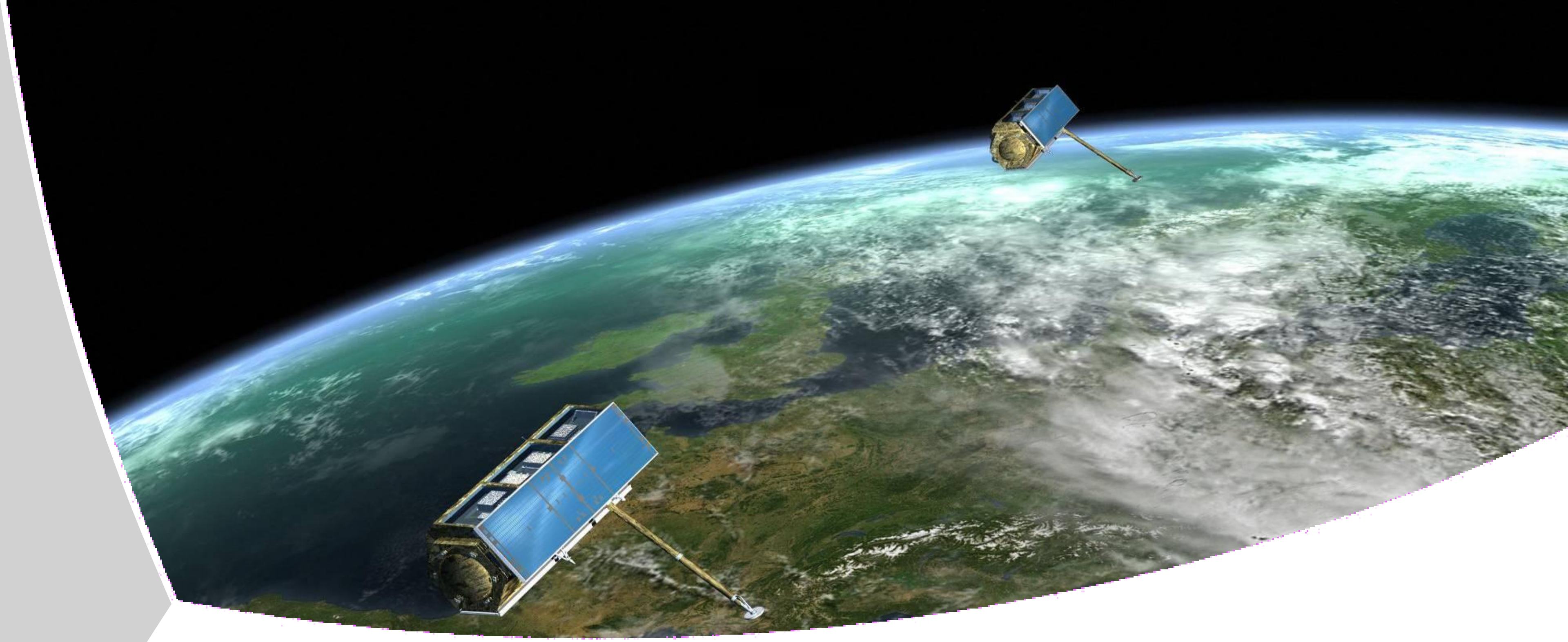

# *Coherent Scatterers (CSs) Detection for Glacier Monitoring by means of TerraSAR-X Data*


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# Introduction

- **<u>Coherent Scatterers (CSs):</u>** relevant class of point (-like) scatterers.
  - Important characteristic of CSs: stable spectral correlation.
  - Spectral correlation techniques have been proposed for their detection.
  - Advantage compared with other point scatterers: the estimation of CSs is possible with a single image basis.

- **Why CSs?**
  - Point scatterers are the only kind of scatterers that can give us information about the phase (not affected by the speckle).

- CSs detection investigated primarily in urban environments and on the basis of airborne data.

- Analysis of the potential of CSs detection for natural scenarios (like ice and glacier terrain) in terms of wide-band spaceborne SAR systems (TerraSAR-X) and possible applications with time series data.

# CSs Detection

- Different approaches for the detection of CSs:

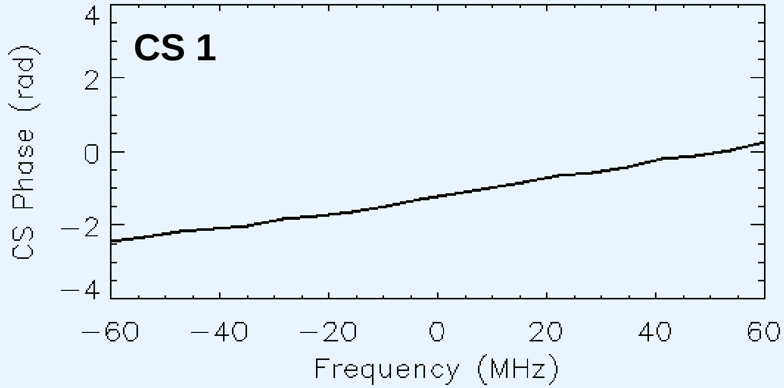
  - **Sublook Coherence Approach:** based on the cross-correlation of two spectral sub-bands. Scatterers with high sublook correlation values are considered as detected CSs.

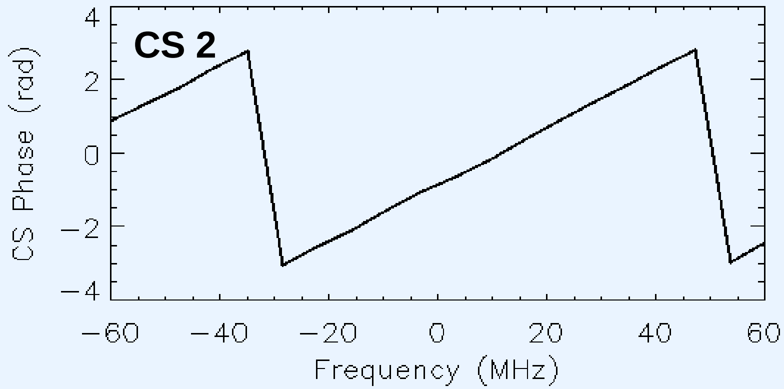
  - **Sublook Entropy Approach:** based on the cross-correlation of multiple spectral sub-bands. In this case, the measure to use is the entropy among the sublook images.
    - It allows a more flexible detection with respect to the spectral characteristics of the individual CSs.

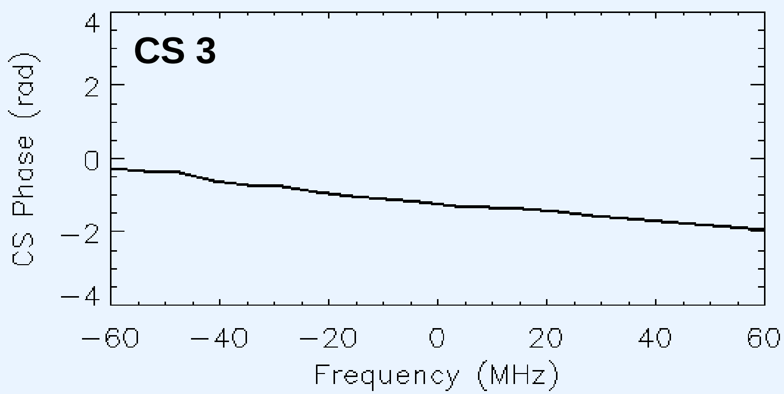
  - **Phase Variance Approach:** based on the deterministic phase pattern across the spectrum characteristic of the CSs.
    - It allows a widely preservation of the spatial resolution in the CSs detection.

