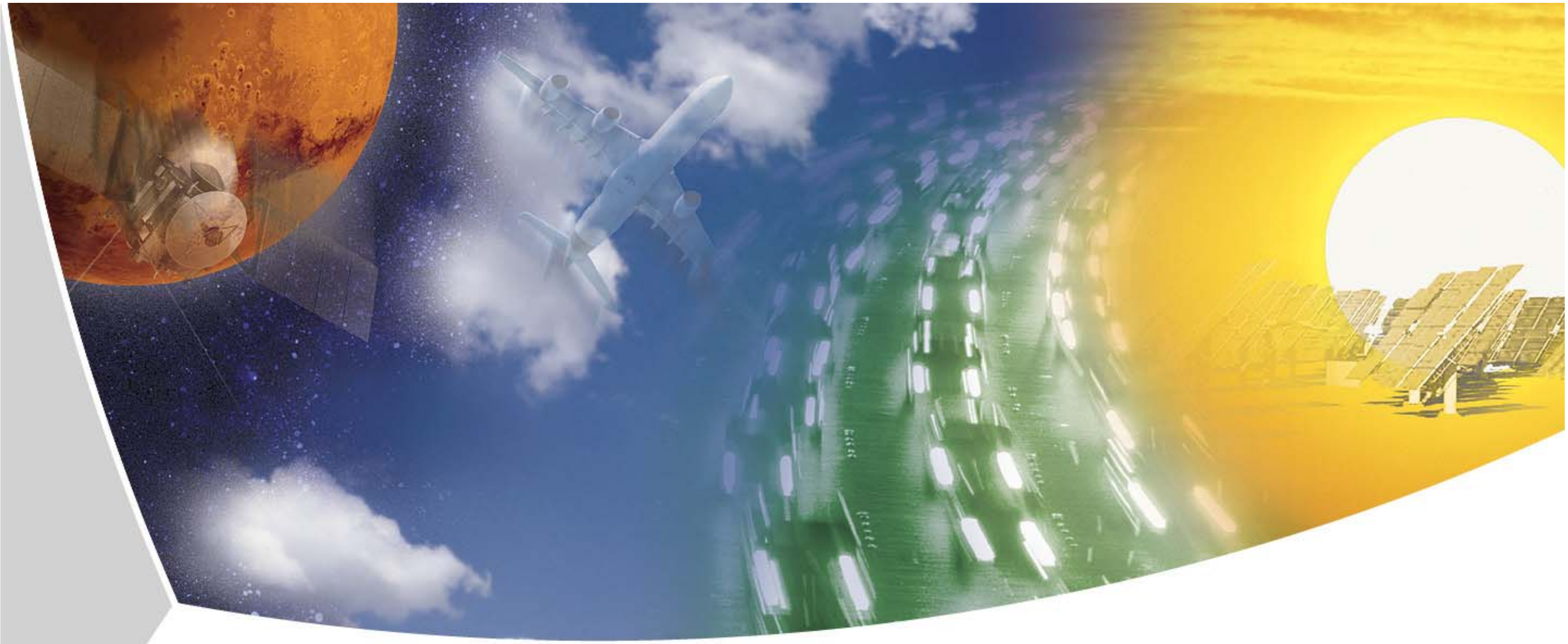

# Coherent Scatterers (CSs) Detection in TerraSAR-X Data


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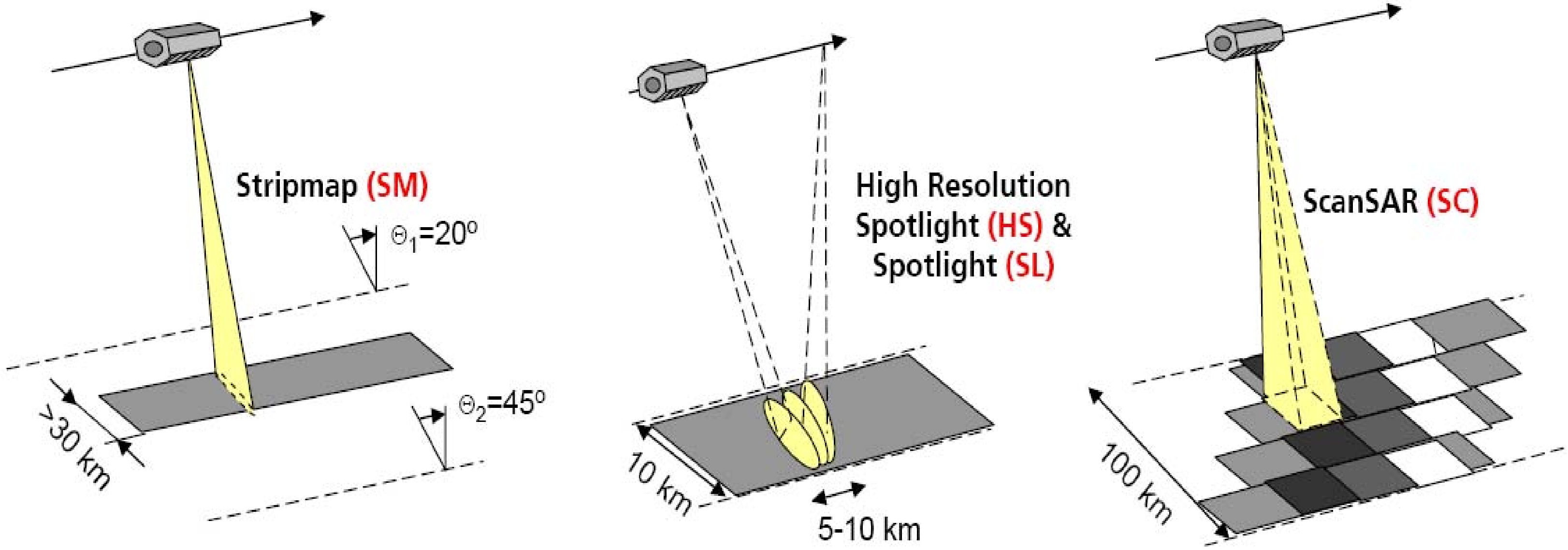
in der Helmholtz-Gemeinschaft

