Digital Photogrammetric System

PHOTOMOD

Version 8.0

USER MANUAL

The GeoCalculator program (Windows x64)

RACURS

Table of Contents

1. About the program 4
2. GeoCalculator installation 4
3. Interface and its elements 9
   3.1. The “Database” menu 9
   3.2. The “Help” menu 9
   3.3. The main toolbar 9
4. GeoCalculator database 10
5. The coordinates transformation 11
6. Coordinate systems management 13
   6.1. The “Coordinate systems” window 13
   6.2. Searching for the coordinate system 14
   6.3. Coordinate system detailed description 15
   6.4. Creating new coordinate system 15
   6.5. Coordinate system’s parameters 18
      6.5.1. Parameters of geodetic coordinate system 18
      6.5.2. Parameters of geocentric coordinate system 19
      6.5.3. Parameters of Cartesian coordinate system 20
      6.5.4. Parameters of cartographic coordinate system 20
      6.5.5. Parameters of topocentric coordinate system 22
   6.6. Import and export of coordinate systems 23
      6.6.1. Batch import and export 24
   6.7. Coordinate systems types 24
7. Coordinate systems elements 25
   7.1. Datums 25
      7.1.1. Creating new datum 25
      7.1.2. Datum transformation parameters presets 26
      7.1.3. Creating new datum transformation parameters preset 26
      7.1.4. Datum transformation parameters 28
      7.1.5. Datum transformation types 33
   7.2. Ellipsoids 34
      7.2.1. Creating new ellipsoid 34
   7.3. Prime meridian 36
      7.3.1. Creating new prime meridian 36
   7.4. Measurement units 37
      7.4.1. Creating new linear units 38
      7.4.2. Creating new scale units 39
      7.4.3. Creating new angular units 40
      7.4.4. The angular formats list 42
   7.5. Cartographic projections 42
      7.5.1. Creating new cartographic projection 42
      7.5.2. Map projections types 44
   7.6. Height systems 45
      7.6.1. EGM2008 height system 46
      7.6.2. Creating custom height system 46
   7.7. Deleting coordinate system elements 48
Appendix A. Coordinate transformations 49
   A.1. Creating new coordinate transformation rule 50
      A.1.1. Affine transformation of XY coordinates 52
      A.1.2. Shift of XY coordinates 52
      A.1.3. Z-axis shift 53
   A.2. The transformation rules types list 54
Appendix B. EPSG and MapInfo codes 55
   B.1. Code assigning 56

B.2. Code generation 56
Appendix C. Hotkeys 59
Appendix D. Coordinate file format 59
Appendix E. GeoCalculator settings 60
Appendix F. Calculating datum transformation parameters 60
F.1. Preparing data sets 61
F.2. Loading data sets 63
F.3. Calculating datum transformation parameters 66
F.4. Viewing the user coordinate system Info 70
F.5. Transformation sequence 76
F.5.1. Checking input data errors when calculating parameters of transformation between coordinate systems 76

1. About the program

The *PHOTOMOD GeoCalculator* (further – *GeoCalculator*, program) is used for coordinates transformation from one coordinate system to another. The program includes to the *PHOTOMOD* system and installing with it automatically, as a separate module. Also it could be installed and used as a separate application, without *PHOTOMOD*.

The coordinate systems database is installed automatically with the program. It is required to work with *GeoCalculator*.

To start the program perform one of the following:

- If *PHOTOMOD GeoCalculator* is installed as a part of the *PHOTOMOD* system:
  - Choose **Service › GeoCalculator** in the main *PHOTOMOD* window;
  - Choose **GeoCalculator** in the right-click menu of the *System Monitor module* (the icon in the *Windows* system tray).
- If *PHOTOMOD GeoCalculator* is installed as separate application – choose **Start › Programs › PHOTOMOD GeoCalc 8 x64 › PHOTOMOD GeoCalc 8 x64** or run `PhGeoCalcApp.exe` manually (stored in *C:\Program Files\PHOTOMOD_8_GeoCalc_x64* folder by default).

2. GeoCalculator installation

The program (as separate application) requires 1.5 Gb of free hard disk space.

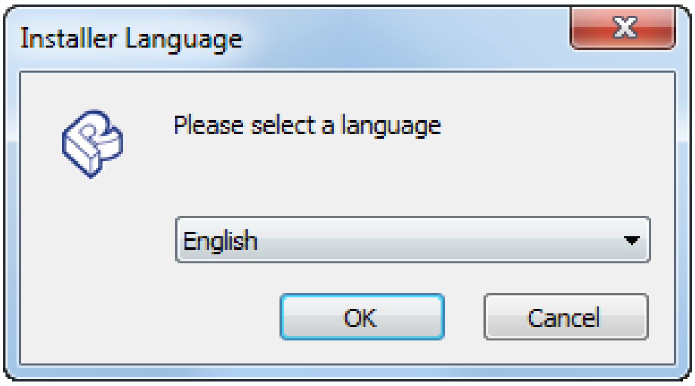
To start the *GeoCalculator* installation, run the `Ph_GeoCalc_NN_[CCCC]_x64.exe` file, where N is the version number, CCCC is the build number.

The system initial installation process consists of a sequence of steps with instructions.

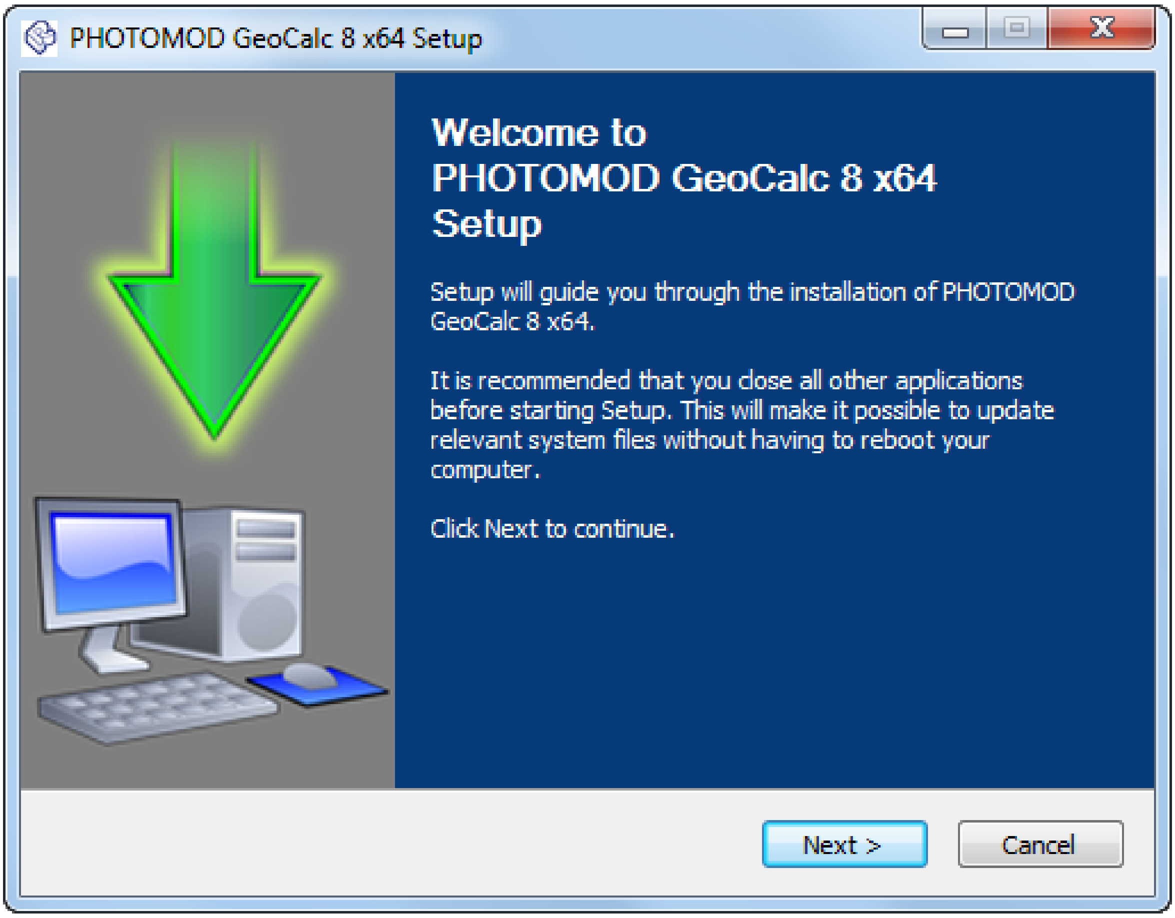
In case of cancel at any step, installed program files and data are not removed. To complete the system installation, restart the `Ph_GeoCalc_NN_[CCCC]_x64.exe` file and go through all steps again.

The installation process consists of the following steps:

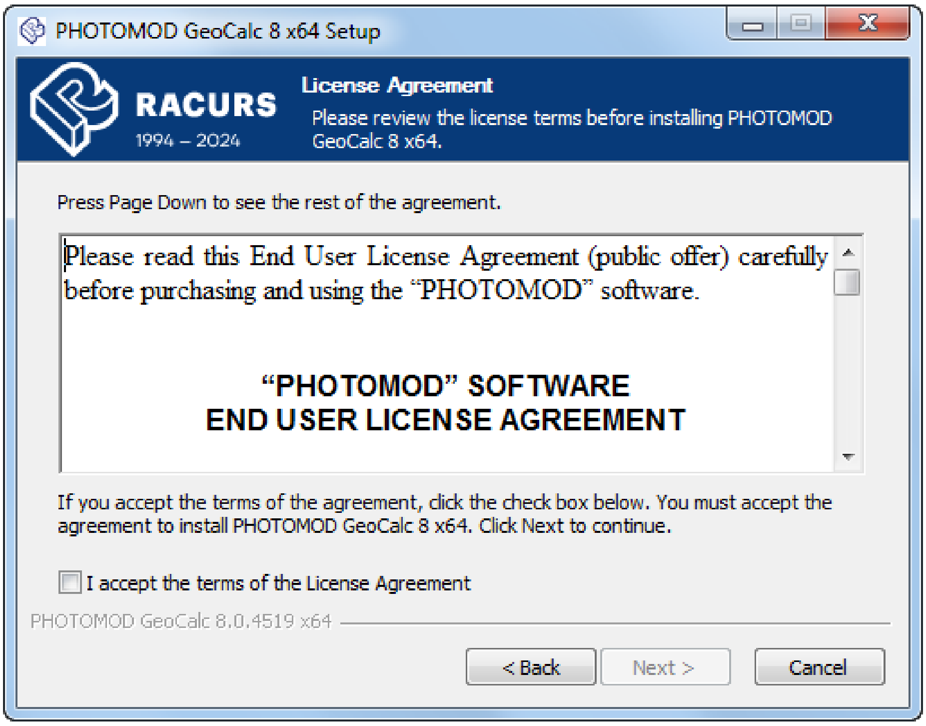
1. Choose the installation language. Click OK;



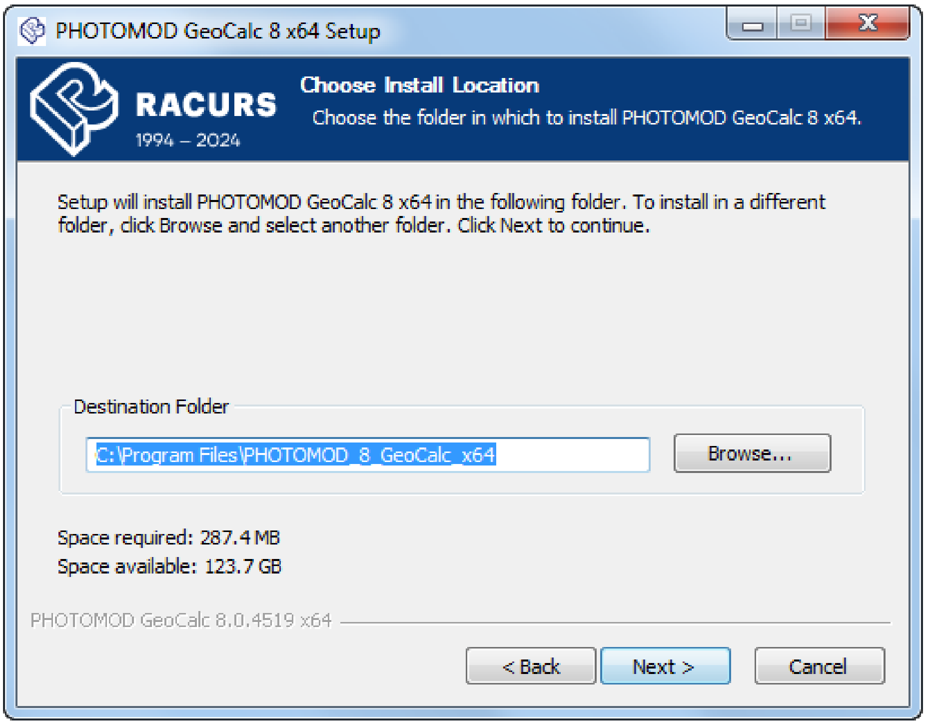
2. Read the welcome and warning messages. Click the **Next** button.



3. Read the license agreement. If you agree with it, set the **I accept the terms of the License Agreement** checkbox on and click the **Next** button.

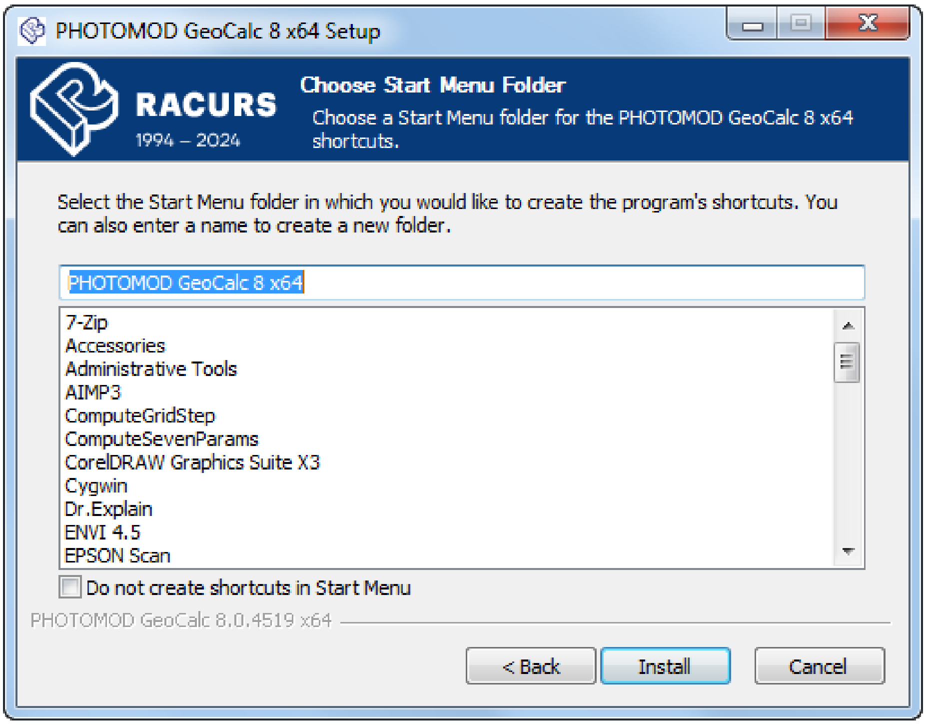


4. [optional] Define the folder to install the program;

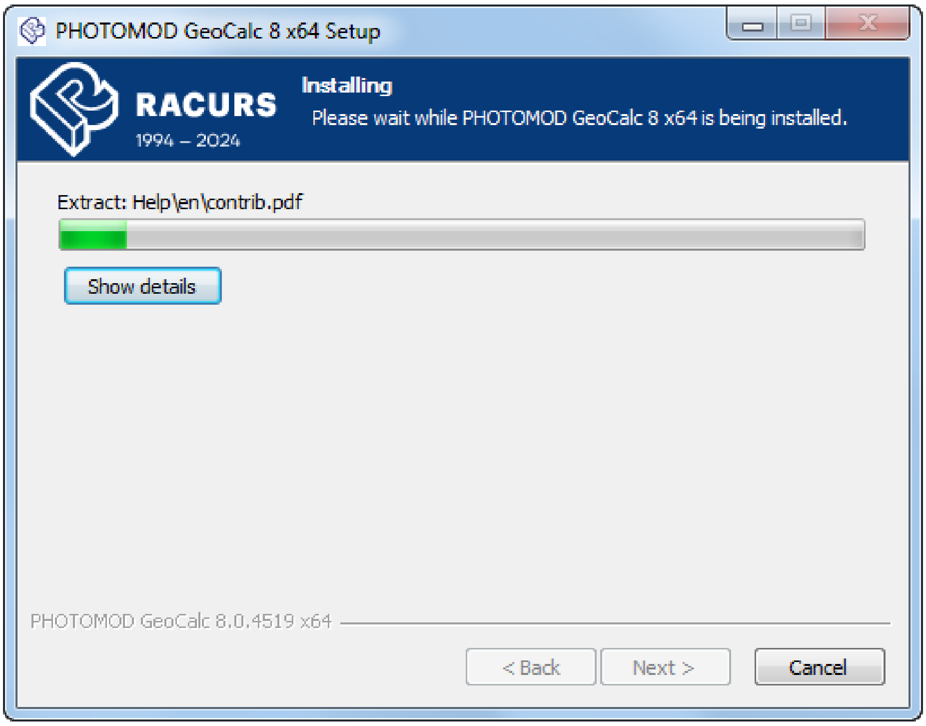


It is strongly not recommended to install the program in folder with name, which contains letters, different from Latin. By default the *C:\Program Files\PHOTOMOD_8_GeoCalc_x64* folder is used.

5. [optional] Enter a folder name for the *GeoCalculator* program in the *Windows* **Start** menu. A shortcuts in the *Windows* **Start** menu will be created by default. Otherwise – set the appropriate checkbox. Click the **Install** button.



6. The installation process begins;



7. When installation complete perform one of the following actions:

- [optional] clear the **Run PHOTOMOD GeoCalc 8 x64** checkbox and click the **Finish** button to complete the installation process without program launch;
- [optional] leave the **Run PHOTOMOD GeoCalc 8 x64** checkbox set and click the **Finish** button to launch the program.

The **Create shortcuts on Windows desktop** checkbox is set on by default. Clear it if needed.

To delete the program (installed as separate application) choose the **Start › Programs › PHOTOMOD GeoCalc 8 x64 › Uninstall PHOTOMOD GeoCalc 8 x64**.

3. Interface and its elements

3.1. The “Database” menu

Table 1. Brief description of the “Database” menu

Menu items	Function
Linear units	opens the window allowing to manage linear units
Angle units	opens the window allowing to manage angular units
Scale units	opens the window allowing to manage scale units
Angular types format	to choose the angular types format
Ellipsoids	opens the window allowing to manage reference ellipsoids
Prime meridians	opens the window allowing to manage prime meridians
Datums	opens the window allowing to manage datums
Types of datum transform	to choose datum transformation type
Datum transform	opens the window allowing to manage the presets of datum transformation settings
Map projections type	to choose map projection type
Map projections	opens the window allowing to manage map projections
Height system	to choose height system
Coordinate systems types	to choose coordinate system type
Coordinate systems	opens the window allowing to manage coordinate system in current database

3.2. The “Help” menu

Table 2. Brief description of the “Help” menu

Menu items	Function
Help	to open the current document
Hotkeys	to open the window with thehotkeys description
About	opens a window indicating the number of system build

3.3. The main toolbar

Table 3. Brief description of main toolbar

Buttons	Functions
	to open the default `PhCoordSys.db` database with current parameters (without restoration of initial data)
	to open the database

Buttons	Functions
	to create an empty database
	to close database
	to close the current database and to open default `PhCoordSys.db` database, restored to its initial settings
	to perform the batch coordinate systems import from the selected folder
	to perform the batch coordinate systems import from the selected database
	to perform the batch coordinate systems export to the selected folder
	to show points in the map (if *GeoCalculator* is installed as a part of the *PHOTOMOD* system)
	to calculate Datum transformation parameters (if *GeoCalculator* is installed as a part of the *PHOTOMOD* system)
	to open the **Settings** window

4. GeoCalculator database

PHOTOMOD GeoCalculator databases contain information on coordinate systems as well as on individual elements of coordinate systems. Database files have `*.db` extensions. A link to the current coordinate system database file is displayed in the bottom left corner of the main program window.

The default international coordinate systems database – `PhCoordSys.db`. This database is installed automatically with the program in *PHOTOMOD8.VAR\GeoCalcDB\en* folder (see the “The PHOTOMOD8.VAR configuration folder” chapter in “General information” User Manual, from the *PHOTOMOD* documentation).

Coordinate systems, as well as sets of coordinate system elements contained in the default database, differ for the Russian and English versions of the program.

The *GeoCalculator* database is intended for combined use with *PHOTOMOD*, so it is always located in the *PHOTOMOD8.VAR* settings folder of the *PHOTOMOD* by default (this folder is used even if *GeoCalculator* is installed and used as a separate application).

If *GeoCalculator* is installed for the first time as a separate application on a workstation where *PHOTOMOD* software products haven’t been installed before, the *PHOTOMOD8.VAR* folder will anyway be created automatically (and can be further used as a settings folder for *PHOTOMOD* software products, in the case if they are later installed on this workstation).

A user can either use the default database as provided and make their own changes to it or create their own databases with optional names and locations (by importing information about coordinate systems there from other databases, from separate files, or by entering it manually).

In the case of the combined use of *GeoCalculator* and *PHOTOMOD*, *PHOTOMOD* can use the coordinate system database currently connected to the *GeoCalculator*, including user databases (however, only if it has access to the location of the user-created file). If the file is not accessible, *PHOTOMOD* will use the `PhCoordSys.db` file by default.

In the event of the system updating or reinstalling, the availability of the `PhCoordSys.db` file in the appropriate *PHOTOMOD8.VAR* folder is to be checked. In order to save user data, if detected, the `PhCoordSys.db` file is not to be overwritten.

To access the updated version of the default database after reinstalling (updating) the program, click the button. If the “old” database previously worked with user coordinate systems, it is strongly recommended to first backup the previous database file in a separate folder (or export the user coordinate systems to files in the *Windows* file system).

5. The coordinates transformation

The main window consists of two similar parts. There are the source data in one part, and the results of calculation in the other part.

It is possible to load source data both in left and in right part of the window.

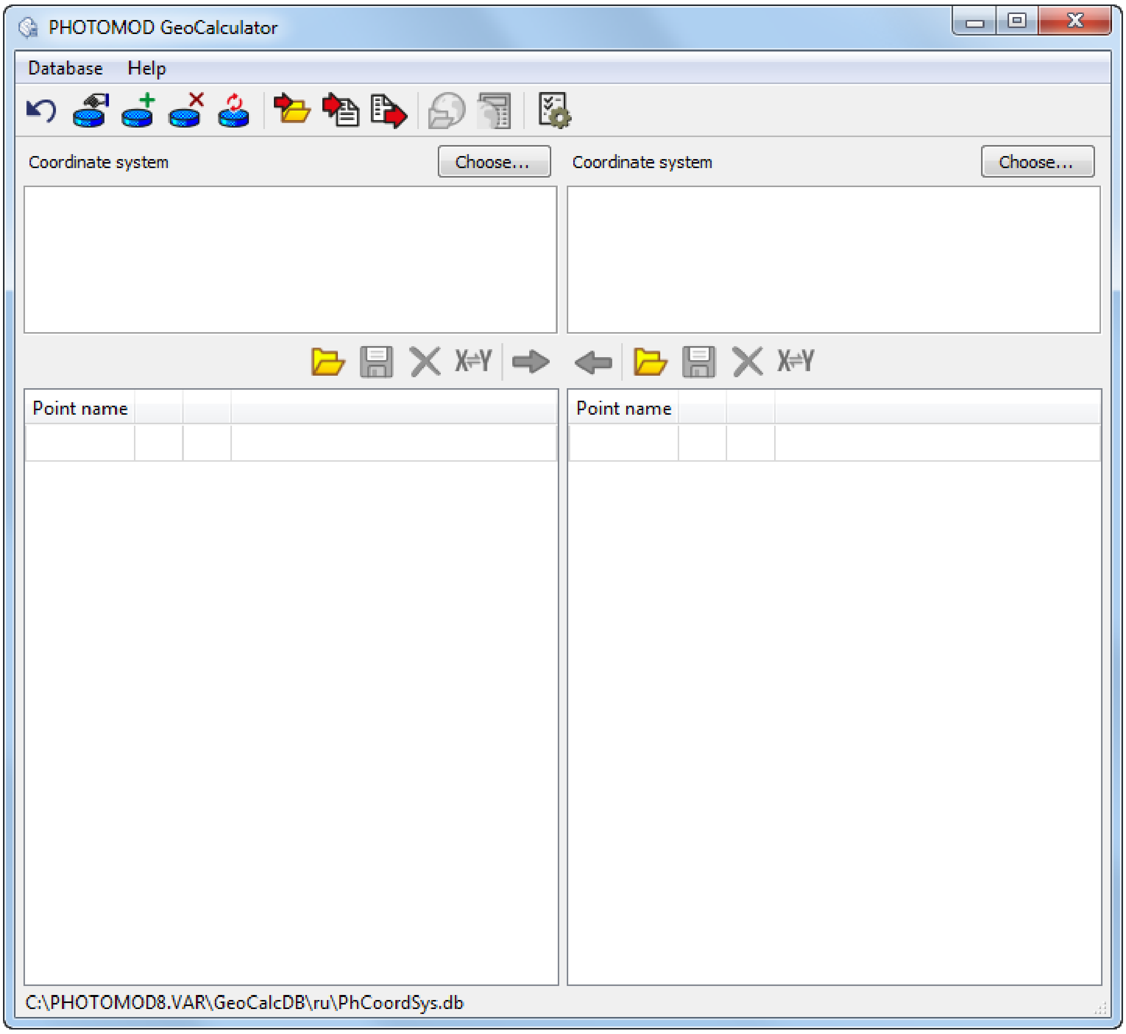


Fig. 1. The main program’s window

To transform coordinates of points from one coordinate system to another perform the following:

1. Click the **Choose...** button in the left part of the main window, in the **Coordinate system** section, to define input coordinate system of source data;

   Information about the selected coordinate system is displayed in the appropriate field in the **Coordinate system** section.

2. Click the button in the left part of the main window, in the **Point name** section, to choose the file in ASCII format with source coordinates of points;

   For correct automatic recognition of point coordinates from a txt file, a comma or semicolon is to be used as a separator between columns in the file. A period must be used as a decimal separator. Commas as decimal separators are not allowed.

   Manual coordinate input is also provided.

   When inputting coordinates as `degrees/minutes/seconds`, use a space as a separator. In this case, to ensure correct recalculation, the coordinate system selected in the corresponding half of the window must have the appropriate latitude and longitude units, i.e. `degrees/minutes/seconds`.

   To clear loaded or entered point data, click the button.

   To swap the **XY** coordinates, click the button in the appropriate table toolbar.

   Hotkeys are available when working with tables, in **point name** sections (see **Help › Hotkeys**).

3. Click the **Choose...** button in the right part of the main window, in the **Coordinate system** section, to choose the output coordinate system;

4. Click the button in the left part of the main window, for coordinates system transformation. As a result the list of points with recalculated coordinates from the left part of the main window is shown in the **Point name** section in the right part.

   To transform coordinates of points, loaded into the right part of the main window, to the coordinate system defined in the left part, click the button on the right part of the main window.

   Click the button in the appropriate part of the main window to save results in ASCII-file.

   If the **Display transform statistics** checkbox is set in the **Settings** window, after performing the operation, the statistics window opens:

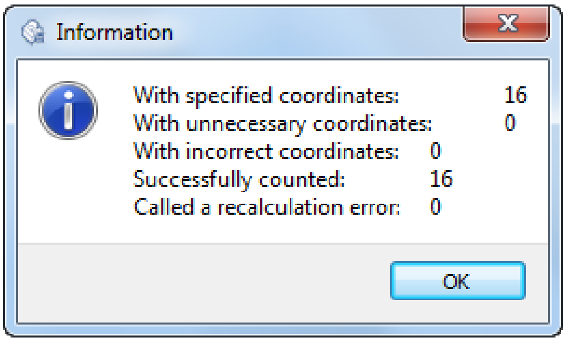


Fig. 2. The statistics window

To not show this window, clear the **Display transform statistics** checkbox in the **Settings** window.

6. Coordinate systems management

6.1. The “Coordinate systems” window

The program provides a possibility to search, view settings, create, edit, remove, import and export coordinate systems. The **Coordinate systems** window’s is used for this.

