

Geodesy in MIKE Zero

Map Projection and Datum Conversion

User Guide





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1 Basic Geodesy

Geodesy is the branch of science concerned with the determination of the size and shape of the earth. This section will in the following discuss the following aspects of geodesy:

1. Geoid
2. Ellipsoid
3. Datum
4. Map Projection
5. Datum Transformation

1.1 Introduction

As the earth is an almost spherical object, mathematical methods have been developed by cartographers to project the curved surface of the earth to the flat surface of a map. These methods, known as map projections involve the concept of wrapping an imaginary cylinder or cone around an ellipsoid model of the geoid, and then projecting from the ellipsoid model to a cylinder or cone. Cylinders and cones are called developable surfaces because they can be cut and placed on a flat surface, such as a map, without distorting the projected features.

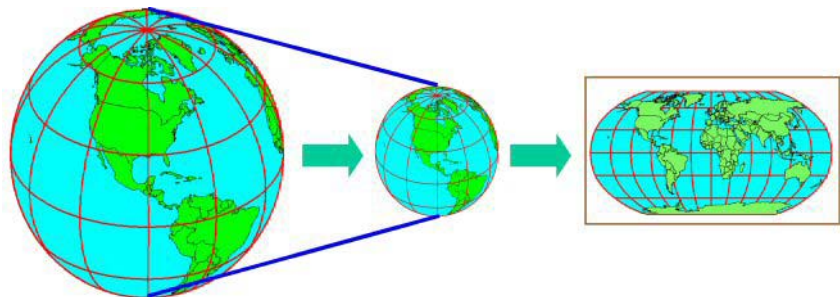


Figure 1.1 Mapping of the world onto plane coordinates

1.2 Geoid

The geoid is an invisible, continuous closed surface and is an equipotential surface or a level surface. It is a surface at which the potential of gravity is constant and the vector sum of the force of gravity and centrifugal force due to the rotation of the earth is normal to the surface at every point. A level surface undulates over a geographic area due to variations in the mass of the earth's terrain and seas. A level surface is chosen that, on average, coincides with the surface of the oceans. This surface is called the geoid. As a result,



the geoid is often defined as the mean sea level. The geoid undulates even in areas of the earth where there are oceans, because the mass and density of the water and rock beneath the ocean are not constant.

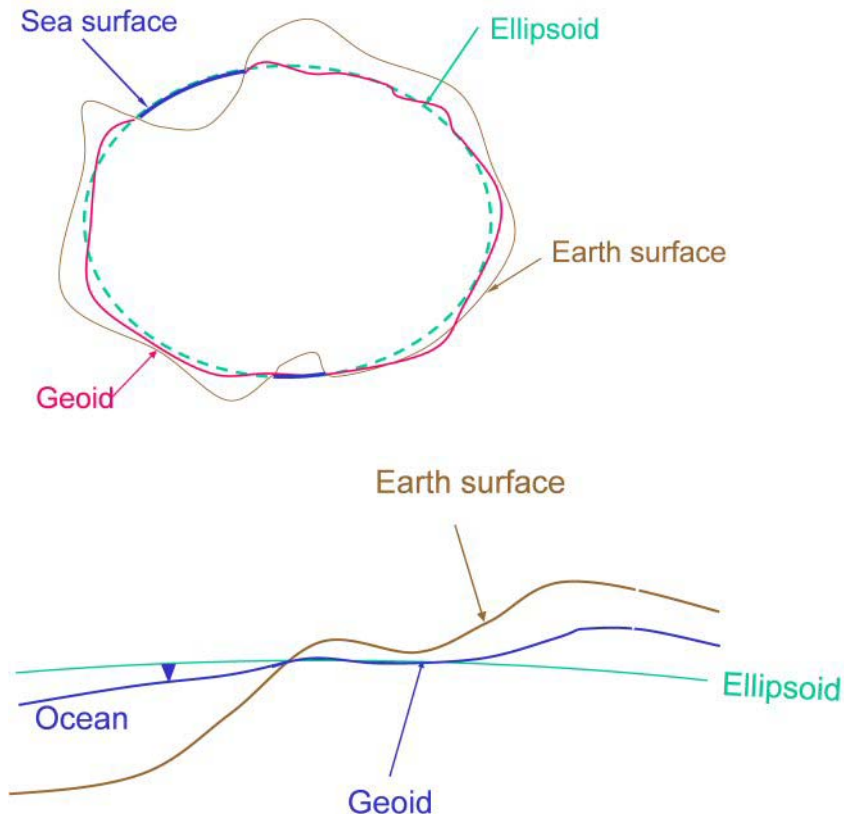


Figure 1.2 Definition of geoid, ellipsoid and the earth surface

1.3 Ellipsoid

The ellipsoid is a three-dimensional model formed by rotating an ellipse about its minor axis. An ellipsoid, sometimes called a spheroid, is used as the reference system of the geoid instead of a sphere because the earth is slightly flattened. The earth's polar axis is shorter than the diameter of the earth measured at the equator. An ellipsoid serves two purposes. It serves as a reference system for creating the geoid model, and it serves as a mathematical model for locating the earth's features geographically. The earth's features are projected from the earth's surface to the ellipsoid.

An ellipsoid is uniformly defined through two parameters:



1. a semi-major axis (a)
2. a semi-minor axis (b)

The inverse flatness parameter is found by eq. (1.1).

$$\frac{a}{a-b} \tag{1.1}$$

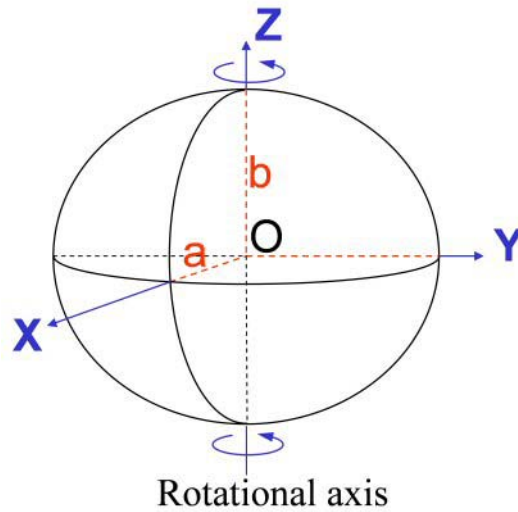


Figure 1.3 Outline of Ellipsoid

From the ellipsoid they are geometrically projected to a map, or their geographic locations on the map are mathematically computed in some manner. There are many mathematical algorithms for transferring features from the ellipsoid to the map. Figure 1.4 show the geographical position of point P described by various parameters related to an ellipsoid.

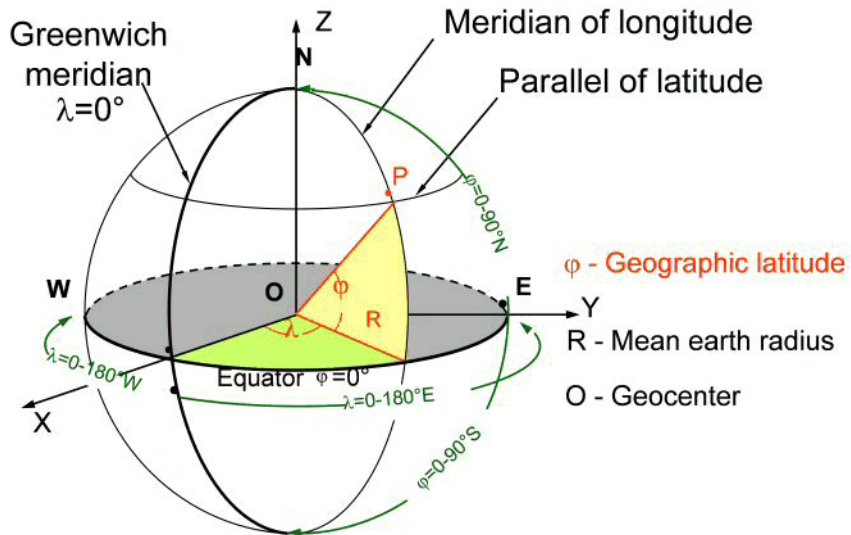


Figure 1.4 Geographical coordinates

1.4 Datum

1.4.1 Geodetic datum

A geocentric coordinate system has its origin at the centre of the earth, with the x axis and y axis in the equatorial plane, with the x axis passing through the prime meridian, and with the z axis along the polar axis. The production of a new ellipsoid and its geocentric and geodetic coordinate systems is called a geodetic datum. Maps using the new geodetic datum will have their features shifted geographically relative to the old datum. Differences between different datums are illustrated in Figure 1.5.

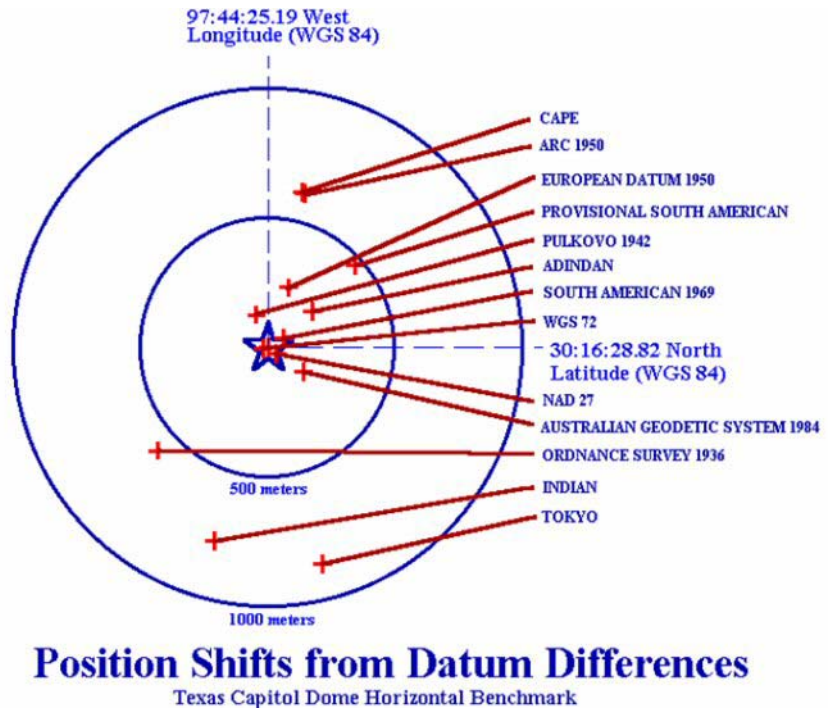


Figure 1.5 Position shifts for a point using different geodetic datums

1.4.2 Vertical Datum

A vertical datum is a network of benchmarks whose elevations (orthometric heights) have been measured and adjusted simultaneously relative to mean sea level (the geoid).

