First Results of Vegetation Height Retrieval from the 2016 UAVSAR AfriSAR Campaign

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Acknowledgements: JPL ISCE Team; L. Fatoyinbo, L. Duncanson, S. Lee, B. Blair (NASA GSFC); M. Hofton, R. Dubayah, J. Armston (UMD)

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Overview of the talk

- Objective
  - Show results of tree height estimation with AfriSAR campaign data and updated multi-baseline UAVSAR PolInSAR processor
- Outline
  - NASA/JPL contribution in the AfriSAR campaign
  - Revisited multi-baseline PolInSAR UAVSAR processor
  - Multi-baseline selection algorithm for tree height estimation
  - UAVSAR PolInSAR vs. LVIS lidar-derived tree height
  - Key messages

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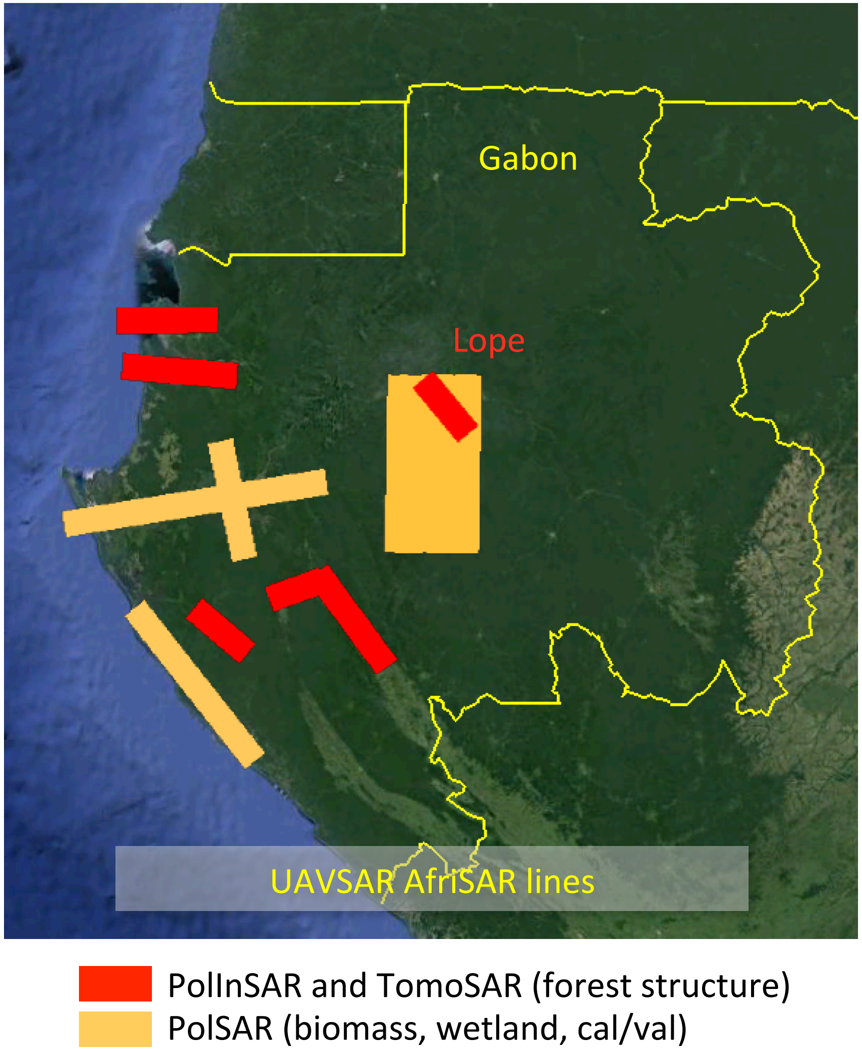
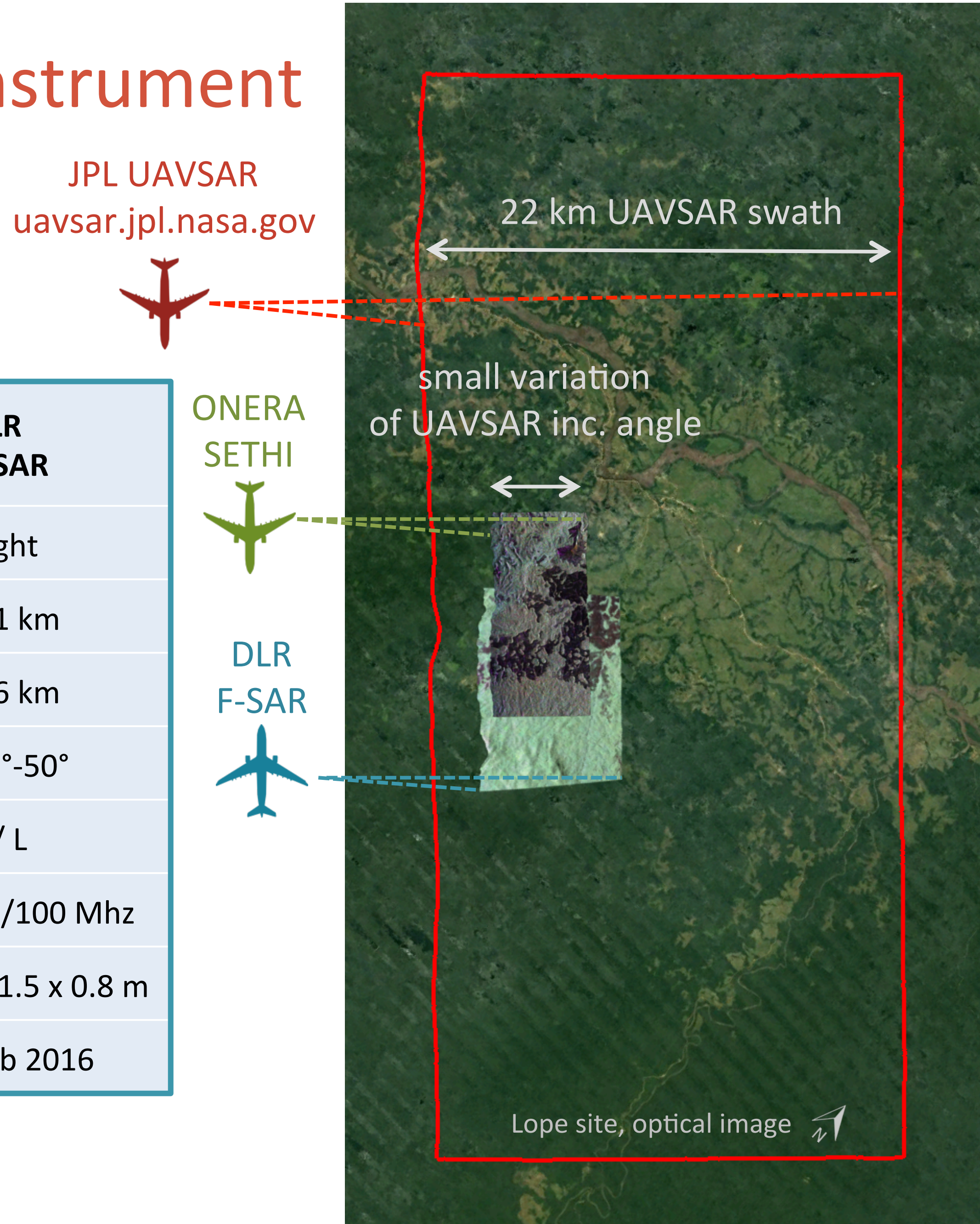
AfriSAR campaign and NASA/JPL contribution

- Joint NASA/ESA campaign to support NISAR, GEDI and BIOMASS missions
- Cal/Val sites and algorithm demonstration
- NASA airborne data
  - UAVSAR: 39.6 flight hours, L-band polarimetric-tomographic data
  - LVIS: 32.4 flight hours
- L/P-band DLR and ONERA data
- 7 sites covered
  - Mabounie, Lope, Mondah, Rabi, Pongara, Ogooué, Mouila



NASA/JPL UAVSAR instrument

	NASA/JPL UAVSAR	ONERA SETHI	DLR F-SAR
Looking	Left	Left	Right
Altitude	12.5 km	6.1 km	6.1 km
Swath width	22 km	5.8 km	6.6 km
Inc. angle	25°-65°	25°-55°	20°-50°
AfriSAR freq.	L	P / L	P / L
Bandwidth	80 MHz	50 / 150 MHz	50/100 Mhz
Resolution	1.66 x 0.6 m	3/0.8 x 0.8 m	3/1.5 x 0.8 m
Visit Gabon	Feb 2016	July 2015	Feb 2016



