ADDRESSING FOREST CHANGE BY MEANS OF POL-INSAR MEASUREMENTS AT L- AND P-BAND

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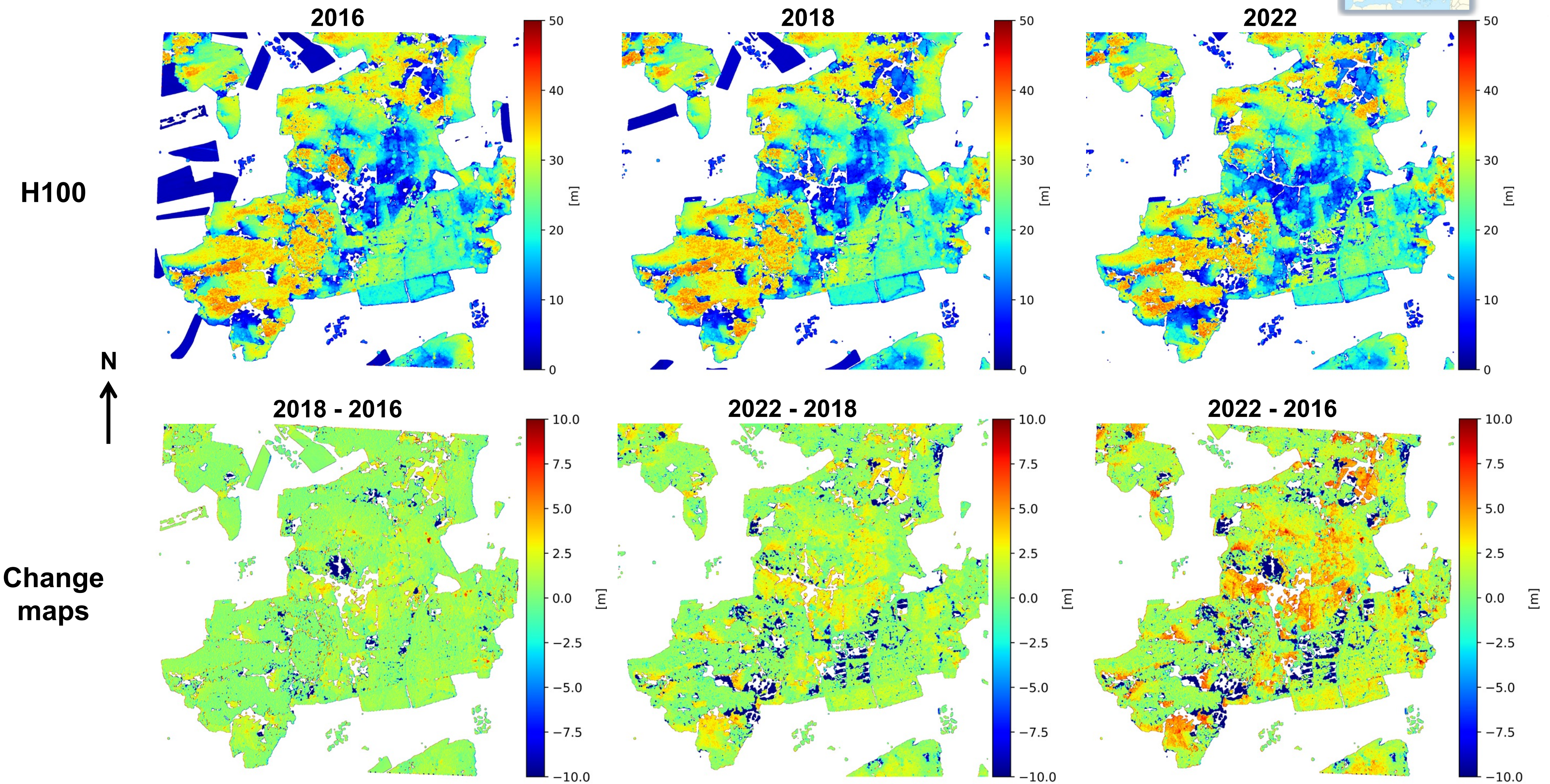
German Aerospace Center (DLR)

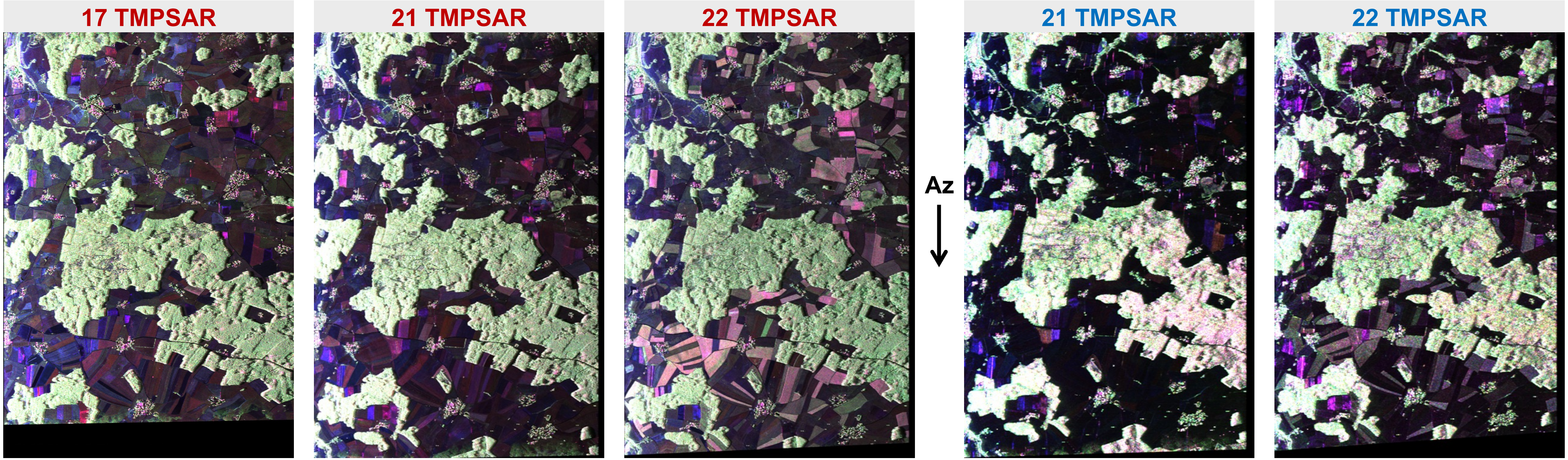
DLR

Test Site and Lidar Data: Traunstein Forest (Germany)



F-SAR Data: TMPSAR Campaigns

Test site	F-SAR Campaign	Date	Baseline [m]	Frequency bands	Polarization
Traunstein (Germany)	17 TMPSAR	11 May 2017	[0, 5, 15, 20] m	**L-band**	Full-pol
	21 TMPSAR	17 June 2021	[0, 5, 15, 20] m	**L-** and **P-band**	
	22 TMPSAR	22 September 2022	[0, 5, 15, 20] m	**L-** and **P-band**	



Pol-InSAR Methodologies to Characterize Change

Polarimetric Change Analysis

Polarimetric contrast

$$P_c(\boldsymbol{Z}_1, \boldsymbol{Z}_2, \mathbf{w}) = \frac{\mathbf{w}^{\mathrm{H}} \cdot \boldsymbol{Z}_2 \cdot \mathbf{w}}{\mathbf{w}^{\mathrm{H}} \cdot \boldsymbol{Z}_1 \cdot \mathbf{w}}$$

Generalized eigendecomposition

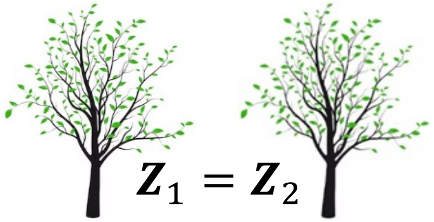
$$|\boldsymbol{Z}_2 - \lambda \boldsymbol{Z}_1| = 0$$

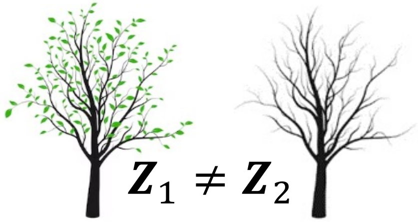
$\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq 0$	Max & min contrast
$\mathbf{w}_1, \mathbf{w}_2, \mathbf{w}_3$	Polarization states

Change power ratios:

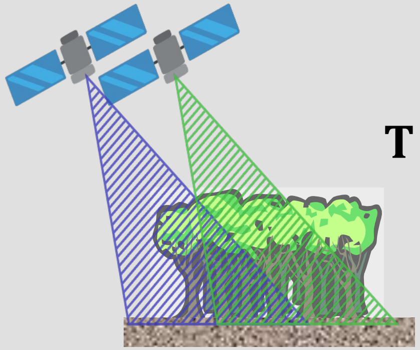
$$\mathbf{p}_{\substack{inc \\ dec}} = 10 \left[\sum_{i|\lambda_i > 1} \left(\pm \log_{10}(\lambda_i)\, \mathbf{p}_i \right)^2 \right]^{\frac{1}{2}},$$

$$\mathbf{p}_i = \left(|w_i^1|, |w_i^2|, |w_i^3| \right)^T$$





[1] A. Alonso-Gonzalez, C. Lopez-Martinez, K. Papathanassiou, I. Hajnsek, "Polarimetric SAR time series change analysis over agricultural areas," in IEEE TGRS, vol. 58, no. 10, pp. 7217-7330, Oct. 2020, doi: 10.1109/TGRS.2020.2981929.



Pol-InSAR MPMB Coherency Matrix

$$\mathbf{T} = \langle \mathbf{k}\mathbf{k}^H \rangle = \begin{bmatrix} \mathbf{T}_{11} & \boldsymbol{\Omega}_{12} & \cdots & \boldsymbol{\Omega}_{1N} \\ \boldsymbol{\Omega}_{12}^H & \mathbf{T}_{22} & \cdots & \boldsymbol{\Omega}_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{\Omega}_{1N}^H & \boldsymbol{\Omega}_{2N}^H & \cdots & \mathbf{T}_{NN} \end{bmatrix}$$

Pol-InSAR Coherence

$$\gamma_{ij}(\mathbf{w}) = \frac{\langle \mathbf{w}^{*\mathrm{T}} \cdot \boldsymbol{\Omega}_{\mathrm{ij}} \cdot \mathbf{w} \rangle}{\sqrt{\langle \mathbf{w}^{*\mathrm{T}} \cdot \mathbf{T}_{\mathrm{ii}} \cdot \mathbf{w} \rangle \langle \mathbf{w}^{*\mathrm{T}} \cdot \mathbf{T}_{\mathrm{jj}} \cdot \mathbf{w} \rangle}} = \frac{\gamma_{ij}^v + \gamma_{ij}^g\, \mu(\mathbf{w})}{1 + \mu(\mathbf{w})}$$

MB Hybrid SKP GV Decomposition

$$\boxed{\mathbf{T} = \mathbf{R}_g \otimes \mathbf{T}_g + \mathbf{R}_v \otimes \mathbf{T}_v}$$

$$\mathbf{R}_l = \begin{bmatrix} 1 & \gamma_{12}^l & \cdots & \gamma_{1N}^l \\ (\gamma_{12}^l)^* & 1 & \cdots & \gamma_{2N}^l \\ \vdots & \vdots & \ddots & \vdots \\ (\gamma_{1N}^l)^* & (\gamma_{2N}^l)^* & \cdots & 1 \end{bmatrix}, \; l \in (g, v), \quad \gamma_{ij}^g = 1$$

[2] A. Alonso-Gonzalez and K. Papathanassiou, "Multibaseline Two Layer Model PolInSAR Ground and Volume Separation," in EUSAR 2018, pp. 1-5, VDE, June 2018.

Polarimetric Change Analysis

Z_1: 17 TMPSAR 0103
Z_2: 21 TMPSAR 0103

L-band

ENL = 34
5 m x 5 m

$\mathbf{p} \in [1,10]$ dB

Z_1: 21 TMPSAR 0103
Z_2: 22 TMPSAR 0403

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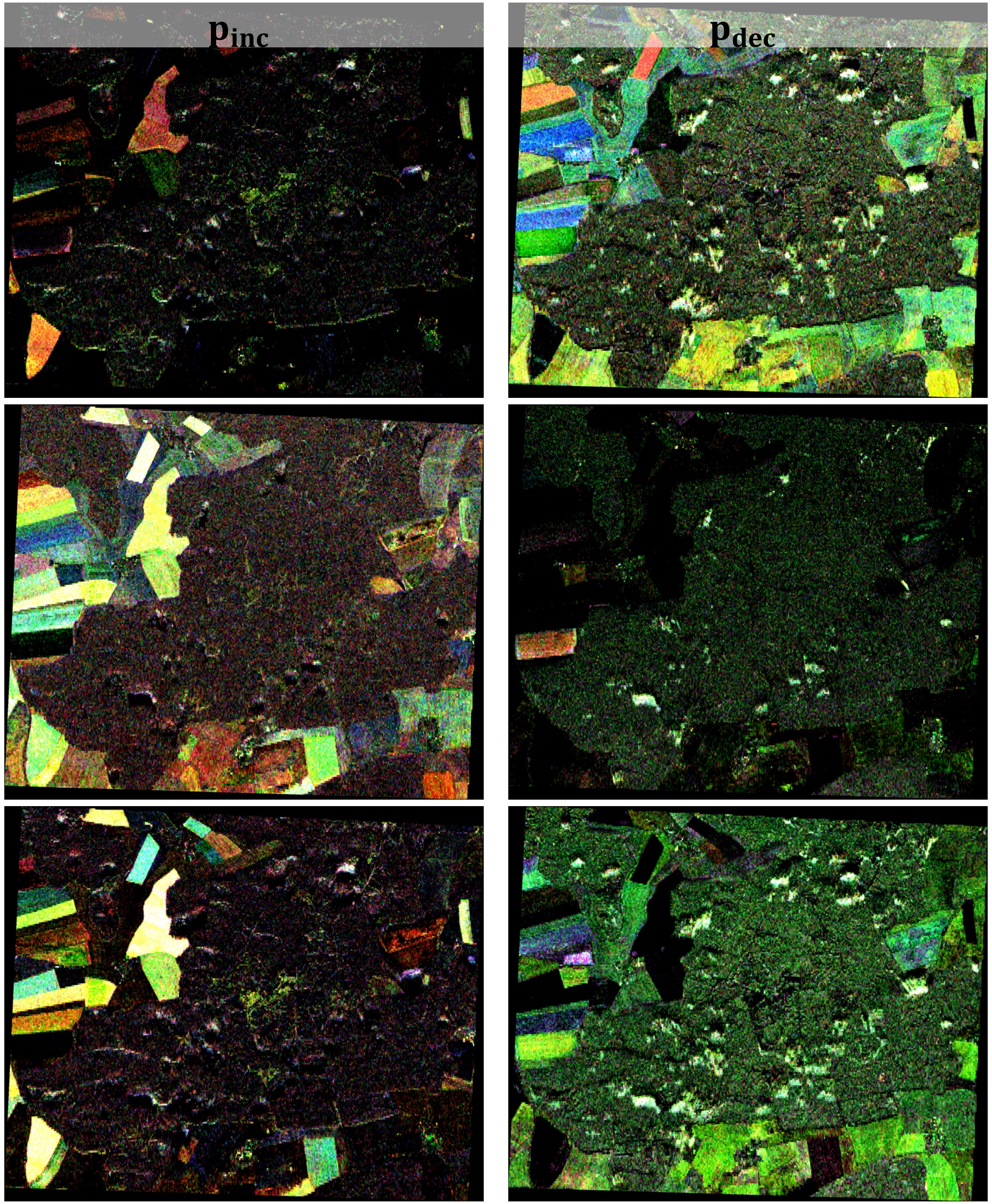

