Grids & Datums

Republic of Iceland

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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 Iceland was originally printed in 2004 but contains updates to their coordinate system since then.

Iceland's first inhabitants were Irish monks who regarded the island as a hermitage until the early 9th century. "Lyoveldio Island" was permanently settled mainly by Norwegians and by some British Isles Vikings in 874 *AD*. The National Assembly or "Althing," was the world's first parliamentary system in 930. Christianity was adopted (under threat of sword!) in 999, and Iceland united with Norway in 1262. Leif Eiriksson was born in Iceland, and he sailed from Greenland to become the first European to reach North America (Vinland the Good) in 1000. In 1380, Iceland united with Denmark, and by Act of Union in 1918, became an independent kingdom in personal union with Denmark. Iceland became a constitutional republic and independent from Denmark on 17 June 1944.

The terrain is mostly plateau interspersed with mountain peaks and ice fields. The coast is deeply indented by bays and fiords. With a coastline of 4,988 km, the highest point is Hvannadalshnúkur (2,119 m). The land area of Iceland is slightly smaller than Kentucky. The maritime claim is 200 nautical miles or to the edge of the continental margin, and the territorial sea claim is 12 nautical miles. Iceland's maritime claims use the "straight baseline system," which are ellipsoidal loxodromes (rhumb lines) that connect 31 points on the coastline perimeter.

According to the National Land Survey of Iceland or Landmælingar Íslands (LMÍ), "It is believed that Guðbrandur Þorláksson, the bishop at Hólar, was the first Icelander to be involved in mapmaking. Guðbrandur lived from 1541 to 1627 and measured the global position of Hólar with amazing precision. A map named after him was published in 1590. Björn Gunnlaugsson, a teacher at Bessastaðaskóli School, made a map of Iceland in 1844. The map was named after him and used for the next 100 years!"

The Reykjavík Datum of 1900 was established by the Danish Army General Staff and published in the *Geodætisk Instituts Publikationer VII, Island Kortlægning* where: Φ_o = 64º 08´ 31.88˝ N and Λ_o = 34º 30´ 31.5˝ West of Københavns (Copenhagen) or Λ_o = 21º 55´ 51.15˝ West of Greenwich. The ellipsoid of reference was the Danish (Andræ) 1876 where a = 6,377,019.25666 m and $^1/_f$ = 300. The classical triangulation was initially used for planetable mapping at the scale of 1:50,000, but the publication scale was changed to 1:100,000 seven years later. Thirty years thereafter, the first oblique aerial photography was flown in Iceland. The original grid system used for the Reykjavík Datum of 1900 was the Islandic Conformal Conic where: the latitude of origin, φ_o = 65º 00´ N, the central meridian, λ_o = 19º 01´ 19.65˝ West of Greenwich, and the scale factor at origin, m_o = 1.0 (tangent conic). There was no false origin used with the grid associated with the Reykjavík Datum of 1900. However, since the conformal conic projection used in Denmark at the time was termed the "Buchwaldt projection," that term might have been also used in Iceland. Colonel Frants Andræs Buchwaldt (1874-1923) was the director of the

Photogrammetric Engineering & Remote Sensing
Vol. 88, No. 8, August 2022, pp. 501-504.
0099-1112/22/501-504

doi: 10.14358/PERS.88.8.501

Army Map Service Memo on old WWII-era Maps of Iceland and their Cartometric Evaluation

As of 20 December 1946, a cartometric analysis of Islandic source material by William W. Baird of Army Map Service stated:

"SUBJECT: Geodetic investigation of source material for AMS 1:50,000 series of Iceland (40045-3, 4, 4)

1. Map series investigated:
   a. S30-DGS-50
   b. S30-GSGS-50 (Grid Shown)
   c. 3-30-37003-100
   d. S30-GI-100
   e. S30-GSGS-100
   f. S30-AMS-100

2. 1:50,000
   The two sets of 1:50,000's have only partial coverage of Iceland. The 50's are quarters of the 100's - detail, features and elevations agree. Both sets of 50's carry a projection based on Copenhagen. To convert to Greenwich a correction of –12º 34´ 40.35˝ must be applied to the meridians.

   a. S30-DGS-50
      The mean differences (control-scaled) were Longitude 1.6˝ and Latitude 1.0˝. Maximum differences were Longitude from +12.0˝ to –2.2˝ and Latitude from +2.3˝ to –0.7˝.

   b. S30-GSGS-50
      The mean differences (control-scaled) were Latitude 1.4˝ and Longitude 1.4˝. Maximum differences were Latitude from –2.8˝ to +0.3˝ and Longitude from –3.3˝ to +0.3˝.

      At the scale of 1:50,000, one second of Latitude equals .024 inches and one second of Longitude equals .010 inches.

