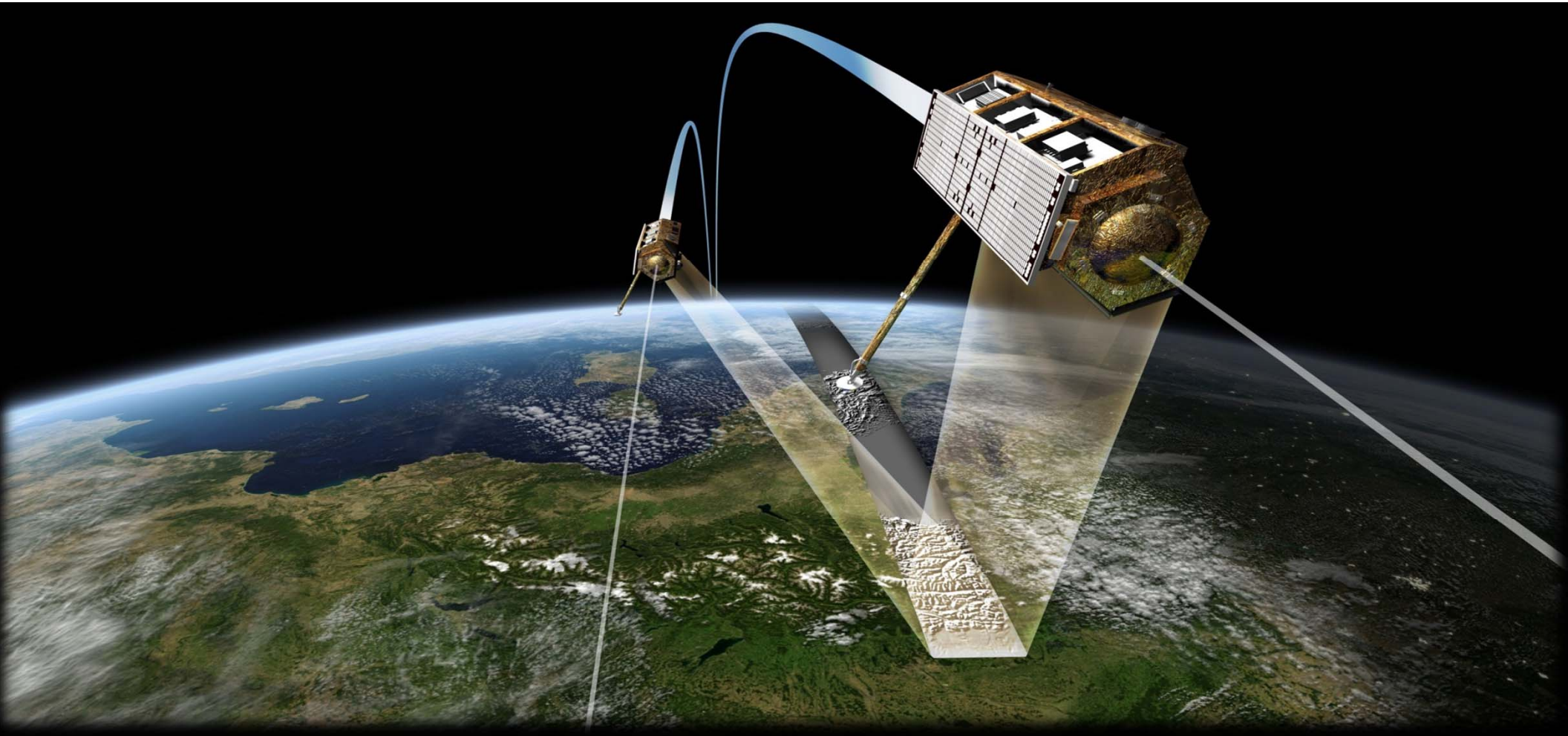

Towards Forest Vertical Structure Monitoring From Space: First Experiments With Multi-Baseline TanDEM-X Data

M. Pardini, F. Kugler & K. Papathanassiou

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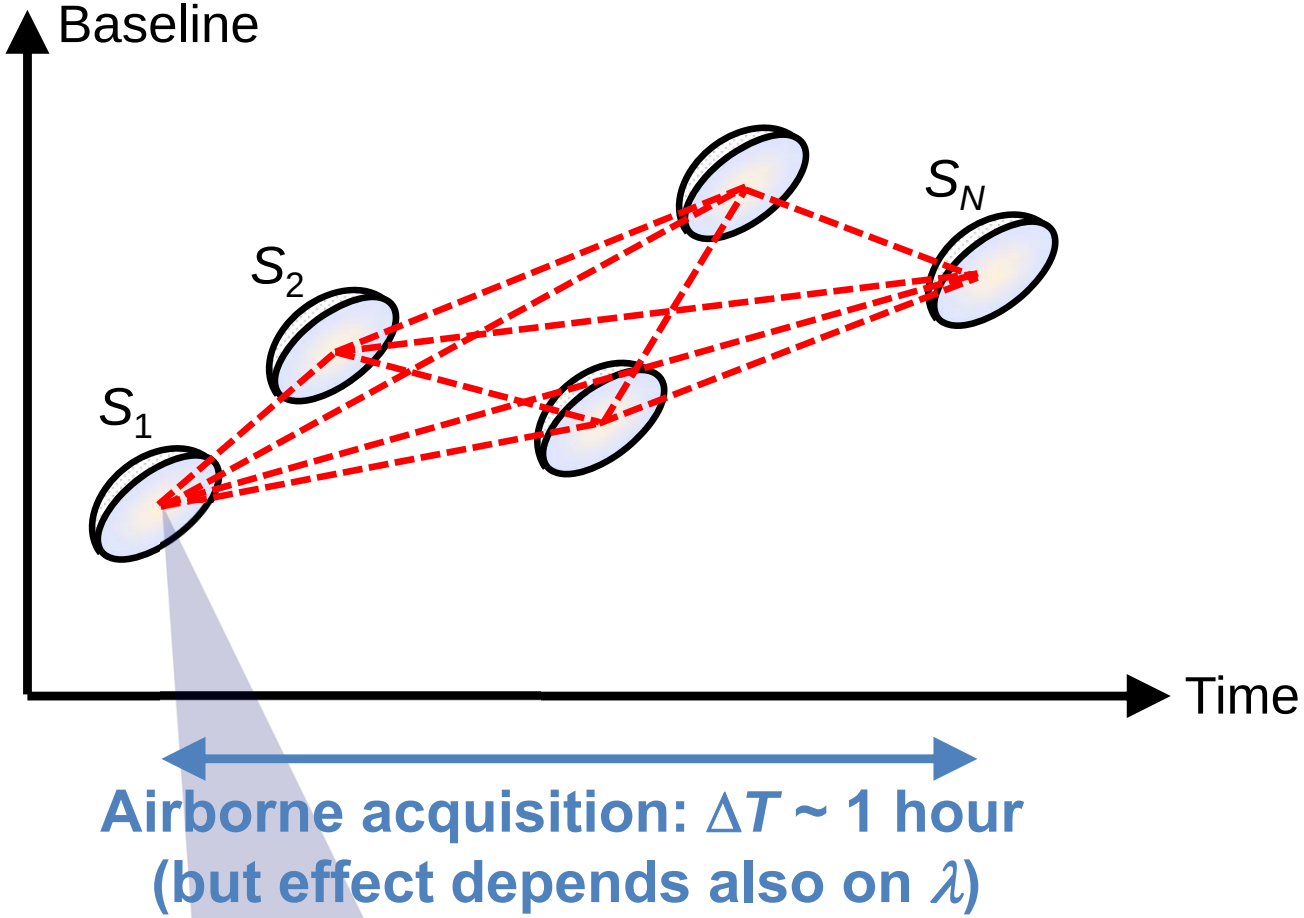
Microwaves and Radar Institute (HR)

