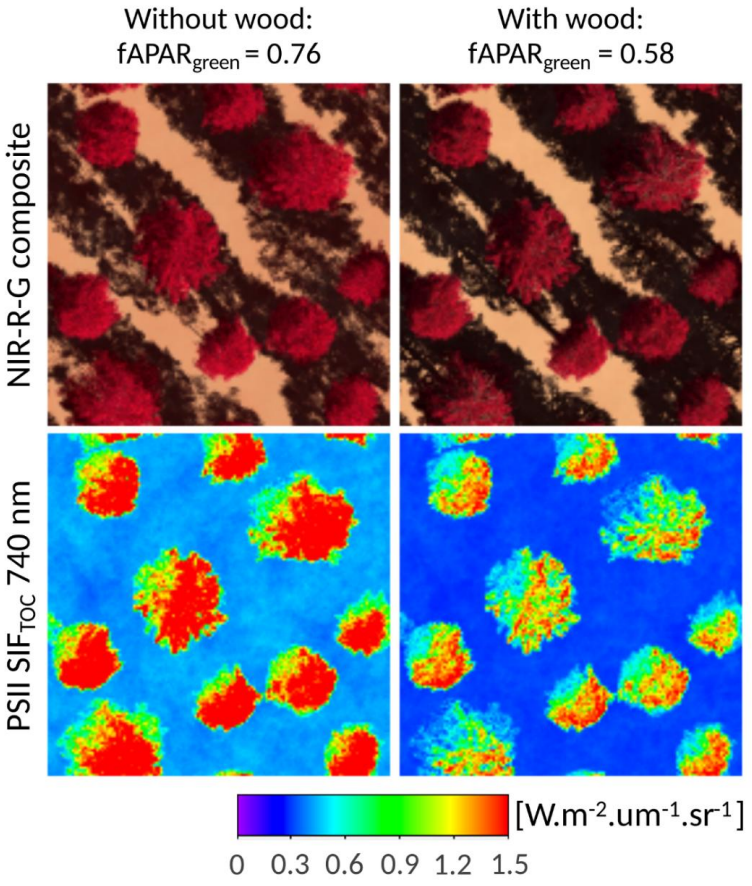
Terrestrial laser scanning for 3D tree species models

Radiative transfer modelling (DART)



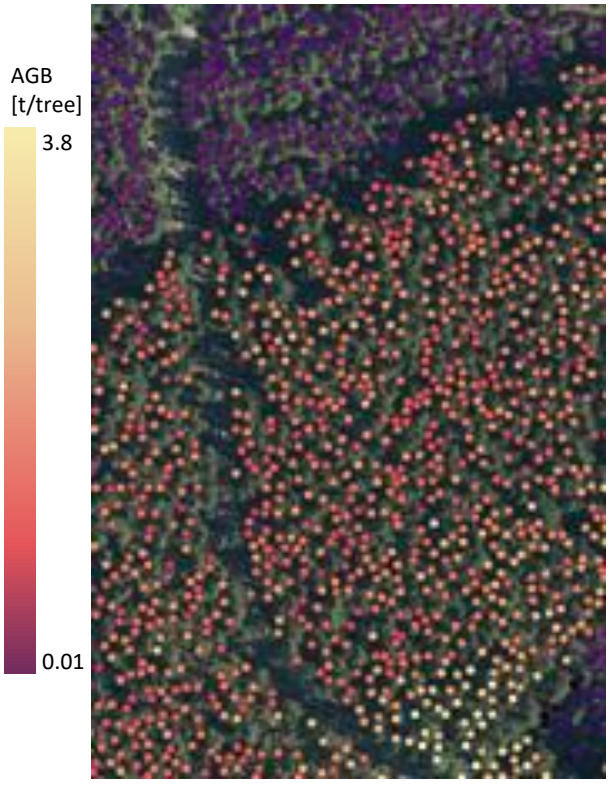


sun-induced fluorescence



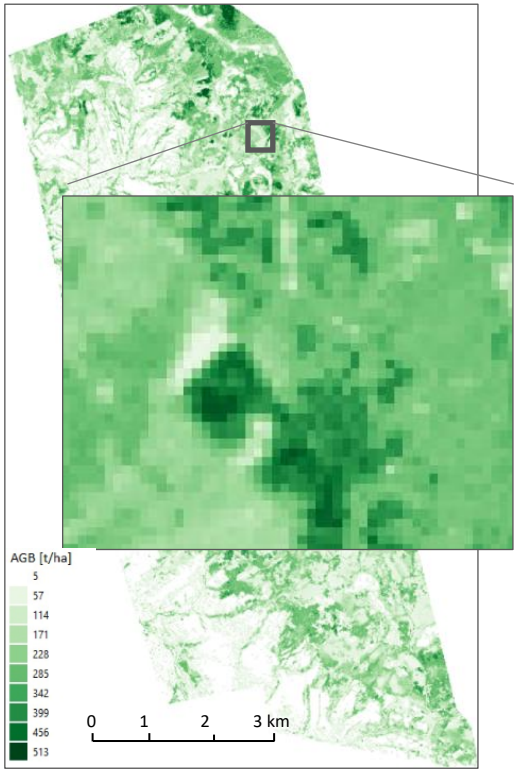
Forest aboveground biomass

Tree level



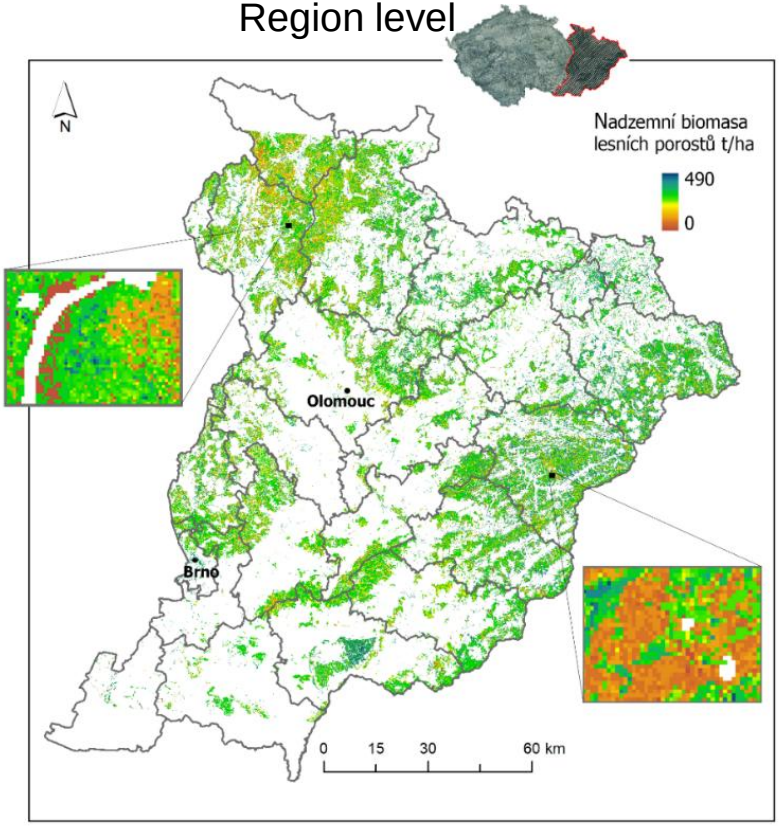
AGB from airborne laser scanning and hyperspectral data using tree allometry.

Forest stand level



AGB modelling using airborne LiDAR and area-based approach.
Spatial resolution is 5-10 m.

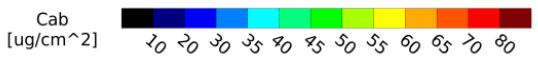
Region level

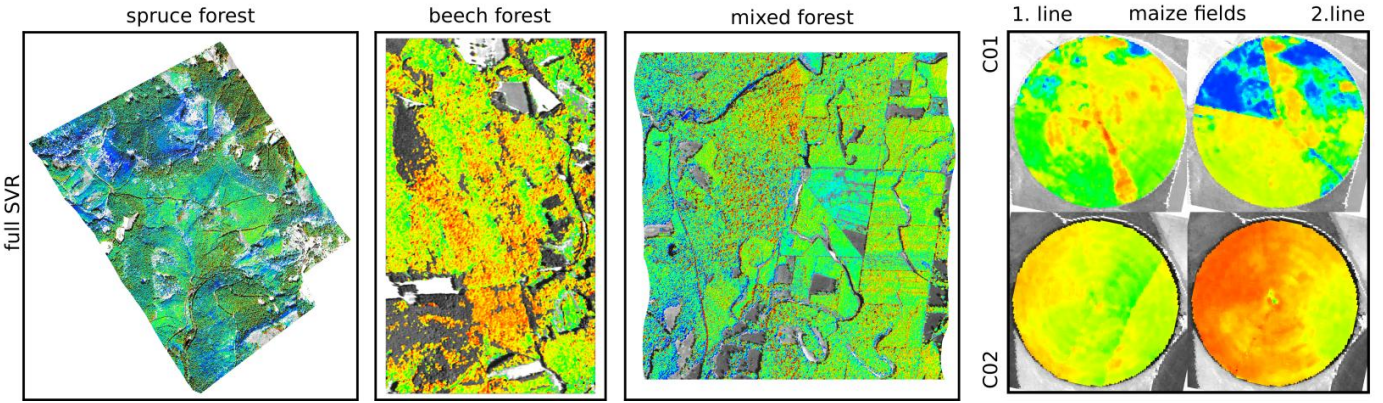


AGB modelling using satellite (optical & radar) data and machine-learning approaches.
Spatial resolution is 20 m.

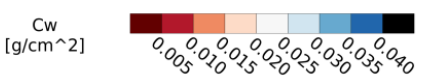
Plant traits

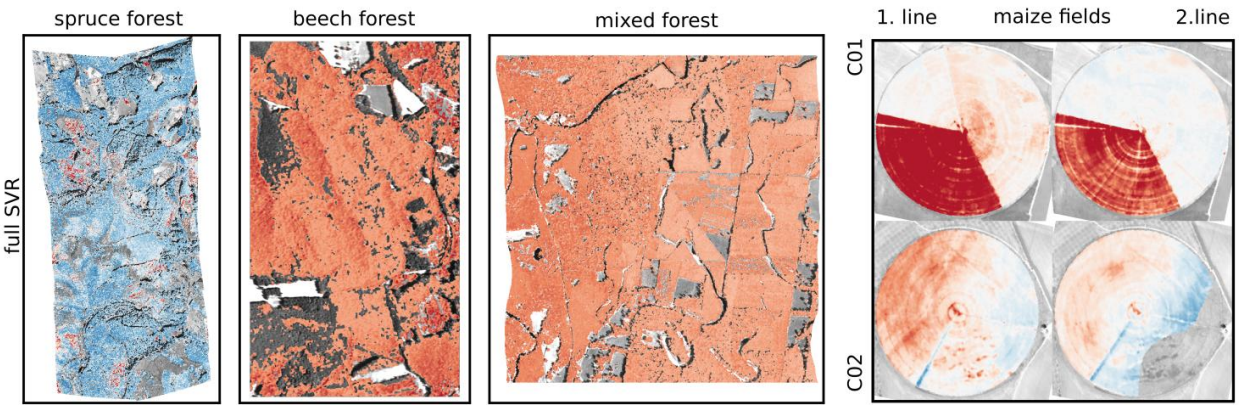
Leaf chlorophyll content:





Leaf water content:





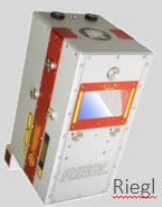
Urban Applications

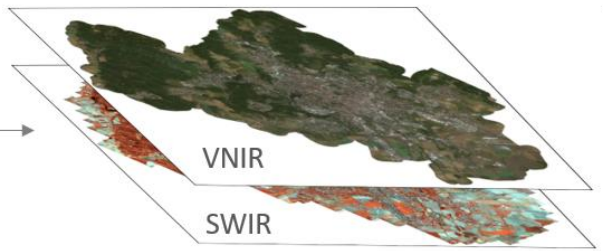
Airborne acquisitions by FLIS → Essential input data → Advanced thematic layers and spatial analysis