To open the **Coordinate systems** window, choose **Database › Coordinate systems** (or click the **Choose** button in the left or right part of the program’s main window). The **Coordinate systems** window opens:

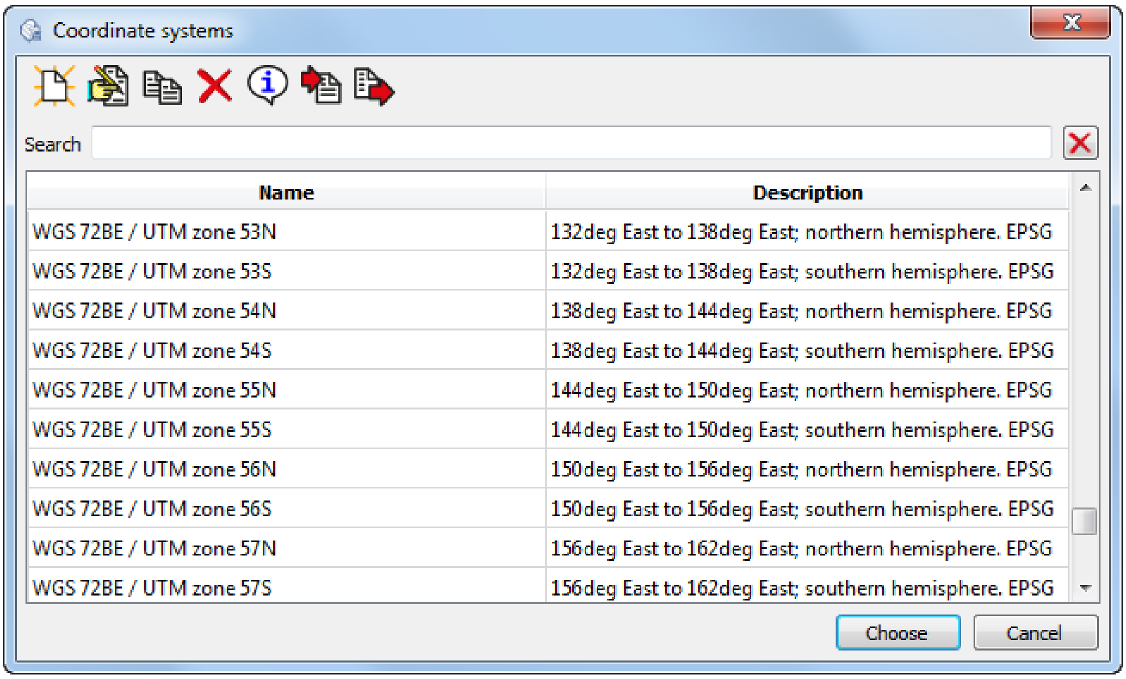


Fig. 3. The window containing coordinate systems list (opened by the **Choose** button)

The **Coordinate systems** window contains the following sections: the table, containing coordinate system's data, the search instruments and the **Coordinate systems** window's toolbar.

Table with coordinate system's data contains two columns: **Name** and **Description**. In the table are displayed parameters, obtained from database or specified during creating of new coordinate system.

It is often required to know the coordinates of all points, recalculated if necessary into one zone.

Thus, the **name** of the coordinate system looks as follows, for example: `Pulkovo 1942 / Gauss-Kruger zone 2`, where `Pulkovo 1942` is the datum name, `Gauss-Kruger` is the coordinate system, and `zone 2` is the zone number.

Abscissa coordinate values in the Gauss-Krüger coordinate system must include the zone number.

It is recommended to enter detailed information in the **Description** field during creating of a coordinate system or its parameters.

To **choose** the coordinate system for the points coordinates transformation – select the coordinate system from the list and click the appropriate button (if the **Choose** button in main window toolbar is used to open the **Coordinate systems** window);

Table 4. Brief description of Coordinate systems window toolbar

Buttons	Functions
	to open a window for creating new coordinate system
	to edit chosen coordinate system
	to duplicate chosen coordinate system
	to remove chosen coordinate system from database
	to show parameters of selected reference system
	to import coordinate system from the selected file
	to export coordinate system to the file of selected format

6.2. Searching for the coordinate system

The list of coordinate systems opens in **Coordinate systems** window. It allows to choose, create new one, edit, remove, export and import coordinate system from external file.

To the coordinate system **search**, input name or its part (or keyword) into appropriate field.

To clear the entered data in the **search** field, click the button.

The string of last previously selected coordinate system is marked by grey color.

6.3. Coordinate system detailed description

A detailed description of the properties of the selected coordinate system is displayed in the **Information** window. To open it, select the needed coordinate system in a table and click the button in **Coordinate systems** window toolbar.

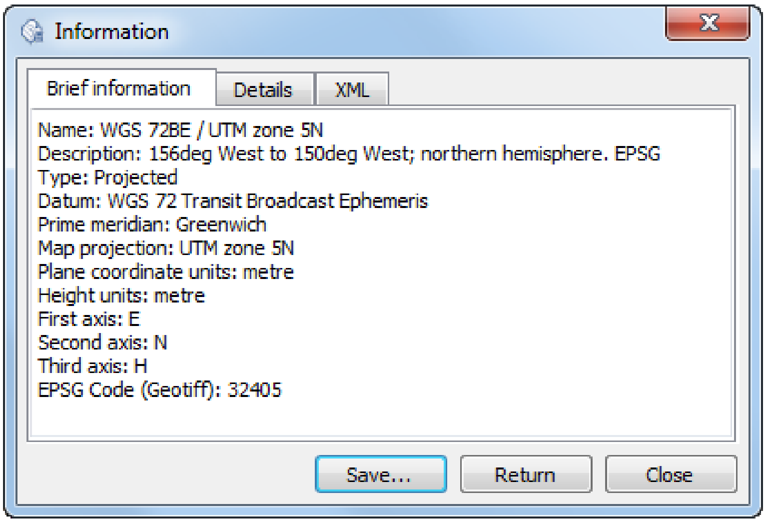


Fig. 4. The Information window

There are three tabs in the Information window: coordinate system **Brief information**, as well as two tabs, where the coordinate system is described in **Details** in an easy-to-view form, and in the original **XML** format.

Quick edit of both coordinate system **Brief information** and **Details** is available in the **Information** window. The **Brief information** is edited in the appropriate tab. Making changes to the detailed description requires editing the data in the original **XML** format. The system allows to **return** information about the coordinate system from the database, canceling changes made by the user.

If the user wants to **save** the changes made working with the **Information** window, both brief and detailed info on the coordinate system will not be edited in the database but saved as separate files in the *Windows* file system, with possible further import of these data.

To edit the coordinate system by saving the information immediately in the database, select the desired coordinate system in the **Coordinate systems** window and click the button. It is highly recommended to back up the selected coordinate system and make changes to its copy ( ).

6.4. Creating new coordinate system

Program provides a possibility both to use existing reference system or to create a new one.

Use the following steps to create a reference system:

1. Choose **Database › Coordinate systems** in the main window of the program. The **Coordinate systems** window opens.

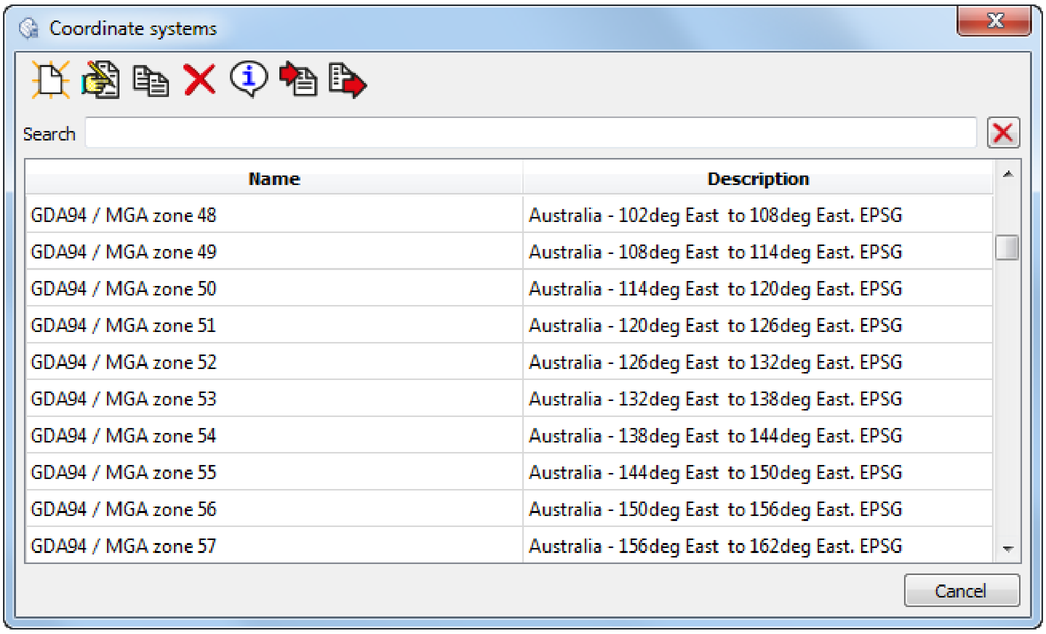


Fig. 5. The Coordinate systems window (opened from the **Database** menu)

2. Click the button in **Coordinate systems** window toolbar. The **Editing the coordinate system** window opens:

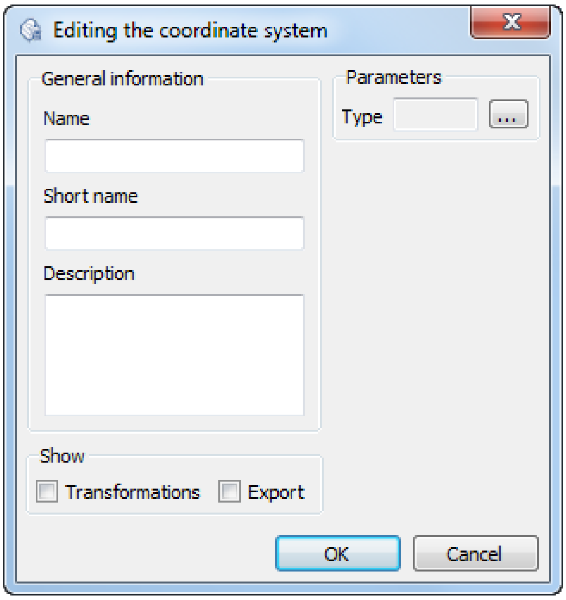


Fig. 6. Reference system creation

3. In **parameters** section click the ... button to select the coordinate system type. The **Types of coordinate systems** window opens:

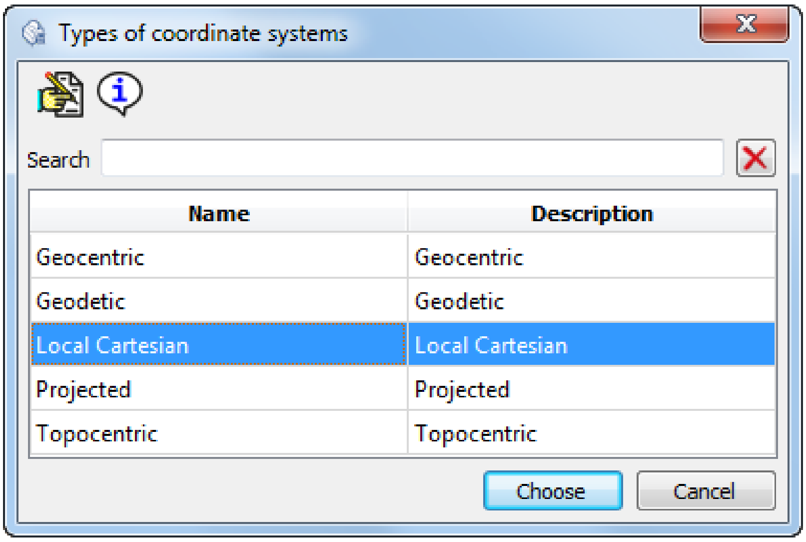


Fig. 7. Selecting of the coordinate system type

   Choose the coordinate system type and click **choose** to close the window;

4. In **general information** section fill the following fields to describe the coordinate system:

   * **Name** – arbitrary name (e.g., Gauss-Kruger, 10 zone);
   * **Abbreviation** – arbitrary short name;
   * **Description** – arbitrary description.

5. Define other settings of the coordinate system depending on chosen coordinate system's type (see the separate chapters below);

6. [optional] to create the additional coordinate **transformation** rules, set the appropriate checkbox and specify the needed parameters;

7. [optional] Set the **export** checkbox to assign an EPSG code (or a *MapInfo* code);

8. Click the **Ok** button. Created reference system is shown in the list with defined name and description.

Do the same actions to edit settings of existing reference system.

6.5. Coordinate system's parameters

6.5.1. Parameters of geodetic coordinate system

To create `Geodetic` (latitude/longitude) coordinate system perform the following:

1. Define the general settings of the coordinate system;

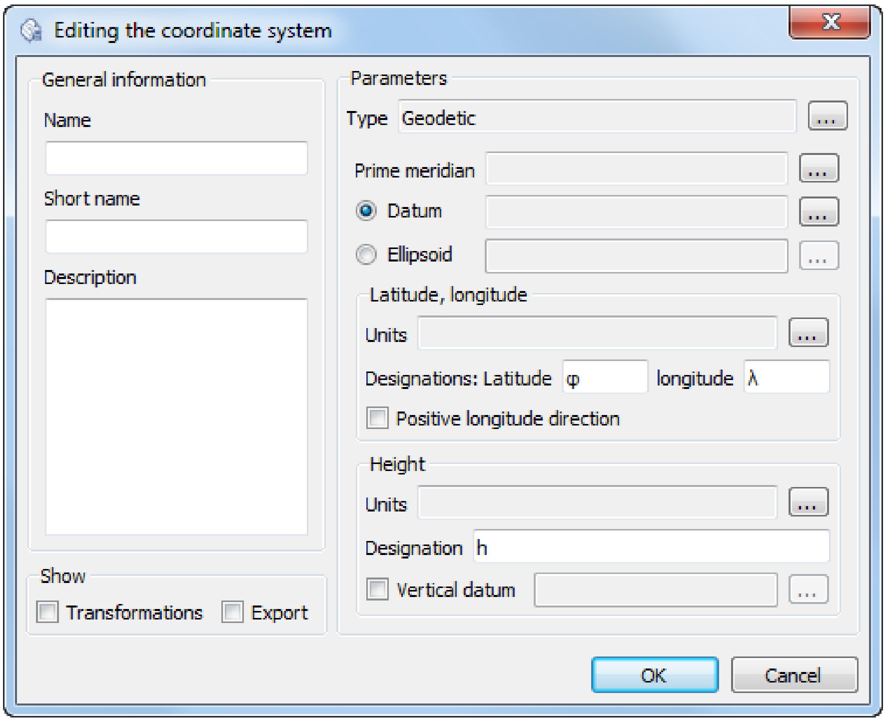


Fig. 8. Creating the Geodetic (latitude/longitude) coordinate system

2. Click the ... button to choose **Prime meridian**;
3. Perform one of the following actions:
   - [optional] Click the ... button to choose the **Datum** from the list;
   - [optional] To set the **Ellipsoid** click the ... button and choose ellipsoid from the list.
4. In the **Latitude, Longitude** section define the following settings:
   - click the ... button rightward to the **Units** field to choose the latitude and longitude angular units from the list (see Section 7.4);
   - set the arbitrary symbol as a **latitude** designation;

- set the arbitrary symbol as a **longitude** designation;
- [optional] to create a coordinate system measured positively to the east from the Greenwich meridian, set the **Positive longitude direction** checkbox.

5. In the **Height** section set the following parameters:
   - click the ... button rightward to the **Units** field to choose the linear units from the list (see Section 7.4);
   - set the **Designation** as an arbitrary symbol for the Height:
   - [optional] to set the **Vertical datum** set the appropriate checkbox and click the ... button (see Section 7.6).

6.5.2. Parameters of geocentric coordinate system

To create a **geocentric** coordinate system perform the following:

1. Set the general parameters of coordinate system.

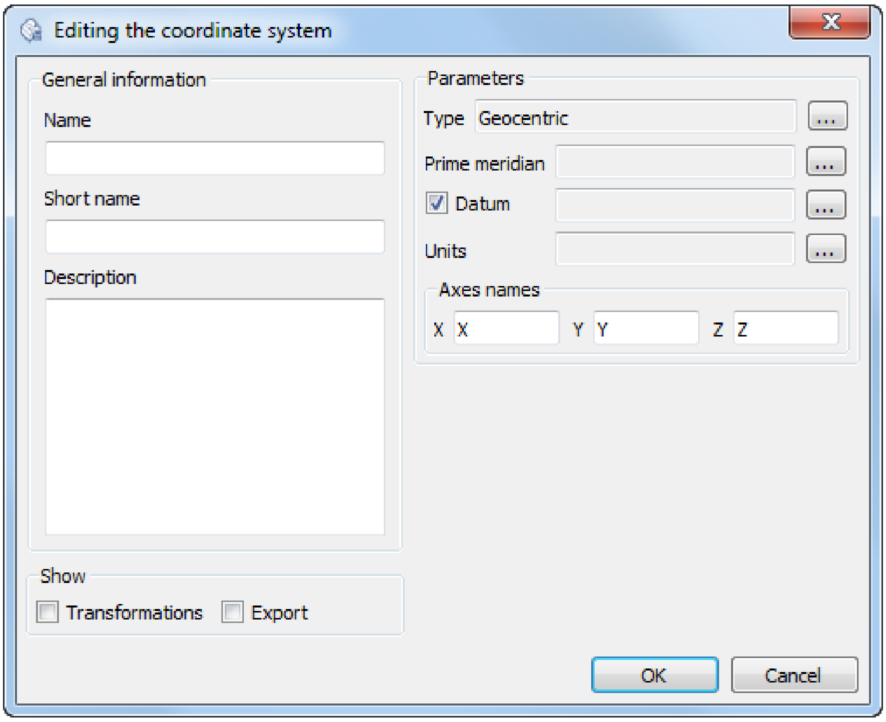


Fig. 9. Creating the geocentric coordinate system

2. Click the ... button to choose **Prime meridian**;
3. [optional] to choose the **Datum**, set the appropriate checkbox and click the ... button to select the datum from the list;

4. Click the ... button rightward to the **Units** field to choose the linear coordinate measure units from the list (see Section 7.4);

5. Set the arbitrary symbol in the **axis names** fields to denote **X**, **Y** and **Z** axis.

6.5.3. Parameters of Cartesian coordinate system

To create a **Cartesian** coordinate system perform the following:

1. Set the general parameters of coordinate system.

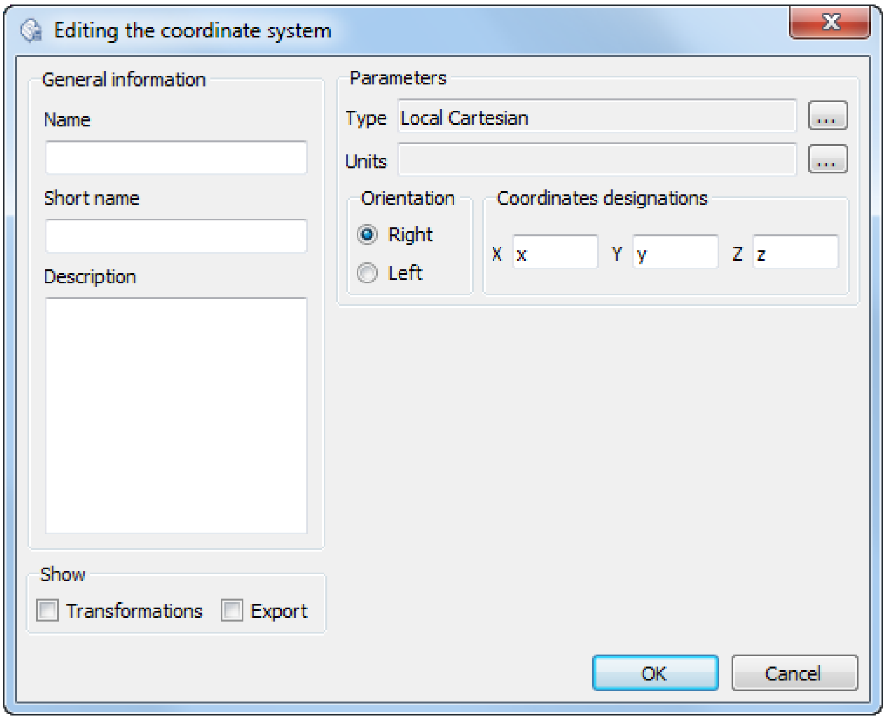


Fig. 10. Creating the Cartesian coordinate system

2. Click the ... button rightward to the **Units** field to choose the linear coordinate measure units from the list (see Section 7.4);

3. Set the arbitrary symbol in appropriate fields to denote the **coordinate designations** for **X**, **Y** and **Z** axis.

4. Set the axis orientation: **Right** or **Left**.

6.5.4. Parameters of cartographic coordinate system

To create a **cartographic** coordinate system perform the following:

1. Set the general parameters of coordinate system.

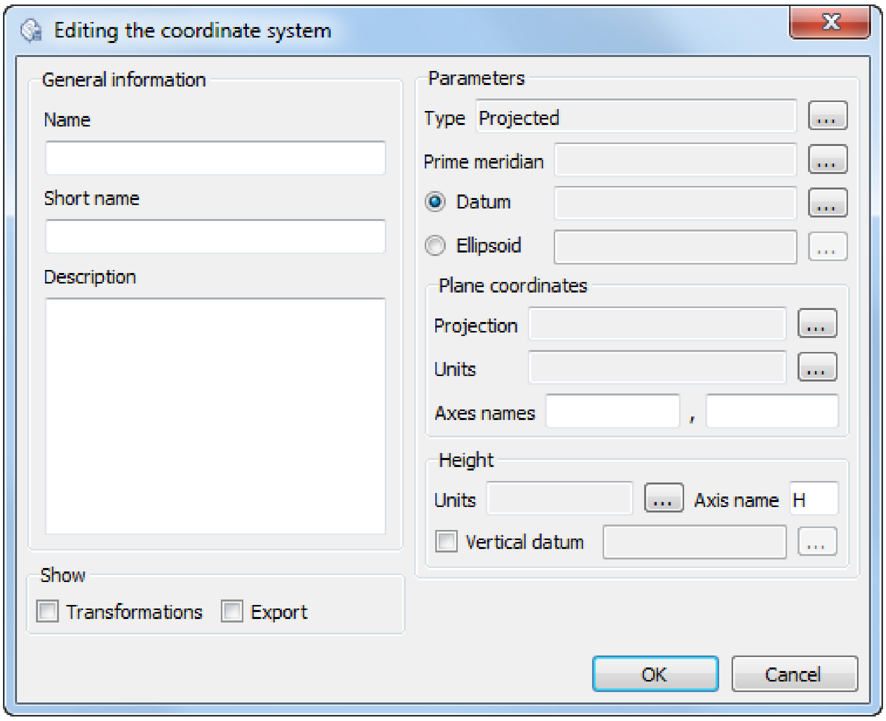


Fig. 11. Creating the cartographic coordinate system

2. Click the ... button to choose **Prime meridian**;
3. Perform one of the following actions:
   - [optional] Click the ... button to choose the **Datum** from the list;
   - [optional] To set the **Ellipsoid** click the ... button and choose ellipsoid from the list.
4. Set the following parameters:
   - Click the ... button to choose the **projection** from the list;
   - Click the ... button rightward to the **Units** field to choose the linear coordinate measure units from the list (see Section 7.4);
   - Define the short **coordinate designations**.
5. Set the following **height** parameters:
   - click the ... button rightward to the **Units** field to choose the linear units from the list (see Section 7.4);
   - Define the short height **designation**;

- [optional] to set the **Height system** set the appropriate checkbox and click the ... button (see Section 7.6).

6.5.5. Parameters of topocentric coordinate system

To create a **topocentric** coordinate system perform the following:

1. Define the general settings of the coordinate system;

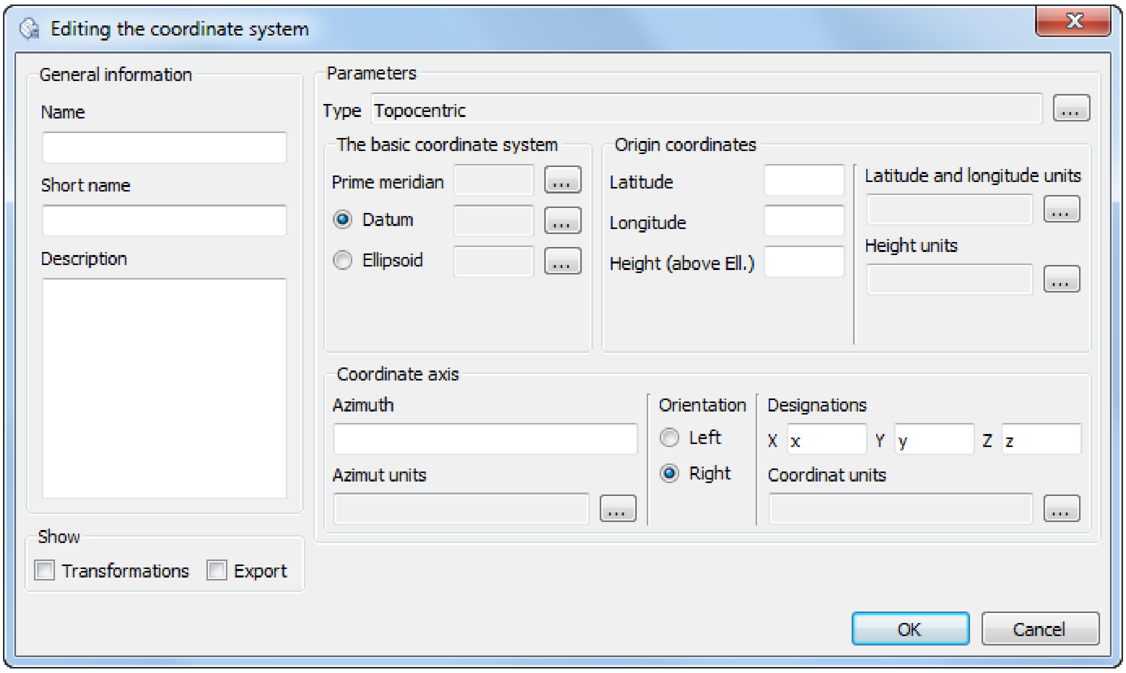


Fig. 12. Creating topocentric coordinate system

2. Click the ... button to choose **Prime meridian**;
3. Perform one of the following actions:
   - [optional] Click the ... button to choose the **Datum** from the list;
   - [optional] To set the **Ellipsoid** click the ... button and choose ellipsoid from the list.
4. Set the following parameters:
   - Input the **origin coordinates** – **latitude**, **longitude** and **height** (above the ellipsoid);
   - click the appropriate ... buttons to choose the latitude and longitude angular units from the lists (see Section 7.4);

- click the appropriate ... button to choose the linear height units from the list (see Section 7.4).

5. Set the **coordinate axis** parameters:
   - Set the **Azimuth** in degrees;
   - Click the appropriate ... button to choose the **azimuth** angular units from the list (see Section 7.4);
   - Set the **orientation** of the axis: **Right** or **Left**;
   - Set the arbitrary symbol in the **X**, **Y** and **Z** axis **designations** fields;
   - Click the appropriate ... button to choose the linear coordinate measure units from the list (see Section 7.4).

6.6. Import and export of coordinate systems

To import the current coordinate system database from the selected file, click in the **Coordinate system** window toolbar and indicate the desired file in the file selection box that opens. Coordinate system import is available for the following types of files:

- XML files (`*.xml`);
- WKT files (`*.wkt`);
- XML files used by *PHOTOMOD* (`*.x-ref-system`);
- text files previously used by *PHOTOMOD* (`*.reference system`).

In the case of the same names, the imported coordinate system will not be written over the existing one but saved as a separate copy.

To export the individual coordinate system, select the required one in the **Coordinate system** window and click in the window toolbar. Export of coordinate systems is available for the following types of files:

- XML files (`*.xml`);
- XML files used by *PHOTOMOD* (`*.x-ref-system`);
- text files previously used by *PHOTOMOD* (`*.reference system`).

6.6.1. Batch import and export

To perform a batch import of coordinate systems from a database file (`*.db`) to the current database, click the button in main window toolbar. This functionality allows one to import coordinate systems from one `*.db` file to another.

To export coordinate systems to a folder from the current database, click the button of the main window toolbar. Each coordinate system in the database will be exported into the chosen folder as a single `*.xml` file.

To perform a batch Import of coordinate systems from a folder into the current database, click the button of the main window toolbar. Select a folder with `*.xml` files that contain data on coordinate systems.

If working with a user coordinate system, ensure periodically creating backups of database files in a separate folder.

6.7. Coordinate systems types

The **Types of coordinate systems** window (**Database › Coordinate systems types**) allows to show provided types of coordinate systems. The **Types of coordinate systems** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

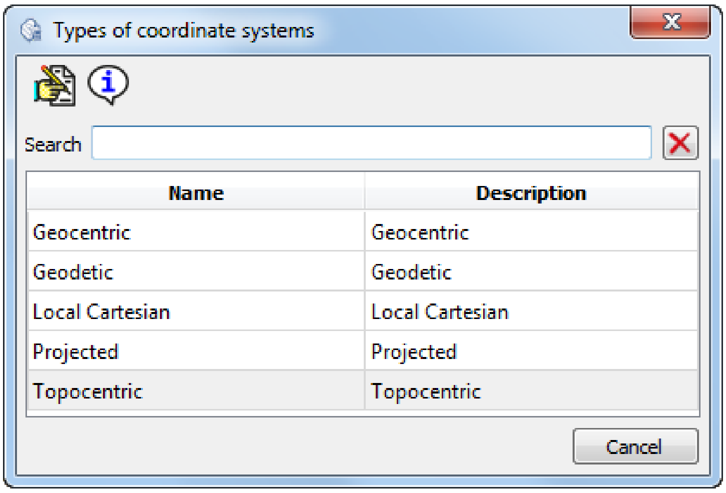


Fig. 13. The list of types of coordinate systems

The program supports the following coordinate system's types:

- **Geodetic**;
- **Geocentric**;
- **Cartesian**;

- **Cartographic**;
- **Topocentric**.

7. Coordinate systems elements

7.1. Datums

Datum – is set of parameters used for shift and transform reference ellipsoind into local geographic coordinates.

