Sub-Canopy Topography Estimation With Multibaseline Pol-InSAR Data: A RELAX-Based Solution

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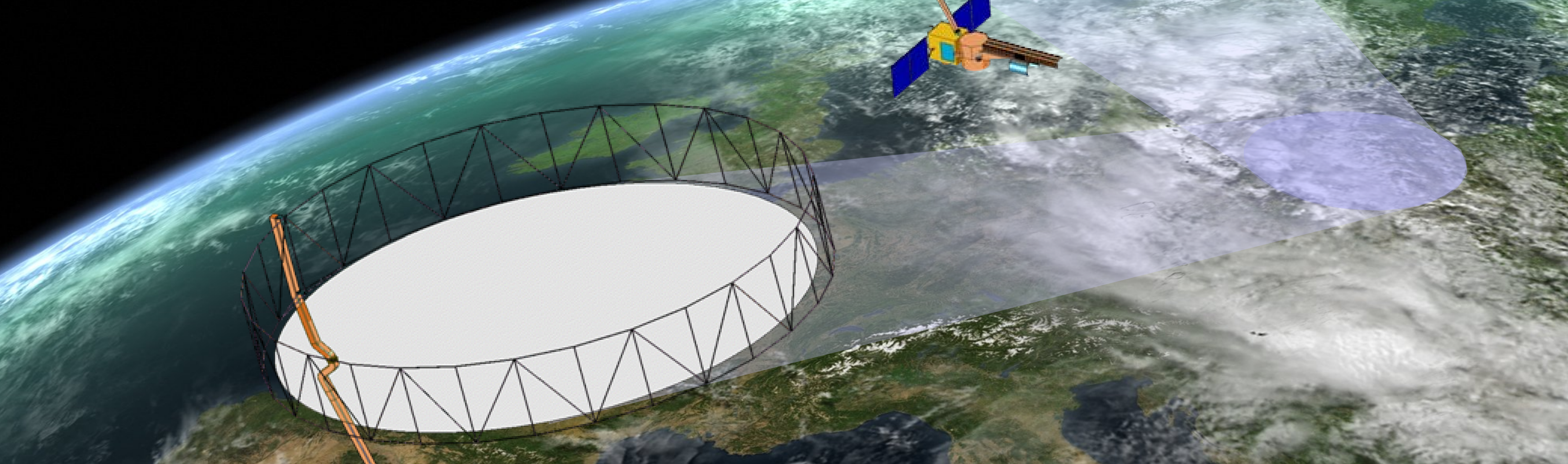
Overview

- ***Introduction***
- ***Ground height estimation @ L-band***
- ***The RELAX method***
  - How it works
  - Comparison with Maximum Likelihood
  - Performance with real data (Traunstein forest):
    - for different baseline distributions
    - for different polarization combinations
- ***Conclusions & future work***

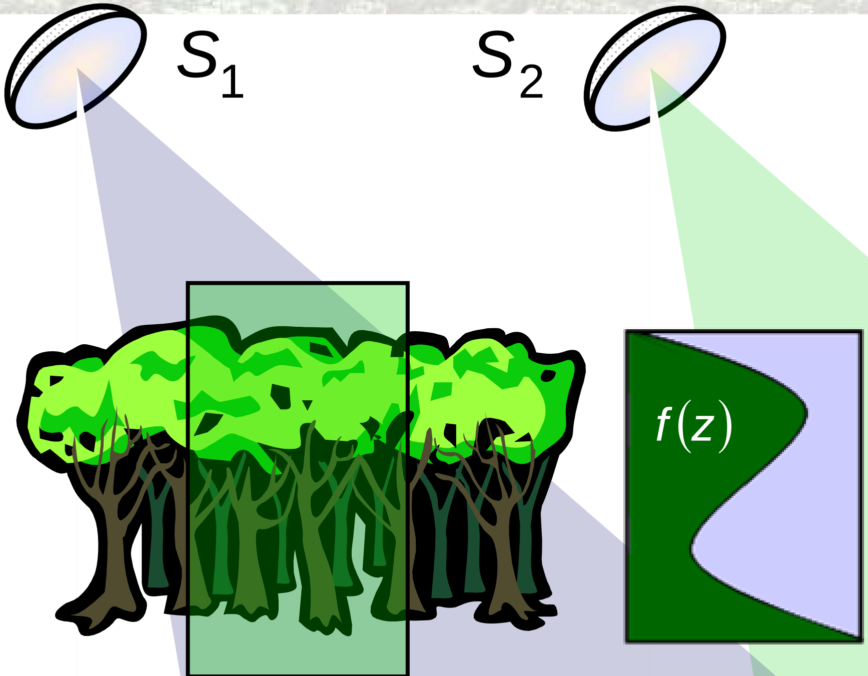
TanDEM-L

A German mission proposal for monitoring dynamic processes on the Earth surface @ L-band



	Science Product	Coverage	Product Resolution	Product Accuracy
Biosphere	Forest Height	All forest Areas (Height ≥ 8 m)	50 m (global) 20 m (local)	~ 10 %
	Above Ground Biomass		100 m (global) ≤ 50 m (regional)	~ 20 % (or 20 t/ha)
	Vertical Forest Structure		50 m (global) 20 m (local)	3 layers
	Underlying Topography		50 m	< 4 m

