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FINNISH GEOSPATIAL RESEARCH INSTITUTE
FGI

EMPIR EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Metrology for Earth Observation and Climate

Exploring hyperspectral drone imaging capabilities for Sentinel-2 Fiducial Reference Measurements over forest site

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Metrology for Earth Observation and Climate

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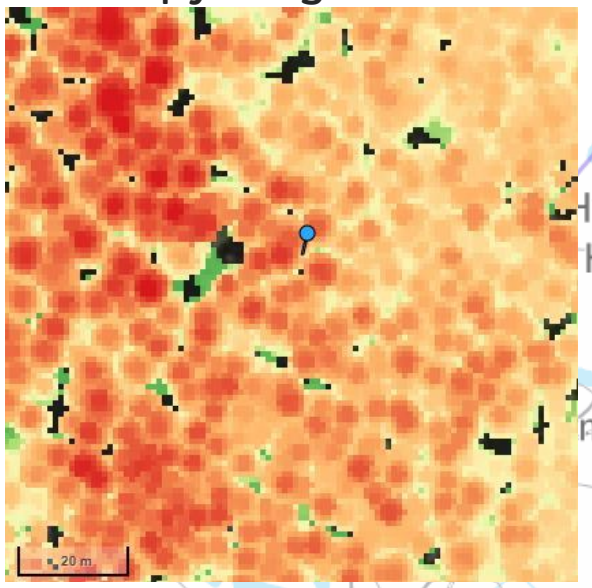
Aim of the work

- MetEOC-4 - Metrology to establish an SI-traceable climate observing system –project coordinated by NPL, UK (9/2020 – 8/2023)
  - WP3: Validating Carbon stocktake: Greenhouse gas (GHG) emissions and biosphere
    - Task 3.3: Validation of vegetation-related variables
- Exploring hyperspectral drone capabilities over forest test site for Fiducial Reference Measurement (FRM) methodologies in order to assess the impact of key factors such as solar geometries, atmospheric conditions, and phenology
  - Drone campaigns +-15 min with Sentinel-2 overpasses with different solar elevations / zenith angles
  - Similar campaigns in UK and in Finland

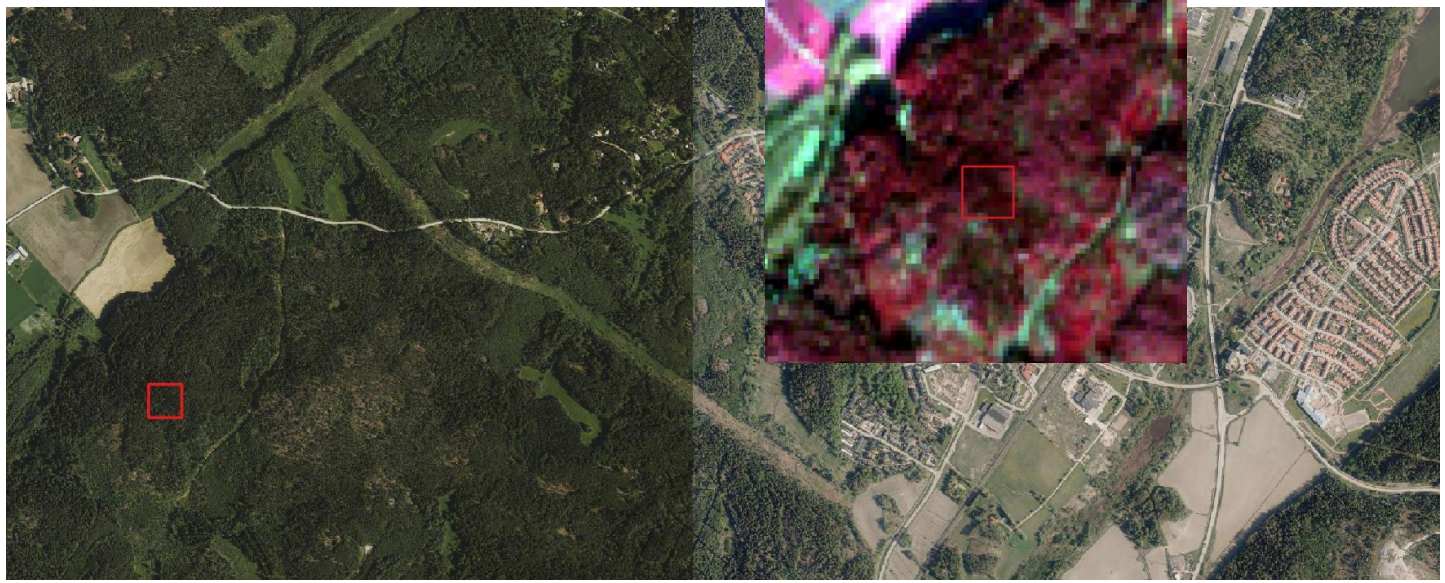
FGI forest test site

1-hectare (100 m x 100 m) dense forest test site, mainly Norway spruce (Picea abies), at Kirkkonummi, Southern Finland

Canopy height model



NLS RGB orthophoto



S2 CIR

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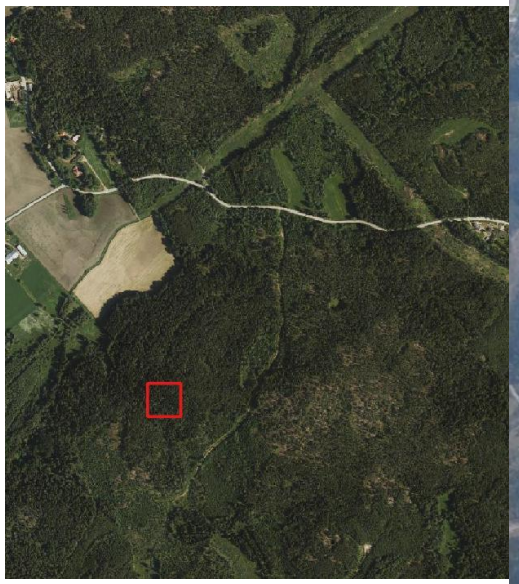
1-hectare (1
forest test si
spruce (Pice
Kirkkonumm

NLS RGB orthophoto



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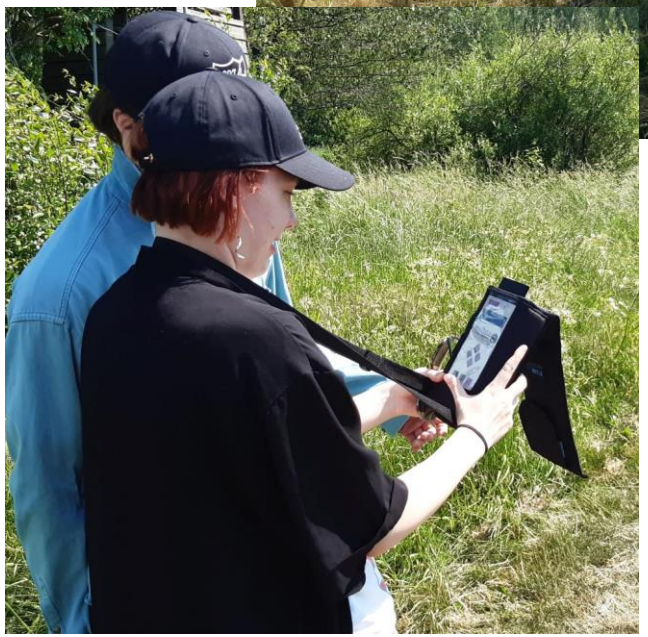
Hyperspectral drone system

Specim AFX10

- Pushbroom camera, computer, GNSS-IMU, storage all in one package
- Real-time and post-mission position and orientation solution for direct georeferencing
- 400-1000 nm, 224 bands, 1024 spatial pixels, 2.1 kg
- GSD 7 cm from 100 m height
- Radiometrically calibrated by Specim -> produces at-sensor radiance images

