Assessment of single baseline PolInSAR in tropical context for vegetation characterisation

P Dubois-Fernandez[1] ,Aurélien Arnaubec[1,2], Xavier Dupuis[1]

1 ONERA
2 Institut Fresnel

Overview of the presentation

- TropiSAR dataset
  - Full resolution and low resolution dataset
- Single baseline PolInSAR inversion method
  - Influence of topography, …
- Inversion results and resolution
- Polarimetric analysis of the volume contribution
- Conclusions

TropiSAR data set

- French Guyana
- Tropical Forest
- P Band BandWidth : 335-460 Mhz

Paracou

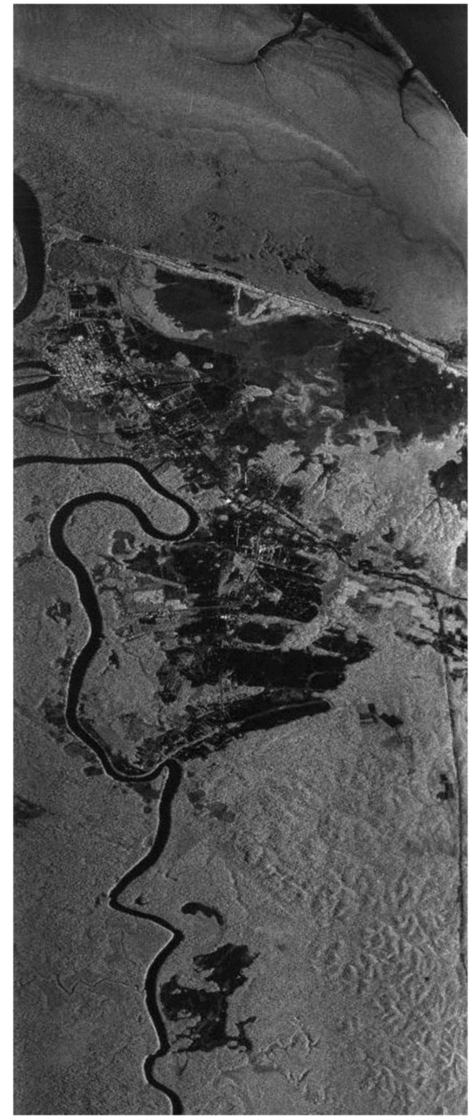
TropiSAR data : Tropical forest at P band

- 7 Full PolSAR images on the Paracou site :
  - acquired in interferometric conditions
- Very high diversity :
  - Tropical forest with more than 1000 trees species



- Available measurements for comparison
  - LIDAR Ground height
  - LIDAR Vegetation height

(we acknowledge Lillian Blanc from CIRAD for those measurements)



BIOMASS reprocessing

	Full resolution	Biomass
Bandwidth [MHz]	125	6
Frequency range [MHz]	335 - 460	432 - 438
Center frequency [MHz]	397.5	435
Range resolution [m]	1.2	25
Azimuth resolution [m]	1.5	10

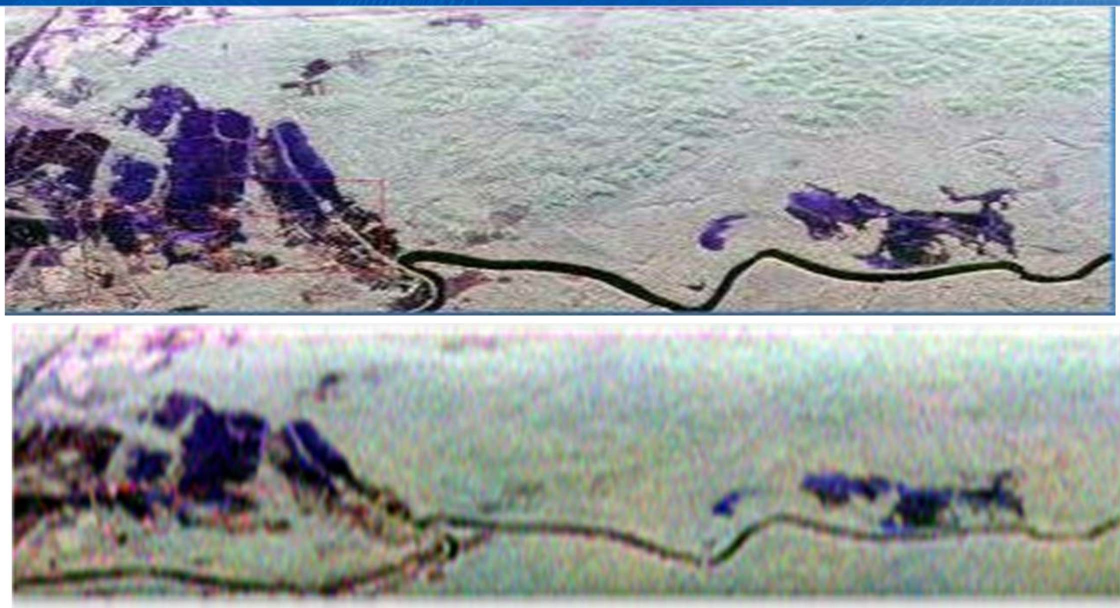
TropiSAR: Illustration

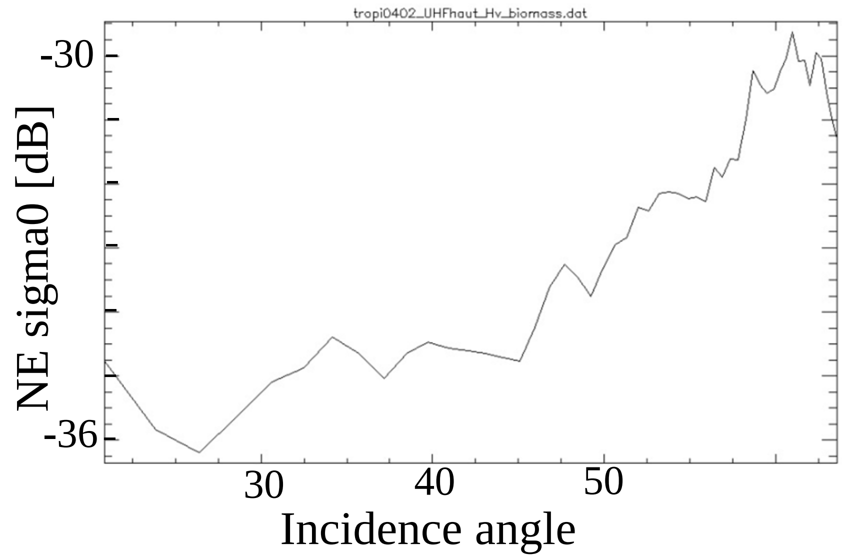
Reprocessing approach

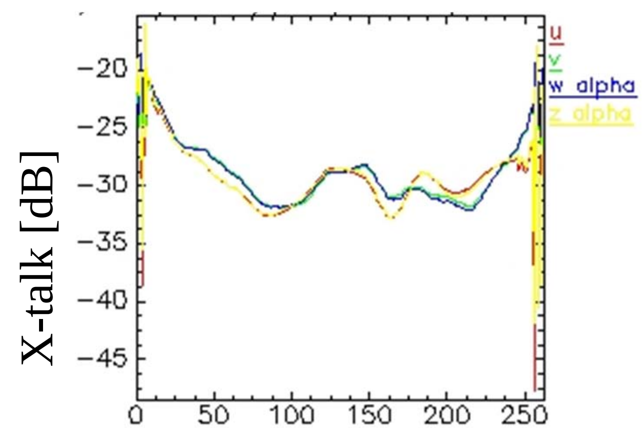
- Processing performed from raw data
  - Provide the proper center frquency
  - Simulate correctly the frequency shift for interferometric processing

- Challenges associated with low resolution processing
  - Radiometric calibration cannot be performed with the deployed trihedrals (too small)
  - Intermediate processing at 50MHz correctly centered at 435MHz – in order to assess the antenna pattern and the calibration key

Data quality assessment







		P-Band
Calibration	Radiometric accuracy *	+/- 0.8dB
	Co-polar phase accuracy*	5°
NE-Sigma0 [dB]	25-50°	-34dB
Cross-Talk Level		-25dB
Geometric accuracy	(if altitude is known)	<10m

