Radiometric calibration aided by Permanent Scatterers: current status and future capabilities

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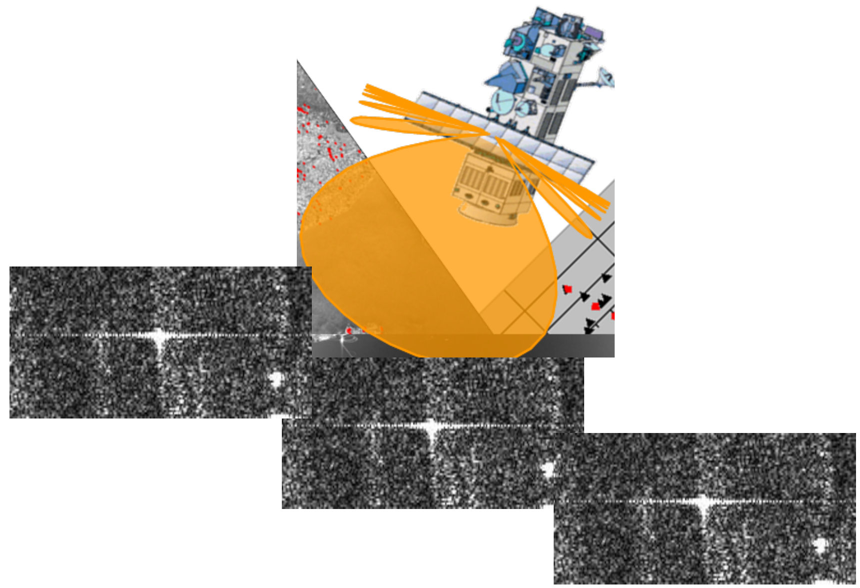

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ESA/ ESRIN

Outline

→ Current Image Calibration Techniques Overview

→The ***PSCal*** Calibration Technique

→Algorithm and Performances on ERS-2 datsets & ESA transponders

→Work in progress / future activities:

→Coregistration

→Stack size vs. Accuracy

→Elevation pattern estimation

→Polarimetric datasets calibration

→ Conclusions

Current calibration techniques

- The SAR calibration aims to:
  - Estimation of the targets radar cross section
  - SAR instrument health status monitoring
    - Antenna Pattern, T/R Modules, Power losses

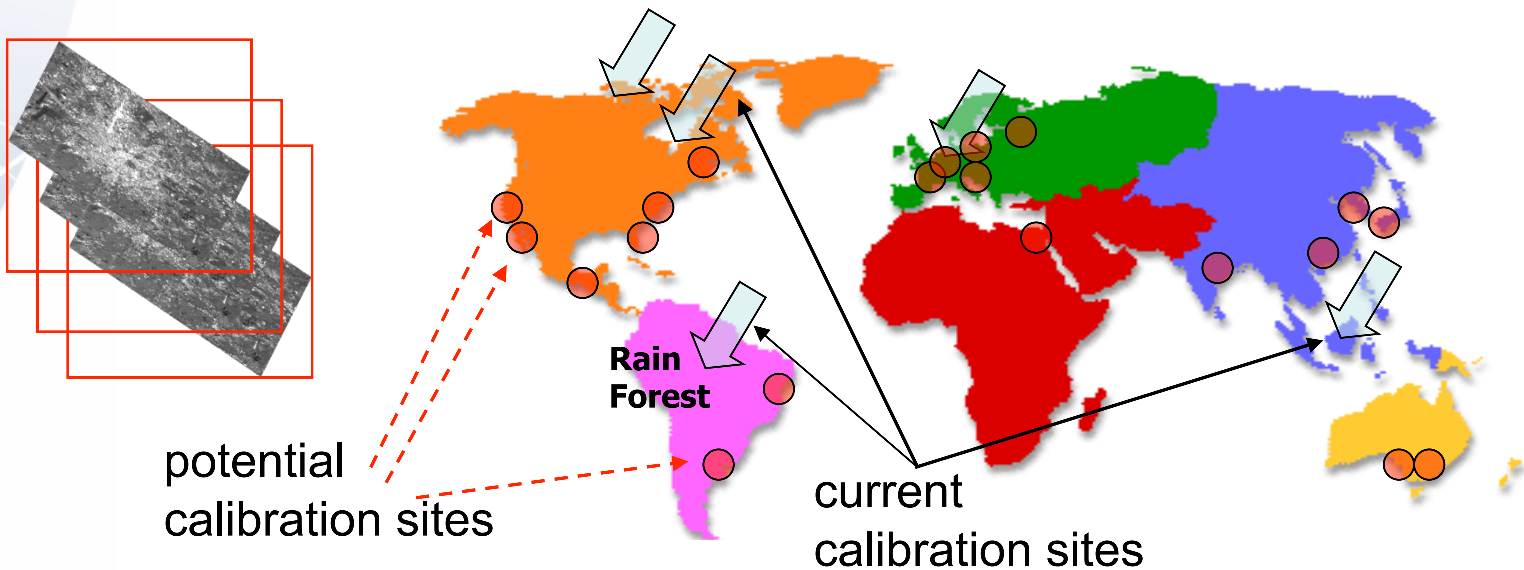
ENVISAT ASAR Transponder

- Current calibration techniques exploit:
    - a proper internal calibration network
    - homogeneous stable targets, mainly the rain forest
    - active and passive reflectors (Transponders, corner reflectors)

- A calibration site is quite expensive to be deployed and even more expensive to be maintained for the mission lifetime. Moreover, it demands for dedicated acquisitions that interferes with the mission operations.

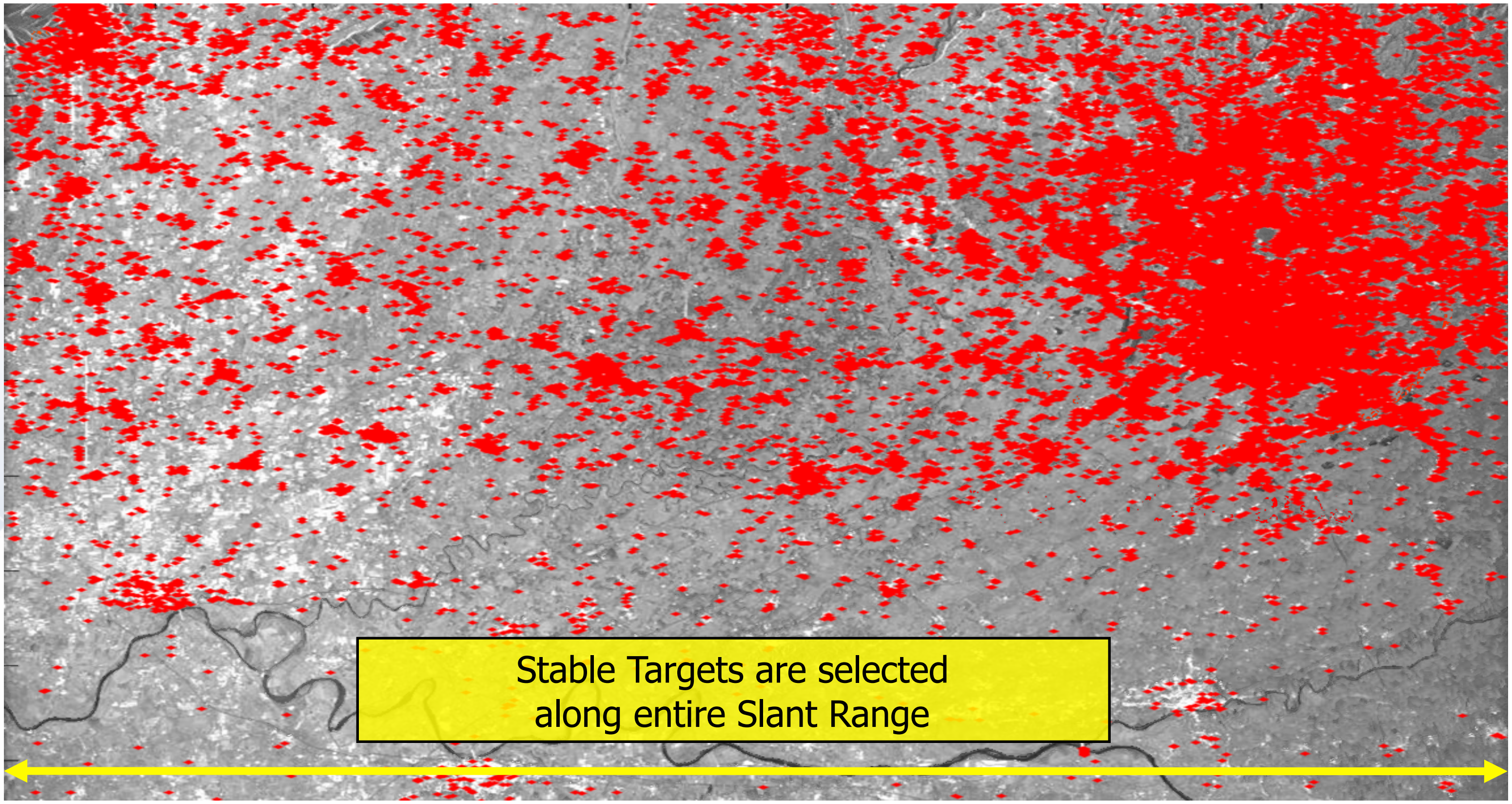
PSCal 's Principle and Aim

- The PS *phases* are currently used for estimating deformations
- The idea is to exploit the PS *amplitudes* for accurate normalization & calibration
- The goal is the estimate of the *calibration constant ,* to carry out image calibration
- A large number of images stacks means a large number of “calibration sites”!



