Exercises Open Source Software for Preprocessing GIS Data for Hydrological Models

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OpenCourseWare
ocw.unesco-ihe.org

Contents

1 Preface

A Geographic Information System (GIS) can be a useful tool for preparing the input of models and tools. Furthermore, in this era of Open Data ample open access data is available that can easily be retrieved from the internet and integrated in open source desktop GIS software, such as QGIS.

These exercises will guide you through different steps that are needed to preprocess data to be used in models and tools. In the first exercise you will learn how to register a scanned topographic map and use it as a backdrop for digitizing vector data. In the second exercise you will learn how to import data from spreadsheets into a GIS and to use it to join tables, manipulate the attribute table and interpolating the data to a continuous raster layer. In the third exercise you will download open access data from OpenStreetMap and use it for further analysis and conversion. The geodatabase will also be introduced in this exercise. In the fourth exercise you will use map algebra for spatial planning. Finally, you will learn how to delineate catchments and streams form digital elevation models and to present them in maps or in an interactive webpage.

The exercises have been developed for different MSc programmes at UNESCO-IHE and tailor made trainings in Uganda, financed by the Vitens Evides International (VEI) fund. I would like to thank Jan Hoogendoorn and Jonne Kleijer, GIS experts from VEI, for their contribution to these exercises. In the near future we will further update the exercises and distribute it as OpenCourseWare so the whole community can use the course materials.

2 Learning Objectives

After following this step-by-step tutorial you will be able to:

- Use QGIS in its main functionalities, also in conjunction with plugins
- Digitize features from a scanned map or satellite image
- Import tabular data in a GIS
- Do simple vector analysis
- Interpolate point data
- Convert vector and raster data
- Reproject vector and raster data
- Use map algebra
- Use online data
- Perform catchment and stream delineation

2.1 Software requirements

During the next exercises we will make use of the following software:

- QGIS ver 2.14 (Essen) or higher,
- Google Earth,
- Firefox Mozilla
- MS Excel or OpenOffice Calc

You need an internet connection to download plugins or to use the open access data.

2.2 Preparation

Please note that QGIS is already installed on the laptops of UNESCO-IHE participants. Please do not change the version and skip this section. The exercises have been tested for QGIS 2.14.x.

1) Download QGIS from http://www.qgis.org/en/site/forusers/download.html
2) Install QGIS
3) Install the exercise data from http://ocw.unesco-ihe.org

2.3 Convention

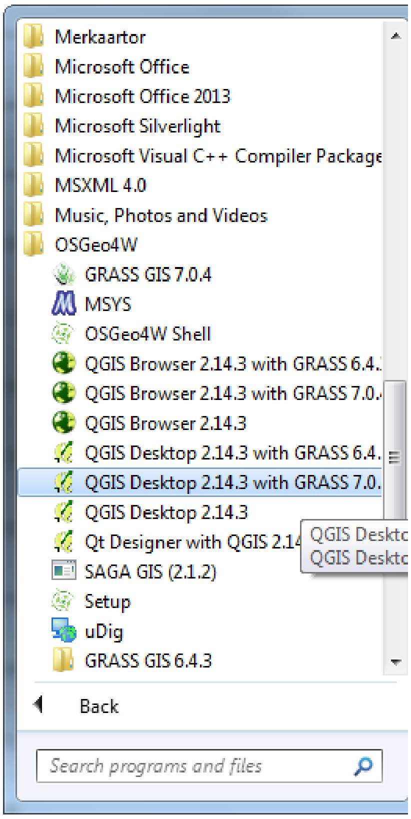
Throughout this guide we have used three different fonts according to what kind of operation we wanted to point at:

- Calibri, is used for the main text
- *Times New Roman, Italic, is used to identify software commands*
- `Courier New is used for text input, that is text that you have to write in the software, or for file names`

3 Getting familiar with QGIS

3.1 Start QGIS 2.14

You can start QGIS 2.14 Desktop by looking for it in the Start menu or using the search function. Make sure you open the QGIS Desktop with Grass in order to have all functionality we need.



3.2 The screen

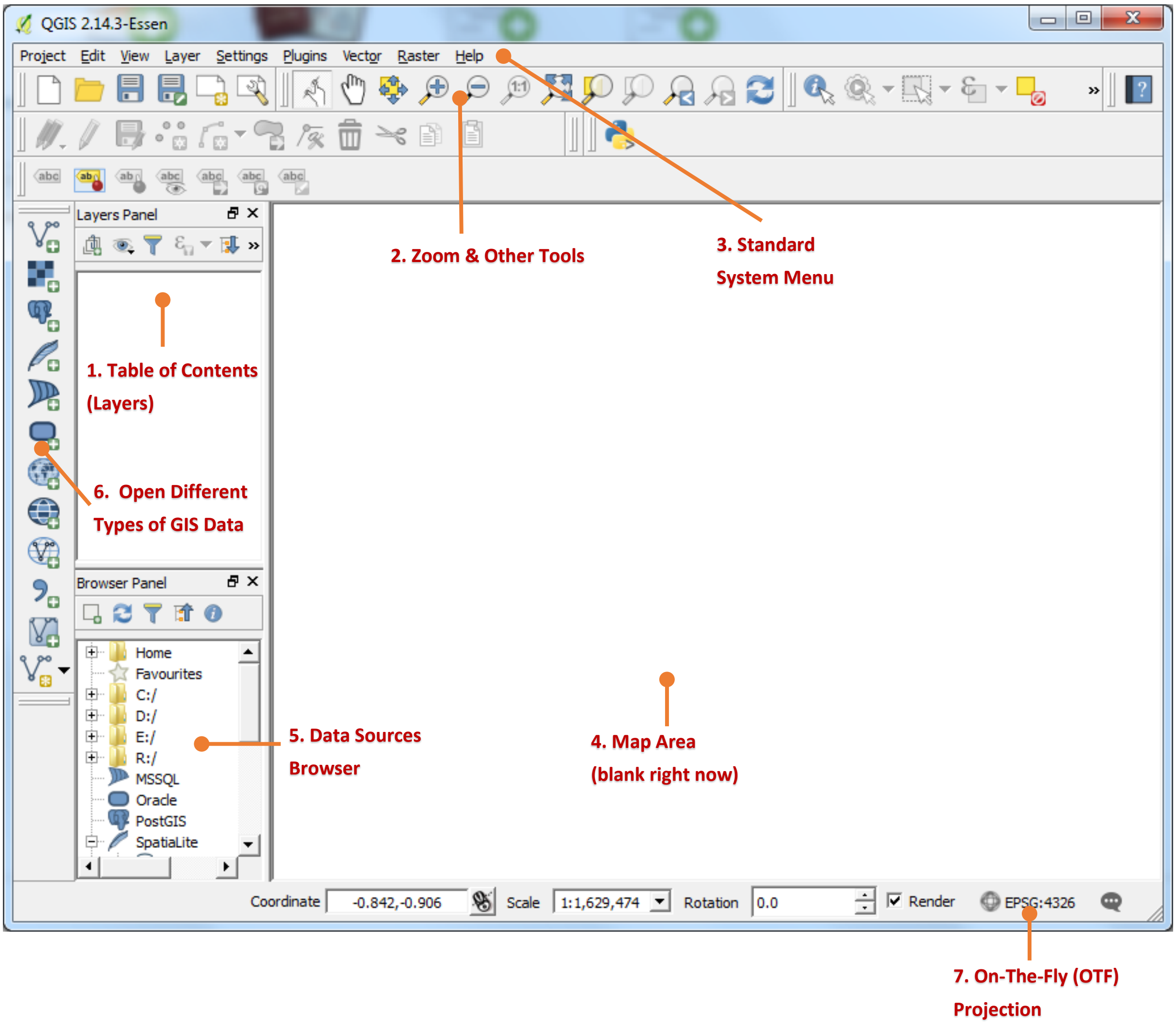
Like many commercial GIS also QGIS has a "traditional" GIS layout.

It is made of the Standard System Menu or Main Menu (we will refer to Main Menu in the following pages) which is always on the top of the software's window, of standard toolbars like the Zoom Tools, or others that can be activated clicking in the Main Menu *View* and then *Toolbars*.

On the left hand side there is the Table of Content (Layers list) area, where all the layers displayed are shown. To the left of this space there is a vertical toolbar, the Manage Layers toolbar.

In the centre of the window stay the Map Area, where all maps will be displayed.

More information about the QGIS Graphical User Interface can be found here:
http://docs.qgis.org/2.14/en/docs/user_manual/introduction/qgis_gui.html



QGIS 2.14.3-Essen
Project
Edit
View
Layer
Settings
Plugins
Vector
Raster
Help
Layers Panel
Browser Panel
Home
Favourites
C:/
D:/
E:/
R:/
MSSQL
Oracle
PostGIS
SpatiaLite
Coordinate
-0.842,-0.906
Scale
1:1,629,474
Rotation
0.0
Render
EPSG:4326
1. Table of Contents (Layers)
2. Zoom & Other Tools
3. Standard System Menu
4. Map Area (blank right now)
5. Data Sources Browser
6. Open Different Types of GIS Data
7. On-The-Fly (OTF) Projection

Exercise 1: Digitizing from a scanned map

4 Digitizing from a scanned map

4.1 Introduction

In order to use hardcopy maps in a GIS, they need to be scanned and georeferenced. Georeferencing is also needed for raw remote sensing images, such as aerial photographs and satellite images.

For the best result, choose a map sheet that is clean and does not have too many folds. Use a scanner that is large enough to scan the whole map. The resolution of the scanner should be large enough (e.g. 1200 dpi) to have enough detail in the resulting raster maps.

For georeferencing we need to link locations on the scanned image to coordinates. There are two ways:

1. Collect ground control points (GCPs) at locations that are clearly visible in the image, such as bridges and junctions.
2. If the hardcopy map contains a coordinate grid, you can use the printed grid as a reference. Make sure that you know the projection of this grid, which usually is stated on the map.

In this exercise we will use a scanned map of Mount Marcy (USGS, 1979) (`Mount_Marcy_New_York_USGS_topo_map_1979.JPG`), which we will georeference with the coordinate grid printed on the map. You can find the data (Data Exercise 1) on the OpenCourseWare website (http://ocw.unesco-ihe.org/course/view.php?id=11).

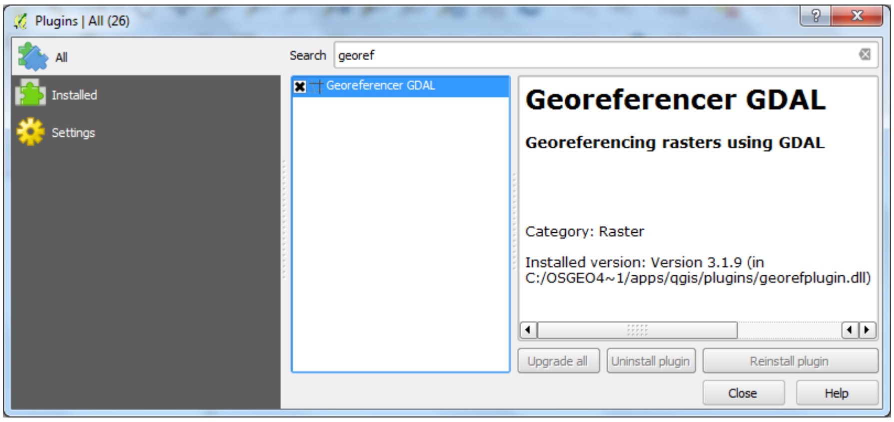
4.2 Choosing the projection

Have a look at the scanned map and try to find the projection that has been used. You can use any image viewing software for this. Which projection was used? Look for the EPSG code in http://www.spatialreference.org and write it down.

