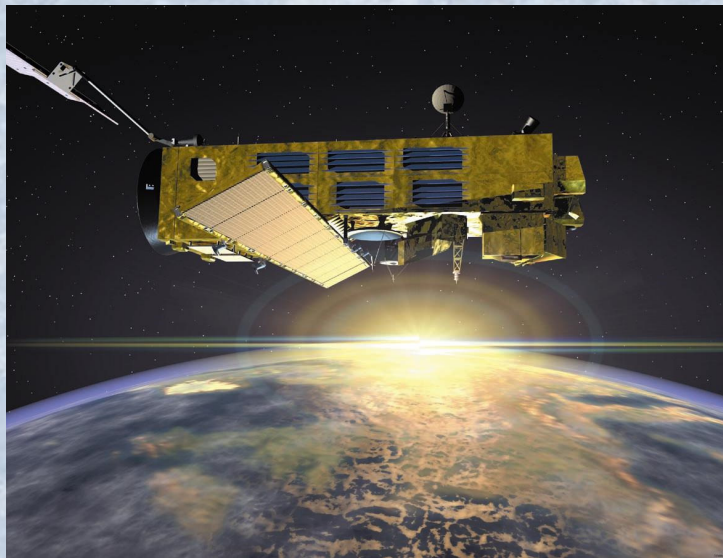


# Multi-temporal SAR Interferometry: techniques and applications

Daniele Perissin

[daniele.perissin@sarproz.com](mailto:daniele.perissin@sarproz.com)



RASER Ltd

# Foreword

## The speaker

2002 Master in Telecommunication Engineering, Politecnico di Milano, Italy  
2006 PhD degree in Information Technology, Politecnico di Milano, Italy  
Till 2009 Assistant researcher in Politecnico di Milano, Italy



Oct 2009 - Oct 2013, Research Assistant Prof., ISEIS, CUHK



Oct. 2013 Aug. 2018, Assistant  
Professor at Purdue University,  
Civil Eng. Dept., Geomatics gr.



# Foreword

The speaker

2002 - now SARPROZ developer

~1,500 licenses distributed all around the world

2013 founder of RASER Ltd (Radar and Software Engineering Research)

Partners in Europe, China, India, Middle East, South America

- Contract Professor at Padova University
- Adjunct Professor at Purdue University
- Collaborator of many more Universities/Research Centers

# Multi-temporal SAR Interferometry: Techniques and Applications

## Intro Outline

- Introduction on SAR, SAR Interferometry, Permanent Scatterers (PSInSAR)
- Applications and examples

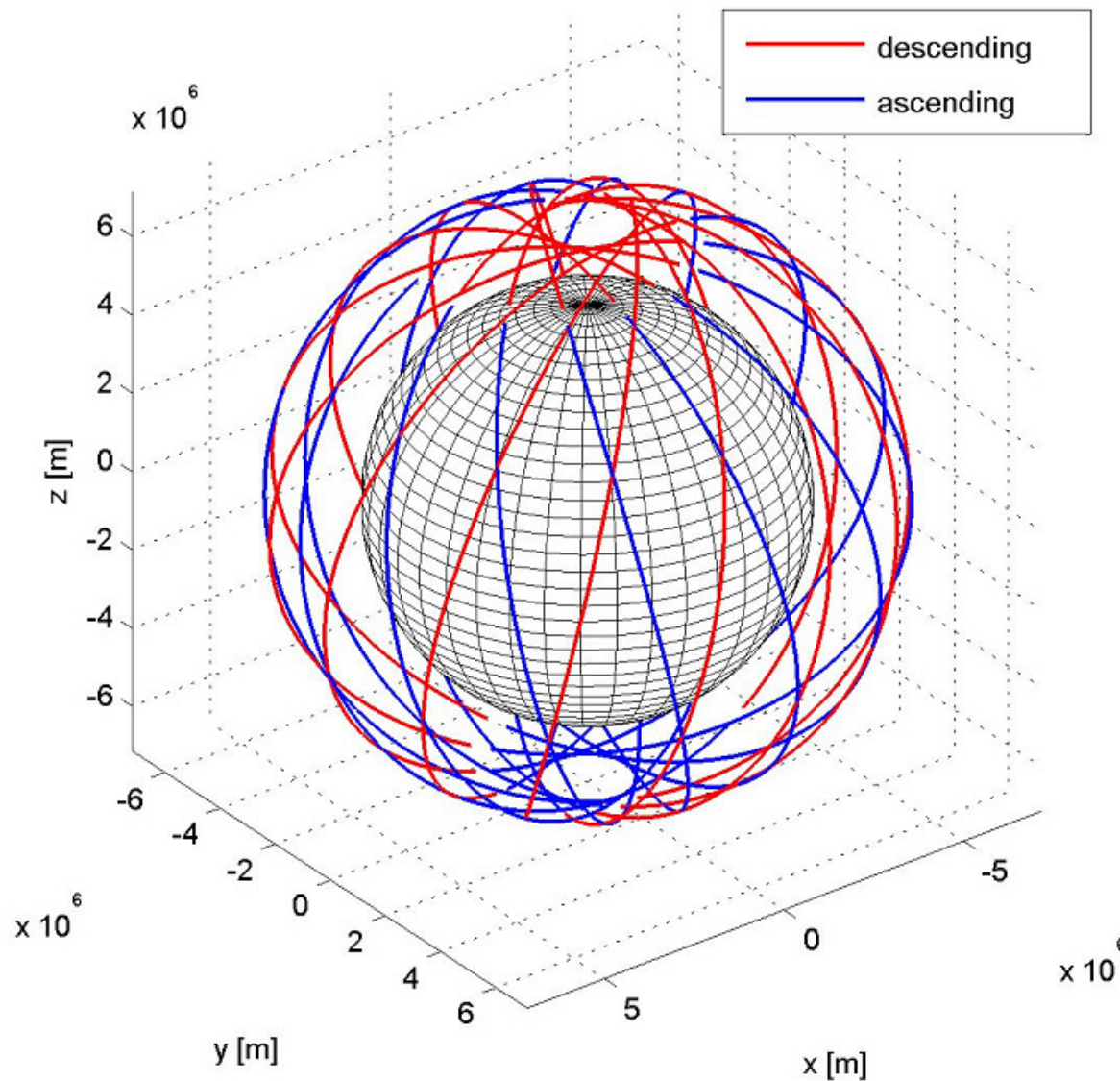


## Introduction (1)

# Synthetic Aperture Radar (SAR)

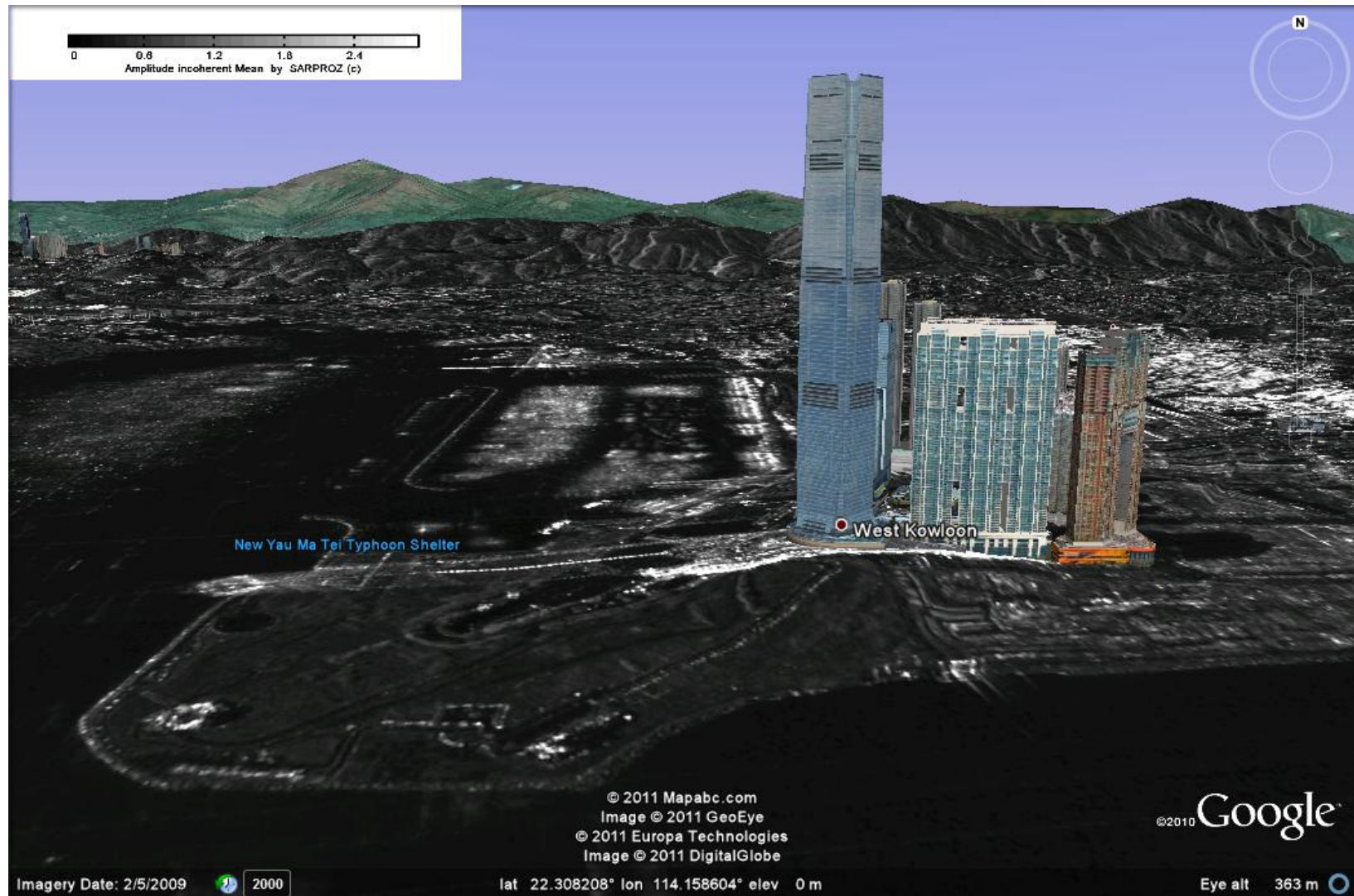
# Spaceborne SAR

## Sun-synchronous polar orbits



The satellite flies over the same area on the ground every given days (repeat cycle)

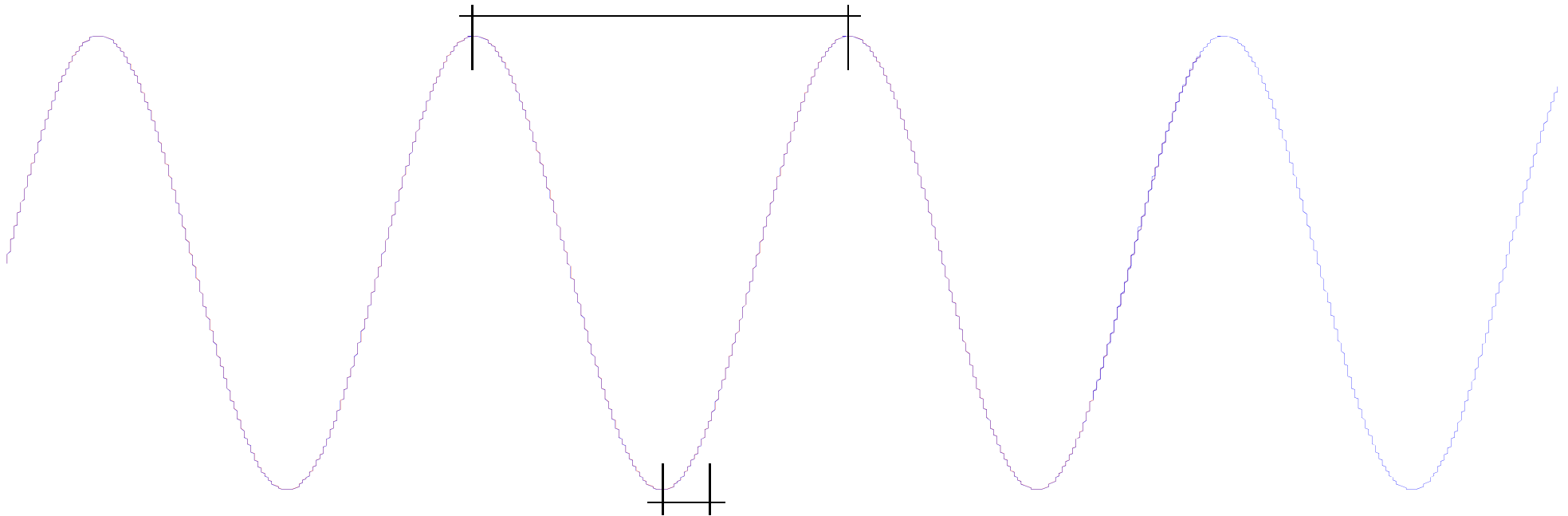
# Geocoded SAR image in Hong Kong



# Electromagnetic Waves

The concept of "Phase"

Wavelength, 1~10cm



Millimetric distances can be  
measured through the phase!!

