PhD Dissertation Defense: Space-based LiDAR for Estimating Vegetation Structure

PhD Candidate: Xiaoxuan (Shawn) Li

PhD Committee Chair: Dr. Konrad Wessels

PhD Committee members:

Dr. John Armston (UMD)

Dr. Paul Houser (GMU GGS)

Dr. John Qu (GMU GGS)

Dr. David Luther (GMU Biology)

November 20th, 2023

Xiaoxuan (Shawn) Li

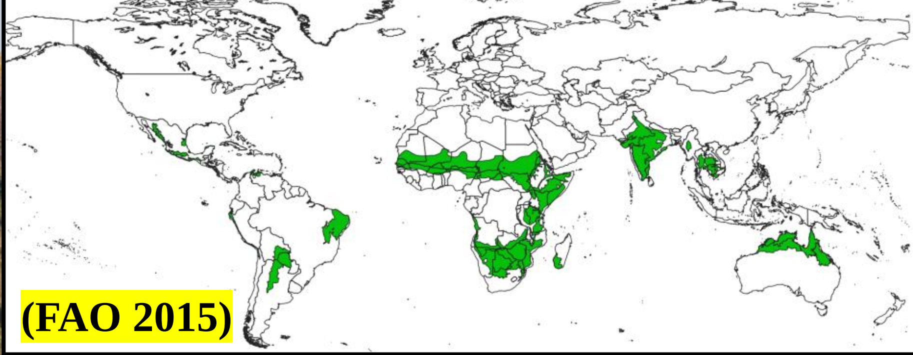
- Academic Experience:
  - B.S. Surveying & Mapping Engineering, Liaoning Technical University, 2012-2016
  - M.S. Geospatial Information Sciences, University of Texas at Dallas, 2016-2018
  - Ph.D. Geography, University of Florida, 2018-2019
  - Ph.D. Earth Systems & Geoinformation Sciences, George Mason University, 2019-2023

- PhD candidate at George Mason University, **Presidential Scholar** (2019-2023)

- Advisor: **Konrad Wessels** (George Mason University)

- Participant in Savanna-Bio project under NASA’s Carbon Monitoring System (PI: **John Armston, UMD**)

Introduction: Savannas



Tropical Dry Forest and Shrubland (Savannas)

- Savannas: “communities with a continuous grass layer and a discontinuous tree layer”
- 20% of the Earth’s land area
- 3rd highest global carbon stock (after rainforest & moist forests)
- 24% of Global GPP – major Carbon sink
- Contain large human population, and majority of livestock and wildlife

Introduction

Savannas challenge

- Rapid structure change due to climate, fire, fuelwood removal, shrub encroachment – impact on carbon stock of various drivers
- AGBD estimation are currently inaccurate – RMSE of 8-30 Mg/ha (Bouvet et al., 2018)
- Complex structures – spatially and vertically heterogenous

Savannas objectives

- To improve accuracy of remotely sensed biomass estimates and their change in global savannas
- To improve the understanding of the drivers of vegetation changes for Monitoring, Reporting and Verification (**MRV**) and climate change mitigation activities under Reducing Emissions from Deforestation and Degradation (**REDD**) +.

Overall objectives

*The overall aim of this research is to improve the estimation of vegetation structure and above-ground biomass (**AGBD**) in savannas with space-based LiDAR (**GEDI and ICESat-2**) and L-band Synthetic aperture radar (**SAR**), to ultimately track changes through time.*

The specific objectives of this PhD study are to:

(i) Assess the accuracy of the on-orbit GEDI relative height metric (**RH98**) by comparison to the reference estimates simulated from ALS and determine potential factors on this error.

(ii) Validate GEDI L4A AGBD and develop locally updated GEDI footprint-level AGBD models using field measurements and ALS datasets in South African savannas.

(iii) Evaluate the accuracy of canopy height (and terrain) estimates derived from on-orbit GEDI and ICESat-2 data using ALS derived canopy height and ground metrics.

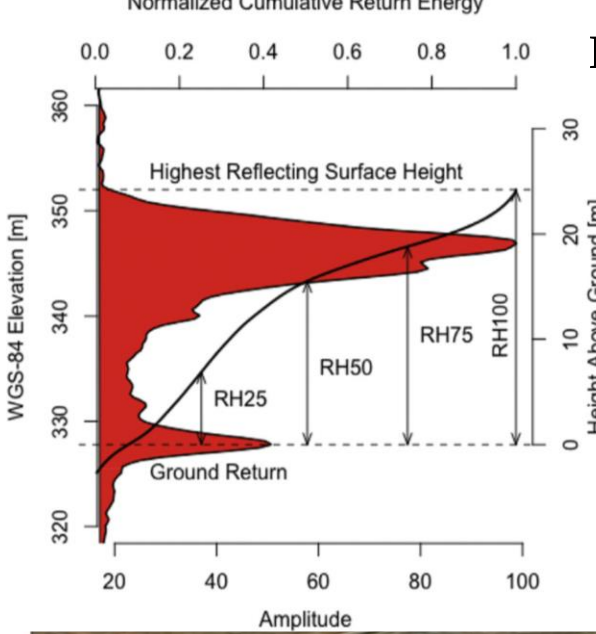
(iv) Develop locally updated wall-to-wall SAR-based AGBD maps in South African savannas using coincident field measurements, ALS, GEDI as reference data and propagate uncertainties from field measurements to the resulting SAR-based AGBD maps.

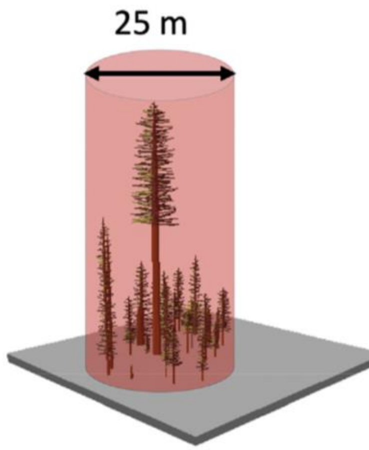

Global Ecosystem Dynamics Investigation
(GEDI)
GEDI
ECOSYSTEM LIDAR
JAXA
Advanced Land Observing Satellite-2 (ALOS-2)
Phased Array L-band Synthetic Aperture Radar-2 (PALSAR-2)
Ice, Cloud and land Elevation Satellite-2
(ICESat-2)
ICESat-2
ICE, CLOUD, AND LAND ELEVATION SATELLITE-2
CSIR
our future through science
80m+
60-80m
35-60m
15-35m
0-15m
Airborne LiDAR

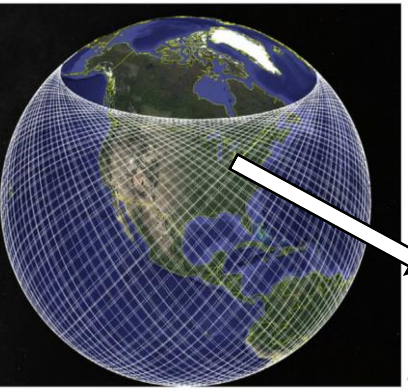
NASA's Global Ecosystem Dynamic Investigation (GEDI)

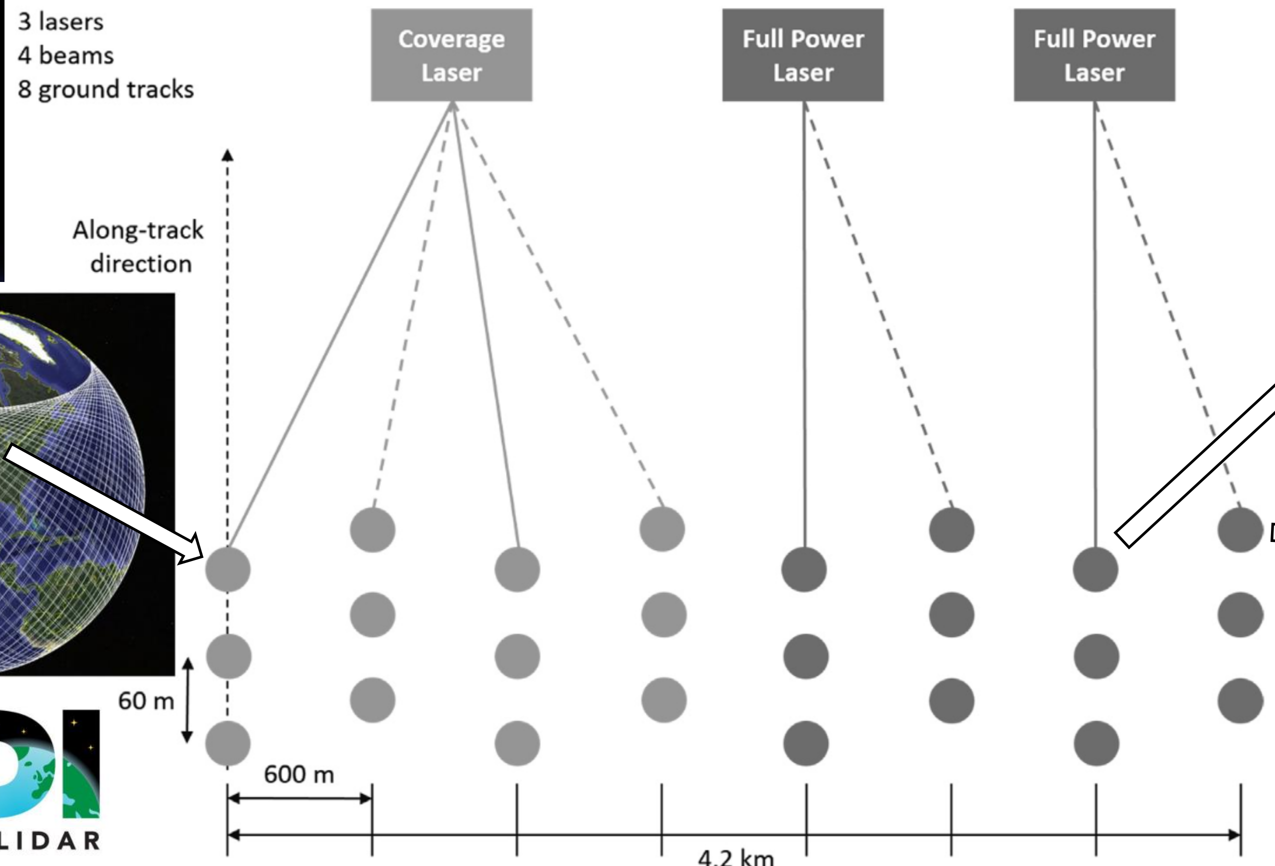
- GEDI produces the first high resolution laser ranging observations of the 3D structure of the Earth.
- GEDI instrument design, algorithm calibration and validation were focused on the measurement of tall, dense tropical and temperate & tropical forests, not savannas.

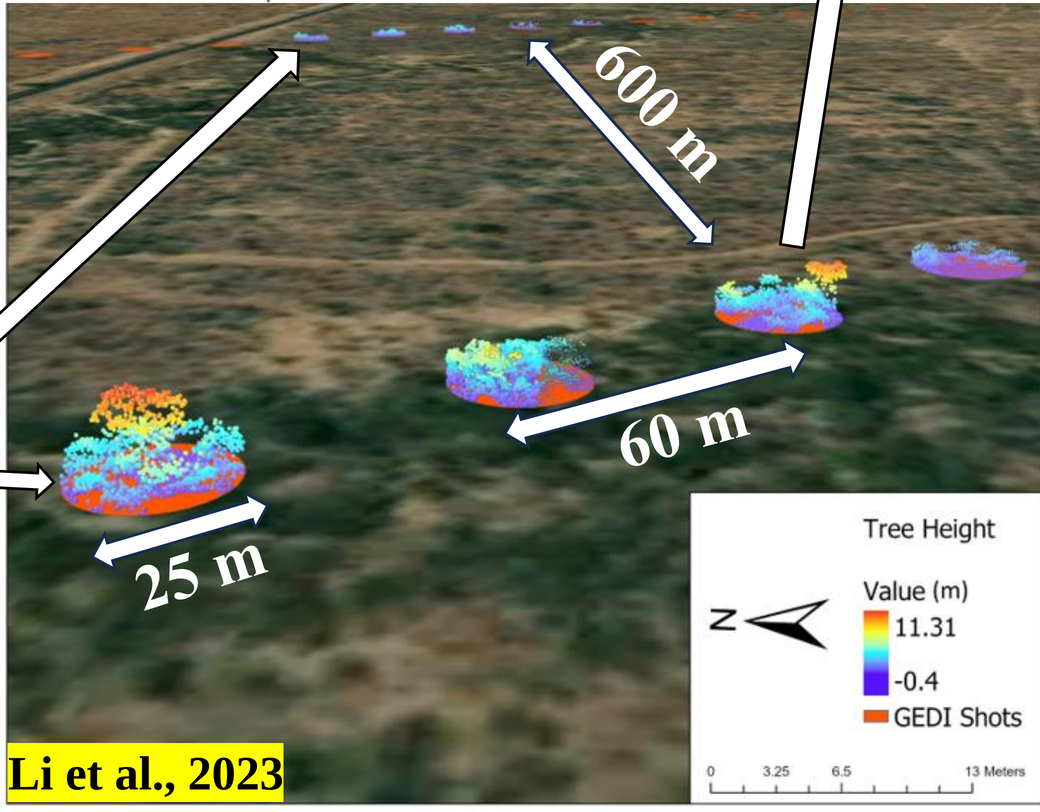
Dubayah et al., 2020





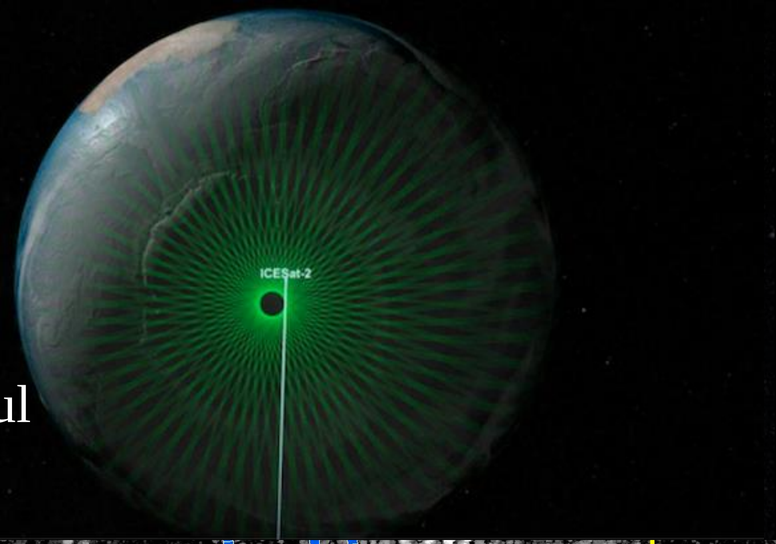


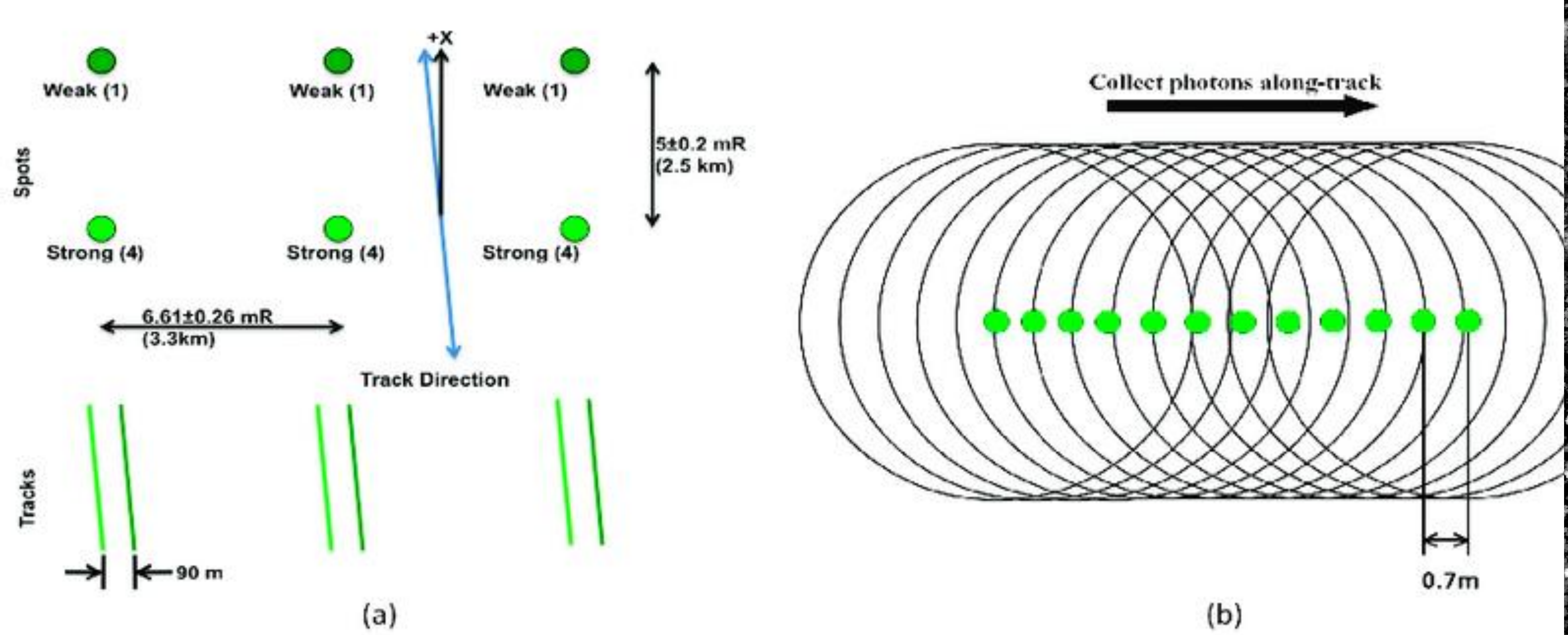


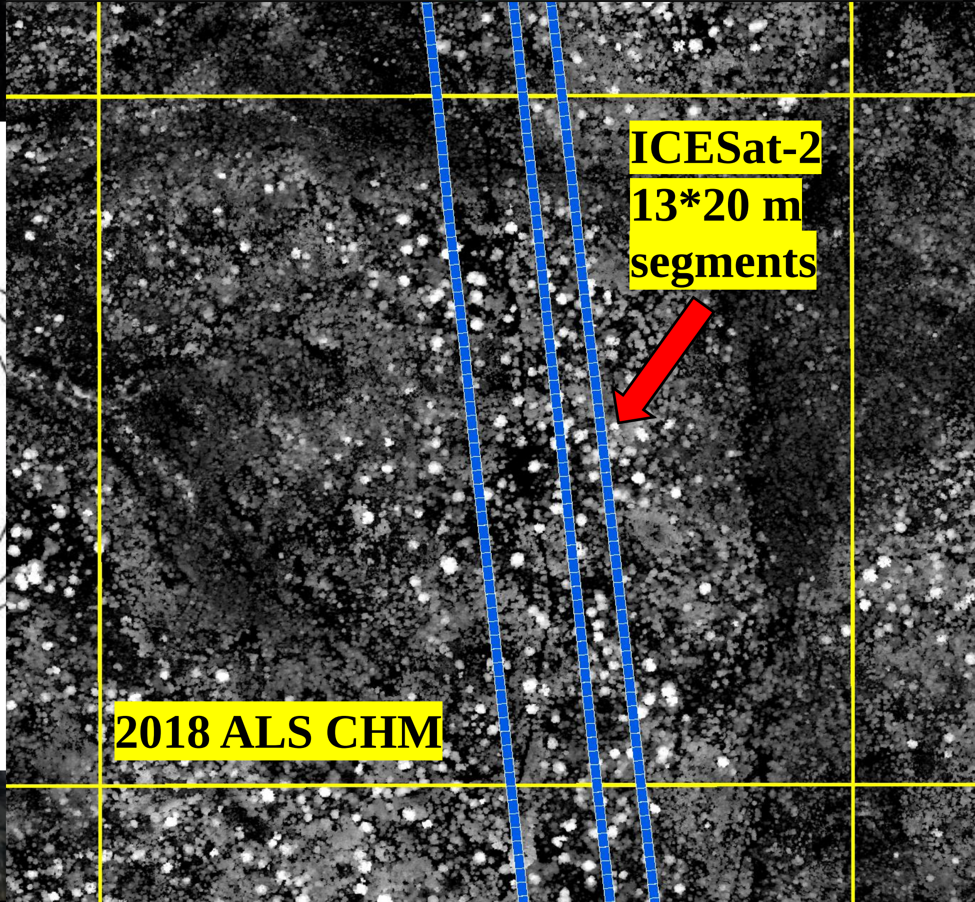


NASA's Ice, Cloud, and land Elevation Satellite-2 (ICESat-2)