Polarimetric Change Analysis

L-band
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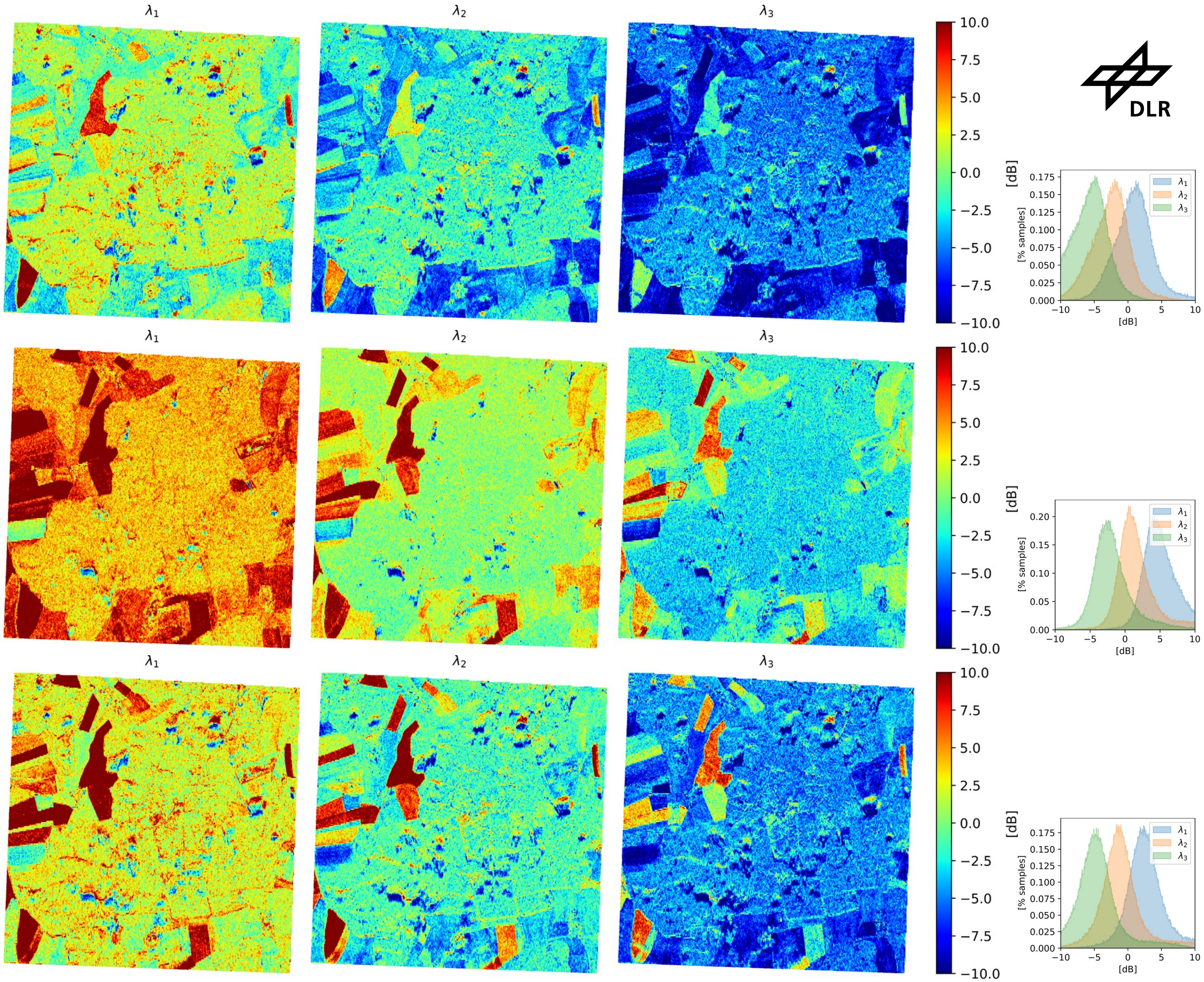

Polarimetric Change Analysis

Z_1 and Z_2 are **normalized**!

L-band

ENL = 34

5 m x 5 m

$\mathbf{p} \in [1,10]$ dB

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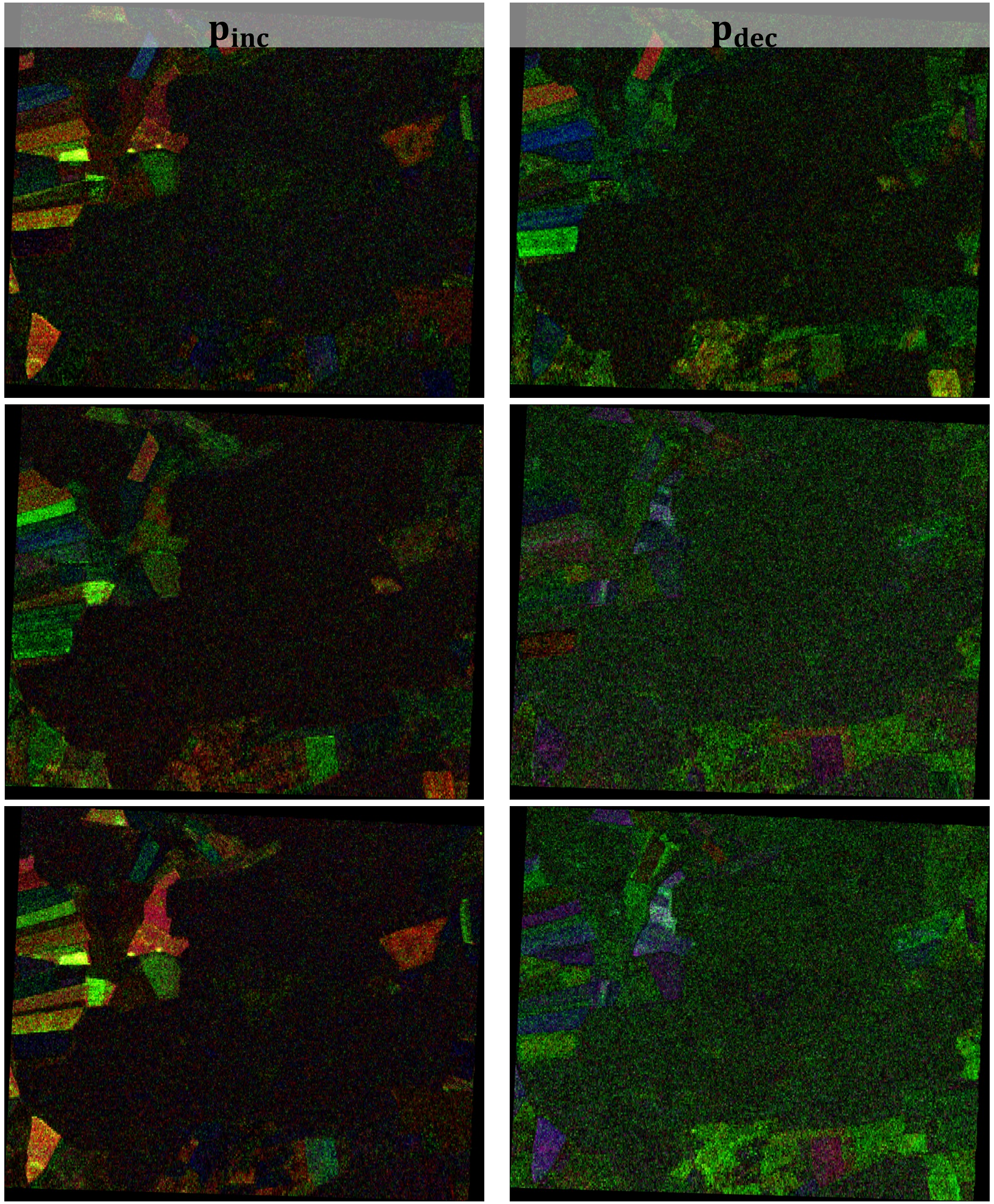
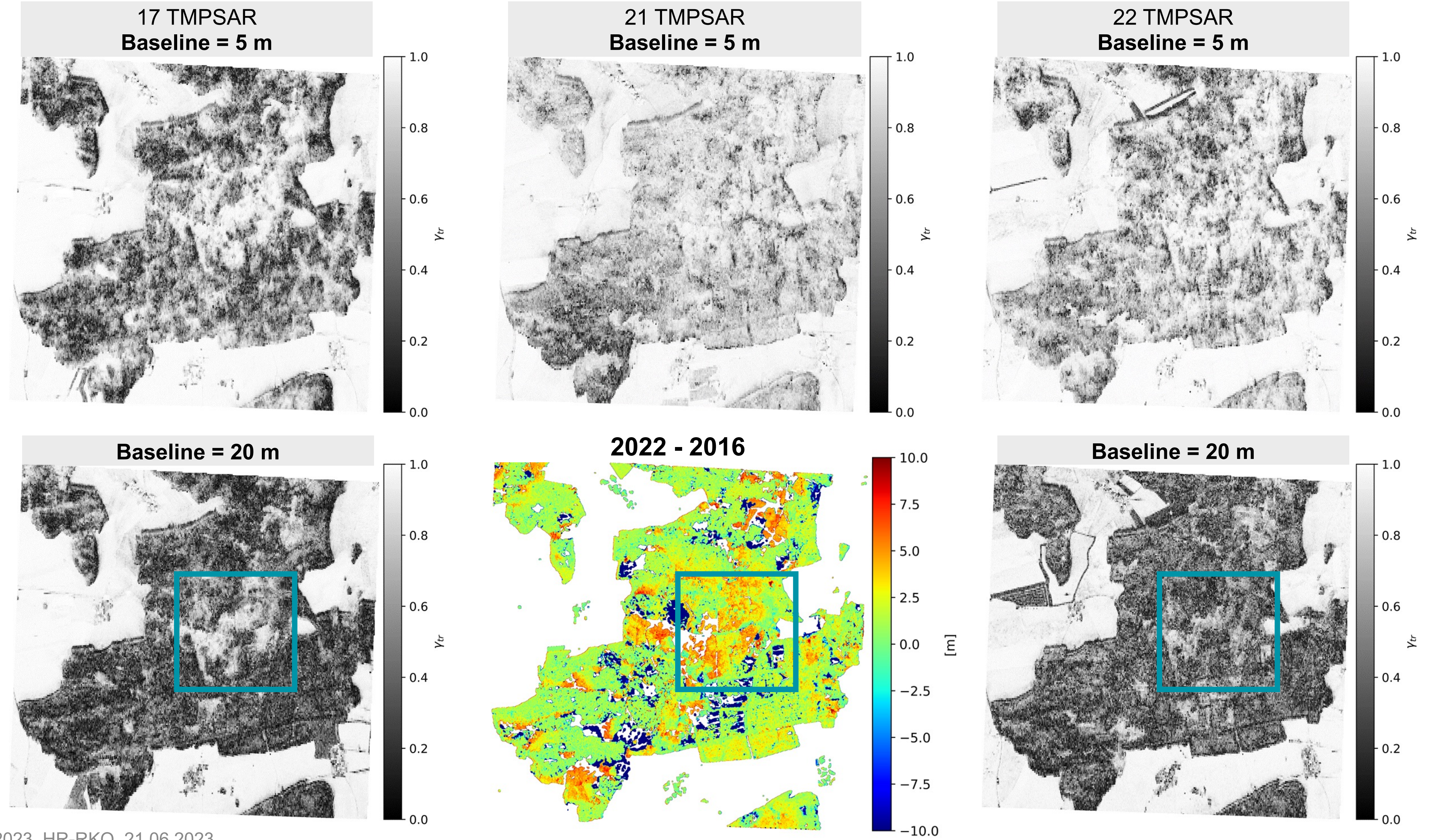
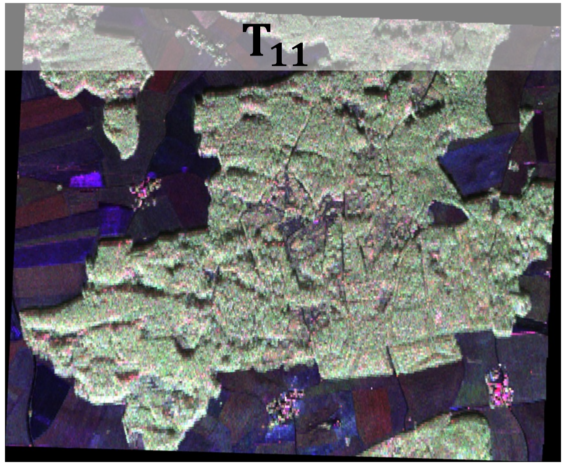


