

# GEODESIC DATUM CONVERSION IN JAPAN

## From Tokyo Datum to WGS84

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### 1. Back Ground

Position is another important factor of bathymetry. If you did not know the exact location where you measured your most accurate depth, it might not help reveal the wonder of ocean bottom. The guideline of GEBCO recommend to measure the position of the soundings within the accuracy of 3 nautical miles, a typical accuracy when you observe you position using stars. It may sound ridiculous if you know the publicly available accuracy of positions obtained by GPS. However, the same background as this three nautical mile rule still governs our daily life. The geodetic datum of the nation.

After we have come to know that the mother Earth is somewhat spherical, geographical position on the ocean is most commonly expressed by latitudes and longitudes. It is a reasonable way to measure your position on the spherical globe, as the angle of polar star above the horizon gives you the latitude. As you are on a spherical surface, distance against one degree of latitude depends on the radius of the sphere where you are on.

Eventually we have come to know that the mother earth is not really spherical but more like a football, or a camembert. Why is this a problem? On an ellipsoidal surface, a distance against the difference of one degree of latitude is different. We now know that the mother earth is more or less ellipsoidal, and in a way a camembert does. Here, at the polar regions, you need to move more to have a difference of one degree when you look at the polar star. Less distance is needed at the equatorial region. Thus navigators and chart makers need to know the radius and flatteningness of the mother Earth.

As there was no way to measure the shape of the Earth from outside of the globe, crawling

method was used. Combination of astronomical observations and land distance measurements was used to determine the shape of the globe. More than 10 ellipsoids were proposed, some of them in early 19th century.

Once you know the shape of the globe and know how many meters (or feet, or whatever) per one degree, the next question is where you are. As the polar axis gives the northern and southern end for the latitude, latitude could somehow be able to determine. Zero point of longitude needed a factitious determination, as we see no east pole of west. In 188x it was decided that the meridian line which crosses the Greenwich Astronomical Observatory be the prime meridian line. Now what you need is to know the relation between where you are and poles and GAO.

Apparently, measuring the location relative to the poles and GAO every time you need to know the latitude and longitude is not an efficient way. Each country started to establish a local reference. Precise astronomical observations were made at each places.

Here two major factors may provoke errors in latitude and longitude. Accuracy of time is crucial in obtaining the longitude astronomically. Longitude is more relative in nature, and Japan used the Imperial Palace located in Kyoto, or Edo Castle where Shogun Tokugawa resided, as the prime meridian, until Japan was connected to Europe by telegram system in 1871.

Plumb line deviation affects both in longitude and latitude. Japanese Government established a national observatory in Tokyo in 1873 and got the latitude and longitude. The longitude was revised twice using better time information, but the latitude remained as was. Problem were identified when the geodetic system was connected to the Chinese one at the root of Korean Peninsula, and also to the Russian one at the middle of Sakhalin Island. Discrepancy of several hundred meters was not reasonably attributed to the error in triangular surveys.

Azabu in Tokyo, where Tokyo Astronomical Observatory was established, is located amid the Kanto Plains. However, geologically the basement is tilted, and also macroscopic topography is not flat, at all. 200 kilometers off Tokyo southeastward, there is a triple junction of three plates, i.e. the Pacific Plate, the Philippine Sea Plate and the North American Plate, where the depth exceeds 9000 meter. On the other hand 100 km west of Tokyo is Mount Fuji, which is some 3800 meters in elevation. Plumb line is, and was, affected by these macroscopic

topography and local geology by more than 10 arc seconds at the Observatory. This caused the Japanese geodetic reference point by 465 meter southeastward.

