Grid InQuest II

Coordinate Transformation Software

for Great Britain and Ireland

Land & Property Services.

OSi Ordnance Survey Ireland

Ordnance Survey

Contents

Introduction

Welcome to Grid InQuest II

The Grid InQuest II desktop application and command line tools provide a means of transforming coordinates between global geodetic coordinates (ETRS89/WGS84) and the national systems of Great Britain and Ireland. It provides a fully three-dimensional transformation incorporating the latest geoid model (OSGM15) and the appropriate polynomial transformation model (OSTN15 or OSi/OSNI) for each of the projected coordinate systems.

This document is a reference for installing and using the Grid InQuest II package. It is intended as a help to getting started with the software and to implement the preferred methods and procedures involved in accurate coordinate transformations within Britain and Ireland.

The following text is divided into four sections. The first two contain general user information. Section one explains how to install and use the main Grid InQuest II desktop application. It contains a description of all the menu items, options and forms used to operate both the interactive and file processing modes. The second section introduces the more advanced utilities designed for command line use.

The last two sections contain information for programmers and other technicians. The first of these describes how to re-use the system's components within other scripts and programs. The final section contains reference information related to the supported coordinate systems and transformations used within Great Britain, Northern Ireland and the Republic of Ireland.

The Grid InQuest II project was jointly developed by the Land and Property Service of Northern Ireland, the Ordnance Survey of the Republic of Ireland and the Ordnance Survey of Great Britain.

Desktop Application

Overview

The Grid InQuest II desktop application has been designed to be as simple as possible to operate and install. It is a graphical program that can be run on any reasonably modern Microsoft Windows computer, Apple Macintosh computer or Linux desktop system.

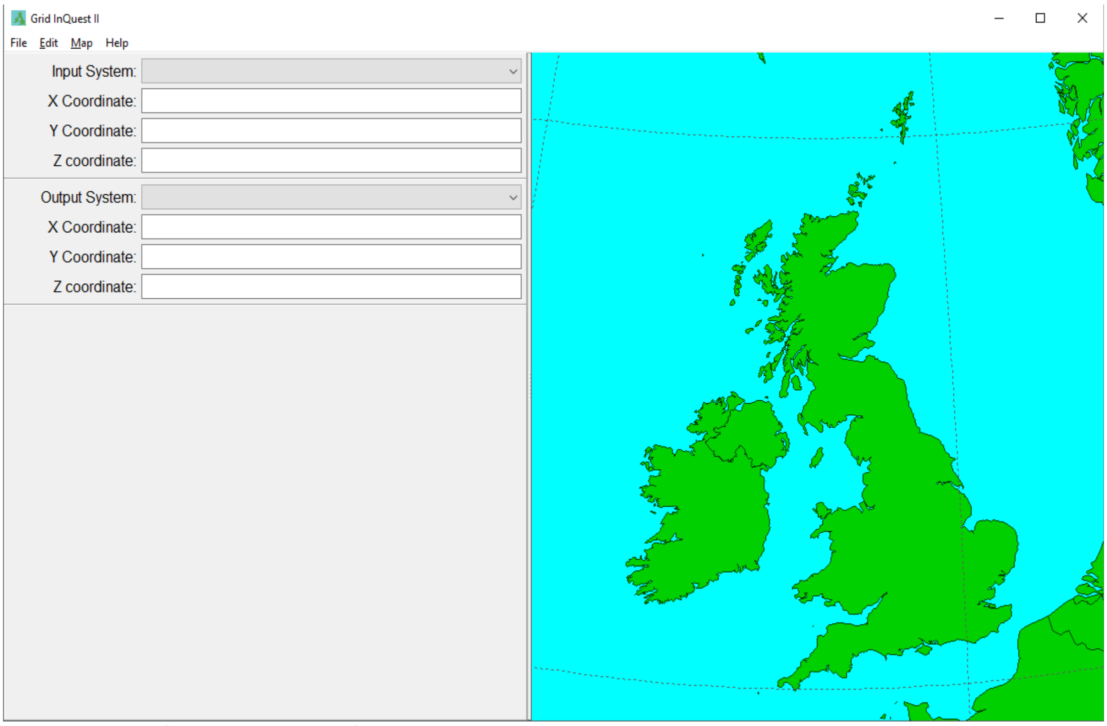


Image 1: Grid InQuest II Application

Installation

The application is available for download from the internet as a compressed archive file in zip format. There are individual archives for each of the supported operating systems:

- Microsoft Windows (32 bit Windows XP or later)
- Apple Macintosh OS X (32 bit Snow Leopard or later)
- Linux (32 and 64 bit with GTK2, tested on Ubuntu 12.04+)

Once downloaded, the zip file can be extracted to any folder. The only requirement is that the user has permission to execute programs from that location. The default folder name is GridInQuestII, but this is not essential. However, files within this folder must be kept together for the proper operation of the application; otherwise the program will not be able to perform the national coordinate system transformations.

On Windows there are no special considerations, beyond the permission requirement to execute programs. Grid InQuest II does not make any use of the Windows registry database, nor does it depend on any other software libraries or configuration files. If the software is being installed for the use of all users on a machine, the convention is to copy the GridInQuestII folder into the “Program Files” or the “Program Files (x86)” folders. A link to the application can then be added to the menu or desktop if desired.

On Macintosh systems, the zip archive contains an Apple disc image file (.dmg). This can be mounted to show the Grid InQuest II application. The application can be run directly from the disc image, or it can be installed by dragging it's icon from the image into the OS X Applications folder. Once copied there, the program will be available in the Launch Pad and the dmg and zip files may be safely deleted as they are no longer required.

Linux installation can be performed in one of three ways. The first two use downloadable zip files as with the Windows and Mac versions. This will only work for Intel CPU based systems and there are two versions of the archive, one for 32 bit systems and the second for 64 bit systems. In both cases the zip file is expanded to create the GridInQuestII folder that contains the application. This folder can be moved anywhere in the user's home folder. The user must grant execute permissions for the programs before they can be run. They should be able to run on any graphical desktop that can support the GTK2 library. Additional operating system packages may be needed depending upon the distribution being used. Ubuntu 12.04 and later will have these pre-installed and so it will run here without any further configuration. The last method of installation on Linux is to perform compilation from the source code. In this way it would be possible to support other platforms (such as the Arm based Raspberry Pi's). Instructions for this procedure are beyond the scope of this manual and should only be attempted by a sufficiently knowledgeable technician.

Getting Started

Once initialised, the Grid InQuest II application will open its main window and start in interactive mode. In this mode the main window is split into two sections: the left being the interactive coordinate transformation interface and the right an interactive map of the globe that will pinpoint the coordinates the user has entered.

The application is primarily controlled from its main menu located just below the application's title bar. The first item on this is the File menu. These commands are used in the file I/O mode when processing the contents of a text file except the last, the Exit command, which is used to quit Grid InQuest II. The second Item is the Edit menu. These commands mostly apply to the interactive mode, except for the Options command, which opens the application's global settings form. The Map menu gives commands for basic control over the map display. Lastly, the Help menu gives access to this manual if it can be found in the application's folder. It also contains the About box which displays the copyright details and other information about the application.

In addition to the Map menu commands the map display can be repositioned by dragging the mouse on the map and the zoom level can be adjusted with the mouse scroll wheel. Also note that many of the menu commands have keyboard short-cuts. These are displayed on the menu following the menu's name. For example, the About box has a short-cut of 'Ctrl+A'. This means that holding down the Control key and then pressing A will display the About box as well.

Interactive Coordinate Transformation

The interactive mode of the program is used to perform individual coordinate transformations. The input and output coordinate systems are arranged vertically on the left side of the program window allowing you to easily enter the values you wish to transform and immediately view the corresponding point within the target system.