In situ reference measurements and data processing

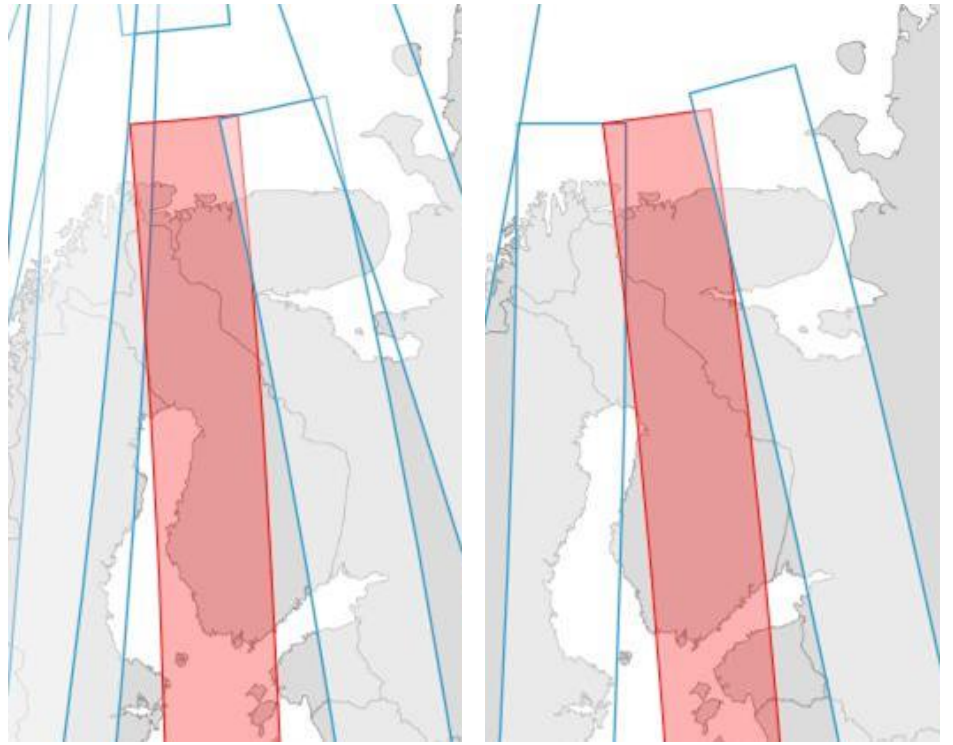
- Aerosol optical depth (AOD) measurements with MicrotopsII
- Four 1 m^2 reference reflectance panels: Labsphere Permaflect 5%, 10%, 20%, 50% reflectance
- AFX10 geometric processing with Specim CaliGeo PRO
- Image line mosaicking with Rese DROATCOR
- Conversion to ground reflectance with empirical line method



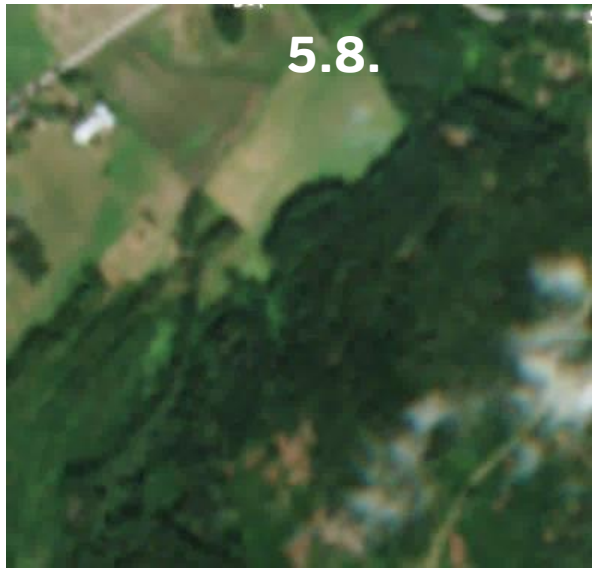
Drone campaigns

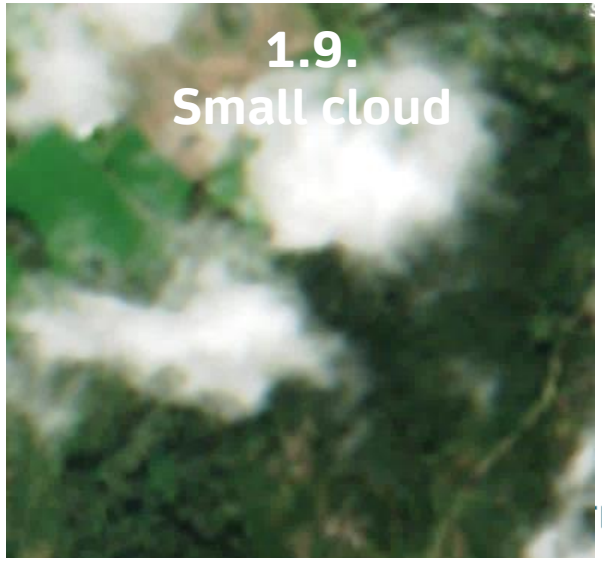
- Sentinel-2 A&B overpasses every 2-5 days over the test site around noon or 1pm (summertime)
- Drone campaign +- 15 mins of the S2 overpass
- 10 flights done, 6 in good conditions

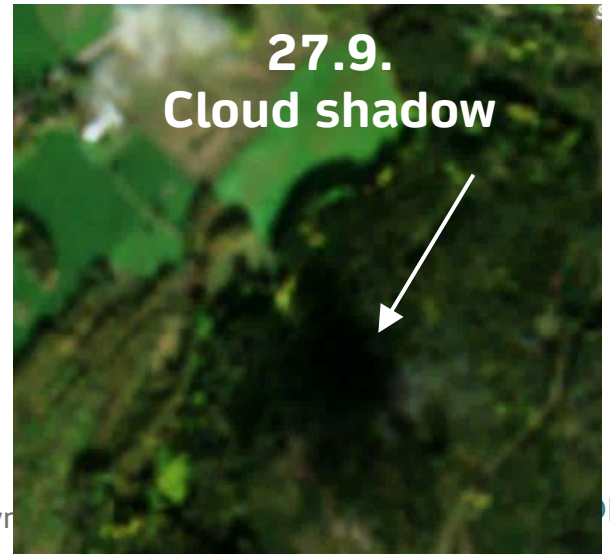
Date	SunZen	Sensor	Comments
21.6.	**37.07°**	**Senop Rikola**	AFX10 did not work
1.7.	**37.49°**	**Specim AFX10**	
14.7.	**38.76°**	**Specim AFX10**	
5.8.	**43.72°**	**Specim AFX10**	
1.9.	52.49°	Specim AFX10	Clouds
9.9.	55.19°	Specim AFX10	Clouds
22.9.	**60.01°**	**Specim AFX10**	
27.9.	61.95°	AFX10 + LiDAR	Conditions varying
19.10.	**70.28°**	**Specim AFX10**	
16.12.	83.40°	Specim AFX10	Clouds