SAR MB-Pol-InSAR data for the vertical structure of forests



Interferometric Coherence

$$\gamma(S_1,S_2)=\frac{E\left\{S_1S_2^*\right\}}{\sqrt{E\left\{S_1S_1^*\right\}E\left\{S_2S_2^*\right\}}}$$

$$\gamma_{VOL}\left[f(z)\right]=$$

$$\gamma=\gamma_T\ \gamma_{SNR}\ \gamma_{VOL}$$

- γ_T: temporal decorrelation
- γ_{SNR} : additive noise decorrelation
- γ_{VOL} : geometric decorrelation

$$k_z=\frac{4\pi}{\lambda}\frac{\Delta\theta}{\sin\theta_0}$$ Vertical wavenumber

Polarization diversity allows to relate coherent scattering models to the resulting Pol-InSAR coherence

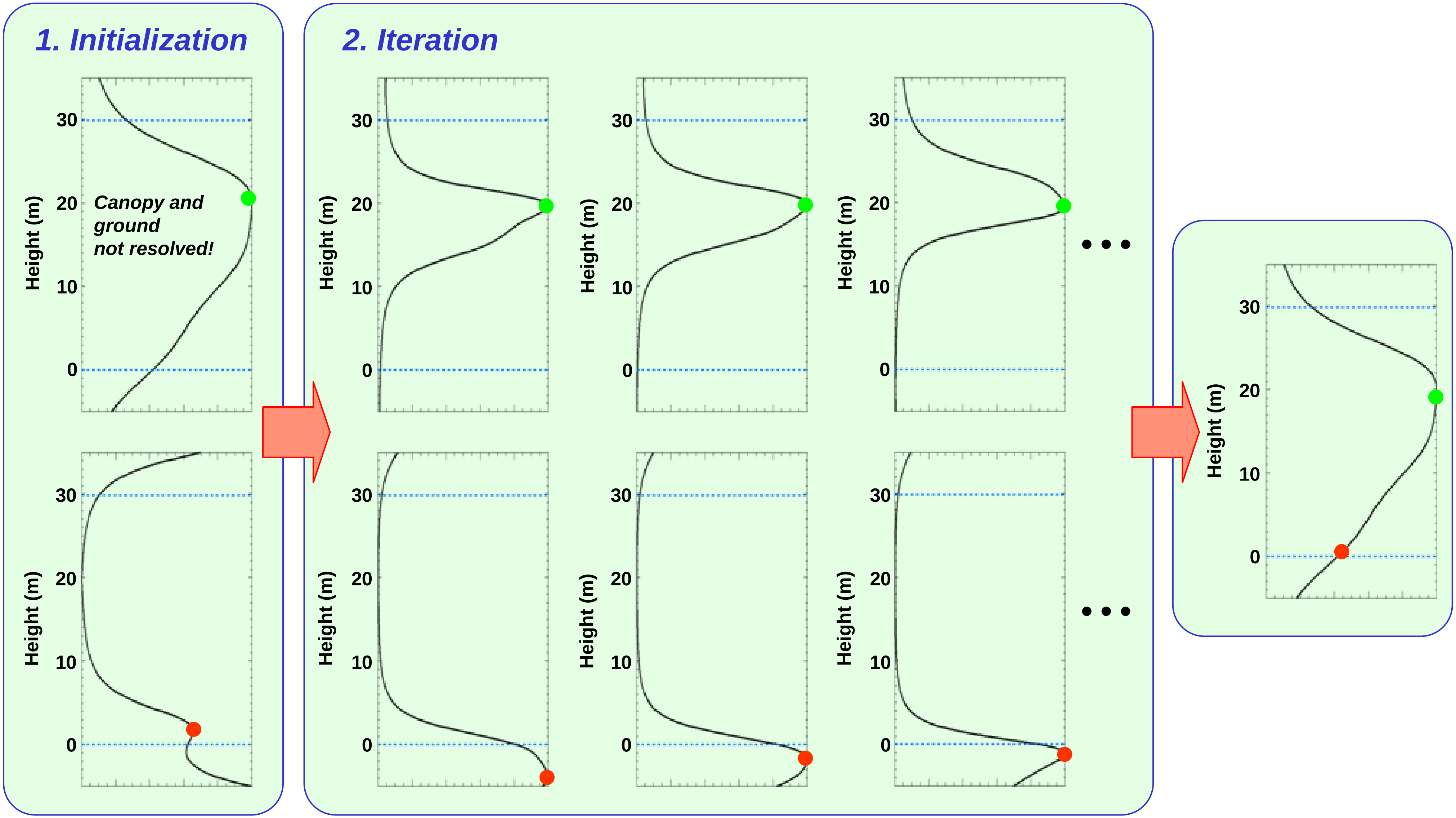
Baseline diversity allows to sample the same vertical structure spectrum at different spatial frequencies

The estimated MB-Pol-InSAR coherences contain all the information necessary for the analysis of the vertical structure of forests