The first step is to select the input coordinate system type from the drop down list of available coordinate systems. Once selected, the appropriate coordinate values may be entered into the coordinate text boxes. Note that the text labels will change to display the usual coordinate names for that system. It is not possible to enter values into the text boxes until an input system has been selected and if the system is changed the text boxes will be cleared.

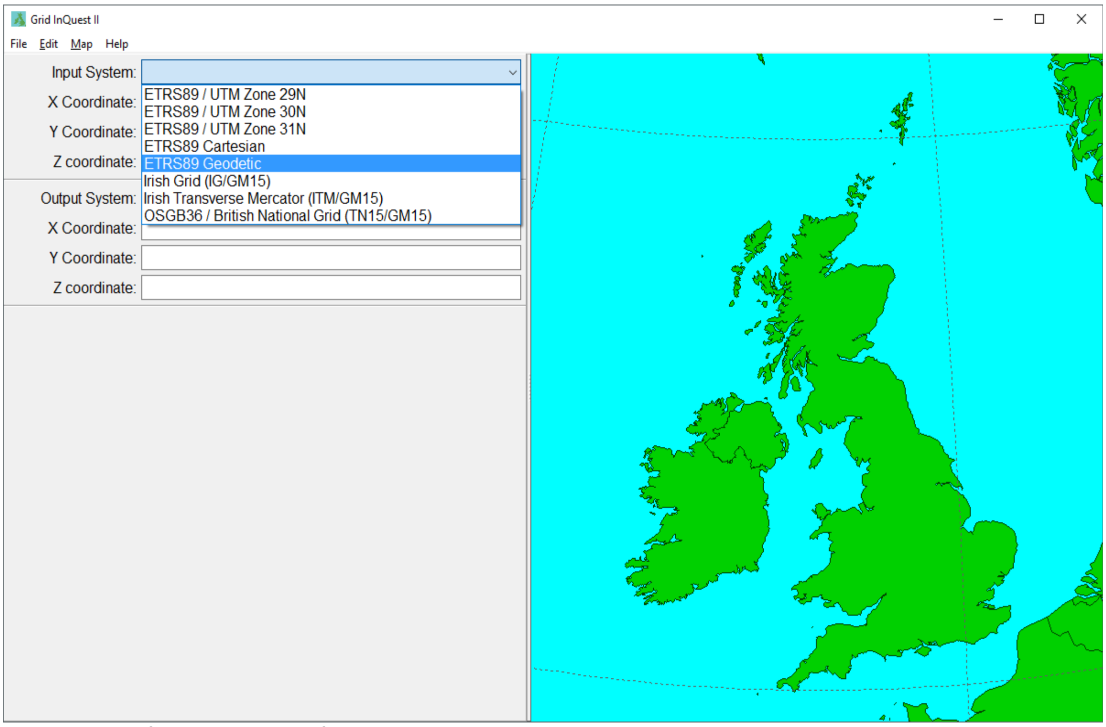


Image 2: Selecting a Coordinate System

Coordinate values themselves can be entered as free text in a format that is appropriate to the type of coordinate system selected. For geodetic coordinates, this would be values of latitude and longitude in decimal or sexigesimal degrees and ellipsoidal height in metres. The Cartesian system requires X, Y and Z coordinates in decimal metres. All projected systems expect values of Eastings, Northings and Orthometric Height in metres.

If a typed value cannot be recognised as valid input for that coordinate the text will be coloured red. Once the value entered is correct the text will turn black. Units do not need to be specified and are assumed for the different value types. Angles may be entered in decimal degrees; degrees and decimal minutes or degrees, minutes and decimal seconds. The program also understands +/-, N/S and E/W to indicate the sign of angle values. Geodetic and projected input systems may be used without entering the vertical component, in which case, it is assumed to be zero and is not displayed in the results.

Underneath the input system display, the output coordinate system can be selected from the output drop down list. This list is filtered to display only the systems which are valid outputs from the selected source system. The new output coordinates will be automatically transformed once you have chosen the output system provided all of the supplied input values are valid. The output values are displayed in blue to indicate that they are valid, but read-only. In addition, a red pinpoint marker will be displayed on the map to the right of the main window indicating the actual point location.

Finally, by using the Copy commands available on the Edit menu it is possible to transfer both the input and output values, as formatted on the display, to the operating system's clipboard. These values can then be pasted directly as text into other applications. The formatting of the output is controlled by the interactive settings available on the Options form as described below.

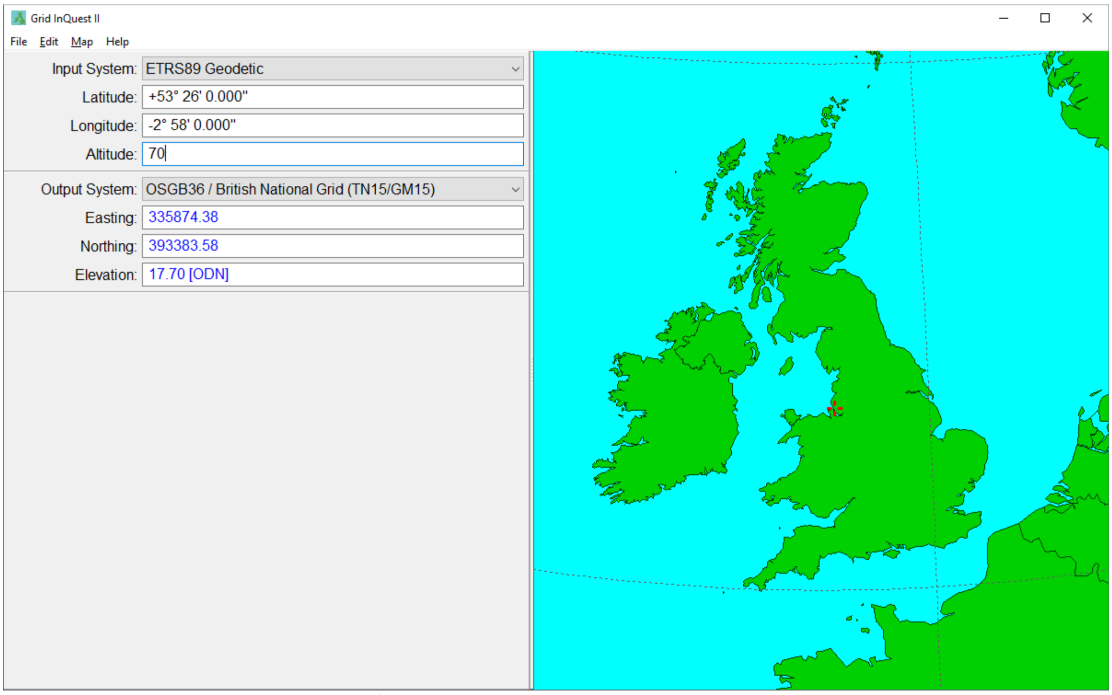


Image 3: The Completed Transformation Display

Step-by-Step Example:

A reading from a GPS receiver (GPS values can be used as ETRS89 geodetic coordinates) is to be transformed to British National Grid. With the “Input System” drop down list, select ETRS89 Geodetic, then enter the Latitude, Longitude and Ellipsoidal Height taken from the GPS receiver. Grid InQuest II can accept most text formats commonly used for geodetic coordinates, and in this example the following values have been entered:

N 53 26	(North 53 degrees, 26 minutes)
-2 58	(West 2 degrees, 58 minutes)
70	(70 metres)

Next select “OSGB36 / British National Grid (OSTN15/OSGM15)” from the “Output System” drop down list since the point is within the UK mainland. It will automatically be transformed into British National Grid eastings, northings and orthometric height:

335874.381m E

393383.579m N

17.70m [ODN]

The optional [ODN] suffix on the orthometric height only applies to British National Grid coordinate values and indicates the vertical datum in use. In this case ODN stands for Ordnance Datum Newlyn, since this is the system used to express heights above sea level on the British mainland.

