SAR INTERFEROMETRY: A COMPARATIVE ANALYSIS OF DTMs

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ABSTRACT:

In this paper results of a comparative analysis of interferometrically derived DTM and topographic map digitised DTM are presented. The RMS error of the INSAR generated DTM was about 11 meters, while that of the control points was 9 meters. The maximum value was found to be 50 meters which has been attributed to atmospheric effects. The INSAR DTM was found to be shifted by 2.3 meters in general.

1. INTRODUCTION

SAR interferometry (INSAR) is a recent promising technique for the application of remote sensing data. It allows the production of detailed and accurate three dimensional relief maps of the Earth's surface directly from two SAR complex image data that can be acquired simultaneously by two SAR receivers in a single pass or by one SAR receiver at different times in multiple passes (Prati et al. 1992) and (Zebker et al. 1994). The technique can also be used to detect very small movements of land surface features in the cm-range, which is known as differential interferometry (Massonet et al. 1993). However, there are limitations in the practical exploitation of the data in the multiple pass (repeat orbit) case, which are: geometrical decorrelation due to the imaging geometry and imposes limits on the baseline; and temporal decorrelation caused by the physical changes in the imaged earth surface which show up as incoherency between the SAR images (Zebker and Villasenor 1992). Although, satisfactory results concerning the validation of interferometrically derived digital terrain models (DTM) have been reported in the literature (Zebker et al. 1994), a comprehensive analysis of the results especially the reproduction of the results from the same test area with different data sets and the comparison of the fringe smoothing filters on the accuracy of the results have not been performed.

Therefore, the intention of this paper was to present results of a comparative analysis of interferometrically derived DTMs and topographic maps digitised DTMs of two different test sites. The work was also to include the assessment of two fringe smoothing filters, namely the moving box averaging and the directional adaptive Gaussian filter (Geudtner et al. 1994), on the accuracy of the DTMs. But, due to lack of results by the time of the deadline for the submission of the papers for inclusion in the proceedings, only the results of an INSAR DTM generated for one of the test sites is presented. The full results, however, will be orally presented at the congress.

2. TEST AREA AND DATA

2.1 Test Areas

Basically, two test areas have been treated. One covering a more flat area to the west of the city of Bonn in Germany, the city of Weilerswist, and the second is also a flat terrain area around the city of Dortmund in Germany too. Reference digital terrain models with a cell size of 50 meters digitised from topographic maps in a scale of 1 : 50000 of these areas were available. They were resampled to cell sizes of 40 x 40 meters for matters of comparison with the interferometric products.

2.2 INSAR Data

For the interferometric test data, suitable baselines from ERS-1 phase B and D data were selected. For the Weilerswist area one phase B interferometric pair was available. The pair was acquired on the 14 and 29 March 1992 corresponding to ERS-1 orbits 3459 and 3674, respectively. Whereas, for the area around the city of Dortmund 4 phase D interferometric quarter scenes were selected. The acquisition dates for these images were 31 December 1993, 03 January 1994, and 13 and 16 March 1994, which correspond to the respective ESR-1 orbit numbers 12864, 12907, 13896 and 13939 in the frame of the area. The baselines for these scenes were relatively small ranging from 60 - 160 meters.

3. INSAR PROCESSING

The INSAR processing starts with the co-registration of the images to a subpixel accuracy of 1/30. This is achieved by first correlating patches of 25x25 pixels to a pixel accuracy and by a subsequent surface fitting in a 3x3 window around the maximum point in order to obtain subpixel accuracy. The correlation measure used is the complex correlation function, which sensetive to fringe visibility. This process is repeated for a number of points covering the whole image, where only those points showing high correlation values are considered. After the offsets determination, one of the images is aligned to the other by polynomial interpolation.

