Surface Motion Monitoring Using SAR Interferometric Techniques

Dr. Giulia Tessari

Senior Earth Observation Specialist, sarmap SA

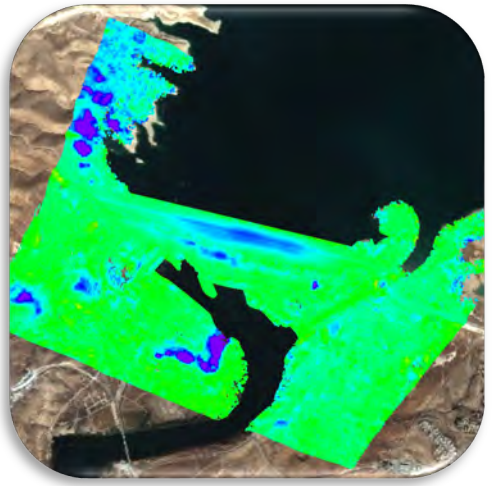
gtessari@sarmap.ch

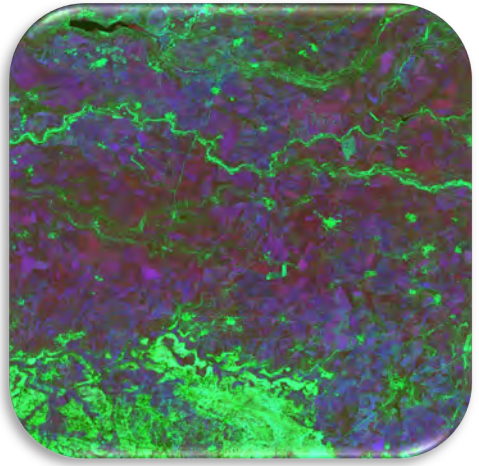
SAR SESSIONS

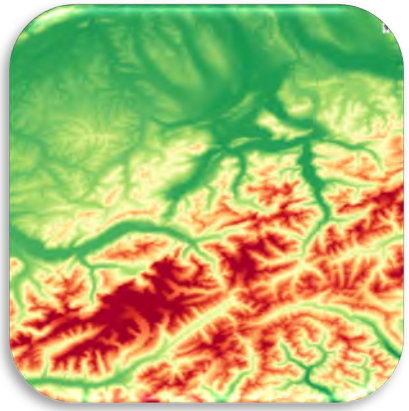
sarmap
your information gateway

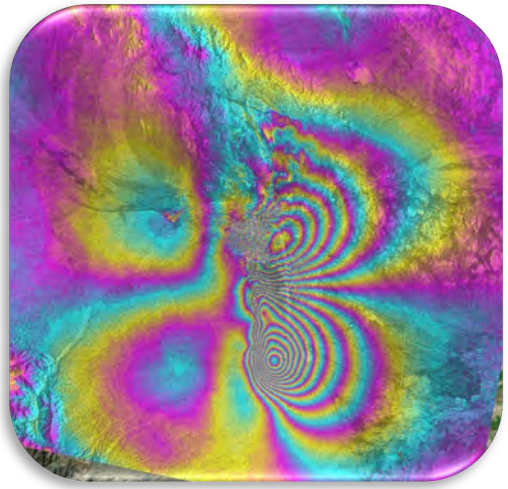
Main Applications of SAR data

- Topography - Digital Surface Model
- Snow and glaciar
- Coastal monitoring
- Deforestation
- Agriculture
- Defence and Security
- Target Detection









- Oil and Gas
- Natural Disasters
- Subsidence
- Landslides
- Land Displacement and modeling
- Infrastructure monitoring
- …

SAR SESSIONS

Surface Deformation!

SAR Interferometry

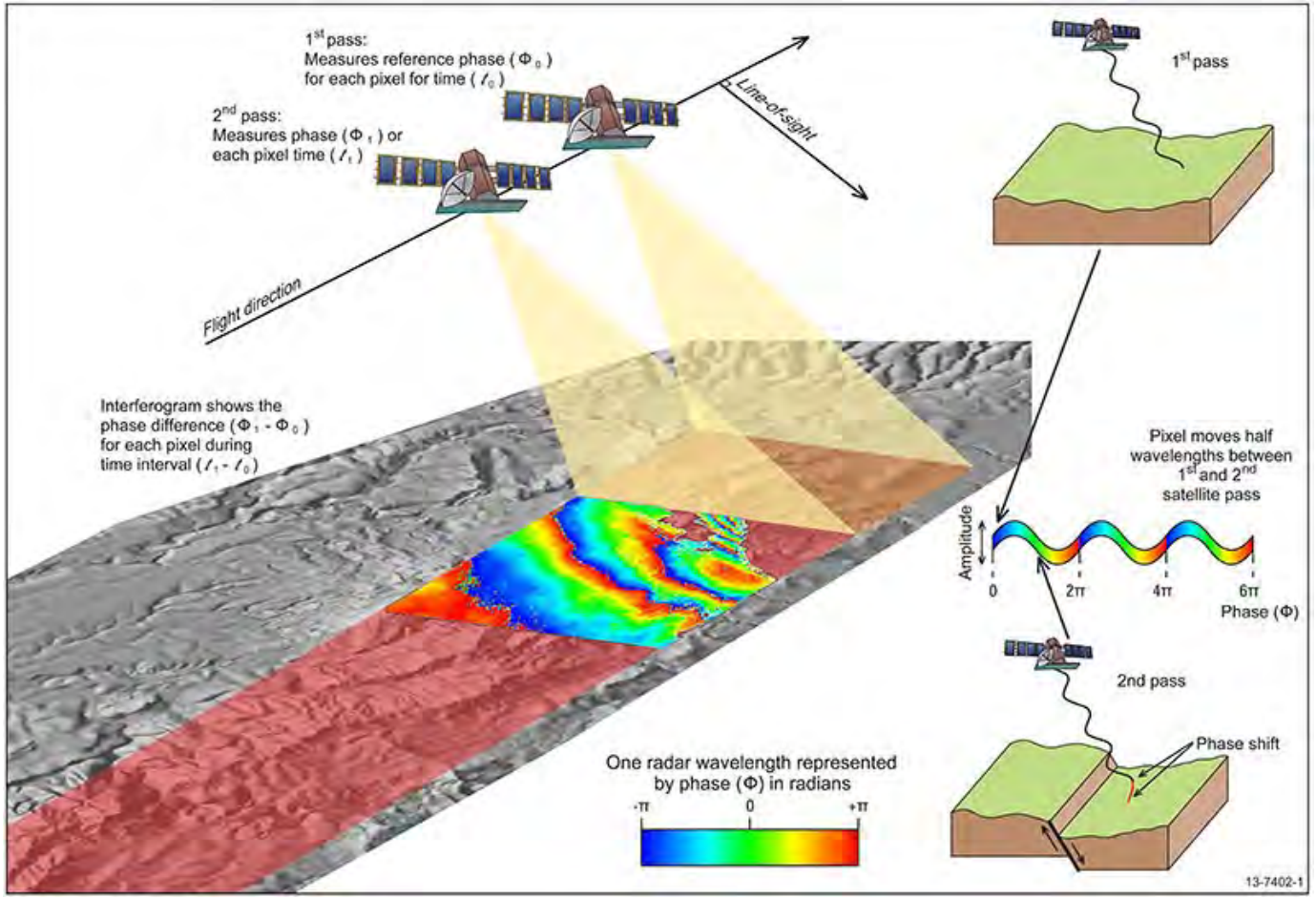
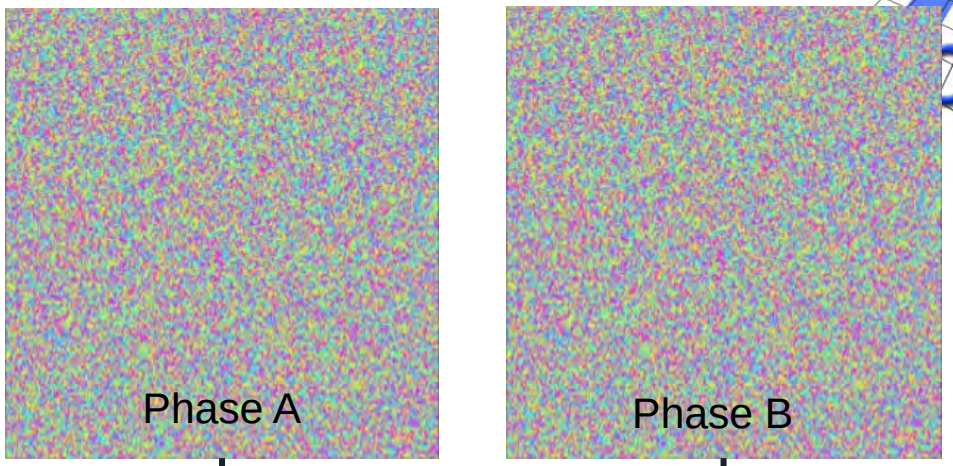
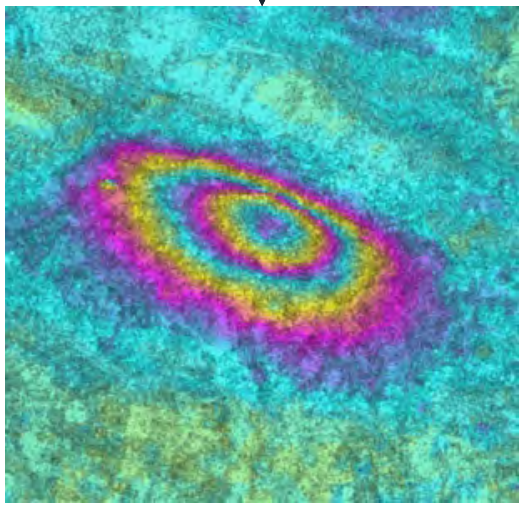


Image: Geoscience Australia

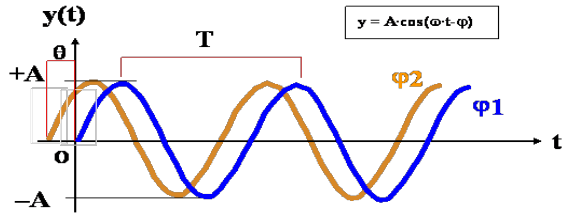
SAR SESSIONS



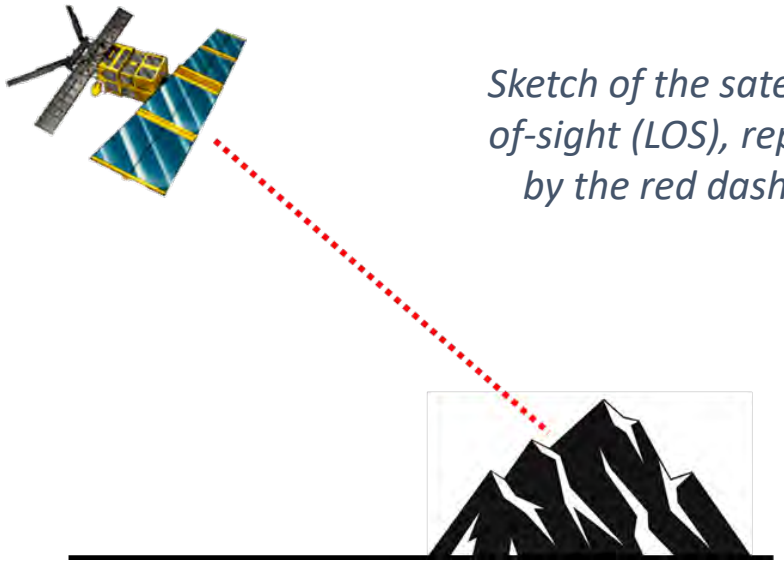
Phase A – Phase B



After removing
Topography,
Satellite
position
Earth curvature



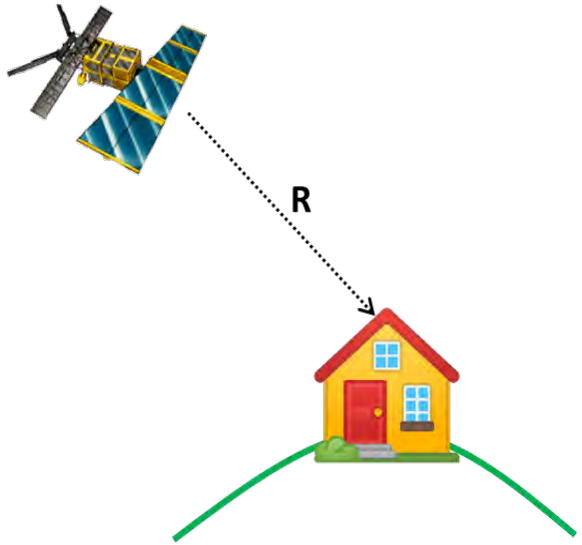
Line-Of-Sight Deformations

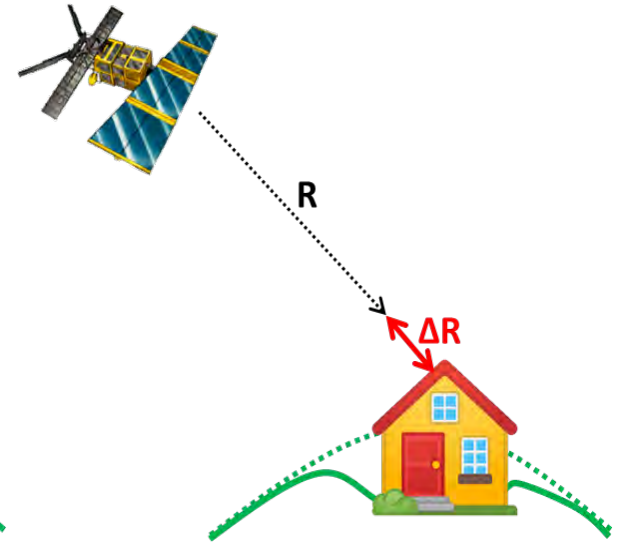


Sketch of the satellite Line-of-sight (LOS), represented by the red dashed line.

Sketch of the measurement of the displacement along the Line-of-Sight (LOS) direction, where the interferometric phase is proportional to the differences of range distances (ΔR).

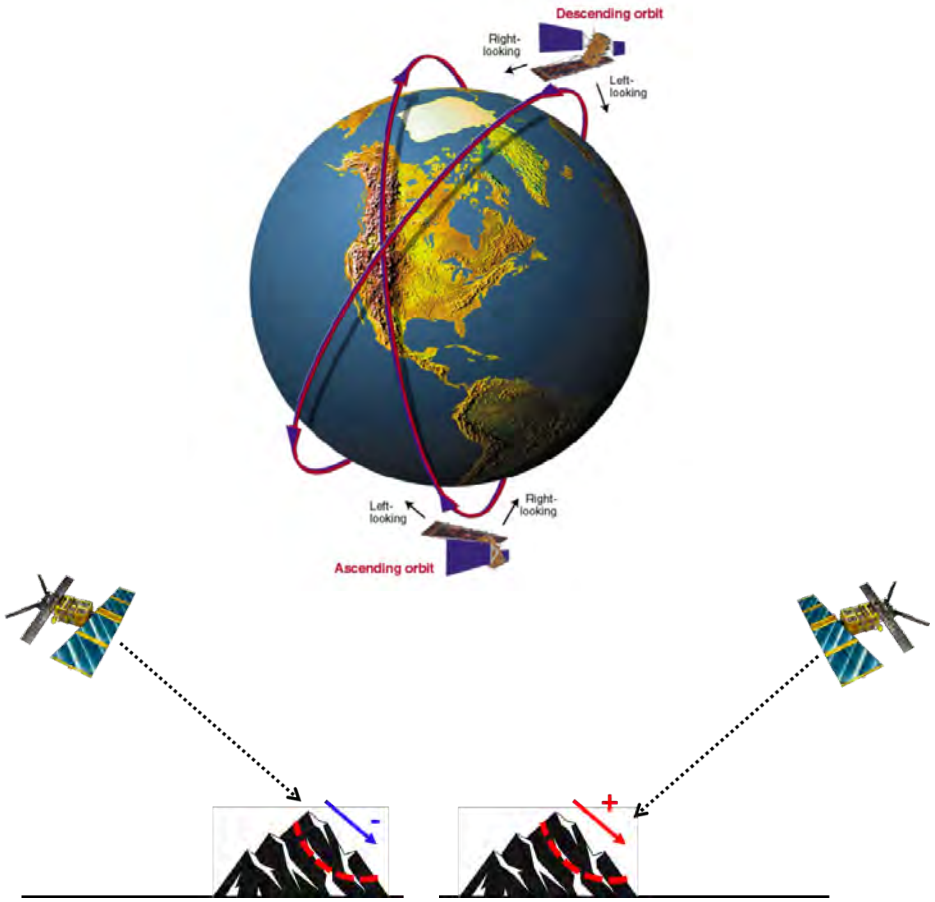
Signal backscatter
- Phase -

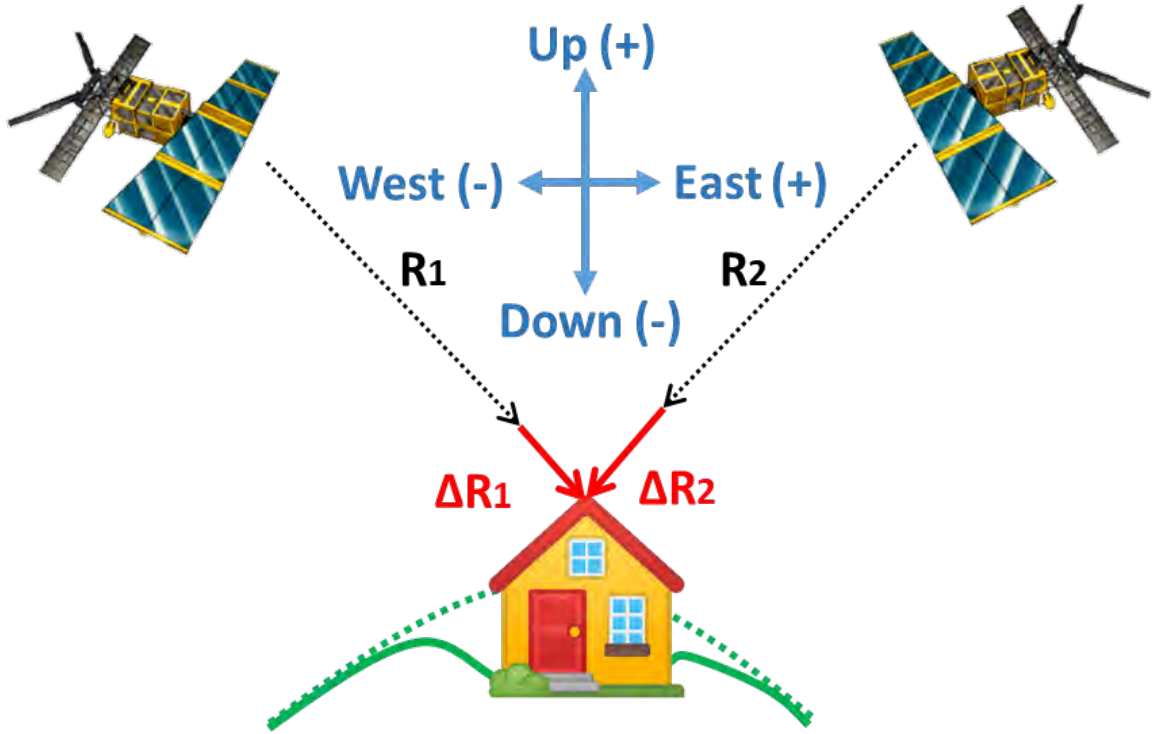




SAR SESSIONS

Deformation Projections

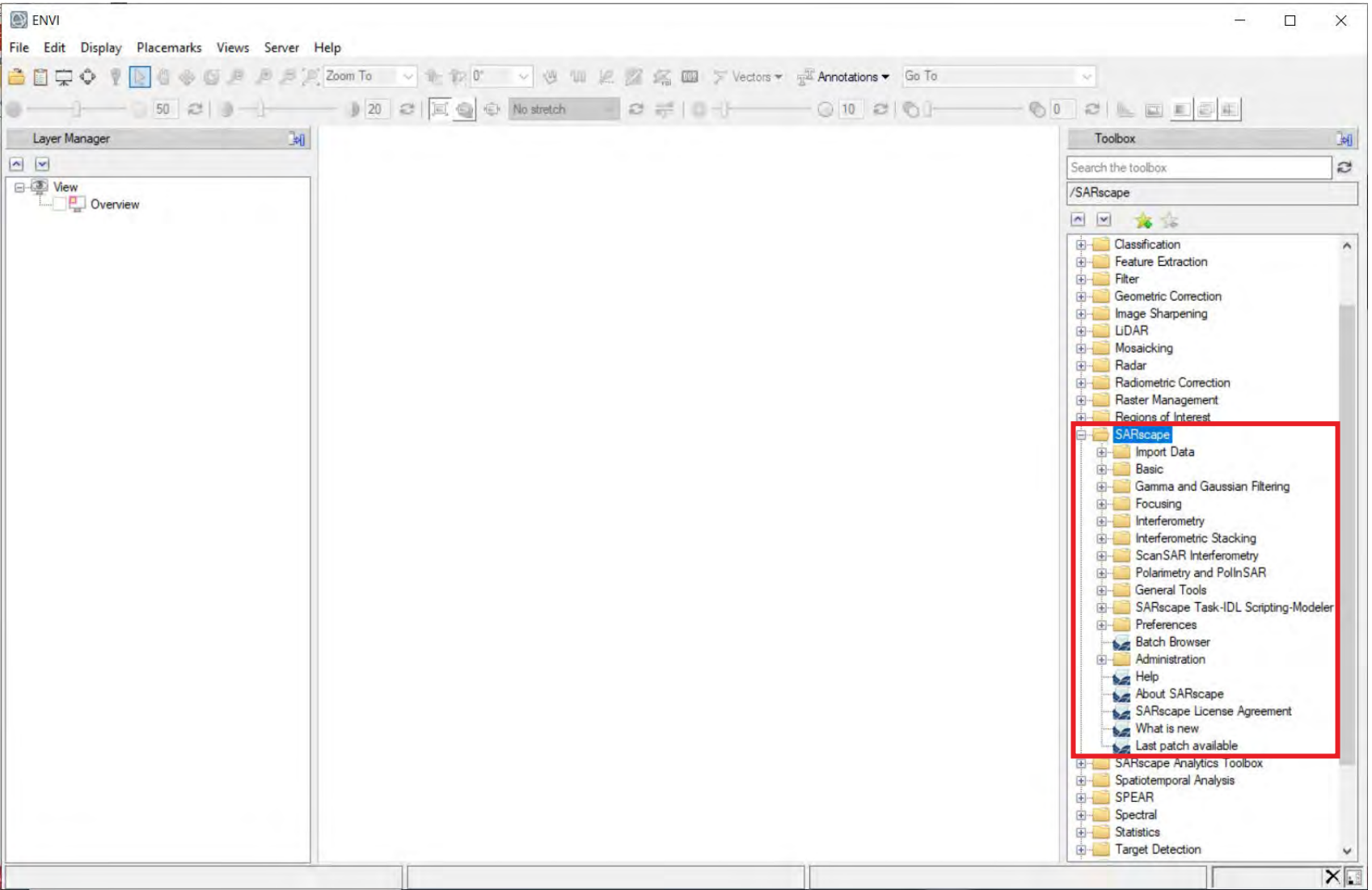


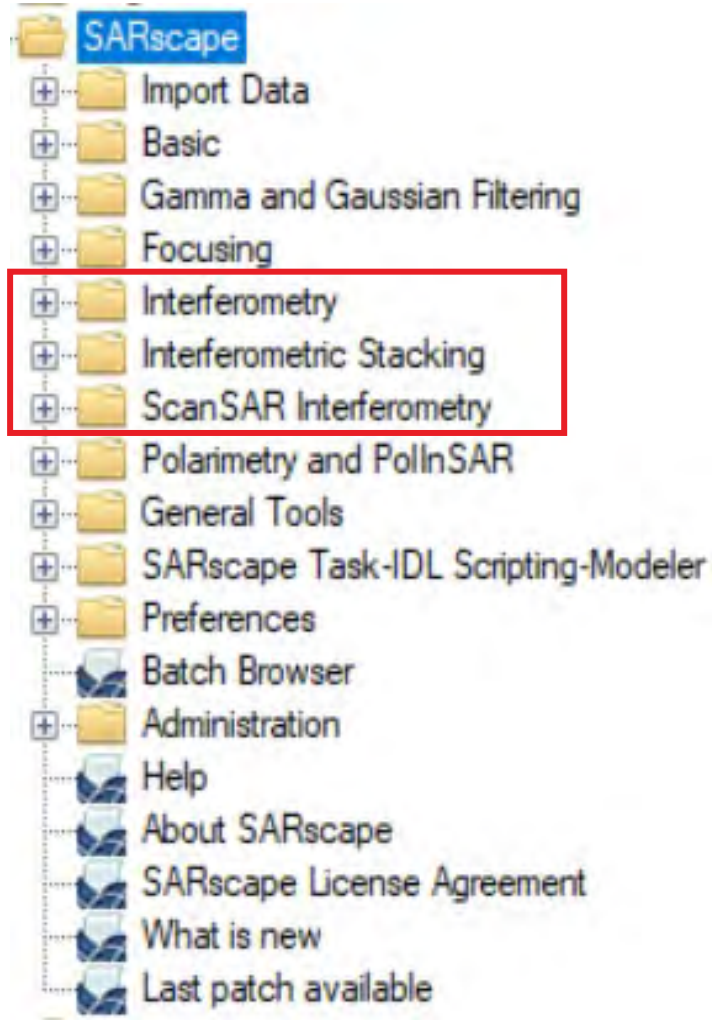


Sketch of the velocity of deformation projection along the vertical (Up-Down) and horizontal (West-East) directions. The projection can be performed if two satellite datasets (ascending and descending) are available.

