A FULLY AUTOMATIC AND CLOUD-BASED P-SBAS DINSAR PIPELINE
FOR SENTINEL-1 PROCESSING

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ABSTRACT

In this work we present a cloud-computing based strategy for generating surface displacement time series and mean deformation velocity maps of very large areas by exploiting Sentinel-1 (S1) data. Our approach relies on the simultaneous exploitation of a fast access to the S1 data archives, High Performance Computing resources and external geodetic data.

The presented pipeline is based on an advanced cloud-computing implementation of the differential SAR interferometry (DInSAR) Parallel Small Baseline Subset (P-SBAS) processing chain, which allows the fully unsupervised processing of huge Interferometric Wide Swath (IWS) Sentinel-1 data volumes.

In particular, for what concerns the S1 data archives, we benefited from the NASA’s Alaska Satellite Facility (ASF) Distributed Active Archive Center (DAAC), which stores and distributes S1 SAR data from Amazon Web Service (AWS) for advancing Earth science research. The ASF-DAAC allowed us to reach a very high performance level in terms of downloading time and system reliability.

Moreover, we exploited the geodetic measurements provided from the Magnet + Global GPS Network Map of the Nevada Geodetic Laboratory at the University of Nevada, Reno, USA (UNR-NGL), which supply GPS measurements daily updated and continuously available. The GPS measurements were used to account for regional trends and to better discriminate the low (tectonic) and high (local) frequency deformation patterns.

The presented solution is highly scalable and has been migrated to the Amazon Web Service (AWS) environment. It runs out along an automatic routine to generate the mean deformation velocity maps of the vertical and horizontal (East-West) displacement components of the whole investigated area.

The developed pipeline has been tested on ascending and descending Sentinel-1 archives acquired over a large area of Southern California (US), which extends over about 150,000 square kilometers.

Index Terms— DInSAR, P-SBAS, Cloud Computing, Sentinel-1, GPS

1. INTRODUCTION

Differential Synthetic Aperture Radar (SAR) Interferometry (DInSAR) is a microwave remote sensing methodology playing nowadays a crucial role in the investigation of Earth surface deformation phenomena with centimeter to millimeter level accuracy [1-3]. Indeed, the DInSAR technique permits to measure ground displacements, more precisely the deformation component along the radar line of sight (LOS), with a very large spatial coverage capability and with an accuracy of a fraction of the wavelength according with the transmitted microwave signal [4-6].

From April 2014 an extremely large SAR data flow is available for the scientific community. In fact, the launch of Sentinel-1A and subsequently of its twin sensor Sentinel-1B (on April 2016) of the European Copernicus program, completely changed the DInSAR scenario. In particular, the main S1 acquisition mode on land, the so-called Interferometric Wide Swath (IWS), implements the Terrain Observation by Progressive Scans (TOPS) technique [7] that has a nominal footprint of about 250 km in range direction, thus allowing the constellation to operate with a global coverage acquisition strategy. Moreover, the S1 revisit time is either 12 or 6 days accordingly with the acquisition data policy. In addition, it is worth noting that the whole S1 archive is available with a free and open access policy, making easier the data access and so increasing the scientific community interested in its exploitation.

With this data flow, it is evident that the full exploitation of the SAR archives needs effective solutions for the data transfer, storage, DInSAR algorithm and parallel processing management.

From the processing point of view, a parallel algorithmic solution for the S1 IWS SBAS approach has recently been developed. Starting from the StripMap implementation referred to P-SBAS [8] a new release for TOPS acquisition mode that is essentially based on a burst parallelization level has been made. Such a new parallel processing chain sets up the full DInSAR-SBAS processing chain (from the Single...
Look Complex (SLC) data ingestion up to the displacement time-series and deformation mean velocity map generation) and is able to exploit distributed computing architectures [9].

This paper presents a fully automatic and cloud implemented pipeline, to process large S1 IWS data volumes for the generation of deformation time series, mean velocity maps and corresponding vertical and horizontal displacement maps at very large spatial scale, in an easy and effective way.

2. RATIONALE OF PROPOSED APPROACH

In this section, we present the basic elements of the developed pipeline for the cloud computing (CC) implementation of the S1 IWS P-SBAS approach. The algorithm permits to properly combine all the LOS mean deformation velocity maps evaluated over ascending and descending passes to retrieve a unique vertical and horizontal (East-West) surface deformation component maps of the analyzed area [10, 11]. In Figure 1 a pictorial block-diagram of the implemented solution is depicted.

2.1 Data Selection and download

To reach the expected results, we partitioned the whole SAR dataset that cover the study area in data clusters with a dimension commensurate with a standard S1 slice. Such an approach allows us to both optimize the exploitation of the computing resources required for S1 DInSAR processing, by also properly balancing the workload over the available computing resources, and to avoid possible problems related to the interferometric processing of very extended area, as for instance the phase unwrapping step [12].

