# ESA SNAP – StaMPS Integrated processing for Sentinel-1 Persistent Scatterer Interferometry

**Conference Paper** · July 2018

DOI: 10.1109/IGARSS.2018.8519545



**8 authors**, including:

Michael Foumelis
French Geological Survey


Jose Manuel Delgado Blasco
Progressive Systems at European Space Agency - Frascati, Italy


Marcus Engdahl
European Space Agency

# ESA SNAP – STAMPS INTEGRATED PROCESSING FOR SENTINEL-1 PERSISTENT SCATTERER INTERFEROMETRY

*Michael Foumelis[(1)], Jose Manuel Delgado Blasco[(2,3)], Yves-Louis Desnos[(4)], Marcus Engdahl[(4)], Diego Fernández[(4)], Luis Veci[(5*)], Jun Lu[(5*)], Cecilia Wong[(5)]*

[(1)] BRGM – French Geological Survey, Orleans, France, e-mail: m.foumelis@brgm.fr
[(2)] Progressive Systems c/o ESA Research and Service Support (RSS), Frascati, Italy
[(3)] Grupo de investigación Microgeodesia Jaén, Universidad de Jaén, Spain
[(4)] European Space Agency (ESA), Frascati, Italy
[(5)] Array Systems Computing Inc., Toronto, Canada
[*] presently at SkyWatch Space Applications, Waterloo, Canada

## ABSTRACT

Recent development by European Space Agency (ESA) involved the extension of the interferometric capabilities of the SentiNel Application Platform (SNAP) to enable SAR interferometric time series analysis through the Stanford Method of Persistent Scatterer (StaMPS) software package. In the current work, we demonstrate the enabled Persistent Scatterers Interferometry (PSI) processing of Copernicus Sentinel-1 mission data through SNAP-StaMPS integrated processing. A detailed overview of the processing steps involved as well as considerations and assumptions to exploit the SNAP-StaMPS synergy are presented. We intend to support the Earth Observation community by providing guidelines for Sentinel-1 TOPS data PSI processing using open source software packages. We demonstrate the SNAP functionality by processing two stacks of Sentinel-1 products over Mexico City (Mexico) and Rome (Italy).

***Index Terms*** **—** Copernicus Sentinel-1, ESA SNAP, StaMPS, Persistent Scatterers Interferometry

## 1. INTRODUCTION

ESA's Earth Observation (EO) Programme plays an essential role in advancing science and in improving our understanding of Earth processes [1]. The programme represents a pathfinder for science and innovation addressing the needs and requirements of the Earth system science community in terms of novel observations, algorithms and open source software packages to promote innovative scientific discoveries.
ESA continued developing appropriate tools for facilitating the EO community in using the Copernicus Sentinel data, by evolving, at the moment, the existing Next ESA SAR Toolbox (NEST) into the Sentinel-1 Toolbox. Finally, after integrating other toolboxes of the newest Sentinel satellites, SeNtinel Application Platform (SNAP) becomes a multi-mission toolbox supporting both SAR and optical data processing.

The Sentinel-1 Mission is the European Imaging Radar Observatory for the Copernicus joint initiative of the European Commission (EC) and the European Space Agency (ESA). Sentinel-1 constellation is composed of two satellites units, Sentinel-1A and Sentinel-1B (launched in April 2014 and April 2016, respectively), sharing the same orbital plane and featuring a short repeat cycle of 6 days optimised for Synthetic Aperture Radar (SAR) interferometry science and applications. The imaging radar operates at C-band in four exclusive acquisition modes dual polarisation capability. The Terrain Observation by Progressive Scans (TOPS) acquisition mode [2], default mode over land, provides high revisiting frequency and large swath coverage (250 km), while retaining high spatial resolution (down to 5 m) (https://sentinel.esa.int). Sentinel-1 data are freely available, typically less than 4 hours from sensing, via the Copernicus Open Access Hub since October 2014.

Being a newly implemented acquisition mode, TOPS required further development in terms of interferometric handling to ensure robust results. The SNAP TOPSAR capabilities were made available to users, at an early stage, just before the start of Sentinel-1 data dissemination, while SNAP TOPS InSAR development and results were first communicated at ESA Fringe 2015 consultation meeting.

Currently, although TOPS InSAR processing is sufficiently documented, the scientific community is lacking efficient and reliable end-to-end open source processing tools. Overpassing current limitation, the SNAP-StaMPS integrated processing appear as gap filling option to facilitate the use of Sentinel-1 TOPS data in advanced SAR interferometric time series analysis.

In the following chapters, given the already proven capabilities of StaMPS [3], we focus mainly on presenting in details a proposed processing scheme for preparation of StaMPS inputs through SNAP semi-automated TOPSAR processing, in support of Sentinel-1 scientific exploitation.

