

# COAST LINE CHANGE DETECTION USING CORONA, SPOT and IRS 1D IMAGES

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## ABSTRACT:

In this paper, the Black Sea coast of European part of Istanbul was studied using Corona (1963) panoramic satellite photo, SPOT-4 PAN (1998) and IRS-1D PAN (2000) satellite images. The temporal coast line change of the study area was aimed to be designated. The change detection analysis was made for the period between 1963, 1998 and 2000. The results of the study can be used for protecting natural areas. Corona reconnaissance panoramic satellite photos were declassified at 1995 by USA for scientific purpose. Challenging features of Corona photos were studied in this study. The first and the most difficult step of the study is rectifying the images. Some geometric experiments were made with known distances and angles. Rubber sheeting method consigned the most significant results. Photogrammetric methods require the whole image to be evaluated. However, by the method mentioned above, the study carried out using only a part of the photo. During the rectification process, 1/5000 scaled orthophoto mosaic was used. After the rectification of all images, the coast line was manually digitized on Corona panoramic photo, SPOT-4 PAN and IRS-1D PAN images. Coast line change detection amount is calculated by subtracting 2000 dated data set from 1963 dated data set, 1998 dated data set from 1963 dated data set and 2000 dated data set from 1998 dated data set. Noteworthy changes were observed.

## 1. INTRODUCTION

Istanbul is a very historic city with a unique land cover, vegetation and position including both Asian and European continents junction through the well-known Bosphorus. Most of the parts of the city are under the threat of rapid urbanization. In addition to this, some valuable land is used to supply the materials necessary for the construction business. Detailed precautions have to be taken for the protection of these priceless features.

The meaning of coastal zone concept may be understood from its name. But, it is very hard to define the borders accurately neither at water body (generally sea) side nor at shore side. The definition of this border changes at different countries. The definition of Commission on Marine Sciences Engineering and Resources is; coastal zone covers generally the zone between the interaction borders of sea and land. The reason of changes occurred on coastal zones not only comes from human factor but natural factors such as storms and climate changes, which have influences on sea level, influence negatively especially the coastal zones which have low elevation (Maktav, D., Erbek, F. S., 2001).

In this paper, the Black Sea coast of European part of Istanbul was studied using Corona (1963) panoramic satellite photo, SPOT-4 PAN(1998) and IRS-1D PAN (2000) satellite images. During the rectification process, 1/5000 scaled orthophoto mosaic was used. The change detection analysis was made for the period between 1963, 1998 and 2000. Noteworthy changes were observed.

During the rectification stage rubber sheeting method was used. Rubber sheeting method consigned the most significant results. Photogrammetric methods require the whole image to be evaluated. However, by the method mentioned above, the study carried out using only a part of the photo.

## 2. MATERIALS and METHODS

### 2.1 Corona Cameras

Throughout the past few years, it has been possible to obtain high-resolution imagery for official and local users. New imaging systems which have higher resolution and accuracy are on the way coming in use within next few years. However, using high-resolution imagery is not the case of recent years. Nearly 40 years ago at August 1960, USA succeeded in starting a satellite mission called CORONA. It was the first photo-reconnaissance satellite system of USA. This program went through many developments during its lifetime (its final mission was flown in 1972), but the entire effort was classified until 1995. (Lillesand, T. M, Kiefer, R. W. 2000).

The series of Corona reconnaissance satellites provided coverage of the Soviet Union, China, and other areas from the Middle East to Southeast Asia. The declassified archive has a limited spatial coverage and much of it is severely affected by cloud cover (Donoghue, D.)

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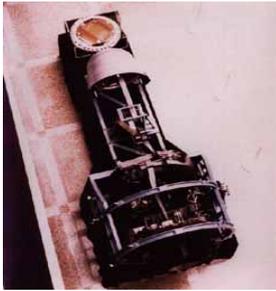


Figure 1. Corona cam.

During the 1960s, digital communication systems was not developed enough to allow real time data transmission. Corona had an interesting method of returning the pictures to Earth. Corona placed exposed film in a canister, then “de-orbited” the containers by sending them to Earth through an orbit who’s altitude decayed quickly. Airplanes then retrieved the canisters in mid-air according to

these guidelines, and sent to the organisers for scanning (Doonan, J.,2002). If mid-air recovery failed, a back-up water recovery with helicopter and ship would secure the capsule (Schenk, T. *et al*, 2003)

