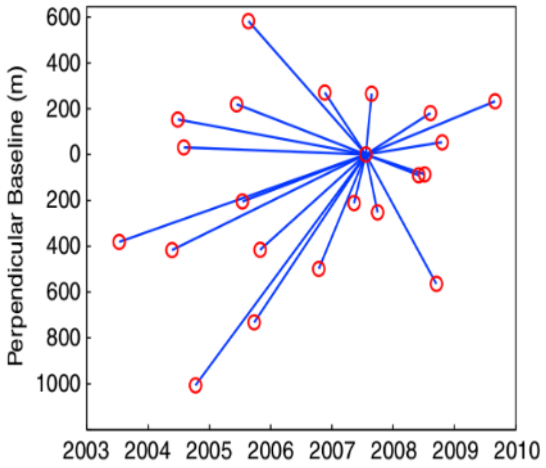
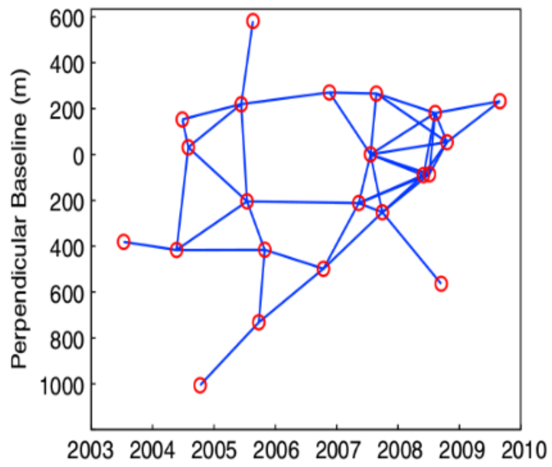
# InSAR ANALYSIS

