Topography of the Cuvette Centrale peat deposits

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University of Edinburgh, University of Leeds, University College London, Université Marien Ngouabi, Brazzaville, University of St Andrews, University of Leicester

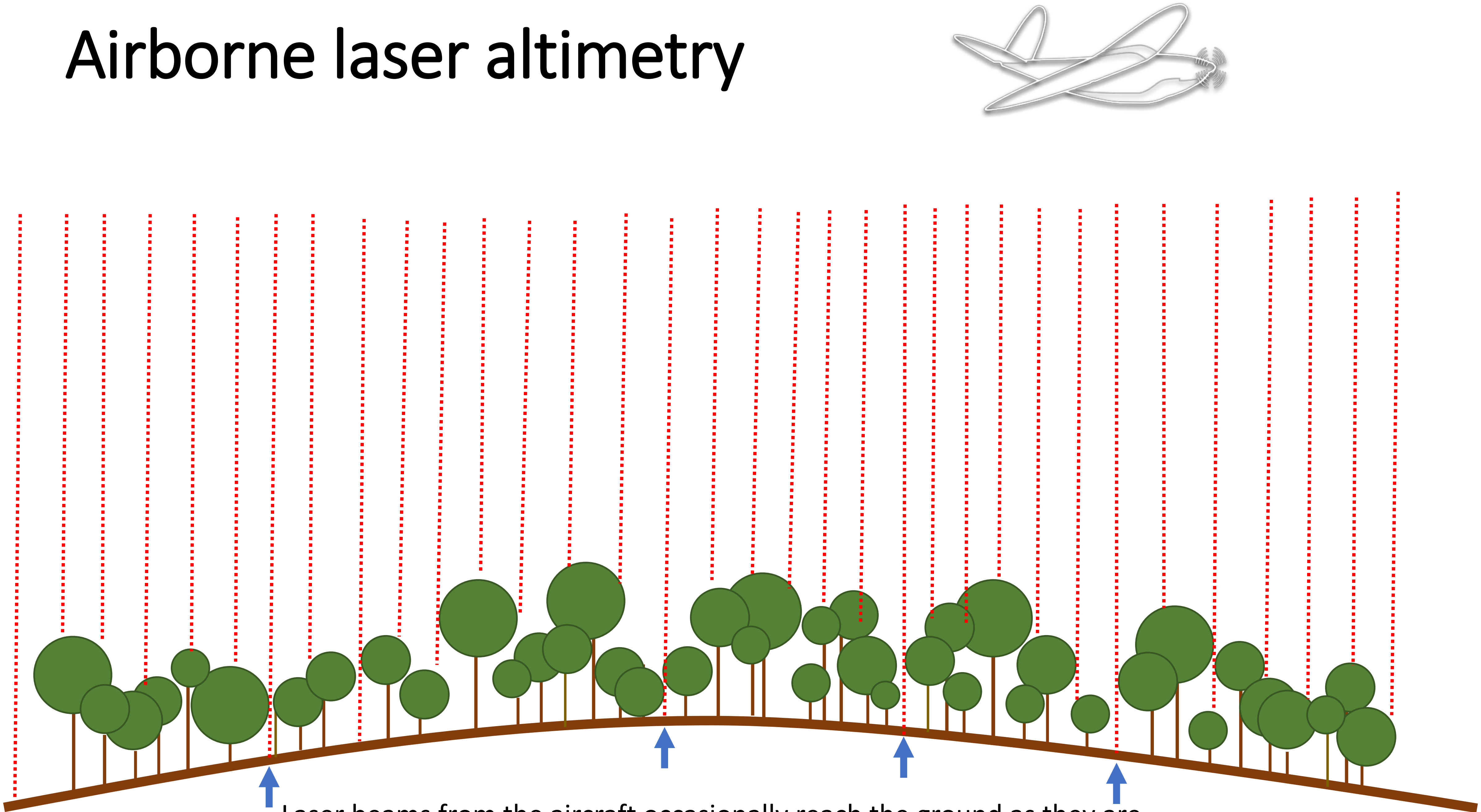
The Cuvette Centrale in the Congo Basin stores close to 29.0 petagrams of carbon, about a third of the global tropical peatland carbon.

Preserving it requires knowledge of its genesis, development and functioning.

Topography is a big part of this, as a domed shape is an indicator of rain-fed peat.


The dense forest prevents most usual ground-based (e.g. GNSS) and remote sensing techniques.
A mixture of UAV-based LiDAR combined with ICESat-2 satellite LiDAR and classification techniques were used to estimate the peat shape

Airborne laser altimetry



Laser beams from the aircraft occasionally reach the ground as they are only 12cm in diameter, and several thousand per second are transmitted.

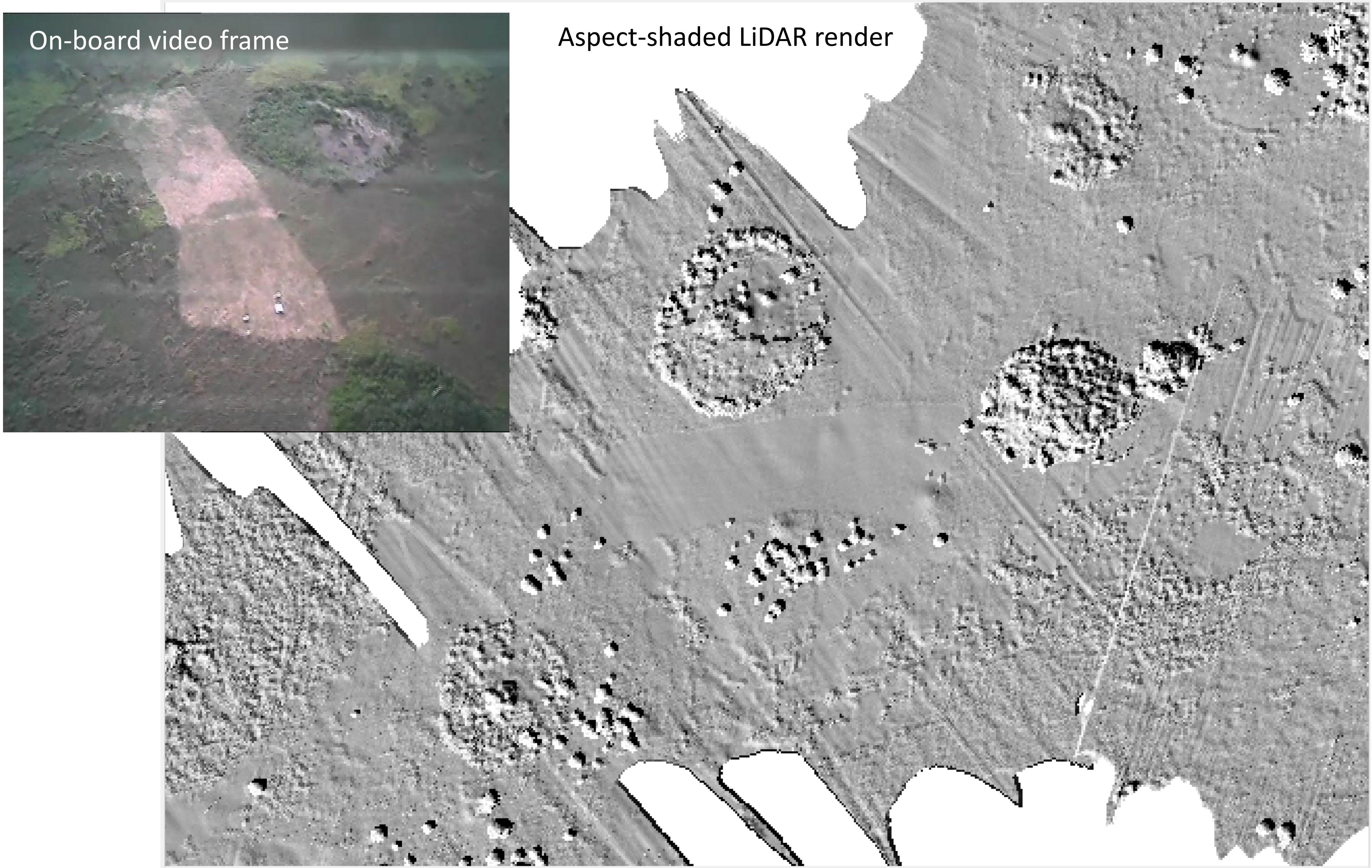
By plane from Brazzaville to Impfondo, boat to Ekolongouma and Epena


We need a large area for landing the drone, so locals cleared an airstrip with machetes…

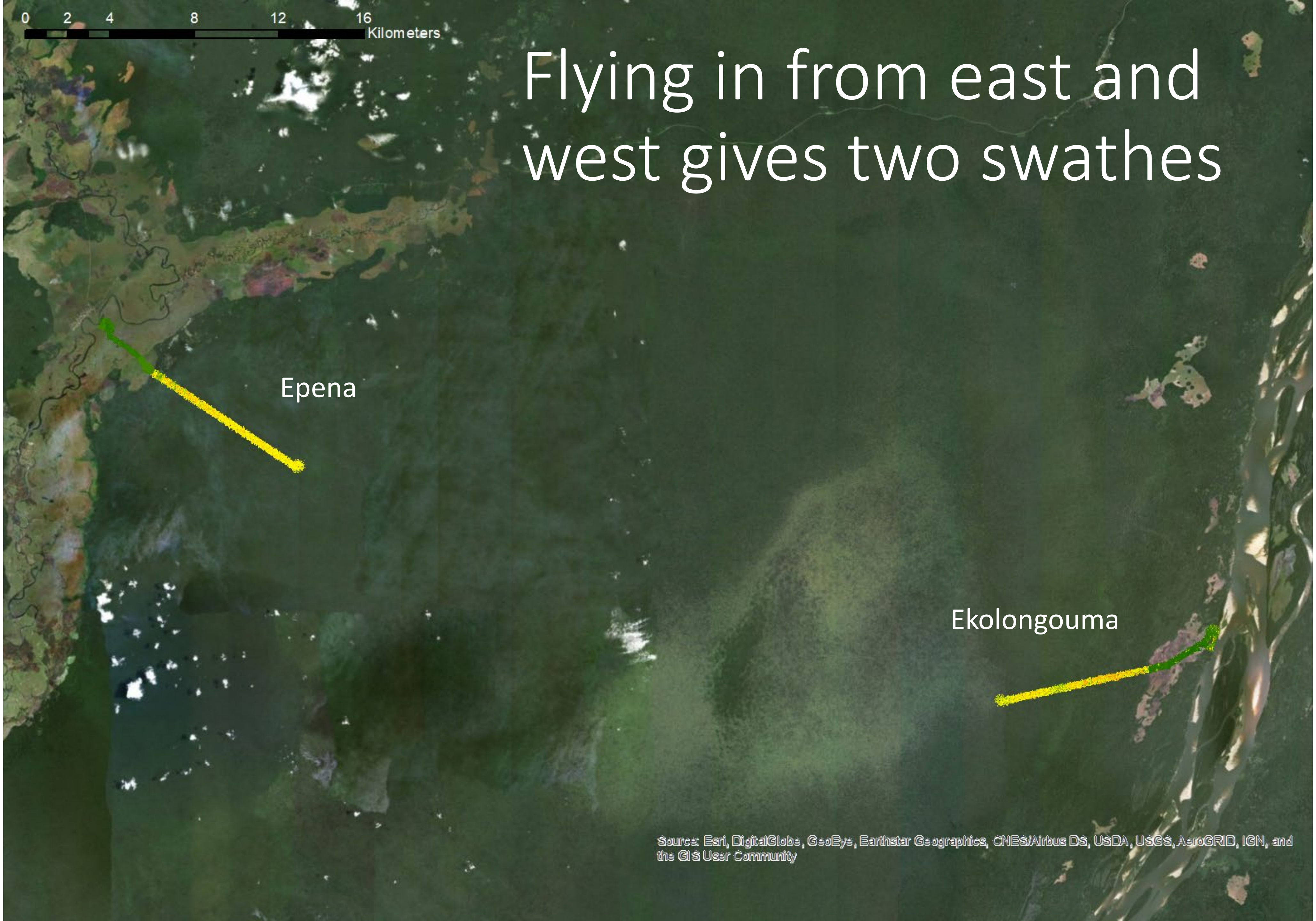
We need a large area for landing the drone, so locals cleared an airstrip with machetes…