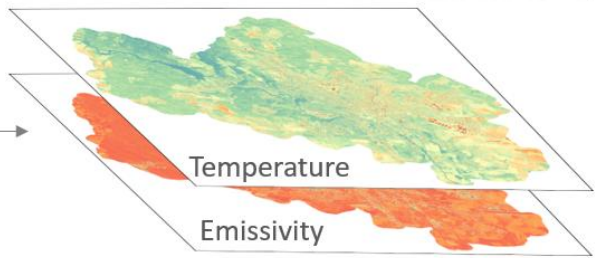
VNIR-SWIR imaging spectroscopy

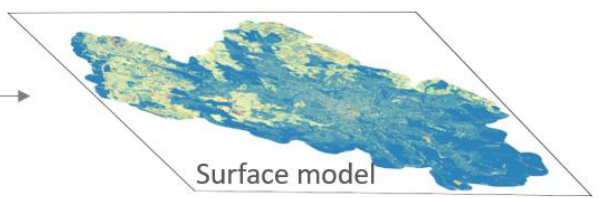
Thermal imaging spectroscopy

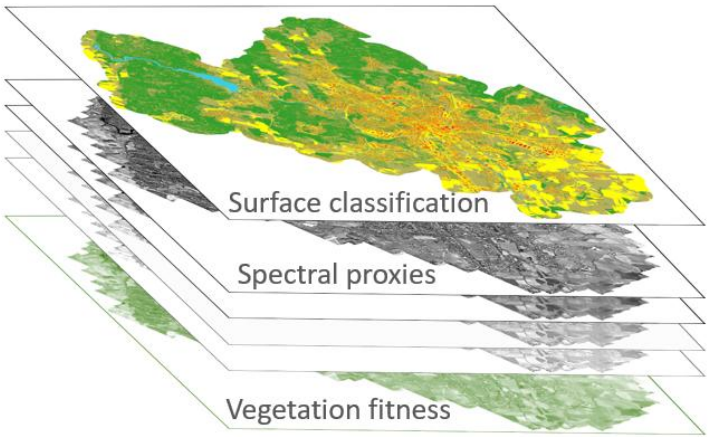
Laser scanning



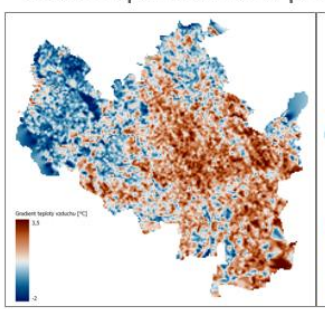


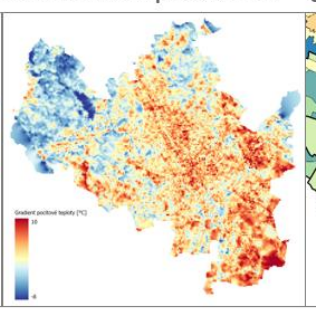




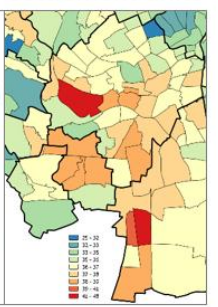


Heat maps of air and perceived temperatures

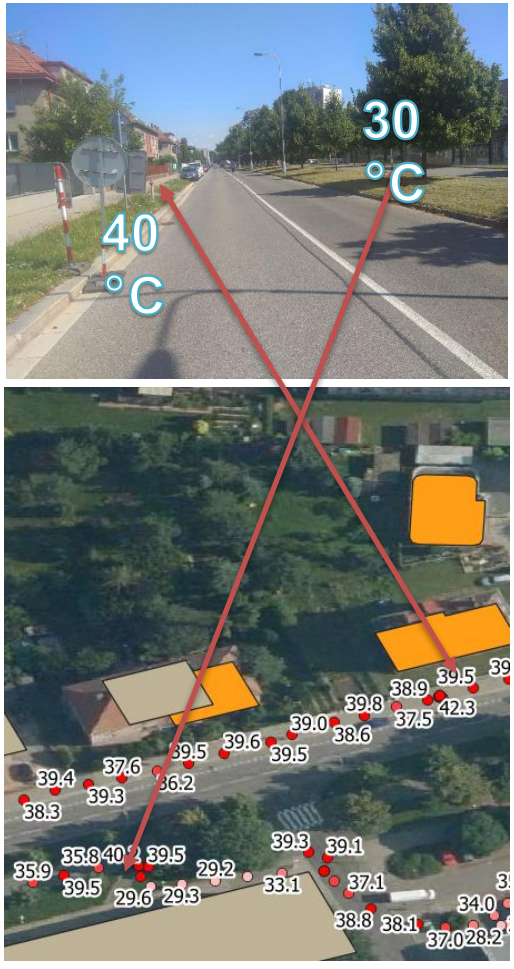




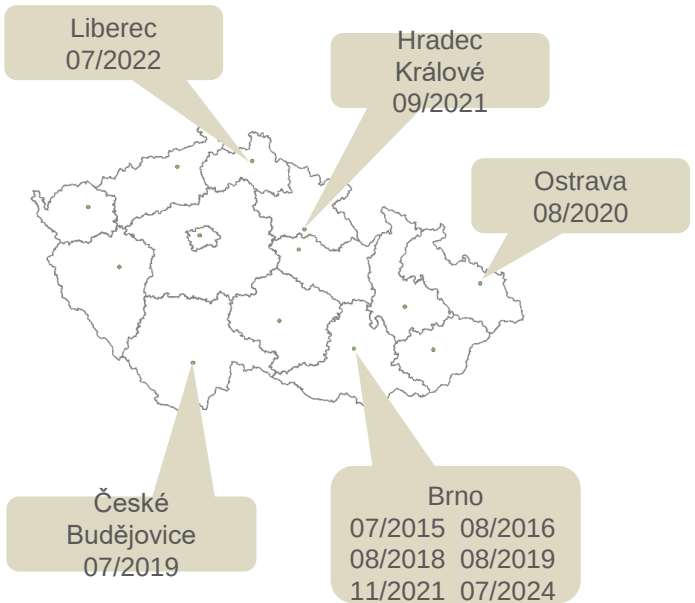
Aggregation by settlement units

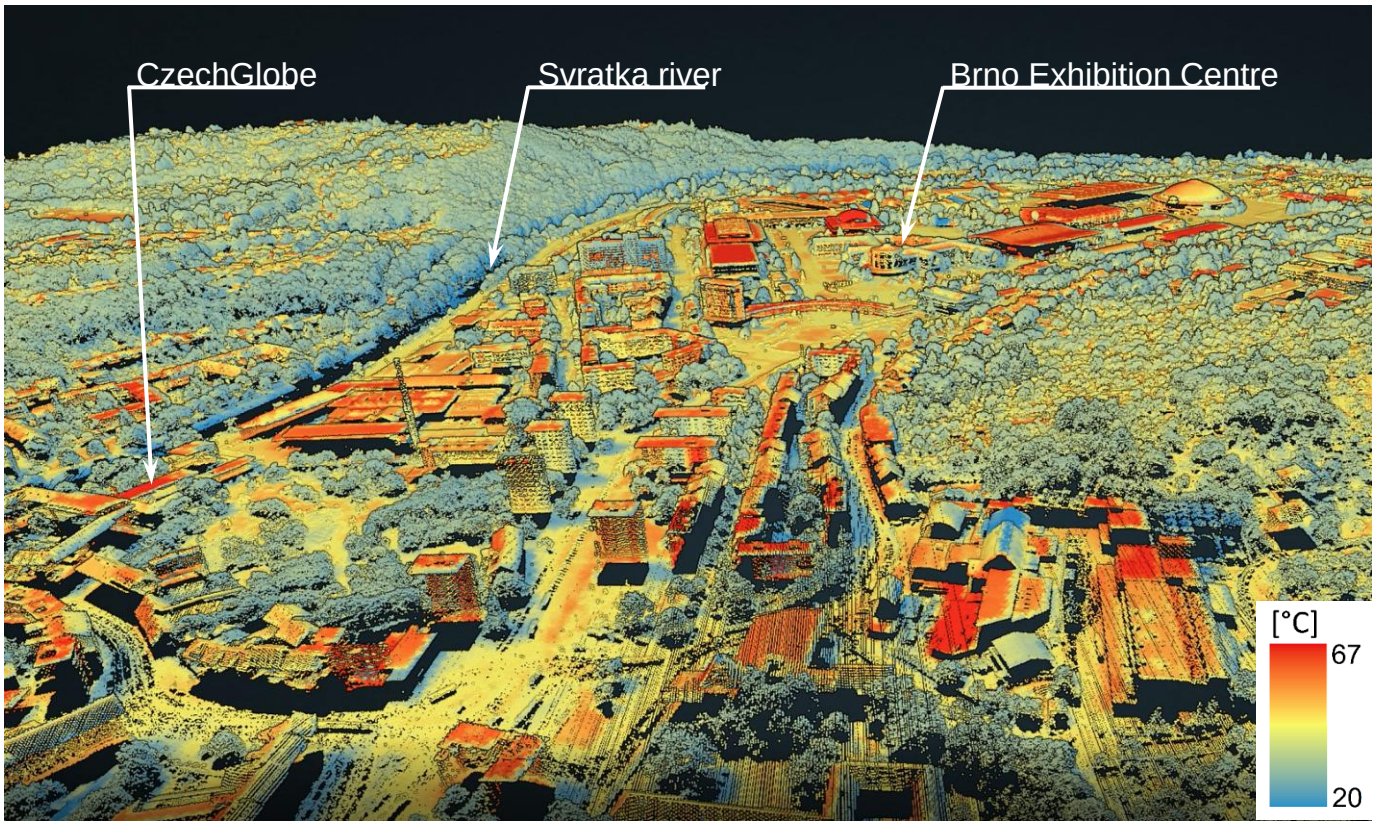


Pocitová teplota odhad z leteckých dat vs. in-situ měření



Thermal regime of urban systems

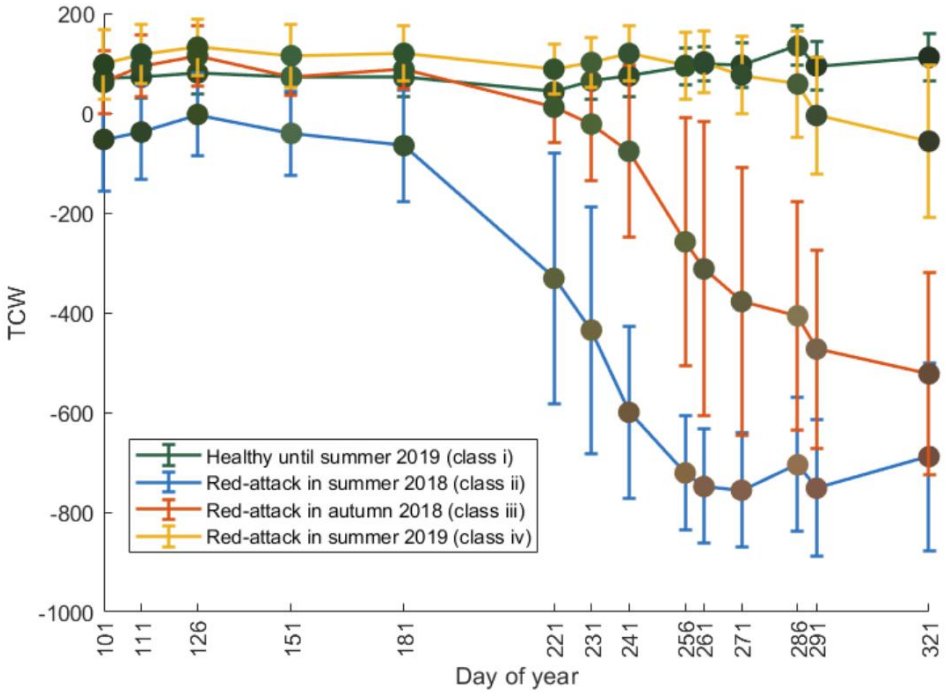




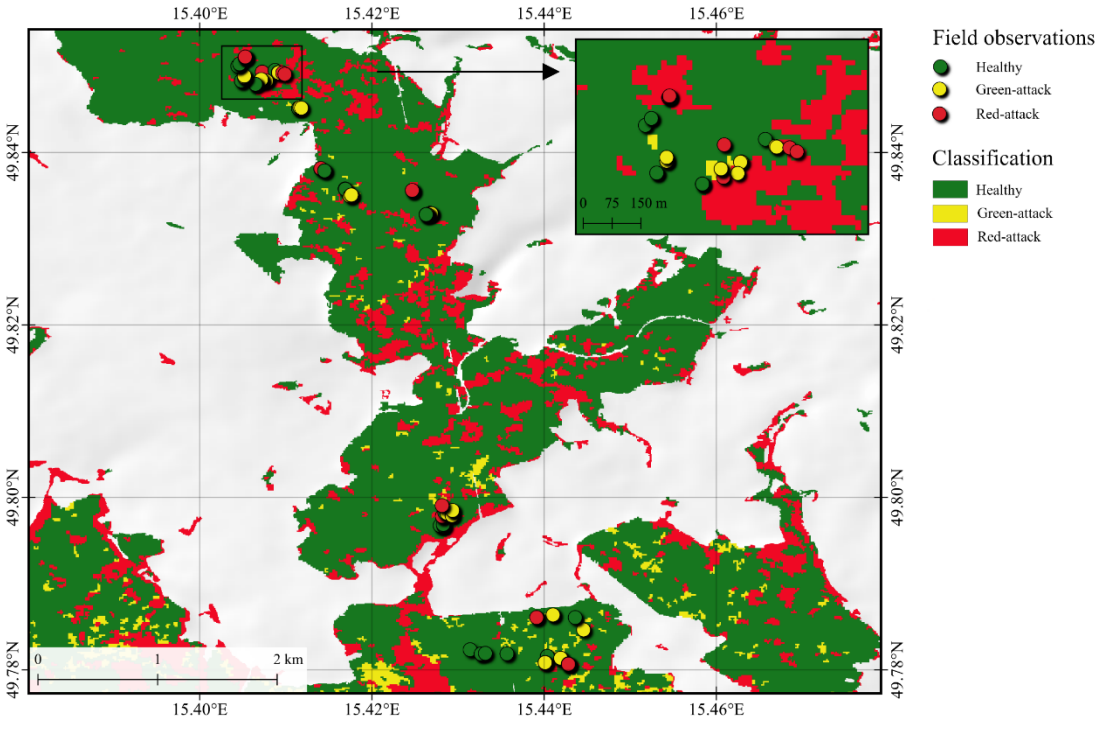
http://tekob.czechglobe.cz/

Bark beetle infestation mapping from S-2

Seasonal trajectory of wetness vegetation

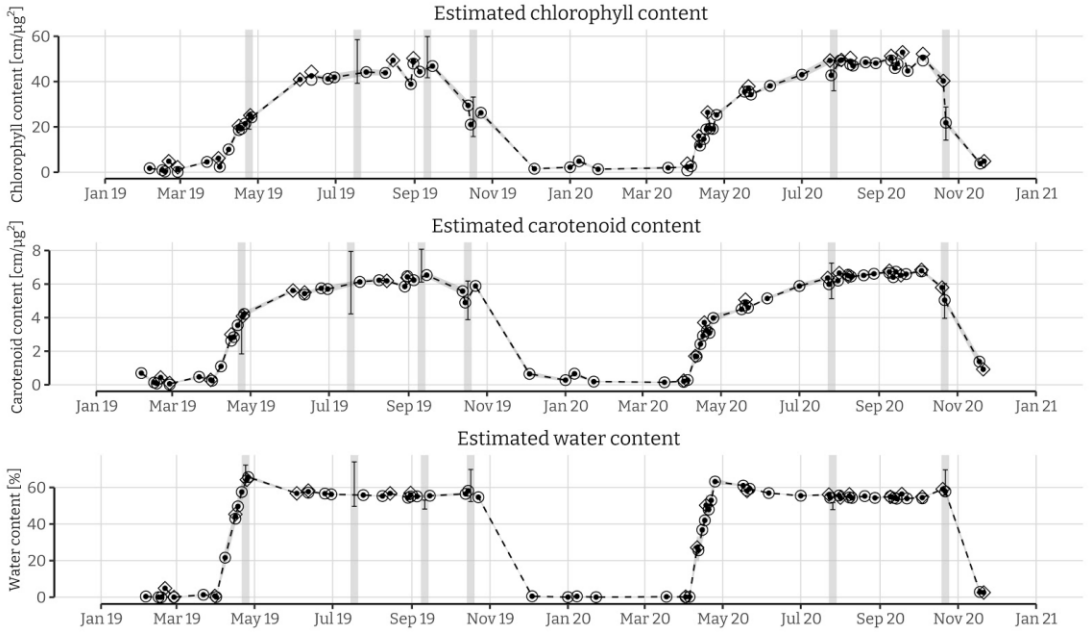


Infestation stages in autumn derived from Sentinel-2

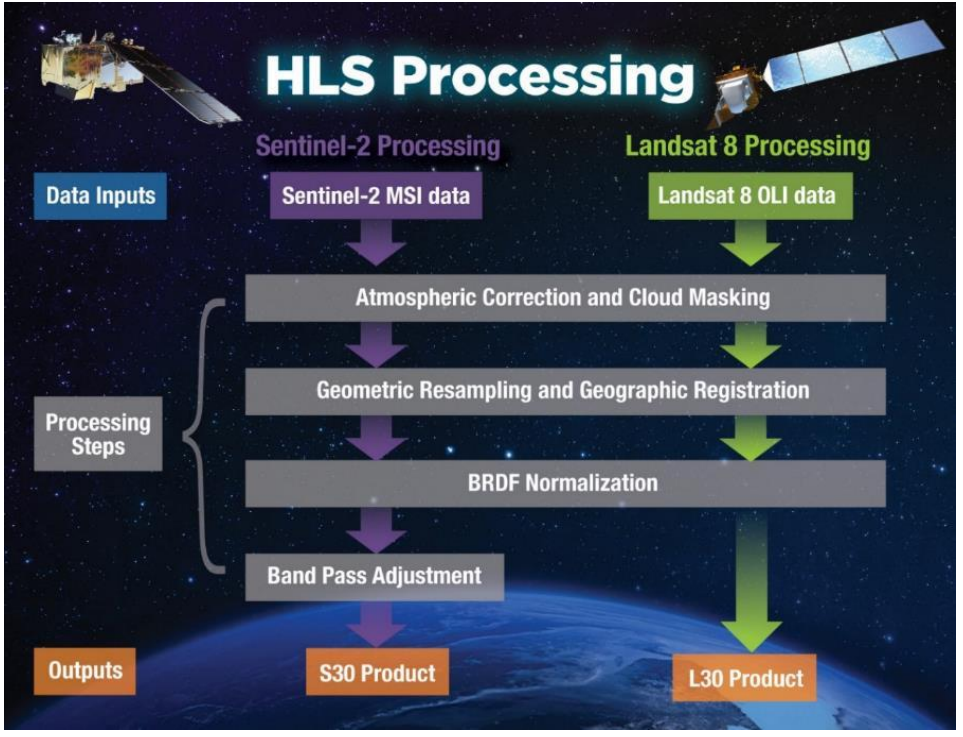


Seasonal course of forest biochemical traits

Floodplain mixed forest (Lanžhot)

