



Linking Changes of Forest Structure, TomoSAR 3-D Reflectivity Profiles and Pol- InSAR Measurements

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German Aerospace Center (DLR)

Microwave and Radar Institute



DLR

Traunstein (South of Germany) 2016 – 2022

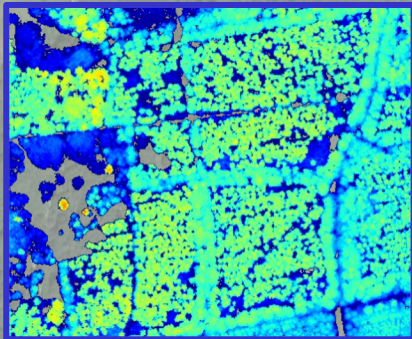
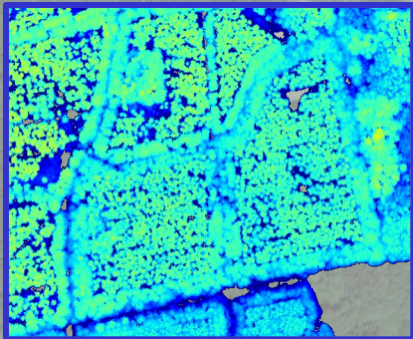
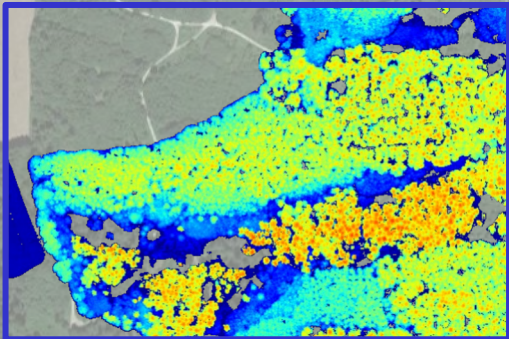
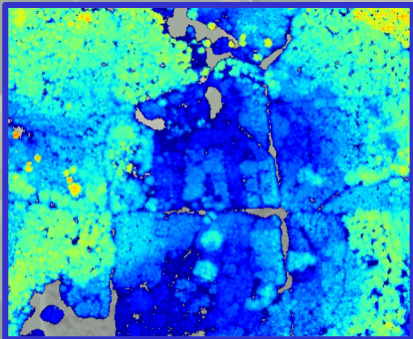
Growth

No change

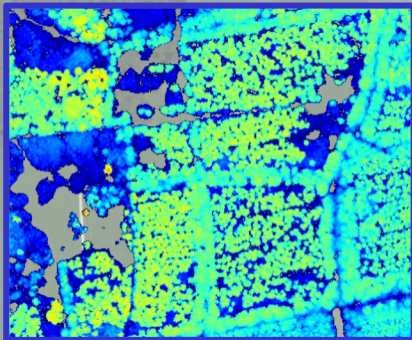
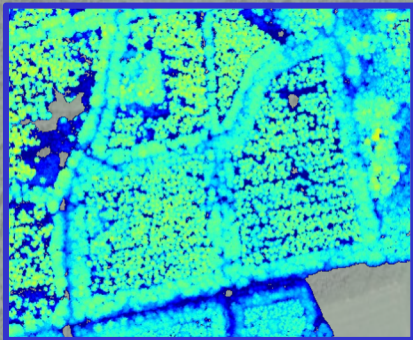
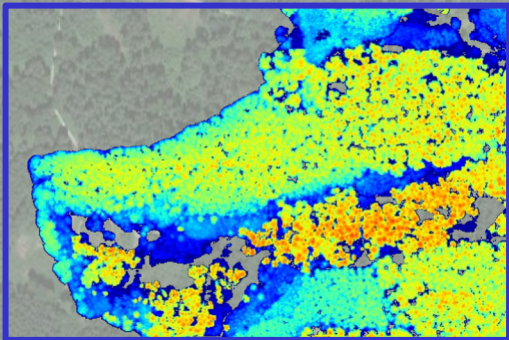
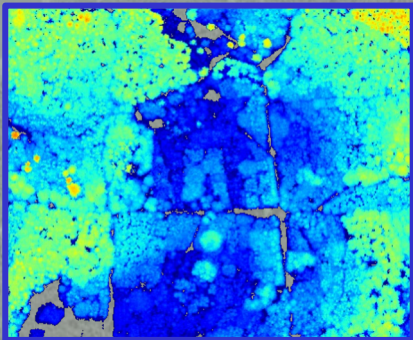
Thinning

Clearing

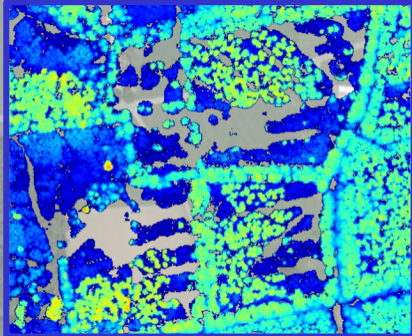
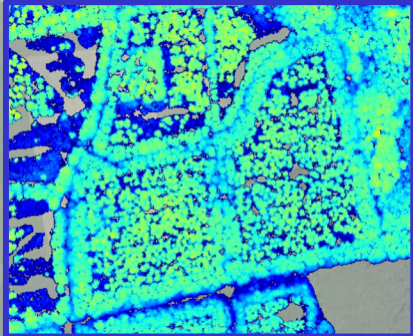
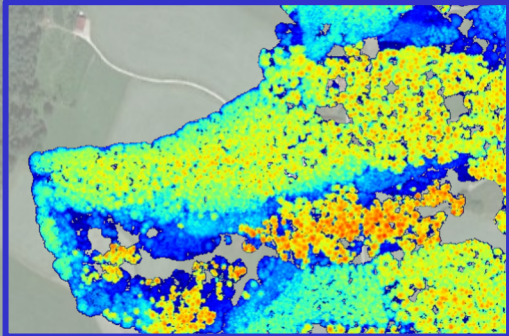
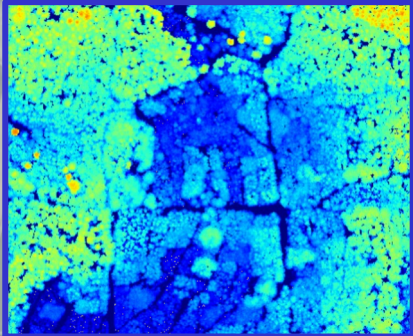
2016



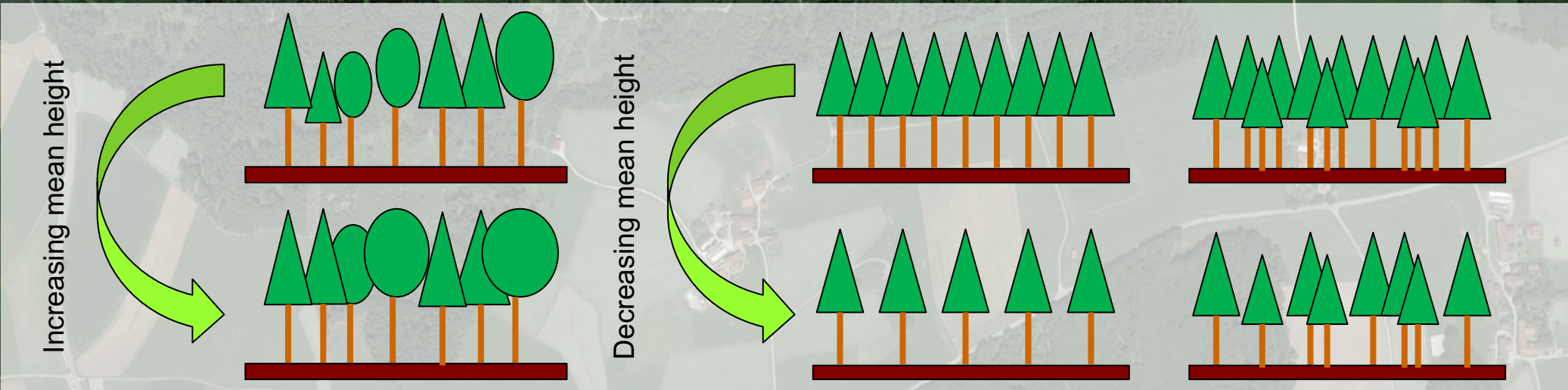
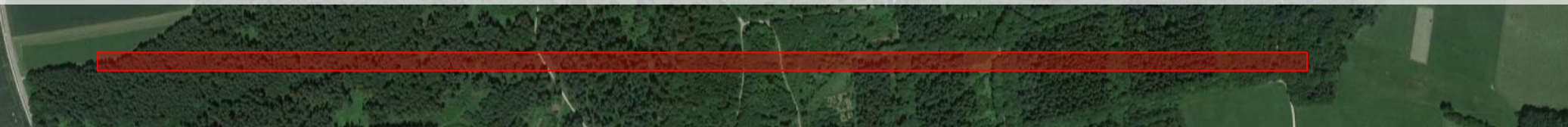
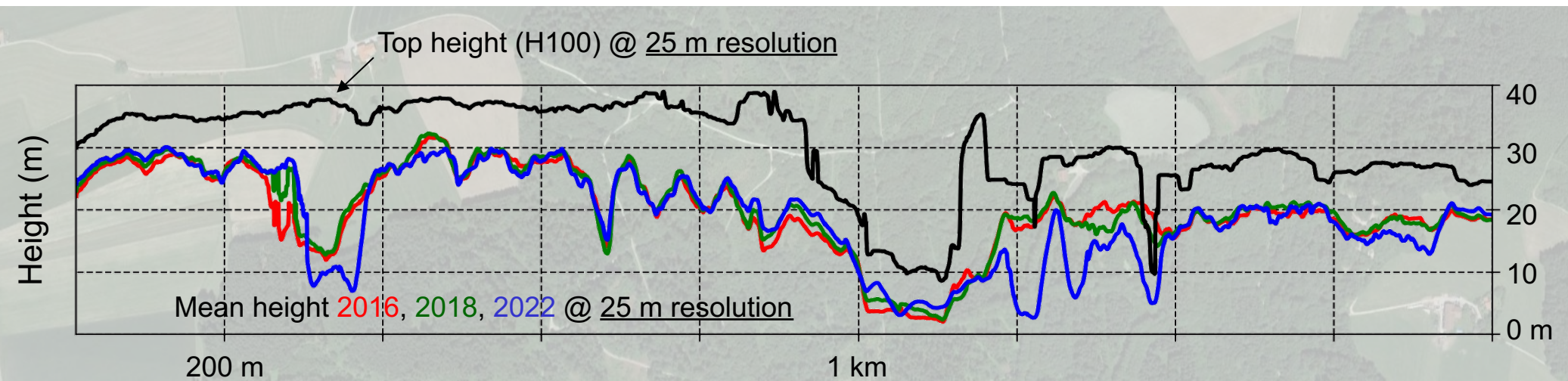
2018



