Part III

Week 3 - Raster data

For our third week, we will learn about the second most common data model for spatial data: raster files. While vectors are good at representing separated and/or well-defined individual regions, rasters excel at representing gradual, continuous data such as surface temperatures or elevations.

ILOs covered

1. Understand the structure of spatial data and choose appropriate data types and models for storing and representing it;
2. Obtain and assess the quality of spatial data from online and offline sources and produce new spatial data using computer and field methods;
3. Create map visualisations that adhere to cartographic principles and can be easily and unambiguously interpreted by the non-specialist public;
4. Plan and execute GIS analytical steps to solve spatial problems successfully;

What will you learn

For every week, we will list the main theoretical and practical learning goals. Use these as a 'checklist' to gauge your learning for each week. If you don't feel confident you have learned any specific topic, then revisit the week's material!

Theoretical knowledge for Week 3:

- What is the raster data model?
  - How are rasters represented?
- What are the components of a raster file (rows, columns, bands/channels, resolution)?
- What are the main raster file formats?
- What data types can rasters represent?
- What kinds of data can we represent using raster data?
- Raster / vector component equivalence
- Raster / vector tool equivalence
  - No concept of ' selection'
- What kinds of questions can we answer using rasters?
- How can we transform rasters to vectors and vice-versa
  - The concept of raster resampling
  - The concept of raster contrast manipulation

Practical knowledge:

Chapter 5

- How to identify raster files
- How to load raster files
- How to get raster properties
- How to reproject raster data
- How to mask rasters
- How to set raster symbology
  - Continuous variables
  - Categorical variables
- How to use the identify tool to get raster information on the fly
- Working with Digital Elevation Models
  - Calculating slope, aspect and viewshed

Chapter 6

- How to calculate raster statistics
- How to 'select' using the raster calculator
  - Boolean operators on the same band
  - Boolean operators between bands
  - Band arithmetic
  - Making flowcharts
- Mosaicking rasters
- How to adjust the stretch of a raster
- Styling raster Images
- Resampling methods

5 Lab 5: Working with raster data

So far, we have been working within the realm of vector data: beautiful topological combinations of vertices and lines to represent the complexity of the Earth's surface. But there are plenty of situations where vectors are not the best choice; any information that varies gradually and continuously over the surface can be better represented by a raster.

You know rasters well - any digital image is a raster. While vectors connect dots with lines, rasters are grid (i.e. a matrix) of numbers, called *pixels*. The numeric value of each pixel can be used the indicate a colour (like on digital photos), or can actually represent a physical quantity, such as temperature or elevation.

Raster files can contain multiple 'images' within them, which call *channels* or *bands*. Digital photos for example, actually contain three bands: one specifying the amount of red colour per pixel, one for the green colour, and one for the blue colour. When you look at a photo you are seeing a *color composition* mixing the amounts of the three primary colours according to the information help by each pixel.

Figure 5.1: Source: https://doi.org/10.5772/63028

For GIS data, multiple raster bands can be thought as vector attributes - each band will hold the values of a specific variable (i.e. one band for temperature, and one for humidity). In fact, it may help to frame rasters in terms of their vector equivalents:

	Vector	Raster
Data variables	Vector Attributes	Raster Bands
Data values	Attribute values	Pixel values
Select ranges of data values	`Select by expression`	`Raster calculator` and/or `Mask`
Calculate new variables	`Field Calculator`	`Raster Calculator`
Calculate feature areas	`Field Calculator` (`$area`)	`Raster layer unique values`
Select by spatial location	`Select By Location` (Vec > Vec)	Extract Raster Values (Points > Raster) Zonal Statistics (Polygons > Raster) Zonal Statistics (Raster > Raster)

We will cover most of the above this week, and then cover how to extract values from raster based on other layers on Week 6. For today, we will learn how to inspect and style raster data, and also how to do some mathematical operations among raster layers using the raster equivalent of the `Field Calculator` - the `Raster calculator`.

5.1 Before you start!

1. Go through the Week 3 preparatory session on Canvas, and watch the seminar recording if you have missed it.

5.2 Guided Exercise 1 - Opening and inspecting raster data

(117) For this exercise we will look at three different raster layers. The data has been pre-packaged and can be downloaded here. It includes the following datasets:

- UK SRTM: This is a single-band raster containing data from the [Shuttle Radar Topography Mission (SRTM)] (https://en.wikipedia.org/wiki/Shuttle_Radar_Topography_Mission), a global dataset of surface elevation. The data can be obtained from a variety of sources online.

- UK Bioclim: The BIOCLIM suite of climate data has been developed to support biodiversity studies and species distribution modelling. It is a single multiband raster file. Read this page for a description of which variable each band represents.
- CORINE land cover: CORINE is a EU-wide land cover map that is produced by the Copernicus Space Program. The pixel values are numerical codes that specify the different land cover classes. A description of each land cover number is given here.
- UK administrative boundaries from the GADM website, in geopackage vector file format.

(118) Download the required data and organise it as you have learned. Create a new QGIS project and add the `UK_SRTM.tif`, `UK_Bioclim.tif` and `CLC2018_CLC2018_V2018_20_UKclip.tif` raster files to your project. All files are in *GeoTIFF'* format, which is the most common and standard spatial raster file format.

(119) For each of the raster layers, right-click on the layer name and go to `Properties > Information`, then:

! Stop and Think

a) What is the *data model* of these files?

b) What is the *file format* of these files?

c) What are the *data types* of each raster file? Why is that important?

d) What are the CRSs of each dataset you have?

e) What are the dimensions (rows, columns) of each raster dataset?

f) How many *bands* does each raster dataset have?

g) What are the *pixel sizes* (spatial resolution) of each raster dataset?

Click for answer

a) raster (vector for the boundaries)

b) GeoTIFF for the rasters, geopackage for the vector

c) The data types can be found when looking at `Properties > Information` for a raster layer. The SRTM and CORINE datasets are sixteen bit signed integer (INT16), the BIOCLIM dataset is a 32-but floating point raster. Raster data types are important as they determine the range and precision of the data that can be stored in the raster, and also impact the size of the raster file. For the same number of rows, columns and bandas, a 32-bit raster is twice as large as a 16-bit raster.

d) GADM, SRTM, BIOCLIM: EPSG 4236 (WGS-84); CORINE: EPSG3035 (ETRS89 / Europe LAEA)

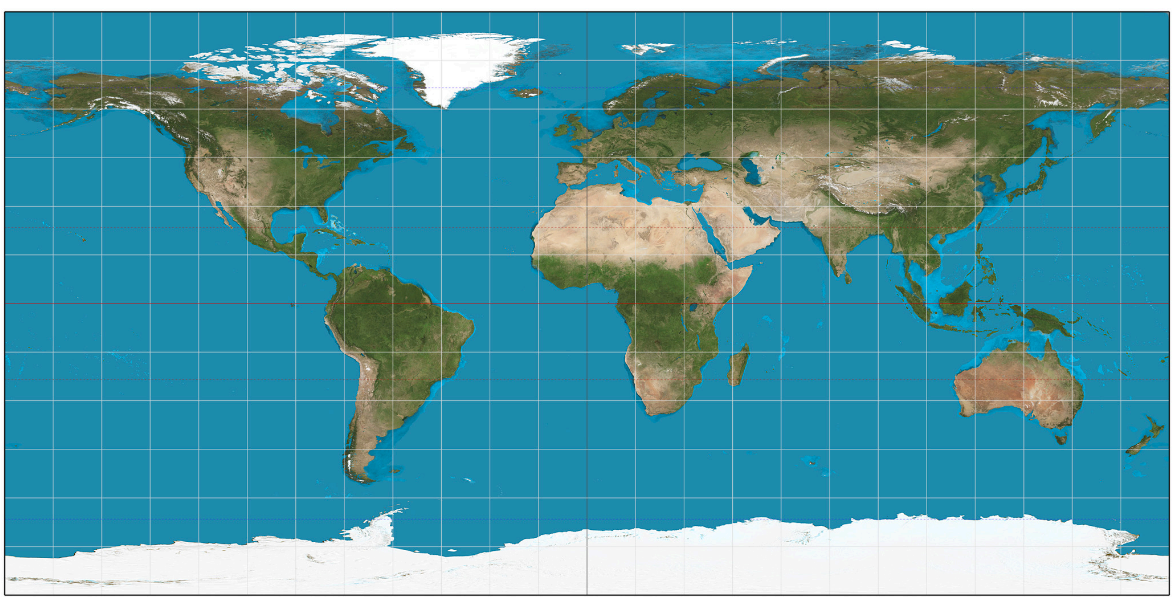
e) These are also found in `Properties > Information`, as `Width` (columns) and `Height`(rows) or in `Dimensions`. SRTM: 16355 cols x 12036 rows; CORINE: 10473 cols x 12261 rows; BIOCLIM: 1471 cols x 1084 rows.

f) These are also found in `Properties > Information`, as a list of bands, or in `Dimensions`. SRTM: 1 band, CORINE 1 band; BIOCLIM: 19 bands.

g) These are also found in `Properties > Information` in `Pixel Size`. SRTM: 0.000808483755707569361 7 degrees; CORINE: 100m; BIOCLIM: 0.00898315284119521537 1 degrees.

5.3 Guided Exercise 2 - Reprojecting raster data

As we learned in week 1, the UK looks "squished" because the data is projected using only the WGS-84 datum and geographic coordinates (EPSG:4236). Although data in geographic coordinates is often referred to as "unprojected," this is not actually true (you are looking at it on a flat screen, right?). For these "unprojected" datasets, what most GIS software do is to simply use a linear function to convert latitudes and longitudes in degrees to x and y values on your screen. This projection can be referred to as Plate Carrée or Equirectangular projection, which has a heavy amount of distortion towards the poles:



(120) To reproject raster data, go to `Raster > Projections > Warp (Reproject...)`. Select your SRTM layer as the Input Layer, and the EPSG: `27700 - OSGB 1936 / British National Grid` as the `Target CRS`. (If you don't see it as an option, click on the small button to the right to bring up the CRS selection window). Set the `Output file resolution...` to `90` (this will be in meters, as meters are the units of the BNG projection). Leave everything else as default. Then click on the `...` button to pick an appropriate folder location. Name uour file `UK_SRTM_BG.tif`. `Run` the algorithm and then `Close` when finished.

(121) Repeat the process for the Bioclim layer (use a cell size of 1000m) and the CORINE land cover map (cell size of 100m). These cell sizes are the meter equivalent of the degree pixel sizes the data currently has. Make sure you add the `_BG` suffix to the new file names to keep track of what has changed from one file to the other.

(122) If it seems nothing has really changed, remember that QGIS does reprojections "on the fly" to make sure data on the screen are all aligned to the project CRS. So as you learned in Week 1, change the project CRS to EPSG:27700 as well. Now everything should look good.

(123) Remove the original layers from the project and keep only the reprojected ones, then save your project.

5.4 Guided Exercise 3 - Masking rasters using vectors

We often want to remove portions (specific cells) of a raster, a process called *masking*. For example, some of our datasets include the Republic of Ireland and bits of mainland Europe, and some datasets include the Shetland Islands, while others don't. Let use the UK boundaries from the GADM dataset to mask our data to the Island of Great Britain (Scotland, England and Wales) only.

(124) First add the GADm data (`gadm36_GBR.gpkg`) to your project. This geopackage holds multiple layers for the different levels of admin boundaries. You can just add the level 0 layer, which gets the UK as a whole.

> **!** Stop and Think
>
> Why did you get a warning window when you added the layer to the project?

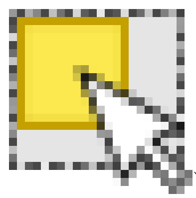
> **Click for answer**
>
> Because this layer has a different CRS than the project, and QGIS it is asking you how to deal with it.

As we learned on Week 1, trying to do clipping (and masking) operations between layers with mismatched CRSs gives us wrong results. So before you do anything, reproject the UK boundaries layer to EPSG 27700. You also need to extract the main British Island from the rest of the dataset. Turns out there is a quick way to do both at once, but first we need to deal with a little issue with the vector layer:

(125) Open the Attribute Table of the UK boundaries layer. How many features does it have?

This is what is called a `multipart` polygon - a set of disjoint polygons all treated as a single feature. Before we can use the layer, we need to split the individual polygons apart to be able to select the main island only:

(126) Go to `Vector > Geometry Tools > Multipart to Singleparts`, and select the GADM layer. You can leave it as a temporary layer since we will only export one polygon for it in the next step. A new temp layer called `Single parts` will be created. Inspect its Attribute Table.

(127) Now use the feature selection tool () to select Great Britain only, and then right-click on the Single Part layer name and choose `Export > Save selected features as...`. Pick a folder location and name the file `GB_Island.shp`. Before you click on OK, however, change the `CRS` drop-down menu to EPSG:27000. That is it, QGIS will now reproject the layer before saving it! Click `OK`to save, and then remove the original GADM and the temp layer from your project to keep things tidy. Save your project.

(128) Double check what is the CRS of the new `GB_island` layer you have created.

(129) You are now ready to mask the raster data. Go to `Raster > Extraction > Clip Raster by Mask Layer...`. As `Input layer`, select the SRTM layer, and as `Mask layer`, select the GB island layer. Then on the option `Assign a specific nodata value to output bands`, enter the number `-32768`. *Make sure you include the minus sign*! Leave the other options as default, but do check both the `Match the extent of the clipped raster to the extent of the mask layer` and `Keep resolution of input raster` options. Pick a folder and name your file `UK_SRTM_BG_GBmask.tif`. Now we can know at a glance that this is the SRTM data, reprojected to British Grid and masked to Great Britain.

! Stop and Think

a) Why did we pick a value of -999 for 'nodata'?

b) Why should we check the `Match the extent...` and `Keep Resolution..` boxes?

