An Assessment of SAOCOM L-Band Pol-InSAR Capabilities For Canopy Height Estimation: A Case Study Over Managed Forests In Argentina

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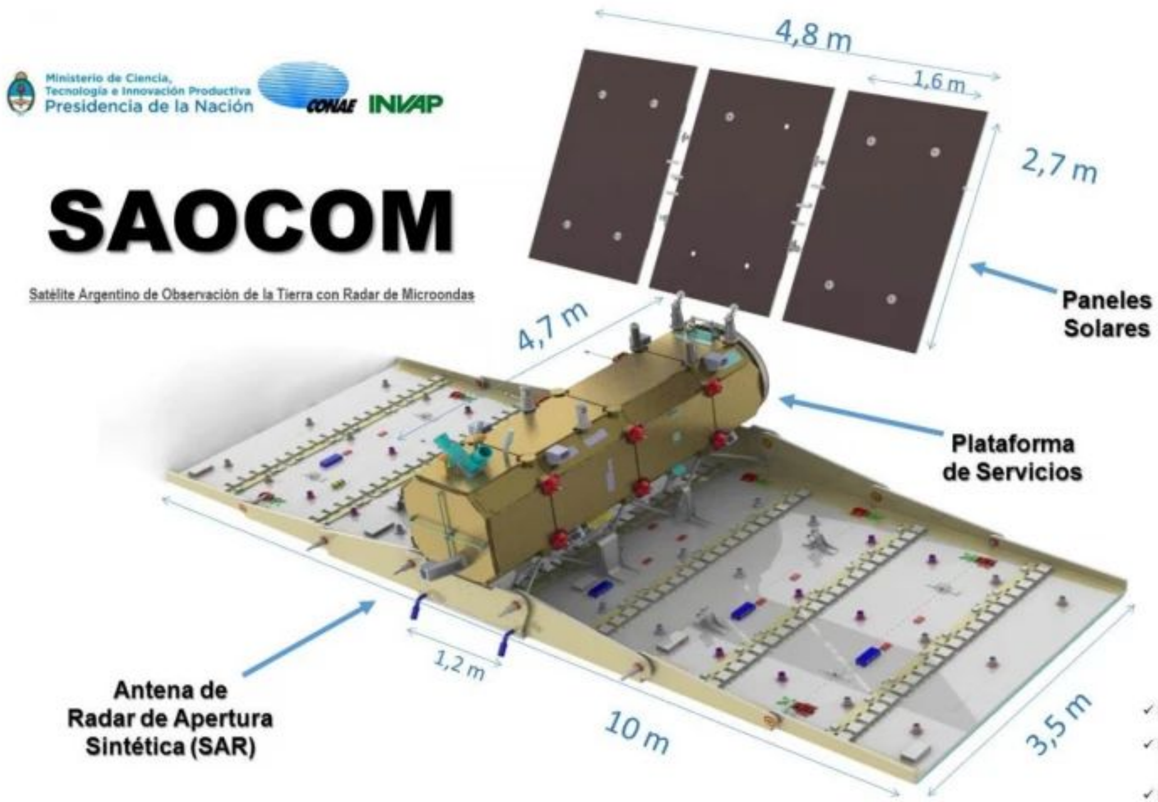
Introduction - CONAE and the SAOCOM Mission

Satélite Argentino de Observación con Microondas (SAOCOM)



Instrument Frequency	L-Band (1.27 GHz)
Spatial Resolution	10 to 100 m.
Swath Width	20 - 350 km
Satellites	2 (SAOCOM 1A and 1B
Revisit time	16 days (8 constellation)

Dimensiones del SAOCOM 1A:

- ✓ Peso: 3 toneladas.
- ✓ Plataforma de Servicios: 4,7 m de altura y 1,2 m de lado.
- ✓ Paneles Solares: 3 paneles. 1,61 m x 2,69 m cada uno.
- ✓ Antena SAR: 10 m de largo y 3.5 m de alto.

Agenzia Spaziale Italiana

Introduction - Research Goals

General Goal:

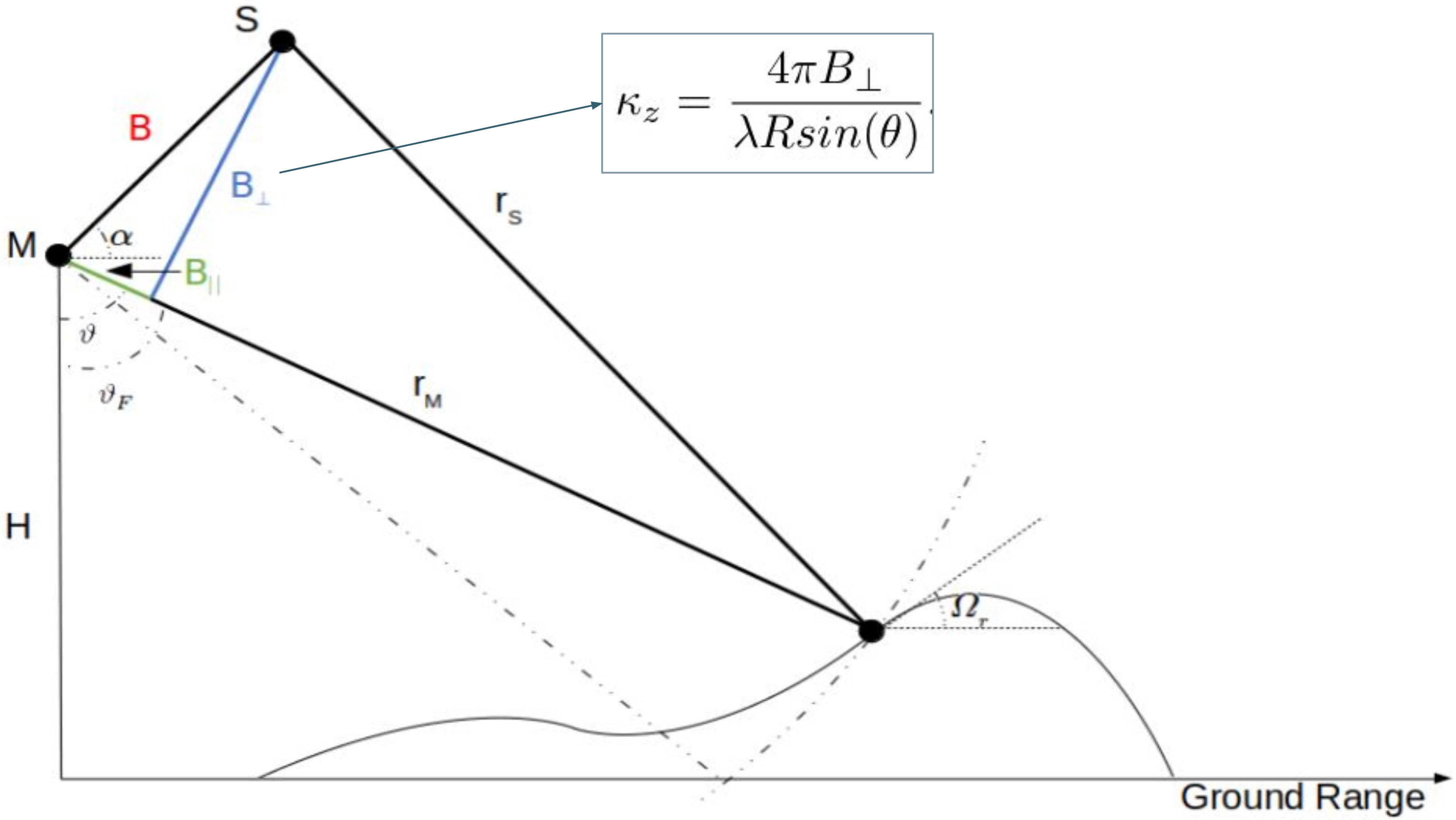
- To assess the polarimetric-interferometric capabilities of the SAOCOM-1 constellation to map forest stand heights in Argentina.

Research questions:

- What is the behaviour of the interferometric coherence in short-temporal baseline interferometric pairs of SAOCOM-1 L-band images?
- What is the capability of the Random Volume over Ground (RVoG) model to retrieve forest heights using L-band orbital data? Whats is the effect or role of the spatial baseline in this context?

Materials and methods: InSAR Basics

InSAR configuration



$$\kappa_z = \frac{4\pi B_\perp}{\lambda R sin(\theta)}$$

Complex coherence

$$\gamma_{12} = \frac{\langle S_1 S_2^* \rangle}{\sqrt{\langle |S_1|^2 \rangle \langle |S_2|^2 \rangle}}$$

$|\gamma_{12}|$ Magnitude (correlation)