4.3 Enable the Georeferencer GDAL plugin

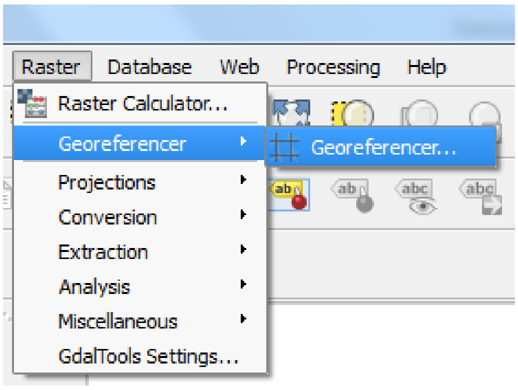
The *Georeferencer GDAL plugin* is a core plugin, which means that it is already installed. In order to use it, you need to activate it. This works as follows:

1. In the main menu go to *Plugins* → *Manage and install plugins…*
2. Search for *Georeferencer GDAL* and check the box
3. Click *Close* to close the dialogue



4.4 Importing the scanned map into the Georeference GDAL plugin

1. From the main menu choose *Raster* → *Georeferencer* → *Georeferencer…*



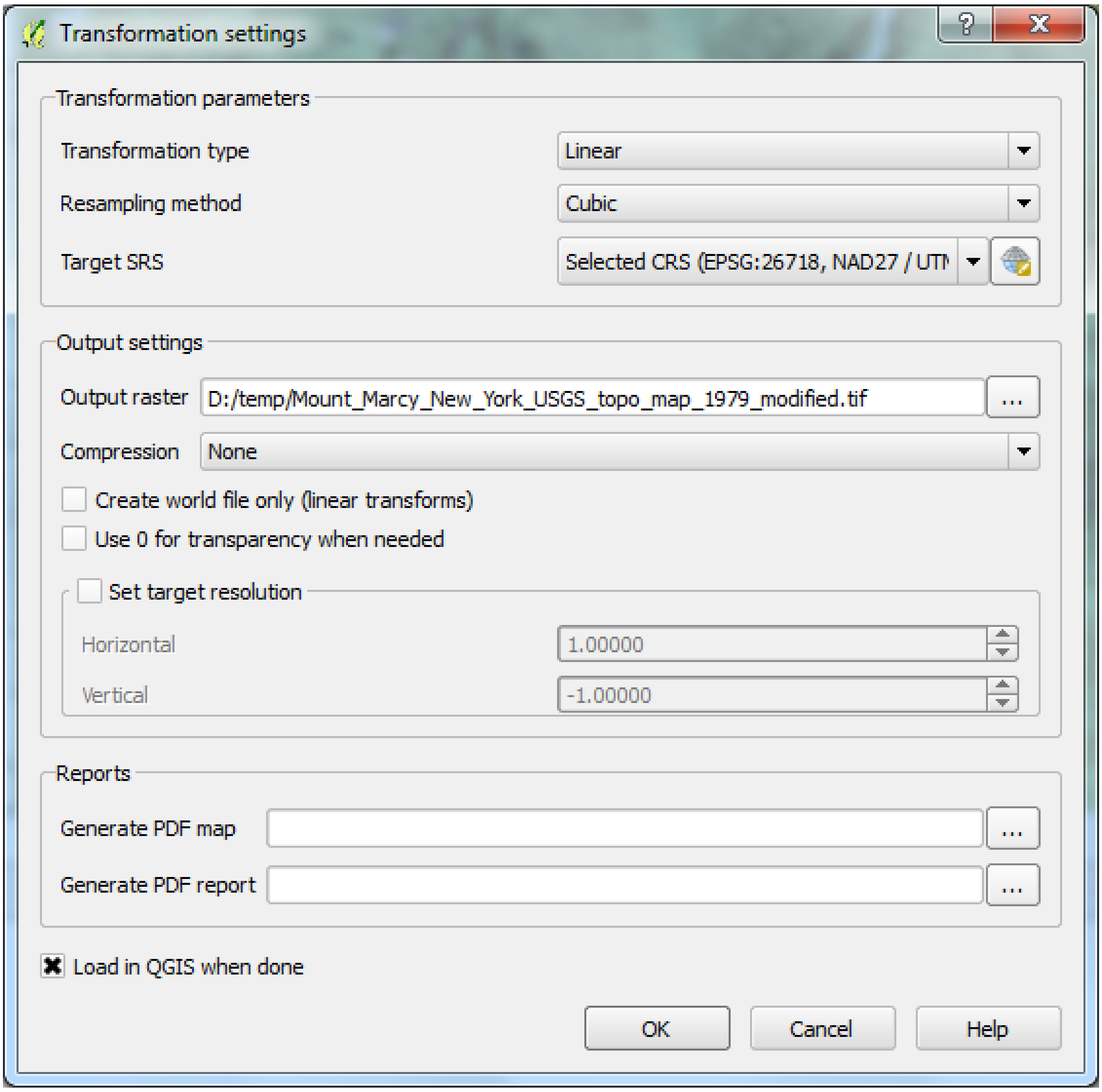
2. Click the Open Raster button 
3. Browse to the `Mount_Marcy_New_York_USGS_topo_map_1979.JPG` file
4. A window will open where you have to specify the *Coordinate Reference System (CRS)* of this input map. It does not yet have a CRS, so you can click *Cancel*.

4.5 Setting the transformation parameters

First we have to set the transformation settings (see also screenshot on next page).

1. In the menu choose *Settings* → *Transformation Settings…*
2. Here you can choose:
    a. Different transformation types. A simple linear transformation can be used if the map is not much deformed. The other ones can be tried when more deformation exists. We will start with a linear transformation.
    b. Resampling method: if you need the pixel values in further calculations, it is best to choose the nearest neighbor option. This resampling method will preserve as much as possible the original pixel values by choosing the nearest one. Visually, however, this method results in a "blocky" map. If the purpose is only for visual use, for example as a backdrop for digitization of vector layers, then it is better to choose another resampling method. Here we will use the cubic method, which uses the average of the 4 nearest pixels.
    c. Target CRS: here choose the code that you have noted before; `EPSG:26718`

   Browse to the folder where you want to safe the georeferenced map. The tool automatically adds `_modified` to the file name. So in our case the georeferenced file will be named `Mount_Marcy_New_York_USGS_topo_map_1979_modified.tif`
   Keep the other settings on default and check the box *Load in QGIS when done*. The dialogue should look like the one below.



4.6 Adding Ground Control Points (GCPs)

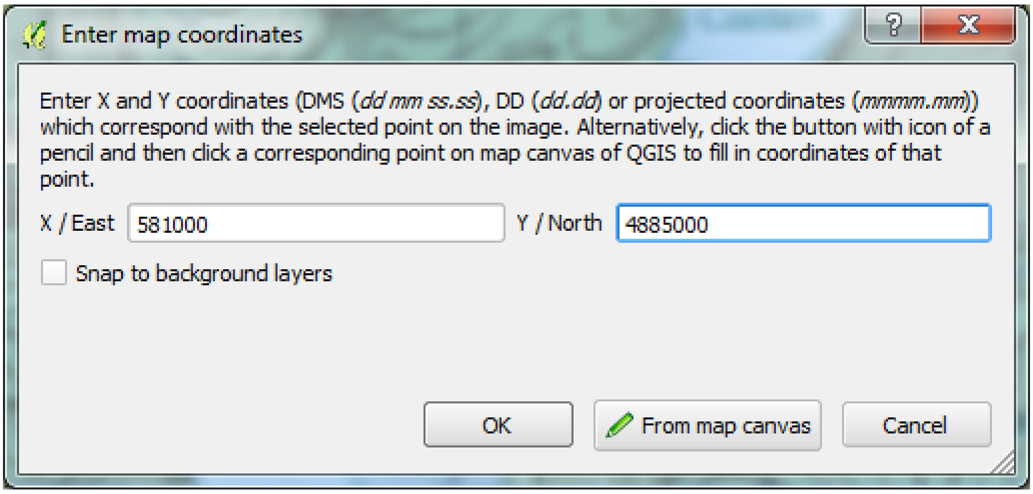
In order to link the file coordinates to real world coordinates, we need to indicate Ground Control Points (GCPs) with known coordinates. We can derive these coordinates in different ways:

- The easiest way is to use the coordinate grid on the scanned map if this is available and if it is in a known projection. We click on a node in the grid and type the corresponding X and Y coordinates in the dialogue.
- Using a reference map in the QGIS map canvas that has already been georeferenced. In this way we can obtain the right coordinates by clicking on the reference map.
- Using GCPs that were measured in the field using a GPS.

Here we will use the coordinate grid that is printed on the map.

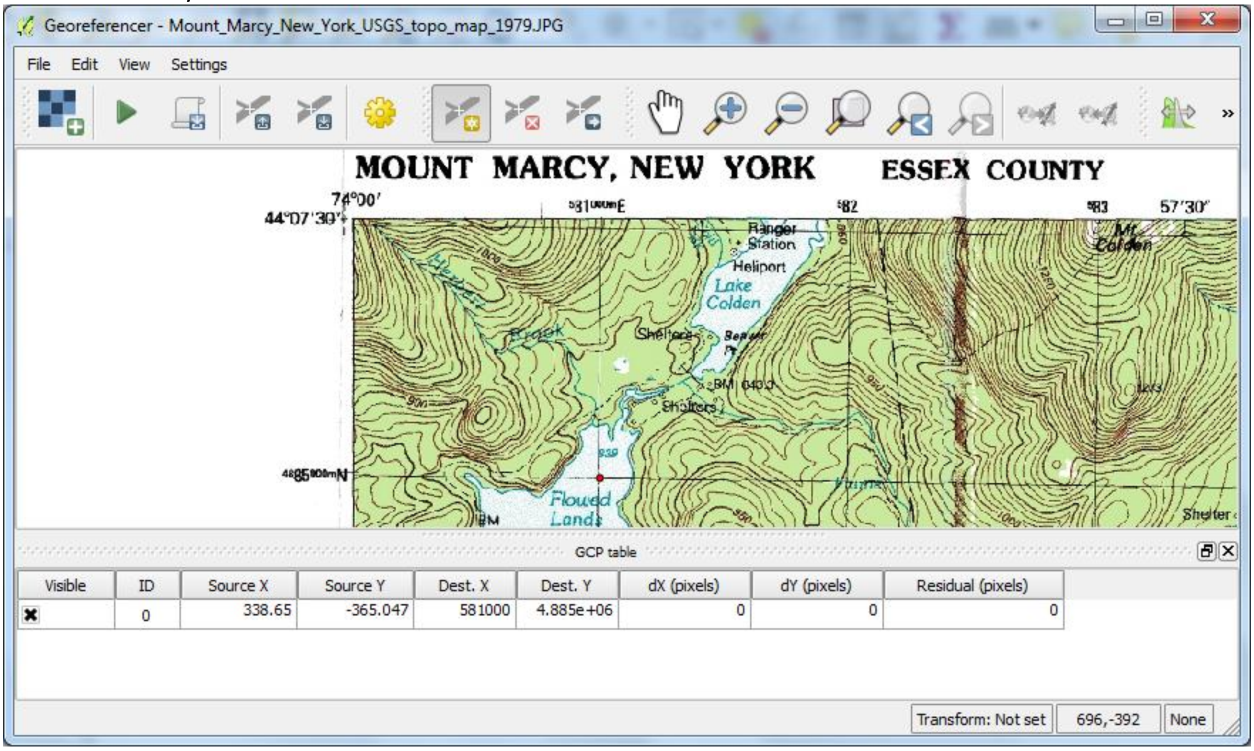
1. Zoom in on the coordinate 581000 East and 4885000 North.
2. Click the Add Point button  to add a GCP.

