



Ministry of Science and Higher Education
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EUROPEAN SPACE AGENCY

15 - 19 June 2026 | Auditorium Maximum of the Jagiellonian University, Kraków, Poland

FRINGE 2026

BIOMASS Tomographic Processing

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POLITECNICO
MILANO 1863



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Stacking

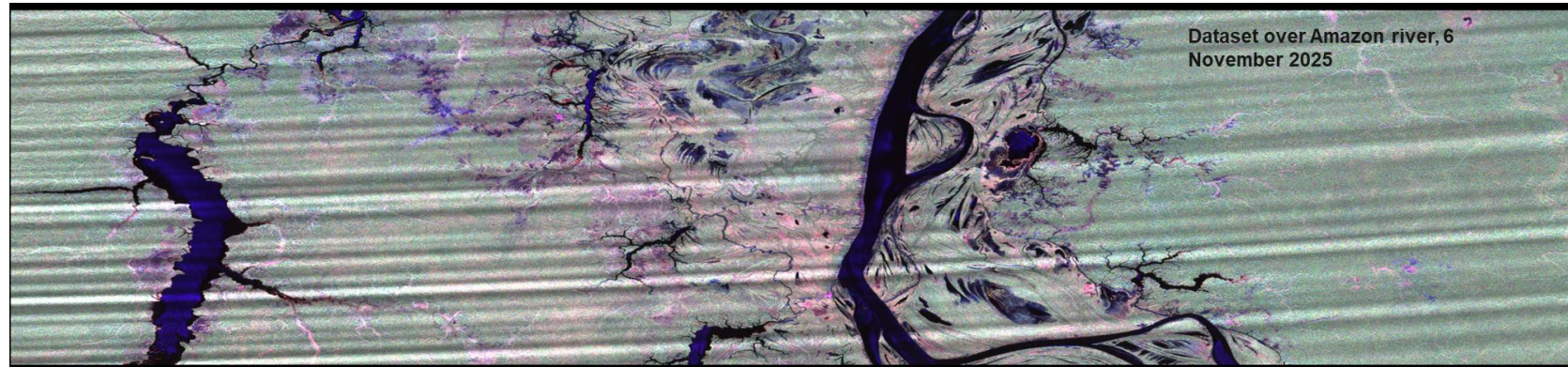
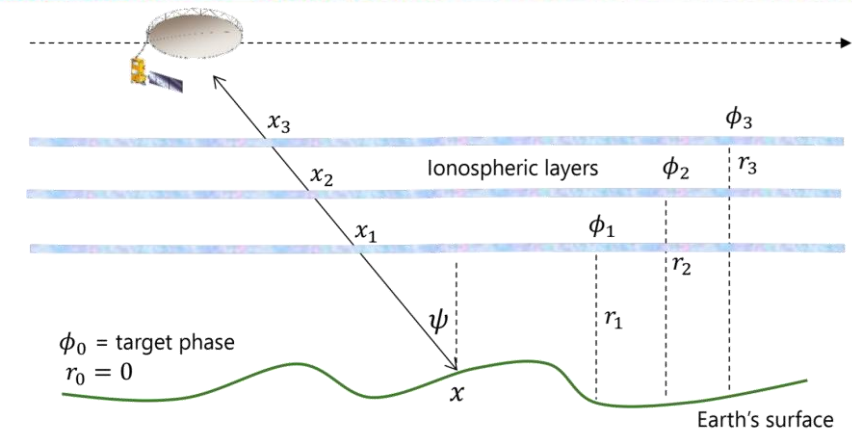


- stacks of 7 acquisitions in TOM phase
- 15% of critical baseline spacing
- vertical resolution of about 23 m (at the equator)

**Dataset over Nabire, Papua
NG, 7-22 October 2025**



$$\phi_{MS}(x, r, \psi) = \angle \{I_s(x, r, \psi) \cdot I_r^*(x, r, \psi)\} = \sum_k \phi_k(x - r_k \psi, r)$$



- **Coregistration with data maybe insufficient**
- Can be tackled with Multi-Squint Interferometry (**MS-InSAR**)
 - allows *correcting a multi-layered ionosphere model by sub-band refocusing*
 - multi-baseline by pair-wise sequential processing
 - *simple case: single layer & semi-focusing*

- *For forests usually ionosphere is not too extreme*
- *But other effects (e.g., F-spread) are observed*

(More MS-InSAR details: DOI: <https://doi.org/10.1109/TGRS.2026.3688410>)

For each single-baseline pair

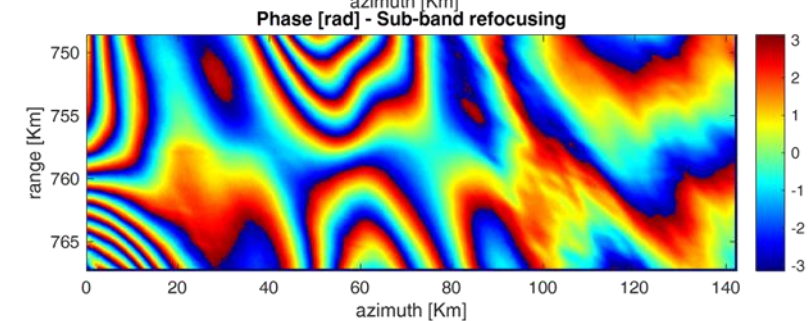
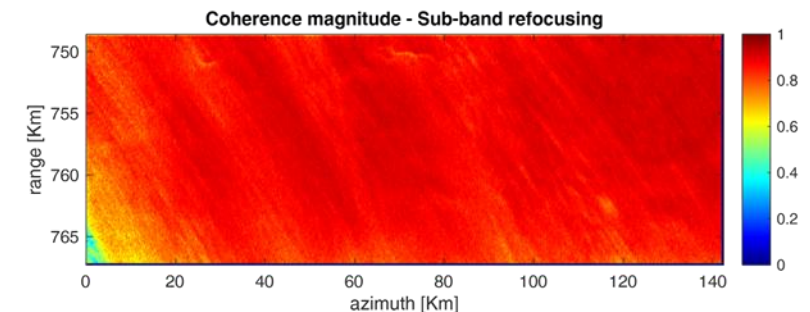
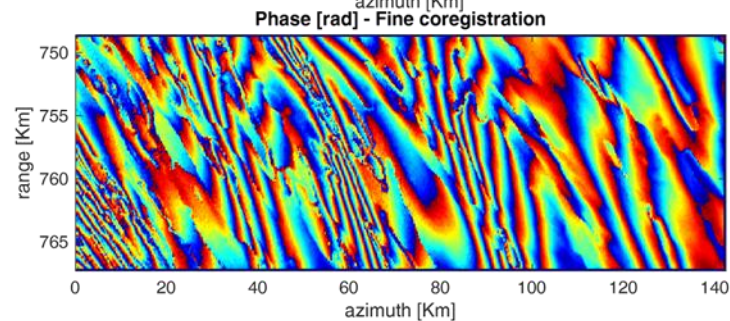
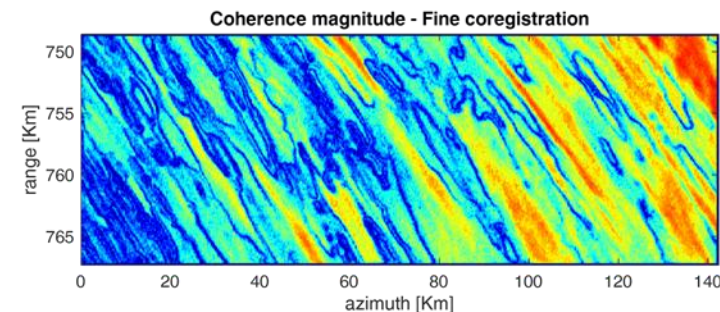
Coregistration is sufficient:
No action is performed

Coherence magnitude

Coherence phase

Ionospheric disturbance can be modeled with single or multiple layers:

- Single: correction by defocusing to ionospheric height
- Multiple: correction by sub-band refocusing



Low ionospheric frequencies are left over!