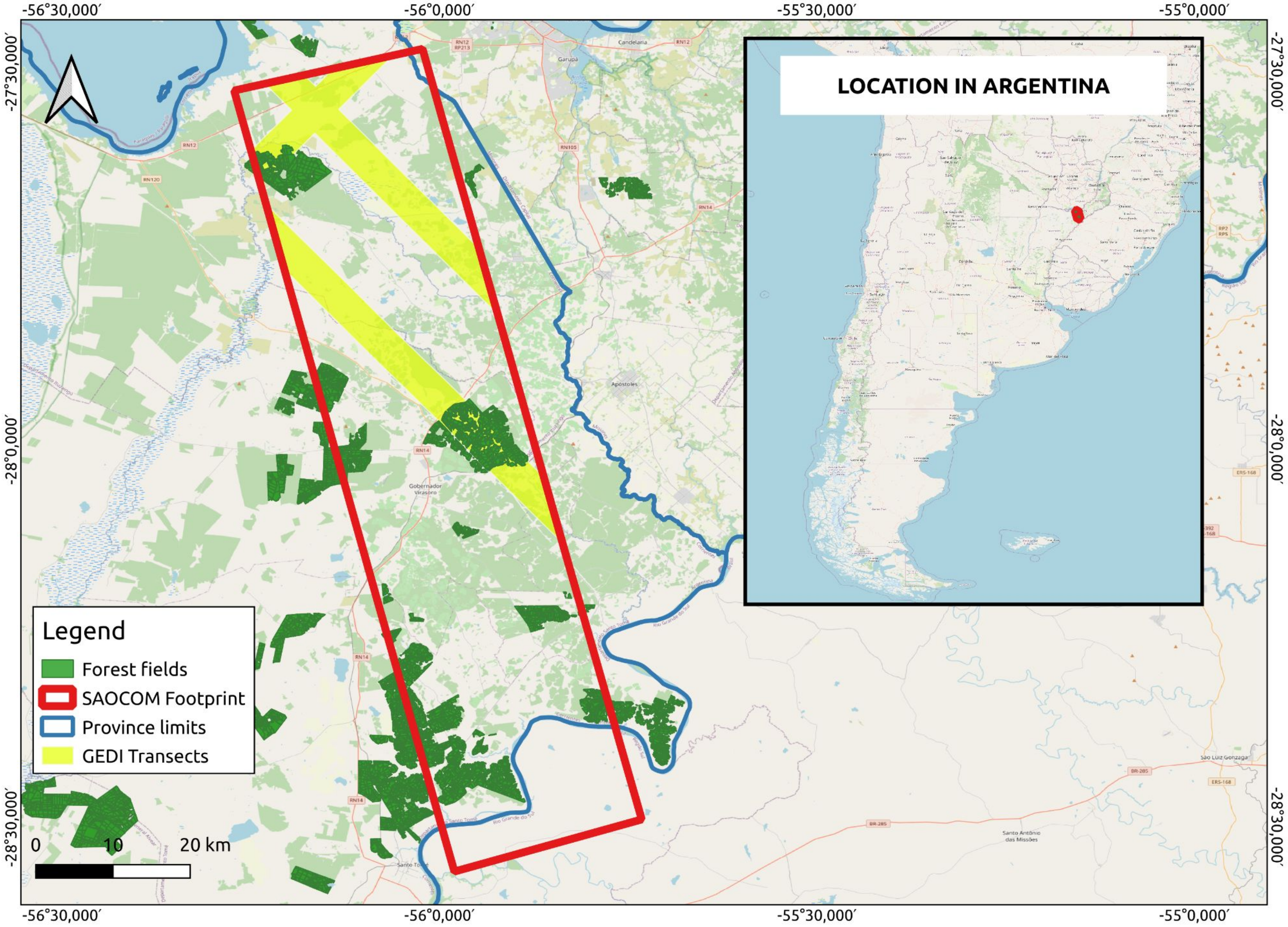
$arg(\gamma_{12})$ Interferometric phase

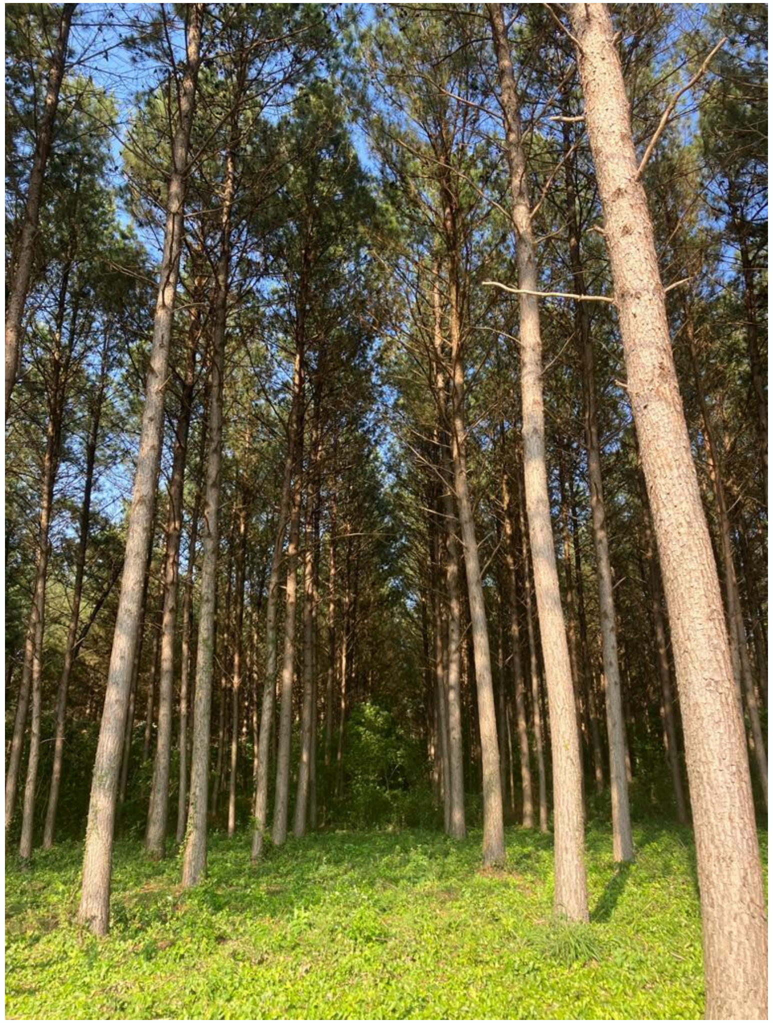
Decorrelation sources

$$\gamma_{12} = \gamma_{vol} \cdot \gamma_{sys} \cdot \gamma_{tmp}$$

RVoG → PolInSAR

Materials and Methods: Study Area





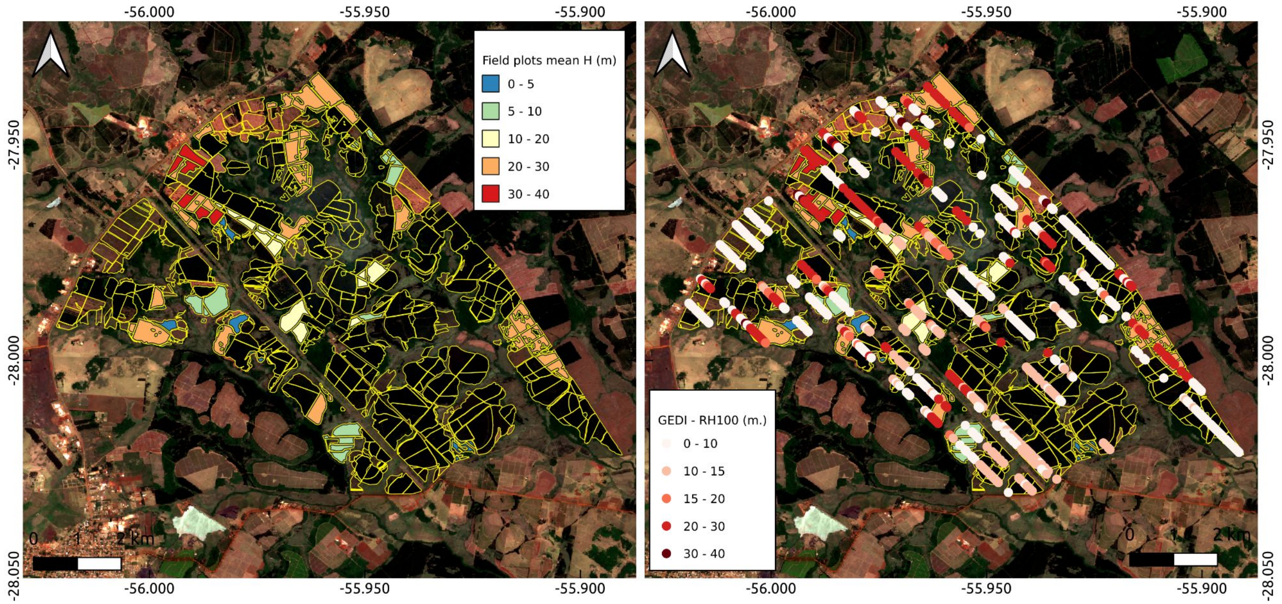
Pinus Taeda - 18 yr.

Materials and Methods: Datasets

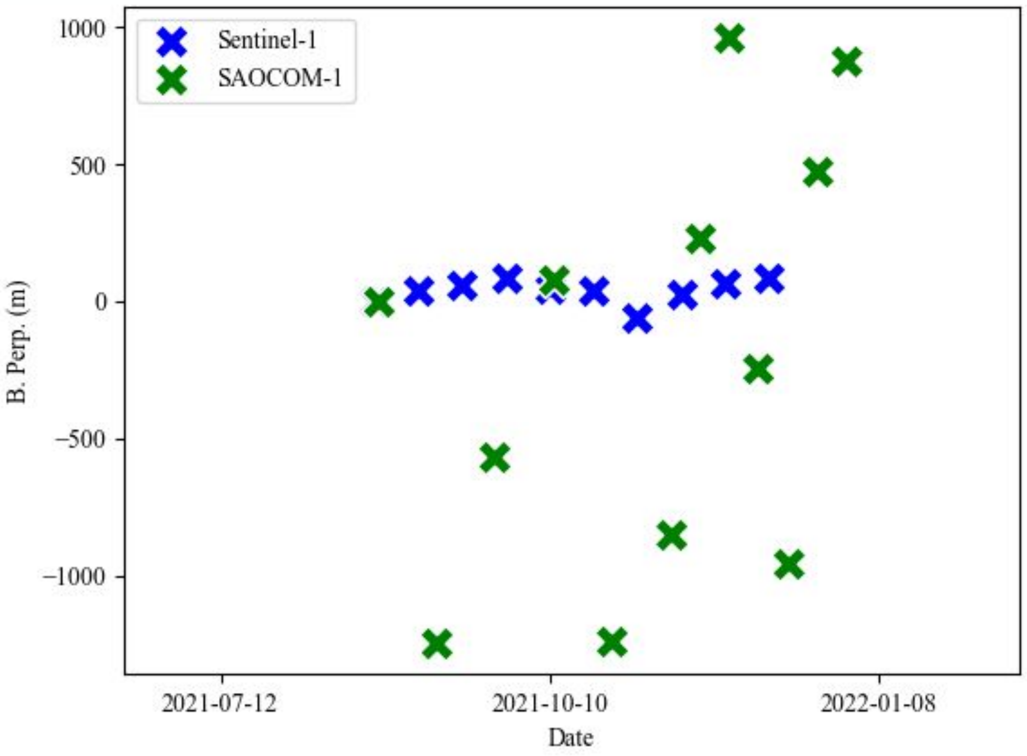
SAOCOM and S1 Datasets

Platform	Pass	$\theta°$	Pol.	N
SAO-1A	A	32	QP	9
SAO-1A	D	19	QP	6
SAO-1B	A	32	QP	3
S1	D	40	VV/VH	10

