Through the rise of the OS's passive and active network of GPS points, Great Britain has a new coordinate transformation. OSTN02 is now the Definitive Transformation for mapping. It does not replace OSGB36 but provides a more accurate and stable transformation to WGS84 than ETRS89 which was fixed at a point in time and is now, due to tectonic movement, some 15cms different from WGS84.

The OS's new Coordinate Transformation for Great Britain

– GPS to OSGB36 National Grid Transformation

By Mark Greaves, Ordnance Survey Geodetic Analyst, Paul Cruddace, Ordnance Survey Geodetic Adviser.

The increasing use of the Global Positioning System (GPS) has brought more people into contact with datum transformations. To relate a position in the GPS system to the same position in a local map system (OSGB36 National Grid, in Great Britain) requires a transformation. Ordnance Survey provides a national transformation from ETRS89 to OSGB36 National Grid. ETRS89 is the European Terrestrial Reference System 1989 – a fixed definition of the GPS datum, WGS84, that is valid across Europe. The transformation is known as OSTN97 and is available on the Ordnance Survey GPS website:

http://www.gps.gov.uk.

OSTN97 aims to achieve the best mean fit between ETRS89 and OSGB36 and is accurate to 0.2 m rmse. By the end of March 2002, Ordnance Survey will release a new version of the transformation – OSTN02, which will be accurate to 0.1 m rmse or better. Not only will this improved transformation offer better accuracy than OSTN97 but it will also herald a fundamental change in the way that the OSGB36 datum is defined.

Brief History of GB Coordinate Systems

Great Britain is one of the few countries to have two triangulations observed in the last two centuries. The first, known simply as the Principle Triangulation, was published in 1858. It was not observed as a single planned scheme but was instead made up in a piecemeal fashion from observations between 1783 and 1853. Two taped bases provided scale and the origin and azimuth were defined at the Royal Observatory, Greenwich. The adjustment was performed in 21 computing blocks using the Airy 1830 ellipsoid.

The second triangulation is known as The Retriangulation. It was observed between 1936 and 1953 and computed by hand in 7 blocks. The original origin at Greenwich had been destroyed but was implied by holding the position of 11 stations fixed to the mean of their Principle Triangulation positions. This means that there is no one point that can be described as the origin of the Retriangulation. The coordinates are on the Airy 1830 ellipsoid and this adjustment is known as the Ordnance Survey of Great Britain 1936 Datum – OSGB36. The OSGB36 datum is very important today since it is currently the basis for the National Grid and all Ordnance Survey map data.

The second coordinate system in Great Britain is the European Terrestrial System 1989 (ETRS89). ETRS89 is a very well defined and stable system which is fully compatible with WGS84 (the coordinate system used by GPS), and has been adopted as the primary system for accurate coordinate positioning across Europe. Unlike WGS84 however, ETRS89 is fixed at a point in time and does not move with the motion of the Earth's tectonic plates. The difference between WGS84 and ETRS89 is now approximately 15 cm (they were synonymous in 1989). Adopting ETRS89 as the primary coordinate system in Great Britain allows an accurate and stable transformation to OSGB36 to be developed. Access to ETRS89 is provided by the National GPS Network which consists of 30 permanent GPS stations (the Active GPS Network) supplemented by a network of over 900 ground stations (the Passive GPS Network), all coordinated in ETRS89. Data, coordinates and information on the National GPS Network stations is freely available at the Ordnance Survey GPS website (*http://www.gps.gov.uk*). If these stations are incorporated when using GPS, then the survey will automatically be coordinated in ETRS89 instead of WGS84.

Transformation Models

The function of a national ETRS89 to OSGB36 transformation is to accurately model the relationship between the two systems. This is not a simple process because OSGB36 contains randomly variable scale errors, mainly due to it being computed

Definitive Transformation Observations on the Isle of Raasay in the Inner Hebrides near Skye.

in blocks and the fact that scale and azimuth were controlled entirely by the 11 stations from the Principle Triangulation. These scale variations mean that OSGB36 can be described as inhomogeneous, as opposed to ETRS89 which is very stable and well defined and therefore homogeneous.

