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Geomatics Aspects of the UN Convention on Law of the Sea – A Case Study

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The United Nations Convention on Law of the Sea (UNCLOS) came into force on November 18, 1994 to provide the legal framework for maritime boundary delimitation. Understanding the geomatics aspects of UNCLOS is vital for coastal nations to claim the ownership of the natural resources within the limits of their Continental Shelf. This paper discusses some of the geomatics aspects of UNCLOS, namely the geodetic and uncertainty issues. A case study for Egypt's outer limits is also presented.

KEY WORDS

1. Law. 2. Geomatics. 3. Maritime.

1. INTRODUCTION. The United Nations Convention on Law of the Sea (UNCLOS) came into force on November 18, 1994 to provide the legal framework for the maritime boundary delimitation. UNCLOS is considered to be one of the most comprehensive and complex treaties in history (Monahan and Wells, 2001). Under UNCLOS, a coastal state has various standard outer limits, which are measured seaward from the territorial sea baseline. The baseline separates the state's internal waters and territorial sea, and comprises either the low-water line of the coastline as shown on large-scale nautical chart officially recognized by the coastal state or straight lines joining low-water points (IHO, 1993). The standard limits define the boundaries of specific maritime zones, namely the territorial sea, the *Contiguous Zone*, the *Exclusive Economic Zone* (EEZ) and, in some cases, the *Continental Shelf*. The coastal state has sovereignty rights over the seabed resources in these zones, provided that the boundary claims of adjacent and/or opposing states are taken into account.

Accurate determination of the baselines, and consequently the various zone limits, is critical, particularly for a coastal state claiming sovereignty over mineral rights. Such accuracy will be affected by several factors, including geodetic and uncertainty factors. This paper shows how the various zone limits can be constructed, and discusses the associated geodetic and uncertainty factors. A case study for Egypt's outer limits is also presented.

2. CONSTRUCTION OF ZONE LIMITS. To establish the various standard outer limits of a coastal state in accordance with UNCLOS, the baselines must first be constructed. The state's outer limits, namely the territorial sea, the

Contiguous Zone, the *Exclusive Economic Zone* (EEZ) and, in some cases, the *Continental Shelf*, are measured seaward from the baseline (Kapoor and Kerr, 1986). Normally, according to Article 5 of the Convention, the *low-water line* of the coastline as shown on large-scale nautical chart, officially recognized by the coastal state, defines the baseline. In exceptional cases, such as a bay closing line, a *system of straight lines* joining low-water points is used (Monahan and Wells, 2001). A combination of normal baselines and straight lines along a particular stretch of the coast are permitted under UNCLOS to suit specific conditions (Kapoor and Kerr, 1986).

Once the baselines have been established, the outer limit of the *territorial sea* can be determined as the line that departs from the baselines by a distance not exceeding 12 nautical miles. Normally, the envelope line method is used for constructing the territorial sea limits, which uses swinging arcs from points along the baseline (Kapoor and Kerr, 1986). The sovereignty of the coastal state is extended to the territorial sea, but regulated by the Convention and other rules of international law (IHO, 1993). The rights of innocent passage for foreign ships, with other limitations, are granted under the Convention. The outer limits of the *Contiguous Zone* and the *Exclusive Economic Zone* are the lines that depart from the baselines by distances not exceeding 24 and 200 nautical miles, respectively. The Convention states that these baselines are those 'from which the breadth of the territorial sea is measured.'

The determination of the outer limits of the *Continental Shelf* is not as straightforward as that of the other jurisdictional zones. Article 76 of UNCLOS provides the details of how the outer limits of the *Continental Shelf* can be constructed. The following seaward limits must first be determined, namely (see Figure 1):

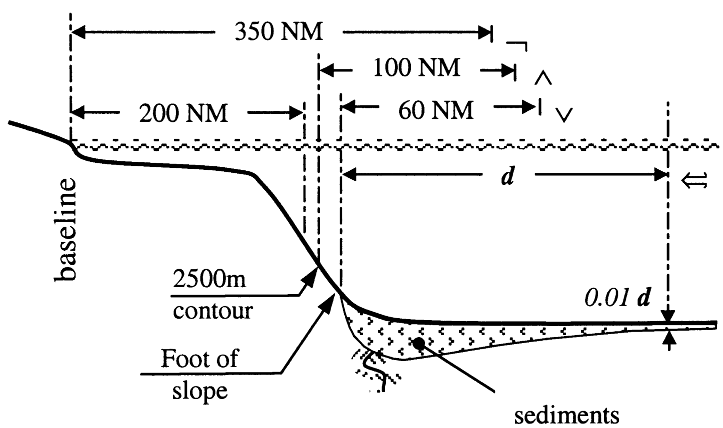

Figure 1. Possible Limits for the Continental Shelf.

