QGIS Guide for Marine Scientists

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Basics

File and data types

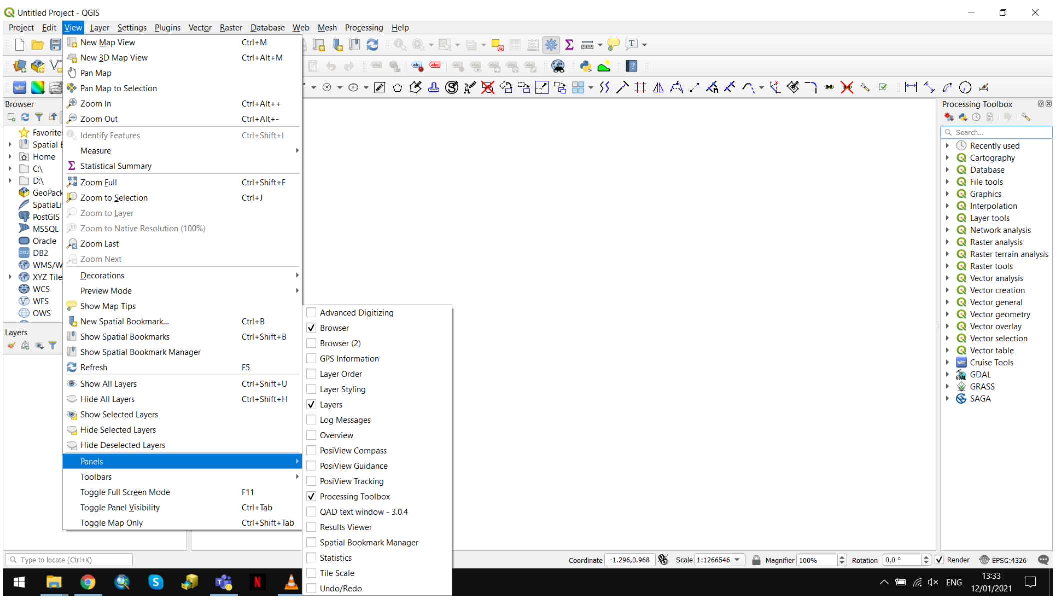
There are three main types of data that are used most often. These are:

- **Raster** data: Geotiffs, netCDF etc.. The data are stored as points or pixels in a raster or array format. The file (e.g. xx.tif) contains a header which holds information about georeferencing, filename, size, resolution and number of layers (bands).
- **Vector** data: The data are stored as geometries like points, lines or polygons. I.e. each vector element has a length, a shape, positions of start and end points etc. In contrary to a raster, vector data can be compressed lossless as they do not have a resolution. In GIS, the most common vector file format the shape file and geopackage.
- **Delimited text:** The data are stored in a human-readable table (.csv, .txt, .xyz, .xls etc.). Text files with geo-related content contain coordinates (e.g. longitudes and latitudes) along with some data values (e.g. depth). They can be converted to raster (by interpolation, gridding) or shape files (e.g. sample points on a map), depending on what you want to display.

Getting started with QGIS

Create a new project

Find the QGIS Desktop App on your computer (e.g. clicking the windows button and search for it with the search function) and double click on the App. QGIS will open and you can choose either a new empty project or a previously saved project. A general note: If you are missing panels or toolbars that will be mentioned throughout the manual, find and check them under '*View*' -> '*Panels/Toolbars*' or by right-clicking the icon bar and activating the tools.



1: Make panels and toolbars visible

To keep things simple, select WGS84 as your project geographic coordinate system (GCS). You can do so by clicking on the CRS symbol in the bottom right corner.

Working with Raster data

Import a Raster

Just like vector data, raster files like geotiffs or netCDFs can be added to the QGIS project by drag & drop. Of course you can also add them via '*Layer*' -> '*Add layer*' and '*Add raster layer*' and navigate to your file.

Once imported, check if the raster has a CRS. If you see a '?' next to the raster layer, you need to assign one by either double-clicking the '?' or right-clicking on the layer and under '*Layer CRS*', select the correct CRS. Note that by doing so, you are only assigning a CRS to the layer within the active QGIS project, you are not actually changing its geometry it. Other than for vector layers, it can happen that a raster doesn't have a valid CRS. If this happens, it is mostly wiser to reproject using the respective tools.

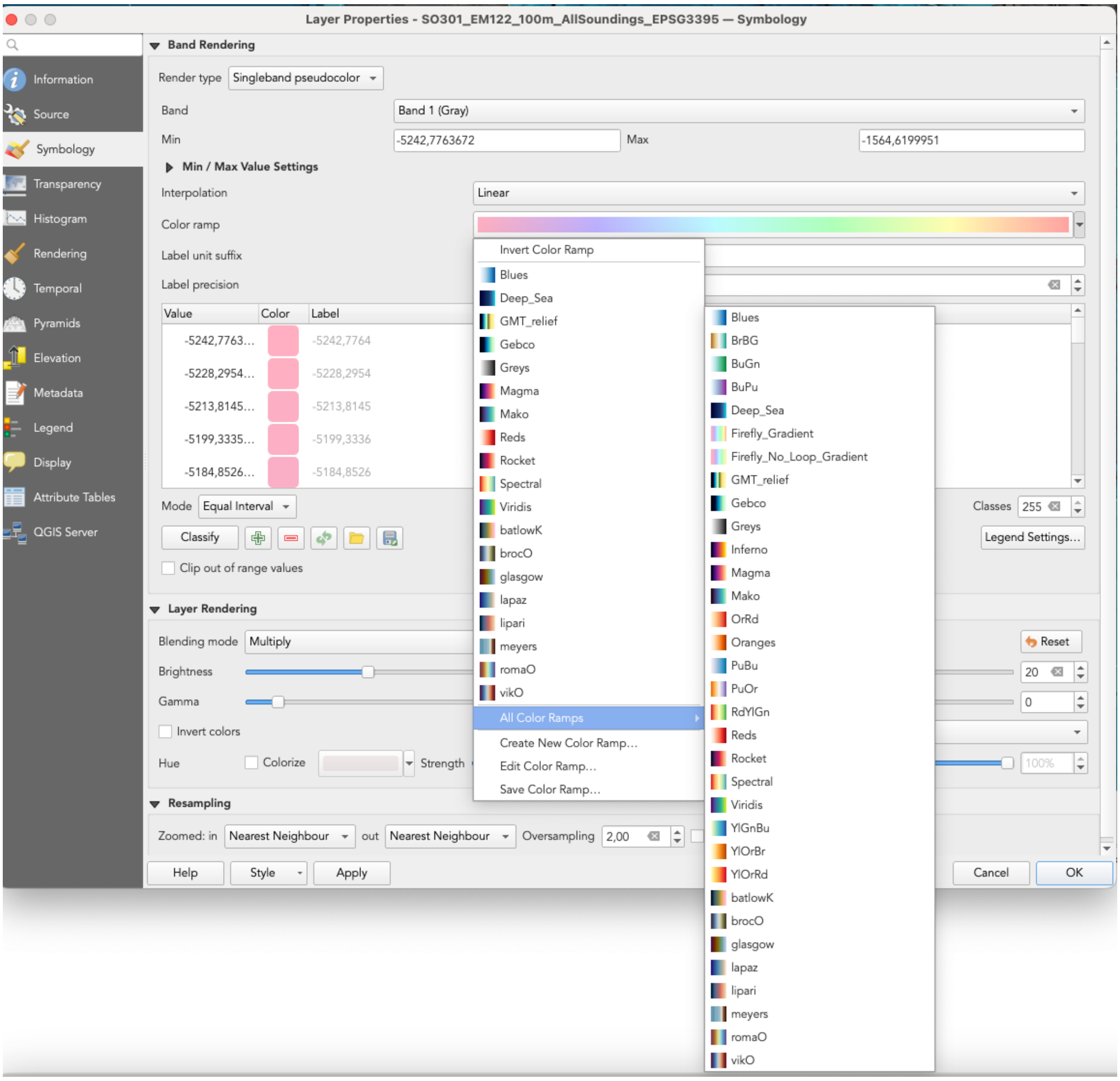
To keep things simple, use the latest GEBCO grid as an example and add it to the project by drag & drop. It comes with WGS84 as native GCS. Next, also import some MBES bathymetry which is mostly delivered in a projected CRS such as UTM or World Mercator/EPSG3395. You can check out mangomaps to find out UTM zones.

Changing colour scheme

With colours, you can make any map looking either great and super-stylish or horrible. There are a few recommendations for scientific use of colour palettes – mostly with respect to colourblind people and also to match ratios of values to their respective colours. You can read more here about scientific colour maps. Below is a basic description of how to generally change colour style of layers:

- Double click on the layer to open its properties
- Under '*Symbology'*, select '*Singleband pseudocolour*' via the dropdown menu
- Leave 'Band and Min/Max values as is
- Choose any colour ramp you like, if necessary, invert the colour ramp
- There are more colour palettes:
- Under '*All Colour Ramps*' you will see all QGIS defaults and Favourites
- Under '*Create New Colour Ramp'*, you can check out the catalogue 'cpt-city' to find even more
- You can even create entirely custom colour palettes if you select '*Gradient'* or '*Random'* under '*Create New Colour Ramp'*
- To go wild and if the above mentioned are still not enough, you can import styles as .xml files e.g. from here or here. Make sure to cite accordingly.

