Analysis of Seasonal Changes in High Resolution Repeat Pass SAR Image Pairs by the CoVAmCoh Method

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Abstract

SAR images are difficult to interpret and there is a need to support human interpreters by image analysis algorithms. The potential of the CoVAmCoh analysis is demonstrated and discussed elsewhere ([7], [8]). The CoV (Coefficient of Variation), the amplitude, and the coherence are calculated and jointly evaluated. This paper is focused on the analysis of seasonal changes by the CoVAmCoh method in 13 TSX image pairs (ascending and descending orbit) of the same location covering nearly half a year. The robustness of the method is demonstrated and discussed. The introduced interpretation rules are evaluated and refined.

1 Introduction

Since 2007 the new generation of spaceborne SAR sensors like TerraSAR-X and Cosmo-SkyMed provides high-resolution ground mapping data with spatial resolution of up to one meter. Such data now offer the opportunity of using the SAR technology for the analysis of urban areas (e.g. [1], [2], [3]). The high precision repeat cycles of the new SAR satellites allow to exploit on a regular basis two or more interferometric images of a scene. The repeat cycle of TerraSAR-X for instance is eleven days only [4]. The coherence between such two interferometric images describes the accuracy of the estimation of the interferometric phase. The coherence decreases with increasing volume scattering and with temporal changes ([5], [6]). The thematic information included in the coherence was used by several authors to improve the interpretation or the classification of SAR images. Especially for the evaluation of vegetation areas (e.g. signatures of forests) it was intensively investigated. Their spatial high resolution and their almost independence to atmospheric perturbations or weather conditions make SAR images complementary useable to optical images. As for example – if a time series of images (image stack in time) is available -, different kinds of scattering characteristics (e.g. surface roughness, soil moisture) could be monitored over a period. In this study, we focus on the analysis of seasonal changes by the already proposed CoVAmCoh method ([7], [8]). Central goal is to derive knowledge about the robustness of the CoVAmCoh classification scheme [7] for basic surface properties. The information contained in a repeat pass image pair is visualized by the CovAmCoh method so that several features can be directly extracted from a color representation of three deduced features. The coefficient of variation (CoV), the amplitude (Am) and the coherence (Coh) are calculated and jointly evaluated. The combined evaluation of these features can be used to identify regions dominated by volume scatterers (e.g. leafed vegetation), rough surfaces (e.g. grass, gravel) and smooth surfaces (e.g. streets, parking lots). Additionally the coherence between the two images includes information about changes between the acquisitions. The method shows a simple way to improve the intuitive interpretation by the human interpreter and it is used to improve the classification of several urban features.

Up to now single image pairs showing different sceneries with urban structures like airports were investigated. In this paper the stability and robustness over a longer time period is discussed and analyzed. Here conclusions about different kinds of surface type changes and especially the monitoring of regions in coherence areas are of interest with the background of detecting man-made changes. A monitoring task which compares the CoV values over a defined period of time could further contain references to changes e. g. in vegetation. From possible changes in the backscattering intensity (amplitude layer), conclusions about changes of ground cover structures (e.g. from grassland to field) could be derived.

This paper is focused on the analysis of seasonal changes in 13 TSX image pairs (ascending and descending orbit) of the same location covering nearly half a year. The robustness of the method is demonstrated and discussed. The introduced interpretation rules are evaluated and refined.

2 Dataset

A time series of almost half a year of interferometric SAR image pairs of Greding, Germany, was used for this study. The data was acquired by the German TerraSAR-X satellite system in HR SpotLight mode at 300 MHz (ascending and descending orbit) and was provided by the Astrium Services / Infoterra GmbH.
The repeat pass cycle between two images was eleven days. The pixel size was about 0.45 m in Slant Range and 0.86 m in Azimuth direction, the incidence angle was about 48.5° in ascending orbit and about 41.9° in descending orbit. The acquisition dates reach from August 8th 2008 to December 7th 2008 in ascending orbit and from August 17th 2008 to December 16th 2008 in descending orbit. Furthermore, there are another two 11 days interferometric image pairs available in both orbit directions covering the January of 2009 acquired after a maintenance break of satellite.
Two magnitude image pairs were radiometric sigma naught (σ^0) calibrated as described in [9]. From each co-registered magnitude image pair, one CoV image [10] was processed with a window size of 5x5 pixel; from each co-registered SLC image pair, one coherence image was calculated with a window size of 5x5 pixel. Finally, from these three layers one CoVAmCoh image ([7], [8]) was created.
This CoVAmCoh analysis improves the interpretation of SAR images and offers the potential to develop rule-based schemes as, for example: yellow appearing objects or surface types have a high CoV and amplitude value: in contrast to a low coherence value. So, these yellow regions represent areas of local spatial changes between the two acquisition times. On the other hand, dark appearing regions have low values in both the three layers – so, homogeneous, incoherent areas of low backscatter could be shadows or water surfaces for example.
Due to the σ^0 calibration procedure, intensity images are used, so that for the mean CoV image (single look) between the two acquisitions the expected value for a homogeneous region is 1 [11]. The CoV symbolizes the local spatial homogeneity and heterogeneity respectively.
As usual, the Coherence is defined between [0;1], so that an ideal coherent scatterer has a value of 1 and a value of 0 is equivalent to complete decorrelation between the two acquisition times.