Ground height estimation

- ***Coeherent combination of MB-Pol-InSAR data***
  - Pol-InSAR inversion, single baseline/MB [Papathanassiou-Cloude, IEEE-TGARS '01] [Neumann-Ferro Famil-et al., IEEE-TGARS '10] [Lopez Martinez-Papathanassiou, subm. IEEE-TGARS '11]
  - 3-D (Polarimetric) SAR Tomography, MB
    - Adaptive beamforming (ABF), model-based spectral estimation, COMET inversion, …
      [Lombardini-Pardini, ESA PolInSAR Workshop], [Tebaldini, IEEE-TGARS '10], [Huang-Ferro Famil-et al., ESA PolInSAR Workshop '11], …
- ***SAR Tomography techniques mostly tested with P-band data***
  - Metric accuracy achievable (demonstrated over different scenarios)
- ***Objective of this work: proposal and testing at L-band of an iterative ground topography estimation technique***
  - Separation of the ground scattering component (~ compact in height) from the dominant one in the canopy
  - At each iteration: estimate the height of one component after the cancellation of the other component (RELAX iteration) [Gini-Lombardini-et al., IEEE-TAES '02], [Li-Stoica, IEEE-TSP '98]
  - Advantages: asymptotically statistically efficient with compact scatterers (e.g. the ground), 1D optimization at each iteration, no model is needed for the canopy
  - Improvement w.r.t. classical RELAX: heights are estimated exploiting the ABF spectrum to take advantage of its higher sidelobe suppression capabilities w.r.t. the Fourier-based beamforming

How RELAX works: an example



The “Traunstein” dataset

Bürgerwald Traunstein

“Close to Nature”
Temperate managed forest

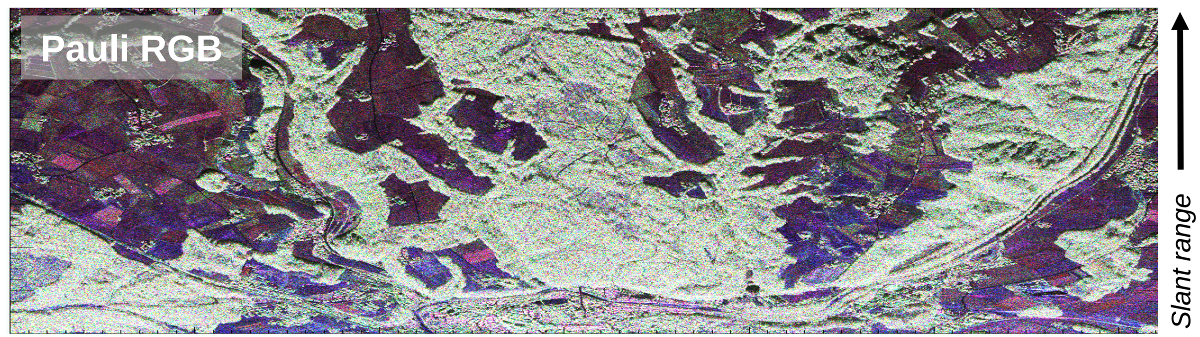
N. Spruce, E. Beech, White Fir
Height Range (H100): 10 - 40m
Biomass Range: 40 ~ 450 t/ha
Moderate Slopes