* On the 50MHz data

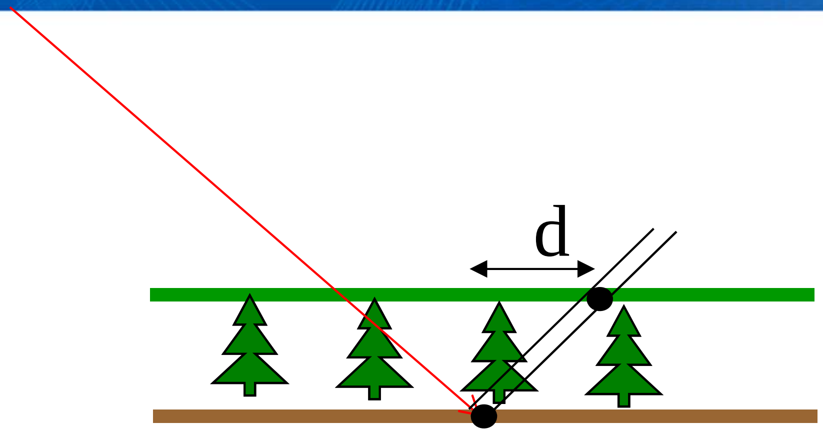
Estimation procedure

- Random volume over ground model
  - Compute the 6x6 covariance matrix
  - Compute the line (Ferro-Famil method)
  - Select the ground point from 2 solutions
    - HH+VV and HH-VV
  - Filter the ground topography (plane fit)
  - Compute the vegetation height based on the smoothed ground and an a priori value of the attenuation

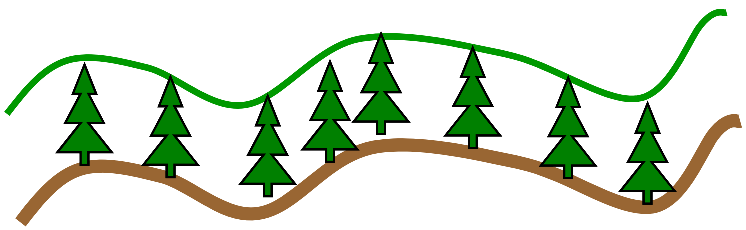
- Output in radar geometry
  - Ground topography
  - Vegetation height

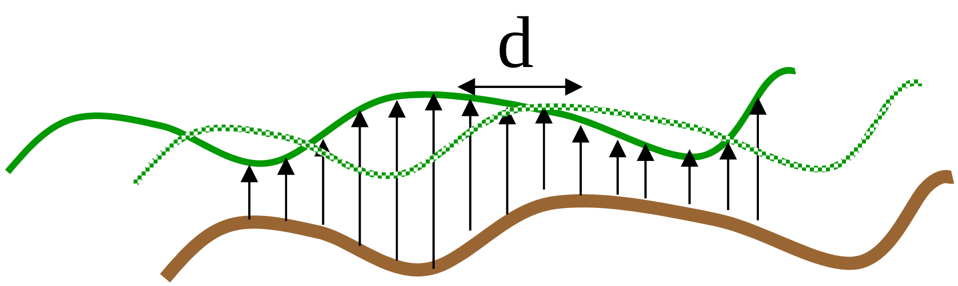
Radar geometry and topography

Radar measured height is a difference in the same range bin
The top of the tree is imaged before its trunk

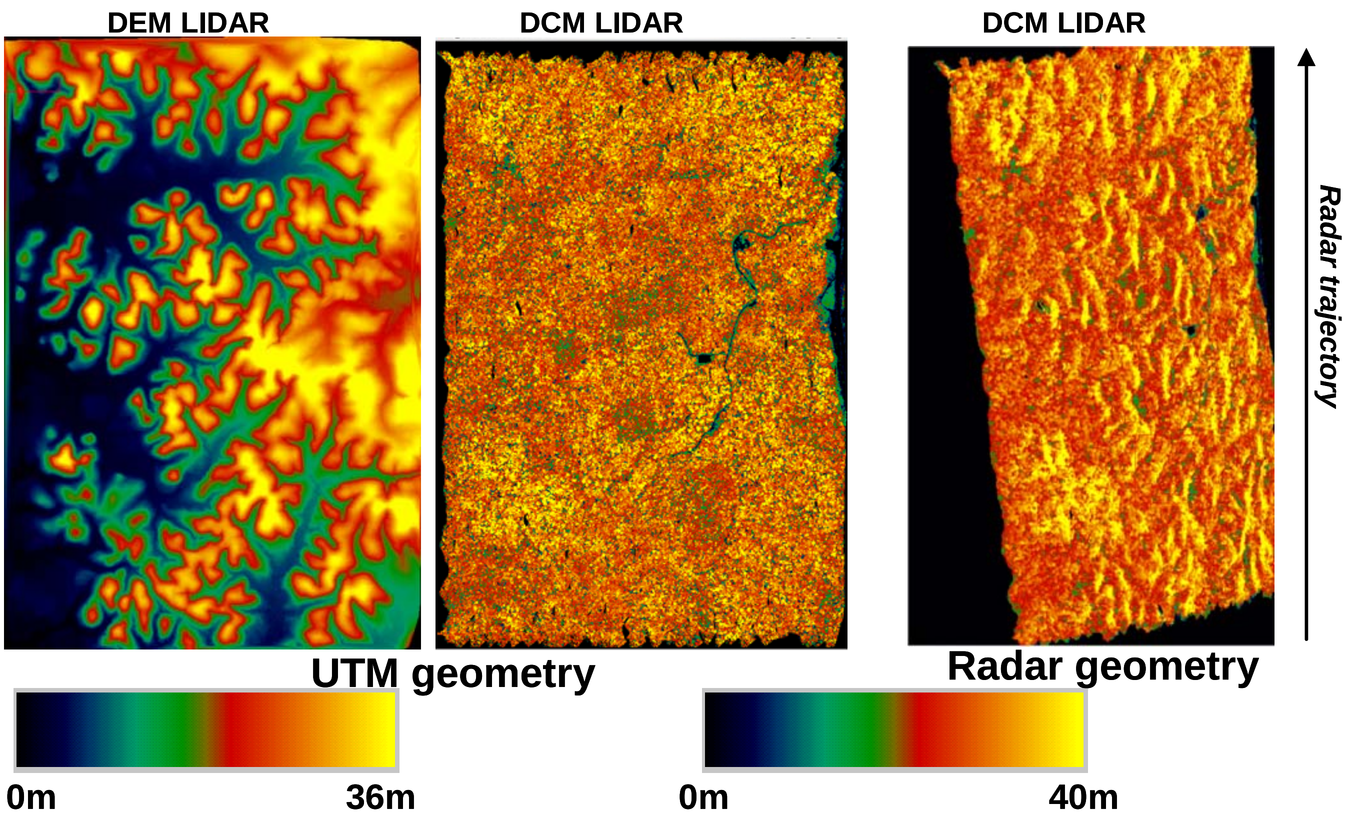


$$d = h/\tan(\theta)$$





In case of topography, this can create a significant spatial variation in the tree height, even for a constant tree height



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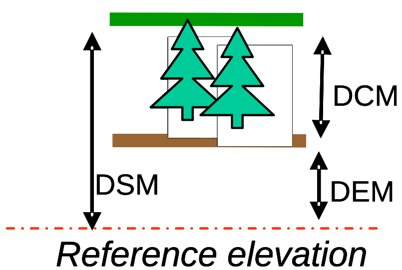
Lidar DEM UTM map