3. Enter the map coordinates in the pop-up window:



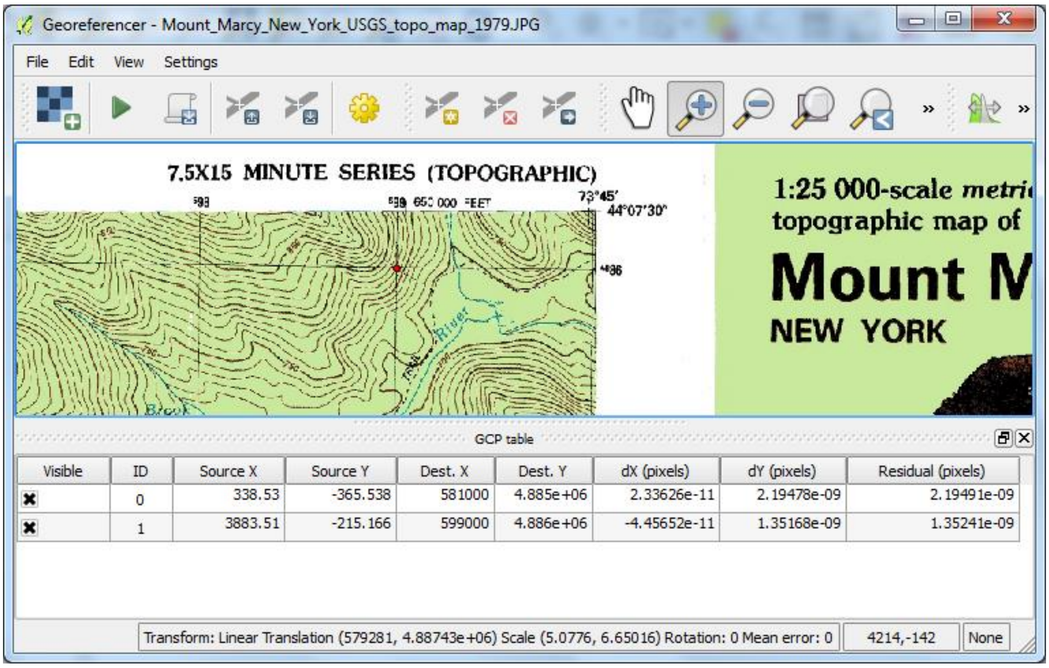
If you have a reference map in the QGIS map canvas, you can use the From map canvas button to capture the coordinate. Here we will only type the coordinates form the map grid.

4. Press *OK*. Now your screen should look like this:



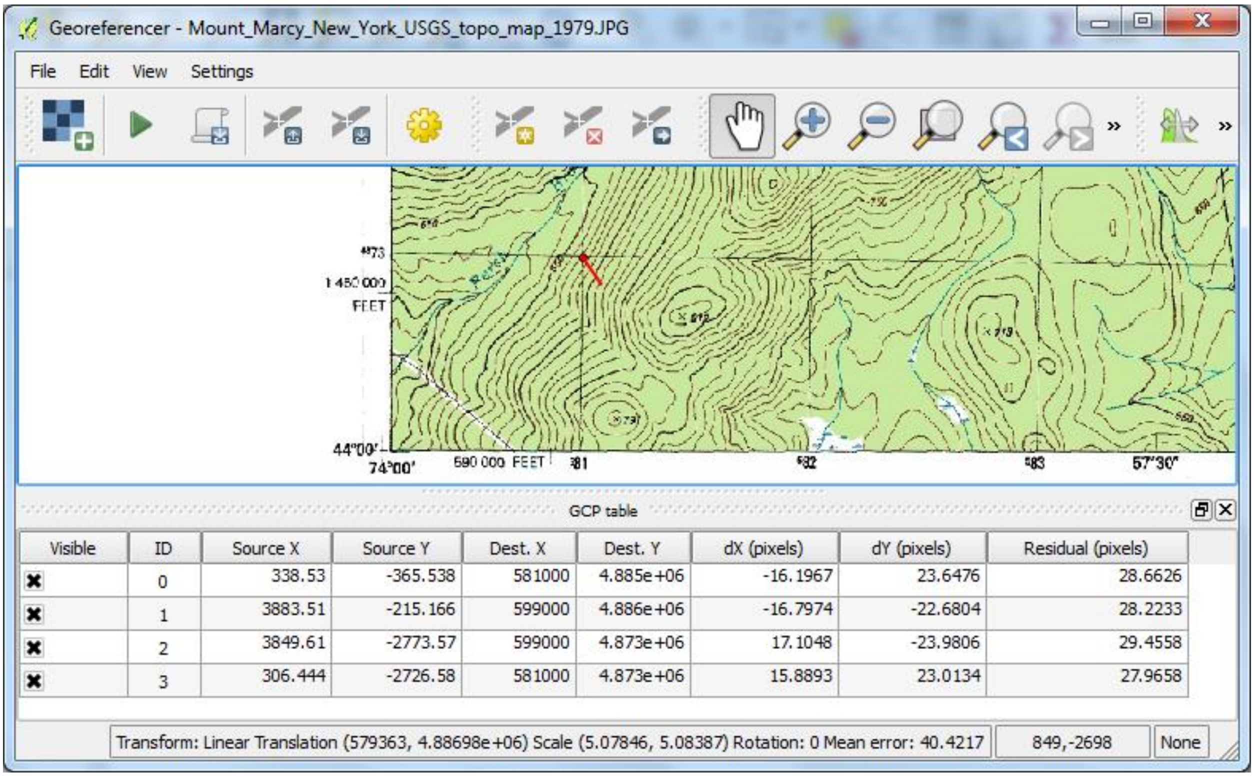
The red dot is the location that you have referenced. In the table below the map, you can see the Source X and Source Y coordinates. These are the unreferenced file coordinates. Their values depend on which pixel you clicked for placing the GCP, so it can differ from the screenshot above. Dest. X and Dest. Y show the real world coordinates that you have linked to this location. The other fields of the table have to do with estimated accuracy and will be filled in after adding more points.

5. Let’s choose a second GCP in the upper right corner of the map and proceed in a similar way as with the first GCP. Your screen should look like this:



You can see that some error statistics have been calculated. With only two points this does not make much sense. The minimum amount of GCPs for a linear transformation should be 4.

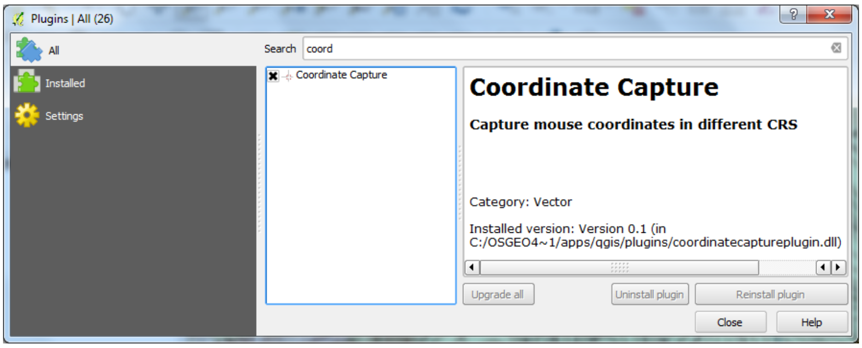
6. Add in a similar way a GCP in the lower left and the lower right corner of the map. If you made a mistake you can remove the GCP by using the *Delete point* button . Your screen should look like this:



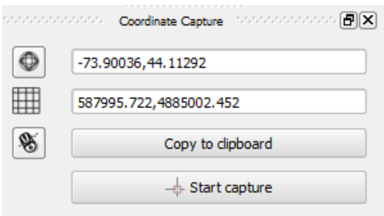
At the bottom of the screen you can see the estimated mean error in the map units (40.4217 meters in our case). The error is also indicated at the GCPs using a red line. The large error suggests that the deformation is too large to use a linear transformation. If we change to another transformation type in the transformation settings, the error values will be recalculated.

7. In the menu go again to *Settings* → *Transformation Settings*… and now let's select a 1st order polynomial (*Polyniomial 1*) instead of the linear transformation. Keep the rest as it was. Click *OK* to return to the GCP table. Now you can see that the mean error has been reduced to 0.505627 m, which is acceptable.

8. Now we can start georeferencing using the  button. After some calculation time the georeferenced map appears in the QGIS map canvas. You can close the Georeferencing plugin. It will ask if you want to save your GCPs. You can click *Discard* if you don't want to use them. If you save them, you can load them again in the Georeferencing plugin.
9. In order to verify the result you can use the Coordinate Capture plugin. If it is not activated yet you can do it by choosing from the menu: *Plugins* → *Manage and Install Plugins*… . Then search for the *Coordinate Capture plugin* and check the box to activate and click *Close*:



10. A panel has appeared under the layers list. Here you click on *Start capture*. Click on a grid node in the map and the coordinates are displayed in the panel:



Read the coordinates from the side of the map and verify if they are correct.

11. Another way to verify the result is to use the *QuickMapServices* plugin web maps as a backdrop. If not yet installed, install the *QuickMapServices* plugin: in the main menu choose *Plugins* → *Manage and Install Plugins*… and search for the *QuickMapServices* plugin and install.
After installing, choose from the main menu *Web* → *QuickMapServices plugin* and try some of the options.