Click for answer

a) Since raster layers are grids (matrices) they must always be rectangular in shape. So when masking a raster using an irregular shape, the pixels outside the polygon will receive a value indicating *nodata*, but they will still exist. The default nodata value for QGIS is zero, but since we are dealing with elevations, zero is still a valid elevation value, and we could even have areas inland that are at sea level or lower, and thus have an elevation of zero or below. We also know our data is a signed 16 bit integer, that can take values from -32,768 to +32,767. So we pick the most negative elevation number within this range, which also would never occur on land (-32768 meters) to use as nodata.

b) By selecting the `Match the extent of the clipped raster to the extent of the mask layer` option when masking, the extent of the raster rectangle will be just enough to cover the GB polygon. If we left that unchecked, QGIS would set the non GB pixels to 'nodata', but leave the raster with the original dimensions. That would be a waste of disk space. We also check `Keep resolution...` to make sure QGIS doesn;t change the pixel sizes to better 'fit' the rectangle to the extent. The spatial resolution of a raster file often has a reason to be, and we don't want to arbitrarily change that.

(130) Use the `Identify Features` tool () to click on blank area of the masked SRTM layer (near the shore). Make sure you have the SRTM layer selected on the Layers panel before you click the tool. What pixel values do you get? -32768 or 'nodata'?

(131) Now go to the `Properties > Transparency` tab of the SRTM raster layer, and uncheck the `No data value -999` box. Look at your raster again, and probe the same areas with the `Identify Features` tool. Can you see now how the actual raster is still a rectangle, with the pixels outside the mask set to -32768? Before you proceed, go back and check the `No data -999` box again.

(132) Now repeat the masking for the CORINE and BIOCLIM layers. You can use the same nodata number for the CORINE and BIOCLIM layers. the CORINE layer actually already has nodata defined as `-32768` so we just keep it. And for Bioclim, it is an unlikely value for any of the climatic variables, and because the climate data is a floating point number (decimal), it is almost impossible that a perfect value of -32768.000000 would exist in the data naturally.

(133) Remove the non-masked raster datasets from your project and save it.

(134) Now zoom in into any place on the coastline, and answer:

! Stop and Think

Why don't the edges of each raster dataset line up perfectly?

Click for answer

a) Again, this is a side effect from raster layers being grids. As each one has a different pixel size, the `decision` of which pixel is inside our outside the GB vector polygon will be different for each layer. Also, the coastline will always appear 'ragged' because we can't represent any detail smaller than a single pixel on a raster file - and the pixel grids of the three layers do not align because of the pixel sizes.

5.5 Guided Exercise 4 - Styling raster data

Just as with vector data, QGIS offers many options for the symbology of raster data. You will see some similarities between the symbology options for vectors and rasters, but also some differences because of the nature of each data model.

(135) Turn off all layers except the CORINE land cover, and then go to its `Properties > Symbology`. Note that the default `Render Type` for single-band rasters is `Singleband gray`. That means pixels are coloured by a shade of grey that is proportional to its numeric value, with higher values being closer to white. Change it to `Paletted / Unique Values`. Maintain the `Band 1` selection (there is only one band anyway) and `Random Colors` options, and then click on `Classify`. Apply the result to your raster and visualise it.

! Stop and Think

a) How many categories are there on this raster?

b) What are the pixel values representing?

c) What would be the vector symbology equivalent of `Paletted / Unique Values`?

Click for answer

a) 36 categories (unique pixel values)

b) Each pixel value is a numerical code that indicates a land cover type.

c) the `Categorized` option.

WHoa, there are a lot of classes, and the random colours selection picked colours that are very similar to one another for some of the classes. Fortunately for us, the data producers of CORINE include a colour map file as part of the metadata. Let us use it!

(136) Back on the `Properties > Symbology` window, click on the `...` button to the right of `Delete All` and choose `Load Color Map from File...`. Within the CORINE files you unzipped, find and select the metadata file named `CLC2018_CLC2018_V2018_20_QGIS.txt`. `Apply`and then click `OK`. Not only we get the colours selected by the CORIEN mapping team, but also all the proper class names! That was nice!

(137) Now let us have a look at the BIOCLIM dataset. First, read the metadata included with the data files (`Bioclim_metadata.txt`) to understand what each band of this dataset represents. Then turn on the BIOLCIM layer and turn the remaining layers off.

! Stop and Think

Why does the BIOCLIM layer appears to be coloured?

Click for answer

When QGIS opens a multiband, single file raster, it always thinks that the file is an image, and thus it automatically assigns the first three bands of the file to the Red, Green, and Blue colour channels. We will look at raster images in the next session, but this color composition clearly doesn't make sense for our climate data, so let us change it.

(138) Go to the `Properties > Symbology` window for the BIOCLIM dataset. Notice the default symbology choice of `Multiband color`. Since each band of our data represents a different climatic variable, with continuous numeric values (not categories or classes), we need to pick the `Single band - pseudocolor` option. Choose the `bio1` band, and for the colour ramp, click on the down-arrow button to the right of the colour palette button, and select the `magma` colour ramp. Classify the existing values and then `Apply` and click `OK`. How does the layer look like now?

! Stop and Think

a) What would be the vector symbology equivalent of `Single band - pseudocolor`?

b) What climatic variable is "bio01" representing?

c) What units are the minimum and maximum values shown on the colour scale?

d) Why such a strange choice for the units?

Click for answer

a) The `Graduated` option.

b) The metadata file tells us it is Annual Mean Temperature.

c) The metadata file also tells us it is °C * 10 (deegrees celsius times ten)

d) This is an old `trick` to reduce file sizes while keeping some precision. Let's say the data creators wanted to record temperatures with one decimal place of precision. If they stored the data as a floating point, we would need 32-bit files. But if we consider that mean annual temperatures on Earth will easily be contained in the range of -100 to +100 degrees Celsius, we could instead multiply all numbers by ten, and store them as 16-bit integers instead, cutting file sizes in half. For example, a temperature of 32.7°C becomes a pixel value of 327.

(139) Explore some of the other climatic variables contained in the BIOCLIM dataset, using different colour ramps.

Finally, let's work on the symbology for the SRTM data. For that, we will take advantage of some nice scientific colour palettes that are built-in on QGIS. We will talk aboout what makes these palettes special on Week 4, but let us just use them now.

(140) On the `Properties > Symbology` window of the SRTM layer, choose the `Singleband Pseudocolor` option, and then on th downarrow button besides the `Color Ramp` option, select Create New Color Ramp. On the small options window that comes up, select Catalog:cpt-city.

(141) Once the catalogue window opens, go to the `Topography` list and select the `cd-a` palette. Then manually enter `Min` and `Max` values, using `0` and `900` respectively. `Apply` and see how it changes. But before clicking on `OK`, go to the `Transparency` tab and drag the slider at the top to around `60%`. That will let other layers under it to show through and blend with the colours.

(142) Right-click on the SRTM layer name and select `Duplicate layer`. This option creates a 'virtual' copy of the layer - it will still point to the same file on disk, but you are able to select a different symbology for it.

(@)Now, on the `Properties > Symbology` of the copied layer, change the render type to `Hillshade`. Leave everything as default, then `Apply` and close the window. Make sure both the coloured and the hillshade SRTM layers are turned on on the Layer Panel, and that the hillshade layer is immediately under the coloured SRTM layer. Zoom in and turn each layer on and off in turn to understand how this neat '3-D' visual effect works.

! Stop and Think

What does the `hillshade` render style does?

Click for answer

It uses the elevation information to simulate how different areas of the terrain would be illuminated or shaded by sunlight coming from a certain sun elevation and azimuth (direction).

5.6 Guided Exercise 5 - Terrain Calculations

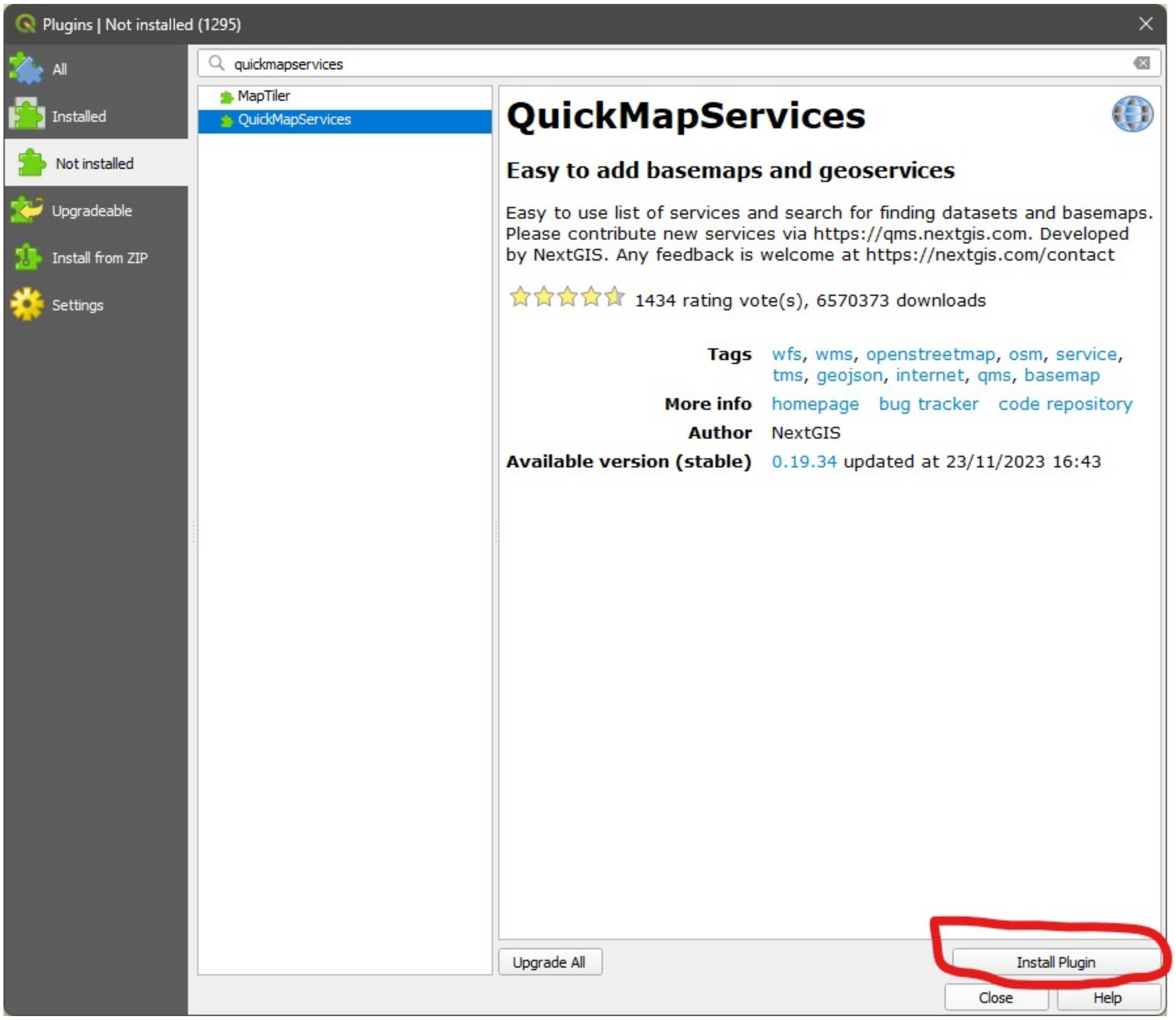
One of the most common raster datasets used in GIS are Digital Elevation Models or DEMS. The structure of raster data is particularly well suited to represent terrain, in its continuous and highly variable nature. Moreover, terrain and elevation data is often a key variable in GIS analysis, as it directly influences most biological, geological and anthropic processes.

For this reason, a few specific terrain analysis tools that are always included in GIS software, and used often. These are the methods to calculate slopes(a.k.a grades, gradients), aspects and viewsheds, using DEMs as the base data.

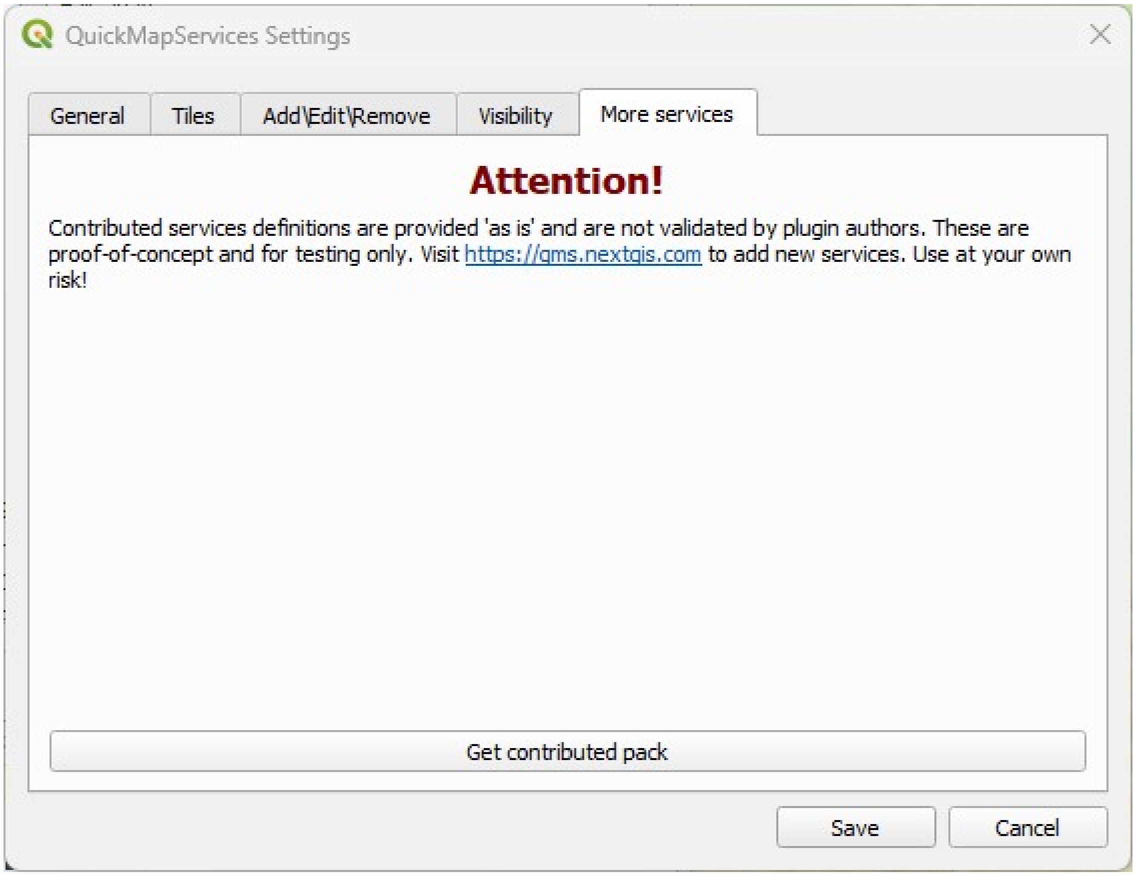
5.6.1 Plugins

In this exercise, you will also learn about one of the most powerful aspects of QGIS: *plugins*. As you may know, QGIS is a free and open-source software, meaning anyone can contribute with the code. QGIS also makes it easy for it's functionality to be extended via plugins, separate little 'apps' that add new tools and capabilities to the main QGIS app. For this exercise, we will install and use two official QGIS plugins, the `QuickMapServices` and `Visibility Analysis`.

