COMPARATIVE ANALYSIS ON AMPLITUDE AND COHERENCE BASED CHANGE DETECTION USING ALOS PALSAR IMAGERY

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ABSTRACT:

As the Microwave is capable of penetrating almost all atmospheric condition with around the clock operation, multidimensional Synthetic Aperture Radar (SAR) imagery has raised as a powerful tool to extract physical information about the Earth surface. With the use of time series images and estimations such as Coherence along with amplitude information can reveal changes more effectively using SAR data. Coherence is a measure of phase correlation, defined as the correlation coefficient. The amplitude of the single look complex (SLC) data is what is generally known as the SAR image. Similarly, the amplitude of the coherence will be referred to as coherence image. SAR images include information about the intensity and phase of the backscattered signal from a target. These two measurements maybe used in different ways, such as detection of deformation based on phase or land cover classification and change detection by utilizing the intensity.

For this study two disaster scenarios, first a flood effect in the Gall district of Sri Lanka and secondly a tsunami and earthquake effect in Tohoku region, Japan is considered for the change detection. Single polarization (HH), of Advanced Land Observation Satellite (ALOS) phased array type L-band SAR (PALSAR) imagery was used in this study. Level 1.1 SLC image pair was co-registered and stacked together with half a pixel precision then the coherence estimation process was completed. Then to obtain multi temporal coherence map the composite image was taken with pre disaster as red image post disaster as green and coherence as blue Coherence value less than 0.4 was taken to distinguish the change. Then coherence image and the multi temporal coherence map were analyzed to detect changes. ACD (Amplitude Change Detection) which is the incoherent method, compares the backscatter of two images acquired using the same imaging parameters. It is sensitive to significant changes that strongly influence the backscatter of an area where the amplitude change less than -3 taken as the change. CCD (Coherence Change Detection) exploits the coherence of two SAR images acquired at different times using the same imaging parameters. According to the derived results and the visual analyze using Landsat 8 NDVI image and Google Earth historical images as reference. Finally it reveals that CCD can be used to detect subtle changes occurring between the two observation dates that would remain undetected by incoherent change detection techniques.

Key Words: Amplitude, Change detection, SAR, Disaster, Intensity

Introduction

In recent years, planet Earth has experienced several natural disasters that had huge environment impact with tremendous effects on earth living (Zhou et al., 2000). These remarkable events highly disturbs the balance of the human life by destroying their settlement economy and even taking the lives of thousands of people every year. It is essential to monitor and assess the damage of the natural disaster and provide valid near real-time information about development of natural disaster, so that rescue work can be conducted in time to keep the loss as less as possible. Many methods have been used to monitor these abrupt events, among them remote sensing plays a major role. Many Remote sensing techniques have been used to measure and monitor these natural disasters. Synthetic Aperture Radar (SAR) is generally known to possess a number of advantages over visible/infrared remote sensing. These include its all-weather, day and night image acquisition capability unhindered by cloud cover. Change detection is the process of identifying differences in the state of damage area mapping due to the natural hazards and the natural disasters have been limited in the optical and infrared remote sensing whereas the microwave remote sensing has the capability of overcome the limitation and observe the ground surface without any affect from the atmosphere. To extract the damage area due to various different hazards and disasters different characteristics of the SAR images can be used. Possibility of using primary and secondary information from SAR images for damage assessment after a hazard or a disaster will be the focus of this paper.

Study Area and Data set

Two study areas have been considered. Area of Galle ,Sri Lanka is considered (figure 1 (a)) for flood identification and flood extent mapping, while for the back scatter and coherence analysis the Tsunami effected area of Japan in 2011 is considered(figure 1 (b)). The study area 1 subjected to flood during the inter monsoon period. The study area 2 is effected by the tsunami as a result of the earth quake off the Pacific coast Tohoku with a magnitude of 9.0 M.

ALOS PALSAR level 1.5 and 1.1 temporal data sets have been used for this analysis the land cover of the study areas have been severely changes due to the insitu disaster occurrence.

Study area 1, Figure 1(a): Land cover changes due to the monsoon rainy season in the region of Galle, Sri Lanaka in the month of July 2008. Pre disaster image on 3rd of March 2008, Post disaster image on the 19th of July 2008

Study area 2, Figure 1(b): Land cover changes due to

Figure 1 (a) Study area 1 (b) Study area 2

the Tsunami and Earth quake disaster occurred in Fukushima, Japan in 201l, Pre disaster image on 20th of November 2010 and Post Disaster image on 7th of April 2011

Methodology

The general flow of the methodology experimented during the process is detailed below in Figure 2 and Figure 3.