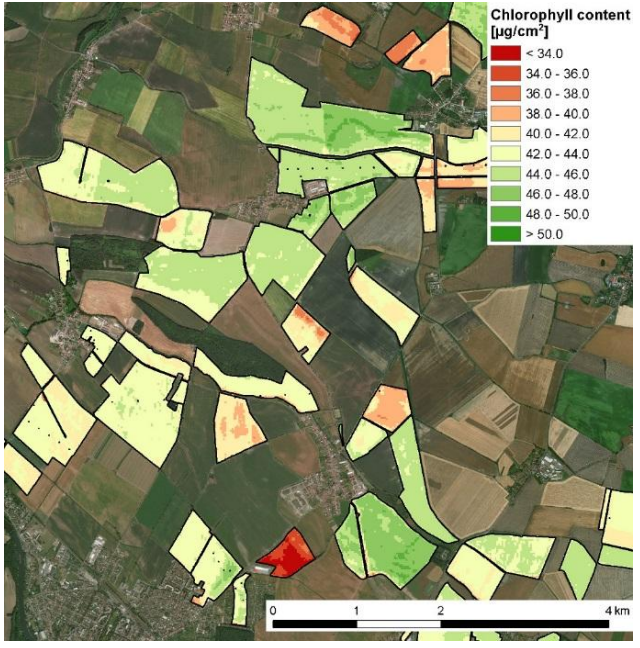


Sentinel (S30) Landsat (L30) Field campaign



Mapping crop properties from Sentinel-2

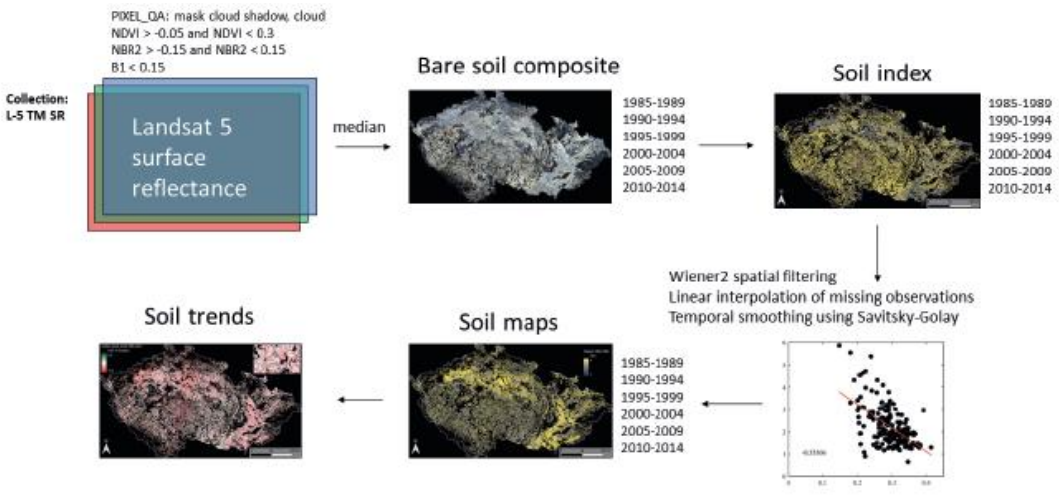
Leaf chlorophyll content



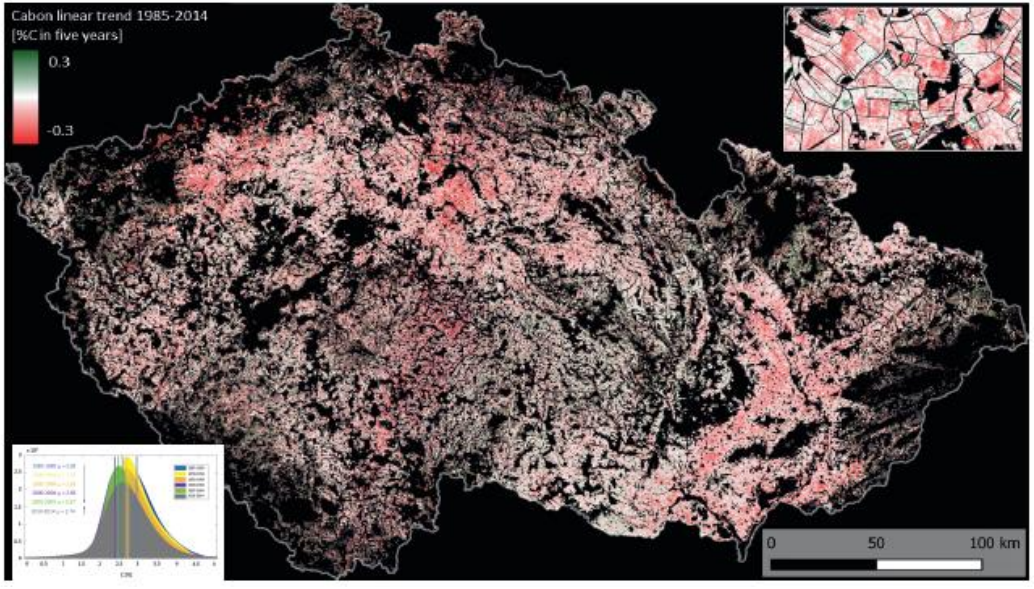
Leaf water content

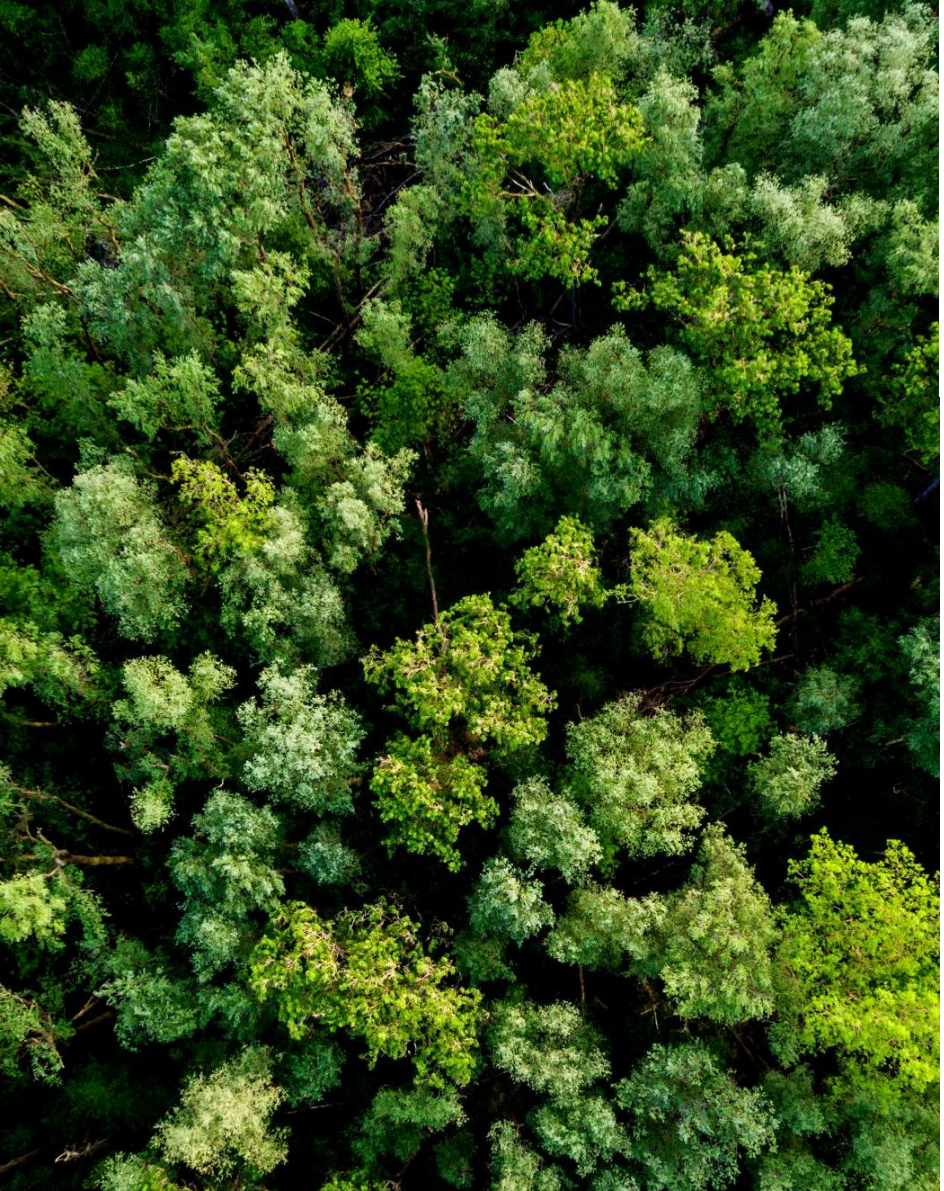
Leaf area index

Soil organic content from satellite time series



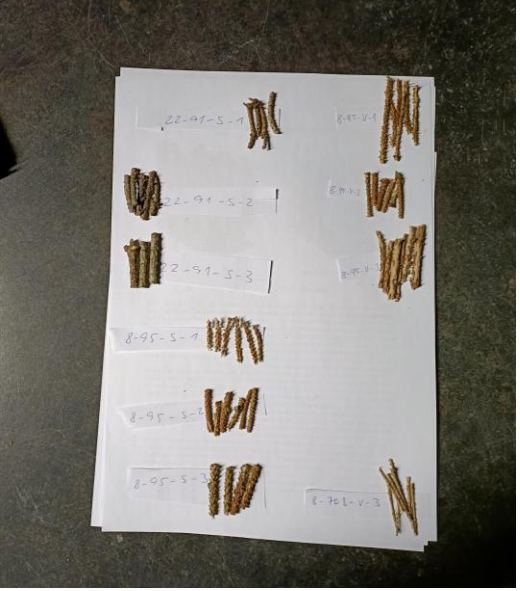
Soil organic content trend 1985 - 2014

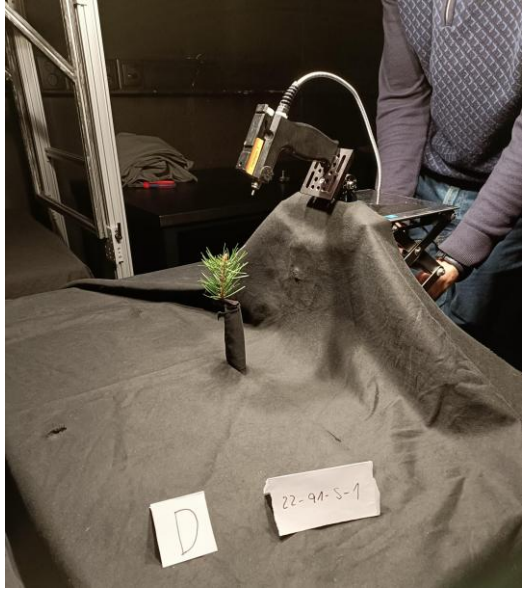


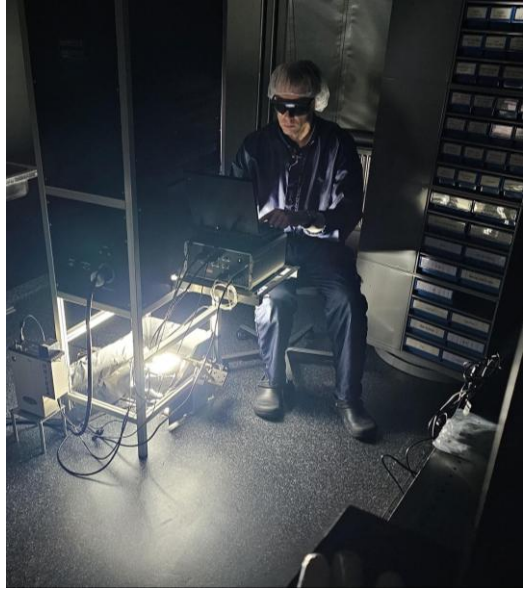


Rekonstrukce lesa pomocí metod DPZ

1. Rekonstrukce jehlic
2. Rekonstrukce stromu
3. Simulace syntetických dat

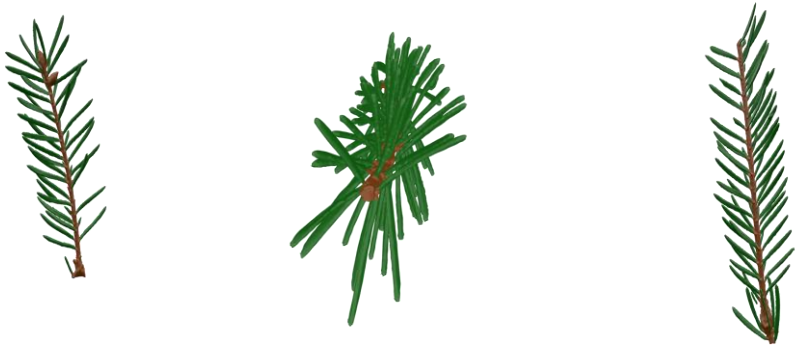


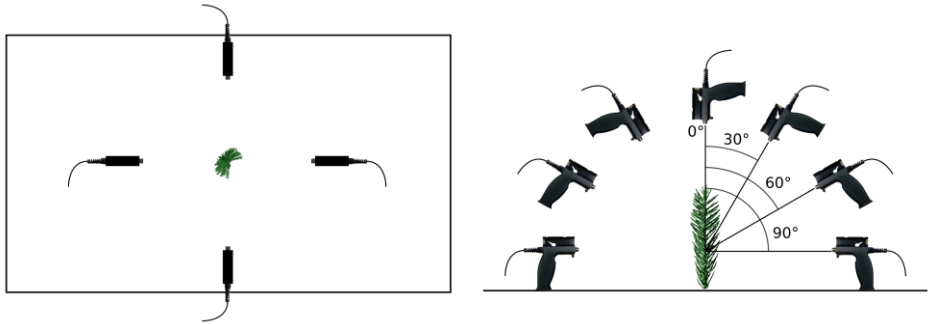


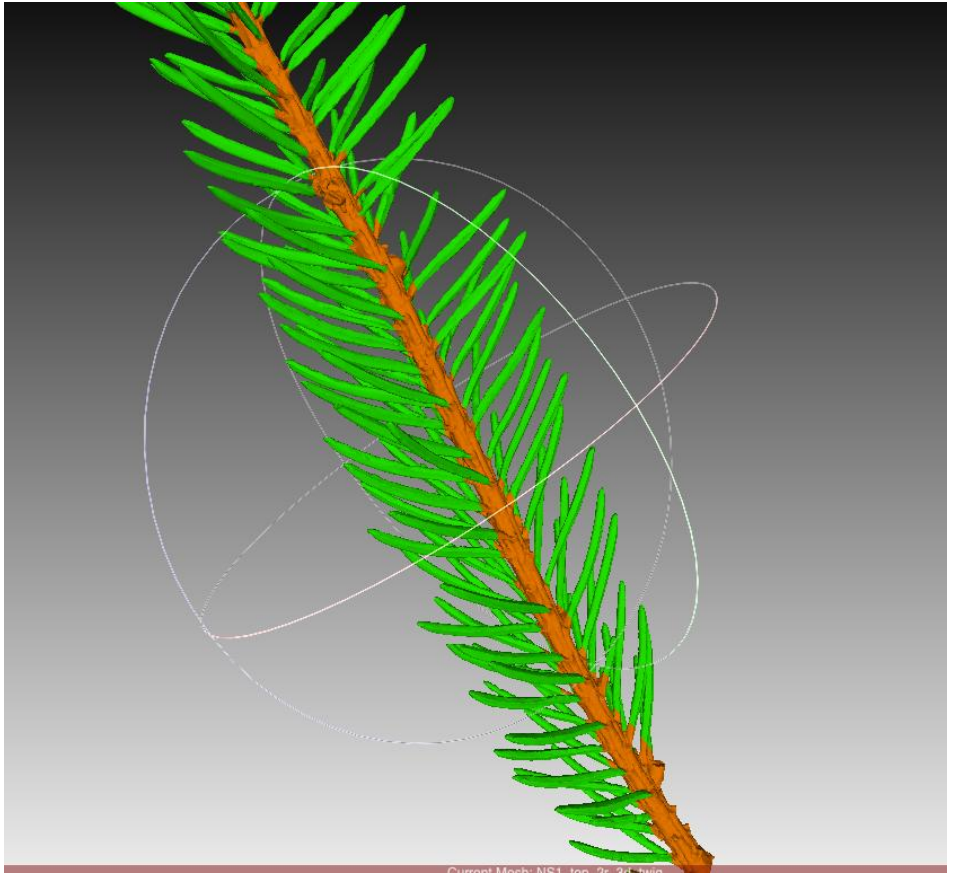


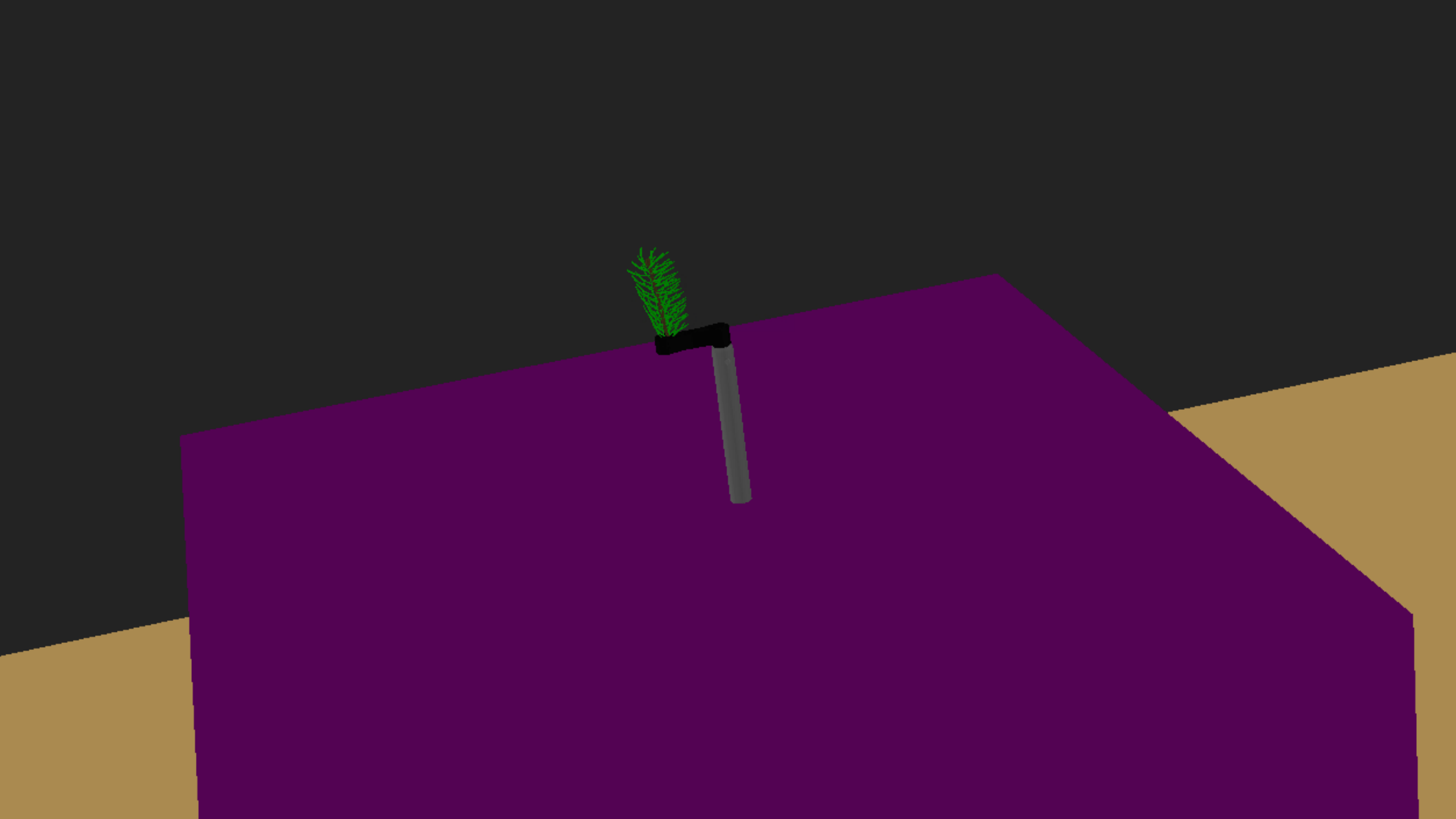
Rekonstrukce jehlic

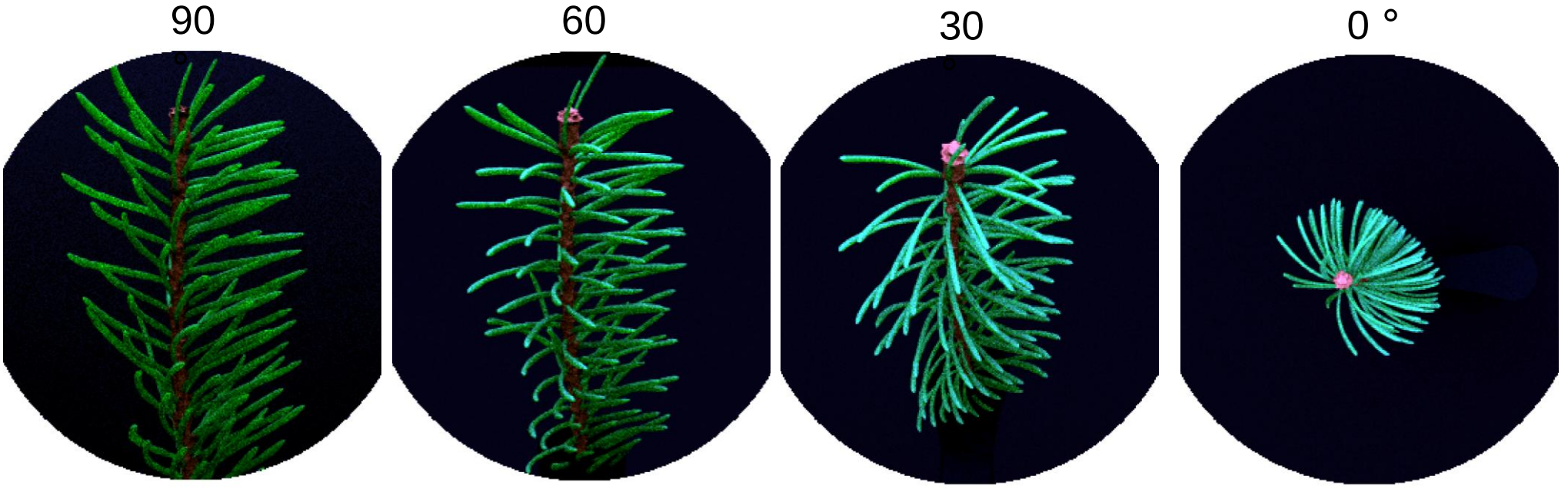
- Snaha vytvořit 3D model
- Přiřazení optické vlastnosti

