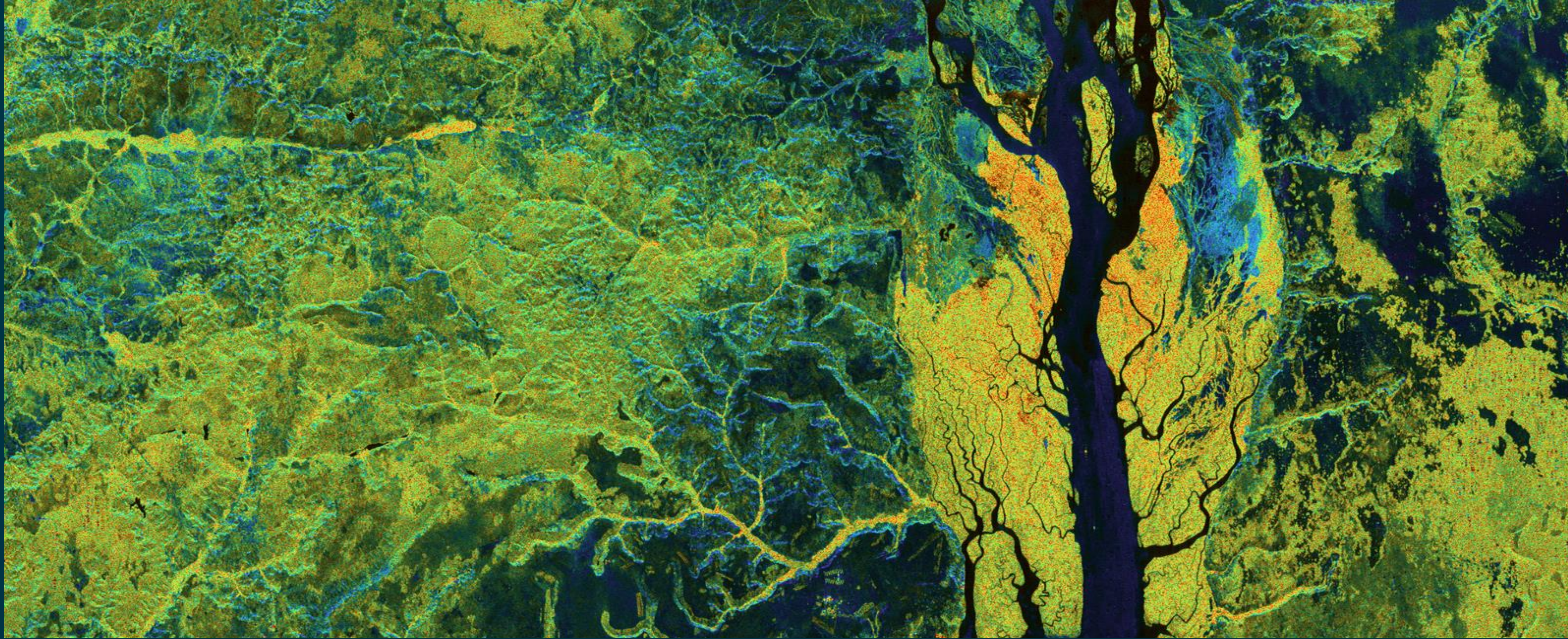
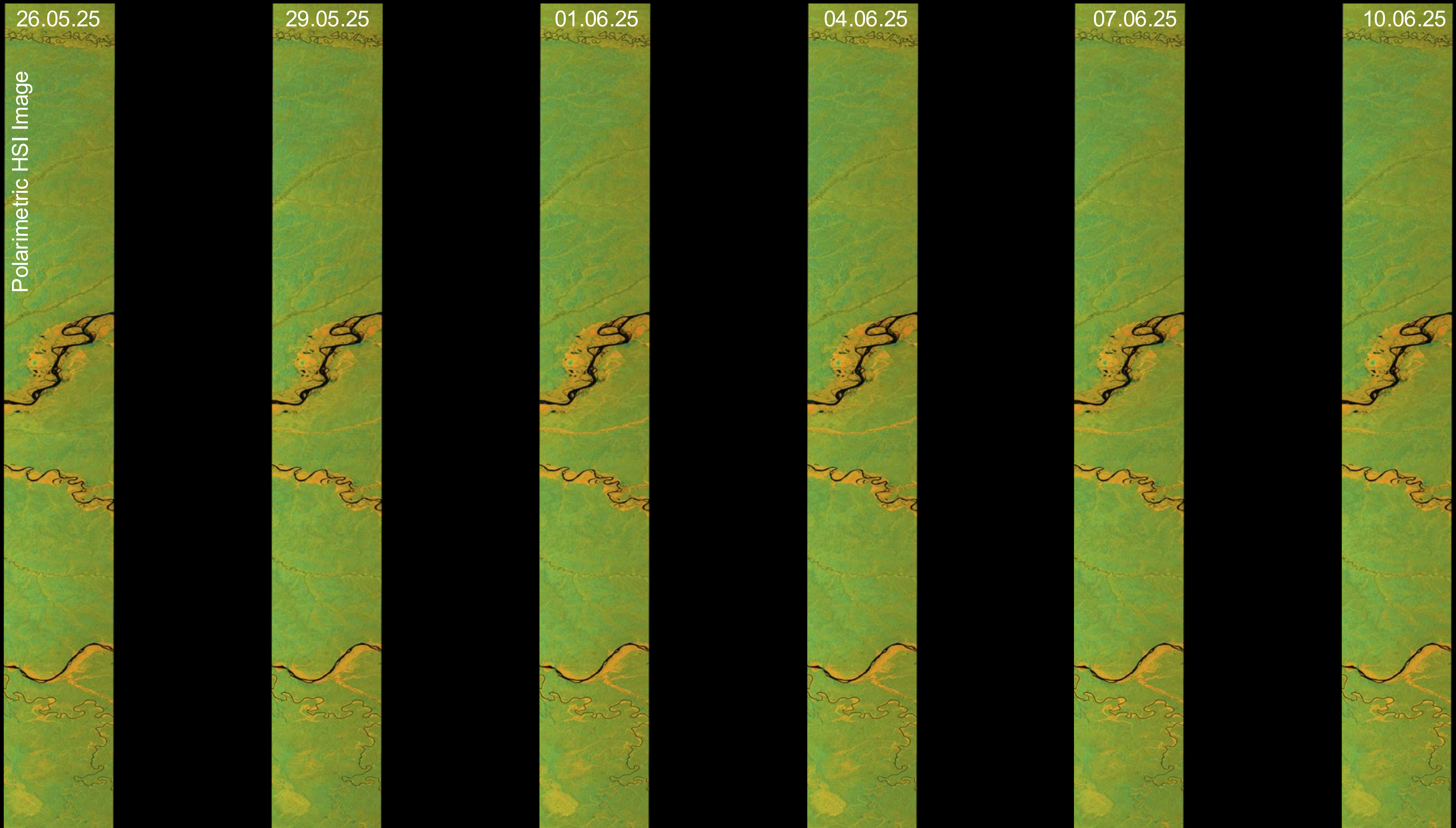
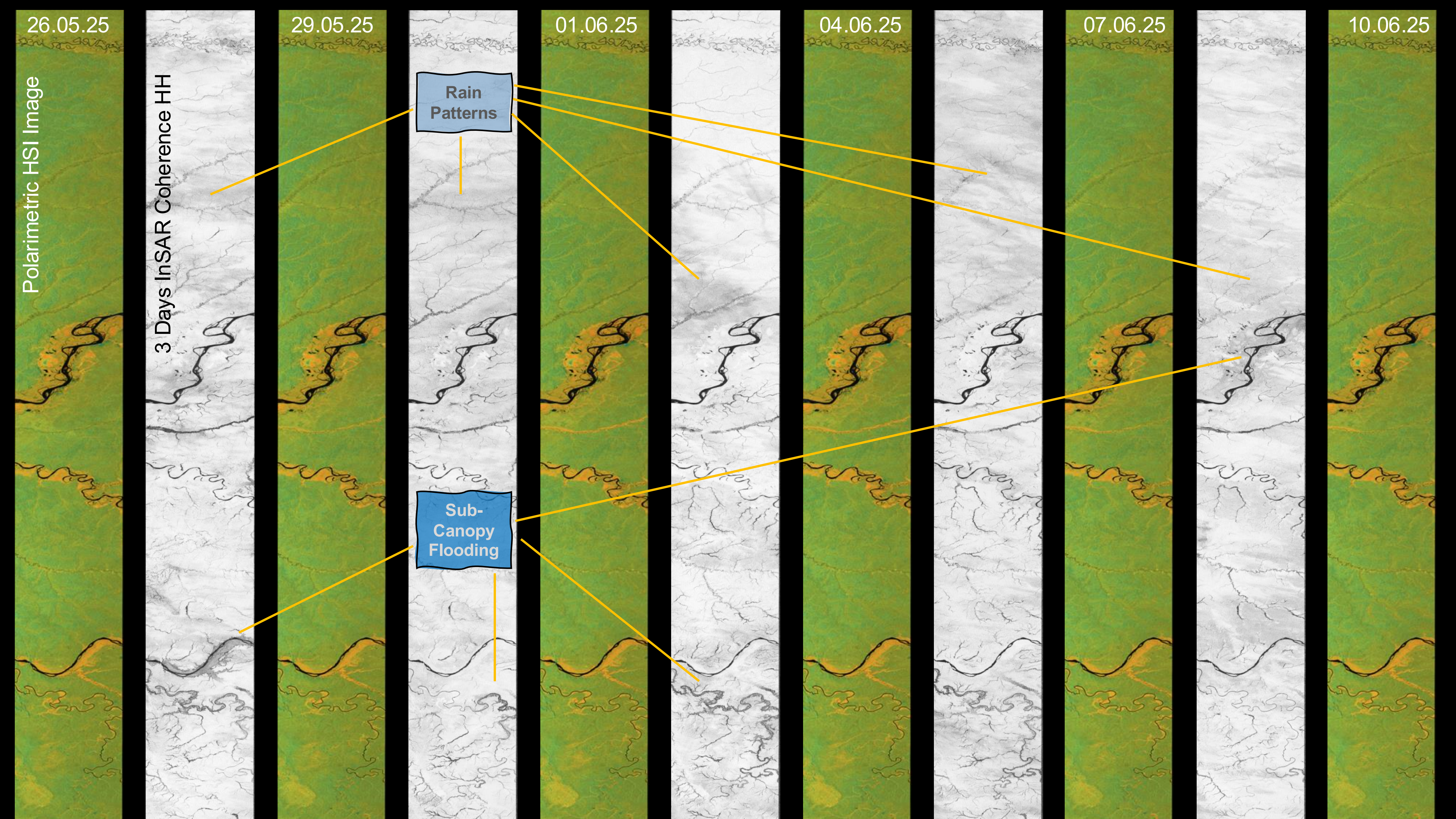


Polarimetric Effects in P-band Interferometric Phase Triplets

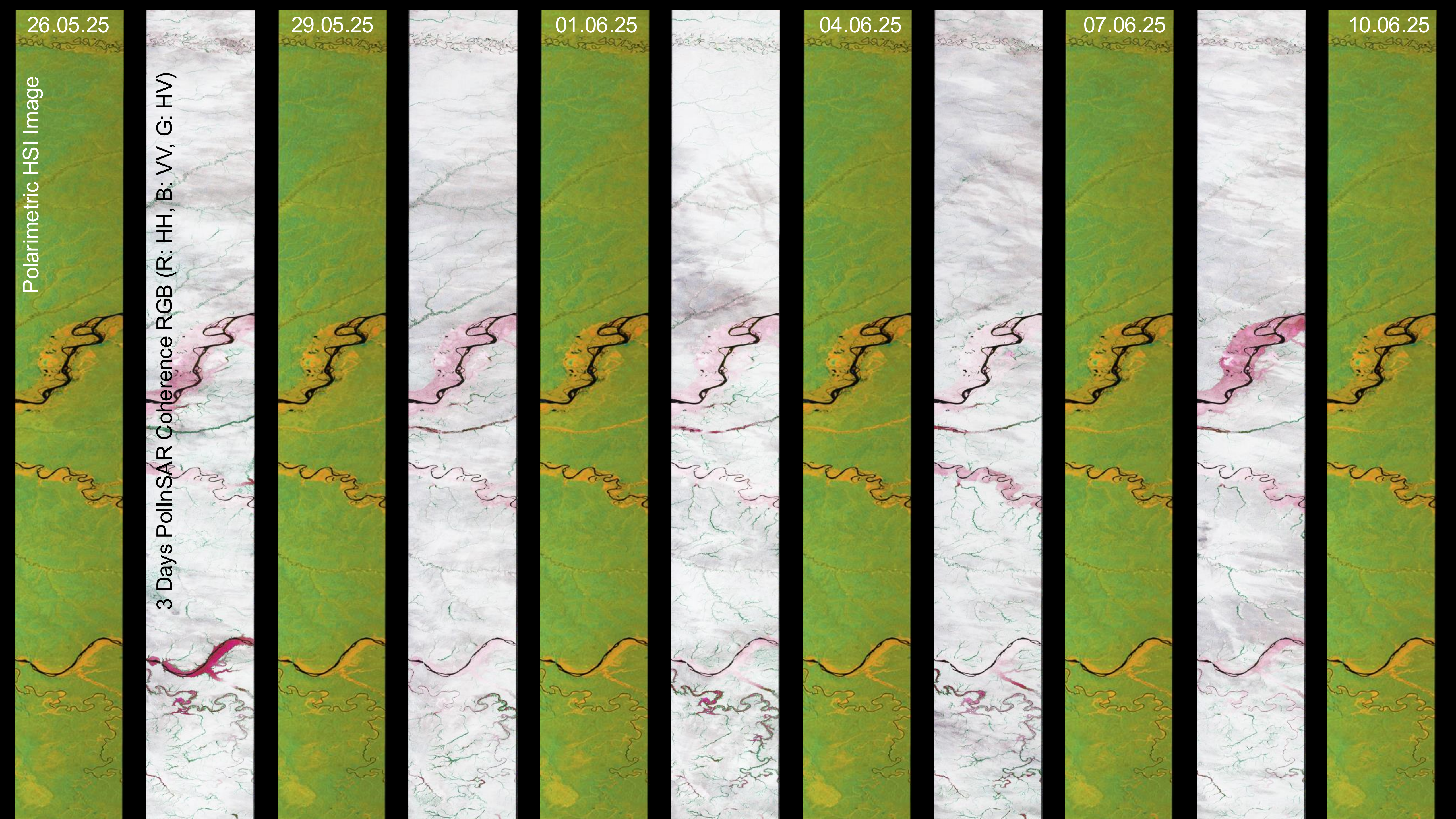
Noelia Romero-Puig, Pau Iraola Prats, Irena Hajnsek, Kostas Papathanassiou