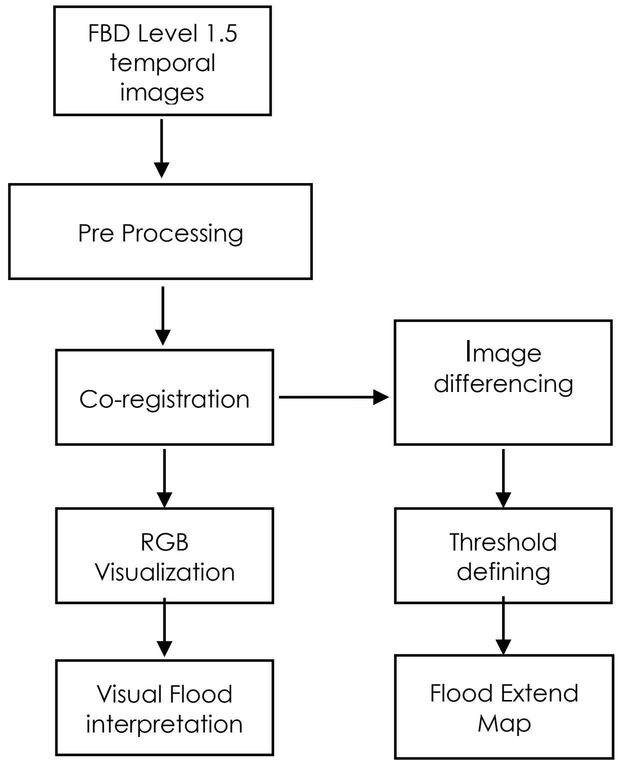

Figure 2: Flow chart for extraction of flood extent

Level 1.5 and level 1.1 SLC temporal image pairs were subjected to the pre-processing which includes radiometric calibration, multilooking, geocoding, speckle filtering according to the processing level of the SAR images. These co-registered temporal images stacked together for the RGB visualization which was then used to identify the land cover changes in the both the study areas and to use sample plots to define threshold regions for flood in the study area 1. Rest of the methodology are vary as mentioned in the figure 2 and 3.

Damage area extraction by coherent and incoherent methods

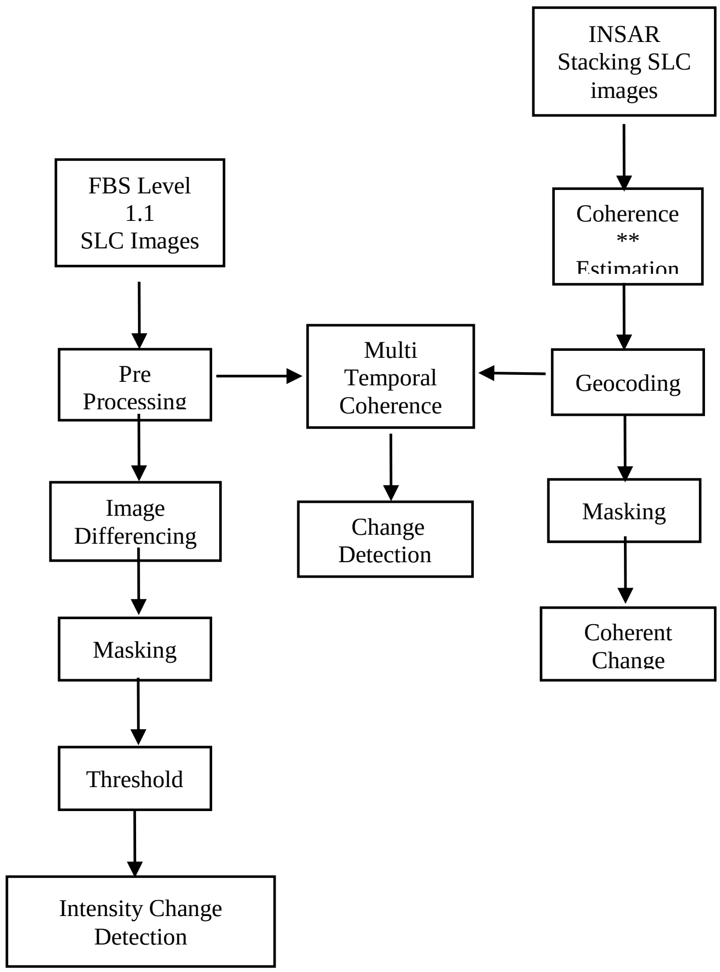

Figure 3: Flow chart for detecting damage in the study area 2

To overcome the problem of over detection in the study area 2 of change due to the vegetation areas, optical satellite images of Landsat 8 optical image in the same season were used to calculate the NDVI value and use the values to mask out the vegetated area.

