& GRIDS & DATUMS

BY Clifford J. Mugnier, CP, CMS, FASPRS

THE KINGDOM OF MOROCCO

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 Morocco was originally printed in 1999 but contains updates to their coordinate system since then.

The Roman province of Mauritania was invaded by Muslims in the 7th century AD, leading to the founding of the present country of Morocco as an independent kingdom in the 9th century. Later centuries saw occupation by the Portuguese, English, Spanish and French. In 1912, two protectorates were established: French Morocco, on the Atlantic coast which included most of the present country and Spanish Morocco on the Mediterranean coast. In recent years, the kingdom has annexed much of the former Spanish Sahara. The geodetic history of the entire country is a combination of Spanish and French influences. The coordinate systems of Morocco are among the more difficult to comprehend and unusual in the entire world.

The first-order Frontier Triangulation of Spanish Morocco was attached to Spain by measurements of the Instituto Geográfico y Catastral de Madrid in 1923-1929. It was composed entirely of one meridional arc and was originally referenced to the Madrid Datum on the Struve ellipsoid. This was locally computed on the Beni Meyimel Gauss-Krüger Transverse Mercator Grid of 1923 that was adjusted in the late 1950's to the European Datum of 1950. Station Beni Meyimel on ED50 is: ϕ_o = 35° 45′ 34.223″ North, λ_o = 5° 41′ 09.5168″ West of Greenwich. The local Spanish Grid origin for Puerto de Tánger (Port of Tangier) was at Faro (Lighthouse) de Malabata where: ϕ_o = 35° 48′ 47.7″ North, λ_o = 5° 44′ 57.0″ West of Greenwich. Neither of these Grids had false origins. The same triangulation arc was later completely recomputed with respect to the namesake of the capital of the former Spanish Morocco, the Tétouan Datum of 1929 where: Φ_o = 35° 35′ 41.493″ North, Λ_o = 5° 19′ 19.545″ West of Greenwich. The azimuth to Tétouan South West Base is: α_o = 231° 44′ 50.67″.

There were two types of classical triangulation in French Morocco. The original triangulation, the "Reconnaissance Triangulation," was started about 1910 and covered a major portion of the country. It was accomplished by Topographic Engineers attached to French Foreign Legion troops engaged in the conquest of Morocco. The work was done on a yearly basis to satisfy military needs, and the officers in charge did their own computations. Errors were cumulative because values for the last 2 or 3 primary stations were accepted by the extending party the following season. The work was accomplished in approximately 40 different portions, and was not as well coordinated as the previous 50 years worth of French efforts in adjacent Algeria. The Reconnaissance Triangulation is referenced to the Agadir Datum of 1921 where: Φ_o = 30° 25′ 25.0″ North, Λ_o = 9° 37′ 48.06″ West of Greenwich. The origin is the minaret of a mosque in the 16th century Port of Agadir. The solar azimuth to Signaux de

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Founti is: α_o = 109° 19′ 36″. A subsequent Polaris observation (2 pointings) was not adopted.

The French North African ellipsoidal Bonne projection was used for the Reconnaissance Triangulation, and this Grid continues to influence mapping systems in North Africa to this day. Proper computation of these Grid coordinates must be performed from the series form of the equations for millimeter accuracy. Texts that suggest the universal use of spherical formulae with the equivalent authalic radius and latitudes are wrong! The Latitude of Origin (ϕ_o) = 35° 06′ North, and the Central Meridian (λ_o) of zero degrees from Paris corresponds to 2° 20′ 13.95″ West of Greenwich. The False Origin is 100 kilometers for both Eastings and Northings. This Grid has perplexed novice cartographers (and many "old pros") for decades. Even more confusing, some implementations of this Grid display no False Origin. The active use of this Grid was terminated in 1942, but it continues to confound, as I shall explain later.

