TECHNICAL SUGGESTION TO JURIDICAL DISCUSSION:

A CASE STUDY FOR AEGEAN SEA

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ABSTRACT

The Aegean is a semi-closed sea that has unique geographical features and bears equal strategic, economic and political importance for two states, Turkey and Greece. These cardinal facts necessitate the establishment and maintenance of a delicate balance between the interests of the two countries in the Aegean Sea. Determining the baseline and the maritime line around the Aegean Sea between Greece and Turkey has been a juridical problem for years. All of the evaluations and decisions are made on a map during the discussions of the Aegean territorial water and continental shelf. A map, which will be used for such a reason, must be accurate, updated and reliable. Turkey and Greece produce their own map sheets according to their own references and standards. Map using remotely sensed imagery should be more suitable carrying the above conditions. In this study, Landsat-MSS images, with 80m

resolution are used for producing of Aegean Sea map. Those images are attached as a raster file into the AutoCAD Map environment after rectification and mosaicking. The coastal lines of the mainland and islands are digitised on screen as polylines. The lengths of lines and the area of the Aegean basin are calculated and compared under different cartographic assumptions. The results, which can be used as reliable criteria for juridical discussions, are presented.

INTRODUCTION

The Aegean Sea has equal strategic, economic and political importance for its two states, Turkey and Greece. Therefore determining the baseline and the maritime line around the Aegean Sea between Greece and Turkey and the line, from which the outer limits of the State's territorial sea are measured, have been discussed and interpreted for years between those countries. In this study, the Landsat MSS satellite imagery is used in order to produce a digital vector map covered this area. Because, remotely sensed multispectral data collected from satellites provide a systematic, synoptic ability to assess conditions over large areas on a regular basis (Jakubauskas and Price, 1997). Geometric reprocessing of the Landsat MSS images was performed using ERDAS Imagine 8.2 software. All images were geometrically corrected by using 1:50 000 scale topographic maps. Rectified images have been used to create image mosaic.

According to the European standards Turkey and Greece produce their national map sheets in Universal Transverse Mercator (UTM) System. Therefore the reference coordinate system is selected UTM by the rectification process. On screen digitised vector data are created first UTM with central meridian 27^0 in 6^0 interval that used for mapping the regions in the sides of

Turkey. The same data are transformed then to the system with 21^0 central meridians, which used mapping the Greek region. It is also transformed using a non-standard central meridian, which goes through the middle of the study area such as 25^0. The length of the coastline belongs two countries has been evaluated according to the three central meridian mentioned above. The water area of Aegean Sea has also been computed. All digitised data was transformed into an equal-area projection surface. On this surface, the total water area of the sea was computed. Finally, true length and area values have been obtained and presented. The results, which can be used as reliable criterion for juridical discussions, are presented and discussed.

THE BOUNDARIES OF THE AEGEAN SEA

The Aegean Sea is surrounded by the western coasts of Anatolia from the east, the southern coasts of Thrace and Eastern Macedonia from the north, the eastern coasts of Thessaly and Peloponnese peninsula from the west and the islands of Crete and Rhodes from the south. It covers an area of 191,000 km^2 approximately.

There is no unique definition on the southern boundary of Aegean Sea. For this study some of the definitions from encyclopedic sources are interpreted (Ana Britannica, 1994, p.101), International Hydrographic Bureau (SP23, 1953), and national atlases (Atlas, 1993, p.59). Using all these sources, a boundary, especially in the southern region of Aegean Sea, may be suggested which can be commonly accepted. This non-natural boundary has to have some characteristics as natural boundary. The deep trough situated to the south of Crete, Karpotos and Rhodes islands, is the surface indication of a major feature, which cuts across the whole lithosphere. This through is a principal element of a plate boundary. It could be either a trench (Le Pichon and Angelier, 1981; Spakman et al., 1988; Makris 1978, Makris and Stobbe,

1984) or a fore-arc (Hellenic) basin (Le Pichon et all.,1982) in “plate tectonics terminology”. A boundary for the Aegean Sea is defined under these decisions with geographic locations shown in Figure 1 (Goksel et al. 1999, Goksel et al. 2001).