Backscatter and coherence analysis

Study area1

Figure 4 is the combination of, Red: Post disaster image - 3rd March 2008 Green: pre disaster image-19th July 2008 Blue: Pre disaster image -19th July 2008. The RGB visualization where flood depicts in cyan, Permanent water body in black, no changes in white.

Sample plots of the areas highlighted as flood in RGB composite images was taken to analyses the back scatter difference of pre and post images. More than 95% of the pixels represent area less -3dB and it was taken as the threshold for flood area extent. Many previous literature have provided threshold region for flood to be less than -3dB to -5dB. After applying the threshold the flooded area can be extracted as follow (figure 5).Blue depicts the area of flood while yellow depicts not effected by flood.

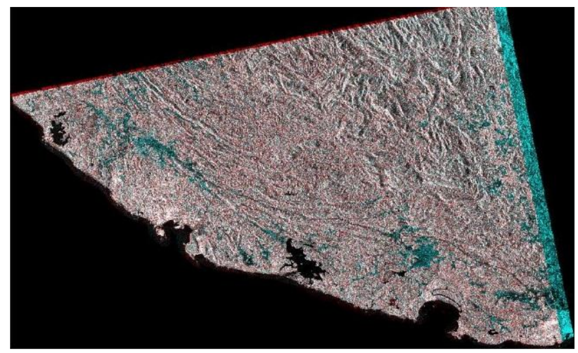

Figure 4: RGB visualization for the study area 1

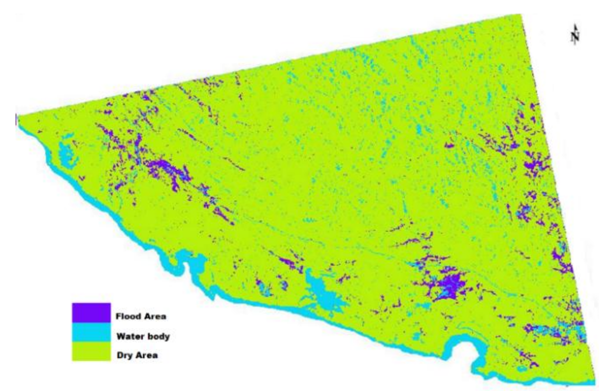

Figure 5: Possible flood area

Study Area 2

Figure 6: Damage area due to the disaster on 11th March 2010

Above figures 6 depicts the damaged area due to the disaster which occurred on the 11th of March 2011, Image acquisition for the pre disaster is on 20th November 2010 and post disaster is on 7th of April 2011. The acquisition of the SAR images is about one month after the disaster so that mostly the water which had come to the land due to the tsunami will not exist in the land but the damages occurred in the region will remain. Therefore the study area 2 had different characteristics compared to the study area 1 where the backscatter value is low due to the water (floods). Back scattering characteristics will be much more complex in the study area 2 mainly due to the intense urban land cover and the form of the disaster.

To detrmine the thresholds for negative and positive changes small subsets of the selected areas were taken by considering the homogeneous area. Google Earth historical images were taken as the reference while choosing the homogenous areas.

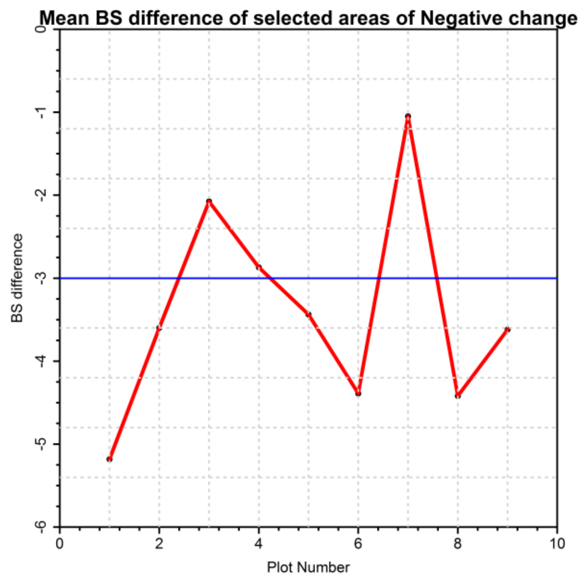

Figure 7: Mean difference of backscatter in selected areas

Figure 7 shows the backscatter difference range for homogenous areas considering this negative change. Threshold value for the possible negative changes of the areas due to the disaster can be taken as -3. Similarly for the threshold value for the positive change due to the disaster can be taken as +3 with respect to the Google earth images and the mean back scatter different plots.