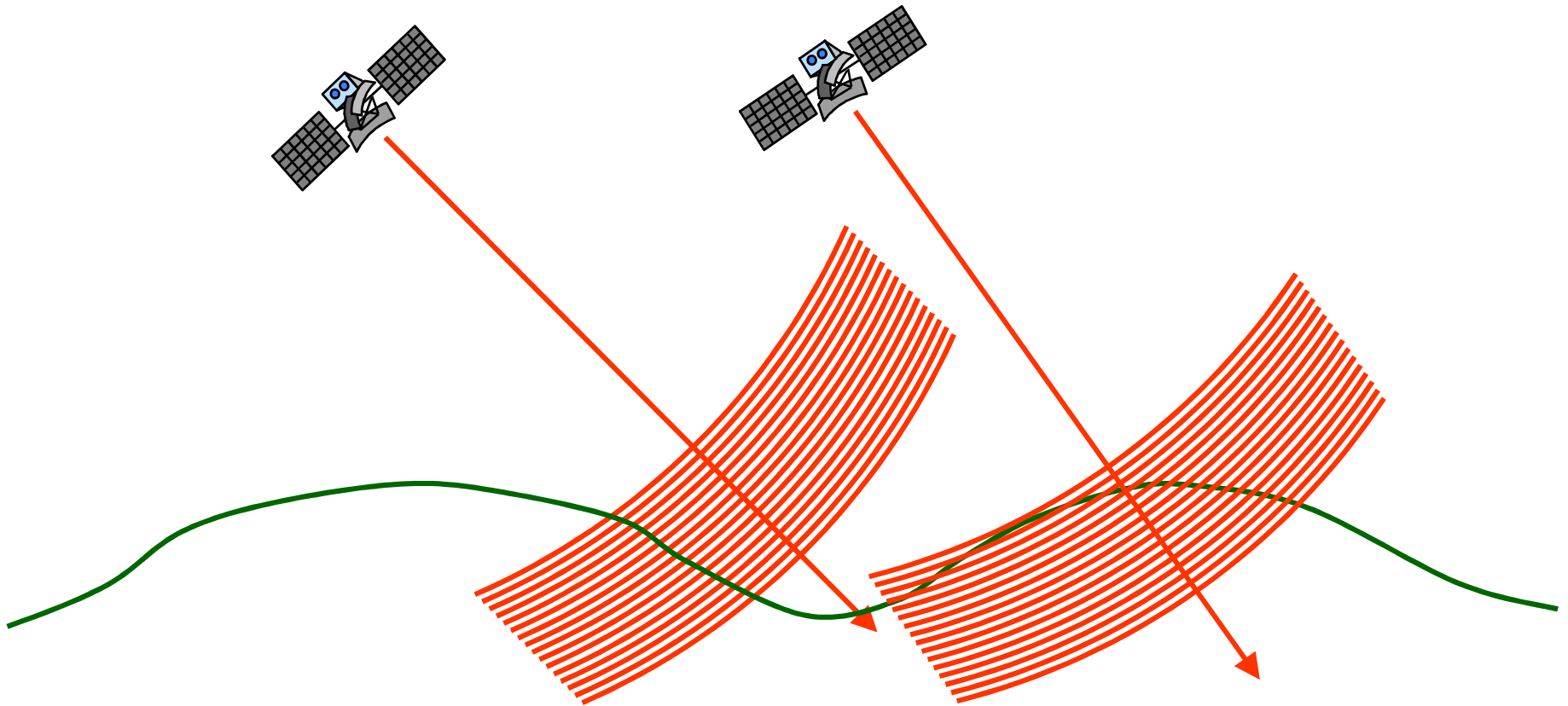


## Introduction (2)

# SAR Interferometry (InSAR)

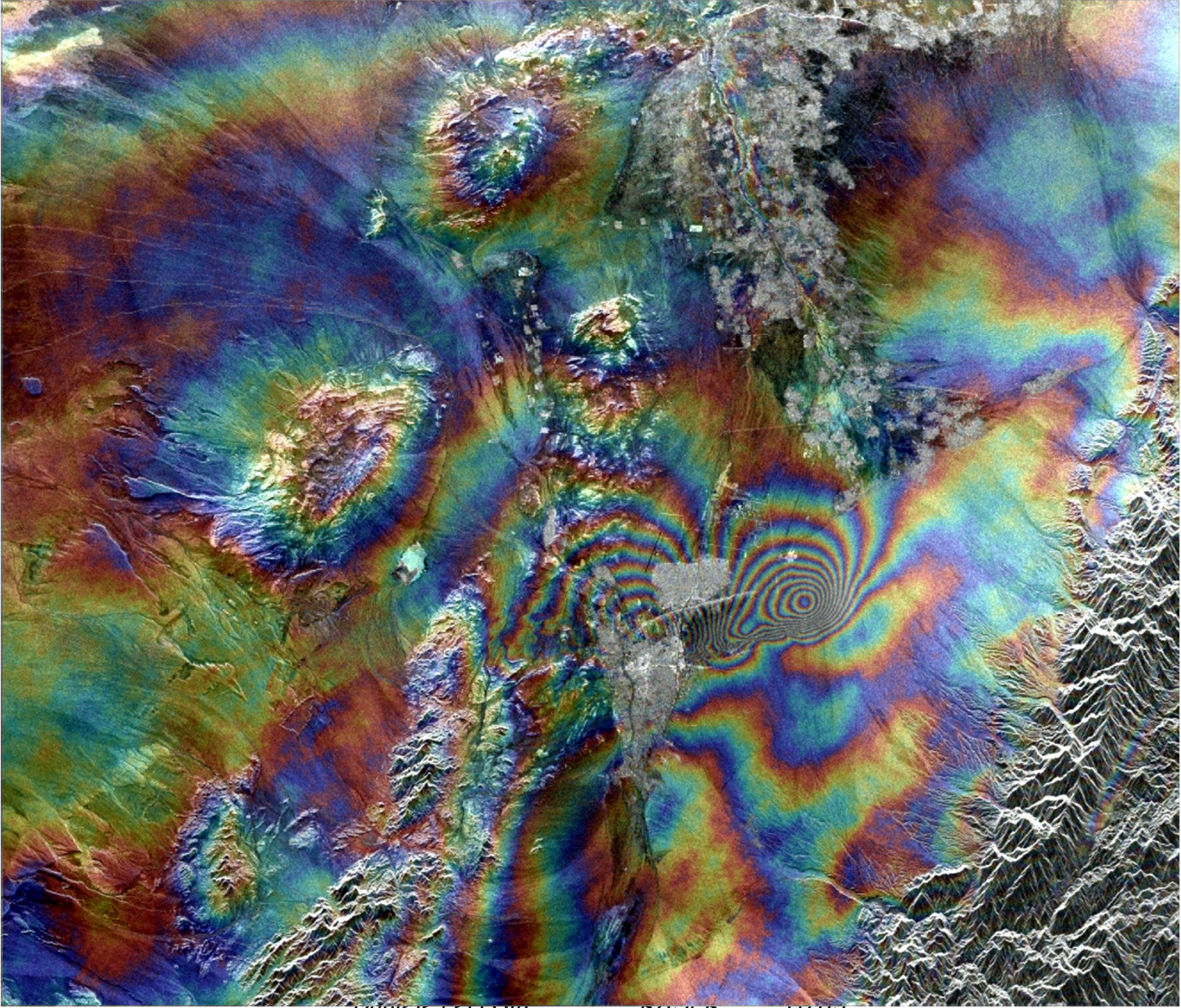
# InSAR

Interferometric phase





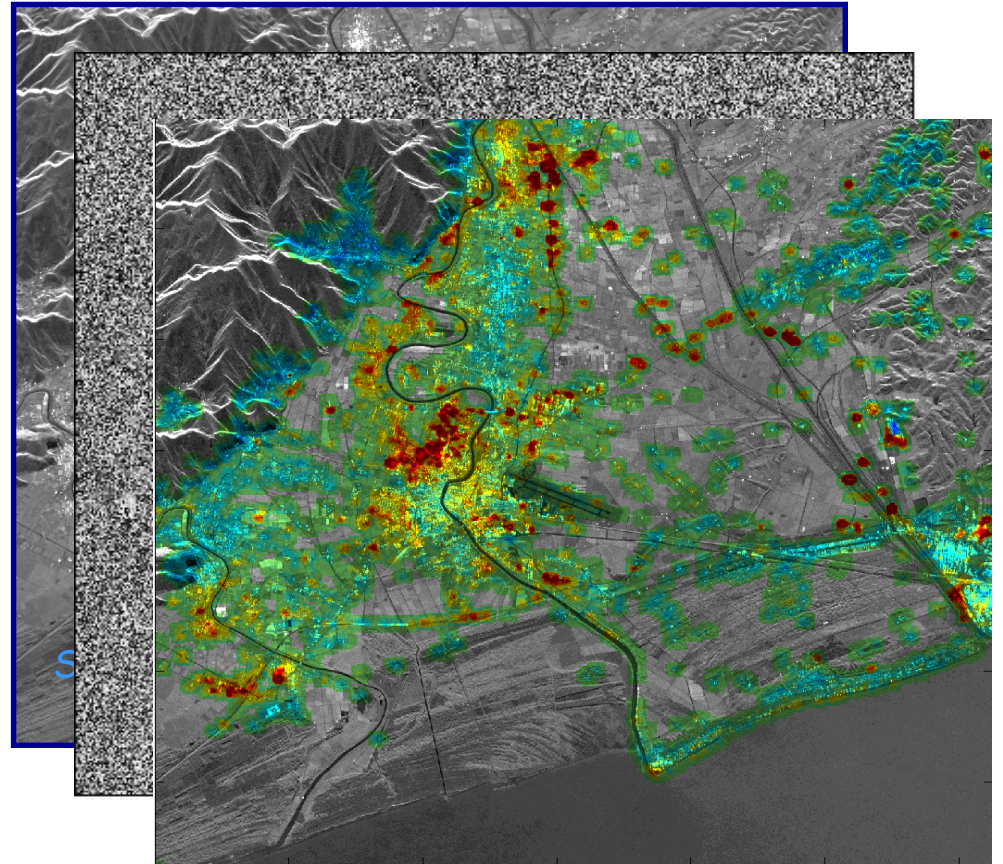
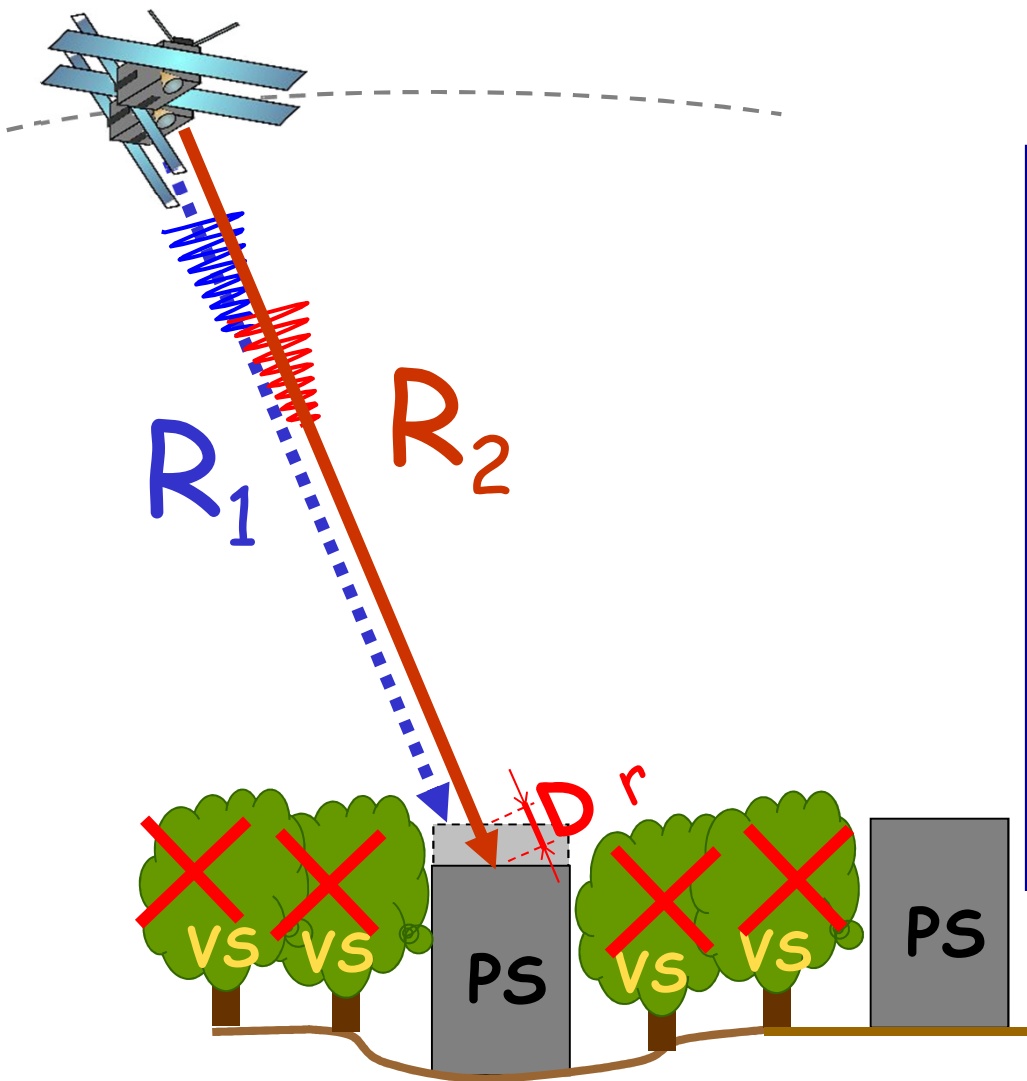
# Interferogram





# InSAR

## The Permanent Scatterers (PS) technique



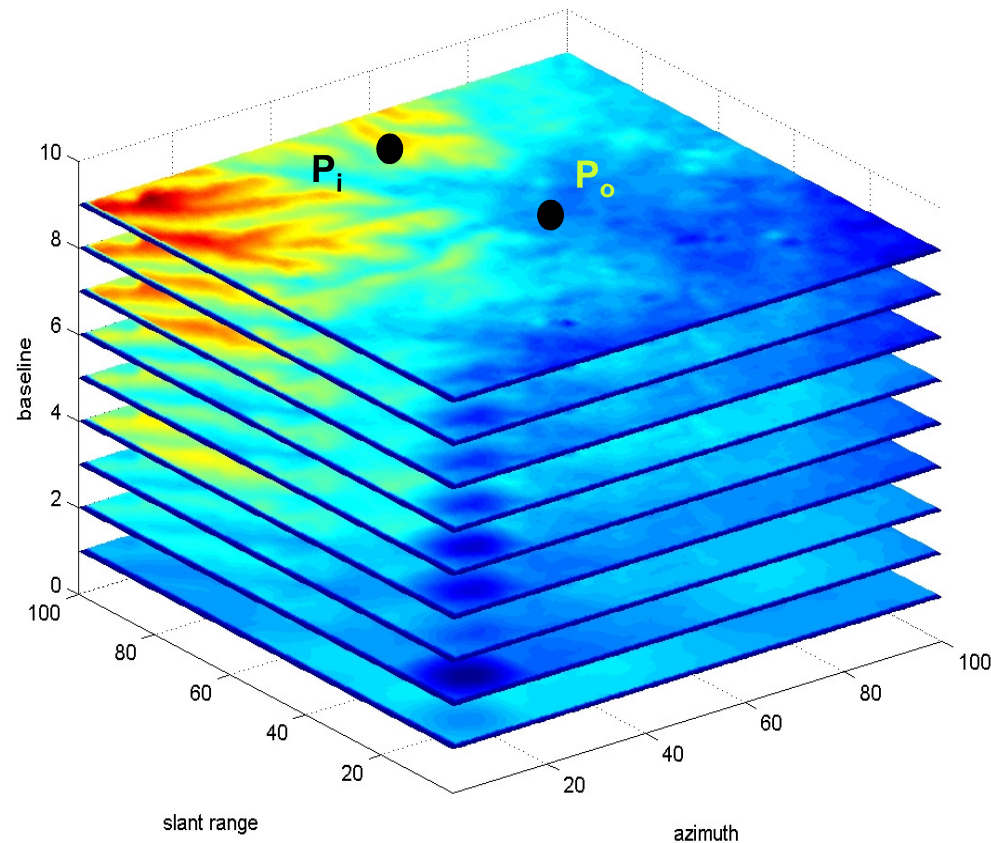


## Introduction (3)

# The Permanent Scatterers (PS) Technique

# PS analysis

Finding a sparse set of coherent targets



**Main ratio (1): multi-temporal analysis**  
We have to look for recurrent features in *time*

# PS analysis

Estimating target height and velocity from a sparse phase field

$$\varphi_{(l,m,i)} = \varphi_{topo,(l,m,i)} + \varphi_{motion,(l,m,i)} + \varphi_{atmo,(l,m,i)} + \varphi_{noise,(l,m,i)}$$

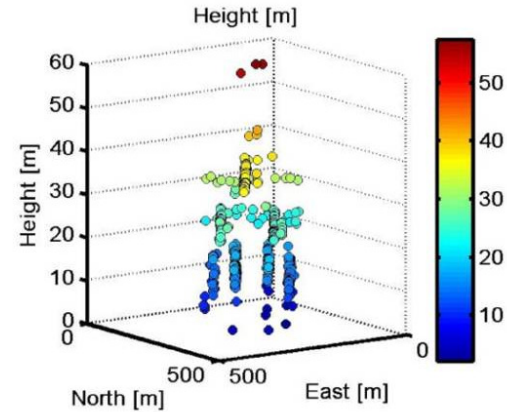
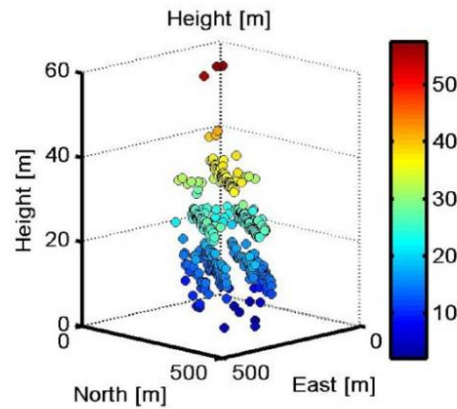
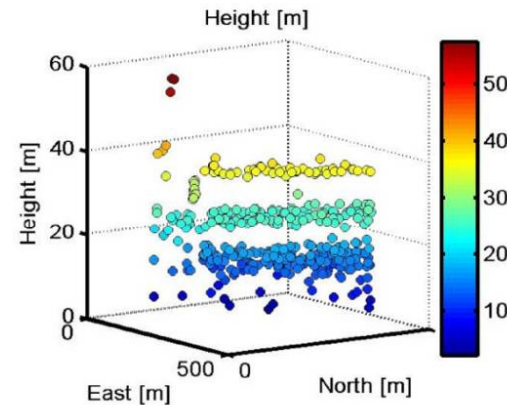
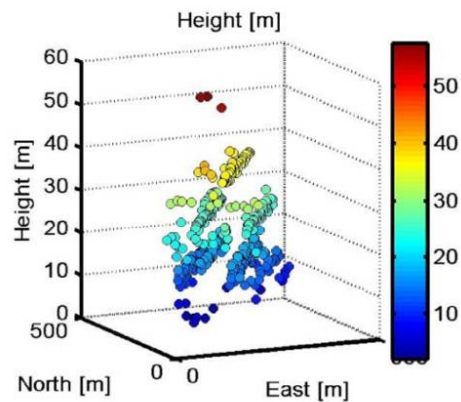
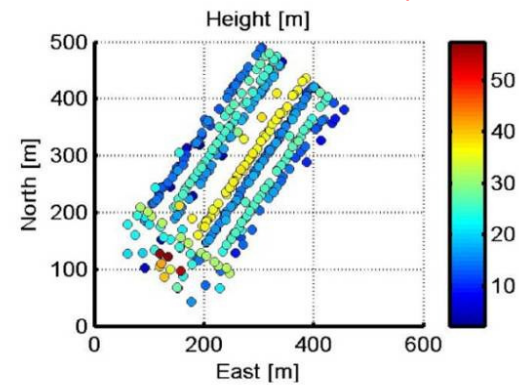
Linear with the  
viewing angle  $\theta$

Linear with time  $t$

Correlated in space,  
uncorrelated w.  $\theta$  and  $t$

**Main ratio (2): multivariate analysis**  
We can separate the different phase terms  
exploiting their different behavior in space-time

## Railway Central Station in Milan (Italy)



3D structure  
of buildings

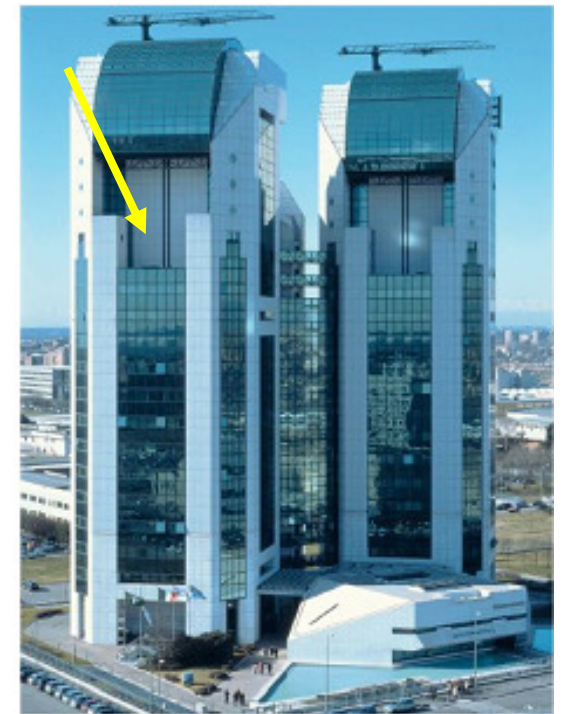
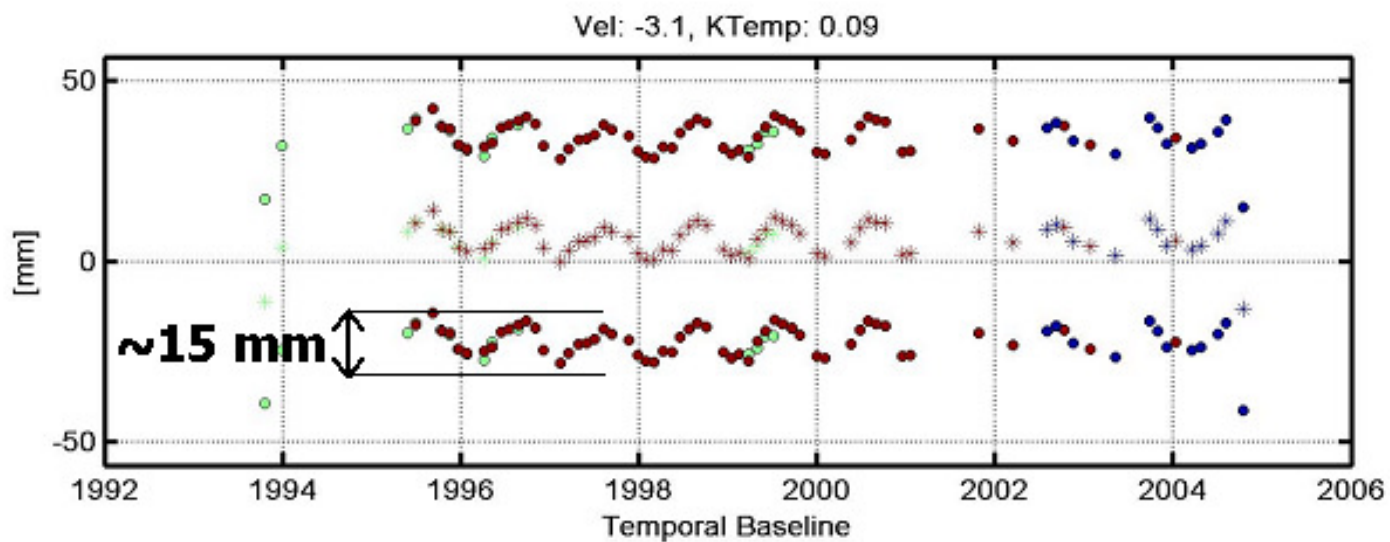
1m location  
accuracy

With ERS  
data!!!



