1,500 RADARSAT scenes for PSInSAR™: the Italian case study

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Over the last decade, the European and Canadian Space Agencies have made significant investments in transforming the use of InSAR technologies from applied research to commercial applications. Has the investment been fruitful? Data processing service providers still appear to rely significantly on ESA and CSA funding for propagating the technology to commercial audiences. This paper seeks to affirm that there is an appetite within both the public and private sectors by presenting some "real life" applications of PSInSAR™ to the monitoring of landslides, volcanoes, seismic faults, subsidence and settlement, in situations where space agency funding has not been involved. Over the last three years, extensive processing of more than 1,500 SAR scenes acquired by the RADARSAT satellite over Italy has demonstrated how multi-temporal data-sets can be successfully applied to surface deformation monitoring. Particular attention is given in the paper to civil protection and oil & gas applications in which the synergistic use of InSAR, GPS and other in-situ measurements has created a network of geodetic information over large areas. Such applications, with significant associated public safety impacts, must respond to the pressures of improved quality of service. Such improvements point to radar sensor design, continuity of data acquisition and standardized acquisition policies for InSAR applications. The paper concludes with a discussion on these issues relating them specifically to satellites that are to be launched in the near future namely TerraSAR-X, RADARSAT-2, Cosmo SkyMed and SENTINEL.

Keywords: DInSAR, Permanent Scatterers, SAR sensors, Acquisition Policy.

Introduction

Rather than addressing technical or scientific topics, the aim of this paper is to highlight some important issues related to the following two questions:

(1) Is there a market for Differential SAR Interferometry (DInSAR) in real-life applications, apart from scientific research?
(2) What are the key-factors that can boost the use of this technology and, thereby, new SAR data?

Within the scientific community, DInSAR has already proven its potential for mapping ground deformation worldwide in applications such as volcano dynamics, co-seismic and post-seismic displacements of faults, and slope instability. The first results date back to the 1980's and were obtained using SEASAT data (1978). Although almost thirty years have passed since the 100-day SEASAT mission and with six other platforms having followed (namely, ERS-1/2, ENVISAT, J-ERS, RADARSAT, ALOS-PALSAR), acquiring data over the Earth at different bands for civilian applications, the market related to this innovative technology is significantly under exploited. Why is this so? The thesis of this paper is that there are two critical elements for successful exploitation of DInSAR:

(1) The availability of high-quality displacement data which translates to the development of high-quality processing algorithms, based on multi-temporal data-stacks; and

(2) Satellite data availability;

Market demand for high-quality displacement data

Apart from the wavelength used by the radar to illuminate the Earth, the quality of the sensor and the stability of the satellite platform, the accuracy of the technique depends on:

(1) the density of good radar targets over the area of interest staying “coherent” over long time periods (often referred to as the Permanent or Persistent scatterers) and the capability of the processing software to detect them among non-coherent scatterers;
(2) the distance of the measurement point with respect to a reference point within the data set; and
(3) the effectiveness of the filtering of the atmospheric components that, in the end, depends on the number of images available and the temporal sampling (i.e. the repeat cycle of the satellite and the regularity of the acquisitions).

The accuracy and the precision of DInSAR data are indeed key-factors for real-life applications where, typically, a client is ready to obtain information on which it can rely. For example, a Municipality may wish to review a town-planning scheme and identify unstable areas that exist within its jurisdiction. Is there movement? How serious is the hazard and how much movement is occurring?

While DInSAR data has been favourably received by seismologists and volcanologists (for whom obtaining real data to work on can be extremely difficult), such progress within the engineering and geodetic communities has been much slower. In reality, most of the market sectors related to surface deformation phenomena are dominated by engineering or geodetic requirements.

With only 2 or 3 images to analyse in conventional repeat pass interferometry, identifying the presence of atmospheric artifacts, quantifying them and - possibly - removing them is an impossible task. Even in high coherence areas - where low-baseline SAR interferograms usually exhibit fascinating fringe patterns, the impact of atmospheric components, in particular in areas characterized by rough topography, can be devastating. The situation is even worse when temporal or geometrical decorrelation phenomena affect most of the area of interest.