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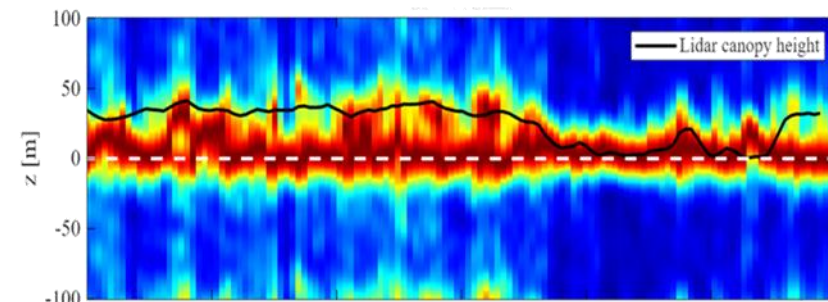
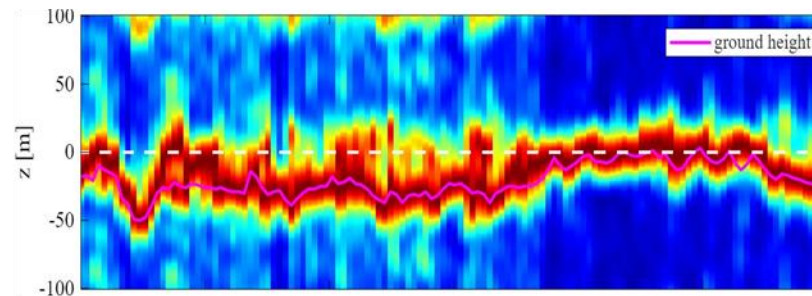
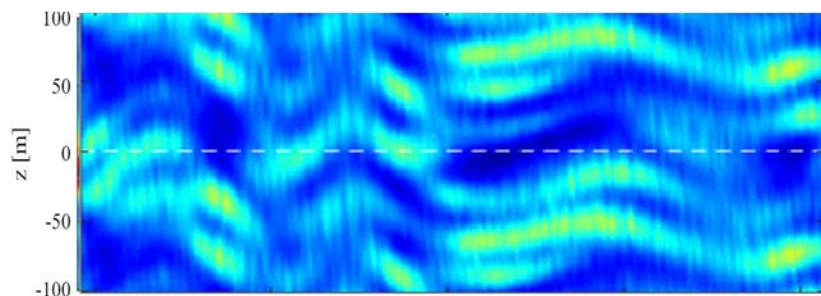
The diagram illustrates the difference between DEM (Digital Elevation Model) and DTM (Digital Terrain Model). On the left, labeled 'DEM', a solid black line represents the ground surface with two green trees on top. On the right, labeled 'DTM', a dashed black line represents the ground surface with two brown trees on top. Blue arrows indicate wind flow over the terrain, showing how the DTM model accounts for the ground surface elevation and vegetation.

- phase calibrating interferometric phases in order to have a common reference **DEM**
- linking the common reference to a physically significant feature of the scene, e.g., ground

$$\varphi_{nm} = \underbrace{(\alpha_n - \alpha_m)}_{\text{Heading error}} + \underbrace{(k_n^z - k_m^z)z_g}_{\text{Ground steering}} + \xi_{nm} \xrightarrow{\text{Ground steering}} \varphi_{nm} = \underbrace{\xi_{nm}}_{\text{Heading error}}$$

Ground phase: causes a vertical shift of each pixel due to DTM-DEM difference

Non triangular terms:
contain information about
forest structure



GROUND STEERING



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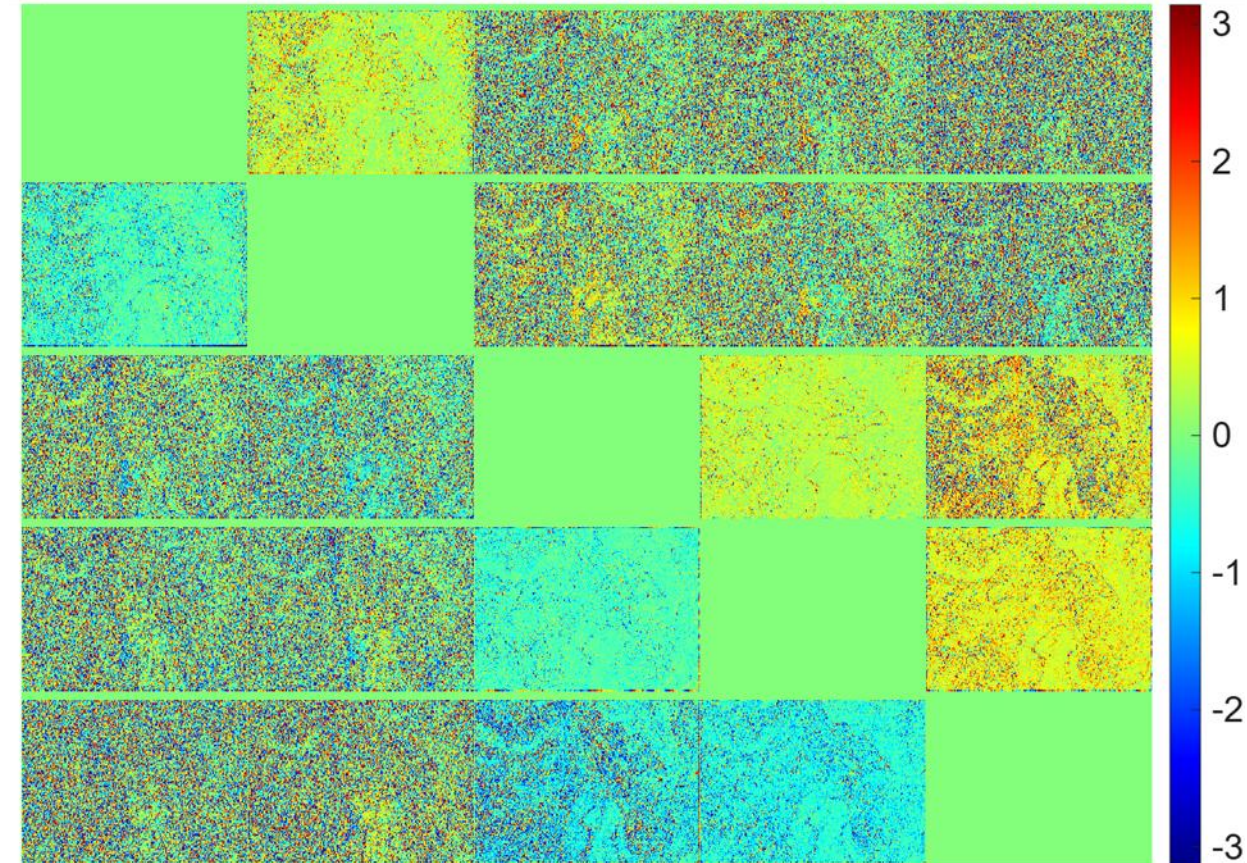
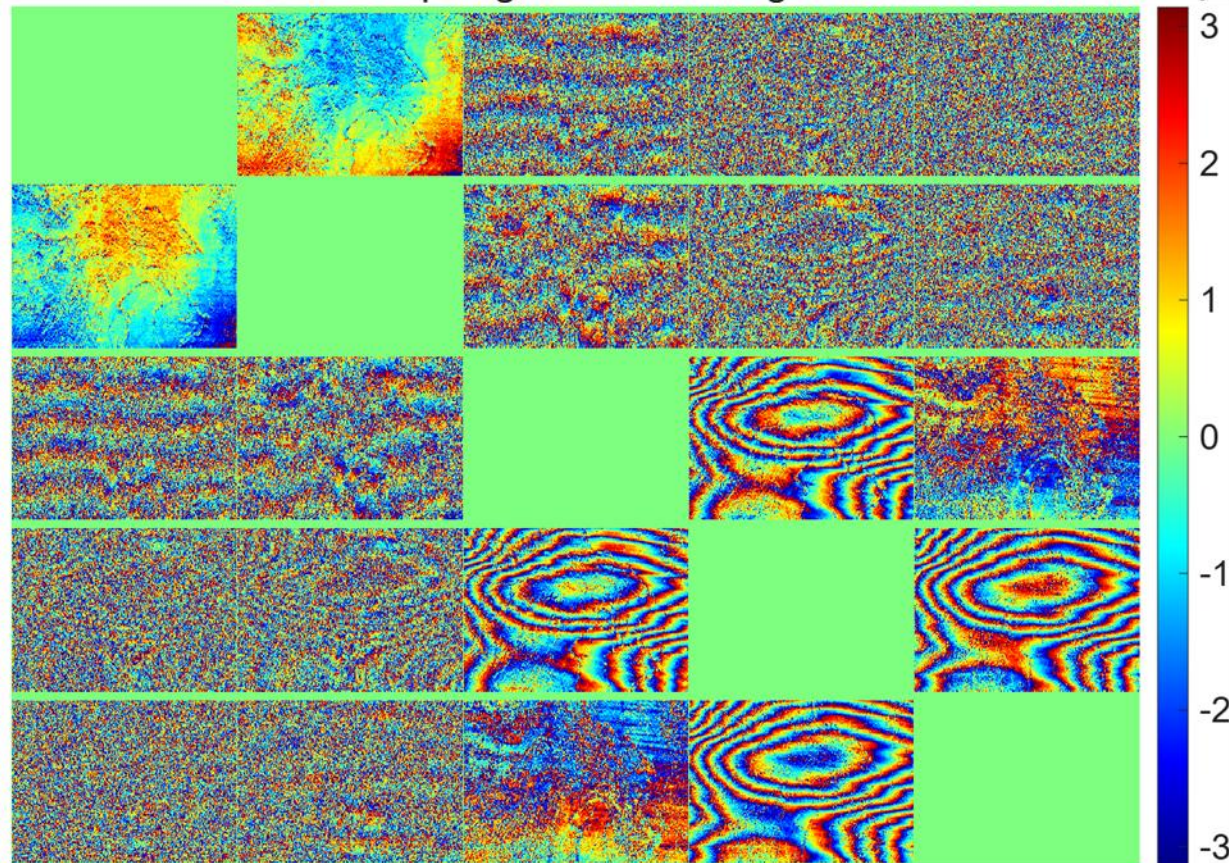
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Currently done with SKPD (PolInSAR) in Tomo processor, alternatively with InSAR techniques (under assessment)