# PSInSAR displacement estimation

Seasonal thermal expansion of a building in Milan



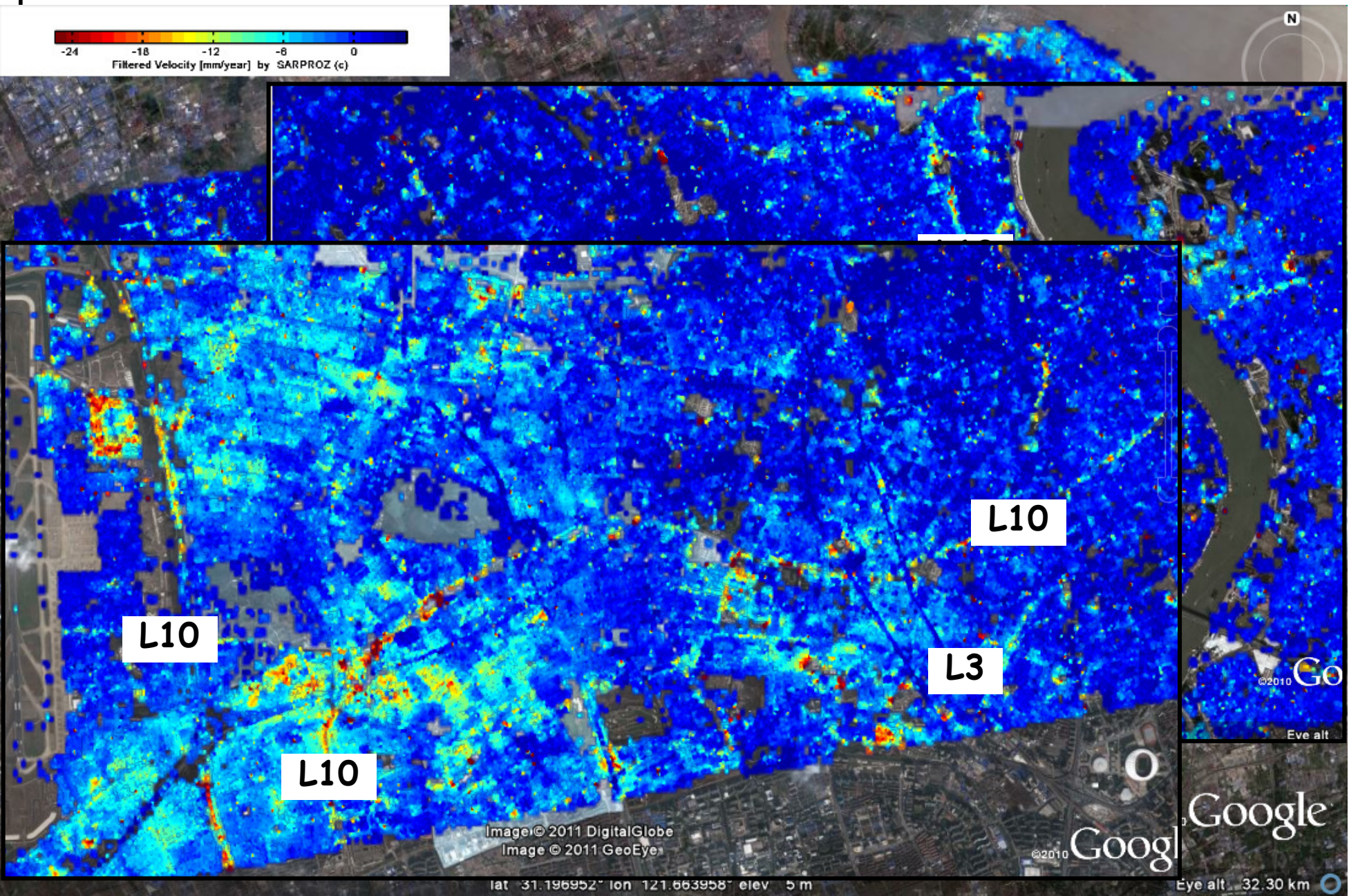
Gemini towers, Milan

## Applications/case studies

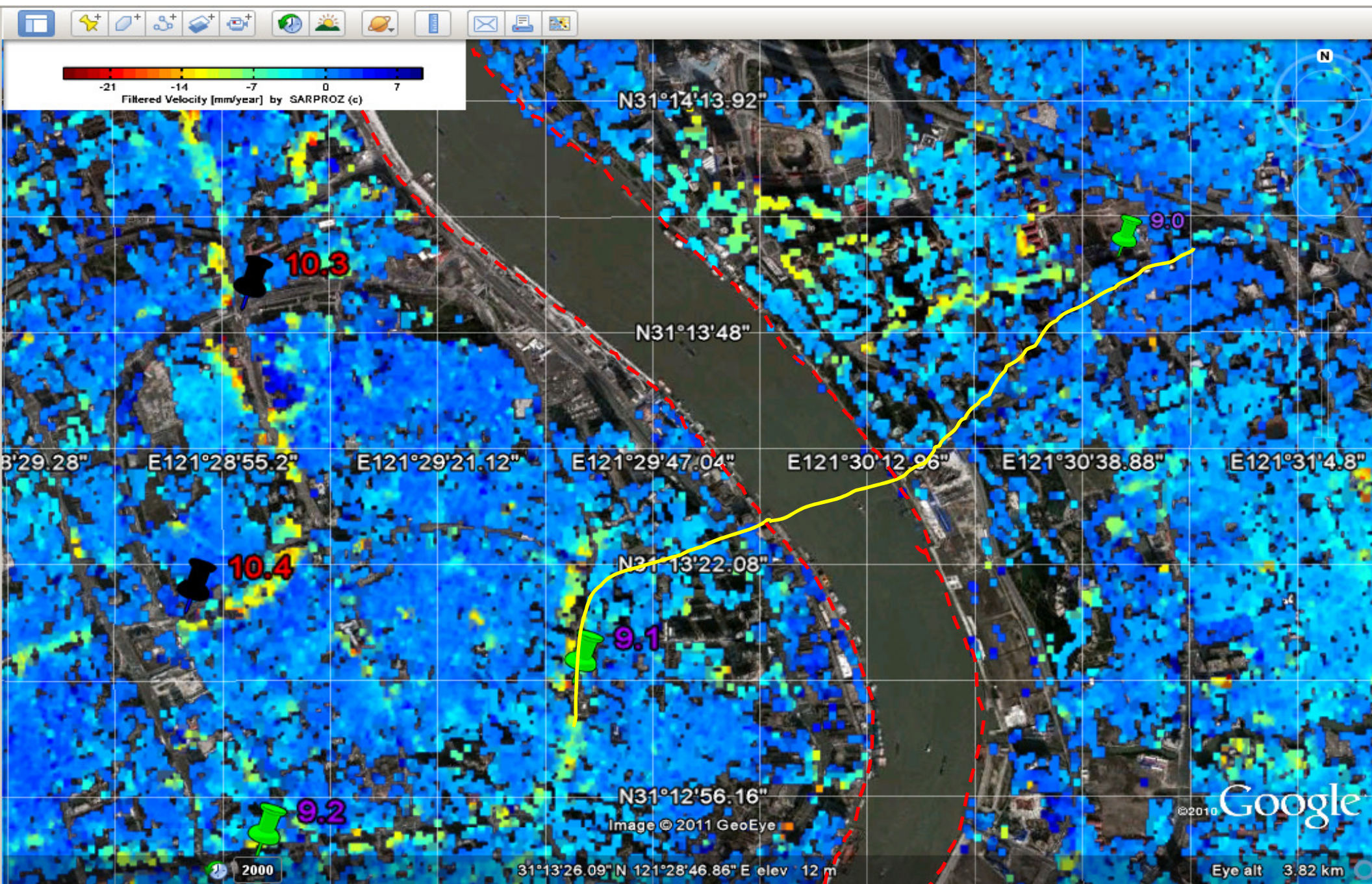
# Shanghai subways monitoring with Cosmo SkyMed



# Shanghai with Cosmo data





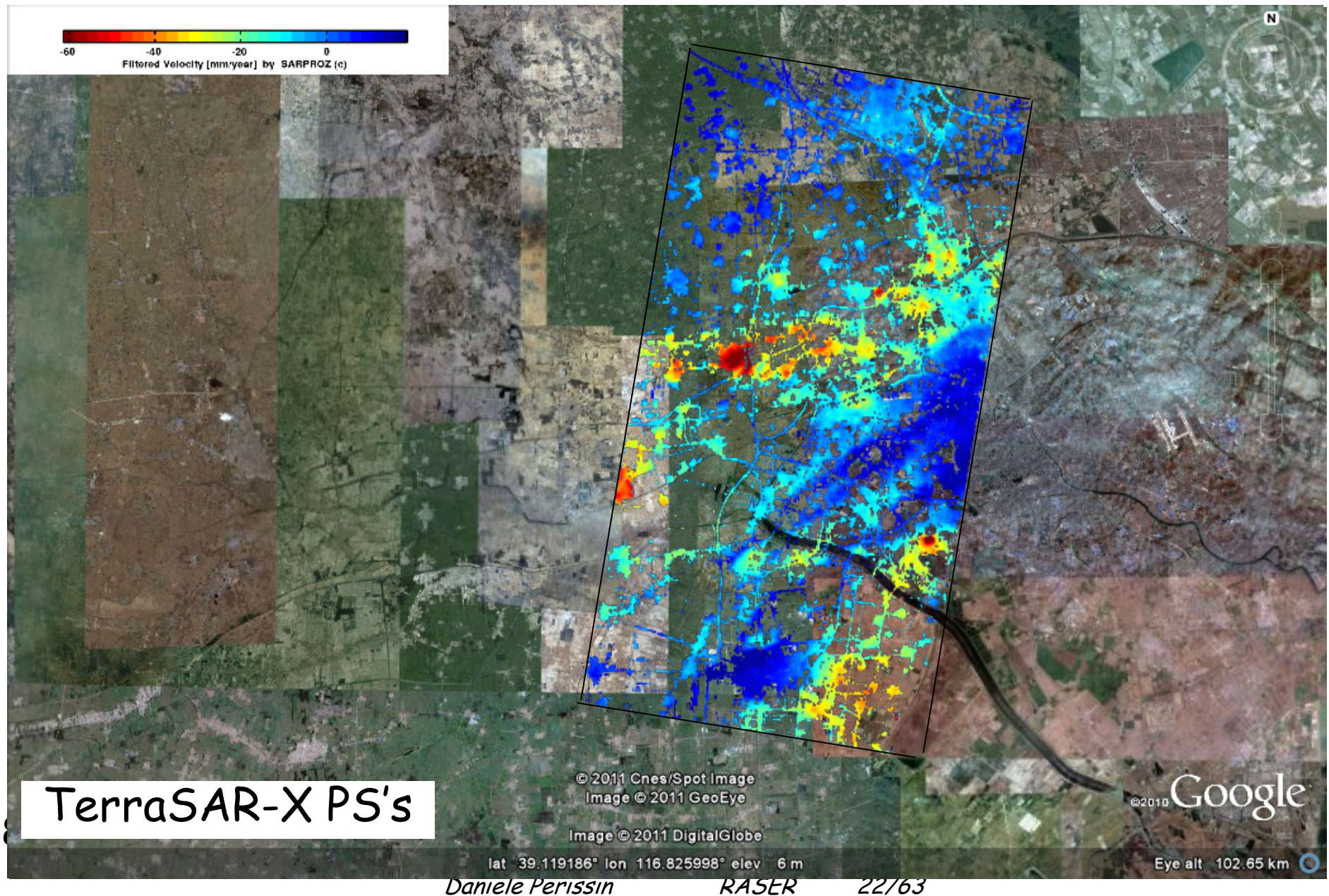




## Applications/case studies

# Tianjin subsidence analysis with L-X band

# Tianjin with TerraSAR and ALOS data





# Highways affected by ground movements



Height w.r.t DTM

Power lines in TSX PS's

© 2011 Cnes/Spot Image  
Image © 2011 DigitalGlobe  
Image © 2011 GeoEye

©2010 Google

Imagery Date: 11/16/2008 2006

lat 39.078712° lon 116.884662° elev 2 m

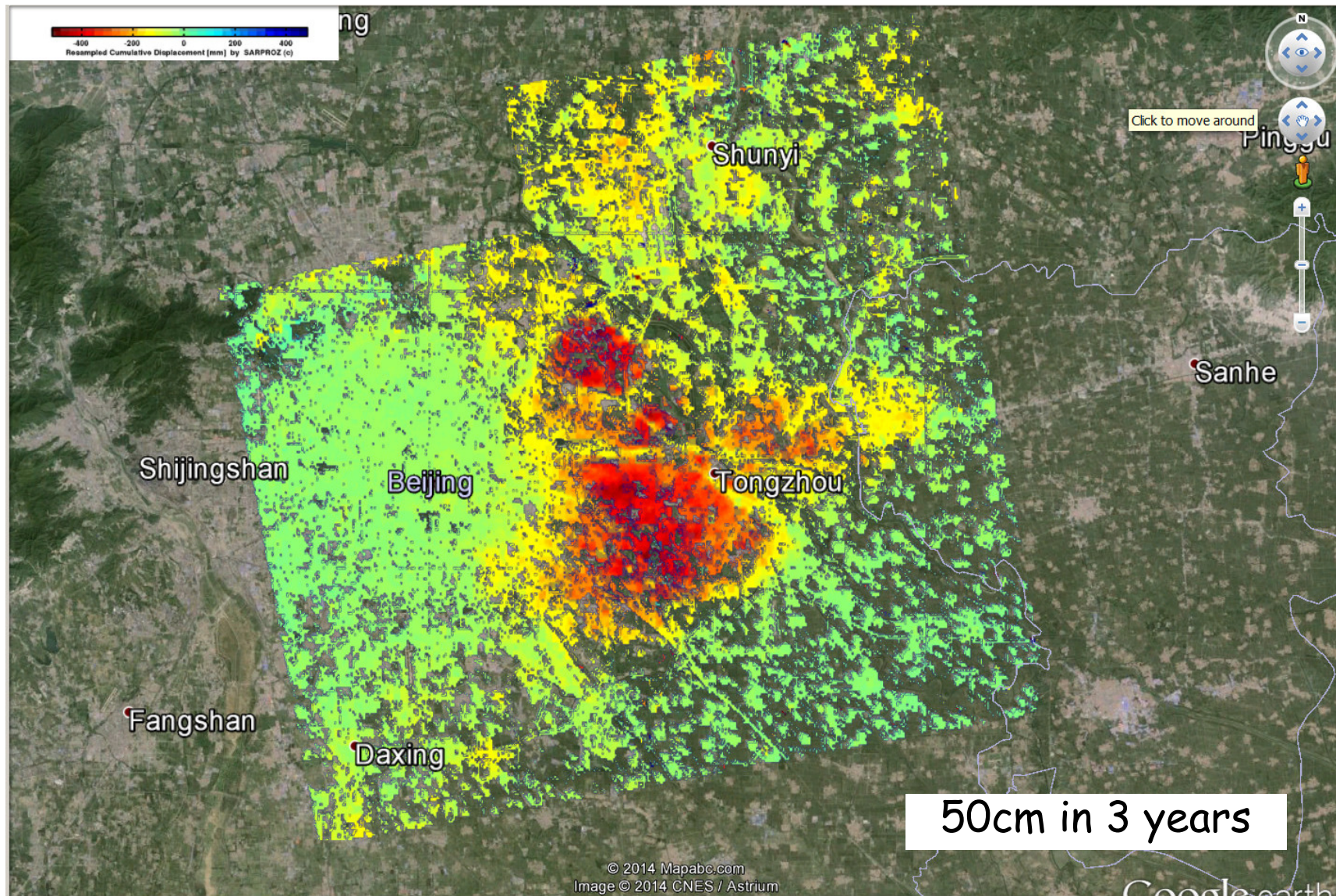
Eye alt 621 m

**Applications/case studies**

# **Subsidence in Beijing**



# Two TSX parallel tracks

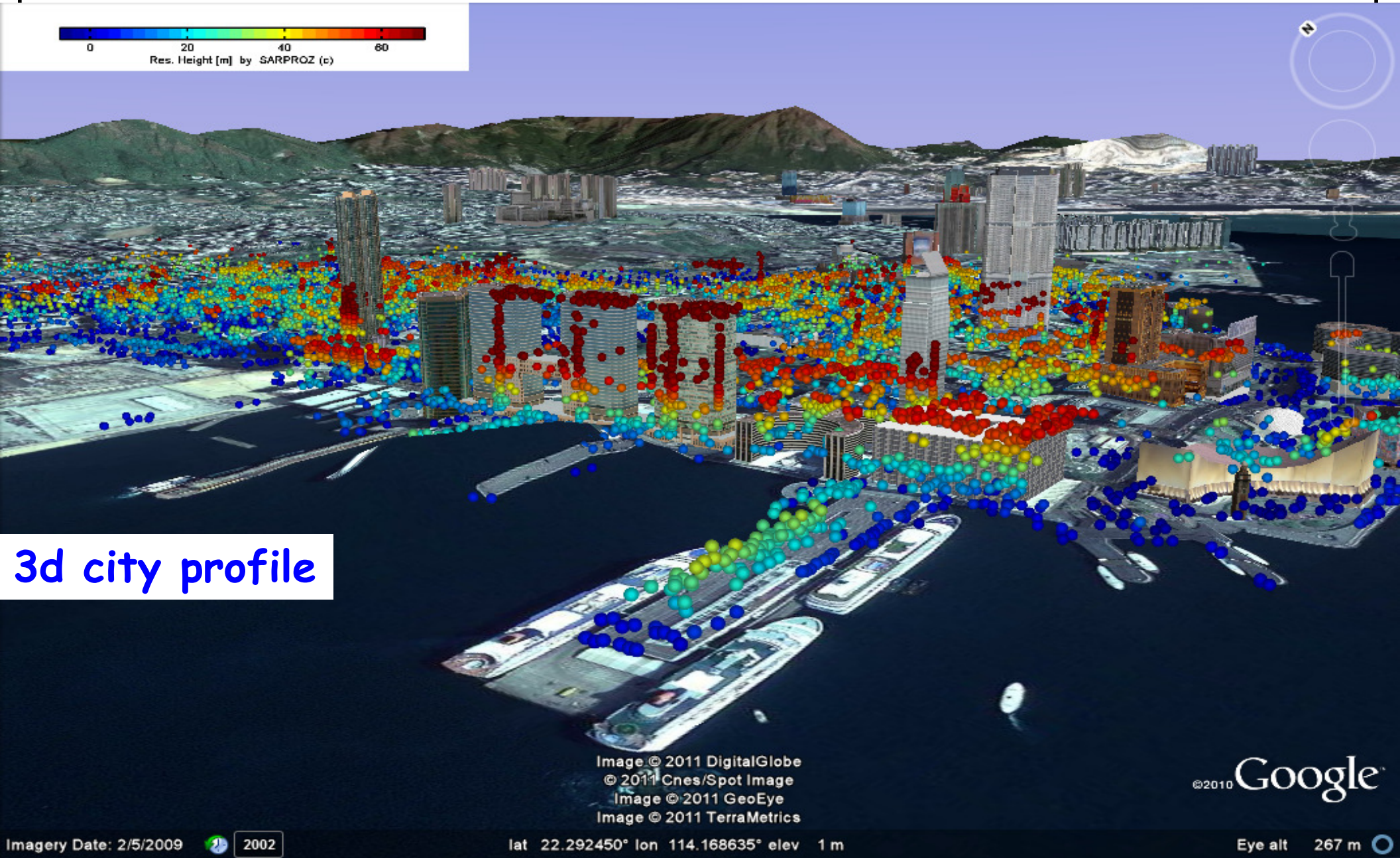
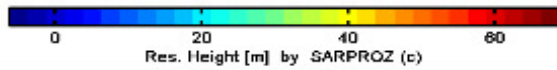




