SAR Interferometry and applications

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Interferometry

measurement of travel path differences
The target's signature is removed

Short term single pass, seconds, 30', 1 day, weeks

- coherence : Vegetation, surface properties
- parallaxis (baseline) : Digital Elevation Models

Long term months, seasons, one to several years

- co-seismic or volcanic motions (Line Of Sight, 2D, 3D)
- subsidence (mm/year); slow landslides (cm – mm/year)
- building pre-collapses, cracks, excavations effects

Summary

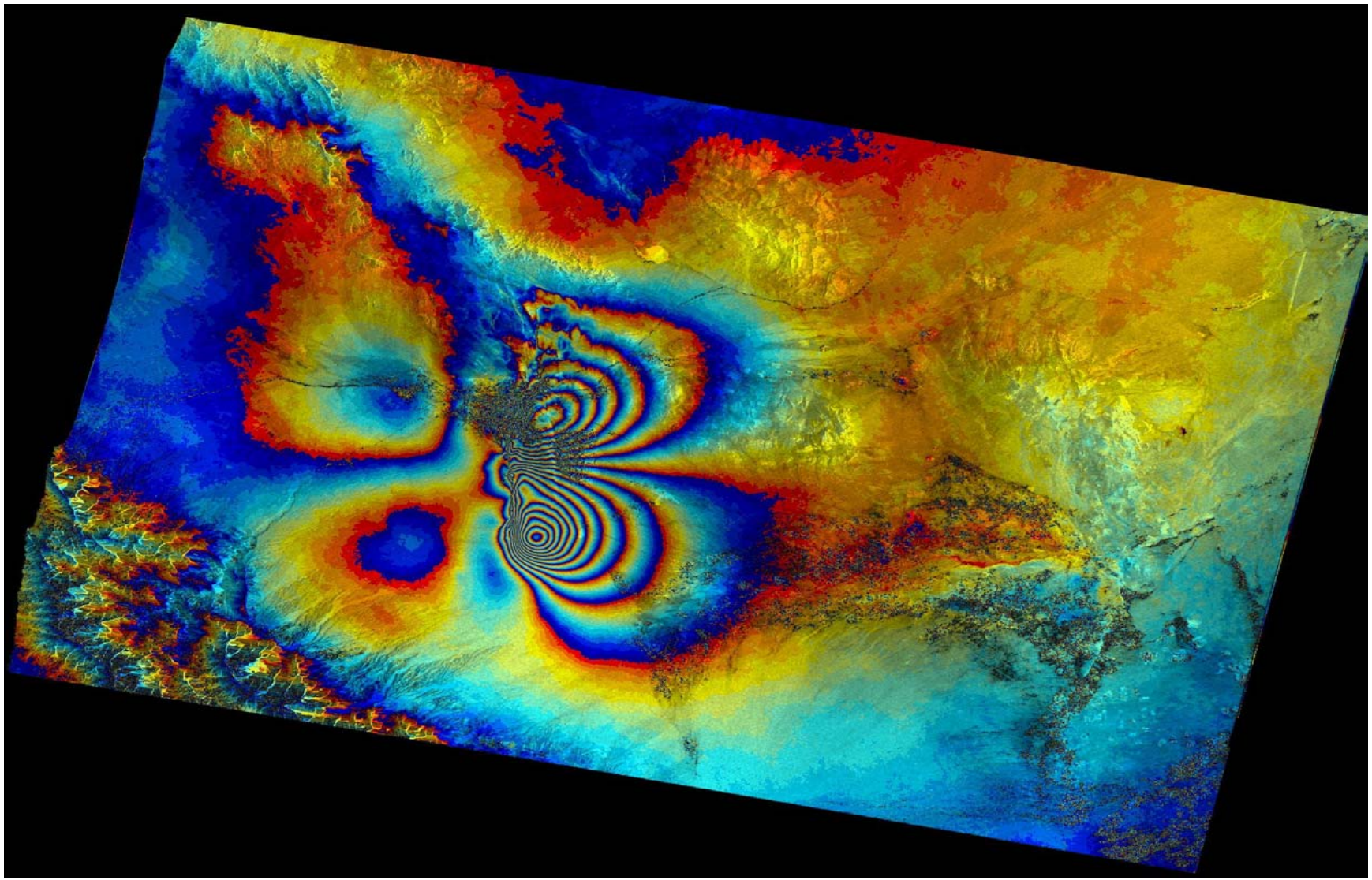
Interferograms, Wide Swath : Bam, Algeria

Wavevelength and revisiting times:
Digital elevation models and ground motion retrieval in Tokyo
Further analyses of the 3 days data in Rome

A simple model to evaluate the implications

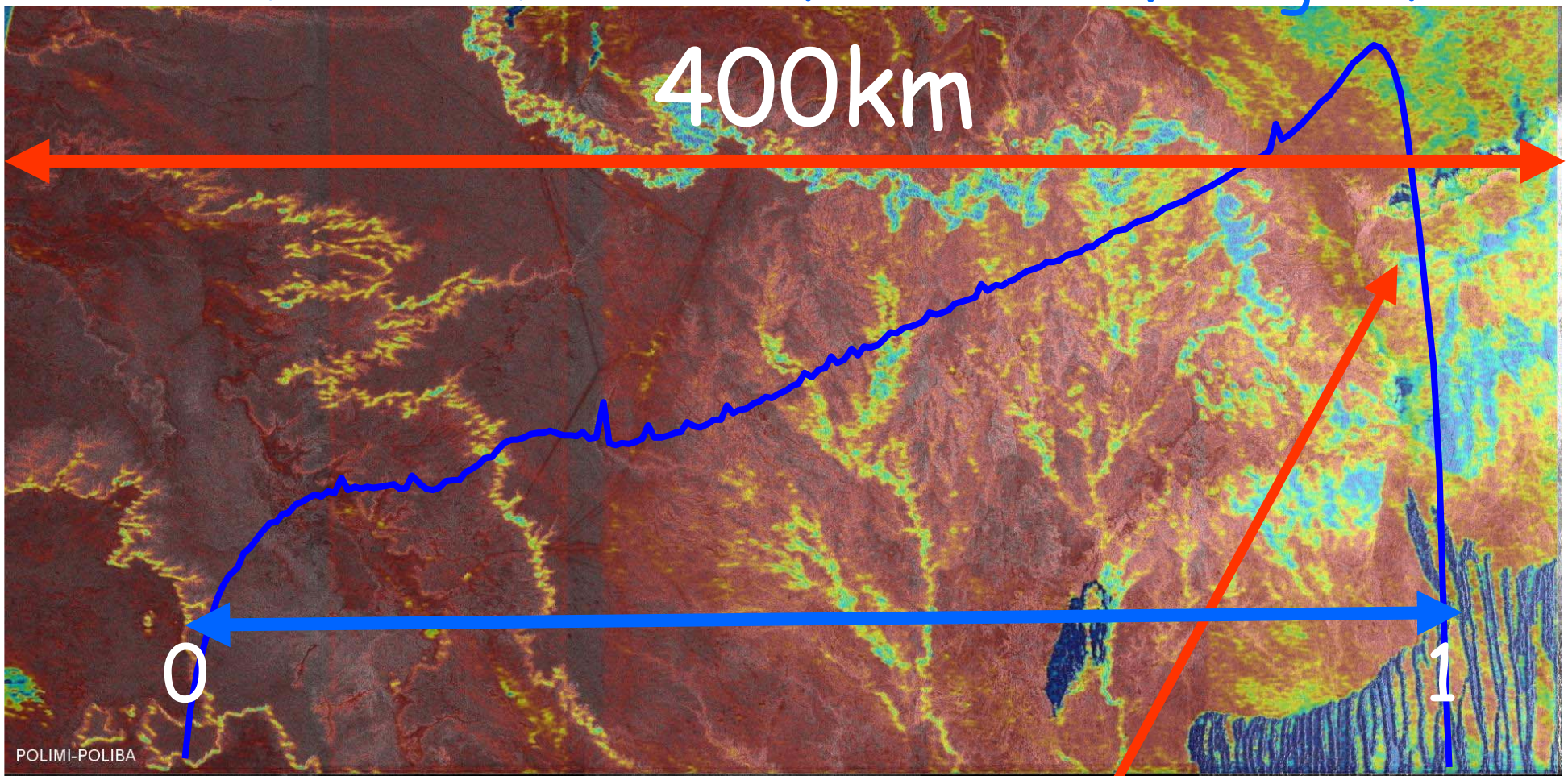
Conclusions

Bam – Iran: Dec. 26, 2003 earthquake



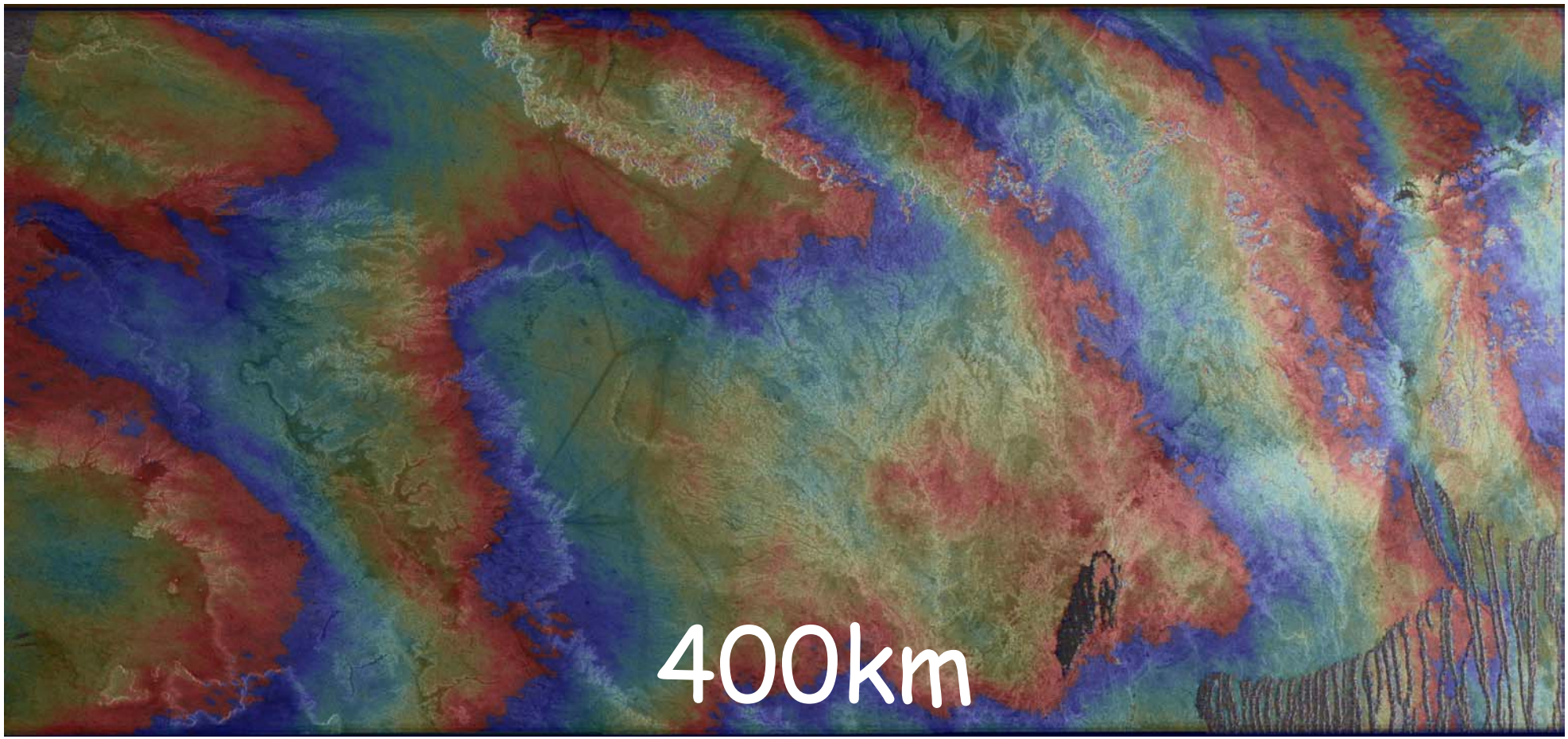
Algeria

WSM - WSM seamless interferogram



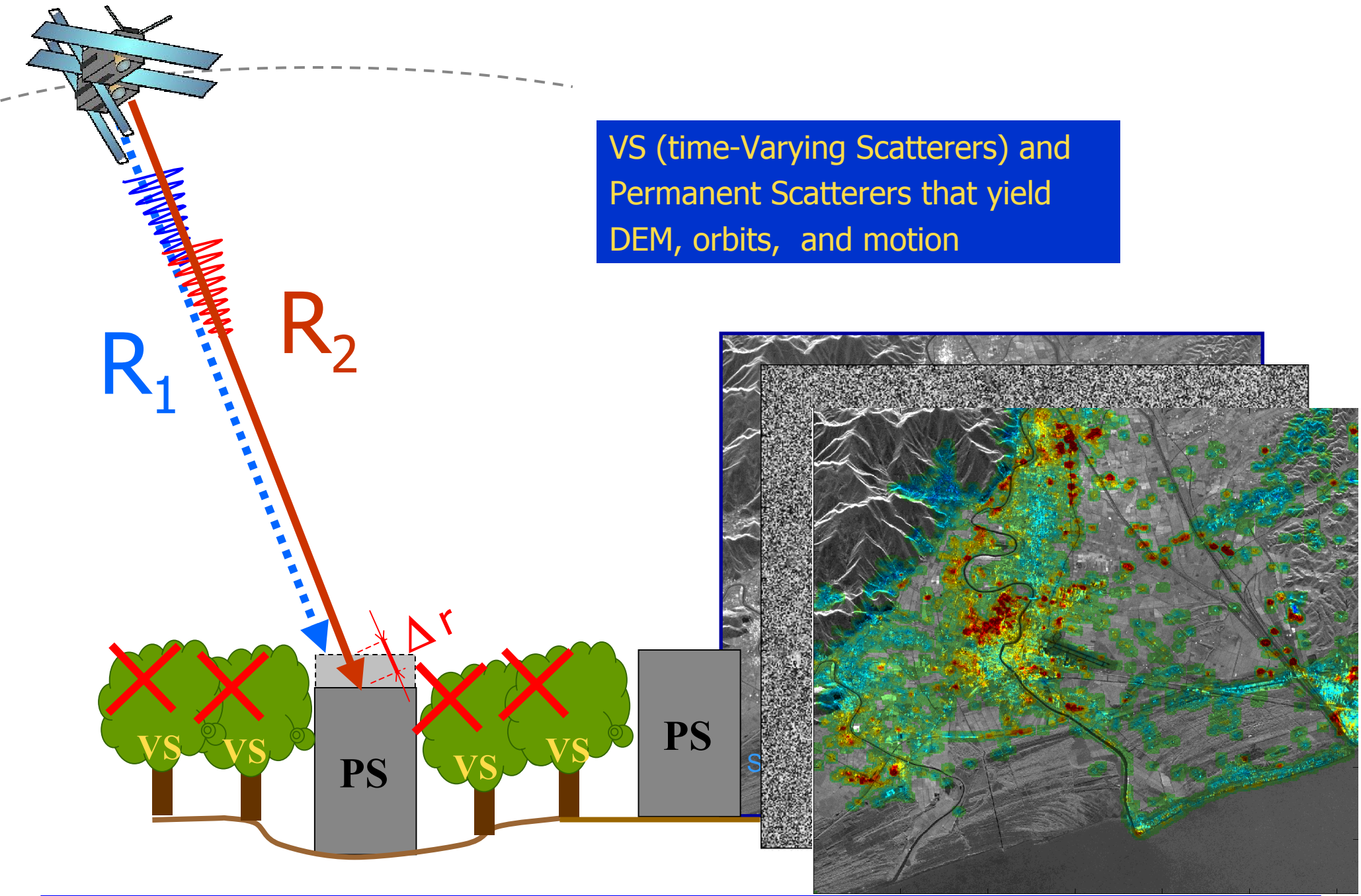
Coherence (forestry): the log histogram is superposed