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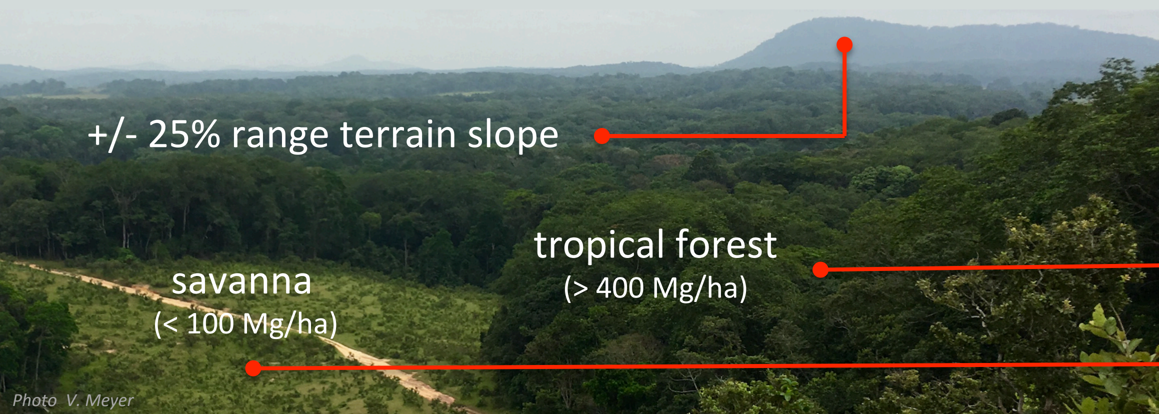
Lope site, data and study area

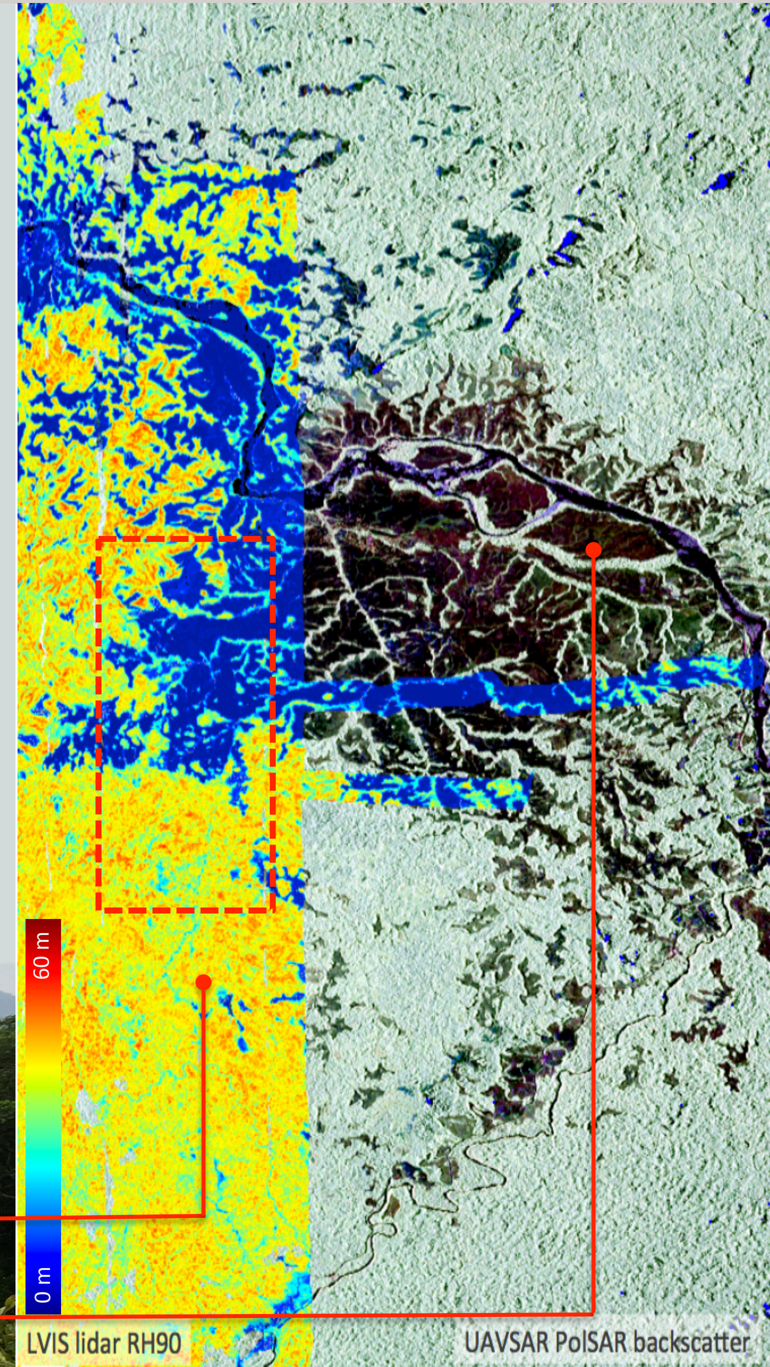
Stack #1 March 8

120 m	142 min	13:43
100 m	129 min	13:20
80 m	90 min	12:41
60 m	67 min	12:18
40 m	45 min	11:56
20 m	22 min	11:33
0 m	175 min	14:06

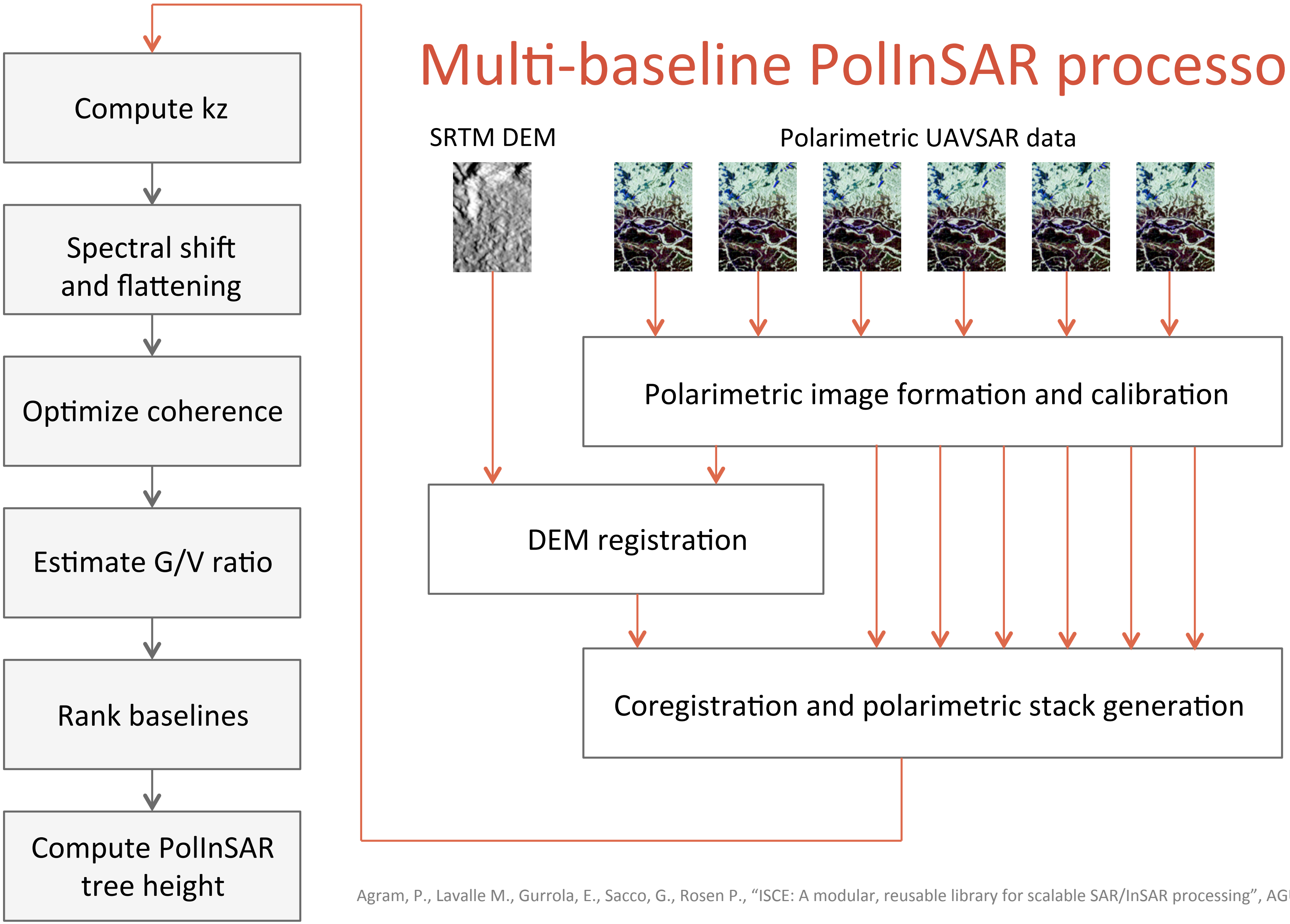
Stack #2 Feb 25

100 m
80 m
60 m
40 m
20 m
0 m





Multi-baseline PolInSAR processor



Agram, P., Lavalle M., Gurrola, E., Sacco, G., Rosen P., "ISCE: A modular, reusable library for scalable SAR/InSAR processing", AGU 2016.