# Phase of CSs and Non-CSs as a Function of Frequency

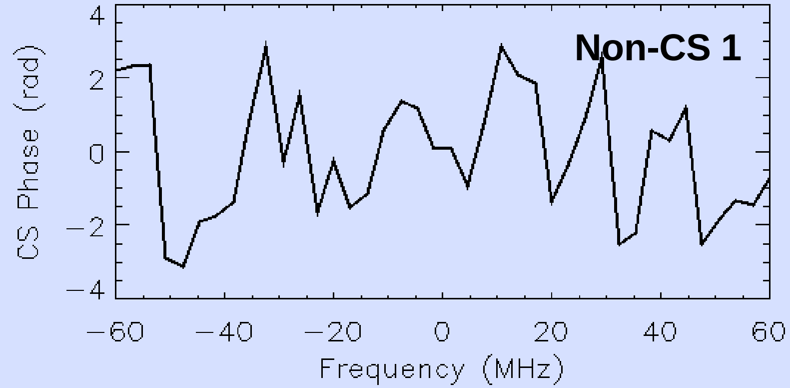
## Coherent Scatterers

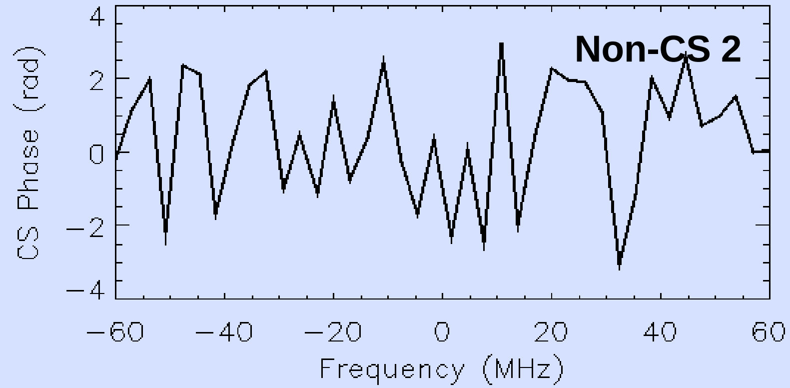


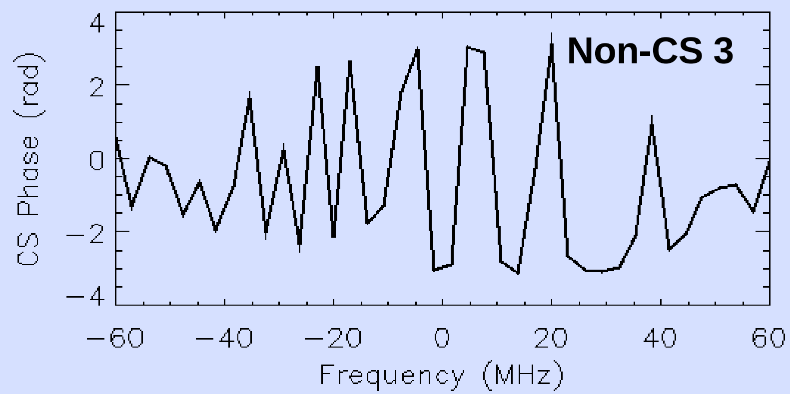




## Distributed Scatterers

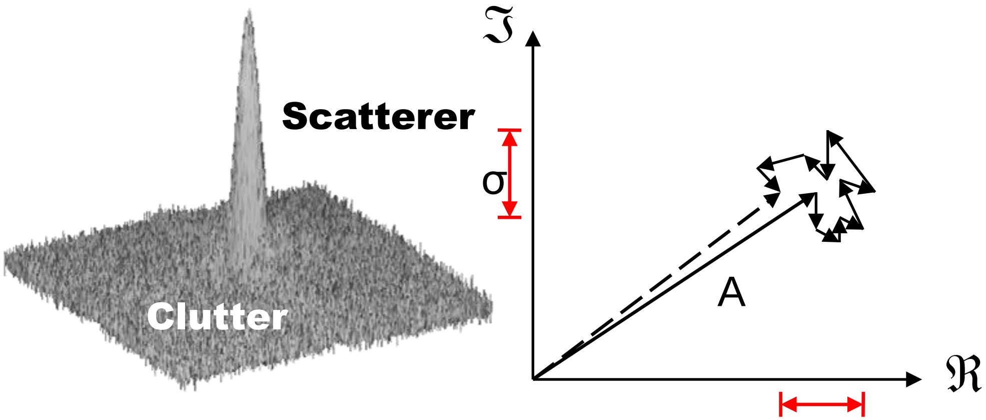


# CSs Statistical Model

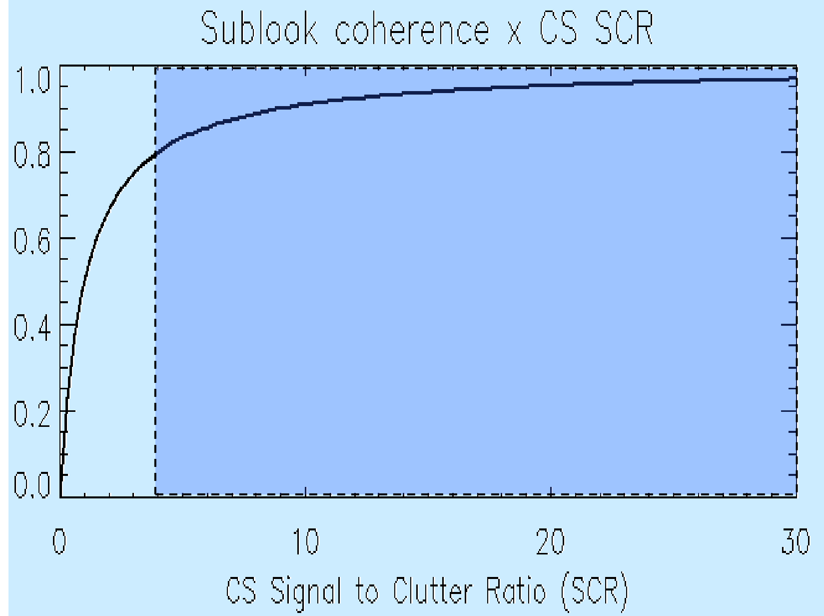
**Assumption:** One dominant (point-like) scatterer + Clutter