Field plots and GEDI transects

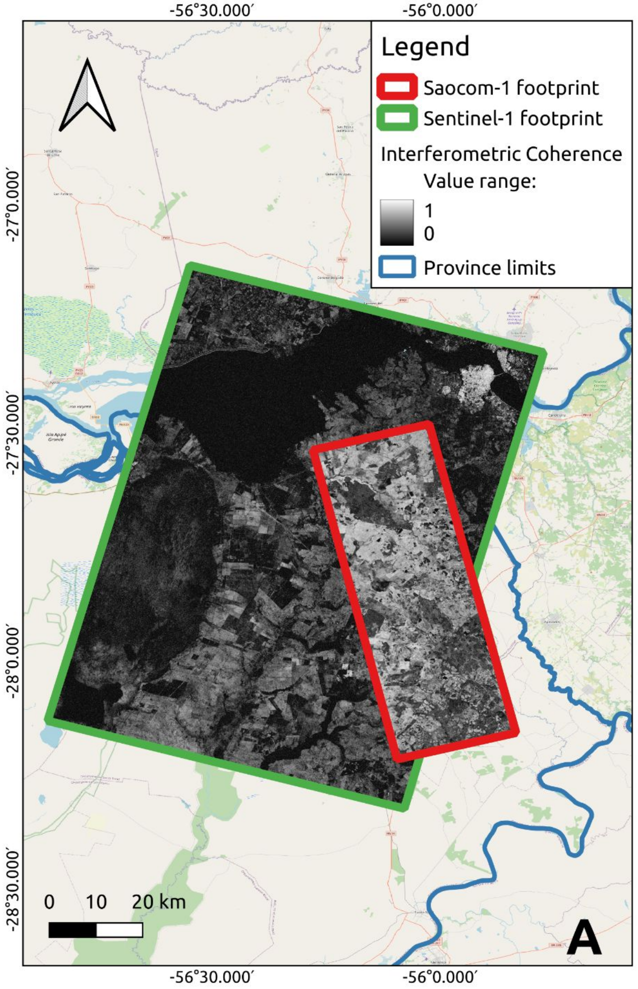


Temporal - Spatial baselines

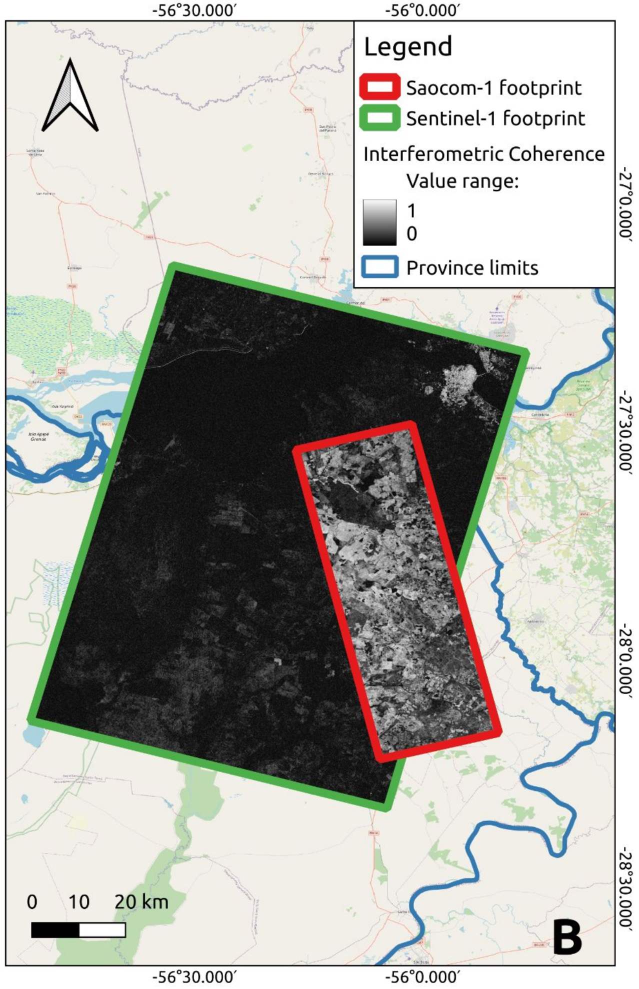


Results: Exploratory Assessment - Temporal Coh.

Sentinel-1 vs SAOCOM



16 d. (SAO) - 12 d. (S1)

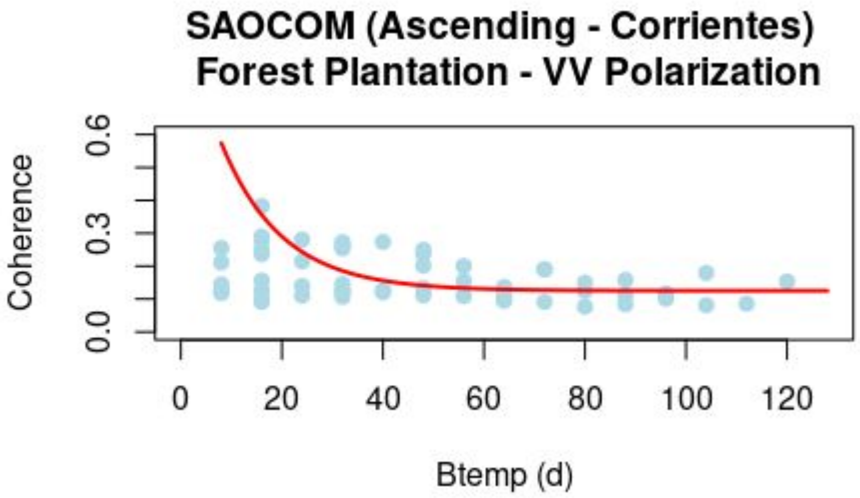


48 d. (SAO) - 48 d. (S1)

$$\gamma_{12} = \gamma_{vol} \cdot \gamma_{sys} \cdot \gamma_{tmp}$$

$$\gamma_{tmp}(t) = (1 - \gamma_{\text{inf}})e^{-t/\tau} + \gamma_{\text{inf}}$$

Sica, F., Pulella, A., Nannini, M., Pinheiro, M., & Rizzoli, P. (2019)



$\tau = 12$ day and $\gamma_{\text{inf}} = 0.125$

Results: Exploratory Assessment - Volume Coh.

$$\gamma_{12} = \boxed{\gamma_{vol}} \cdot \gamma_{sys} \cdot \gamma_{tmp}$$

RVoG:

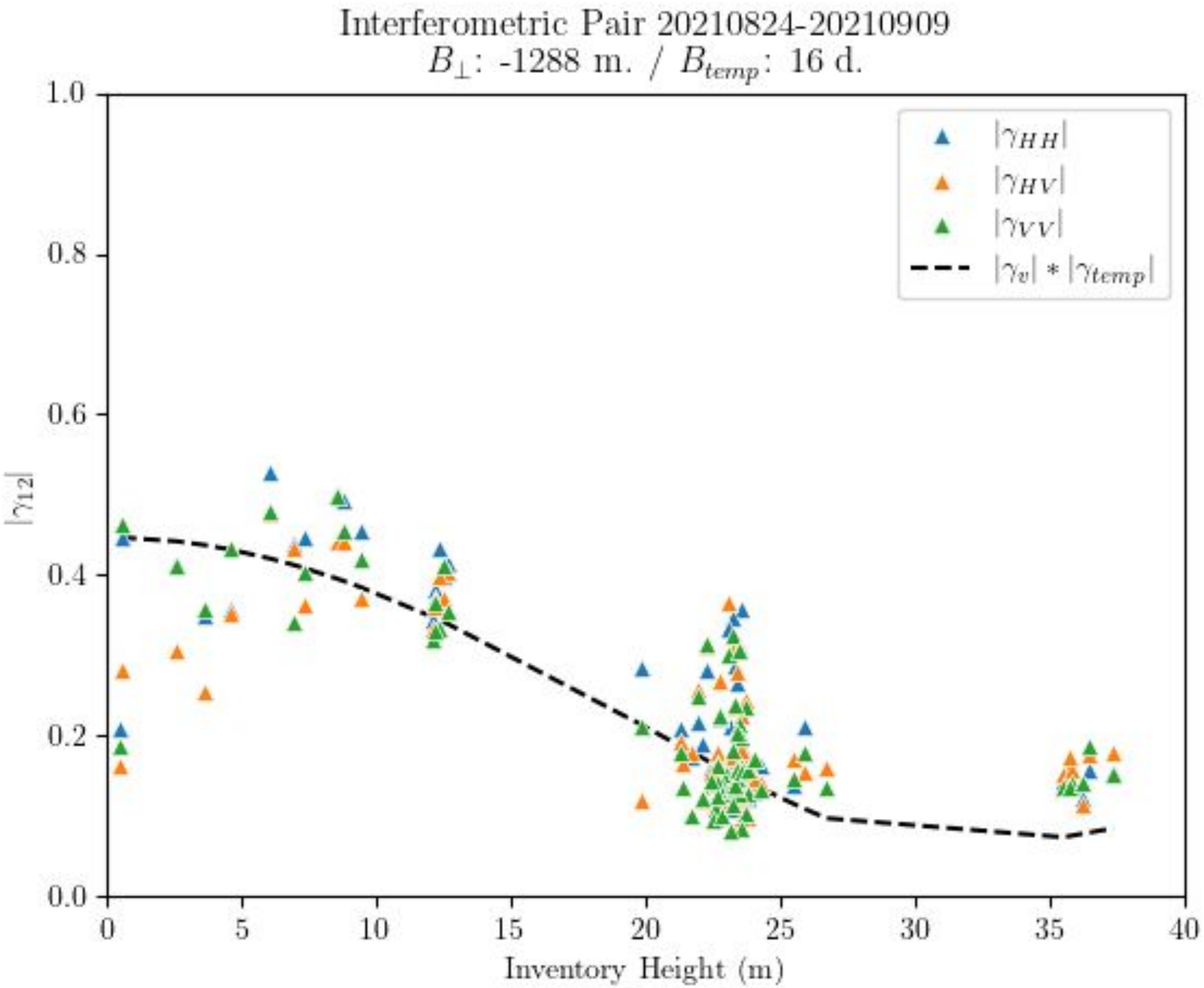
$$\gamma_{vol} = e^{-j\kappa_z \phi_0} \frac{|\gamma_{tmp}| * \gamma_v + \mu}{1 + \mu}$$