This is exactly why the Permanent Scatterer Technique was developed in the late 90’s at Politecnico di Milano and then further improved within its commercial spin-off, TRE. The PSInSAR™ (i.e. Permanent Scatterer InSAR) approach is one way to overcome most of the difficulties encountered in single interferogram DInSAR, taking advantage of long temporal series of SAR data to identify stable measurement points (i.e. the PS) and to filter out atmospheric artifacts or – at least – to reduce their impact on the estimated displacement values. When many measurements (i.e. multiple interferograms) are available, the reliability of the results can be strongly improved, especially for the velocity field of the area of interest, for which error bars can indeed be provided for each PS, as is not the case with single interferogram InSAR methods.

We make a brief digression here to clarify the difference between two acronyms, i.e. PSI and PSInSAR™, sometimes erroneously used without distinction. The PSInSAR™ approach is a patented technology and PSInSAR™ is an international trademark. PSI and PSInSAR™ are not synonymous. The term Persistent Scatterer and the acronym PSI (i.e. Persistent Scatterer Interferometry) was defined within the ESA scientific community to refer to the wider class of multi-interferogram algorithms that, since the introduction of the PS technique, were developed by other SAR teams. The PSInSAR™ approach can be defined as a PSI algorithm, but the opposite is not true since PSInSAR™ refers to a specific set of algorithms protected by specific IPR.

Market demand for raw SAR data

The growing demand for high quality displacement data leads inevitably toward reliability in the supply of raw SAR data. Reliability has several facets principal among which are:

(1) consistent quality of data;
(2) easy-to-use tools for browsing the archive and ordering data;
(3) uniform temporal baselines;
(4) balanced territorial coverage.

Of the four characteristics listed above, item 1 is being realized and item 2 is slowly improving. However, items 3 and 4 miss the mark. Perhaps the major contribution to this deficiency is the "on-demand" acquisition policy of satellite operators and their apparent reluctance to speculate on future multiple sales of specific data stacks. This is probably compounded by satellite owners choosing to build satellites with multiple purposes leading, inevitably, to conflicts in acquisition priorities, as has occurred with the Envisat satellite, for example.

The PS technique and all the other PSI algorithms owe much to the ESA ERS missions. Furthermore, all InSAR applications have benefited by these two sensors for the following reasons:

(1) good SAR data quality;
(2) good platform stability;
(3) no need for data planning;
(4) simple acquisition policy, simple mission management, one acquisition mode, all leading to an absence of conflict of acquisition priorities;
(5) low data cost.

The ERS-1 and ERS-2 satellites were simple, uncomplicated satellites and were operated on a global acquisition policy, more or less. Since "interferometric data stacks" were available over many areas of the world, with dozens of image acquisitions, the development of the "second generation DInSAR algorithms" (i.e. PSI) became possible. Testing with real data was made easier because of the low cost of individual images.

With the arrival on the scene of multi-sensor satellites in 1995 (Radarsat) and 2003 (Envisat), with their "on demand" image acquisition policies, interferometry suffered a partial setback. Historic InSAR analyses commissioned in 2007 often had to rely on data stacks from 1992 to 2000 (ERS), by now truly historic and perhaps of questionable value, because data sets after 2000 were fragmented and minimal in numbers of scenes. It must be said, however, that while the "on demand" acquisition policy has not proven itself to be too helpful for interferometry, the multiple look-angle options available on these later satellites has allowed the users to increase the "temporal sampling" of specific target areas with a significant improvement over the ERS satellites, with their fixed look angle. This, however, hindered the creation of uniform archives at the regional level. Most interferometric applications ask for a regular acquisition of SAR data using an optimal acquisition mode.

