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# Spatial accuracy analysis of Sentinel-1 SAR satellite images by comparing maps

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Standard Deviation

**ABSTRACT**

Synthetic Aperture Radar (SAR) images are used in several different applications for Remote Sensing purposes. SAR is an imaging sensor that can detect high-resolution ground images under a wide variety of imaging conditions. As SAR is an active system, the data are already acquired with geo-position information. To investigate to verify the image spatial accuracy, a part of the Antalya region of Turkey was selected as test site. The Open Street Map (OSM) and Photogrammetric Digital Map (PDM) data of the area on the Antalya O25 map were used in comparison. First, characteristic common points were selected on the OSM data and the SAR satellite image both. The projected coordinates of these points were calculated with the QGIS software. Normal distribution of the coordinate differences in these data sets were plotted. It was confirmed that the data sets were in normal distribution and standard deviation and 2 * standard deviation values were calculated. The maximum and minimum confidence interval (95%) was determined according to the standard deviation limit values. X and Y coordinate differences were calculated for 49 selected points from both image pairs SAR&OSM and SAR&PDM. Finally, the maximum differences show that the SAR positional accuracy respect to OSM and PSM is below 1 pixel azimuthal resolution.

## 1. INTRODUCTION

Synthetic Aperture Radar (SAR) images are used in applications for Remote Sensing purposes. SAR data is an imaging sensor that can detect high-resolution ground images under a wide variety of imaging conditions (Demirci 2005). To investigate the accuracy of this receiver, the Antalya region test area was chosen.

The OpenStreetMap (OSM) and Photogrammetric Digital Map (PDM) data of the area on the Antalya map were used in comparison. It is also part of the open data movement.

OSM is used as a basic or data source in many websites and mobile applications (Ünen 2013). The attribute accuracy and positional accuracy (51.5%) of OSM data in the Wuhan region of China were determined (Wang 2015). In Turkey has made similar studies. For example (Çabuk 2015) 1: 50.000 scale OSM dataset is not enough to support the production process alone, when used with production. It has been observed that it will increase the quality.

Photogrammetric Digital Maps(PDM) are made for the use of public institutions and organizations and to provide data to the Geographical Information System (GIS). The accuracy analysis of Photogrammetric Digital Maps was carried out within the provincial borders of Erzincan (Kara 2019), the horizontal coordinate average was calculated as 6cm and the vertical coordinate average 10cm.

Synthetic Aperture Radar; S1A data products are already consistently providing highly accurate geolocation (Schubert 2015). Thus, we tried to expolore the spatial accuracy of Sentinel 1 SAR data in respect to the available existing sources OSM and PDM.

First of all, characteristic common points were determined on these data sets. 55 points were used in each data set. These points are building corners, road intersections, etc. Geographical coordinates system and perpendicular coordinates system of the selected points were calculated with the QGIS software. The QGIS Python software plug-in was used in the calculation process. This data was put into the process as raw data. The orthogonal coordinates of the raw data and the

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coordinate differences between the OSM and the SAR data and the PDM and the SAR data coordinate differences were found. It was decided that the data showed a normal distribution (Chart 1 & Chart 2).

Standard deviation and 2*Standard deviation values were calculated in the second step in order to remove the erroneous data points in these raw data. Maximum and minimum confidence intervals (95%) were determined according to the 2*Standard deviation limit values. Thus, erroneous data points were removed and 49 error-free data points were obtained in each data set. Coordinate differences (Ya-Yc) of 49 common points in OSM and SAR data set; Coordinate differences (Yd-Yc) of (Xa-Xc) and 49 common points in PDM and SAR data set; (Xd-Xc) were calculated separately. The standard deviations of these coordinate differences were 11.646m, 7.842m and 10.520m, and 8.438m, respectively.(Table1 & 2) Coordinate difference graphs and location graphs of these data sets were drawn. Finally, according to the comparison in these two data sets, it is understood that the SAR image data is have about 20m accuracy.

## 2. MATERIALS

In this study, Antalya is selected as a test site as shown in Figure 1. The used datasets are Sentinel 1 SAR image, OpenStreetMap(OSM) and photogrammetric digital map (PDM) which was provided by Municipality of Antalya.

Sentinel 1 has C band RADAR sensor, operated by European Space Agency, and the respective data can be provided from Copernicus data hub. The data have Range and Azimuth resolution 20x22 m respectively. They are provided with 10 m pixel spacing through Ground Range Detected (GRD) file format.

OSM is an online geodatabase with OpenData Commons license in the background (Çabuk 2015). OpenStreetMap is a dataset service, created by a OpenStreepMap Foundation that provide data about revery kind of features in the Earth. PDM dataset is created by Antalya Municipality with 1/5000 scale.

