Grids & Datums

The Republic of Moçambique

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 Republic of Moçambique was originally printed in 1999 but contains updates to their coordinate system since then.

The first Portuguese explorer to arrive in Moçambique was Pero de Covilha who was dispatched in 1487 to find a route to India, which he reached via Egypt and Aden. On his return trip in 1489, he visited several places on the East Coast of Africa, including the ancient port of Sofala. The flourishing Arab port city on the Island of Moçambique was visited by Vasco de Gama in 1498, following the rounding of the Cape of Good Hope the previous year by Bartolomeo Dias. Soon a Portuguese trading port, the region remained under the control of Portugal through a complicated series of arrangements until its independence in June of 1945. That port city remained the capital until 1907 when the capital was moved to the southern port of Lourenço Marques (now Maputo). Moçambique has 10 provinces, some of which are the namesakes of local datums: Cabo Delgado, Gaza, Inhambane, Manica, Maputo, Nampula, Niassa, Sofala, Tete, and Zambézia.

Before the peace accord of October 1992, Moçambique had been devastated by civil war and was one of the poorest countries on the globe. Prospects have subsequently improved, and with its solid economic performance in 1996-97, Moçambique has begun to exploit its sizable agricultural, hydropower, and transportation resources. The restoration of electrical transmission lines to South Africa and the completion of a new transmission line to Zimbabwe (permitting the giant Cahora Bassa hydropower plant to export large amounts of electricity) will greatly improve foreign exchange receipts. Land surveying and boundary surveys were authorized by the Portuguese crown in 1857. Topographic mapping for Moçambique was designed by the Portuguese "Junta das Investigações do Ultramar" (Board of Overseas Research) in Lisbon, Portugal. The Junta coordinated the activities of the geographic mission that established horizontal and vertical control for photogrammetric mapping accomplished by Serviços Geográficos e Cadastrais (SGC) in Maputo. Control surveys for systematic mapping was initiated in 1931 by the SGC with the assistance of the Junta, and all 61 sheets at 1:250,000 scale were completed by 1955.

The Dutch ceded South Africa to the British in 1814. The last two decades of the 19th century saw extensive African development by the European powers. The geodetic survey of the 30th Meridian West of Greenwich became a symbol of the progress of documenting the British Empire borders

Photogrammetric Engineering & Remote Sensing
Vol. 83, No. 5, May 2017, pp. 337–340.
0099-1112/17/337–340

doi: 10.14358/PERS.83.5.337

in Africa. This was the same rationale as had already been established by Everest 100 years prior in India. The goal was for "continuous British pink on the map from the Cape to Cairo." The classical triangulation of the 30th Meridian arc has its roots both in South Africa that extended northward from the Cape and also southward from British Central Africa.

The Cape Datum has its initial origin point in Port Elizabeth, South Africa, at station Buffelsfontein where: Φ_o = 33° 59′ 32.000″ South, Λ_o = 25° 30′ 44.622″ East of Greenwich. The ellipsoid of reference is the Clarke 1880, where: a = 6,378,249.145 meters, $^1/_f$ = 293.465. The azimuth to station Zurrberg is: α_o = 004° 15′ 26.311″, and the geoidal height (H_o - h_o) at the origin is defined by implication to be zero. The deflection of the vertical at Buffelsfontein was initially assumed to be zero, and although non-zero values were subsequently published in the middle 1960s, this has been ignored. The Cape Datum theoretically covers a substantial portion of South East Africa, but has been subjected to several regional adjustments that effectively separate into a variety of individual local systems. The countries surrounding Moçambique that are on the Cape Datum include South Africa and Swaziland.

The Arc Datum has the same origin as the Cape Datum, but its initial fieldwork started in Uganda and Kenya. Individual country adjustments of this meridional chain (or arc) of quadrilaterals have resulted in the countries surrounding Moçambique that are on the Arc Datum to include Tanzania which is on the Arc Datum of 1960. This particular adjustment is carried further north into the Sudan. Malawi, Zambia, and Zimbabwe are on the Arc Datum of 1950. Note that Zimbabwe was formerly Southern Rhodesia, Zambia was formerly Northern Rhodesia, Malawi was formerly Nyasaland, and Tanzania was formerly Tanganyika, which had been formerly Ger-man East Africa. After World War I, the British assumed colonial administration of Tanganyika. The consequence of this was that Moçambique was now surrounded by British colonies, and its borders were subsequently entirely surveyed by the British Royal Engineers.

