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Sar Image Registration using Minimum Eigen Value Algorithm

Abdelhameed Said Eltanany
Radar Department
Military Technical College (MTC)
Cairo, Egypt

Ahmed Saleh Amein
Radar Department
Military Technical College (MTC)
Cairo, Egypt

***Abstract*—Procedures for Digital Elevation Model (DEM) generation involve applied software and it usually includes some basic steps. These steps are performed in three major stages including data search; data processing; and product validation. Data processing stage comprises of five steps; Co-registration is one of the most important steps for DEM generation. Before DEM generation; a precise co-registration step is required. Pixel-to-pixel match between common features in SAR image pair is very important. As precise of co-registration is more accurately; the coherence of the Interferogram increases. Critical steps for image registration are collection of feature points and estimating a spatial transformation besides matching of feature and slave image resampling to the master image geometry. In this paper, employing automatic Minimum Eigen Values algorithm for SAR image registration is investigated.**

Keywords*—Digital Elevation model (DEM), Interferometric SAR (InSAR), Coregistration, Minimum Eigen Value algorithm, and Coherence Image

I. INTRODUCTION

Use of space borne SAR as interferometers became popular only recently. Interferometric Synthetic Aperture Radar is a radar technique used in geodesy and remote sensing. The technique can potentially measure centimeter scale changes in deformation over time spans of days to years. Elevation data is a fundamental layer for any Geospatial Information System (GIS) and critical for many applications. Conventional SAR image applications use magnitude only, so the phase component is discarded. SAR Data Collection Scheme is as shown in figure 1 [1]. SAR data processing to form an interferogram includes six steps; the most important one is co-registration of the two complex SLC SAR images to an accuracy of less than 0.1 pixel. SAR image problems can occur due to platform, sensor, and processing problems.

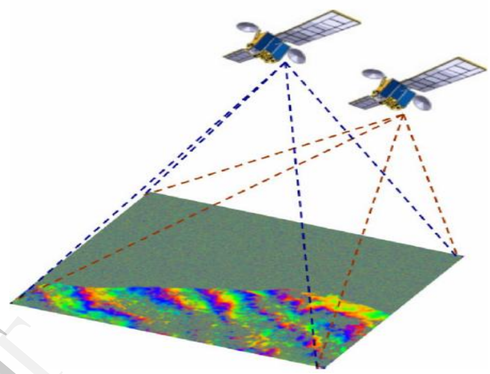

Fig.1. Formation of an Interferogram

II. IMAGE CO-REGISTRATION

Image registration is defined as a method to find the offset or misalignment between two or more image for a certain place. There are two main Approaches for Co-registration, Area based matching method (ABM) and Feature based matching method (FBM). Image registration in automatic mode requires sequential and iterative execution of different phases for generating quality registered data products. The main phases / steps in image registration are Feature Detection, Feature Matching, Model Estimate, Image Resampling and Transformation. The most commonly used method for co-registration is to compute the complex cross correlation function between the two SAR images [2].

Given two SAR images with corresponding complex pixels P_1 and P_2, where$P_1 = R_1 + jI_1$ and $P_2 = R_2 + jI_2$. The coherence of these two SAR images is given by (1) [3],

$$\gamma = \frac{E[p_1 p_2^*]}{\sqrt{E[p_1 p_1^*]E[p_2 p_2^*]}} \quad (1)$$

where (γ) is a complex number, so $|\gamma|$ is usually used. The estimation of coherence, $|\gamma|$, can be written as (2) [3].

$$|\gamma| = \frac{|E[p_1 p_2^*]|}{\sqrt{E[p_1 p_1^*]E[p_2 p_2^*]}} = \frac{|E[p_1 p_2^*]|}{\sqrt{E[|p_1|^2]E[|p_2|^2]}} \quad (2)$$