…and removed termite nests

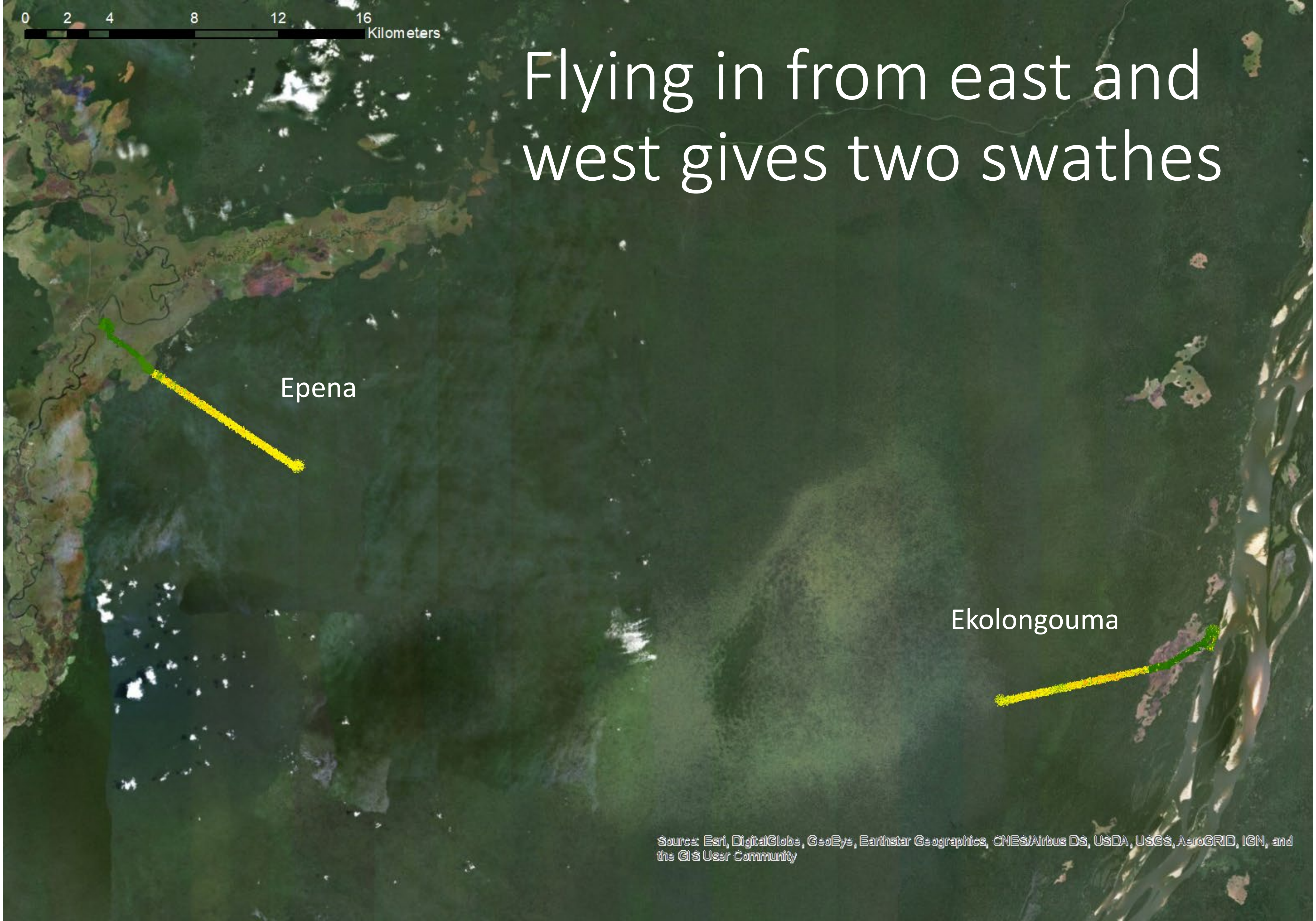
We set up a launcher


On-board video frame
Aspect-shaded LiDAR render

Flying in from east and west gives two swathes



Flying in from east and west gives two swathes



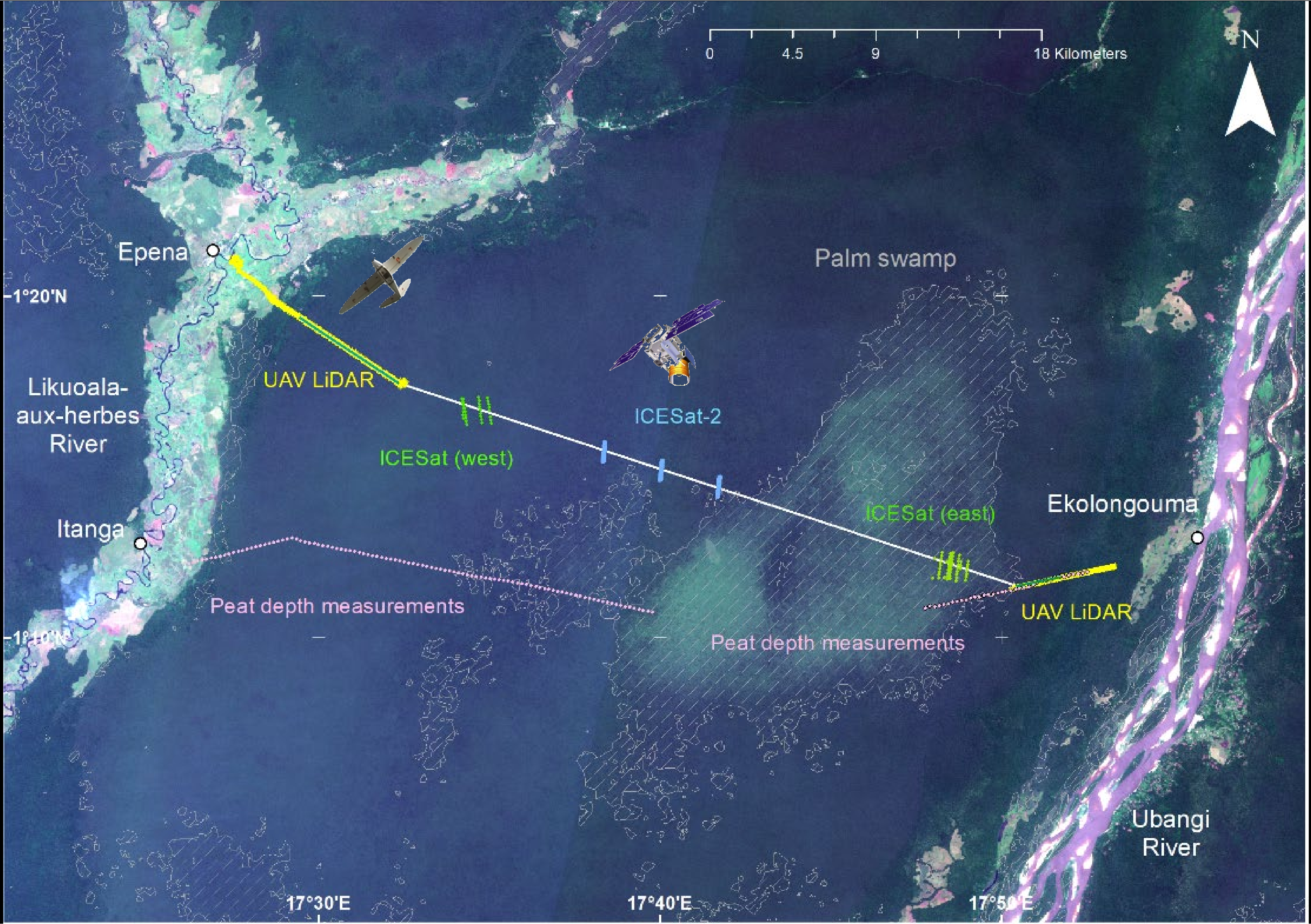
Fill in the gaps with satellite measurements?

NASA's ICESat-2 has a laser altimeter on board similar to an airborne system.

It's designed to measure the polar ice sheet.

Beams are 14m in diameter, so a complete beam wouldn't slip between the canopy gaps.

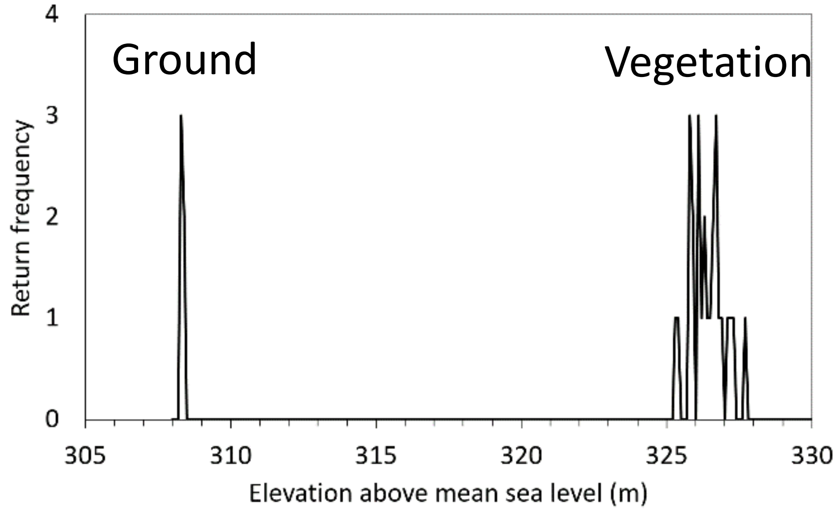
But the sensor measures individual photon returns, so there's a good chance of measuring some ground returns.



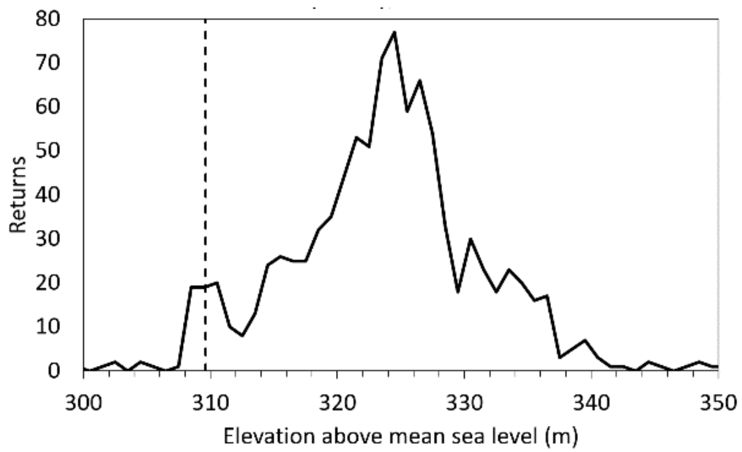
0
4.5
9
18 Kilometers
N
Epena
Palm swamp
-1°20'N
UAV LiDAR
Likuoala-
aux-herbes
River
ICESat-2
ICESat (west)
ICESat (east)
Ekolongouma
Itanga
Peat depth measurements
UAV LiDAR
Peat depth measurements
Ubangi
River
17°30'E
17°40'E
17°50'E