The cost of raw SAR data is a significant component in conducting a PSI analysis. As satellites become more complex and sophisticated so, one imagines, will the cost of images escalate. To whose benefit? The Envisat satellite, with its multiple sensors and its conflicts in acquisition priorities cost US$ 2.5 billion to build and launch. A single purpose satellite dedicated to InSAR would cost in the order of US$ 150 million, enabling competitive image pricing. The latter would suffer no conflicts in acquisition priorities. Is it time to reconsider the design concept for radar-carrying satellites?

These supply and demand imbalances prompted TRE to investigate the impact, post-2003, of regular, scheduled acquisitions of SAR data, irrespective of whether or not an application for their use existed. In other words, in a market that was maturing in its awareness of the value of InSAR, would the uptake of InSAR analyses be favourably impacted by a recent archive of planned acquisitions?

The Italian case study

For a number of operational and technical reasons, TRE selected Radarsat data for this exercise. With the cooperation of Radarsat International (now MDA Geospatial Services) and Eurimage (MDA distributor for the Italian territory), SAR scenes were acquired speculatively on a scheduled programme to which TRE made a commitment to purchase a proportion. This programme commenced in 2003 and is ongoing with as many as 1800 scenes having been purchased at the time of writing, covering a vast area of Italy. Figures 1 and 2 show the extent of cover of Radarsat images over Italy.

Fig. 1 : Radarsat S3 Descending data coverage

Fig. 2 : Radarsat S3 Ascending data coverage

The result was most encouraging with the Civil Protection and Regional Governments showing significant response. The annual volume of TRE's business from these two sectors has rocketed by 250 %, since 2003. The SAR data supplier would never have realized the same level of sales had the "on demand" acquisition policy prevailed. Figure 3 shows some of the results obtained from these recent PSInSAR™ analyses.

An interesting fallout of this proactive approach was the shift, within TRE's customers, from the use of GPS data alone to a synergistic use of GPS and InSAR data. While these two technologies have overlapping properties they also have elements that complement and add value to each other's measurements.

One of the challenges to proliferating the use of InSAR is the cost of raw SAR images. By guaranteeing minimum bulk orders of scenes, the cost of image purchase was significantly reduced, enhancing the appetite for InSAR among the end-user community. The owners of satellites and their data distributors must come to terms with the reality that competitive pricing of raw SAR data is a must for the growth and survival of InSAR, as much as it is for other SAR related technologies.