The **Datum** window (**Database › Datums**) is used for the datums management. The **Datum** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

7.1.1. Creating new datum

To create a new datum perform the following actions:

1. Choose **Database › Datums**. The **Datum** window opens:

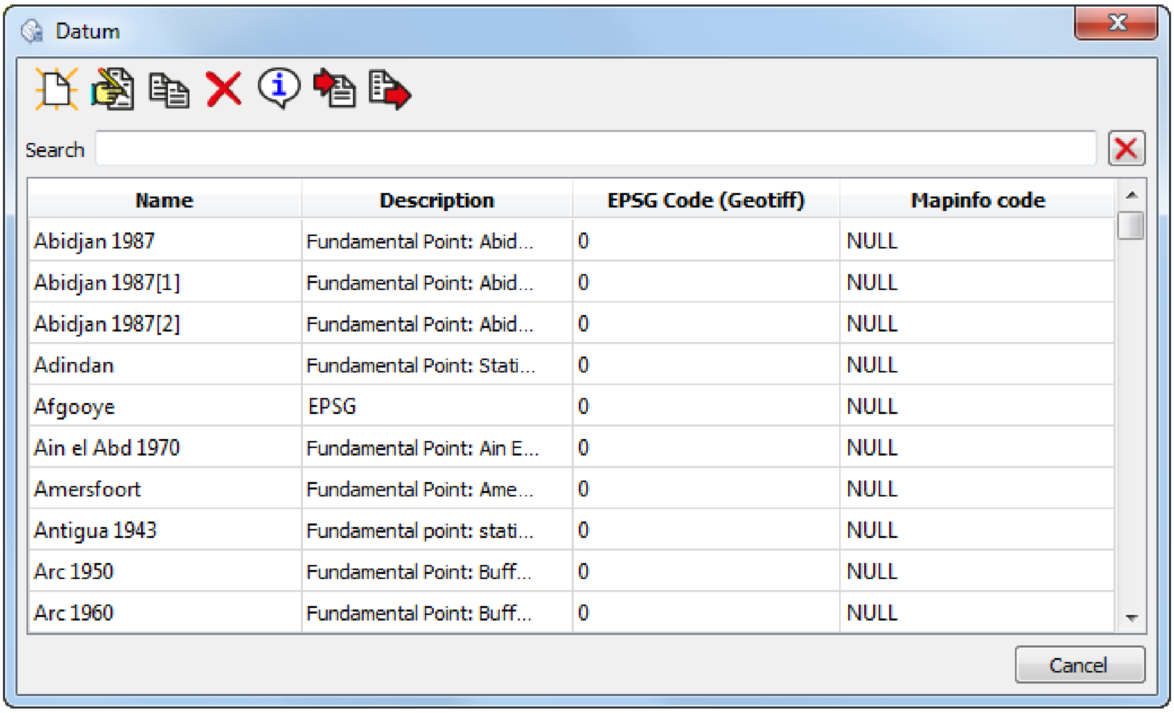


Fig. 14. The Datum window

2. Click the  button in **Datum** window. The **Datum editing** window opens:

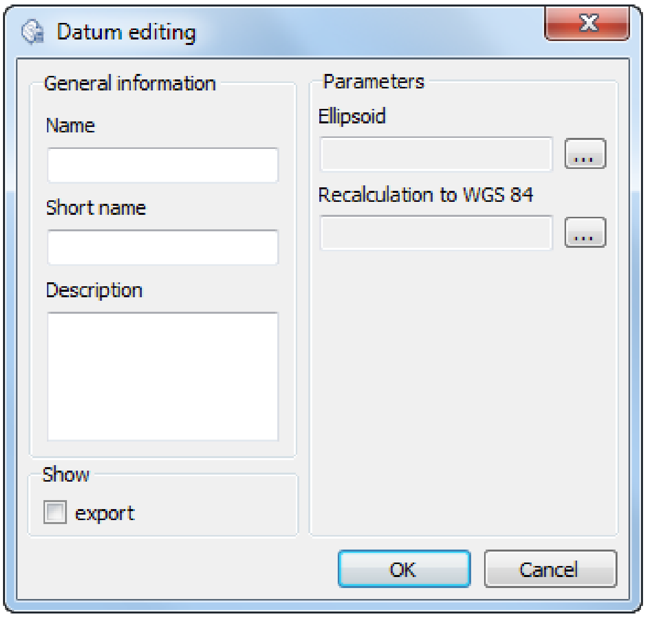


Fig. 15. Datum settings window

3. Define the datum **General information** – **Name**, **Short name** and **Description** of the datum in appropriate fields;
4. Click the ... button rightward to the **Ellipsoid** field to choose reference-ellipsoid from the list (see the Section 7.2);
5. Click the ... button rightward to the **Recalculation in WGS 84** field to choose the datum transformation parameters preset;
6. [optional] Set the **export** checkbox to assign an EPSG code (or a *MapInfo* code);
7. Click the **Ok** button. Created datum is shown in the list with defined name and description.

7.1.2. Datum transformation parameters presets

The default database contains the list of most popular datum transformation parameters presets. Besides, it is possible to create a new set of datum transformation parameters.

The **Datum transformations** window (**Database › Datum transform**) is used for the datum transformation presets management. The **Datum transformations** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

7.1.3. Creating new datum transformation parameters preset

To create a set of datum transformation parameters, perform the following actions:

1. Choose the **Database › Datum transform** in the main window of the program. The **Datum transformations** window opens:

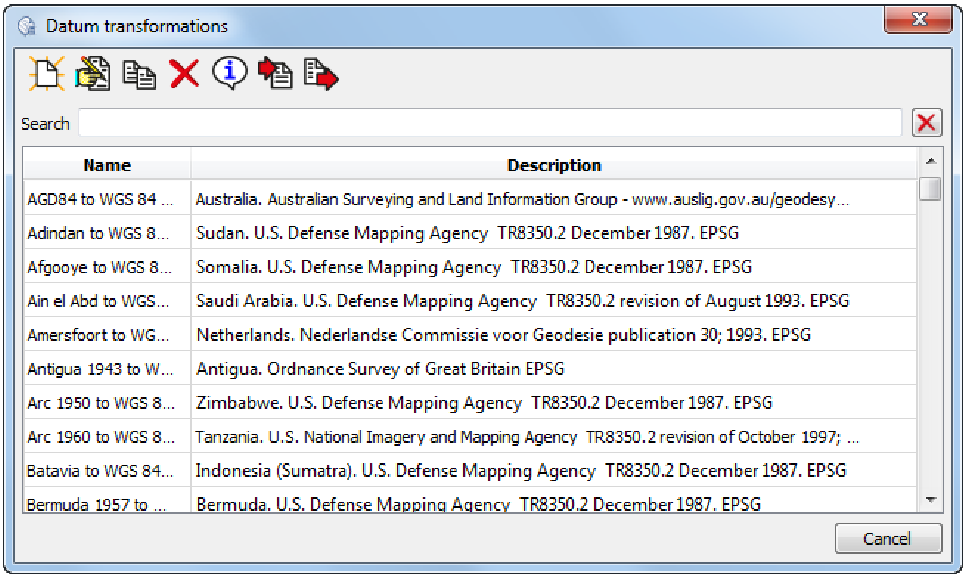


Fig. 16. Default datum transformation parameters presets

2. Click the button. The **Datum transformation parameters** window opens:

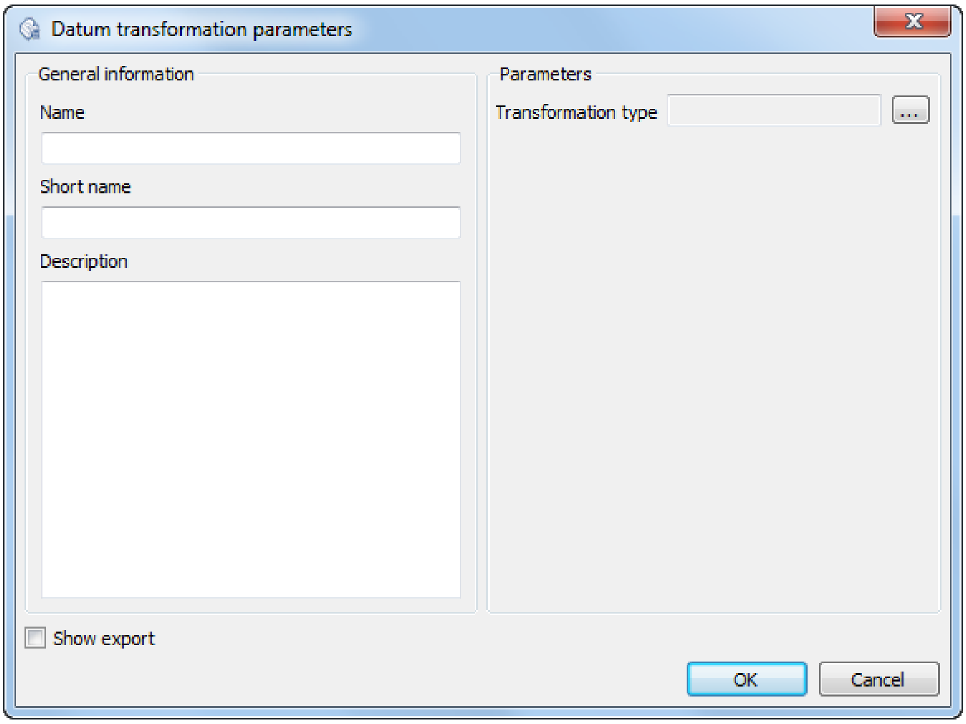


Fig. 17. Datum shift parameters

3. Choose the datum **transformation type**:

   - **Helmert** – datum rotation Bursa-Wolf;
   - **Molodensky** – three shifts;
   - **Molodensky-Badecas (Helmert)** – datum rotation Bursa-Wolf;
   - **Molodensky-Badecas (rotate-shift-scale)** – datum rotations used in Russian Federation;
   - **Rotate-shift-scale** – datum rotations used in Russian Federation;

4. Define the following parameters of datum:

   - **Name**;

     It is recommended to include names of source and target datum in the name of shift parameters.

   - **Short name** – arbitrary short name of datum shift;
   - **Description** – arbitrary text, description of shift's physical meaning.

5. Define other datum transformation parameters, depending on chosen datum **transformation type** (see below in the separate chapter);

6. [optional] Set the **export** checkbox to assign an EPSG code (or a *MapInfo* code);

7. Click the **OK** button. Created datum is shown in the list with defined name and description.

7.1.4. Datum transformation parameters

The Helmert transformation

1. Configure the general settings of datum transformations;

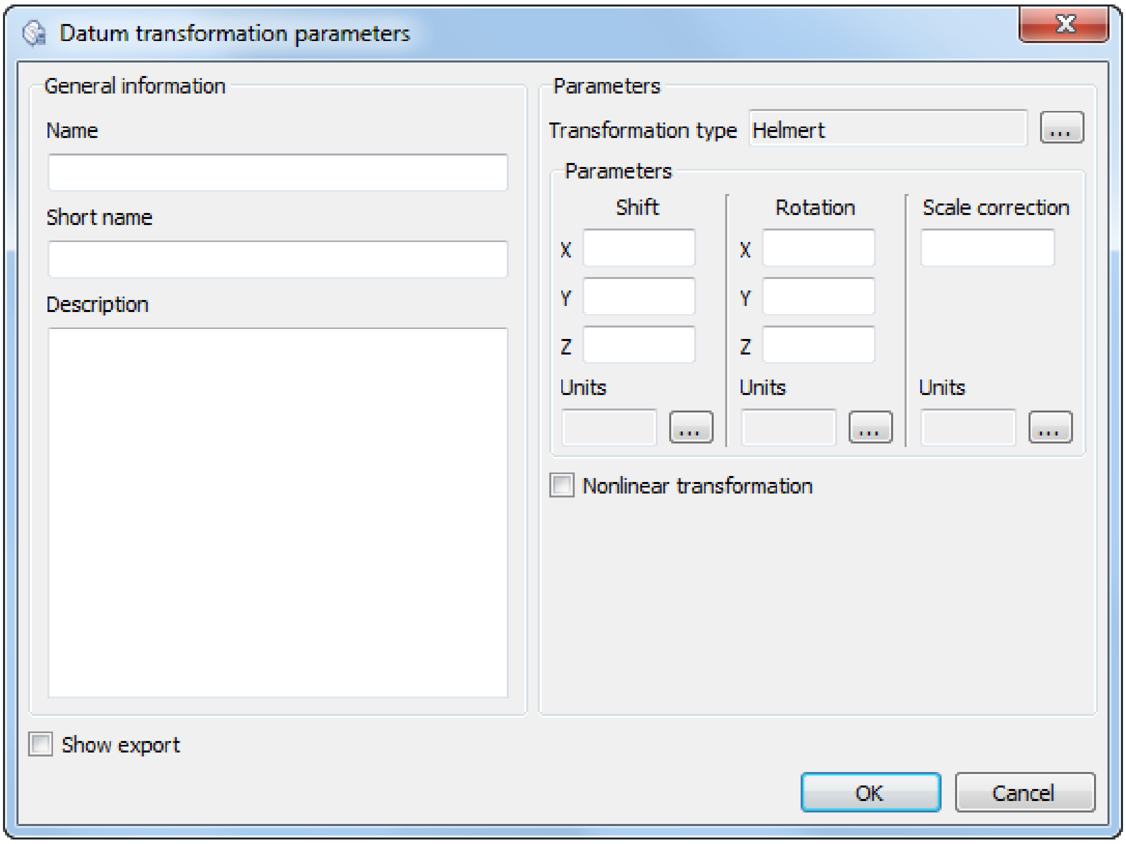


Fig. 18. The Helmert transformation

2. Configure the following parameters, in the appropriate sections:

   - **Shift** – shift units and Tx, Ty, and Tz values;
   - **Rotation** – rotation units and Rx, Ry, and Rz values;
   - **Scale correction** – scale factor, S units and values.

   Click ... to select **units** of shift, rotation, or scale from the list.

3. [optional] If a quite large value (about tens of angular seconds or more) is entered in at least one of the fields describing the rotation parameters, it is strongly recommended to set the **nonlinear transformation** checkbox in order to ensure sufficient accuracy of calculations (at the expense of system performance).

The Molodensky transformation

1. Configure the general settings of datum transformations;

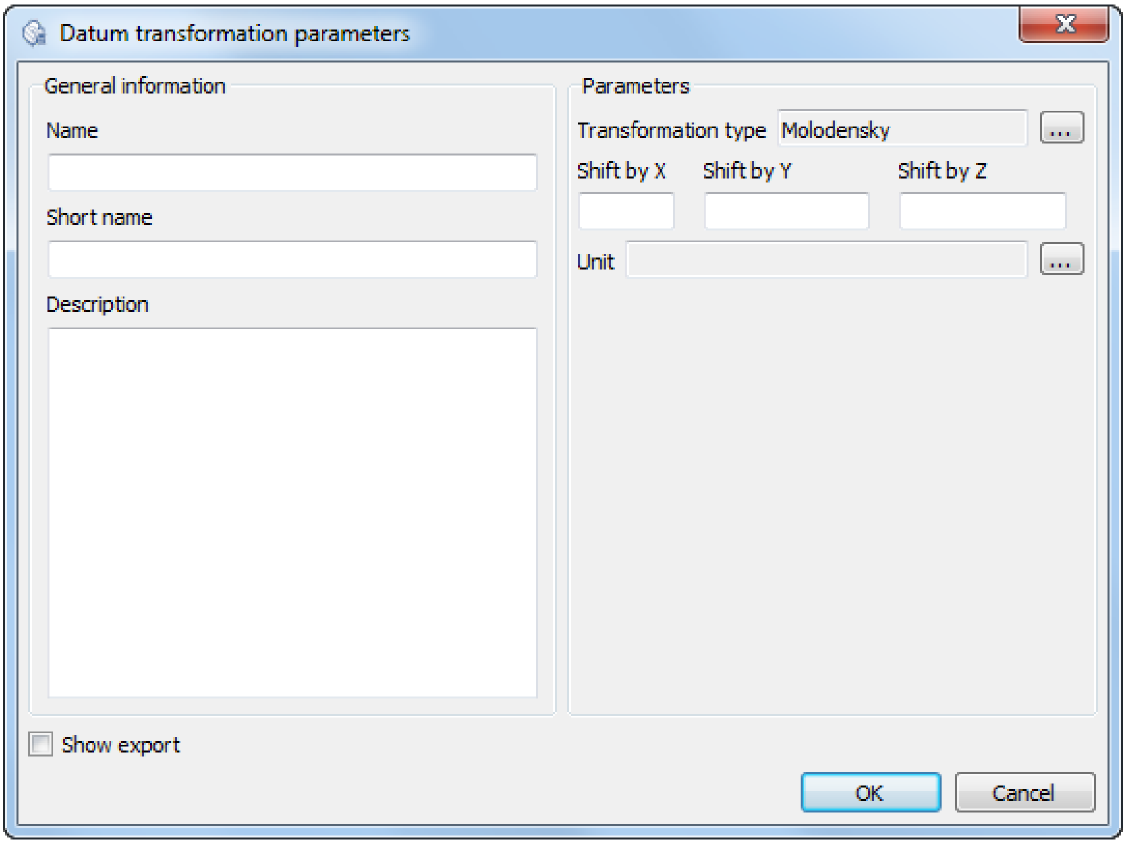


Fig. 19. The Molodensky transformation

2. **Shift** – shift units and Tx, Ty, and Tz values;

   Click ... to select **units** of shift from the list.

The Molodensky-Badekas (Helmert) transformation

1. Configure the general settings of datum transformations;

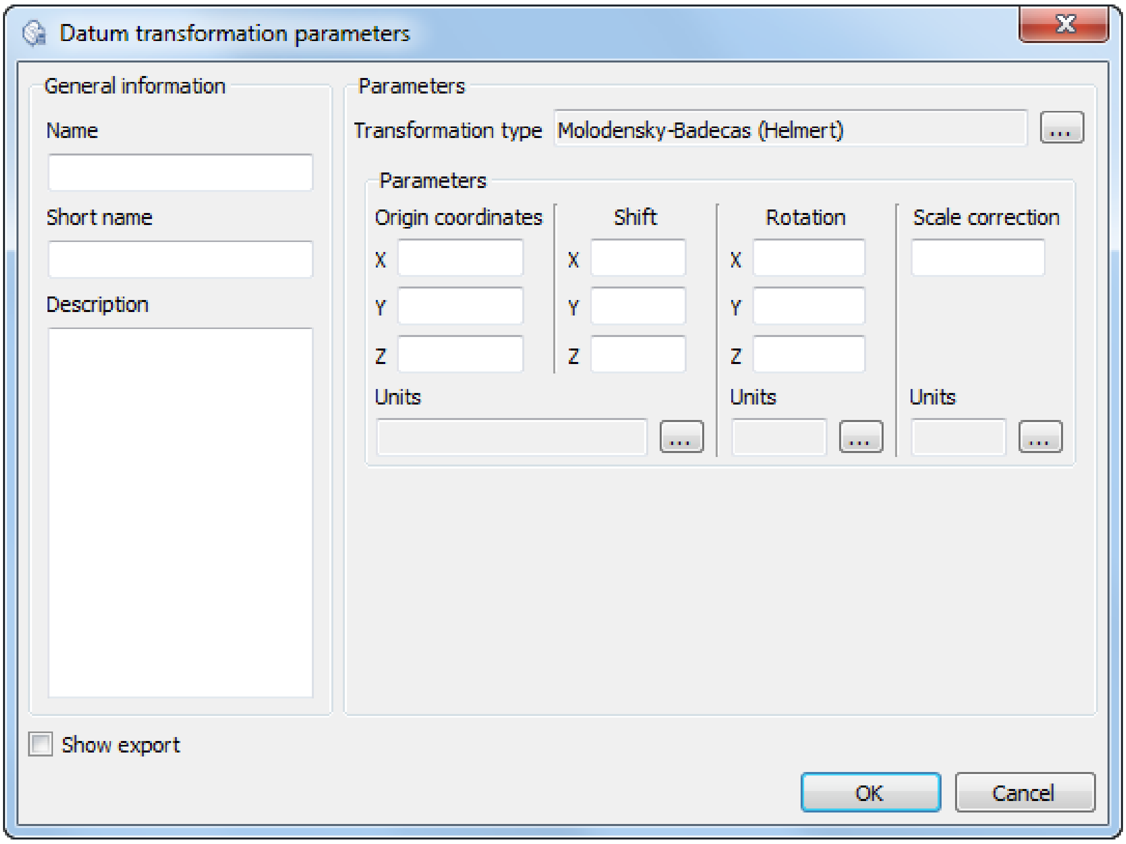


Fig. 20. The Molodensky-Badekas (Helmert) transformation

2. Configure the following parameters, in the appropriate sections:

   - **Origin coordinates** – units and X, Y, and Z coordinates;
   - **Shift** – shift units and Tx, Ty, and Tz values;
   - **Rotation** – rotation units and Rx, Ry, and Rz values;
   - **Scale correction** – scale factor, S units and values.

   Click ... to select **units** of shift, rotation, or scale from the list.

The Molodensky-Badekas (rotate-shift-scale)

1. Configure the general settings of datum transformations;

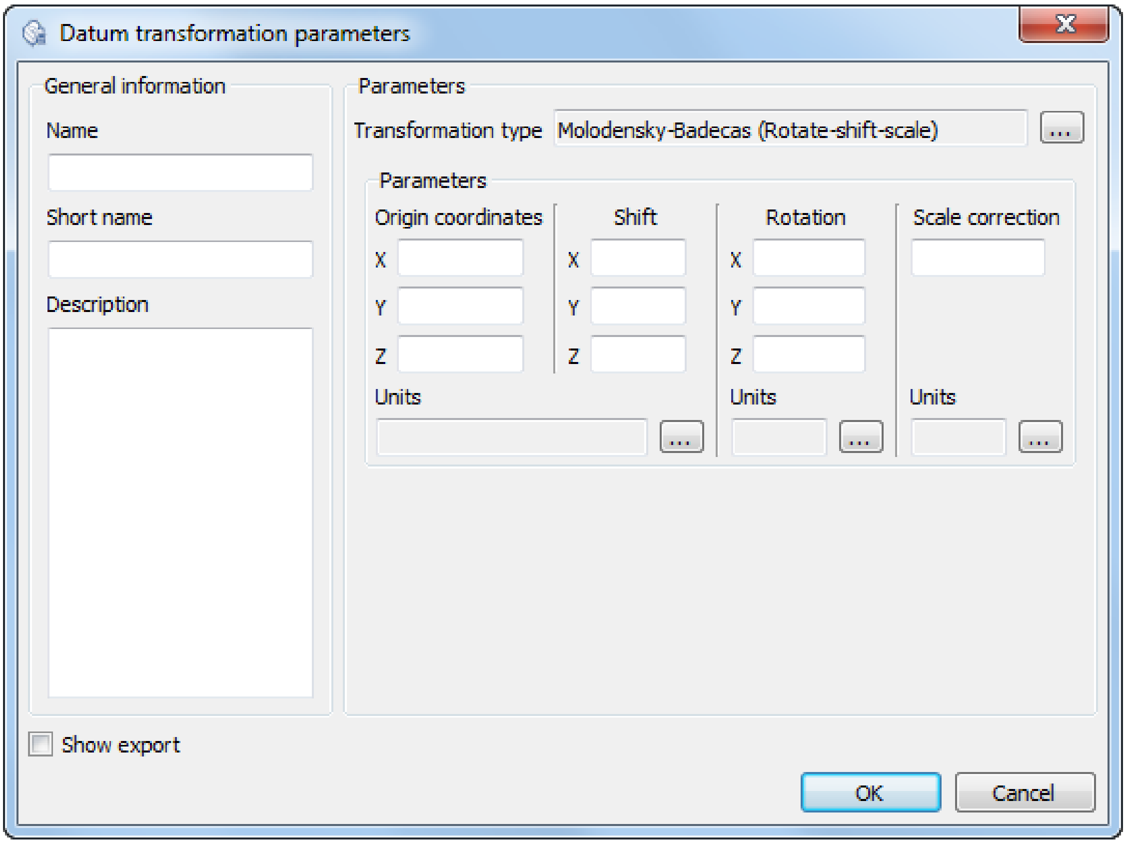


Fig. 21. The Molodensky-Badekas (rotatie-shift-scale)

2. Configure the following parameters, in the appropriate sections:

   - **Origin coordinates** – units and X, Y, and Z coordinates;
   - **Shift** – shift units and Tx, Ty, and Tz values;
   - **Rotation** – rotation units and Rx, Ry, and Rz values;
   - **Scale correction** – scale factor, S units and values.

   Click ... to select **units** of shift, rotation, or scale from the list.

Rotation-Shift-Scale

1. Configure the general settings of datum transformations;

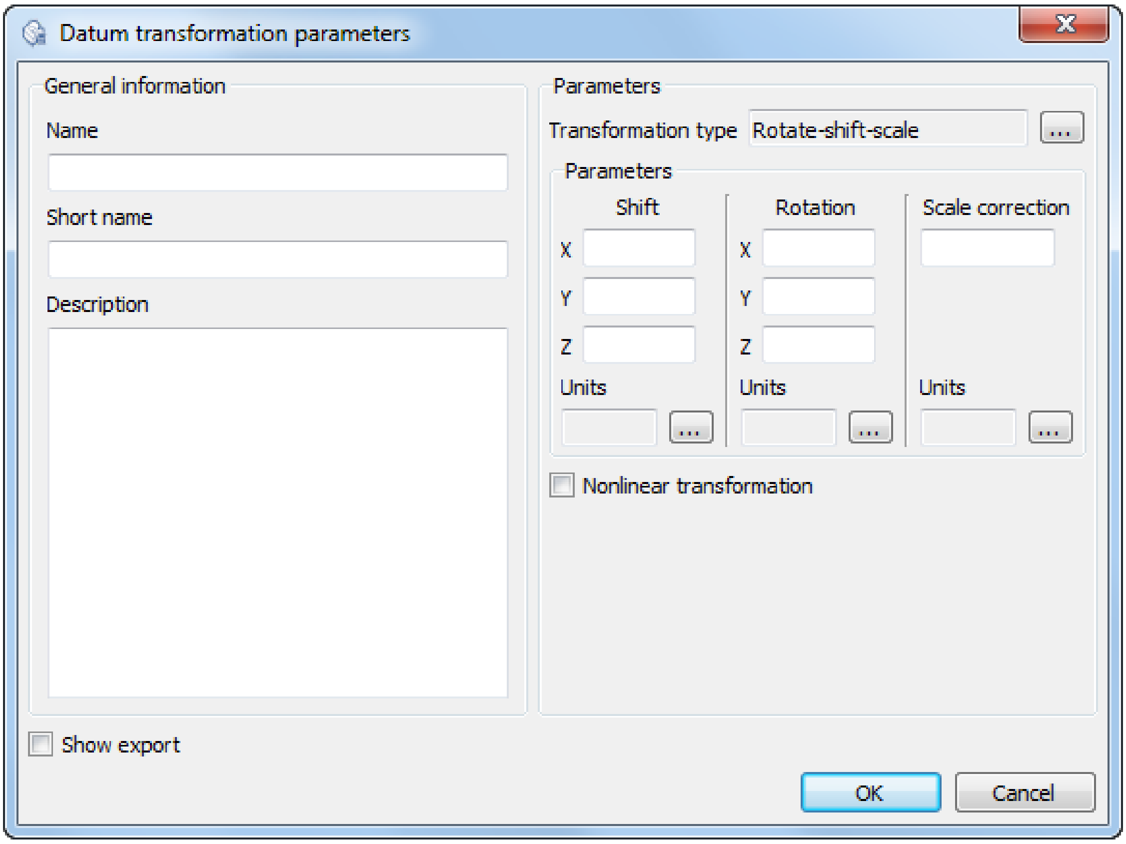


Fig. 22. Rotation-Shift-Scale configuration parameters

2. Configure the following parameters, in the appropriate sections:

   - **Shift** – shift units and Tx, Ty, and Tz values;
   - **Rotation** – rotation units and Rx, Ry, and Rz values;
   - **Scale correction** – scale factor, S units and values.

   Click ... to select **units** of shift, rotation, or scale from the list.

3. [optional] If a quite large value (about tens of angular seconds or more) is entered in at least one of the fields describing the rotation parameters, it is strongly recommended to set the **nonlinear transformation** checkbox in order to ensure sufficient accuracy of calculations (at the expense of system performance).

7.1.5. Datum transformation types

The **Types of transformations of datums** window is used for choosing datum transformation type (**Database › Types of transformation of datums**). The **Types of**

transformations of datums window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

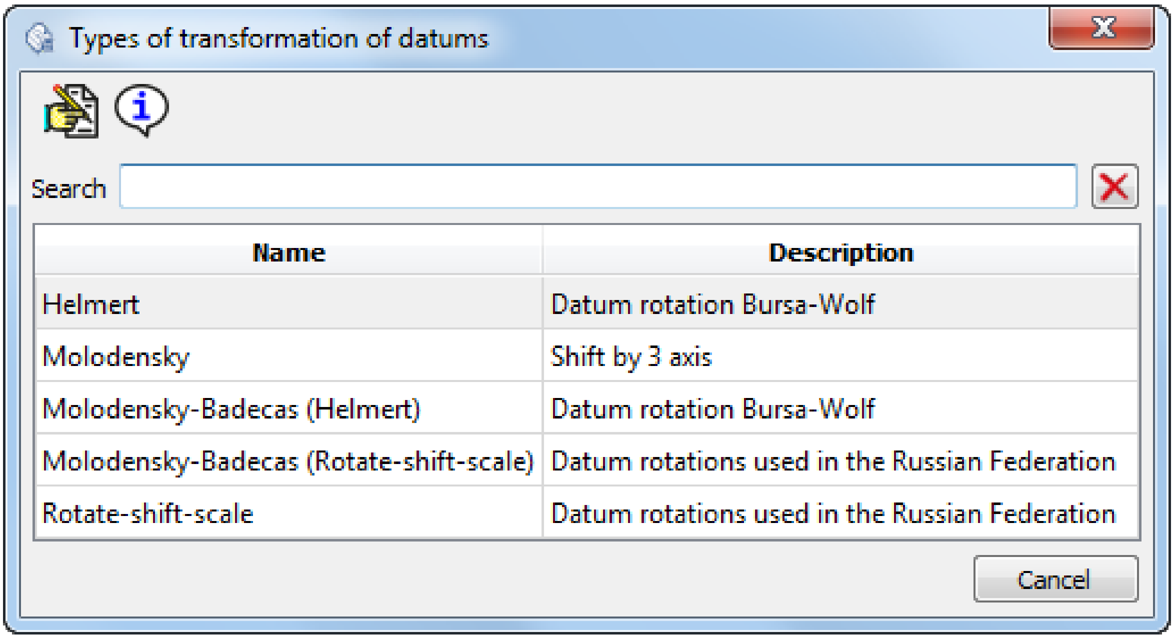


Fig. 23. The list of available datum transformation types

7.2. Ellipsoids

Reference ellipsoid is a mathematically-defined surface that approximates the geoid, the truer figure of the Earth, or other planetary body. Because of their relative simplicity, reference ellipsoids are used as a preferred surface on which geodetic network computations are performed and point coordinates such as latitude, longitude, and elevation are defined. Reference ellipsoid figure is best suited for the area of one country or several countries.