- Click '*OK*' or '*Apply*' if you want to stay in the properties



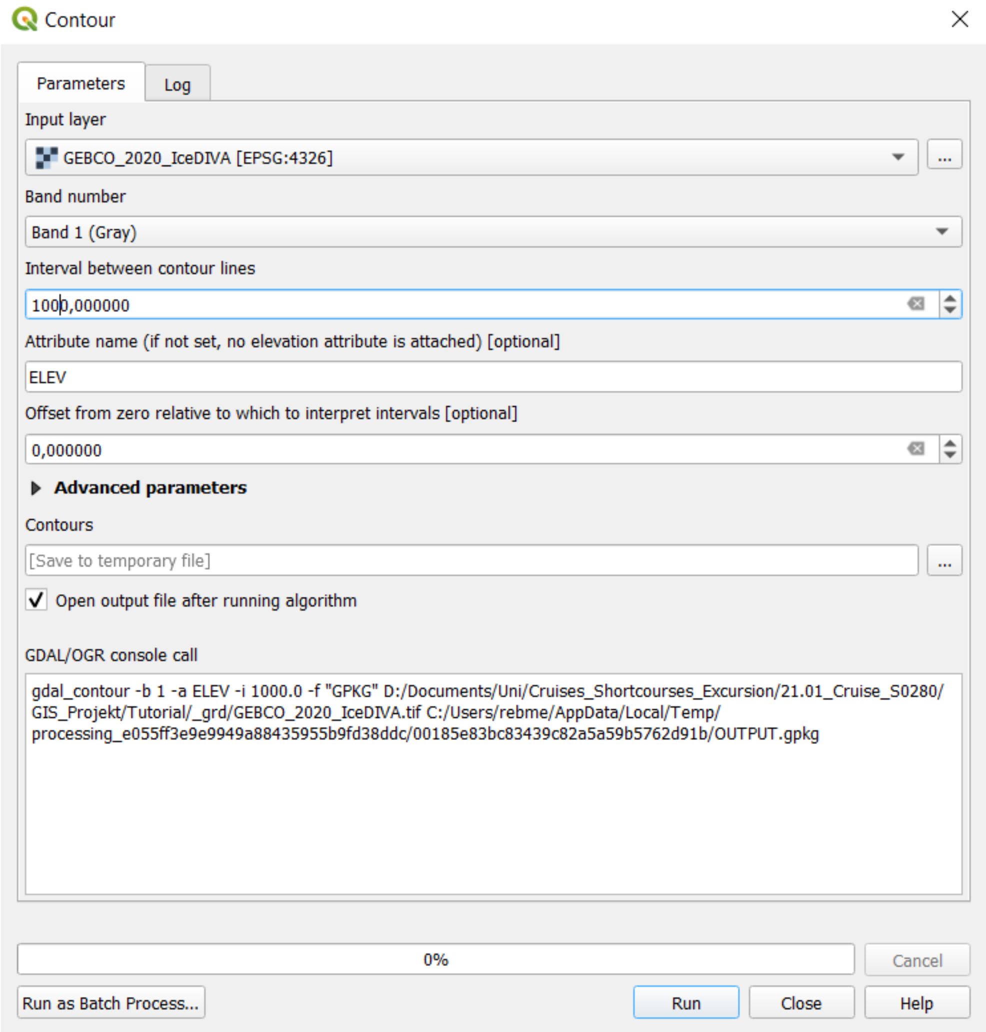
2: Adjust colours

Create Contour lines

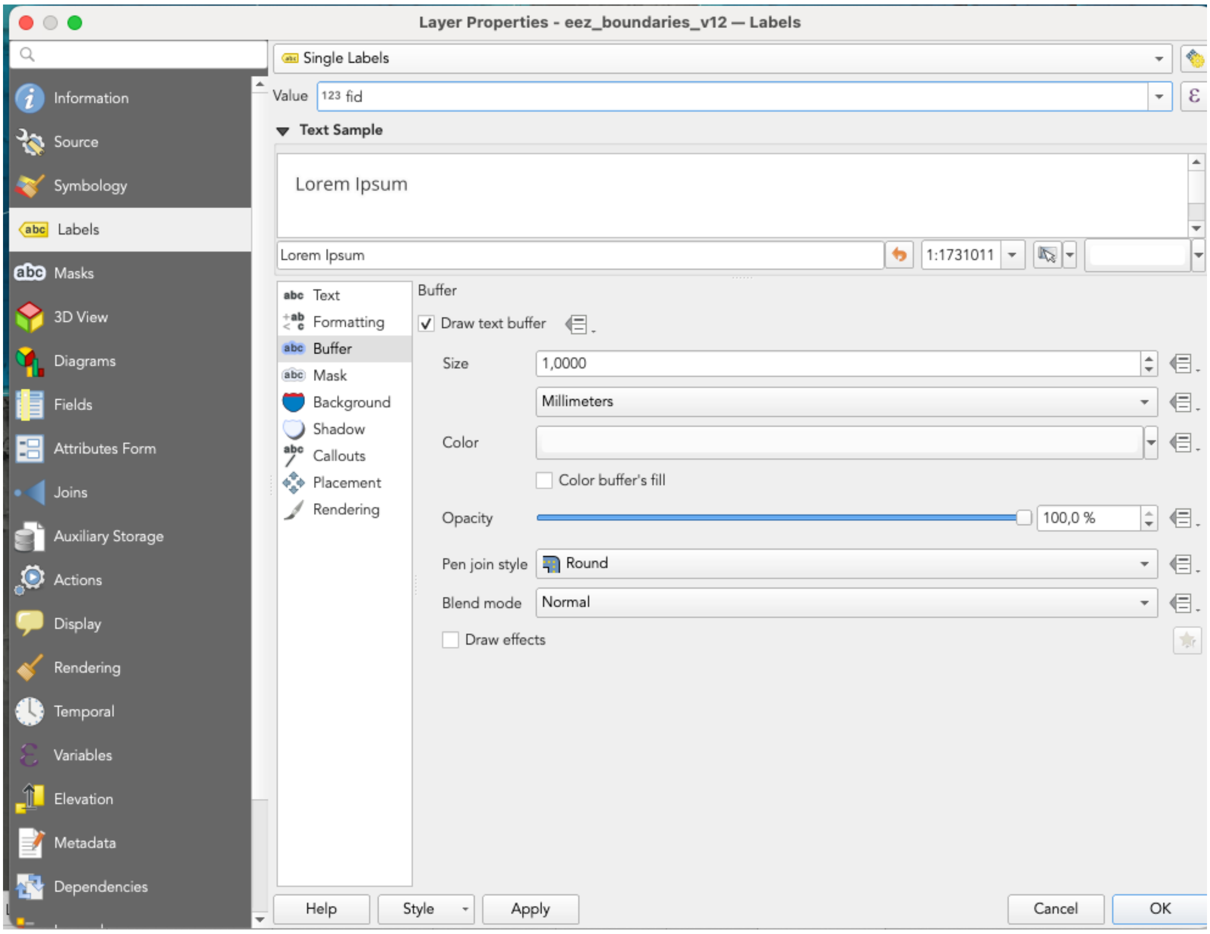
An easy measure how to quantify depths or heights for is to draw contour lines, or **isohypses/isobaths** (lines of equal height/depth). Here comes how to do it:

- In the Processing Toolbox, search for '*Contour Lines*'
- Select the GDAL tool '*Contour*'
- In the windows that pops up, select:
- the raster you would like to draw contours from (e.g. GEBCO) as '*Input Layer*'
- Chose appropriate line distances; **Note**: Don't do too small intervalls as this can cause QGIS to crash if it is a large raster. For a global grid, e.g. GEBCO, a good interval would be 1000m

- Click '*Run*'
- To label the lines, double-click the new line layer to enter its properties
- Under '*Labels*', select '*Single labels*' and under '*value*', select the respective value field that contains the labels, in this case it's the depth values for each contour line feature
- For better visibility, you can check the '*Draw text buffer*' in the '*Buffer*' field



3: Contour Line Tool dialogue



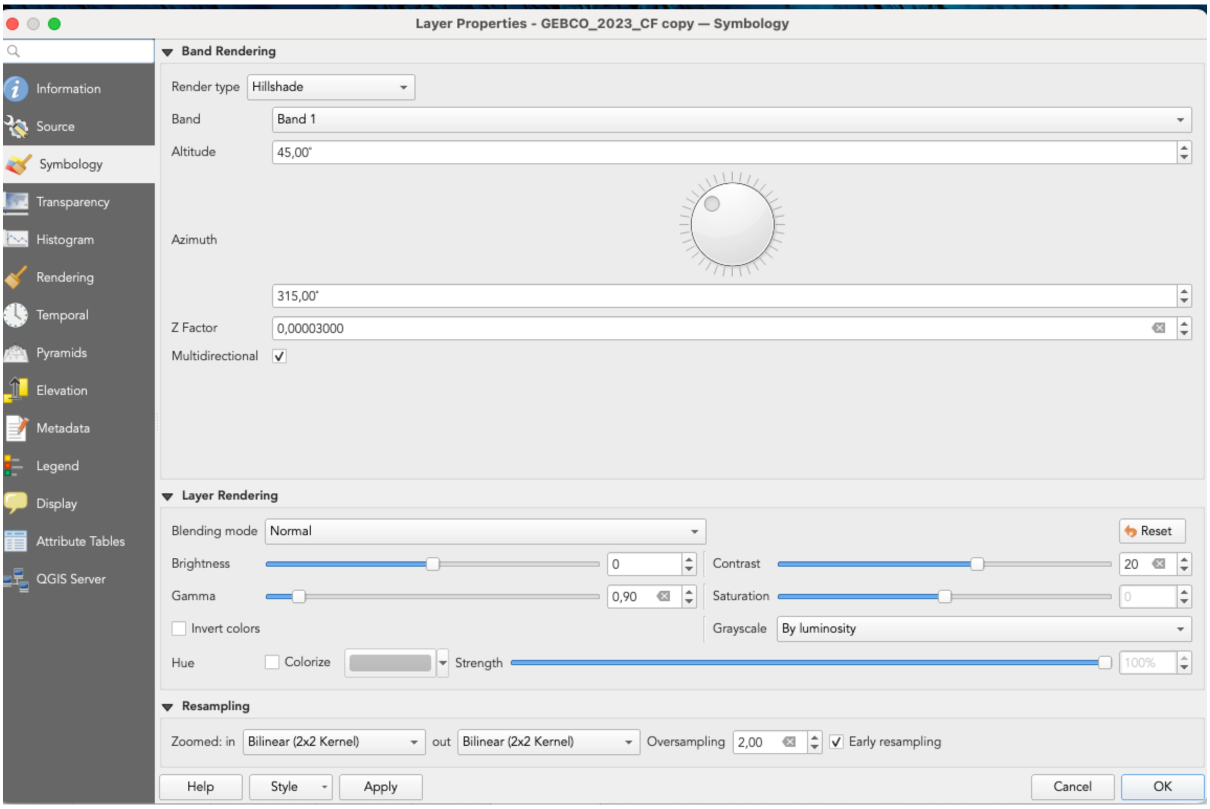
4: Label contour lines

Create Hillshade

Hillshade can make raster DEM (Digital Terrain Models) look 3D giving it an appropriate relief style. It does this by pretending that the surface is illuminated and throws shadows in selected directions and by applying vertical exaggeration. This however depends on the latitude and also on the coordinate system you're using, mostly geographic versus projected. You can find a table listing Z-factors for geographic unprojected GCS (e.g. WGS84) on the right. In this case, the Z-factor is nothing else than **meters expressed in degrees**. For projected CRS (e.g. UTM or World Mercator), Z-factors are optional (because CRS units are usually equal to depth/height units), and can be set to 1. But you should check this visually. Check out the example images below.
There are a few ways to apply hillshade, but the most commonly used and modern one is described below:

- Colorize the raster you'd like to hillshade with the colour palette you like
- In its properties under '*Symbology*' and '*Layer Rendering*', select 'Multiply'
- Right-click the raster and hit 'duplicate layer'
- Double-click the duplicate and go to '*Symbology*'
- Under 'Render Type', select 'Hillshade'
- Enter the correct value of the **Z-factor**, it is dependent on your latitude and your CRS (e.g. for unprojected GEBCO, chose 0. 00003)

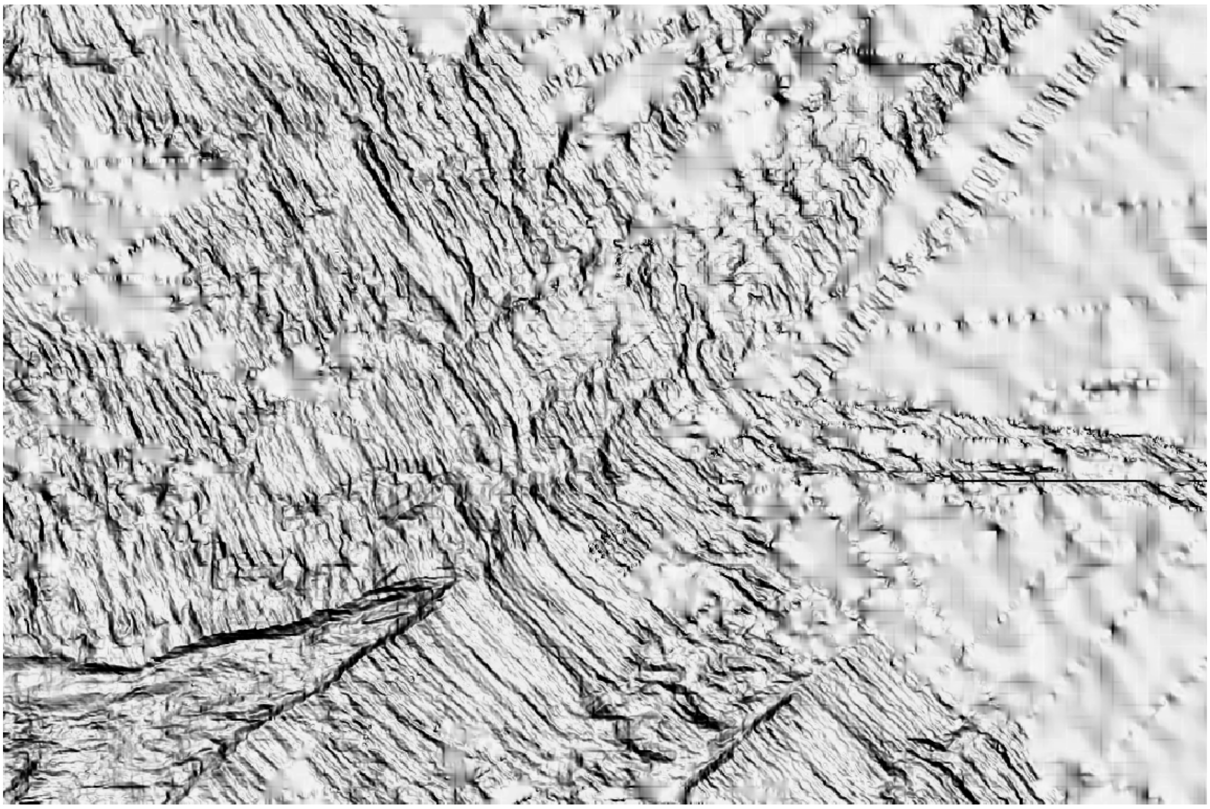
- Check 'Multidirectional'
- Under '*Layer Rendering*', you can also play around with brightness et al.
- Optional (if you encounter pixelation): Under '*Resampling*', select '*Bilinear*' for in and out, and set '*Oversampling* ' to 5
- Click '*OK*'
- Make sure the hillshade is located under the raster layer used for colorisation



5: Hillshading unprojected raster layer

Latitude		Z factor (in meters)	Z factor (in feet)
0		0.00000898	0.00000273
10		0.00000912	0.00000278
20		0.00000956	0.00000291
30		0.00001036	0.00000316
40		0.00001171	0.00000357
50		0.00001395	0.00000425
60		0.00001792	0.00000546
70		0.00002619	0.00000798
80		0.00005156	0.00001571

6: Z-factors for unprojected CRS



7: Correct Z-factor (0.00003) for hillshade of unprojected GEBCO grid, pixelation visible on the right


8: Incorrect Z-factor (0.0003) for hillshade of unprojected GEBCO grid, pixelation visible on the right

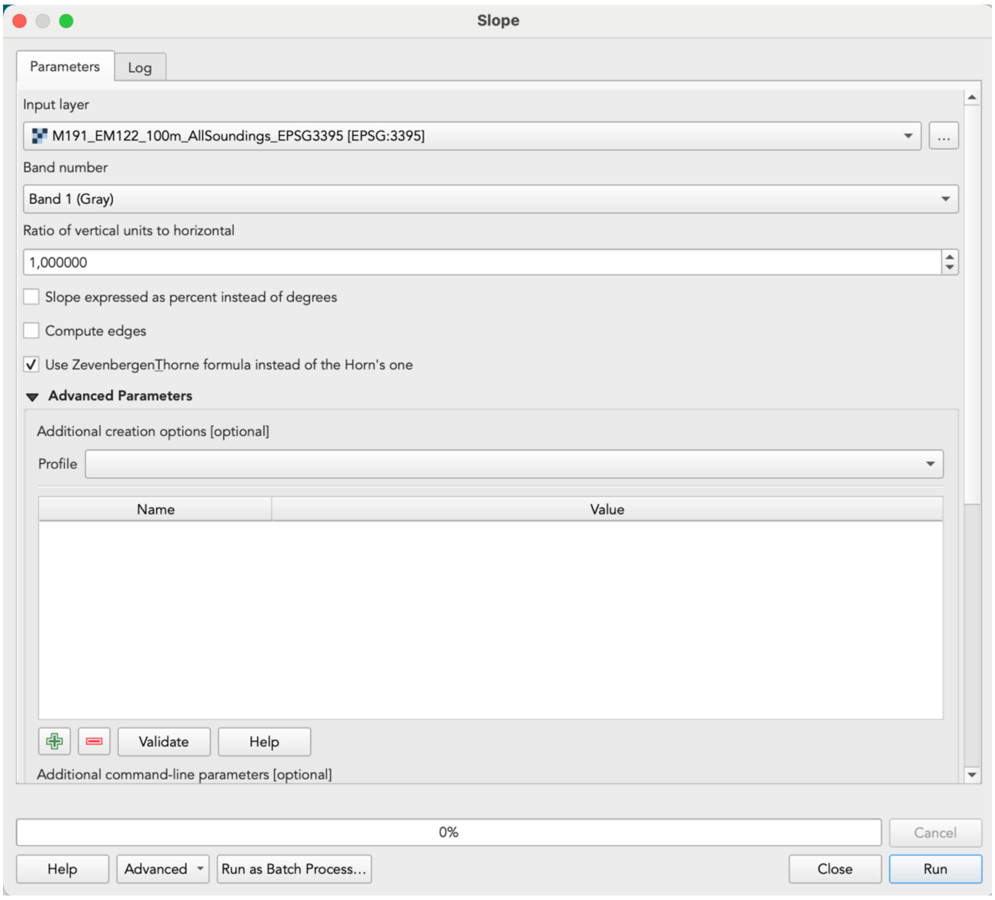
Calculate Derivatives

Derivatives are mathematical tools that give information about the change of a function at a given point. For DEMs, the most important are **slope, aspect and curvature**. Slope describes the angle of inclination (= rate of change of elevation for each cell in x, y direction) and is expressed in degrees. Aspect groups cells based on their compass directions, hence gives information about the orientation. Curvature is basically the change of slope (i.e. the 2nd derivative). Further measures are Terrain Ruggedness Index (**TRI**), which measures the difference of a central cell and its neighbours. Whereas Topographic Position Index (**TPI**) measures the difference of a central cell and the mean elevation of its neighbours. It is best practise to calculate all of these measures on **projected DEMs** where the units of x, y and z are equal (in meters at best, UTM is most accurate for these kinds of distance-based analyses). More information can be found here.