Changing Application Options

The various settings used to control the output formatting of Grid InQuest II can be changed on the Options form. This form is displayed by selecting 'Options' from the Edit menu. It is arranged into two tabbed sections, one for the interactive mode and one for the file output mode. These two sets of settings have identical values but govern the output of the two modes of operation of the application. This form is also where Irish users can set their preferred vertical datum for performing conversions to and from Irish projections.

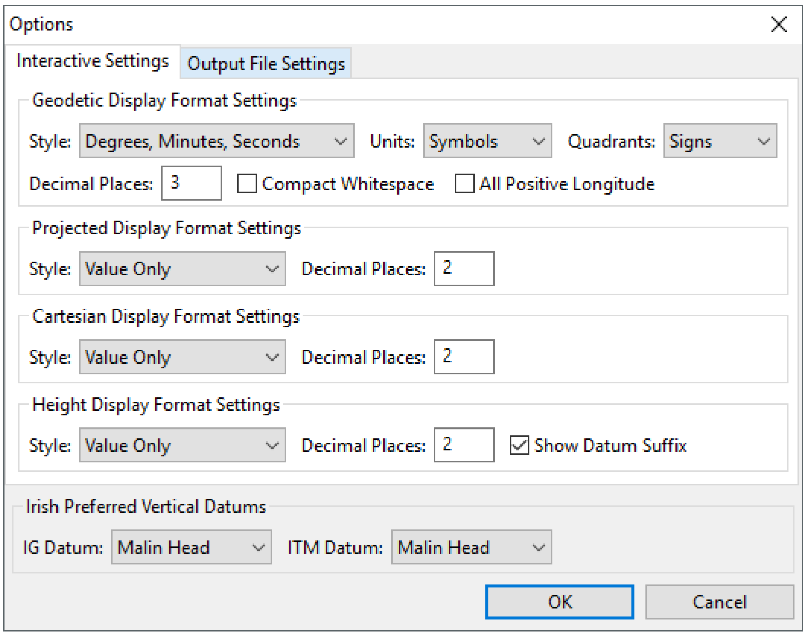


Image 4: The Options Form

Using Output Settings

The settings are divided into sections that apply to the system's coordinate types. The first section controls the format of the angular components of geodetic coordinates (Latitude, Longitude) with the following values:

Style - Simple decimal or sexigesimal type numeric representation.
Units - If conventional symbols, letter suffixes or no units used.
Quadrants - Use of plus and minus or hemisphere letters to indicate signs.
Decimal Places - The number of decimal places displayed.
Compact Whitespace - Tick to remove the spacing between sexigesimal values.
All Positive Longitude - Tick to display longitudes in the range of 0-360°.

The second section controls the horizontal components of projected coordinates (Eastings, Northings) with the following values:

Style - Options for including axis suffix or prefix characters.
Decimal Places - The number of decimal places displayed.

The third section controls cartesian coordinates (X, Y, Z) with the following values:

Style - Options for including axis suffix or prefix characters.
Decimal Places - The number of decimal places displayed.

The fourth section controls the height (vertical) component of any geodetic or projected coordinates with the following values:

Style - Option to including a unit suffix.
Decimal Places - The number of decimal places displayed.
Show Datum Suffix - Tick to add a datum abbreviation suffix in parenthesis.

Irish Border Vertical Datum Options

For the areas which are close to the border between Northern Ireland and the Irish Republic, it is possible to select the preferred Vertical Datum to be used to express height values. This can be selected independently for both the Irish Transverse Mercator (ITM) and the Irish Grid (IG) coordinate systems.

Transforming Text File Coordinates

In addition to the program's interactive mode, Grid InQuest II is capable of performing bulk transformations on data points stored in standard text files. This is the application's file mode. The capacity of this method is only limited by the available free RAM on the host machine. This mode is engaged by opening a data file with the 'Load Data Points' command found in the File menu. Once a file is open, the interactive controls on the left side of the main window are replaced with a display grid containing the data from the loaded file.

Now that the program is in file mode additional items are enabled on the File Menu. The 'Data Settings' command enables the import settings to be adjusted. The 'Transform Data' command will perform the actual process once the desired settings have been set.

'Save Data Points' enables the transformed data to be saved back to a file and the 'Unload Data Points' command will close the file data grid and return the system to interactive mode.

Loading Text Data Files

When using the load data command, the application will first show a standard open file dialogue box. This is used to select the text file containing the point data to be transformed. This presents a choice of three file extensions that can be selected. The first two suggest a particular type of text file: a CSV extension indicates it will have commas as the field delimiter; a TAB extension that it would use the tab character instead and a file with a TXT extension can contain any delimiter and potentially other formatting settings. Whatever the file extension used, opening the file will present the Data Settings form. Here the input settings can be adjusted if the default values do not suit the given file.

Data Settings

Grid InQuest II only accepts data files in text format. However, it is quite flexible regarding the exact layout that is used for the text. The settings can be adjusted to accommodate all of the most commonly used data arrangements. The main classification is achieved by selection from the 'File Format' list. The choice is between 'Character Delimited Text and 'Fixed Width Text'. Character delimited files use a special character to mark the split between successive data items, such as commas or tabs. The actual character used is selected from the 'Column Delimiter' list. There is also an option to treat two consecutive delimiters as one column break.

Fixed width data has the split between data items based on the count of characters from the beginning of each line. This requires that the items are exactly the same size in every row. This is usually achieved by padding the smaller values with space characters to make them the same length as the longest. The position of these splits is entered in the 'Fixed Column Breaks' text box as a comma separated list. Notice that the application will only allow the use of settings that are appropriated for the selected file format and will disable the other controls.

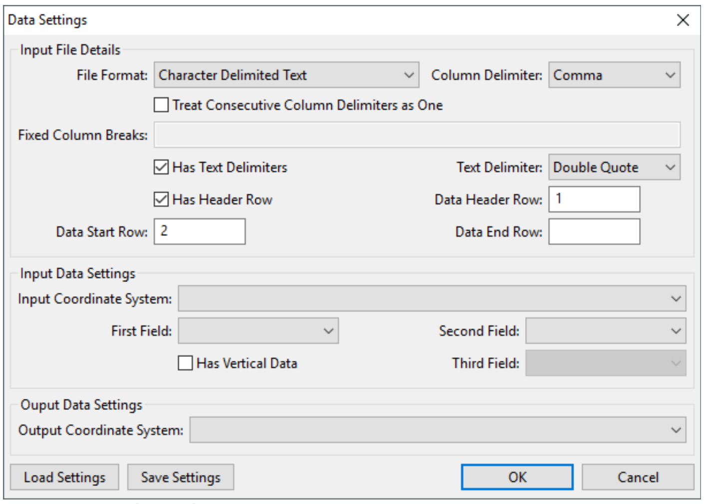


Image 5: The File Data Settings Form

Other common text file settings can also be applied from this form. Selecting 'Has Text Delimiters' enables the text items to be enclosed between matching pairs of delimiter characters, usually double quotes. This is useful for handling text that may contain the field delimiter character itself. The 'Has Header Row' enables a particular row in the data (usually the first row) to contain column names for the data items. The 'Data Start Row' and 'Data End Row' boxes enable non-data lines at the start and end of the file to be skipped, if there are any.

Once the input file format settings have been selected, the input and output coordinate systems must be selected. This is very similar to selecting the systems in the interactive mode, with the addition that the columns containing the input data must be selected as well, so that the data processor knows which columns to inspect to find the input coordinate values. Note that the third dimension can be ignored for geodetic and projected coordinate systems if the height is unknown or of no interest in that case.