Vertical datums are independent of horizontal datums (i.e. geodetic datums).

1.5 Map Projection

A projection is a mathematical expression for the curved surface of an ellipsoid on a rectangular coordinate grid. Distortions of the Map characteristics (conformality, distance, direction, scale, and area) always result from a map projection.

1.5.1 Types of projection

Some projections minimize distortions in some of the Map characteristics at the expense of maximizing errors in others. Some projections are attempts to only moderately distort all of these characteristics.



Cone

In normal aspect, the cone is placed tangent to the globe along a parallel of latitude or secant to the globe, intersecting the globe along two parallels. Meridians are represented as straight lines radiating from the apex of the cone and parallels of latitude are represented as concentric circular arcs. The standard parallel(s) is/are true to scale.

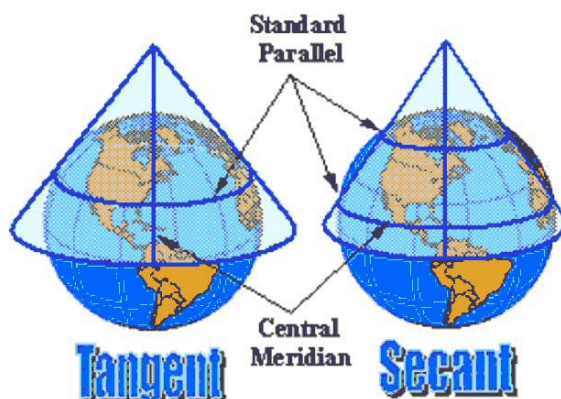


Figure 1.6 Map projection: Cone

Distortion is minimized in a narrow band along the standard parallel(s) and increases with distance from the standard parallel(s).

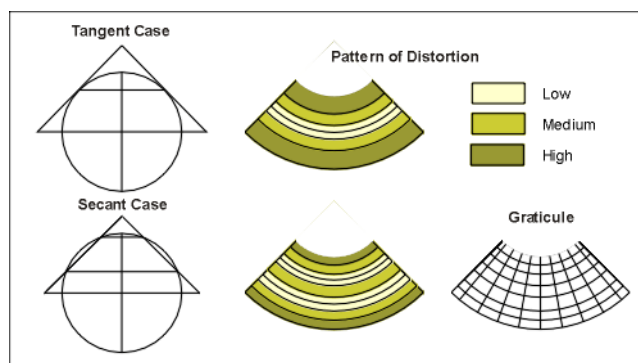


Figure 1.7 Pattern of distortion

Cylinder

The normal aspect for cylindrical projections assumes that the cylinder is tangent to the globe along the Equator. In this orientation, the graticule appears as a rectangular grid. Meridians of longitude are straight lines, equally spaced along, and perpendicular to the Equator. Parallels of latitude are represented as straight line parallel to and having the same length as the Equator.

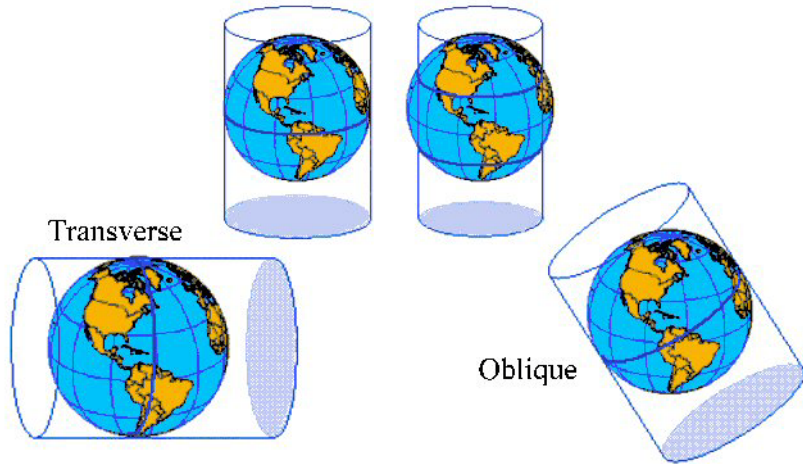


Figure 1.8 Map projection: cylinder

In the tangent case, the Equator is true to scale and distortion increases with distance from the Equator. In the secant case, the standard parallels which lie equidistant north and south of the Equator are true to scale and distortion increases with distance from the standard lines.

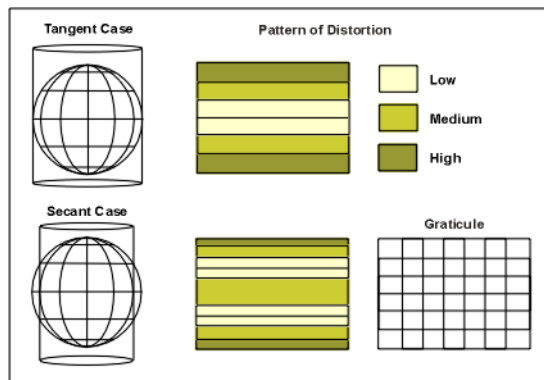


Figure 1.9 Pattern of distortion

Transverse Mercator Projection is a type of cylinder projection that result from projecting the sphere onto a cylinder secant around a central meridian (e.g. rotated 90 deg from equator). Transverse Mercator maps are often used to portray areas with larger north-south than east-west extent. Distortion of scale, distance, direction and area increases away from the central meridian.

Plane

Plane projections are projections to a plane placed tangent to the globe at a point. In normal (or polar) aspect, the point of tangency is either the north or



south pole and meridians of longitude are represented as radial straight lines through the pole while parallels of latitude appear as concentric circles.

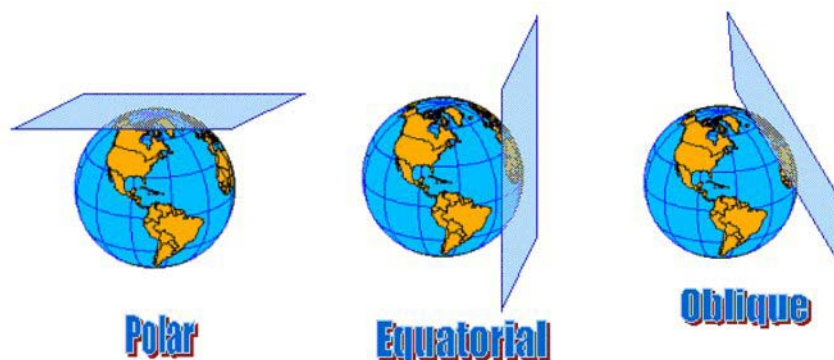


Figure 1.10 Map projection: plane

Distortion in the map increases with distance from the point of tangency. Since distortion is minimal near the point of tangency, azimuthal projections are useful for representing areas having approximately equal extents in the north-south and east-west directions.

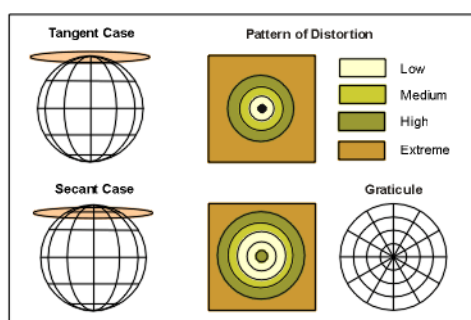


Figure 1.11 Pattern of distortion

1.5.2 Map characteristics

Map projections are attempts to portray the surface of the earth or a portion of the earth on a flat surface. Some distortions of conformality, distance, direction, scale, and area always result from this process. Some projections minimize distortions in some of these properties at the expense of maximizing errors in others. Some projection are attempts to only moderately distort all of these properties.



Conformality

When the scale of a map at any point on the map is the same in any direction, the projection is conformal. Meridians (lines of longitude) and parallels (lines of latitude) intersect at right angles. Shape is preserved locally on conformal maps (Transverse Mercator projections).

Distance

A map is equidistant when it portrays distances from the centre of the projection to any other place on the map.

Direction

A map preserves direction when azimuths (angles from a point on a line to another point) are portrayed correctly in all directions.

Scale

Scale is the relationship between a distance portrayed on a map and the same distance on the earth.

Area

When a map portrays areas over the entire map so that all mapped areas have the same proportional relationship to the areas on the earth that they represent, the map is an equal-area map.

1.5.3 Mercator Projection

The projection can be thought of as being mathematically based on a cylinder tangent at the equator.

The use of the Mercator map projection as the base for nautical charts is universal. (Which does not mean that all nautical charts are based on the Mercator projection, but most are)

The major navigational feature of the projection is found in the fact that a sailing route between two points is shown as a straight line, if the direction or azimuth of the ship remains constant with respect to north. This kind of route is called a loxodrome, or rhumb line. Conversely, it is also true that any straight line depicts a rhumb line. This implies, that all angles maintain the sizes that they have on the surface of the globe.

Lines of longitude and latitude are both straight and parallel. The linear scale is not true, i.e. not isometric. Aerial distortion is extreme away from the equator. Shape is true only within any small area.

1.5.4 Transverse Mercator Projection

Transverse Mercator projections result from projecting the sphere onto a cylinder secant around a central meridian (longitude). Transverse Mercator maps are often used to portray areas with larger north-south than east-west



extent. The projection is not valid in polar regions. Distortion of scale, distance, direction and area increases away from the central meridian.

The Transverse Mercator projection is also called the Gauss-Kruger (or Gauss) projection in some parts of the world. Many national grid systems are based on the Transverse Mercator projection.

Universal Transverse Mercator (UTM)

A commonly used projection system is the Universal Transverse Mercator System (UTM). UTM coordinates are isometric coordinates referred to a specific UTM zone. There are 60 UTM zones, together covering all of the globe. However, UTM is not defined north of 84° North and south of 80° South.

Figure 1.12 show the UTM zone numbers as distributed across the world. For example UTM Zone 32 extend from 6° East to 12° East and covers most of Denmark.