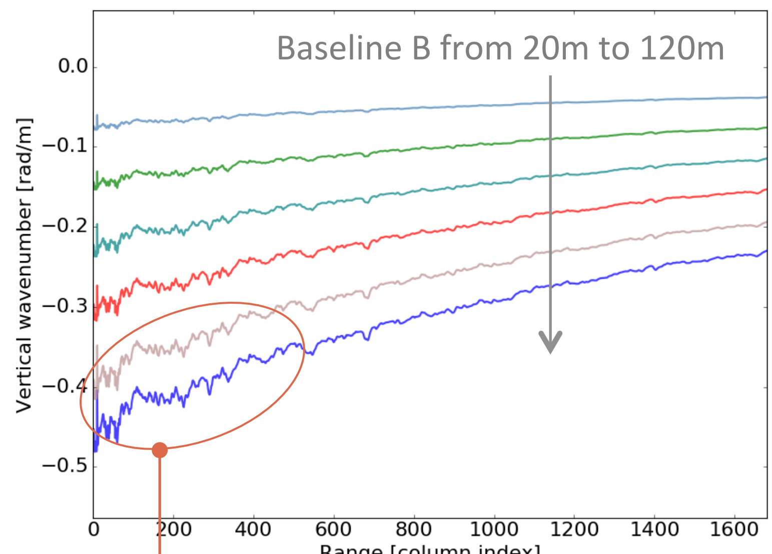
Lavalle, M., Shiroma G.H.X., Agram P., Gurrola E., Sacco, G., and Rosen, P., "PLAnT: Polarimetric-Interferometric Lab and Analysis Tool for Ecosystems and Land-Cover/Land-Use Change Applications", in Proceedings of IGARSS 2016, Beijing, Jul. 2016.

- **Compute kz**
- Spectral shift and flattening
- Optimize coherence
- Estimate G/V ratio
- Rank baselines
- Compute PolInSAR tree height

UAVSAR vertical wavenumber

$|k_z|$ smaller on slopes away from radar and far range

- Calculated from vector geometry
- Derivative of look vector *wrt* vertical
- Spectral-shift and DEM included



effect of terrain slope

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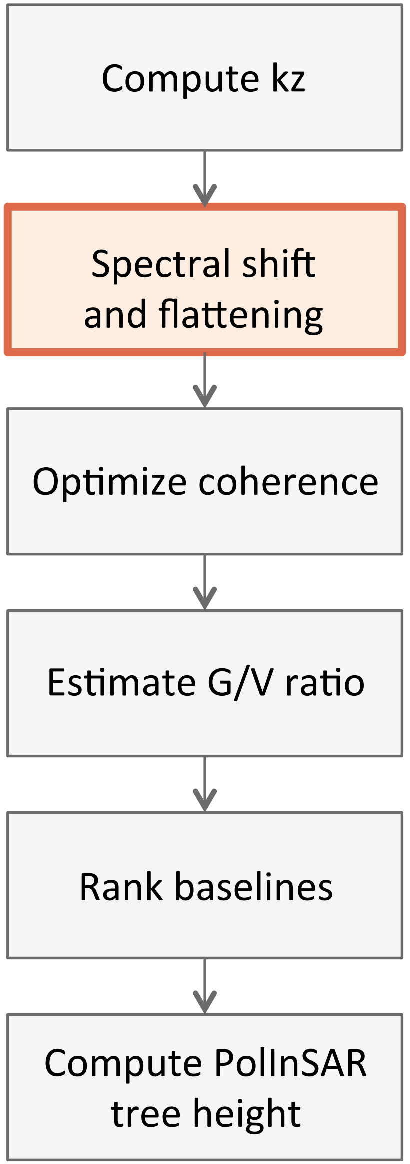
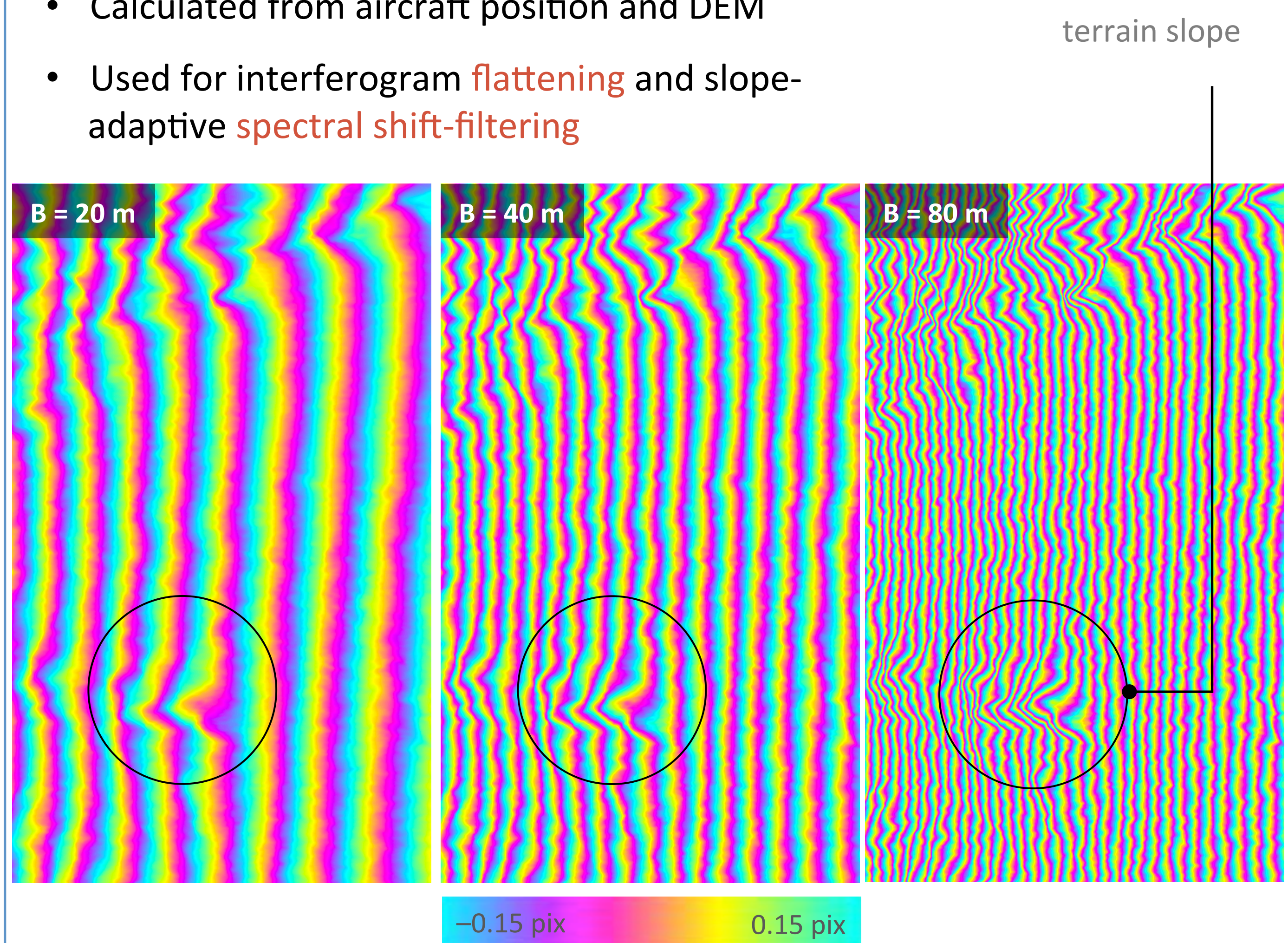
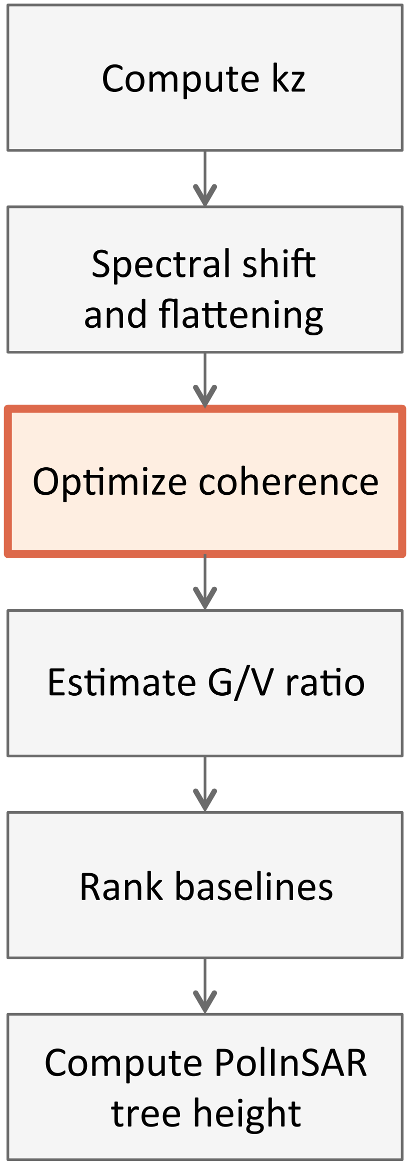