*Techniques and applications*

Time Series InSAR

- Persistent Scatterer PS
- Small Baseline SBAS



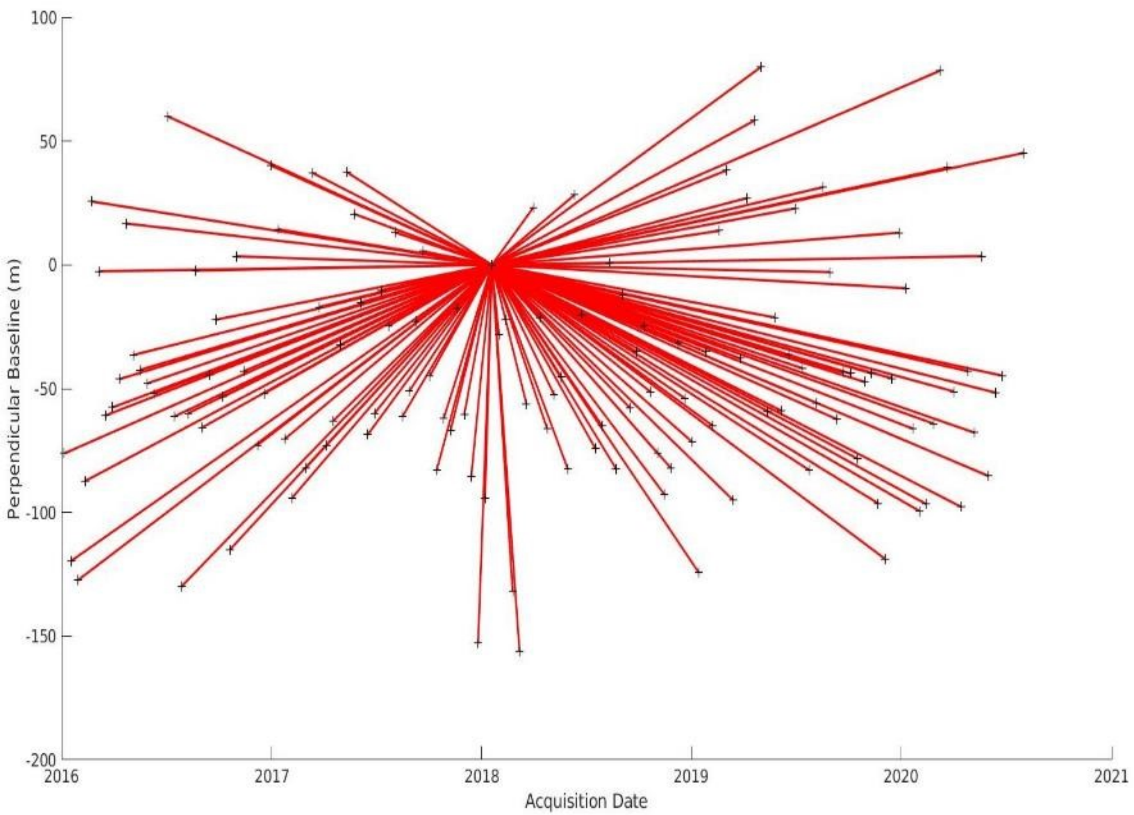
# PSI PROCESSING

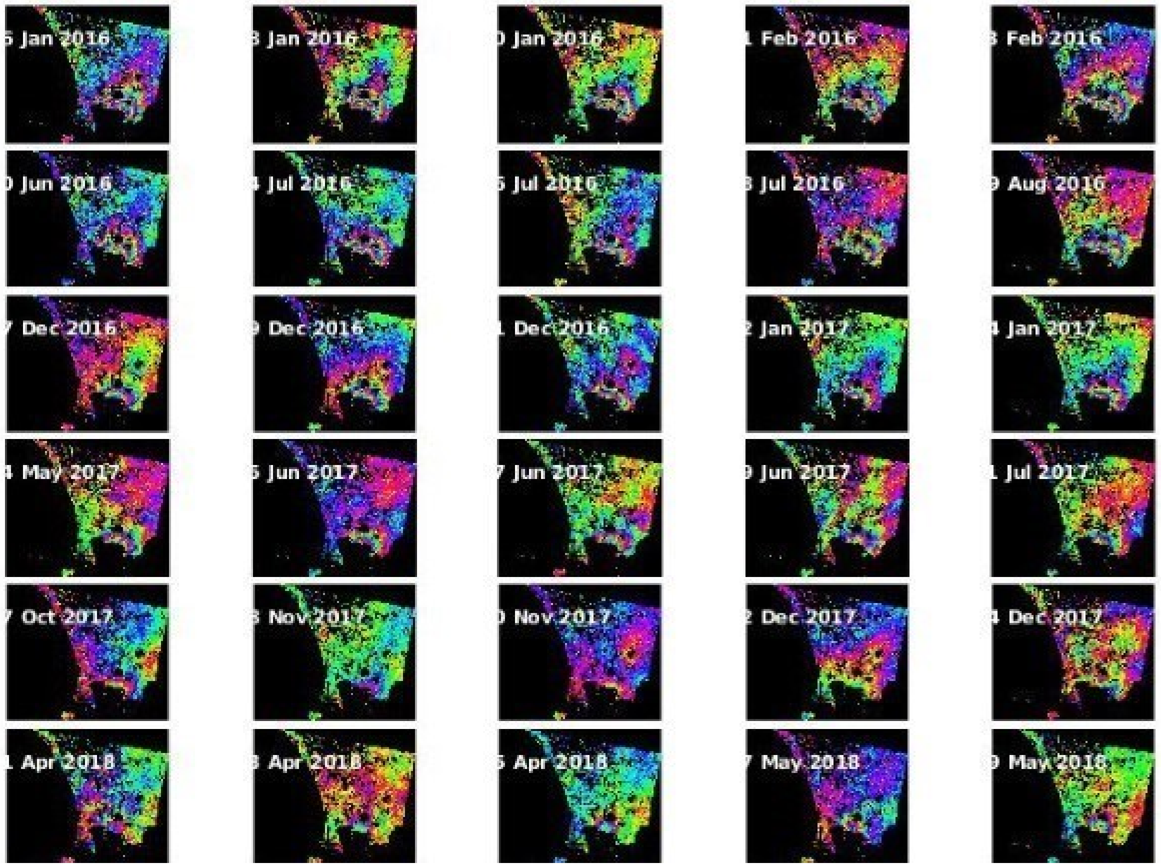
## Training objectives

- Understand main features of InSAR techniques.
- Compare each techniques’ pros and cons.
- PSI processing guidance.
- PSI data GNSS calibration.

# PS Technique

- Relies on pixels that exhibit low decorrelation with spatial and temporal baseline.
- Non-deformation signals are reduced by modelling and filtering.
- All interferograms are formed with the same “master” image.
- No spectral filtering is applied (to maximize resolution).
- Reduction of interferometric phase using a priori DEM to minimize ambiguities.