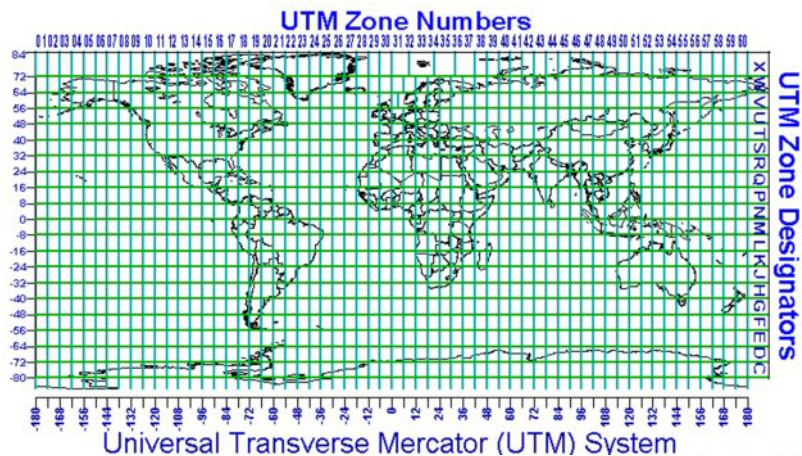


Figure 1.12 UTM Zone numbers

The relation between central meridian (CM) and primary UTM Zone is given below. CM is negative for western meridians and positive for eastern meridians.

Calculation of UTM Zone

$$\text{Equation: Zone} = (177 + \text{CM})/6 + 1$$

Example: Central Meridian 9° East equals zone 32:

$$\text{Zone} = (177 + 9)/6 + 1 = 31 + 1 = 32$$

Calculation of Central Meridian

$$\text{Equation: CM} = 6 * (\text{Zone} - 1) - 177$$



Example: Zone 33 has a Central Meridian of 15° East:
 $CM = 6 \times (33 - 1) - 177 = 192 - 177 = 15$

Coordinates are not always referred to the primary UTM Zone. When an area spans several UTM zones, it may be more practical to refer all coordinates within an area to the same UTM zone. Therefore, it must always be ascertained just what UTM zone coordinates refer to, and when UTM coordinates are passed on to someone else, they should be accompanied by the proper UTM zone information.

1.6 Datum Transformation

1.6.1 Introduction

The process of converting coordinates from one datum to another datum is called a datum transformation. Some commonly used geodetic datums and their ellipsoids are shown in the following table

Table 1.1 Sample of geodetic datums and ellipsoids

Geodetic datum	Ellipsoid
WGS 84 World Geodetic System of 1984	WGS84
NAD 27 North American Datum of 1927	Clarke Spheroid of 1866
OSGB36	Airy 1830

Ideally, a single datum should be used in a country or region so that all data can be referenced to a common coordinate system. In practice it is never so: it is frequently necessary to deal with two or more datums (for example, a local datum for existing mapping and a newer geocentric datum for satellite navigation).

The latitude, longitude and height of a point defined on Datum 1 will be different to its latitude, longitude and height defined on Datum 2 as a consequence of:

- the ellipsoids being different shapes
- the centres of the ellipsoids being displaced
- the Cartesian coordinate axes of the two datums not being parallel or being subject to a scale difference

Coordinates can be converted from one datum to another if the relationship between the two is known. The relationship is described by two components, being:



1. a set of Formulae, which describes the mathematics of the transformation process
2. a set of Parameters, referred to as transformation parameters

1.6.2 Formulae

Two common transformation models are available for the conversion of parameters from one datum to another.

Molodensky transformation

The Molodensky transformation requires 3 parameters, see Equation (1.2) and Figure 1.13.

$$\begin{aligned} X_1 &= X_2 + \Delta X \\ Y_1 &= Y_2 + \Delta Y \\ Z_1 &= Z_2 + \Delta Z \end{aligned} \tag{1.2}$$

where

X_1, Y_1, Z_1 is the Cartesian Coordinates of Datum 1,
 X_2, Y_2, Z_2 is the Cartesian Coordinates of Datum 2 and
 $\Delta X, \Delta Y, \Delta Z$ is the difference between the centres of the two spheroids.

1 common point is adequate for the determination of the 3 parameters.

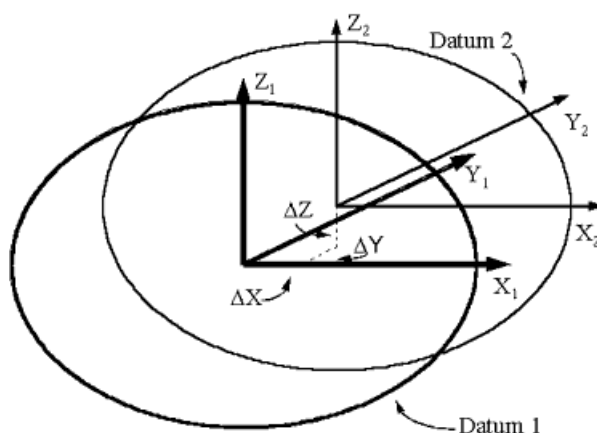


Figure 1.13 Molodensky transformation parameters.



3D Helmert transformation

The 3D Helmert Transformation requires 7 parameters, see Equation (1.3) and Figure 1.14.

$$\begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + (1 + S_c) \begin{bmatrix} 1 & -R_Z & R_Y \\ R_Z & 1 & -R_X \\ -R_Y & R_X & 1 \end{bmatrix} \begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} \quad (1.3)$$

where

X_1, Y_1, Z_1 is the Cartesian Coordinates of Datum 1,
 X_2, Y_2, Z_2 is the Cartesian Coordinates of Datum 2,
 $\Delta X, \Delta Y, \Delta Z$ is the difference between the centres of the two spheroids,
 R_X, R_Y, R_Z is the rotations around the three coordinate axes and
 S_c is the scale difference between the coordinate systems.

The sign convention of R_X, R_Y and R_Z is such that a positive rotation about an axis is defined as a clockwise rotation of the position vector when viewed from the origin of the Cartesian coordinate reference system in the positive direction of that axis.

3 common point are adequate for the determination of the 7 parameters.

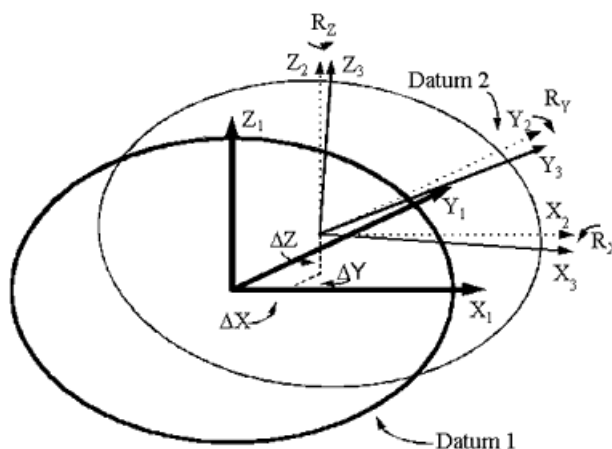


Figure 1.14 3D Helmert Transformation

1.6.3 Parameters

The transformation parameters which are substituted into the Formulae (i.e. $\Delta X, \Delta Y, \Delta Z, R_X, R_Y, R_Z$ and S_c) identify the relationship between the particular



datums in question. They are calculated by comparing coordinate sets from the two datums.

You may find examples of transformation parameters in the following link:
<http://www.arcwebservices.com/arcwebonline/services/dattrans.htm>.

The transformation parameters are derived by analysing survey control stations which have coordinates on both datums. The minimum number of stations required for this process depends on the transformation method being proposed. However, there is no maximum limit, and in general, as many stations as possible are normally used.



NOTE: Others may specify the R-parameters in a different way than DHI.

1.7 References

Further reading about geodesy and map projections in general can be found on the following web-sites:

http://www.posc.org/Epicentre.2_2/DataModel/Examples-ofUsage/eu_cs34.html

<http://mathworld.wolfram.com/LambertConformalConicProjection.html>



2 Geodesy in MIKE Zero

2.1 Introduction

All MIKE Zero products that work with spatial data relate the data elements to geographical positions on the planet earth. This is managed through the use of map projections. A map projection is basically a formula for converting between Cartesian (x,y)-coordinates - often in map projections referred to as easting and northing - and longitudes and latitudes.

Most data files in MIKE Zero are tagged with:

- The map projection that the actual data is given in, and
- The coordinates - expressed in the given map projection - of a reference point within the data.

This makes it possible for MIKE Zero to calculate the exact geographical position of each point in a given data file.

MIKE Zero provides a comprehensive list of pre-defined map projections. However, there might be situations where you will need a projection not supplied with the predefined projections available in the MIKE Zero installation. For these situations MIKE Zero provides a simple utility tool that allows you to create new map projections (see section 3.2 New Map Projection (p. 26)).

2.2 Definition of Map Projection

The map projections used in MIKE Zero must be defined in one of two type of format:

1. By specification in a DHI pfs-file, or
2. By using Open Standard GIS projection files

A collection of pre-defined map projections in both formats are included in the installation of MIKE Zero.

2.2.1 DHI map projection

The pre-defined DHI map projections are specified by 5 files situated in the bin directory for MIKE Zero:

- one file containing the available ellipsoids (elipsoid.pfs)



- four files containing projection parameters for a number of map projections. The map projections are generally sorted in separate files according to their datum:
 - Miscellaneous (Map_projection.pfs)
 - North American Datum 1927 (State_plane_nad27.pfs)
 - North American Datum 1983 (State_plane_nad83.pfs)
 - User defined (Custom_projection.pfs)

The latter file contains custom projections, e.g. map projections you can define yourself by giving a set of projection parameters. This is done from the menu item "Edit Map Projections" found in the MIKE Zero File menu under "Options".

2.2.2 Open standard GIS projection

Included in the installation is a sample of the open standard GIS projection files, similar to those used in ESRI's ArcGIS information system.

The files are self-extracted during the installation and installed in a directory within the DHI common files folder.

It is not possible to edit these files.

2.3 Selection of Map Projection

When specifying a map projection, just select from the drop down list in the different programs. The drop-down list will contain names of the latest 10 map projections that has been used along with a browse facility that enables you to select from all the available map projections or to create a new map projection.

2.4 Grid Orientation

Model areas in MIKE Zero can (among others) be specified by a grid series file (dfs2), that is defined by the grid extension, map projection, geographical position of origin and grid orientation.

The grid orientation is defined as the angle between True North and the y-axis of the grid measured clockwise. A mnemonic way of remembering this definition is by thinking of NYC, which normally means New York City, but which for our purpose means "from North to the Y-axis Clockwise", see Figure 2.1.

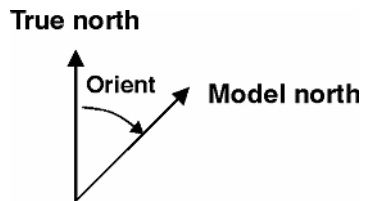


Figure 2.1 Definition of grid orientation

When plotting a grid in the Plot Composer, you have the option to plot an Indication of Convergence. The convergence defines the angle between the longitude at the specific location and the northing line for the specific map projection. As such it is independent of the grid orientation.