Multi-baseline Interferometric phase [rad],
pre-ground steering

Dataset over La Lopé, Gabon, 7-22 October 2025

Multi-baseline Interferometric phase [rad],
after ground steering



FIRST TOMOGRAPHY



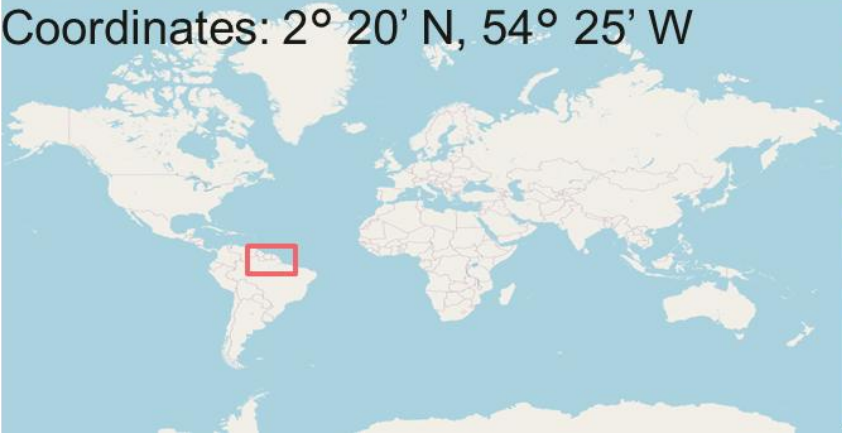
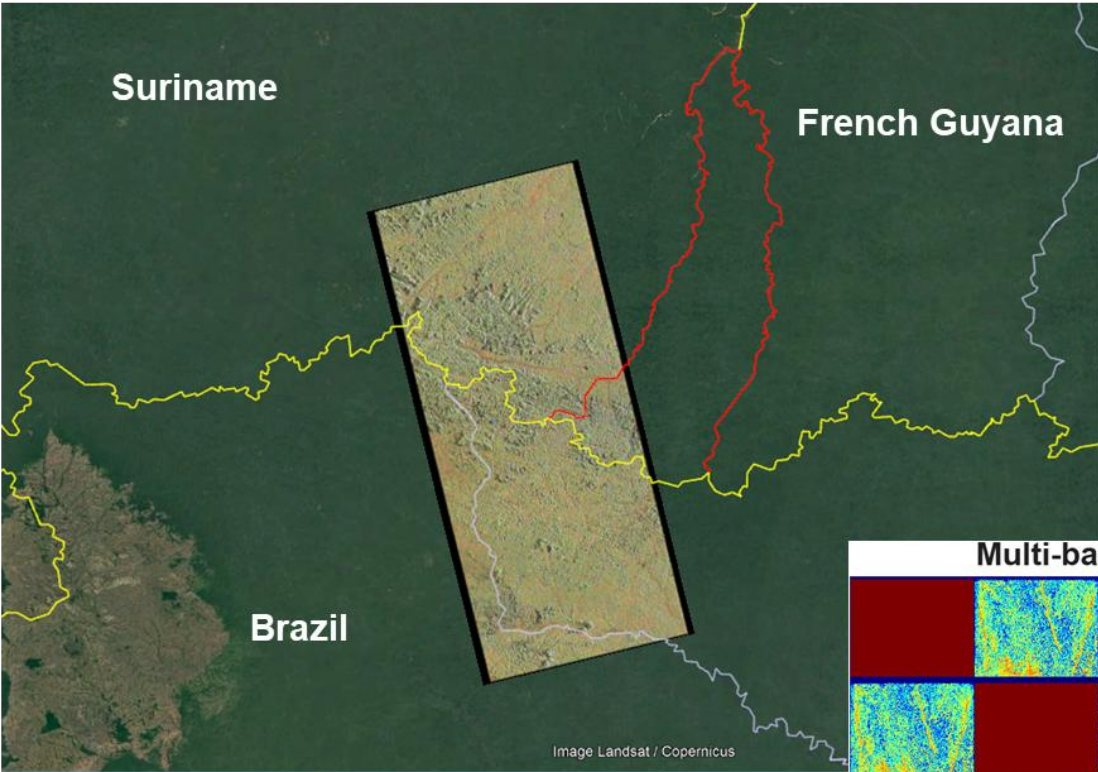
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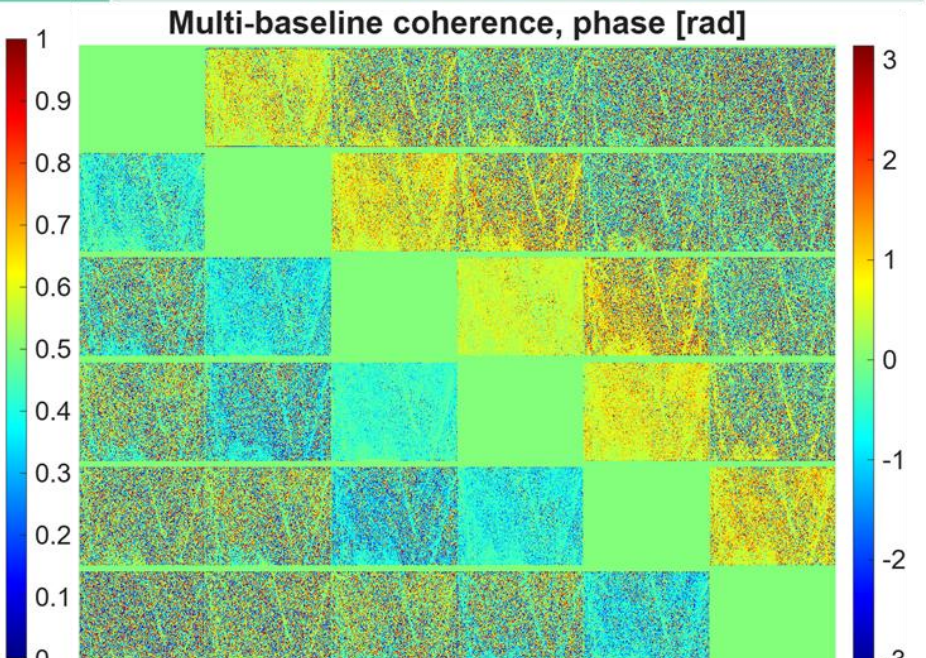
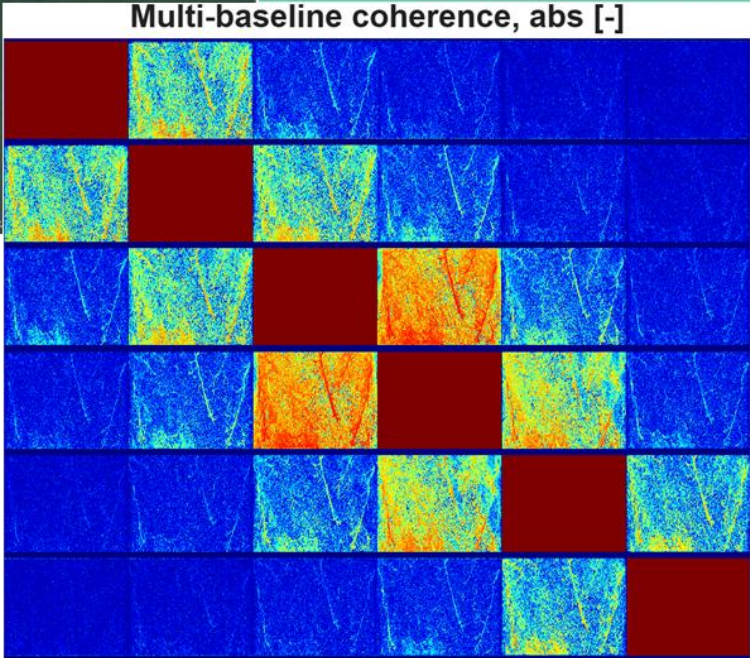
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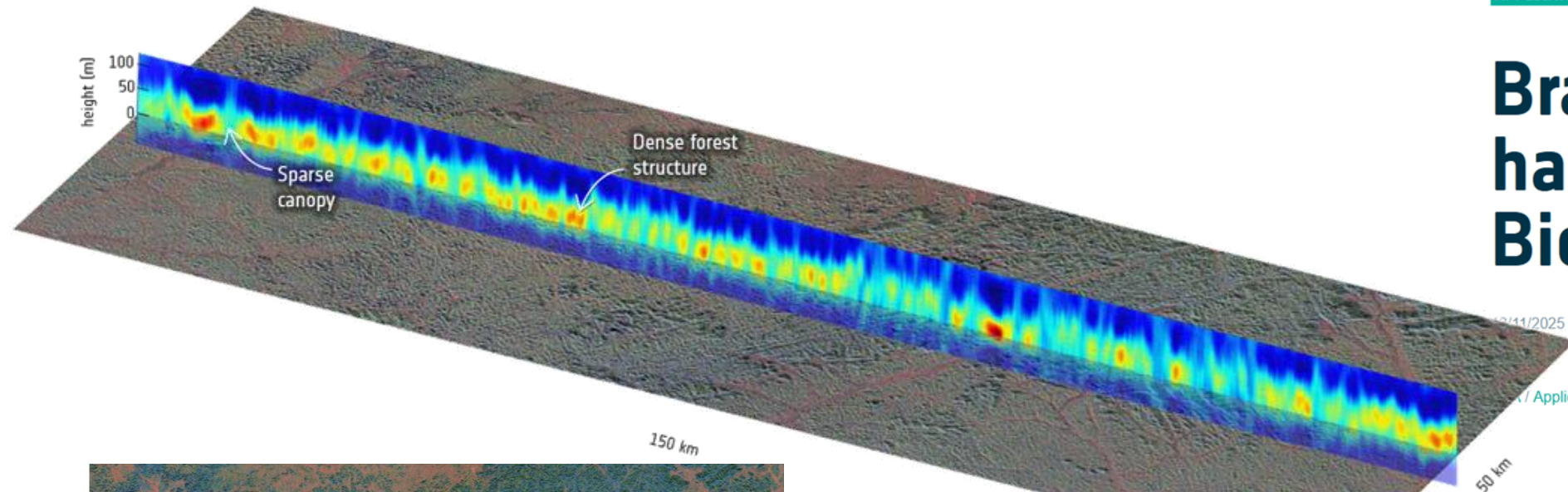
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Tumucumaque, Brasil, 2° North					
First acquisition on October 9, 2025					
Last acquisition on October 24, 2025					
Number of passes: 6					
Max expected baseline is 75% of the critical value for acquisitions at the Equator					
Incidence angle: 29.2°					
Max baseline	Expected	Max kz	Expected	Vertical resolution	Expected
4112 m	4415 m	0.2012 rad/m	0.2160 rad/m	31 m	29 m
Baseline progression error [m]			Progression error relative to critical baseline		
32	116	-273	-38	163	
			0.54%	1.97%	-4.63%
			-0.65%	2.77%	