Algeria

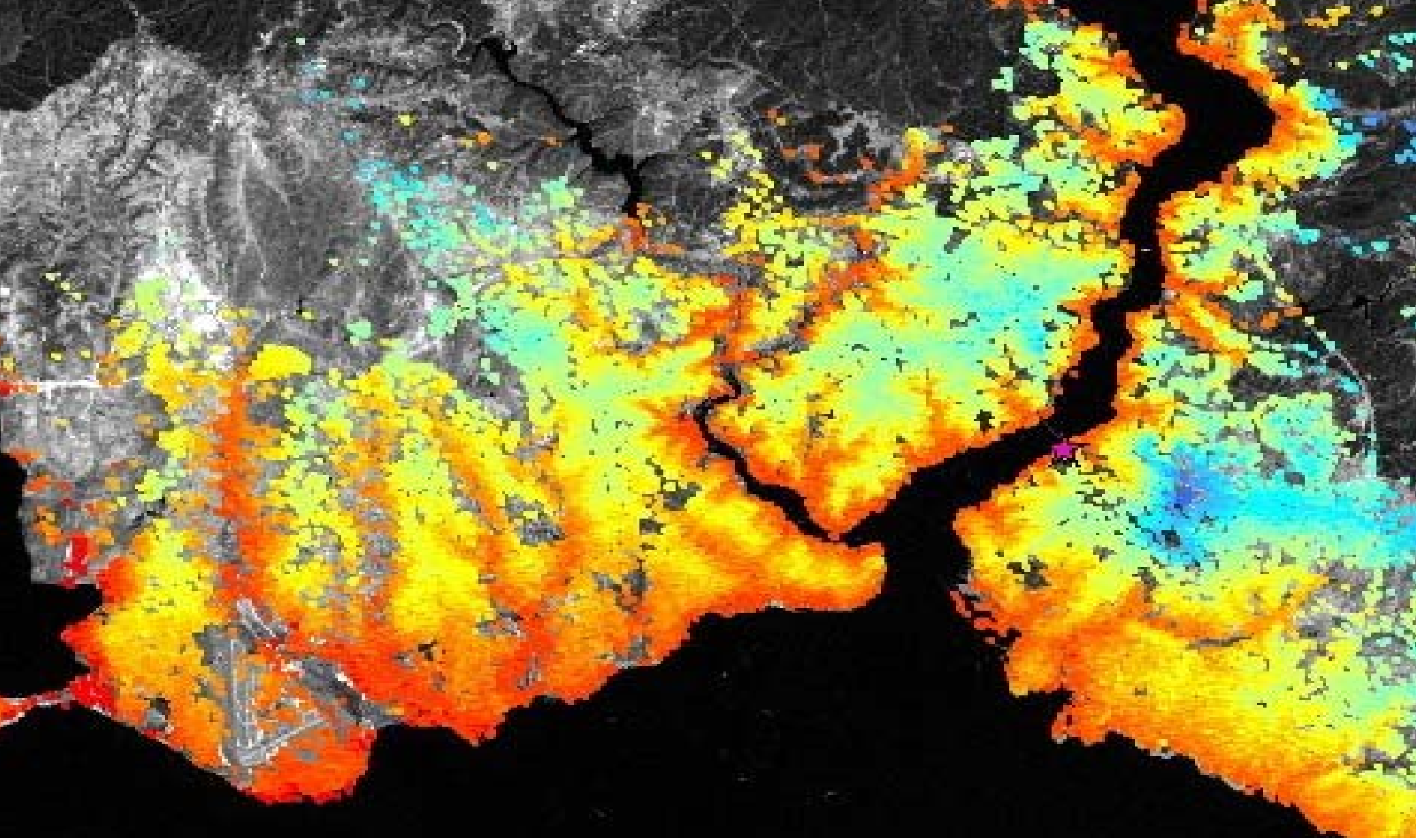


ASAR WSM/WSM interferogram: phases

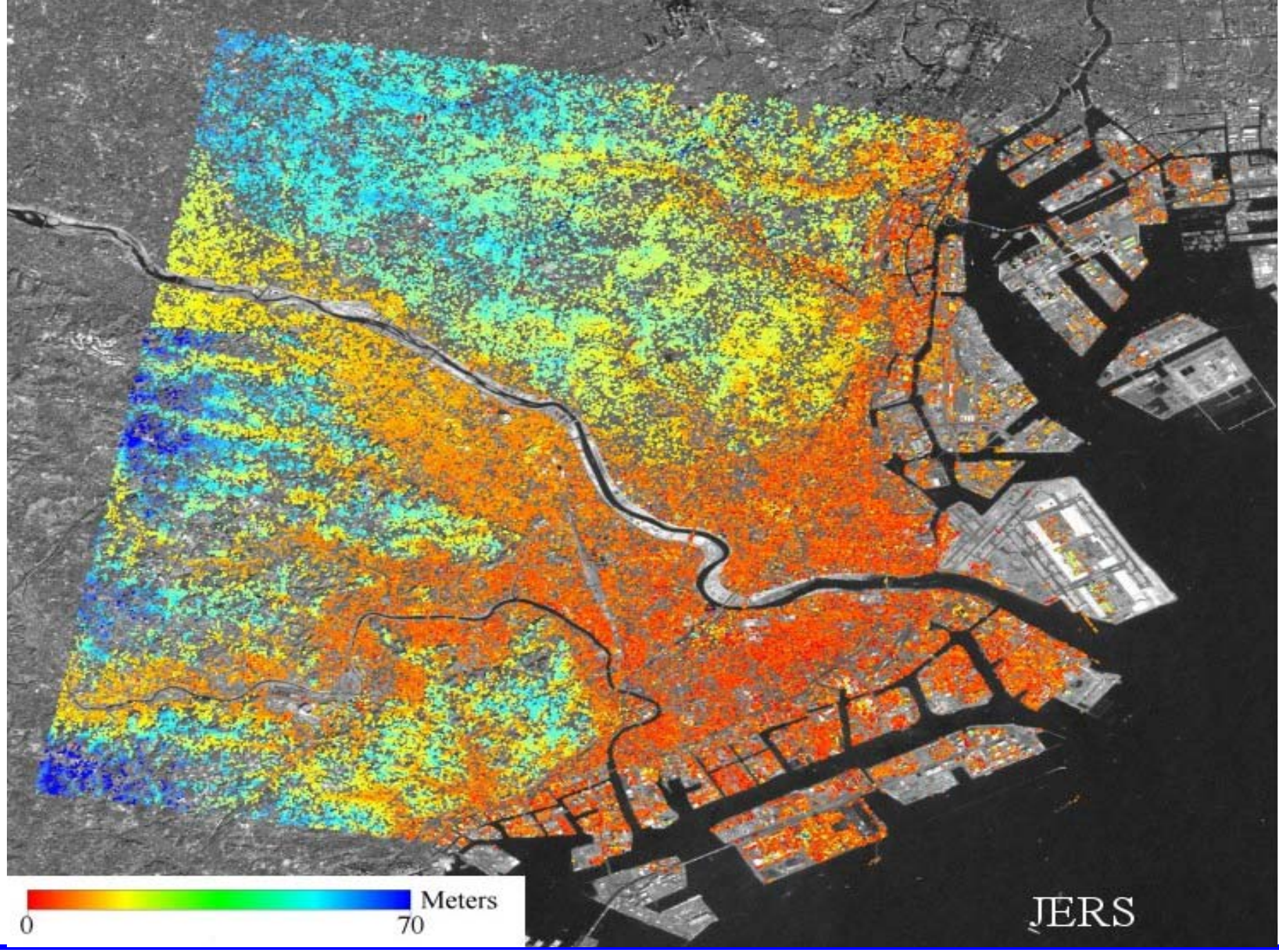
VS (time-Varying Scatterers) and Permanent Scatterers that yield DEM, orbits, and motion

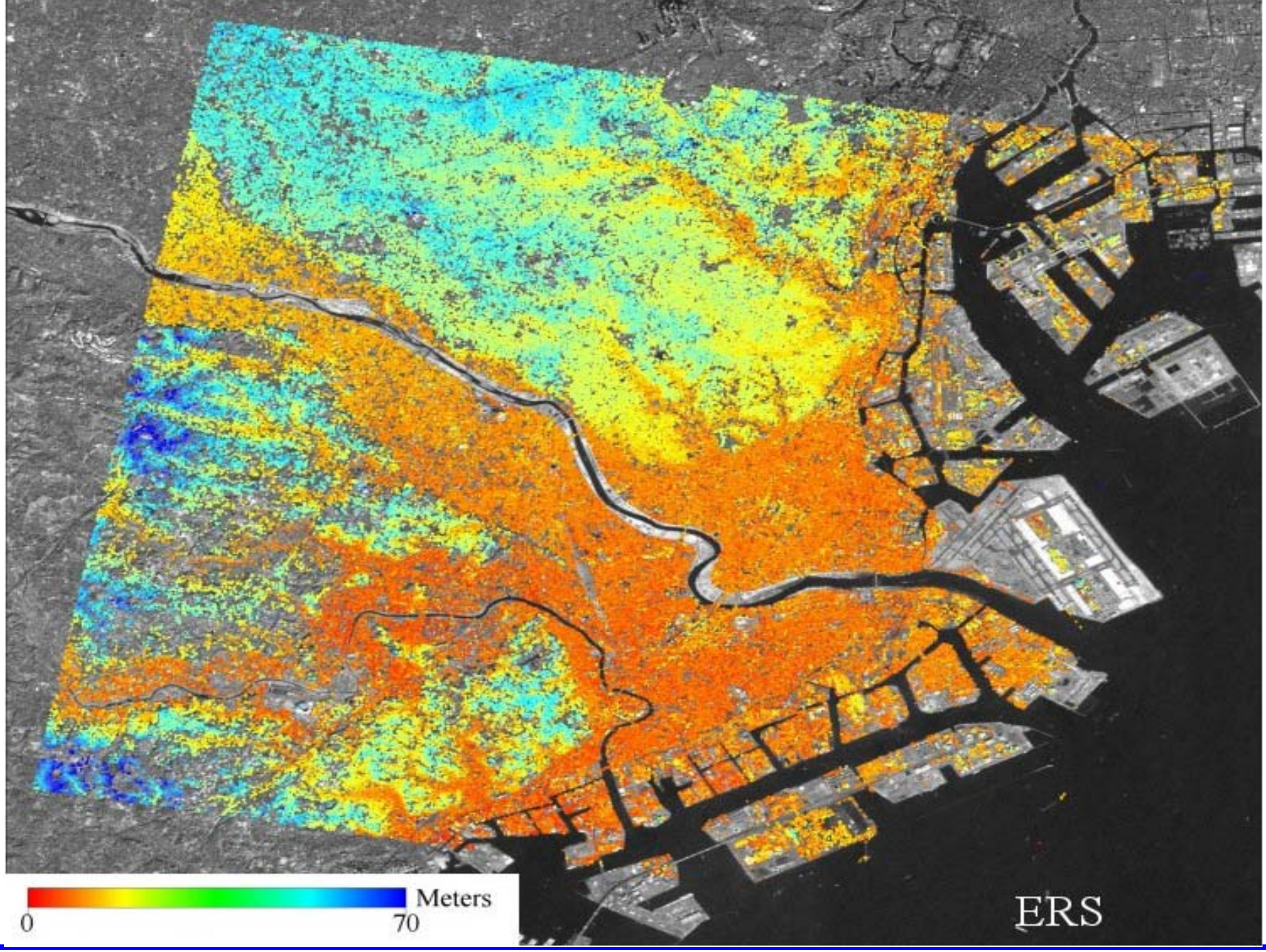


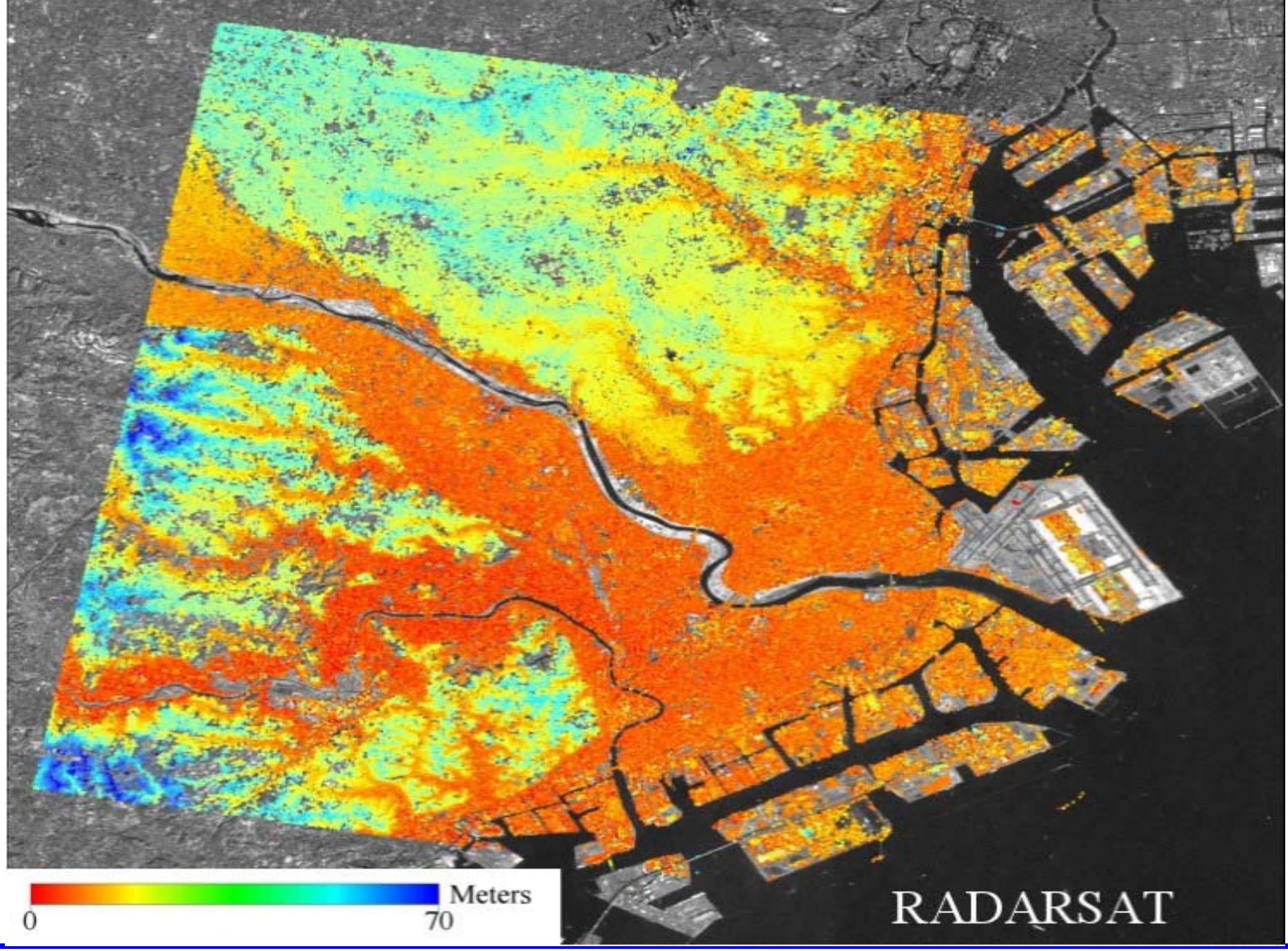
Digital elevation models



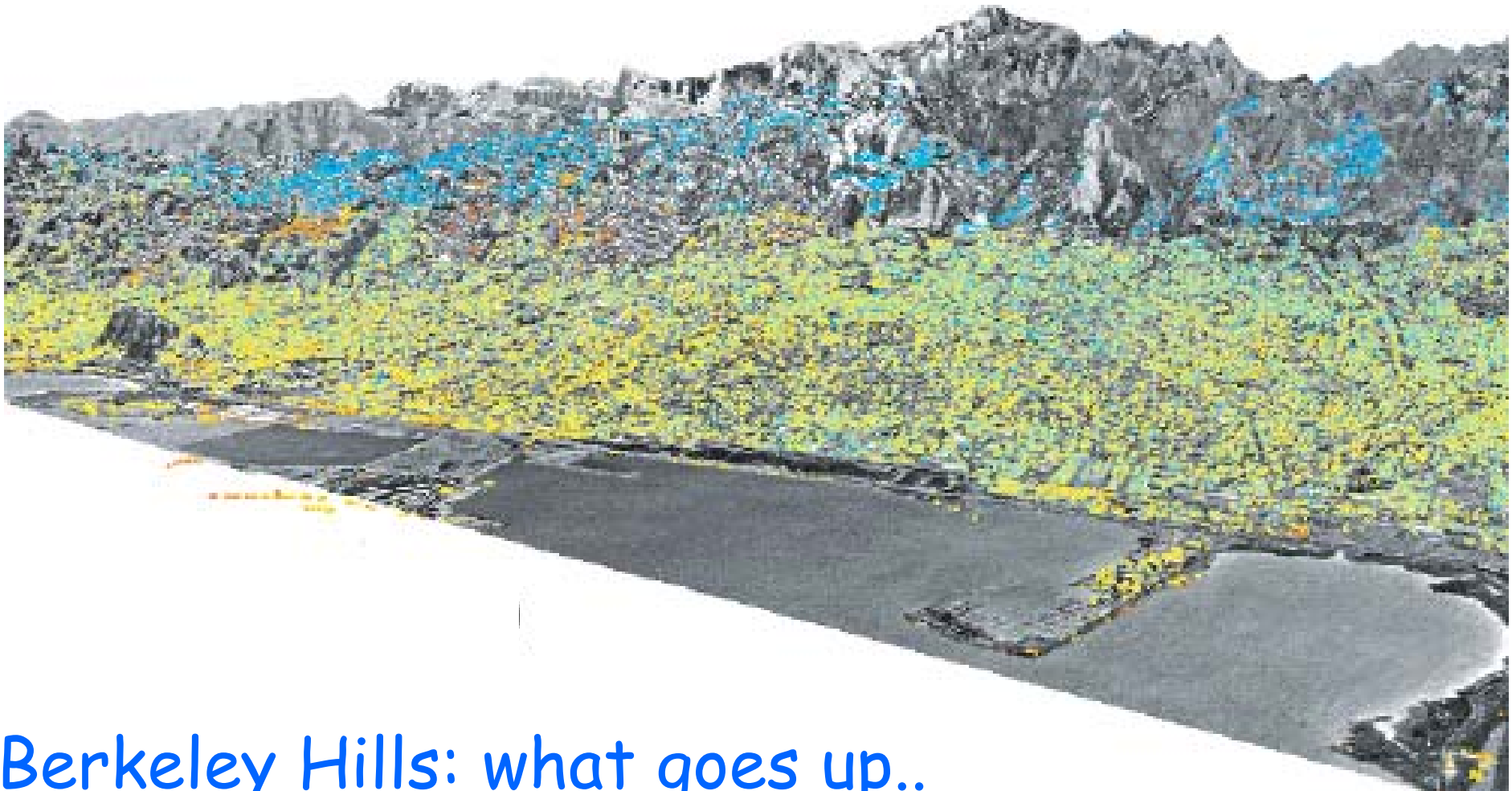
Old rivers in Istanbul (shales liquefaction)


Meters
0
70
JERS


Meters
0
70
ERS


Meters
0
70
RADARSAT

Ground motion



Berkeley Hills: what goes up..