3 Map Projection Editing

You use the menu item "Edit Map Projections..." menu item in the MIKE Zero File menu under "Options" (see Figure 3.1).

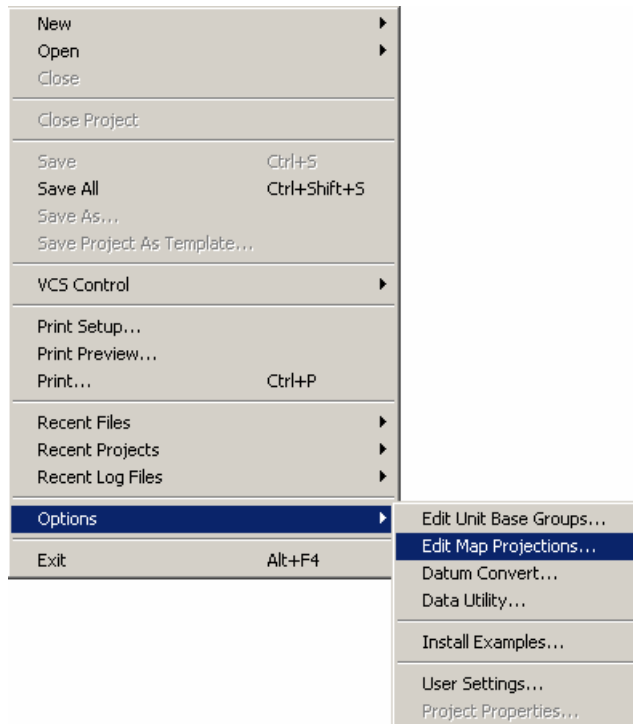


Figure 3.1 MIKE Zero File pull-down menu

After you have selected the menu item, you will be presented with a dialog from where you can create a new map projection, delete or edit an existing one (see Figure 3.2).

3.1 Map Projection Dialog

You use the map projection dialog to view, create, edit and delete map projections. The dialog is shown below in Figure 3.2.

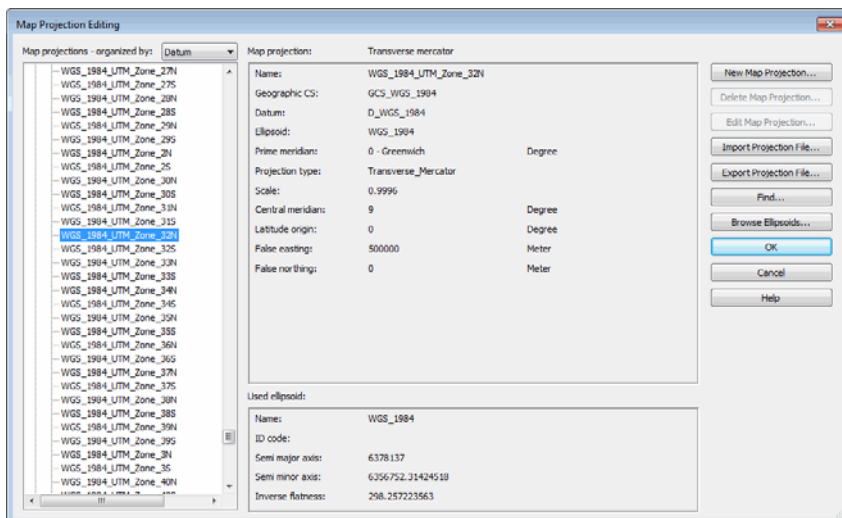


Figure 3.2 Map Projection Dialog



Note: All new map projections you create will be accessible in the map projection list under the “User Defined” group node.

3.2 New Map Projection

You define a new projection by specifying a set of map projection parameters, see Figure 3.3.

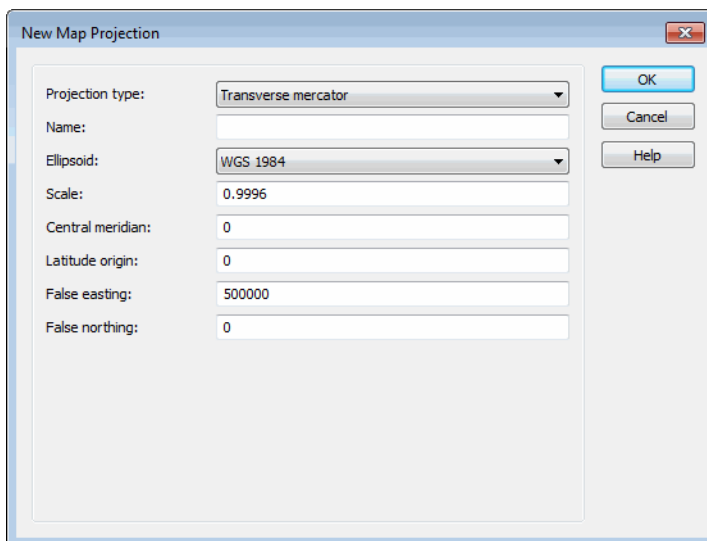


Figure 3.3 New Map Projection dialog when selecting Lambert Conic Projection with 2 standard parallels.



The number and type of parameters depends on the type of map projection.

MIKE Zero presently understands the following types of map projections:

1. Albers equal area
2. Cassini-Soldner
3. Equidistant conic
4. Geographical
5. Hotine oblique mercator
6. Krovak oblique conformal conic
7. Lambert azimuthal equal area
8. Lambert conformal conic with 1 standard parallel
9. Lambert conformal conic with 2 standard parallels
10. Mercator
11. New Zealand map grid
12. Oblique mercator
13. Rectified skew orthomorphic
14. Rotated longitude/latitude
15. Stereographic
16. Stereographic North Pole
17. Stereographic South Pole
18. Transverse Mercator (e.g. UTM)



Note: All new map projections you create will be saved in the file 'custom_projection.pfs' located in the local application data folder, e.g. C:\Users\[User]\AppData\Local\DHI\[Year]\MIKE Zero where [User] is the user identification name and [Year] the release year.

3.2.1 Albers equal area

For an Albers equal area projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The first and second parallel
- The central meridian
- The latitude origin
- The false easting and northing



3.2.2 Cassini-Soldner

For a Cassini-Soldner projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The central meridian
- The latitude origin
- The false easting and northing

3.2.3 Equidistant conic

For a equidistant conic projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The first and second parallel
- The central meridian
- The latitude origin
- The false easting and northing

3.2.4 Geographical

For a Geographical projection you only need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon

3.2.5 Hotine oblique mercator

For a Hotine oblique mercator projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The scale of the projection
- The longitude of the center of the projection
- The latitude of the center of the projection
- The Azimuth value
- The false easting and northing



3.2.6 Krovak oblique conformal conic

For a Krovak oblique conformal conic projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The scale at pseudo parallel
- The pseudo parallel
- The longitude and latitude of the center of the projection
- The Azimuth
- The XY plane rotation
- The X and Y scale
- The false easting and northing

3.2.7 Lambert azimuthal equal area

For a Lambert azimuthal equal area projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The central meridian
- The latitude origin
- The false easting and northing

3.2.8 Lambert conformal conic with 1 standard parallel

For a Lambert conformal conic projection with 1 standard parallel you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The scale of the projection
- The central meridian
- The latitude origin
- The false easting and northing

3.2.9 Lambert conformal conic with 2 standard parallels

And for a Lambert conformal conic projection with 2 standard parallels you specify:



- The name of your new projection
- The ellipsoid the projection is based upon
- The first and second parallel
- The longitude and latitude origin
- The false easting and northing

3.2.10 Mercator

For a Mercator projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The first parallel
- The central meridian
- The false easting and northing

3.2.11 New Zealand map grid

For a New Zealand map grid projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The longitude origin
- The latitude origin
- The false easting and northing

3.2.12 Oblique mercator

For an Oblique mercator map projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The scale of the projection
- The longitude of the center of the projection
- The latitude of the center of the projection
- The Azimuth
- The false easting and northing



3.2.13 Rectified skew orthomorphic

For a Rectified skew orthomorphic map projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The scale of the projection
- The longitude of the center of the projection
- The latitude of the center of the projection
- The Azimuth
- The XY plane rotation
- The false easting and northing

3.2.14 Rotated longitude/latitude

For a Rotated longitude/latitude map projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The longitude of the south pole
- The latitude of the south pole
- The angle of rotation

3.2.15 Stereographic

For a Stereographic projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The scale of the projection
- The central meridian
- The latitude origin
- The false easting and northing

3.2.16 Stereographic North Pole

For a Stereographic North Pole projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon



- The first parallel (per default set to 60 degrees)
- The central meridian
- The false easting and northing

3.2.17 Stereographic South Pole

For a Stereographic South Pole projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The first parallel (per default set to -60 degrees)
- The central meridian
- The false easting and northing

3.2.18 Transverse Mercator

For a Transverse Mercator map projection you need to specify:

- The name of your new projection
- The ellipsoid the projection is based upon
- The scale of the projection
- The central meridian
- The latitude origin
- The false easting and northing



Note: This map projection type is the basis for the UTM projections.

3.3 Edit Map Projection

You use the Edit Map Projection dialog to redefine the map projection parameters defining the projection. The dialog is shown in Figure 3.4.

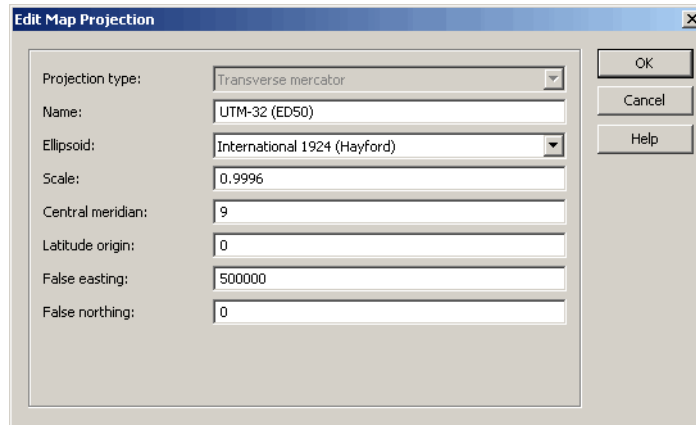


Figure 3.4 Edit Map Projection dialog when selecting Transverse Mercator

Usually the pre-defined projections that are installed along with the MIKE Zero are write-protected and cannot be edited.



Note: The number of parameters you can modify in an existing projection depends on the projection itself.

