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Estimating Forest Stand Height in Savannakhet, Lao PDR Using InSAR and Backscatter Methods with L-Band SAR Data

Helen Blue Parache ¹

Tim Mayer ¹

Kelsey E. Herndon ¹

Africa I. Flores-Anderson ¹

Dr. Yang Lei ²

Quyen Nguyen ³

Thannarot Kunlamai ³

Dr. Robert Griffin ¹

¹ NASA SERVIR / University of Alabama Huntsville

² California Institute of Technology

³ SERVIR-Mekong / Asian Disaster Preparedness Center

Agenda

1. Introduction

- a. Motivation
- b. Study area

2. Objectives

3. Data

4. Methods

- a. InSAR
- b. Backscatter

5. Results

6. Discussion

7. Conclusions

SERVIR focuses on countries in Asia, Africa, & the Americas



FOCUS COUNTRIES
ADDITIONAL REACH

SAR Handbook: Comprehensive Methodologies for Forest Monitoring and Biomass Estimation

- ▶ **Freely-available** eBook, interactive pdfs, and training modules; result of a 2-year joint collaboration between **NASA SERVIR & SilvaCarbon**
- ▶ **Applied content, hands-on trainings** to get started using Synthetic Aperture Radar (SAR) for **forest monitoring, biomass estimation, mangrove extent, time-series analysis**
- ▶ Authored by **world-renowned SAR experts** from the NISAR Science Team, US Forest Service, academia
- ▶ Reviewed and tested by the SERVIR-Global network
- ▶ **Downloadable open-source scripts** and sample datasets for a variety of forestry applications; useful for **beginners to experts**

Download the SAR Handbook here: <https://bit.ly/2UHZtaw>
 SAR Handbook training modules and more: <https://bit.ly/2GeKvAN>
 For more information, visit the SERVIR booth and website @ SERVIRglobal.net
 Contact: Africa Flores-Anderson (Africa.flores@nasa.gov)



Selected pages from Chp 6:
 Radar Remote Sensing of Mangrove
 Forests (by Dr. Marc Simard, Sr.
 Scientist & mangrove specialist, NASA
 Jet Propulsion Laboratory)



Objectives

Assess **to what extent** the fusion of InSAR and backscatter methods add information beneficial for **estimating forest height**:

- (1) in **tall forest** stands (e.g. above 10 m)
- (2) in areas with **less-than-ideal input** data
- (3) in different forest types, particularly **tropical forest**

Use Case: Savannakhet, Lao

SERVIR-Mekong focus country

Deforestation/degradation Drivers:

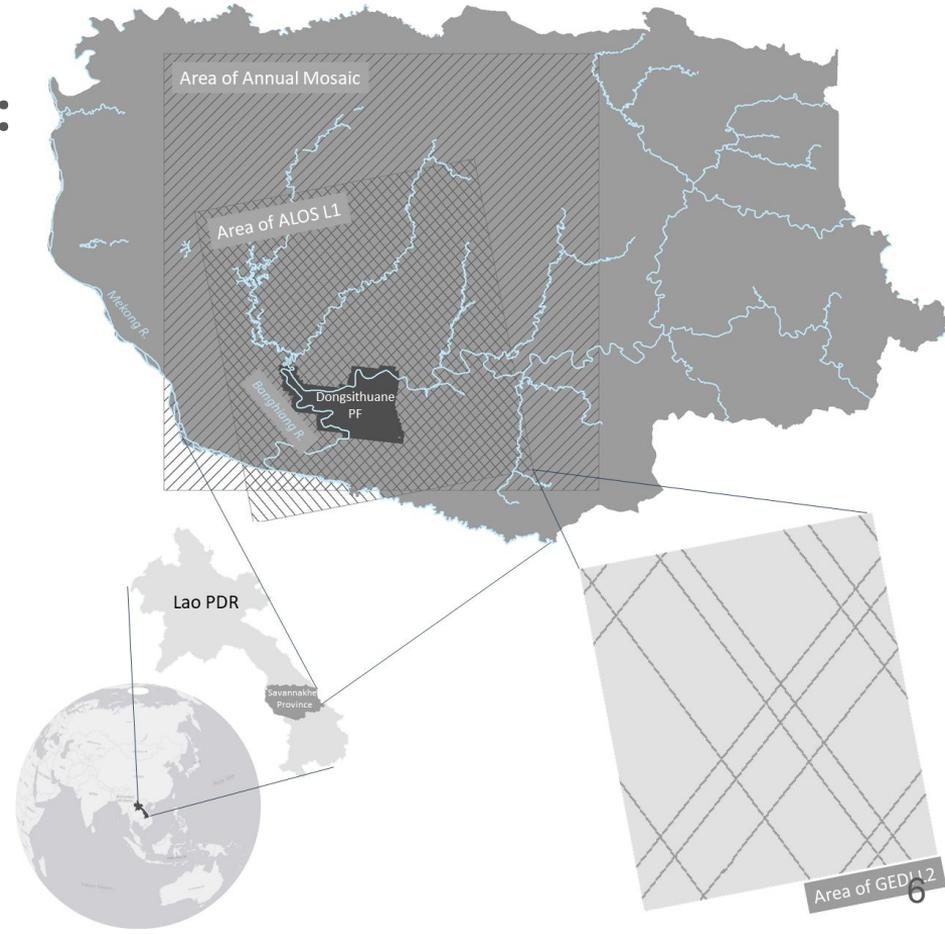
- agribusiness, tree plantations, mining, hydropower projects
- shifting cultivation by small-scale farmers