- ICESat-2 measures global scale ice sheet mass, land topography and vegetation characteristics.
- NASA's ICESat-2 is not optimized for vegetation studies, but it can be useful for forest height and potentially AGB estimation (Duncanson et al., 2020)



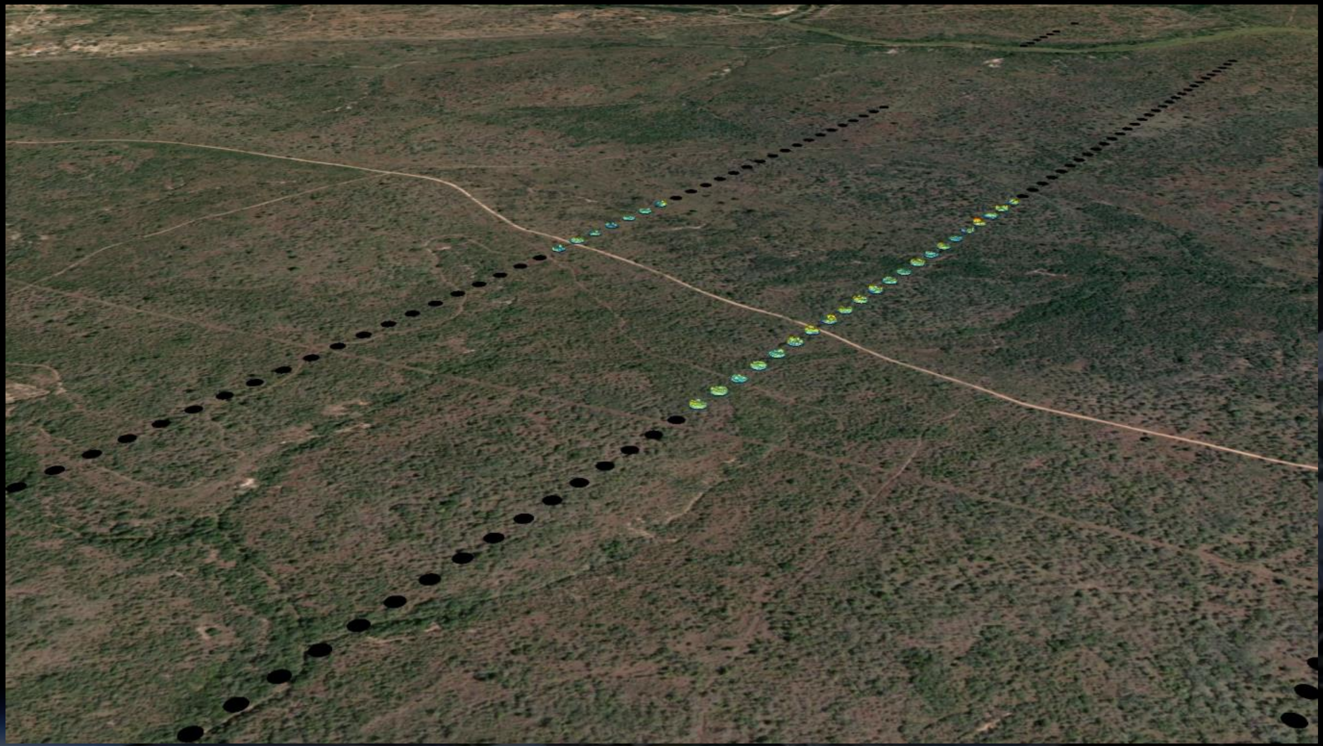


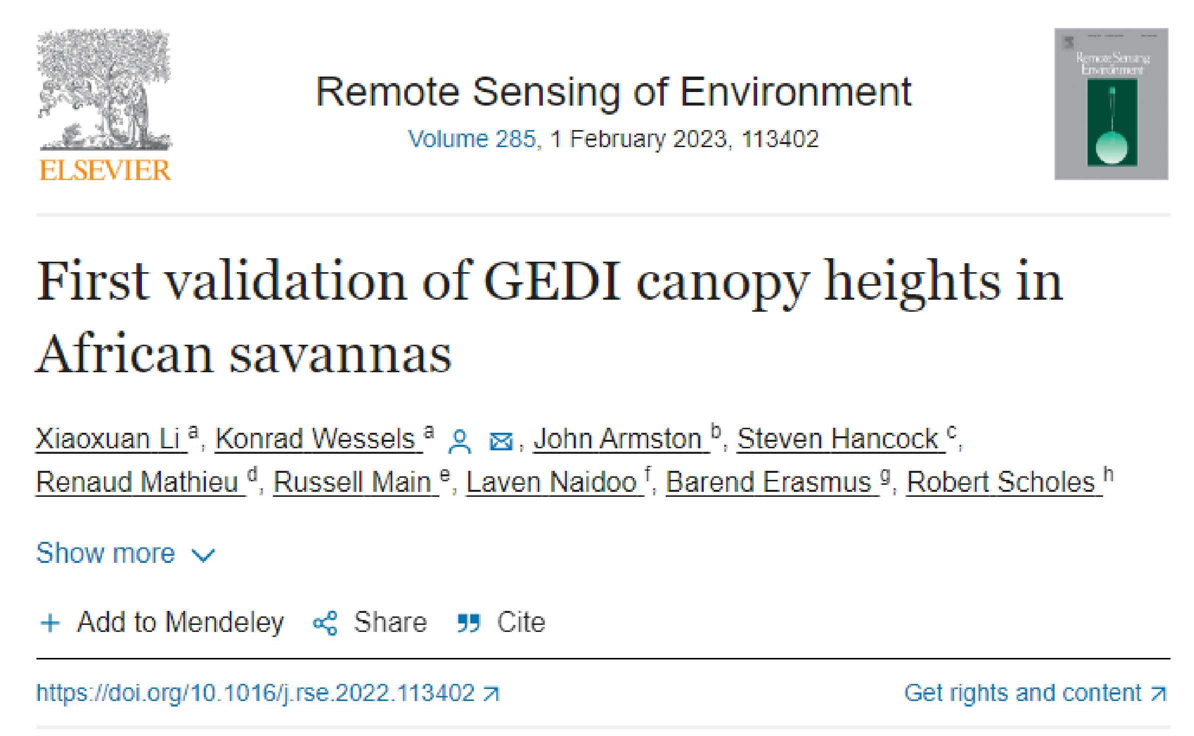


JAXA Advanced Land Observing Satellite-2 (ALOS-2) Phased Arrayed L-band Synthetic Aperture Radar-2 (PALSAR-2)

- L-band SAR has the appropriate sensitivity range for savannas that typically vary from 10~90 Mg/ha.
- A number of studies have demonstrated a strong relationship between L-band SAR and savanna (Naidoo et al., 2015, Bouvet et al., 2018, Urbazaev et al., 2018)

First validation of GEDI-RH98 (published in RSE)





ELSEVIER

Remote Sensing of Environment

Volume 285, 1 February 2023, 113402

First validation of GEDI canopy heights in African savannas

Xiaoxuan Li [a], Konrad Wessels [a], John Armston [b], Steven Hancock [c], Renaud Mathieu [d], Russell Main [e], Laven Naidoo [f], Barend Erasmus [g], Robert Scholes [h]

Show more

+ Add to Mendeley   Share   Cite

https://doi.org/10.1016/j.rse.2022.113402

Get rights and content

Datasets used:

1. Airborne LiDAR collected in 2018 (dry season)
2. Spaceborne LiDAR GEDI L1B and L2A data product from 2019 to 2021
3. Optical remote sensing MODIS NDVI (2000 to 2020)

Objective

(i) assess the accuracy of on orbit GEDI relative height metric (RH98) by comparison to the reference estimates simulated from ALS

(ii) determine the influence of various factors on this error, e.g. algorithm setting group (SGs), beam type, day vs. night, sensitivity, and vegetation phenology.

GEORGE MASON UNIVERSITY

UNIVERSITY OF MARYLAND 18 56

CSIR Touching lives through innovation

THE UNIVERSITY OF EDINBURGH

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

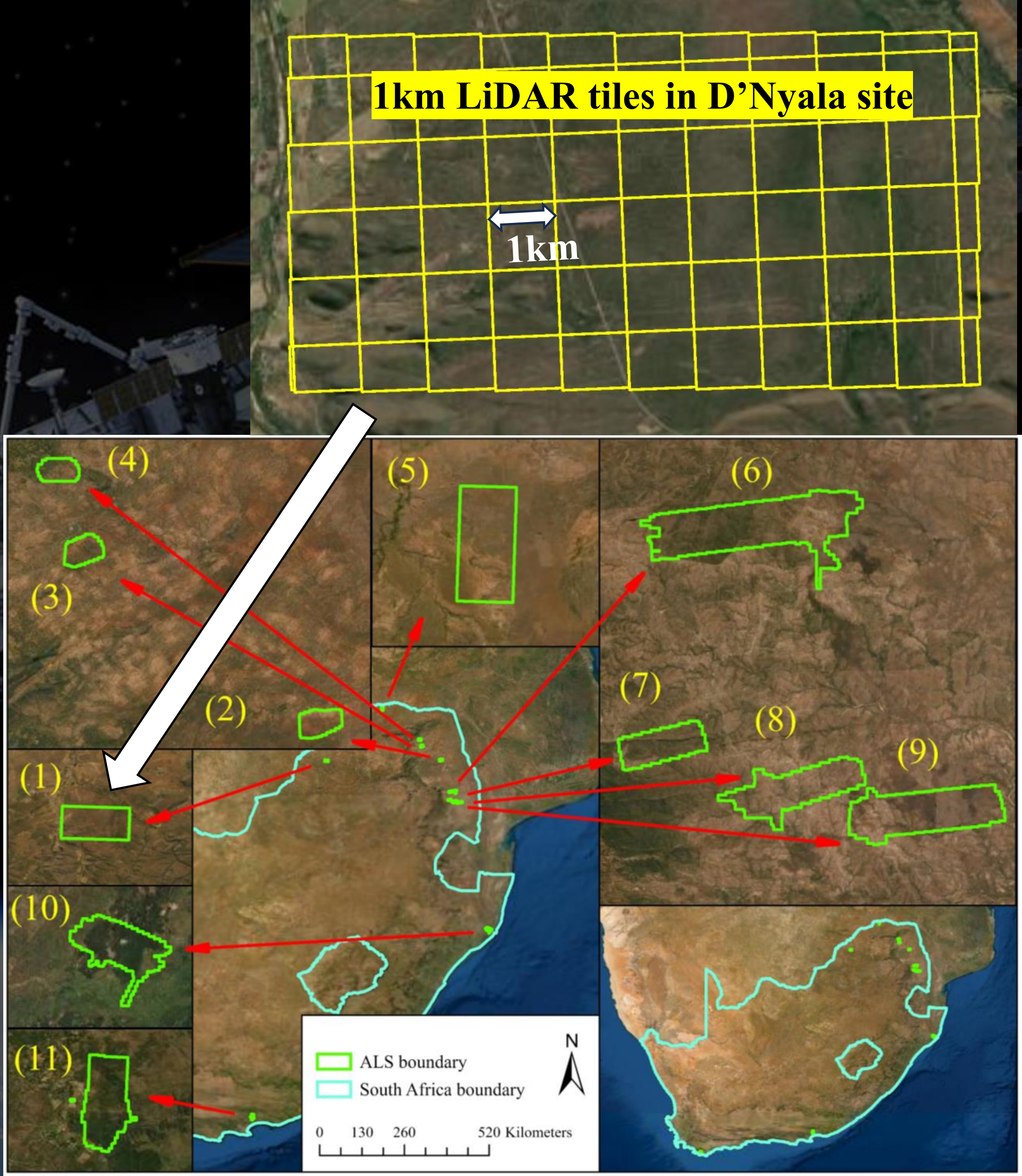
Data and sensors

Airborne Laser Scanning (ALS)

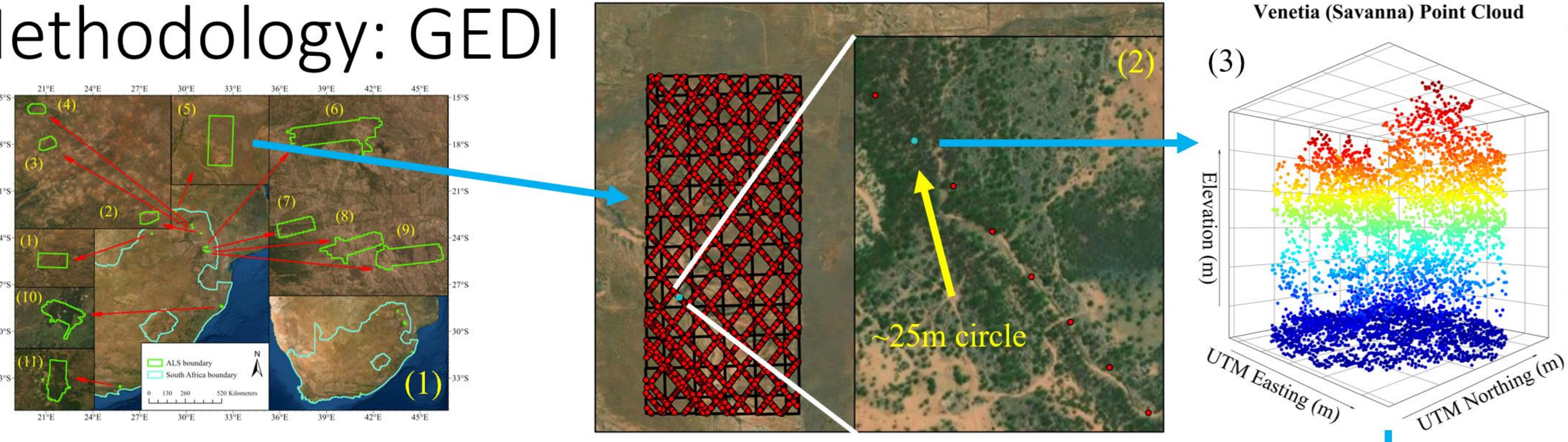
Area: approximately 800 km^2 over the 11 study sites.
Date: March and June of 2018 (leaf-off season)
Aircraft: a fixed wing aircraft (700 m above ground)
Sensors:
1. Optech ALTM M300 (13SEN327)
2. Optech Gemini (09SEN258)

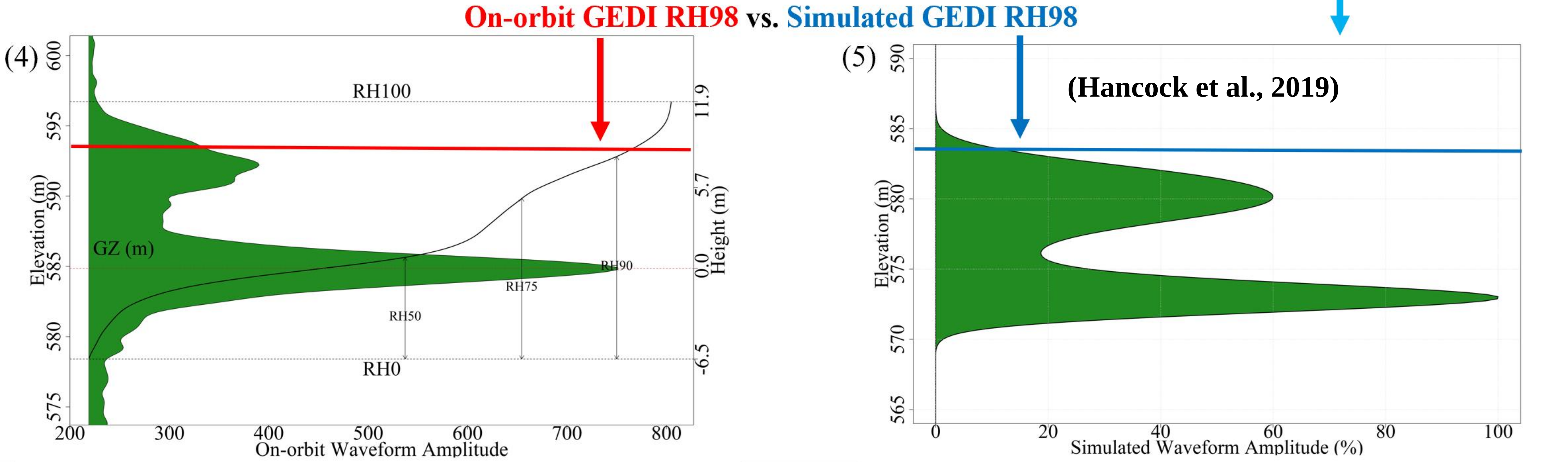
Point density: 8.6 pts/m^2.

(1) D'Nyala,
(2, 3, 4) Limpopo,
(5) Venetia,
(6) Welverdiendt,
(7) Agincourt,
(8) Ireagh,
(9) Justicia,
(10) Dukuduku,
(11) Addo



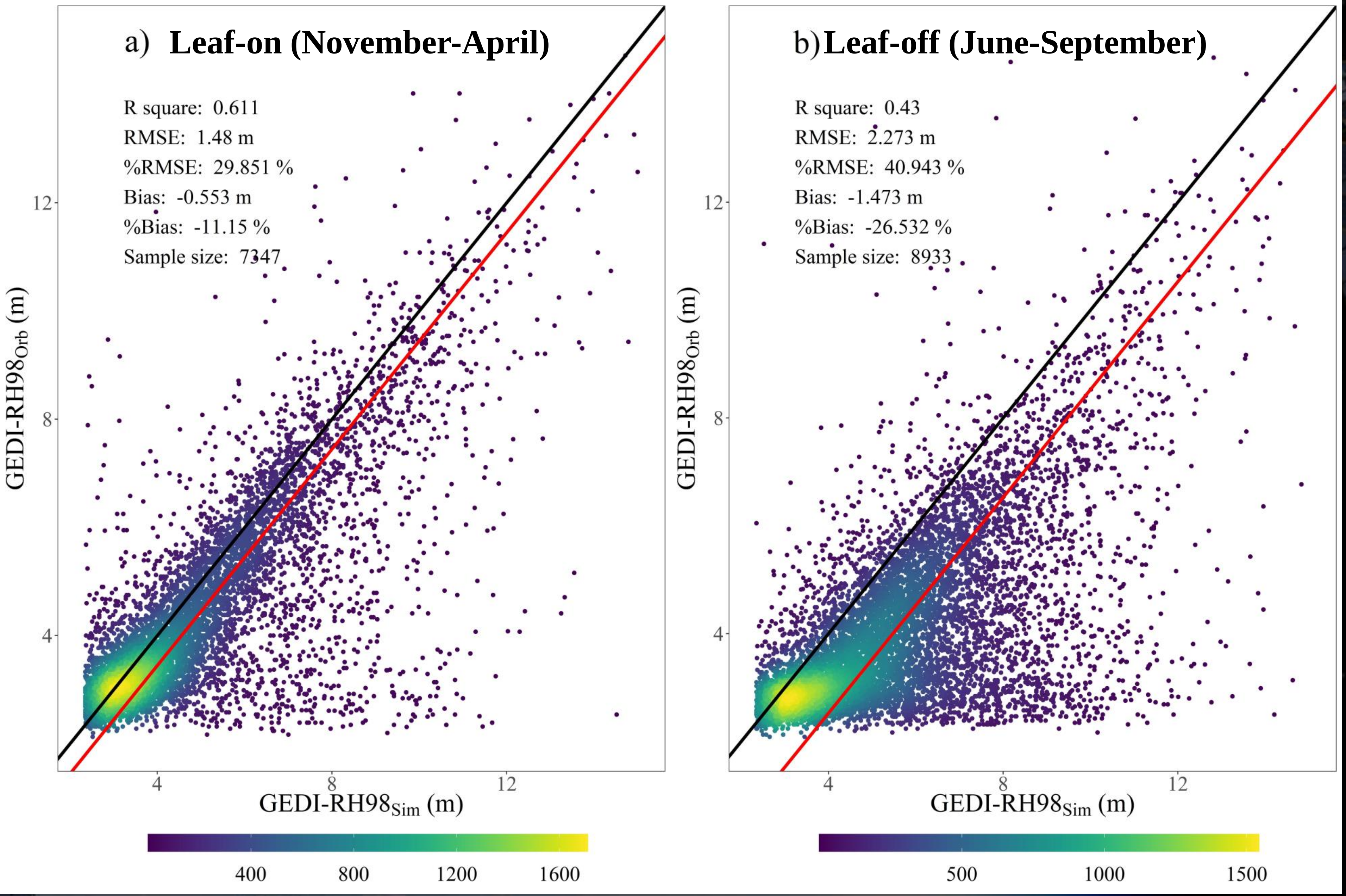
Methodology: GEDI





Li et al., 2023

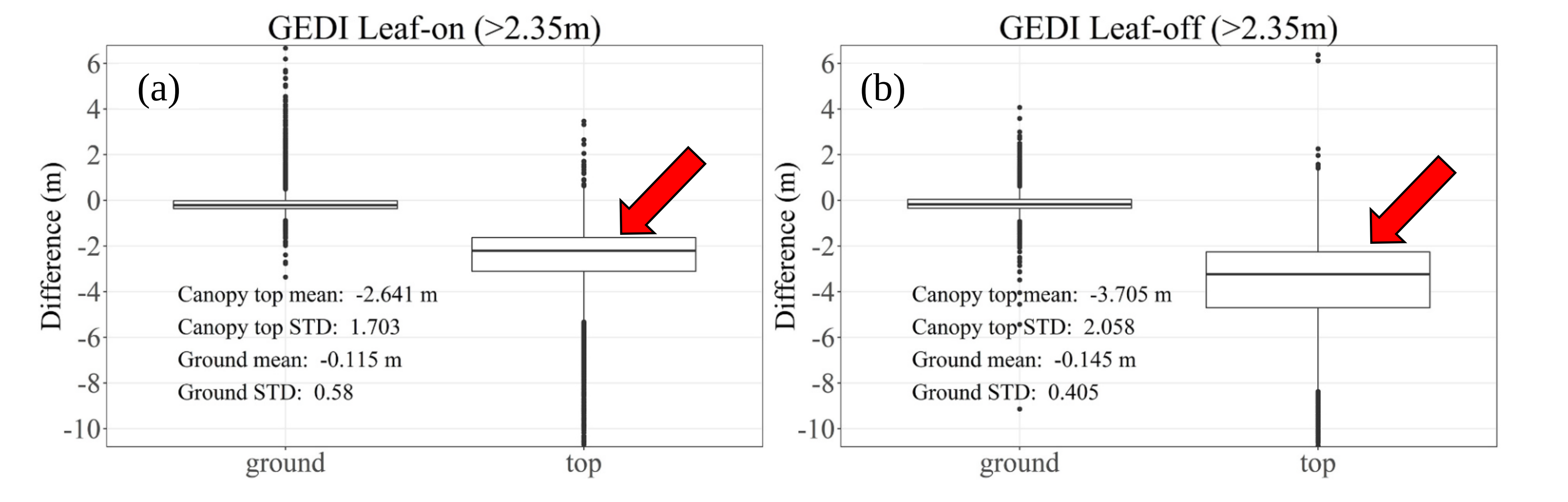
Result



Density plots of on-orbit GEDI RH98 (GEDI-RH98$_{orb}$) vs. simulated GEDI RH98 (GEDI-RH98$_{sim}$) below 15 m for all test cases with leaf-on (a) and leaf-off (b) conditions.