The accuracy of dataset is depending on the used data source (e.g. Satellite imagery, mainly optical) and the digitizer accuracy.

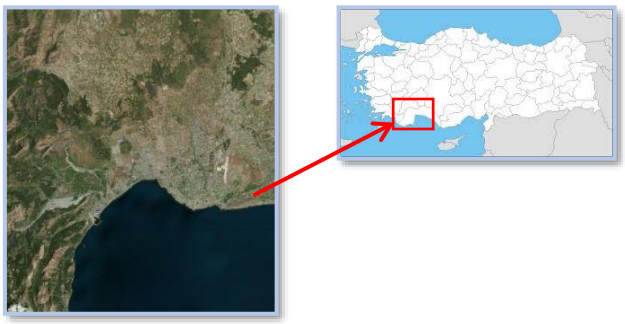

**Figure 1. Study Area**

## 3. METHOD

In this study, QGIS (3.12) and SNAP (7.0) software developed by ESA were used to evaluate the data in the study area. QGIS software is a multi-platform free and open source Geographic Information System (GIS) software that provides data viewing, editing, and analysis capabilities. SNAP software, on the other hand, is a common software called Sentinel Application Platform (SNAP) and is developed for fast viewing, layer management, geocoding and correction using ground control points.

The Subset calibration, Speckle filtering and Geometric correction procedures were applied to the SAR Sentinel-1 Satellite data in the SNAP program.

55 identical point data were selected from OSM (A) and SAR Sentinel-1 satellite data (C). OSM data (A) and SAR (C) data of the study area were registered using the QGIS program.

Orthogonal Coordinates were obtained with Python code software according to TUREF TM 30 reference information.

In the first step, the coordinate differences of these 55 data sets (Ya-Yc) and (Xa-Xc) were calculated and the histogram graphs of these coordinate differences were drawn. (Chart 1 & Chart 2)

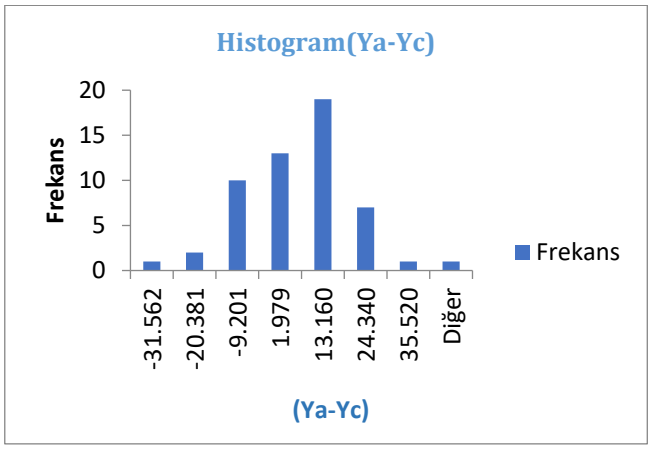


**Chart 1.** (Ya-Yc) Coordinate Differences Histogram

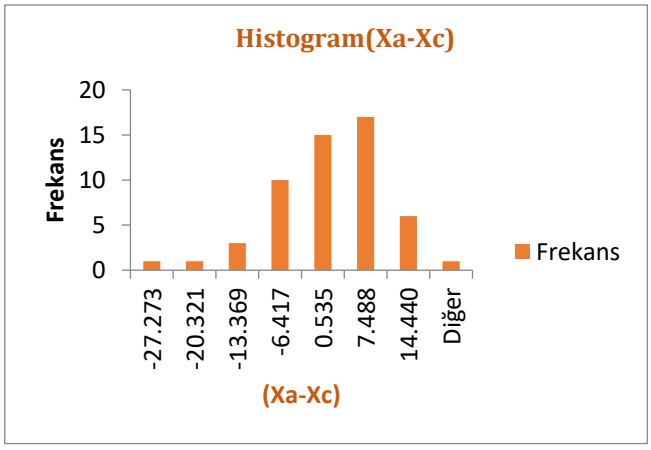


**Chart 2.** (Xa-Xc) Coordinate Differences Histogram

In the second step, 55 points were used in comparison of SAR (C) and PDM (D) data. These common points (Yd - Yc) and (Xd - Xc) coordinate differences were calculated and histogram graphics were drawn. (Chart 3 & Chart 4)

OSM (A), SAR (C) and PDM (D) data sets were determined to be in normal distribution.