$$\gamma_v = \frac{e^{\frac{2\alpha}{\cos(\theta)} h_v + j\kappa_z h_v} - 1}{e^{\frac{2\alpha}{\cos(\theta)} h_v} - 1} \frac{2\alpha}{2\alpha + j\kappa_z \cos(\theta)}$$

If we assume μ=0 ϕ and ϕ_0 = 0:

$\gamma_{vol} = \gamma_v * |\gamma_{tmp}|$

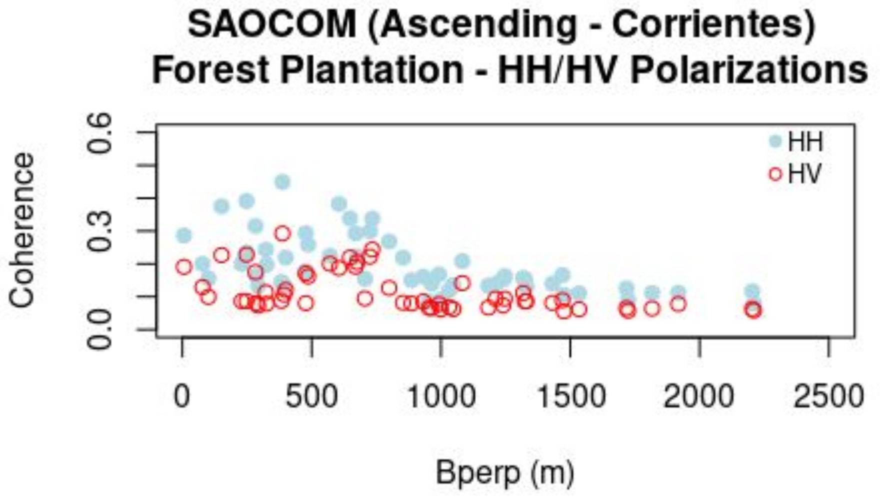
Field H_v vs. $|\gamma_{12}|$



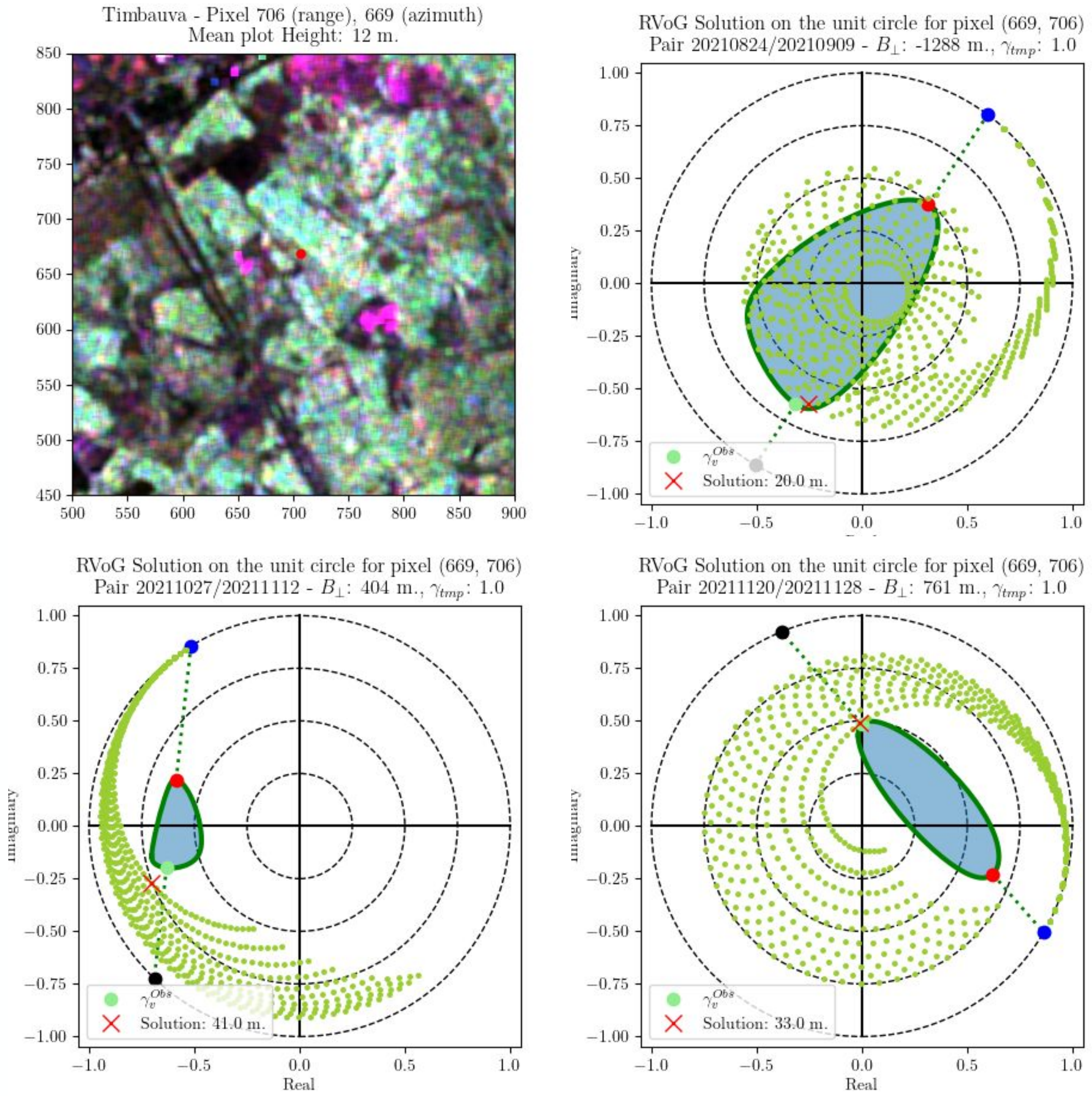
$|\gamma_{temp}| = 0.45$

Results: Exploratory Assessment - $B_{\perp}$ and RVoG

The influence of varying $B_{\perp}$

