800 ANNI 1222·2022

UNIVERSITÀ DEGLI STUDI DI PADOVA

Prevention of Potential Catastrophes Depending on Interferometric Radar Technique and Artificial Intelligence

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Meeting - 08/09/2021

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Bibliographic Research

1. Monitoring infrastructure displacements depending on the traditional radar interferometry methodologies using Sentinel-1

Methodologies

- ✓ Is it sufficient to obtain only ascending or descending images?
- ✓ What is the possible procedure to select Master image?
- ✓ How could we investigate if the point is valid as a Persistent Scatterer (PS) and how could we acquire sufficient PS points?
- ✓ What is the right threshold of coherence and could it be changed for a particular reason?
- ✓ How to ensure that no errors will occur through the co-registration of the data?
- ✓ What is the required criteria to consider the points reliable?
- ✓ What could be done to remove the atmospheric effect?

Bibliographic Research

1. Monitoring infrastructure displacements depending on the traditional radar interferometry methodologies using Sentinel-1

Results

- The maximum displacement that can be detected by InSAR techniques depends on the spatial correlation of the displacement phenomena and the non- linearities
- C band is very attractive for monitoring major infrastructure (like dams and long-span railway bridges) over wide areas in spite of the coarse spatial and temporal resolutions
- The most important InSAR technique nowadays is the Multi Temporal InSAR (MT-InSAR) according to the excellent, comprehensive and detailed results it achieves (the exact subsiding direction, deformation components and a description of the revealed motions)
- The main and minor roads follow the railways as the second infrastructure vulnerable type

Bibliographic Research

1. Monitoring infrastructure displacements depending on the traditional radar interferometry methodologies using Sentinel-1

Limitations

- The characteristics of the studied area
- The lack of images availability
- The image resolution or poor quality of the results
- The inability of obtaining direct information about the processes occurring inside the studied infrastructure or information about the structural state of infrastructures
- The short observation period
- The different ground movement potentials for multiple soil types contained in the soil map of the studied area
- The imperfections in the supposed mathematical models for estimated parameters
- Other reasons of incoherence like sub-pixel position, side-lobe observations, orbital inaccuracies, atmospheric disturbances etc..

Bibliographic Research

1. Monitoring infrastructure displacements depending on the traditional radar interferometry methodologies using Sentinel-1

Validations

The most important methods were either to compare the obtained results with historical geodetic data or to compare with other data like leveling data or Global Positioning System (GPS) data for a number of sites in the studied area.

2. Monitoring and predicting infrastructure displacements depending on artificial intelligence and radar interferometry methodologies

Methodologies

A) - ANN modeling procedure :

1. Choosing the input and output data: the input data for the time series models were the obtained subsidence data from PS-InSAR. and the output is the forecasted subsidence
2. Data learning process: the "nnet" function is utilized to train the model after determining the structure of the ANN model
3. Model testing: to assess the performance of an ANN model, the root mean square error (RMSE) is used

2. Monitoring and predicting infrastructure displacements depending on artificial intelligence and radar interferometry methodologies

Methodologies

B) - Another prediction model was developed taking the inspiration from the U-Net and the densely connected convolutional networks (DenseNet). The model was formulated as a spatiotemporal sequence learning and forecasting problem. The **DCNN** was used to train the monitored deformations -which are the settlement of the reclaimed lands due to consolidation of fills and the seasonal thermal expansion of the buildings due to temperature changes- and to predict the new time series deformation

2. Monitoring and predicting infrastructure displacements depending on artificial intelligence and radar interferometry methodologies

Methodologies

C) - RT model identifies the features that influence the infrastructure instabilities the most. After providing the modeling process with the required parameters (i.e. ,splitting percentage for the training set, splitting percentage for the test set, number of folds, splitting criterion, termination criterion, termination threshold), the model is trained to predict the surface motion and then validated

Bibliographic Research

2. Monitoring and predicting infrastructure displacements depending on artificial intelligence and radar interferometry methodologies

Results

- The ANN model is able to predict with fewer observations and non-linear developing trend. Also, the RMSE of the ANN model indicates high performance in predicting the infrastructure deformations (like railway subsidence)
- DCNN's is efficient for short-term prediction of surface deformation. Thus it can be used as a universal method for predicting complex surface deformation and InSAR time-series deformation and it can also be used in early warning systems
- RT model is a satisfactory tool for the prediction of PS-InSAR based surface motion estimations. It allows to predict the subsidence rate in areas where there is not enough PS data too

Bibliographic Research

2. Monitoring and predicting infrastructure displacements depending on artificial intelligence and radar interferometry methodologies

Limitations

- The lack of observations affects quality of the simulation assessment
- The Regression Tree (RT) has a poor prediction accuracy and instability (small changes in the training data can lead to significantly different models). The RT model is unable to predict the slight differences between PS measurements in highly urbanized areas

2. Monitoring and predicting infrastructure displacements depending on artificial intelligence and radar interferometry methodologies

Validations

The most popular criteria for the validation and the assessment for the performance of the prediction models is the root mean square error (RMSE)

Contents

DATA

geohazards tep

Sponsorship

By: NoR esa

Prevention of Potential Catastrophes Depending on Interferometric Radar Technique and Artificial Intelligence

First: Using Intelligent algorithms in developing a methodology that can automatically analyze large InSar data packets and identify areas where infrastructures are at risk of displacement due to ground movement Second: Establishing a predictive model for the displacements of the infrastructure st…

Workplan: Jul 14th 2021 -> Jul 14th 2022

Version: 1 (active)

ACTIVATED Feb 2nd 2021 Payment received and on-boarding operations activated.