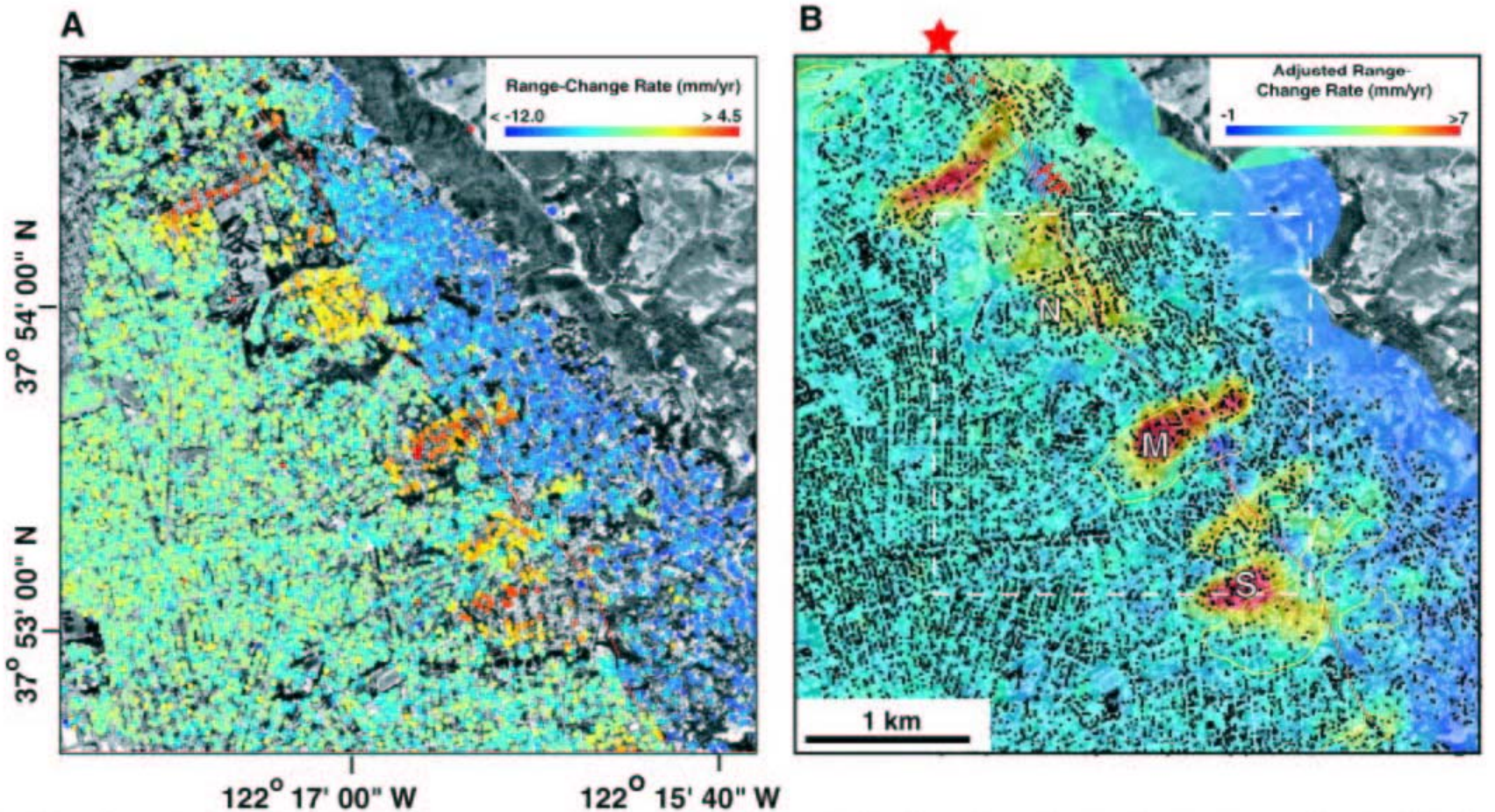
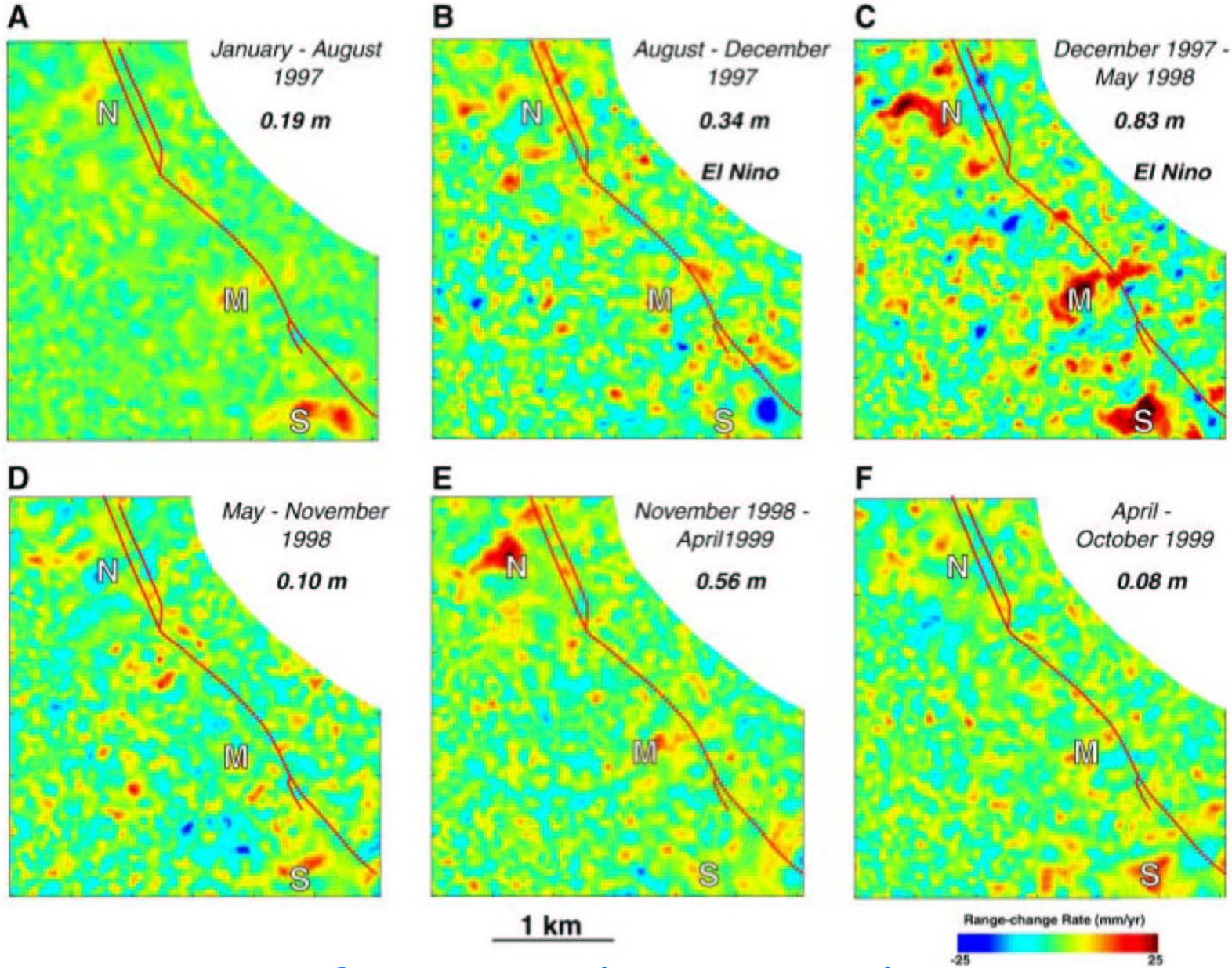


Fig. 1. (**A**) Map view of PS-InSAR range-change rate measurements for the study area. Underlying image is an orthorectified air photo of the area; HF trace is indicated by a red line (*28*). (**B**) Map view of interpolated range-change rates (colors) adjusted for shallow creep (4 to 5 mm/year) along the HF and uplift (0.4 mm/year) of the EBH (black dots show PS locations). Yellow outlines show the location of mapped active landslides (*14*). Dashed box indicates the extent of panels in Fig. 2. N, M, and S denote locations of the northern, middle, and southern landslides investigated. Red star shows location of M_L = 4.1 earthquake on 4 December 1998 (*8*, *18*).

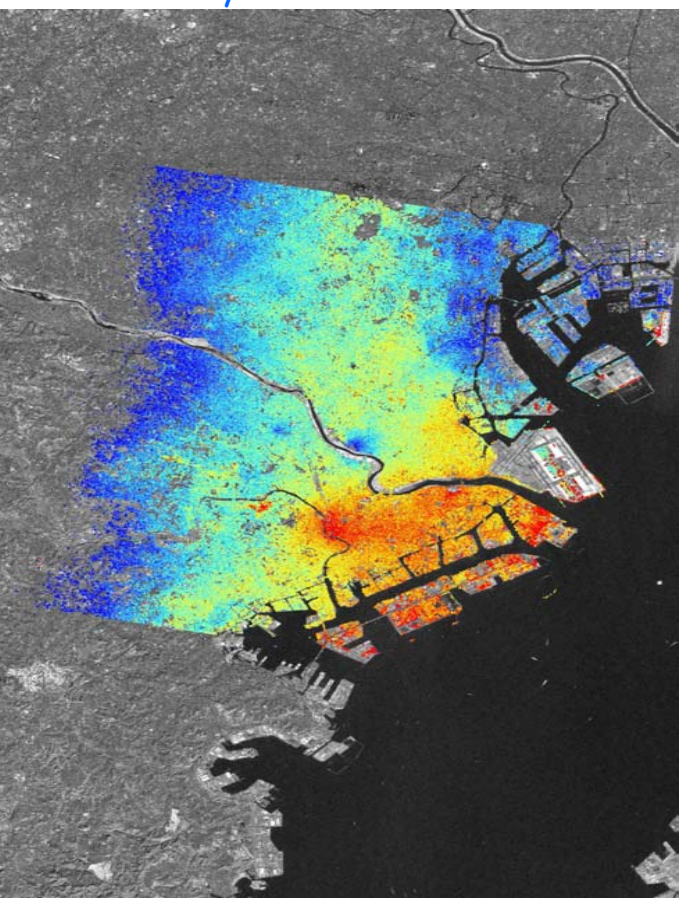
...then goes down: landslides in Berkeley



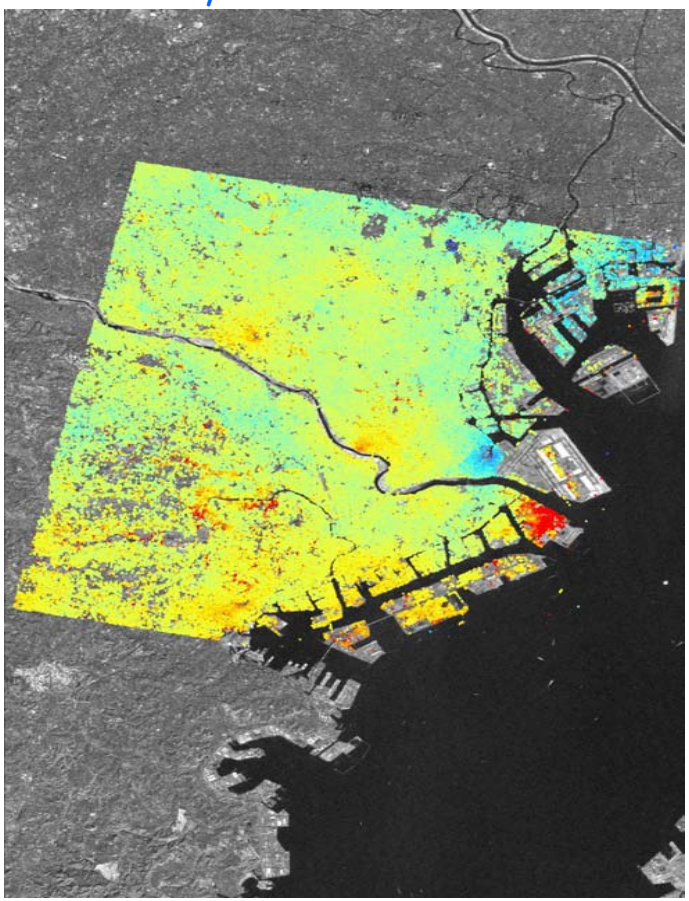
but faster when wet !

Ground motion

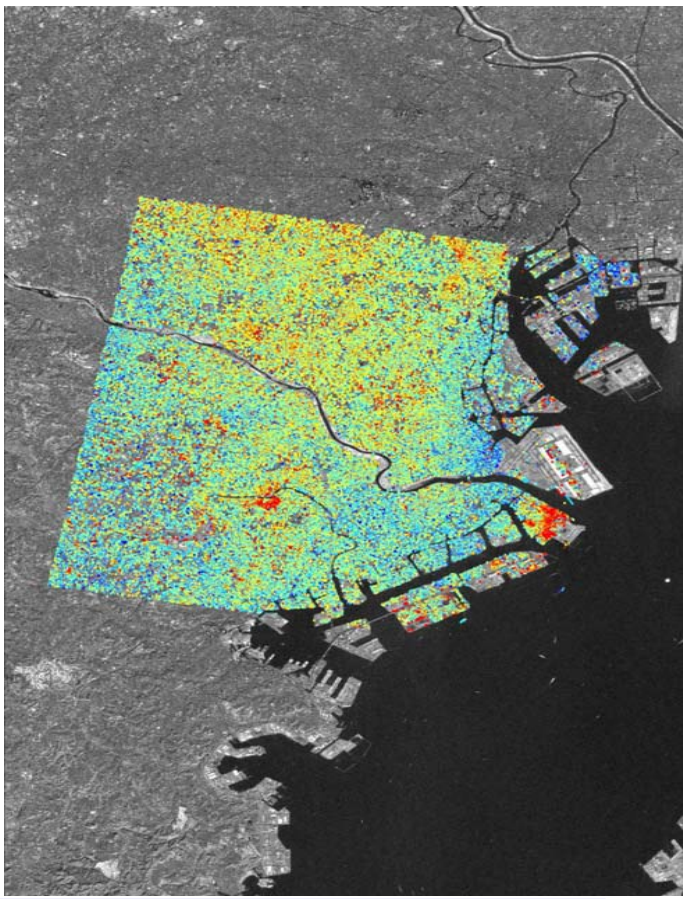
RADARSAT C-band HH pol.
30 images (ERS-like mode)
24 days revisiting period
2.5 years time interval



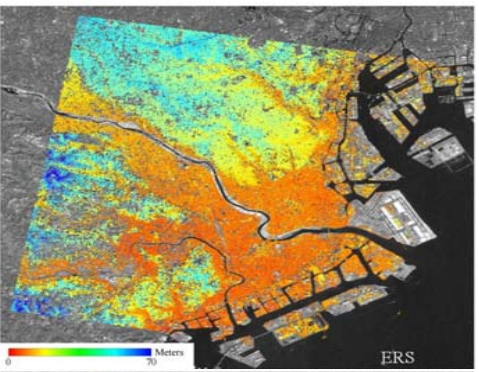
ERS1/2 C-band VV pol.
30 images
35 days revisiting period
10 years time interval

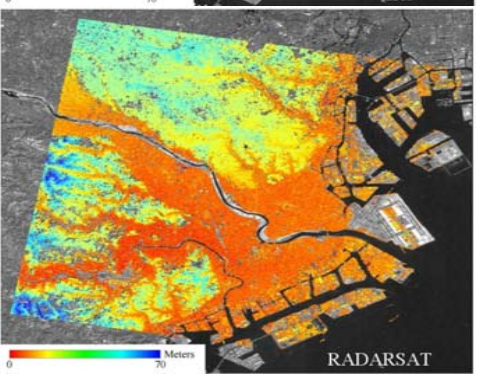


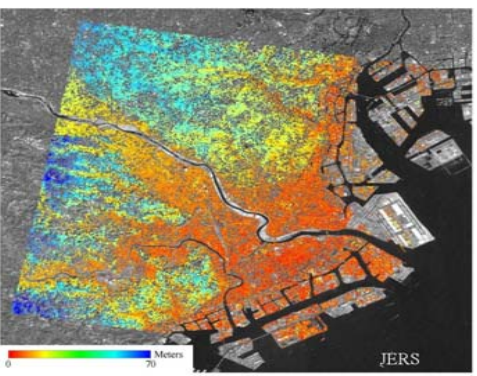
J-ERS L-band HH pol.
46 images
44 days revisiting period
6 years time interval