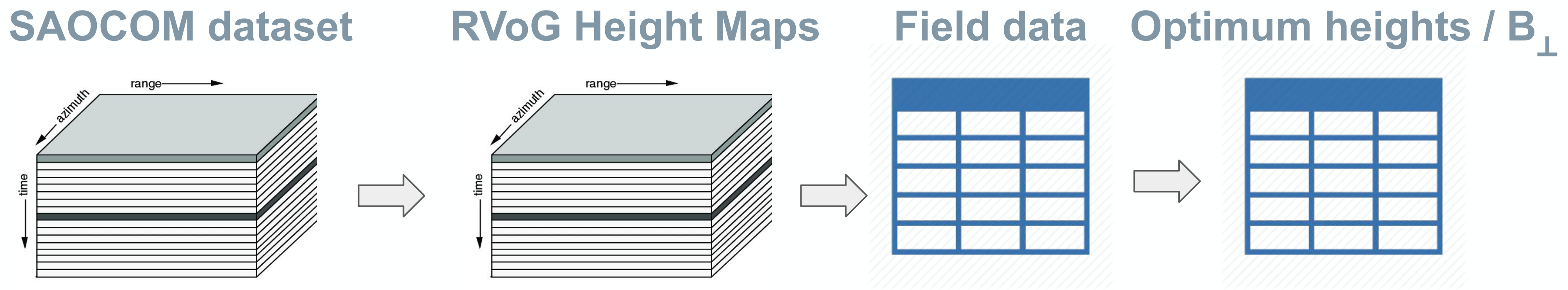


Solution: Use multiple $B_{\perp}$

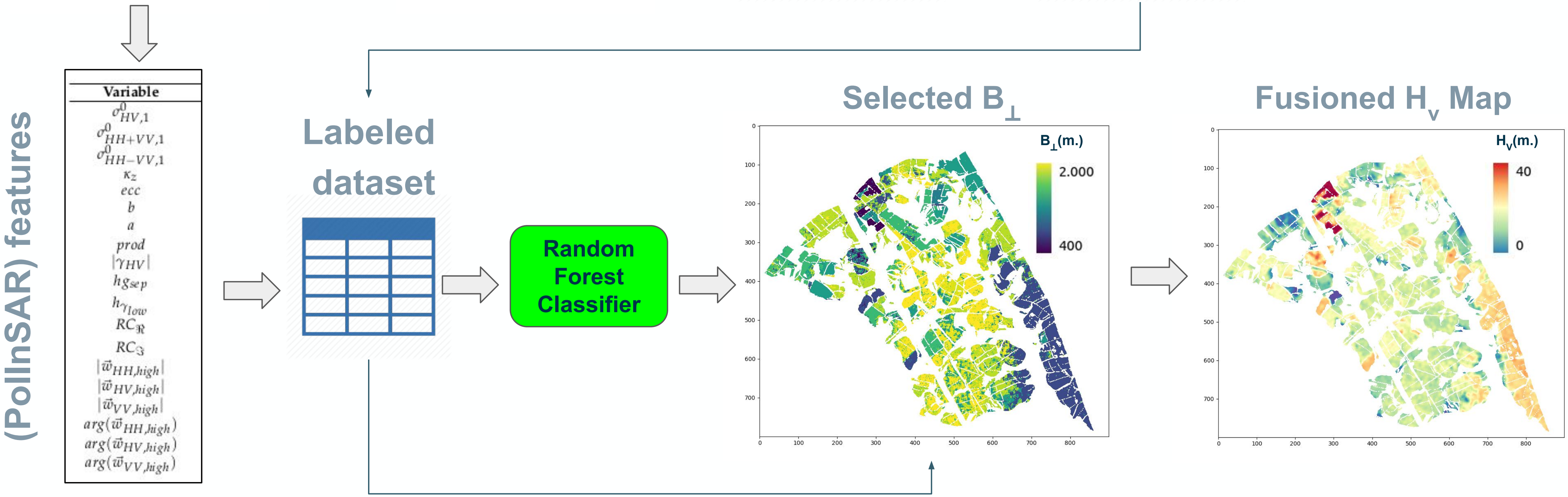


No temporal decorrelation assumed!

Materials and Methods: Combination of multiple $B_\perp$

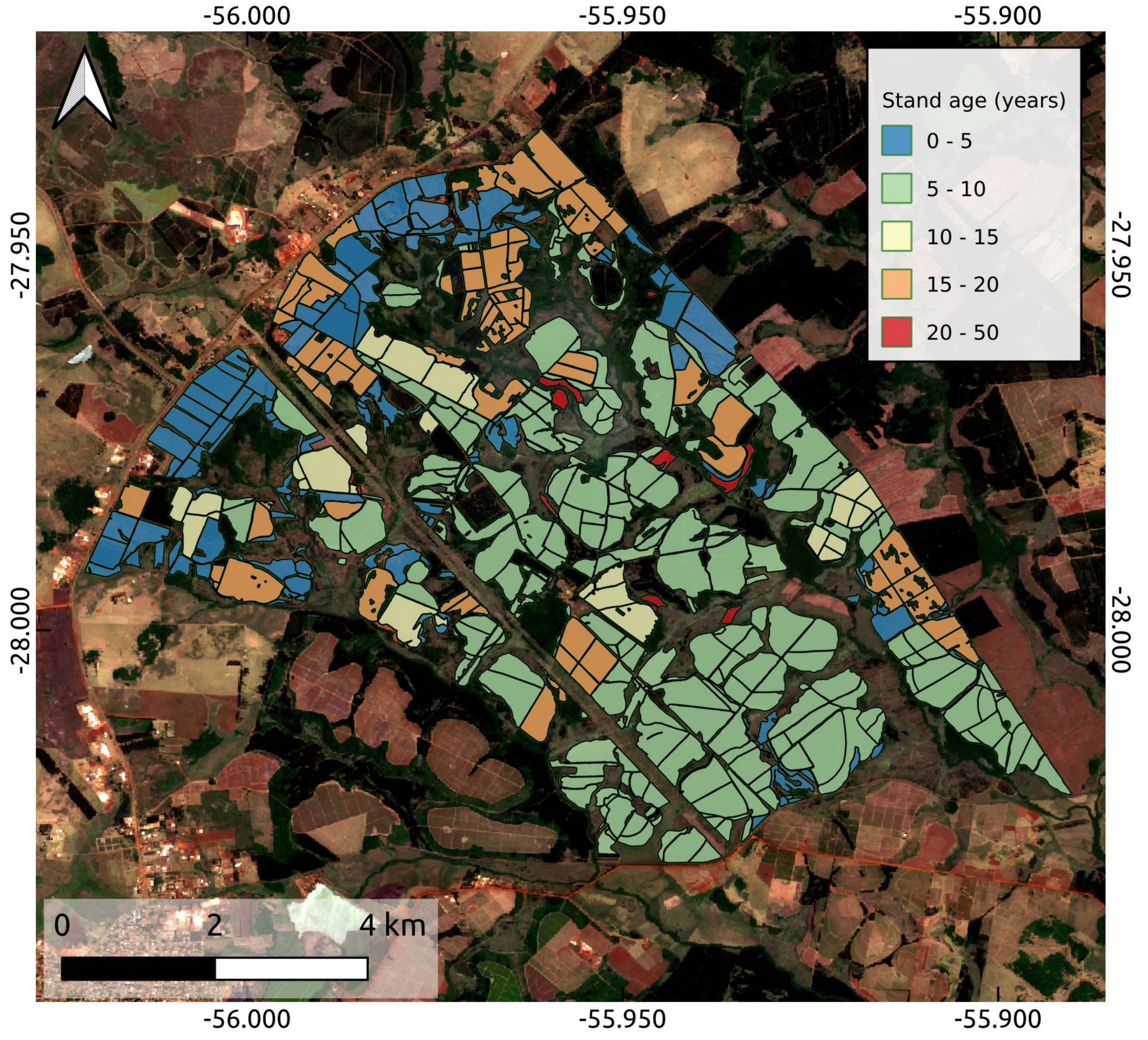


Source: Denbina, M., Simard, M., & Hawkins, B. (2018). Forest height estimation using multibaseline PolInSAR and sparse lidar data fusion. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *11*(10), 3415-3433.