Savannakhet Province

- 2000 to 2010: 70% to 41% tree cover

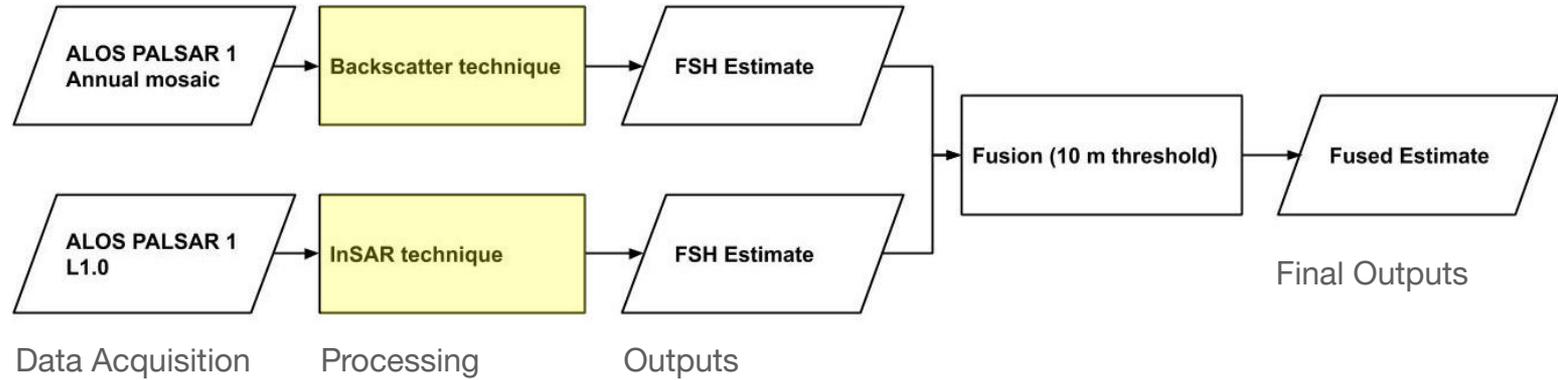
Dongsithuane Production Forest

- Primarily deciduous (Dipterocarpaceae family)



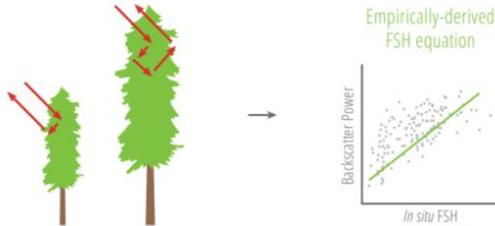
Dataset	Date	Purpose
SERVIR-Mekong Regional Land Cover Monitoring System (RLCMS) (Saah et al, 2020)	2009	Forest non-forest mask
ALOS PALSAR L-band L1.0 (JAXA)	06/13 & 07/27, 2009	InSAR Method
Annual ALOS PALSAR mosaic (Shimada et al, 2014)	06/13, 09/30, & 10/12, 2009	Backscatter Method
LiDAR (Hou, 2011)	Feb. 2009	Training/testing
Global Ecosystem Dynamics Investigation (GEDI) Level 2B Canopy Cover and Vertical Profile Metrics (Beck et al., 2020)	2019 - 2020	Comparison
Global Land Analysis and Discovery (GLAD) Global Forest Canopy Height, 2019 (Potapov et al, 2020)	2019	Comparison

Methodology Overview



As a general rule, as Forest Stand Height (FSH) increases, the number of scatterers—and therefore, backscatter power—increases.

This relationship allows us to derive an empirical relationship between *in situ* FSH data and backscatter power.



As a general rule, the taller the FSH, the more movement exists between two SAR observations. This movement, or TD, can be calculated from repeat-pass InSAR.

We can thus derive an empirical relationship between *in situ* FSH data and temporal decorrelation.