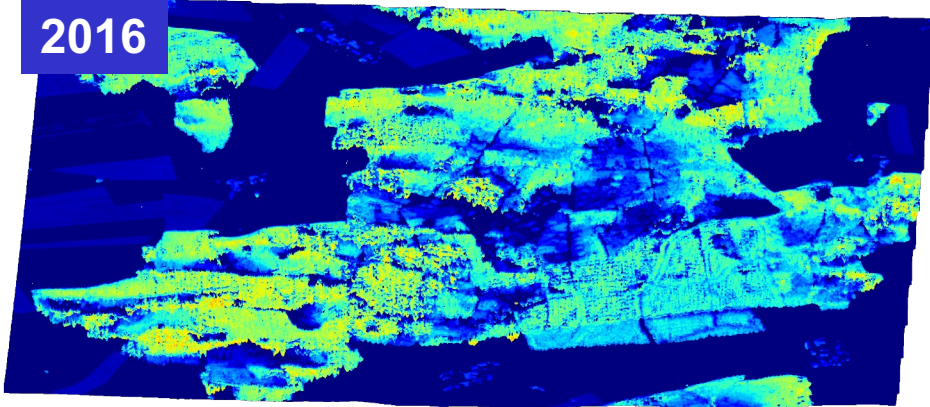
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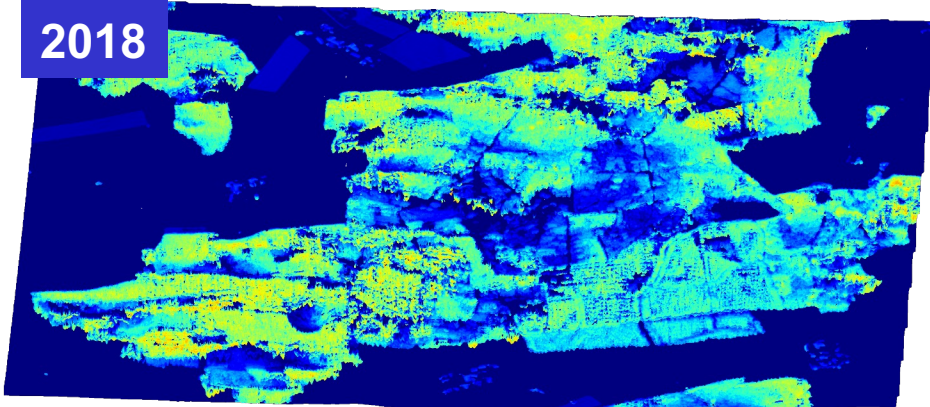
Froshham (Traunstein, South of Germany) 2016 – 2022



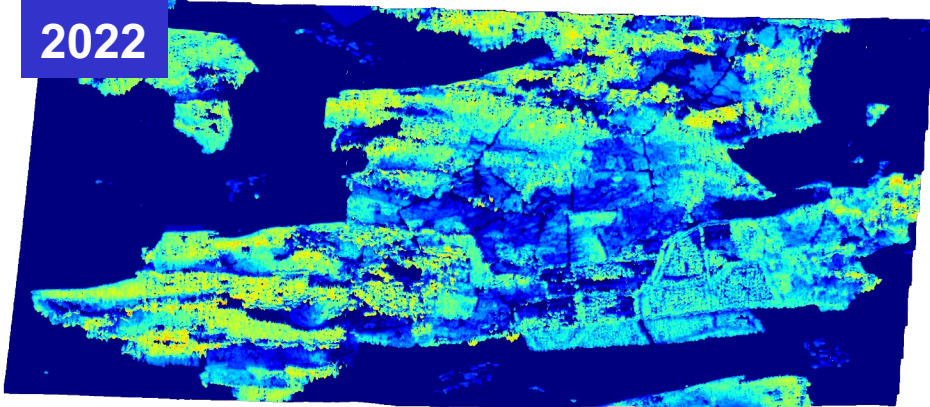
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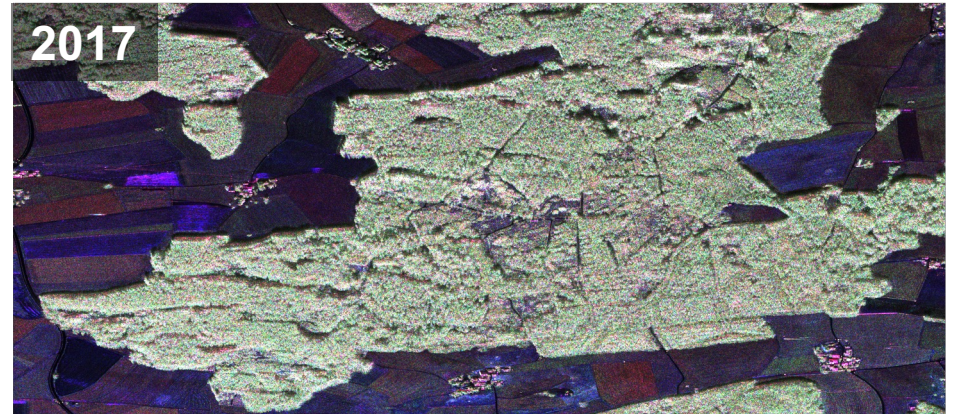
2018



2022



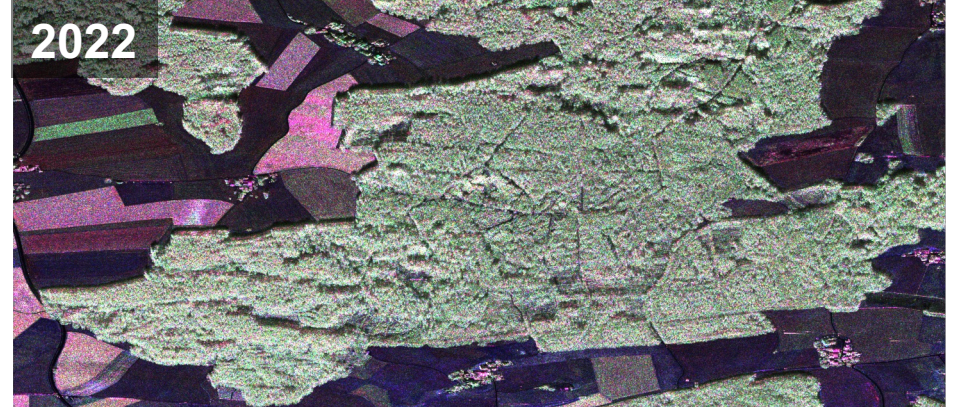
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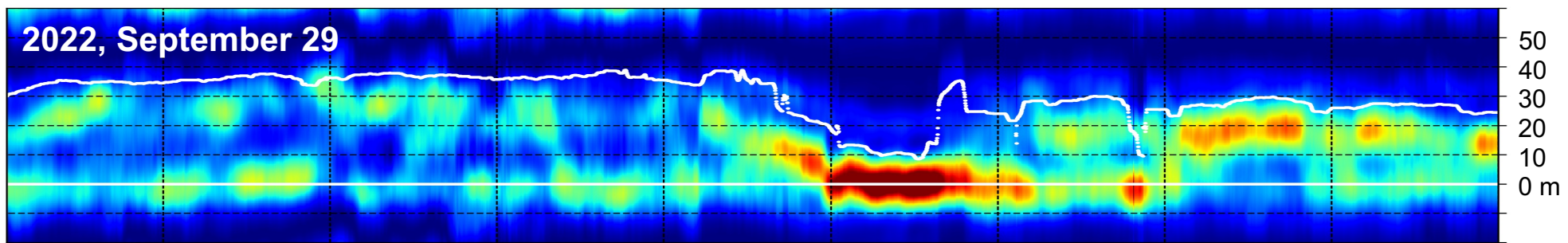
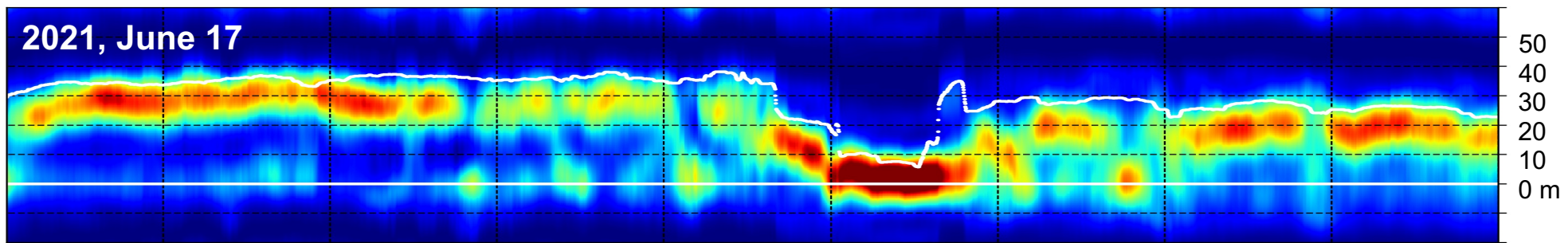
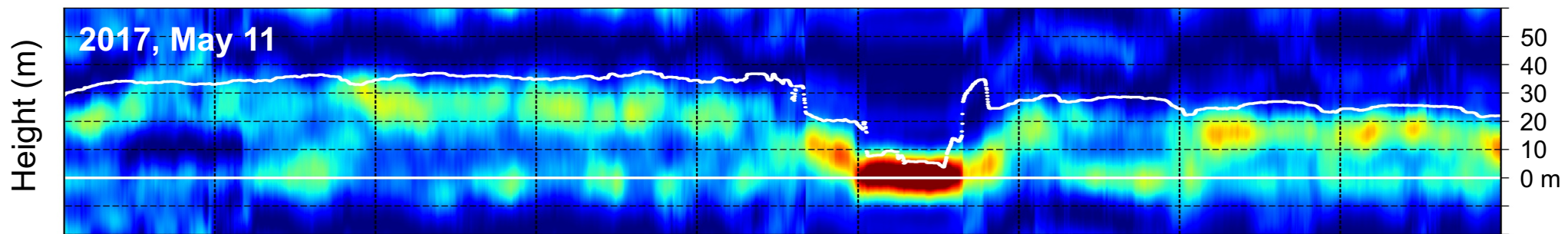
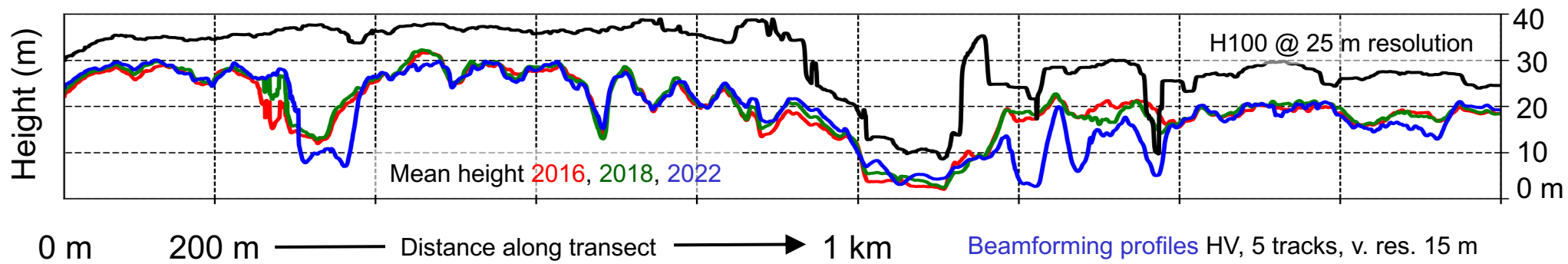