Introduction and overview

- SAR Tomography of forests from space is challenging due to temporal decorrelation problems
- Single-pass InSAR acquisitions with variable baseline are *one* possible answer, and after more than two years of mission TanDEM-X archives can be exploited
- **In this work:**
  - **First evaluation of the tomographic capabilities of TanDEM-X**
  - **Preliminary exploration of the information content**
  - **Discussion of some potential applications**

SAR Tomography for forest monitoring…



Airborne acquisition: ΔT ~ 1 hour
(but effect depends also on λ)

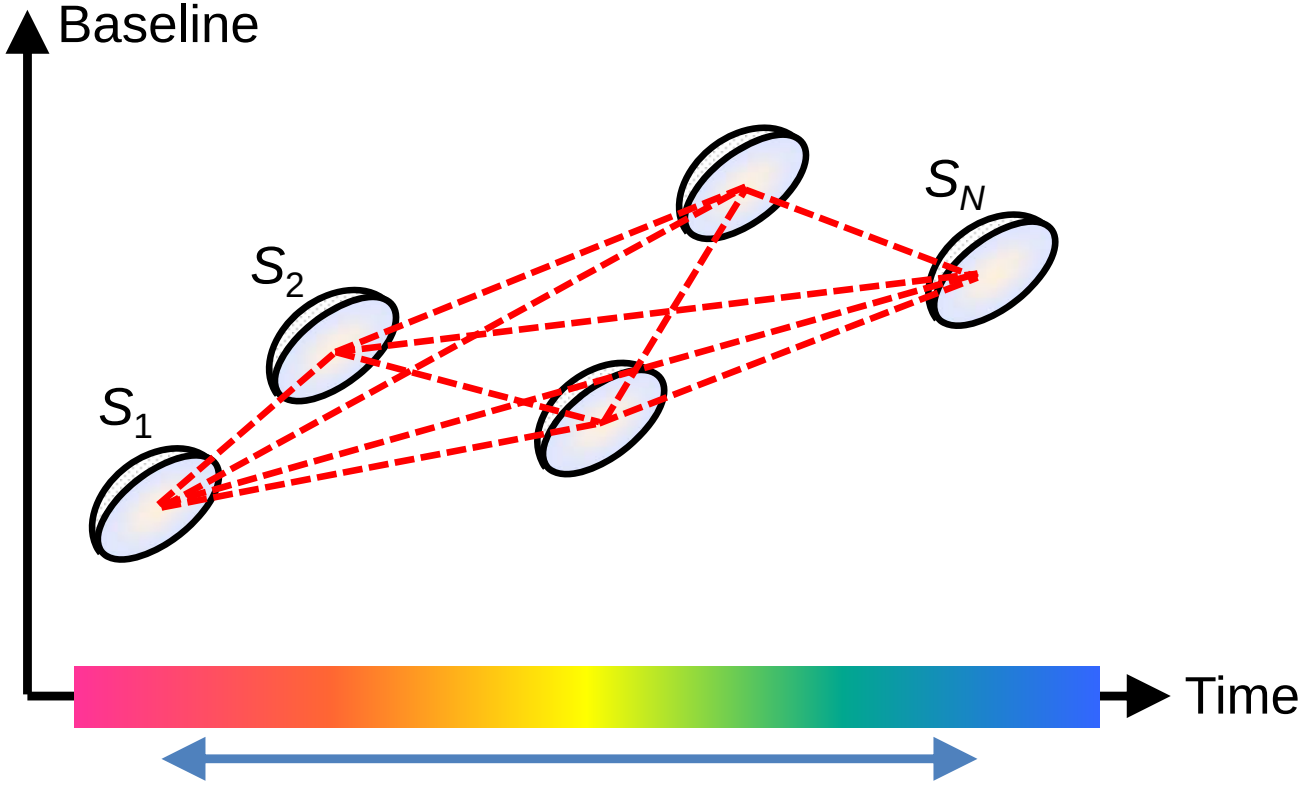
Observables:
$[S_1, S_2, \ldots, S_N]$

$$\mathbf{R} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1N} \\ r_{21} & r_{22} & \cdots & r_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ r_{N1} & r_{N2} & \cdots & r_{NN} \end{bmatrix}$$

Output:
3-D forest profile
(tomogram)

- ❑ Spectral estimation
- ❑ Model-based
- ❑ Compressive sensing
- ❑ ….

… towards spaceborne implementation…



Spaceborne acquisition: ΔT ~ weeks/months
(but effect depends also on λ)

Observables:
$[S_1, S_2, \ldots, S_N]$

$$\mathbf{R} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1N} \\ r_{21} & r_{22} & \cdots & r_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ r_{N1} & r_{N2} & \cdots & r_{NN} \end{bmatrix}$$