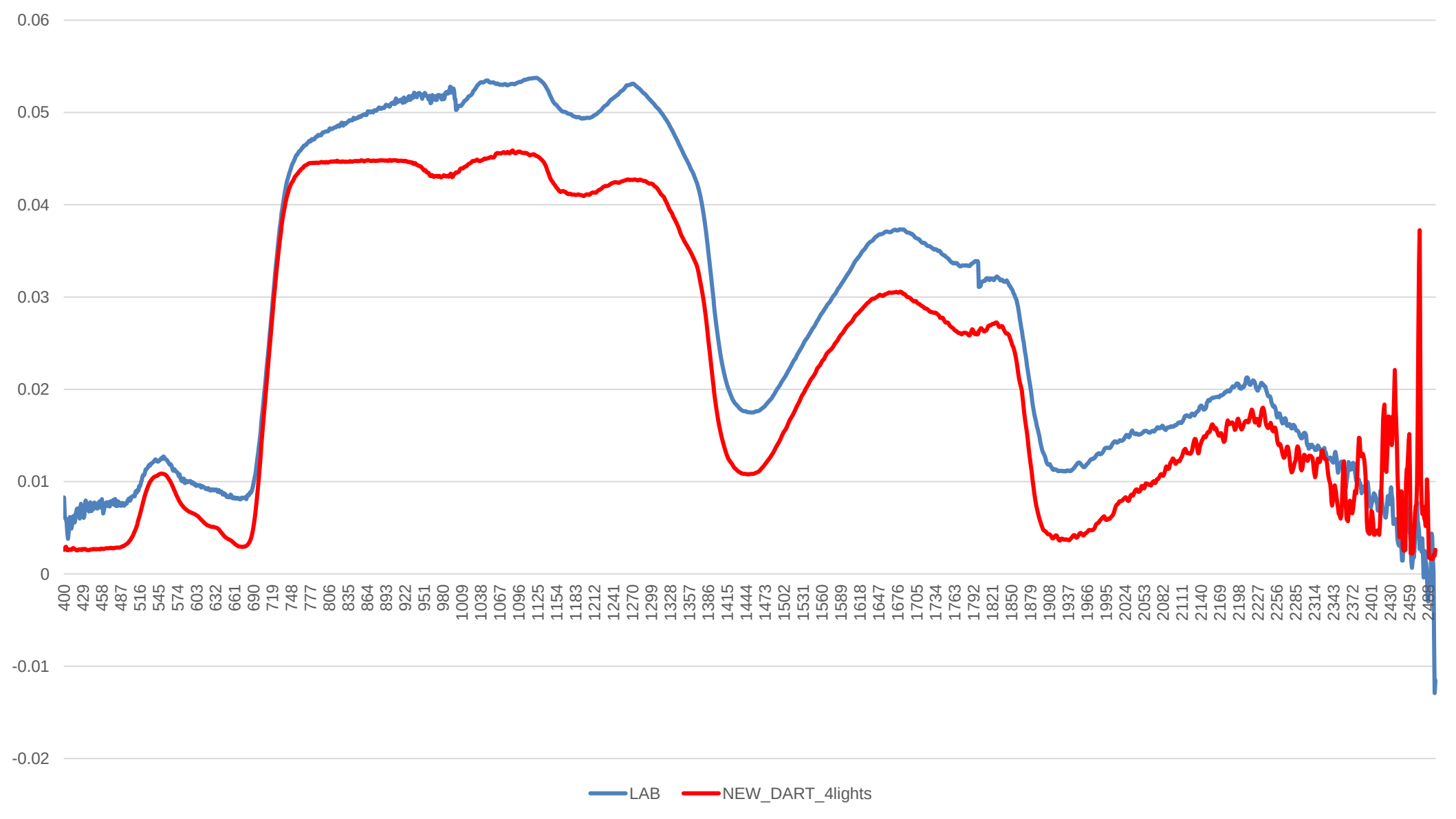



0°
30°
60°
90°





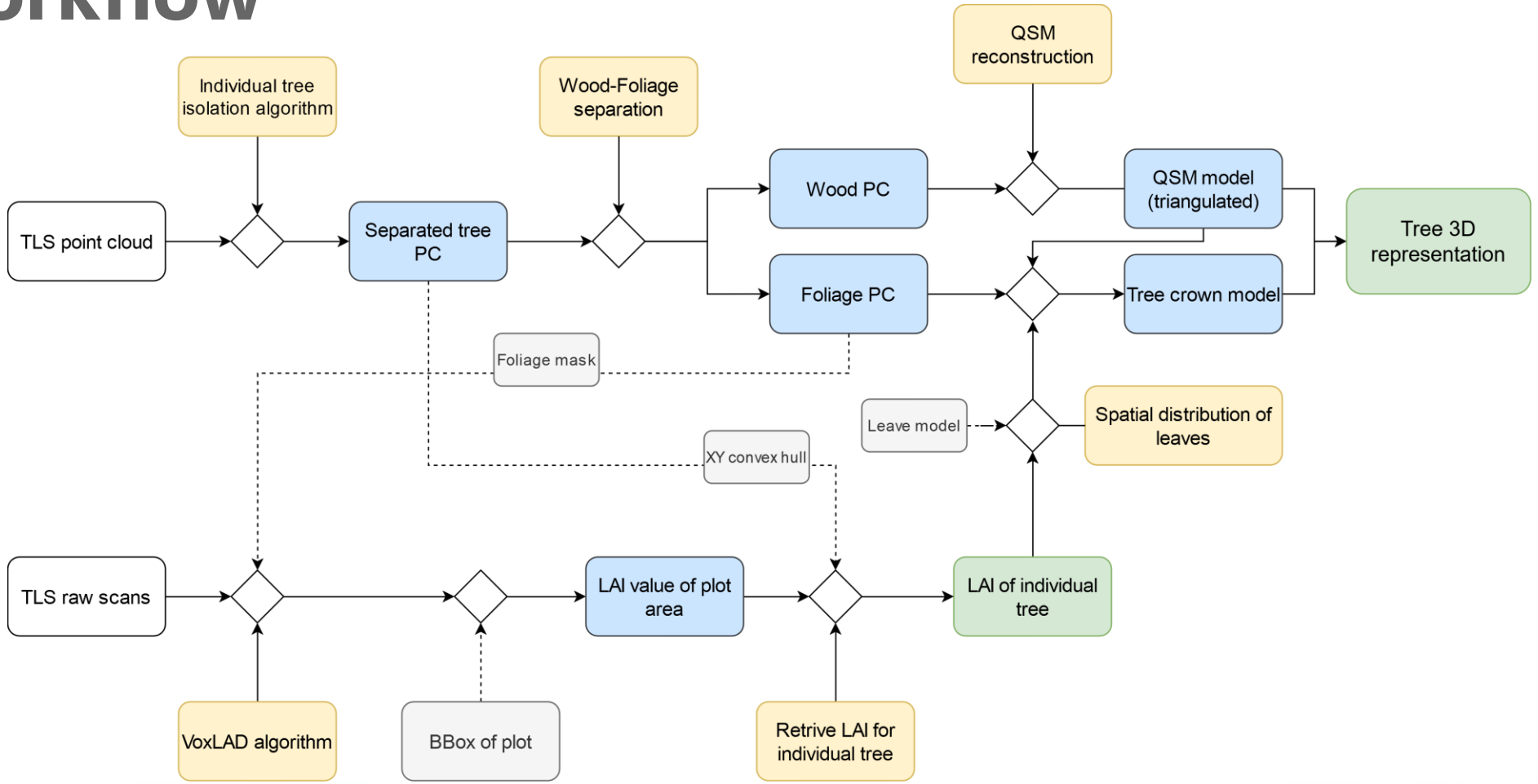

90
60
30
0 °


0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
400
429
458
487
516
545
574
603
632
661
690
719
748
777
806
835
864
893
922
951
980
1009
1038
1067
1096
1125
1154
1183
1212
1241
1270
1299
1328
1357
1386
1415
1444
1473
1502
1531
1560
1589
1618
1647
1676
1705
1734
1763
1792
1821
1850
1879
1908
1937
1966
1995
2024
2053
2082
2111
2140
2169
2198
2227
2256
2285
2314
2343
2372
2401
2430
2459
2488
LAB
NEW_DART_4lights

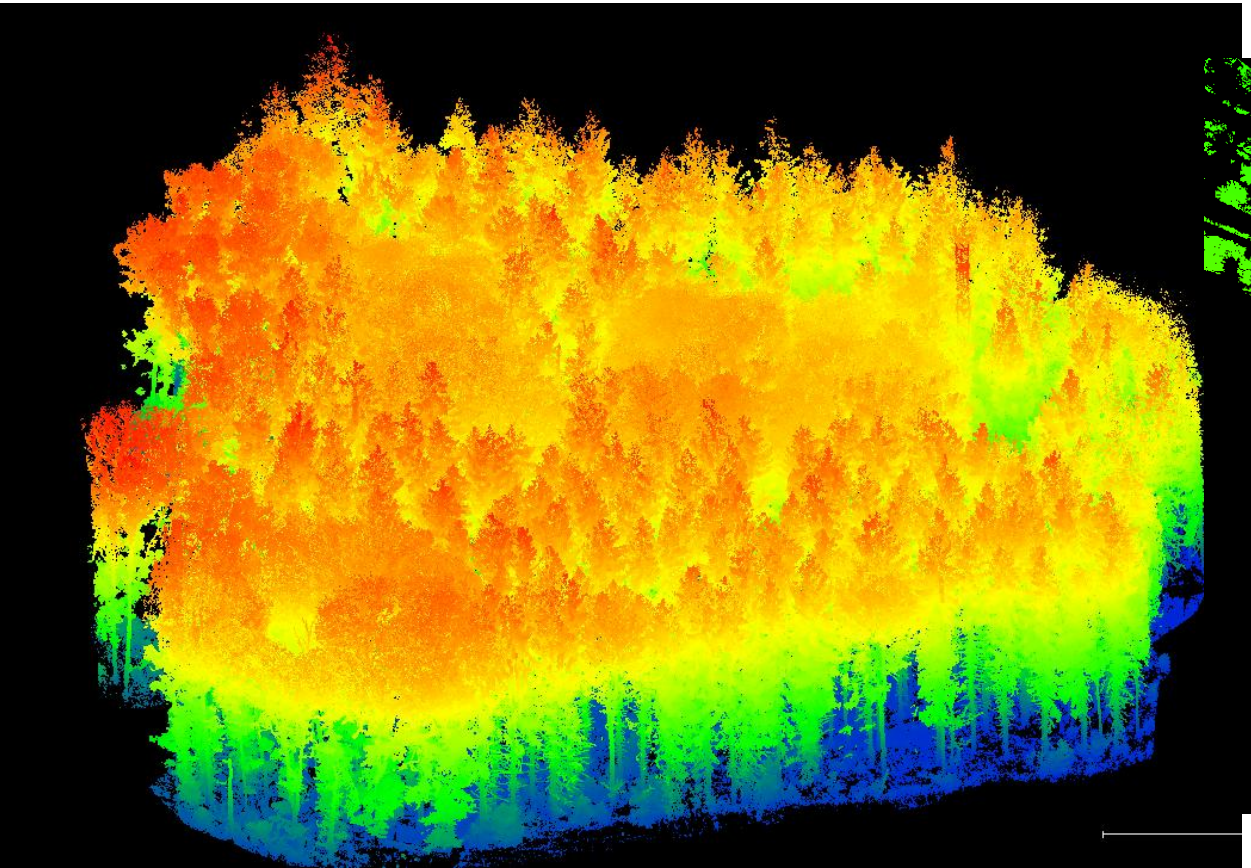
Rekonstrukce stromu

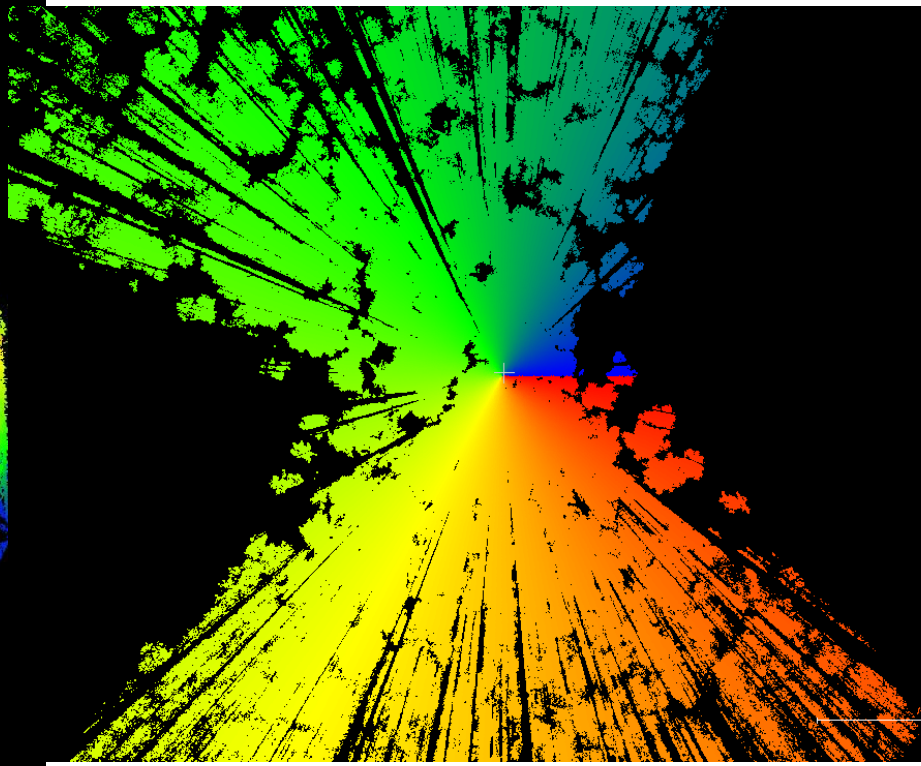
- Další krok po tvorbě modelů jehlic/ listí
- Užití TLS dat
- Separace bodů dřeva a listí
- Tvorba QSM modelů kmene

Workflow


QSM reconstruction
Individual tree isolation algorithm
Wood-Foliage separation
Wood PC
QSM model (triangulated)
TLS point cloud
Separated tree PC
Tree 3D representation
Foliage PC
Tree crown model
Foliage mask
Leave model
Spatial distribution of leaves
XY convex hull
TLS raw scans
LAI value of plot area
LAI of individual tree
VoxLAD algorithm
BBox of plot
Retrive LAI for individual tree

