Revisiting Methods and Potentials of SAR Change Detection

Abubakr A. A. Al-Sharif, Biswajeet Pradhan, Sinan Jasim Hadi, Neda Mola

Abstract: **Change detection is one of the important applications in earth environment observation, risk management and security. Synthetic Aperture Radar (SAR) provides a dependable and valuable source of information for monitoring changes and change detection applications.**
In this work, different methods and different SAR data that used in change detection application and factors which effect on this application have been studied. It has been found that the use of SAR data in monitoring and detecting changes is beneficial and advantageous; especially if SAR data integrated with optical data. Combination of methods and considering target conditions and other factors, overcomes the deficiencies that affect the use of SAR data in change detection. The use of combination technique gives an indication that we can combine other methods to enhance monitoring changes based on study area conditions; also we can develop new algorithms based on which combination would be used.

Keywords: ***change; detection; SAR ;image***

I. INTRODUCTION

Change detection is the comparison of remotely sensed data (images) which collected in different time; change detection is one of the important techniques in earth environment observation, risk management and security. In remote sensing field there are different sensors can be used for this purpose.

SAR (Synthetic Aperture Radar) is an imaging system with high coherent resolution sensors, its useful and strong when the weather conditions and light conditions are unfavorable; SAR can works in case of cloudy skies, day and night. Now days high resolutions of SAR satellites are available like (e.g. Radarsat-2, Terra-SAR and Cosmo/ Sky-Med) which enhance the techniques of change detection.

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Discriminating areas of changes on digital images between different dates is the main objective of change detection process. There are various types of changing features depend on origin and duration of change, which allow us to categorize them into several families of applications, for example: 1) land use monitoring, which is function in human activities, like deforestation or urbanization; 2) land cover monitoring, like detecting the changes in vegetation; and 3)damage mapping, like localization of changes happened due to natural disasters like earthquake, forest fires or floods, which are usually considered as fast changes.

In addition Change detection is important for updating maps (after a number of years following the making the base map), and emergency evaluation after a natural catastrophe, and monitoring of site.

Detecting and Monitoring of changes between two or more dates for above mentioned remote sensing applications, is depending on the application, requirements and the sensitivity of the measurement. For long term changes, the data sources may not same; the difficult task is to find changes on the required scale and find changed features map between the two reference dates. That mean change detection is recognized on feature level. On the other hand if available data collected from the same sensor, hence the task becomes easier in that case, and we can compare the two scenes directly.

One of the important advantages of using Active remote sensing systems like SAR is the consistency of the signal which provides the data. Synthetic Aperture Radar (SAR) provides a dependable and valuable source of information for monitoring changes and change detecting [27].

Synthetic aperture radar (SAR) interferometry from space borne satellite systems is used in detecting dynamic changes, retrieving elevation information and in mentoring phenomenon's that affecting the Earth's surface, this technique is considered a relatively new technique in this area.

The lack of using of radar data in thematic application of detecting changes has been reported in some studies [23]. Another studies reported that it is much fewer and more recent change detection studies used satellite-based SAR imagery if we compare it with optical-based ones [34]. Nevertheless, synthetic aperture radar (SAR) sensors have a robust potential for change detection studies, like weather mapping, and can also guarantee operational systems in case of critical atmospheric situations and night conditions.

II. RADAR IMAGERY IN CHANGE DETECTION

For remote sensing application there are many satellites data have been used to study and detect spatial and temporal changes for example in fluvial hydrology, vegetative cover, snow accumulations, movements of sea ice, and many other applications. On the other hand, in many conditions (e.g. polar ice covers with long period of darkness; tropical regions with extensive cloud covers; or during periods of full rainfall or tropical storms) radar almost the sensor that can regularly provide correct imagery through long period of time. Hence, in order to monitor some dynamic actions radar data may be required [19].

Look angle and look direction are the most important factors affect the use of SAR imagery for change detection, in some cases look direction is more important for change detection, the look direction of the radar should have little effect if any on the nature of the return backscatter. In some situations of targets which are arbitrarily oriented like forests, it affect the detecting ability of the feature and its change through time [2].

It has been showed by Some Empirical observations that if the radar antenna is pointed at an (azimuth) angle of less than approximately 11-15 ° to the normal of the target orientation, the target will give a stronger return backscatter because of that, brighter grey tone on the image than if the angle between the radar signal orientation and the target orientation is larger than that range [14].