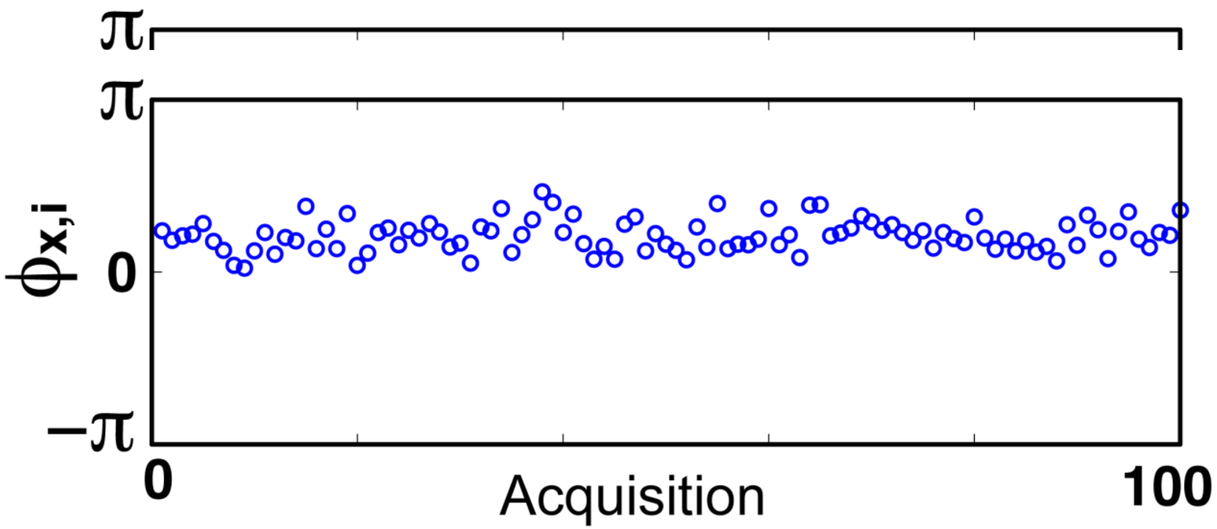


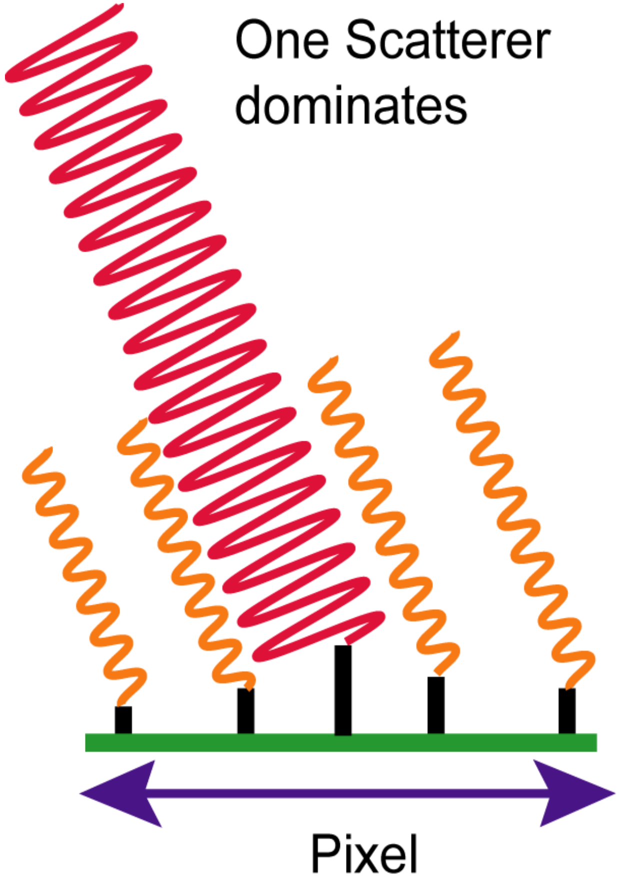



# Persistent Scatterer (PS) InSAR

PS-InSAR was developed to give solutions to the conventional InSAR decorrelation especially those due to temporal and geometric effect.

Differential SAR interferometry (DInSAR) is a very effective technique for measuring crustal deformation. However, almost all interferograms include large areas where the signals decorrelate and no measurements are possible. Persistent scatterer interferometry (PS-InSAR) overcomes the decorrelation problem by identifying resolution elements whose echo is dominated by a single scatterer in a series of interferograms.



# Interferometric Phase

For each pixel in each interferogram (after correction for topography):

$$\phi_{int} = \phi_{defo} + \phi_{atmos} + \Delta\phi_{orbit} + \Delta\phi_{topo} + \phi_{noise}$$

Deformation in LOS

Atmospheric Delay

Orbit Error

DEM Error

“ Noise”

# Persistent Scatterer technique: StaMPS PS approach

Relying on correlation in space: StaMPS, Hooper et al. (2004, 2007, 2012)

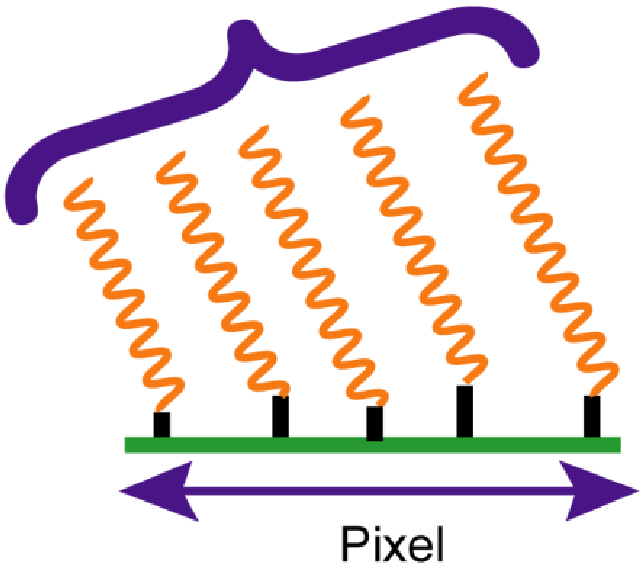
Spatial Correlation PS Algorithm

$$\phi_{int} = \phi_{defo} + \phi_{atmos} + \Delta\phi_{orbit} \begin{matrix} + \Delta\phi_{topo}^{uncorr} \\ + \Delta\phi_{topo}^{corr} \end{matrix} + \phi_{noise}$$