To avoid the over detection of change due to the vegetation areas vegetation masking was done. With the use of NDVI value in Landsat 8 optical image and building mask with a suitable threshold the vegetation mask was created. Then this mask was applied to the back scatter difference image. By this way most of the changes due to the vegetation was removed. Figure 8 depicts negative change in red and the positive change in blue. With reference of the Google historical image as in figure 6. These red and the blue areas are the potential damage areas.

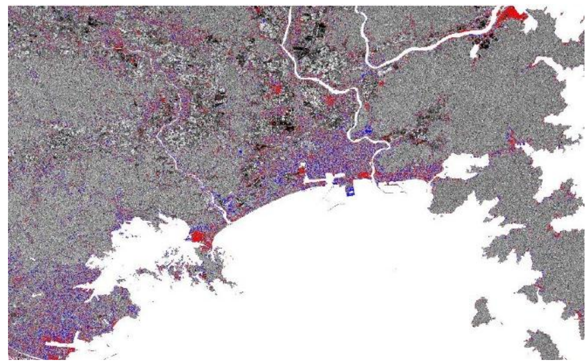

Figure 8: Possible Damage area due to the disaster background -SAR image of the back scatter difference image.

Coherence analysis study area 2

The coherence of the temporal SAR image pair is used to analyse and extract the damage area with the coherence image which may contain valuable information about the land cover to identify the possible damage area. Coherence will measure the correlation between the backscatter and the phase of the pre and post disaster image pair.

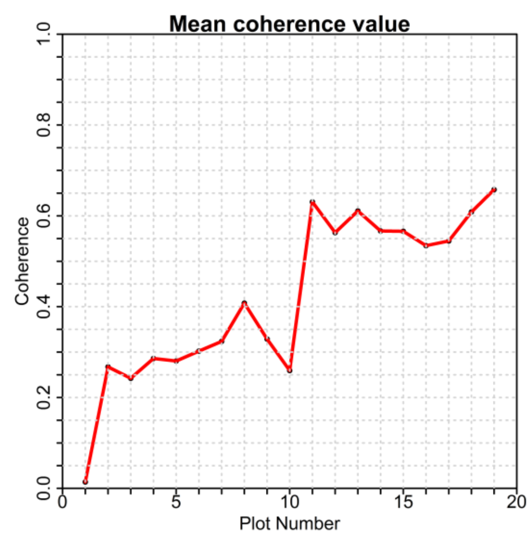

Figure 9: Mean coherence value of the selected plots

Figure 9 depicts the mean coherence of the random plots of damage and no damage area. First 10 plots represent damaged area while the rest is no damage area. The graphical plot clearly shows the higher deviation after the sample area number 10 where a rise in the coherence value is evident. Due to the factors such as base line decorrelation resulted in decorrelation apart from the temporal change. We can come to a conclusion that the area with less coherence that is less than a value of 0.4 is changed area which is taken in to consideration when generating the possible damage map.

Figure 10 shows the area of change after masking the vegetation. Green area depicts the area of change and area of no change with coherence values higher than 0.4 depicts in yellow colour.

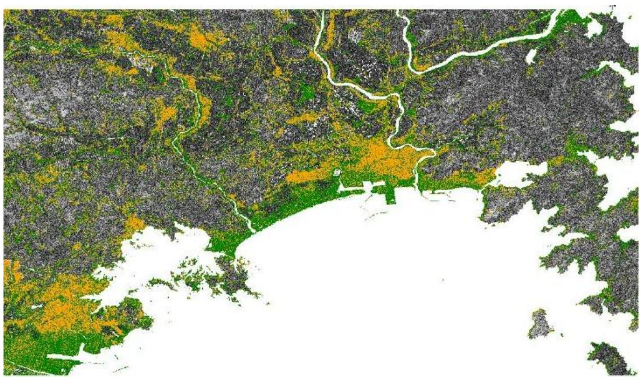

Figure 10: Coherence value over 0.4 in yellow and below in green

Confusion matrix was used to show the accuracy of the classified image by comparing the classification result. Overall accuracy of 52.331% present in the classification based on the threshold in the backscatter different image.

Overall accuracy of 73.452% present in the classification based on the threshold in the coherence image.

