Grids & Datums

The Portuguese Republic

BY Clifford J. Mugnier, CP, CMS, FASPRS

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 Portuguese Republic was originally printed in 2002 but contains updates to their coordinate system since then.

Inhabited by late Stone Age people, many megalithic tombs date from 2500 BC. Portugal is one of the oldest nation states in Europe, and its foundation in 1139 pre-dates Spain by nearly 350 years. The Ro-mans arrived in 216 BC, and named the entire peninsula Hispania. However, the region between the Douro and Tagus Rivers was named Lusitania by the Celt-Iberian inhabitants. Later overrun by Ger-manic tribes and then by the Moors, eventually the kingdom of Portucale, comprising León and Castile, was declared independent by King Afonso Henriques. Portugal is slightly smaller than Indiana; it is mountainous north of the Tagus River, and has rolling plains in the south. With its only border being Spain to the east and north, the North Atlantic Ocean is on Portugal's west and south. Portugal holds sovereignty over the Azores and Madeira Islands; both archipelagos are strategic locations along the western sea with approaches to the Strait of Gibraltar. The highest point is Ponta do Pico on Ilha do Pico in the Azores at 2,351m.

According to the Portuguese Instituto Geográfico do Exército (Army Map Service), in 1420, aware of the navigational importance of cartography, Prince Henry the Navigator commissioned the master cartographer Jácome of Majorca to teach apprentice cartographers in Portugal the art of preparing navigational charts. One of the oldest existing maps, thought to have been pre-pared by the cartographer Pedro Reinel, dates from 1500. Portuguese cartographers of the period were considered the most skilled in the world, their maps pro-viding the most accurate representation of the Earth. Conscious of the importance of cartography in tackling the country's economic problems, Queen Mary of Portugal created the Royal Military Archive in 1802, in order to house the different national cartography departments. This body

was the precursor of the Military Geographic Institute. At the end of the eighteenth century, having closely followed the progress of this science, it was the Portuguese military cartographers that established and developed the geodesic (*sic*) network in Portugal. Modern Portuguese cartography dates back to 1778 when work began on the first fundamental geodetic triangulation network, which lasted until 1848. The survey work for the 37 sheets which make up the Carta Geral do Reino (General Map of the Kingdom), also known as The Chorographic Map of Portugal, at a scale of 1:100,000, lasted from 1853 to 1892. Produced al-most entirely by Army officers, the map series was awarded the "Lettre de Distinction" during the Paris International Congress of Geographic Sciences in 1875. Based on the Castello de Sâo Jorge Da-tum in Lisbon, the ellipsoid of reference was the Bessel 1841 where a = 6,377,397.155 meters and the reciprocal of flattening ($^1/_f$) = 299.1528128. The *projection de jour* in Europe at that time was the ellipsoidal Bonne, and for this series the Latitude of

Photogrammetric Engineering & Remote Sensing
Vol. 86, No. 5, May 2020, pp. 271–273.
0099-1112/20/271–273

doi: 10.14358/PERS.86.5.271

Origin (φ_o) = 38º 42′ 43.631″ N and the Central meridian (λ_o) = 9º 07′ 54.806″ West of Greenwich. The scale fac-tor at origin was equal to unity, and there was no False Easting or False Northing.

In 1881 the Army Staff Department published the Carta Itinerária da 1ª Divisão Militar (*Itinerary Map of the 1st Army Division*) at a scale of 1:250,000. In 1891 the Army Staff Department began work on the publication of the Carta dos Arredores de Lisboa (Map of the Outskirts of Lisbon) at a scale of 1:20,000. This was the first military topographic map, which later became known as the Map of Portugal. The ellipsoidal Bonne projection was used for this series also, and the Latitude of Origin (φ_o) = 39º 40′ N and the Central meridian (λ_o) = 8º 07′ 54.806″ West of Greenwich. The scale factor at origin was equal to unity, False Easting = 200 km and False Northing = 400 km. The two baselines were observed in 1886-1889, and were at Batel-Montijo and at Melriça.

In 1911 the Military Cartographic Section of the Army General Staff was created and continued the work on the Map of the Outskirts of Lisbon at 1:20,000 scale, and the Map of Portugal at 1:250,000 scale. Later, work was sus-pended on these two series during the restructuring process of the services which started in 1926 and ended in 1932 with the creation of the Serviços Cartográficos do Exército (Army Cartographic Service).