The **Ellipsoids** window (**Database › Ellipsoid**) is used for the ellipsoids management. The **Ellipsoids** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

7.2.1. Creating new ellipsoid

To create a new reference ellipsoid with c defined parameters, perform the following actions:

1. Choose **Database › Ellipsoid**. The **Ellipsoids** window opens:

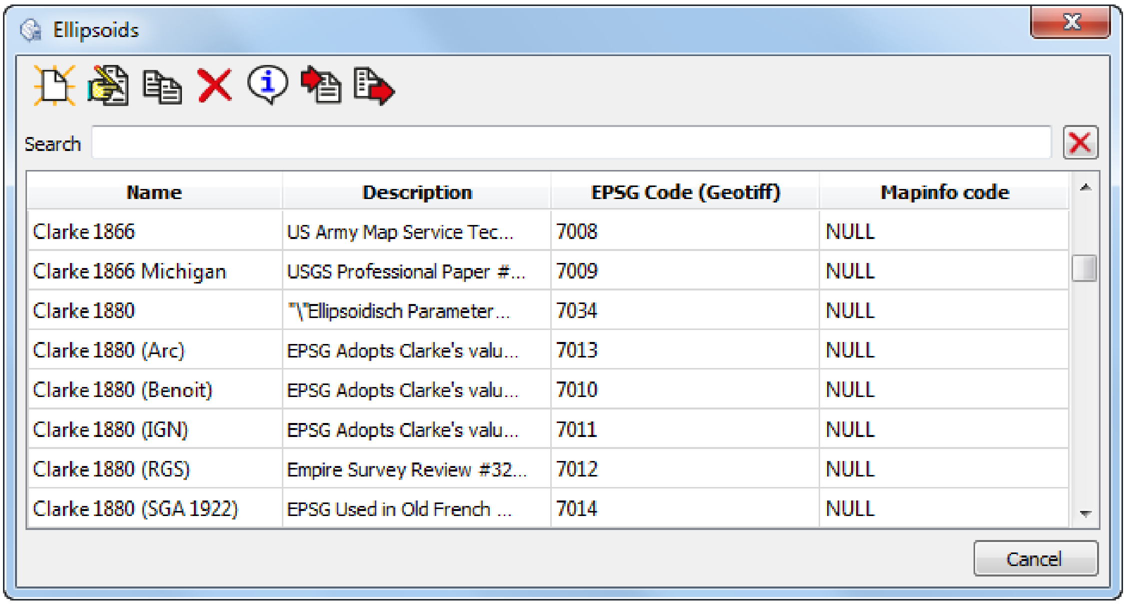


Fig. 24. The list of default ellipsoids in database

2. Click the button. The **Ellipsoid** window opens:

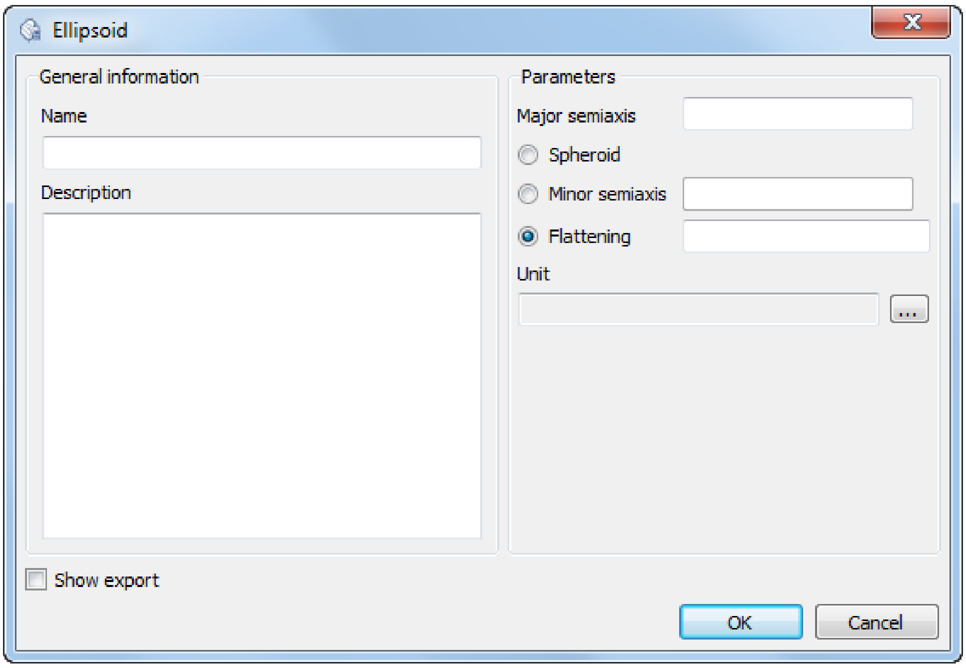


Fig. 25. Reference ellipsoid parameters

3. Define the **Name** and **Description** of the reference ellipsoid in the fields;

4. Specify the folowing ellipsoid **parameters**:

- **Major semiaxis**;
- [optional] **Minor semiaxis** or **flattening** (or create the **Spheroid**).

5. Click the ... button rightward to the **unit** field to choose linear units from the list (see the Section 7.4);
6. [optional] Set the **export** checkbox to assign an EPSG code (or a *MapInfo* code);
7. Click the **OK** button. Created reference ellipsoid is shown in the list with defined name and description.

7.3. Prime meridian

The program provides an opportunity to choose **prime meridian** for used reference system. The **Prime meridian** window (**Database › Prime meridians**) is used for the ellipsoids management. The **Prime meridian** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

7.3.1. Creating new prime meridian

To create prime meridian, different from standard, perform the following actions:

1. Choose the **Database › Prime meridians** in the main window of the program. The **Prime meridian** window opens:

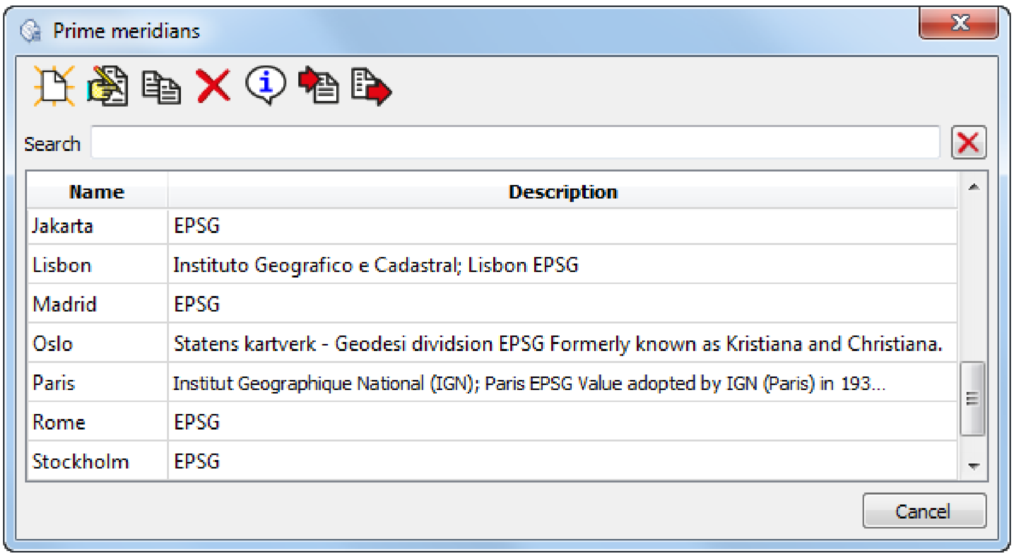


Fig. 26. The list of prime meridians in default database

2. Click the button. The **Prime meridian** window opens:

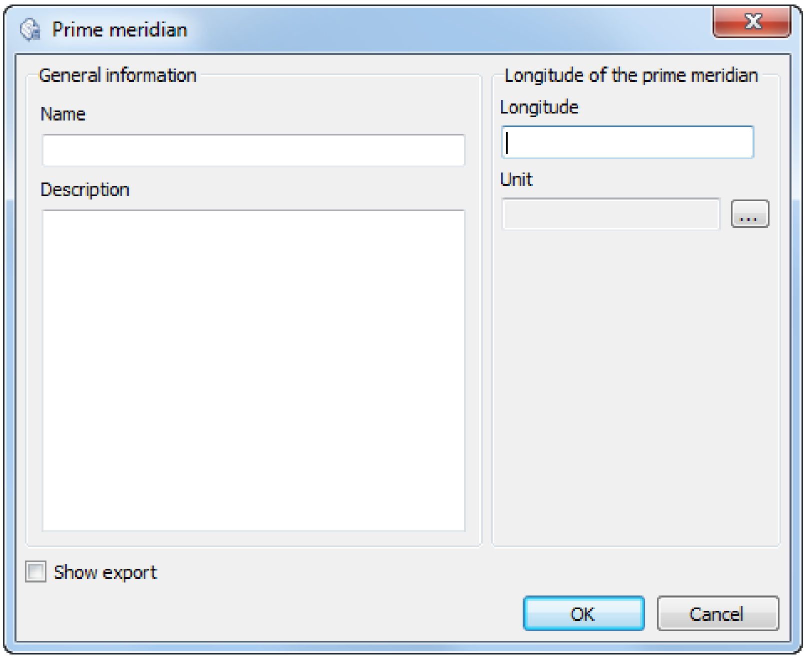


Fig. 27. Prime meridian settings

3. Define the **Name** and **Description** of the prime meridian in the fields;
4. Define the **Longitude** of the prime meridian;
5. Click the ... button rightward to the **Unit** field to choose linear units from the list (see the Section 7.4);
6. [optional] Set the **export** checkbox to assign an EPSG code (or a *MapInfo* code);
7. Click the **OK** button. Created prime meridian is shown in the list with defined name and description.

7.4. Measurement units

The program provides an opportunity to choose angular, linear and scale units for parameters that have a dimension.

The following windows are used to manage the units of measure:

- **Linear units** (**Database › Linear units**);
- **Angular units** (**Database › Angle units**);
- **Scale units** (**Database › Scale units**).

The user interface of these windows (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

7.4.1. Creating new linear units

To create a new **linear** unit, perform the following:

1. Choose **Database › Linear units**. The **Linear units** window opens:

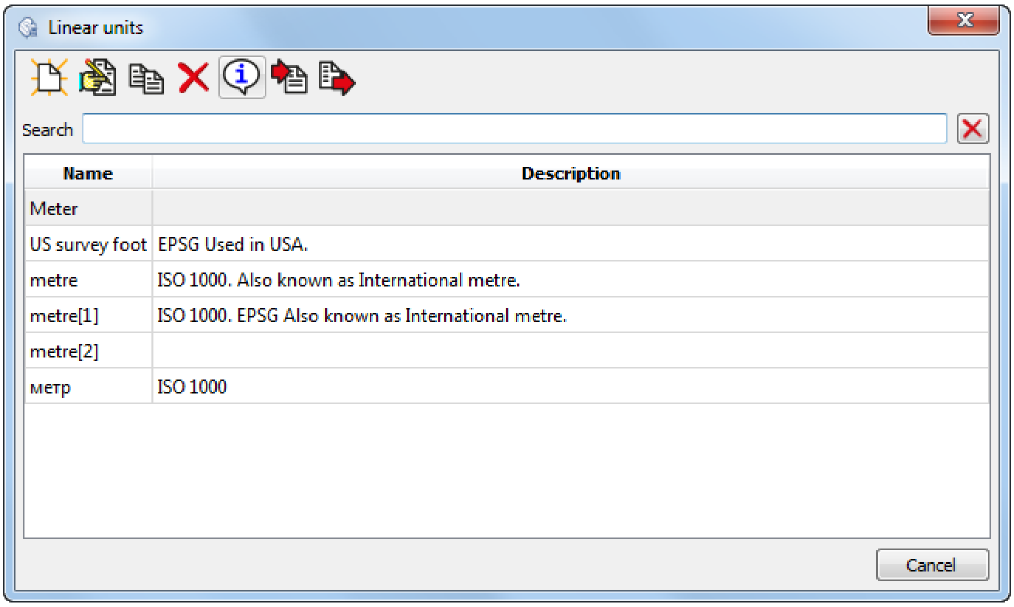


Fig. 28. The Linear units window

2. Click the  button. The **Linear units** window opens:

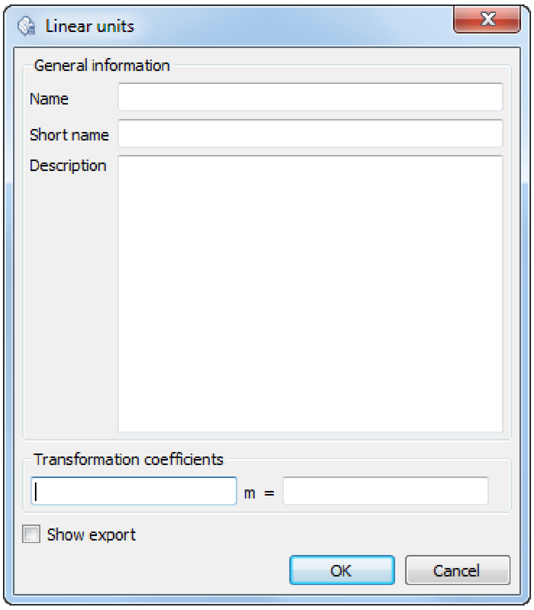


Fig. 29. The Linear units window

3. Enter **Name**, **Short name** and **Description** in the appropriate fields. The **Short name** is used for the dimension abbreviation (for example *m* for meters).

4. Enter the following data in the **transformation coefficients** input fields:

   - In the left input field, enter the value in meters;

   - In the right input field, enter the part of the selected unit value that corresponds to the value specified in the left input field.

5. [optional] Set the **export** checkbox to assign an EPSG code (or a *MapInfo* code);

6. Click **OK**. The created unit is displayed in the list with the specified name.

7.4.2. Creating new scale units

To create a new **scale** unit, perform the following:

1. Choose **Database › Scale units**. The **Scale units** window opens:

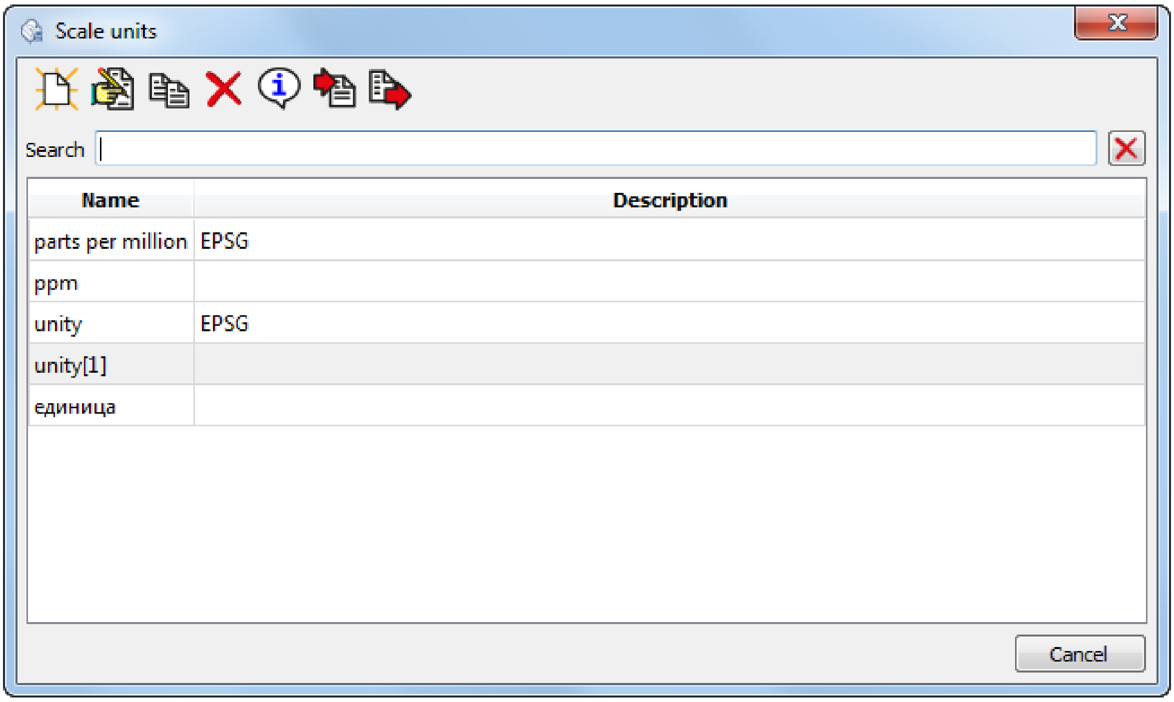


Fig. 30. The Scale units window

2. Click the  button. The **Scale units** window opens:

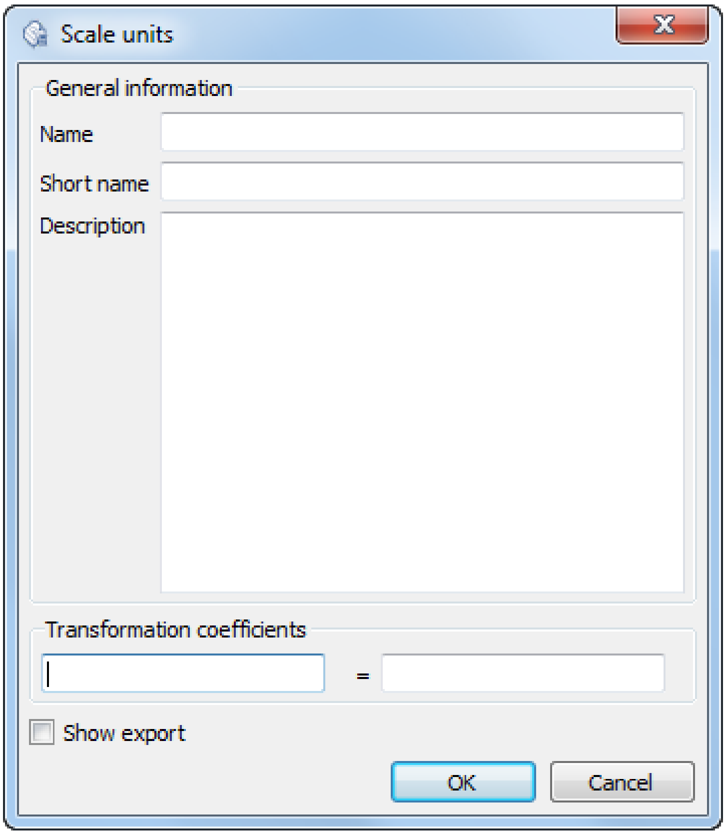


Fig. 31. The Scale units window

3. Enter **Name**, **Short name** and **Description** in the appropriate fields. The **Short name** is used for the dimension abbreviation (for example *ppm* for parts per million).
4. Specify the needed parameters in **transformation coefficients** input fields;
5. [optional] Set the **export** checkbox to assign an EPSG code (or a *MapInfo* code);
6. Click **OK**. The created unit is displayed in the list with the specified name.

7.4.3. Creating new angular units

To create a new **angular** unit, perform the following:

1. Choose **Database › Angle units**. The **Angular units** window opens:

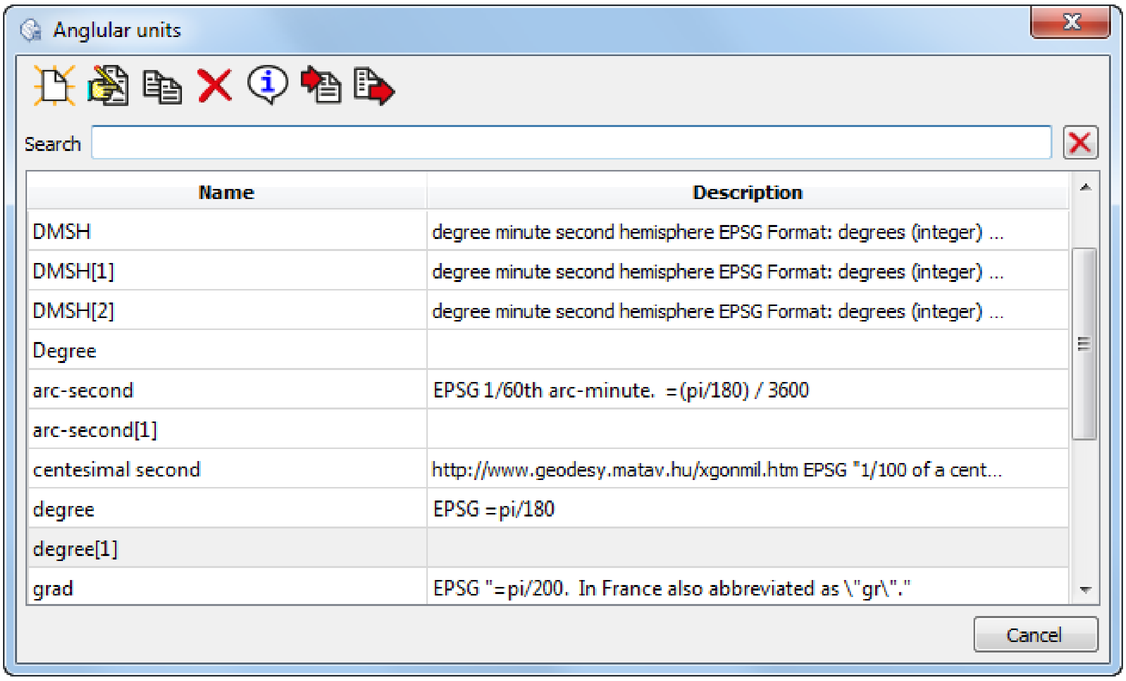


Fig. 32. The Angular units window

2. Click the button. The **Angular units** window opens:

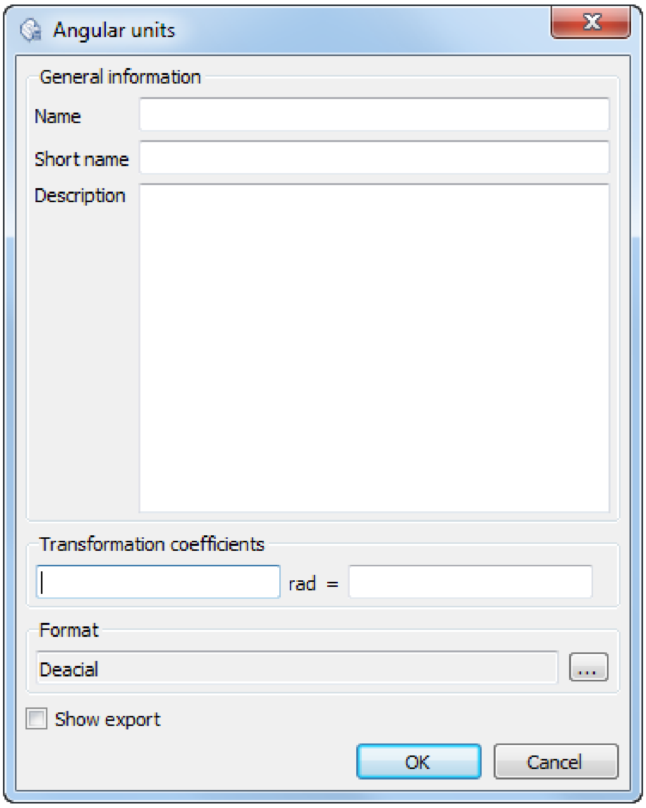


Fig. 33. The Angular units window

3. Enter **Name**, **Short name** and **Description** in the appropriate fields. The **Short name** is used for the dimension abbreviation (for example *deg* for degree).

4. Enter the following data in the **transformation coefficients** input fields:

   • In the left input field, enter the value in radians;

   • In the right input field, enter the part of the selected unit value that corresponds to the value specified in the left input field.

5. Click the ... button to choose the angular unit **format**;

6. Click **OK**. The created unit is displayed in the list with the specified name.

7.4.4. The angular formats list

The **Angular formats** window is used for choosing angular units **format** (**Database › Angular types formats**). The **Angular formats** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

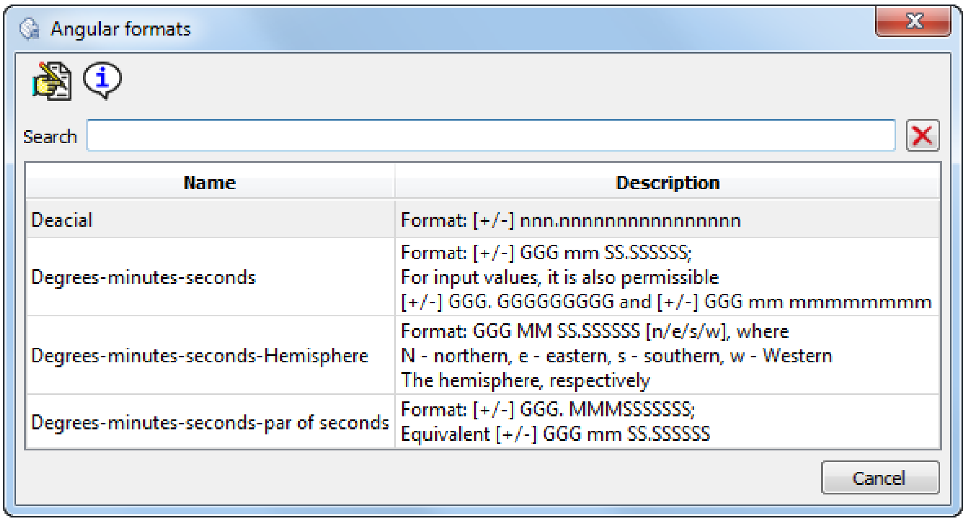


Fig. 34. The available angular formats list

7.5. Cartographic projections

The values of parameters of cartographic projections window is used for viewing the available types of map projections in default database (**Database › Map projections**). **The values of parameters of cartographic projections** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

7.5.1. Creating new cartographic projection

To define parameters of cartographic projection manually, perform the following actions:

1. Choose the **Database › Map projections** in the main window of the program. **The values of parameters of cartographic projections** window opens:

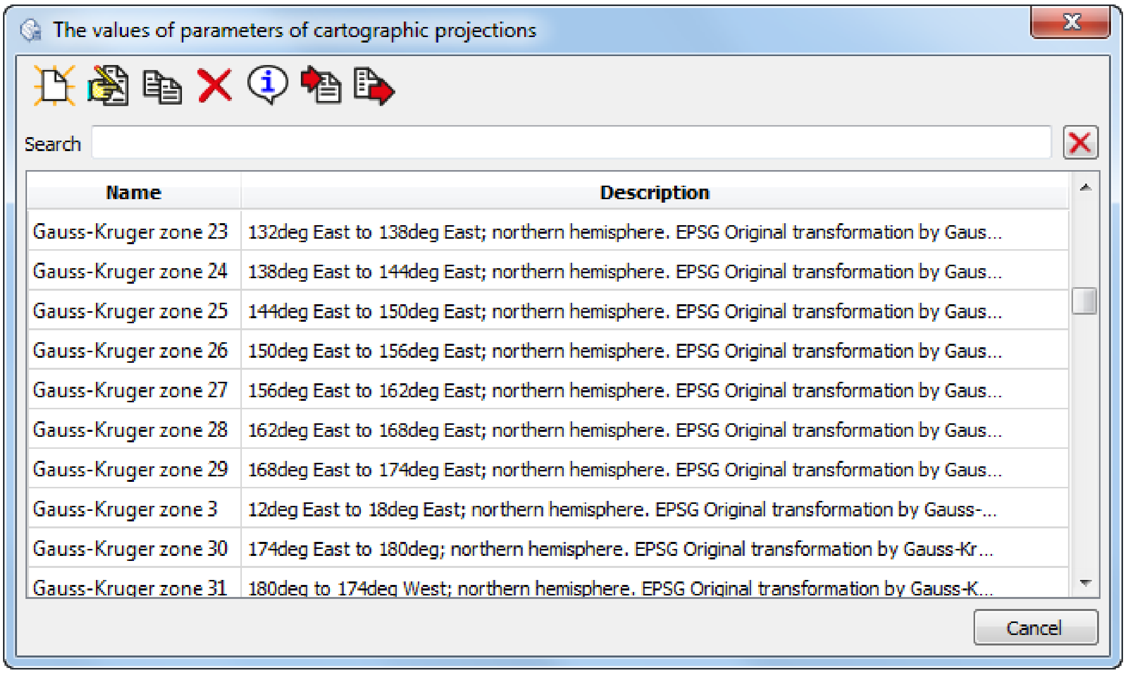


Fig. 35. The values of parameters of cartographic projections window

2. Click the button. The **Projection** window opens:

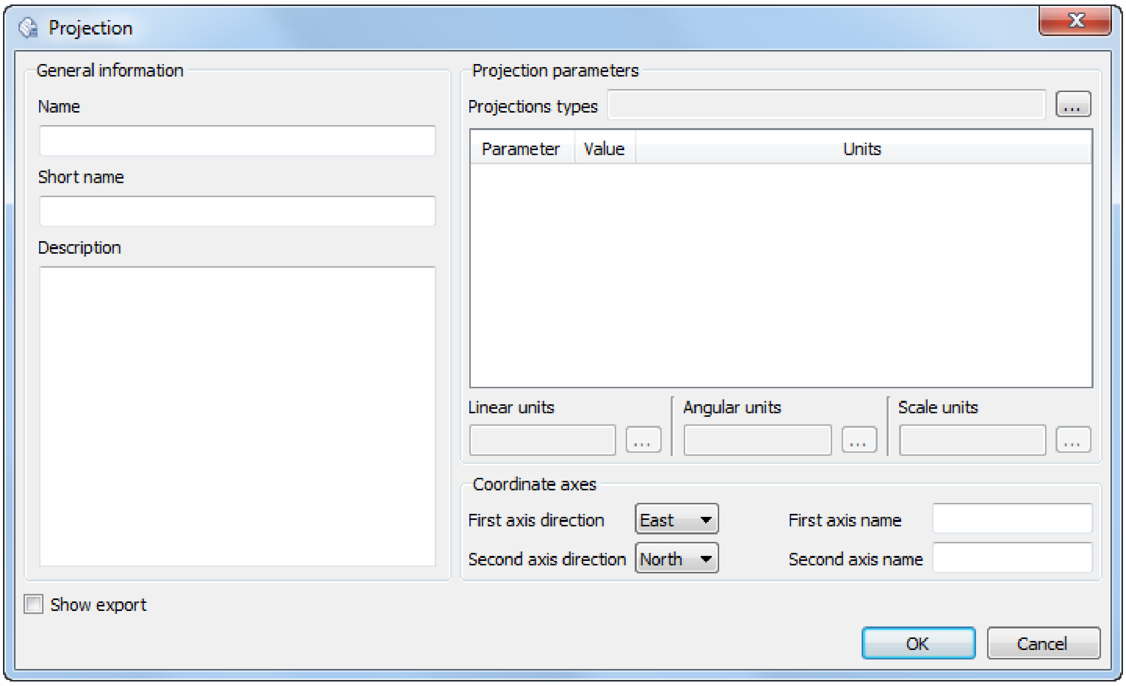


Fig. 36. Creating map projection

3. Set the general map projection parameters:
   - **Name** – arbitrary name of projection;
   - **Short name** – arbitrary short name;
   - **Description** – arbitrary description it's additional information to identify projection in the list.
4. Click the ... button and choose **Projection type**.
5. Specify in table the detail parameters of projection depending on its type.