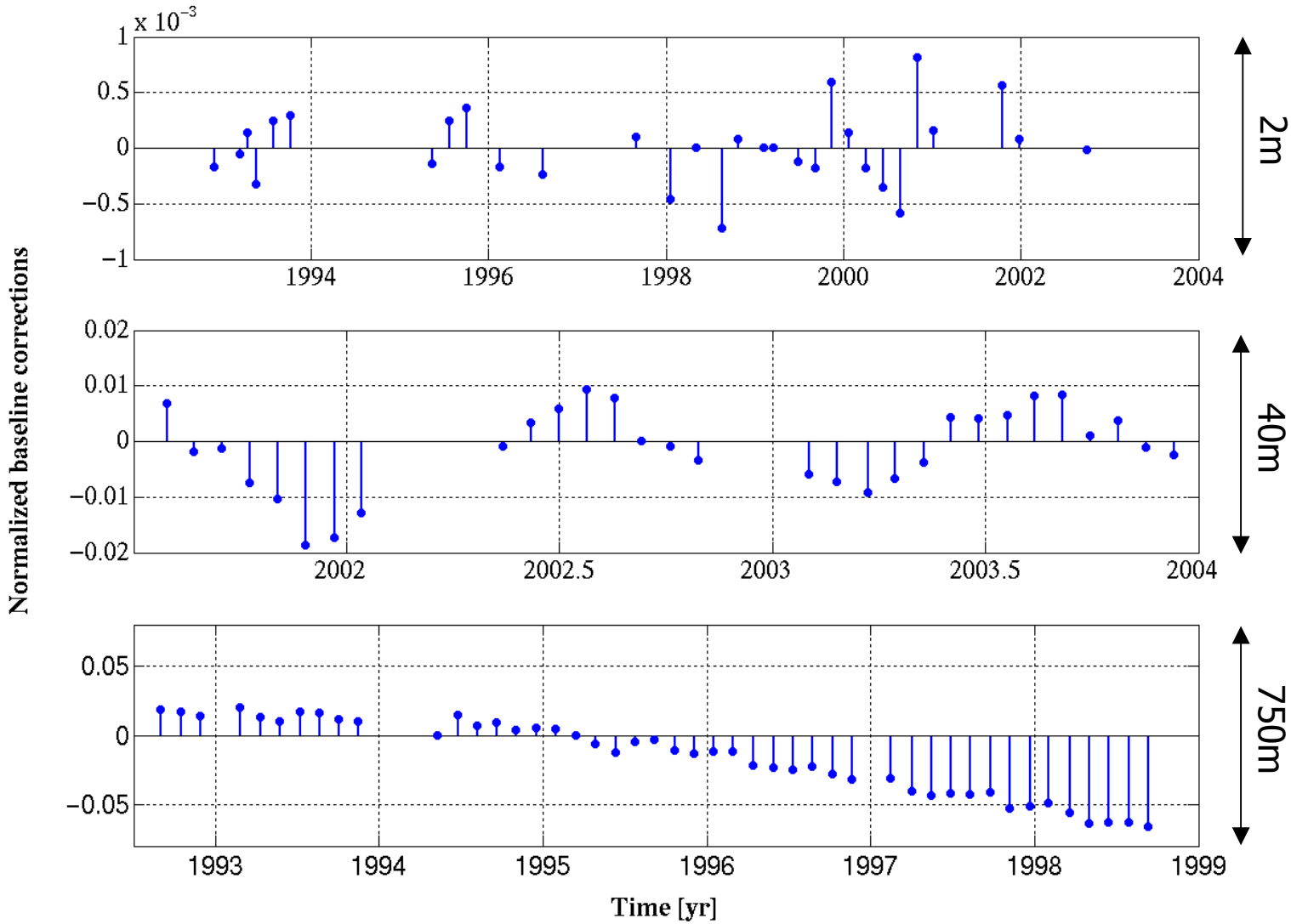


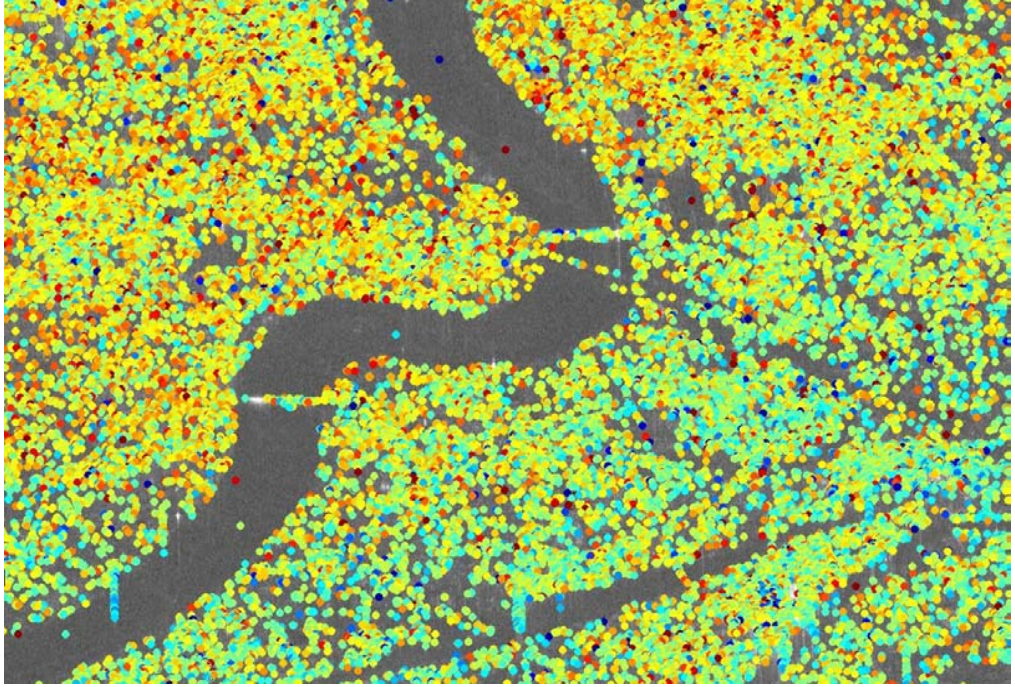
Accuracy of the measured orbits

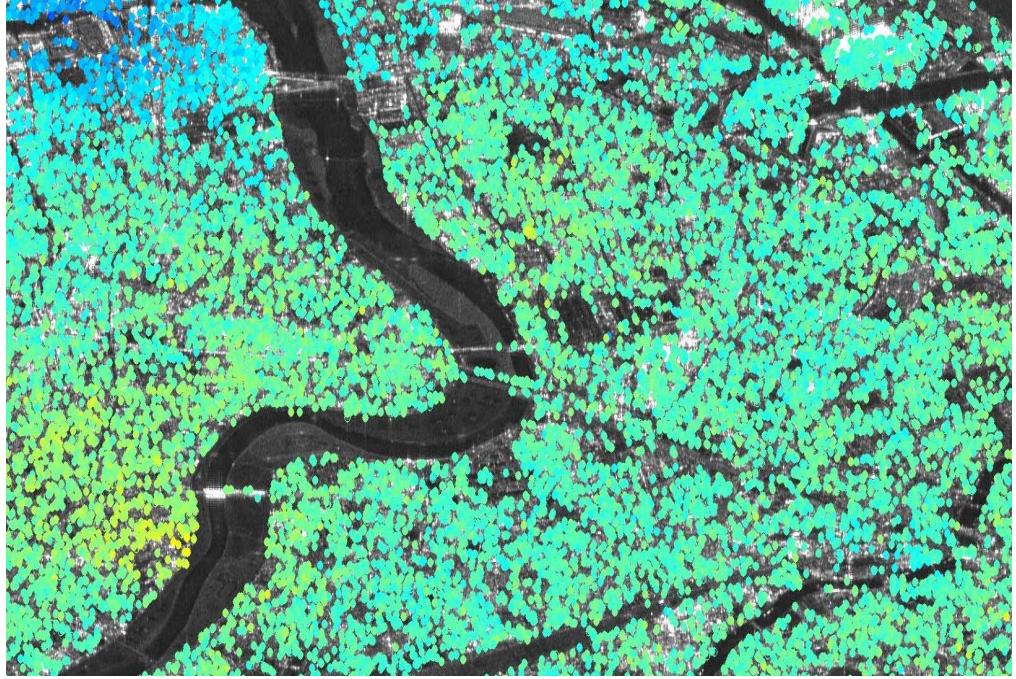




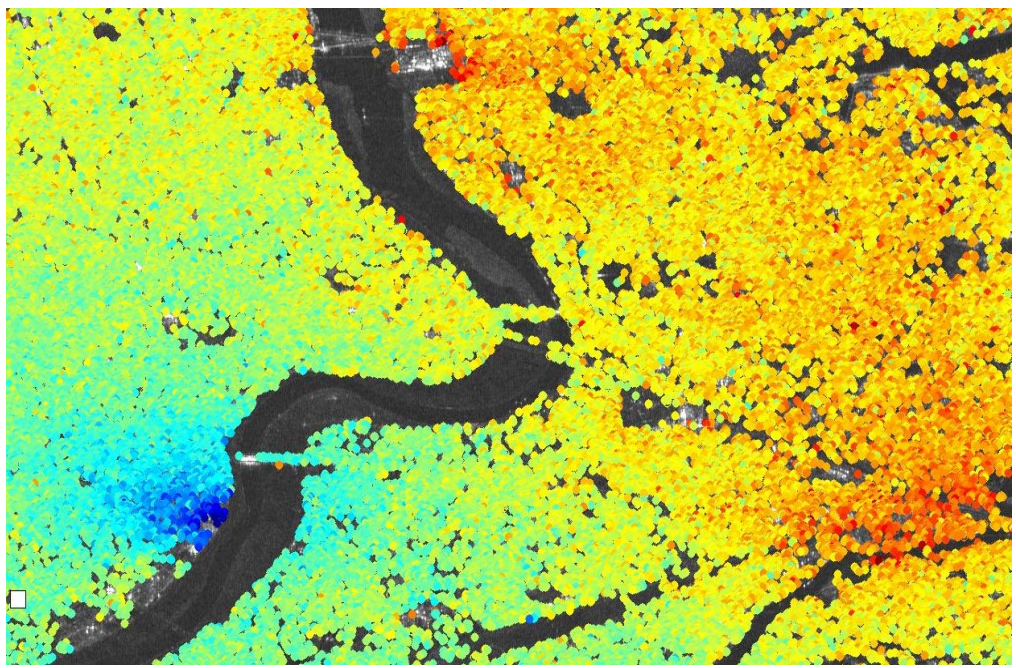








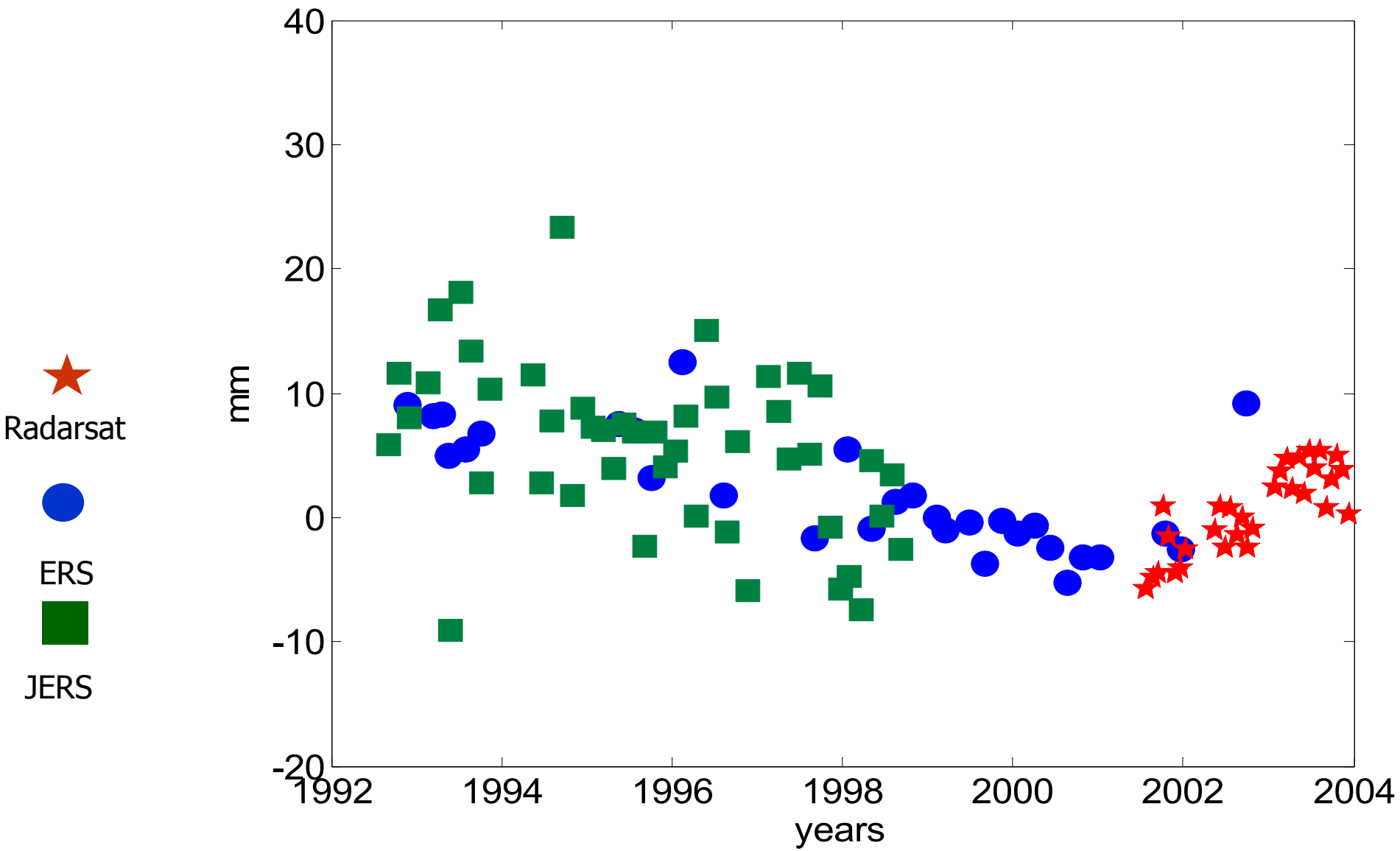
JERS



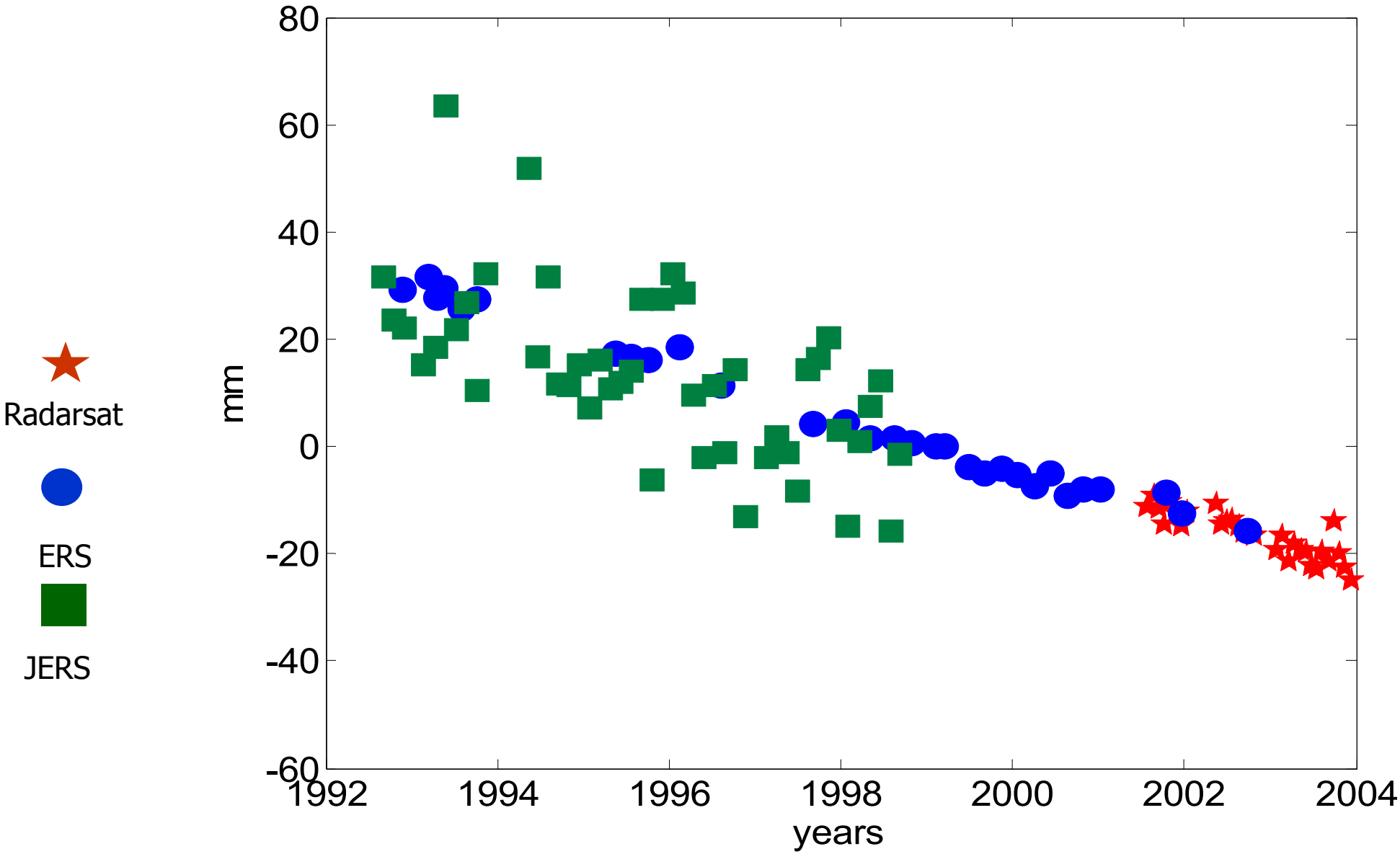
ERS

Radarsat

Precision of C band measurements: ~ 3mm



Precision of C band measurements: ~ 3mm

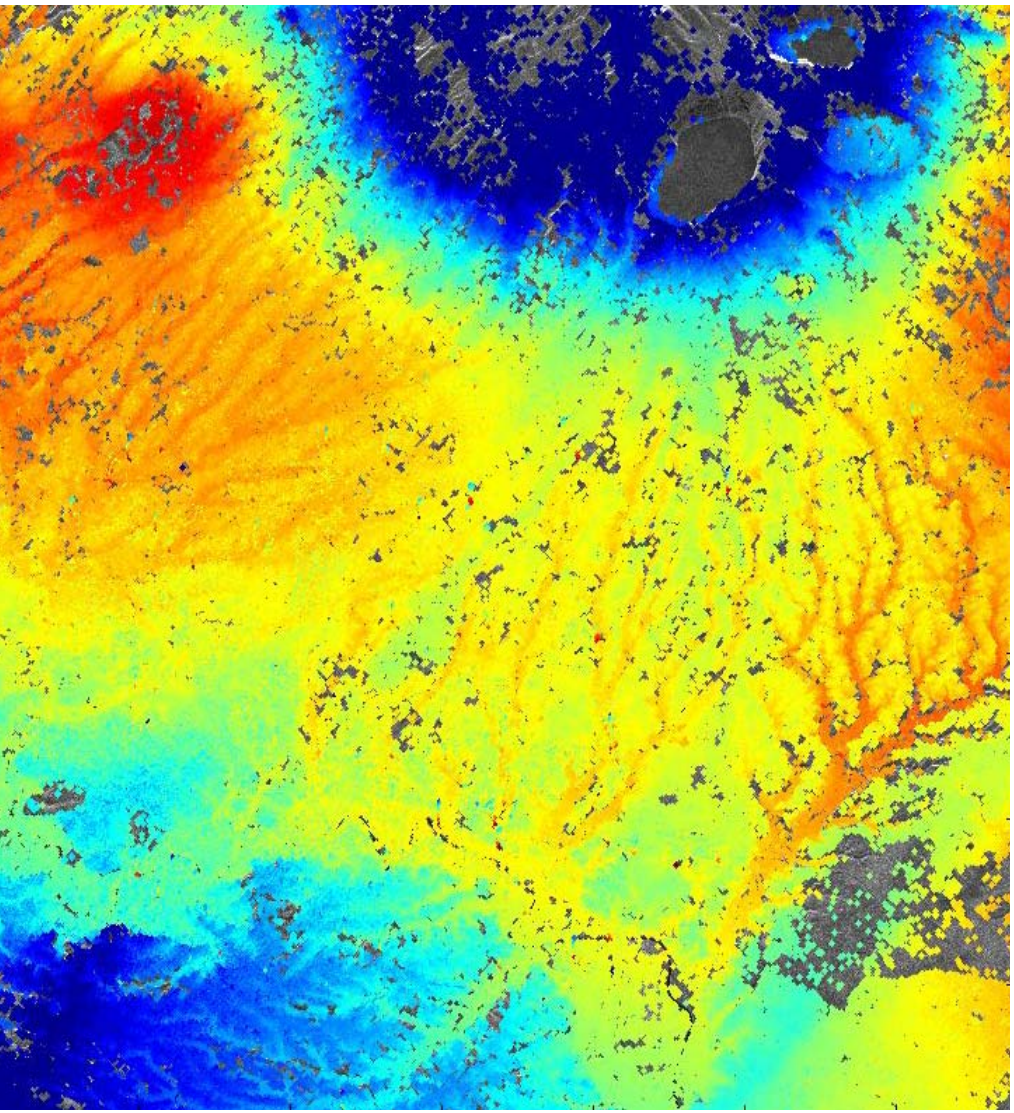


