COMBINATION OF ERS AND MULTIPLE MODES OF ENVISAT SAR DATA FOR DIFFERENTIAL INTERFEROMETRIC APPLICATIONS

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ABSTRACT

This article describes the use of long series of ERS SLC data combined together with the ENVISAT ASAR complex products from different modes of acquisition in order to obtain long term subsidence displacements. Emphasis is put in the continuity between the ERS and ENVISAT Image Mode measurements, the use of the prototype Wide Swath Mode complex products (WSS) and the Alternating Polarization Mode complex products (APS) to minimize the frequency at which information is provided.

1 INTRODUCTION

Multiple applications have arisen since the launch of the ERS-1 and ERS-2 satellites which use repeat pass interferometric techniques. In order to commercialize these applications and give long term information it is required that the availability of each acquisition over a certain area is ensured with a certain frequency which is specific of each application and under certain conditions. The launch of ENVISAT in 2002 carrying onboard the more advanced SAR (ASAR) gives continuity to this data acquisition and offers the possibility to continue providing good quality services. The instrument's capability has been enhanced with respect to the ERS SARs by extending the acquisition modes to those in different polarization combinations and/or the use of ScanSAR to increase the swath length. However this is not always an advantage since it enters in conflict with the use of the ERS like mode systematically necessary for the long-standing applications (Image Mode in IS2 incidence angles and VV polarization) and the acquisition does not always take place in the desired mode. This article is focused on the adaptation of the data acquired in the two ASAR ScanSAR modes to generate interferograms with acquisitions in Image Mode and the continuity in the application results obtained by the Stable Points Network (SPN) processing chain developed by Altamira Information to derive small subsidence measurements.

2 ERS – ASAR IM COMBINATION

The combination of ERS and ASAR data in Image Mode has already been demonstrated by the use of large baselines in classical interferometry as well as the continuity in their phase measurements on man-made structures by the use of the SPN technique [1] [4]. The implemented procedure makes use of either ERS SAR or ASAR differential phase measurements to generate long term terrain movement and precise DEM maps related to building height with the same resolution as the original SAR images. This by-product is of great importance since the information extracted from these very high precision height maps derived from long series of ERS data can be reused to compensate the phase values of the ASAR differential interferograms when calculating the subsidence measurements. Moreover it allows to correct the positioning of each pixel by its "true" height, giving the possibility to obtain a very accurate map geocoding, with an absolute positioning error of less than 2 meters. Estimations are done on every image pixel without spatial interpolation after atmospheric artefact correction.

The exploitation of this stripline ASAR mode allows to extract information from the whole azimuth spectrum since the scatterers are seen during the whole integration time, maximizing in this way the interferogram resolution and the number of common persistent scatterers detected between ERS and ASAR. For this purpose, a pre-requisite is that data needs to be acquired in the same polarization (VV) and geometry (IS2 swath) although other viewing geometries could as well be used with the consequent loss of common scatterers considered as "stable".

Verification of the continuity information was basically tested by comparing the yearly subsidence rates of independent series of ERS and ASAR data and the scatterer vertical positioning continuity of mixed ERS and ASAR interferograms in two main test sites, the cities of Paris and Barcelona. Fig. 1a shows the yearly subsidence rate of an area in the city of Barcelona where some buildings have been affected by vertical terrain displacements. The profile in Fig. 1b shows the time evolution of the position of the point selected in Fig. 1a. In this profile, the continuity between the ERS

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measurements (in blue) and the ENVISAT ones (in magenta) is clearly revealed.