Lidar DSM UTM map

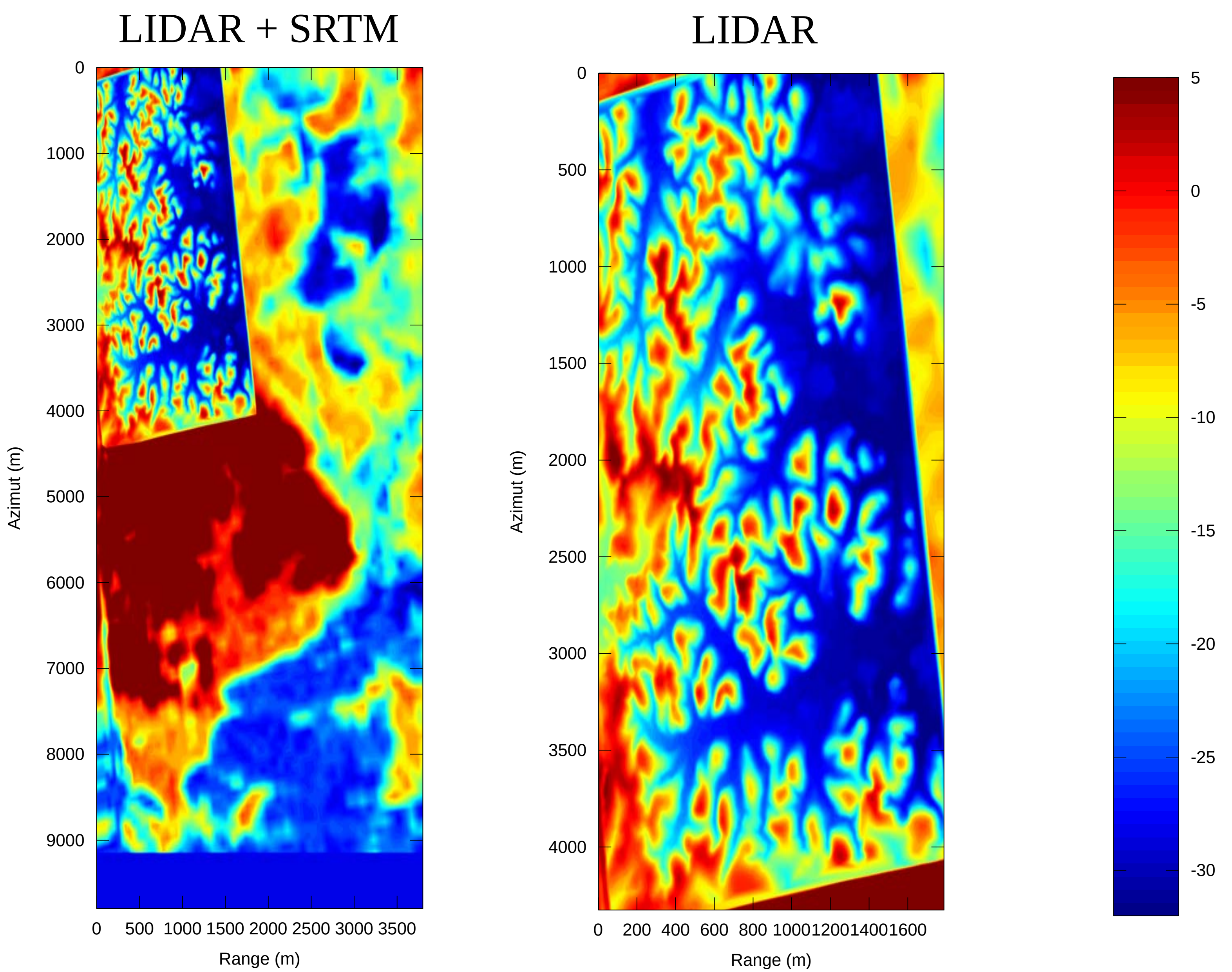
PolInSAR DEM Radar geometry

PolInSAR DCM Radar geometry



DSM=DEM+DCM

Available reference data



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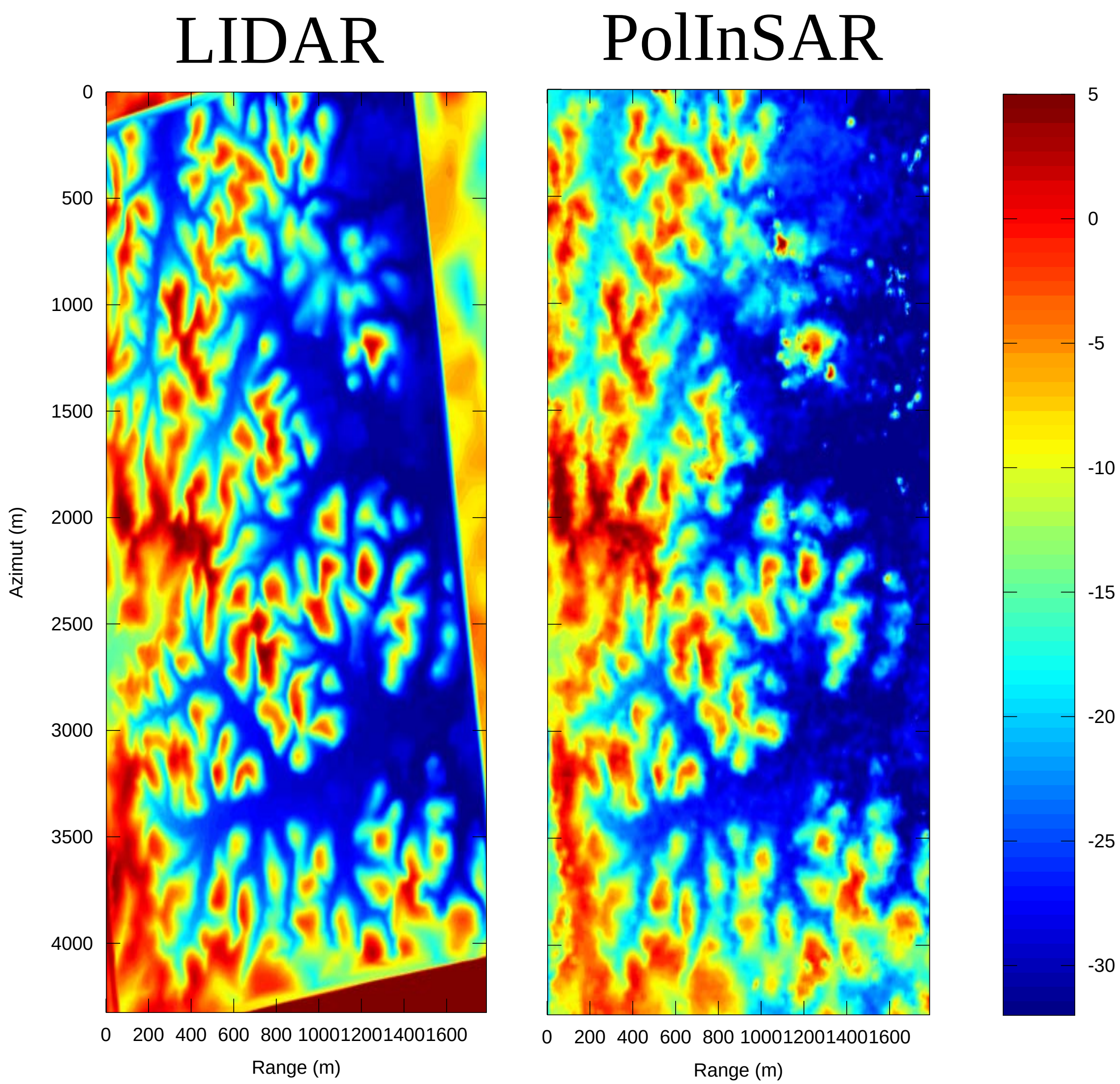
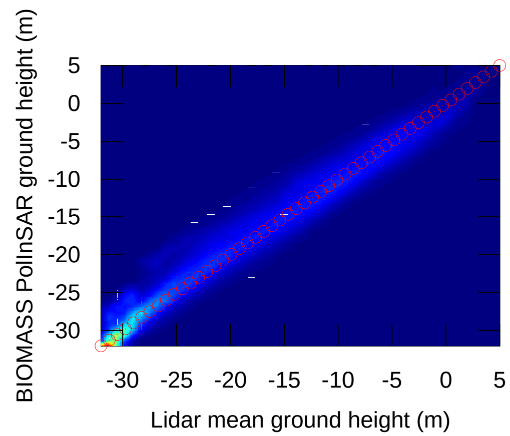
Ground height from high resolution images





