

DEFORMATION MAPS RETRIEVAL OF URBAN AREAS USING GROUND-BASED POLSAR ACQUISITIONS

Luca Pippia, Xavier Fabregas, Albert Aguasca, Sergi Duque, Jordi J. Mallorqui, Carlos Lopez-Martinez

Remote Sensing Lab. (RSLab), Universitat Politècnica de Catalunya (UPC),
c./ Jordi Girona 1-3 Building D3, E-08034 Barcelona, Spain
E-mail: luca.pippia@tsc.upc.edu

1. ABSTRACT

One of the great challenges of remote sensing SAR community in the very next years is to exploit the high amount of information contained in the polarimetric SAR data to improve the performance of already assessed single-polarization techniques. Owing to its remarkable achievements, differential interferometry is one of the most representative cases. The complementary techniques of the Permanent Scatterers (PS) [1] and Coherent Pixels (CPT) [2] have been demonstrated to be extremely successful depending on the features of the environment to be monitored. In both cases, a critical issue is the selection of points to be trusted for the retrieval of an accurate deformation map. The lack of polarimetric SAR sensors mounted on satellite platform, and consequently of long temporal PolSAR data, prevented from trying to extend the mathematical formulation of these advanced methods to multiple polarization channels. The coherence optimization of pixels along the whole interferograms stack through polarization basis transformations or the search of stable pixels among the HH-HV-VV channels are subjects never investigated before. The revisiting time reduction is the most troublesome point the satellite monitoring has not overcome yet. The necessity to perform an almost real-time coverage of critical areas is turning out to be fundamental for hazard prevention issues and is pushing for planning new missions focused on this purpose. The employment of satellite constellations [3][4] and the exploitation of polarimetric information define two of the guidelines that international space agencies are moving towards. Nevertheless, the temporal stability of the polarimetric description of an environment still remains an unexplored topic due to the lack of reliable collection of PolSAR data. From this point of view, ground-based SAR sensors play a new key-role. Despite the intrinsic limitations in the use of any terrestrial platform, like the small area that can be observed or the high sensitivity to positioning errors related to the short synthetic aperture, they give the opportunity to look into the temporal dimension of the phenomenon to be studied.

The Research Laboratory (RSLab) of the Universitat Politècnica de Catalunya (UPC), in collaboration with the Institut Geològic of Catalunya (IGC), has carried out a measuring campaign for the monitoring of a mining induced subsidence phenomenon in the village of Sallent [5], northeastern Spain, using its ground-based SAR sensor. PolSAR data that have been monthly acquired at X-Band for approximately one year, giving for the first time the opportunity to explore the temporal evolution of the backscattering mechanism's properties from a fixed scenario [6].

In this paper, a first attempt to exploit the knowledge of the whole scattering matrix [S] to improve the estimation of the deformation velocity of the area under observation is carried out. For this purpose, the CPT [7] approach is employed. In order to analyze the benefits that the use of PolSAR data might provide with respect to a single-polarization study, the classical CPT process is applied to each channel of [S].

As well known, the first step of this technique is the generation of all the possible combination of two datasets among the whole set of temporal acquisitions at disposal. For each pair, the differential coherence γ and the interferometric phase ϕ are estimated for each pixel of the image. A first selection of points whose time-averaged coherence is higher than a fixed threshold is performed. The points fulfilling this condition are then triangulated using the Delaunay method. The evolution of the differential phase difference between linked pixels is fit to a linear model and a quality parameter, denoted by O , is estimated. O equal to 1 describes data perfectly fitting the model while it tends to 0 when the decorrelation between the data and the model is total. All the pixels whose O is lower than a minimum value are filtered out and the triangulation process is applied again to the remaining ones. The resulting grid is used to construct a linear equation system whose solution provides the increment of deformation velocity between neighboring pixels. The map of the absolute deformation velocity is obtained by the final integration of these increments.

In [8][9] it has been shown that the instability characterizing the temporal behavior of urban targets in GB-SAR

acquisitions affects the polarization channels in a different way. Moreover, the quantitative results reported in the same work have shown that pixels instable in one channel are likely to be stable in another one. The total number of reliable pixels is generally expected to increase when the information of the whole [S] is used.