Tumucumaque Mountains National Park

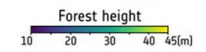
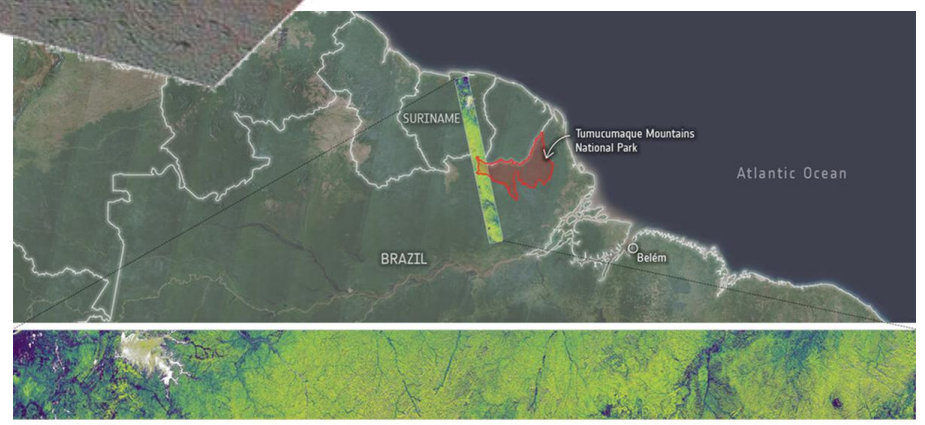
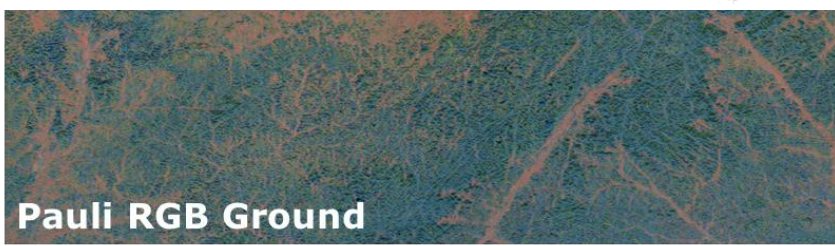


APPLICATIONS

Brazil gears up to harness ESA's Biomass data

12/11/2025 3405 VIEWS 42 LIKES

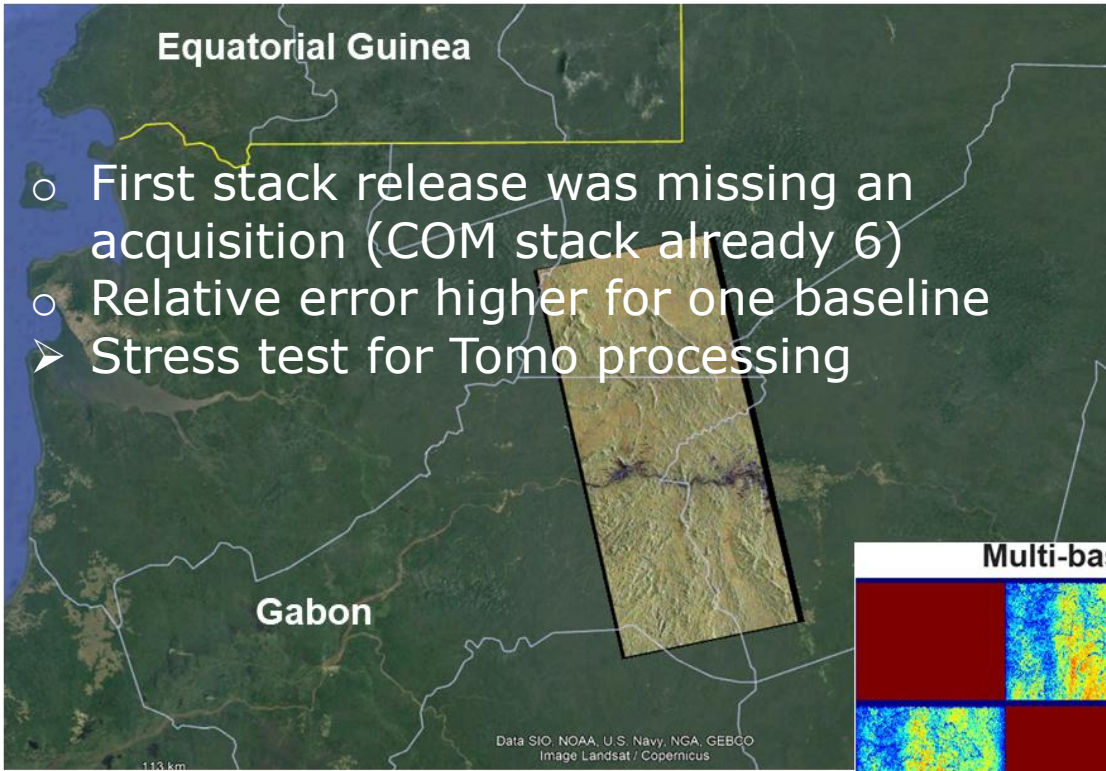
Applications / Observing the Earth / FutureEO / Biomass



