National Space Science Center (NSSC)
Chinese Academy of Sciences (CAS)

Multistatic Radar Workshop 2025

Demonstration of Spaceborne L-band Bistatic InSAR from Chinese Lutan-1 Mission for Forest Vertical Structure Retrieval

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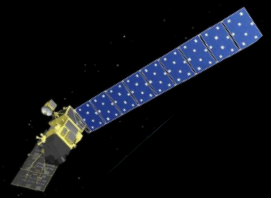
InSAR Satellites

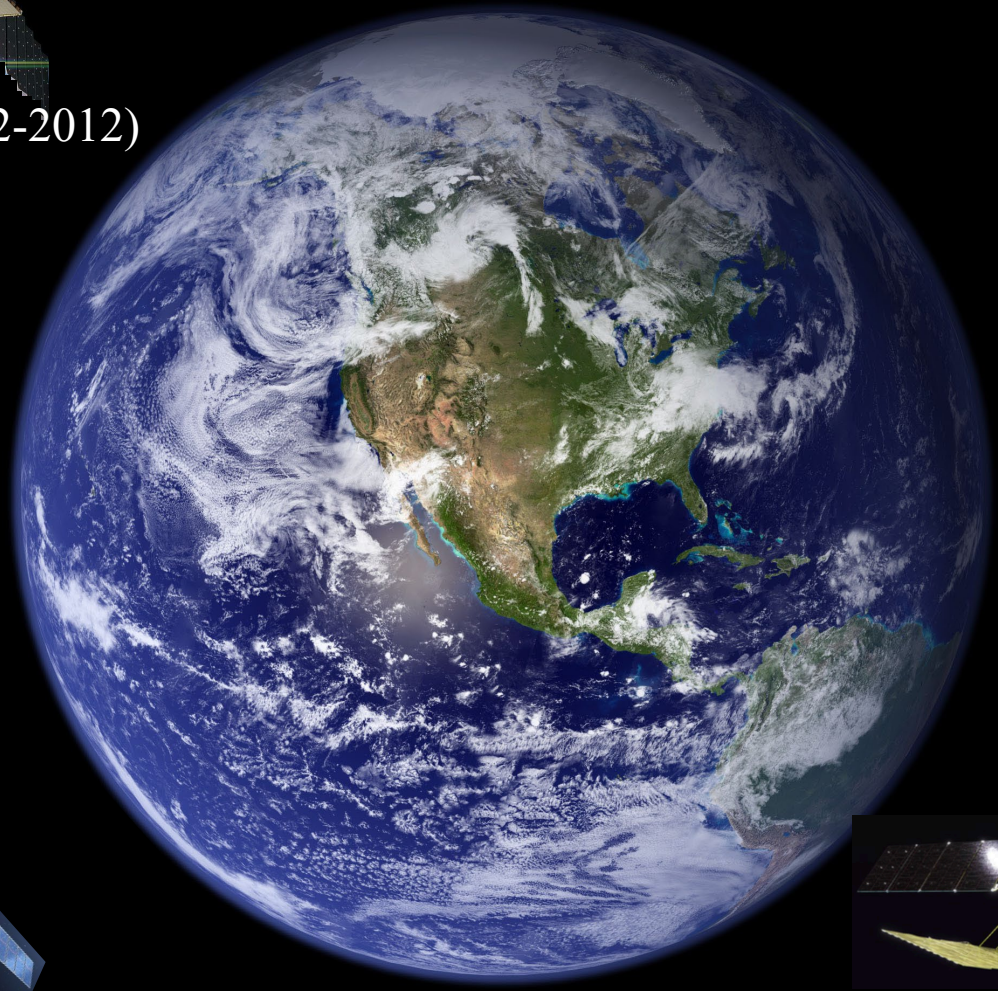
ENVISAT (2002-2012)



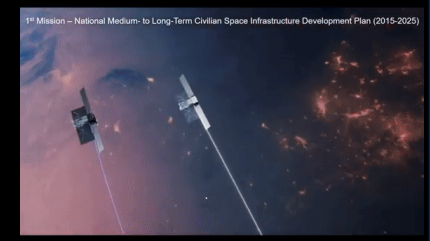
ALOS (2006-2011)

TanDEM-X (2010-)

ALOS-2 (2014-)

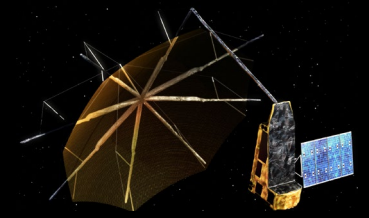


Sentinel-1 (2014-)

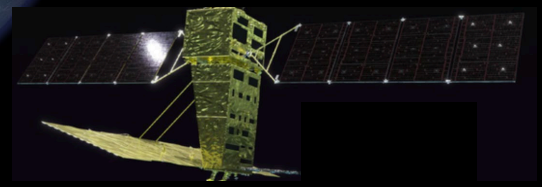


Lutan-1 (2022-)

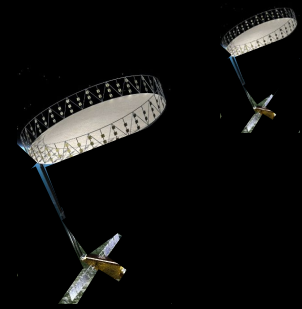
NISAR (2024-)



BIOMASS (2025-)

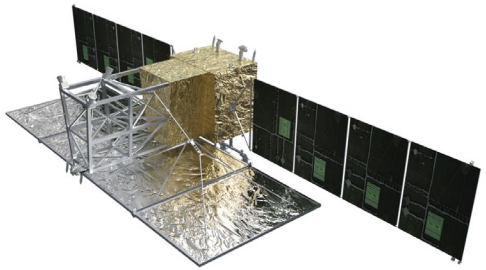


ALOS-4 (2024-)

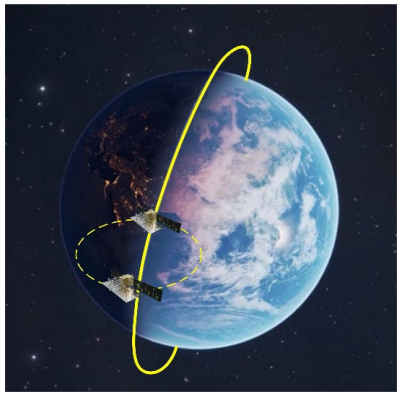


TanDEM-L (?-)

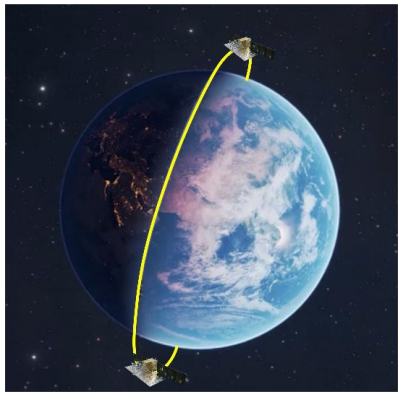
Lutan-1 Mission



bistatic

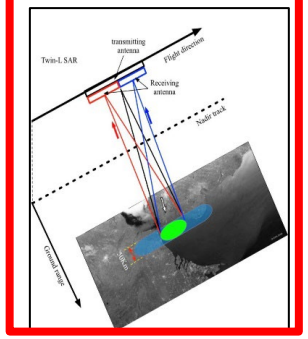


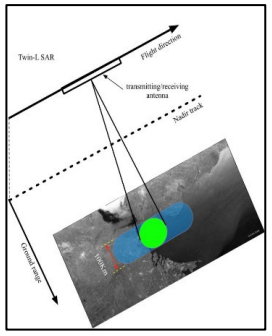
repeat-pass

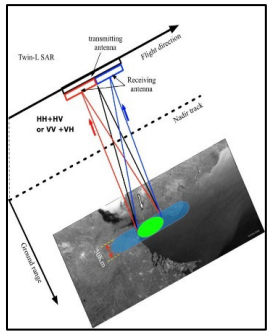


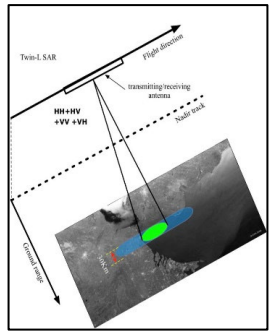
Mission Specifications	
constellation	Repeat-pass (primary), bistatic (secondary)
Orbit type	Sun-synchronous
Orbit alitude	607.05km
Latitude limits	±85°
Imaging mode	6
Polarization	Full-pol
Repeat cycle	8 days (single satellite), 4 days (twin satellites)
Inclination	97.8°
Precise Orbit Control	10 cm
National coverage cycle	44 days

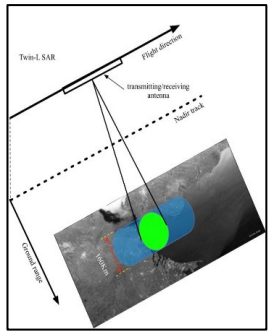
Imaging mode	Stripmap1	Stripmap2	Stripmap3	Stripmap4	Stripmap5	ScanSAR
Polarization	HH or VV	HH or VV	HH + HV or VV + VH	HH + HV + VV+ VH	HH or VV	HH or VV
Resolution	**3m×3m**	**12m×12m**	**3m×3m**	**6m×6m**	**24m×24m**	**30m×30m**
Swath width	**50km**	**100km**	**50km**	**30km**	**160km**	**400km**

