& GRIDS & DATUMS

THE REPUBLIC OF ANGOLA

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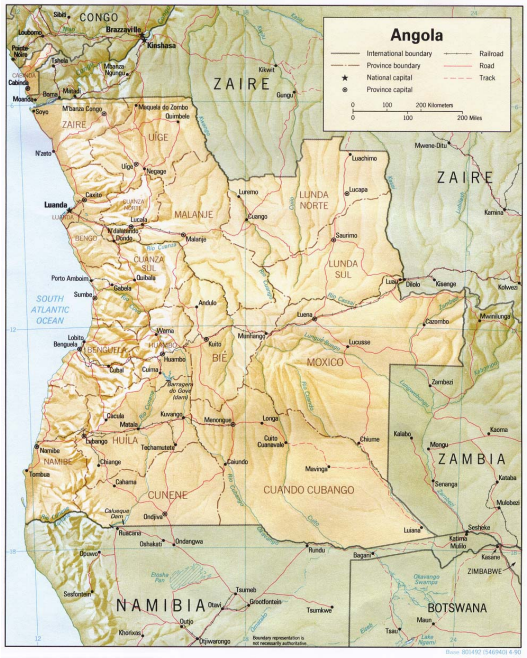
The Grids & Datums column has completed an exploration of every country on the Earth. For those who did not get to enjoy this world tour the first time, *PE&RS* is reprinting prior articles from the column. This month's article on the Republic of Angola was originally printed in 2001 but contains updates to their coordinate system since then.



The original peoples of what is now Angola were probably Khoisan speaking hunters and gatherers (bushmen). During the first millennium AD, large-scale migrations of Bantu speaking people moved into the area and eventually became the dominant ethno-linguistic group of southern Africa. The most important Bantu kingdom in Angola was the Kongo, with its capital at Mbanza Kongo (called *São Salvador do Congo* by the Portuguese). South of the Kongo was the Ndongo kingdom of the Mbundu people. Angola got its name from the title for its king, the **ngola**. In 1483, Portuguese explorers reached Angola, Christianized the ruling family, and engaged in trade and missionary work. By the early 17th century, some 5,000+ slaves were being exported from Luanda annually. Angola received its independence from Portugal in 1975, but has been plagued by civil war and insurrections since independence. A familiar Bantu word in the U.S. is kwanza, which is Angola's unit of currency.

The interior forms part of the Central African Plateau, with elevations that range from 1,220 to 1,830 m (4,000 to 6,000 ft). The coastal plain is about 1,610 km long (1,000 miles) and varies in width from 48 to 160 km (30 to 100 miles). The highest point is Mt. Moco in the west at 2,559 m (8397 ft). The chief rivers include the Congo, Cuanza, and Cuene to the north, while south of the Lunda Divide some flow into the Zambezi River and others flow into the Okavango River.

Angola consists of two geographically separate expanses: Angola proper and Cabinda. Portuguese authority was not exercised continuously north of the Congo River in the present-day district of Cabinda until a relatively recent date. It was occupied by the Portuguese in 1783, but a French expedition forced them to evacuate the area 11 months later. Portugal laid definite claim to Cabinda in an additional convention to the Anglo-Portuguese treaty of January 22, 1815. Again, on February 26, 1884, an Anglo Portuguese treaty acknowledged claims by Portugal that included not only Cabinda and the Congo River inland to Nóqui but the whole Atlantic coast between 5° 12′ and 8′ South latitude. This produced a storm of protests in Europe, and Portugal proposed a conference on the Congo that resulted in the Berlin Conference held between November 15, 1884 and February 26, 1885. Consider then, that the borders of Cabinda are in common with Congo (Brazzaville), which was part of the former Congo Français (French Congo), and is currently the Republic of the Congo. The southern border is in common with Congo (Kinshasa), once the Belgian Congo, later called Congo, then Zaire, and currently the Democratic Republic of Congo. The controlling classical datum for southern Africa and most surrounding countries of Angola proper is the Arc Datum of 1950 whose point of origin is station Buffelsfontein where Φ_0 = 33° 59′ 32.00″ South, Λ_0 = 25° 30′ 44.622″ East of Greenwich, and the azimuth from south to station Zuurburg is α_0 = 183° 58′ 15″. The reference ellipsoid for the Arc 50 Datum is the Clarke 1880 where the semi-major axis a = 6,378,249.145 m and the