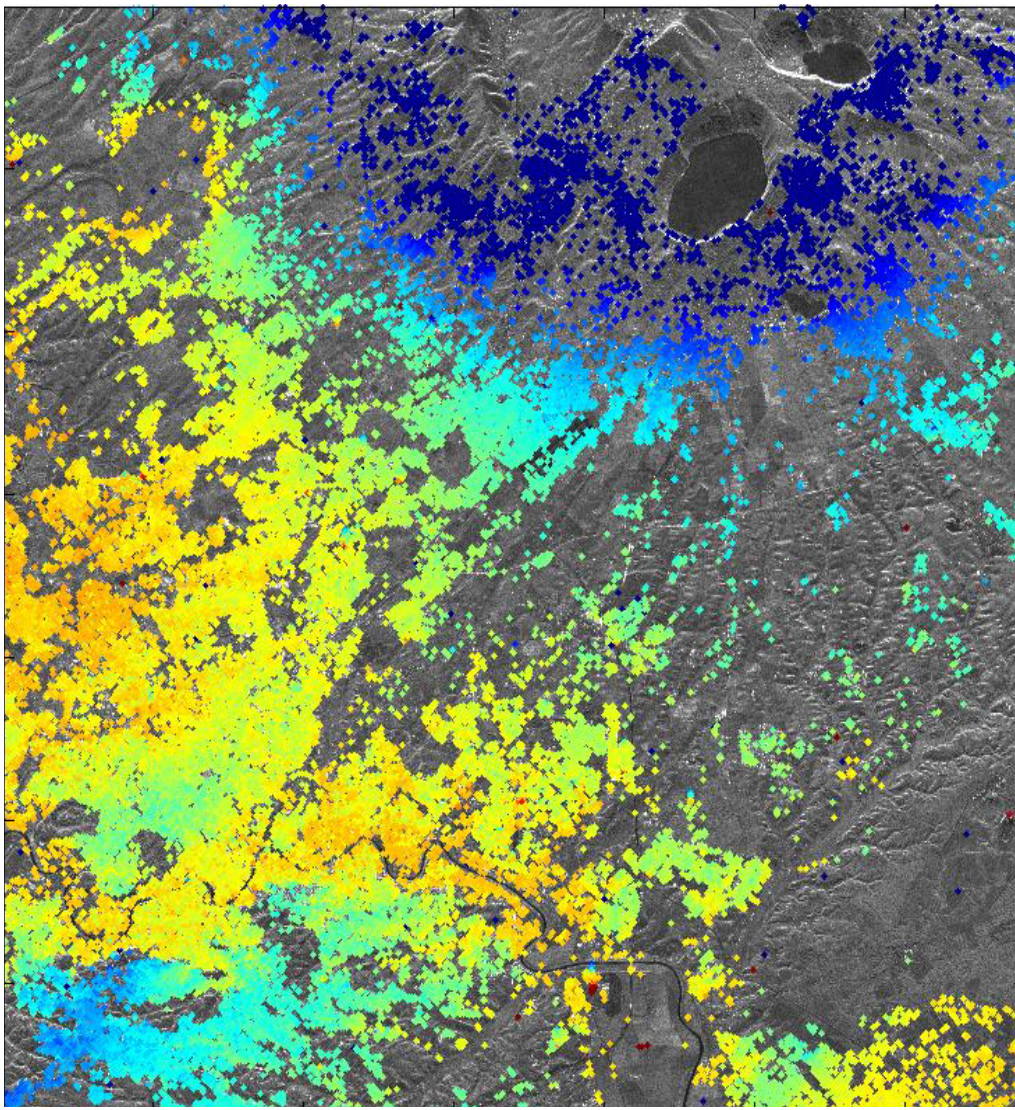
3 days data in Rome

ERS: 3 vs 35 days revisiting interval – PS elevation

3 days

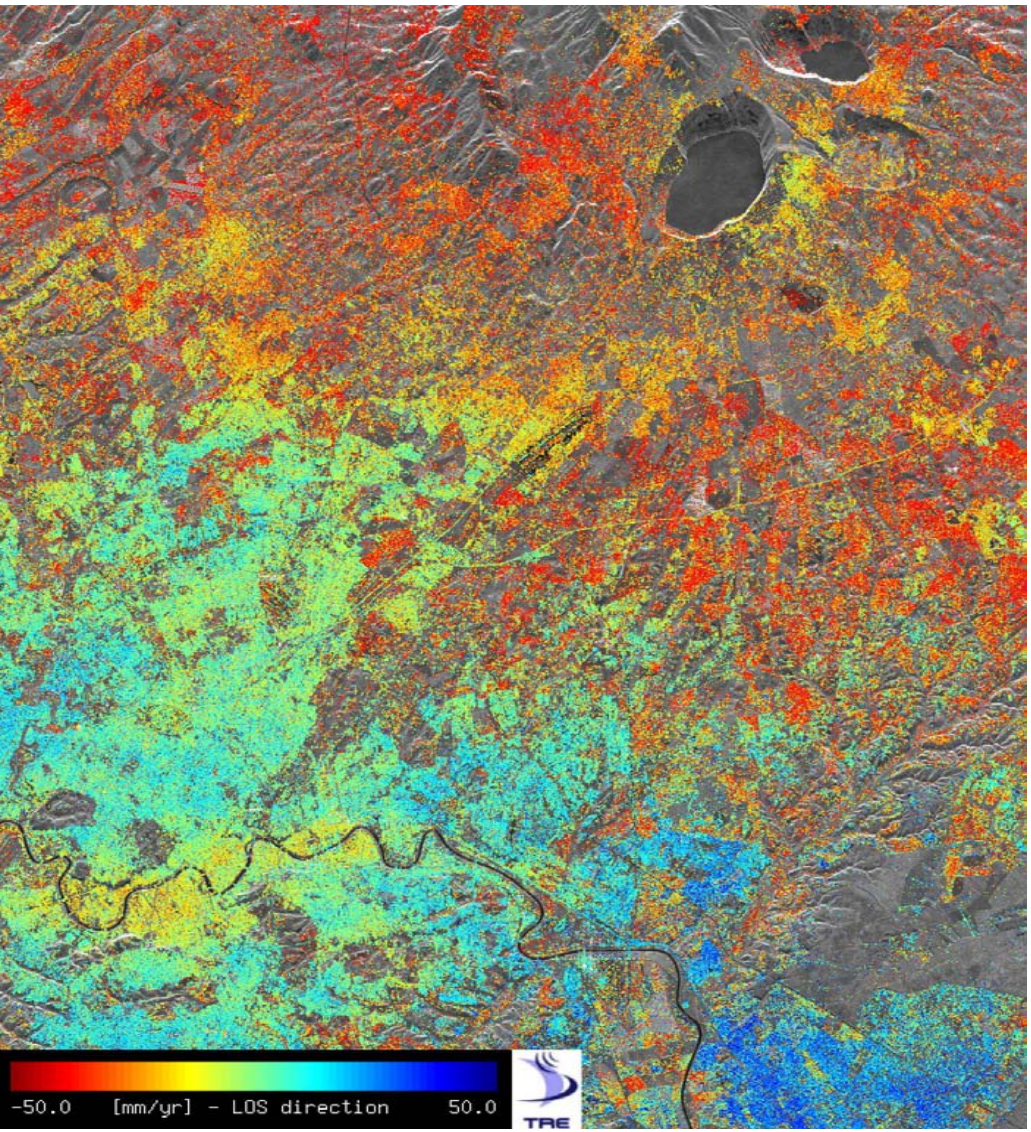
35 days



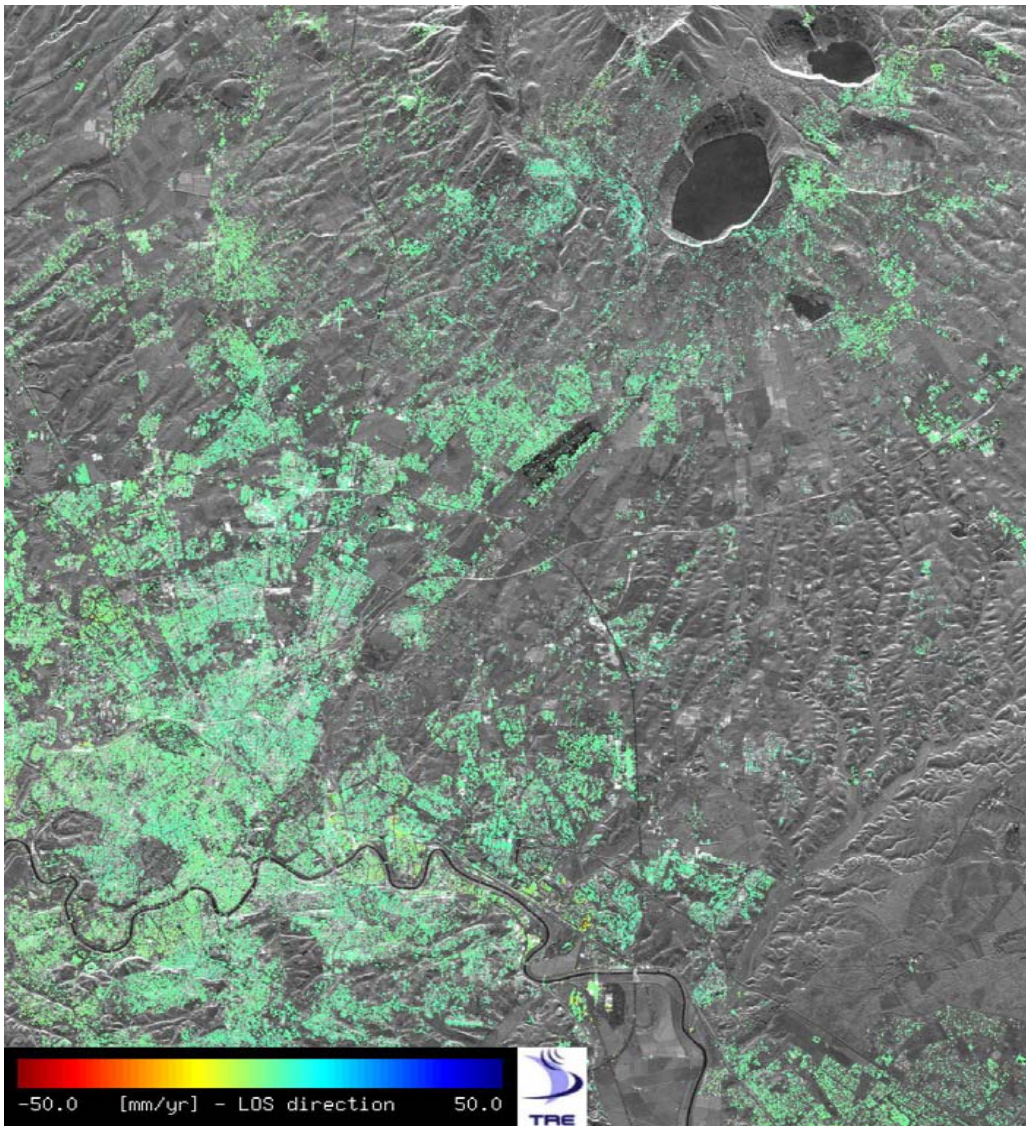


ERS: 3 vs 35 days revisiting interval - PS motion

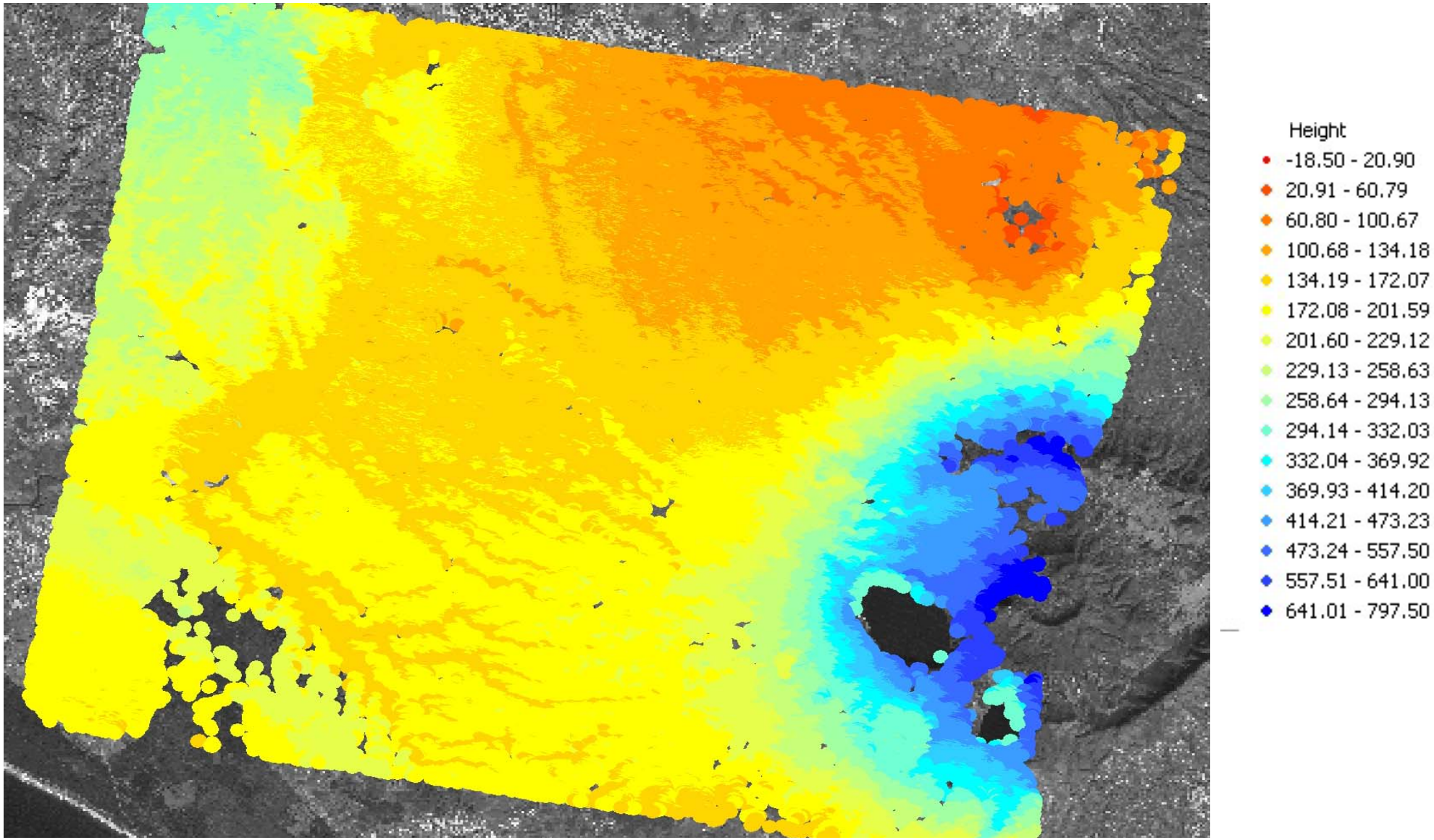
3 days

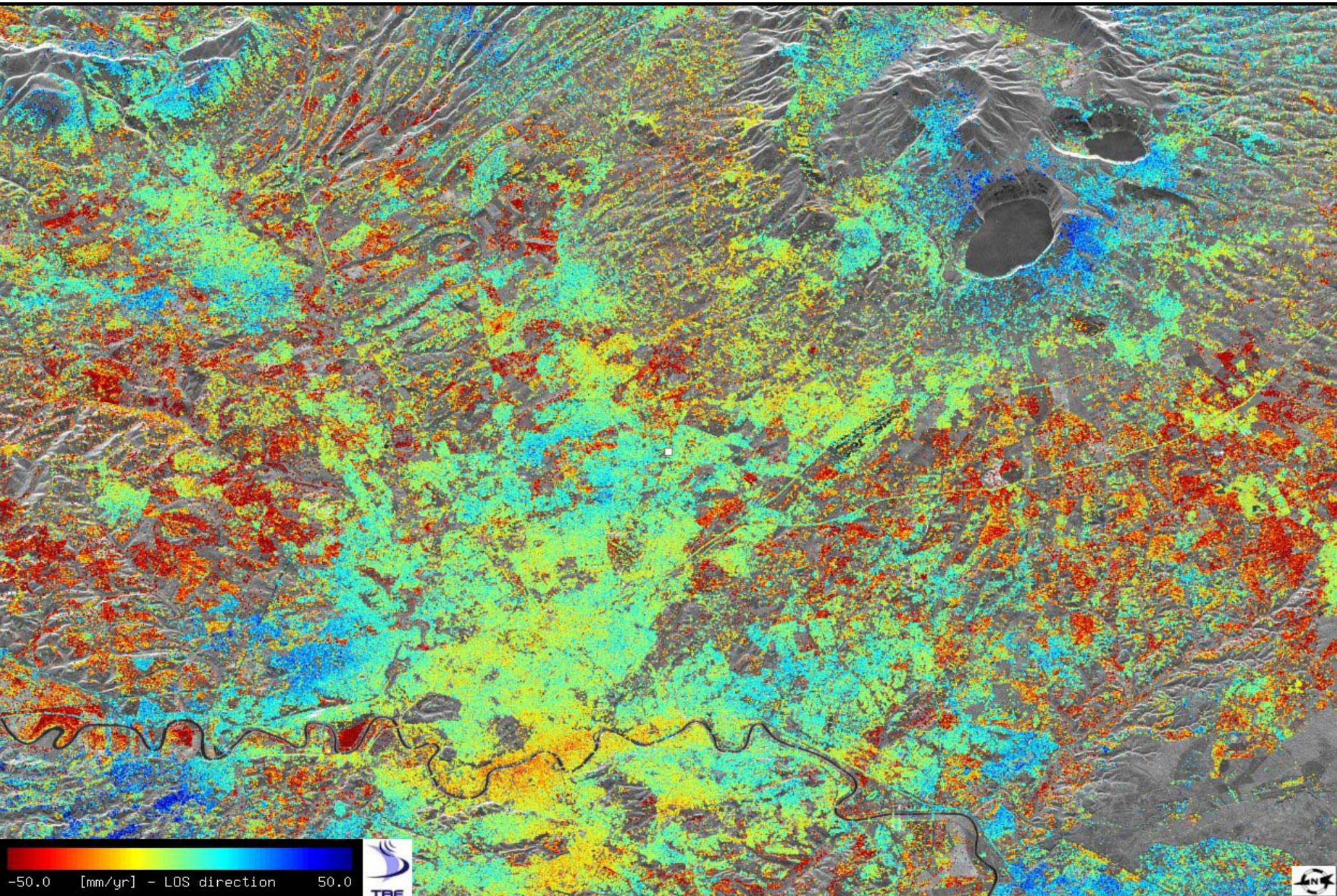


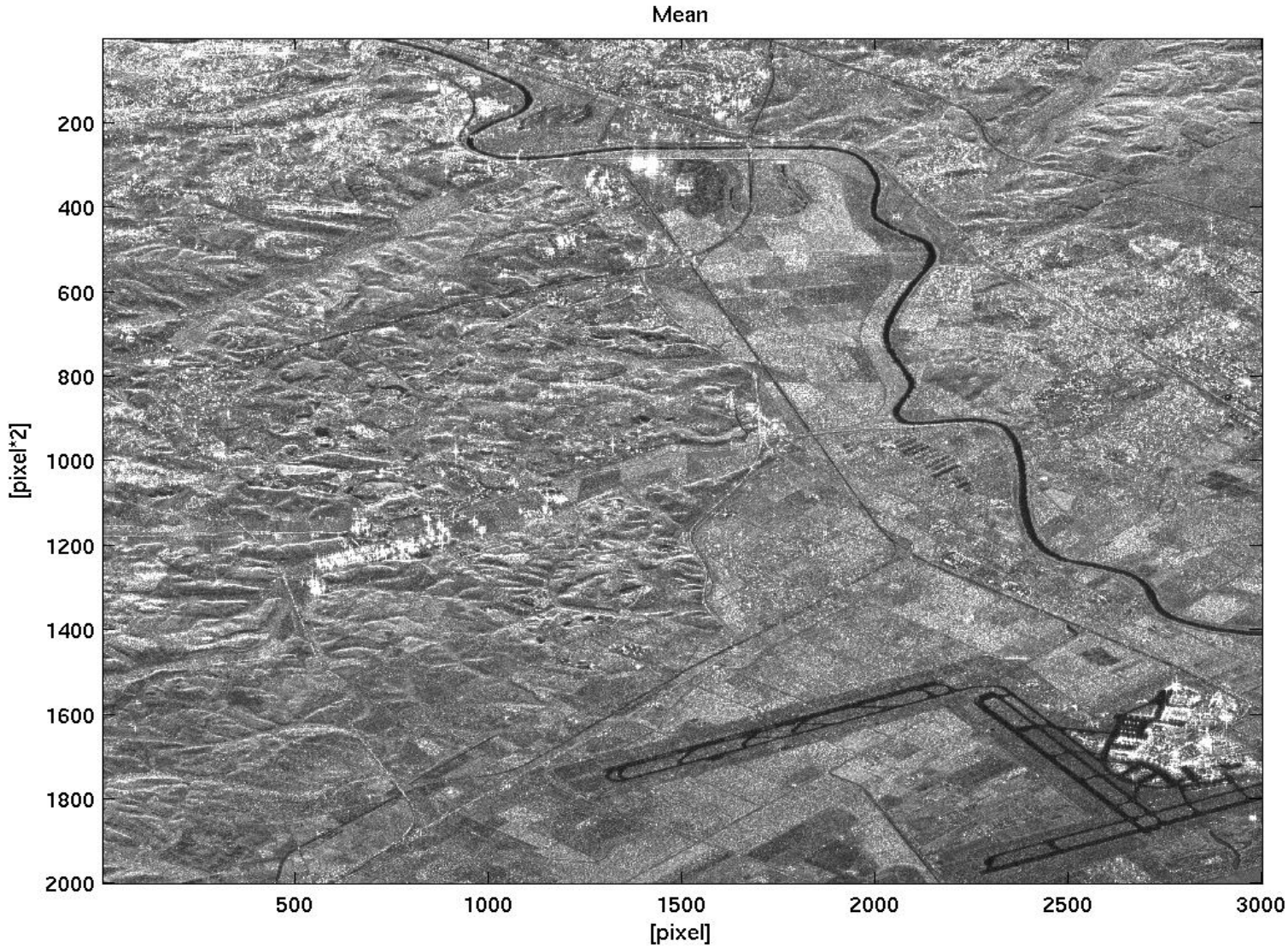
35 days



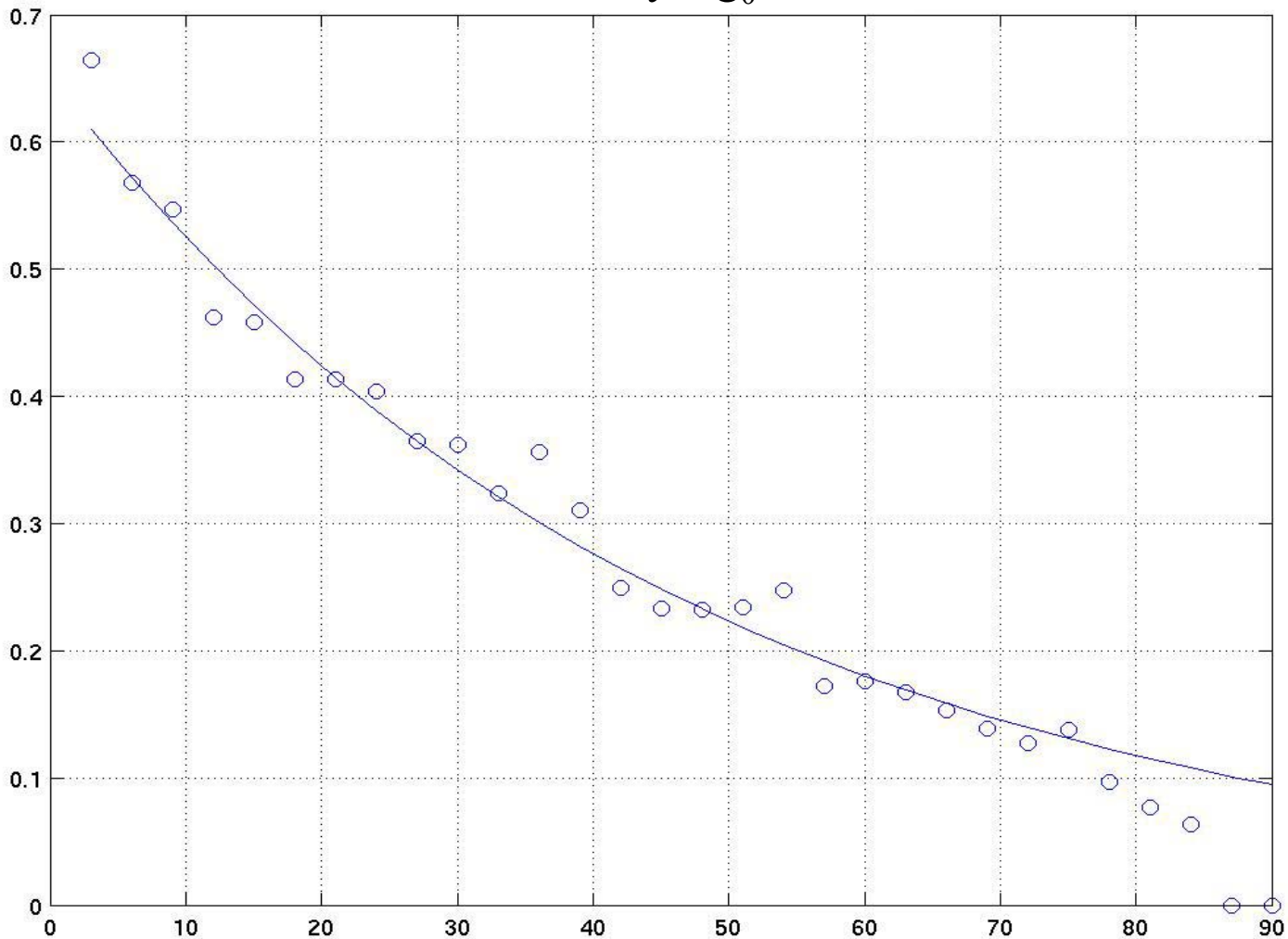