3 Seasonal Analysis

Six areas of interest (aoi) were chosen: an agricultural field (area 1), a field near by a river (area 2), another agricultural field (area 3), one not inclined forest area (area 4), one inclined forest area (area 5) and one urban building area (area 6). In each aoi, the CoV, the mean magnitude (σ^0) and the Coherence were calculated and observed in an image time stack of almost half a year. CoV, magnitude and Coh values are derived in the areas described above, were the CoV values were extracted from the calibrated master scene (single look intensity image). As master scene, the older one of each image pair was chosen. All CoVAmCoh values and the particular evaluated areas are shown in **Figure 1**.
Referring to **Figure 1**, it can be seen that the areas with field structures (area 1 to area 3) have quite robust CoV values over the period of time from August to December 2008 – in fact for both orbit directions. These values are close to 1, which means that these areas are almost ideal local homogeneous. This is caused by the lack of structuring elements (corners, edges, lines etc.). As expected the two forest areas (area 4 and area 5) have a greater CoV – both in ascending and descending orbit. The forests areas are more textured resulting in a higher CoV compared to the homogeneous agriculture fields. Exceptional, focusing on the two image pairs covering the January of 2009, area 2 exhibits relative high CoV values which are caused by a flooding in this area. The area 4 shows nearly the same constant values for ascending and descending orbit. The inclined forest area 5 shows a different behavior. Both curves show an unexpected distinct decrease from summer to winter. The reason for this seasonal change is still under investigation. For the urban area, CoV values between 5 and 10 (ascending orbit) and 15 and 20 (descending orbit) were observed. Hence, these values are not directly comparable to the CoV values of the other investigated areas and are not illustrated in **Figure 1**.
Analyzing the mean σ^0 values derived from the calibrated sum of magnitude images, it can be seen that two areas (area 1 and area 3) have similar backscatter characteristics in both orbits. These areas are agricultural used fields in contrast to area 2, which is a grass-like surfaced field (**Figure 1**). Furthermore, the backscatter values of area 1 and area 3 show a higher variability in time, so that conclusions about changes in usage of those fields can be directly extracted. The non-agricultural used field (area 2) shows by trend a lower backscatter intensity as the two agricultural used fields (area 1 and area 3), which is caused by a surface type that appears a little bit "smoother" for the SAR signal (e.g. short grass). In fact of the occurring flooding in this area in January of 2009, the backscatter values decrease (surface becomes "smooth"). The urban area of a building roof (area 6) causes higher backscatter in fact of roof corner structures which are completely or partly oriented to the sensor. Comparing the two forest areas (area 4 and area 5), it can be seen that the backscatter intensity directly depends on the local surface elevation and the particular orientation of the objects relative to the sensor. The inclined

forest area (area 5) is oriented to the sensor in descending orbit, and averted from sensor in ascending orbit. So, the backscatter intensity varies with orbit direction for this area, which is illustrated in **Figure 1**. Furthermore, a nearly not inclined forest area (area 4) has a low variability of backscatter intensity values over the two orbit directions.

Focusing on the coherence values of the investigated areas, it is, referring to **Figure 1**, obvious that agricultural fields have a great variability over a seasonal period - dependent on the form of usage. When fields are harvested, for example, temporally short increases in coherence can be measured (area 1 and area 3). Other fields with no agricultural usage, for example area 2, have no significant variability in coherence. The urban area with the building roof (area 6) has a great variability in coherence, which is caused by the roof structure. The roof cover is split into one half of gravel and in another half of grass-like surface, so that seasonal changes can be seen also by analyzing this object (**Figure 1)**. Focusing on January of 2009 (descending orbit), it can be seen that there is an increase of coherence values relative to December of 2008, which is probably caused by snow (evaluated by weather database information). This effect is actually under investigation.

4 Conclusions and Outlook

In this paper, the focus is on the temporal analysis of seasonal changes by the CoVAmCoh method. Six areas (three field areas, two forest areas and one urban area) of interest were analyzed for two orbit directions (ascending and descending) during a time period of almost half a year.