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reciprocal of flattening $^1/_f$ = 293.465. Angola's southern border is with that country once called German Southwest Africa, and Namibia is the only country in the African continent to utilize the Bessel 1841 ellipsoid for its Schwarzeck Datum where, for Namibia, the semi-major axis a = 6,377,483.865 International meters and the semi-minor axis b = 6,356,165.383 International meters. Values actually used in Namibia are a = 6,377,483.865 legal meters and $^1/_f$ = 299.1528128. The origin point is Schwarzeck, near Gobabis, where Φ_o = 22° 45′ 35.820″ South, and Λ_o = 18° 40′ 34.549″ East of Greenwich. (Our Paul M. Hebert School of Law here at Louisiana State University is helping build a Law Library at the University of Namibia).

The earliest geodetic observation in Angola is to the 1884 meridional distance from the mid-Atlantic island of St. Helena to Baie dos Elefantes (Elephant Bay) in Angola and thence north to São-Paulo de Loanda (Luanda). This revealed a probable error between 6′ and 6½′ in longitude in the existing Portuguese charts. This error was again reported in 1888 in a "Hydrographic Note" using meridional distances from Cape Town Observatory to the two ports mentioned above and to Moçãmedes. In 1891, *Annales Hydrographiques* of the French Navy published the telegraphic determination of longitudes for three sites in Angola as determined by Commander Pullen of the Royal English Navy. Those determinations were São-Paulo de Loanda – at the pavilion slab of the Fort of San Miguel –where Φ_o= 08° 48′ 24″ South, Λ_o = 10° 53′ 05″ East of Paris, Benguela – at the Bureau Télégraphique (Telegraph Office) – where Φ_o = 12° 34′ 43″ South, Λ_o= 11° 03′ 40″ *East of Paris*, and Moçãmedes – at the pavilion slab of Ponta da Noronha – where Φ_o = 12° 34′ 43″ South and Φ_o = 11° 03′ 40″ East of Paris.

In 1918, the Portuguese authorities established a new position for Luanda Observatory and supplied details of the triangulation of that area. "A Missão Geográfica de Angola criada na …," "The Geographic Mission of Angola was created in the province in 1921 to establish a geodetic net in order to provide for a cartographic survey of the territory; after more than three campaigns, when it was dissolved, the Mission had surveyed two arcs of triangulation – one from Benguela to Huambo and the other along the" (*meridian*) "14° 00′ East of Greenwich from adjacent figures to Lubango. Subsequently, for geodetic operations, a hydrographic mission, which had campaigns from 1930 to 1933, established geodetic figures along the Zaire (Congo) River with common vertices with the Congo (Kinshasa) Triangulation, and executed a geodetic base with astronomical observations for latitude in eight stations, for longitude in five stations, and two for azimuth. Furthermore, the systematic and regular occupation of geodetic points in the province was initiated in the beginning of 1941 as an actual activity of the Geographic Mission of Angola.

The instructions were formulated by the "Junta de Investigações do Ultramar" (Overseas Research Commission) of which the following points, with respect to the geodetic activities, were

1. complete the geodetic coverage of the province, including the principal triangulation figures and the secondary triangulation, first to involve two arcs of the meridian and the parallel at a 2° interval, and second, to densify adequately for cartographic operations at comprehensive spaces in the principal triangulation figures;
2. establish geodetic bases at distances of about 400 km along principal figures, and provide for the distribution that forms a precision of European second-order triangulation – which is a precision less than attributed to the principal triangulation;
3. observe Laplace stations at 200-km by 200-km spacings;
4. obtain the following precision for the geodetic and astronomic observations as principal triangles –6″, secondary triangles – 10″, latitude – 0.2″, longitude – 0.5″, and azimuth – 0.5″." To paraphrase, the Chief of the Geographic Mission later sent instructions in 1946 to observe arcs of the meridian and the parallel at a multiple interval of 3°. In 1953, the first order triangulation was adjusted using tables from the U.S. Coast and Geodetic Survey (*based on the Clarke 1866 ellipsoid*). "This adjustment was based on the condition equations formed by 269 triangles."