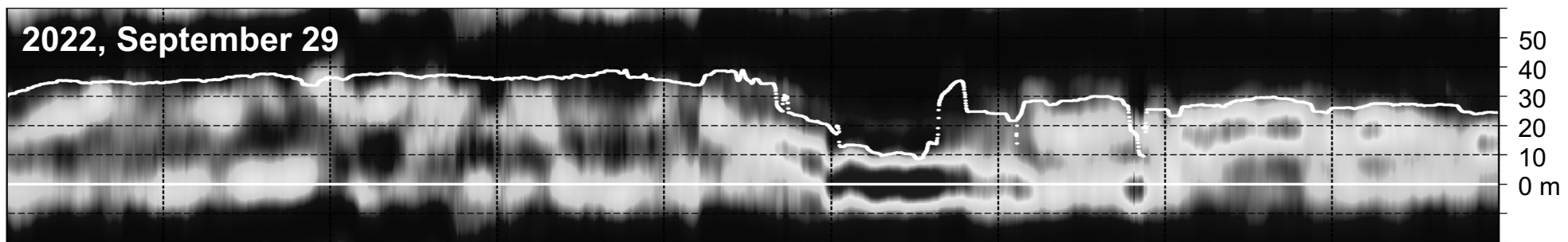
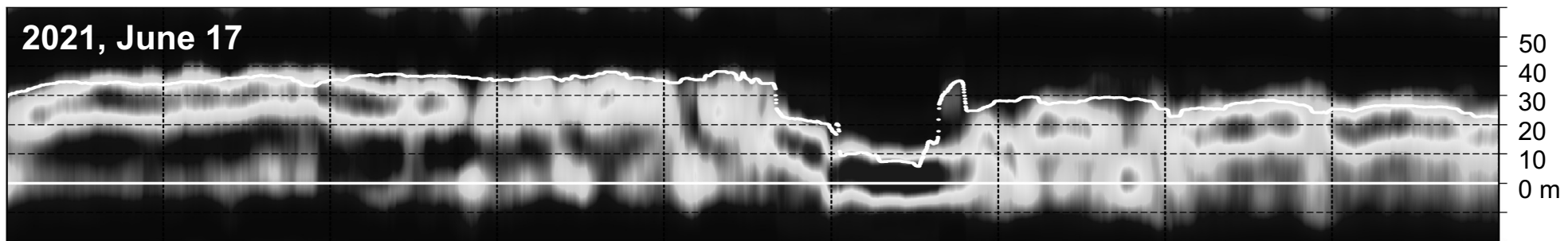
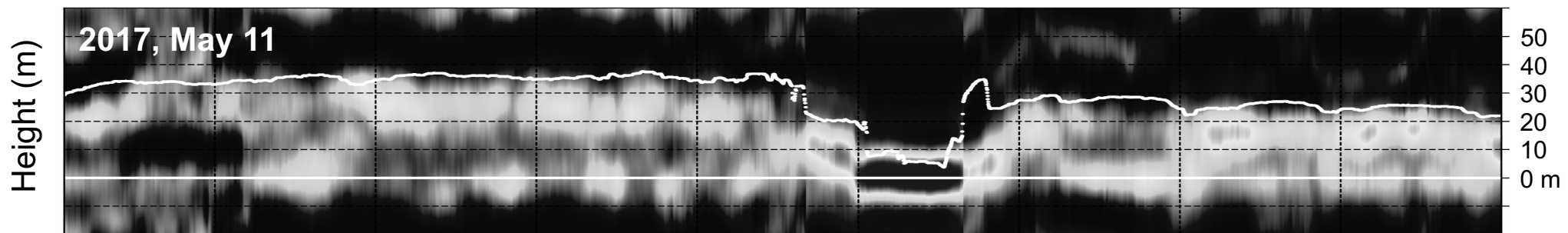
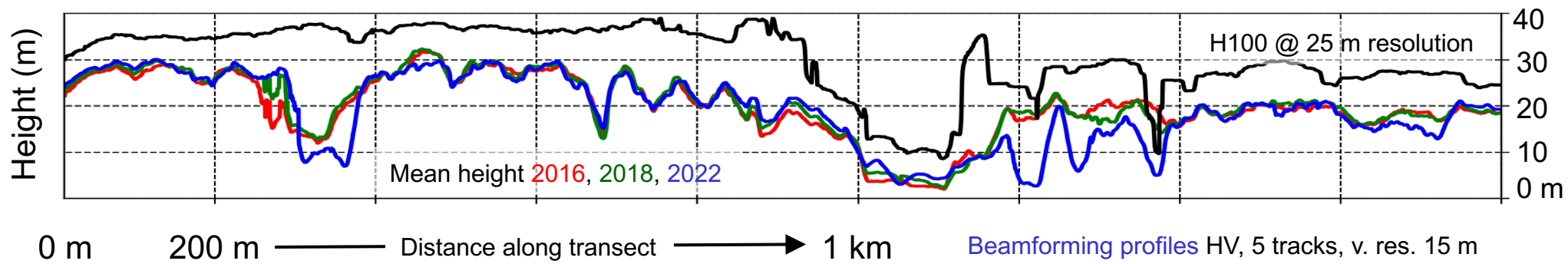
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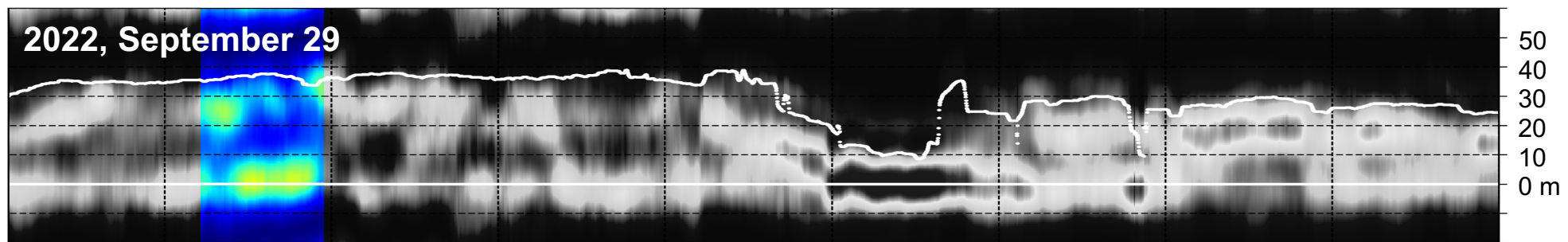
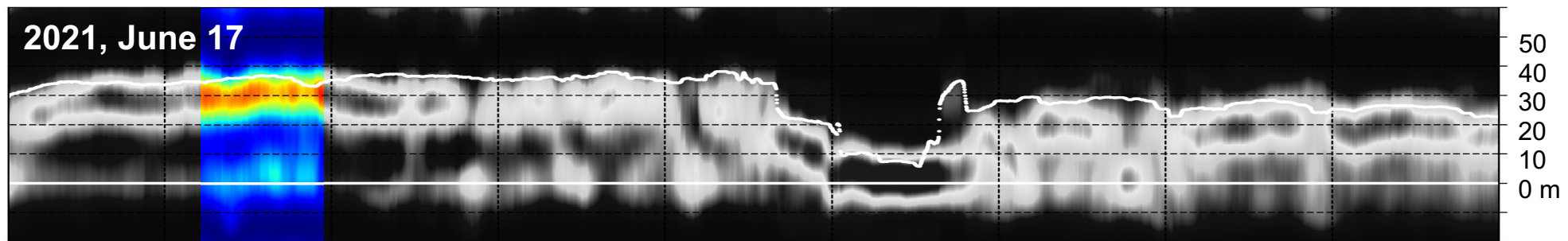
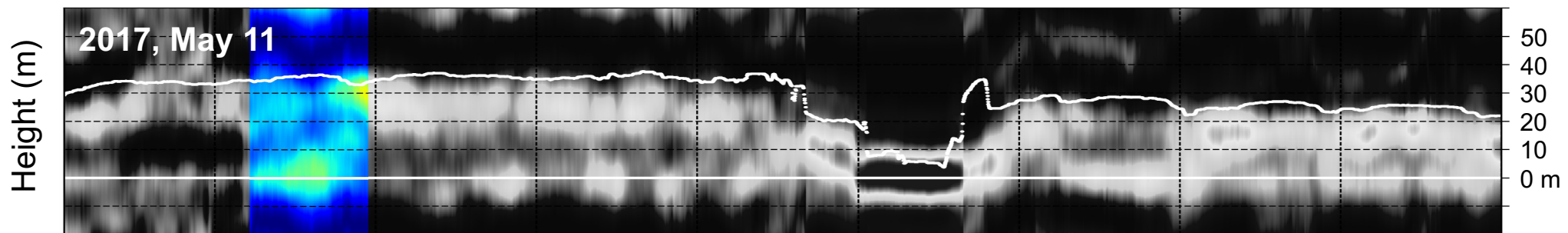
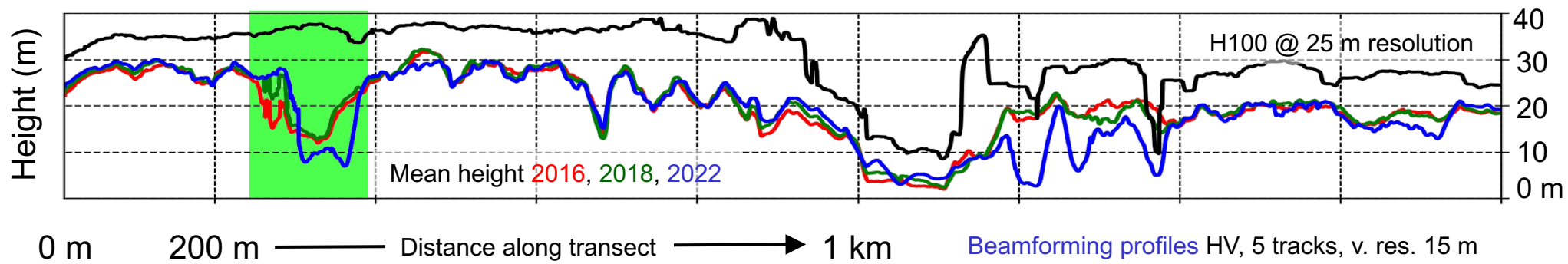