## 2. ESA SENTINEL APPLICATION PLATFORM

Developing, validating and maintaining open-source scientific software packages and making these research tools freely available to scientists worldwide, is one of the key objectives of the ESA EO Envelope Programme.

The SentiNel Application Platform (SNAP) is built on prior open source toolbox development (such as BEAM, NEST and ORFEO) and presents a strong evolution, in particular, by sharing a common architecture and by introducing innovative functionalities and new processing capabilities. SNAP is being developed, under GNU GPL open source license, in a coordinated joint venture by several industrial partners and scientists. The SNAP architecture has been designed to ensure highest performance when dealing with very large imagery such as the Copernicus Sentinels. Downloads of SNAP currently exceed 120.000 (statistics on September 2017).

The Science Toolbox Exploitation Platform (STEP) presents a state of the art effort to involve the scientific community in the further development and innovative exploitation of ESA's open source toolboxes (http://step.esa.int). Through this community platform, scientists are encouraged to participate in the beta testing phase of new releases, communicate with developers through forums, easily report bugs and track issues and access training material examples and video tutorials. The development of STEP and SNAP are key contributions to ESA's new approach on EO data exploitation via dedicated platforms referred to as "EO Open Science" (http://eoopenscience.esa.int).

Valuable inputs to SNAP regarding proper scientific exploitation and optimum InSAR processing of Sentinel-1 TOPS data were introduced through ESA's Scientific Exploitation of Operational Missions (SEOM) INSARAP studies (http://insarap.org) [4-5].

Further development involved the extension of the interferometric capacity of SNAP to enable Persistent Scatterers Interferometry (PSI) via a "link" to existing open source software packages, and specifically StaMPS. The functionality was delivered initially in beta state. After several bug fixing, improvements and testing, it is included in SNAP v6 (released in January 2018.

## 3. SNAP-STAMPS INTEGRATED PSI PROCESSING

For the demonstration of SNAP-StaMPS integrated PSI processing, we had selected two areas of interest (AOI), with known ground deformation signal, namely Mexico City [6] and Rome [7]. Hence, we have processed approximately one year of Sentinel-1A data over each region, as detailed in Table 1. In order to minimize processing resources employed, the satellite relative orbits were selected ensuring the full AOI is located within a single Sentinel-1 sub-swath.

**Table 1.** Sentinel-1A datasets utilized in the demonstration

| AOI | Relative Orbit | Nu Scenes | Start Date | End Date |
|---|---|---|---|---|
| Mexico | 143 | 17 | 2015/11/15 | 2016/11/09 |
| Rome | 22 | 22 | 2016/01/06 | 2016/12/31 |

The entire processing workflow is designed using the SNAP Graph Builder interface and saved as several XML files (Fig. 1). The Graph Builder allows the user to assemble graphs from a list of available operators and connect operator nodes to their source. The splitting of the workflow into separate XML files facilitates better use of computing resources.

In the following sections, the processing steps performed in SNAP in order to get a fully compatible output usable in StaMPS as well as some basic StaMPS suggestions for data ingestions are described. A single master interferometric processing approach for PSI-like analysis is considered. For processing, resources of the ESA Research & Service Support were employed [8].

### *3.1 Image splitting and update of orbits*

The selection of a master acquisition, that minimizes geometric baselines within the dataset, is supported by the InSAR Stack Overview operator.

Initial processing steps involve the splitting of Sentinel-1 IW SLC core products and the update of their orbital information (Fig. 2). The selected TOPS master scene is first split by defining sub-swath, polarization and bursts covering entirely the AOI (S-1 TOPS Split). Then, the rest of the dataset (slave images) must also be splitted based only on the defined single sub-swath and polarization. In subsequent processing common bursts between master and slaves are automatically considered.