(a) 350 nautical miles measured from the baseline;
(b) the distance measured from the baseline to the 2500 m bathymetric contour plus 100 nautical miles;
(c) the distance measured from the baseline to the foot of the slope, i.e. the point of maximum change in the seafloor gradient at its base, plus 60 nautical miles; and

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(d) the distance measured from the baseline to the foot of the slope plus a distance *d* at which the sediment thickness is 1% of *d*.

Clearly, not only hydrographic services are required to determine these issues but also geological and geophysical services. Limits (a) and (b) are combined to determine the most seaward segments, which form the cut-off line for the *Continental Shelf*. Similarly, limits (c) and (d) are combined to determine the most seaward segments, which form the combined formula line. Finally, the cut-off line and the formula line are combined to determine the most landward segments, which form the final outer limit of the *Continental Shelf*.

In circumstances involving the maritime boundary delimitation of adjacent or opposing states, the above outer limits are modified to ensure an equitable solution for the neighbouring states. The Convention uses the principles of equidistance and median line for this purpose (IHO, 1993). It should be pointed out that, unless the neighbouring states adopt the same geodetic datum as well as the same system of baselines for defining the equidistant line (i.e. the low-water line or a system of straight lines) technical problems could occur (Kapoor and Kerr, 1986).

3. GEODETIC EFFECTS.

3.1. *The Datum Issue*. In the past, positions with respect to horizontal and vertical datums have been determined independent of each other (Vanicek and Krakiwsky, 1986). In addition, horizontal datums were non-geocentric and were selected to best fit certain regions of the world. As such, those datums were commonly called *local datums*. Over 150 local datums are used by different countries of the world. Examples of the local datums are the Old Egyptian 1906 and the North American datum of 1927 (NAD 27). Local systems are distorted due to a number of factors including: the geometrical weakness in the control network, the unavailability of an accurate geoid and non-rigorous estimation methods (Pinch, 1990). With the advent of space geodetic positioning systems like GPS, it is possible to determine the three-dimensional positions with respect to global geocentric datums, e.g. the World Geodetic System of 1984 (WGS 84). WGS 84 was originally realized using a number of Doppler stations. It was then updated several times to bring it as close as possible to the International Terrestrial Reference Frame (ITRF) by defining it with particular reference stations within ITRF. The International Hydrographic Organization (IHO) has adopted the WGS 84 system for nautical charts (IHO, 1993).

Old maps and nautical charts were produced with local datums, while the newer ones are mostly produced with the geocentric datums, e.g., WGS 84. Therefore, to ensure consistency, it is necessary to establish the relationships between the local datums and WGS 84. Such a relationship is known as *datum transformation*. The former US Defence Mapping Agency (DMA now incorporated into a new agency, NIMA) has published the transformation parameters between WGS 84 and the various local datums used in many countries. It should be clear, however, that these transformation parameters are only approximate and must be used with care. The best way to obtain the transformation parameters is by comparing the coordinates of well-distributed common points in both datums. Some hydrographic offices have already published new nautical charts in the WGS 84 (or NAD 83) system. The UK hydrographic office has also published new editions of nautical charts in the WGS 84 system for various countries, including Egypt.

Vertical datum, on the other hand, is used as a reference surface to which the heights of points (or depths) are referred (El-Rabbany, 2001). To maximize the safety of marine navigation, depths shown on nautical charts are referenced to a chart datum (CD), which represents the lowest normal tides (Kapoor and Kerr, 1986). The definition of the lowest normal tides, however, is ambiguous as it varies among the different hydrographic offices. The IHO has recently adopted the Lowest Astronomical Tide (LAT) as the international standard.

