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An Experiment on Atmospheric Effects in Airborne Interferometric SAR Data

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Abstract

In this contribution we present an experiment in order to investigate on tropospheric effects in airborne SAR interferometric data. The analysis was carried out using differential Interferometry between two acquisitions with different tropospheric conditions. No pronounced effects were detected in the investigated weather conditions, i. e. a layer of fog.

1. Introduction

An atmospheric SAR experiment called ATMOSAR was conducted in October 2005 at the Microwaves and Radar Institute (HR), DLR - German Aerospace Center, where microwave remote sensing has a long tradition. The main purpose of the experiment was to investigate the influence of the troposphere on Airborne Synthetic aperture radar measurements, acquired by DLR's experimental E-SAR System. E-SAR is an airborne system flown on a modified Do 228 -212 with high operational flexibility and imaging capabilities in a variety of frequency bands. It has to be mentioned here that investigations on atmospheric propagation effects in the context of the space-borne case have been done several times (cf. e.g. [1] [2]).

The main idea behind the experiment was to collect data sets at different atmospheric conditions and to compare the measurements by performing a differential interferometric analysis described in more detail in Section 2. At the onset of the experiment design phase, a configuration with pronounced differences between atmospheric conditions on day one and two of acquisition was sought. Ideally, a heavy thunderstorm (convective cell) on day one and a calm and clear-sky day two with no precipitation was anticipated and considered best. However the maximum acquisition altitude for E-SAR is restricted to about 4000 m and the danger of corresponding wing icing above the melting band and/or the potential impact of hail stones put constraints on the selection of the respective weather conditions for acquisition. Thus due to staff and equipment security reasons it was impossible to operate E-SAR during a so called convective weather situation. Instead, conditions with a fog layer between sensor and illuminated surface was finally chosen.

2. Description of the Experiment and the Aquisition conditions - Analysis and Data processing

The data acquisition took place at the testsite of Oberpfaffenhofen on the 4th and the 7th of October, 2005. The detailed times and additional parameters characterizing the weather conditions are summarized in Table 2. On both days two passes with zero baselines were flown where the operating frequency was L-band (Rf-centre frequency 1.3 GHz). The datasets itself were processed using an extended chirp scaling algorithm [3]. Furthermore, residual motion compensation was performed according to [4]. The co-registration which is indispensable for producing interferograms was done using a method developed by [5].

Day one was dry with no precipitation; however the sky was fully covered by a closed fog layer approximately reaching from 750 to 1500 m above sea-level, corresponding to a fog-layer thickness of about 750 m. The average height of the test site was around 580 m above sea-level. Temperatures reached

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11.3 ° Celsius and humidity was 100 %. Air pressure was quite similar on both days and around 1024 hPa.

On day two clear sky conditions were prevailing during the data takes. Due to the missing fog cover and advanced time of the day temperatures were reaching about 18 ° Celsius at the time of acquisition; the humidity dropped down to 50 % of day one.

Thus four data sets have been acquired allowing for a differential interferometric SAR image generation as in [6]. The main principle behind the analysis is to generate two interferograms using one "master"- and two "slave"- images. The master image stems from the first day of acquisition and the "slave"- images were acquired on the first and on the second day.

The respective differential interferogram shall provide insight into any tropospheric changes between acquisitions of day one and day two, assuming stationary/unchanged topography.

3. Interpretation

The final result given in Fig. 3 shows the differential interferogram generated by using two interferograms and a DEM. Azimuth direction coincides with the horizontal and the range direction is pointing perpendicular. The colour bar on the right hand side of Fig. 3 covers the delay and/or displacements with values reaching from −60 mm to maximum of +60 mm.

Blue coloured zones, especially appearing in the upper half of Fig. 3 is due to residual motion errors, indicated by the homogenous spreading along the range direction [7]. The suspicious yellow spots below the centre of the image indicate differential effects maybe due to different soil moisture content, since they are correlating with agricultural structures, but for sure these areas are not related to atmospheric propagation effects.

The areas appearing black in Fig. 3 are due to coherence values smaller than 0.3. The coherence values are within the parameters zero and one. Bright areas correspond to high coherence whereas dark or black pixels correspond to low coherence values, in some cases even a total loss.

By comparing the coherence images in Fig. 1 and 2, one observes as expected, an increase of decorrelation due to the increased time span between the data takes. Especially the wooded and vegetated surfaces are vulnerable to decorrelation processes, whereas built up areas and point targets show better correlation.

The green coloured zones in Fig. 3 are dominating and refer to no differential changes or only minor phase changes below the processing accuracy.

4. Conclusions

The conducted experiment revealed that moderate and homogeneous differences of the chosen and imaged weather situations deliver no pronounced indication of atmospheric effects according to the image provided in Fig. 3. This leads to the conclusion that atmospheric effects under the given acquisition parameters do not exist, or are below the processed interferometric phase accuracy, due to the homogeneous layer of fog with no major variations within the length of the synthetic aperture or during the integration time. This means that the changes in the atmospheric conditions are rather gradual within the imaged scene of 2 x 3 km.

