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Introduction to CM SAF data processing with QGIS

Author:
Jakub Walawender
CM SAF Visiting Scientist at
Deutscher Wetterdienst (DWD)

e-mail: jakub.walawender@dwd.de

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1. About QGIS

QGIS (previously known as ***Quantum GIS***) is a free, open source and cross-platform desktop Geographic Information System which:

- offers standard GIS functionality, including: viewing, editing, analysis and mapping
- supports most geospatial vector and raster file types, database formats and map projections for integrated analysis and visualisations
- incorporates other open-source GIS packages, including PostGIS, GRASS GIS, SAGA GIS and MapServer, providing extensive functionality
- uses plugins which further expand its capabilities by providing additional tools
- runs on a number of operating systems (Windows, Linux, MacOS X, BSD and Android)
- remains an official project of the Open Source Geospatial Foundation (OSGeo)
- is licensed under the GNU General Public License.

Downloading and Installing QGIS:

Instructions on how to download and install *QGIS* can be found on the official website of the *QGIS Project*:
http://www.qgis.org/en/site/forusers/alldownloads.html.

QGIS version 2.18.4 was used in this Tutorial.

Self-Training resources:

QGIS functionality is very well documented. Complete documentation can be found on the official website of the *QGIS Project* in section *Documentation*. Most of the documents are only in English but some of them (e.g. *User guide*) are also available in other languages.

Further useful sources of help / information:

1. *QGIS* Tutorials: http://www.qgistutorials.com/en
2. *QGIS* on Stack Exchange Q&A site:
   http://gis.stackexchange.com/questions/tagged/qgis
3. *QGIS* Users Mailing List: https://lists.osgeo.org/mailman/listinfo/qgis-user
4. *QGIS* Gitter Chat:
   https://gitter.im/qgis/QGIS?utm_source=badge&utm_medium=badge&utm_campaign=pr-badge&utm_content=badge
5. Steven Bernardt and Klas Karlsson youtube channels:
   https://www.youtube.com/channel/UCrBM8Ka8HhDAYvQY1VX2P0w/videos
   https://www.youtube.com/user/klakar70/videos
6. GeoAcademy: https://fossgeo.org

2. Getting started

2.1. Tutorial data

Download and unzip *QGIS_demo_data_SIS_Poland.zip.*

2.2. Launching QGIS

QGIS can be launched as any other application on your platform.
For Windows QGIS can be launched by:

- double clicking the QGIS icon on your desktop or in the applications folder
- typing *qgis* at a command prompt (only from the QGIS installation folder or if QGIS is added to your PATH system environment variable)
- double clicking an existing QGIS project (.*qgs*) file (this will open the whole project)

2.3. QGIS GUI

QGIS **G**raphical **U**ser **I**nterface (**GUI**) consists of 5 major elements (Fig. 1):

- **Map canvas (1)** – a viewing window where the thematic layers are displayed
- **Panels (2)** – different QGIS widgets (e.g.: **Browser panel** is used for managing GIS datasets, **Layers panel** lists all the layers used in the QGIS project)
- **Toolbars (3)** – provide access to various tools and functions
- **Menu bar (4)** – the top-level standard hierarchical menu which provides access to various QGIS features.
- **Status bar (5)** – shows information about the current map, allows to adjust the scale, change the coordinate reference system (CRS), and display coordinates of the mouse cursor.

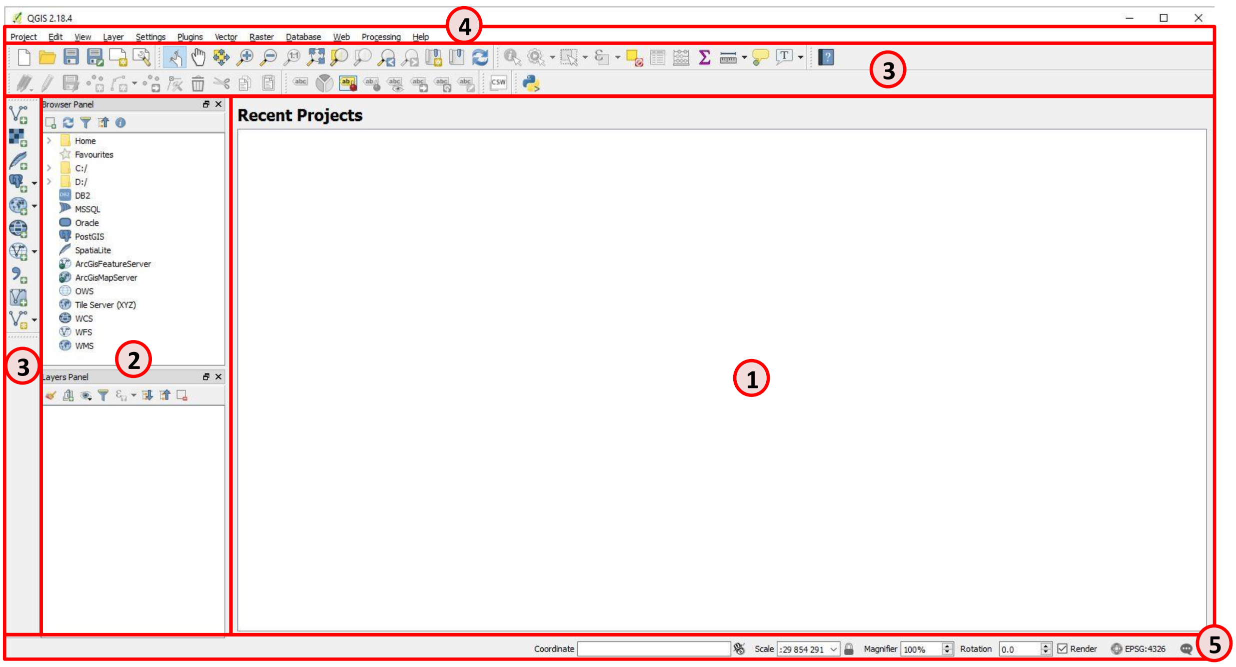


Fig. 1. QGIS GUI when started for the first time

2.4. Installing plugins.

Plugins provide additional, useful functionality to the QGIS software. QGIS plugins are created by QGIS developers or independent users and made available for every QGIS user.

There are 2 categories of QGIS plugins:

- **Core plugins** – are already part of the standard QGIS installation
- **External plugins** – have to be installed before using them

Some of the external plugins are marked as **experimental** (in early stage of development) or **deprecated** (not maintained anymore). These plugins are not recommended for use unless there are no other alternatives available. Most of the External plugins are currently written in Python. They are available in the official QGIS Plugins Repository or in external repositories and are maintained by the individual authors.

When starting QGIS for the first time only some of the core plugins are enabled. To browse, enable/disable or install additional plugins use **QGIS Plugin Manager** (*Plugins → Manage and Install Plugins*).

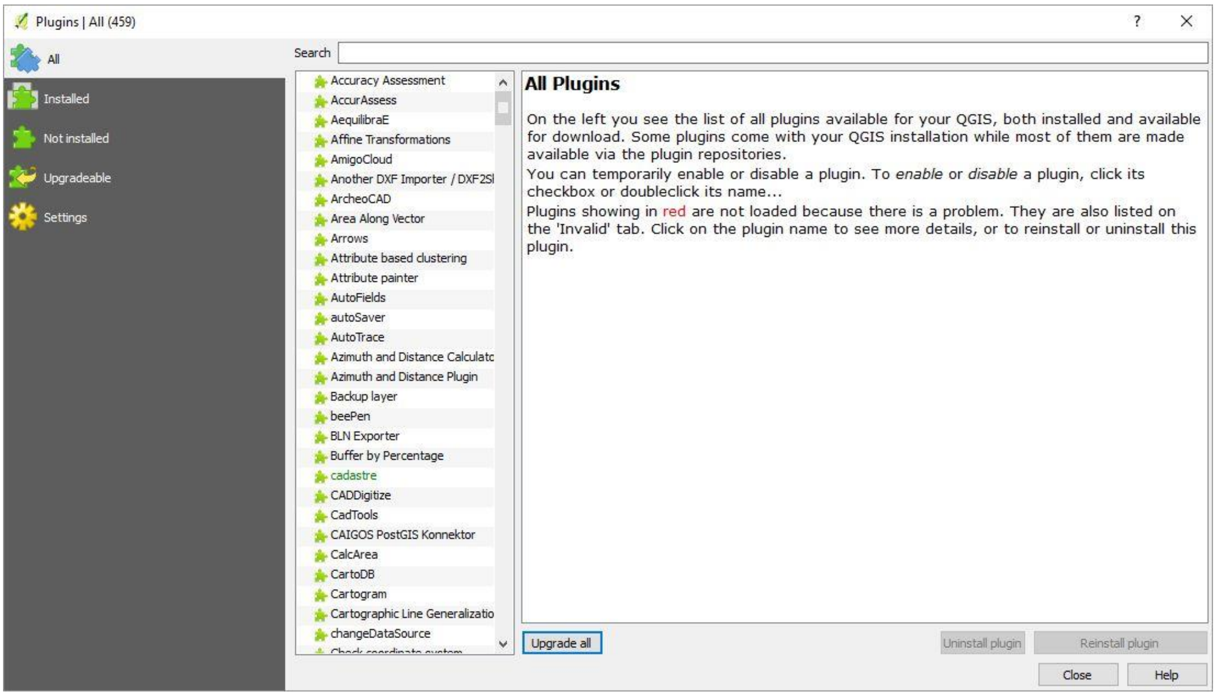


Fig. 2. QGIS Plugin Manager

All tab lists all the plugins available in the repository. Find a plugin on a list or use *Search* box. Trusted plugins are depicted in green font. After selecting a plugin on the list, a short description is displayed. Click *Install plugin* to install the selected plugin. A plugin is enabled when the checkbox is checked. *Installed*, *Not installed* or *Upgradable* plugins can be listed separately. Experimental and deprecated plugins can be allowed in *Settings* tab. It is also possible to add another plugin repository or to set automatic check for plugins updates every time QGIS is started.

Install the following external plugins: *NetCDF Browser*, *Value tool, MultiQml*

2.5. Adding and modifying raster layer

Click on the Add Raster Layer icon  from the Manage Layers Toolbar (or select: *Layer → Add Layer → Add Raster Layer…*) and open *SRTM_Poland_wgs84.tif* from the *QGIS Demo data* folder. This is a digital elevation model for the area of Poland and the surroundings (Source: http://srtm.csi.cgiar.org). Pixel values represent elevation above sea level)

Click the *Right Mouse Button* (*RMB*) on the layer and select Properties. Go to the Style tab and make the following changes (Fig. 3): Choose Render type: *Singleband pseudocolor*. Expand *Load min/max values* and select *Min/max*. Click on *Load*. Select *Color* palette (*RdYGn*).

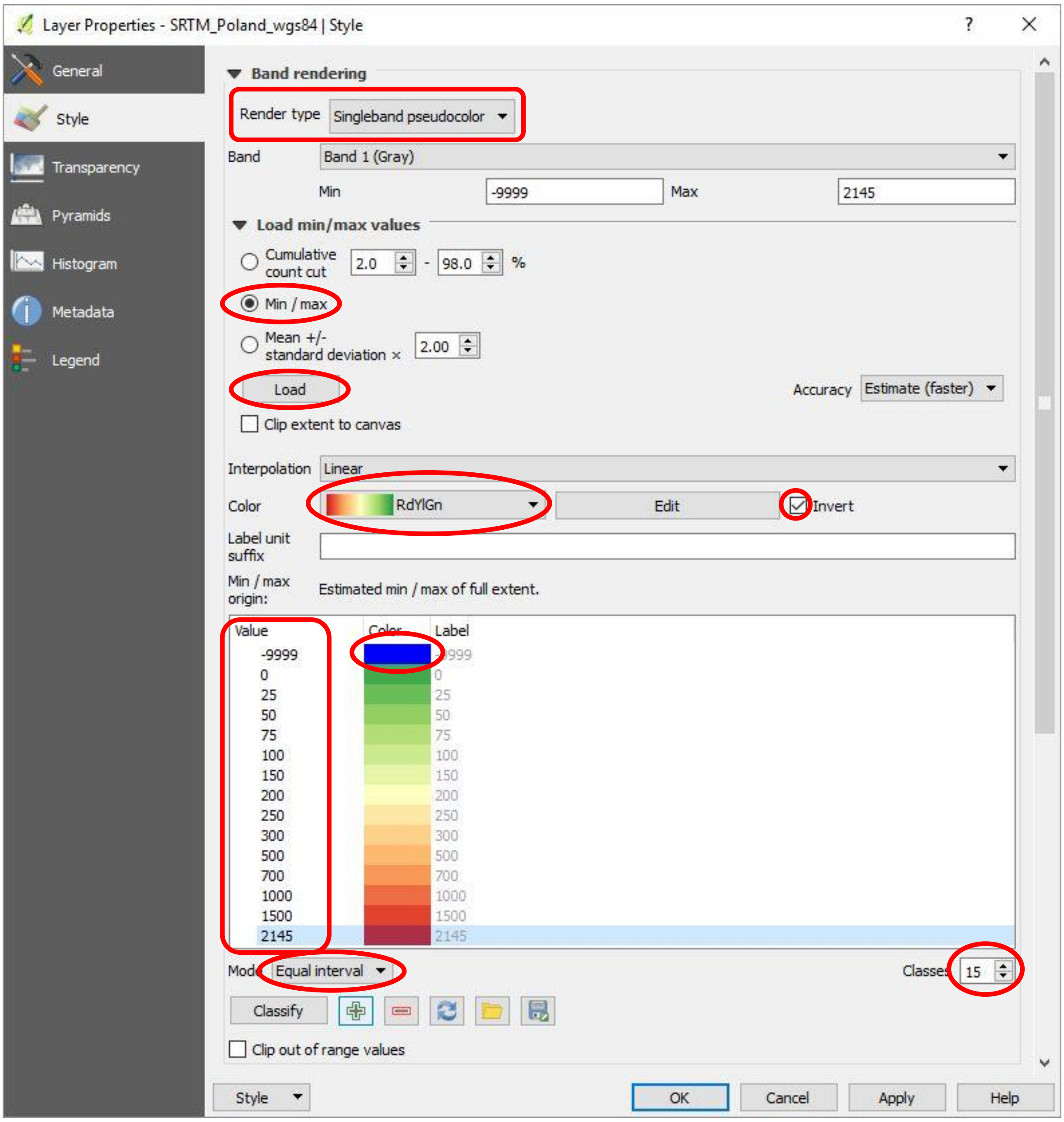


Fig. 3. Modifying display properties of the SRTM layer.