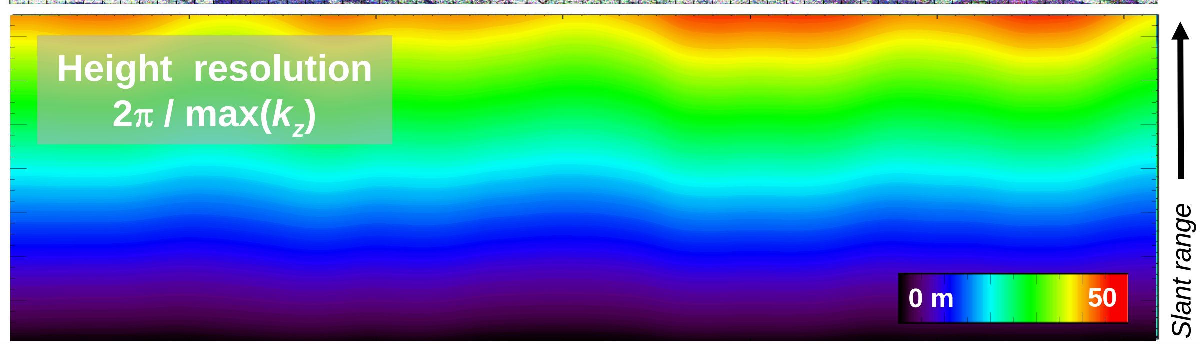
DLR E-SAR dataset

5 full-pol images (June 2008), L-band
~1 hour time span

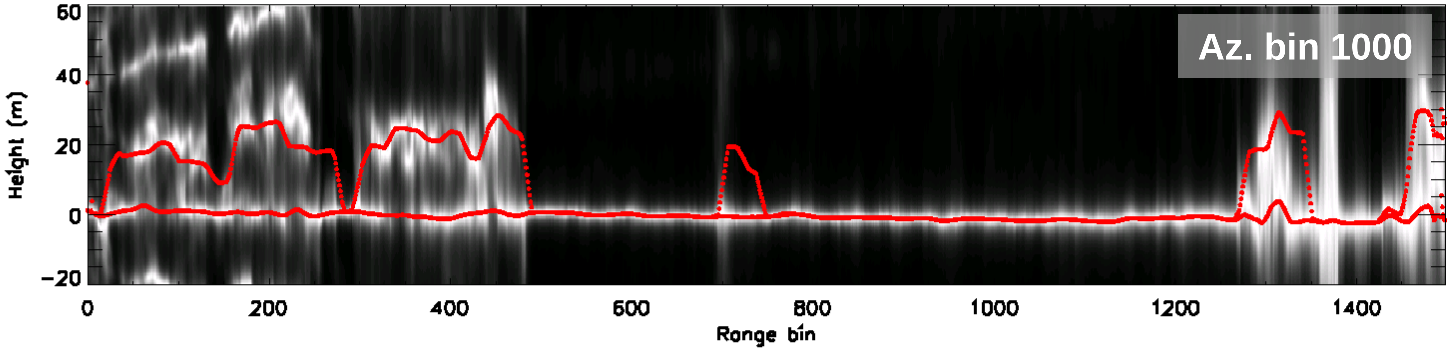
Baselines: -15 ,-5 ,5 ,10 m
wrt master acquisition

LIDAR DTM/forest height available

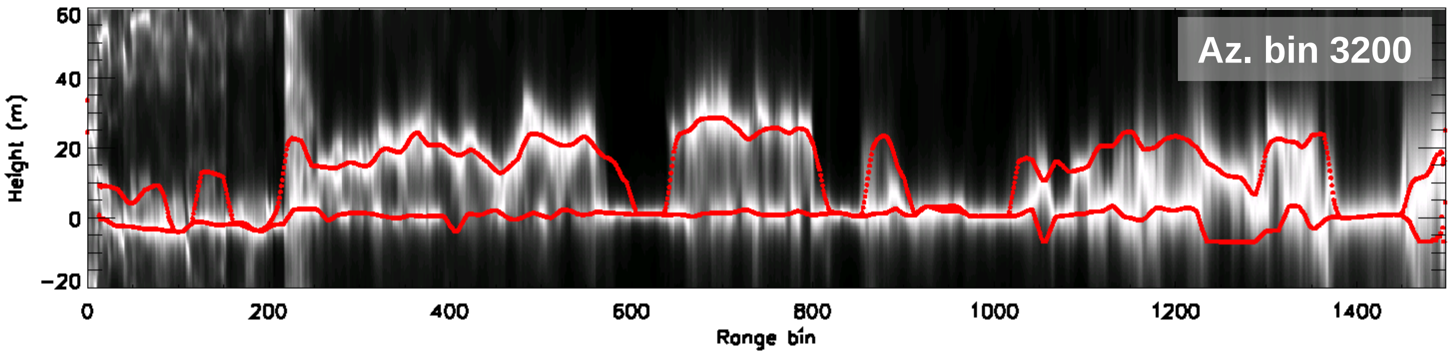




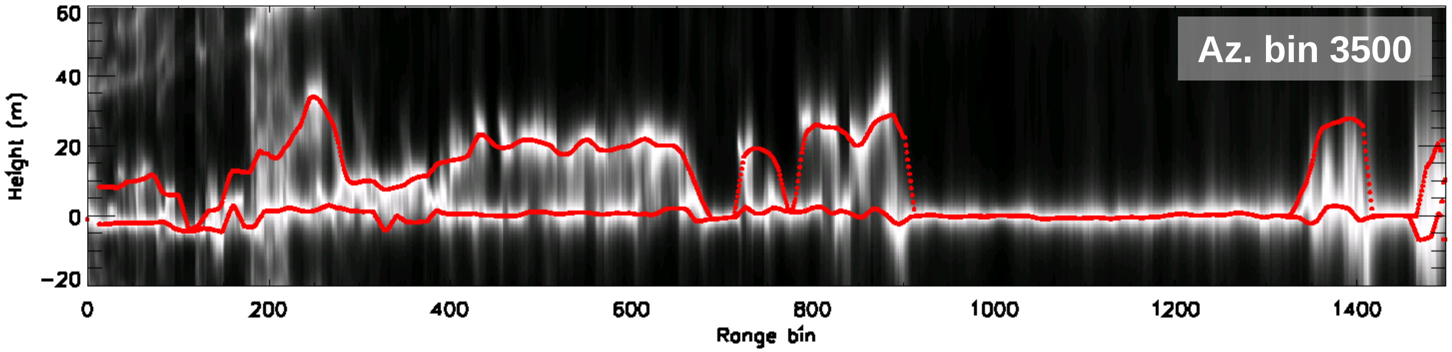
Real data results: Tomographic slices (HH)