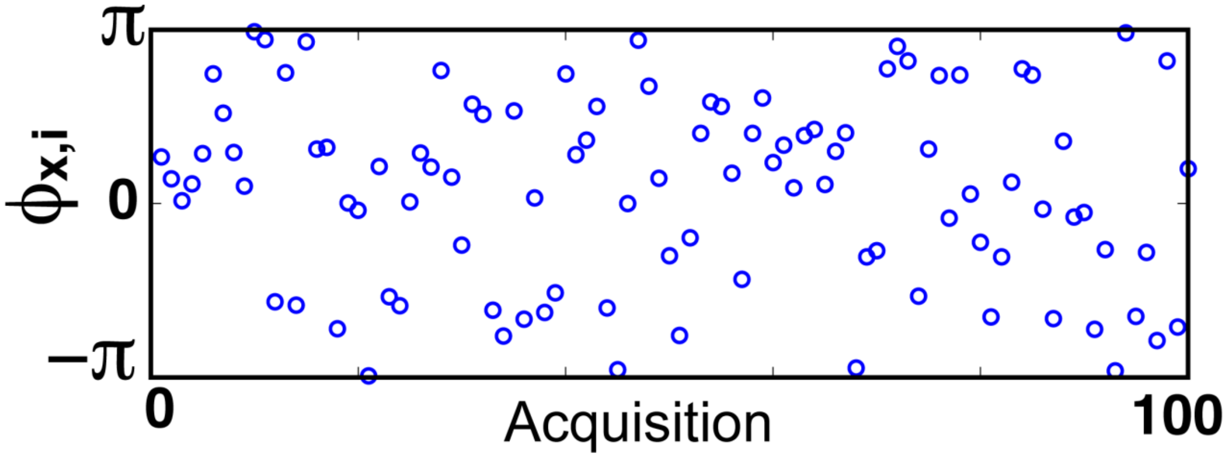
- Correlated spatially - estimate by iterative spatial bandpass filtering (Hooper et al., 2004), Hooper et al., 2007, Goldstein and Werner, 1998
- Correlated with perpendicular baseline - estimate by inversion

# Cause of Decorrelation

The echoes sum to give one phase value for the pixel.



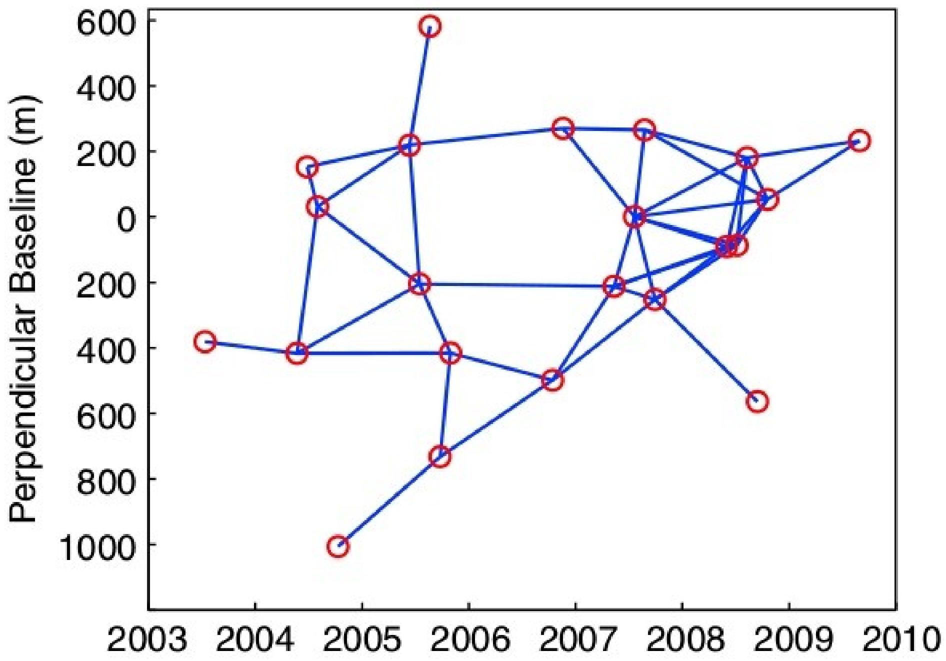

If scatterers move with respect to each other, the phase sum changes.




Hooper Lecture UNAVCO InSAR Course August 1-5, 2016

# SBAS Technique

## **S**mall **BA**seline **S**ubset




( Hooper et al., 2012)

- Interferograms are formed between image pairs that have small perpendicular, temporal baselines.
- In the StaMPS approach (Hooper, 2008) basically applies same algorithm as PS processing to filtered small baseline interferograms.
- These are then unwrapped using 3-D algorithm and inverted using least-squares.
- Redundancy in small baseline network allows checking for unwrapping errors.

# SBAS Small BAseline Subset

- The small Baseline (SBAS) method is one of the differential synthetic aperture radar interferometry algorithms for studying temporal evolution of ground deformation characterized by the small baseline separation between the SAR pairs used to generate interferograms.

- This algorithm aims to limit the spatial decorrelation taking into account the spatial and the temporal information from the SAR data.

- The SBAS algorithm relates the different SAR acquisitions having a short baseline (short spatial separation) in order to generate series of interferograms under some circumstances.

- By reducing the spatial separation between SAR images, the decorrelations especially due to the large baseline separation are reduced and correlated interferograms are obtained