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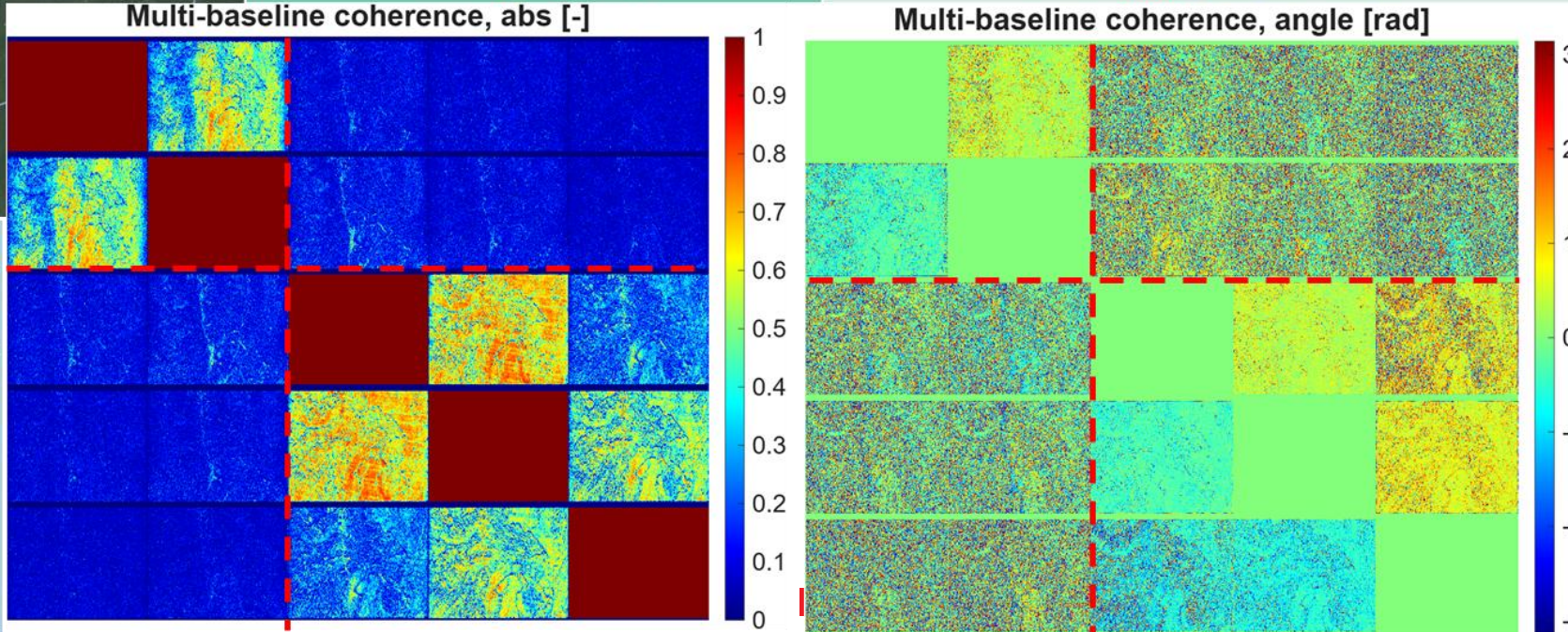


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- First stack release was missing an acquisition (COM stack already 6)
- Relative error higher for one baseline
- Stress test for Tomo processing

Lope, Gabon, 0° North							
First acquisition on October 7, 2025							
Last acquisition on October 22, 2025							
Number of passes: 5 (data acquired on October 13 are missing from the MAAP)							
Max expected baseline is 75% of the critical value for acquisitions at the Equator							
Incidence angle: 29.1°							
Max baseline	Expected		Max kz	Expected		Vertical resolution	Expected
3800 m	4395 m		0.1867 rad/m	0.2159 rad/m		34 m	29 m
Baseline progression error [m]			Progression error relative to critical baseline				
-301	739	-388	-50	-5.14%	12.61%	-6.62%	-0.85%



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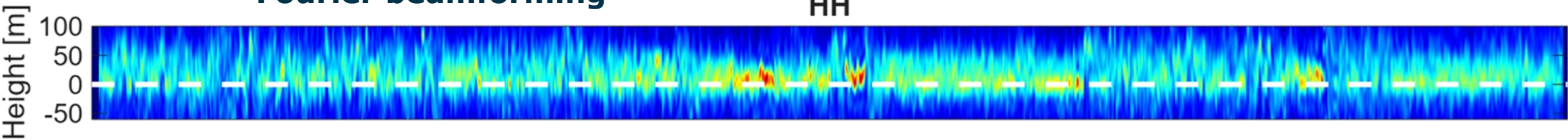
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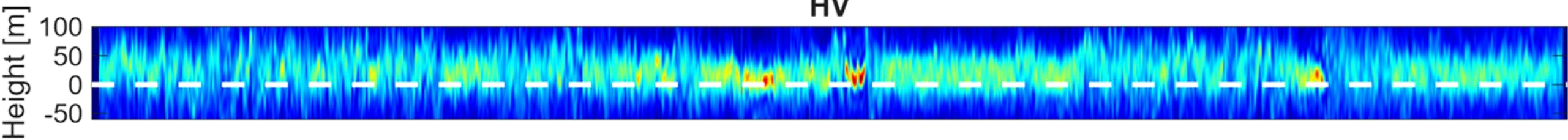
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Fourier beamforming

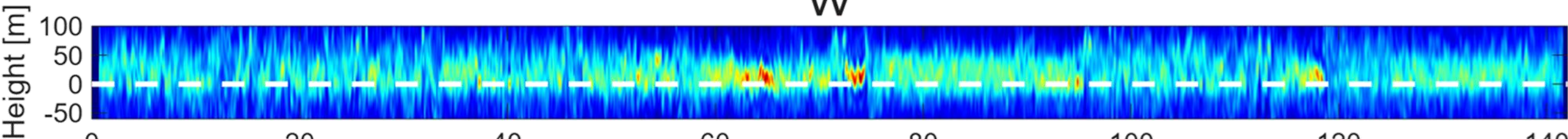
HH



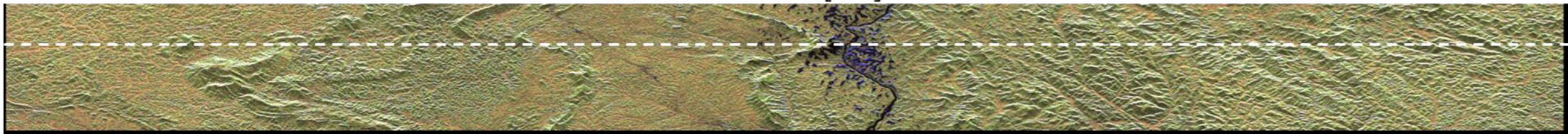
HV



VV



Azimuth [km]



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LA LOPE NATIONAL PARK

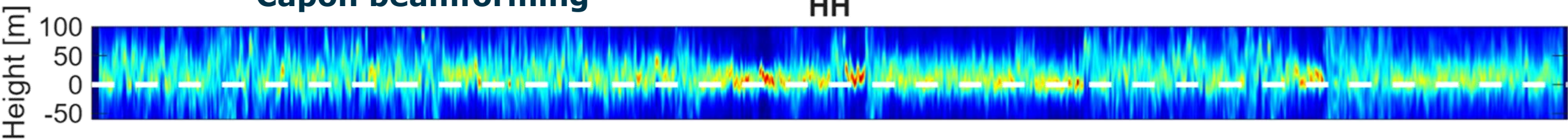


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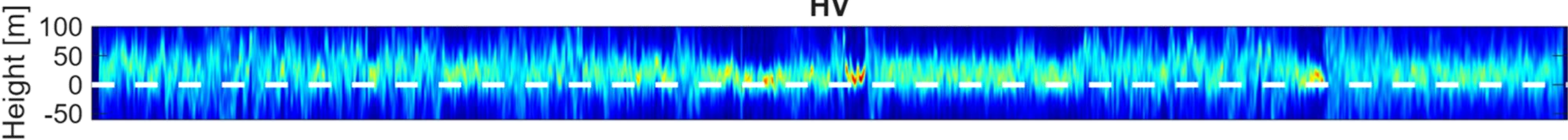