There are different ways how to calculate the derivatives using QGIS tools. They all work kind of similar hence we'll introduce one of them (Slope) and just mention the others:

- In the Processing toolbox search bar, type 'slope' and find the tool *GDAL/Raster Analysis -> 'Slope'*
- This algorithm by default calculates slope based on a 3x3 kernel (moving window)
- Select your DEM as input layer
- '*Ratio of vertical units…*' is nothing else than the 1/Z-factor. If you work on a projected DEM (which you should), then leave it set to 1

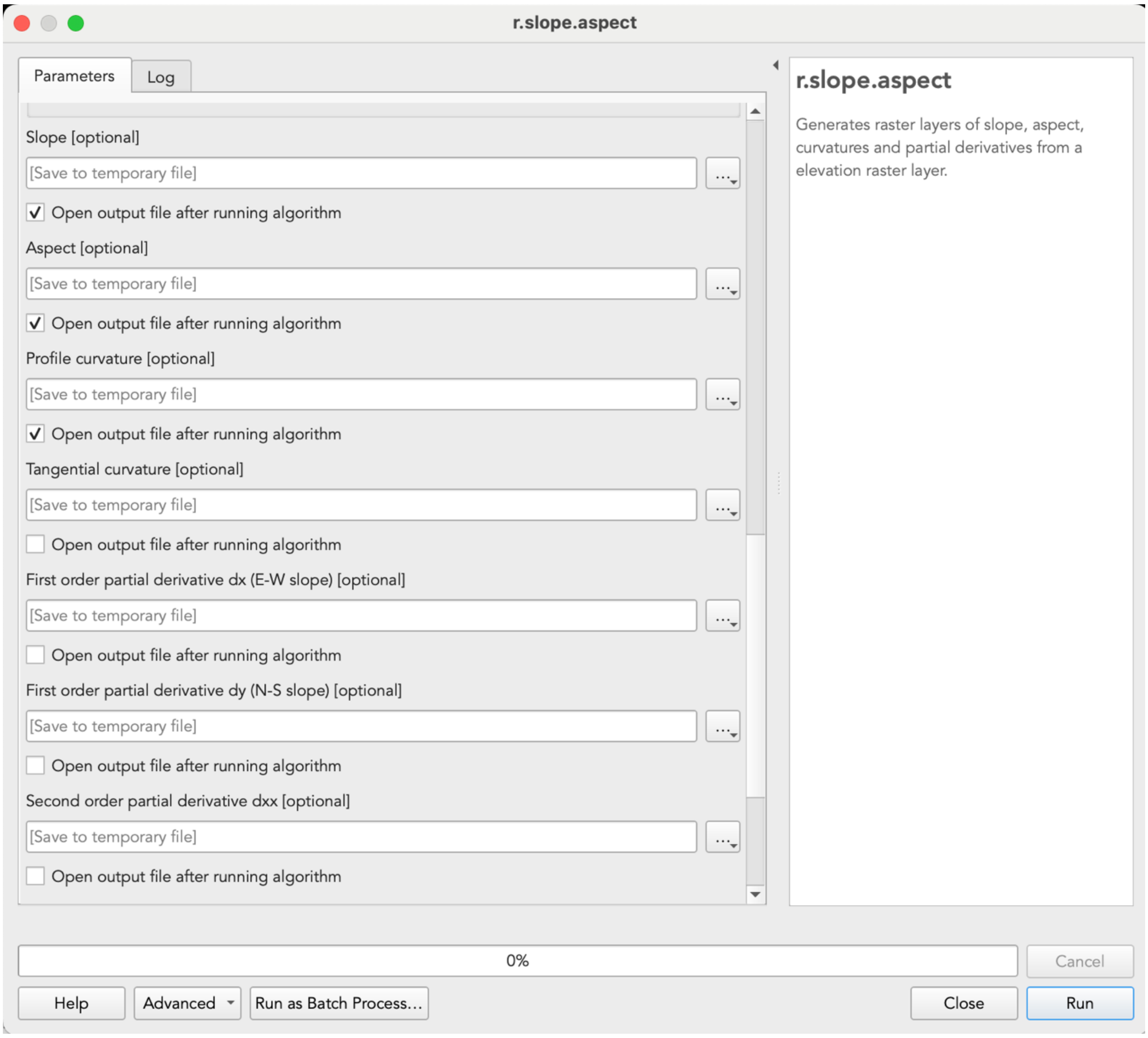
- '*Compute edges*': Interpolate cells when missing data and at DEM edges. Leave unchecked.
- '*Zevenbergen & Thorne*' (vs. '*Horn*') formula: Z&V more suitable for smooth terrain
- Select an output directory and a suitable name and hit '*Run*'



9: GDAL Slope dialogue

Aspect, TRI and TPI work very similar – just look for them in the processing toolbox and click yourself through them. They also per default use a **3x3 moving kernel size** (= 9 neighbouring cells).

There also is a one-in-all solution provided by the **GRASS GIS core plugin** that calculates all derivatives at once (slope, aspect, curvature). It is called '*GRASS/Raster -> r.slope.aspect*' and accessible via the processing toolbox. If you can't find the GRASS provider in the processing toolbox, activate it by checking the '*GRASS GIS Provider*' plugin under the '*Installed*' tab in '*Plugins*' -> '*Manage and Install Plugins*'. Open the tool dialogue and select the derivatives you want to calculate – there are options to calculate partial and second order derivatives as well and you may not need all of them.



10: GRASS DEM derivative tool

Working with Vector data

Import existing Vector data

Vector data can be anything but mostly come as ESRI Shapefiles (.shp) or GeoPackage (.gpkg). Both formats have multiple additional files containing metadata, without them they cannot be opened in most cases. Hence when moving or copying such data, it is important to copy all the files that belong to the main layer. To import an existing vector layer, you can just drag & drop the respective file into the '*Layer*' panel of your QGIS project. You can also go via the '*Layer*' menu, select '*Add layer*' and '*Add vector layer*' and navigate to your file.

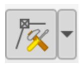
Create a new Shapefile (point, line, polygon)

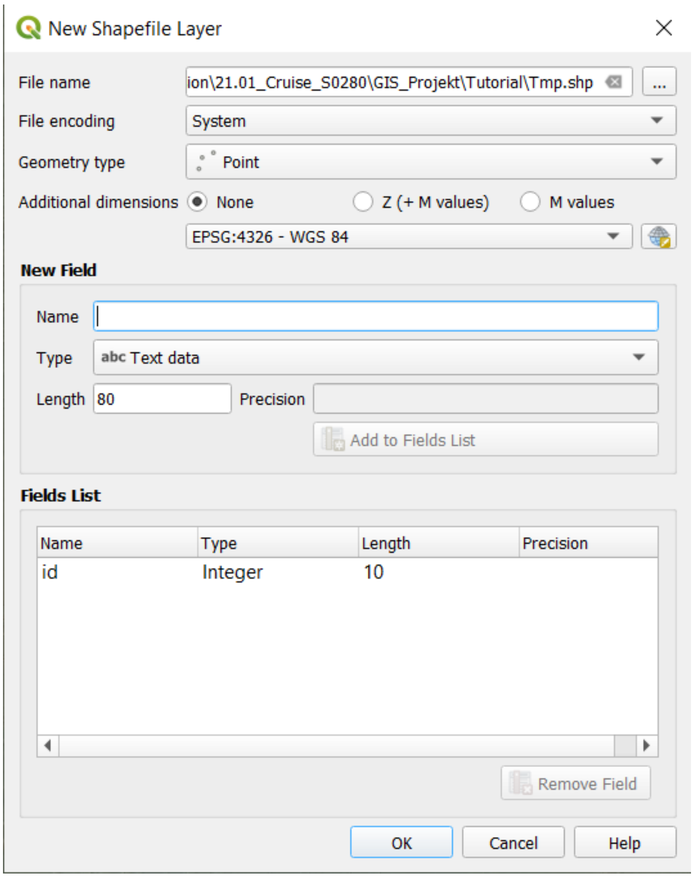
Sometimes we want to create new layers from scratch to plan surveys, set sampling locations etc. Find the instructions below:

- At the top panel, under *Layer* go to *'Create Layer'*, and select *'New Shapefile Layer'* in the dropdown menu
- A new window will open
- Navigate to the folder where you want to save the shapefile to via the "…" button and enter a (reasonable) name
- Select the **geometry type** you want (polygon, point, line)
- You can add new columns here but you can always do that later as well
- Leave everything else as is and press "Ok"
- Right-click on the layer or press the *"Toggle Editing"* icon in the upper panel to activate editing mode
- Now select the *'Add X Feature'* icon to the right of the pen
- You can now draw lines or polygons and set points anywhere on the canvas
- Once you created your feature, a new window will open and asks you to *enter an ID*; this can be any integer number but you may want to give it **reasonable numbering**. If you created other fields, you can now populate them here, too
- Once done, untoggle editing mode by pressing the pen icon again and save edits

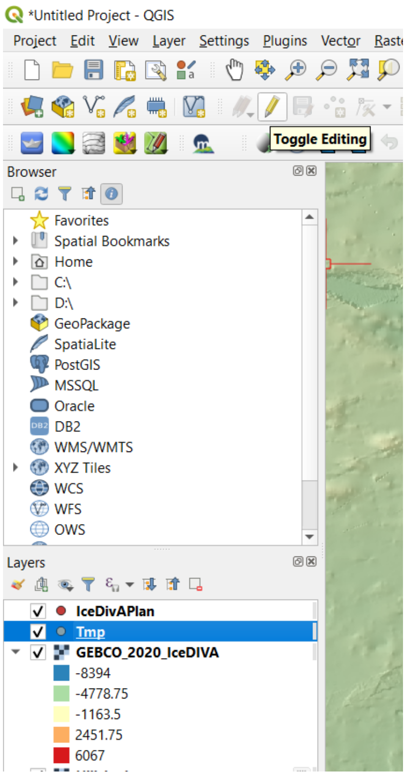
Drawing a Polygon Bounding Box with given coordinates

Unfortunately, it is not too straightforward to draw a bounding box using given coordinates. It's not too difficult though- first, we'll draw points to a point layer and snap the polygon edges to those points in a second step. You'll need a plugin '*Lat Lon Tools*' and a point and a polygon layer:

- Under 'Layer', click 'Create New Temporary Scratch Layer' and chose 'Point' as 'Geometry Type'
- Use the '*Lat Lon Tools*' plugin to add features by typing the bounding box coordinates
- You should see your points on the map
- Now create a new polygon layer
- Enable snapping: Under 'Project' and 'Snapping Options', select 'All Layers' and 'Snapping on Intersection'
- Now draw any polygon anywhere on the canvas in the polygon layer
- Enable the '*Vertex Tool*' in the upper panel 
- Drag and snap the polygon's corner to the points



11: New Shapefile Import dialogue

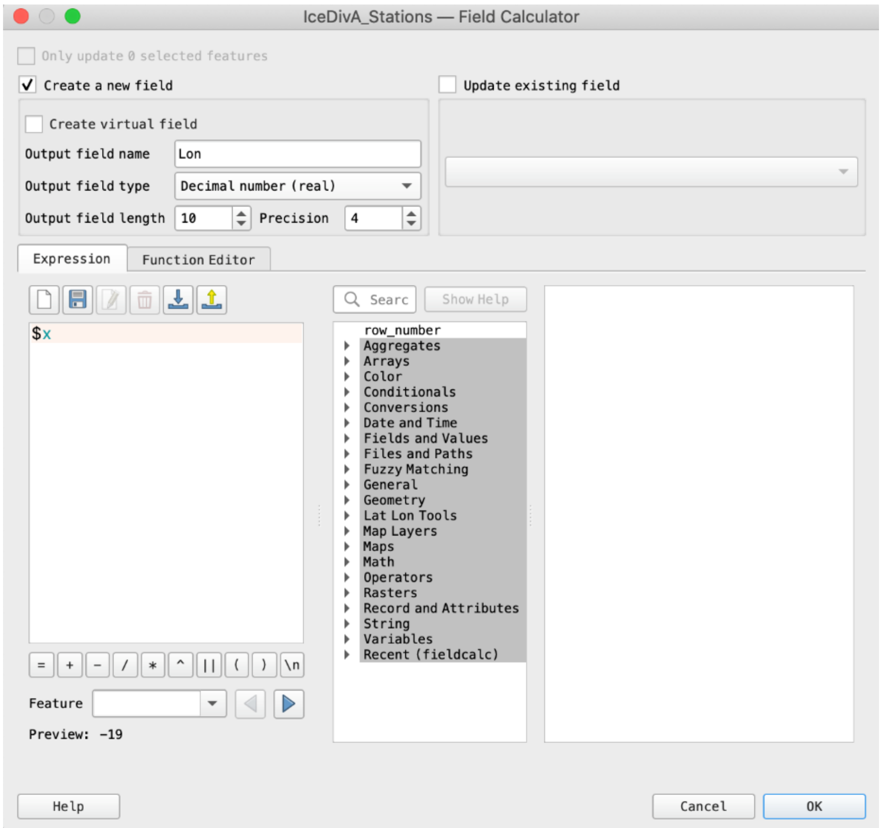


12: Toggle editing button

Add Coordinates from Points in Vector layer

Each vector layer has an **attribute table** that holds information about all features contained within that layer. This table can be populated with new fields and values for any kind of information. Here is how to add coordinates to the attribute table for each point of a point shape file:

- Open the attribute table by right-clicking on the layer
- Toggle editing
- Make sure to either select or deselect all lines
- Open *'field calculator'* by pressing the calculator icon or cmd/Crtl+I
- On the left side of the field calculator window, tick *'Create a new field'* -> Give it a reasonable name (e.g. Longitude/Latitude) -> chose field type '*Decimal*' -> set the '*output field length*' to 10 with precision 4 (= significant numbers, 4 is enough for bridge file)
- In the expression field, type '*$x*' for longitude or '*$y*' for latitude and hit *'OK'*
- A new column should show up with Lons and/or Lats
- Deselect all lines/fields (otherwise your entries will vanish for some reason) and click the little pencil icon for untoggling editing; answer '*Save*' when asked



13: Get coordinates using expression

Add Names and Dates to points in Vector layer

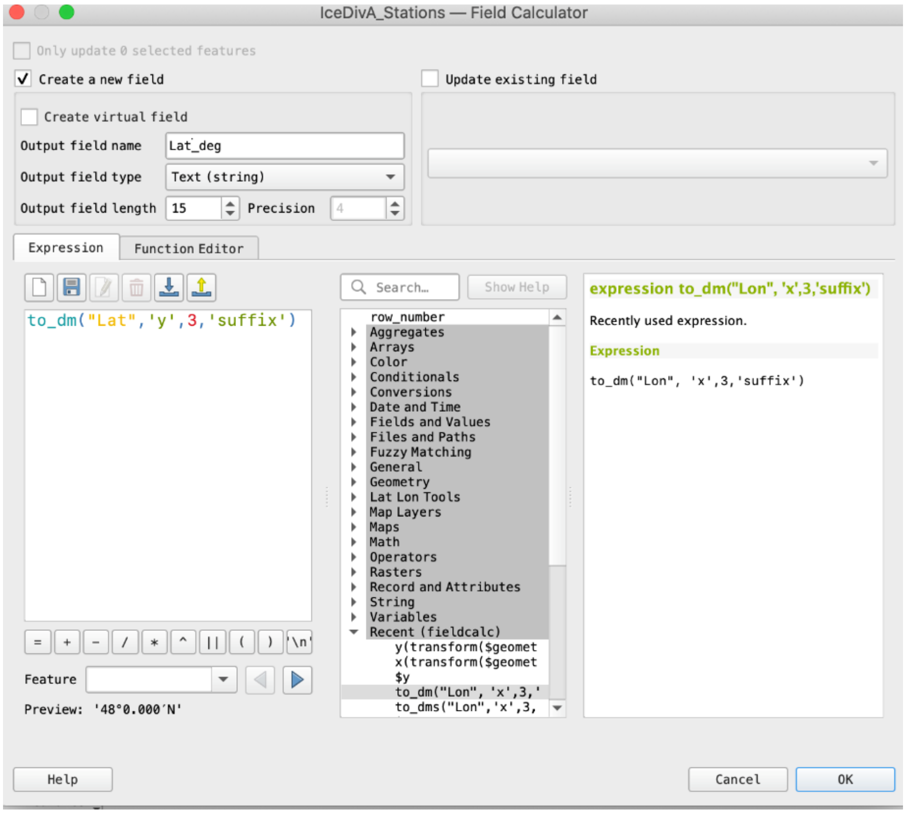
Similar to the procedure above, you can add columns with text or date fields, to describe or comment your sample locations:

- Follow the first 3 steps from the Add Coordinates from Points in Vector layer section
- Open '*New Field*' by pressing the icon or use Ctrl+W
- Choose a name
- Select '*Text (string)*' or '*Date*' from the '*Type*' – drop-down menu
- Click '*OK*'
- You can now enter comments or dates in the new column/s

Coordinate Conversion

Sometimes we need coordinates in a different format. Following a similar approach as before, we can easily do coordinate conversion between different formats:

- In the attribute table, toggle editing mode, select or deselect all lines and open '*field calculator*'
- On the left side of the field calculator window, tick '*Create a new field*' -> Give it a reasonable name (Lon_deg or Lat_deg, respectively) -> chose '*field type text*' -> set the '*output field length*' to 15
- In the expression field, type *to_dm("Lat" ,'y','3','suffix')* where in "" you type the name of the column which you would like to convert (i.e. when your column containing latitude coordinates is called Lat, then type "Lat")
- A new column should turn up with Lons and/or Lats in degree and decimal minutes
- Deselect all lines/fields (otherwise your entries will vanish for some reason) and click the little pencil icon for untoggling editing; answer '*Save*' when asked

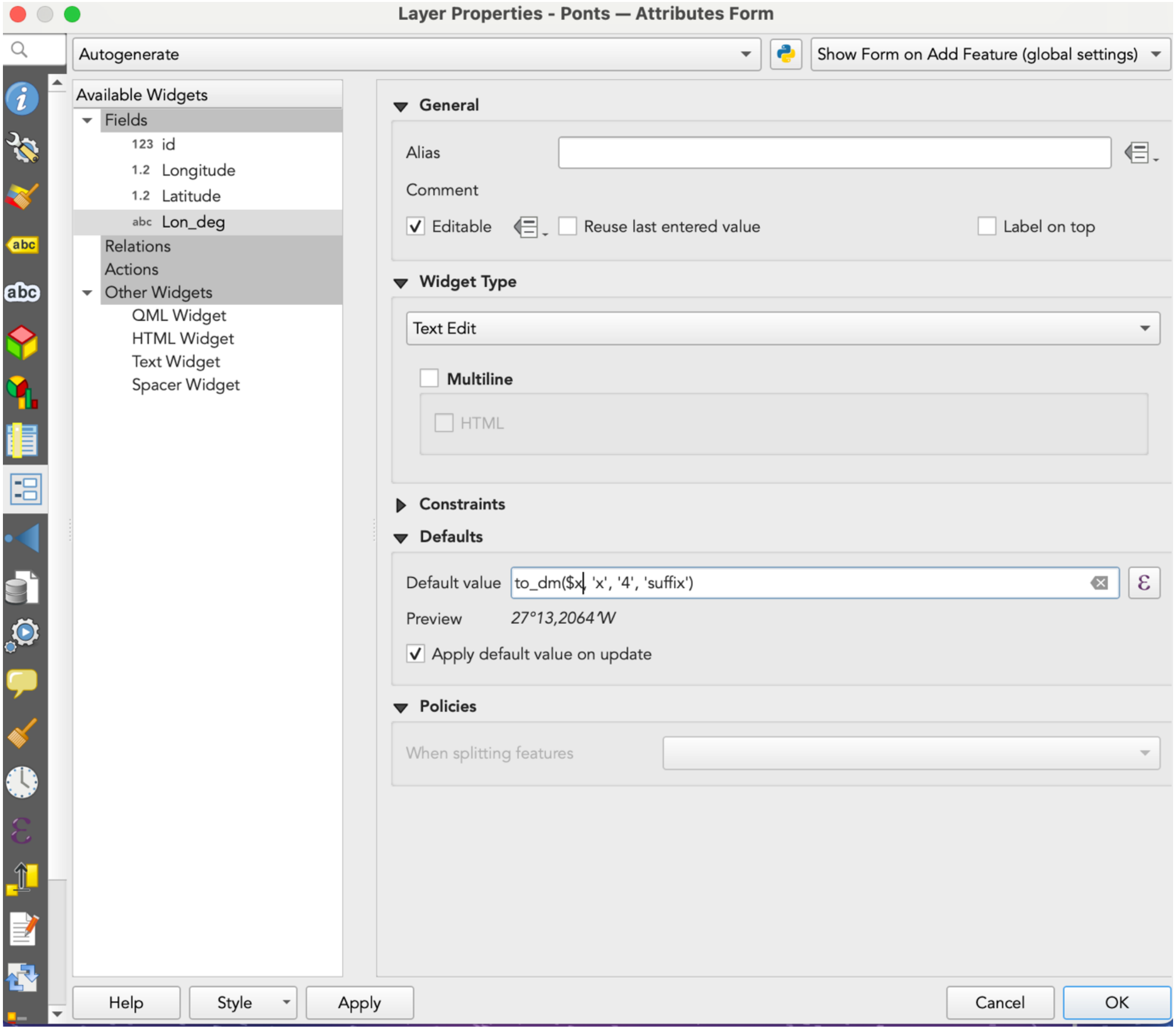


14: Convert Coordinates using expression

Automatically populate fields with attributes

You can set default values for the attribute field that are filled when new features are added to a vector layer. The *default-default* is '*NULL*', but you can change this to anything. E.g. if you add a point and would like the coordinates to be written to the layer's attribute table automatically, you can do so:

- Go to the layer properties by double clicking on the layer and find the '*Attributes Form*' tab
- Under '*Available Widgets*', find '*Fields*' and click on the field you want to set the defaults (if the field doesn't exist yet, create it in the attribute table)
- Under '*Defaults*', enter the expression you want to set as default. E.g. '*to_dm($y, 'y', '4', 'suffix')*', if you want to write the coordinates in degree, minutes



15: Set default field values

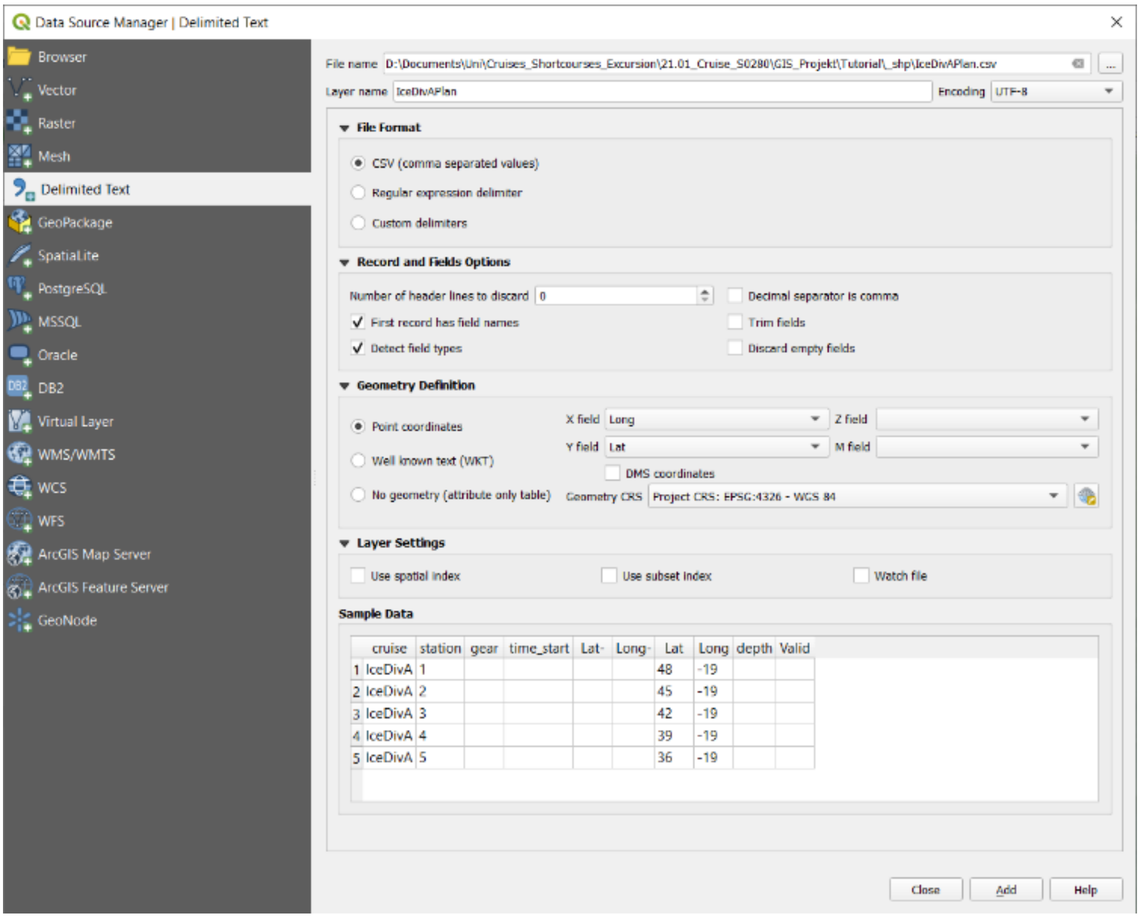
Working with delimited Text Data

Import existing files

Delimited text layers can be anything, from lists with samples to survey coordinates. To import them to QGIS, they need to contain coordinates somewhere and they should be formatted uniformly – meaning that each column is separated by the same symbol for each line, the coordinates are in uniform CRS etc. QGIS has a very handy import tool which is described in the following:

- At the top panel, go to '*Layer*' -> '*Add Layer*' and select '*Add delimited text layer*'
- In the new windows, navigate to your file by pressing the "…" button
- If needed, under '*File Format*', select the correct separator (e.g. ';' or 'tab' or so)
- If you have unnecessary header lines (e.g. for CTD files), then you can skip them in the nect panel under '*Number of header lines to discard*'
- If you want QGIS to take over the field (i.e. column) names, you can do so by checking '*First record has field names*'

