Impact of Perpendicular and Temporal Baseline Characteristics on InSAR Coherence Maps

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Key words: InSAR, coherence, perpendicular baseline, temporal baseline, Konya Closed Basin

SUMMARY

Interferometric SAR (InSAR) technique produces a high resolution topographic map and also gives information about changes on the Earth's surface during the repeat pass cycle of a satellite from the correlation properties of the radar echo. This technique is often limited by temporal and geometrical decorrelation, therefore phase noise occurs on results. This phase noise can be measured by the amount of decorrelation defined between two SAR images as coherence. Its magnitude is bounded between 0 (implying total decorrelation, no phase information) and 1 (no phase noise).

In this paper, the relationship between coherence and impact of the perpendicular and temporal baseline on results was examined and interpreted by using the several ENVISAT ASAR interferometry pairs on Konya Closed Basin (KCB) in Turkey. Our study area of interest generally lies on a slope that is mainly oriented towards the west; it would be foreshortened on SAR ascending images (since the ENVISAT antenna looks to the right). Thus, descending ENVISAT orbits was selected. By analyzing the image pairs for the study area, the highest coherence is found with the shortest perpendicular baseline in image pairs. As it is expected, the longer perpendicular baseline is the worse coherence. This is so because the change of the look angle causes different backscattering characteristics over the study area. The coherence values in the interferograms decreases with increasing the perpendicular and temporal baseline because of time span between the images acquisitions. We find that the coherence measurement from water bodies as Sugla Lake and vegetation cover areas have low coherence, therefore appear black or dark grey in coherence map. Urban areas as Konya City center and areas with exposed rocks as Mount Karadag have high level of coherence therefore appear light grey in coherence maps.

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1. INTRODUCTION

Radar interferometer is a measuring technique that composes a certain map of earth through using phase differences of two images that have already been obtained by radar method. Interferogram that was composed by pixel base phase differences is a contour line map of distance between earth and radar satellite. The maps in question have a unique pixel density (~ 100 pixel/km^2) and ~ 1 cm linear at the direction of radar (Massonnet and Feigl, 1998). SAR (Synthetic Aperture Radar) that occurs through using of radar technique, in other words Synthetic Aperture Radar technique at the satellites operates with microwave frequencies. This feature enables the system to operate, as being able to take image of geometric and electrical features of night and day surface in every kind of air conditions (Rosen and et al., 1998).

The applications conducted by the means of InSAR, provides a different viewpoint to issues that are included in science and other views in society interest and obtained information is quite significant regarding readability of earth's structure and evolutions. However classic InSAR technique is often limited by temporal and geometrical decorrelation, especially in the context of long time series analysis.

In this study, deformation that is assumed to have been formed after land subsidence from the ground water in Konya Closed Basin, is probed by InSAR method. Examining determined deformation dispersion and qualification (scale) of the region is aimed. However, due to the decorrelation between the interferometric pairs, we couldn't get the accurate subsidence measurement of the study area. This paper discusses detection and interpretation of temporal and geometrical effects in an area of interest using coherence maps in InSAR.

ENVISAT images, provided from European Space Agency (ESA), will be used to achieve coherence maps. Interferogram will be composed between radar image pairs by DORIS Software, developed by Delft University, and coherence information will be tried to determine by assistance of those interferograms.

2. SELECTION OF ENVISAT ASAR DATA AND DATA PROCESSING STEPS

2.1 Data Selection

The track and frame numbers of the satellite are needed in image selection for the images showing a part of the region. At the beginning, using an appropriate software, whether there are satellite images showing the borders roughly should be investigated and if found the dates and the orbits belonging them should be determined. The most important point in selection of images is the distance (base) value between the perpendicular satellite location in different orbits and time.

The method and image investigation in this study is implemented to ensure the monitoring of land subsidence are appropriate. In order to get data (SAR images), project application is done to European Space Agency (ESA) and the images provided by the institution. In this study, several ASAR data selected between 2003 and 2009 belonging to ENVISAT satellite that gather interferometric SAR image from 2002 are used. The subsidence and time-dependent changes in the basin will be monitored by using differential interferograms obtained from satellite images. The DORIS software developed at Delf University is used to evaluate and create the interferograms (http://enterprise.lr.tudelft.nl/doris/). The primary parameters taken into account in this study are perpendicular baseline and day difference between primary and secondary image.
Figure 2.1 shows the location of the area covered by the track 207 and frame 2853, track 207 and frame 2835, track 436 and frame 2853 according to Konya closed basin.