The second type of French triangulation commenced in 1922, and is known as the Triangulation Réguliere (regular triangulation). This work was carried out entirely by Topographic Brigades of the Service Géographique de l'Armee (Army Geographic Service), sent from Paris to Morocco. All computations were performed in Paris. The Réguliere Datum of 1922 is based on the origin at the astronomic station Merchich 1921 (south of Casablanca), where: Φ_o = 33° 26′ 59.672″ North, Λ_o = 7° 33′ 27.295″ West of Greenwich. The azimuth to station Mohammed El Kebir is: α_o = 46° 52′ 11.291″ (from south), and the ellipsoid of reference is the Clarke 1880 where: a = 6,378, 249.145 meters, and $^1/_f$ = 293.465. During the same era, of 7 baselines that were measured for the classical triangulation, Ber Rechid and Agourai were locally adopted as temporary datum origins. The Ber Rechid 1920 Datum is defined where: Φ_o = 33° 17′ 41.6″ North, Λ_o = 9° 56′ 02.05″ West of Paris. The azimuth from North Base to South Base is: α_o = 169° 34′ 15.3″. The geodetic definition of the Agourai Datum seems to be lost, but it may exist somewhere in Rabat or Paris. The remaining baselines of the Réguliere Datum of 1922 included Marrakech, Guercif, Taroudant, Bon Denib, and Sidi Ben Zekri, where "sidi" is an Arabic term of obeisance, similar to "my lord." In the 1950's, the U.S. Army Map Service (AMS) found the Réguliere classical triangulation to be intrinsically correct.

The Lambert (partially conformal) Conic projection is used for the Réguliere Datum of 1922, and this Grid also confounds cartographers to this day. There are two original zones: for Zone Nord, the Latitude of Origin (ϕ_o) = 33° 18′ North (or 37^G where 100 grads = 90°), the Central Meridian (λ_o) = 5° 24′ (6^G) West of Greenwich, and the Scale Factor at Origin (m_o) = 0.999625769. For Zone Sud, the Latitude of Origin (N_o) = 29° 42′ North, the Central Meridian (λ_o) = 5° 24′ West of Greenwich, and the Scale Factor at Origin (m_o) = 0.999615596. The False Origin is 500 kilometers for Eastings and 300 kilometers for Northings *for both zones*. The formulae used with this Grid have a long and lurid history dating back to the 19th century, courtesy of the French way of doing things.

During the 19th century, France was the center of cartographic research in the mathematics of map projections. Because projection table computations were performed by hand, all formulae were commonly truncated past the cubic term to ignore infinite series terms considered at the time, too small to warrant the extra effort. For instance, the Lambert Conformal Conic projection was used only to the cubic term in the formulae for the tables of the developed meridional distances. This resulted in French Army projection tables that have become part of the arcane lore of computational cartography. This "secret" has been explicitly detailed in the French literature for a century, but apparently ignored by readers of English-only papers. Standard Lambert formulae will not work for Morocco, and the use of fully conformal formulae will yield computational errors that exceed 15 meters! Note that mathematical elegance is not what matters in a country's coordinate transformations; what matters is computational conformity to local *legal* standards. In Morocco, one had better use the French Army Truncated Cubic Lambert Conic projection. Watch out for that "shrinkwrap" software in perfect conformity with United States Standards.

The Maroc Nord and Maroc Sud zones have an eastern limit to their Grids that are defined by the 448,000 meter Easting (X) coordinate of the North African ellipsoidal Bonne projection. The intersection of this Grid limit with the graticule was a graphical simplicity but a computational nightmare until the paper of Karl Rinner was used at AMS. In the 1930's, Professor Rinner published a paper (in German) detailing his development of the formulae for the ellipsoidal Bonne projection in series form. AMS developed a reversion of his series, and computational algorithms were developed for the North African Bonne in Morocco among other places.

In the past 50 years or so, a couple of other places on the Atlantic coast have been rumored to be datums in Morocco. Those places are Modagor and Sidi Ifni. Neither of these are datums; rather, they are local Grids based on the Réguliere Datum of 1922. In particular, the Sud d'Ifni 1955 Hatt Azimuthal Equidistant Grid is defined at the origin point (Camp monument at Maison Guizol) where: (ϕ_o) = 29° 02′ 06″ North, the Central Meridian (λ_o) = 10° 30′ 06″ West of Greenwich, and the Scale Factor at Origin (m_o) = 1.0. The False Origin is 50 kilometers each for Eastings and Northings. The orientation of the Grid is defined to "Fourmi" as: α_g = 40° 19′ 47″. The Mogador 1957 Lambert Grid origin is: (ϕ_o) = 31° 30′ North, the Central Meridian (λ_o) = 10° 00′ West of Greenwich, and the Scale Factor at Origin (m_o) = 0.999932968. The False Origin is 200 kilometers each for Eastings and Northings. In 1921, the position of Mogador Mat on the Reconnaissance Triangulation was: ϕ = 31° 30′ 36.7″ North, λ = 9° 46′ 31.2″ West of Greenwich. The same point on the Réguliere Datum of 1922 is: ϕ = 31° 30′ 13.178″ North, λ = 9° 46′ 23.643″ West of Greenwich. The Mosque d'Agadir has also been recomputed on the Réguliere Datum of 1922 as: ϕ = 30° 25′ 54.785″ North, λ = 9° 37′ 36.811″ West of Greenwich.