If a certain set of parameters need to be retained for future use, there is the option to save them as a settings file (SET file extension). They can then be loaded back into Grid InQuest II to quickly transform other similar files. There is no limit on the number of different settings files that can be created. They are stored in XML format and can be manually edited if needed. Settings files are also used by the command line tools to describe input text file formats and using the save settings option is the easiest way to create them. If the settings are not correctly selected during the data file loading, the 'Data Settings' command from the File menu can be used to re-open this dialogue box to make adjustments before actually performing the data transformation.

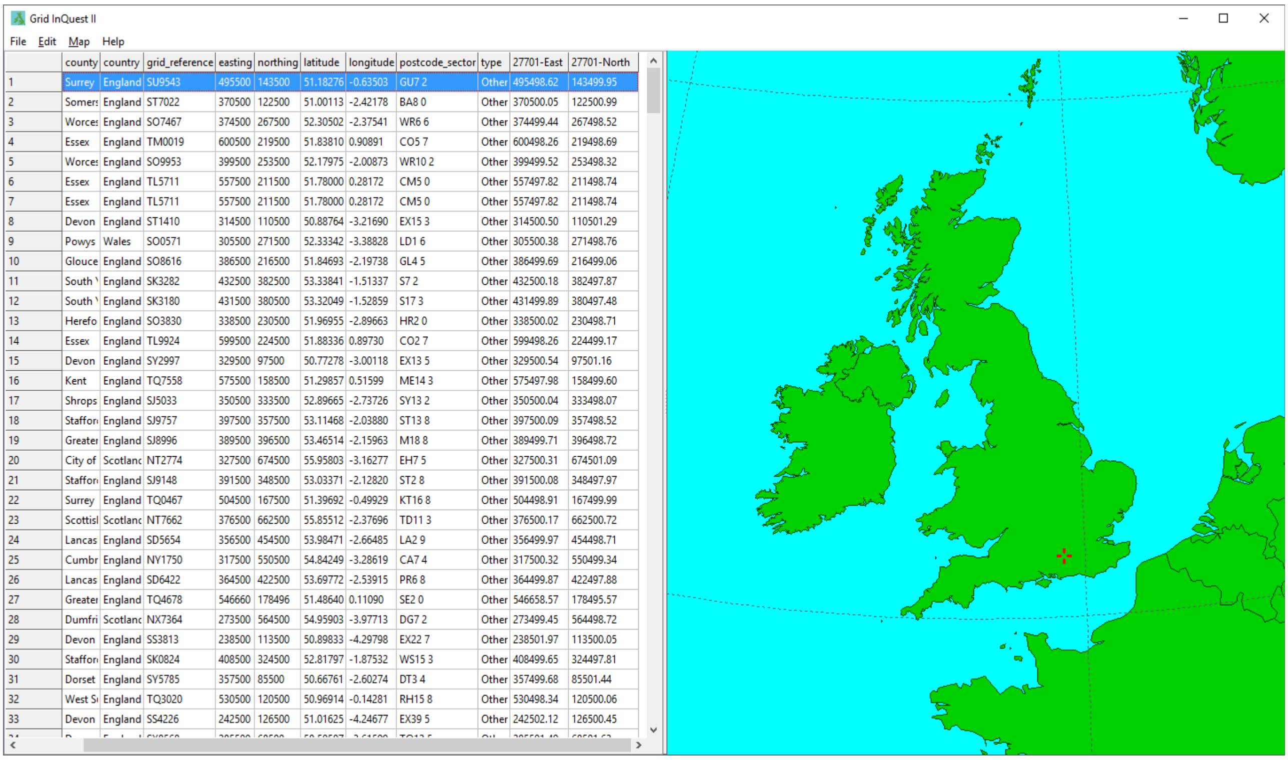


Image 6: A Completed File Transformation

Performing the Data Transformation

If the settings are complete the 'Transform Data Points' menu command will be enabled. This will perform the actual transformation process. If the data file will take more than a second to complete, a progress box will be displayed for each stage of the process. Once completed, additional columns are added at the end of the table containing the new output coordinates for each row of the data. Selecting any of these rows will pinpoint the location on the overview map confirming that the transformation has worked.

Saving Data Files

If the data is to be used elsewhere, it may be saved back into a text file with the 'Save Data Points' command. These output files can easily be imported into other programs such as word processors or spreadsheets. They can even be converted into standard GIS files with applications such as QGIS or file conversion tools like Gdal.

Command Line Programs

Overview

Whilst Grid InQuest II is a relatively easy-to-use application, it is not the most efficient way of transforming data in large text files on a regular basis. This kind of task is better handled with simpler utilities that can be integrated with other management processes. For this purpose the project supplies two additional utilities. The first, GIQTrans, provides similar file processing capabilities to the desktop application, but without using a complex graphical display. The second utility is OSGMUpdate. This is used for the special case of generating new national coordinates (BNG, ITM, IG) for files containing coordinates created using the old OSTN02/OSGM02 transformation models.

In addition to these two utilities there is, for FME users, a Point Transformer add-in that will enable FME to use the Grid InQuest II transformation library within an FME workflow for point type geometries.

GIQTrans Operation

GIQTrans is run from the command prompt with the following parameters:

giqtrans <SettingsFileName> <InputFileName> <OutputFileName> [Options]

The first three parameters are required, but the options are not always needed. The first parameter is the settings file name. This identifies the file that describes the structure of the input file, the input coordinate system and the required output coordinate systems. Settings files are discussed in detail in a separate section below. The next two parameters are the names of the input and output text files. The optional parameters may be any, or none, of the following:

--help or -h	Display a summary of the available command parameters.
--list or -l	List all available coordinate reference systems.
--protect or -p	Prevent the output file from being over-written if it already exists.
--silent or -s	Suppress all command line output during execution.

OSGMUpdate Operation

OSGMUpdate is designed to update data containing OSGM02 orthometric heights to OSGM15 orthometric heights. It is almost identical in operation to using GIQTrans, the only practical difference being that the output coordinate system does not need to be supplied in the settings file as this is the same as the source. It can therefore only be used with coordinate systems that make use of these geoid models. They are:

British National Grid
Irish Grid
Irish Transverse Mercator

For the result to be valid, the source coordinates <u>must contain OSGM02 orthometric heights</u>. If they already contain OSGM15 orthometric heights, the program has no way of knowing and it will produce inaccurate output.

Settings File Format

The purpose of a settings file is to encapsulate a description of the input file format and the input and output coordinate systems. It is actually a text file that uses the XML data structuring convention. These files may be hand-coded by technicians who understand the layout of XML.