In this work, we propose two new criteria for the selection of good pixels. Both are based on the assumption that the differential phase is related just to the deformation along the radial direction under the hypothesis of temporal stationarity of targets' answer. In the first one, the temporal behavior of a pixel of the image is still described using the same channel of [S]. The idea is now to make this channel change from pixel to pixel, depending on the polarization that for each point provides the highest value of time-averaged coherence. In this case the differential phase information of two pixels linked by the triangulation and compared for the estimation of O might come from two different polarizations. The use of high threshold for the minimum value of coherence guarantees that the stationarity hypothesis is fulfilled and that this operation is completely correct.

In the second method we propose, the channel used to extract the differential information concerning the same pixel might vary for each pair of datasets. When two acquisitions are analyzed, the coherence is estimated for the three channels of [S]. For each pixel of the image it is selected the polarization with the highest value of γ . Theoretically, this allows to choose the polarimetric channel that fulfills in the best way the hypothesis of stationarity for the target the pixels belongs to. The corresponding differential phase is expected to be more robust to target modifications and it is likely to contain just information about the deformation process. This process is hence repeated for each combination of datasets. At the end, the temporal evolution of the differential phase characterizing each point of the image might come from different polarizations. The only requirement to employ the two methods is that data must be polarimetrically calibrated in order to avoid any offset among the terms of the scattering matrix. Once the selections of reliable points are obtained and the corresponding differential phase information is calculated, the CPT algorithm is applied again. Now, the first step of the single-polarization algorithm, the selection, is obviously skipped. The process of the new sets of pixel starts from the first Delaunay triangulation and ends with the final integration step. The results obtained in the two cases are compared with the deformation map retrieved using the classical CPT approach. Finally, the advantages provided by the polarimetric analysis are pointed out.

2. REFERENCES

- [1] A. Ferretti, C. Prati and F. Rocca, "Permanent Scatterers in SAR Interferometry," *IEEE Trans. Geosci.Remote Sens* vol. 39, N.1, January 2001
- [2] O. Mora, J. Mallorqui, A. Broquetas, "Linear and Nonlinear Terrain Deformation Maps From a Reduced Set of Interferometric SAR Images," *IEEE Trans. Geosci.Remote Sens*, Volume 41, Issue 10, October 2003.
- [3] L. Amorusi, A. Notarantonio, E. Calì, C. Galeazzi, E. Scorzafava, "COSMO-SkyMed constellation control," *SpaceOps 2006*, Rome, Italy, June 19-23, 2006.
- [4] Guy Seguin, "RADARSAT Constellation Mission Overview," *Advanced SAR 2007 Proceedings*, 11-13 September 2007, Vancouver, Canada.
- [5] L. Pipia et al., "Mining Induced Subsidence Monitoring in Urban Areas with a Ground-Based SAR," *2007 Urban Remote Sensing Joint Event*, 11-13 April 2007, Paris, France.
- [6] L. Pipia, X. Fabregas, A. Aguasca, C. Lopez-Martinez, J.J. Mallorqui, "Urban Environment Characterization using a PolSAR GB Sensor: short and long temporal analysis at X-Band" *Advanced SAR 2007 Proceedings*, 11-13 September 2007, Vancouver, Canada.
- [7] O.Mora, J.J.Mallorqui, A.Broquetas, "Linear and Nonlinear Terrain Deformation Maps From a Reduced Set of Interferometric SAR Images," *Trans. On Geoscience and Rem. Sensing*, Vol.41, No.10, October 2003.
- [8] L. Pipia, X. Fabregas, A. Aguasca, C. Lopez-Martinez, J.J. Mallorqui, O.Mora "Polarimetric Information Merging for Urban Deformation Map Retrieval," *Igarss07 Proceedings*, 23-27 July 2007, Barcelona, Spain.
- [9] L. Pipia, X. Fàbregas, A. Aguasca, C. López-Martínez, J.J. Marturià, "Polarimetric Multi-temporal SAR Information in Urban Environments," submitted to *Transaction on Geoscience and Remote Sensing*, December 2007.