(143) Head to the menu `Plugins > Manage and Install Plugins`. You will se a window like the one below. Then select the `Not Installed` tab, and then on the search bar search for `QuickMapServices`. Select it on the left panel, and then click on `Install Plugin`. Then repeat this process to find and install the `Visibility Analysis` plugin.



(144) The `QuickMapServices` plugin will add a new menu entry: `Web > QuickMapServices`. Once yo8u click on it, you will see a list of web map services - but there is more. Go to `Web > QuickMapServices > Settings`, and then click on the `More services` tab. Then read the warning and click on `Get contributed pack`, and once you get a confirmation message, click on `Save` and exit the window.



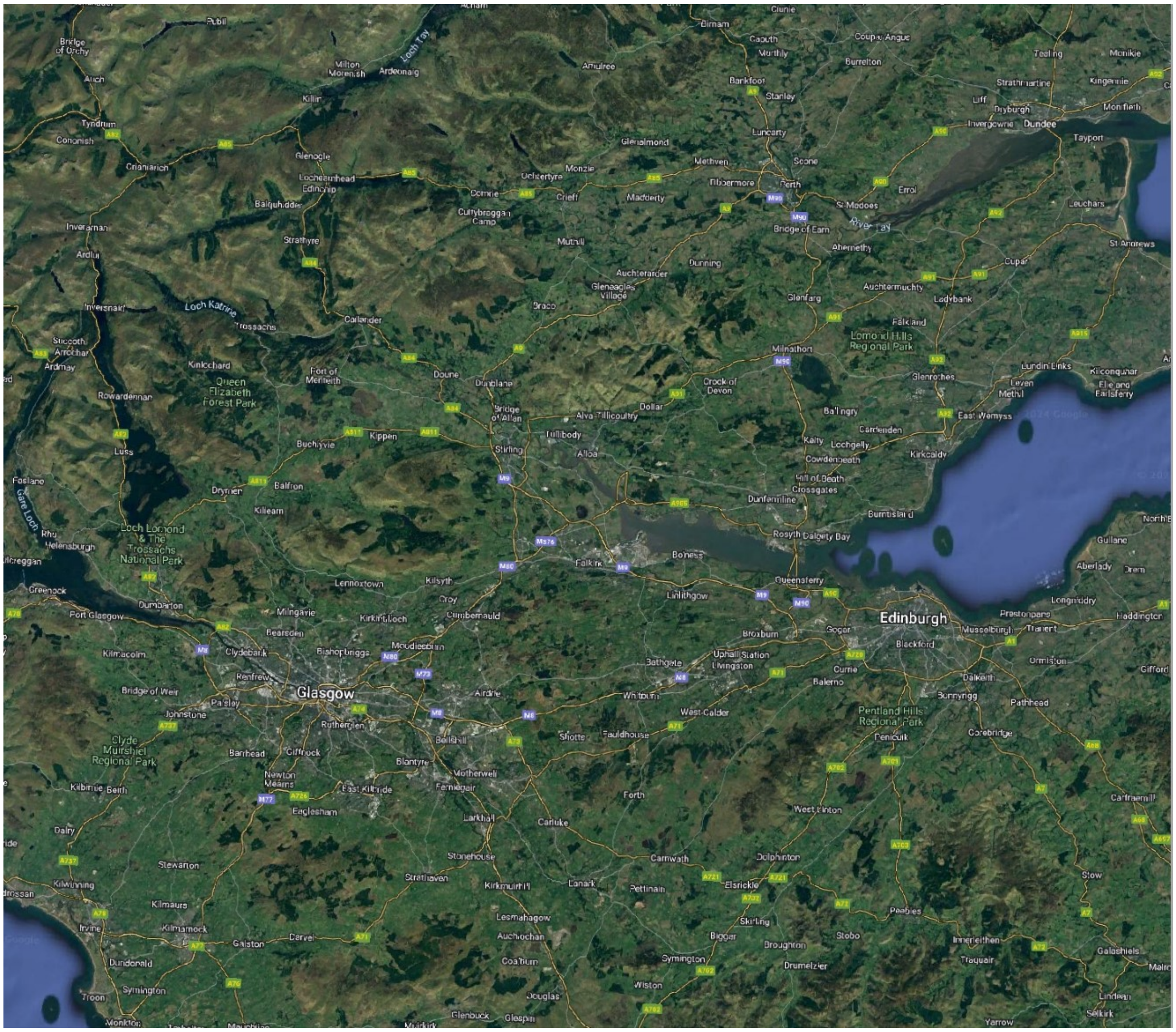
(145) Now go back to `Web > QuickMapServices > Settings`, and you will see a list of providers. For example, go to the `Web > QuickMapServices > Google` option and add the `Google Hybrid` dataset directly as layer in your project! These layers will require you to be connected to Internet to work, and they won;t give you many symbology options, but they are very handy to help in navigation when working on a project.

(146) Take some time to explore the layers available in this plugin.

5.6.2 Masking by area

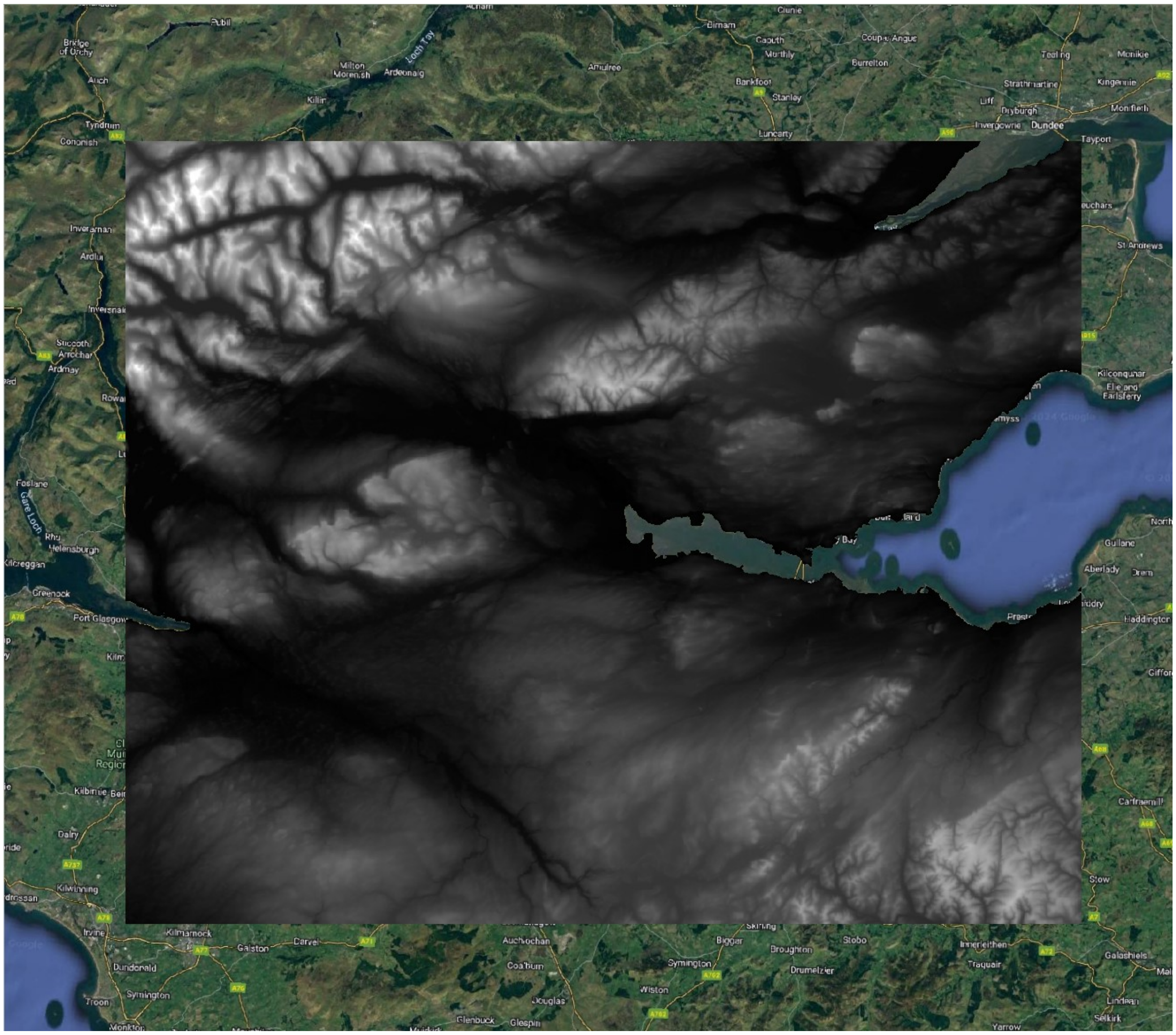
Earlier today you have learned how to use a vector polygon to mask a raster layer. But sometimes we just want to 'freeform' cut a piece of a raster, without the need to be too precise. In that case, we can use the `Clip Raster by Extent` function.

(147) Make sure you `Google Hybrid` web layer is visible, and navigate until you frame the 'Stirling-Glasgow-Edinburgh triangle' in your canvas, like the image below:



(@) Then go to `Raster > Extract > Clip Raster by Extent...`. Pick the SRTM layer as `Input layer`, and then for `Clipping Extent`, click on the small button to the right with a small arrow figure. That will set the `cut area` to be exactly what you are viewing on the canvas. But there are other options. If you click on the small down-arrow button to the right, you can use the extent (bounding box) of another layer, as well some more advanced options. You can also click on `Draw on map canvas` to be allowed to drag a rectangle over your map canvas that sets the extent of the cut.

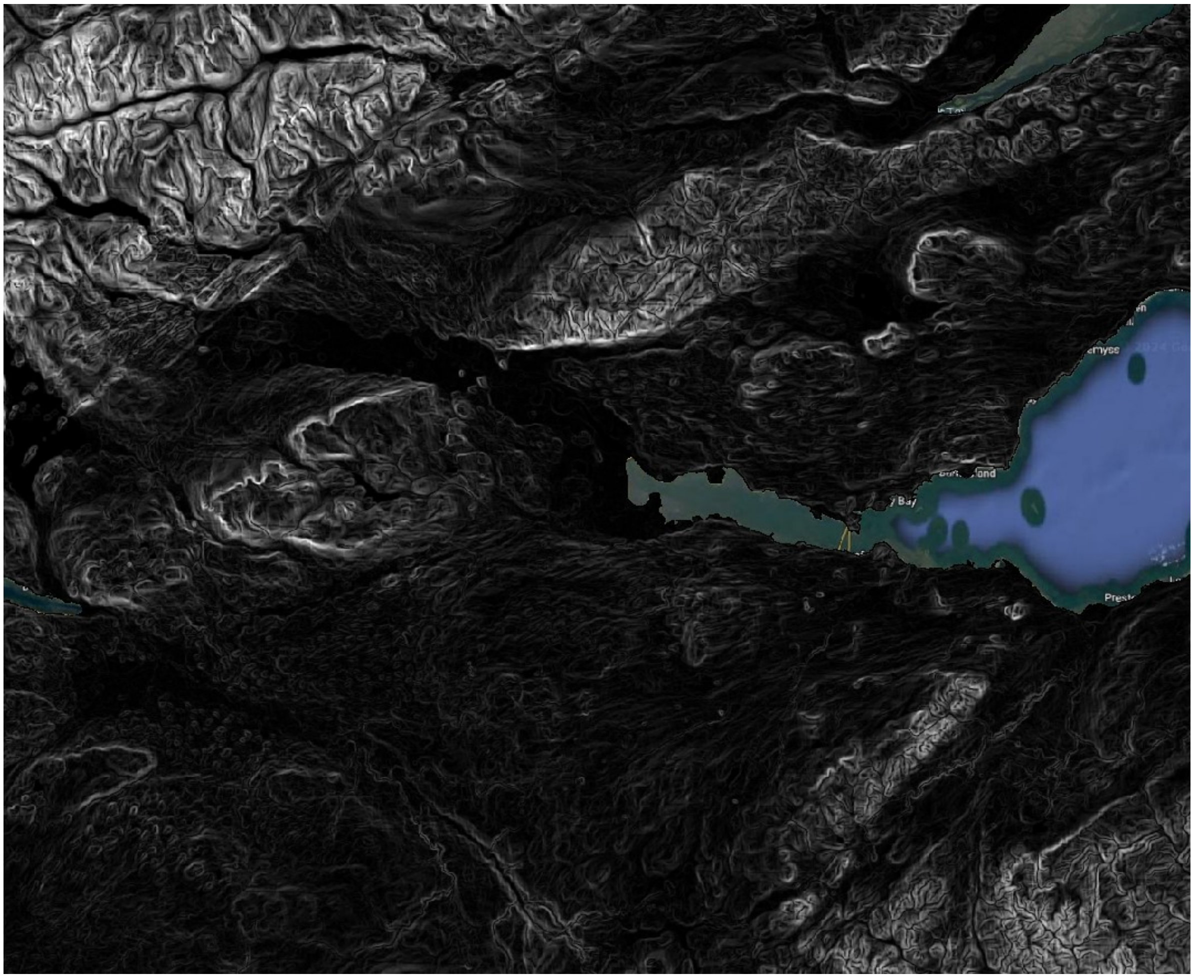
(148) Mask the SRTM layer to the region including Stirling, Glasgow and Edinburgh, either by setting you map canvas zoom and using it as extent, or by clicking and dragging to set the extent. Then pick a proper folder and save it as `UK_SRTM_BG_centralscotland.tif`. You should end up with something like this (but your extent will likely vary):



5.6.3 Calculating slope and aspect

We can now use our Central Scotland subset to demonstrate how to calculate slope and aspect.