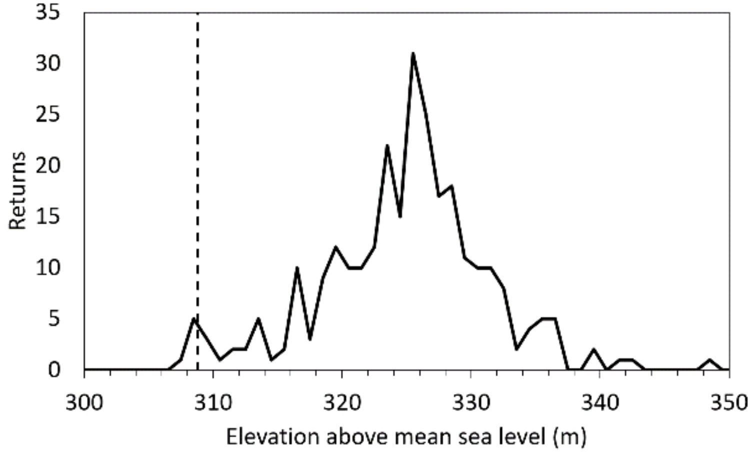
Photon return elevation histograms

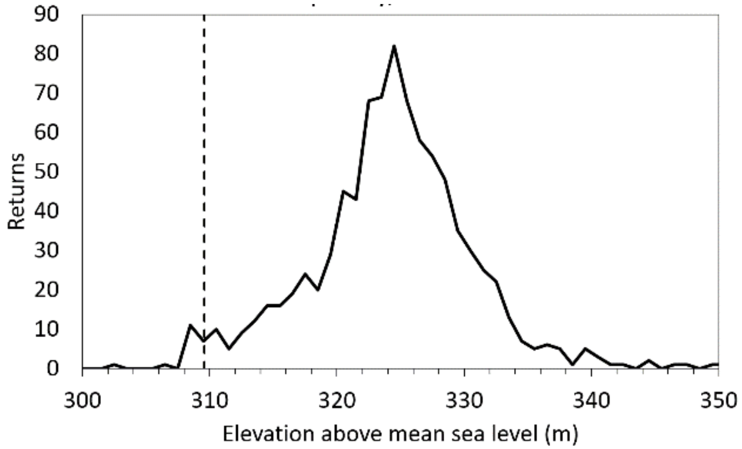
ICESat GLAS

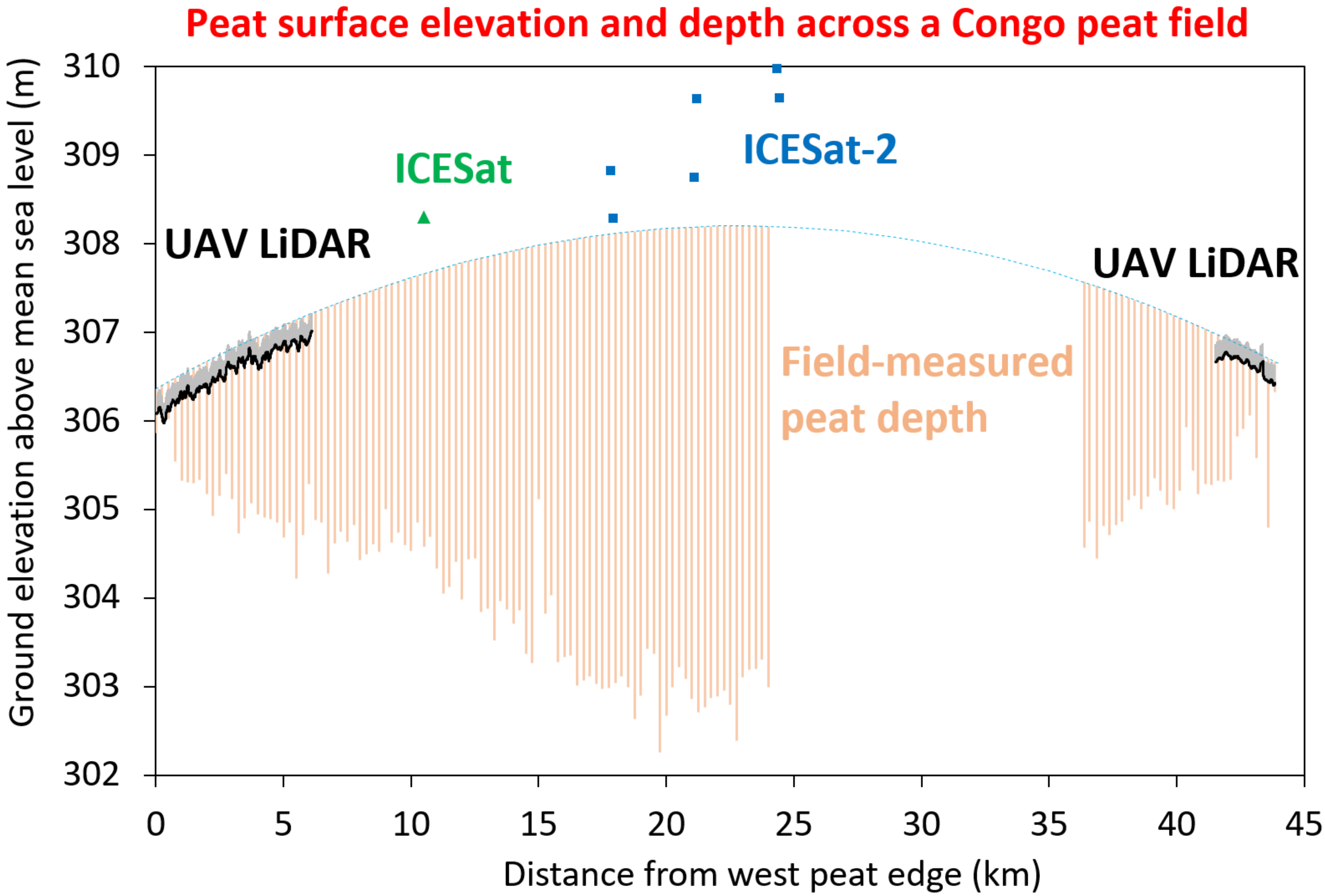


ICESat-2 ATLAS

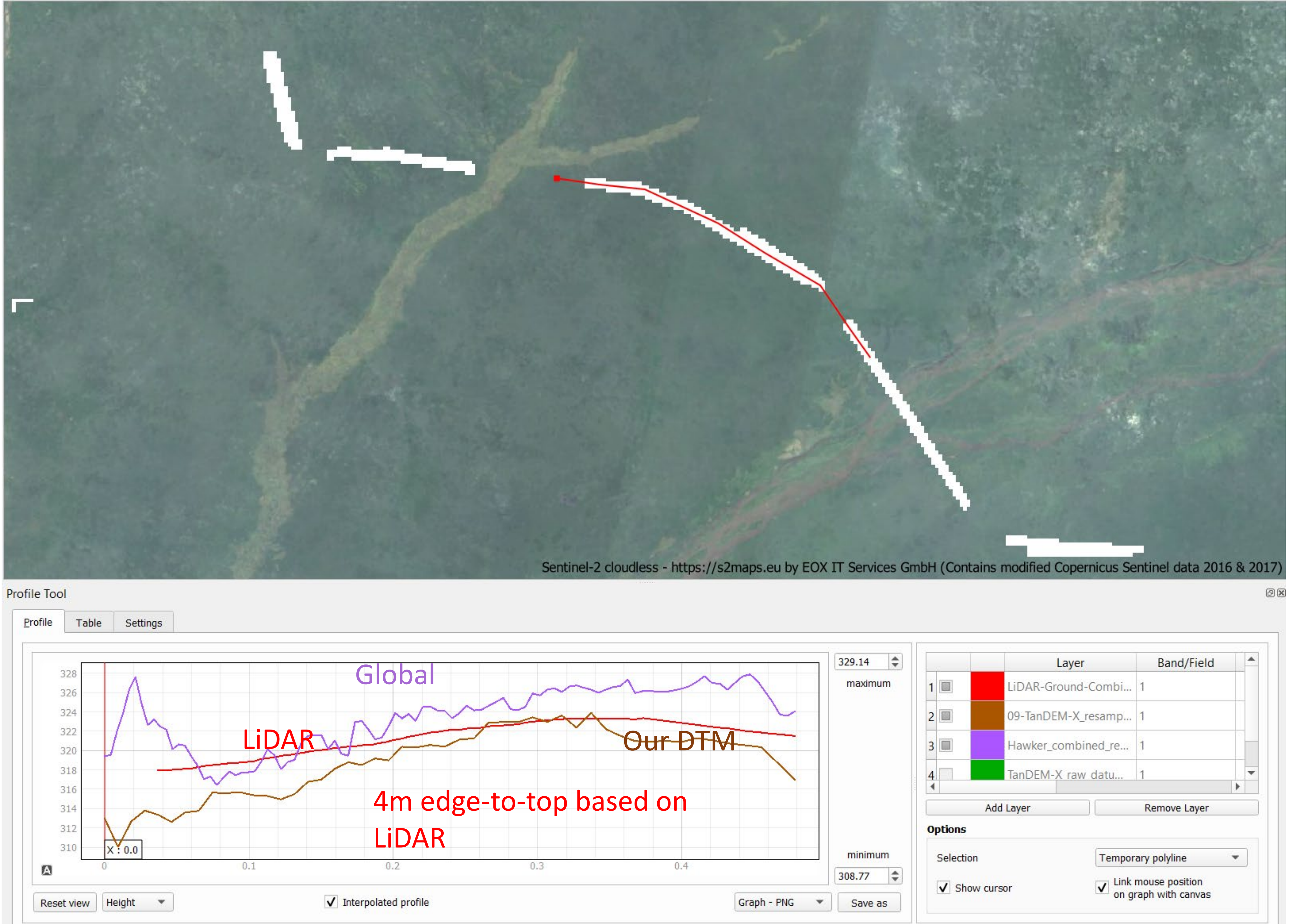








This suggests peat formation in a shallow basin.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Profile Tool
Profile
Table
Settings
Global
LiDAR
Our DTM
4m edge-to-top based on LiDAR
328
326
324
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320
318
316
314
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X : 0.0
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minimum
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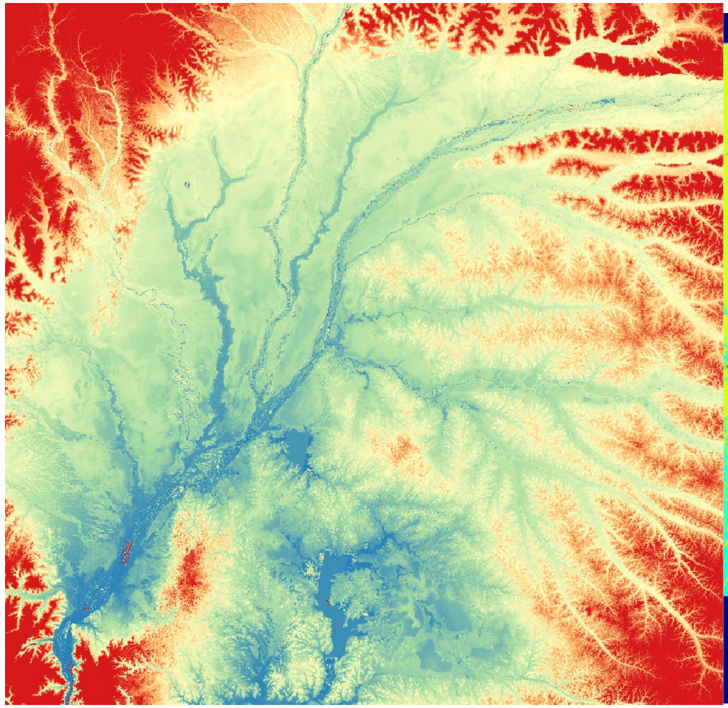
Layer
Band/Field
LiDAR-Ground-Combi... 1
09-TanDEM-X_resamp... 1
Hawker_combined_re... 1
TanDEM-X raw datu... 1
Add Layer
Remove Layer
Options
Selection
Temporary polyline
Show cursor
Link mouse position on graph with canvas
Reset view
Height
Interpolated profile
Graph - PNG
Save as

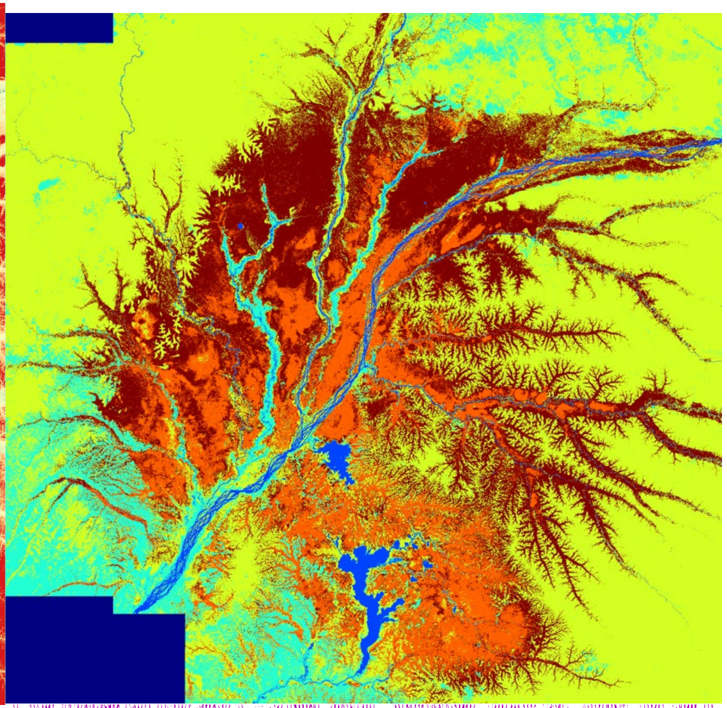
Conclusion

- There's some evidence for peat domes of 3-4m height over 40km in the Congo Basin.
- Peat domes in South-East Asia have peaks of 20m for a 40km wide peat field, so we have some confidence that we're not seeing domes on that scale,
- Possibly because rainfall in the basin is somewhat lower, around 1700 mm yr^{-1} in the central Congo Basin cf. 3000 mm yr^{-1} in southeast Asian and Peruvian sites.

Combine these data to make a digital terrain model?