The Moçambique–Tanzania boundary initially delimited German and Portuguese spheres of influence in East Africa. In accordance with the terms of a German-Portuguese declaration signed at Lisbon in 1886, a boundary was established between the Indian Ocean and Lake Nyasa. Subsequent treaties delimited the boundary in additional detail, and a joint expedition in 1907 changed the boundary slightly in the west and demarcated the land segment by pillars. Following WWI, the former German territory of Tanganyika was made a British mandate, and during 1936 and 1937 an exchange of notes between Portugal and the United Kingdom determined the sovereignty of the island in the Rio Rovuma (Ruvuma River) which forms more than 90 percent of the total boundary. With a total length of 752 km (470 miles), streams comprise 712 km (445 miles) of the distance of which the Rio Rovuma and its tributaries account for all but about 1½ km (1 mile). The Rule of the Thalweg (thread of the stream) is specified for this riparian boundary. The parameters published by DMA/NIMA for the Tanzania Arc 1960 Datum to WGS84 are: ΔX = –175m ± 6m, ΔY = –23 m ± 9m, ΔZ = –303 m ±10m.

The Moçambique–Malawi boundary is approximately 1560 km (975 miles) in length and was originally demarcated in 1899-1900 with errors. It traverses Lake Nyasa for about 328 km (205 miles) including lines around Likoma Island and Chisumulu Island, which are part of Malawi. Southward from Lake Nyasa to the Malosa River, the boundary extends along straight-line segments for 312 km (195 miles) passing through both Lake Chiuta and Lake Chilwa. It follows consecutively the thalwegs of the Malosa, Ruo, and Shire rivers downstream for 240 km (150 miles). The boundary then continues northwestward to the Zambia tripoint utilizing features along the Shire-Zambezi and the Lake Nyasa-Zambezi drainage divides for most of the remainder of the distance. The parameters published by DMA/NIMA for the Malawi Arc 1950 Datum to WGS84 are: ΔX = –161m ± 9m, ΔY = –73 m ±24m, ΔZ = –317 m ±8m.

The Moçambique–Zambia boundary commences in the Northwest at the tripoint (with Malawi) where the Lake Nyasa–Zambezi River drainage divide meets at the 14th parallel in accordance with the agreement of June 11, 1891 between the United Kingdom and the Kingdom of Portugal. The tripoint was determined to be located at ϕ = 14° 00′ 00″ S, λ = 33° 14′ 32″ E by a joint boundary commission in 1904. The commission was led by Captain (later Admiral) Carlos Viegas Gago Coutinho of the Portuguese Navy and by Major O'Shee of the United Kingdom. The boundary proceeds to the southwest along the Zambesi River drainage divide until it meets the River Aroangwa or Luangwa. Thence, the boundary follows along that river until it meets the Zambesi River to tripoint (with Zimbabwe) Beacon Number 1 where: ϕ = 15° 37′ 27″ S, λ = 30° 25′ 20.3″ E. Note that Zambia is where the Livingstone Memorial is located. ("Dr. Livingstone, I presume …?") The parameters published by DMA/NIMA for the Zambia Arc 1950 Datum to WGS84 are: ΔX = –147m ± 21m, ΔY = –74 m ±21m, ΔZ = –283 m ±27m. Coutinho and O'Shee later spent 1904-1905 correcting and re-marking the border north of the "14°S" Malawi tripoint.

The Moçambique–Zimbabwe boundary is about 1224 km (765 miles) in length. It is demarcated throughout this distance by pillars or rivers. The tripoint (with Zambia) Beacon Number 1 addressed in "The Northern and Southern Rhodesia Order in Council 1963" indicated that their common boundary joined the Moçambique tripoint at the *medium filum acquae* (median line) of the Zambesi River. This is very close to the Moçambique village of Zumbo, where the old Madzansua Datum origin is located. In the central part, the boundary traverses an area of numerous escarpments and peaks including the Inyanga Mountains and the Chimanimani Mountains. The parameters published by DMA/NIMA for the Zimbabwe Arc 1950 Datum to WGS84 are: $\Delta X = -142m \pm 5m$, $\Delta Y = -96$ m $\pm 8m$, $\Delta Z = -293m \pm 11m$.