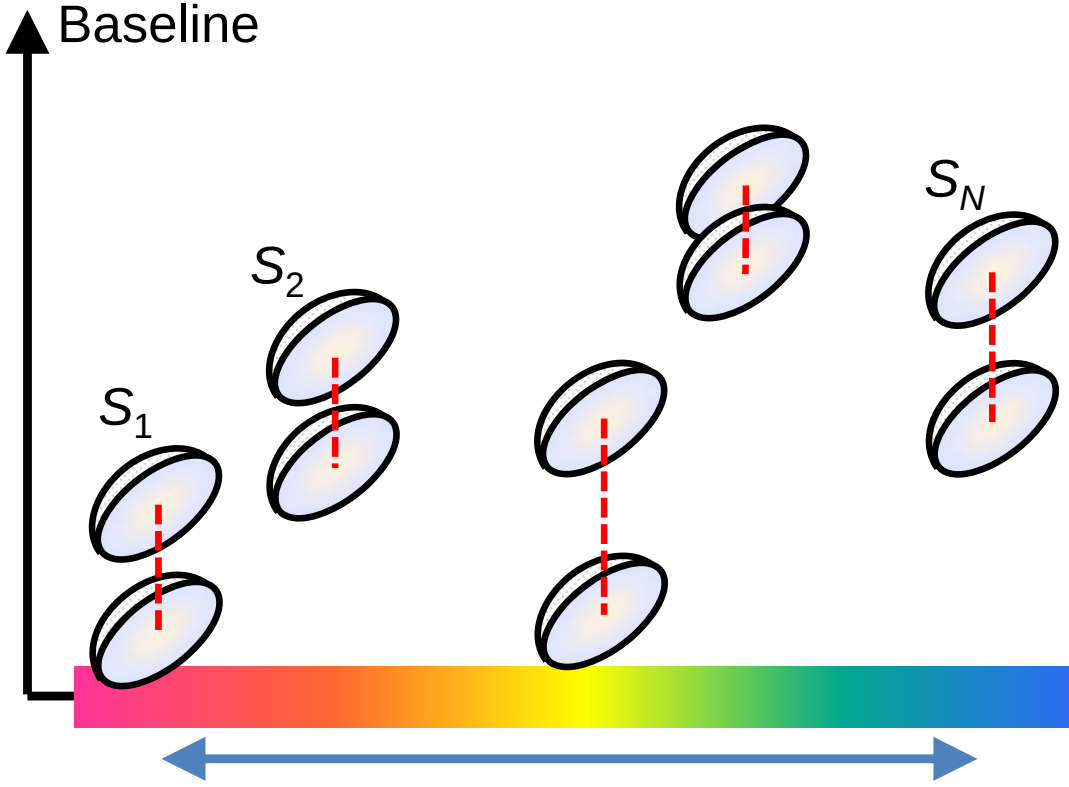
Temporal decorrelation

1st option:
tackle temporal decorrelation

Differential Tomography
RMoG
Robust MB PolInSAR
…

Basic hp: No changes in the vertical structure!

… through single-pass coherences



Spaceborne acquisition: ΔT ~ weeks/months

2nd option:
Design a single pass interferometer… and change observables!

Observables:
Single –pass coherences
$[\rho_1, \rho_2, \ldots, \rho_N]$

- ***No temporal decorrelation***
- ***No need for phase calibration***

… it exists: TanDEM-X!

Coherence tomography

❑ *How to use single-pass coherences to estimate the vertical structure?*

- ❑ **Use Fourier transform:** coherence $\rho(k_z) \Leftrightarrow F(z)$ vertical structure
- ❑ **Problem 1:** only a limited k_z interval is acquired

➔ ***loss of resolution + sidelobes***

- ❑ **Problem 2**: k_z is normally sampled non-uniformly

➔ ***ambiguities arise***

Problems 1+2 very well-known, but here no covariance matrix

➔ ***No classical super-resolution method can be applied***

❑ *Alternatives?*

- ❑ **Interpolate** to a regular k_z grid – **effective for sidelobes, but not for resolution…**
- ❑ **After interpolation, fill a Toeplitz matrix, and apply classical super-resolution methods**

➔ ***Non-negativeness of the covariance matrix is not guaranteed***

- ❑ **(Polarization) Coherence Tomography:** estimate a set of coefficient on a (orthonormal) basis, provided **ground topography** and **top canopy height**

- ❑ **Here: automated fitting of a number of line components (i.e. point-like scatterers)** , like a very simple deconvolution algorithm

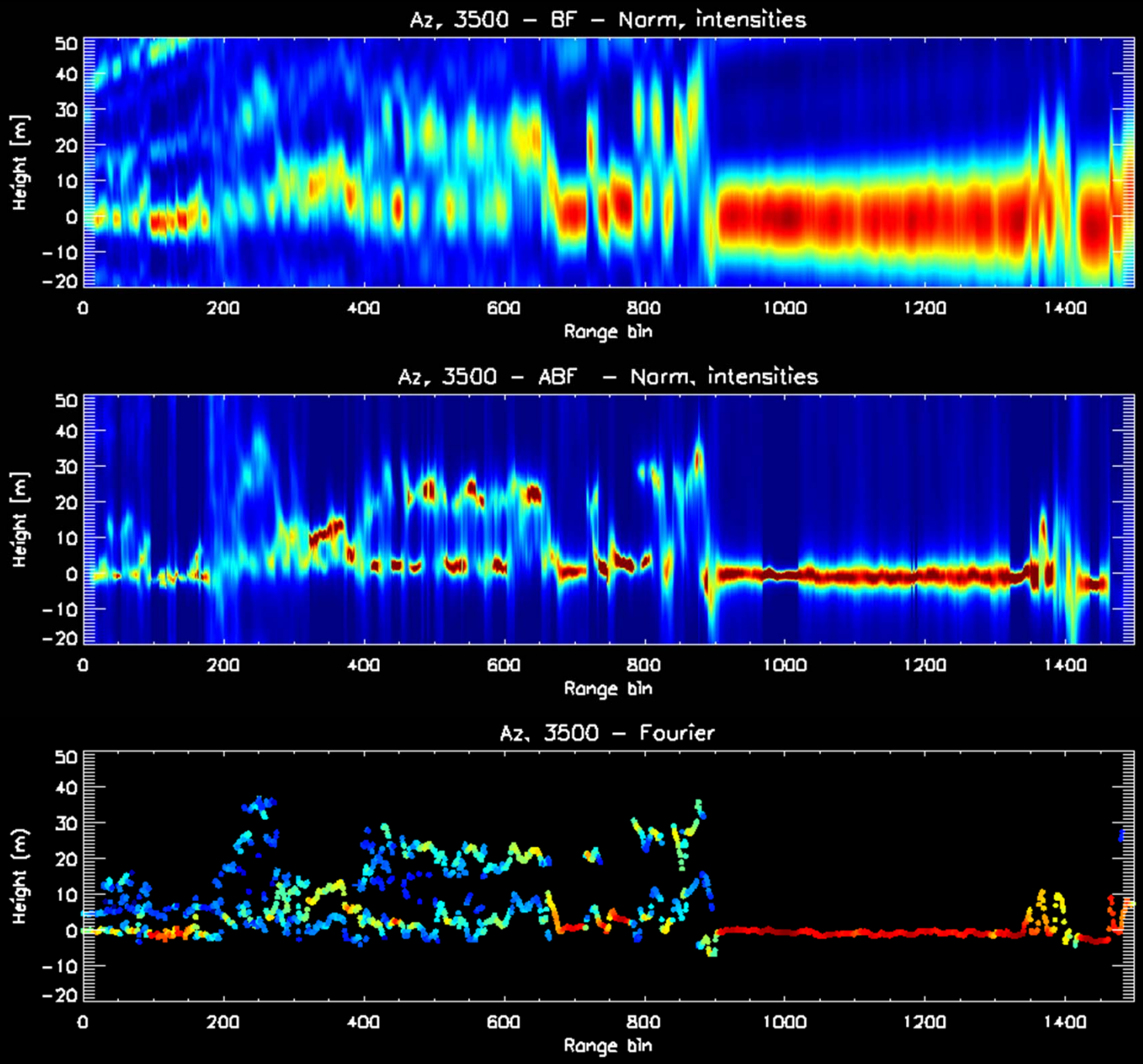
➔ ***Outputs: heights and amplitudes***

DLR

Coherence tomography in Traunstein @ L-band

$$\mathbf{R} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1N} \\ r_{21} & r_{22} & \cdots & r_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ r_{N1} & r_{N2} & \cdots & r_{NN} \end{bmatrix}$$

$$\rho = [\, \rho_1, \rho_2, \ldots, \rho_N \,]$$



DLR

Tapajos National Forest (Brazil)