# Imaging Modes of TerraSAR-X for Basic Products

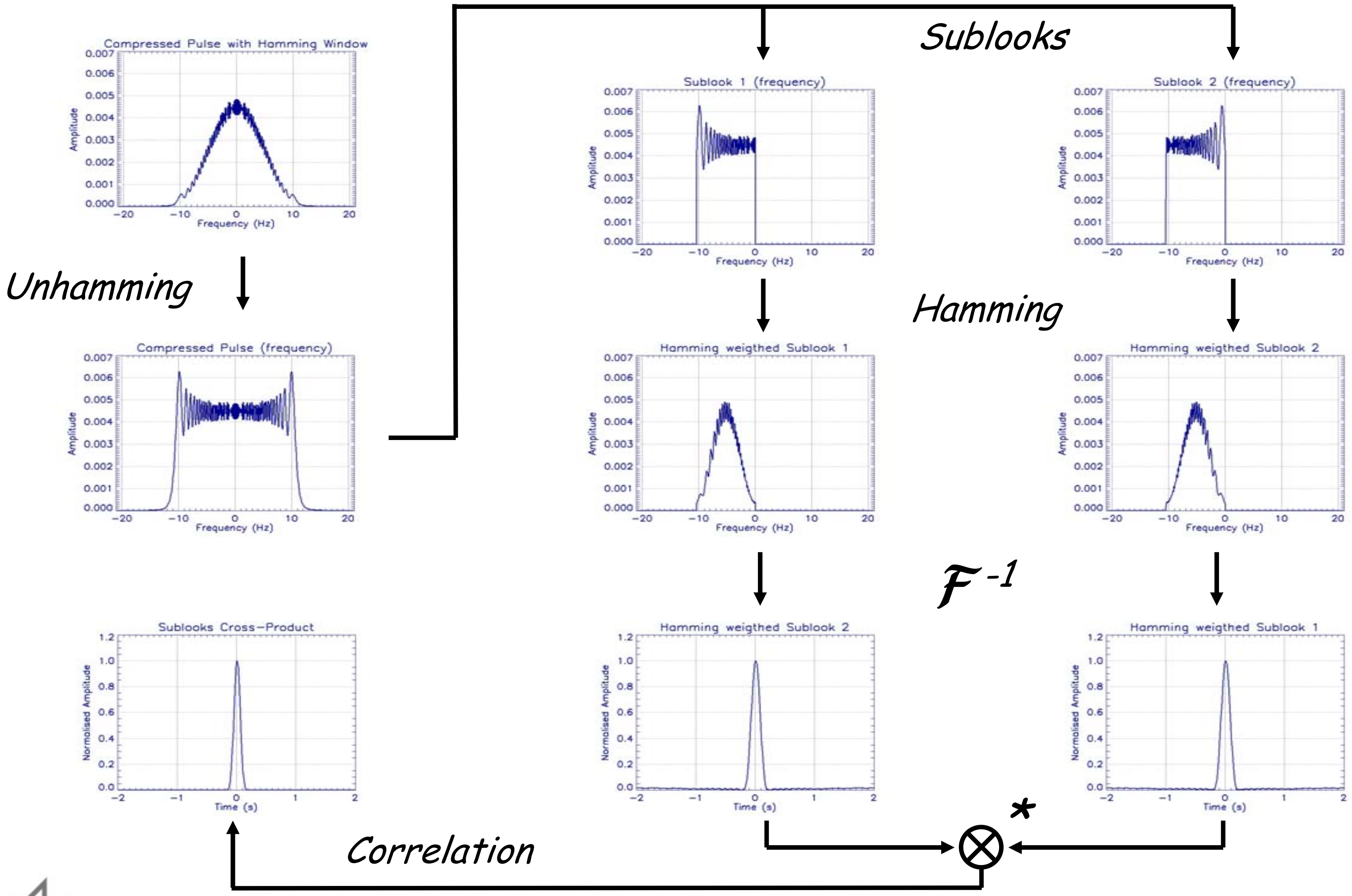



| | **Stripmap** | **Spotlight** (HS & SL) | **ScanSAR** |
|---|---|---|---|
| *swath width* | 30 km (single & twin pol.)<br>15 km (dual & quad pol.) | 10 km @ *150 MHz chirp BW*<br>azimuth: 5 / 10 km (HS / SL) | 100 km |
| *full performance incidence angle range* | 20° - 45° | 20° - 55° | 20° - 45° |
| *azimuth resolution* | 3 m (single pol.)<br>6 m (**dual pol**.) | 1 m / 2 m (HS , single / **dual pol.**)<br>2 m / 4 m (SL , single / **dual pol.**) | 17 m<br>(1 look, 4 beams) |
| *ground range resolution @ 150 MHz chirp BW* | 1.7 m - 3.5 m (@ 45°.. 20°) | 1.5 m - 3.5 m (@ 55°..20°) | 1.7 m - 3.5 m (@ 45°.. 20°) |