Figure 1. The boundaries of Aegean Sea

IMAGE PROCESSING AND DIGITIZING

The satellite images used here are Landsat-MSS Images, with 80m spatial resolution. The MSS scene is defined as an image representing a ground area approximately 185km in the east-west direction and 178km in the north-south direction. The MSS scene is an array of pixel values (in each of four bands) consisting of about 2400 scan lines, each composed of 3240 pixel. There is a small overlap about %5 between scenes in the path to the north and south. The side overlap to the east and west depends on latitude. It can be said that there is an approximately %30 sidelap near the 40° latitude(Campbell, 1996).

A series of image frames has been joined to form a mosaic. This mosaic is covered spatially by 17 Landsat MSS images. All imagery was collected from July to September 1993. 1:50000 scaled standard topographic maps are used for rectification process. The study area covered by 17 frames includes approximately 115 map sheets. In this study 91 of them are used for selecting ground control points. Totally 279 ground control points are selected on the 1:50 000 scale maps and they used for the rectification map to image. Approximately 100 control points are also used for image to image rectification. So it can be said that approximately 20 control points was used for each frame. The 1:50 000 scale topographic maps belong to the Turkey are produced in the UTM projection system, zone 35. The Greek maps are produced in the same projection system, but in a different zone (zone 34). The coordinates of ground control points which lies in UTM zone 34 are transformed to the UTM zone 35 (Goksel et al. 1999). Positional accuracy of satellite images generally means the degree of accuracy of an image corrected geometrically. Correction, in this sense, contains a register into a reference coordinate system with a resampling method (Goksel, 1998; Irish, 1990; Jansen and Van der Well, 1994). First order polynomial rectification method and nearest-neighbor resampling method are used in this process. A total root mean square (RMS) error between 0.35 and 0.55 pixel is reached for each of the images. ERDAS Imagine 8.2 version is used a mosaic of Aegean Sea has been prepared, which is shown in Figure 2 (Goksel et al. 1999).

The natural coastal line belongs two countries has been digitised using this mosaic with on screen digitising method. The digitised coastal line has been examined in respect of digitising errors like undershoots, overshoots etc. After some corrections, lines are enhanced which topologically consistent.