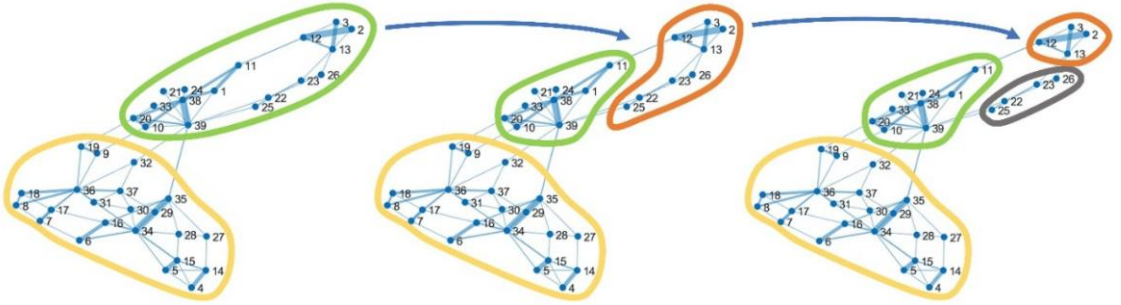
TLS bodové mračno

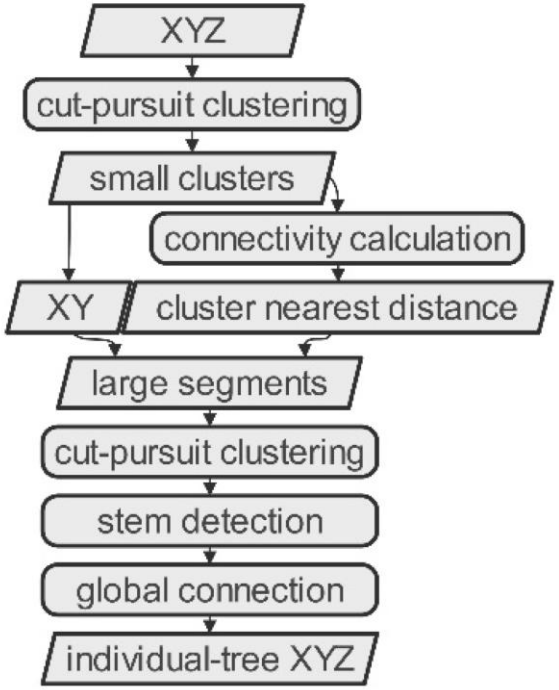


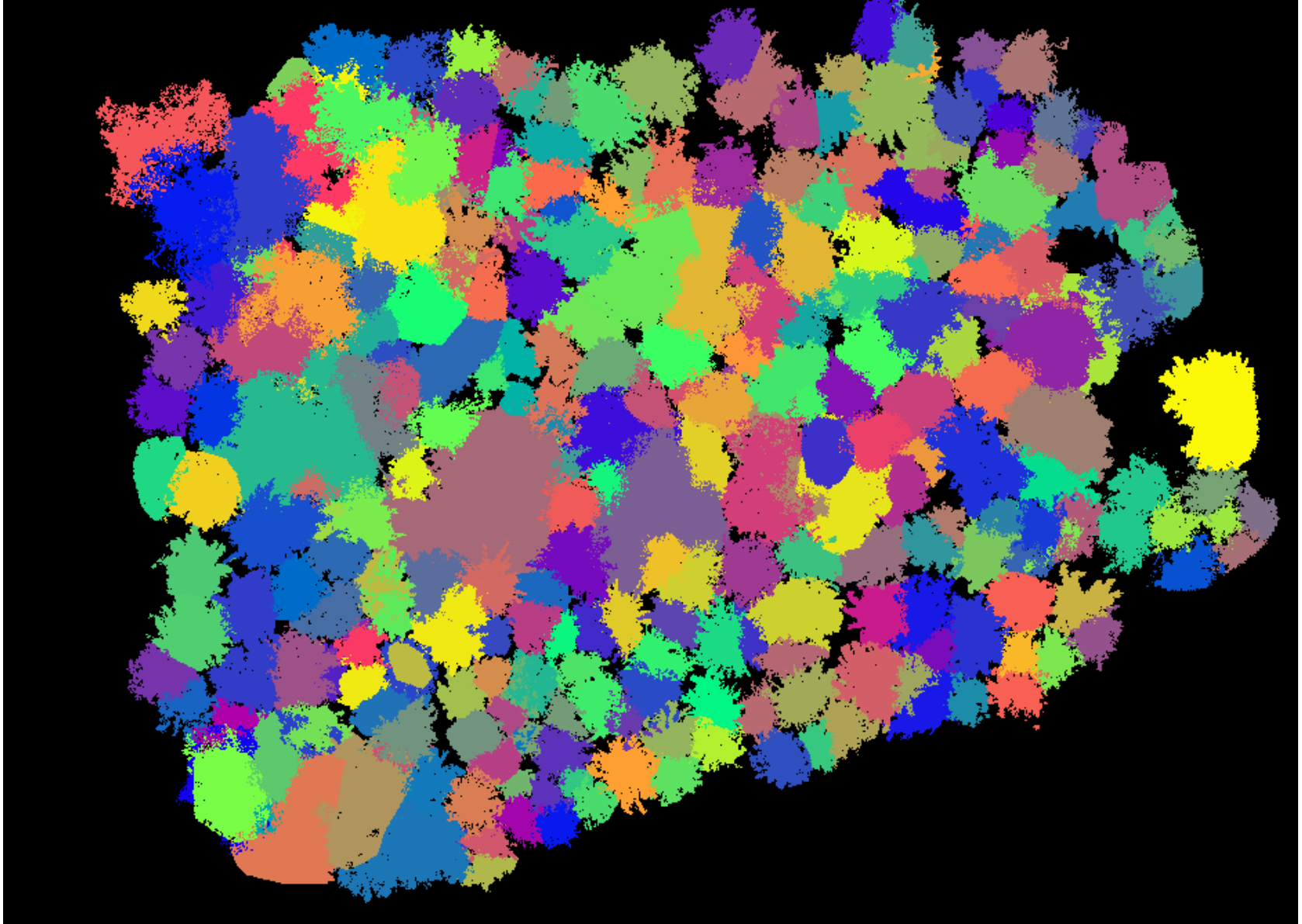


Segmentace individuálních stromů

- Pro rozdělení stromů používám metodu shlukování bodů založenou na metodě grafů a vzdálenosti mezi body
- Nalezení kořenového shluku a propojení ostatních shluků na základě nejkratší cesty







Rozdělení dřeva a listí

- Trénování PointNet++ DL pro rozdělení b… zem/dřevo/listí
- 56 ručně olabelovaných stromů

SPEC	Number	Train	Val	Test
Beech	20	10	5	5
Oak	4	2	1	1
Spruce	20	10	5	5
Pine	8	4	2	2
Eucalyptus	4	2	1	1
Sum	56	28	14	14
%	100	50	25	25

Overall Accuracy: 0.9462

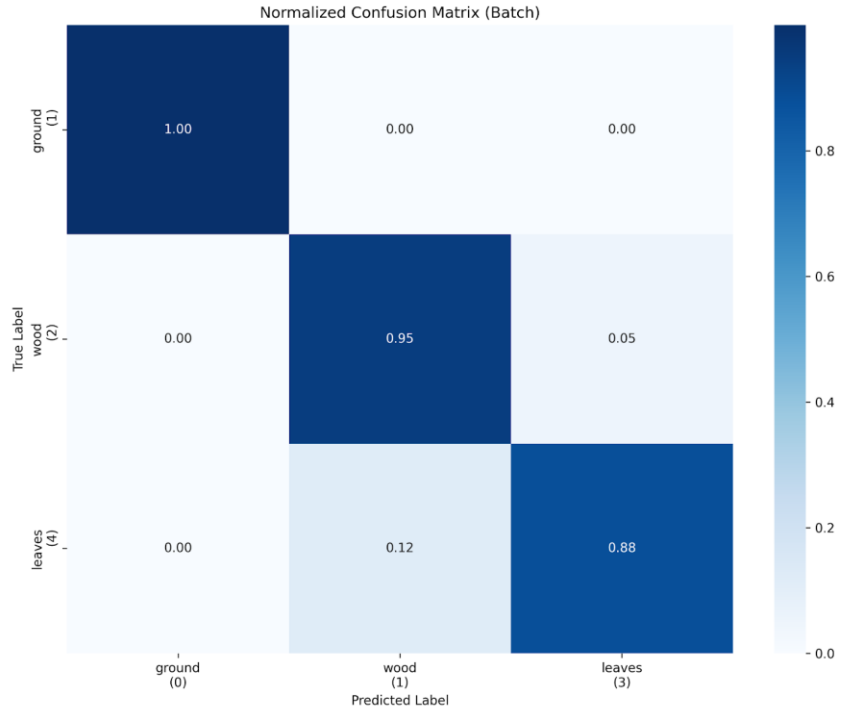
Macro Avg Precision: 0.9226

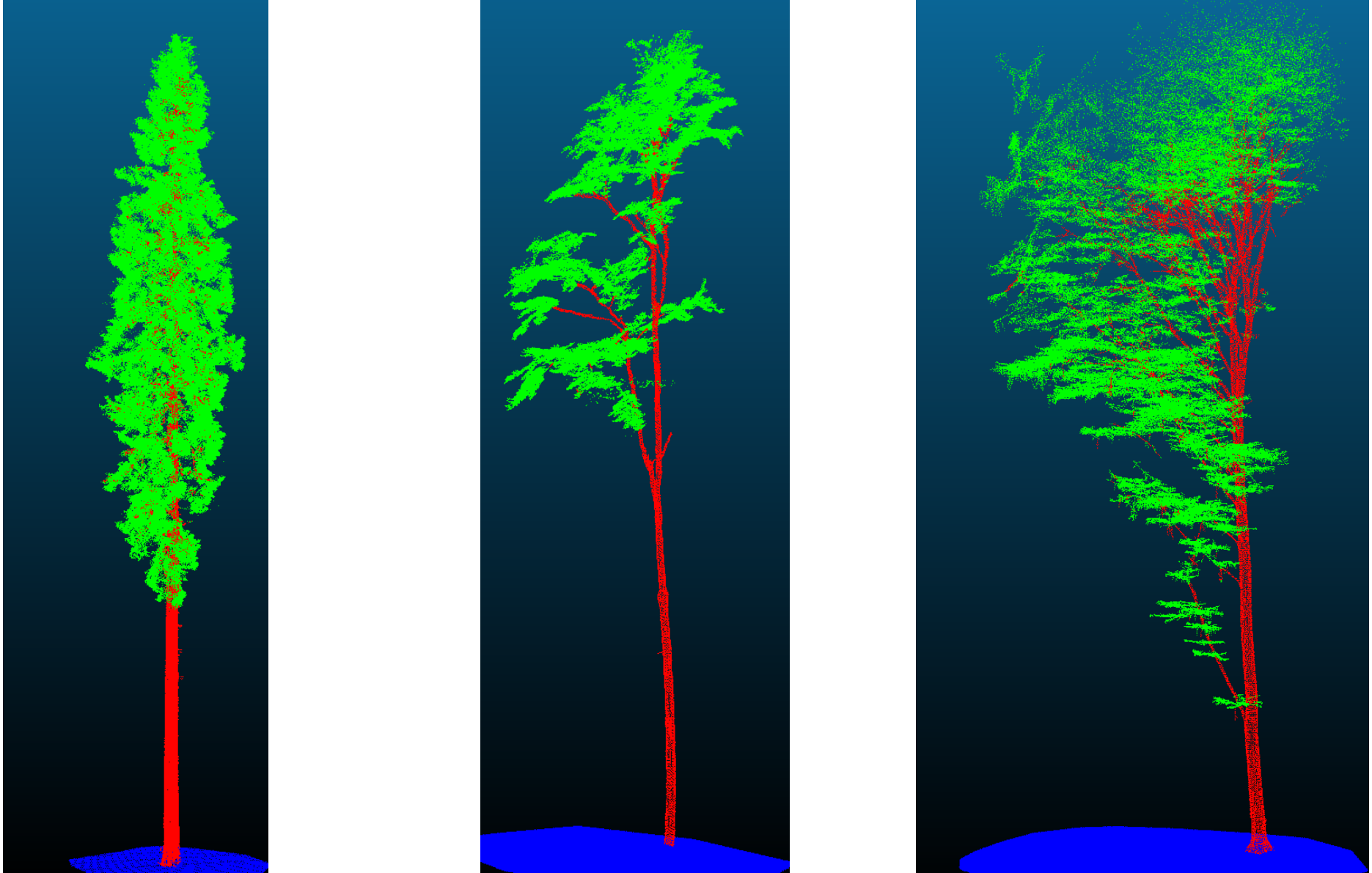
Macro Avg Recall: 0.9429

Macro Avg F1-Score: 0.9320

Macro Avg IoU: 0.8801

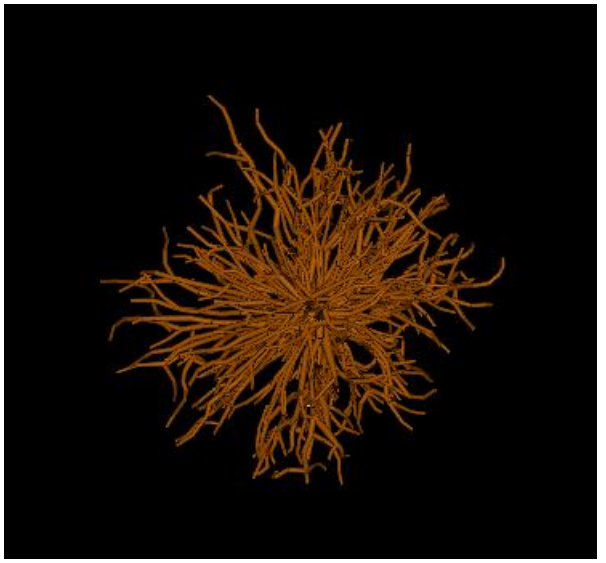
Weighted Avg IoU: 0.9037

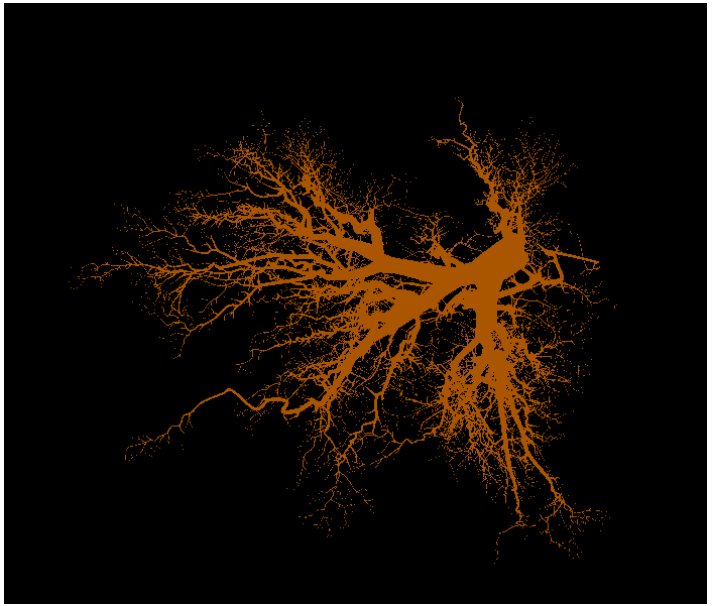




Rekonstrukce kmene a větví

- Pro jehličnany používáme vlastní algoritmus na tvorbu QSM (Quantitative Structure Mode) a prázdné strany pak vyplňujeme metodou triangulace.
- Pro listnáče v současné době používáme software AdQSM, který vytvoří QSM a následně celý model trianguluje.



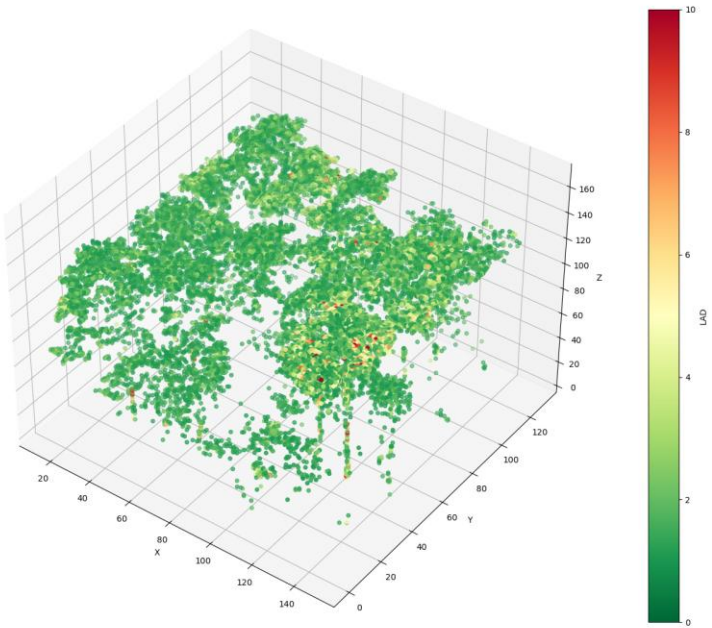


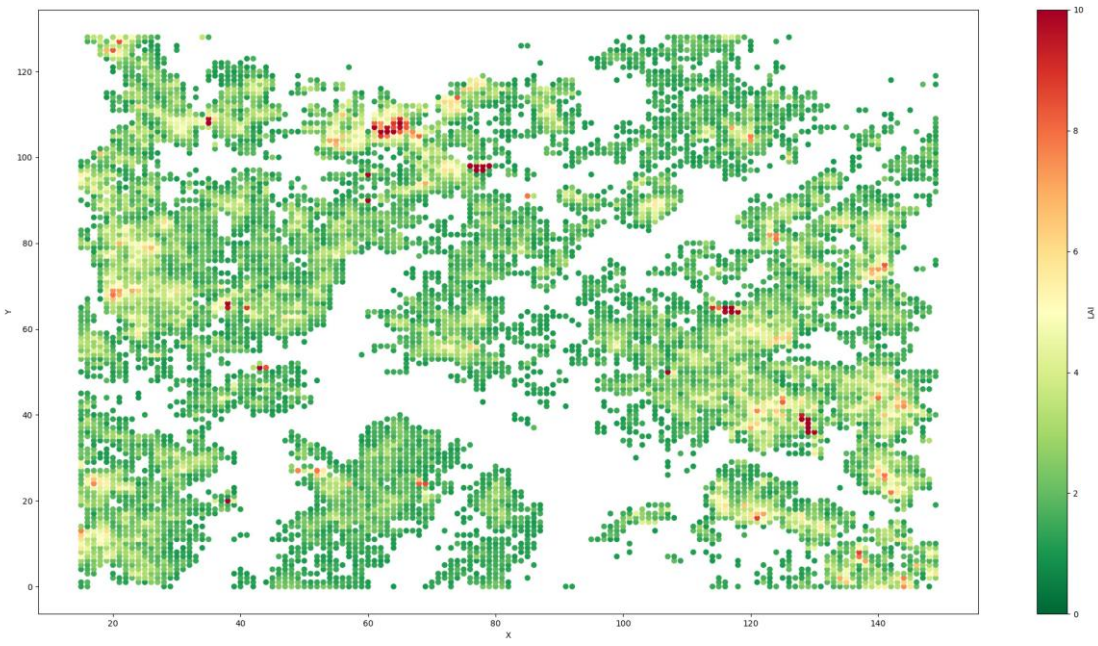
Olistění stromů

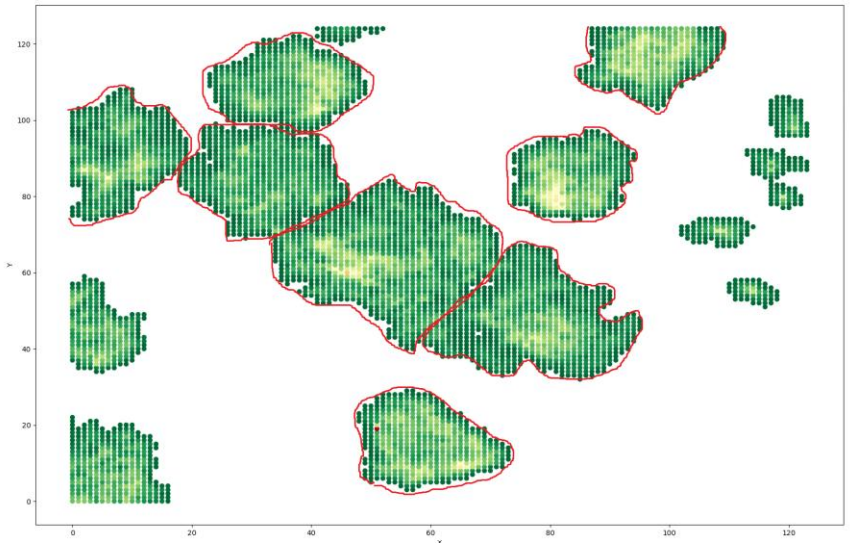
- Výpočet/odhad LAI (Leaf Area Index) pro určení množství listí
- Určení plochy koruny
- Plocha listu/jehlic
- Úhel listí dle druhu/měření