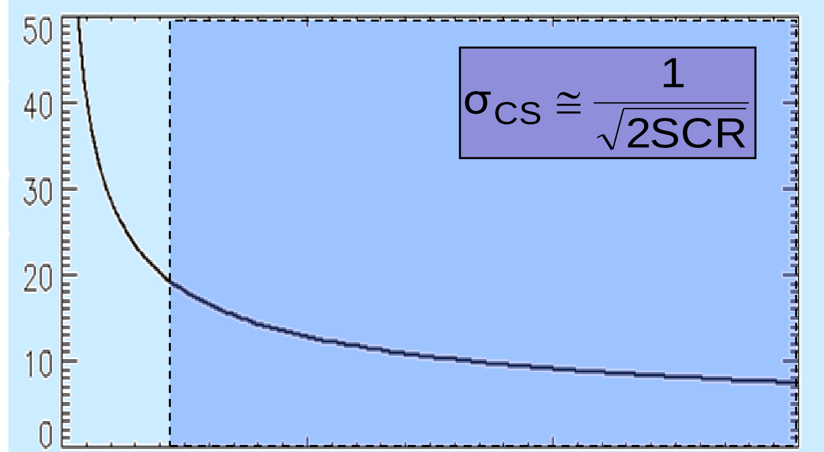


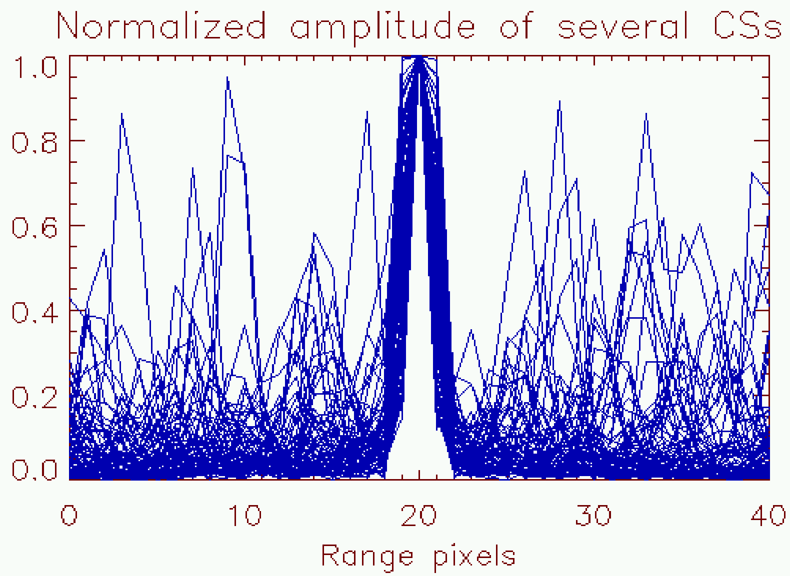

**Signal to Clutter Ratio:** $SCR = \frac{A^2}{2\sigma^2} = \frac{\gamma_{sub}}{1-\gamma_{sub}} = R$

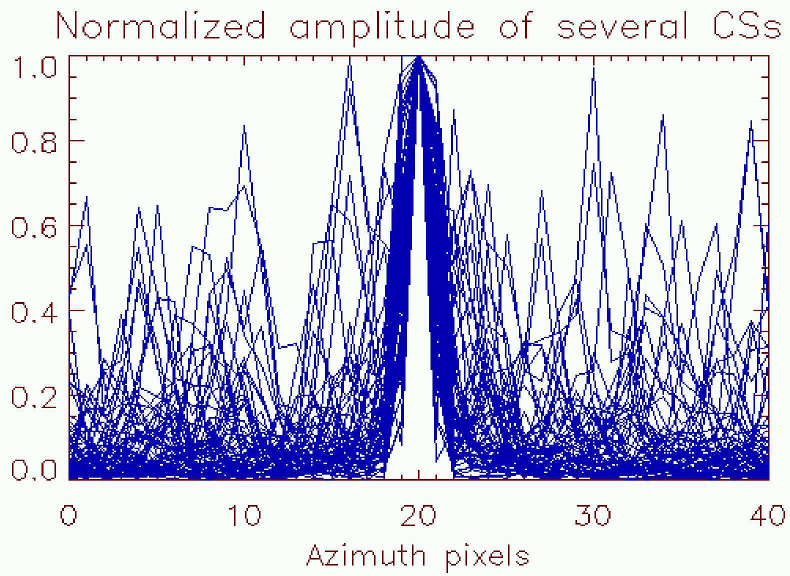
**Sublook Coherence:** $\gamma_{sub} = \frac{A^2}{A^2 + 2\sigma^2} = \frac{1}{1+SCR^{-1}}$

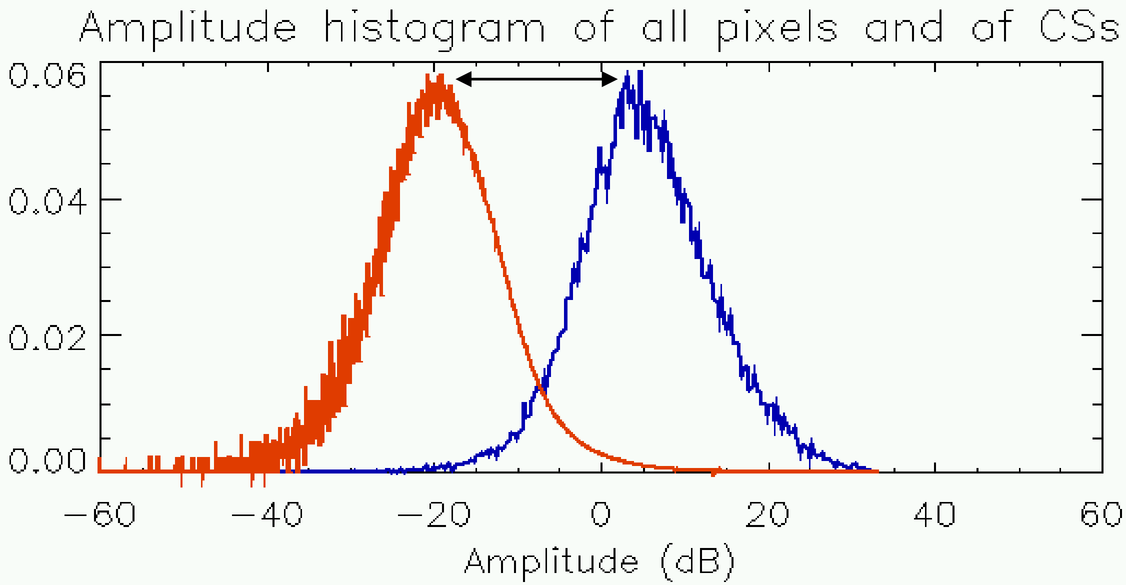
**CSs Phase Variance:** $\sigma^2_{CS} \cong \frac{1}{2\ SCR}$ for large SCR