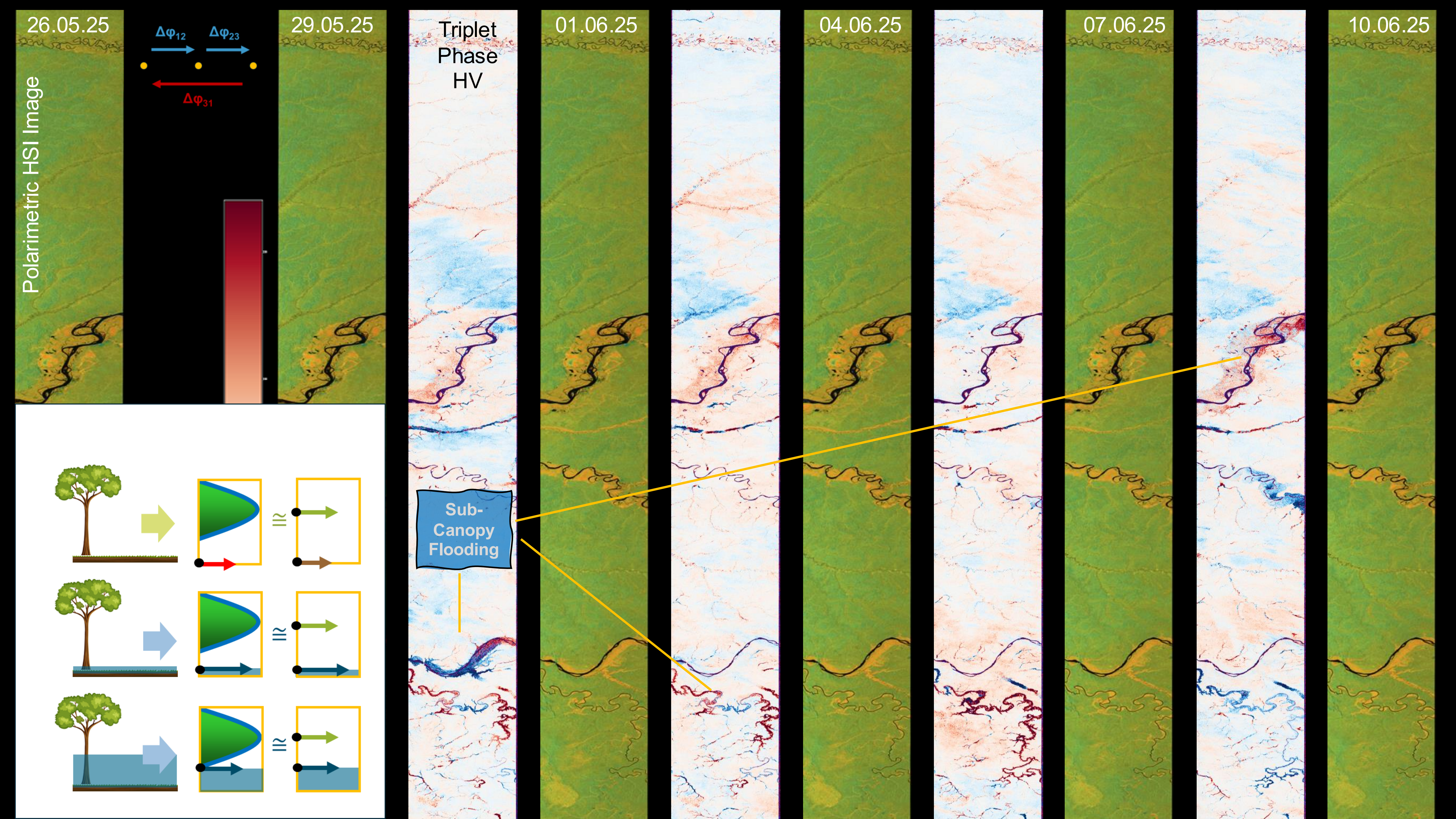
German Aerospace Center (DLR), Microwaves and Radar Institute (DLR-HR)


26.05.25
29.05.25
01.06.25
04.06.25
07.06.25
10.06.25
Polarimetric HSI Image

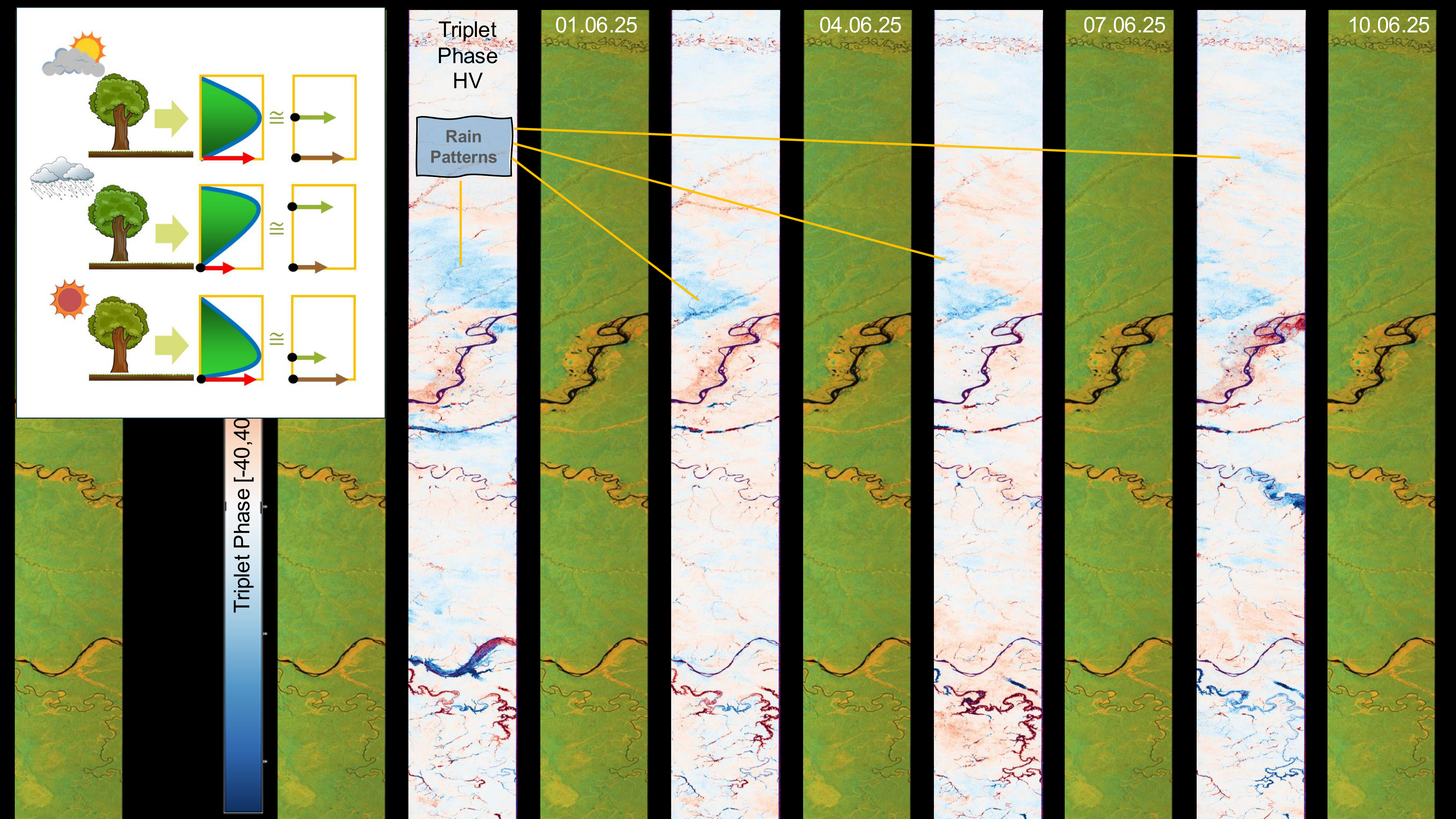


26.05.25
29.05.25
01.06.25
04.06.25
07.06.25
10.06.25
Polarimetric HSI Image
3 Days InSAR Coherence HH
Rain Patterns
Sub-Canopy Flooding

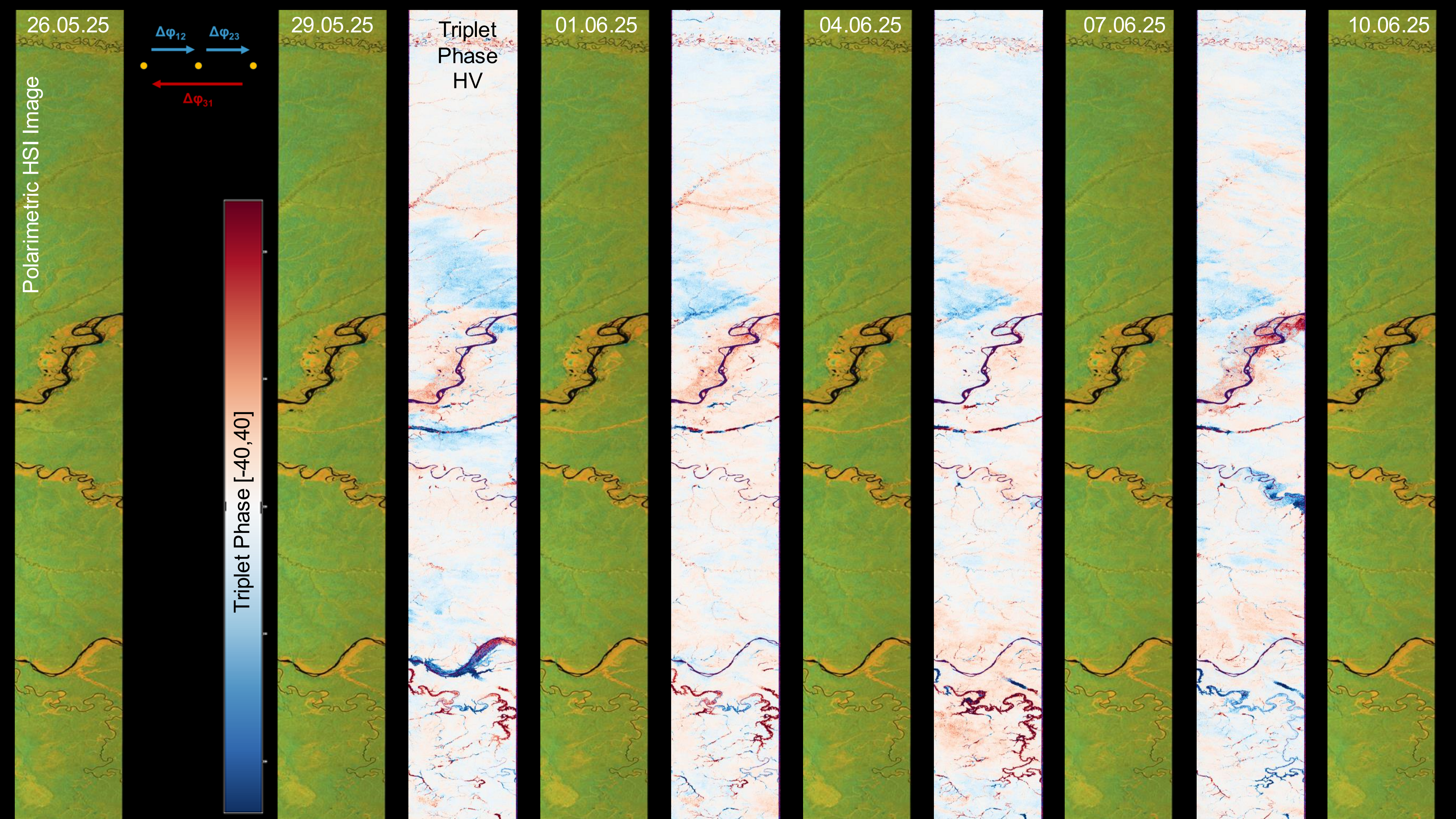

26.05.25
29.05.25
01.06.25
04.06.25
07.06.25
10.06.25
Polarimetric HSI Image
3 Days PolInSAR Coherence RGB (R: HH, B: VV, G: HV)