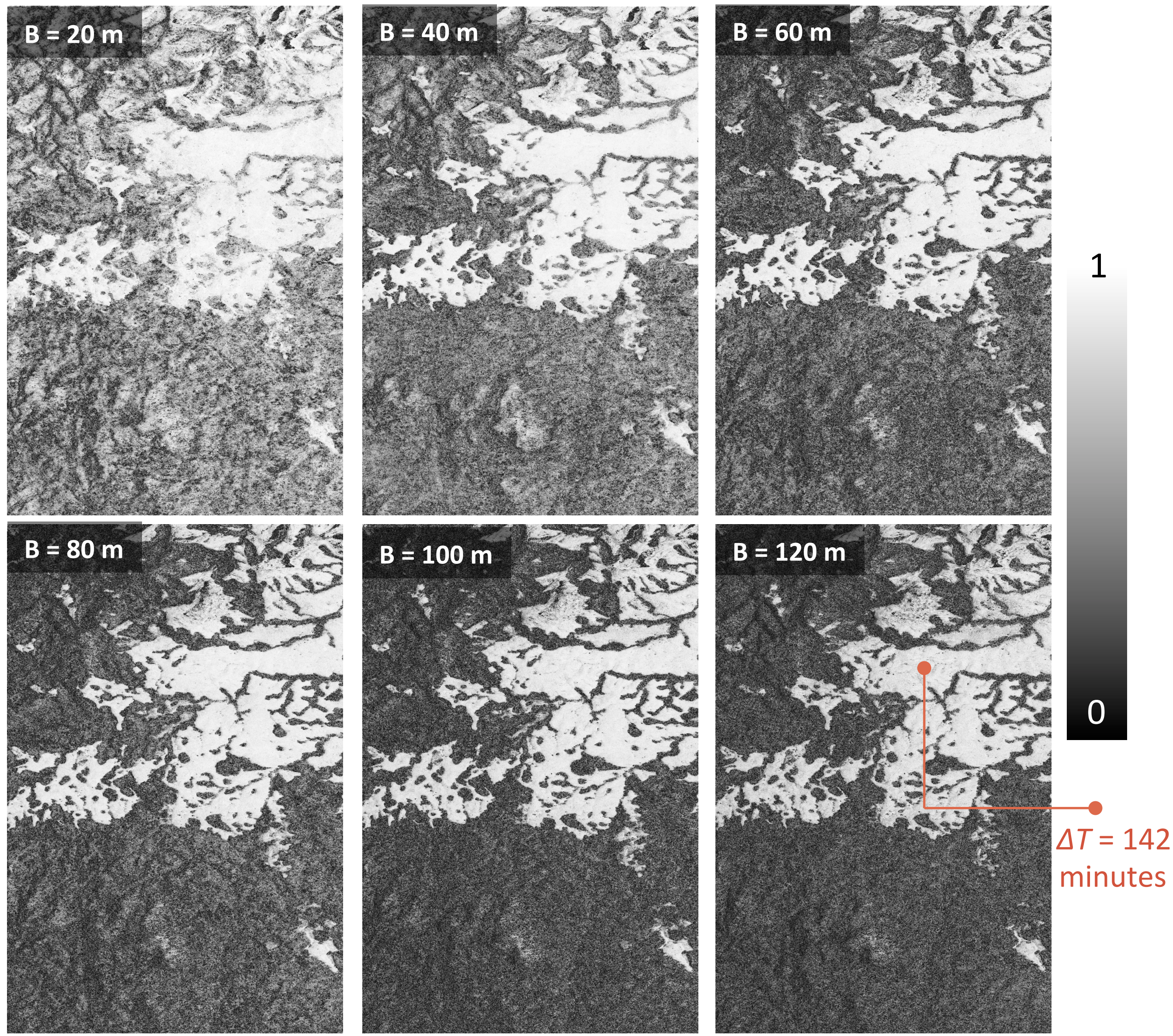
UAVSAR synthetic fringes

- Applied independently to each pair
- Calculated from aircraft position and DEM
- Used for interferogram flattening and slope-adaptive spectral shift-filtering

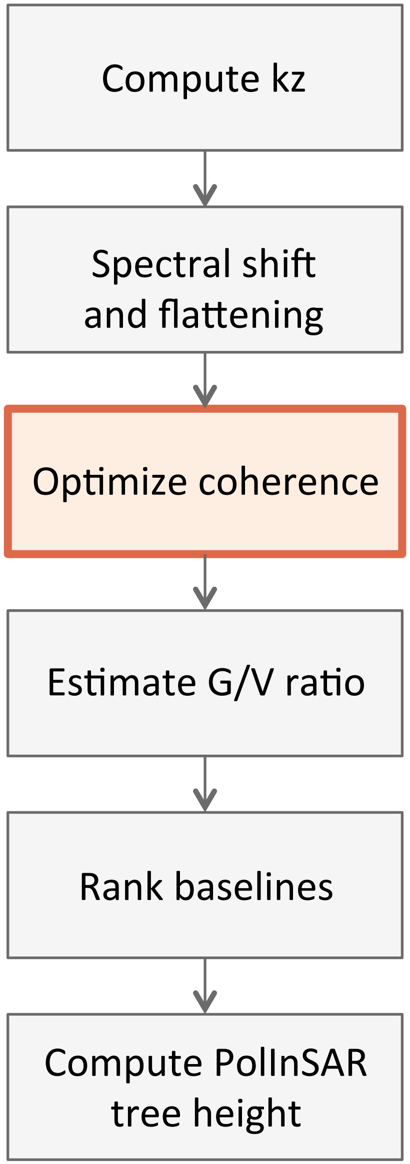


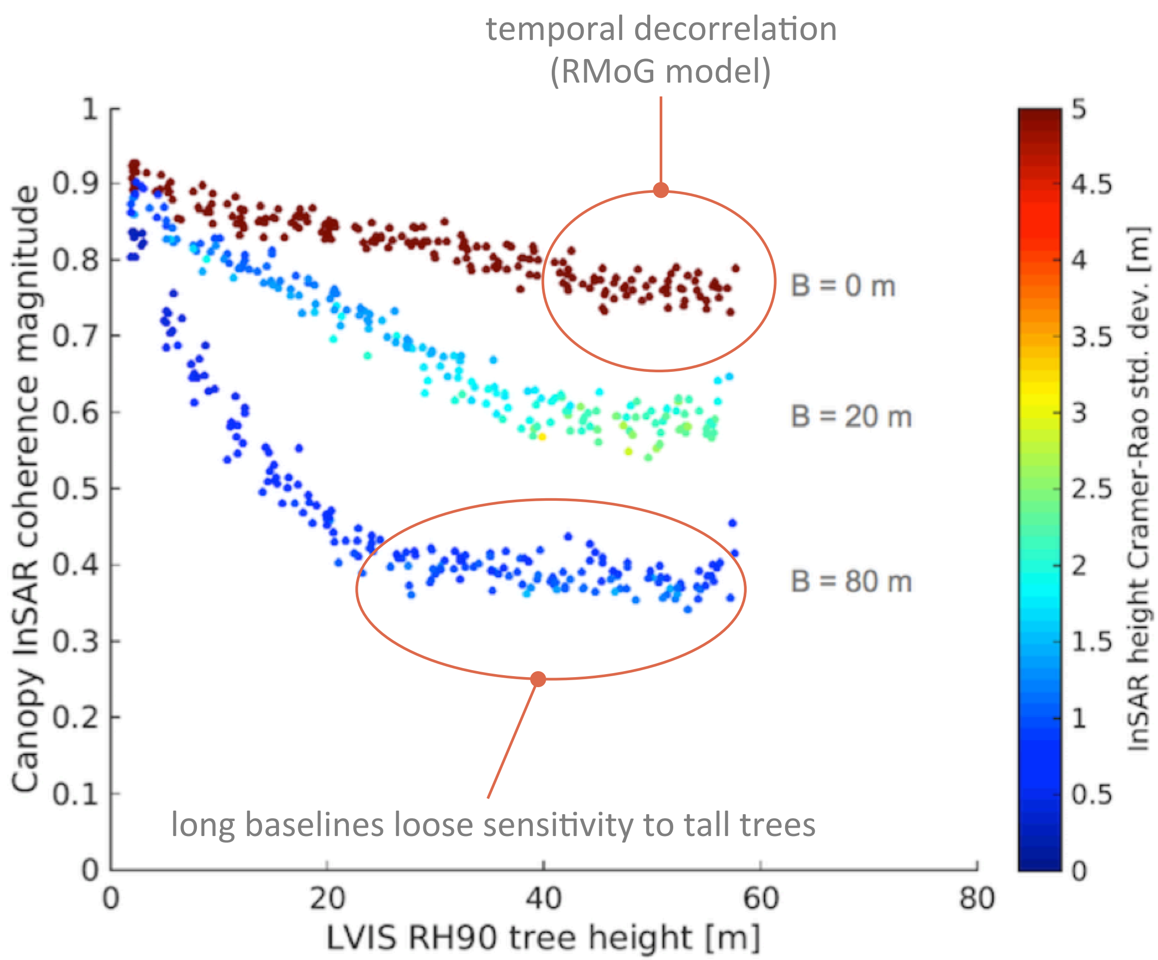
UAVSAR volume PolInSAR coherence





UAVSAR volume coherence vs. lidar height





Lavalle et Al. (2012), "A temporal decorrelation model for polarimetric radar interferometers," IEEE TGRS.