Contents

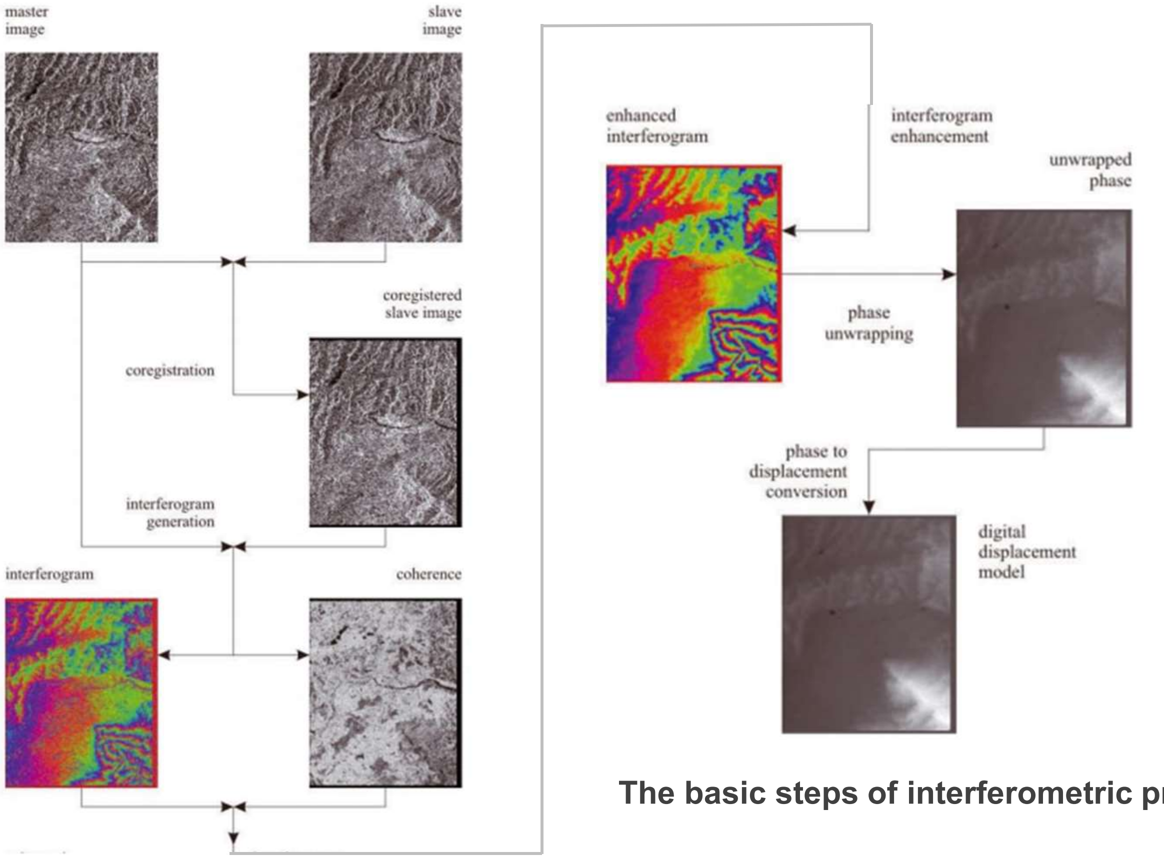
PSI vs P-SBAS (PSI)

- Permanent Scatter Interferometric Synthetic Aperture Radar or PSInSAR technique is an upgrade of DInSAR
- A statistical minimization of the DInSAR disturbances (changes in the reflection of objects or areas, atmospheric influences, and signal disturbances) can be achieved by using radar data over a longer period and by determining coherent radar targets – permanent scatterers

PSI vs P-SBAS (PSI)

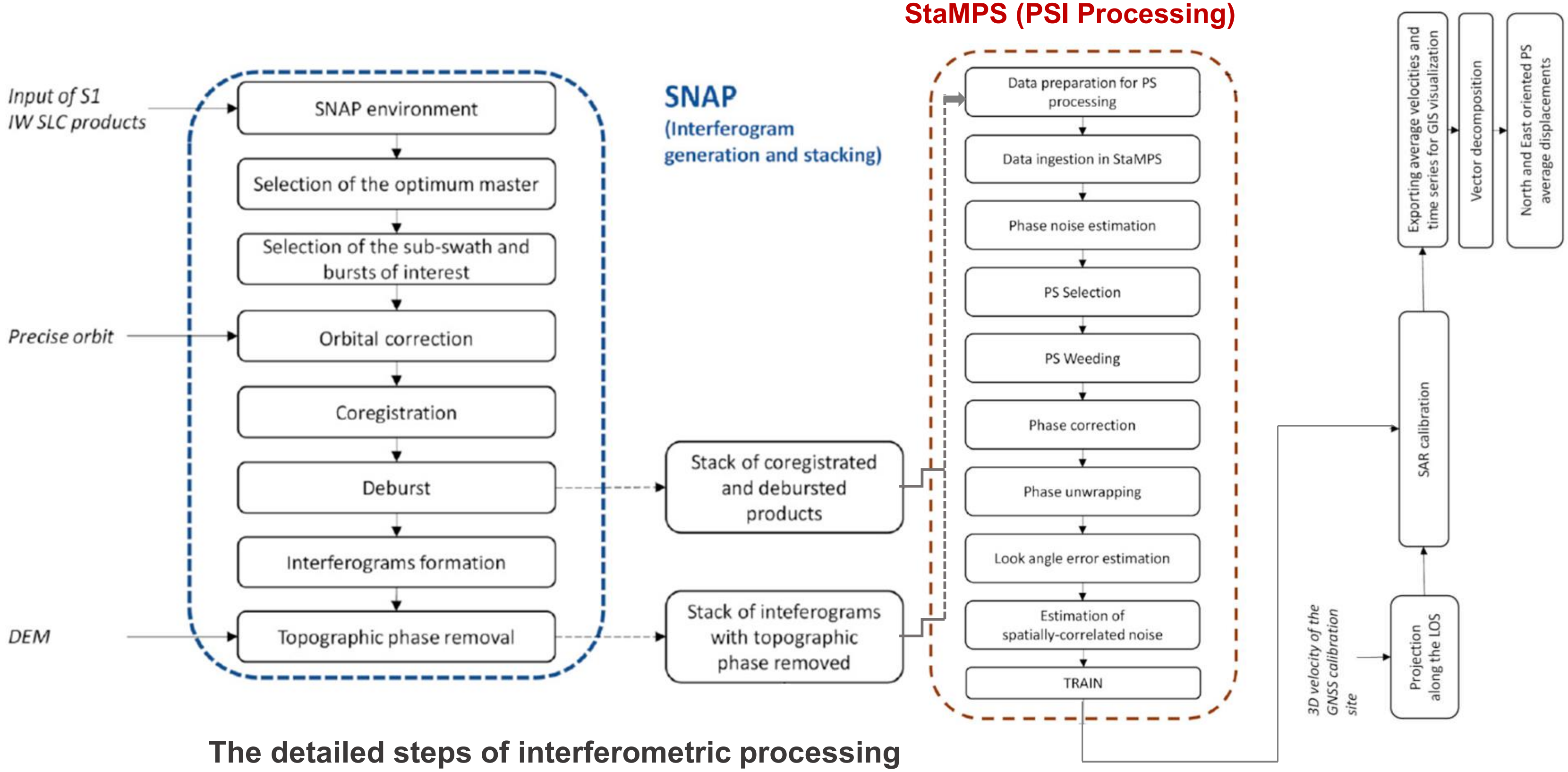
- The main advantages of PSI are a large density of measurement points, long-term observation and the possibility of observation without preliminary installation of instruments
- The drawback of this method is a loss of data continuity
- Its biggest limitations are a more complicated analysis or interpretation, the need for additional spatial modeling in case a continuous model is required (where a combination with DInSAR may be of significance),and a patent protection of the processing procedure

PSI vs P-SBAS (PSI)



The basic steps of interferometric processing

PSI vs P-SBAS (PSI)