DEM (estimated precision: 2 m)

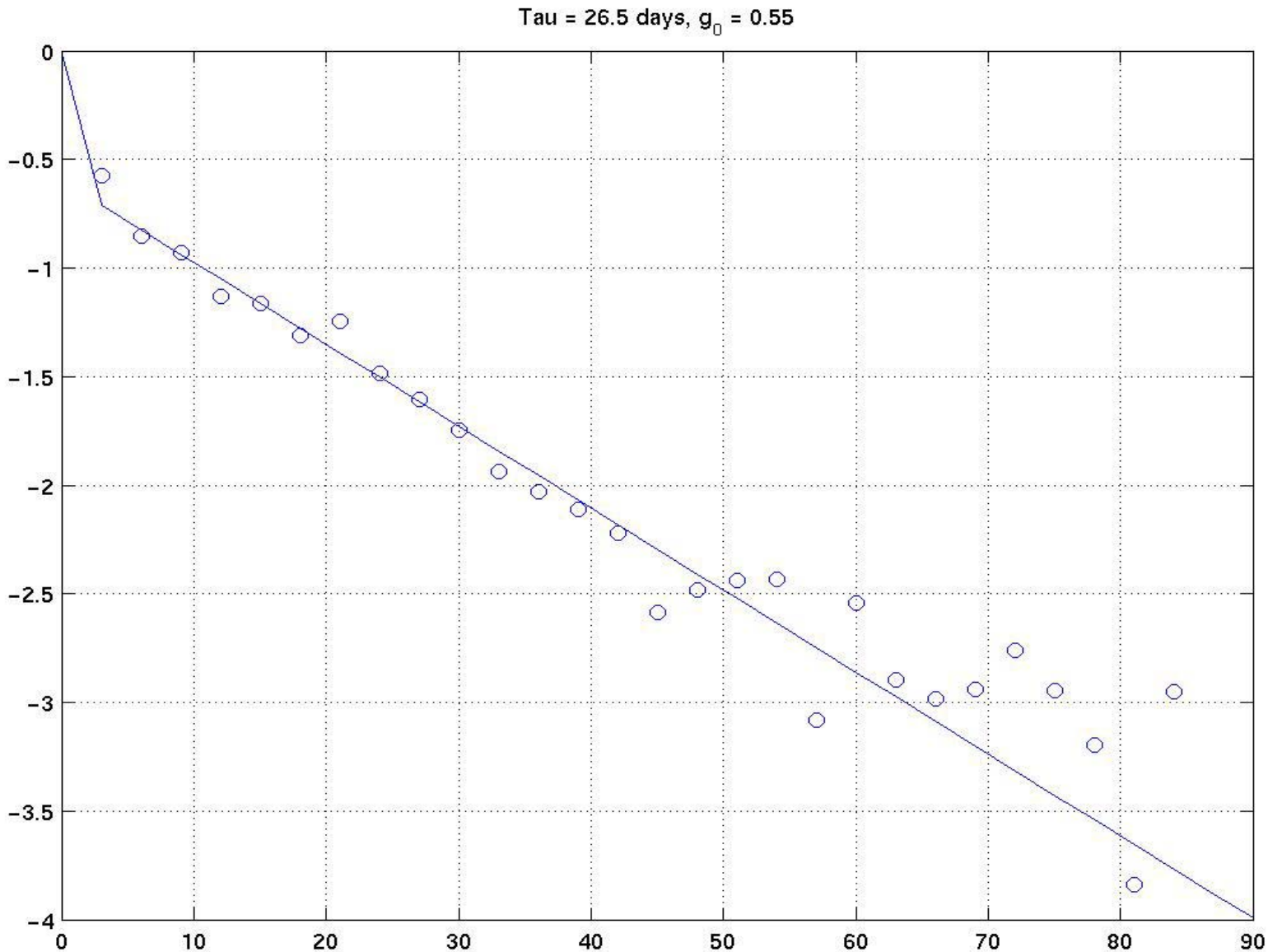



-50.0 [mm/yr] - LOS direction 50.0

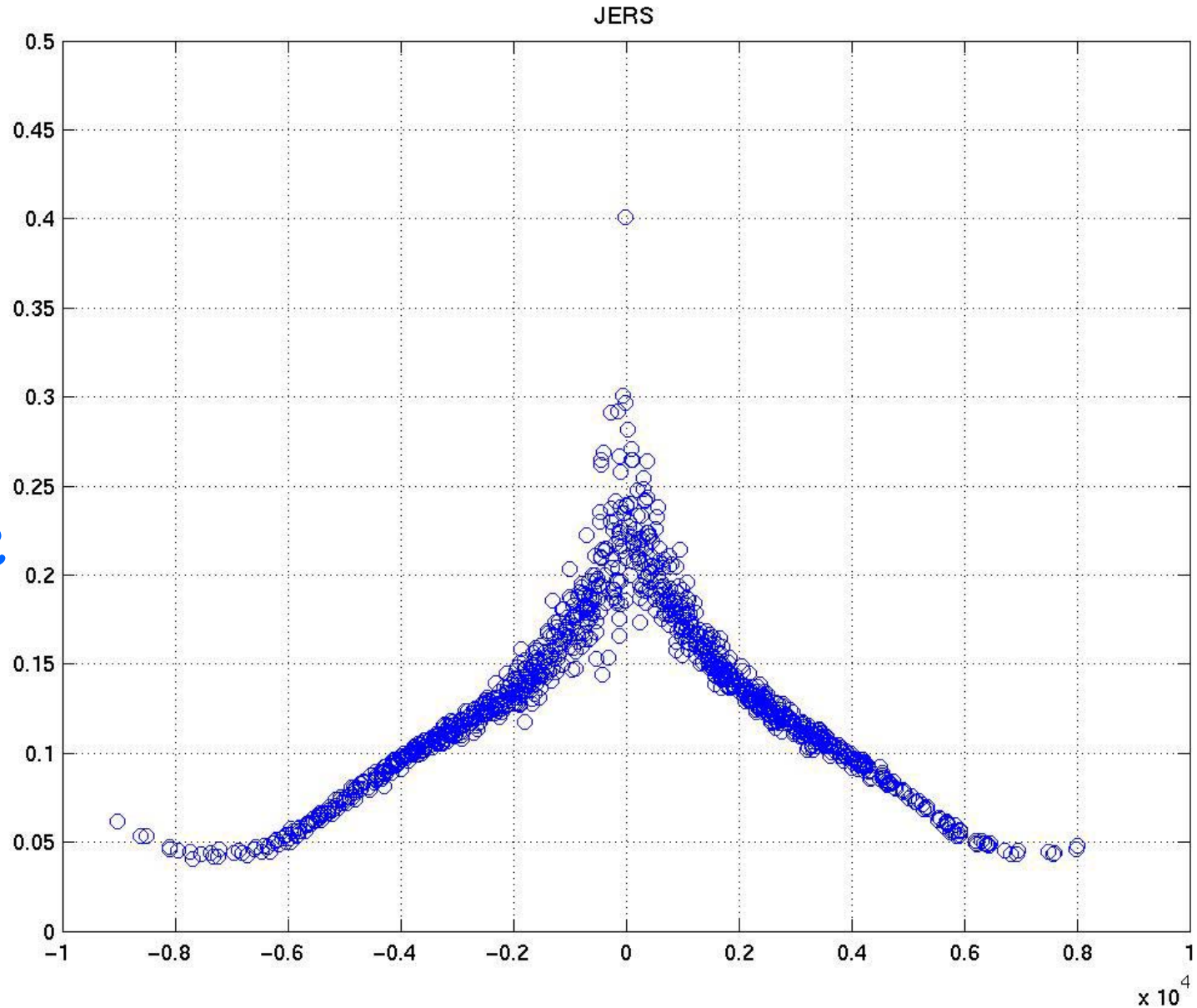

Mean
200
400
600
800
1000
1200
1400
1600
1800
2000
[pixel*2]
500
1000
1500
2000
2500
3000
[pixel]

Tau = 46.75 days, g_0 = 0.65

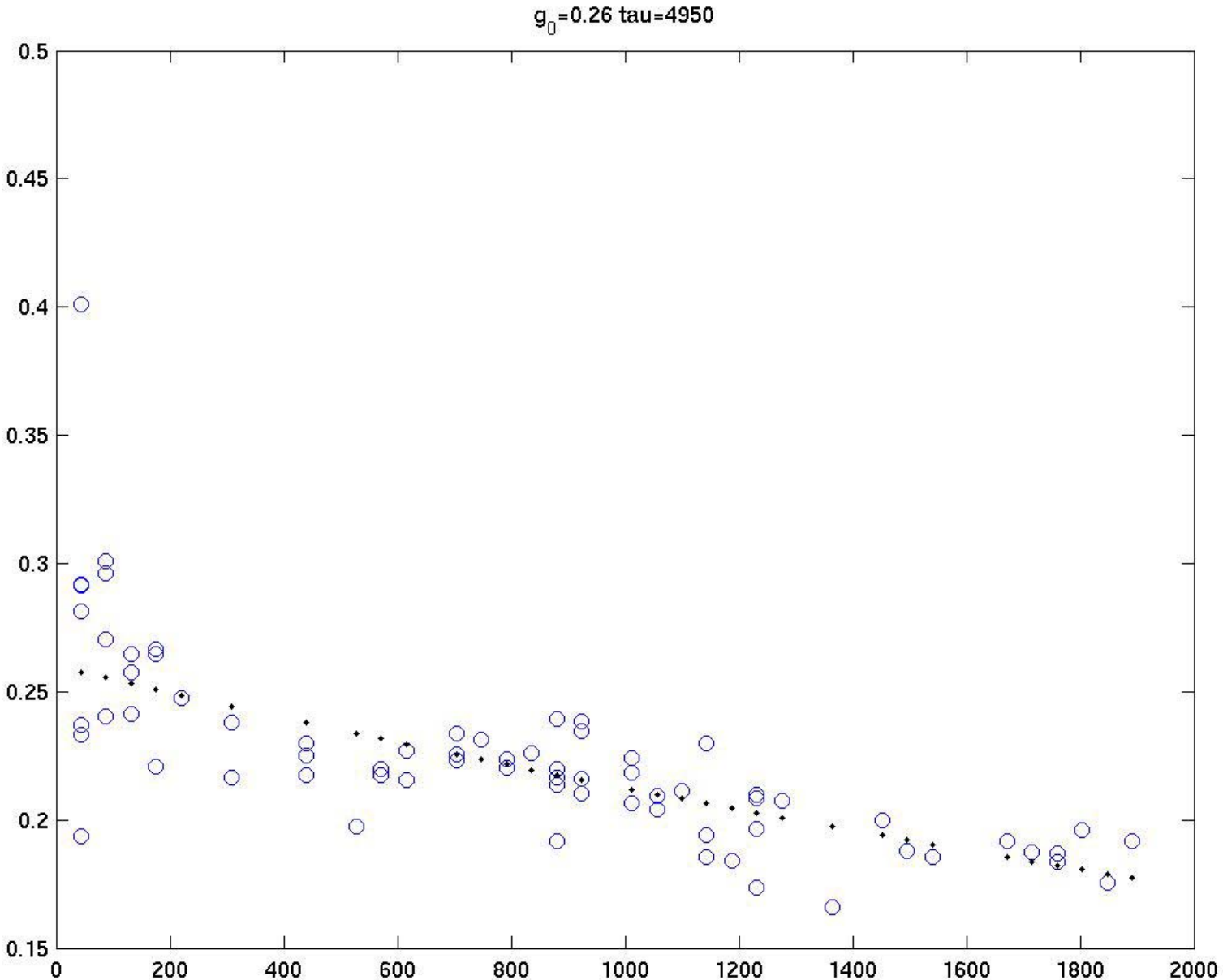



Tau = 26.5 days, g_0 = 0.55
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
10
20
30
40
50
60
70
80
90

