Maritime Boundary Delimitation in Accordance with the UN Convention on Law of the Sea — Some Technical Issues

By Dr. Ahmed El-Rabbany, Dept. of Civil Engineering, Ryerson University

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. The UNCLOS is considered to be one of the most comprehensive and complex treaties in history (Monahan and Wells, 2001). Understanding the technical aspects of the UNCLOS, namely the geodetic and uncertainty factors, is vital for coastal nations to claim the ownership of the natural resources within the limits of their Continental Shelf.

1. Introduction

Under the 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 article shows how the various zone limits can be constructed, and discusses the associated geodetic and uncertainty factors.

2. Construction of Zone Limits

To establish the various standard outer limits of a coastal state in accordance with the 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 a large-scale nautical chart, officially recognized by the coastal state, defines the normal 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, and 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 the 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 the 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 (Figure 1): (1) 350 nautical miles measured from the baseline; (2) the distance measured from the baseline to the 2500m bathymetric contour plus 100 nautical miles; (3) 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 (4) 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 by also geological and geophysical services. Limits (1) and (2) are combined to determine the most seaward segments, which form the cut-off line for the Continental Shelf. Similarly, limits (3) and (4) 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 the circumstances involving the maritime boundary delimitation of

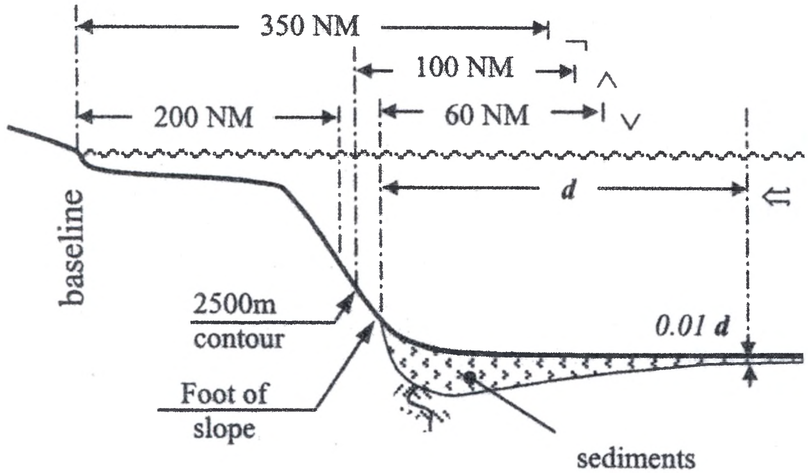

Figure 1. Possible Limits for the Continental Shelf

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 (El-Rabbany, 2001). 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*. An example of the local datums is 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). The 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). The International Hydrographic Organization (IHO) adopted the WGS 84 system for nautical charts (IHO, 1993).

Old maps and nautical charts were produced with the local datums while the new 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 the WGS 84. Such a relationship is known as the *datum transformation*. 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 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 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 from 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 projection, the angles on the surface of the ellipsoid are preserved after being projected on 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 projection. Apart from the polar regions, most nautical charts use 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 2). This means that, on Mercator projection, the same angle of bearing can be preserved with respect to successive meridians. A major disadvantage with Mercator projection, however, is that the scale factor changes as a function of latitude (Figure 2). This characteristic makes the Mercator projection inappropriate for constructing the maritime boundaries, particularly for distances greater than the breadth of the territorial sea.

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 Mercator chart will be different from

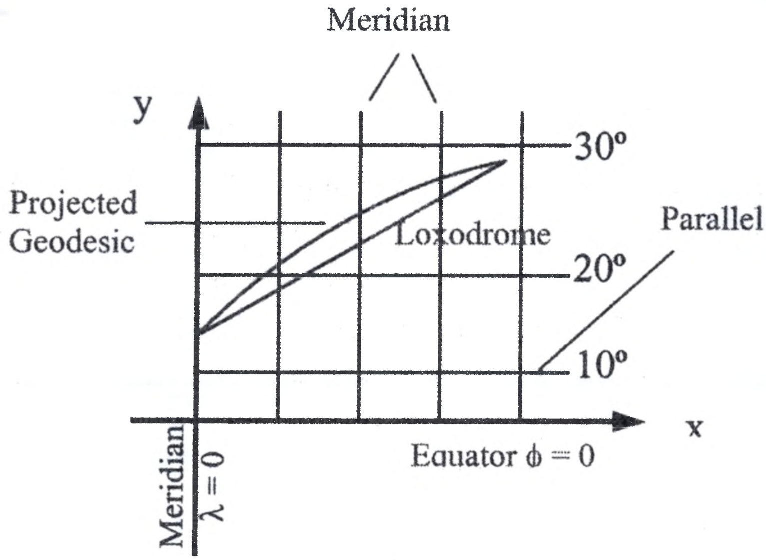

Figure 2. Appearance of Mercator Projection

the geodesic curve, which is the intended straight line in the Convention. Such a difference could be significant, depending on the length of the line, the direction and the latitude (IHO, 1993).

4. Uncertainty Effects

The determination of the state's maritime boundaries involves various types of field measurements, namely: (1) geodetic, hydrographic and tidal measurements, which are required for the creation of the nautical charts; and (2) 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, which 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 modeled 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, the transformation parameters cannot be determined accurately in many cases, due mainly to the inconsistent distortions in the old datums. Therefore, the associated uncertainty parameters must be considered when estimating the limits of the state's outer limits. As well, 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 among 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 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 2500m bathymetric contour may reach 100s 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 slope and sediment thickness (Monahan and Wells, 2001).

5. Conclusions

This article examined some of the geodetic and uncertainty issues of the UNCLOS. 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 the nautical charts is yet another factor that must be considered in the maritime boundary delimitation. The construction of the outer limits of the Continental Shelf is the most challenging 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.

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