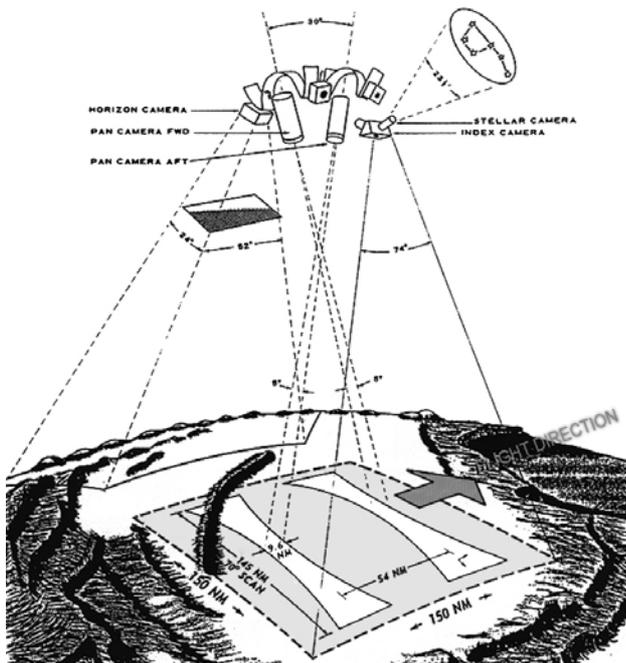


Figure 2. Corona data block format [1]

Corona’s reconnaissance cameras are referred to by the designator “KH” (from **Key**Hole). Fairchild manufactured the first two cameras, KH-1 and KH-2 that were flown on five successful missions from 1960 to 1961. Other Corona cameras included KH-3 (operated from 1961-1962), KH-4 (1962-1963), KH-4A (1963-1969), and KH-4B (1967-1972), all designed, revised and manufactured by Itek. On the majority of the 95 successful Corona missions, the KH-4, KH-4A and KH-4B cameras have been used. These three cameras are very similar (Schenk, T. *et al*, 2003).

The KH-4 is a twin panoramic camera with a convergence angle of  $30^{\circ}$ . The lens system employs a Petzval configuration with five positive lenses and a focal length of 2'. The lens barrel is about 3' and the distance from the first lens to the film is 4', resulting in a relatively bulky system. The lens constantly rotates about its rear nodal point and so does the slit that scans the image to the film. The film format is  $2.18'' \times 29.8''$  and the scan angle is about  $70^{\circ}$ . The film base is polyester and the film load capacity of KH-4A and KH-4B is 32,000', allowing a

mission life of up to 19 days. In longer missions, the film would be ejected twice. (Schenk, T. *et al*, 2003)

<b>Lens</b>	Petzval f/3.5 T 3.8
<b>Focal Length</b>	609.602mm (24.0 in)
<b>Scan Angle</b>	70 deg +/- 35 deg from track)
<b>Field of View</b>	5.12 deg (along track)
<b>Usable Format</b>	29.323" X 2.147"
<b>Shutter</b>	Focal Plane
<b>Slit Widths</b>	Variable-- from 0.17 in to 0.30 in
<b>Film Load</b>	1. 70mm Wide 2. 8,000 ft per recoverable sub-system (part 1 or 2 of a mission) for each camera 3. 16,000 ft per recoverable sub-system 4. 16,000 ft per camera per mission 5. 32,000 ft total load for both cameras for a mission (part 1 and 2)
<b>End Lap</b>	7.6&percent;
<b>Image Motion Compensation</b>	Camera nods proportional to velocity/height (V/H) ratio
<b>Stereo Angle</b>	30.46 degrees
<b>Filter</b>	Variable -2 position commandable
<b>Film Type</b>	3404, Estar Base

Table 1. Corona panoramic camera data [1]

In this study, Corona photo acquired at the date “19/07/1963” by KH-4A panoramic forward camera was used. The pass was descending from north to south. Panoramic cameras are mounted in the photographic vehicle at a 15 degree angle from the vertical, thus forming a 30 degree convergence angle. The cameras are designated as forward-looking and aft-looking.



Figure 3. Small portion of a Corona image depicting historic peninsula of Istanbul (3m spatial resolution)

**2.1.1 Coverage of Corona KH-4 Camera:** Figure 2. shows the angles covered by the several cameras. KH-4A panoramic forward-looking and aft-looking cameras have swath width of 145 nautical miles (268.54 kilometers).

The cameras mounted on Corona system are:

- Panoramic cameras
  - Forward-looking camera
  - AFT-looking camera
- Horizon cameras (2)
- Index (terrain) camera
- Stellar camera

**2.1.2 Panoramic Camera Specifications:** Panoramic cameras view only a comparatively narrow angular field at any given instant through a narrow slit. Ground areas are covered by either rotating the camera lens or rotating prism in front of the lens. The scale variation, called panoramic distortion, is a result of the cylindrical shape of the focal plane and the nature of scanning. Also, scan positional distortion is introduced in panoramic imaging due to forward motion of the aircraft during the time a scan made. Compared to frame cameras, panoramic cameras cover a much larger ground area. With their narrower lens field of view, panoramic cameras can produce images with greater detail than frame images (Lillesand, T. M, Kiefer, R. W. 2000).