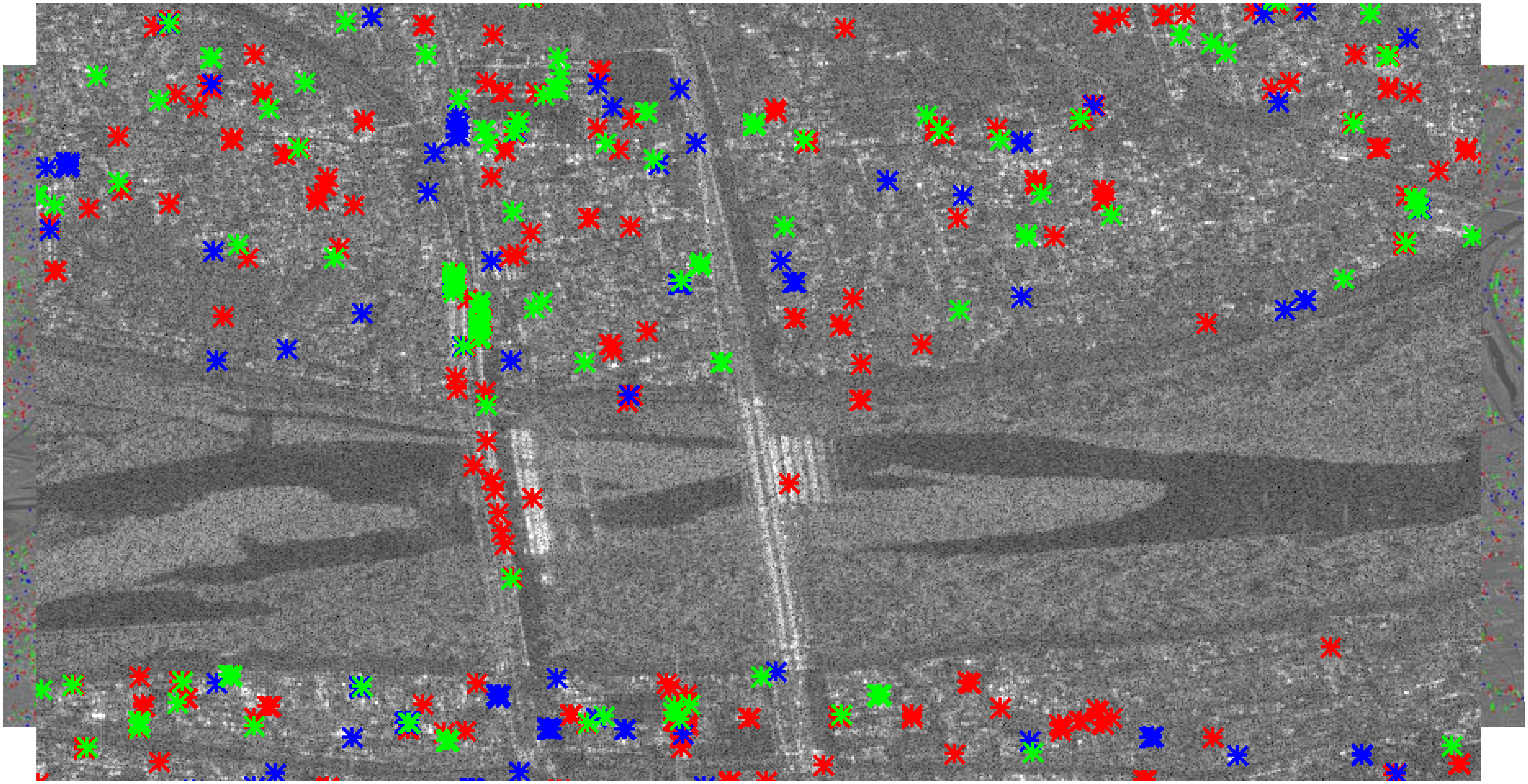
# Outline (TerraSAR-X)

- Wide bandwidth:
  - CSs detection (based on frequency correlation)
  - Alternative CSs detection
  - Bandwidth effects on the CSs detection and properties
- Dual polarization:
  - Do not allow a full CSs polarimetric description
  - But a more complete description than single pol data
- Frequency comparison using ALOS data of the same region

# Coherent Scatterers Technique



# TerraSAR-X Coherent Scatterers Detection (150 MHz, dual-polorization)



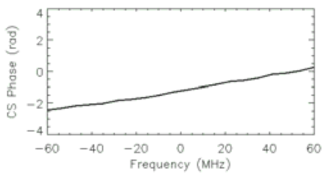
Test site: Gifu, Japan    Red: Dihedral, Green: Dipoles, Blue: Flat plates

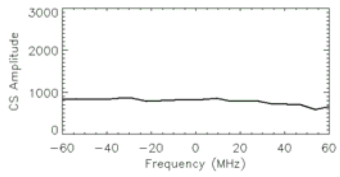
# Phase and Amplitude of CSs and Non-CSs as a function of frequency

## Coherent Scatterers:

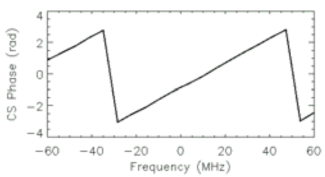
Phase | Amplitude

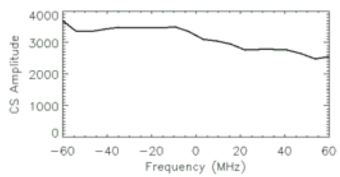
CS 1:



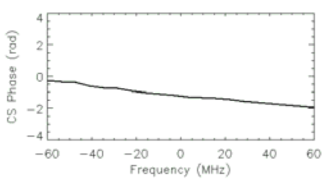



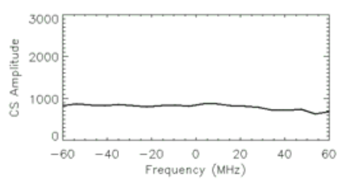

CS 2:




CS 3:

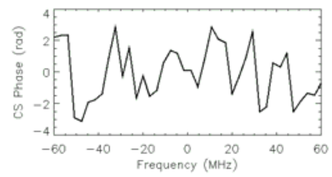


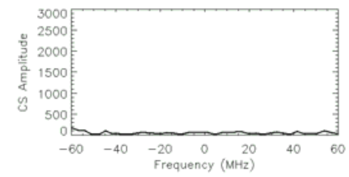




## Distributed Scatterers:

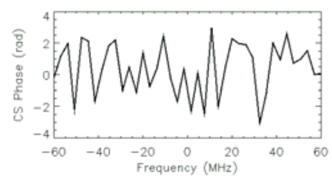
Phase | Amplitude

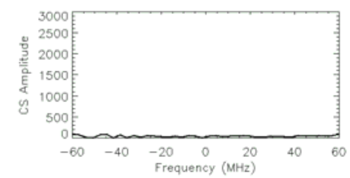
Non-CS 1:



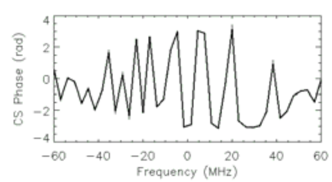



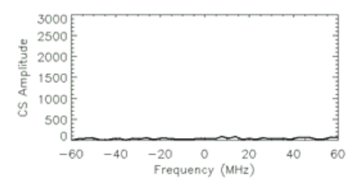

Non-CS 2:




Non-CS 3:



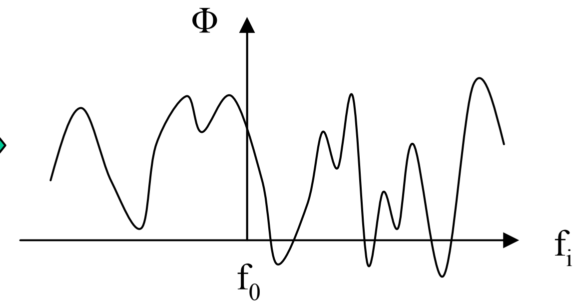
# Alternative CSs Detection

Sublook phase Φ:

$$\phi = \frac{4\pi}{c} f_i (R_N - R) - \frac{4\pi}{c} f_0 R_N + \phi_s$$

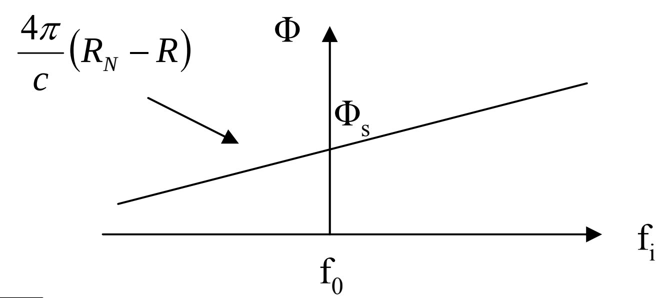
Distributed scatterer

$\Phi_s$ is random




Coherent scatterer

$\Phi_s$ is constant




- $f_0$: Central frequency
- $f_i$: Sublook central frequency
- $R_N$: Nominal range
- R: Actual range
- $\Phi_s$: Scatterer phase

---

m: Mean of phase derivative

$$m = \frac{1}{N} \sum_{i=1}^{N} \frac{\partial \phi_i}{\partial f}$$

σ: Standard deviation of phase derivative

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^{N} \left( \frac{\partial \phi_i}{\partial f} - m \right)^2$$