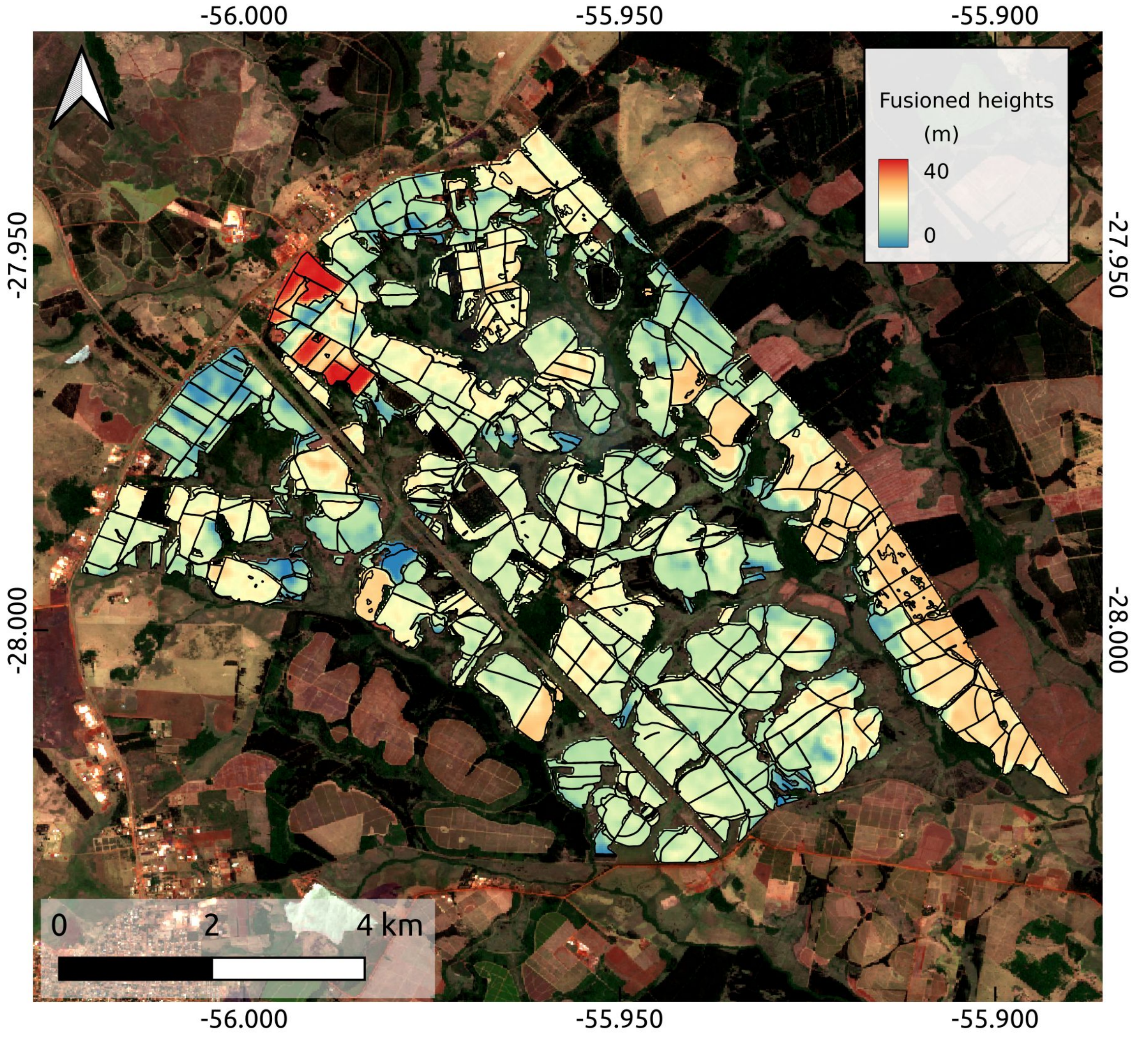


Results: Combination of multiple $B_{\perp}$ - Hv Maps

Forest stands by age - Training/Test Field

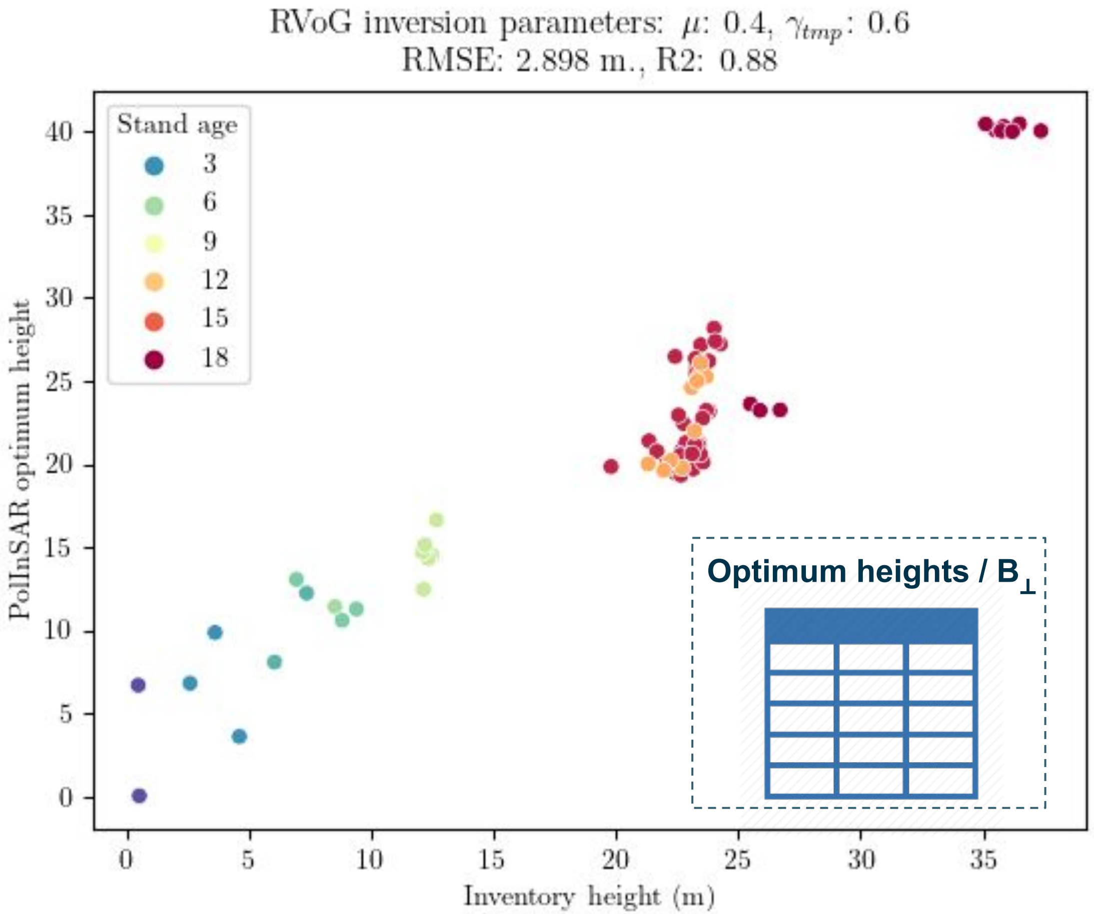


Features from pair 20210824/20210909

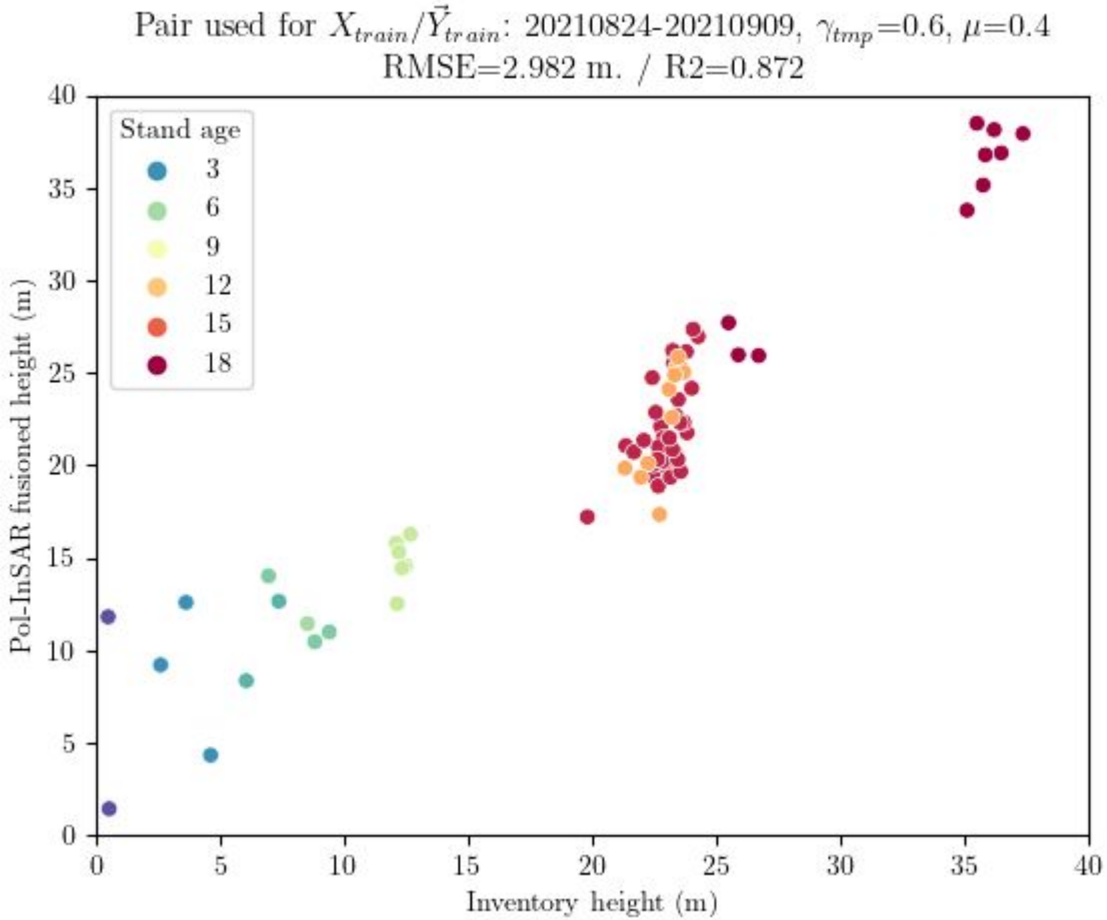


Results: Combination of multiple $B_\perp$ - Error metrics

Optimum Heights (Training/Test field)

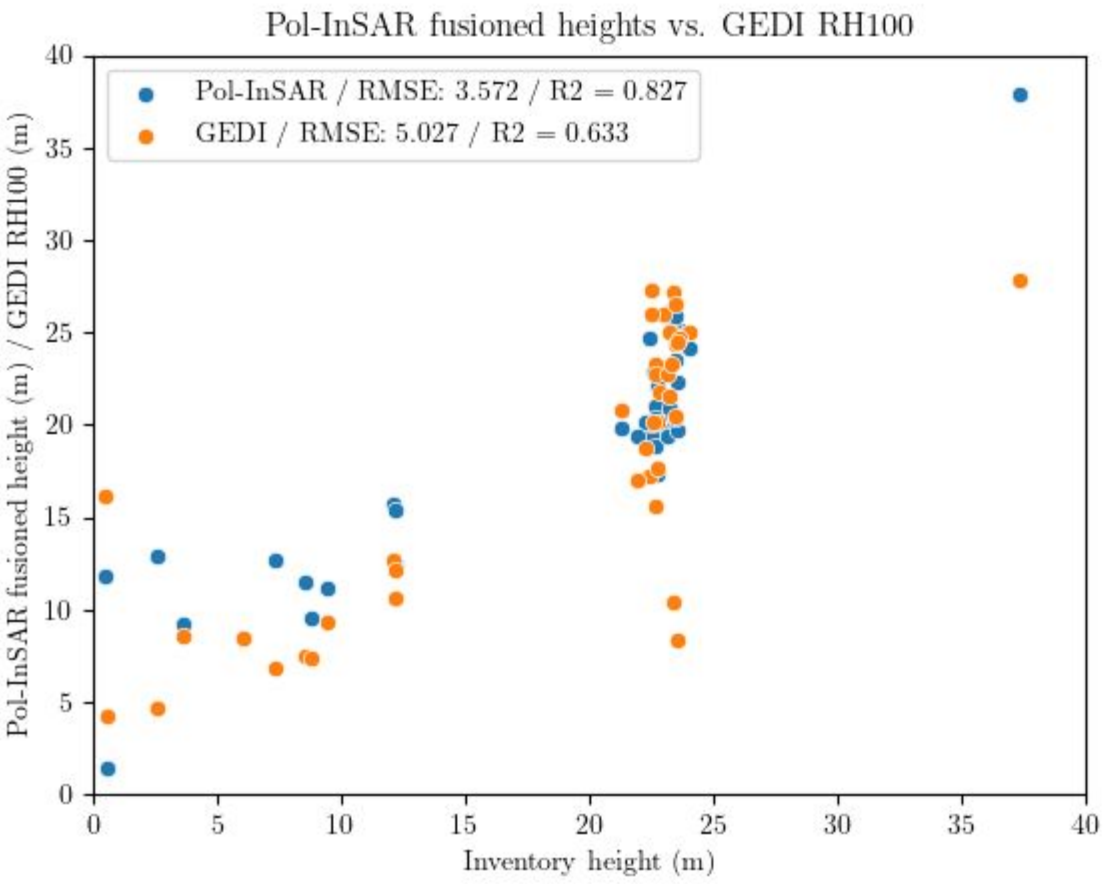


Fusioned Heights (Training/Test field)