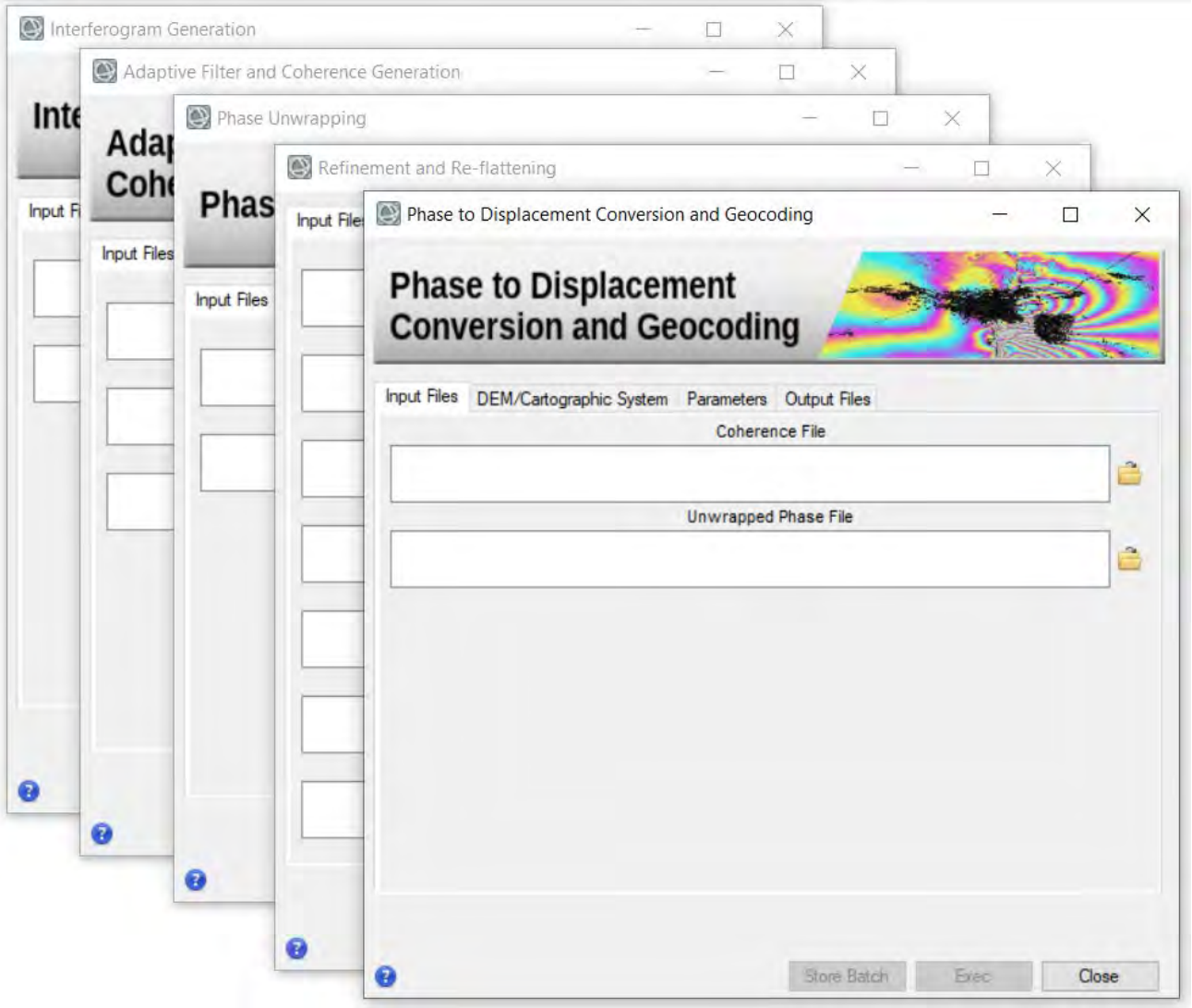
SAR SESSIONS

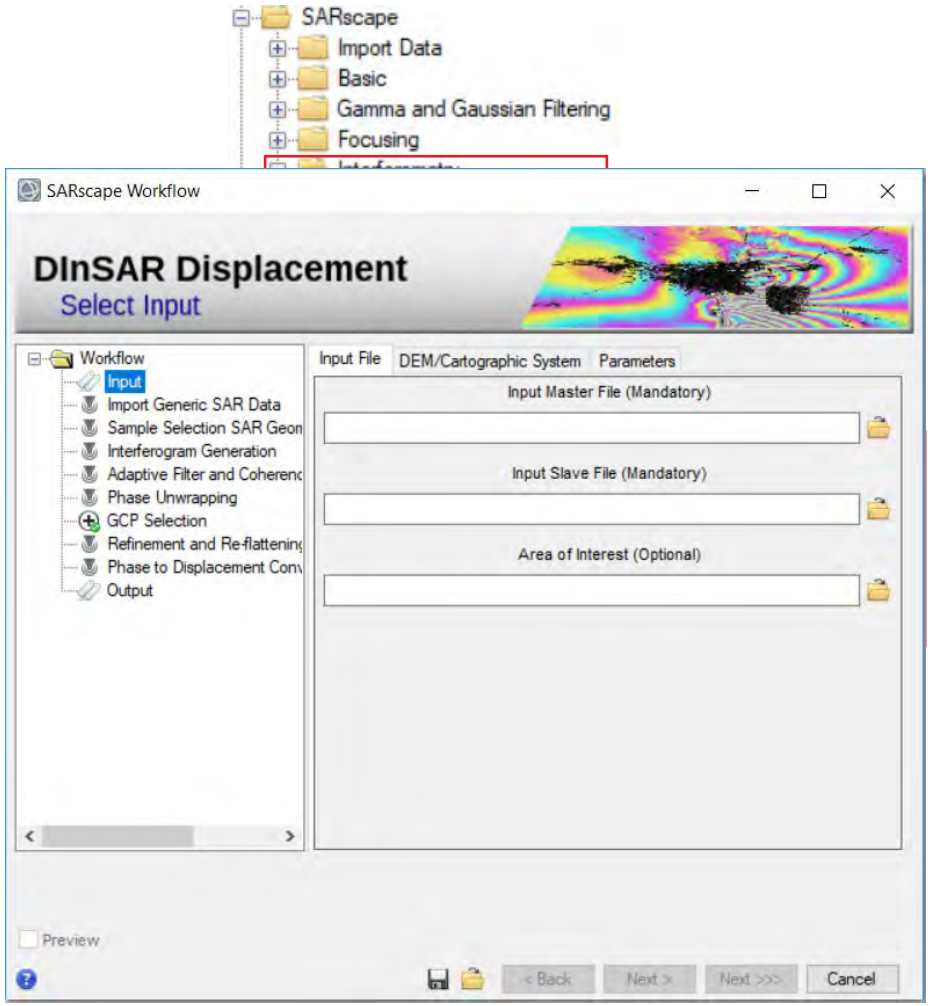
ENVI SARscape





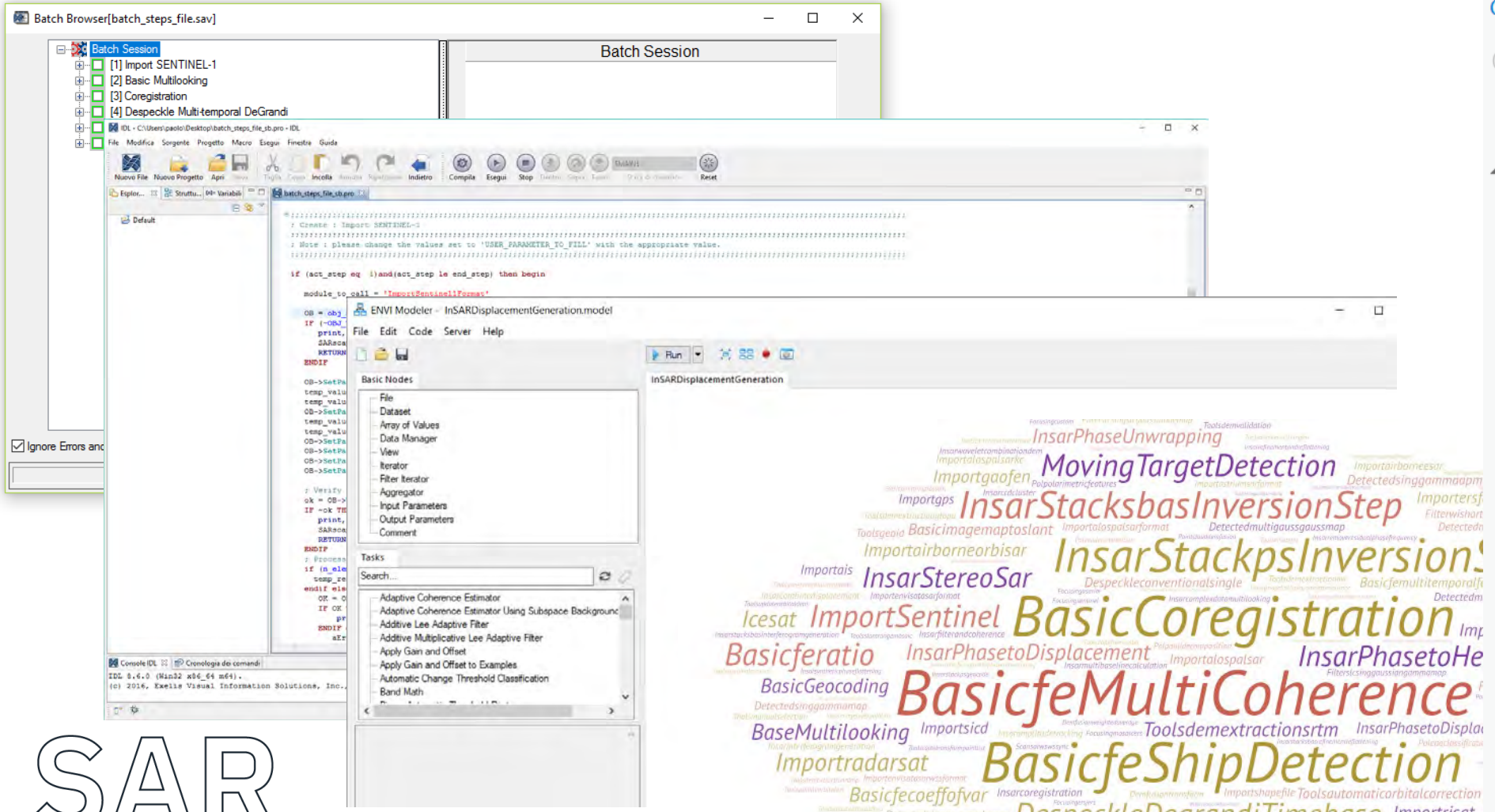
ENVI SARscape



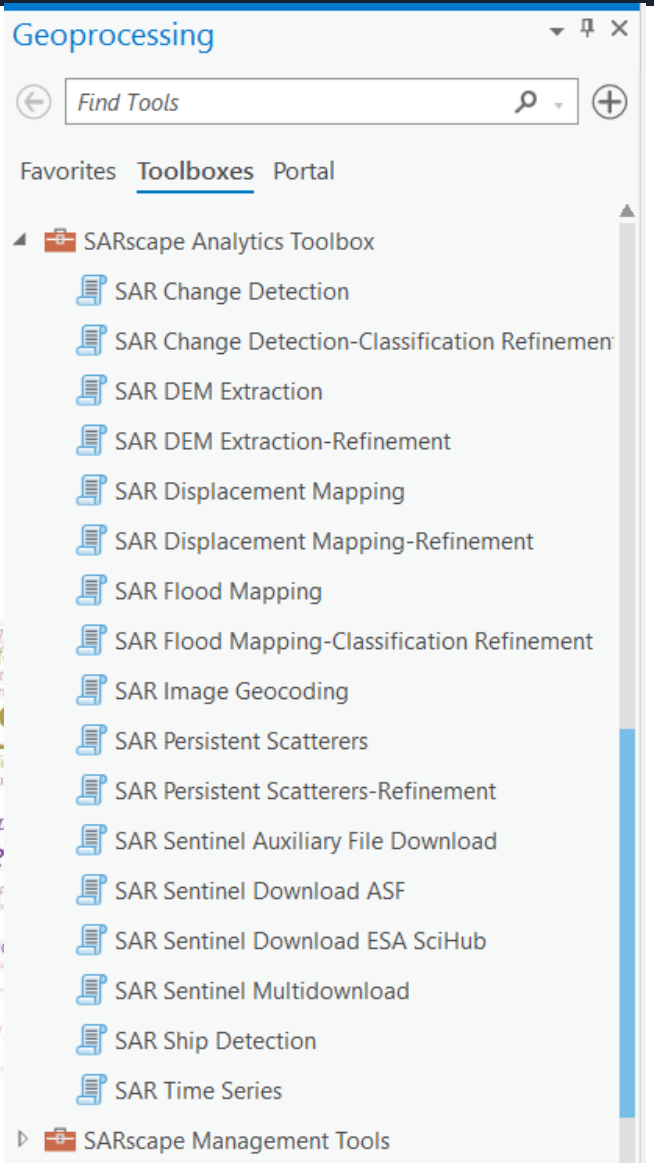


SESSIONS

ENVI SARscape



SAR SESSIONS



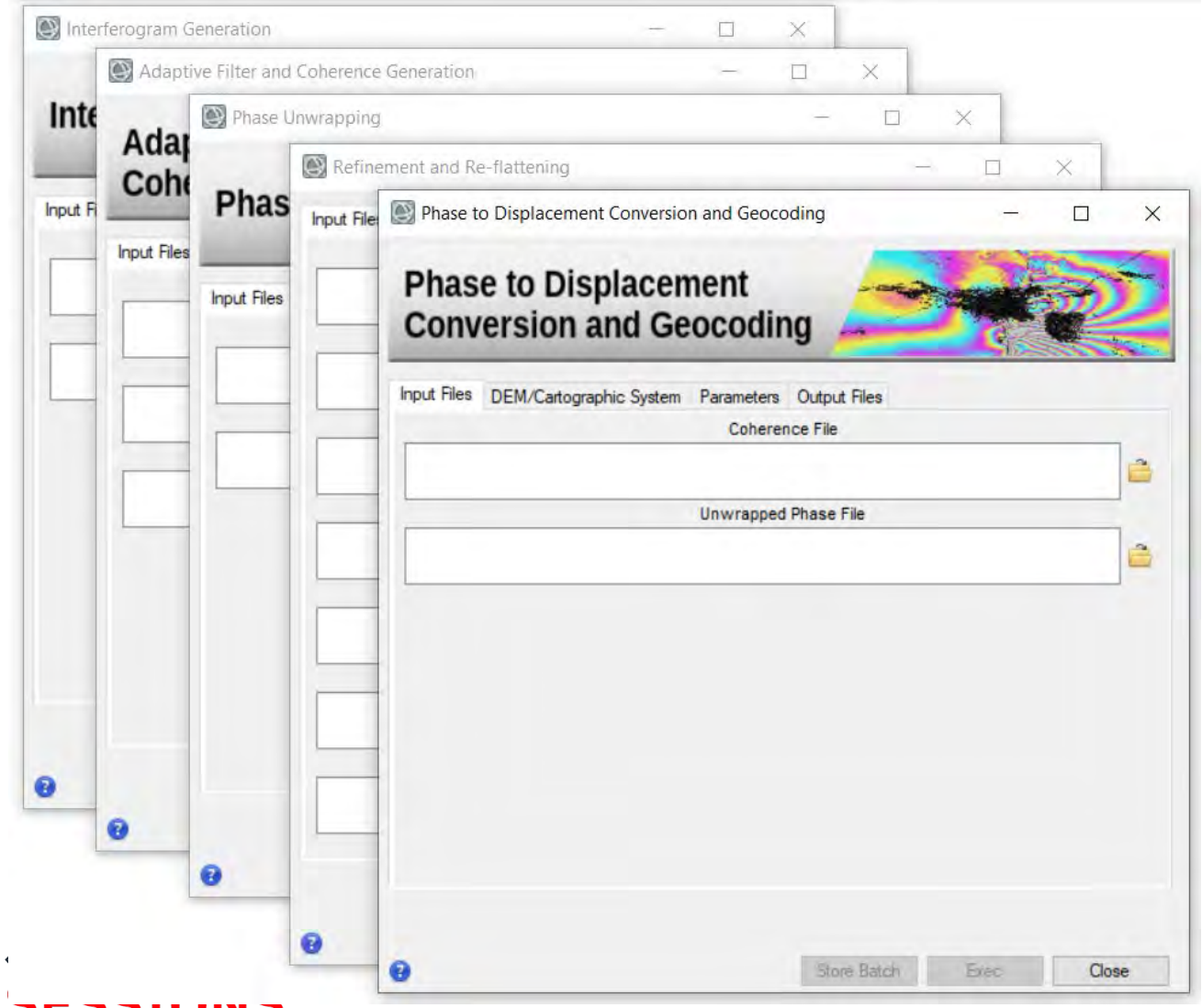
Differential SAR Interferometry and Geophysical Modeling