Odhad LAI z TLS

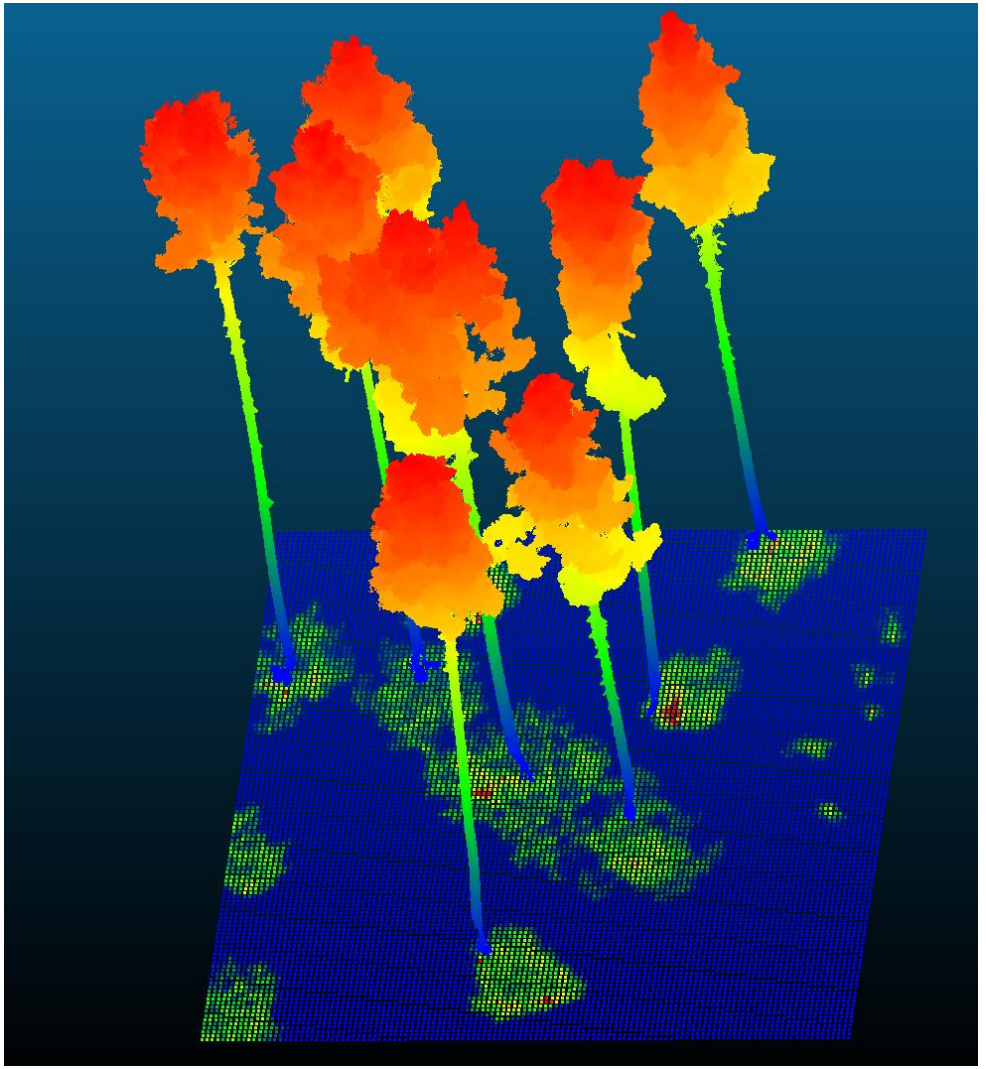
- LAD per voxel -> LAI ve 2D; grid 20 cm





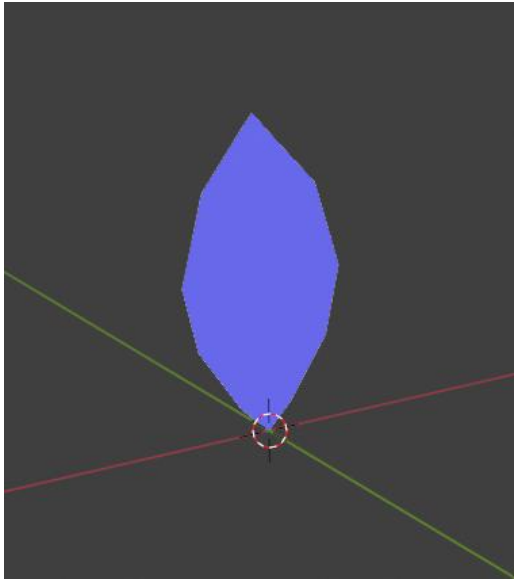


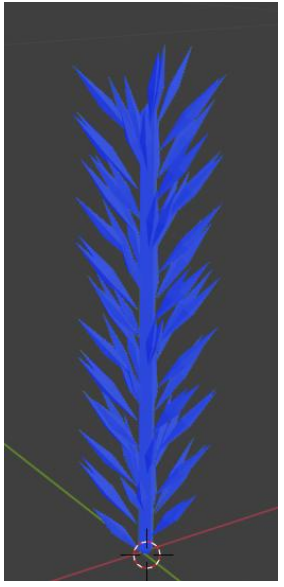

```
Tree_10,5.994500262915919
Tree_12,7.616194501612145
Tree_13,5.110890768354769
Tree_16,3.848462080696577
Tree_17,7.003354158949421
Tree_19,6.817706493816321
Tree_6,4.112898409743725
Tree_8,4.085412631693949
```

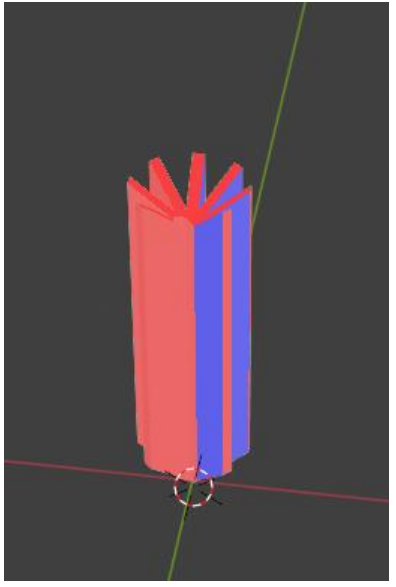


Modely listí

- Používáme většinou zjednodušené modely (výpočetní náročnost)
- Jehlice budeme ještě validovat dle laboratorního měření

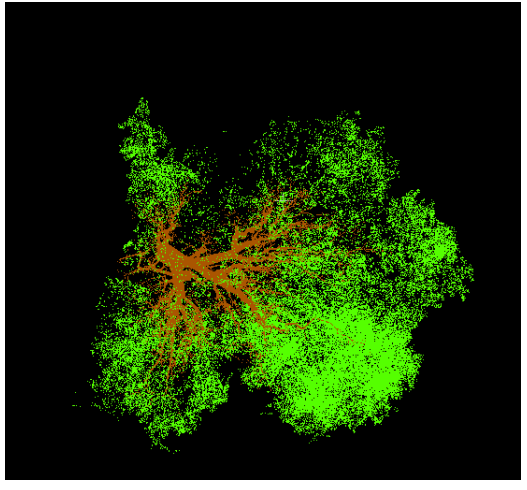






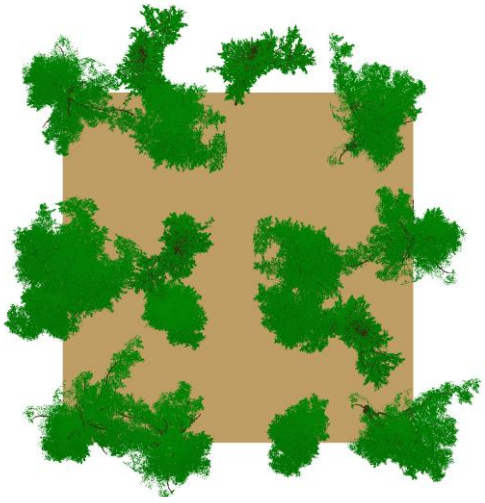
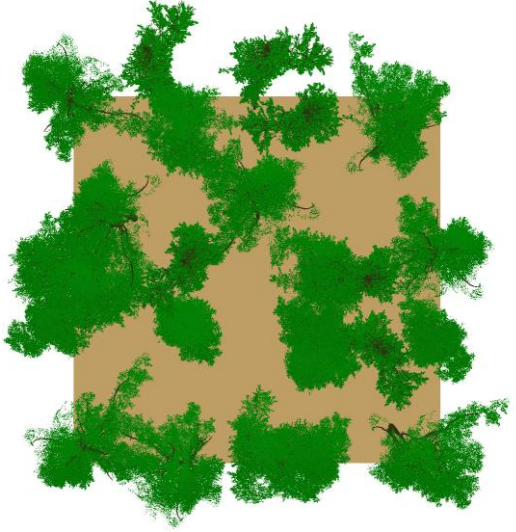
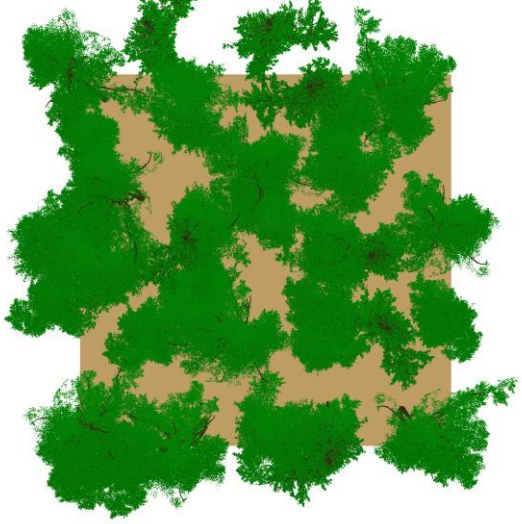
3D Reprezentace stromů

- XZY
- Dva objekty (L, W)

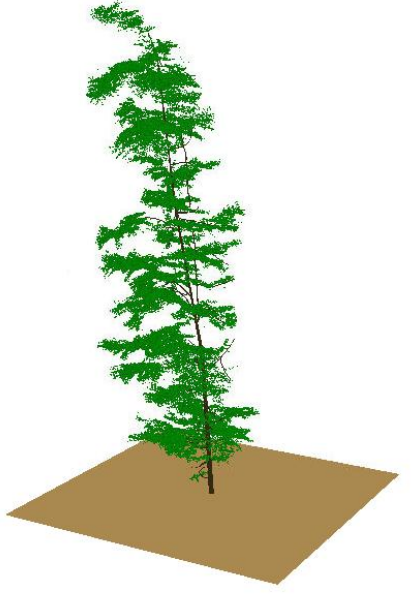


Simulace syntetických dat

- Tvorba 3,5 mil kombinací hyperspektrálních dat listnatého lesa
- Trénování ML nad těmito daty, díky tomu, že poskytuje rozmanitou a komplexní datovou sadu přizpůsobitelnou různým lokalitám, časovým rámcům a hyperspektrálním/multispektrálním senzorům.
- Jsme součástí CHIME projektu a data budou použita při vývoji Level-2B procesoru a jeho validaci

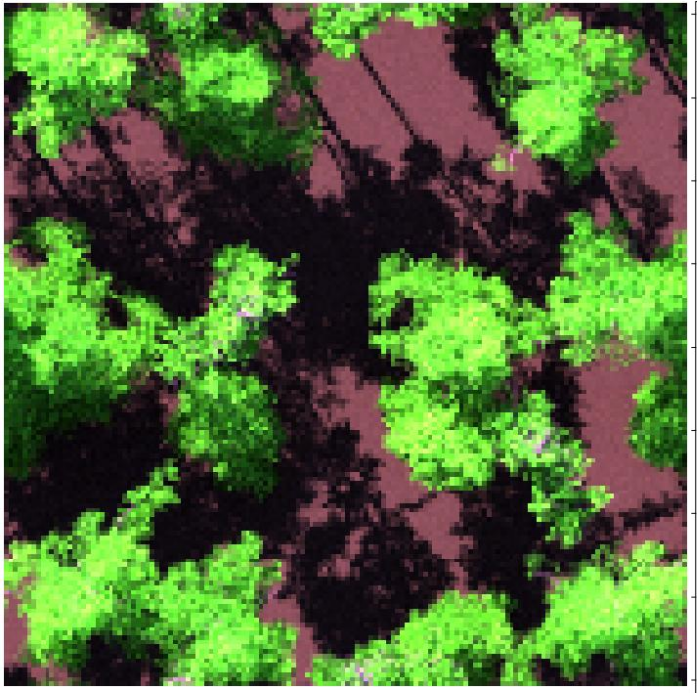


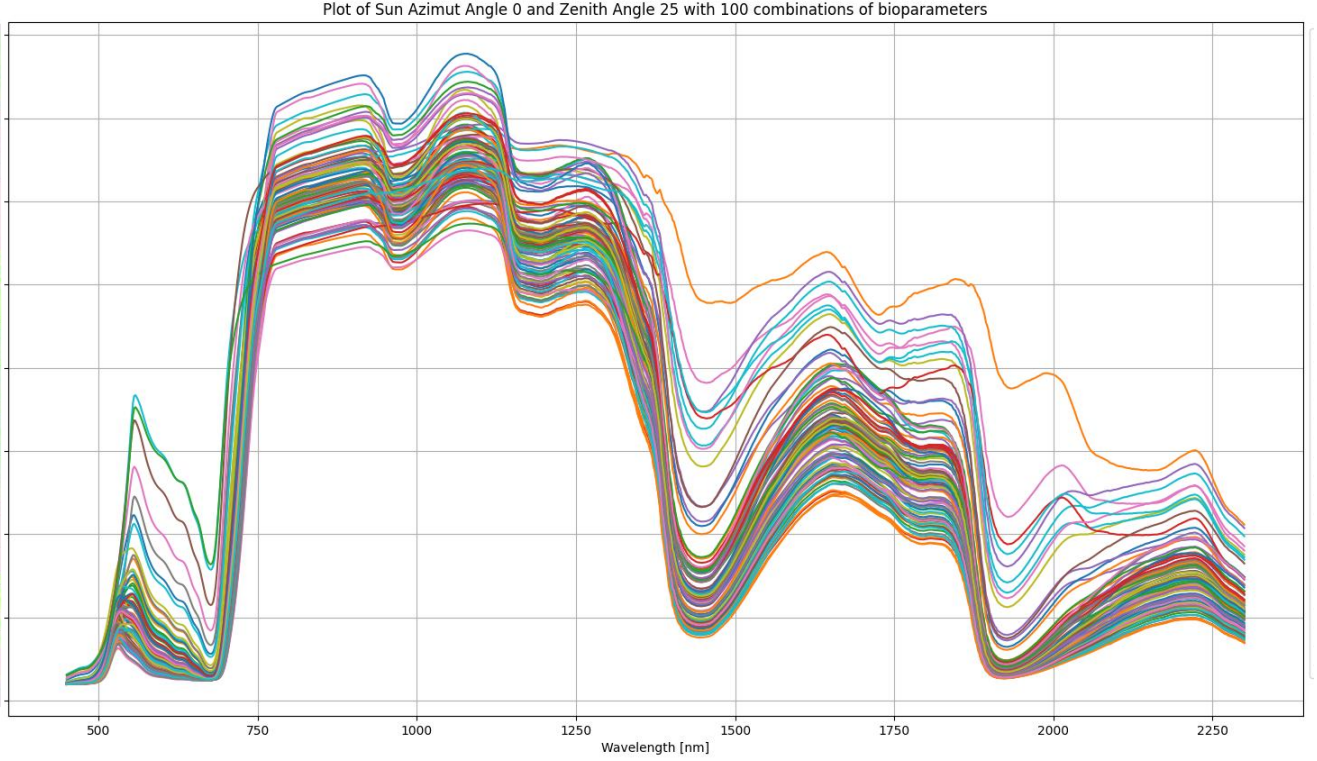


Continues vegetation variables for leaves optical properties						
		distribution	mean	std	combinations	notes
Chlorophyl content	Cab	normal	34.003	16.04424	**2000**	
Carotenoid content	Car	normal	5.427387	1.433608		
Leaf water content	Cw	normal	0.009018	0.00427		
Dry matter content	Cm	normal	0.0048	0.00134		
Structural number	N	normal	1.39	0.1757		