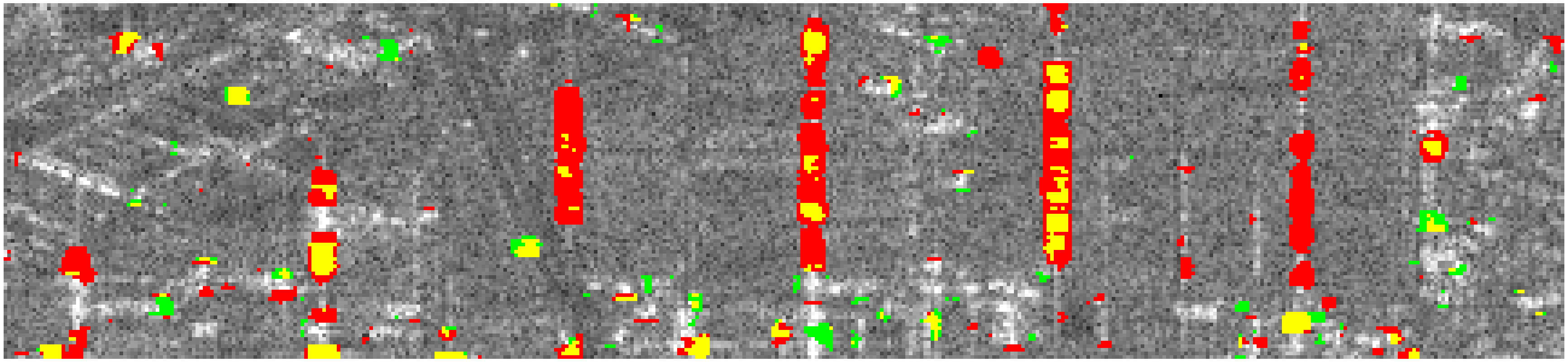
$\sigma <$ threshold

↓

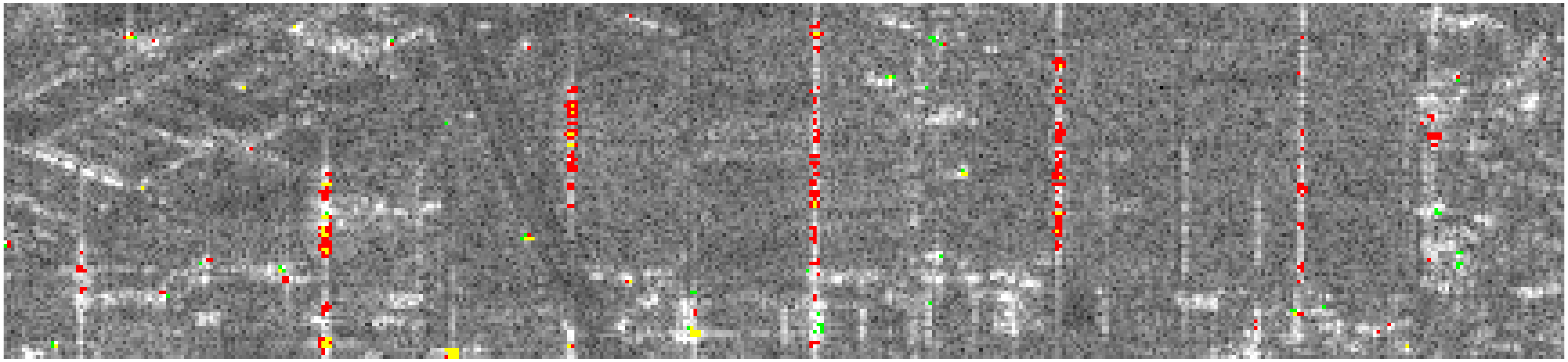
Coherent Scatterer!

# TerraSAR-X Coherent Scatterers Alternative Detection

Standard CSs detection (without filtering)



Alternative CSs detection (frequency phase stability)



**Test site: Gifu, Japan**

# Full Polarimetric Data

## Scattering Matrix Parametrization in Terms of LOS Symmetries

$$S = R(\psi)S_{uC}R(\psi)^T = \begin{bmatrix} \cos\psi & -\sin\psi \\ \sin\psi & \cos\psi \end{bmatrix} S_{uC} \begin{bmatrix} \cos\psi & \sin\psi \\ -\sin\psi & \cos\psi \end{bmatrix}$$

$S_{uC}$: Underlying Scatterer Signature

$$S_{uC} = \| S_{uC} \| e^{j\phi_a} (\cos\alpha S_a + e^{j\phi_{ba}} \sin\alpha \cos\delta S_b - j \sin\alpha \sin\delta S_c)$$

- $\Phi_a$: Absolute phase
- $\|S_{uC}\|$: Amplitude
- $\psi$: LOS rotation

3 parameters describe the CS geometrical properties

- $\alpha$: Rotation symmetry
- $\delta$: Reflection symmetry
- $\Phi_{ba}$: Characteristic phase

3 parameters describe completely the CS scattering mechanism

Pauli basis:

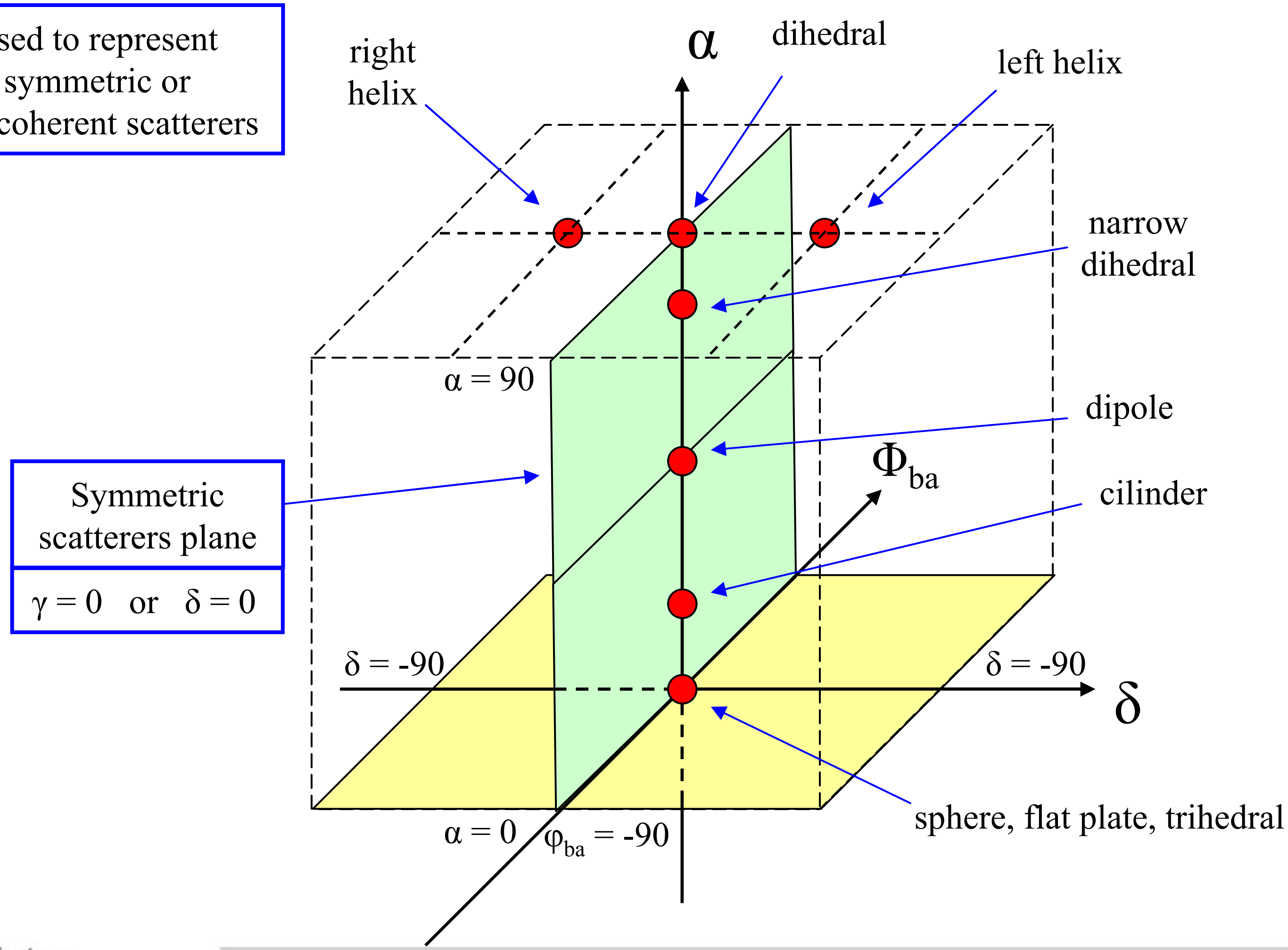
$$S_a = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$S_b = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