(149) Go to `Raster > Analysis > Slope...`, and pick the Central Scotland DEM you created as `Input Layer`. Leave everything else as default and then pick a proper folder to save the new file as `UK_SRTM_BG_centralscot_slope.tif`. Then `Run` and `Close`. You will get a new raster layer, where the pixel values indicate the steepness of each pixel, in degrees. Steep slopes will appear as light grey/white, and flat areas will appear dark:

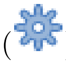


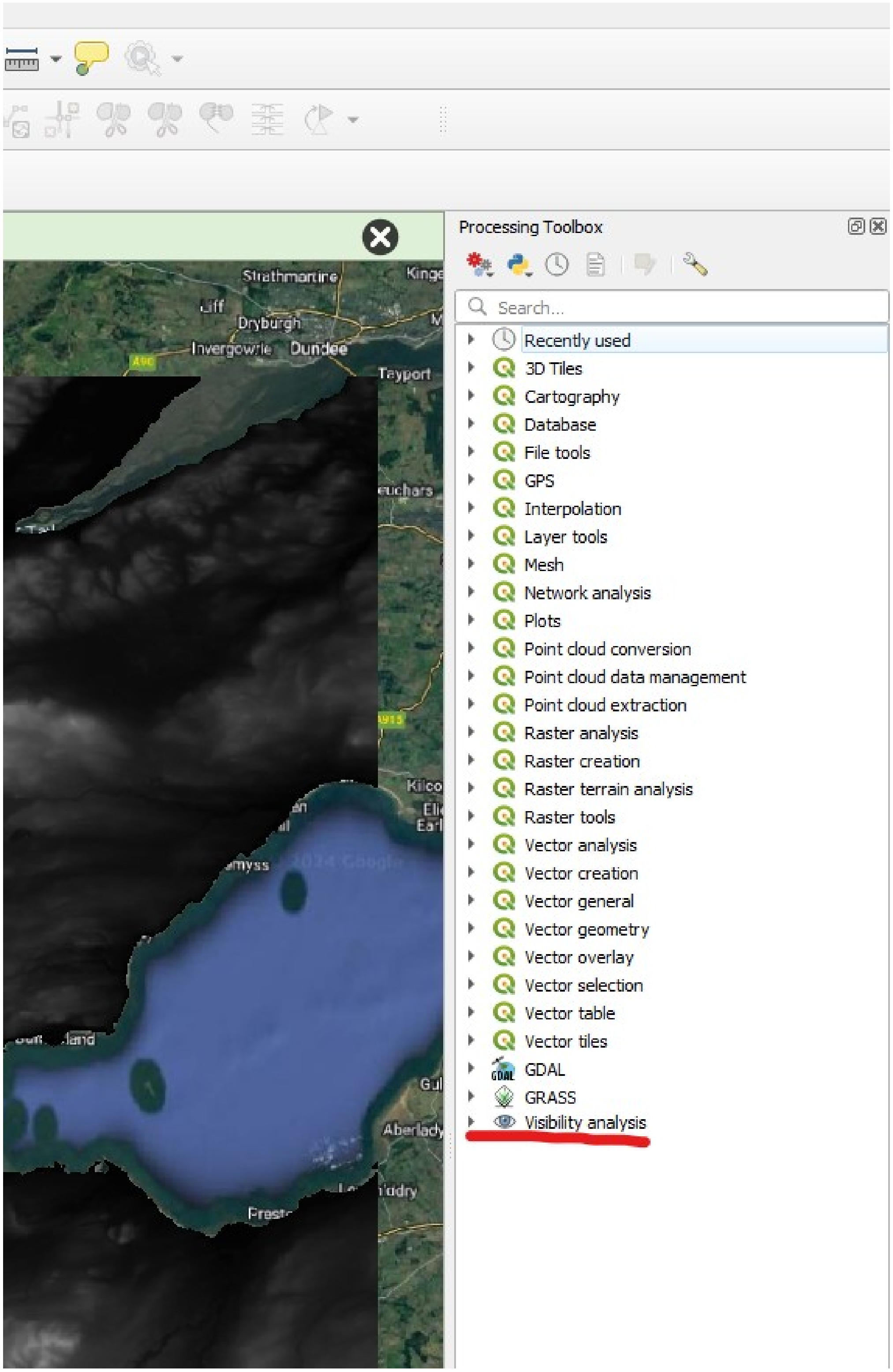
(150) Now go to `Raster > Analysis > Aspect...`, and again pick the Central Scotland DEM you created as `Input Layer`. Leave everything else as default and pick a folder to save the new file as `UK_SRTM_BG_centralscot_aspect.tif`. `Run` and `Close`. This layer will now tell you the cardinal direction, in degrees (North = 0/360),, that each slope is facing.

(151) Use the `Indentify Features...` tool to explore some of the aspect and slope values you have calculated.

5.6.4 Viewshed analysis

Finally, let us calculate a 'viewshed' - raster indicating which points in the Earth surface are visible from a given point, considering the topography. Viewshed analysis is often used for landscape planning - for example, determining from where a wind power turbine may be visible or not.

The `Visibility Analysis` plugin adds some option to the `Processing panel` of QGIS. To see it, click on the `Processing Toolbox` button on the main QGIS toolbar (), and the panel will open to the right. This panel houses many, many more GIS functions beyond those available on the `Vector` and `Raster` menus, and we will use it often during the last weeks of the module.


Processing Toolbox
Search...
Recently used
3D Tiles
Cartography
Database
File tools
GPS
Interpolation
Layer tools
Mesh
Network analysis
Plots
Point cloud conversion
Point cloud data management
Point cloud extraction
Raster analysis
Raster creation
Raster terrain analysis
Raster tools
Vector analysis
Vector creation
Vector general
Vector geometry
Vector overlay
Vector selection
Vector table
Vector tiles
GDAL
GRASS
Visibility analysis
Strathmartine
Dryburgh
Invergowrie
Dundee
Tayport
Aberlady

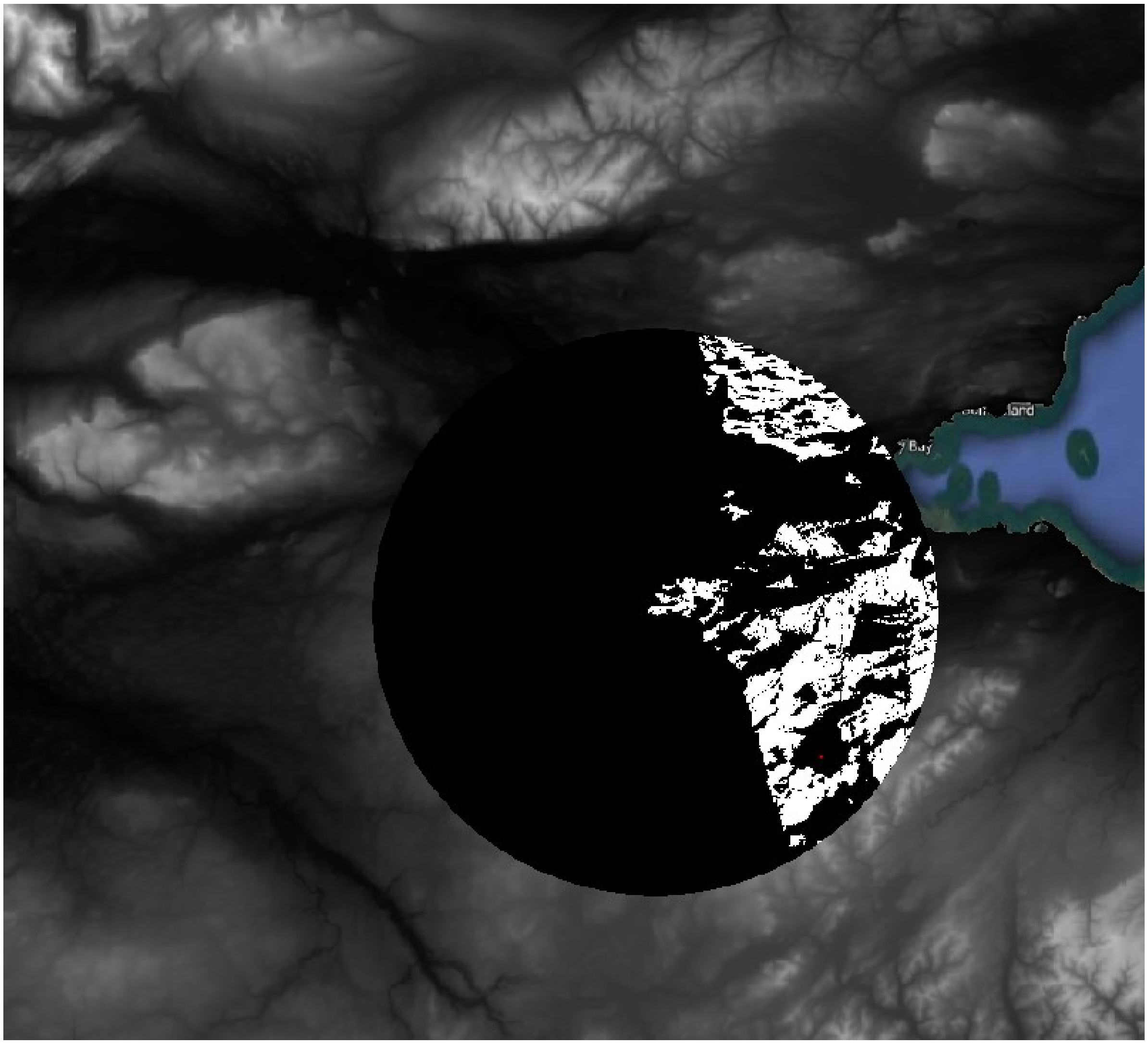
(152) Load the `observation_point,shp` file you have downloaded as part of the lab data.

(153) Open the `Visibility Analysis` heading on the `Processing Toolbox`, and then double click on `Create Viewpoints`. A new window will open. On this window, you need to pick the `Observer Location`, which will be the Observation point layer, and then the DEM, which will be the Central Scotland SRTM (make sure you *don't* pick the slope or aspect layers by mistake!).

(154) There are many options that you don't need to worry about for now, but three warrant some explanation: `Radius of Analysis` specifies how far you want to calculate the viewshed - it is an expensive computation so it may make sense to limit it. Let's use 20,000 meters for our analysis. Then pat attention to `Observer Height` and `Target Height`. They determine what is the height of the observation being made (above the elevation of the observation point), and also what would be the height of the target. So again, if you are wondering if a wind power turbine would be visible from that location, you should add the height of the turbine to the `Target Height` field. You can leave these options at 1.6m and zero, respectively. Then pick a folder and save the viewpoint as `viewpoint.shp`, and `Run` the tool.

(155) Now go back to the `Processing Toolbox` and double click on `Viewshed`. Pick the `Viewpoint` layer as `Observer Location`, and the Central Scotland DEM as `Digital Elevation Model`. Leave everything else as default, and pick a folder to save your viewshed analysis as `viewshed.tif` (it wil be a raster file).

You should get an output similar to the figure below, where white pixels (value `1`) indicate 'visible' and black pixels (value `0`) indicate "not visible'.



Guided Exercise 6 - Cleaning up and saving your project for the next lab

We will use the data you produced on this lab to get started on the next, so let us 'package'it properly.

(156) Remove all layers from the project except for the SRTM, CORINE, BIOCLIM and GADM layers that you have reprojected and masked for the GB island. Save your project

(157) Delete from the folder all files except for the files for the four data layers above. If you saved the GB island vector as a shapefile, remember you need to keep all files with the same name but different extensions (`.shp`, `.shx`, `.dbf`, `.prj`)

(158) On your systems file explorer, find the base folder for today's lab according to your organization, and right click on it. On Windows, choose `Compress to...` to create a zipfile containing your entire project. Name it as `lab_5_final_results.zip` or something similar.

(159) Now store this zipfile on your university's OneDrive or on some external drive, so that you can re-download it when you need it for the next session.

Congratulations, you reached the end of Lab 5. You should now understand the raster data model and how to mask it and style it. You have also learned some common terrain analysis tools. In the next lab, we will learn about the `Raster Calculator`, which fulfils the role of both the `Field Calculator` and `Select by Attribute` for rasters.

6 Lab 6: The raster calculator and other rastery bits

In this lab, we will continue working with rasters, and will learn how to do several new operations using them, including using the all-powerful *Raster Calculator*. We will also see the effects of *raster resampling* in practice.

6.1 Before you start!

1. Go through the Week 3 preparatory session on Canvas, and watch the seminar recording if you have missed it. Also make sure you have completed all labs prior to this one.

6.2 Guided Exercise 1 - Global raster statistics

In this exercise, we will use the layers from the previous lab to learn about raster statistics and the raster calculator.