Capon beamforming

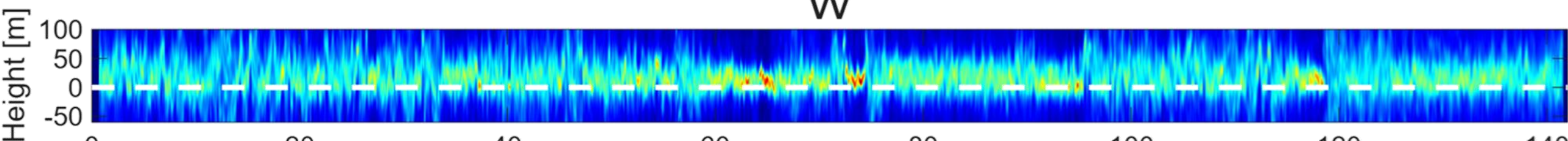
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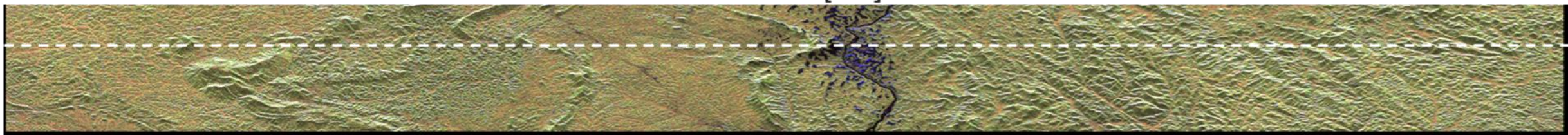
HV



VV

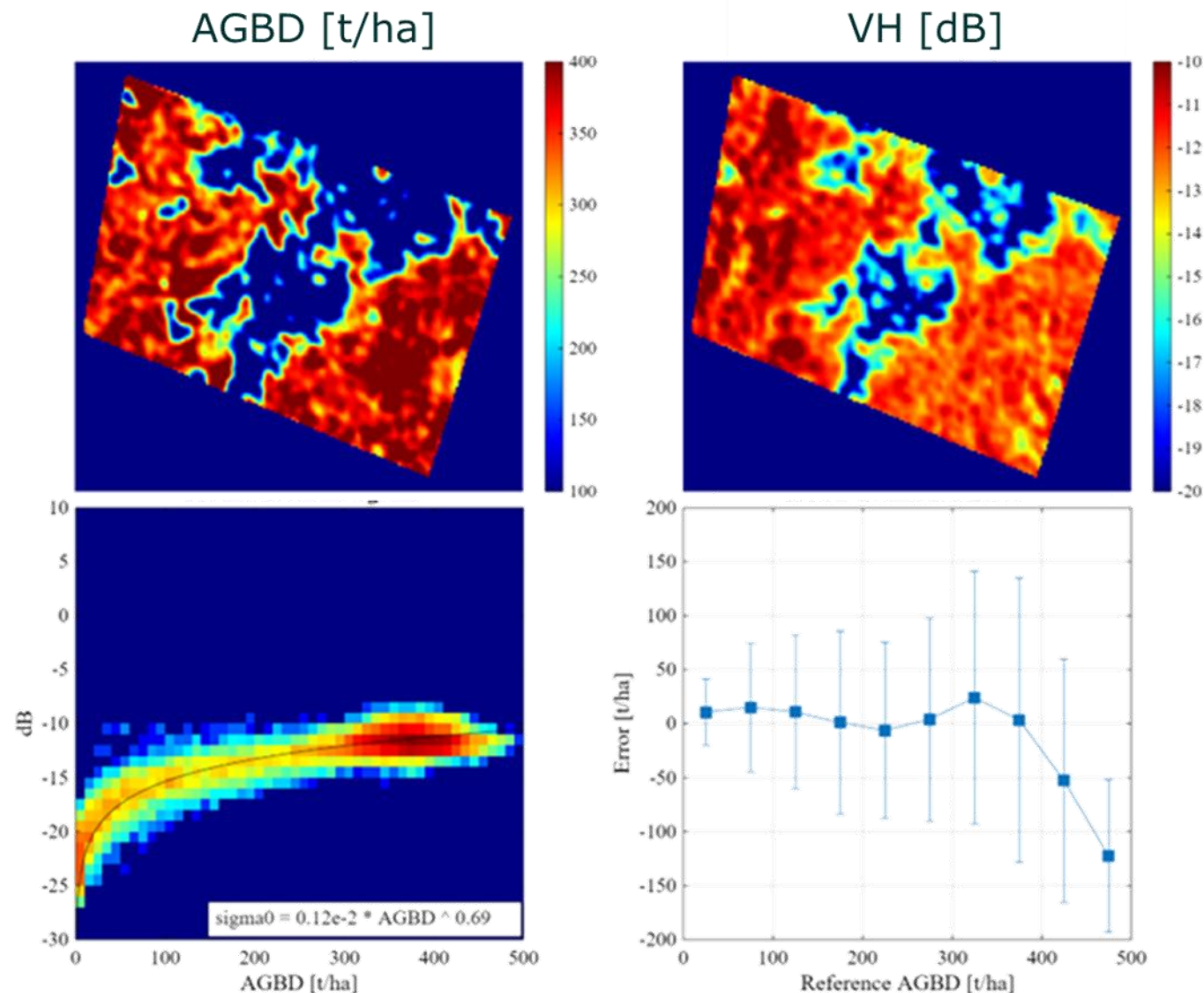


Azimuth [km]



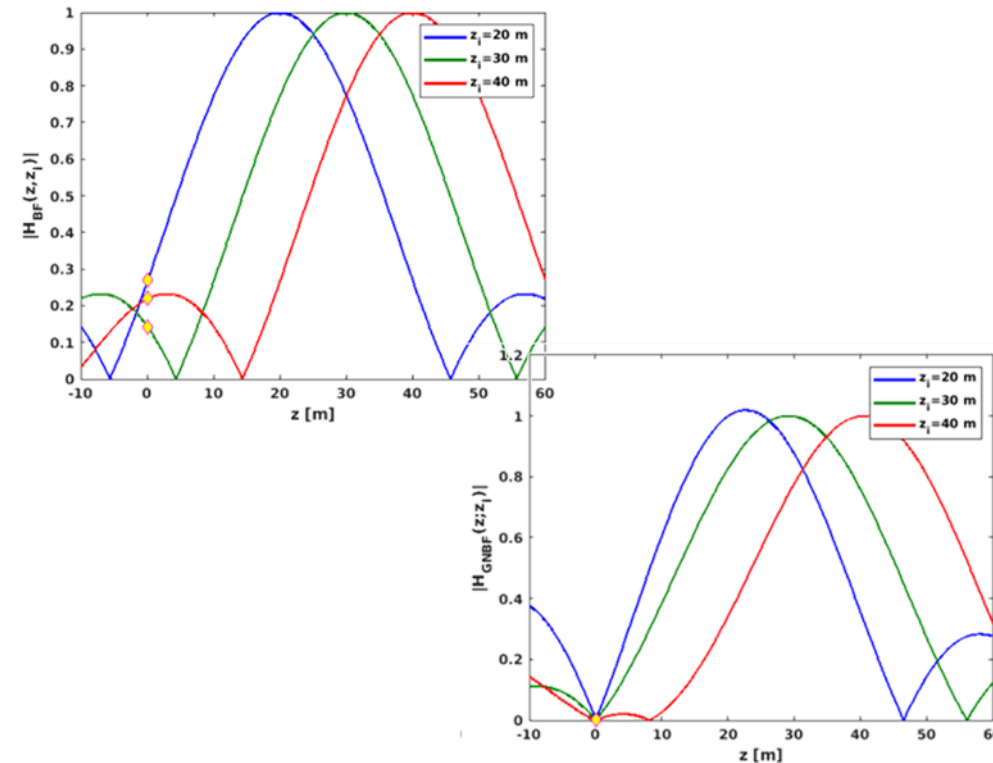
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- An example of application of Tomography is AGBD estimation
- **Tomo slices at canopy (e.g., 30 m) show higher correlation with AGBD**
 - fit a model
- Tomo processing will implement also
 - radiometric corrections for slopes/geometry,
 - interpolation for missing baselines
 - Geocoding
- In INT phase, with 3 baselines, Ground Notching, i.e. coherent terrain cancellation, is applied