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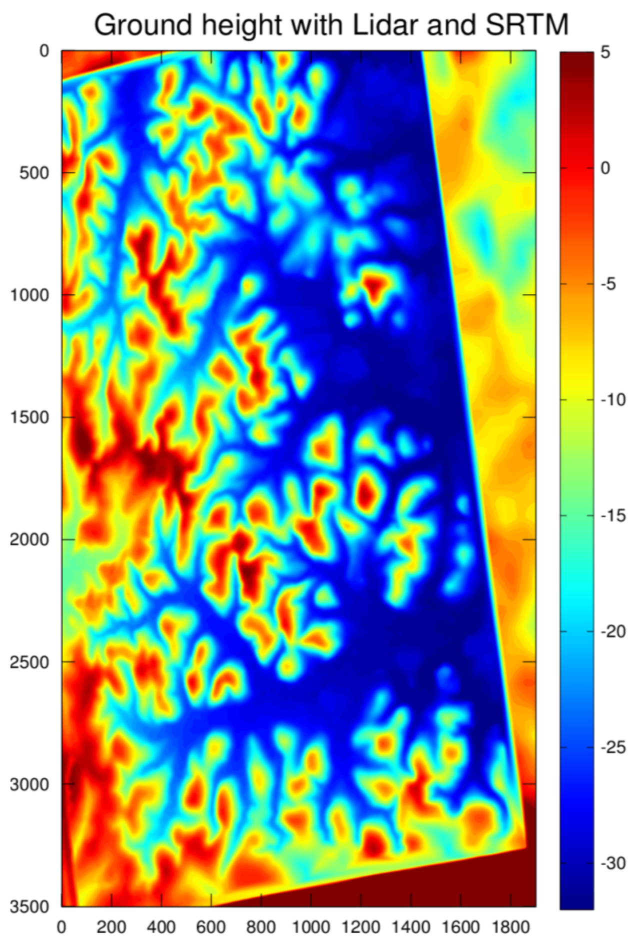
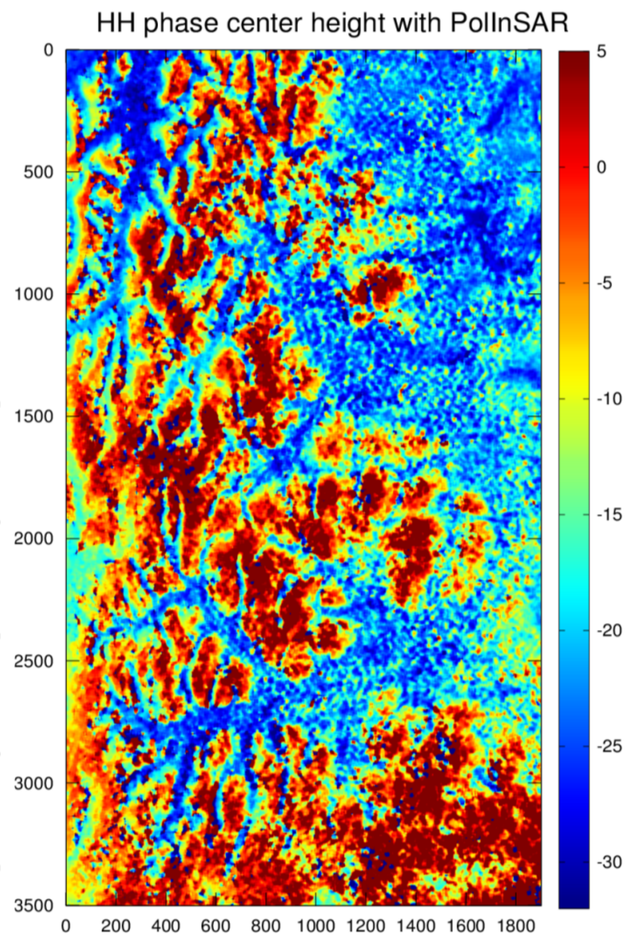
Ground height estimation results