The detailed steps of interferometric processing

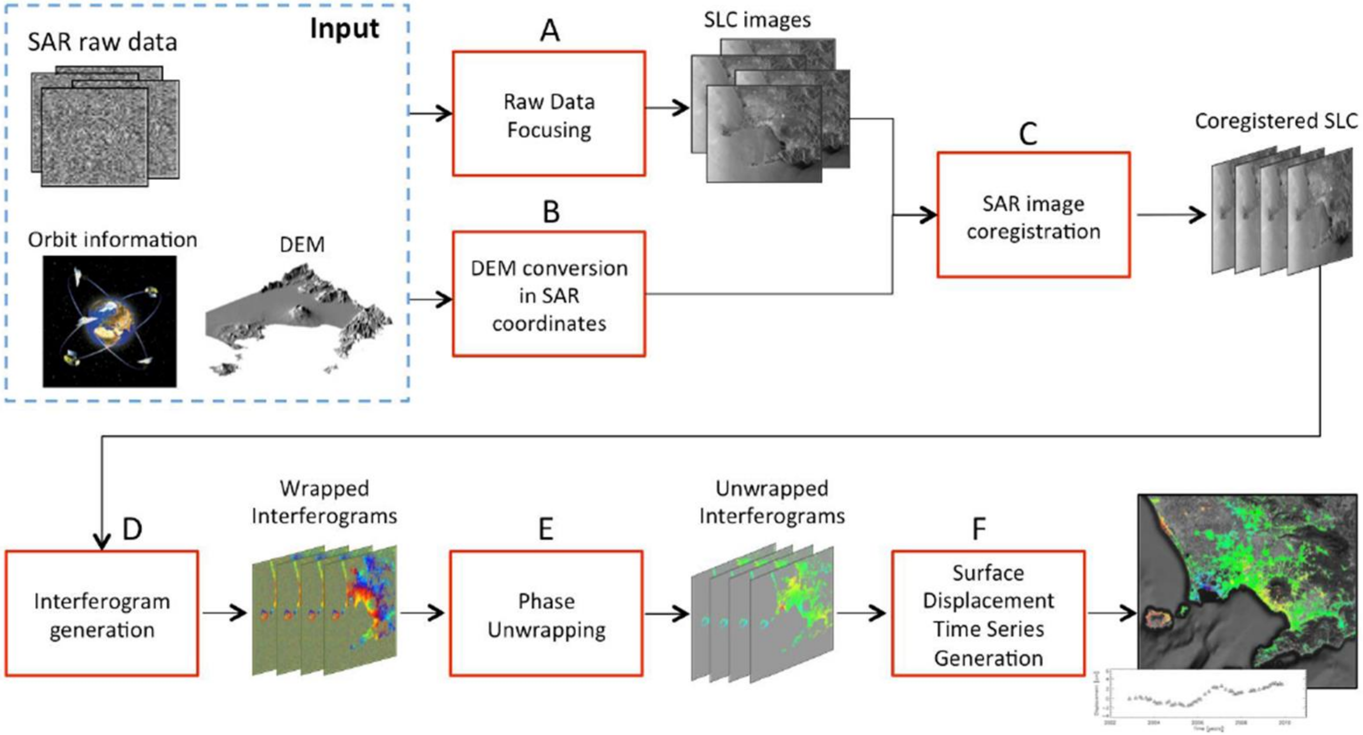
PSI vs P-SBAS (P-SBAS)

- The Small BAseline Subset (SBAS) approach relies only on small spatial and temporal baseline interferograms, which define a system of equations that can be inverted to retrieve the deformation time series, through a method based on Singular Value Decomposition (SVD)
- The Geohazards Exploitation Platform (GEP) provides the Parallel Small BAseline Subset (P-SBAS) service which is a web tool for the unsupervised generation of Earth's surface deformation mean velocity maps and time series from Synthetic Aperture Radar (SAR) satellite data in a very short time

PSI vs P-SBAS (P-SBAS)

- According to the exploited hardware configuration at GEP and the investigated SAR datasets, the full P-SBAS processing requires an average time from1 day to 1 day and a half
- This tools expanded the access to high quality multi-temporal DInSAR results by allowing the provisioning of P-SBAS processing service to non-expert users, as well as to expert ones that can benefit from a tool that permit a fast exploration of a study area and a better control of the processing chain

PSI vs P-SBAS (P-SBAS)



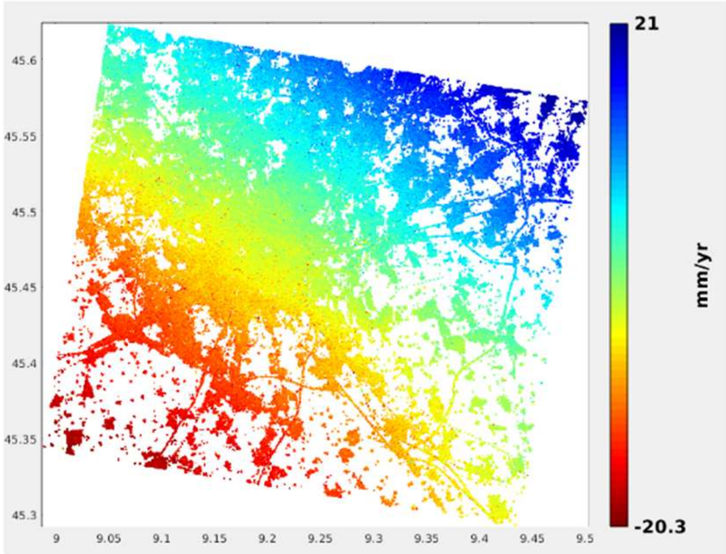
Simplified block diagram of the P-SBAS processing chain

PSI vs P-SBAS (Comparision)

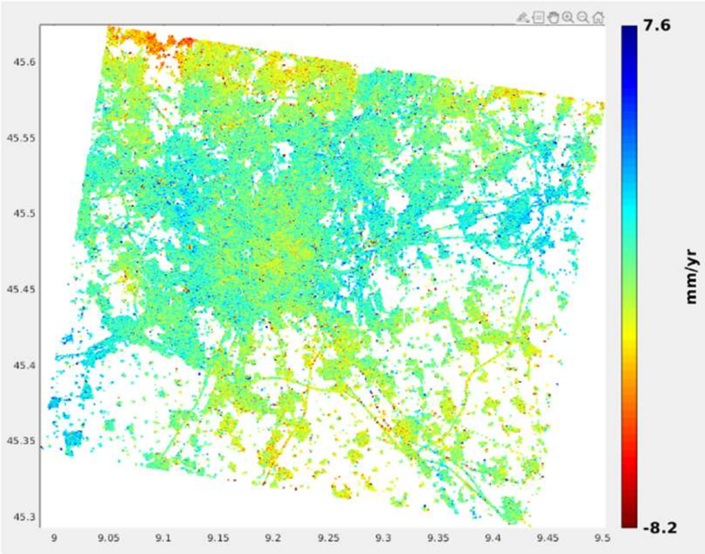
- **50 descending** images, acquired by **Sentinel-1** satellites between **2020** and **2021** were used; that lead to the generation of **49 interferograms for PSI** while **138 interferograms for P-SBAS**
- The spatial extent of the investigated area is **about 35x33 km**
- the case study was chosen based on the preliminary data analyses and geological prospection. The location of the reference point is **45°29´05.52´´N, 9°12´10.87´´E**, and its velocity is **– 0.5** mm/year. The overall coherence is **0.84** and the dispersion amplitude is **0.4**