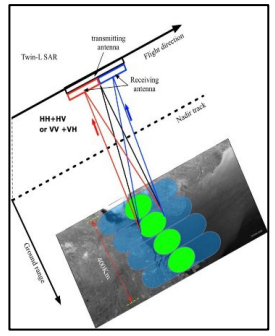












Few-look InSAR phase height (PH) histogram method

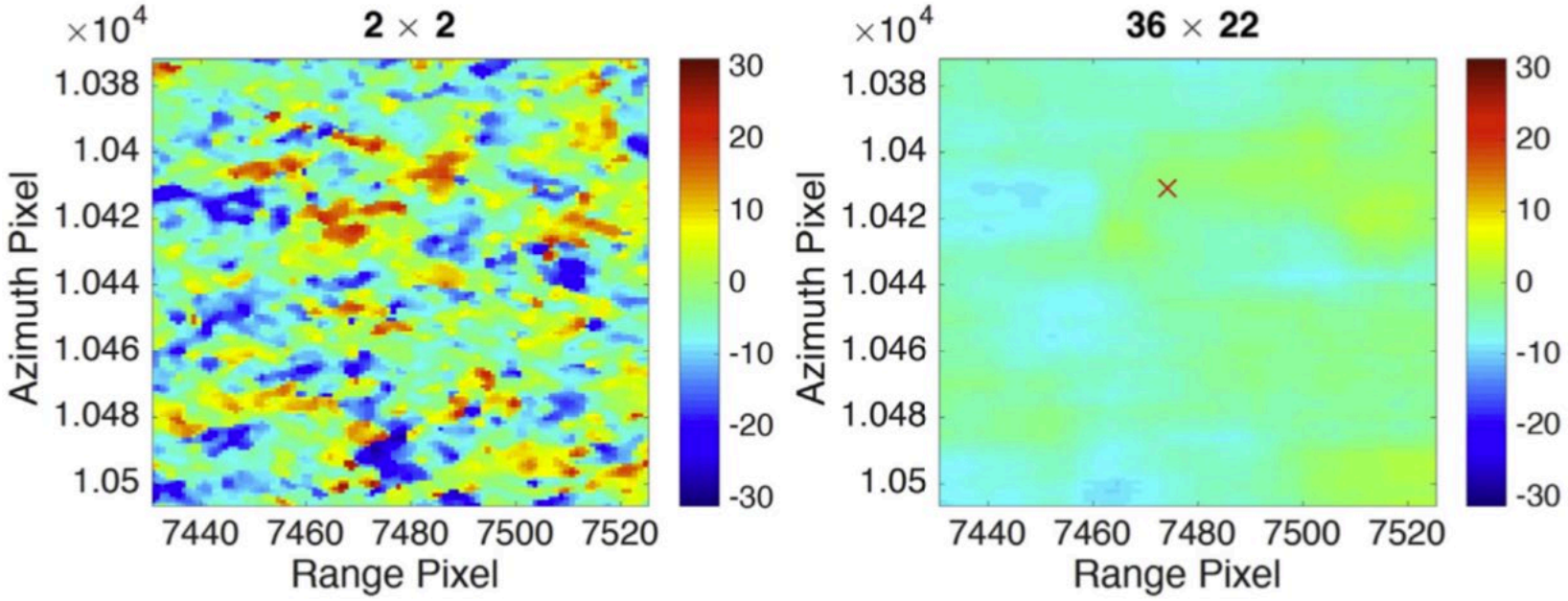
- **Automated ground finding approach**

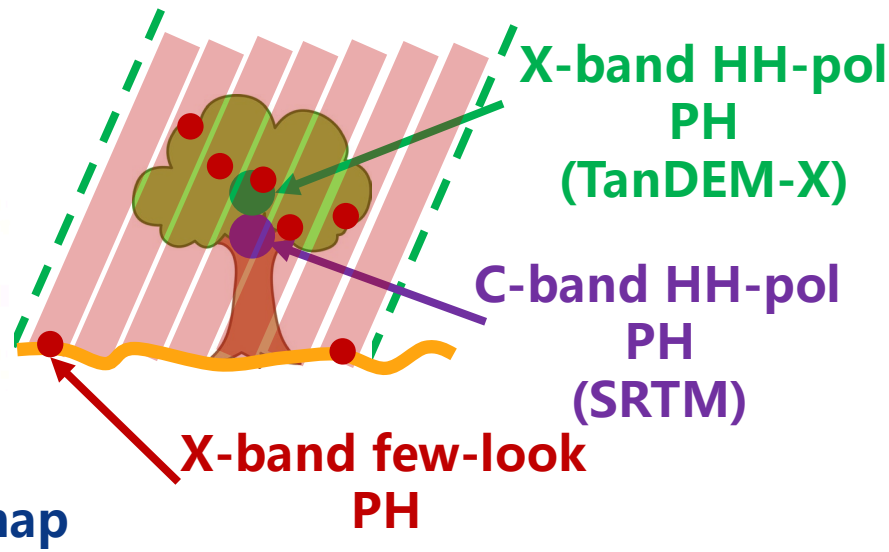
Y. Lei, R. Treuhaft, F. Goncalves, 2021, "Automated estimation of forest height and underlying topography over a Brazilian tropical forest with single-baseline single-polarization TanDEM-X SAR interferometry," ***Remote Sensing of Environment***, 252, pp.112-132.

multi-look

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

few-look | **Conventional multi-look**



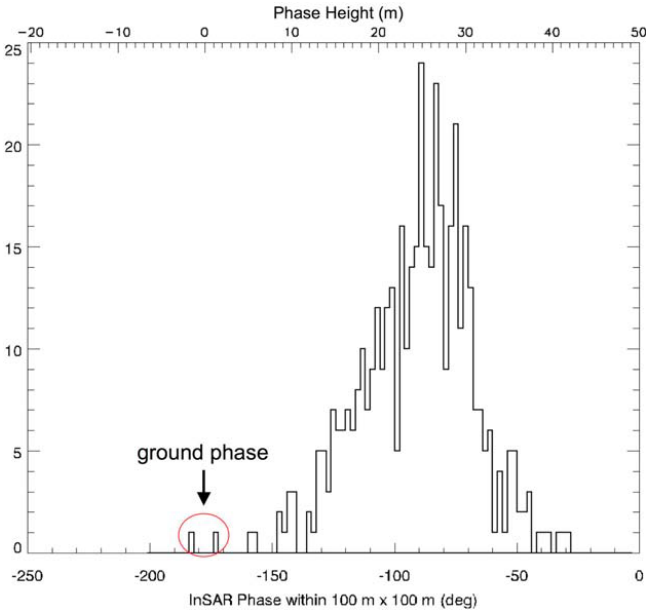


Brazilian Amazon TanDEM-X InSAR (relative) phase height map

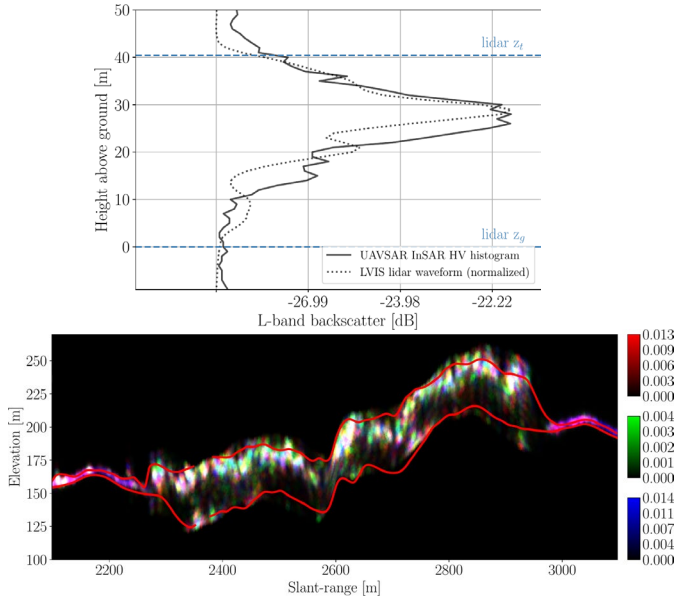
TanDEM-X relative to SRTM phase center height difference (0 means SRTM DEM)

Few-look InSAR phase height (PH) histogram method

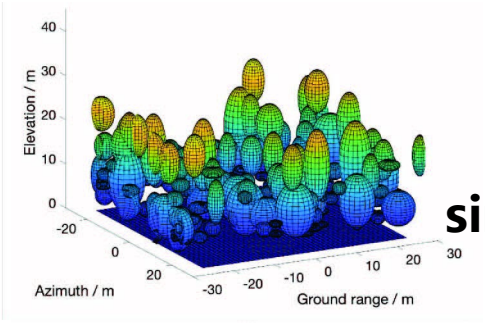
- ✓ **High-resolution** radar signals can **penetrate the gaps** among the forest canopy, and scattered back by **clustered "hard" targets** at different heights
- ✓ Take the **histogram** of the different **phase heights** within a spatial window, to get a lidar/TomoSAR-like forest **vertical profile**



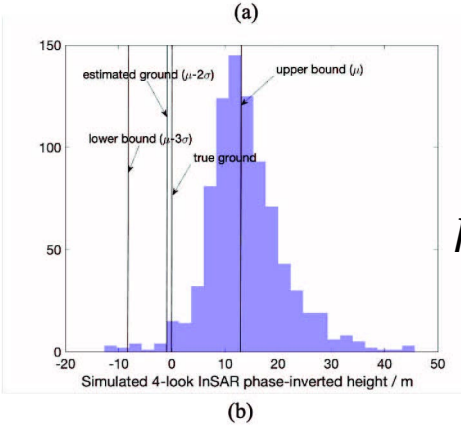
(R. Treuhaft et al, JGR 2008)
C-band airborne demo
manual approach



(G. Shiroma et al, TGRS 2020,
C. Wu et al,. IGARSS 2023)
L-band airborne demo
automated by thresholding



EM simulation



$$h_g = \alpha \cdot \mu - \beta \cdot \sigma$$

(Y. Lei et al, RSE 2021)
X-band spaceborne demo
automated by EM simulation &
statistical relationship

Few-look InSAR phase height (PH) histogram method

Refined approach for automated ground finding

- **Previous Automated Ground Finding:**

$$h_g = \alpha(h_v, \lambda, \vartheta, \rho_x, \rho_r, \dots) \cdot \mu - \beta(h_v, \lambda, \vartheta, \rho_x, \rho_r \dots) \cdot \sigma$$

- **Constant coefficient:**

$$h_g = \alpha \cdot \mu - \beta \cdot \sigma$$

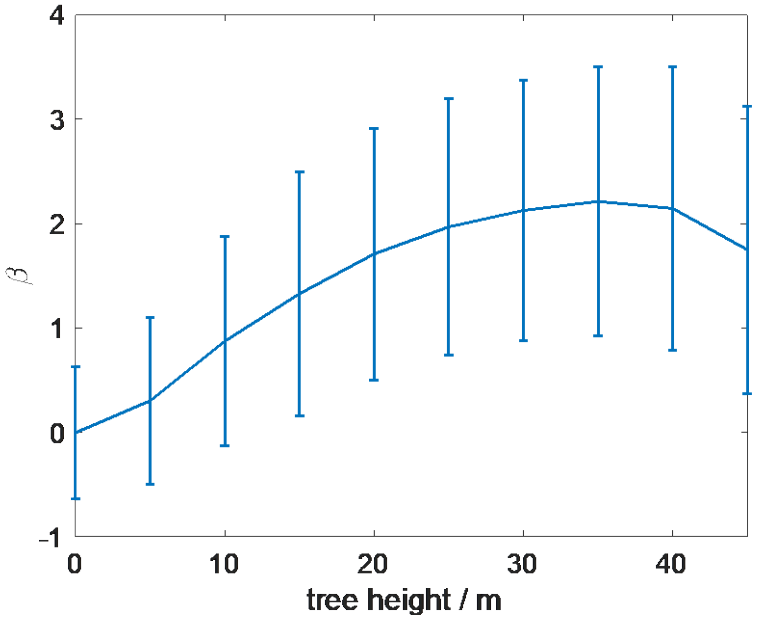
$\alpha = 1, \beta = 2$ is proved sufficient for Tapajos tropical rainforest in Brazilian Amazon (Lei et al., RSE, 2021)

- **Spatially varying coefficient:**

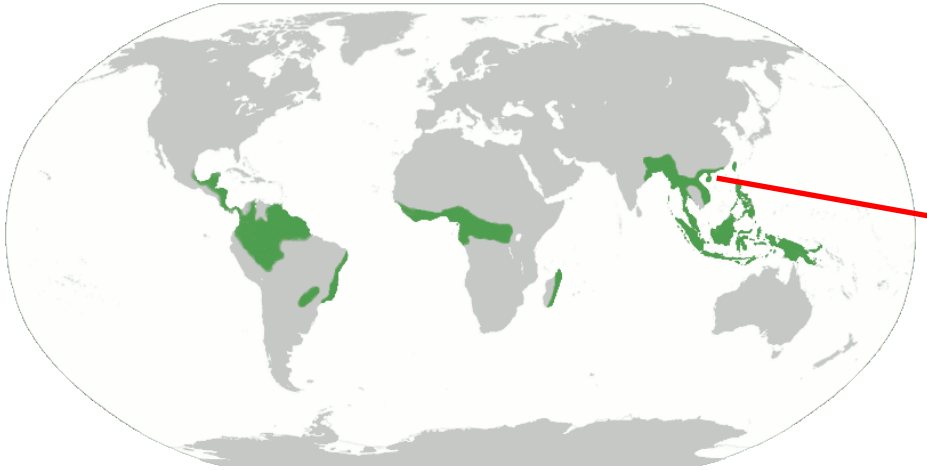
Using spaceborne lidar samples, β can be further refined to spatially vary depending on various tree species, tree heights, density and etc.

