GRIDS & DATUMS

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THE KINGDOM OF SPAIN

The Grids & Datums column has completed an exploration of every country on the Earth. For those who did not get to enjoy this world tour the first time, *PE&RS* is reprinting prior articles from the column. This month's article on The Kingdom of Spain was originally printed in 2000 but contains updates to their coordinate system since then.

The Greeks and the Phoenicians settled Spain on the southern and eastern coasts. The Mediterranean coastal region was ruled by Carthage, which ceded it to Rome in 201 *B. C.* Invaded by Vandals in 409 *A. D.*, the Muslims of North Africa conquered Toledo from 711-719. The last of the Moors were expelled from Granada in 1492. Spain occupies the greater part of the Iberian Peninsula, and the Kingdom claims the Balearic and Canary Islands. Most of the pen-insula is plateau – averaging 1,250 meters (4,100 feet).

Spain's cadastre began in 1854, but the Law of Cadastre established the way to perform the work in 1906. This was essentially a rural method for taxation until 1964 when urban areas of the Kingdom were brought into the cadastre.

The Spanish first-order triangulation of 1858-1885 consists of ten principal arcs: the meridional arcs of Salamanca, Madrid, Pamplona and Lerida; the parallel arcs of Palencia, Madrid and Badajoz; and the diagonal arcs of the North, East and South coasts. The origin of the Madrid Observatory Datum of 1853 is Φ_0 = 40° 24′ 29.70″ North (after 20 years of observations), Λ_0 = 03° 41′ 14.546″ West of Greenwich. The defining azimuth was determined from the observatory to station Hierro as: α_0 = 154° 31′ 06.90″ from south, and is referenced to the Struve 1860 ellipsoid where a = 6,378, 298.3 meters, and $^1/_f$ = 294.73. However, the Spaniards did not use Greenwich as a Prime Meridian at the time; they used Madrid. Every country in Europe used their own Royal Observatory as their national prime meridian back then. The original triangulation comprised 235 triangles, which was observed with Repsold, Pistor, Brunner and Kern theodolites. A poly-hedric system of projection has been reported for the early topo-graphic maps. In 1875, the Spanish Military adopted the Lambert Con-formal Secant Conic Grid that has a Latitude of Origin (ϕ_0) = 40° 00′ North, a Scale Factor at Origin (m_0) = 0.9988085293 and a Central Meridian (λ_0) = 03° 41′ 14.546″

West of Greenwich. The False Northing and False Easting were both equal to 600 km. That Grid is still in use. However, in 1880, the Military adopted a Bonne projection for the Itin-erario Militar (military route map) with a Latitude of Origin (ϕ_0) = 40° 45′ North, a Scale Factor at Origin (m_0) = 1.0 and a Central Meridian (λ_0) = 04° 26′ 14.55″ West of Greenwich. That Bonne base re-mained in use until 1951 when the UTM was adopted for all military applications in Spain.

During World War II, the Iberian Peninsula Lambert tangent Zone was used by the Allied Forces. This Grid had a Latitude of Origin (ϕ_0) = 40° 00′ North, and a Central Meridian (λ_0) = 03° 41′ 14.546″ West of Greenwich. The False Northing = 600 km, and the False Easting = 530 km. A later triangulation densification in 1930-33 was observed with Wild T3 theodolites. During the war, the Germans developed a series of computations for the Spanish Triangulation Network referenced to the Clarke 1880 ellipsoid. After the war, those German tables were useful in the re-computation of the classical triangulation of the Kingdom onto the European Datum of 1950 (ED50) which was referenced to the Interna-

tional Ellipsoid. The subsequent transformation of the Spanish Net to ED50 was based on a two-step two-dimensional Helmert transformation. The initial step computed by the Axis (Germans) was still on a Lambert Con-formal Conic projection, but referenced to the Clarke 1880, which was the standard for France. That series of collocated points that started computations in the Pyrenees Mountains was continued into a substantial portion of the Iberian Peninsula. After the war, the U. S. Army Map Service decided that the best way to merge the Madrid Observatory Datum of 1858 into the new ED50 was to use the existing German data as an intermediate step. In computing the new French datum values of the Spanish triangulation, use was made of the German adjustment of 1938. Values of the New Triangulation of France (NTF) were available for the following 11 Spanish triangulation stations: Forceral, Canigou, Licuses, Rouge, Cabére, Maupas, Anie, Orhi, Baigura, La Rune, and Biarritz. Computations to the Madrid Datum of 1858 were performed by V.U.K.A. 631 (April 1943) and by Kriegskarten und Bermessungsamt, Paris (August 1943).

Other Datums of Spain include San Fernando Observatory where: $\Phi_o = 36° \: 27' \: 54.6''$ North, $\Lambda_o = 06° \: 12' \: 17.8''$ West of Greenwich. Another version of the same point is where: $\Phi_o = 36° \: 27' \: 41.52$ North, and $\Lambda_o = 06° \: 12' \: 19.5''$ West of Greenwich. This same point on the "Salamanca Datum" is: $\Phi_o = 36° \: 27' \: 54.65''$ North, and $\Lambda_o = 06° \: 12' \: 18.00''$ West of Greenwich.