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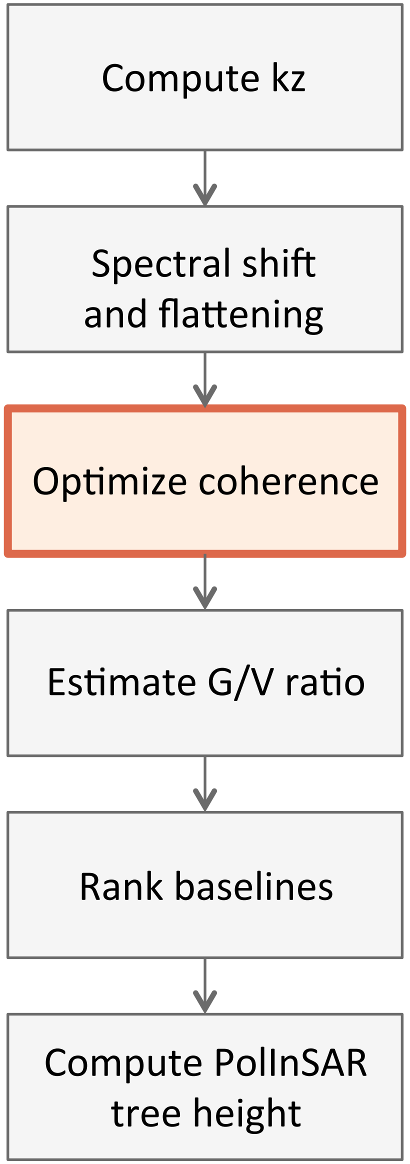
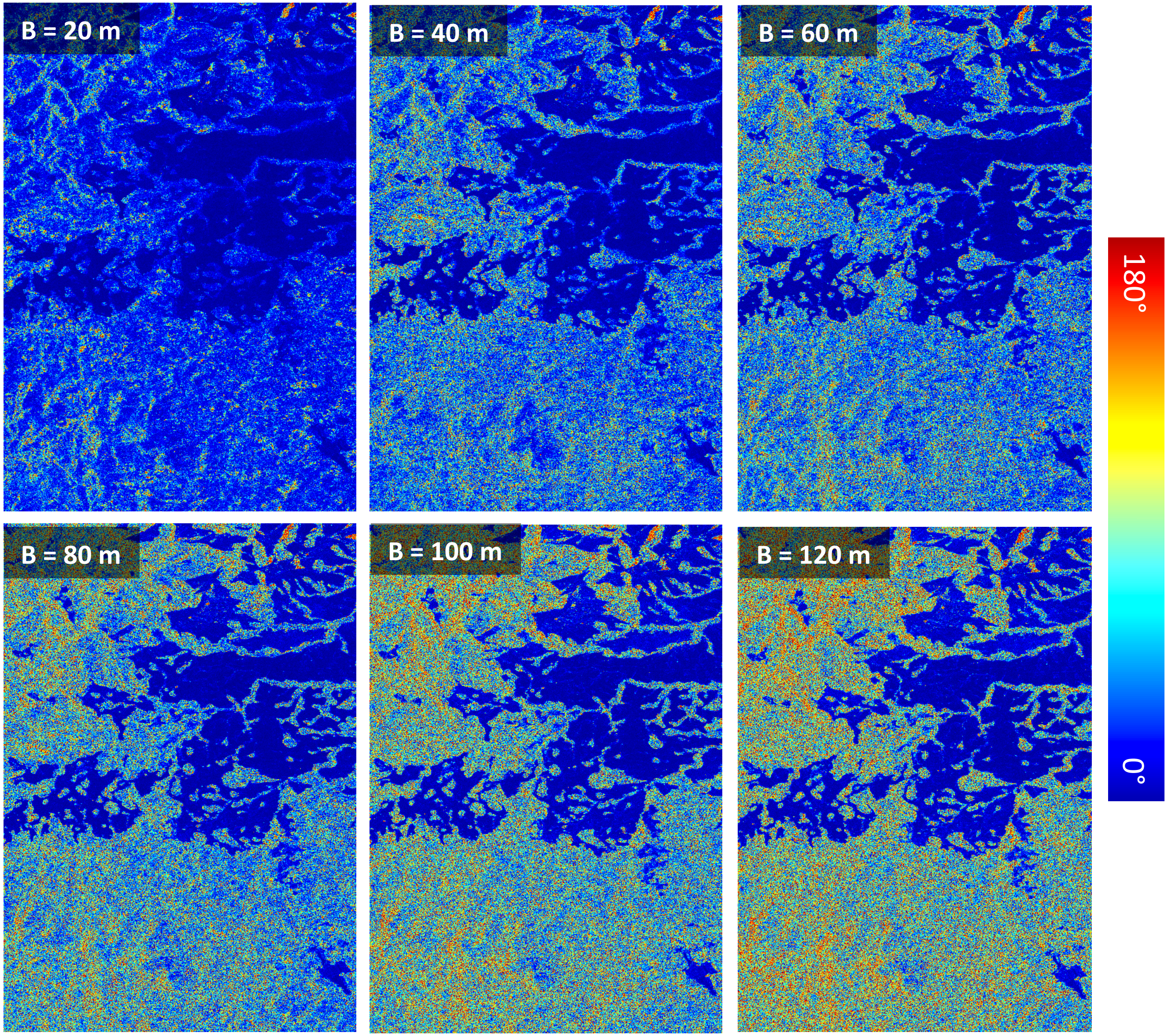


Ground/Volume PolInSAR phase difference



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- Compute kz
- Spectral shift and flattening
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- **Estimate G/V ratio**
- Rank baselines
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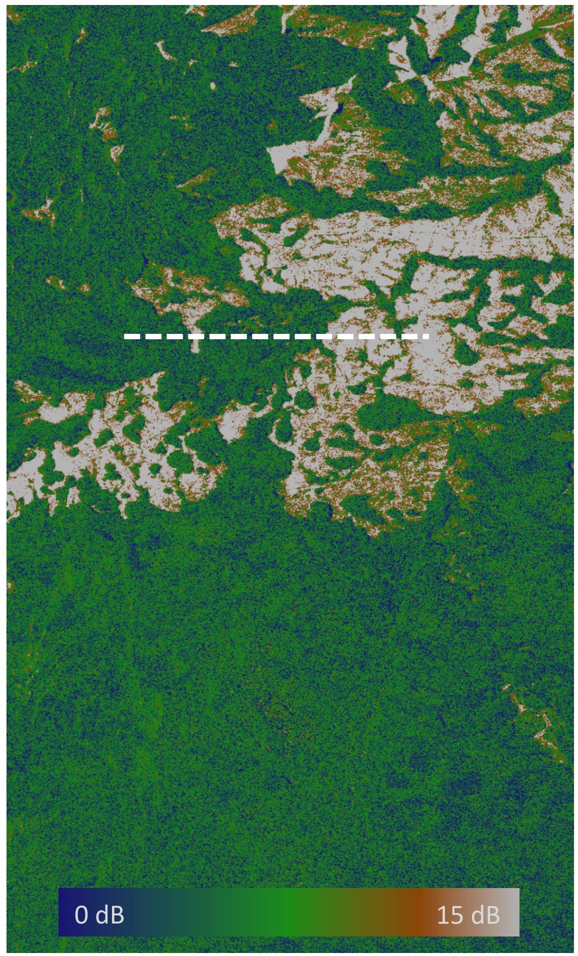
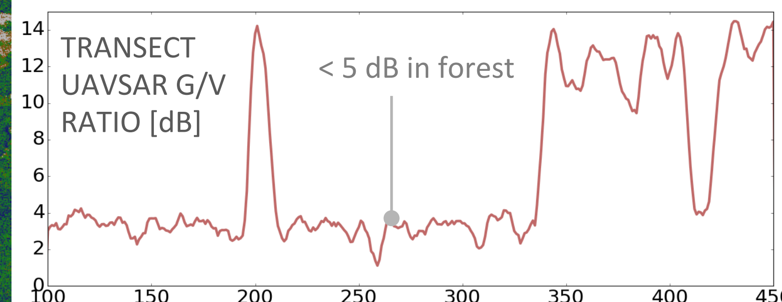
Ground/Volume scattering ratio