Change the classification mode to *Equal Interval* and set the number of classes to *15*. Check the Invert checkbox to invert the colours. Change the colour of the first class to blue (R|G|B

= 0|0|255). Modify the elevation values as it can be seen in the figure. Confirm changes (*OK*). The result should look like in Fig. 4.

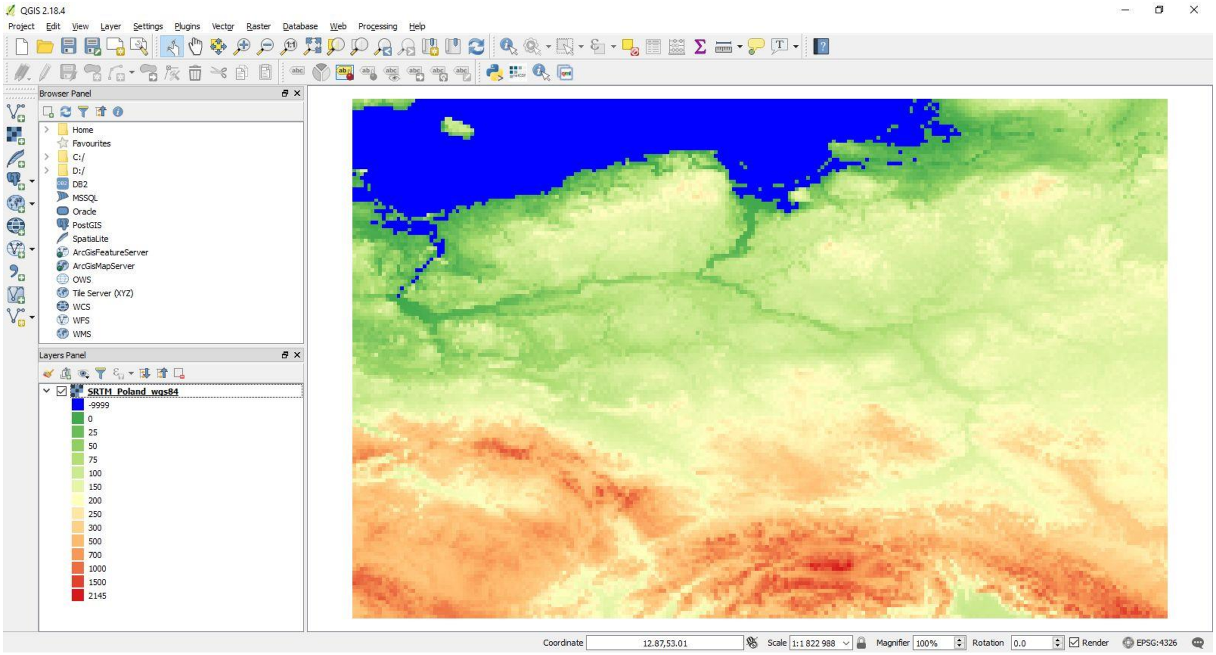


Fig. 4. Classified Elevation based on SRTM.

2.6. Adding and modifying vector layer

Click on the Add Vector Layer icon  from the *Manage Layers Toolbar* (or select: *Layer* → *Add Layer* → *Add Vector Layer…*) and open *Poland_wgs84.shp* from the *QGIS Demo data* folder. This is the country boundary of Poland (source: GADM, http://gadm.org)

Click the *RMB* → *Properties*. Go to *Style* tab. Select *Simple fill,* set *Fill* to *Transparent fill* and *Outline width to 0.5 (Fig. 5).* Confirm changes (*OK*). The result should look like in Fig. 5.

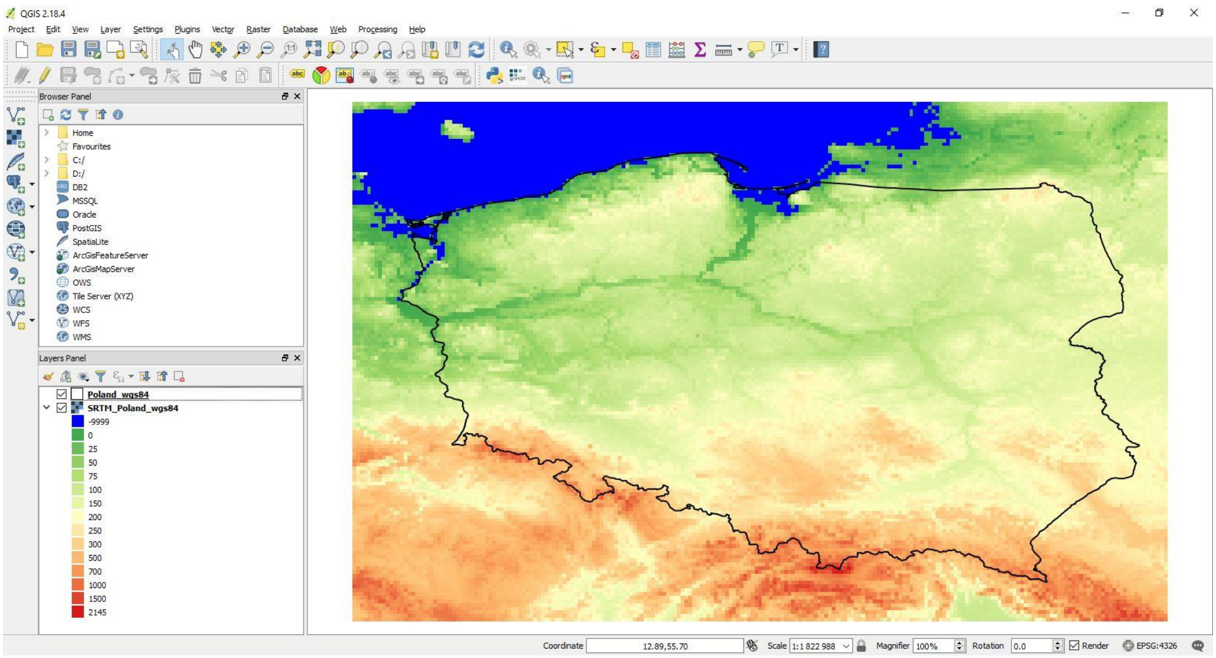
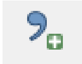


Fig. 5. Country boundary of Poland on top of classified SRTM.

2.7. Importing Spreadsheets or CSV files as vector layers

Click on the Add Delimited Text Layer icon  from the *Manage Layers Toolbar* (or select: *Layer → Add Layer → Add Delimited Text Layer…*) and open *Krakow.xls* from the *QGIS Demo data* folder.

These are the geographic coordinates of the Main Market Square in Krakow:

- Lat = 50.061897 °N,
- Lon = 19.936756 °E.

Geographic coordinates of any place in the World can be identified on the websites:

- https://itouchmap.com/latlong.html
- http://www.latlong.net

While opening *Krakow.xls*, define the following settings (Fig. 6):
Select *Custom delimiters*, check *Semicolon* and *First record has field names*. Verify if the values are displayed in three columns and click OK.

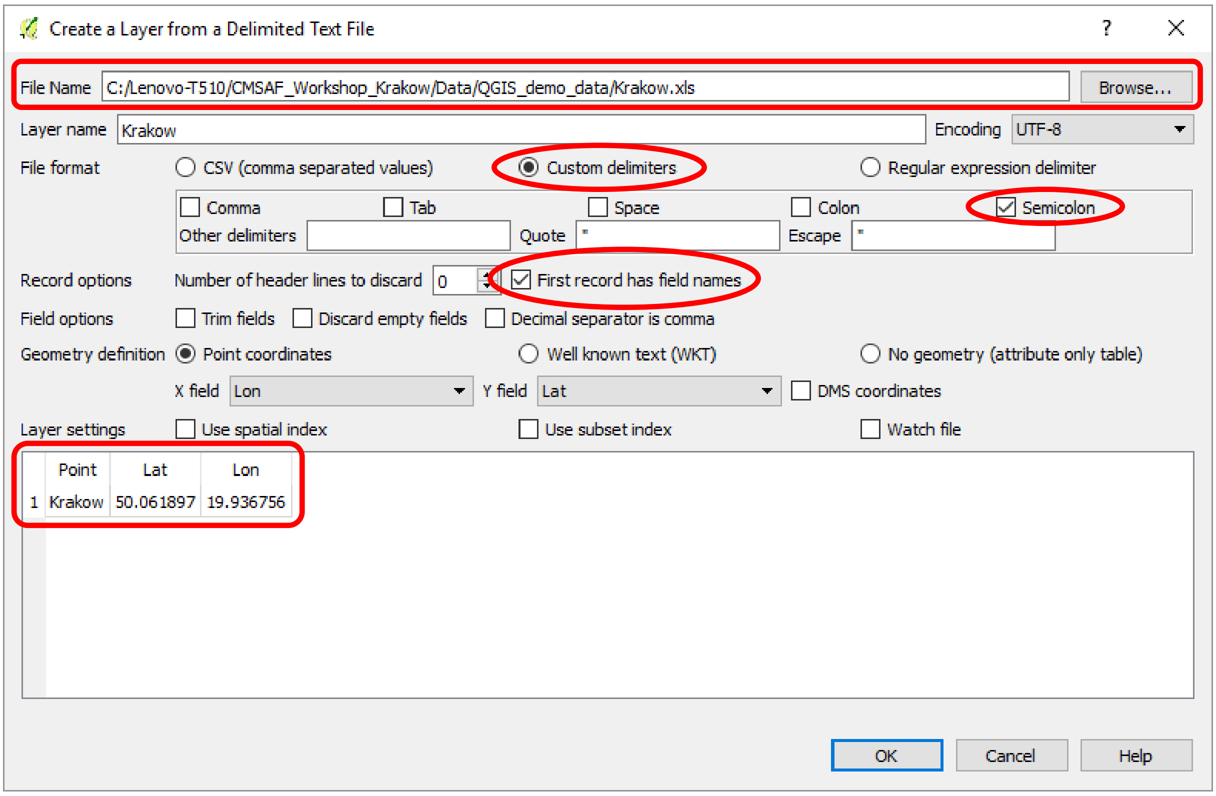


Fig. 6. Correct settings to create point layer representing Krakow.

A point layer representing Krakow should appear in the canvas. Save the point layer as shape file (*RMB → Save As…)*. Name it *Krakow_wgs84/shp.* Change the colour of the point to a one you like. You can add a point label (*RMB → Properties → Labels* tab).

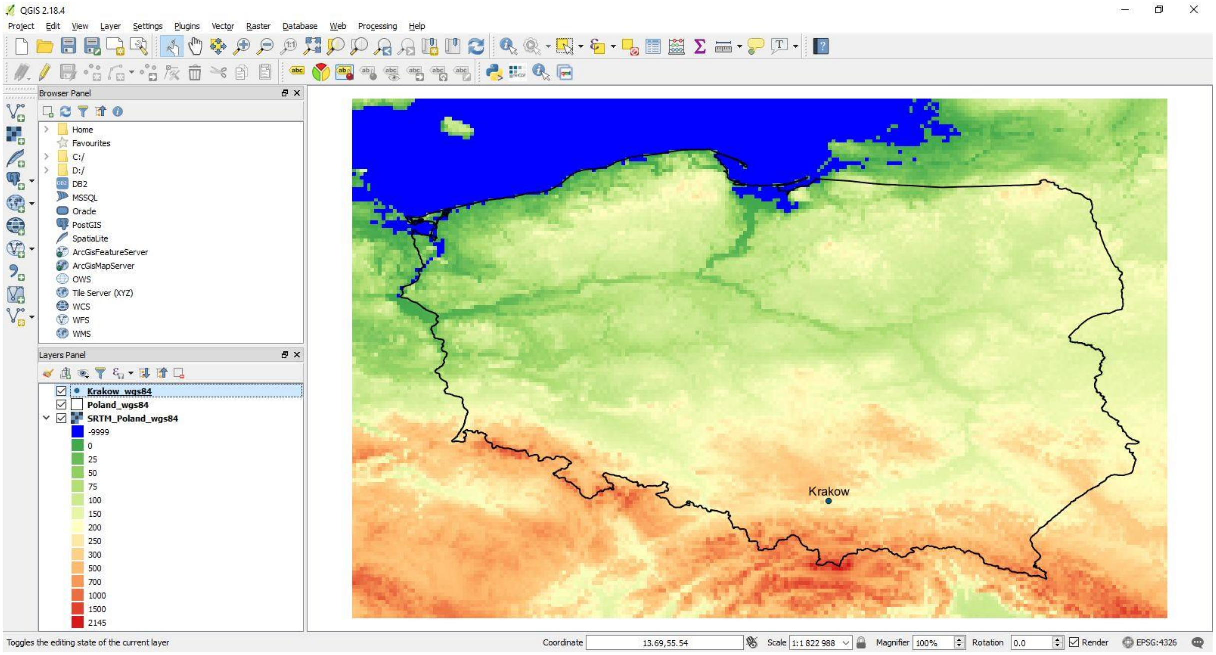


Fig. 7. Location of Krakow in Poland on top of classified elevation (SRTM).

2.8. Saving QGIS Project

Save the project (*Project →Save as…*) as *cmsaf_1.qgs*. You can save it in the *QGIS Demo data* folder.

3. Working with netCDF files

NetCDF is not a native GIS format and therefore working with this format in a GIS environment (such as QGIS) can be challenging. Complex geoprocessing may require transformation of the source netCDF files to GeoTiff.

Input CM SAF climate data record (*SIS_Poland.nc*):

Monthly mean SARAH-2 SIS clipped to the area of Poland and the surrounding areas (13.5 – 24.5°E, 48.5 – 55.5°N) with the use of *Prep.Data.R* tool included in CM SAF R Toolbox. *SIS_Poland.nc* is in netCDF-3 format.