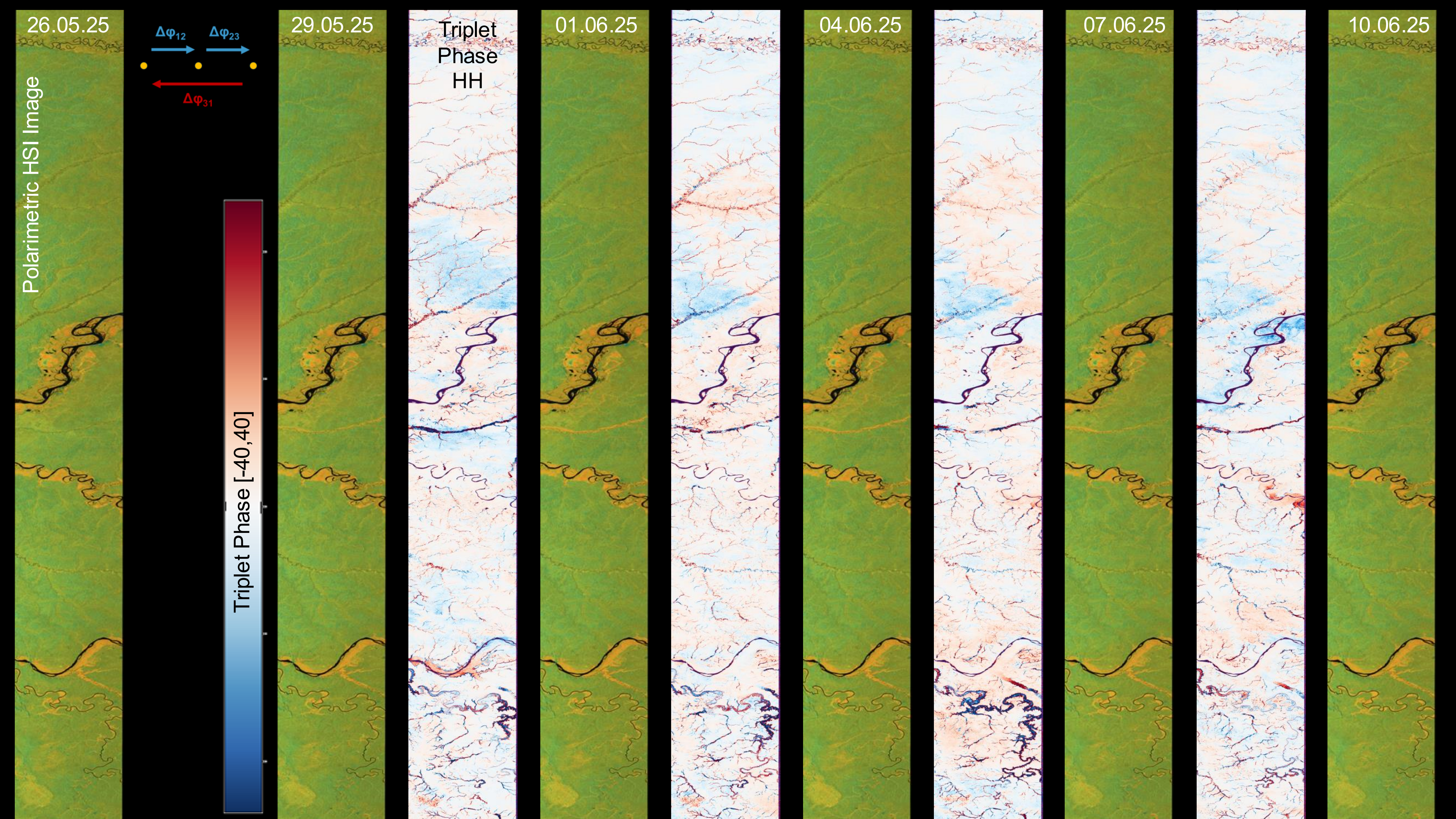
26.05.25
29.05.25
Triplet Phase HV
01.06.25
04.06.25
07.06.25
10.06.25
Polarimetric HSI Image
Δφ12
Δφ23
Δφ31
Sub-Canopy Flooding
≅
≅
≅



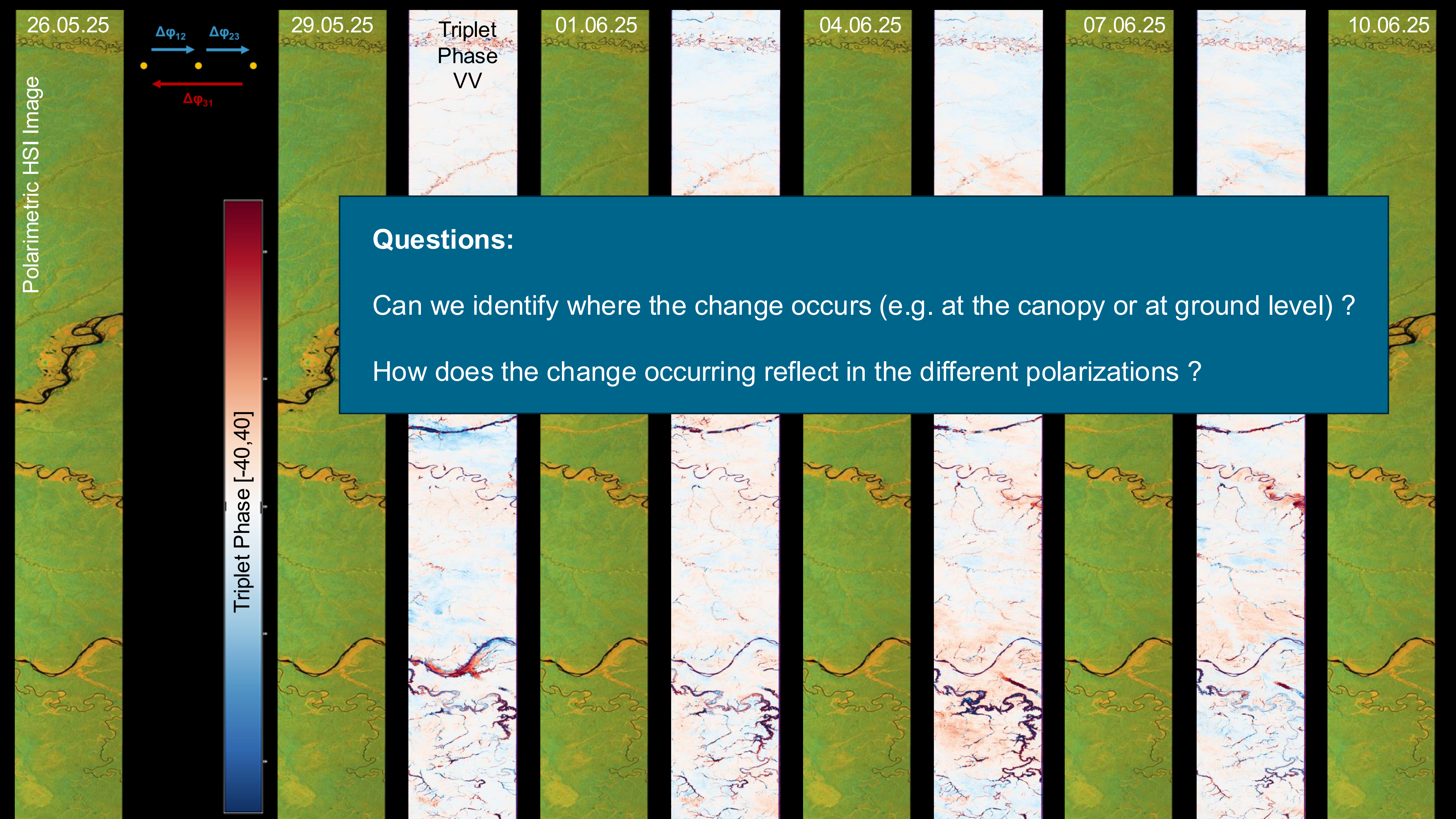
Triplet Phase HV
01.06.25
04.06.25
07.06.25
10.06.25
Rain Patterns
Triplet Phase [-40,40



Polarimetric HSI Image
26.05.25
$\Delta\varphi_{12}$
$\Delta\varphi_{23}$
$\Delta\varphi_{31}$
Triplet Phase [-40,40]
29.05.25
Triplet Phase HV
01.06.25
04.06.25
07.06.25
10.06.25



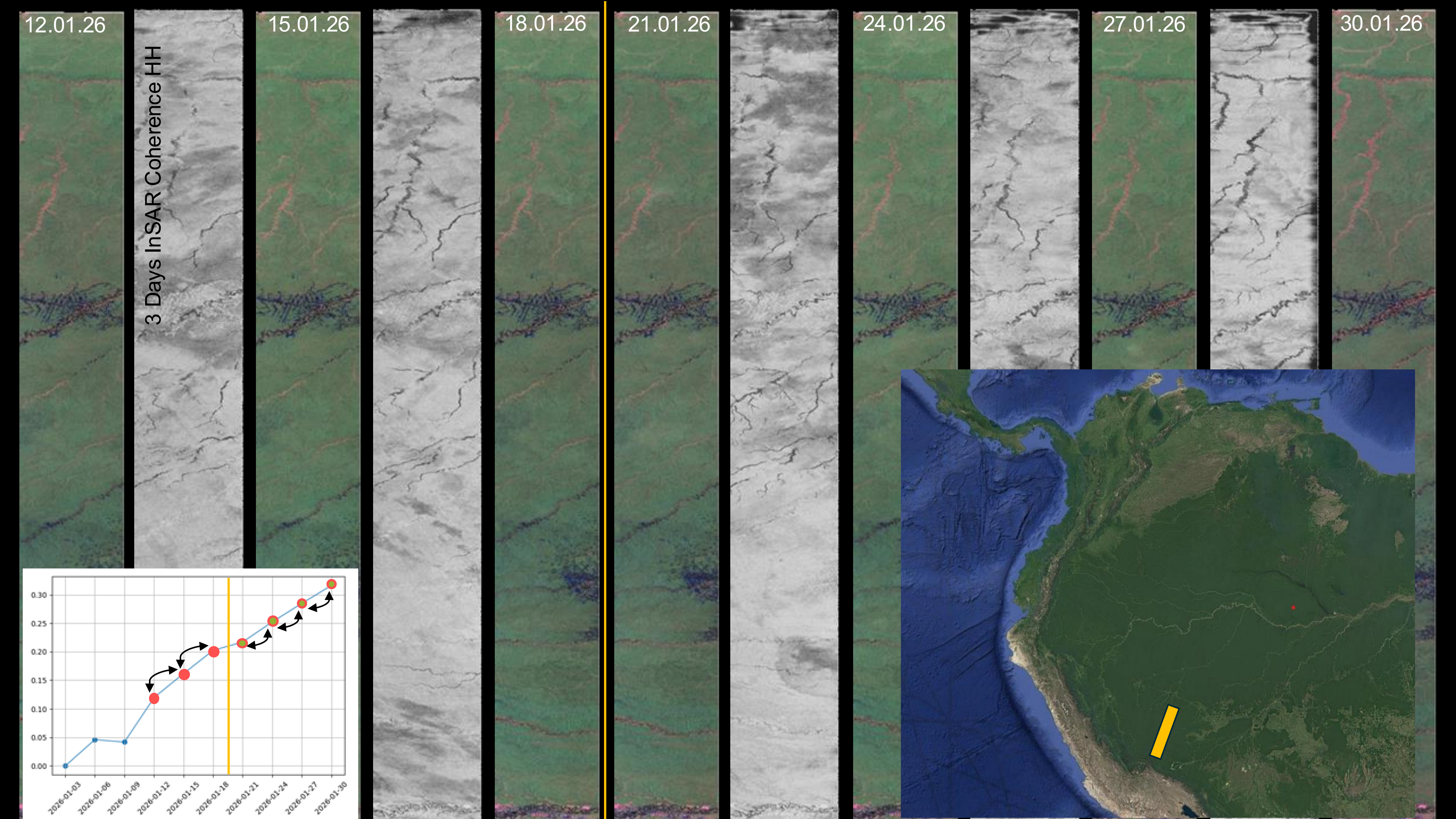
26.05.25
Polarimetric HSI Image
Δφ12
Δφ23
Δφ31
Triplet Phase [-40,40]
29.05.25
Triplet
Phase
HH
01.06.25
04.06.25
07.06.25
10.06.25