6.2.1 Recovering your data

At the end of last week's lab you saved the final results of your project as a zipfile. Retrieve this file, extract the contents, and re-open your project. It should have these four layers in it:

- Polygon vector layer of the Island of Great Britain
- Raster layer of the SRTM digital elevation model (reprojected to EPSG:27700 and masked to the GB island)
- Raster file of the CORINE land cover dataset (reprojected to EPSG:27700 and masked to the GB island)
- Raster file of the BIOCLIM climatic dataset (reprojected to EPSG:27700 and masked to the GB island)

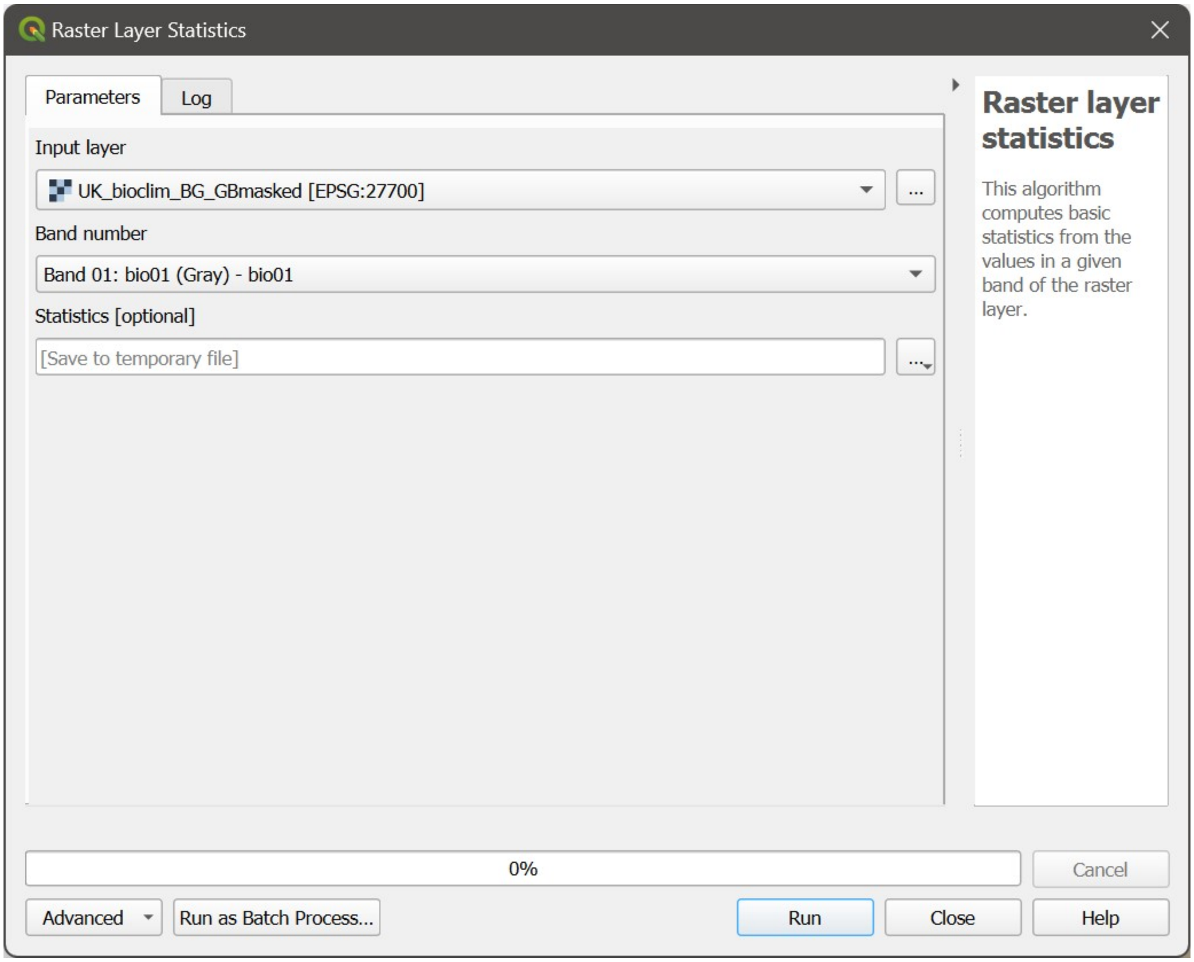
6.2.2 Global raster statistics

Winter is coming, and you want to escape the worst of the cold and rain. You therefore decide to use your GIS skills to find the ideal place to spend your winter in the UK - an urban area with lower precipitation and higher minimum temperatures. For convenience, we will restrict oour search to the Island of Great Britain, as we already have data for it ready to go.

To get started, you would like to know what is the overall range of precipitation and temperature values for the entire island, using the BIOCLIM data. If this was a vector dataset, you would use the `Statistical Summary Tool` - but it is a raster. What would be the equivalent operation?

(160) The tool we need is called `Raster Layer Statistics`, but it is *not* located in the `Raster` menu. Instead, we need to launch the `Processing` panel (. This panel contains a lot of additional GIS functions, and we will use it often now.

(161) Once you have the `Processing` panel open, you can either search for `Raster Layer Statistics` or find it under the `Raster analysis` heading. Double click on it to launch the tool window. It should look like this:



Looking at the BIOCLIM data description, the two useful pieces of climatic data you need to get statistics for are *BIO6 - Minimum Temperature of the Coldest Month, and BIO12 - Annual Precipitation*. The BIO variables are ordered in the file, so *band 6* is BIO6, and *Band 12* is BIO12.

(162) In the `Raster Layer Statistics` window, select the BIOCLIM layer as `Input Layer` and `band 06` as band number. You can keep the results as a temporaty file. `Run` it and `Close` the window. A new panel will have appeared under the `Processing` panel, called `Results Viewer`. It will have an entry called `Statistics`. Double click on it and take note of the minimum and maximum BIO6 values (-75 and 33).

! Stop and Think

Do these values seem too extreme for the UK? What is going on here?

Click for answer

The metadata for the BIO layers states that temperature values are scaled by a factor of 10, so you need to divide these numbers by 10 to get proper Celsius units.

(163) Now repeat the process to get the Min and Max values for BIO12 (532 and 2311)

! Stop and Think

What are the units for precipitation?

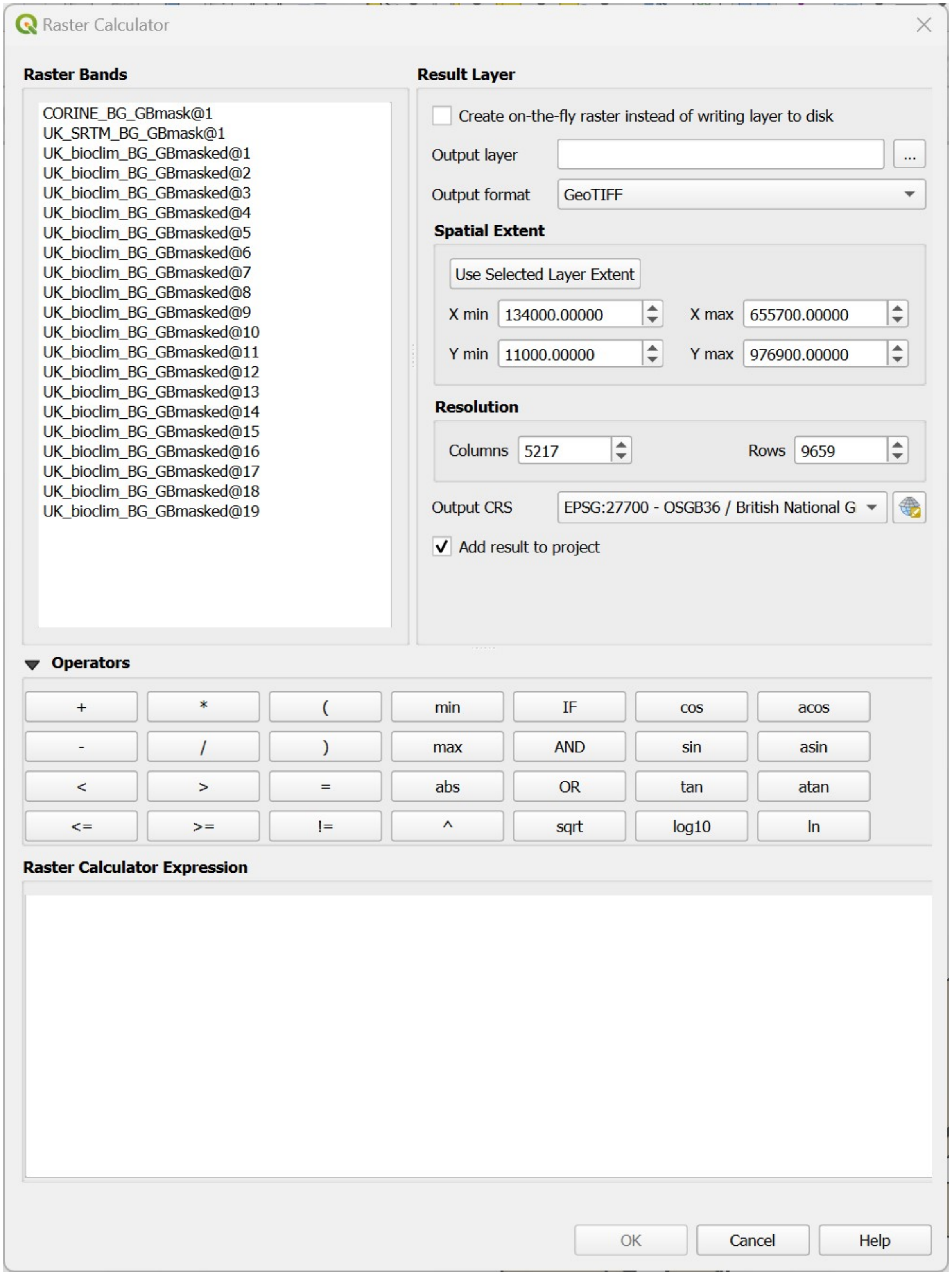
Click for answer

The metadata for the BIO layers states that annual precipitation is given in mm. One milimitre of rain is equal to one liter per squared metre.

6.3 Guided Exercise 2 - Per-pixel calculations with the raster calculator

Although it is easy enough to covert the temperature pixel values to Celsius in our heads, it would be useful to have the data in the proper units, especially if we want to map it later. Let us use the `Raster Calculator` to apply the conversion factor to all pixels.

(164) Go to the menu `Raster > Raster Calculator` to launch the calculator. It will look like this:


Raster Calculator
Raster Bands
CORINE_BG_GBmask@1
UK_SRTM_BG_GBmask@1
UK_bioclim_BG_GBmasked@1
UK_bioclim_BG_GBmasked@2
UK_bioclim_BG_GBmasked@3
UK_bioclim_BG_GBmasked@4
UK_bioclim_BG_GBmasked@5
UK_bioclim_BG_GBmasked@6
UK_bioclim_BG_GBmasked@7
UK_bioclim_BG_GBmasked@8
UK_bioclim_BG_GBmasked@9
UK_bioclim_BG_GBmasked@10
UK_bioclim_BG_GBmasked@11
UK_bioclim_BG_GBmasked@12
UK_bioclim_BG_GBmasked@13
UK_bioclim_BG_GBmasked@14
UK_bioclim_BG_GBmasked@15
UK_bioclim_BG_GBmasked@16
UK_bioclim_BG_GBmasked@17
UK_bioclim_BG_GBmasked@18
UK_bioclim_BG_GBmasked@19
Result Layer
Create on-the-fly raster instead of writing layer to disk
Output layer
...
Output format
GeoTIFF
Spatial Extent
Use Selected Layer Extent
X min
134000.00000
X max
655700.00000
Y min
11000.00000
Y max
976900.00000
Resolution
Columns
5217
Rows
9659
Output CRS
EPSG:27700 - OSGB36 / British National G
Add result to project
Operators
+
*
(
min
IF
cos
acos
-
/
)
max
AND
sin
asin
<
>
=
abs
OR
tan
atan
<=
>=
!=
^
sqrt
log10
ln
Raster Calculator Expression
OK
Cancel
Help

The general idea is similar to the `Field Calculator`, with a slightly different layout. The top right panel lists all raster *bands* in the project (so `UK_bioclim_BG_GBmasked@19` means band 19 of the BIOCLIM raster). The top right panel lets us pick some options for our raster creation, and the bottom panel lets us type expressions.

(165) We need to divide all BIO6 temperature values by 10. Double click on the BIOCLIM band 6 in the bands list to add it to the expression panel, and then add the division by `10`. On my project, the final expression panel reads as `"UK_bioclim_BG_GBmasked@6" / 10`, but your BIOCLIM layer may not be named the same as mine. Note that the bottom of the expression panel should say `Expression Valid`. If it says `Expression Invalid`, check your typing (did you use the double quotes?)

(166) For `Output Layer`, click on the `...` button and pick a folder to save the new file. Name it `UK_bioclim_BG_GBmasked_BIO6_celsius.tif`. Leave the rest as default and click in `OK`.

! Stop and Think

How many bands has your newly created file?

Click for answer

Only one band, holding the results of the calculation.

Every time you enter an expression involving a raster band and a single number in the `Raster Calculator` you are telling QGIS to apply the same expression to each pixel of that band. In our case, we divided all pixel values by 10.

6.3.1 Guided Exercise 3 - Boolean (logical) operations with the raster calculator

The `Raster Calculator` also fulfills the role of the vector `Select by expression` tool for rasters. The result of any raster logical operation is either `1` (True) or `0` (False), i.e. a *binary raster*, sometimes called a *raster mask*.

Let us find the warmer places in Great Britain. Our highest minimum temperature of the coldest month (BIO6) value was 3.3 degrees, not too far from zero. So let us limit our search to any places that don't go below 0 Celsius.