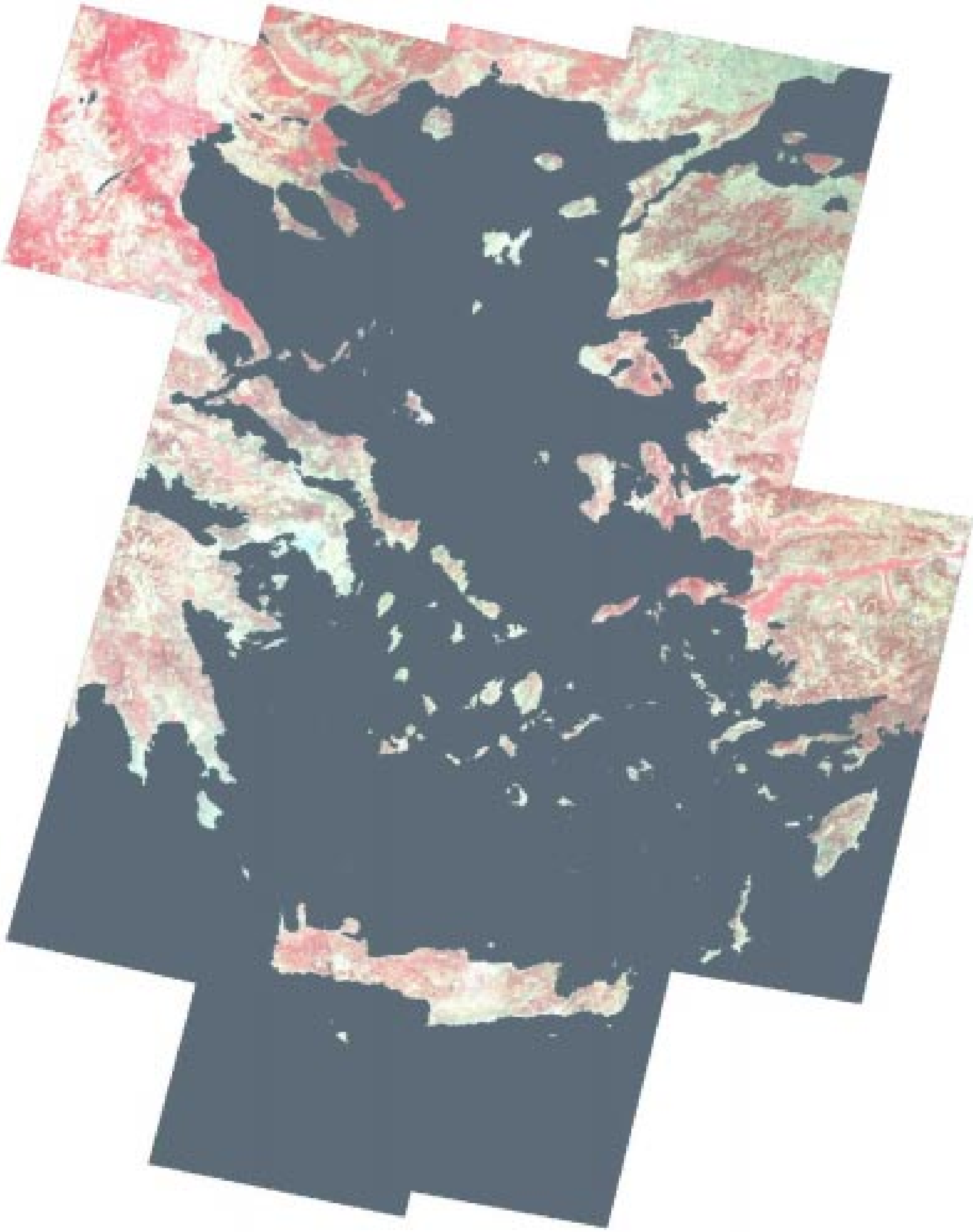

Figure 2. The mosaicked Landsat MSS image of the Aegean Sea

Six layers for classification of the lines are generated as COAST_TURK (coastal line of Turkey), ISLAND_GREEK (islands belong to Greece), ISLAND_TURK (islands belong to Turkey), COAST_GREEK (coastal line of Greece), CONNECTION *LINE* (the southern extremity of Aegean basin in water region) and ISLANDGREEK_MIX (the northern coastal lines of the Greek islands on the southern part of the Aegean Sea). The digitised vector data are represented in Figure 3.

Figure 3. Digitised data

For each category the lengths and area have been calculated (Goksel et al. 1999). These categories and related results of the first part of the study are shown in Table 1.

Table 1: The lengths and area for each category (km^2-km)

	Turkey	**Greece**	**Aegean Sea**
Number of islands and rocks	96	460	556
Total area of islands and rocks	427,29	12613,04	13040,33
Total perimeter of islands and rocks	470,02	6792,96	7262,98
Length of natural coastal line of partial Aegean islands (Kithira, Crete, Karpatos and Rhodes)	0,00	948,72	948,72
Length of natural coastal line without islands	2327,81	2732,04	5059,85
Length of natural coastal line with islands	2797,83	10473,72	13271,55
Total water area	--	--	193950,33
Total perimeter of sea	--	--	6337,14

DISTANCE AND AREA COMPARISIONS UNDER DIFFERENT APPROACHES

Using the digitised data, the lengths of coastal lines belong to Turkey and Greece respectively and the area of the Aegean basin are calculated and compared under different cartographic assumptions in order to analyse the differences obtained from different reference parameters.

Aegean Sea takes place in the UTM zones with the numbers 34 and 35. The central meridians of these zones are λ_o=21° and λ_o=27° respectively. The digitised coordinates are the UTM coordinates according to the central meridian λ_o=27° East. The ellipsoidal longitudes and latitudes are then computed from these UTM plane coordinates using inverse solution. Using this geographical data the UTM coordinates are computed according to the central meridian λ_o=21° and to a non-standard meridian λ_o=25° which goes through the middle of the Aegean Sea. The length of the geodesic for each segment between the consecutive points is calculated using the ellipsoidal coordinates (Maling 1992, Pearson 1990 and Leick 1995).