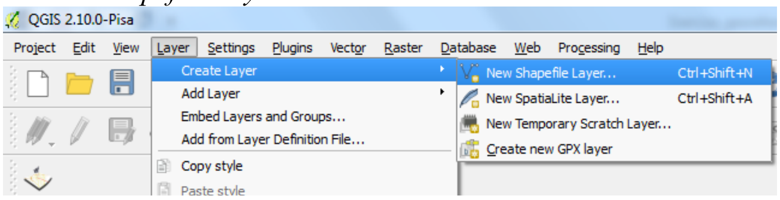
4.7 Digitizing vector layers from a georeferenced backdrop

Our georeferenced scanned map can now be used as a backdrop to digitize vector layers. Vectors can be points, (poly)lines or polygons. In this exercise we are going to digitize:

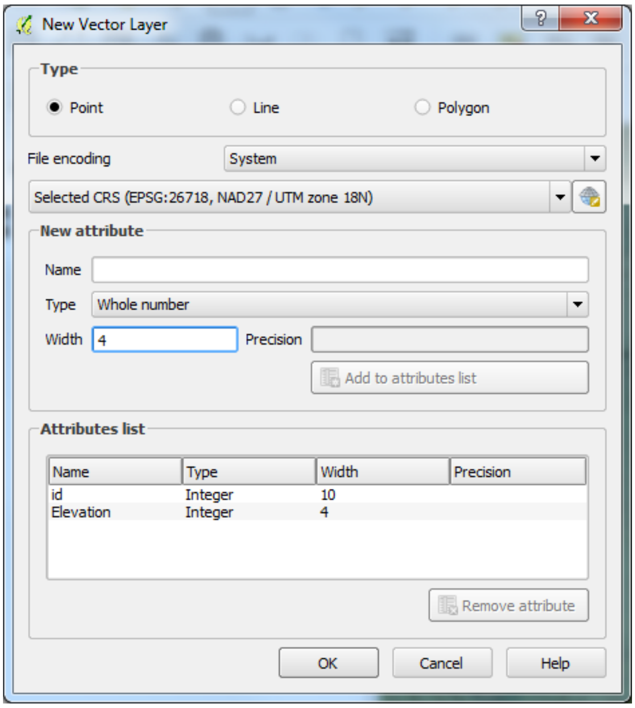
- Mountain tops as points
- Rivers as (poly)lines
- Lakes as polygons

The following steps guide you through the process.

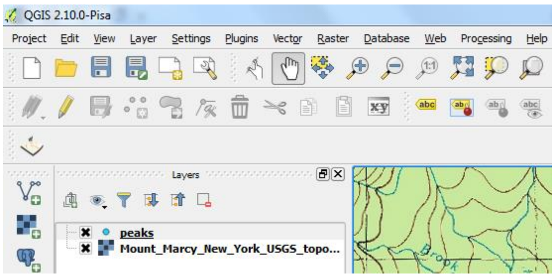
1. First we have to create an empty shapefile. In the main menu select *Layer* → *Create Layer* → *New Shapefile Layer…*



2. In the *New Vector Layer* dialogue we specify that we are creating a Point layer. For the CRS we select the one of the topographical background map (`EPSG:26718`). You can use the arrow to choose the right projection from the dropdown list. Next, we have to create a new attribute. In the attribute list you can see that by default there is an attribute called `id`. We will create one with the name `Elevation`. For type we choose *Whole number* and *Width* `4`. This means that we can store integer values up to 9999, which is sufficient for any mountain on Earth.
3. Click the button *Add to attributes list*. The attribute is now added. The dialogue should look like this:

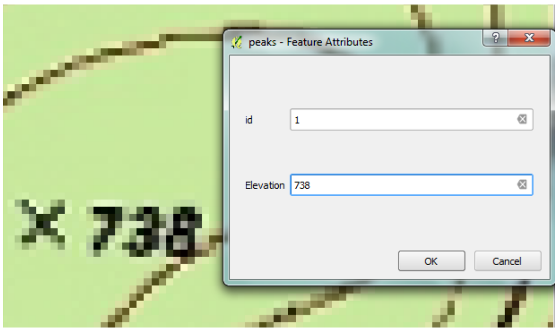


4. Click *OK*.
5. Browse to the folder where you want to store your data and name it `peaks.shp` and press *OK*.
6. The empty shapefile has now been added to your layers list.

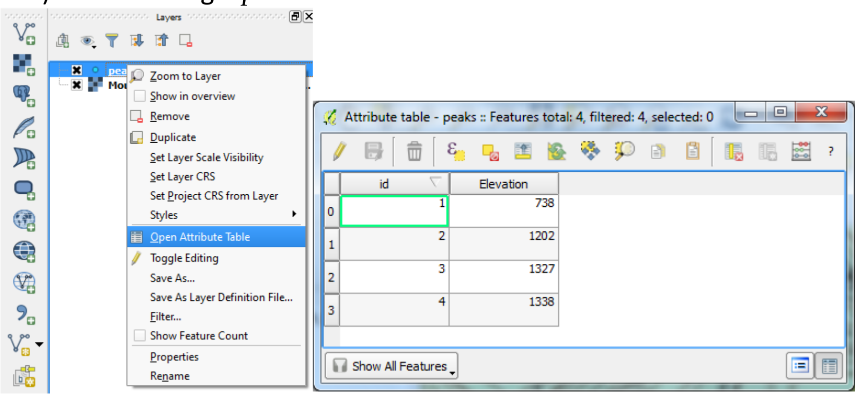


7. In order to start digitizing, you have to toggle to edit mode. Click on the `peaks` layer so it is selected.
8. Click on  to toggle to editing mode. Now the other editing buttons become active and a pencil before the layer name shows that we are editing the layer.
9. In the topographical map navigate to a spot height of a mountain. They are indicated with x and an elevation value. If you have found one, zoom in and click the Add Feature button .
10. Move the mouse to the mountain top. The cursor changes in a crosshair. Click on the mountain top.

11. A dialogue with a form shows up. Here you can fill in the attribute values: `id = 1` and `Elevation = 738`

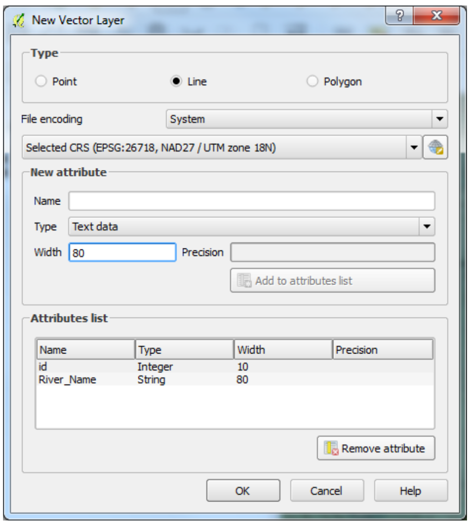


12. Repeat this step for a few other peaks. If you made a mistake, you can use  to select the point feature and  to delete the selected point feature. This button  can be used to move a point feature. Use  to save the edits.
13. When done, click again on the  button to toggle editing. If you didn't save edits yet, it will ask you to *Save* or *Discard*. With *Discard* you can always undo your edits until the last time it was saved.
14. You can check the attribute table of your new point vector layer by right clicking on the layer name (`peaks`) and selecting *Open Attribute Table*

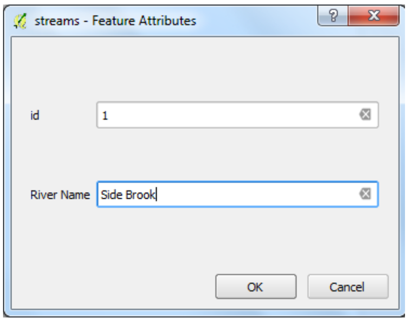


Now you can see the attributes that you have added and their id and elevation values.

15. Our next task is to digitize line features. The procedure is similar to creating a point layer. In the *New Vector Layer* dialogue now you choose *Line*. As a new attribute we add `River Name` with the type *Text*. Keep the *width* at `80`. Check if the dialogue resembles the one below and click *OK*. Call the new vector layer `streams.shp`.



16. In the layers list select the streams layer and toggle editing.
17. Click on to add a new line feature. Zoom and pan on the map to find a stream to digitize.
18. Click on the starting point of the line (node) and click when necessary to make a vertex. You can use the zoom and pan buttons to trace the stream. You can also change the symbology to visualize clearer the line that you are digitizing. After you placed the end node of the line, click right.
19. In the dialogue, fill in `id = 1` and the name of the river.



20. Repeat these steps for a few streams and save your edits. Check the attribute table. If you want to add tributaries that connect to streams, play around with the snapping settings (in the main menu go to *Settings* → *Snapping options*…)
21. Finally we are going to create a polygon vector layer for some lakes. Try to find out yourself how to do this. It is very similar to the procedure for lines. The only difference is that the first node should be the same as the last node in order to close the polygon.

4.8 Image to image registration

Try to use the *Georeferencer* plugin to register the scanned map (JPG file) to a satellite image from the *OpenLayers* Plugin. In this way you can perform an image to image registration. Please make sure you use the right projection. Does the image to image registration give better results?

This whole exercise can be viewed in a screencast at: https://youtu.be/4lWyVeGhzog

Exercise 2: Importing tabular data into GIS and interpolation

5 Importing tabular data into a GIS

5.1 Introduction

After this exercise you are able to import tabular data into a GIS. In this example we are going to import a table with the daily average temperature on September 1st 2013 at several meteorological stations in the Netherlands. The data was downloaded from the KNMI Data Centre (KNMI, the Royal Netherlands Meteorological Institute, http://data.knmi.nl), but reformatted for the purpose of this exercise.

In this exercise we'll use the following data:

- `KNMI_20130901_tday.xls`: table with average daily temperatures for different stations
- `KNMI_stations.xls`: table with station number and coordinates of the location of the stations

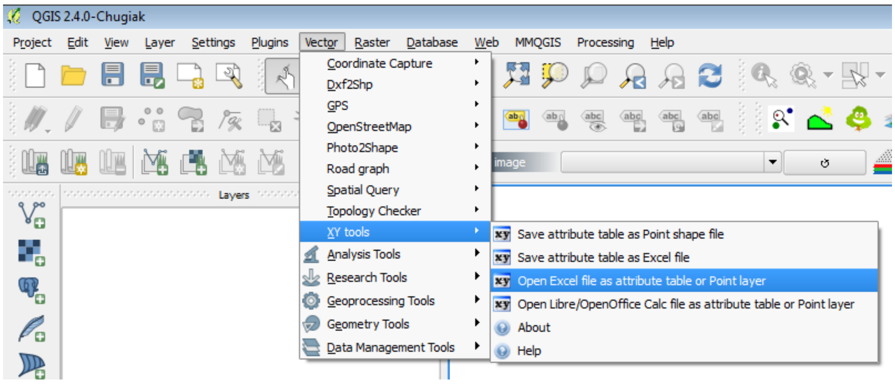
This data can be downloaded from the OpenCourseWare website (http://ocw.unesco-ihe.org/course/view.php?id=11). You can find the data under Data Exercise 2.