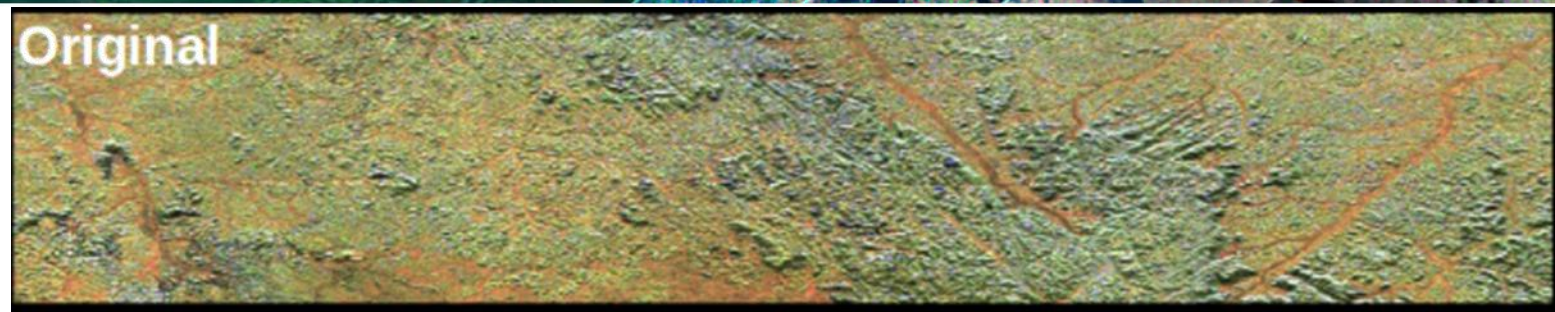


NOTCHING

- Coherent cancellation of ground or canopy with ≥ 2 (steered) acquisitions
- Enhancement of the selected height/layer, **reducing leakage**
- **Enhancement of scattering features**

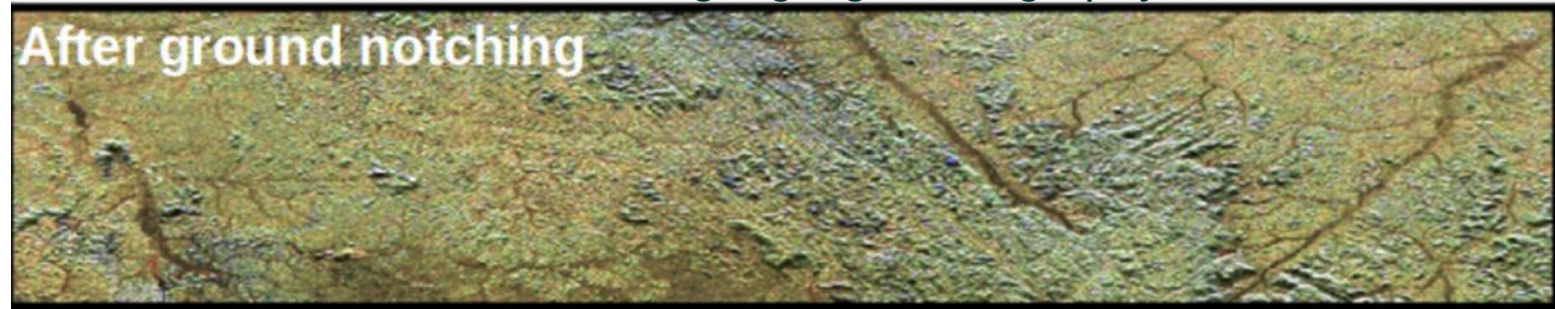


Original



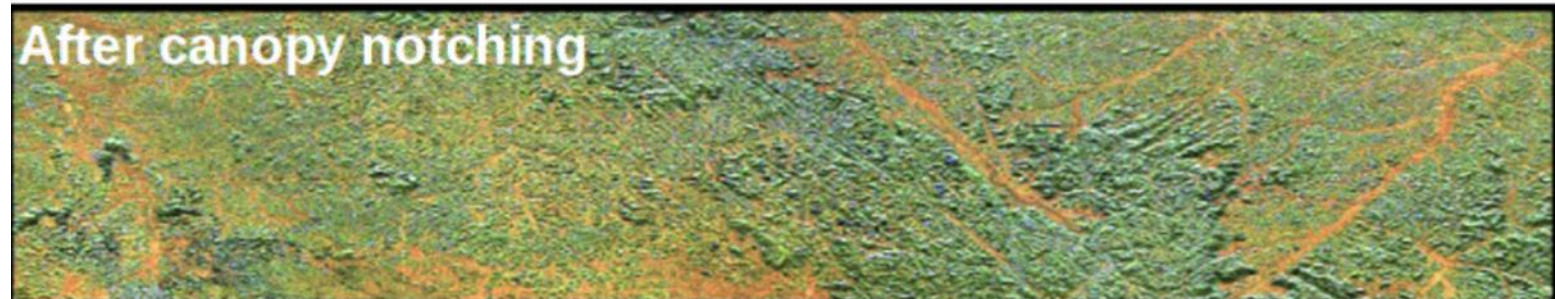
Ground Notching highlights orography

After ground notching



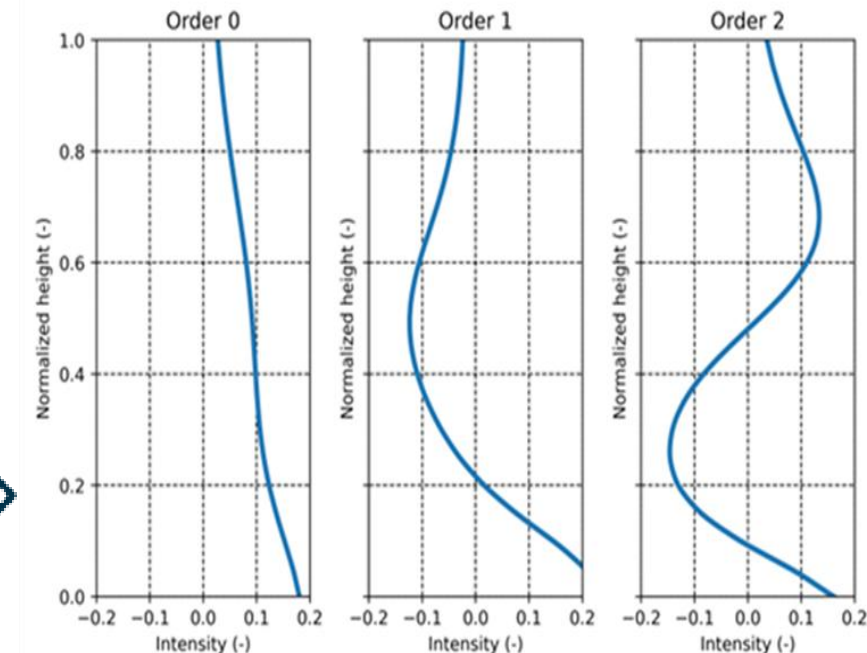
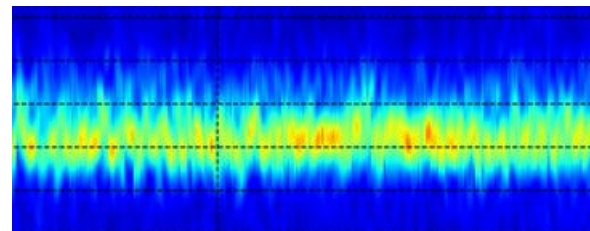
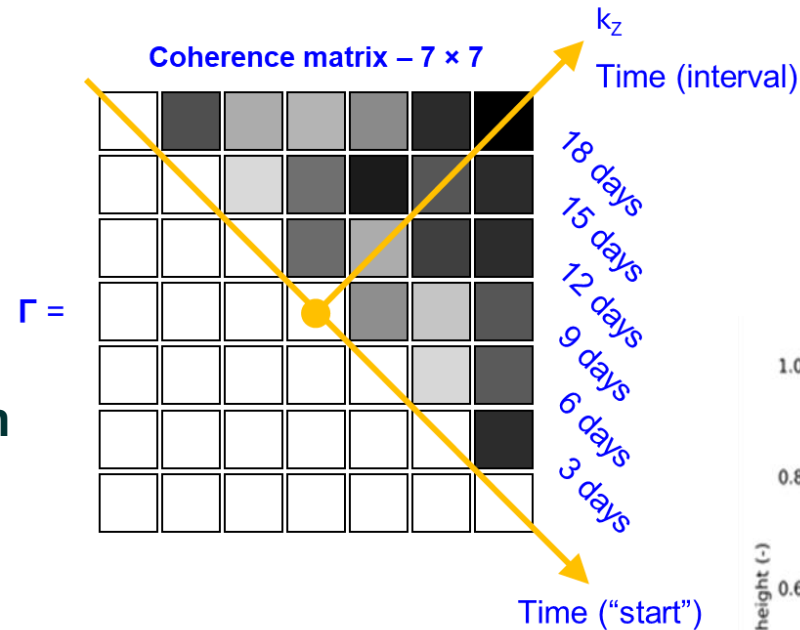
Canopy notching highlights double-bounce