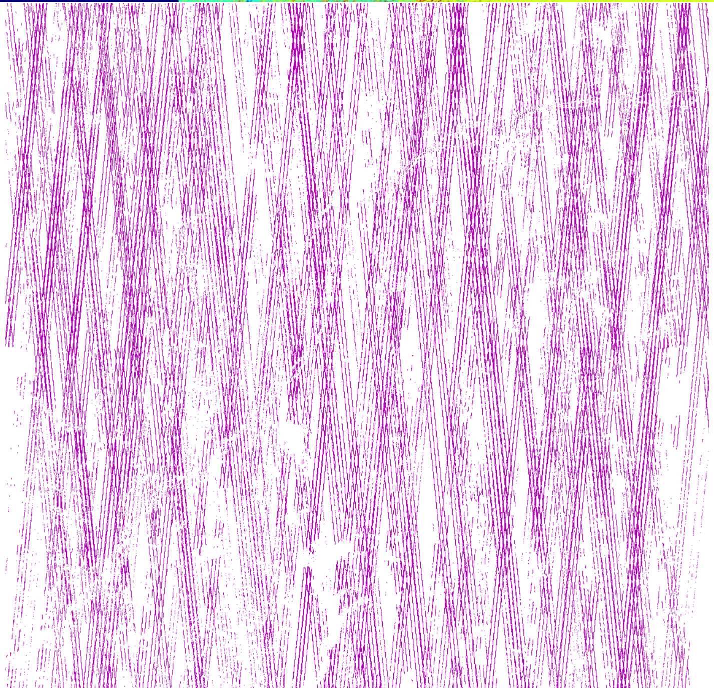


TanDEM-X DSM – canopy top elevation



Classification into vegetation types

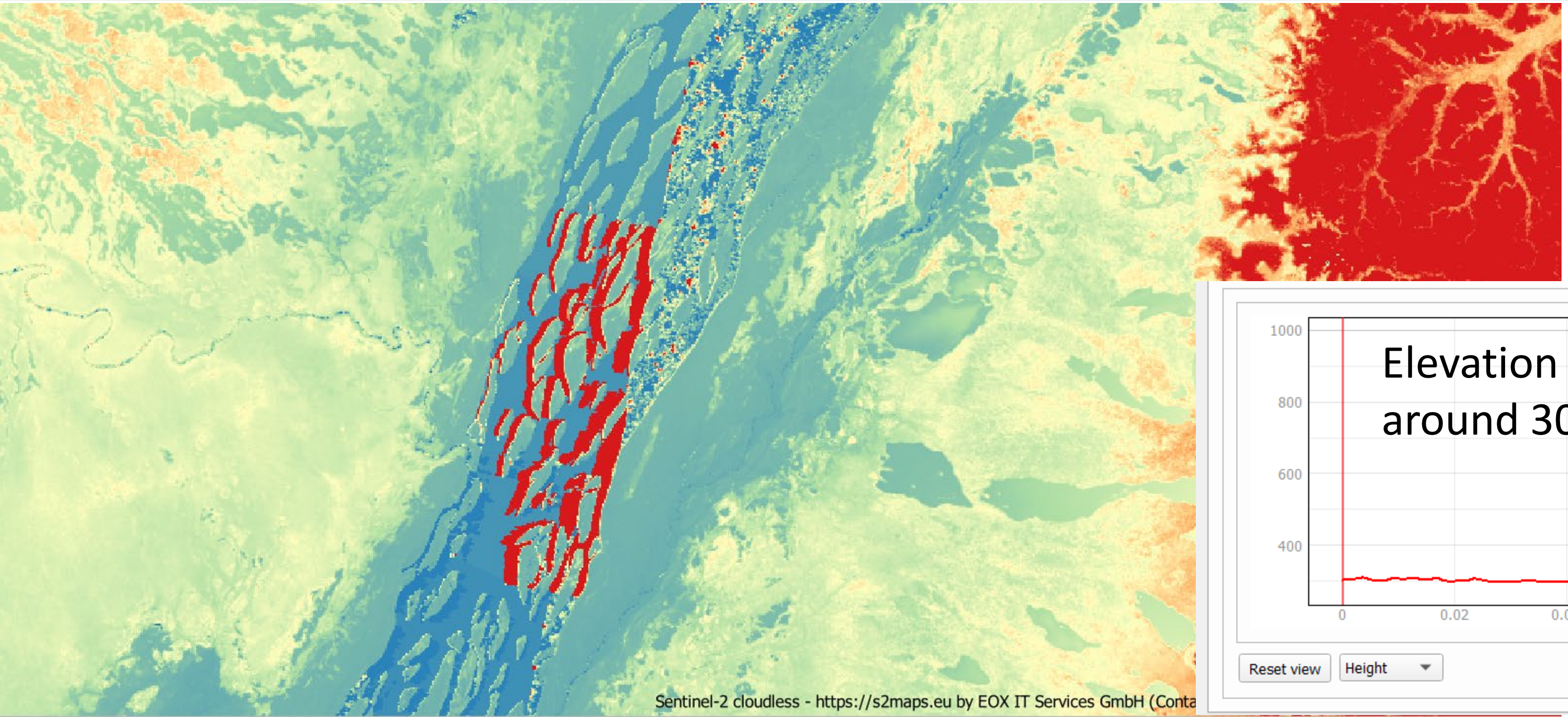
Airborne LiDAR

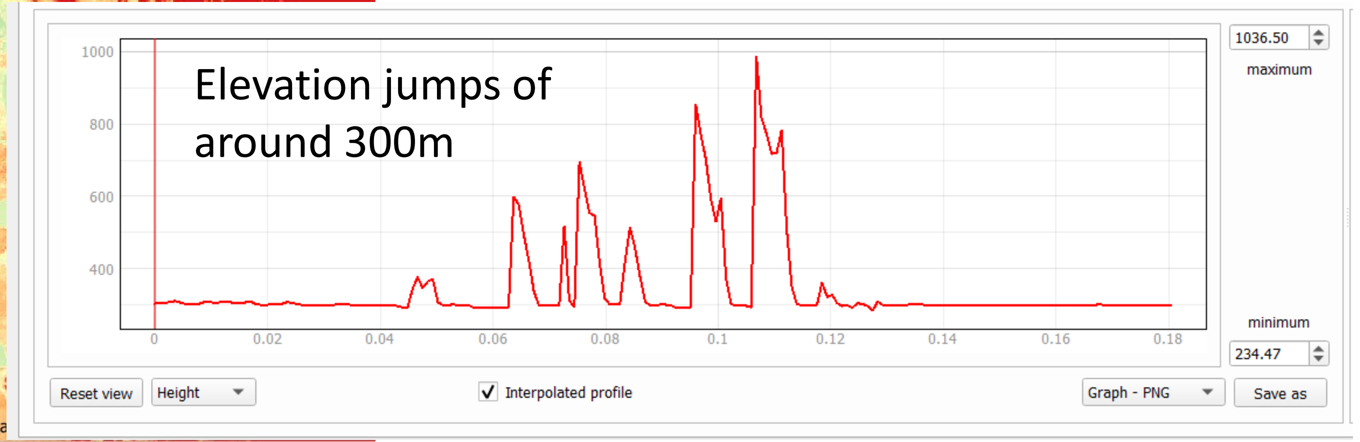


ICESat-2 canopy height estimate

Quality Control

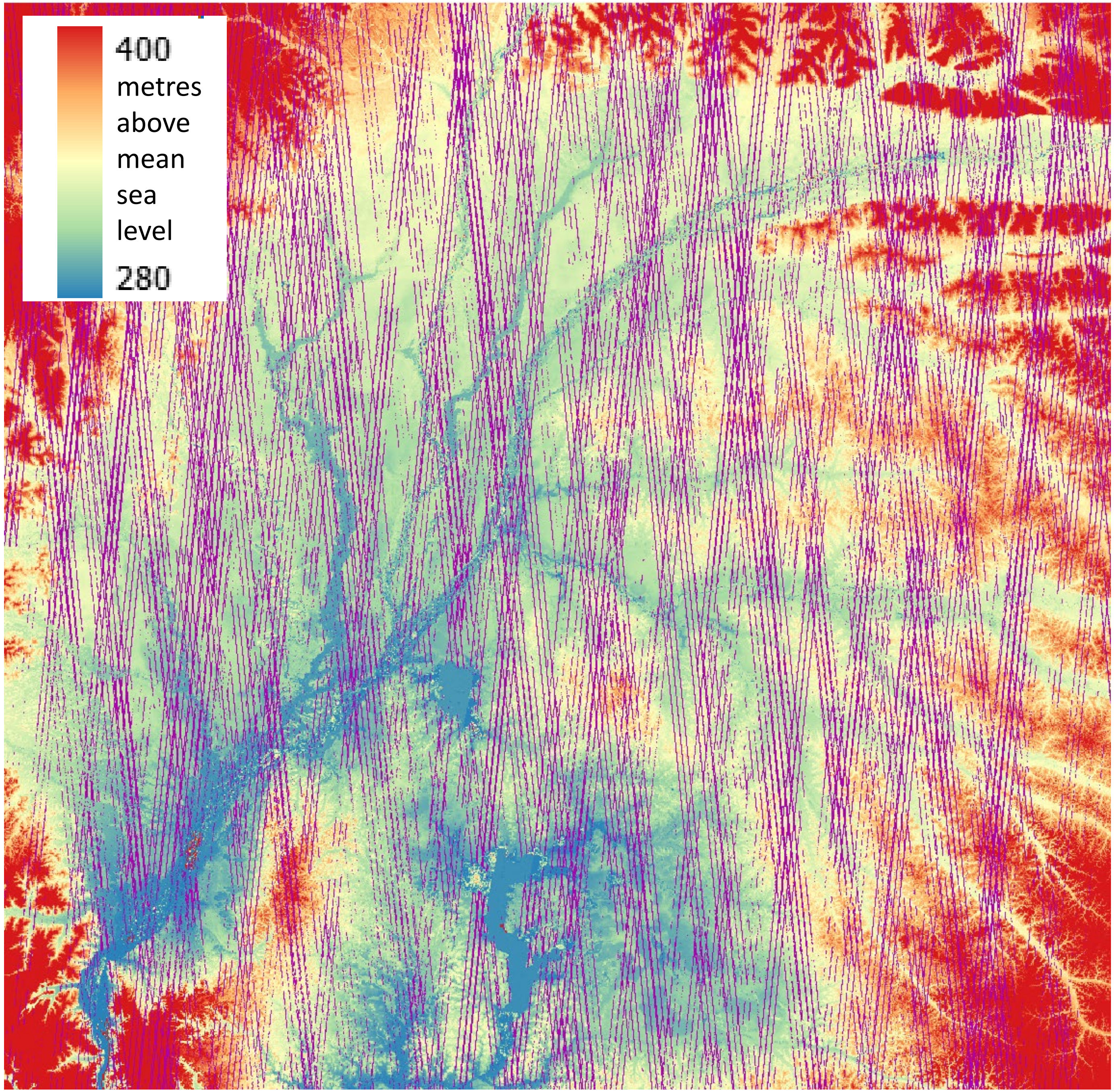
Elevations near water have to be removed.