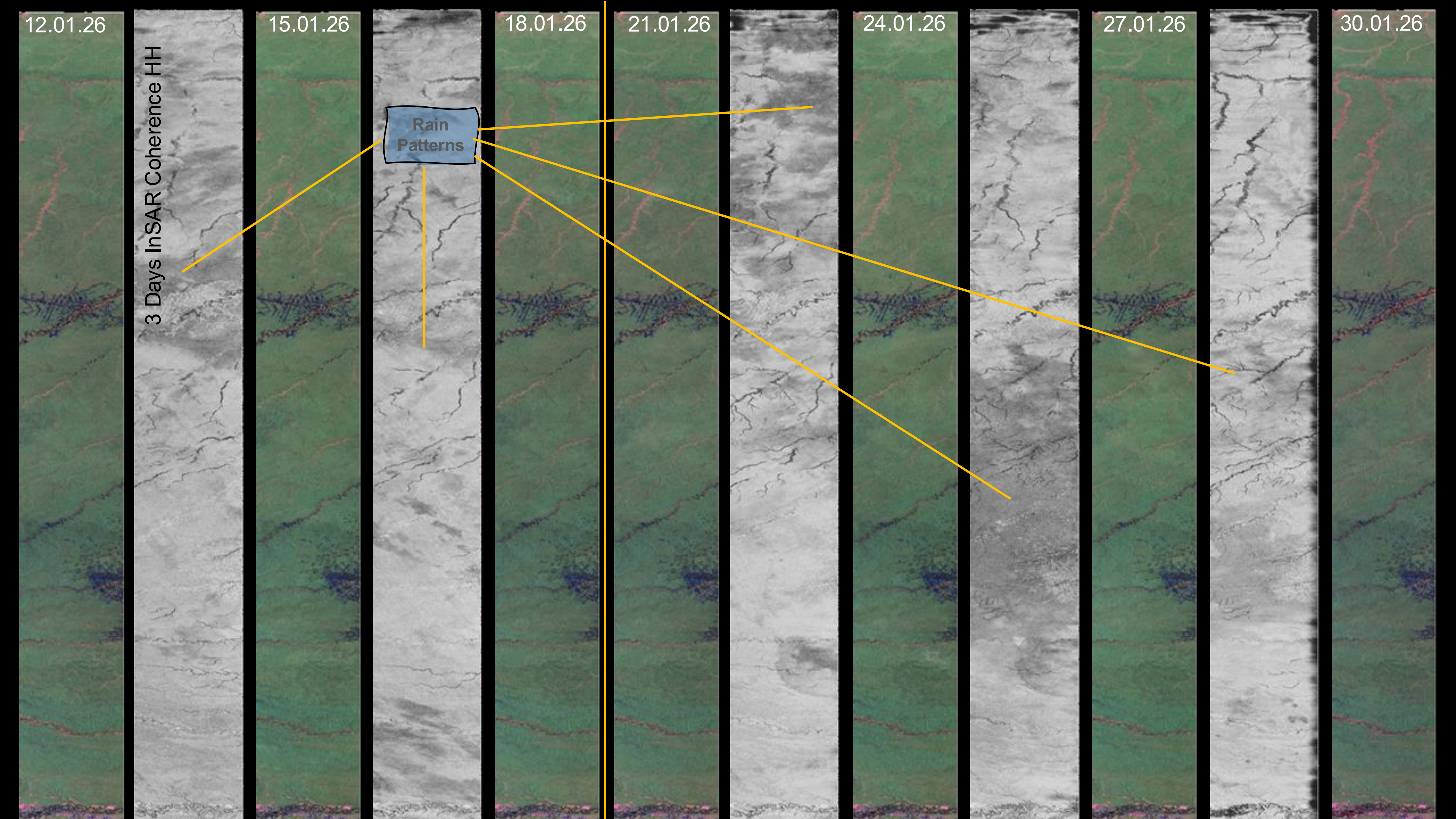


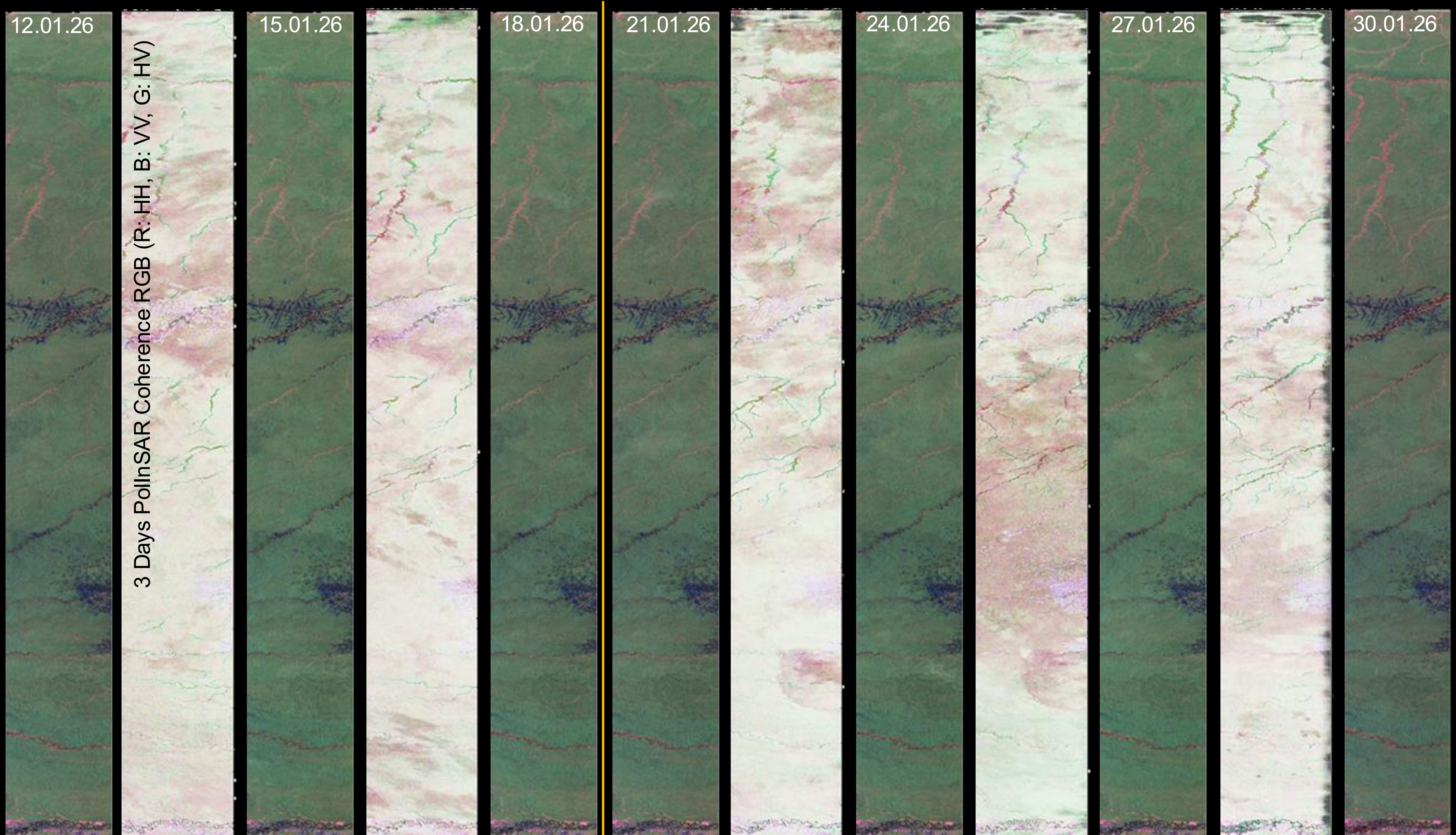
Questions:

Can we identify where the change occurs (e.g. at the canopy or at ground level) ?

How does the change occurring reflect in the different polarizations ?

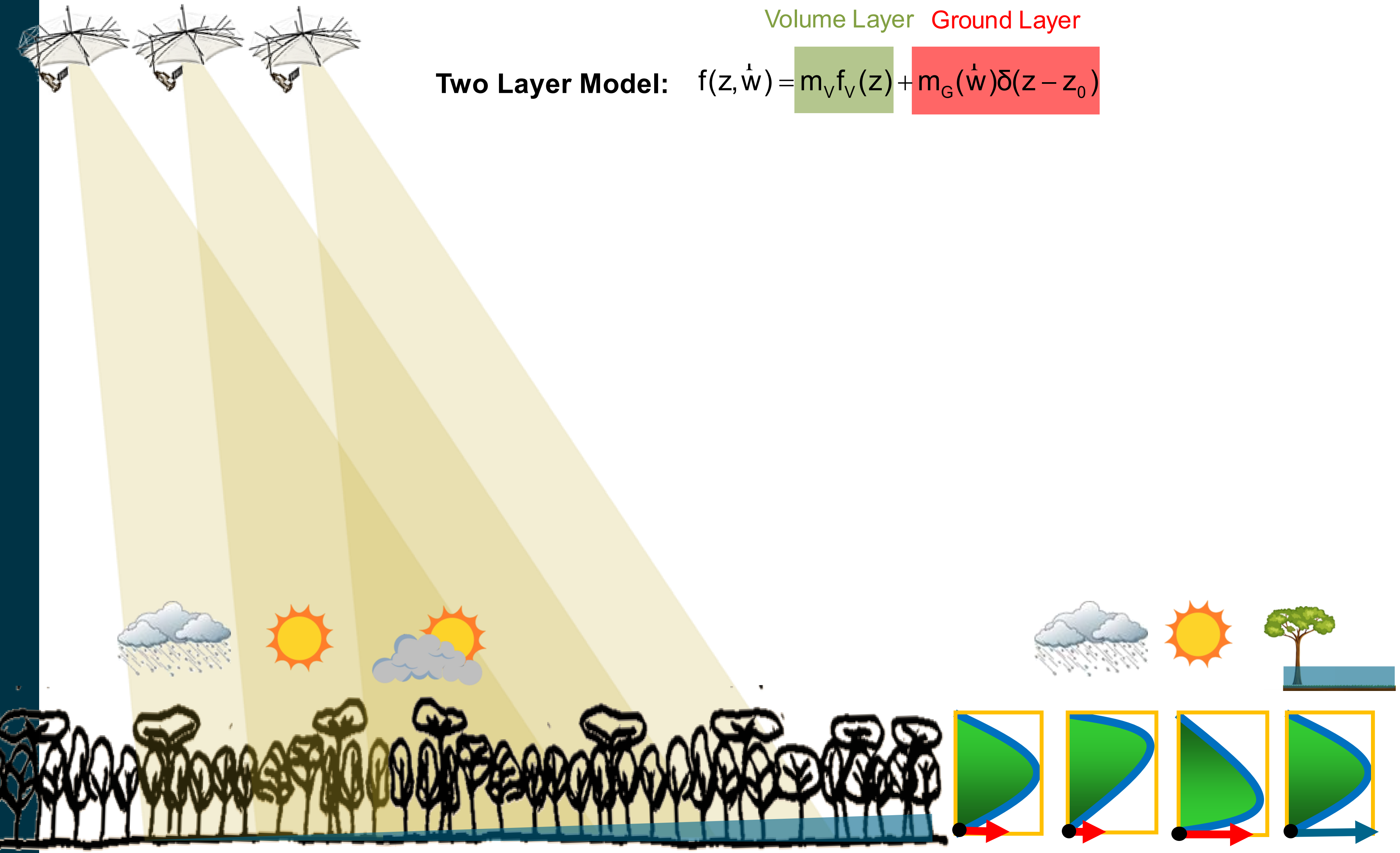

12.01.26
3 Days InSAR Coherence HH
15.01.26
18.01.26
21.01.26
24.01.26
27.01.26
30.01.26
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2026-01-03
2026-01-06
2026-01-09
2026-01-12
2026-01-15
2026-01-18
2026-01-21
2026-01-24
2026-01-27
2026-01-30

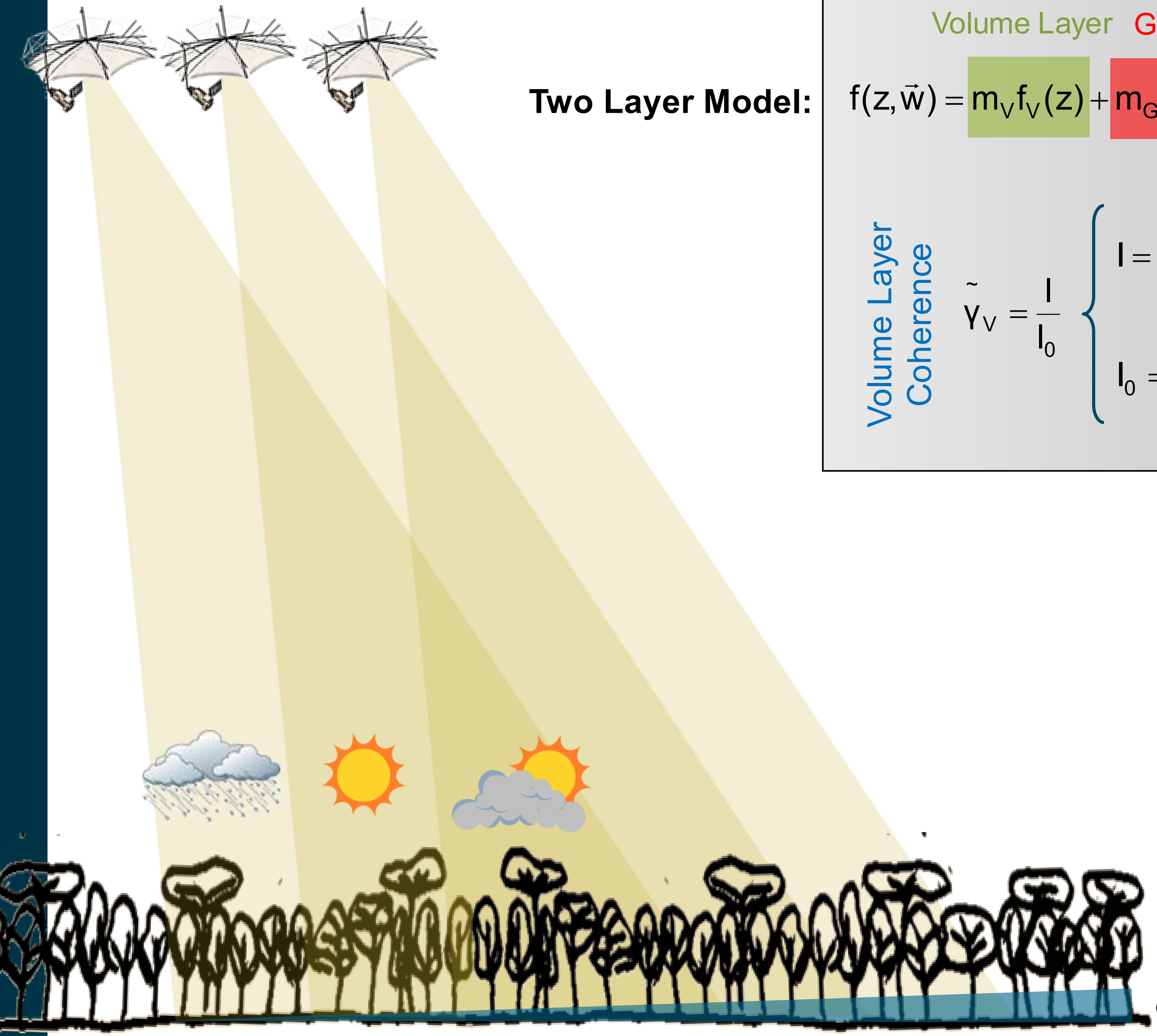

12.01.26
3 Days InSAR Coherence HH
15.01.26
Rain Patterns
18.01.26
21.01.26
24.01.26
27.01.26
30.01.26


12.01.26
15.01.26
18.01.26
21.01.26
24.01.26
27.01.26
30.01.26
3 Days PolInSAR Coherence RGB (R: HH, B: VV, G: HV)

Volume Layer Ground Layer

Two Layer Model: $f(z,\vec{w}) = \boxed{m_V f_V(z)} + \boxed{m_G(\vec{w})\delta(z - z_0)}$





Two Layer Model:

Volume Layer | Ground Layer

$$f(z,\vec{w}) = \underbrace{m_V f_V(z)}_{\text{Volume Layer}} + \underbrace{m_G(\vec{w})\delta(z-z_0)}_{\text{Ground Layer}}$$

$$\tilde{\gamma}_{Vol}(\vec{w},\kappa_z) = \exp(i\varphi_0)\frac{\tilde{\gamma}_V(\kappa_z)+m(\vec{w})}{1+m(\vec{w})}$$

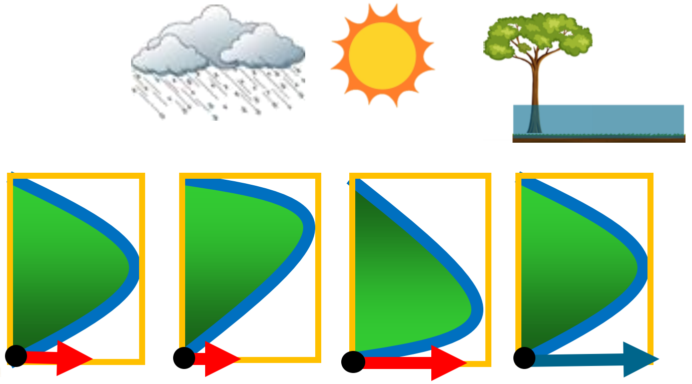
Volume Layer Coherence

$$\tilde{\gamma}_V = \frac{I}{I_0} \quad \begin{cases} I = \int_0^{h_V} \exp(i\kappa_z z') f_V(z')\,dz' \\ I_0 = \int_0^{h_V} f_V(z')\,dz' \end{cases}$$

$$m(\vec{w}) = \frac{m_G(\vec{w})}{m_V(\vec{w}) I_0} \qquad \kappa_z = \frac{\kappa\Delta\theta}{\sin(\theta_0)}$$