Sentinel-2 images



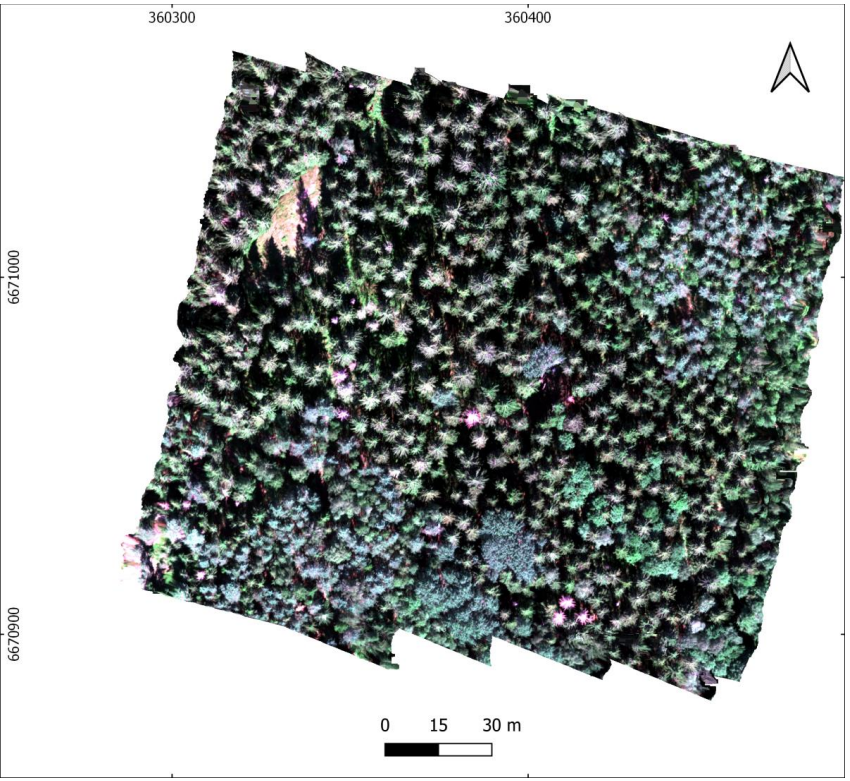




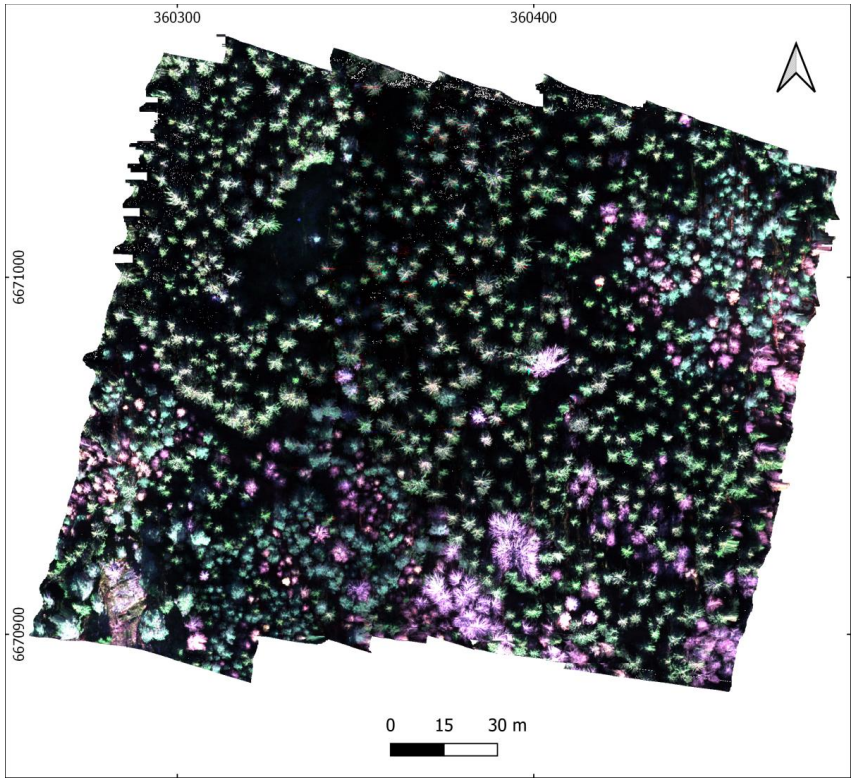
Example images

AFX10 mosaics, GSD 10 cm, R = 666 nm, G = 561 nm, B = 489 nm

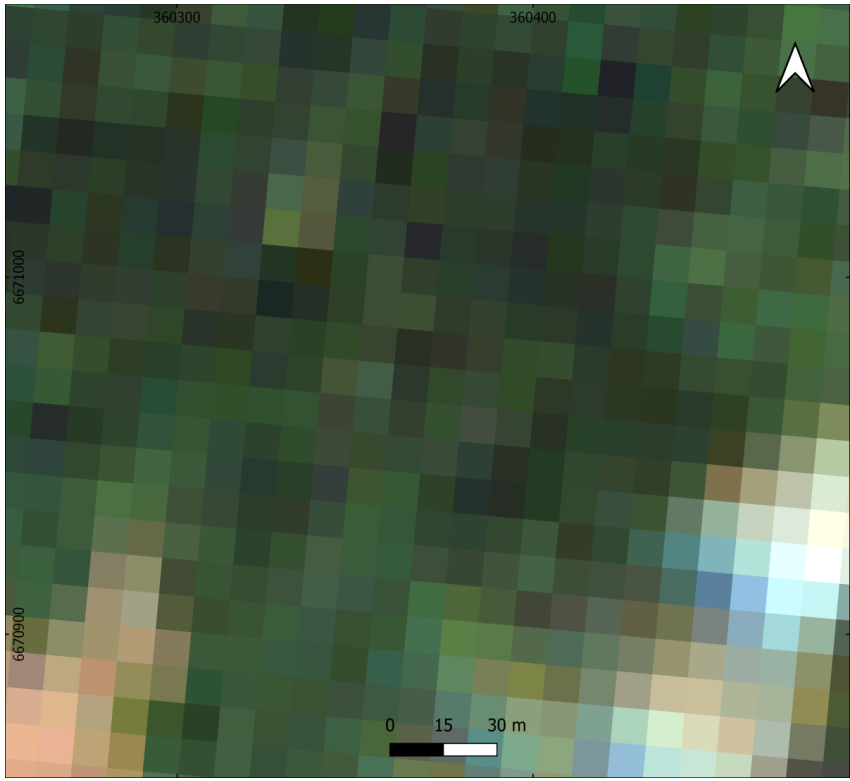