Validation #1: ERS-2 dataset - Milan

- SLC stack of 40 ERS-2 images over Milan urban area: 1995 to 2000

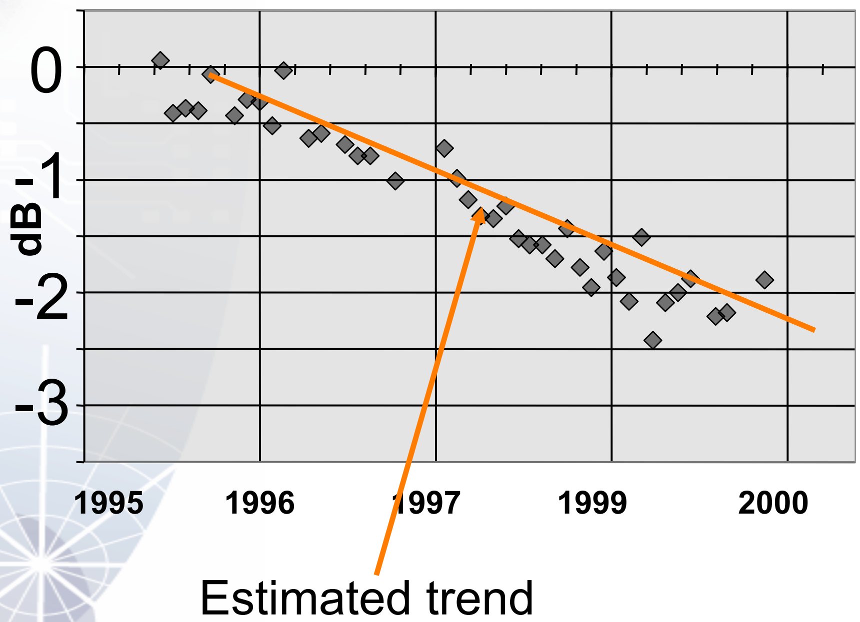


110000
Selected Targets

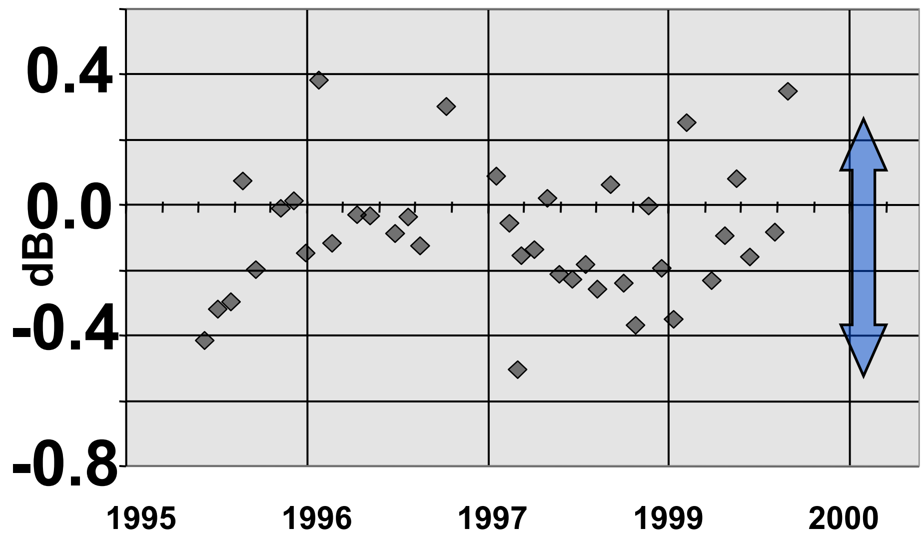
PSCal calibration: Milan ERS-2 – Results

The ***PSCal*** retrieves the ERS-2 gain decay with time

Milan – NORM Constants Estimation



Milan – **Detrended** NORM Constants

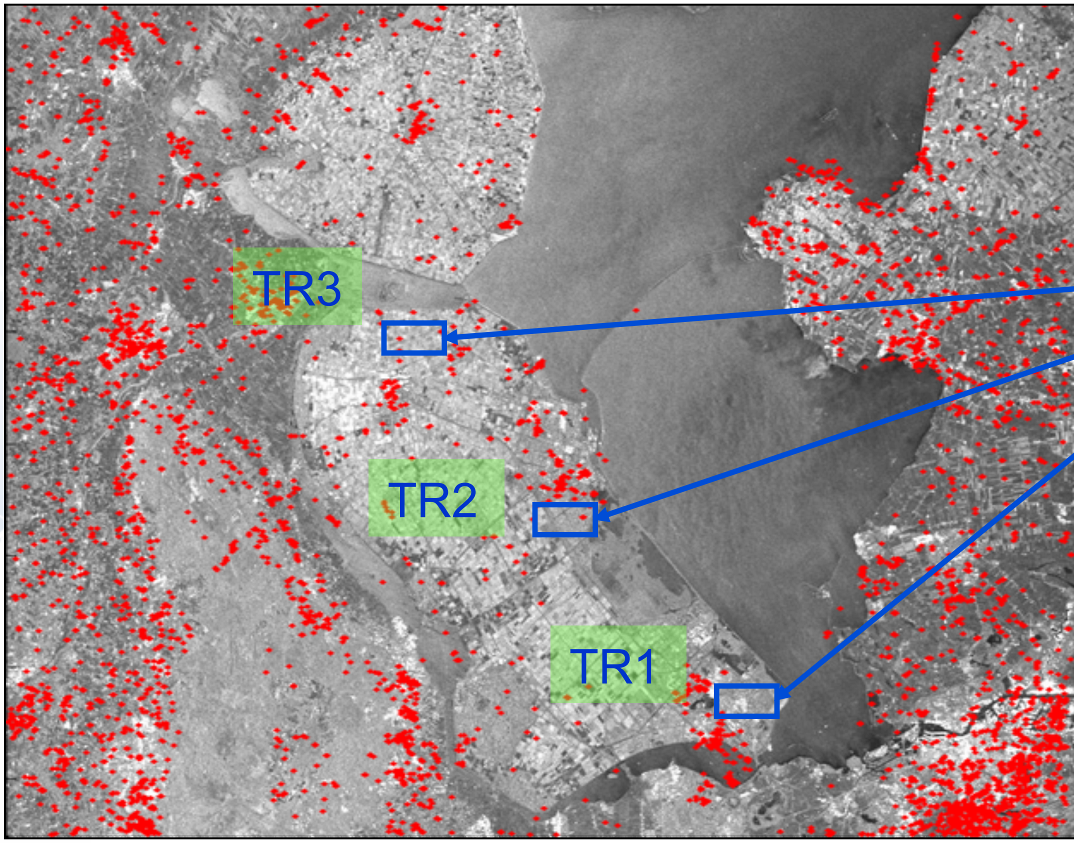


Estimated dispersion of the

detrended NORM : 0.2 dB

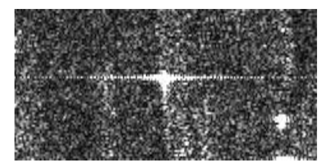
Validation #2: ERS-2 dataset - Flevoland

- SLC stack of 46 ERS-2 images over Flevoland (NL), 1995-2000



ERS-2

3 Transponders available

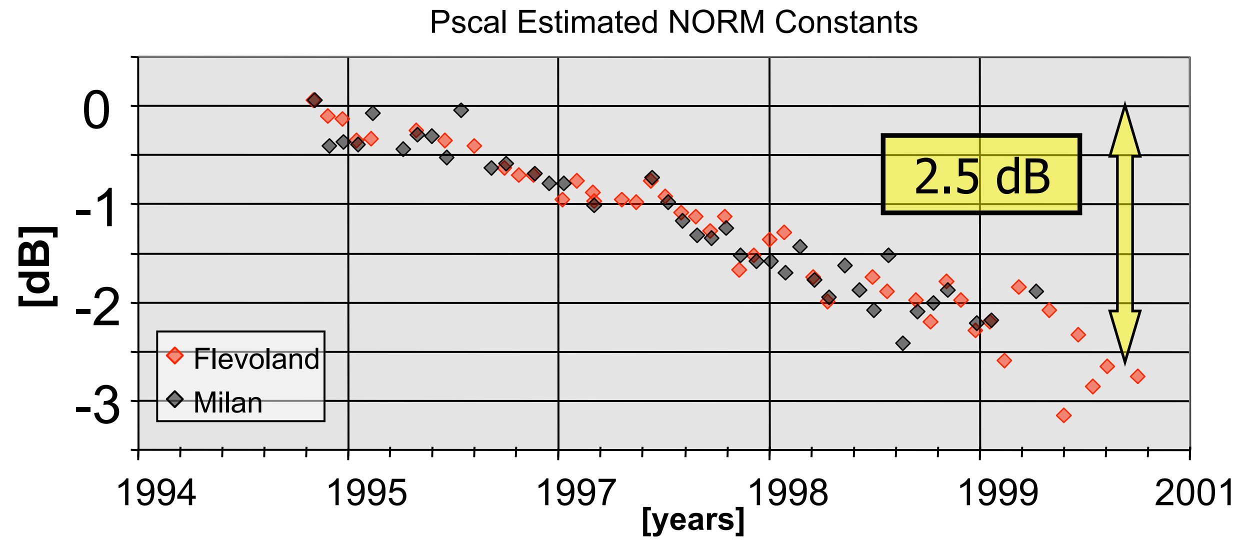


TR1

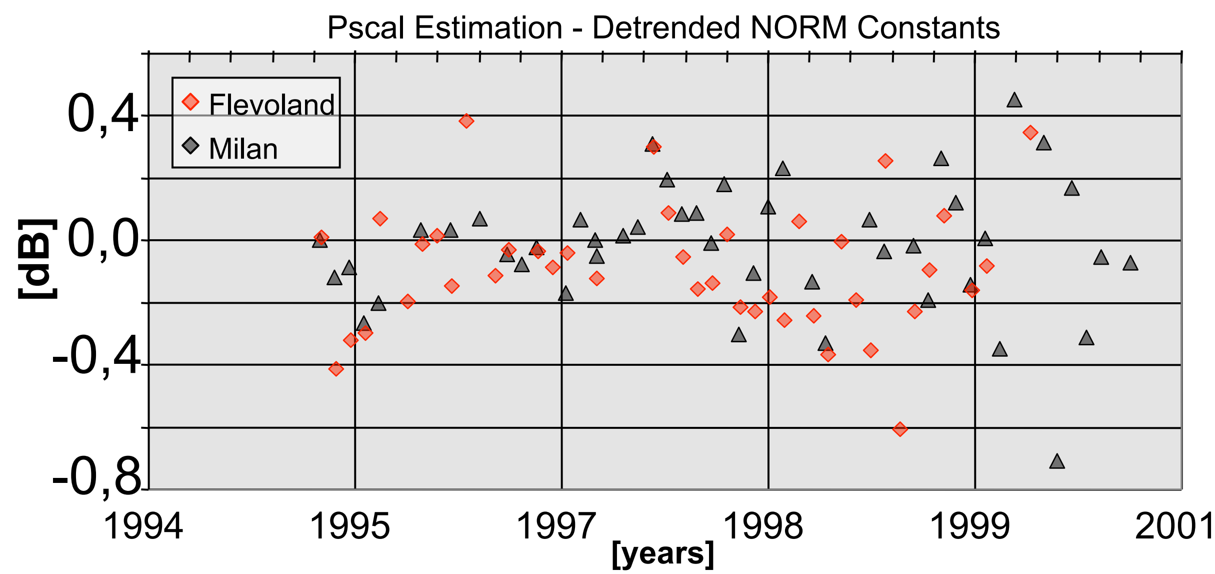
66000
Selected Targets

PSCal ERS-2: Flevoland vs. Milan

• Comparison between results from Flevoland and Milan Dataset:



Both temporal series show a decrease of about 2.5 dB from 1995 to 2000.