- You should now see a reasonable preview o your file in the lower panel wih each field containing one column and its values
- Under '*Geometry Definition*', select the correct fields for longitude and latitude (and optional value):
  x-Field: Longitude
  y-Field: Latitude
  z-Field: Value (optional)
- For unprojected geographic coordinates, select WGS84 in the Geometry CRS dropdown menu
- Click 'Add' and 'Close'
- Troubleshooting: If *'Add'* button is greyed out, probably there is something wrong with the geometry settings

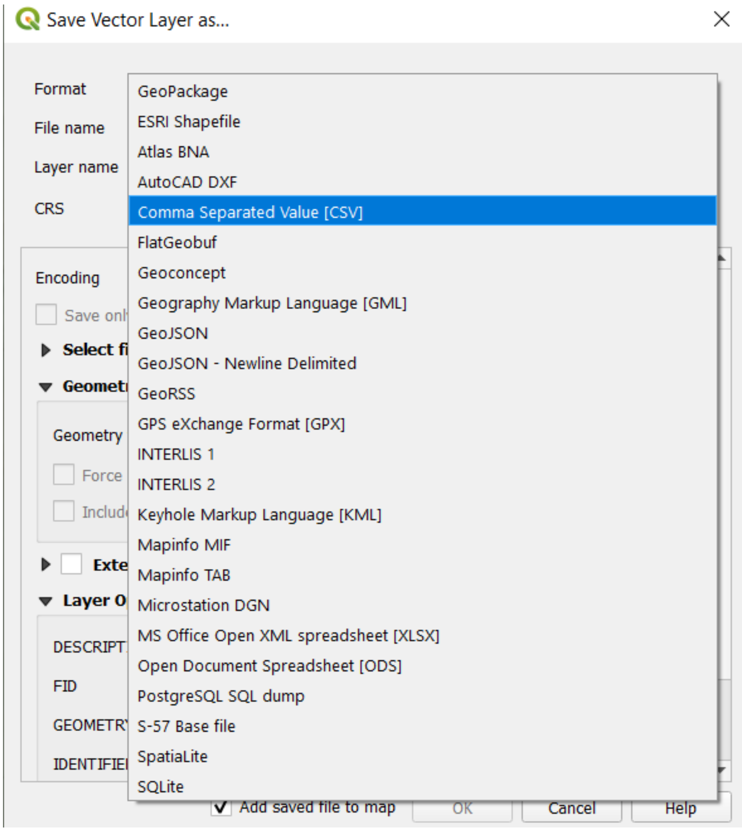


16: Import delimited text file dialogue

Export delimited text as vector and vice versa

With delimited text files, there is limited options concerning styling, labelling etc. compared to vector data. Hence they sometimes need to be converted to vector format such like shape files or similar (e.g. geopackage (.gpck)). It is very simple:

- Right-click the vector file you want to export
- Select 'Export' -> 'Save features as…'
- Depending what you want export to what format, either select '*Comma Separated Value (CSV)*' as format, '*GeoPackage*' or '*ESRI Shapefile*' or anything else
- Navigate to the output folder frist(!) and then enter a reasonable file name
- Click '*OK*'



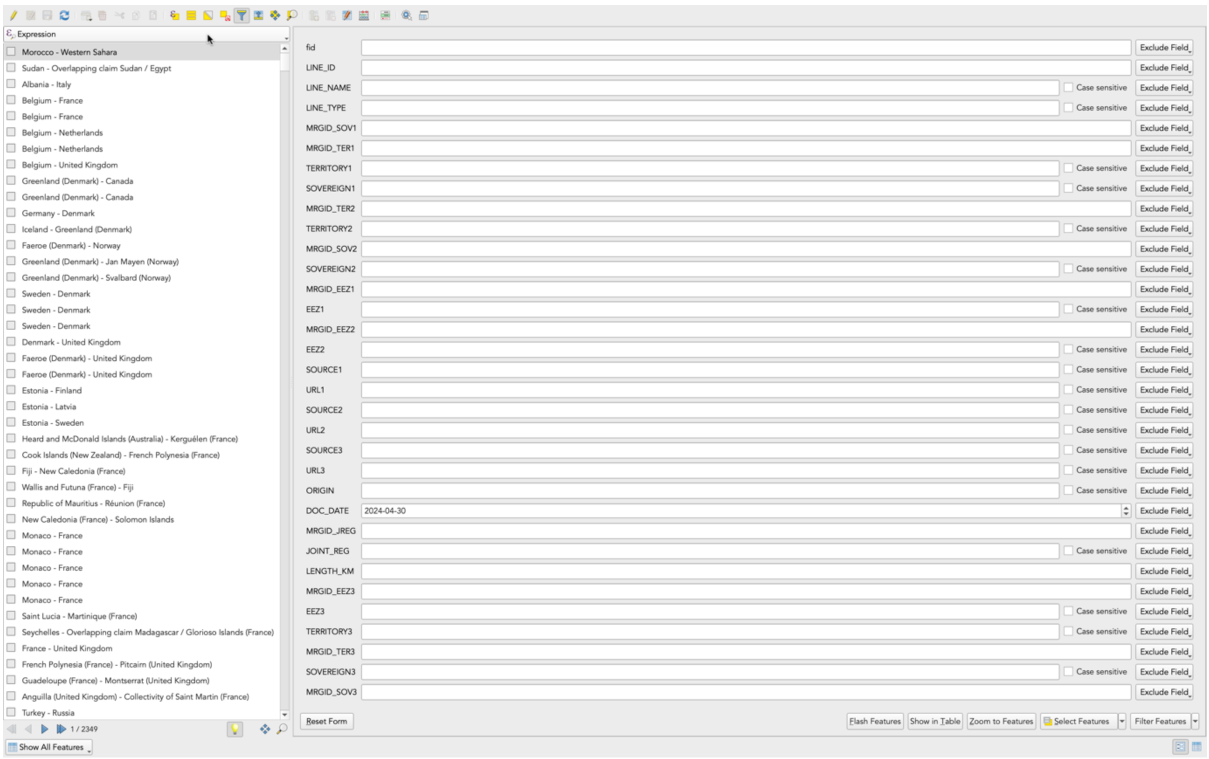
17: Export as... dialogue

Feature Selection/Filtering

Filtering is a crucial and incredibly helpful thing – especially if you have messy or non-uniform data. There are multiple options to filter, the most straightforward one is via a layer's attribute table. The following will be based on the example of the global EEZ layer taken from [marineregions]:

- Open the attribute table of a vector layer (either right-click the layer or click the '*table*' icon in the icon bar)

- In the upper panel of the attribute table, click the 'Select/f*ilter features using form'* icon (or Ctrl/Cmd + f) and you should see that the view changed
- In the respective field, enter the attribute value that you would like to filter by. There will be suggestions according to existing attributes
- Next to each field there is a box that let's you select what to do with this field and by default says '*Exclude field*'. It changes automatically to an appropriate option once you enter an attribute value.
- **Example**: In the EEZ layer in the field '*LINE_TYPE*' type '*200 NM*' (you should see '200 NM' appearing below). In the dropdown menu next to it should have switched to '*contains*' – translated, this means you will filter all features that contain '*200 NM*' in their '*LINE_TYPE*' attribute field. Click '*Select Features*' and you should see them highlighted.
- You can also select features by multiple attribute values by chaining selections: Click the arrow next to '*Select Features*' and add/remove additional attribute values.
- **Example:** Now enter '*Unsettled (maritime)*' in the '*LINE_TYPE*' field and press '*Add to Current Selection*'. You should now see all features with '*200 NM*' and '*Unsettled (maritime)*' highlighted. Spoiler: This covers almost all the 200nm Zones.

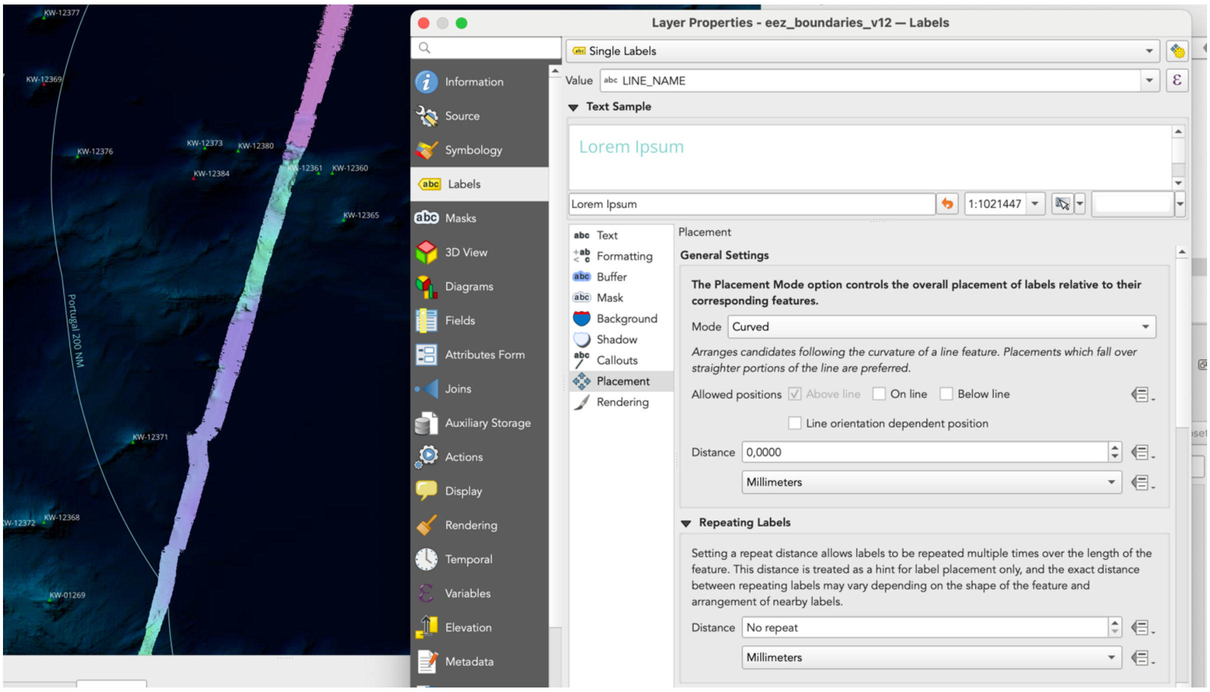


18: Filter features using form

Label Data

Labelling data can help adding crucial information to a map – but it can also quickly overload a design. Try to avoid unnecessary labelling. The procedure described here works for vector and delimited text and uses fields from the layer's attribute table for automatic labelling. There are very sophisticated methods for labelling, we'll stick to the basic, most used one here:

- Right click on the layer you want to label to open its '*Properties*'
- Under '*Label*, select '*Single Labels*'
- For '*Value*', select the field from the attribute table that contains the labels
- Chose colour, font and style in the '*Text*' and '*Formatting*' fields
- You can also draw a buffer (in the '*Buffer*' field) which mostly makes the labels more visible
- If you have curved lines like e.g. contours, it can make sense to also curve the labels. You can do so in the '*Placement*' field with '*Mode*' set to '*Curved*'
- If you only want to display labels at a certain scale, adjustments can be done in the '*Rendering*' field
- There are many ways how to style labels, there's also the option of smart rule-base labelling – check them out!



19: Labelling dialogue - Mode 'Curved'

Clip Features

Clipping can be very useful not only to reduce file size but also to concentrate on the main focus and my other reasons. Both vector and raster data are clippable and different clipping option can used.

Clip Raster/Vector file from mask layer/extent

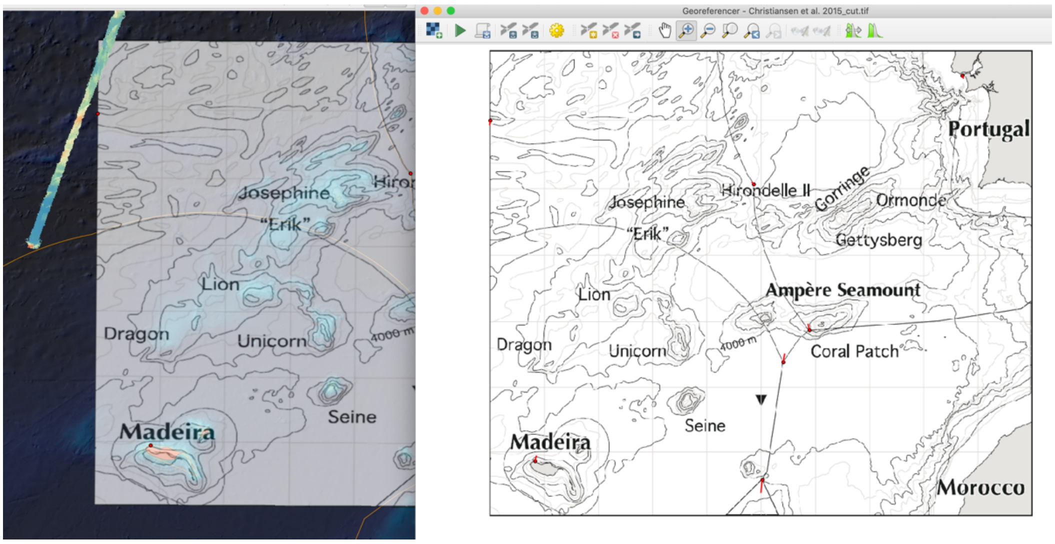
- In the toolbox, under raster/vector, respectively, find the '*Clip by mask layer*'/'*Clip by extent*' tool. You can use the proprietary tool or the GDAL.
- For '*Clipping by mask layer*': Select the layer you want to clip as '*input layer*' and the mask (the regions you want to cut off) as '*overlay layer*'

- For '*Clipping by Extent*': Select the layer want to clip as '*input layer*' and click the "…" button next to 'Extent' to select the layer, which you want to take the extent from
- This works for both raster and vector data

Georeferencing

Georeferencing is referred to as assigning coordinates to an image without CRS. This can be just any normal image. E.g. if you want to add a screenshot of a map to your project, you could use georeferencing to place it to its location. You can also georeferenced vector data, but we'll stick to raster for now. The basic procedure is to add Ground Control Points (GCP) to match features from the image to the real map:

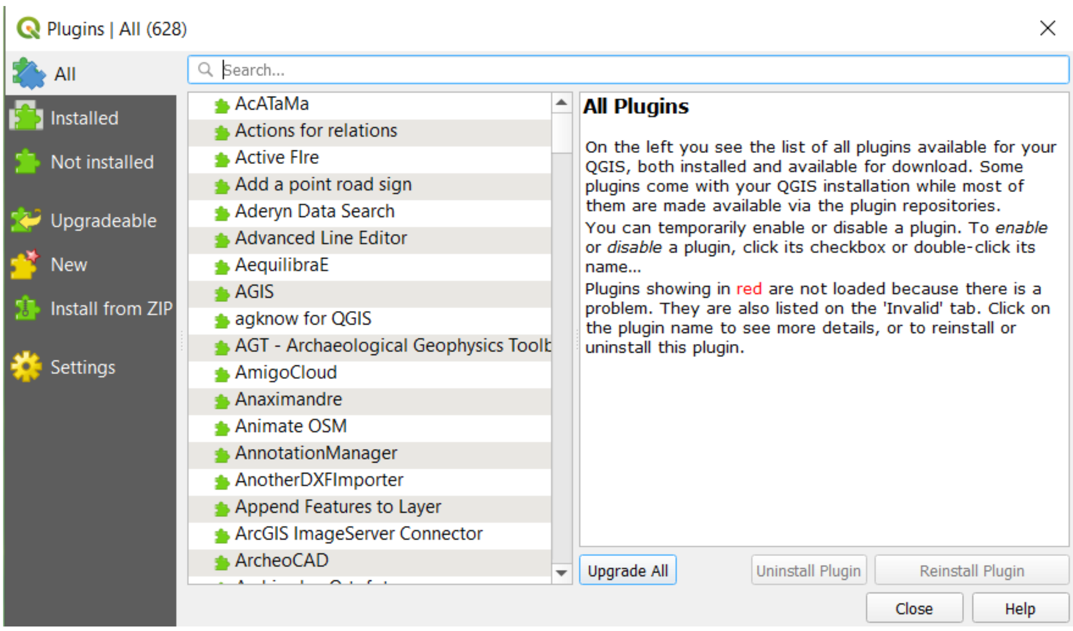
- In the menu bar, under '*Layer*' select '*Georeferencer...*' and click the '*open raster*' button
- **Remember**: If the Georeferencer tool is not visible, activate it in the '*Installed*' section of the 'Plugins' dialogue
- In the new window, import the image you want to georeferenced
- Then click the 'Add Point' button which enables you to enter GCPs
- On the image, pick a point witch is easy to recognise, such as prominent features, sea- or landmarks. Find the exact same location on the map and click on the spot
- In the '*Enter coordinates*' dialogue, either select 'Add from canvas' which automatically takes over the coordinates from the clicked spot on the map or type the coordinates manually
- Repeat this several times – the more points and the further apart from each other, the better will be the result. You should at least use four GCPs, on at each image corner.
- Once finished, click the '*Setting*' wheel icon:
- Select 'Linear' as 'Transformation Type'
- 'Nearest Neighbour' or 'Thin Line' as 'Resampling Method'
- Chose the target CRS
- Hit the '*Play*' button
- You should now be able to see the image on your map – if it is distorted, go back and modify the GCPs
- To get rid of the black frame, open the new layer's properties:
- Under 'Transparency' and 'Transparency Pixel List' click on 'Add values from display' (pointer with '?')
- Click on the black frame (or any unwanted colour) on the canvas



20: Georeference an image

Working with Plugins

QGIS' processing toolbox is great, but even with all its tools, it is sometimes not enough. Luckily, QGIS is open to any development and has the possibility to use plugins additional to the toolbox. (Hint: If you have a cool idea, you can even write plugins yourself.). You can install any plugins via the top panel, under '*Plugins*' go to '*Manage and Install Plugins*' either using a pre-downloaded .zip file or directly from the catalogue. If you can't see a plugin although you have installed it, activate it by checking the box next to the respective plugin in the '*Installed*' list.

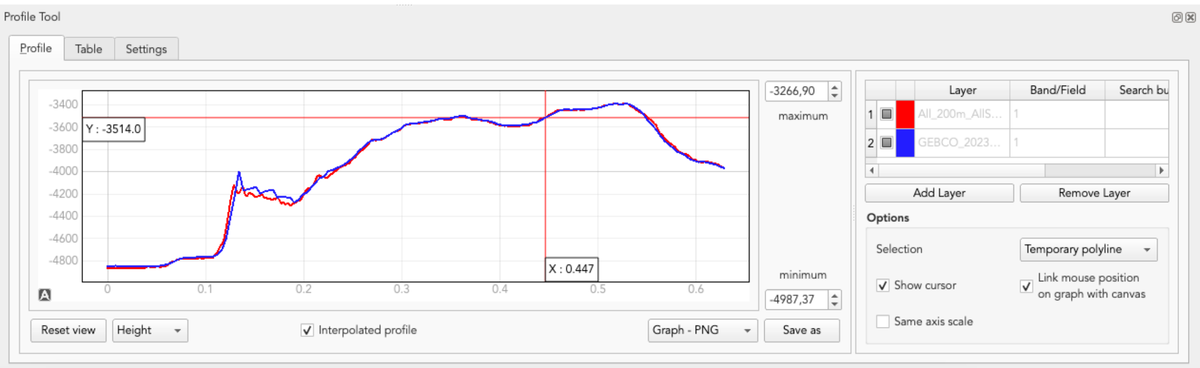


21: Plugin dialogue

In the following we'll introduce some of the useful plugins.

Profile line tool

- To start working with the tool, click the '*Profile*' symbol
- Select the layer that you want to take a profile from,(e.g. GEBCO or any DEM) and click '*Add Layer*'
- You can also select multiple layers for comparison
- Now click a start and an end point of the profile and you should be able to see a profile in the lower window
- You can also export the created line by clicking on '*Save as*'



22: Profile Tool

PosiView

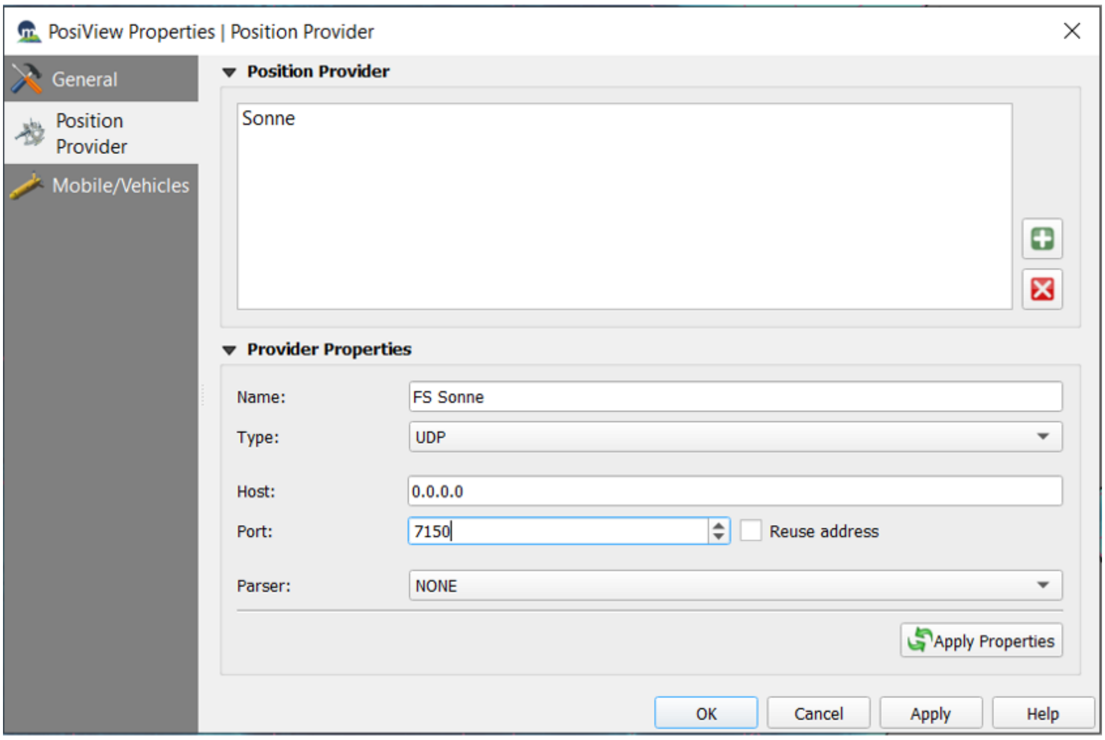
PosiView is a very neat tool to visualise real-time position of e.g. a ship and e.g. an OFOS/ROV directly on the map canvas. It works best with an ethernet connection via UDP protocol.

- To open PosiView, click the PosiView icon 
- To set things up, click the toolbox icon '*Configure PosiView*' and go to the '*Position Provider*' tab
- The '*Position Provider*' is the device on the platform that delivers position data, mostly as nmea strings. If you want to set up PosiView to indicate the vessel position, name it after the vessel , e.g. 'R/V SONNE'
- Under '*Provider Properties*', enter the correct information – if you don't know what to enter here, ask your WTD
- For R/V SONNE, this is:
  - *Type*: UDP
  - *Host*: 0.0.0.0
  - *Port*: 7150
  - *Parser*: None
- Press '*Apply*'
- Now go to the '*Mobile/Vehicles*' tab. Here are several things to add:
  - With the '+' sign create a new mobile and name it after your vessel

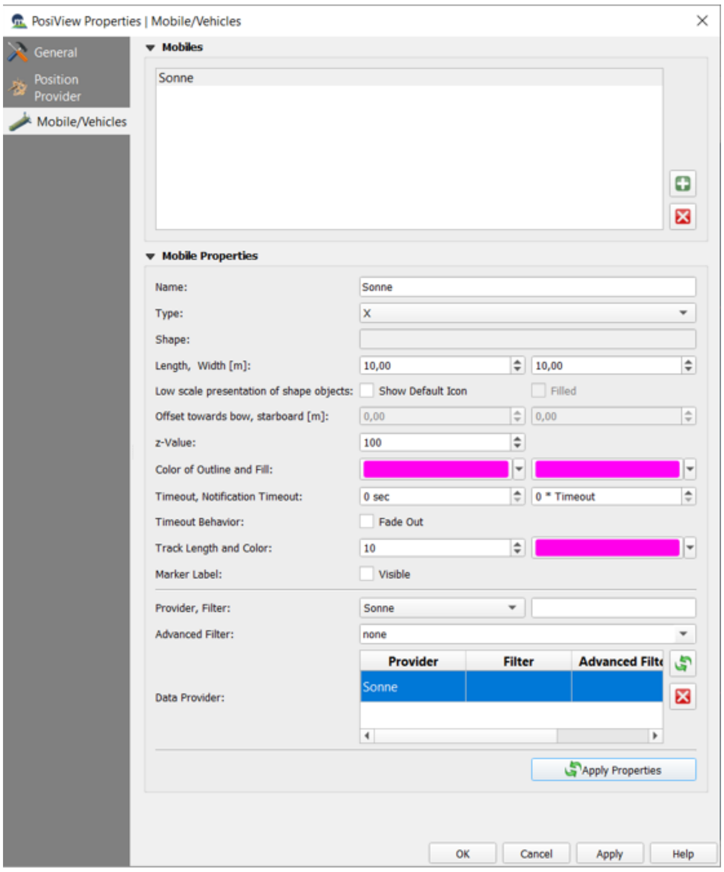
- Choose which shape the tracking point should have (box, cross, circle etc) under '*Type*' and set length, colour and forward track (play around a little with the settings)
- You can also set the label to '*visible*'

- Under '*Provider Filter*', select the vessel you've created from the dropdown menu
- The '*Data provider*' needs to be the same as in the '*Provider Filter*'. To do so, click the button with the green arrows on the right
- Click '*Apply Properties*', '*Apply*' on the bottom page and close the window
- Click the play symbol next to the '*PosiView*' icon in the upper panel
- You should be able to see R/V SONNE's position on the map now
- To add vehicle such as OFOS or ROV, repeat the above procedure setting the correct protocols and ports and using the correct position provider. If successful, you should see two position points on the map.

Disclaimer: Unfortunately PosiView does not always work the way we hope. So if it doesn't work it is not necessarily your fault. Just try again, play around with possibly some timeout settings in the 'Mobile/Vehicles' Header discussed above and see if it helps.



23: PosiView Position Provider



24: PosiView Vehicles

Create A Map Layout

Creating nice maps can be a challenge and it's not for nothing that there are entire study programs dealing with map designs. You can lose yourself in details here and, that said, the following guide is not meant to create award winning map designs, it shall rather help gain an overview of how to make a basic map (like e.g. Fig.). If you're interested in map design, [this guide by mapbox] maybe a good start.

