# **ASAR ERS Interferometric Phase Continuity**

Alain Arnaud<sup>1</sup>, Nico Adam<sup>2</sup>, Ramon Hanssen<sup>3</sup>, Jordi Inglada<sup>4</sup>, Javier Duro, Josep Closa<sup>1</sup>, Michael Eineder<sup>2</sup>

Altamira Information C/ Roger de Llúria 50, àtic B, 08009 Barcelona, Spain Phone: +34 934677396, Fax: +34 934677398 Email: alain.arnaud@altamira-information.com <sup>2</sup> DLR, Oberpfaffenhofen, Germany <sup>3</sup>Delft University of Technology, Delft, The Netherlands

<sup>4</sup>CNES, Toulouse, France

*Abstract-* During the last ten years, a long history of data was acquired by the SAR sensors on the satellites ERS-1 and ERS-2 offering a wide range of interferometric applications. In 2002, the more advanced satellite ENVISAT was launched. The SAR on board of ENVISAT (ASAR) can continue the success of the remote sensing mission of the ERS satellites and preserve or even increase the value of the archived ERS data. The subject of this study is to demonstrate the continuity of the interferometric measurements by the combination of the SAR scenes of the different sensors to interferograms (cross interferometry).

# I. INTRODUCTION

Radar interferometry is a well-established remote sensing technique. Up to now, acquisitions from one and the same or from compatible radar sensors were processed. During the past ten years, a huge amount of data was acquired by the SAR sensors of the satellites ERS-1 and ERS-2 offering a wide range of applications. Last year, ESA launched the new radar sensor Envisat/ASAR.

The interferometric combination of ENVISAT and ERS data is not as simple as it used to be with the similar constructed SAR sensors on board the ERS-1 and ERS-2 satellites. Especially, the difference of 31 MHz between both radar center frequencies prevents the simple combination of the different sensor data because the interferometric phase is obviously strongly dependent on the wavelength and thus on the radar frequency. The radar center frequency of ENVISAT/ASAR (5.331 GHz ) has been slightly changed compared to the sensors ERS-1 and ERS-2 (5.300 GHz). To compensate for this frequency change, the interferometric observation geometry needs to fulfil certain requirements, i.e. large baselines or point scatterers.

The two examples presented in this paper - one crossinterferogram processed by DLR over the Las Vegas (U.S.A.) area and tandem cross-interferogram processed by ALTAMIRA INFORMATION over the city of Paris (France) - demonstrate that this cross-interferometry is still possible for the case of distributed targets and large baselines.

Since atmospheric delays bias the interferometric phase considerably, a method for the estimation of atmospheric

phase screen artifacts using ENVISAT/MERIS data is presented.

## II. ERS-ENVISAT PHASE CONTINUITY

Gatelli et al. [2] presented the theoretical basis for radar cross interferometry. After the launch of ENVISAT and the fading performance of ERS, the practical demonstration of radar cross interferometry was of scientific and operational interest. Radar cross-interferometry guarantees the continuity in the monitoring of the Earth despite the change of sensors. Consequently, the value of the archived ERS data is preserved or even increased. First of all, extended time series can be analysed. They may be composed of mixed ERS-1, ERS-2 and ENVISAT/ASAR data. Hence, very slow geophysical effects on the Earth's surface can be monitored and effects unnoticed so far can be detected.

In the case of ENVISAT/ASAR and ERS, the optimal effective baseline for cross-interferometry on distributed targets is about 2300 m. The enormous height sensitivity of about 4 meters poses some problems with volume decorrelation, but also allows the mapping of topography with unprecedented accuracy.

## A. The first radar cross-interferogram.

The first ERS-ENVISAT cross-interferogram was computed using the following data :

- ENVISAT/ASAR acquisition of 29-NOV-2002; radar frequency: 5.331 GHz; beam: IS2; Doppler centroid frequency: 186 Hz.
- ERS-2 acquisition:acquisition of 27-AUG-1999; radar frequency: 5.300 GHz; Doppler centroid frequency: 94 Hz.
- interferometric parameters: length of effective baseline: 1120 m; height of ambiguity: 8.4 m/2π.

The data were selected in an opportunistic approach to match the Doppler centroid frequency values, the baseline and the acquisition times. The ERS/ENVISAT pair finally selected has a baseline of about 1120 m and a temporal separation of more than 3 years. On the one hand, the observation geometry is not optimal. But on the other hand, the height ambiguity is decreased from about 4 m per cycle to over 8 m per cycle.

The radar intensity image and the interferogram are overlayed in figure 1. In the center of the image the city of Las Vegas is visible. Note the large number of fringes due to the large baseline. (interferometric processing: DLR Oberpfaffenhofen - Remote Sensing Technology Institute (IMF); processing of ERS-2 SLC: ESA/ESRIN; processing of ENVISAT/ASAR SLC: D-PAC for ESA).



Figure 1. ERS-ENVISAT cross-interferogram on the Las Vegas area.