• Both detrended series show the same dispersion around central value:

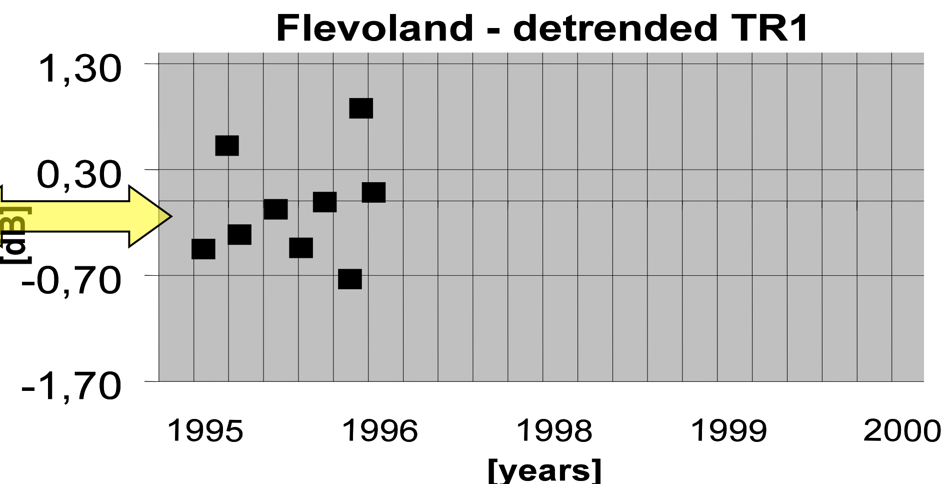
≈ 0.2 [dB]

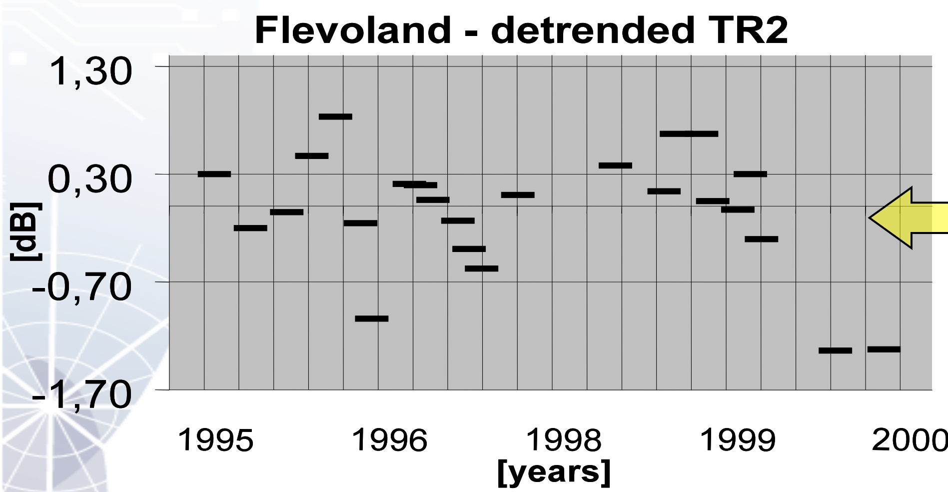
Flevoland – Transponder Measures

- 3 TR measures from Flevoland images are considered .

TR1: **9** measues available

Dispersion: **0.5** [dB]



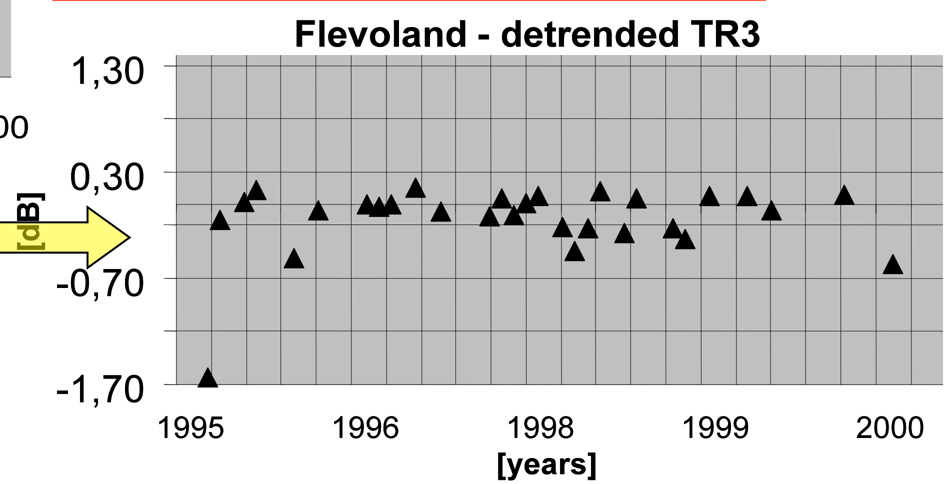


TR2: **25** measues available

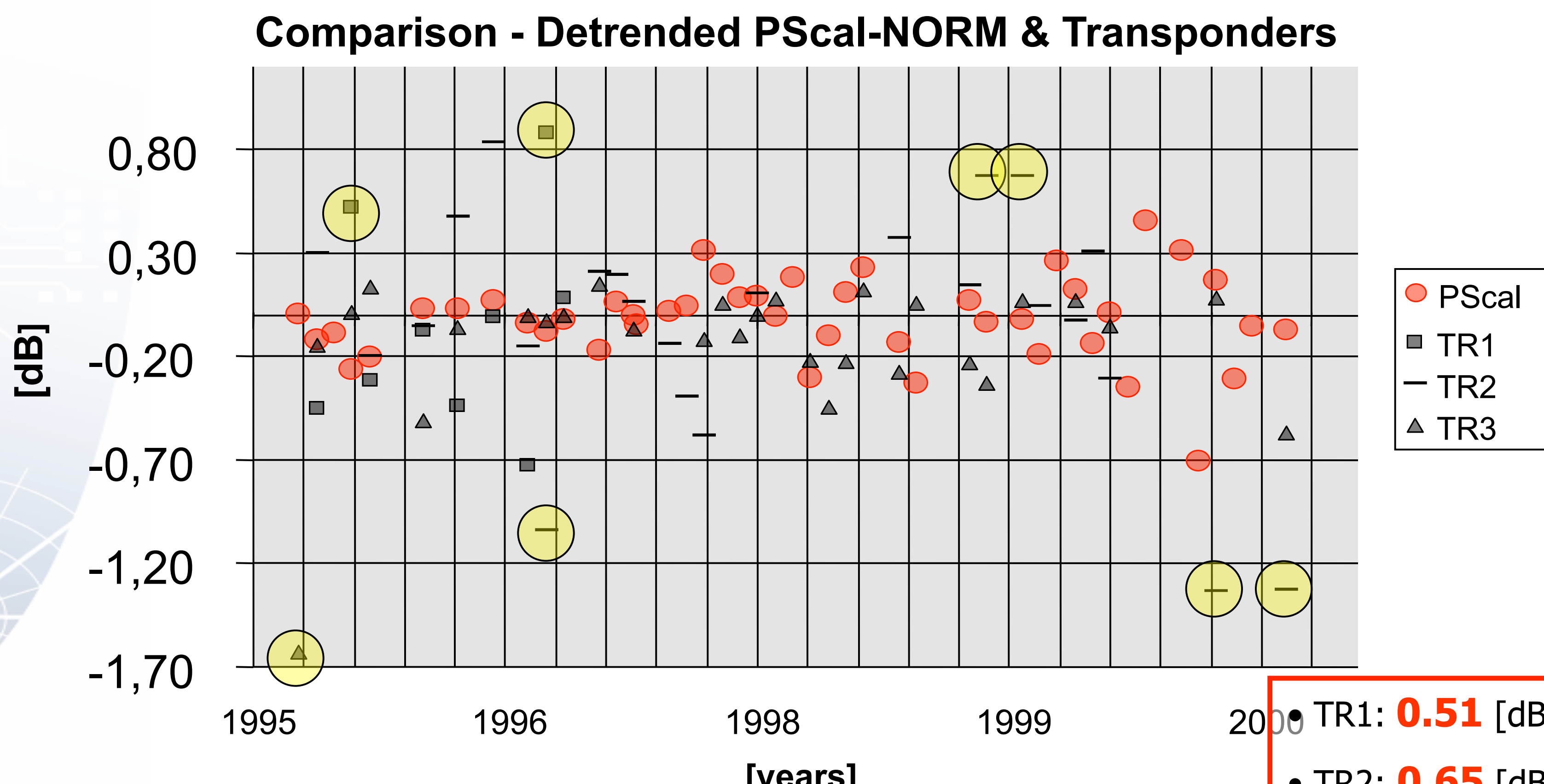
Dispersion: **0.6** [dB]

TR3: **29** measues available

Dispersion: **0.3** [dB]



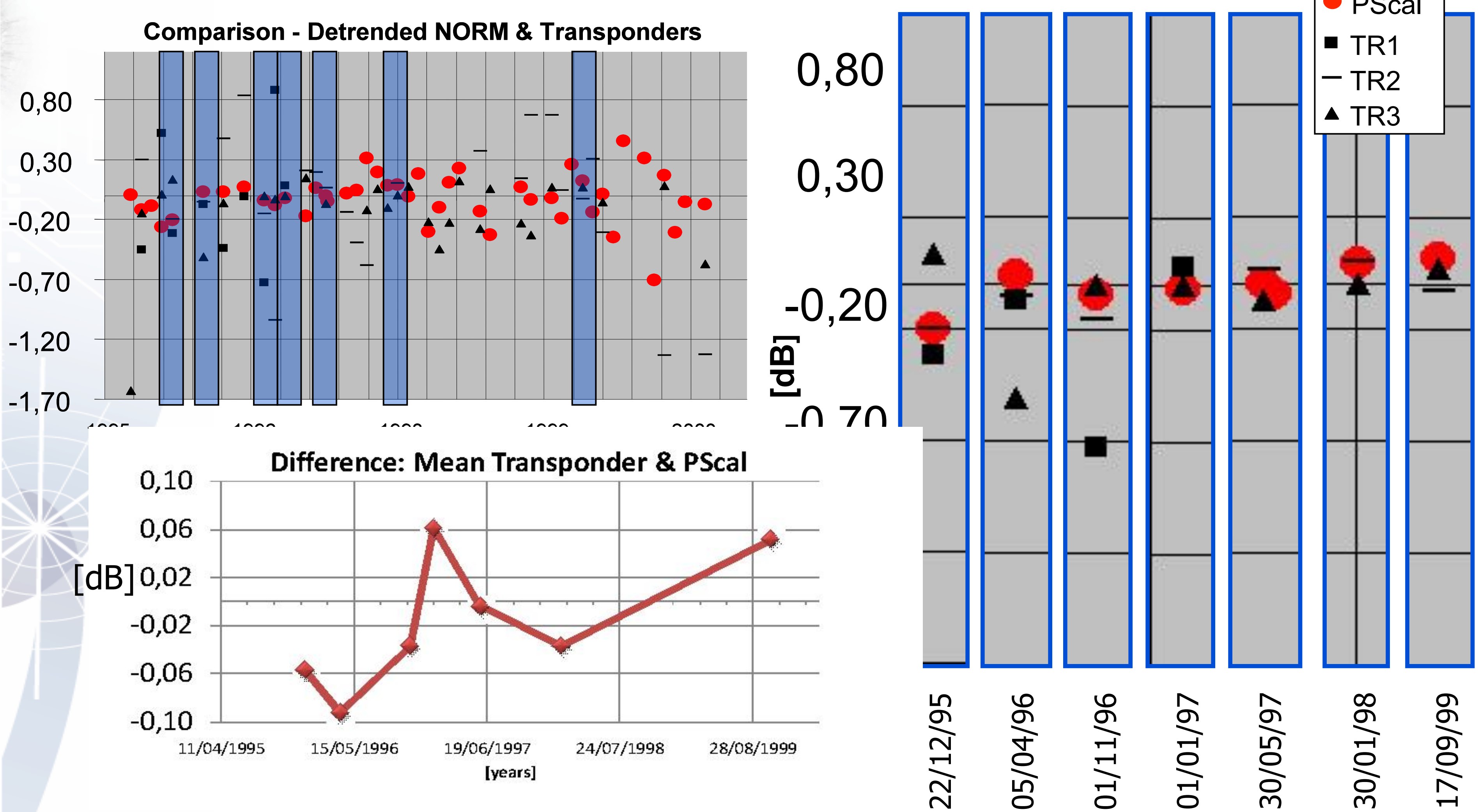
Flevoland – *PSCal* vs. Transponders



- Dispersions:
  - TR1: **0.51** [dB]
  - TR2: **0.65** [dB]
  - TR3: **0.35** [dB]
  - PScal: **0.2** [dB]

Flevoland – *PSCal* vs. Transponders

- Let's analyze data with at least 2 TR measures that go togheter.