PSI vs P-SBAS (Comparision)

Average yearly movements were calculated for all the 316425 scatterers.
The master image is on 27 Sept. 2020

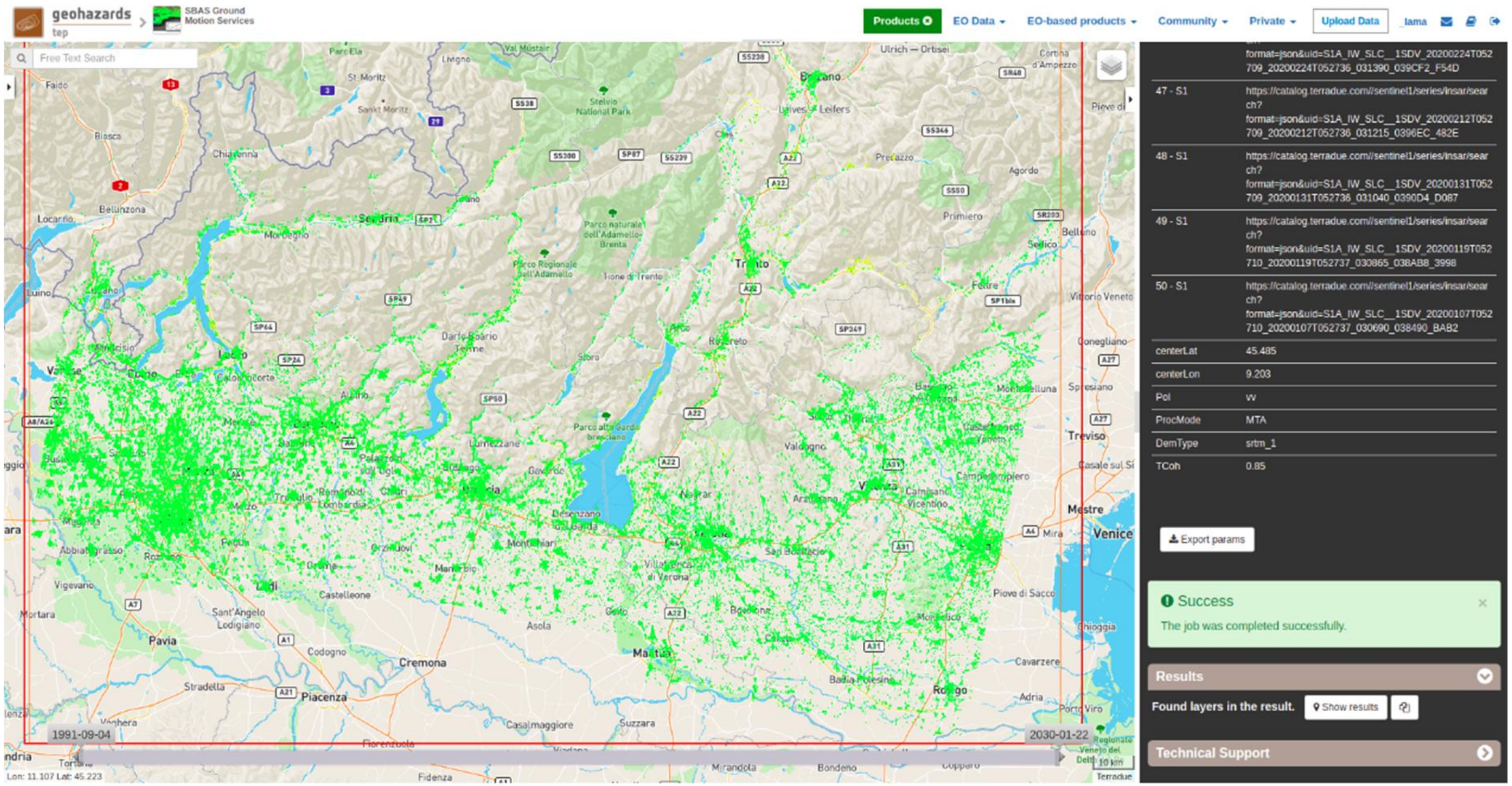


Velocity map without corrections (PSI within StaMPS)