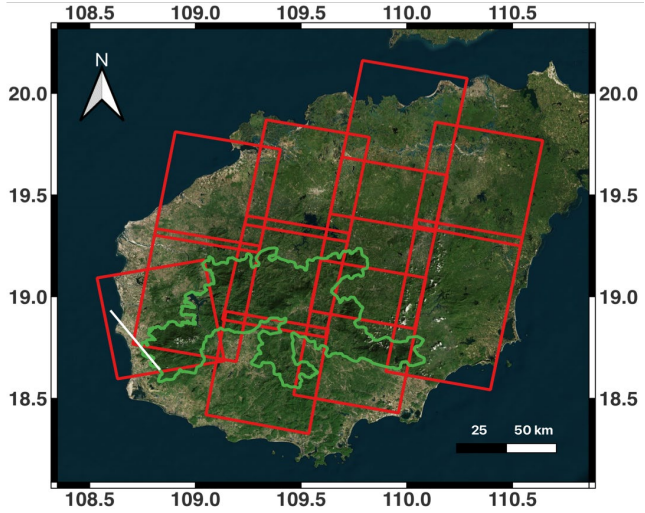
$$h_g = \mu - \beta(x, y) \cdot \sigma$$

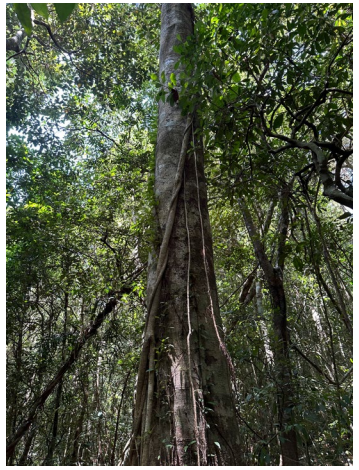
β – tree height relationship

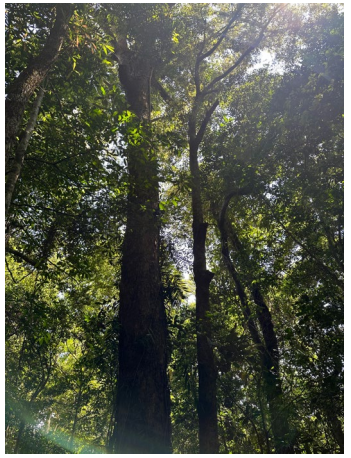


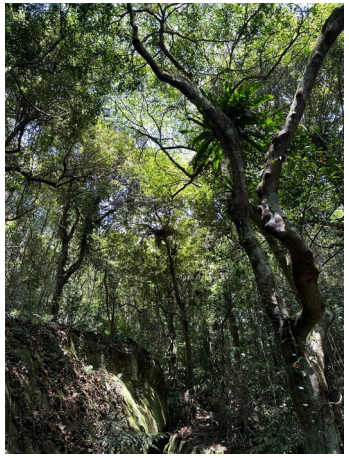
Hainan Tropical Rainforest

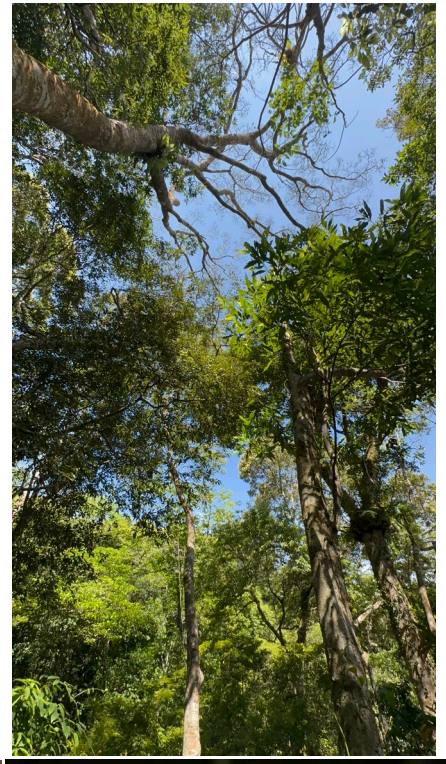


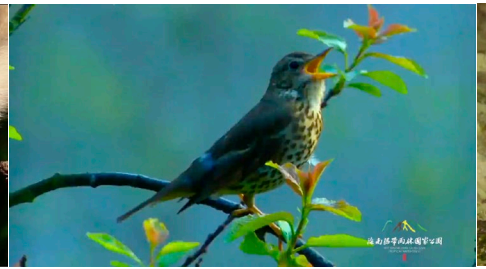






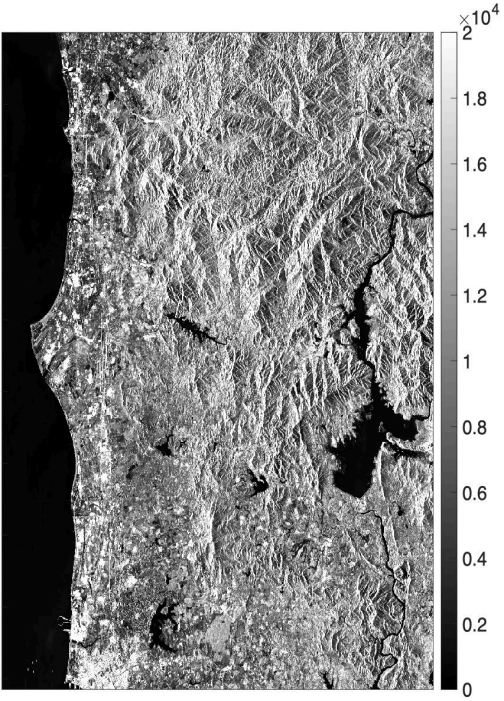




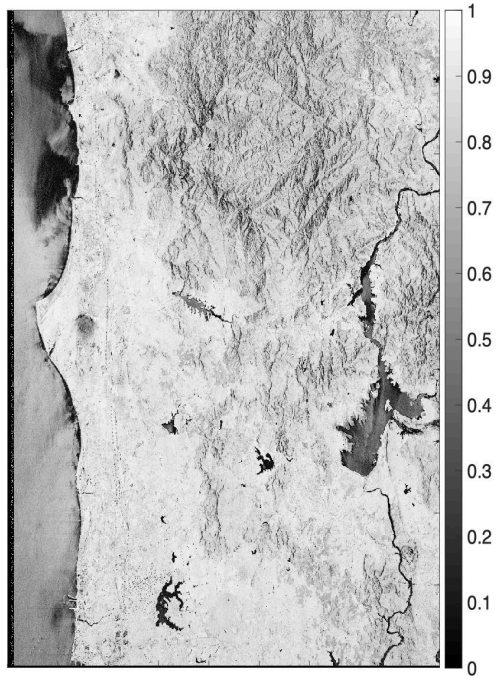


Lutan-1 Bistatic InSAR data

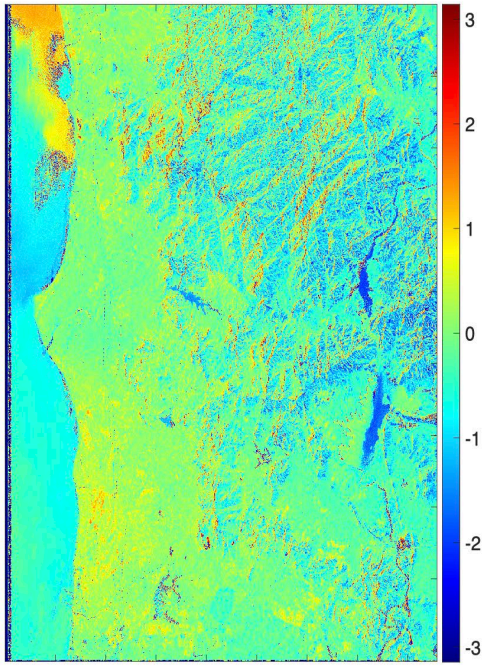
SAR Backscatter