PS cal: work in progress

- Currently, there are four developement directions :

1. Very precise coregistration

2. Convergence test: estimation accuracy vs. Number of images needed

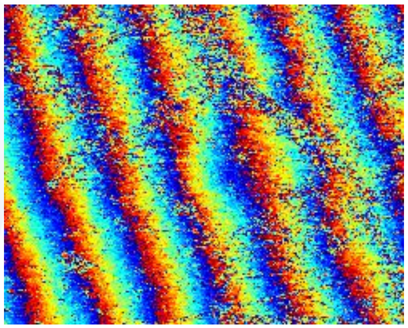
3. Elevation antenna pattern estimation

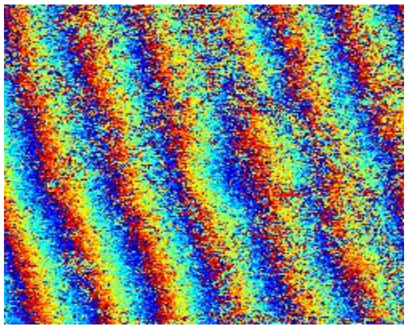
4. Investigation of the polarization effect on calibration using multi-polarimetric Radarsat-2 datasets.

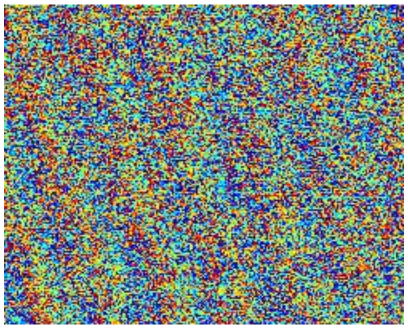
Precise coregistration the requirements for phase

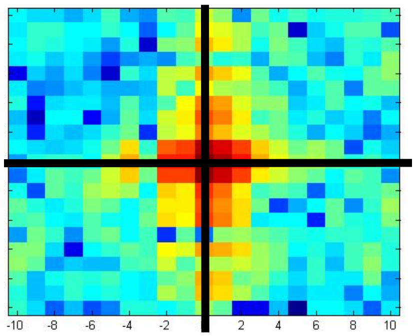
- For phase-related applications, a coregistration error of 0.5 samples is tolerated

Sample interferogram

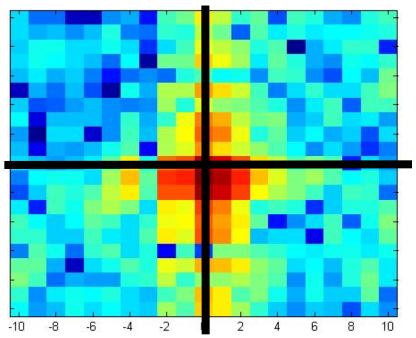




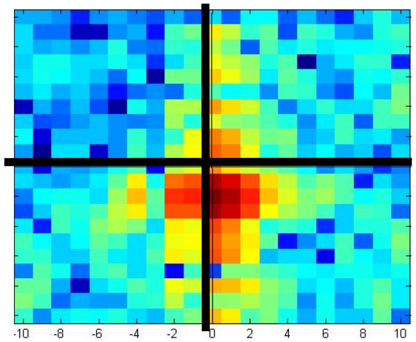




Error = 0.2 samples



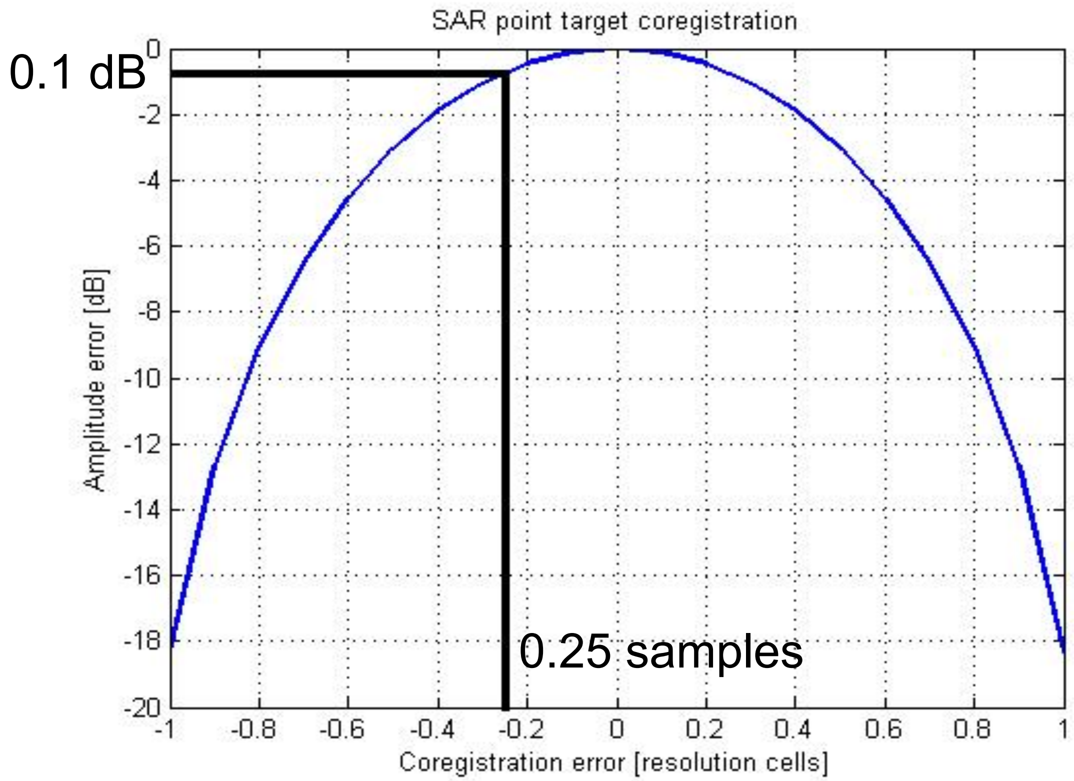
Error = 0.5 samples



Error = 1 sample

Precise coregistration: the requirement for amplitude

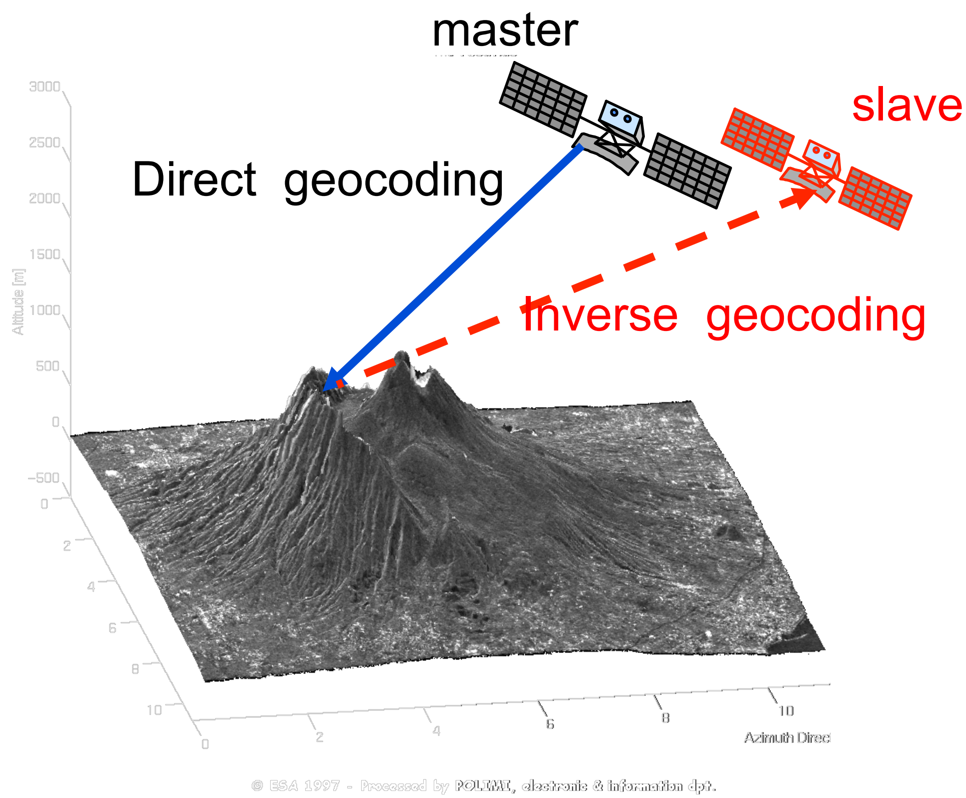
• Coregistration accuracy requirements are stronger for amplitude than for standard phase-related applications



Coregistration Error = 0.25 samples → Amplitude Error = 0.1 dB

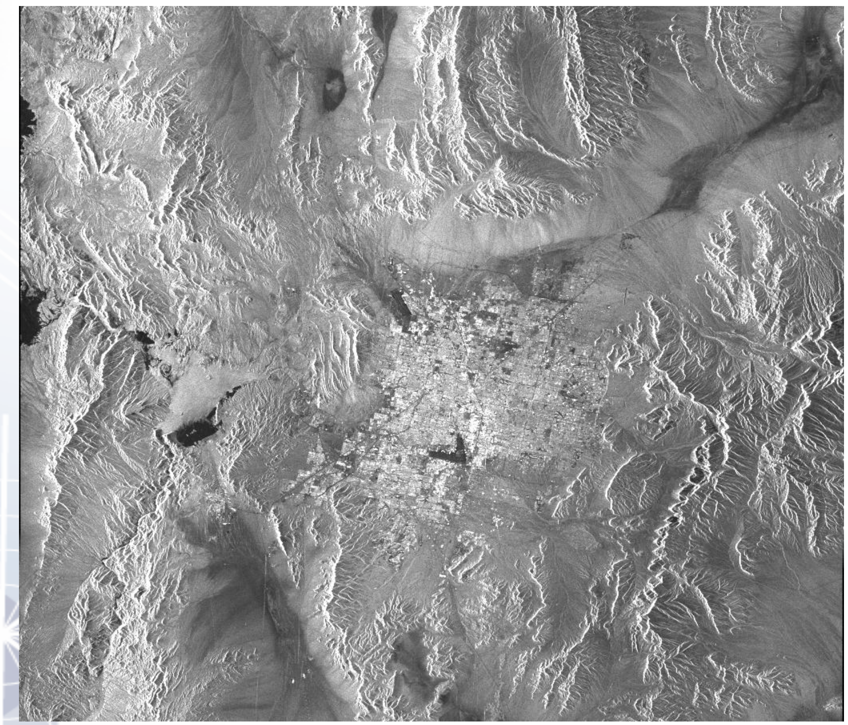
Coregistration: shift estimation from orbits