$f_V(z)$ … volume reflectivity function

$\varphi_0 = k_z z_0$ … underlying topography



Two Layer Model:

Volume Layer — Ground Layer

$$f(z,\vec{w}) = \underbrace{m_V f_V(z)}_{\text{Volume Layer}} + \underbrace{m_G(\vec{w})\,\delta(z - z_0)}_{\text{Ground Layer}}$$

$$\tilde{\gamma}_{Vol}(\vec{w},\kappa_z) = \exp(i\varphi_0)\,\frac{\tilde{\gamma}_V(\kappa_z) + m(\vec{w})}{1 + m(\vec{w})}$$

Volume Layer Coherence

$$\tilde{\gamma}_V = \frac{I}{I_0} \quad \begin{cases} I = \int_0^{h_V} \exp(i\kappa_z z') f_V(z')\,dz' \\ I_0 = \int_0^{h_V} f_V(z')\,dz' \end{cases}$$

$$m(\vec{w}) = \frac{m_G(\vec{w})}{m_V(\vec{w}) I_0} \qquad \kappa_z = \frac{\kappa\Delta\theta}{\sin(\theta_0)}$$

$f_V(z)$ … volume reflectivity function

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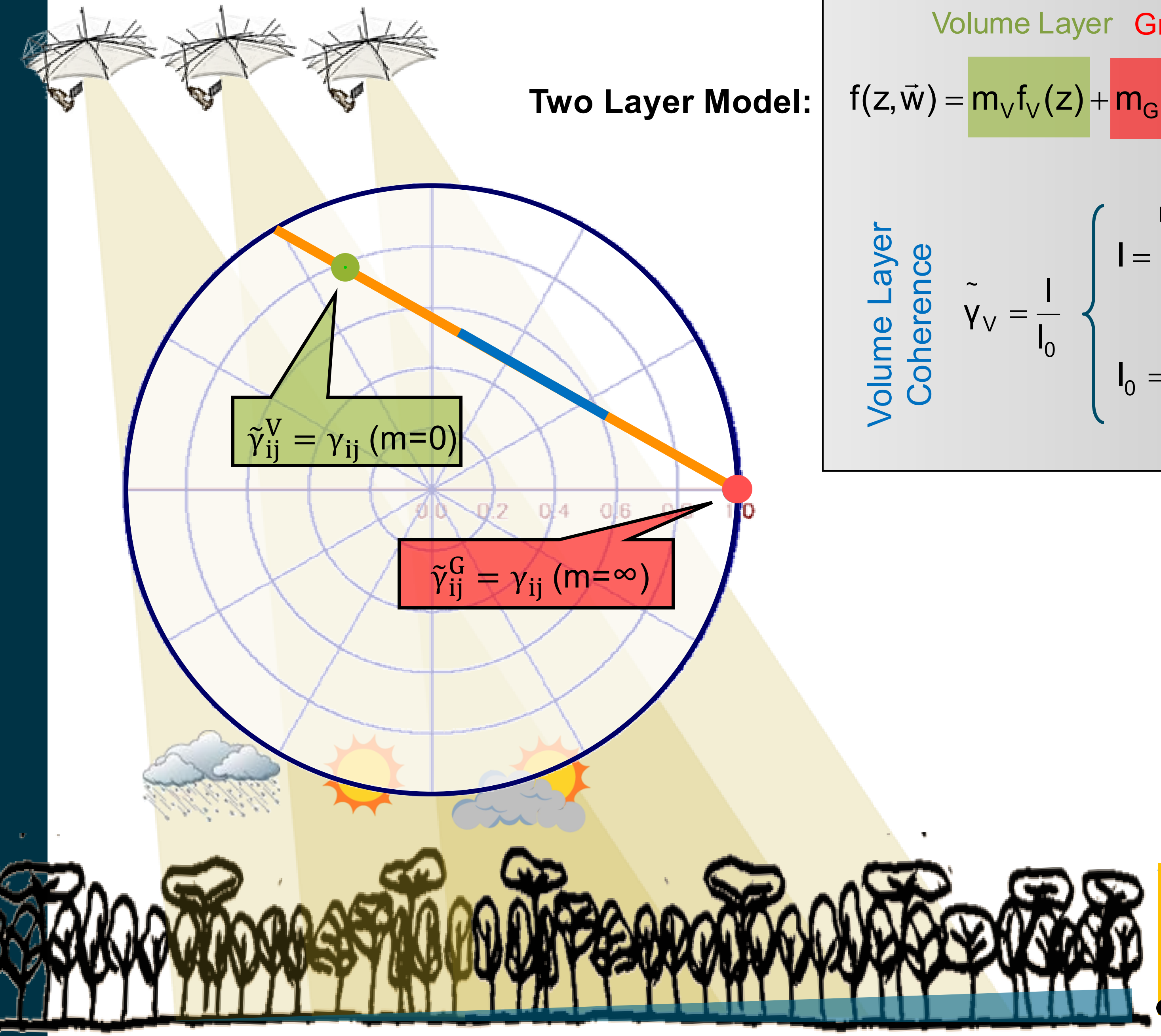
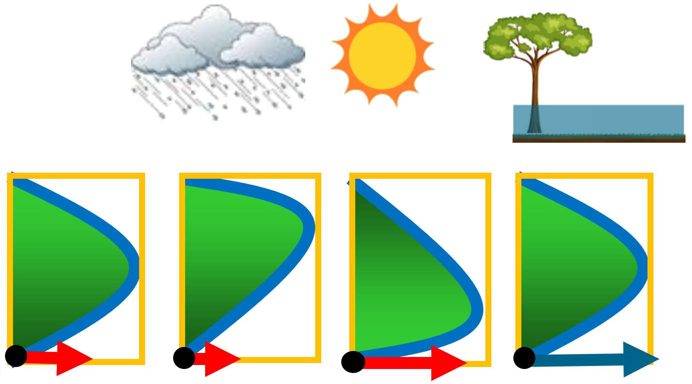
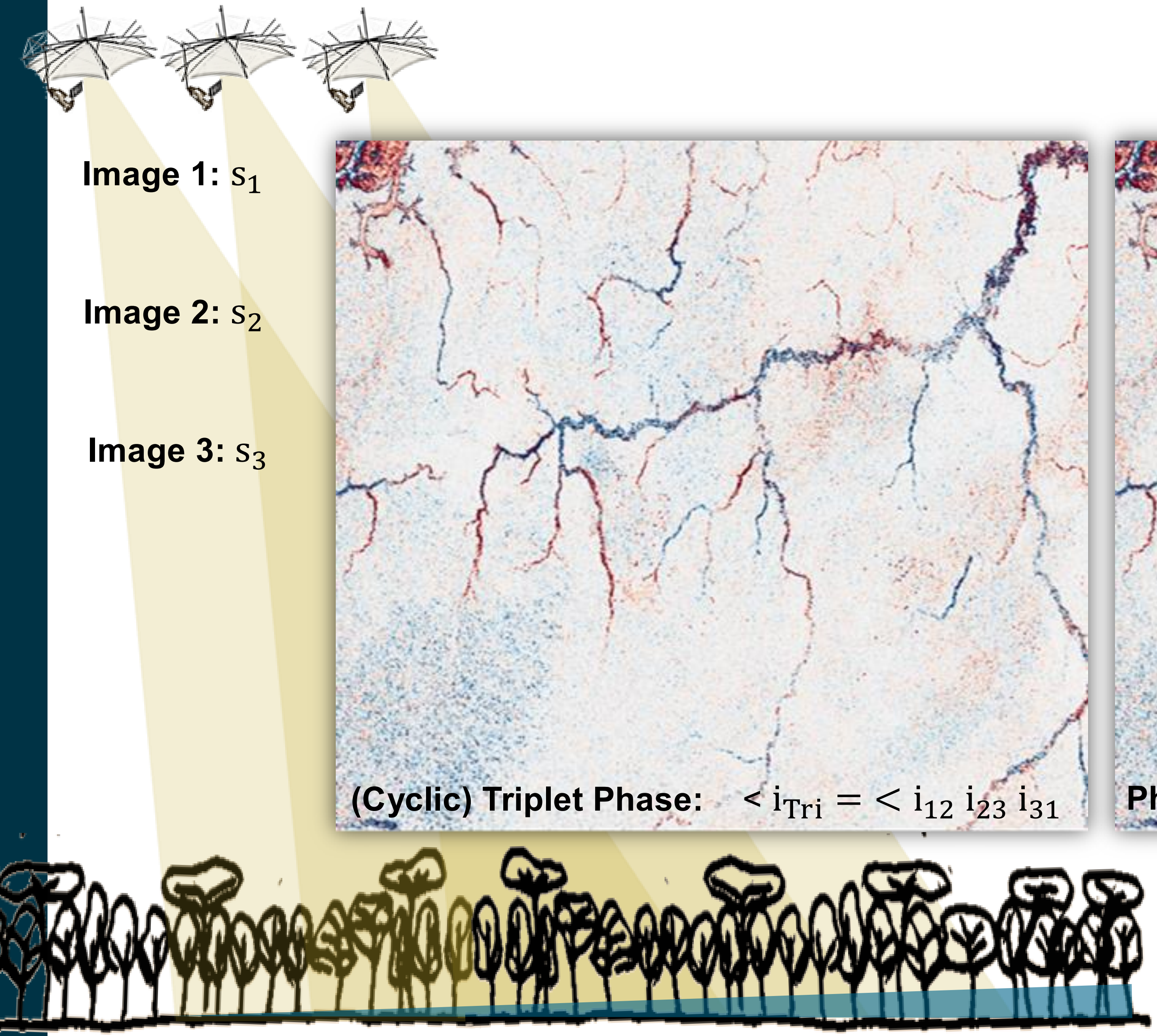
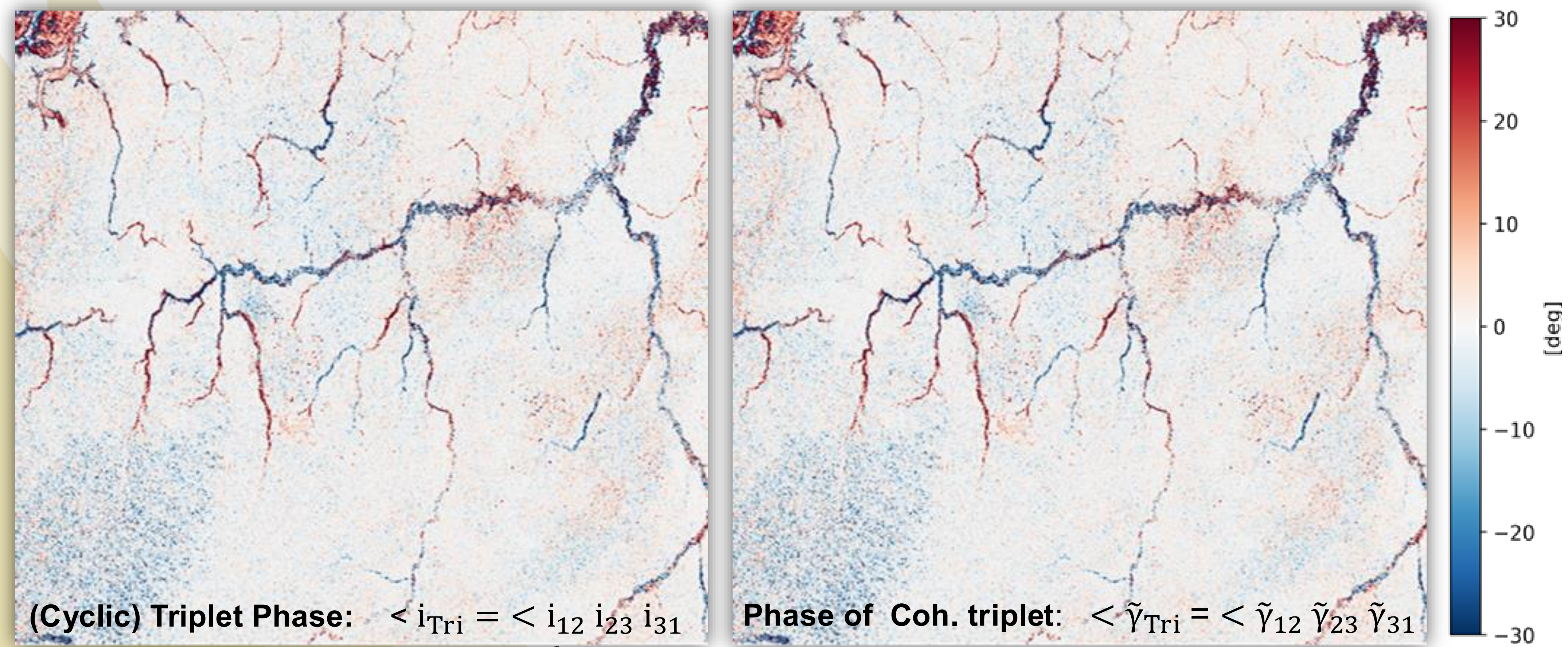