**Applications/case studies**

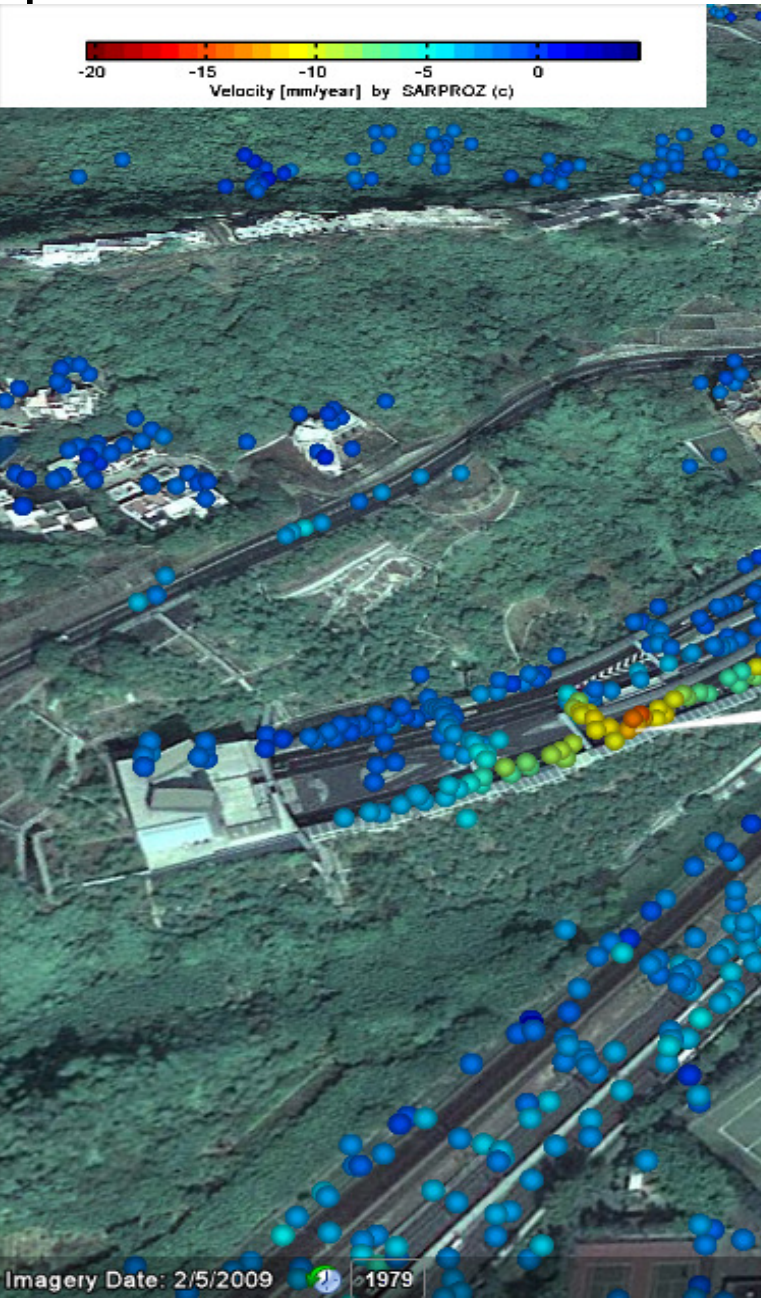
# Examples in Hong Kong

# Hong Kong with TerraSAR-X data





# Hong Kong with TerraSAR-X data



ID: 169765

Ellipsoidal Height (WGS84) [m]: 33

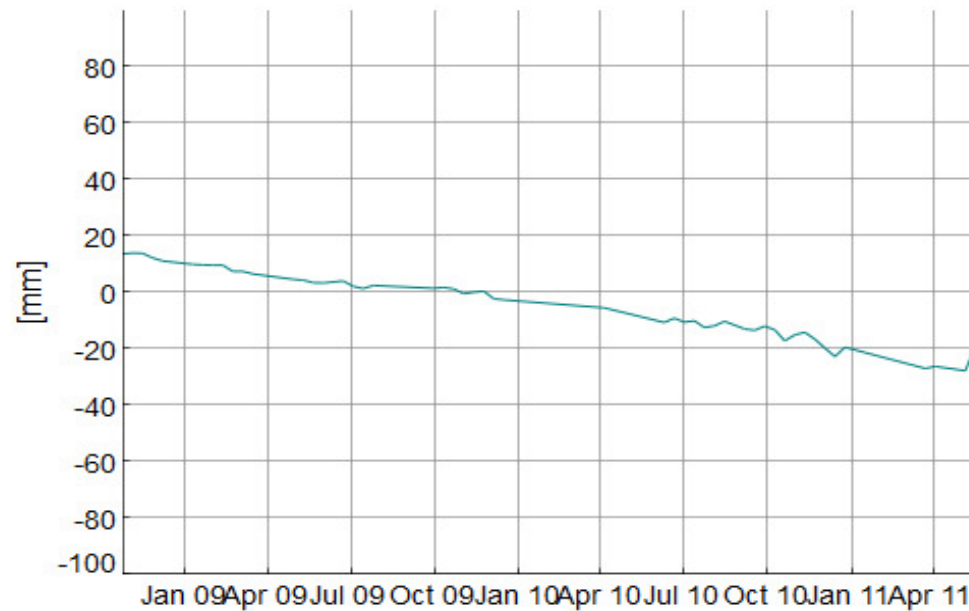
Res. Height [m]: 15.8

Velocity [mm/year]: -14.1

Displ. to Temper. Ratio [mm/degC]: 0.04

Temporal Coherence: 0.83

Sample: 9667, Line: 4632



by SARPROZ (c)

Directions: [To here](#) - [From here](#)

Imagery Date: 2/5/2009

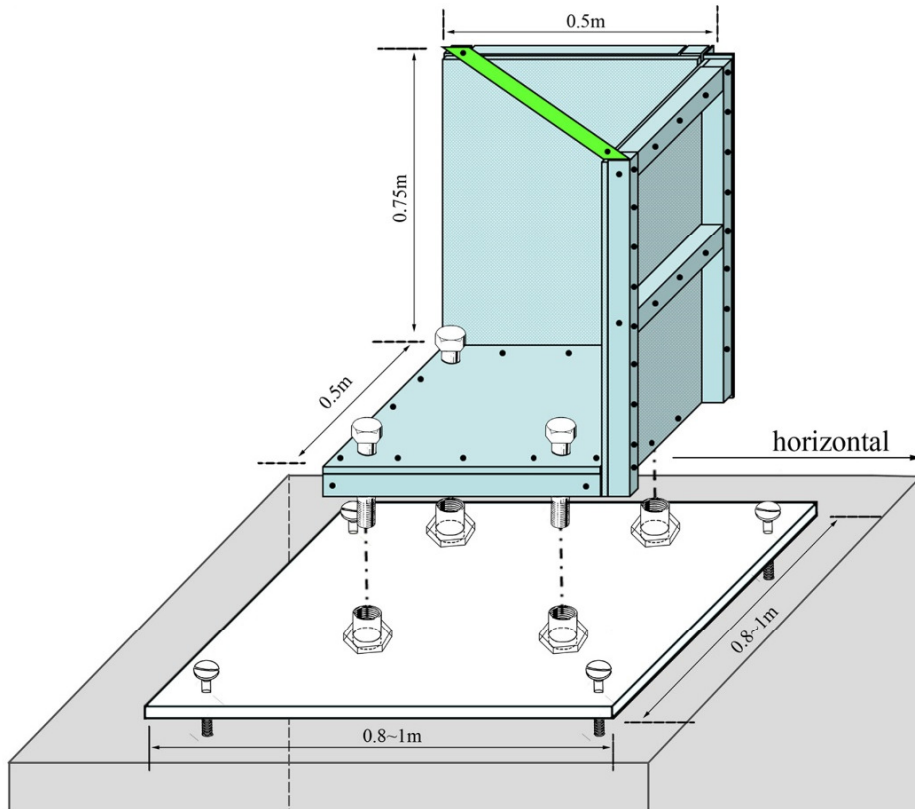
1979

lat 22.367813° lon 114.172808° elev 14 m

Google

Eye alt 414 m

# Corner reflectors design and experiments



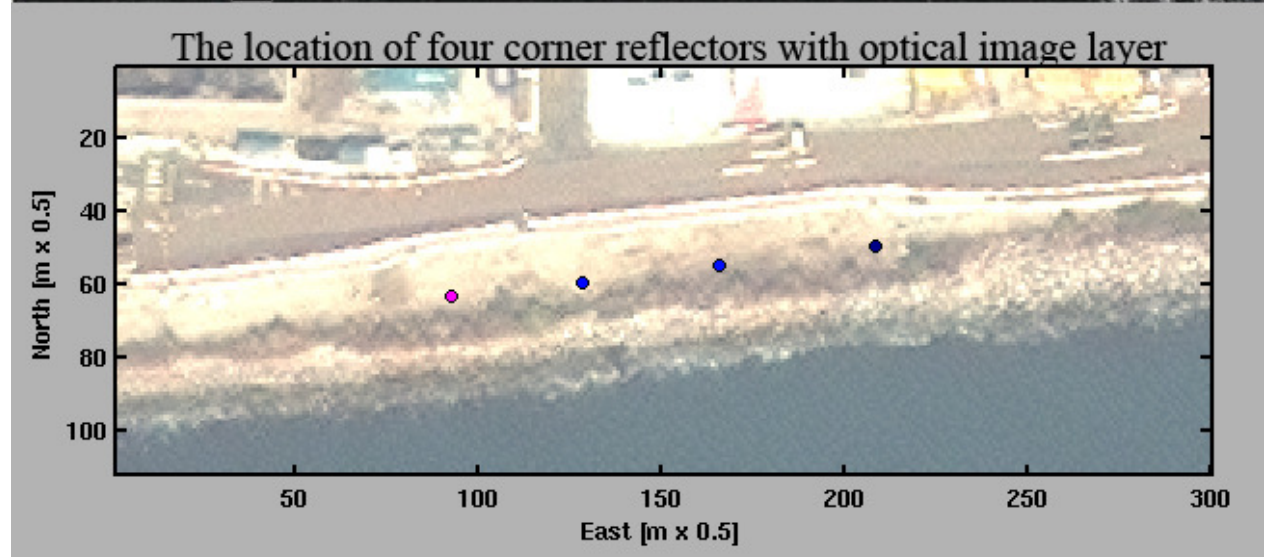
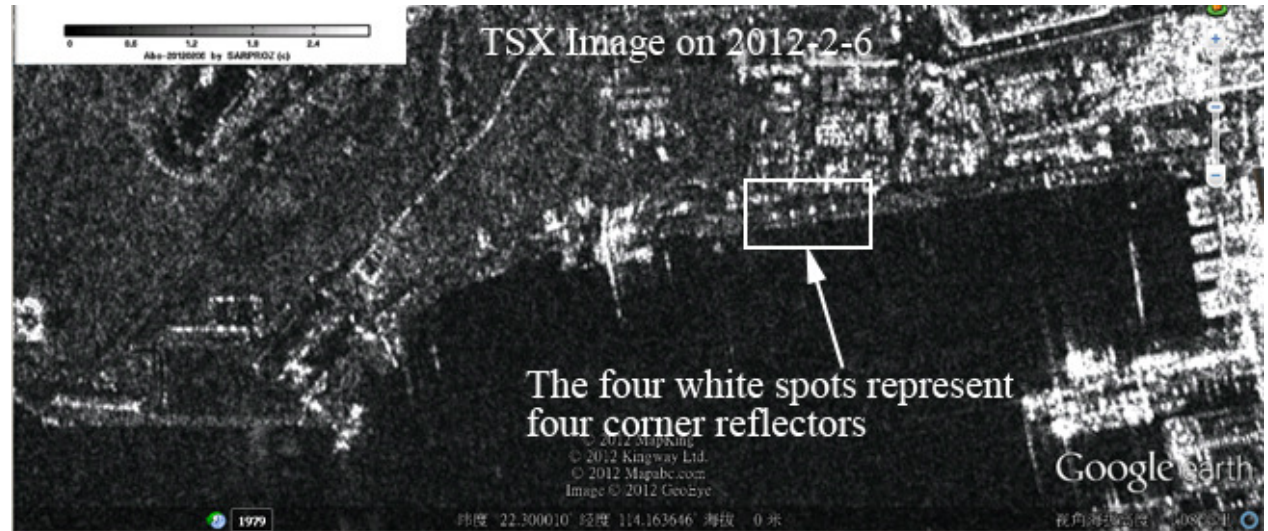
Drawings