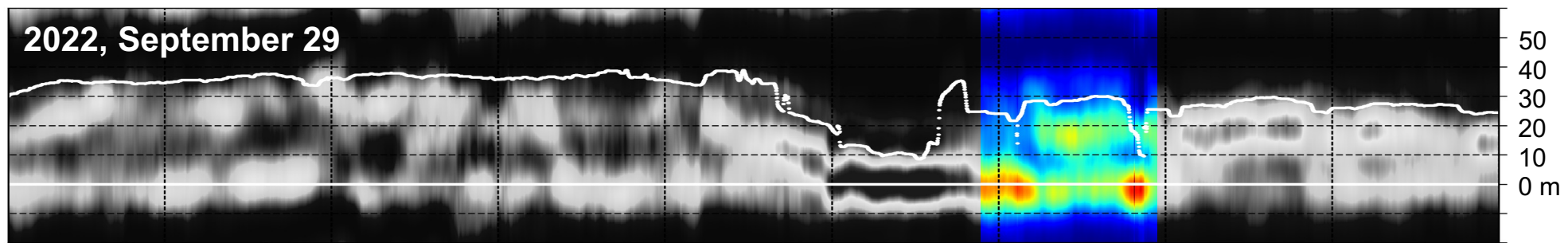
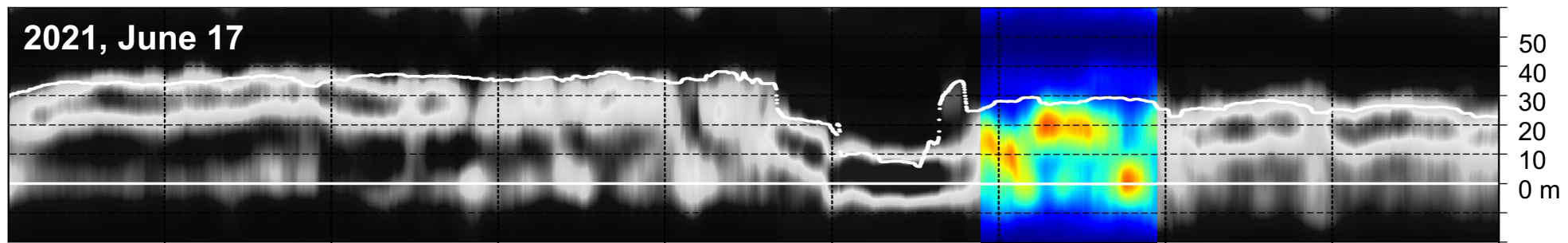
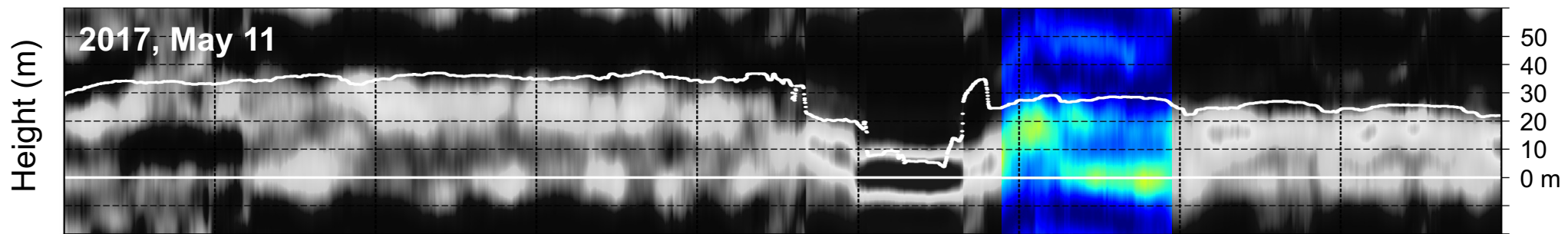
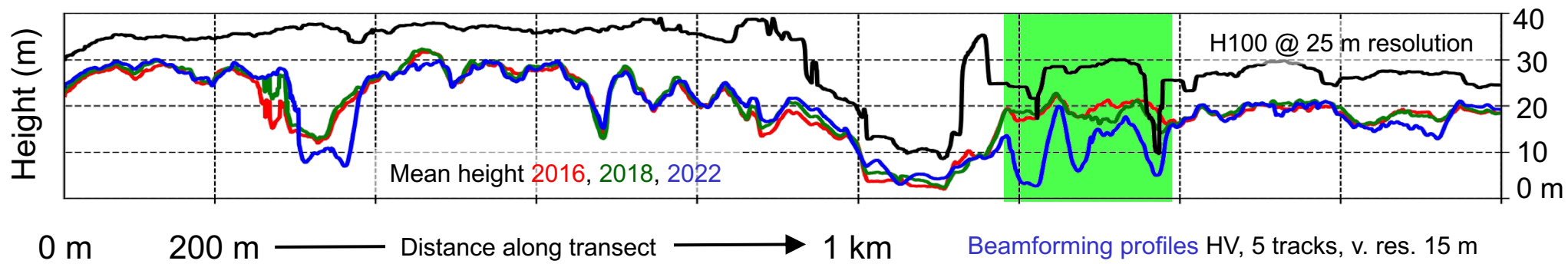
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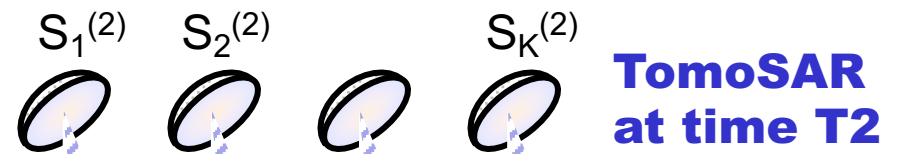












TomoSAR coherence matrix at T1: $[R^{(1)}]$

TomoSAR coherence matrix at T2: $[R^{(2)}] = [R^{(1)}] + \Delta$

Eigen-decomposition of the change matrix Δ into contributions in orthogonal directions:

$$[\Delta] = \begin{bmatrix} | & & | \\ \vec{v}_1 & \dots & \vec{v}_k \\ | & & | \end{bmatrix} \cdot \begin{bmatrix} \lambda_1 & & \\ & \ddots & \\ & & \lambda_k \end{bmatrix} \cdot \begin{bmatrix} - & \vec{v}_1^{*T} & - \\ \vdots & & \vdots \\ - & \vec{v}_k^{*T} & - \end{bmatrix} = \sum_{k=1}^K \lambda_k \cdot \vec{v}_k \vec{v}_k^{*T}$$

Beamforming reconstruction at T2:

$$P^{(2)}(z) = \vec{a}^{*T}(z) \cdot [R^{(1)}] \cdot \vec{a}(z) + \vec{a}^{*T}(z) \cdot [\Delta] \cdot \vec{a}(z)$$

$$= P^{(1)}(z) + \sum_{k=1}^K \lambda_k \cdot \vec{a}^{*T}(z) \cdot \vec{v}_k \vec{v}_k^{*T} \cdot \vec{a}(z) = P^{(1)}(z) + \sum_{k=1}^K \lambda_k \cdot P_{vk}(z)$$

$\lambda_k > 0$: contribution added from T₁ to T₂
 $\lambda_k = 0$: contribution not changing from T₁ to T₂
 $\lambda_k < 0$: contribution removed from T₁ to T₂