3.2. *The Chart Projection Issue*. Chart projection is defined, from the geometrical point of view, as the transformation of the physical features on the curved earth's surface onto a flat surface, i.e., the nautical chart. Unfortunately, because of the difference between the ellipsoidal shape of the earth and the flat projection surface, the projected features suffer distortion. A number of projection types have been developed to minimize chart distortions, with the conformal projection being the most widely used (El-Rabbany, 2001). With conformal projections, the angles on the surface of the ellipsoid are preserved after being projected onto the flat projection surface. However, both the areas and the scales are distorted. The most popular conformal map projections are Mercator, transverse Mercator, Lambert Conformal and Stereographic. Apart from the polar regions, most nautical charts use the Mercator projection as it is the most suitable for navigational use (IHO, 1993). On the Mercator projection, the Loxodrome, a line on the surface of the ellipsoid that crosses the successive meridians at the same angle, will be projected as a straight line (Figure 2a). This means that, on the Mercator projection, the same angle of bearing

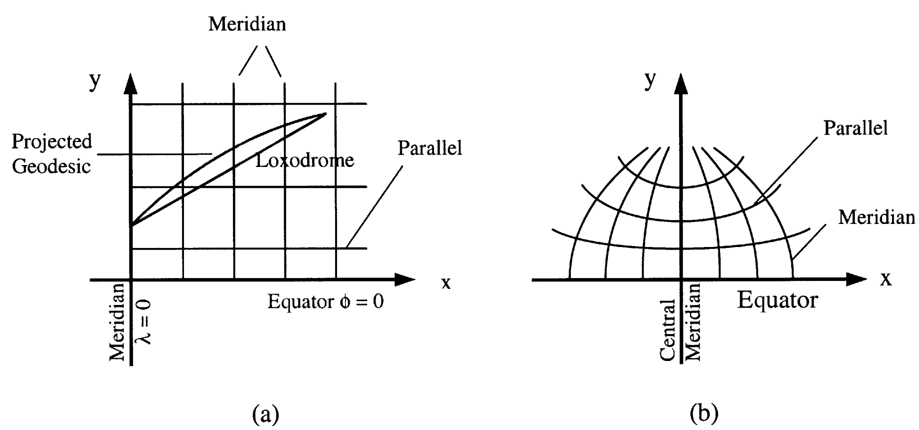

Figure 2. (a) Mercator Projection; (b) Transverse Mercator Projection.

can be preserved with respect to successive meridians. However, a major disadvantage with the Mercator projection is that the scale factor changes as a function of latitude. This characteristic makes the Mercator projection inappropriate for constructing maritime boundaries, particularly for distances greater than the breadth of the territorial sea. Some regions of the world, such as Alexandria, Egypt, use the transverse Mercator projection (Figure 2b). With this projection, the scale is true along the central meridian. The scale factor increases symmetrically with movement away from the central meridian, causing distortion to the projected features.

3.3. *The straight line issue*. The Convention specifies that a straight line shown on a large-scale nautical chart, officially recognized by the coastal state, be used for measuring the distances to the outer limits. In general, however, a straight line on the nautical chart will be different from the geodesic curve on the reference ellipsoid, which is the intended straight line in the Convention. The latter is defined by the differential equations (Sjoberg, 2002):

$$\cos\alpha \, \mathrm{d}S = M \, \mathrm{d}\phi, \tag{1}$$

$$\sin\alpha \, \mathrm{d}S = N \cos\phi \, \mathrm{d}\lambda, \tag{2}$$

and

$$\mathrm{d}\alpha = \sin\phi \, \mathrm{d}\lambda, \tag{3}$$

where dS is the infinitesimal arc length of the geodesic curve, M and N are the meridianal and prime vertical radii of curvature of the reference ellipsoid, α is the geodetic azimuth, and ϕ and λ are the geodetic latitude and longitude, respectively.

The relationship between the geodesic curve and the straight line on the transverse Mercator chart, for example, is given by (Krakiwsky, 1973)

$$S \approx d\left[1 - \frac{1}{6NM}(x_1^2 + x_1 x_2 + x_2^2)\right], \tag{4}$$

where x_1 and x_2 are the x-components of the mapping coordinates of the two end points of the geodesic line, and d is the chord length.

It should be pointed out that equation (4) assumes that the projected geodesic can be approximated by the chord. The difference between the geodesic curve and the straight line on the chart could be significant, depending on the length of the line, the direction and the latitude (IHO, 1993).

4. UNCERTAINTY EFFECTS.

The determination of a state's maritime boundaries involves various types of field measurements, namely:

(a) geodetic, hydrographic and tidal measurements, which are required for the creation of the nautical charts; and
(b) hydrographic, geological and geophysical measurements, which are needed for the construction of the limits of the *Continental Shelf*, if applicable.

Field measurements, on the other hand, contain errors that are of a random and, in some cases, a systematic nature. Random errors can be treated using stochastic models, while the systematic errors can generally be modelled using deterministic models.