Li et al., 2023

Result

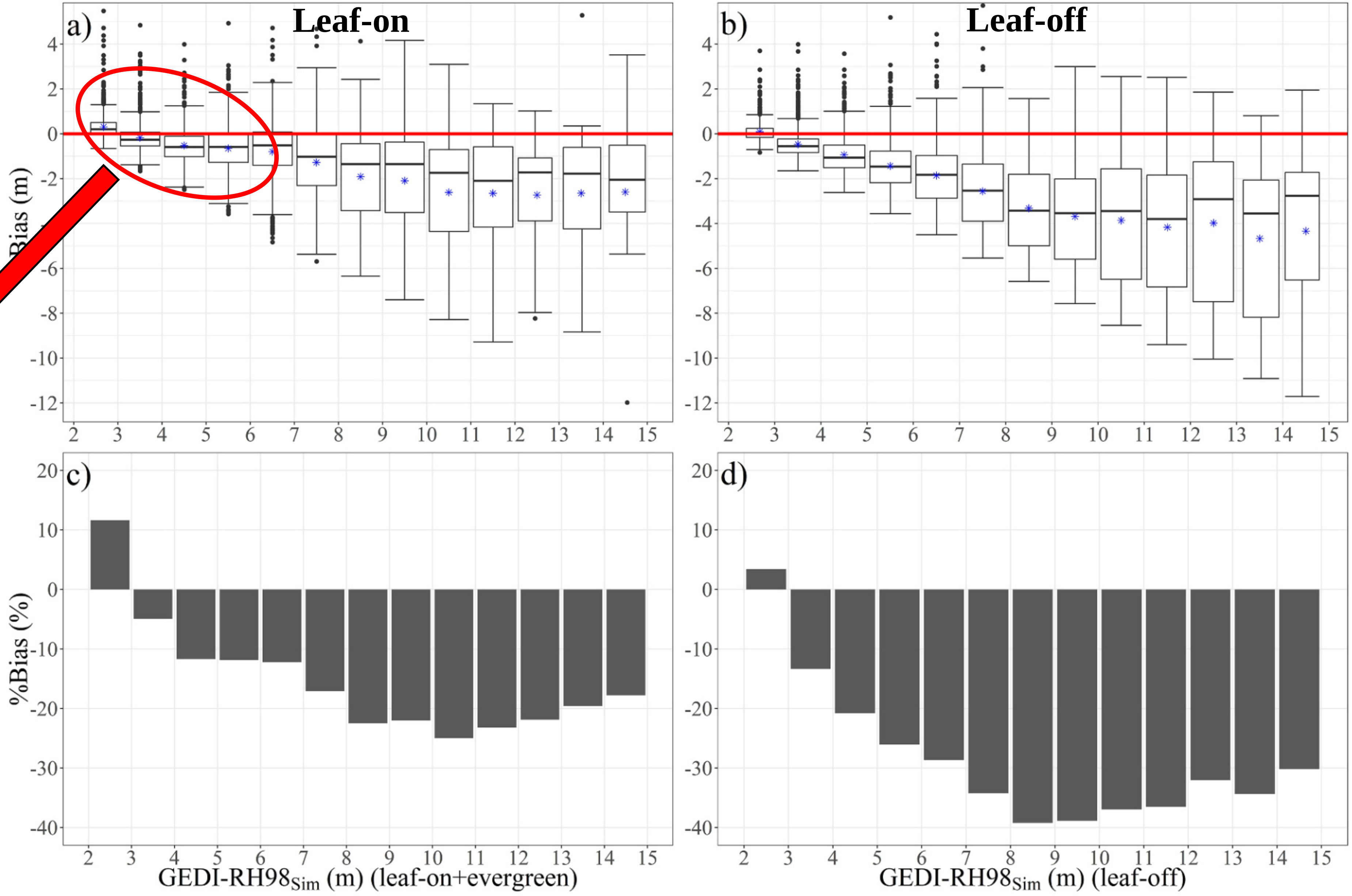


The difference between GEDI and ALS-derived ground and canopy top elevations for two scenarios: leaf-on (>2.35 m) (a), and leaf-off (>2.35 m) (b). The RH98 bias was mainly due to the underestimation of canopy top elevation.

Li et al., 2023

Result

80% of all the data



Bias (a, b), and %bias (c, d) vs. GEDI-RH98$_{sim}$ (0–15 m) for leaf-on (left) and leaf-off (right) test cases. Mean Bias values are indicated with blue asterisks. The lowest bin range is 2.35–3 m.

Lower limits of GEDI – Shrubs < 2.34m

- Given the pulse width of 15.6 ns (FWHM) of the GEDI laser, GEDI canopy height has an expected minimum height of retrieval equal to 2.34 m, which may be above the maximum height of short shrub.

- Detecting short shrubs may require intricate deconvolution of the waveform (on-going work at UMD).

- Points (N= 390 , 3.9%) with on-orbit and simulated RH98 below 2.34 m were excluded from the analyses a priori.

Conclusions

- First validation of GEDI canopy height estimates (Relative Height 98) in savannas, anywhere in the world.
- Leaf-on vs. leaf-off conditions had a very large influence on results.
- GEDI provides reliable canopy height estimates in savannas, for height classes > 2.34 m (bias = −0.55 m, RMSE = 1.64 m.).
- Canopy height (RH98) is primary variable used to estimate GEDI foot-print level AGBD
- While the GEDI instrument design focused on tropical and temperate forests, it could also provide useful, accurate estimates of canopy height in lower stature, discontinuous savanna vegetation.

Evaluation of GEDI Footprint-level Biomass Models in Southern African Savannas using ALS and Field Measurements (Manuscript in progress)

25m GEDI footprints over vertical slice of airborne LiDAR point cloud

AGBD

AGB is defined as “dry-weight of the standing live or dead woody component of aboveground vegetation”. The individual tree-level AGB estimates are summed within a plot with a specific area to calculate plot-level aboveground biomass density (**AGBD**) that quantifies the amount of AGB per unit area (megagrams per hectare - **Mg/ha**).

GEDI footprint-level AGBD

- Global model: GEDI L4A footprint-level AGBD (**$\mathbf{AGBD_{L4A}}$**): developed from simulated GEDI RH predictors (RH98 only) for southern Africa (global Grassland, Shrub, Woodland (GSW) model) without on-orbit GEDI and local reference data included.
- Local model:

  (1) Locally updated South African Savannas (SAS) GEDI AGBD using **Generalized Linear Model (GLM) ($\mathbf{AGBD_{SAS\_GLM}}$)**: developed from on-orbit GEDI L2A (**RH98, RH50**) and L2B (**Foliage Height Diversity** - FHD) using GLM (gamma distribution, linear link function) and airborne Lidar data (ALS – 2018)

  (2) Locally updated South African Savannas (SAS) GEDI AGBD using **Random Forest (RF) ($\mathbf{AGBD_{SAS\_RF}}$)**: developed from on-orbit GEDI L2A (RH50, RH75, RH90, RH98) and L2B (FHD, Plant Area Index, and Canopy Cover) using RF

Objectives

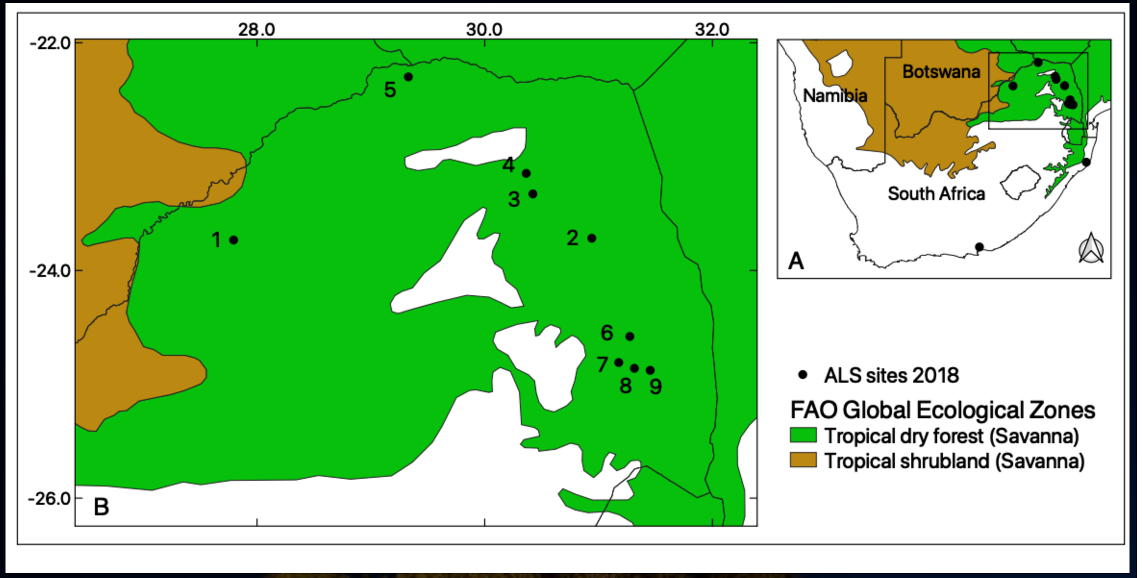
(i) validate GEDI L4A AGBD in southern African savannas using field measurements and ALS datasets

(ii) develop and evaluate locally updated GEDI footprint-level AGBD estimates using field measurements and ALS datasets following the steps below:

(1) developing local ALS-based AGBD models using reference field measurements.

(2) applying the resulting ALS-based AGBD models to predict GEDI AGBD using on-orbit GEDI L2A and L2B metrics

(3) accessing the accuracy of $\mathbf{AGBD_{SAS\_GLM}}$ and $\mathbf{AGBD_{SAS\_RF}}$ by comparing them to the reference ALS-based AGBD estimates.



Study area

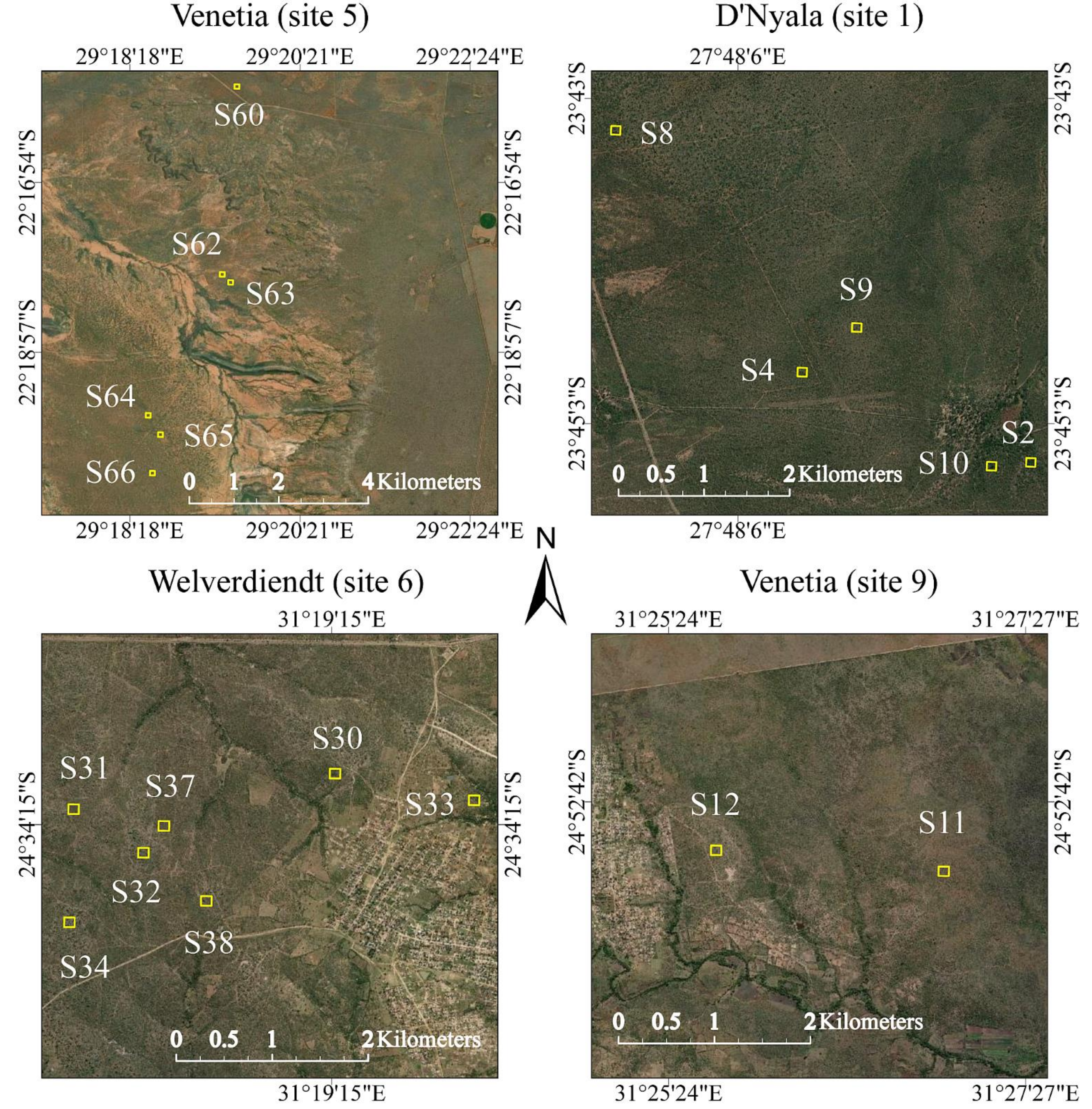
1 ha field plots within sites:

Venetia (site #5, S60, S62-66)

D’Nyala (site #1, S2, S4, S8-10)

Welverdiendt (site #6, S30-34, S37-38)

Justicia (site #9, S11-12)

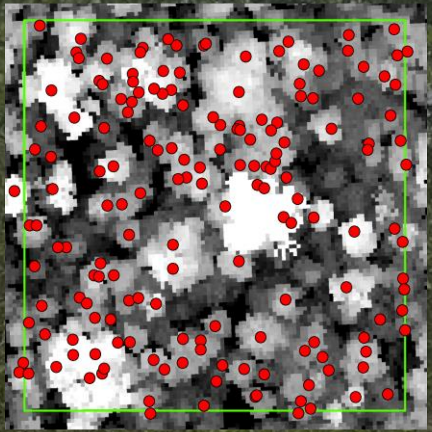


Data: field measurement

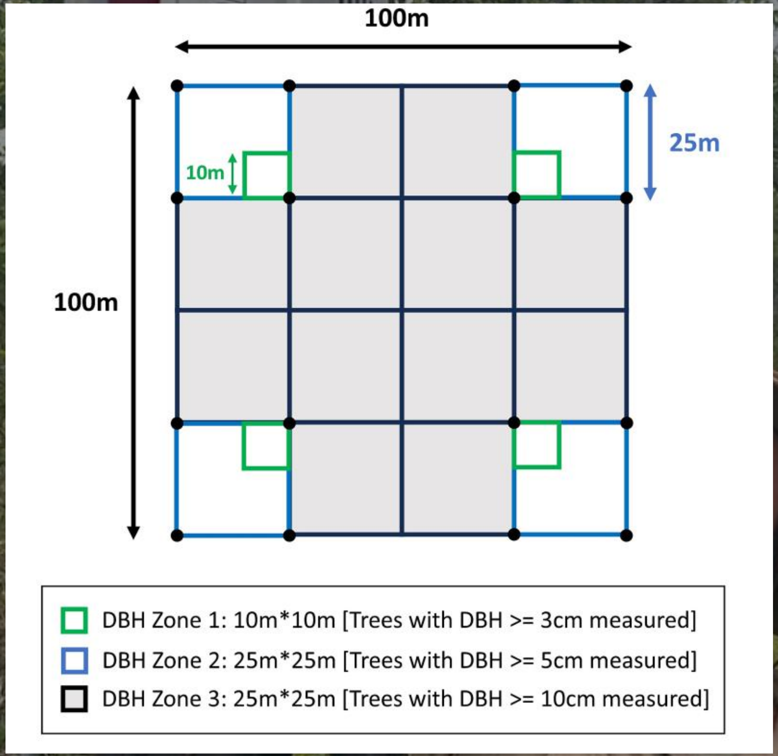
Individual-tree AGB were calculated from height and stem diameter measurements using the following allometric model (Colgan et al., 2013):

$$M = 0.109 \times D^{(1.39+0.14\times\ln(D))} \times H^{0.73} \times \rho^{0.8}$$

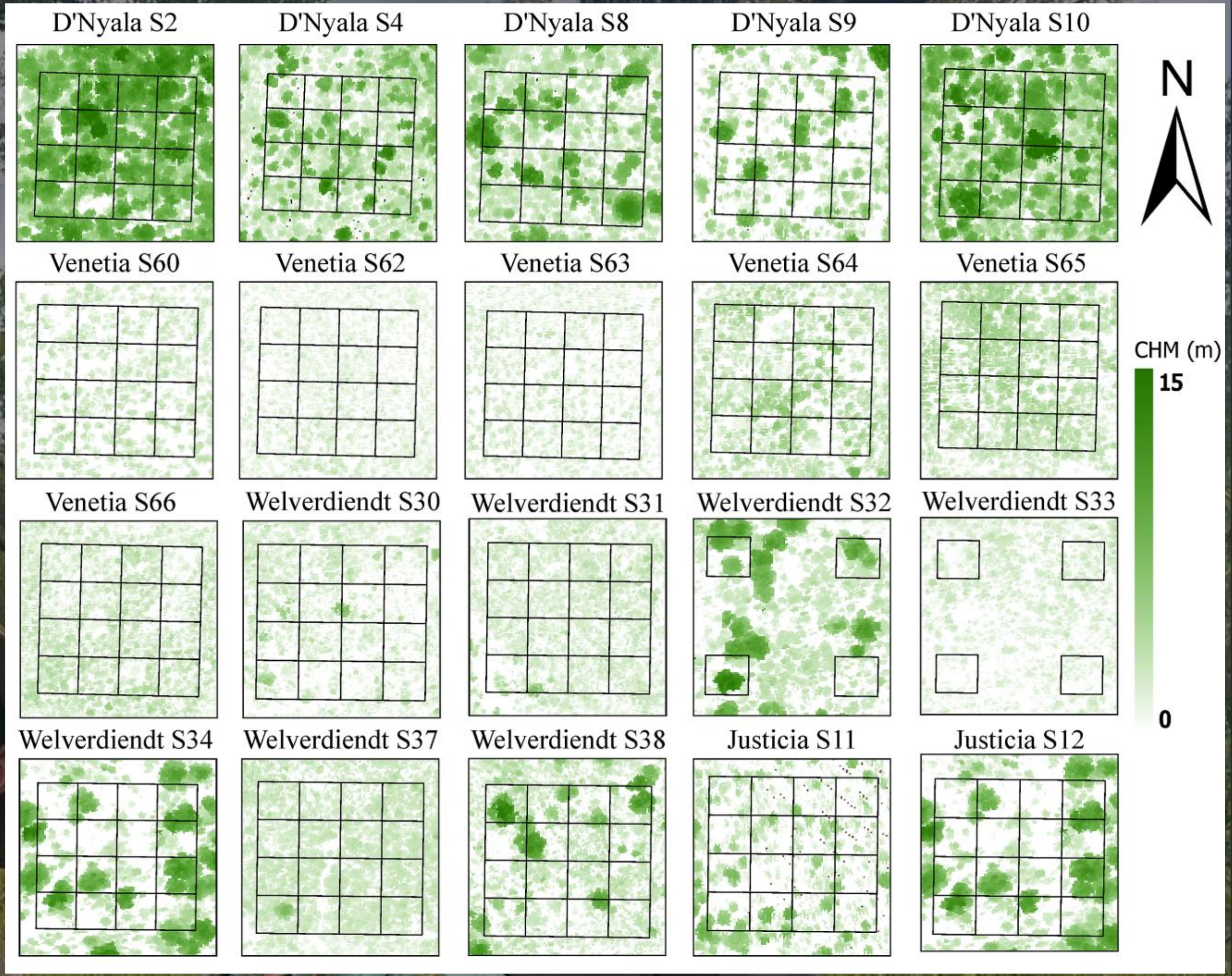
where M = AGBD in kg, D = Diameter at Breast Height (DBH) in cm, H = height of tree in m, and ρ = mean wood specific gravity (unitless and fixed at a mean value of 0.8).