- Amazonian tropical forest

- Mostly covered with undisturbed primary forest
- Selective (close to nature) logging activities in some parts
- Large regions dominated by secondary forests (less dense than primary)

- Average canopy height: ~45m
- Fairly flat topography (*planalto*) that becomes steep close to the river (*flanco*)

Tapajos river

N

Google earth

3°06'29.09" S 55°21'39.52" W elev 592 ft

Eye alt 72.21 mi

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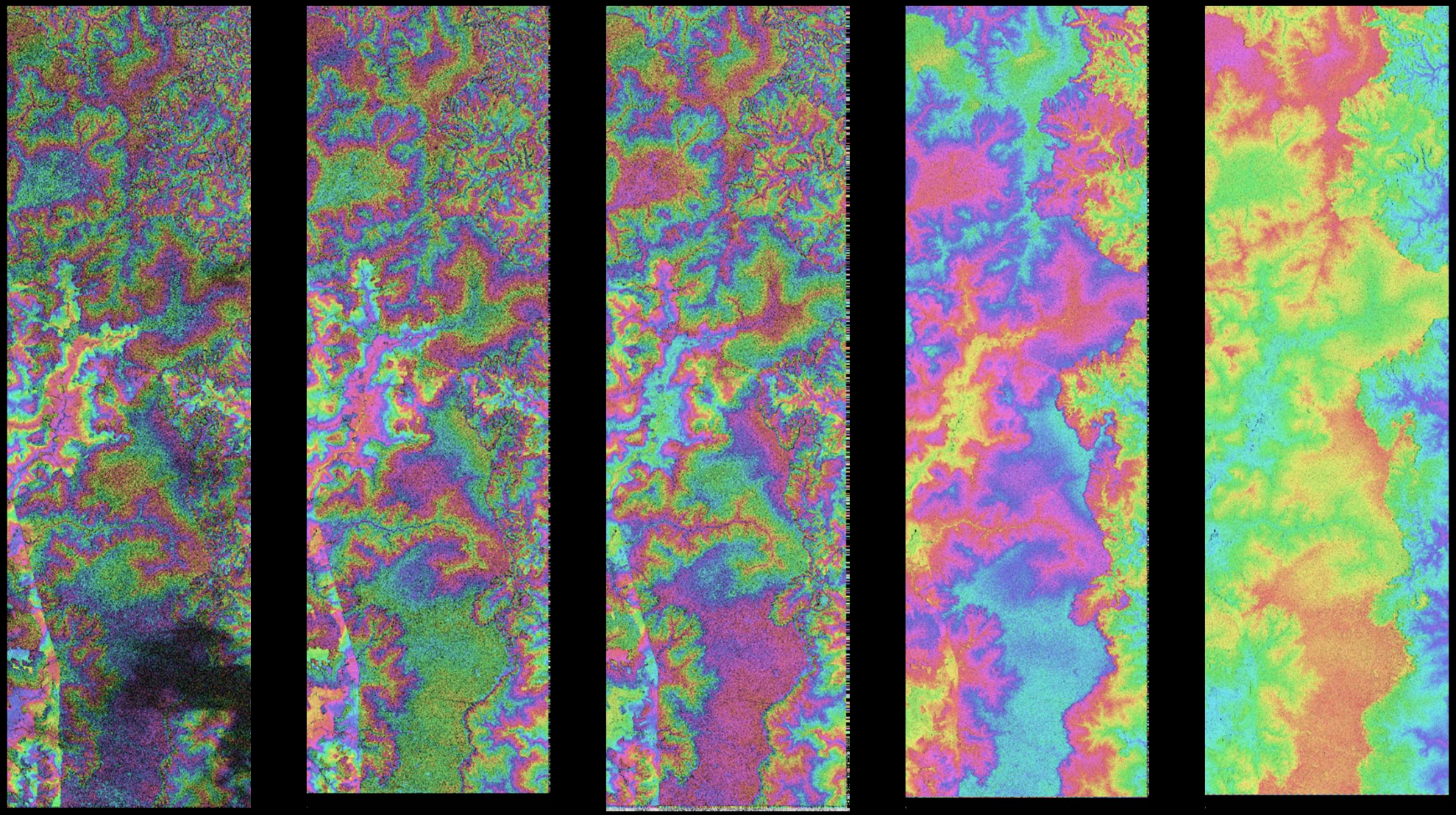
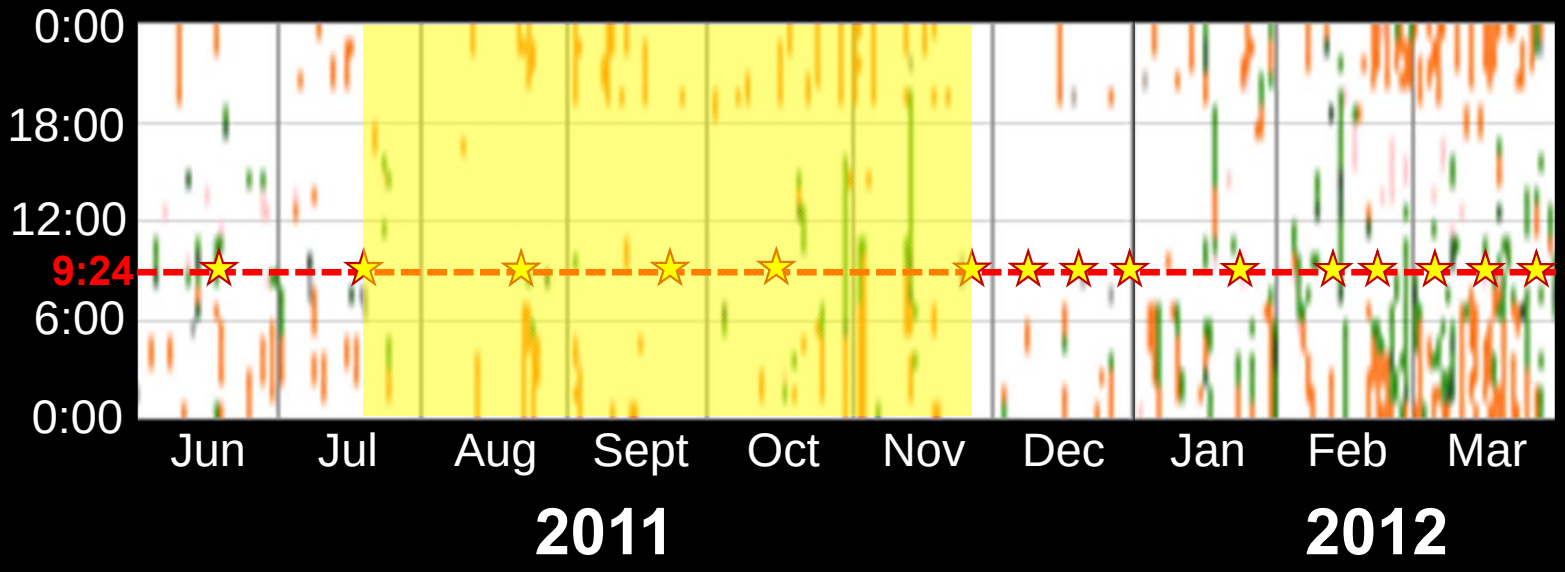
A TanDEM-X dual-pol InSAR time series in Tapajos