The inhomogenity of OSGB36 does not affect its adequacy as a mapping datum but it does make a simple transformation between ETRS89 and OSGB36 too inaccurate for national use. For example, the accuracy of a national 7 parameter (3 shifts, 3 rotations and a scale change) transformation is approximately 5 metres (see information on the Ordnance Survey GPS website at:
http://www.gps.gov.uk/guide6.asp).
Figure 1 indicates the residual transformation errors between ETRS89 and OSGB36, resulting from the application of a national 7 parameter transformation. It is these varying differences that need to be modelled in order to produce a more accurate transformation.

There are two transformation models which are suitable for modelling such random datum differences. The first type is the polynomial transformation (also known as multiple regression transformation). This type of transformation attempts to model the varying differences between two datums as a surface described by a polynomial function. Tests on polynomial transformations have shown that they cannot achieve the desired 0.1m rmse accuracy. Also, the effect of the scale variations in the OSGB36 datum makes the polynomial transformations very unstable near the edges of the transformation area. The magnitude of the residuals around the edges of the polynomial transformation is in the region of several metres.

The second type of transformation model is known as the Grid Look Up Table and it is this type which is used by the Ordnance Survey for the national ETRS89 to OSGB36 transformation.

The Current Transformation – OSTN97

The OSTN97 transformation is modelled as a 1 km grid of varying parameters which covers the entire country. An ETRS89 coordinate (latitude and longitude or XYZ) is first projected to a plane easting and northing coordinate using National Grid projection parameters. The corresponding 1 km square in the transformation grid is then selected. At each grid intersection there is a set of transformation parameters, expressed as linear shifts between the two systems. The four sets of parameters around the chosen grid square are interpolated to give a pair of shifts (one easting and one northing) valid at the ETRS89 coordinate. These shifts are applied to the ETRS89 coordinate to transform it to an OSGB36 coordinate. OSTN97 will also perform the reverse operation from OSGB36 to ETRS89.

OSTN97 achieves an accuracy of 0.2 m rmse. This figure is an indication of the overall mean fit achieved between ETRS89 and OSGB36. The 0.2m refers to the expected difference between the transformed OSGB36 value of a coordinate and the OSGB36 value of the same coordinate if it had been determined by terrestrial means from the local triangulation points. The parameters in the transformation grid do not change rapidly, so all ETRS89 coordinates from a single survey (covering up to a few square kms) will retain their original high level of relative accuracy after transformation to OSGB36, i.e. the entire survey is transformed by almost the same amount.

The data set used to compute OSTN97 consists of approximately 3300 points with coordinates in both ETRS89 and OSGB36. Approximately 200 of these points have ETRS89 coordinates derived from direct observation of the point with GPS. These points are mainly National GPS Network Passive stations. The rest of the ETRS89 coordinates are derived from a re-adjustment in ETRS89 of the Retriangulation terrestrial observations, using the 200 passive stations as fixed control.