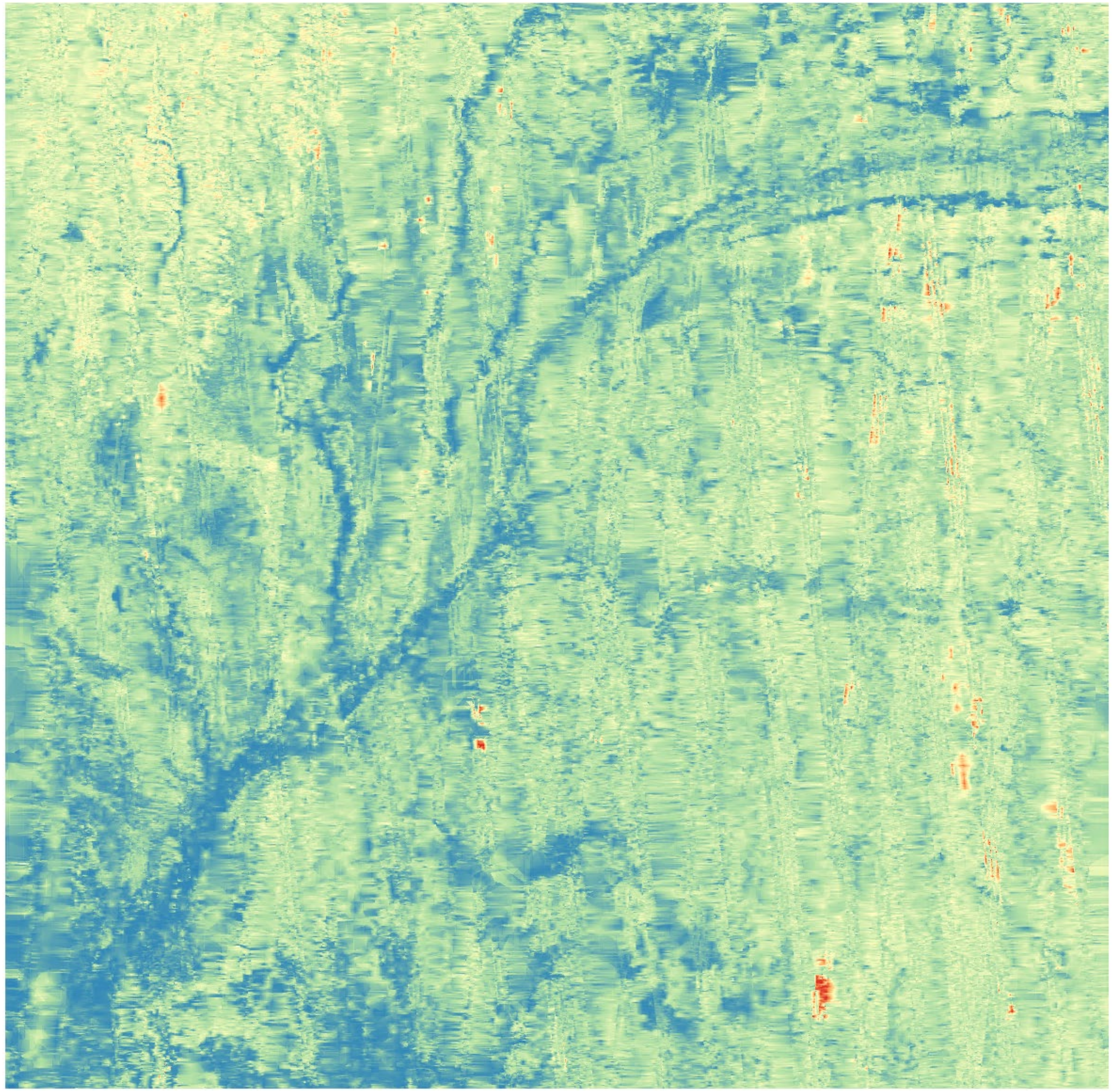


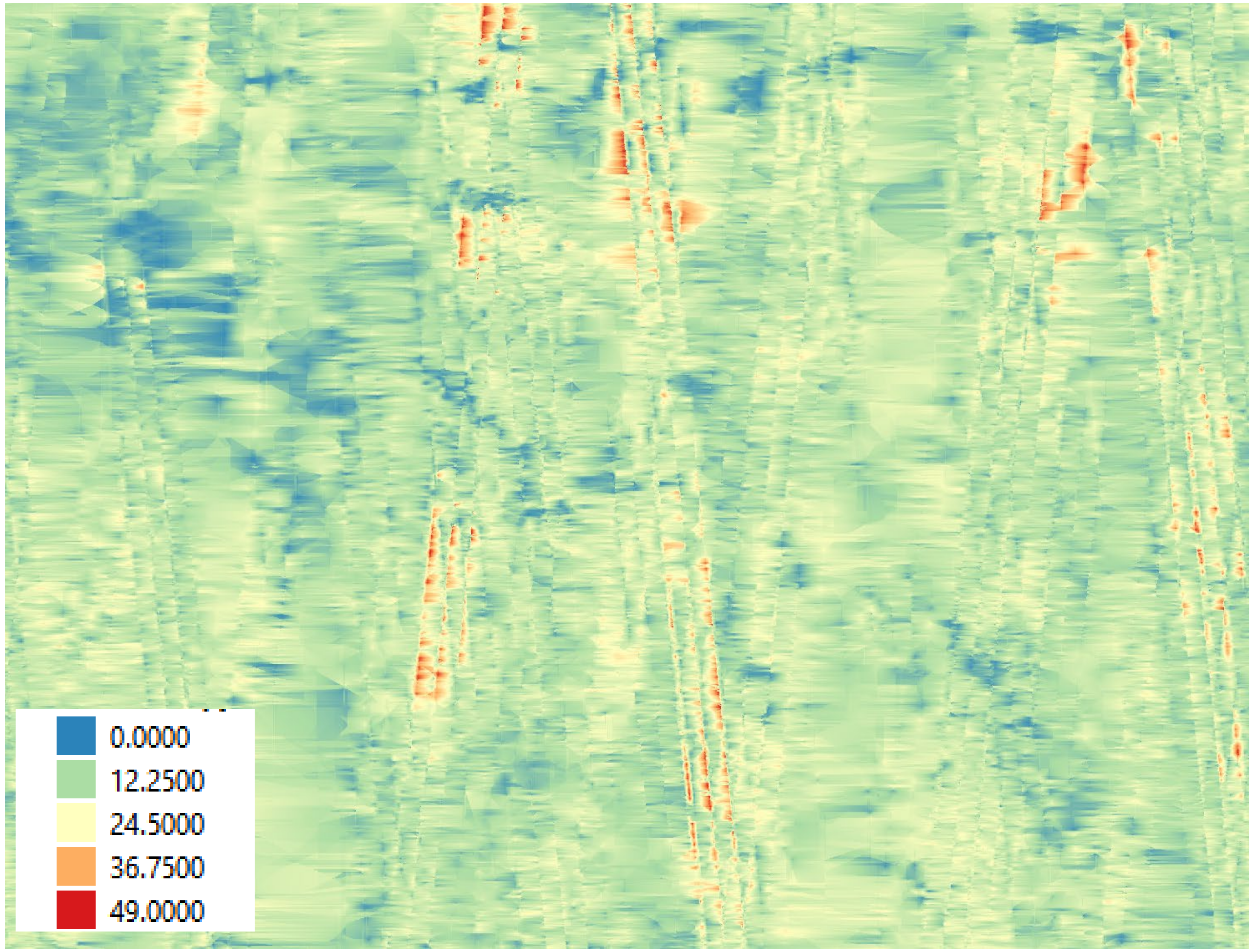


10^6 estimates of canopy height

Can’t use ground estimates as the product is not designed for forest canopies this dense.



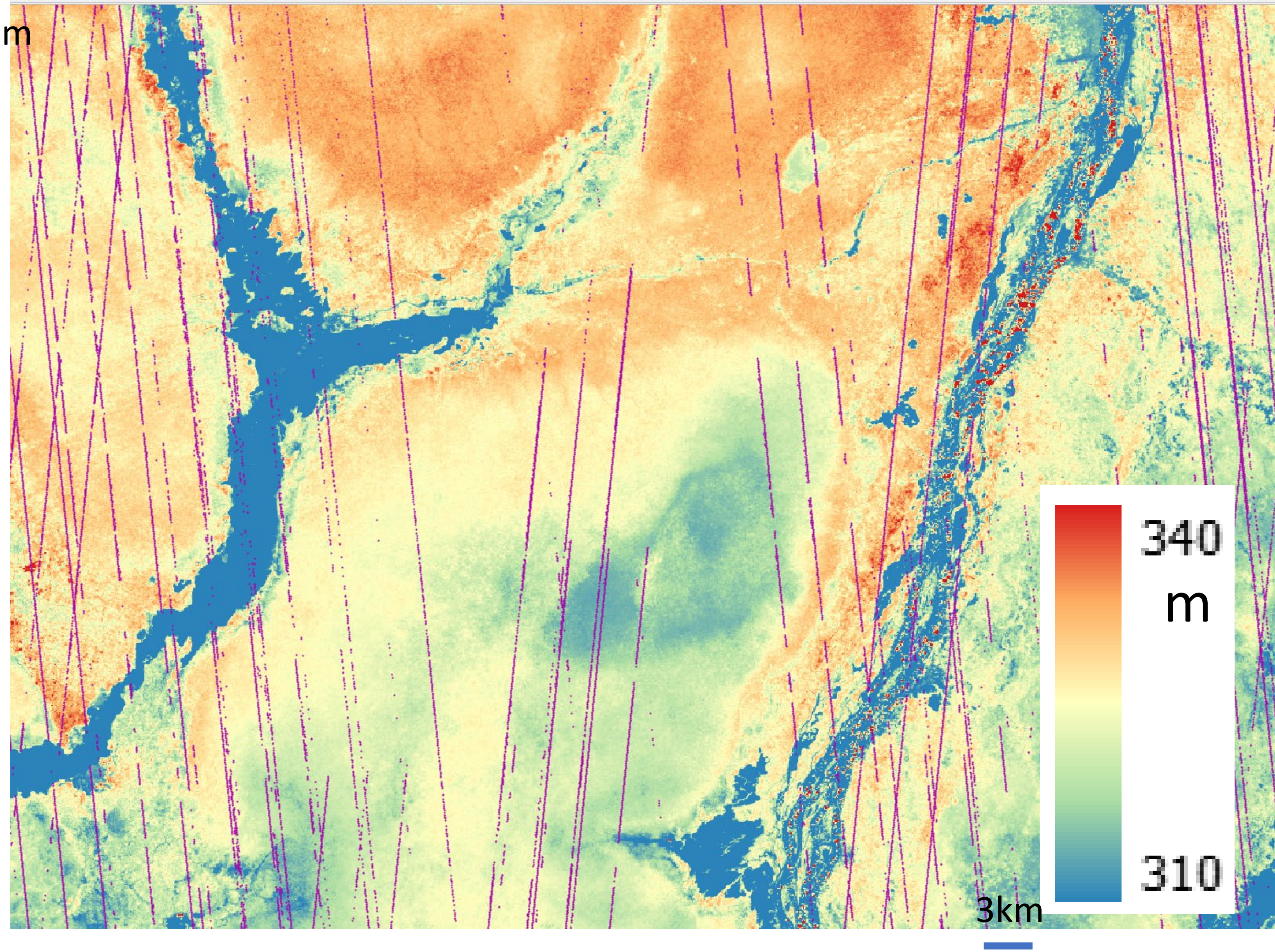


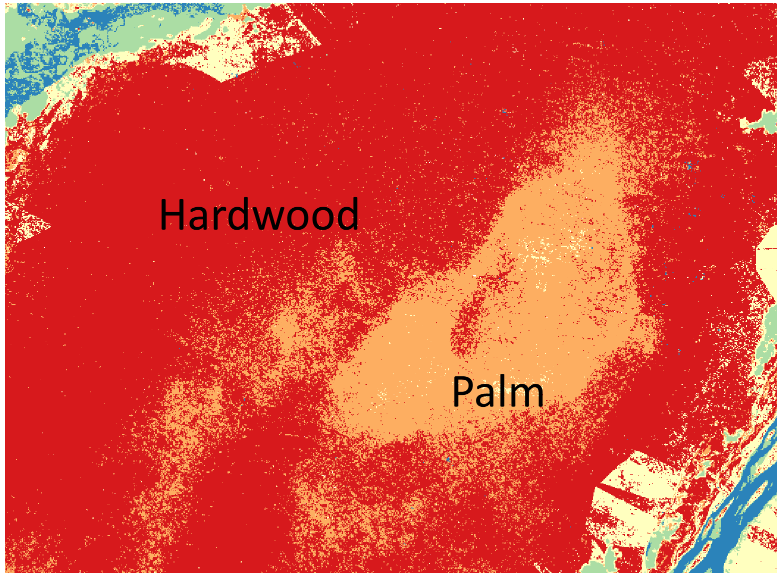


Render of Canopy height (m)

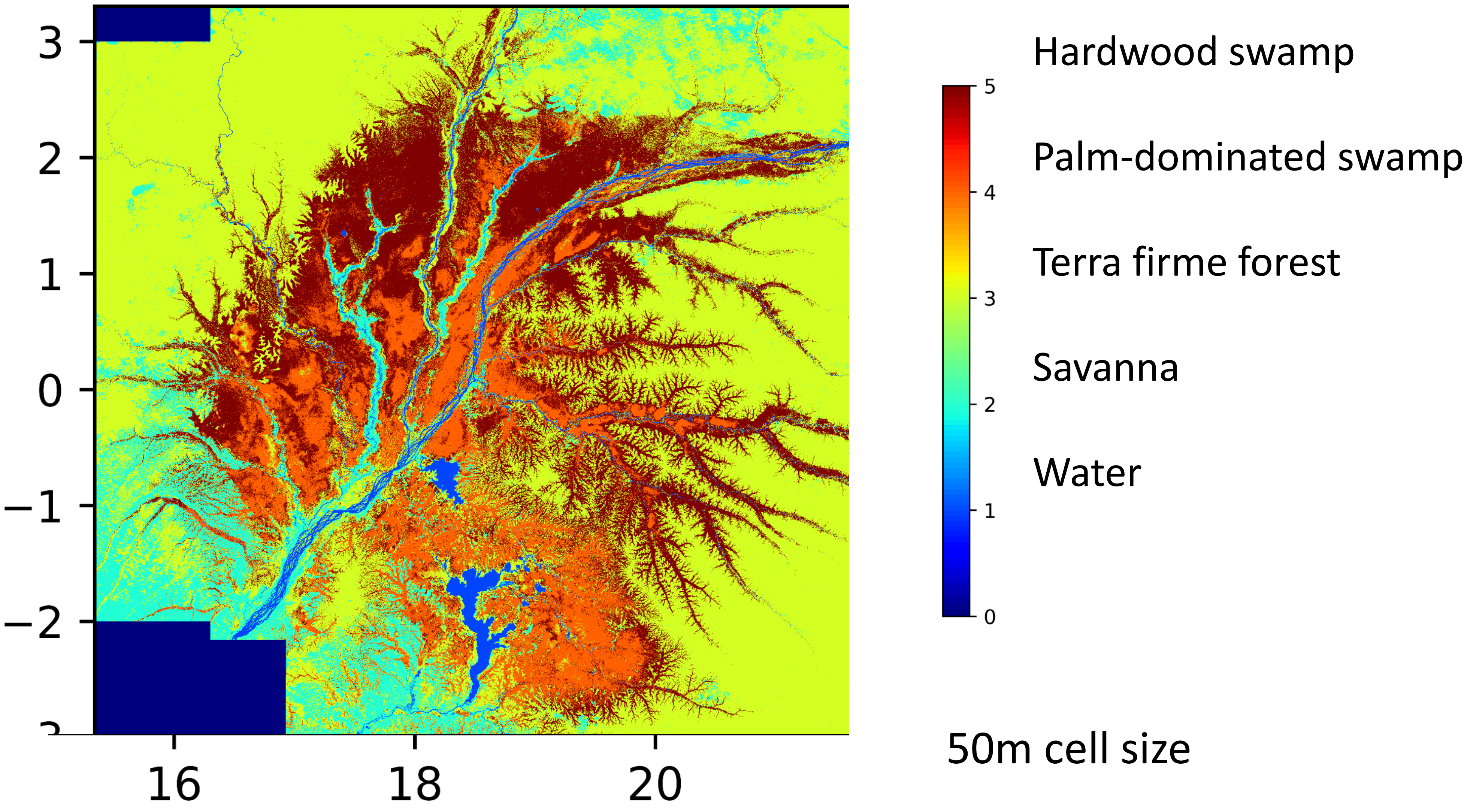
This means that areas of different vegetation will not be resolved in the ICESat-2 canopy data.