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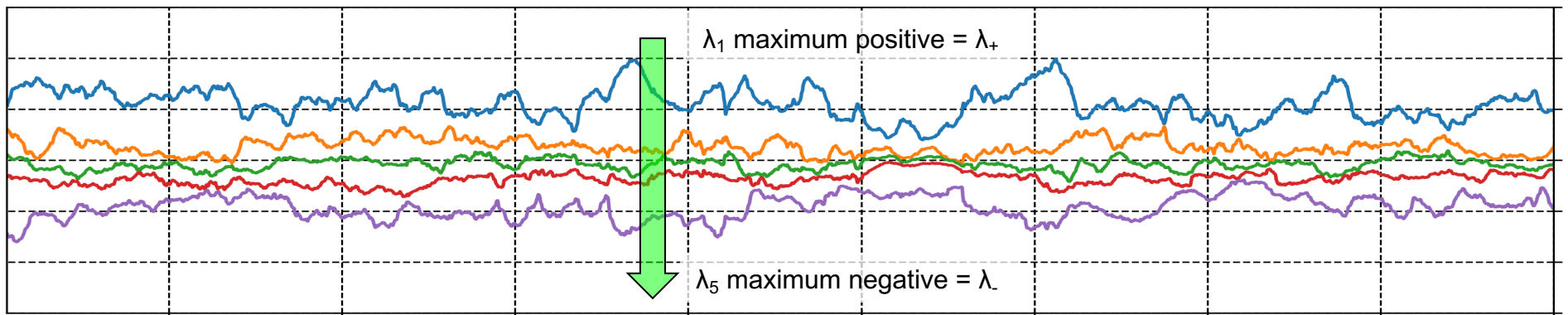
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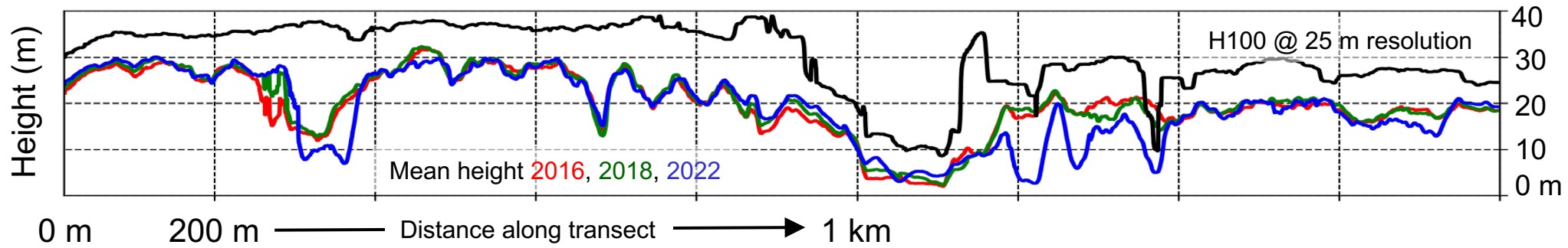
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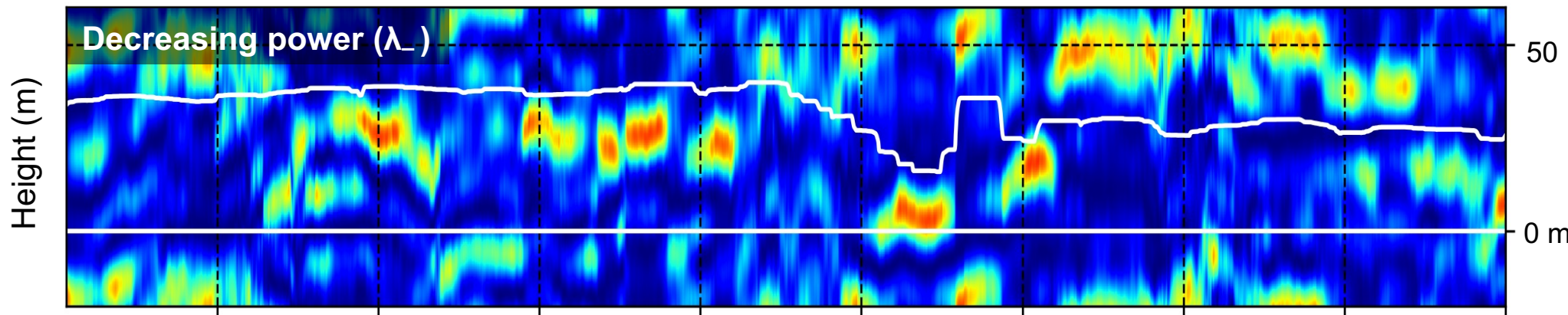
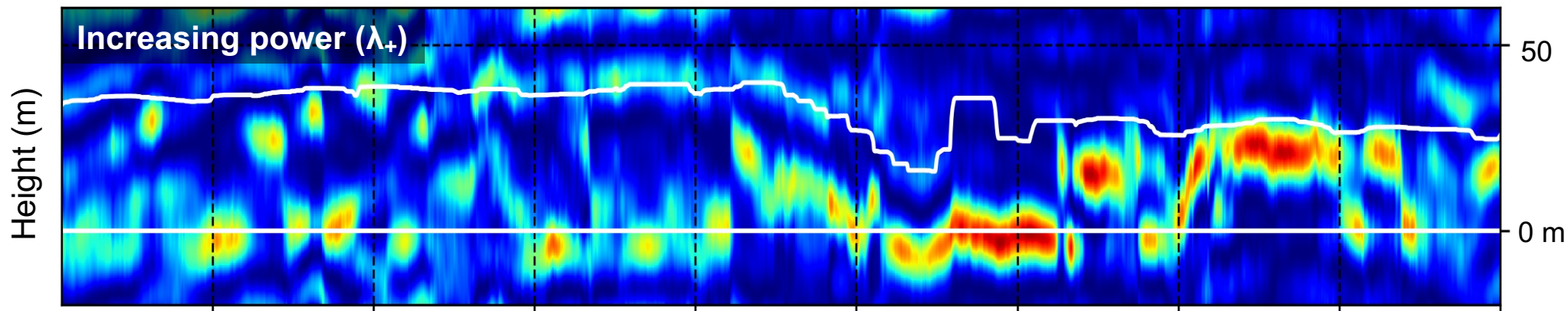
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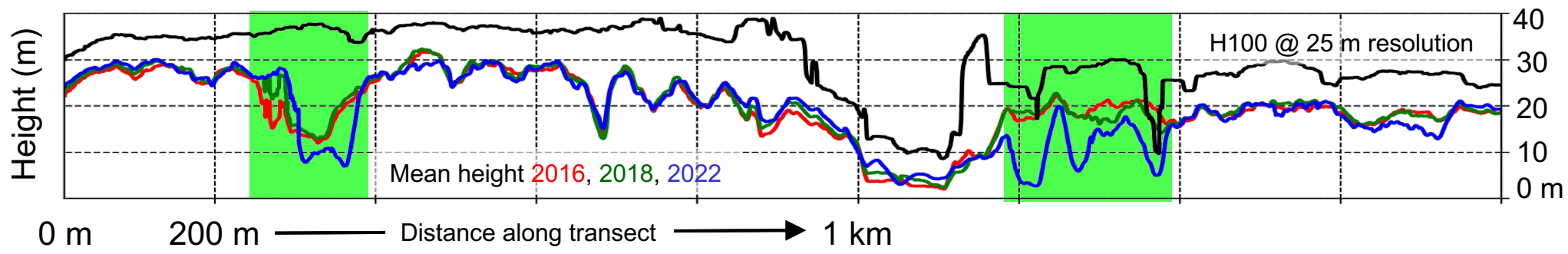
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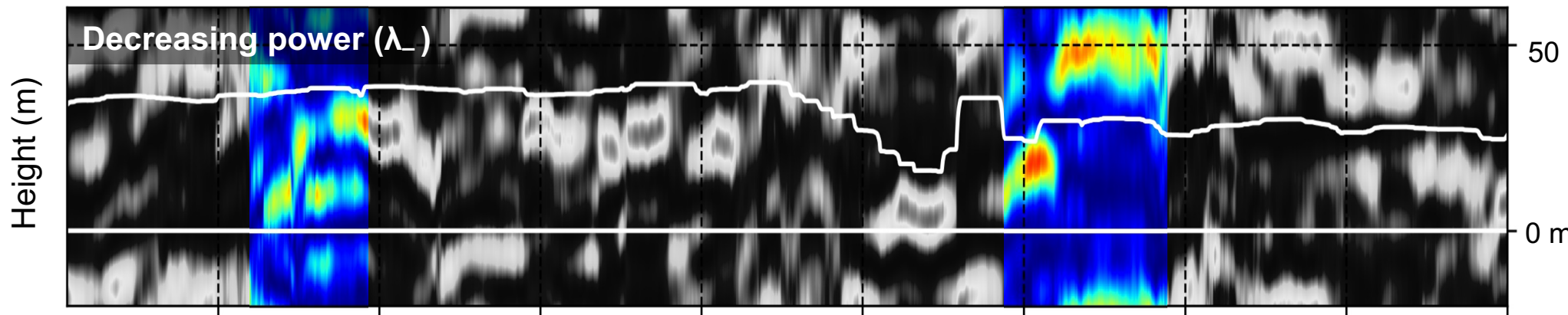
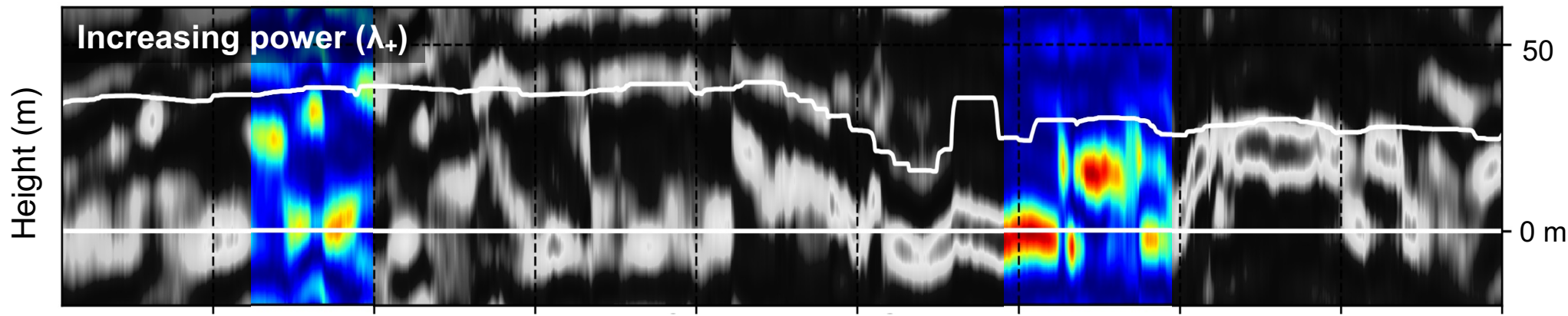