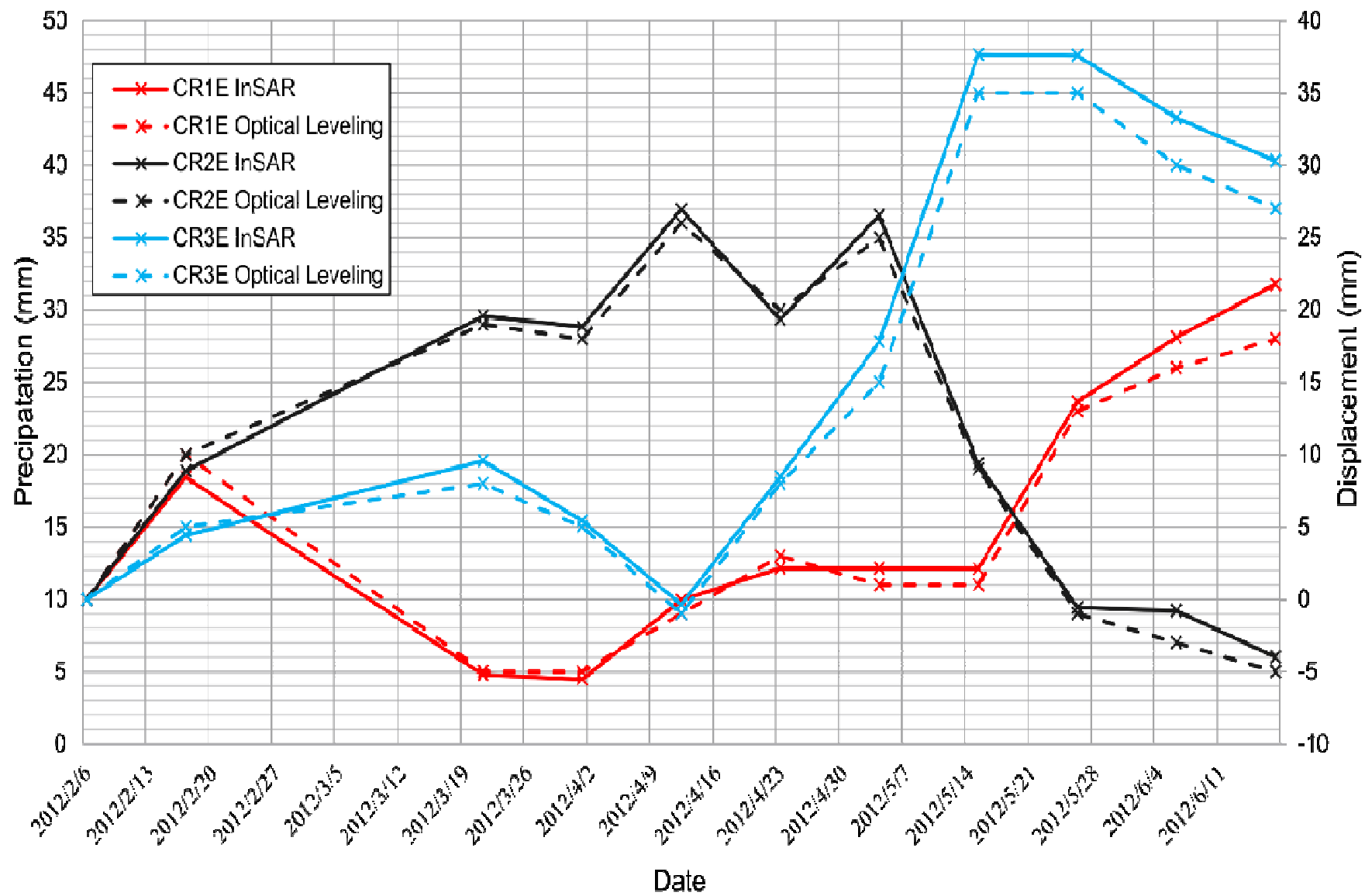
Prototype



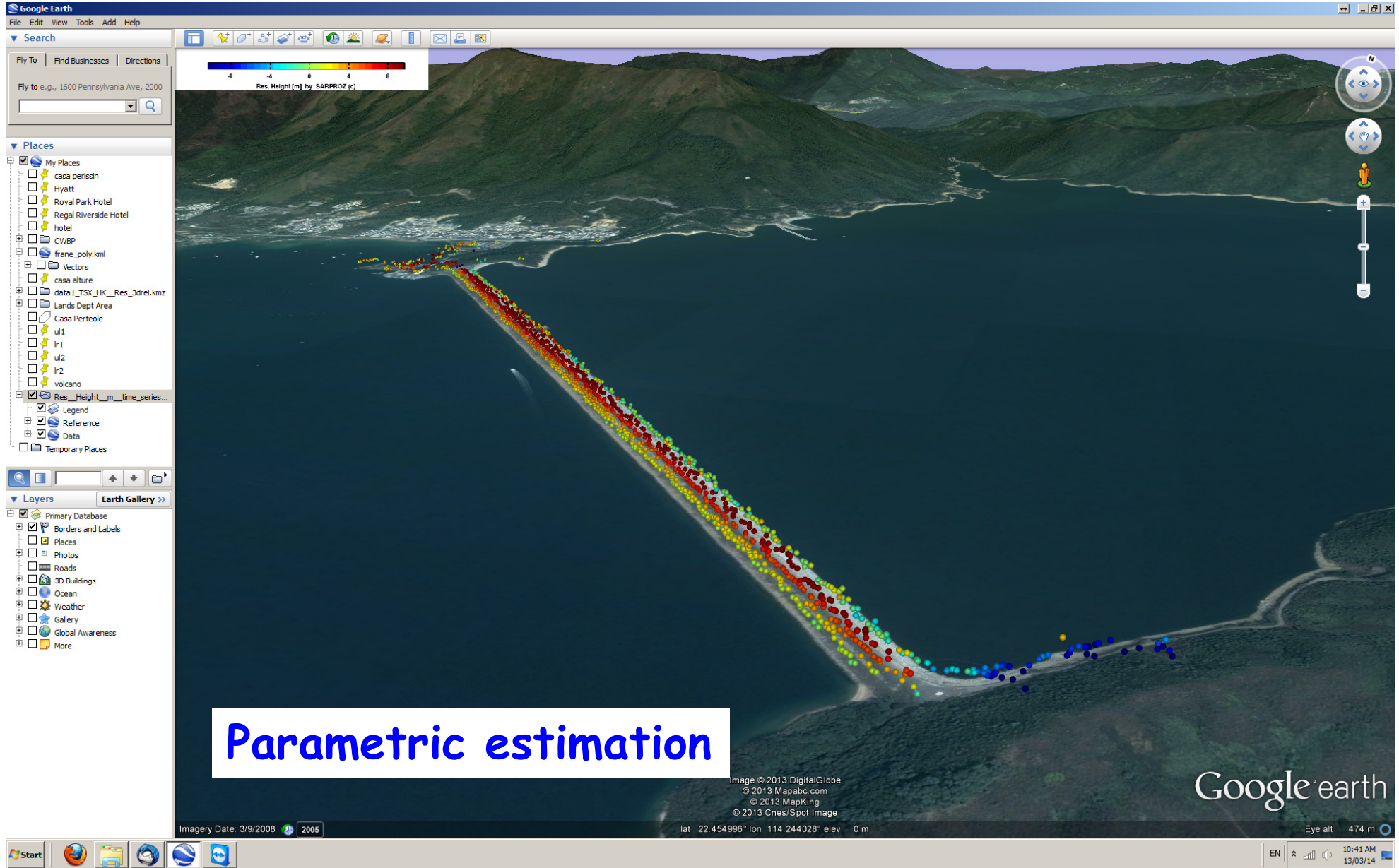
# Project for the Highways department of HK