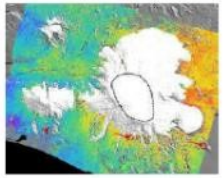
# PS & SBAS TECHNIQUES

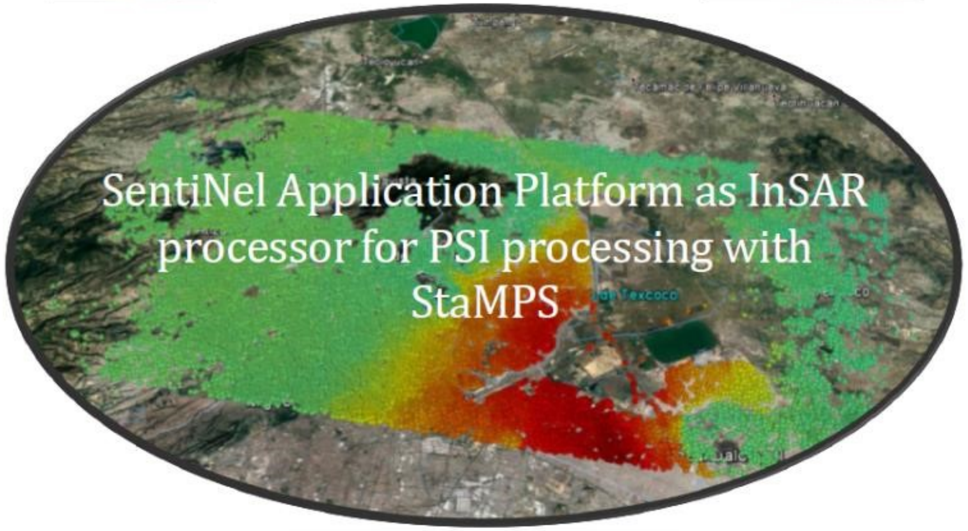
***SUMMARY***

- Persistent Scatterer (PS) approach relies on pixels that exhibit low decorrelation over whole time series.
- Small Baselines (SB) approach relies on pixels that exhibit low decorrelation with short times and small perpendicular baselines.
- Non-deformation signals are reduced by modelling and filtering in both cases.
- PS techniques work best in urban environments, but can also be applied in rural environments.
- SB approach works more generally.
- Combined approach is possible.

# SNAP2StaMPS

## SentiNel Application Platform as InSAR processor for PSI processing with StaMPS






Foumelis, M., Delgado Blasco, J. M., Desnos, Y. L., Engdahl, M., Fernández, D., Veci, L. Lu, J. and Wong, C.
SNAP - StaMPS Integrated processing for Sentinel-1 Persistent Scatterer Interferometry.
In Geoscience and Remote Sensing Symposium (IGARSS), 2018 IEEE International, IEEE

Authors: *José Manuel Delgado Blasco*

*Michael Foumelis*

The Sentinel application platform (SNAP) consists of a collection of processing tools, data product readers writers display and analysis application to support the large archive of data from ESA SAR missions. The Sentinel-1 Toolbox is a multi-platform, multi-sensor, multi-thread software which enables the preprocessing InSAR.

StaMPS is a postprocessor compatible with the output generated by the ESA SentiNel Application Platform (SNAP). It can use both PS and SBAS algorithms.

SNAP allows the user to define a series of xml files which contain user defined processing workflow by using its Graph Builder.

snap2stamps is a package that contains a set of graphs, together with python wrappers that allow to automatize the interferogram processing chain for single master interferograms compatible with StaMPS PSI. Information about the provided functionalities and their instructions can be found in the user manual provided within snap2stamps.

# Using **SNAP** as InSAR processor for StaMPS

Repository → https://github.com/mdelgadoblasco/snap2stamps

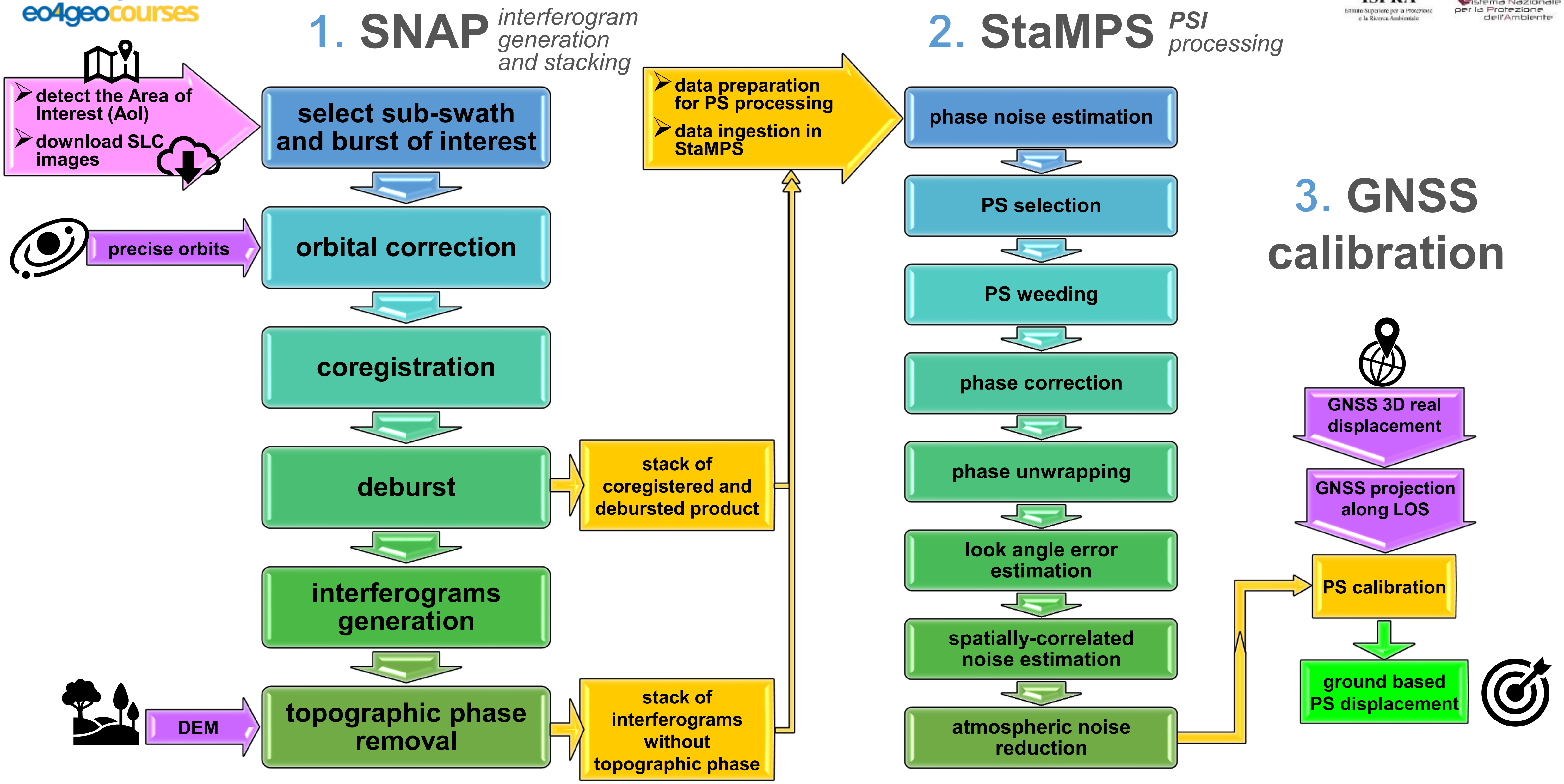
Manual → https://github.com/mdelgadoblasco/snap2stamps/blob/master/Manual/SNAP2StaMPS_User_Manual.pdf