GPS location of individual tree records



Ground sampling design for AGBD estimation (Naidoo et al., 2015).



25 m plots within the 1 ha field plots displayed over ALS-derived CHM in D’Nyala, Venetia, Justicia, and Welverdiendt.

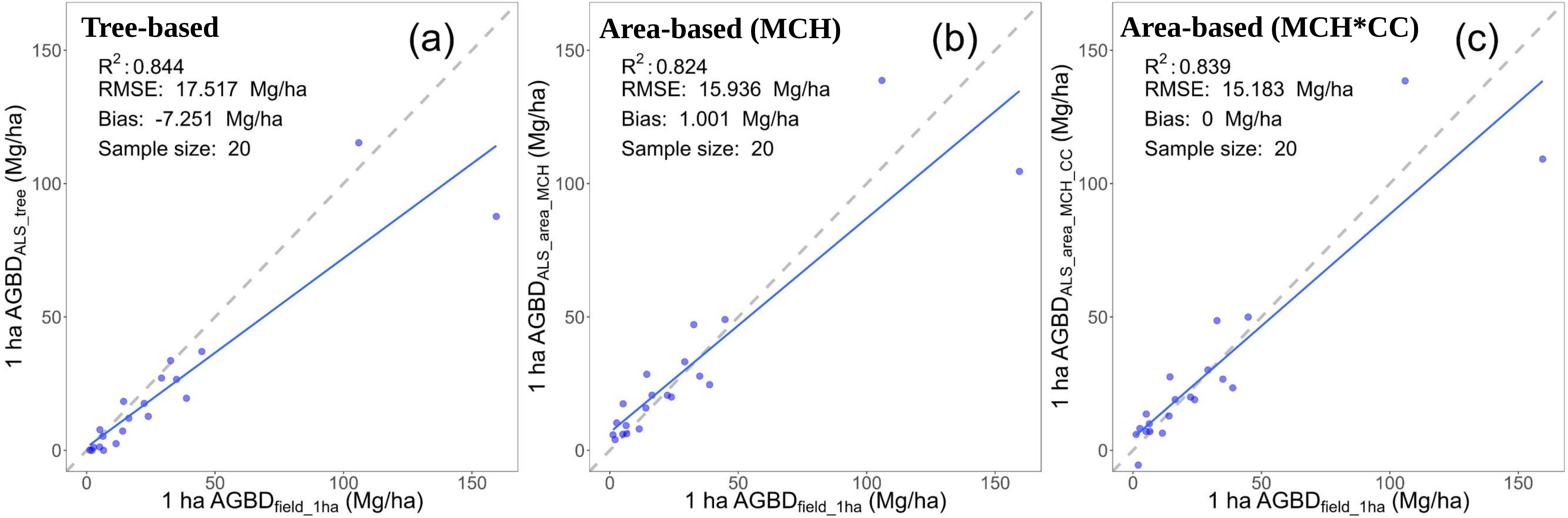
Results: AGBD estimation using ALS data at 1 ha plot level

$$\text{Tree-based AGB} = 10^{0.0207+0.3\times(log10(CA)+0.196*(log10(CA))^2+1.74\times(log10(H)))}$$

$$\text{Area-based (MCH)} = a \times MCH^b$$

$$\text{Area-based (MCH*CC)} = a \times MCH \times CC + b$$

CA: Crown Area (m2)
H: Maximum canopy top height (m)
MCH: Mean canopy height (m)
CC: Canopy Cover (%)

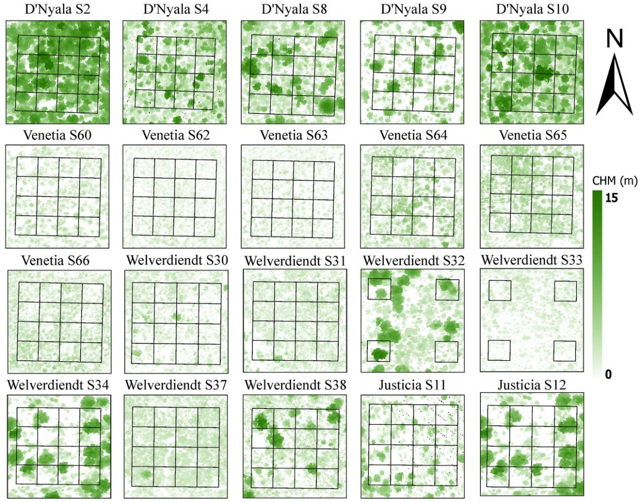


Results: AGBD estimation using ALS data at 25 m plot level

$$\text{Tree-based AGB} = 10^{0.0207+0.3\times(log10(CA)+0.196*(log10(CA))^2+1.74\times(log10(H)))}$$

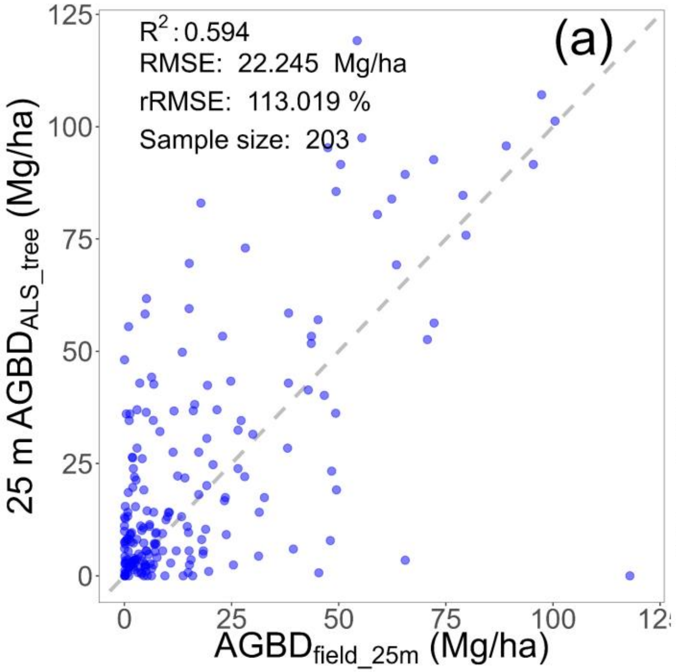
$$\text{Area-based (MCH)} = a \times MCH^{b}$$

$$\text{Area-based (MCH*CC)} = a \times MCH \times CC + b$$

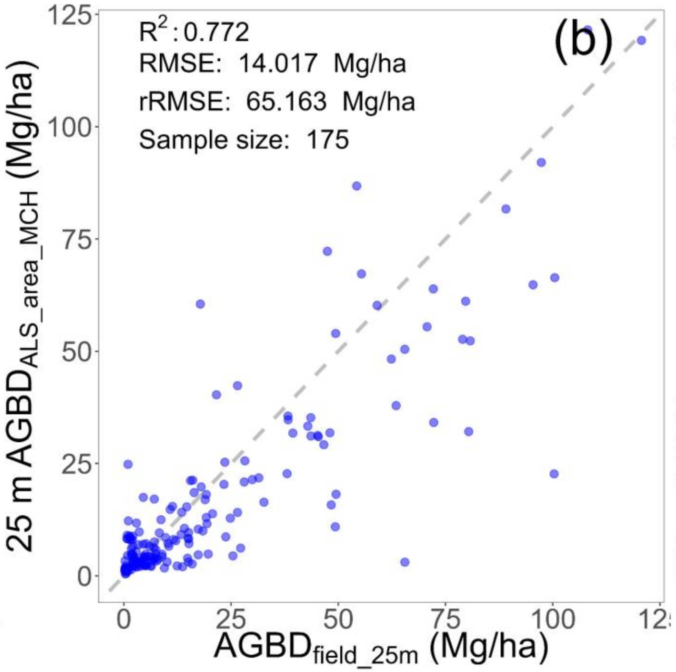


The area-based model (MCH×CC) was selected and used in the following sections.

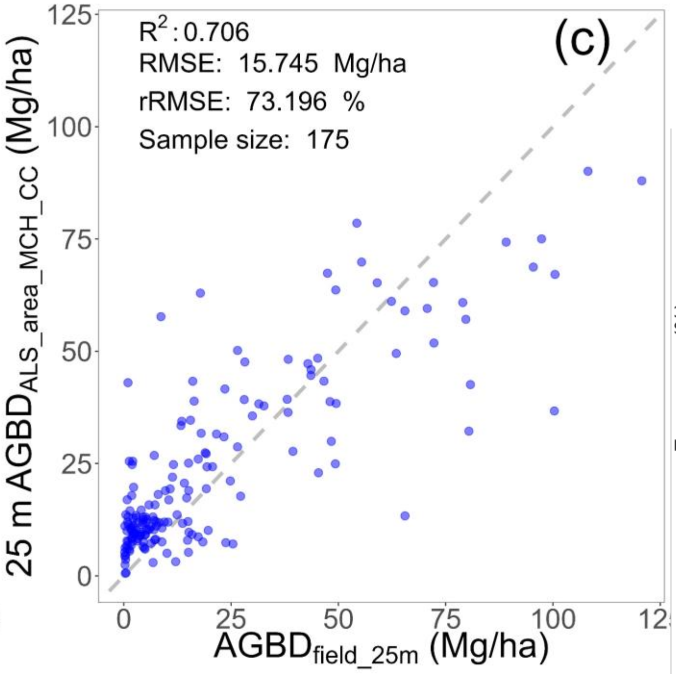
Tree-based



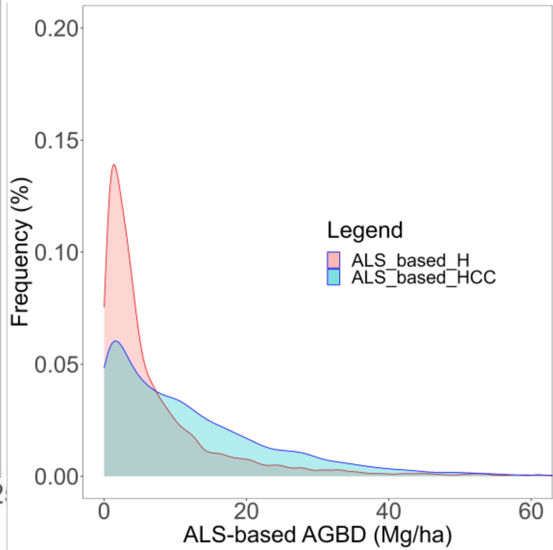
Area-based (MCH)



Area-based (MCH*CC)



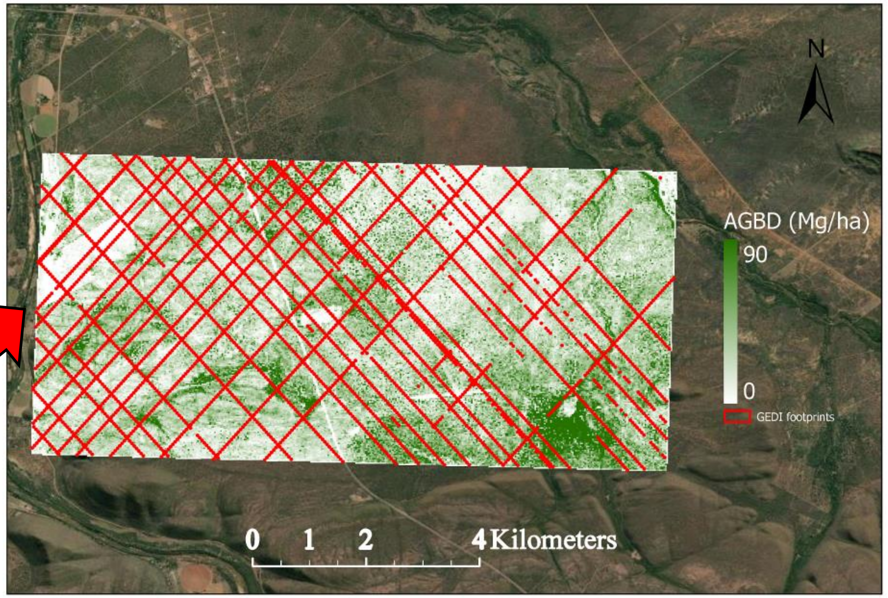
AGBD (MCH) have a more skewed distribution than AGBD (MCH×CC) results.

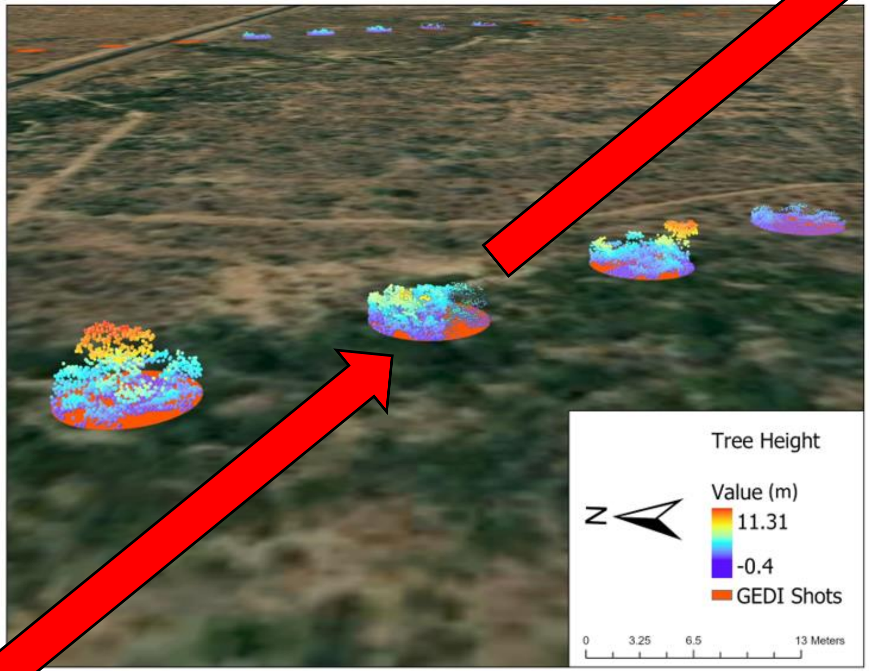


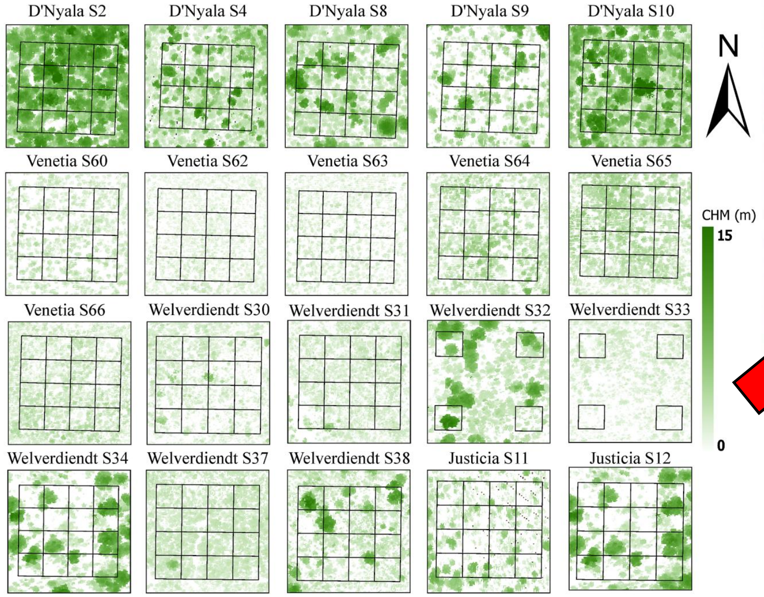
Results

ALS point clouds inside 25 m GEDI footprints.