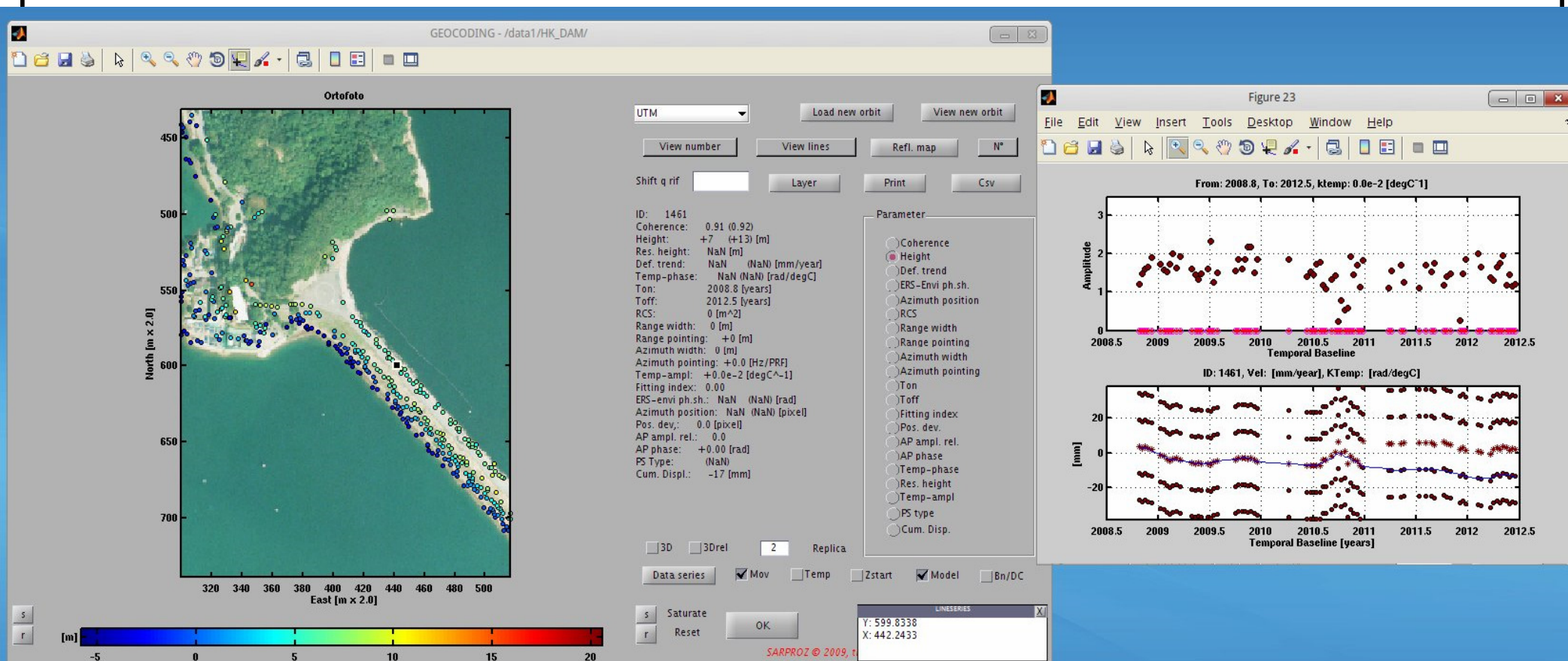




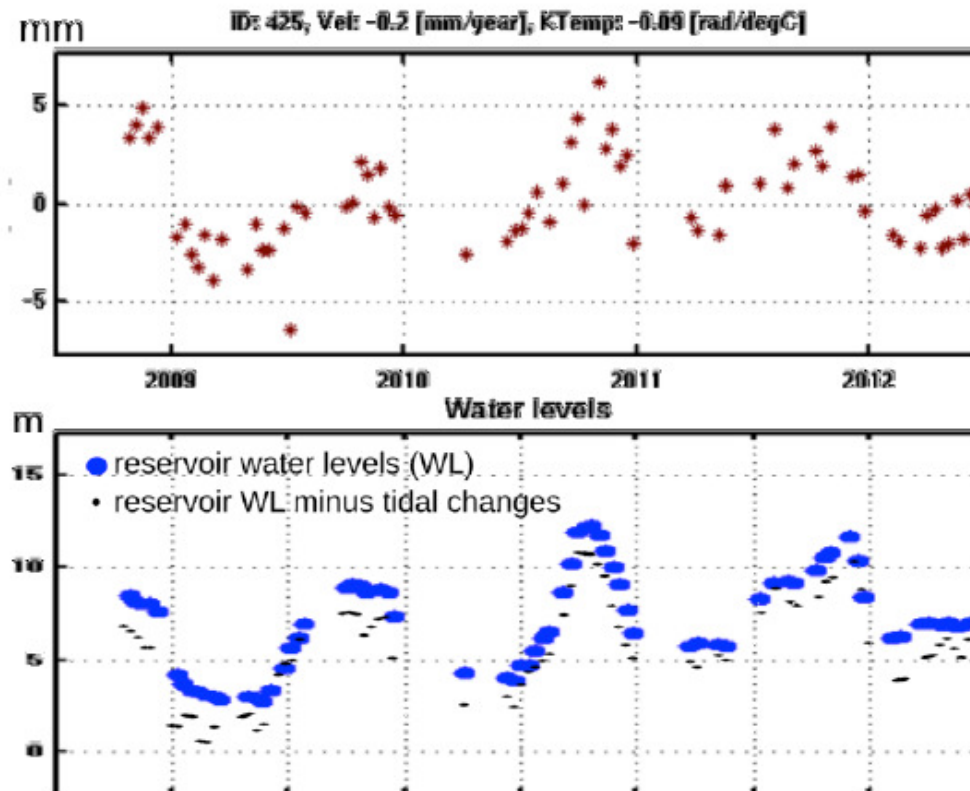
# The Plover Cove Dam



# The displacement of the Dam

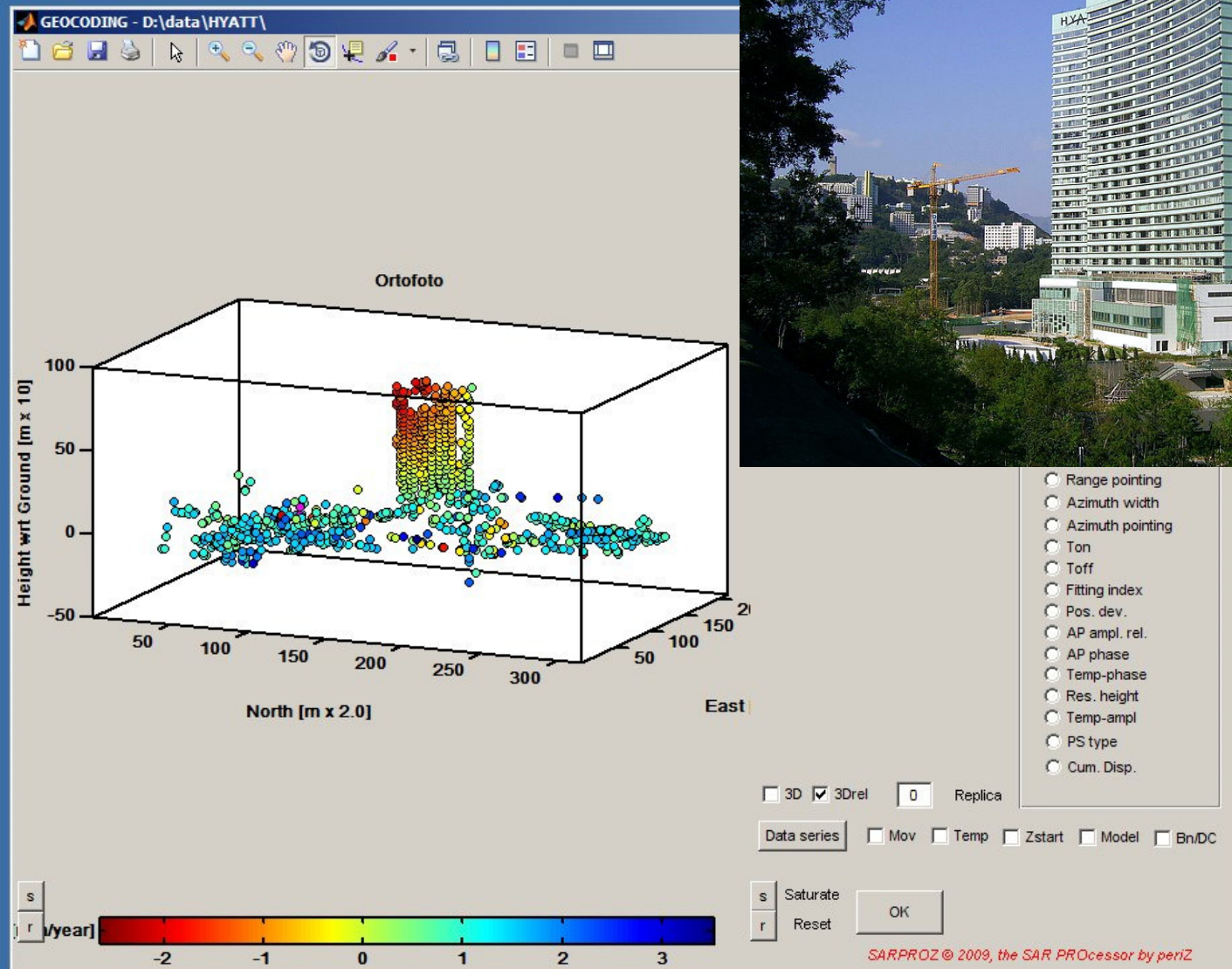


# The correlation between Dam displacement and water level





# The Hyatt Hotel



## Applications/case studies

# The building collapse in Kowloon

Temporary target + acceleration



# The Kowloon Collapse

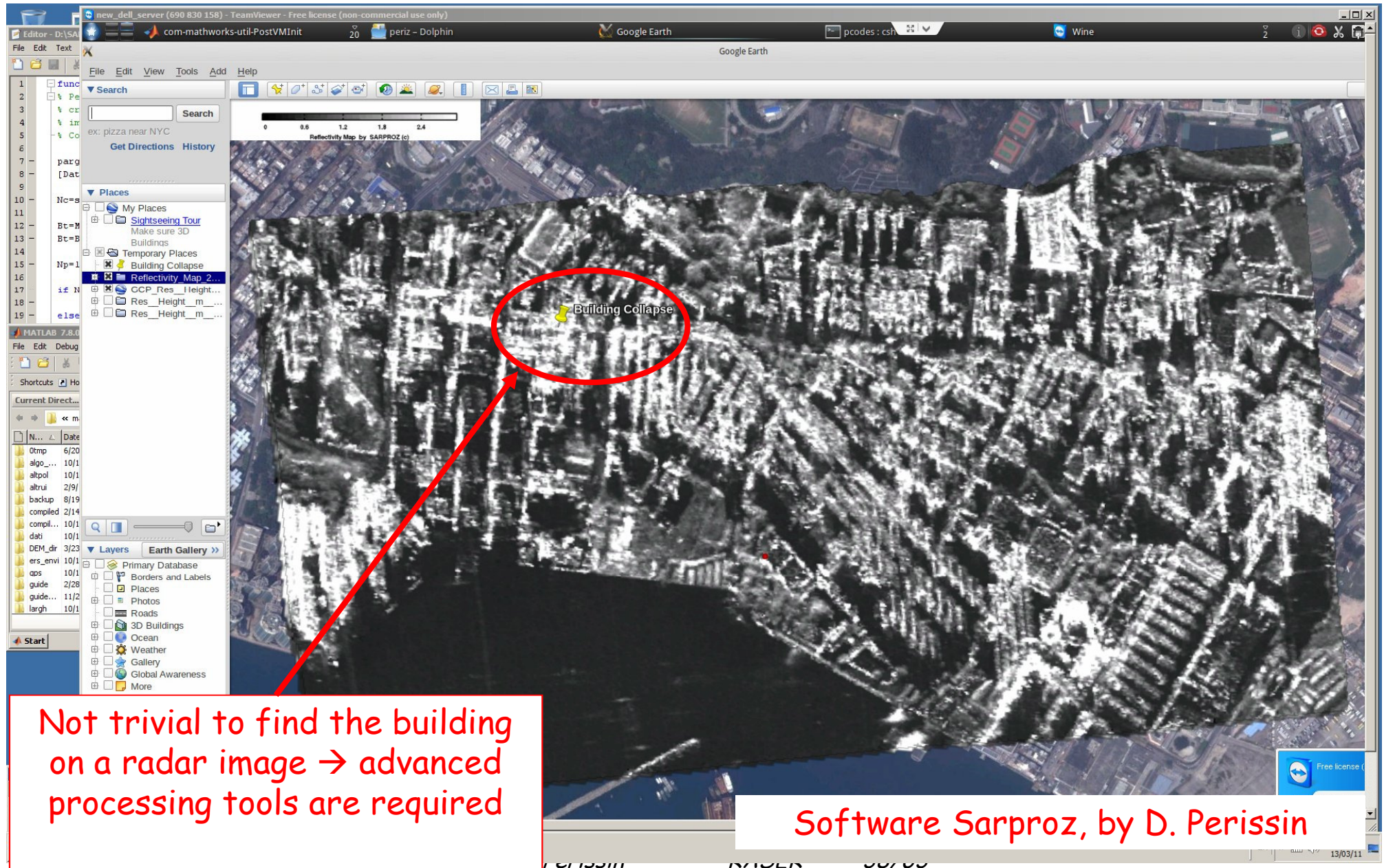
AT 45J MA TAU WAI ROAD  
TO KWA WAN, KOWLOON - K.I.L. 8627  
ON 29 JANUARY 2010



Dani

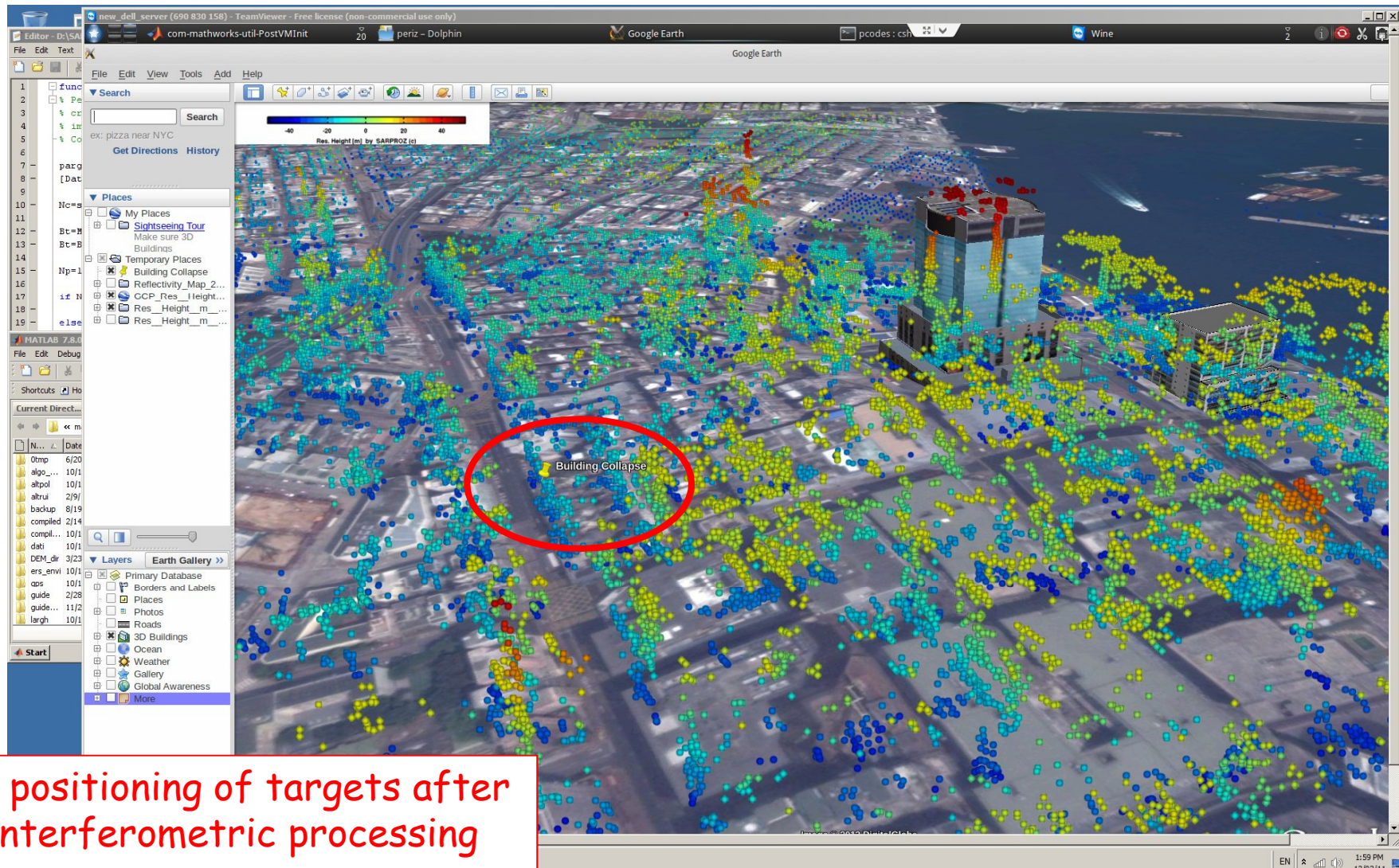


# Radar Reflectivity Map in Google Earth





# Detected Radar Targets in Google Earth



3D positioning of targets after  
Interferometric processing

Software Sarproz, by D. Perissin

Daniele Perissin

RASER

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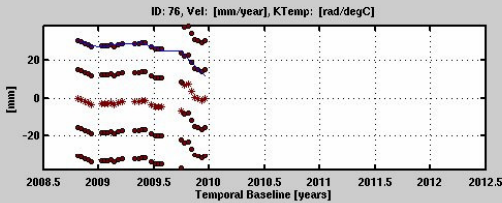
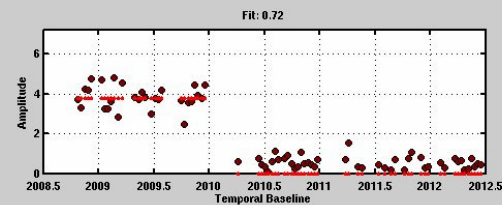


# The Kowloon Collapse

Software Sarproz, by D. Perissin

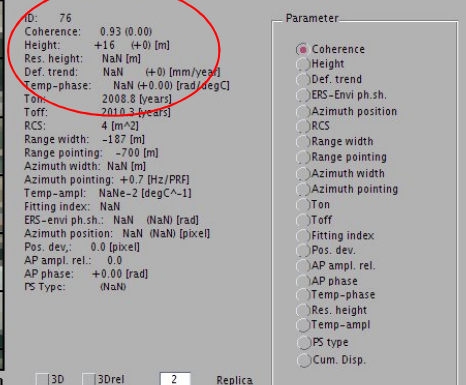
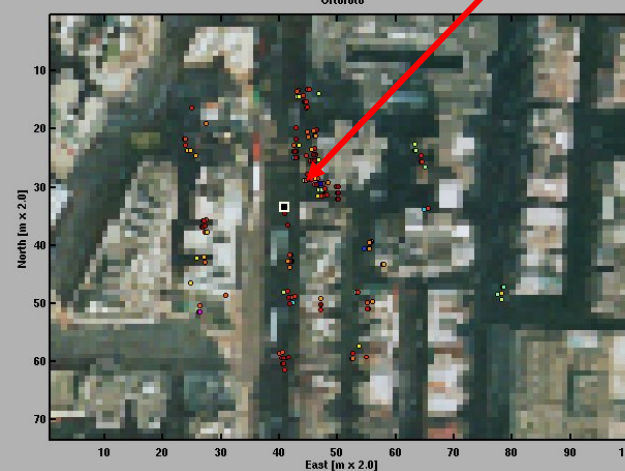
This plot shows the radar return from the building which collapsed in January 2010  
(strong signal before Jan, weak signal after)

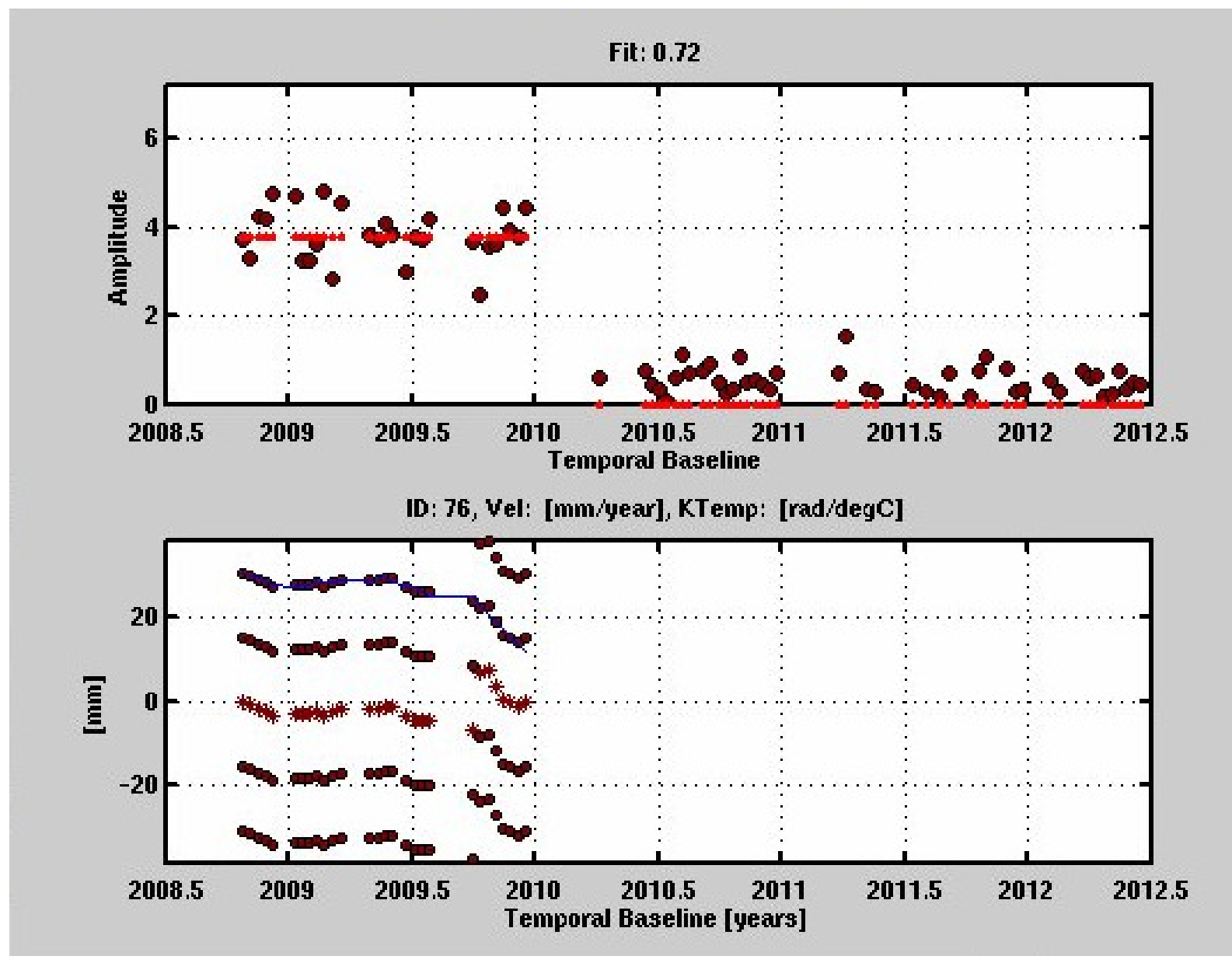
Accurate location,  
estimated height: 16m



This plot shows that the building started sinking at the end of June 2009 (~4mm), and had a strong acceleration in Nov 2009 (~8mm).

Altogether, since the beginning of 2009, the total displacement before the collapse was about 20mm