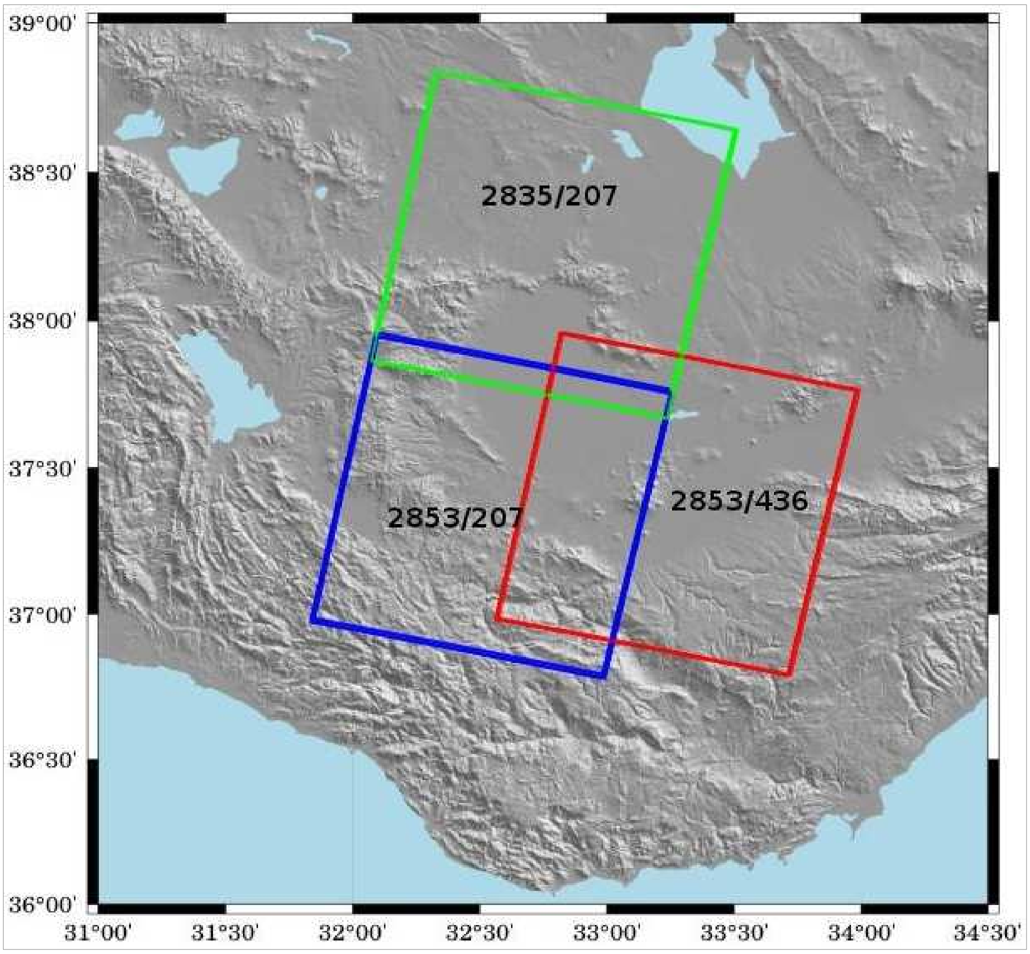

Figure 2.1: Location of Envisat ASAR image at study area on digital elevation model.

2.2 Data Processing

The images used in InSAR applications may be provided as processed (SLC single look complex) or not processed. The interferogram creation for processed images is performed by process steps shown in Figure 2.2.

