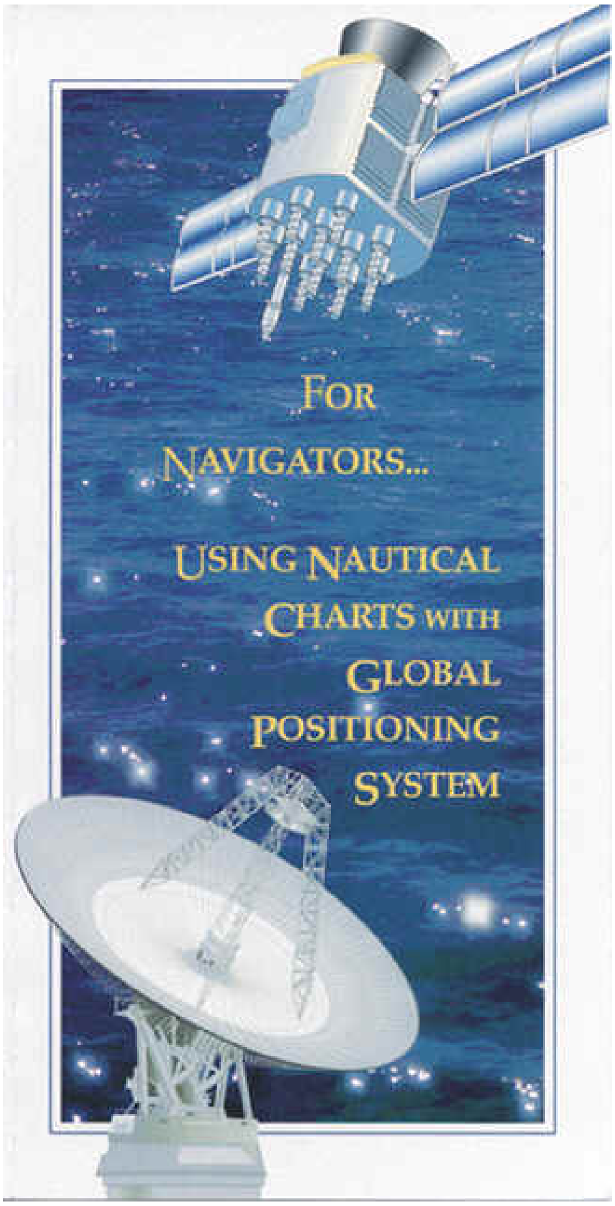
NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

Using Nautical Charts with Global Positioning System

INTRODUCTION

With the advent of the Global Positioning System (GPS), mariners can now navigate with much greater precision than ever before possible. This discussion focuses on the inherent limitations of nautical charts when plotting positions from GPS receivers.

For the chart maker, accuracy of the chart must take into account the limitations of the navigator's acuity of vision, the lithographic processes and plotting techniques used, and the symbolization of features (e.g., line widths).



GPS users must ensure that latitude/longitude shifts are made when plotting GPS-derived positions on a chart with a different datum than the GPS. All new NGA charts are compiled on WGS Datum, the same datum used by GPS receivers in the default datum setting, although other datums can often be selected. Positions derived prior to the implementation of GPS were determined using various optical instruments focused on navigational aids, shore features, or celestial bodies. Knowing the limitations of these methods, mariners gave a wide berth to hazards depicted on charts, including aids to navigation, shoals and obstructions. The available navigational information and cartographic processes used by the chart maker to position hazards were more accurate than the means of navigation available to users of the chart. The situation is now reversed; using GPS, mariners now can obtain a more accurate position fix than the data used to compile the chart.

With GPS providing such accuracy, the mariner now needs to pay closer attention to the reliability of the chart. For example, mariners, to save steaming time, may become more trusting and rely on their GPS to pass hazards depicted on charts much closer than is prudent. However, the charted hazards may have been positioned by less accurate navigation means than GPS, and, in fact, may be significantly misplaced. In other words, the chart being used may contain unintentional errors due to limitations of the technology used at the time of data collection, which in many cases is a generation or more in the past.

GPS ABSOLUTE ACCURACY

Military User Under Selective Availability (SA) and Anti-Spoofing (A/S). The military user always has access to full GPS accuracy, called the Precise Positioning Service. The horizontal accuracy is 21 meters, with a 95% probability that the GPS-derived position is within 21 meters of the true position on Earth. This accuracy equates to approximately 0.01 minute of latitude.