14 July 2021



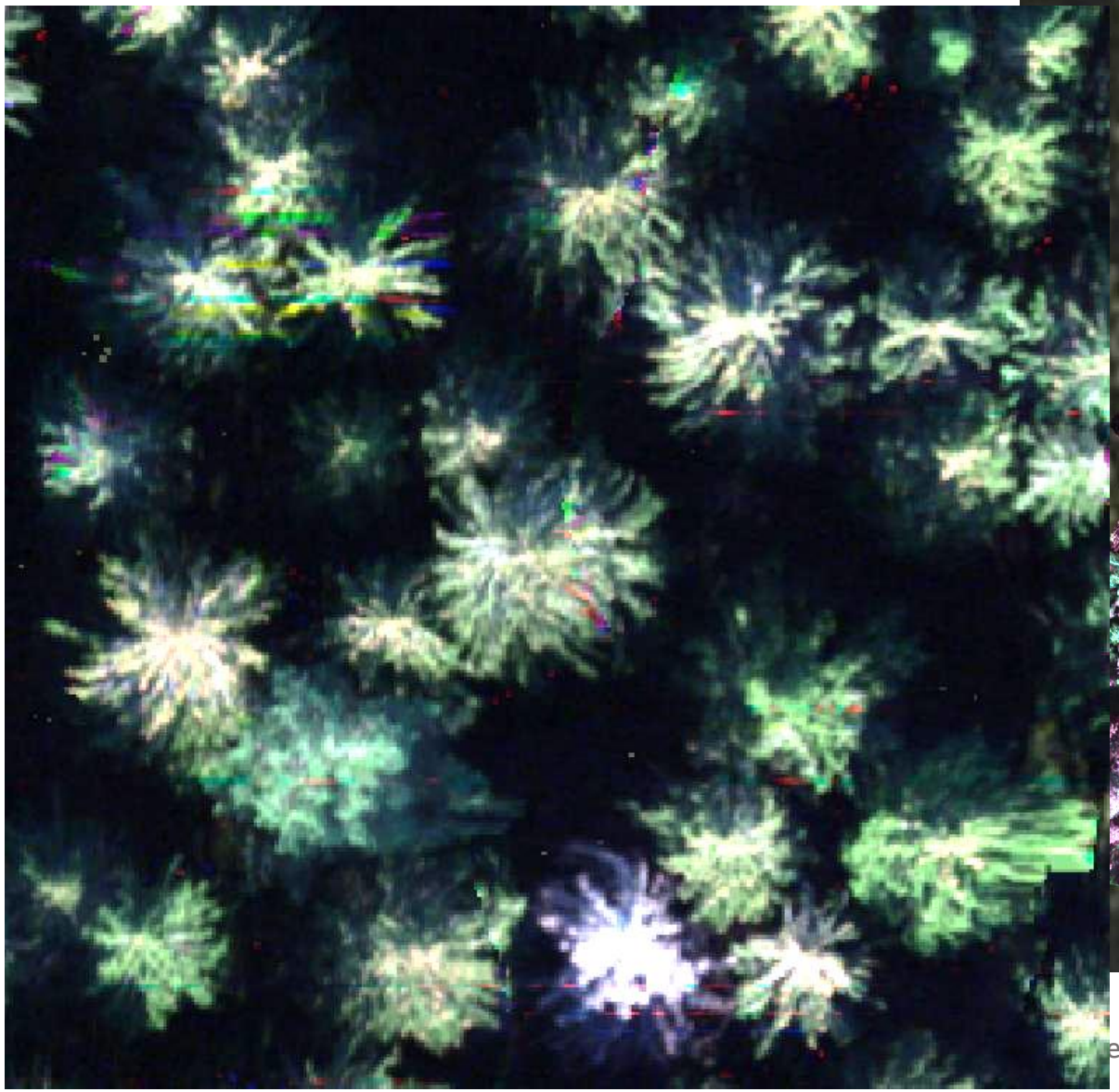
19 October 2021



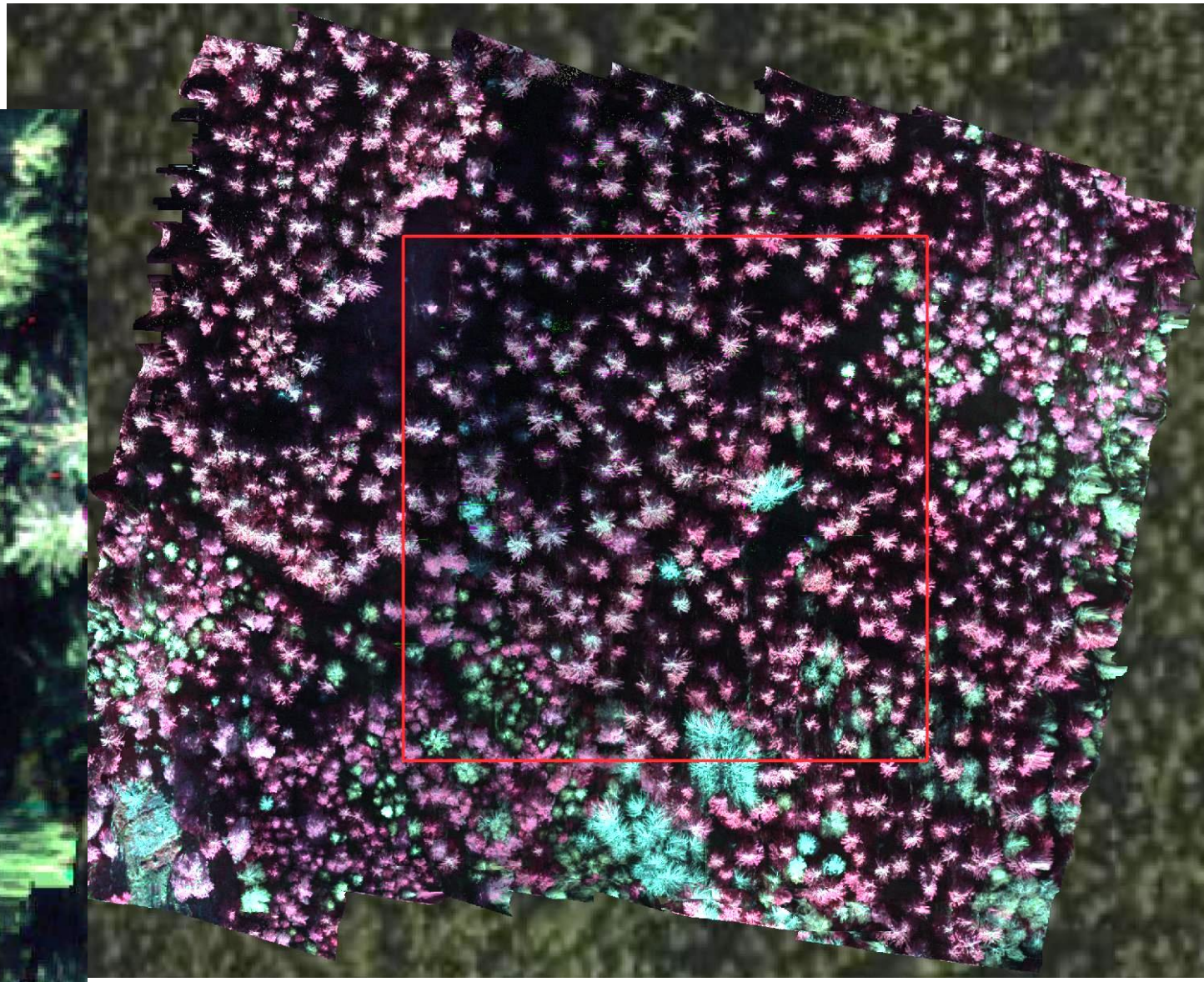
Sentinel-2 10 m
5 August 2021



Example images

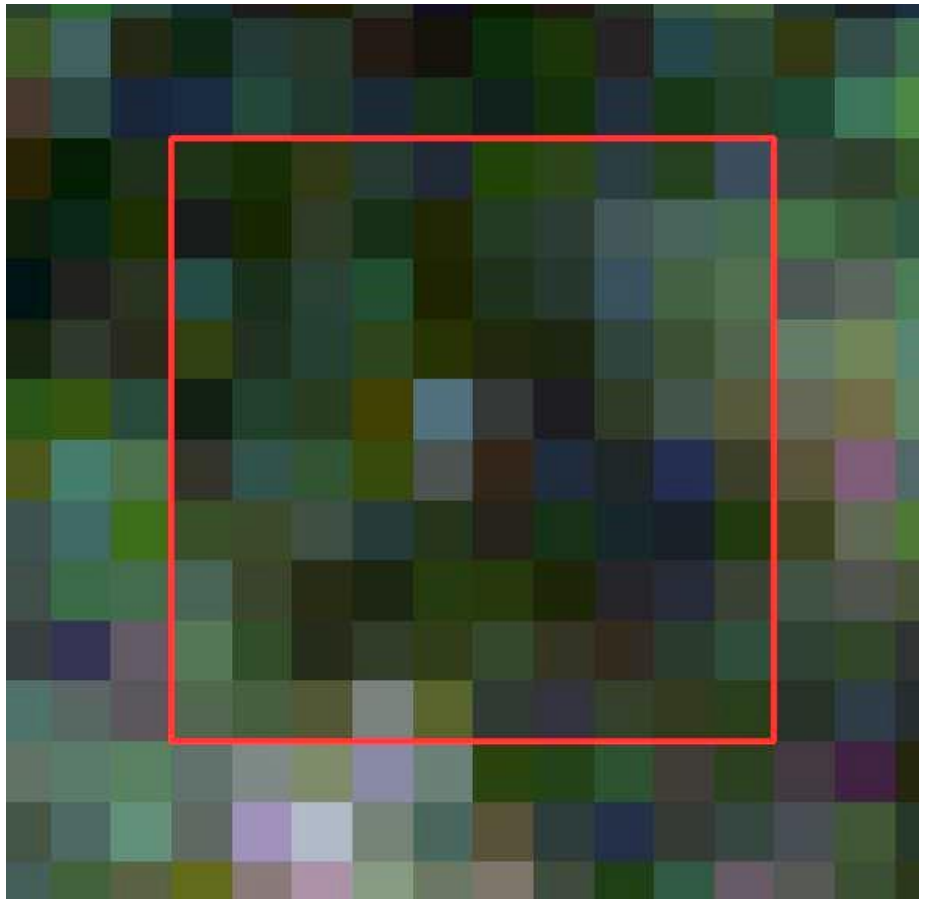


One hectare test area