   Click the empty field in parameter row to add detain parameters in the table.

6. Define the following parameters of map projection:
   - **Linear/Angular/Scale units** – allows to set units of measure for parameters;
   - **First/Second axis direction** – allows to set the direction of reference axis;
   - **First/Second axis name** – allows to set abbreviation for axis.

   Units, direction and names of axis are defined automatically, but they can be edited later.

7. [optional] Set the **export** checkbox to assign an EPSG code (or a *MapInfo* code);
8. Click the **OK** button. Created map projection is shown in the list with defined name and description.

7.5.2. Map projections types

The **Map projections type** window is used for choosing projections type (**Database › Map projections type**). The **Map projections type** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

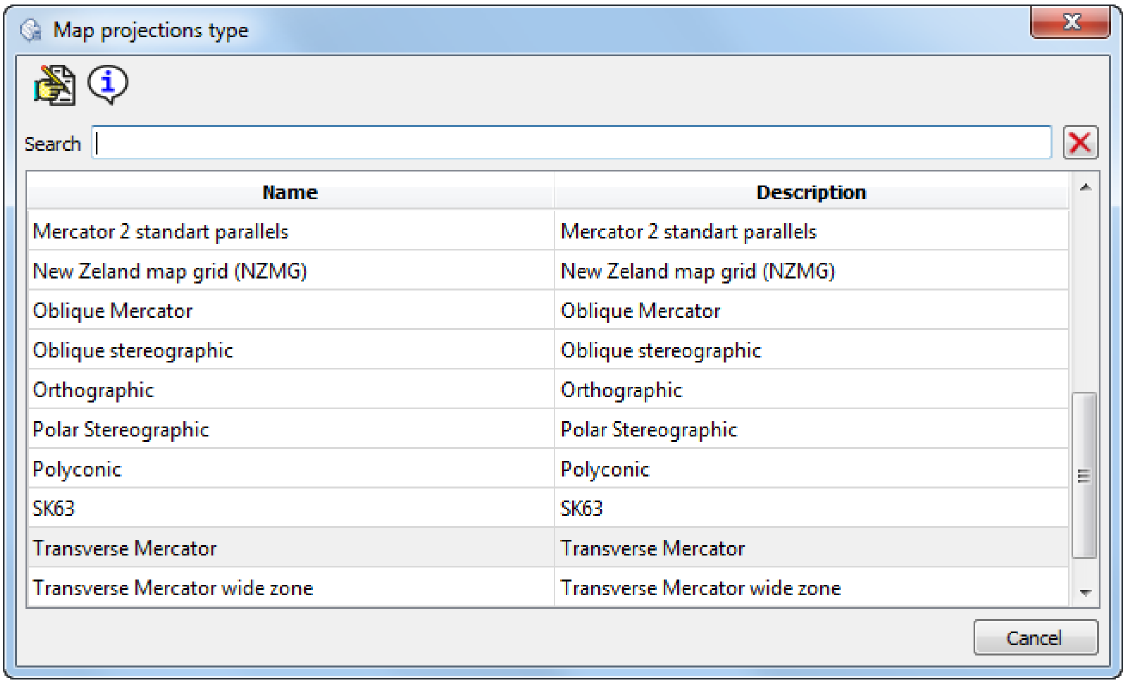


Fig. 37. Типы картографических проекций

7.6. Height systems

The **Vertical datums** window is used to manage the height systems (**Database › Height system**). The **Vertical datums** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

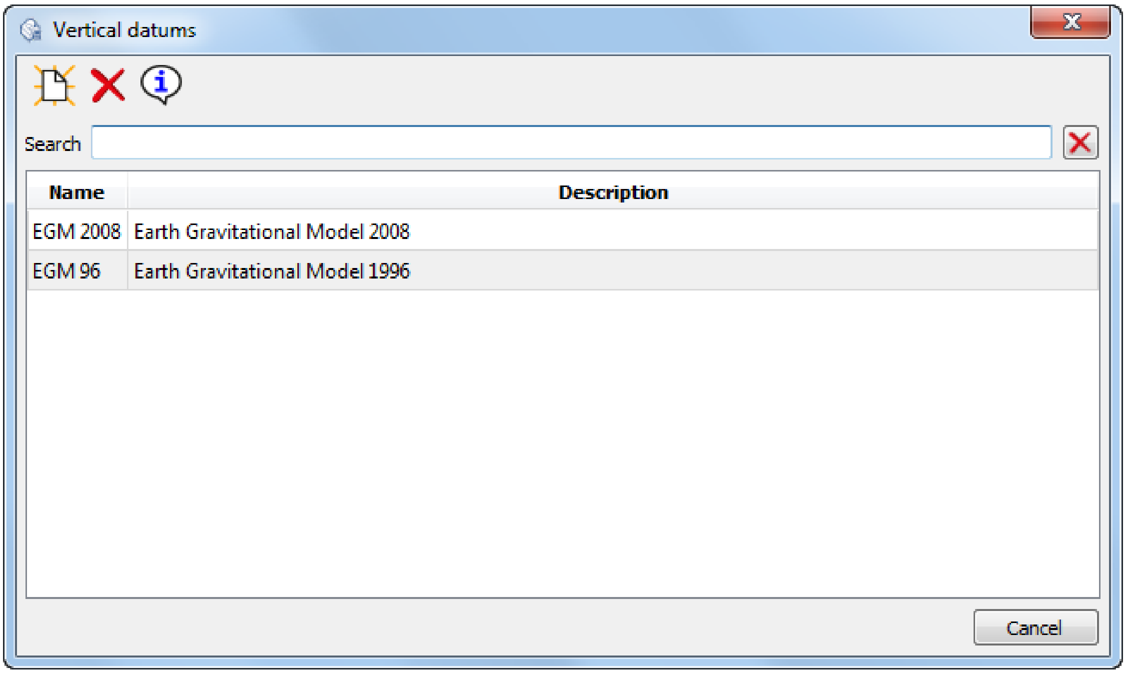


Fig. 38. The Vertical datums window

7.6.1. EGM2008 height system

The *GeoCalculator* delivery package includes the table of elevations for the **EGM96** geoid model. The system also provides for importing the **EGM2008** geoid model table of elevations. The **EGM2008** geoid is the Earth gravitational model, which includes detailed gravitational anomalies and is more accurate compared to the **EGM96** model (see the “EGM2008 Geoid installation” User Manual).

To observe changes in the *GeoCalculator* interface (the **Height systems** window), restart *PHOTOMOD GeoCalculator* after geoid installation (or removal).

PHOTOMOD GeoCalculator shares the installed **EGM2008** geoid with *PHOTOMOD*. The information about the installed geoid is stored in the *PHOTOMOD* settings folder (*PHOTOMOD8.VAR*), which is shared by *PHOTOMOD* and *PHOTOMOD GeoCalculator*.

If user intend to use the **EGM2008** geoid in conjunction with *PHOTOMOD GeoCalculator* installed as a separate application, to ensure correct interaction of the program with the **EGM2008** geoid, install *GeoCalculator* first, and then the geoid itself.

The system provides for removing the **EGM2008** geoid. It is strongly discouraged to remove the installed **EGM2008** geoid from the workstation if it is planned further to use already existing user coordinate systems created using this geoid when working with *PHOTOMOD* (and/or *PHOTOMOD GeoCalculator*).

If, when trying to use such a coordinate system, the **EGM2008** geoid is not found by the programs, then the default **EGM96** geoid will be used for recalculations.

In the case of **EGM2008** reinstallation, such coordinate systems will be able to use this geoid again (without any additional user’s operations required).

7.6.2. Creating custom height system

The system provides for creating a user height system with preset parameters.

To do this, perform the following:

1. Choose the **Database › Height system** in the main window of the program. The **Vertical datums** window opens:

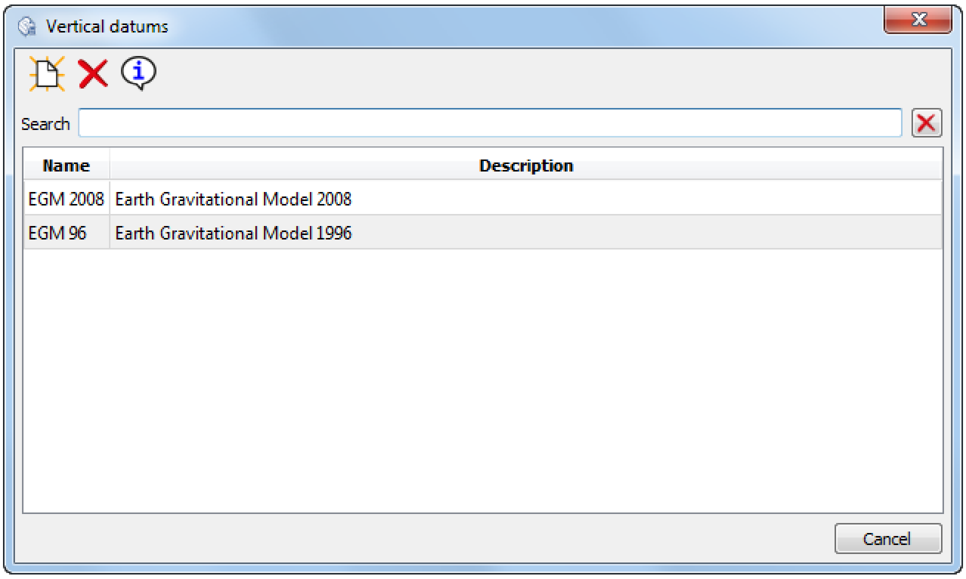


Fig. 39. The Vertical datums window

2. Click the button. The **Vertical datum** window opens:

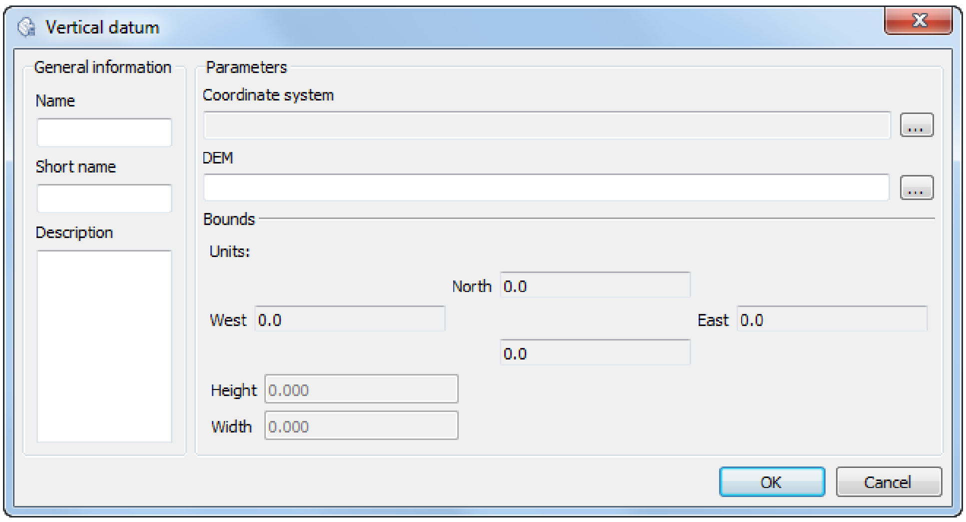


Fig. 40. The “Vertical datum” window

3. Set the general vertical datum parameters:

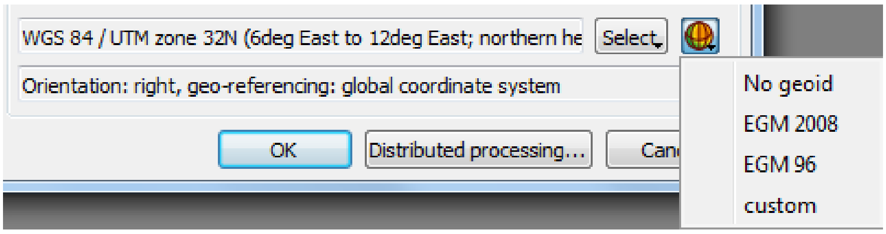
   - **Name** – arbitrary name;
   - **Short name** – arbitrary short name;
   - **Description** – arbitrary description it’s additional information to identify height system in the list.

4. In the **Parameters** section, click the ... button to select the **coordinate system**:

5. In the **Parameters** section, click the ... button to select the **DEM**. In the **North**, **West**, **East**, **South**, **Height** and **Width** fields the system displays calculated DEM size and size of DEM border in meters;

6. Click the **OK** button. Created height system is shown in the list with defined name and description.

To use the custom vertical datum in *PHOTOMOD* system, click the button that allows to choose geoids from a list or cancel the using of the geoid.



To delete the custom vertical datum the is used. The system vertical datums **EGM 96** and **EGM 2008** could not be deleted.

7.7. Deleting coordinate system elements

To delete coordinate system elements, use the button in the toolbar of the window intended for viewing and managing the list of corresponding entities (CS elements). Confirm this operation in the following box:

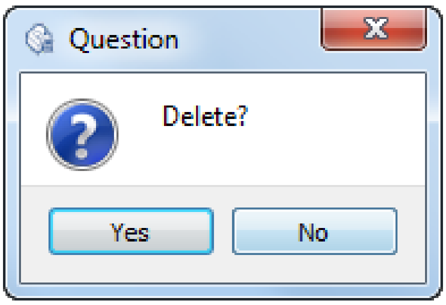


Fig. 41. Deleting an entity from the coordinate system database dialog box

To confirm the deletion, click **Yes**.

Since the database of coordinate systems and their elements has an hierarchic structure, the deletion of child elements of any entity (for example, a set of parameters for shifting the datum that is a child of another datum) may cause database errors.

Thus, before deleting any entity from a database, an automatic check of the links between the objects that the database operates on is performed. If it is not possible to delete the selected object, the **Relative database objects** window opens, listing the objects that depend on the one being deleted (see **The listed objects depend on the deleted** section):

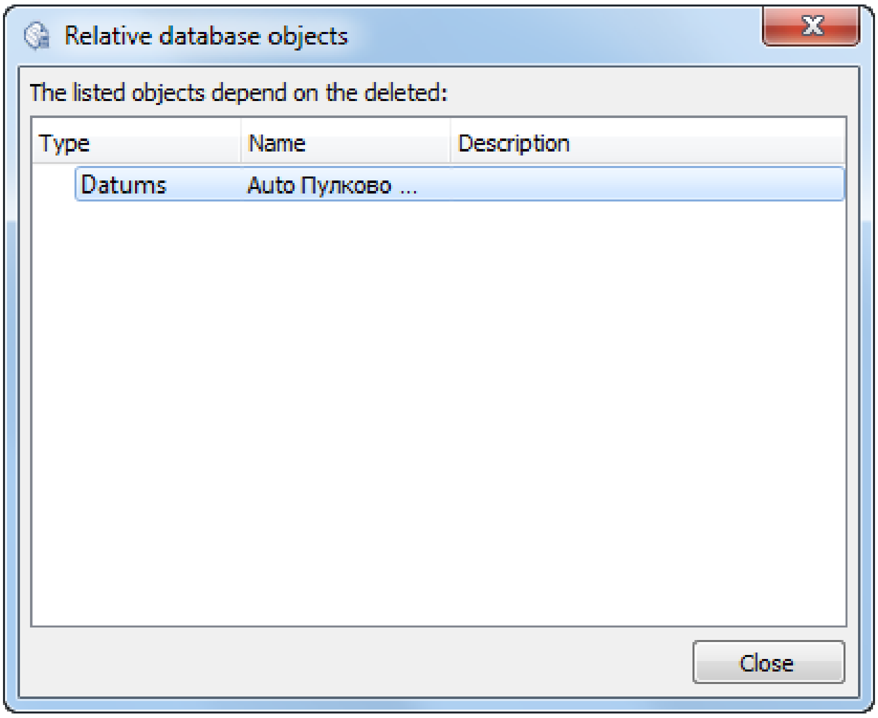


Fig. 42. The Relative database objects window

To ensure correct database operation, first remove parent objects from the database that are placed on the upper level of the hierarchy (coordinate system), and then, if needed, delete the coordinate system elements remaining in the database if there are any.

When deleting coordinate systems and their elements, note that the *GeoCalculator* (coming with *PHOTOMOD*) database is shared with *PHOTOMOD*. Thus, *GeoCalculator* coordinate systems can be used for processing *PHOTOMOD* projects.

The button in the main *GeoCalculator* toolbar opens the `PhCoordSys.db` database provided by default (without database reset).

The button in the main *GeoCalculator* toolbar allows you to reset the coordinate system database. The current database will be closed, the `PhCoordSys.db` database supplied with the program will be returned to its original parameters and opened as the current database.

Appendix A. Coordinate transformations

The system allows the user to define extra coordinate **transformations** for the coordinate system or height system.

To configure the coordinate **transformations**, set the appropriate checkbox in the current window (**Editing the coordinate system** for example). The **Transformation** section opens

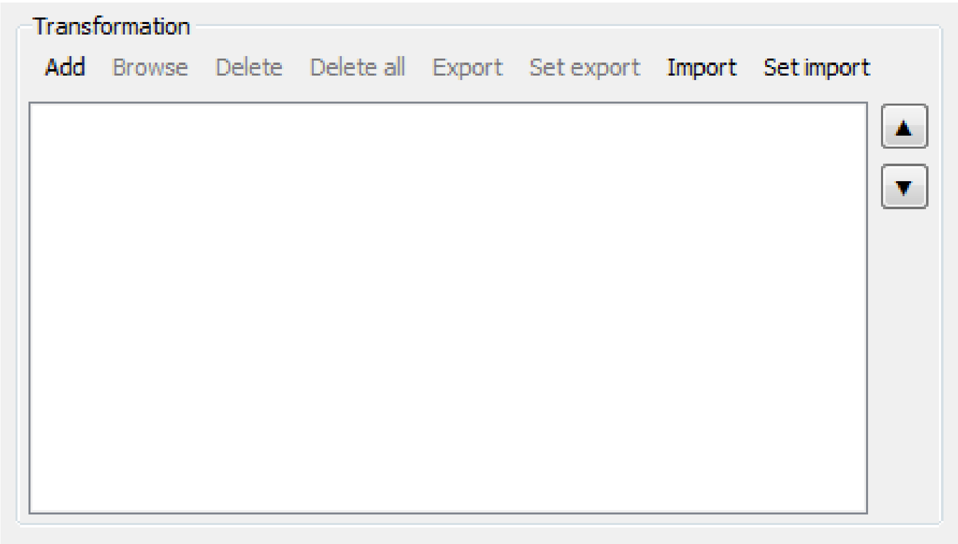


Fig. A.1. The “Transformation” section

The **Transformation** section has the following interface elements

- A look up field for created transformations;
- Buttons ▼ and ▲, are designed to configure the sequence of transformations;
- A button to **Add** a new transformation rule;
- A button to **Change** a transformation rule;
- A button to **Export** data on the transformation into the `*.xml` format;
- A button to **Import** data on the transformation into the `*.xml` format;
- A button to **Delete** a transformation;
- A button to **Delete everything** (all the transformations);
- A button to export a set of data on several transformations into the `*.xml` format;
- A button to import a set of data on several transformations from the `*.xml` format.

A.1. Creating new coordinate transformation rule

To **Add** a new transformation rule, perform the following:

1. Click **Add**. The **Transformation** window opens:

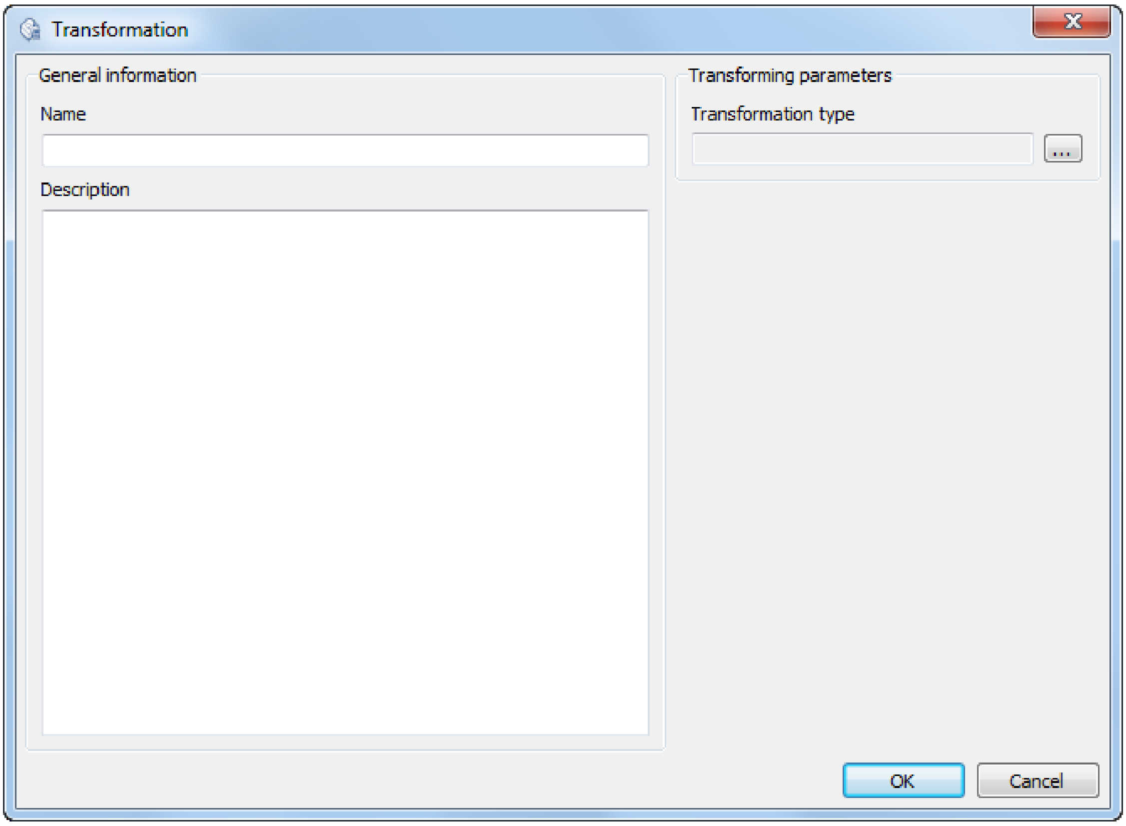


Fig. A.2. The Transformation window

2. Enter transformation common parameters:
   - **Name**;
   - **Description**.
3. Click the ... button to select the **transformation type**;
   - **Affine transformation of plane coordinates**;
   - **Plane coordinates shift**;
   - **Height shift**.
     - Click ... to select a linear unit.
4. Specify the detail transformation parameters depending on its type;
5. Click **OK**.

A.1.1. Affine transformation of XY coordinates

1. Configure the basic options of the coordinate transformation rule.

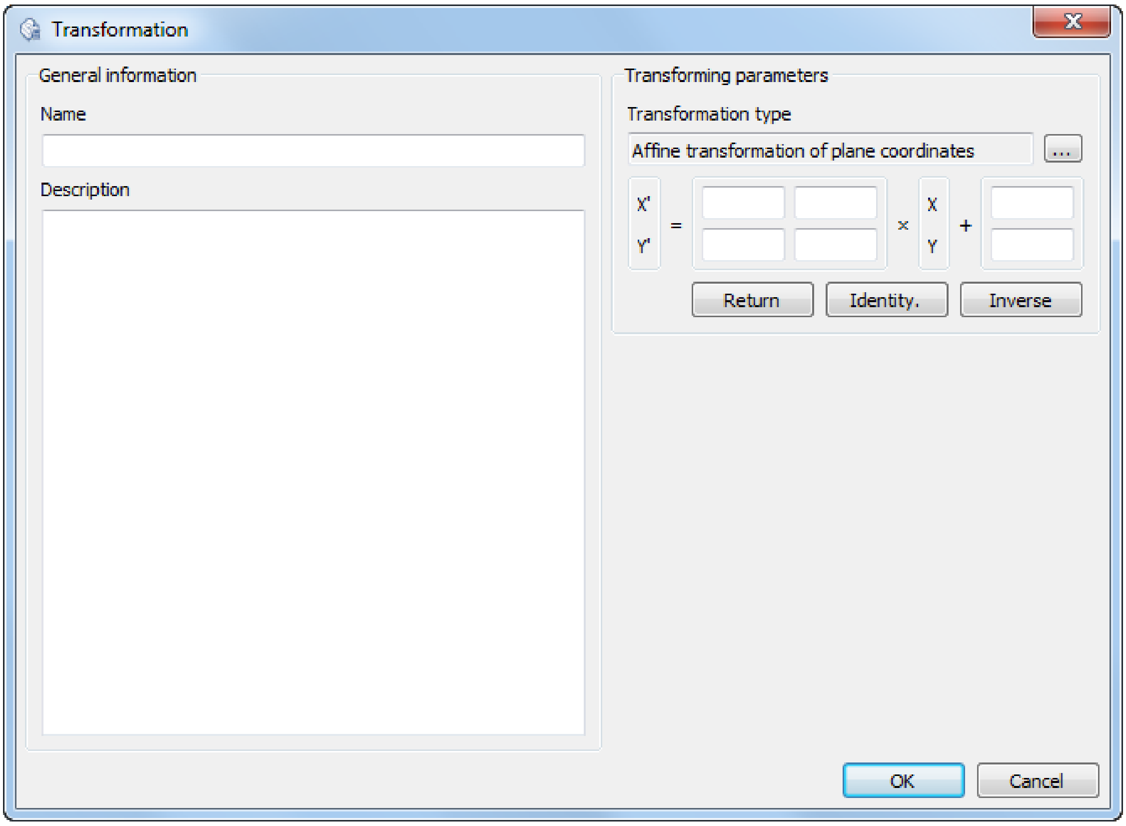


Fig. A.3. The Transformation window

2. Configure affine transformation options in the appropriate fields:

   - [optional] To clear the data entered, click **Undo**;
   - [optional] To enter the identity transformation options, click **Identity**;
   - [optional] To invert transformation parameters, click **Invert**.

A.1.2. Shift of XY coordinates

1. Configure the basic options of the coordinate transformation rule.

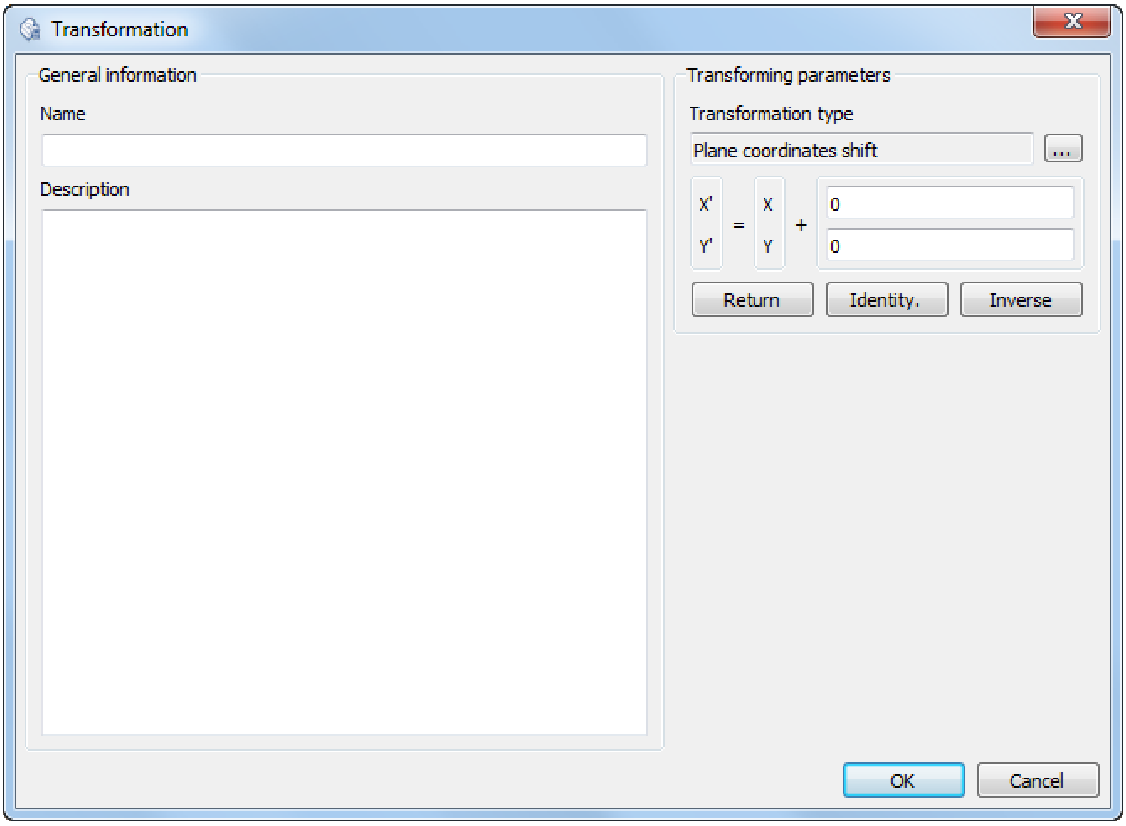


Fig. A.4. The Transformation window

2. Configure Shift of XY coordinates options in the appropriate fields:
   - [optional] To clear the data entered, click **Undo**;
   - [optional] To enter the identity transformation options, click **Identity**;
   - [optional] To invert transformation parameters, click **Invert**.