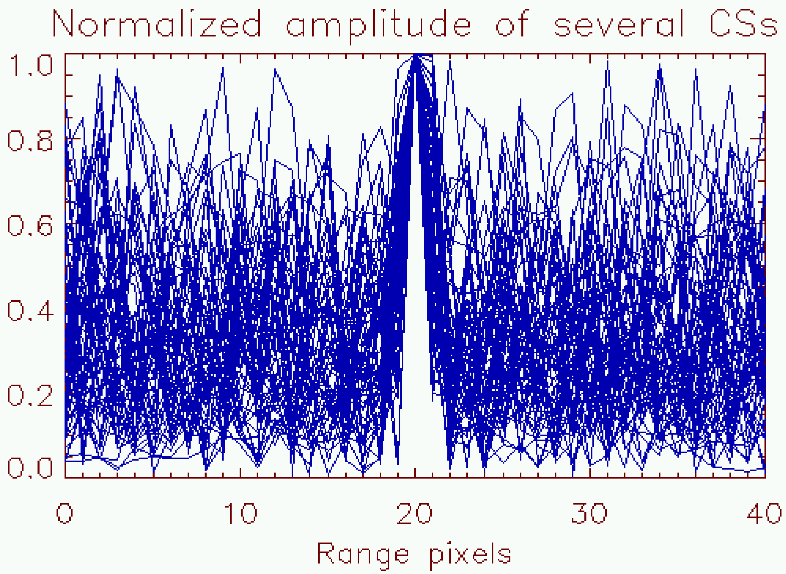



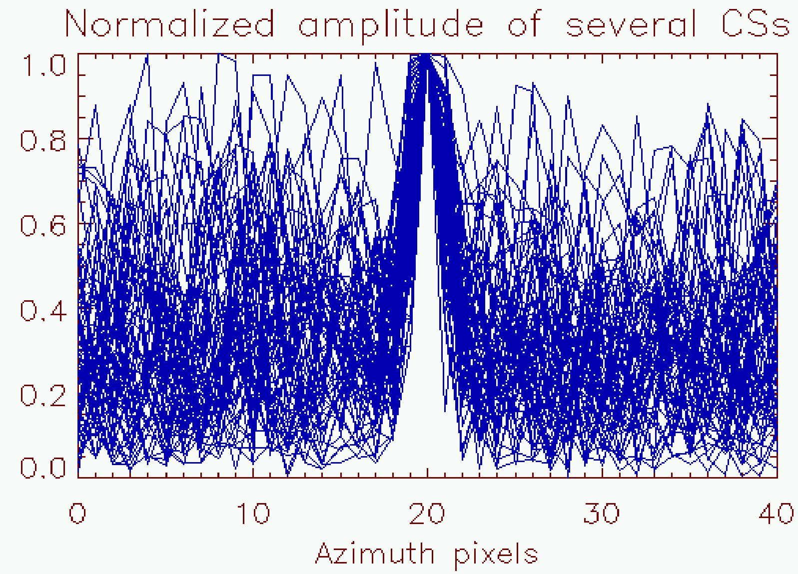

**Test site:** Paris, France

**Sensor:** TerraSAR-X

**Bandwidth:** 300 MHz

**Mode:** Spotlight




**Test site:** Salar de Uyuni, Bolivia

**Sensor:** TerraSAR-X

**Bandwidth:** 300 MHz

**Mode:** Strip-map

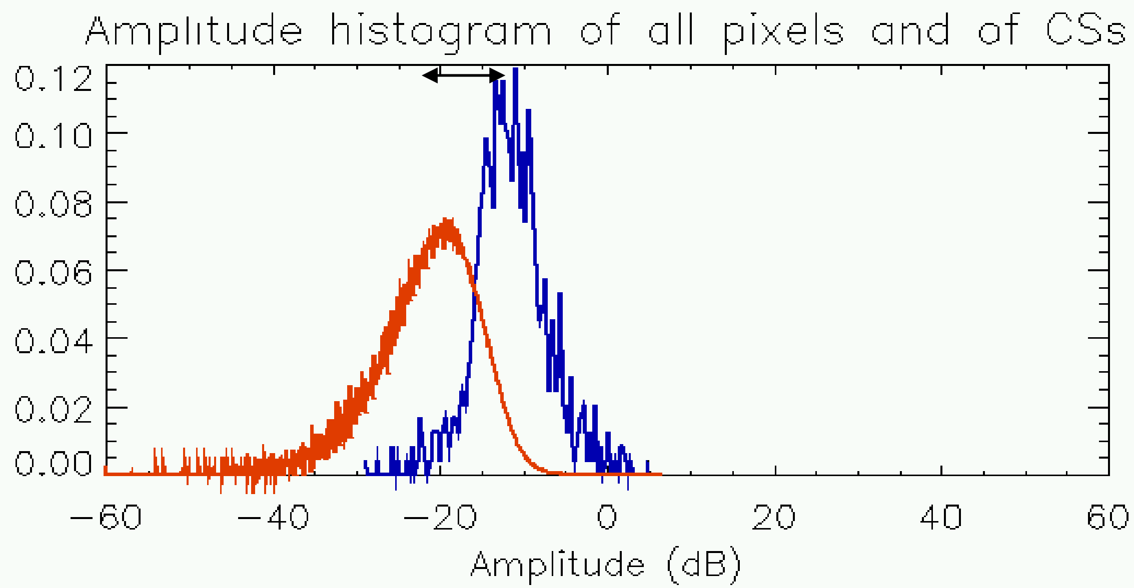


IMAGE1: 19-06-09

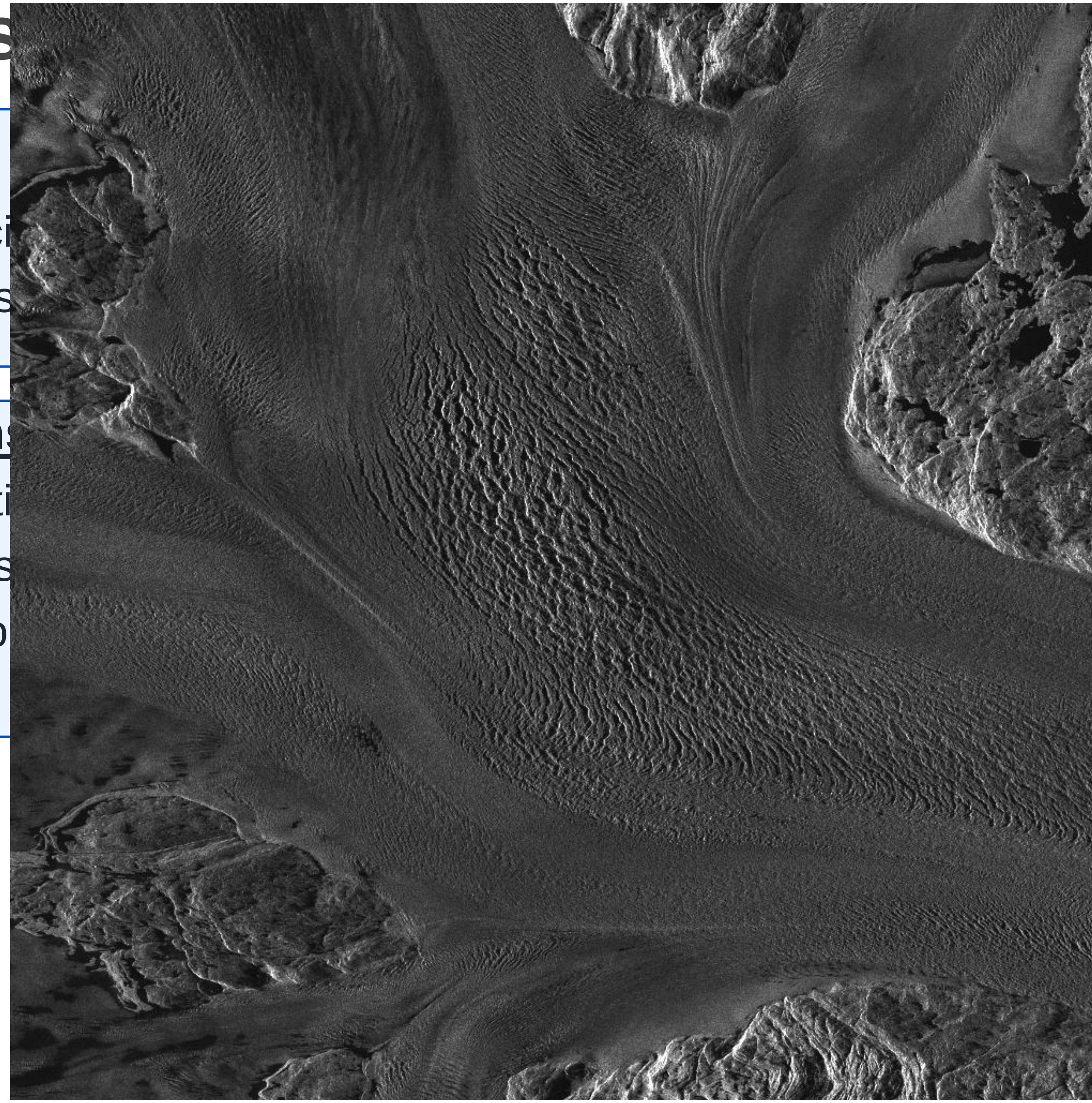
IMAGE2: 30-06-09

IMAGE3: 11-07-09

# CSs

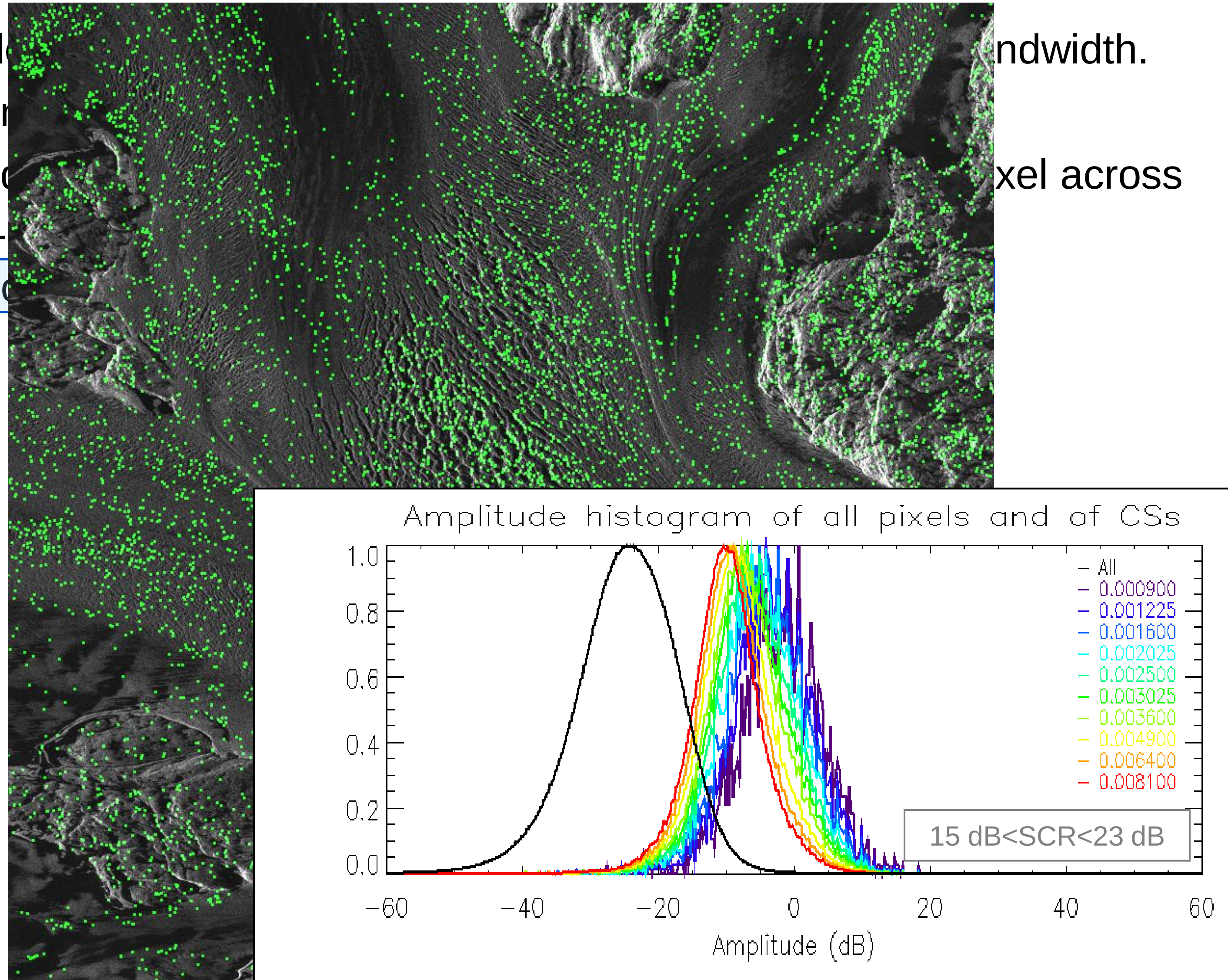
- **Test site:**
  - Helheim Glaci
  - One of the fas

- **SAR acquisitions**
  - TerraSAR-X ti
  - Period: Augus
  - 11 days, Strip angle.