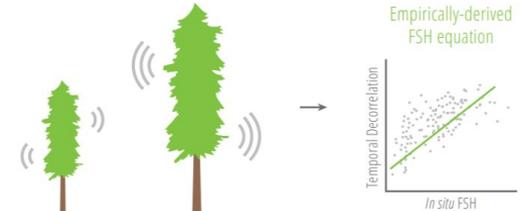
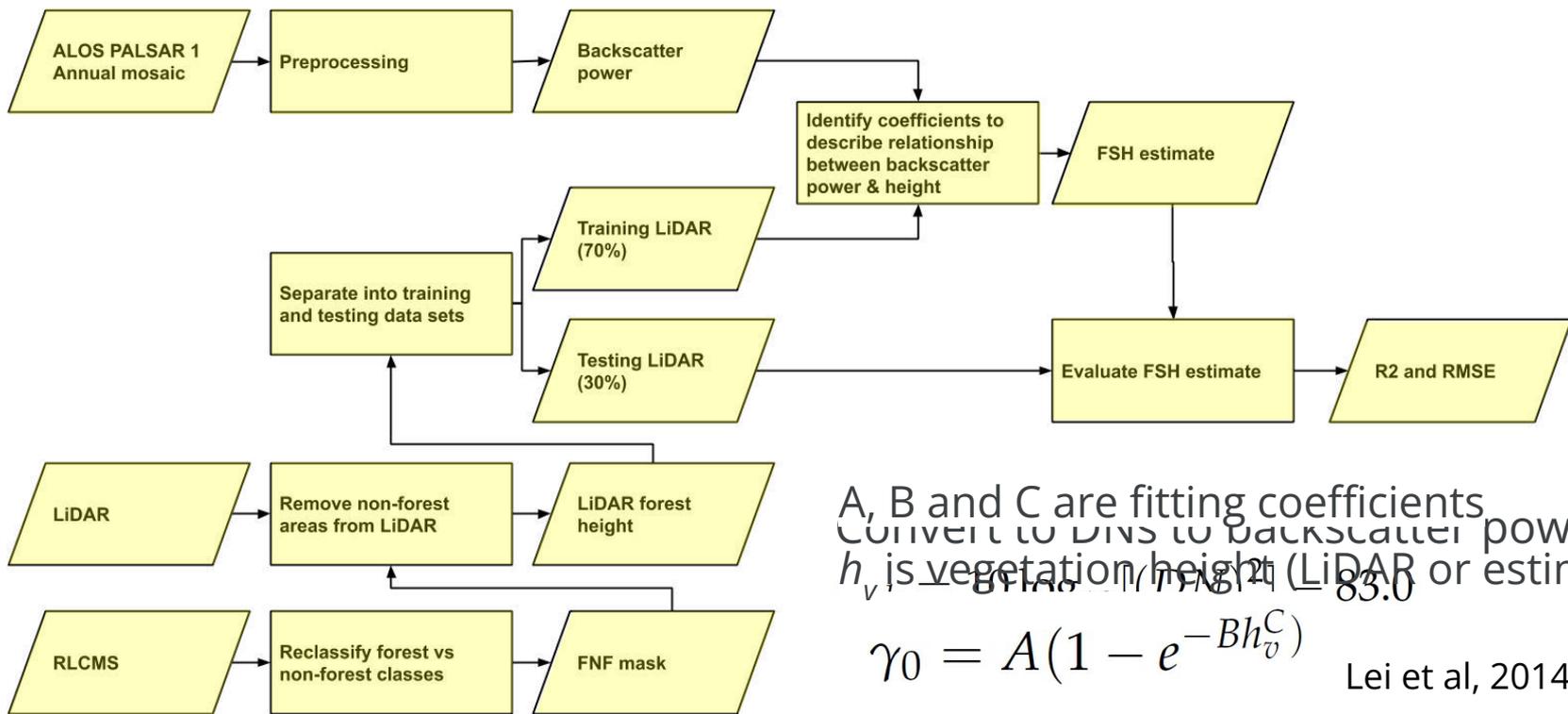


Figure Source: Flores, Africa & Herndon, K. & Thapa, Rajesh & Cherrington, Emil. (2019). *The SAR Handbook: Comprehensive Methodologies for Forest Monitoring and Biomass Estimation*. 10.25966/nr2c-s697.

Backscatter Technique (Lei et al., 2019; Yu et al., 2016)



A, B and C are fitting coefficients
 Convert to DBS to backscatter power (γ_{pw})
 h_v is vegetation height (LiDAR or estimated)
 $h_v = 83.0$

$$\gamma_0 = A(1 - e^{-Bh_v^C})$$

Lei et al, 2014; 2019

γ , interferometric correlation, is defined as:

$$\gamma = \frac{\langle E_1 E_2^* \rangle}{\sqrt{\langle |E_1|^2 \rangle \cdot \langle |E_2|^2 \rangle}}$$

E_1 and E_2 are the signals received by the platform during two different orbits (repeat-pass interferometry)

