Grids & Datums

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THE REPUBLIC OF ARGENTINA

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

The Río de la Plata (Silver River) was discovered by Solís in 1516, and Argentina was first explored by Sebastian Cabot from 1526-30. Pedro de Mendoza founded the first permanent colony at Buenos Aires (good winds) in 1536. Argentina received its independence from Spain in 1816, and it is the second largest country in South America after Brazil. The northern Chaco and thecentral Pampas are vast expanses of flat land, which is the home of the Argentine cowboy, the Gaucho. Elevations in Argentina range from –40 m to +6962 m (+22,841 ft.) on Aconcagua, the highest peak in the Western Hemisphere.

In 1826, the Topographic Department of the Province of Buenos Aires was founded. A national agency responsible for mapping the entire country was created on the 5th of December, 1879 as the Oficina Topográfica Militar (Military Topo- graphic Office). By 1901, the Army General Order No. 37 changed the name to the Instituto Geográfico Militar (Military Geographic Institute) which is a name that continues to this day. By 1943, the Argen- tine version of "La Ley," (The Law) was legislated giving the Army's Instituto Geográfico Militar (IGM) the national monopoly on large-scale topographic mapping. (See my column on Ecuador that had a short sociological commentary on the common Latin American mapping monopolies – Honduras was an exception). Argentina's organization or its mapping agency followed the European practice of the time. The early Argentine "Anuarios" (yearbooks) of the 1900's actually de- tailed the various military topo- graphic organizations of Europe.

In 1887 the old astronomical observatory at Córdoba established the longitude of its meridian circle as: Λ_o = -68° 12´ 03.3˝ West of Greenwich. The first geodetic-quality astronomical ("Astro") station observed was in 1894 at the geodetic pillar in the Army Barracks in Mendoza where: Φ_o = –32° 52´ 54.8˝South, Λ_o = –68°51´ 22.8˝West of Greenwich. At the time, the Argentines were using the Bessel 1841 ellipsoid where the semi- major axis (a) = 6,377,397.155 meters and the reciprocal of flattening ($^1/_f$) = 299.1528128. Initial plans for establishing geodetic control in the country were for a perimeter survey of the Atlantic coastline, as well as along the international and provincial borders. This plan was modified in 1912 to consist of 2° x 2° quadrilaterals formed by chains of triangulation. The classical geodetic triangulation network of Argentina reflects strict adherence to this plan as it exists today. Practically every- where else in the world the chains have been dictated by the topogra-phy. That is, triangulation stations commonly are located on the summits of hills and mountains. Since so much of the Argentine country consists of the very flat Chaco and Pampas, the topography had no

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influence on the shape of the primary triangulation chains. Consequently, since observation towers had to be built anyway, the plan for chains of man-made towers to follow strict graticule lines was a logical system to implement.

The longitude of the IGM circle in Palermo was determined in 1902 which was $\Lambda_o = -58° 25' 25.05''$West of Greenwich and was later transferred to Belgrano in 1910, whose value was $A_o = -64° 13' 10.8''$ W. This is significant in the development of the Argentine network because of the technology of the time. Longitude transfers were a major technological accomplishment over long distances, and were done with telegraph wires. The successes of such longitude (time) transfers document the modern development and settlement of the Americas as well as the world. When we attempt to model the systematic error in these old networks that form the metric base of existing large-scale topographic maps, we need to recognize that the major component of error is time = longitude.

Early Argentine topographic mapping followed the European model of the times, just like the or ganization of their mapping agency. A common projection of the time was the "Poliédrica," (Polyhedric). As I have pointed out in the past, this projection is mathematically equivalent to the local space rectangular implemented in analytical photogrammetry software. It is an ellipsoidal version of the gnomonic projection, and it is easy to draft a graticule from modest projection tables. The sheets were cut on the graticule and were 2° of latitude by 3° of longitude. That longitudinal spacing was convenient in later years when the IGM changed its basic projection.