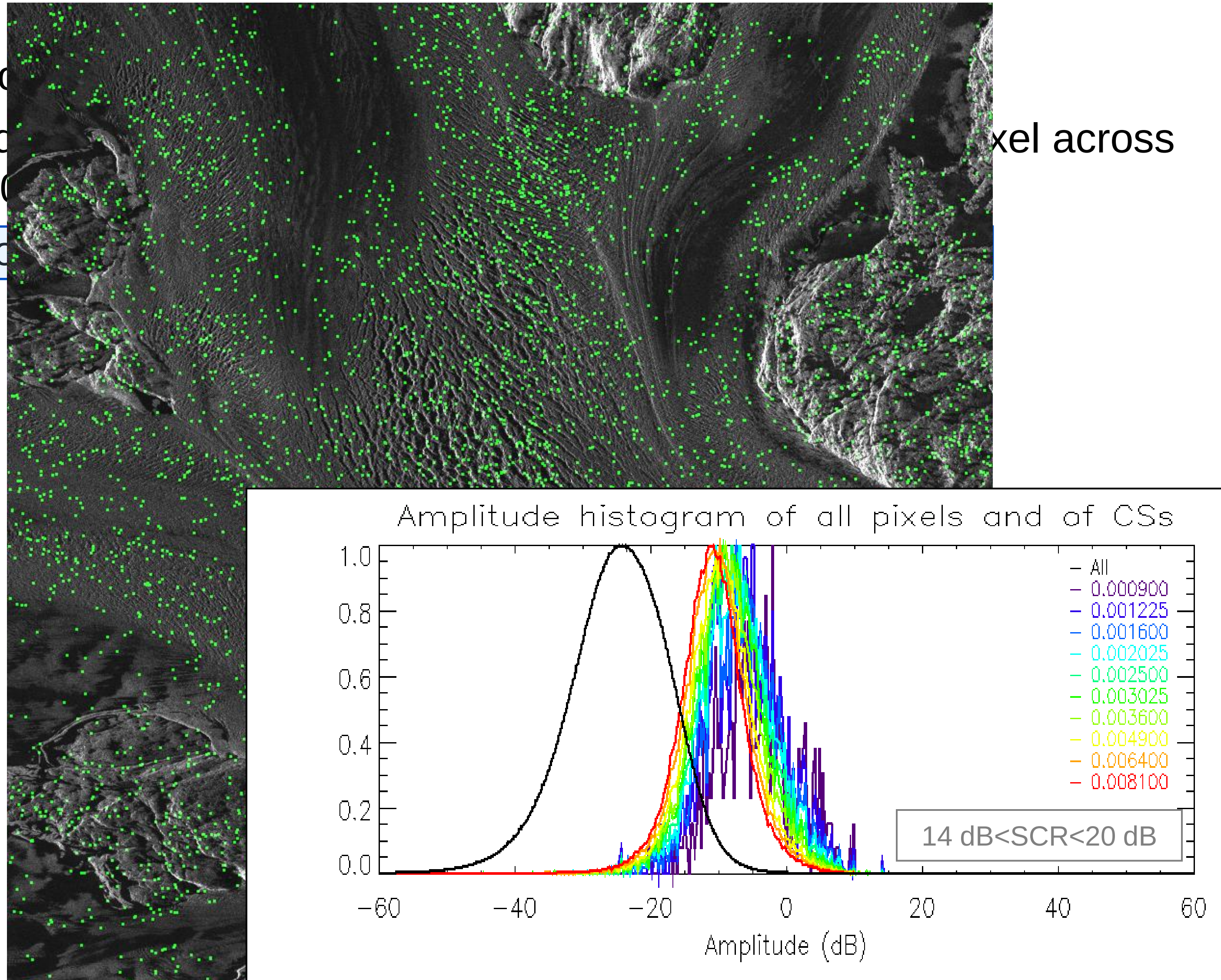
# Results: Range CSs Detection

- 10 subl… …ndwidth.
- Spannin…
- Phase … …xel across these 1…
- Thresh…



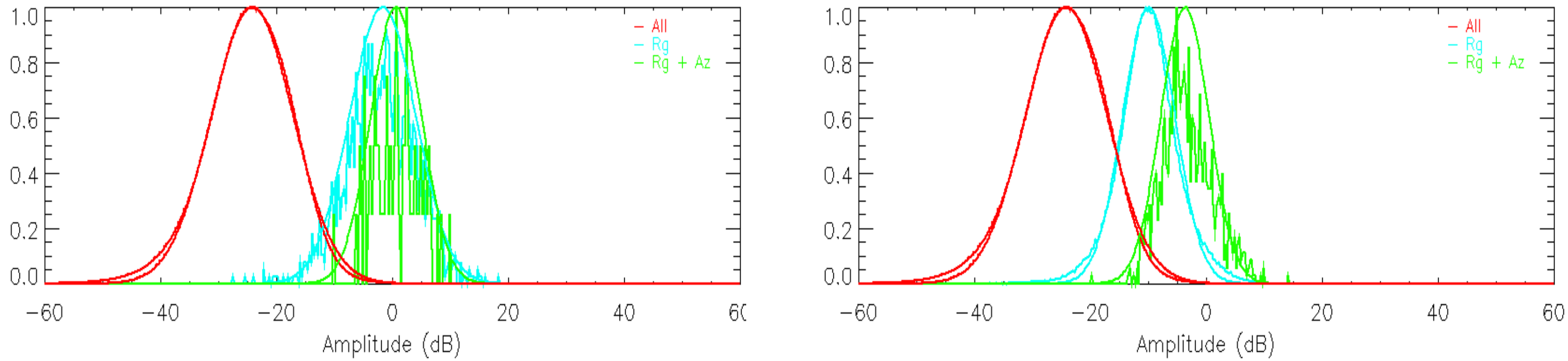
# Results: Azimuth CSs Detection

- 10 subl
- Phase c xel across these 1(
- Thresh



# Detection Analysis: Common detection

- <u>Improvement of Range Detection using Azimuth Information</u>
  - 10 sublooks of 60 MHz each out of the 150 MHz range bandwidth are formed and the variance $\sigma^2$ of the phase derivative for every pixel is estimated.
  - CSs are detected for a given range threshold ($\sigma^2$ = 0.0009 and 0.0081 rad²).
  - 10 sublooks of 1106 Hz each out of the 2765 Hz azimuth bandwidth and the variance of the phase derivative for every pixel is estimated.
  - From the CSs detected in range, the ones that have an azimuthal variance $\sigma^2$ < 0.0016 rad² are selected.