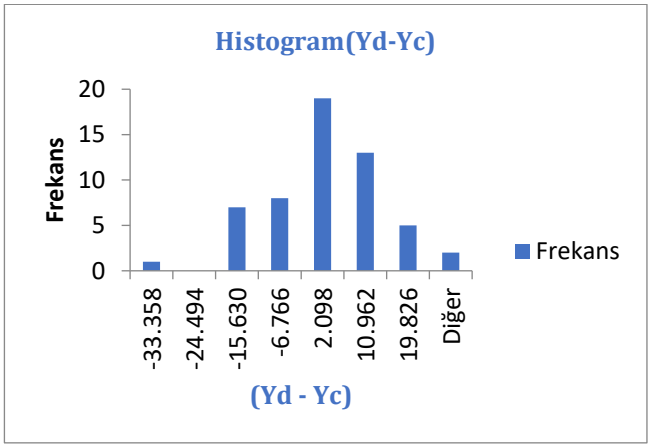


**Chart 3.** (Yd-Yc) Coordinate Differences Histogram

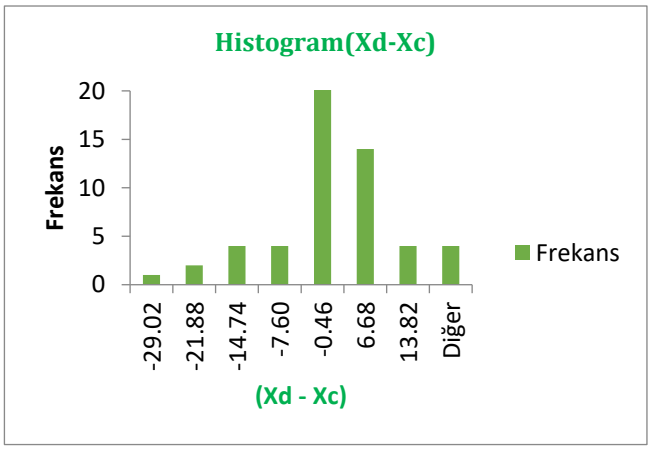


**Chart 4**. (Xd-Xc) Coordinate Differences Histogram

## 4. RESULTS

OSM data (A) and SAR (C) data set were determined to be normally distributed. The mean value of the (Ya - Yc) and (Xa - Xc) coordinate differences and standard deviation values were calculated. The standard deviation according to the 2 * standard deviation value (95%) is the minimum and maximum limit values have been determined and 49 error-free points were found to be compatible. (Table 1)

$$(\bar{X} - 2\sigma) \leq \mu \leq (\bar{X} + 2\sigma)$$

The standard deviation is 11.646m in the (Ya-Yc) differences and 7.842m in the (Xa-Xc) differences. In addition, according to the 2 * Standard Deviation limit values, in (Ya-Yc) differences; in the range of [-22.730m to 23.855m] and (Xa-Xc) differences; values have been reached in the range of [-17.216m to 14.152.86m]. (Table 1)

**Table 1.** Calculation Summary of 49 error-free point

| Calculation 1 | [Ya-Yc] m | [Xa-Xc] m |
|---|---|---|
| Ortalama | 0.563 | -1.532 |
| Std.Sapma | 11.646 | 7.842 |
| 2*Std.Sapma | 23.293 | 15.684 |
| Minimum | -22.730 | -17.216 |
| Maximum | 23.855 | 14.152 |

In this case, the percentage error rates [(Ya-Yc)/ Ya]*100 and [(Xa-Xc)/Xa]*100 of the difference values of the 49 points were calculated and found that it varies between [-0.004 to +0.004] and [-0.001 to +0.001], respectively.

The difference and position graphs of remaining 49 points were drawn. (Chart 5 & Chart 6)