The triangulation eventually comprised 17 bases at Quimongo, Congo Yala, Quitinda, Luanda, Lucala, Camacupa, Catumbela, Alto Catumbela, Cimo, Serpa Pinto, Quipungo, Moçãmedes, Humbe, Baia dos Tigres, Sare, Namatuco, and Luiana – determined 1722 points based on observations of 3809 triangles of which 856 points were not occupied – made astronomical observations of latitude, longitude, and azimuth at 15 station – and performed the leveling of 943 km.

Immediately prior to WWII, the Belgians published booklets in French and Flemish, listing the coordinates and geodetic positions for Bas-Congo that extended from the Atlantic Ocean to Leopoldville. In those booklets are some 38 points that are referred to the Congo-Yella Datum. Some of those points are Portuguese control points common with Angola that shares the river. The fundamental point for the Congo-Yella Datum is the east base terminal of Congo-Yella where Φ_o = 06° 00′ 53.139″ South, Λ_o = 12° 58′ 29.287″ East of Greenwich, and the ellipsoid is Clarke 1880. Transformation parameters from the Congo-Yella Datum to the Angola Datum (also Clarke 1880) are ΔX = –35.08 m, ΔY = +184.83 m, and ΔZ = +63.02 m (±3.7 m); and from Congo-Yella Datum to the Camacupa Datum of 1948 are ΔX = –44.47 m, ΔY = +179.47 m, and ΔZ = +59.30 m (±2.0 m). The similarity of values gives confirmation that, in this region, the Angola Datum is equivalent to the Camacupa Datum of 1948. From the Congo-Yella Datum to the WGS 84 Datum, ΔX= –93.28 m, ΔY= –164.11 m, and ΔZ= –169.02 m (±5 m). Grids based on the Congo-Yella Datum are the Belgian Congo Gauss-Krüger Transverse Mercator Fuseau 13 (Zone 13) where latitude of origin (φ_o)= 2° 30′ South, Central Meridian (λ_o) = 13° E, FN = 700 km, FE = 220 km, and the scale factor. (m_o) = 1.0; Fuseau 14 where latitude of origin (φ_o) = Equator, Central Meridian

(λ_o)= 14° E, FN= 10,000 km, FE = 500 km, and the scale factor (m_o) = 0.9999; and Fuseau 16 where latitude of origin (φ_o) = Equator, Central Meridian (λ_o) = 16° E, FN = 10,000 km, FE = 500 km, and the scale factor (m_o) = 0.9999. The Gabon Belt (Fuseau Gabon) is found in use along the northern coast (*PE&RS*, September 1998). Of course, the UTM grid is common in Angola.