Video tutorial → https://www.youtube.com/watch?v=Xy7Y4Ea5mOo&t=6s *(1.10 h)*

# **Sta**nford **M**ethod for **P**ersistent **S**catterers
## (**StaMPS**)

A software package to extract ground displacements from time series of synthetic aperture radar (SAR) acquisitions. → https://github.com/dbekaert/StaMPS

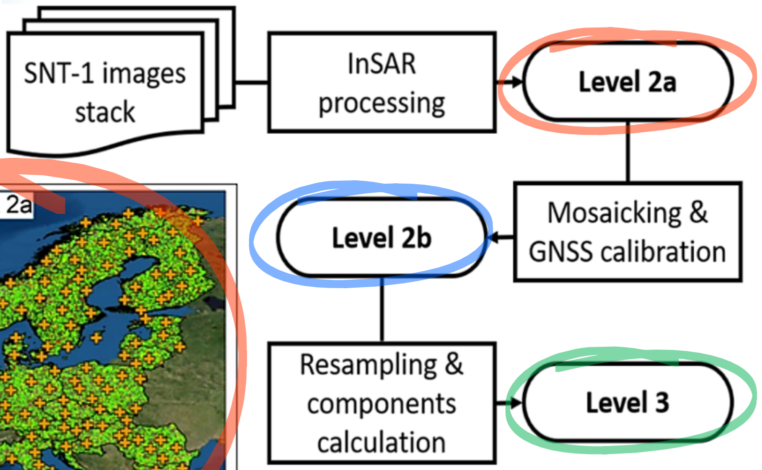
| | | |
|---|---|---|
| Repository | → | https://github.com/dbekaert/StaMPS |
| Manual | → | https://homepages.see.leeds.ac.uk/~earahoo/stamps/StaMPS_Manual_v4.1b1.pdf |
| Training/Exercise | → | http://seom.esa.int/landtraining2015/files/Day_4/D4P2a_LTC2015_Hooper.pdf |
| Video tutorial | → | https://www.youtube.com/watch?v=sFxcgLxe-4M&t=236s *(1.5 h)* |




[Modified from: Mancini et al., 2021 – https://doi.org/10.3390/rs13040753]