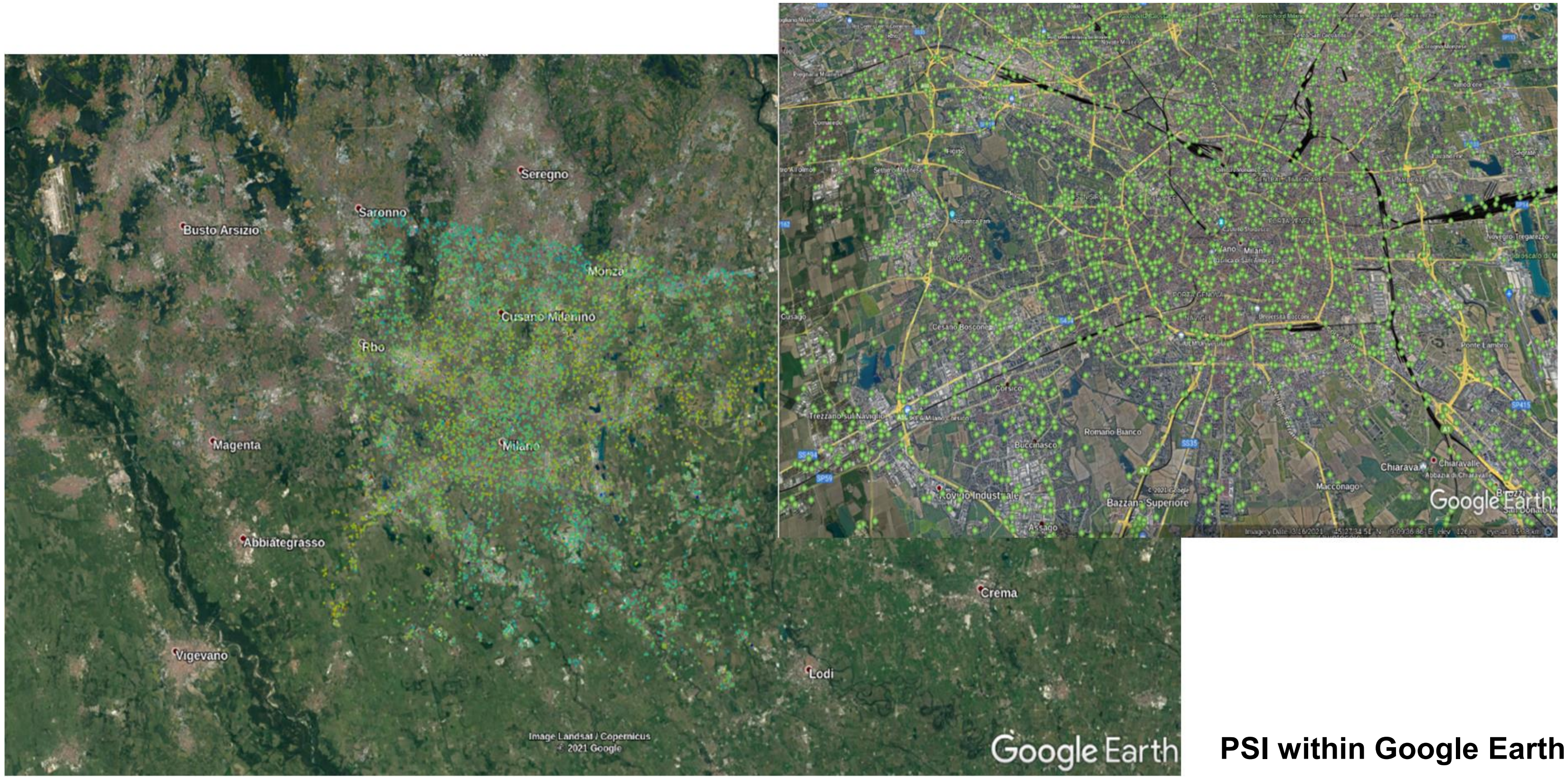


Velocity map with total DEM error, ramps estimation and linear atmosphere corrections (PSI within StaMPS)

PSI vs P-SBAS (Comparision)



PSI vs P-SBAS (Comparision)

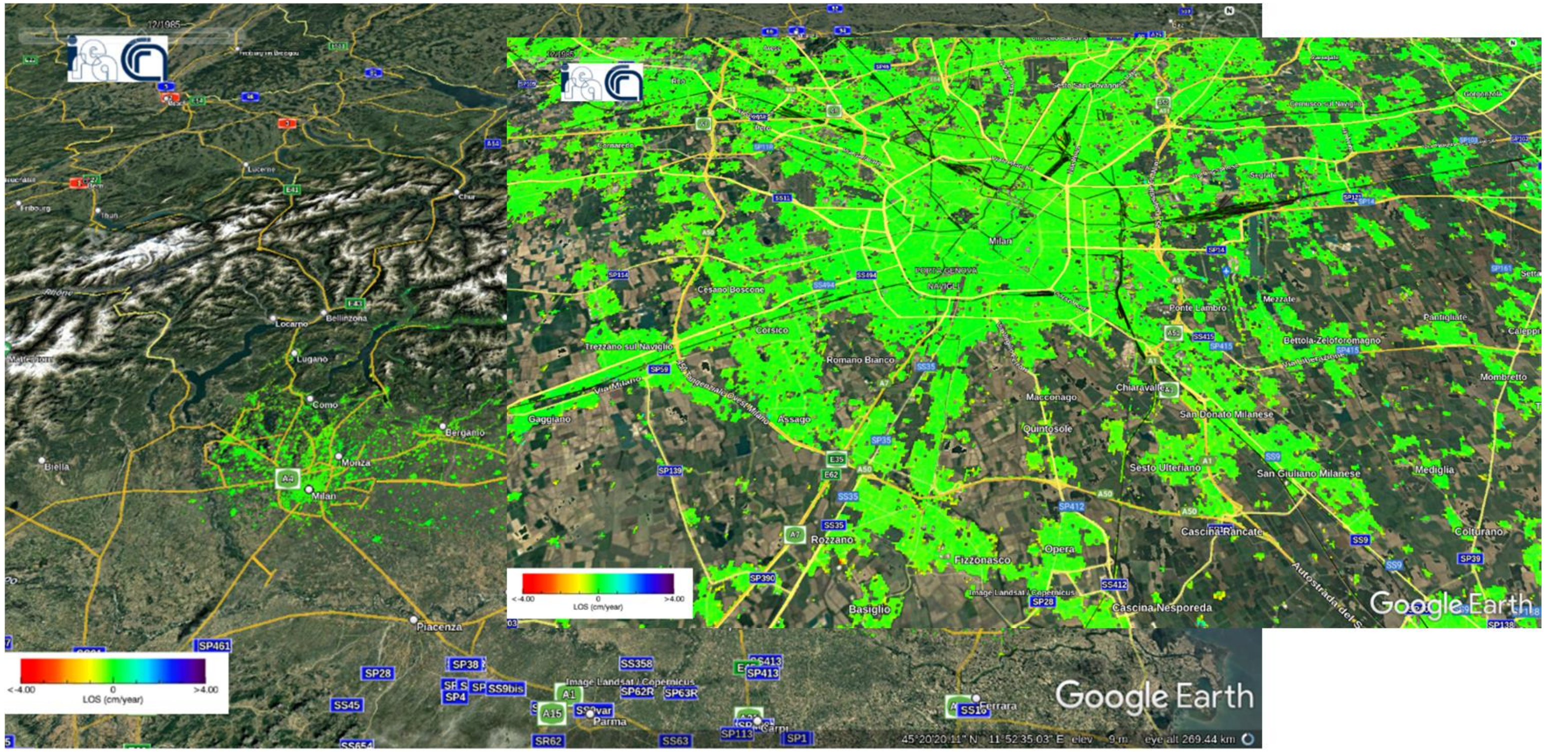


PSI within Google Earth

PSI vs P-SBAS (Comparision)