The Moçambique–South Africa boundary, which is about 488 km (305 miles) in length, consists of two discontinuous parts. The longer part extends southward from the confluence of the Limpopo River and the Luvuvhurivier River for 408 km (255 miles) along straight line segments to the northern tripoint with Swaziland and the M'Pundweni Beacon. The remainder of the boundary from the southern tripoint with Swaziland to the Indian Ocean follows the Maputo River (Great Usutu) downstream for about 17 miles and then continues by straight-line segments for another 53 km (33 miles). The parameters published by DMA/NIMA for the South Africa Cape Datum to WGS84 datum shift are not as accurate as those are according to Rens & Merry. Professor Charles Merry of the University of Cape Town found a substantial improvement with a 4-Parameter transformation such that: X = –190.0m ± 7.7m, DY = –137.9m ±3.7m, Z = –257.4m±4.7m, scale = +11.0x10-6, and the aggregate positional rms = ±2.9m. Note that the values quoted are the most reliable for points within Moçambique.

The Moçambique–Swaziland boundary has two tripoints with South Africa. Northward from the Maputo River it extends along the summit of the Lebombo Mountains for approximately 106 km (66 miles) to M'Pudweni Beacon. The boundary consists of various straight-line segments demarcated by trigonometrical and/or boundary beacons. The original treaty in this area dates back to 1869, and portions remained in dispute until 1927. The M'Ponduine Geodetic Station (MGM 677) was used as the origin of a local boundary grid that, based on an ellipsoidal polyhedric projection, has the origin as: $\phi_o = 25° 56' 47.19''$ S, $\lambda_o = 31° 58' 40.46''$ E. No false origin was used, and the M'Uguene Geodetic Station (MGM 658) given as a computational check is: $\phi = 26° 07' 25.98''$ S, $\lambda = 32° 16' 31.58''$ E and X = –29,757.40 meters, Y = +19,691.48 meters. There is no doubt that this boundary Grid is on the Cape Datum, Clarke 1880 ellipsoid. Professor Merry's solution for Swaziland is a 3-parameter shift to WGS84 Datum where: $\Delta X = -136.8m \pm 0.5m$, $\Delta Y = -106.6m \pm 0.5m$, $\Delta Z = -293.0m \pm 0.5m$, and the aggregate positional rms = ±0.7m.

There are three classical geodetic Datums in Moçambique, and all are referenced to the Clarke 1866 ellipsoid where a = 6,378,206.4 meters and $^1/_f = 294.9786982$. This ellipsoid was a favorite of the Portuguese in Africa — they used it in Angola, too! The oldest is the Madzansua Datum of 1904 with its origin at point MGM 2 (near the village of Zumbo), where: $\Phi_o = 15° 35' 20.7''$ S, $\Lambda_o = 30° 28' 09.3''$ E and $H_o = 1010.9$ meters.

The most often quoted classical datum for Moçambique in Western literature is the Observatorio Campo Rodrigues Datum of 1907. Its origin is near Lourenço Marques (Maputo) at station MGM 650 where: $\Phi_o = 25° 58' 06.99''$ S, $\Lambda_o = 32° 35' 37.75''$ E. The defining azimuth is unknown. I was surprised to learn that before 1971 it wasn't used for much other than the 1:50,000 topographic mapping from the southern border to no further north than the coastal village of Moebase. The Cape Datum was connected to the Observatorio Datum of 1907 by the M'Ponduine and Ypoy (MGM 675) stations through the Transvaal triangulation. Both of these old datums were established by Captain Coutinho.