The uncertainties in the geodetic measurements originate mainly from the limitations in the employed geodetic technique, i.e. terrestrial or space. Such uncertainties will be propagated into the estimated positions, which can be represented geometrically by the error ellipses in the case of horizontal positions. Old charts were based on terrestrial techniques, which are far less accurate than modern space techniques. In addition, the distribution of the positioning uncertainty is not expected to follow a consistent pattern across the chart. This is mainly due to the inconsistent datum distortion as well as the discrepancy in the measuring techniques in the subsequent chart versions.

A number of hydrographic offices are currently involved in producing ECDIS databases by digitizing existing paper charts. This, however, has the disadvantage that the paper charts are generally based on local datums as indicated above. This means that the proper datum shifts must be applied to ensure consistency.

Unfortunately, due mainly to the inconsistent distortions in the old datums, the transformation parameters cannot be determined accurately in many cases. Therefore, the associated uncertainty parameters must be considered when estimating the limits of a state's outer boundaries. Also, the existing paper charts in some areas were based on old hydrographic surveying methods, for example, the leadline method, which are far less accurate than the required standards for either navigational or boundary delimitation purposes. A complete resurvey of those areas might be required to overcome this problem. A final paper-chart-related problem is the shrinking or stretching of the chart due to the environmental changes. This, however, may not be significant if the chart was handled with care (IHO, 1993).

The low-water line shown on nautical charts represents the lowest normal tides, which, as stated above, is defined differently by the various hydrographic offices. Although the IHO adopted the LAT as the international standard in 1997, the implementation of such adoption will take years (Monahan and Wells, 2001). This is mainly due to the lack of enough tide data over 19 years, which is required for LAT. Uncertainties in the tide measurements as well as tide prediction will affect the determination of the low-water line, and consequently the construction of the state's outer limits. The size of the horizontal displacement error of the low-water line could reach several tens of metres, depending on the shore-face slope and the uncertainty in the tide measurements.

The construction and determination of the limits of the *Continental Shelf* is the most challenging, as it requires extensive hydrographic, geological and geophysical surveys of the seafloor. The size of error in the determination of the 2500 m bathymetric contour may reach hundreds of metres, depending on the slope of the seafloor and the precision of the depth measurements. However, an error in the order of several kilometres is expected in the determination of the foot of the slope and sediment thickness (Monahan and Wells, 2001).

5. CASE STUDY: THE EGYPTIAN MARITIME BOUNDARIES.

Nautical charts for the Egyptian coasts are produced, to the author's knowledge, by the UK hydrographic office. The charts use hydrographic data that were collected mainly by the Egyptian, the US and the British governments. Unfortunately, as shown in Table 1, the charts in some areas of Egypt were based on old survey

Table 1. Chart Data Sets for the Port of Alexandria (Source: Admiralty chart No. 3119).

Agency	US Gov.	British Gov.	British Gov.	British Gov.
Year	1995–96	1933–43	1935–36	1920
Scale	1:5000	1:4000–10000	1:18500	1:100000

methods, which are far less accurate than the required standards. In fact, some areas of the Egyptian waters were surveyed in the 19th century. As such, a complete resurvey of those areas might be required to overcome the large and inconsistent uncertainties, as explained above. Although the UK hydrographic office has published new editions of nautical charts in the WGS 84 system for the Egyptian coasts, chart distortion remains, which leads to inaccurate determination of Egypt's maritime outer limits. In addition, since the charts are produced by UK Hydrographic

Office, official recognition of these charts should be considered in the determination of Egypt's maritime outer limits.

Egypt ratified UNCLOS on August 26, 1983. Egypt may claim various outer limits, as discussed above, subject to bilateral agreements with neighbouring states. Due to the limited breadth of the Red Sea, the concept of equidistant line should be used, subject to bilateral agreements with the neighbouring states. Egypt may not need to conduct geological and geophysical surveys of the seafloor due to the limited breadth of both the Red and the Mediterranean Seas.

6. CONCLUSIONS. This paper examined some of the geomatics issues of UN Convention on Law of the Sea. It was shown that, unless the geodetic and uncertainty factors are considered, inaccurate determination of the state's maritime outer limits would be expected, which in turn could lead to serious economic and sovereignty problems. The inconsistent uncertainty distribution across nautical charts is yet another factor that must be considered in maritime boundary delimitation. The construction of outer limits of the *Continental Shelf* is the most challenging, particularly for developing nations, due to the cost and the time constraints. In the circumstances involving bilateral maritime boundary delimitation, it is essential that the neighbouring states use a common geodetic datum, and adopt the same system of baselines for defining the equidistant line. To ensure accurate determination of Egypt's outer maritime boundaries, new editions of nautical charts, based on modern measurement techniques, are required for the Egyptian waters.

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