# European Ground Motion Service approach

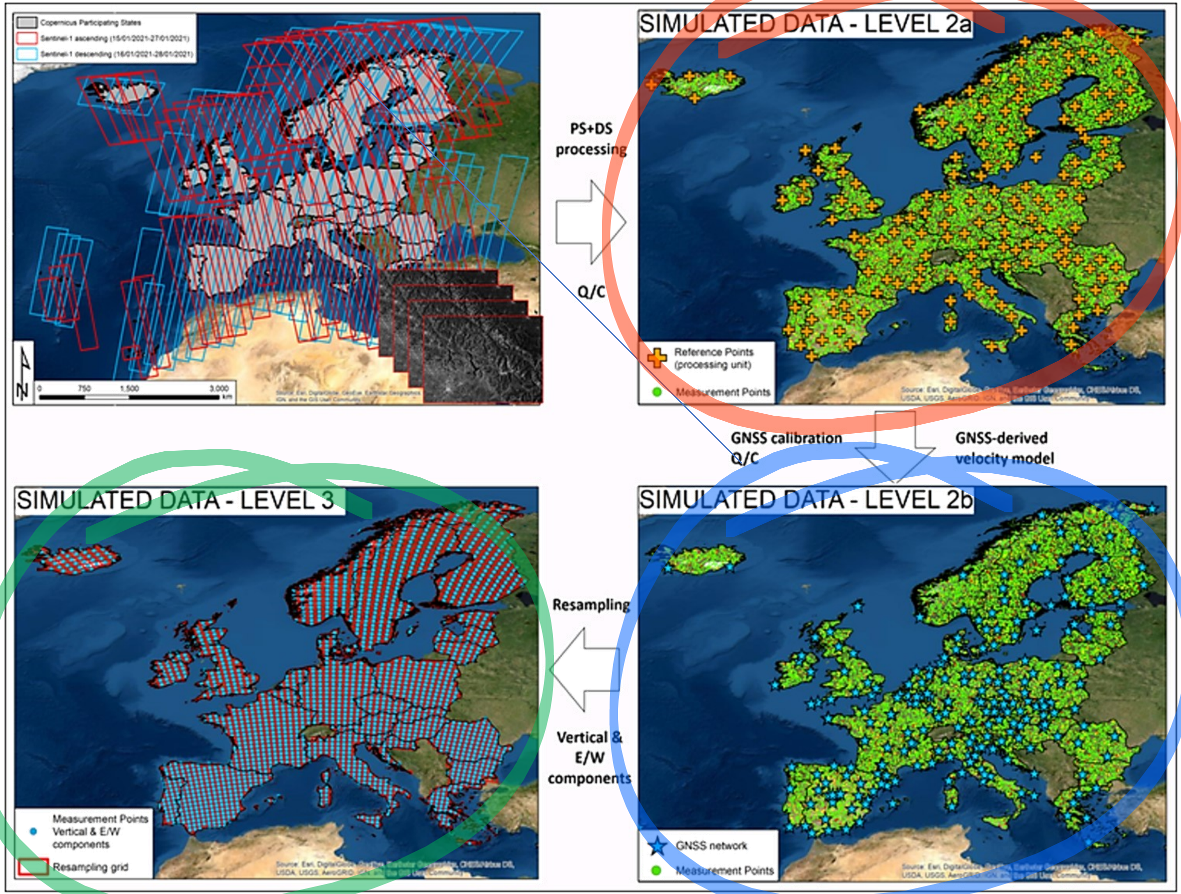
With regards to the detail of data processing **COPERNICUS EGMS** defines 3 level of products:



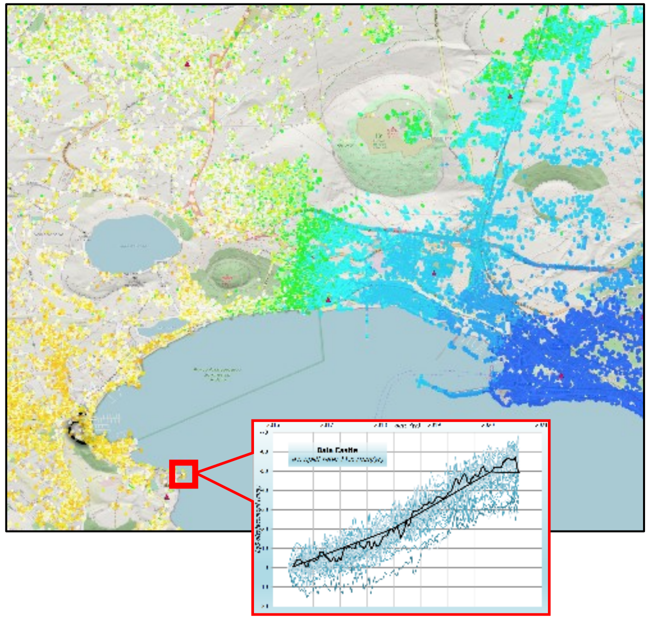

**Lev. 2a (basic)**
displacement maps and time series with measurements along the LOS; delivered for individual and consistent frames of the original SAR image stacks; the measurements are referred to one single Reference Point for each frame; processing performed at full Sentinel-1 resolution.

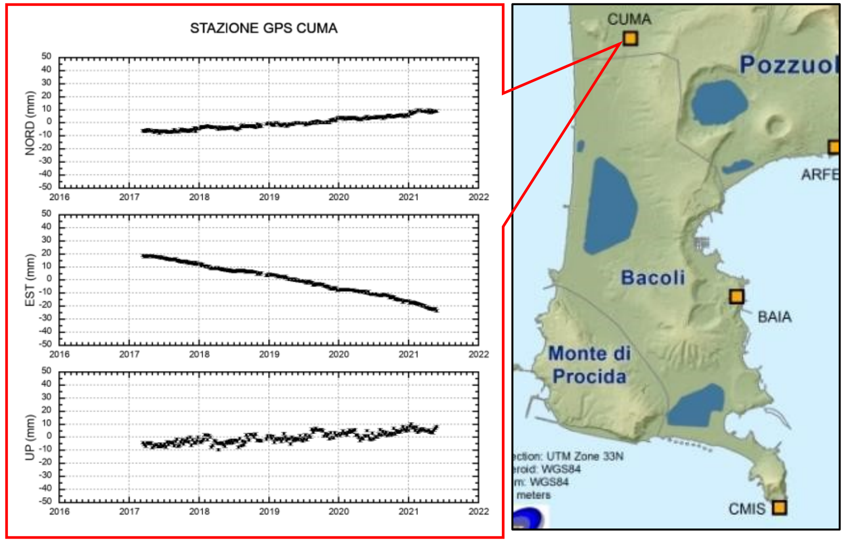
**Lev.2b (calibrated)**
same as Lev.2a;
+ mosaic of frames;
+ calibration with a reference GNSS.