Elevation from TanDEM-X





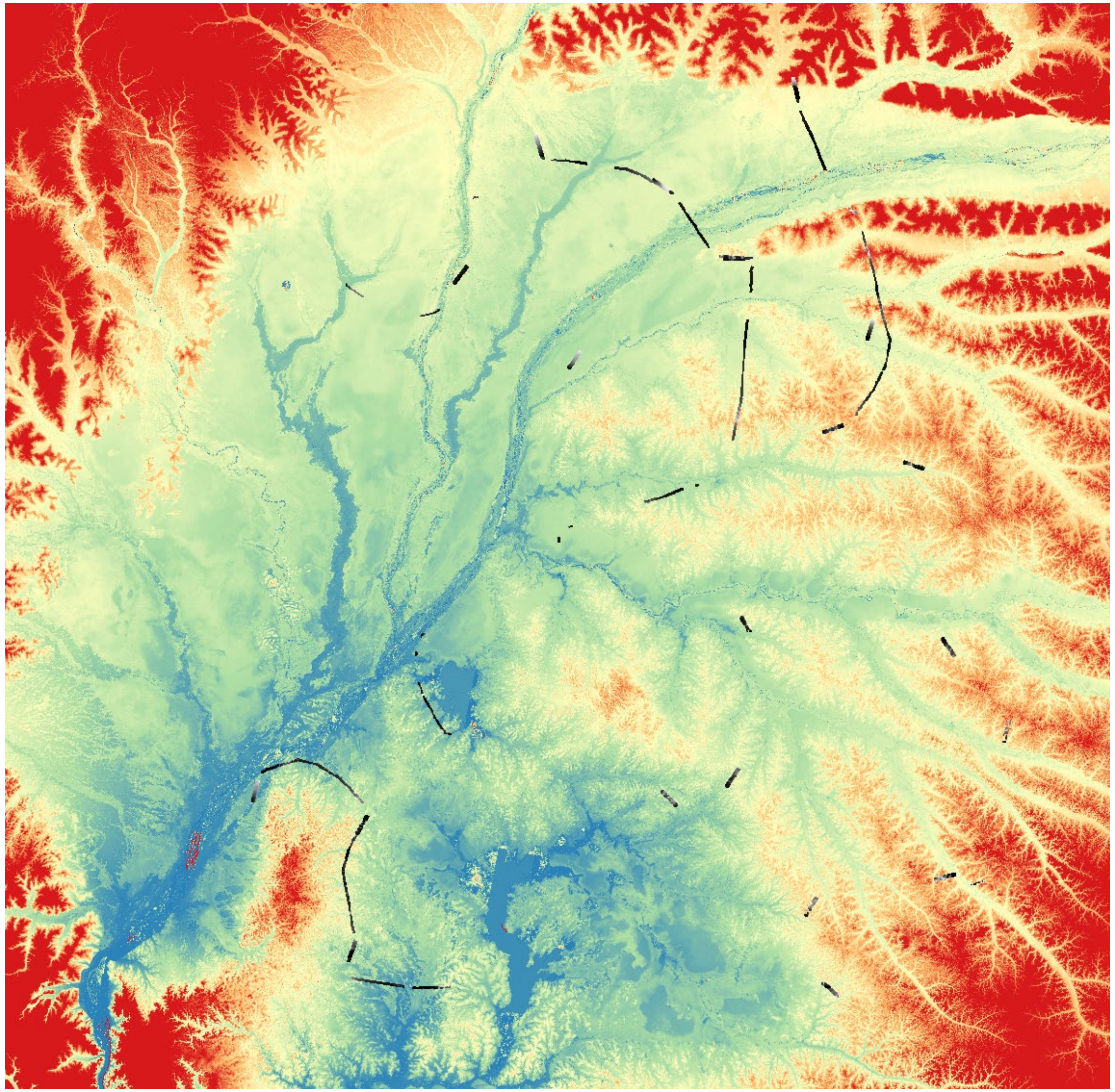
Classification



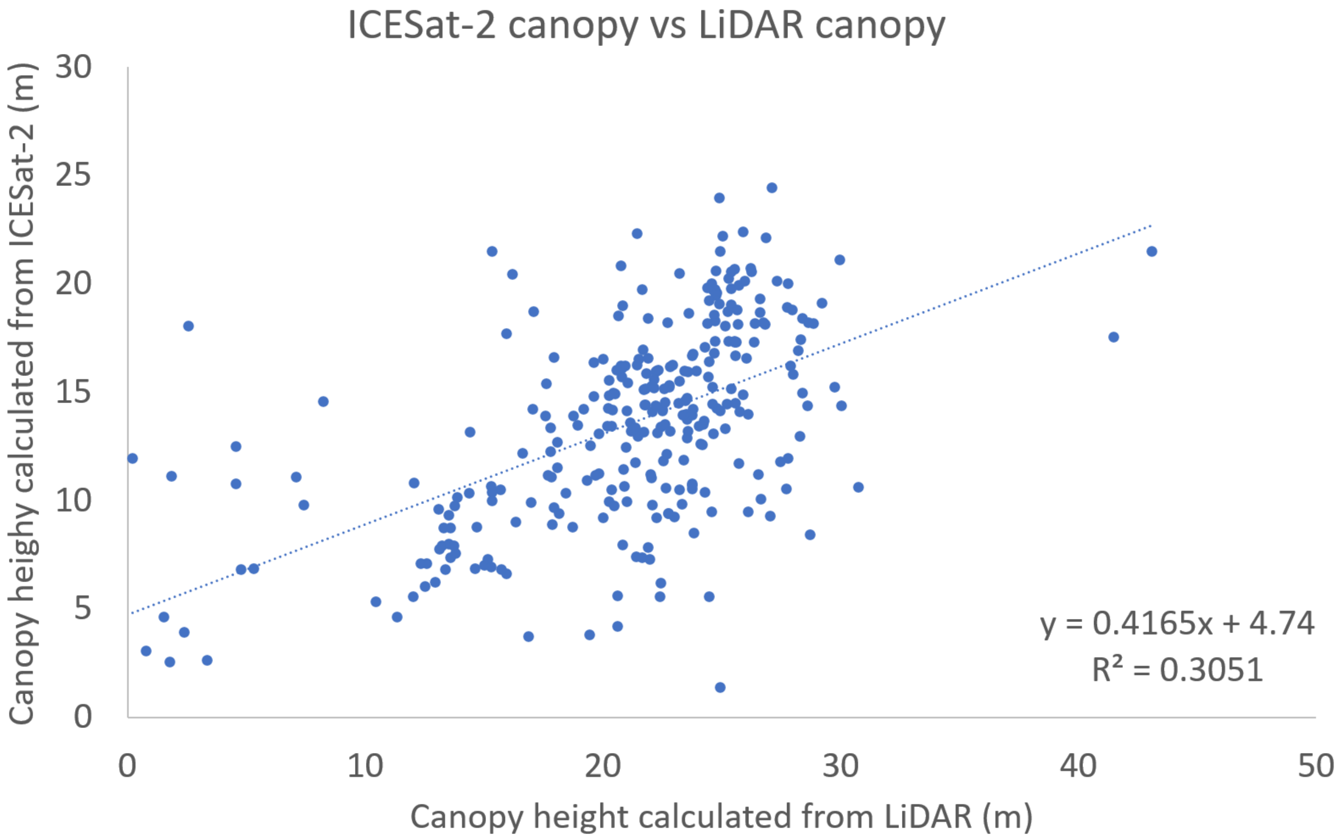
50m cell size

We have 2 UAV swathes and 33 DRC LiDAR swathes provided by the World Wide Fund for Nature acquired in 2014 via light aircraft for a carbon audit of the Democratic Republic of Congo.

About 8 x 10^9 points in total



How accurate is ICESat-2 canopy height?



LiDAR

Ground estimated from LiDAR 500m cells.
LiDAR canopy estimated from 95th percentile elevation of points above ground.
Cells with topography change >1m per 500m removed.
Cells where main class occupies <50% of cell removed.

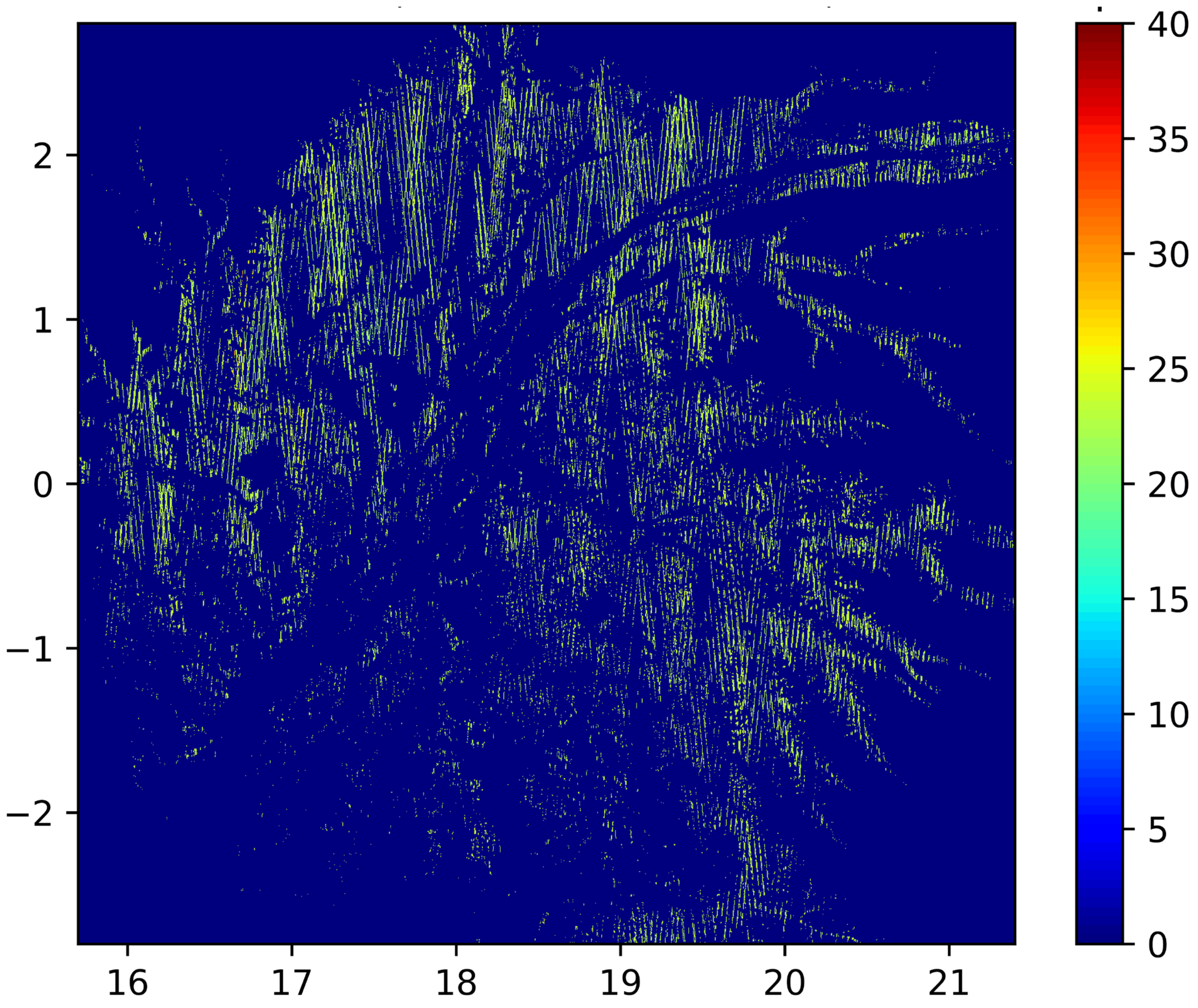
ICESat-2

Strong and weak canopy returns used.

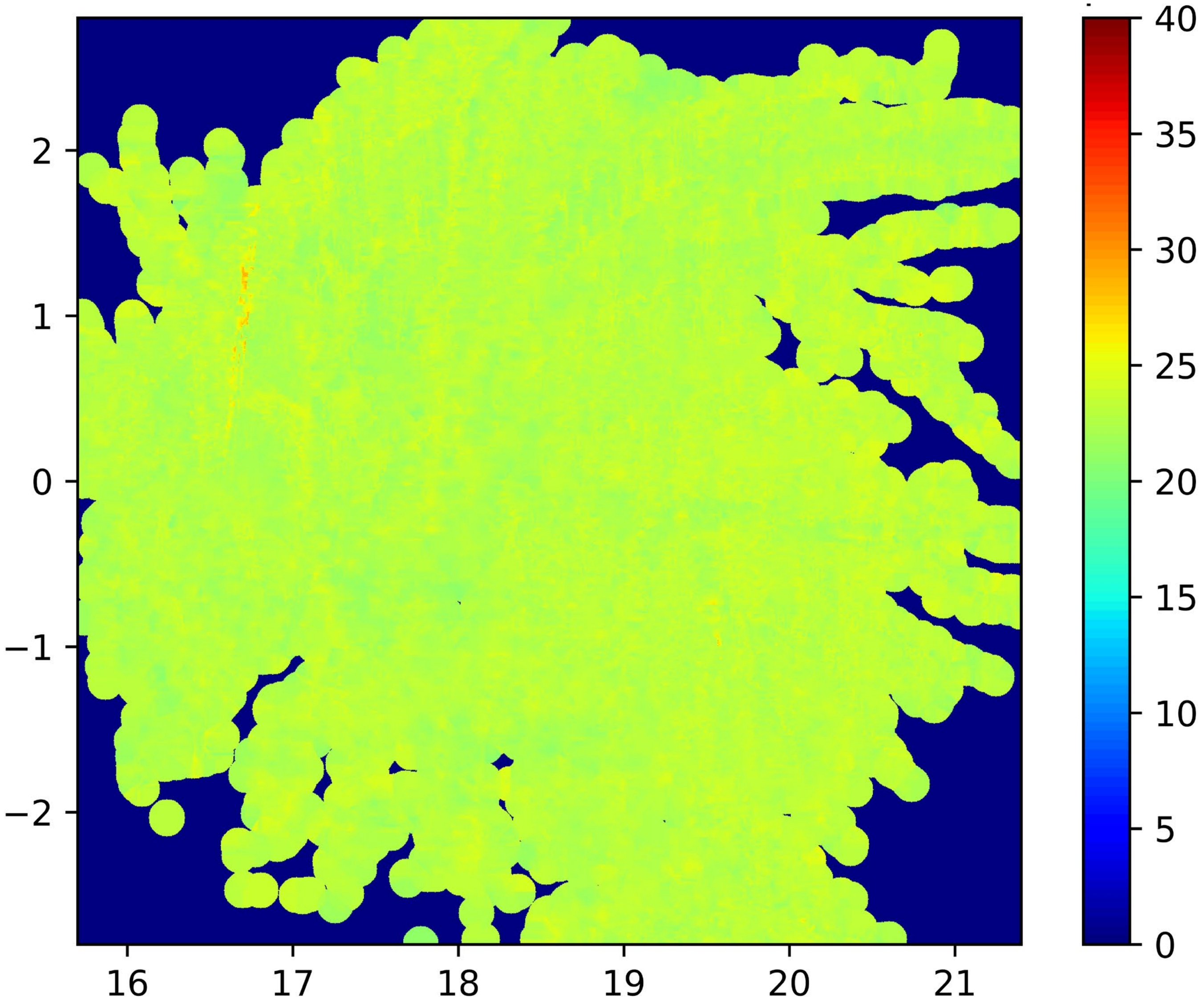
Regression carried out per class.