(167) Open the `Raster Calculator` again, and this time use the expression `"UK_bioclim_BG_GBmask_BIO6_cels` `> 0`. Notice we used here the layer that we just converted to degrees Celsius. Save the results in a proper folder with the name `GB_mintemp_gt_0.tif` (gt for 'greater than') and run the calculation. You should get something like this:

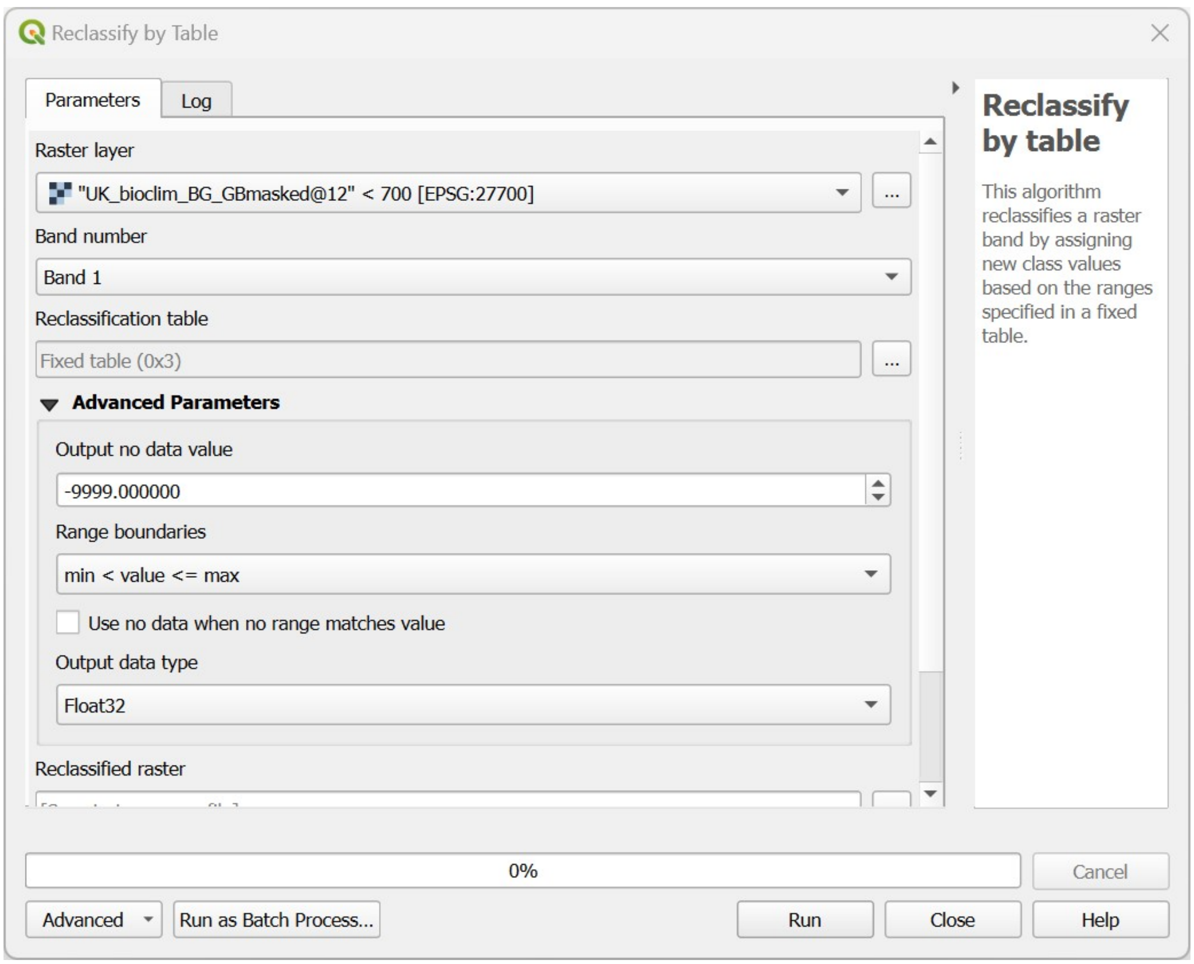
By default,

QGIS will paint pixels with a value of `1` white, and `2` black. So the white areas now show us all regions of Great Britain that *on average* don't go below zero in the worst of winter (these are long term climatic averages). Use the `Identify Features` tool to check if the pixel values are really `0` and `1`.

(168) Now repeat the process for the precipitation layer. Our minimum annual precipitation value was just above 500, so let us limit us to areas under 700mm of precipitation. Save the result as `GB_anprec_lt_700.tif`.

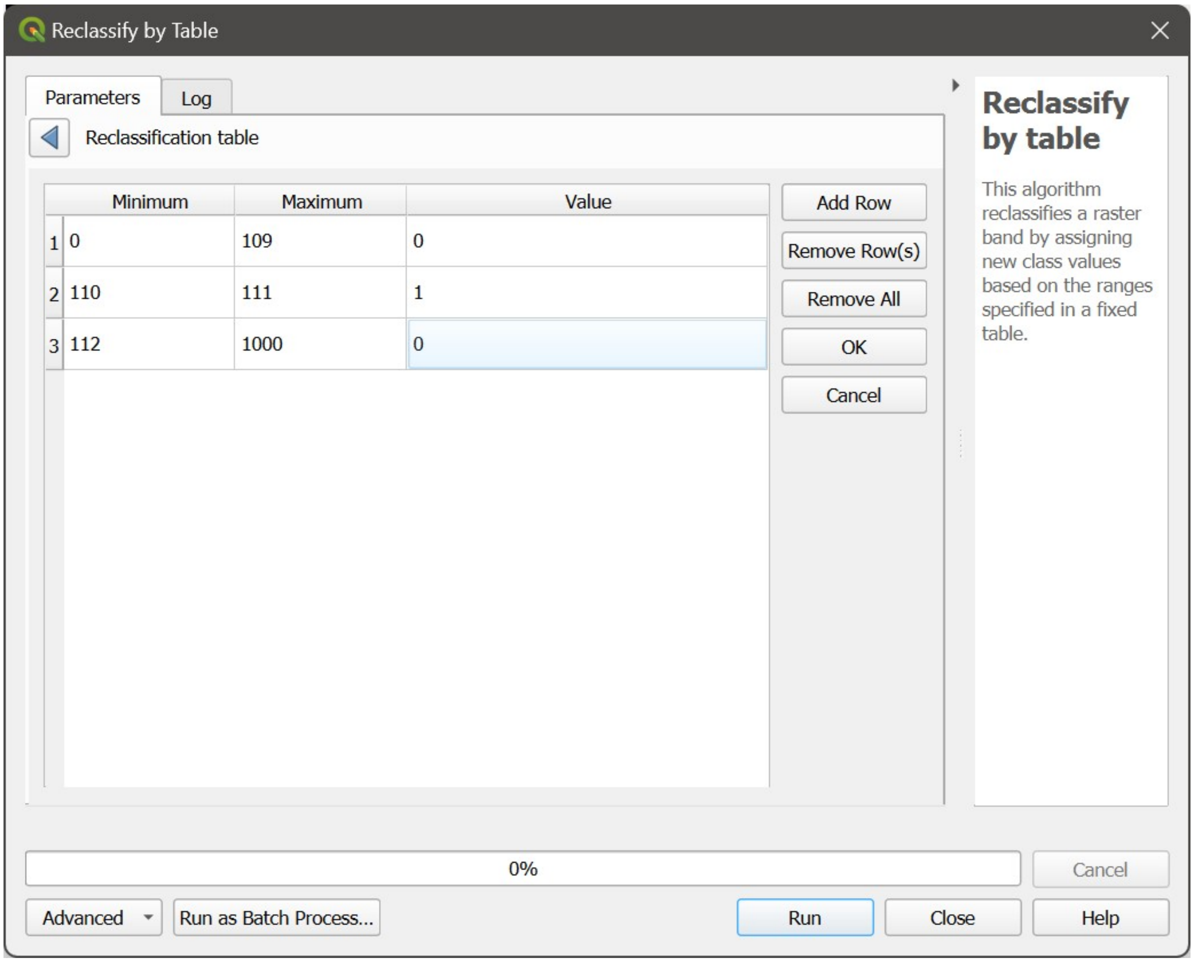
6.3.2 Guided Exercise 4 - Raster reclassification

An alternative to the `Raster Calculator` that can be handier when you have multiple ranges to recode is the `Reclassify by table` tool in the `Processing` panel, also under the `Raster Analysis` heading. Find the tool and open it, and you will see this:



Let us use this tool to extract the urban areas from the CORINE dataset. looking at the metadata, the two classes od interest are `Continuous Urban Fabric` (pixel value 111) and `Discontinuous Urban Fabric` (112) classes, which are the classes were we would expect existing housing to be located.

(169) On the `Reclassify by table` window, pick the CORINE layer as your `Raster layer`, and `band 1` as your `Band Number`. Then click on the `...` button besides the box to open the `Reclassification table`, and fill the table like the figure below. Click to add rows as necessary.



(170) Click on te blue arrow to go back to main tool window, then set the `nodata value` back to `-32768`, the `Range Boundaries` to `min <= value <= max` and the `Output Data Type` to `Byte`. Save it as `GB_urban_areas.tif`.

(171) Repeat the process above with the expression .

❗ Stop and Think

How could you have done the analysis above using the `Raster Calculator` instead?

Click for answer

You could do `"CORINE_BG_GBmask@1" = 111 OR "CORINE_BG_GBmask@1" = 112`. Notice how you can use `AND` and `OR` to chain logical expressions as you can for vectors - but because computers are dumb, you need to repeat the name of the layer after the `OR` (and for each additional expression you add).
You could also do ranges, using an expression such as `"CORINE_BG_GBmask@1" > 110 AND "CORINE_BG_GBmask@1" < 113` (notice the use of `AND` instead of `OR` for ranges) since they are consecutive values, or use `"CORINE_BG_GBmask@1" >=111 AND "CORINE_BG_GBmask@1" <= 112`). Using ranges is more quicker than using `=` and `OR` when you have many consecutive values to search for.

6.3.3 Guided Exercise 5 - raster vs. raster calculations

We now have three *raster masks* showing us 1) all the GB areas that don't go below zero Celsius, 2) the areas that have less than 700mm of rain, and 3) the areas that are urban. How can we combine them into a single layer?

The answer to the above question is still the `Raster Calculator`. We know the pixels we 'want' are numbered `1` on each layer, otherwise they are `0`. So if we could multiply one layer by the other, i.e. multiply the value of each set of overlapping pixels, we would get a new raster whith values of $1 \times 1 \times 1 = 1$ when both conditions are met, and a result of 0 if any of the the conditions is not met. This is why binary rasters are also called raster *masks* - when you multiply any other raster by it, it *masks* (i.e. zeroes out) anything that is not `True` in the mask.

Doing it using the `Raster Calculator` is as simple as it sounds:

(172) Open the `Raster Calculator` and enter the expression `"GB_anprec_lt_700@1" * "GB_mintemp_gt_0@1" * GB_urban_areas@1`. Then save you layer with name `UKs_winter_havens.tif`.

6.3.4 Guided Exercise 6 - Vectorizing rasters

The final result of your analysis should consist of only a handful of pixels - such is lifev in the UK. And since these are discrete locations, it may occur to you they would be better represented and visualised as vectors. Turns out we can convert raster to vectors and vice versa:

(173) Go to `Raster > Conversion > Polygonize (Raster to Vector)...`. In the new window, pick your results layer as the `Input Layer`, `Band 1` as the `Band number`, and leave the rest as default (`DN` here means *digital number*, another name for pixel values. Then pick a folder ans save the results as `UK_winter_havens_poly.shp` (or geopackage if you prefer).

(174) You will notice that a very large polygon was also created for the 0 areas of the raster. You can then put the new vector layer in editing mode, use the `Selection Tool` to select this polygon, and then hit the `Delete` key on your keyboard to get rid of it. Then save the changes and exit edit mode.

> ⚠ Warning
>
> Polygonising rasters can be a very computationally-heavy operation if you have large rasters and/or many scattered pixel values (for example, vectorising the original CORINE layer with all classes). And it is virtually useless for continuous rasters such as temperature or elevation (you would end up with one polygon per pixel as there would be no adjacent pixels with the same value).
> So if you start an analysis with raster data, try to do as much as you can in the raster domain, before vectorising anything. But if your raster results represent isolated small regions within a large matrix of 'no data' or zero values, then vectorising is a good idea.

You now have polygons representing all adjacent areas that were values as '1' in your raster. But many of them are still only one pixel. What if you wanted to have points instead of polygons?

(175) In the `Processing` panel, you will find a tool called `Raster Pixels to Points`, which you can use to generate the points. I'll leave the detauils to you, but here is a tip: before you use the tool, go the `Properties > Transparency` of your raster results layer, and set 0 as an `Additional Nodata Value`. Otherwise `Raster Pixels to Points` will create one point for every pixel, including the pixels with a value of 0. That's a lot of points.

6.3.5 Guided Exercise 7 - Mosaicking and Stacking rasters

Raster files are often very large and 'heavy', so it is common to distribute them as *tiles* or *scenes*, i.e. smaller adjacent pieces that can be merged back together to cover a certain area of interest. For satellite images, it is also common for each image band to be stored as a separate file (unlike regular photos that only have Blue, Red and Geeen bands, satellite images can have several more bands, covering areas of the spectrum we can't normally see. The Sentinel-2 satellite, for example, has a total of 13 bands:

Band	Wavelength	Description
B1	443 nm	Ultra Blue (Coastal and Aerosol)
B2	490 nm	Blue
B3	560 nm	Green
B4	665 nm	Red
B5	705 nm	Visible and Near Infrared (VNIR)
B6	740 nm	Visible and Near Infrared (VNIR)
B7	783 nm	Visible and Near Infrared (VNIR)
B8	842 nm	Visible and Near Infrared (VNIR)
B8a	865 nm	Visible and Near Infrared (VNIR)
B9	940 nm	Short Wave Infrared (SWIR)
B10	1375 nm	Short Wave Infrared (SWIR)
B11	1610 nm	Short Wave Infrared (SWIR)
B12	2190 nm	Short Wave Infrared (SWIR)

In this exercise, we will learn how to a) *mosaic* rasters - 'glue' them together side by side to cover a larger area and b) *stack* rasters - merge the different band files into a single file.

(176) Download the data for this specific exercise from this link. It contains four aerial photographs covering the University of Stirling campus and the Wallace Monument area. Extract the data and organise it as usual.

Tip

These images were originally downloaded from the 'Aerial' section of Digimap - if you ever need very detailed imagery of the UK land, check it out!

(177) Each image is stored within its own folder, named `nsXXXX`, where `XXXX` is a four digit number. *Start a new project* and load into QGIS all the `.tif` files in all four folders. There should be six files in total.