This exercise will guide you through the following steps:

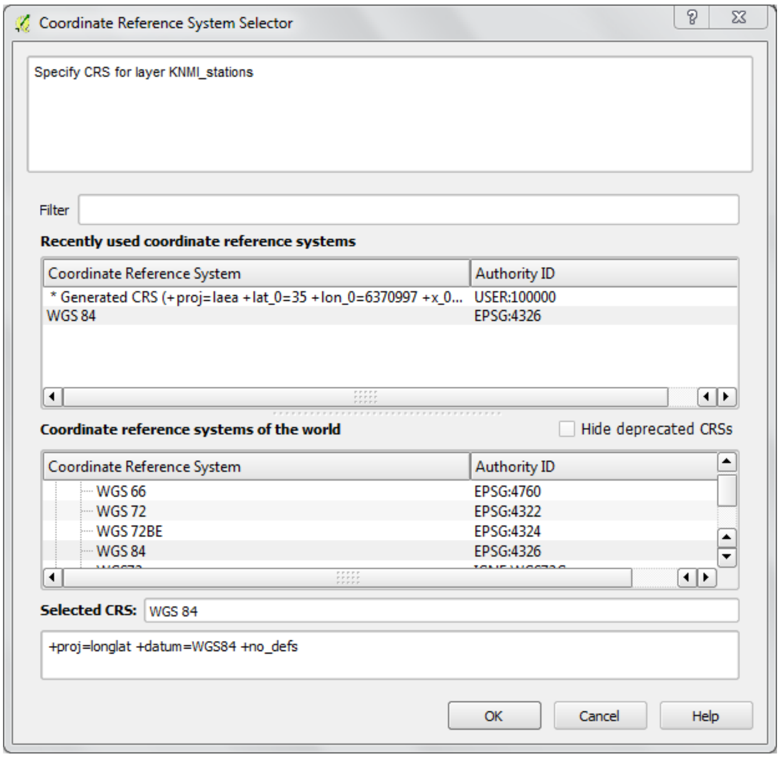
- Convert Excel tables to comma separated files
- Import tables into GIS
- Join table with data to vector layer with locations
- Reproject dataset to local projection
- Recalculate values in an attribute table
- Interpolate vector to raster

5.2 Convert Excel tables to GIS format

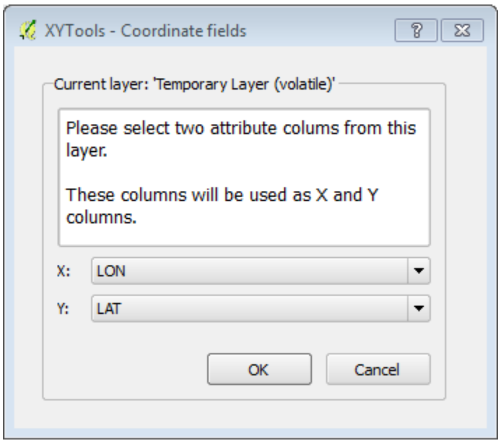
1. Open the files `KNMI_20130901_tday.xls` and `KNMI_stations.xls` in a spreadsheet program (e.g. MS Excel) and check the contents. Which file contains coordinates? Is there a way to link both files? How could we do that?
2. Start QGIS Desktop
3. In the menu go to *Plugins* → *Manage and install plugins...* and check if *XyTools* is installed. If not, you should install the plugin. Plugins are developed by the community to add extra functionality to QGIS. With the *XyTools* plugin you can import from/export to Excel files for example. Note that *XyTools* can only work with `.xls` files. If you have files in `.xlsx` format, you need to save it in `.xls` format from Excel.
4. Now in the menu choose *Vector* → *XyTools* → *Open Excel files as attribute table or Point layer*



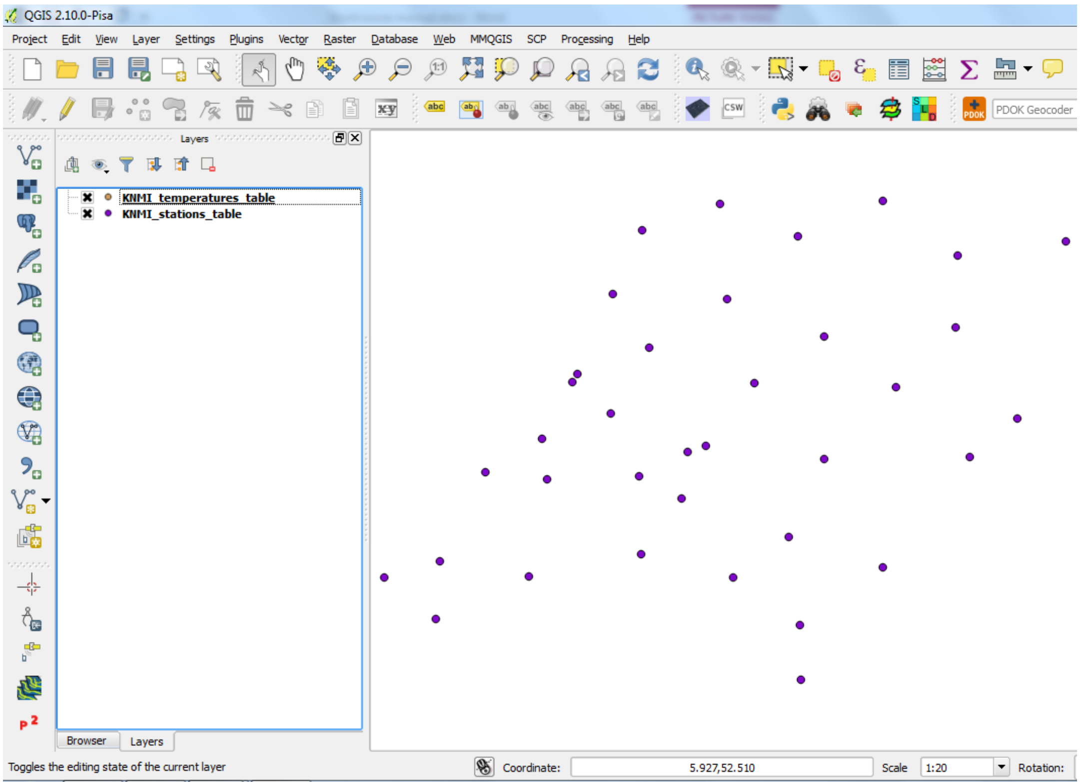
5. In the dialogue browse to the file with the locations of the meteorological stations (`KNMI_stations.xls`)
6. Browse to the file and give the proper parameters in the dialogue and click OK.
7. Next you're asked to give the Coordinate Reference System (CRS). Here choose WGS 84 (EPSG:4326), which is lat/lon with datum WGS 84. Click *OK* to proceed.



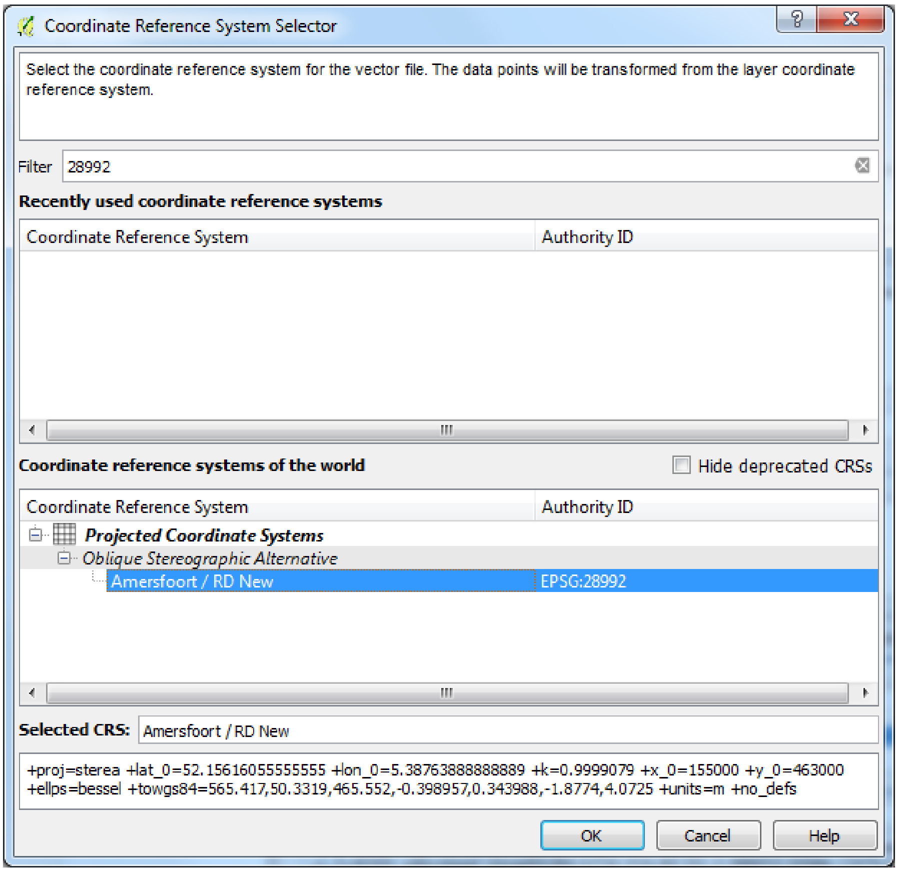
8. Next, a dialogue pops up where you have to choose the columns with the x and y coordinates. Which columns are those? Select those and click *OK*.



9. Now a map with the meteorological stations is displayed. If you don't see the map, you probably need to zoom to the extent of the map: click right on the layer name (**Temporary layer (volatile)** and choose *Zoom to layer*.
10. Rename the layer to **KNMI_stations_table** (Click right on the layer and select *Rename*).
11. Now add the table with the temperature data in the same way. When the Coordinate Reference System is asked, click *Cancel*. When the popup comes that asks for the columns with x and y coordinates, also click *Cancel*. This is because this table doesn't contain georeferenced data. We have to link the two tables to make it georeferenced.
12. Rename also this layer. We call it **KNMI_temperatures_table**.