3.1. Opening a netCDF file and displaying specific time steps

There are at least two possibilities to open a netCDF file in QGIS.

The first one is to add it as a raster:

Click on the Add Raster Layer icon  from the Manage Layers Toolbar (or select: *Layer → Add Layer → Add Raster Layer…*) and open *SIS_Poland.nc* from the *QGIS Demo data* folder.

NetCDF by default displays as a multiband raster and the program is not able to read the coordinate reference system (CRS) from the file but it assigns WGS84 (*EPSG:4326*), which is the correct one in this case (Fig. 8)

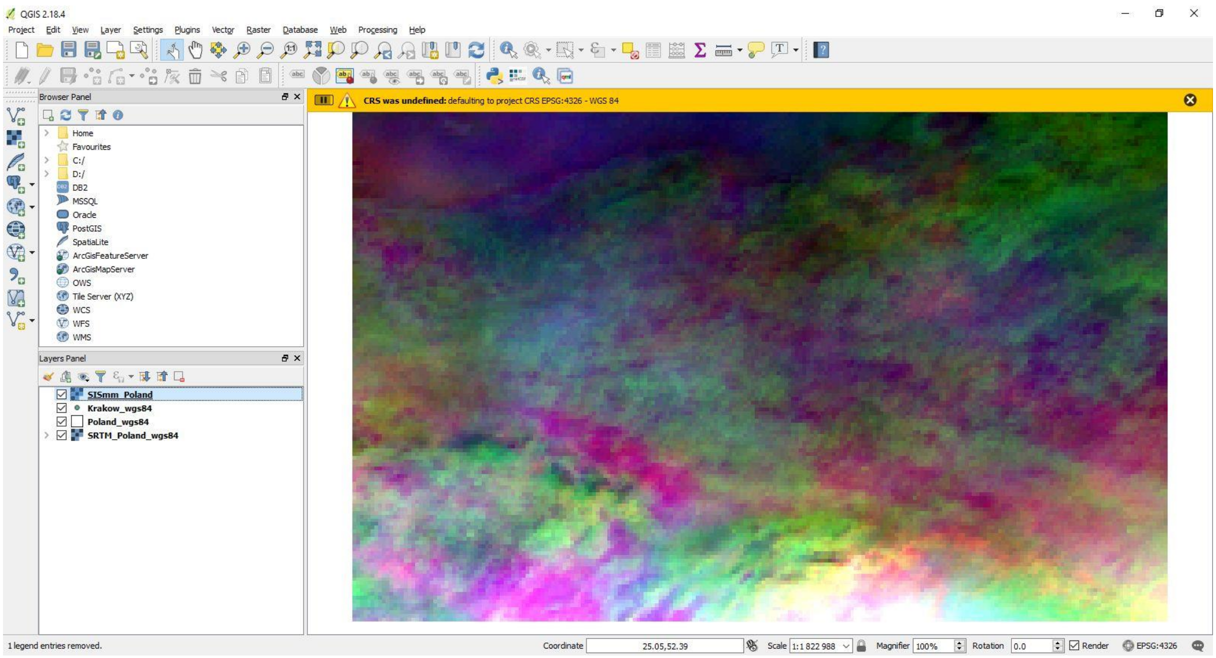


Fig. 8. The netCDF file (*SIS_Poland.nc*) displayed as multiband raster

Change the display to single band (*RMB → Properties → Style* tab) and modify the following band rendering options (Fig. 9):

- Render type: *Singleband gray*
- Contrast enhancement: *Stretch to MinMax*
- Load min/max values: *Min/max* (+ click on *Load*)

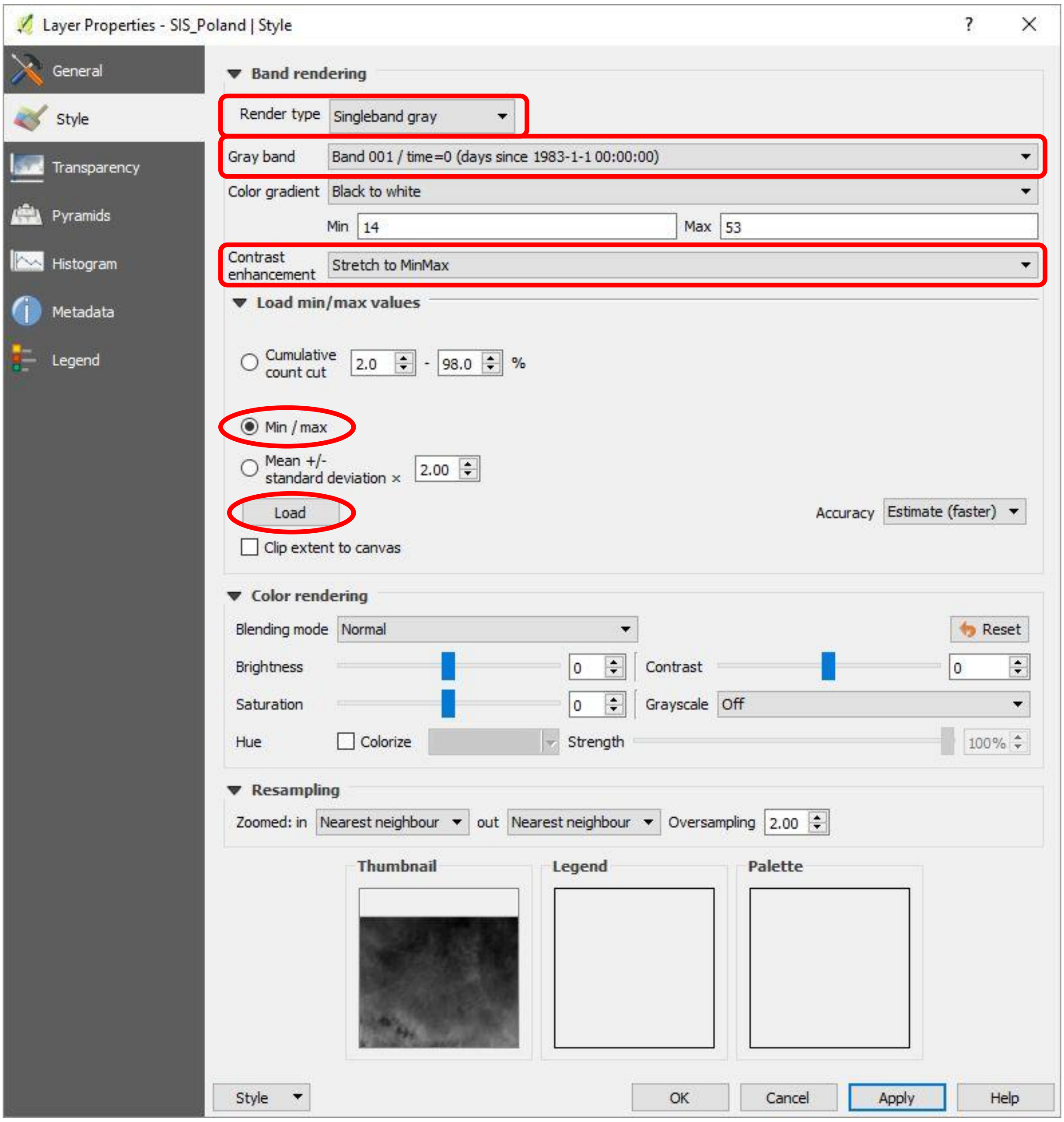


Fig. 9. Modifying netCDF display properties

You can display the data for any other time step by changing the Gray band.

In the *Layers Panel*, move the administrative border of Poland (*Poland_wgs84*) to the top and change the outline colour to red (*RMB* → *Properties* → *Style* tab)

The resulting gray scale image showing spatial distribution of the mean surface incoming shortwave radiation in Januray 1983 is presented in Fig. 10

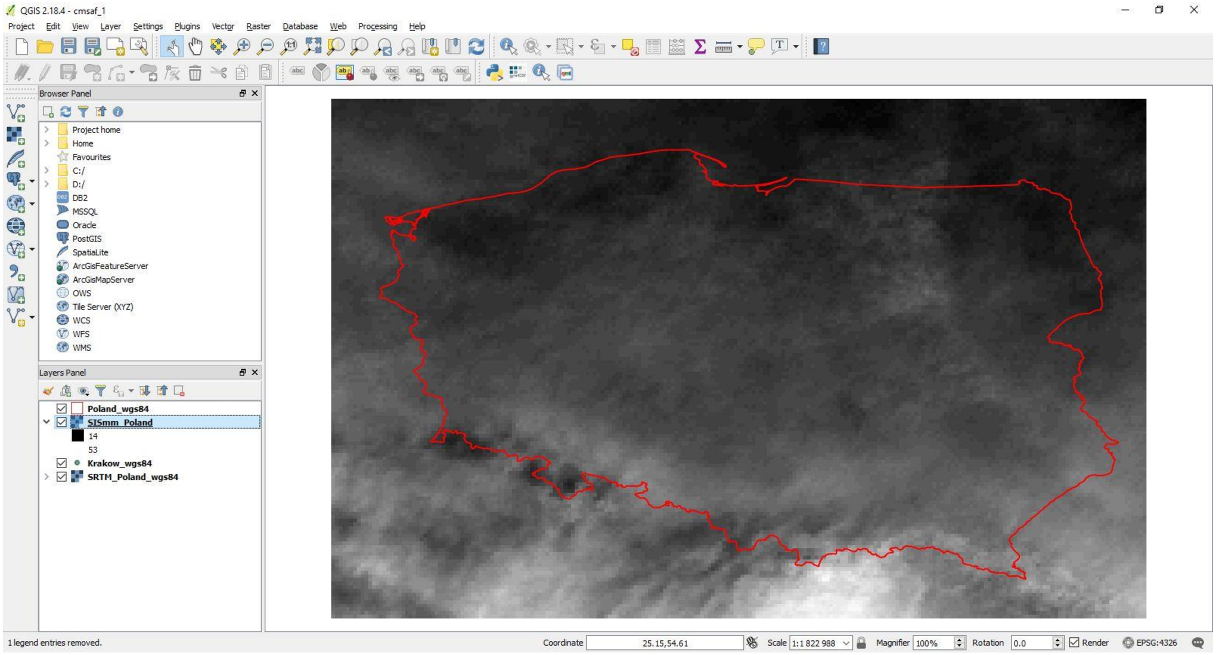


Fig. 10. The netCDF file (*SIS_Poland.nc*) displayed as single band raster (January 1983)

An alternative option to display netCDF file in QGIS is to use *netCDF Browser* plugin.
Make sure the *netCDF Browser* plugin is installed and enabled (*Plugins → Manage and Install Plugins*).
Click on the *netCDF Browser* plugin icon  from the Plugins Toolbar to start the plugin. (Fig. 11). A single time step can be selected or by checking the *multi-selection* check box a multiple time steps can be selected. Than the selected time steps can be added to the project by clicking *Add selection*.

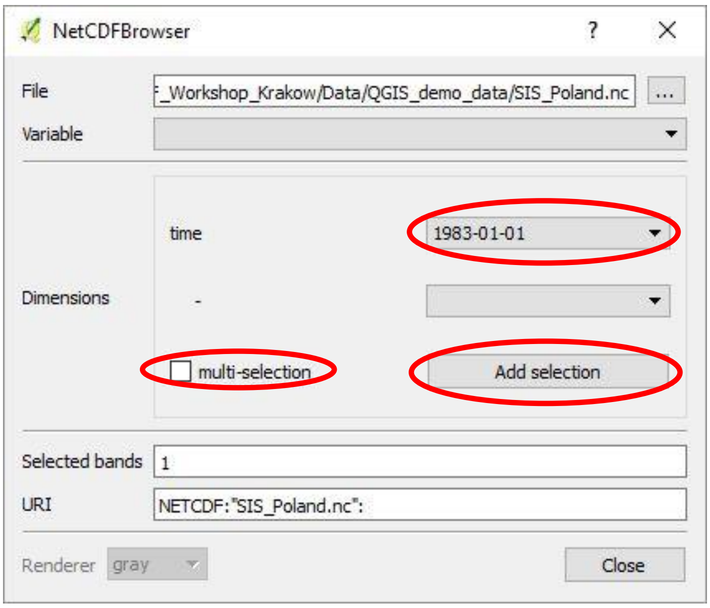


Fig. 11. NetCDF Browser plugin

3.2. Checking information on the netCDF dataset

Basic information such as layer name, source and CRS: *RMB* → *Properties* → *General* tab
More detailed information (for each time step): *RMB* → *Properties* → *Metadata* tab (or: *Raster* → *Miscellaneous* → *Information)*

3.3. Saving netCDF as a multi-band GeoTiff.

Conversion netCDF to multi-band GeoTiff: *RMB* → *Save As…* (Output mode: *Raw data*)

By changing the Output mode to: *Rendered image* only the image (without source data) for the selected time step will be saved.