**2.2 SPOT-4 and IRS 1D**

	Acquisition Date	Spatial Res.	Swath Width
SPOT-4 PAN	1998	10 m	60 km
IRS-1D PAN	2000	5.8 m	70 km

Table 2. Summary of SPOT and IRS-1D satellite characteristics

**2.3 Study Area**

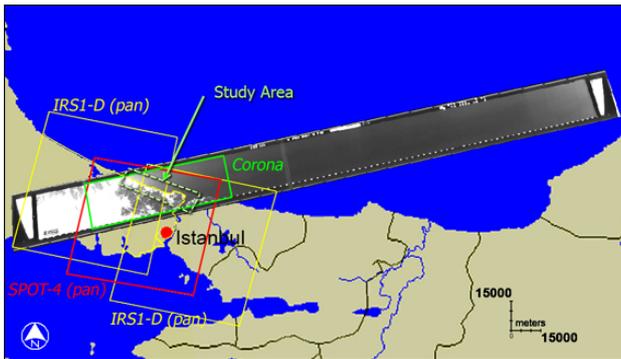


Figure 4. Localization of the study area and coverage areas of Corona, SPOT-4 PAN and IRS-1D PAN images

The study area is situated in the European peninsula of Istanbul, located in eastern of Durusu (Terkos) Lake, northwestern of Bosphorus between 41°20' and 41°10' North and 28°43' and 29°07' East (Figure 4).

**2.4 Creating georeferenced bases for change detection**

Rectification of an image requires accurate and homogeneously distributed ground control points. IRS-1D images were rectified on 1/5000 scaled orthophoto mosaic. To perform the rectification process, affine transformation method was used and the image was resampled by using nearest neighbor method. IRS1-D satellite images has been rectified on orthophoto mosaic using 40 control points with an RMS error of 0.6789 m. Likewise, SPOT4-PAN satellite imagery has been rectified on georeferenced IRS1-D images using 87 control points with an RMS error of 2 m. Consequently, the contemporary georeferenced basis was created for the scanned Corona panoramic film.

**2.4.1 Georeferencing scanned Corona panoramic film:** In this study, the changes of coastal lines were detected. Therefore, most of the control points were measured on costal

line zone on both the reference and input images. Naturally, the homogeneous distribution of the control points on the image has been taken in to account (Figure 5).

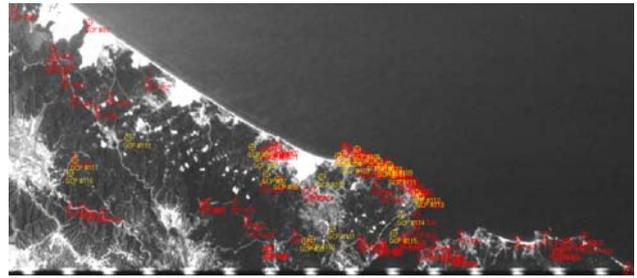


Figure 5. Distribution of GCP's on Corona image

The ratio between the altitude of Corona satellite (185200 m.) and the maximum exaggeration of elevation difference on the study area (100 m.) was calculated, it was seen that the relief displacements because of the elevation difference, can be ignored. Therefore, the study area was assumed to be flat and the polynomial rectification methods were realized.

To obtain best rectification result, three different methods were applied. These are affine, projective and rubber sheeting rectification methods.

**2.4.1.1 Rectification using Affine Transformation Method:**

The amounts of the residual errors were between ~10-20 m. in the areas which the control points were placed closely. However, the errors were within ~ 130 m. where control points set widely apart. These errors were occurred because of the panoramic structure of the Corona.

**2.4.1.2 Rectification using Projective Transformation Method :**

The full frame film of the Corona was rectified by using projective transformation method as a second step. The camera calibration report of Corona did not exist. Therefore the camera and film information were downloaded from internet and the fiducial mark coordinates were calculated.

Extent of the film : Width : 756.92 mm  
 Height : 55.372 mm  
 Focal distance : 609.6000 mm

The interior orientation was performed by using fiducial mark coordinates with 0.27 pixel (8.74micron) accuracy. After performing the interior orientation, the exterior orientation parameters were calculated by referencing the rectified IRS1-D image and measuring 30 control points with 2.8672m RMS error (mx=3.504, my=1.597).

