

CHANGE ANALYSIS WITH TERRASAR-X DATA

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Commission VII

KEY WORDS: Analysis, Change Detection, Monitoring, Change, SAR

ABSTRACT:

Change analyses play an important role for different applications, ranging from small- to large-scale monitoring. To identify changes from SAR images of repeat pass acquisitions different methods are commonly applied, which differ with respect to the parameter as an indicator of changes. The backscatter intensity is analysed in incoherent change detection methods, whereas in the coherent change detection the complex correlation coefficient is analysed as a change indicator. These methods provide complementary characterisations, since they are sensitive to different measures of a SAR scene.

However, often not only the detection of changes, but also the assessment of the detected changes is of interest, which automated is a challenging task.

In this paper a combination of detection and assessment of changes is shown. Additional information is integrated into the proposed scheme to separate relevant changes from less relevant ones in order to decrease unrequested changes and evaluate the type of change. Texture measures provide information on the spatial variation of the backscatter and thus information of the local surface characteristics within the scene. This information is used to restrict the search for areas and changes of interest as well as for the assessment of changes.

The goal of our analysis is to support the implementation of an operational change detection process and to define a suitable assessment of changes from TerraSAR-X data regarding different customers' requirements.

1. INTRODUCTION

In many different geoinformation applications, the detection and assessment of changes is of much interest. These applications can vary from specific site monitoring to large-scale assessment after certain events and for updating existing geoinformation databases.

Satellite SAR missions like TerraSAR-X entail potential for such applications, not only because of the large coverage in combination with high resolution, but also due to the independence regarding daytime and weather conditions.

The identification of changes implies a comparison of datasets or knowledge about a scene of different dates, like e.g. updating of existing geoinformation with recent remote sensing data. Different approaches for change detection have been studied depending on the sensor and available data.

In this paper the focus is set on the image-to-image change detection with TerraSAR-X data, and in particular on repeat-pass images with the same acquisition parameters, which allow a direct comparison. Therefore, acquisitions of pre- and post events are required.

Detecting changes means that every variation causing a different echo signal/backscatter is detected. However, often customers are only interested in relevant changes concerning their applications. To be able to offer the user-specific change information, an assessment of the detections is required. The

preferably automatic detection and assessment is a goal for a worldwide operational process and service. The integration of additional information, like e.g. GIS data, in such a process can be helpful for this purpose. However, in many regions often this required a-priori information is missing or not available in the time frame for rapid assessment. Therefore, the used pre- and post-event imagery for change detection as a single source has to be exploited also to assess the changes. Hence, different measures have to be deduced from the images to derive more information about the scene.

2. CHANGE DETECTION

Change detection based on SAR images has been subject in different publications. To identify changes from SAR images of repeat pass acquisitions different methods are commonly applied. These methods differ with respect to the parameter which is used to indicate changes and the method to reduce the noise. Since SAR data contains amplitude and phase information, both parameters can be used as change indicators.

A common method is the analysis of the radar backscatter intensity in time to identify changes between different acquisitions, also called incoherent change detection (Preiss et al., 2003). This power change estimate is affected by the speckle noise component, whose reduction is discussed in several publications, e.g. in (Schmitt et al., 2009).

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In SAR data, additionally the interferometric phase information is sensitive to surface changes and ground motion. The coherence, which expresses the complex correlation of two SAR scenes, can be used as an indicator of changes (Scheuchl et al., 2009; Wright et al., 2005). However, since the phase is sensitive to sub-wavelength changes, the information is related to very subtle changes, especially for X-Band. Therefore, change detection based on the interferometric coherence is susceptible to high false alarm rates, since several impacts, like e.g. weather and surface properties, can cause decorrelation.

Incoherent and coherent change detections provide complementary characterisations, since they are sensitive to the different measures of a SAR scene: backscatter intensity and phase. Therefore, the joined use of both statistics often provides a better description of surface changes. Preiss et al., 2006 showed a statistical test for change detection combining incoherent and coherent change statistics.

To respond to certain customer-specific applications, the detected changes have to be assessed in a fast and efficient way. However, the automatic assessment of changes is a challenging task. Classification of the scene gives information about surface characteristics (Wegmüller et al., 2003), which can be used to restrict the search areas and reduce unrequested changes. Additionally, this information gives an indication about the type of change.