$$S_c = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

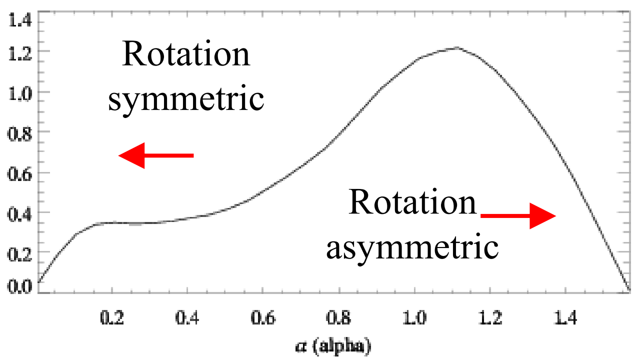
# General Polarimetric Coherent Scatterers Space

May be used to represent general symmetric or asymmetric coherent scatterers

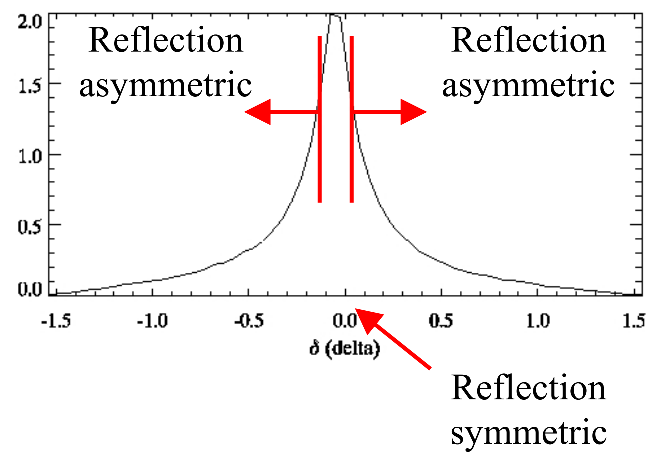


# CSs Experimental Assessment – Munich (E-SAR system)

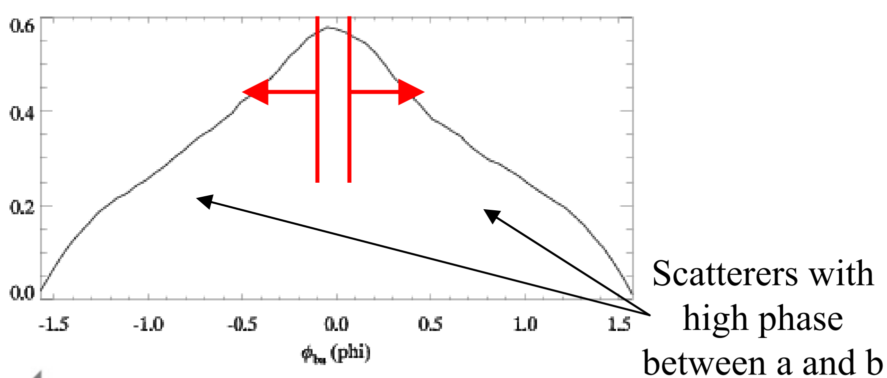
## Rotation symmetry



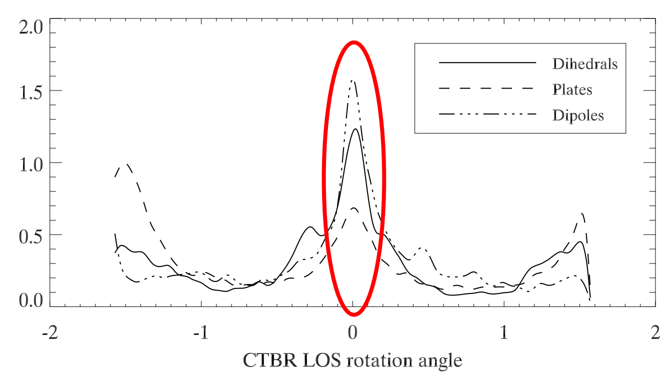

## Reflection symmetry




## Internal characteristic phase




## Scatterer LOS rotation



# Dual-pol TerraSAR polarimetric parameters

**What can be assessed if just dual-pol data are available?**

$$S = R(\psi)S_{uC}R(\psi)^T = \begin{bmatrix} \cos\psi & -\sin\psi \\ \sin\psi & \cos\psi \end{bmatrix} S_{uC} \begin{bmatrix} \cos\psi & \sin\psi \\ -\sin\psi & \cos\psi \end{bmatrix} \xrightarrow[\psi=0]{\text{Assuming}} S = S_{uC}$$

$S_{uC}$: Underlying Scatterer Signature

$$S = \| S \| e^{j\phi_a}(\cos\alpha S_a + e^{j\phi_{ba}} \sin\alpha \cos\delta S_b - j \sin\alpha \sin\delta S_c)$$

Assuming $\delta = 0 \longrightarrow S = \| S \| e^{j\phi_a}(\cos\alpha S_a + e^{j\phi_{ba}} \sin\alpha S_b)$

$$\underbrace{S_a = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad S_b = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}}_{S_{HH} \text{ and } S_{VV}} \quad \cancel{S_c = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}}$$