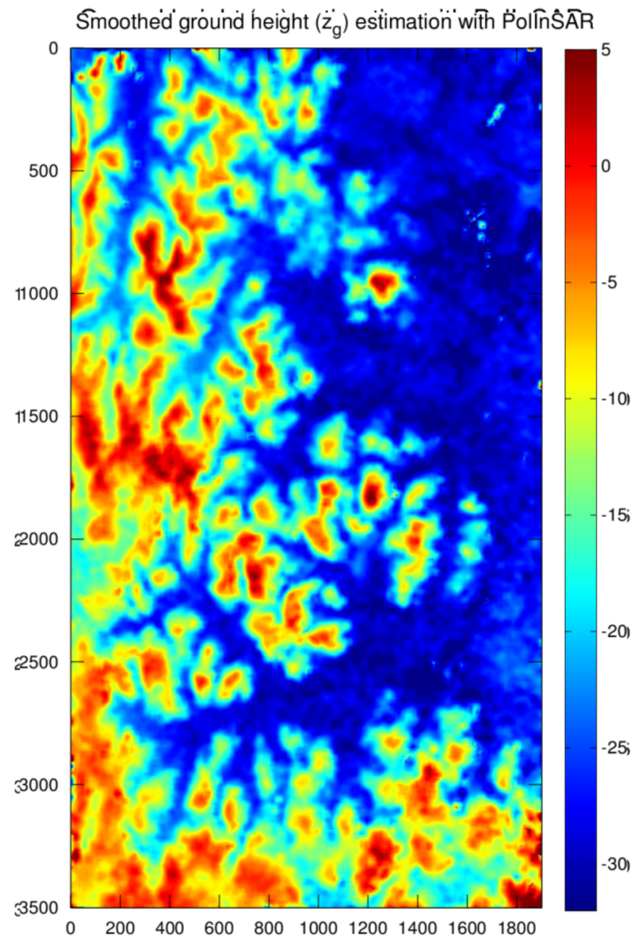
Lidar Ground



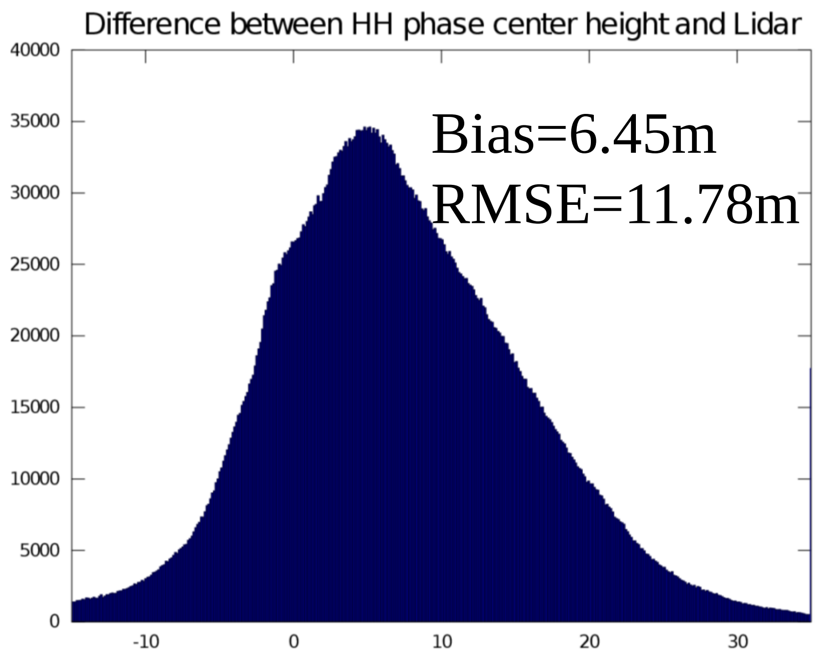
HH phase center height

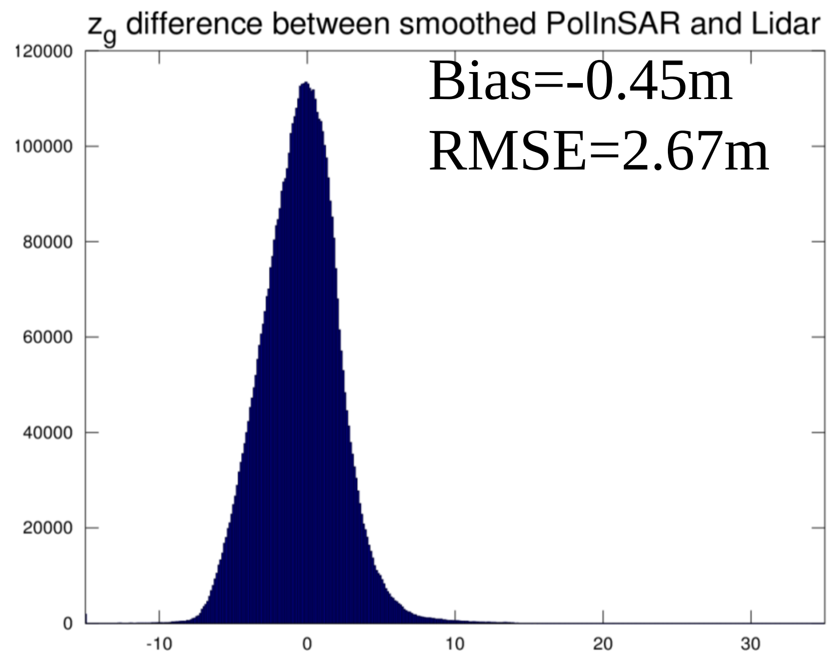


PolInSAR Ground



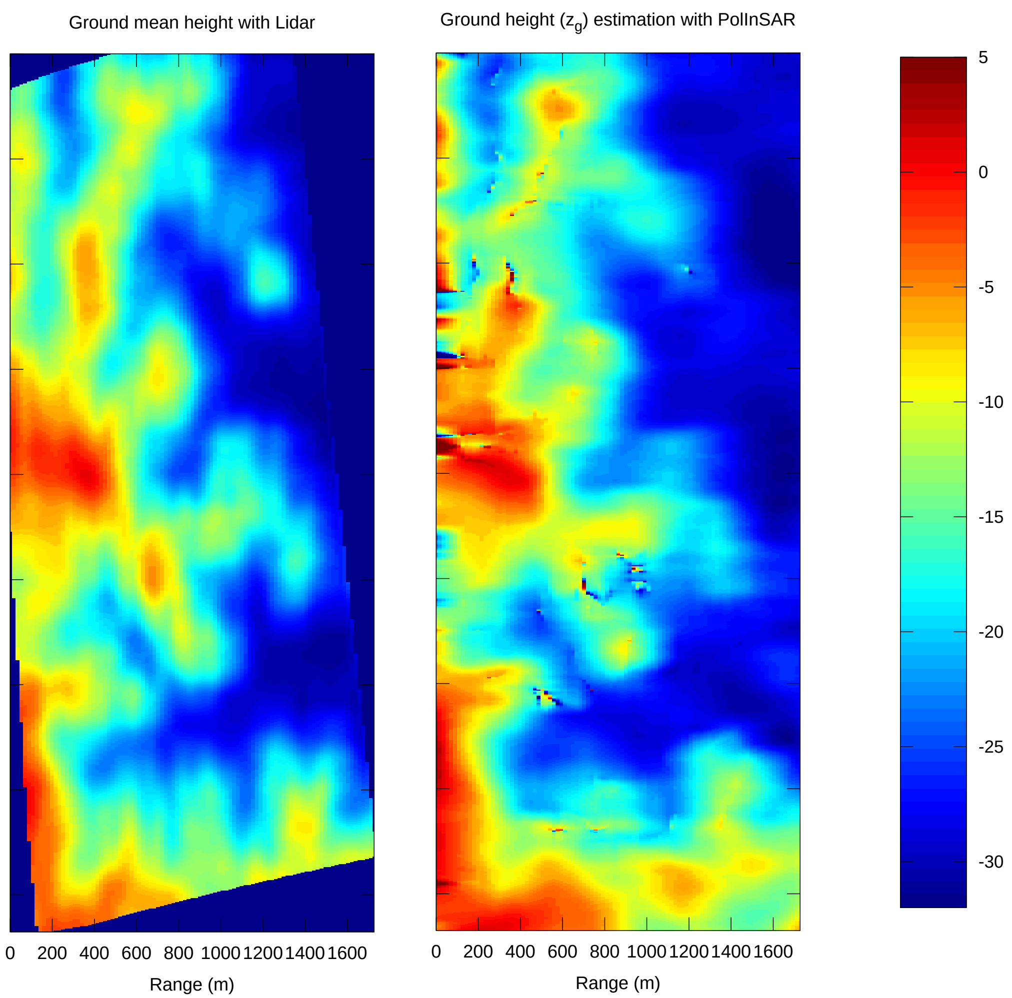
Ground under canopy estimation results

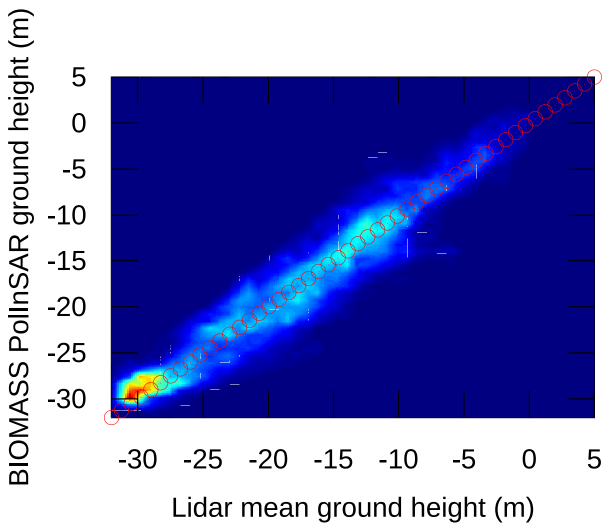




- Low bias and good RMSE for the PolInSAR approach
- Wider distribution for HH phase center height, high bias and RMSE

Ground height from low resolution images





Bias = - 0.0m

Std dev = 3.7m

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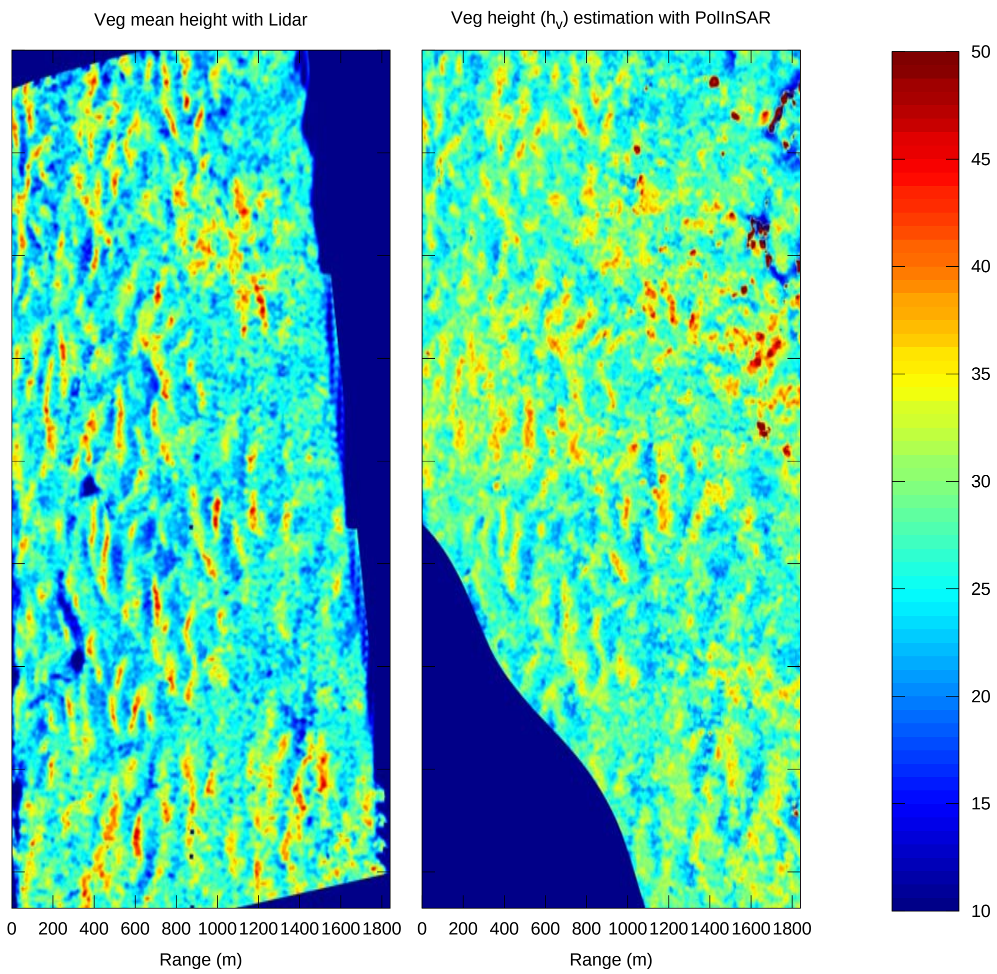
Vegetation height

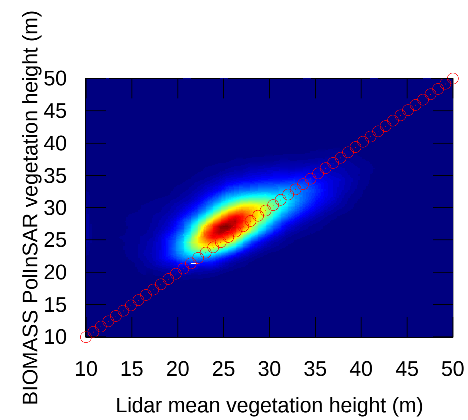
- PolInSAR vegetation height from high resolution SAR data
  - Radar geometry
  - UTM geometry

- PolInSAR vegetation height from low resolution SAR
  - Radar geometry
  - UTM geometry