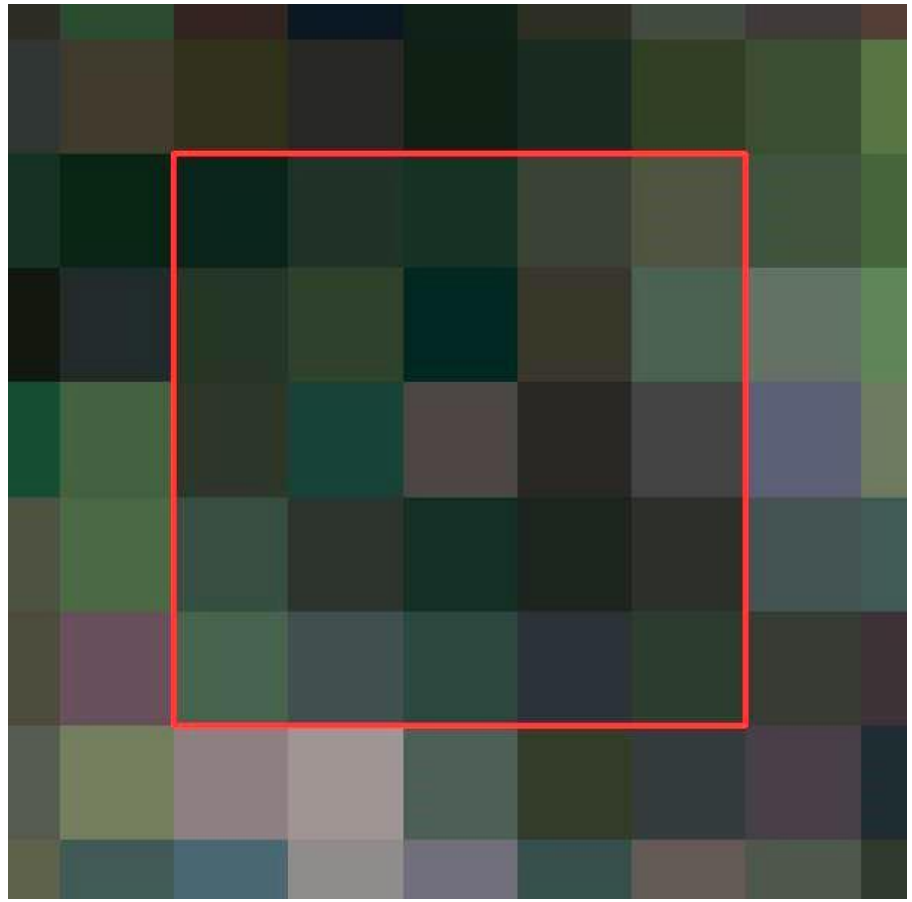


Example images 2: resolution

S2 GSD 10m

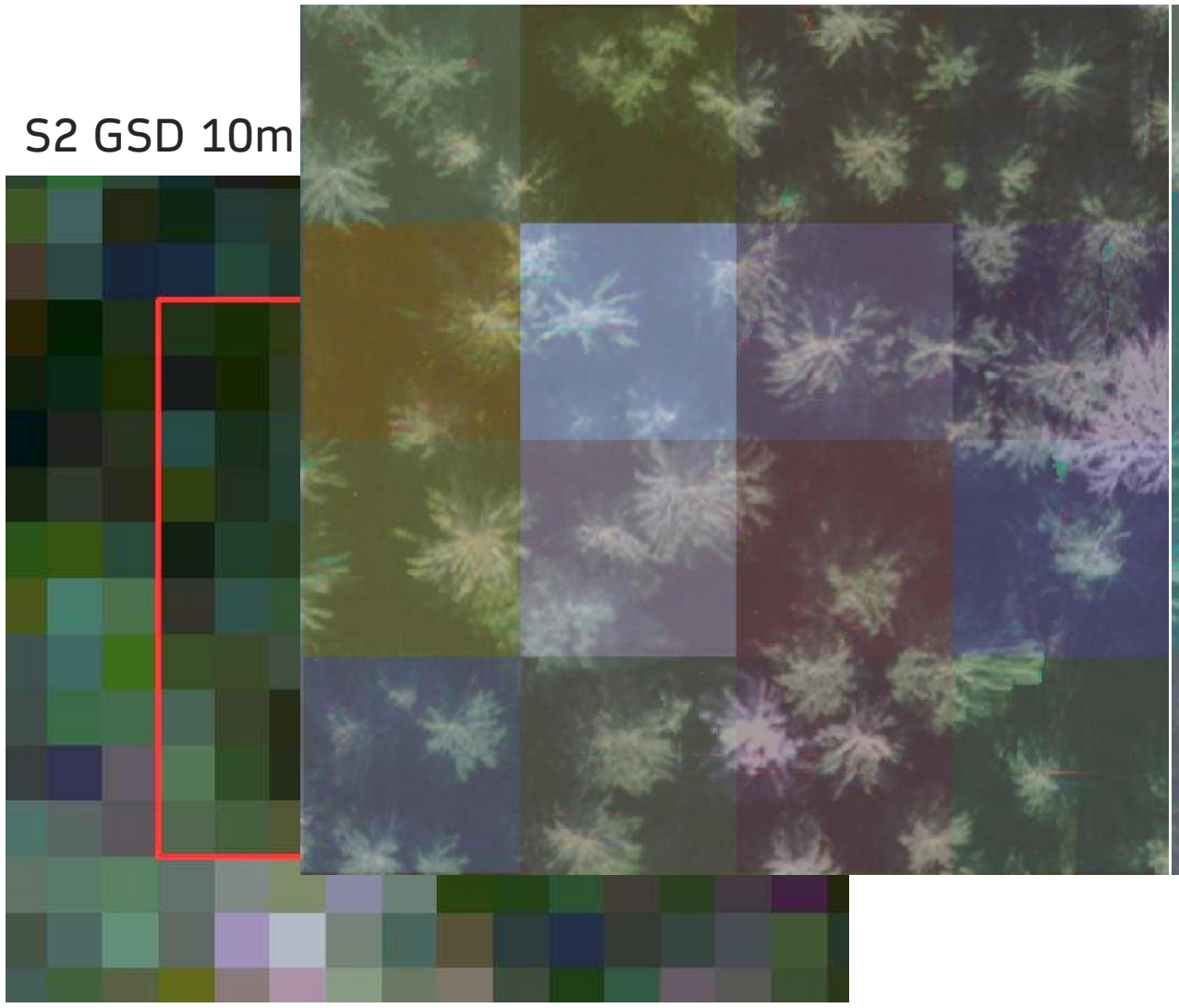


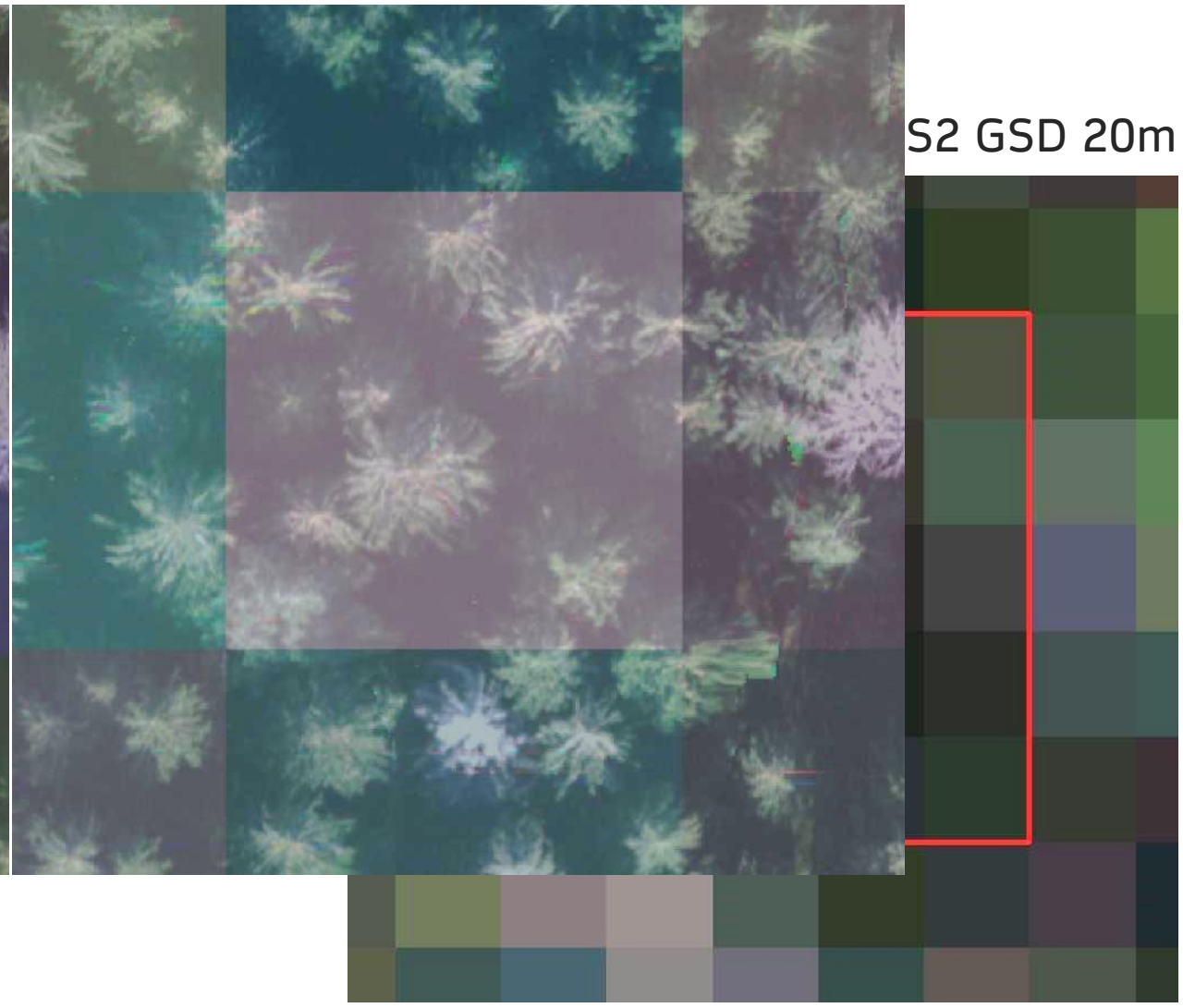
S2 GSD 20m



Example images 2: resolution

S2 GSD 10m