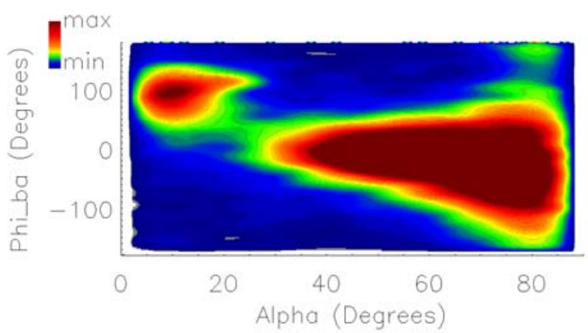
Polarimetric Entropy: $\vec{k}_{2L} = [S_{HH} \quad S_{VV}]^T$

$$[C_2] = \langle \vec{k}_{2L} \vec{k}_{2L}^H \rangle = \lambda_1(\vec{e}_1 \cdot \vec{e}_1^{+}) + \lambda_2(\vec{e}_2 \cdot \vec{e}_2^{+})$$

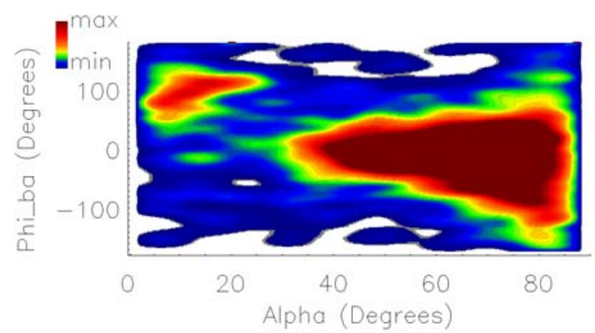
$$P_i := \frac{\lambda_i}{\lambda_1 + \lambda_2} \qquad H := \sum_{i=1}^{2} P_i \log_2 P_i$$

# TerraSAR-X: Bandwidth effect on CSs polarimetric parameters

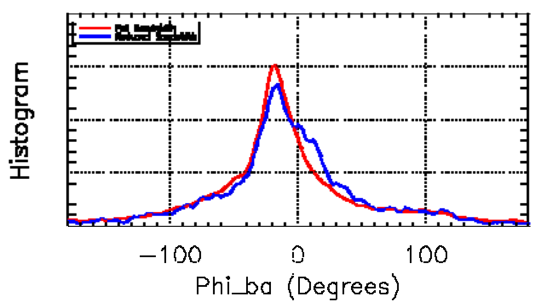
## Full resolution (150 MHz)



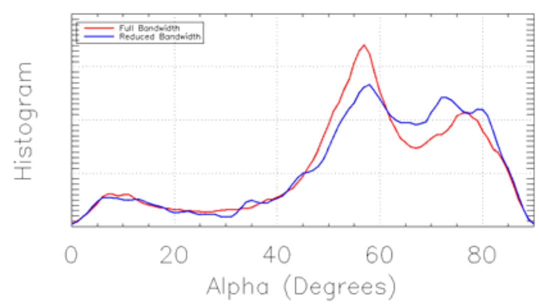

## Reduced resolution (15 MHz)



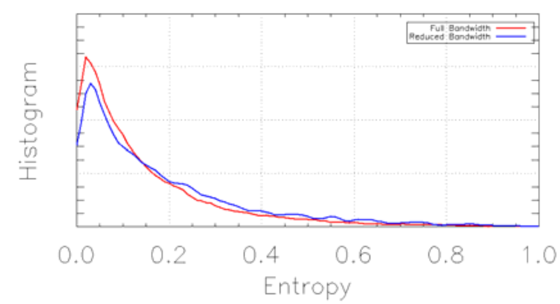

## Characteristic phase $\Phi_{ba}$




## Rotation symmetry $\alpha$

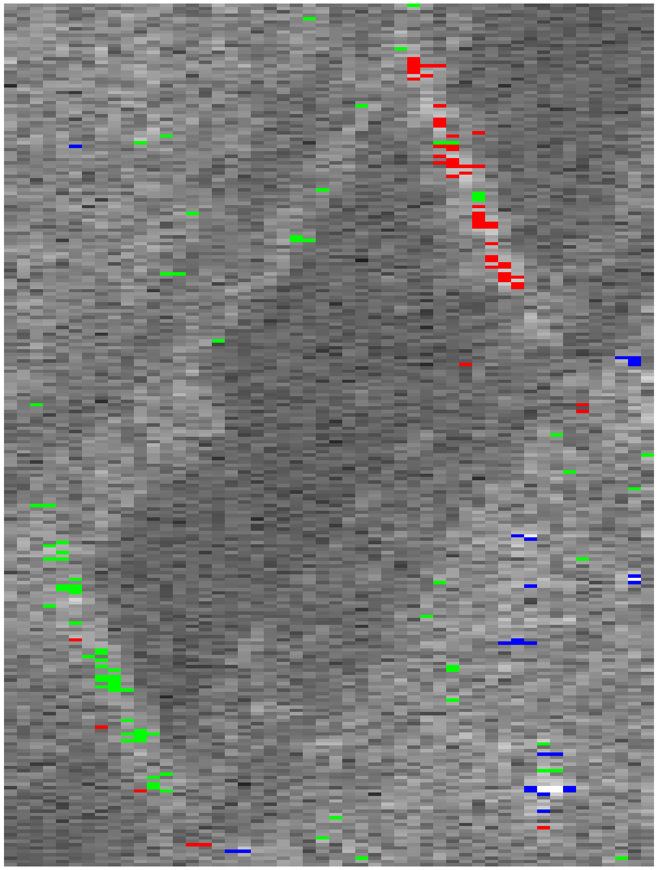
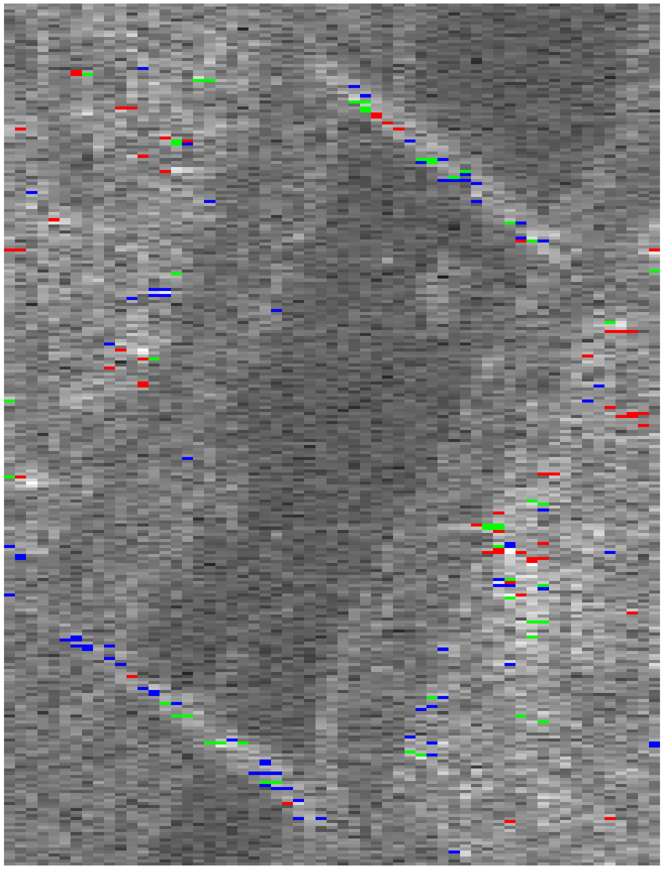