	RELAX
Bias (m)	0.10
Std (m)	0.87



	RELAX
Bias (m)	0.36
Std (m)	2.25



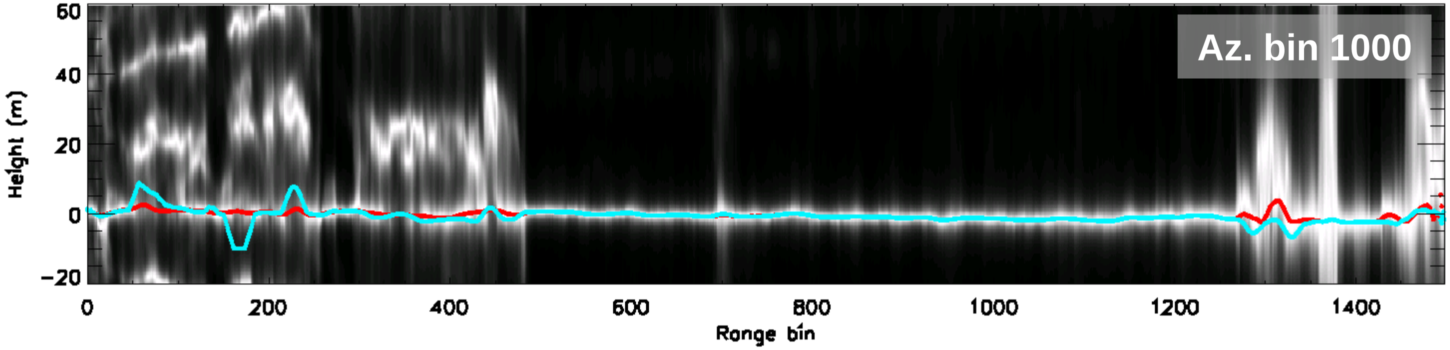
	RELAX
Bias (m)	0.18
Std (m)	1.06

HH polarisation

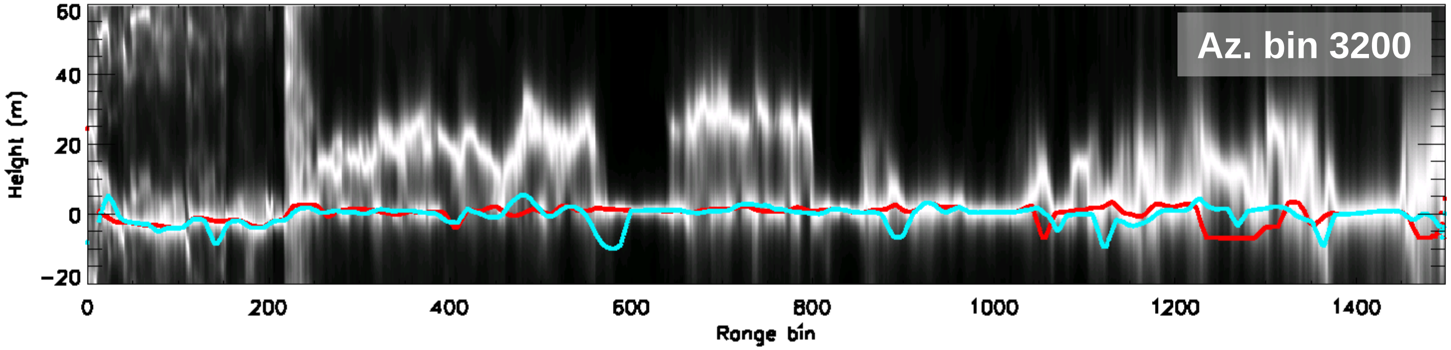
RELAX estimates of the ground height and canopy centroid height superimposed to the ABF tomographic slices

Note: For better visualization, the LIDAR DTM has been compensated in the data

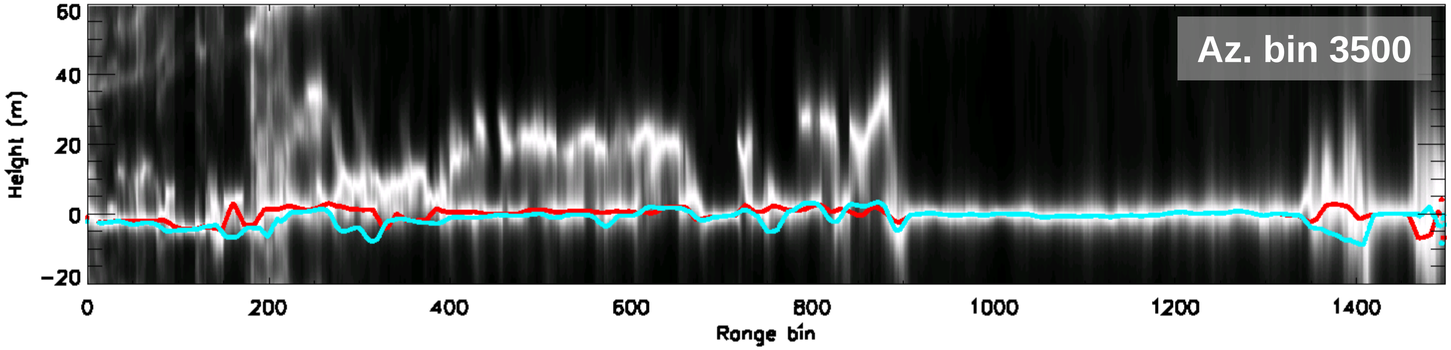
Comparison with Maximum Likelihood (ML) estimation