3. CHANGE ANALYSIS – DETECTION AND ASSESSMENT

To detect changes, the different parameters of a complex SAR signal can be exploited, see Sec. 2. In the suggested process further information is integrated to decide whether the change is of interest or not for the customer-specific case. The following sketch shows a brief processing overview for the automatic detection and assessment of changes.

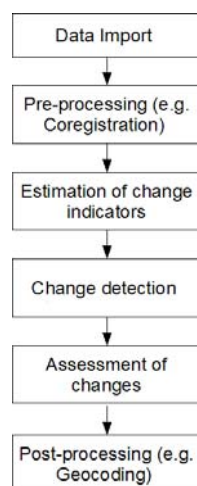


Figure 1: Processing scheme – change detection and assessment

3.1 Change Detection

In our work we use both, the intensity ratio and the coherence as change indicators. We assume certain distributions of those

features to estimate the thresholds to distinguish changes. The known distribution functions of the intensity ratio (Touzi et al., 1988) and of the coherence (Hanssen, 2001) are used to separate changed from non-changed pixels, assuming a certain false alarm rate.

The intensity ratio contains, not only the information that a change happened, but also if the backscatter increased or reduced between the acquisition dates. This information will be kept and can also be used in the following assessment step.

3.2 Assessment of changes using additional information

Into the proposed scheme further information for the assessment is integrated resulting in a context based change detection approach. Broad land cover classification of the pre-event scene is used as context information.

Since there is not a unique descriptor applicable to various surfaces, different textures and statistics are estimated to improve land cover discrimination. Texture measures provide information on spatial variation of the backscatter and thus information of the local surface characteristics within the scene. This information together with coherence and backscatter statistics is used in a classification approach to restrict the search for areas and changes of interest and for the evaluation of changes.

In a first attempt a straight forward pixel-wise classification based on coherence and backscatter intensity has been tested and achieved in general reasonable results concerning broad land cover classes such as urban, forest, open land, water and coastal areas. However, combining the classification result with the change indicator showed that the pixel-wise classification approach is too noisy to reduce unrequested changes.

Therefore, object based classification methods have to be applied in order to first divide the image into homogeneous regions (segmentation) and second, derive image characteristics such as co-occurrence texture measures, coefficient of variation, and class related features from resulting image objects. Based on these features a simple decision tree can be set up to classify the pre-event scene.

This kind of information gives a hint about the type of change. Additionally the change direction of the backscatter can be used to evaluate if an object disappeared or showed up. Hence it supports the classification of the type of change.

4. APPLICATION TO DATA

The combined detection and assessment of changes has been applied to TerraSAR-X StripMap acquisitions to demonstrate the approach.

4.1 Available Data and Scenery

Two TerraSAR-X StripMap (3m resolution) acquisitions are available. The images are repeat-pass acquisitions with the following acquisition parameters: HH polarisation, ascending orbit, incidence angle: 36-38,6 °.

The scene is located in Panama close to the capital and the southern entrance to the Panama Canal. The following Figure 2 and Figure 3 show only a detail of the StripMap scenes with an airport in the south western part, the entrance to the Panama

canal at the right top of the image and a wetland in between them. Most of the rest of the scene is covered by forest.

4.2 Results

The high degree of vegetation cover and the time difference of three month between the acquisitions result in an overall low coherence due to temporal decorrelation which is typical for temperate and tropical regions. Following, the emphasis for the change indicator was put on the intensity ratio. The detection mask overlaid on the first image is shown in Figure 4. The red pixels signify areas where the backscatter reduced and the blue ones stand for an increased backscatter.

Different kinds of changes are detected within this scene. For example on the left bottom of the subset a clearing of the forest was conducted, which is clearly visible in the changing backscatter of the two images. Also new constructions are detected in the north of the buildings belonging to the airport. Regions where varying soil moisture in the wetland caused a different backscatter, as well as temporarily present objects, like e.g. wagons on the runway and ships on the sea appear also in

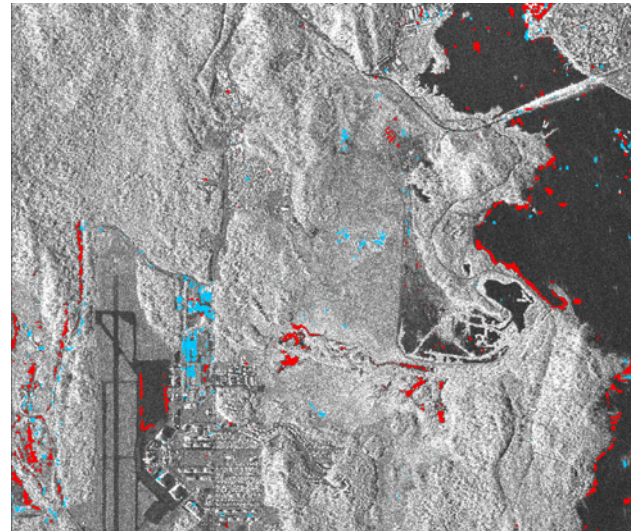


Figure 4: Change detection mask; red: backscatter reduced, blue: backscatter increased.