Starting in 1894, Astro stations were determined throughout the Re- public. By 1919 there was at least one point observed in every province of Argentina except for the northern provinces of Chaco, Formosa, and Catamarca and the southernmost provinces of Santa Cruz and Tierra del Fuego. The majority of these points were located at junctions or planned junctions of railroad tracks. Some of these Astro stations were used as local datums until the national chains of triangulation were able to incorporate the hinterlands into the network. Mendoza 1894 was one example. Others include Paraná 1908 where:$\Phi_o = -31° 44' 00.7''$ S, $\Lambda_o = -60° 31'58.5''$ W, which is the capital of Entre Ríos Province, and Santo Tomé 1908 where: $\Phi_o = -28° 32' 34.380''$ S, $\Lambda_o = -56° 02' 09.225''$W. Another old datum that is still occasionally used in connection with oil exploration is the Chos Malal 1914 Datum where: $\Phi_o = -37° 22' 30.3''$ S, $\Lambda_o = -70° 17' 01.8''$ W. All of these old datums were established when the Bessel 1841 was the ellipsoid of reference for Argentina. However, the Chos Malal Datum of 1914 is probably used on the International 1924 ellipsoid, which was later adopted for all mapping in the country since 1926.

In 1926, the IGM adopted a new ellipsoid as well as a new projection for the national topographic series. The Gauss-Krüger Transverse Mercator was selected as the new projection and Grid system. The scale factor at origin (m_o = 1.0), the central meridians of the belts (C. M. = λ_o = 72°, 69°, 66°, etc., West of Greenwich), the False Easting at C. M. = 500 km, and the False Northing = 10,002,288.299 m. Note that the central meridians of the TM belts are the same interval as the predecessor Poliédrica. The defining parameters of the International ellipsoid (also called the Hayford 1909 and the Madrid 1924), are a = 6,378,388 meters, and $^1/_f$ = 297. By 1926, the entire province of Buenos Aires (and more) was completely triangulated, so the present origin of the Argentine Datum of 1926 was included. The point of origin is the Campo Inchauspe triangulation station in the town of Pehuajó where: $\Phi_o = -35° 58' 16.56''$ S, $\Lambda_o = -62° 10' 12.03''$ W. Different from most of the world, the proper name of the Argentine classical da- tum is the same name as the town and the origin point: "Campo Inchauspe Datum."

According to Mr. Rubén C. Rodriguez, by 1954 ten loops formed by chains of double triangles running along even-numbered meridians and parallels were completed and the first datum adjustment of Argentina was performed. All the angle measurements, baselines at chain intersections, and Laplace Azimuths determined at the same intersections and at half distances on meridian chains were included in that adjustment. By 1969 the network had grown to 19 loops, with a few baselines determined with electronic distance meters. There were 5,000 direction observations from 1000 vertices (stations), and two Argentine geodesists adjusted the network at the U.S. Army Map Service in Washington, D.C. The mean error of the least squares adjustment by variation of coordinates was 0.4″. Simultaneously, Dr. Irene Fisher directed the adjustment of the South American Datum of 1969 at Army Map Service (AMS) that included the Argentine data set in all the observations of the entire continent.

As a side note, I was assigned to AMS at the time, and later attended a classified symposium at Cameron Station, Virginia where Dr. Fisher presented a paper on the SAD 69. I believe I was the only junior officer attending, but there was a veritable constellation of stars with all the generals and admirals there. The flag rank officers sat in front of the audience, the senior civilian geodesists sat in the middle of the audience, and I sat in the rear with the rest of the peasants. Dr. Fisher walked onto the stage, and the retired Austrian school teacher-turned Senior Geodesist of the Army Map Service and Director of the Department of Defense Gravity Control Library stopped at the edge of the podium. She was about 4' 10" tall (1.5 m), Dr. Fisher paused, turned to the front row of 2, 3, and 4-star generals and admirals and looked at one particular Navy admiral. She frowned, addressed that giant of a man who was seated, and started scolding the admiral as if he were a child. She told the admiral (who was the commander of the U.S. atomic submarine fleet), that "Your Captains are not taking the proper observations for their gravity measurements. If your Captains cannot provide the data in proper scientific detail, do not waste my geodesists' time trying to decypher such garbage!" The Admiral cringed, said not a word, but he nodded acknowledgement. The audience was in stunned silence, the rest of the flag-rank officers had tears of silent laughter streaming from their eyes, and the tiny Dr. Irene Fisher turned, stepped onto the platform behind the podium so that she could reach the microphone, and presented her paper on the South American Datum of 1969.