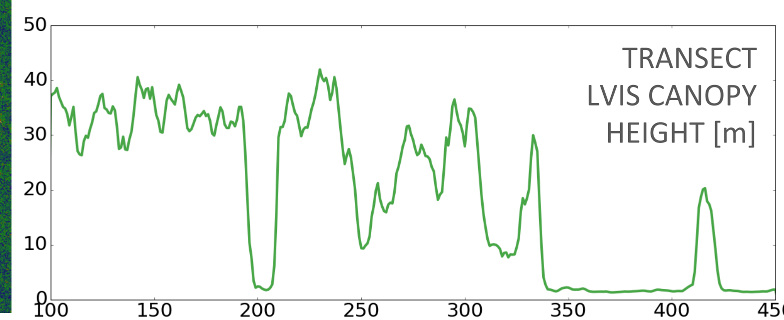


- Polarimetry only, no interferometry
- Eigenvalue decomposition of ground/volume covariance matrix

$$[T_v]^{-1}[T_g]w = \lambda w$$

- Robust to terrain slope





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Compute kz

Spectral shift and flattening

Optimize coherence

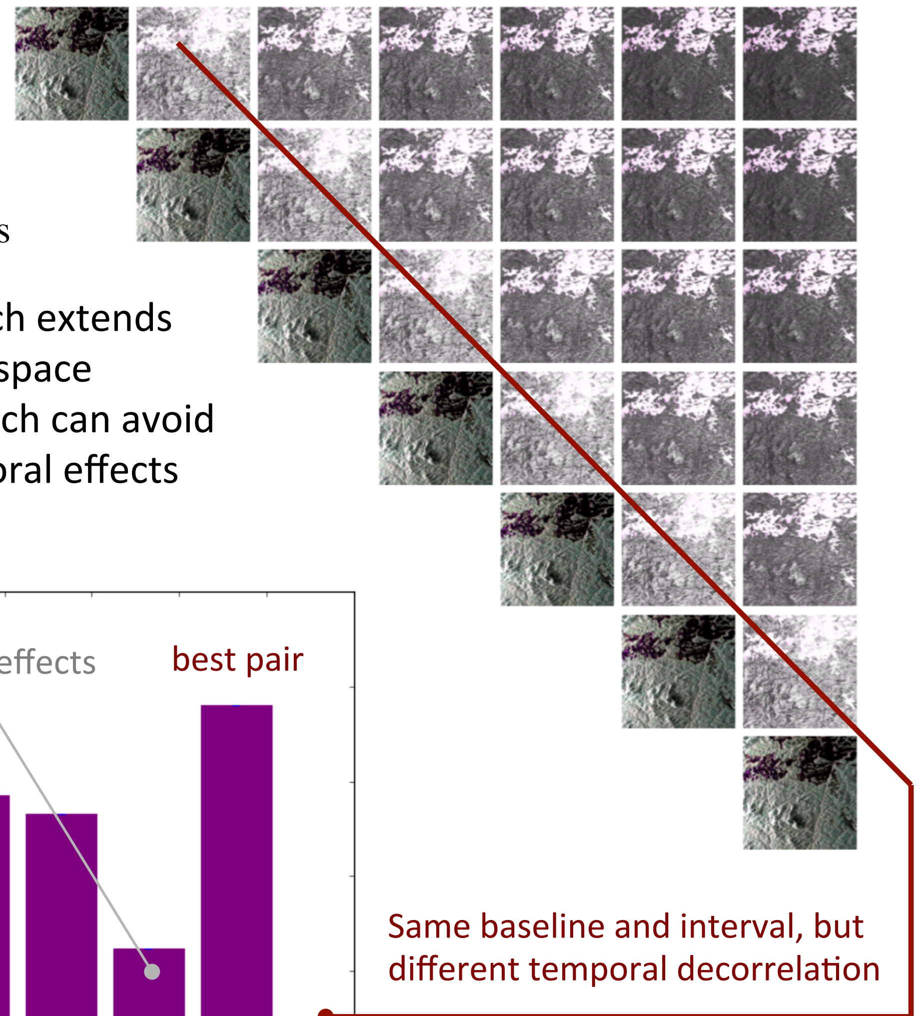
Estimate G/V ratio

Rank baselines

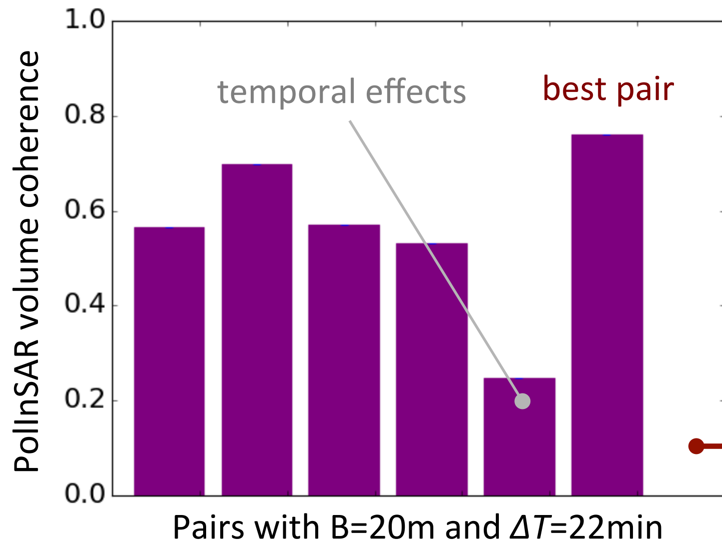
Compute PolInSAR tree height

All-pairs vs. Best-pair approach

Polarimetric tomographic coherence stack



- $\dfrac{N(N-1)}{2} = 21$ pairs
- All-pairs approach extends the observation space
- Best-pair approach can avoid undesired temporal effects



Compute kz

↓

Spectral shift and flattening

↓

Optimize coherence

↓

Estimate G/V ratio

↓

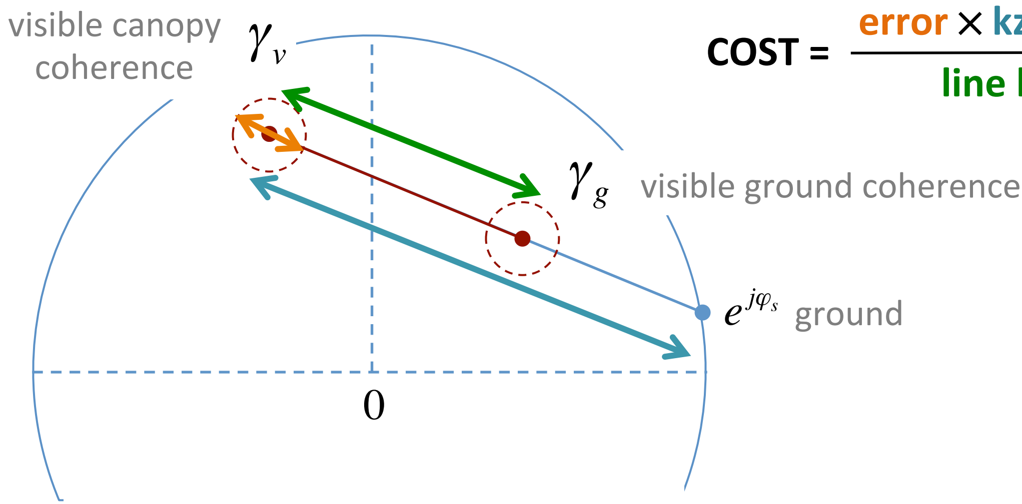
Rank baselines

↓

Compute PolInSAR tree height

Which UAVSAR baseline?

$$\text{COST} = \frac{\text{error} \times \text{kz-structure}}{\text{line length}}$$

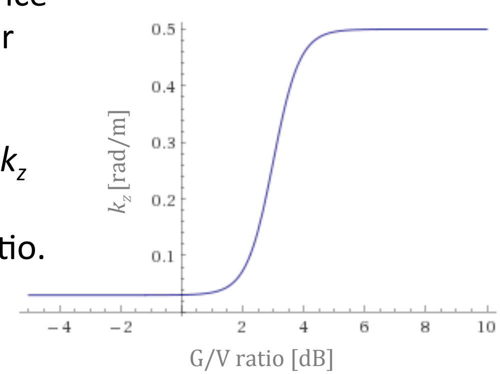


From literature

Error	Phase standard deviation divided by vertical wavenumber
Line length	Volume/ground phase difference scaled by vertical wavenumber

We added

Kz-structure	Departure of k_z from optimum k_z for a given forest structure. E.g. Sigmoid function of G/V ratio. Depends on campaign design.