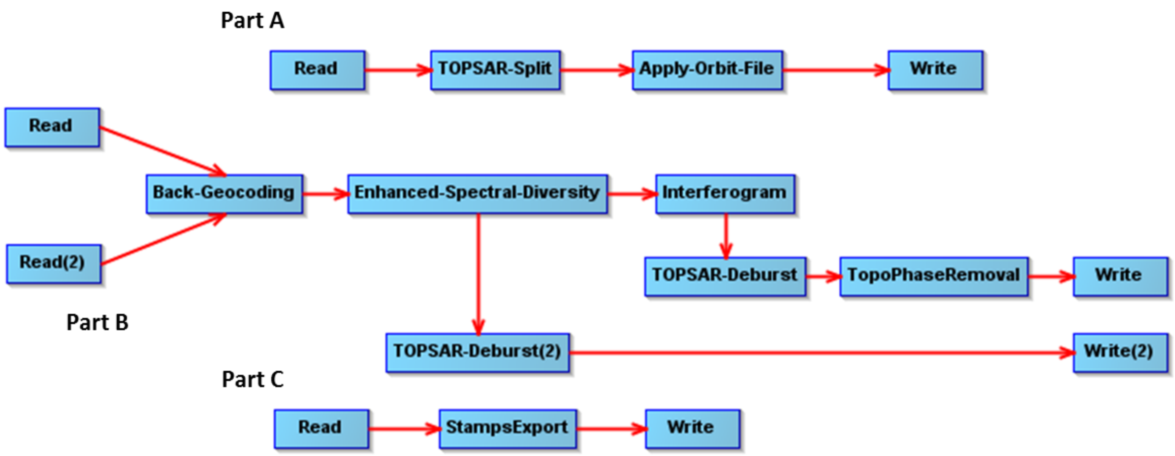


**Fig 1.** Schematic diagram presenting different parts of the SNAP-StaMPS integrated PSI processing workflow.

Finally, the annotated orbit information are updated (*Apply Orbit File*) using, preferably, precise orbit state vectors (https://qc.sentinel1.eo.esa.int), automatically downloaded by SNAP.

*3.2 TOPS co-registration and interferogram formation*

Each master-slave pair is used to create two independent stacks, one for the pair of master and co-registered slave SLCs and a second for the corresponding differential interferograms. The proposed TOPS co-registration approach includes both geometric co-registration (*S-1 Back-geocoding*) as well as the *S-1 Enhanced Spectral Diversity* (ESD) refinement (Fig. 2). Co-registration residuals and ESD offset estimates, including other InSAR-related information can be checked through the *InSAR Stack* overview window.

The generation of the complex interferogram, including the removal of the flat-Earth phase, is then proceeded (*Interferogram Formation*). Topographic phase is simulated and subtracted using the SRTM 3 arc-seconds Digital Terrain Model (DTM), using the automatic downloaded option in SNAP (Topographic Phase Removal). For newer versions of SNAP (v6 or higher), removal of topographic phase can also be applied within the *Interferogram Formation* operator. To generate orthorectified latitude and longitude coordinate raster files, required by StaMPS for accurate PS points geocoding, the corresponding export option should be selected.

Debursting of both the SLCs and the differential interferograms is at that point required to obtain spatially continues images (*S-1 TOPS Deburst*). Finally, as an optional step, spatial subsetting (*Subset*) can be applied to the co-registered and debursted TOPS SLC-pair stacks and interferogram stacks. It should be noted, that no subset of Sentinel-1 SLC data is recommended prior to this point.

*3.3 SNAP export to StaMPS format*

Once pairs of co-registered master-slave SLCs and differential interferograms are successfully generated, each data stack is exported individually using the *StaMPS export* operator. By defining a common directory, the SNAP TOPS InSAR results are exported in a StaMPS compatible format separated into sub-folders. At this point, it is required to merge the various sub-folders into the specific folder structure required by StaMPS.

*3.4 Ingestion into StaMPS*

After properly merging all the exported folders, the *mt_prep_gamma* script is launched over the dataset to proceed with extraction of sensor and acquisition parameters, detection of initial PS candidates and extraction relevant data (phase, height etc.) over those point candidates. Since SNAP output both SLCs and differential interferograms as raster files in fcomplex binary format, proper handling during ingestion into StaMPS should be ensured. For further discussion on interferogram formatting issues during StaMPS integration please refer to ESA STEP Forum (http://forum.step.esa.int).

*3.5 StaMPS processing*

All the steps could be follow as explained in StaMPS manual, but we had also applied the Toolbox for Reducing Atmospheric InSAR Noise (TRAIN) [9] using the linear approach, in order to ensure that the full functionalities were able to run without encountering any issues with the provided input datasets.

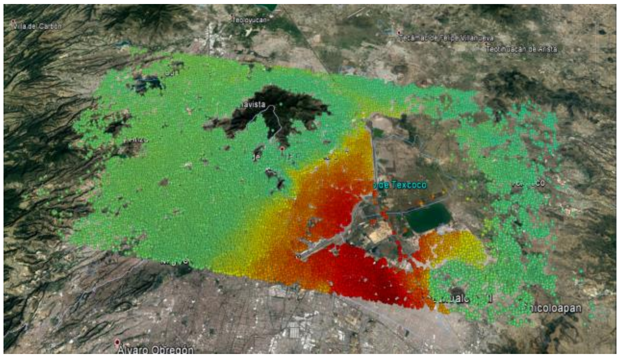

**Fig 2.** PSI ground displacement rates of Mexico City as obtained by SNAP-StaMPS integrated processing. Google Earth in background.