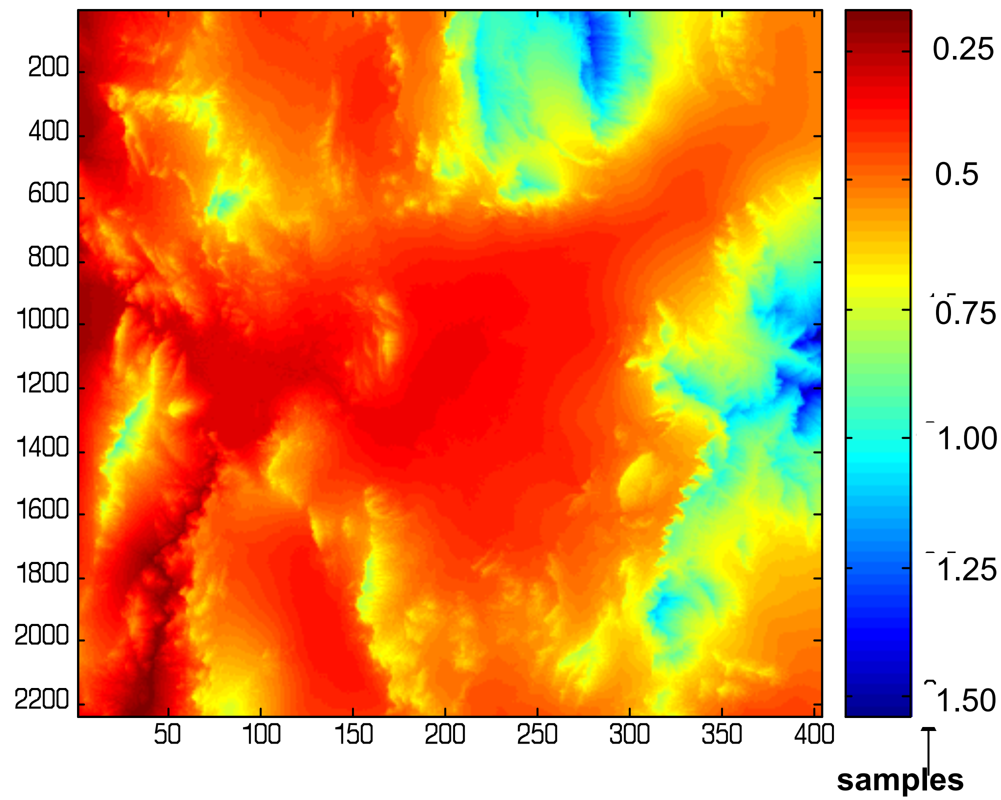
• Considering the orbits of the Master and of the Slave Image and a DEM, the shift can be estimated



Shift estimation from orbits: the influence of topography

Test on LAS-VEGAS area. Images: 20030103 and 20030418 (Bn=-1238m)



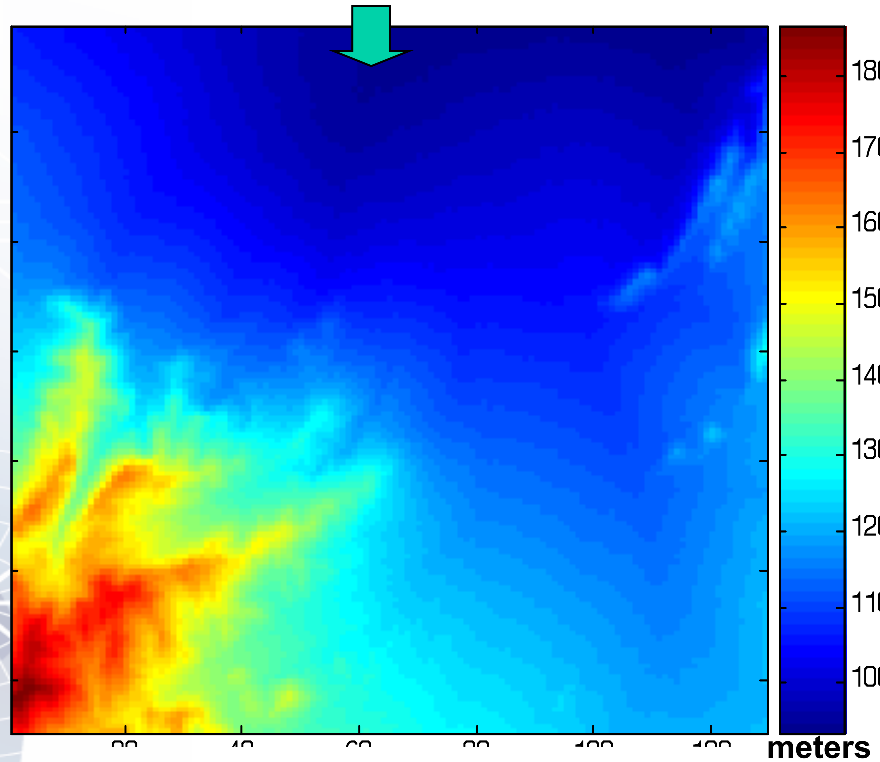


The righthand plot shows the DIFFERENCE between shifts computed with FLAT topography and the shifts computed with the SRTM DEM.

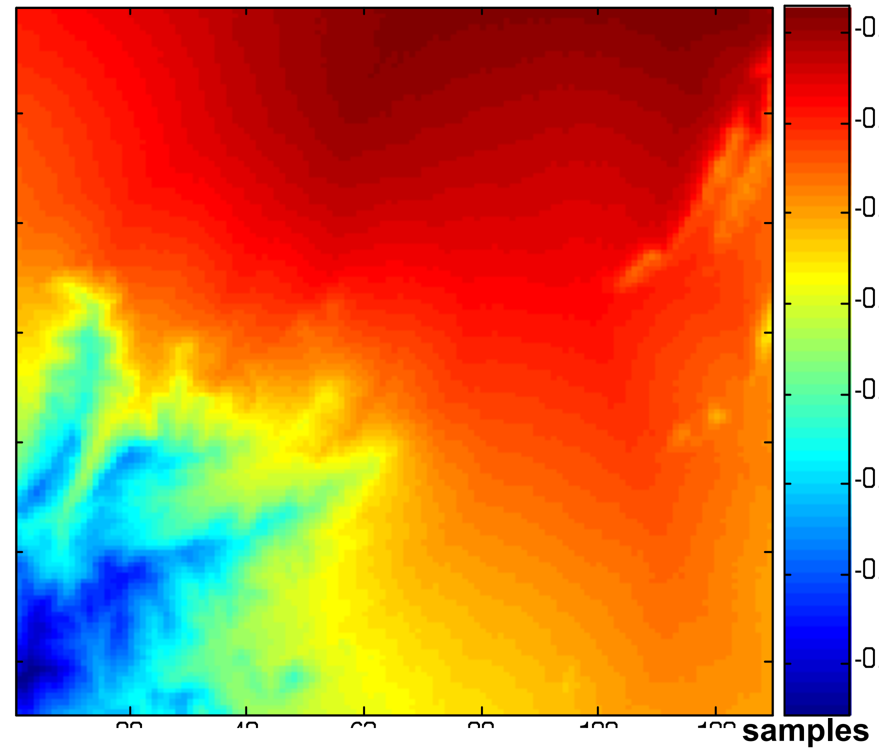
The altitude information introduces: (1) a constant shift, (2) a shift varying with topography.

Shift estimation from orbits: the influence of topography (detail)

SRTM DEM



Range-Shift estimations difference



The righthand plot shows the DIFFERENCE between shifts computed with FLAT topography and the shifts computed with the SRTM DEM.

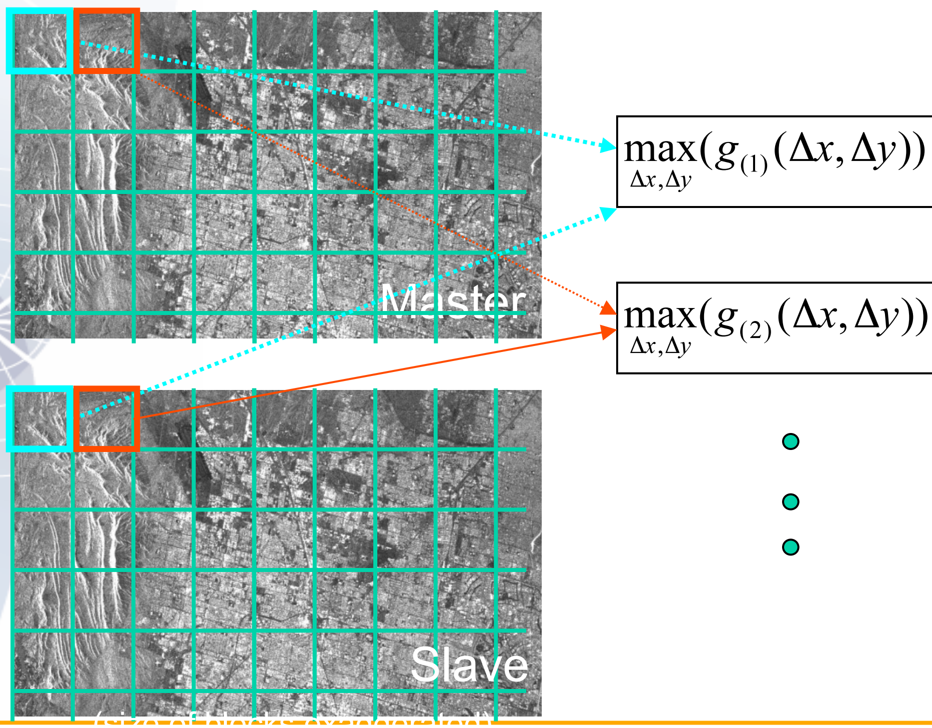
The altitude information introduces: (1) a constant shift, (2) a shift varying with topography.

Computing shifts with cross-correlation

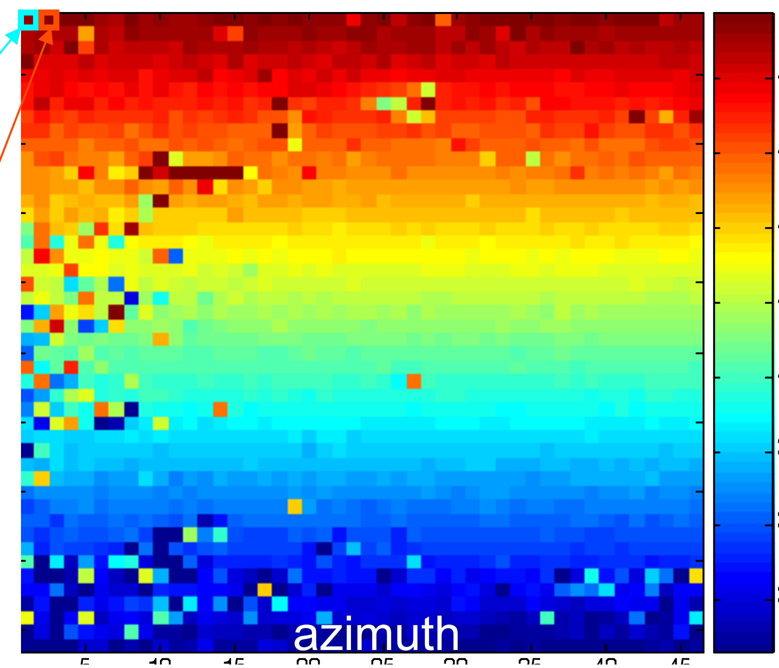
Master and slave image are divided into N small blocks W_n. For each block azimuth and range shifts are estimated, evaluating cross-correlation maximum:

$$g_{(n)}(\Delta x, \Delta y) = \sum_{(x,y)\in W_n} I_2(x-\Delta x, y-\Delta y) I_1(x,y)$$

$$(\Delta x, \Delta y)_{(n)} = \max_{\Delta x, \Delta y} g_{(n)}(\Delta x, \Delta y)$$



