Grids & Datums

NEW ZEALAND

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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 New Zealand was originally printed in 2005 but contains updates to their coordinate system since then.

New Zealand is the southernmost extent of colonization by Polynesians. It is believed that the colonization took place in at least two major waves, the first of which is thought to have occurred around 950 AD and the second around 1200 to 1400 AD. The first group consisted of hunters who depended for survival on the flightless "Moa" bird that is now extinct. The second Polynesian group was more agrarian, and archeological evidence indicates that the two cultural groups overlapped. Abel Janszoon Tasman, a captain for the Dutch East Indies Company, was the first European to discover the Maori of New Zealand. He sighted a "large land, uplifted high" near the modern day town of Hokitika on the West Coast of South Island on 13 December 1642. He sailed northwards to a bay which he subsequently named Murderer's Bay (now renamed Golden Bay), after four of his men were attacked and killed by Maori warriors. The entire region was once thought by Tasman to be part of Tierra del Fuego, so he named it Staten Landt. Soon after Tasman's voyage it was discovered that it was not Staten Landt, and it was renamed Nieuw Zeeland.

In the late 1800s, modern surveying had begun. Captain James Cook, son of a Scottish migrant farmhand, was apprenticed to a Quaker ship owner and he learned his trade in the difficult waters of the North Sea. He studied mathematics at night during off seasons, and later in Nova Scotia he mastered surveying with the plane table and alidade. He was chosen to command a scientific voyage to the Pacific Ocean. He was commissioned Lieutenant prior to his first survey and he was promoted to the rank of Captain before his third and last survey voyage. On the first voyage (1768-1771), his charter was to first go to Tahiti and observe the transit of Venus. These observations were to be later combined with other simultaneous observations (by others) in different locations in order to establish the magnitude of one astronomical unit (AU), which is defined as the mean distance of the Earth from the Sun. (See "The Republic of Mauritius," *PE&RS*, February 1999). After making these observations, Cook was to sail south and discover or not the supposed Antipodes or great Southern Continent. The East Coast of

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North Island was sighted 07 October 1769. Cook circumnavigated North and South Island while taking almost continual observations. It took six months to produce an "astonishing" chart of New Zealand that mapped 2400 miles of coastline. On this first voyage, Cook did not sail with John Harrison's chronometer but instead used Dr. Maskelyne's Lunar Almanac, published in 1767, which he used to fix his longitudes. However, Cook did use Harrison's chronometer on his two subsequent voyages (1772-1775, 1776-1780); he verified his longitudes to within 30 minutes. Cook's chart was used for the next 100 years as the settlement of New Zealand began. Thanks to Peggy Haeger for the above research done in the late 1990s for a graduate-level course on coordinate systems that I used to teach at the University of New Orleans.

According to L.P Lee in *First-order Geodetic Triangulation of New Zealand 1909-49* and *1973-74*, "In New Zealand, as indeed in many a similar young country, … the settlement survey proceeded well in advance of the triangulation, which should have controlled it. Even the triangulations were done in reverse order, the smaller networks being observed first, the larger and more accurate networks later. Thus, the procedure has been one of successive approximations, and each stage has led to a revision or recalculation of the work done earlier."

The first use of triangulation to control local surveys was by Felton Mathew, the first Surveyor-General in 1840-41; the limited area covered was near Auckland. In 1849 another small triangulation was begun near Christchurch. Both of these were superseded by more accurate surveys. In 1852, six Provincial Governments were formed to administer New Zealand, and later this increased to nine provinces; each of which had its own survey department. (A special department of the General Government conducted Surveys of native Maori lands). Henry Jackson based his land surveys on triangulation in Wellington Province beginning in 1865. The principal sections were in Wellington, Wairarapa, and Rangitikei covering the three districts where settlements were located, and each section was erected upon its own baseline, with several check bases included for verification.

The specifications for surveying the New Zealand public lands with steel tapes originated with experiments on the Thames gold-fields in 1869. The specifications were finally written to require steel tapes only (no chains) by James McKerrow in 1886, which preceded both the Swedish Jäderin steel wire apparatus in 1887, and the U.S. Coast & Geodetic Survey steel tapes in 1891!