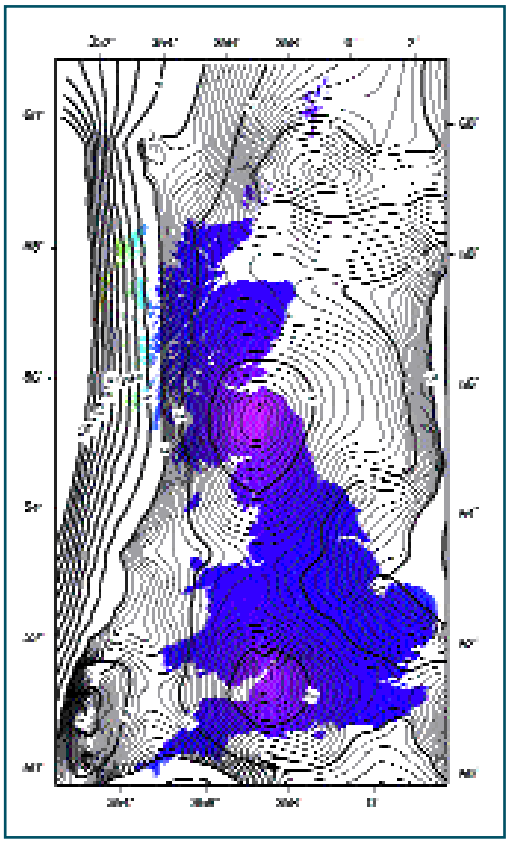

Figure 1 – residuals following a 7 parameter transformation.

The OSTN97 transformation is available as a free utility or as a standalone program to be downloaded to the PC. Developers are invited to include OSTN97 into third-party applications. This can be achieved by either freely downloading the raw parameters and algorithm, or paying a small fee for a pre-developed .dll. Data and information on OSTN97 can be found at the Ordnance Survey GPS website (*http://www.gps.gov.uk* – go to the "Coordinate Converter" page).

The New Definitive Transformation – OSTN02. What is Different?

The main aim of OSTN02 is to improve the accuracy of the existing OSTN97 transformation to 0.1m rmse. This will be achieved by significantly increasing the point density of the transformation computation data set. Many more OSGB36 points are being coordinated in ETRS89, using GPS observations and the National GPS Network. The observation campaign has been running since October 1999 and is almost complete. So far over 3000 extra points have been coordinated and all areas of Great Britain, no matter how small or remote, now contain transformation points occupied with GPS. The size of the final data set for the transformation computation will be over 6000 points.

Apart from providing a more accurate ETRS89 to OSGB36 transformation, OSTN02 will also herald a fundamental change in the definition of Great Britain's mapping datum. For this reason OSTN02 will also be known as the Definitive Transformation

". . OSTN02 will provide a much more accurate realisation between OSGB36 National Grid and ETRS89."

At the present time, despite having a National GPS Network and transformation (OSTN97), the mapping datum of Great Britain (OSGB36) is still defined by the National Grid positions of the original points in the Retriangulation. When the Definitive Transformation (OSTN02) is complete, it will be used to define the National Grid in conjunction with the ETRS89 positions of the National GPS Network stations. This change will mean that, for example, the National Grid coordinates of an existing OSGB36 point, refixed using GPS from the National GPS Network and the Definitive Transformation, will be the correct ones. The original archived OSGB36 National Grid coordinates of the point will be wrong, by definition, but the two coordinates (new and archived) will agree on average to better than 0.1 m. This is a subtle change in definition only and will not mean that existing OSGB36 coordinates need to be changed in any way.

The format of OSTN02 will be the same as with OSTN97, enabling software and systems that have incorporated the existing transformation to simply replace the look-up table of values.

Conclusion

The new 'Definitive Transformation' – OSTN02 will provide a much more accurate realisation between OSGB36 National Grid and ETRS89[1]. OSTN02 will also fundamentally change the definition of OSGB36, from the fixed triangulation network to the National GPS Network and the transformation itself.

It should be stressed that ETRS89 coordinates only need to be transformed to OSGB36 National Grid when they have to be displayed against other map data that is also in OSGB36. If there is no need to display the ETRS89 coordinates in this way then they can be left in the ETRS89 datum. For the same reason, all GPS processing and adjustment should take place in the ETRS89. However, the transformation of coordinates from ETRS89 to OSGB36 (if required) should always be the final stage of any GPS survey.

Where there is a need to transform to OSGB36, the Definitive Transformation will allow users to adopt the latest GPS data collection techniques, and have their data founded in the more stable ETRS89 datum, without sacrificing compatibility with existing OSGB36 data.

Footnote

[1]A new Geoid model is dealing with the issue of the height difference between Ordnance Datum Newlyn and ETRS89. This will be discussed in another paper. GW