15-06-2011 18-07-2011 20-08-2011 30-12-2011 27-03-2012

Acquisitions: Distribution in time



Santarem station

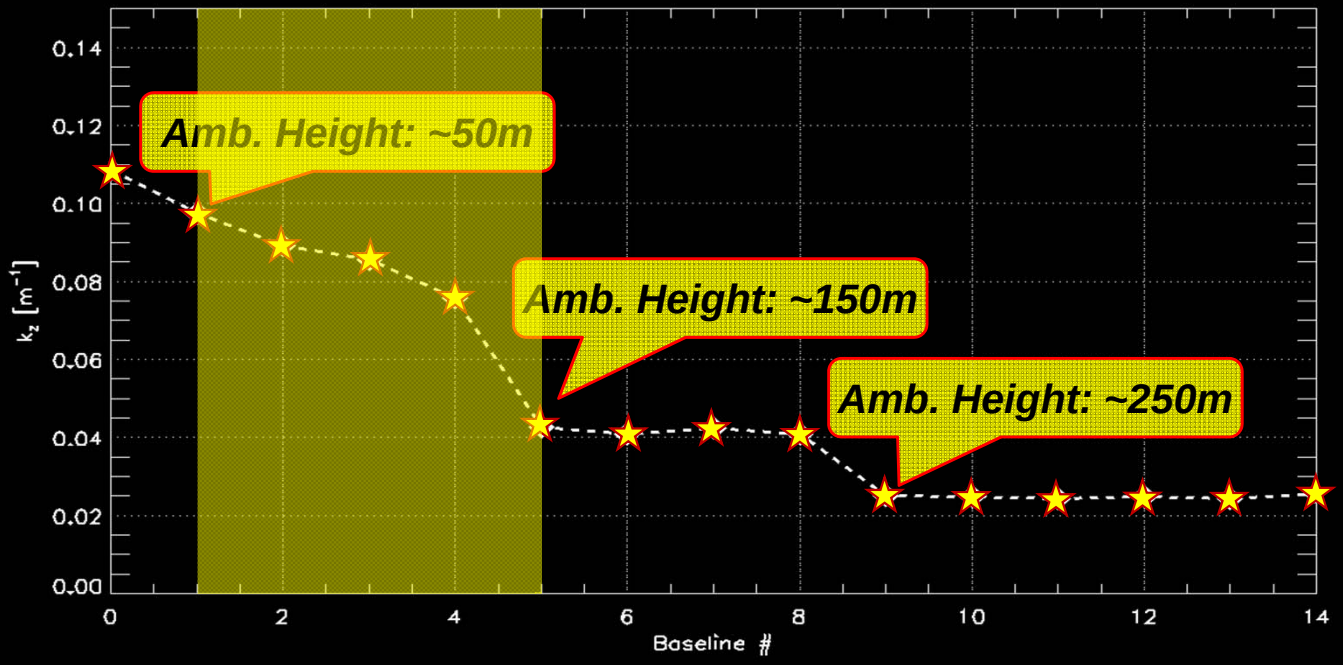
Thunderstorms

Rain

Source:
http://weatherspark.com

Acquisitions: Distribution in space (baselines)