InSAR Coherence – L-band

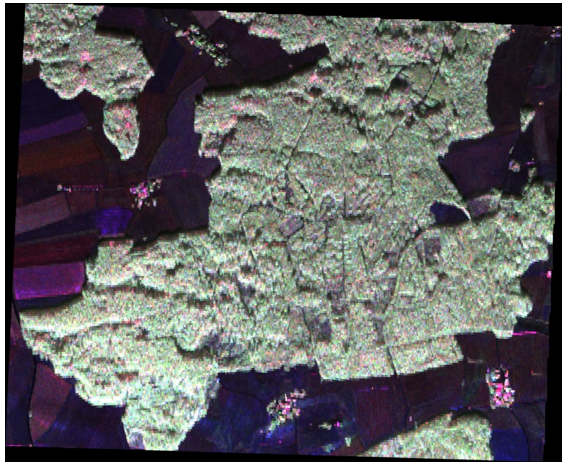


Ground & Volume Separation

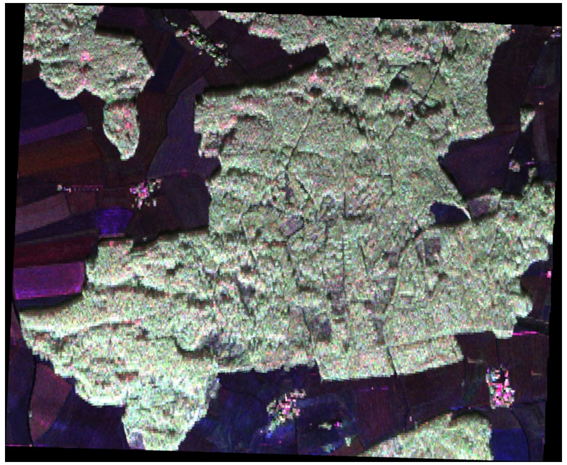
17 TMPSAR



21 TMPSAR



22 TMPSAR



L-band

ENL = 34
5 m x 5 m

Ground & Volume Separation

Multi-Baseline Hybrid model-based SKP approach

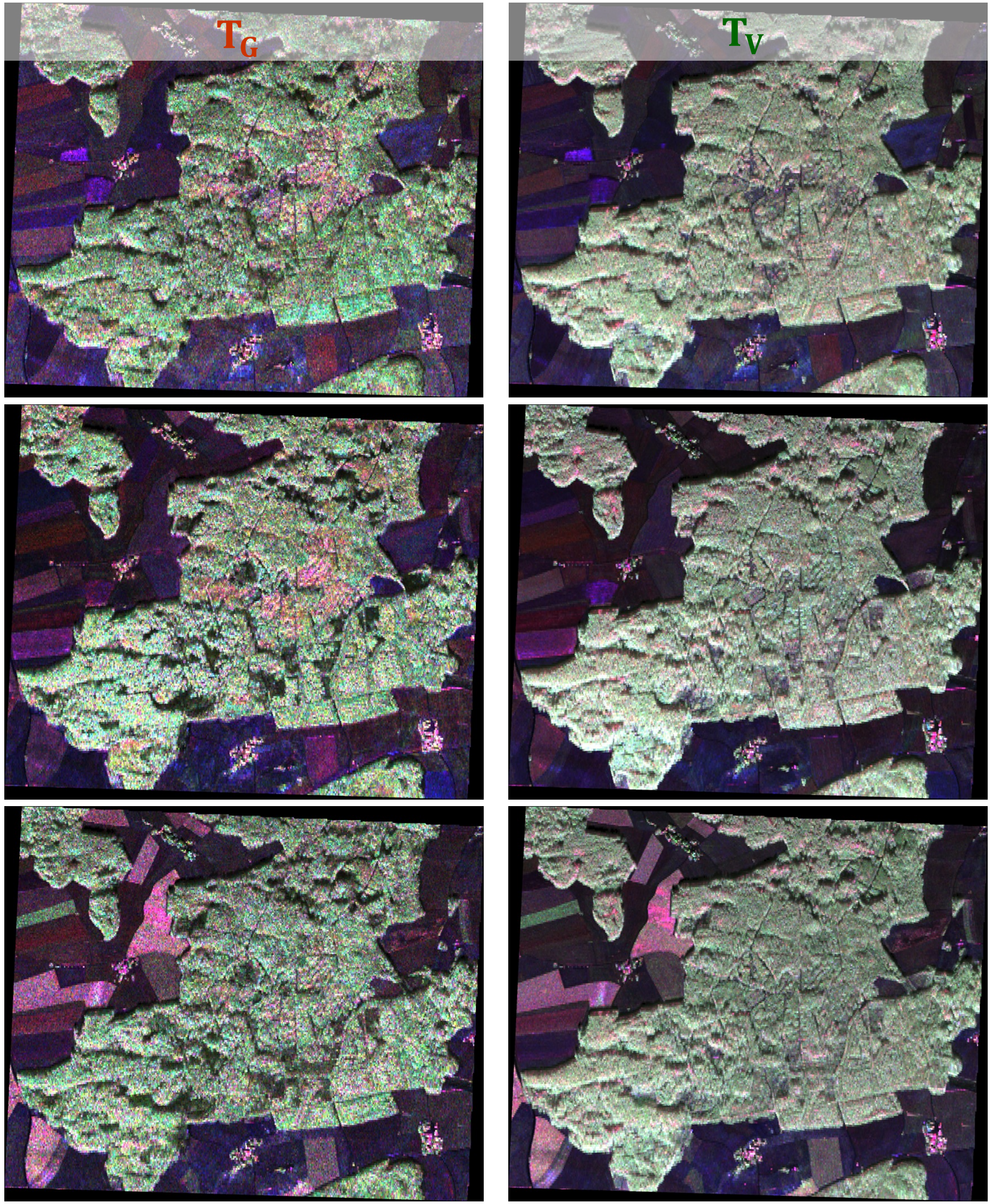
L-band

ENL = 34
5 m x 5 m

17 TMPSAR

21 TMPSAR

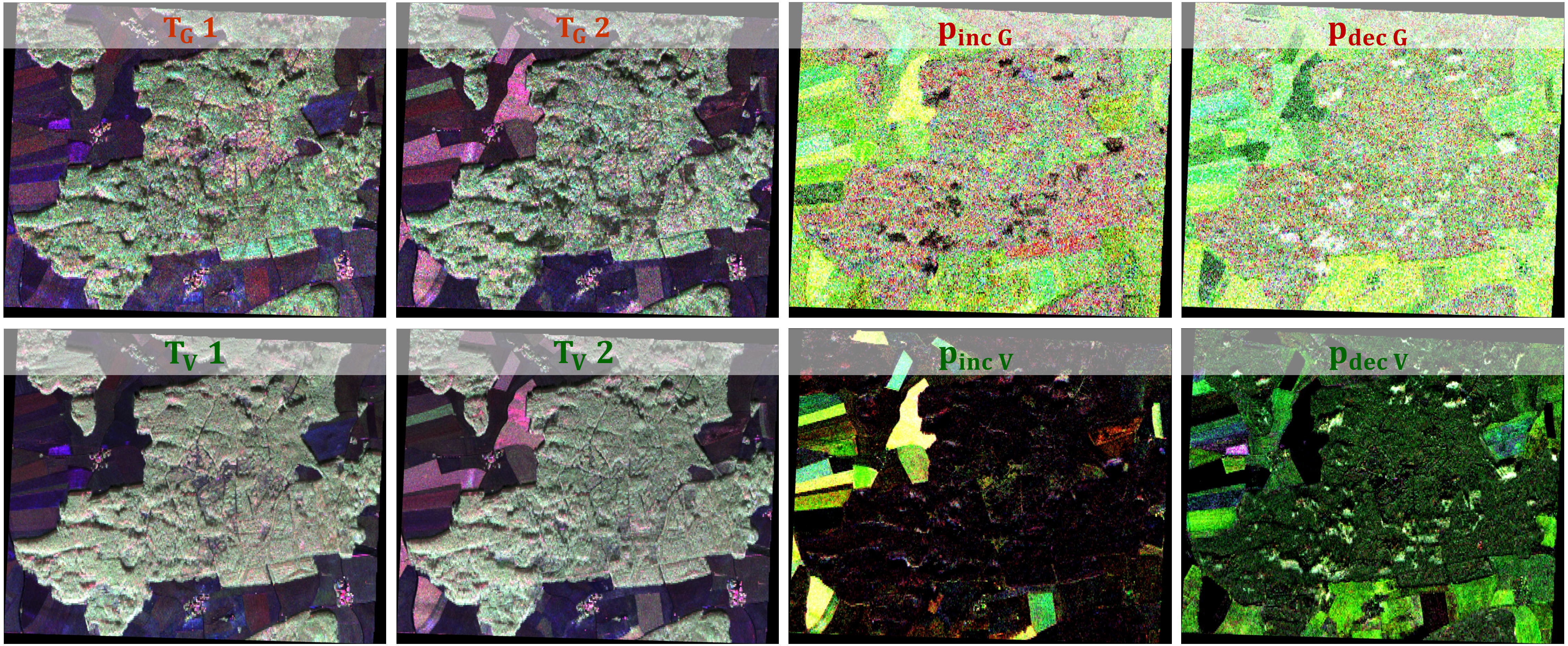
22 TMPSAR



Polarimetric Change Analysis over G&V Components

L-band
ENL = 34, 5 m x 5 m
$\mathbf{p} \in [1,10]$ dB

17 TMPSAR	22 TMPSAR



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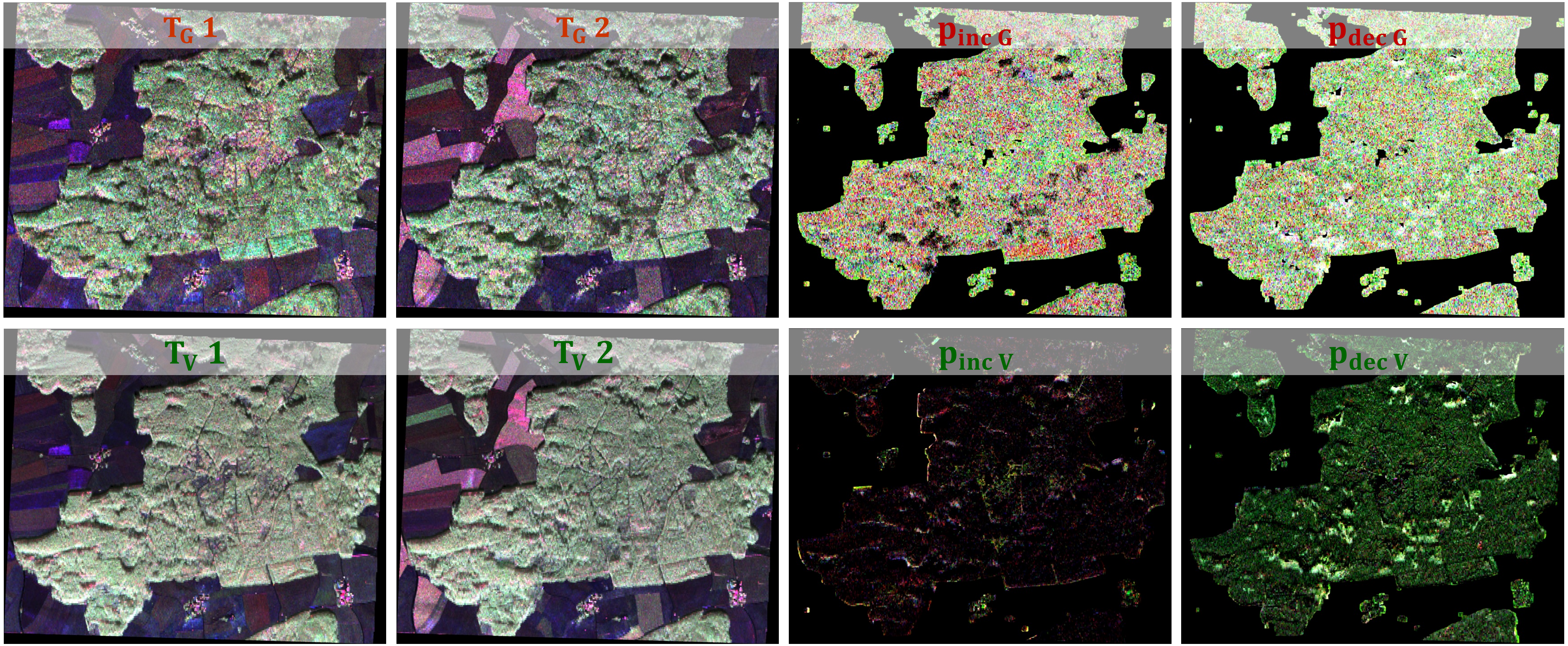

Polarimetric Change Analysis over G&V Components

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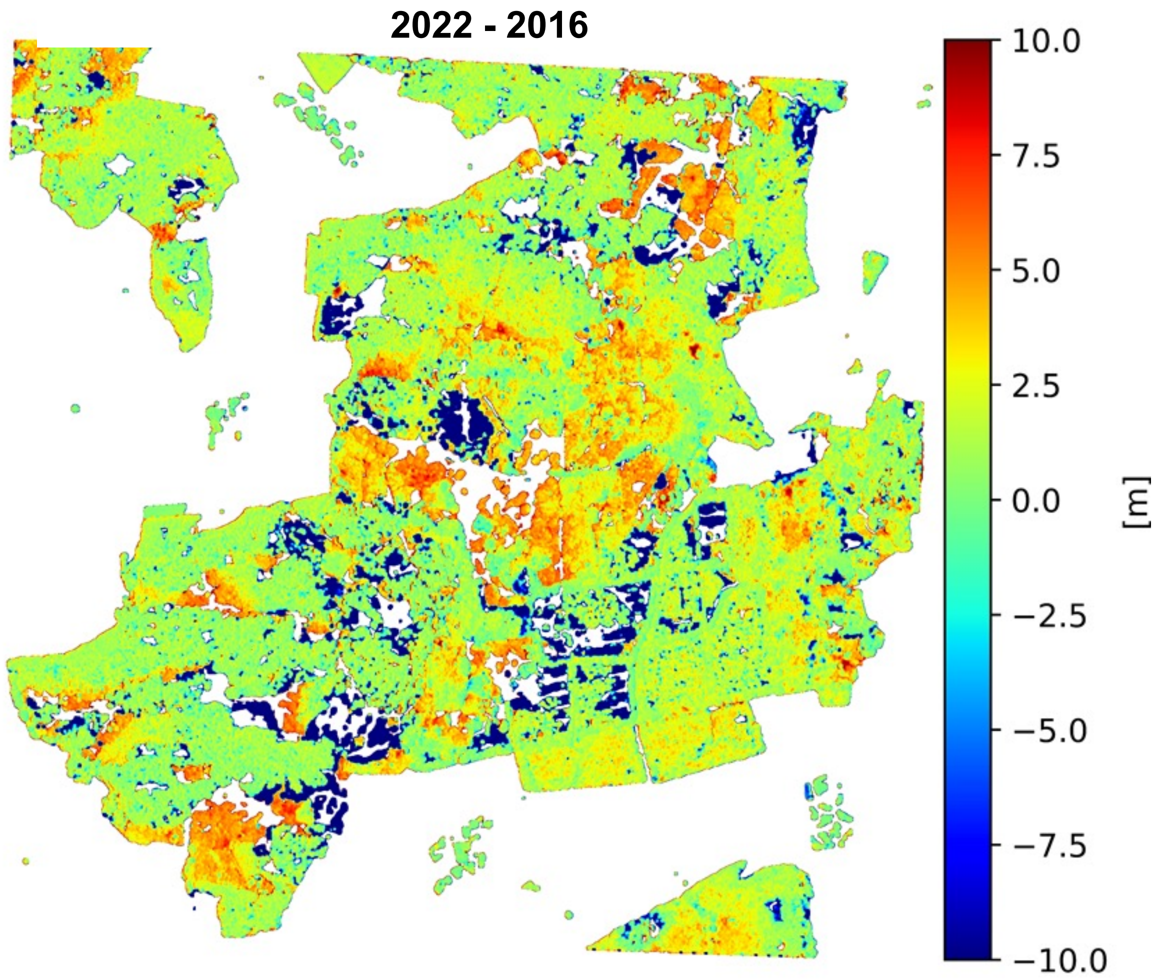