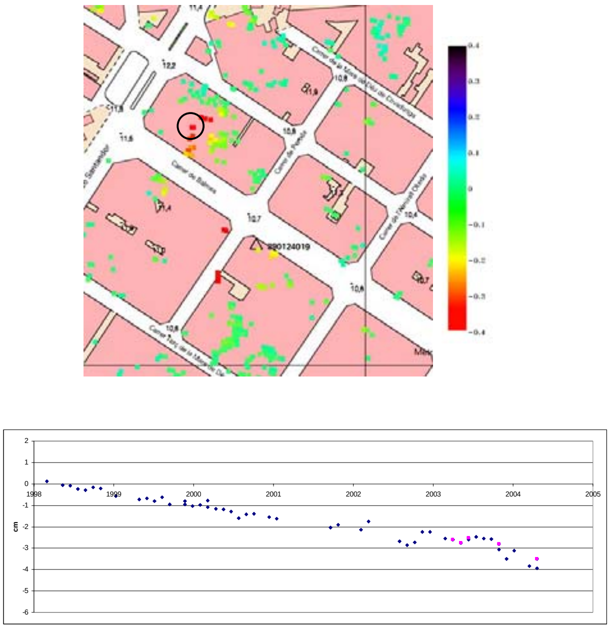

Fig. 1 a) Top: Linear yearly subsidence rate of an area in the city of Barcelona. b) Bottom: Time profile of the point selected in the top image. ERS in blue, ASAR in magenta.

3 ASAR IM - WSS INTERFEROMETRY

ASAR can operate in three different ScanSAR modes: Alternating Polarization mode, Global Monitoring Mode and Wide Swath mode. In this last mode, five different subswaths are used to achieve a larger coverage (400km), four of which are common to the image mode swaths. Images can be acquired in either H or V polarization on transmit and receive (HH or VV images). After the mode optimisation performed during the cal / val phase, the original transmitted bandwidths were doubled to the values shown in Table 1 and since, interferometric applications favoured.

	SS1	SS2	SS3	SS4	SS5
Original chirp bandwidth (MHz)	7.15	5.33	4.39	3.01	2.82
Optimised chirp bandwidth (MHz)	14.7	12.8	10.4	9.54	8.78

Table 1. Transmitted chirp bandwidth in WSM

Presently, the only product commercially available at ESA is a three azimuth look detected image. However, the development of a new product type derived from the Wide Swath Mode of acquisition is finished and currently being under integration testing in the ground segment of ENVISAT. The product (ASA_WSS_1P), which is experimentally distributed from a prototype processor, is a high-resolution complex, version of the current ASA_WSM_1P. It follows the same format with the exception that the imaged bursts are consecutively included in the product for each of the subswaths. Each of them contains more processed lines than the original acquisition making the imaged bursts overlap. Data is as well sub-sampled in azimuth in order to limit the product size.

For the long term monitoring of small displacements, where long series of ERS data are used, (and recently ASAR data acquired in the IS2) only the SS1 subswath overlaps with the same viewing geometry of ERS and consequently it is the only one that is treated to combine with the SLC products. This gives also the most favourable case in terms of available bandwidth in the range direction. In azimuth, however, the available look bandwidth is the one corresponding to the 50 range lines contained in each SS1 burst, which corresponds approximately to 72 Hz.

3.1 Simulations

To assess the impact of resolution decrease due to the use of products derived from the ScanSAR acquisition modes, a previous simulation was performed. The azimuth bandwidth of one of the ERS images in the time span series was filtered to that of a single burst Wide Swath Mode look. The azimuth resolution decreased interferograms were input to the SPN processing chain and the impact on the time series profiles analysed.

Two different types of areas (shown in Fig. 2) containing high concentration of persistent scatterers characterized by different scattering mechanisms were considered: one in a very dense constructed area of high buildings and another in an industrial district where scatterers come from low buildings with metallic flat roofs.

Fig. 2 Different scattering areas analysed during the WSS product simulation and location of the scatterer considered for analysis.

Fig. 3 shows the time profiles of the simulation results before and after the change in resolution. For a certain point corresponding to each of the areas it can be seen how its original position has been changed as a result of the resolution decrease. In the case of scatterer in A, the phase in the interferogram hardly changes and its vertical position remains almost the same. In the second case, however, the point is displaced by almost 1 cm. This might be explained by the fact that the low resolution scatterering cell might be composed of multiple scatterers not detected in the full resolution one. As a general rule from the analysis of other points it could be stated that those scatterers showing a good linear subsidence model coherence do not seem to be affected by the loss of resolution.