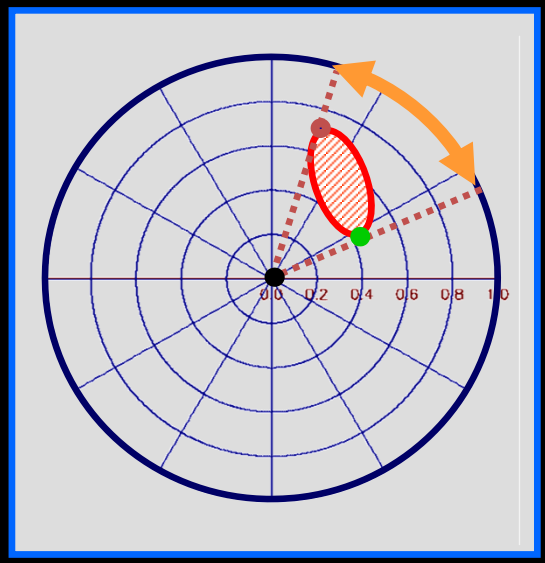
$k_z \propto$ baseline

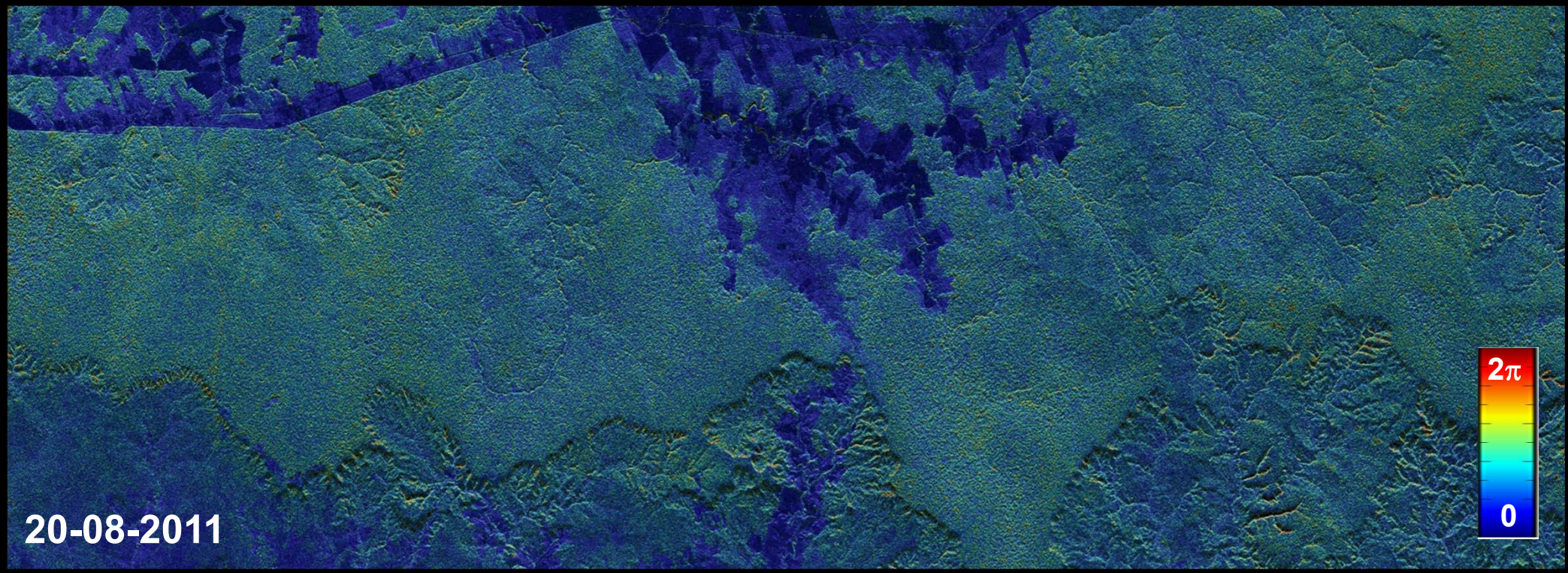


Penetration capabilities @ X-band, Tapajos

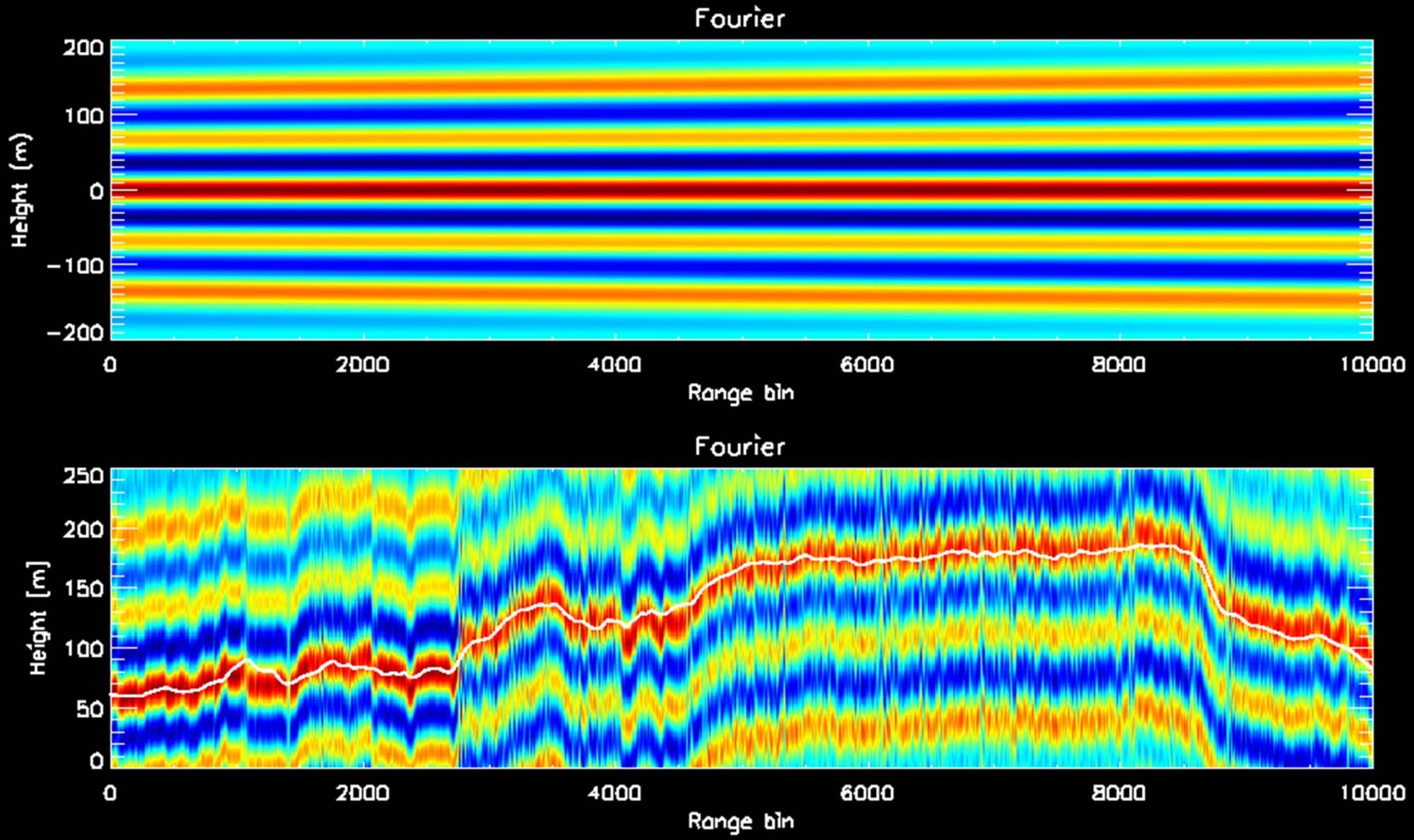
Phase difference between the points in the dual-pol coherence region leading to **maximum and minimum coherence**