The Camacupa Datum of 1948 is based on the origin at Campo de Aviação where Φ_o = 12° 01′ 19.070″ South, Λ_o = 17° 27′ 19.800″ East of Greenwich, and h_o = 1508.3 m. Thanks to John W. Hager, "This is the principal vertex marked by a concrete monument, constructed on a high part of the Camacupa Air Field, immediately to the north of the runways." (*This is*) "defined as the "Datum Point" of the main triangulation network of Angola. A concrete monument with the dimensions 70 × 60 × 100 cm (length E-W × width N-S × height), topped by a white marble slab on which is cut in black: M.G.A. –P.F.- 1948; in the center of which is placed the top mark of the base, which is defined as the extreme West of the Geodetic Base of Camacupa. The mark found here is protected by a masonry casing with a metallic cover, easily removed to permit observations over the base when necessary." Remarkably, some Datums established by the Portuguese in Angola (and Moçambique) were referenced to the Clarke 1866 ellipsoid (the same as used in the U.S. for the North American Datum of 1927) where a = 6,378,206.4 m and and b = 6,356,583.8 m. The only transformation parameters I have ever been able to scrounge <u>from</u> this Datum <u>to</u> WGS84 were obtained from Prof. Charles L. Merry at the University of Cape Town where ΔX = –49 m, ΔY= – 301 m, and ΔZ = –181 m; and Prof. Merry estimates the accuracy at ±60 meters. According to Hager, "sometime in the 1960s or 1970s, DMA was asked to put Angola, then on the Camacupa Clarke 1866 Datum, on the Camacupa Clarke 1880 and the Arc 50 Datums. The Portuguese provided all the coordinates based on the Clarke 1866 Datum. They also provided tables to convert from the Clarke 1866 Datum to the Clarke 1880 Datum assuming that the tangent point of the two ellipsoids was at Camacupa. I think that the tie was on the 12th Parallel South to the Zambian Triangulation. (*It was*). The 6th Parallel south and Bas Congo surveys of Congo occupy common points with the Angola surveys and were adjusted to the Arc Datum of 1950. A comparison of the Angola values showed that Arc 50 Datum in Angola was adequate for mapping purposes. Angola is on the UTM Grid. I did find a local grid for Luanda and would expect other similar ones. For Luanda, the 1:2,000-scale city map plots directly on top of the UTM Grid of the 1:100,000-scale map. The 50,000 50,000 intersection is, in UTM coordinates, N = 9,024,000 and E = 306,000. This then results in a local Grid, Transverse Mercator projection, Clarke 1880 ellipsoid, φ_o = 0°, λ_o = 15° E, FN = 1,026 km, FE = 244 km, and (m_o) = 0.9996. The UTM scale factor at local 50,000 50,000 is 1.00006581. A unity scale factor would be expected for a City Grid, and this is pretty close to unity. The math for the false coordinates is FN = 10,000,000 – 9,012,000 + 50,000 = 1,026,000 and FE = 500,000 – 306,000 + 50,000 = 244,000.″ The Camacupa Clarke 1880 Datum is oftentimes referred to by the hydrographic community as the Camacupa-Vumbatumba Datum of 1950 based on the origin surveyed by MHCA in 1950 as Φ_o = 06° 26′ 17.111″ South and Λ_o = 12° 27′ 22.978″ East of Greenwich. Transformation parameters used by Western Geophysical from the Camacupa-Vumbatumba Datum of 1950 to the WGS 84 Datum are ΔX = –39.44 m, ΔY = –353.66 m, and ΔZ = –224.16 m, and the transformation parameters used by the British Navy are ΔX = –48.81 m, ΔY = –343.58 m, ΔZ = –228.32 m, ±10 meters for the northern part of the country.

Thanks to parameters published into the public domain by the European Petroleum Studies Group (EPSG) headed up by Mr. Roger Lott of British Petroleum, there are a number of transformations from the Clarke 1880 version of the Camacupa Datum of 1948. For instance, Camacupa 1948 to WGS 72BE: ΔX = –37.2 m, ΔY = –370.6 m, and ΔZ = –228.5 m; this was derived by Geophysical Services, Inc. in 1979. Camacupa 1948 to WGS84, used by Conoco for Offshore Block 5: ΔX = –42.01 m, ΔY = –332.21 m, and ΔZ= –229.75 m. Camacupa 1948 to WGS84 and used by Topnav at PAL F2, by Elf in blocks 3 and 17 since 1994, and by Total in block 2 since 1994: ΔX = –50.9 m, ΔY = –347.6 m, and ΔZ = –231 m. An additional eight versions of parameters are used for the "same" transformation in offshore areas spanning the entire coast of Angola.

The MHAST Datum of 1951 (Missão Hidrográfica de Angola e São Tomé) fundamental point is a concrete block, point Y, at Malongo lighthouse that is at Φ_o = 05° 23′ 30.81″ South, Λ_o = 12° 12′ 01.59″ East of Greenwich, and is referenced to the International ellipsoid of 1924 where a = 6,378,388 m and $^1/_f$ = 297. From MHAST to WGS84: ΔX = –252.95 m, ΔY = –4.11 m, and ΔZ = –96.38 m. The Malongo Datum of 1987 replaced the MHAST Datum of 1951, and is also referenced to the same fundamental point (new coordinates unknown). The same ellipsoid is used; however, the transformation parameters have changed to become Malongo 1987 Datum to WGS 84: ΔX= –254.10 m, ΔY= –5.36 m, and ΔZ= –100.29 m, thanks to Mal Jones of Perth, Australia.