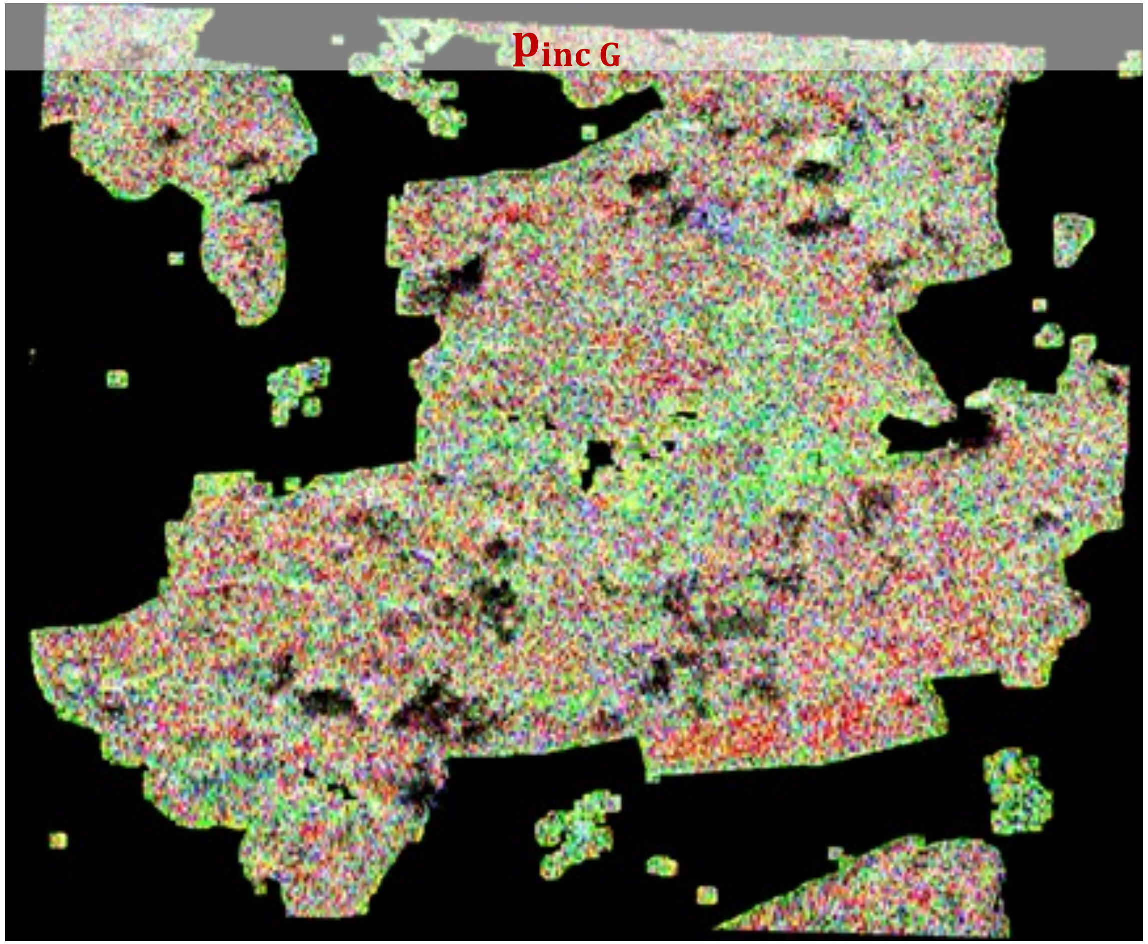

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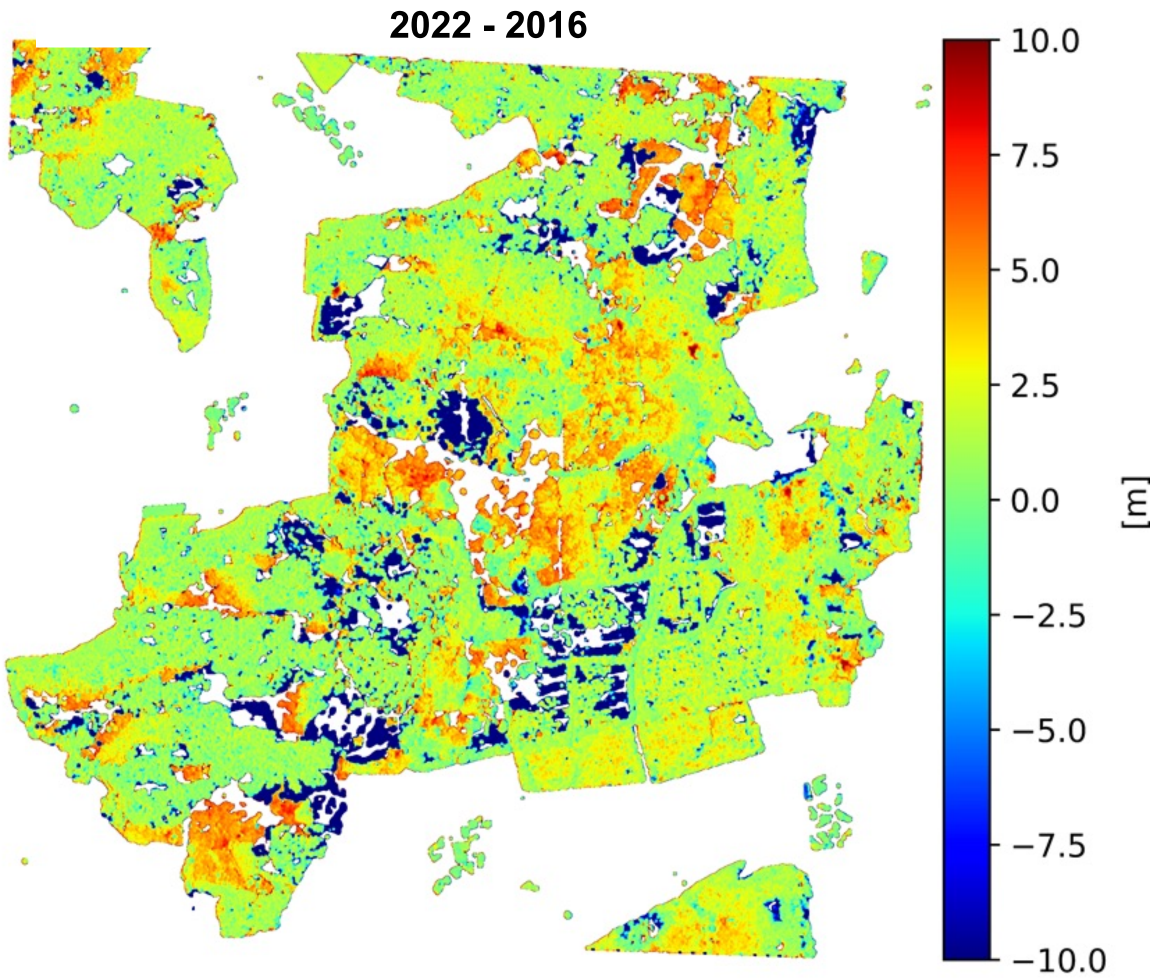
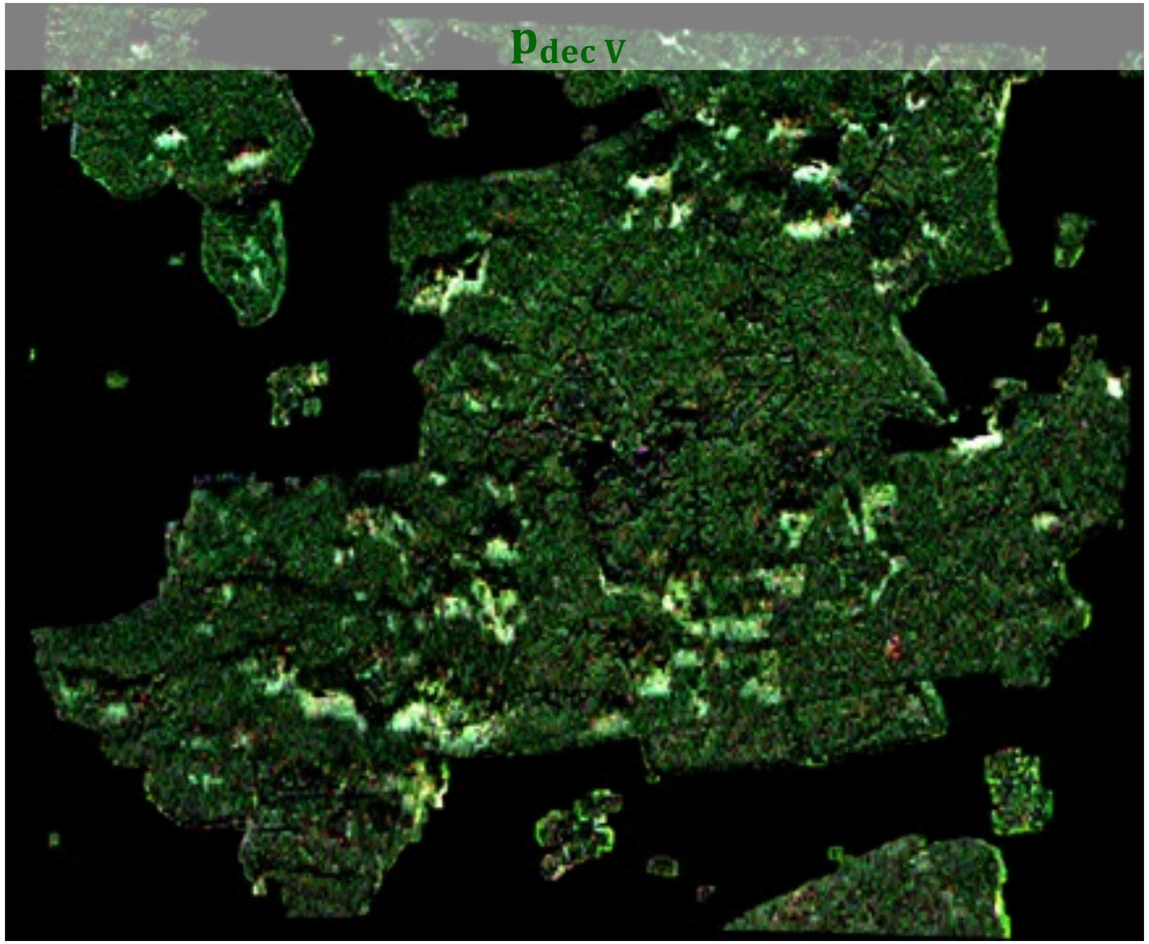
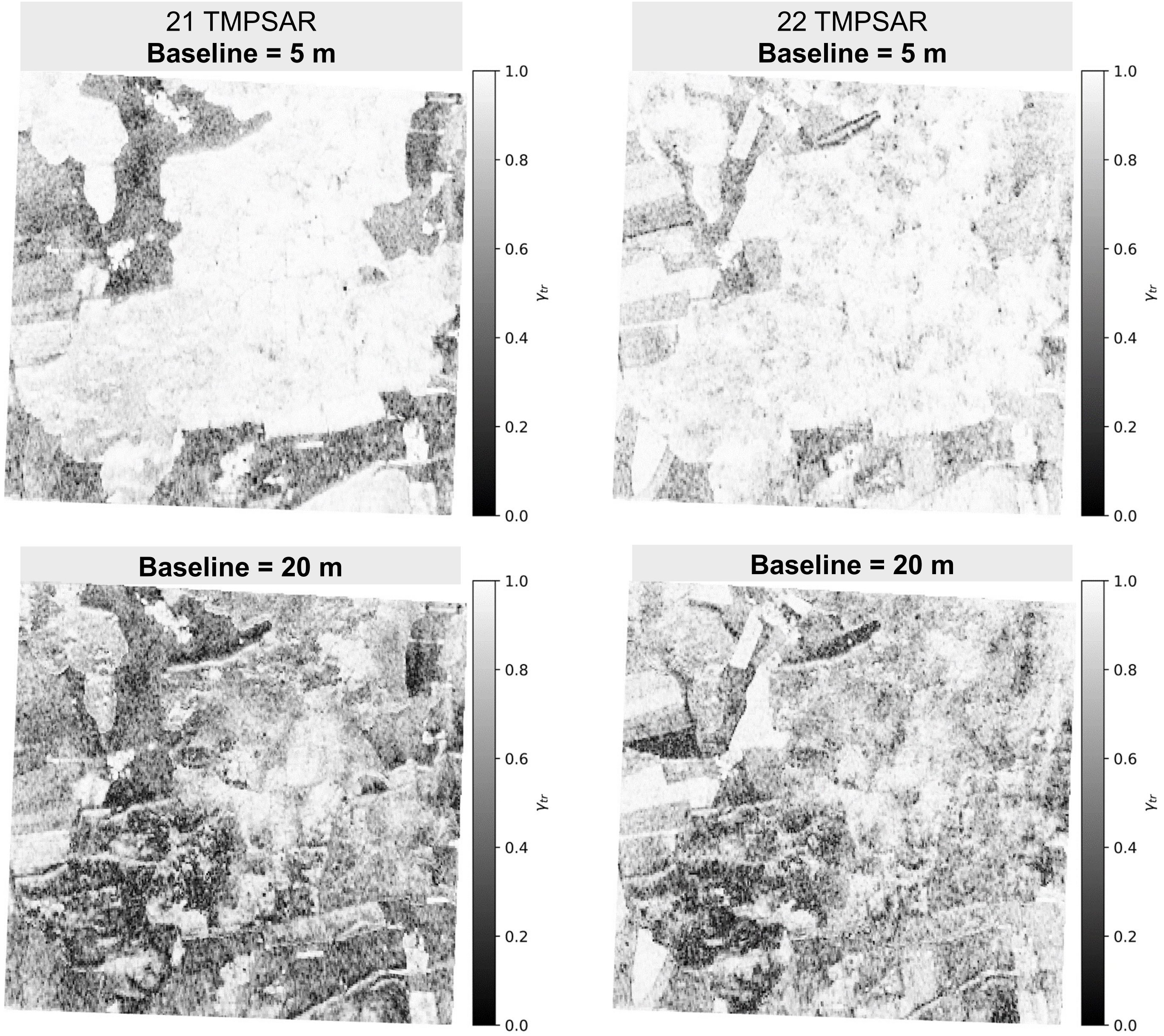