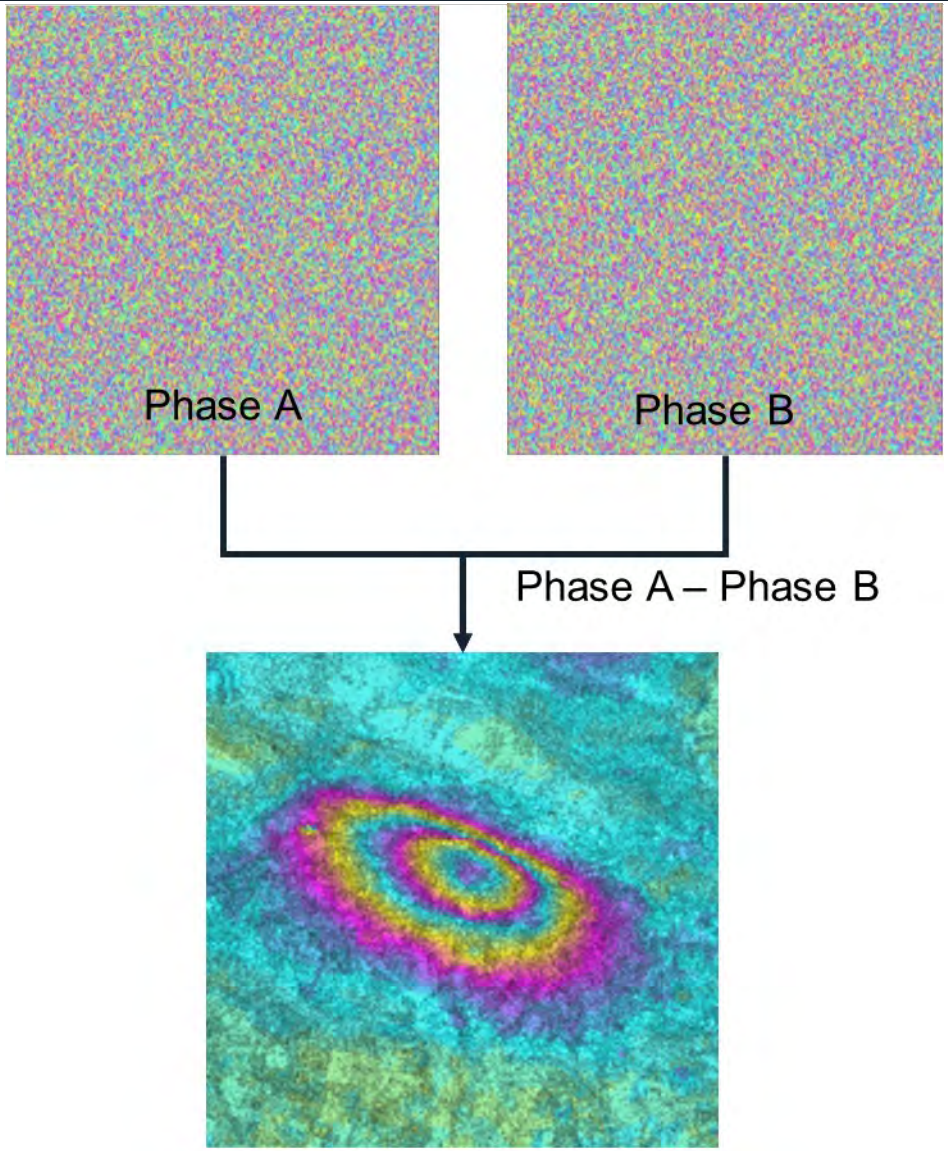
The December 2020 Greek Earthquake

SAR SESSIONS

sarmap
your information gateway

The Earthquake affecting Boeotia area, Central Greece, on the 2nd December 2020



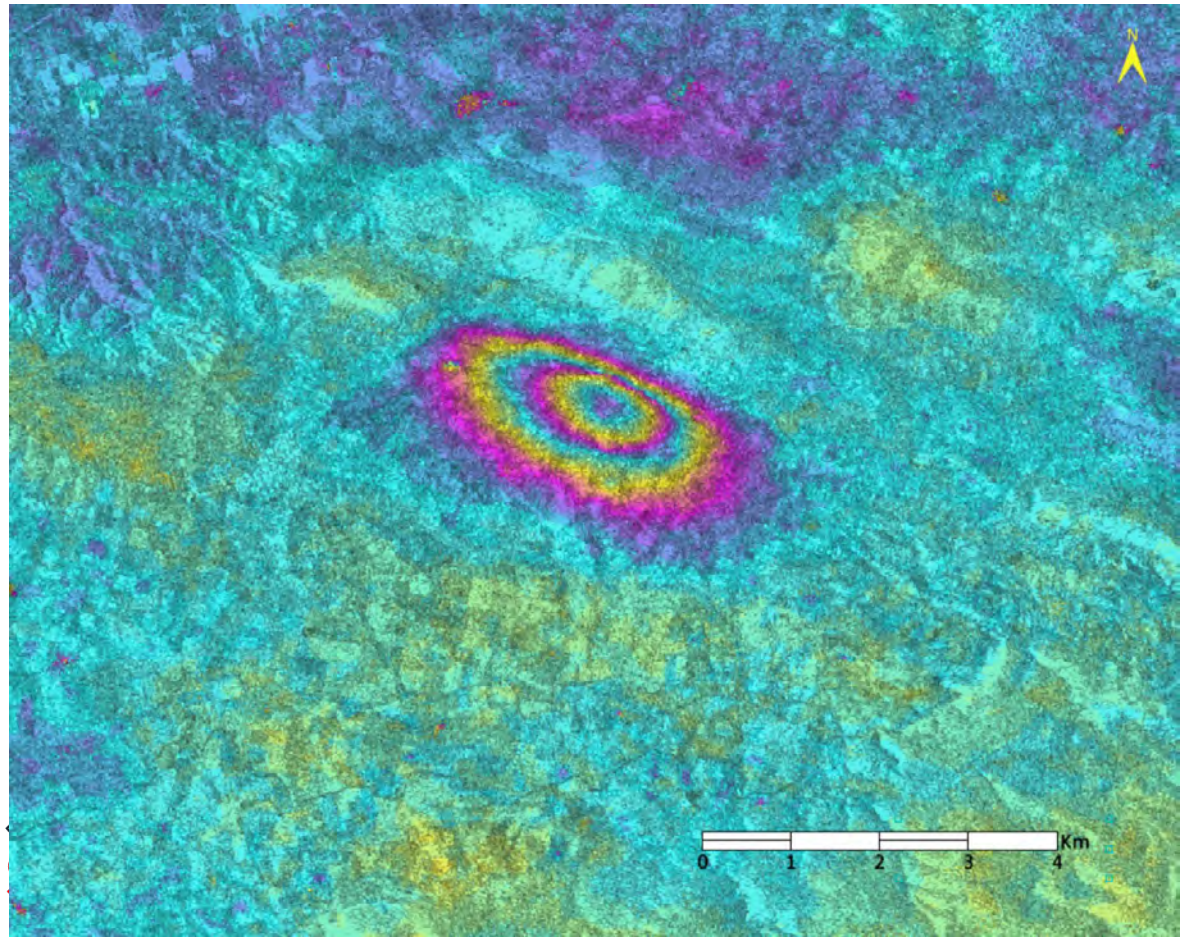


SESSIONS

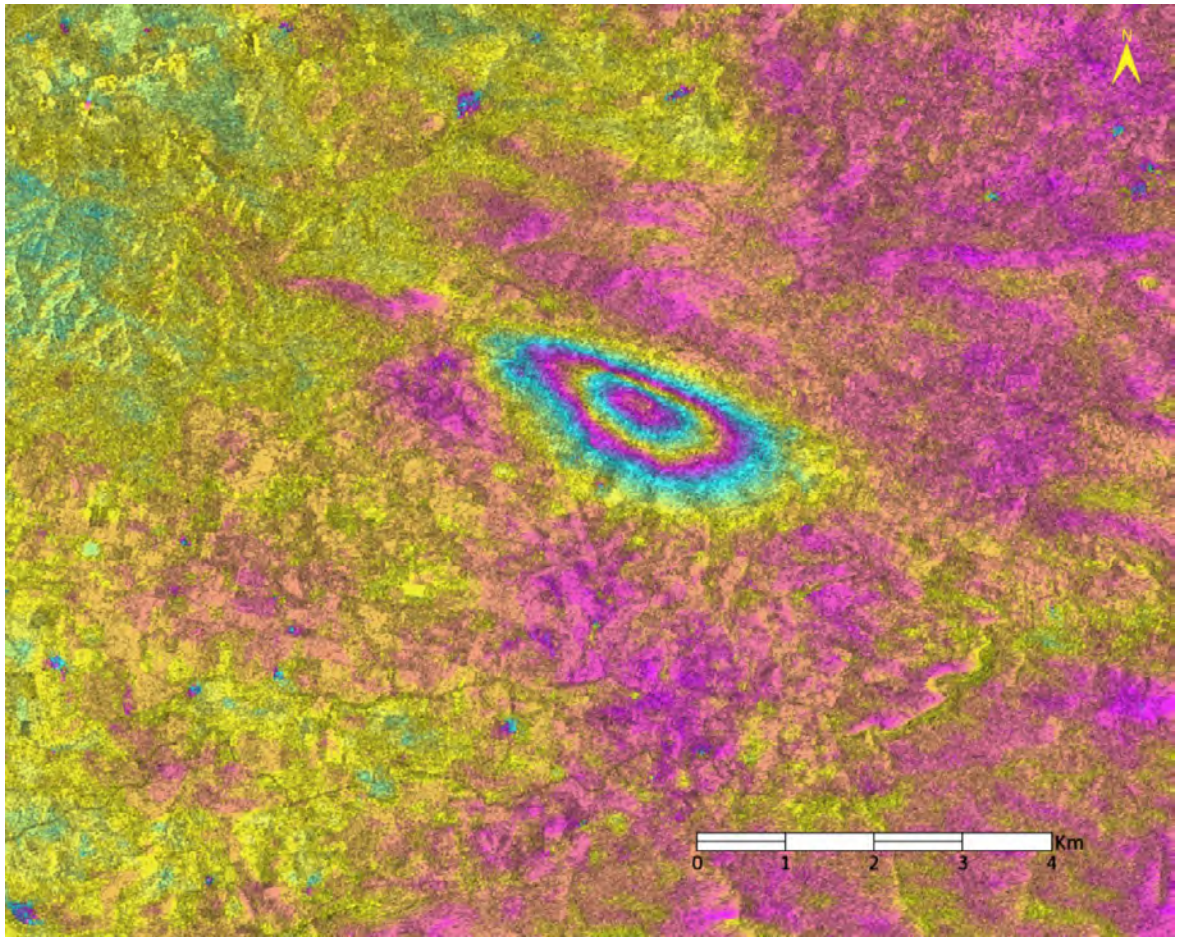
The Earthquake affecting Boeotia area, Central Greece, on the 2nd December 2020

Differential Interferometric processing using Sentinel-1 SAR data

Relative Orbit 201 Ascending. Master 20201127 – Slave 20201203



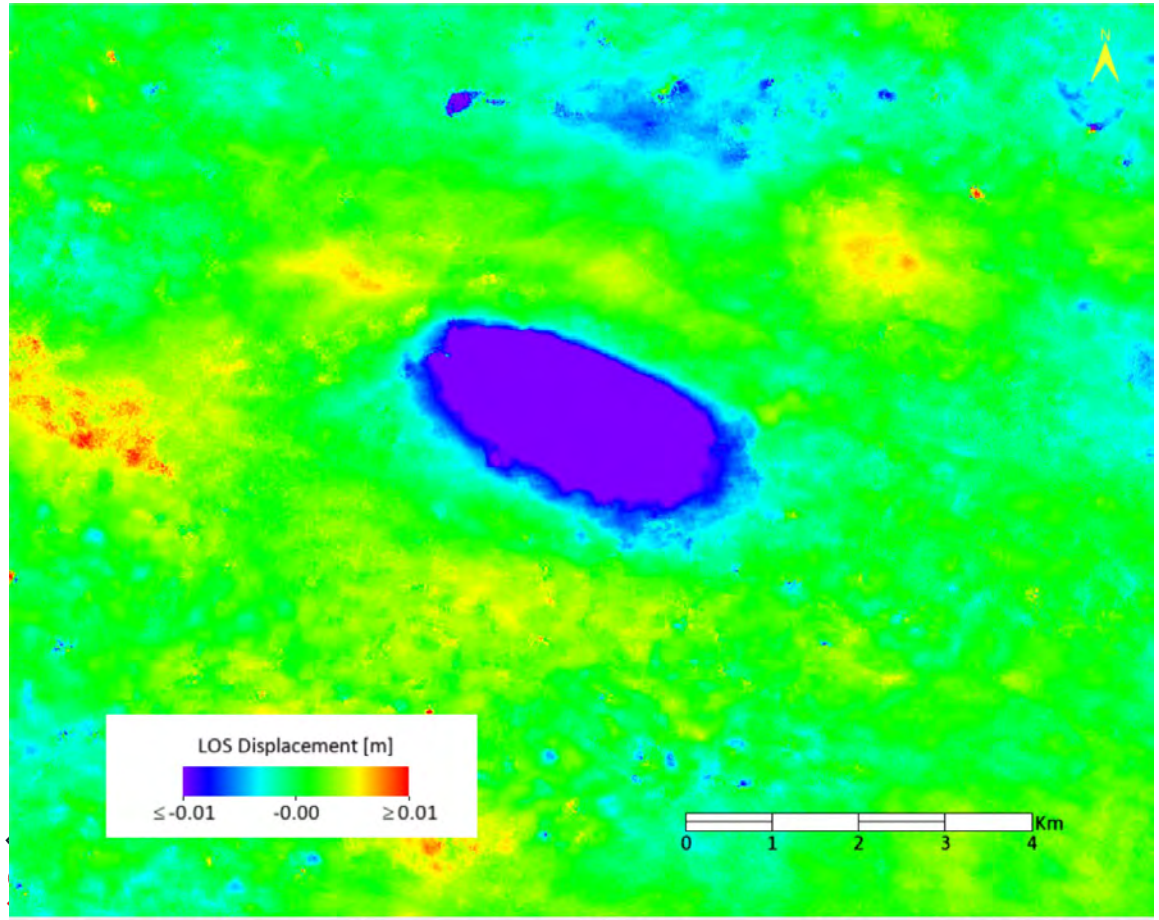
Relative Orbit 7 Descending. Master 20201127 – Slave 20201203



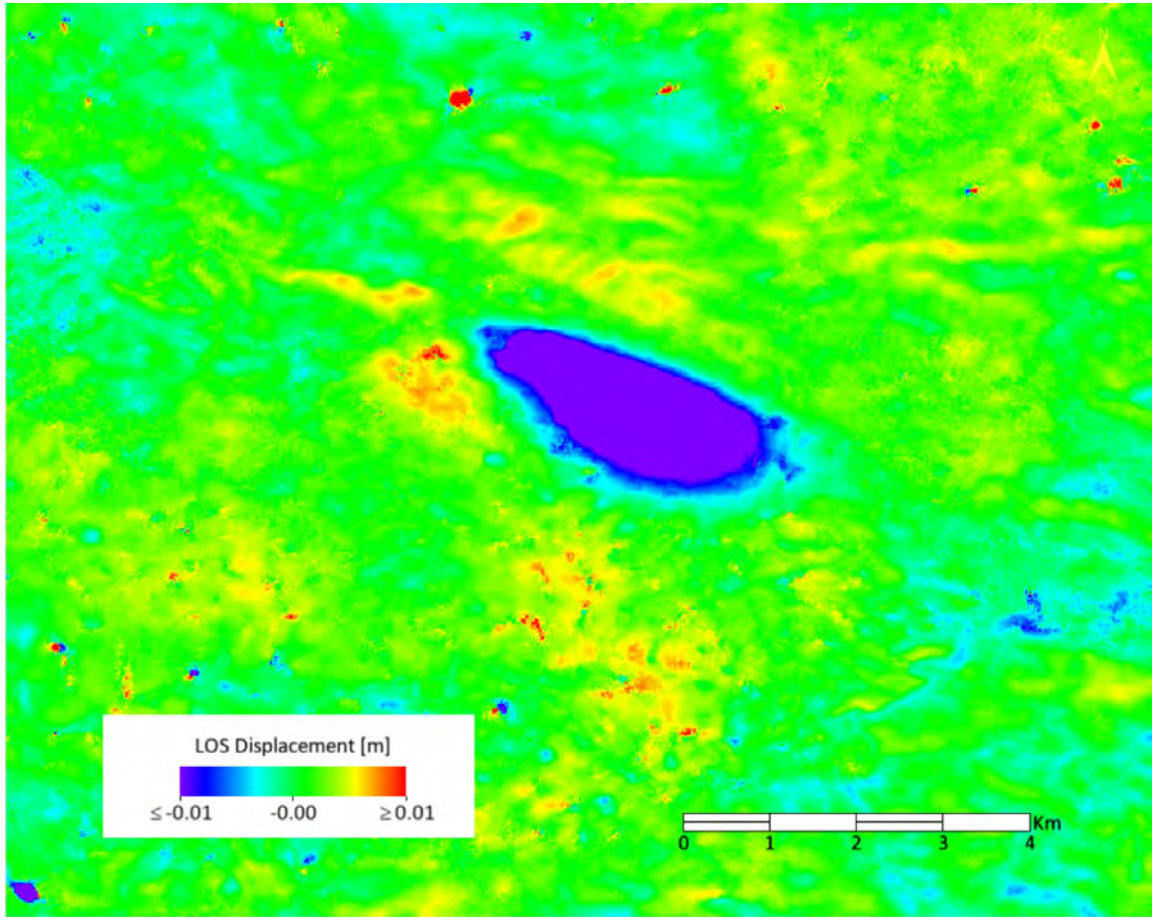
The Earthquake affecting Boeotia area, Central Greece, on the 2nd December 2020

LOS displacementsDifferential Interferometric processing using Sentinel-1 SAR data

Relative Orbit 201 Ascending. Master 20201127 – Slave 20201203



Relative Orbit 7 Descending. Master 20201127 – Slave 20201203



Geophisycal modeling of the seismic event

M 4.5 - 3 km WNW of Árma, Greece

USGS Information

2020-12-02 10:54:58 (UTC) | 38.361°N 23.453°E | 10.0 km depth

Moment Tensor

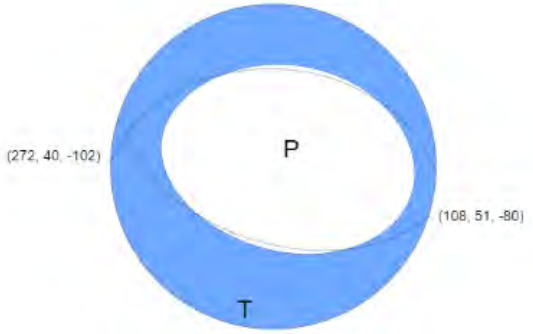
View all moment-tensor products (1 total)

Contributed by US [1] last updated 2020-12-02 11:13:27 (UTC)

✓ The data below are the most preferred data available
✓ The data below have been reviewed by a scientist

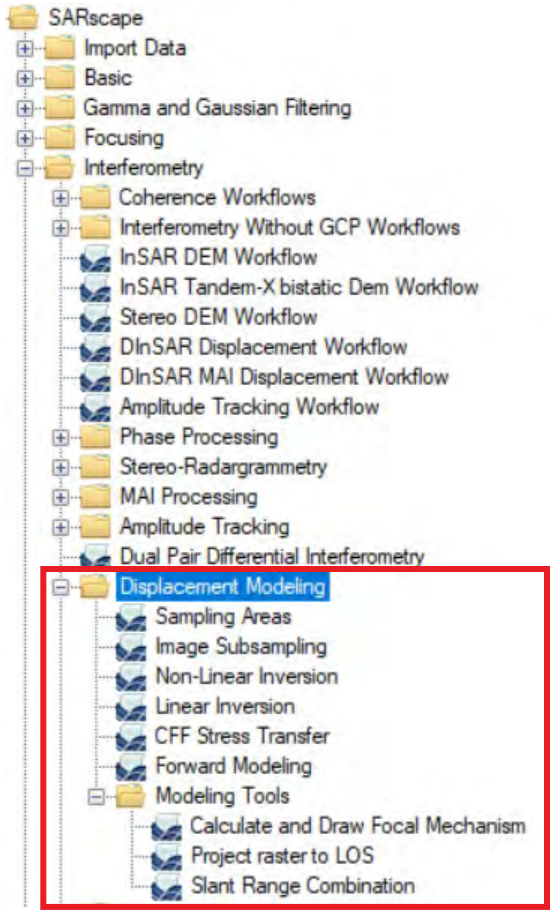
Regional Moment Tensor (Mwr)

Moment	6.940e+15 N-m
Magnitude	4.49 Mwr
Depth	2.0 km
Percent DC	66%



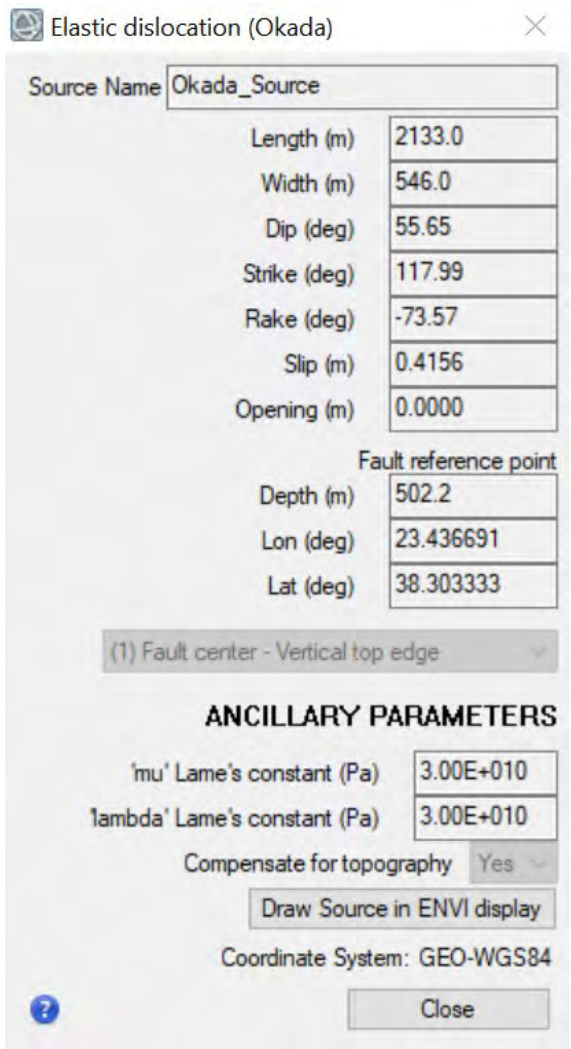
Nodal Planes

Plane	Strike	Dip	Rake
NP1	272°	40°	-102°
NP2	108°	51°	-80°



Sarscape

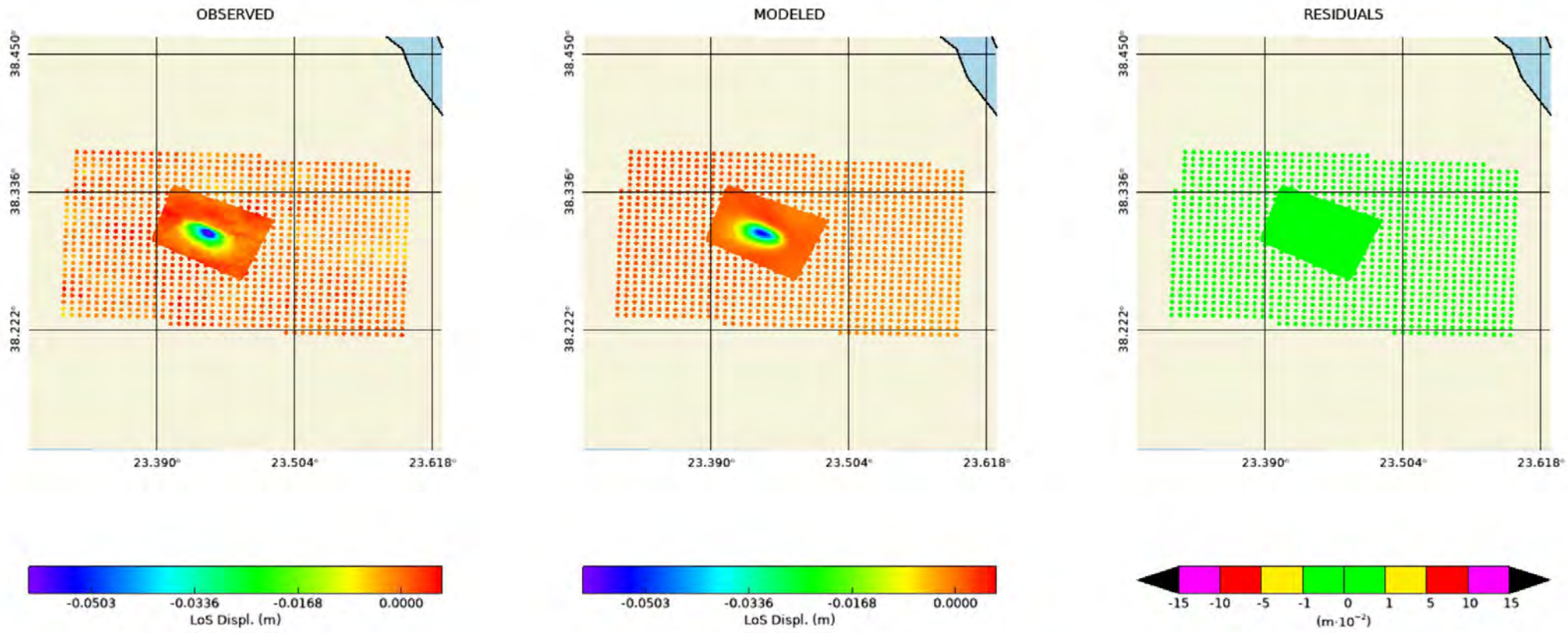
Geophysical modeling tool



SAR SESSIONS

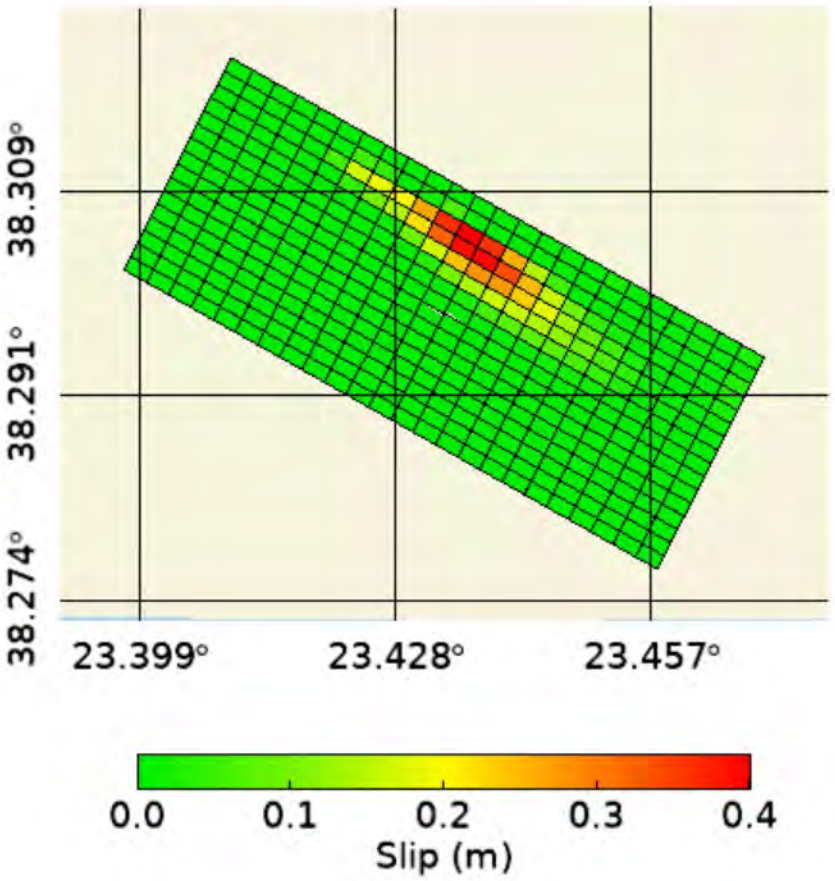
Geophisycal modeling of the seismic event