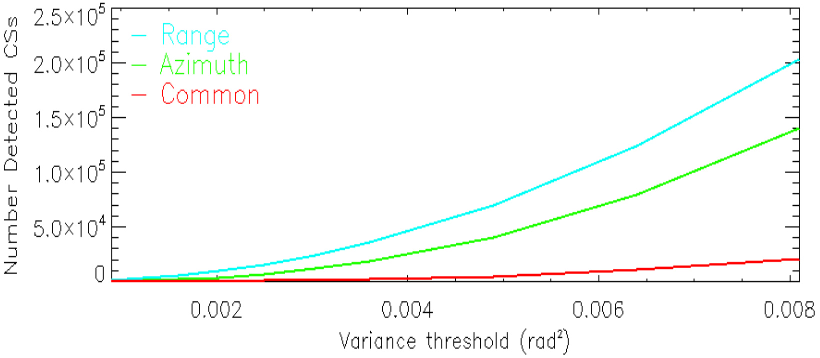


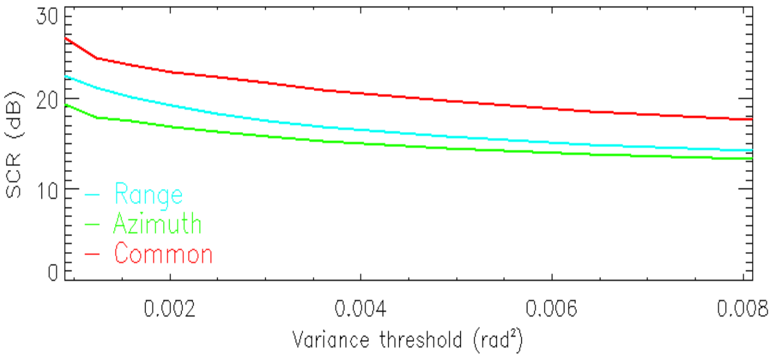

$SCR_{improv}$ = 2 dB

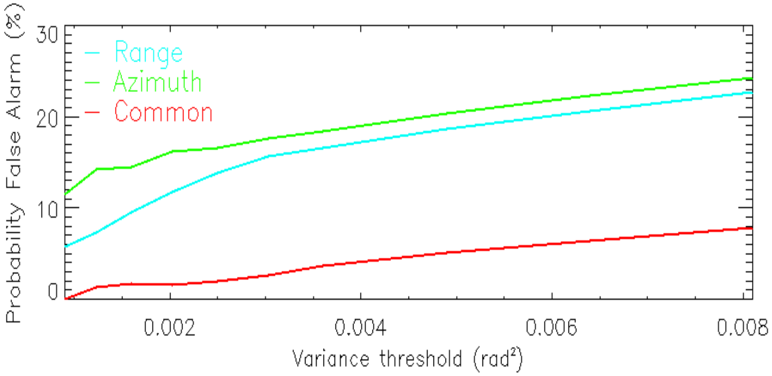
$SCR_{improv}$ = 6 dB

# Detection Analysis: Common detection (II)

- <u>Detection in common</u>
  - Comparison between range only, azimuth only and common range-azimuth detection.
  - Common detection: only the CSs that have a phase derivative variance $\sigma^2$ lower than a given threshold in both direction are considered as CSs.



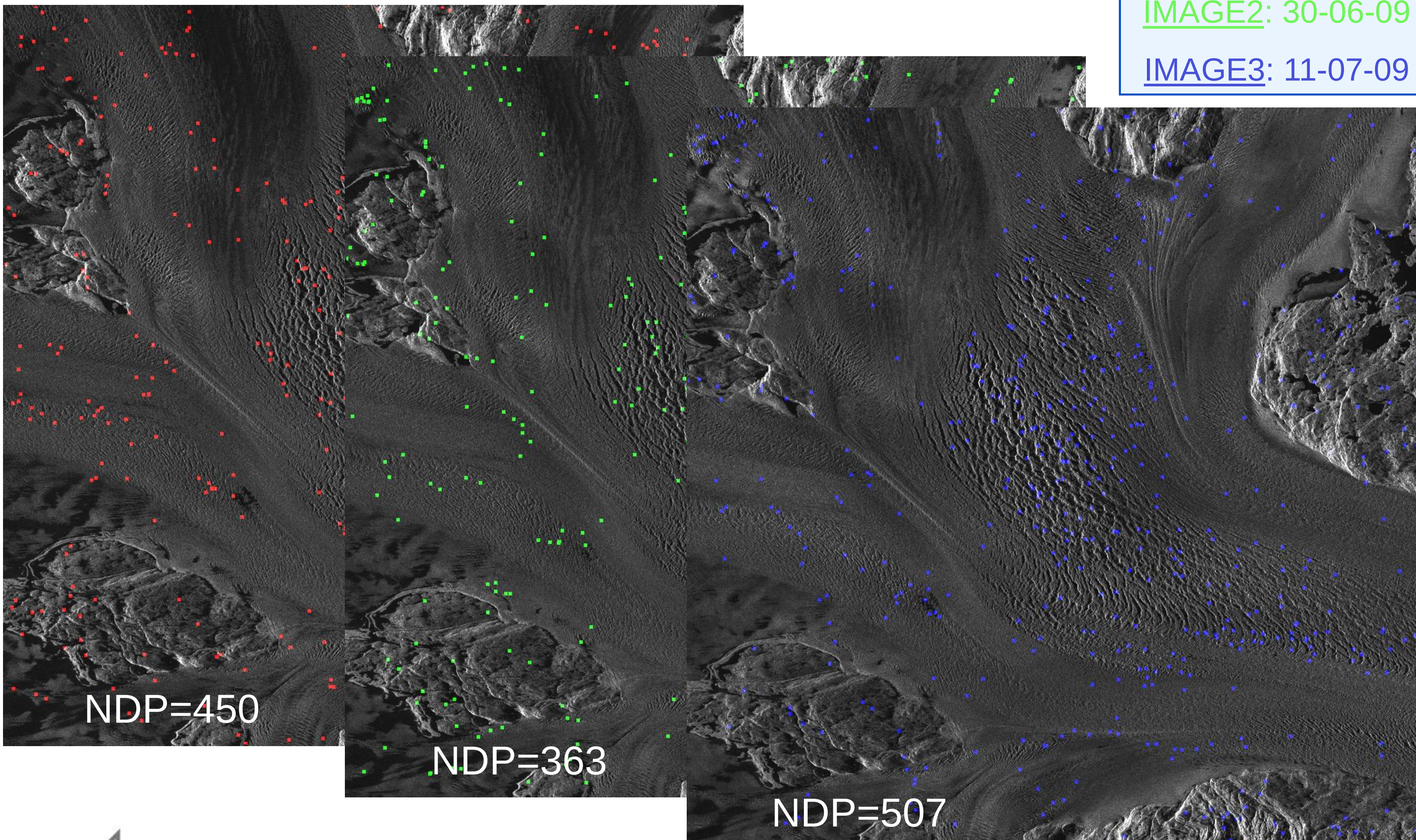



# CSs in Time Series

IMAGE1: 19-06-09

IMAGE2: 30-06-09

IMAGE3: 11-07-09

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# CSs in Time Series (II)