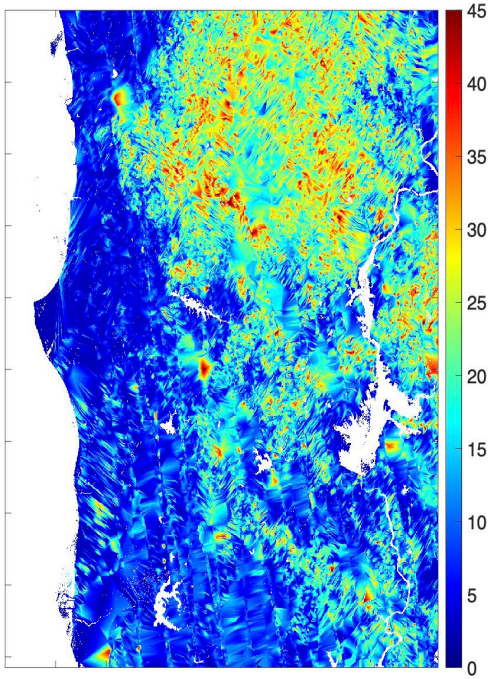
InSAR Coherence

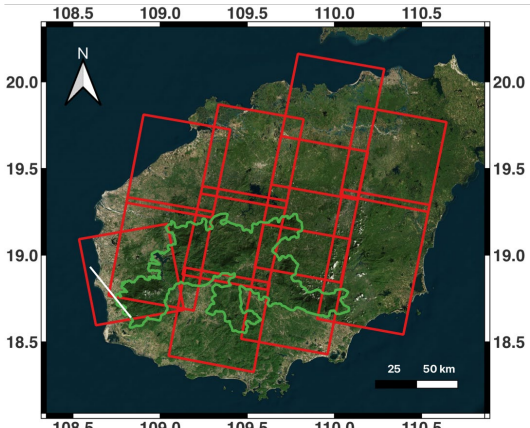


InSAR Phase



Lidar Height

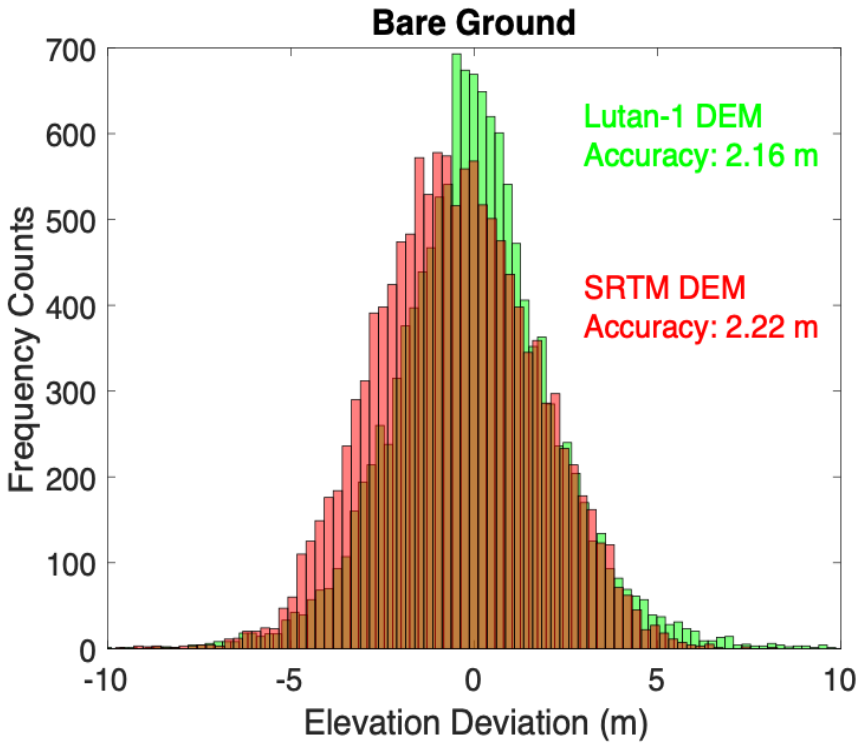




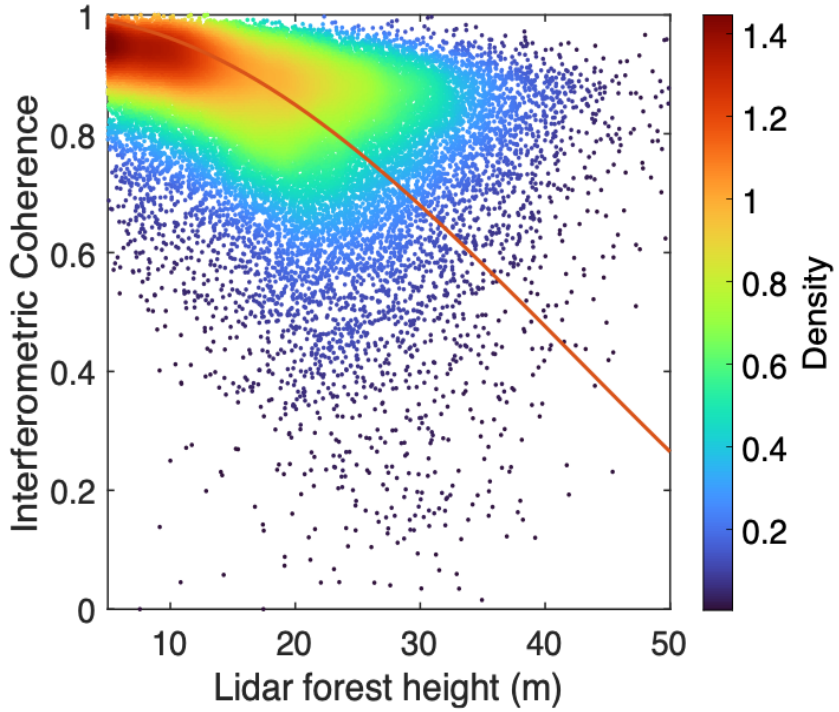
Lutan-1 Bistatic InSAR data

InSAR Data Quality Check

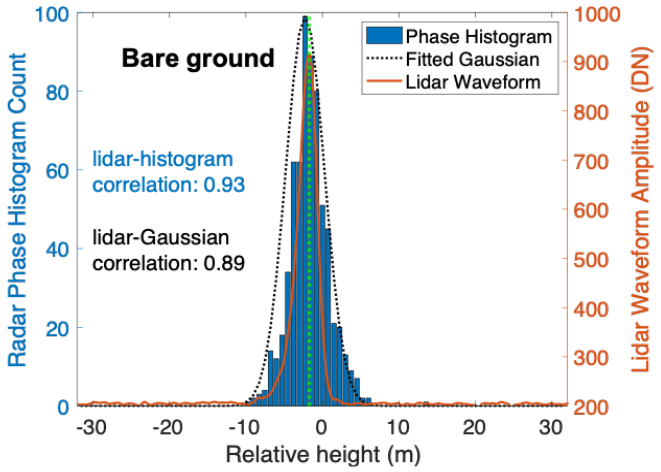
Phase



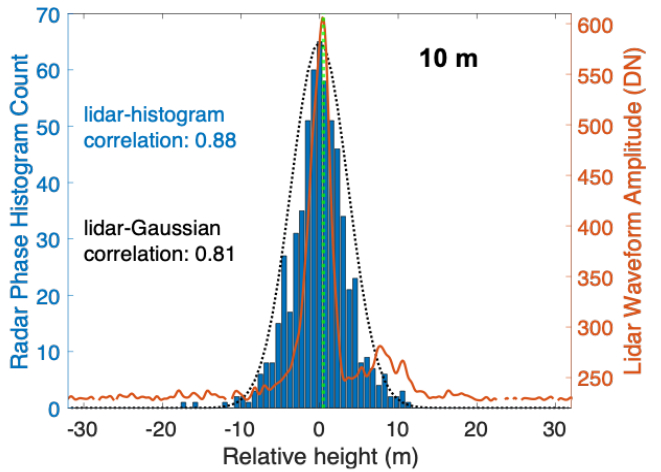
Coherence



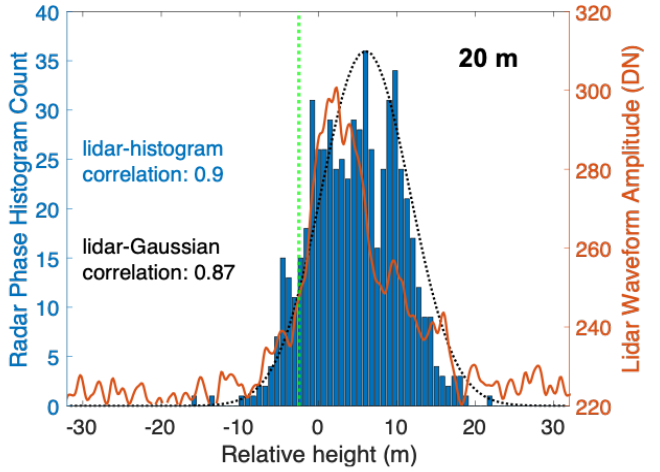
Forest Vertical Structural Profile



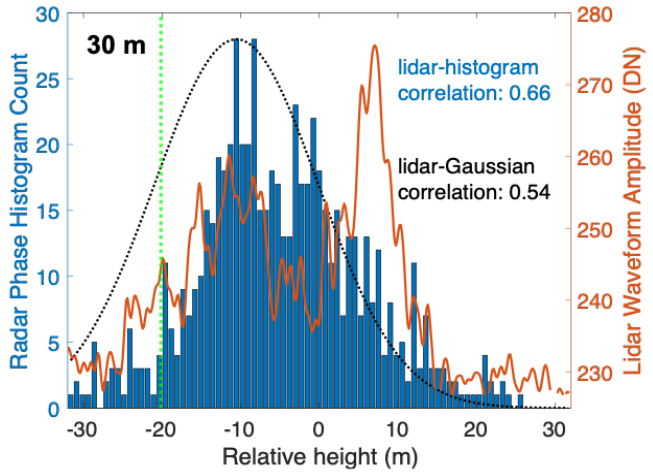
Bare



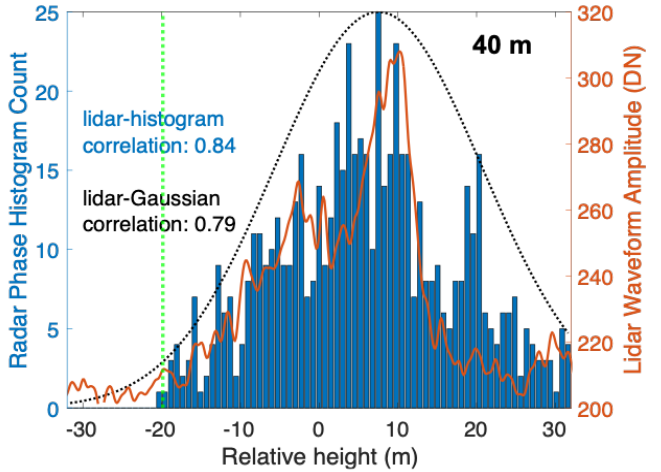