Non-Linear Inversion step - Descending dataset

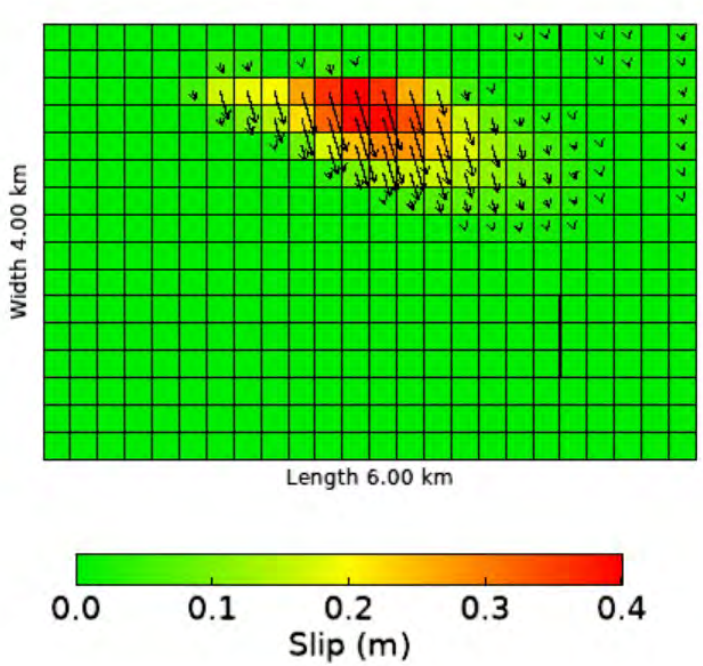


This inversion approach is used to find the best-fit source parameters by minimizing a Cost Function based on the difference between observed and predicted geodetic data. In this inversion every source parameter are inferred from geodetic data. Specifically Non-Linear inversion is retrieving the fault parameters for the earthquake (source dimension, location, depth, mechanism, etc.)

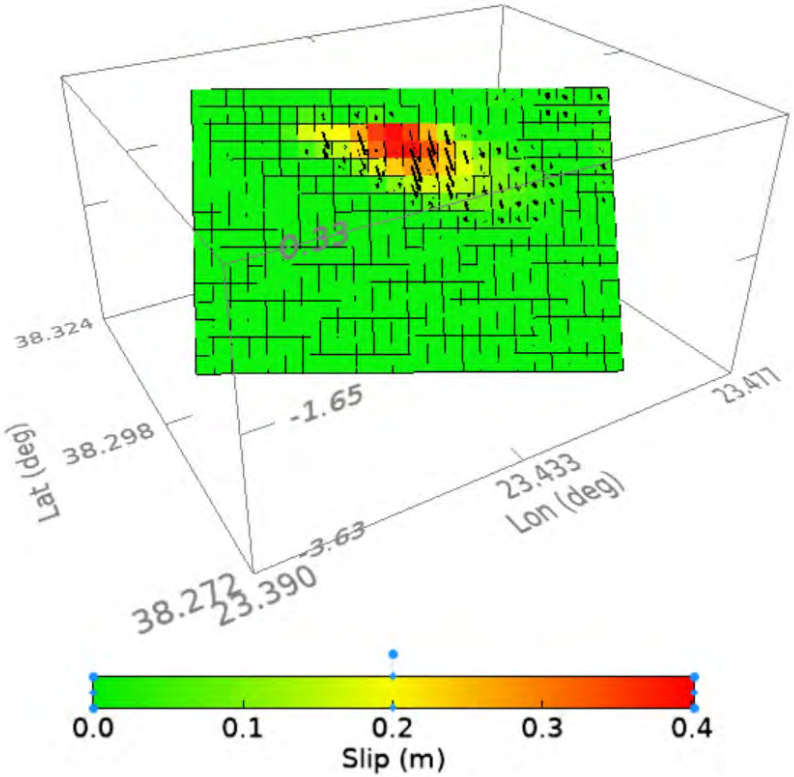
Geophisycal modeling of the seismic event



Linear Inversion step



The linear inversion is generally carried out after the Non-Linear Inversion out to retrieve a slip distribution over a fault

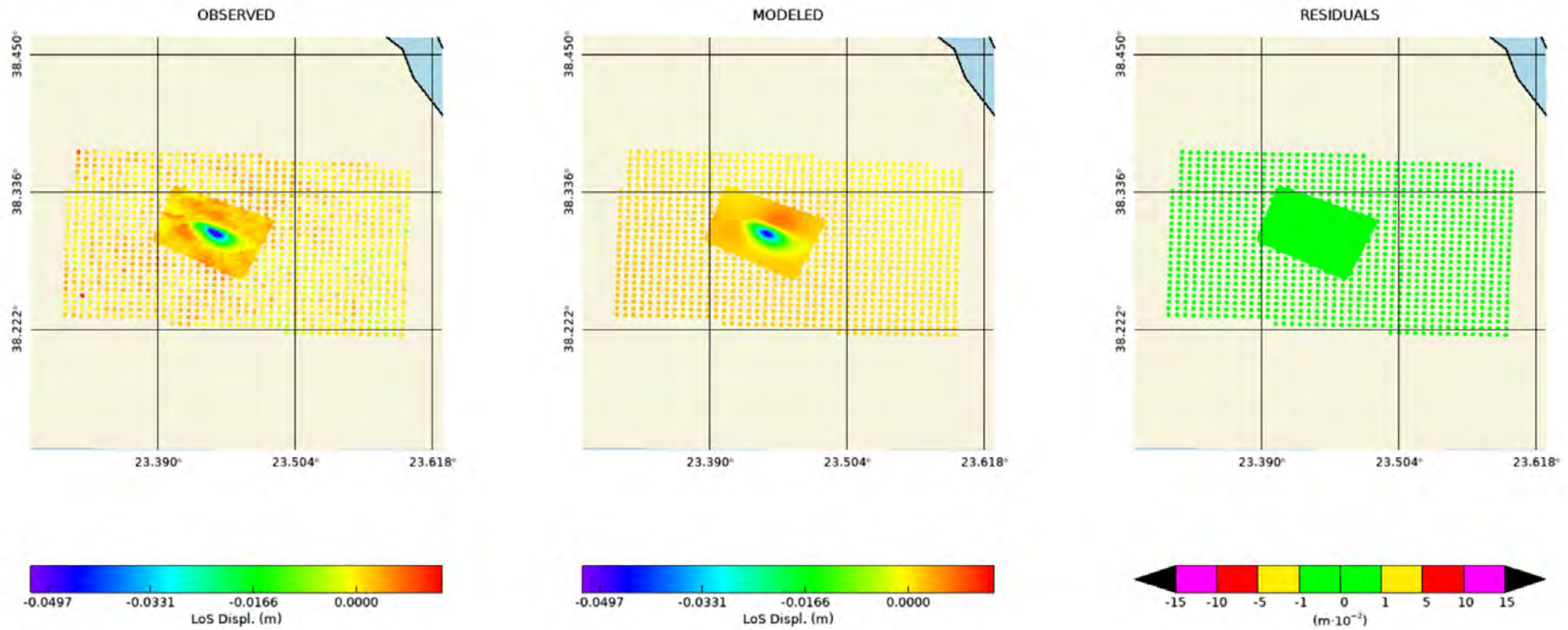


INVERSION RESULTS:
Overall geodetic moment: 1.63E+016 N*m
Moment Magnitude: 4.77

Okada_Source (OKADASOURCE type)
Number of source features: 384
Geodetic Moment: 1.63E+016 N*m
Strike, Dip, Rake (deg): Multiple values, 55.65, -73.57
Slip values (min/max): 0.0000/0.4013 m
Invert for: Distributed and positive slip with fixed rake
Topography compensation applied
Reference point: (4) Fault trace center - Along dip top edge

Geophisycal modeling of the seismic event

Linear Inversion step - Ascending dataset



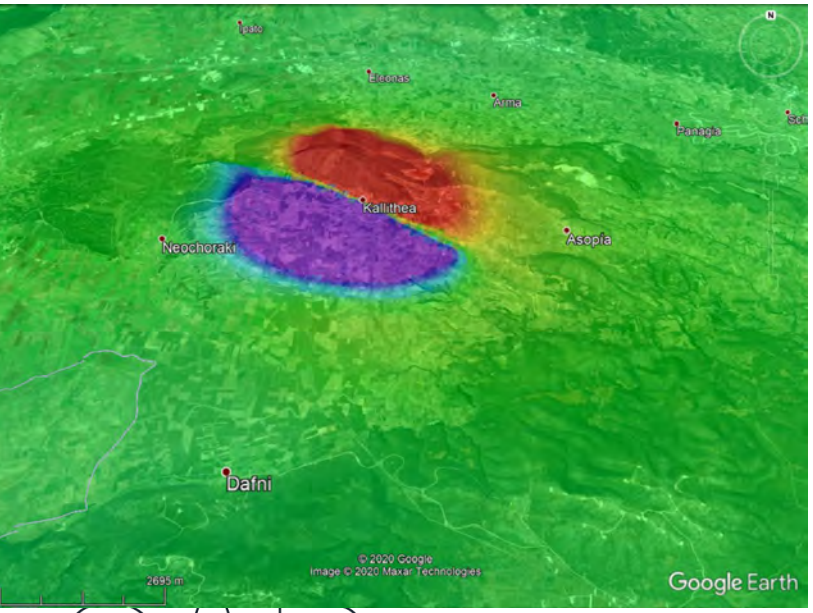
SAR SESSIONS

Geophisycal modeling of the seismic event

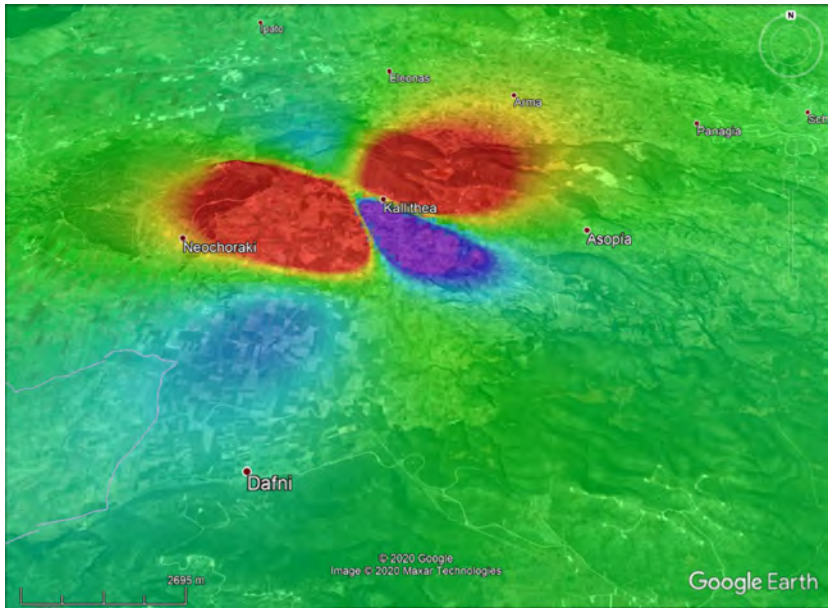
Forward model

Forward modeling is used to generate the surface displacement due to any combination of geophysical sources, in a geocoded or slant range geometry

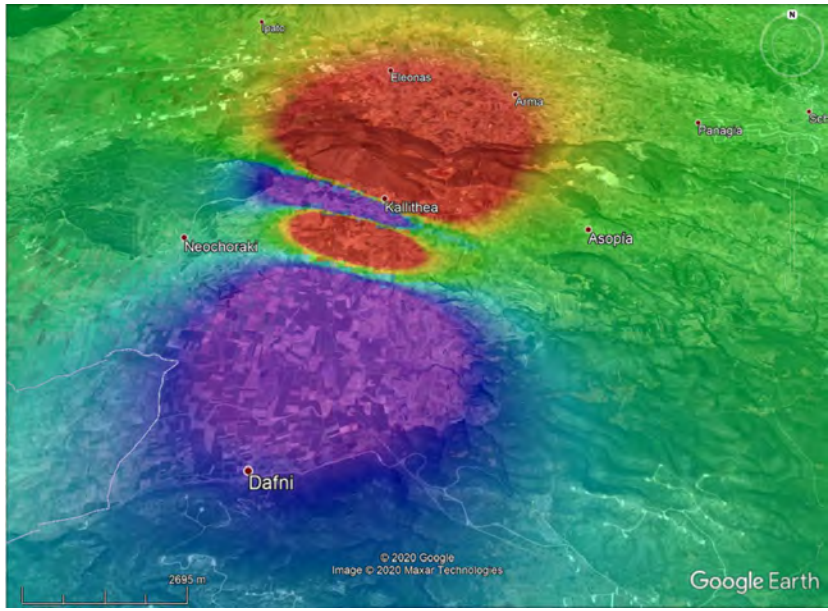
Vertical component



East-West component



North-South component



SAR SESSIONS

Multi-temporal Interferometric Techniques

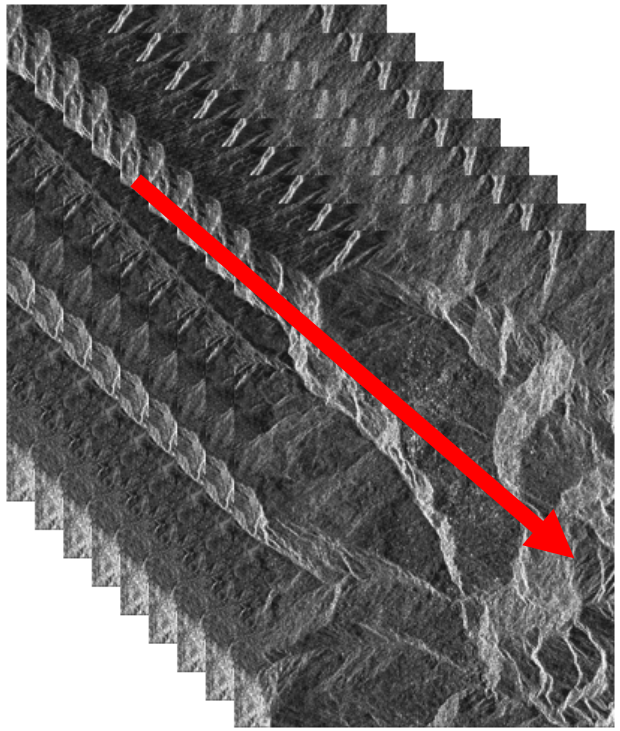
PS vs SBAS

SAR SESSIONS

sarmap
your information gateway

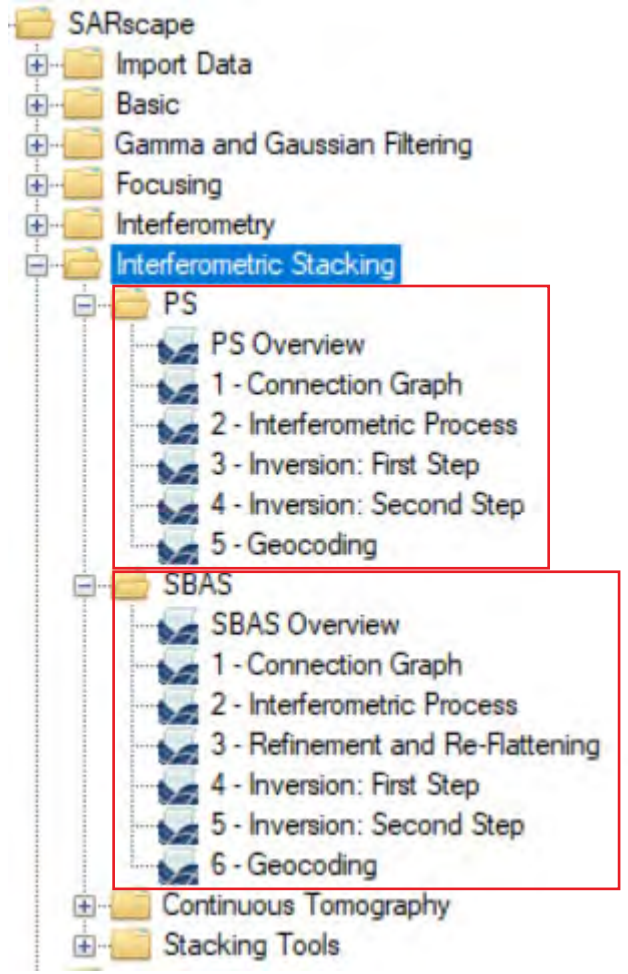
Multi-temporal Interferometric techniques

$$\phi_{Int} = \phi_{Topography} + \phi_{Change} + \phi_{Movement} + \phi_{Atmosphere}$$



- Persistent Scatterers (PS)
- Small Baseline Subset (SBAS)

PS	SBAS
Independent, incorrelated motions	At best spatially correlated motions
Pixelwise continuous time series	Possibility of handling time seriers with temporal holes
Time interval between two acquisitions limited by displacement rate	Time interval between two acquisitions limited by temporal decorrelation
Very accurate on PS	Slightly less accurate
Linear displacements favoured	Larger variety of parametric models possible. Non-parametric modeling possible



SAR SESSIONS

Cadia Mine - Australia

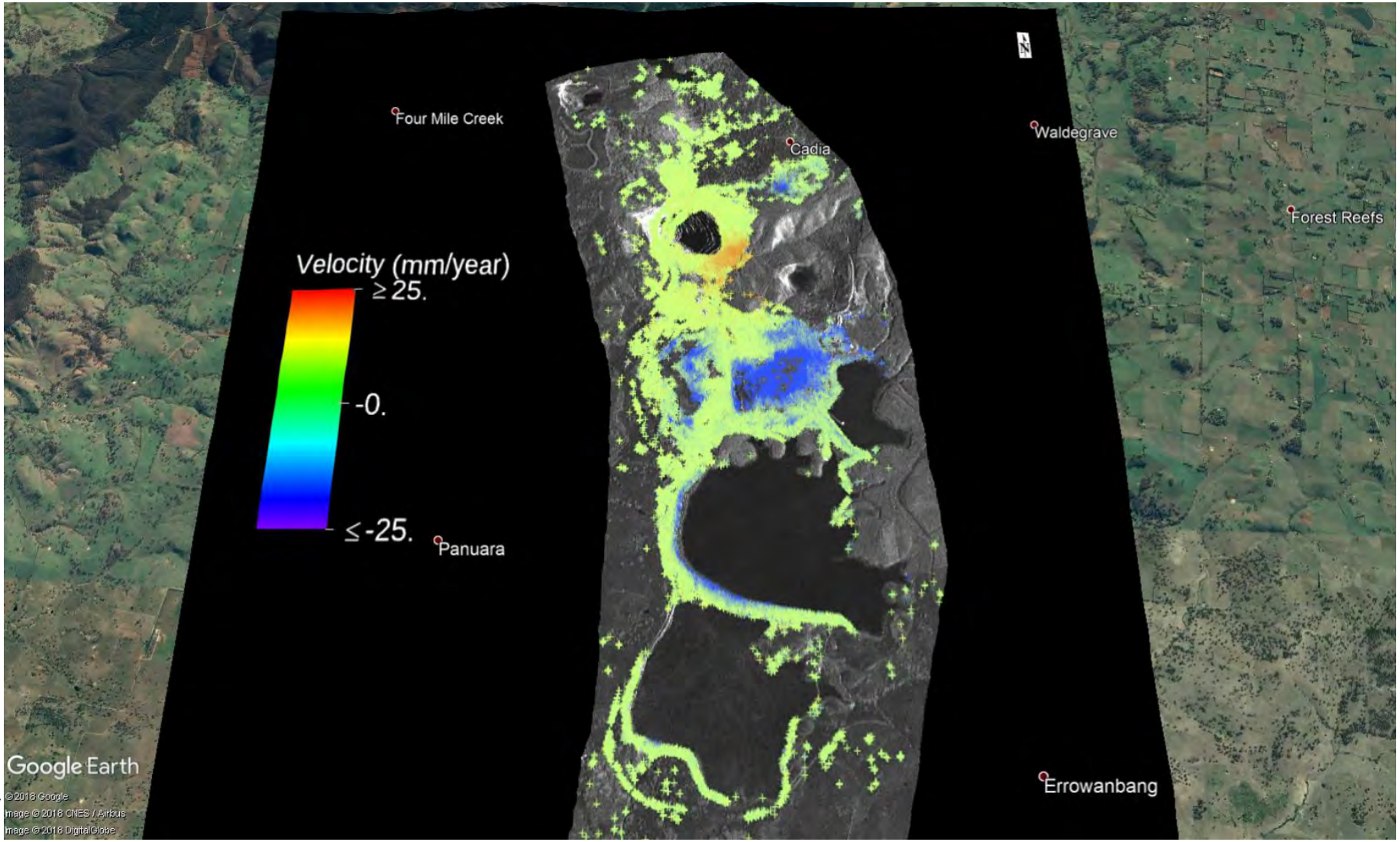
An aerial image showing the collapsed section of the tailings dam.
Photo: Supplied