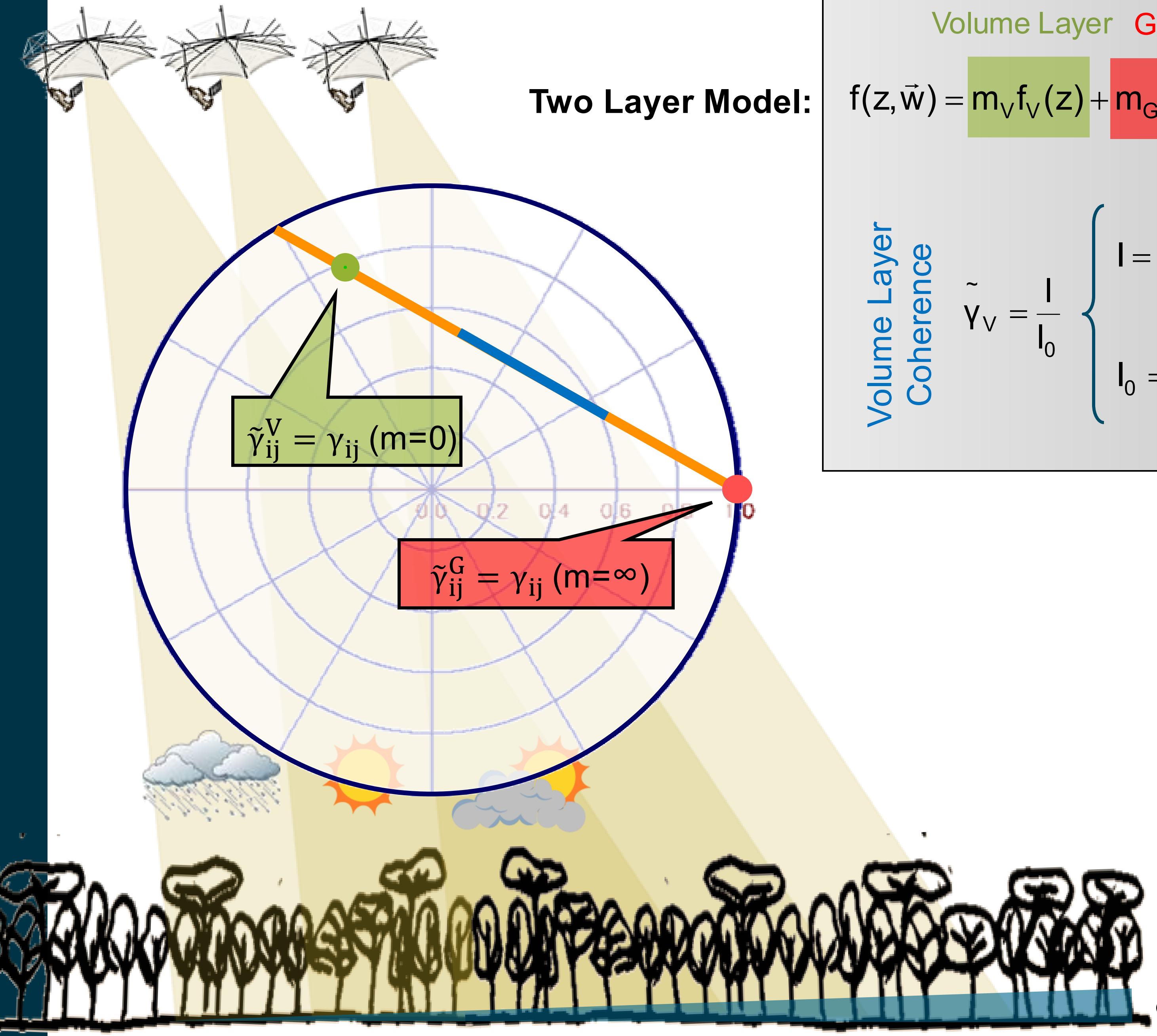




(Cyclic) Triplet Phase: $\angle i_{Tri} = \angle i_{12}\, i_{23}\, i_{31}$

Phase of Coh. triplet: $\angle \tilde{\gamma}_{Tri} = \angle \tilde{\gamma}_{12}\, \tilde{\gamma}_{23}\, \tilde{\gamma}_{31}$

Important: Same Multi-Looking at the same Stage !



Two Layer Model:

Volume Layer Ground Layer

$$f(z,\vec{w}) = m_V f_V(z) + m_G(\vec{w})\delta(z-z_0)$$

$$\tilde{\gamma}_{Vol}(\vec{w},\kappa_z) = \exp(i\varphi_0)\frac{\tilde{\gamma}_V(\kappa_z)+m(\vec{w})}{1+m(\vec{w})}$$

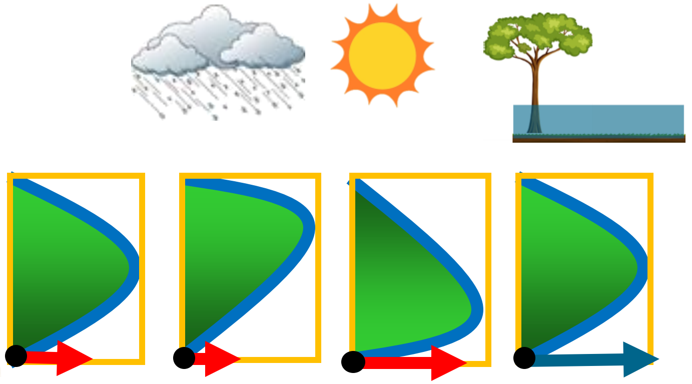
Volume Layer Coherence

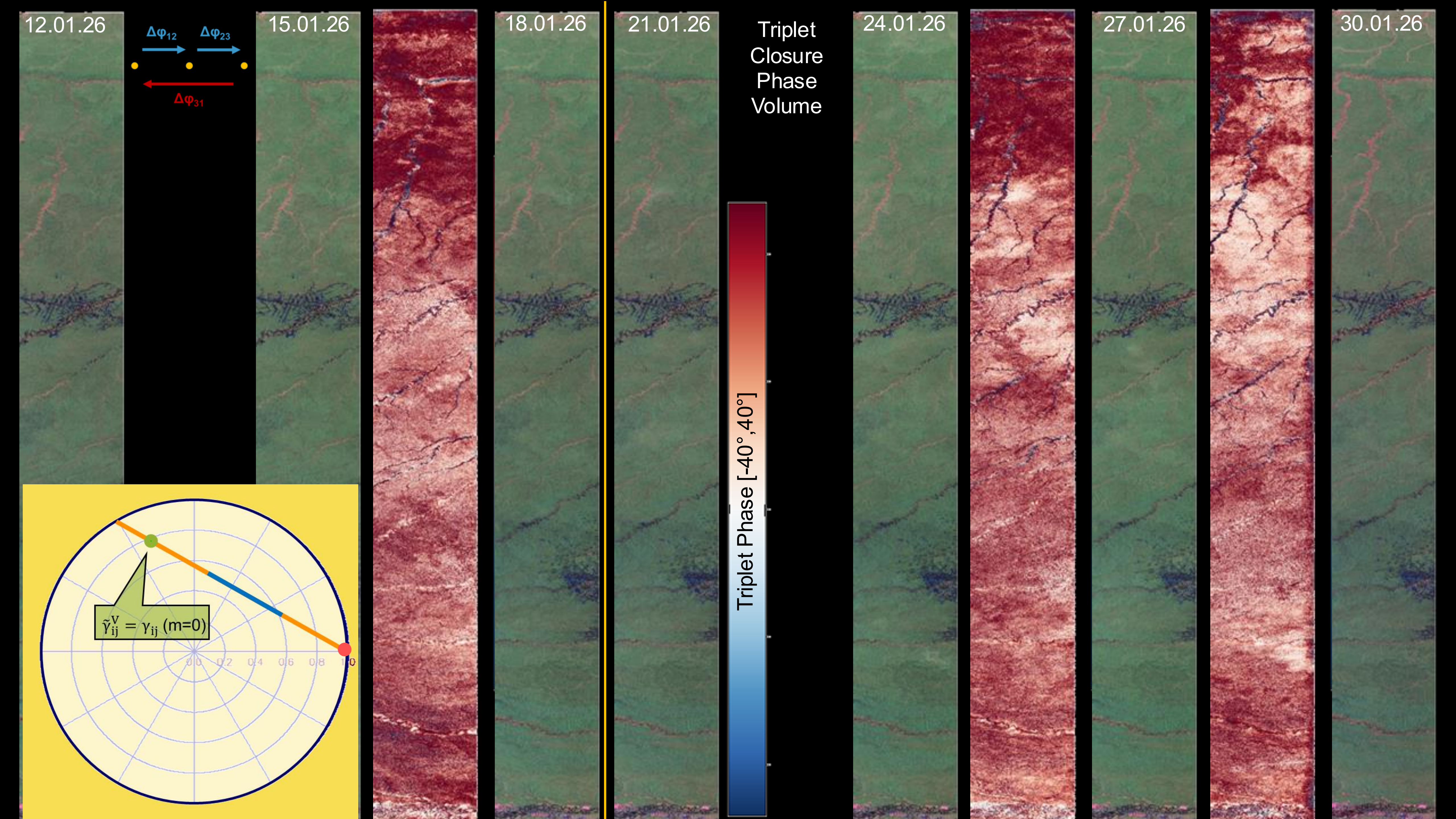
$$\tilde{\gamma}_V = \frac{I}{I_0} \quad \begin{cases} I = \int_0^{h_V} \exp(i\kappa_z z') f_V(z')dz' \\ I_0 = \int_0^{h_V} f_V(z')dz' \end{cases}$$

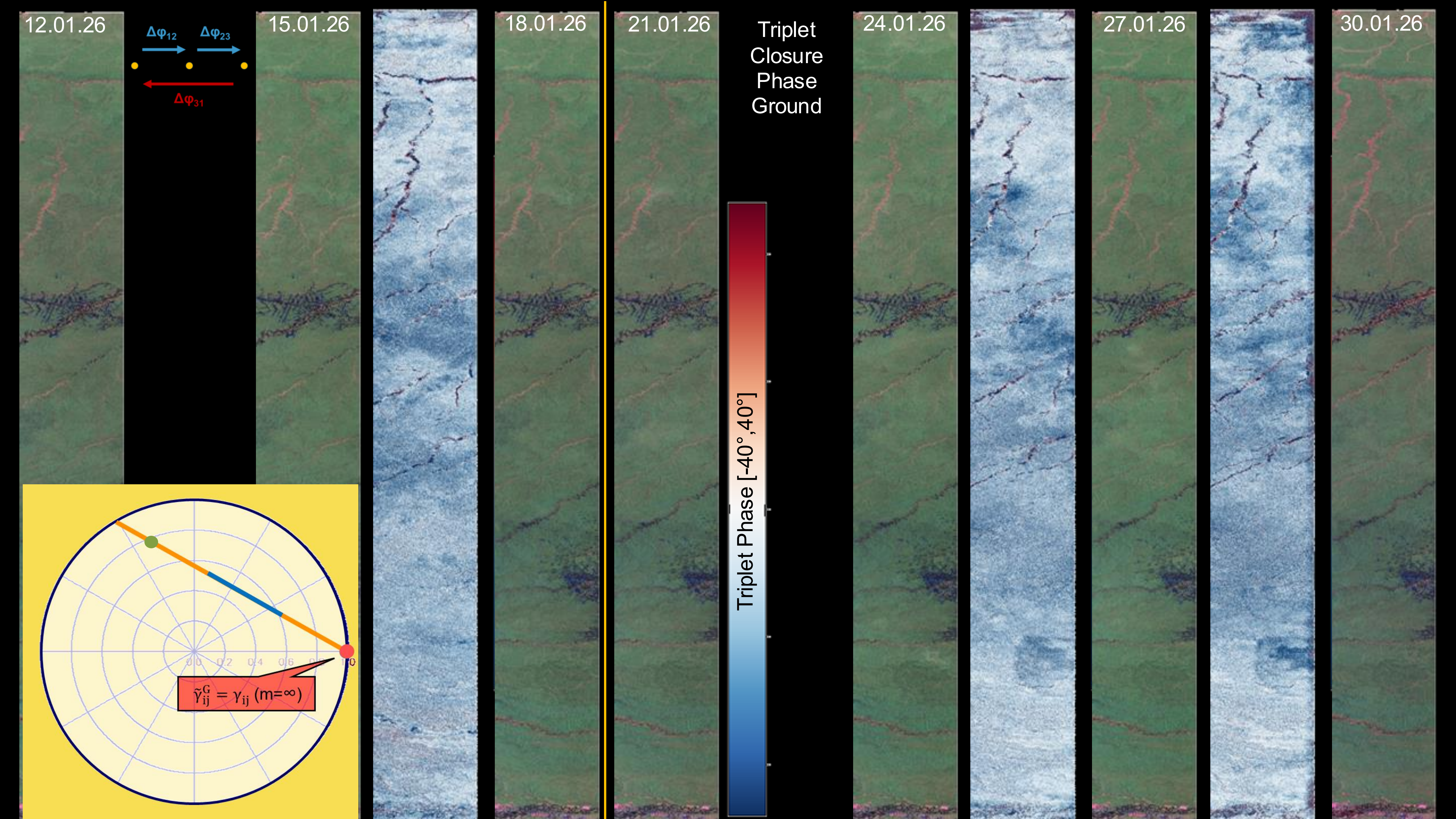
$$m(\vec{w}) = \frac{m_G(\vec{w})}{m_V(\vec{w}) I_0} \qquad \kappa_z = \frac{\kappa\Delta\theta}{\sin(\theta_0)}$$