10 m



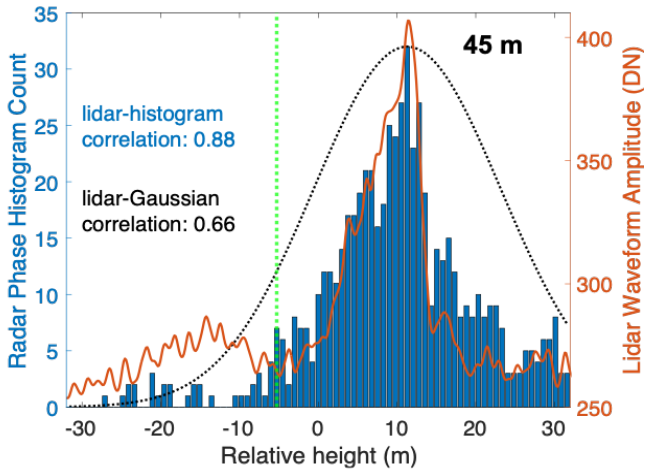
20 m



30 m

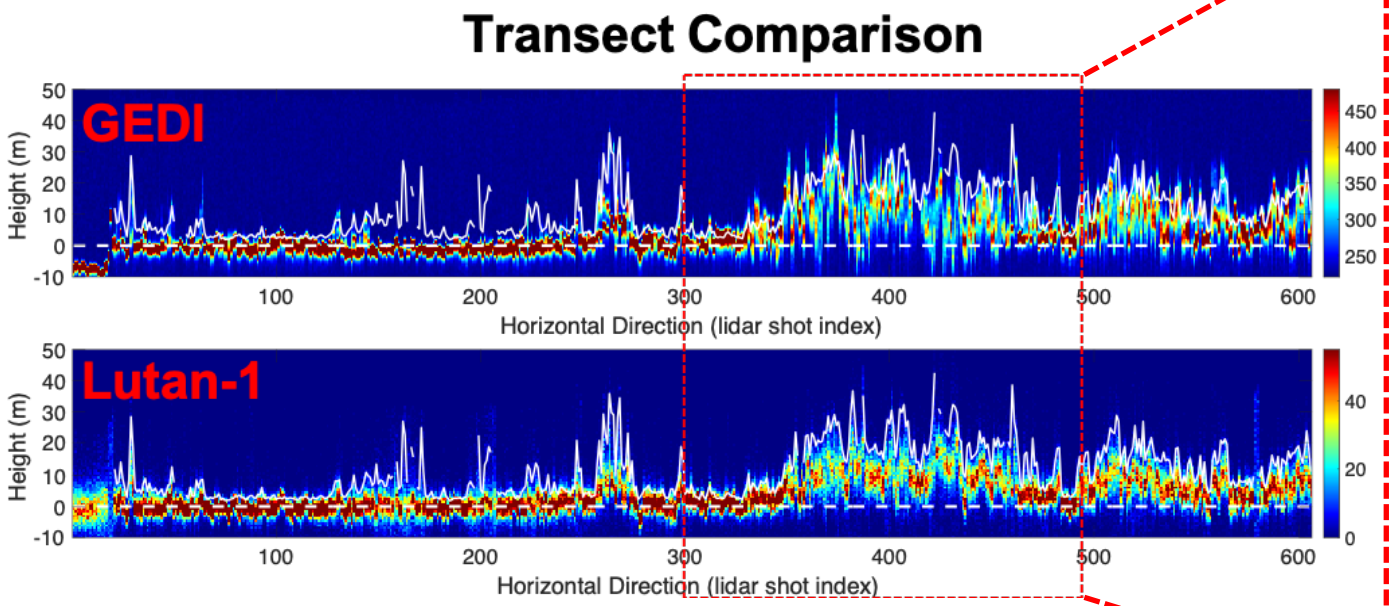


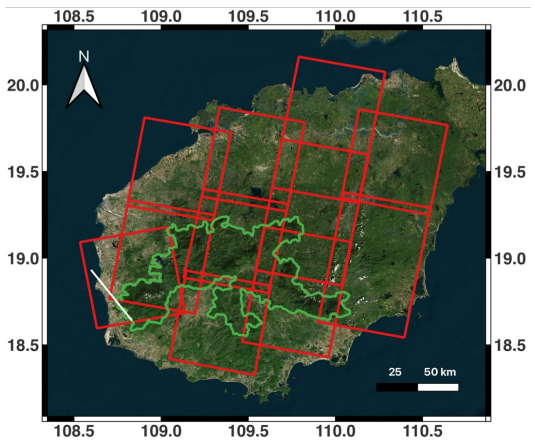
40 m

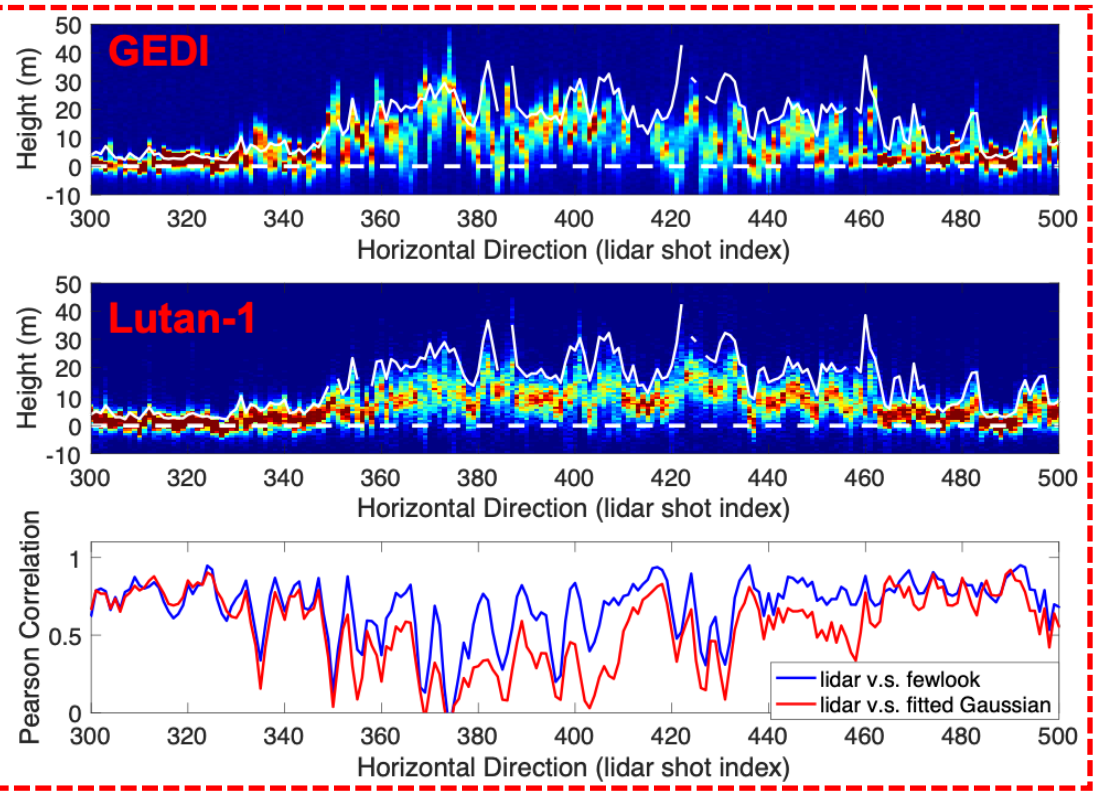


45 m

Forest Vertical Structural Profile

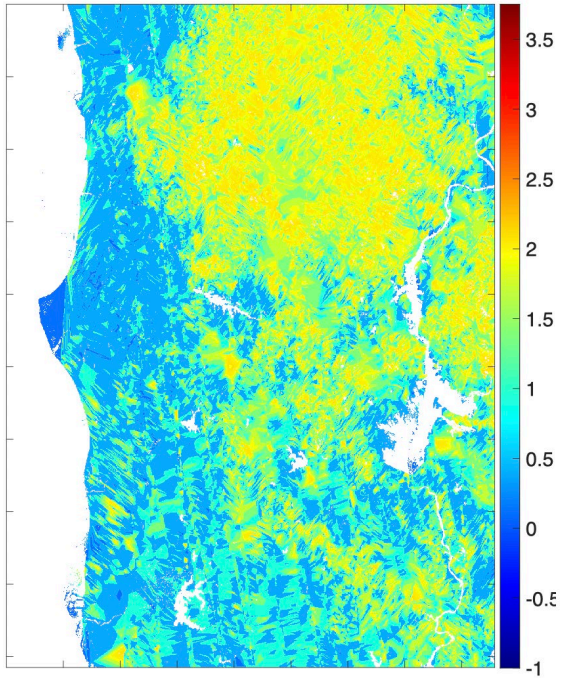




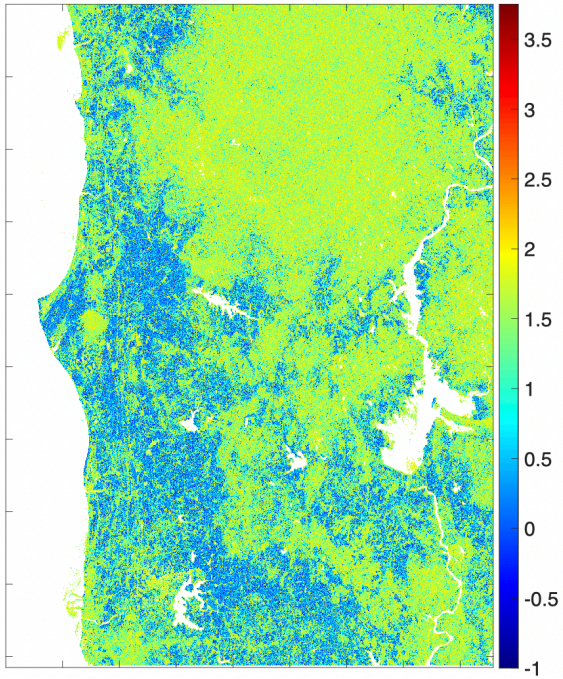


Digital Terrain Model (DTM)

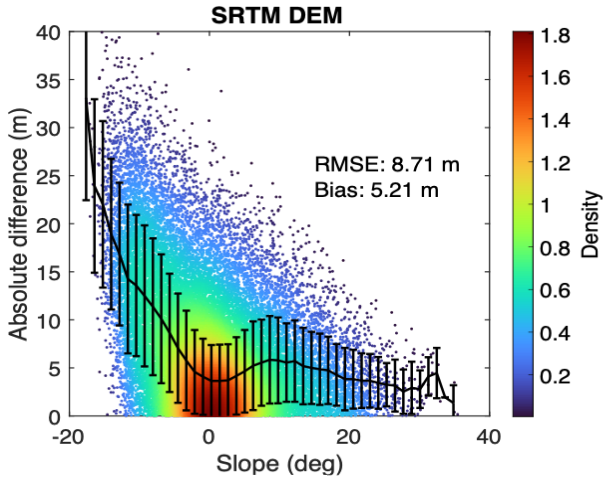
β factor (lidar-based)

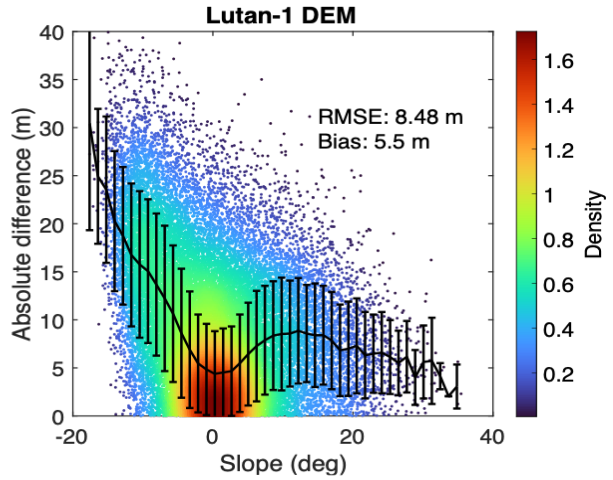


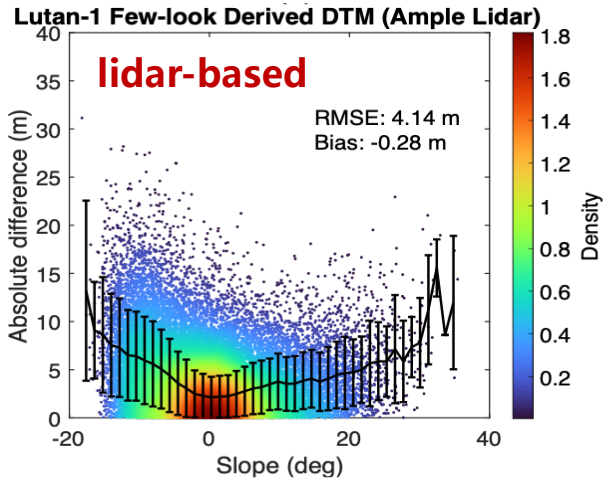
β factor (histogram-based)