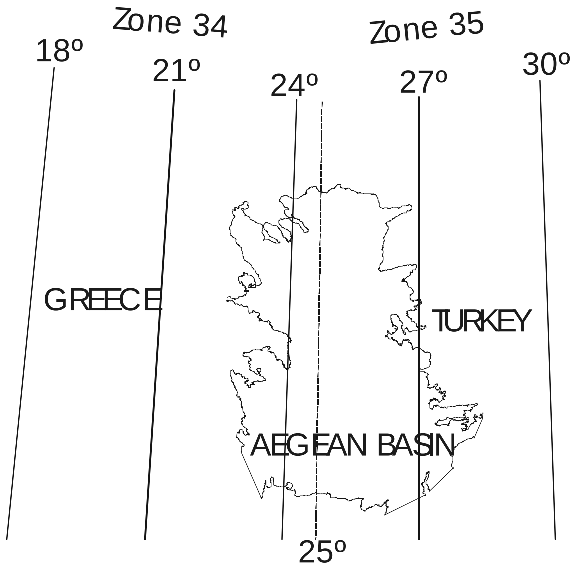

Figure 4. The meridian interval covers Aegean Basin

In UTM system, distortions increase away from the central meridian. The effect of such distortions causes wrong comments during discussions about the length of the coastal lines. Turkey is approximately 200km far away from the 21°meridian. Greece is approximately 275km far away from the 27° meridian. Because of these reasons calculations made in two zones 35 and 34 respectively. The lengths of the lines for each layer are computed for those two zones and compared with the lengths of geodesic. As a suggestion non-standard central meridian is chosen as 25° which goes through the middle of the study area. The calculations are repeated for this central meridian. The results are presented in Table 2. The differences of the lengths from the true lengths of geodesic are also presented in Table 3 (Goksel et al. 2001).

Table 2: The lengths computed from UTM coordinates using different central meridian (m)

Layer	**Length of Geodesic**	**λ_o=21°** **(ZONE 34)**	**λ_o=25°** **(non-standard)**	**λ_o=27°** **(ZONE 35)**
COAST_TURK	2328640.455	2336191.443	2328832.937	2327807.118
ISLAND_GREEK	6792776.086	6803017.685	6791117.209	6792962.766
ISLAND_TURK	470182.299	471460.468	470147.977	470018.038
COAST_GREEK	2729884.068	2730438.442	2729492.849	2732040.255
CONNECTION_LINE	328529.493	329335.863	328561.787	328573.026
ISLAND_GREEK_MIX	948645.503	950425.984	948517.200	948719.539
AEGEAN BASIN	6335699.507	6346391.719	6335404.761	6337139.938

Table 3: The differences from the length of geodesic (m)

Layer	**λ_o=21°**	**λ_o=25°**	**λ_o=27°**
COAST_TURK	7550.988	192.482	-833.337
ISLAND_GREEK	10241.599	-1658.877	186.68
ISLAND_TURK	1278.169	-34.322	-164.261
COAST_GREEK	554.374	-391.219	2156.187
CONNECTION_LINE	806.370	32.294	43.533
ISLAND_GREEK_MIX	1780.481	-128.303	74.036
AEGEAN BASIN	10692.212	-294.746	1440.431

As can be seen the differences in Table 3, if the central meridian 21° is selected, so the length of the coastal line of Turkey is calculated approx. 7.6km long as it should be. Oppositely, if the central meridian 27° is selected, so the length of the coastal line of Greece is calculated approx. 2.2km long as it really should be.

During distance calculations with the UTM coordinates it is suggested that if the distance reduction adds to the coordinates the computed distance has closed to the distance on the ellipsoid (Leick 1995). Therefore all of the calculations are repeated using these reductions for each central meridian mentioned above. The results are presented in Table 4. The differences of the lengths computed with reductions are also compared with the lengths of geodesic and the results are presented in Table 5 (Goksel et al. 2001).

Table 4: The lengths computed from UTM coordinates with distance reduction

Layer	**Length of Geodesic (m)**	**λ_o=21°** **(ZONE 34)**	**λ_o=25°** **(non-standard)**	**λ_o=27°** **(ZONE 35)**
COAST_TURK	2328640.455	2328173.628	2328200.100	2328201.213
ISLAND_GREEK	6792776.086	6791455.370	6791476.050	6791477.599
ISLAND_TURK	470182.299	470089.892	470093.855	470093.971
COAST_GREEK	2729884.068	2729383.322	2729378.051	2729370.655
CONNECTION_LINE	328529.493	328445.532	328449.064	328450.114
ISLAND_GREEK_MIX	948645.503	948457.287	948459.723	948461.388
AEGEAN BASIN	6335699.507	6334459.757	6334486.926	6334483.371