The origin point for the South American Datum of 1969 is at station "Chua" in Brazil where: Φ_o = 19° 45′ 41.6527″ S, Λ_o = 48° 06′ 04.0639″ W, and the azimuth to Uberaga is: α_o = 91° 30′ 05.42″. The ellipsoid of reference for the SAD 69 is the "South American Datum of 1969" ellipsoid where a = 6,378,160 meters and $^1/_f$ = 298.25. The country of Argentina continued to favor and use the Campo Inchauspe Datum after 1969, and for precise positioning applications in the geophysical industry, the old classical datums prevailed. The Chos Malal Datum mentioned previously is still used for "oil patch" work in the central mountains near Chile, and in Patagonia, the Pampa del Castillo Datum is used for "oil patch" work. The geodetic coordinates of the origin point that bears the same name as the town is: ϕ_o = –45° 47′ 30.2911″ S, λ_o = –68° 05′ 27.7879″ W, and h_o = 732 m. Of course, both these latter two local classical datums are referenced to the International ellipsoid.

Back in May of 1982, the Deputy Director of IGM informed me that the 3-parameter datum shift values from the National Datum (Campo Inchauspe) to WGS 72 were: ΔX = +160.69m, ΔY = –129.19m, ΔZ = –84.98m; this solution was based on observations at 21 stations. NIMAcurrently offers a 10-station solution to the WGS 84 Da- tum as: ΔX = –62m ± 5m, ΔY = –1m ± 5m, ΔZ = –37m ± 5m. Some years ago, I became privy to an "oil patch" solution for the Pampa del Castillo Datum. From Pampa del Castillo Datum to WGS 84 Datum, the 2-point solution reported was: ΔX = +27.488m, ΔY = +14.003m, ΔZ = +186.411m, but I would strongly recommend truncating the parameters to the closest 25 meters! This is a good example of an analyst becoming enraptured with the "power" of the decimal point display, and implying that the data is as good as the format statement allowed in the 3-parameter solution on the computer. Remember that for trivial single-digit numbers of stations observed for the determination of systematic error from a classical geodetic datum to the WGS 84 datum, NIMA quotes the accuracy at no better than 25 meters. Millimeter level reporting does not equate to millimeter level accuracy. As a test point solution, for geodetic station Lagarto, ϕ = –45° 54′ 36.2683″ S, λ = –68° 29′ 40.3391″ W (Campo Inchauspe Datum). The corresponding "oil patch" coordinates are: ϕ = –45° 54′ 40.316″ S, λ = –68° 29′ 34.389″ W (Castillo del Pampa Datum), and: ϕ = –45° 54′ 35.4876″S, λ = –68° 29′ 44.4146″ W (WGS 84 Datum). Presumably, the ellipsoid height was constrained to zero. For the geodetic purist, the aforementioned solutions are substantially less than desirable, but they do reflect the common level of quality from some "oil patch" consultants.

The IGM currently publishes the POSGAR positions of its fiducial stations in Argentina that are part of the South American solution of geodetic positions referenced to the WGS 84 system of coordinates. Although in its preliminary stages of adjustment, the current 1999 POSGAR coordinates of station Campo Inchauspe are: ϕ = –35° 58′ 1.9731″S, λ = –62° 10′ 14.8175″W, h = 106.697m. I would consider the coordinate precision quoted by the Argentina Instituto Geográfico Militar as significant.