(Google, © 2020 Maxar Technologies)







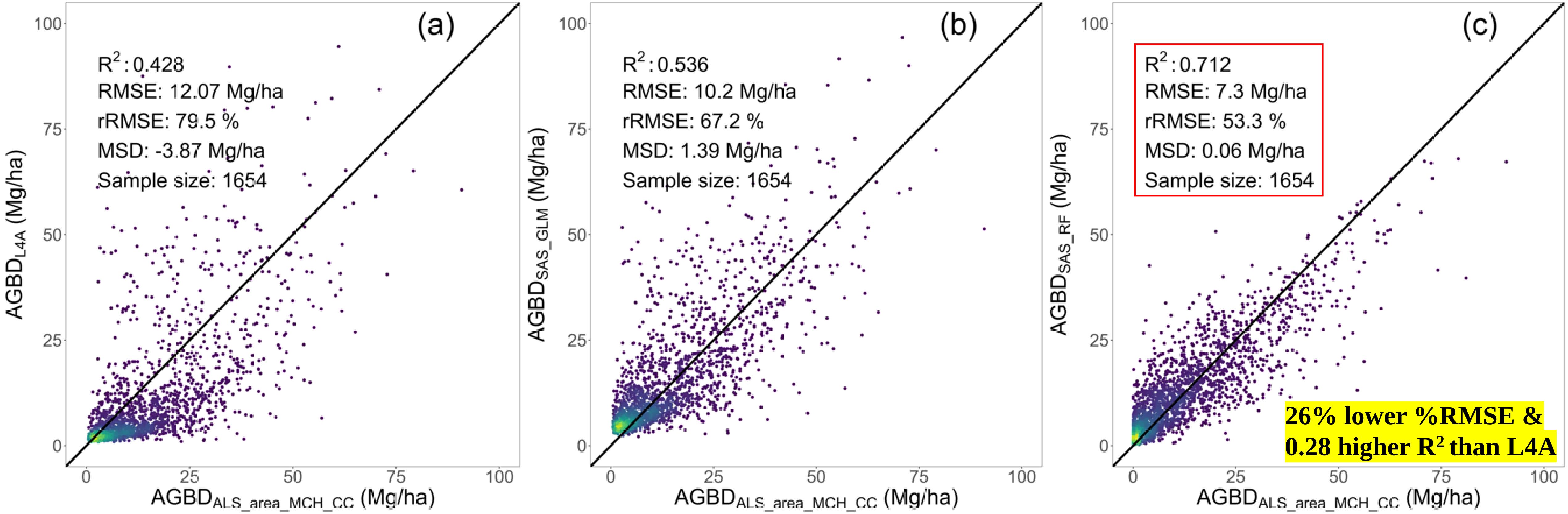
Area-based AGBD (MCH*CC) model was applied to 25m footprint-level GEDI

Results

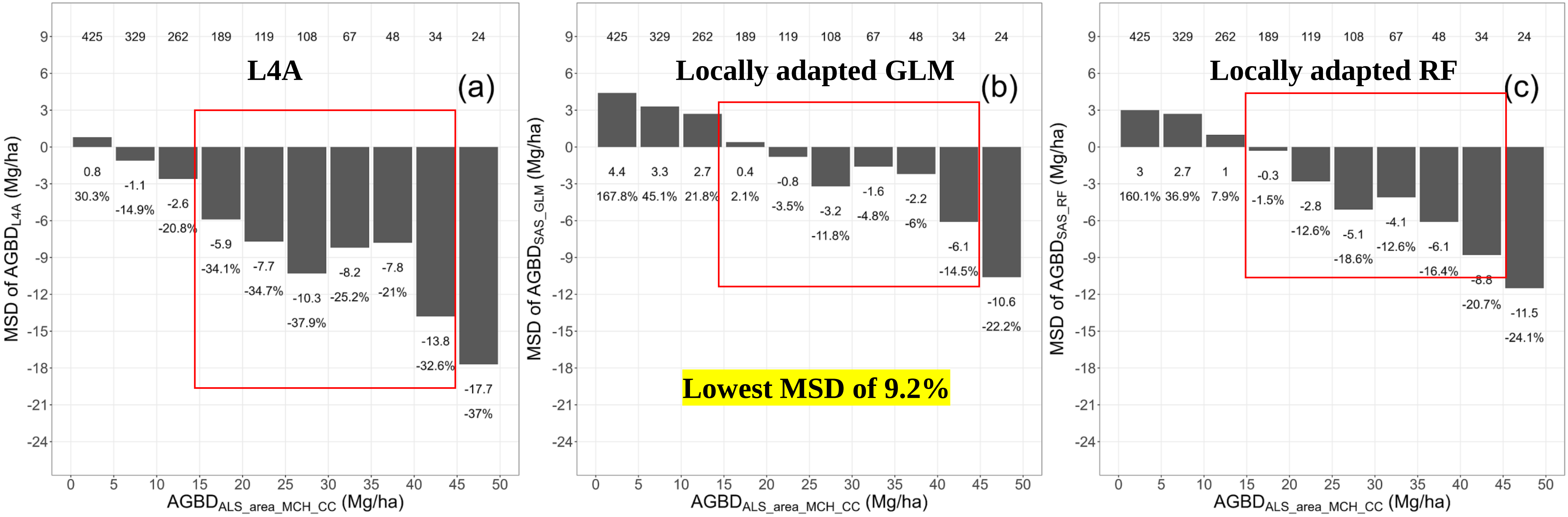
L4A $AGBD_{L4A}$ ~ lm(sqrt($RH98_{sim}$))

Locally adapted GLM
$AGBD_{SAS\_GLM}$ ~ GLM(RH50+RH98+FHD)

Locally adapted RF
$AGBD_{SAS\_RF}$ ~ RF(RH50-98+FHD+PAI+CC)



Result: Validation of GEDI L4A and locally updated GEDI AGBD estimates using on-orbit GEDI metrics



The Mean Systematic Deviation (MSD) and the Relative Mean Systematic Deviation (RMSD) histogram of GEDI AGBD (a: GEDI L4A AGBD (AGBD$_{L4A}$); b: locally updated GEDI using generalized linear model (AGBD$_{SAS_GLM}$); c: locally updated GEDI using random forest (AGBD$_{SAS_RF}$)) vs. ALS-based AGBD (MCH×CC) (AGBD$_{ALS_area_MCH_CC}$).

Conclusions

- The area-based ALS AGBD methods performed better than the tree-based method, the area-based model using MCH*CC was preferred because its AGBD estimates are more representative to the study area.

- The $AGBD_{SAS\_RF}$ had the highest R^2, while the $AGBD_{SAS\_GLM}$ model provided the lowest mean systematic deviation.

- Locally updated models performed better than GEDI L4A because they used **local reference data** and on-orbit GEDI metrics, however, we are not sure if these models can be representative of much larger regions.

- South Africa field and ALS data have been contributed to the GEDI science team global data base and will help improve global / regional models (future L4A versions).

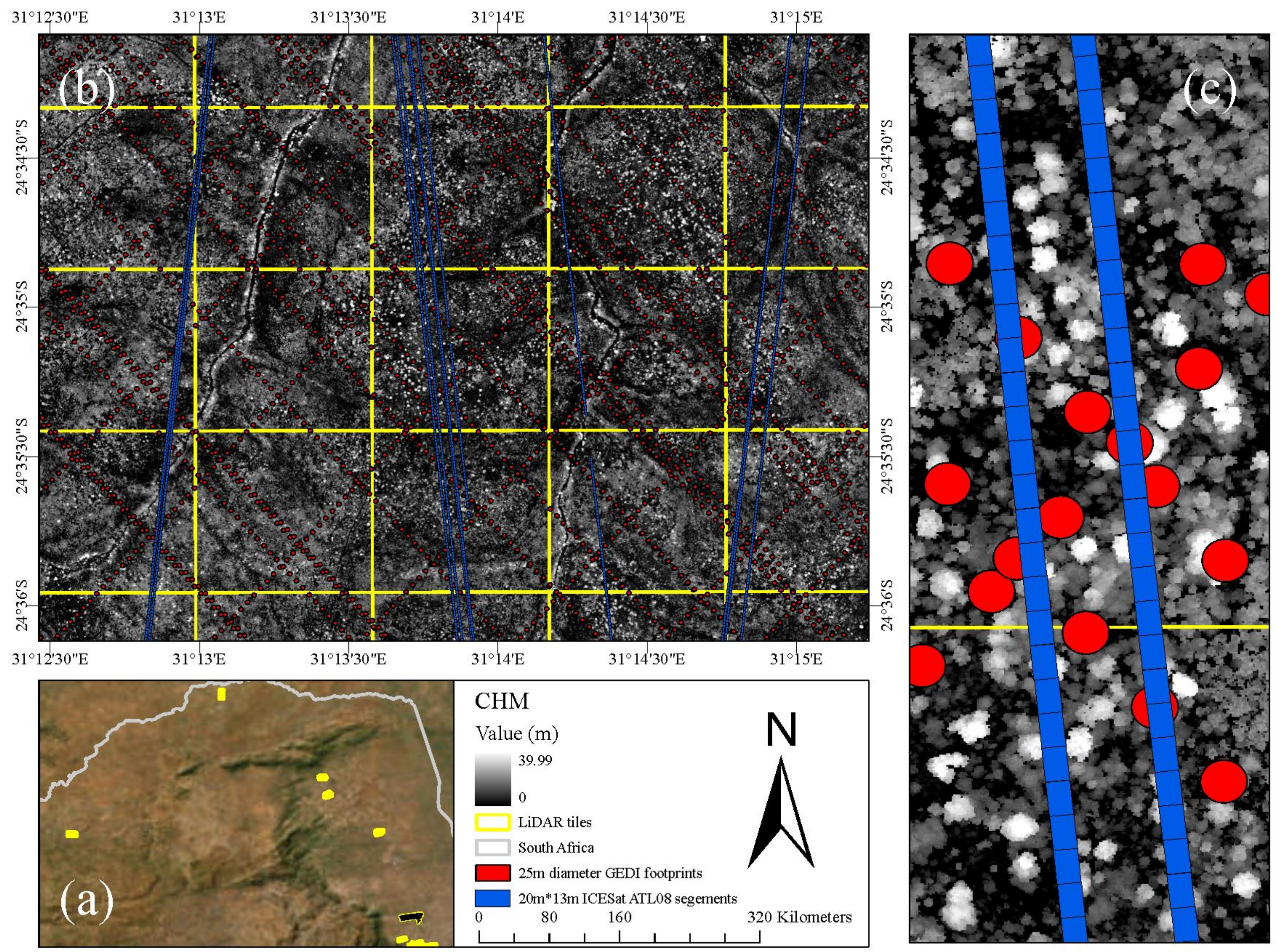
Comparison of GEDI and ICESat-2 Terrain and Canopy Height Estimates

Data

1. Airborne LiDAR collected in 2018 (dry season)
2. GEDI L1B and L2A data product from 2019 to 2021
3. ICESat-2 ATL08 from 2018 to 2021

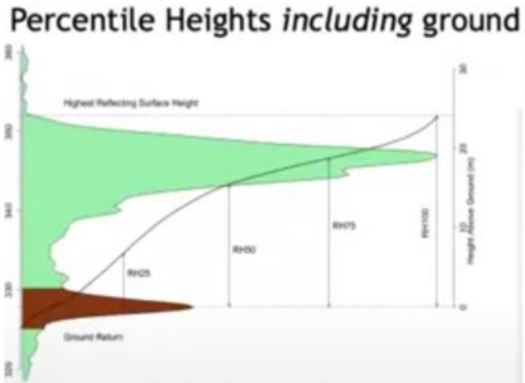
Objectives

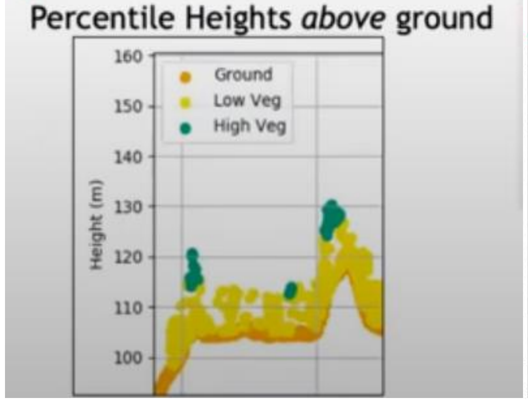
Compare canopy height and ground estimates from GEDI and ICESat-2 separately using ALS-derived canopy height and ground as reference data in southern African savannas.

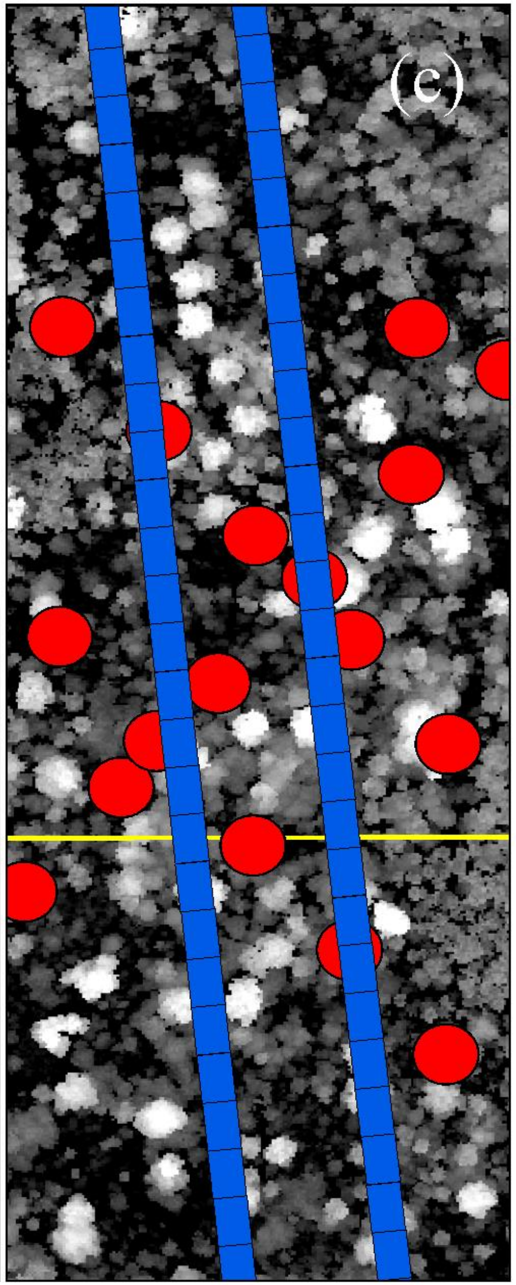


Challenge of GEDI and ICESat-2 comparison

- GEDI and ICESat-2 are sampling lidar and they never revisit the same area
- Different definitions of RH metrics
  - GEDI RHs used percentile heights including ground
  - ICESat-2 canopy heights used percentile heights above ground
- Different resolutions
  - GEDI footprint is a 25 m diameter circle
  - ICESat-2 segment is a ~13*20 m rectangle.
- Different canopy penetration capability
  - GEDI has higher canopy penetration capability than ICESat-2





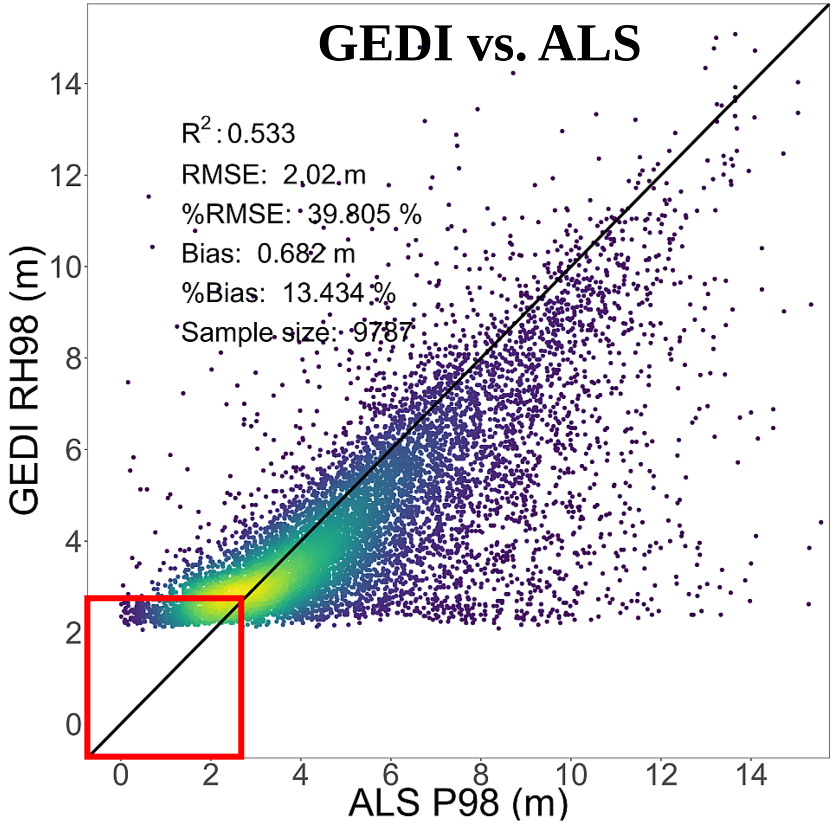


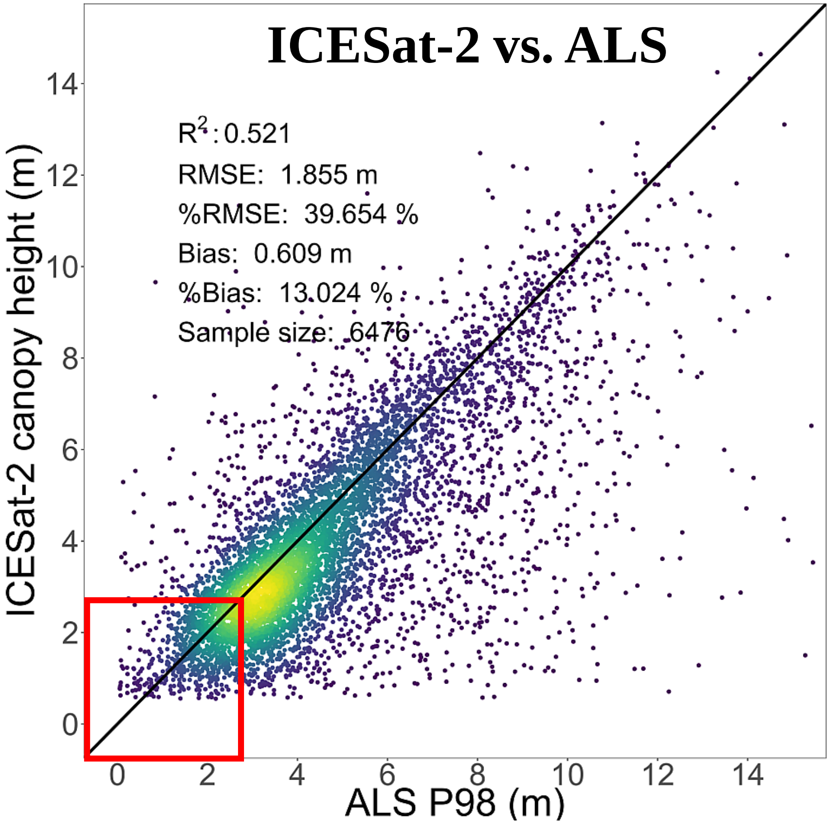
Results: scatterplot

Shrubs < 3m

Summary table of bias and RMSE of spaceborne LiDAR (GEDI and ICESat-2) vs. reference ALS ground

Spaceborne LiDAR	Reference	R^2	Bias	RMSE
GEDI	ALS ground	0.99	-0.09 m	1.03 m
ICESat-2	ALS ground	0.98	1.36 m	1.96 m