The value of $|\gamma|$ is always between 0 and 1. Coherence can be improved by minimizing the noise, by using azimuth pre-filtering, and by correcting local slope. For SAR single look complex images, E [] is the spatial averaging over an M x N window. Thus the last equation can be restated as a sample statistic as (3) [3]

$$|\gamma| = \frac{|\sum_{M\times N}(R_1 + jI_1)(R_2 - jI_2)|}{\sqrt{\sum_{M\times N}(R_1^2 + I_1^2)\sum_{M\times N}(R_2^2 + I_2^2)}} \qquad (3)$$

III. METHODOLOGY AND ALGORITHM

As mentioned before; the SAR co-registration procedure consists of coarse co-registration and fine co-registration. Coarse co-registration, is a process to match two SAR images at up to one or two pixel accuracy including searching for coarse image offsets and shifting the slave image. Fine co-registration, is a process to find Sub-pixel tie points on two SAR images, for sub-pixel accuracy including searching for sub-pixel tie points and fitting transformation equations onto these tie points then resampling one of these two SAR images based on the transformation equations [1,3]. Both co-registration performance and final InSAR DEM accuracy are usually evaluated by coherence Image. SAR images must be assigned as a master and a slave images. During whole co-registration process, only the slave image will be treated by shifting in coarse co-registration and resampling in fine co-registration. Figure 2 shows a typical work flow for InSAR image co-registration.

A. Coarse Co-registration

Coarse co-registration is the step where two SAR images are co-registered at up to one or two pixels accuracy. The Coarse Co-registration process is based on Fast Fourier Transform (FFT) Algorithm. Cross correlation is the most commonly used approach for checking the accuracy of coarse Co-registration. The slave SAR image will be shifted by the offset value in both range direction and azimuth direction [1,3].

B. Fine Co-registration

It must be noted that the cross correlation is not only for coarse co-registration, but also a common criterion for fine co-registration [1,3]. Fine co-registration will be investigated using Minimum Eigen Value Algorithm. After coarse co-registration, the remaining offsets between two SAR images mainly exist in range direction. That is because the parallel baseline component ($B_{\parallel}$) between two platforms varies almost linearly from near range to far range. Very small offsets in the azimuth direction can be detected after coarse co-registration, thus a number of researchers apply only the following four parameter transformation equations (4) onto sub-pixel tie points [1,2,3].

$$\begin{aligned} X &= x + ax + c \\ Y &= y + dy + f \end{aligned} \qquad (4)$$

where (X, Y) are the coordinates of tie points in the slave image, and (x, y) are the coordinates of corresponding points in master image. Most offsets are only proportional to the range pixel location, so that there is no first order coefficient for y. These equations are also employed in commercial software

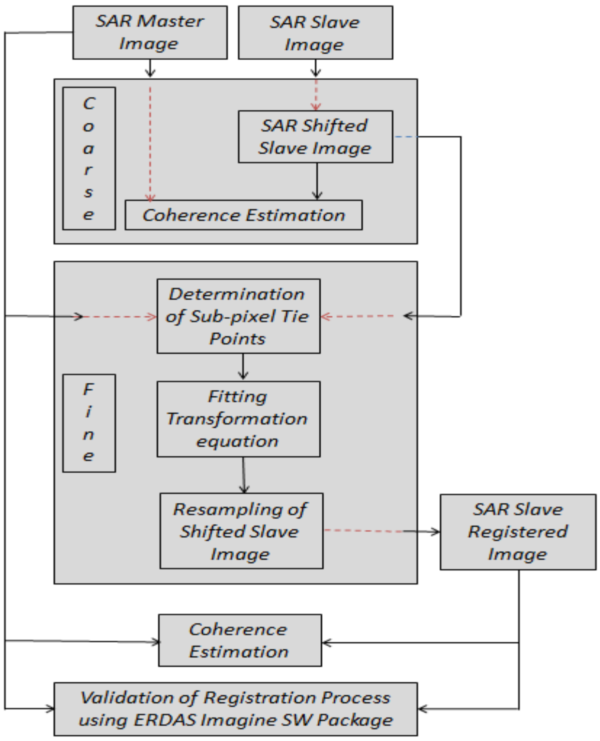

Fig.2. Typical work flow for SAR image coregistration

packages like Leica ERDAS IMAGINE and ASF SAR tools. If the distortion along the (y) direction increases, one can use the first order transformation equations, 6-parameter equations (5) [1,3]

$$\begin{aligned} X &= x + ax + by + c \\ Y &= y + dx + ey + f \end{aligned} \quad \text{or} \quad \begin{aligned} X &= ax + by + c \\ Y &= dx + ey + f \end{aligned} \qquad (5)$$