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Compute kz

↓

Spectral shift and flattening

↓

Optimize coherence

↓

Estimate G/V ratio

↓

Rank baselines

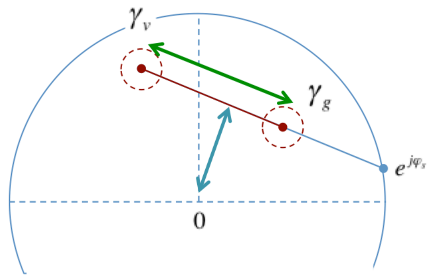
↓

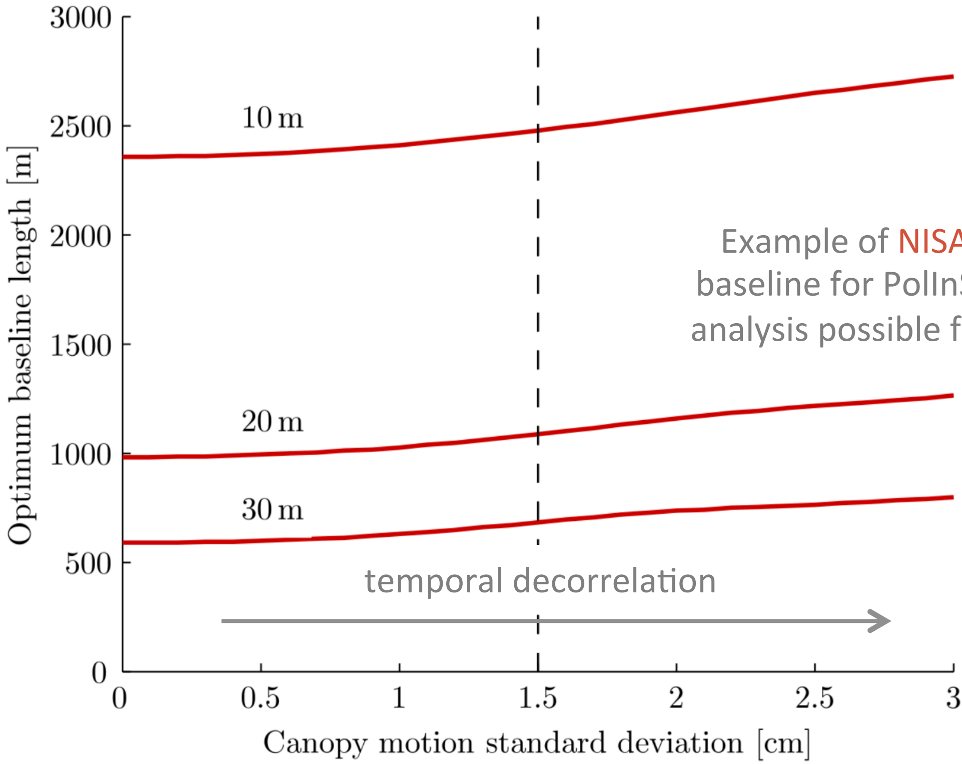
Compute PolInSAR tree height

Cost function is robust against motion-induced temporal decorrelation

RMoG-model based temporal decorrelation shrinks and tilts the PolInSAR line, but cost function remains stable

$$\gamma = e^{j\varphi_g} \frac{\mu \gamma_{t_g} + \gamma_{vt} e^{-j\varphi_g}}{\mu + 1}$$





Example of NISAR optimal baseline for PolInSAR. Similar analysis possible for BIOMASS

Lavalle et Al. (2012), "A temporal decorrelation model for polarimetric radar interferometers," IEEE TGRS.

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Compute kz
↓
Spectral shift and flattening
↓
Optimize coherence
↓
Estimate G/V ratio
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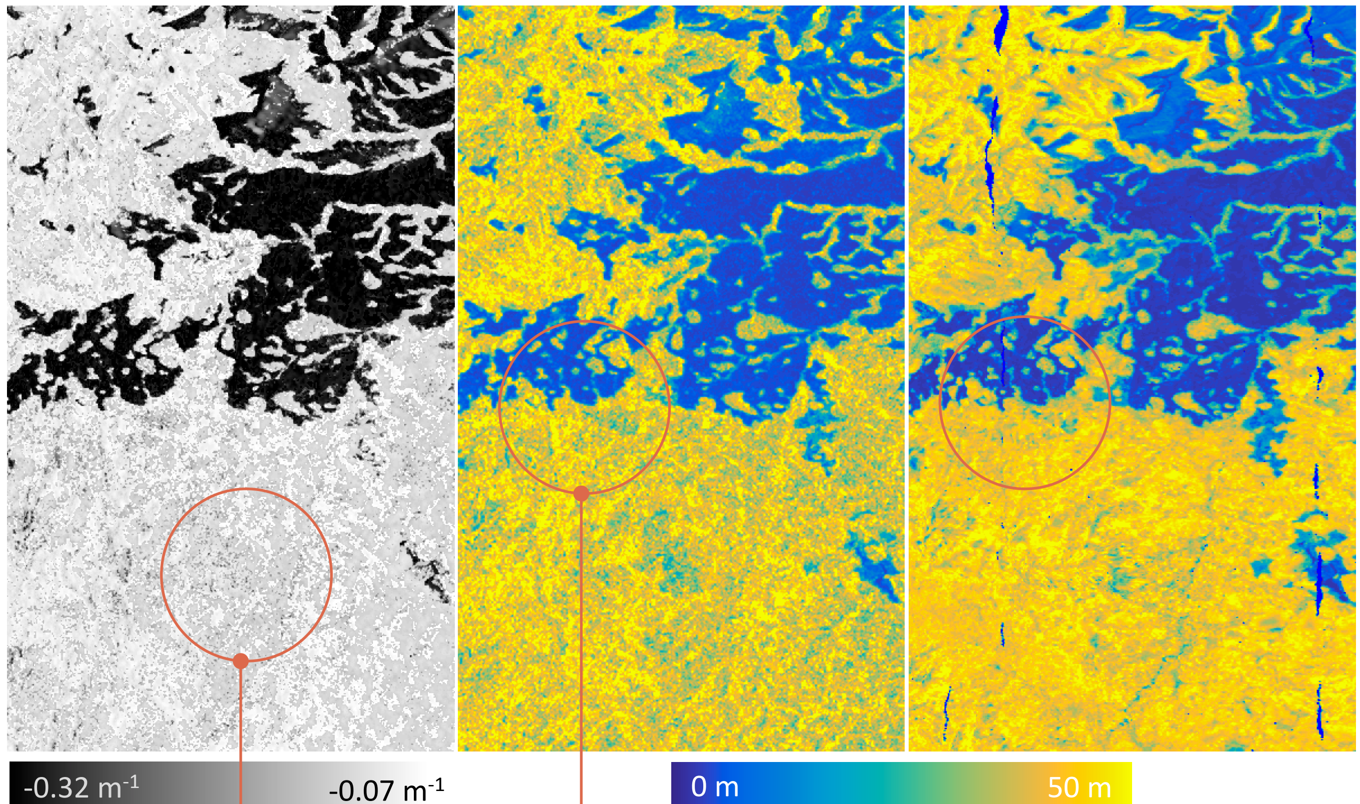
↓
Compute PolInSAR tree height

Preliminary PolInSAR tree height

Selected vertical wavenumber	UAVSAR multi-baseline PolInSAR tree height	LVIS lidar-derived tree height



terrain slope not visible

current estimation is better in savanna and savanna-forest transition compared with dense tropical forest

Blair, J.B., el Al. (1999), "LVIS: A medium-altitude, digitization-only, airborne laser altimeter for mapping vegetation and topography", ISPRS J. Ph. and Rem. Sens.