Save the *SIS_Poland.nc* as *SIS_Poland_wgs84.tif*. Remember to set the right CRS (Fig. 12)

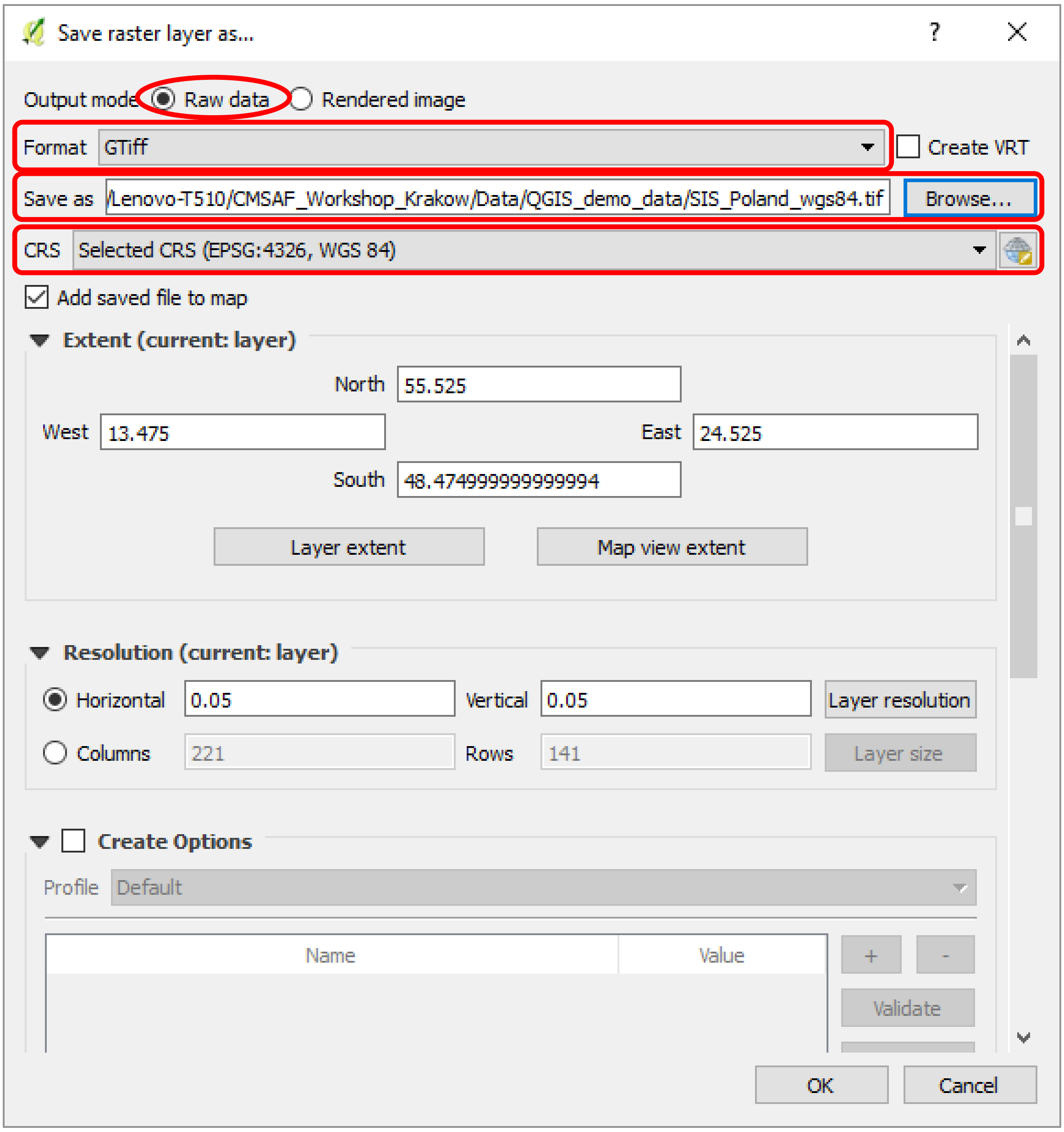


Fig. 12. Saving netCDF as GeoTiff

3.4. Splitting netCDF into single band GeoTiff-s

Extracting selected time steps from a netCDF file can be done with GDAL (***G**eospatial **D**ata **A**bstraction **L**ibrary*), which is an open source translation library mainly for raster geospatial data formats. For more information check GDAL website: http://www.gdal.org.

GDAL Tools is a core QGIS plugin which provides GUI to the collection of GDAL tools.

Before converting all the time steps from the *SIS_Poland.nc* to geoTiff, the input netCDF file needs to have the right spatial reference system assigned so that QGIS could recognise it. It would also be good to have the floating-point values. This can be achieved with GDALwarp - image reprojection and warping tool (*Raster → Projections → Warp (Reproject)…).* Start the tool and select the Input file: *SIS_Poland.nc,* define the output file: *SIS_Poland_float_wgs84.nc* and chose WGS84 (EPSG:4326) as the Target reference system. Then modify the script below by adding *-of netCDF –ot Float32* according to Fig. 13. Click *OK* to run the *Warp* tool.

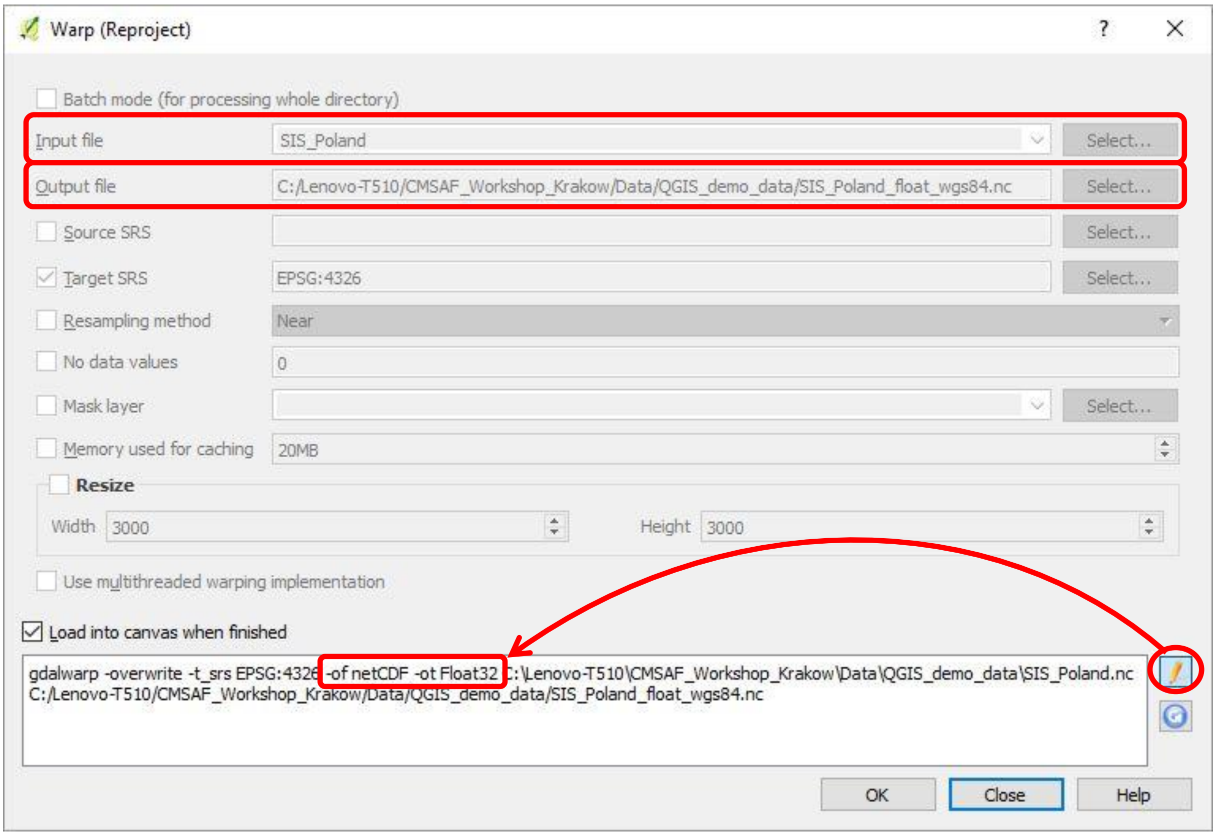


Fig. 13. Assigning target reference system and floating-point data values (*GDAL warp*).

Splitting and converting the netCDF file to geoTiff can be done with GDALtranslate – raster format conversion tool (*Raster → Conversion → Translate (Convert format)…).* Start the tool and select the Input (*SIS_Poland_float_wgs84.nc*) and the output file (*SIS_Poland_float_wgs84.tif*). Check *Sds* to copy subdatasets to individual output files. Compare with Fig. 14.

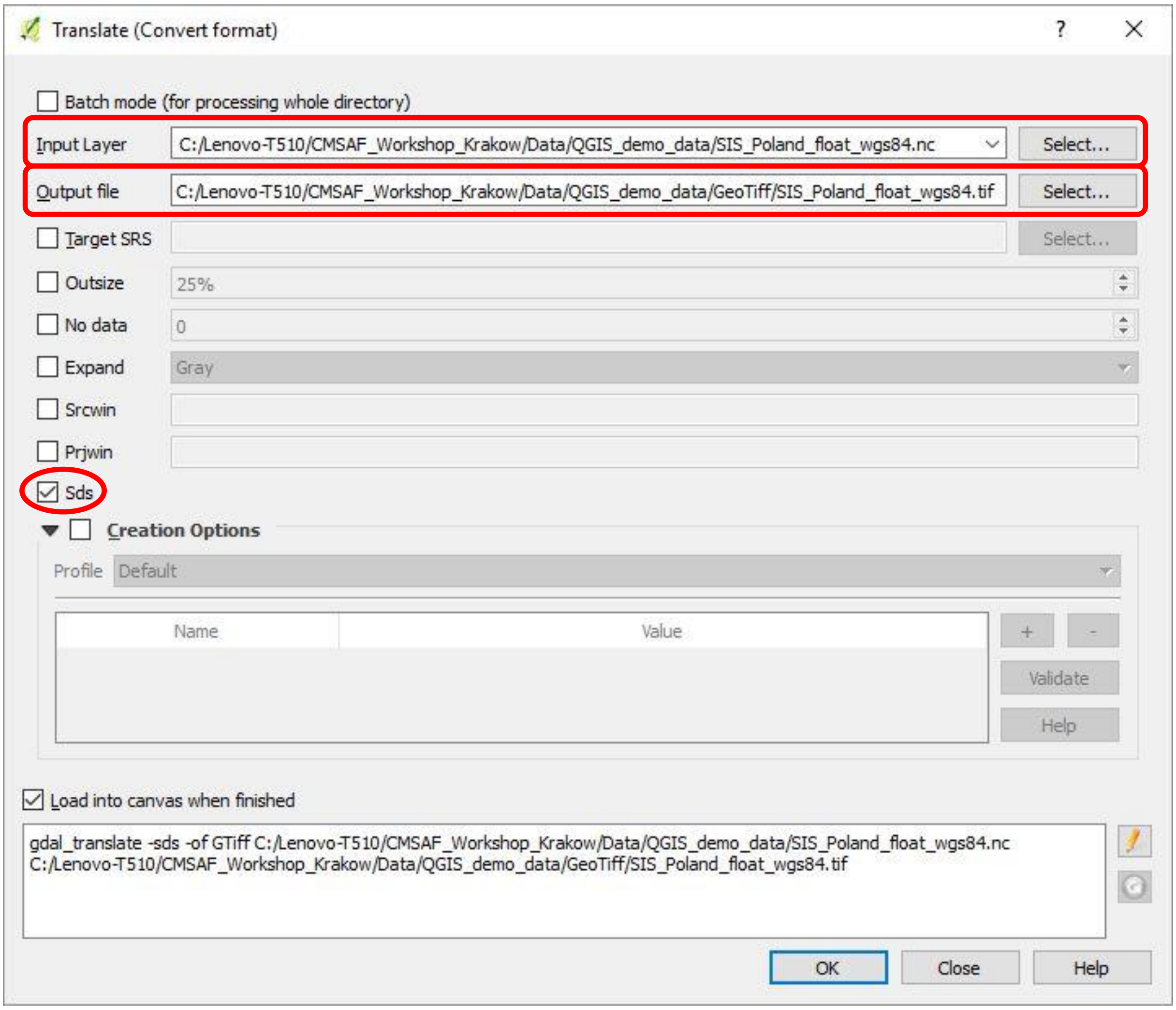


Fig. 14. Converting netCDF to geoTiff and splitting the time steps (*GDAL Translate*)

Unfortunately date is missing in the output file. The name of the file contains only the band number representing consecutive month starting (1-396) from January 1983. Check the date corresponding to each band number in the Index.csv file or run *XXX_to_YYYY_MM.bat* (*…\QGIS_demo_data\GeoTiff*) to add appropriate date to each file name. The name of the input file must have the following format:

SIS_Poland_float_wgs84_XXX.tif

where *XXX* is the band number.
Otherwise, the *XXX_to_YYYY_MM.bat* file has to be adjusted.

4. Basic geoprocessing

4.1. Time series plotting

Extracting time series for selected location can be done in two ways.

Value tool plugin is useful to quickly check the time series over mouse pointer location. Merged netCDF file can be used as input.

Make sure the *Value tool* plugin is installed and enabled (*Plugins* → *Manage and Install Plugins*).

Click on the *Value Tool* plugin icon  from the *Plugins Toolbar* to start the plugin. In the *Value Tool* window, go to *Graph* tab. Move the mouse pointer over the *SIS_Poland.nc* layer displayed in canvas. A time series plot over all time steps will be displayed (Fig. 15).