25: Basic Map

Create a Map Layout

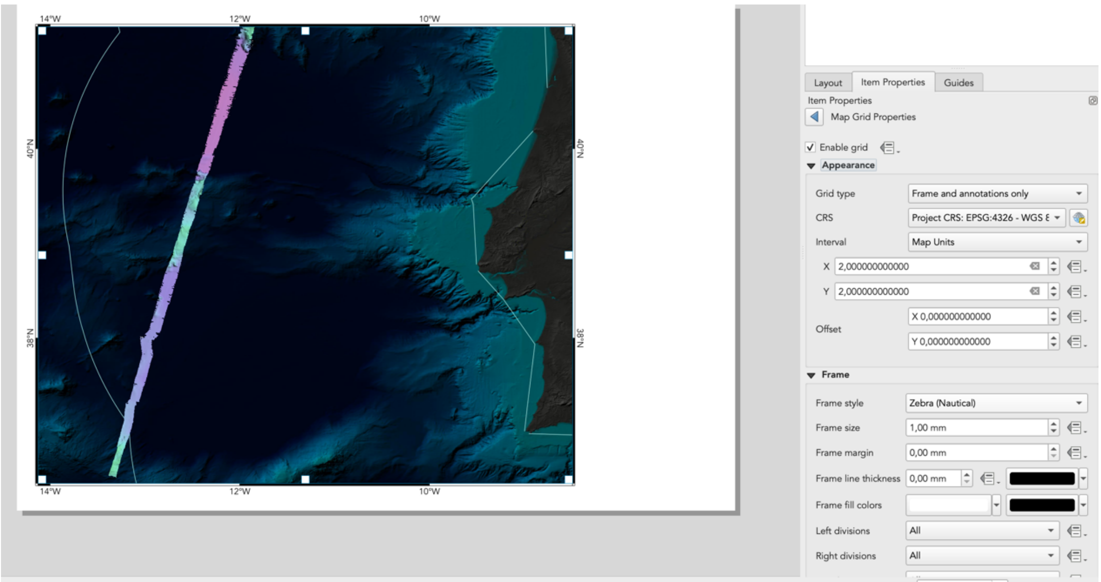
A proper map contains a coordinate frame, scale bar, a legend, information about projection and reference coordinate system, maybe authors and date of creation and of course the map itself. Here is how to create a printable map:

- In the menu bar, under '*Project*' click '*New Print Layout..*' and give it a name
- To add a map, under '*Add item*', select '*Add map*' and draw a rectangle on the canvas
- On the right panel, find the '*Item Properties*'. You can change scale, projection, styles etc. here – for now make sure, that the '*CRS*' is the same as the CRS of your QGIS project, e.g. '*EPSG3395 – World Mercator*'.
- To change zoom and extent manually, click the move icon ( ) and grad and drop or zoom directly in the layout map

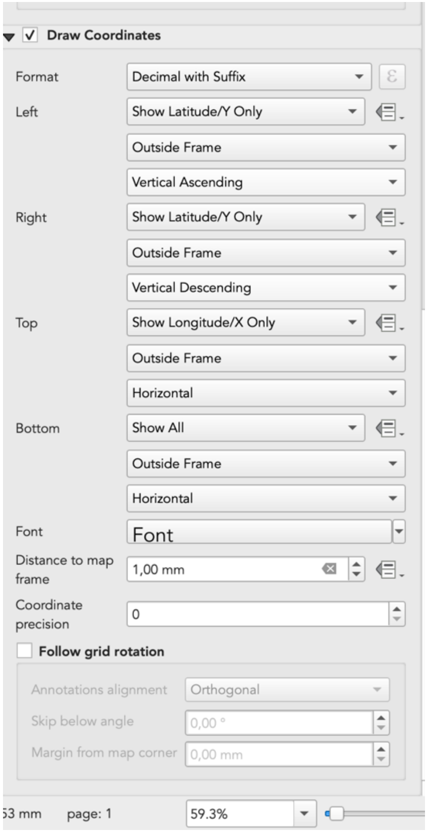
Add a Coordinate Frame

The following will describe how to add longitude and latitude, hence unprojected, geographic coordinates. You can of course add any CRS, but this guide will stick to the basic WGS84.

- In the '*Item Properties*' of the '*Map1*' layer on the right panel, scroll down until you find the '*Grids*' section
- Add a new grid by pressing '+' button and click '*Modify Grid*'
- Under '*Grid type*', chose your favourite style
- Set '*CRS*' to '*EPSG4326 - WGS84*' to get the coordinates in latitude and longitude and set '*Interval*' to '*map units*' (i.e. degree)
- For '*X*' and '*Y*', respectively, select a reasonable tick/annotation interval in map units (e.g. 10 of you would like to have ticks and annotations every 10 degrees)
- Select a frame style and you should see a frame around the map
- **Note**: If the coordinates or the frame look weird, there is something wrong with the projection you've chosen
- Now to add coordinates, scroll down and check '*Draw Coordinates*' and select annotation style for each edge in the drop-down menus



26: Add a grid



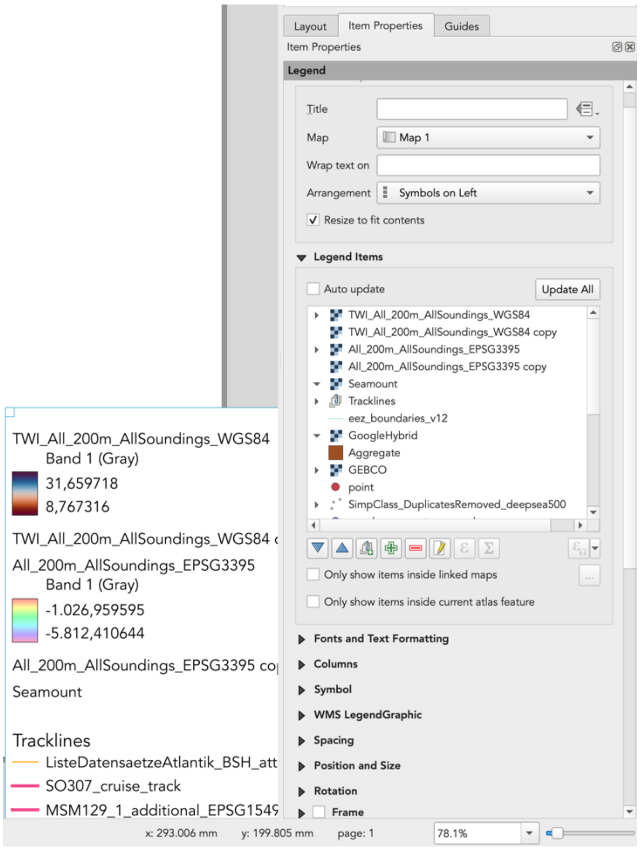
27: Add coordinates

Add Scale Bar

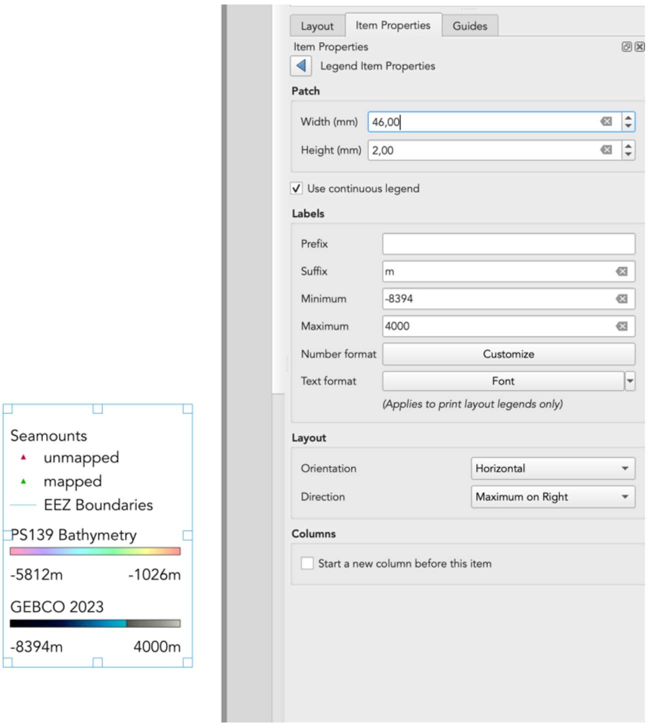
- Under 'Add Item', select 'Add Scale Bar'
- Draw a rectangle where you want to have the scale bar
- You can change appearance and other properties in the '*Item Properties*' tab

Add a Legend

- Like before, under '*Add Item*', select '*Add Legend*'
- Draw a rectangle where you want to have the legend
- The default setting is '*Auto update*', meaning that the legend automatically updates does what happens in the main map canvas (QGIS project); uncheck for manual editing
- With the '+' and '-' buttons, you can add or delete legend entries
- Double-clicking on an entry lets you change the entry's properties
- There are a lot of settings here like different fonts, backgrounds, frames, annotation etc. You can also change the depth colour bars. Play around with it to make your legend look fancy!



28: Map legend – before editing



29: Change colour bars in map legend

More Info

QGIS map layout is a very powerful tool that lets you basically do anything you like – from adding pre-set shapes like rectangles and circles, labels, north arrows, more maps to create inlays and much more. You can also add custom images. In the '*Item Properties*', you can always change styles and properties and you can also **save styles** to your favourites to re-apply them to other layouts. Try it out yourself to find the best way to go. If you like a map, you can save it as a **template** for next maps you want to create, under '*Layout*' and '*Save as Template*'. You can also export map layouts to different file formats e.g. pdf, jpeg or geotiff. The latter two have the option to create a **world file** for a georeferenced map.

The Long and Odd Story of Coordinate Systems and Projections

Projections and coordinate systems can be a true pain if you're not familiar with it. The basic concept for CRS in QGIS is that each QGIS project is **assigned** a CRS or GCS. This can be WGS84 – unprojected GCS - or anything else like World Mercator or UTM (projected CRS). **Note**: This is for the **visualisation** of your map canvas only and doesn't have anything to do with the layers you add. **Assigning** a CRS in QGIS refers to visual aspects only. **Reprojecting** however changes geometry of a layer. The layer can come in different projections – you can add a layer in UTM projection to a QGIS project in WGS84 and everything will be in place. More information can be found here.

Select Projection for the QGIS Project

- In the main menu, under '*Project*' go to '*Properties*' and '*CRS*'
- Uncheck the first box '*No CRS …*' otherwise you won't have any reference coordinate system
- For most tasks, selecting '*WG84*' as coordinate system is fine. Note that WGS84 only is not a projection, just a coordinate system!
- For a projected map (i.e. when measuring distances, calculating areas etc.), select a projected CRS such as '*UTMXX*'
- You can switch between CRSs by clicking the world icon in the bottom right corner of the GIS project

Assign Projection for Single Layers

- Right-click on a layer and go to '*Select CRS*' and chose any of the proposed CRS
- This is especially relevant e.g. if you import a projected raster such as e.g. a bathymetry grid in UTM29. The **assigned** layer's CRS must be the same as the layer's **projection**. If you cannot see the layer where it should be, then either assign the correct CRS or **reproject** it to the CRS you want. **Remember**: Assigning is for visualisation only, reprojecting changes a layer's geometry.

- Try it out: Assign a different CRS than the layer's proprietary and you shouldn't be able to see the layer anymore

Reproject Single Layers

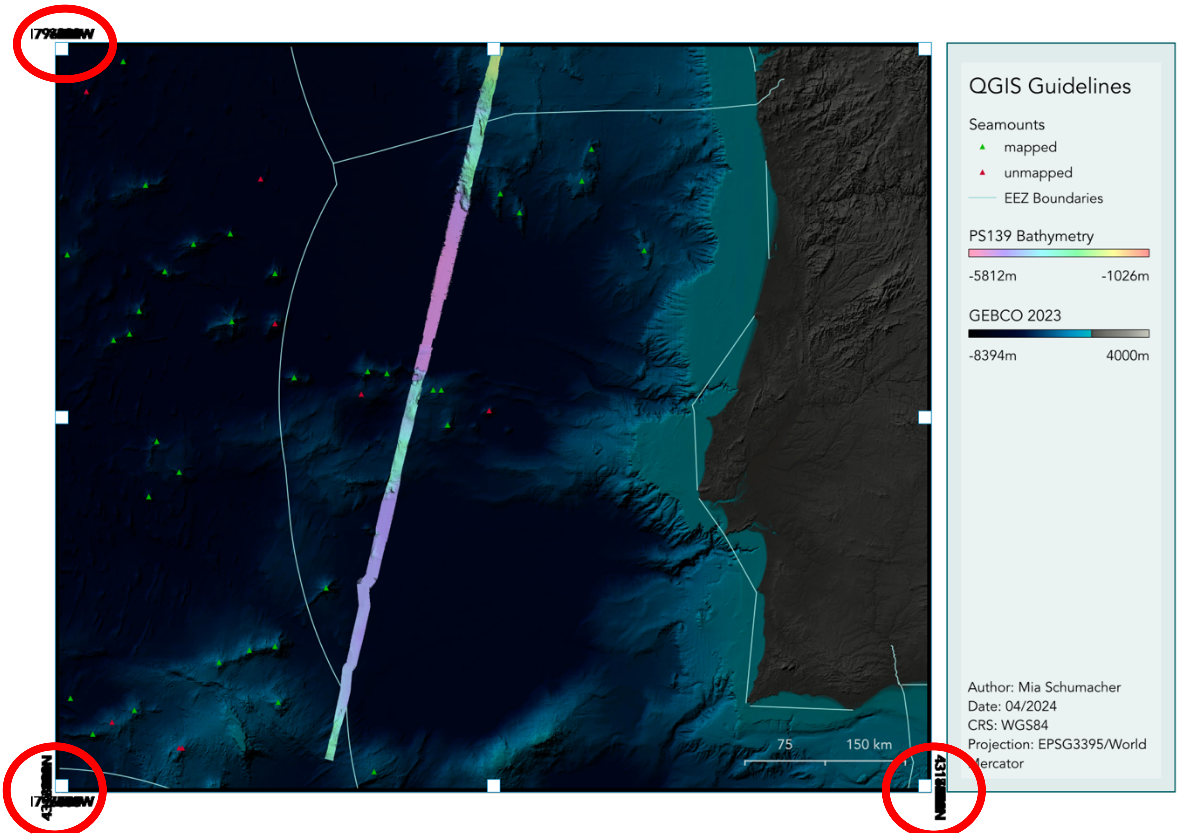
As mentioned before, reprojection changes a layer's geometry. This works for raster and vector data and is useful, if you e.g. need to project an unprojected layer to do distance calculations etc. Here is how:

- In the 'Processing toolbox', find 'GDAL/ Reproject (Warp)' (for raster) or 'Vector general/Reproject layer' (for vector)
- Select input file
- Define source (e.g. WGS84) (only GDAL) and target (e.g. UTM29) projection
- Hit '*Run*'