3.4 Find Map Projection

You may find a pre-defined map projection from the list by searching a text string that is a part of the map projection name. The dialog is shown in Figure 3.5.

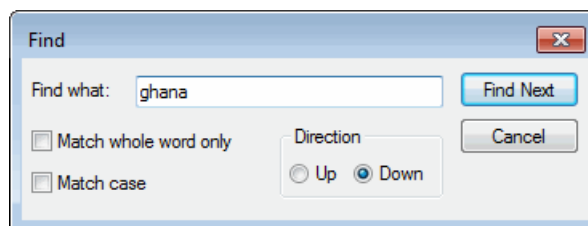


Figure 3.5 Find Map Projection dialog

3.5 Ellipsoids

You use the ellipsoid dialog to view, create, edit and delete ellipsoids. The dialog is shown below in Figure 3.6.

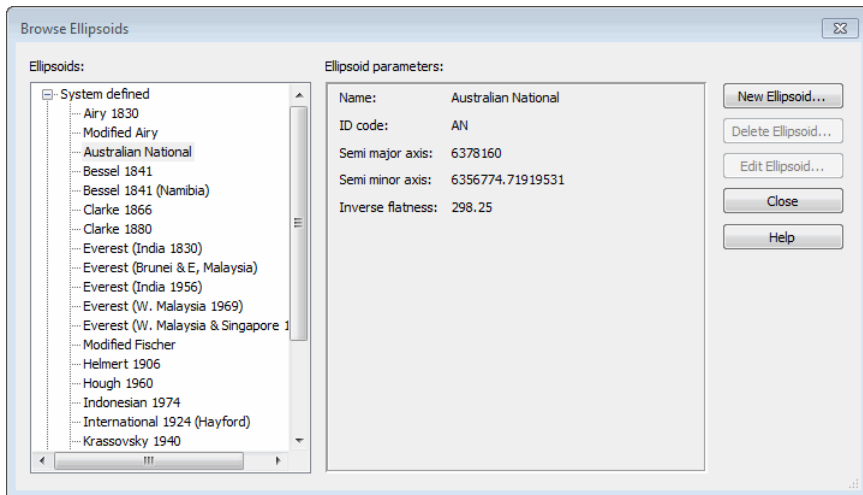


Figure 3.6 Browse Ellipsoids dialog

This functionality is typically only used in connection with creating a New Map Projection when the existing ellipsoids are not applicable.



Note: All new ellipsoids you create will be accessible in the ellipsoid list under the “User Defined” group node.

3.5.1 New ellipsoid

You define a new Ellipsoid by specifying a name along with the values for semi-major axis and inverse flatness, see Figure 3.7.

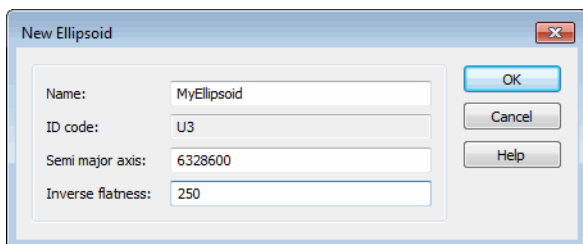


Figure 3.7 New ellipsoid dialog



Note: All new ellipsoids you create will be saved in the file ‘custom_ellipsoid.pfs’ located in the local application data folder, e.g. C:\Users\[User]\AppData\Local\DHI\[Year]\MIKE Zero where [User] is the user identification name and [Year] the release year.



3.5.2 Edit ellipsoid

You use the Edit Ellipsoid dialog to redefine the ellipsoid parameters defining the ellipsoid.

Usually the pre-defined ellipsoids that are installed along with the MIKE Zero are write-protected and cannot be edited.





4 Datum Conversion Utility

You use the menu item "Datum Convert..." menu item in the MIKE Zero File menu (see Figure 4.1).

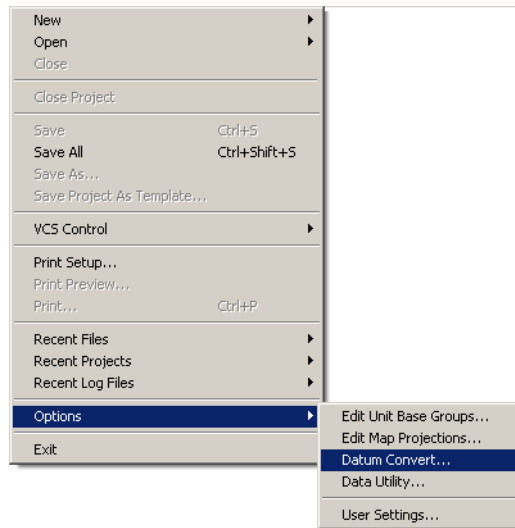


Figure 4.1 MIKE Zero File pull-down menu

After you have selected the menu item, you will be presented with a dialog from where you can convert xyz data between different coordinate systems (see Figure 4.2).

4.1 Datum Conversion

The Datum Conversion utility is a tool for converting spatial data coordinates from one coordinate system to another. This can be between two different projected coordinate systems, from projected data to geographical data (or vice-versa), and with or without datum transformation.

A log containing the session history keeps track of the conversions for the active data set.

You may save the conversion parameters in a conversion template for future use.

The dialog is shown below in Figure 4.2.

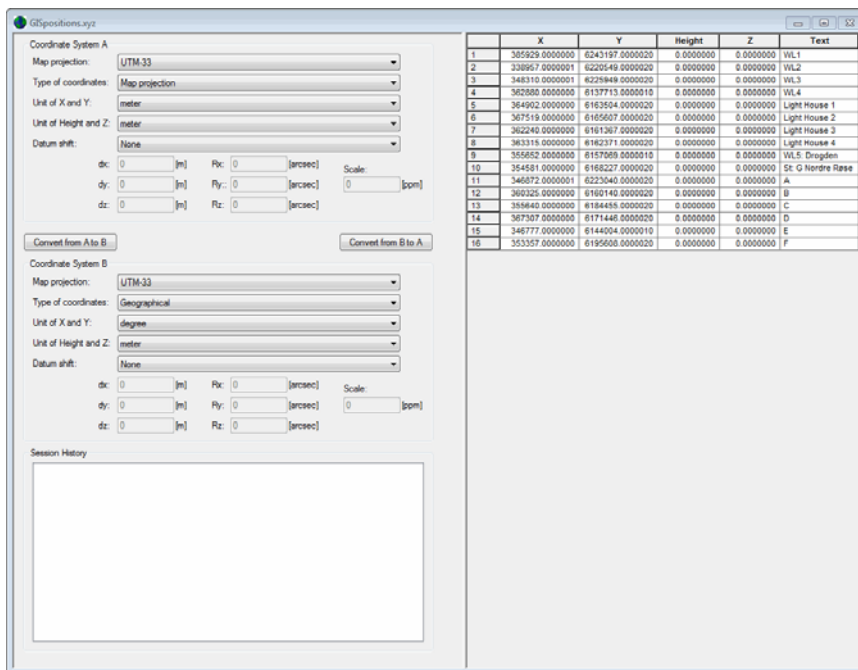


Figure 4.2 Datum Conversion dialog

4.1.1 Batch execution

You can convert spatial data without using the dialogs attached by executing the program by a batch command from a DOS-prompt.

The syntax for executing the program is:

DatumConvert inputfile.xyz -template template.cvt [-dms2dd] [-a2b] [-b2a] [-dd2dms] [-save] [-save_as outputfile.xyz]

A template must be created beforehand to define the Datum properties for the two coordinate systems. How to create a template for Datum Conversion is described in section 4.6.4 Conversion Template (p. 43).

You specify **-a2b** or **-b2a** to define if the conversion is from Coordinate System A to Coordinate System B, or vice versa, respectively.

You specify **-dms2dd** or **-dd2dms** to enable a conversion from degrees, minutes and seconds to decimal degrees, or vice versa, respectively.

You specify **-save** if the output is to be saved in the input file. Otherwise you specify **-save_as** and an output file name.



4.2 Spatial Data

The Datum Conversion utility converts spatial XYZ data, shown in the spreadsheet to the right in the dialog, according to the definitions of coordinate system A and B, respectively. Note that you need to specify the applied units for the data.

You can add the spatial data to the dialog in two ways:

- By manual input in the spreadsheet to the right (press Enter in the lower right Text cell to add new line)
- By opening an ascii-file containing rows with spatial coordinates (and maybe text) organised in columns (Select File->Open).

NOTE: In an ascii-file the first three columns must be numeric data. All characters in the line after the third column are regarded as text and inserted in the last column in the spreadsheet, including spaces. Please see 4.6.6 Options (p. 44) for how to interpret the value in the third column in an ascii file.

You can export the data in the spreadsheet to an ascii-file at any time by selecting File->Save or File->Save as.

Per default the program search for ascii-files with extension .xyz, but it is possible to apply other extensions.

4.2.1 Vertical dimension

The spatial data is defined by a geodetic height (height above ellipsoid) or a Z-value (height above datum level). During the data conversion both height and Z-value may change if the coordinate systems utilize different ellipsoids.

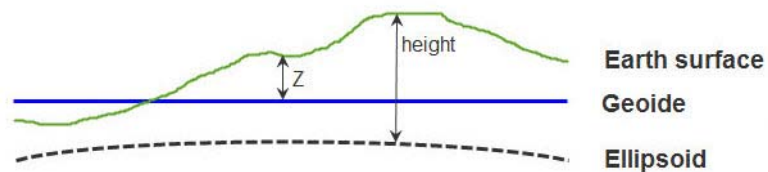


Figure 4.3 Definition of Z and height value in spatial data
Note: at open waters the geoid can be interpreted as the mean sea level

Please see 4.6.6 Options (p. 44) for how to interpret the value in the third column.

4.3 Coordinate System

When converting XYZ data you need to specify the properties for the coordinate system that the data is defined by now AND the properties for the coordinate system by which you want to define your data after the conversion.

A coordinate system used for the conversion is defined by a Map projection, the Type of coordinates and Datum shift.

4.3.1 Map projection

You must specify the map projection of the data. You can select from a wide assortment of map projections installed with MIKE Zero.

4.3.2 Type of coordinates

You must specify the type of coordinates. The XYZ data can be displayed in two ways:

- Cartesian coordinates (Map projection, meters)
- Geodetic coordinates (Geographical, longitude/latitude)

The definition of cartesian and geodetic coordinates, respectively, is shown in Figure 4.4.