The dataset preparation is carried out with a pre-processing selection of the footprints covering the area of interest. Such footprints allow us to identify the geographical area where automatically retrieve the S1 data clusters on. The data cluster generated in the data preparation phase are depicted in Figure 2 for both ascending and descending orbits. The data covering the area of interest are downloaded automatically for each data cluster before launching the S1 IWS P-SBAS processing. Data clusters are constructed considering an overlap with the consecutive cluster. Such a solution guarantees no gap in the large-scale interferometric analysis.

In our experiment, we downloaded the S1 data from the Alaska Satellite Facility (ASF) Distributed Active Archive Center (DAAC), which is supported by NASA. The choice of exploiting ASF-DAAC allowed us to reach a very high performance level in terms of downloading time and system reliability. Indeed, the bandwidth available for the data download allowed us to carry out 20 parallel downloads without saturating the bandwidth.

It is worth noting that our DInSAR pipeline can work by using different S1 data mirrors as several Copernicus Data and Information Access Service (DIAS) and S1 data-hub as well.

2.2 S1 IWS P-SBAS processing on AWS environment

After the data preparation, the DInSAR cloud pipeline proceeds launching and managing all the parallel S1 IWS P-SBAS processing. Regarding this part of the pipeline, we took advance by our previous experience in the migration of the P-SBAS processing chain to the Amazon Web Service (AWS) CC environment [12-14]. Leveraging on the above-mentioned experience the cloud computing resources have been selected in order to sustain the processing of Big Data volumes and to reduce the computing elapsed times. In addition, to optimize data access speed to ASF-DAAC’s S1 data holdings, the CC instances have been initialized in a specific geographical region. Considering that the ASF-DAAC mirror is already making most of its S1 data holding available through AWS East-1, we chose the AWS instances in the U.S. North Virginia region for processing. In particular, we exploited for the S1 IWS P-SBAS processing the i3.16xlarge instances, whose hardware features are reported in Table 1. As highlighted in Figure 1, in the developed pipeline we are directly linked with a global positioning system (GPS) network. In particular, the GPS measurements have been retrieved from the Magnet + Global GPS Network Map [15] of the Nevada Geodetic Laboratory at the University of Nevada, Reno, USA (UNR-NGL), where the GPS measurements are daily updated and continually available. Simultaneously with the data clusters selection, in the pre-processing phase we retrieved all GPS stations that cover the area selected for the advanced DInSAR analysis.

As a consequence of the large ground coverage of S1 images, the impact of tectonic trend in the ground deformation maps is even more evident. Indeed, taking advantage from the information available from external GPS measurements we accounted for regional trends to better discriminate both the low (tectonic) and high (local) frequency deformation pattern.

The automatic pipeline described in this paper, just after the generation of the displacement maps, proceeds with the copy of the DInSAR results to the Amazon S3 permanent storage. Such procedure is fundamental both to preserve in permanent way the obtained results and to free
space on the AWS instances to allow the processing of a new S1 data cluster. Finally, after the overall S1 IWS P-SBAS processing over ascending and descending orbits, the pipeline implements an ad-hoc post-processing step for the automatic generation of the vertical and horizontal (East/West) deformation components of the whole investigated area (i.e., the common area among all the exploited ascending and descending tracks), accordingly with the methodology mentioned in [11].

3. CONCLUSION

In this paper we present an efficient and robust cloud computing DInSAR pipeline for the generation of displacement time series and corresponding mean deformation velocity map of very large areas by exploiting Sentinel-1 data. The proposed approach jointly employs the efficient DInSAR processing chain referred to as P-SBAS, the very high performance AWS infrastructure, the data archives with very high access bandwidth referred to ASF-DAAC, and the external geodetic measurements continually processed and available corresponding to the Magnet + Global GPS Network Map of the Nevada Geodetic Laboratory at the University of Nevada. This complete pipeline has been tested through an experimental analysis involving the full SLC IWS data archive, acquired by Sentinel-1 constellation, from both ascending and descending orbits, over a Southern California region extending for about 150,000 square km. In particular, we have divided the study area in 8 data clusters (4 clusters for both ascending and descending orbits). As final results, we computed the deformation time series and the corresponding mean deformation velocity maps of the investigated region for both ascending and descending orbits. Moreover, through an automatic post-processing step, which corresponds to the last step of the developed pipeline, we retrieved the mean deformation velocity maps of the vertical and horizontal (East-West) displacement components of the whole investigated area.

It is worth noting that for a better estimation of the high frequency deformation pattern, in our DInSAR pipeline we took advantage of the measurements available from the GPS station located in the investigated area. The results that we will show are going to demonstrate how the cooperation of different research entities and different kind of data can be essential for both the data intensive exploration and the accuracy of the DInSAR measurements, so as to trace an innovative path in the Earth Observation field.

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4. REFERENCES

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Figure 2: Data clusters generated during the data preparation phase for the Sentinel-1 P-SBAS automatic DInSAR pipeline. In particular, the tracks that have been selected along the descending (71, 173) and ascending (64, 166) orbits are represented in (a) and (b), respectively.