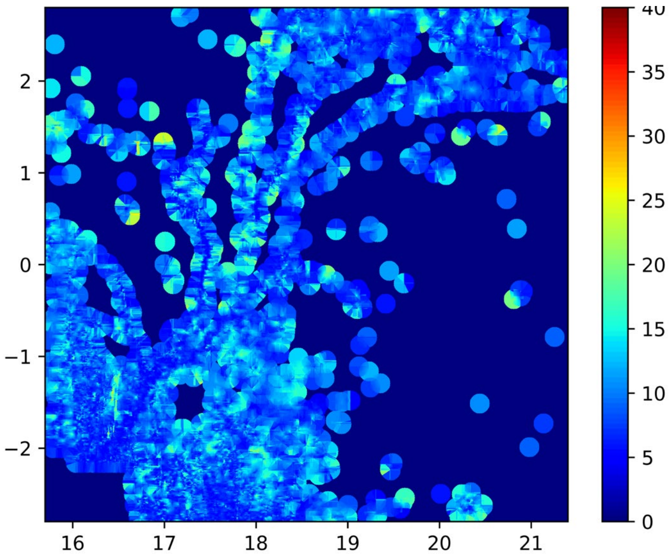
A linear fit between LiDAR-derived and ICESat-2-derived canopy height calibrates ICESat-2 canopy heights, and yields a RMSE of about 4m.

ICESat-2 canopy estimates classified as hardwood swamp, calibrated by airborne LiDAR.

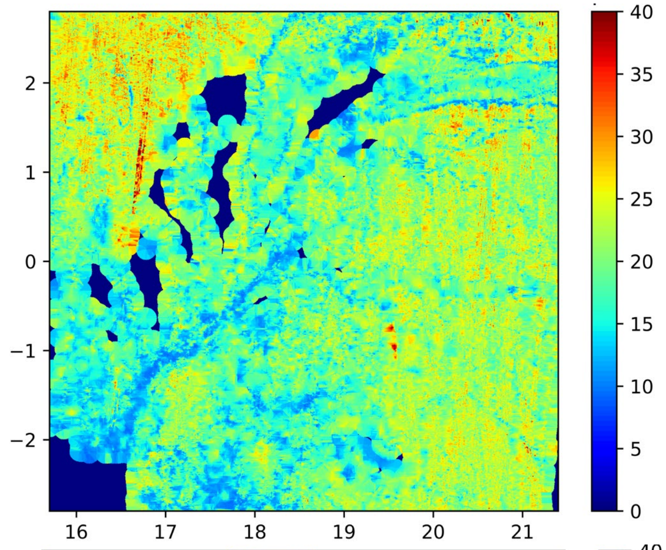


Interpolated to enable a best-guess estimation of canopy estimates where no ICESat-2 data is available.

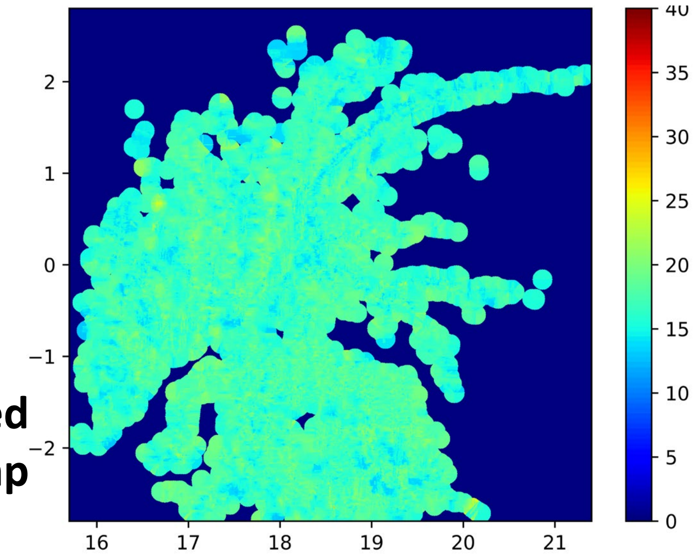




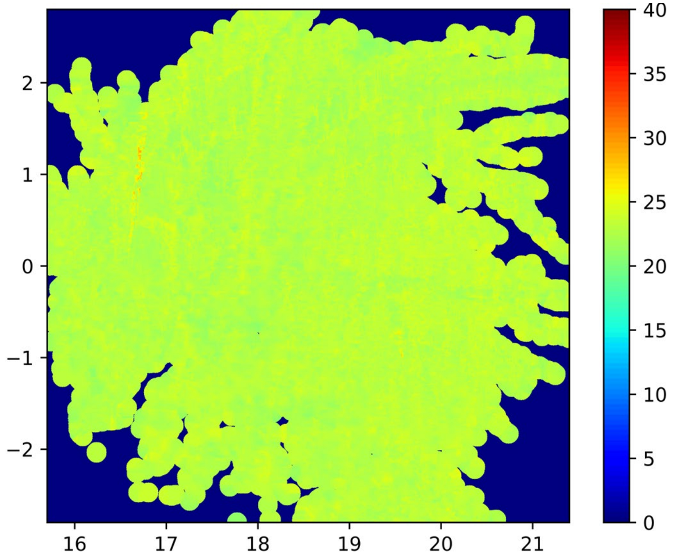
Savanna



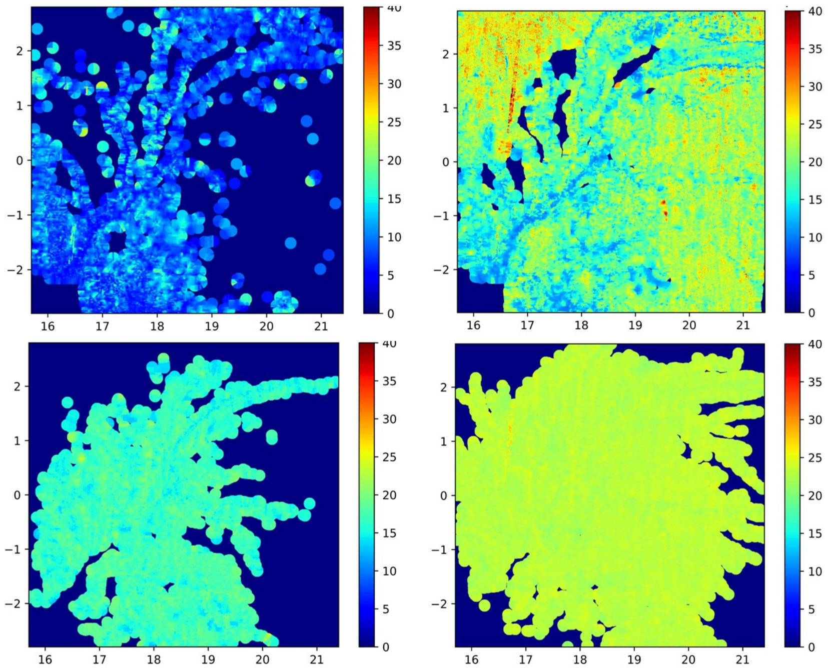
Terra firme forest



Palm-dominated swamp

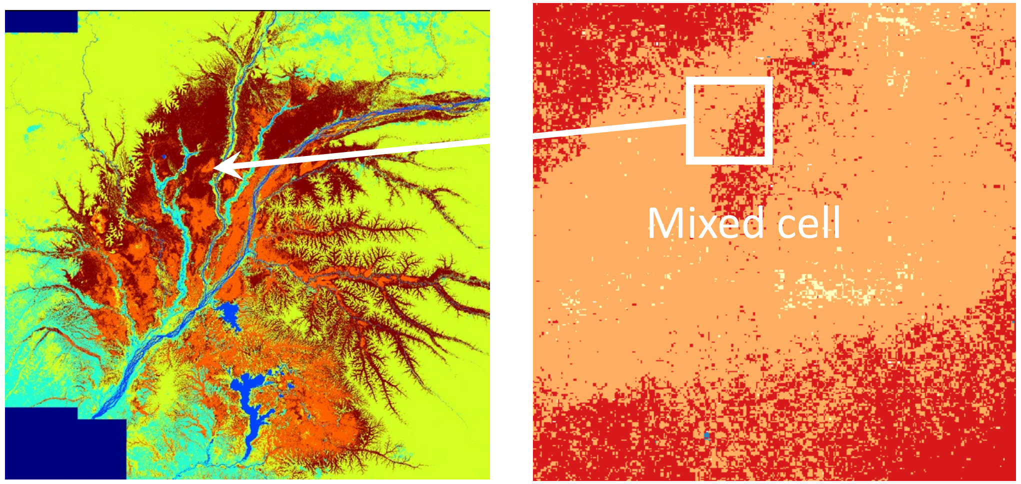


Hardwood swamp



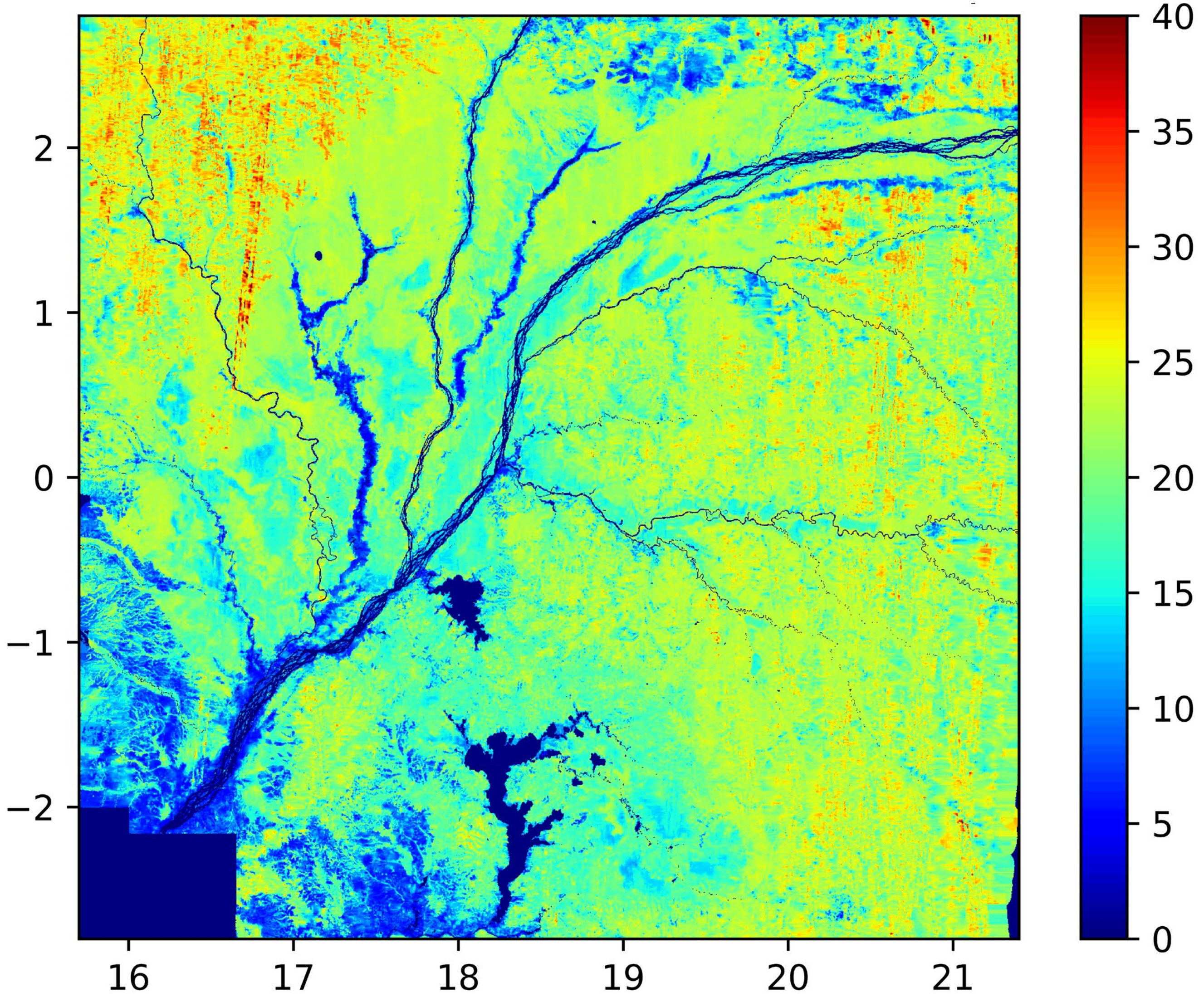
Canopy estimates for each vegetation type