A.1.3. Z-axis shift

1. Configure the basic options of the coordinate transformation rule.

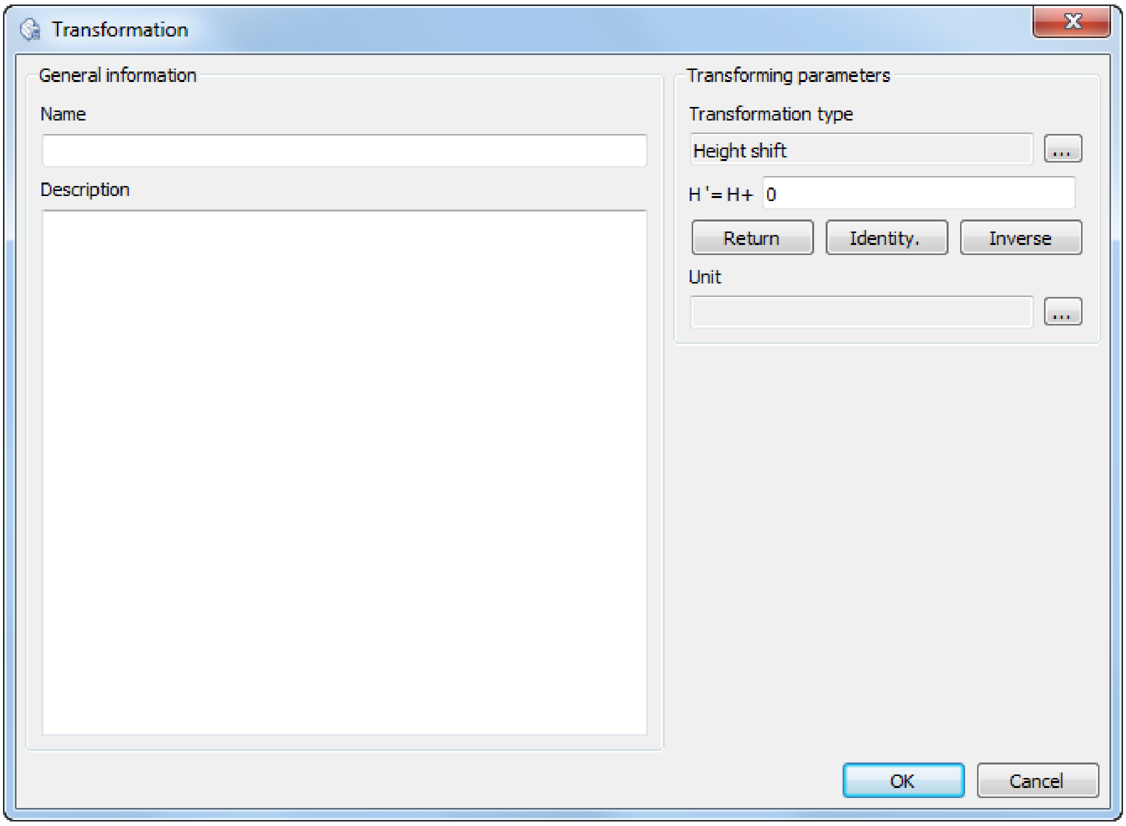


Fig. A.5. The Transformation window

2. Set a value in the **H' = H++** field;
   - [optional] To clear the data entered, click **Undo**;
   - [optional] To enter the identity transformation options, click **Identity**;
   - [optional] To invert transformation parameters, click **Invert**.
3. Click  to select the linear unit.

A.2. The transformation rules types list

The **Types of transformations** window is used for choosing transformation rule type. The **Types of transformations** window user interface (the table, toolbar, search tools) is similar to the interface of the **Coordinate systems** window.

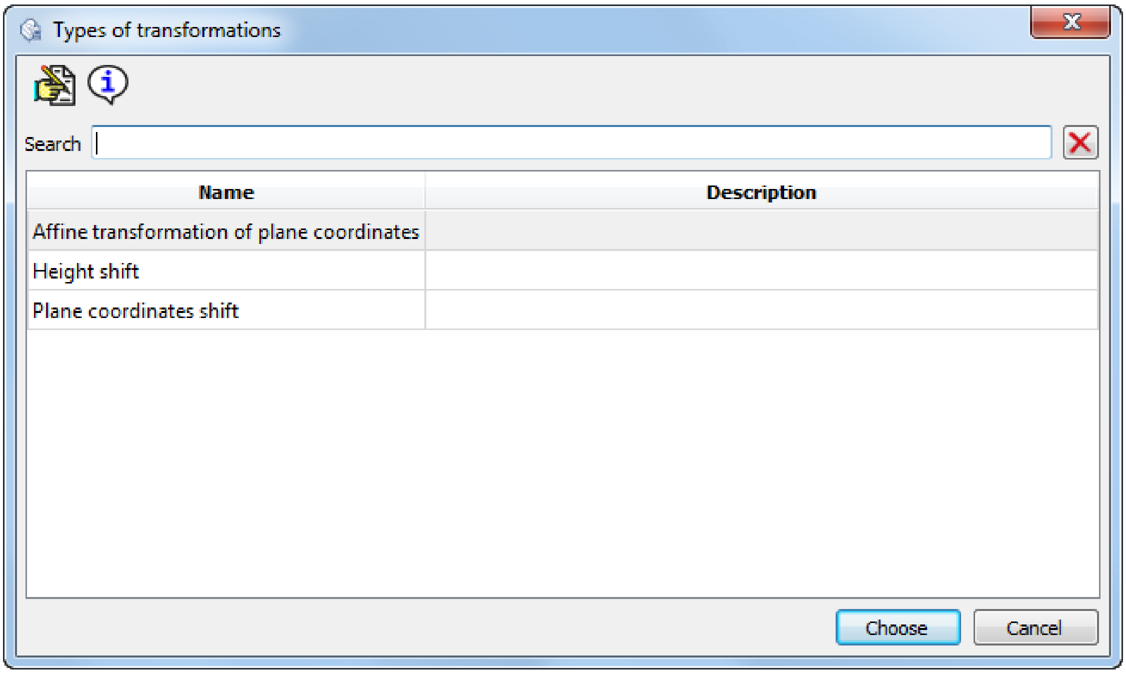


Fig. A.6. The transformation rules types list

Appendix B. EPSG and MapInfo codes

The *GeoCalculator* supports *EPSG* registry codes (and also *MapInfo* codes) used for the description of both coordinate systems and their individual elements, such as datums, ellipsoids, measurement units, etc.

The *EPSG* code is a convenient brief identifier of different coordinate systems (along with all their parameters). *EPSG* codes were introduced by the European Petroleum Survey Group (now *OGP*, *International Association of Oil and Gas Producers*). The *EPSG* abbreviation itself is still widely used.

EPSG codes containing information on the coordinate system can be used, in particular, as metadata elements of TIFF imagery. The default *GeoCalculator* database already includes assigned *EPSG* and *MapInfo* codes for certain database entities.

Assigning EPSG codes is supported for **Coordinate systems**, as well as for the following coordinate system elements:

- **Distance units**;
- **Angular units**;
- **Scale units**;
- **Ellipsoids**;
- **Datums**;

- **Datum shift** option sets.

Assigning *MapInfo* codes is supported for the following:

- **Distance units**;
- **Ellipsoids**;
- **Datums**.

The system allows:

- Preliminary generation a code for any database entity (if codes are provided);
- Assigning a code to an entity.

B.1. Code assigning

To assign an entity a EPSG code (or *MapInfo* code) created for this entity in advance, set the **Export** checkbox in the current window for creating or editing this entity (,). The **Export** section opens:

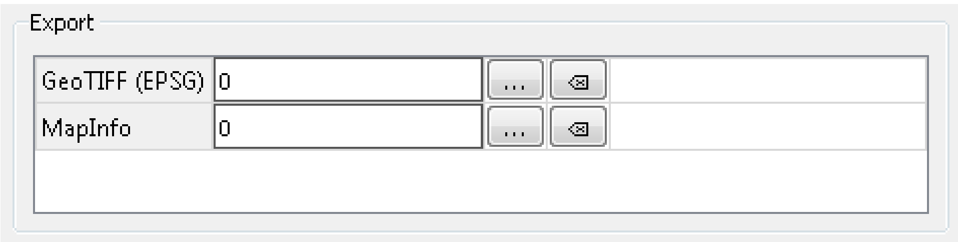


Fig. B.1. The Export section

The transformation section has the following interface elements:

- The , button is to assign a code from a pre-prepared list;
- The , button is to clear a code.

B.2. Code generation

To assign an EPSG code (or a *MapInfo* code) to the database to some entity, perform the following:

1. Open the window for creating or editing an entity (e.g., **Datum**) for which EPSG (or code *MapInfo*) assigning is supported
2. Set the **Export** checkbox in the current window. The **Export** section opens:

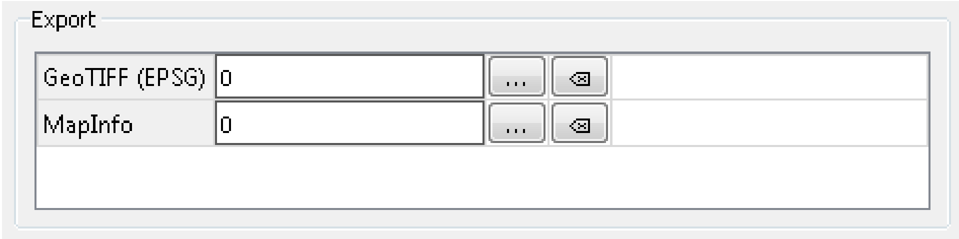


Fig. B.2. The Export section

3. In the **Export** section, click the ... button that corresponds, e.g. the **GeoTIFF (EPSG)** line. The **EPSG datum codes** window opens

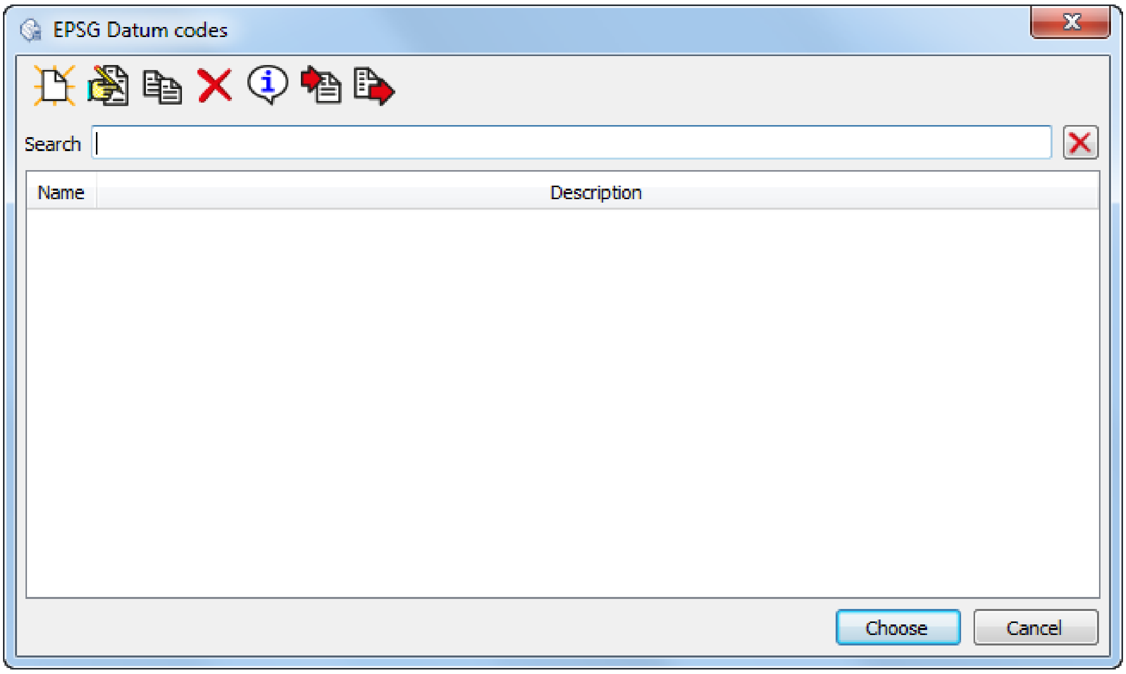


Fig. B.3. The EPSG datum codes window

To view the already existing code, select its entry in the table and click .

4. Click the button. The **EPSG code editor** window opens:

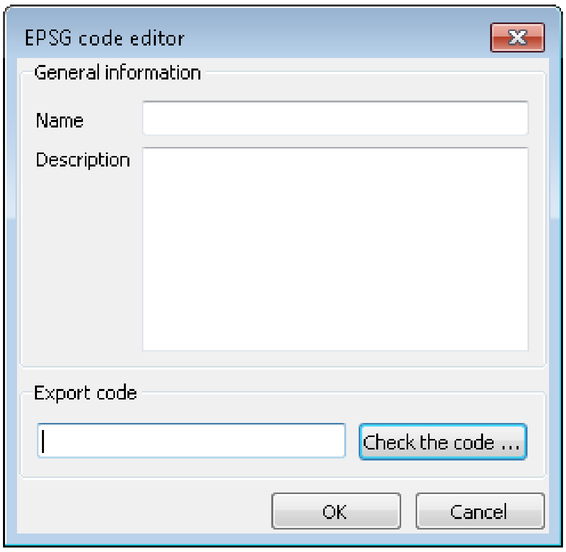


Fig. B.4. The EPSG code editor window

5. Enter the following:
   - **Name**;
   - **Description**.
6. Enter the numerical code from the *EPSG* registry in the **Export code** input field;
7. [optional] To **check the code**, click the appropriate button. Checking for code matching is carried out using the internal database of the *GeoCalculator* program:
   - [optional] If the given code is not found in the database, an appropriate info message is issued:

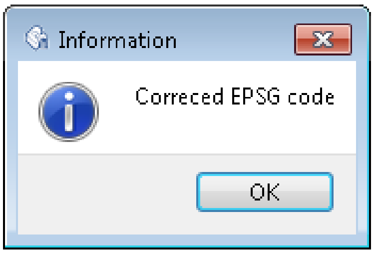


Fig. B.5. The info message

   - [optional] If the given code is already found in the database, an appropriate info message is issued:

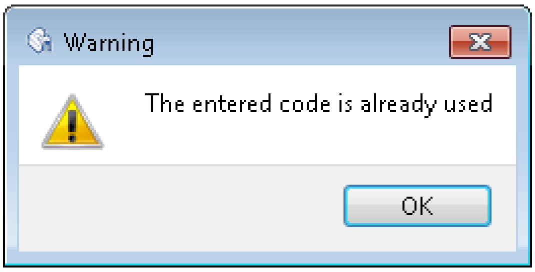


Fig. B.6. The info message

8. Click OK.

Generating codes for other entities, as well as *MapInfo* codes, is carried out in a similar way.

Appendix C. Hotkeys

The following hotkeys are designed for working with tables placed in the **points** sections of the main window.

Table C.1. Hotkeys

Button combinations	Purpose
Ctrl+Insert	Insert a line in the point list
Ctrl+Delete	Remove a line from the point list
Ctrl+N	Counting lines in the point list
Ctrl+I	Searching for incorrect points
Ctrl+D	Delete incorrect points
Ctrl+E	Delete empty lines
Ctrl+U	Swap point lists

Appendix D. Coordinate file format

Content of a coordinate txt file (ASCII format) is to be as follows:

For correct automatic recognition of point coordinates from a txt file, a comma or semicolon is to be used as a separator between columns in the file. A period must be used as a decimal separator. Commas as decimal separators are not allowed.

```
NAME,X,Y,Z

IMG_0009,51.959359,104.763096,1064.804463

IMG_0010,51.959356,104.762557,1064.986490
```

```
IMG_0011,51.959355,104.762057,1065.002512

IMG_0012,51.959357,104.761507,1065.300536
```

Appendix E. GeoCalculator settings

To open **Settings** window click the button on the main toolbar.

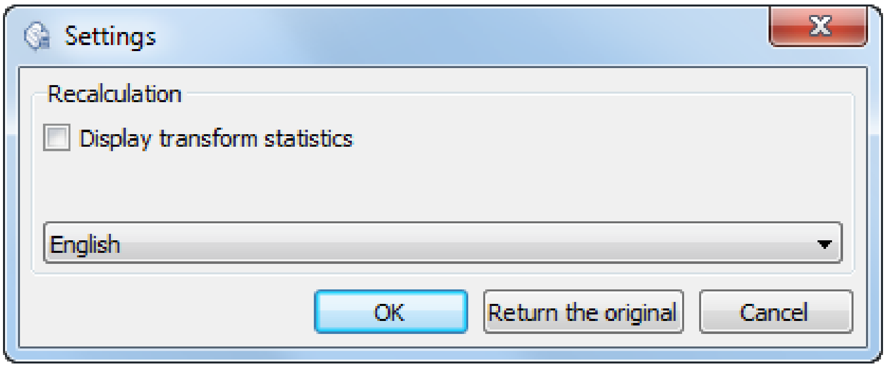


Fig. E.1. Program settings

To **display transform statistics** on coordinate **recalculation** after every recalculation operation, set the appropriate checkbox. To revert to default settings, click the appropriate button.

[optional] To change the interface language of a program launched as a separate application, select the desired language in the drop-down list, close, and restart *PHOTOMOD GeoCalculator*.

The reason of the program's restart is due to the fact that the coordinate systems, as well as sets of coordinate system elements contained in the default database, differ for the Russian and English versions of the program.

For *GeoCalculator* installed as a part of *PHOTOMOD*, as well as for all other *PHOTOMOD* modules, it is possible to switch the interface language in the *System Monitor* service module (see "System Monitor service module" in the "General information" User Manual of the *PHOTOMOD* documentation kit).

Appendix F. Calculating datum transformation parameters

Calculating datum shift means refining the transformation parameters between two spatial coordinate systems. This allows, using two sets of identical points (at least three points in a set), to determine the parameters to transform the first set points' coordinates to the second set coordinate system.

The transformation parameters include: **scaling**, **three axis rotation angular elements**, and **three linear elements** of the coordinate system center shift. Such transformations are necessary, for example, when referring the received GPS measurement data to the stations of the state geodetic network.

When processing data, it may be necessary to compare two sets of identical points on the earth's surface, measured at different times, using different methods, and recorded in different coordinate systems.

When converting coordinates of points from one coordinate system to another and subsequently analyzing the results, the need to clarify the transformation parameters between two spatial coordinate systems may arise due to many possible factors, from measurement errors to changes in the terrain itself, as a result of natural and anthropogenic processes.

Calculating datum shift parameters is available using the *GeoCalculator* software provided with *PHOTOMOD*, as well as using a separate *Seven-Parameter Calculation* application available for downloading from the **Racurs** Company website racurs.ru.

The *GeoCalculator* program (provided with *PHOTOMOD*) allows for immediate use of refined transformation parameters by automatically generating a user coordinate system, with a custom datum that includes a datum transformation parameter set that use the refined **rotation-shift-scaling** parameters.

A user coordinate system saved in *GeoCalculator* database can be further used when processing a project directly in *PHOTOMOD* (see "Coordinate systems" in the "Creating project" User Manual, *PHOTOMOD* documentation)

F.1. Preparing data sets

To determine transformation parameters between two coordinate systems, first prepare two data sets: two TXT files with point coordinates. One file must contain points in one coordinate system only.

The data in the files must meet the following criteria:

- The *number of lines* in both files must be the *same*;
- Point coordinates in each file must be entered in the following order:

  If there are errors in sequence, incorrect data may be obtained.

  ```
  1,6235070.742,12520067.725,100.000,
  ```

  Where `1` – is the point name, `6235070.742` – is the point coordinate (**northward** coordinate axis), `12520067.725` – is the point coordinate (**eastward** coordinate axis), `100.000` – is the Z-coordinate.
- Each file must contain *no less than three lines*;
- The *order* of coordinates in both files must be the *same*;
- In Gauss-Krüger projection files, the coordinate values must include the *zone number*;

Point coordinates in the *Gauss-Krüger projection* (on the territory of the Russian Federation) are to be recorded as follows: `point_name`, **X** coordinate, **Y** coordinate; since Gauss-Krüger abscissa (**X**) is northward and ordinate (**Y**) is eastward.

- в файле с проекцией UTM (Universal Transverse Mercator) координаты точек должны *соответствовать номеру зоны*;

  In UTM projection (Universal Transverse Mercator) files, point coordinates *must correspond to the zone number*;

UTM point coordinates are to be recorded as follows: `point_name`, **Y** coordinate, **X** coordinate; since UTM abscissa (**X**) is eastward and ordinate (**Y**) is northward.

- Gauss-Krüger and UTM files must contain data for the ellipsoid divided into 60 6°-zones;
- The following characters must be used as separators:
  - The separator between X and Y coordinates is a `comma`,
  - The decimal separator is a `period`.

  If coordinates are presented as degrees-minutes-seconds, the separators are to be:
  - The separator between degrees and minutes (and minutes and seconds as well) is a `space`,
  - The decimal separator is a `period`.

Local_coordinate_system.txt

```
1,4955381.037,141467.417,-141.358
2,4957273.061,136682.518,-127.944
3,4962455.190,140516.577,-141.424
4,4960094.892,146255.044,-102.993
5,4944062.214,146256.320,-105.844
6,4947368.126,138264.536,-133.132
7,4951135.503,144658.537,-129.094
8,4966696.866,147210.165,-111.355
9,4966232.640,136697.274,-139.366
10,4969056.198,141478.133,-134.744
11,4969536.426,135110.786,-137.924
12,4940764.585,139855.786,-112.620
13,4952092.885,133160.695,-140.182
14,4957268.011,151041.646,-123.013
15,4968585.708,151349.412,-112.592
16,4962006.499,129038.594,-155.379
```

Fig. F.1. An example file with point coordinates

Geodetic_(Lat,Long,Height).txt

```
1,47 33 28.92857,1 34 46.07143,84.000
2,47 34 33.21429,1 30 45.00000,97.500
3,47 37 30.00000,1 33 57.85714,84.000
4,47 36 9.64286,1 38 47.14286,122.327
5,47 27 3.21429,1 38 47.14286,119.357
6,47 28 55.71429,1 32 5.35714,92.214
7,47 31 4.28571,1 37 26.78571,96.184
8,47 39 54.64286,1 39 35.35714,114.000
9,47 39 38.57143,1 30 45.00000,86.143
10,47 41 15.00000,1 34 46.07143,90.714
11,47 41 31.07143,1 29 24.64286,87.633
12,47 25 10.71429,1 33 25.71429,112.653
13,47 31 36.42857,1 27 48.21429,85.276
14,47 34 33.21429,1 42 48.21429,102.214
15,47 40 58.92857,1 43 4.28571,112.714
16,47 37 13.92857,1 24 19.28571,70.214
```

Fig. F.2. Example file with point coordinates in the geodetic coordinate system

F.2. Loading data sets

1. Load two prepared point coordinate sets in the right and left parts of the *GeoCalculator* windows using buttons. Use **Choose** buttons to specify the coordinate systems corresponding to them.

   The program calculates the parameters of transformation from the first coordinate system (data on the *left*) to the second coordinate system (data on the *right*). When calculating the transformation parameters, the formulas given in the reference book are used *Map projections: A working manual* [J.P. Snyder, 1987].

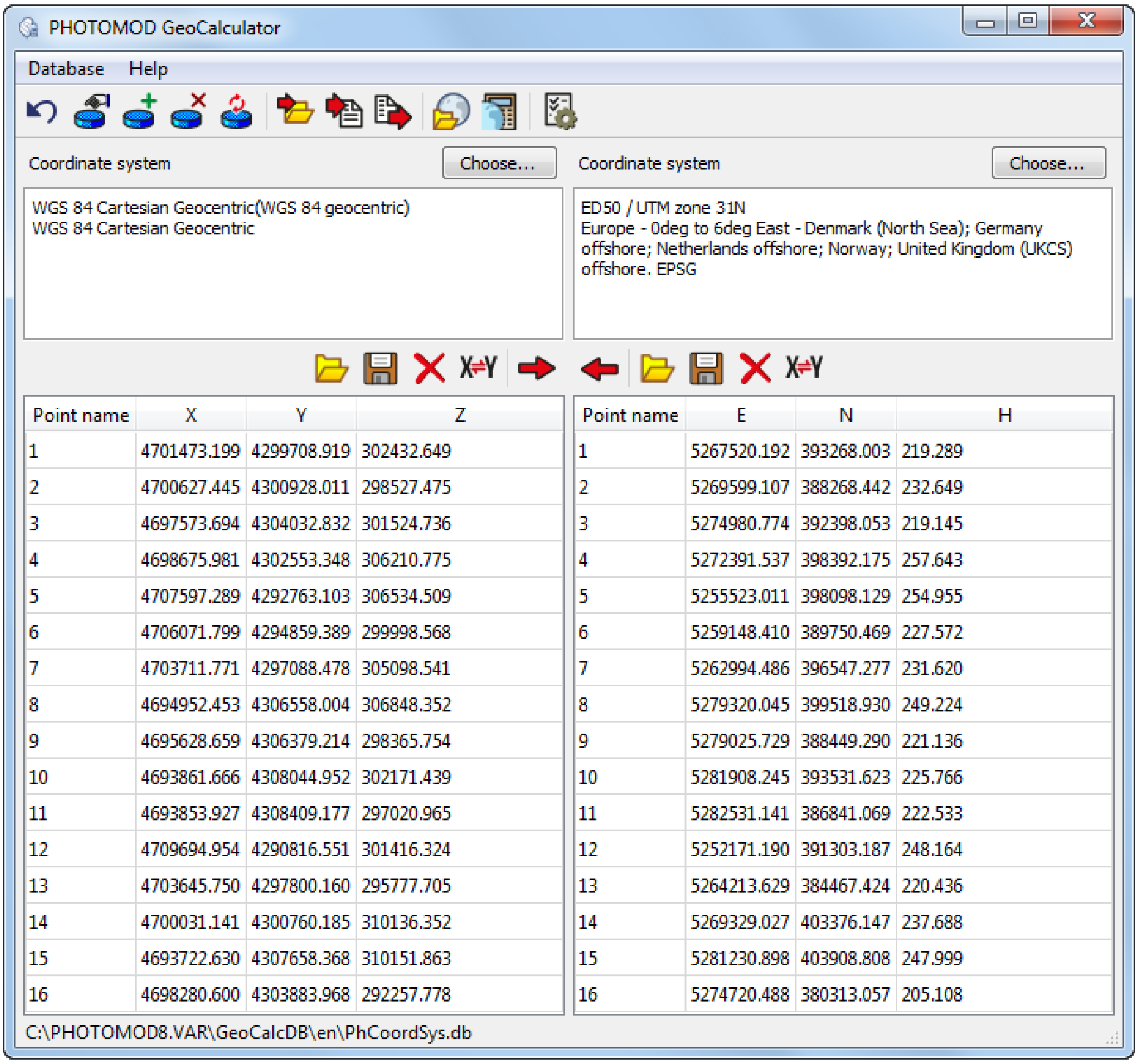


Fig. F.3. Main program window showing loaded data

2. [Optional] Click in the main *GeoCalculator*. The **Web-map** window opens, that allows you to estimate at-a-glance whether it is required to refine transformation parameters between the two coordinate systems:

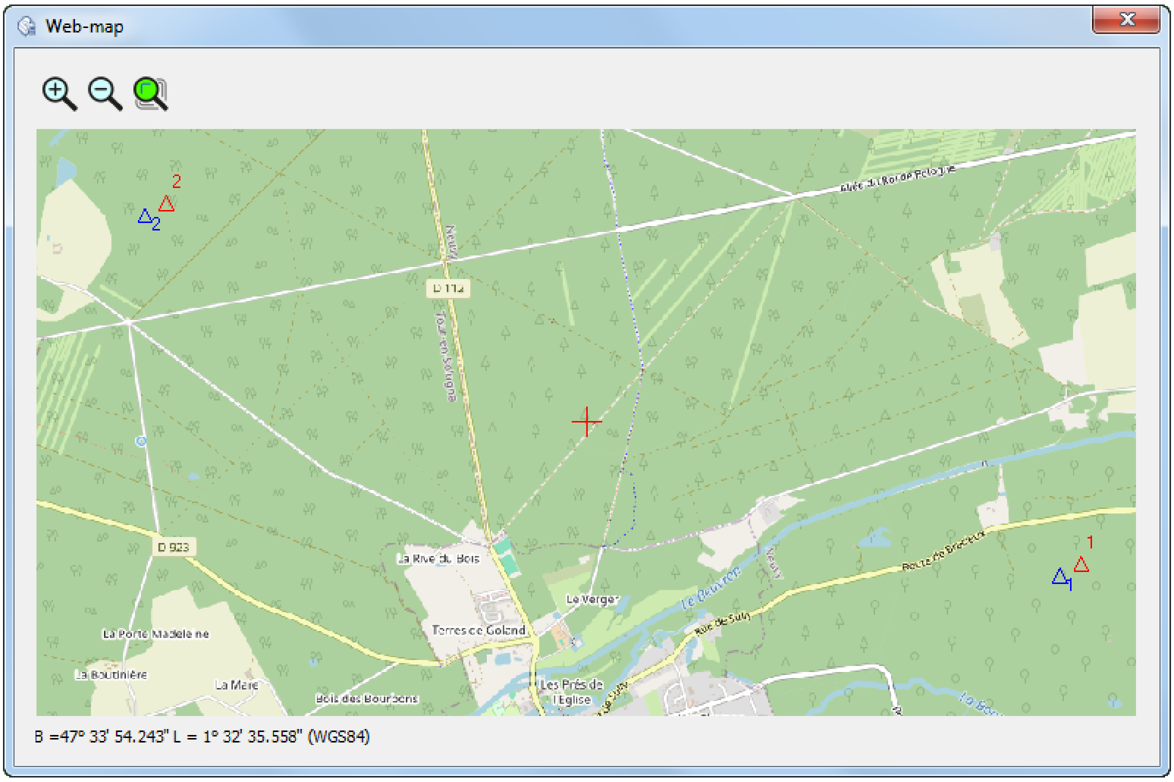


Fig. F.4. The Web-map window (refined rotation-translation-scaling datum transformation parameters are not in use)

This window contains layers with loaded point sets as well as the geographic *OpenStreetMap*. Points loaded in the *left* part of the *GeoCalculator* window are shown in *red*. Points loaded in the *right* part of the *GeoCalculator* window are shown in *blue*. Current marker coordinates (WGS84) are shown in the bottom of the window.