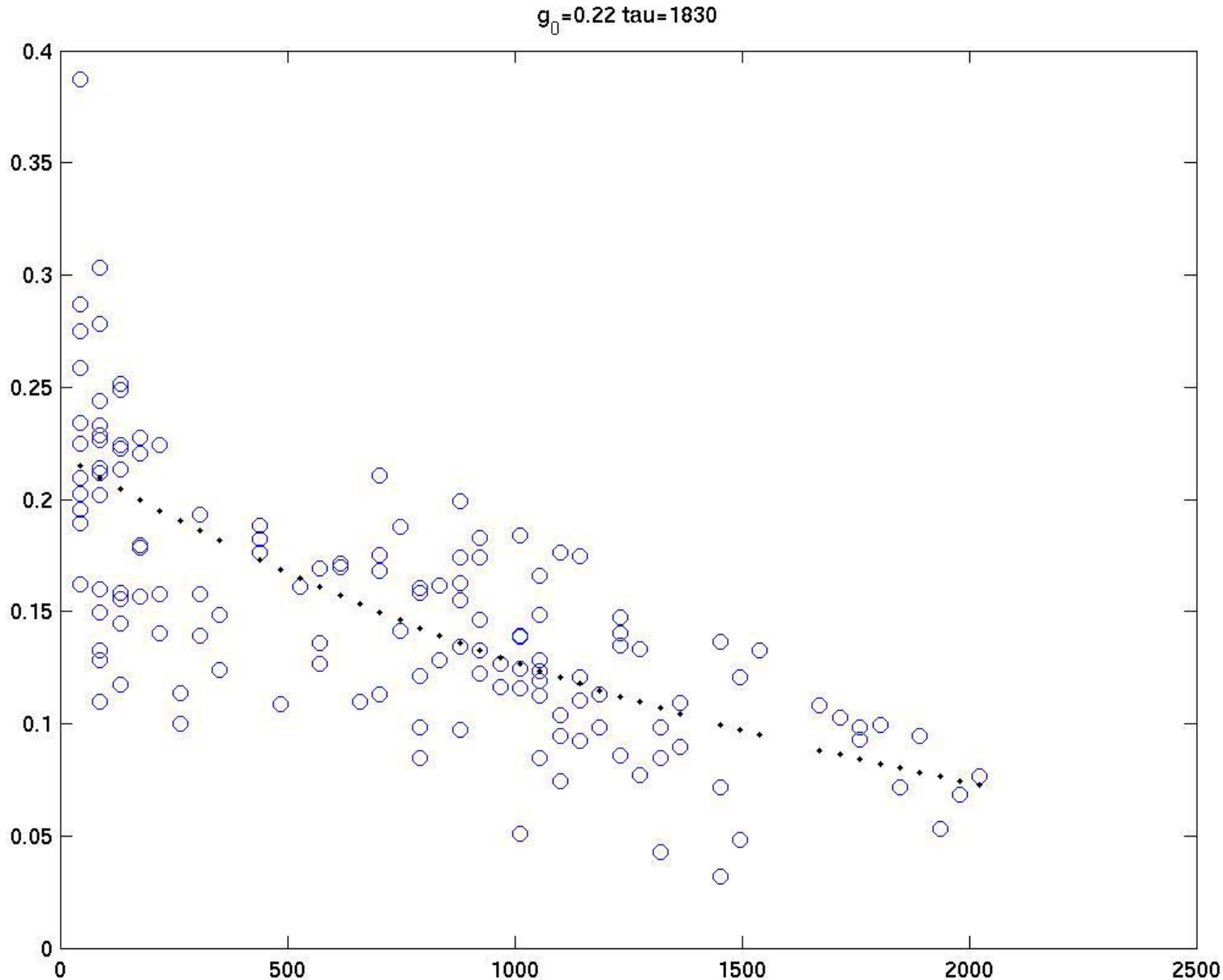
JERS: Coherence Vs baseline



JERS 300 days

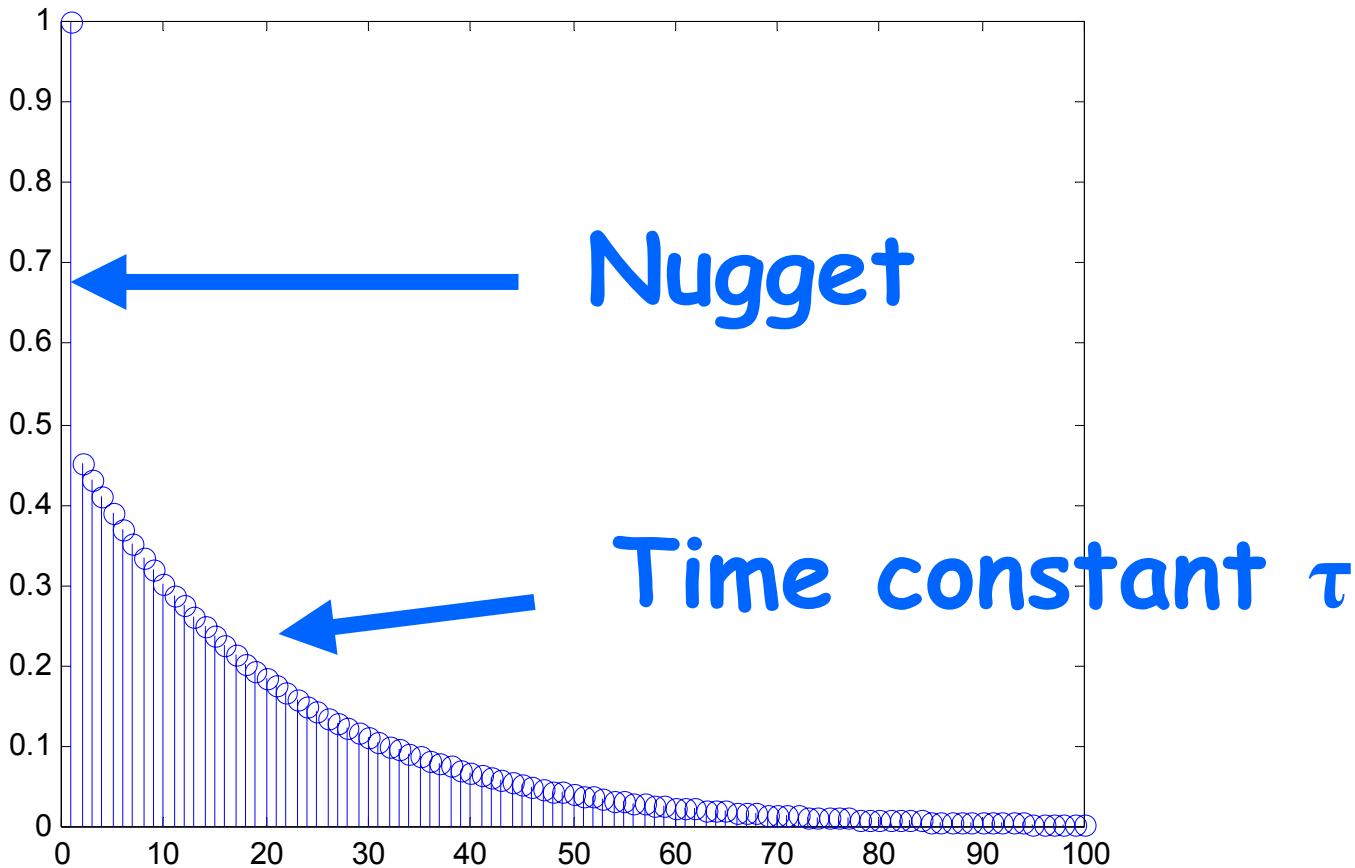


JERS
600
days

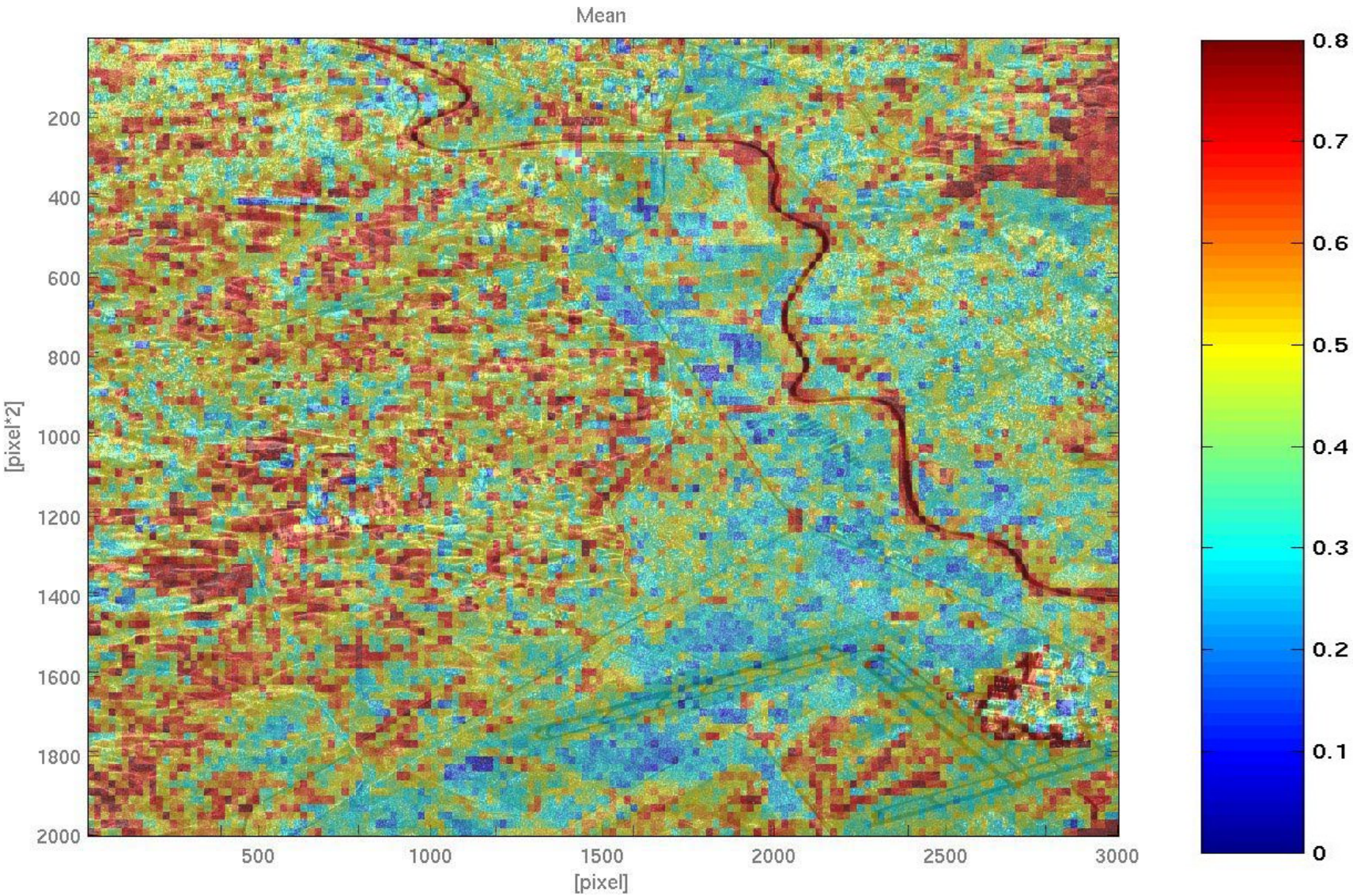


The model

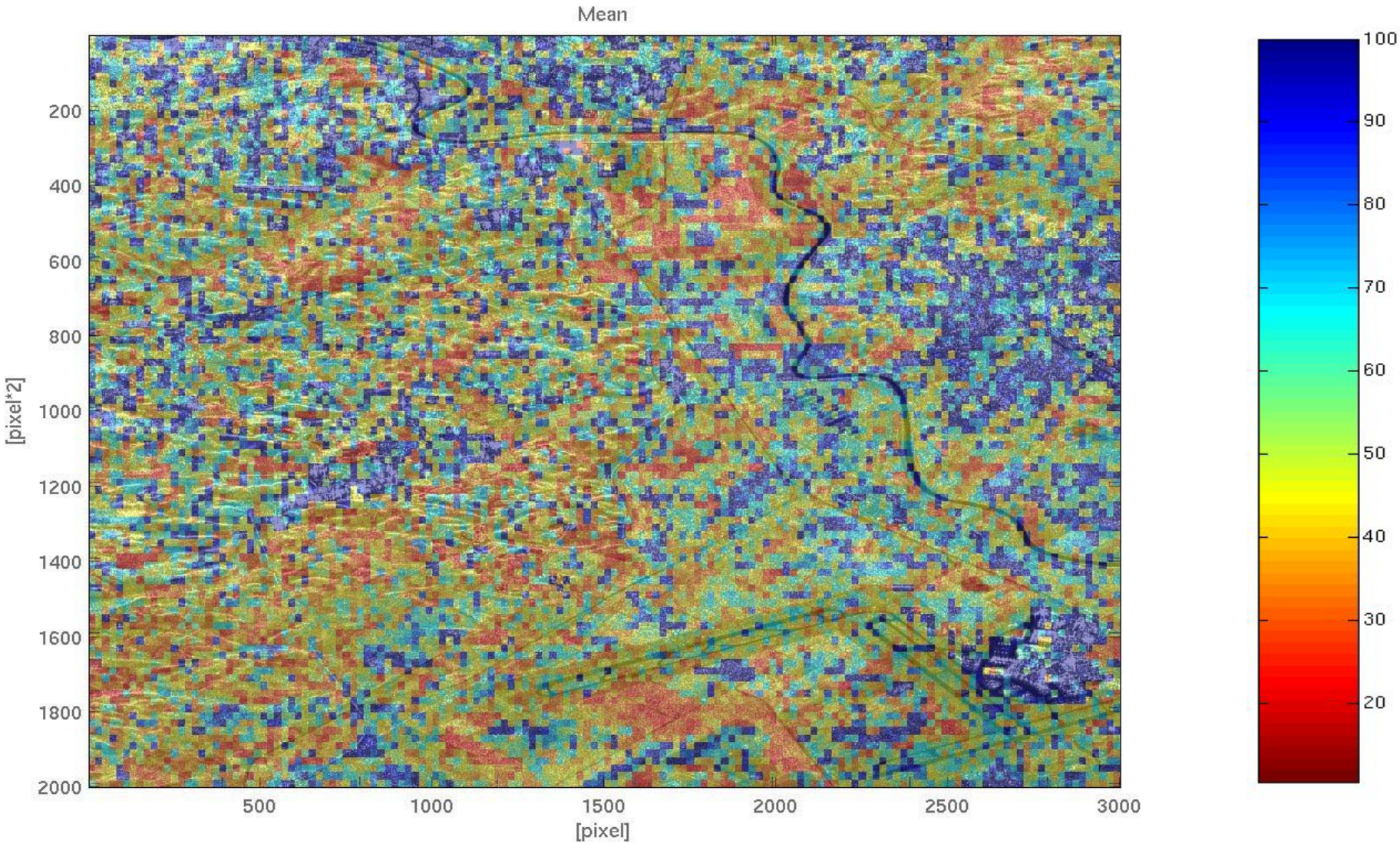
Temporal behavior of the scatterers

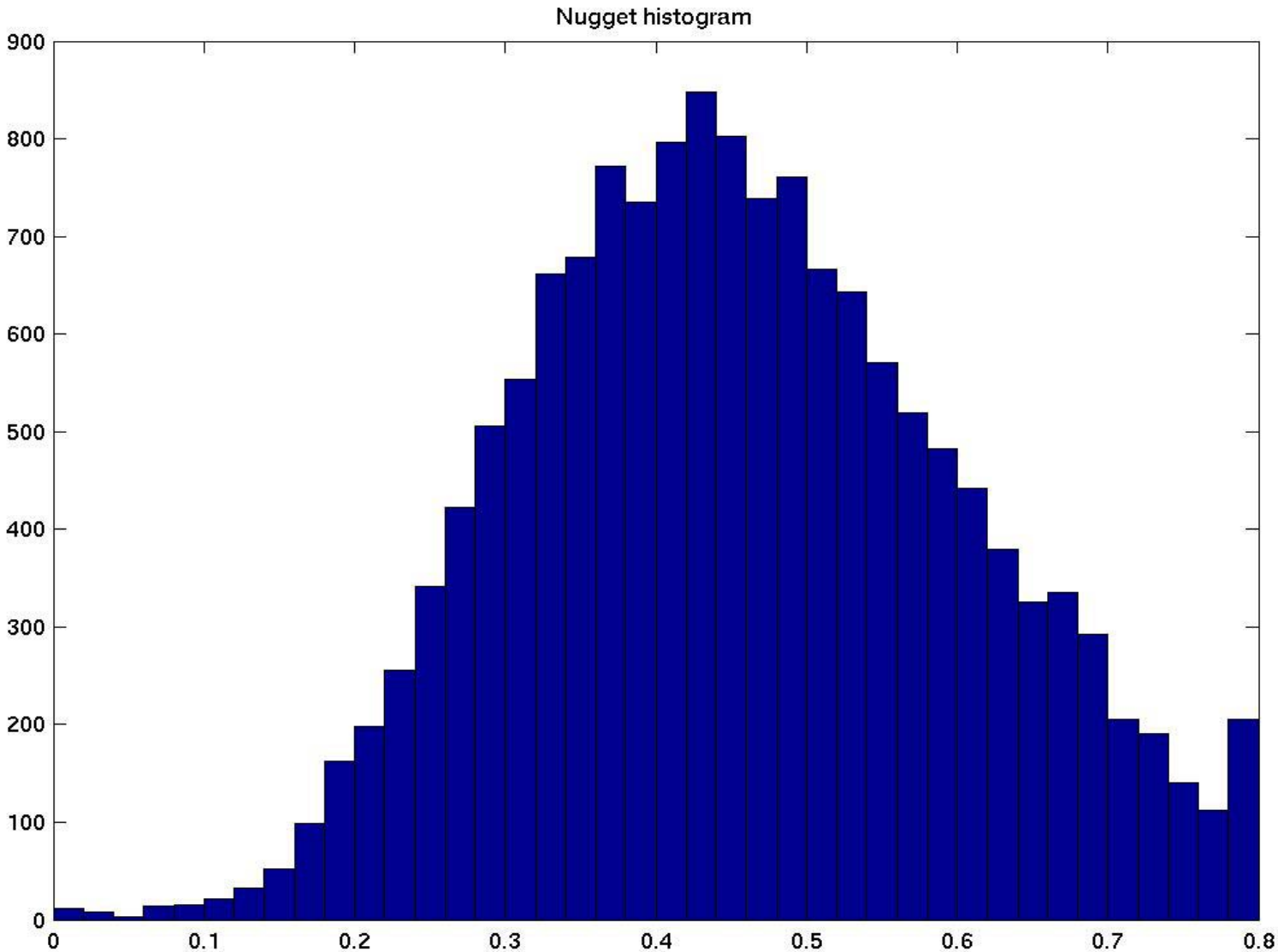


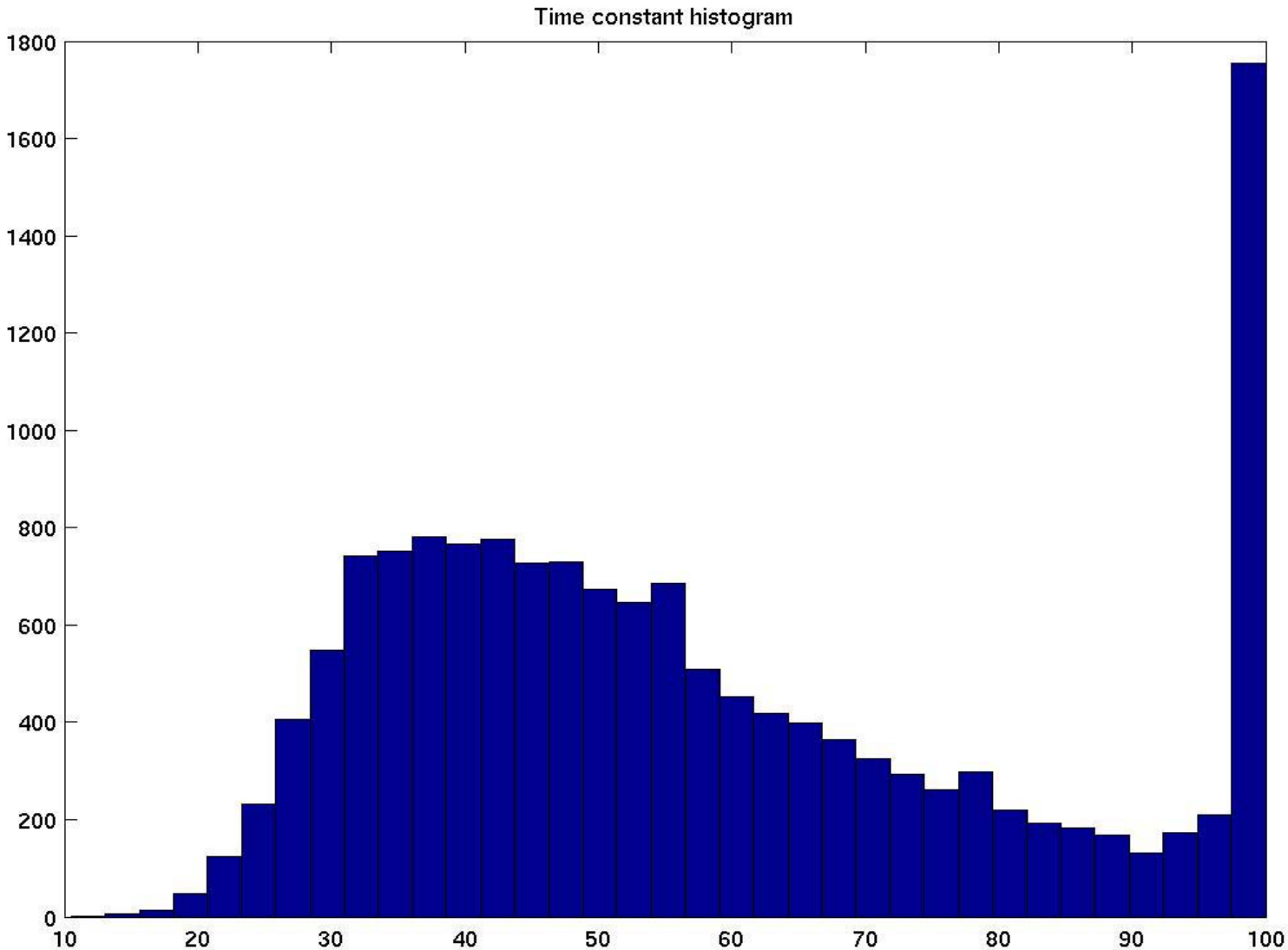
nugget


Mean
[pixel^2]
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000
2500
3000
[pixel]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Tau


Mean
[pixel*2]
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000
2500
3000
[pixel]
100
90
80
70
60
50
40
30
20


Nugget histogram
900
800
700
600
500
400
300
200
100
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8


Time constant histogram
1800
1600
1400
1200
1000
800
600
400
200
0
10
20
30
40
50
60
70
80
90
100

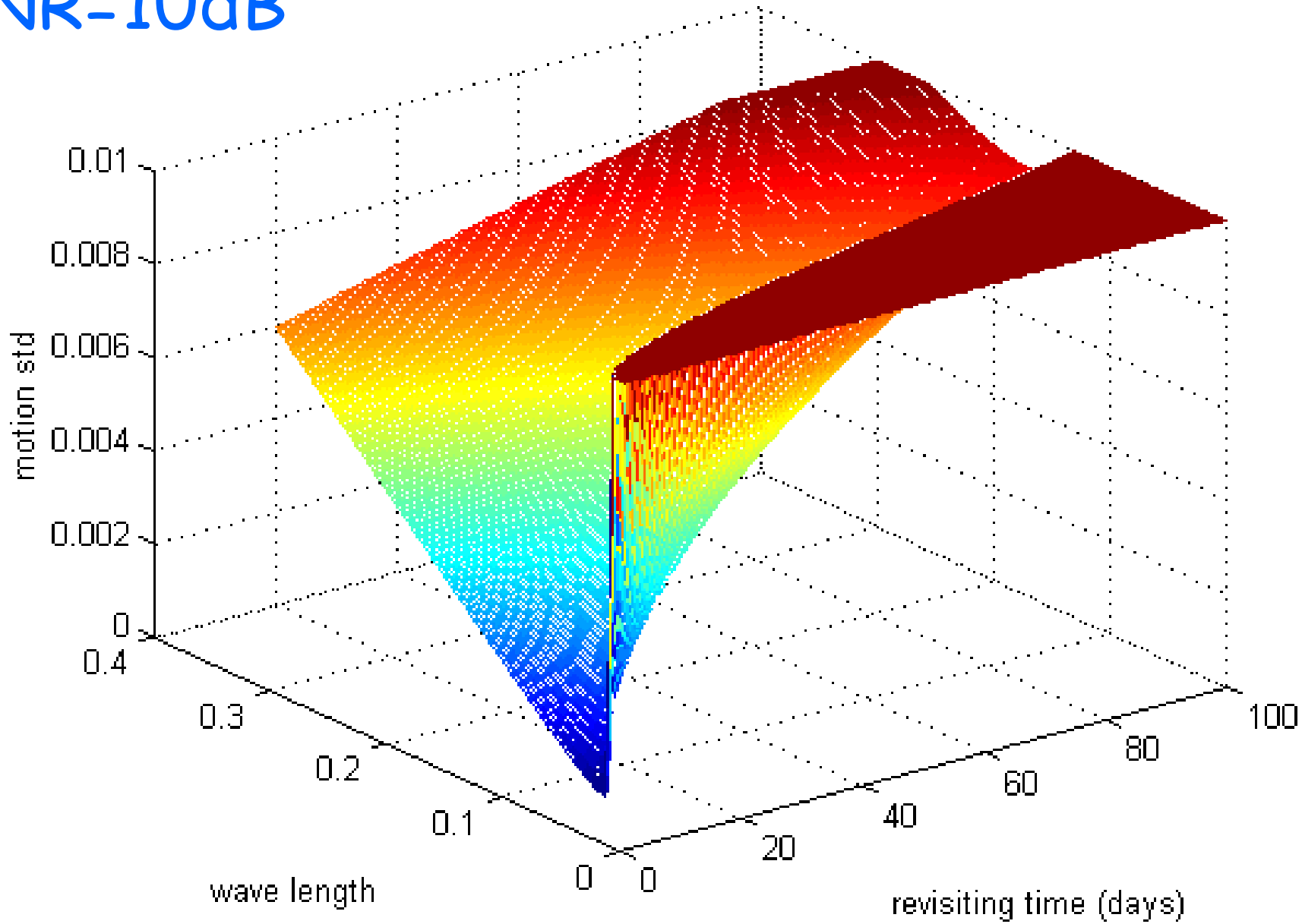
$$\gamma(\lambda, M) \approx \frac{SNR}{1+SNR} \exp\left(-\frac{M}{M_C}\frac{\lambda_C^2}{\lambda^2}\right)$$

$$\sigma_\varphi = \sqrt{\frac{1-\gamma^2}{2\gamma^2}} \qquad p = erfc\left(\frac{\pi}{\sqrt{2}\sigma_\varphi}\right);$$

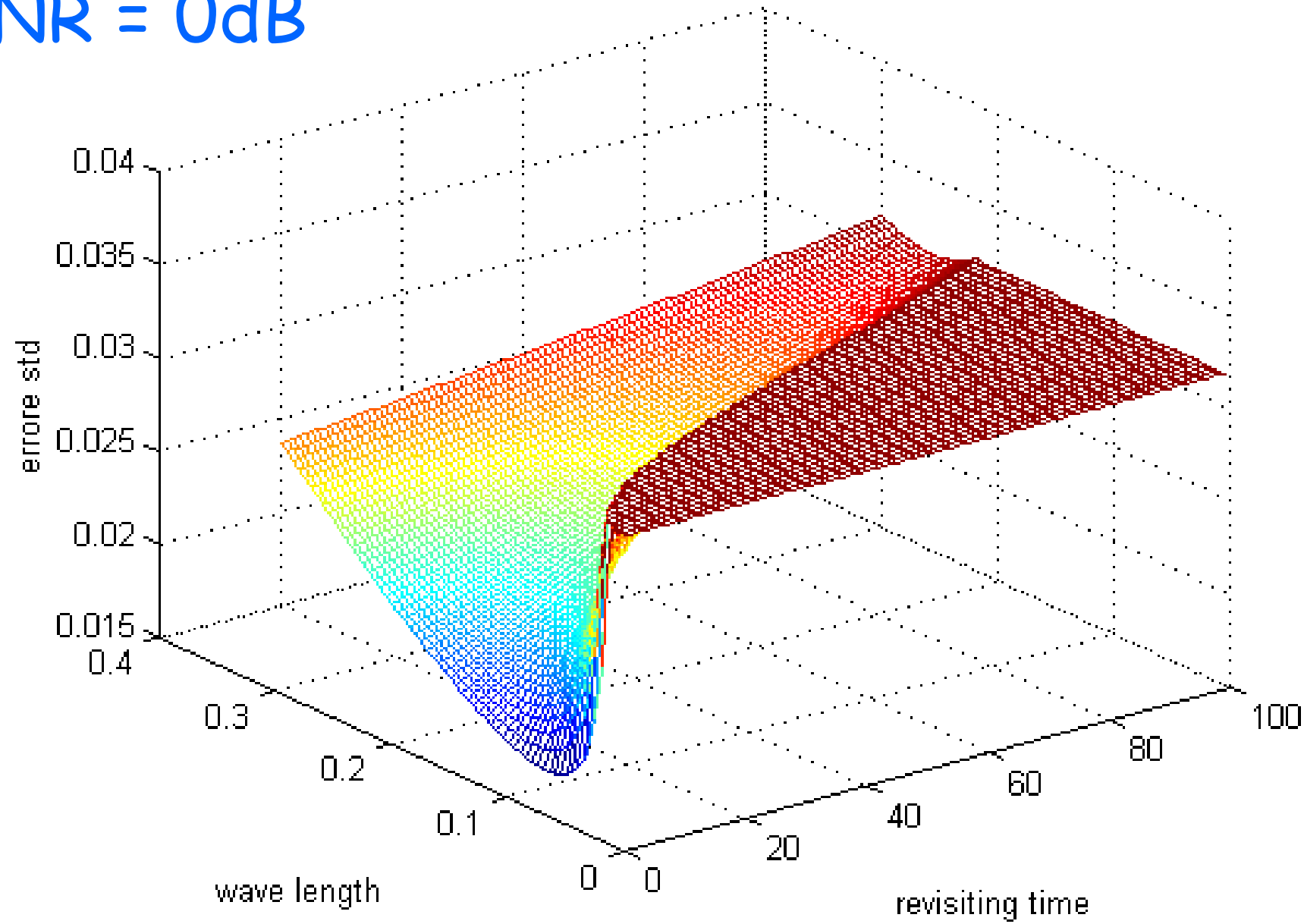
$$\sigma_m = p\sigma_n \frac{\lambda}{4\pi} + (1-p)\sigma_{apriori}$$

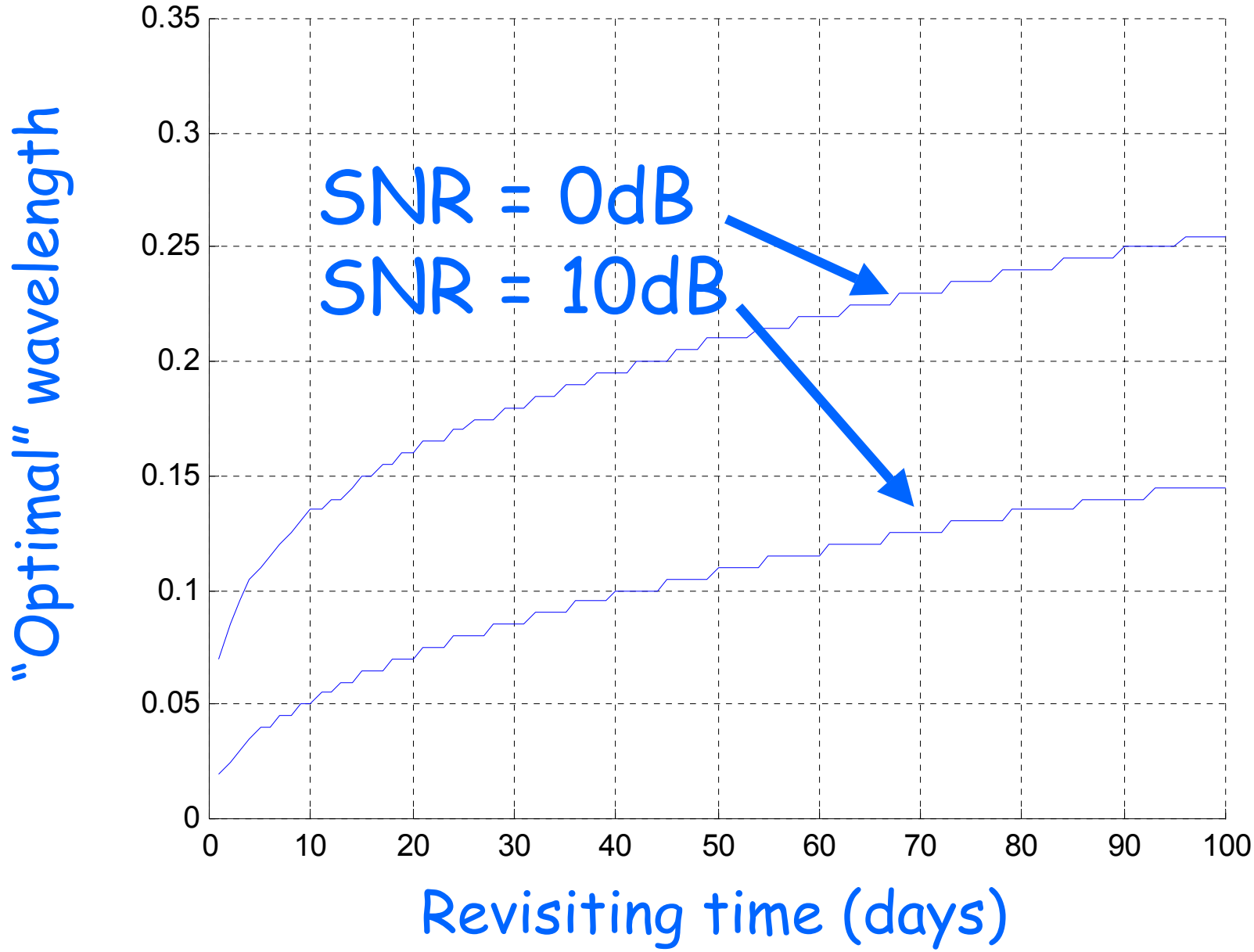
p = Probability of phase shifts greater than π

SNR=10dB


0.01
0.008
0.006
0.004
0.002
0
motion std
0.4
0.3
0.2
0.1
0
wave length
0
20
40
60
80
100
revisiting time (days)

SNR = 0dB


0.04
0.035
0.03
0.025
0.02
0.015
errore std
0.4
0.3
0.2
0.1
0
wave length
0
20
40
60
80
100
revisiting time


"Optimal" wavelength