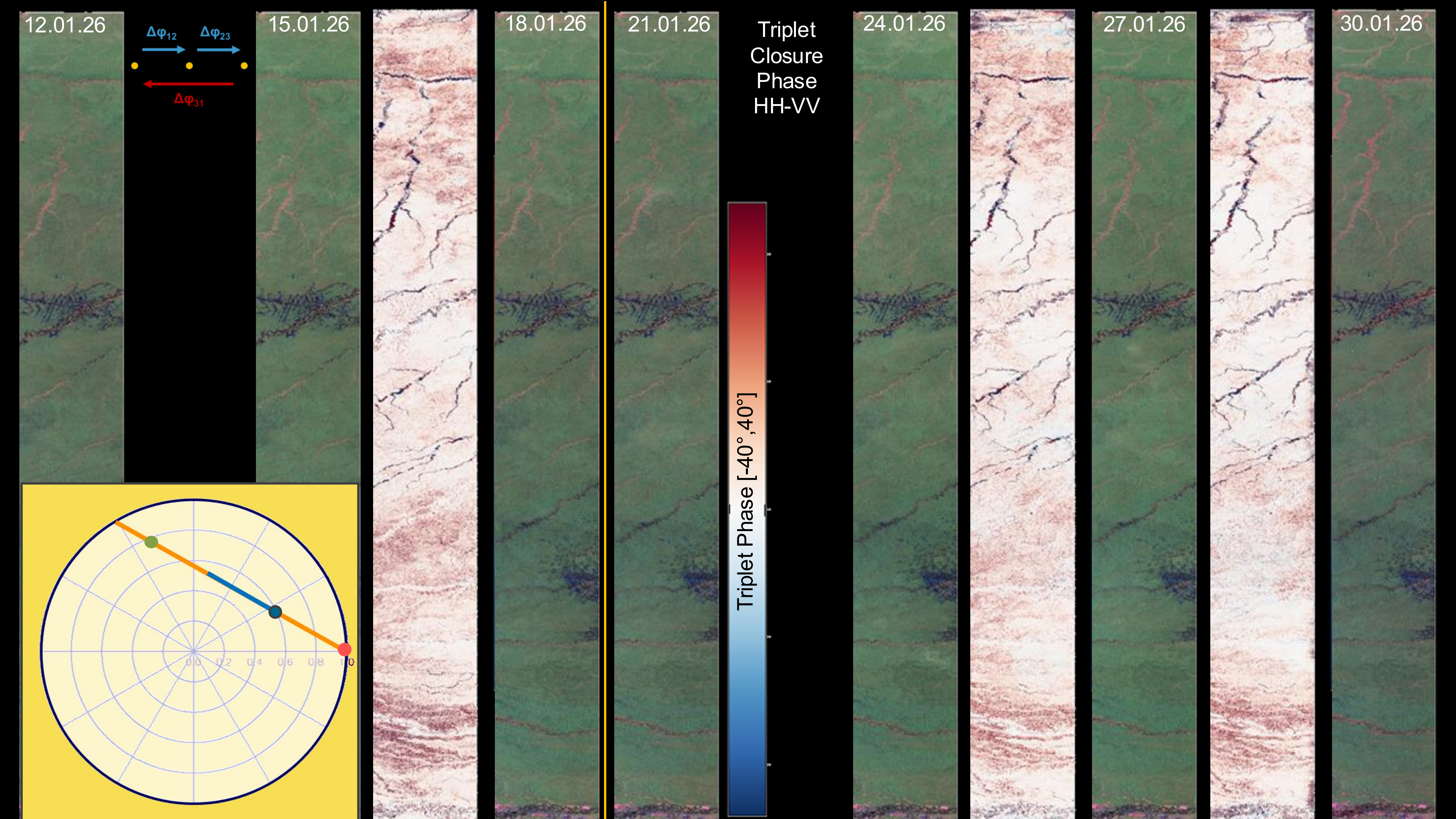
$f_V(z)$ … volume reflectivity function

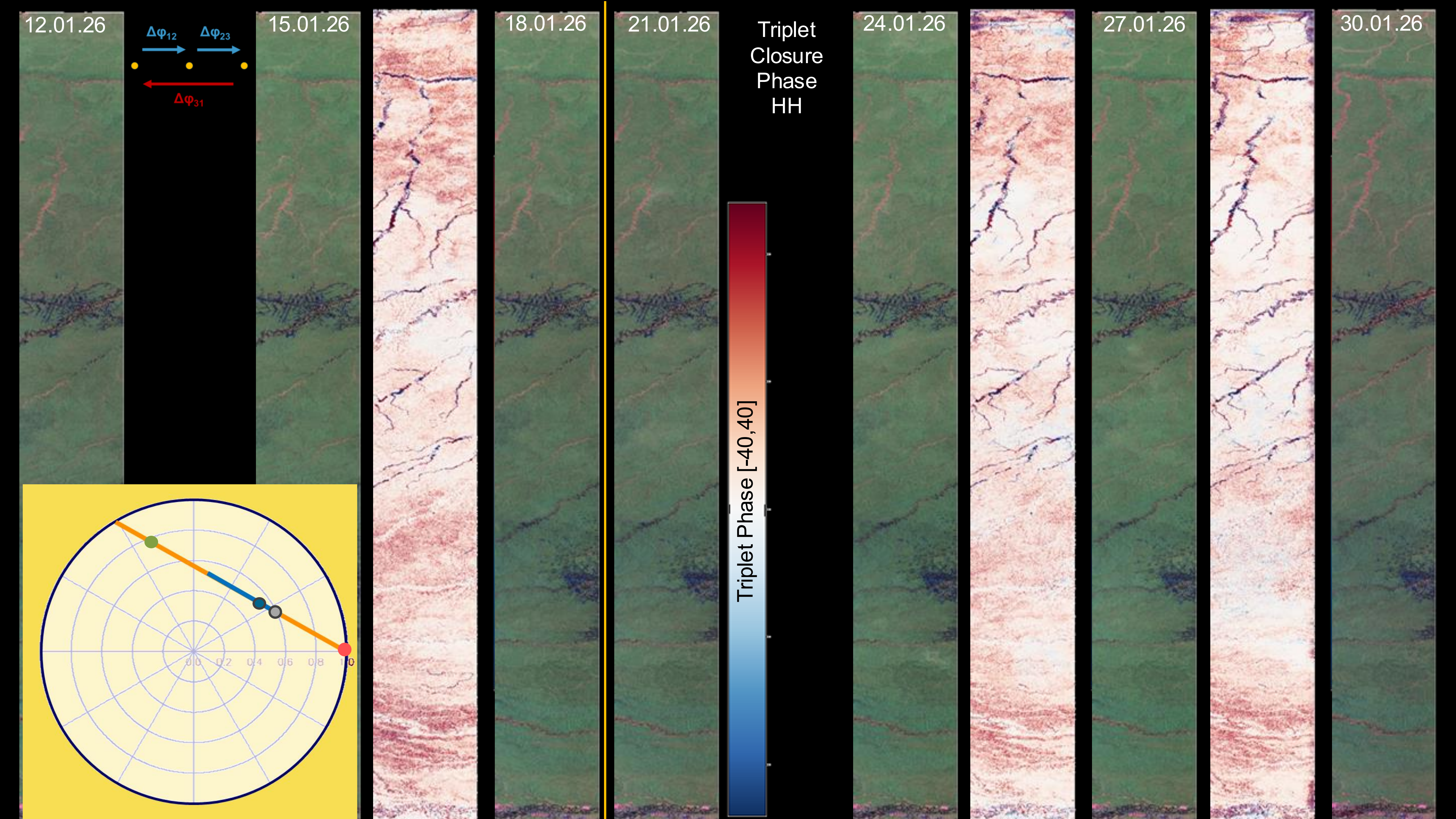
$\varphi_0 = k_z z_0$ … underlying topography

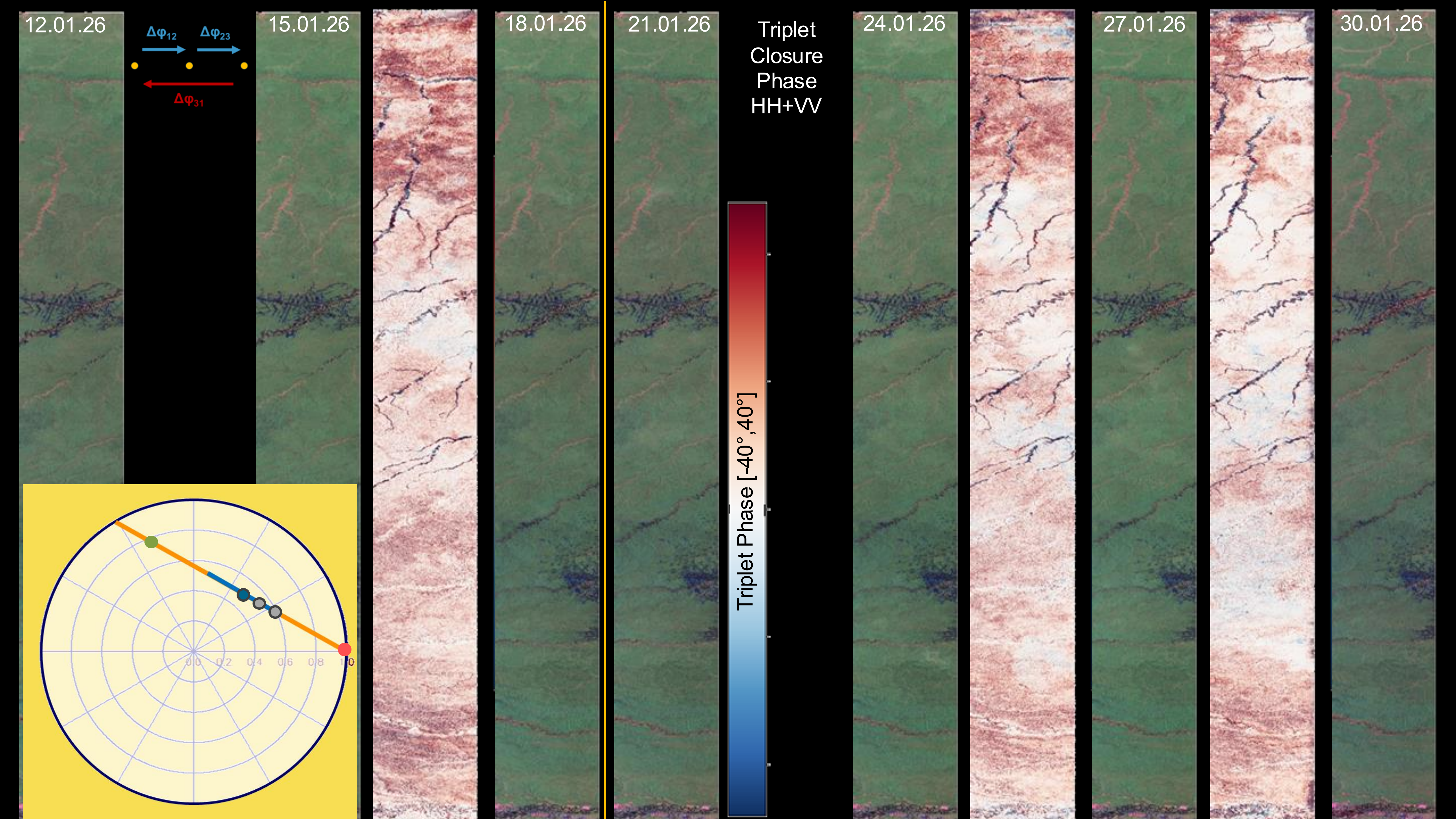



12.01.26
15.01.26
18.01.26
21.01.26
24.01.26
27.01.26
30.01.26
$\Delta\varphi_{12}$
$\Delta\varphi_{23}$
$\Delta\varphi_{31}$
Triplet Closure Phase Volume
Triplet Phase [-40°,40°]
$\tilde{\gamma}^{V}_{ij} = \gamma_{ij}$ (m=0)
0.0
0.2
0.4
0.6
0.8
1.0

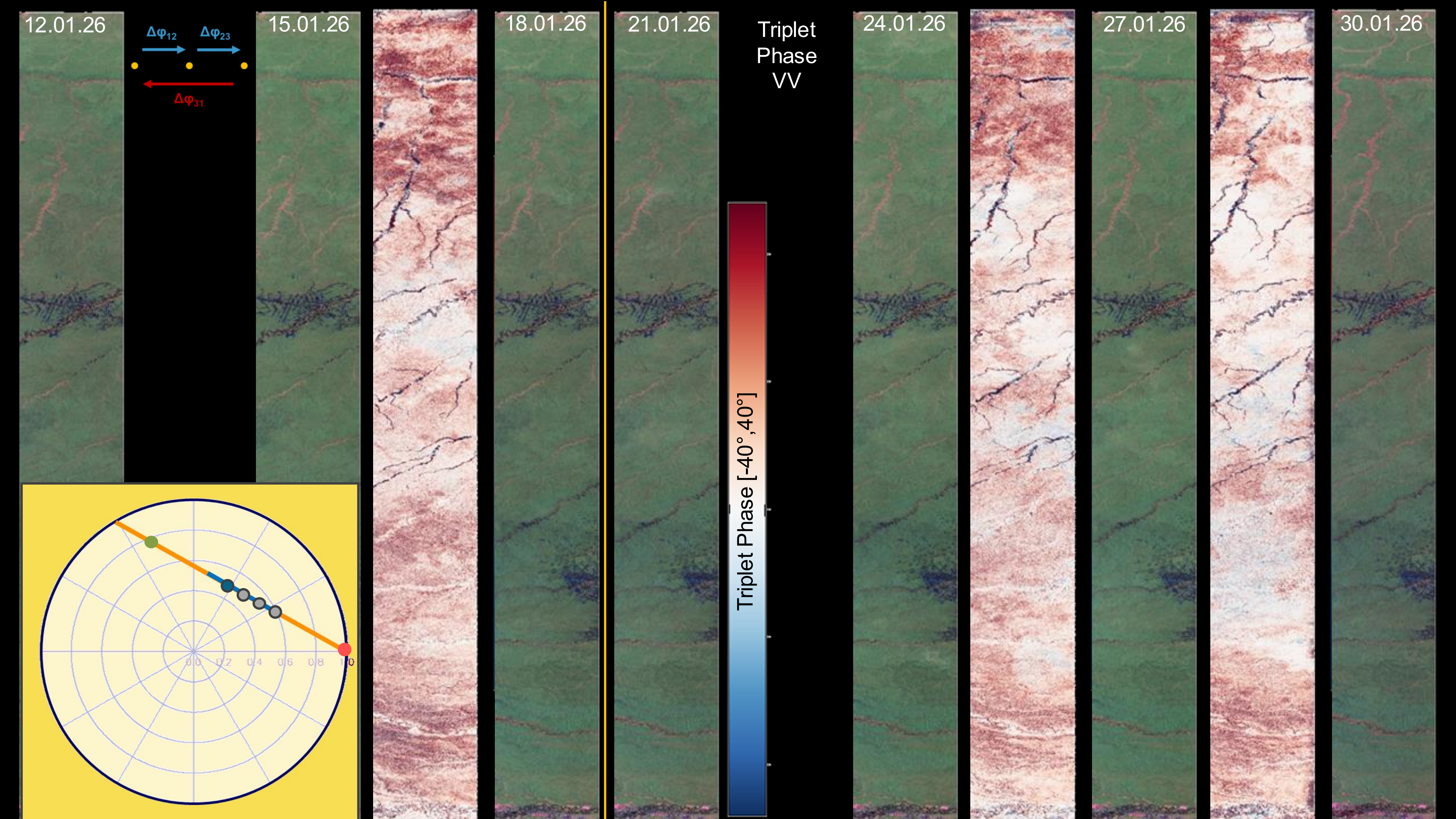

12.01.26
$\Delta\varphi_{12}$
$\Delta\varphi_{23}$
$\Delta\varphi_{31}$
15.01.26
18.01.26
21.01.26
Triplet Closure Phase Ground
Triplet Phase [-40°,40°]
24.01.26
27.01.26
30.01.26
0.0
0.2
0.4
0.6
$\tilde{\gamma}_{ij}^{G} = \gamma_{ij}$ (m=∞)