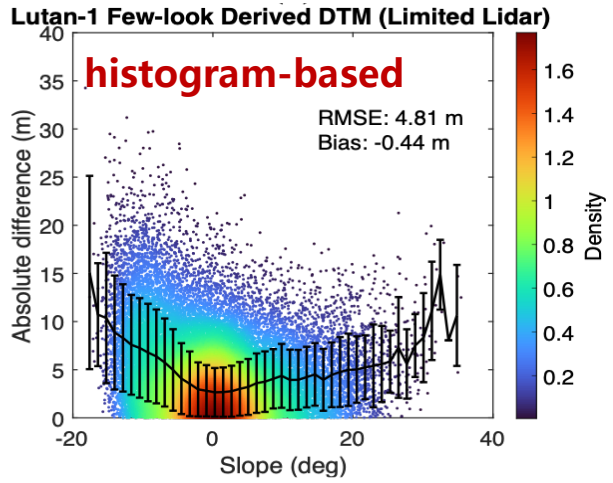


$$h_g = \mu - \beta(x, y) \cdot \sigma$$



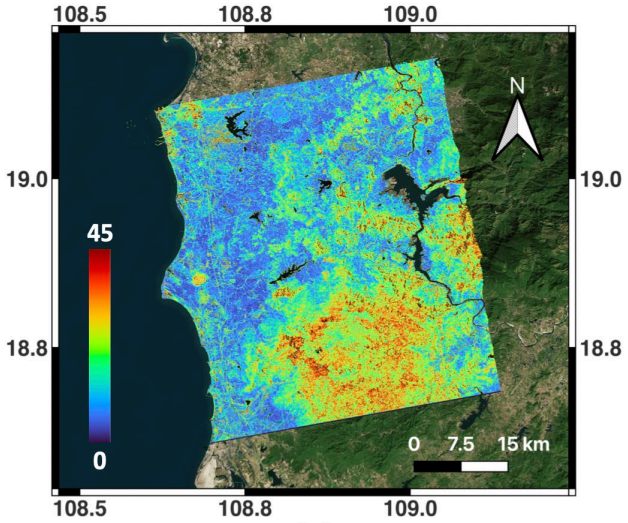


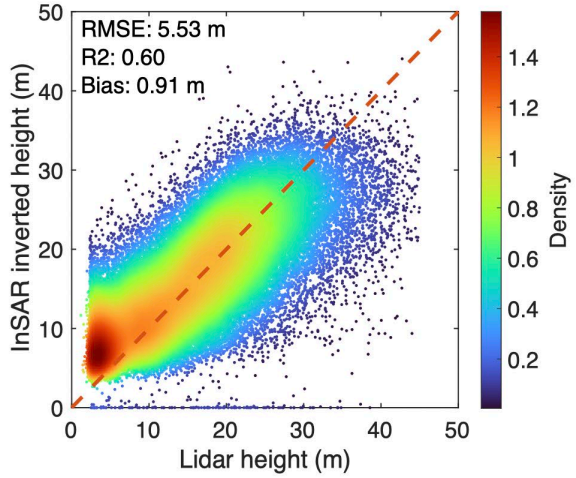




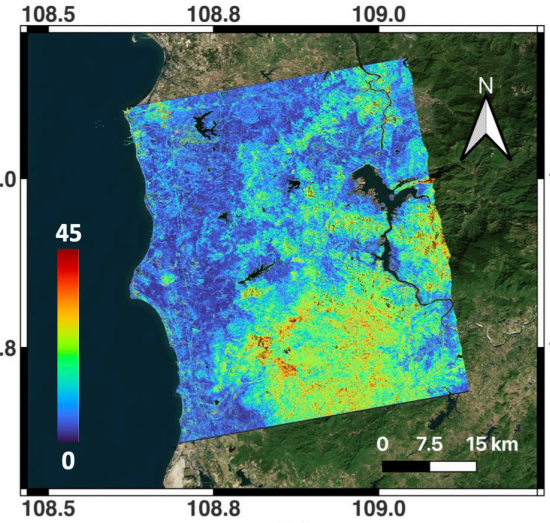
Forest Height

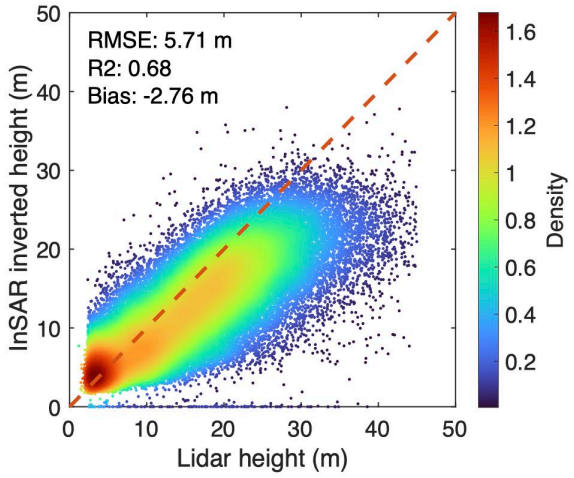
ERH98



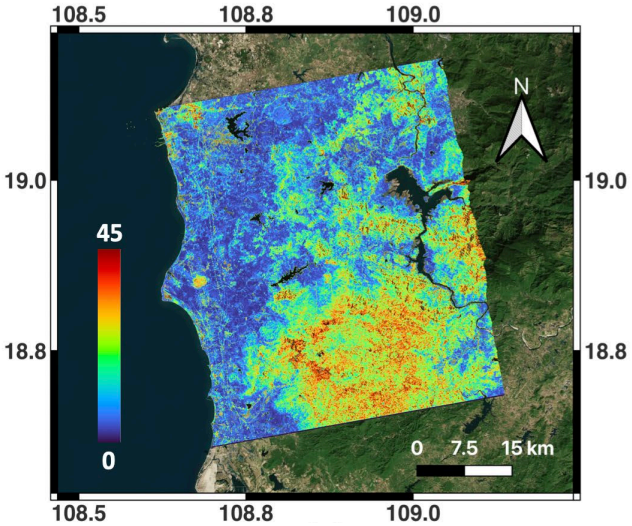


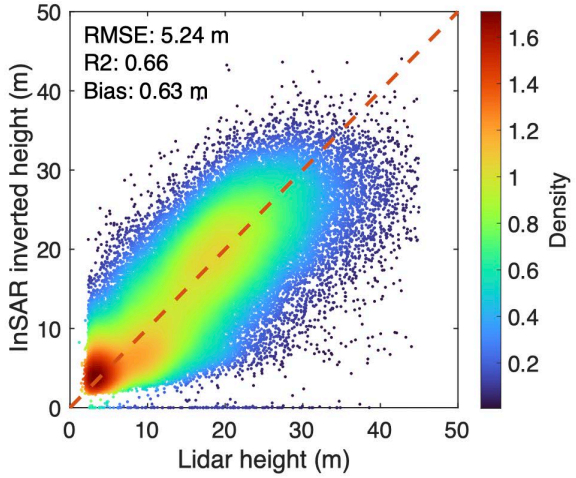
3dB





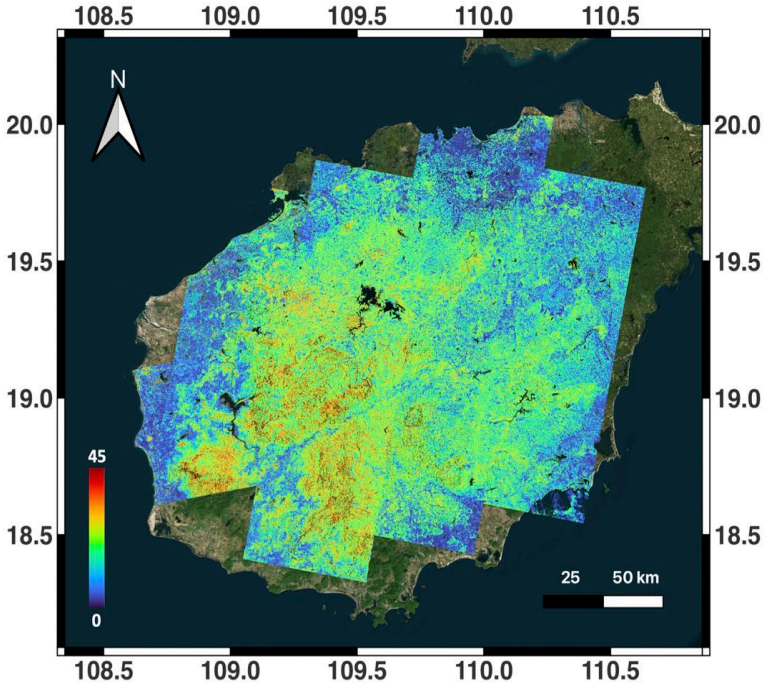
Merged



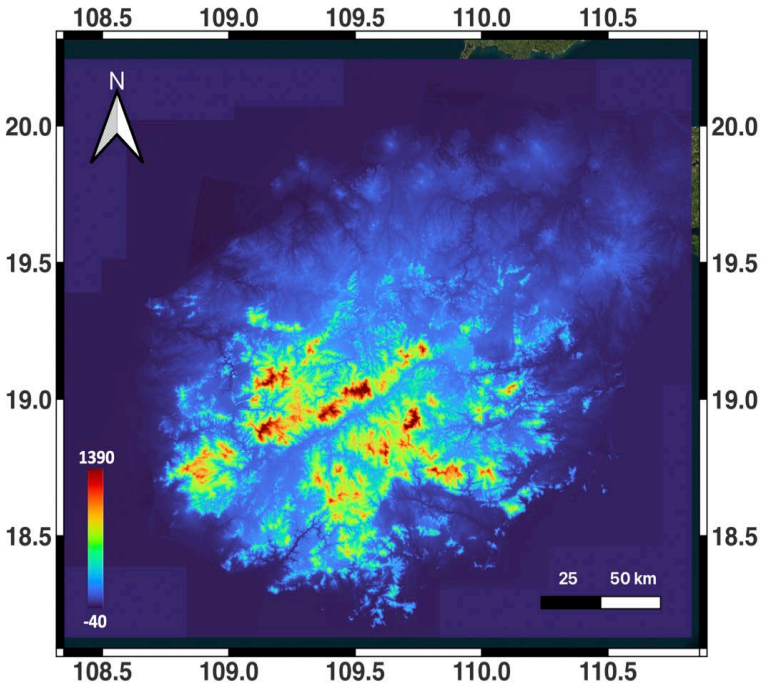


Large-scale Demo

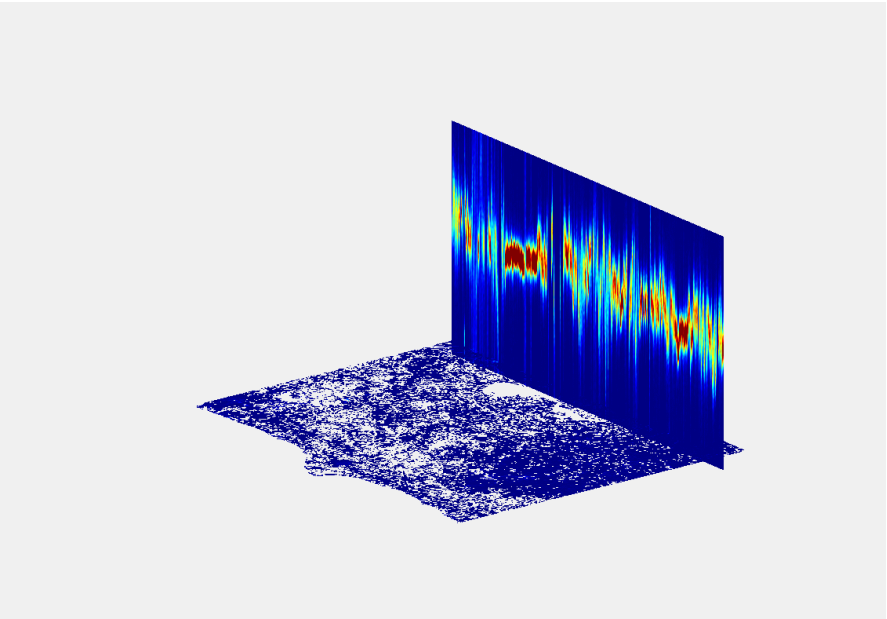
Forest Height



DTM

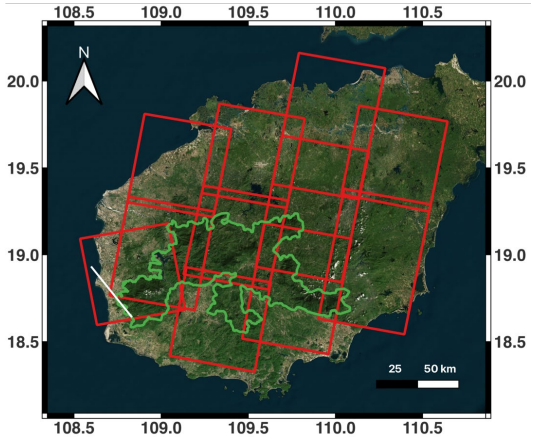


Vertical Structural Profile



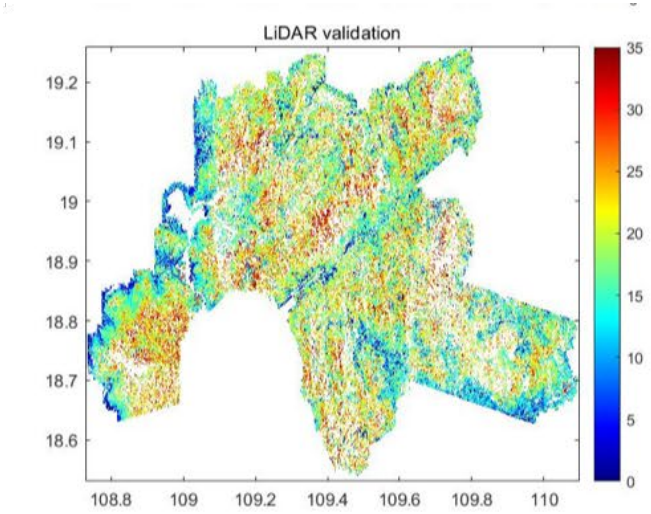
3 MHa

Large-scale Demo

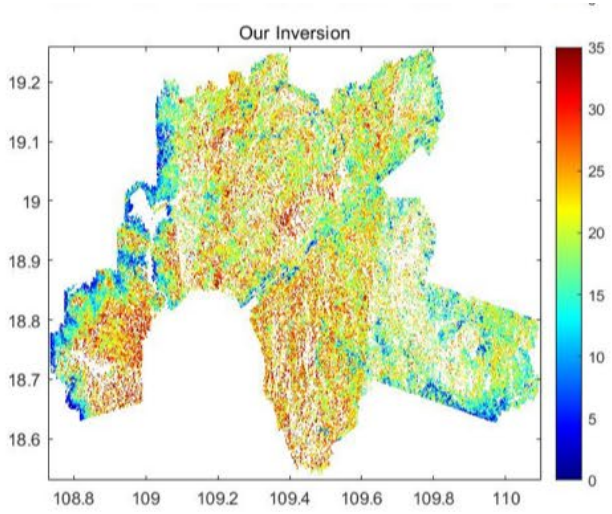


Validation

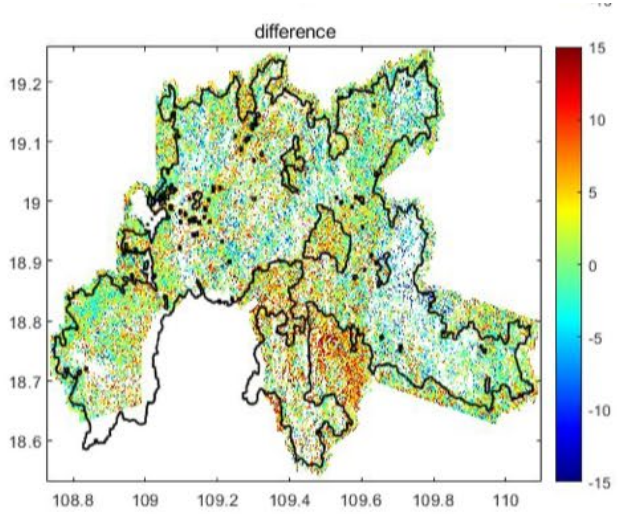
ALS

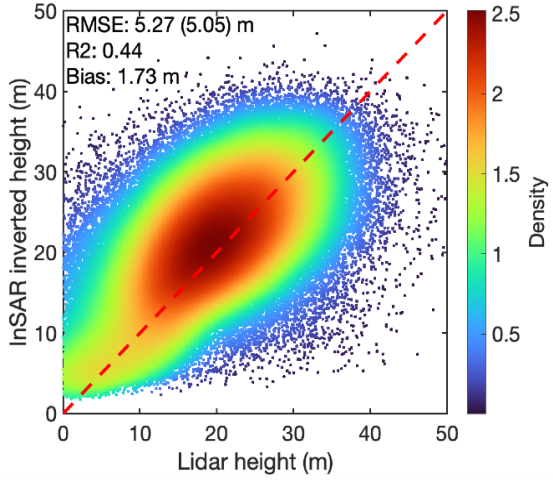


Lutan-1



Difference





Take-home messages

- **High-resolution bistatic InSAR** can be used to retrieve both **DTM** and forest **vertical structure** information (e.g. height and profile)
- **Few-look phase height (PH) histogram method** is a promising technology for future high-resolution bistatic InSAR missions
- **First demo** of the few-look PH method using **spaceborne L-band bistatic InSAR data** from the Chinese Lutan-1
- **Multiple products** are generated and validated, e.g. tree heights, phase center heights, vertical profiles, DTM…

中国科学院国家空间科学中心
National Space Science Center . CAS

Thank you!