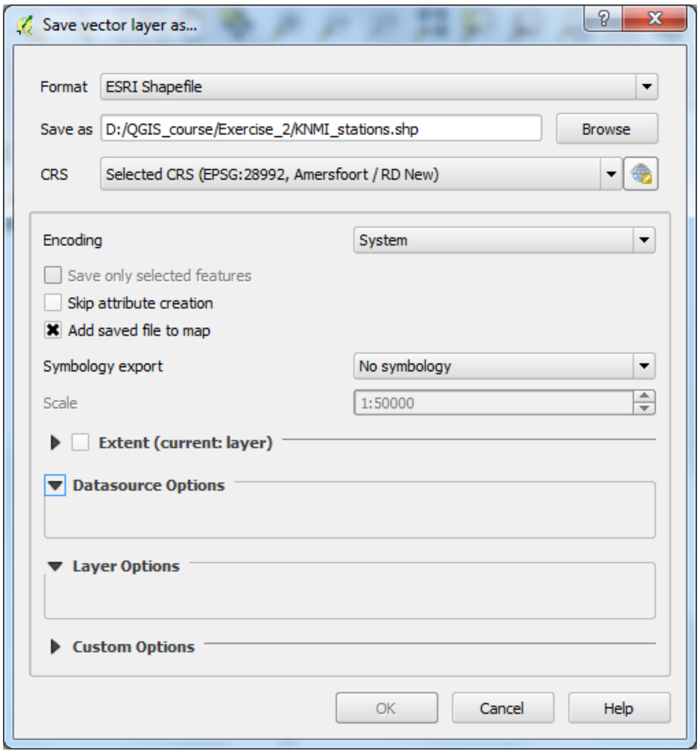


13. The next step is to convert **KNMI_stations_table** to a GIS vector format, i.e. shapefile. Click right on **KNMI_stations_table** and choose *Save as...*
14. In the dialogue Browse to the folder to save the file as `KNMI_stations.shp`. In order to change the projection to the local Dutch projection choose for CRS "Selected CRS" and Browse to Amersfoort / RD New by clicking on the  button. Tip: use the *Filter* field to lookup EPSG code 28992:



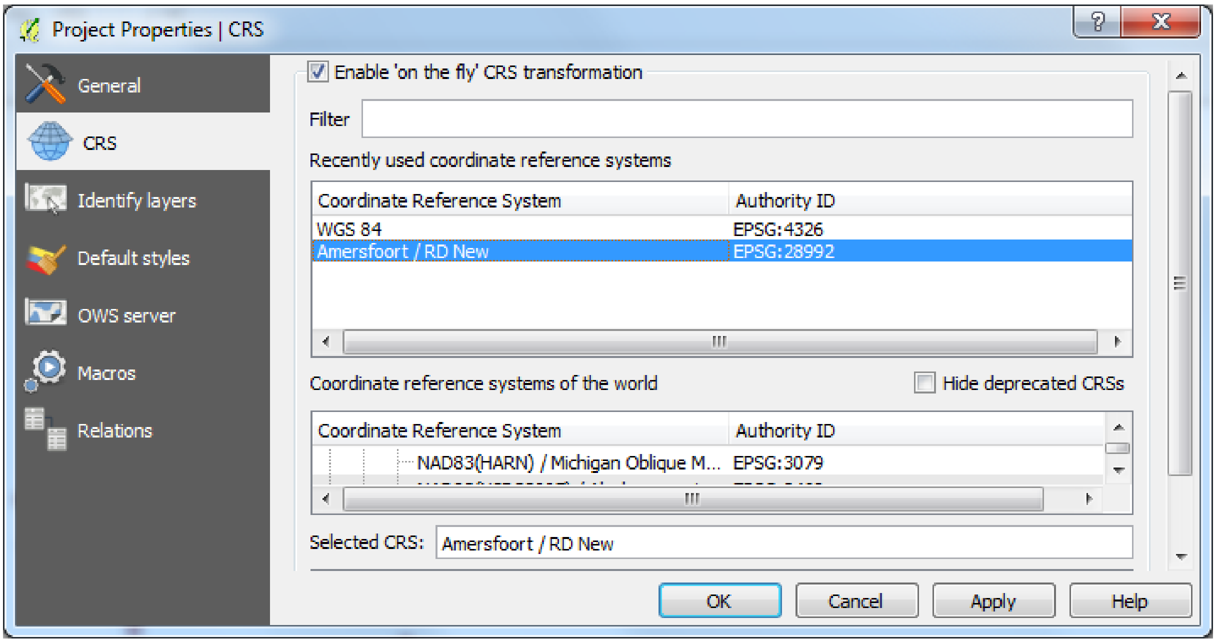
Here you see the advantage of using EPSG codes: it standardizes the projection. So it is useful to determine the EPSG code of the projection you want to work within your project. Also note that all maps in your project need to be in the same projection if you want to combine them in a GIS analysis or modelling.

Click *OK*. Now the dialogue looks like (also check the box *Add saved file to map*):



Click *OK* to proceed.

15. Remove the **knmi_stations_table** from the display by clicking right and selecting Remove. Be sure to remove the right one. If you hover your mouse over the layer name it will show the file name. With Remove you only remove it from the display, the file will still be on your harddisk.
16. Although the `knmi_stations.shp` dataset is in the EPSG 28992 projection (Amersfoort / RD New), the QGIS display still uses the EPSG 4326 projection (lat/lon WGS 84) and has reprojected `knmi_stations.shp` ***on the fly*** for visualisation. In order to visualise all layers in EPSG 28992 we have to change the QGIS Project properties. In the menu choose *Project* → *Project Properties...*
17. Choose the Coordinate Reference System (CRS) tab
18. Check the box "*Enable 'on the fly' CRS transformation*" (by default it is already checked, so keep it checked)
19. Choose from the recently used coordinate reference systems EPSG:28992 and click *OK*.



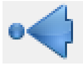
Note that the projection of the project is indicated in the lower right of the screen 

. You can always check there if the EPSG code is okay. You can change the on-the-fly projection also by clicking on that EPSG code.

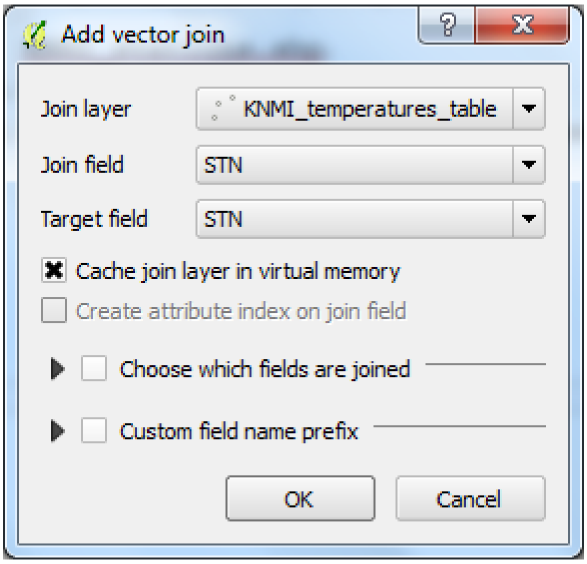
5.3 Join attribute tables

20. We still have the locations of the stations and the temperature data in separate tables. We have to combine them in one shape file. In GIS terms this is called a "join" operation. We can only join tables if they have a column in common. Check the attribute table of `KNMI_stations` (right click on `KNMI_stations` and choose Open attribute table) and in the same way check the `KNMI_temperatures_table`. Which column both attribute tables have in common?
    After determining which column both tables have in common we can join the data of `KNMI_temperatures_table` to the attributes of our shapefile `KNMI_stations.shp`.
21. First close the attribute tables.

22. Next, click right on `KNMI_stations` and choose *Properties*.

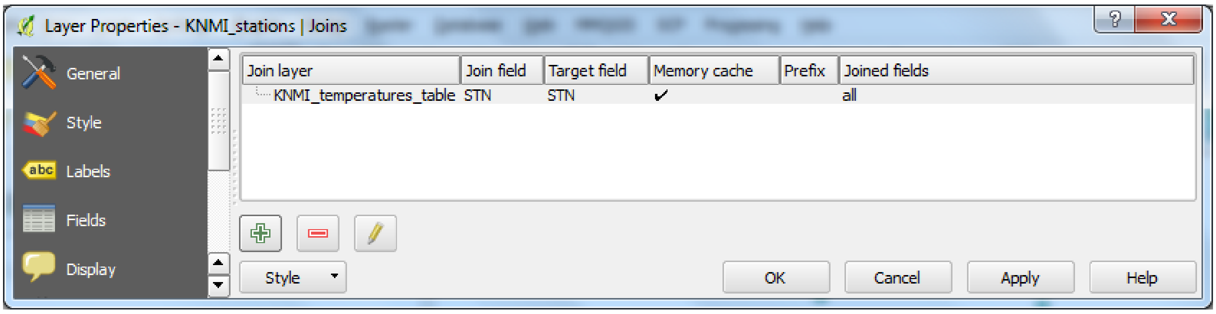
23. In the dialogue choose the button *Joins*  .

24. Click the + sign and choose check if the dialogue looks like this one:



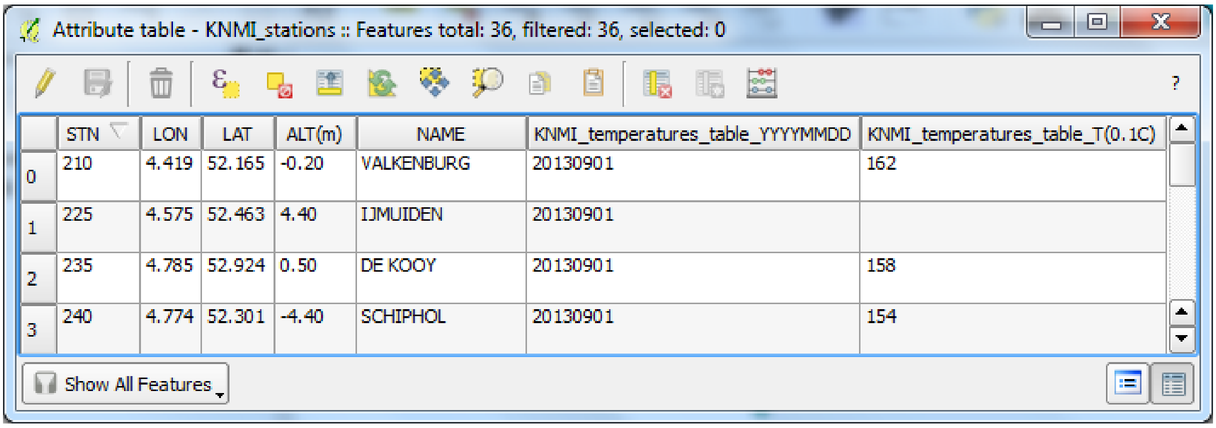
Note that the common field is `STN` (the station number) and click *OK*.

25. Now the *Joins* dialogue looks like this:



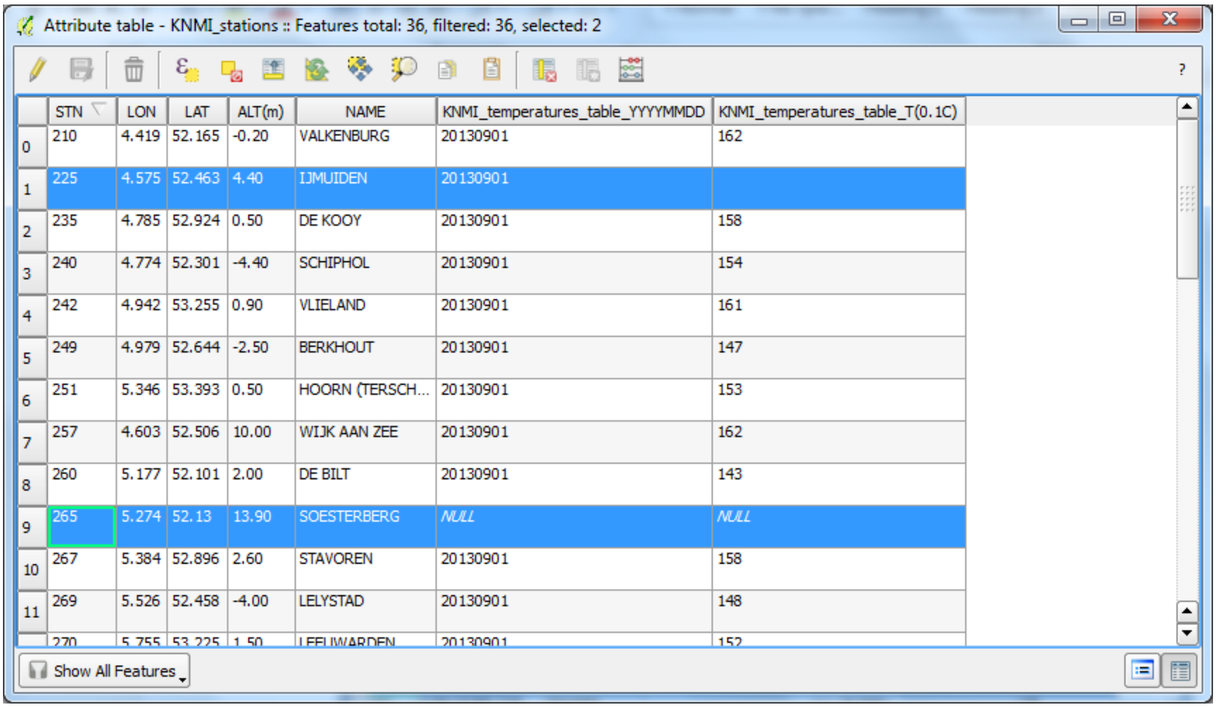
Click *OK* to perform the Join operation.