OpenStreetMap (OSM) is a non-profit web resource with a free geographic world map. To download the *OpenStreetMap* map, your workstation must be connected to the Internet.

The **Web-map** toolbar contains the following buttons

- – allows to zoom in an image by one step (*****);
- – allows to zoom out an image by one step (**/**);
- – allows to fit to page data of opened layers (**Alt+Enter**).

3. Click in the main *GeoCalculator* toolbar, to open the **Calculate Datum parameters** window.

F.3. Calculating datum transformation parameters

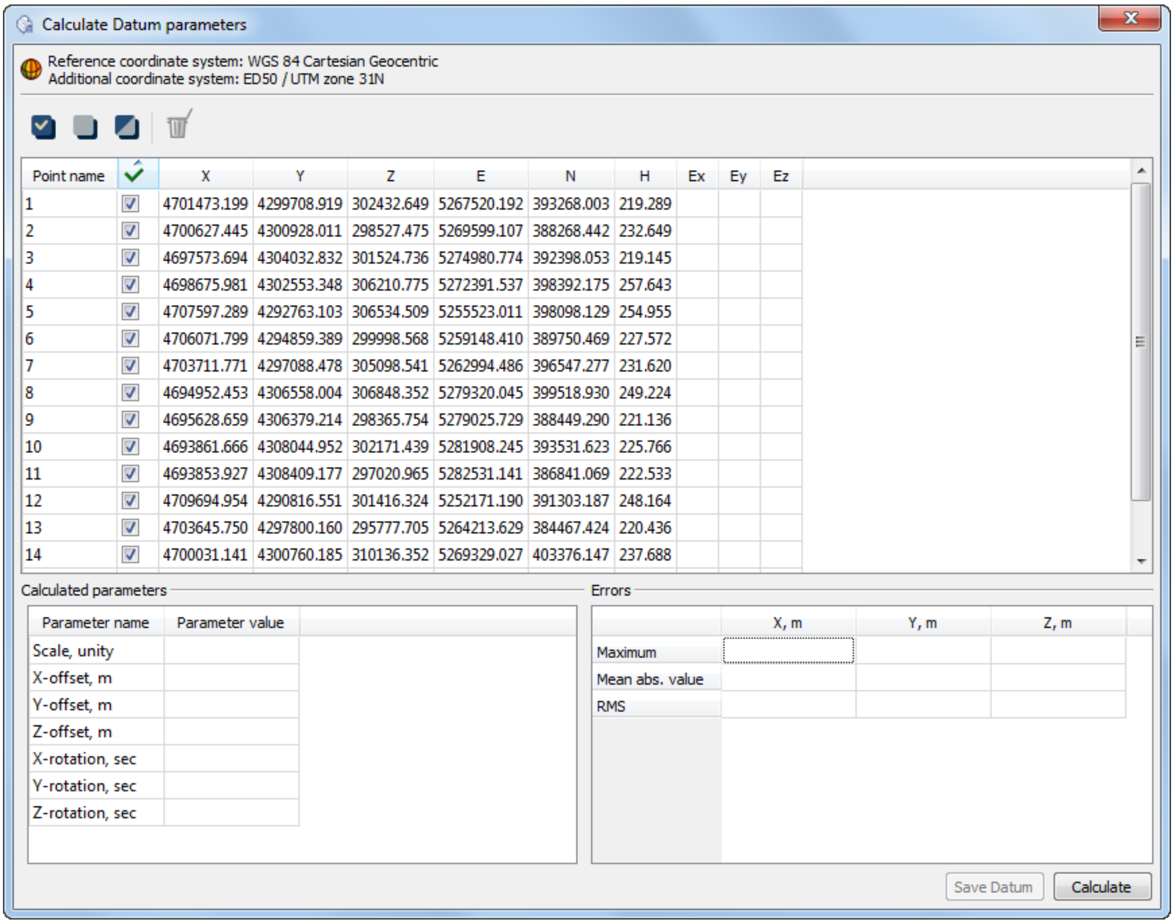


Fig. F.5. The Calculate Datum parameters window

The **Calculate Datum parameters** window contains the following interface elements:

- A panel displaying information about the user-specified coordinate systems of two loaded sets of point coordinates:
  - **Reference coordinate system** – is the coordinate system of the point set loaded into the left part of the *GeoCalculator* window;
  - **Additional coordinate system** – is the coordinate system of the point set loaded into the right part of the *GeoCalculator* window.

  The program calculates the parameters of transformation from the reference coordinate system to the additional one.

- A summary table containing information about the loaded sets of point coordinates and including the following columns:

- Point name column;
- A column containing checkboxes to include or exclude certain point pairs from the calculation of Datum transformation parameters;
- Three columns containing the point coordinates from the left-hand *GeoCalculator* coordinate set;
- Three columns containing coordinates of the point that corresponds to the left-hand one from the right-hand *GeoCalculator* coordinates;
- Three columns containing Ex, Ey and Ez discrepancy data (to be displayed after the calculation is complete).

• Main **Calculate Datum parameters** toolbar to manage records in the table. The system allows either temporarily excluding specific point pairs from the calculation of Datum transformation parameters, or deleting a point pair from the user-loaded sets. The toolbar contains the following buttons

- – select all pairs of points;
- – deselect all pairs of points;
- – invert the selection of pairs of points;
- – delete the selected pair of points from the loaded sets.

Changes made to the table are displayed in the **Calculate Datum parameters** window only. To return to the originally loaded point sets, close this window and open it again by clicking in the main *GeoCalculator* toolbar.

The buttons of the main toolbar are partially duplicated by the checkboxes in the second column of the table described above, as well as by the items of the context menu that opens when you right-click on the corresponding row of the table. The menu contains the following items:

- **Delete selected point** button is to delete the selected point from both loaded sets;
- **Exclude selected point** from calculations;
- **Return selected point** into calculations;
- **Return all** – include all pairs of points in calculations.

• A table in the lower left part of the window containing the **Calculated parameters** of transformation between two spatial coordinate systems, **scaling**, **three axis rotation**

angular elements, and **three linear elements** of the coordinate system center translation (will be displayed after the calculations are completed);

- A table in the lower right part of the window displaying the calculated **Errors** (will be displayed after the calculations are completed).

To **calculate** the refined transformation parameters between the spatial coordinate systems, click the appropriate button. The calculation results are displayed in two tables below: **Calculated parameters** and **Errors** (and also in the Ex, Ey and Ez columns of the main table). Seven shift parameters (scaling, X, Y, Z-translation, and X, Y, Z-rotation) are displayed in the lower left table, and errors and residual discrepancy in the lower right one).

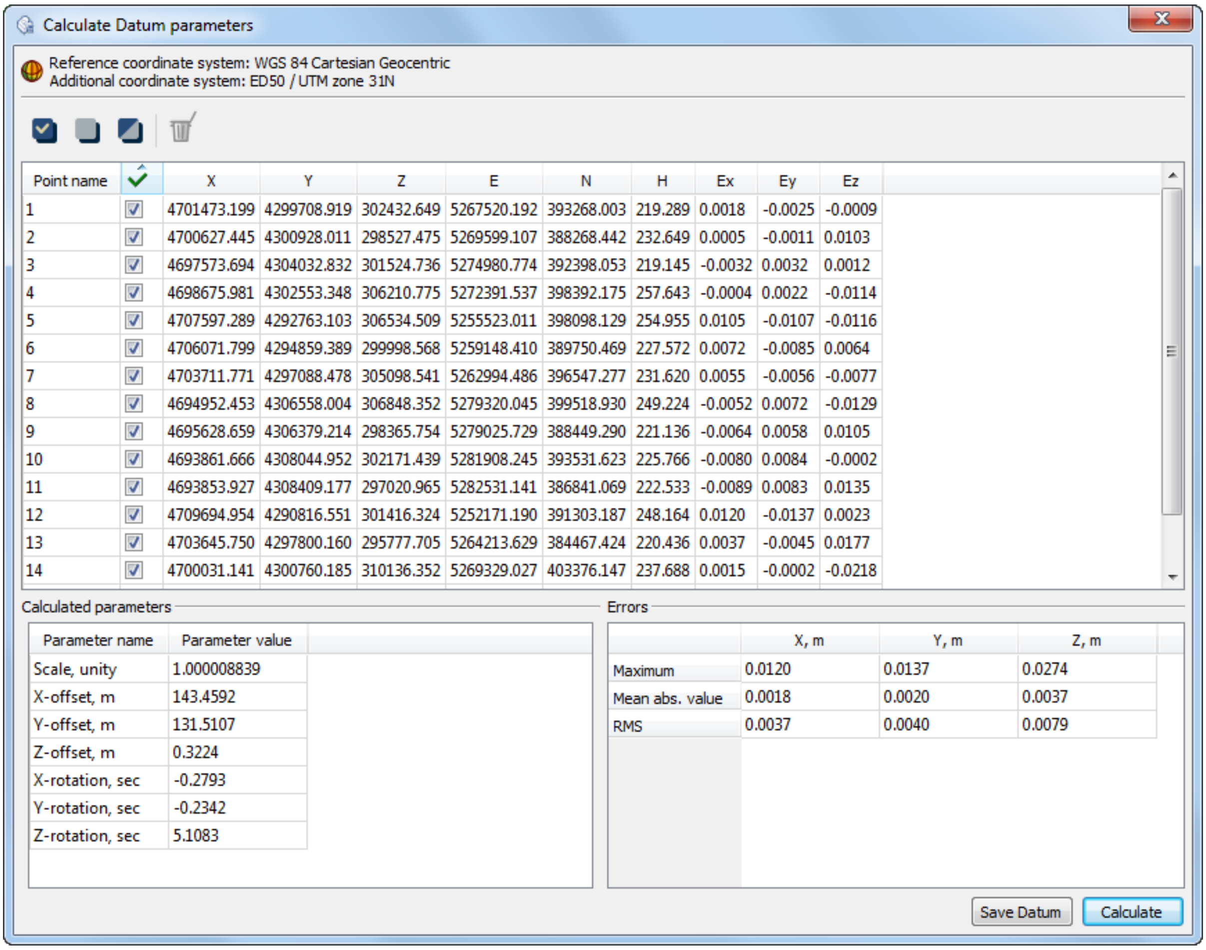


Fig. F.6. The results of Datum parameter calculations

To create a user-copy of the additional coordinate system with a custom Datum that includes the set of datum transformation parameters using the *rotation-translation-scaling* **Calculated parameters**, click **Save datum**.

The following information box appears:

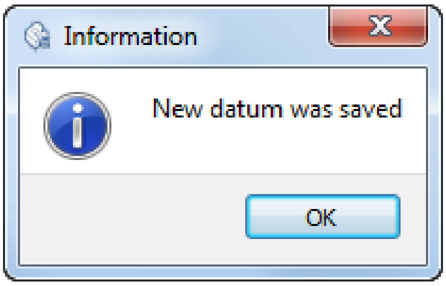


Fig. F.7. An information message

To view the created user coordinate system in the *GeoCalculator* window, click OK. The information message and **Calculate Datum parameters** window will be closed. Do not close the *GeoCalculator* window with loaded point sets.

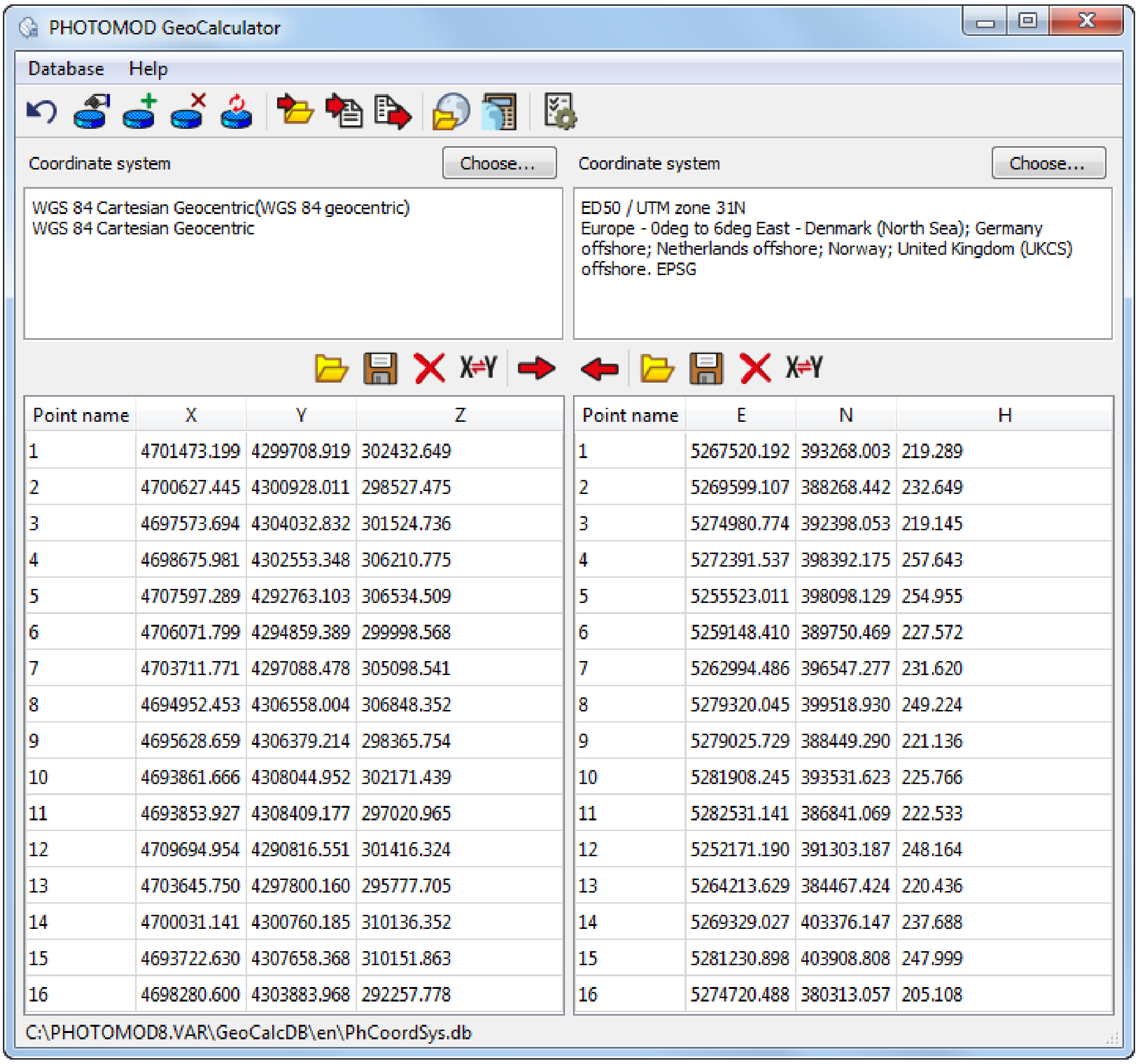


Fig. F.8. The main GeoCalculator window with loaded data

F.4. Viewing the user coordinate system Info

To view the information about the user coordinate system created, perform the following:

1. Click **Choose** in the right part of the *GeoCalculator* window. The **Coordinate systems** window opens:

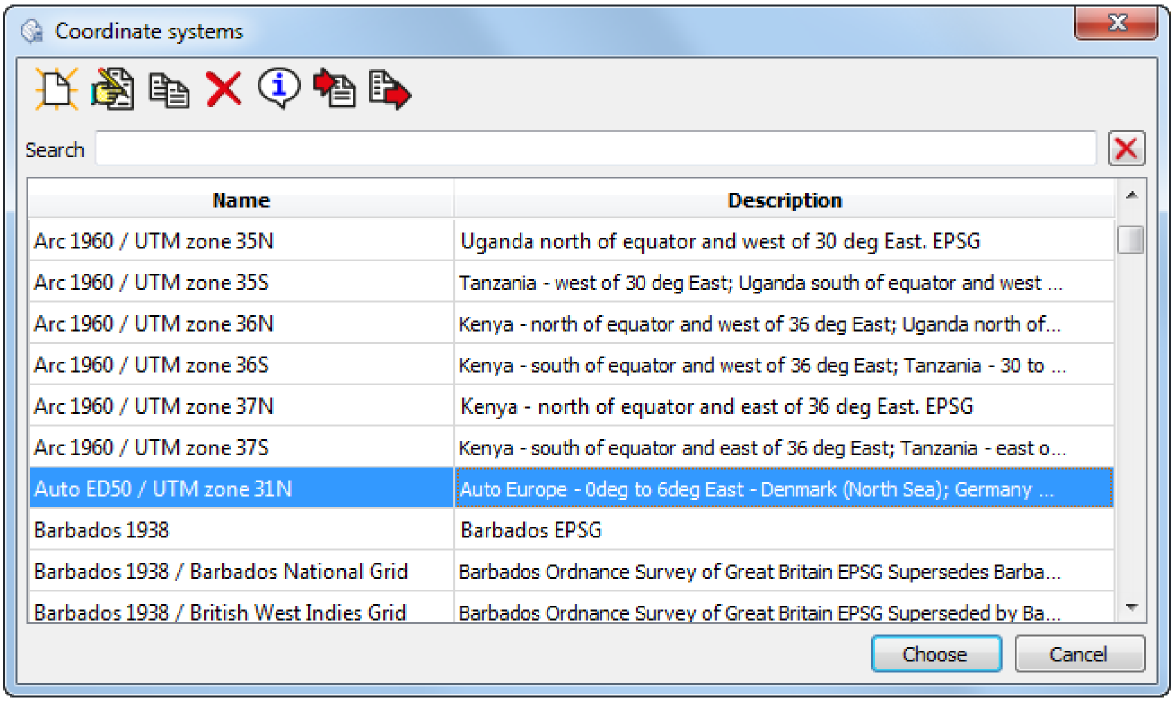


Fig. F.9. The window with coordinate systems listed

2. Find and select the created user coordinate system in the list. The name of the user coordinate system is generated automatically, according to the following template: `Auto <parent_coordinate_system_name>` (the coordinate system selected in the *right* side of *GeoCalculator* window). Click . The **Editing the coordinate system** window opens

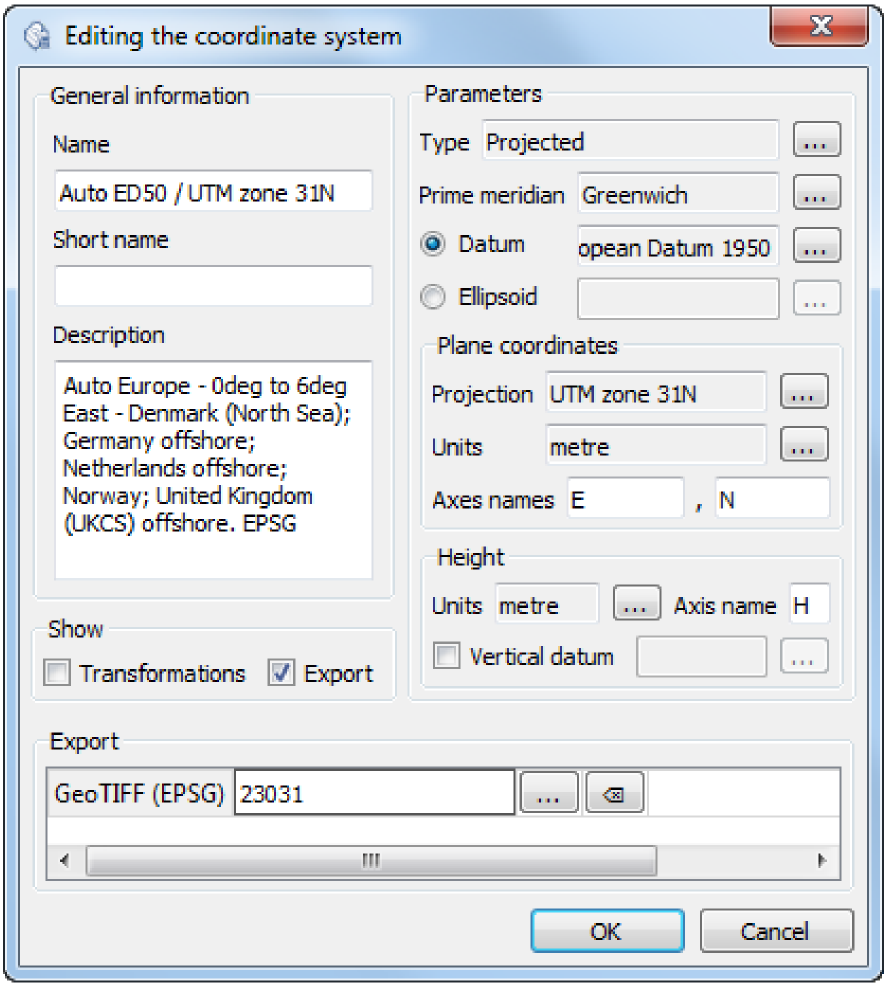


Fig. F.10. The Editing the coordinate system window

The **Datum** field displays the name of the custom datum created together with the user coordinate system.

The custom datum name is generated automatically according to the following template: `Auto <parent_datum_name>` (corresponding to the parent coordinate system).

3. To view custom datum parameters click ... next to the **Datum** field. The **Datum** window opens:

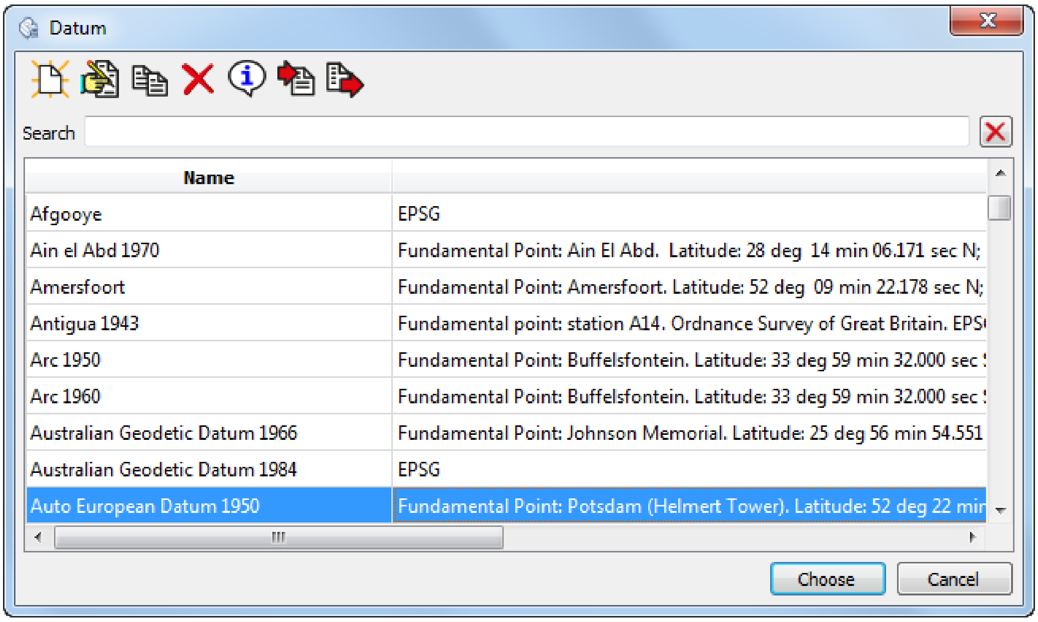


Fig. F.11. The Datum window

4. Find and select the custom datum (see the previous item). Click . The **Datum editing** window opens:

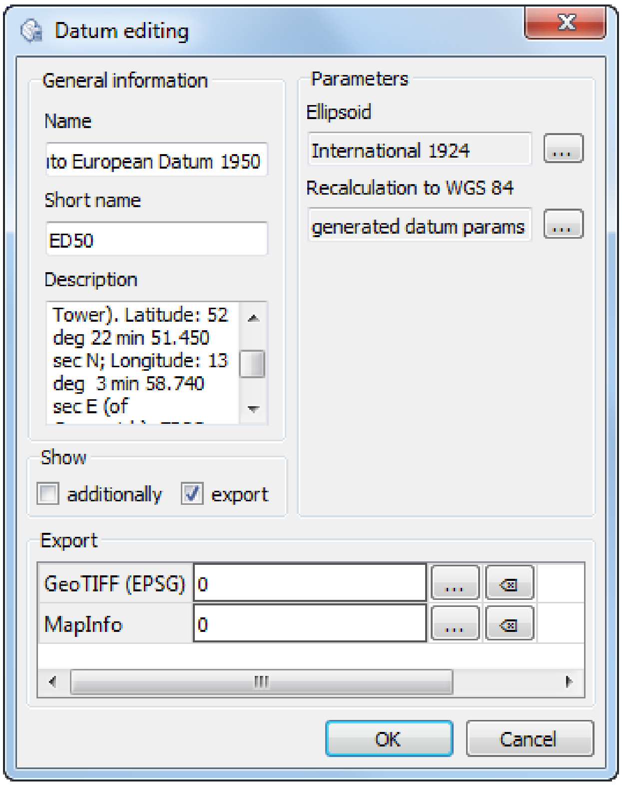


Fig. F.12. The Datum editing window

The **Recalculation to WGS 84** field displays the name of the custom datum parameter set created along with the custom datum and coordinate system.

The name of the custom datum parameter set is generated automatically according to the following template:

`Auto generated datum params;`

`Auto generated datum params[1];`

`Auto generated datum params[2]`, etc. (according to the order of creating user sets of transformation parameters).

5. To see the custom set of datum parameters, click ... next to the **Recalculation to WGS 84** field. The **Datum transformations** window opens:

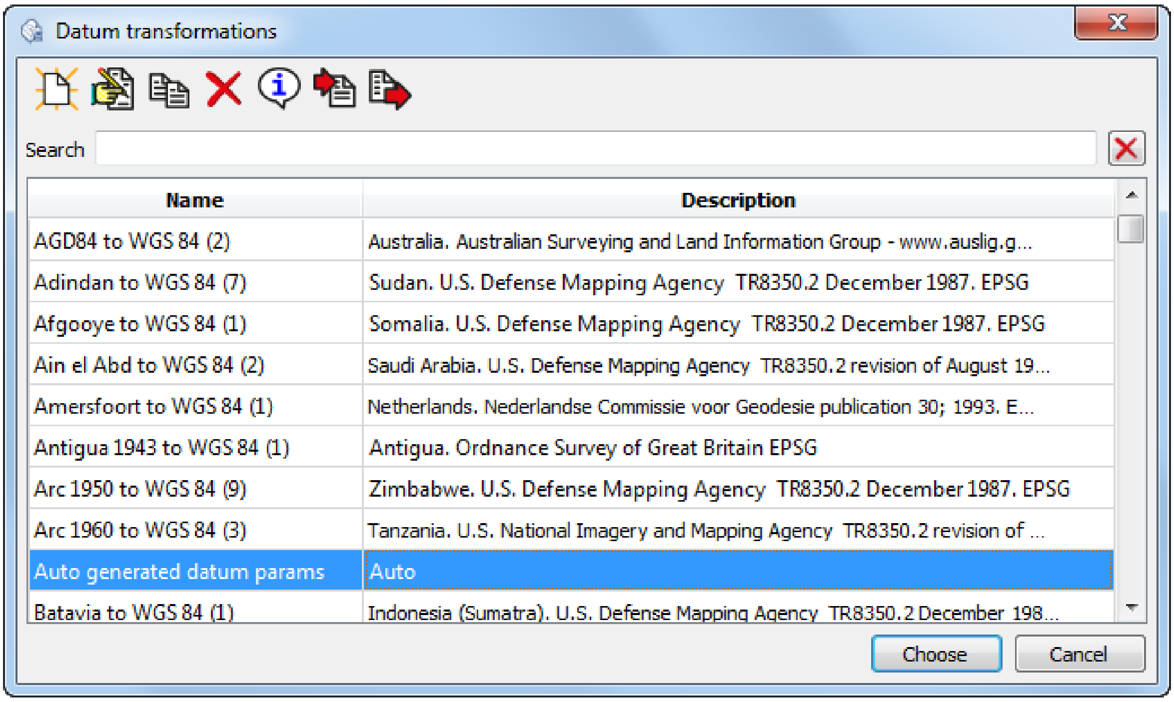


Fig. F.13. The Datum transformations

6. Find and select the desired `Auto generated datum params` (see above). Click . The **Datum transformation parameters** window opens:

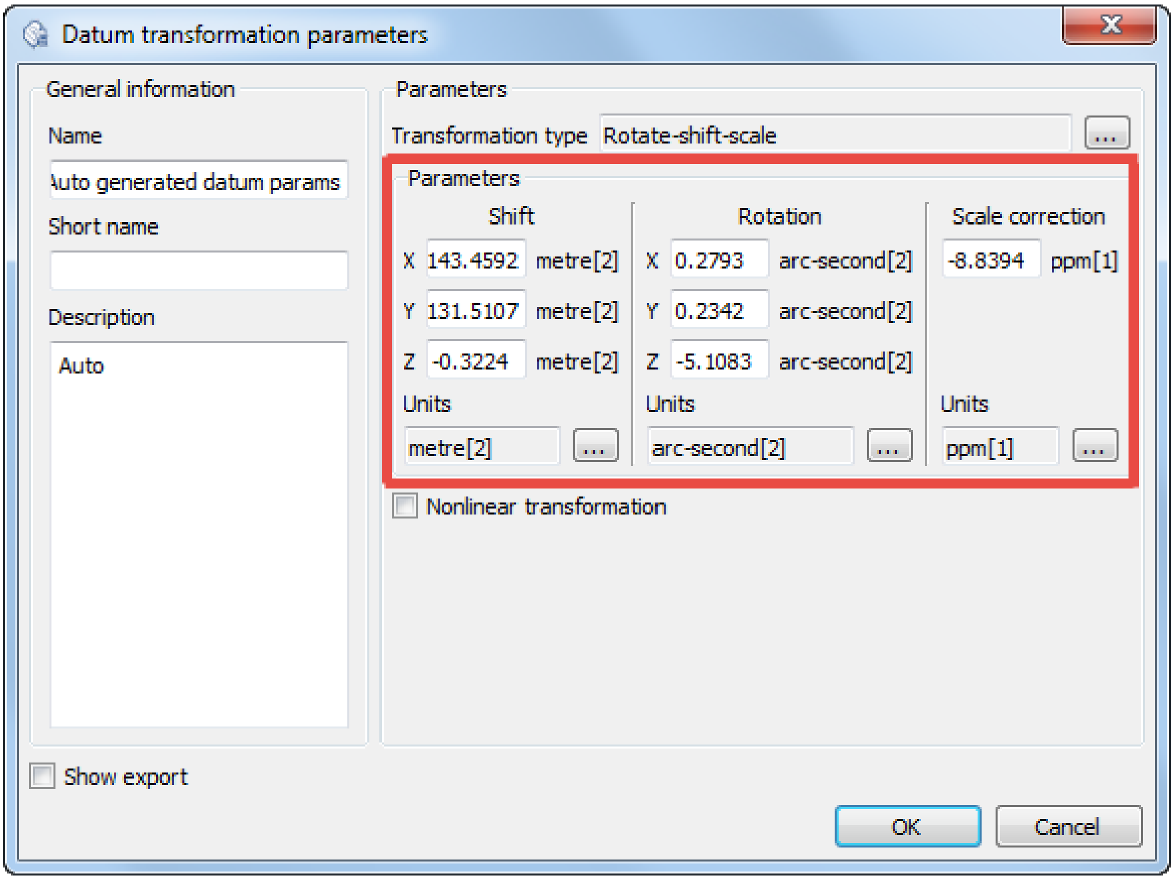


Fig. F.14. The Datum transformation parameters window

The **parameters** section displays calculated datum transformation parameters, i.e. **scale**, **three axis rotation angular elements**, and **three linear elements** of the coordinate system center shift.