Next, the images are cross correlated to generate the interferogram, which is a complex image by its self. Selecting a flat terrain area in the image and performing a 2D FFT on its interferogram, the azimuth and range phase trends for a plane approximating the observed surface are determined. These trends are then subtracted from the interferograms. The interferogram is then multi-looked by typically 10 pixels in azimuth and 2 pixels in range. The interferogram image is smoothed by adaptive low pass filtering, i.e. moving box averaging and directional gauss filter, before being unwrapped. For the unwrapping the cuts placing algorithm was used. For display purposes, the resulting wrapped and unwrapped phases are also scaled to gray value images.

The unwrapped data are then converted to a ground range DTM by selecting control tie points (GCP) from a reference map of the area and the use of the orbit information extracted from the CEOS format file header information. For details of the DTM generation procedure see (Kenyi and Raggam 1995).

4. RESULTS

The Weilerswist data, fringes could only be generated from the first third of the scene. Therefor, the analysis were only concentrated on this area. Luckily, for the area around the city of Dortmund the coherency was excellent, almost the whole quarter scene and all two orbit pairs. Good quality fringes were generated which implies generation of a DTM for the whole quarter scene (partial quarter scenes INSAR DTMs are mostly presented in the literature).

Normally, the wrapped or unwrapped phase images follow the contour or shape of the topography of the imaged terrain. However, as observed in the phase images generated, it is not the case for Weilerswist area test data. Deviations from the local topography were observed in the fringe image of this area. These phase deviations have been identified as atmospheric effects (Kenyi and Raggam 1995). Figure 1 shows the flatten fringe image of the Weilerswist area, where the phase anomalies are clearly visible in the center of the image. However, no such phase anomalies were detected in the fringes of the area around the city of Dortmund; instead small details such as artificial hills and man made features could be clearly detected. Figure 2 shows a flatten fringe of the dortmund area, namely orbit pair 13896 - 13939.

In figure 3, the INSAR generated DTM for the Weilerswist area is shwon in a contour lines presentation. For comparison a DTM was created from digitised contour lines of a topographic map in a 1:50.000 scale. Figure 4 shows this map-derived reference DTM in a contour lines coding similar to that of the INSAR generated DTM. In order to assess the errors in the INSAR DTM, a difference of the two DTMs was computed. Figure 5 shows the difference DTM in contour lines presentation too. Whereas, in tables 1 and 2 the statistical errors for respectively, the generated DTM (GCPs) and the difference DTM are presented.

5. DISCUSSION

For the entire area the standard deviation of the elevation differences was about 11 meters. This is slightly worse than the RMS height error of about 9 meters for the GCPs (see Tables 1 and 2). Moreover, the interferometric DTM is shifted on average by 2 meters in comparison to the map derived DTM. The maximum error was around 50 meters, whereas that of the GCPs was about 14 meters. The 50 meters error turned out as local deviations due to the atmospheric turbulence.

6. CONCLUSIONS

Although, work is still going on for the generation of the DTMs from the unwrapped fringes of the Dortmund test area by the time of preparation of this paper, it can be concluded that even at relatively small baseline INSAR derived DTMs gives height information with acceptable errors. However, enough care must be exercise due to the fact that atmospheric turbulence can introduce errors of large magnitude in the INSAR height measurements. Whereas, concerning fringe smoothing, the moving box averaging filter performs best within largely spaced fringes and conversely the Gaussian directional filter.

7. REFERENCES

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Table 1: Statistics of GCPs phase and co-ordinate residuals, where E, N and H stands for East, North and Height respectively.

Residuals (14 GCPs)	Phase		GCP Coordinates		
	rad.	deg.	E	N	H
RMS	0.98	56°	28.2	25.4	8.9
Minimum	-1.72	-99°	-50.7	-58.4	-11.6
Maximum	1.96	112°	47.9	40.7	13.7

Table 2: Statistics of difference DTM.