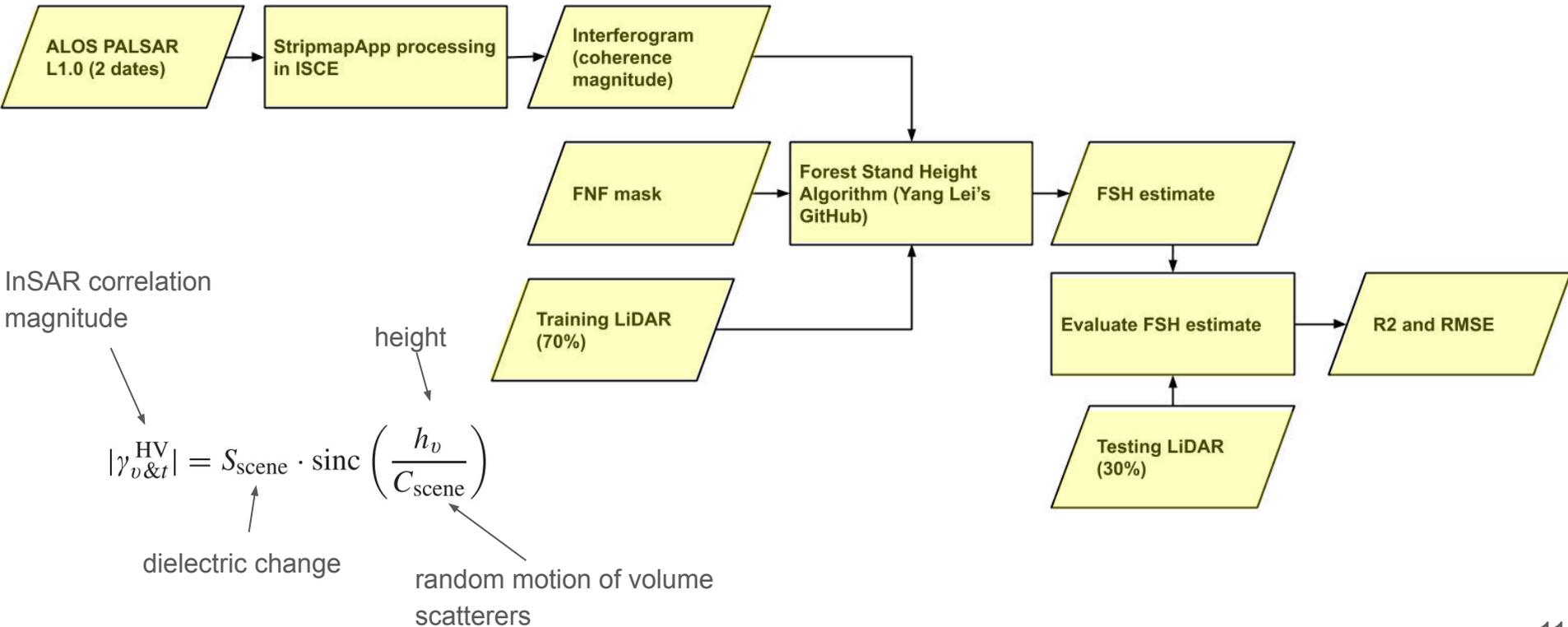
Correlation = Coherence
Decorrelation = Incoherence

Correlation is composed of:

- geometric correlation (γ_{geo})
- thermal noise correlations (γ_{SNR})
- coupled **volume scattering** and temporal changes ($\gamma_{v\&t}$)

$$\gamma = \cancel{\gamma_{geo}} \cdot \cancel{\gamma_{SNR}} \cdot \boxed{\gamma_{v\&t}}$$