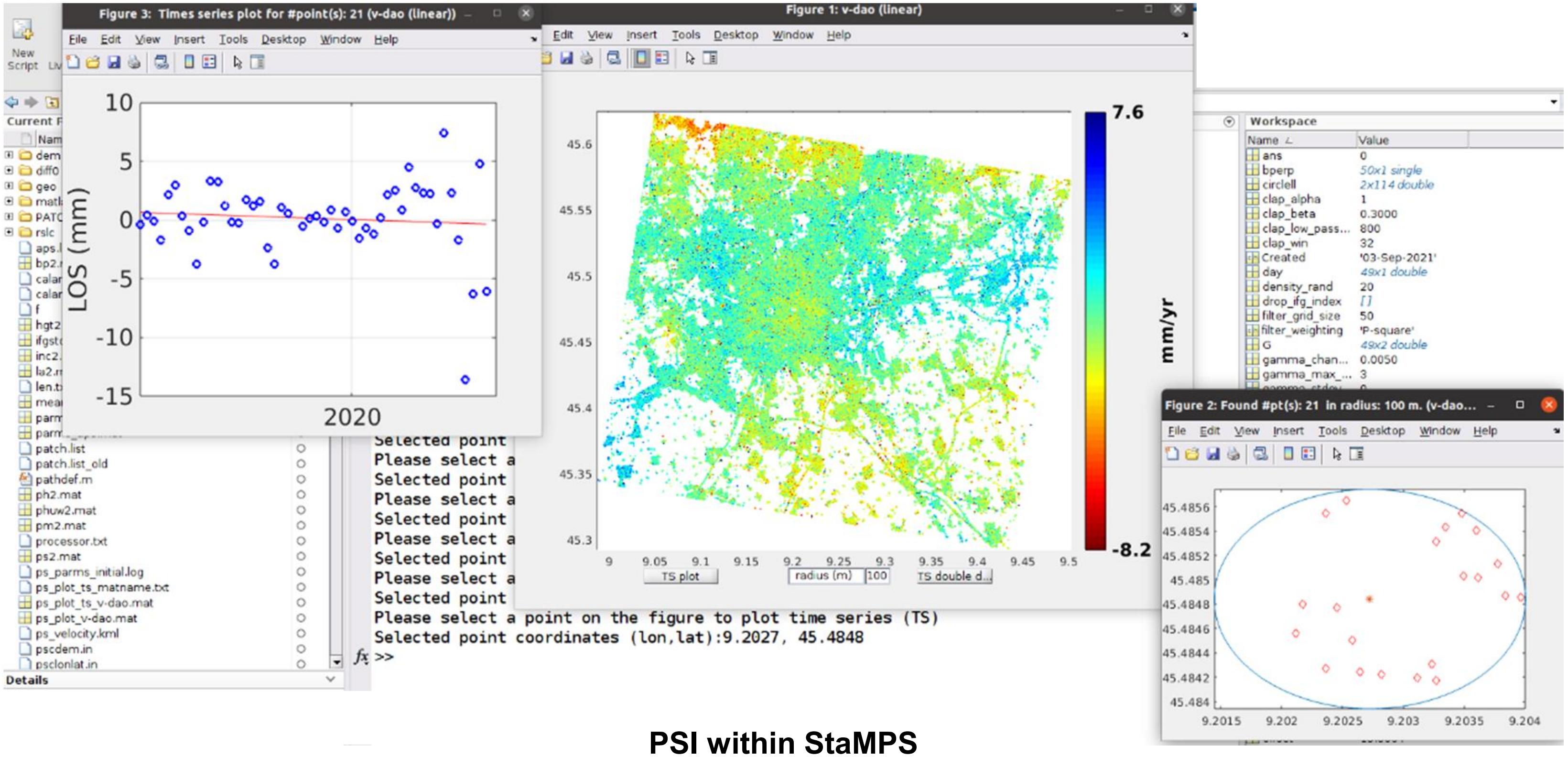
PSI within Google Earth

PSI vs P-SBAS (P-SBAS)



P-SBAS within Google Earth

PSI vs P-SBAS (Comparision)

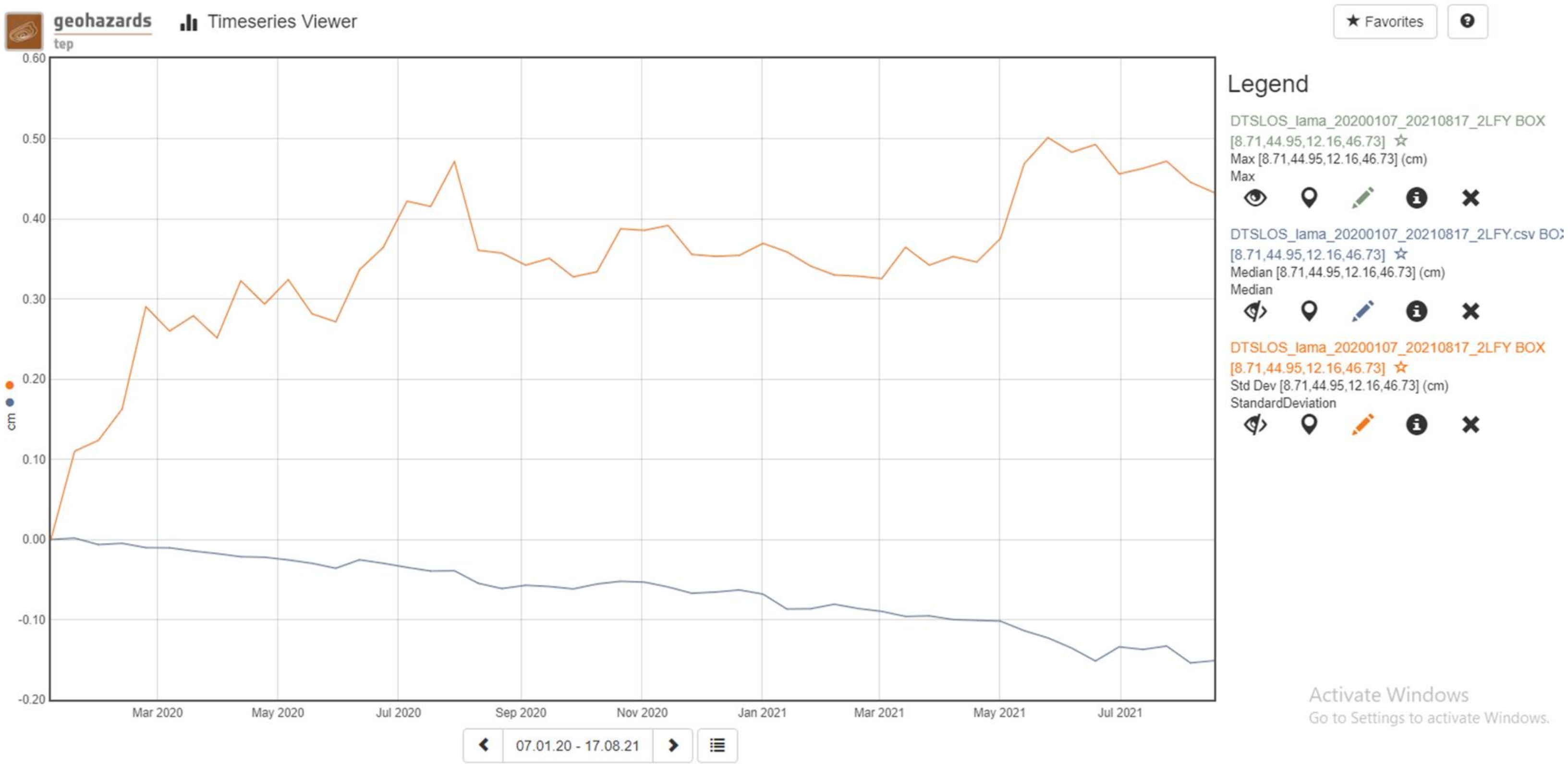


PSI within StaMPS

PSI vs P-SBAS (Comparision)