Damage area depiction is more clear in coherence image than the backscatter difference image due to its capability of identify the small changes than the BS difference image.

Multi coherence mapping

RGB composite image was created by assigning calibrated pre disaster intensity image for red, calibrated post disaster intensity image for green and coherence image for blue. Resultant image depicts red and green as the change area due to the higher backscatter value in pre disaster image than post disaster image and wise versa respectively for the low coherence value. Yellow depicts no change in back scatter value of post disaster and pre disaster images but low coherence value. This is due to the change which has occurred due to the movement of the objects on the ground but the backscatter characteristics including the roughness have been similar. White and the blue values have no change in the ground no movement and no backscatter change.

Figure 11: Multi coherence mapping, Red: pre disaster, Green: Post disaster, Blue: coherence

Various objects observed in the acquired pre and post SAR images and the coherence in the damage area as the red and green channels contain the two intensity images, bright red and green represent the presence of an object in either of the days and a lower backscattering value in the other day of those pixels. Since these objects are not fixed in the same pixel, a low coherence and low blue content is contributing to the colouring.

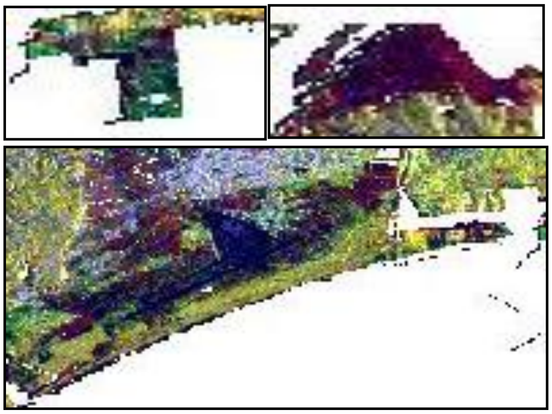

Figure 12: Sample area of composite SAR image

In the top images of figure 12, red and green spots appear, resulting from level of backscatter in this incident change of backscatter due to the effect of the disaster. From manmade structures as can be seen around the centre of the bottom image in figure 12 Buildings remain fixed in between recording dates and often have structures that result in high coherence in pixels coinciding with high intensities. These regions are recognized as areas of white towards blue according to intensity and coherence levels which indicates there is no change in between the acquisition of the image. Yellow colour formed by combining red and green with absence of blue. These parts of the image depicts no backscatter difference but low coherence which results most of vegetation in yellow and damage areas as in the lower part of the bottom image in figure 12, and this yellow object gives a very good silhouette match with the concept of similar backscatter values but low coherence resulting possible damage area in coastal area which are not detectable in intensity (backscatter).

Conclusion

Rapid flood area extraction using multi temporal ALOS PALSAR level 1.5 SAR data is a simple process due to most of its pre-processing such as range and multi look azimuth compression as well the geo coding process have already been completed. Unlike other natural phenomena the dielectric property and roughness of water reduce the back scatter where the back ground of the water areas has higher back scatter which enable to identify the water areas. This concept is generally used to extract water area. Image differencing process proved useful in finding change areas in the temporal period of the image acquisition meanwhile after finding the thresholds the negative change less than -3 dB was identified as floods. Identified flooded areas are mostly the paddy areas to compute accuracy of the output field inspection has to be done

Detecting flood extent with the use of SAR images is a rapid process with the capabilities of the radar to penetrate the atmosphere in almost any condition which makes the SAR more suitable for rapid flood mapping.

In the case of flood the backscatter reduces significantly but in disaster or hazard other than the influence of water has no significant reduction of backscatter the backscatter varies from positive change to negative change as explained in the previous chapter.

Although both positive and negative change can be extracted out from the backscatter difference image damage area due to the disaster cannot be extracted. As discussed in the previous chapter to extract the damage area, the land cover changes due to many other phenomena has to be omitted. So finally the vegetation masked change image has a high possibility of highlighting damage area in the coastal region.

The study led to the conclusion that the backscatter difference due to the disaster changes differently in different land cover areas to extract the area of damage will become very tedious process but when a disaster occurs with the effect of water this changes extracting flood area will be less complicated process.

In the case of coherence change detection changed area are more clearly shown in the coherence because coherence is very sensitive even for small movements. With the analysis and accuracy of the classes experimented we could come to a conclusion that coherence is much more sensitive to the change than the backscatter but to get a more reliable output only coherence image cannot be used alone. One solution is to use three different temporal images and use the differential coherence technique to extract the damage area or build up. A novel method is to combine both coherence and backscatter for more reliable and effective output.

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