SAR SESSIONS

Cadia Mine – Australia
Sentinel-2 Optical image

SAR SESSIONS

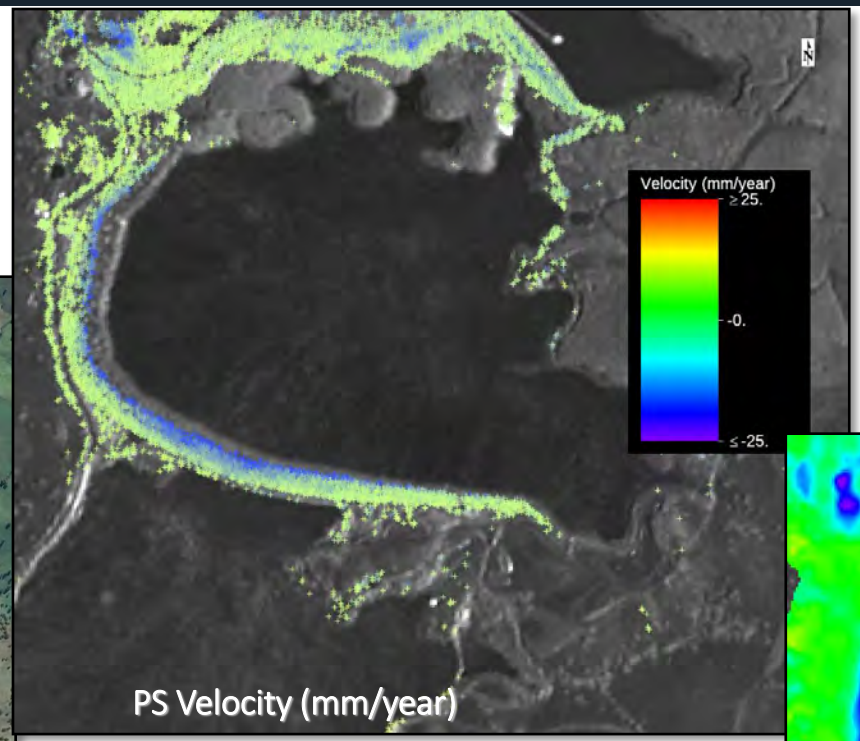
Cadia Mine – Australia
Sentinel-1 PS Deformation map [mm/yr]

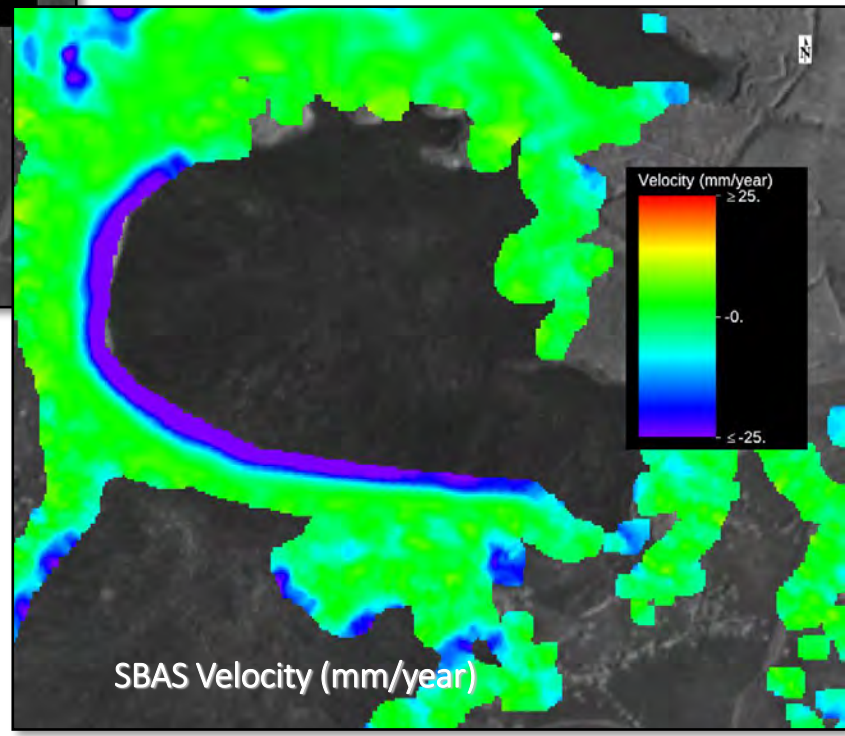


SAR SESSIONS

Cadia Mine – Australia
Sentinel-1 Deformation map [mm/yr] PS vs SBAS

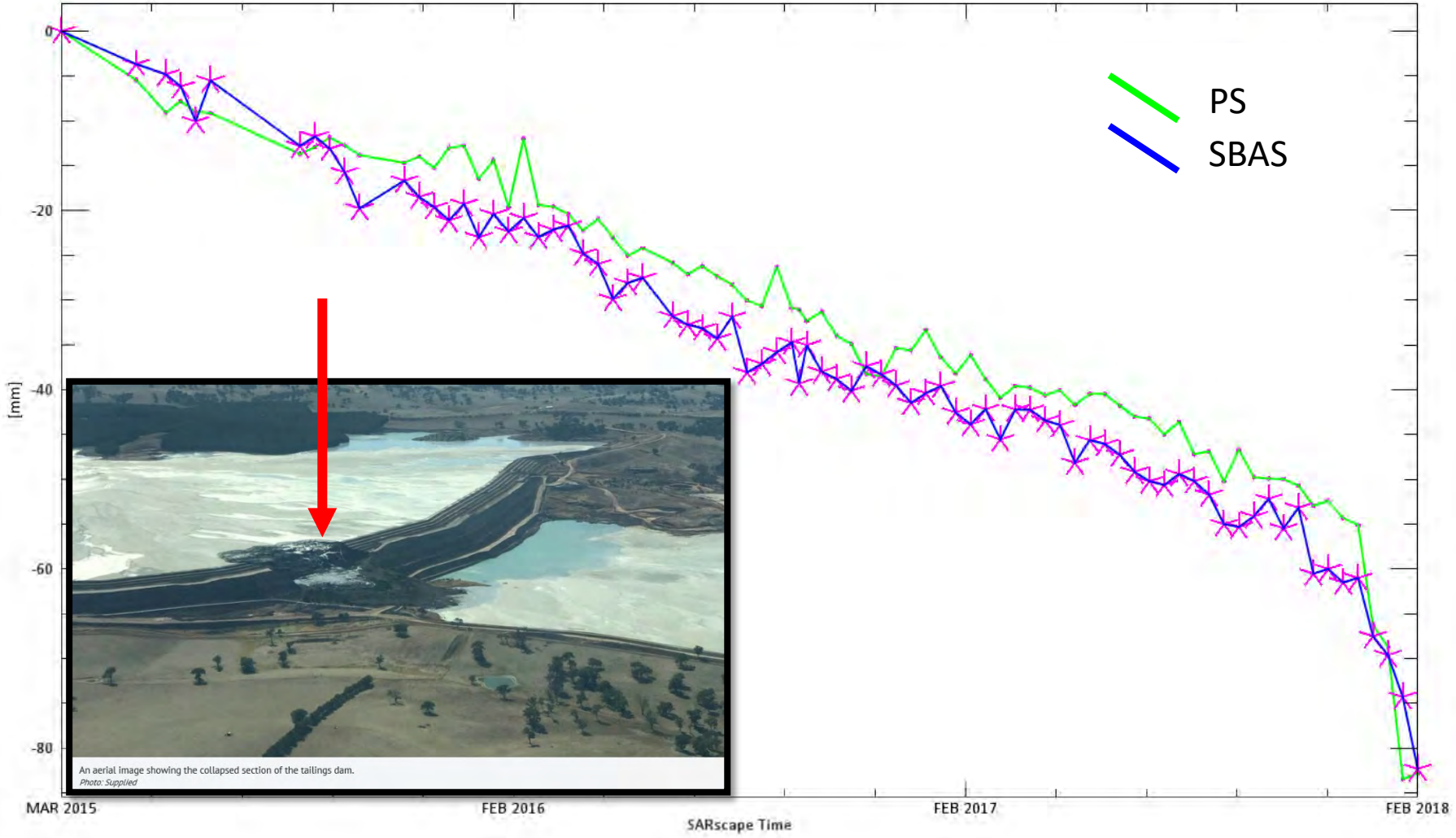
Stacking analysis Results on the tailing dam





SAR SESSIONS

Cadia Mine – Australia
Time-series of deformation [mm] PS vs SBAS



SAR SESSIONS

Mosul Dam, Iraq – PS, Cosmo-SkyMed

61 ascending Stripmap data from December 2012 to July 2015

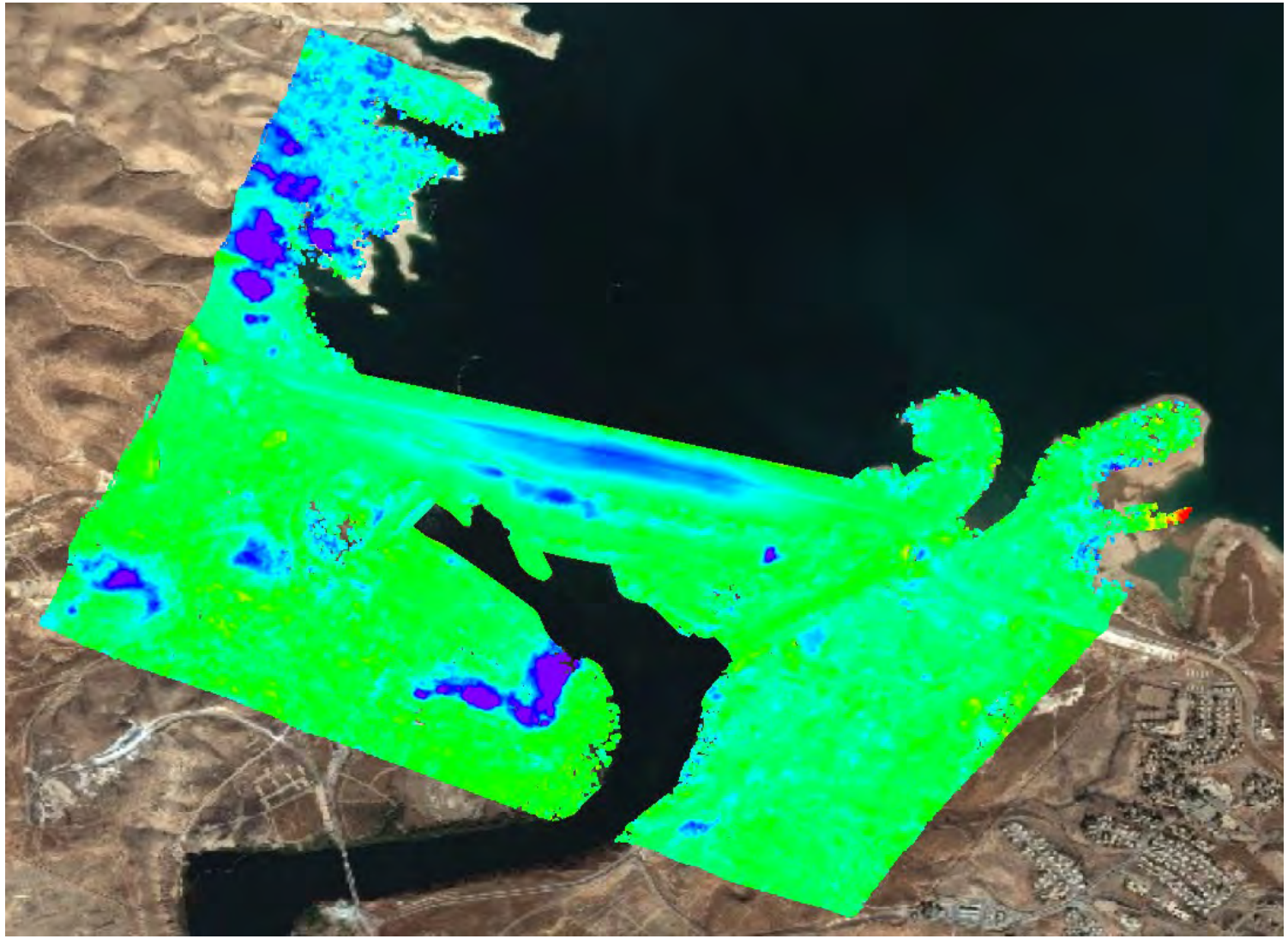
Vel [mm/yr]

-10

+10

SAR SESSIONS

Mosul Dam, Iraq – SBAS, Cosmo-SkyMed



61 ascending Stripmap data from December 2012 to July 2015

Vel [mm/yr]

-10

+10

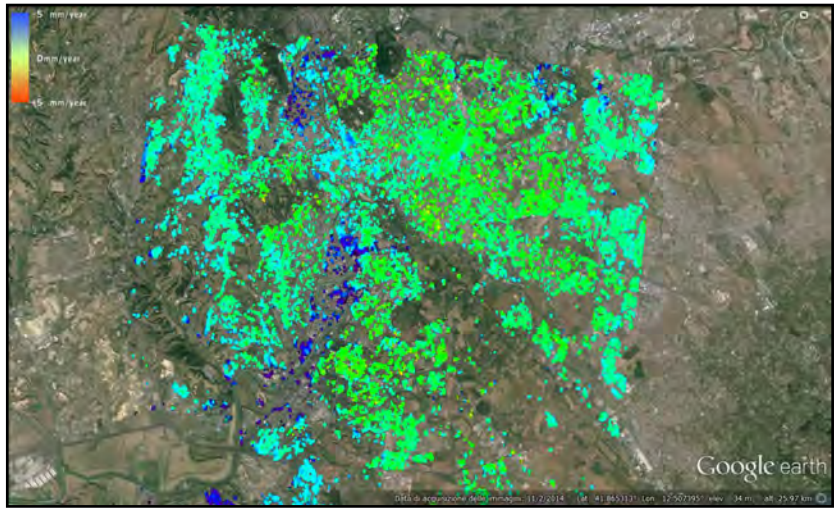
SAR SESSIONS

When should you use the Persistent Scatterers (PS) technique?

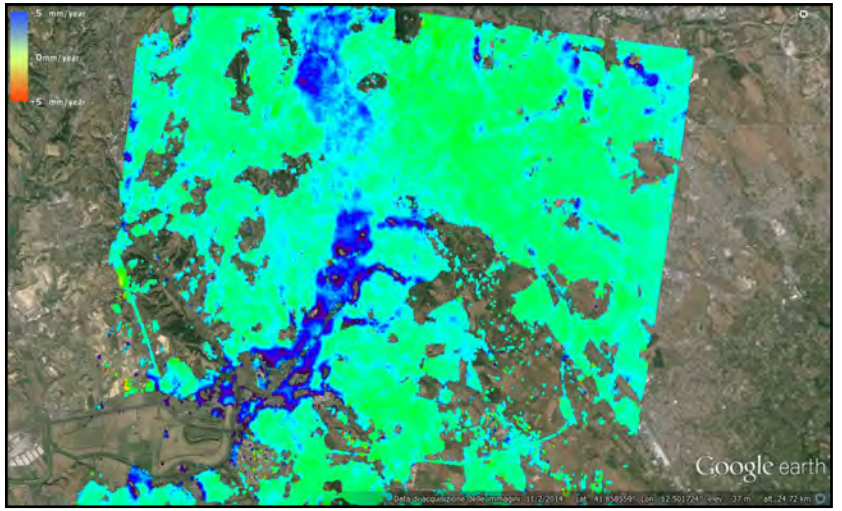
SAR SESSIONS

sarmap
your information gateway

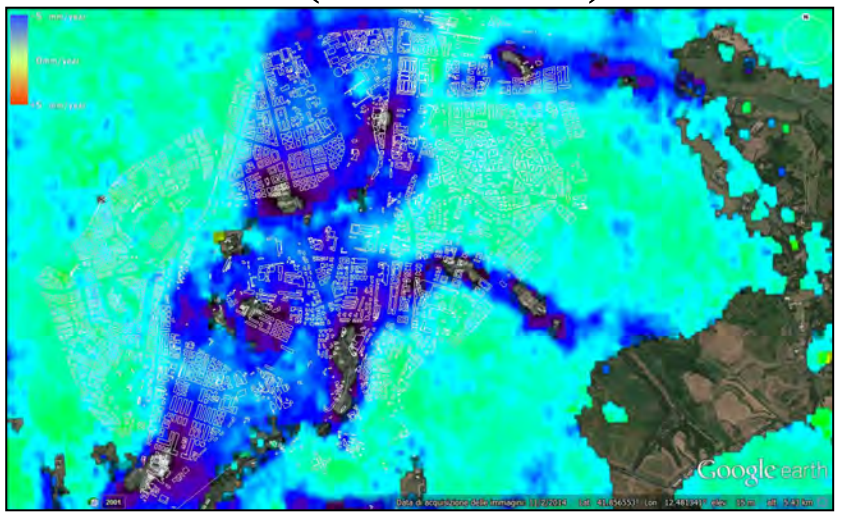
Subsidence in Rome,
ERS and ENVISAT



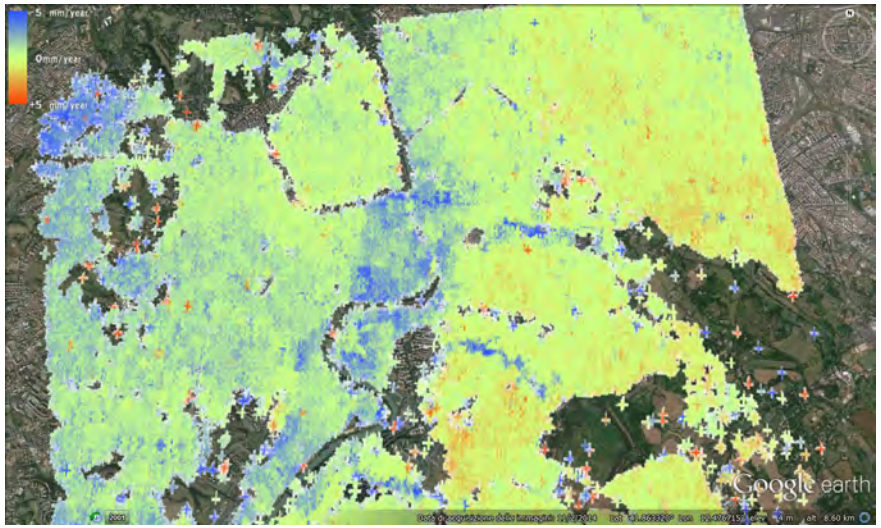
ERS-1/2 (1992 – 2000)



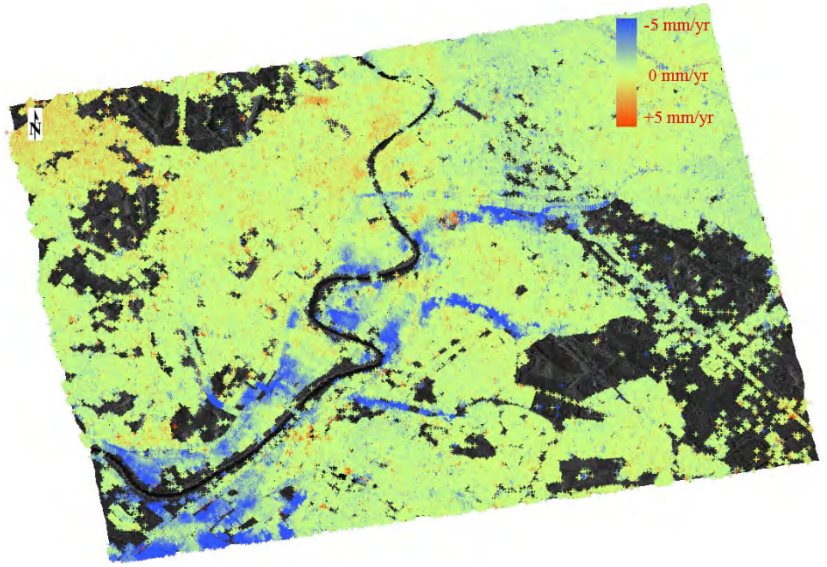
ENVISAT (2002 – 2010)



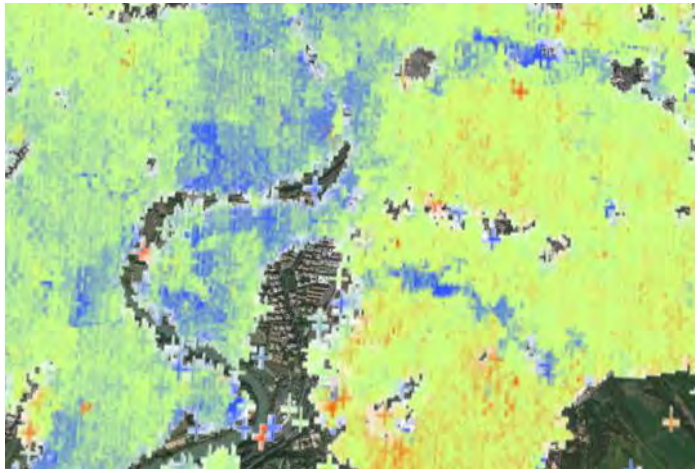
Subsidence in Rome, CosmoSkyMed and TerraSAR-X

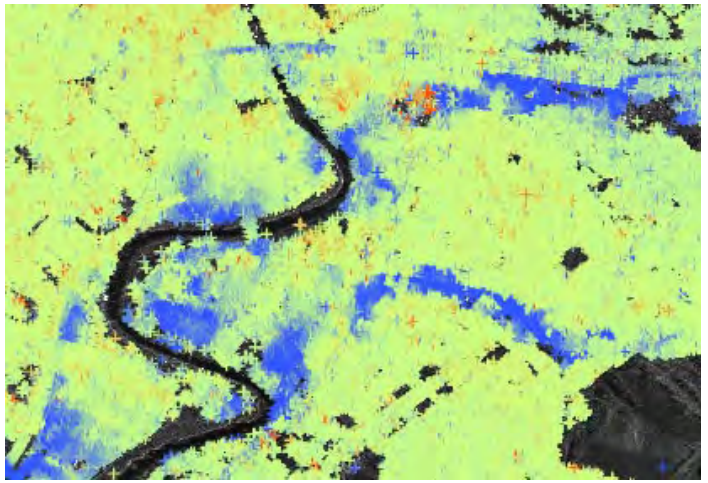


COSMO-SkyMed (2011 – 2012)