Thus, the best accuracy that a GPS fix could be plotted in this mode is 0.01 minute, regardless of the number of decimal places the GPS receiver displays. This accuracy is suitable for plotting in all normal navigation situations.

Military User with Real-Time Differential GPS. A military user of GPS in a differential mode may reach an accuracy of 2 to 7 meters.

Commercial GPS User. For the commercial GPS user the Standard Positioning Service, which may be limited by the engagement of Selective Availability (SA, a means of degrading the GPS signal to be used during a national emergency), is available all of the time. When SA is turned off, as it has been since May 1, 2000, civilian and military GPS receivers have the same accuracy. If SA were to be engaged, as during a national security emergency, the result would be degradation to 100 meters horizontal accuracy, again at 95% probability. This degradation still would result in a position accuracy of 0.05 minute, but this reduced accuracy would only become apparent when plotting these positions on larger scale charts (approximately 1:30,000 and larger). With these charts, the commercial GPS user should use extra caution when piloting with GPS in restricted waters. An accuracy of 2 to 7 meters (same as the military user) can be achieved, however, when GPS is used in a differential mode.

Many marine GPS receivers have technology installed that can use the Wide Area Augmentation Service (WAAS), a system designed primarily for aircraft use, but often available in the vicinity of ports and harbors. Accuracy using WAAS is similar to differential GPS.

CHART ACCURACY

Specified Chart Accuracy. The NGA-specified accuracy standard for harbor, approach, and coastal charts is that features plotted on a chart will be within 1 mm at chart scale with respect to the datum, at a 90 percent confidence level. For a chart of 1:15,000 scale, a 1 mm error equates to � 15 meters (16.2 yards) on the real earth, which is of the same order of magnitude as the absolute GPS error. For a smaller scale chart of 1:80,000, the chart error is � 80 meters (86.4 yards), which is therefore the limiting factor in position plotting accuracy. The reverse can be true for large-scale (small area) charts, such as a harbor plan inset at 1:5,000 scale. In this case, the navigator's plotting accuracy is limited by the absolute accuracy of GPS, rather than the chart; however, features on this chart should be accurate to � 5 meters.

Cartographic Presentation. "Cartographic license" may also be a factor. When depicting two or more closely spaced features on a chart, the chart maker may displace one feature slightly so the symbols do not overlap. This adjustment will normally keep the feature within the limit of 1 mm plotting accuracy.

Positioning of Survey Data. Errors in the underlying hydrographic survey data will also affect accuracy. While NGA makes every effort to produce the most accurate chart possible given the available data, the prudent navigator should pass shoals or isolated dangers with utmost caution, no matter what navigation method is used. Few coastal surveys of years past were possible to differential GPS accuracies, and shoals may have moved significant distances since the surveys were done.

Pencil Width. Although seemingly trivial, the width of a pencil line becomes a significant source of error at some scales. At 1:15,000, the 0.5 mm line width of a mechanical pencil lead equates to 7.5 meters (8.1 yards) on the chart. At 1:80,000, the same pencil line width equates to 40 meters (43.2 yards) on the chart. Thus a dull pencil can become the largest source of error, and thus the standard of accuracy, in the use of the chart.