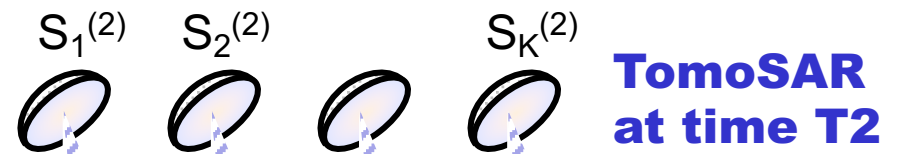
2017, May 11 → 2022, September 29





2017, May 11 → 2022, September 29





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Beamforming reconstruction at T2: $P^{(2)}(z) = P^{(1)}(z) + \sum_{k=1}^K \lambda_k \cdot P_{vk}(z) \cong P^{(1)}(z) + \lambda_+ \cdot P_{v_+}(z) + \lambda_- \cdot P_{v_-}(z)$

Further approximation: $\vec{v}_+ \approx \vec{a}(z_+)$, $\vec{v}_- \approx \vec{a}(z_-)$

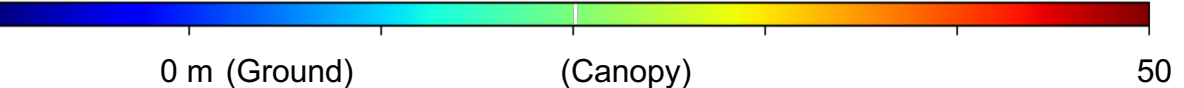
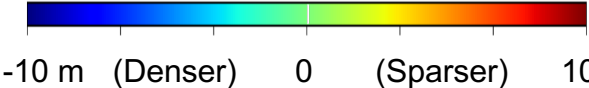
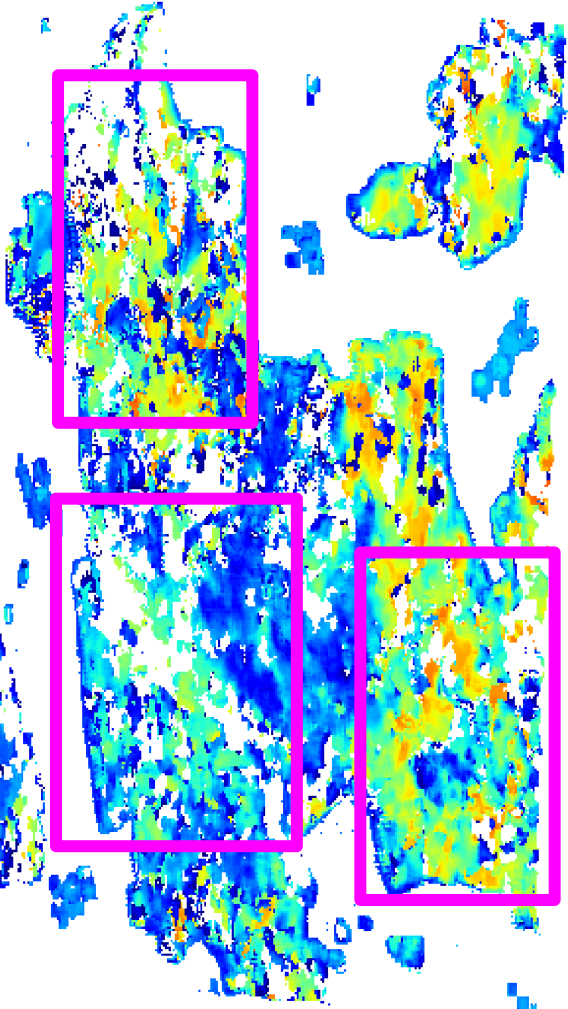
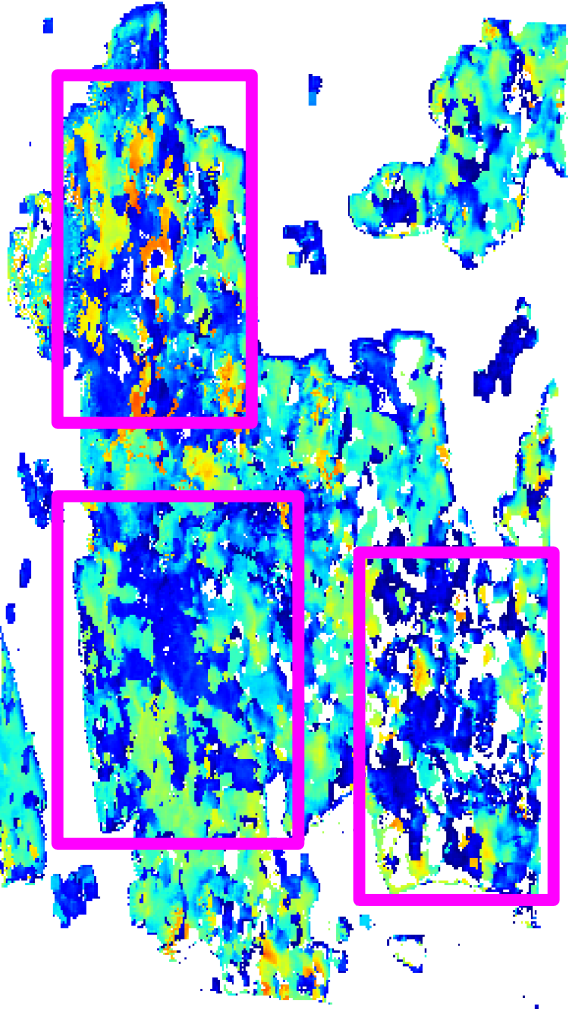
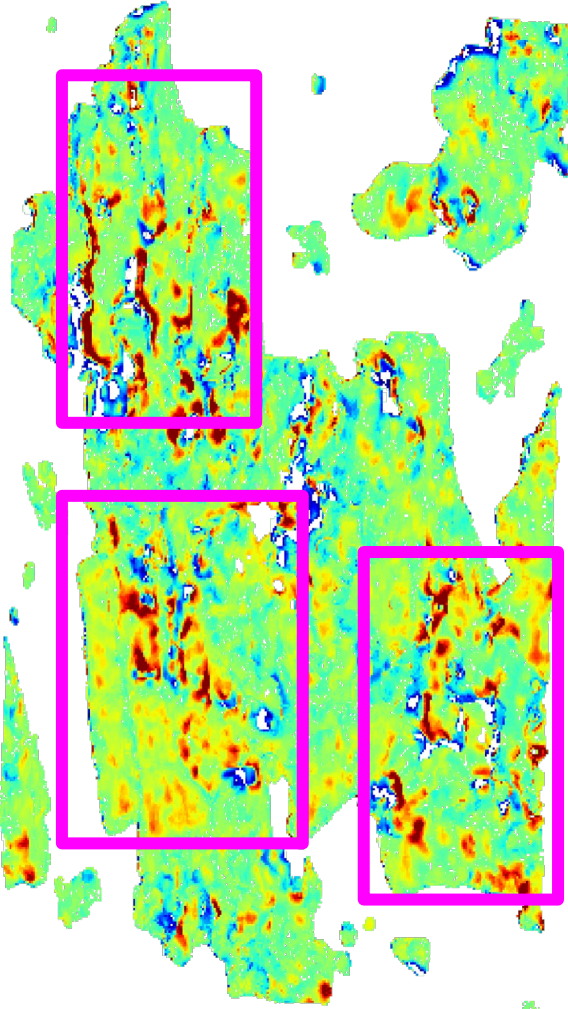
Steering vectors (= Dirac- δ profiles) calculated for two phase center heights z_+ and z_-

Heights of TomoSAR changes, 2017-2022

Change of difference between H100 and mean height

Increasing power (z^+)

Decreasing power (z^-)