InSAR Coherence – P-band

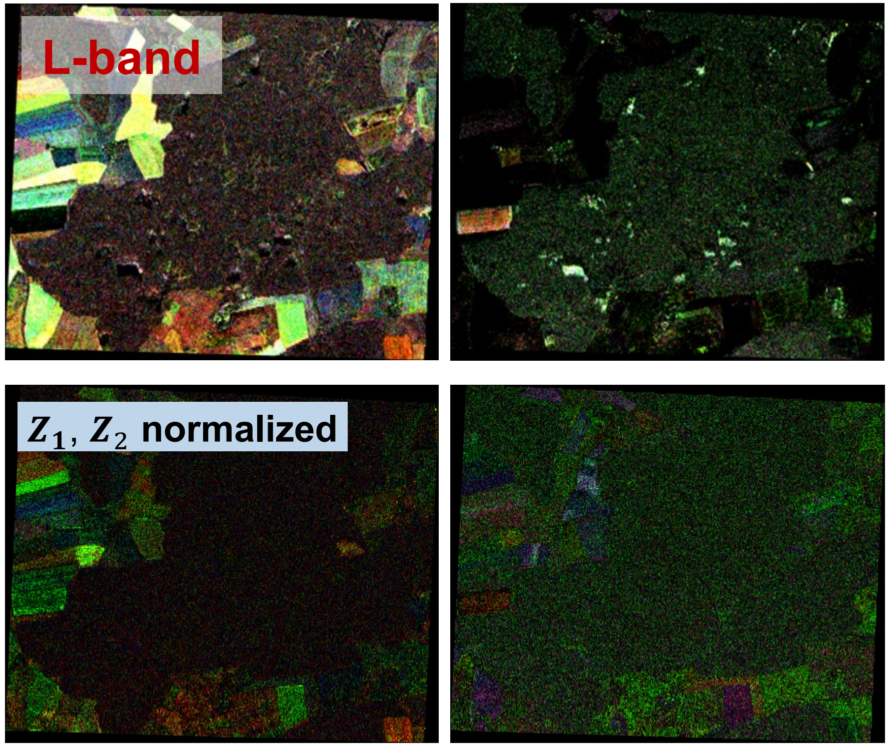


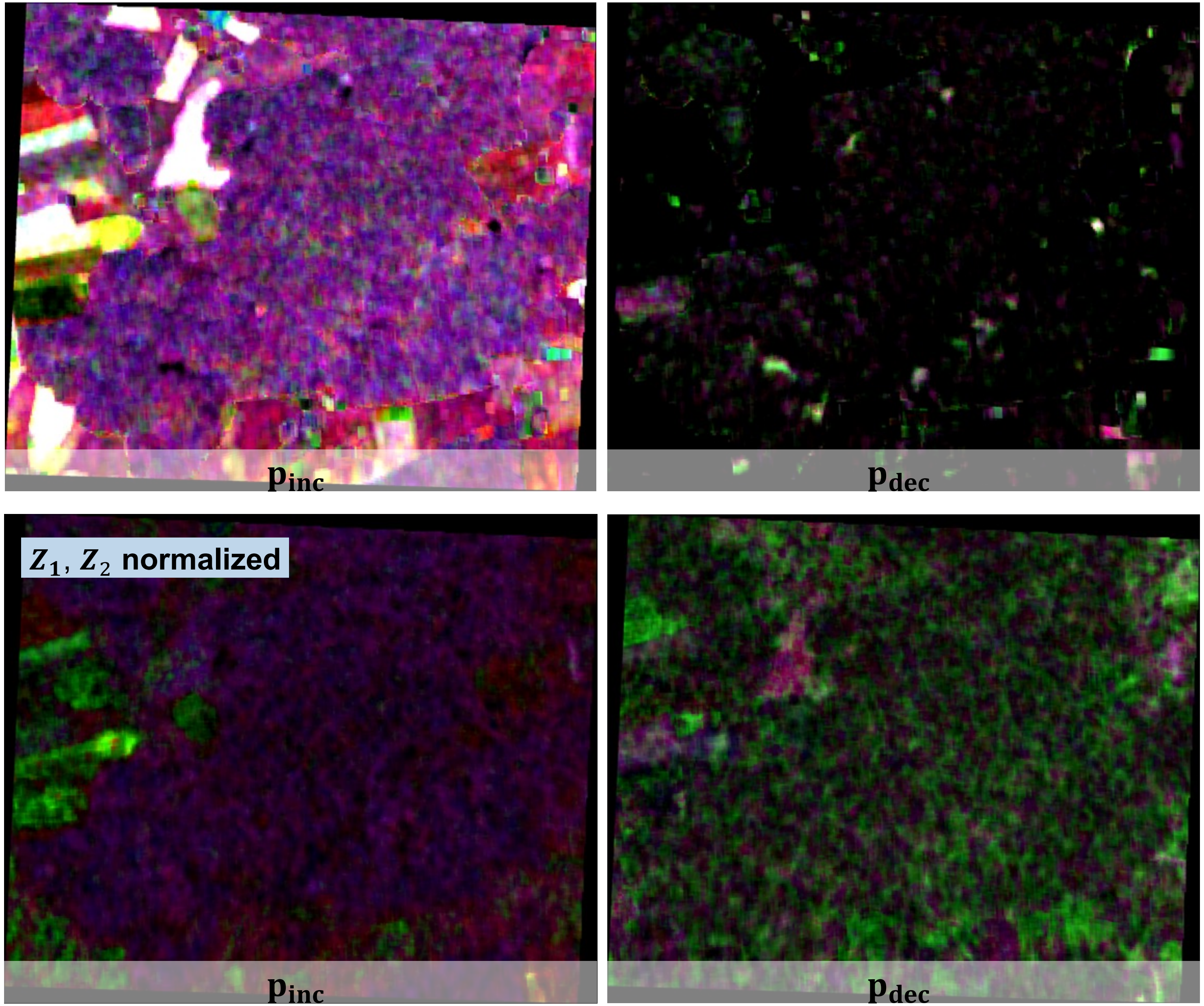
Polarimetric Change Analysis

Z_1: 21 TMPSAR 0103
Z_2: 22 TMPSAR 0403

$\mathbf{p} \in [1,10]$ dB

P-band
ENL = 138
30 m x 30 m





Polarimetric Change Analysis

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Z_2: 22 TMPSAR 0403

$\mathbf{p} \in [1,10]$ dB

L-band
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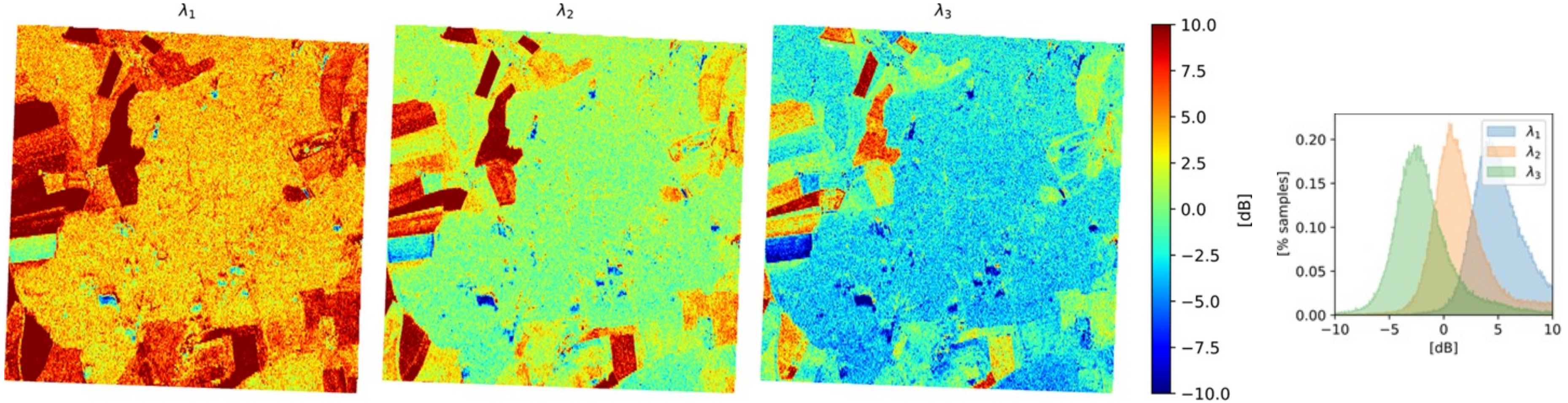
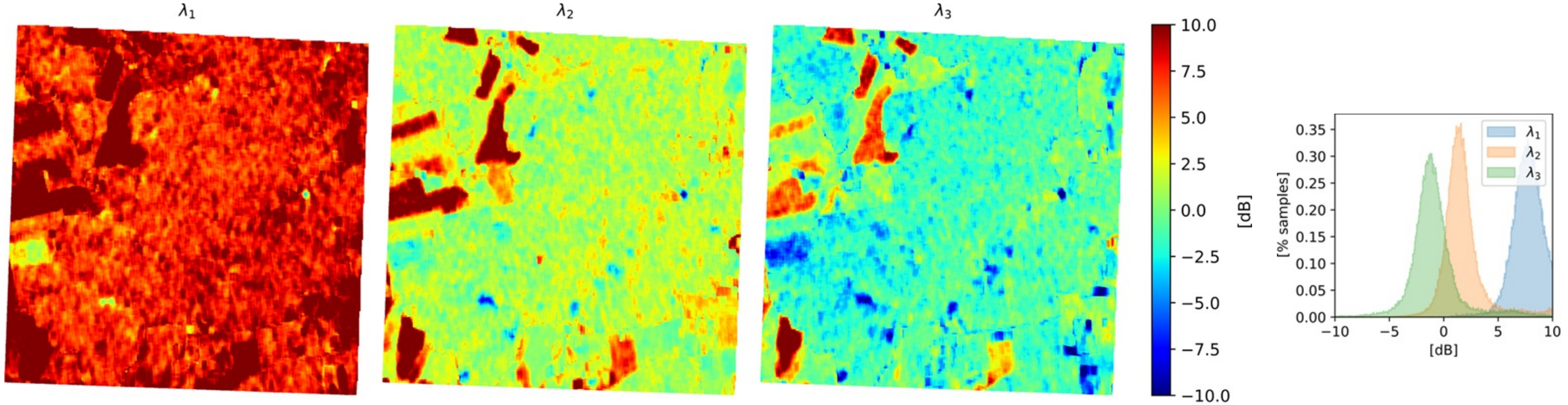
5 m x 5 m



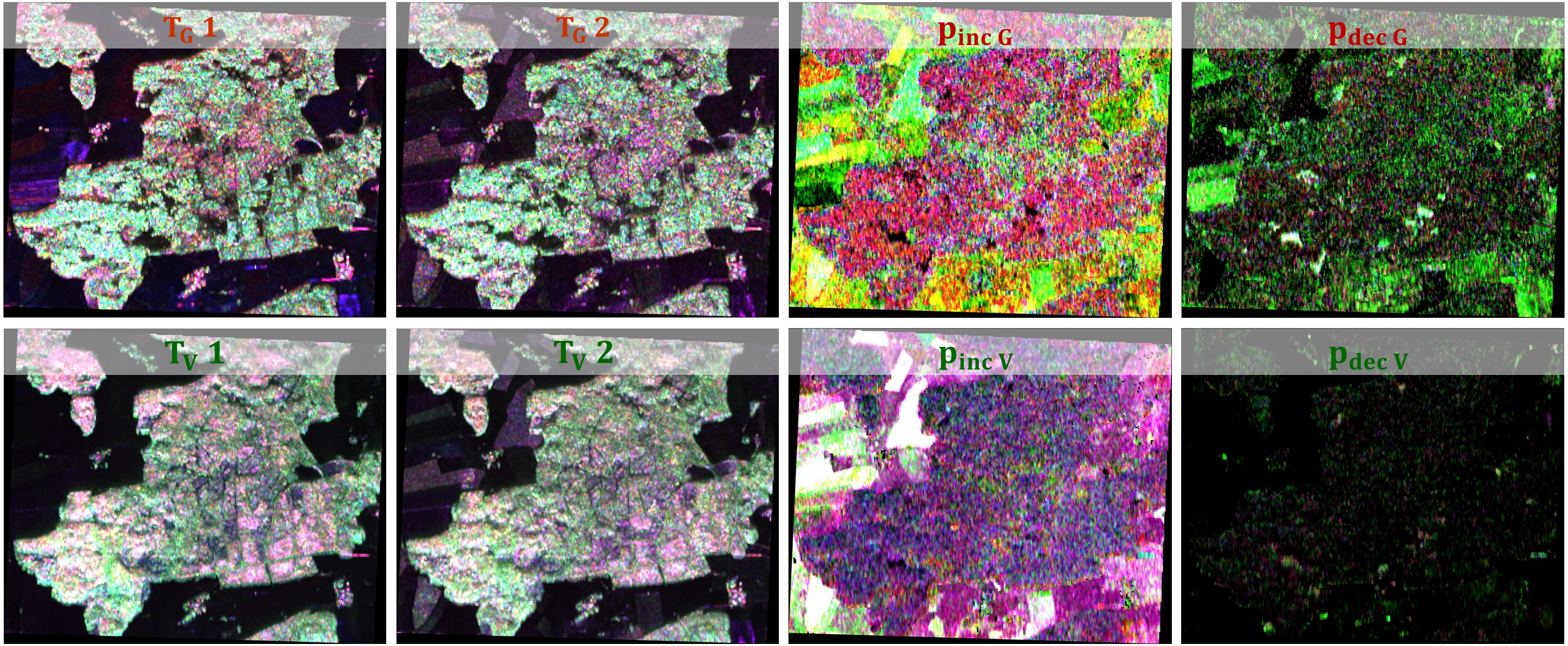
P-band
ENL = 138
10 m x 10 m



Polarimetric Change Analysis over G&V Components

P-band ENL = 15, 10 m x 10 m	**P-band** ENL = 138, 30 m x 30 m $\mathbf{p} \in [1,10]$ dB

21 TMPSAR	22 TMPSAR



Conclusions

- **PolSAR Change Analysis**: Sensitive to changes in forest structure changes;
  - **L-band:** Forests are high entropy environments where almost only intensity changes are detectable. The change in scattering mechanisms (associated with the nature of change) is widely veiled.
  - **P-band:** The lower (compared to L-band) polarimetric entropy allows not only the detection intensity but also scattering mechanism changes.
- **Interferometry** increases the sensitivity to structural change(s). It lifts the veil !
- The **separation of ground and volume scattering** increases the dynamic range of detectable changes and their interpretability.
- Physical interpretation started / is ongoing.

THANK YOU!