The Regulatory Decree dated 24 November 1932 established the Serviços Cartograficos do Exercito (SCE) (*Army Cartographic Service*) under the aegis of the Army Staff (EME), and the heirs of Portuguese cartographic traditions. The initial priority of the SCE was to publish the Military Map of Portugal, the Itinerary Map of Portugal, and other documentation necessary for the defense of Portugal. The first sheet, produced at a scale of 1:25,000, covered the Abrantes region. Thus, in 1937, the SCE adopted purely classical methods in their survey activities. From then on, photogrammetric processes were initiated, and by 1940 were exclusively used in medium-scale mapping.

In 1995 the survey for the Military Map of Continental Portugal was completed at a scale of 1:25,000 with a total of 639 sheets. The Gauss-Krüger Trans-verse Mercator Grid was used for this series where the Latitude of Origin (φ_o) = the equator (by definition) and the Central meridian (λ_o) = 8º 07′ 54.862″ West of Greenwich. The scale factor at origin was equal to unity, False Easting = 300 km, and False Northing = 200 km. This is based on the Castello de Sâo Jorge Datum where Φ_o = 38º 42′ 43.631″ N and the Central meridian Λ_o = 9º 07′ 54.8446″ West of Greenwich. The ellipsoid of reference is the Hayford 1909 or the Inter-national (Madrid) 1924 where a = 6,378,388 m and $^1/_f$ = 297. This series was then followed by the survey of the islands of Azores and Madeira with 51 sheets at the same scale. The Gauss-Krüger Transverse Mercator Grids for the islands of the Azores Archipelago are quite similar in that the parameters are φ_o = 0º, the scale factor at origin is equal to unity, False Easting = zero, and False Northing Latitude of Origin (φ_{FN}) = 38º 45′ N. For Ilha de Sâo Jorge, the Central Meridian (λ_o) = 28º West of Greenwich; for Ilha do Faial, λ_o = 28º 42′ W; for Ilha do Pico, λ_o = 28º 20′; and for Ilha Graciosa, λ_o = 28º W. For the Madeira Archipelago, the Ilha de Porto Santo Gauss-Krüger Transverse Mercator φ_o = 0º, the scale factor at origin is equal to unity, False Easting = zero, False Northing Latitude of Origin (φ_{FN}) = 33º 03′ 23.9412″ N, and λ_o = 16º 20′ 01.2304″ West of Greenwich. For the Ilha de Madeira e Desertas, φ_o = 0º, the scale factor at origin is equal to unity, False Easting = zero, False Northing Latitude of Origin (φ_{FN}) = 32º 45′ N, and λ_o = 16º 55′ West of Greenwich.

In the 1960s and at the outset of the 70s, various types of cartographic survey work were carried out. These included orthophoto and image maps of the former Portuguese territories in Africa (Angola, *PE&RS* March, 2002 and Moçambique, *PE&RS* September, 1999) and important photographic documentation taken during combat in the last colonial war and today considered of extreme historical importance.

The complete survey of the Cape Verde archipelago at a 1:25,000 scale and with identical specifications to those of the Military Map of Portugal is also of particular importance. The said series is composed of 64 sheets, being concluded in 1980 under the terms of a cooperative agreement signed with the Republic of Cape Verde. The current existing cartography of the Republic of Guinea-Bissau at a scale of 1:50,000 and totaling 75 sheets was also produced by the Portuguese Army Cartographic Services. Aerial triangulation techniques became regularly used in the cartographic production chain from 1968 onwards. The year of 1974 saw the beginning of the systematic use of analysis and research with technical documentation related to computerized cartographic processes. In 1986, the SCE acquired an auto-mated cartographic system.

The first GPS (Global Positioning System) receivers arrived at the SCE during the year 1992, and a marked improvement was witnessed in the speed, economy, and precision of survey work. In 1992 the research work on the building and design of the Geographic Information System (SIG) was started. The Serviço Cartográfico do Exército (SCE) became the Instituto

Ad Index

Geográfico do Exército (IGeoE) (The Army Geographic Institute) on 01 July 1993 upon order of the Ministry of Defense, thus becoming the heir to the longstanding Portuguese military cartographic traditions. IGeoE became the organization responsible for the production of Military cartography under the aegis of the Logistic Command.