For future experiments the improvement of motion compensation techniques is mandatory and will allow for a more accurate visualization of any effects in connection with the atmosphere.

Difficulties arise in the selection of appropriate acquisition scenarios, since flight altitudes with the E-SAR system are not high enough for convective precipitation events. Low stratiform scenarios are probably better suited and might be in some cases more accessibly for study.

Acknowledgments

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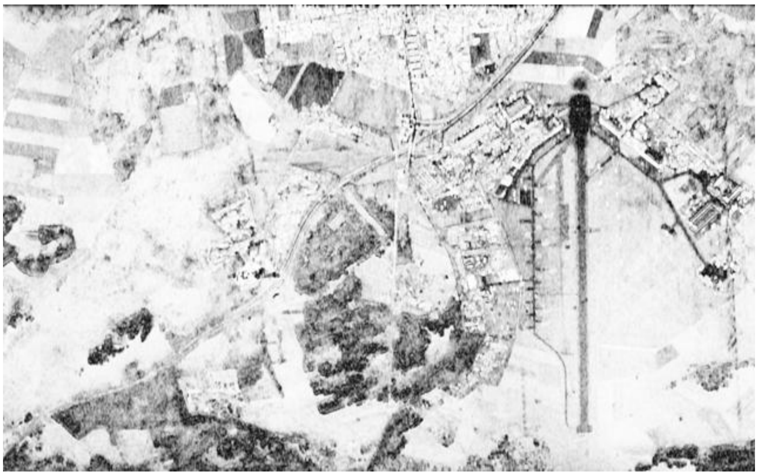

Figure 1: Coherence image between two different passes on day one

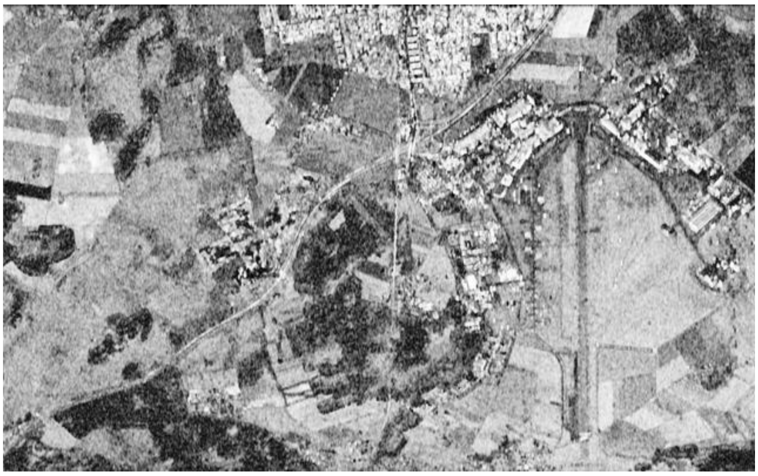

Figure 2: Coherence image between two different passes on day one and two

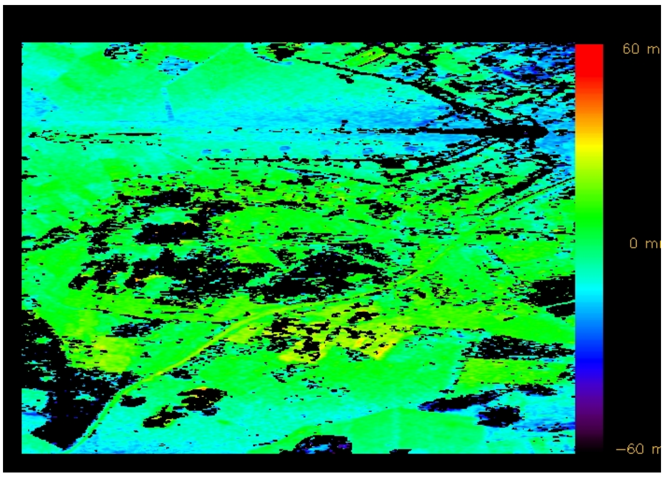

Figure 3: Differential Interferogram

Parameter	**Value**
Wavelength/ Frequency band	0.2305 m / L
PRF	400 Hz
Flight velocity	85 m/s
Range sampling fraquency	100 MHz
Bandwidth	100 MHz
Range delay	19.5210 μs
Azimuth pixel spacing	0.042 m
Range pixel spacing	1.49 m
Azimuth dimension	2415 px/ 1014 m
Range Dimension	2048 px/ 3051 m

Table 1: E-SAR system acquisition parameters

Scene ID	**Date** [yy.mm.dd]	**Time** [MEZ]	**Air-pressure** [hPa]	**Humidity**	**Temp.** [° C]	**Zentith delay** [m]
0301	05.10.04	10:13	954	100 %	11.3	2.32
0302	05.10.04	10:23	954	100 %	11.3	2.32
0405	05.10.07	12:20	952	54 %	18.5	2.292
0406	05.10.07	12:39	954	53 %	18.5	2.2913

Table 2: Weather and aquisition parameters

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