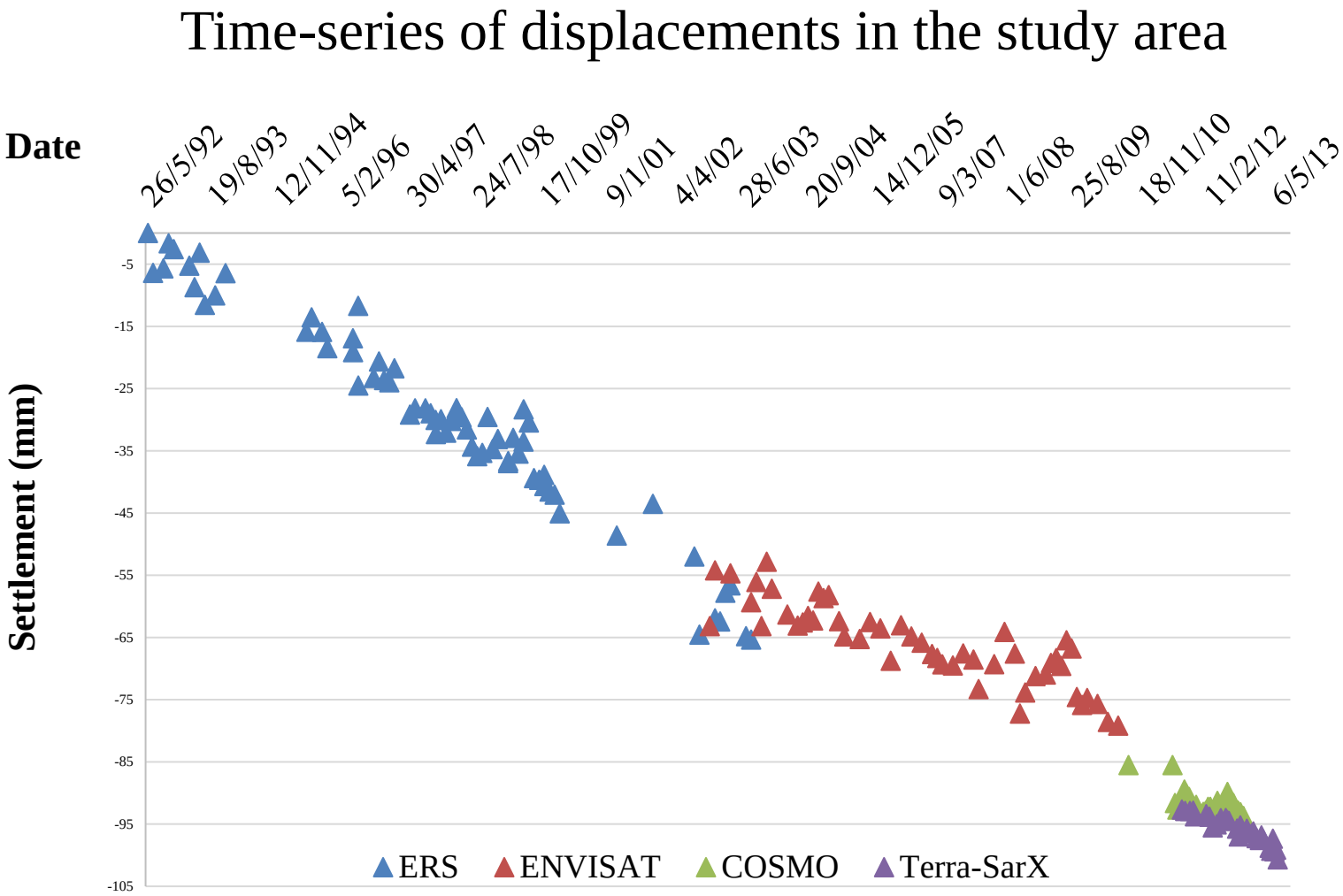
TerraSAR-X (2011 – 2013)



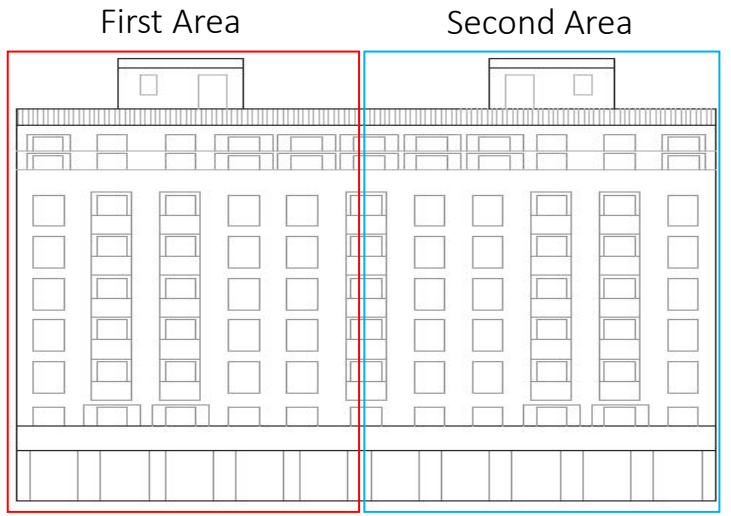


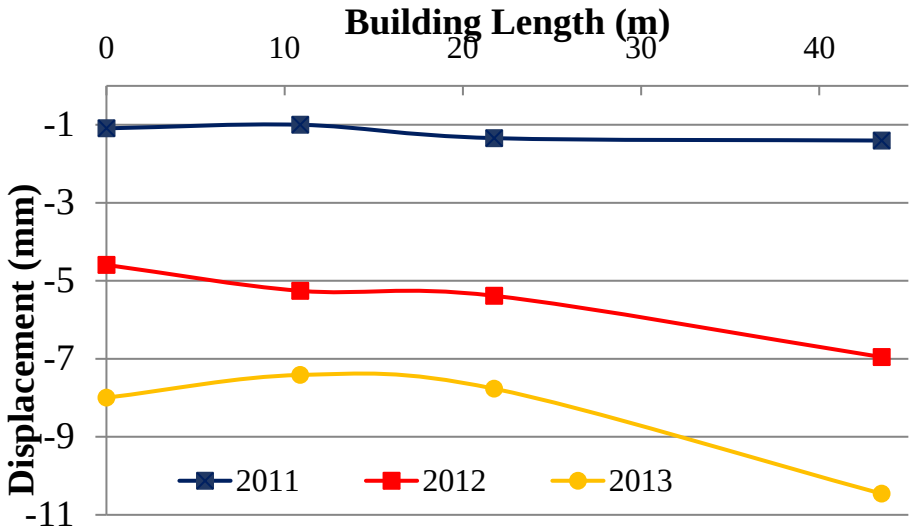
SAR SESSIONS

Subsidence in Rome
Time-series of deformation [mm]



Subsidence in Rome





SAR SESSIONS

Persistent Scatteres
Astana Kazakhstan, Cosmo-SkyMed data

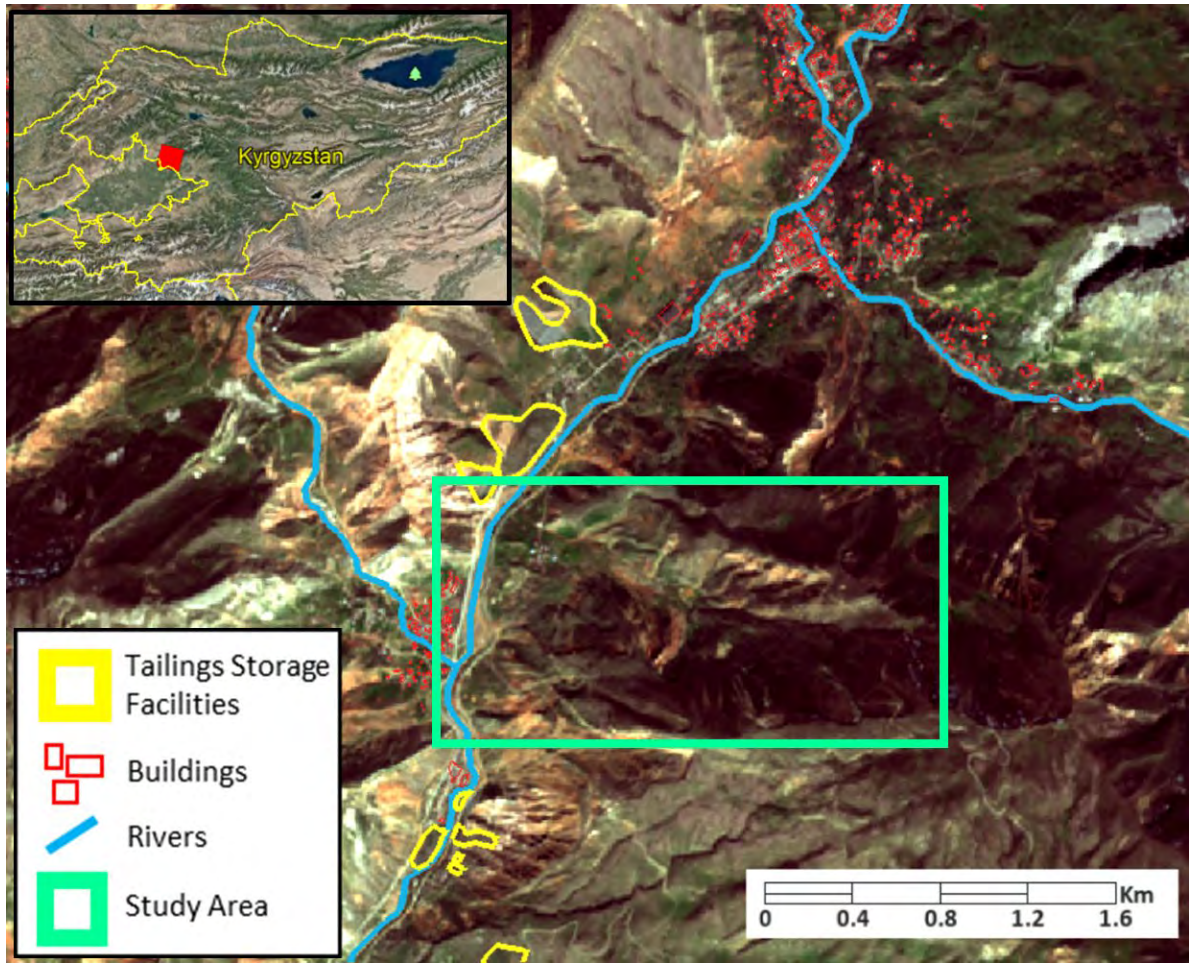
SAR SESSIONS

And when should you use the Small Baseline Subset (SBAS) technique?

SAR SESSIONS

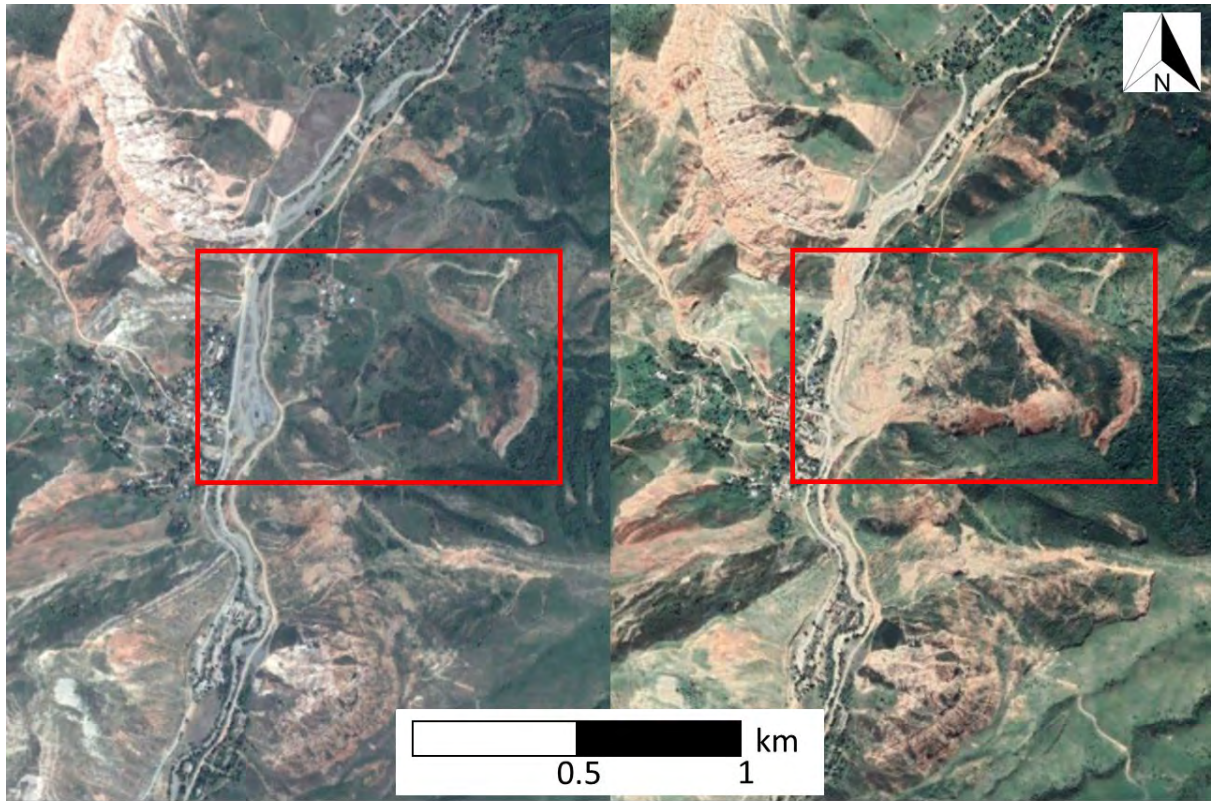
sarmap your information gateway

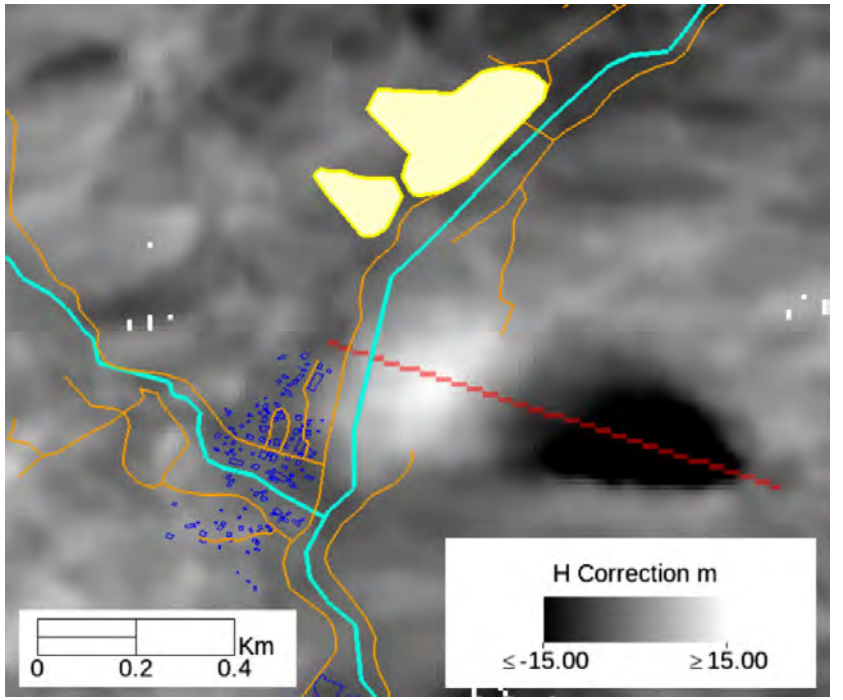
Koitash landslide, Kyrgyzstan



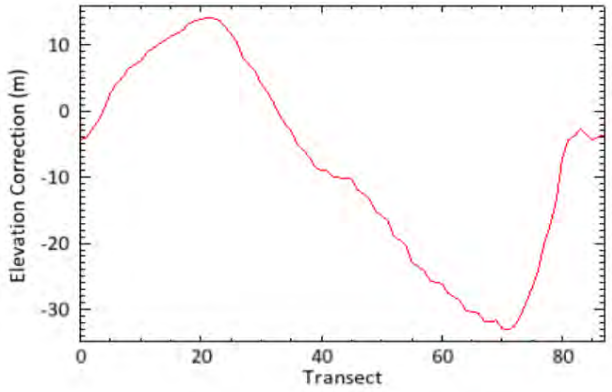
SAR SESSIONS

Koitash landslide, Kyrgyzstan
Topographic correction - SBAS



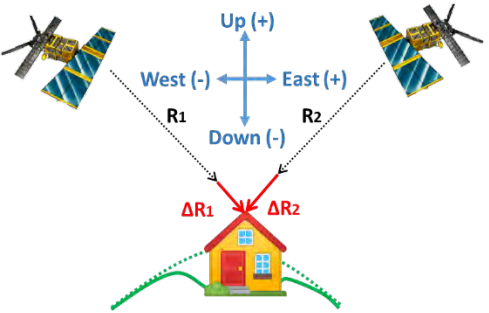


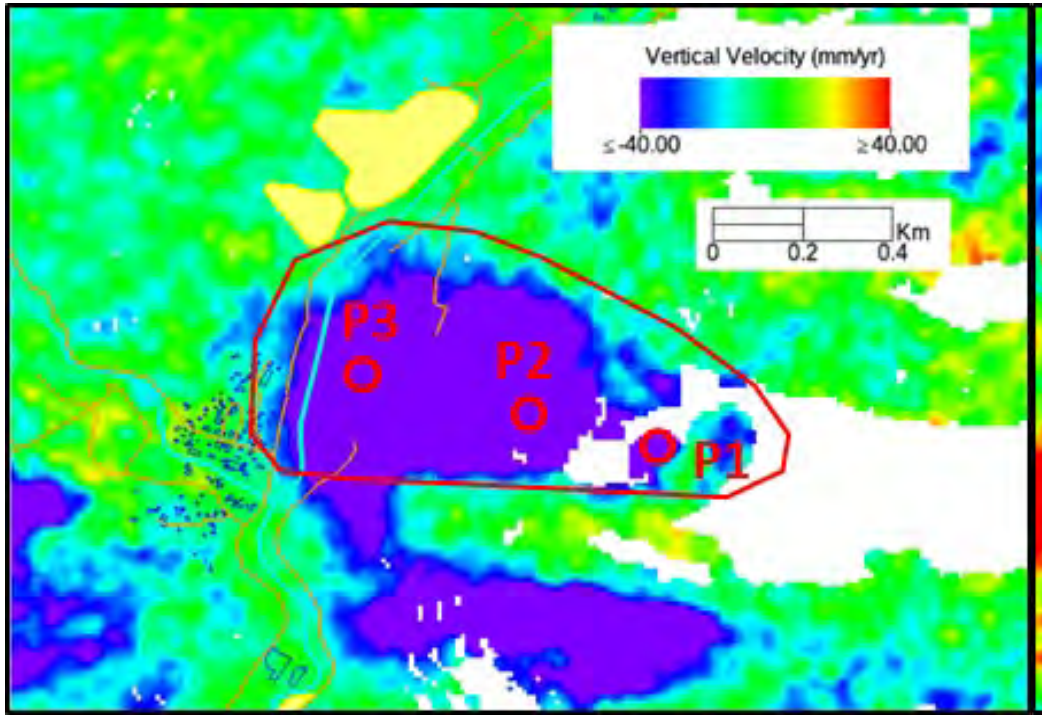
Tailings Storage Facilities
Buildings
Roads
Rivers
Cross section

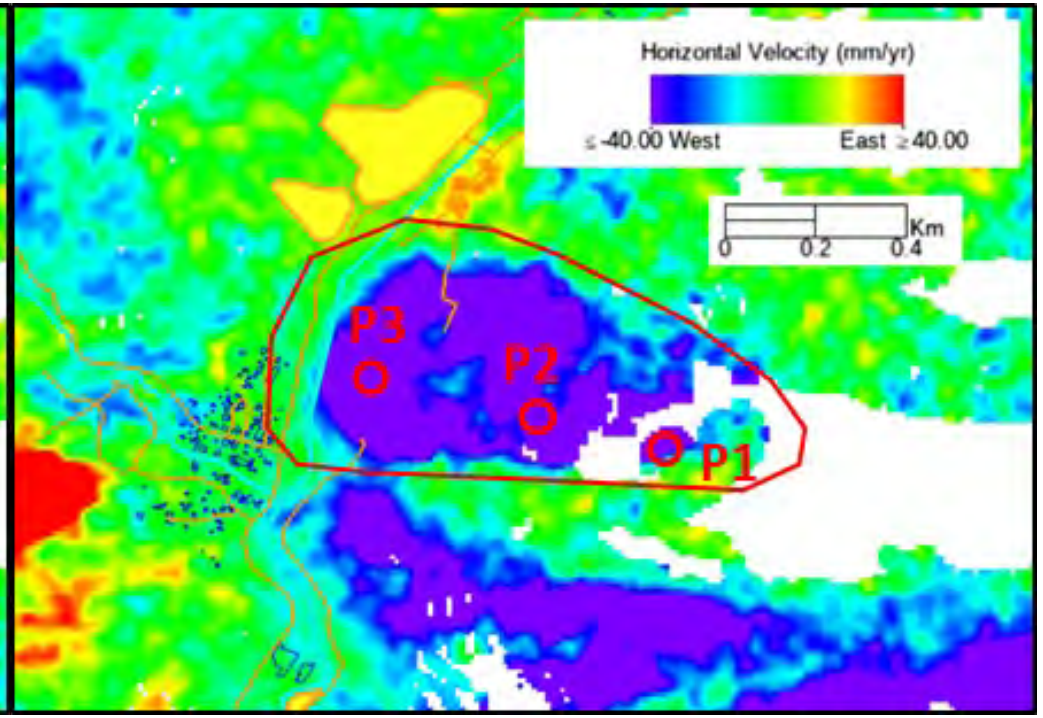


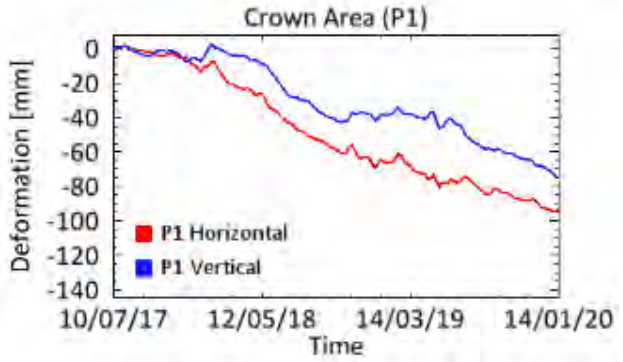
SAR SESSIONS

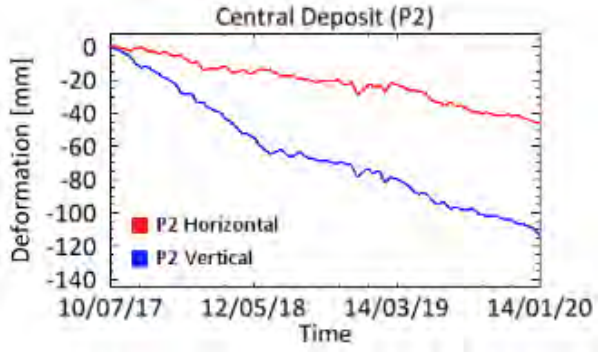
Koitash landslide, Kyrgyzstan
Vertical and Horizontal deformation maps [mm/yr]