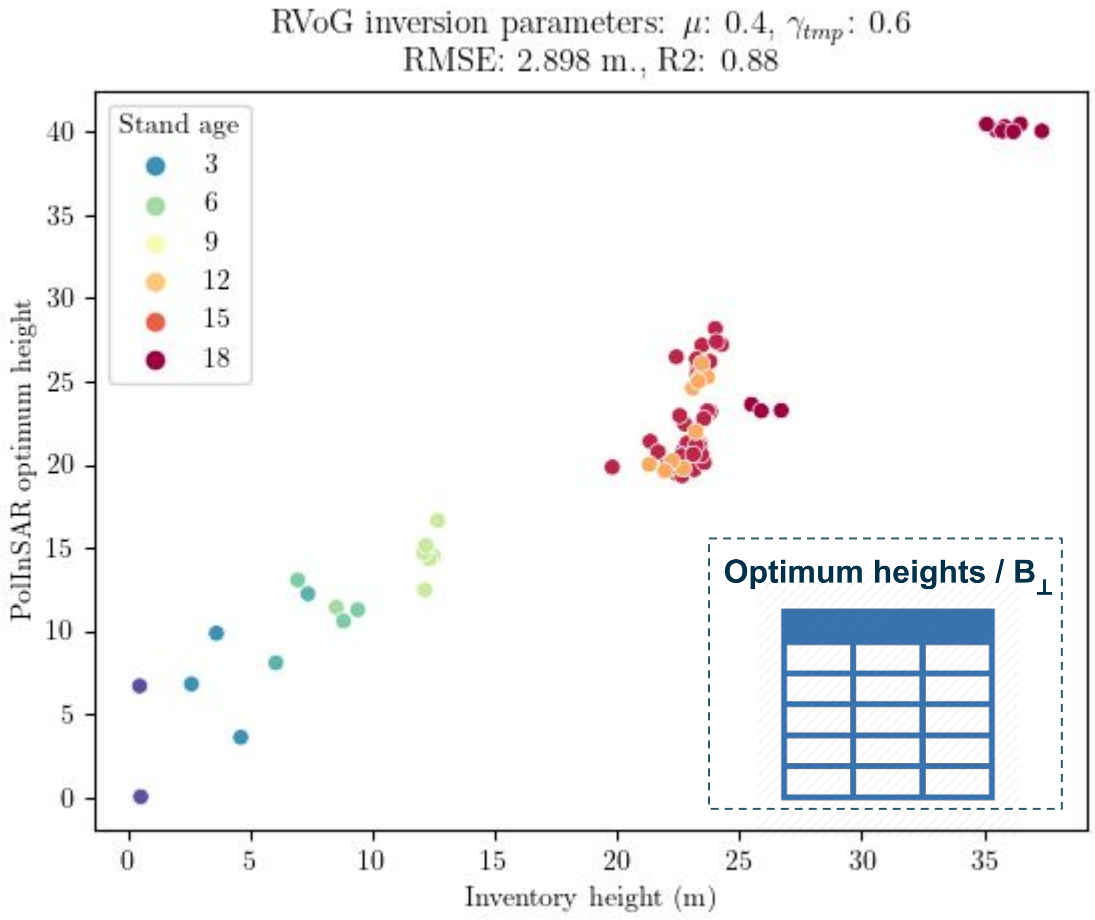


Results - Combination of multiple $B_\perp$ - Error metrics

PolInSAR vs GEDI (Training Test Field)



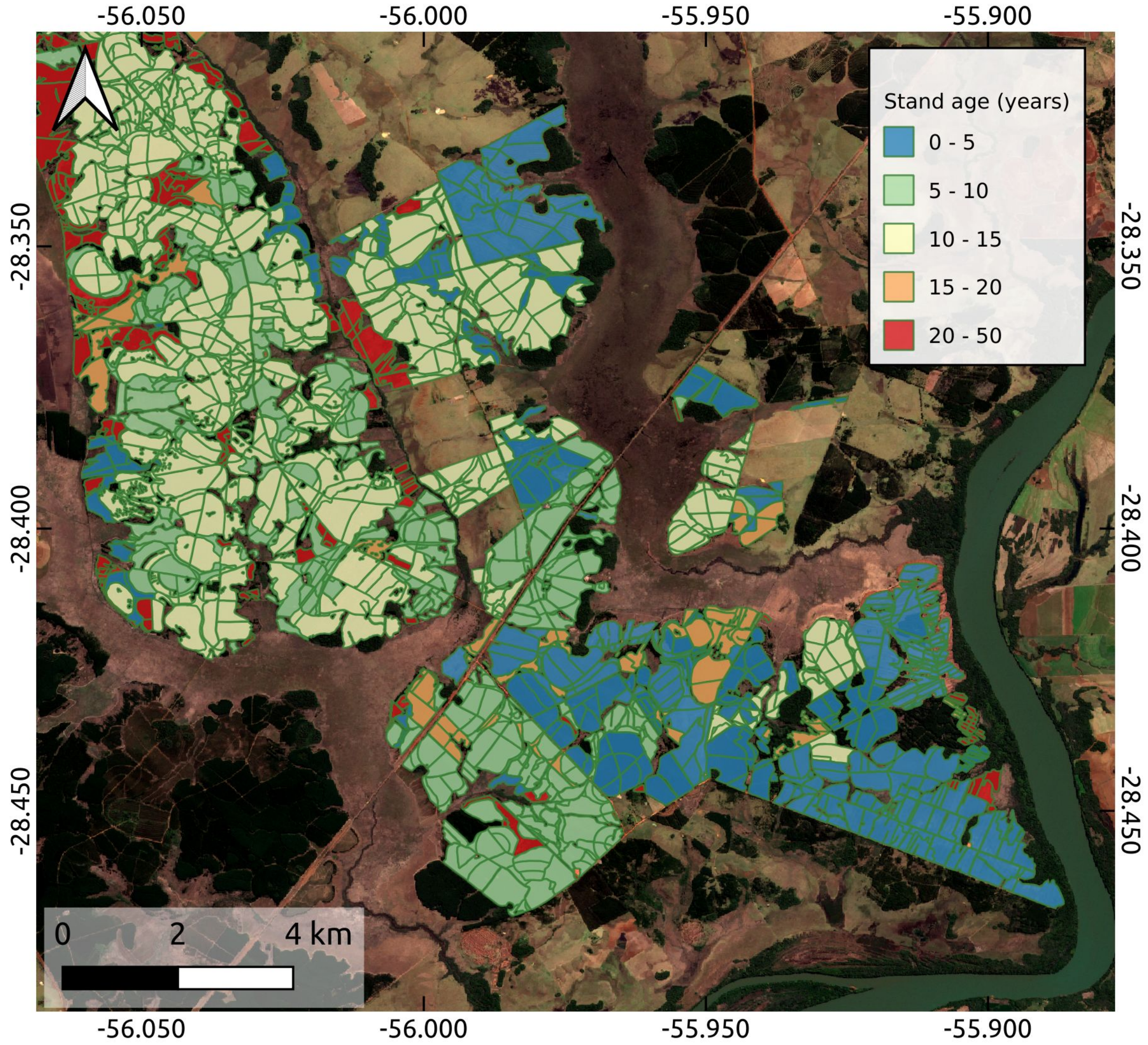
Optimum Heights (Training/Test field)



Training and test might be spatially correlated!