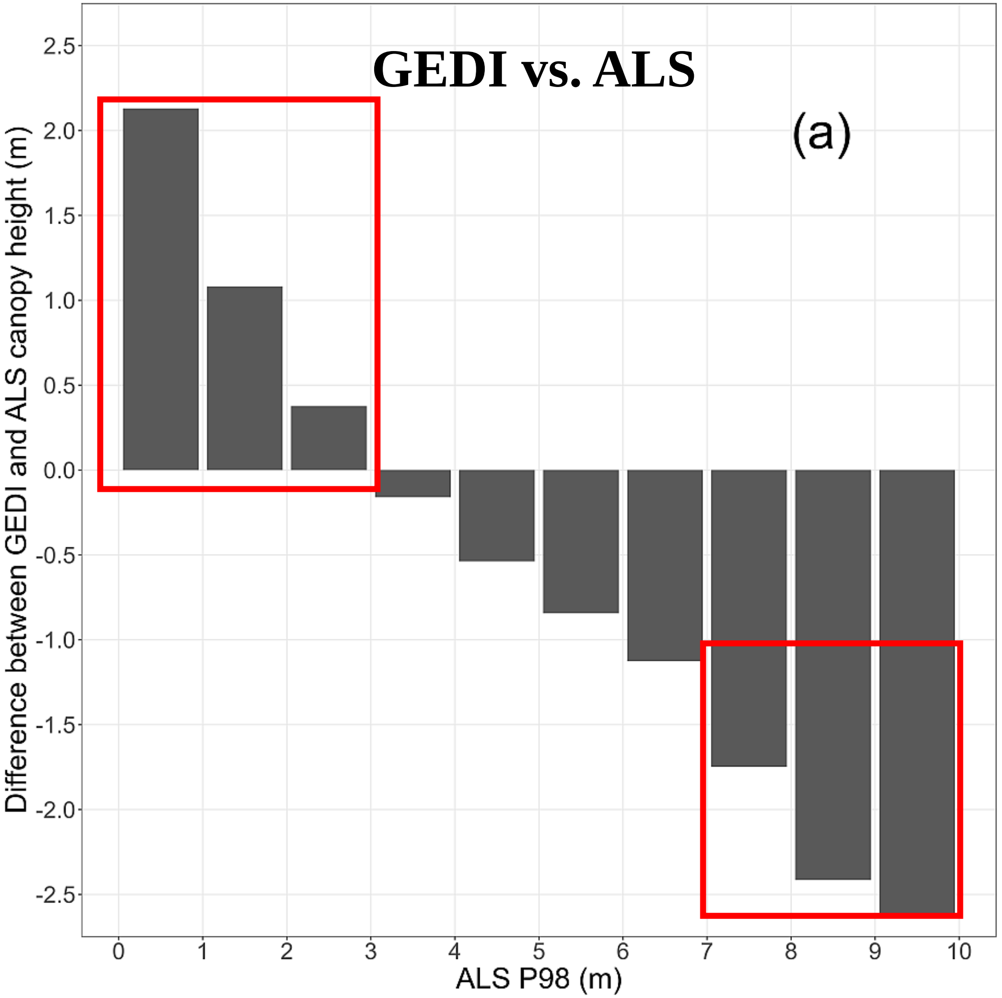


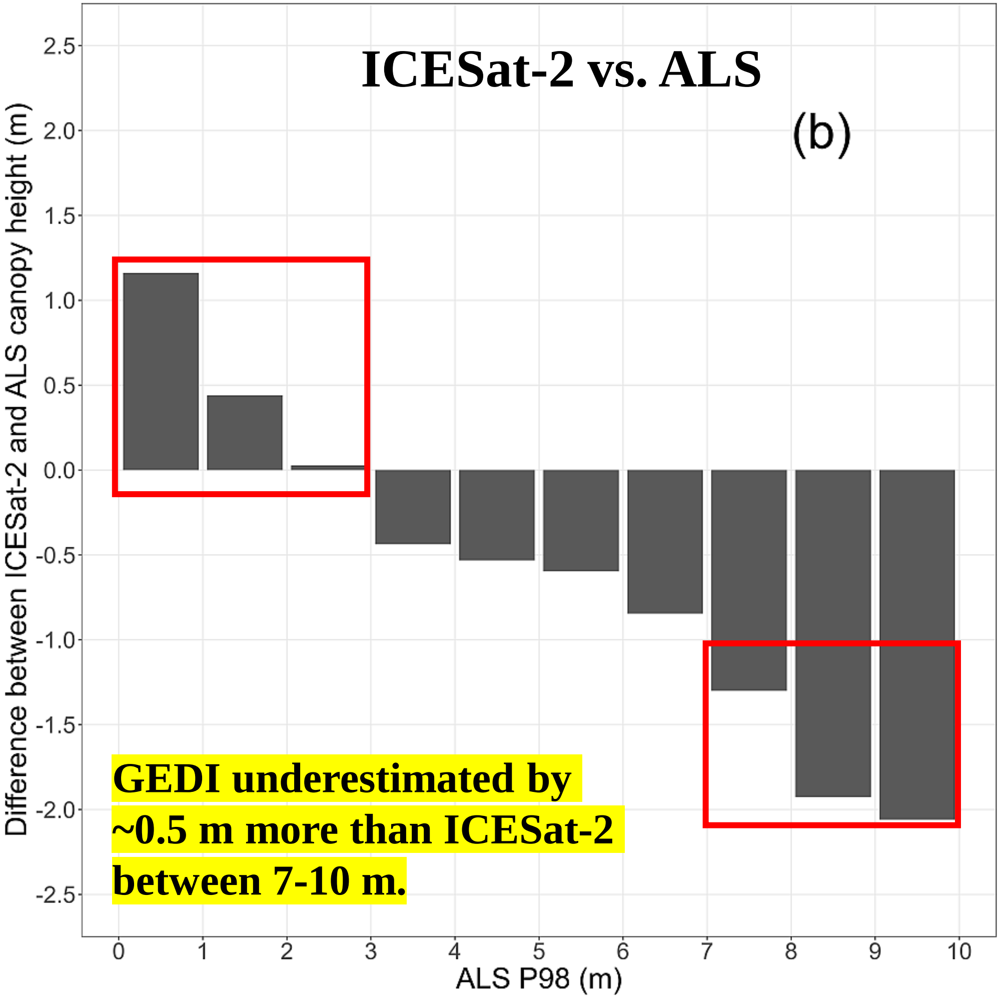


The scatterplots of GEDI RH98 (left) and ICESat-2 canopy height (right) vs. ALS P98.

Results: Mean Systematic Deviation (MSD) distribution

Shrubs < 3m





The distribution of GEDI RH98 (a) and ICESat-2 (b) canopy height vs. ALS P98.

Conclusions

- GEDI and ICESat-2 performed similarly in comparison to ALS.
- GEDI has a detectability limitation at 2.34 m, whereas ICESat-2 can effectively detect very low shrubs below that range, but still overestimates under 2m.
- The bias distribution of ICESat-2 canopy height consistently showed less underestimation (~0.5m less) than GEDI from 7 to 10 m.
- Given their comparable performance, these two space-based LiDAR may be combined to produce biomass maps in the future research. ICESat-2 could help improve the accuracy of GEDI canopy height estimates, especially in very low vegetated areas.

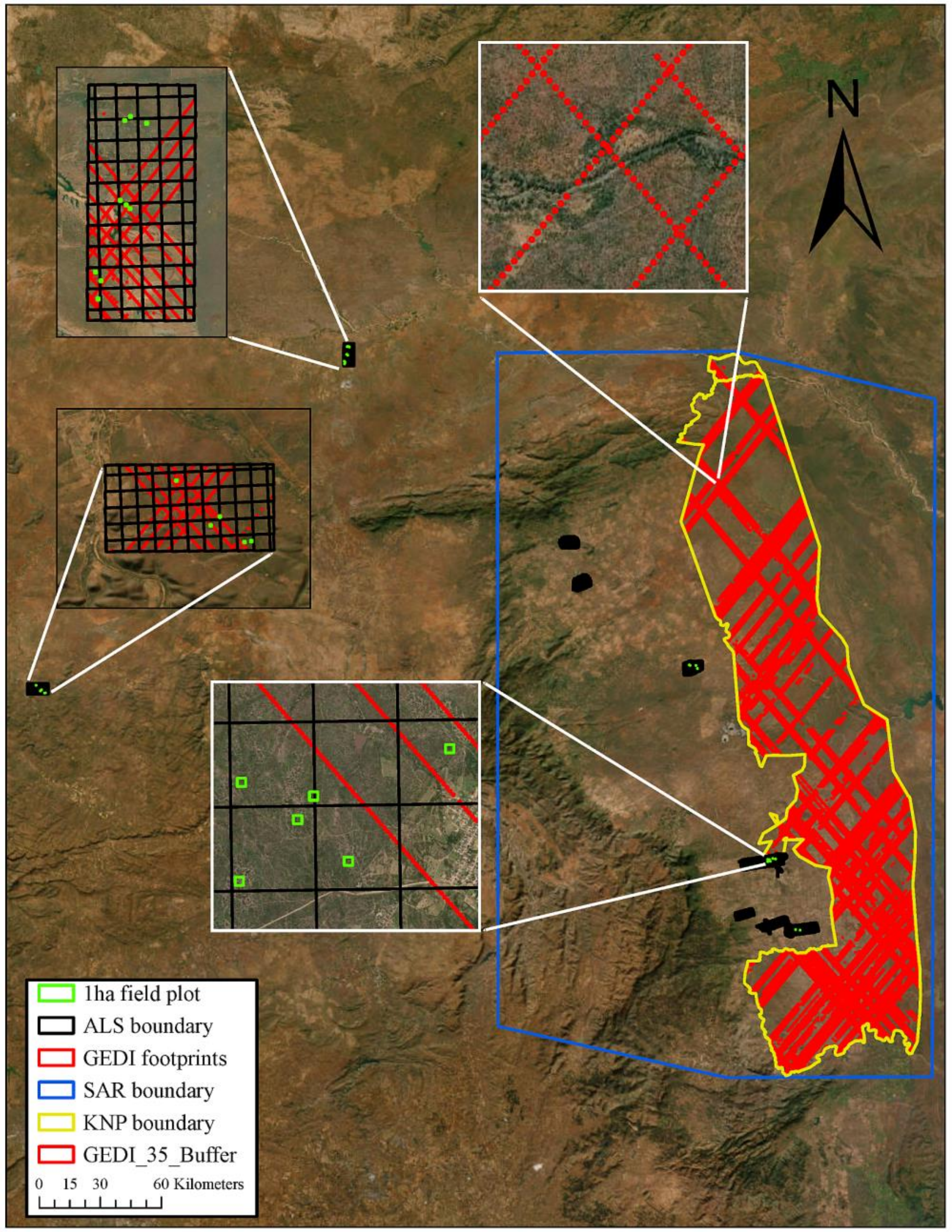
SAR-based AGBD Modeling Using Field, ALS and GEDI Data

Objectives:

- Leverage the availability of field plot, ALS, GEDI, and SAR data to develop multi-scale AGBD models
- Examine the contribution of including GEDI footprint-level AGBD (N = ~220,000) in an additional step in the SAR-based AGBD modeling.
- Implement error propagation analysis at each sample for multi-stage upscaling modeling scenarios using Monte Carlo simulations (Urbazaev et al., 2018).

Datasets used:

- 2018 field measurements
- 2018 Airborne LiDAR
- GEDI L1B, L2A, L2B, L4A data from 2019 to 2023
- ALOS-2 PALSAR-2 ScanSAR from 2014 to 2022 and Fine Beam SAR from 2017.

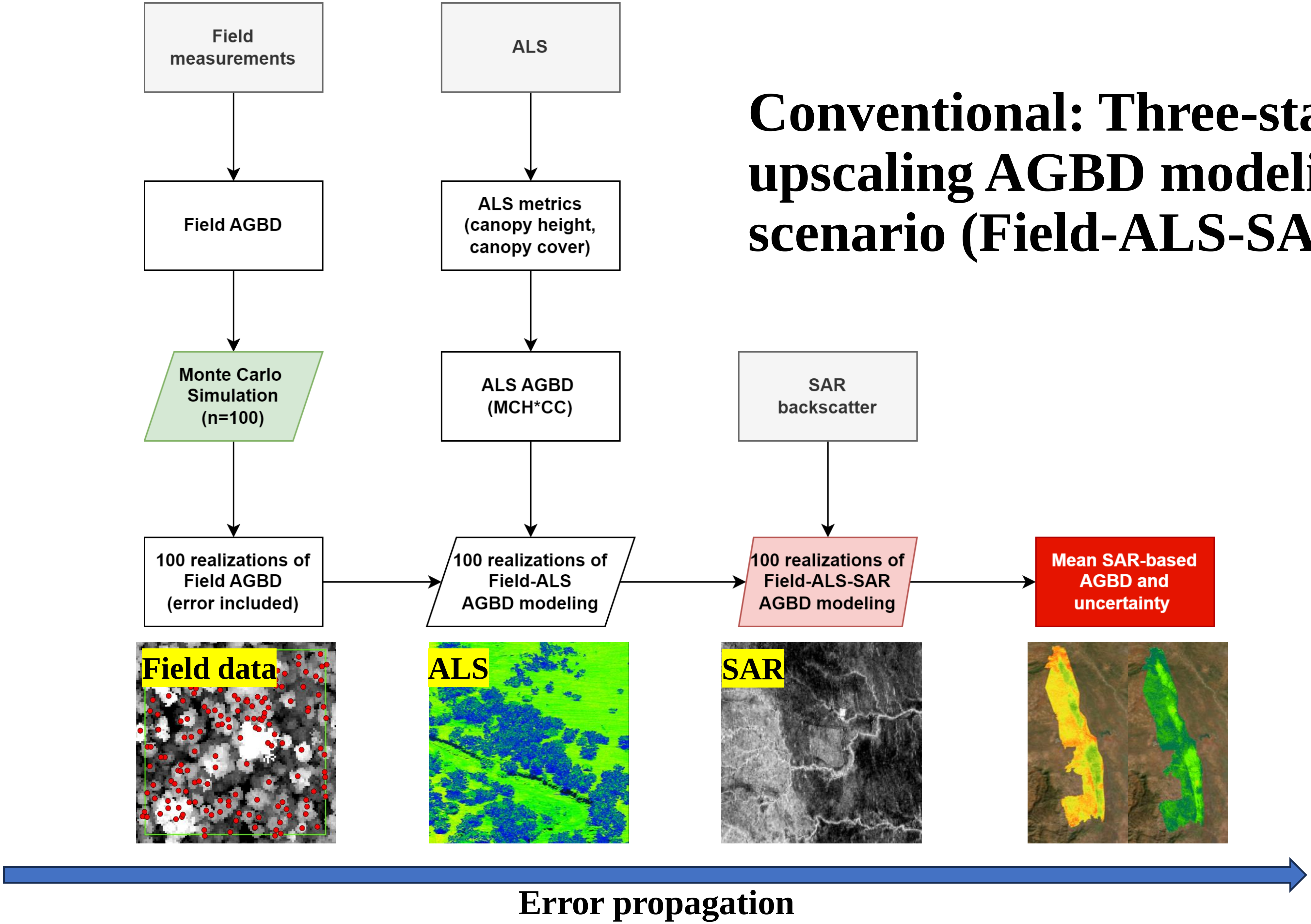


Uncertainty

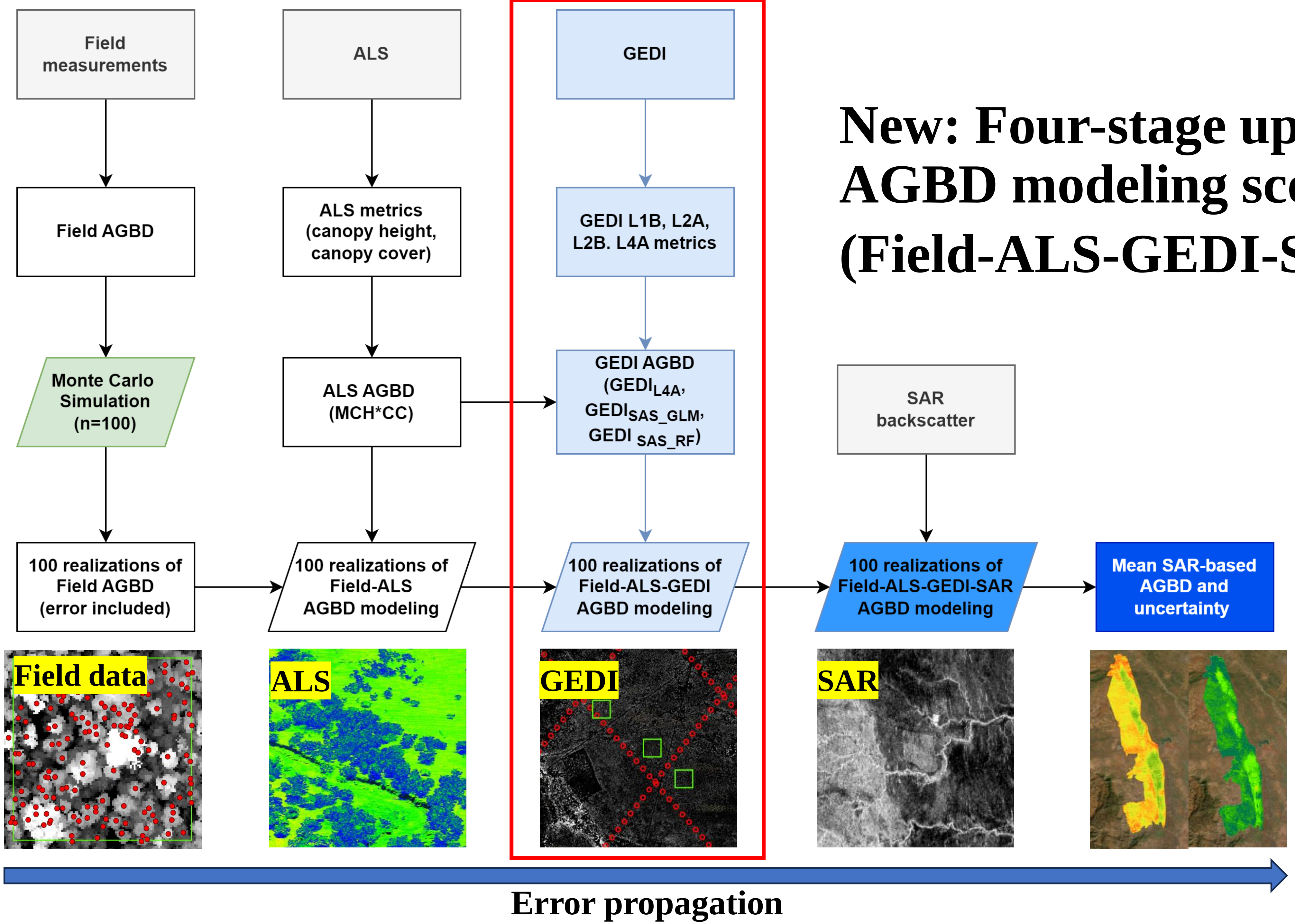
The IPCC specifies practice guidelines for greenhouse gas (GHG) inventories: "**uncertainties are reduced as far as practicable**".

- The uncertainties in SAR-based AGBD estimates were assessed by propagating errors from **field measurements (measurement error, allometry error, sampling error)**.
- The **Monte Carlo algorithm** was implemented for propagating uncertainties.
- 100 independent bootstrapped samples following **normal distribution** were generated per pixel.
- 100 predictive models were trained, each on one of the bootstrapped samples.
- We produced **mean AGBD map** by averaging the AGBD values and calculated the associated uncertainties using **95% confidence intervals**.
- The resulting uncertainty maps reflect the **precision** of SAR-based AGBD estimates based on the model inputs, **not necessarily their accuracy**.

Conventional: Three-stage upscaling AGBD modeling scenario (Field-ALS-SAR)



New: Four-stage upscaling AGBD modeling scenario (Field-ALS-GEDI-SAR)



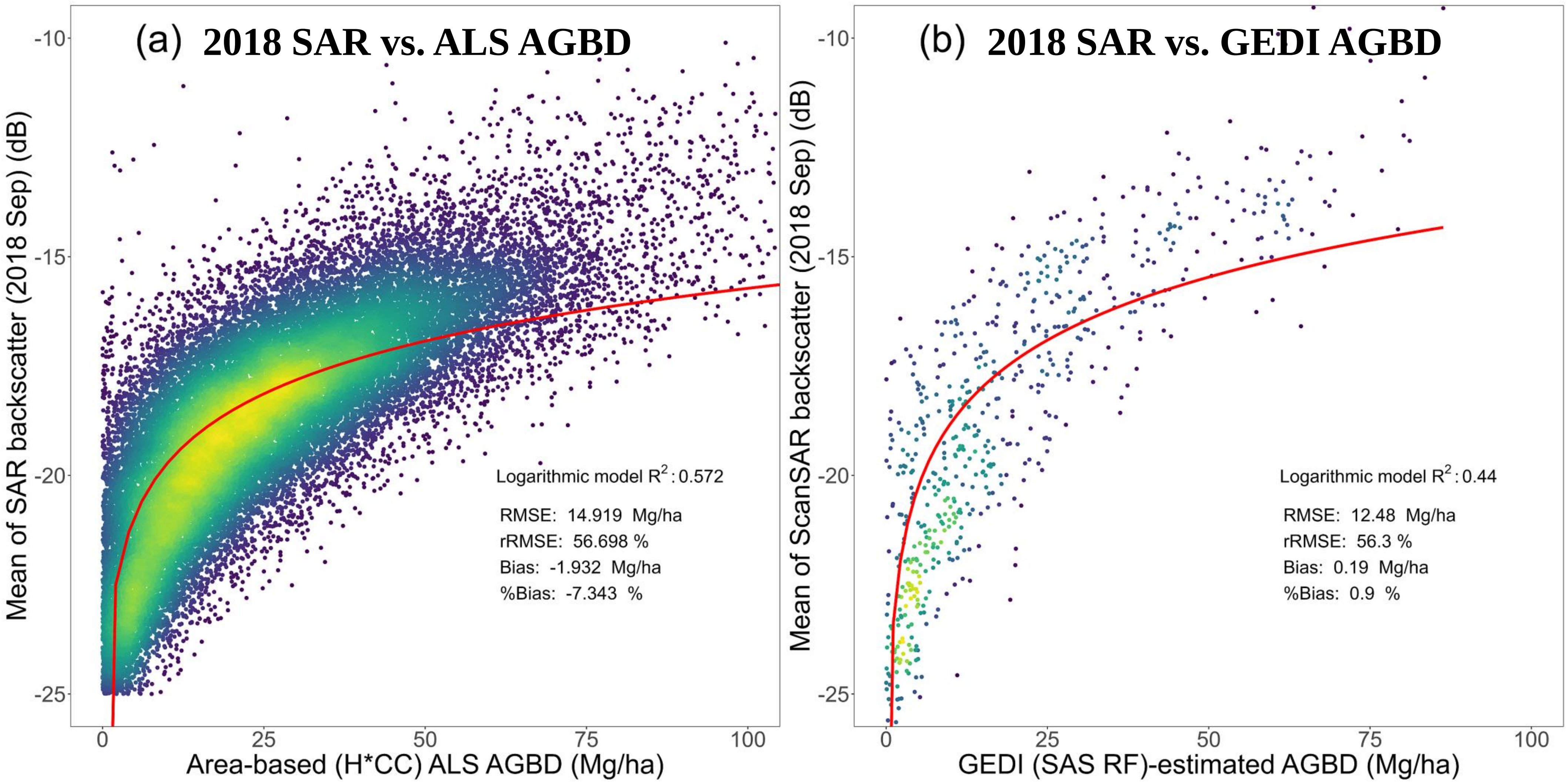
Results: Accuracy assessment of SAR backscatter vs. ALS-based AGBD for individual years