Vegetation height - radar geometry



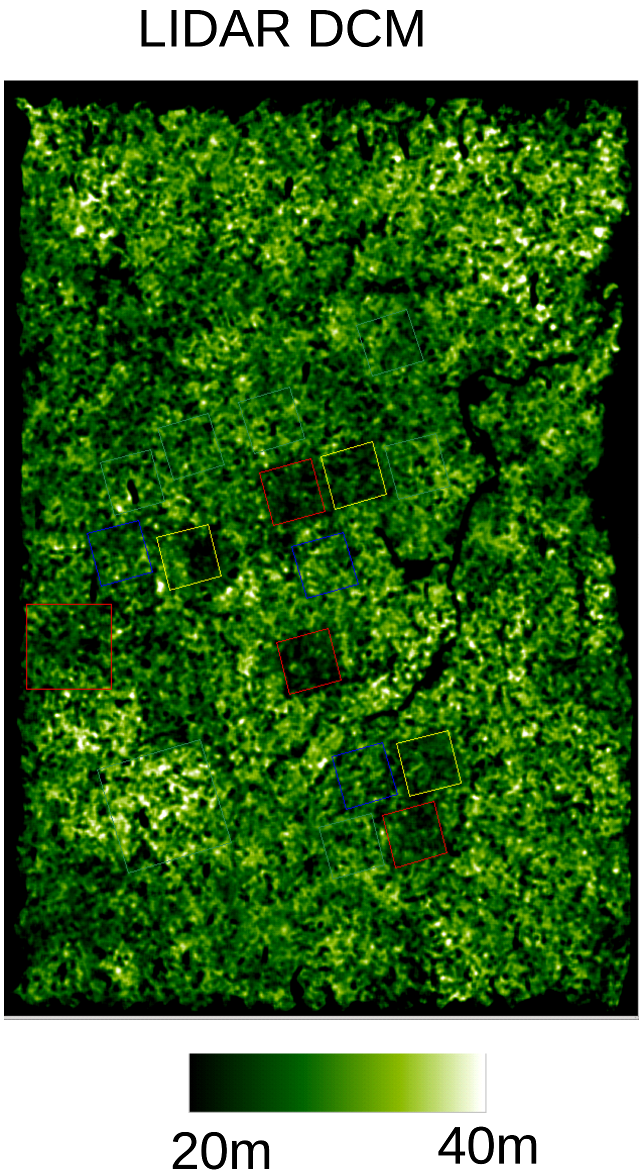
High resolution data

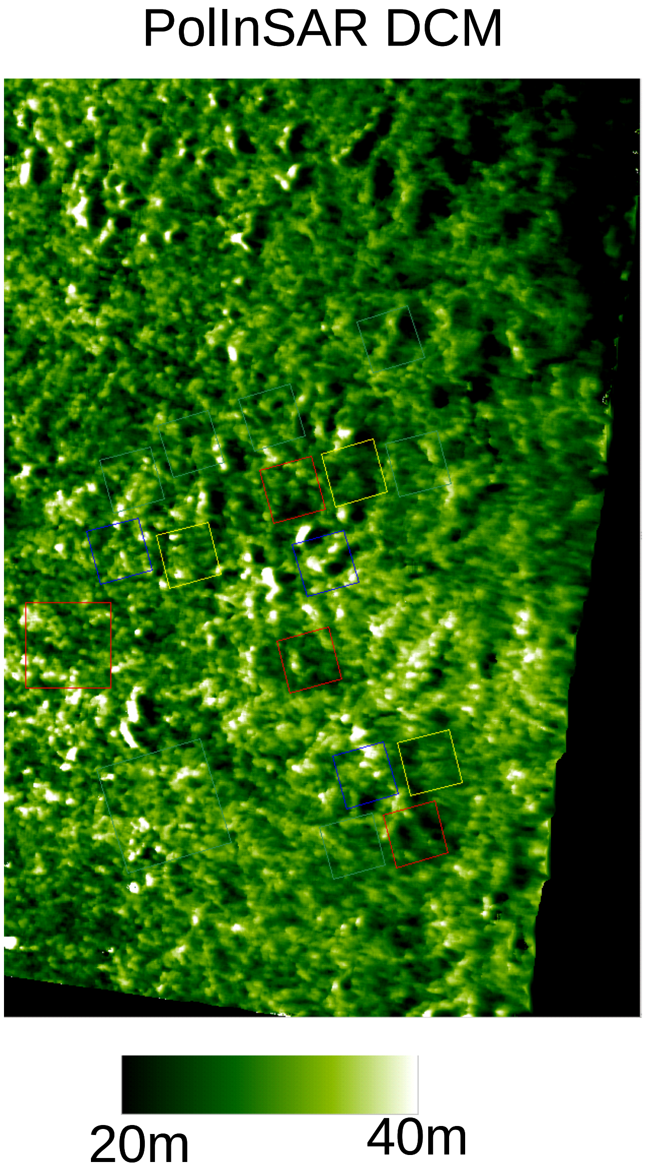


	Biais	Std Dev
403-405	1.99m	4.38m

Vegetation height - UTM geometry

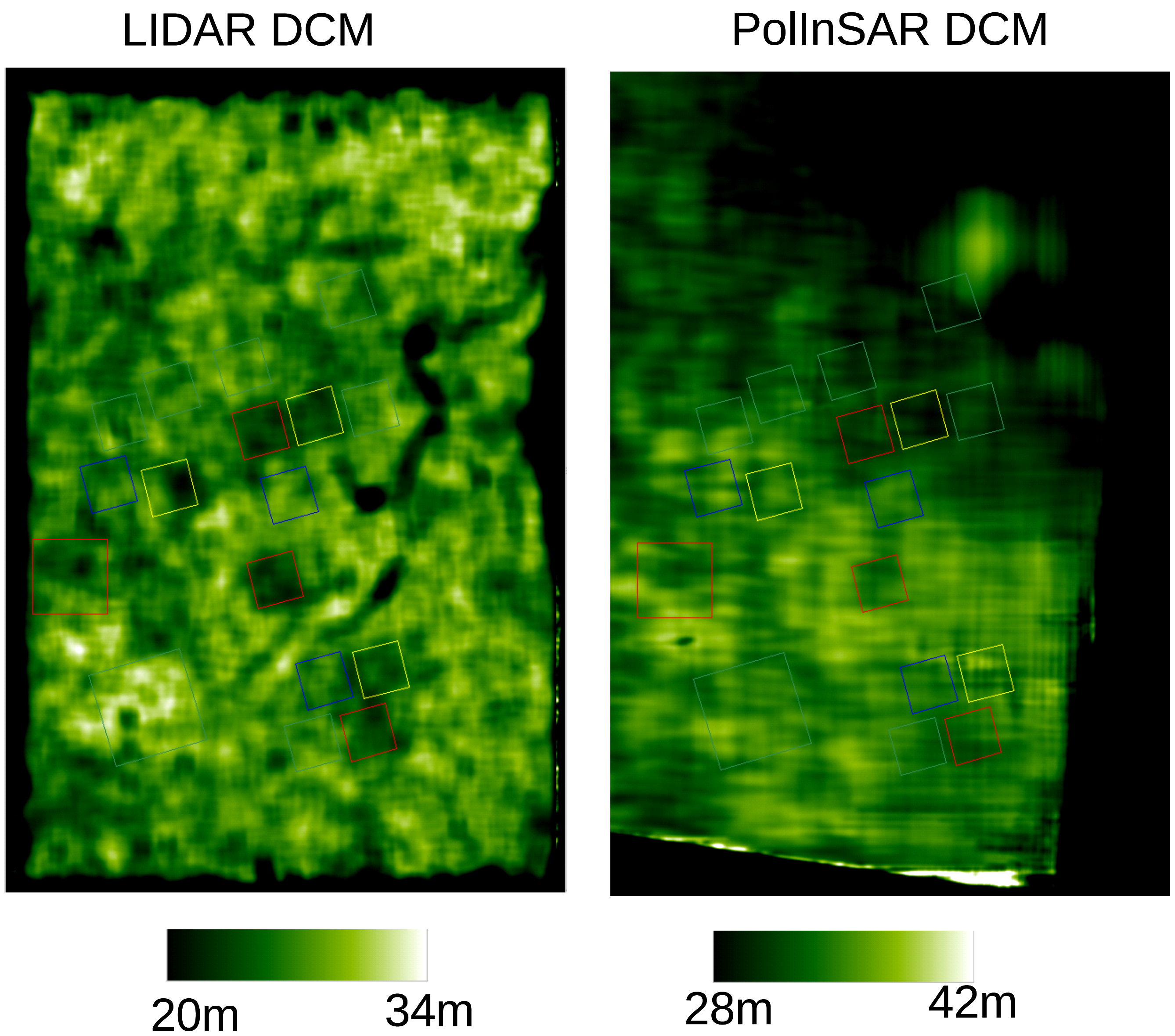
High resolution data





LR data: vegetation height in UTM geometry

Low resolution data



Summary of SB polInSAR estimation

- Good performance for the under canopy ground topography for both high and low resolution data
- Good performance for the vegetation height estimation for high resolution data
- For low resolution data, over-estimation of the vegetation height.
- High sensitivity to the baseline
- Importance of topographic correction for an accurate vegetation height assessment