In case of change detection in urban areas, it has been reported that changes in look direction as small as 0.8 ° between the orientation of urban target and the differences in the radar azimuth can cause major changes in the radar backscatter, which affect the capability to detect the changes [5].

The other important factor which affecting the use of SAR imagery for change detection is depression angle. In the case of using aircraft radars, the depression angle of the radar becomes more important than space-borne radar to interpreters because it varies extensively from near nadir. Common operating rules that should be considered for change detection in case of space borne radar systems are: gathering data using a constant bearing for any geographical location (assuming ascending or descending passes), gathering data over an long period of time, assemble data at fixed wavelength and polarization, gathering data with a small depression angles (6 °).The use SAR data sets separated only in time is better than those separated in time and look direction for change detection studies [19].The major concern in using SAR data in change detection is speckles , it is reported due to speckles in the images which cannot be avoided results in uncertainty and decrease value of the image, hence analysis of the image automatically becomes very difficult. Also, when the size of the objects in a SAR image is comparable with the resolution of the imaging system, this issue becomes significantly more serious. In some cases collateral information is desired (in some cases essential) when the image analysts not able to differentiate between very clear objects such as building and vehicle.

In order to perform change detection task, two major problems must be overcome; speckle noise in radar imageries is the first problem. These speckles are assumed to have no information, in order to be considered as noise which must be removed before using these images for change detection and in order to reduce any noise (e.g. speckle); the imagery underlying model description is required, and image alignment results the second problem.

Another two major components must be taken into consideration: Geometric correction (with the presence of unknown atmospheric confusion and aircraft motions), and image interpretation (with the presence of speckle that cannot be avoided and without use of collateral information) [32].

In addition, it has been demonstrated that image registration and suppression of the signatures from common objects are the two major challenges that must be faced by any change detection algorithm. Firstly, due to the lack in the possibility of keeping the platform of the radar in the same geometry from a data acquisition mission to another, the two SAR images (i.e. in change detection known as reference and test image), usually, are not aligned. Moreover change detection result will go worse greatly in case of the alignment is not well implemented before starting processing of change detection algorithm. Locally image registration is used and assuming the local geometry changes, by performing this method, we can achieve better result because it may not be possible to achieve a good result of registration by using large areas due the variation in the alignment over large areas. Secondly, the suppression of the signatures from common objects which appears in the two (reference and test images) of the process is considered as the second major component of change detection. Ideally, after registering the two images carefully, the signatures of an object in the two images should be the same and hence change detection algorithm should well suppress the common objects signatures in the two images. But, in the real situation, the same object signatures in the two images are usually different because of many reasons such as change in aspect angle, radar calibration error, noise, etc.). This difference usually gives a false alarm in identifying the change due to the difficulty of suppressing these differences by the change detection algorithm [26].

III. CHANGE DETECTION PROCESSING TECHNIQUES USING SAR DATA

a) Using Optical Data With SAR Data

Many studies have been carried out on using integrated SAR data with optical sensor. Using fusion of SAR from the (ERS) European Remote sensing Satellite with SPOT was done before by some researchers [25], and the same Radar sensor data were used also with LandSat data in other studies [1]. Sometimes the use of optical data in change detection or any another application is restricted by the existence of fog, clouds, and darkness or smoke while SAR system works in case of presence of these restriction and has

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the ability of extracting more information by using microwave interval of the spectrum [31]. Furthermore, it has been stated that due to the ability of radar satellite to acquire data in every pass and regularly, SAR data are suitable for analyzing the changes, while the cloud usually impede the optical data [16];[24].

By using optical sensors with moderate resolution such as LandSat in urban areas, many of man-made features spectrally appear similar. Also, optical sensors with high resolution such as IKONOS are not efficient in discriminating among man-made objects which are constructed by using different materials. On the other hand, several of these objects can be distinguished based on their geometrical and dielectical properties by using Radar images. Walls of buildings for example have relatively strong backscattering signal due to the corner reflectors as these wall oriented orthogonally on the radar look direction while surface of bare soil has low backscattering signal because it acts as a specular surface which reflects the signal away from the radar [3].

A methodology shown in figure.1 used for detecting the changes based on the fusion of SAR, PolSAR and hyper-spectral data. It was stated that features which extracted from SAR imagery are complementary for the information obtained from hyper-spectral data. Also it was found SAR features are essential for the classification of man-made objects covered or made by the same material [3].

