ScanSAR Interferometry for land use applications and terrain deformation

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Abstract—**ScanSAR interferometry is an attractive technology thanks to its wide swath imaging capabilities. It allows efficient interferometric mapping for various applications such as deformation or landuse monitoring. The motivation for this work is the availability of the new Envisat ASAR Wide Swath Mode Single Look Complex Product (WSS) produced by ESA. Furthermore, other sensors as Radarsat, Radarsat 2, and ALOS PALSAR can be operated in ScanSAR mode resulting in an increased relevance of repeat-pass ScanSAR interferometry and related applications. With the launch of the new Envisat product, a large archive of historical wide swath Envisat ASAR data is now available for ScanSAR interferometry. First applications include deformation mapping, topographic mapping, large-scale athmosphere monitoring, and landuse mapping.**

Keywords-Scansar interferometry, SAR, Interferometry, land use

I. INTRODUCTION

The objective of our work is a first assessment and demonstration of the potential of ScanSAR interferometry based on the new Envisat ASAR WSS product. ScanSAR interferometry is an attractive technology for various SAR interferometric applications that benefit from the large swath at the cost of a coarser azimuth resolution. In the first part of this paper we present the processing methodology used. In the second part we discuss the potential of ScanSAR interferometry for landuse mapping based on the interferometric coherence and terrain deformation mapping based on ASAR WSS data covering Bam (Iran). In the past the interferometric coherence of image mode SAR data was successfully demonstrated as potential for distinguishing between vegetated and non-vegetated area [e.g. 1]. Similar results are expected using ScanSAR interferometry for larger areas but at a lower resolution

II. SCANSAR DATA

ScanSAR uses the burst-mode technique to image large swaths at the expense of azimuth resolution. Typical swath widths of current satellite based systems are 250 to 500km at azimuth resolutiona of 50m to 1km. In contrast to the traditional strip-map mode SAR, the raw data consists of bursts of radar echoes with azimuth extent shorter than the synthetic aperture length. This is the reason for the azimuth dependent spectral properties of the signal and complicates signal processing and interferometric processing.

A. Envisat WSS product

In order to support the development of new applications with the ASAR ScanSAR data, a new WSM product providing phase information has been developed and implemented in the ESA ASAR processor, the Wide-Swath Single-Look complex product ASA_WSS_1P (WSS). It is expected that this new product will be mainly used for INSAR applications based either on wide-swath/wide-swath pairs or wide-swath/image mode pairs, applications of ocean current mapping, large-area ocean wave retrievals, and atmospheric water vapor characterization [2]. Wide-swath ScanSAR mode is a system configuration in which Envisat ASAR's steerable antenna transmits 50 to 70 consecutive pulses (one burst) and acquires the corresponding echoes whilst pointing at one of five fixed off-nadir sub-swaths. Then the antenna pointing angle is changed, a new burst is transmitted and the echoes are acquired with a repeat time of about 0.2s. The Envisat WSS is a phase preserving product (multiple burst method as described e.g. [3]). Other key characteristics of the Envisat WSS product are:

- Processing is fully phase preserving
- Data is sampled in a common grid both in range and in azimuth
- The standard product is 60 sec long with 80 m azimuth. pixel spacing
- Auxiliary timeline information has been added
- Elevation antenna pattern correction is applied by default
- Each spot on the surface is typically covered by 2-3 bursts.
- The spatial radiometric resolution along track is about 120 m, in range about 20 m.
- Collection of bursts for all 5 swaths (see Figure 1).

III. SCANSAR INTERFEROMETRY

Interferometric applications benefit from the increased swath width of ScanSAR data. More frequent coverage for differential applications such as deformation mapping and a faster coverage of larger areas for medium resolution landuse mapping applications based on repeat pass interferometric coherence information are major benefits.

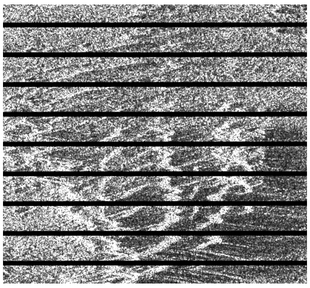

Figure 1: Power image of a subsample of one swath of the WSS product.

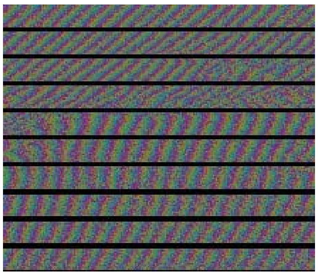

Figure 2: Interferograms of every 3rd burst.

A. *WSS-WSS interferometry*

Thanks to its phase preserving character the Envisat WSS product can be used for SAR Interferometry. Interferometric SAR (InSAR) applications can either be based on WSS/WSS pairs or WSS/IM (Image Mode) pairs. The WSS/WSS combination allows the coverage of large areas, while the WSS/IM combination allows a short reaction time for image acquisition after an event. Here we will focus on WSS-WSS interferometry.