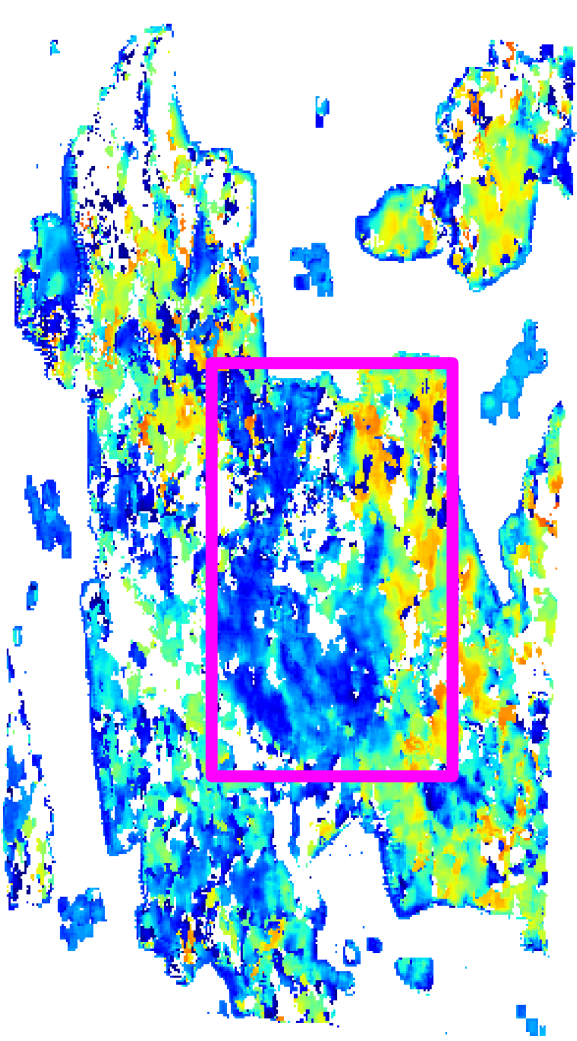
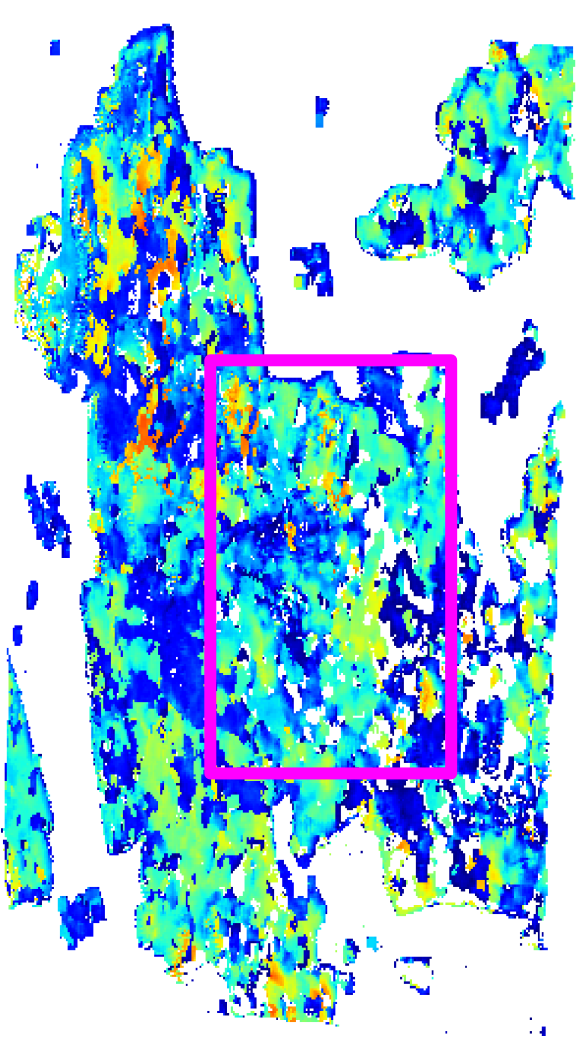
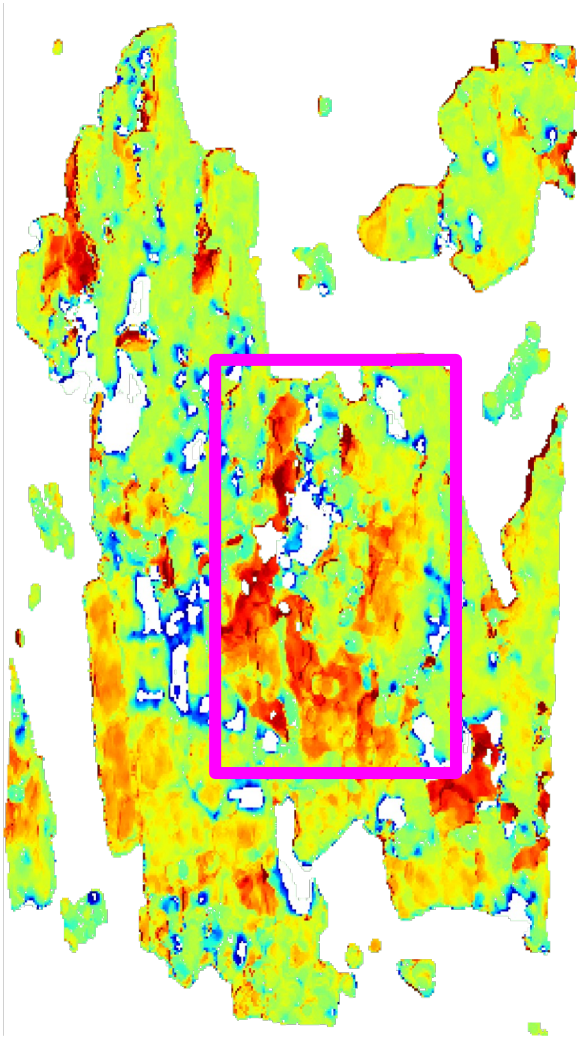


Heights of TomoSAR changes, 2017-2022

Change of H100

Increasing power (z^+)

Decreasing power (z^-)



-6 m (Clear / thin) 0 (Growth) 6

0 m (Ground) (Canopy)

50

Changes of the TomoSAR ground-to-volume (G2V) ratio

2017, May 11

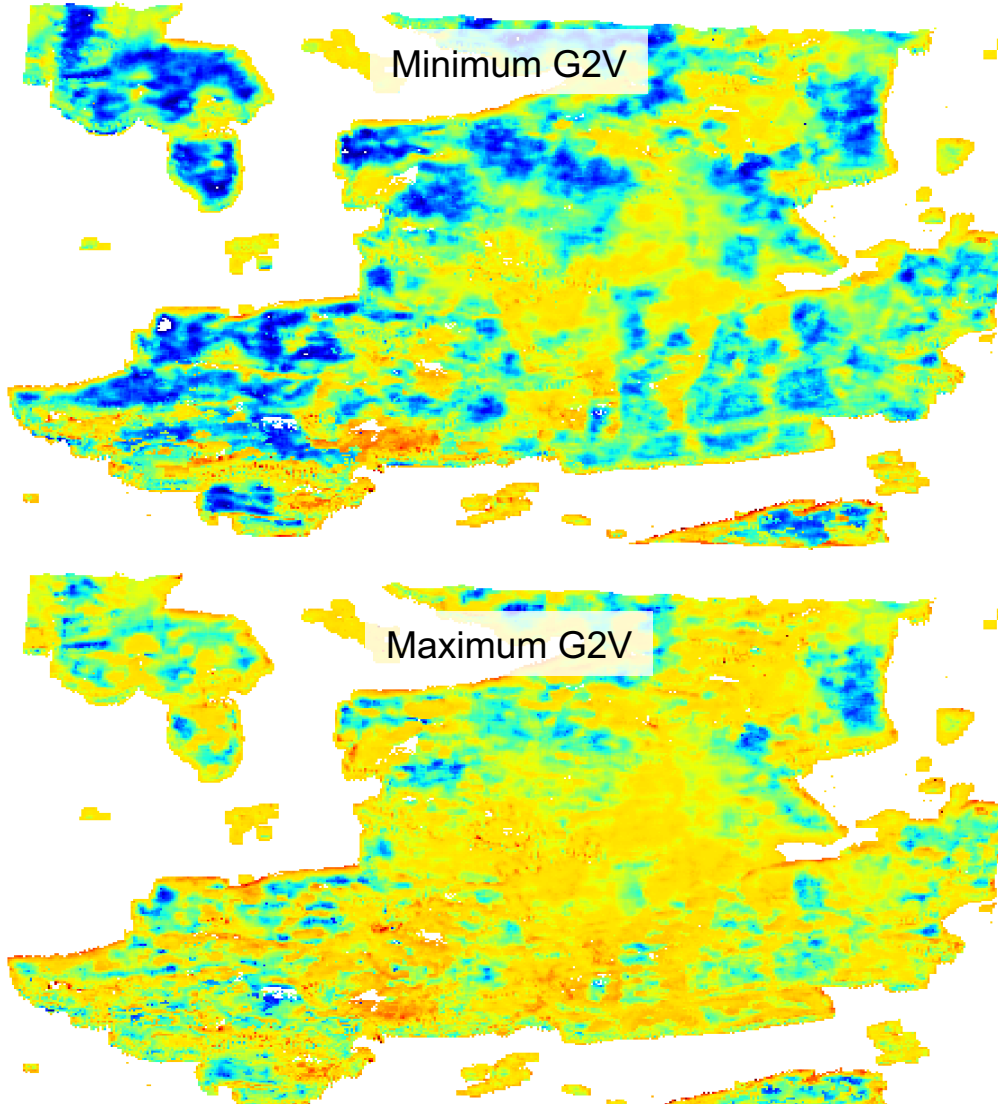
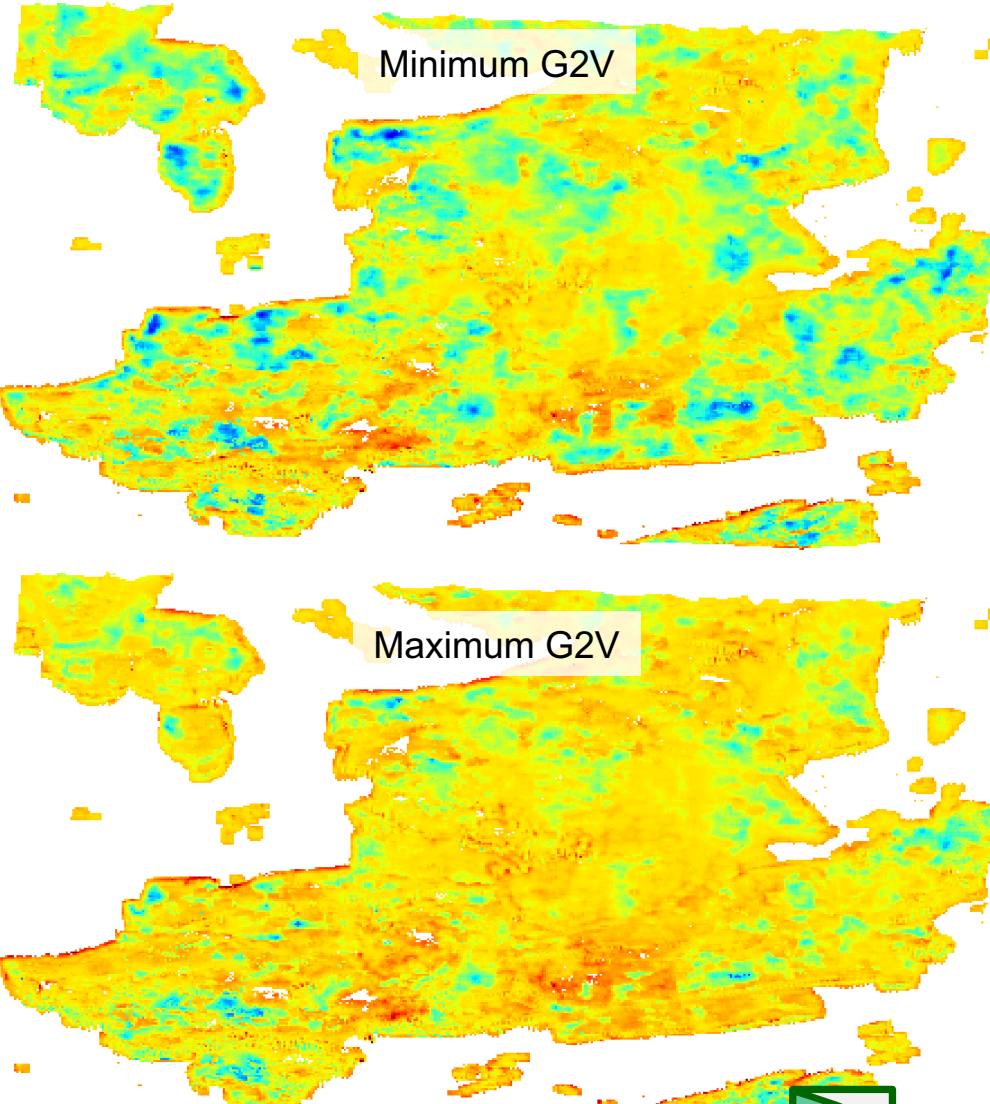
Minimum G2V