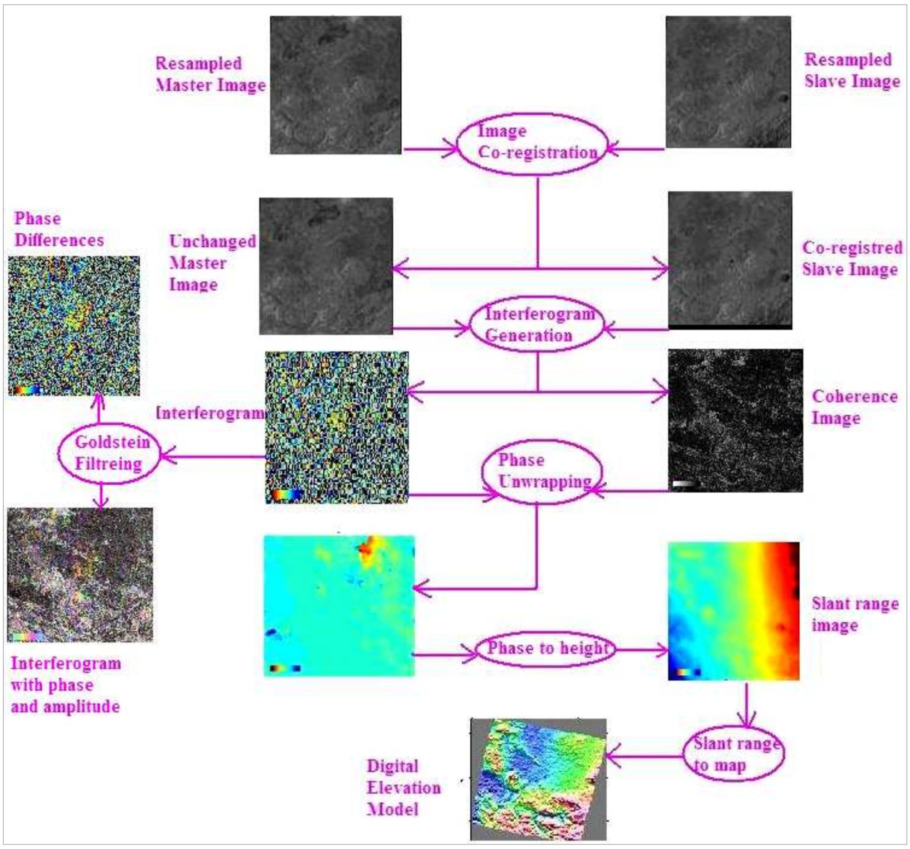

Figure 2.2: Diagram for InSAR data processing

The images must be aligned to resolve sliding probably originated by geometry between two image or another reasons. The phase component of each complex valued pixel in the reference image is subtracted from conjugate phase component on the other image after the images aligned to each other. The image created is a complex one and it is called interferogram. The phase value of this interferogram is the multiple of 2π.

The other stage follows the interferogram creating is filtering. In this study, weighted power spectrum is used as the filter developed by Goldstein and Werner (1998) .

The geometric reference surface of earth impacts the interferometic phase. This process step is called flattening when influence is extracted from phase values.

Analysis (unwrapping) process is needed because the fridges in the result interferogram are local. The filter type chosen for interferogram filtered before analysis process has great importance to describe analysis process successfully.

After analysis process completed, the last operation is to associate terrain coordinate system and result product (Geocoding). Interferogram in the same direction with line of sight is associated with real coordinates (i.e. geographical) throughout the entire process.

3. DETECTION OF INTERFEROGRAM QUALITY USING COHERENCE MAPS

3.1 Study Area

Konya closed basin, which is located in a 62 000 km^2 area of Anatolian peninsula, is the biggest closed basin of Turkey involving Konya, Karaman, Nigde and Aksaray provinces. The soil of this basin, which is exposed to the characteristics of Central Anatolia's climate, comprised on an old lake, sediments and volcanic rocks in a flat and slightly undulating topography. There are some volcanic rock covered altitudes such as Karadag and Tertiary sediments in Karaman province which is part of this basin (Gocmez et. al., 2004). Toros Mountains limit the closed basin in the south. While, the height in the middle part of the basin is around 850-1000 m (almost 65% of the whole basin), the height at Toros Mountains is around 3900m. Water sources of the basin are the rivers and ground waters fed by Taurus Mountains.