Estimated range shifts example



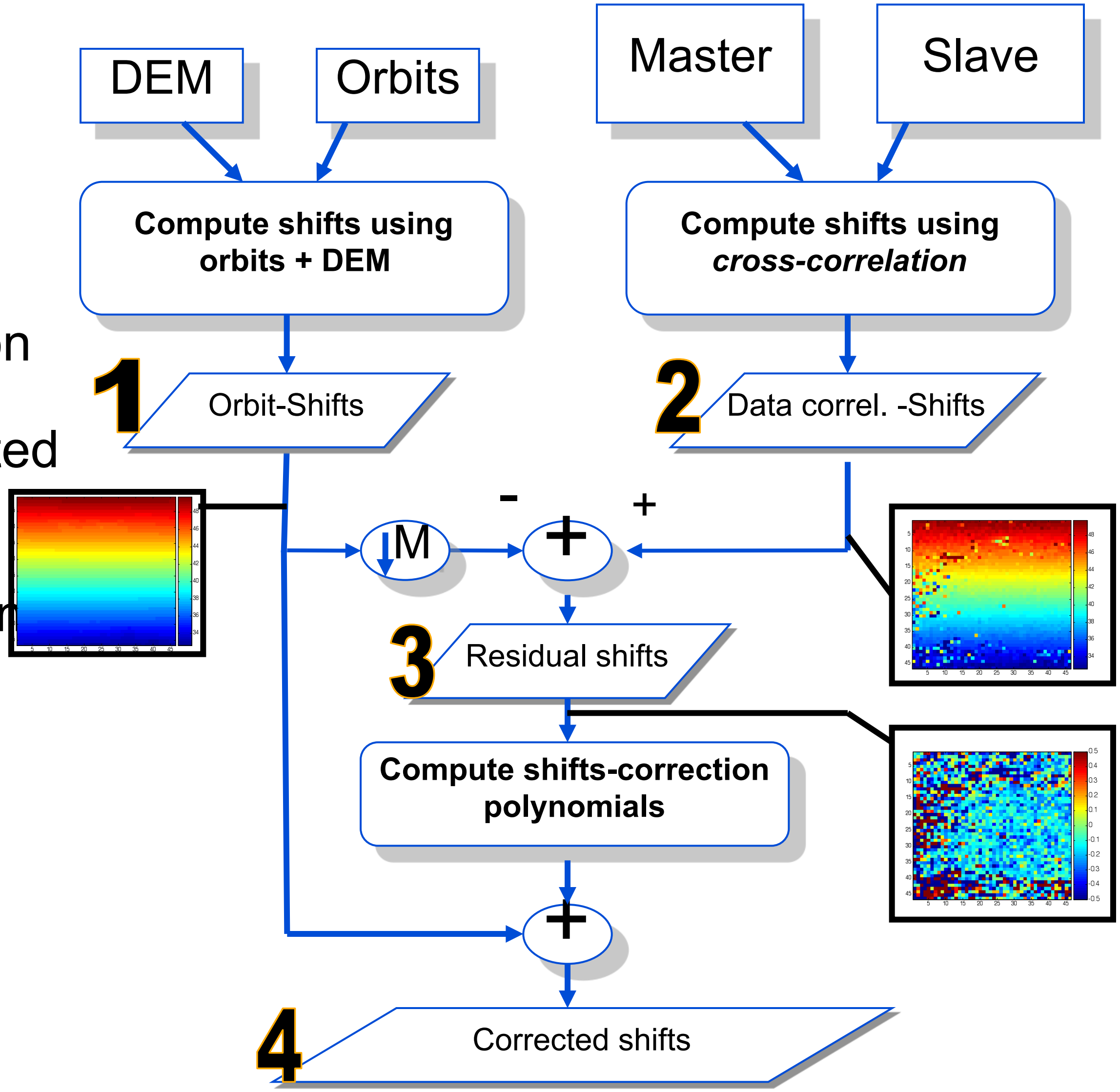
Shift estimation from orbits and from data: Pros and cons

Shift estimation approach	PROS	CONS
ORBITS + DEM	- Not affected by temporal scenario de-correlation - Takes into account of the topographic variations - Computationally Fast - Punctual estimation of the shift	- Precision limited to orbits knowledge accuracy - Instrument timing errors may cause wrong shift estimates
DATA CROSS-CORRELATION	- Very precise for bright/high-contrast scenarios	- Shift estimation accuracy strongly depends on the type of scenario - Shift estimation accuracy depend on scenario temporal de-correlation - Estimated shift accuracy depends from resolution

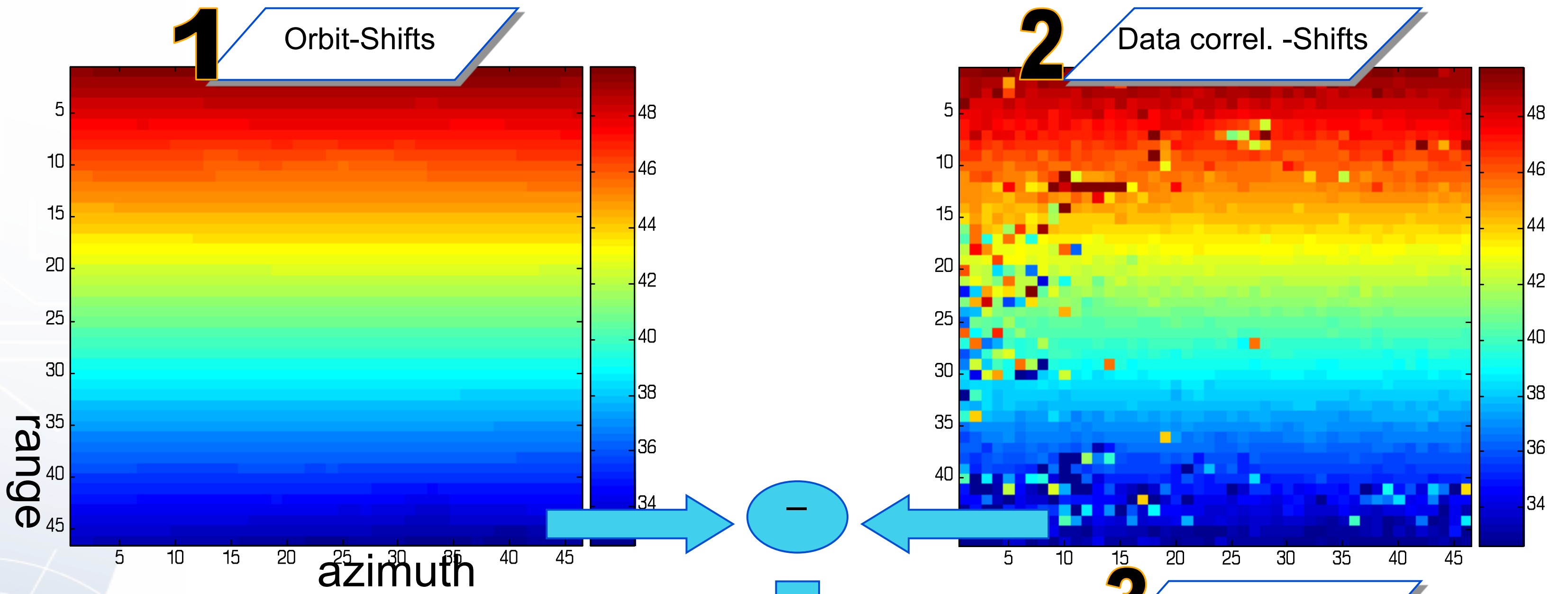
A combined algorithm for coregistration

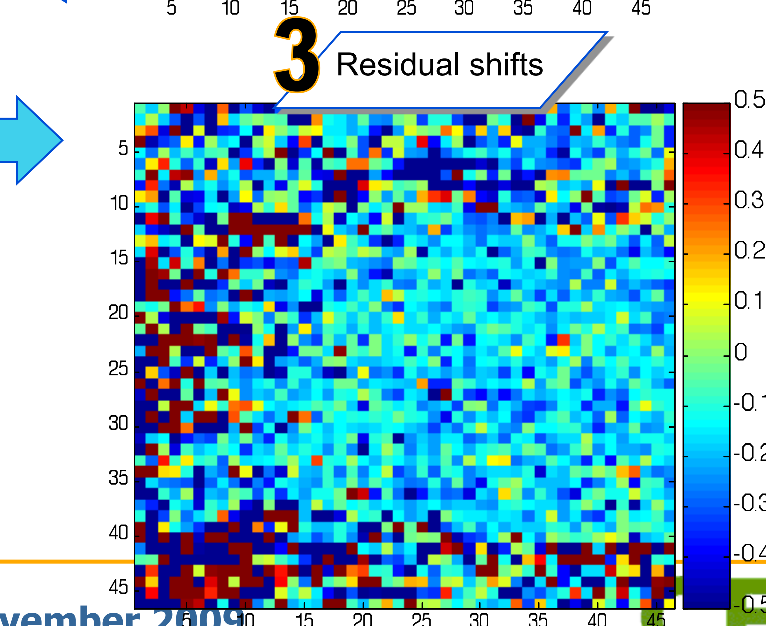
- Combined use of
  - orbits
  - DEM
  - data correlation

- The shifts computed with ORBITS and DEM are refined by data cross-correlation



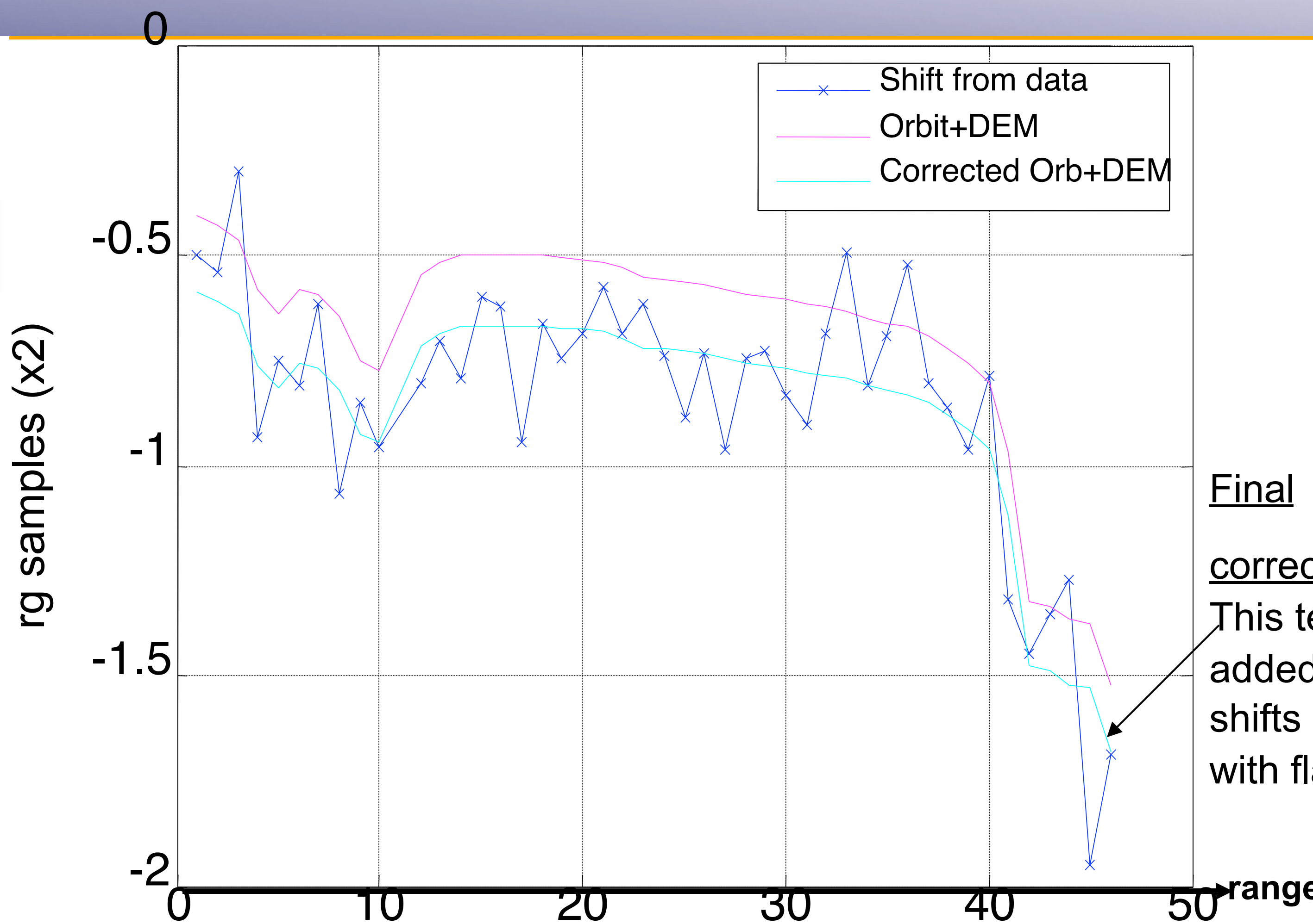
Residual Range shifts





The estimated shifts from orbits (1) and from data correlation (2) are subtracted to obtain a residual correction term (3) that can correct timing errors.