Update

"Measurements for updating the POSGAR 07 (Argentine Geodetic Positions 2007) National Geodetic Frame began in 2005. Said Frame was linked to the ITRF05 (International Terrestrial Reference Frame 2005) and SIRGAS (Geocentric Reference System for the Americas, solution DGF08P01). The final solution which was published in 2009 consists of 178 coordinates monumented on the ground, and all the permanent GPS stations coordinates from the RAMSAC (Argentine Network for Continuous Satellite Monitoring) network. On the other hand, this Reference Frame had the challenge to integrate all the existing Provincial Geodetic networks and PASMA (Support to the Argentine Mining Sector Project) network. To this aim, about 500 points were measured and, as a result of this, the transformation parameters were computed in order to integrate all the Geodetic Networks in Argentina into one a unique National Geodetic Reference Frame, originating a network of about 4500 points. The National Geodetic Reference Frame that preceded POSGAR 07 was called POSGAR 94 (Argentine Geodetic Positions 1994). Upon the arrival of the Global Positioning System (GPS) and its great advantages, the *(Instituto Geografico Militar-Ed)* IGN understood the need of having a geocentric reference frame compatible with the accuracies provided by this new technology, with accuracies close to WGS84 global reference system (World Geodetic Systems 1984). The POSGAR 94 monuments were measured by the IGN in 1993 and 1994, and the data processing was made by the La Plata National University (UNLP). This is how the coordinates, which related the 127 monuments, were determined all over the country.

"The development of the first National Geodetic Reference Frame and System, named Campo Inchauspe, required more than 100 years Institute work. Traditional techniques (triangulation and traverse survey) were used and every single inch of the Argentine territory was explored creating a geodetic network of about 18,000 monuments.

When determining the coordinates for each point (I, II, III and IV order), the network was divided into accuracy orders, depending on the error. The basic network consists of I and II Order Points, while the III and IV ones were used for topographic densification and measurements. This network was performed by using different high accuracy instruments that were used at that time. At present, the Triangulation Basic Network has now already been made obsolete by the satellite technology and many of those points are no longer used. The GPS system provides a new conception and vision about positioning on the Earth surface. The significant technical improvements and cost reduction of GPS technology made this technology open to everyone, being civilian or military. At present, reference frames are being accurately defined by means of permanent stations set up all over the planet. These stations continuously receive data from the NAVSTAR and GLONASS satellites. This system is named after its English acronym: GNSS (Global Navigation Satellite System), and the stations globally make reference frames materialized on the ground.

"In 1988, following the international trend, Argentina generated a Project related to the installation of permanent GNSS stations which contribute to the National Geodetic Reference Frame. The Project is named RAMSAC (Argentine Continuous Satellite Monitoring Network) and its main goals are: Contribute to the maintenance and updating of the National Geodetic Reference Frame (The Argentine National Geographic Institute is responsible for it). Contribute with permanent GNSS stations in order to keep the International Terrestrial Reference Frame (ITRF). Meet technical requirements from users of modern satellite positioning techniques. Advise and cooperate with all Agencies willing to join the RAMSAC Network and set up new permanent GPS stations, so their data may be uploaded on the internet and easily and freely accessed.

"The National Altimetric Network consists of about 2000 leveling lines which consist of 35,000 monuments built up all over the Argentine Republic, located next to routes and roads. These monuments show the height above sea level. The IGN determined the zero reference level by means of mareographic observations in the city of Mar del Plata. That is to say, that the height of monuments is referred to the mean sea level determined in Mar del Plata" *(Mr. Ruben Rodriguez, Personal Communication, July 2017).* http://www.ign.gob.ar/NuestrasActividades/Geodesia/Introduccion.

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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'truth'. Together, Monmonier's work and Brewer's give a full grip of the tenuous position of the mapmaker in today's society – data manager, marketer, artist… tasked with representing the world's shifting complexity in two-dimensional space.

Those familiar with ESRI publications of the last decade or so might expect this book to be a glossy coffee table publication, not far removed from an overgrown marketing brochure – long on looks, light on practical content. But this book is clearly the result of decades of the author's experience both authoring expert maps and teaching courses on data analysis/representation. Making Better Maps put some depth and breadth back into ESRI's suite of publications, and we hope there are more like this to come.

Ellie Maclin is a Project Manager at Allworld Project Management and she thanks Jessie Baker, Allworld cartographer extraordinaire, for her suggestions and input.