However, the simplest way to create a settings file is by saving one with the desired options from within the Grid InQuest II application. This can be achieved by loading the source file into GridInQuest II and then opening the 'Data Settings' form. From here the 'Save Settings' button will create a settings file containing the required XML for that data and also the selected input and output coordinate systems. Here are the contents of a sample settings file:

```xml
<?xml version="1.0" encoding="utf-8"?>
<Settings>
  <InputSettings>
    <Format Value="Delimited"/>
    <FieldTerminator Value=","/>
    <ConsecutiveDelimiters Value="False"/>
    <TextDelimiter Value="&quot;"/>
    <NameRow Value="1"/>
    <FirstRow Value="2"/>
    <SRIDNumber Value="4937"/>
    <XColumn Value="3"/>
    <YColumn Value="2"/>
    <ZColumn Value="4"/>
  </InputSettings>
  <OutputSettings>
    <SRIDNumber Value="29903"/>
    <NameRow Value="1"/>
    <IncludeDatum Value="True"/>
    <PreferredDatum Value="14"/>
  </OutputSettings>
</Settings>
```

The actual values within the XML are straight forward, except for the coordinate system codes. They are identified by their European Petroleum Survey Group (EPSG) spatial reference identification (SRID) numbers, which for the currently supported systems are:

4936	ETRS89 Cartesian
4937	ETRS89 Geodetic
25829	ETRS89 / UTM Zone 29N
25830	ETRS89 / UTM Zone 30N
25831	ETRS89 / UTM Zone 31N
27700	OSGB36 / British National Grid
2157	Irish Transverse Mercator
29903	Irish Grid

FME Point Transformer

Installing the Grid InQuest II Point Re-projector Transformer first requires a fully working installation of FME Workbench for Windows on the target system. Then from the unzipped Grid InQuest II folder, copy the 'LibGIQ.dll' file and all of the files with a '.dat' extension to the FME transformers folder which is usually found here:

C:\apps\FME\transformers

Finally copy the 'GridInQuestIIPointReprojector.fmx' file from the 'Examples/FME' subfolder to the FME transformers folder as well. When FME is restarted, the new transformer will be installed in the Coordinate Systems category.

Do not confuse this with the GridInQuestReprojector which is the transformer for the first version of GridInQuest which cannot perform OSTN15/OSGM15 based transformations.

Programming with Grid InQuest II

Introduction

The Grid InQuest II system can be reused in other programming environments in several ways. Firstly, the command-line tools can be called from operating system scripts; the utility GIQTrans can be used as a CGI binary and the LibGIQ project can be compiled as a dynamic link library for Windows, or a shareable object on POSIX based systems. Finally, as all of the Grid InQuest II software is fully open source, it is possible to directly change the programs, or even rebuild them for other currently unsupported operating systems. The source code is available for download from the internet in a separate archive file. To use this will also require a functioning Free Pascal compiler and the Lazarus IDE, available from here:

http://www.lazarus-ide.org

Operating System Scripts

The simplest type of programming task that can be performed with Grid InQuest II is to call the command line utilities from within an operating system script. These are batch files (.bat) on Windows or shell scripts (.sh) on Linux or Mac OS X. These scripts are simple text files containing commands as they would be typed in at the command line. They can also contain simple looping and conditional structures, so that, for example, a utility can be executed for every file in a folder that has a certain file type. The syntax for this varies between operating systems and will be documented by the OS supplier.

Grid InQuest II has several examples of this type of programming in the distribution archives. For Windows there are a couple of examples in the 'Examples/BatchFiles' folder showing simple usages of this method. There are also identical examples for Linux shell scripts in the 'Examples/ShellScripts' folder.

Web Server CGI Programming

In addition to it's file processing capability, GIQTrans also contains a Common Gateway Interface (CGI) which is automatically used when a valid parameter list is passed to the program. This enables it to be called as a URL resource from within any web server that supports CGI binary files, such as Apache.

A CGI command is called using the following syntax for any arbitrary number of parameters:

```
giqtrans?<param1>=<value1>&<param2>=<value2>&..&<paramN>=<valueN>
```

The input parameters can be supplied in any order and the 'PreferredDatum' is optional for non-Irish coordinate systems. The currently available input parameters are:

SourceSRID	Input coordinate system's SRID number.
TargetSRID	Output coordinate system's SRID number.
Geometry	Input point geometry in GeoJSON format.
PreferredDatum	Preferred Irish vertical datum code.

The result of this CGI request is the transformed point geometry in GeoJSON format with an additional attribute, 'datum' that contains the actual OSGM vertical datum used by the transformation when the output coordinate system uses one of the OSGM geoid models. Here is an example of a GeoJSON point for a UTM30N location in England. Note the datum value is zero, as UTM does not use an OSGM model:

```
{
"type": "Point",
"coordinates": [500000.0000, 5872270.5282, 100.0000],
"datum": 0
}
```

A returned datum code of zero is also used to indicate an out-of-area error for OSGM based results, in which case the coordinates array may be ignored as invalid.

There is a full example of using GIQTrans as a CGI binary in the 'Examples/Web' sub-folder. This creates a simple web page that uses an AJAX method to invoke the CGI command and process the result. To use this requires a functioning web server where the GIQTrans program, the DAT files and the supporting HTML and Javascript code can be uploaded.

LibGIQ Dynamic Link Library

Grid InQuest II comes with a pre-build Windows 32 bit dynamic link library supplied in the Win32 project archive. For other platforms, it is possible to produce a similar library file, but this would require building the LibGIQ project from source for that platform.

On Windows, to use the supplied DLL on a host system, the library and all of the DAT files must be stored in a folder accessible to that host environment. The DLL can be used with any programming language capable of interfacing with C libraries. Grid InQuest II comes with two examples of this usage, one with Python and one with Visual Basic in Microsoft Access. These examples are described in the following sections.

When using the Library interface it is important to realise that the programmer is completely responsible for ensuring that the input values to the transformation routine are valid. All coordinate systems are identified by their SRIDs as used in the settings files. OSGM vertical datums are identified by an index code as follows:

0	None (Out-of-Area)
1	Ordnance Datum Newlyn
2	St. Marys
3	Douglas02
4	Stornoway15
6	Lerwick
7	Orkney (Newlyn)
13	Malin Head
14	Belfast
15	Offshore
16	Outside Official Extent

LibGIQ with Python

The first example uses the Python language's ctypes foreign function library to connect to the LibGIQ.dll with the following code:

```
# Load the LibGIQ dynamic library.
SourceFolder = os.path.dirname(__file__)
giqdll = WinDLL(os.path.join(SourceFolder, "LibGIQ.dll"))
```

This code forms the connection as long as the DLL and DAT files are in the same folder as the python program itself. The actual transformation call is defined as follows:

```
# Define the library coordinate structure.
class coordinates(Structure):
     _fields_ = [("x", c_double),
                 ("y", c_double),
                 ("z", c_double)]

# Reference the library convert function.
convert = giqdll.ConvertCoordinates
convert.argtypes = [c_int, c_int, POINTER(coordinates),
                    POINTER(coordinates), POINTER(c_int)]
convert.restype = bool
```

The key thing to note here is the definition of the custom structure to contain the axis values of a coordinate point. Two are required; one to hold the source location and the second to receive the transformed result. The first two integer parameters are the source and output SRIDs for the required coordinate systems. The last integer parameter passes the preferred Irish vertical datum (when used with IG or ITM) and receives the actual vertical datum used by any of the OSGM based output coordinate systems.

LibGIQ with Visual Basic

Visual Basic contains a similar method to Python for interface with dynamic link libraries. The language contains a special Declare statement that enables DLL commands to be called from basic code. For LibGIQ the declare looks like this:

```
' LibGridInQuestII Coordinates record declaration.
Public Type Coordinates
  X As Double
  Y As Double
  Z As Double
End Type

' LibGridInQuestII API declarations.
Declare Function ConvertCoordinates
            Lib "LibGIQ.dll" (ByVal SourceSRID As Integer,
                              ByVal TargetSRID As Integer,
                              ByRef InputCoordinates As Coordinates,
                              ByRef OutputCoordinates As Coordinates,
                              ByRef Datum As Integer) As Boolean
```

As with Python, the coordinates data structure must be defined to handle the input and output geometry values. The source and target coordinate systems are identified by SRIDs and the Datum parameter is used to pass a preferred datum for use with Irish coordinate systems. It is also updated on return with the actual vertical datum employed by the transformation, otherwise it will be zero for out-of-area or not applicable.