"In the Province of Otago a control net of triangulation was not used, but a uniform system to govern the orientation of surveys was introduced by J.T. Thomson in 1856. The Province was divided into for large districts called 'meridional circuits.' Within each circuit an initial station was selected and true meridian was determined by astronomical observation. Bearings, but not distances, were carried outwards by traverse from the initial station to the boundaries of the circuit, following the chief valleys suitable for settlement. Points on these traverses were called 'geodesic stations,' and were usually from 15 to 25 km apart, providing a series of reference points by which any survey within the meridional circuit could be oriented in terms of the meridian of the initial station. Any further control was merely local, being based upon a small triangulation net extending only over the region where is was immediately required, so that a large number of independent triangulations came to be distributed throughout the settled area of the Province. Each such triangulation was regarded as the control for an area around it called a 'survey district,' and each meridional circuit was eventually divided into many such districts, often irregular in shape: although the later additions tended to be bounded by lines parallel to and perpendicular to the meridian of the initial station. Local surveys could be coordinated with reference to the geodetic stations within a survey district."

The original datum for New Zealand was the Mt. Cook Datum of 1883, located in the city of Wellington.

Thompson eventually adopted the meridional circuit system for all of New Zealand in 1877 as modeled by his original system earlier used in Otago. A total of 28 Meridional Circuits were established: nine in the North Island and 19 in the South Island. Those Meridional Circuits with their original initial origins are: Mt. Eden/Mt. Eden, Bay of Plenty/Maketu, Poverty Bay/Patutahi, Taranaki/Huirangi, Tuhirangi/Thuirangi, Hawkes Bay/Hawkes Bay, Wanganui/Mt. Stewart, Wairarapa/Opaki, Wellington/Mt. Cook, Collingwood/Parapara, Nelson/Botanical Hill, Karamea/Karamea, Marlborough/Goulter Hill, Buller/Buller Initial, Grey/Grey Initial, Amuri/Isolated Hill, Hokitika/Hokitika Initial, Okarito/Abut Head, Mt. Pleasant/Mt. Pleasant, Gawler/Gawler Downs, Jacksons Bay/Mt. Eleanor, Timaru/Mt. Horrible, Lindis Peak/Lindis Peak Initial, Mt. Nicholas/Mt. Nicholas, Mt. York/Mt. York, Observation Point/Observation Point, North Taieri/North Taieri, and Bluff/Observation Spot. Computations on these meridional circuits were performed on the plane with the point of origin being the initial point. With the geodetic coordinates known for each initial point, the survey computations were equivalent to using the Polyhedric projection, which is the same as the Local Space Rectangular, commonly used in computational photogrammetry.

In 1901 a new secondary triangulation was started in order to bring all the different nets of triangles into harmony in the Wellington and Taranaki districts. The North Island geodetic triangulation of 1921-1938 started actual field observations in 1923 and continued until being suspended during the Great Depression of the early 1930s. It resumed in 1936. The South Island geodetic triangulation of 1938-1942 started with the observations across Cook Strait in a quadrilateral with one line measuring 120 km from Papatahi to Attempt Hill. Final fieldwork was observed from 1947-1949 including baseline-measuring equipment obtained on loan from Tanganyika (now Tanzania), which was used for three South Island bases. In 1948, 12 LaPlace stations were observed with time signals transmitted from Dominion Observatory especially for this purpose. When the computations were completed, the "New Zealand Geodetic Datum 1949" (NZGD49) was established where the initial station of origin was: Papatahi Trig Station Φ_o = 41º 19´ 08.9000˝ S, Λ_o = 175º 02´ 51.0000˝ E of Greenwich, azimuth to Kapiti No. 2 α_o = 347º 55´ 02.500˝, and the ellipsoid of reference is the International 1924 where a = 6,378,388 m and $^1/_f$ = 297. Papatahi is a centrally situated station of the main net and one of the corner stations of the subsidiary net containing Kelburn. The values of deflection of the vertical for the north-south component at 65 latitude stations and deflection of the vertical for the east-west component at 39 azimuth stations from the first adjustment were known, and the latitude and azimuth at Papatahi were chosen so as to make the means of these differences equal to zero. The longitude adopted for Papatahi was that derived from Kelburn. The stations were coordinated on the National Grids, each island being on an independent Transverse Mercator projection, which had been selected by H.E. Walshe just before WWII. The New Zealand North Island Belt Latitude of Origin φ_o = 39° S, Central Meridian, λ_o = 175° 30´ E, Scale Factor at Origin, m_o = unity, False Northing = 400,000 yards, False Easting = 300,000 yards where 1 foot = 0.304799735. The New Zealand South Island Belt Latitude of Origin, φ_o = 44° S, Central Meridian, λ_o = 171° 30´ E, Scale Factor at Origin, m_o = unity, False Northing = 500,000 yards, False Easting = 500,000 yards. No further first-order work was contemplated for about 25 years, and in 1972-1974, some reobservation and extension was done with theodolites and Geodimeter Model 8 electronic distance meters.