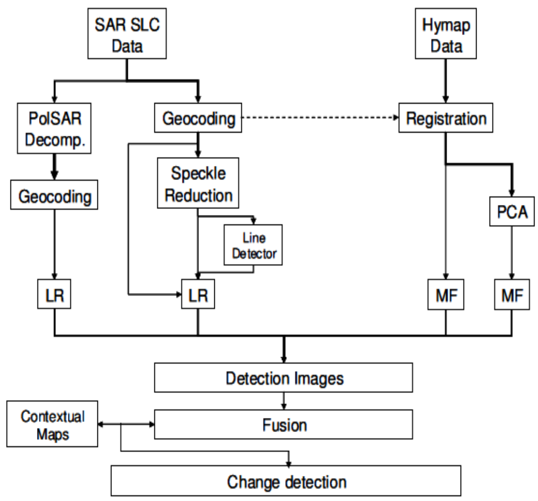

Fig. 1 Methodology of change detection method by data fusion of SAR and Hyper spectral.(PCA= Principal Component Analysis, MF= Matched Filter, LR= Logistic Regression) [16].

b) Post-Classification Change Detection

Post-classification change detection is carried out after classification into land cover or land use. In this method of change detection, the classification results of two imageries are compared. Because of that the accuracy of post-classification change detection is strongly depends on the accuracy of classification.

The results of post-classification change detection show low accuracies for classification of the radar images, comparing classified images results in many wrong alarms, i.e. there is no change. It is demonstrated that Post-classification of other SAR data shows low accuracies [12].

Synthetic aperture radar (SAR) and Interferometric Change-Detection (ICD) maps are highly sensitive to both macro and micro temporal changes in SAR surface reflectivity. This change is detected as decorrelations in the complex cross-correlation between two SAR complex images collected at different times. There are some studies carried out about using dual-antenna interferometric SAR (IFSAR) and dual-pass SAR data in ICD post-processing. A high-resolution (0.37-m) of dual-antenna airborne interferometric SAR (IFSAR) is used in a repeat-pass mode to collect temporal change detection pairs and it were able to identify over 70 percent of the ICD correlations less than 0.80 as non-temporal changes, or false changes. It is illustrated that the remaining temporal changes coincided well with controlled changes made in the scene. The post-processing results also showed that IFSAR coherence maps to be the most informative SAR data component for such false temporal change analysis [33].

A new Post-Classification approach has been presented to extract urban land-use/land-cover changes information from RADARSAT fine-beam SAR imagery. It is mentioned that the proposed three-step routine produced good classification result for SAR imagery. The compression of SAR images from 16-bit depth to 8-bit improved segmentation performance and made consequent processes less time-consuming, and the proposed approach results in very good classification accuracy about 87.9%, the post-classification change detection is able to identify the areas of significant change, for example, new low-density and high-density built up areas, major new roads, and golf courses, even though the change detection results contained large amount of noise due to classification errors of individual images [17].

c) Pre-Classification Change Detection

In this type of change detection, changes are detected before classification process. Generally there are four methods included under Pre-Classification Change Detection as following: 1) Constant False Alarm Rate (CFAR) detection, 2) Adaptive filtering, 3) Multi-channel segmentation, 4) Hybrid methods. The main disadvantage of pre-classification change detection is that the changes still have to be classified.

1) CFAR Detection

Moving kernel and comparing the pixel-value of the central pixel with its background pixels is the main feature of CFAR detection technique. CFAR detector is applied to the ratio image in the case of change detection. Ratio image is found by dividing the after image by the earlier image. Dividing images is preferable above differencing, in which the images are subtracted [28].

Background statistics are calculated in CFAR detection for every pixel, the decision whether the central pixel is (part of) a target or not is based on these statistics. The

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order-statistics CFAR detector is stronger in case more targets enter the kernel. When the changes are small compared to the resolution, i.e. when changes cover a few pixels, change detection by CFAR detection is generally realistic [12].

2) Adaptive Filtering

This method is founded on the adaptive filter which is applied to reduce speckle-noise in the ratio image which is attained by dividing the later image by the earlier image [11]. It is more effective to apply one filter to the ratio image then one on the original SAR images because filters give errors in guessing the underlying radar cross section. The filter is referred to preserves edges, lines and points targets.

Comparing to the CFAR detector the advantage of using the adaptive filter is that it can be used to detect distributed changes as well. This method can be more effective in case of small changes [10].