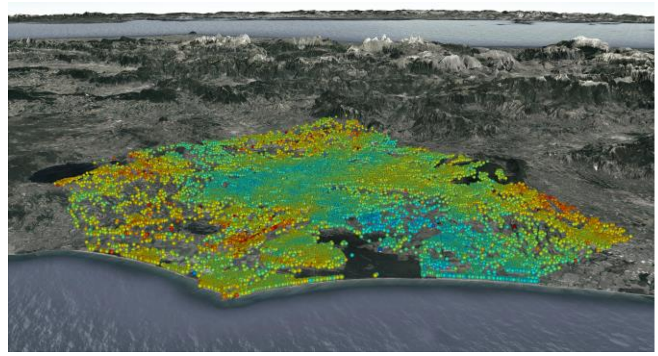

**Fig 3.** PSI ground displacement rates of broader Rome area as obtained by SNAP-StaMPS integrated processing. Google Earth in background.

## 4. DEMONSTRATION RESULTS AND DISCUSSION

SNAP-StaMPS integrated processing for semi-automated Sentinel-1 TOPS interferometric time series analysis was successfully demonstrated over Mexico City and the broader area of Rome (Fig. 2 & 3). The obtained results are in agreement to those of previously published studies [7-10]. Since it is not of the aims of the work to investigate ground displacements, no further interpretation is attempted.

Although significant part of the described processing workflow is practically automated through SNAP Graph Builder, still some manual work is required for defining the input/output for each interferometric pair. SNAP Bash Processing option cannot be of use in such case. The build of external scripts for product names substitution would be a suggested alternative solution. In that case, saved SNAP graphs (*.xml files) can be used in the command line via the Graph Processing Tool (GPT) with a different set of i/o data products.

Our main objective is to facilitate scientific exchange, informing on the latest developments of ESA open source SNAP toolbox regarding the use of Sentinel-1 TOPS data for SAR interferometric time series analysis. This will enable the scientific community to address new research and applications pathways by exploiting the free and open data policy adopted for the Copernicus Sentinel missions.

## 5. ACKNOWLEDGMENTS

Authors would like to acknowledge Magdalena Fitrzyk (RSAC c/o ESA) for her support to SNAP development.

## 6. REFERENCES

[1] Y-L. Desnos, M. Borgeaud, M. Doherty, V. Liebig and M. Rast, "The European Space Agency Earth Observation Program," IEEE Geoscience and Remote Sensing Magazine, pp. 37-46, 2014.

[2] F. De Zan and A.M.M. Guarnieri, "TOPSAR: Terrain observation by progressive scans," *IEEE Transactions on Geoscience and Remote*, 44(9), doi: 10.1109/TGRS.2006.873853, 2006.

[3] A. J. Hooper, 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, L23611, doi:10.1029/2004GL021737*, 2004.

[4] P. Prats-Iraola, M. Nannini, R. Scheiber, F. De Zan, S. Wollstadt, F. Minati, M. Costantini, A. Bucarelli, S. Borgstrom, T. Walter, M. Foumelis and Y-L. Desnos, "Sentinel-1 assessment of the interferometric wide-swath mode," IGARSS 2015, pp. 5248-5251, 2015.

[5] Y. Larsen, H. Johnsen, P. Marinkovic, A. Hooper, T. Wright, Z. Perski, and J. Dehls, "SEOM – Sentinel-1 InSAR Performance Study with TOPS Data – Team B: First Results," Proceedings of FRINGE '15, European Space Agency (CD), 2015.

[6] B. Osmanoğlu, T. H. Dixon, S. Wdowinski, E. Cabral-Cano, and Y. Jiang, "Mexico City subsidence observed with persistent scatterer InSAR," *International Journal of Applied Earth Observation and Geoinformation*, 13(1), pp. 1-12, 2011.

[7] S. Stramondo, F. Bozzano, F. Marra, U. Wegmuller, F. R. Cinti, M. Moro and M. Saroli, "Subsidence induced by urbanisation in the city of Rome detected by advanced InSAR technique and geotechnical investigations," *Remote Sensing of Environment,* 112(6), pp. 3160-3172, 2008.

[8] J. M. Delgado, G. Sabatino, R. Cuccu, G. Rivolta and P.G Marchetti, "Challenges and achievements in supporting research and services development for big data," Proceedings of the 2016 Conference Big Data from Space, 2016.

[9] D. P. S. Bekaert, R. J. Walters, T. J. Wright, A. J. Hooper and D. J. Parker, "Statistical comparison of InSAR tropospheric correction techniques," *Remote Sensing of Environment*, 170, pp. 40-47, 2015.