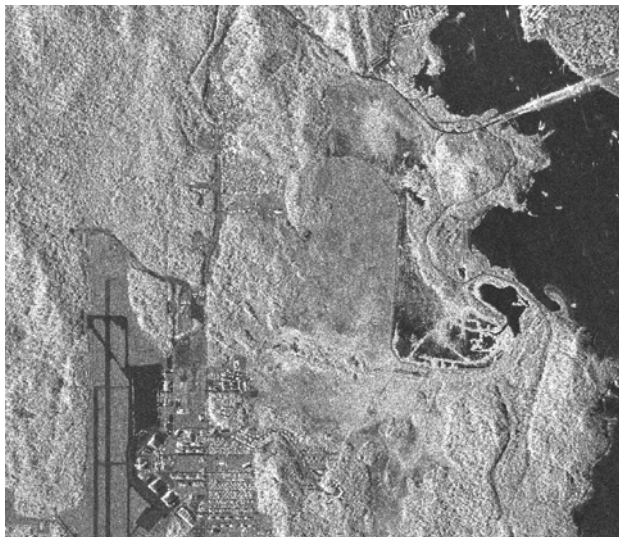


Figure 2: TerraSAR-X acquisition of 25.01.2009.

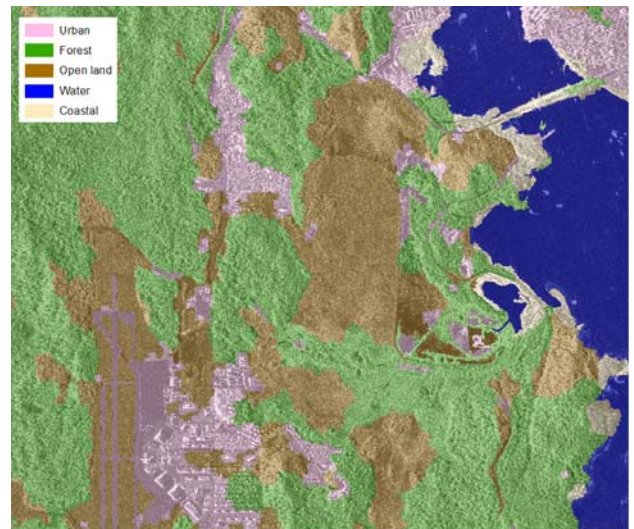


Figure 5: Land cover classification of TerraSAR-X derived features (25.01.2009).

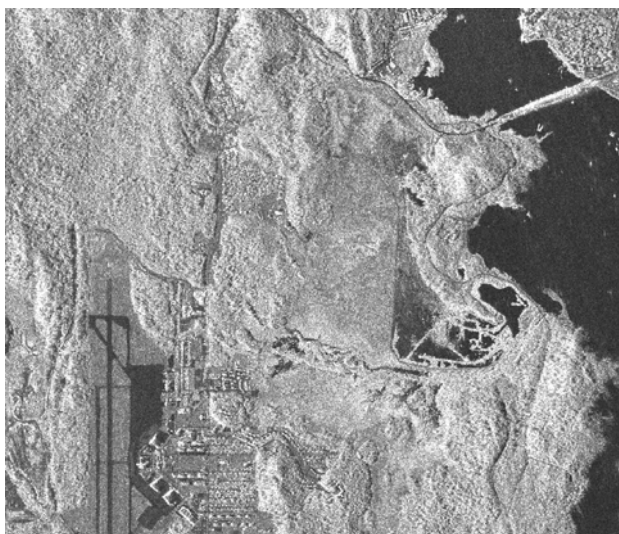


Figure 3: TerraSAR-X acquisition of 12.04.2009.