	RELAX	ML
Bias (m)	0.10	0.8
Std (m)	0.87	1.15



	RELAX	ML
Bias (m)	0.36	0.1
Std (m)	2.25	2.51



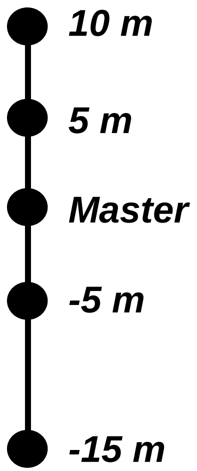
	RELAX	ML
Bias (m)	0.18	-0.61
Std (m)	1.06	1.78

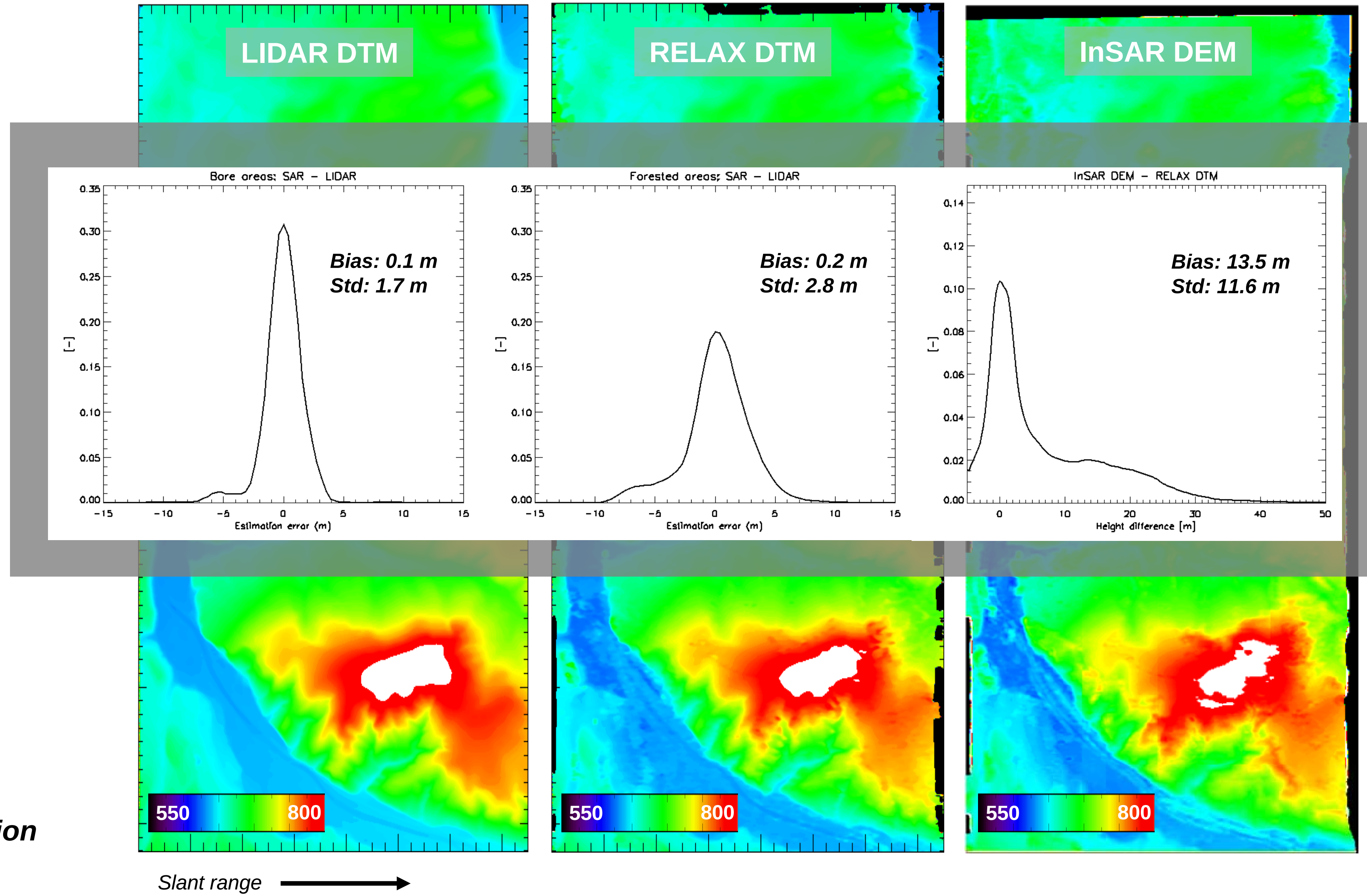
HH polarisation

RELAX ground height

Maximum Likelihood (RVOG) ground height [Göransson-Ottersten, IEEE-TSP '99]

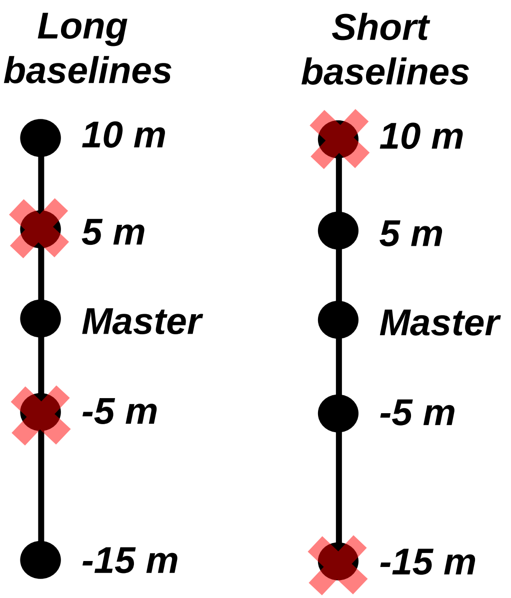
Estimated DTM (1/2)