Polarimetric Decomposition from RVoG

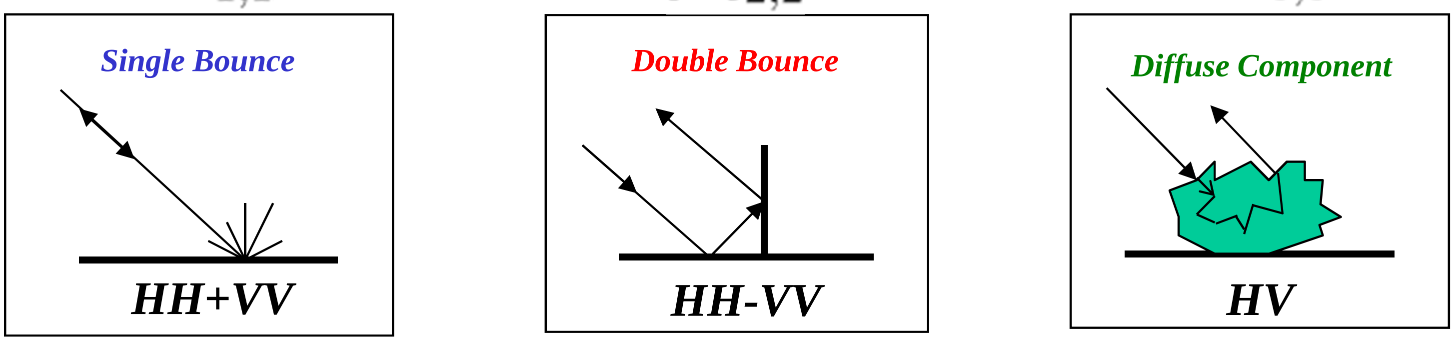
Ground contribution Volume contribution

- The 3x3 RVoG Polarimetric coherency matrix $\boldsymbol{T}$ is the sum of two contributions :

$$\boldsymbol{T} = \boxed{a\boldsymbol{T}_{ground}} + \boxed{I_1 \boldsymbol{T}_{vol}}$$

- In the Pauli basis each diagonal component is associated to one mecanism :

$[\boldsymbol{T}]_{1,1}$ $[\boldsymbol{T}]_{2,2}$ $[\boldsymbol{T}]_{3,3}$



- $\boldsymbol{T}_{vol}$ and $\boldsymbol{T}_{ground}$ can be estimated without constraint from Cloude and Papathanassiou or Tabb's approach

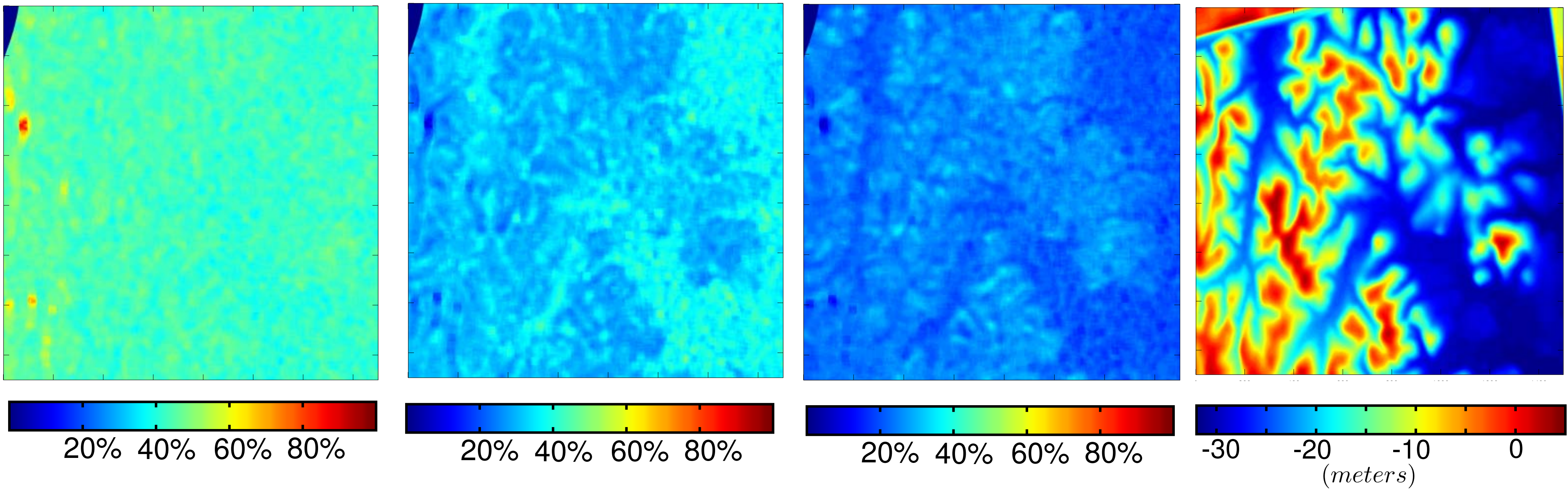
Polarimetric signature before decomposition

$$\frac{[\boldsymbol{T}]_{1,1}}{[\boldsymbol{T}]_{1,1}+[\boldsymbol{T}]_{2,2}+[\boldsymbol{T}]_{3,3}}$$

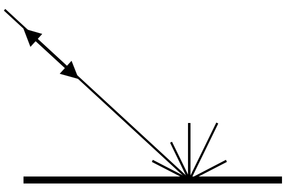
$$\frac{[\boldsymbol{T}]_{2,2}}{[\boldsymbol{T}]_{1,1}+[\boldsymbol{T}]_{2,2}+[\boldsymbol{T}]_{3,3}}$$

$$\frac{[\boldsymbol{T}]_{3,3}}{[\boldsymbol{T}]_{1,1}+[\boldsymbol{T}]_{2,2}+[\boldsymbol{T}]_{3,3}}$$

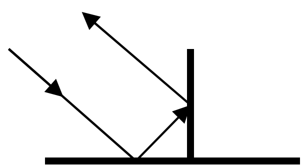
Lidar Ground



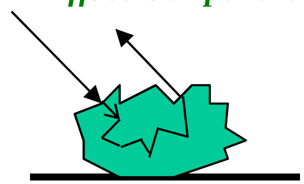
Single Bounce



Double Bounce



Diffuse Component



Focus on double Bounce contribution after decomposition

Total Resp.

$$\frac{[\boldsymbol{T}]_{2,2}}{[\boldsymbol{T}]_{1,1}+[\boldsymbol{T}]_{2,2}+[\boldsymbol{T}]_{3,3}}$$

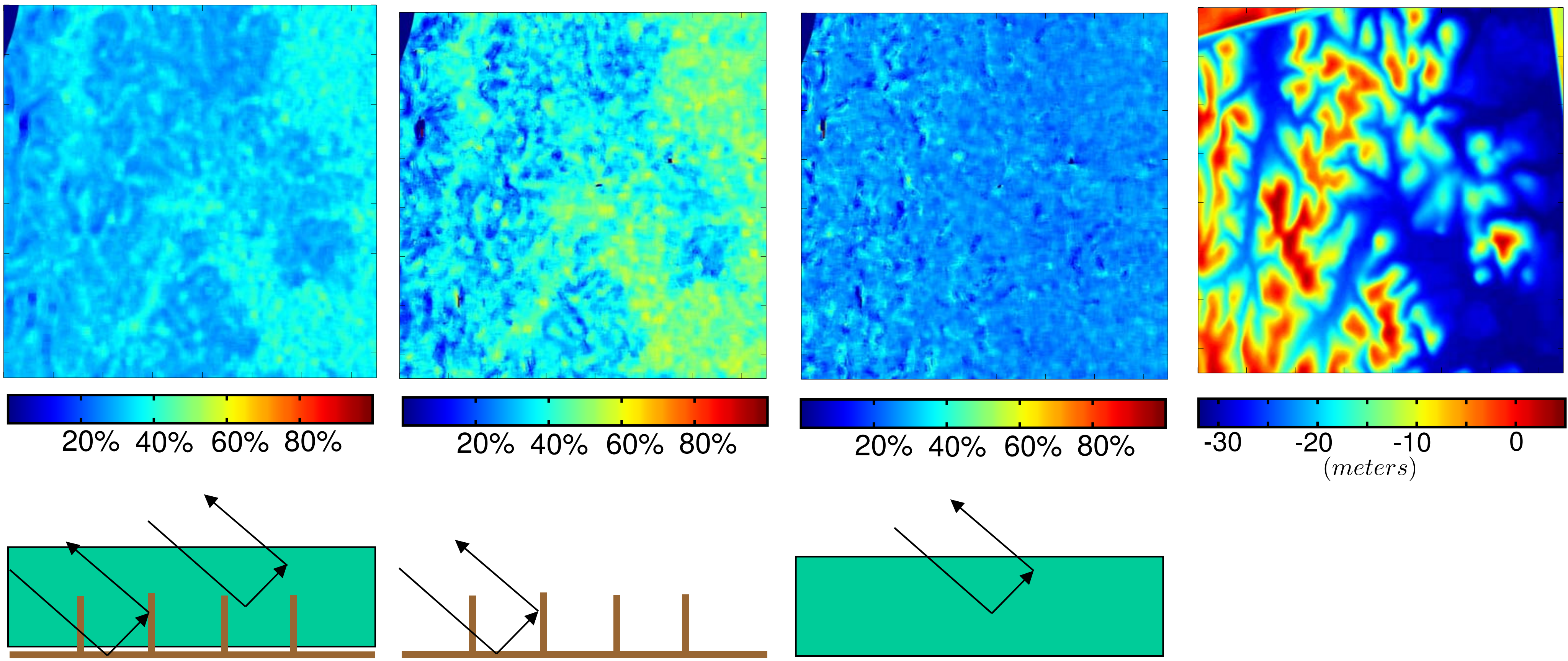
Ground Resp.