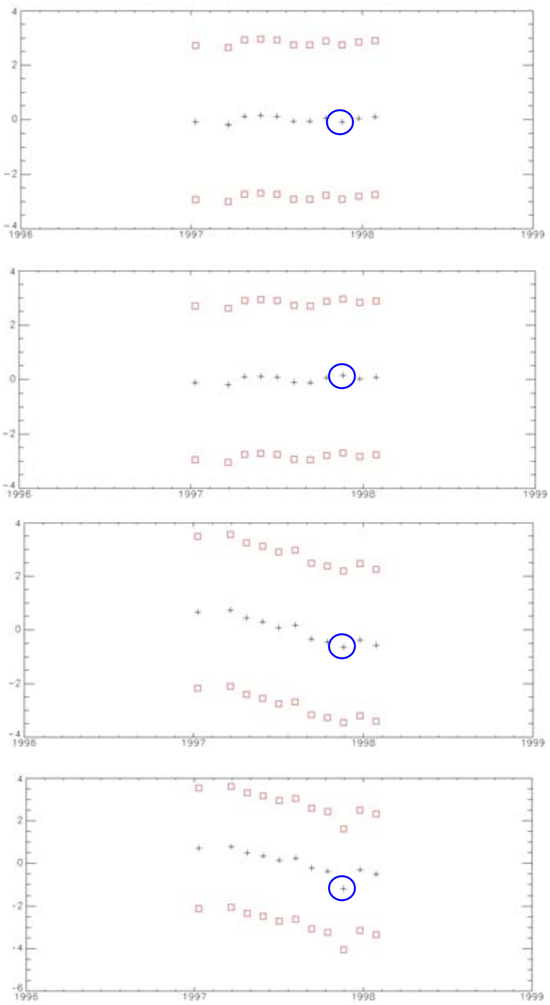

Fig. 3 Time profiles of the simulation results for points A and B (before and after resolution change) in Fig. 2.

3.2 IM – WSS Interferogram generation

The generation of an interferogram between data acquired in stripline mode and scanSAR mode requires various special considerations. First the processed bursts are extracted from the WSS product and an amplitude image is generated and resampled to the Image mode acquisition parameters to derive the co-registration matrices between both images together with the orbital and timing information.

One of the ScanSAR spectral properties is that the center of the azimuth spectrum is variant in time and that its bandwidth is range dependant. This variability can be overcome if data is deramped by a chirp signal with phase slope corresponding to the azimuth Doppler rate so that all the signals a baseband transformed. The same compensation needs to be applied to the IM data. After this pre-processing step both complex images are filtered in range and azimuth such that both spectral components in both directions are common. Finally, the interferometric step has been performed with the commercial Diapason processor.

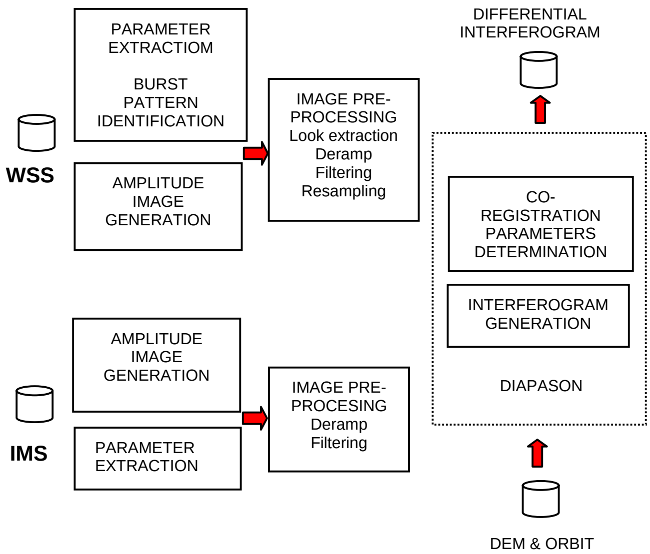

Fig. 4 ScanSAR – IM processing scheme

3.3 Continuity results

Validation of the implemented technique was performed in the Barcelona test site for which two valid WSM acquisitions had taken place. For orbit 7720 in WSM and 8221 in IM the differential interferogram was obtained and input to the SPN chain. The resulting profiles are plot in Fig. 5 for points A and B used during the simulations. It can be seen how in the first case continuity is kept and the same trend than the ERS and ASAR acquisitions in IM is followed by the data acquired in the WSM mode. In the second case, even if the point keeps following the same trend and is placed in almost the same position as the ERS measurement occurred 30 minutes later, the profile is less linear and is difficult to assess the preservation of the scatterer measurement.