Since the ConvertCoordinates function returns a Boolean value indicating success or failure it can be called within an 'If' statement to branch the code depending upon the outcome. Visual Basic code to perform the transformation in this way looks like this:

```
If ConvertCoordinates(SourceSRID, TargetSRID, InputCoordinates,
                      OutputCoordinates, OutputDatum) Then
    MsgBox “Conversion OK”
Else
    MsgBox “Conversion Failed”
End If
```

There is a fully worked example of using this method in the 'Examples/MSAccess' sub-folder.

Library Source Code Reuse

The source code to all of the Grid InQuest II applications, utilities and libraries is available for use under the terms of the GNU General Public License Version 2. This permits re-use of the code provided its source is acknowledged.

All of the core software is written in Free Pascal and the main application uses the Lazarus Class Library to create the cross-platform user interface. It is possible to build this code for more platforms than are provided in the initial release of Grid InQuest II, but this could only be undertaken by an experienced Lazarus/Free Pascal programmer.

Since the Project's source code is highly modular, Pascal programmers are able to take out individual units and directly incorporate them into their own programs written in Free Pascal. Also, since Free Pascal can compile units in a format compatible with the GCC linker, it is also possible for a programmer with the necessary technical competences, to directly combine parts of this system with programs written in C or C++ that are compiled using the GCC compiler.

Technical Information

Overview

Grid InQuest II implements the most commonly used coordinate systems for representing location within Great Britain and Ireland. This section will describe these coordinate systems and the transformation methods used to transform to and from the national coordinate systems.

Grid InQuest II's Supported Coordinate Systems

This software is capable of bi-directional transformation between the following coordinate systems:

ETRS89 / UMT Zone 29N

ETRS89 / UMT Zone 30N

ETRS89 / UMT Zone 31N

ETRS89 Cartesian

ETRS89 Geodetic

Irish Grid (IG/GM15)

Irish Transverse Mercator (ITM/GM15)

OSGB36 / British National Grid (TN15/GM15)

In addition, depending on where the coordinates are located, it will transform between ETRS89 ellipsoidal heights and the following orthometric height datums when the transformation involves one of the national projected coordinate systems:

Ordnance Datum Newlyn [ODN]

St Mary's [MAR]

Douglas02 [DOU]

Stornoway15 [STO]

Lerwick [LER]

Orkney (Newlyn) [ORK]

Malin Head [MAL]

Belfast [BEL]

Offshore [OFF]

Outside Official Extent [OUT]

NB: The transformations to Ordnance Survey local vertical datums are only valid for mainland Great Britain, Northern Ireland and the Republic of Ireland. However, for convenience, OSGM15 now incorporates an additional code, not available in OSGM02, to support approximate height values for locations offshore in British coastal waters. This is the purpose of the Offshore [OFF] datum code.

ETRS89 UTM Coordinates

The European Terrestrial Reference System 1989 can be projected using the Universal Transverse Mercator system into various zones of longitude. Three of these zones cover the British Isles and Ireland, Zones 29N, 30N and 31N. Zone 29N is only available for Northern Ireland and the Republic of Ireland and Zone 31N only for Great Britain. Zone 30N overlaps the east of Ireland and west and central Britain. Heights are ellipsoidal and refer to height above the GRS1980 ellipsoid.

ETRS89 Cartesian Coordinates

The European Terrestrial Reference System 1989 locations can be expressed as 3D Cartesian coordinates, where the individual axis values are expressed in metres from the origin, which is located at the Earth's centre of gravity. The Z axis is defined as passing through the Earth's rotational North pole. The X axis passes through the equator on the Greenwich Meridian and the Y axis is orthogonal to these.

ETRS89 Geodetic Coordinates

The European Terrestrial Reference System 1989 locations can be expressed in geodetic coordinates, where the latitude and longitude are given in degrees and the height given above the GRS1980 ellipsoid in metres.

Irish Grid Coordinates

This system is also a Transverse Mercator projection, but one using the Airy Modified ellipsoid which gives a closer fit to the actual figure of Earth for Ireland than that used for the ETRS89 UTM systems. It also has a central meridian positioned along the middle of the Irish landmass to minimize distortion. Heights are expressed with respect to the Malin Head datum for the Republic of Ireland and Belfast Lough for use within Northern Ireland. These orthometric heights are now determined by an extension of the OSGM15 geoid model to cover the island of Ireland.

Irish Transverse Mercator Coordinates

The Irish Transverse Mercator projection is a new system, intended to supercede the Irish Grid as it's definition was directly based upon GPS compatibility. This makes it simpler to integrate with modern systems, whilst at the same time preserving many of the characteristics of Irish Grid that make it ideally suited for use within the island of Ireland. To avoid confusion with the older system though, the false origin has been moved further into the Atlantic so as to create substantially different co-ordinates for any given location. As with Irish Grid, the vertical datum in Northern Ireland is fixed to Belfast Lough and to Malin Head within the Republic. It also employs the OSGM15 geoid model to determine height values.

OSGB36 / British National Grid Coordinates

The British National Grid was originally defined through classical survey techniques but in 2002 a new definition was introduced that employed direct transformation from ETRS89 to OSGB36 coordinates called the National Transformation OSTN02. In 2015 this method was updated to improve the accuracy and the newer version OSTN15 now replaces OSTN02 as the definitive horizontal transformation for British National Grid. A similar method for determining height values relative to local sea level was also developed. This was known as the Ordnance Survey Geoid Model OSGM02. This has similarly been replaced by a newer version in 2015 and this is known as the OSGM15.

British and Irish Transformation Systems

All Ordnance Survey mapping relates to a coordinate reference system. In Great Britain OSGB coordinates relate to OSGB36 (the National Grid), within Northern Ireland and the Republic of Ireland the coordinate reference system is the Irish Grid. These reference systems were traditionally realised on the Earth's surface by monumented triangulation stations. The users of mapping products, in both the public and private sectors, have invested in geographical information systems (GIS) and asset management systems based on these Grid systems which have been accepted as de facto national standards.

In order to relate GNSS-derived positions to the Ordnance Surveys' mapping, GNSS-derived coordinates need to be transformed to Irish Grid or to National Grid, which requires a specialised datum transformation. For this reason, the Ordnance Survey of Northern Ireland and Ordnance Survey Ireland have developed a polynomial transformation, which is the standard datum transformation for use throughout Ireland. The Ordnance Survey of Great Britain initially developed OSTN02, the standard datum transformation for Great Britain, and this has now been upgraded to OSTN15.

Ordnance Survey mapping also includes height information that relates to a regional vertical datum. Height information in Great Britain refers to Ordnance Datum Newlyn (ODN), which is established from mean sea level. Although ODN is the national height datum used across mainland Great Britain there are a number of additional datums that are used on the surrounding islands, namely: Lerwick on the Shetland Islands; Stornoway15 on the Outer Hebrides; Douglas02 on the Isle of Man and St. Marys on the Scilly Isles. The Ordnance Survey of Northern Ireland relates heights within Northern Ireland to Belfast Lough datum, and Ordnance Survey Ireland relates heights within the Republic of Ireland to the Malin Head datum. The resulting Ordnance Survey Geoid model (OSGM15) incorporates all the above vertical datums. OSGM15 is an improvement to the original OSGM02 model and incorporates additional gravity data and better fitting of the geoid to the sea level based datums especially in the surrounding islands. Some small island datums that were in OSGM02 are not supported in OSGM15.

National Transformation Model: OSTN15

The OSTN15 transformation consists of a 700km (east/west dimension) by 1250km (north/south dimension) grid of transformation vectors at 1km resolution. This provides a fit between the GNSS compatible coordinate system ETRS89 and the OSGB36 National Grid. ETRS89 coordinates can be determined in Great Britain by linking a GNSS survey to Ordnance Survey's 'OS Net', a network of continuously operating reference stations, see https://www.ordnancesurvey.co.uk/gps/os-net-rinex-data/.