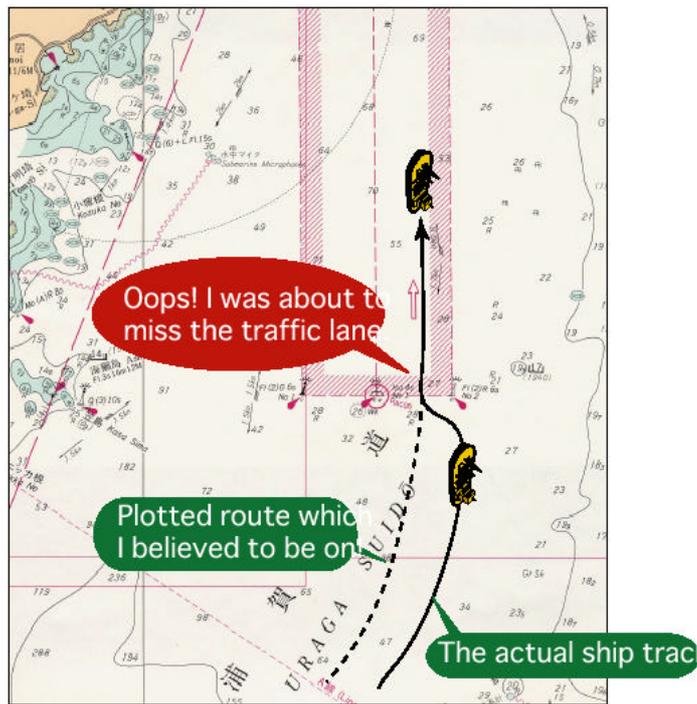


As the position consists the framework of the geography in Japan, the geodetic system was provided in laws, i.e. in the Survey Law, and the Hydrographic Activity Law, where Bessel Ellipsoid and the Azabu Reference Point, or Tokyo Datum, was legally identified as the Japanese geodesic system. Once it obtained a legal status, everything had to base on it.

## 2. New days of Navigation

GPS has obtained the de facto standard for marine navigation with its precise accuracy and continuous service timewise. As early as in 1983 IHO identified that charts be based on WGS84, which would be used in the coming satellite navigation system. In 1990s GPS came into full service and won the popularity from mariners. Ships coming to Japan from abroad navigated using GPS with WGS84 as the geodesic system, and when coming into Japanese waters, such as Bay of Tokyo, problem arose. As the Japanese Charts were compiled in Tokyo Datum, there was some 500-meter difference in position. Uraga Strait, which is the entrance of the Bay of Tokyo has a traffic separation Scheme and has a designated navigational channel, with the width of 700 meters. 500-meter was a major size to enter into the 700-meter bandwidth of the channel. However mariners did not want to switch the geodesic datum of GPS positioning system from WGS84 to Tokyo Datum on entering Japanese waters. As they switch the geodesic datum, a sudden change of location by some 500 meters were taken as a major error of positioning system by the auto-pilot system and the

system was shut down, which was not welcomed by navigators.



Grounding were reported several times to Japanese Hydrographic Department, where the depth was more than enough. Every time I looked at 400 to 500-meter southwest, where I found shoals. Apparently navigators in trouble did not pay due attention to the note given in the chart stating "positions obtained by satellite navigation system should be shifted by..."



It is controversial that a better positioning system leads to position-derived accidents. Japanese Hydrographic Department started to change all its charts to WGS84, and Japanese Government decided to amend the laws, recognizing the importance of the safety of navigation, and also it minded the coming GIS era.

### 3. Tokyo Datum to WGS84

At first overprinting of WGS84 grid in green color was made for 9 charts, which were for busiest traffic especially at narrow channels with TSS in 1999. Soon after this, a three-year program to change all 900 charts to WGS84 was started. The Hydrographic Department was well prepared by itself of having the conversion, with its satellite laser ranging observation since 1982. Care was taken to avoid the misunderstanding of mariners which chart he/she was using. We decided to give different colors to the WGS84 charts. Detailed chromatic survey was made, to be safe for any brightness. It is surprising to know that at certain dusk inter-tidal area may look like land, or like sea, depending on the colors used for shallow water and land. Also education, training and propaganda were carried out systematically. As the amendment of the law was accepted by the Diet, the three-year program was shortened to two-year. The first WGS chart was printed in April 2000, and by March 2002, all the charts published by JHD became the WGS84 basis, which was in time for the enforcement of revised SOLAS convention in July 2002.

### 4. Legal matters

Many regulations, permissions etc. depends on latitude and longitude at sea. It has never paid attention which geodetic datum the latitude and longitude were on. One interesting observation in the case of Japanese legal system is Okinawa Islands, returned from the US in 1972 was defined by latitudes and longitudes. At one place the line defining Okinawa did fall on the island itself if it were taken as the WGS84 latitude. Many regulations such as defining boat heaven, fishery rights, etc. needed to be amended.

### 4. And the science in new era

All the bathymetric data was provided in Tokyo Datum, until the law was amended in April 2002. Japanese geophysical and bathymetric data included in GEODAS is in Tokyo Datum. It is interesting to know that the satellite altimetry derived bathymetry, which used the GEODAS for control is biased by the difference of geodesy. Global bathymetry did not care too much about the positioning error of hundreds of meters sometimes. However the sharp foot print of multibeam echo sounders and really accurate GPS positions nowadays require the problem of geodetic system.