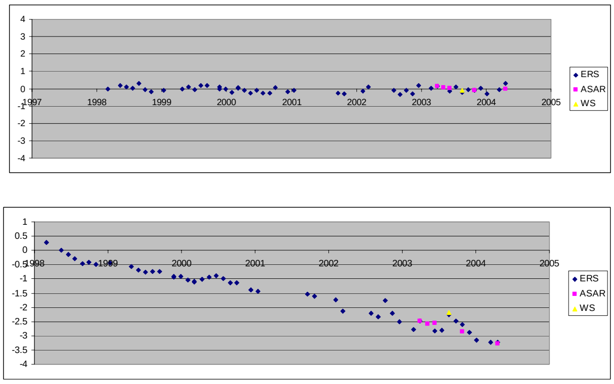

Fig. 5 Time profiles for points A and B in Fig. 2: Blue: ERS, Magenta: ASAR-IM, Yellow: ASAR-WSM.

4 ASAR IM-AP INTERFEROMETRY

In the Alternating Polarization mode, bursts of either V or H polarization are transmitted and received alternatively in the following combinations HH-VV, VV-VH, HH-HV. Instrument timeline and processor design are such that the corresponding Alternating Polarization product (ASA_APS_1P) contains two superposed images corresponding to the two polarization combinations with two discontinuous azimuth looks each covering approximate ¼ of the total PRF band. In the specific case of the IS2 swath (ERS geometry) the chirp bandwidth is the same as the one in Image Mode and the number of lines in the burst allow for a look bandwidth of 240 Hz.

APS products can be used in two different ways when performing long term displacement monitoring. In a first approximation the interferograms between AP and IM data can be obtained either following the scheme shown in Fig. 4 or in a nominal interferometric processing with additional azimuth common band filtering to take into account the two looks position. In this case only the VV polarization image would be used in the overall data series.

A second approach suggested in [5] would be to use the phase difference information extracted from the a co-polar alternating polarization mode image, first to identify which scatterers behave as dihedrals (phase difference between HH and VV images of Π rad) and which as trihedrals (phase difference between HH and VV images of 0 rad) and then once this relationship is established to enable the use of data acquired in IM but in the HH polarization within the VV polarized series. As can be seen from the phase difference on punctual targets between co-polar channels in Fig. 6, most of the point targets within an image behave either as dihedrals or trihedrals and can be treated in such a way.

Unfortunately, in none of the test sites where long series for which ERS-ASAR data was available there was not any catalogued Alternating Polarization acquisition and the technique has not been validated yet.

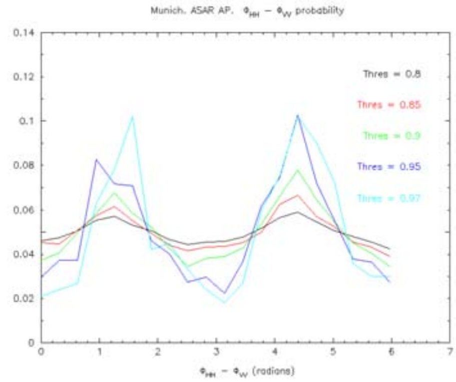

Fig. 6 Histogram phase difference between the HH and the VV image over the area of Munich

5 CONCLUSIONS

The feasibility of using data acquired in different modes of ASAR operation in order to derive long term millimetric displacements has been demonstrated. The SPN technique uses indistinctively interferograms generated with the ASAR IMS and either WSS or APS complex products giving continuity to the obtained subsidence terms. A pre-processing step is needed to adapt to the spectral properties of the ScanSAR data to generate the interferograms. Alternating Polarization mode co-polar acquisitions could also be used to establish the relationships between VV and HH phases on point target scatterers acquired in Image Mode.

6 REFERENCES

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