PSI within StaMPS Visualizer

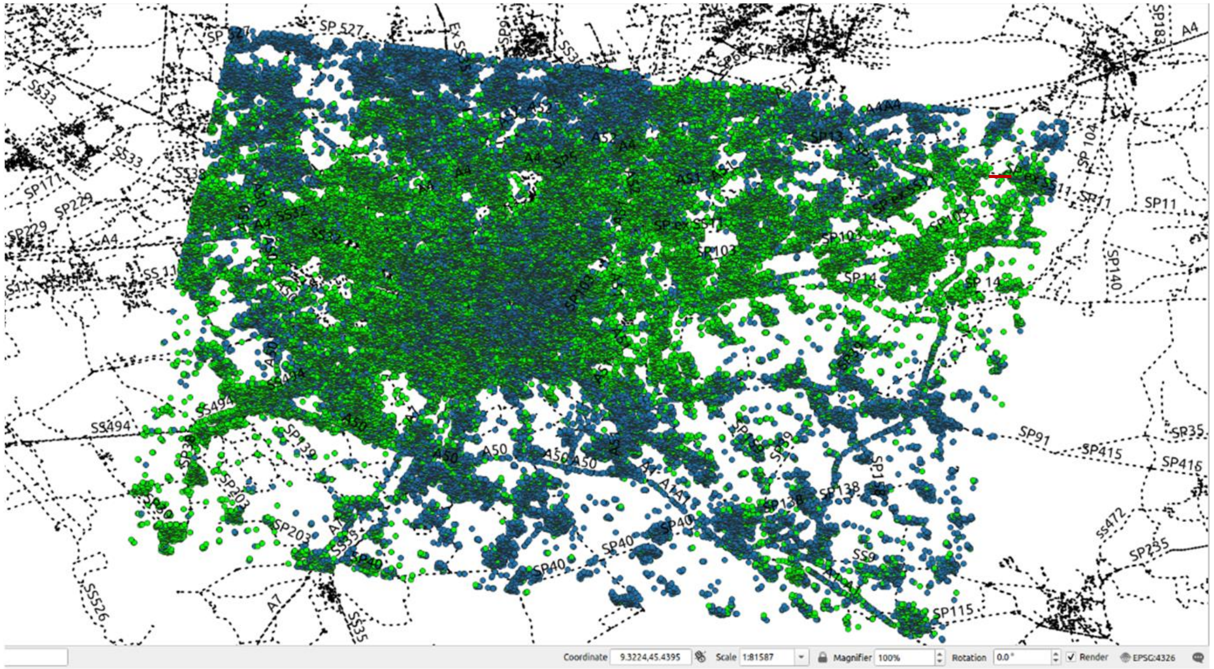
PSI vs P-SBAS (Comparision)



PSI vs P-SBAS (Comparision)

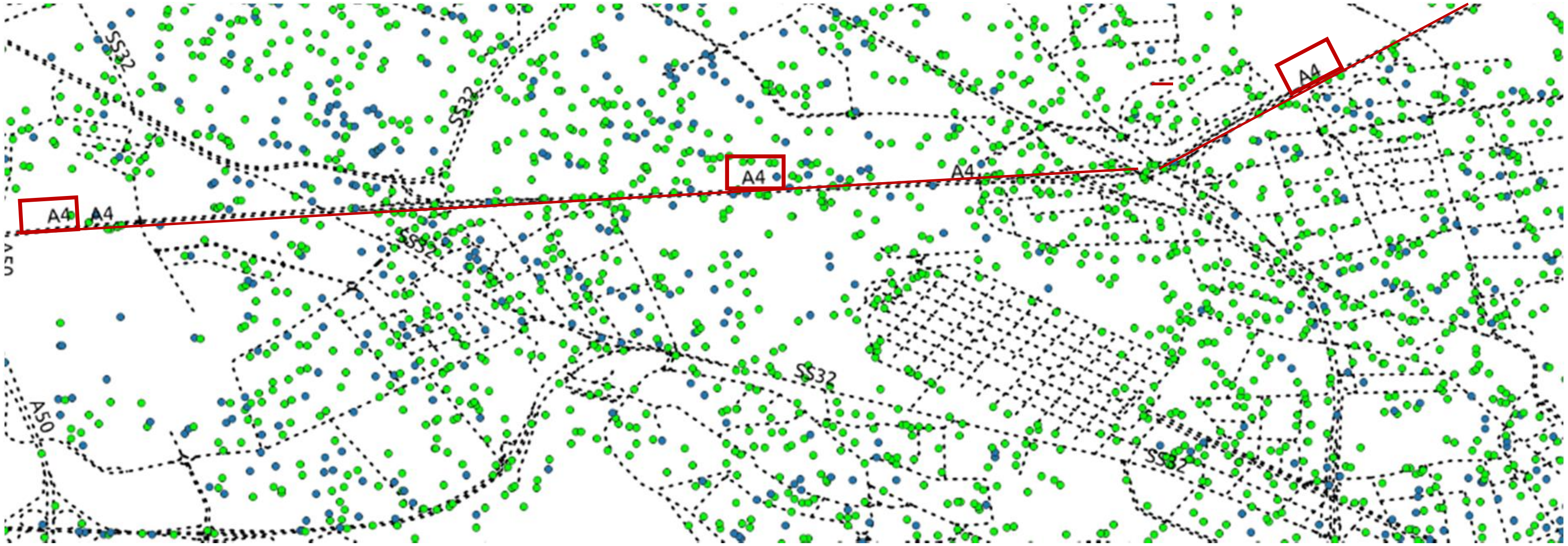
The velocity values within 1KM long for each road have been analyzed.

PSI vs P-SBAS (Comparision)