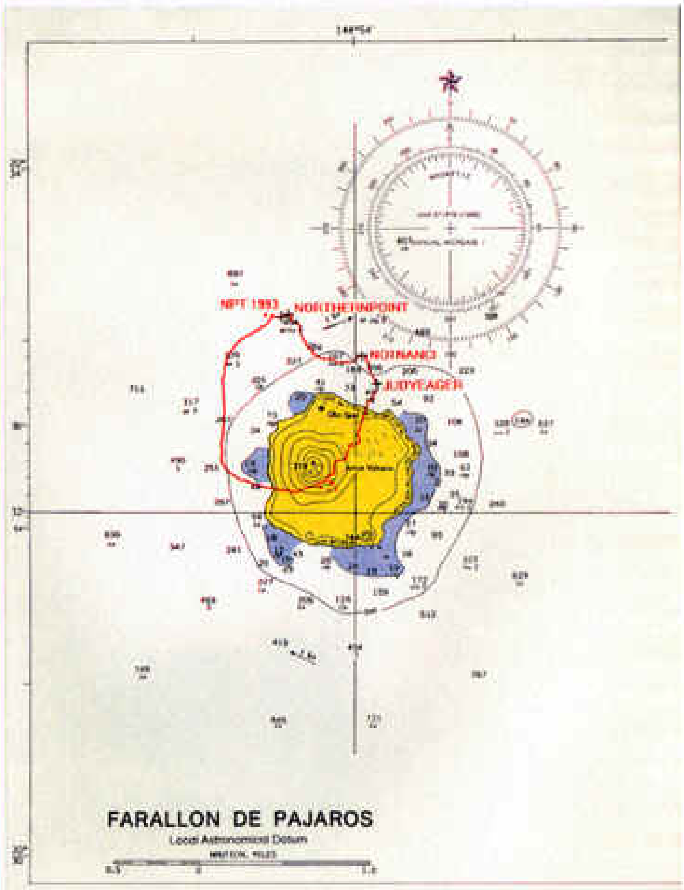
DATUM TRANSFORMATION

World Geodetic System (WGS). GPS receivers operate on the World Geodetic System (WGS) global geocentric reference system, or datum. It is global because, unlike other datums that only apply to certain regions, WGS can be used over the entire Earth. It is geocentric because, unlike other datums that use arbitrary points within the Earth as their origin, the origin of WGS is at the actual center of the globe. Most military and commercial receivers allow the user the capability to select the reference datum, but the receiver will default to WGS if none is selected.

Other Datums. Among other major datums used around the world, the Tokyo datum is an example of one that requires significant adjustments in both latitude and longitude to conform to GPS positions. Older Japanese and Korean charts are referenced to the Tokyo datum, for which positions must be shifted more than 700 meters to convert to WGS 84 datum.

Isolated datums, such as those used to position many islands in the Pacific Ocean, can be in error by a half mile or more (see figure). The datum shift to WGS 84 can be quite large, depending on the area of the world and the local datum in use. Remember that the chart and the navigation system used must always be referenced to the same datum.

GPS SURVEY SHOWS ISLAND SHIFT OF OVER HALF NAUTICAL MILE



COURTESY NATIONAL GEODETIC SURVEY DIVISION, NOS

GPS RECEIVER LIMITATIONS

Some GPS receivers may not have a selectable datum feature and with these, extra care must be taken. However, accuracy should not be a problem if the chart in use is based on WGS. Some US charts that are not currently based on WGS 84 datum include a note that specifies the necessary adjustment in position to correctly place a WGS 84 position on the chart. The majority of such charts are of such small scale that differences in datum are of no consequence.

USE OF TEMPLATES

The use of templates for plotting is an easy way to get reasonably accurate and repeatable plots. However, each template must be tied to the chart for which it will be used. Unlike topographic line maps, nautical charts are not published with consistent scales (such as at 1:50,000 or 1:100,000), but are scaled individually for the best use in navigating a particular area. This practice leads to a range of scales from 1:5,000 to 1:180,000, with various scales in between. Additionally, because of the projection used to display the curved surface of the earth on a flat sheet of paper, the latitude scale is not constant over the chart. The navigator must ensure that any locally produced templates are for the correct scale of the chart in use, and are used only in the latitude intended.

ELECTRONIC CHARTS

Commercial and military vessels are now using various versions of electronic charts together with GPS for navigation, voyage planning and situational awareness. With an established maintenance system, electronic charts will be the navigation method of choice for most mariners.

For US military navigators, NGA's Digital Nautical Chart (DNC®) forms the basis for paperless ship navigation. The Digital Nautical Chart (DNC®) is a comprehensive, vector-based, geo-relational database containing maritime features essential for safe marine navigation. The database, on WGS datum, is compiled from a global portfolio of over 5,000 NGA and National Oceanic and Atmospheric Administration charts that supports marine navigation between 84° North latitude and 81° South latitude.

However, all paper chart accuracy cautions apply to the DNC® (or other electronic charts based on paper charts) when used with GPS for navigation.

Summary

GPS-derived positions are often more precise than the charts used for navigation. Navigators should be aware of all the factors that may affect the use of GPS positions when plotting these positions on nautical charts. Mariners should continue to give wide berths to charted hazards, and ensure that the datum used by both the chart and the positioning system are the same, or that any difference is accounted for.

For further information, please contact:

Maritime Safety Office - MS N64 SH
National Geospatial Intelligence Agency
7500 GEOINT Drive
Springfield, VA 22150

Return to the Maritime Safety Information Home Page.

If you have questions or comments pertaining to the information provided on this website or if you are experiencing technical difficulties, please contact: *webmaster_nss@nga.mil*

HTML last updated 26 January 2012