! Stop and Think

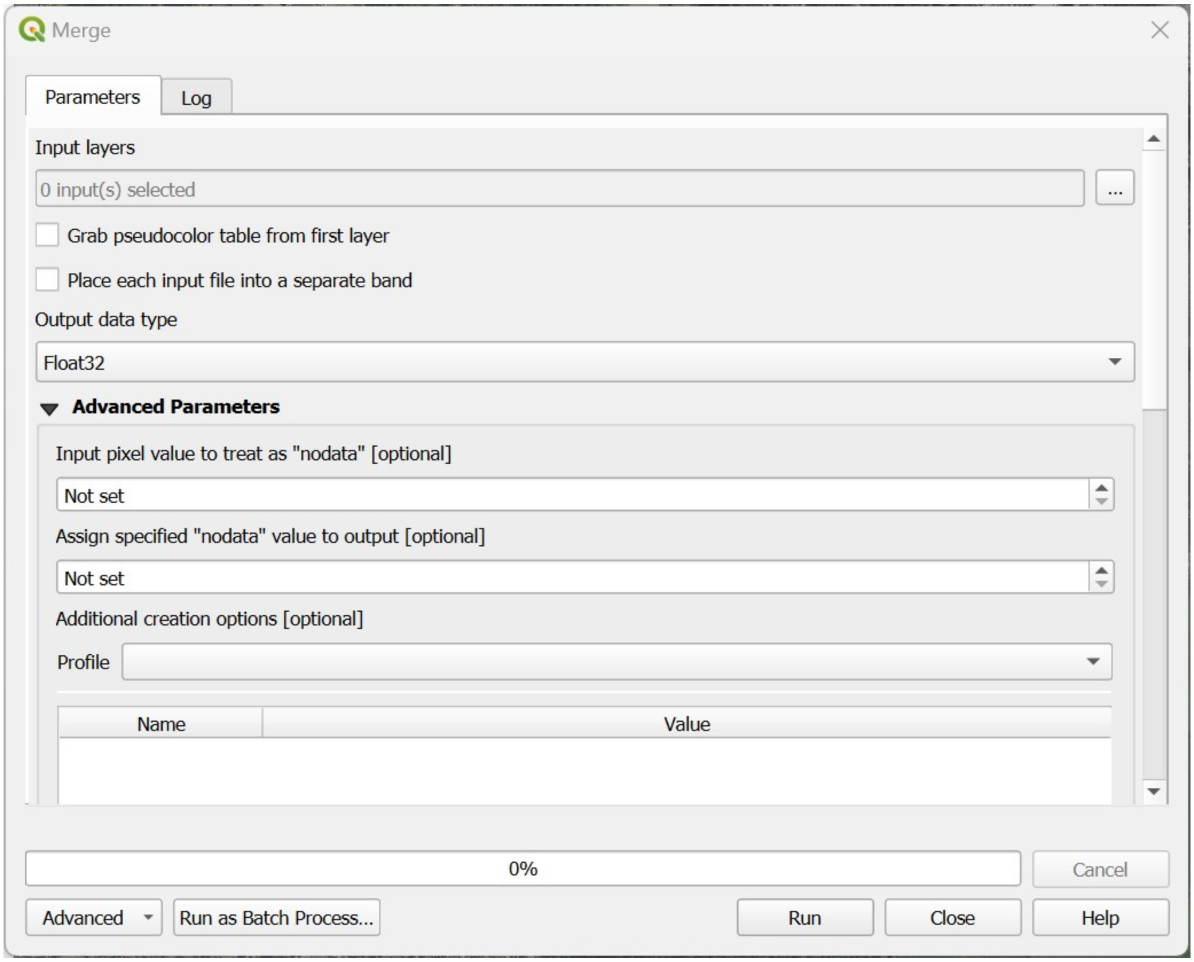
What do you think is the meaning of the `nsXXXX` folder names?

Click for answer

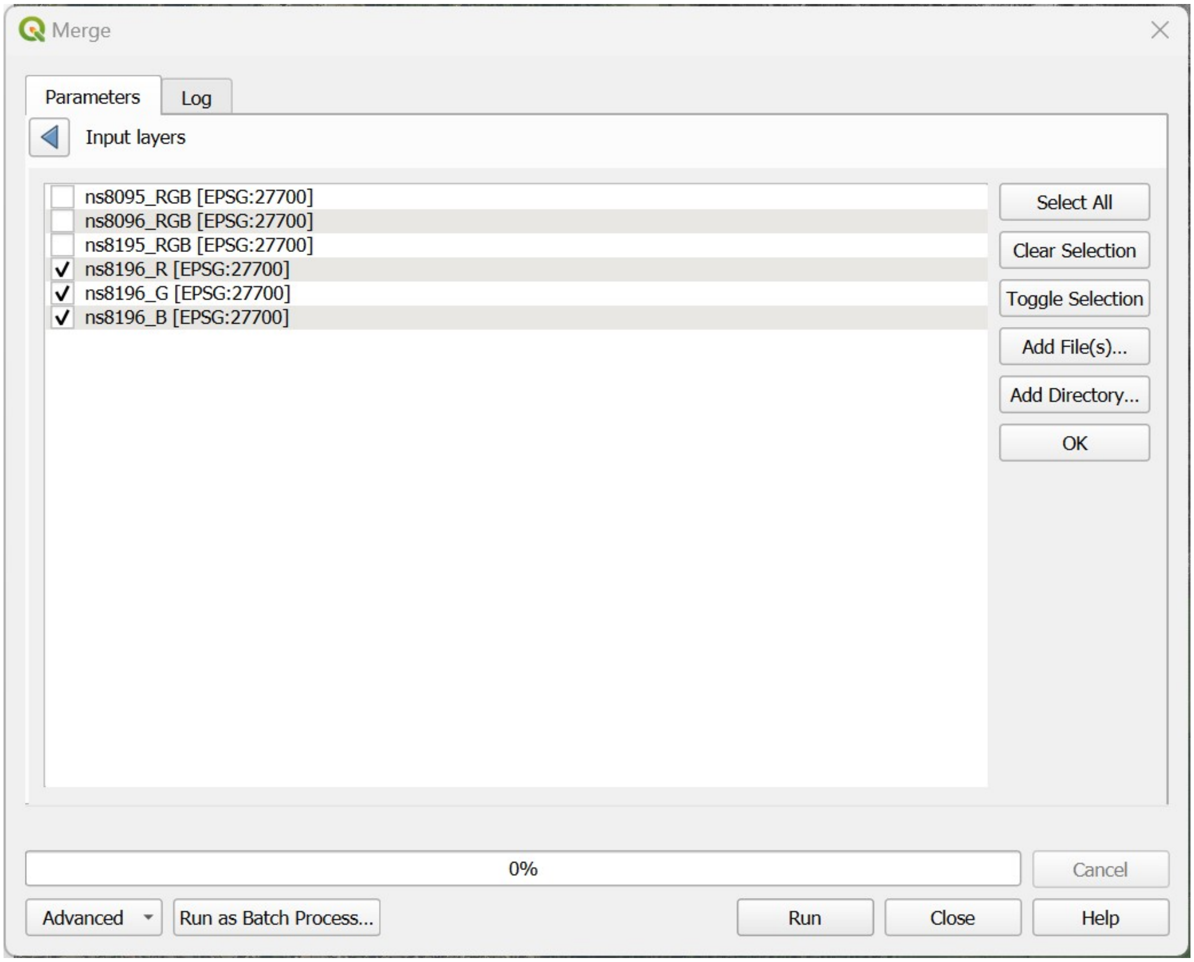
They indicate tiles in the OS British Grid system.

Notice that the airphoto for tile ns8196 has been provided with its three colour bands (RGB) as separate files - simulating what you would expect for satellite files. To be able to see this aerial photo in colour, we must first *stack* these bands into a single file. The operation is called *stack* because you could visualise it as physically stacking them one on top of the other.

(178) Go to `Raster > Miscellaneous > Merge...`. You will get a window like this:



(@) For `Input Layers`, click on the `...` button, and a list of all available raster layers in your project will appear. You can drag the layer names to reorder them, and your final selection should the `ns8196_R`, `ns8196_G`, and `ns8196_B` layers, in the order below from top to bottom. This sets the order of the bands inside the file.



(@) Once you have selected the layers, click on the blue arrow to go back to the main window, then set the following parameters: *check the box* for `Place each input file into a separate band` (that tells QGIS you want a *stack*), and the `Output Data Type` to `Byte`. Then save the resulting file as `ns8196_RGB.tif`, in the same folder where you had the three separate band files.

! Stop and Think

Why do we change `Output Data Type` to `Byte`?

Click for answer

The RGB colour system uses one byte (8-bits, 0-255 integer numbers) per colour channel to designate any colour. For example, the University of Stirling official green colour ( ) is R=0 G=105 B=56. The `Byte` option ensures we only use 8-bits per band, and keep the file size smaller. If we left it as `Float32`, the same 0-225 integer numbers would be stored as 32-bit decimal numbers, quadrupling the size of the file for no reason.

(179) You should now have a properly colored image for tile ns8196. Remove the three original single band layers from the project and then save it.

Everything looks good colour-wise now, bur our airphoto is still actually four separate adjacent photos. That means any processing we may want to do involving the entire area would have to be repeated four times. We can however merge these four tiles in a single airphoto *mosaic*.

(180) Go back to `Raster > Miscellaneous > Merge...`. Yes, it is a bit confusing, QGIS uses the same tool for both stacking and mosaicking.

(181) This time, check the four tiled RGB images as your `Input Layers` - order doesn't matter. Then make sure to **not check** the `Place each input file into a separate band` option. That will tell QGIS you want a mosaic and not a stack. Set the `Output Data Type` to `Byte` again, and save it as `UoS_RGB_mosaic.tif`. You should now have a single airphoto layer covering the entire area. Remove the previous individual layers from the project and save it again.

6.3.6 Guided Exercise 8 - Raster image stretching

When working with multiband color images in a GIS environment, we can often manipulate the contrast of an image by applying different *contrast stretches* to each band. Especially when working with satellite images, which tend to look a bit 'faded' because of the atmospheric effect, stretching can make our images more vivid and easier to interpret.

(182) Right-click on the airphoto mosaic layer you created and go to `Properties > Symbology`. You will se that the symbology type is `Multiband color`, which is the correct choice for representing images. Note that each band is associated to a colour channel (R, G, B), but this association can be changed at will. Change the `Red band` to band 2, and the `Green band` to band 1, then `Apply`. Now the vegetation appears red! Change it back to the proper colour order and `Apply` again.

Tip

This is a useful feature when working with satellite images, which often have bands representing spectral regions that we cannot see, such as Near Infrared or Microwave. We can then freely associate these bands to colour channels and create `false colour compositions` that highlight different surface features. The example below shows the UoS campus as seen from the Sentinel-2 satellite. Here we place Band 13 - Short Wave Infared (SWIR) in the blue channel, Band 8 - Near-Infrared band (NIR) in the green channel, and Band 11 - SWIR in the red channel. Since water does not reflect IR, the loch appears black. Plants reflect strongly in the NIR region so they appear bright green, and bare ground / concrete reflects mostly in the SWIR, thus appearing purplish (red+blue).

(183) Notice how the `Min` and `Max` values for each band are `0` and `255`, meaning we are mapping our screen colours to the entire range of possible values (0-255). But quite often the colours in an image do not cover the entire 8-bit range, so we are 'wasting' colour discrimination.

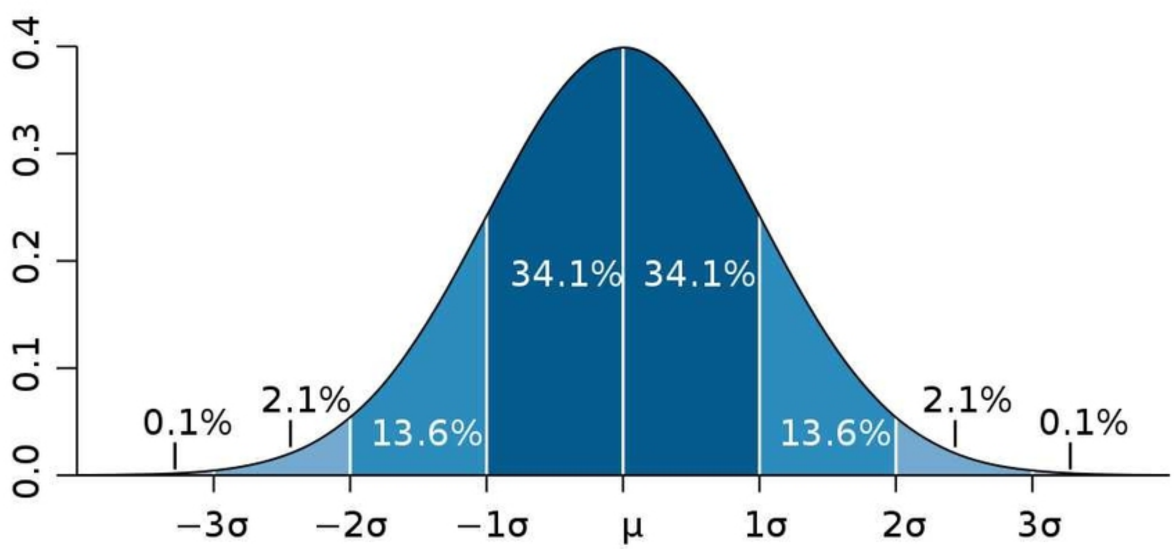
(184) Change the `No Enhancement` option to `Stretch to Min/Max`, and then expand the `Min/Max Value Settings` heading. Pick the `Min/Max` option, and select `Whole Raster` for `Statistics Extent` and `Actual(slower)` for `Accuracy`, then click on `Apply`. You will see that while band 1 and band 3 do use the entire 0-255 range, band 2 uses the 2-255 range only.

To further enhance the contrast of images, we can tell QGIS to 'cut off' the extreme values of the range, using different methods.

(185) Change the `Min/Max Value Settings` option to `Cumulative Count Cut`, and then`Apply`. Now the `Min` and `Max` colour values for each band are (13-189, 29-187,and 31-164 respectively), and the image should look more vivid. What QGIS did was remove the values in the lowest 2% (0.2 percentile) and highest 2% (0.98 percentile) of the existing range before calculating Min/Max values, thus *stretching* this smaller number range to the full colour range of the screen.

(186) Progressively increase the lower percentile (i.e. from 2% to 3%) and decrease the upper percentile (i.e. from 98% to 97%) and notice how the contrast gets progressively stronger. If you go too far (i.e. too narrow a range) you will start to see *pixel saturation* - many of the pixels will be outside the range and thus mapped to fully black or fully white.

A second way to calculate the stretch is to use standard deviations. You may remember from statistics that when you assume a Normal distribution, a distance of $\pm 1\sigma$ from the mean will capture about 68% of the data, $\pm 2\sigma$ will capture 98%, $\pm 3\sigma$ will capture X % and so on:



(187) Change the `Min/Max Value Settings` option to `Mean +/- Standard Deviation x`, and leave the multiplier at `2`. Aplly and check the contrast. Then change the multiplier to `1` and `Apply`, and compare the contrast of using $\pm 1\sigma$ vs. $\pm 2\sigma$.

(188) Set the final image contrast to your linking, and exit the `Properties` window. Save your project.