Hager went on to say; "A survey was done across Congo (Kinshasa) connecting Angola proper to Cabinda but the data were destroyed by a fire in Lisbon so Cabinda is on a local datum. About all the booklet for Cabinda will say is that it is not on Camacupa 1948 Datum. The values of the boundary marks in the northwest of Cabinda are in agreement with those published by (the French) IGN and used by Congo (Brassaville)."

Other datums existing in Angola include the Lobito Datum of 1937 based on the origin point at the astronomical pillar Restinga do Lobito, Extremo NE da Base do Lobito, where Φ_o = 12° 19′ 00.86″ South, Λ_o = 13° 34′ 45.67″ East of Greenwich, Clarke 1866 ellipsoid. Dr. José Carvalho of Maputo, Moçambique states that the Camacupa Datum of 1948 coordinates of the same point are Φ_o = 12° 19′ 01.357″ South, Λ_o = 13° 34′ 58.375″ East of Greenwich. The transformation from the

Lobito 1937 Datum to the WGS 84 Datum is ΔX = –256.73 m, ΔY = 0.00 m, and ΔZ = –103.67 m (±10 m).

The Luanda Datum is based on the origin point at Luanda Observatory where Φ_0 = 08° 48′ 46.8″ South, Λ_0 = 13° 13′ 21.8″ East of Greenwich, Clarke 1866 ellipsoid. The Moçamedes Datum of 1956 origin point is at the Moçamedes Meteorological Station where Φ_0 = 15° 11′ 16.34″ South, Λ_0 = 12° 07′ 34.53″ East of Greenwich, Clarke 1866 ellipsoid.

Many thanks to Sequoia Read of the Defence Geographic Centre and the Geodesy Section of the United Kingdom Hydrographic Office.

Update

One recent article[1] found is by Sebastian J.F.[2], Kutushev S.B.[3], in 2015, called Modernization of "Geodetic Net" of the Republic of Angola. The "Base Tasks."[4] Printed in the Russian journal Geodesy and Cartography [Geodezija i kartografija / Геодезия и Картография], 2, pp. 19-24. However, the article itself was not available (21JAN2019).

The article's abstract reads:

The National Surveying and Mapping Organization needs to be provided with legal support and technical documentation. In general, modernization should involve three types of reference nets – Geodetic, Leveling and Gravimetric.

It seems there have been many calls for the modernization of Angola's geodetic network as far a field as the United Nations Framework Convention on Climate Change[5] to a variety of dissertations[6,7] from Moscow State University.

The 2012 dissertation, outlines the main tasks of an organizational and technical nature, which, according to the authors, is necessary to solve when upgrading the cartographic-geodetic of the Republic of Angola, State Geodetic Survey

In a recent email note from Dr. Rui Fernandes,[8] he mentioned that he inquired as to what the Angolan government had accomplished in terms of a new datum and coordinate system. Their reply was "We used your past project," and they offered no further details (personal communication, January 2019).

1 Geodesy and Cartography. http://geocartography.ru/en/scientific_article/2015_2_19-24, Accessed 4 February 2019.
2 Department of Geography and Military Cartography of the General Staff Angola Armed Forces, Luanda, Angola.
3 Bashkir State University, Ufa, Russia.
4 DOI: 10.22389/0016-7126-2015-896-2-19-24.
5 Angola Initial National Communication https://unfccc.int/resource/docs/natc/agonc1.pdf, Accessed 4 Febuary 2019.
6 Alves, Antonio. 2012. "Development of methods for upgrading the planned geodetic network of the city using modern satellite technologies". http://www.dissercat.com/content/razrabotka-metodiki-modernizatsii-planovoi-geodezicheskoi-seti-goroda-s-ispolzovaniem-sovrem, Accessed 4 February 2019.
7 Lucian, Damiao. 1998. "Development of a project for the creation of the State Geodesic Network of Angola using satellite technologies." http://www.dissercat.com/content/razrabotka-proekta-sozdaniya-gosudarstvennoi-geodezicheskoi-seti-angoly-s-primeneniem-sputni#ixzz5eZrvgUUr, Accessed 4 February 2019.
8 Universidade da Beira Interior Department of Computer Science SEGAL, Covilhã, Portugal.

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