Statistics of Difference DTM (meters)	
Mean	-2.3
Standard Deviation	11.1
Minimum	-46.0
Maximum	50.0

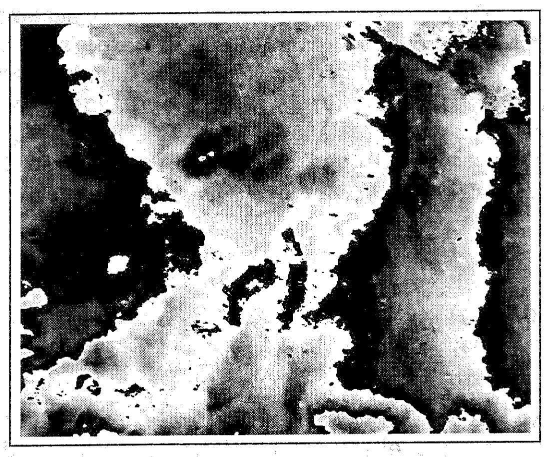

Figure 1: Fringe image of Weilerswist test area.

Figre 2: Fringe image of Dortmund test area.

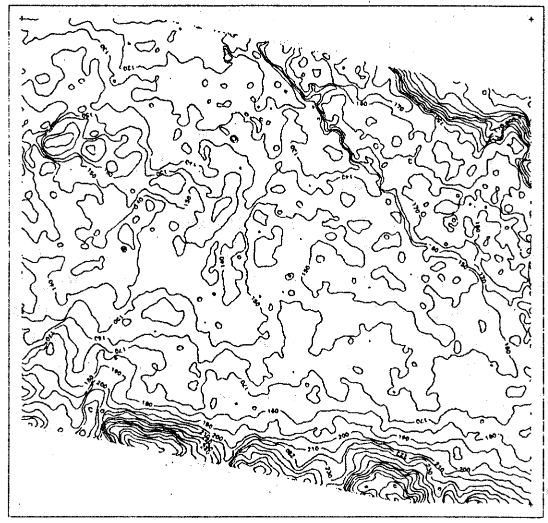

Figure 3: Contour lines of INSAR DTM of Weilerswist test area.

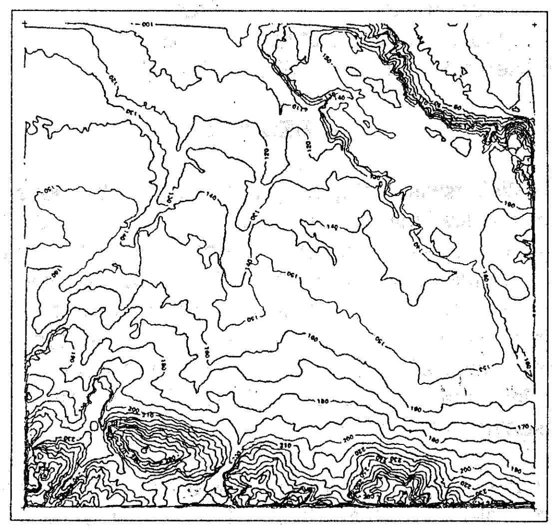

Figure 4: Contour lines of reference DTM of Weilerswist test area.

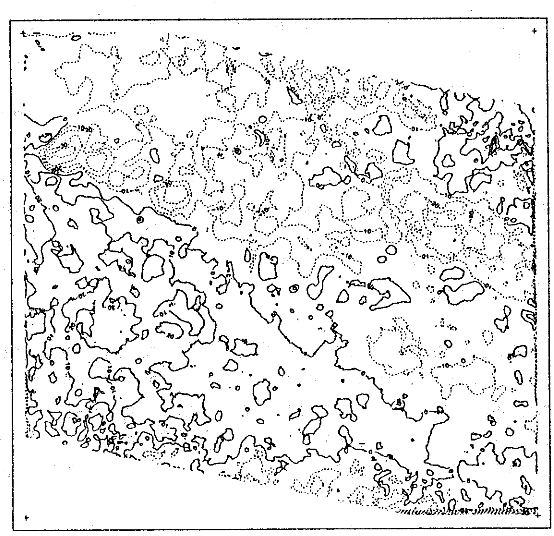

Figure 5: Contour lines of difference DTM of Weilerswist test area.