After canopy notching



TEMPORAL CHANGE

- BIOMASS has **spatial and temporal baselines intertwined**
 - possible changes due to weather
 - stack Tomo reconstructs average reflectivity
- A **functional basis** can be retrieved from **Tomo** (e.g, EVD)
 - with two components reconstruction is good
 - PolInSAR can enhance ground/volume separation
 - mixing coefficient estimated from data
 - can be used single-baseline/single-timelag



$$F(z) = F_0(z) + \alpha \cdot F_1(z)$$

TEMPORAL CHANGE

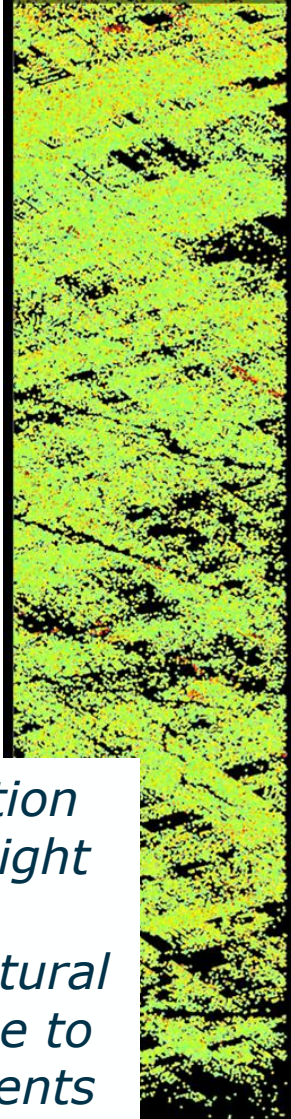


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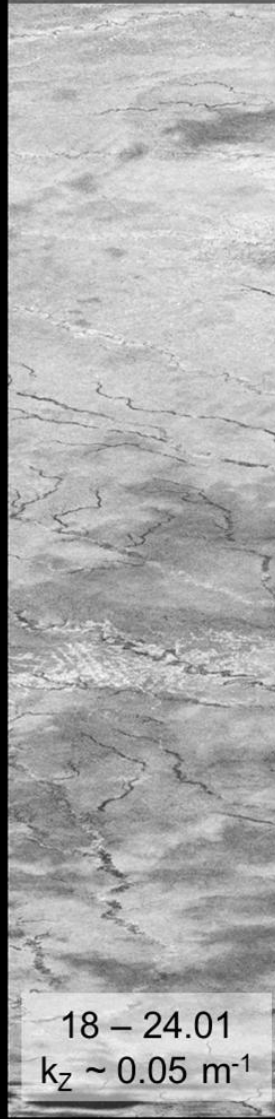
GEDI RH98

0 60 m

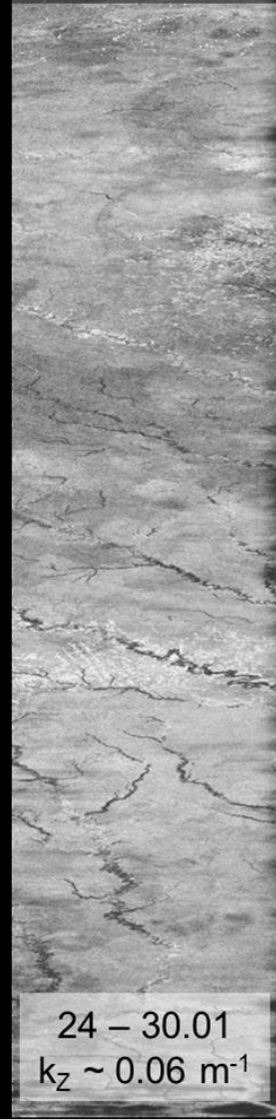


Interferometric coherences – HV

0 1



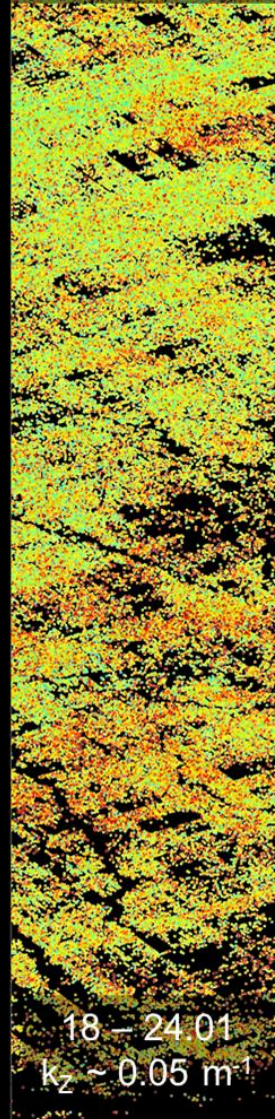
18 – 24.01
 $k_z \sim 0.05 \text{ m}^{-1}$



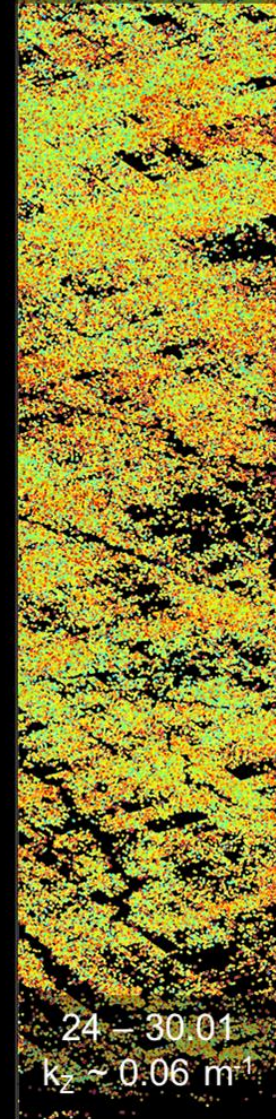
24 – 30.01
 $k_z \sim 0.06 \text{ m}^{-1}$

Pol-InSAR ground phase

-1.5 1.5



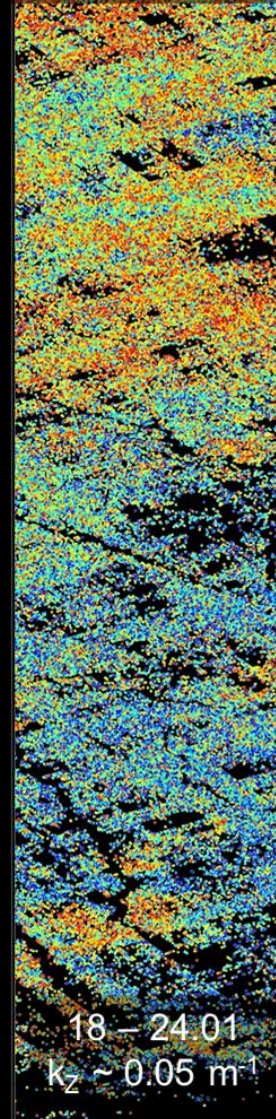
18 – 24.01
 $k_z \sim 0.05 \text{ m}^{-1}$



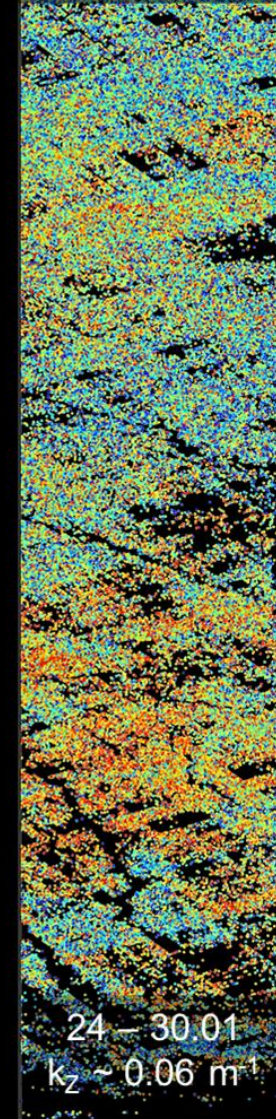
24 – 30.01
 $k_z \sim 0.06 \text{ m}^{-1}$

PCT coeff. α – Volume

min max



18 – 24.01
 $k_z \sim 0.05 \text{ m}^{-1}$



24 – 30.01
 $k_z \sim 0.06 \text{ m}^{-1}$

*Long strip
over Peru*

*Decomposition
might highlight
information
about structural
changes due to
weather events*

CONCLUSIONS



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- We have presented an overview of the processing designed to generate BIOMASS Tomographic cubes, as well as example of applications and more advanced processing
- The generation of Tomo cubes is being developed as a **python processor in BIOTOMEX project** (which includes also DTM), to be later released as an **open-source software** in the framework of BIOMASS open science activities
- More information about BIOMASS at: **<https://biomass-disc.info/>**





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Thanks for your attention!



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