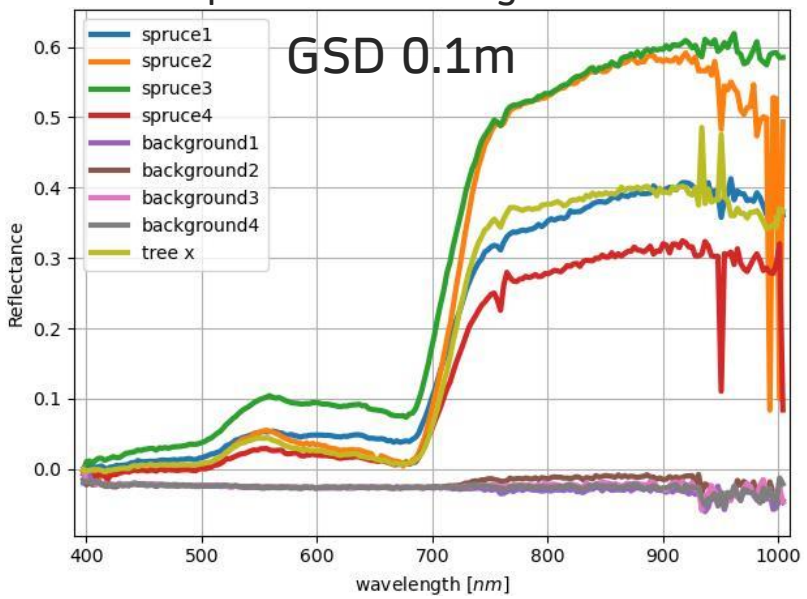




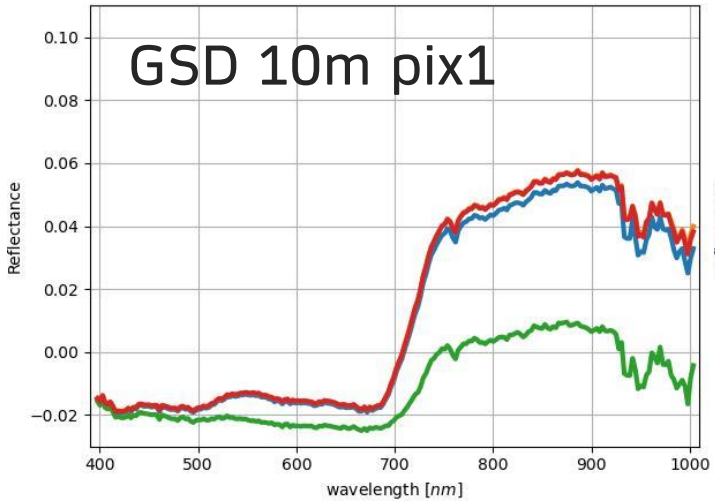
S2 GSD 20m

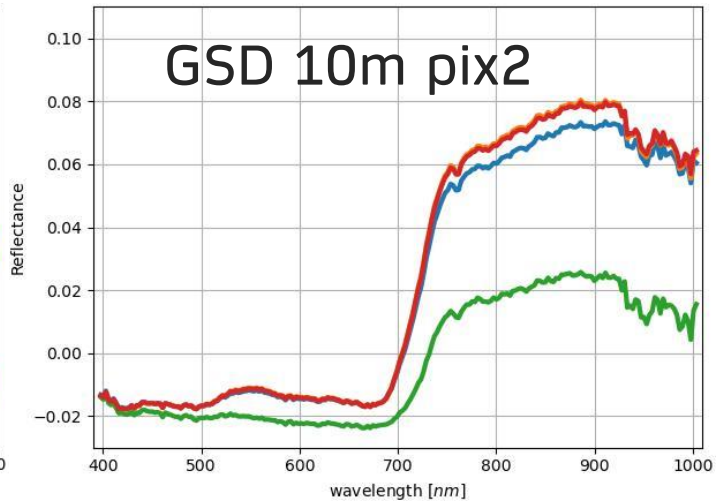
AFX10 spectra

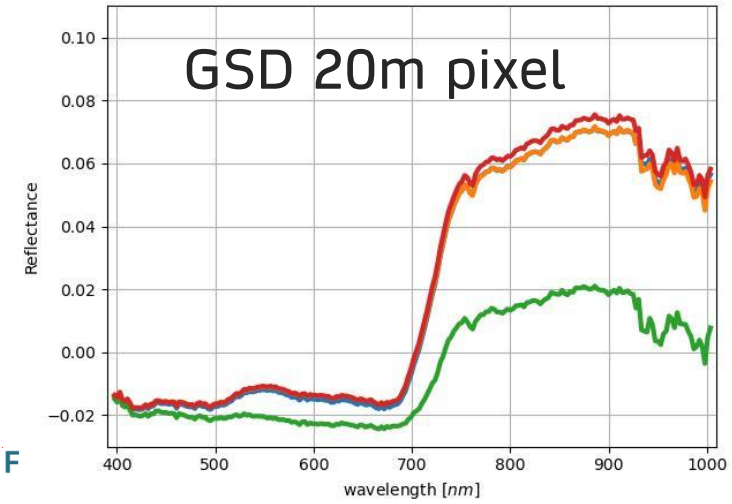
Individual pixel spectra of Spruce and background