Penetration capabilities seen in different forest scenarios

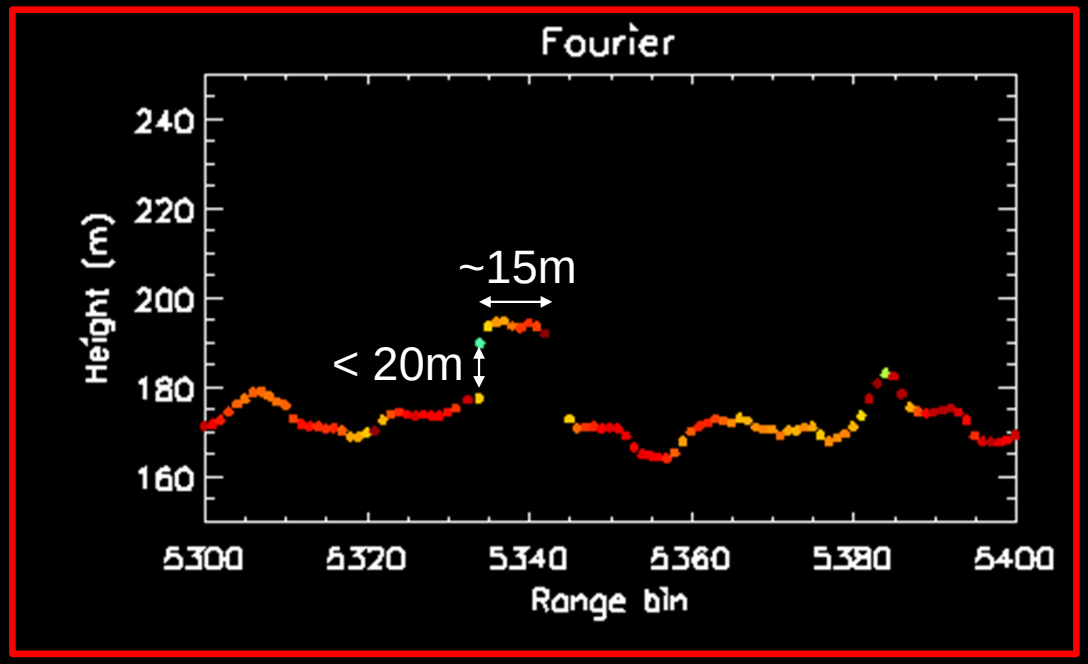


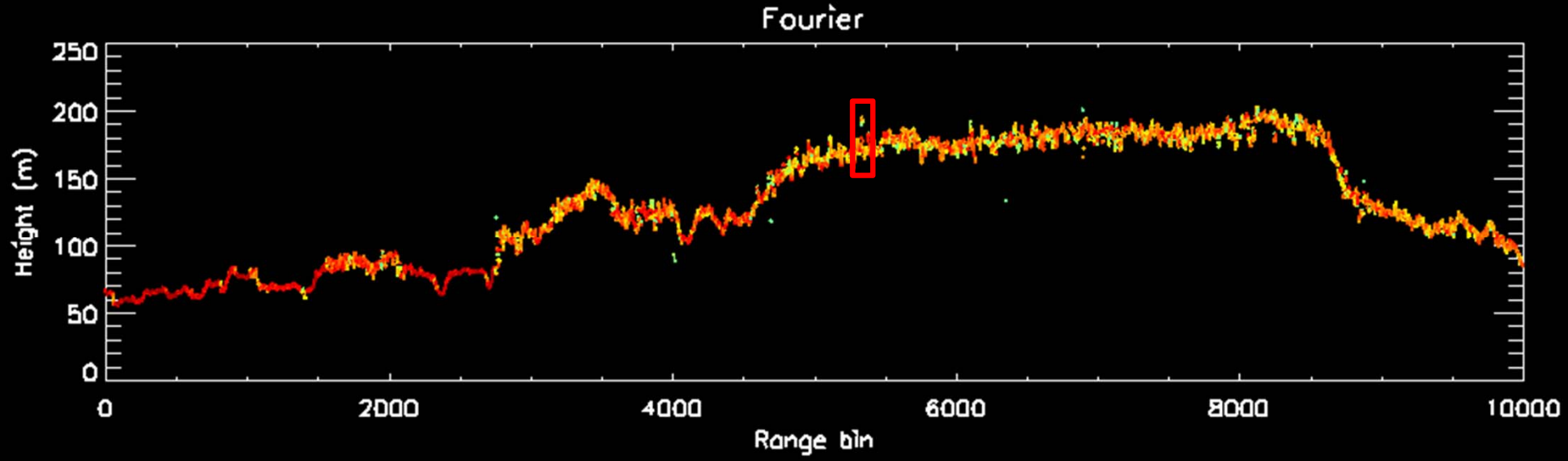


Tomographic results

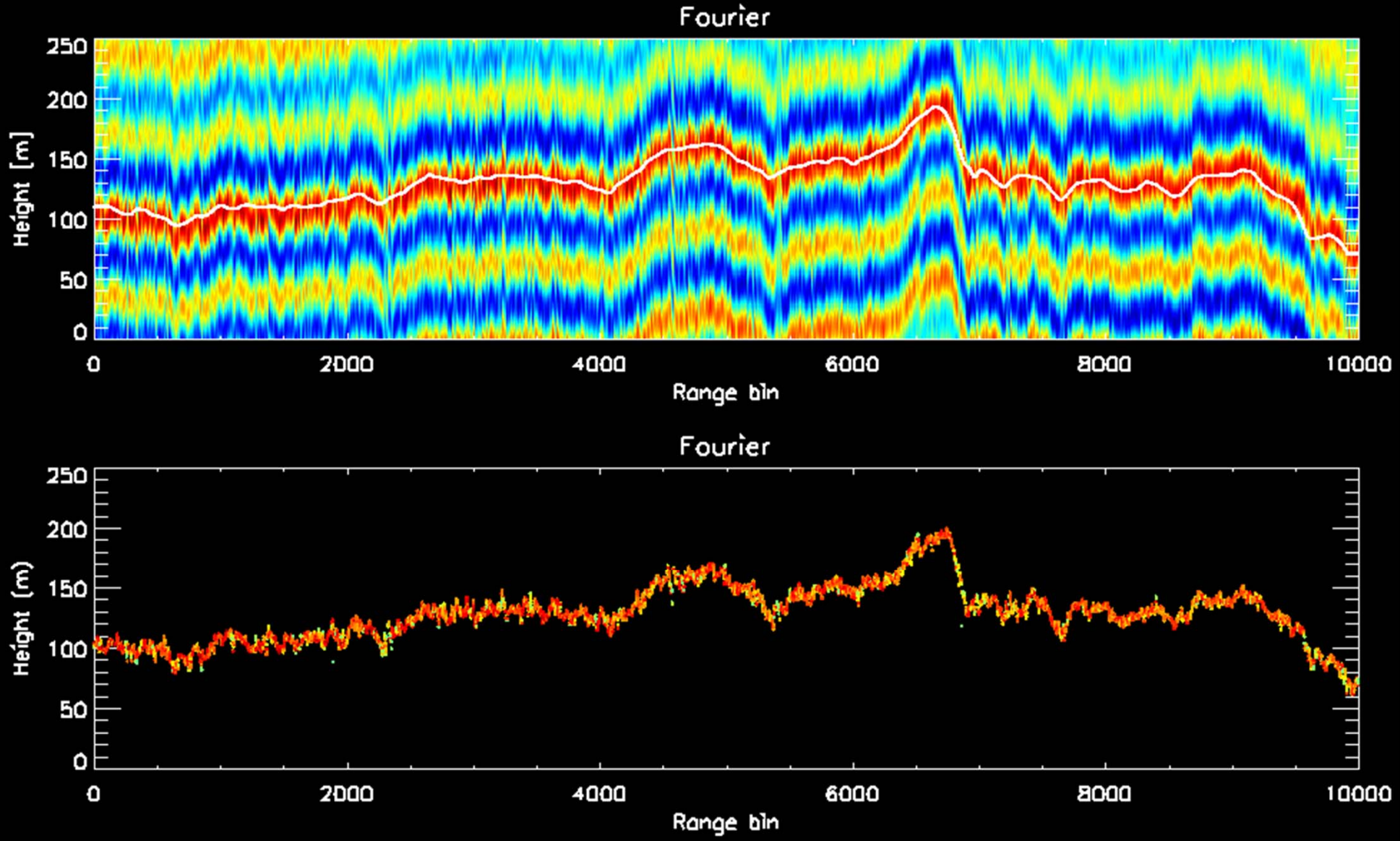


Tomographic results





Tomographic results



Conclusions

- **Single-pass polarimetric InSAR acquisitions**: make **SAR tomography** of volumetric decorrelating scenarios **possible from space**
- **First tomographic slices of a forest from space** have been shown with **TanDEM-X data** with variable baseline over the Tapajos test site
- Indications of penetration @X-band, **potentials for vertical structure monitoring**
- A door is open for **spaceborne data integration for tomographic analyses** e.g. @ different frequencies
- These experiments also useful for:
  - increasing the **exploitation of TanDEM-X data archives**
  - **Tandem-L mission study**

What's next?