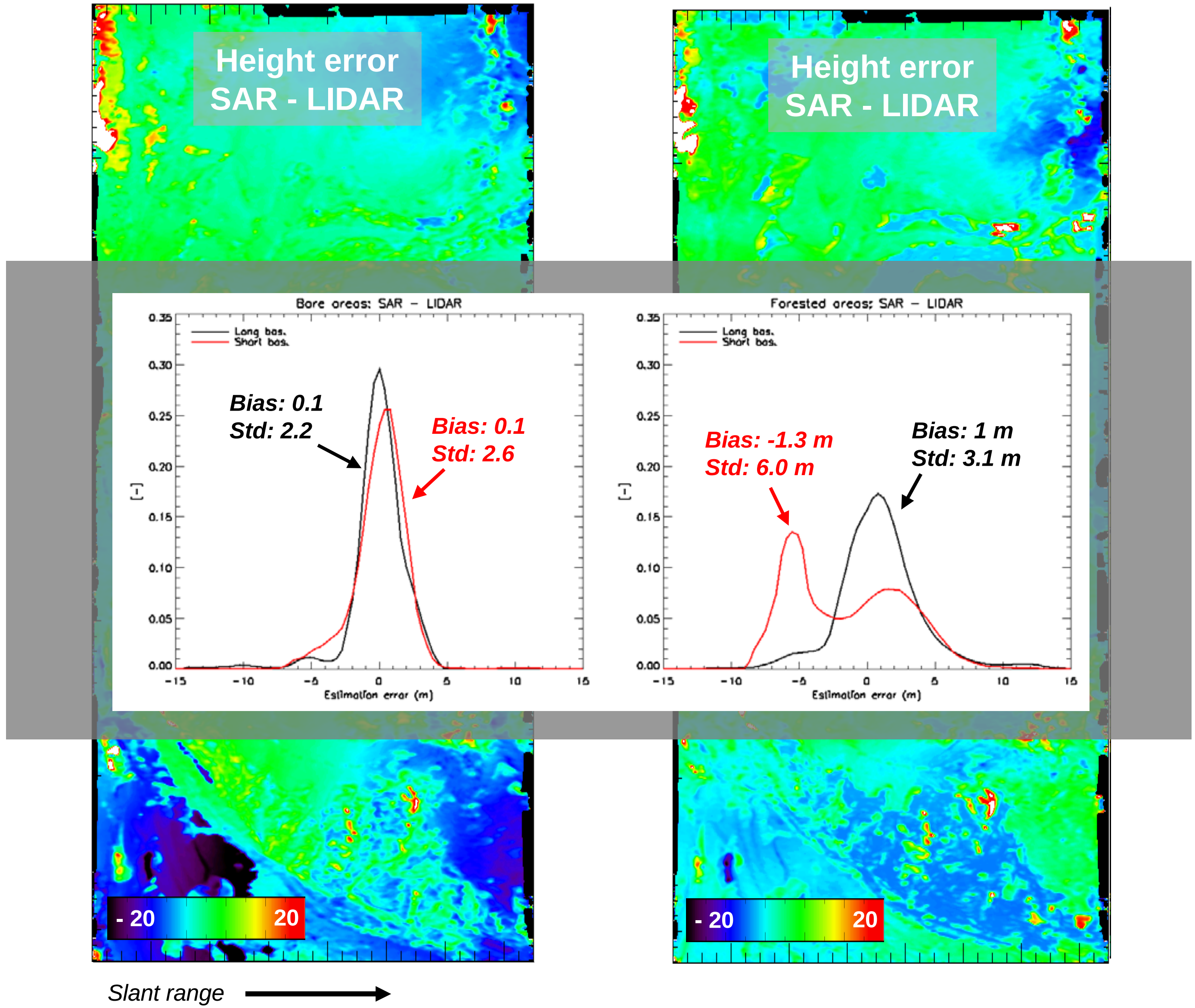


HH polarisation

Estimated DTM (2/2)