3) Multi-Channel Segmentation

This method of pre-classification change detection is based on multi-channel segmentation. The segmentation is the process of grouping adjacent pixels into multi-pixel similar objects that can be processed as one unit. The gain of this method is that, in case of not too much speckle noise, it decreases the remaining speckle [7].

As a result of this method the number of changed objects is less than the result of the adaptive filter, especially smaller objects are omitted. Nevertheless, the shape of the changed objects is better reproduced [12].

of combining methods. Multichannel segmentation method can be improved by: (1) adding an adaptive filter to reduce speckle-noise for segmentation of distributed changes and (2) adding a CFAR detector to detect smaller changes such as vehicles [13].

4) Incoherent and Coherent Change Detection

Comparing the backscatter of two images acquired using the same imaging parameters is one of the incoherent methods like ACD (Amplitude Change Detection), it is sensitive to significant changes, i.e. changes which intensely influence the backscatter of a target. The methods that exploit the coherence of two SAR images acquired at different dates using the similar imaging parameters is considered coherent methods like CCD (Coherence Change Detection). Whereas CCD (Coherence Change Detection) is more sensitive than ACD (Amplitude Change Detection), its use is limited by vegetation cover. The use of combination ACD (Amplitude Change Detection) and CCD (Coherence Change Detection) gives a more comprehensive photo of any changes detected [29].

Highlight environmental changes, stability and terrain morphology can be revealed by coherence images derived from synthetic aperture radar (SAR) data. The estimations of the changes in physical and electrical properties of the ground over the resolution of the sensor and at the scale of the radar wavelength are provided by the coherence of Scene. Over the period of time between two data acquisitions, minor changes in these characteristics are not essentially apparent in detected images, and normally controlled by the amplitude of radar backscatter [6].

The advantage that can be used is phase component of the complex backscatter value, with knowing of the satellite location the phase difference between two radar observations can be calculated, that means the phase measurement from a single radar observation is not by itself a useful parameter, coherence images have good ability as a tool for environmental monitoring and Detection of change [20].

The primary value of coherence imagery lies in its ability to efficiently record very subtle random changes on the land surface in an otherwise stable environment .A case study of land surface change detection and interpretation in an arid area of the Sahara desert in Algeria using ERS SAR multi-temporal coherence images is done before. It has been found that decoherence of individual dune features was due to micro-scale surface transport of mobile sand but not dune movement. This process was active over all the dune surfaces in the study area, thus allowing their effective identification over short time intervals. With 30m resolution coherence images in just over one year period, there was no adequate evidence of any traverse dune migration. Nevertheless, analysis of coherence imagery is an effective and efficient tool in the mapping of mobile sand and dune distributions over large desert areas. Also it is found that ephemeral lakes and temporary water bodies in desert areas can be effectively detected by coherence images and characterized as medium coherence features over a relatively short period (35 days in this study) and decoherence features over a long period (e.g. a year). It is illustrated that the human-induced disturbances such as seismic survey lines can be accurately identified as decoherence features on SAR coherence imagery. Coherence images with different time intervals show different seismic survey lines dug over these periods. The phenomena are not shown in the relevant SAR multi look amplitude images. Coherence imagery can therefore be used as a reconnaissance tool for monitoring the environmental impact of human activities [22].

Small -baseline multi-temporal sequence and long time-scale ERS coherence data are used for identifying the change and mapping it within South Wales. Small developments were not identified consistently while major building developments were identified in the study area using coherence method. Also, they predicted the future sensors such as Terra-SAR and Light SAR (they were not launched at the time of their research) would be capable of obtaining these changes. Moreover, they stated the approach which they used might be generalizable for ERS coherence data and they might be used on a time basis more than the ordinary remote sensing approaches for identifying urban changes [16].

A set of six ERS-1/2 InSAR images over the Shanghai city in China were used to detect the changes that have taken

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place in the urban land cover through utilizing a proposed approach. This approach is a combination of using two change measures: Backscattering Intensity Variation (BSIV), and Long-term Coherence Variation (LTCV), and they utilized on the two difference images an unsupervised 2D thresholding technique which was performed to obtain change map that contain two classes: change and no change. Consequently, they have found that applying both change measures (BSIV and LTCV) gives better result than using backscattering intensity variation individually as the result being shown in table (1) that the false alarms are 2012 by using BSIV alone, while it is reduced to 235 by using both measurements together [21].