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
SNR = 0dB
SNR = 10dB
0
10
20
30
40
50
60
70
80
90
100
Revisiting time (days)

New missions

C band yields sub-millimeter motion and sub-meter elevation accuracy in populated areas.

L band revisiting intervals may be much longer. However, a much lower noise level is needed to obtain small motion sensitivity; optimal for forest penetration.

X band has lower penetration; revisiting intervals should be short to keep coherence and avoid alias. Constellations will help to reduce conflicts.

Better ground motion monitoring

Competing Techniques	TIME Presence	SPACE Location	TIME Continuity	SPACE Continuity
GPS - Galileo	- after	+ at choice	+	-
Interferometry	+ before	- random	-	+

Improving interferometry

- Regular and frequent revisiting times
- Synchronized SCANSAR for wide areas monitoring
- Better artificial reflectors
- Geosynchronous illuminator, geosynchronous or LEO receivers

Better Digital Eelevation Models

Competitors:

Optical, high resolution	(all times, everywhere ?)
LIDAR	(shallow penetration ?)
Airplane, UAV interferometry	(availability ?)

Satellite interferometry must achieve
submetric precision to stay on the market

Proposed Solutions

Multistatic Configurations
Tandem in X band,
Cartwheel, Pendulum etc.

Conclusion

With more or better:

Revisiting times, spatial resolution
LOS directions, frequencies, baselines
multistatic receivers
stable artificial reflectors

SAR interferometry will even better fulfill its promises.

Many useful results have been achieved already; new services are operational throughout the world.