- Improve implementation (e.g. baseline selection, detection of temporal changes, SNR corrections, …)
- Tomographic analyses of the impact of seasonal effects
- Algorithms
- Experiments in different forest environment and volumetric scenarios

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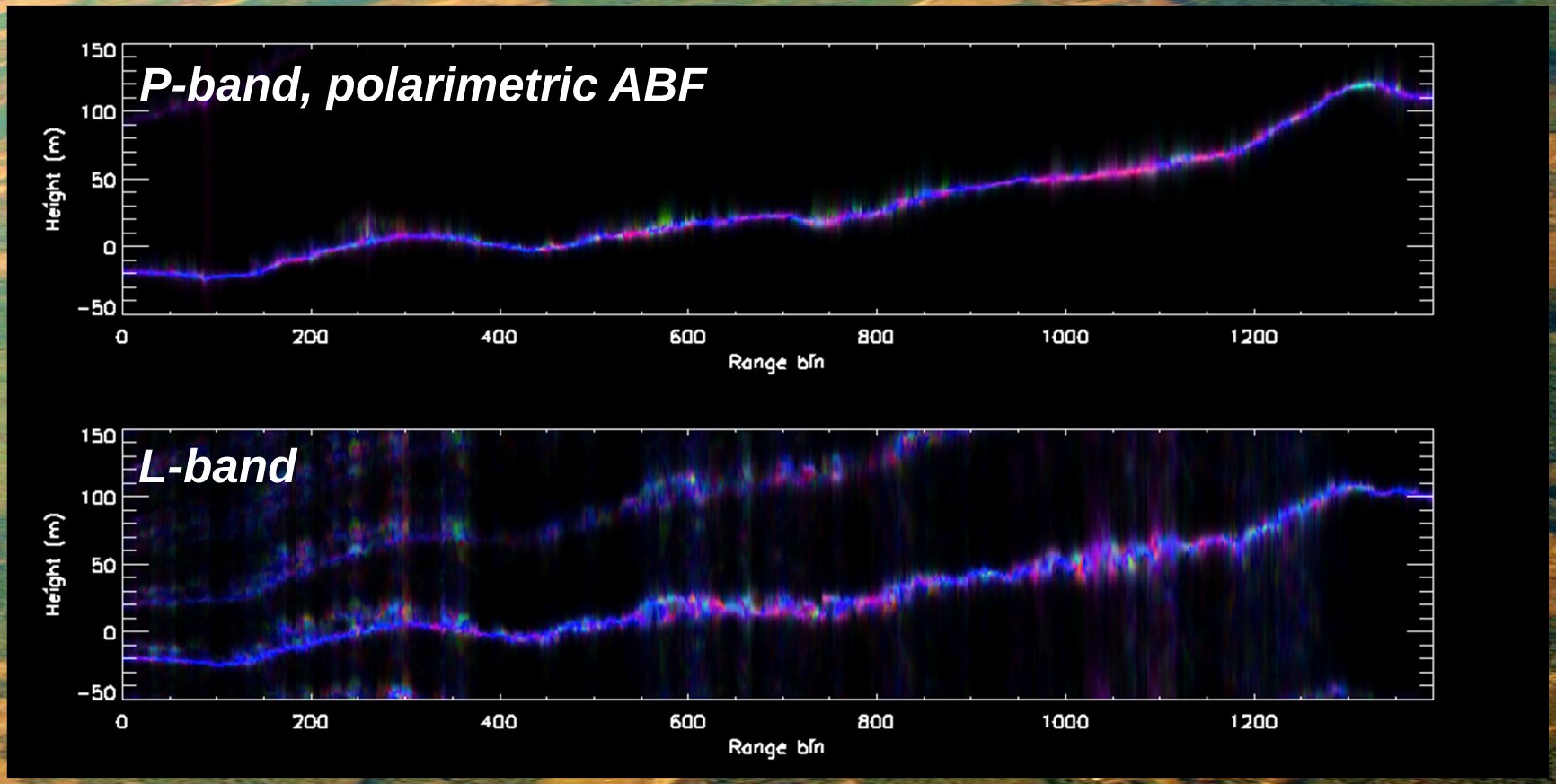

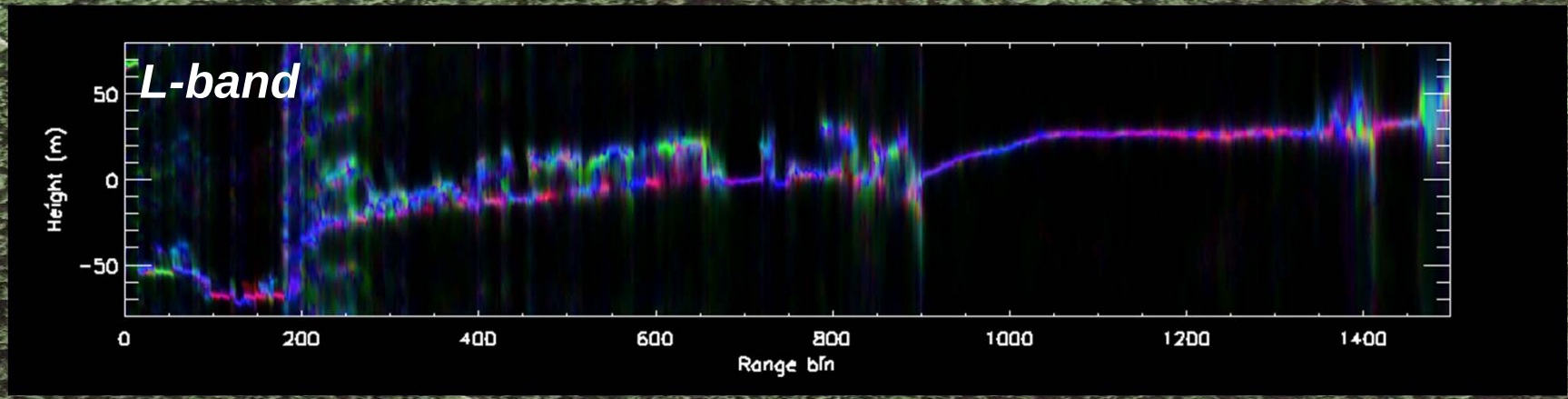

Traunstein (Germany) – DLR E-SAR, TempoSAR 2008