Results - Combination of multiple $B_\perp$ - Hv Maps

Forest stands by age - Validation Field



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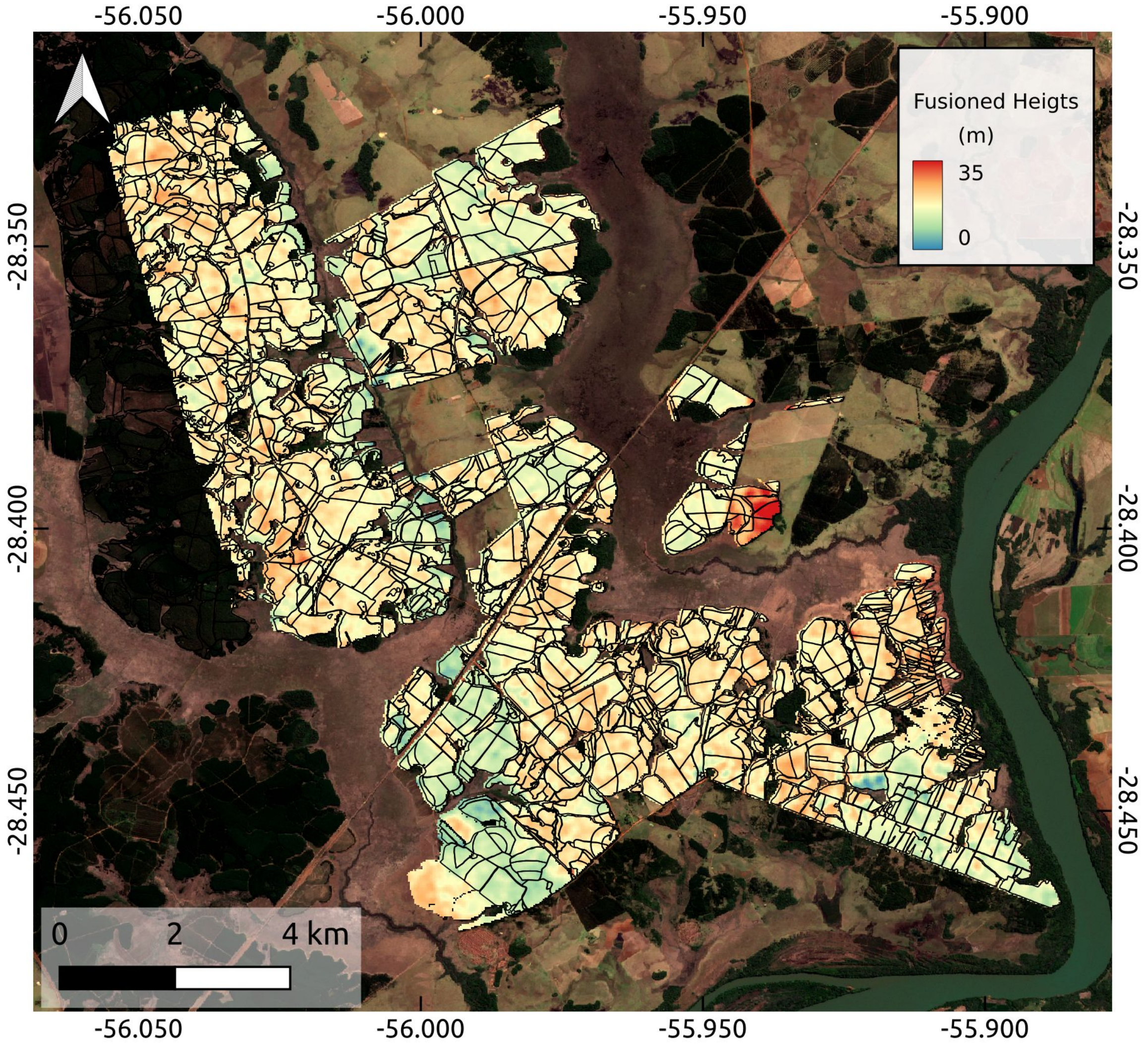
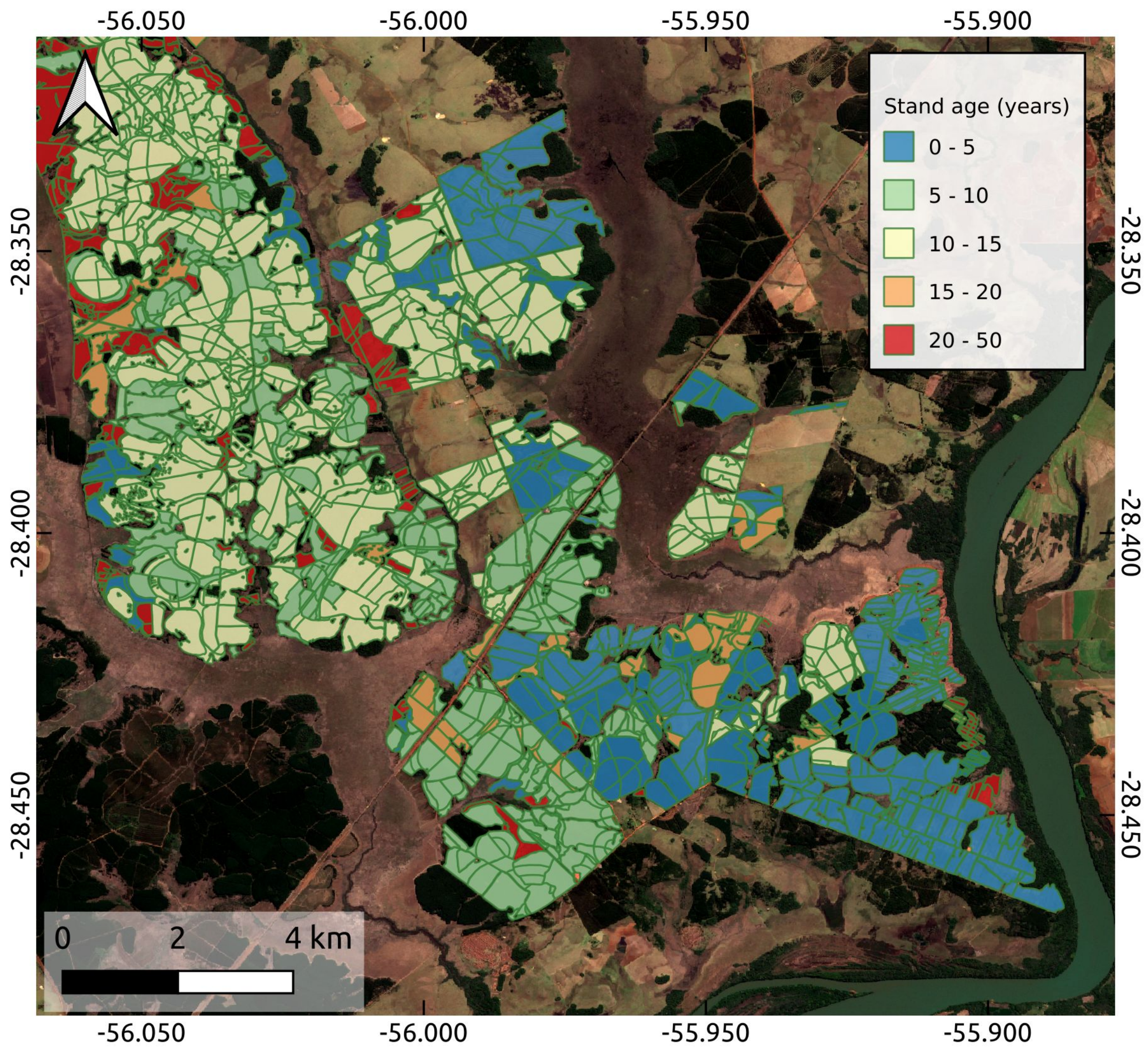
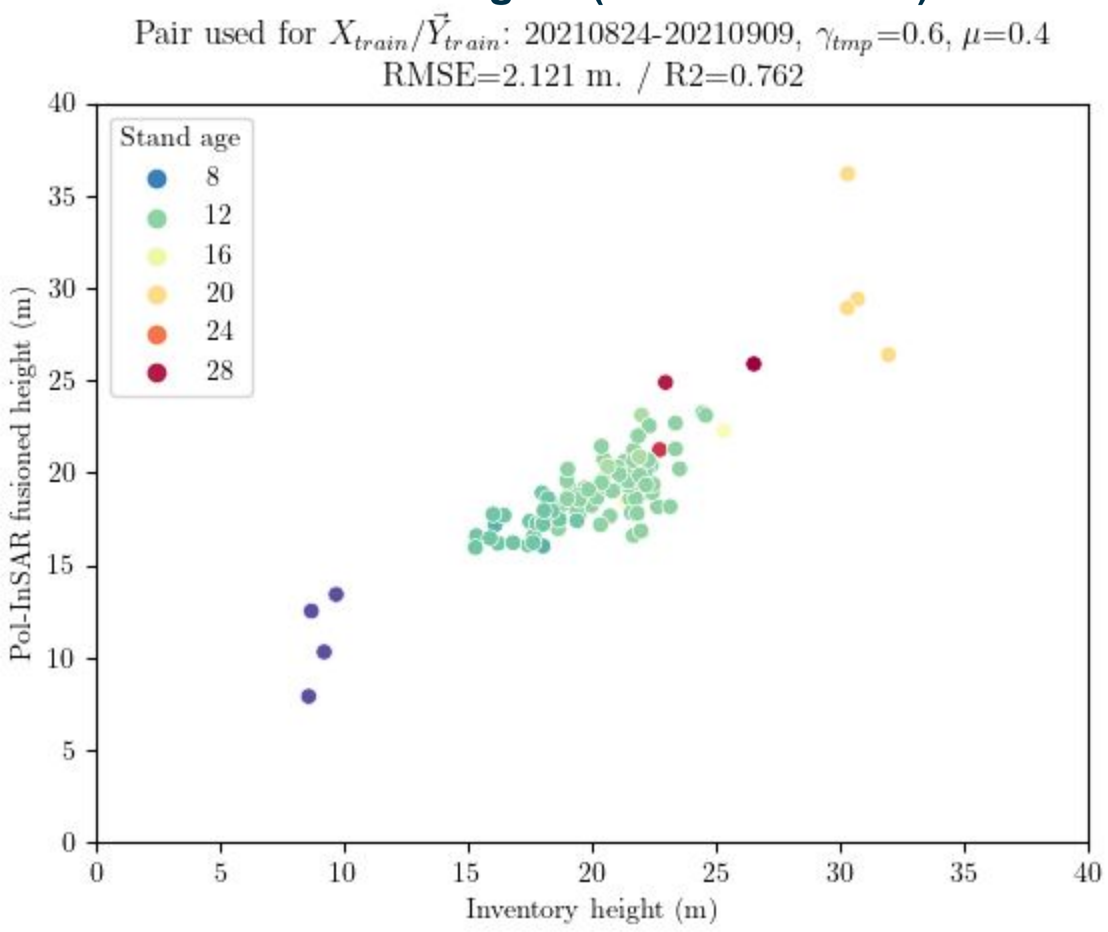


Results - Combination of multiple $B_{\perp}$ - Hv Maps

Forest stands by age - Validation Field



Fusioned Heights (Validation Field)



Conclusions

1) When working with L-band orbital data on forested areas, using B_{tmp} > 16 d. leads very high temporal decorrelation
2) The high variability of $B_{\perp}$ values in the SAOCOM dataset imposes the need of combining multiple pairs.
3) The proposed classification approach to select the proper $B_{\perp}$ value can suffer from overfitting due to the spatial correlation of the samples, given the way field data was provided → Independent validation fields are important
4) In order to effectively assess the validity of the RVoG model the value of temporal decorrelation must be considered. Switch from constant value to pixel dependent value.
5) GEDI LF data can play an important role both in providing more dense ground truth to address points 3 and 4.
6) **Relevance in the context of orbital L-band missions (NISAR, ROSE-L)**

THANK YOU