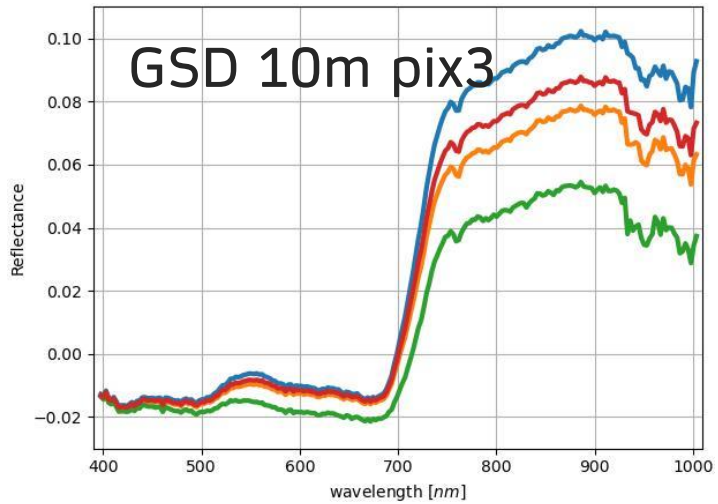


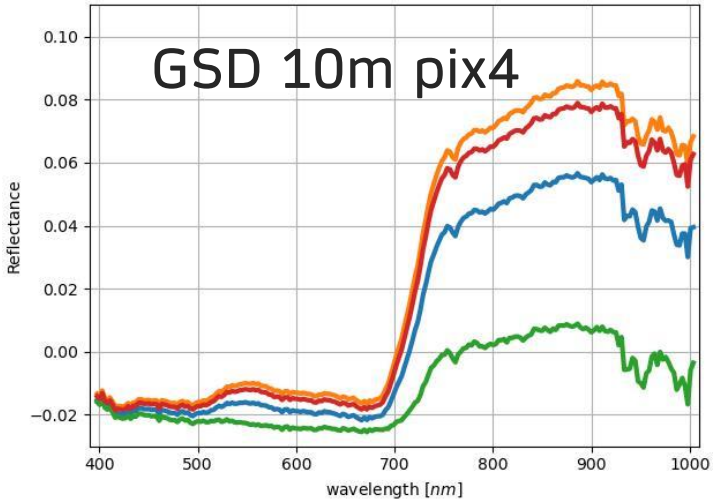
19.10. AFX10 GSD 0.1 m image resampled to S2 10 m and 20 m GSD with different algorithms: **Average**, **Bilinear**, **CubicSpline** and **Median**







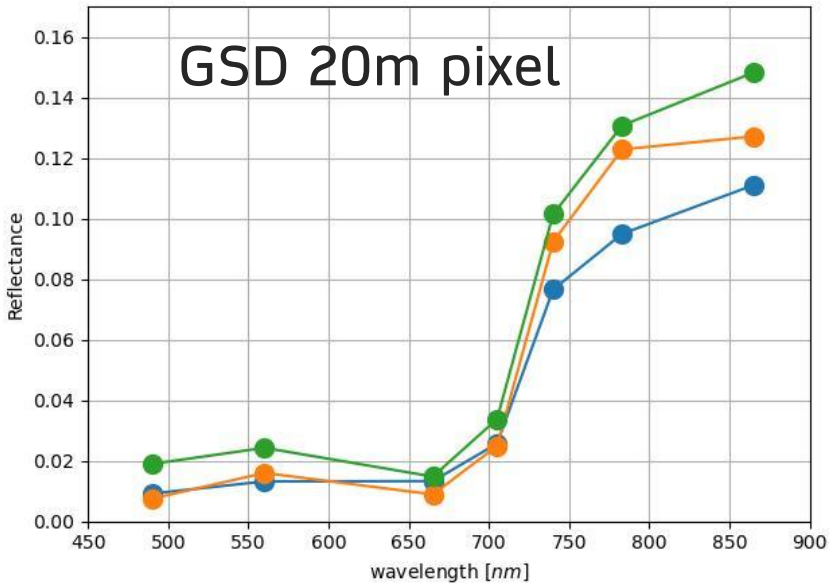


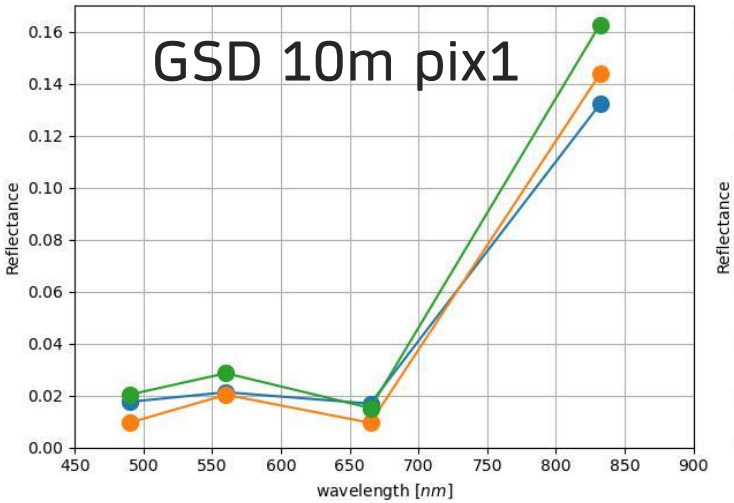


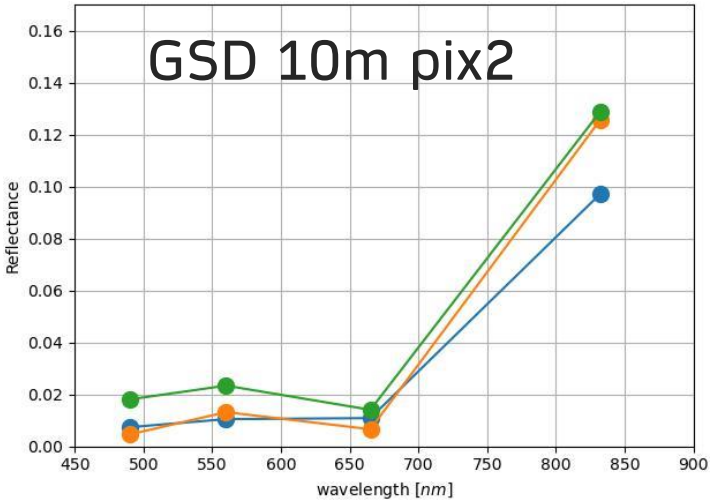
S2 spectra

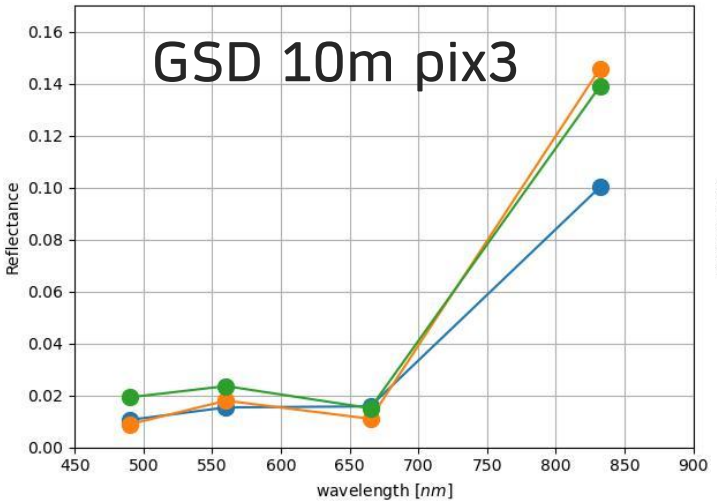
Sentinel-2 bands
GSD 10m: B2, B3, B4, B8
GSD 20m: B2, B3, B4, B5,
B6, B7, B8a

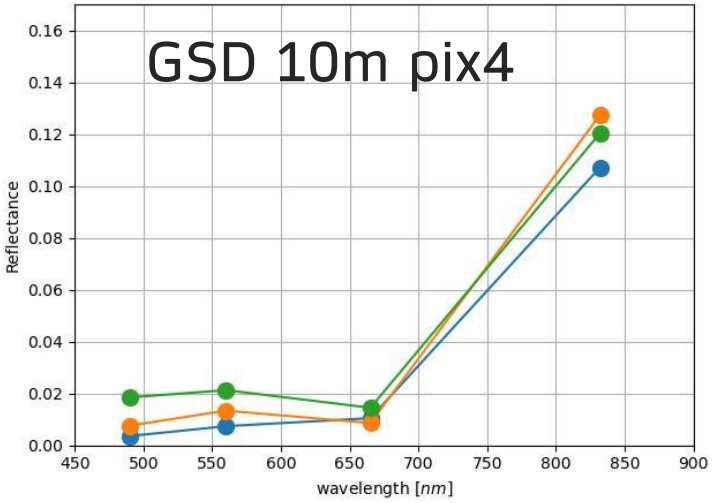
Sentinel-2 pixel spectra from three dates: **14.7.**, **22.9.**, **19.10.**,
SunZen: **39°** **60°** **70°**