$$\frac{[\boldsymbol{T}_g]_{2,2}}{[\boldsymbol{T}_g]_{1,1}+[\boldsymbol{T}_g]_{2,2}+[\boldsymbol{T}_g]_{3,3}}$$

Veg. Resp.

$$\frac{[\boldsymbol{T}_v]_{2,2}}{[\boldsymbol{T}_v]_{1,1}+[\boldsymbol{T}_v]_{2,2}+[\boldsymbol{T}_v]_{3,3}}$$

Lidar Ground



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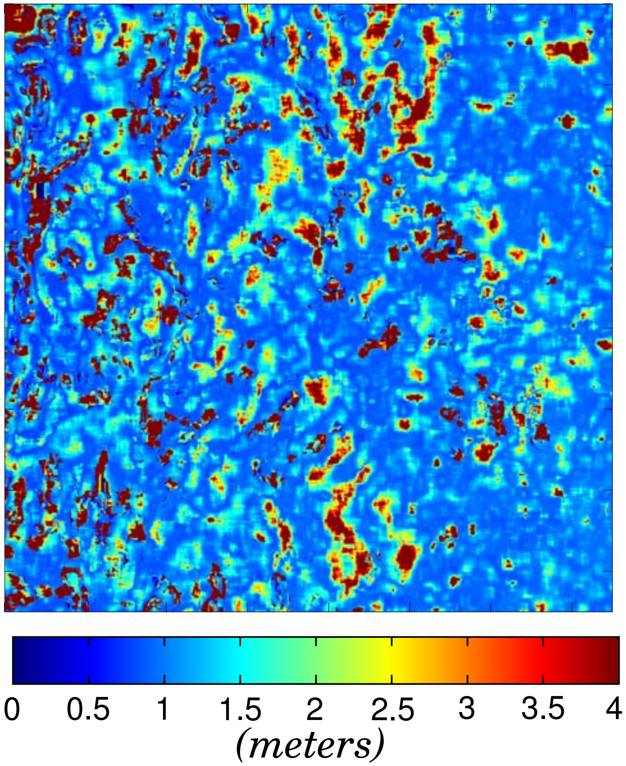
Relation with the theoritical performances: CRB

Minimal standard deviation
for h_v for 100 pixels



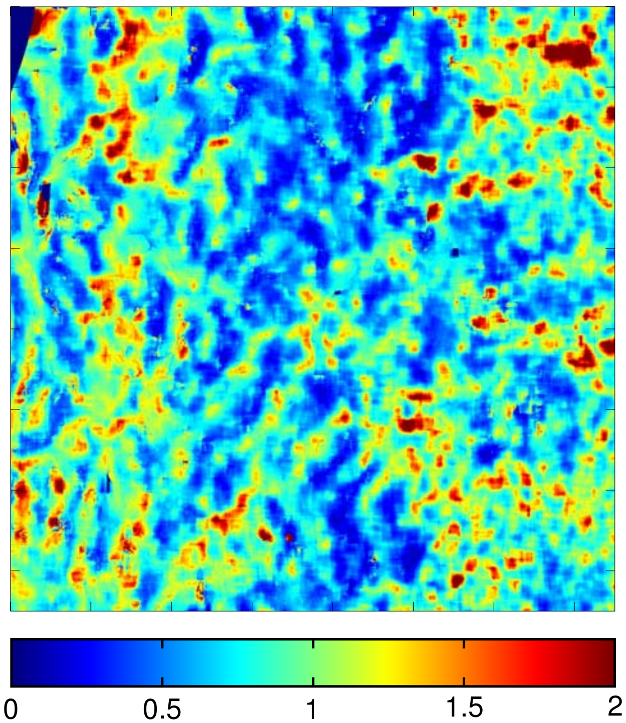
The Cramer-Rao bound for the RVoG corresponds to the best achievable variance for unbiased estimator [Roueff et al. 2011] (more details in the poster session)

In the following we compare :

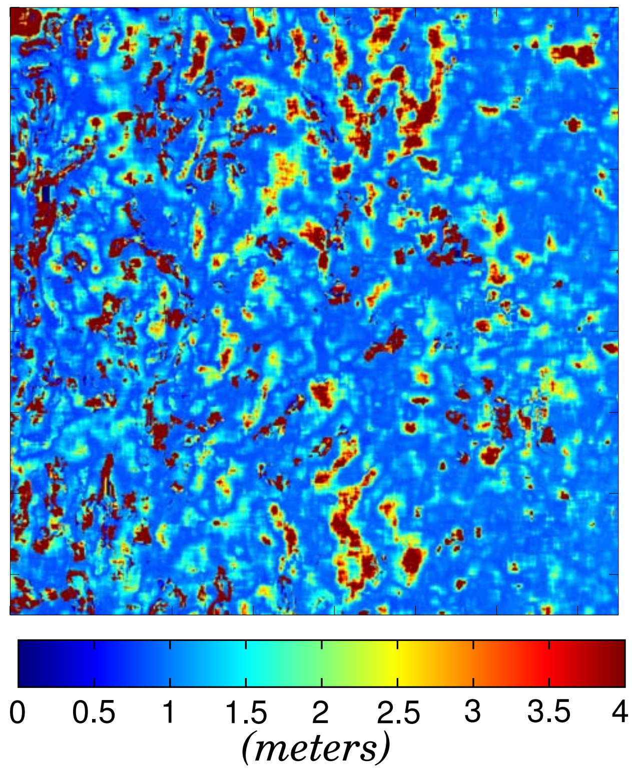
Ground to Volume ratio and the CRB

Relation with the theoritical performances

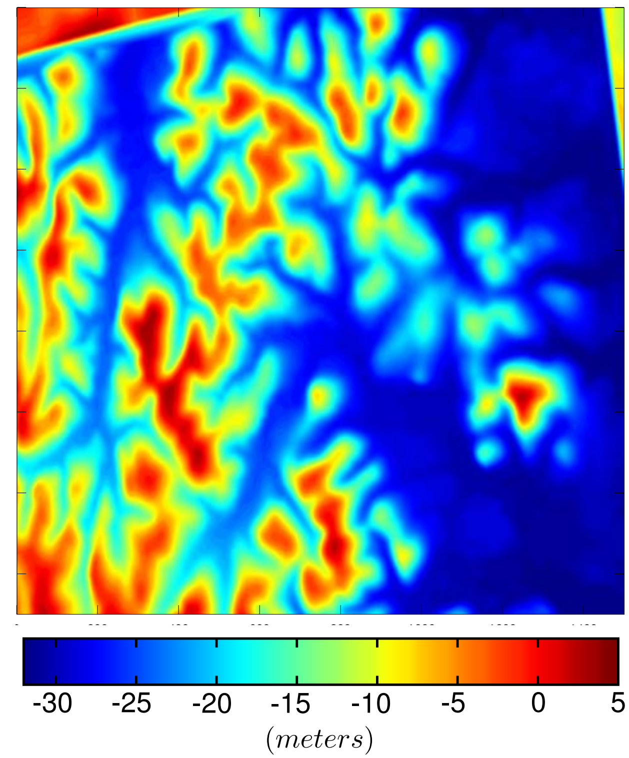
Ground over Volume ratio



Minimal standard deviation
for h_v for 100 pixels



Lidar Ground



The best Cramer-Rao Bound is obtained when approximately the same energy comes from the volume and the ground : (ie. especially on flat ground)

Conclusions

- Under canopy ground height can be estimated with a good accuracy

- Vegetation height estimation performance
  - is sensitive to temporal decorrelation
  - strongly depends on the baseline choice
  - Single baseline: overestimation for low resolution data

- RVoG Polarimetric decomposition
  - enables to separate ground and volume contribution
  - can help to understand the estimation performance in correlation with the Cramer-Rao bound

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Thank you
Questions?