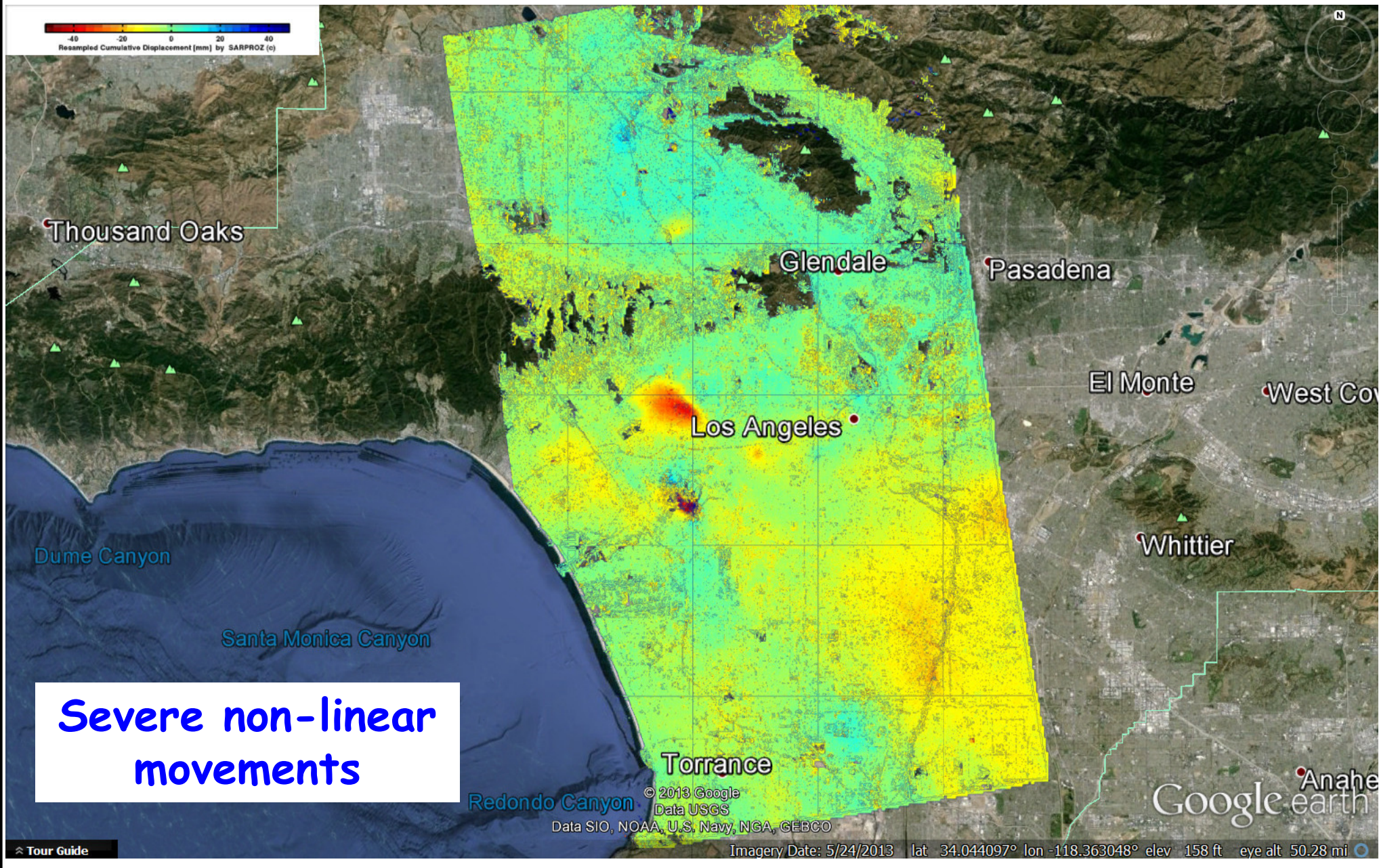
# Applications/case studies

## Los Angeles

80 TerraSAR-X images

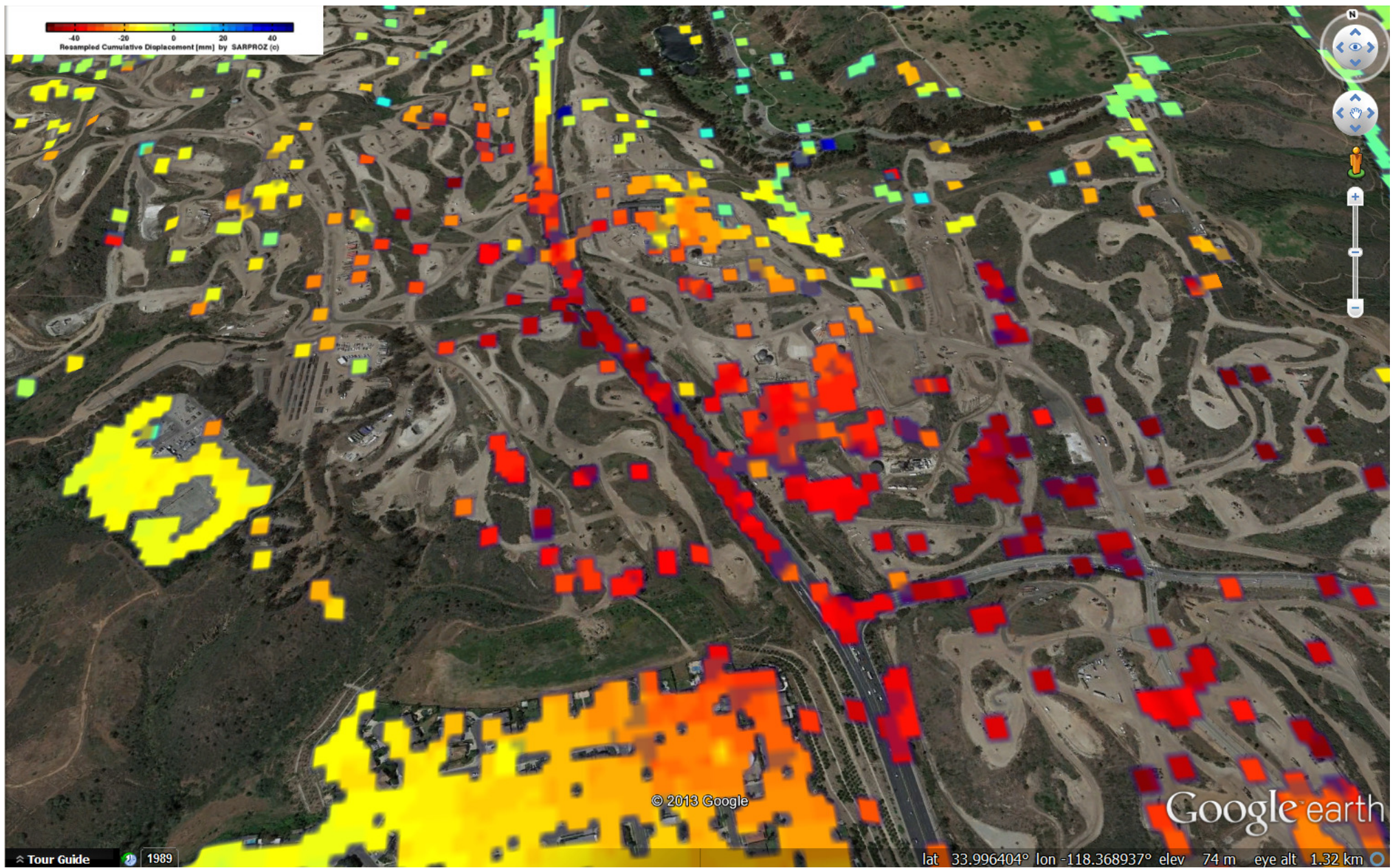


# Los Angeles with TSX images





# Oil extraction

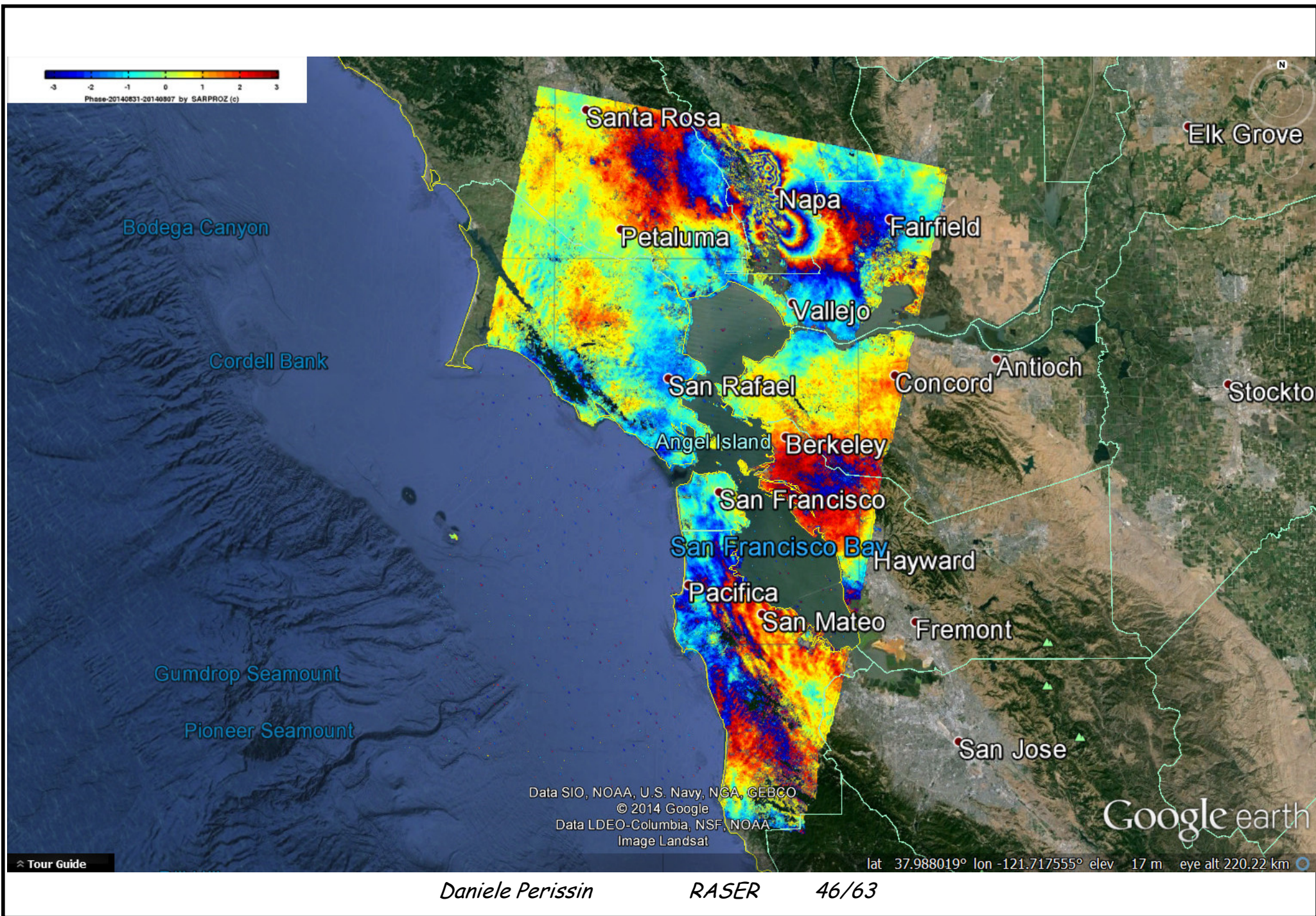


Applications/case studies

# The Napa Earthquake

Sentinel-1 data





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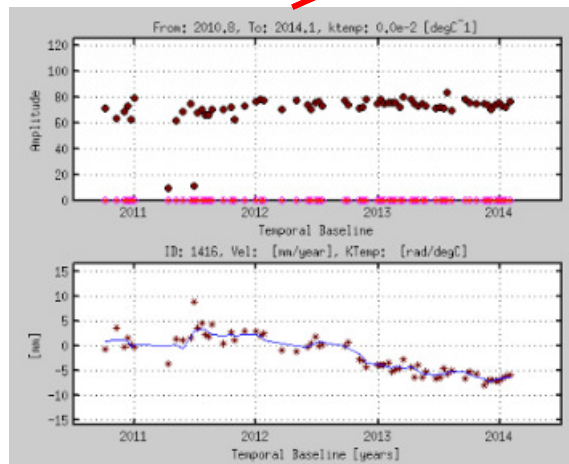


Applications/case studies

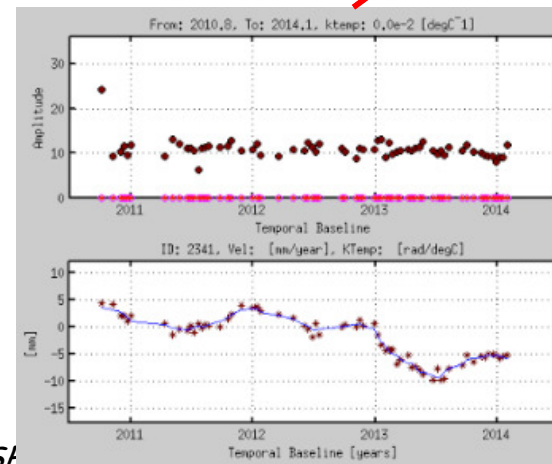
# Bridges monitoring

TerraSAR-X data



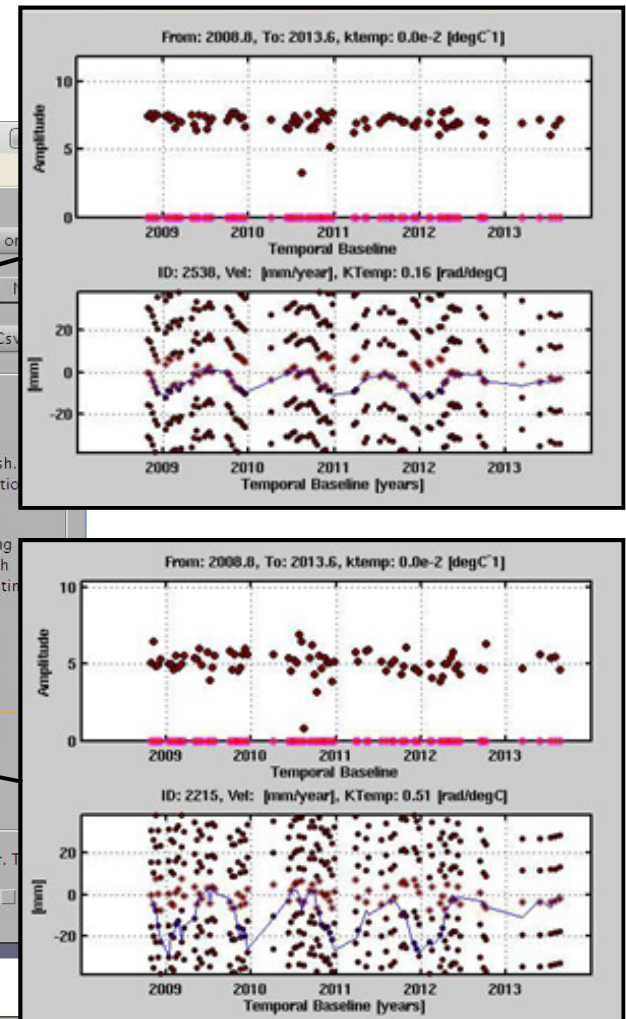
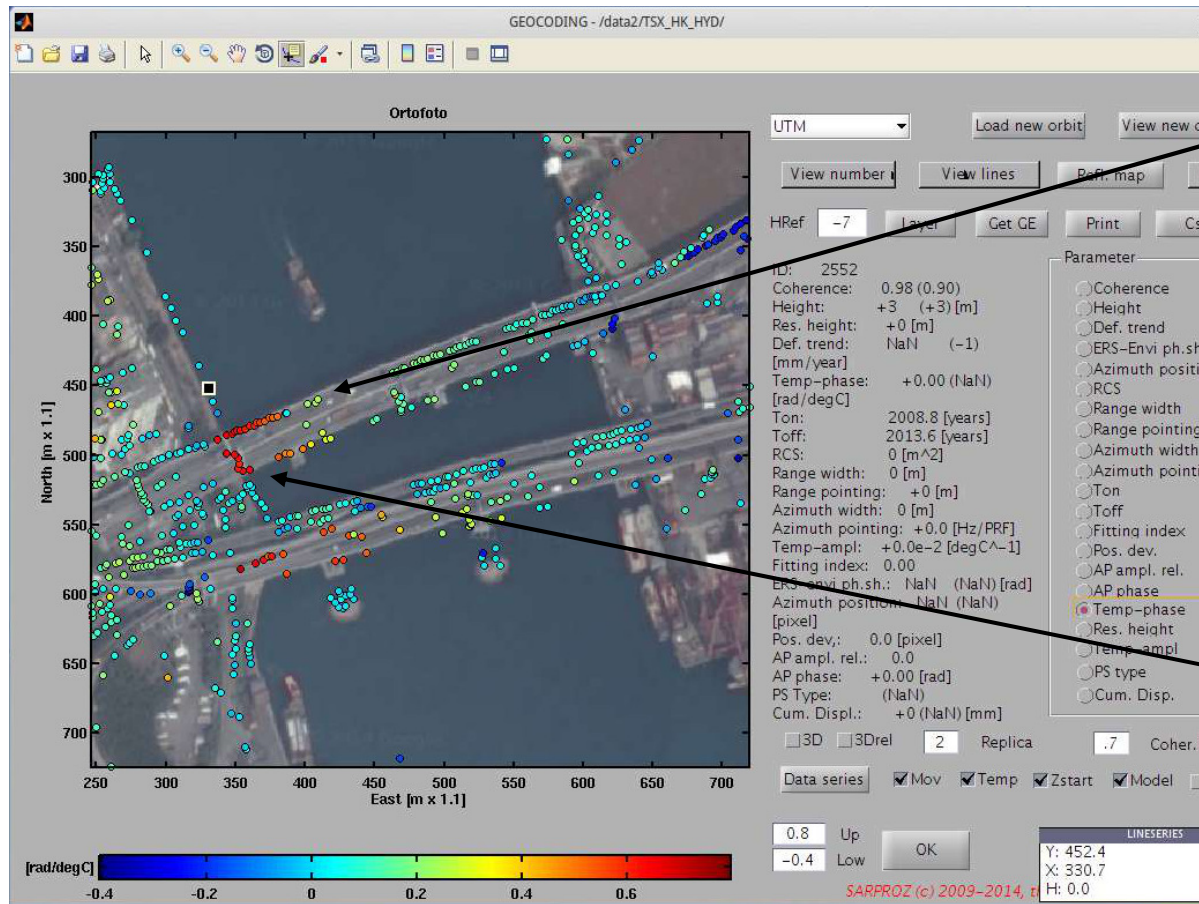


e Perissin



RAS

# Thermal Expansion of a bridge, Hong Kong



M. Lazecky, I. Hlavacova, M. Bakon, J. J. Sousa, D. Perissin, and N. Real, "Bridge Displacements Monitoring Using Space-Borne X-Band SAR Interferometry," IEEE JSTARS, 2016.

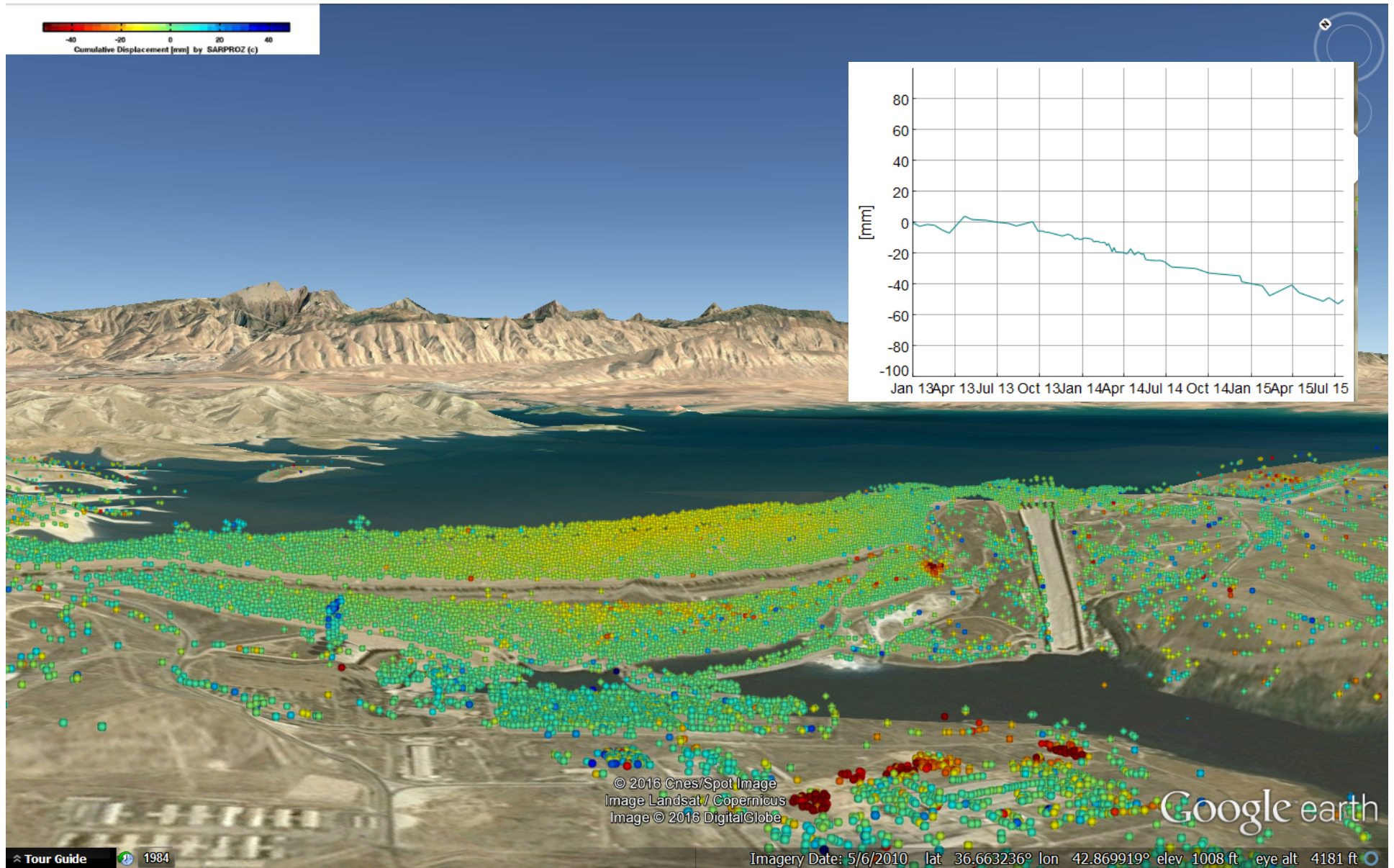


Applications/case studies

# The Mosul Dam (Iraq)

Cosmo SkyMed and Sentinel

# The Mosul Dam, Iraq

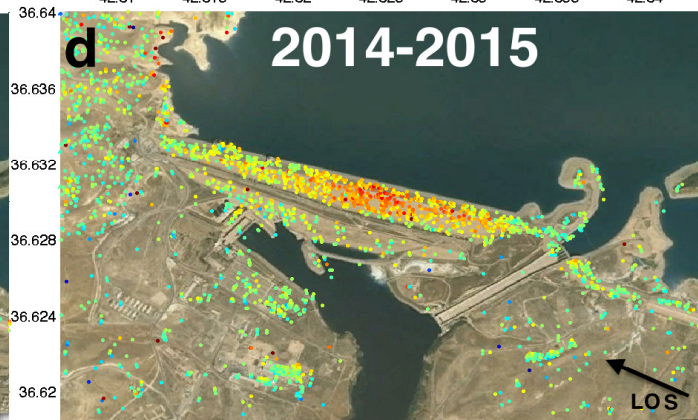
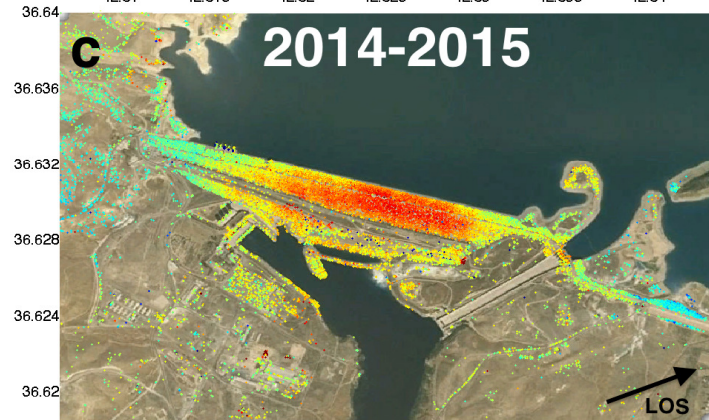
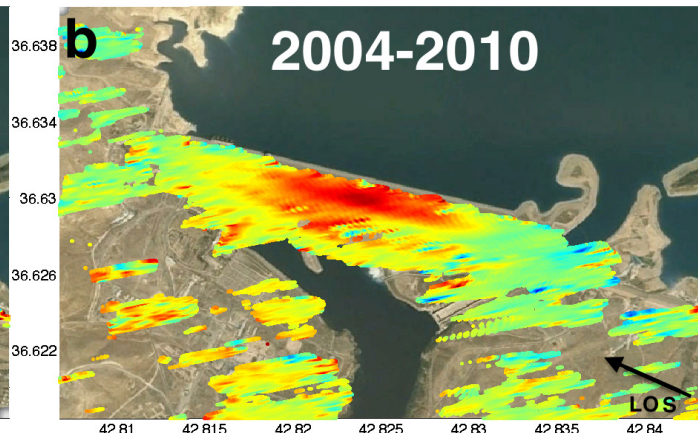
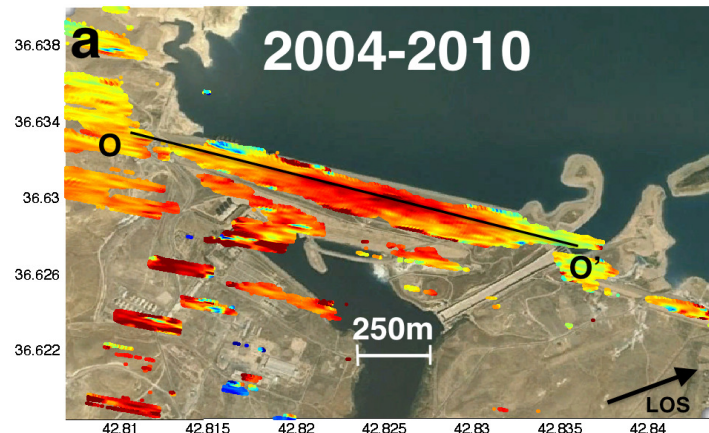




# The Mosul Dam, Iraq

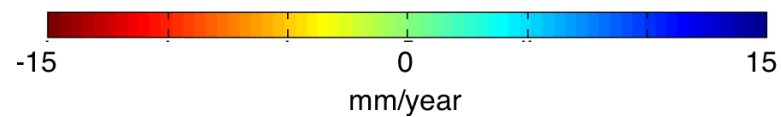
Envist Ascending

Envist Descending



Cosmo SkyMed Asce

Sentinel Descending



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## Applications/case studies

# The Chuquicamata mine (Chile)

Cosmo SkyMed and Sentinel





Look at the proportions!