26. Now check again the attribute table of `KNMI_stations`. What happened?



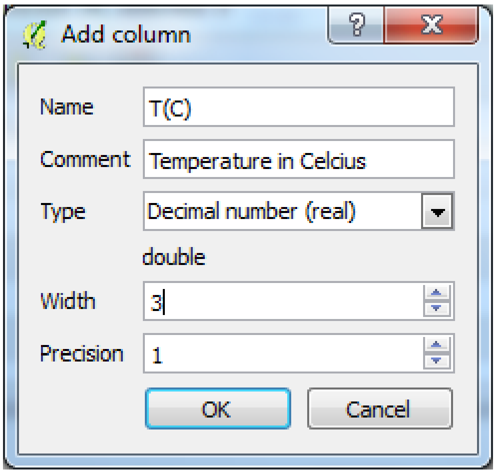
	STN	LON	LAT	ALT(m)	NAME	KNMI_temperatures_table_YYYYMMDD	KNMI_temperatures_table_T(0.1C)
0	210	4.419	52.165	-0.20	VALKENBURG	20130901	162
1	225	4.575	52.463	4.40	IJMUIDEN	20130901	
2	235	4.785	52.924	0.50	DE KOOY	20130901	158
3	240	4.774	52.301	-4.40	SCHIPHOL	20130901	154

27. First we need to remove the missing values. Click on row numbers with NULL or no values for temperature, while keeping the `Ctrl` button pressed. Now the attribute table looks like this:

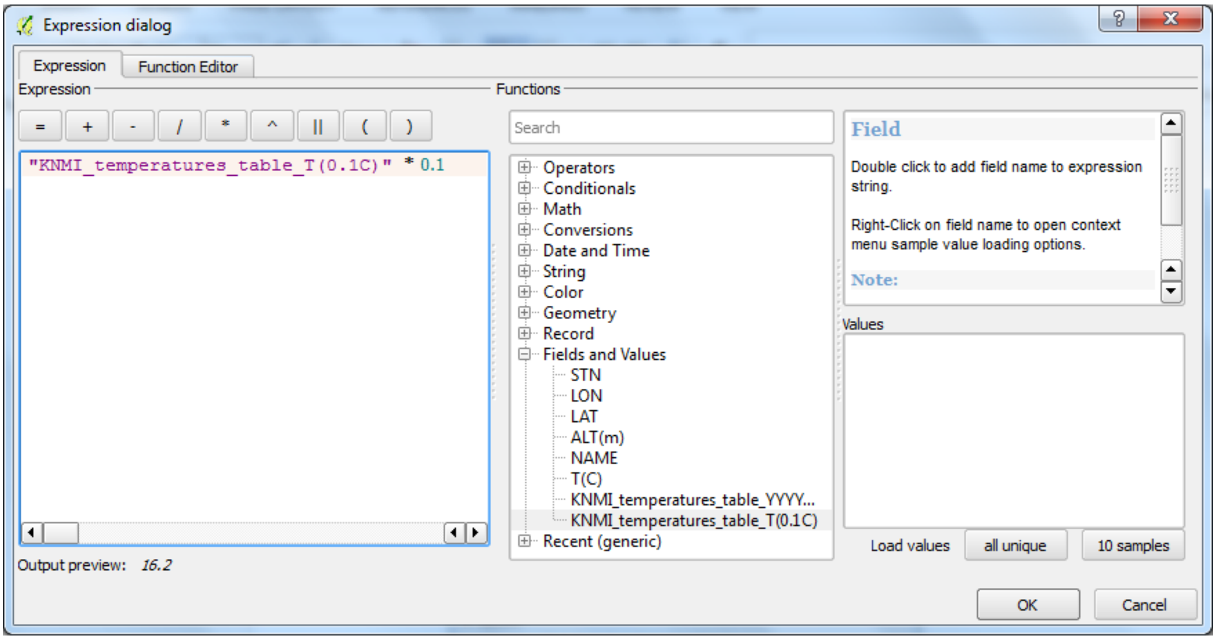


	STN	LON	LAT	ALT(m)	NAME	KNMI_temperatures_table_YYYYMMDD	KNMI_temperatures_table_T(0.1C)
0	210	4.419	52.165	-0.20	VALKENBURG	20130901	162
1	225	4.575	52.463	4.40	IJMUIDEN	20130901	
2	235	4.785	52.924	0.50	DE KOOY	20130901	158
3	240	4.774	52.301	-4.40	SCHIPHOL	20130901	154
4	242	4.942	53.255	0.90	VLIELAND	20130901	161
5	249	4.979	52.644	-2.50	BERKHOUT	20130901	147
6	251	5.346	53.393	0.50	HOORN (TERSCH...	20130901	153
7	257	4.603	52.506	10.00	WIJK AAN ZEE	20130901	162
8	260	5.177	52.101	2.00	DE BILT	20130901	143
9	265	5.274	52.13	13.90	SOESTERBERG	NULL	NULL
10	267	5.384	52.896	2.60	STAVOREN	20130901	158
11	269	5.526	52.458	-4.00	LELYSTAD	20130901	148
	270	5.755	53.225	1.50	LEEUWARDEN	20130901	152

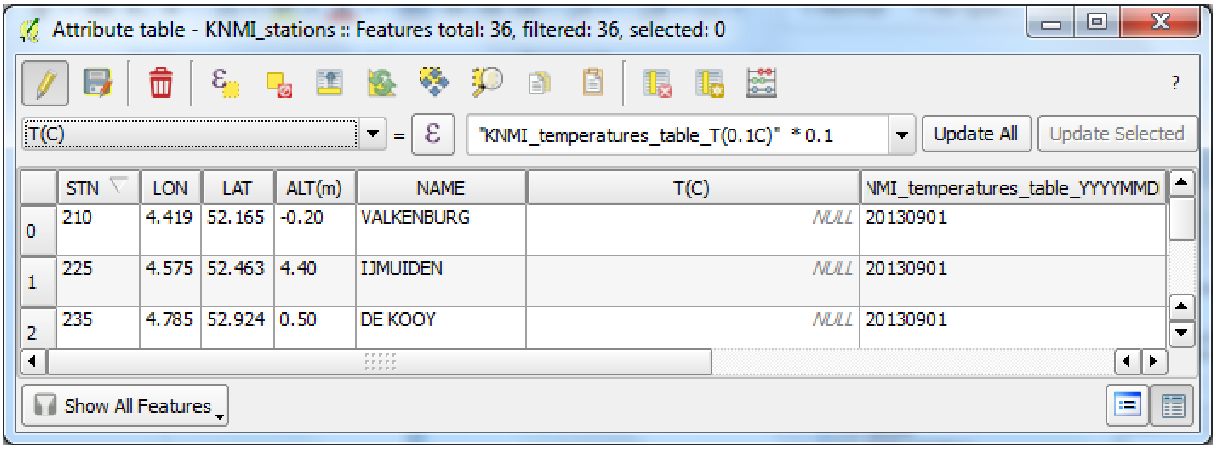
28. In the attribute table click on above the table to toggle editing mode.
29. Click the icon (in the toolbar above the attribute table) to remove the 2 features with missing data.
30. The only problem now is that the temperatures in the table are in 0.1 °C. We need to convert the values to °C.
31. Click to add a new column to the table. And fill in the dialogue according to this screenshot:



Width is the amount of numbers, *Precision* is the amount of decimals.
Click *OK* to proceed.
32. Now the attribute table shows an extra column with NULL values. In order to calculate the right values click above the table to open the *Field Calculator* dialogue.
Fill the dialogue like the screenshot below. To avoid typos the best practice is to double click on the field name in the middle of the dialogue screen and to click the * button. Then type 0.1. Click *OK* to proceed.



33. Make sure the *Attribute table* window looks like below (with T(C) indicated as column to assign the calculation). Click *Update All*.



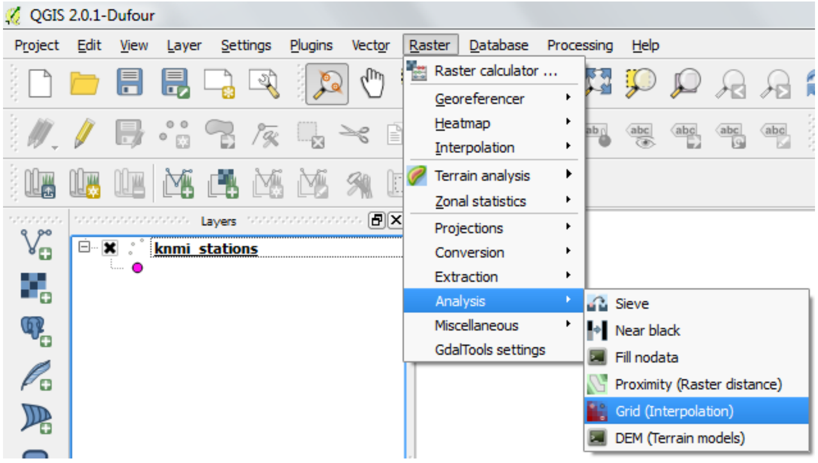
34. Now check the result in the attribute table.

35. Click again on the  to toggle back to non-editing mode. Click *Save* to save the changes when asked and close the attribute table. If you made a mistake choose *Discard* to undo all changes since last save.

36. Now remove the table `KNMI_temperatures_table` and check the attribute table of **KNMI_stations**. What columns do you see now? What can you conclude about the join function? You could have saved the entire attribute table by saving **KNMI_stations** to a new shapefile using the previously used *Save as…* function.