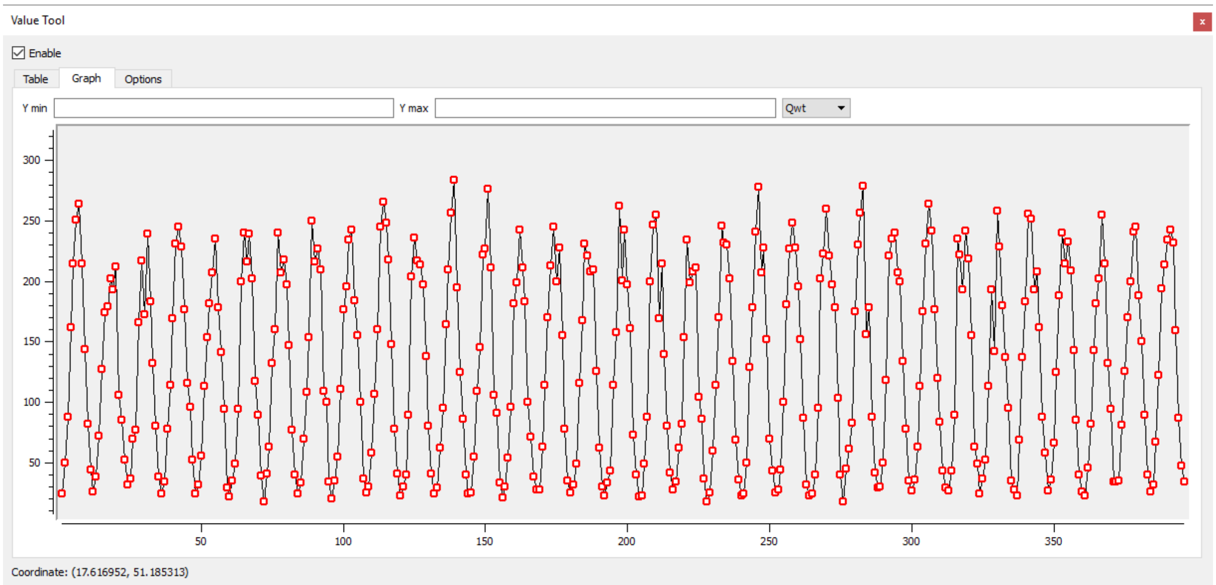
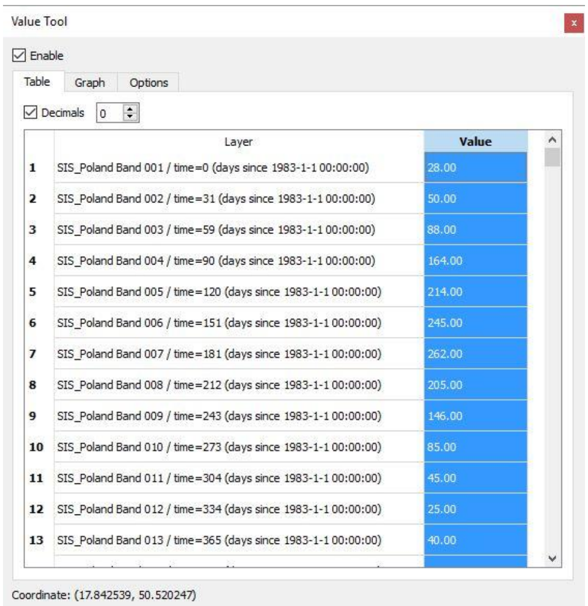


Fig. 15. Time series over all the time steps plotted for random location (*Value Tool*).

Go to *Table* tab. The values are stored in the Value column and can be easily copied (Ctrl+C → Ctrl+V) to an Excel spreadsheet, ASCII file, etc…

Go to *Options* Tab. Check the checkbox to plot values only when clicking with the mouse button.



	Layer	Value
1	SIS_Poland Band 001 / time=0 (days since 1983-1-1 00:00:00)	28.00
2	SIS_Poland Band 002 / time=31 (days since 1983-1-1 00:00:00)	50.00
3	SIS_Poland Band 003 / time=59 (days since 1983-1-1 00:00:00)	88.00
4	SIS_Poland Band 004 / time=90 (days since 1983-1-1 00:00:00)	164.00
5	SIS_Poland Band 005 / time=120 (days since 1983-1-1 00:00:00)	214.00
6	SIS_Poland Band 006 / time=151 (days since 1983-1-1 00:00:00)	245.00
7	SIS_Poland Band 007 / time=181 (days since 1983-1-1 00:00:00)	262.00
8	SIS_Poland Band 008 / time=212 (days since 1983-1-1 00:00:00)	205.00
9	SIS_Poland Band 009 / time=243 (days since 1983-1-1 00:00:00)	146.00
10	SIS_Poland Band 010 / time=273 (days since 1983-1-1 00:00:00)	85.00
11	SIS_Poland Band 011 / time=304 (days since 1983-1-1 00:00:00)	45.00
12	SIS_Poland Band 012 / time=334 (days since 1983-1-1 00:00:00)	25.00
13	SIS_Poland Band 013 / time=365 (days since 1983-1-1 00:00:00)	40.00

Fig. 17. Time series for a random location (*Value Tool*).

Extracting values over time steps can be done with *Add raster value to points* – a SAGA tool, which can be accessed from QGIS Processing Toolbox. (*Processing* → *Toolbox*). Start typing tool name in the *Search…* window, than double-click to open the tool. Select shapefile representing points and the grids from which you would like to extract values. Leave the default interpolation method (*[0] Nearest Neighbor*) and define the output shape file name (*SIS_Krakow_wgs84*). Click: Run. This tool extracts values to multiple points (in this case only one – Kraków). Output is written to the attribute table.

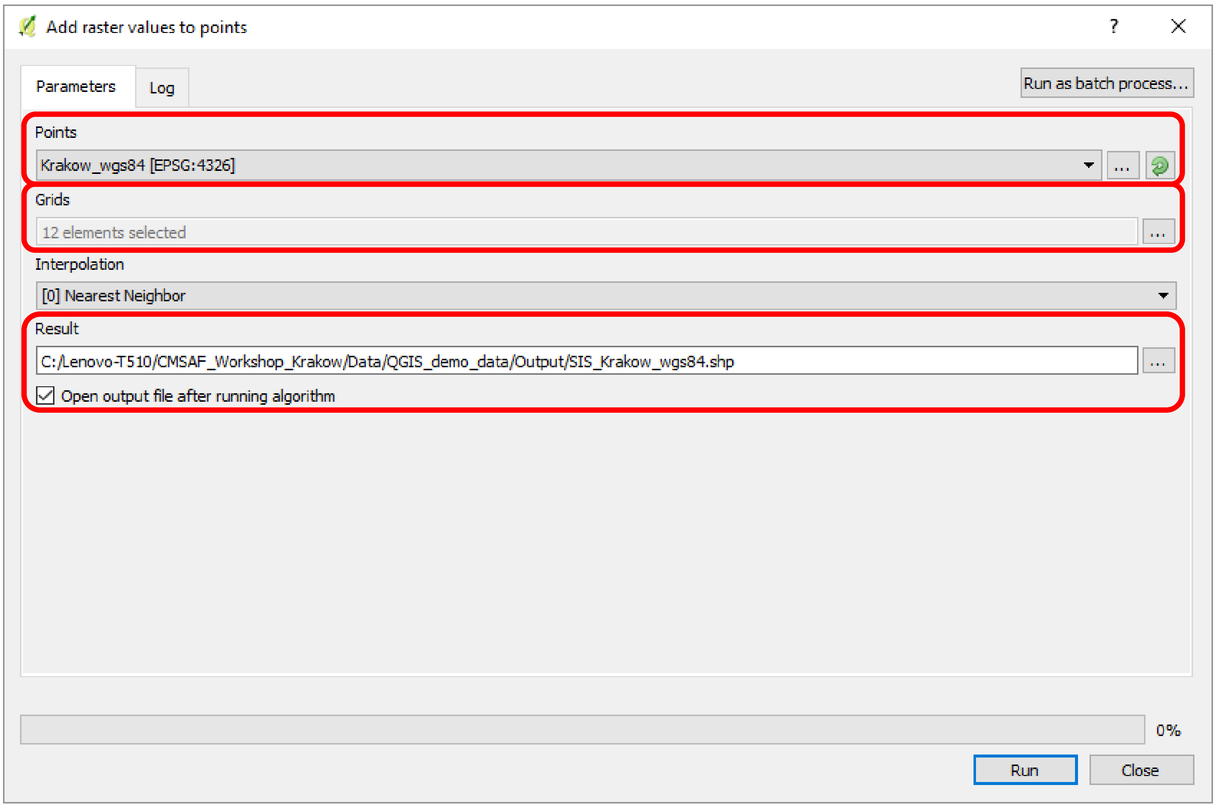


Fig. 18. Extracting monthly mean SIS values over one year - 1983 (*Add raster values to points*).

4.2. Comparing two raster datasets.

If there is a need to compare two raster datasets (all the pixels), a GDAL tool called *gdal2xyz* can be useful. It can be accessed through Processing toolbox as well. The tool save selected raster as XYZ table (field_1 → *lon* | field_2 → *lat* | field_3 → *pixel value*).

Run the *gdal2xyz* tool. Select *SRTM_Poland_wgs84.tif* as the input dataset and save the output to a csv file. Check the checkbox to *Open output file after running algorithm* and click on *Run* – the output table will be added to the *Layers panel*. You can nor run the tool again for a selected SIS time step and check the statistical relationship between these two variables (elevation vs. SIS) using software of your choice. Another idea would be to compare two different SIS time steps.

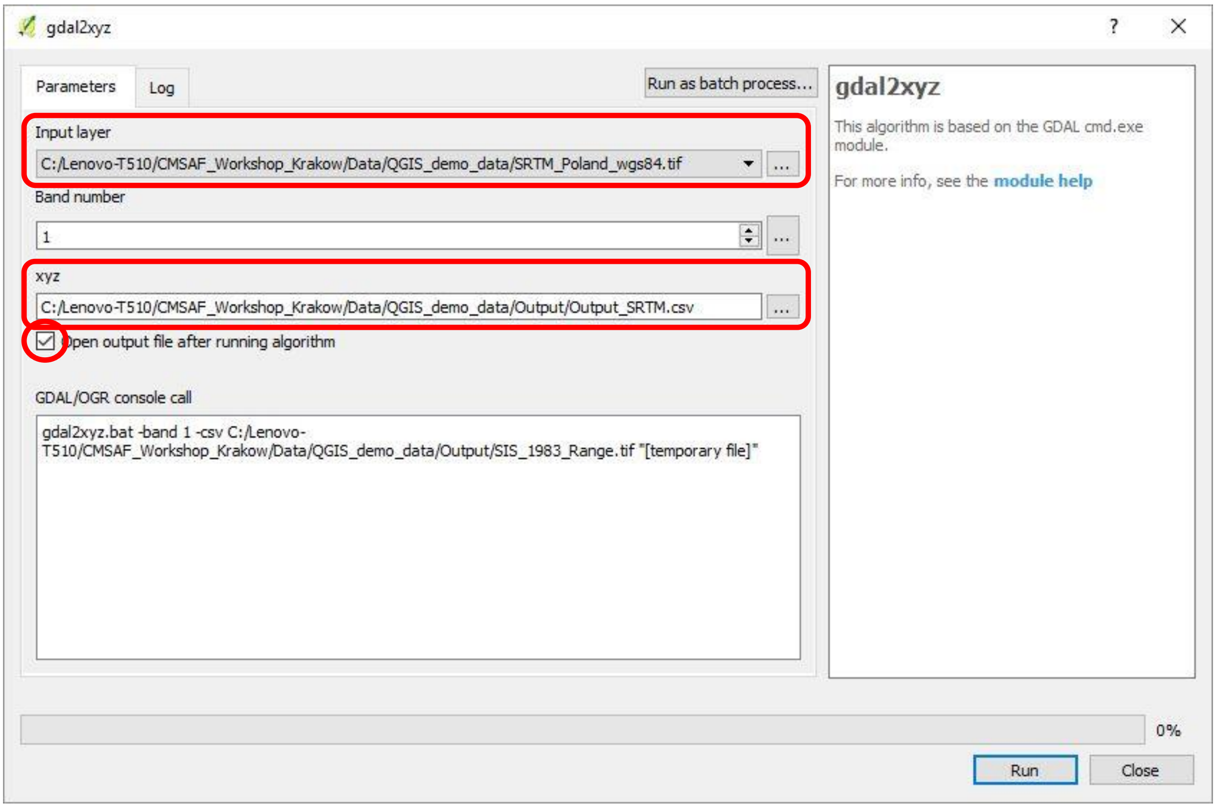


Fig. 19. Saving raster dataset as XYZ table (*gdal2xyz)*

4.3. Raster (grid cell) statistics

Raster statistics (statistics of values in each grid cell over all the time steps) can be calculated using *r. Series* tool, which is a GRASS tool available in QGIS through Processing toolbox. Available statistics are: *average, count, median, mode, minimum, min_raster, maximum, max_raster, standard deviation, range*

Add all the 368 monthly mean SIS raster datasets or just the datasets for a period of interest, for example 5 years (*r.Series* tool does not read multi-band rasters). Run *r.Series* tool. Select Input raster layers and apply statistic of your choice. Save the output as a geoTiff (Fig. 20). Examine the datasets with different statistics. Close *r.Series* tool when completed.

Run *Split_months.bat* (*…\QGIS_demo_data\GeoTiff*) to divide the splitted raster files for each month into subfolders (1-12). Run *r.Series* tool in batch mode (*RMB → Execute as batch process*). Add nine more rows so that there were 12 rows in total. Insert all the 33 raster datasets for each month as *Input raster layer(s)*. It will be easier to select files from created subfolders *(… → Select from filesystem*). Leave aggregate operation as *average*. Insert 0 in the first row of the *GRASS GIS7 region cell size (leave 0 for default)* than double click on the column's label. Zero's will fill in automatically in the remaining rows as well. Name the output files (*Aggregated*). Use */…/* for setting the output workspace first. You can use *autofill mode* to fill the output file names automatically with numbers. Set *load in QGIS* to No. Compare your batch *r.Series* processing settings with Figures 21a and 21b.