3. 1:100,000
   The 1:100,000 series has almost complete coverage of Iceland and on most of the sheets the projection is based on Greenwich, but a few sheets carry meridians based on Copenhagen. To convert to Greenwich, use the same correction as was given for the 50's.

   a. 3-30-37003-100 and S30-GI-100 are original Danish map work. S30-GSGS-100 is a British G.S.G.S. War Office series and S30-AMS-100 is an A.M.S. redraft of the G.S.G.S. series. All four series seem equally reliable for most areas, but the original Danish maps have a few spots which do not agree with the control values by several seconds, mostly in the vicinity of Akureyri.

   b. About fifty points were scaled from the various 1:100,000 series and the mean differences (control-scaled) were Longitude 3.7˝ and Latitude 1.5˝. Maximum differences were Longitude –0.5˝ to +28.1˝ and Latitude from –1.4˝ to +3.4˝.

4. Horizontal Datum
   The horizontal datum appears to be based on the astronomical station of Reykjavik.

   Latitude. 64º 08´ 31.88˝N.

   Longitude 34º 30´ 31.5˝W. –
   Meridian of Observatory at Copenhagen

   Longitude. 21º 55´ 51.15˝ W. – Greenwich

5. Vertical Datum – Mean Sea Level
   To determine the altitude of certain convenient points a levelling was carried to them starting from mean sea level and ending on trigonometric stations near the coast and from these points the height of all other points was determined by trigonometric leveling.

6. Recommendations

   a. The 1:50,000 maps appear to be sufficiently accurate to be used for position in the contemplated new 1:50,000 series of Iceland.

   b. The 1:100,000 series is not as accurate as the 50 series. The position of control points is fairly reliable but the detail between control stations is generalized and does not agree exactly with multiplex compilations made in a stereo test for portions of two sheets."

Geodetic Service of Denmark. (I have noticed that one reference published by LMÍ includes a Danish paper authored by another Buchwaldt in 1976.) The datum shift parameters (in standard military "3-parameter Molodensky" form) from the Reykjavík Datum of 1900 to the WGS 84 Datum are: $\Delta a = -1118$ m, $\Delta f = -0.0000195$, $\Delta X = -636$ m, $\Delta Y = +21$ m, $\Delta Z = -934$ m. An official notice states, "All maps on a scale of 1:100,000 published by Landmælingar Íslands are currently provided in Reykjavík 1900 datum. In the available map scales Reykjavík 1900 differs significantly from WGS84. … In case of the 1:50,000 map scale the available maps are provided in two different series first published before and after 1955. For those published after 1955 the horizontal datum is Hjörsey55 as indicated in the map legend. For those published before this threshold the phrase *Horizontal Datum is based on the Astronomic Station of Reykjavík; 21°55´51.15˝ West of Greenwich, 64°08´31.88˝* indicates the Reykjavík 1900 datum. For a variety of technical reasons it is impossible to obtain transformation parameters with high accuracy and nationwide validity. However, for navigational purposes (e.g. hiking) a set of transformation parameters has been derived from graphical comparisons. Although they proofed (sic) to be useful for orientation with the LMÍ maps they do NOT provide geodetic accuracy! In average, from WGS84 towards Reykjavík 1900, a point requires a horizontal shift of approx. 200m westwards resp. 25m southwards (±25m)."

The same document that originally listed the Reykjavík Datum of 1900 included another, the Akureyri Datum of 1900. Thanks to John W. Hager: "For Akureyri I have latitude (Φ_o) = 65º 40´ 15.2˝ N ±0.2˝ or 15.8˝ N ±0.1˝ and longitude (Λ_o) = 18º 05´ 12.6˝ W ±09.0˝. … I was in Akureyri earlier this year and tried, using my GPS, to locate the position but was not able to do so. Time was very limited. Suspect that the point is in the area of the botanical gardens and the hospital." Although this apparent "astro" station represents an obsolete local datum, the U.S. Army Map Service (AMS) noticed that several 1:100,000 scale maps in the region of the town of Akureyri "did not agree with the control values by several seconds (*of arc – Ed.*)." This notation was dated 20 December 1946 by William W. Baird, AMS.

When Denmark was occupied during WWII, Iceland petitioned for independence. That was granted in 1944 as mentioned above, and the United Kingdom and the United States subsequently moved in because of wartime concern for the island's vulnerability. An interim datum was computed apparently for cartometric purposes and is locally termed the Reykjavík 1945 datum referenced to the Hayford 1909 (International 1924) ellipsoid. In 1955, a new classical triangulation and geodetic survey was initiated by Denmark and the United States. The following year, the LMÍ was founded. The new survey established the Hjörsey Datum of 1955 where: Φ_o = 64º 31´ 29.26˝ N and Λ_o = 22º 22´ 05.84˝ West of Greenwich and the ellipsoid of reference is the Hayford 1909 (International 1924) where: a = 6,378,388 m and $^1/_f = 297$. The grid system devised by AMS for the new datum was the Icelandic Gauss-Krüger Transverse Mercator with four belts (1-4) where the central meridians, λ_o = 15ºW, 18ºW, 21ºW, and 24ºW, the scale factor at origin, $m_o = 1.0$, and the False Easting of each belt = 500 km. However, it appears that LMÍ ignored the Transverse Mercator devised by AMS and instead utilized another Lambert Conformal Conic zone where: the latitude of origin, φ_o = 65º 00´ N, the central meridian, λ_o = 18º West of Greenwich, and the scale factor at origin, $m_o = 1.0$ (*another tangent conic*), and the False Easting = False Northing = 500 km. The datum shift parameters published by NGA in *TR8350.2* from the Hjörsey Datum of 1955 to the WGS 84 Datum are: $\Delta a = -251$ m, $\Delta f = -0.14192702$, $\Delta X = -73$ m ±3 m, $\Delta Y = +46$ m ±3 m, $\Delta Z = -86$ m ±6 m, and this solution is based on 6 points. A 7-parameter Bursa-Wolfe transformation published by LMÍ from the Reykjavík Datum of 1900 to the Hjörsey Datum of 1955 (rotations changed to the U.S. Standard –Ed.) is where: $\Delta X = +629.020$ m, $\Delta Y = -214.701$ m, $\Delta Z = +1028.364$ m, $R_x = -4.154˝$, $R_y = +0.269˝$, $R_z = +2.279˝$, $\Delta s = -3.729$.