7. Go back to **Coordinate systems** (see item **1**) closing the relevant windows. Select the user coordinate system and click **Choose**.

   The **Coordinate systems** window will be closed. The selected user coordinate system will be displayed on the right side of the *GeoCalculator* program window.

8. Click  in the main *GeoCalculator* toolbar. The **Web-map** window opens. Here you can evaluate at-a-glance the results of using the refined parameters of shift between two coordinate systems:

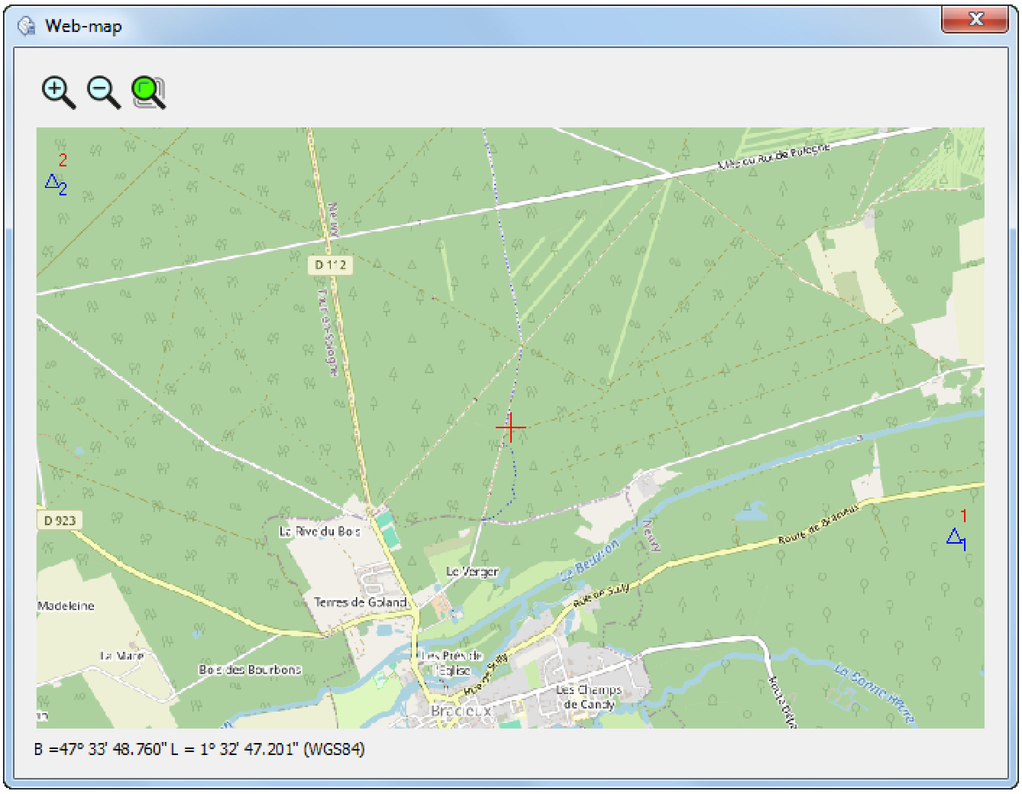


Fig. F.15. The Web-map window (refined rotation-translation-scaling datum transformation parameters are applied)

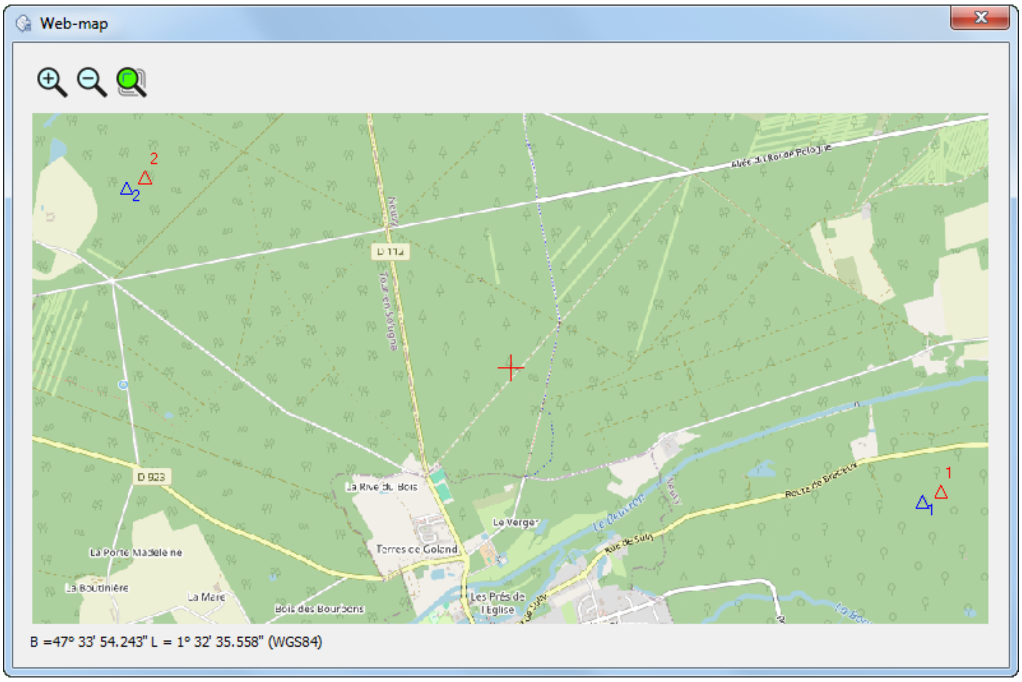


Fig. F.16. The Web-map window (refined rotation-translation-scale datum transformation parameters are not applied, see Section F.2)

F.5. Transformation sequence

The calculation of shift between two coordinate systems is according to the following scheme:

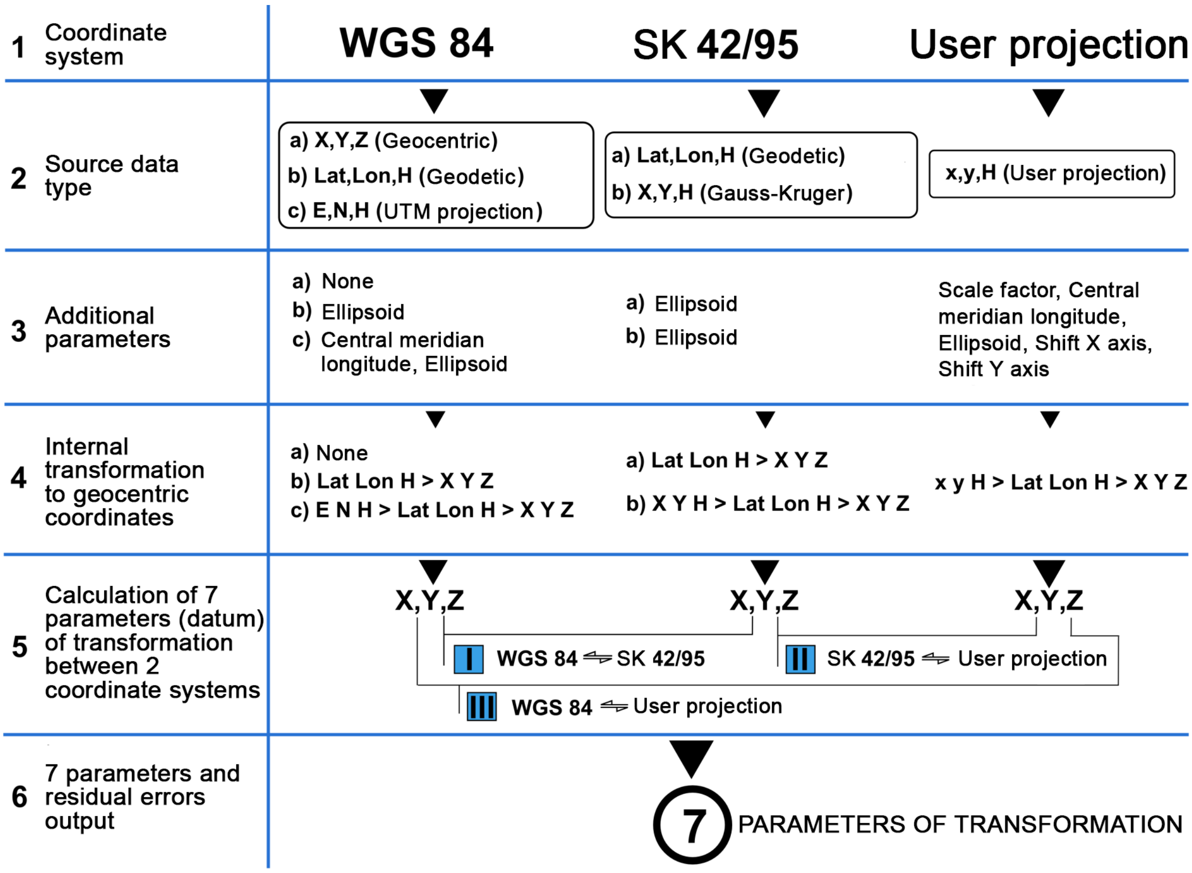


Fig. F.17. Calculating shift between two coordinate systems

F.5.1. Checking input data errors when calculating parameters of transformation between coordinate systems

Let us consider the features of calculating the parameters of transformation between two coordinate systems with an error in the input data using the following example:

1. There is an elevation error in the fourth file line.

The system allows you to manually correct the loaded data in the main *GeoCalculator* window. There is no such feature in the **Calculate Datum parameters** window.

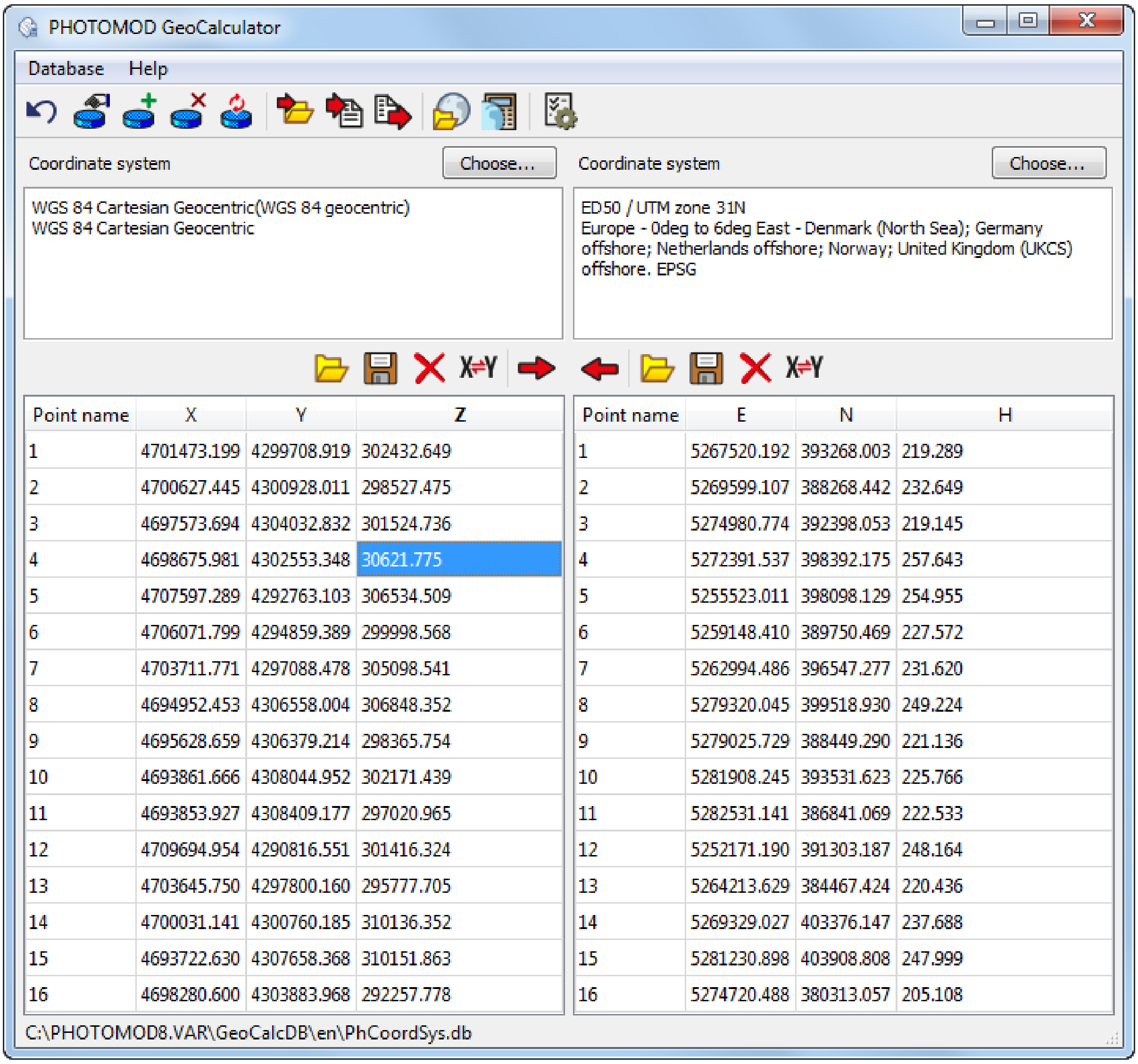


Fig. F.18. Original data with an elevation error

2. When calculating the transformation parameters between two coordinate systems, coordinates with an error are taken into account. As a result, the transformation parameters are calculated incorrectly: the residual discrepancies at a given point exceed the allowable values.

   In case of very large residual discrepancies, an appropriate information message is issued.

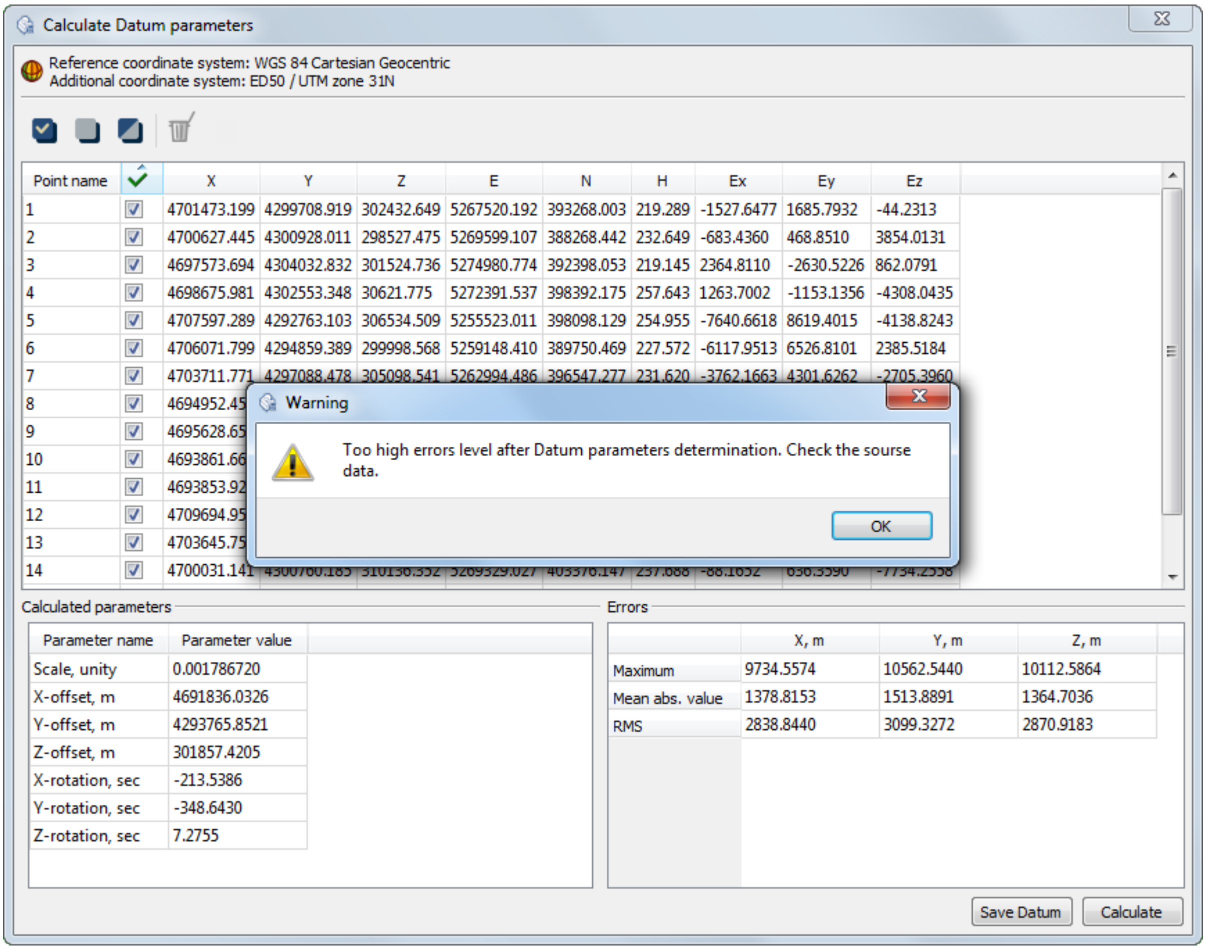


Fig. F.19. The result of calculating parameters with an error in the source data

3. [optional] Click OK to close the warning;

4. In order to exclude a point with erroneous coordinates from calculations, right-click on the desired row (in the corresponding table) and select **Exclude selected point** in the context menu that opens.

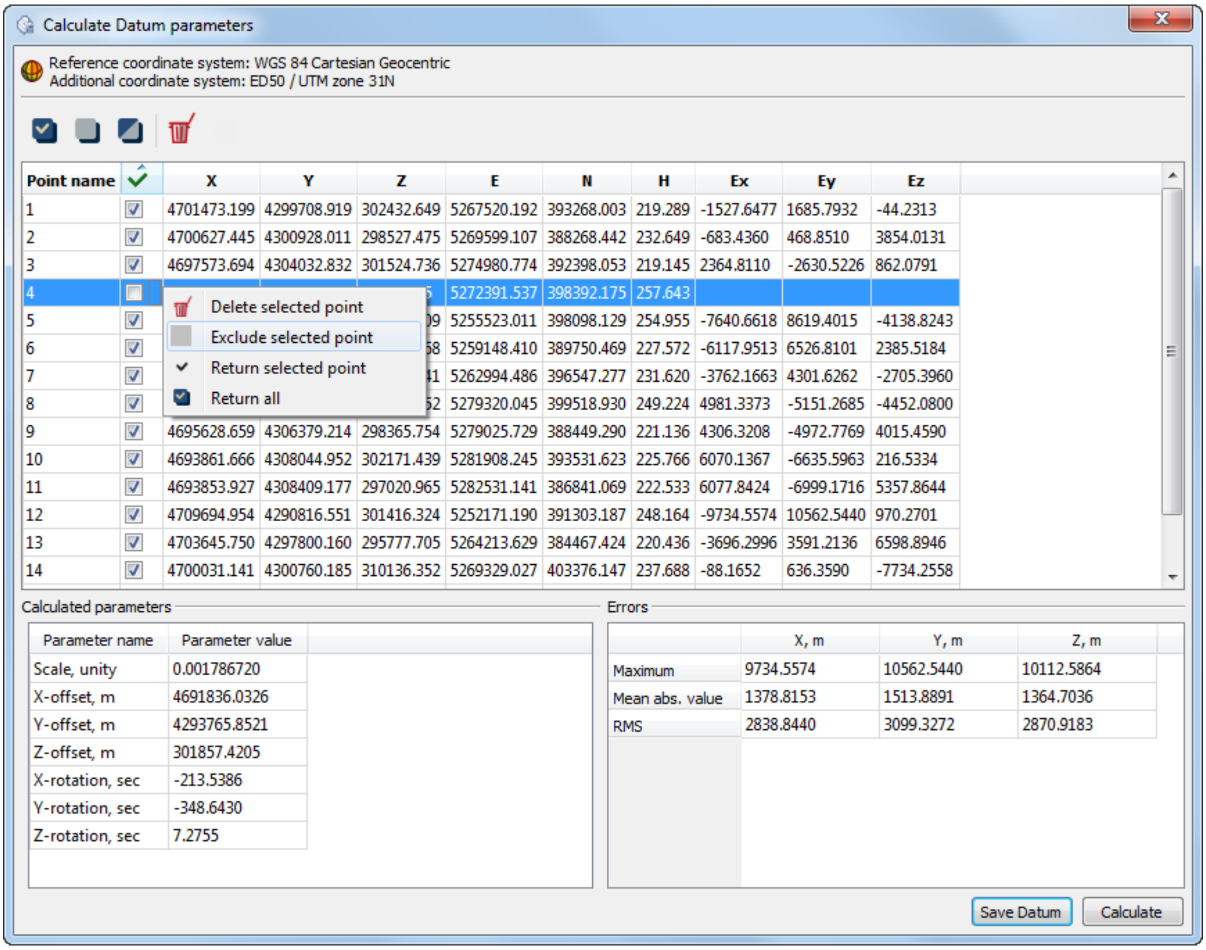
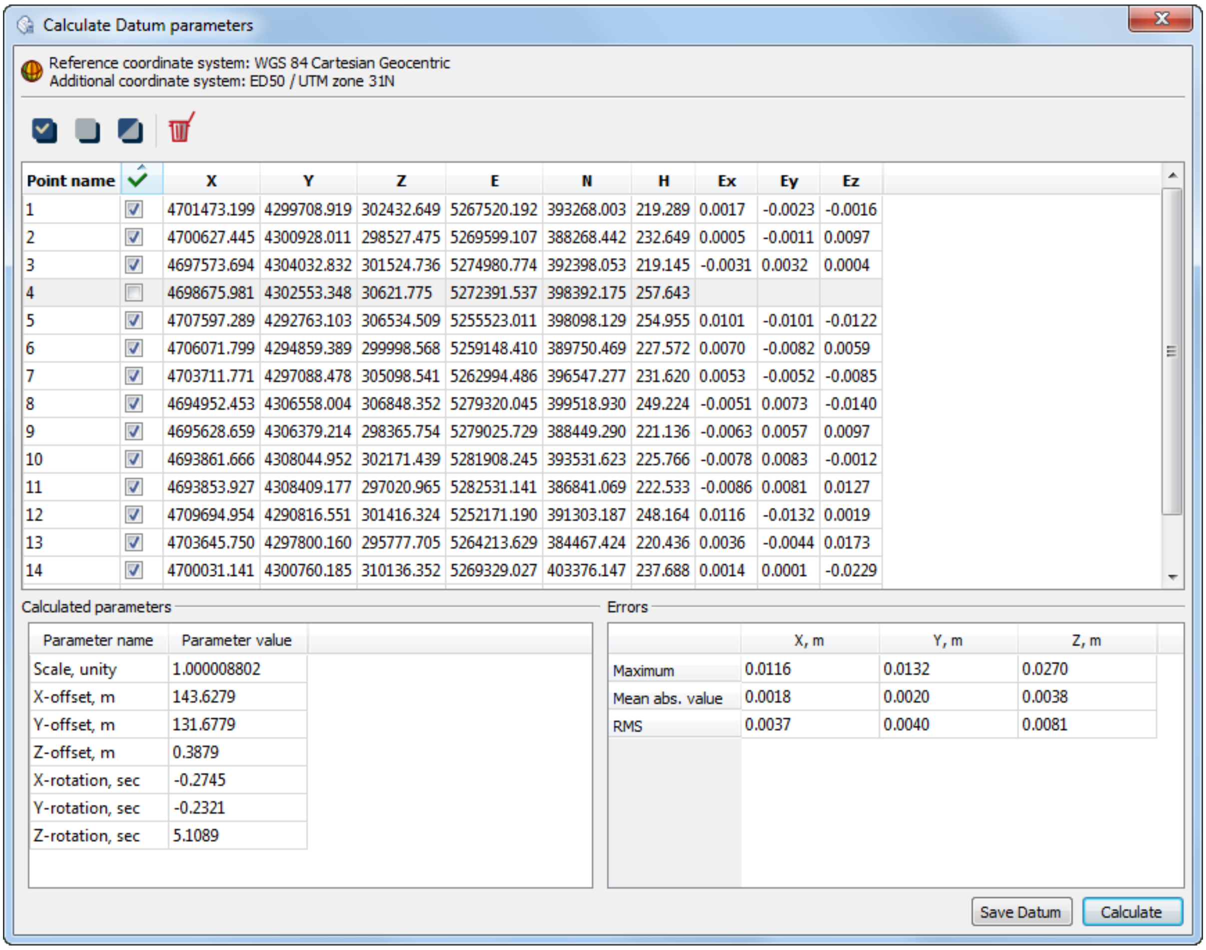


Fig. F.20. The result of calculating parameters with an error in the source data

5. Click **Calculate** again. When the point containing erroneous coordinates is excluded, the parameters are calculated correctly (residual discrepancies at all remaining points are within tolerance).


Calculate Datum parameters

Reference coordinate system: WGS 84 Cartesian Geocentric
Additional coordinate system: ED50 / UTM zone 31N

Point name	✓	X	Y	Z	E	N	H	Ex	Ey	Ez
1	☑	4701473.199	4299708.919	302432.649	5267520.192	393268.003	219.289	0.0017	-0.0023	-0.0016
2	☑	4700627.445	4300928.011	298527.475	5269599.107	388268.442	232.649	0.0005	-0.0011	0.0097
3	☑	4697573.694	4304032.832	301524.736	5274980.774	392398.053	219.145	-0.0031	0.0032	0.0004
4	☐	4698675.981	4302553.348	30621.775	5272391.537	398392.175	257.643			
5	☑	4707597.289	4292763.103	306534.509	5255523.011	398098.129	254.955	0.0101	-0.0101	-0.0122
6	☑	4706071.799	4294859.389	299998.568	5259148.410	389750.469	227.572	0.0070	-0.0082	0.0059
7	☑	4703711.771	4297088.478	305098.541	5262994.486	396547.277	231.620	0.0053	-0.0052	-0.0085
8	☑	4694952.453	4306558.004	306848.352	5279320.045	399518.930	249.224	-0.0051	0.0073	-0.0140
9	☑	4695628.659	4306379.214	298365.754	5279025.729	388449.290	221.136	-0.0063	0.0057	0.0097
10	☑	4693861.666	4308044.952	302171.439	5281908.245	393531.623	225.766	-0.0078	0.0083	-0.0012
11	☑	4693853.927	4308409.177	297020.965	5282531.141	386841.069	222.533	-0.0086	0.0081	0.0127
12	☑	4709694.954	4290816.551	301416.324	5252171.190	391303.187	248.164	0.0116	-0.0132	0.0019
13	☑	4703645.750	4297800.160	295777.705	5264213.629	384467.424	220.436	0.0036	-0.0044	0.0173
14	☑	4700031.141	4300760.185	310136.352	5269329.027	403376.147	237.688	0.0014	0.0001	-0.0229

Calculated parameters

Parameter name	Parameter value
Scale, unity	1.000008802
X-offset, m	143.6279
Y-offset, m	131.6779
Z-offset, m	0.3879
X-rotation, sec	-0.2745
Y-rotation, sec	-0.2321
Z-rotation, sec	5.1089

Errors

	X, m	Y, m	Z, m
Maximum	0.0116	0.0132	0.0270
Mean abs. value	0.0018	0.0020	0.0038
RMS	0.0037	0.0040	0.0081

Save Datum
Calculate

Fig. F.21. The result of calculating the parameters without taking into account the error in the source data