Prerequisites for good stripmap mode interferograms are a reasonable small baseline and low temporal decorrelation. In Scan-SAR interferometry additionally a sufficient burst spectra overlap of the SLC pair is necessary. The bursts need to be synchronized. Envisat WSS switches between the 5 subswaths leading to a low (theoretical) probability of burst overlap if the acquisitions of the two images are not coordinated. For successful interferometric WSS pair acquisitions synchronization is required.

Interferometric WSS data processing includes coregistration of the respective bursts, Doppler common band filtering in range and azimuth, burst aggregation and swath recomposition. Multi-look images (MLI) are created by detection and summary of the bursts. These MLI images have the full range and azimuth resolution. Accurate resampling (<0.01 pixel) is required to assure phase coherence between single burst interferograms [4]. Therefore the terrain height was taken into account for the image coregistration. Using residual offsets detected from resampling of the SAR data using the DEM, the SLC data is precisely resampled into common geometry. The SRTM3 DEM was used also for the simulation of the topographic phase used in the calculation of the differential interferograms.

Specific Data processing steps

- Coregistration of the slave SLC in the master SLC slant range geometry using the SRTM3 DEM
- Common band filtering in range and azimuth
- Burst interferograms generation (Figure 2)
- Burst interferograms aggregation
- Subtraction of the simulated phase (based on SRTM3 DEM)
- Interferometric correlation map generation
- (Full swath recomposition)
- Terrain geocoding
- (Mosaicking)

IV. RESULTS

Interferometric ScanSAR data of two different tracks before and after the disastrous earthquake in Iran in December 2003 were available. For the pairs given in Table 1 the differential interferograms and the interferometric coherence was computed. The perpendicular baselines were in the range of 100 to 460m and burst synchronisation of 30% to 90% was found.

PERPENDICULAR BASELINES AND BURST SYNCHRONIZATION FOR THE BAM WSS DATA

Track	**Date1**	**Date2**	**Bperp [m]**	**Burst overlap**
77	20030921	20040208	160	91 %
306	20030902	20040608	105	82 %
306	20030902	20040713	350	30 %
306	20040608	20040713	457	48 %

Figure 3 shows the full swath co-seismic differential interferogram between 20030921 and 20040208. For flattening the SRTM3 DEM was used. The remaining fringes are due to deformation, baseline errors, height errors and atmosphere. In the upper central part of the image Bam (Iran) can be seen with its characteristic butterfly-like fringe pattern due to the terrain deformation during the earthquake on December 21 2003. Figure 4 shows the area around Bam for all available interferometric pairs. The three co-seismic pairs show a strong deformation pattern with an extent of about 50km. The deformation shape and deformation rates are consistent for all 3 pairs. Coherence is lost over the devastated areas of the city of Bam. The pair 20040608/20040713 was acquired well after the earthquake and shows no further movements.

In [5] the potential of repeat-pass interferometry for arid surface type mapping is shown. Erosion, sand, changes in roughness, salt lakes and deposits have a strong impact on the signatures. Figure 5 shows the coherence product of the pair 20030921/20040208. The interferometric coherence is indicated in red, mean backscattering in green, and backscatter change in blue. Despite the very long time interval between the acquisitions (4 and a half months), the coherence is in most areas very well preserved. Different landuse types can clearly be distinguished. The deserted areas show up in red and yellow due to the high coherence and low backscattering intensity. Vegetated and mountainous areas appear in green

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because of temporal decorrelation or layover/shadowing effects. Some top areas in the mountains appear in blue. This should be due to variations of the dielectric and geometric properties of the snow cover in February 2004 (low coherence and high backscatter variation). Figure 6 shows the corresponding Landsat mosaic from the Landsat7 ETM+ multi-spectral mosaic of 2000.

V. CONCLUSIONS

With the new Envisat ScanSAR SLC ESA made a powerfull data source for large scale applications available. First investigations and results confirm the utility of the presented methodology. The co-seismic interferograms over Bam, show consistent strong deformation patterns around the city of Bam for the December 2003 earthquake, confirming the usefulness of ScanSAR interferometry for deformation mapping. The first results indicate a good potential of the ScanSAR interferometric coherence for large scale landuse applications.