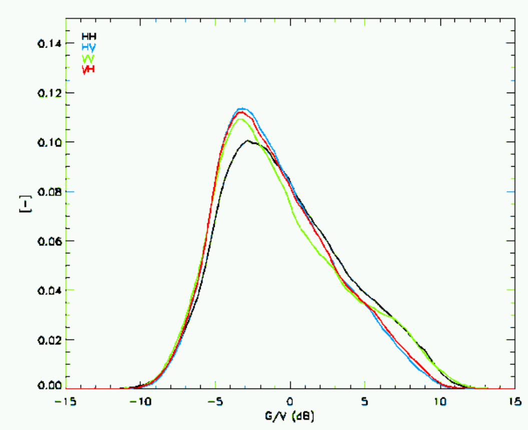
Long baselines | Short baselines



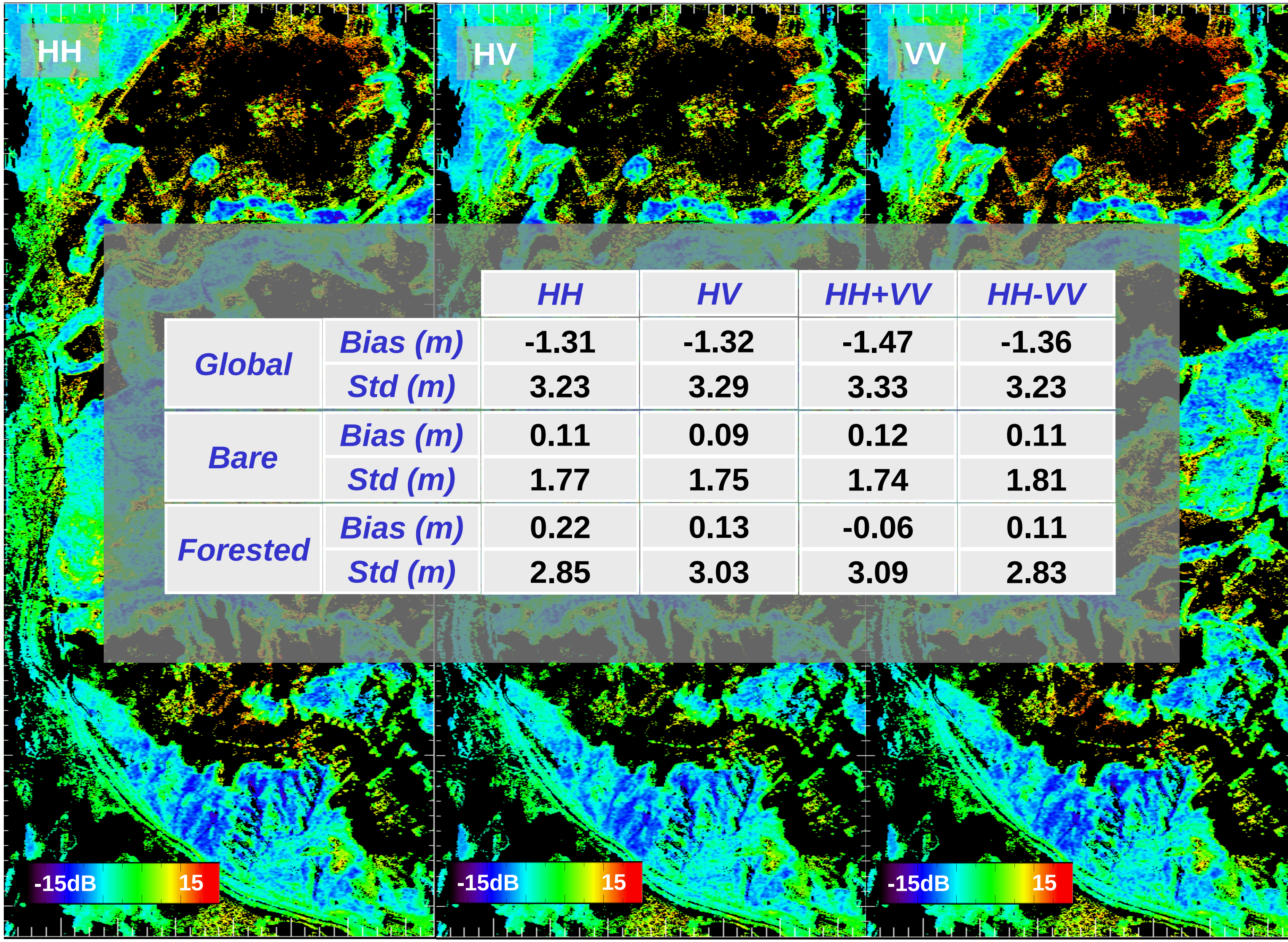
HH polarisation

Influence of polarisation

MB estimated Ground-to-Volume power ratio



Full baseline set



		HH	HV	HH+VV	HH-VV
Global	Bias (m)	-1.31	-1.32	-1.47	-1.36
	Std (m)	3.23	3.29	3.33	3.23
Bare	Bias (m)	0.11	0.09	0.12	0.11
	Std (m)	1.77	1.75	1.74	1.81
Forested	Bias (m)	0.22	0.13	-0.06	0.11
	Std (m)	2.85	3.03	3.09	2.83

Slant range →

Conclusions & perspectives

- ***In this work:***
  - A simple (yet effective) RELAX-based estimator of the ground height has been proposed and tested with L-band real data.
  - The proposed method has been shown to reach a metric estimation precision and to reduce the vegetation bias with a realistic small number of acquisitions.
- ***Perspectives:***
  - Tests with airborne datasets acquired over other forests.
  - Improvement of the proposed method in order to better handle the polarization diversity.
  - … temporal decorrelation (must be afforded sooner or later!)
- ***Further on this topic (and more):***
  - “Theoretical Performance Bounds on the Estimation of Forest Structure Parameters From Multibaseline SAR data”, by M. Pardini, F. Lombardini & K. Papathanassiou (Poster session, today)

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