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Email: leiyang@nssc.ac.cn

Remote Sensing Methods

Optical

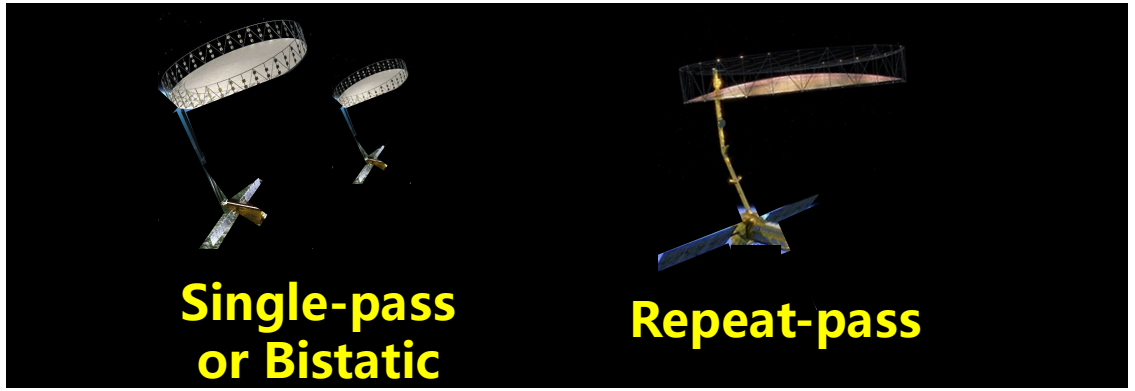
- Passive Optical (NDVI, LAI, etc) → cloud, less sensitivity 3D structure
- lidar → cloud, sparse sampling

Microwave

- SAR backscatter → saturation
- InSAR → unknown ground
- PolInSAR → expensive payload resources

Manual Approach

InSAR Satellites



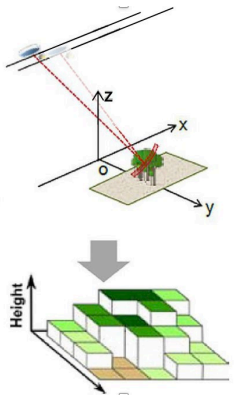
Data Availability and Methods

unknown ground

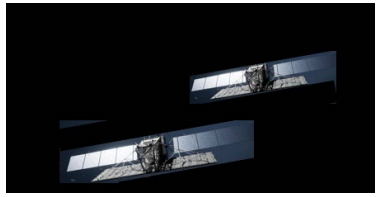
L-band Repeat-pass (single-pol)

HV

- SAR backscatter regression
- InSAR temporal decorrelation

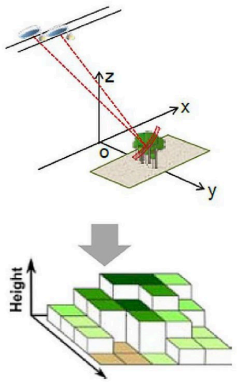


Bistatic (single-pol)

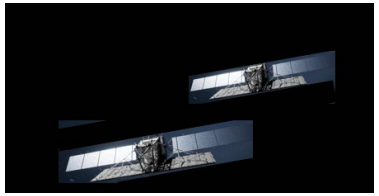


HH

- Lidar DTM
- InSAR sub-aperture
- InSAR coherence
- InSAR few-look PH histogram



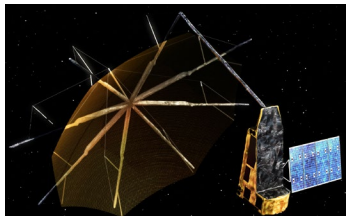
Bistatic (full-pol)



HH, HV, VH, VV

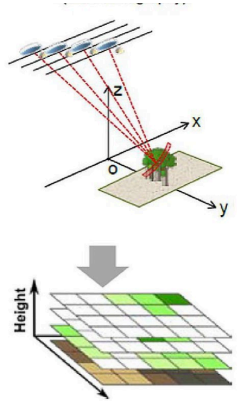
- PolInSAR

Multi-baseline Bistatic / P-band Repeat-pass



HH/HV/VH/VV

- TomoSAR



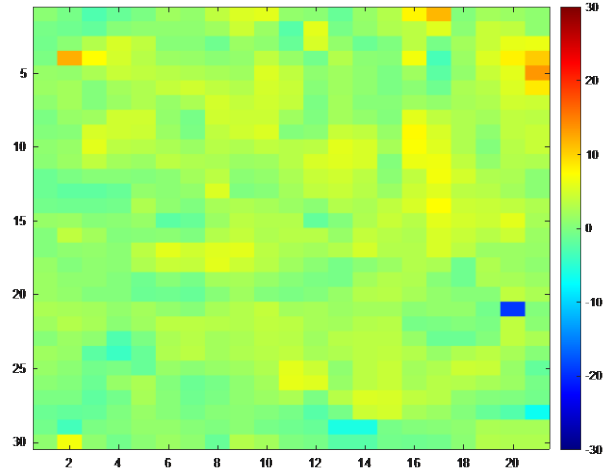
Lutan-1 few-look InSAR phase histograms

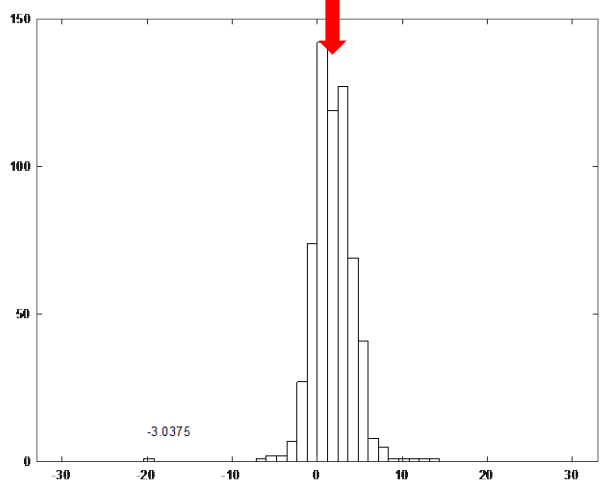
Vertical Profile

Mount Jianfeng, Hainan

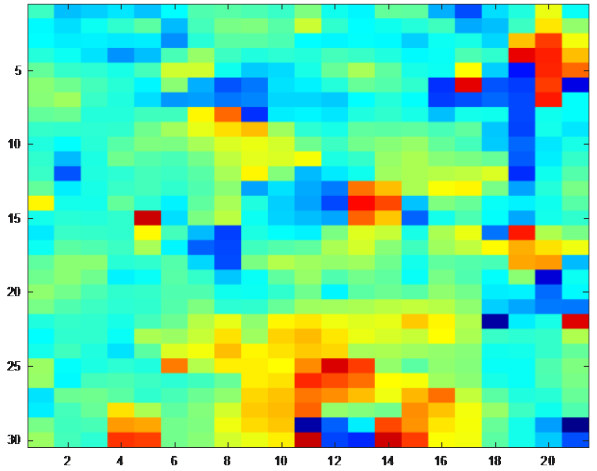
lidar DTM

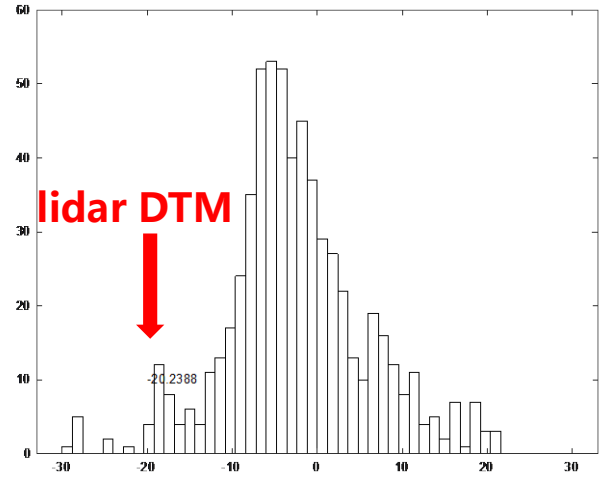
Bare ground





Mountainous Vegetation





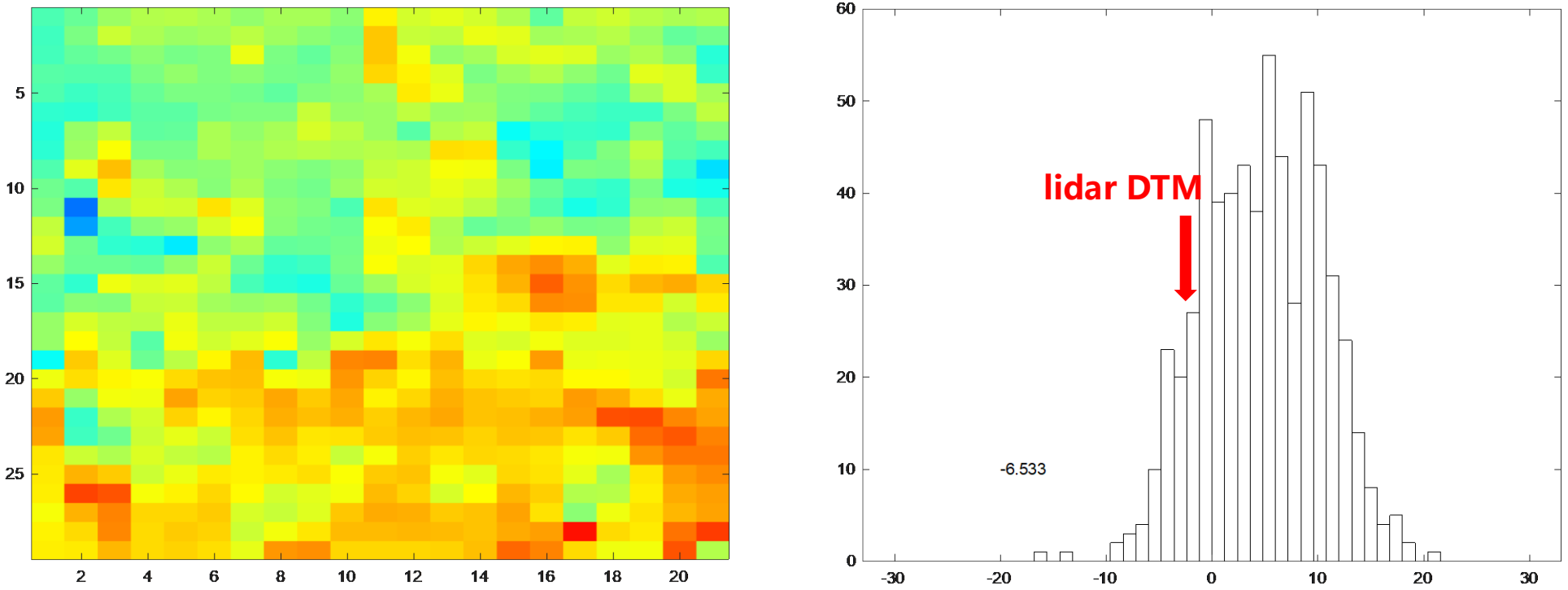
Relative height (0 is the elevation of SRTM DEM)