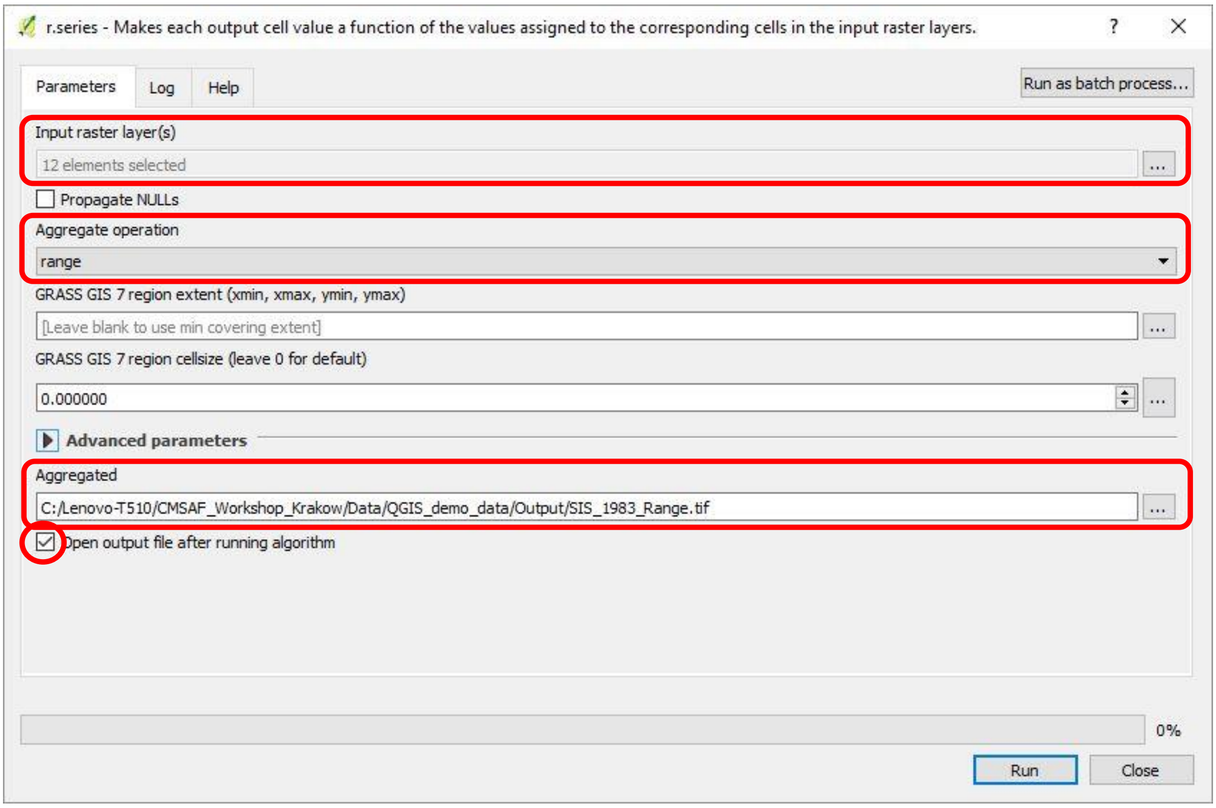


Fig. 20. Calculating raster statistics (*r.Series*)

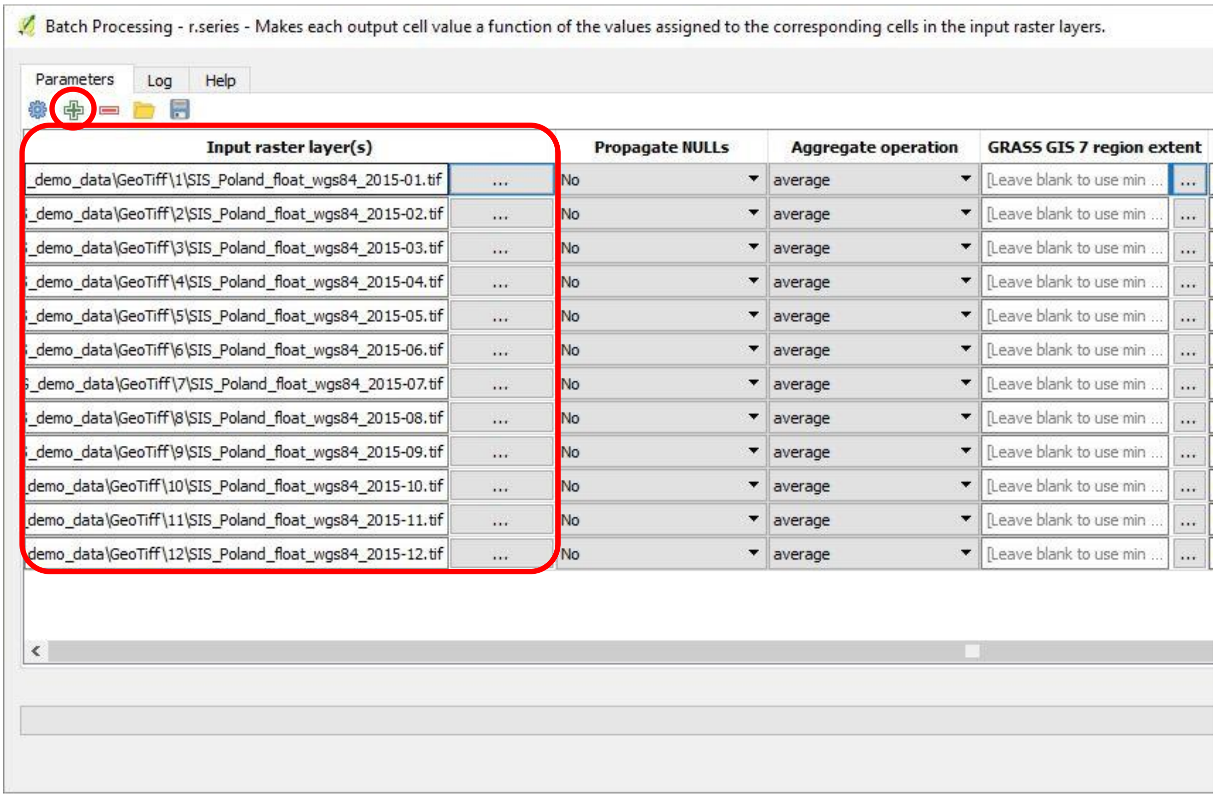


Fig. 21A. Calculating raster statistics (*r.Series*) in batch mode (left side)

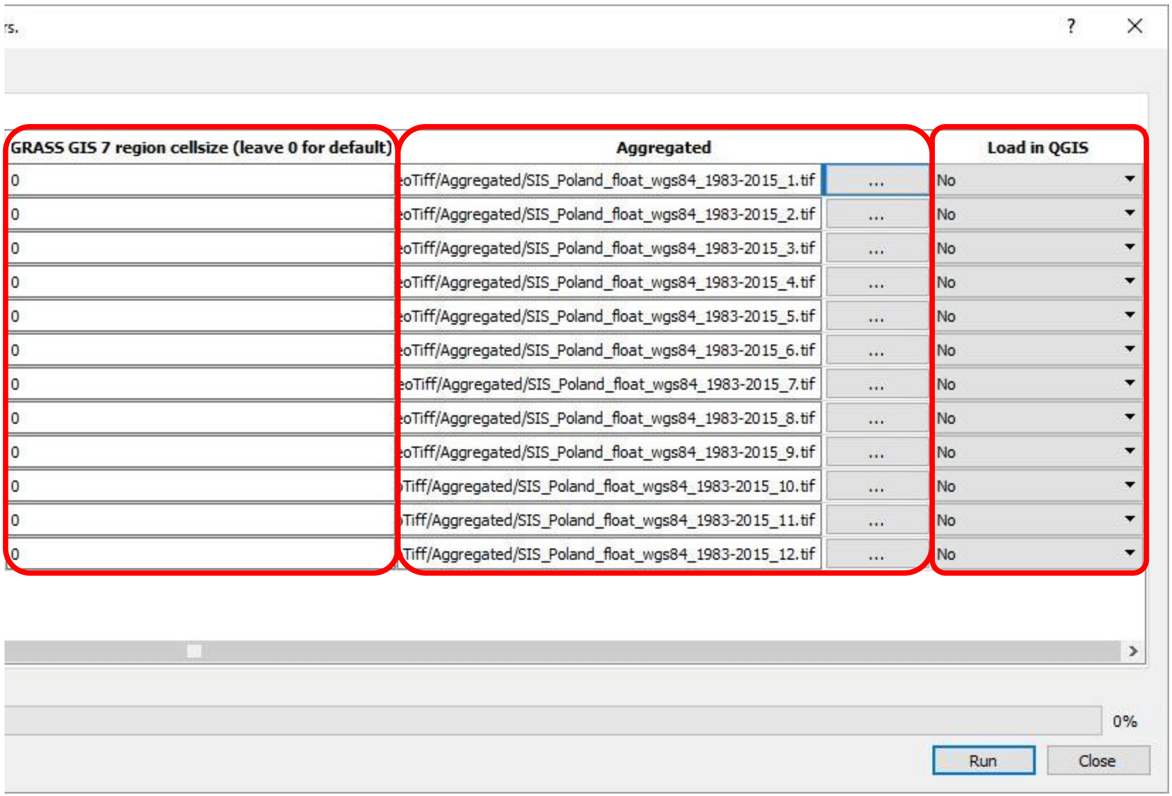


Fig. 21B. Calculating raster statistics (r.Series) in batch mode (right side)

5. Creating a map

5.1. Clipping raster layers to the country boundary.

Run SAGA tool *Clip raster with polygon* (accessible through *Processing toolbox*) in batch processing mode. Expand number of rows to 12. Select al the 12 multi-year monthly mean SIS layers as *Input*. Insert *Poland_wgs84.shp* in the first row of the *Polygons* column and double click on the column's label to insert it automatically in the remaining rows. Name the output raster files (e.g. *SIS_Poland_float_wgs84_1983-2015_X_clipped.tif*, where *X* = month). Set *load in QGIS* to: *No*. Run the tool.

Add all the 12 clipped multi-year monthly mean SIS layers for each month to *Layers panel*. Keep the administrative border of Poland (*Poland_wgs84.shp*) on top. Remove all the other layers from the *Layers panel* (Fig. 22). Save the project (*Ctrl+S*).

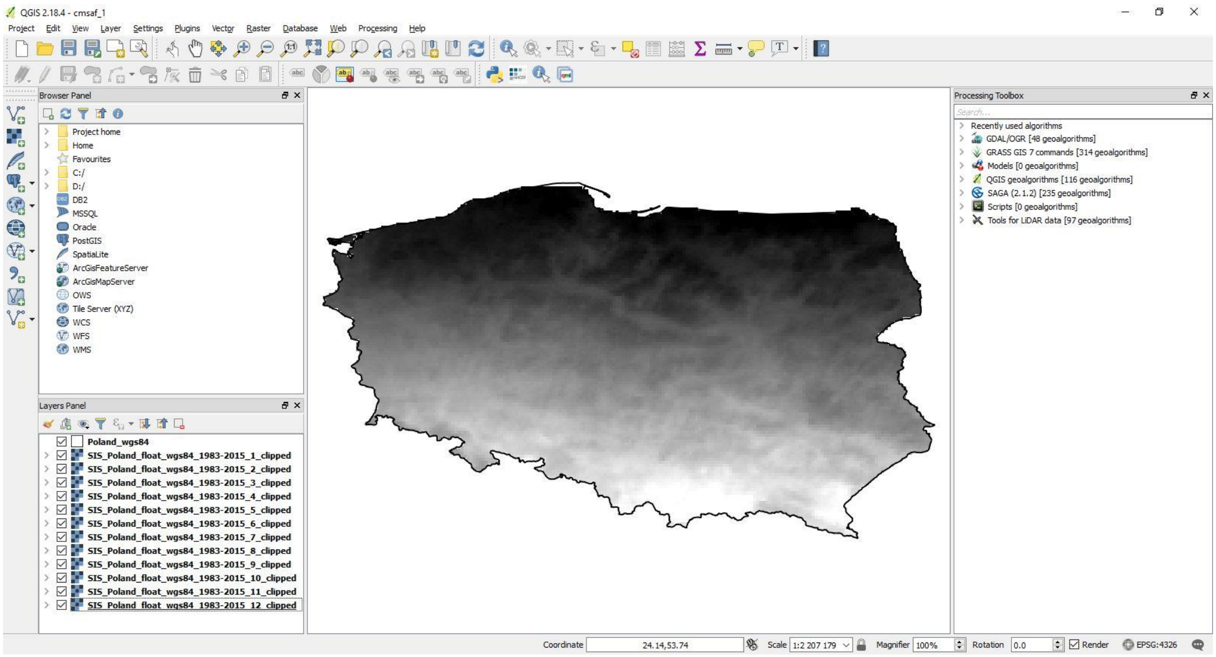


Fig. 22. Multi-year monthly mean SIS layers for each month clipped to the administrative boundary of Poland displayed in WGS 84.

5.2. Changing map projection

For the mapping purposes all the layers should be displayed in an appropriate national projected coordinate system. All the layers in the project are currently displayed in geographic coordinate system (WGS84) whereas the official coordinate system for medium and small scale (1:10 000 and smaller) maps of Poland is PUWG-92 (reference system: ETRS89 / projection: Gauss~~a~~-Krüger).

Click on the current CRS button: *EPSG: 4326* on the Status bar, in the lower right corner of the screen. This will open *Project properties | CRS* window. Check the checkbox next to *Enable 'on the fly' CRS transformation (OTF)*. Use filter to find all the available coordinate systems for Poland. Select *ETRS89 / Poland CS92* (EPSG code: 2180). Compare settings with Fig. 23. The output result should be like in Fig. 24.

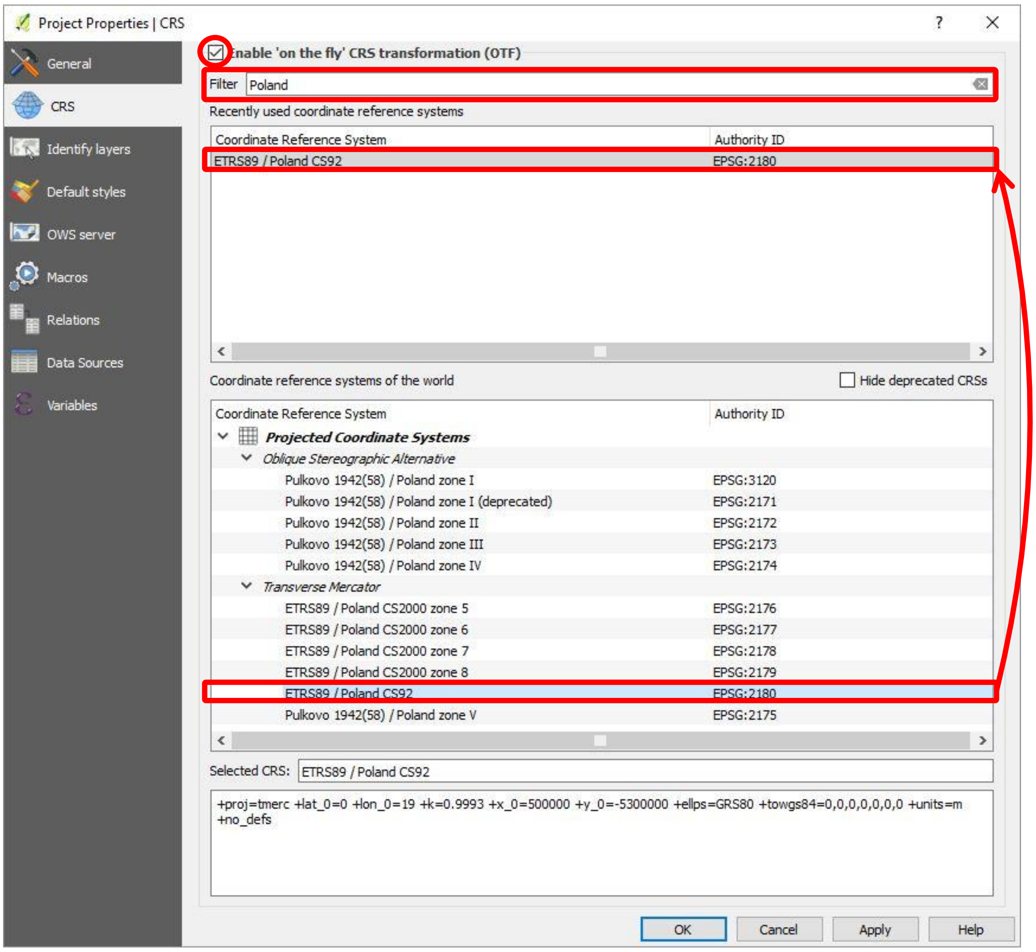


Fig. 23. Changing CRS from WGS 84 to PUWG-92.