Table. I The result of using BSIV alone and BSIV and LTCV together [21].

Change Measures	Overall Error	False Alarms	Missed Alarms
BSIV	2533	2012	521
BSIV & LTCV	713	235	478

5) TFFV Algorithm

SAR image change detection leads to realize the qualitative or quantitative analysis of an object. It is a technology that aims at SAR image feature to found data analysis method which used to recognize the change of state for an object or phenomena. Change detection method of multi-temporal SAR images from the spatial textural features has been studied, and a new change detection algorithm called TFFV algorithm is proposed. A novel multi-temporal SAR image change detection algorithm with the spatial texture feature of SAR images and some experiments are used to test the proposed algorithm. It has been showed that the proposed method is feasible using experimental results. Some real SAR image data performs comparative experiments between the gray difference method and the TFFV method. But the proposed method needs more reduction in speckle noise that influence SAR image [18].

6) Unsupervised Multi-scale Approach

Using a brief review of the Dual-Tree Complex Wavelet Transform (DT-CWT) and description of the proposed multi scale change detection algorithm, we can notice it is assumed that the changes between two images are only caused by the physical changes in the geographical area. It is proposed an automatic change detection approach by analyzing long-ratio image of two SAR images acquired from the same area of coverage at two different time instances. Some experimental results of the proposed approach are provided for both noise-free and noisy images if compared with the state of the art methods. The Experimental results obtained from SAR images acquired by the ERS1, and JERS satellites confirm the effectiveness of the proposed approach, and shows that the proposed algorithm's performance is almost invariant to the filter selection scheme .Furthermore; the proposed algorithm is fairly robust against speckle noise [9].

For implementing change detection by using multi-temporal SAR images, transform-domain analysis recently it is applied by the use of Discrete Wavelet Transform (DWT) in order to cure speckle noise problems [4]. They suggested multi-scale decomposition of DWT-based of the log-ratio image (i.e. can be gained by logarithm of the two co-registered observations pixel ratio of the same scene) that intended to achieve various scales of representing the image of the difference. A tradeoff between preserving of image information and reducing of the speckle noise characterize each one of these scales. Finally, based on an algorithm of an adaptive scale-driven fusion the result is obtained. On the other hand it was reported that a good result can be achieved by this method but it has a main two drawbacks: the shift-variance of DWT property and an appropriate threshold selection. In the same time there was trails to solve these disadvantages by proposing a method that based on a DT-CWT multi-scale decomposition of the long-ratio images that designed to achieve various scale of representing the change signal. It was confirmed that efficiency of the proposed method by getting experimental result extracted from multi-temporal SAR images that are captured by JERS, and ERS-1 satellites [8].

7) Image Differencing and Speckle Decorrelation

Two methods were used for change detection using: the difference and decorrelation of speckle, it has been found that the second method (temporal decorrelation of speckle) shows best result by using one-look SAR complex amplitude images. However, this method can be used with multilook data which provide a small number of looks. On the other hand, the differencing method (Rationing the intensities) gives best result with multi-look data. Also, an important investigation he found is that the area identified as changed area in the two methods under the same environment is not always matching. For example, even though there are identifiable changes in the signal backscatter detected, speckle might be still greatly correlated. In addition, ratio method (differencing) gives the information of the quantity of the changes that are observed while decorrelation method gives help in detecting changes in the scatterers position. For example, in case of knowing there is no change in the position of scatterers, it will be obvious that the change in the backscattering signal is not due to the objects structure but is a result of a change in the electrical properties. Also it has been mentioned if the change happens in scattering properties and position of scatterers, the detection will be more difficult, and due to that these two methods are considered as complimentary and should be used together in monitoring studies [28].

8) Combine Feature-Based And Area Based Extraction

Another approach of obtaining better result of change detection has been proposed, this method is a combination between feature-based techniques and area-based technique.

Basically the methodology can be described by several steps shown in Figure. 2, it starts with applying feature extraction algorithm in both (for time 1 and time 2) images and also area-based algorithms, then the result of these procedures are fused by using suboptimal approach as the logical operator (AND) used that considering only the areas have been changed in both algorithms. Finally, the change map is produced. They stated that although the method is simple, it is effective in overcoming some of the common SAR multitemporal change detection problems such as misregistration resulting from reprojection problems or variations in the viewing geometry [15].