The Lisboa Datum to WGS84 Datum transformation parameters are ΔX = –302.581m ±0.49m, ΔY = –61.360m±0.65m, and ΔZ = +103.047m ±0.49m. The Datum 73 to WGS84 Datum transformation parameters are ΔX = –223.116m±0.11m, ΔY = +109.825m ±0.15m, and Z = +36.871m ±0.11m. The European Datum of 1950 (EU50) to WGS84 Datum transformation parameters (my ten-point solution) are ΔX = –85.858m±0.19m, ΔY = –108.681m ±0.26m, and ΔZ = –120.361m ±0.19m. The National Imagery and Mapping Agency (NIMA) published a mean solution of 85 points in Europe that are ΔX = –87m ±3m, Δ–98m ±3m, and ΔZ = –121m ±5m. The Porto Santo Datum of 1936 for Ilha de Madeira to WGS 84 Datum parameters (my six-point solution) are ΔX = –542.544m±0.31m, ΔY = –235.514m ±0.31m, and ΔZ = +285.877m ±0.31m. NIMA published a two-point solution in 1991 where ΔX = –499m ±25m, ΔY = –249m ±25m, and ΔZ = +314m ±25m. The Sâo Brás Datum on Ilha Sâo Miguel to WGS84 Datum parameters (my 4 point solution) are ΔX = –203.584m ±0.26m, ΔY = +96.902m±0.26m, and ΔZ = –62.965m ±0.26m. NIMA published a two-point solution in 1987 where ΔX = –203m ±25m, ΔY = +141m ±25m, and ΔZ = –53m ±25m.

Thanks go entirely to Jorge Teixeira Pinto, director of Geodetic Services, Instituto Portugués de Cartografia e Cadastro.

Update

Portugal has adopted a new map projection, based on the ETRS89 datum, as a national coordinate system for topographic mapping purposes. This new map projection is designated as PT-TM06 (EPSG:3763). The Portuguese Geographic Institute (IGP) has observed with GPS more than 1000 points of the national geodetic network and provides their coordinates. Older reference systems are still in use, in particular Datum 73 (epsg:4207) and Datum Lisboa (epsg:4274), both based on the Hayford ellipsoid. Usual projections of these datums are identified with epsg codes epsg:27493 (D73) and epsg:20790 (DLisboa). Coordinates of more than 8000 points (1st, 2nd and 3rd order points of the geodetic network are provided by IGP) as well as Bursa-Wolf parameters to convert from these to ETRS89. Coordinates in these projections can be transformed to ETRS89 using PROJ.4 command cs2cs. The RMSE of coordinates transformed using these parameters are of approximately 0.40 m (for D73) and 1.50 m (for DLisboa).

Using around 900 of the points provided by IGP, datum shift grids were calculated, using standard kriging interpolation, for the differences: Datum 73 to ETRS89 (pt73_e89.gsb) and Datum Lisboa to ETRS89 (ptLX_e89.gsb). These files are in format NTv2 and can be placed in the directory pointed to by environment variable PROJ_LIB.

Tests made with a set of around 140 points not involved in the generation of the grids provided RMS errors of 5 cm in the case of Datum 73 and 8 cm for Datum Lisboa.

The grid files can be also easily configured in ArcGIS (as a Custom Geographic Transformation) and other commercial and open-source GIS programs.

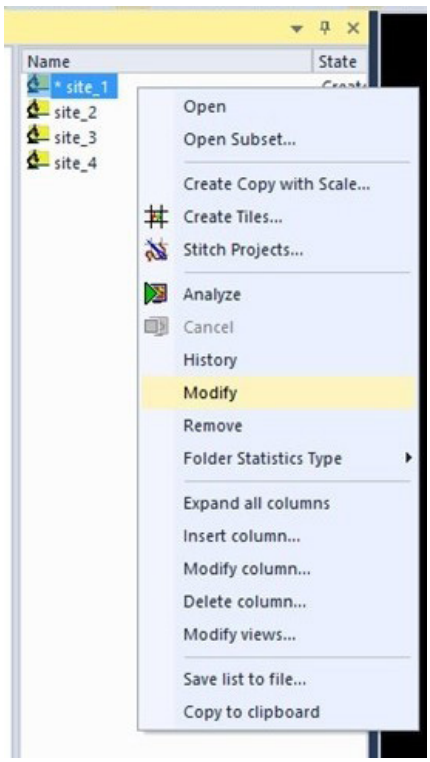
Gonçalves, J., 2009. *Conversões de Sistemas de Coordenadas Nacionais para ETRS89 Utilizando Grelhas*. Paper presented at the 6th National Conference of Geodesy and Cartography.

https://www.fc.up.pt/pessoas/jagoncal/coordenadas/index_en.htm.

GIS Tips & Tricks

continued from page 269

5. Your data will now be divided into individual projects which then can be used and reference. In this example, an eCognition™ project was created the data from each site. You can review or modify the information in each project folder by right clicking and select modify project.



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