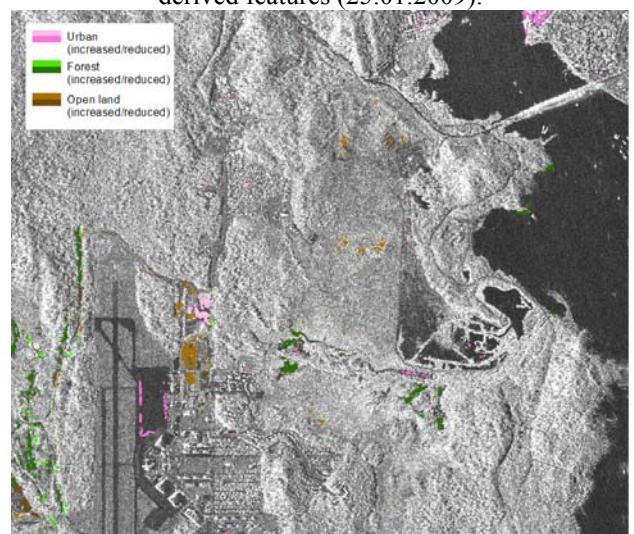


Figure 6: Detected and assessed changes.

the detection mask. Varying water level can result in detected changes at the coast.

Obviously, every object or parameter which caused a significant backscatter change will result in a detection. However, customers may only be interested in specific changes, like e.g. in new constructions.

To analyse the scenery to gain additional knowledge for the qualification of detected changes, different measures have been used for segmentation and classification: Coefficient of variation, Coherence and statistics of the intensity.

Five broad classes have been evaluated: water, forest, open land, urban and coastal areas. The result of this classification is shown in Figure 5.

Assuming a certain application and that a user is only interested in changes on land and not in variations on the sea e.g. due to waves, varying water level and ships, the following reduction has been applied. Changes on water and coastal areas have been eliminated as unrequested changes.

The information about the change direction of the backscatter (reduced or increased) has been combined with the classification results of Figure 5. The result is shown in Figure 6 and a detail of it in Figure 7.

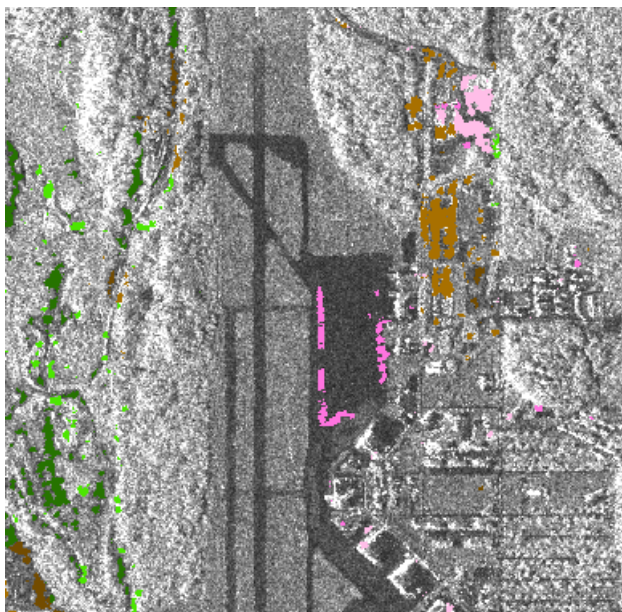


Figure 7: Detail of detected and assessed changes.

The clearing on the left hand side has been classified as a change type in forest areas with a decreased backscatter, which is typically the case for clearings. At the new forest edges an increased backscatter is caused by layover.

The new construction at the area around the airport were classified as open land, which is true since in the first acquisition there was bare soil and the increased backscatter gives the indication of a new object. The temporarily parked wagons at the runway are classified as a change in urban areas, where usually many changes are occurring independent on the change direction. Domain specific interpretation knowledge is needed to verify the plausibility of such changes and qualify it as temporary change.

The detected and assessed changes are plausible. However, the assessment depends on the quality of the classification. Even

though no apriori information and only a small amount of SAR data sets have been available the customer can be provided with, a rough idea about the type of occurring changes.

5. CONCLUSION

In this paper an approach for a combined detection and qualification of changes has been presented. The integration of additional information derived directly from the images is helpful to restrict search areas and to give more information to judge the plausibility of changes, if other a-priori information is not available.

The assessment depends on the accuracy of the classification of the imagery. However, an indication about the change direction can be given and can be helpful for further interpretation.

In future tasks, the improvement of the assessment can be conducted by using e.g. dual-polarised data and a comparison of classifications of pre and post event images.

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