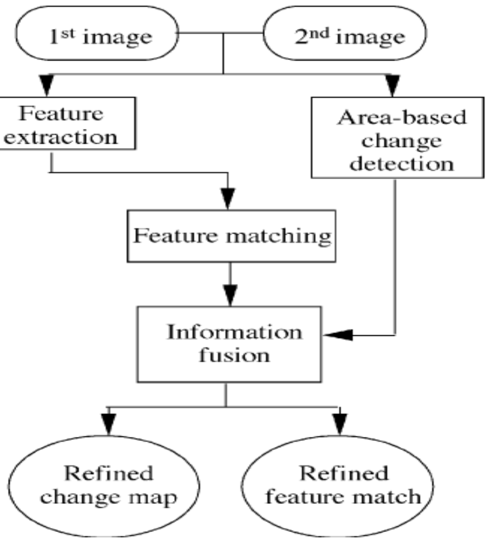

Fig. 2 Conceptual framework of a proposed approach combines Feature-based and area based extraction [15].

3.9) Curvelet-Based Approach

An approach of SAR images enhancement and change detection that is called Curvelet-based approach was presented. This approach is considered as a flexible approach because of the ability of the user to select accurately which types of structures are needed to be identified. Also it can be readily involved in a processing chain (e.g. fast damage mapping) because it can be designed to work as fully automatic routine. Specifically when the TerraSAR-X Enhanced Ellipsoid data are used in this approach, co-registration is not needed as their geolocation is adequate and used a construction site as an experimental result in order to approve their method (curvelet-based approach). Through examining the result of this site, they found that it is not an easy to discriminate between the places of the detected changes that are man-made and changes that are due to the environment conditions. Also they stated that in order to interpret the detected changes correctly it is very important to have collateral information such as land cover classification. In disaster applications particularly it is crucial for the analyst to identify whether the changes detected between the two images are on cropland or in settlement [30].

IV. DISCUSSION

Synthetic aperture radar (SAR) is considered one of suitable tools used for change detection; studies that have been reviewed showed that SAR data is very good for those kinds of applications, especially in conditions that optical data cannot give clear information. However, prior starting change detection study, it should be selected the suitable field which we can implement this technique, and understanding the nature of the target surface is another important point because properties of target have great effect on backscatter, like moisture content and dielectric constant...etc., which affect ability of detecting changes. The accuracy of post-classification change detection is low and it may not considered reliable, method in case of using SAR data, where it is strongly depends on classification accuracy for example results may contained large amount of noise due to classification errors of individual images. The combination of pre-classification methods that mentioned previously is suitable and appropriate techniques for detecting distributed and small changes, even for noisy SAR images. Methods combination which can be proper for using in detecting changes is dependent on the type of application.

Incoherent change detection is sensitive and it may not suitable enough for detecting changes especially in case of subtle changes, in contrast change detection using coherence images has great potential for environmental monitoring, and the primary value of coherence imagery lies in its ability to efficiently record very subtle random changes on the land surface, for example detecting changes in snow cover over specified time frames and detect and interpret changes in a desert environment.

Nevertheless the incoherent Amplitude change detection is less sensitive to subtle changes, but it is still gives valued information. The combined use of incoherent and coherent techniques gives a more complete picture of any changes. Ancillary information of studying area of interest (e.g. environmental conditions) will help in the analysis of the result, information and spatial analysis is important for the identification of changes.

Radar has been successfully used in change detection in many fields (Urban, LULC, and Coastal monitoring and so on) by using different methodologies and approaches. However, important considerations must be taken into account in any change detection study by SAR: Speckle reduction and Image registration (Geometric correction).

V. Conclusion

Taking everything into account, the use of SAR data in monitoring and detecting changes is beneficial and advantageous; especially if SAR data integrated with optical data it becomes more powerful. Understanding the environment (target) that SAR will be used in, is very helpful to detect and interpret the results. Coherent change detection is more reliable than incoherent change detection, which has the ability to record very subtle random changes. The combination of methods and considering target conditions, overcomes the deficiencies like noise that affect the use of SAR data in change detection. Important considerations must be taken into consideration in any change detection study by SAR: Speckle reduction and Image registration (Geometric correction). To sum up, methods used in change detection using SAR data have been revisited, some of them adopt combination technique; that gives an indication that we can combine other methods for monitoring changes based on study area conditions, also we can develop new algorithms based on which combination would be used.

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