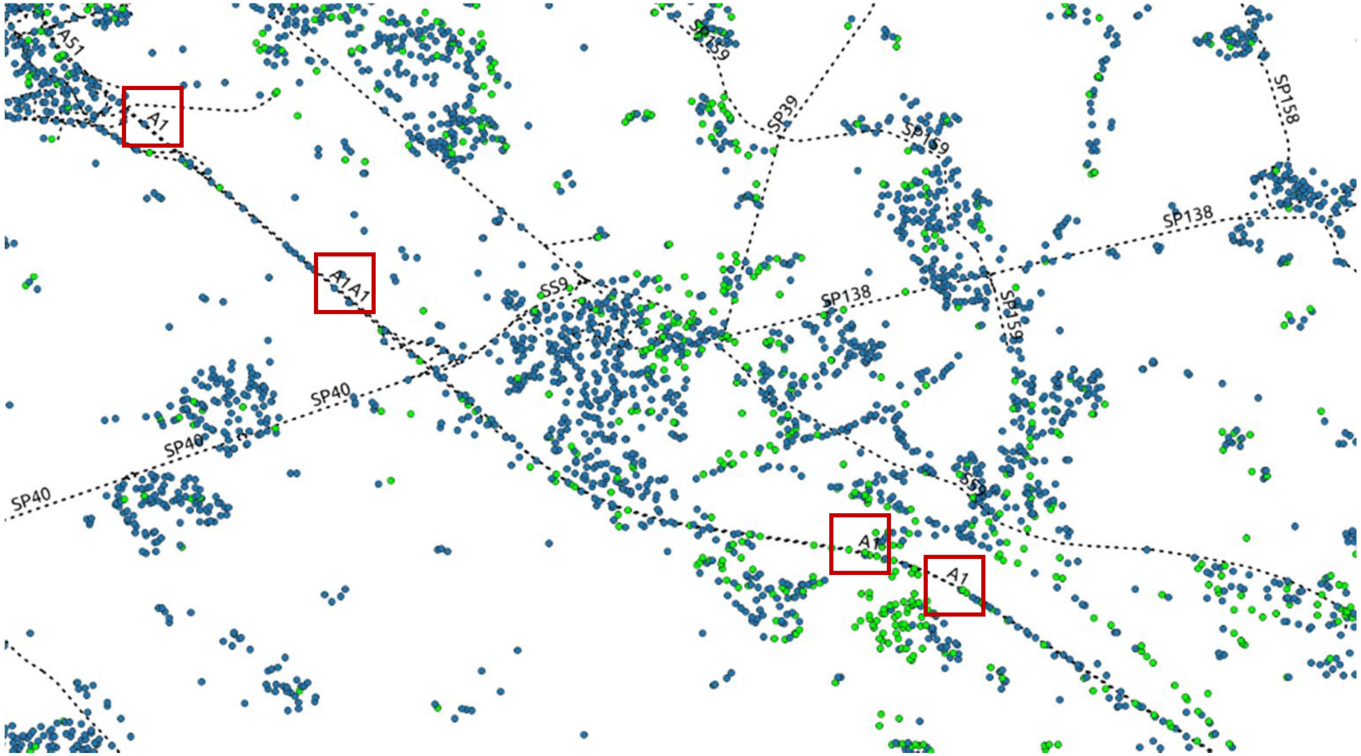
PSI Results in the QGIS Environment

PSI vs P-SBAS (Comparision)



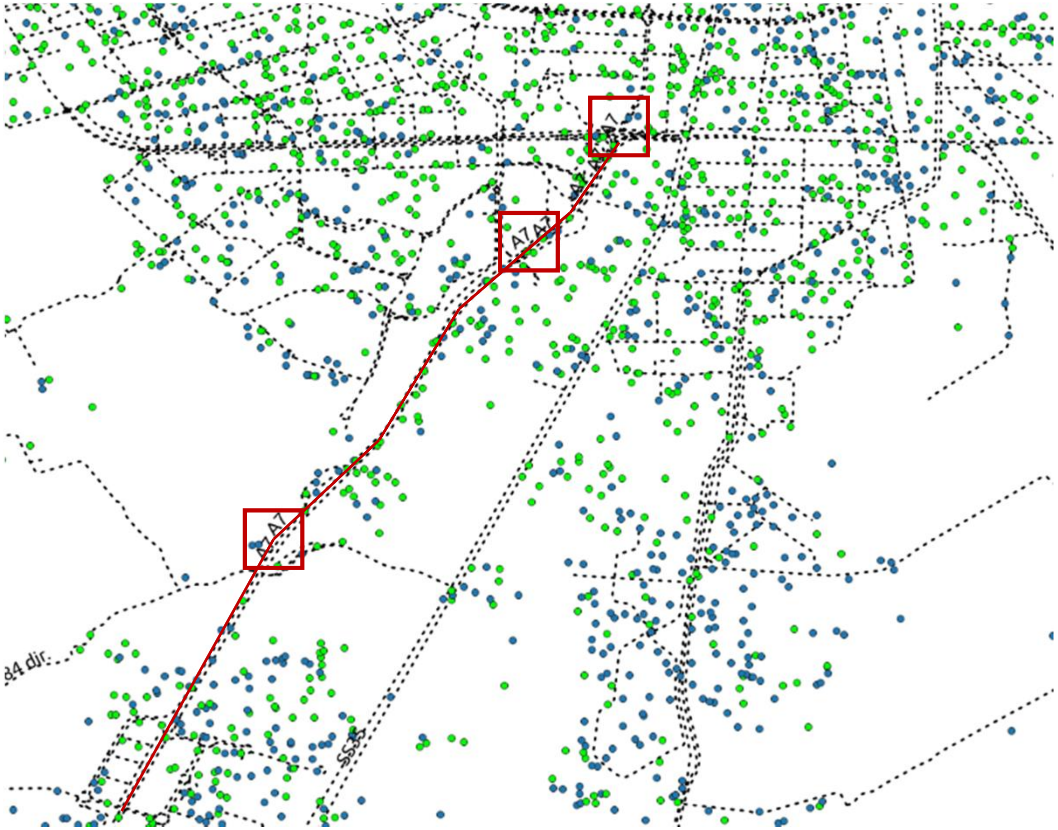
PSI Results in the QGIS Environment

PSI vs P-SBAS (Comparision)



PSI Results in the QGIS Environment

PSI vs P-SBAS (Comparision)



PSI vs P-SBAS (Comparision)

According to the produced velocity map by PSI technique (StaMPS):

- The areas near the roads have the fastest subsidence velocity
- Most of the persistent scatterers on A1 or near it (about 150m) have negative velocity values. Hence, this part of the road is subsiding
- Most of the persistent scatterers on A4 or near it (about 150m) have a positive velocity values. The velocity values of A4 are much larger than the velocity values of A7, so it is more sensitive to the displacements
- Most of the persistent scatterers on A7 or near it (about 150m) indicate that A7 has the least sensitivity to subsidence or heave according to the related velocity values

PSI vs P-SBAS (Comparision)

According to the produced velocity map by P-SBAS technique (GEP), the velocity values ranged between -1 cm/year and +1 cm/year which was very similar to the PSI velocity results

Finally..

The PSI technique is more sensitive than the P-SBAS technique for the subsidence monitoring in urban area, while the coverage of the P-SBAS technique is larger than the PSI technique

The difference between the results of these two methods is not too much

Both of them are suitable for the small subsidence monitoring for a long time period

Contents

The Current Research Work

- Fixing the choice of input data (interferograms, coherence, complex SLCs or amplitude data, or a combination thereof). Each choice of data has its own challenges in modeling
- Solving the problem of defining the labeled training set for the displacements hazards to train the network

Contents

Educational Activities

Many of the required courses and seminars for my project

+

Other courses concerning CISAS in general

+

The Planetary Mapping Winter School

The level of accomplishment is 59.5%

Thank You for the Attention

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