The parameters are:

Xo : 516121.585 m  
 Yo : 4638002.163 m  
 Zo : 220809.223 m  
 Omega : -12.45414 °  
 Phi : 4.21308 °  
 Kappa : 12.38176 °

As a result of check point measurement on the rectified image, spatial errors were occurred between 100-250 m.

**2.4.1.3 Rectification using Rubber Sheeting Method:** To perform the triangle-based rectification, it is necessary to triangulate the control points into a mesh of triangles. Delaunay triangulation is most widely used and is adopted because of the smaller angle variations of the resulting triangles. This triangle based method is appealing because it breaks the entire region into smaller subsets. If the geometric problem of the entire region is very complicated, the geometry of each subset can be much simpler and modeled through simple transformation. For each triangle, the polynomials can be used as the general transformation form between source and destination systems (Erdas Imagine field guide).

The most popular method to register images (image to image, image to map), is rubber sheeting. Here, a low order 2D polynomial is fitted through data points and control points in order to transform an image to another image or to a map. The polynomial coefficients are then used to transform noncontrol points. The simplest transformation in this scheme is an affine transformation (Schenk, T. *et al*, 2003).

X	1.1554 meters
Y	1.0977 meters
Total	1.5937 meters

Table 3. Check Point Error

The final step of Rubber Sheeting method was performed by measuring 94 control and 24 check points with 1,6 m. accuracy (Table 3.). Best results were obtained by using Rubber Sheeting method as shown in Table 4.

	Affine	Projective	Rubber Sheeting
RMS Errors	~130 m.	100-250 m.	1.6 m.

Table 4. The error comparison of three methods

## 2.5 Detecting the temporal coast line changes of the study area

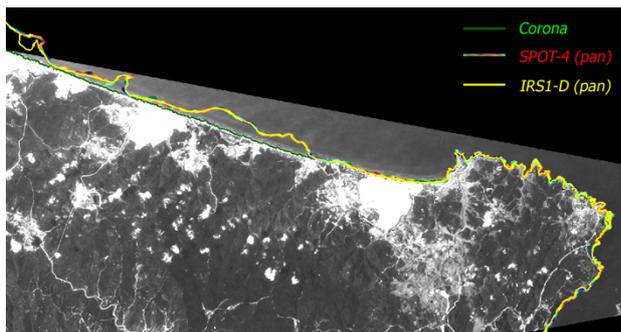


Figure 6. Coast lines of the study area at acquisition dates of images; Corona(1963), SPOT-4(1998) and IRS-1D(2000)

The coast line was manually digitized on georeferenced Corona, SPOT-4 PAN and IRS-1D PAN images. Coast line change detection amount is calculated by subtracting 2000 dated data set from 1963 dated data set, 1998 dated data set from 1963 dated data set and 2000 dated data set from 1998 dated data set. Noteworthy changes were observed.

The coastal zone differences between the data sets are shown at the table below.

Period	Amount of change	
	Increase(hectares)	Decrease(hectares)
1963-1998	633.126	66.000
1998-2000	11.535	153.079
1963-2000	488.950	63.367

Table 5. The coastal zone differences between the data sets

## 3. CONCLUSION

Detection of temporal changes especially at metropolis cities such as Istanbul provides more reliable estimates for future of the city. Corona photographs acquired on 1963, because of their high spatial resolution, present us very rich information about the study area. These photos have property of documentation of history, therefore natural and human made changes can be detected with the aid of these photos.

The critical point of the study was georeferencing stage of the scanned Corona photographs. The unknown parameters of the camera and its interior orientation elements, made us put into practice different methods. Affine and projective transformation methods gave unacceptable errors. The erroneous results of affine transformation emanate from the panoramic structure of Corona. On the other hand, the erroneous results of Projective transformation emanate from, fiducial marks does not exist on Corona film, consequently principal point of the photo could not be designated with enough accuracy. The probable error (even 1 pixel) could be made at designation of the principal point of the photographs changes the projection geometry completely. This problem was eliminated with the use of Rubber sheeting method, independent from central projection geometry, using only a part of the film that includes study area. Corona image was registered to IRS-1D PAN image with 1.6 m. RMS error. Registered Corona, SPOT-4 PAN and IRS-1D PAN images were compared and temporal changes at coastal zone was determined.

It's thought that Corona panoramic photographs can be used to detect especially the temporal changes of land use. Thus, the information of the texture of the cities, when it was not corrupted, could be obtained. This information can be used in GIS studies and planning applications which have realistic criterion. Then, more concrete precautions could be taken by local authorities to protect the texture of the city. The most important advantage that Corona photographs have is providing synoptic view more quickly and more economically.

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