By evaluating the CoV, the mean magnitude (σ^0) and the Coherence values of interferometric image pairs, the signature stability of comparable surface objects was observed for not inclined areas. Also a maintenance break of the satellite did not lead to remarkable system based changes of the three features but scene dependant changes are present (flooding, snow). Furthermore, other considerations about the status of cultivation (e.g. harvested or not) could be extracted by analyzing the coherence.

In future, it would be of interest to explore the possible benefit of the seasonal CoVAmCoh analysis presented in this paper for the determination of the change category.

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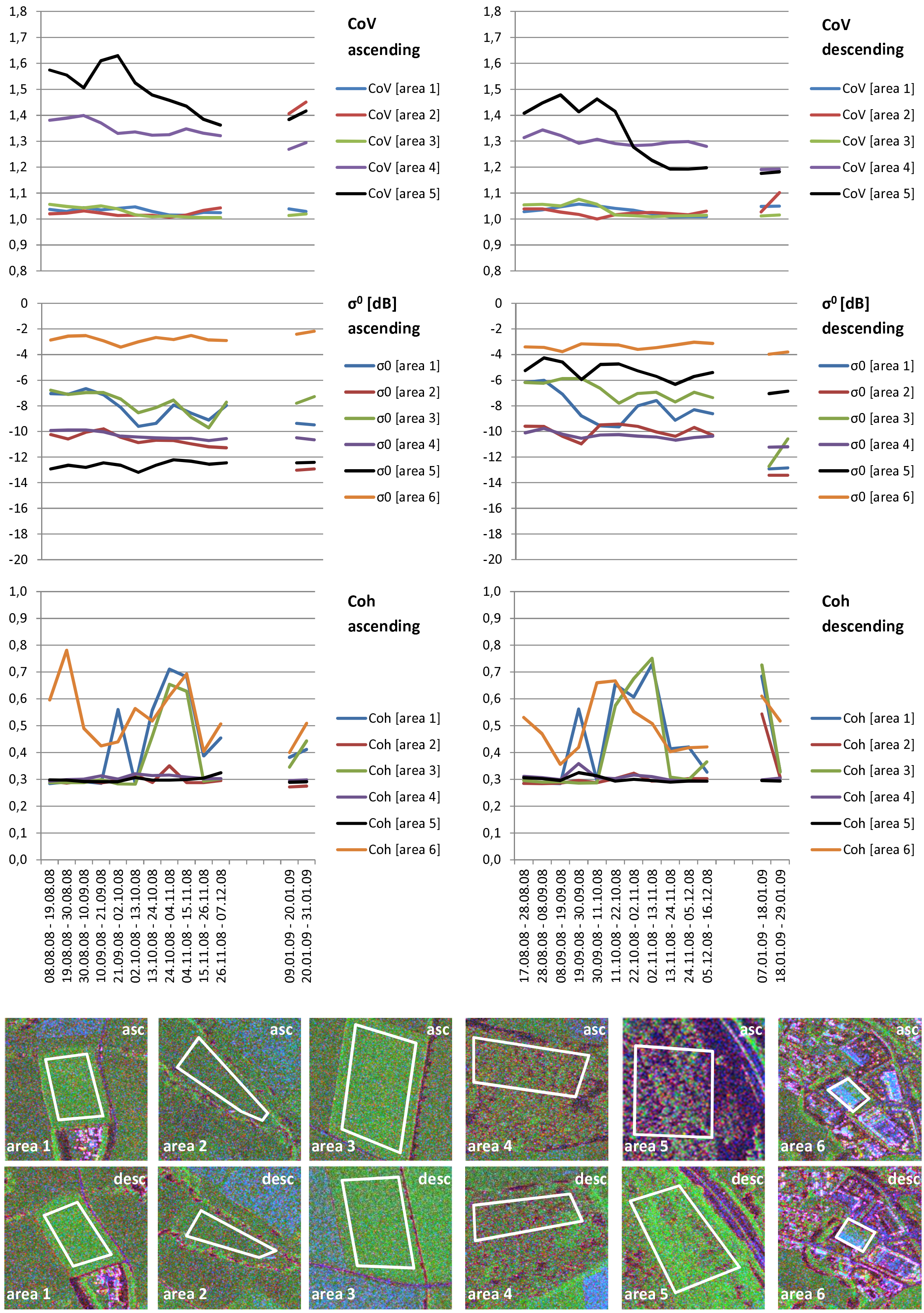

Figure 1: CoVAmCoh values over time period and areas in CoVAmCoh RGB illustration.