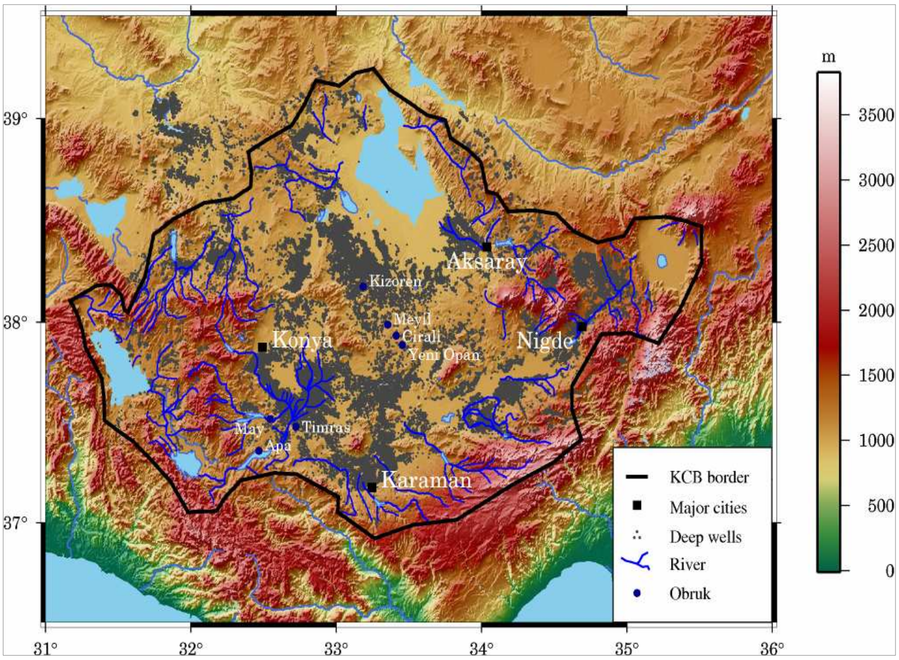

Figure 3.1: Konya Closed Basin (Ustun et al., 2010)

The 48.4% of the watershed has the features of arable land in terms of land use and quality. The annual ground water drawdown reserves in Turkey is 13,66 km^3/year. Konya closed basin corresponds to 10% of the country reserves in general. 80% of this reserve is used for agricultural irrigation by State Hydraulic Works and the rest, 20% of the reserve is used by individuals. The amount of water used at agricultural irrigation reach up to %70 of the whole country (Iscioglu and Hamarat, 2004). The basin has a significant water potential, but because of some reasons, small amount of rain and unconscious usage of the water, underground water levels are decreasing and the basin is faced with the risk of drought (Gocmez et. al., 2008).

3.2. Coherence Maps and Importance of Appropriate Baseline Value

Any source of phase noise can be characterized by the amount of decorrelation it introduces. A commonly used measure for the interferogram quality is coherence γ defined as mutual correlation between coefficient between two images. The coherence value ranges from 0 (the interferometric phase is just noise) to 1 (complete absence of noise).The complex coherence image between two images is defined as:

$$\gamma_c = (E\{M.S^*\})/(E\{M.M^*\}.E\{S.S^*\})^{1/2} \qquad (1)$$

Where:

E{.} is the expectation;   is the complex conjugated; γc is the complex coherence;

M is the complex master image; S is the complex slave image.

In this study, the obtained interferograms include atmospheric effects and have generally low coherence due to the vegetation cover and long temporal baselines necessary to monitor long-term surface changes. Coherence in the interferograms decreases with increasing temporal and geometrical baseline.

As a result we generated several coherence maps from interferograms. These are generally incoherence because of decorrelation but for this research we choose three sample which give significant results. As an example, the coherence map related to the Konya Closed Basin (KCB) interferogram is shown in Figure 3.2.