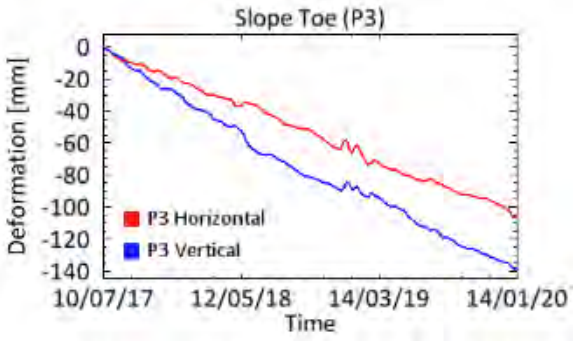












SAR SESSIONS

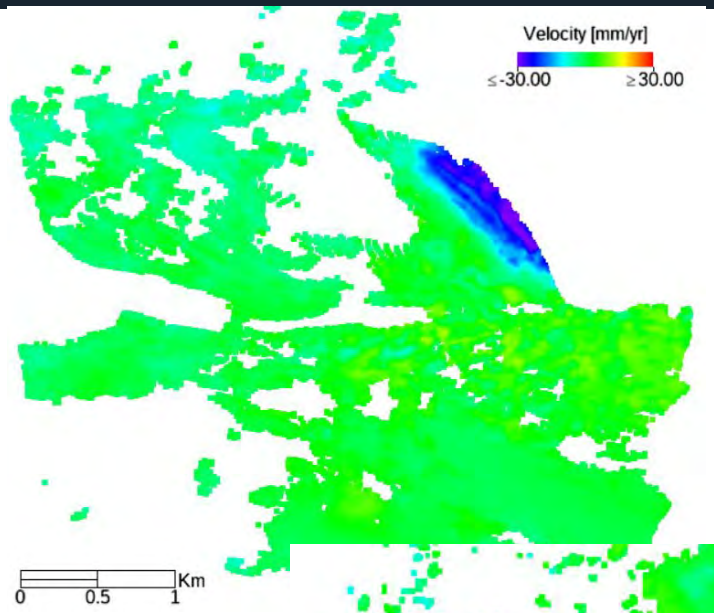
Some more applications

Ataturk Dam, Turkey

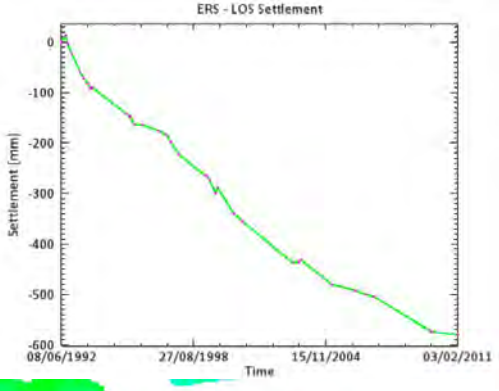
SAR SESSIONS

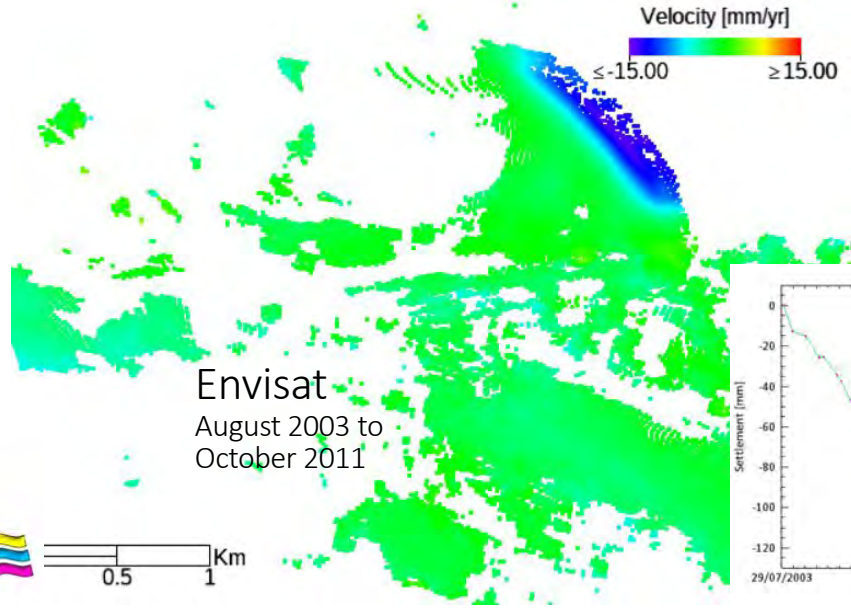
sarmap your information gateway

Ataturk Dam, Turkey
Average deformation maps [mm/yr]

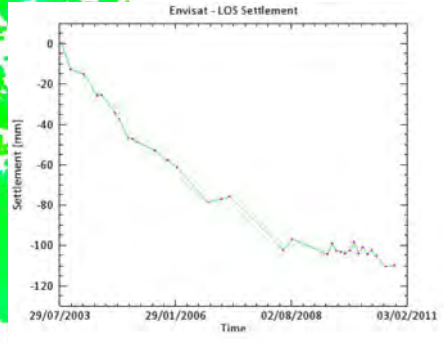


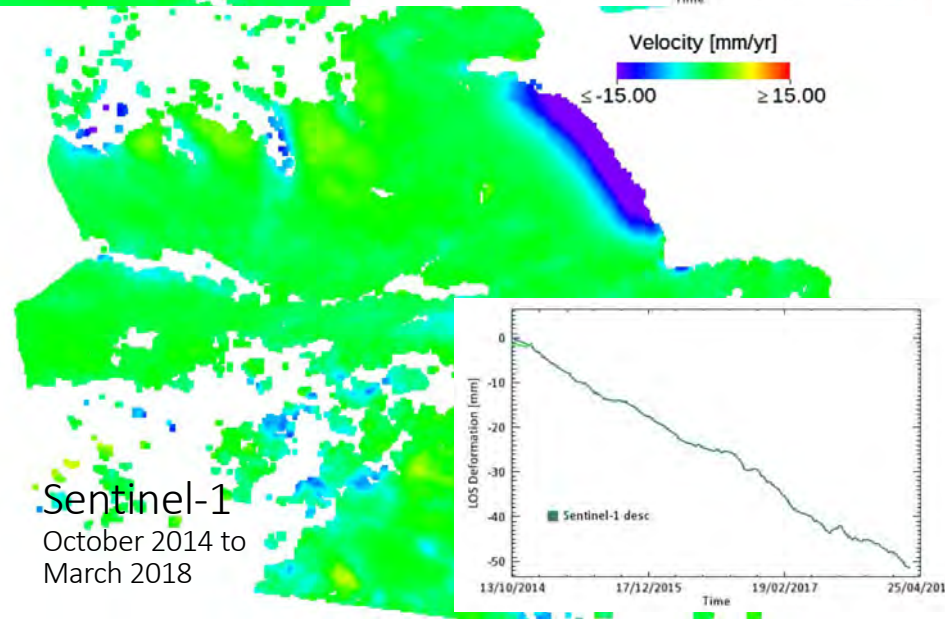
ERS
June 1992 to February 2011





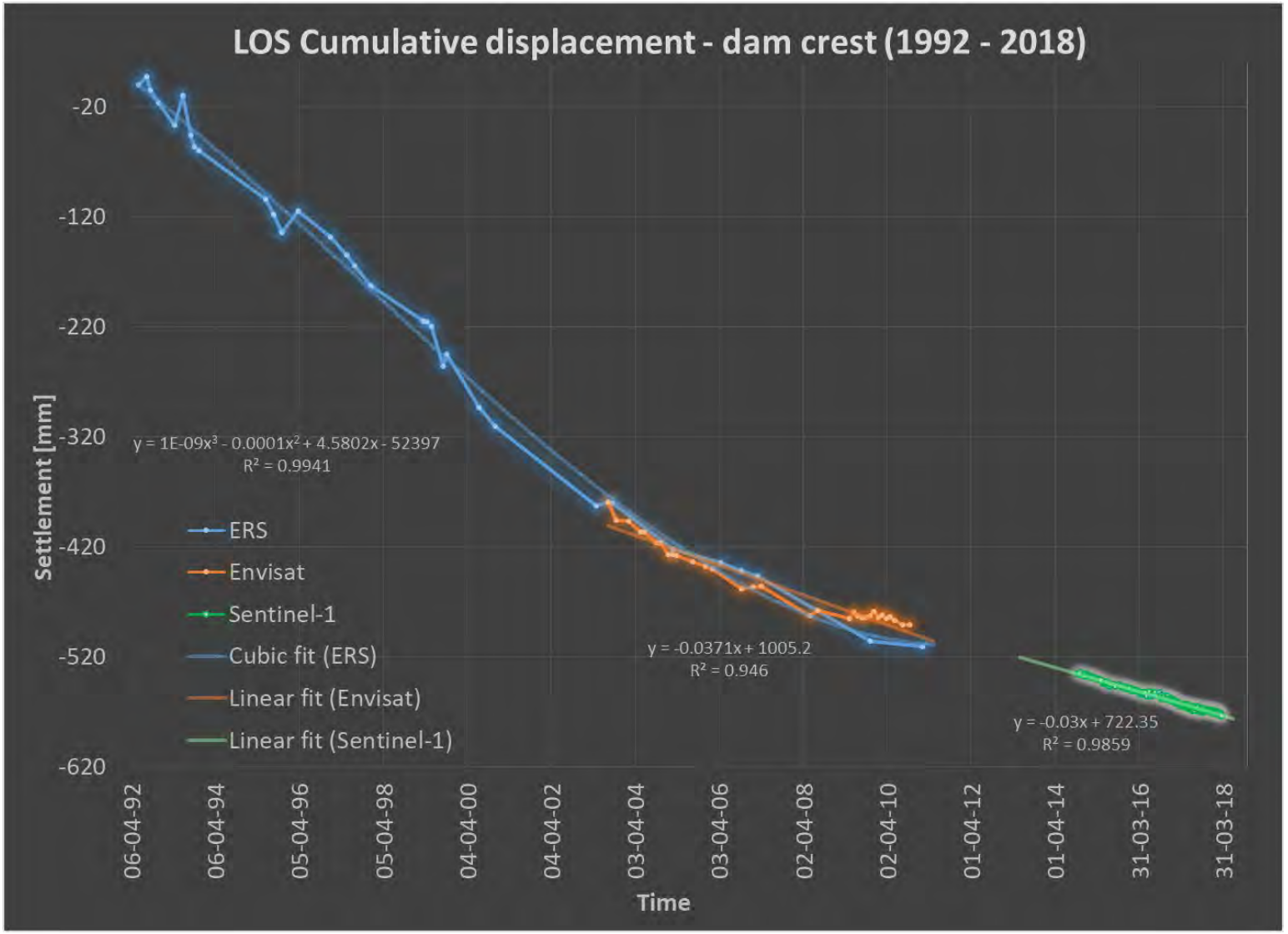
Envisat
August 2003 to October 2011





Sentinel-1
October 2014 to March 2018

Ataturk Dam, Turkey
Time-series of Deformations



Some more applications

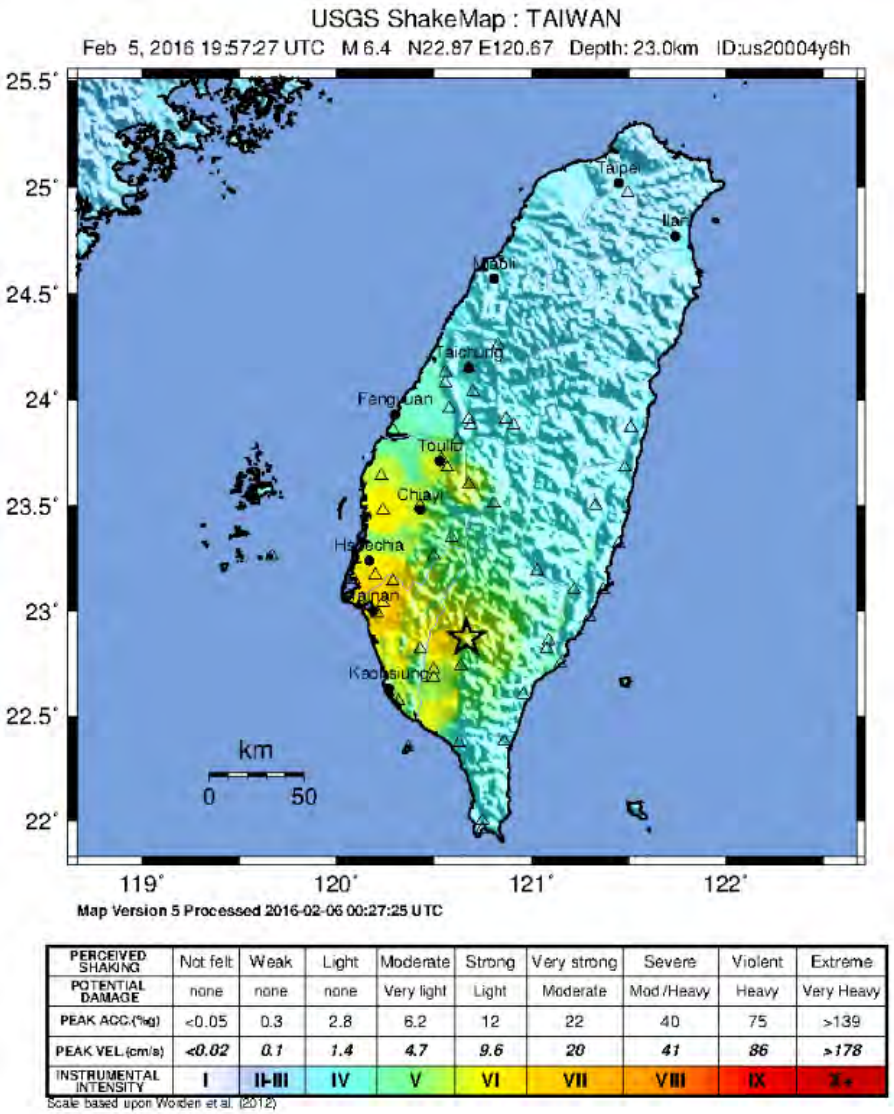
The February 2016 Mw 6.4 Taiwan Earthquake

SAR SESSIONS

sarmap your information gateway

The February 2016 Mw 6.4 Taiwan Earthquake

Date: 06 February 2016
Magnitudo: 6.4
Fatalities: 117



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

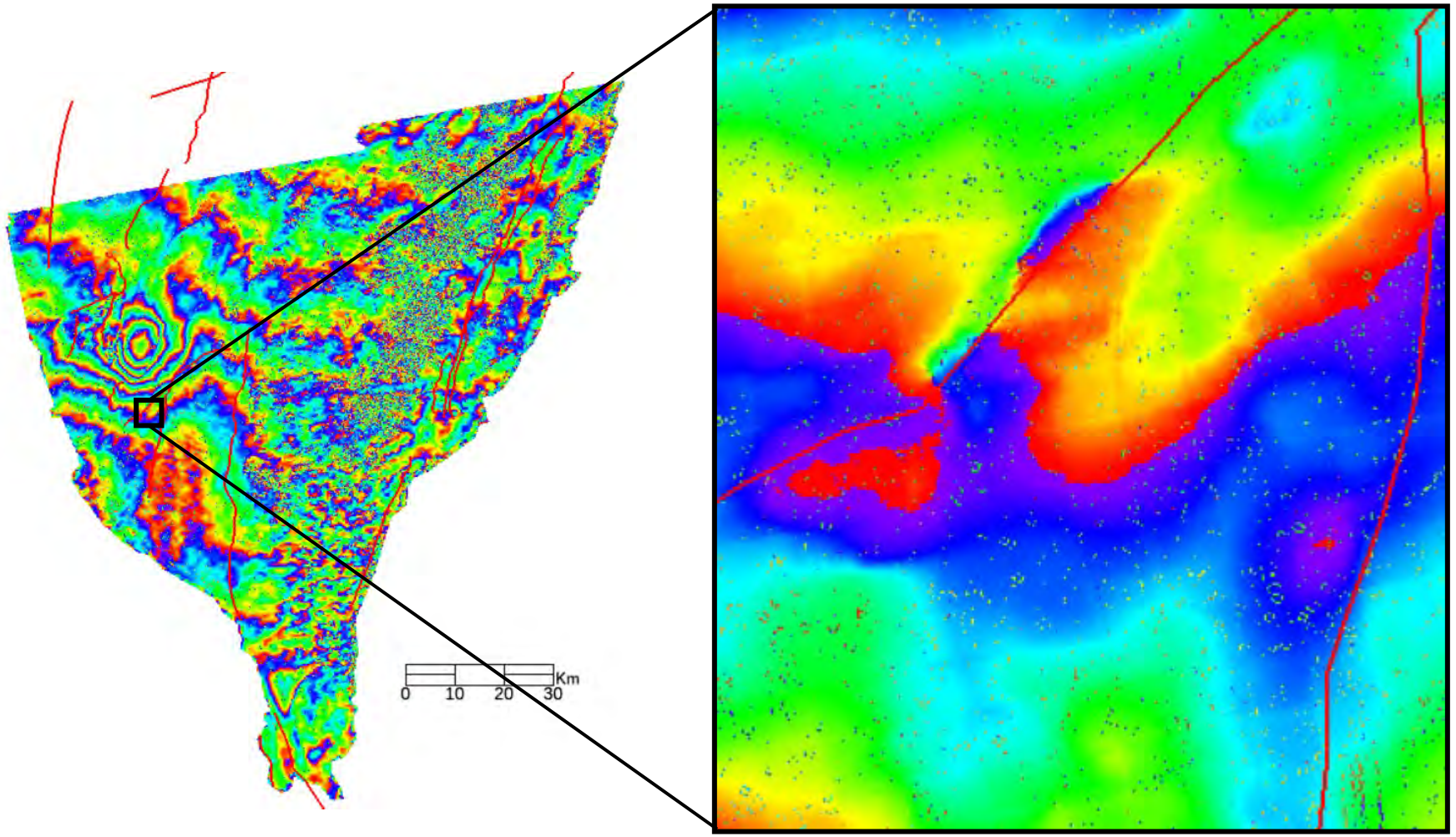
Scale based upon Worden et al. (2012)

SAR SESSIONS

The February 2016 Mw 6.4 Taiwan Earthquake

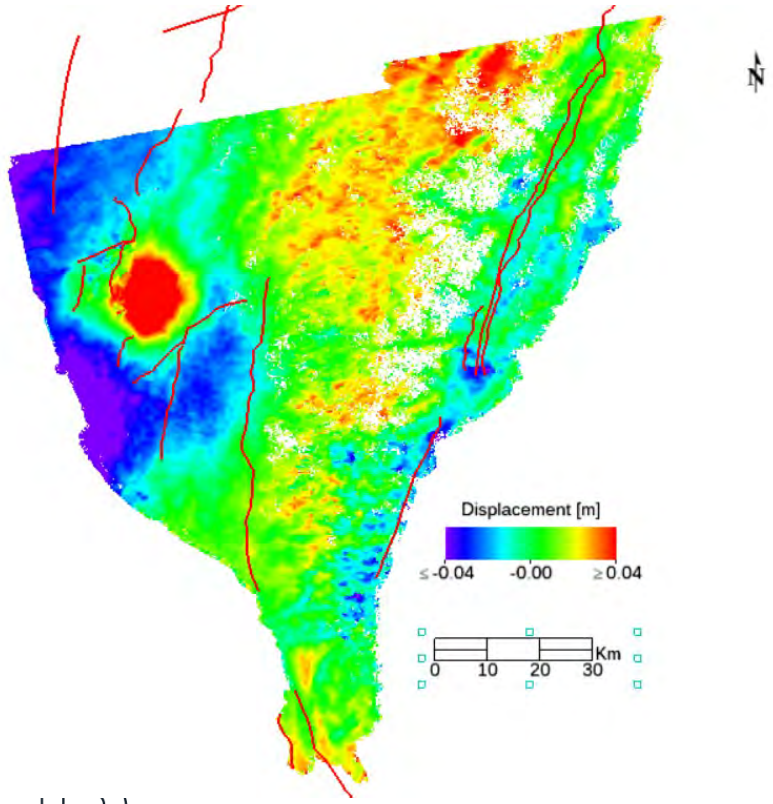
Co-seismic fringes (2016/02/02 – 2016/02/14)

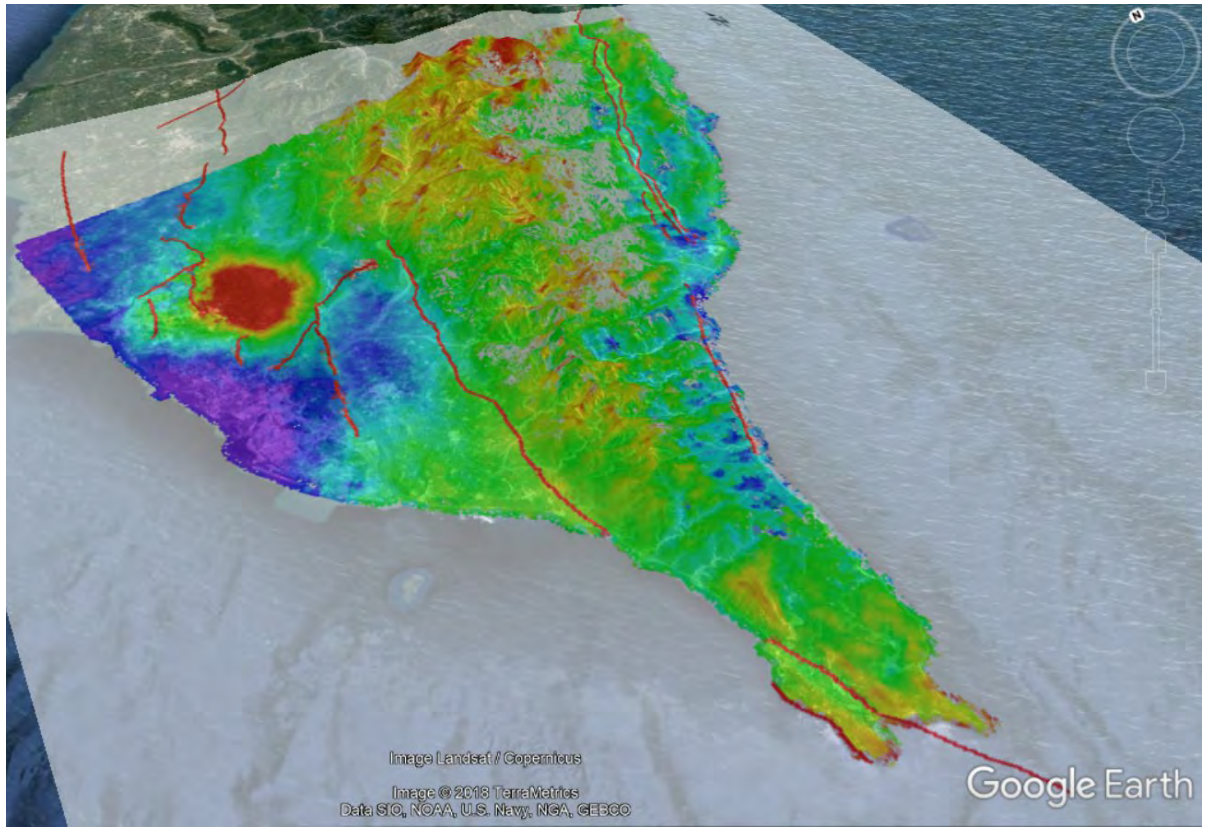
sarmap
your information gateway



SAR
SESSIONS

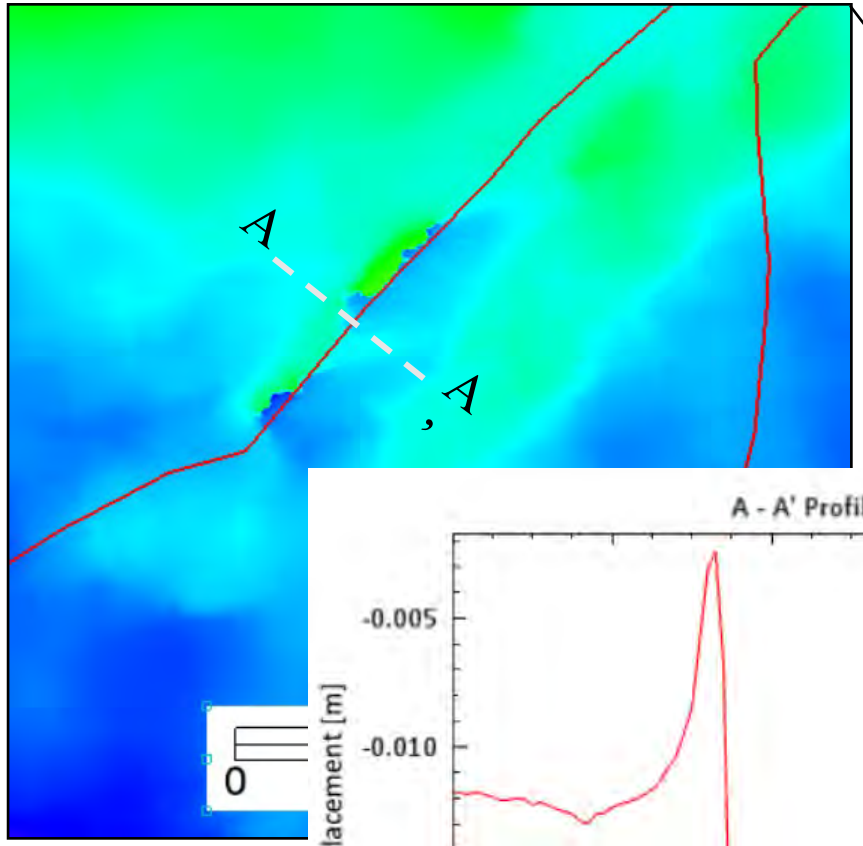
The February 2016 Mw 6.4 Taiwan Earthquake
Displacement (2016/02/02 – 2016/02/14)