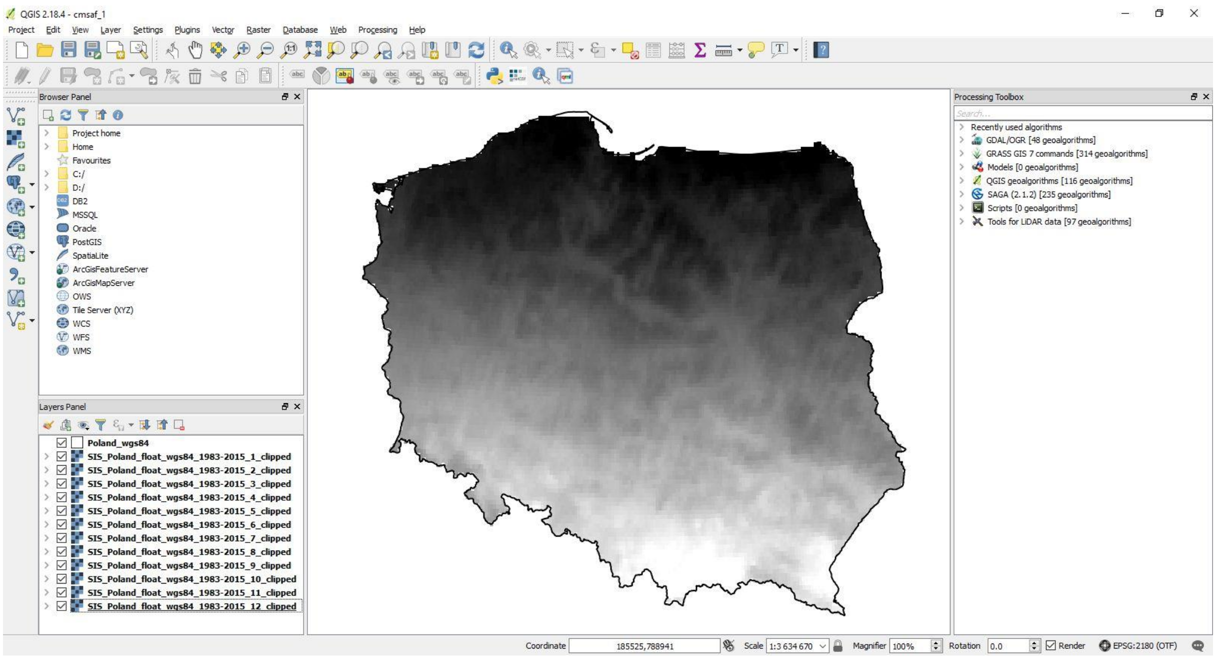


Fig. 24. Multi-year monthly mean SIS layers for each month clipped to the administrative boundary of Poland displayed in PUWG-92.

It is easier to identify a coordinate reference system using EPSG code. The EPSG codes for any CRS can be found on this website: http://spatialreference.org.

Note, that all the layers in the *Layers panel* are not transformed to the new CRS but just displayed in the new CRS 'on the fly' in the canvas.

5.3. Classifying multiple raster layers

For the mapping purposes also all the multi-year mean SIS raster layers should be classified in equal intervals and presented in an adequate colourful palette so that the interpretation of spatial distribution of surface solar irradiance values was easier and more intuitive for the map users. In this case we would like to create one legend covering the whole range of multi-year mean SIS values for each month.
The minimum value in the whole dataset is: 13.8788 W/m^2 (December)
The maximum value in the whole dataset is: 239.485 W/m^2 (June)

Go to style properties of the multi-year mean SIS values for December (*RMB → Properties → Style*). Make the following changes (Fig. 25): Choose Render type: *Singleband pseudocolor*. Assign minimum and maximum values as *10* and *240* respectively. Change interpolation method to *Discrete*. Select *Color* palette (*Spectral*) and check the checkbox to invert the colours. Change the classification mode to *Equal Interval* and set the number of classes to *23*. Save the created style in *qml* format (*Style → Save Style…*). Close the window.

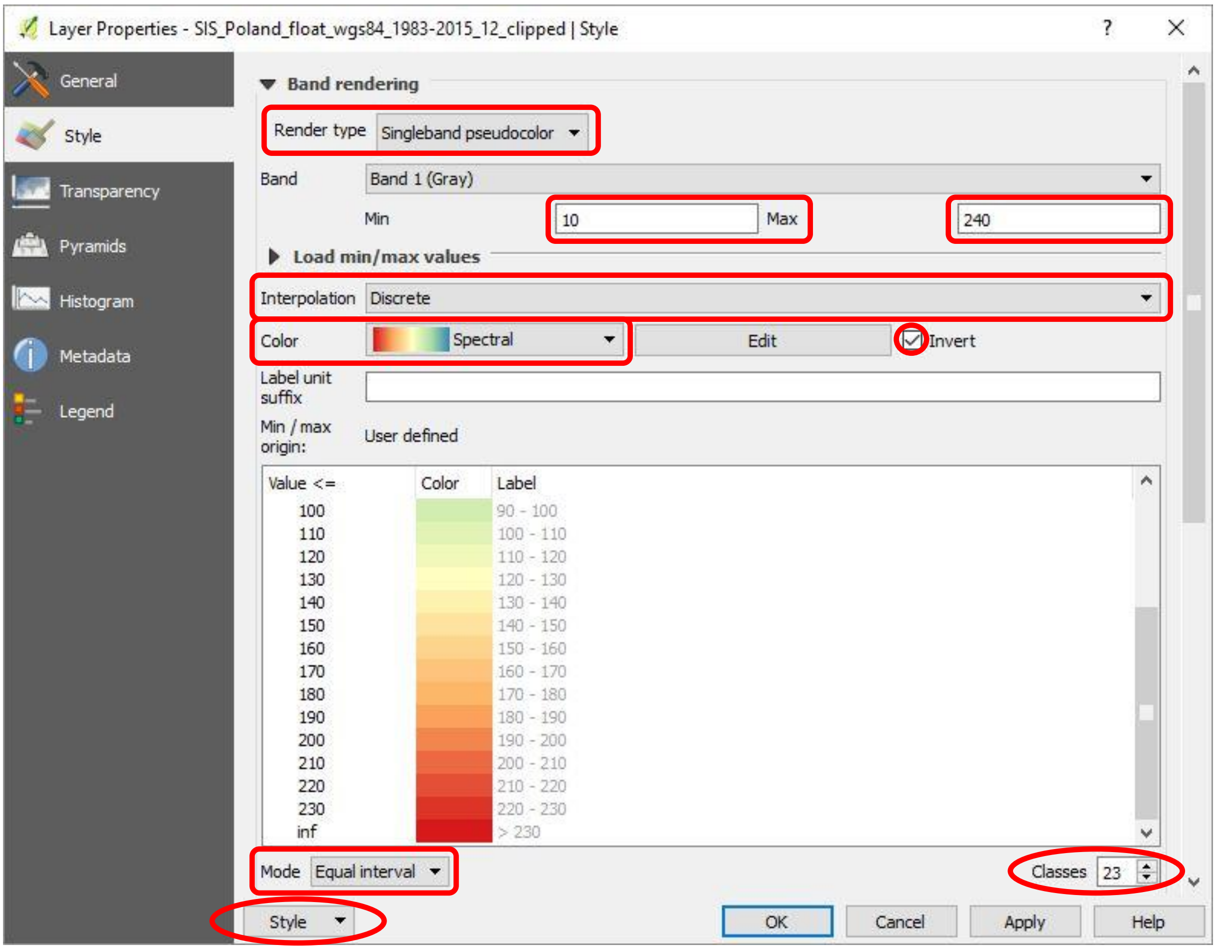
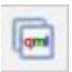


Fig. 25. Multi-year monthly mean SIS layers for each month clipped to the administrative boundary of Poland displayed in PUWG-92.

Run *MultiQml* plugin:  .

Select all the 12 multi-year mean SIS raster layers and click on *Apply style …* (Fig. 26). Find the saved style in *qml* format and open it. The style will be assigned to all the layers. The results should be like in Fig. 27.

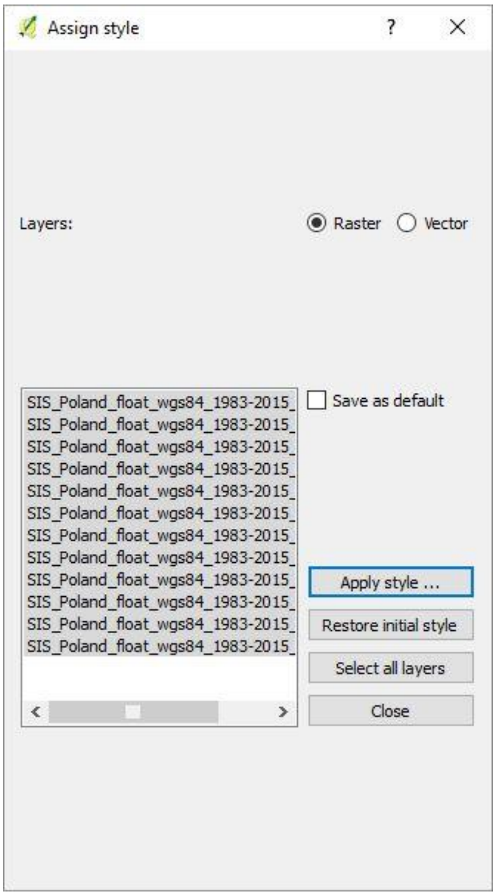


Fig. 26. Assigning classification style to multiple raster layers.

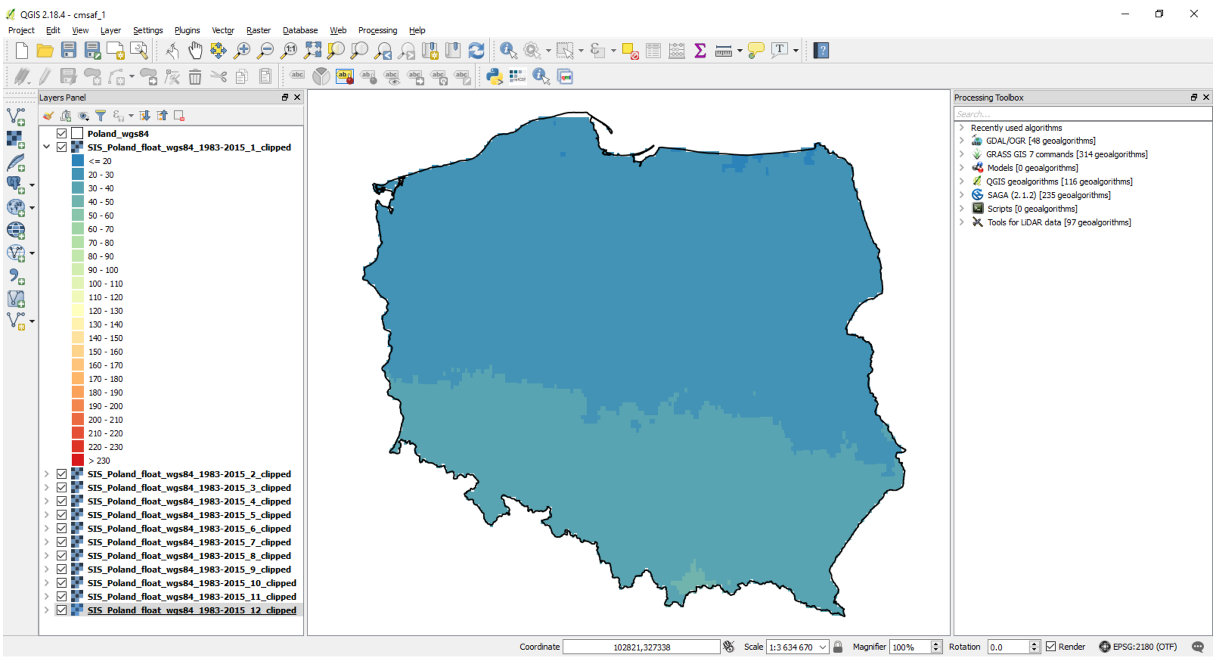


Fig. 27. Multi-year monthly mean SIS layers for each month clipped to the administrative boundary of Poland classified in equal intervals of 10 W/m^2

5.4. Designing a map layout

QGIS has a separate tool for creating maps which is called *Map Composer*.
Run Map Composer (*Project → New Print Composer*). Enter a composer title (e.g. *SISmm Poland*) or leave it empty to assign a default name such as *Composer 1*. You can go back to previously saved composer through *Composer Manager* (*Composer→ Composer Manager*).
Adjust the page size and orientation (*Composition properties / Page size*: change *Presets* to *Custom* and *Orientation* to *Portrait*, change the page Height to 240.00 mm). Zoom to display the full extent of the Layout. Check the result with Fig. 28.