IMAGE 1 - 2

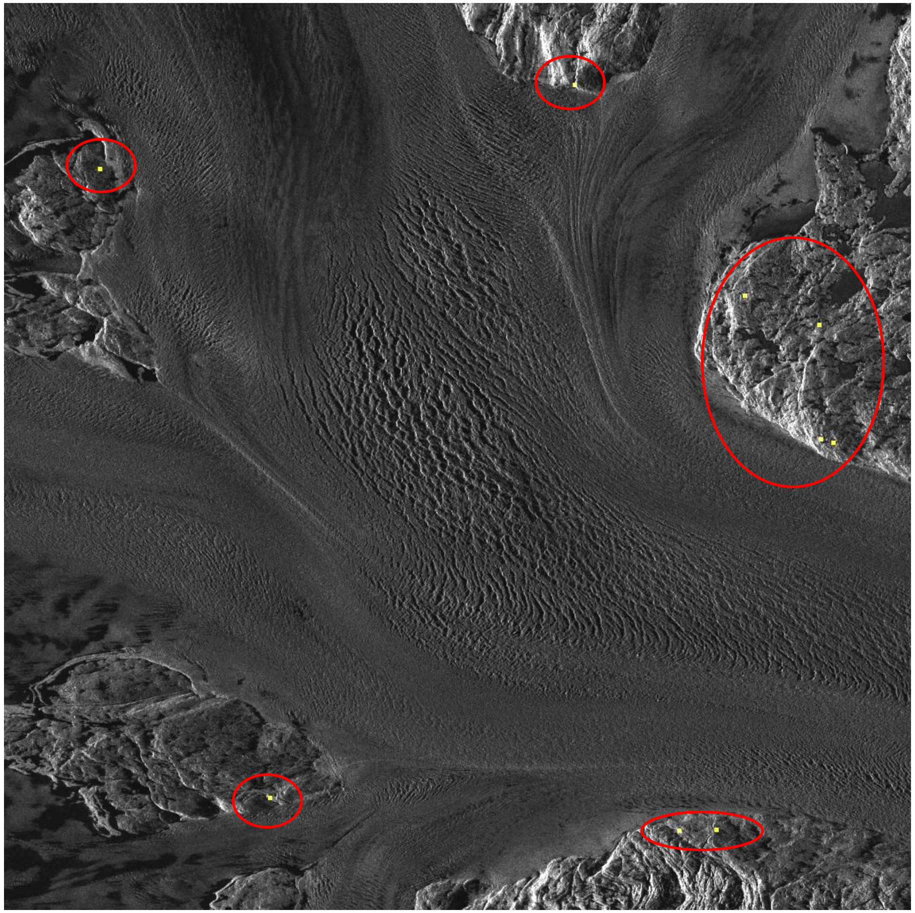
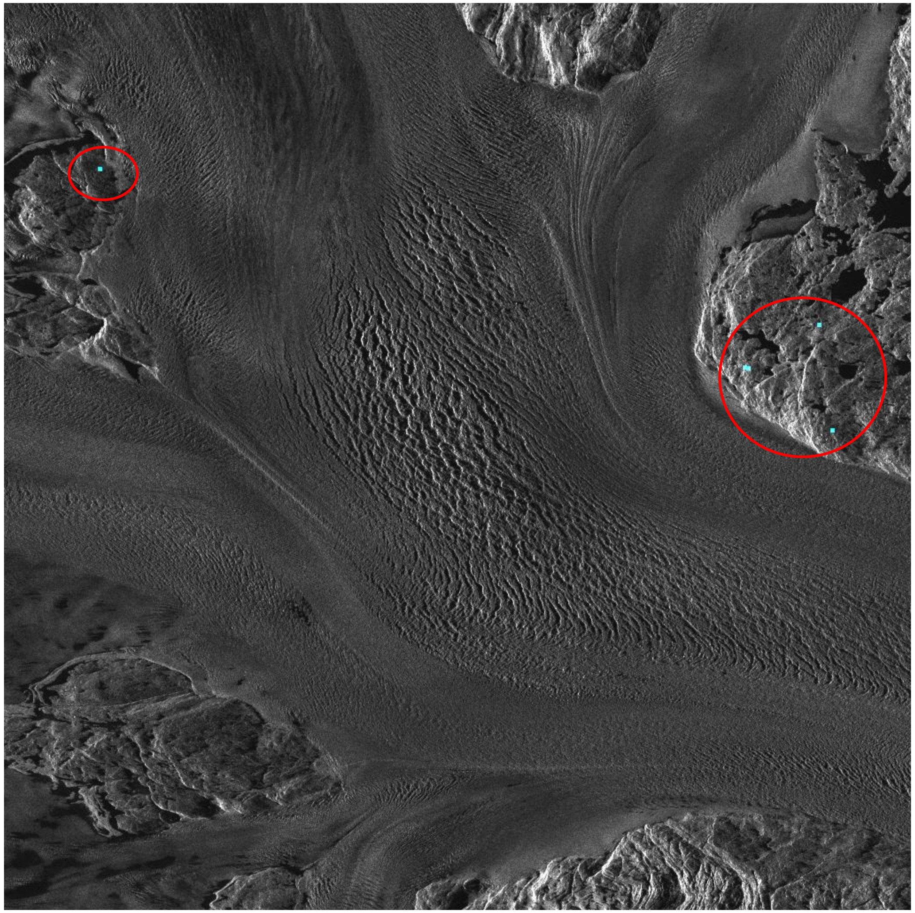
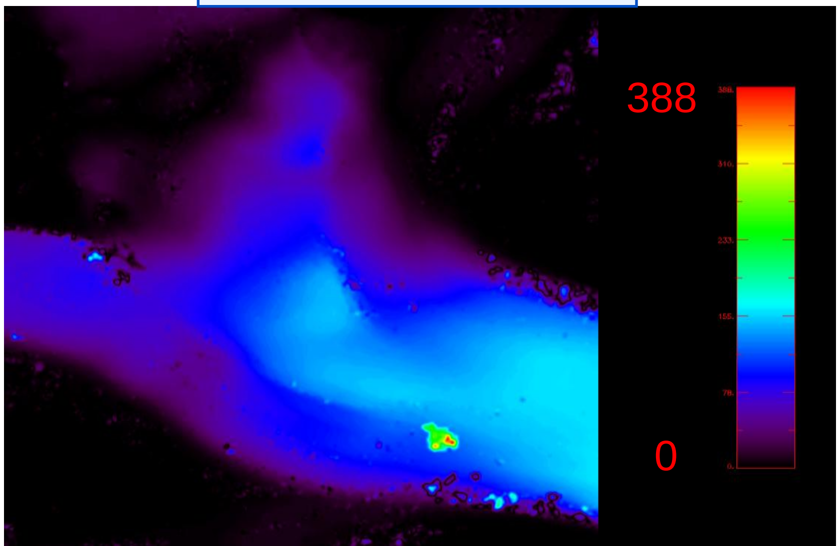