SAR date	SAR mode	ALS metrics	R^2	Bias	RMSE	%bias (%)	%RMSE (%)
20140906	ScanSAR	AGBD (Mg/ha)	0.52	-2.78	14.67	-10.7	56.5
20160903	ScanSAR	AGBD (Mg/ha)	0.55	-2.15	14.77	-8.2	56.2
20170706	FineBeam	AGBD (Mg/ha)	0.58	-2.47	11.58	-10.5	49.2
20170902	ScanSAR	AGBD (Mg/ha)	0.55	-2.17	15.84	-8.3	60.7
20180929	ScanSAR	AGBD (Mg/ha)	0.57	-1.93	14.92	-7.3	56.7
20190928	ScanSAR	AGBD (Mg/ha)	0.54	-2.47	14.32	-9.4	54.3
20200926	ScanSAR	AGBD (Mg/ha)	0.53	-2.65	14.21	-10.1	54.0
20210925	ScanSAR	AGBD (Mg/ha)	0.49	-3.19	15.01	-12.2	57.5
20220924	ScanSAR	AGBD (Mg/ha)	0.44	-3.87	16.06	-14.9	62.0

Results: Accuracy assessment of mean SAR backscatter vs. GEDI-based AGBD for 2014-2022

GEDI AGBD	R^2	Bias (Mg/ha)	RMSE (Mg/ha)	%bias (%)	%RMSE (%)
L4A	0.35	-2.33	9.22	-30.2	119.2
SAS (RF)	0.44	0.01	13.09	0.11	58.6
SAS (GLM)	0.42	1.64	17.18	7.47	76.8

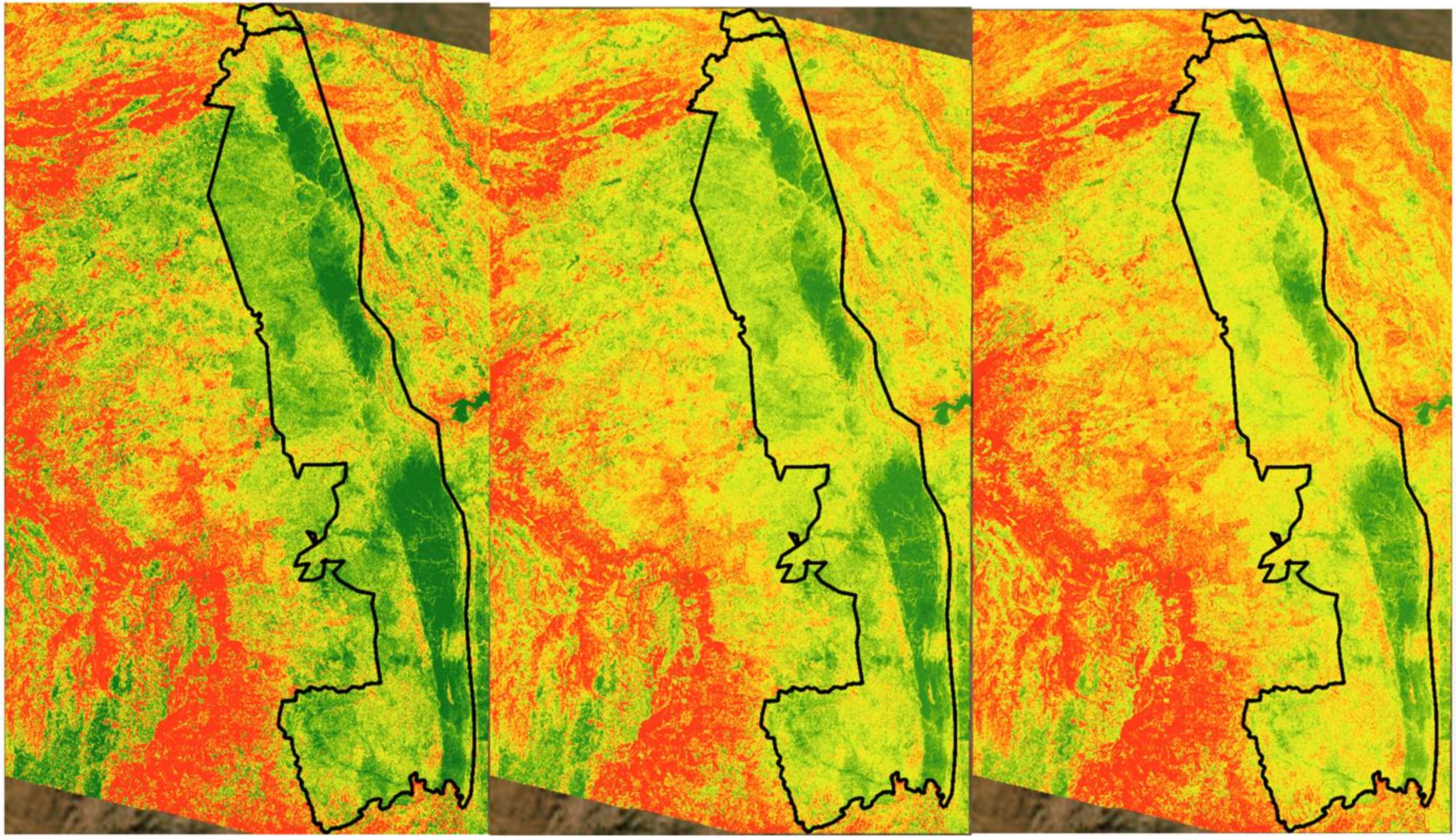
Results



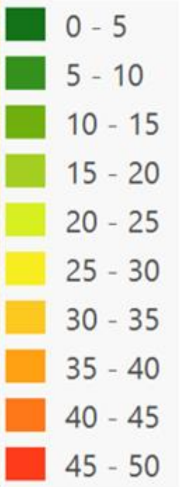
Density plots of 100 m aggregated 2018 ScanSAR HV backscatter and AGBD derived from ALS (a) and GEDI SAS RF (b).

Results:100 m SAR-based AGBD map using different modeling scenarios

(a) Field-ALS-SAR (b) Field-ALS-GEDI (RF)-SAR (c) Field-ALS-GEDI (GLM)-SAR



Model	Mean (STD) AGBD (Mg/ha)
a	15.5 (10)
b	19.1 (7.5)
c	23.4 (7.8)

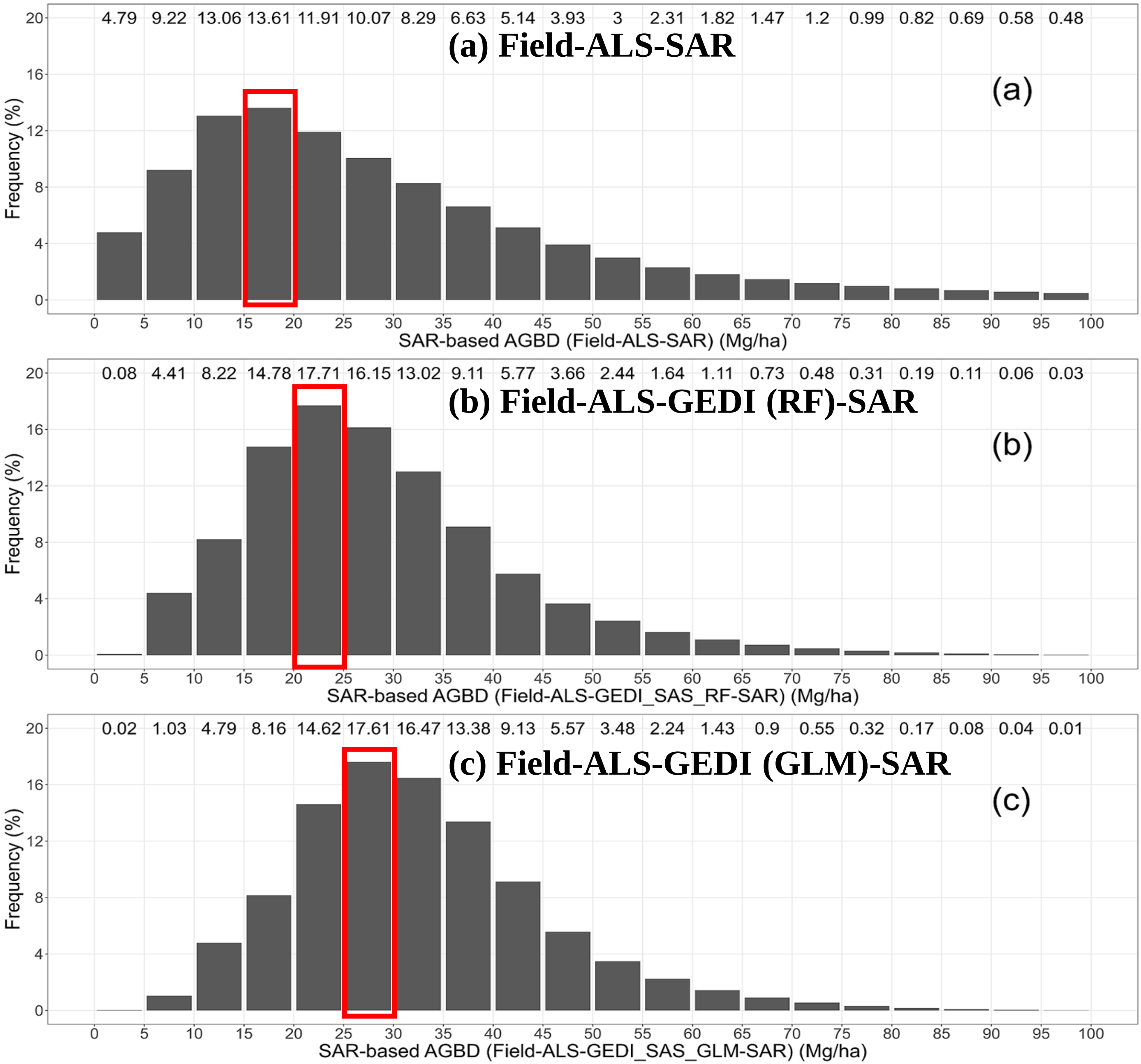


Results: Histogram (KNP only) of SAR-estimated AGBD based on different modeling scenarios

(a) field-ALS-SAR

(b) field-ALS-GEDI (RF)-SAR

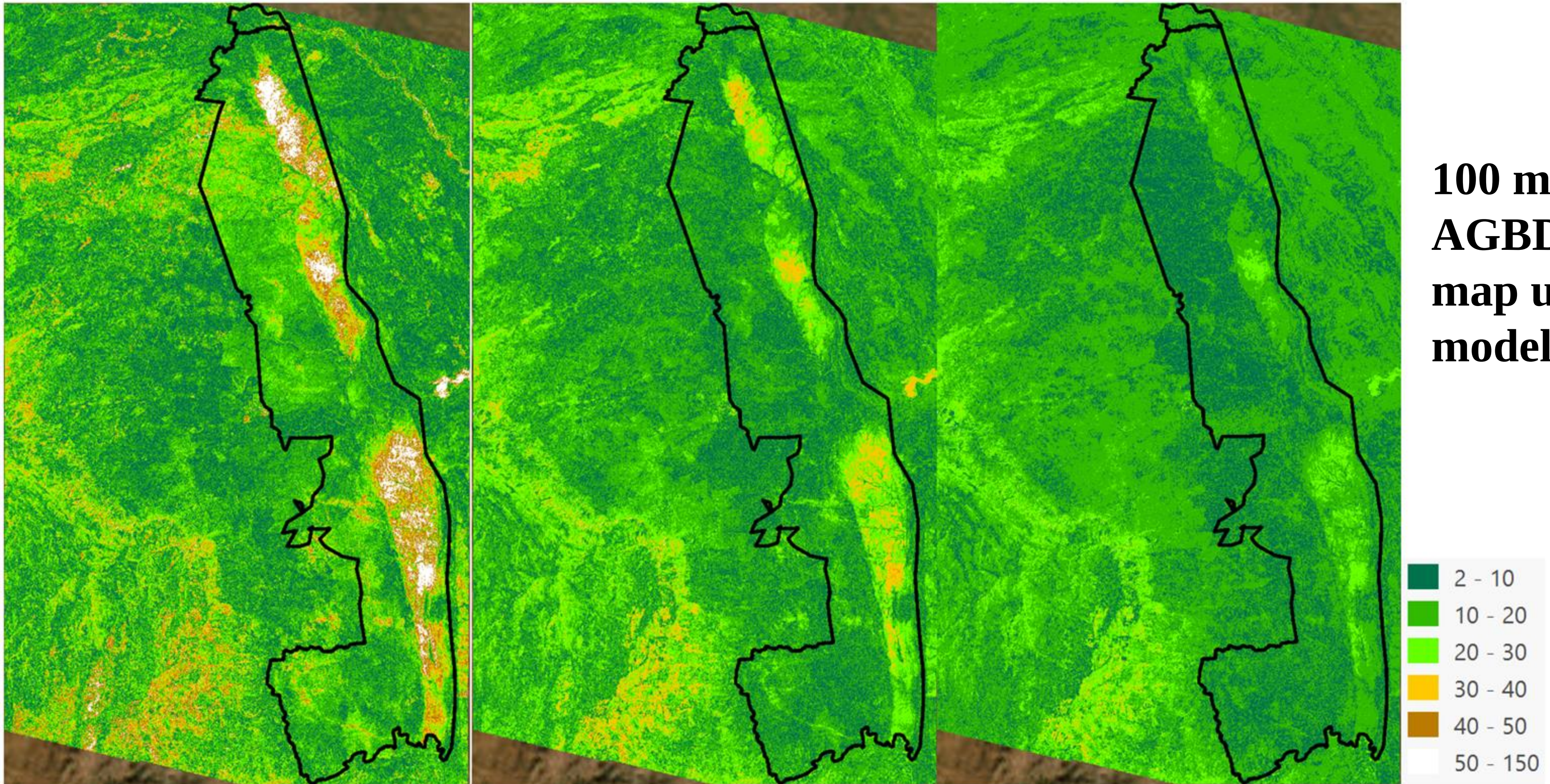
(c) field-ALS-GEDI (GLM)-SAR



Results

Model	Mean uncertainty (%)	STD uncertainty (%)	Min uncertainty (%)	Max uncertainty (%)
a	17.8	10.9	7.1	233.4
b	15.2	6.8	8.9	153.6
c	13.5	4.7	9.2	143.2

(a) Field-ALS-SAR (b) Field-ALS-GEDI (RF)-SAR (c) Field-ALS-GEDI (GLM)-SAR



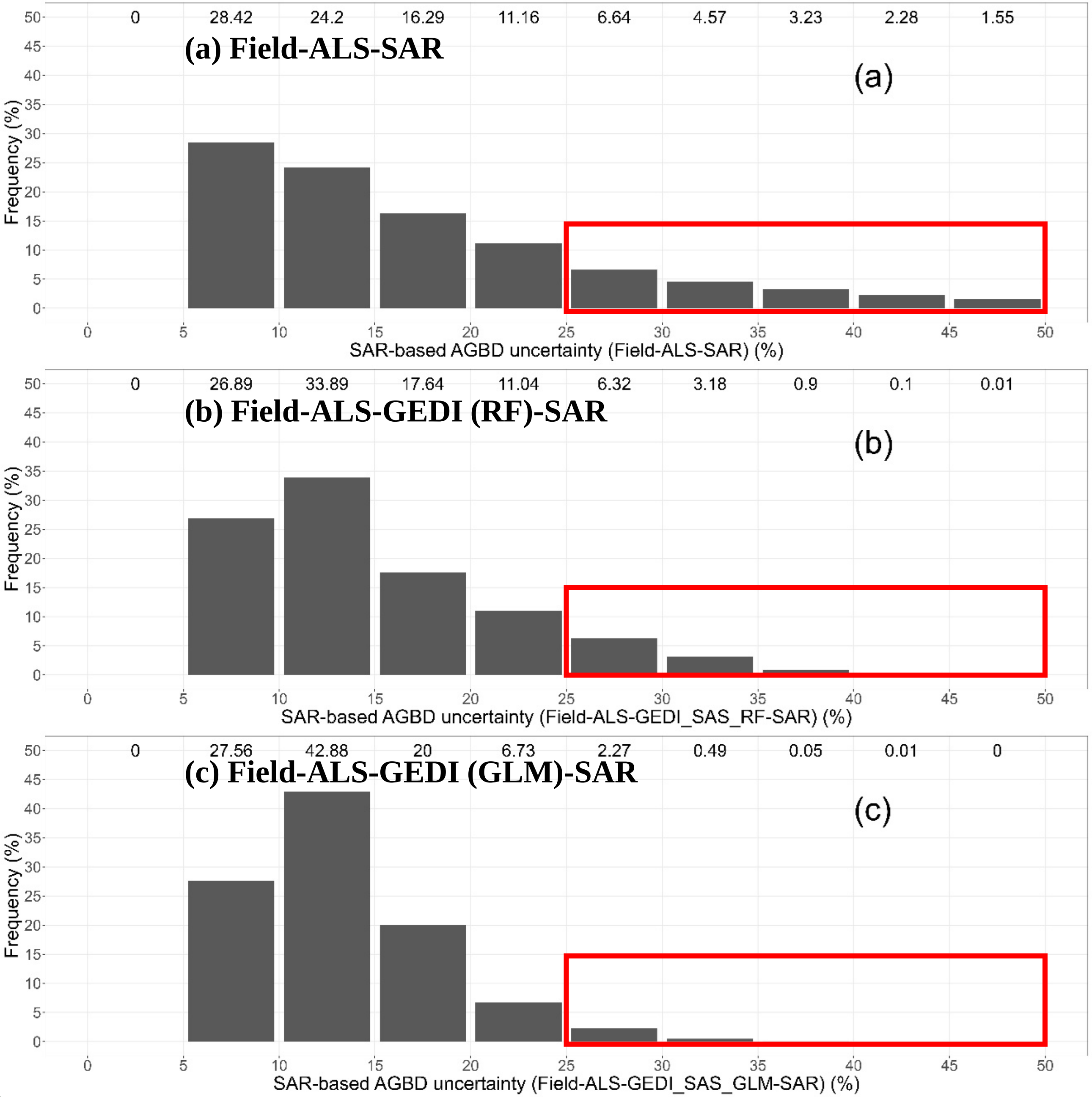
100 m SAR-based AGBD uncertainty map using different modeling scenarios

Results: Histogram (KNP only) of SAR-estimated AGBD uncertainty based on different modeling scenarios

(a) field-ALS-SAR

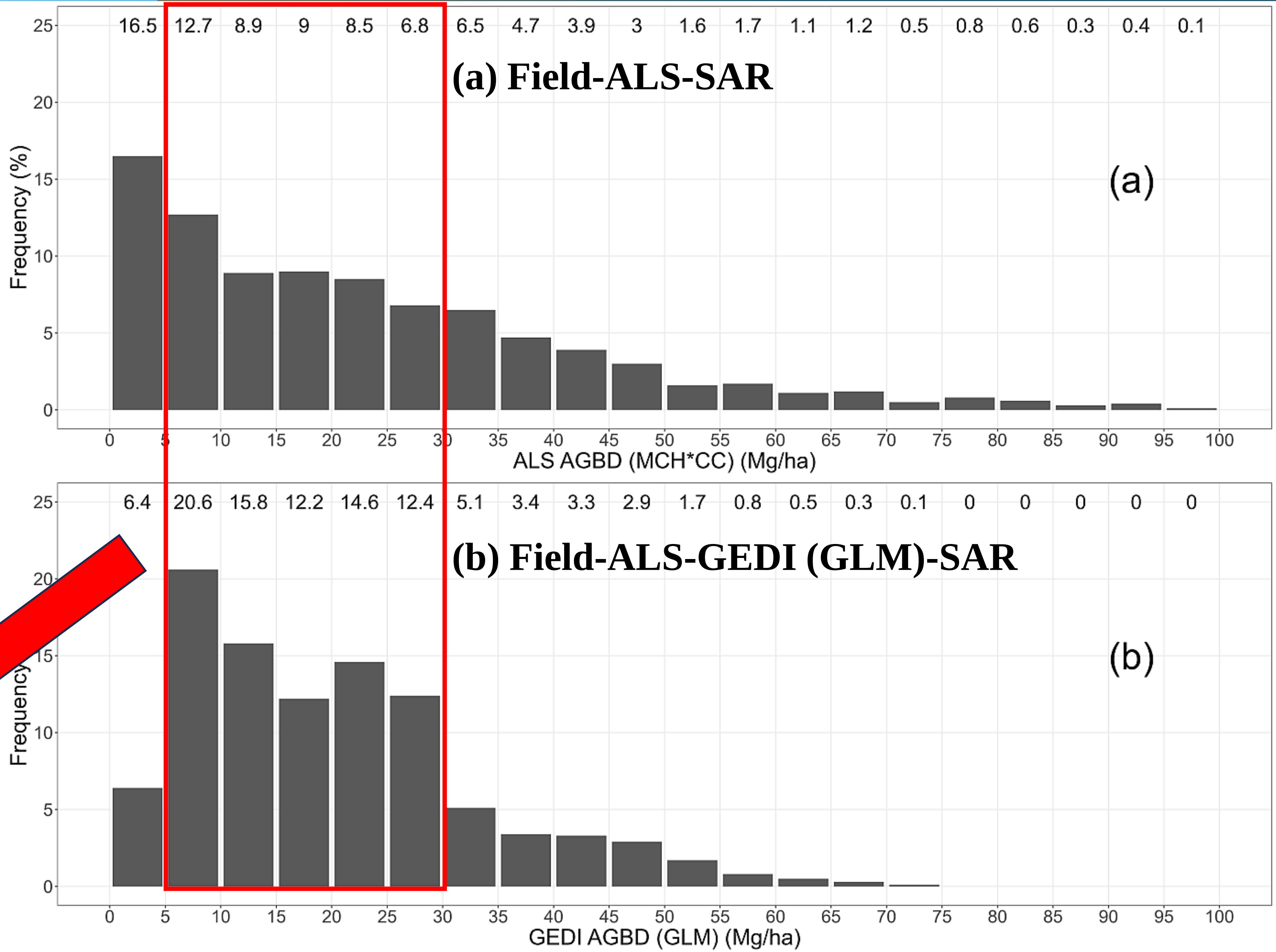
(b) field-ALS-GEDI (RF)-SAR

(c) field-ALS-GEDI (GLM)-SAR



Results: Histogram of
(a) ALS-based AGBD (MCH×CC)
(b) GEDI-based AGBD (GLM) as an example