Maximum G2V

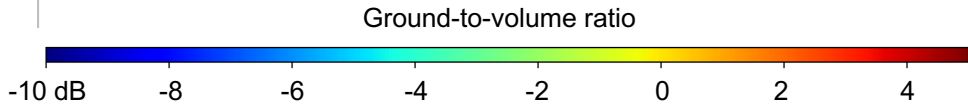
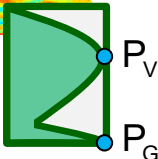
2021, June 17

Minimum G2V

Maximum G2V

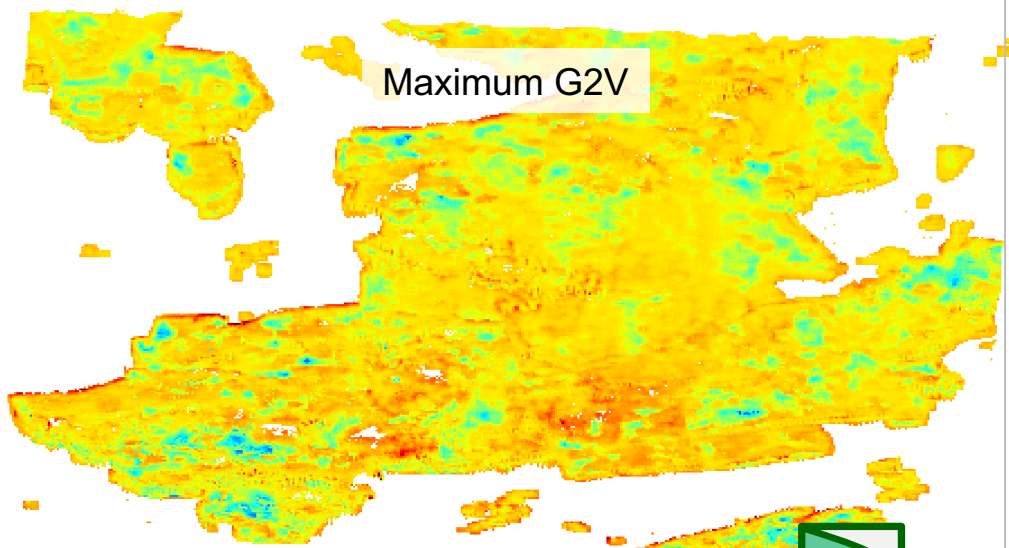
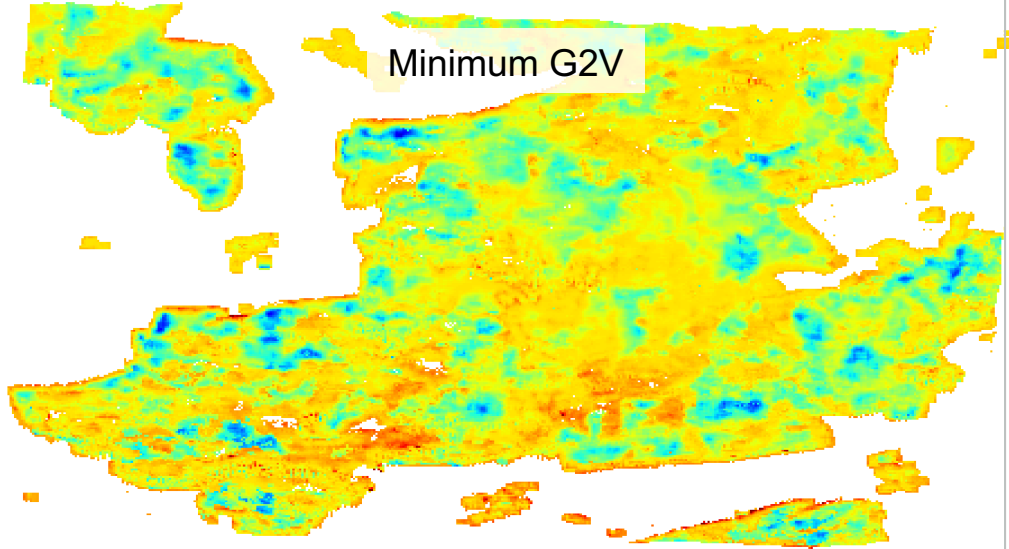


$$G2V = \frac{P_G}{P_V}$$

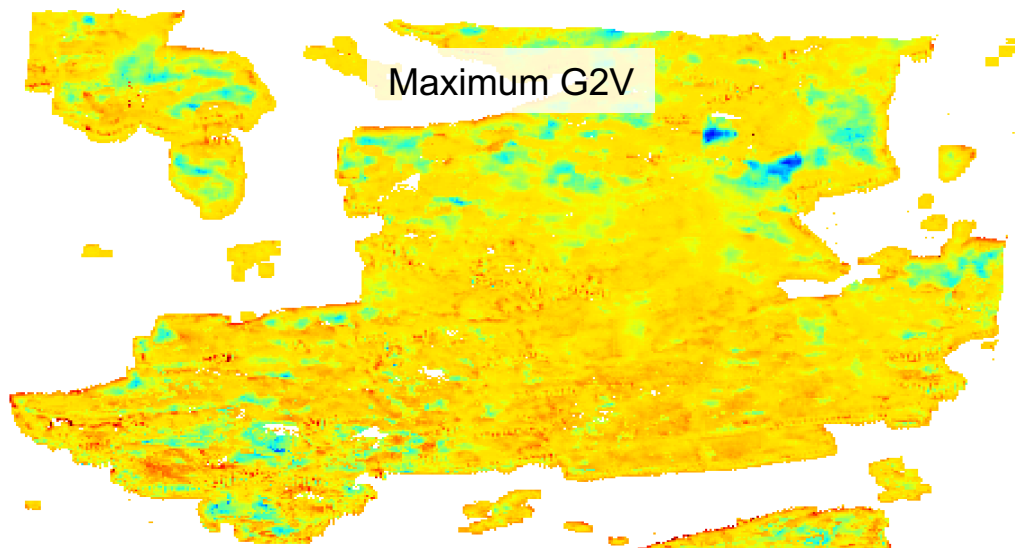
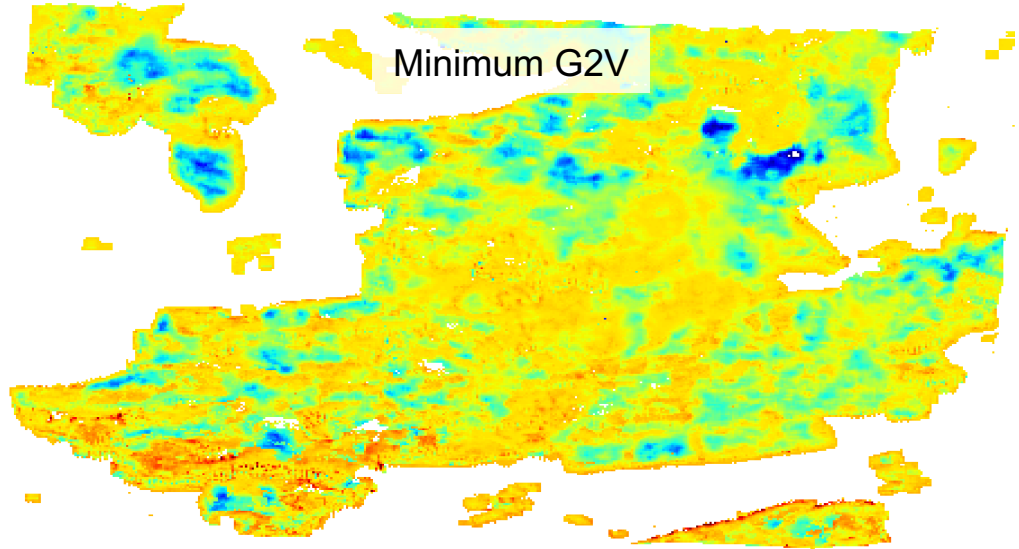


Changes of the TomoSAR ground-to-volume (G2V) ratio

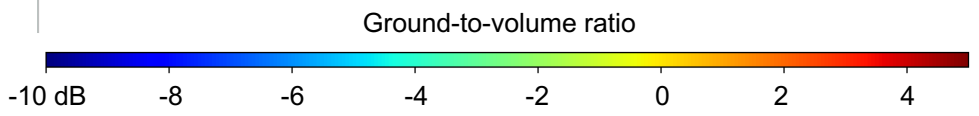
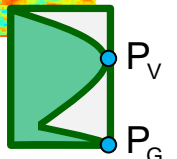
2017, May 11



2022, September 29



$$G2V = \frac{P_G}{P_V}$$



Conclusions

- Case study: 7-year change in the Traunstein forest.
- Structural changes are reflected in TomoSAR profiles at different times, together with seasonal ones.
- The analysis was supported by an eigen-based framework to interpret profile changes in terms of amplified / attenuated scattering contributions.
- The potential: locate 3D changes even with just TomoSAR + InSAR configurations.
- The challenges: separation between structural and dielectric changes, especially without systematic acquisitions in time.
- One perspective: Investigate change of Pol-InSAR parameters together with profiles / heights. Here: min / max G2V ratio across polarimetric channels.
- Not (yet) understood: How strong should be a change to be actually seen in TomoSAR / InSAR measurements, and in which way it could effect them.



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