Data-corrected orbits-shifts



<u>Final</u>

<u>correction term:</u>
This term is added to the shifts computed with flat earth.

The plot shows the *differences* wrt the shifts computed considering flat earth, computed with the orbits (magenta) and with data cross correlation (blue).

PRO/CONS of the combined algorithm

The algorithm allows very fine coregistration of images with:

- high topography variations within the image
- high normal baseline

The key point is the combination of the advantages of the 2 most used coregistration parameters estimation techniques:

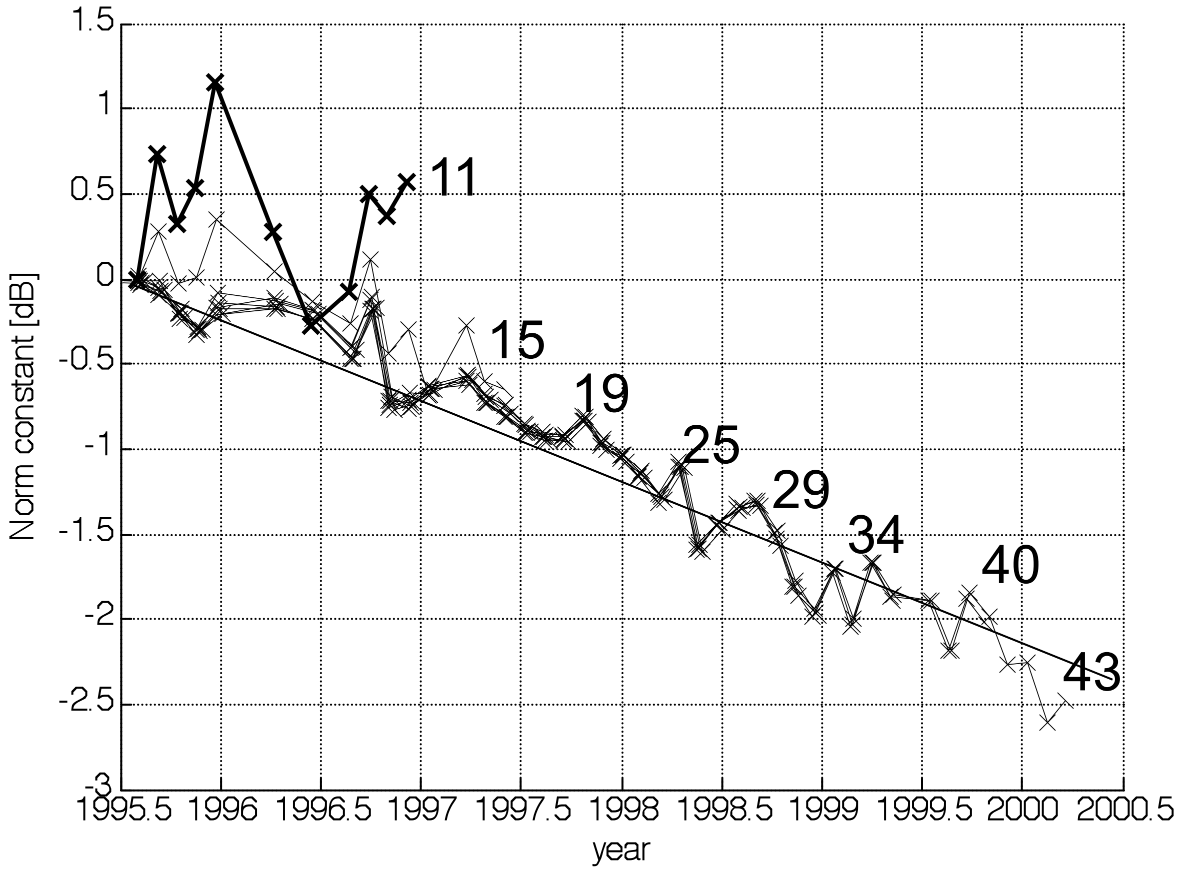
- The orbits provide fast estimates, robust against temporal decorrelation

- The estimates obtained with orbit information and the DEM are corrected with data-correlation,making the output estimates proof from orbital errors

- The combined estimation of the coregistration parameters using inverse geocoding and cross-correlation makes the total processing time more less the sum of the time needed to perform the single estimations.

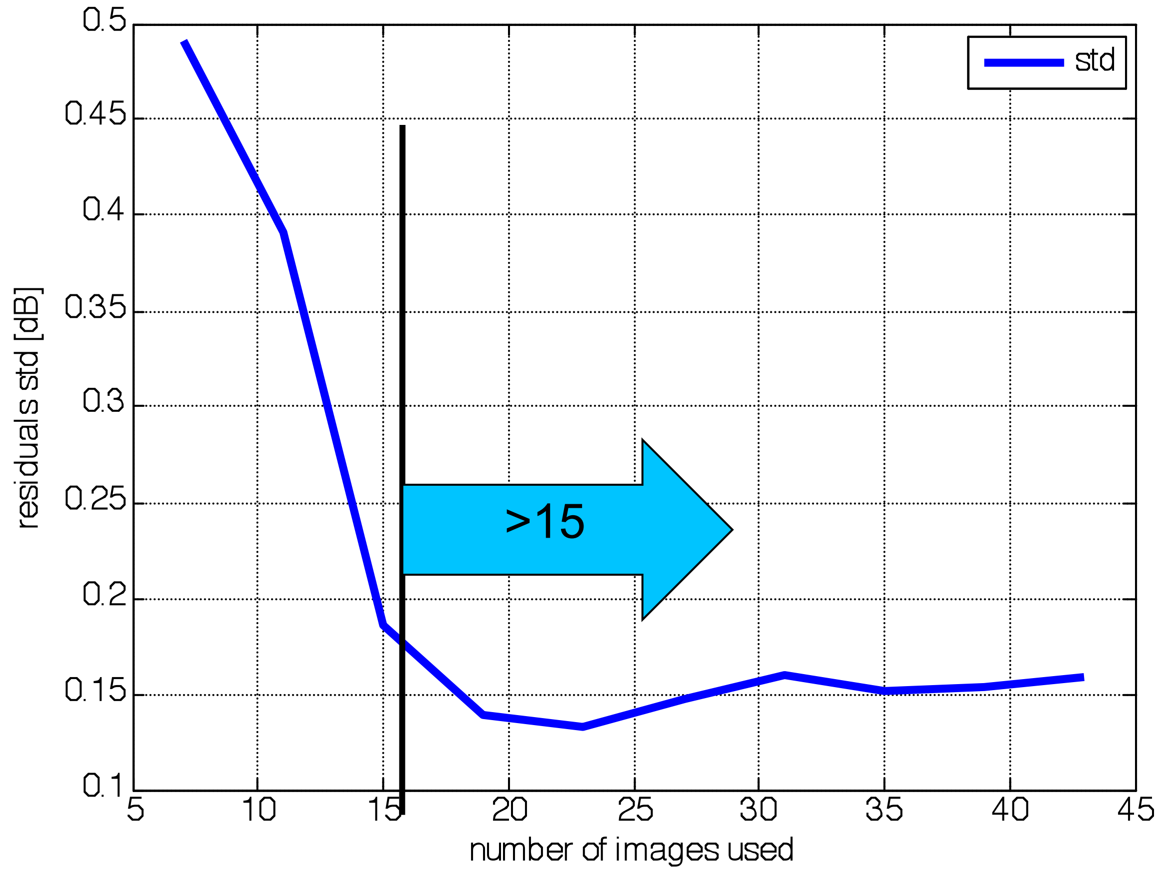
Convergence test – Number of images needed

- A convergence test has been done to estimate the number of images required to obtain algorithm convergence.



Convergence test – Standard deviation vs. # of images

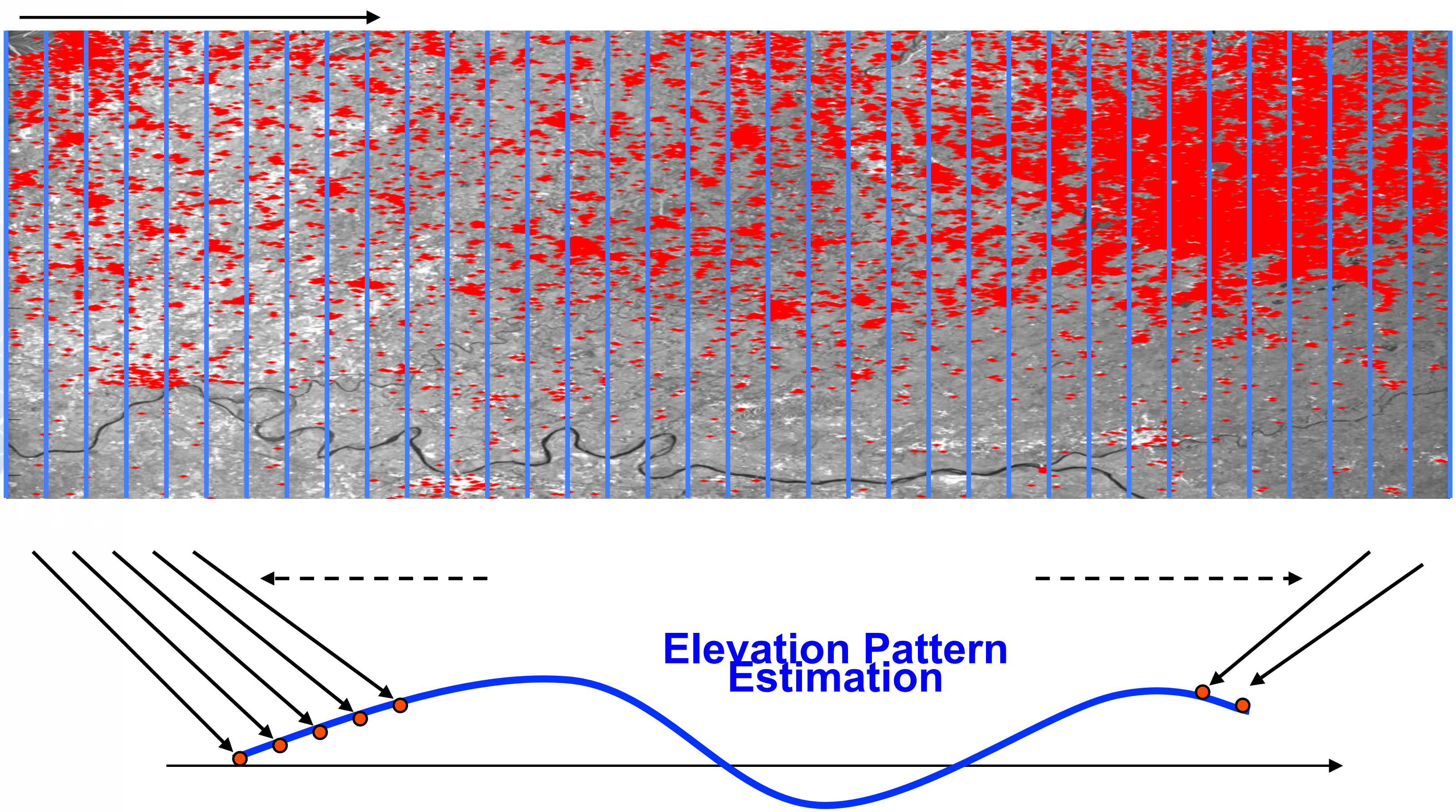
• Let’s analyze the estimate residual wrt the linear trend as a function of the images used.