ACKNOWLEDGMENT

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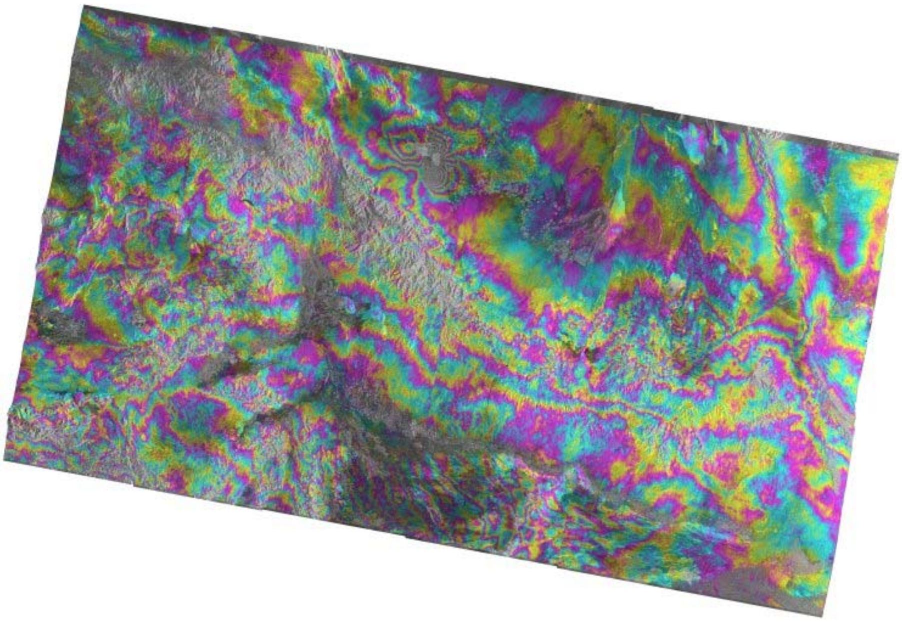

Figure 3: Geocoded full swath co-seismic differential interferogram between 20030921 and 20040208. Image width is about 480km.

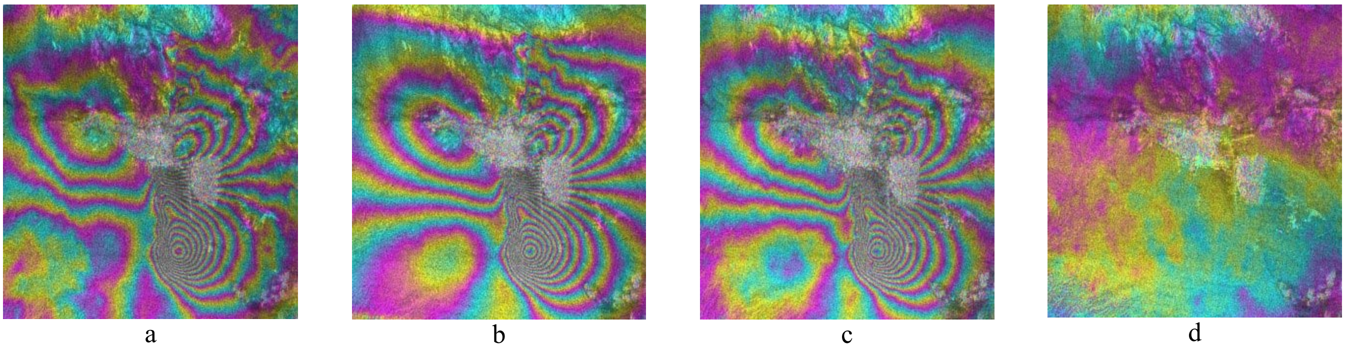

Figure 4: Geocoded (UTM) differential interferograms of the BAM area. Image width is about 38km. a) 20030921-20040208, b) 20040608_20030902, c) 20040713_20030902, d) 20040608_20040713.