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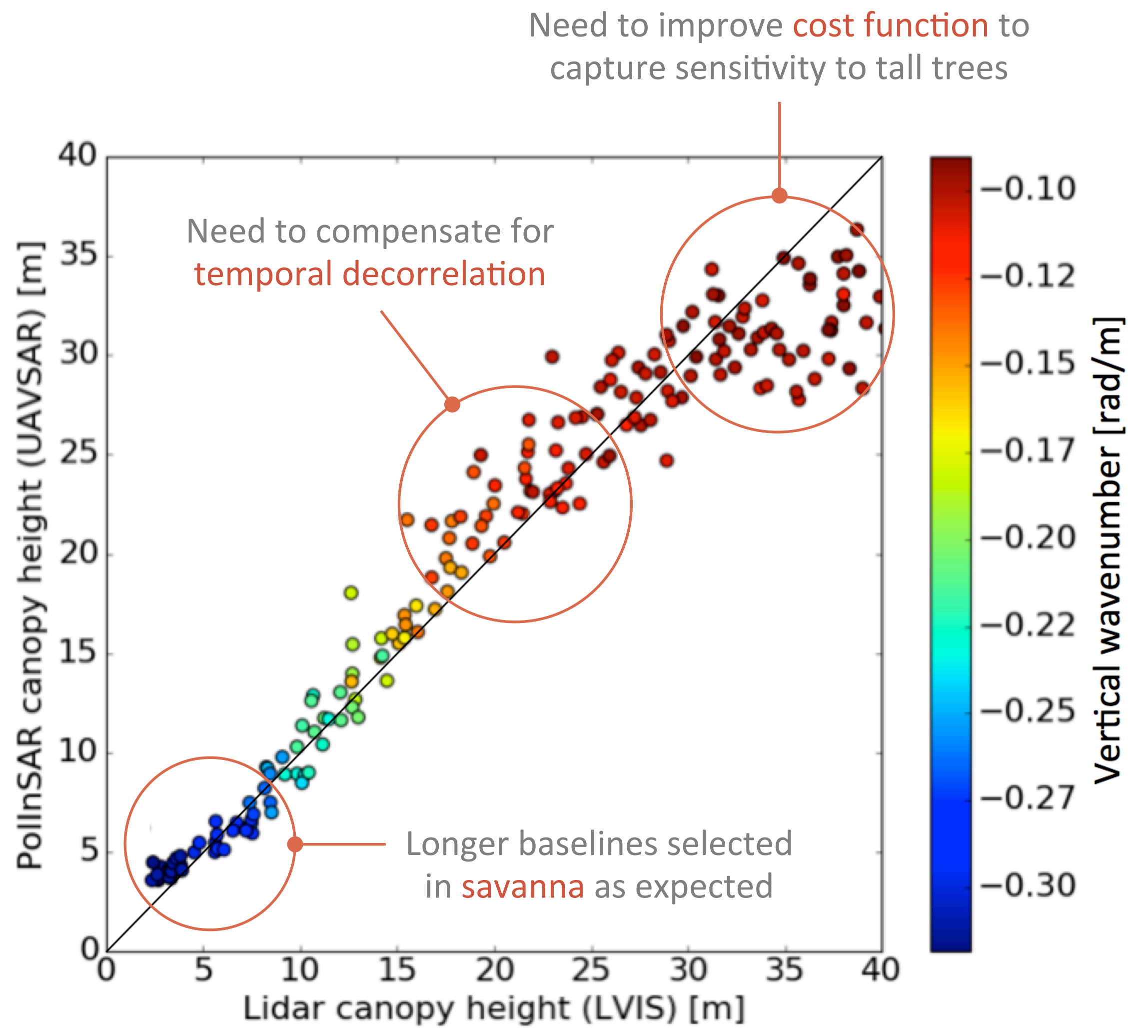
- **Compute PolInSAR tree height**

Preliminary PolInSAR tree height



Multi-baseline RVoG-model inversion. Quantitative assessment in progress.

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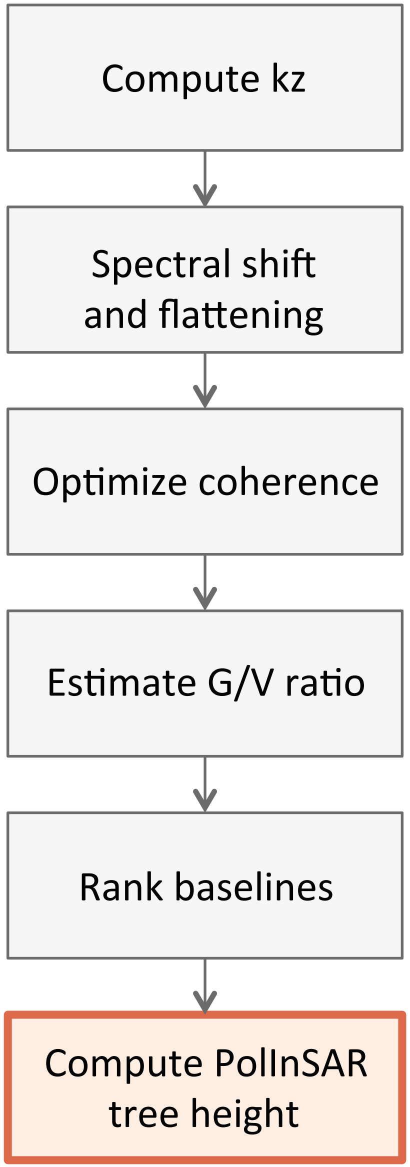
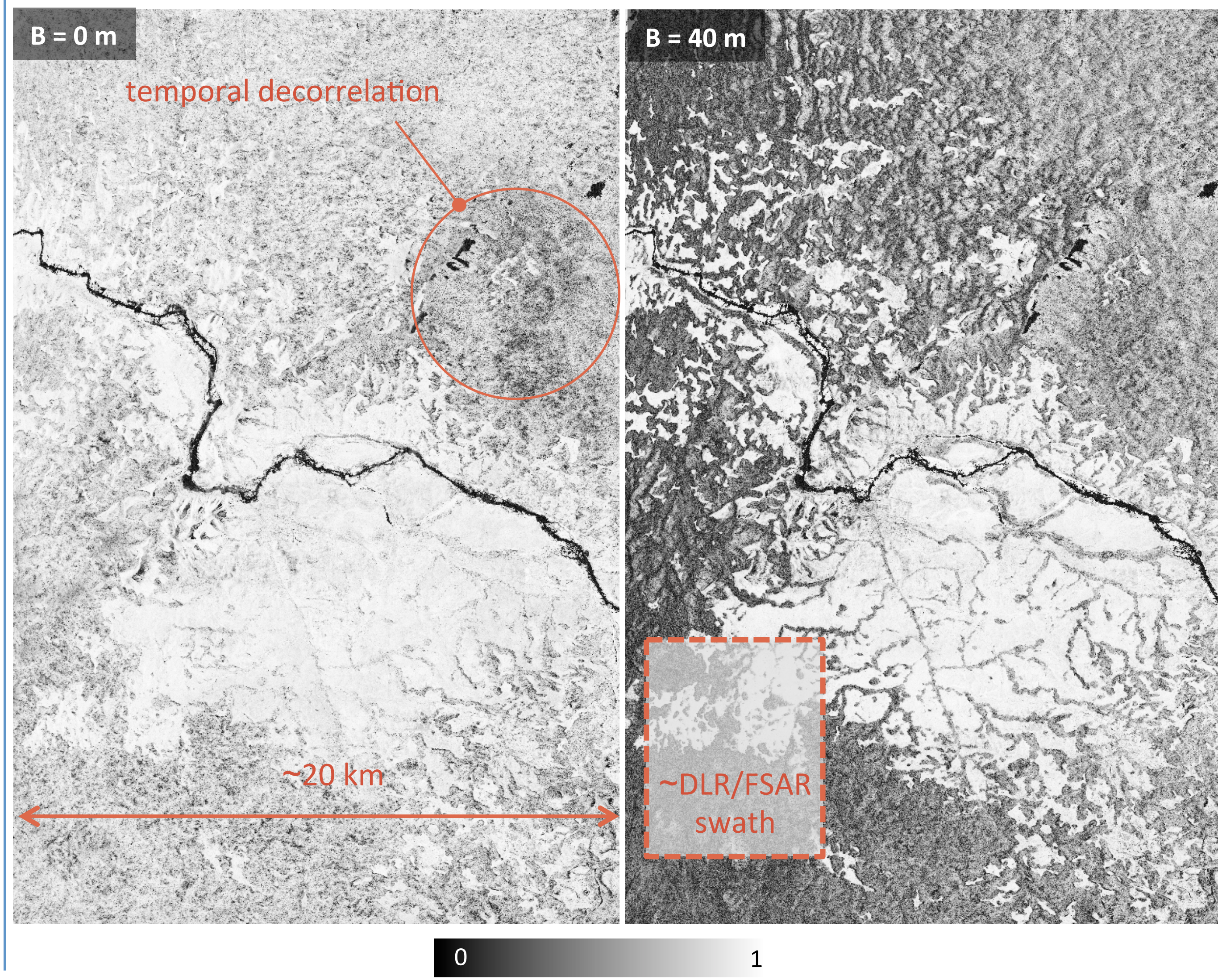
UAVSAR Temporal-Volume coherence across the swath





Key messages

- Revised experimental, multi-baseline UAVSAR PolInSAR processor gives excellent coherence results
- Baseline length and temporal decorrelation are main drivers in PolInSAR tree height estimation
- Best-pair approach in multi-baseline PolInSAR helps maximize PolInSAR sensitivity to structure
- Cost function is robust to temporal decorrelation, but compensation for its effects is still needed
- Partial ground visibility at L-band in dense tropical forest is sufficient for PolInSAR height estimation
- PolSAR and TomoSAR experiments in progress (IGARSS 2017) → uavsar.jpl.nasa.gov
- Comparison and inter-validation with ESA-funded portion of AfriSAR campaign planned

UAVSAR HV 5-scene mosaic