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Polarimetric Change Analysis

L-band

ENL = 34
5 m x 5 m

$\mathbf{p} \in [1,10]$ dB

$\boldsymbol{Z_1}$: 17 TMPSAR 0103
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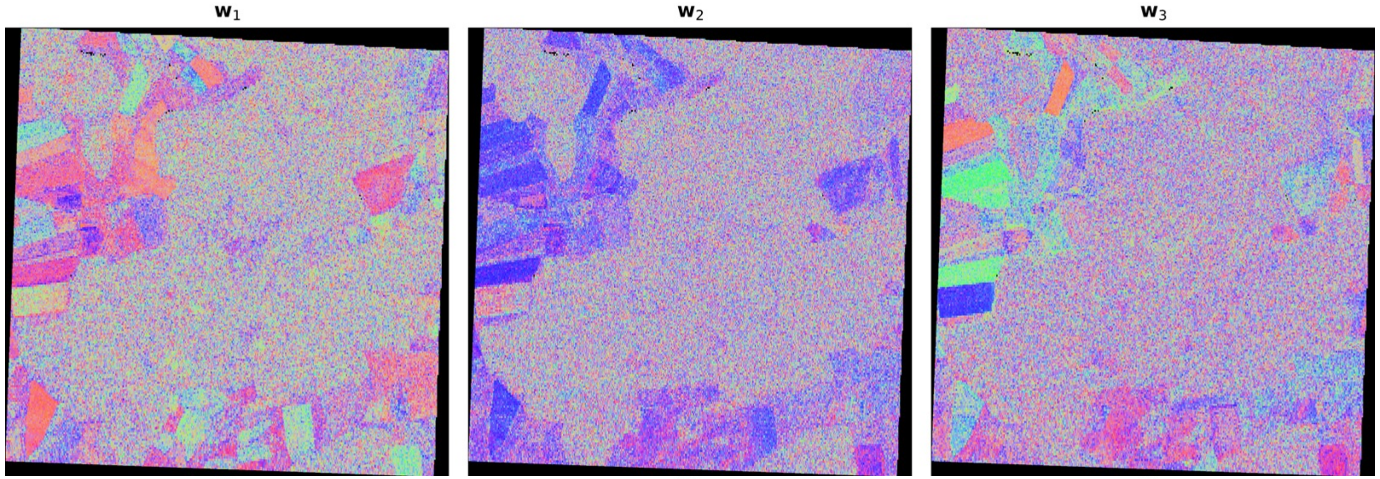

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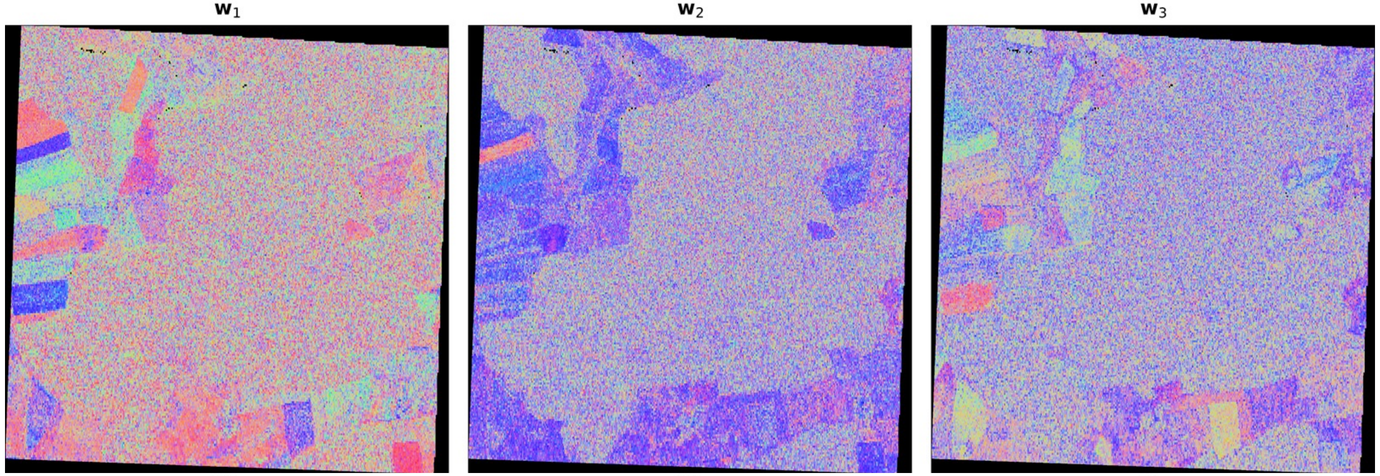

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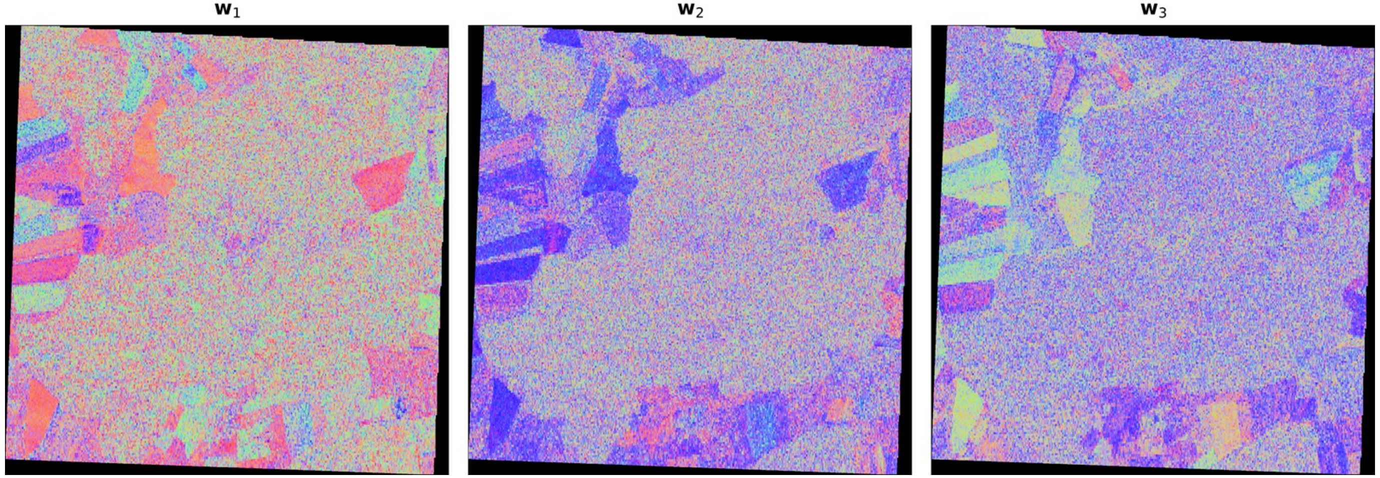

Polarimetric Change Analysis

$\boldsymbol{Z_1}$: 17 TMPSAR 0103
$\boldsymbol{Z_2}$: 21 TMPSAR 0403

$\boldsymbol{Z_1}$ and $\boldsymbol{Z}_2$ are **normalized**!

L-band
ENL = 34
5 m x 5 m
$\mathbf{p} \in [1,10]$ dB

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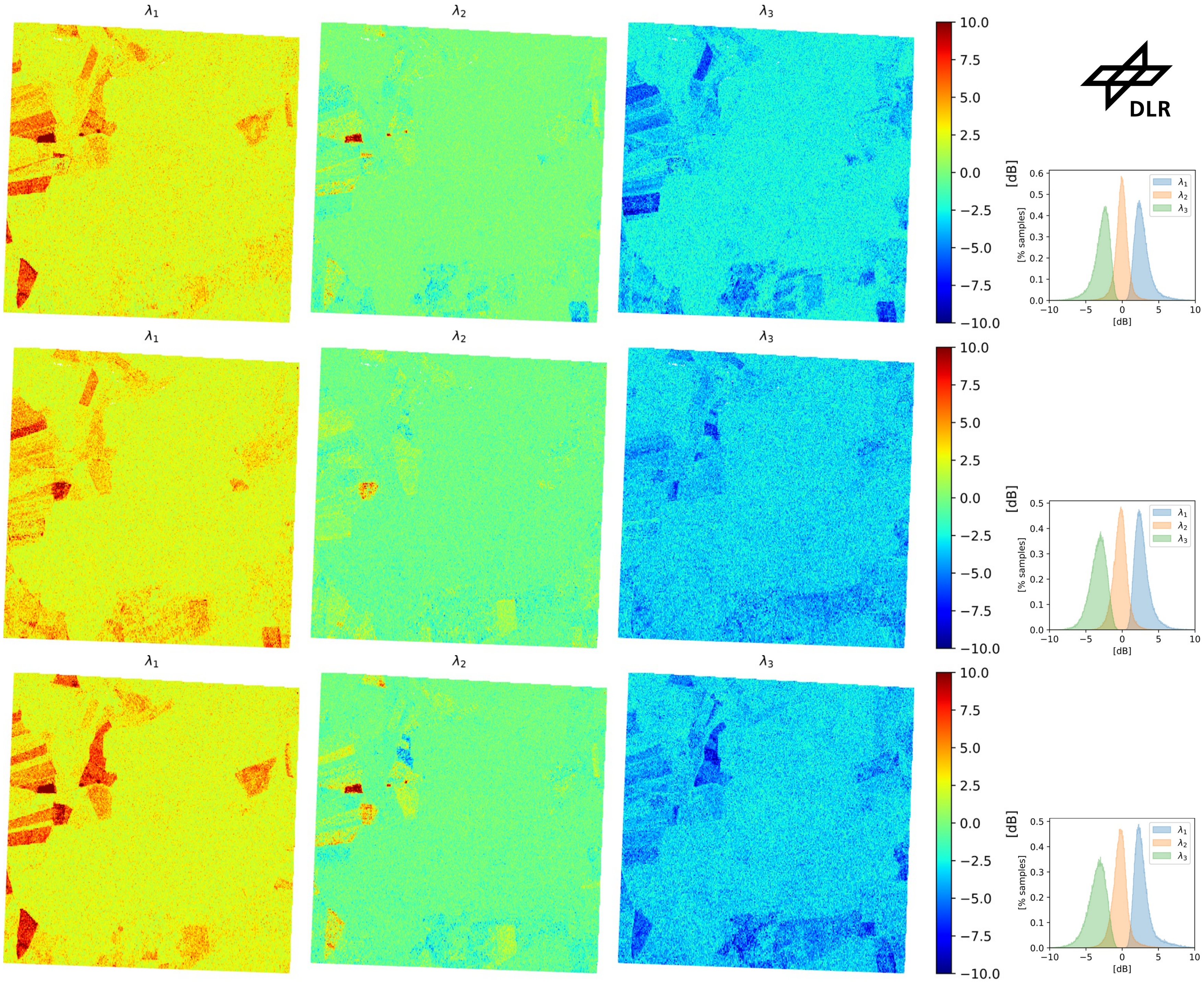

Polarimetric Change Analysis

Z_1 and Z_2 are **normalized**!

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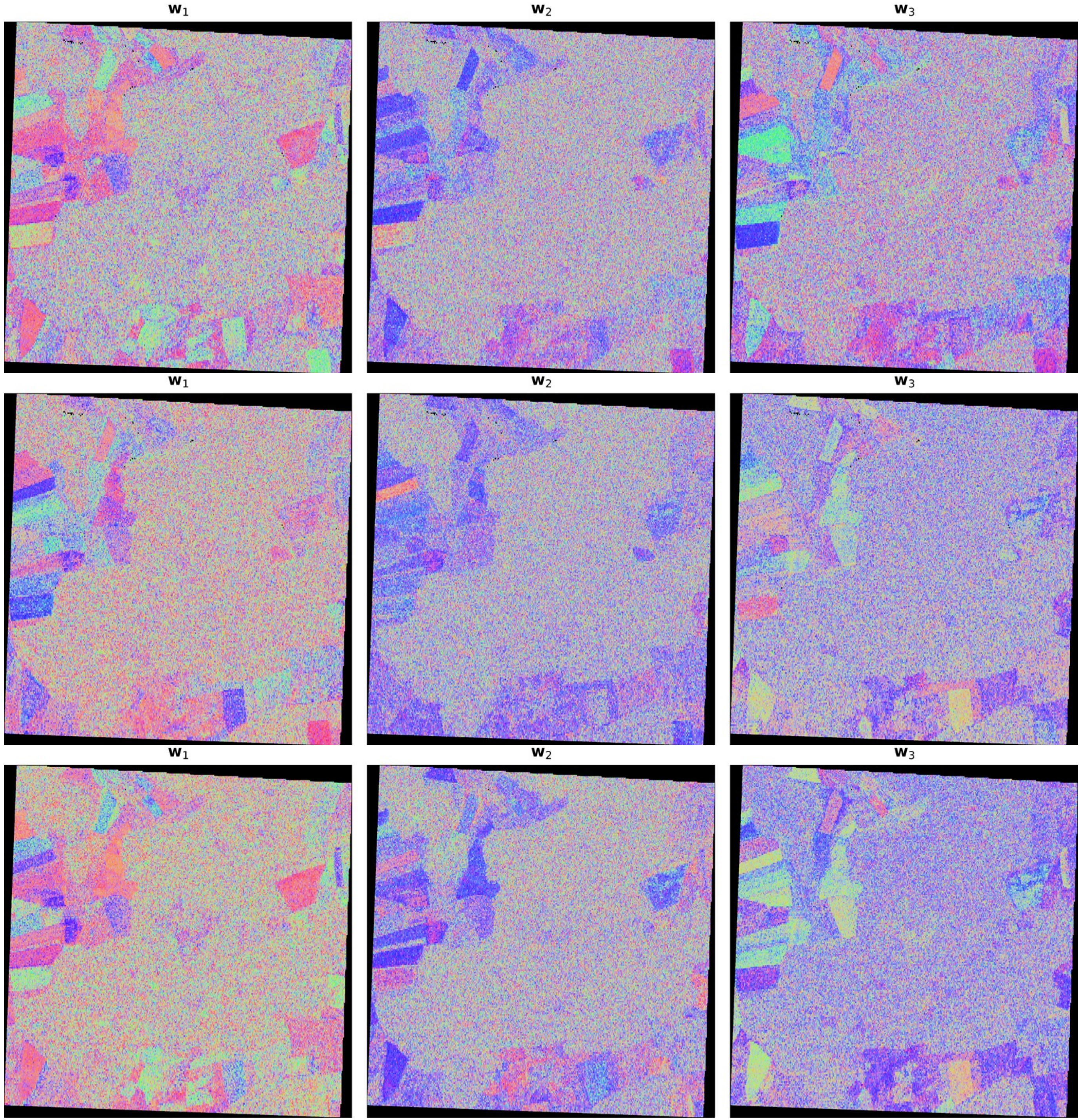