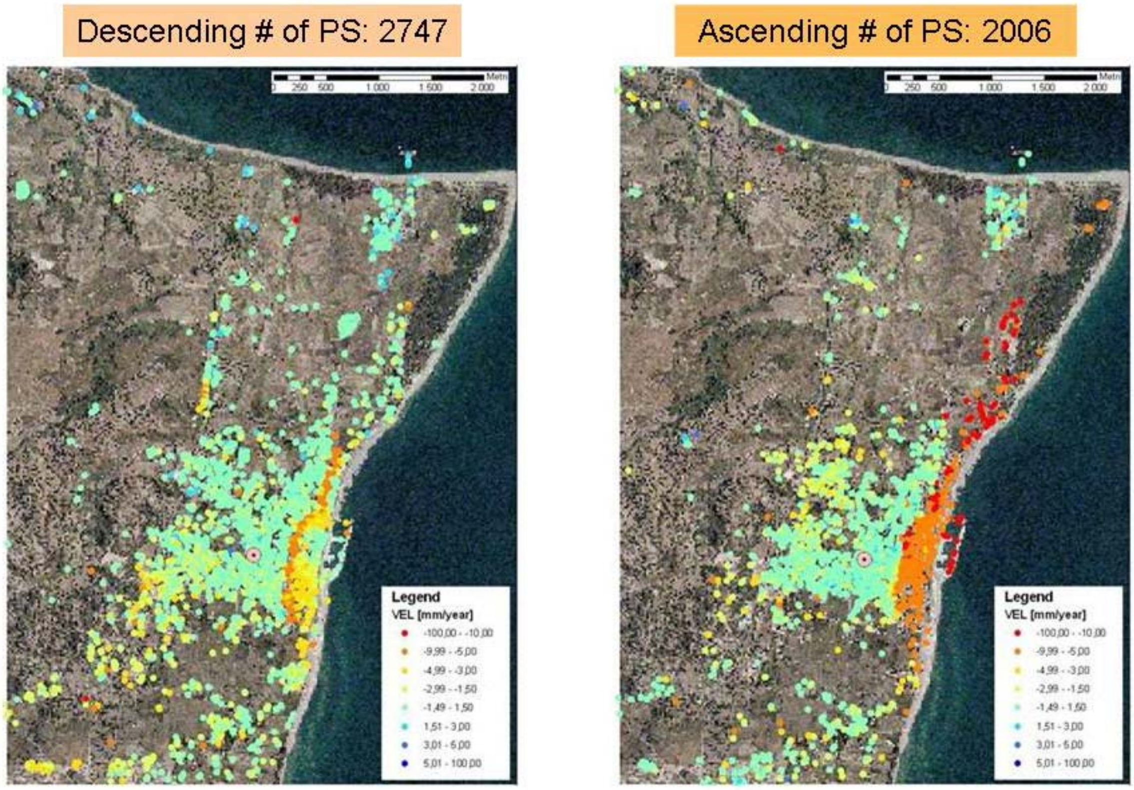

Figure 3**:** Example of two PSInSAR™ analyses obtained from RADARSAT S3 scenes acquired over a village in Italy affected by a sliding area.

As customers became increasingly familiar with the technology, through greater use, so their interest was roused in the availability of data archives. To engage its customers in discovering, for themselves, the archive of data available for their jurisdictions, TRE developed its own cataloging product, referred to as SIMCAT™, whereby clients could search the entire ERS, Envisat and Radarsat archives for SAR images. This interactive involvement has contributed to growing enthusiasm for InSAR among those of its customers who have access to SIMCAT™.

Conclusions

By way of a general conclusion, based on the supply and demand situation for high quality InSAR data, the complexity of multi-sensor satellites with its associated conflicts in acquisition priorities is not particularly satisfactory for InSAR and may not be so for other applications of SAR data. Thus, future satellite development should consider more simple, single-purpose designs that would be relatively less costly and could be operated in constellations. In so doing, short repeat orbit cycles are unnecessary for individual satellites and there is the added security of data acquisition, should one of the constellation's satellites fail.

With regard to TRE’s experience in Italy, some lessons can be drawn from its experiment in the market.

Firstly, the existence of an up-to-date archive of speculative scheduled raw data acquisitions stimulates the confidence of the end-user community in using InSAR and therefore, in the sale of SAR scenes.

Secondly, based on TRE’s experience in Italy, the market benefit of speculative scheduled SAR acquisitions places a responsibility on satellite owners and their distributors to be participants in such programmes.

References

1. A. Ferretti, Prati C., Rocca F. “Permanent Scatterers in SAR Interferometry,” IEEE Trans. on Geoscience and Remote Sensing, Vol. 39, no. 1, pp. 8-20, 2001.
2. A. Ferretti, F. Novali, R. Bürgmann, G. Hilley and C. Prati, “InSAR Permanent Scatterer Analysis Reveals Ups and Downs in San Francisco Bay Area,” EOS, Vol. 85, N. 34.
3. G. E. Hilley, R. Bürgmann, A. Ferretti, F. Novali and F. Rocca, “Dynamics of Slow-Moving Landslides from Permanent Scatterer Analysis,” *Science*, 25 June 2004, Volume 304, Number 5679, Pages 1952-1955.
4. T.H. Dixon, F. Amelung, A. Ferretti, F. Novali, F. Rocca, R. Dokkas, G. Sella, S.W. Kim, S. Wdowinski, D. Whitman, “Subsidence and flooding in New Orleans,” *Nature*, Vol 441, June 2006, pp. 587-588.