This is the histogram for the reference data, not the resulting map product

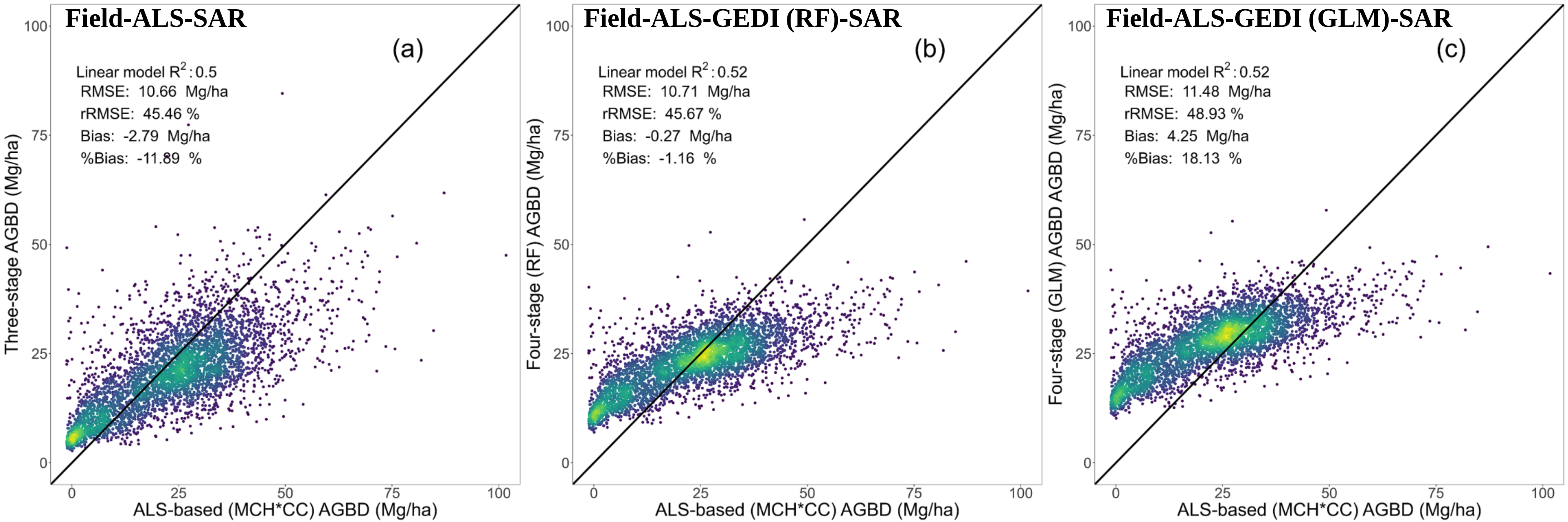


~30% more data within the bins between 5-30 Mg/ha in b than a

Results: Validation of SAR-based AGBD maps with 30% of ALS data

70% for modeling, 30% for independent validation

Model	R^2	Mean AGBD (Mg/ha)	RMSE (Mg/ha)	rRMSE (%)	Bias (Mg/ha)	%bias (%)
(a) Field-ALS-SAR	0.5	20.6	10.66	45.46	-2.79	-11.89
(b) Field-ALS-GEDI (RF)-SAR	0.52	23.1	10.71	45.67	-0.27	-1.16
(c) Field-ALS-GEDI (GLM)-SAR	0.52	27.8	11.48	48.93	4.25	18.13



Density plots of SAR-based AGBD based on multi-stage modeling scenarios (a: Field-ALS-SAR; b: Field-ALS-GEDI (RF)-SAR; c: Field-ALS-GEDI (GLM)-SAR) vs. ALS-based (MCH*CC) AGBD below 100 Mg/ha.

Conclusions

- The strong relationship between ALS-derived AGBD and SAR highlights the performance of SAR in predicting vegetation metrics.
- GEDI data as an additional reference dataset leads to lower AGBD uncertainty compared to the results using ALS only.
- GEDI AGBD could help improve the accuracy of large-scale SAR-based AGBD model in intermediate and high AGBD range.
- CMS team is working on statistical framework (e.g. GHMB) that propagates model error (Saarela et al., 2016), which maybe applied in the future research.

Impact of PhD research

Remote Sensing of Environment 284 (2023) 113369

Contents lists available at ScienceDirect

Remote Sensing of Environment

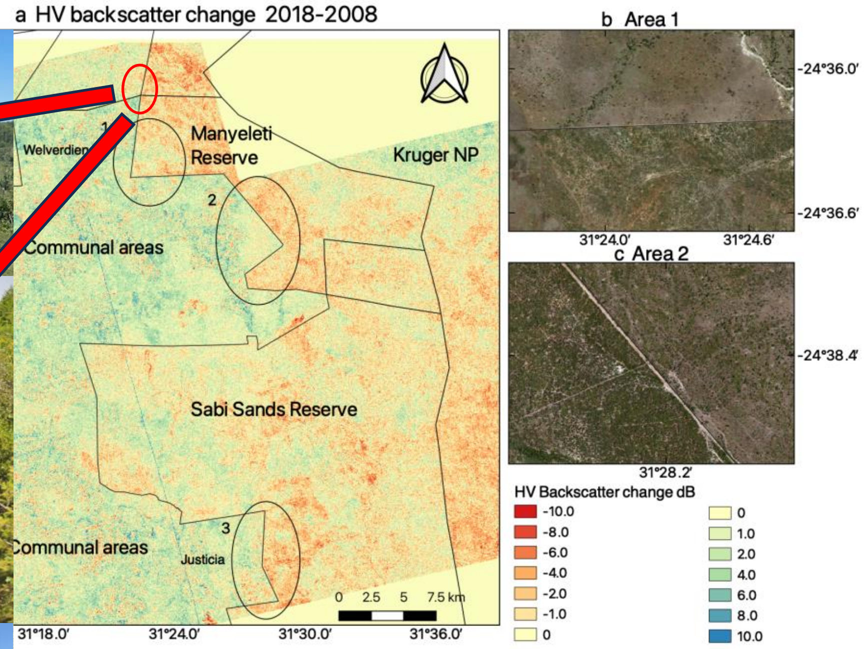
journal homepage: www.elsevier.com/locate/rse

Quantifying the sensitivity of L-Band SAR to a decade of vegetation structure changes in savannas

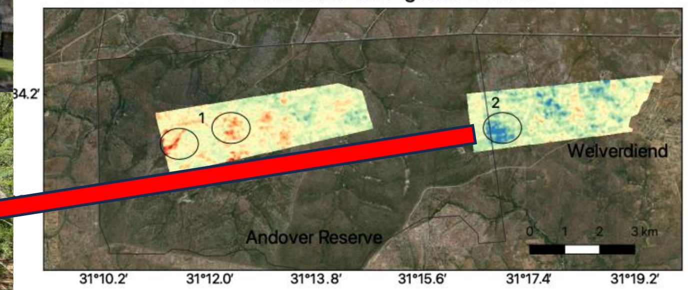
Konrad Wessels [a,*], Xiaoxuan Li [a], Alexandre Bouvet [b], Renaud Mathieu [c], Russell Main [d], Laven Naidoo [e], Barend Erasmus [f], Gregory P. Asner [g]

[a] Department of Geography and GeoInformation Science, George Mason University, Fairfax, VA, USA
[b] Centre d'Etudes Spatiales de la Biosphère (CESBIO), Université de Toulouse, CNES/CNRS/INRAE/IRD/UPS, Toulouse, France
[c] International Rice Research Institute, South Asia Research Center, Varanasi, India
[d] Council for Scientific and Industrial Research (CSIR), Pretoria, South Africa
[e] Gauteng City-Region Observatory (GCRO), Johannesburg, South Africa
[f] Faculty of Natural and Agricultural Sciences, University of Pretoria, South Africa
[g] Center for Global Discovery and Conservation Science, Arizona State University, Tempe, USA

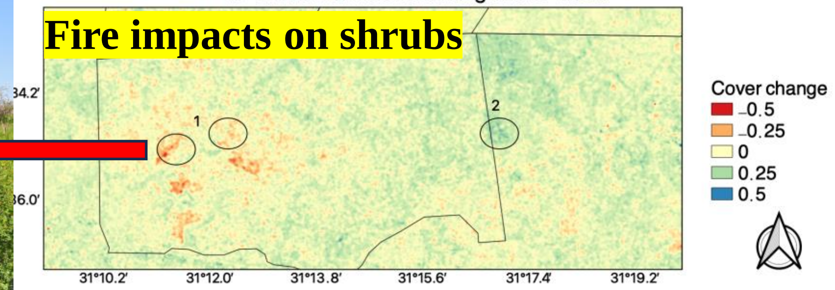
- First study to use rare repeat ALS datasets to demonstrate the sensitivity of L-band SAR to longer-term (8-10 year) changes in low biomass savannas (published in RSE, Jan 2023)
- Regional SAR-based maps of change captured management impacts in savannas.



Shrub encroachment,

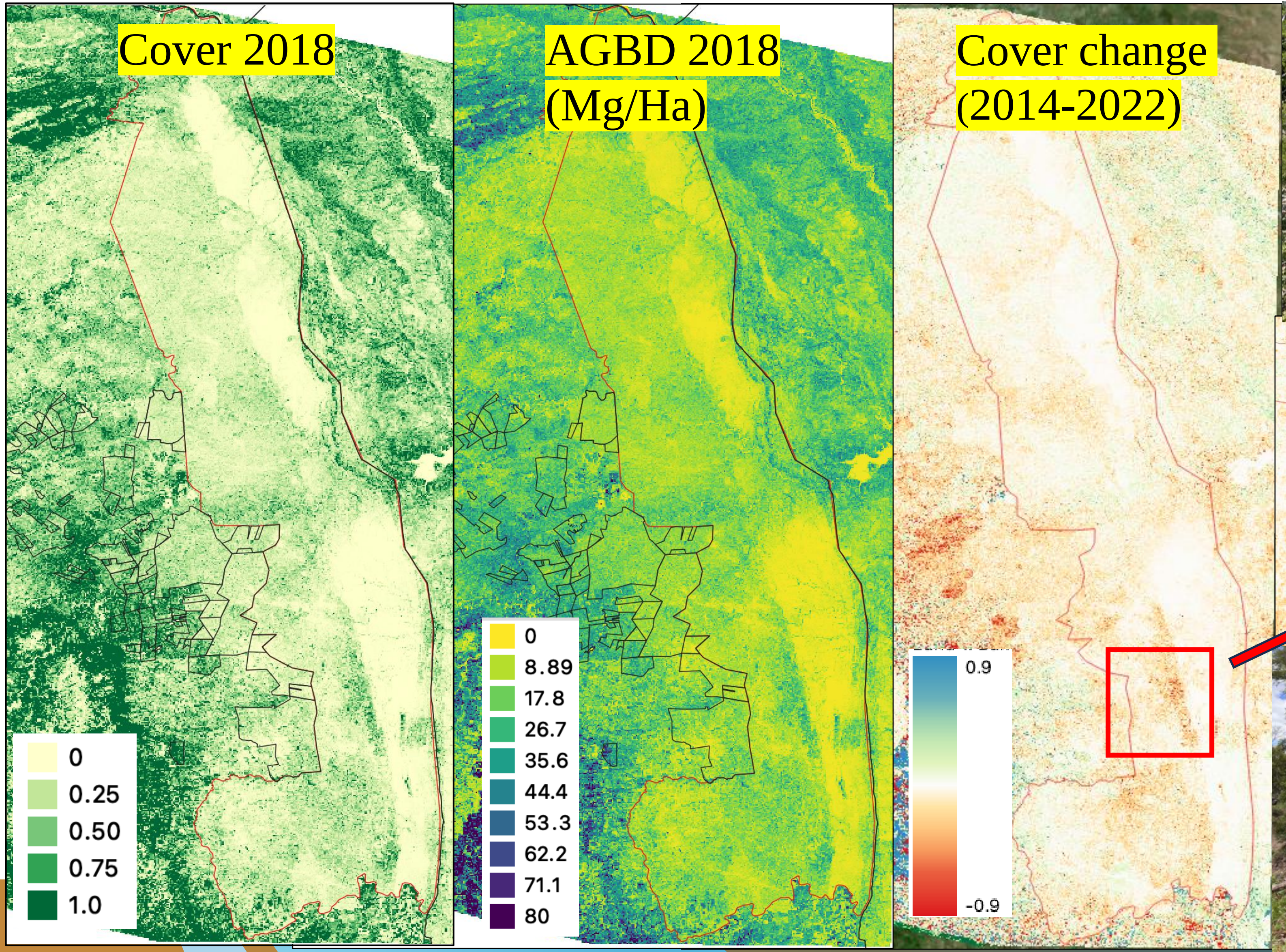


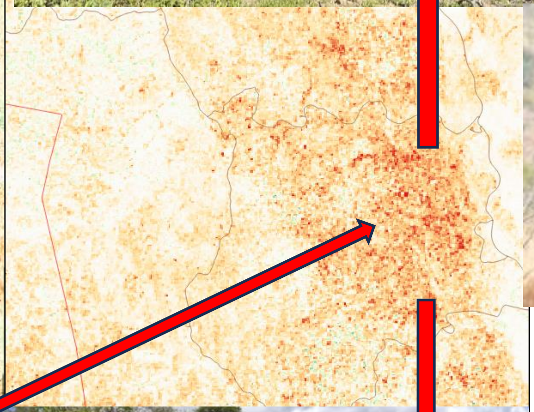
Fire impacts on shrubs



Impact of PhD research

- Produced annual ALOS PALSAR-2 ScanSAR cover, AGBD and change maps (2014-2022) (manuscript in progress)
- Used by **South African National Parks** as baseline to identify drivers of change, e.g. elephant impacts





South African NATIONAL PARKS

Elephant impacts on trees, Nov 2023

Novelty and Contributions

- The study provided the first baseline calibration and validation of spaceborne LiDAR (GEDI and ICESat-2) canopy height in southern African and anywhere in global savannas.
- This study validated GEDI L4A data products and developed locally calibrated footprint-level GEDI AGBD products using local field measurements and ALS in southern African savannas.
- This study developed SAR-based AGBD and uncertainty maps by leveraging L-band SAR with field measurements, ALS, and GEDI as reference.
- The SAR-based maps were used by South African National Parks and other stakeholders to identify areas of woody vegetation change and their potential causes.
- This work paves the way for forthcoming NASA/ISRO (NISAR) vegetation monitoring projects in global biomass savannas.

NASA/ISRO SAR (NISAR) is coming!

- Expected launch date: April 2024
- SAR resolution: 3–10 m mode-dependent
- NISAR is sensitive to low biomass of savannas.
- NISAR will observe Earth’s land surfaces globally on average every 6 days for a baseline 3-year mission.
- Our CMS projects are going to carry on with new field measurements and NISAR data.
- The follow-up projects will benefit from the knowledge and workflows of my PhD research.

CMS field work, Oct 2023

NISAR

NASA - ISRO SAR Mission

Acknowledgements

- PhD dissertation committee members (Konrad Wessels, John Armston, Paul Houser, John Qu, David Luther)
- George Mason University (Presidential Scholarship)
- UMD & CMS team (John Armston, Steven Hancock, Laura Duncanson, Mikhail Urbazaev)
- CSIR colleagues (Laven Naidoo, Russell Main, Renaud Mathieu)

Related Publications

- **Li, X.,** Wessels, K., Armston, J., Duncanson, L., Urbazaev, M., Naidoo, L., Mathieu R., & Main, R. (2023). Evaluation of GEDI Footprint-level Biomass Models in Southern African Savannas using ALS and Field Measurements. (In progress)
- **Li, X.,** Wessels, K., Armston, J., Hancock, S., Mathieu, R., Main, R., ... & Scholes, R. (2023). First validation of GEDI canopy heights in African savannas. **Remote Sensing of Environment**, 285, 113402.
- Wessels, K., **Li, X.**, Bouvet, A., Mathieu, R., Main, R., Naidoo, L., ... & Asner, G. P. (2023). Quantifying the sensitivity of L-Band SAR to a decade of vegetation structure changes in savannas. **Remote Sensing of Environment**, 284, 113369.

Related Talks & Presentations

- **Li, X.** (2023). Space-based LiDAR for Estimating Vegetation Structure in Savannas, **University of Washington**, May 18th, Seattle, WA.
- Urbazaev, M., Armston, J., **Li, X.**, Wessels, K., Duncanson, L., Bhogapurapu, N., Siqueira, P. (2023). Improving the applicability of canopy structure measurements from GEDI and ICESat-2 to global savannas, Dec 11th, San Francisco, CA.
- Bhogapurapu, N., Siqueira, P., Armston, J., **Li, X.**, Urbazaev, M., Wessels, K., Duncanson, L. (2023). Forest canopy height estimation using C- and L-band InSAR coherence over savannas and dry forests, Dec 11th, San Francisco, CA.
- Urbazaev, M., Armston, J., **Li, X.**, Wessels, K., Duncanson, L., Bhogapurapu, N., Siqueira, P. (2023). The Efficacy of GEDI and ICESat-2 for Estimation of Vegetation Cover and Height in Savannas, June 21st, Toulouse, France.
- Bhogapurapu, N., Siqueira, P., Armston, J., **Li, X.**, Urbazaev, M., Wessels, K., Duncanson, L. (2023). Large-Scale Canopy Height Estimation using C-band InSAR Correlation, June 21st, Toulouse, France.
- **Li, X.**, Wessels, K., Armston, J., Duncanson, L., Urbazaev, M., Hancock, S., Mathieu, R., Main, R., Naidoo, L., & Erasmus, B. (2022). Comparison of GEDI and ICESat-2 Terrain and Canopy Height Estimates in African Savanna Vegetation, **American Geophysical Union Annual Meeting**, December 15th, Chicago, IL.
- Bhogapurapu, N., Siqueira, P., Armston, J., **Li, X.**, Urbazaev, M., Wessels, K., Duncanson, L. (2022). Temporal analysis of C-band InSAR decorrelation for canopy height mapping over dry forests and tropical savannas, **American Geophysical Union Annual Meeting**, December 15th, Chicago, IL.
- **Li, X.**, Wessels, K., Armston, J., Hancock, S., Mathieu, R., Main, R., Naidoo, L., Erasmus, B., & Scholes, R. (2021). First Validation of GEDI Canopy Height in African Savannas, **American Geophysical Union Annual Meeting**, December 13th, New Orleans, LA.
- **Li, X.**, Wessels, K., Armston, J., Hancock, S., Mathieu, R., Main, R., Naidoo, L., Erasmus, B., & Scholes, R. (2020). First Validation of GEDI Vegetation Structure Metrics in South African Savannas, **American Geophysical Union Annual Meeting**, December 8th, online.