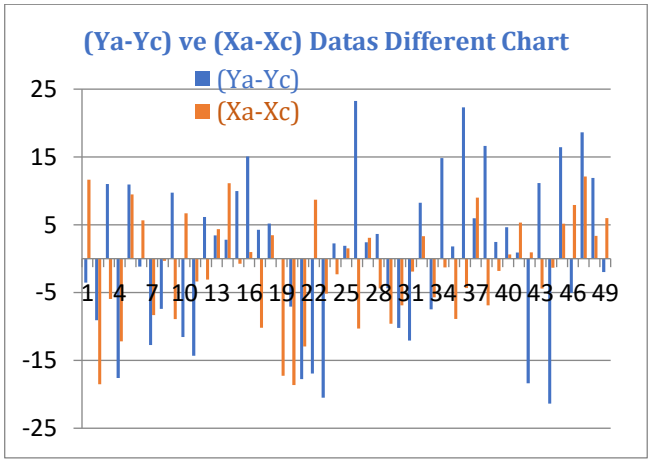


**Chart 5.** OSM and SAR data error free plot of coordinate differences of points.

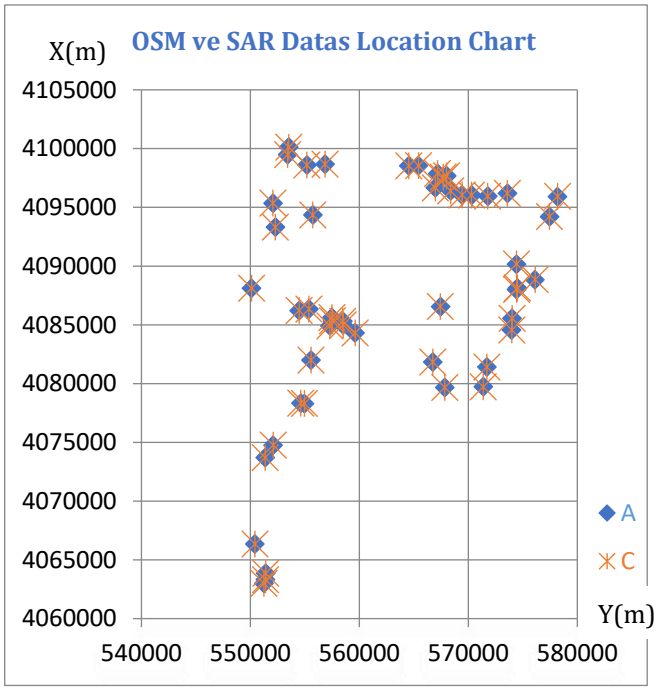


**Chart 6.** OSM and SAR data error free position graph of points.

It was decided that the PDM (D) and SAR (C) data set showed normal distribution. The average value of the (Yd - Yc) and (Xd - Xc) coordinate differences and standard deviation values were calculated. The standard deviation according to the 2 * standard deviation value (95%) is the minimum and maximum limit values have been determined and 49 error-free points were found to be compatible. (Tablo.2)

$$(\bar{X} - 2\sigma) \leq \mu \leq (\bar{X} + 2\sigma)$$

The standard deviation was 10.520m in the (Yd-Yc) differences and 8.438m in (Xd-Xc) differences. In

addition, according to the 2 * Standard Deviation limit values, in (Yd-Yc) differences; in the range of [-22.044m to 20.035m] and (Xd-Xc) differences; values in the range of [-18.298m to 15.452m] have been reached. (Table 2)

**Table 2.** Calculation Summary of 49 error-free point

| Calculation 2 | [Yd-Yc] m | [Xd-Xc] m |
|---|---|---|
| Ortalama | -1.004 | -1.423 |
| Std.Sapma | 10.520 | 8.438 |
| 2*Std.Sapma | 21.040 | 16.875 |
| Minimum | -22.044 | -18.298 |
| Maximum | 20.035 | 15.452 |

In this case, the percentage error rates of the difference values of 49 points were calculated using the formulas [(Ya-Yc) / Ya] * 100 and [(Xa-Xc) / Xa] * 100 and found that it varies between [-0.004 to +0.004] and [-0.001 to +0.001], respectively

The difference and position graphs of remaining 49 points were drawn. (Chart 7 & Chart 8)