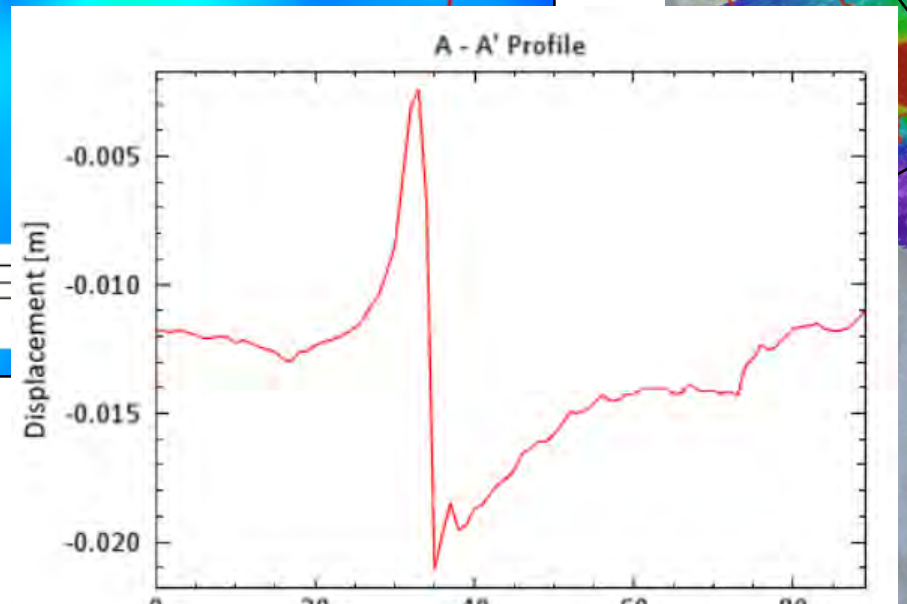


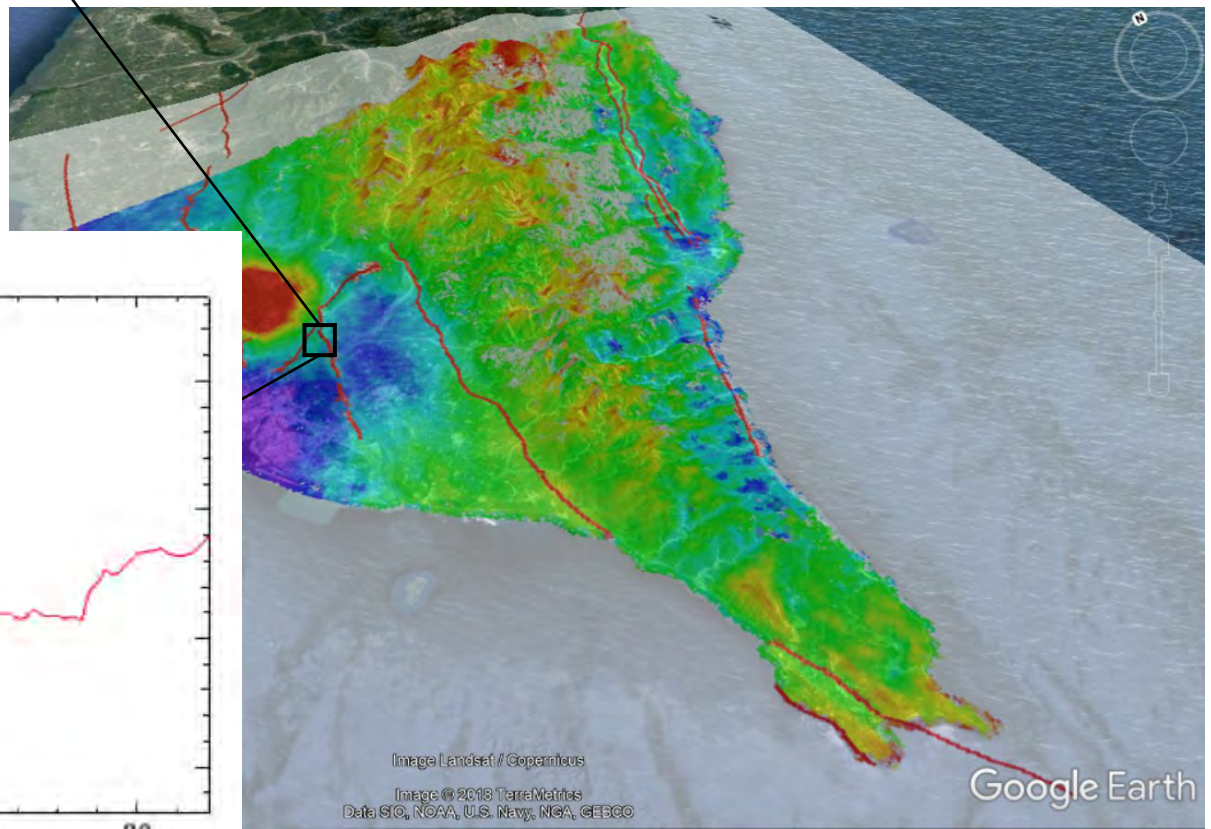


SAR SESSIONS

The February 2016 Mw 6.4 Taiwan Earthquake
Displacement (2016/02/02 – 2016/02/14)

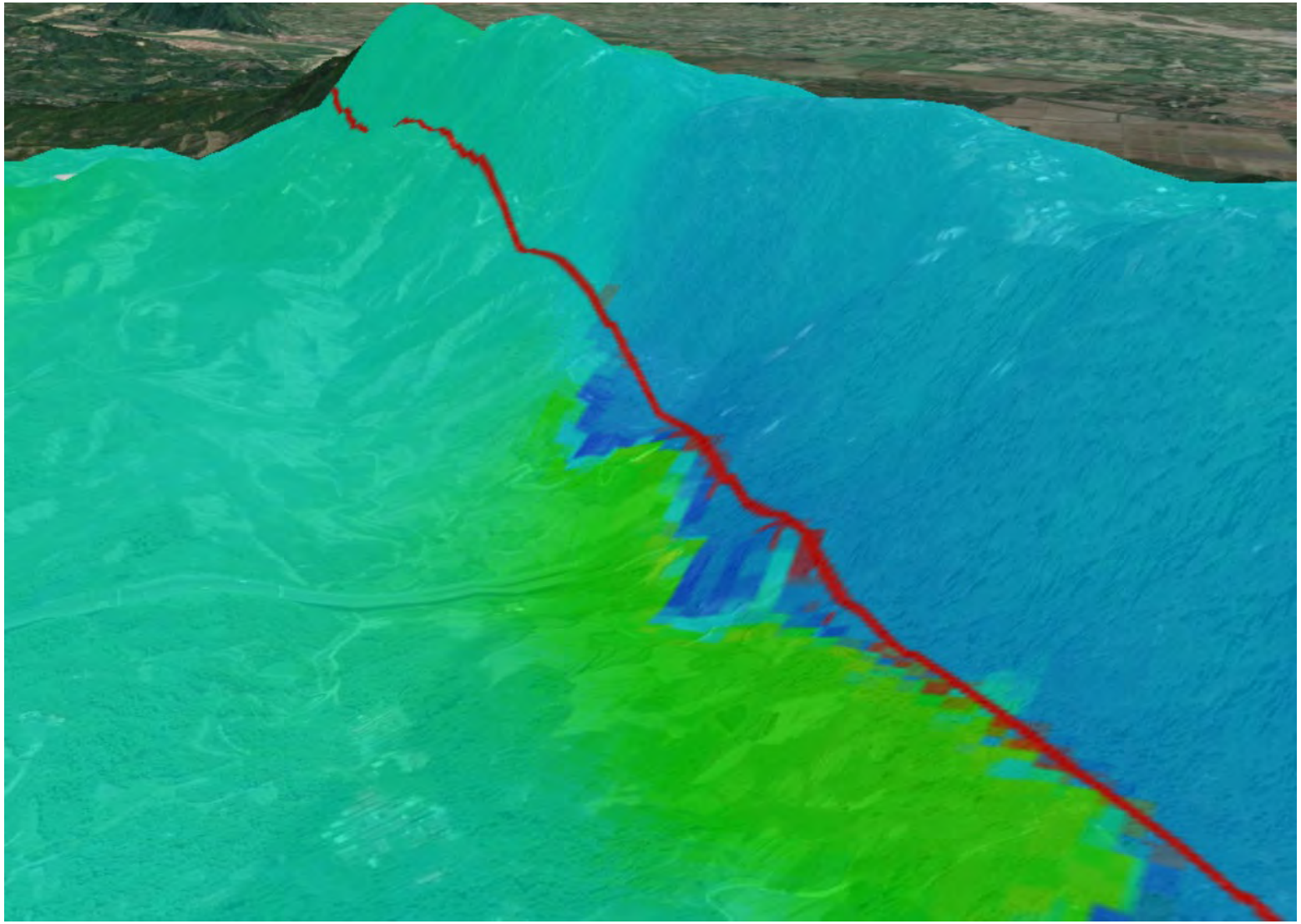






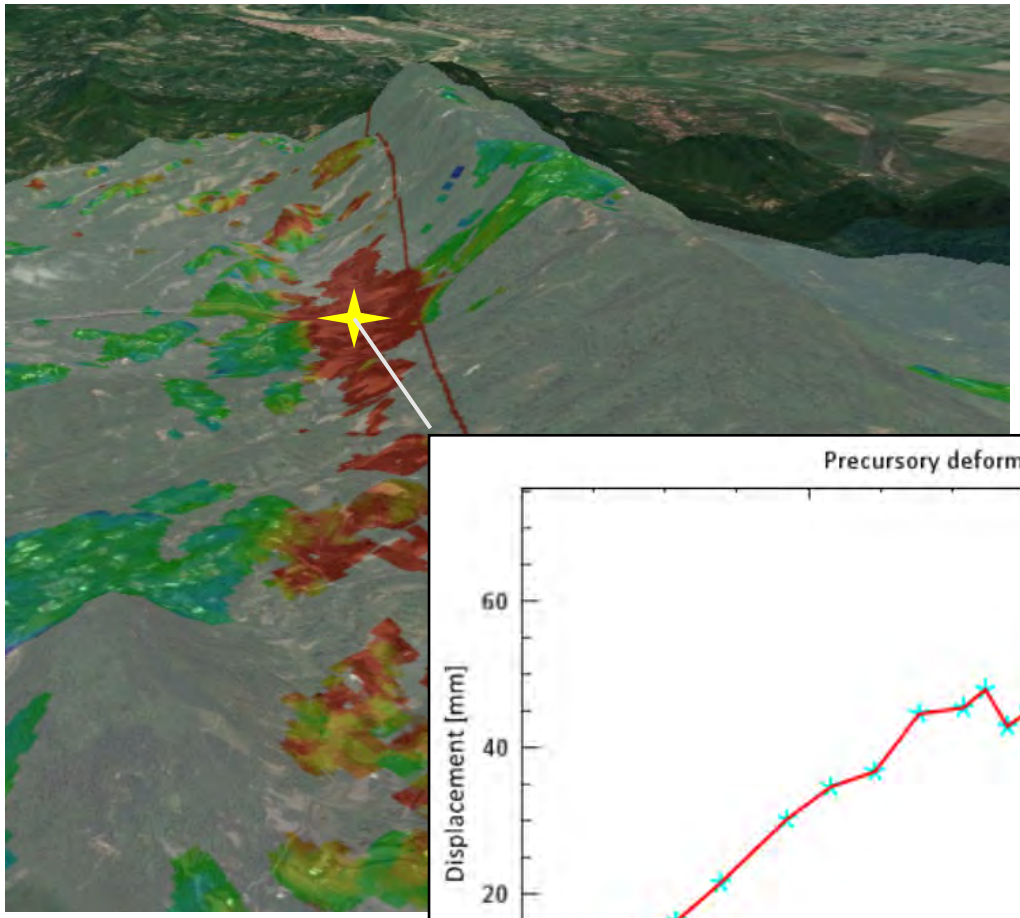
SAR SESSIONS

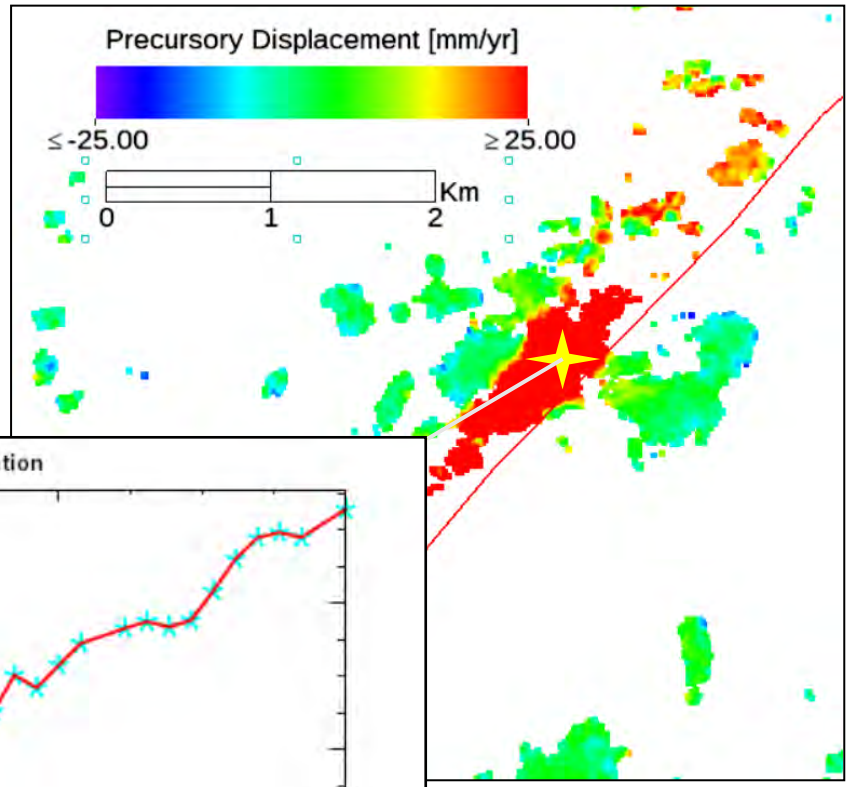
The February 2016 Mw 6.4 Taiwan Earthquake
Displacement (2016/02/02 – 2016/02/14)

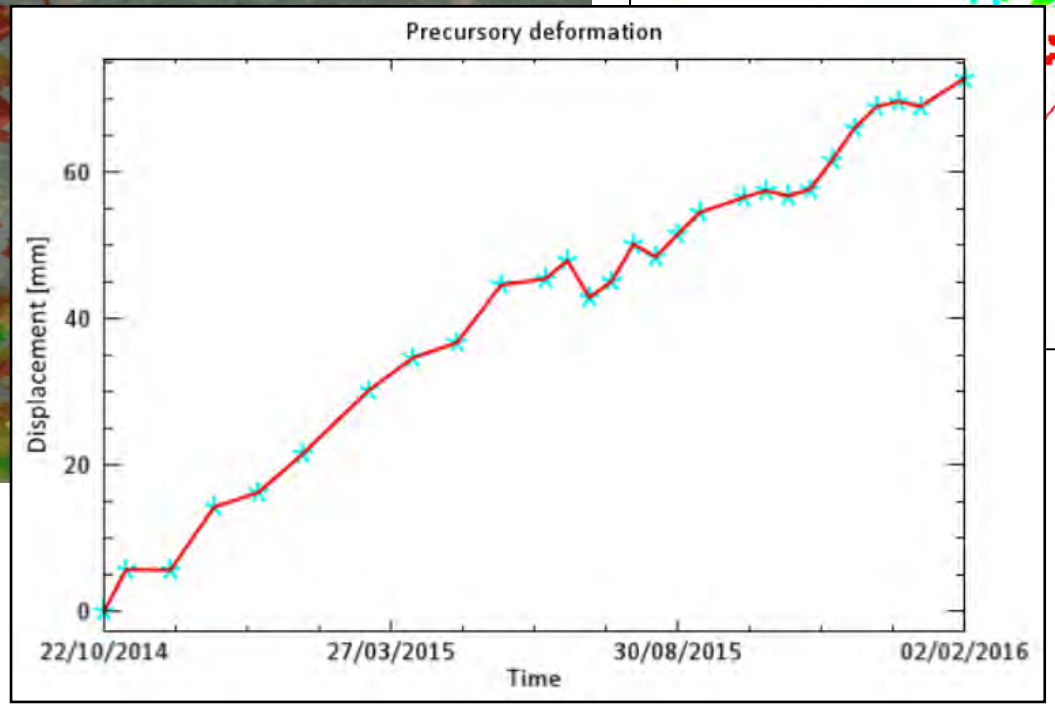


SAR SESSIONS

The February 2016 Mw 6.4 Taiwan Earthquake
Precursory displacement (2014/10/22 – 2016/02/02)







SAR SESSIONS

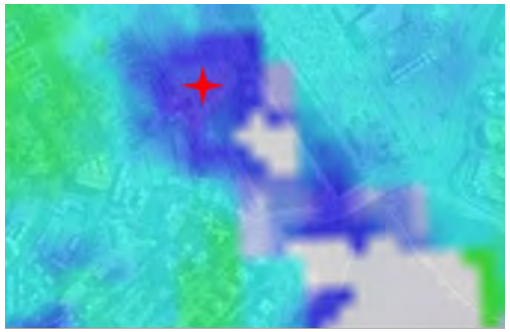
Some more applications

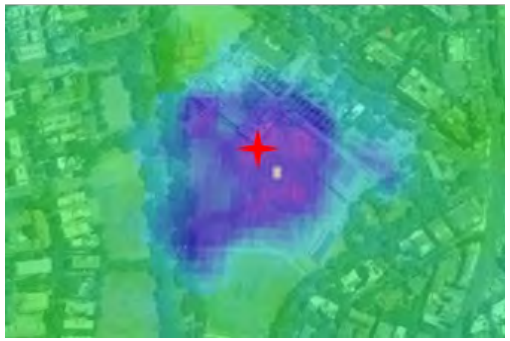
Mumbai Metro-Line 3

SAR SESSIONS

sarmap
your information gateway

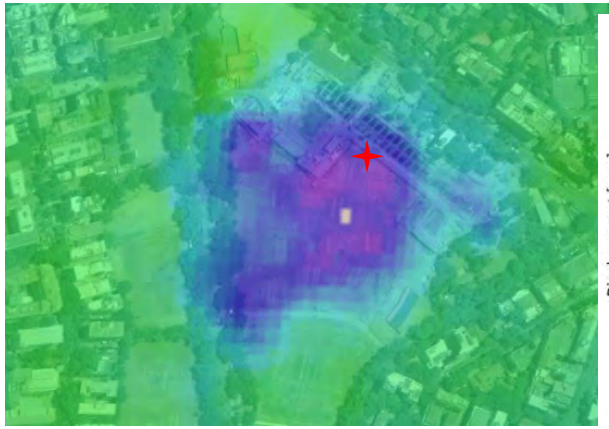
Mumbai metro-line 3
Sentinel-1, SBAS

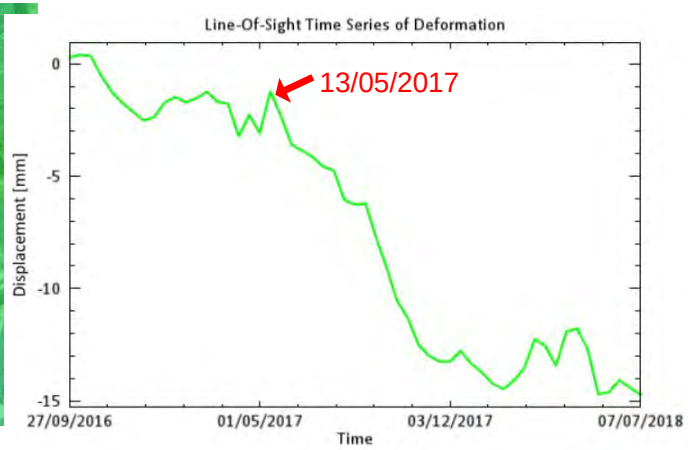




SAR SESSIONS

Mumbai metro-line 3
Sentinel-1, SBAS





SAR SESSIONS

Surface Motion Monitoring Using SAR Interferometric Techniques

- When you should use DInSAR, PS and SBAS
- Sensitivity to few millimiter deformations
- Capability of covering wide surfaces
- Spatial resolution related to the SAR sensor, up to 0.5 -1 m
- Temporal resolution of few days
- Increasing availability of SAR data
- Growing flexibility of the processing tools
- Monitoring of infrastructures, mines, natural hazards

SAR SESSIONS

gtessari@sarmap.ch

www.sarmap.ch

sarmap
your information gateway

Dr. Giulia Tessari

Senior Remote Sensing Specialist

gtessari@sarmap.ch

sarmap SA

www.sarmap.ch

SAR SESSIONS