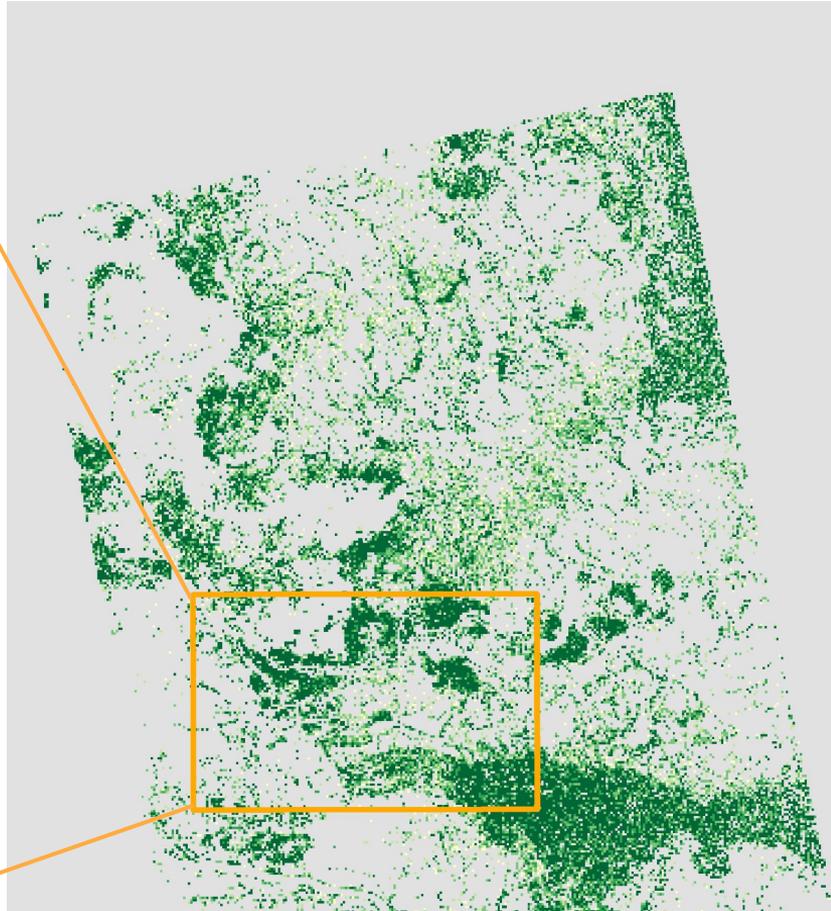
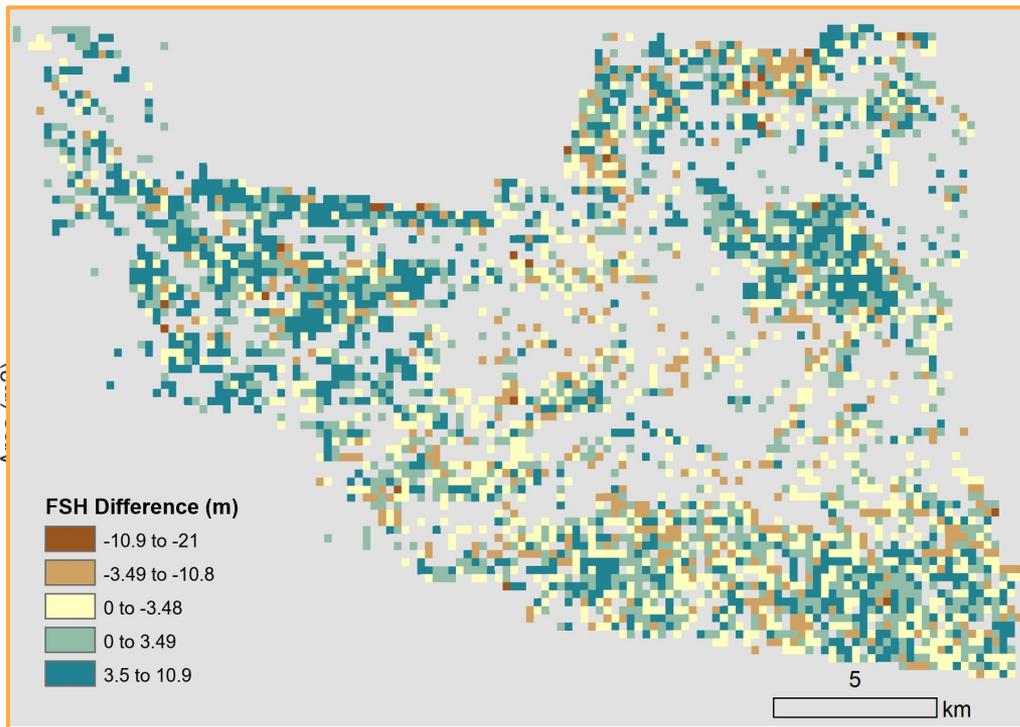
InSAR Technique