The Corner Detection finds corners in an image using minimum eigen value (by Shi & Tomasi) method. The block finds the corners in the image based on the pixels that have the largest corner metric values. For more accurate results, we use Minimum Eigen value Method. This method is more computationally expensive because it directly calculates the Eigen values of the sum of the squared difference matrix M. The sum of the squared difference matrix M is defined as (6) [4]

$$M = \begin{bmatrix} A & C \\ C & B \end{bmatrix} \qquad (6)$$

The previous equation is based on the following values (7) [4]

$$\begin{aligned} A &= (I_x)^2 \otimes w \\ B &= (I_y)^2 \otimes w \\ C &= (I_x I_y)^2 \otimes w \end{aligned} \qquad (7)$$

where I_x and I_y are the gradients of the input image (I) in x and y directions. The symbol () denotes a convolution operation. Use the Coefficients for separable smoothing filter parameter to define a vector of filter coefficients. The block multiplies this vector of coefficients by its transpose to create a matrix of filter coefficients w. The block calculates the smaller eigen value of the sum of the squared difference matrix. This minimum eigen value corresponds to the corner metric matrix. The corner metric values computed by Minimum Eigen value method is always non negative [4].

After transformation equations are set up, one can resample the slave image according to the sub-pixel transformation [1,3]. Interpolators commonly used for resampling are nearest neighbor (NN); bilinear interpolation (BI); and cubic convolution (CC). Each degree error of the phase data is directly related to the InSAR DEM error.

C. Co-registration Evaluation

As mentioned, the coherence image is used to evaluate the performance of SAR image co-registration. In this paper, the average of the whole coherence image is used as criteria, to evaluate the co-registration results using the above co-registration functions and algorithms. The final InSAR DEM is certainly another good criterion for estimating image co-registration. The better co-registration performance should result in a higher InSAR DEM accuracy, i.e. a lower InSAR DEM error. The Root Mean Square Error (RMSE) between the InSAR DEM and the reference DEM is computed to evaluate InSAR DEM accuracy, in order to evaluate SAR image co-registration[1,2,3]. The better co-registration performance should result in a higher InSAR DEM accuracy.

IV. DATA AND TOOLS

The data used for search contains 2 pairs of SAR Images. The first pair of images is X-band image for the volcano Kilauea which was taken on October 4, 1994, by the Space borne Imaging Radar-C/X-band Synthetic Aperture Radar. The Second one can be obtained from ERDAS IMAGINE V.13 where there are two SAR images were captured for Death Valley area. Matlab is the main tool that was employed for SAR image co-registration and coherence computation. Also, ERDAS IMAGINE V.13 was used to check the Co-registration results.

V. EXPERIMENTS AND RESULTS

The Proposed algorithm is based on combining both area based methods and feature based methods. The cross correlation function is used to detect the coarse offset between the master image and the slave image. The slave image is mapped to the master image using this offset. In this case, Fine co-registration will be investigated using Minimum Eigen Value algorithm. The transformation model "affine" is estimated using Random Sample Consensus (RANSAC) algorithm and the algorithm is evaluated by using the coherence map. Nearest neighbor resampling algorithm was used with spline interpolator. The proposed algorithm using Minimum Eigen Value leads to good results. With respect to Death Valley InSAR Images, Average Coherence before Registration equals 0.3419 and Average Coherence after Registration equals 0.7993. With respect to volcano Kilauea, Hawaii InSAR Images, Average Coherence before Registration equals 0.4891 and Average Coherence after Registration equals 0.5645. Figure 3 and Figure 4 show results using matlab and visualization using Erdas Imagine V.13, for Death Vally and volcano Kilauea Hawaii InSAR Images respectively where a) Cross Correlation peak before and after Registration Process, b) Swipe visualization between Master and Slave images, and c) Swipe visualization between Master and Slave registered images.