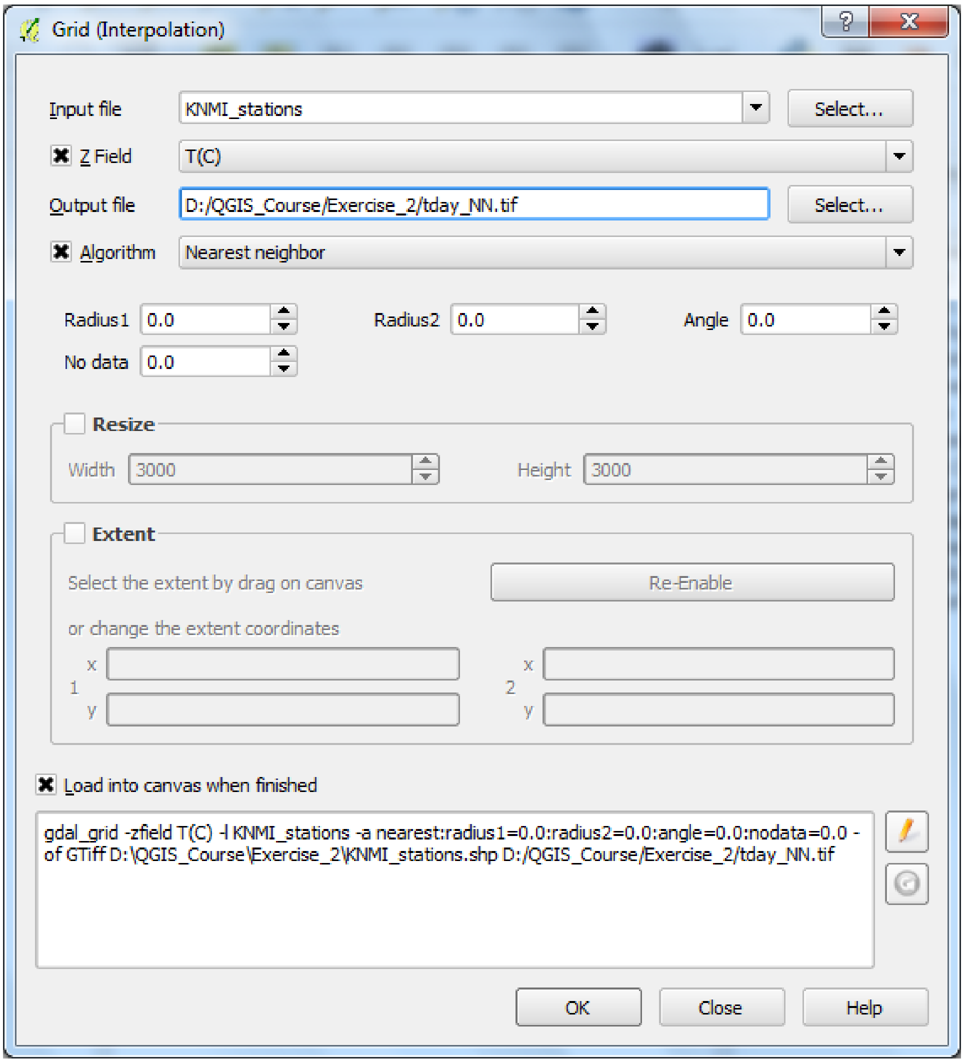
5.4 Interpolate point features to raster

37. The final task is to interpolate the temperature values to a raster. In the menu choose *Raster* → *Analysis* → *Grid (Interpolation)*
If you don't see this, your *GdalTools* plugin is not activated. You can activate it from the *Plugins* menu.



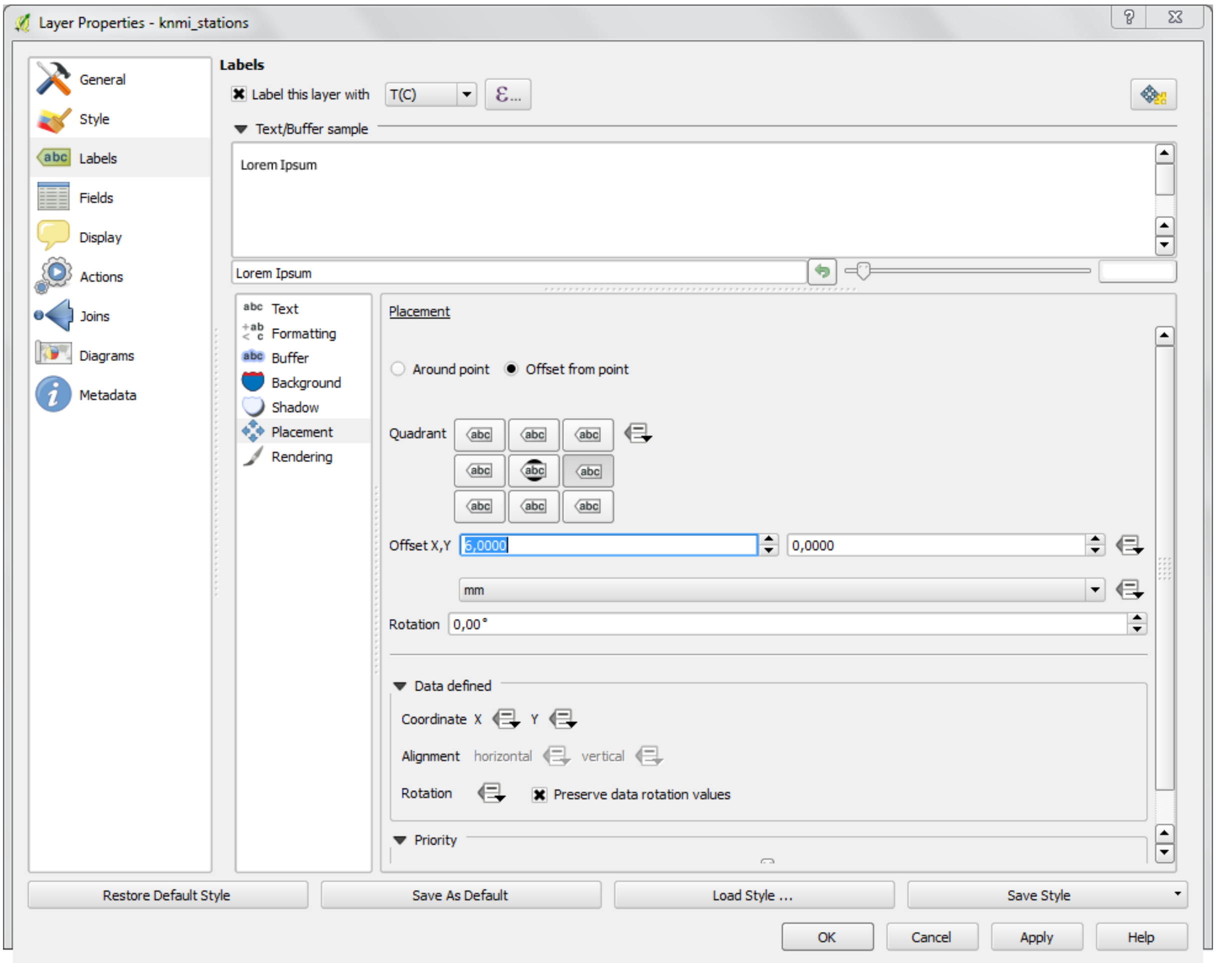
38. In the dialogue specify the output file: `tday_NN.tif` by using the browse window and specifying the `.tif` format.

    Check the *Z-field* checkbox and select `T(C)`. This is the field that we will interpolate.
    Check the *Algorithm* checkbox and select *Nearest Neighbor*. This is the interpolation function that creates Thiessen polygons.
    Check the *Load into canvas when finished* checkbox.
    For the rest of the dialogue keep the defaults. The dialogue should now look like this:

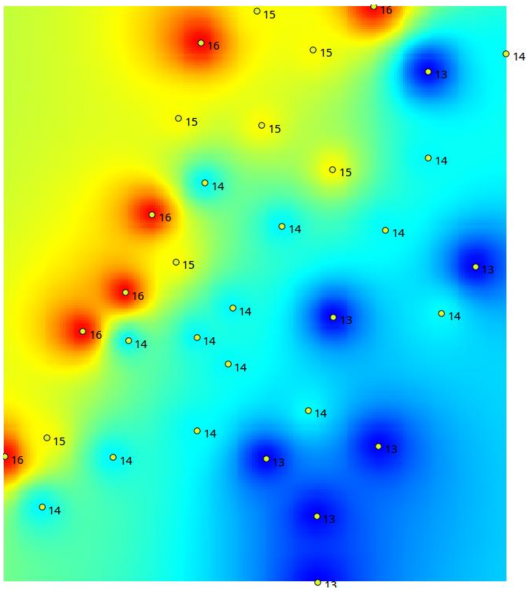


Note that the dialogue generates a GDAL command that is given in the edit field.
Click *OK* to proceed.
Click 2 x *OK* to close the popup windows and click *Close* to close the dialogue

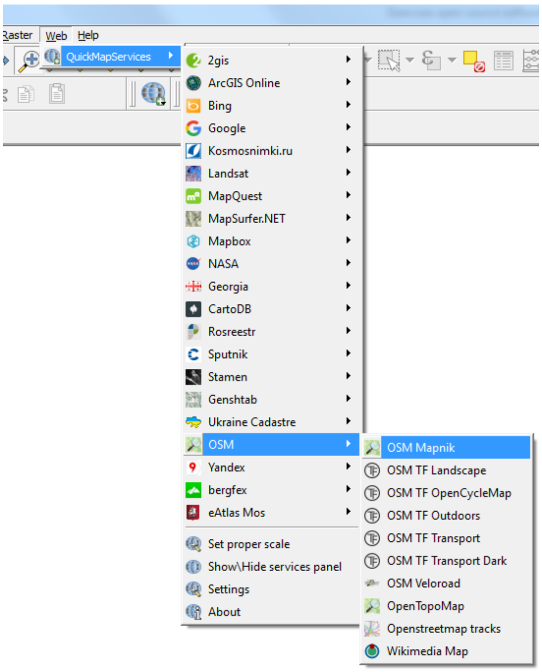
39. The interpolated temperature map is now loaded into the display. It is visualised in greyscale, so you have to set the visualisation options. Click right on the map and select *Properties*.
40. Under the *Style* tab, play around with the different options and click *OK* to return to the display.
41. Now drag the `knmi_stations` file to the top in order to display the stations on top of the temperature grid.
42. Click right on the `knmi_stations` layer and select *Properties*.
43. Select the Labels icon and check the *Label this layer with* checkbox. Choose `T(C)` as the Field containing the label. Play around with the placement options (see screenshot below) to make a nice map. Click *Apply* to test and *OK* to visualise.



44. Now repeat the interpolation using the Inverse distance to a power (IDW) algorithm (repeat from step 37). Call the result file `tday_IDW.tif`. Visualise the result. Which interpolation method is better? Why? Can you explain the temperature gradient in the map?



45. You can save your QGIS project at this point by choosing from the menu *Project* → *Save as...*. Now you can close QGIS and load the project the next time you use QGIS.
46. We can also plot our newly created GIS data over a topographical map. For this purpose you have to install the **QuickMapServices Plugin**. In the menu go to *Plugins* → *Manage and install plugins...* and install the *QuickMapServices* plugin if it is not yet installed.
47. Choose from the menu *Web* → *QuickMapServices* → *OSM* → *OSM Mapnik*. Make sure your point vector layer is on top.



This whole exercise can be viewed in a screencast at: https://youtu.be/LKNga7cedt8