Pico de las Nieves Datum of 1934 in the Canary Islands is where the origin is: $\Phi_o = 27° \: 57' \: 41.273''$ North$\pm0.130''$, and $\Lambda_o = -15° \: 34' \: 10.524''$ West of Greenwich $\pm0.380''$. The defining azimuth was observed to station Iselta as: $\alpha_o = 212° \: 34' \: 48.30''$ from south, and the elevation is 1949.14 m. It is referenced to the International ellipsoid of 1909 (Madrid 1924) where a = 6,378,388 meters and the reciprocal of flattening ($^1/\rho$) = 297. Also found on the Canary Ise Abona Datum that is referenced to the International 1909 ellipsoid. The origin of that Datum is: $\Phi_o = 28° \: 08' \: 22.93''$ North $\pm0.102''$, and $\Lambda_o = -16° \: 25' \: 01.92''$ West of Greenwich $\pm0.105''$. The defining azimuth was observed to station Roja as: $\alpha_o = 221° \: 48' \: 27.48'''$, and the elevation is 16.82 m. The Royal Spanish "Servicio Geografico del Ejercito" (Army Map Service) Grid of 1945 for the Canaries is on the International 1909 ellipsoid. The Latitude of Origin (ϕ_o) = 28° 30′ North, and a Central Meridian (λ_o) = –12° 00′ West of Madrid (therefore, λ_o = –15° 41′ 14.546″ West of Greenwich). The Scale Factor at Origin (mo) = 0.9999244799, and the False Northing (FN) and the False Easting (FE) = 400 km.

Interestingly, the British Grid system for the Canary Islands used during WWII by the Allies was also based on a secant Lambert Conformal Conic projection. The Latitude of Origin (ϕ_o) = 27° 00′ North, and a Central Meridian (λ_o) = –17° 00′ West of Greenwich. The Scale Factor at Origin (mo) = 0.9993817, the False Northing (FN) = 100 km, and the False Easting (FE) = 200 km. This Grid was referenced to the Clarke 1880 ellipsoid presumably because the Canary Islands are so close to Africa. That ellipsoid is/was the (British) standard for that continent. (Some of the WWII-era British Grids were based on ersatz Datums "cooked up" for reasons of expediency during the war.)

The Balearic Islands in the Mediterranean Sea are said to be on the Madrid Datum of 1858, but I do not think that is true. Ten years later, station Mola was observed for the Balearic Islands Datum of 1868 where: $\Phi_o = 38° \: 39' \: 53.17''$ North, and Λ_o = +5° 13′ 19.94″East of Madrid (therefore, +1° 32′ 05.394″East of Greenwich). The longitude is also defined as –0° 48′ 11.26″ West of Paris, which leaves a discrepancy of 2.71″ in Longitude between Greenwich and Paris. This is not a large error for an "Astro" shot done on an island in 1868, but it is quite large for the relation between two national observatories. The defining azimuth was observed to station Furnas as: $\alpha_o = 177° \: 39' \: 11.03''$ from south, and to station Camp Vey as: $\alpha_o = 160° \: 15' \: 40.48''$ from south. The elevation of Mola is 192.25 m, and, of course, the ellipsoid of reference is the Struve 1860.

NIMA lists the three-parameter datum shift from the European Datum 1950 (in Spain) to WGS84 as: $\Delta X = -84m \pm 5m$, $\Delta Y = -107m \pm 6m$, $\Delta Z = -120m \pm 3m$, and is based on an 18-station solution.

UPDATE

The National Geodetic Network of GNSS Reference Stations (ERGNSS) Descriptive information: Currently 75 stations make up the network, of which 24 are integrated into the European network of EUREF and 3 (YEBE, MELI and LPAL) in the global network of the IGS (International GNSS Service). In addition, in order to make a more efficient management of expenditure and with a view to having an adequate density of stations throughout the national territory, the IGN shares the ownership of some stations of the ERGNSS with other institutions, such as Autonomous Communities and Ports of the State. , through collaboration agreements. The stations are equipped with multi-frequency geodetic receivers, with reception capacity of other constellations, such as GLONASS or GALILEO and geodetic antennas, almost all "Choke ring" type and with calibration of the phase center variation (part of them with individual calibrations).

The network of permanent stations of the IGN is the basic reference that gives access to the ETRS89 system directly. The objectives of this network can be summarized as:

- Obtaining very precise coordinates and speed field in all points of the network.

- Contribution to the definition of the new Global Reference Systems (ITRF) in the national territory.

- To be fundamental points of the European EUREF network of permanent stations (EPN) for the densification of global frameworks and definition of the ETRS89 system.

- Use of continuous data records for studies of Geodynamics, troposphere, ionosphere, meteorology, *etc*.

- Define a fundamental network as support for real-time applications of differential corrections (DGNSS) and RTK.

- To provide GNSS users, publicly, data for geodetic, cartographic, topographic and positioning work in general.

In order to make a more efficient expenditure management

and with a view to having an adequate density of stations throughout the national territory, the IGN shares with other institutions some of its stations of the ERGNSS network. The institutions that share these facilities are Autonomous Communities and Ports of the State through collaboration agreements. In the following list the institutions that share stations are mentioned.

Services of the ERGNSS network: Post-process services : in the form of RINEX files of all stations, with different intervals (hours at 1, 5, 10 and 30 seconds or daily to 30 seconds), accessible by the user in different ways:

- Directly through an FTP server.
- Through this web page in the utility "Geodetic Data".
- Through the Geodetic Applications Program (PAG).

• Real-time positioning services: by connecting to the different "streams" of data available in the Real-Time Services section. They allow instant precise positioning for the user by connecting through the Internet to the real-time servers of the IGN. For more detailed information, consult the real-time positioning services page.

GNSS data analysis center: The IGN is a GNSS Data Analysis Center that performs continuous data processing for several projects from both the permanent stations of the ERGNSS network and from other networks, as well as being a EUREF Local Analysis Center (acronym IGE) from September 2001. The different continuous calculation processes for these projects are carried out in Bernese 5.2, they are automated. For any query about the geodesy services provided by the National Geographic Institute and the GNSS

Permanent Station Network, the contact is buzon-geodesia@fomento.es (*www.ign.es, January 2018*).

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