VI. CONCLUSION

The entire purpose of the co-registration is to align the samples for phase differencing. Definition of registration is based on geometrical transformations. Computing cross correlation with magnitude only is adequate for both coarse and fine co-registration of SAR data. This study indicates that a higher coherence area leads to a better co-registration location, and the proposed algorithms may lead to good results with areas have the same featured as discussed.

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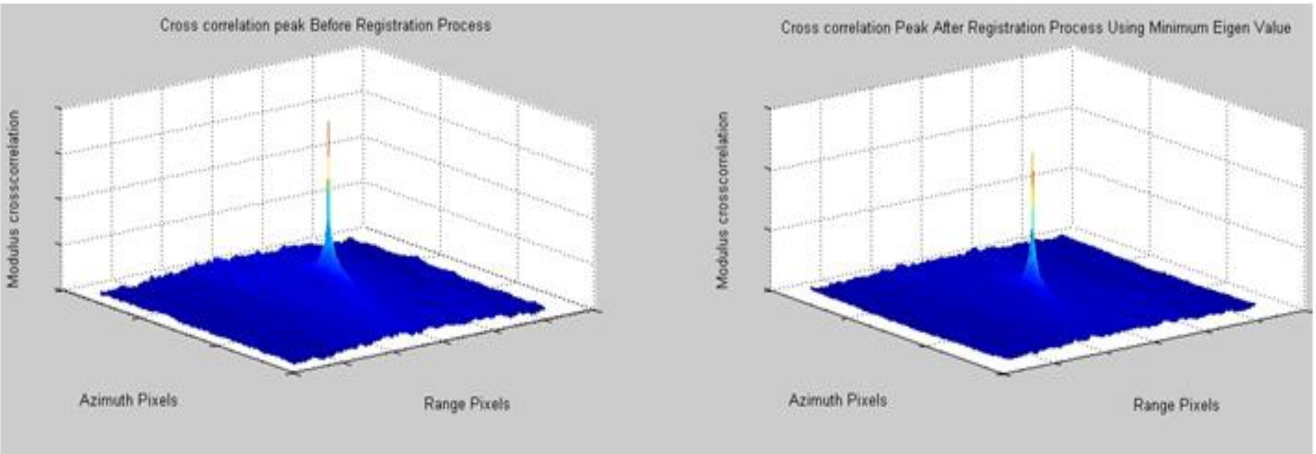
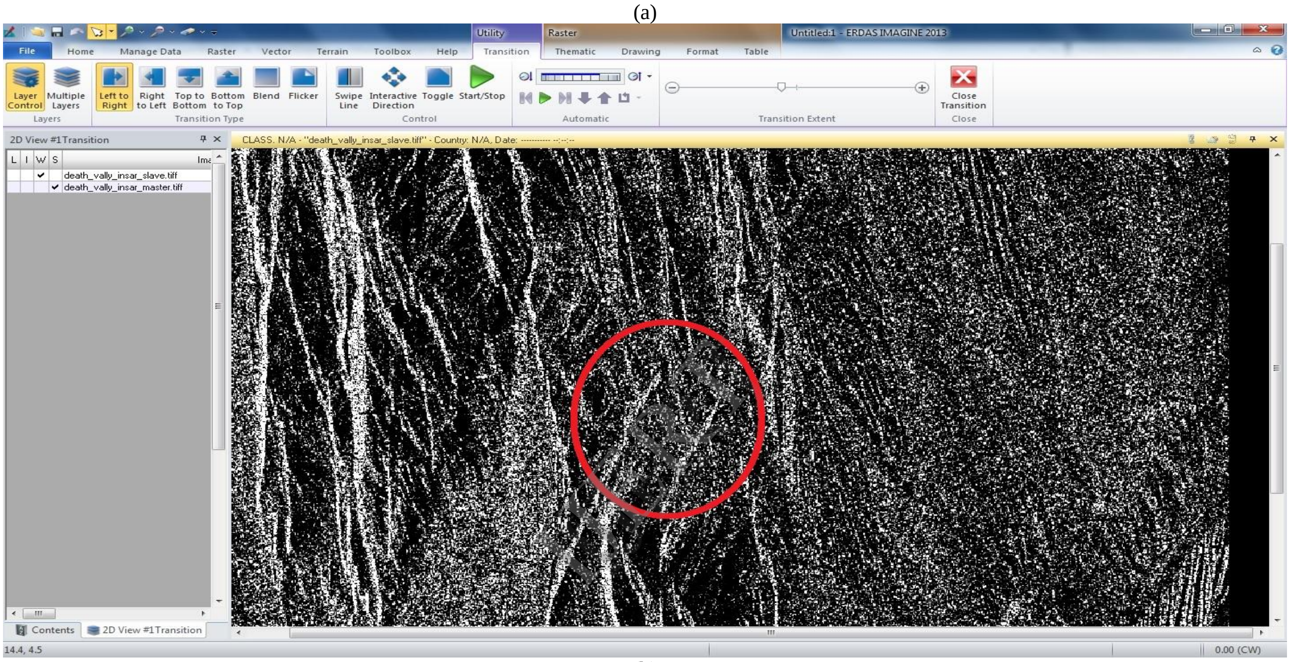
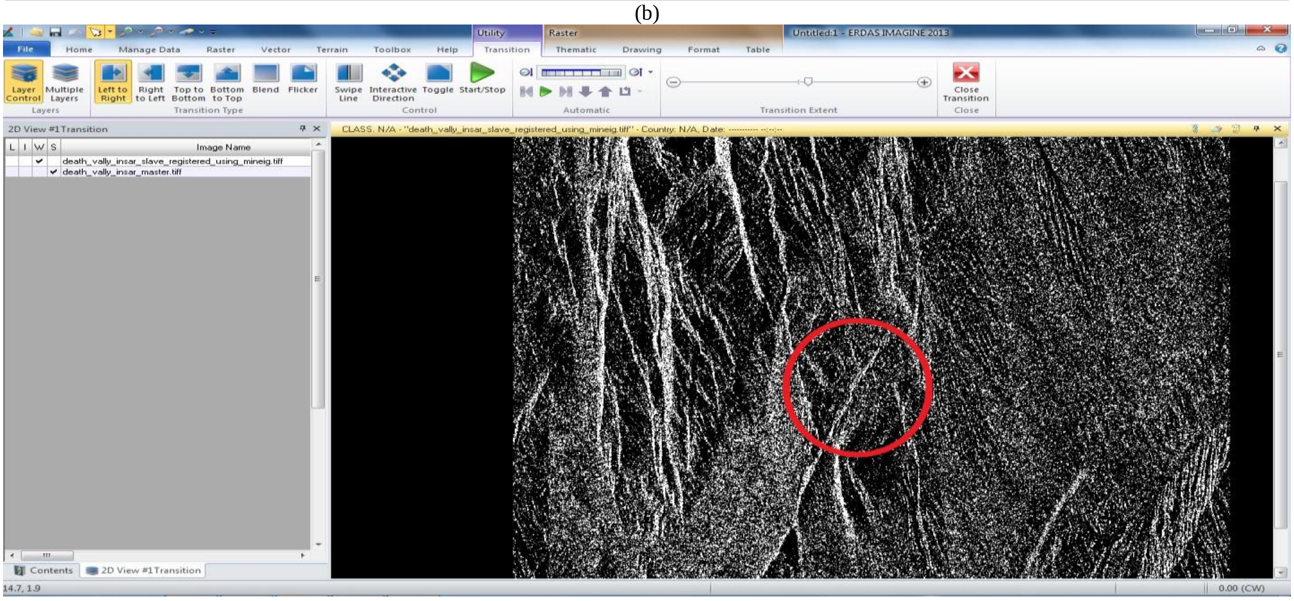