Table 5: The differences from the length of geodesic

Layer	**λ_o=21°**	**λ_o=25°**	**λ_o=27°**
COAST_TURK	-466.827	-440.355	-439.242
ISLAND_GREEK	-1320.716	-1300.036	-1298.487
ISLAND_TURK	-92.407	-88.444	-88.328
COAST_GREEK	-500.746	-506.017	-513.413
CONNECTION_LINE	-83.961	-80.429	-79.379
ISLAND_GREEK_MIX	-188.216	-185.780	-184.115
AEGEAN BASIN	-1239.750	-1212.581	-1216.136

As can be seen in Table 4 and the differences in Table 5, in case for an arbitrary choice of central meridian the results will be relatively correct considering the distance reduction.

During juridical discussions on the water area liability between countries, the main problem is often the comparison of the areas of islands and their percentage to the total water area. Therefore method which is used for the area calculations is very important and critical.

UTM system is based on the ellipsoidal transverse Mercator projection, which has a cylindrical and conformal feature. On conform projections the areas are not preserved cause of the area deformations and therefore it is not suitable for area comparison. In order to analyse the distortions of the area values obtained from the UTM coordinates, it is decided to calculate an area on an equal-area projection. The Lambert azimuthal equal-area projection is selected for this purpose. The plane coordinates are computed for this projection using ellipsoidal longitude and latitude values obtained from the inverse solution (Snyder 1982). The area values for the total Aegean basin are calculated using UTM coordinates with central meridians 21°, 25° and 27° respectively and using the Lambert equal-area projection coordinates. The results are presented in Table 6. The differences of the areas from the area computed from the equal-area projection coordinates are shown in Table 7 (Goksel et.al 2001).

Table 6: The Aegean water area (km^2)

Area computed from the Lambert equal-area projection coordinates	206964.50
Area computed from UTM coordinates (λ_o=21°)	207555.01
Area computed from UTM coordinates (λ_o=25°)	206964.84
Area computed from UTM coordinates (λ_o=27°)	206990.66

Table 7. The area comparison of the Aegean water area (km^2)

	(λ_o=21°)	(λ_o=25°)	(λ_o=27°)
Difference (m^2)	-590.52	-0.34	-26.16

The centre point for the Aegean Sea is calculated as φ_o=38°17′27″ and λ_o=25°04′49″. The area reduction values are also computed using these coordinates according to the central meridians 21°, 25° and 27° respectively by using Gaussian radius of curvature as 6373.363km for the central latitude (Maling 1992). The differences from the true area are also compared with the area reduction values and the results are shown in Table 8 (Goksel et.al 2001).

Table 8. Comparison of the differences with the area reductions

	(λ_o=21°)	(λ_o=25°)	(λ_o=27°)
Area Reduction (km^2)	-649.041	-0.251	-143.618
Difference (km^2)	-590.516	-0.340	-26.160

CONCLUSION

The aim of this study was to determine the natural coastal line of Aegean Sea up to date. For this purpose the Landsat MSS Satellite imagery is used. The accuracy of the results is limited to spatial resolution of this imagery. In the case of using of national topographic maps of Turkey and Greece, some important problems could occurred as; different data, projections, scale and generalisation level of national map sets, different production time of map sets, different data acquisition and evaluation methods and different data sources.

The benefits of the natural coastal line of this study are summarised as follows: up to date satellite imagery was used; this satellite imagery is more reliable than existing maps; the coastal line was digitised according to objective criteria; the spatial accuracy is sufficient for global analysis of Aegean Territory.

On juridical discussions for determining the baseline between Turkey and Greece in the Aegean Sea it is suggested that it will be more reasonable to study with the UTM coordinates computed for a non-standard central meridian such as 25° which goes through the middle of the Aegean region. By calculating distances or the lengths of coastlines, the distance reduction bring to sufficient results. It is also suggested that it is necessary to select an equal area projection for area calculations. If this is not possible, in that case it is highly recommended that to add the area reduction values to the areas obtained from the UTM coordinates.

For future studies about same subject to reach excellent results, it is also suggested that it would be increase the accuracy, processing with the homogeneous distributed data collected from satellites of the Global Positioning System (GPS) and using remote sensing images which provide higher resolution than Landsat MSS.

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