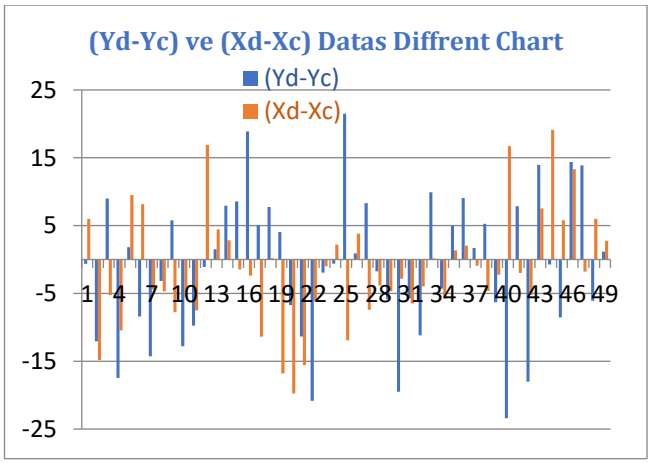


**Chart 7.** PDM and SAR data error free plot of coordinate differences of points.

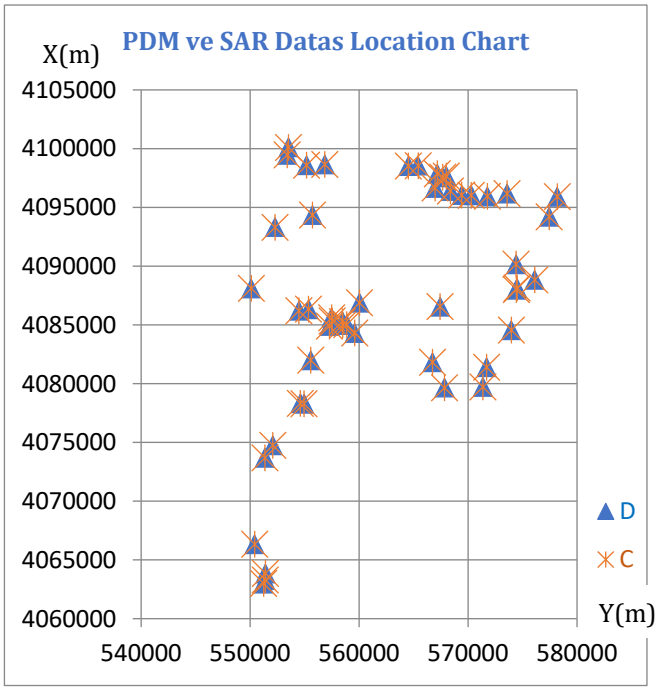


**Chart 8.** PDM and SAR data error free position graph of points.

Finally, a graph is drawn showing the coordinate difference values of both data sets. In both comparisons, it was observed that 95% of the coordinate differences were within the ± 25 m radius circle. The ratio of the (Yd-Yc) and (Xd-Xc) coordinate differences of the blue points within the ± 10m circle to all blue points is 53.1%, the coordinate differences (Ya-Yc) and (Xa-Xc) of the orange points within the ± 10m circle are its ratio compared to orange spots is 36.7%. (Chart 9)

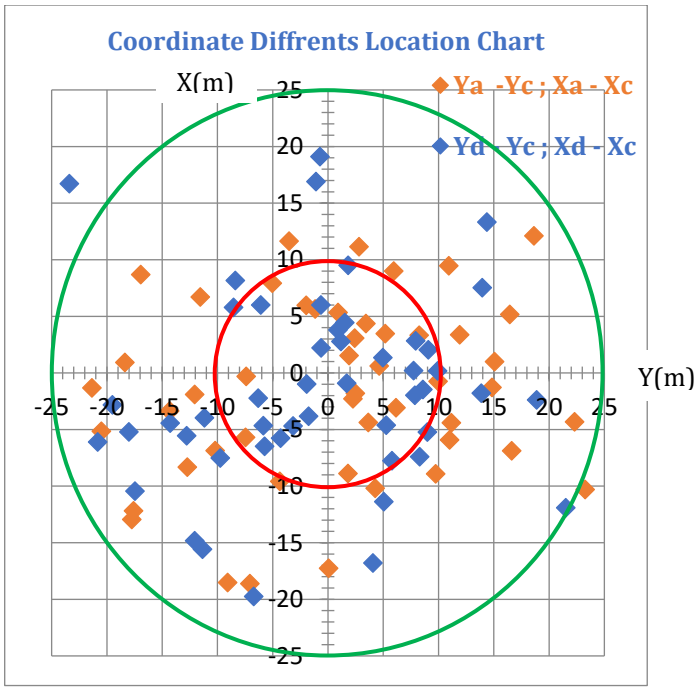


**Chart 9.** Location graph created according to OSM, PDM and SAR coordinate differences.

## 5. CONCLUSIONS

In the study of the spatial accuracy of Sentinel-1 SAR satellite images, Open Street Map (OSM) and Photogrammetric Digital Map (PDM) data were used for comparison. Open Street Map (OSM) and Photogrammetric Digital Map (PDM) data sets were used as precise data and SAR satellite data as experimental data set.

55 points were used to compare OSM (a), SAR (c) and PDM (d) data sets. 6 pieces of data were excluded from each data set because they were incompatible. Coordinate differences were calculated with 49 points in the comparison of the data sets without error on OSM (A), SAR (C) and PDM (d). Average and standard deviation values were found. The minimum and maximum values were determined according to the value of 2 * standard deviation (95%).

It was observed that the coordinate differences (Yd-Yc) and (Xd-Xc) were represented better than the coordinate differences (Ya-Yc) and (Xa-Xc) within the ± 10m radius circle.

As a result, it is concluded that SAR data with an maximum difference with 20m well fit with other data sources OSM and PDM.

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