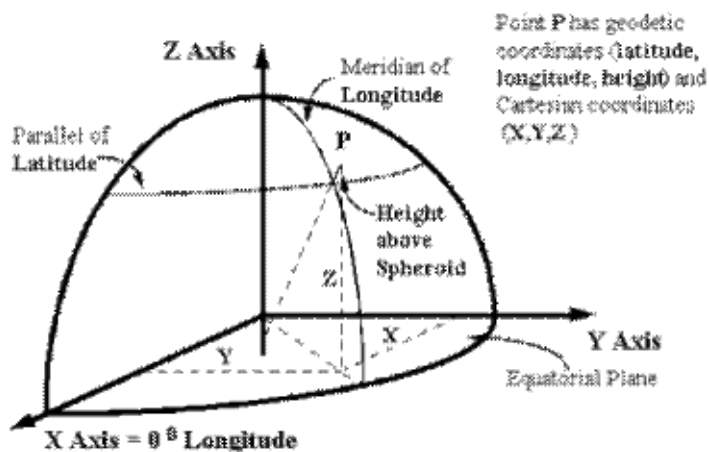


Figure 4.4 Geodetic coordinates versus Cartesian coordinates



4.3.3 Datum shift

If you want to simply translate spatial coordinates between a map projection and corresponding geographical coordinates, keeping the same datum, you specify 'none' for Datum shift.

If you want to add a datum shift to the map projection already defined you must specify some datum transformation parameters. The parameters are as follows:

- dx, dy, dz
The difference between the centres of the two spheroids
- Rx, Ry, Rz
The rotations around the three coordinate axes)
- Sc (scale difference between the coordinate systems)

NOTE: In general the datum parameters are sign reversible. The Datum Converter use the Markus convention for rotation parameters. This may be of opposite sign compared to other sign conventions.

Additional description of how the parameters are defined and how the datum shift is calculated can be found in Datum Transformation (p. 17) and below.

4.4 Datum Transformation Process

The sequence in converting coordinates from Datum '1' to Datum '3' is given below and illustrated in Figure 4.5 (Datum '2' denotes the reference datum, handled internally by the program).

1. Transformation of map grid coordinates (eg. UTM) on Datum '1' to geodetic coordinates on Datum '1'.
2. Conversion of the geodetic coordinates on Datum '1' to XYZ Cartesian values on Datum '1'.
3. Conversion of the XYZ Cartesian values on Datum '1' to XYZ Cartesian values on Datum '2' or '3'.
4. Convert the XYZ Cartesian values on Datum '2' or '3' to geodetic coordinates on Datum '2' or '3'.
5. Convert the geodetic coordinates on Datum '2' or '3' to map grid coordinates on Datum '2' or '3'.

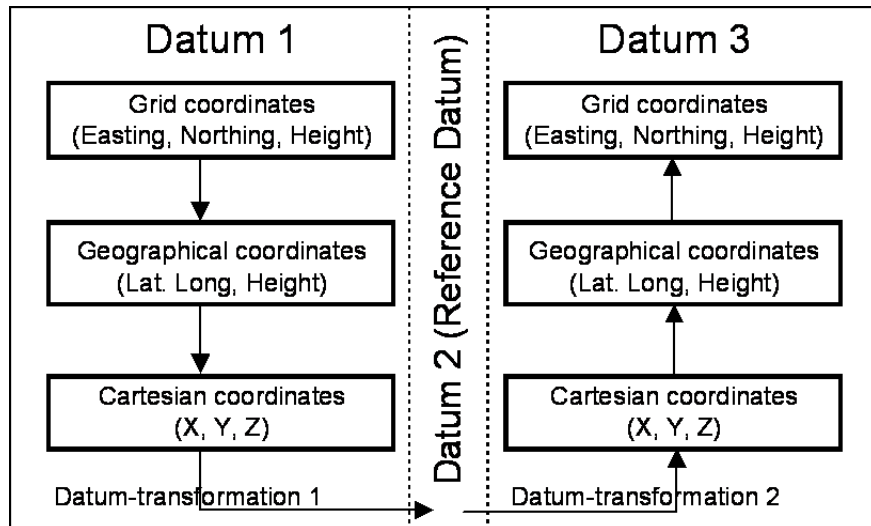


Figure 4.5 Datum transformation process

4.5 Session History

After each conversion of xyz data, the program writes the conversion parameters in the Session History log window located down left in the dialog. This enables you to keep track of the conversions taken place after the initial input of XYZ data into the spreadsheet.

4.6 Tools

A number of utilities can be accessed through the Tools menu in the top menubar.

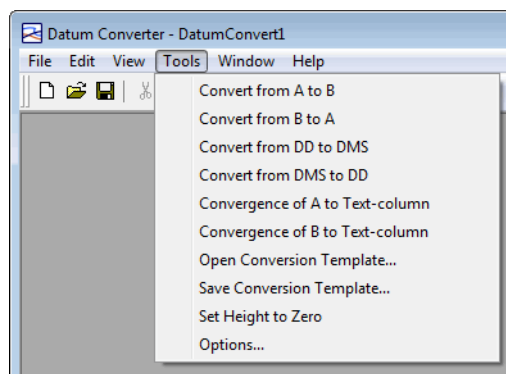


Figure 4.6 Available tools



4.6.1 Conversion between A and B

Converts data between coordinate system A and coordinate system B. Holds the same functionality as pressing the 'Convert from...' buttons.

4.6.2 Conversion between DD and DMS

Geographical coordinate values may be expressed by decimal degrees (DD) or degrees, minutes and seconds (DMS).

The definition of a coordinate in DMS is deg.mmss where the value in front of the digit is degrees (deg) and the values behind the digit is minutes (mm) and seconds (ss), respectively.

The relation between DD and DMS is as follows:

$$DD = \text{deg} + (\text{mm} \cdot 60 + \text{ss})/3600$$

4.6.3 Convergence of A or B to Text-column

The convergence defines the angle between the longitude at the specific location and the northing line for the specific map projection.

You can calculate the convergence angle for each coordinate point. The convergence angle will be written to the text column in the display (the last column).



Note: Any existing data in the text column will be overwritten.

4.6.4 Conversion Template

If you are frequently going to convert data from coordinate system A to coordinate system B, it can be time saving to save the conversion parameters in a Conversion Template (extension .cvt) that can be opened and re-applied on a new data set.

As an example Qatar_WGS84.cvt is shown in Figure 4.7. This file defines the entire transformation.



```
Qatar_WGS84.cvt - Notepad
File Edit Format View Help
// Created : 2006-04-26 0:37:52
// DLL Id : C:\PROGRA-1\COMMON-1\DH1\MikeZero\pfs2004.d11
// PFS version : Apr 25 2006 19:16:33

[Conversion_Template]
[Coordinate_System_A]
Map_Projection = PROJCS["Qatar_National_Grid",GEOGCS["GCS_Qatar",DATUM["D_Qatar",SPHEROID
["International_1924",6378388,297]],PRIMEM["Greenwich",0],UNIT["Degree",0.017453292519943295]],PROJECTION
["Transverse_Mercator"],PARAMETER["False_Easting",200000],PARAMETER["False_Northing",300000],PARAMETER
["Central_Meridian",51.21666666666667],PARAMETER["Scale_Factor",0.9999900000000001],PARAMETER
["Latitude_of_Origin",24.45],UNIT["Meter",1]]
Type_of_Coordinates = 0
Datum_Shift = 2
Dx = -119.4248
Dy = -303.65872
Dz = -11.00061
Rx = 1.164298
Ry = 0.174458
Rz = 1.096259
Scale = 3.657065
EndSect // Coordinate_System_A

[Coordinate_System_B]
Map_Projection = PROJCS["WGS_1984_UTM_Zone_39N",GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID
["WGS_1984",6378137,298.25723563]],PRIMEM["Greenwich",0],UNIT["Degree",0.017453292519943295]],PROJECTION
["Transverse_Mercator"],PARAMETER["False_Easting",500000],PARAMETER["False_Northing",0],PARAMETER
["Central_Meridian",51],PARAMETER["Scale_Factor",0.9996],PARAMETER["Latitude_of_Origin",0],UNIT["Meter",1]]
Type_of_Coordinates = 0
Datum_Shift = 0
EndSect // Coordinate_System_B

EndSect // Conversion_Template
```

Figure 4.7 Template content displayed in NotePad.
Coordinate system A: Qatar National Grid + datum shift
Coordinate system B: WGS 84 UTM Zone 39N.

4.6.5 Set height to zero

When the applied coordinate systems utilize different ellipsoids the height may be converted to a value besides 0. This value may affect the outcome of further conversions.

This functionality holds the opportunity to reset the height value to 0.

4.6.6 Options

The spatial data values may be listed by columns in an ascii file. You have the opportunity to define how the Vertical dimension in the third variable is to be interpreted during reading or writing the data.

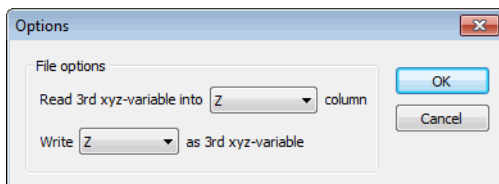


Figure 4.8 Options for reading and writing ascii data file



5 Using the Geodesy in MIKE Zero

This chapter shows how to apply the mapping functions included with MIKE Zero.

5.1 New bathymetry based on two different map projections

5.1.1 Introduction

The example demonstrates how to establish a bathymetry for the Bay of Kirkwall at the Orkney Islands using OSGB as map projection. The bathymetry is created using the Bathymetry Editor and saved as a dfs2 data file.

In order to create the bathymetry, depth contours have been extracted from MIKE C-MAP. The extracted data is given in geographical coordinates based on the WGS84 ellipsoid.

When specifying a map projection, just select from the drop down list in the given dialog or browse to the desired projection. Sometimes the data to import is not in the same map projection as the working area, however the program includes automatic conversion of the data.



Note: The automatic conversion of data does not consider datum shift.