## Polarimetric entropy H



# TerraSAR-X versus ALOS/PalSAR: Frequency effect on CSs detection

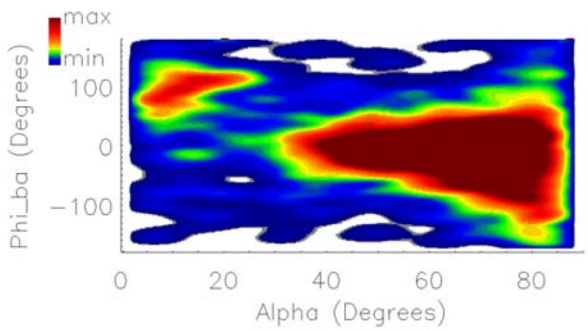
**L-band: ALOS/PalSAR** **X-band: TerraSAR-X (reduced resolution)**

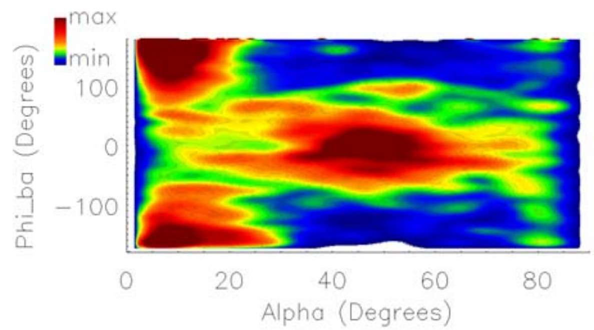
**Gifu test site**

# TerraSAR-X versus ALOS/PalSAR: Frequency effect on CSs polarimetric parameters

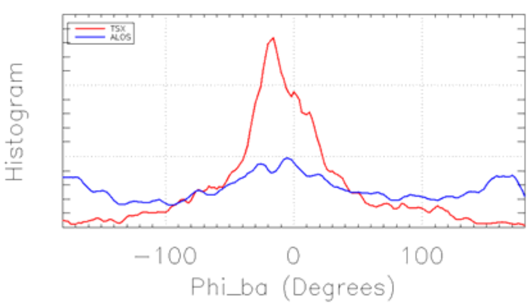
**TerraSAR-X (X-band)**



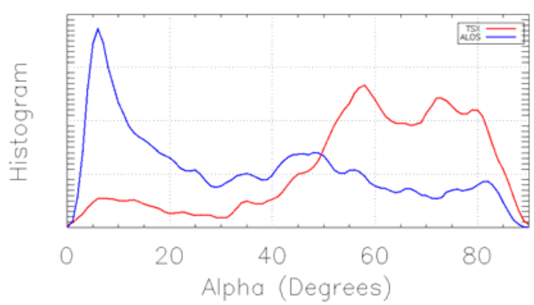

**ALOS/PalSAR (L-band)**



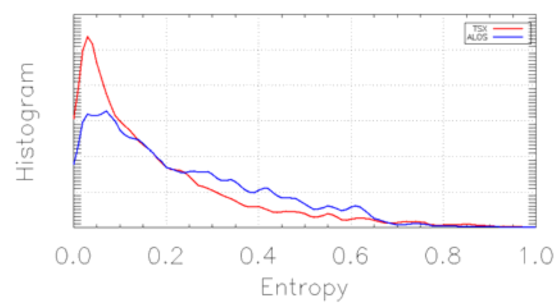

**Characteristic phase $\Phi_{ba}$**




**Rotation symmetry $\alpha$**




**Polarimetric entropy H**



# Conclusions

- Feaseability to detect CSs on TerraSAR-X data has been demonstrated
- The proposed alternative detection:
  - has the advantage of a pixel basis detection
  - has the disadvantage of resolution lost if narrow bandwidth sublooks are generated, and longer computational time for several sublooks
- Dual polarization data:
  - does not allow a full polarimetric CSs description
  - but allows a partial description if assumptions are made
- The carrier frequency influences the CSs scattering mechanism.

- The full polarimetric TerraSAR-X experimental mode will allow a more complete polarimetric description of CSs;
- Time series will allows the observation of the temporal behavior of CSs.