The largest classical horizontal geodetic datum is the Tete Datum of 1960. It's origin is at the station at the NW Tete Baseline (MGM 799) where: $\Phi_o = 16° 09' 03.058''$ S, $\Lambda_o = 33° 33' 51.300''$ E. The reference azimuth to station Caroeira (MGM 40), $\alpha_o = 355° 50' 21.07''$ from south, and $H_o = 132.63$ meters. A French memo from Maputo observed that "the astronomic coordinates = geodetic coordinates, but it is suspected (according to the results of the computations) which is such that the deviation of the vertical are at the point chosen for the 'datum.' In effect for each zone north and to the NW, there are concentrated deflection forces due to iron mineral deposits, whereas to the south and SE coal and less dense minerals are found. If that hypothesis is likely, then the coordinates of the 'datum' of all the points in Moçambique will need correction." The Tete Datum of 1960 coordinates of MGM 2 are: $\phi = 15° 35' 15.349''$ S, $\lambda = 30° 28' 15.057''$ E. The Tete Datum of 1960 coordinates of MGM 650 are: $\phi = 25° 58' 10.359''$ S, $\lambda = 32° 35' 40.056''$ E.

In 1995, a comprehensive readjustment of the entire geodetic network of Moçambique was initiated by Norway Mapping in collaboration with the government. The project was concluded in January of 1998, and the result was a 32-point constrained adjustment of 759 two-dimensional triangulation points throughout the country and the designation of a new datum called MOZNET/ITRF94, compatible with the WGS84 Datum. A 7-parameter Bursa-Wolf transformation was developed, but the national model yields residual errors as high as 30 meters. Four "regional" models were developed, but these accuracies vary between 1 to 10 meters, depending on the "region." This seems to be an ideal country for the development of a multiple regression equation model for a single national datum shift model. Probably a "NADCON" sort of solution would be even better! The MOZNET 98 adjusted coordinates of MGM 2 are: $\phi = 15° 35' 18.7529''$ S, $\lambda = 30° 28' 12.3667''$ E, of MGM 650 are: $\phi = 25° 58' 12.7520''$ S, $\lambda = 32° 35' 38.4687''$ E, of Base Tete NW are $\phi = 16° 09' 07.0480''$ S, $\lambda = 33° 33' 49.7778''$ E, and of M'Ponduine are: $\phi = 25° 56' 52.6154''$ S, $\lambda = 31° 58' 39.6248''$ E. The government of Moçambique adopted the use of the UTM Grid in 1954, and, with the exception of the M'Ponduine Polyhedric Grid, no other Grids are used.

Thanks for much of the historical and geodetic details contained herein go to Mr. J. Carvalho of Maputo.

Update

"The 1^{st} order Moçambique geodetic network still presents zones with low precision, such as the north coast. The conjunction of GPS and terrestrial observations of well distributed points within the territory would by a good solution to improve the equality of this network. The prediction of re-observation of more than 30 well distributed points within the whole territory using GPS, in order to obtain a valid group of vectors is included in the Portugal and Moçambique cooperation protocol. This will make the conversion to ITRF94 datum more consistent and will allow the integration of all networks in the same system" *(Adjustment of the Classical Terrestrial Geodetic Network of Moçambique Tied to ITRF, Santos, P., et al., Workshop – AFREF I, 5^{th} FIG Regional Conference, Accra, Ghana, March 8-11, 2006.)*

"The adoption of MozNet is a decisive step for the modernization of the geo-referencing activities in Moçambique. Moçambique has now a network of permanent GPS stations that permit the definition and realization of a geocentric datum This network still needs to be densified. The difference between MozNet/ITRF94 and MozNet/ITRF2008 is around 2 cm between the extreme north and south of the country which is negligible for practical purposes. Since the differences between MozNet/ITRF94 and MozNet/ITRF2008 are small, it was decided to adapt MozNet/ITRF94 as the new official reference system realized by the permanent network (MozPerm) and the already observed points" *(Validation and Implementation of MozNet – the geocentric reference frame of Moçambique, Fernanedes, R.M.S., et al., MozNet – Luxembourg, 13-17 October 2014.)*

Dr. Fernandes informs me that two years ago an aerial gravimetric survey was completed of the entire country in support of a national geoid. *(Personal communication, 28 March 2017.)*

The contents of this column reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the American Society for Photogrammetry and Remote Sensing and/or the Louisiana State University Center for GeoInformatics (C^4G).

This column was previously published in *PE&RS*.