**Lev.3 (ortho product)**
combined ASC+DESC components to obtain East-West and Up-Down interpolated displacement.



# GNSS calibration



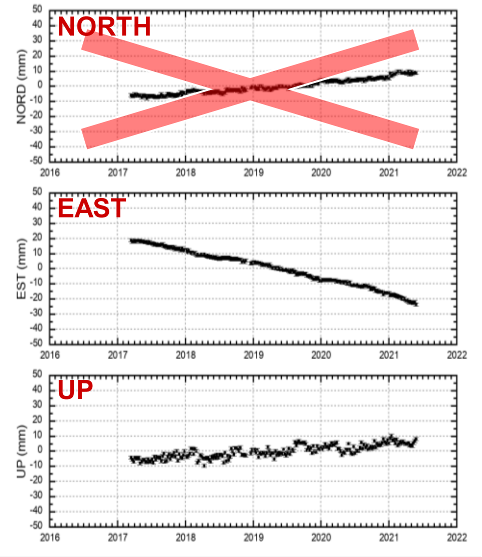



**PSI** measure displacements over time of many targets on the ground, but these values are relative to a reference point, usually selected by the algorithm.

**GNSS** measure absolute ground displacements, but these measures refer only to the installed stations.

To ensure a proper interpretation, PSI data need to be **calibrated** with absolute control point, such as GNSS stations, thus obtaining a quasi continuous distribution of absolute ground displacements measures.

# GNSS calibration




To calibrate PS data with GNSS reference station it is necessary to:

- sum the GNSS displacement vector EAST and UP components (the NORTH component is negligible, because it is not detected by PSI);

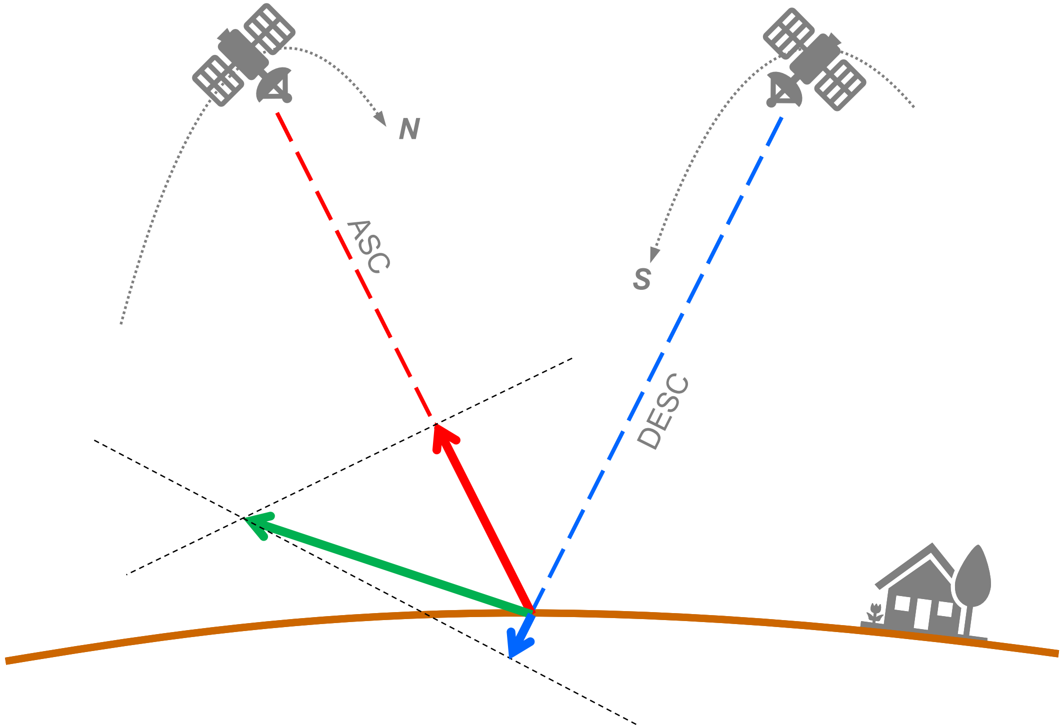
< see

- project the EAST+UP displacement along each, ascending and descending, Line of Sight (LOS);

see >

- subtract the GNSS along LOS component from each PS dataset.

This procedure leads to a dataset of ground based PSI displacement.




ASCending LOS

DESCending LOS

GNSS East+Up displacement

GNSS along ASC LOS component

GNSS along DESC LOS component

# REFERENCES

Hooper, A., H. Zebker, P. Segall, and B. Kampes, A new method for measuring deformation on volcanoes and other natural terrains using InSAR persistent scatterers. Geophys. Res. Lett., 31, 2004. doi: 10.1029/2004GL021737

Hooper, A., P. Segall, and H. Zebker, Persistent scatterer InSAR for crustal deformation analysis, with application to Volcan Alcedo, Galapagos. J. Geophys. Res., 112, 2007.

Hooper A; Bekaert D; Spaans K; Arikan M (2012), Recent advances in SAR interferometry time series analysis for measuring crustal deformation. Tectonophysics, 514-517, pp.1-13.

More material at:

https://land.copernicus.eu/pan-european/european-ground-motion-service

https://land.copernicus.eu/user-corner/technical-library/egms-white-paper

https://land.copernicus.eu/user-corner/technical-library/egms-specification-and-implementation-plan