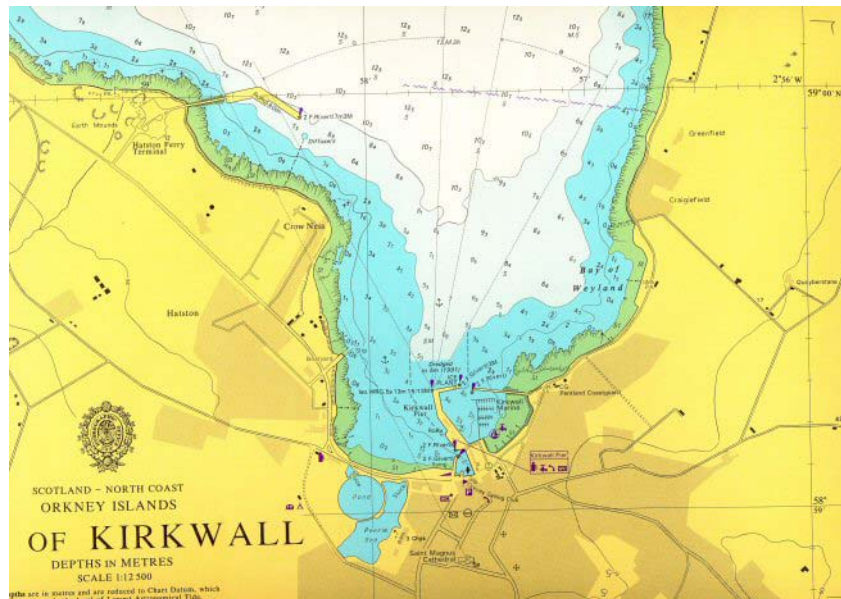


Figure 5.1 Sea chart showing Bay of Kirkwall

5.1.2 Defining working map projection

The area of interest is shown in Figure 5.1. The approximately coordinates covering the area (expressed in OSGB) are as follows:

- Easting 344200
- Northing 1010800
- Area width of 3000m
- Area height of 2600m

The MIKE Zero Bathymetry Editor is started and the working area defined accordingly. Please note, that the map projection has been defined as OSGB.

The map projection for the working area is defined as shown in Figure 5.2.

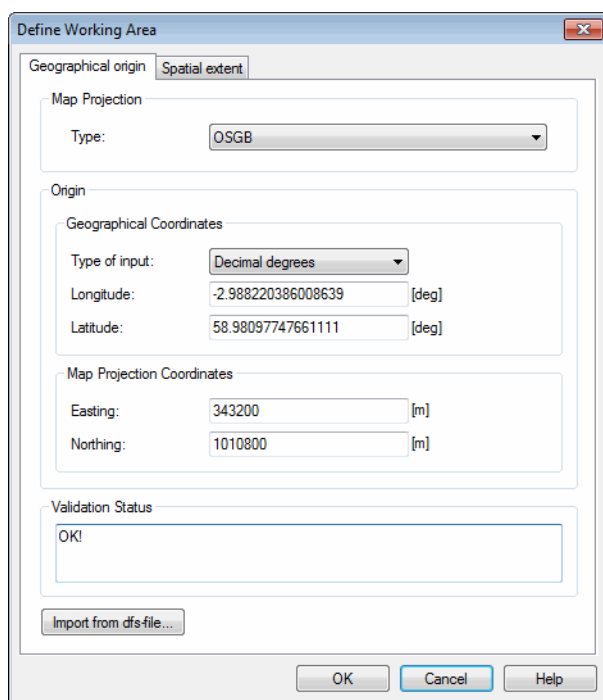


Figure 5.2 Defining map projection for the working area

After pressing OK on the working area definition dialog the working area is as presented in Figure 5.3.

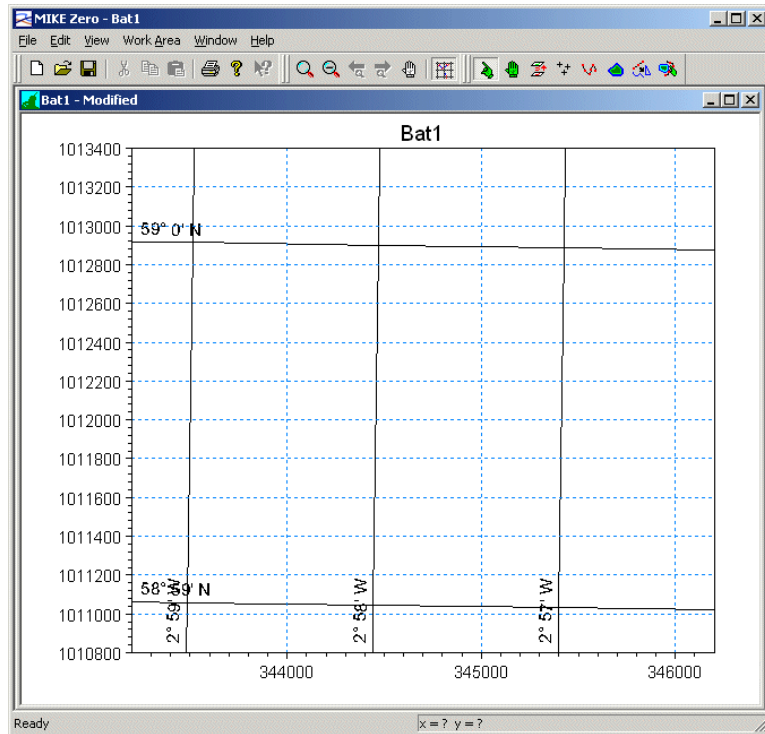


Figure 5.3 Working area in OSGB

5.1.3 Importing geographical points

It is now possible to the land and water values extracted from MIKE C-Map. From the "Work Area" menu "Background Management" is selected and then "Import xyz files".

Hereafter the files 'water.xyz' and 'land.xyz' is selected. The data is given in geographical coordinates based on the WGS84 ellipsoid. Thus, in the "Convert from" box the map projection is selected as LONG/LAT. The data will - after clicking "Open"- be converted from LONG/LAT to OSGB automatically. This is illustrated in Figure 5.4.

After importing both 'water.xyz' and 'land.xyz', the working area will look as shown in Figure 5.5. Note that the imported XYZ data is converted and shown in the OSGB map projection.

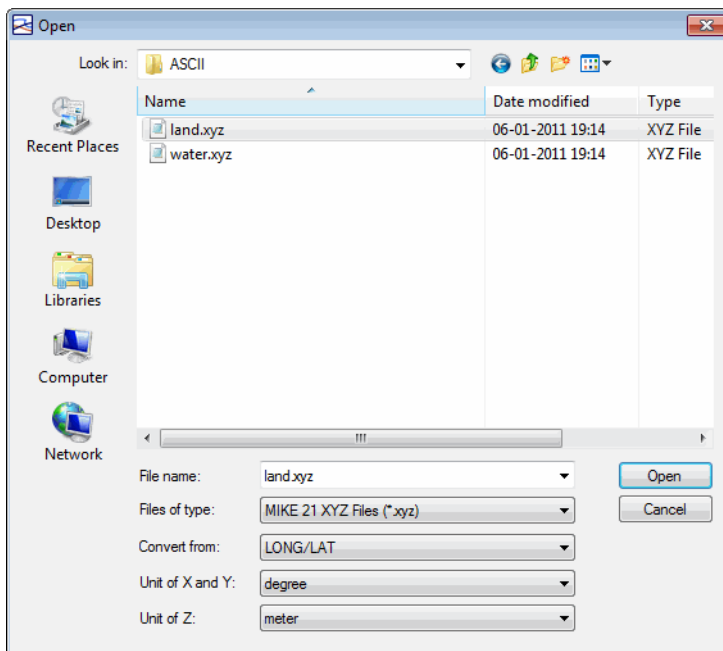


Figure 5.4 Importing xyz-files from Longitude, Latitude in WGS84

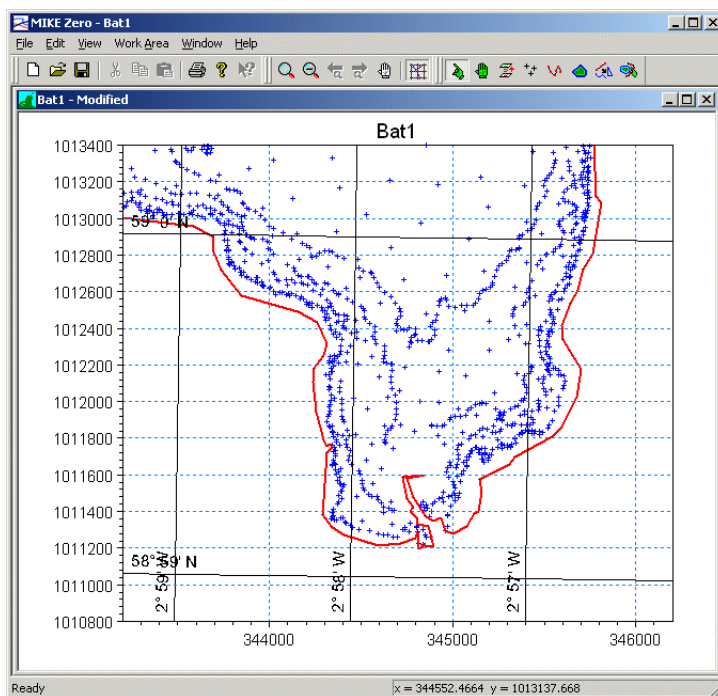


Figure 5.5 After import of land and water from MIKE C-MAP in Long/Lat WGS84



The example comes with additional data files. These are already in OSGB and shall therefore not be converted during import, i.e. the option "No conversion" is selected in the "Open" dialog. After importing all data the working area looks like the one presented in Figure 5.6.

The points are used for generation of the bathymetry. The interpolated bathymetry is always generated based on the working area map projection, e.g. OSGB in this example.

A plot (generated by MIKE Animator) of the bathymetry is shown in Figure 5.7.