DLR

Ground & Volume Separation

Multi-Baseline Hybrid model-based SKP approach

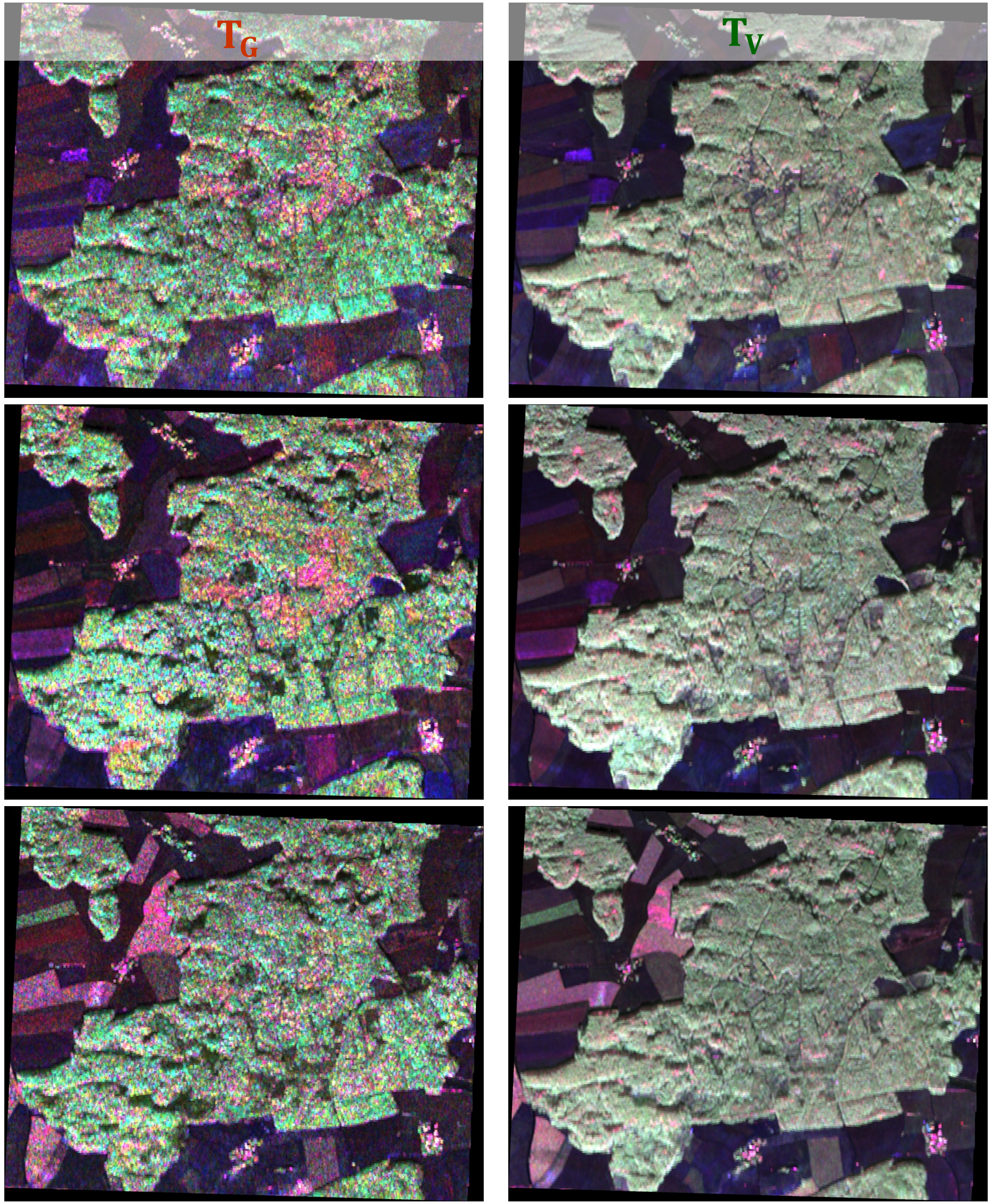
L-band

ENL = 133
10 m x 10 m

17 TMPSAR

21 TMPSAR

22 TMPSAR



Ground & Volume Separation

Single-Baseline
model-based approach

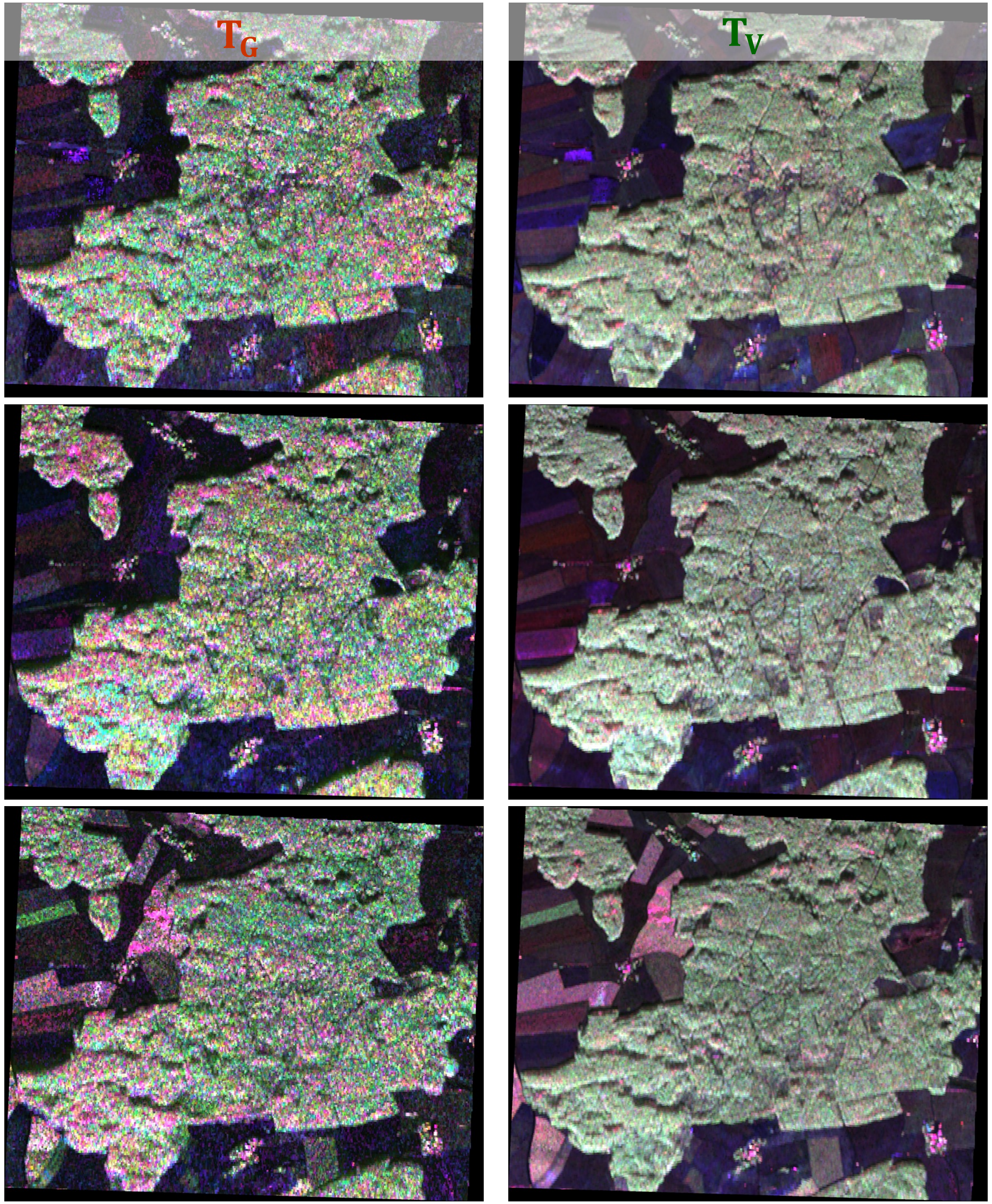
L-band

ENL = 133
10 m x 10 m

17 TMPSAR
0103 – 0105
Baseline = 5 m

21 TMPSAR
0103 – 0123
Baseline = 5 m

22 TMPSAR
0403 – 0405
Baseline = 5 m



Ground & Volume Separation

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Baseline = 5 m

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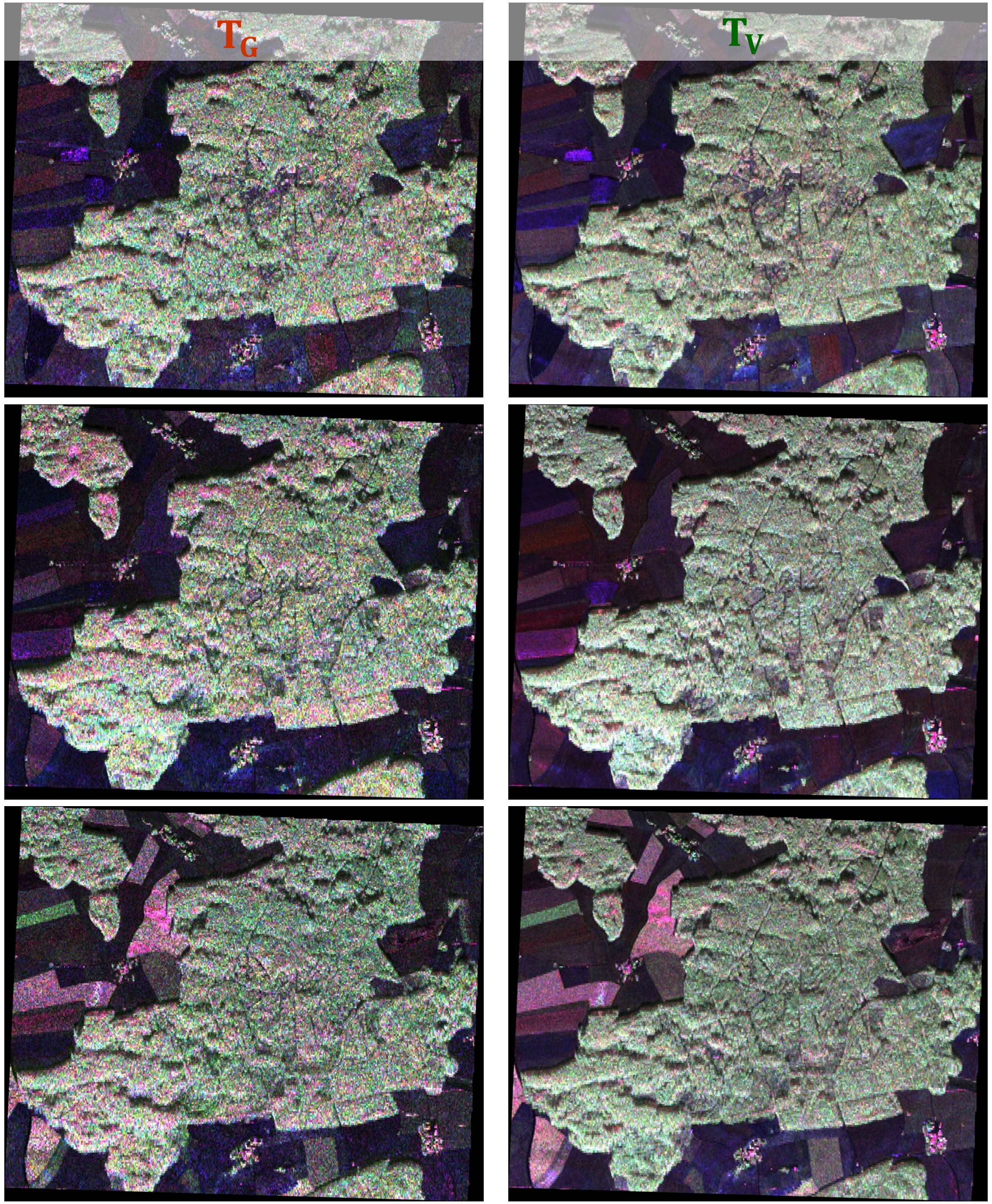
0403 – 0405
Baseline = 5 m