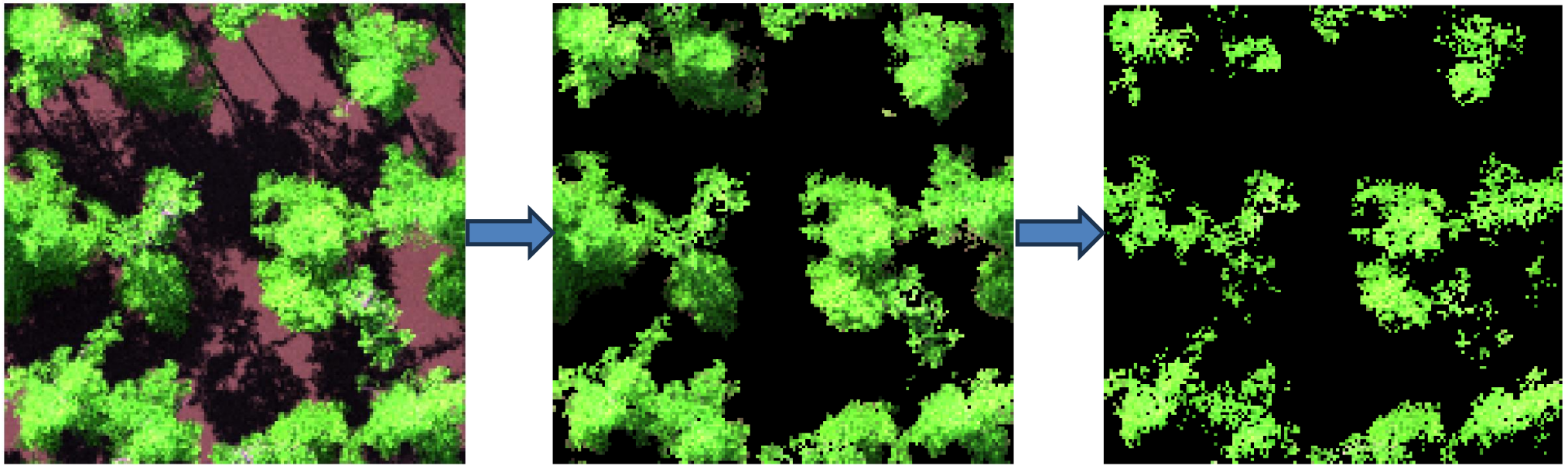
Scene variables						
		start range	end range	step	combinations	notes
canopy cover	CC	60	90	15	**3**	
leaf area index	LAI	3	10	1	**8**	Not for all CC
sun zenith angle	sza	25	65	5	**9**	
sun azimuth angle	saa	0	360	30	**12**	

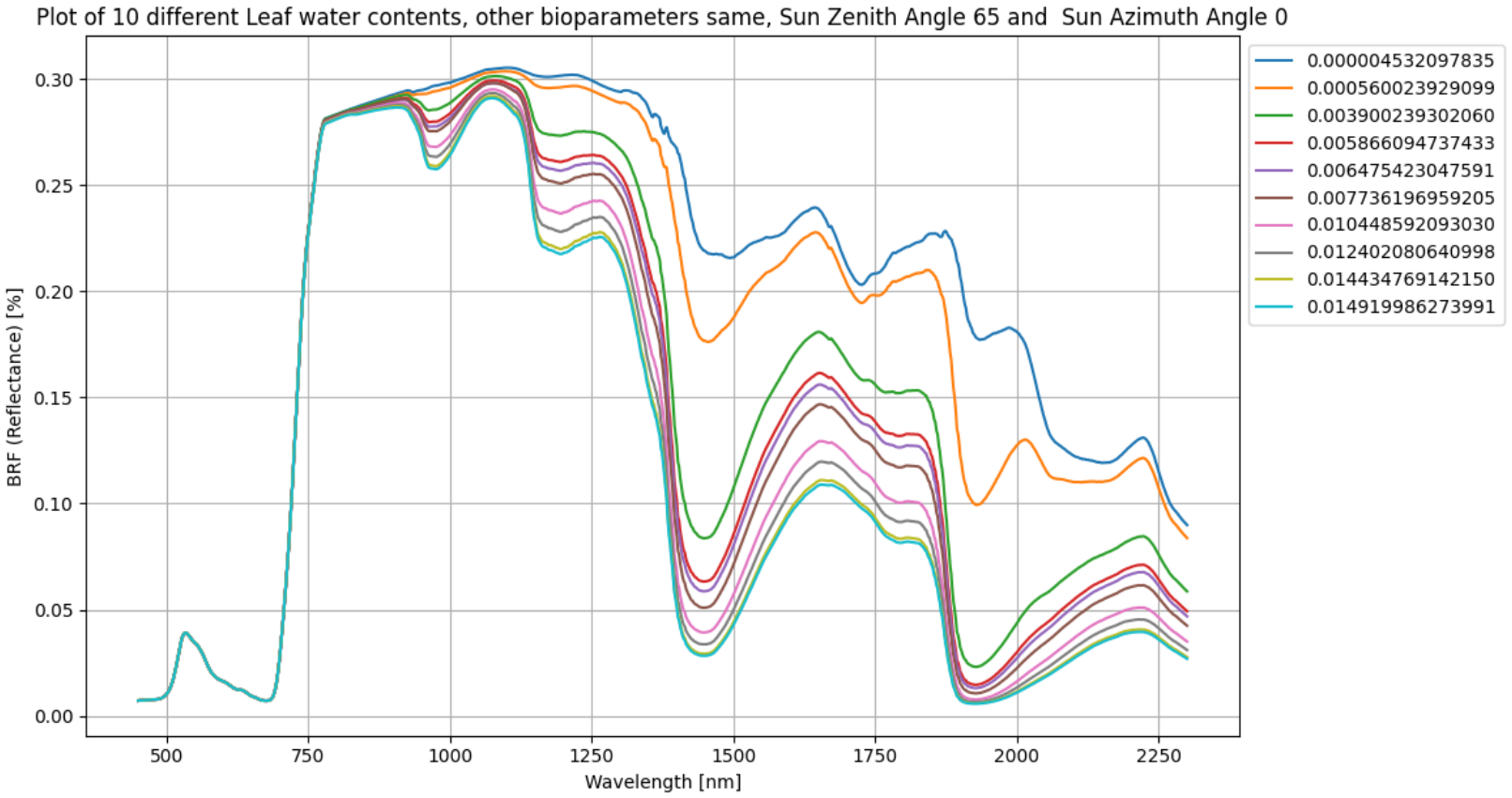
Ukázka dat

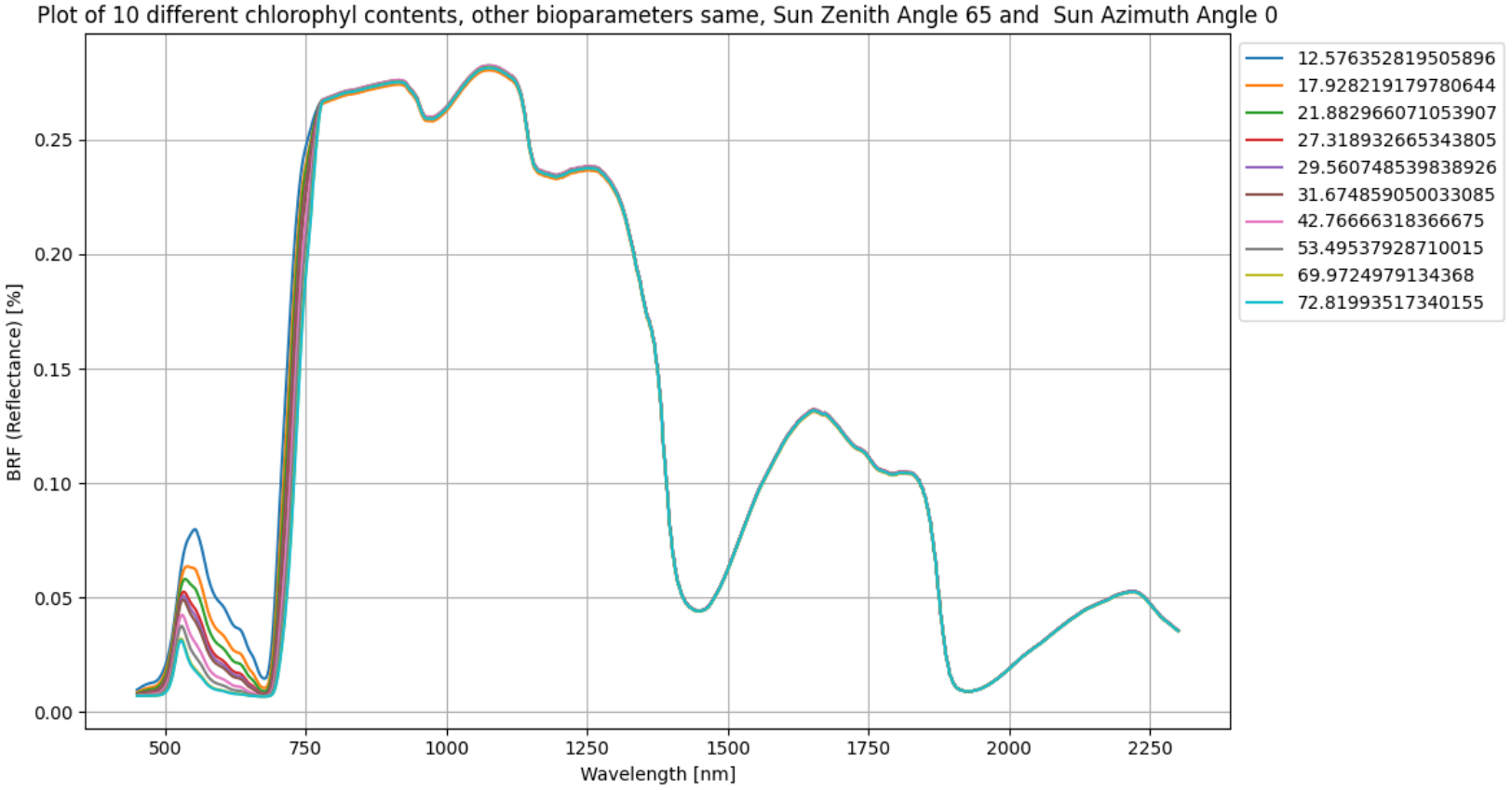



Plot of Sun Azimut Angle 0 and Zenith Angle 25 with 100 combinations of bioparameters
500
750
1000
1250
1500
1750
2000
2250
Wavelength [nm]

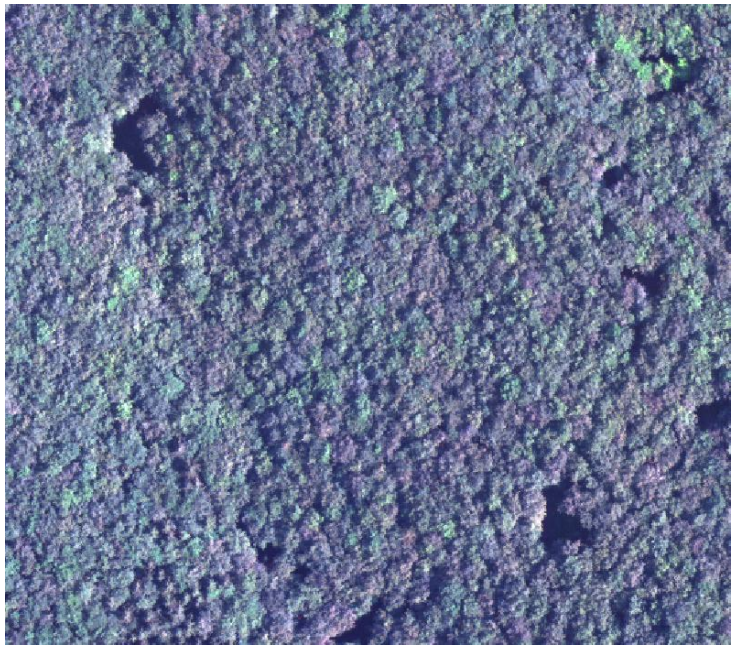
Maskování jen osluněných pixelů

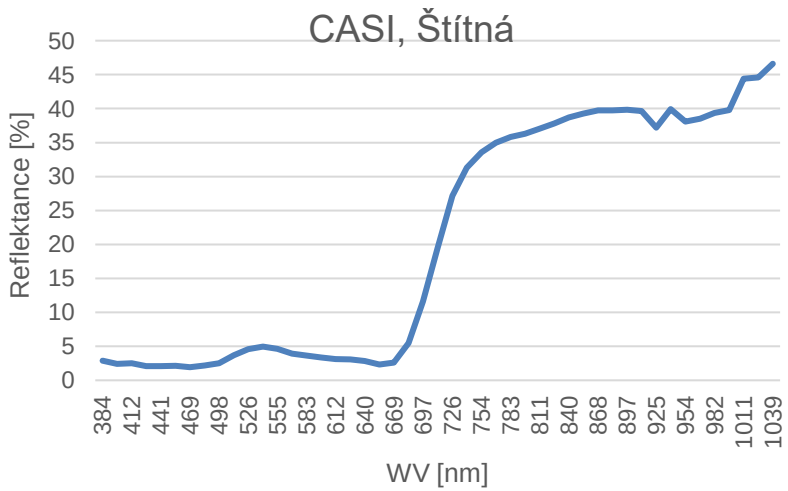


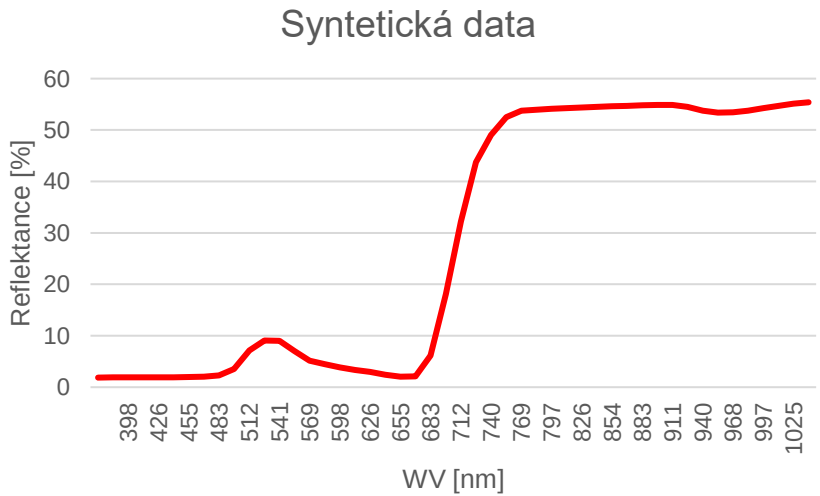

Plot of 10 different Leaf water contents, other bioparameters same, Sun Zenith Angle 65 and Sun Azimuth Angle 0
BRF (Reflectance) [%]
0.00
0.05
0.10
0.15
0.20
0.25
0.30
500
750
1000
1250
1500
1750
2000
2250
Wavelength [nm]
0.000004532097835
0.000560023929099
0.003900239302060
0.005866094737433
0.006475423047591
0.007736196959205
0.010448592093030
0.012402080640998
0.014434769142150
0.014919986273991