(a)

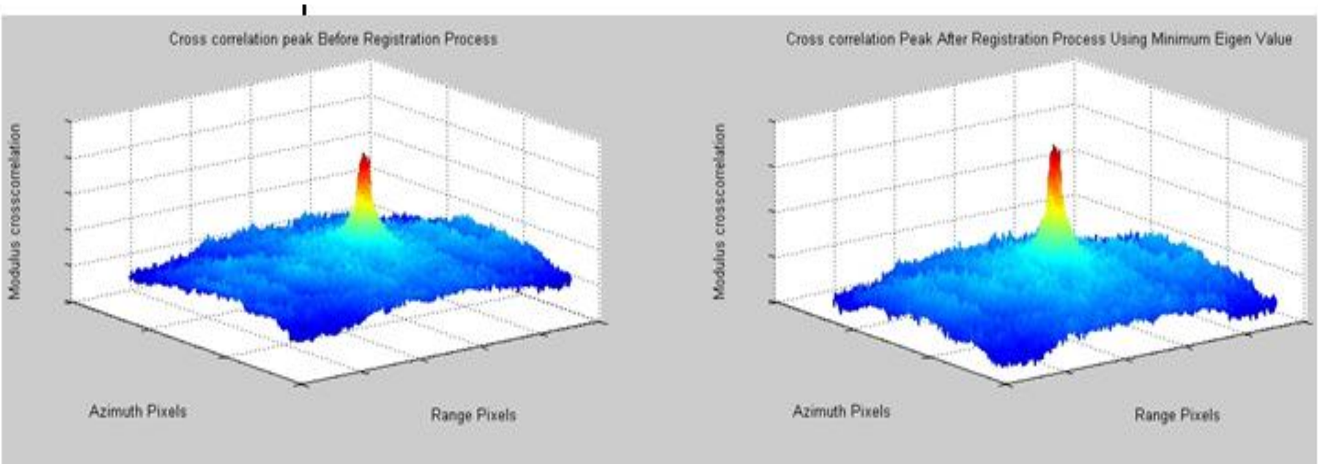


(b)