Ground & Volume Separation

Single-Baseline
model-based approach

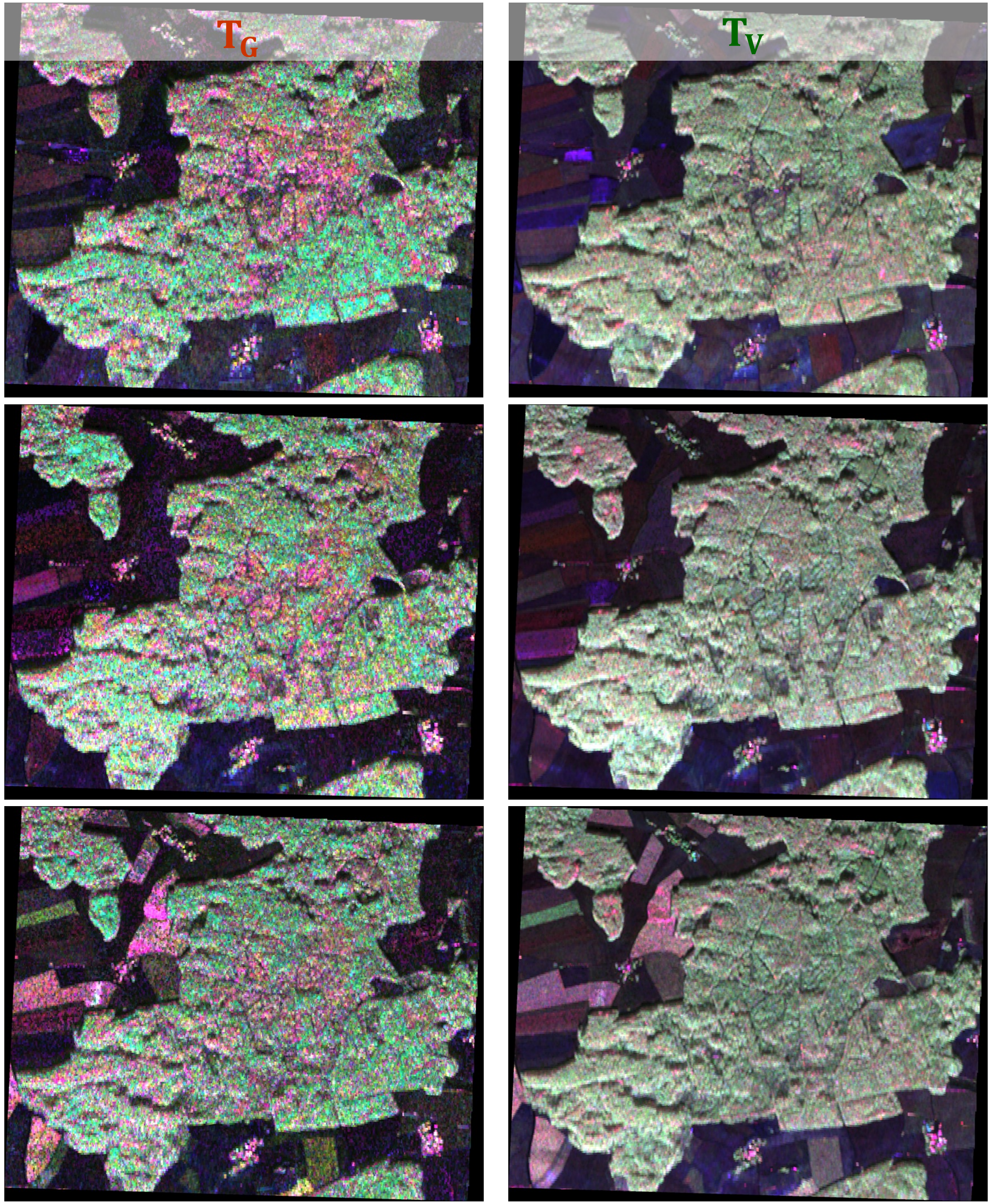
L-band

ENL = 133
10 m x 10 m

17 TMPSAR
0103 – 0111
Baseline = 20 m

21 TMPSAR
0103 – 0107
Baseline = 20 m

22 TMPSAR
0403 – 0409
Baseline = 20 m



Ground & Volume Separation

Single-Baseline
model-based approach

L-band

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0103 – 0111
Baseline = 20 m

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0103 – 0107
Baseline = 20 m

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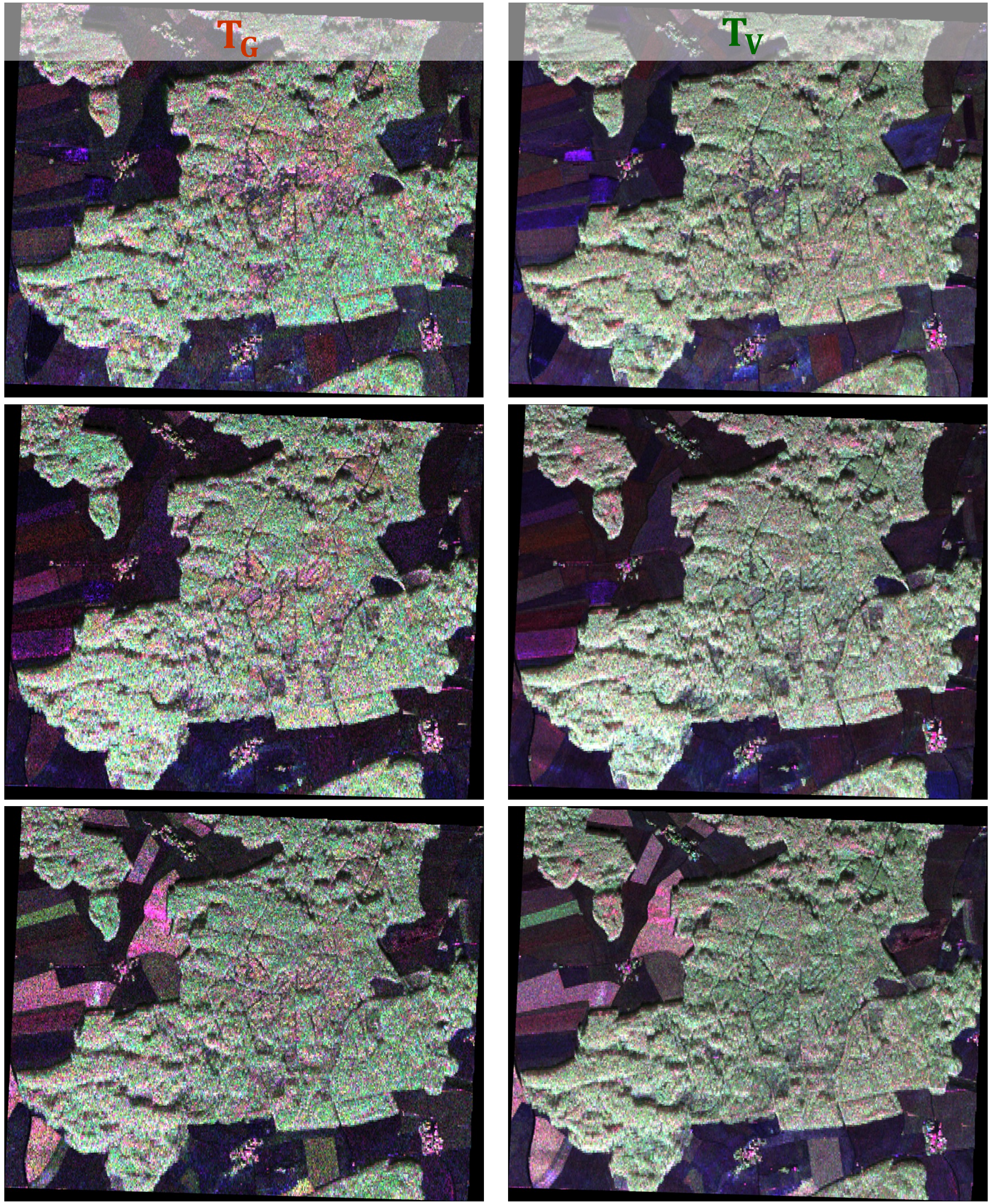
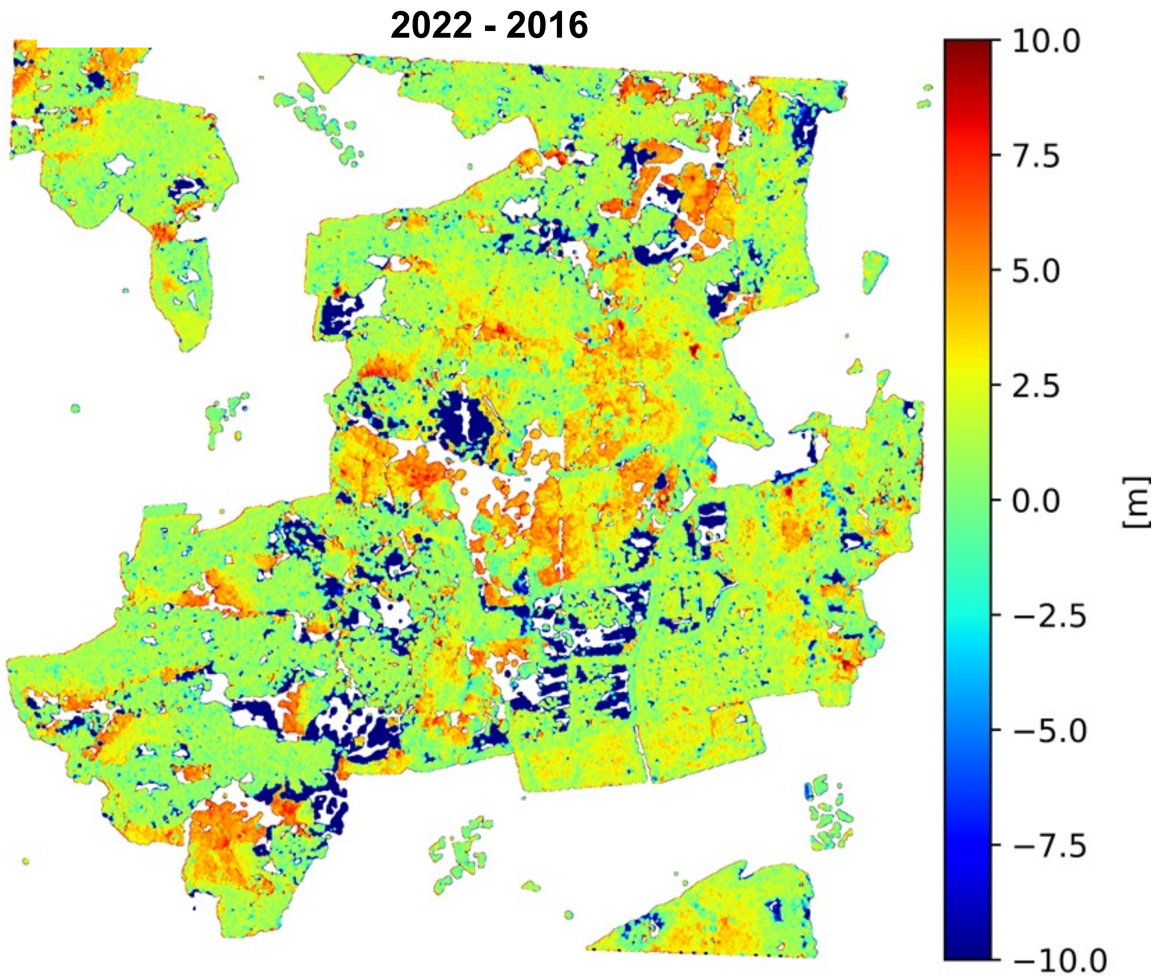
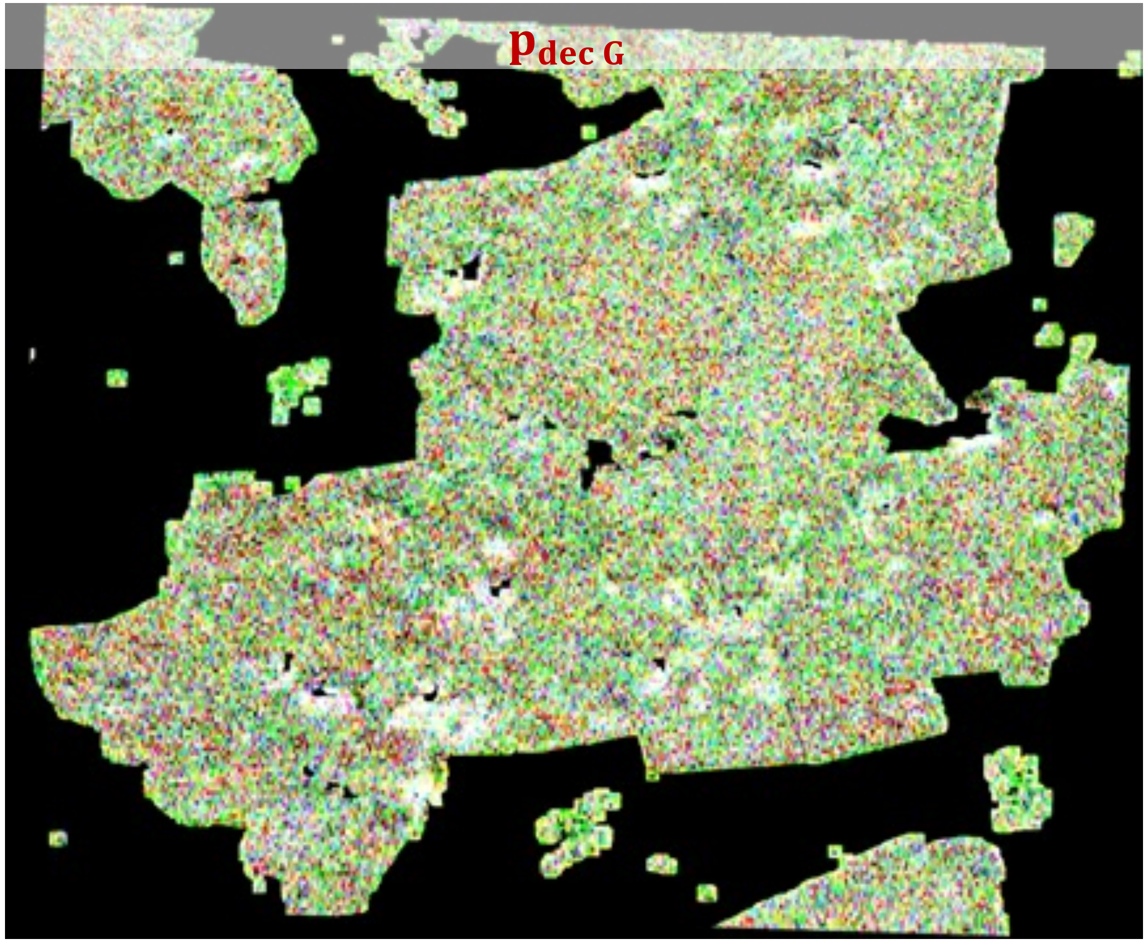
0403 – 0409
Baseline = 20 m



Polarimetric Change Analysis over G&V Components

L-band
ENL = 34, 5 m x 5 m
$\mathbf{p} \in [1,10]$ dB



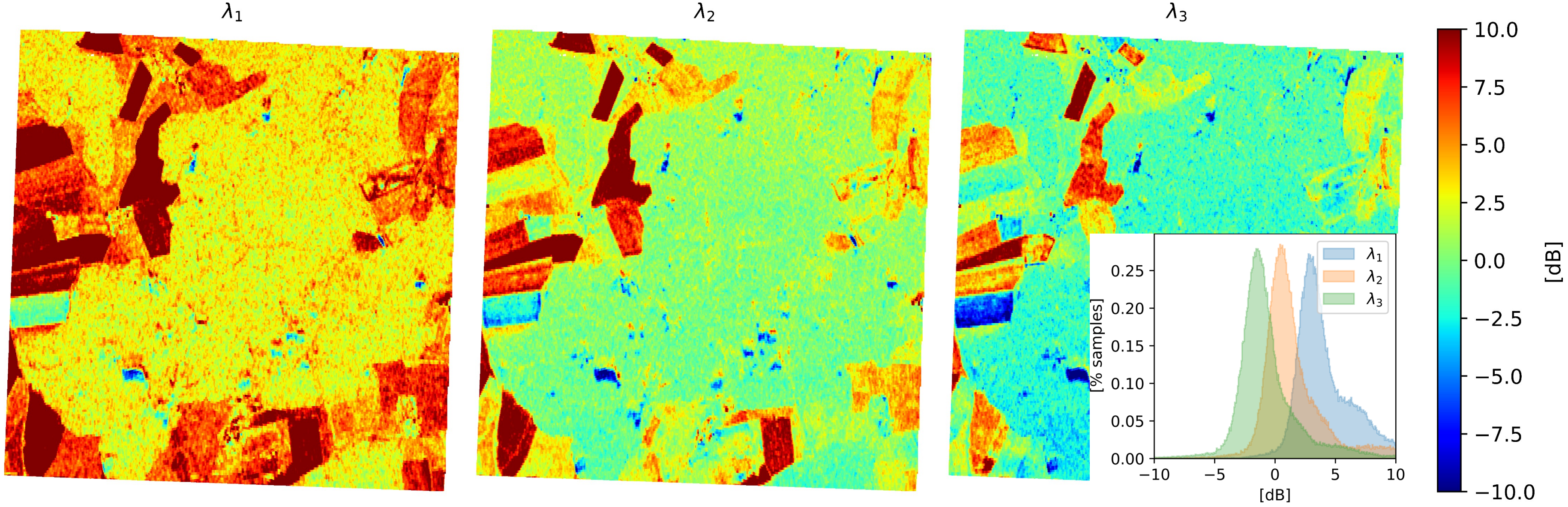


Polarimetric Change Analysis – Z_1, Z_2 of different years

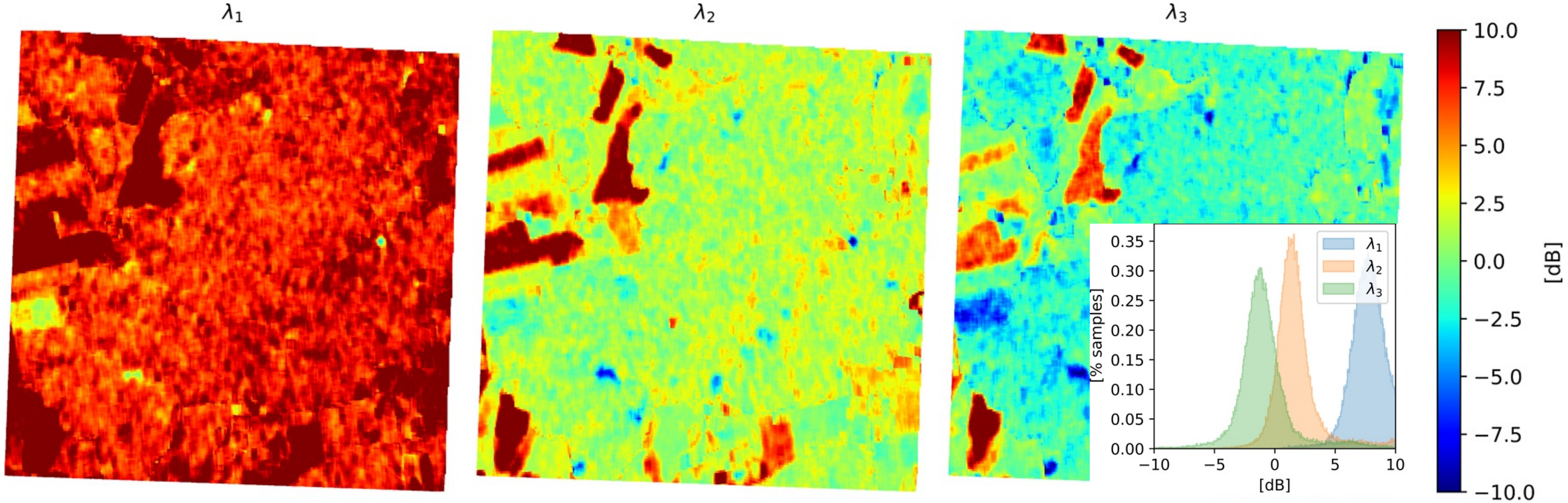
$\boldsymbol{Z_1}$: 21 TMPSAR 0103
$\boldsymbol{Z_2}$: 22 TMPSAR 0403

$\mathbf{p} \in [1,10]$ dB

L-band
ENL = 133
10 m x 10 m



P-band
ENL = 138
10 m x 10 m



Polarimetric Change Analysis

Z_1: 21 TMPSAR 0103
Z_2: 22 TMPSAR 0403

$\mathbf{p} \in [1,10]$ dB

P-band
ENL = 138
10 m x 10 m

Z_1 and Z_2 are **normalized**!