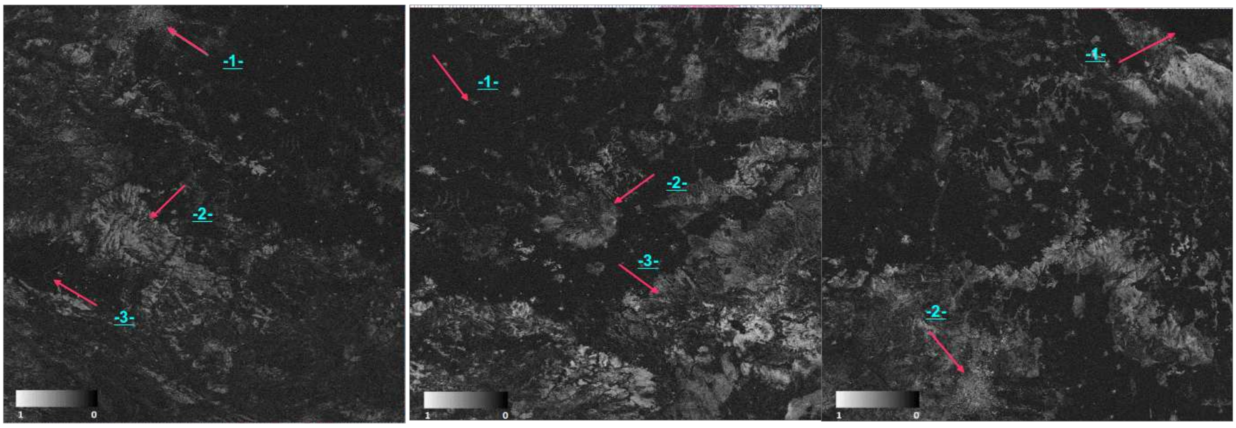

Figure 3.2: Coherence maps over KCB. Left panel shows 207 track - 2853 frame, second panel shows 436 track - 2853 frame and right panel shows 207 track 2835 frame.

In Figure 3.2 on the left panel, number one shows south part of Konya City Center and number two shows areas with exposed rocks maintain a high level of coherence, number three shows Sugla Lake and it is seen as dark in the image because of low coherence. On second panel number one shows vegetated areas and agricultural fields show low coherence, however number two which shows Mount Karadag and number three which shows Karaman City

Center have high coherence value. The last panel shows a part of Tuz Lake and it doesn't gives coherence value as Sugla Lake, lastly number two on last panel shows north part of Konya City Center is seen light-Grey it means high coherence.

Nine Envisat ASAR mission data pairs acquired in 2003 to 2009 are used (Table 3.1).

Frame	Track	Acquisition Date (Master-Slave)	Temporal Baseline (date)	Perpendicular Baseline (m)	Mean Coherence
2835	**207**	30 Sept. 2003 – 13 Jan. 2004	105	432	0.439862
		30 Sep. 2003 – 1 Jun. 2004	245	315	0.461686
		26 May. 2009 – 30 Jun.2009	35	-97	0.684723
2853	**207**	15 July.2008 – 30 Jun.2009	350	-64	0.618105
		13 March.2007 – 1 Apr. 2008	385	101	0.544005
		13 March.2007– 15 July. 2008	490	331	0.516425
2853	**436**	22 Feb.2007 – 7 May.2009	805	274	0.588917
		31 Jul.2008 –13 Nov. 2008	185	-86	0.715729
		31 Jul.2008 – 7 May.2009	280	245	0.576934

Table 3.1: Temporal and perpendicular baseline values with different acquisition dates

The perpendicular baseline at the scene center varies from about 64 to 432 m. The coherence is estimated within a 5x5 window in a 4x20 multilooked interferogram, and the mean coherence value for each interferogram ranges from 0.43 to 0.71 (see table 3.1).

The highest coherence is found with the both of shortest perpendicular and temporal baseline in the image pair of 31 July 2008 and 13 November 2008. The longer perpendicular baseline is, the worse coherence found. This is so because the change of the look angle may cause different backscattering characteristics over the KCB area.

There is two sample of relation between absolute error and correlation in range and azimuth direction. These show incoherence and significant coherence results in Figure 3.3.

As seen at the relation between absolute error and correlation (corresponding to image pairs in Table 3.1) from top to bottom, that can be interpret of temporal and geometrical effects on coherence maps results in an area of interest.