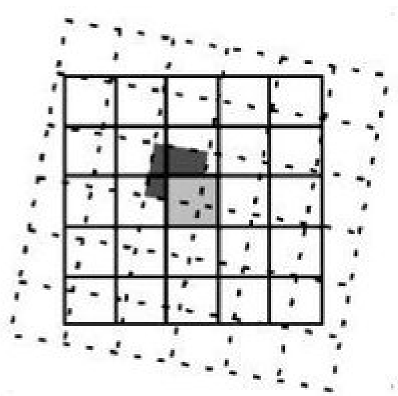
6.3.7 Independent Exercise - Raster resampling

As you have learned, raster data consists of a *grid* of pixel values (i.e. a matrix). So quite often, when working with rasters, you may need to shift the pixels from one grid to another. One main example is raster reprojection - if you reproject your raster to a different CRS, the new raster grid will be aligned with this new CRS, and won't match the original perfectly, as in the figure below.

FIGURE mismatched grids.

That is why the raster reprojection tool is called `Warp(Reproject)` - it is as if you are *warping* the image during the transformation. Other times you may need to make two different raster datasets match the same extent and pixel size, which would also require warping one of the rasters to match the other.

A key step when doing these transformations is choosing a *resampling* method, i.e. in which way will the original pixel values be transferred to the new grid. The most common and fast method is called *Nearest Neighbour* (NN) - if you imagine the old and new grids partially overlapping, NN resampling just looks for the closest old pixel to the new pixel, and transfers the value:



NN is fast because it requires no additional computations, and also has the benefit of not changing the original data values. But if your data has a lot of fine and/or linear elements, it may result in a 'jagged' appearance. For that reason, other methods exist that try to *interpolate* the new pixel values based on a combination of the original ones. Two common methods are the *bilinear* and *bicubic* interpolations, which will average the 4 and 16 closest pixels, respectively. That has the benefit of creating smoother resulting rasters:

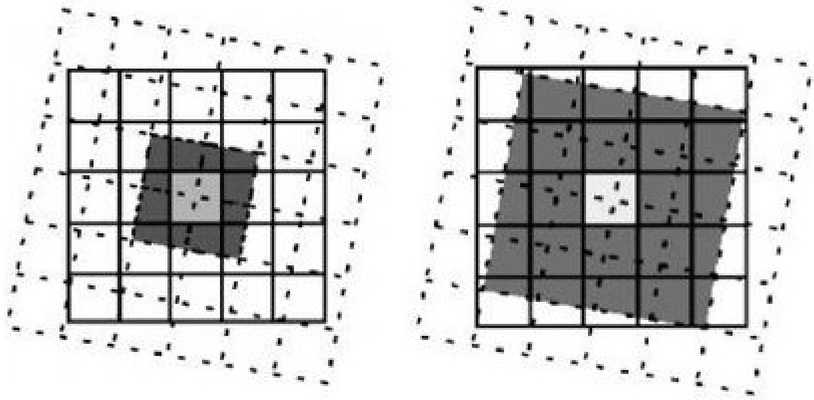
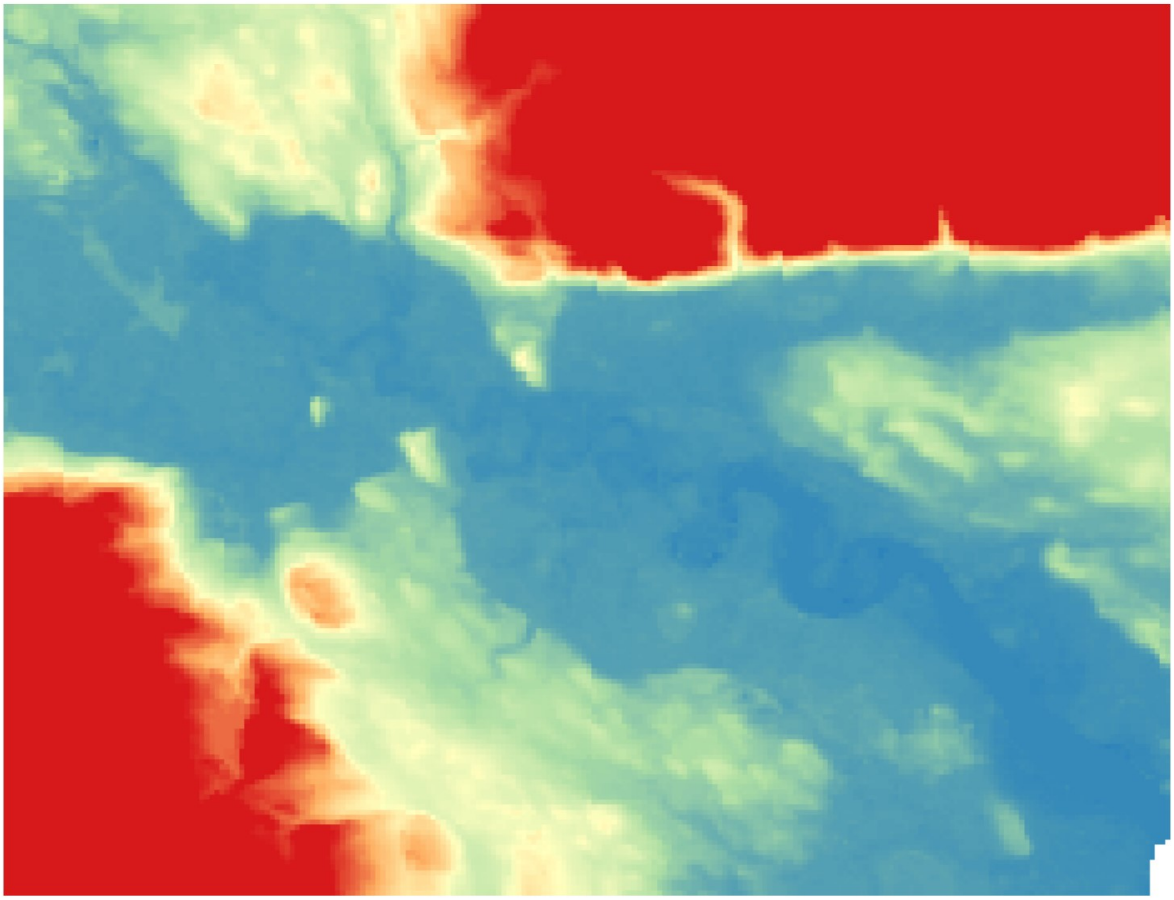


Figure 6.1: Source:10.13140/RG.2.2.16038.27207

Let us now practice our raster skills in an independent exercise, while also demonstrating the effect of resampling:

1. On your UK SRTM layer, find the location of Stirling and the university campus, and then use the `Raster > Extraction > Clip Raster by Extent` function to clip it to an area similar to the image below. For reference, I am using a `Singleband Pseudolcolor` symbology with the inverted `Spectral` colour palette, *stretched* to the values between 0 and 200m. If you find it hard to find Stirling, use the OpenStreetMap online layer as a reference. Don't worry about matching my area perfectly, the clip is just to speed up our computations.



2. Now use `Warp(Reproject)` to reproject this dataset back to EPSG:4326, but twice. Do it the first time using `Nearest Neighbour` as the `Resampling method to use`, and then a seocnd time using the `Cubic(4x4 kernel)` resampling method. Remember to pick the correct layer to reproject (it should be your Stirling-clipped SRTM layer). **Hint:** If you save it as a temporaty file, it may not recognise the CRS after the warp - you will see a question mark to the right of the layer name. If that happens, just click on the question mark and pick ESPG:4326 as the CRS.

3. Apply a symbology to the original Stirling SRTM that makes it easier for you to see all terrain features. Then use `Copy Style` and `Paste Style` to make sure both of the new warped versions have the same symbology.

4. Flick back and forth between the original, NN resampled and cubic resampled rasters - can you see how NN results in more 'jagged' edges where you have sharp terrain transitions?

5. Calculate the global raster statistics for the three layers and assess how much impact NN vs. cubic resampling has had on the new layers, compared to the original.

One instance where we should *always* use NN resampling is when we have categorical rasters such as the CORINE dataset. In these cases, any sort of resampling that averages multiple pixel values will create 'fake' new numbers that don't represent any class. Let us test it:

6. Using `Raster > Extract > Clip Raster by Extent`, clip a portion of the CORINE dataset that matches the extent of the clipped Stirling SRTM layer. Hint: ask QGIS to use the extents of the SRTM clip for the CORINE clip.
7. Again, reproject this clipped CORINE dataset using both `Nearest Neighbor` and `Cubic(4x4 kernel)`, as you did for the terrain.

8.Now use the `Raster Layer Unique Values Report` tool from the `Processing` panel to count the unique pixel values in the original CORINE clip and the two reprojections. What happened when you used the bicubic resampling?

Return to the Symbology window, and expand the option Min / Max Value Settings. What is the default option selected? Experiment with the other options (with different percent clips and standard deviations) and see how the Symbology changes. Remember to Apply the changes every time you change any options. Still, on the Symbology window, change the Classification options (drop-down menu to the left, under the classes) from Continuous to Equal Interval. To the right of it, select the number of classes as 3. Then Apply and evaluate. Without changing your number of classes, change the Interpolation option above the classes from Linear to Discrete. Apply and evaluate. Take some time to play with these visualisation options to analyse the distribution of different Bioclimatic variables in the UK, and think about what they mean for plants, (non-human) animals and in terms of social and economic factors. Finally, let's work on the Symbology for the SRTM data. On the Symbology window, choose the Singleband Pseudocolor option, and then on the Color Ramp option, select Create New Color Ramp. On the small options window that comes up, select Catalog:cpt-city. Once the catalogue window opens, go to the Topography list and select the cd-a palette. Then classify your elevation values using the User Defined Min /Max option, and type 0 as Min and 900 as Maximum. Apply and visualise. Then, before closing the Properties window, go to the Transparency table and drag the slider at the top to around 60%.

Right-click on the SRTM layer name and select Duplicate layer (this step is useful to create a copy of a layer and retain symbology. Remember, this is a temporary layer). Now, on the Symbology of the copied layer, change the render type to Hillshade. Apply and close the window. Make sure the copied layer is immediately under the original layer, and alternate each layer between on and off.

Stop and think:

What does the hillshade render style does? You may zoom in on an area of interest and examine how the topographical data appear now. Guided Exercise 3 - Mathematical and boolean operations using the Raster CalculatorLinks to an external site. Go to the menu Raster > Raster Calculator…. This tool allows you to apply several mathematical functions to raster layer values and even to do calculations among values.

First, find the Bio1 layer of the Bioclim raster. From the metadata, we know it is the first band, so double-click UK_bioclim@1 to add it to the expression area. In this context @1, @2, etc. indicate the respective raster band number.

As we saw above, the Bio1 layer corresponds to Annual Average Temperature, with a unit of degrees Celsius multiplied by ten. Let's convert it to regular degree Celsius units. On the expression area, after UK_bioclim@1, use the operator / then write 10. Then, in the top right corner, select a folder to save your file and name it appropriately (e.g. UK_bioclim_C.tif). Then click OK.

Style your new layer in the same style used for the original Bio1 layer, using the full Min / Max range, and observe the laughable maximum average temperature values for the UK (sorry, couldn't resist). Can you spot the London heat island effect (urban heat island - UHILinks to an external site.)? Can you recognise other heat islands?

Let us say we would like to relocate to the hottest (in average) locations in the UK. Go back to the raster calculator, and enter the expression UK_bioclim@1 > 100 (or use your new layer and select areas > 10). Save the result as UKs_last_hope.tif. (or more likely future_tropical_UK.tif, considering the heat waves during the last summer 2022).

Go to the Symbology layer of your newly created layer and select Paletted / Unique Values, then Classify. Then, remove the 0 values from the legend using the - (minus) button. Click on the colour box for the 1 values and select a strong red colour. Finally, go to the Transparency tab and drag the slider to around 50%. Then Apply and close the window. Position your temperature range layer just above the terrain + hillshade layers, and make sure only these three layers are visible. Pretty, isn't it?

Optional: add the UK counties layer from hereLinks to an external site.. Symbolise using "outline", no fill. Make sure the counties layer appears on the top. Can you identify the counties with the highest average temperature?

For example, let's say we want to get the mean average annual temperature and visualize the temperature ranges for our "last hope" region only. Let us go to the Raster Calculator, and use the expression (UK_Biolcim@1 / 10) * UKs_last_hope@1. Name the resulting layer and save it, then style the result using a Pseudocolor colour ramp. However, this time manually specify the Min value as 10. It may take a few minutes, so be patient.

Stop and think:

What happened to the temperature values when we applied the expression above? Use the information tool to probe a few values of the new raster to help you think about it. Return to the Properties of the new masked layer, and select the Transparency tab. On the table named Transparent pixel list, click on the + (plus) button to add a new line. Fill the line with the values from = 0, to = 0 and Percent Transparent = 100. Apply and evaluate the result. Stop and think: did you actually change the values of the raster layer when you set the transparent pixels?

Vectors can also be used as masks. Go to Raster > Extraction > Clip Raster by Mask Layer…. Select your Celsius converted average temperature raster as input layer, the gadm36_GBR_0 as your mask layer, and check the keep the resolution of the input raster box. Run the algorithm (it will take a while) then Close the window when finished. Set the transparency to 60%. Zoom to the original UK_SRTM layer extent and compare the results before and after the masking.

Now click on the menu Processing > Toolbox…. Welcome to the QGIS toolbox! You will find many additional functions here to process vectors and rasters, as well as functions from external software that can be accessed through QGIS. On the search bar at the top, search for Raster layer zonal statistics. Double-click on the tool with the name that comes up from the search. As Input layer, select the degree Celsius temperature layer you created, and as Zones layer, select the "last hope" layer (the one with the 0/1 values, not the masked temperature layer). Run (it will take a while) and then Close.

Open the attribute table of the new "statistics" layer and see what the number represents. Independent Exercise Is there any difference in mean values of average annual temperature between urban areas and forests in the UK? Make a map (including legend and scale) showing your results visually.

Hint 1: To ensure raster operations work properly, all rasters must be in the same projection.

Hint 2: You can also use AND and OR to create compound expressions (such as raster@1 > 20 OR raster@2 < 50) on the raster calculator (just make sure you type them in all caps).

Optional: Open a new project. Add the online Mapzen Global Elevation layer by going to the QGIS Browser and choosing XYZ Tiles > Mapzen Global Elevation, and then download the plate tectonic data from HERE Download HERE.

Image showing where to load the Mapzen layer on the QGIS Browser

Open the properties of the DEM and select the Hillshade symbology, with a Z factor of 10. Add the earthquake and country data from Week 2. Now see if there are any clear relationships between high elevations, plate boundaries and earthquake locations.