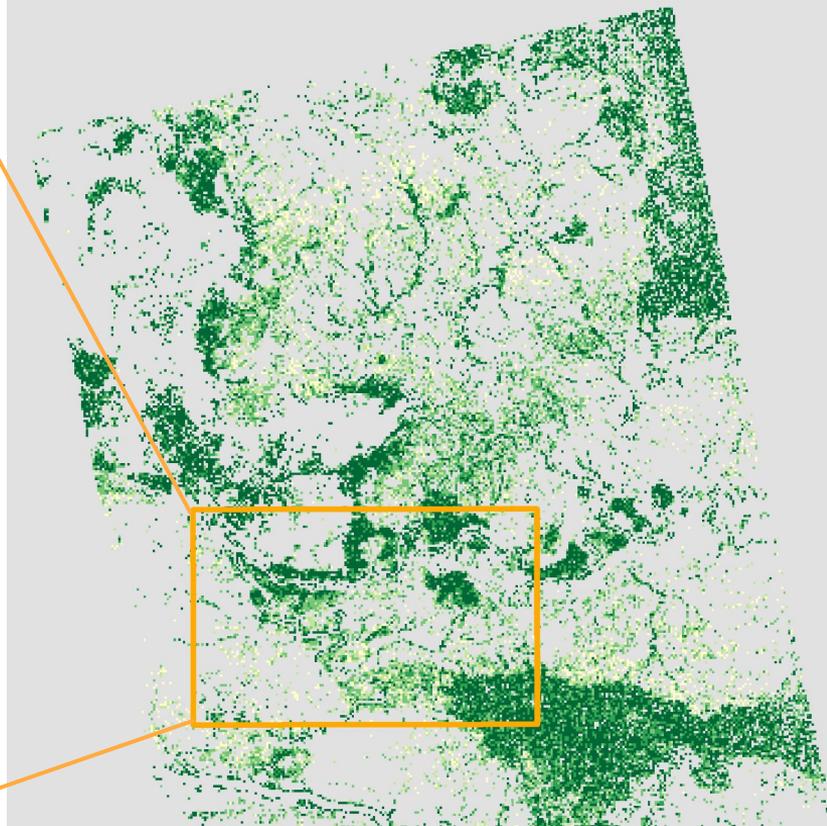
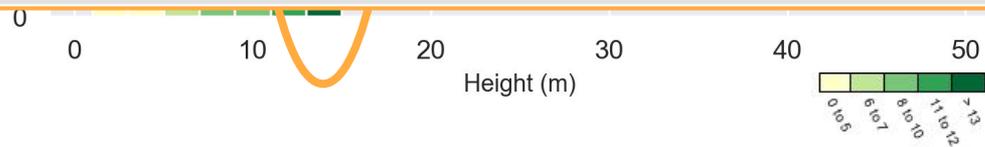
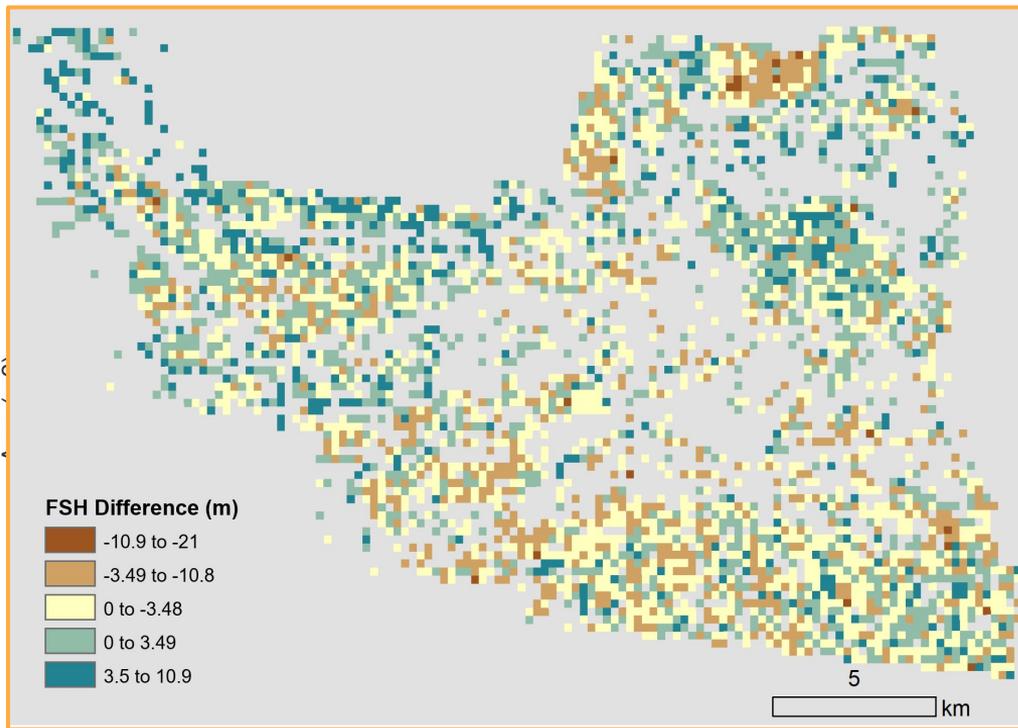
Results