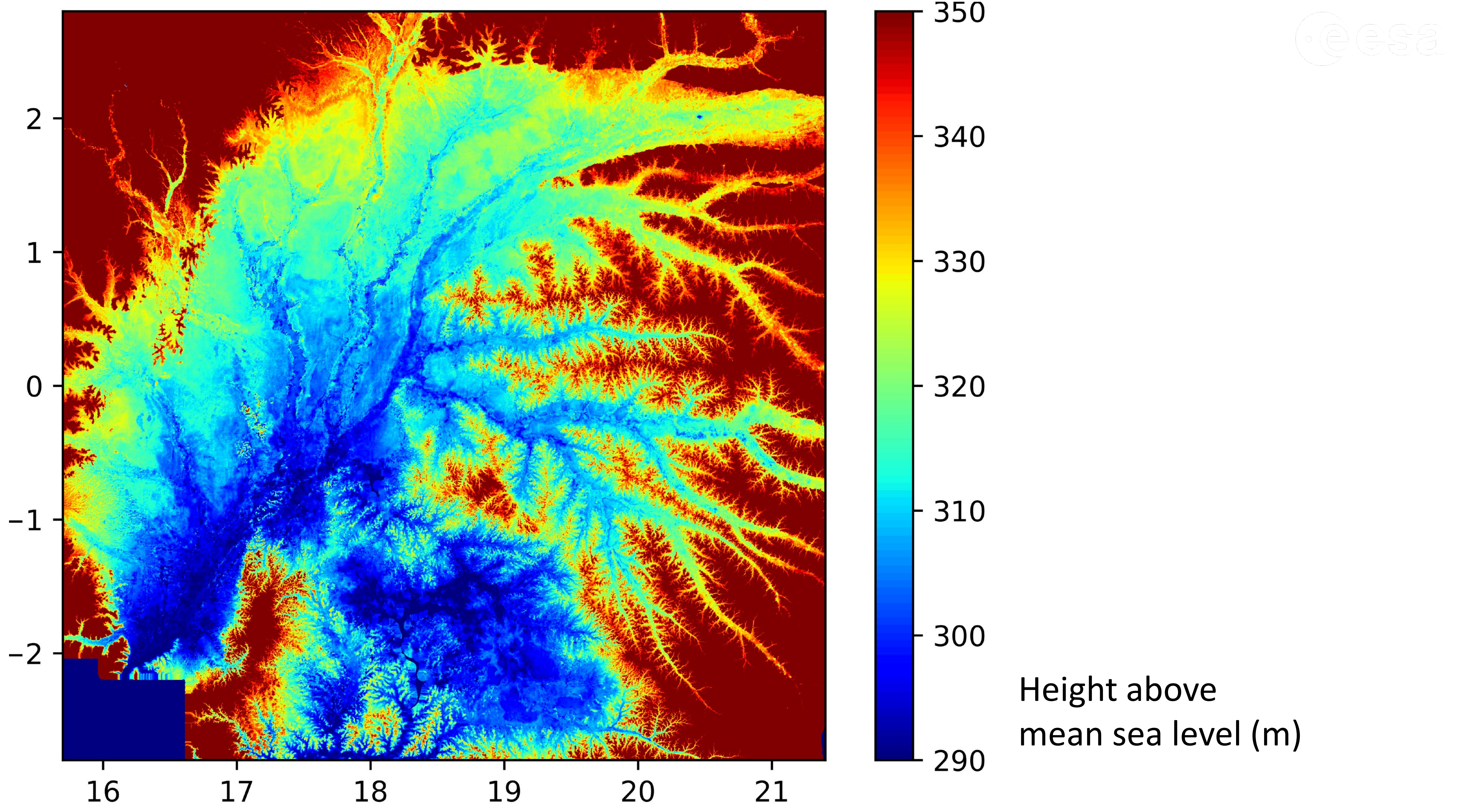
+



Classification

=





2
1
0
−1
−2
16
17
18
19
20
21
350
340
330
320
310
300
290
Height above mean sea level (m)
esa

A recently-published global DTM estimates ground elevation globally at 30m using the TanDEM-X derived GLO-030 DSM, LiDAR and ICESat-2 via machine learning.

Is it useful in our area?

IOP Publishing Environ. Res. Lett. 17 (2022) 024016 https://doi.org/10.1088/1748-9326/ac4d4f

ENVIRONMENTAL RESEARCH LETTERS

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LETTER

A 30 m global map of elevation with forests and buildings removed

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Keywords: digital elevation model, bare-earth, terrain, remote sensing, machine learning

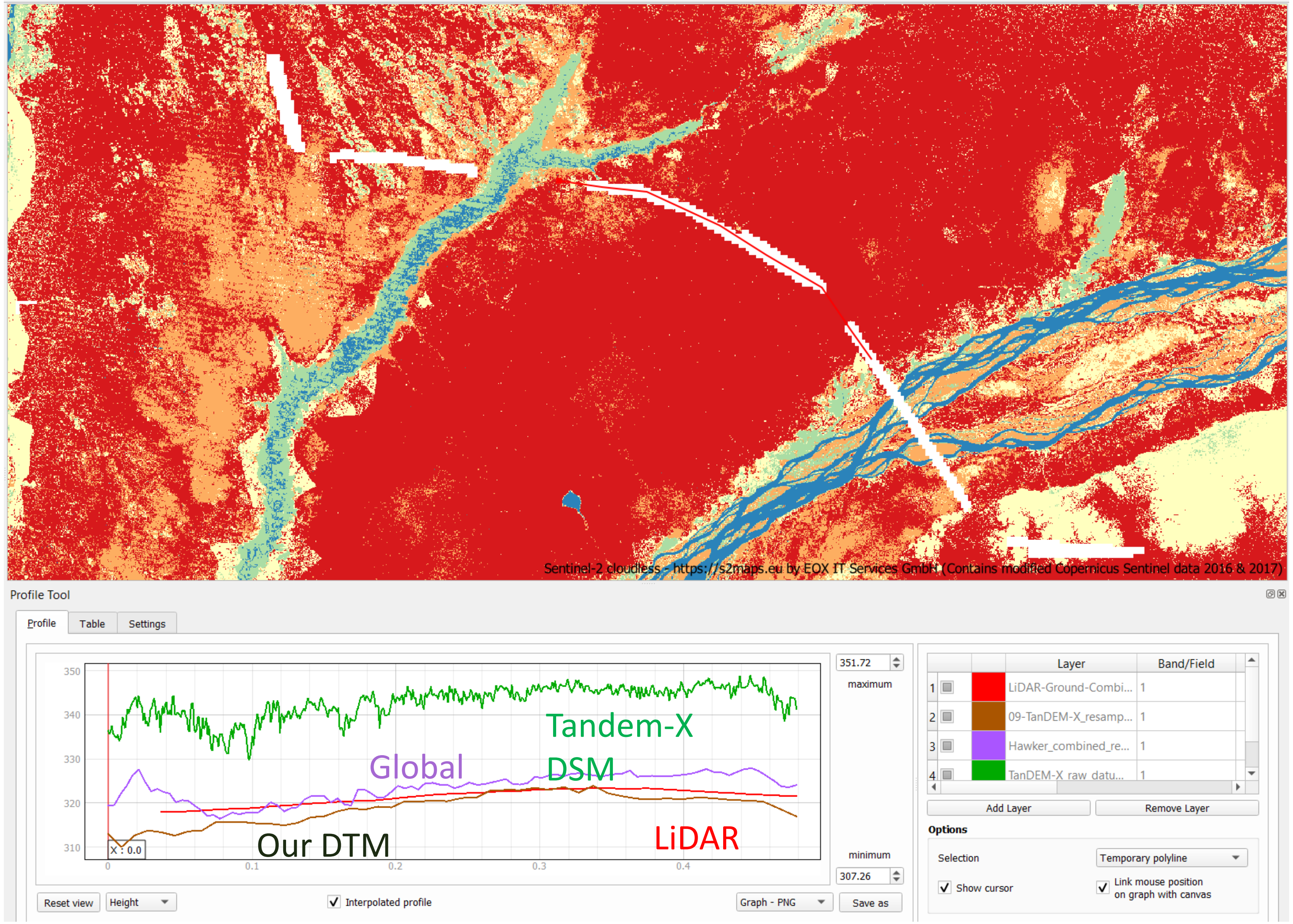
Supplementary material for this article is available online

Abstract

Elevation data are fundamental to many applications, especially in geosciences. The latest global elevation data contains forest and building artifacts that limit its usefulness for applications that require precise terrain heights, in particular flood simulation. Here, we use machine learning to remove buildings and forests from the Copernicus Digital Elevation Model to produce, for the first time, a global map of elevation with buildings and forests removed at 1 arc second (∼30 m) grid spacing. We train our correction algorithm on a unique set of reference elevation data from 12 countries, covering a wide range of climate zones and urban extents. Hence, this approach has much wider applicability compared to previous DEMs trained on data from a single country. Our method reduces mean absolute vertical error in built-up areas from 1.61 to 1.12 m, and in forests from 5.15 to 2.88 m. The new elevation map is more accurate than existing global elevation maps and will strengthen applications and models where high quality global terrain information is required.

- The standard deviation of difference between the LiDAR estimates of ground level and the derived DTM is 4.8m over 3934 LiDAR 500m × 500m squares.

- For comparison, the Global machine-learning based DTM has SD of 4.6m, reducing to 4.3m if the DTM is resampled to 450m.


Sentinel-2 cloudless - https://s2maps.eu by EOX IT Services GmbH (Contains modified Copernicus Sentinel data 2016 & 2017)
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Profile
Table
Settings
350
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0
0.1
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0.3
0.4
X : 0.0
Tandem-X
DSM
Global
Our DTM
LiDAR
351.72
maximum
minimum
307.26
Layer
Band/Field
1 LiDAR-Ground-Combi... 1
2 09-TanDEM-X_resamp... 1
3 Hawker_combined_re... 1
4 TanDEM-X_raw_datu... 1
Add Layer
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Options
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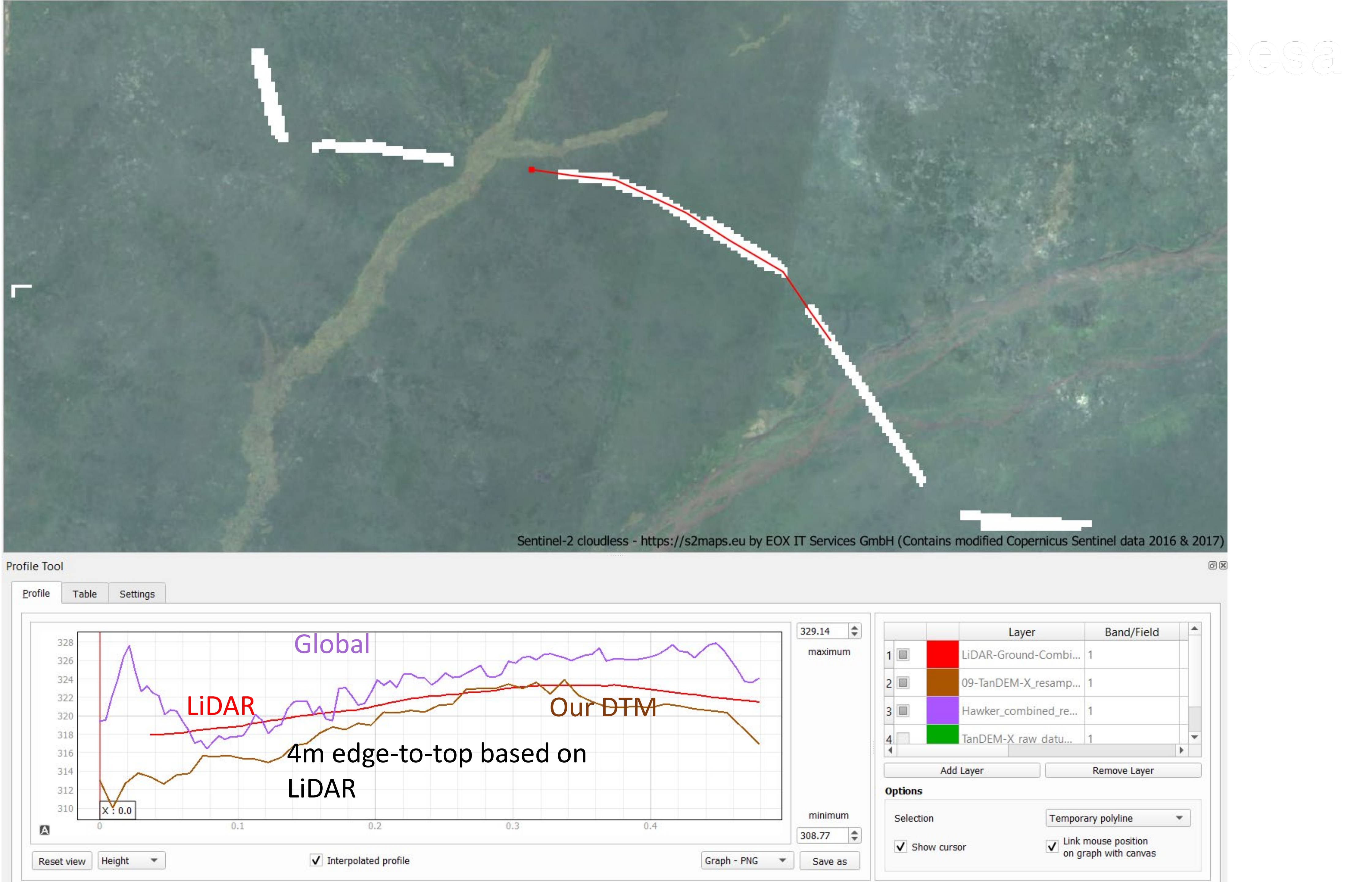
Temporary polyline
Show cursor
Link mouse position on graph with canvas
Reset view
Height
Interpolated profile
Graph - PNG
Save as



esa
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4m edge-to-top based on LiDAR
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X : 0.0
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Layer
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LiDAR-Ground-Combi... 1
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Hawker_combined_re... 1
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Add Layer
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Show cursor
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Height
Interpolated profile
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The Global DTM does have discontinuities around water, which seems to be based on not properly filtering out TanDEM-X ground estimates near water.

Conclusions

- The Digital Terrain Model is accurate to about 5m in elevation, and identifies domes above this, some of 10m.

- Peat domes in South-East Asia have peaks of 20m for a 40km wide peat field, so we have some confidence that we're not seeing domes on that scale, possibly as rainfall in the basin is somewhat lower, around 1700 mm yr^{-1} in the central Congo Basin cf. 3000 mm yr^{-1} in southeast Asian and Peruvian sites.

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