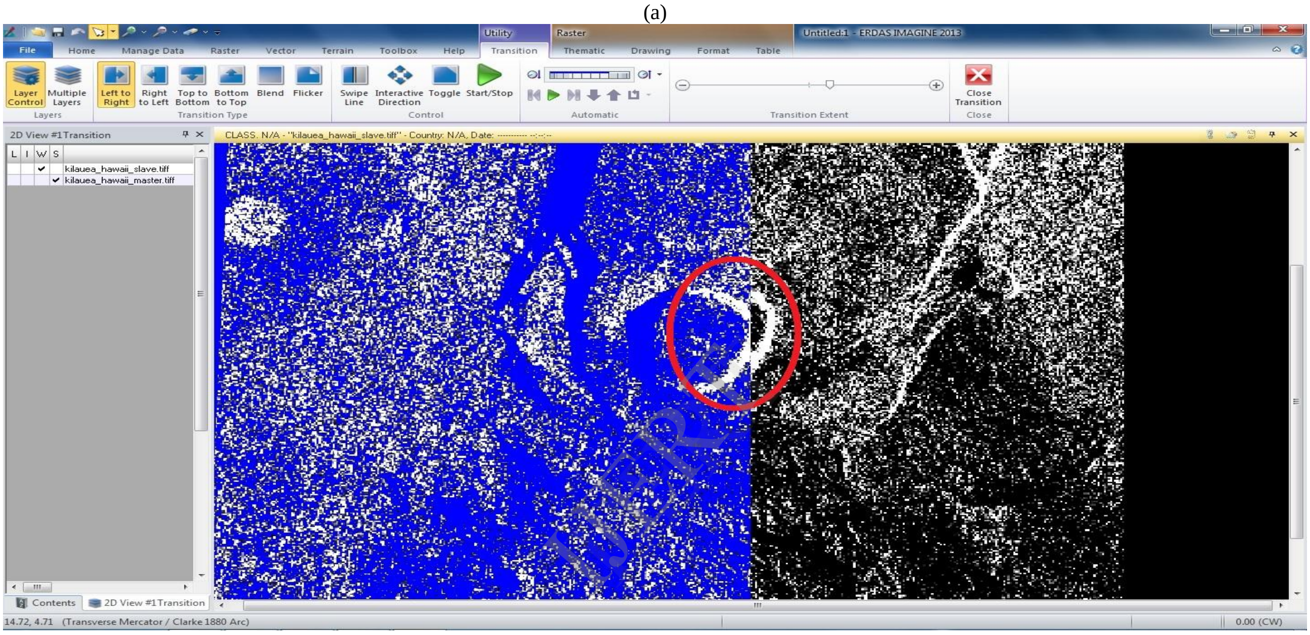


(c)

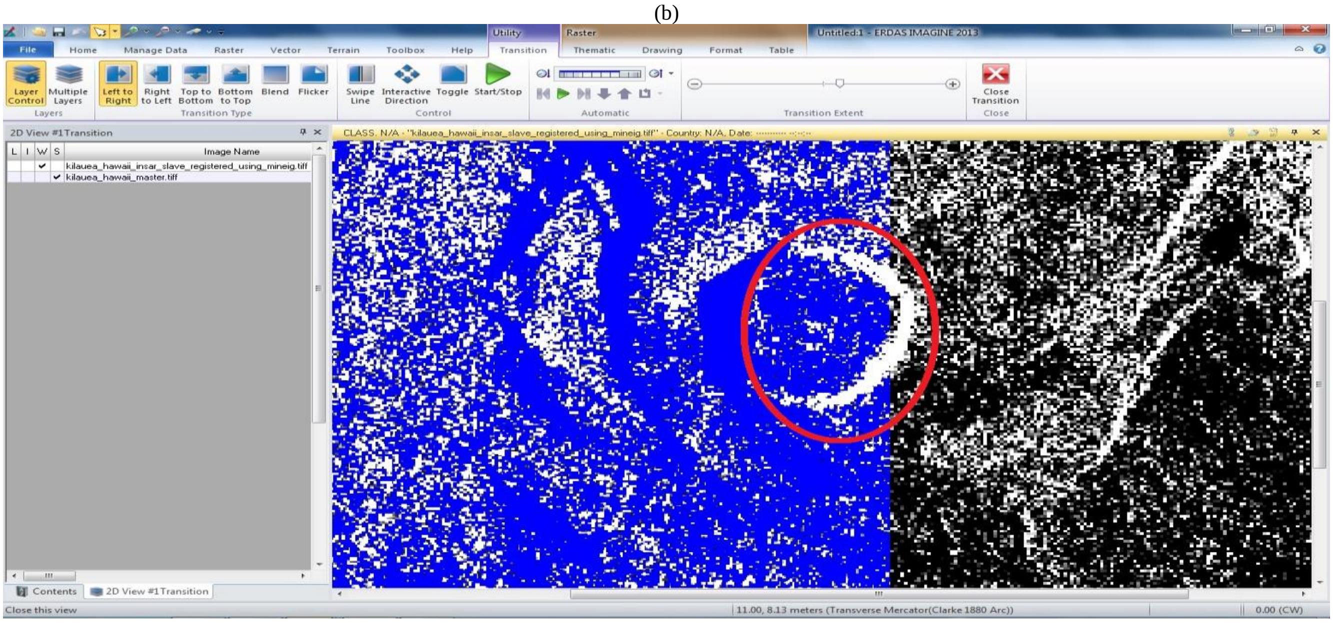
Fig.3. Results of Death Vally InSAR Images



(a)



(b)



(c)

Fig.4. Results of volcano Kilauea, Hawaii InSAR Images