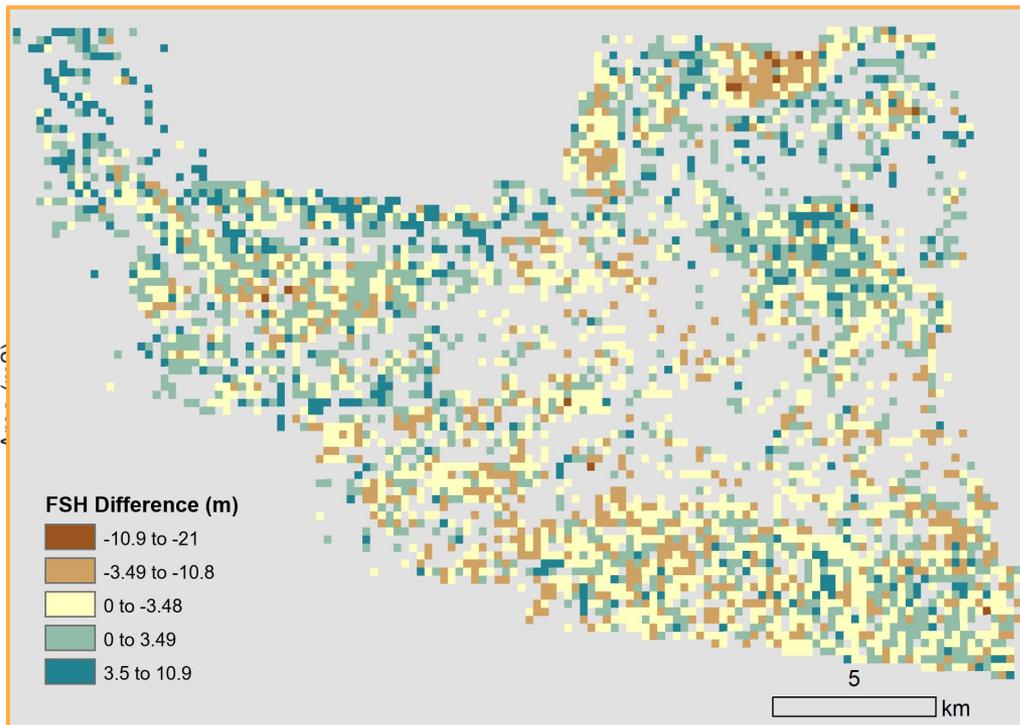
Backscatter



InSAR

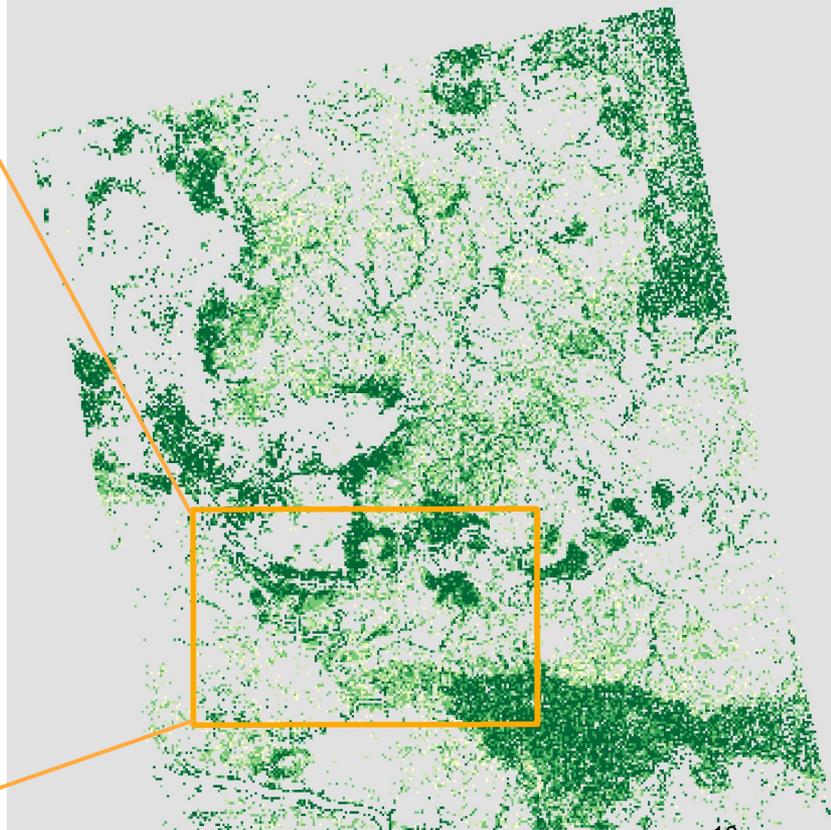
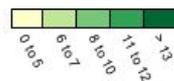