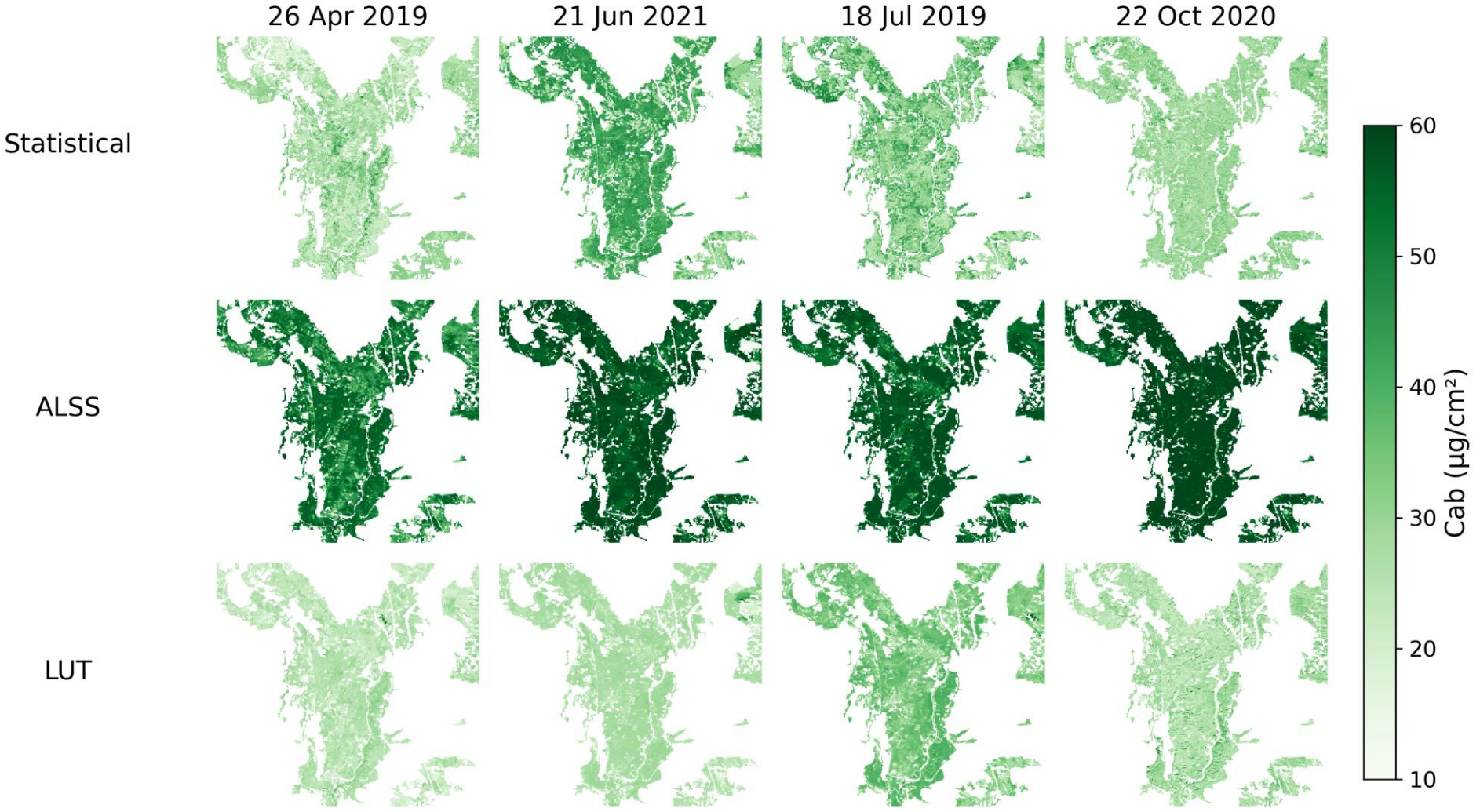

Plot of 10 different chlorophyl contents, other bioparameters same, Sun Zenith Angle 65 and Sun Azimuth Angle 0
BRF (Reflectance) [%]
0.00
0.05
0.10
0.15
0.20
0.25
500
750
1000
1250
1500
1750
2000
2250
Wavelength [nm]
12.576352819505896
17.928219179780644
21.882966071053907
27.318932665343805
29.560748539838926
31.674859050033085
42.76666318366675
53.49537928710015
69.9724979134368
72.81993517340155

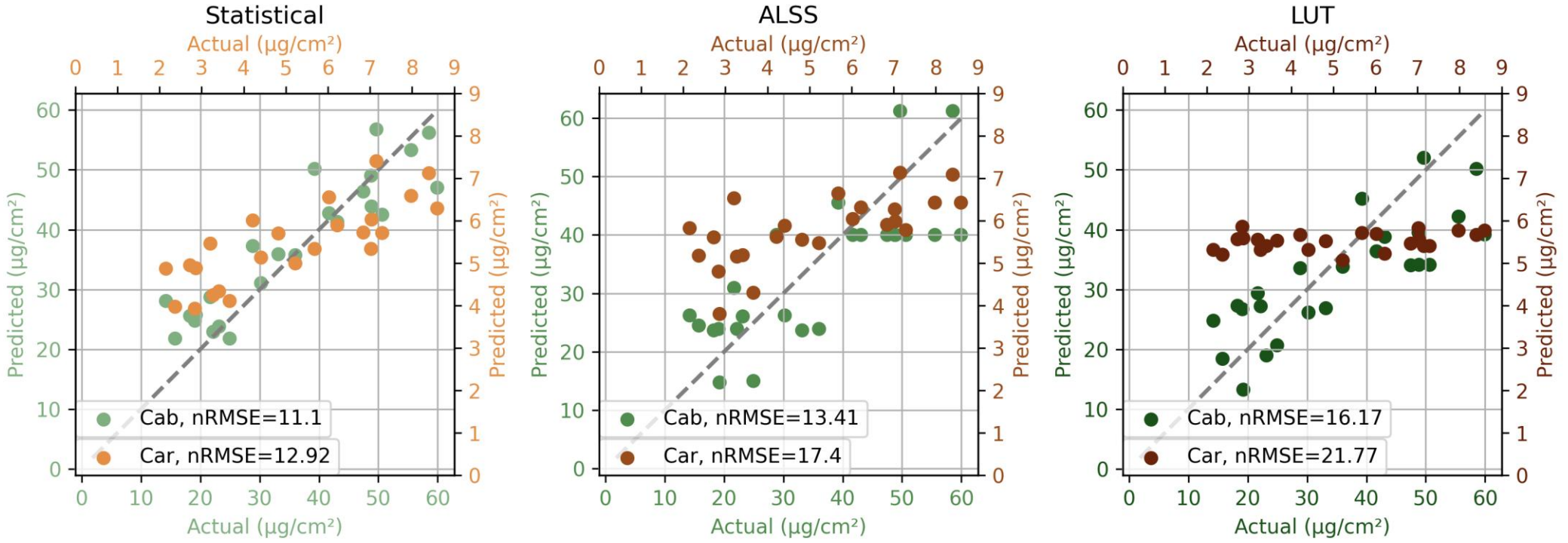
Využití syntetických dat k učení ML



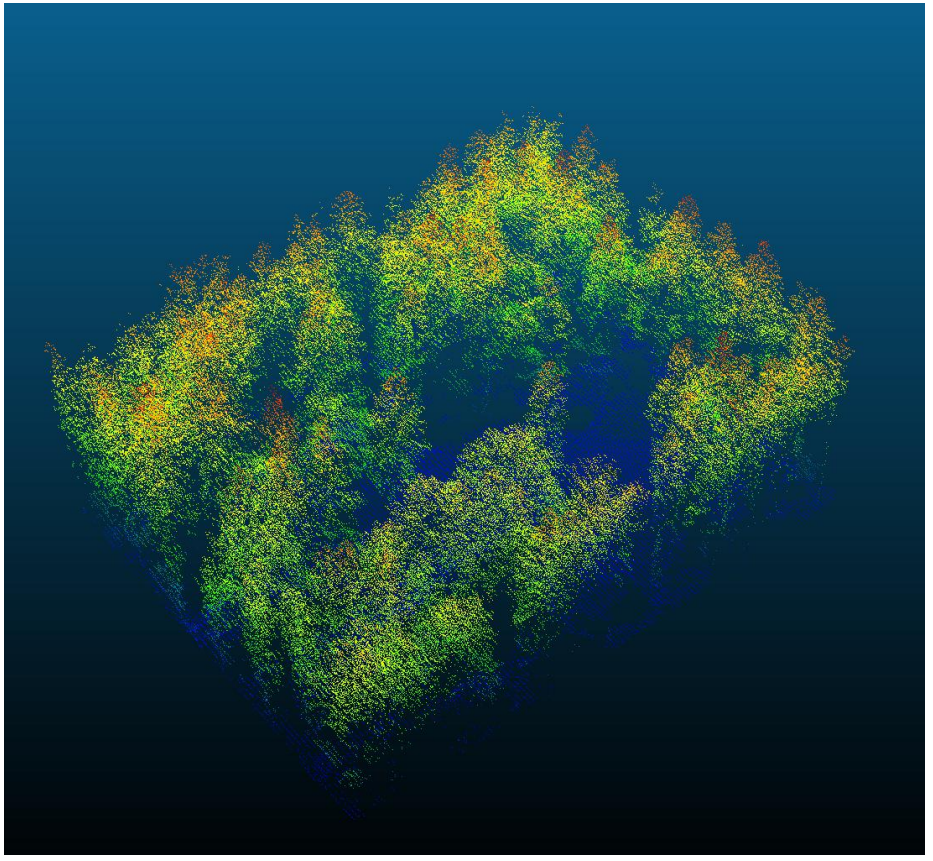


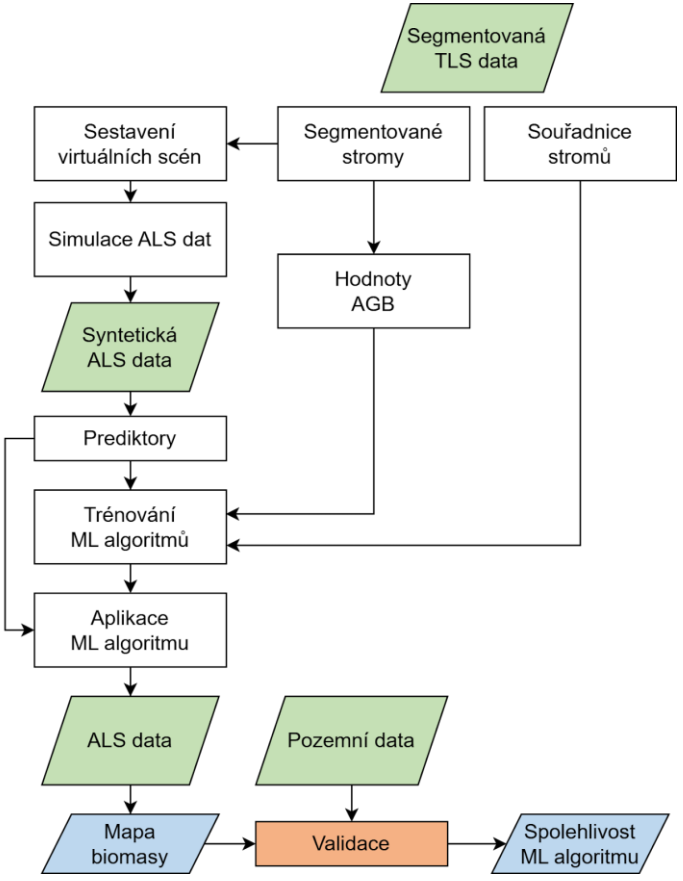


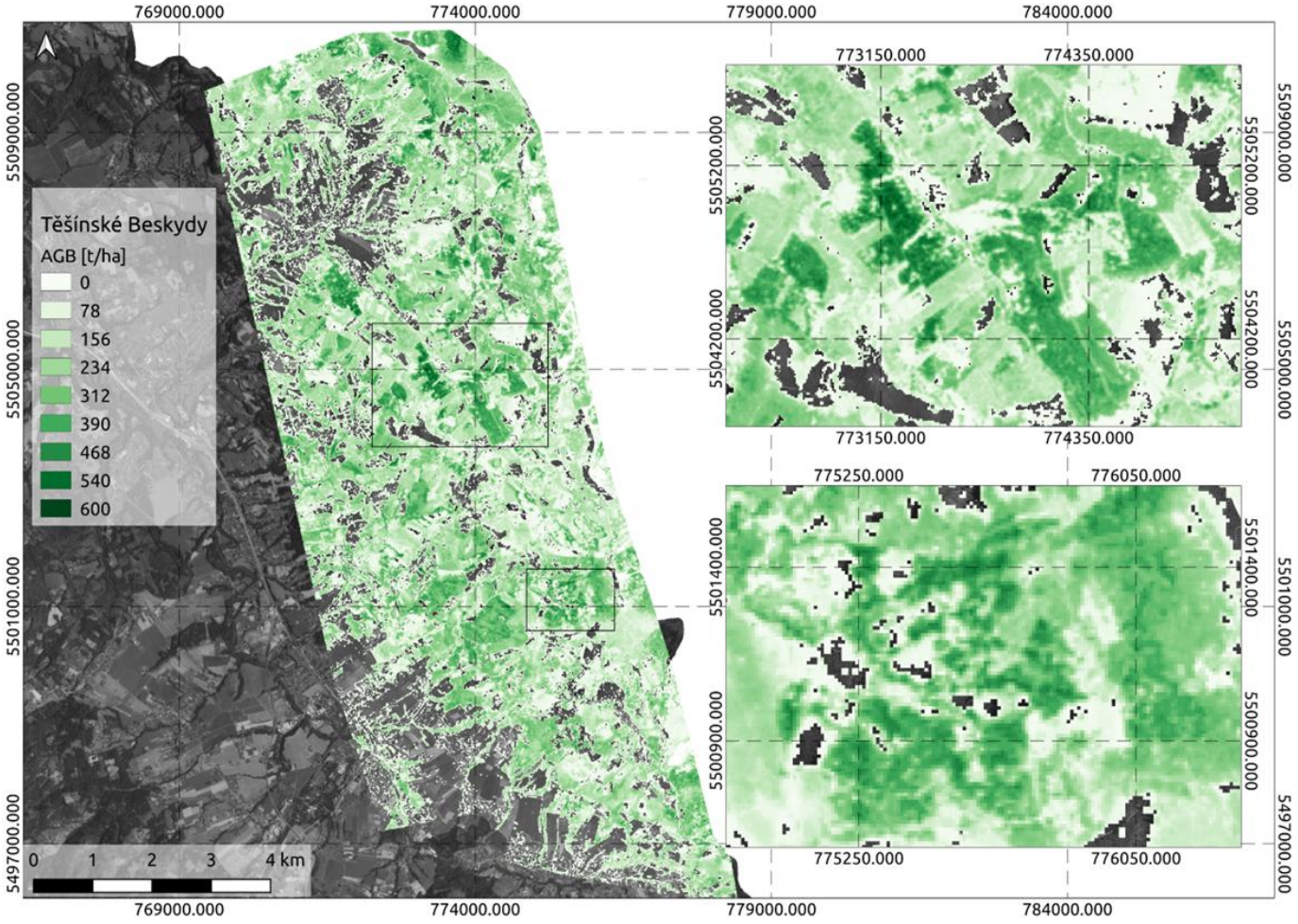

26 Apr 2019
21 Jun 2021
18 Jul 2019
22 Oct 2020
Statistical
ALSS
LUT
60
50
40
30
20
10
Cab (µg/cm²)


Statistical
Actual (µg/cm²)
Predicted (µg/cm²)
Cab, nRMSE=11.1
Car, nRMSE=12.92
ALSS
Actual (µg/cm²)
Predicted (µg/cm²)
Cab, nRMSE=13.41
Car, nRMSE=17.4
LUT
Actual (µg/cm²)
Predicted (µg/cm²)
Cab, nRMSE=16.17
Car, nRMSE=21.77

Simulace lidaru a výpočet biomasy

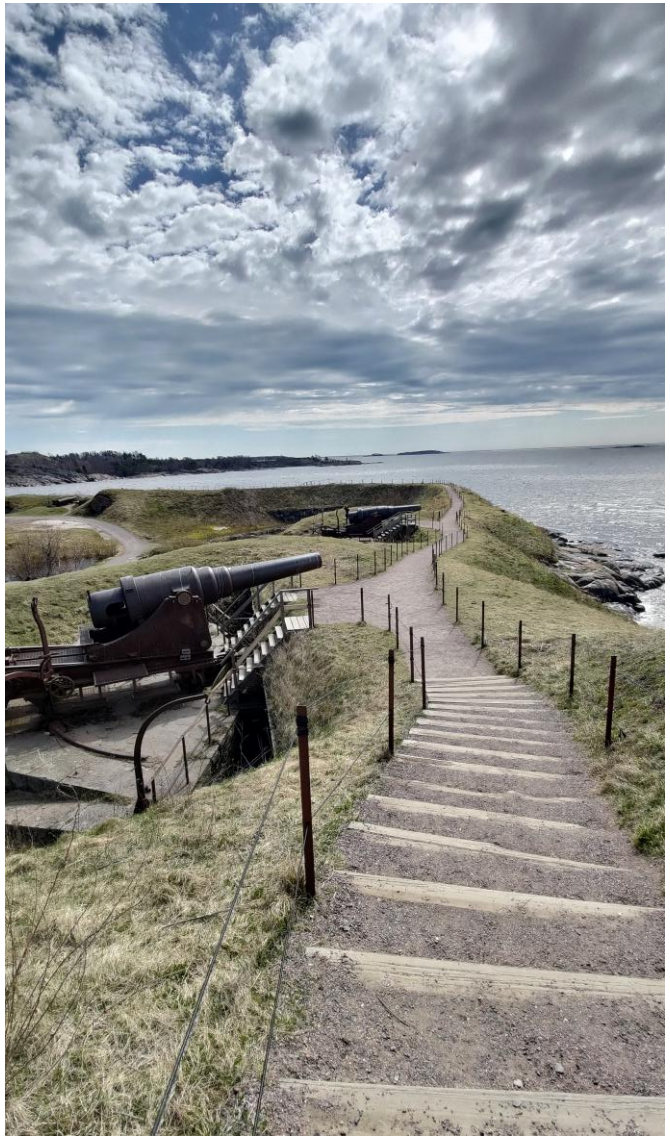





Těšínské Beskydy
AGB [t/ha]
0
78
156
234
312
390
468
540
600
0 1 2 3 4 km
769000.000
774000.000
779000.000
784000.000
5509000.000
5505000.000
5501000.000
5497000.000
773150.000
774350.000
5505200.000
5504200.000
775250.000
776050.000
5501400.000
5500900.000

Stáže

- Finsko, Helsinki – Aalto University – Květen 2024
  - Remote Sensing Research Team (Miina Rautiainen)
- Německo, Bonn – Uni. Of Bonn – Listopad 2024
  - Remote Sensing Research Group (Zbyněk Malenovský)
- Estonsko, Tartu – Uni. Of Tartu – Mobility projekt (2 týdny ročně)
- Francie, Toulouse – J.P.Sabatier Uni, Leden 2025
  - DART development team




3rd Workshop
on International Cooperation
in Spaceborne Imaging Spectroscopy
13–15 November 2024 | ESA–ESTEC | Noordwijk, The Netherlands
esa


AIR FRANCE

Nabídka práce/brigády

- Na oddělení leteckých činností hledáme technika na zpracování leteckých dat
- Možnost půl úvazku při škole, ale i plný úvazek po absolvování
- Rozvoj směrem, kterým budete chtít (víc DPZ, programování, databáze, GIS)

Děkuji za pozornost

hanousek.t@czechglobe.cz