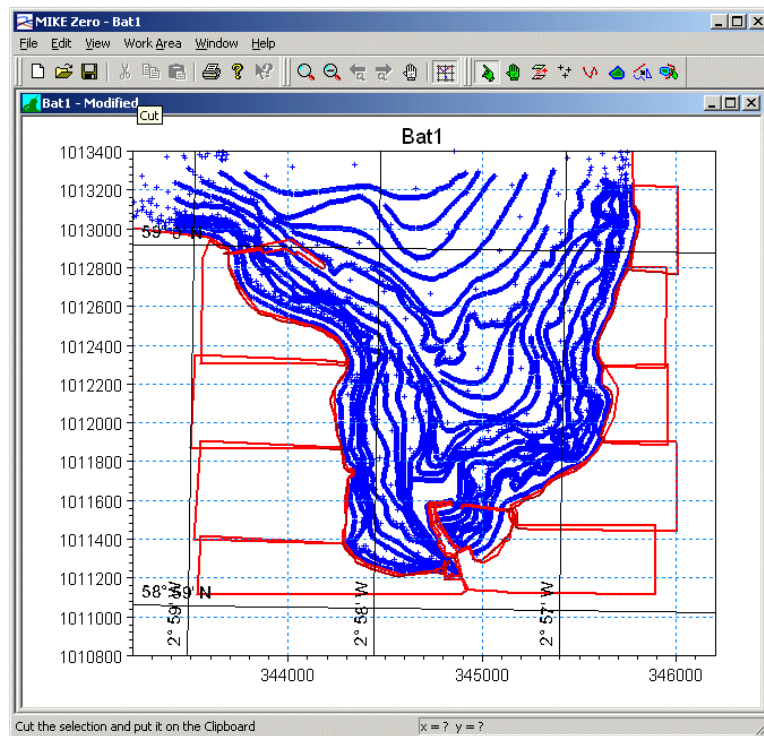


Figure 5.6 Working Area after importing xyz-files from OSGB

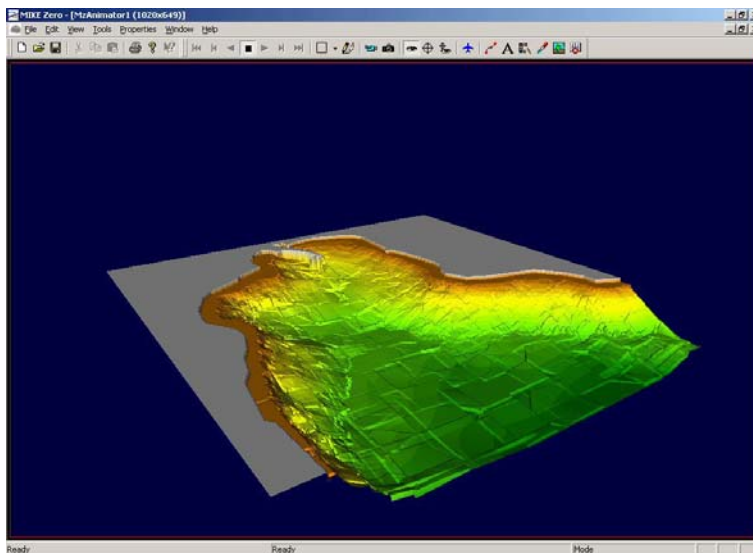


Figure 5.7 Coarse unfiltered grid bathymetry

5.2 Converting spatial data

You can use the Datum Convert utility for both simple conversion and more complicated transformations.

The files used in the following examples are positioned in the DatumConvert example directory at (default installation):
.\Examples\MIKE_Zero\DatumConvert

5.2.1 Simple conversion

Assume that you have some spatial data given in the map projection UTM-33 and you want to translate the data so your coordinates are given in longitude-latitude for the same ellipsoid.

To convert the data do the following:

1. Open Datum Convert utility
2. Use File->Open and select the file positions.xyz
3. Define Coordinate system A as UTM-33, Map Projection coordinates
4. Define Coordinate system B as UTM-33, Geographical coordinates (the dialog should now resemble Figure 5.8).
5. Press button 'Convert from A to B'.
6. This converts the data and you will see the coordinates as longitude/latitude in the spreadsheet as shown in Figure 5.9.



7. Use File->Save As to save the data under a new filename.

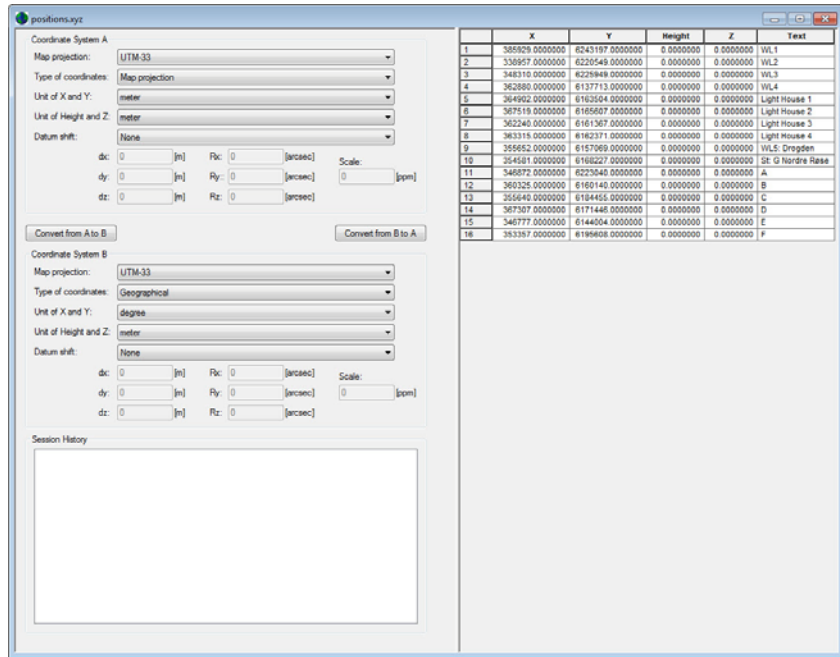


Figure 5.8 Datum Convert dialog before conversion of data.

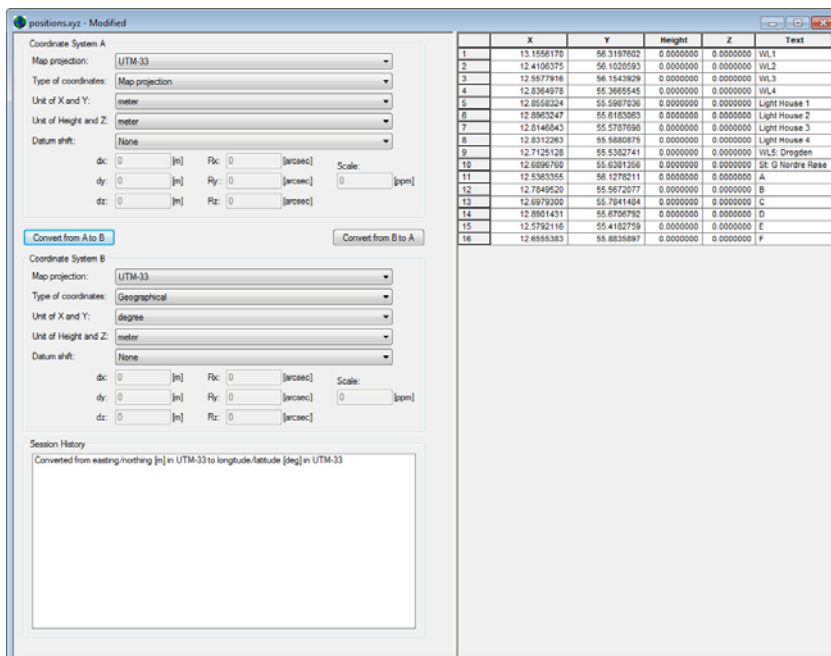


Figure 5.9 Datum Convert dialog after conversion of data.

5.2.2 Conversion with Datum shift

Assume that you have some spatial data coordinates in Map Projection WGS_1984_UTM_Zone_39N and you want to convert these to a National grid, namely Qatar National Grid. This map projection grid use the ellipsoid International 1924, different from the WGS 1984 ellipsoid.

To convert these data it is necessary to include Datum Shift for the conversion. The datum shift parameters for the Qatar National Grid are as follows:

$$\begin{aligned}\Delta X &= -119.4248 \text{ [m]}, \\ \Delta Y &= -303.65872 \text{ [m]}, \\ \Delta Z &= -11.00061 \text{ [m]}, \\ R_X &= 1.164298 \text{ [arcsec]}, \\ R_Y &= 0.174458 \text{ [arcsec]}, \\ R_Z &= 1.096259 \text{ [arcsec]}, \\ \text{Scale} &= 3.657065 \text{ [ppm]}\end{aligned}$$

To convert the data do the following:

1. Open Datum Convert utility
2. Use File->Open and select the file QatarPoints.txt (this file is positioned at .\Examples\MIKE_Zero\DatumConvert)



3. Define Coordinate system A as WGS_1984_UTM_Zone_39N, Map Projection coordinates.
4. Define Coordinate system B as Qatar National Grid, Map Projection coordinates and the Datum shift parameters listed above.
5. Press button 'Convert from A to B'.
6. This converts the data and you will see the coordinates as Qatar National Grid coordinates in the spreadsheet as shown in Figure 5.10.
7. Use File->Save As to save the data under a new filename.

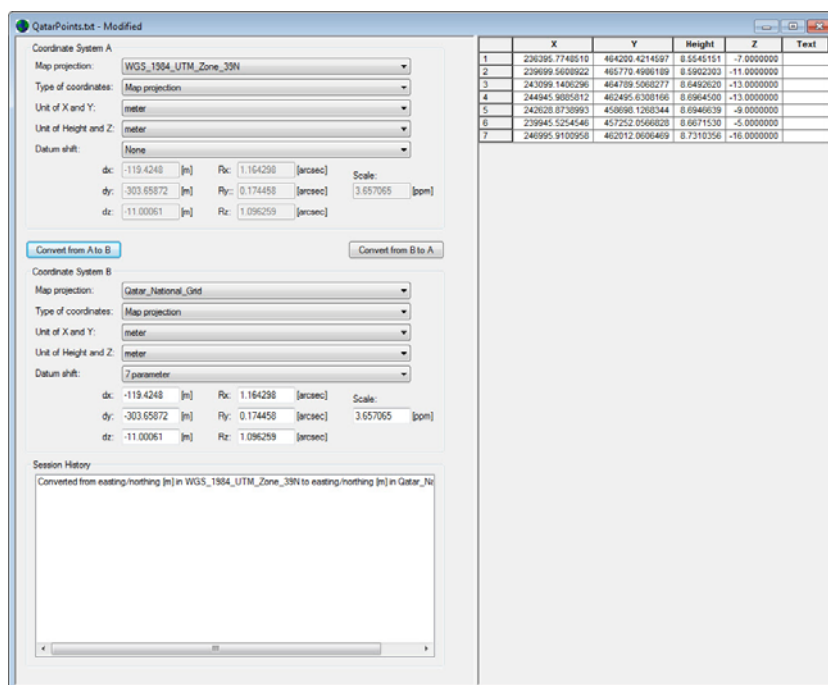


Figure 5.10 Converted data from WGS 1984 UTM Zone 39 N to Qatar National Grid

5.2.3 Datum Conversion in Batch

Consider the Qatar data given in the previous example. You can convert these data by a batch command.

A conversion template has already been created (Qatar_WGS84.cvt):

- Coordinate System A defines the Qatar National Grid including the Datum shift parameters.
- Coordinate System B defines WGS 84 UTM Zone 39N.

To convert the data in batch mode do the following:



1. Open a DOS-prompt in the DatumConvert example directory
2. Execute the following command:
DatumConvert QatarPoints.txt -template Qatar_WGS84.cvt -b2a -
save_as QatarPoints_New.xyz

The coordinate points given in the output file are the same as the data shown in Figure 5.10.



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