Fusion

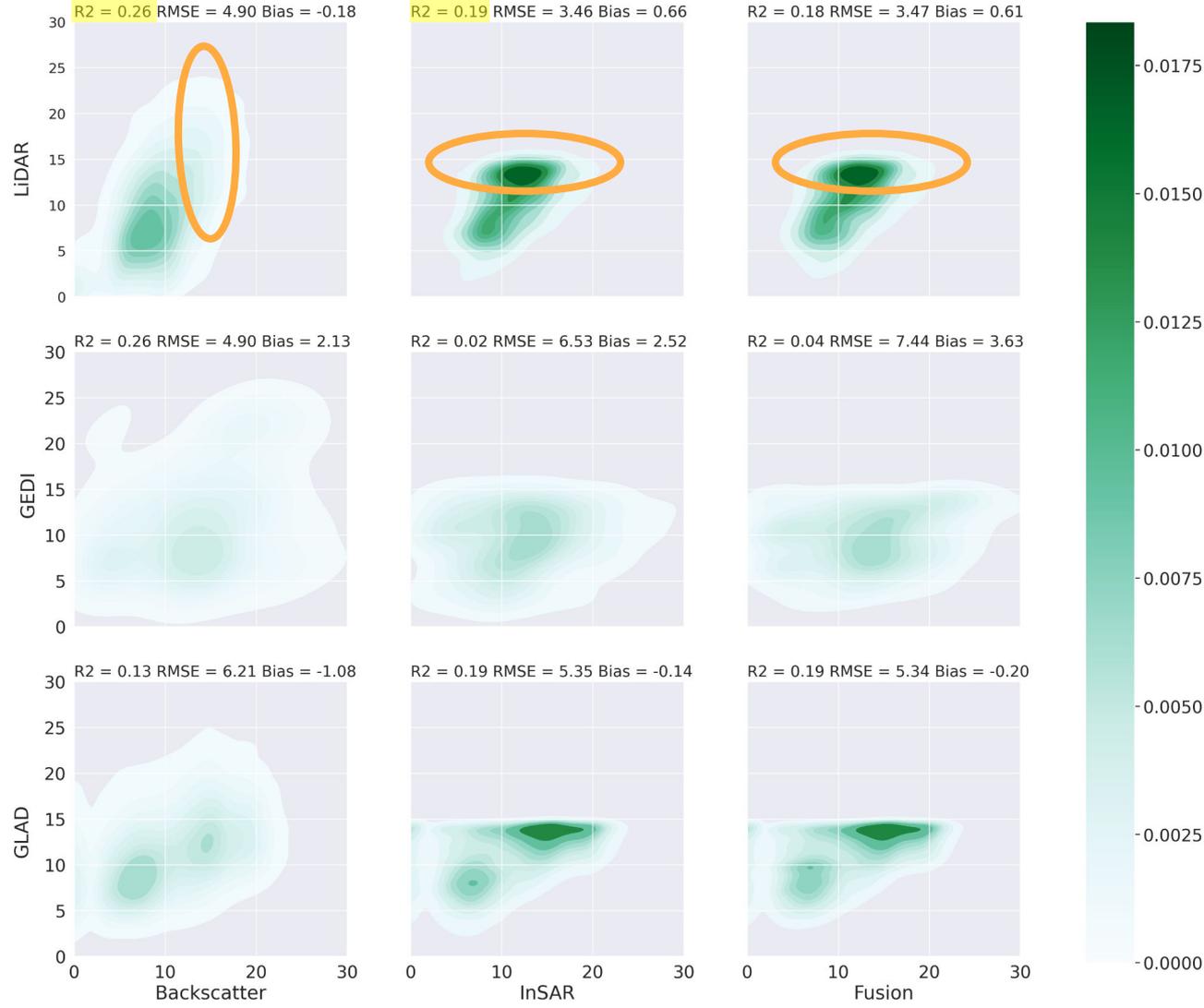


0 10 20 30 40 50

Height (m)



10 km



Error Metrics for Maine Use Case

(Lei et al., 2019)

Technique	R^2	RMSE
Backscatter	0.4	6.12
InSAR	0.17	5.22
Fused	0.4	4.16

- **Data availability**
 - 45 day temporal baseline
 - 3 available pairs (2007, 2009, 2010)
- **Seasonality**
 - Wet season: May to October
 - More precipitation leading up to July 29
- **Interferogram quality**
 - Average coherence over forest class = 0.2
 - Overall average coherence = 0.15
- **Forest structure**
 - Boreal vs. tropical
 - production vs. “overmature”



"*Dipterocarpus alatus* Roxb. Dipterocarpaceae" by LennyWorthington is licensed under CC BY-SA 2.0



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"Pinabete / Martinez Spruce (Picea martinezii)" by "Hij Tech Bio" is licensed under CC BY-NC 2.0

Conclusions

Assess **to what extent** the fusion of InSAR and backscatter methods add information beneficial for **estimating forest height**:

(1) in **tall forest** stands (e.g. above 10 m)

InSAR-estimated heights saturate before backscatter-estimated heights

(2) in areas with **less-than-ideal input** data

Data quality and quantity negatively impact results □ future NISAR mission may alleviate some issues

(3) in different forest types, particularly **tropical forest**

The distribution of the backscatter-estimated heights more closely aligned with testing (LiDAR) and comparison datasets (GEDI, GLAD)

- Continued demand for capacity building in SAR for forest monitoring, area of opportunity for SERVIR
- **Published:** Parache, H.B.; Mayer, T.; Herndon, K.E.; Flores-Anderson, A.I.; Lei, Y.; Nguyen, Q.; Kunlamai, T.; Griffin, R. Estimating Forest Stand Height in Savannakhet, Lao PDR Using InSAR and Backscatter Methods with L-Band SAR Data. *Remote Sens.* 2021, 13, 4516. <https://doi.org/10.3390/rs13224516>



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