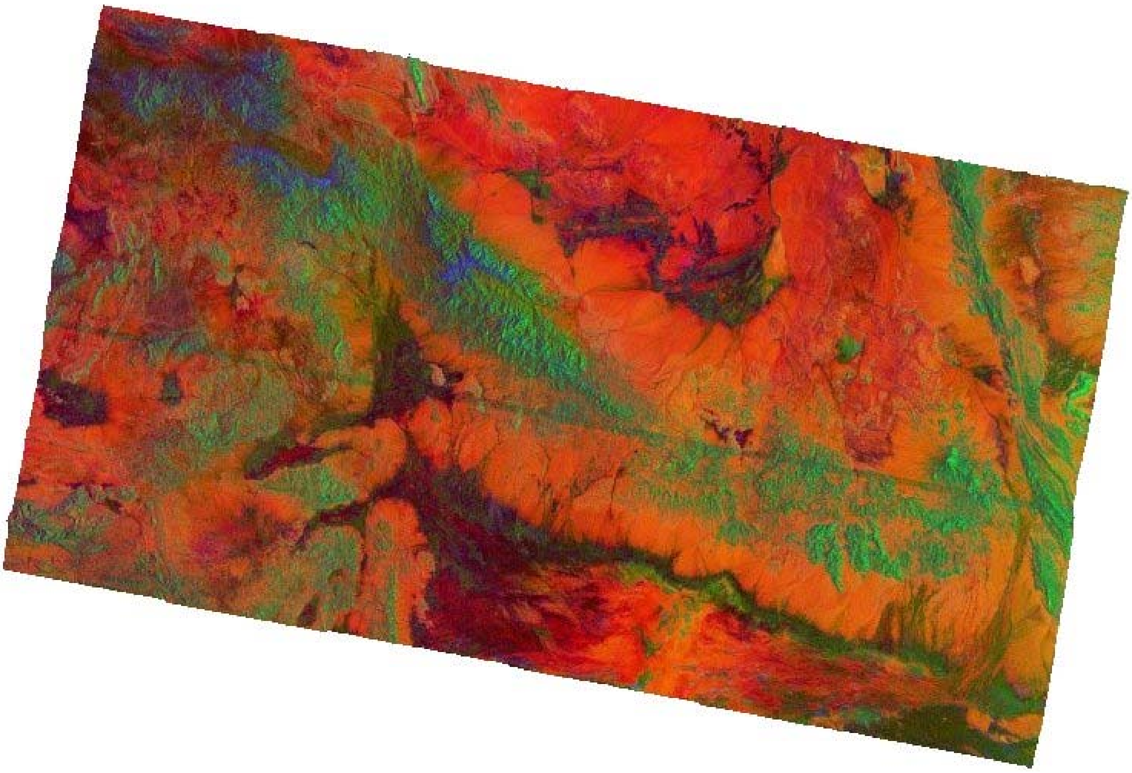

Figure 5: Geocoded false color composite of the interferometric WSS pair 20030921 and 20040208. Red: interferometric coherence, green: average backscattering coefficient, blue: backscattering ratio. Image width is about 480km.

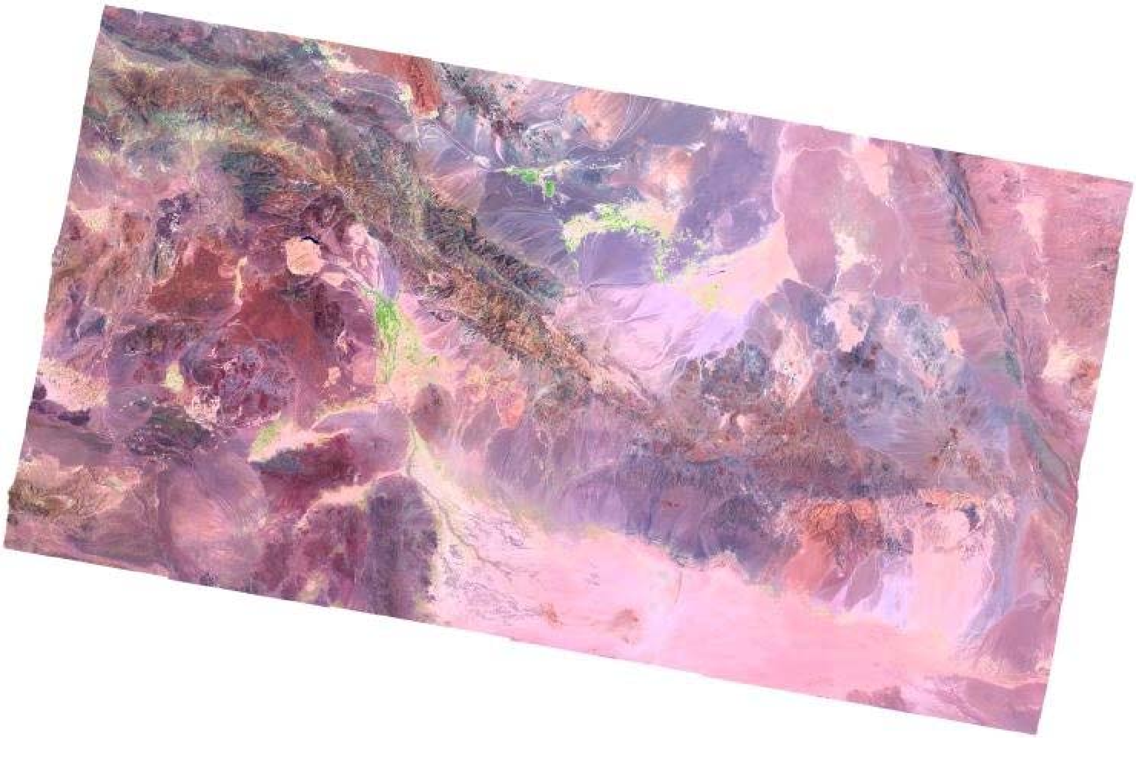

Figure 6: Corresponding section to Figure 6 of the Landsat7 ETM+ multi-spectral mosaic of 2000.