Elevation Pattern Estimation

IDEA: to perform PS-CAL estimation on different range blocks.

the difference between the various blocks gives an estimation of the elevation pattern

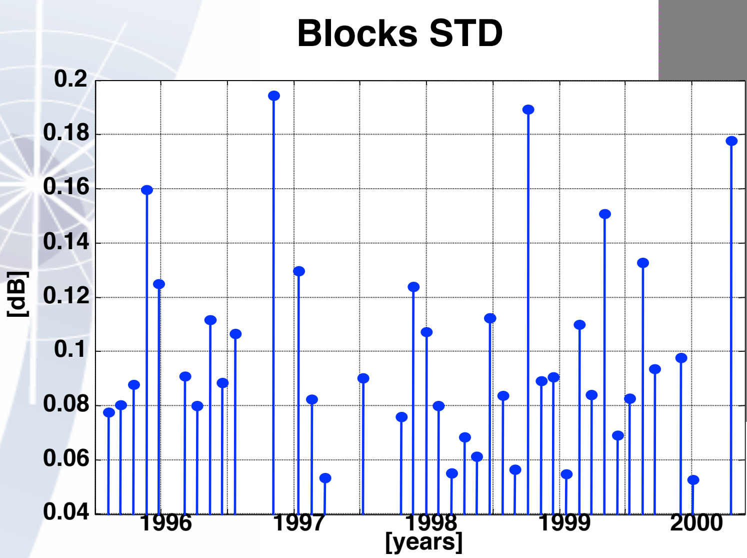


Elevation pattern Results

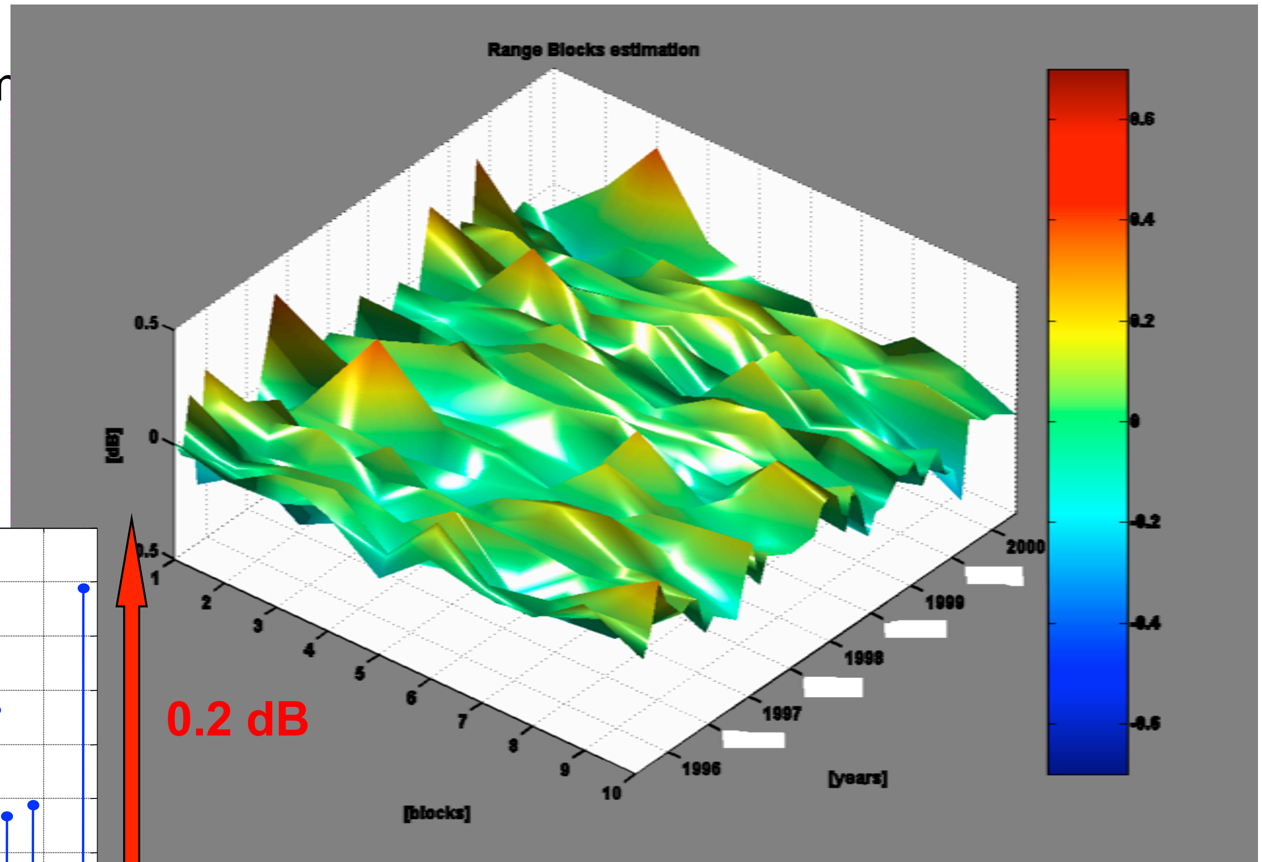
• Estimation was performed dividing the entire image into **10** equally spaced range blocks.

• ERS-2 range pattern is alm

Estimation Standard Deviation for each image:



0.2 dB



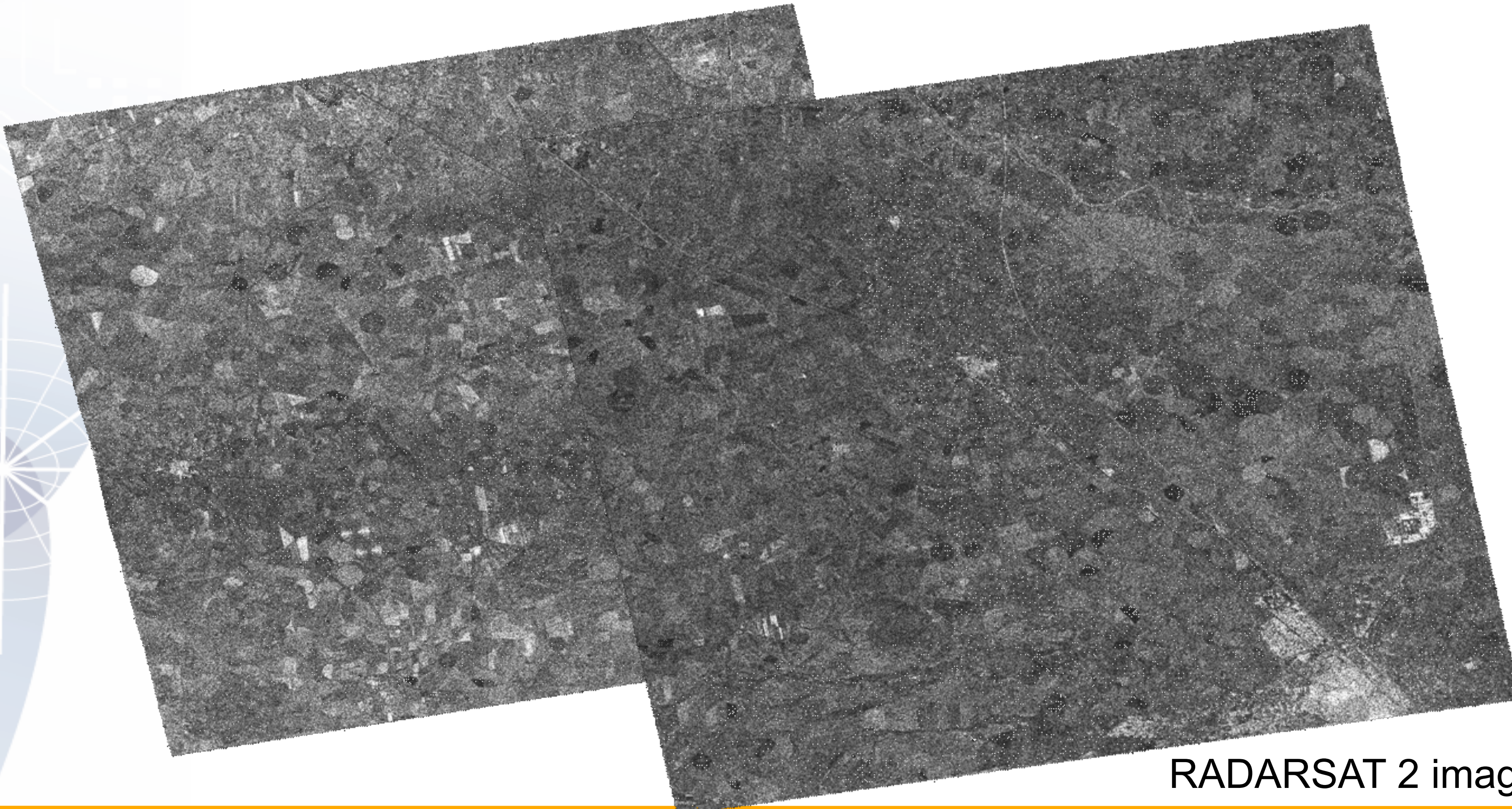
• Furhter validation activity is needed

Next step: PScal application to multi-polarimetric data

• Goals:

1.Evaluation of impacts of polarization on PS amplitudes

2.estimation of one normalization constant for each polarization



RADARSAT 2 images

Conclusions

- The PS cal approach integrates initial calibration measures, available in the commissioning phase in a limited set of cal-sites, with Permanent Scatterers measures.
- It allows for a large number of costless calibration sites, all around the world, without interfering with mission operations.
- Preliminary validation on ERS-2 series shows an accuracy comparable with the best results selected form a set of three transponders (0.06 dB).

- Future capabilities will include:
  - antenna pattern estimation (the validation of this approach is on-going).
  - evaluation of polarization impact using multi-polarimetric datasets.