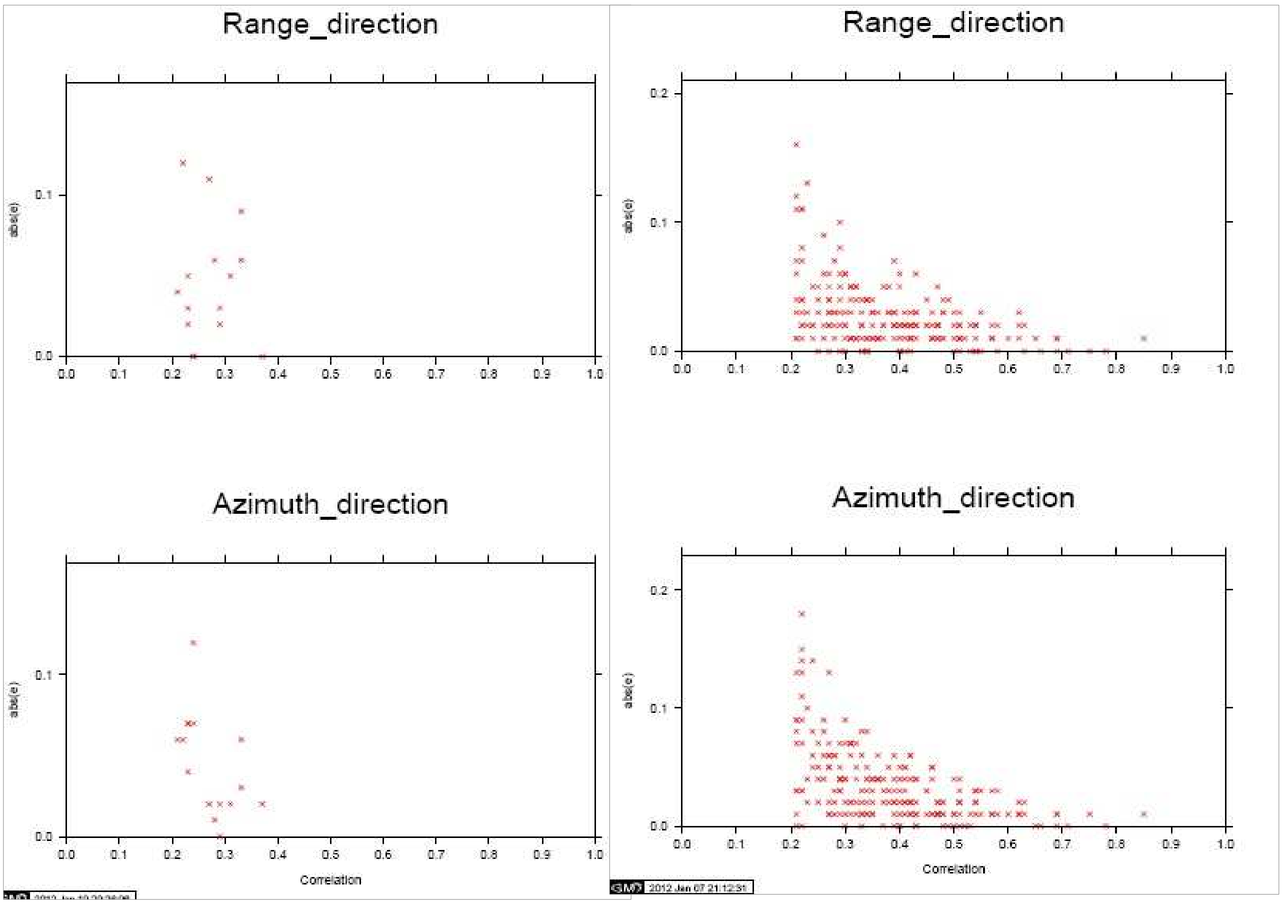

Figure 3.3: Sample of incoherence and significant coherence results on range and azimuth direction.

In this study we also generate a graphic with the help of numerical values of perpendicular and temporal baseline relationship to mean coherence. These are presented in Figure 3.4.

The graphics are clearly shown that the perpendicular baseline effect is a little greater than temporal baseline effect.