Lutan-1 few-look InSAR phase histograms

More examples of vertical profile

Mount Jianfeng, Hainan

Tree height: 20m



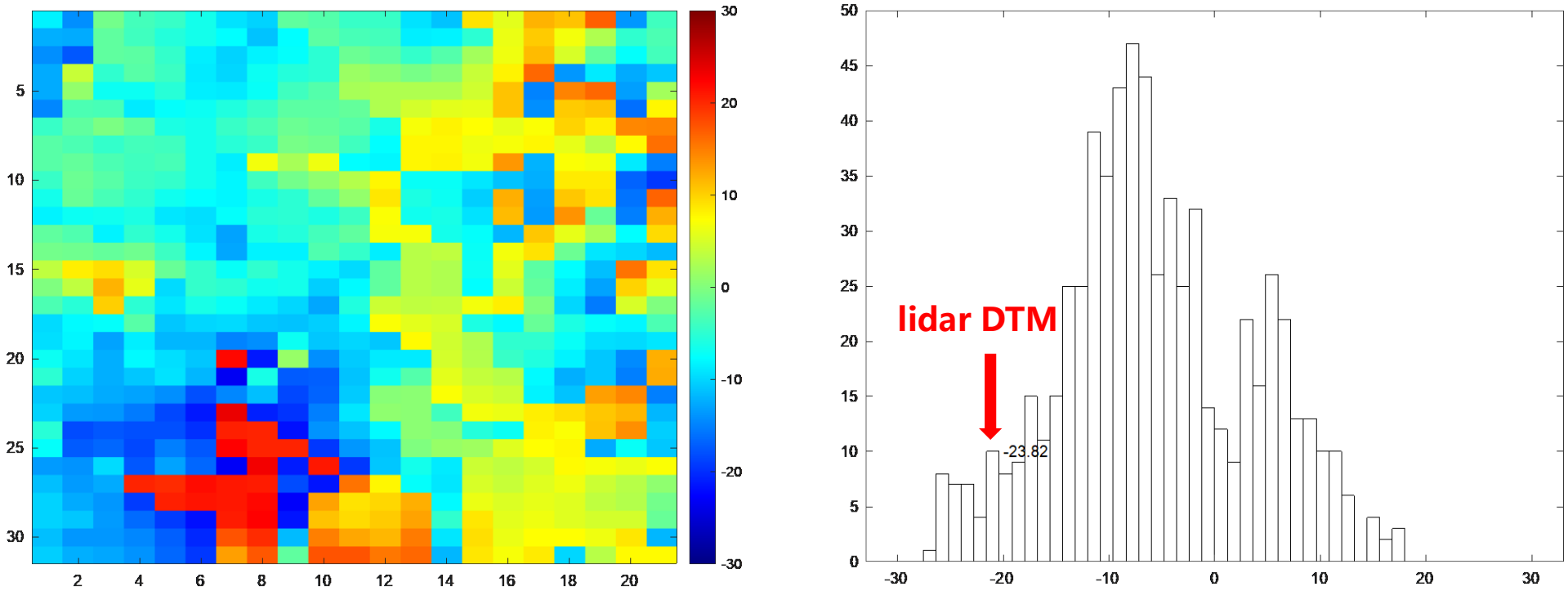
Relative height (0 is the elevation of SRTM DEM)

Lutan-1 few-look InSAR phase histograms

More examples of vertical profile

Mount Jianfeng, Hainan

Tree height: 40m



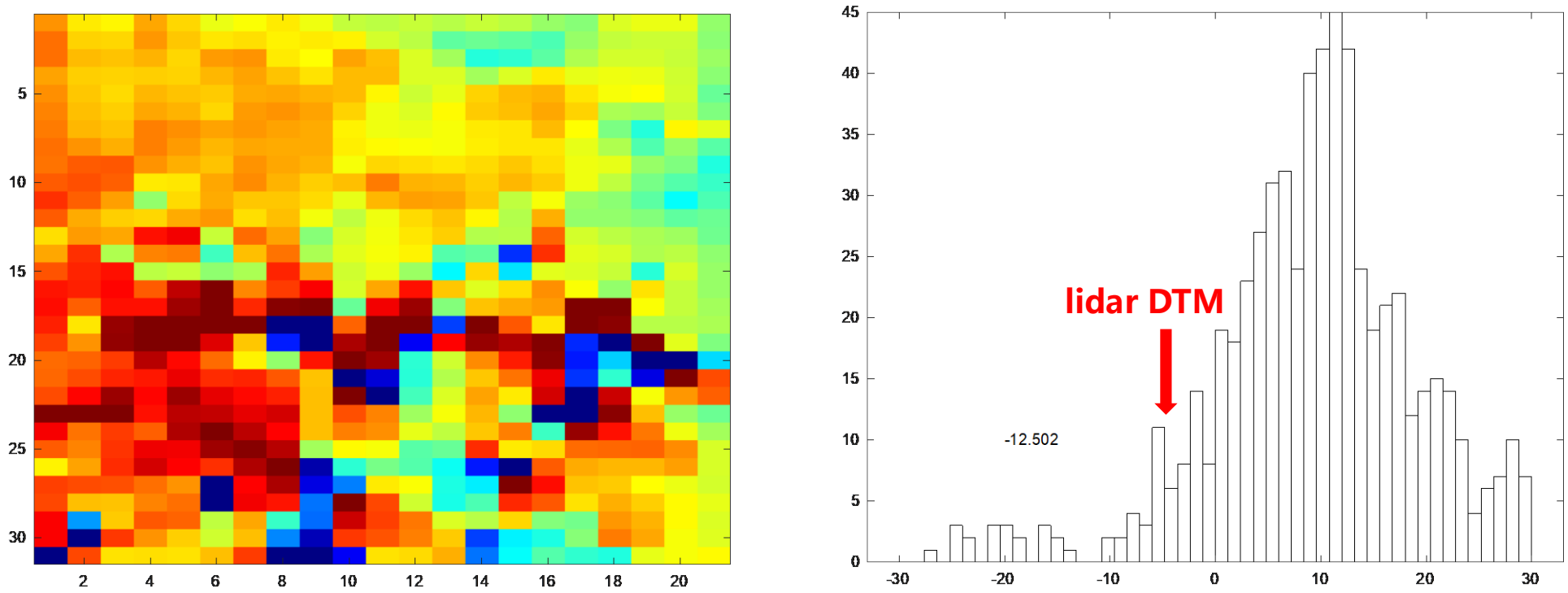
Relative height (0 is the elevation of SRTM DEM)

Lutan-1 few-look InSAR phase histograms

More examples of vertical profile

Mount Jianfeng, Hainan

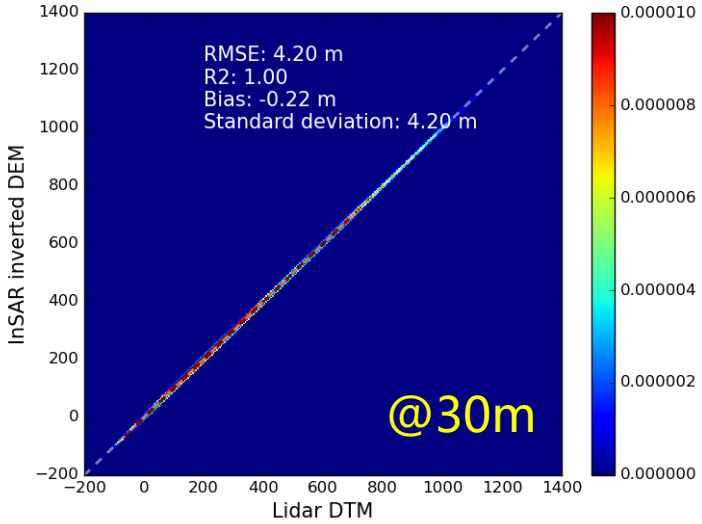
Tree height: 45m



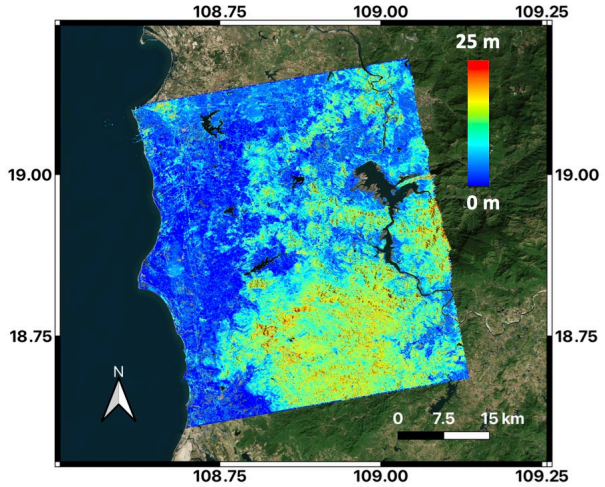
Relative height (0 is the elevation of SRTM DEM)

Tree height & DTM inversion results

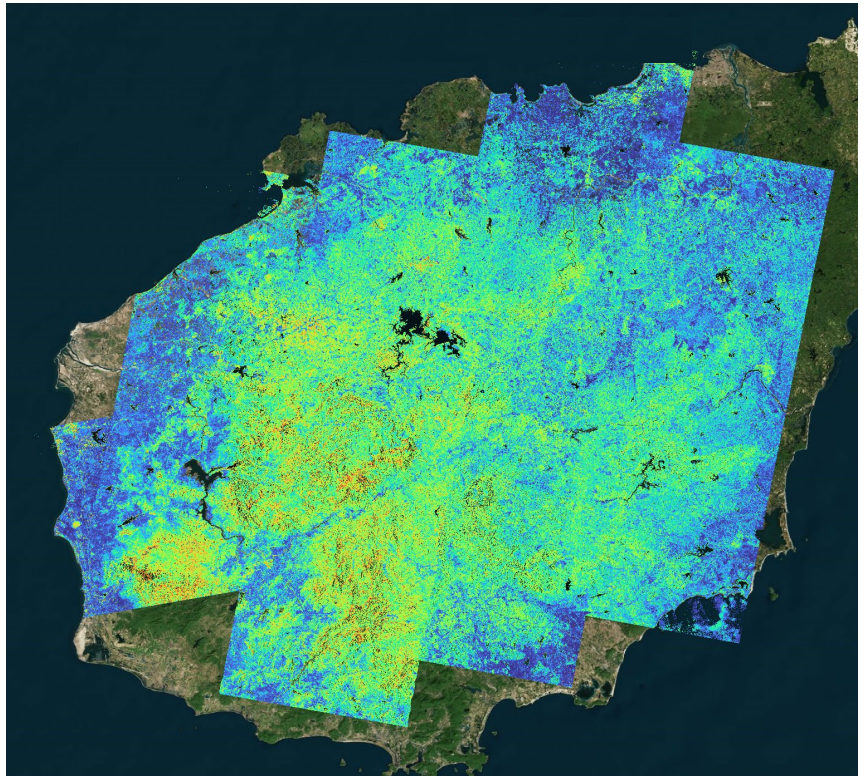
DTM



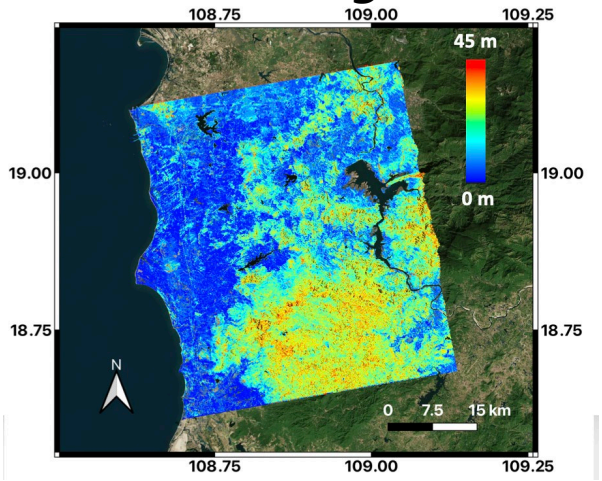
Phase Center Height



Hainan CHM map



Total Height



Total Height