A geodetic surveying campaign was carried out by "Icelandic and German agencies for the purpose of establishing a new horizontal geodetic datum in Iceland. The work culminated in a GPS-campaign named ISNET93 during 3-13 August 1993. The associated new geodetic datum is named ISN93. It will replace the Hjörsey-1955 datum established by terrestrial observations in 1955-56." (*GPS-mælingar í grunnstöðvaneti 1993*). A 7-parameter Bursa-Wolfe transformation published by LMÍ from the Reykjavík Datum of 1900 to the ISN93 (*rotations changed to the U.S. Standard – Ed.*) is where: $\Delta X = +556.020$ m, $\Delta Y = -168.701$ m, $\Delta Z = +942.364$ m, $R_x = -4.154˝$, $R_y = +0.269˝$, $R_z = +2.279˝$, $\Delta s = -3.729$, and the ellipsoid of reference is the GRS 1980 where a = 6,378,137 m, and $^1/_f = 298.257222101$. LMÍ does offer a free interactive coordinate transformation service (cocodati) through the Internet. The new grid system adopted is the ***secant*** Lambert Conformal Conic projection with standard parallels 65º 45´ N and 64º 15´ N, and central meridian 19º W. False Eastings = False Northings = 500 km at 65º N and 19º W. The GPS network consists of 119 stations, of which 63 are pillars and the remainder are benchmarks in bedrock. Thanks to Gunnar Þorbergsson for his historical accounts of the Icelandic datum relations recorded in exquisite detail.

Republic of Iceland Update

"In the summer of 2016, the National Land Survey of Iceland (NSLI) re-measured the national geodetic reference system. The Icelandic Geodetic Reference System is the basis for all other surveys in Iceland and is used for example in construction, detailed mapping or monitoring volcanoes. In addition to data from about 100 permanent stations, the NLSI surveyed 150 benchmarks during the campaign. The initial results of these surveys were available at the end of

December and revealed that the country continues to drift apart at a very steady rate of about 1 cm per year in each direction. This is though not always the case in the most active geological areas in Iceland where this movement is not as homogenous in speed or direction. Movements north of Vatnaj kull glacier stand out as a result of the Holuhraun eruption in 2014-2015. Significant elevation changes are also seen in that 12-year period. The greatest land uplift was surveyed in J kulheimar on Vatnaj kull glacier, about 40 cm. It can be presumed that the reasons are thinning of the icecap and there is also evidence of increased magma in the magma chambers underneath the glacier. In comparison, the uplift in the period 1993 to 2004 was 20 cm. It is also interesting to note that around the geothermal power plants in Hengill and Reykjanes there is a subsidence of 1.5 cm per year, or 18 cm since 2004. Elevation changes along the beach are also important as they can either work with or against the effects of rising sea level. It is very important that the new datum is made available as soon as possible because it can be assumed that the distortion in the current datum (ISN2004) is 20-60 cm and distortion of ISN93 is 40-90 cm.

"The IceCORS Network at the NLSI will play a key in making it possible to have a semi-dynamic datum in Iceland. The permanent stations are essential to improve the quality of geodetic work, whether it is for construction or for monitoring natural hazards such as volcanos. Users can use the data from the permanent stations, free of charge, to correct their own data, either in real time or for post-processing. Two stations were added to the IceCORS Network in 2016. Both stations are operated by the Icelandic Meteorological Office, one is at Selfoss airport and the other at Nýlenda farm in Reykjanes. In total, the network now has 18 stations connected, but to ensure demands for accuracy 13 more are planned for a network with 31 permanent stations in service.

"Rising temperatures and melting of the Arctic icecap is something which will inevitably contribute to sea level rise in the world. In order to monitor sea level, it is important to have a network of tide gauges in the country and connect it to the Icelandic Vertical Reference System ISH2004. The NLSI has emphasis on determining the mean sea level of Iceland and that an accurate coastline will be calculated. Functioning and calibrated network of sea level gauges around the whole country is one of the prerequisites for that to be possible." National Land Survey of Iceland Annual Report 2016 – UN-GGIM.

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