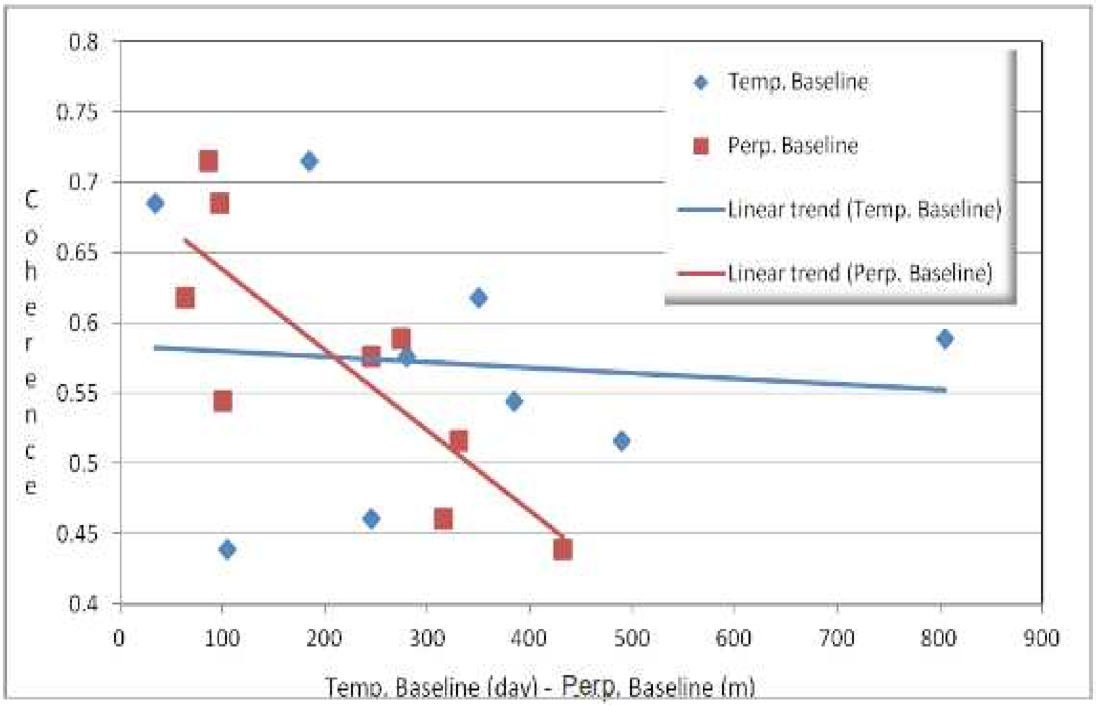

Figure 3.4: Perpendicular and temporal baseline correlation to mean coherence.

4. CONLUSIONS

Coherence, when associated with interferometry, is related to phase variance between the two SAR images. For the purpose of processing the interferometry data into topography of motion information, the coherence can be useful tool in indicating areas of noisy phase.

This study investigated the effect of perpendicular and temporal baseline to the map of coherence values and reflected from this result, both effects were proportional to each other on coherence value.

From the analysis of InSAR images the following general conclusions on the obtained coherence can be drawn:

- Urban areas as seen in especially Konya and Karaman City Center and areas with exposed rocks mountain like Mount Karadag, a high level of coherence even after several years.
- Vegetated areas and agricultural fields generally show low coherence. Nonetheless, a suitable coherence value has often been detected by comparing images acquired with a temporal interval of an integer number of years, i.e. at the same period of the year. Usually winter to winter data is best, when there is the least amount of vegetation on the ground.
- Water basins do not show a sufficient level of coherence like Sugla and Tuz Lake .
- Areas in foreshortening become non-coherent as soon as the perpendicular baseline is greater than a few metres.

• Areas with opposite slopes usually show the best coherence if not in shadow, since the spatial resolution is higher and the actual critical baseline is greater than that of flat terrain.

The findings may be improved with new interferograms created by using radar images have less atmospheric effects to improve the study. More detailed maps of Konya Closed Basin can be created to analyze the land subsidence in detail by using PSInSAR (Permanent Scatterer Interferometric Synthetic Aperture Radar) method used on maps created by processing the results obtained by radar interferometry.

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BIOGRAPHICAL NOTES

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