On land OSTN15 is in agreement with major triangulation stations at the level of 0.1m root mean square (RMSE). Out away from the GB landmasses the transformation is an extrapolation based on a limited 7 parameter transformation so the accuracy degrades to the 3m level.

Within Great Britain OSTN15 (the Ordnance Survey National Grid Transformation), in conjunction with the ETRS89 positions of the OS Net stations, is the official definition of OSGB36 National Grid. This means that usingOSTN15 with OS Net, surveyors using GNSS have no need to occupy triangulation stations in order to relate GNSS coordinates to National Grid coordinates.

OSi/OSNI Polynomial Transformation

Ordnance Survey Ireland and Ordnance Survey of Northern Ireland recommend the OSi/OSNI polynomial transformation for all horizontal transformations in the Republic of Ireland and Northern Ireland. This transformation has been developed in association with the Institute of Engineering Surveying and Space Geodesy, University of Nottingham. The transformation is based on 183 points evenly distributed throughout Ireland and Northern Ireland. The precise ETRS89 and Irish Grid coordinates of these points are determined by GPS and terrestrial survey methods, and a one-dimensional 3rd order polynomial individually fitted to the latitude and the longitude. The resulting polynomial allows calculation of the coordinate differences at additional points. The polynomial transformation has an accuracy of 0.4m (95% data).

Ordnance Survey Geoid Model: OSGM15

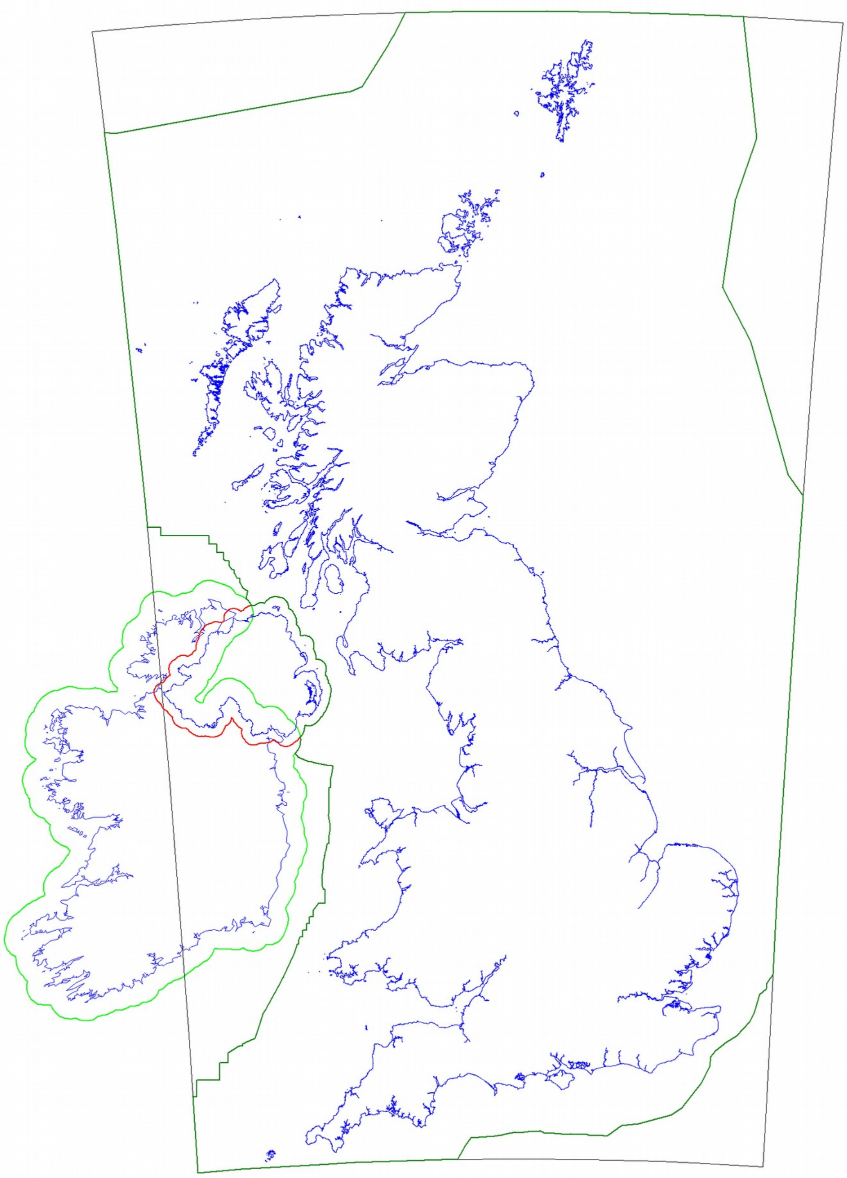
To provide the third dimension of the transformation, the Ordnance Surveys developed, with others, the Geoid model OSGM02 and this has now been improved to OSGM15. The model is derived from precise gravity surveys across UK, Ireland, and surrounding waters. Additionally the model includes data from the global geopotential model (EGM96). For OSGM15 the model was improved by incorporating long wavelength gravity field data from the GRACE mission. Alignment to each regional vertical datum is based on precise GNSS observations at Ordnance Survey levelling marks. Within Great Britain these include the Ordnance Survey fundamental benchmark network. For OSGM15 a significant number of marks on the island datums were included to improve the geoid fit in these areas.

The Geoid model in Great Britain is on the same 700km x 1250km (1km resolution) grid as OSTN15 with geoid-ellipsoid separation values at each grid node. In Ireland and Northern Ireland OSGM15 is delivered as a latitude/longitude graticule from N51° to N56° and W5° to W11.5°. The latitude separation is 48” (0.01333°) and the longitude separation is 1’12” (0.02°).

OSGM15 can be used with GNSS determined positions to establish height above mean sea level, as defined by the respective vertical datums, to the accuracies shown in the table below. The Ordnance Surveys recommend the use of OSGM15 and the national GNSS permanent networks to produce orthometric height compatible with Ordnance Survey mapping.

OSGB intend that OSGM15 is the official definition of the relationship between GNSS ellipsoid heights and orthometric height in Great Britain. In the way that GNSS and the transformation model OSTN15 define the horizontal coordinate system, precise GNSS surveying using OS Net in conjunction with OSGM15 is the standard method of determining orthometric height.

OSTN15 and OSGM15 Model Extents Map



Country outlines	**Blue** line
OSTN15 file extent	**Black** trapezoid
OSTN15 and GB OSGM15 boundary	**Dark green** line
Northern Ireland OSGM15 10km buffer	**Red** line (coincides with OSTN15/OSGM15 boundary)
Ireland OSGM15 20km buffer	**Bright green** line

Model Coverage

OSTN15 covers Great Britain and the Isle of Man. In OSTN02 the model was “cookie cut” to 10km offshore and parameters outside this boundary were zeroed. In OSTN15 the entire 700km x 1250km transformation grid is fully populated so as to avoid a transformation “cliff” at the 10km boundary. **HOWEVER – great caution should be exercised to avoid using OSTN15 in areas where OSGB36 National Grid is not practical or required**.

The OSi/OSNI polynomial transformation covers the Republic of Ireland and Northern Ireland. It should be noted that the Irish Grid and the National Grid are two independent coordinate reference systems, and that Irish Grid coordinates are not directly compatible with OSGB36 coordinates.

OSGM15 covers all of Great Britain, Isle of Man, Republic of Ireland, and Northern Ireland. The Geoid model comprises of 9 patches in order to relate to mean sea level as defined by the specific vertical datum for each region. A “Datum Flag” forms part of each data record and specifies to which datum the geoid/ellipsoid separation value relates.