# B. The first tandem cross-interferogram

This interferogram (figure 2) was generated from two images acquired on the 7th of December 2002 by the ENVISAT ASAR at 10:14:34 (Image Mode, IS2, VV polarization, orbit 4027, Doppler centroid frequency : 236 Hz) and the ERS-2 SAR (Orbit 39899, Doppler centroid frequency : 918 Hz), only 30 minutes later. The perpendicular baseline is of 1650 meters, relatively close to the best theoretical conditions for flat terrain of 2300 meters. It enables a maximum bandwidth overlap between the ERS and ASAR transmitted signals for low incidence angles (see figure 3). Therefore the quality of the interferogram is better at the near range of the image, where there is almost 100% of bandwidth overlap than for far range where this value is less than 50%.

It's interesting to note that urban areas are not coherent in contrast to areas containing distributed scatters. The only coherent parts in the city of Paris are the different parks included in the image. This is explained by the fact that the baseline change compensates only the frequency shift for flat pixels presenting a fully developed speckle. The ones in the city, formed by the reflection on different objects with complicated geometry and important height variation cannot preserve their phase value. Note that total volume decorrelation will appear if scatterers within a resolution cell have height differences of 4 meters [6].



Figure 2. ERS-Envisat tandem cross-interferogram on the Paris area.



Figure 3. Evolution of the range bandwidth overlap between ERS and ENVISAT as a function of the range position for a baseline of 1650 m.

#### III. Use of Meris for Atmospheric Phase Screen Estimation

Spatial variability in atmospheric delay may cause significant errors in SAR interferograms, mainly induced by the water vapor distribution, (Hanssen et al., 1999). Correction of this error signal based on additional complementary measurements is restricted to temporal coincidence, high resolution, and total atmospheric column WV content measurements. Such measurements have not been available before the launch of ENVISAT with ASAR and MERIS on-board. Satellite microwave radiometers are able to retrieve columnar total water vapor content with a resolution of about 50x60 km, independent of cloud cover, with an accuracy (mean error in water vapor column content) of 7%. Unfortunately, this only works over water surfaces. Over land surfaces, infrared sounders can be used for this goal, under cloud-free conditions, with an accuracy of 20%, and with coarse resolutions.

Spectrometer data can be used to determine total water vapor content, as demonstrated by Gao and Goetz (1990). Using two channels for water vapor measurement (800 nm and 900nm), MERIS will produce the columnar amount of water vapor over water, land, and clouds, with an accuracy of 1.6 kg/m2 over land and 2.6 kg/m2 over water. Note that total water vapor column observations will only be obtained in cloud-free conditions. MERIS spatial resolutions of 300x300 m, will be averaged to 1.2x1.2 km to allow for noise reduction (Fischer and Bennartz, 1997). An accuracy of 1.6 kg/m2 maps to an integrated precipitable water (IPW) vapor accuracy of 1.6 mm, which corresponds to a delay accuracy of 1.04 cm.



Figure 4. MERIS simulation.A) Atmospheric delay due to water vapor in a 100x100 km ERS-1/2 tandem interferogram over the Netherlands. B)
Simulated noise-free MERIS WV product, assuming cloud free condidions.
C) Simulated MERIS WV product including uncorrelated noise of 1.6 kg/m2.
D) Corrected SAR interferogram, after subtraction of MERIS WV information

Figure 4.A shows atmospheric signal in an ERS-1/2 tandem interferogram, expressed in millimeters delay difference. Interpreting this image as groundtruth, assumed to be observed under cloud-free conditions, we can simulate a noise-free MERIS WV product, as shown in figure 4.B. Additional uncorrelated noise of 1.6 kg/m2 results in the image of figure 4.C. Finally, subtraction of this signal from the interferogram yields figure. 4.D. Although the uncorrelated noise results in a speckled visual appearance,

overall RMS values of atmospheric signal have decreased considerably.

# IV. FINE DEM ESTIMATION

One advantage of using together ERS and ENVISAT images with the constraints explained above is the possibility of making large-baseline interferograms. This technique allows for high vertical accuracy DEM estimation.

The large baseline allows for improving the altitude resolution. However, the elevation of ambiguity is very low, making difficult the phase unwrapping task. So the application of this kind of interferogram can be used for improving the high spatial frequencies of an existing lower resolution DEM. This existing DEM would be used to unwrap the large-baseline DEM, then the low pass filtered residues can be used to improve the initial DEM.

# V. CONCLUSIONS

The possibility of ERS and ENVISAT cross-interferometry has been demonstrated. Even if the selection of the data and the processing requires some care, surprising results could be achieved on two test sites within relatively short time, demonstrating that cross-interferometry is not just a theoretical possibility but feasible in practice. This fact opens the path for new applications requiring e. g. large baselines. The possibility of using ENVISAT/MERIS data for the estimation of atmospheric phase screen artifacts produced by water vapor has also been proposed.

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