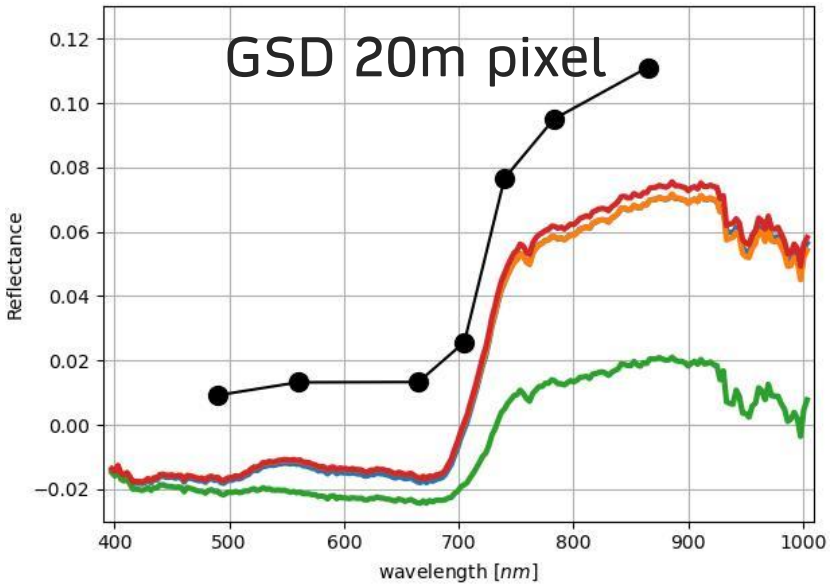


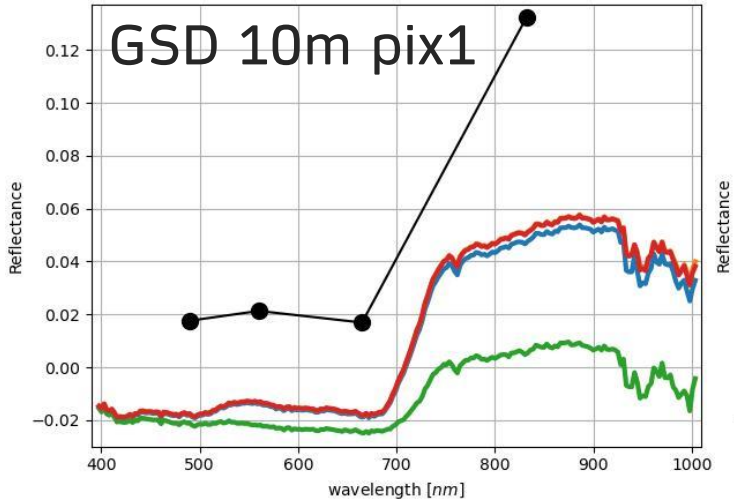


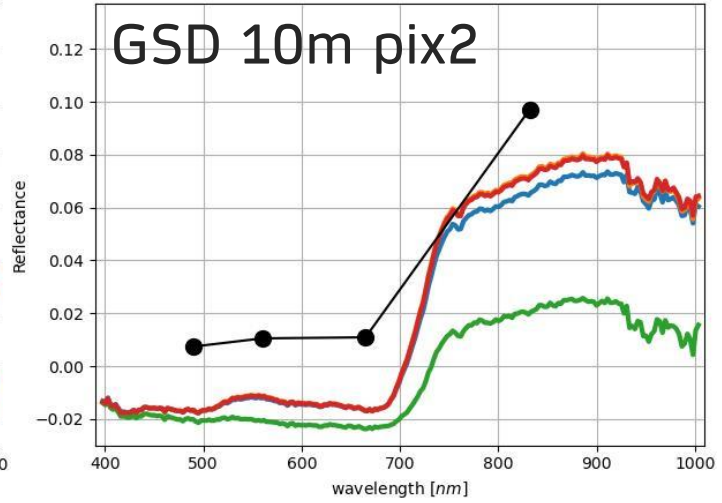


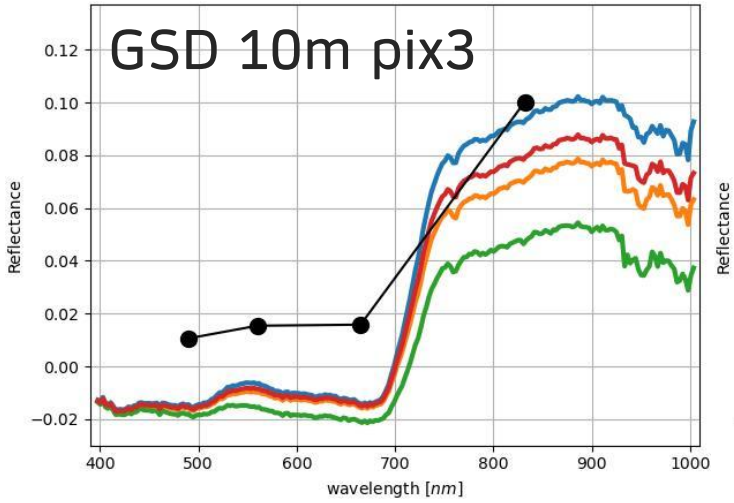
AFX10 vs S2 spectra 19.10.

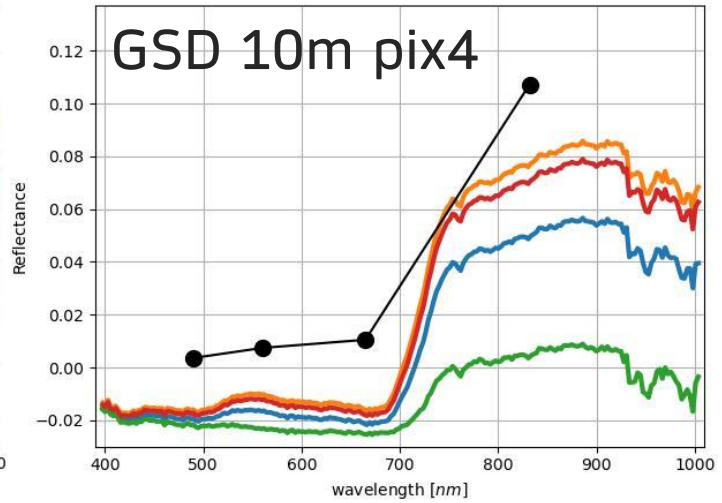
AFX10 GSD 0.1 m image resampled to **S2 10 m** and **20 m** GSD with different algorithms: **Average**, **Bilinear**, **CubicSpline** and **Median**











Conclusions and future work

- We have collected six hyperspectral drone data sets matching with Sentinel-2 overpasses
- Sun zenith angles from 37° to 70°
- One LiDAR data set

- Process all AFX10 campaign data from 6 dates
- AFX10 spectral resampling to S2
- Choose optimal spatial resampling method for drone data
- Estimate AFX10 reflectance data accuracy
  - Fix offset from AFX10 reflectance
- Check weather and AOD measurements for each date
- Compare different solar zenith angles / dates

Thank you!
Smarter aerial sensing

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Dronefinland.fi

DroneFinland is drone-based remote sensing innovation center at FGI NLS

- Drone research since 2008
- Lead by Prof. Eija Honkavaara
- Drone photogrammetry, laser scanning, hyperspectral imaging, thermal imaging
- New sensors, rigorous sensor data processing
- Efficient and intelligent processing algorithms
- Test fields, calibration and validation
- Application know-how, collaboration
- Success stories