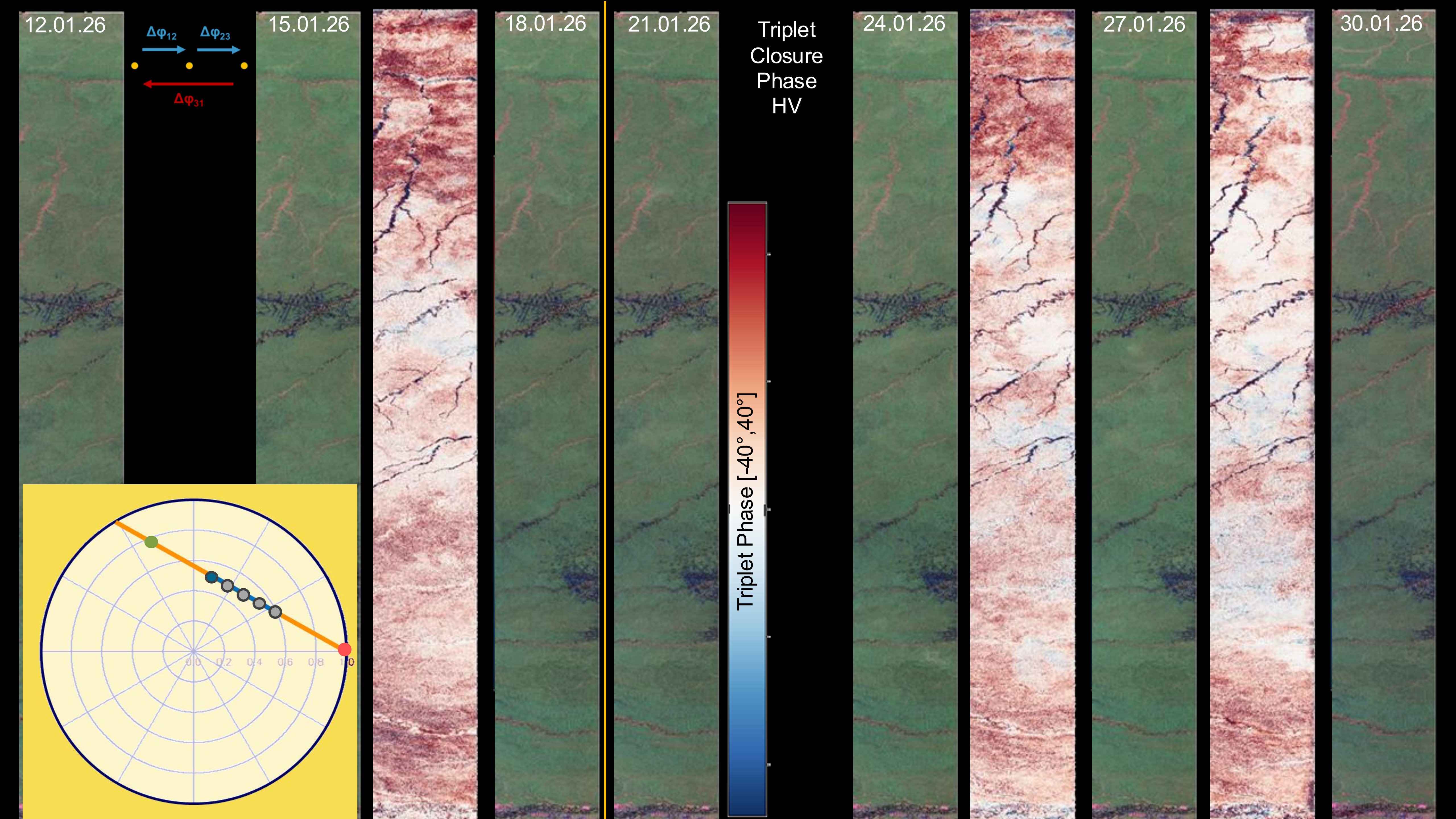

12.01.26
$\Delta\varphi_{12}$
$\Delta\varphi_{23}$
$\Delta\varphi_{31}$
15.01.26
18.01.26
21.01.26
Triplet
Closure
Phase
HH-VV
Triplet Phase [-40°,40°]
24.01.26
27.01.26
30.01.26
0.0
0.2
0.4
0.6
0.8
1.0

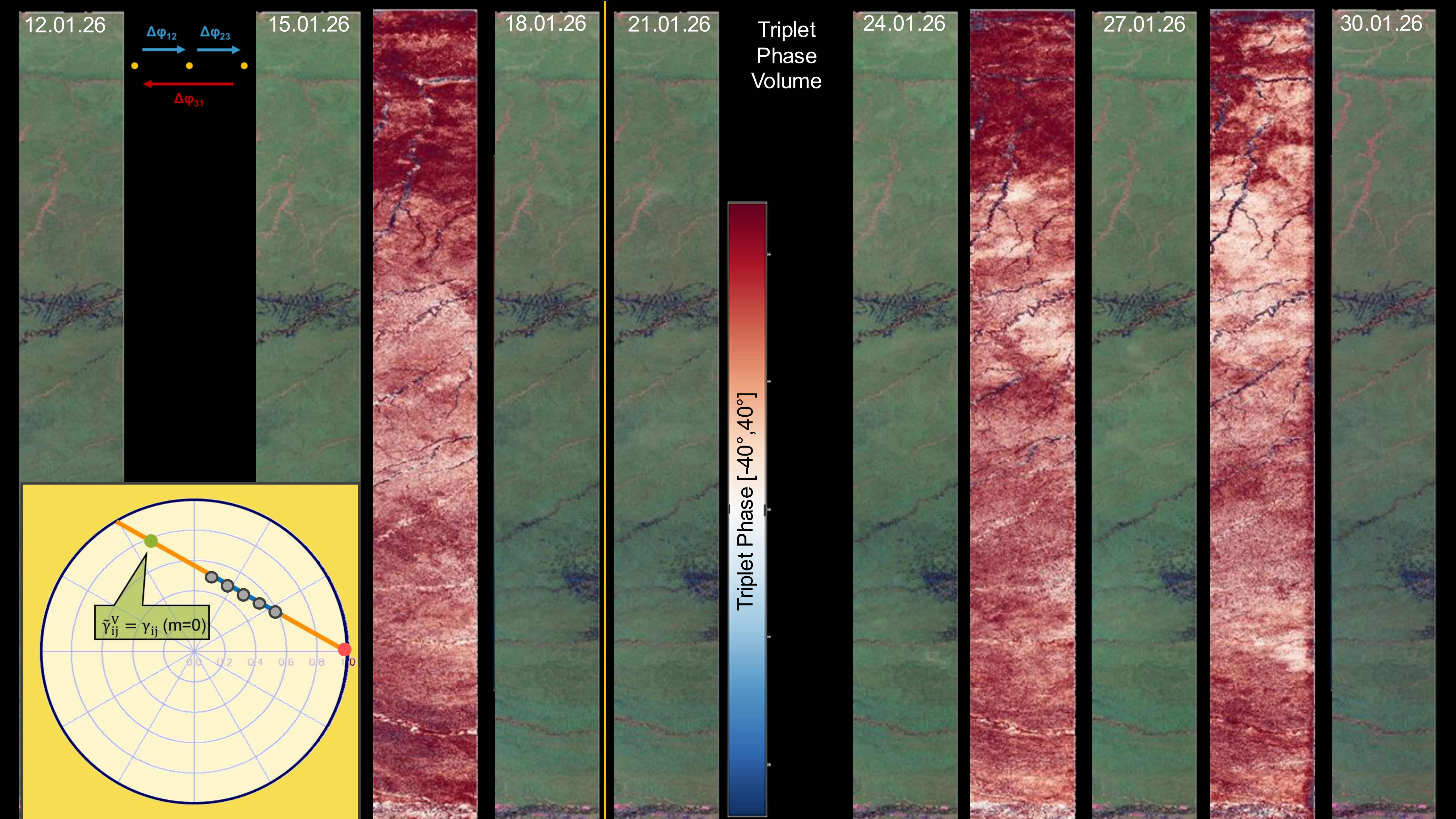

12.01.26
Δφ12
Δφ23
Δφ31
15.01.26
18.01.26
21.01.26
Triplet
Closure
Phase
HH
24.01.26
27.01.26
30.01.26
Triplet Phase [-40,40]
0.0
0.2
0.4
0.6
0.8
1.0



12.01.26
15.01.26
18.01.26
21.01.26
24.01.26
27.01.26
30.01.26
Δφ12
Δφ23
Δφ31
Triplet Closure Phase HH+VV
Triplet Phase [-40°,40°]
0.0
0.2
0.4
0.6
0.8
1.0

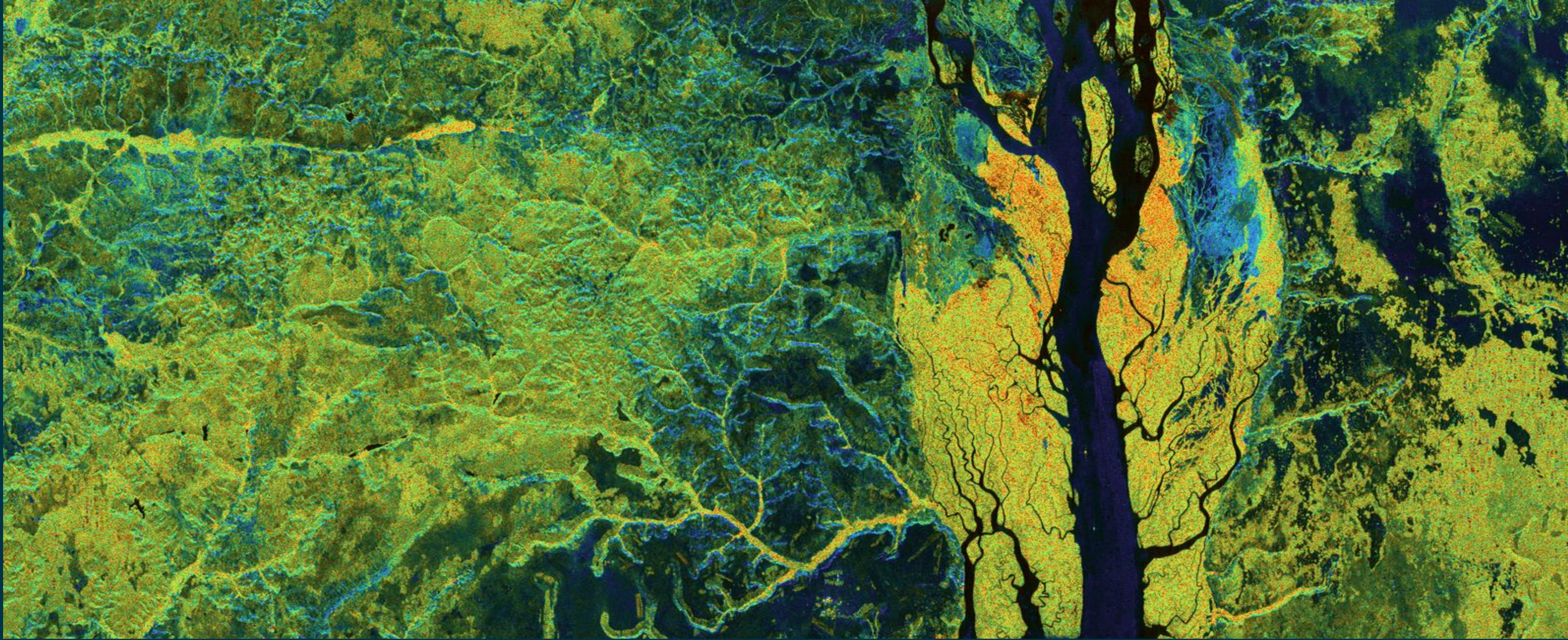

12.01.26
$\Delta\varphi_{12}$
$\Delta\varphi_{23}$
$\Delta\varphi_{31}$
15.01.26
18.01.26
21.01.26
Triplet
Phase
VV
Triplet Phase [-40°,40°]
24.01.26
27.01.26
30.01.26
0.0
0.2
0.4
0.6
0.8
1.0


12.01.26
$\Delta\varphi_{12}$
$\Delta\varphi_{23}$
$\Delta\varphi_{31}$
15.01.26
18.01.26
21.01.26
Triplet Closure Phase HV
Triplet Phase [-40°,40°]
24.01.26
27.01.26
30.01.26
0.0
0.2
0.4
0.6
0.8
1.0


12.01.26
15.01.26
18.01.26
21.01.26
24.01.26
27.01.26
30.01.26
$\Delta\varphi_{12}$
$\Delta\varphi_{23}$
$\Delta\varphi_{31}$
Triplet Phase Volume
Triplet Phase [-40°,40°]
$\tilde{\gamma}_{ij}^{V} = \gamma_{ij}$ (m=0)
0.0
0.2
0.4
0.6
0.8
1.0

Some First Conclusions

- BIOMASS with its low frequency and Pol-InSAR capability opens a new perspective on monitoring dynamic effects in forests (… and not only) !
- Non-zero spatial baselines allow to separate different scattering contributions occurring at different heights.
- The BIOMASS data indicate a very dynamic behavior of all scattering components, with changes from interferogram to interferogram, including the ground. Especially in the Tropics due to rain events.
- Stationarity, assumed in many processing techniques, does not hold in (a significant subspace of) the BIOMASS data.
- Exciting times ☺ !



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DLR