When the metrication of surveys was begun in 1973, a one-projection coordinate system was adopted for topographic maps (the New Zealand Map Grid), but for cadastral surveying it was decided to retain the meridional circuit systems but the Polyhedric coordinates were replaced by Transverse Mercator coordinates referred to the old origins.

In August 1998, "Land Information New Zealand" (LINZ) approved the adoption and implementation of a new geocentric datum, New Zealand Geodetic Datum 2000 (NZGD2000). The new coordinates of points changed by approximately 200 meters relative to the old datum, NZGD49. A one-projection coordinate system was adopted for 1:50,000 scale and 1:250,000 scale topographic maps (the New Zealand Transverse Mercator 2000) that replaces the NZMG. The NZTM2000 Latitude of Origin, φ_o = 0°, Central Meridian, λ_o = 171° E, Scale Factor at Origin, m_o = 0.9996, False Northing = 10,000,000 meters, and False Easting = 1,600,000 meters. For cadastral surveys in terms of NZGD2000 the 28 new meridional circuits replace the existing circuits, which were in terms of NZGD49. The new circuits are referred to as "<name> Circuit 2000," to distinguish them from the old circuits. The origins of latitude and longitude of the NZGD2000 circuit projections are almost the same as their NZGD49 equivalents being rounded down to the nearest arc second. The central meridian scale factors at origin of the NZGD2000 circuit projections are the same as those of their NZGD49 equivalents. The false origin coordinates of NZGD2000 circuit projections are 100 km greater then their NZGD49 equivalents, being 800 km N and 400 km E. This is to reduce the risk of confusion between the NZGD2000 and NZGD49 projections. The NZGD2000 circuit projections are based on the GRS80 ellipsoid of revolution where a = 6,378,137 m and $^1/_f$ = 298.257222101. The SI standard for the meter has been adopted. The NZGD2000 circuit projections have a scale factor at origin of unity except for North Taieri 2000 (0.99996) and Mt. Eden 2000 (0.9999).

The Circuit Parameters are as follows: Mount Eden 2000 - φ_o = 36º 52´ 47˝ S, λ_o = 174° 45´ 51˝ E, m_o = 0.9999; Bay of Plenty 2000 - φ_o = 37º 45´ 40˝ S, λ_o = 176° 27´ 58˝ E, m_o = 1.0; Poverty Bay 2000 - φ_o = 38º 37´ 28˝ S, λ_o = 177° 53´ 08˝ E, m_o = 1.0; Hawkes Bay 2000 - φ_o = 39º 39´ 03˝ S, λ_o = 176° 40´ 25˝ E, m_o = 1.0; Taranaki 2000 – φ_o = 39º 08´ 08˝ S, λ_o = 174° 13´ 40˝ E, m_o = 1.0; Tuhirangi 2000 - φ_o = 39º 30´ 44˝ S, λ_o = 175° 38´ 24˝ E, m_o = 1.0; Wanganui 2000 - φ_o = 40º 14´ 31˝ S, λ_o = 175° 29´ 17˝ E, m_o = 1.0; Wairarapa 2000 - φ_o = 40º 55´ 31˝ S, λ_o = 175° 38´ 50˝ E, m_o = 1.0; Wellington 2000 - φ_o = 41º 18´ 04˝ S, λ_o = 174° 46´ 35˝ E, m_o = 1.0; Collingwood 2000 - φ_o = 40º 42´ 53˝ S, λ_o = 172° 40´ 19˝ E, m_o = 1.0; Nelson 2000 - φ_o = 41º 16´ 28˝ S, λ_o = 173° 17´ 57˝ E, m_o = 1.0; Karamea 2000 - φ_o = 41º 17´ 23˝ S, λ_o = 172° 06´ 32˝ E, m_o = 1.0; Buller 2000 - φ_o = 41º 48´ 38˝ S, λ_o = 171° 34´ 52˝ E, m_o = 1.0; Grey 2000 - φ_o = 42º 20´ 01˝ S, λ_o = 171° 32´ 59˝ E, m_o = 1.0; Amuri 2000 - φ_o = 42º 41´ 20˝ S, λ_o = 173° 00´ 36˝ E, m_o = 1.0; Marlborough 2000 - φ_o = 41º 32´ 40˝ S, λ_o = 173° 48´ 07˝ E, m_o = 1.0; Hokitika 2000 - φ_o = 42º 53´ 10˝ S, λ_o = 170° 58´ 47˝ E, m_o = 1.0; Okarito 2000 - φ_o = 43º 06´ 36˝ S, λ_o = 170° 15´ 39˝ E, m_o = 1.0; Jacksons Bay 2000 - φ_o = 43º 58´ 40˝ S, λ_o = 168° 36´ 22˝ E, m_o = 1.0; Mount Pleasant 2000 - φ_o = 43º 35´ 26˝ S, λ_o = 172° 43´ 37˝ E, m_o = 1.0; Gawler 2000 – φ_o = 43º 44´ 55˝ S, λ_o = 171° 21´ 38˝ E, m_o = 1.0; Timaru 2000 - φ_o = 44º 24´ 07˝ S, λ_o = 171° 03´ 26˝ E, m_o = 1.0; Lindis Peak 2000 - φ_o = 44º 44´ 06˝ S, λ_o = 169° 28´ 03˝ E, m_o = 1.0; Mount Nicholas 2000 - φ_o = 45º 07´ 58˝ S,