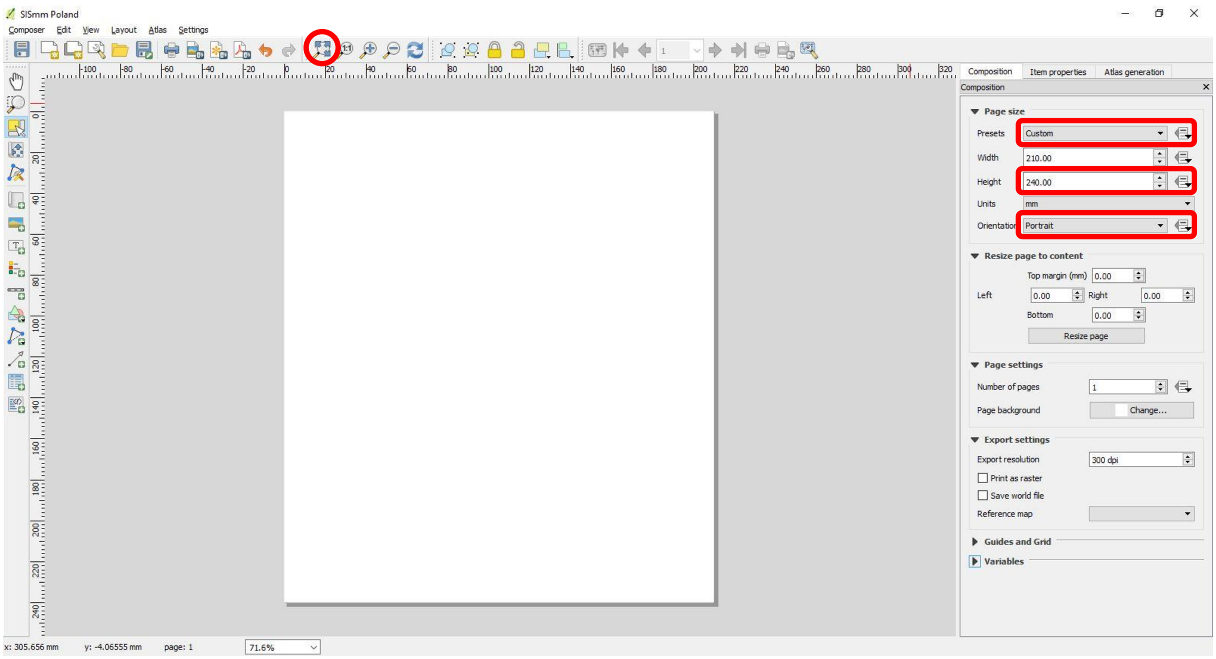


Fig. 28. Map Composer: adjusting page size and orientation

Click on *Add Map* button on the side toolbar or go to *Project → New Print Composer*. Insert the map by holding the left mouse button and drawing a rectangle frame. By default the current canvas view is always displayed. Set the size of the window frame to 50 x 50 cm (*Item properties / Position and Size*) and copy it 11 times (*Ctrl+C → Ctrl+V*). Align the window frames in 4 lines and 3 columns closer to the left side of the layout (alignment lines can be helpful). Now, go back to the main QGIS window and display mean SIS for March in canvas keeping the administrative border on top. Return to Map Composer, select the first window frame and click on *Update Preview* in the *Item properties / Main Properties*. Check the *Lock Layers* checkbox (*Item properties / Layers*). Then go back to the main QGIS window again, display mean SIS for April, return to Map Composer, select the next frame to the right, click on *Update Preview* and lock layers. Repeat these steps for all the twelve months in the right order (from March to February).
Compare the result with Fig. 29.

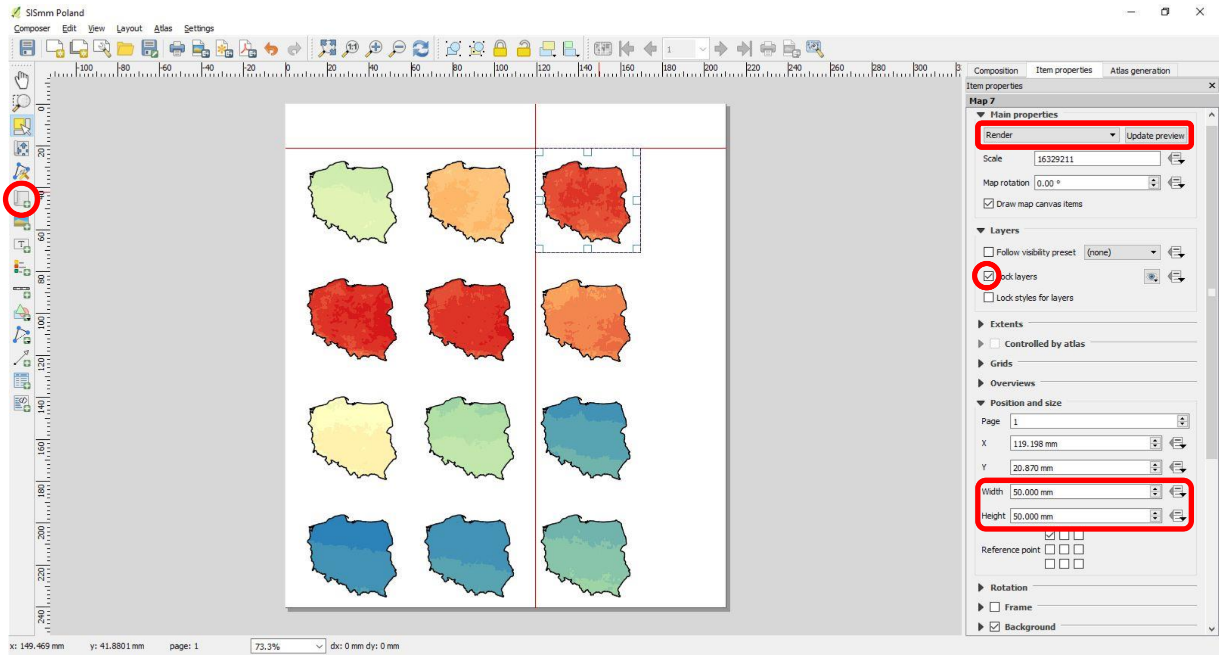


Fig. 29. Map Composer: bringing the layers view from the main QGIS window and aligning maps.

Add layout title: *Multi-year (1983-2015) mean monthly surface incoming solar irradiance over Poland*. Add map labels: *MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC, JAN, FEB* and additional labels for each season on the left side: *SPRING, SUMMER, AUTUMN, WINTER* (rotate them at 270.00°). Use *MS Shell Dlg2* font, 12 points, bold.

Add legend. Clear the legend title (*Legend properties / Main properties*). Keep only the first raster layer (*Legend properties / Legend items*) and change its name to: SISmm (W/m^2). Place the legend on the right side of the Layout (Fig. 30).

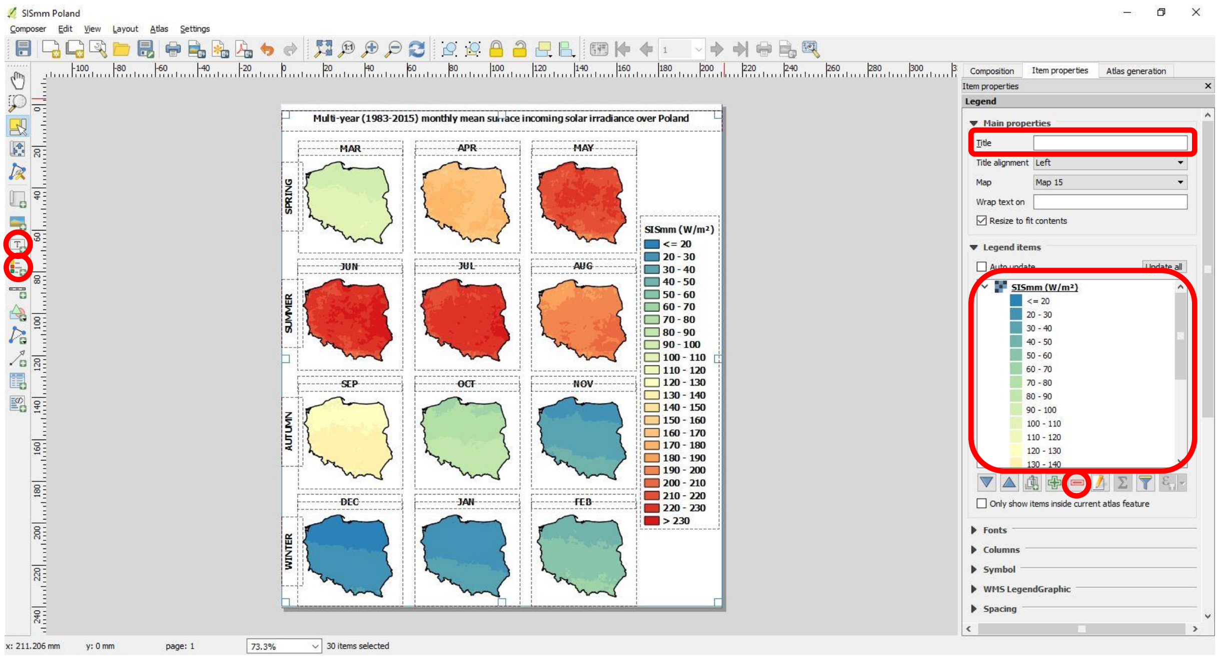


Fig. 30. Map Composer: adding titles, labels and legend.

Export the map as image: Composer → *Export as image…* The final result is demonstrated in Figure 31.

Created layout can also be saved as template (Composer → *Save as Template…*) and easily reused in future.

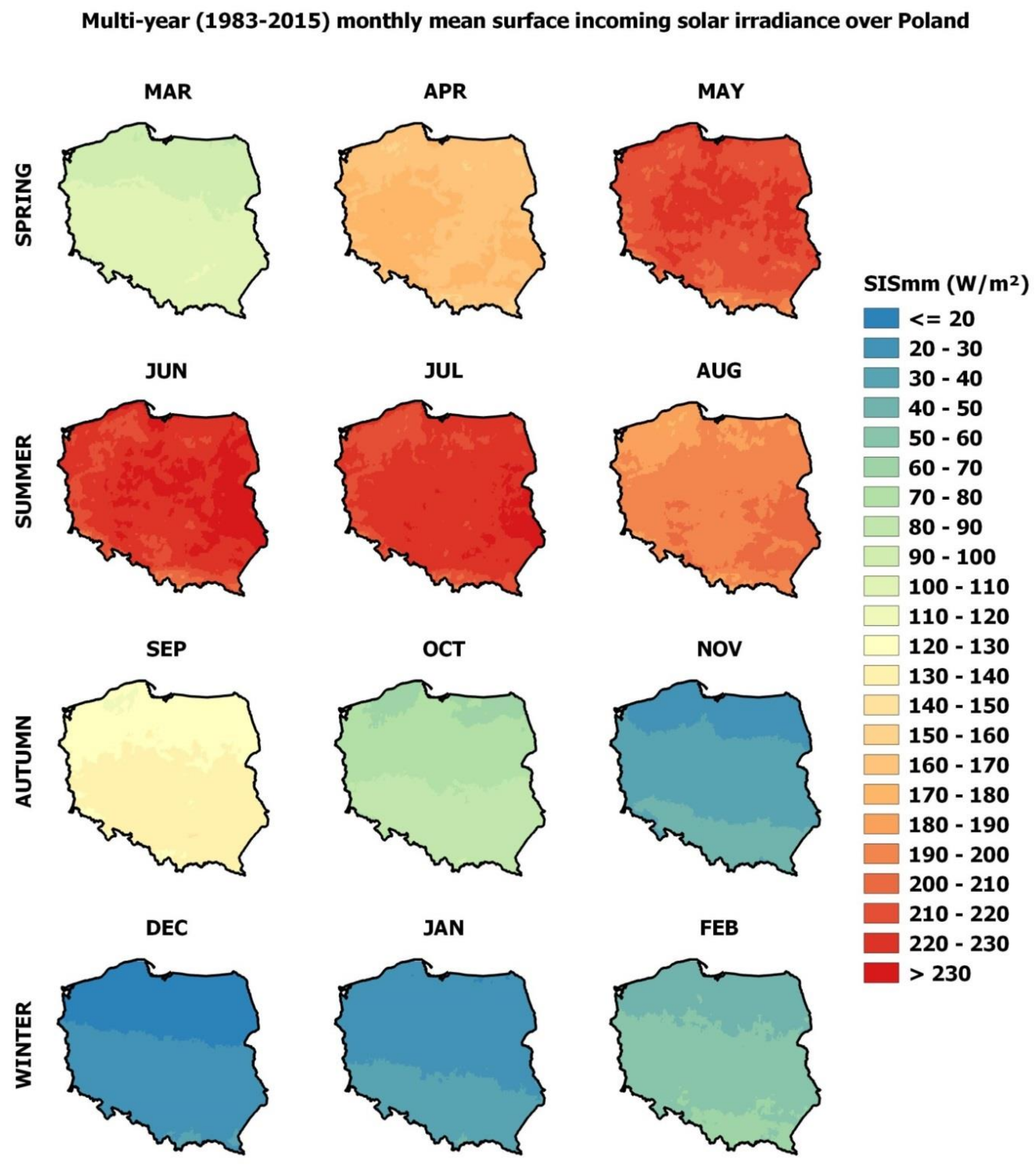


Fig. 31. The final map composition.

References:

Giuliani G., 2014, NetCDF in QGIS Tutorial, University of Geneva – EnviroSPACE Laboratory: http://www.ggiuliani.ch/download/netcdf_qgis_GG.pdf

QGIS User Guide, Release 2.14: http://docs.qgis.org/2.14/pdf/en/QGIS-2.14-UserGuide-en.pdf

QGIS Tutorials and Tips by Ujaval Gandhi: http://www.qgistutorials.com/en