IMAGE 2 - 3

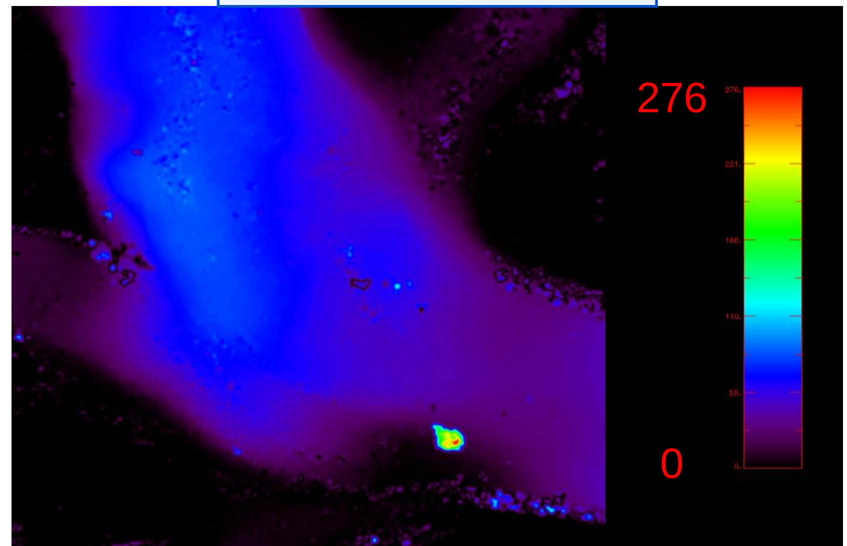


# CSs in Time Series(III)

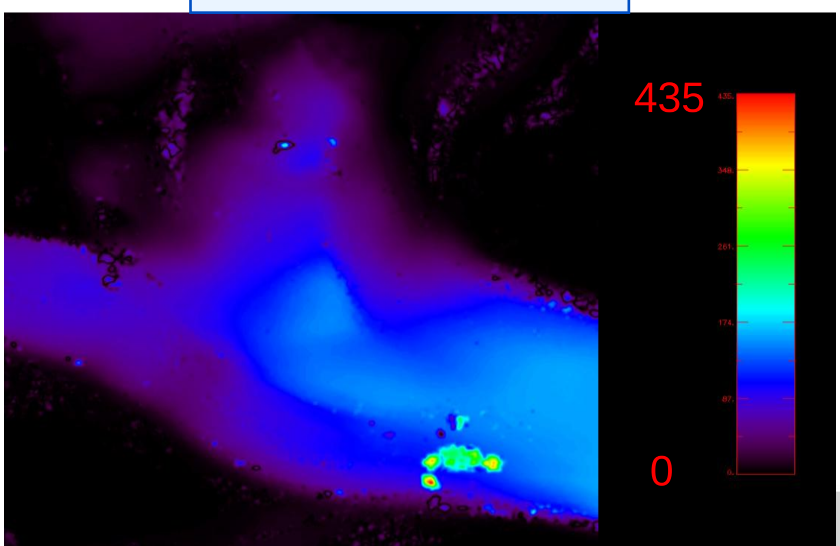
**RG SHIFT IMAGE 1-2**



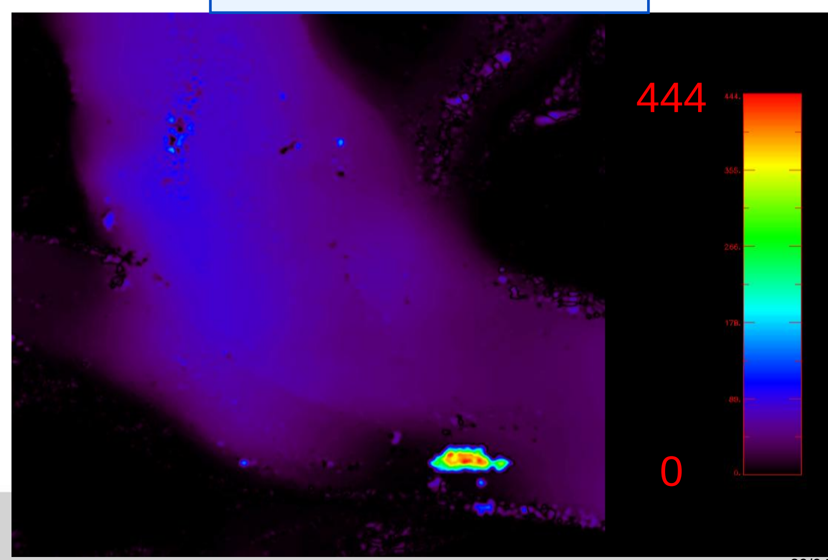

**AZ SHIFT IMAGE 1-2**




**RG SHIFT IMAGE 2-3**




**AZ SHIFT IMAGE 2-3**



# CSs in Time Series (IV)

IMAGE 1 - 2

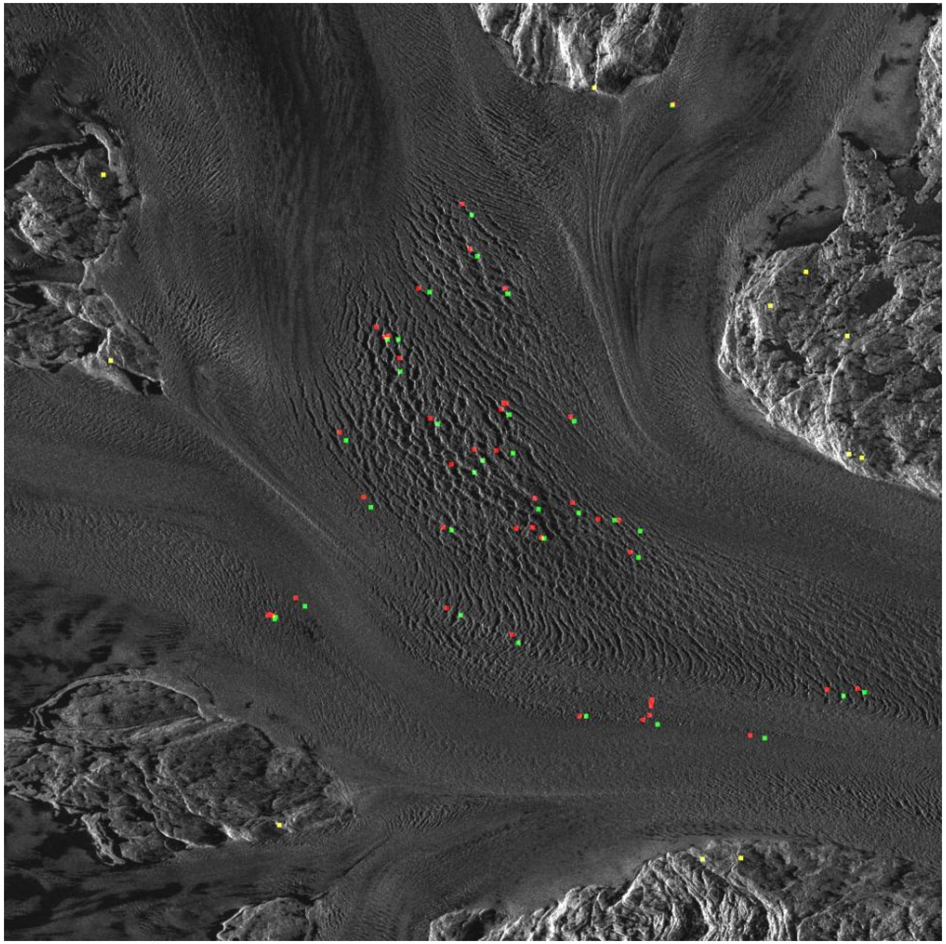
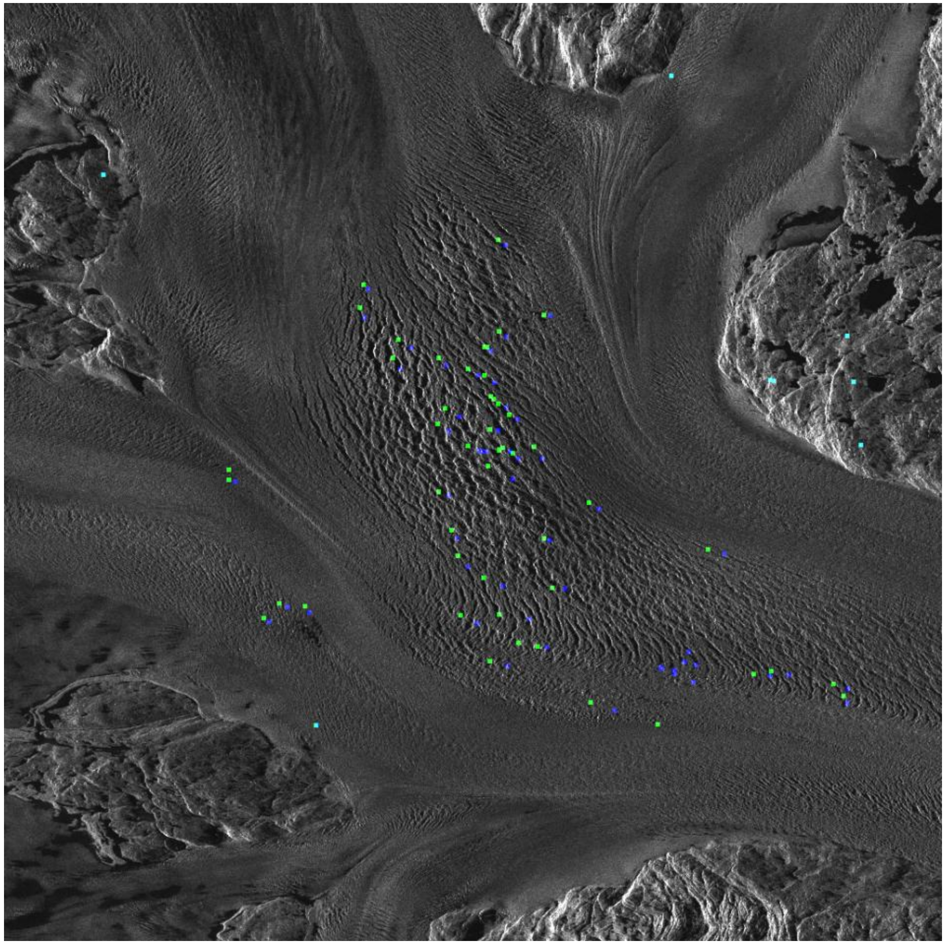


IMAGE 2 - 3



# Conclusions

- CSs (i.e. quasi deterministic scatterers with partial developed speckle pattern) can be detected in natural (extended) scattering environments by means of (high resolution) space-borne SAR data:
  - Detection on the Helheim glacier using TerraSAR-X time series images.
- CSs in natural scattering environments can be potentially used for calibration and/or bio-geophysical parameter estimation.
- Natural CSs are characterised by low(er) SCR levels (i.e they are less deterministic that man-made CSs in urban areas).
  - False Alarms (FA) suppression becomes an issue for their detection.
  - Wide Range/Azimuth bandwidths are an advantage.
  - The combination of Range/Azimuth correlation can be used for FA suppression.
- Natural CSs have a limited “life time” due to the temporal and/or dynamic environmental effects within the scene:
  - CSs at high(er) frequencies (X-band) live short(er).
  - Detection in multiple images depends on the temporal separation of the images.
- FA and CSs mortality make the identification (especially within dynamic environments) challenging.