λ_o = 168° 23´ 55˝ E, m_o = 1.0; Mount York 2000 - φ_o = 45º 33´ 49˝ S, λ_o = 167° 44´ 19˝ E, m_o = 1.0; Observation Point 2000 - φ_o = 45º 48´ 58˝ S, λ_o = 170° 37´ 42˝ E, m_o = 1.0; North Taieri 2000 - φ_o = 45º 51´ 41˝ S, λ_o = 170° 16´ 57˝ E, m_o = 0.99996; and Bluff 2000 - φ_o = 46º 36´ 00˝ S, λ_o = 168° 20´ 34˝ E, m_o = 1.0.

Thanks to Graeme Blick of LINZ for a copy of L.P. Lee's monograph on the history of geodetic triangulation in New Zealand and to Mal Jones of Perth Australia for his continuing generous help.

New Zealand Update

"The geodetic system has been and will continue to be upgraded and enhanced. Often this is in response to increased accuracy requirements, but it is also to meet the needs of an increasing range of users. Accurate positioning is increasingly carried out by non-surveyors, often in a fully automated manner. LINZ must therefore consider how the geodetic system can support the needs of applications such as Intelligent Transportation Systems (ITS), indoor positioning and precision agriculture.

"From a user perspective, a geodetic system would ideally provide the highest levels of absolute and relative accuracy without changing coordinates. In a country such as New Zealand, these requirements are mutually exclusive. At the same time, the exploding use of GNSS-enabled technology providing ITRF coordinates through techniques such as precise point positioning (PPP) requires that LINZ provide greater support for the global reference frame.

"To support these diverse user needs LINZ is considering how to implement a two-frame system whereby both national and global datums are actively supported, with well-defined transformations between them (Donnelly et al. 2015). This would effectively be a formalization of existing practice. Applications such as cadastral surveying might continue to use NZGD2000, but other applications could then work directly in ITRF." *From Static to Dynamic Datums: 150 years of Geodetic Datums in New Zealand*, G. Blick & N. Donnelly, 2016. https://www.tandfonline.com/doi/full/10.1080/00288306.2015.1128451.

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Book Review

continued from page 760

prose to illustrate technical principles. For example, he makes an analogy to Clapton's "Layla and other Love Songs" to demonstrate a point. He often takes into consideration the reader's perspective to help make technical concepts understandable to the new students. The viewer finds blue insert boxes at chapter endings throughout the book which are very interesting, informational, and fun to read. The author provides more information in those insert boxes to support the points of view presented in each chapter.

The book cover is well designed, the font size of the book makes for easy reading. The illustrations are well placed to keep the subject matter relevant to the chapter content. The print quality of the book is good for the most part, but some minor improvement might be possible. Some of the SAR images in the book could be better colorized and larger size of some image could better convey the author's messages. If used as a text book, the instructor of the course would have to invest his/her time to develop questions for homework for students since no homework exercises are provided in the book. Nevertheless, the book is highly recommended for the student of SAR technology or for the remote sensing professional who wants to enhance his/her knowledge of SAR.