In GB land patches extend to 2 km offshore from the relevant landmass and any geoid value outside these areas is flagged as “Offshore” to indicate that the value is an extrapolation of the land based model. The Irish datum patches (Malin and Belfast) have been cookie-cut to a boundary which extends 20km offshore for Malin Head and 10km offshore for Belfast Lough. Any point outside these boundaries will be flagged as “Outside Transformation Boundary” and return null values in the shift and datum flag records.

Within Ireland and Northern Ireland, OSGM15 returns orthometric heights relative to the Malin Head and Belfast Lough datums respectively. OSGM15 will return orthometric height relative to the Malin Head datum for points 20km beyond the border between the Republic of Ireland and Northern Ireland. It will return orthometric heights relative to the Belfast Lough datum for points 10km beyond the border between Northern Ireland and the Republic of Ireland.

Transformation Accuracy

Within Great Britain, OSTN15 is the definitive OSGB36/ETRS89 transformation. OSTN15 in combination with the ETRS89 coordinates of the OS Net stations, rather than the fixed triangulation network, now define the National Grid. This means that, for example, the National Grid coordinates of an existing OSGB36 point, refixed using GNSS from OS Net and OSTN15, will be the correct ones. The original archived OSGB36 National Grid coordinates of the point (if different) will be wrong, by definition, but the two coordinates (new and archived) will agree on average to better than 0.1m (0.1m rmse, 68% probability). Out from the GB landmass the accuracy of OSTN15 degrades from 0.1m to the 3m level since the transformation is extrapolated from the land based core data set and is increasing based instead on a simpler 7 parameter transformation.

Within the Republic of Ireland and Northern Ireland, the OSi/OSNI polynomial transformation is recommended for coordinate transformations between ETRS89 and Irish Grid. Transformed ETRS89 coordinates will agree with Irish Grid coordinates derived from traditional survey control to within 0.4m (95% data).

Accuracy of OSGM15

The heights output by precise GNSS positioning in the ETRS89 coordinate system are geometric distance above the GRS80 reference ellipsoid. Note that GNSS heights are typically two to three times less precise than horizontal positions. OSGM15 transforms ETRS89 ellipsoidal heights to orthometric heights above mean sea level.

In Great Britain, Northern Ireland, Ireland and surrounding islands mean sea level is defined by specific independent vertical datums which are all incorporated in OSGM15 and hence OSGM15 is compatible with the products from each of the Ordnance Surveys. Other Geoid models may give mean sea level heights that are incompatible with the Ordnance Surveys products.

The estimated accuracies of OSGM15 for each regional vertical datum are included in the table below. The figures quoted assume precise ellipsoidal heights are used, for lower quality GNSS observations additional error budget must be included. The figures are derived from post fit residual statistics (between levelling surface and gravimetric geoid surface) generated during the creation of the model.

Regional Datum	**Standard Error (m)**
Mainland GB (ODN, Newlyn)	0.008
Republic of Ireland (Mailn Head)	0.023
Northern Ireland (Belfast Lough)	0.014
Orkney	0.017
Shetland	0.018
Outer Hebrides	0.011
Isle of Man	0.03
Scilly Isles Single offset from ODN	

Any discrepancy found between an Ordnance Survey levelled bench mark (OSBM) and a OSGM15 computed orthometric height is likely to be due to bench mark subsidence or uplift and, assuming precise GNSS survey has been carefully carried out, the orthometric height given by OSGM15 should be considered correct in preference to archive bench mark heights. For more information on the accuracy of the OSGM15 transformation model see the final report available from the Ordnance Survey website.

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Version 2, June 1991

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Glossary

A

Accuracy:
The degree of closeness or conformity of an observation to its true value.

D

Datum:
The survey reference system used in a specific country or region. All geographical coordinates will be referenced to a chosen datum. Two principle datum types exist, namely global datums and astrogeodetic datums. A datum is created when a reference spheroid is tied to the earth at a particular point and coordinates are defined for that point. See spheroid, WGS84

E

Ellipsoid:
A closed quadric surface that is a three-dimensional analogue of an ellipse. Often used in geodesy as an alias for spheroid.
(See Spheroid)

ETRS89:
The European Terrestrial Reference System 1989, used as the standard precise GPS coordinate system throughout Europe. In 2000, the difference between the WGS84 and ETRS89 coordinates was about 25 cm, and increasing by about 2.5 cm per year. ETRS89 has been officially adopted as a standard coordinate system for precise GPS surveying by most national mapping agencies in Europe.

G

Geoid:
A model of the level surface which is closest to MSL over the oceans. This surface is continued under the land and acts as the fundamental reference surface for height measurement, as an approximation of MSL on land.

GNSS:
Global Navigation Satellite System. The term used to describe any individual or combination of satellite system(s) with global coverage.

GPS:
Global Positioning System. A satellite based navigation system which in the last five years has become the industry standard survey tool for positioning and navigation.

I

IG:
Irish Grid - The standard two-dimesional grid reference for Irish coordinates. Divided into 25 squares (each measuring 100 square kilometres) they are all represented by letters in alphabetical order excluding 'I'. The letters A, E, P, K, U, Y and Z do not cover any landmass in Ireland.

ITM:
Irish Transverse Mercator - The geographic coordinate system for Ireland. It was implemented jointly by the Ordnance Survey Ireland (OSI) and the Ordnance Survey of Northern Ireland (OSNI) in 2001. The name is derived from the Transverse Mercator projection it uses and the fact that it is optimised for the island of Ireland.

<u>N</u>

National Grid:
The primary coordinate system used in Great Britain.
(See OSGB36)

<u>O</u>

ODN:
Ordnance Datum Newlyn is the national standard vertical reference system for measuring height above MSL in GB. ODN is measured relative to a value taken at Newlyn, Cornwall.

Orthometric height:
Height above mean sea level

OSGB36:
The national standard coordinate system for topographic mapping, including all Ordnance Survey mapping, and for geographically referencing many kinds of information in relation to Ordnance Survey mapping.

OSGM02:
Ordnance Survey National Geoid Model 2002. A gravimetric model used to convert ETRS89 ellipsoidal heights to ODN orthometric heights.

OSGM15:
Ordnance Survey National Geoid Model 2015. A gravimetric model used to convert ETRS89 ellipsoidal heights to ODN orthometric heights.

OSTN02:
Ordnance Survey National Grid Transformation 2002. A horizontal transformation from ETRS89 to OSGB36 coordinates and vice versa.

OSTN15:
Ordnance Survey National Grid Transformation 2015. A horizontal transformation from ETRS89 to OSGB36 coordinates and vice versa.

P

Precision:
The degree of repeatability or closeness that repeated measurements of the same quantity display. Precision is used to describe the quality of data with respect to random errors. Measurements that are closely grouped are said to have a high precision because their random errors are small.

S

Spheroid:
A mathematical figure used to closely model the geoidal surface of the earth. The figure is described by the semi-major axis (a), semi-minor axis (b) and inverse flattening. Many spheroids are used to describe the figure of the geoid on different parts of the earth. The spheroid will be intrinsically tied to the geodetic datum and once a datum is used in a particular country or region it is unlikely to be changed.

T

Transformation:
A procedure to change from one coordinate system to another. GridInquest II's primary function.

U

UTM:
Universal Transverse Mercator. Special case of the Transverse Mercator projection where by the earth is divided into 60, 6 degree zones. All the zones have identical characteristics with the exception of their central meridians which increase by a factor of 6 degrees between adjacent zones. UTM projections are used extensively in oil exploration and particularly favoured for their ease of use. One down side is that they are not preferable when mapping large extents in an east-west direction.

W

WGS84:
The spheroid and datum used to model the geoidal surface for the entire globe. It has been the principle datum for GPS since January 1987.