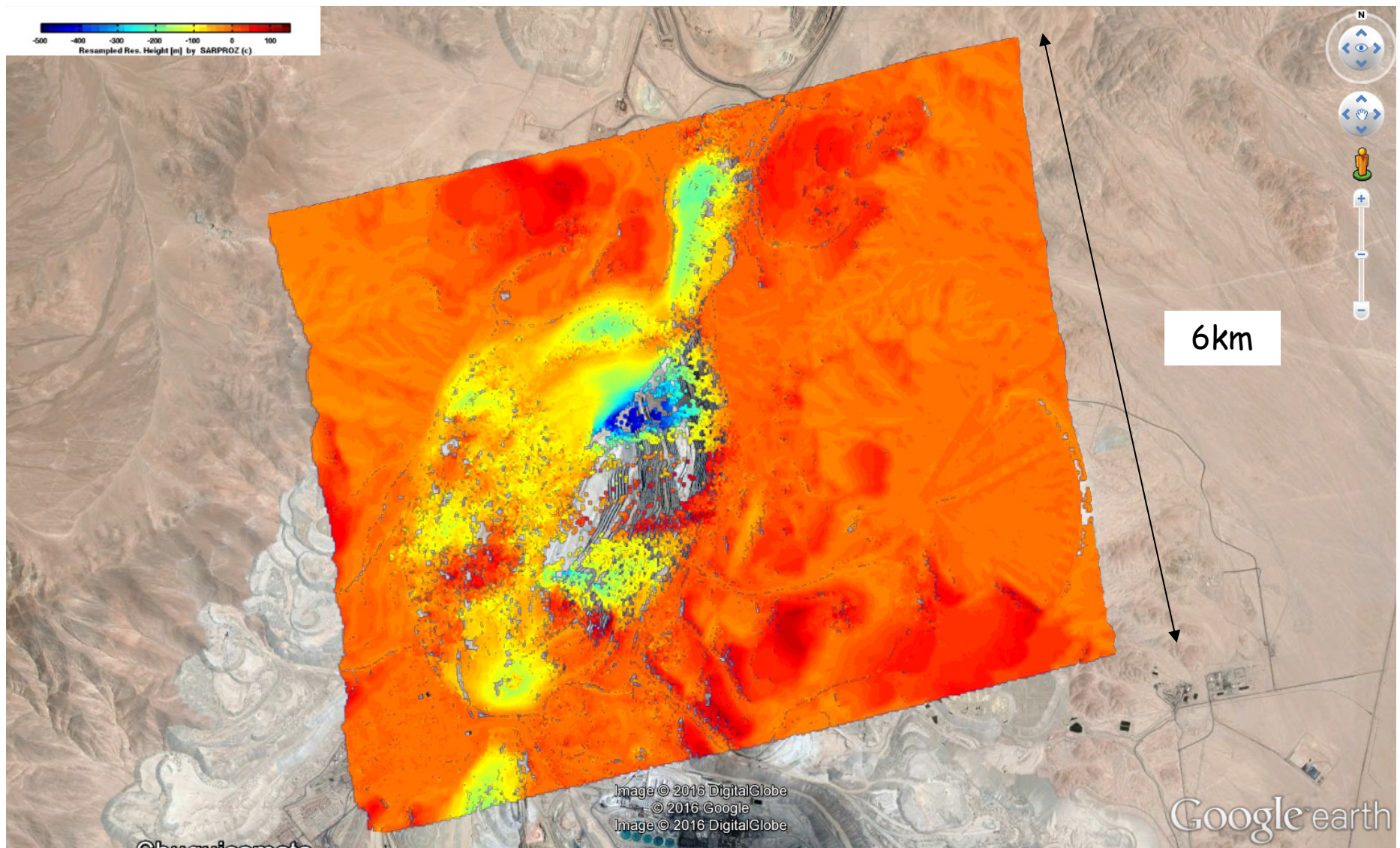
*Daniele Perissin*

*RASER 54/63*



# The Chuquicamata mine

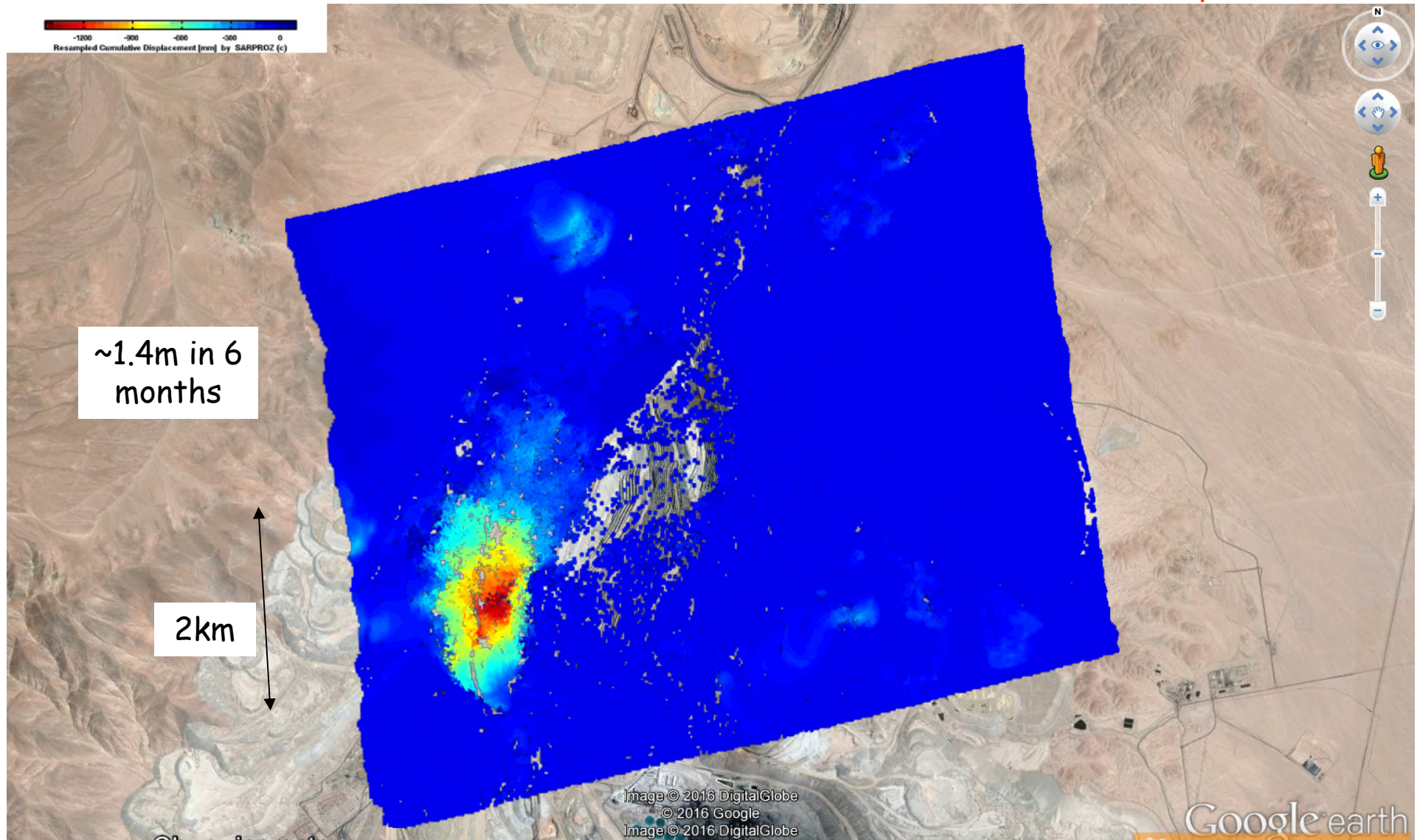
Residual DEM





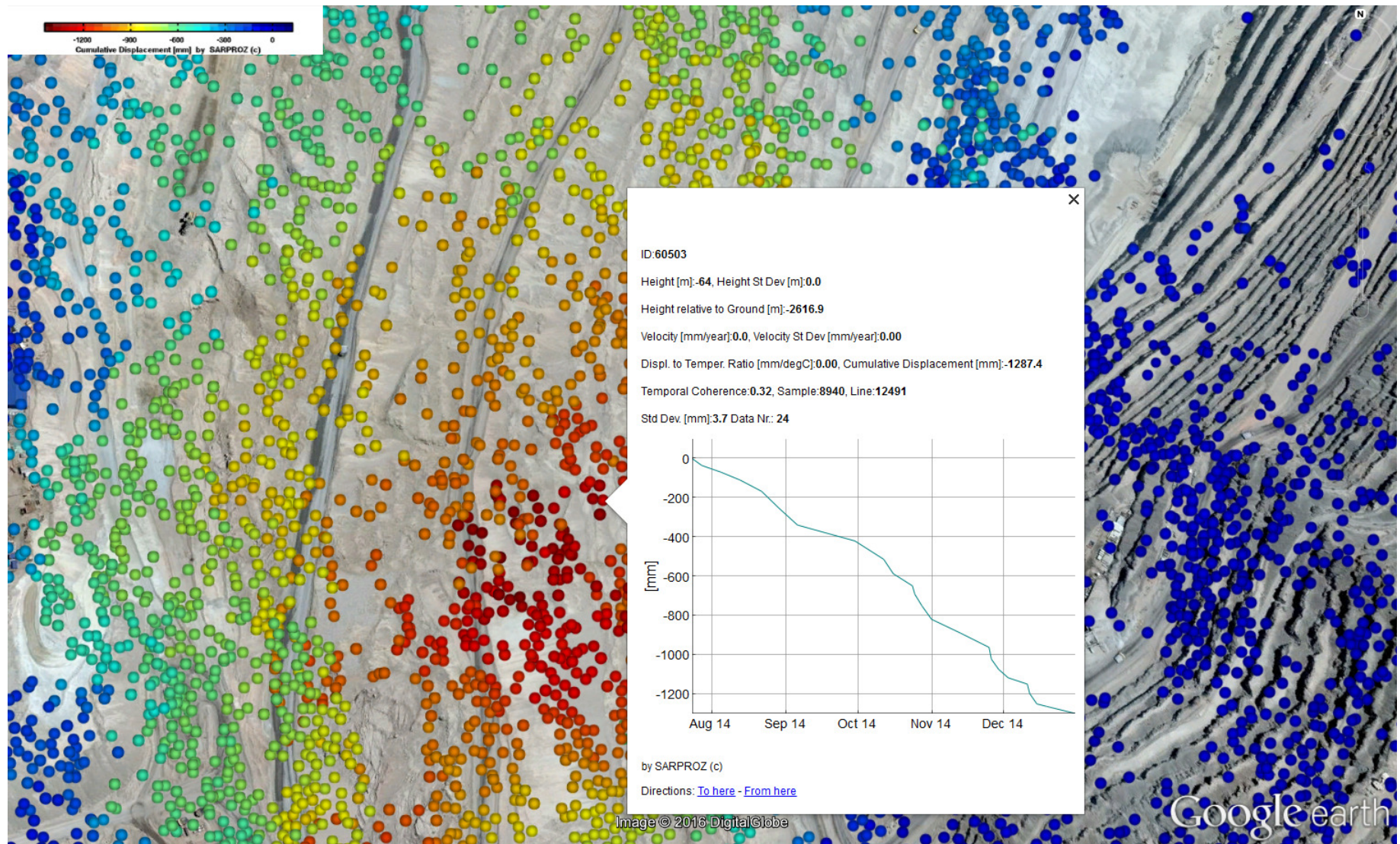
# The Chuquicamata mine

Cumulative  
displacement





# The Chuquicamata mine



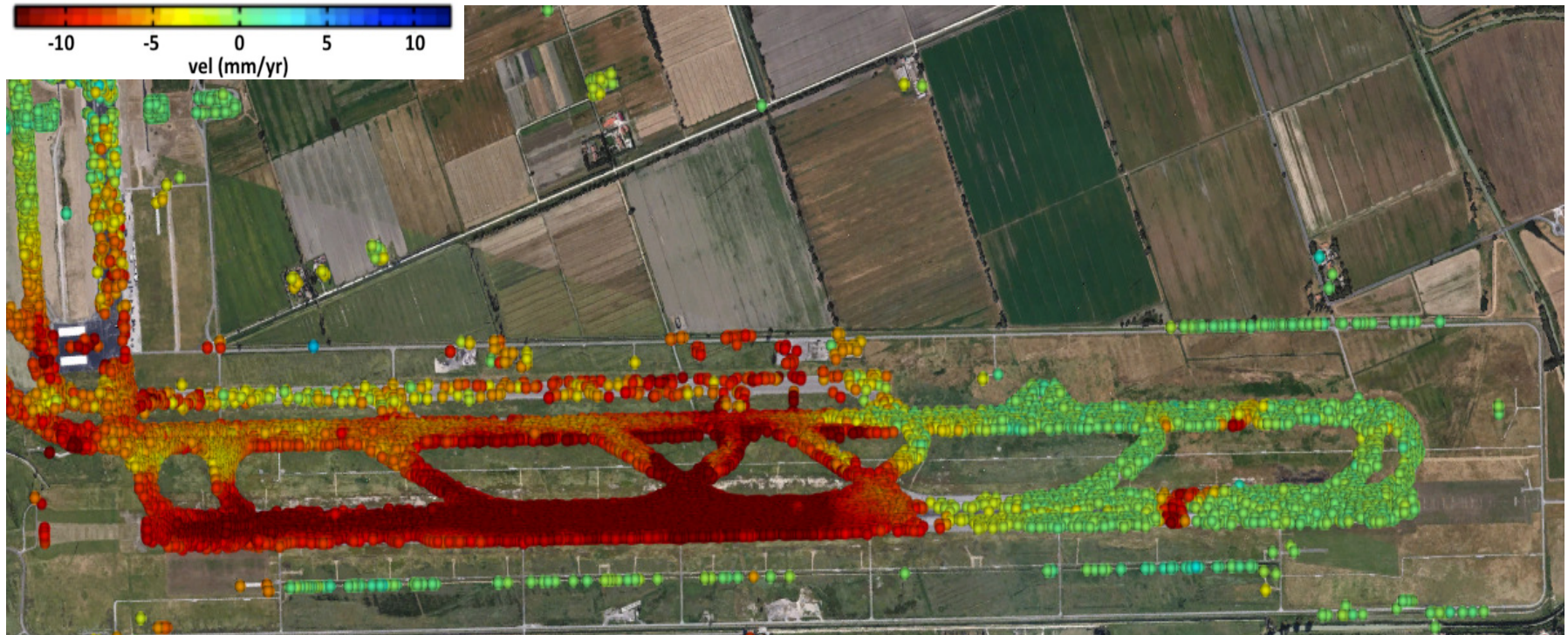


**Applications/case studies**

# **Infrastructure monitoring: airports**

# The deformation of the Fiumicino Airport (Rome)

Well identified displacement patterns





The software used for obtaining the results shown in this presentation

**SARPROZ**

The SAR processing tool by PeriZ

[www.sarproz.com](http://www.sarproz.com)

# The SARPPOZ interface

**MAIN - E:\TerraSAR\_Harbour\**

**SARPROZ**  
The SAR, InSAR, PSInSAR, ... PROCESSOR, by periz

Select Dataset      Dataset Statistics

Site Processing      Small Area Processing

**SITE PROCESSING - E:\TerraSAR\_Harbour\**

Preliminary analysis

Reflectivity map and amplitude stability index

Mask for sparse points selection

InSAR processing

Phase to height constants generation

Phase to flat constants generation

MST estimation

Residual fringes estimation and removal

Second order fringes removal

Interferograms processing

Coherence map generation

Synthetic coherence map generation

Sparse points selection

Load mask

Post-analysis

Geographic coordinates estimation

UTM coordinates estimation

DEM post-analysis

PS classification

Multi-sensor analysis

Tests

Preliminary geocoding

External DEM selection (default: SRTM)

DEM visualization

Geocoding through external DEM

Geocoding through manual GCP selection

External DEM and synthetic amplitude in SAR coordinates

Amplitude processing

Images equalization

Amplitude time series analysis

Sub-pixel positions analysis

Flat Cartesian coordinates estimation

Multi Image InSAR processing

APS estimation

Sparse Points

Visualization tools

Histograms

**Figures - GEOCODING - E:\TerraSAR\_Harbour\**

Ortofoto

UTM

View number  Load new orbi  Print

Shift q rif  View new orbi  Layer

View lines  Reflectivity map  N°

Coherence: 0.95 (0.95)  
Height: +19 (+19) [m]  
Def. trend: -1 (-1) [mm/year]  
ERS-envi ph.sh.: NaN (NaN) [rad]  
Azimuth position: NaN (NaN) [pixel]  
Temp-phase: -0.00 (-0.00) [rad/°C]  
RCS: 0 [m²]  
Range width: 0 [m]  
Range pointing: +0 [m]  
Azimuth width: 0 [m]  
Azimuth pointing: +0.0 [Hz/PP]  
Ton: 2008.8 [years]  
Fitting index: 0.00  
Pos. dev.: 0.0 [pixel]  
AP ampl. rel.: 0.0  
AP phase: +0.00 [rad]  
Res. height: +15 [m]  
Temp-ampl: +0.0e-2 [°C⁻¹]  
PS Type: Root (1.00)

☒ 3D ☐ Saturate

Data series ☐ Mov ☐ Temp

**Parameter Thresholding**

Amp. Stab. Index ...

**Amplitude Extraction**

☐ Local Maxima

Ampl. Thres.

☐ Lobes suppression

☐ Sref ☐ Lref

☐ Pend ☐ Delta

Selected Points: 836

50 100 150 200 250 300

Lines

Mouse Click on Plotted Data...

**GEOCODING - E:\TerraSAR\_Harbour\**

Ortofoto

UTM

View number  Shift q rif  View lines

Coherence: 0.94 (0.94)  
Height: +31 (+31) [m]  
Def. trend: -0 (-0) [mm/year]  
ERS-envi ph.sh.: NaN (NaN) [rad]  
Azimuth position: NaN (NaN) [pixel]  
Temp-phase: -0.00 (-0.00) [rad/°C]  
RCS: 0 [m²]  
Range width: 0 [m]  
Range pointing: +0 [m]  
Azimuth width: 0 [m]  
Azimuth pointing: +0.0 [Hz/PP]  
Ton: 2008.8 [years]  
Fitting index: 0.00  
Pos. dev.: 0.0 [pixel]  
AP ampl. rel.: 0.0  
AP phase: +0.00 [rad]  
Res. height: +27 [m]  
Temp-ampl: +0.0e-2 [°C⁻¹]  
PS Type: Root (1.00)

☐ 3D ☐ Saturate

Data series ☐ Mov ☐ Temp

50 100 150 200 250 300

Lines

Mouse Click on Plotted Data...



# Multi-temporal SAR interferometry: Techniques and Applications

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[www.sarproz.com](http://www.sarproz.com)