The Kingdom of Morocco added two more zones to their national Grid system to cover the annexed former Spanish Sahara. Maintaining a single national Central Meridian (λ_o) = 6^G West of Greenwich; for Zone III the Latitude of Origin (ϕ_o) = 29^G North, the Scale Factor at Origin (m_o) = 0.999616304, and the False Origin is 1,200 kilometers Easting, 400 kilometers Northing. For Zone IV the Latitude of Origin (ϕ_o) = 25^G North, the Scale Factor at Origin (m_o) = 0.999616437, and the False Origin is 1,500 kilometers Easting, 400 kilometers Northing. The National Imagery and Mapping Agency (NIMA) lists the shift from "MERCHICH Datum" (sic) to WGS 84 Datum as: ΔX = +31 meters ±5 m, ΔY = +146 meters ±3 m, ΔZ = +47 meters ±3 m. This relation is based on nine stations somewhere in Morocco.

Update

In 2004 a team of Spanish and Moroccan geodesists performed a GPS campaign to map the Strait of Gibraltar and produce a map at the scale of 1:25,000. Referenced to the GRS80 ellipsoid and projected on the Lambert Conformal Conic secant projection, the point of origin is at φ_o = 35° 57′ N, λ_o = 5° 37′ 30″ West of Greenwich, and a scale factor at origin of m_o = 0.999995266 (*Geodetic works carried out in the Strait of Gibraltar, Almazan Garate, J.L., et al, Human and Social Sciences at the Common Conference, Nov. 18-22, 2013, pp. 301-306*). In 2011, The Cartographie et Geodesie Nationale du Maroc reported that the fundamental network of Morocco consists of approximately 9,000 points, a permanent GPS network of 15 stations, a new national leveling network covering 13,806 kms, and a unification of the system of coordinates (*Cartographie et Geodesie Nationale, Hmamouchi, Y., FIG Working Week 2011, Marrakech, Morocco, 18-22 May 2011*).

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).

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Project Management
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- What level of process or control make sense relative to the number of individuals in the organization?
- Transparency – How visible is this process going to be to others.
- Opinion or fact based – Are the process steps driven by facts or opinions or both. Often our processes can be improved if they are driven by opinions vs facts. Likewise, there can be processes that are driven by numbers (facts) only but lack input from other sources of consideration.
- Is there real value in each step? Are we not doing something because it is easier not to. Is it labeled a waste of time by the user? Is it being done incorrectly?

Where to start? Begin by assessing what you already have in place. Stop and consider the PMBOK® process groups and what you would ideally need or want to accomplish in each of those areas. If your process is all oral and just "known by all" and simply passed down, then start with writing it down. Consider in general where things have always been "tough" during your projects or areas that never really seem to work and enhance those. Like all good quality improvement activities this isn't static This activity should be considered as ongoing. No matter what you come up with today, to remain viable and useful it should be revisited as time and circumstances change.

The internet is full of resources that can be used as jumping off points. Be aware that it's not always going to be simple and at times will be messy. Documents and processes will come into being and then will phase out. That said a good process is one that grows and considers the changes that are taking place around it, controlled change can be a real indicator of a process's health.

When is enough? It's hard to get the ball moving but once it's going it's easy to get on a roll. The one thing you don't want to do is paralyze anyone through process. If "no process" is one end of the spectrum "paralysis by process is the other". Here again we are looking for balance, enough rigor to control the outcome but without adding unnecessary steps.

There are opportunities to improve first time right, on time and bottom line all along in the project management process, we just have to find it. Consider reviewing and improving your project management process, creating one if you don't already have it and move forward from there. You'd be amazed at what it is that you can find that will improve your project and organizational health.

Raquel Charrois is the executive vice president of Continental Mapping Consultants, Inc., a Project Management Professional (PMP), and an ASPRS Certified Photogrammetrist.

Raquel is very focused on process based approaches that unite program and business objectives, resulting in portfolio success.

If you have questions or topics that you would like to see discussed, please email them to PMP@asprs.org.