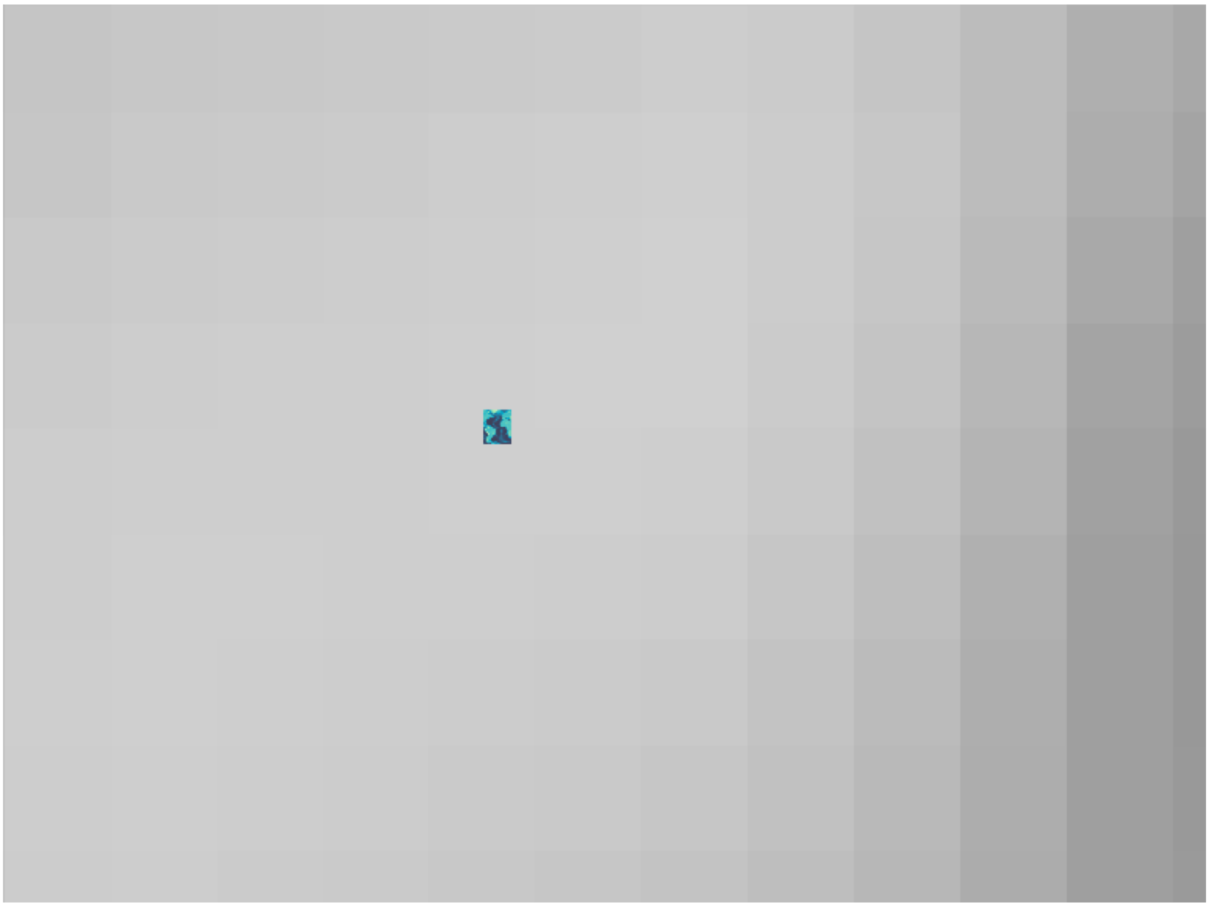
Select Projection in Map Layout and Map Frame Coordinates

The map layout should usually have the same coordinate system and projection as your project Remember: If you want longitudes and latitudes in degrees around your map frame, select '*WGS84*' in the grid properties.

Generally, if things start to look weird (e.g. one layer is in a complete non-realistic scale or location) this has most likely something to do with the projection. Also if the map frame annotations have strange intervals or no intervals at all, you messed up the projection (:. Go and check your project's properties, layer CRSs and map layout as well as grid CRSs! See below for typical examples of projection failures. And don't worry – we've all been there!



30: Coordinate notation weirdness



31: Scaling failure

Where to find Data

There are lots of data publicly available that can be downloaded and used as basemaps or data layers. The following list does not claim to be complete, but hopefully is a good start:

General

Pangaea: https://www.pangaea.de/
Seadatanet: https://cdi.seadatanet.org/search
SHOM (French): https://data.shom.fr/donnees/catalogue/
World Ocean Database: https://www.ncei.noaa.gov/access/world-ocean-database-select/dbsearch.html
Copernicus Marine Environment Monitoring Service (Global Ocean Satellite data): https://myocean.marine.copernicus.eu/data?view
ZENODO general prupose open-access repository: https://zenodo.org/
DAM Marine Data Platform: https://marine-data.de/?site=home
NOAA: https://www.ngdc.noaa.gov/ngdcinfo/onlineaccess.html
ODIS Catalogie (Belgian): https://catalogue.odis.org/
EEA Geospatial Data Catalogue/Map View: https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/map
Copernicus: https://browser.dataspace.copernicus.eu/?zoom=5&lat=50.16282&lng=20.78613&themeId=DEFAULT

-THEME&visualizationUrl=https%3A%2F%2Fsh.dataspace.copernicus.eu%2Fogc%2Fwms%2Fa91f72b5-f393-4320-bc0f-990129bd9e63&datasetId=S2_L2A_CDAS&demSource3D=%22MAPZEN%22&cloudCoverage=30&dateMode=SINGLE
ESA Earth Observation Catalogue: https://eocat.esa.int/sec/#data-services-area and https://fedeo-client.ceos.org/
Marine Geosience Data System: https://www.marine-geo.org/index.php

Geomorph

Hydrothermal Vents: https://vents-data.interridge.org/ventfields-osm-map
Sediment Thickness: https://ngdc.noaa.gov/mgg/sedthick/
Seamount vector dataset: https://doi.pangaea.de/10.1594/PANGAEA.757564
Sediment Trap data: http://usjgofs.whoi.edu/mzweb/data/Honjo/sed_traps.html
Undersea Feature names: https://www.ngdc.noaa.gov/gazetteer/

Bathymetry

GEBCO: https://www.gebco.net/data_and_products/gridded_bathymetry_data/
IHO/DCDB: https://maps.ngdc.noaa.gov/viewers/iho_dcdb/
NOAA: https://noaa.maps.arcgis.com/apps/mapviewer/index.html?layers=0441041574c544dc9b6b8a513cad5e95
EMODnet: https://portal.emodnet-bathymetry.eu/
GMRT: https://www.gmrt.org
SRTM15+V2: https://catalog.data.gov/dataset/shuttle-radar-topography-mission-srtm-version-2
Jamstec: http://www.godac.jamstec.go.jp

Biodiversity

Ocean Biodiversity Information System: https://obis.org/manual/access/
World Register of Marine Species: http://www.marinespecies.org/index.php
Ocean Biodiversity Information System Map: https://mapper.obis.org/
Bio-ORACLE (Marine data layers for ecological modelling): https://bio-oracle.org/
Quiet Ocean Project: https://iqoe.org/acoustic-data-portal
MBARI Mars sound snippets: https://freesound.org/people/MBARI_MARS/packs/19487/
Sediment types: http://instaar.colorado.edu/~jenkinsc/dbseabed/kml/
Deep Sea Sediment types: https://doi.pangaea.de/10.1594/PANGAEA.911692
Sediment map: https://portal.gplates.org/cesium/?view=seabed
AquaMap: https://www.aquamaps.org/search.php

Institute/Regional Databases

BSH: https://data.bsh.de/
Flemish Ministry of Mobility and Public Works, Agency for Maritime and Coastal Services, Coastal Division: https://bathy.agentschapmdk.be/spatialfusionviewer/mapViewer/map.action
Ireland: https://maps.marine.ie/infomarbathymetry/
https://experience.arcgis.com/experience/50f0522dceaa4582a808558c0cbe8bb0

Nordic Seas: https://dybdedata.kartverket.no/DybdedataInnsyn/
Norway MAREANO: https://www.mareano.no/en/maps-and-data
Ifremer:
https://sextant.ifremer.fr/eng/Data/Catalogue#/map?owscontext=https:%2F%2Fwww.ifremer.fr%2Fsextant_doc%2Fsextant%2Fcontexte%2Fbathymetrie_emodnet_2016.xml
Iceland: https://www.hafogvatn.is/en/research/seabed-mapping
Canadian Hydrographic Service Non-Navigational (NONNA): https://data.chs-shc.ca/map; How-To-Use: https://pacgis01.dfo-mpo.gc.ca/FGPPublic/NONNA_100/CHS_NONNA_Data_Portal_Guidance_Document_en.pdf
United Kongdom Hydrographic Office (UKHO):
https://datahub.admiralty.co.uk/portal/apps/webappviewer/index.html?id=1d001f91ed114a5996e953b5cdd62b06 and https://seabed.admiralty.co.uk/
IEO Spanish Repo: http://datos.ieo.es/geonetwork/srv/eng/catalog.search#/home
OSPAR Viewer: https://odims.ospar.org/
British Oceanographic Data Centre BODC:
https://www.bodc.ac.uk/data/bodc_database/nodb/search/
Meeresumweltdatenbank (MUDAB): https://geoportal.bafg.de/MUDABAnwendung/
Data from Observation Océanographique Villefranche sur mer: http://www.obs-vlfr.fr/cd_rom_dmtt/

Human Activities

Offshore Installations: https://www.ospar.org/work-areas/oic/installations
Global Fishing Watch: https://globalfishingwatch.org/map/
Marine Litter: https://litterbase.awi.de/interaction
Skytruth Flaring Map:
https://viirs.skytruth.org/apps/heatmap/flaringmap.html#zoom=6&lat=55.45365&lon=9.32216&offset=15&chunk=2012
Skytruth Oilspill Map: https://alerts.skytruth.org/issue/cerulean

Protection & Conservation

Protected Planet: https://www.protectedplanet.net/en
Natura 2000: https://natura2000.eea.europa.eu/
MPA- Viewer: https://mpatlas.org/zones/
Marine Ecoregions of the World (MEOW): https://www.worldwildlife.org/publications/marine-ecoregions-of-the-world-a-bioregionalization-of-coastal-and-shelf-areas
EUSeaMap: https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/
MPA- Viewer (also based on mpatlas): https://marine-conservation.org/high-seas-protection-portal/
Classify MPAs based on RBCS: https://www.classifympas.org/en/
Biodiversity Hopespots Viewer: https://mission-blue.org/hope-spots/
Key Biodiversity Areas (KNAs): https://www.keybiodiversityareas.org/kba-data
HELCOM Baltic: http://maps.helcom.fi/website/mapservice/

Marine Classifications

Ecosystem Types of Europe - Marine Habitats:
https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/aa791cf1-ead5-4364-b0c3-4c54dc83c7e4

Global Seafloor Feature Map (GSFM): https://www.bluehabitats.org/?page_id=9 Note: To download data, fill in this form: https://www.bluehabitats.org/?page_id=58
Emodet Seabed Habitats: https://www.emodnet-seabedhabitats.eu/access-data/download-data/?linkid=eusm2019_group

Model Builder

We will introduce a new concept called the **model builder**. The model builder lets you **chain several tools together** – e.g. if you need multiple DEMs to all go through the same processing pipeline, then using the model builder can be very helpful. You can build a pipeline such that the output of one algorithm goes straight into the next. You can also create layers from all processing steps if you like. We'll use the model builder to calculate Topographic Wetness Index (**TWI**) for a DEM as an example. **Important note here**: This is mainly an exercise to introduce the model builder and doesn't claim to give a perfect terrain analysis. It's adapted from here. If you use the tool presented in the following section, please do some further research on which parameters to set how.

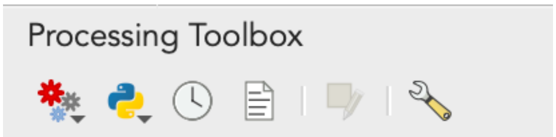
TWI is a measure to estimate where a fluid accumulates in a DEM and is based on slope and upstream contributing area:

$TWI = \ln(a/\tan(b))$ where a= upstream contributing area (m^2)
b = slope in radians

You will need **GRASS GIS** processing tools. If not yet implemented, activate the GRASS tools like described in the Calculate Derivatives section.

Here is the chain for calculating TWI with the model builder:

- In the top panel of the processing toolbox, find the '*gearwheel* 'icon and select '*Add new Model*'



32: Gear Wheel Icon to open Model Builder

- First of all, you'll need to define the input layer: On the left side under '*Inputs*', double-click '*Raster layer*' and enter a suitable description (e.g. '*DEM*')
- Now you need to fill gaps if any in your DEM: In the '*Algorithm*' section, find '*GDAL/Raster Analysis -> Fill Nodata*' and drag and drop to the centre canvas (or double-click)
- In the window that has opened, under '*Input Layer*' select '*Using Model Input*' and '*DEM*'. This automatically takes the output of the previous model step as input
- If you want, you can create an output layer here. To do so, scroll down and enter a reasonable output name (something like '*filled*' for example)

- If you have larger voids (data holes), play around with the other parameters, else leave them as they are
- Next, do the same for '*GDAL/Raster Analysis -> Slope'*. Make sure to select the previous '*filled*' layer as input here: If you want slope as an extra layer, name the output '*slope*'
- Now we need slope in radians and to do this, each cell needs to be multiplied by:

  *2*π/360° = π/180° ~ 0.0715*

  - Like before, use the gdal raster calculator to apply this conversion to the '*slope_nozero*' grid
  - Find the '*GDAL Raster Calculator*' in the '*Algorithm*' section and select '*slope*' as input. It will be referred to as '*A*' later on in the equation
  - Type '*1*' into the '*Band number*' field
  - In the 'Calculation in gdalnumeric…' field, type:

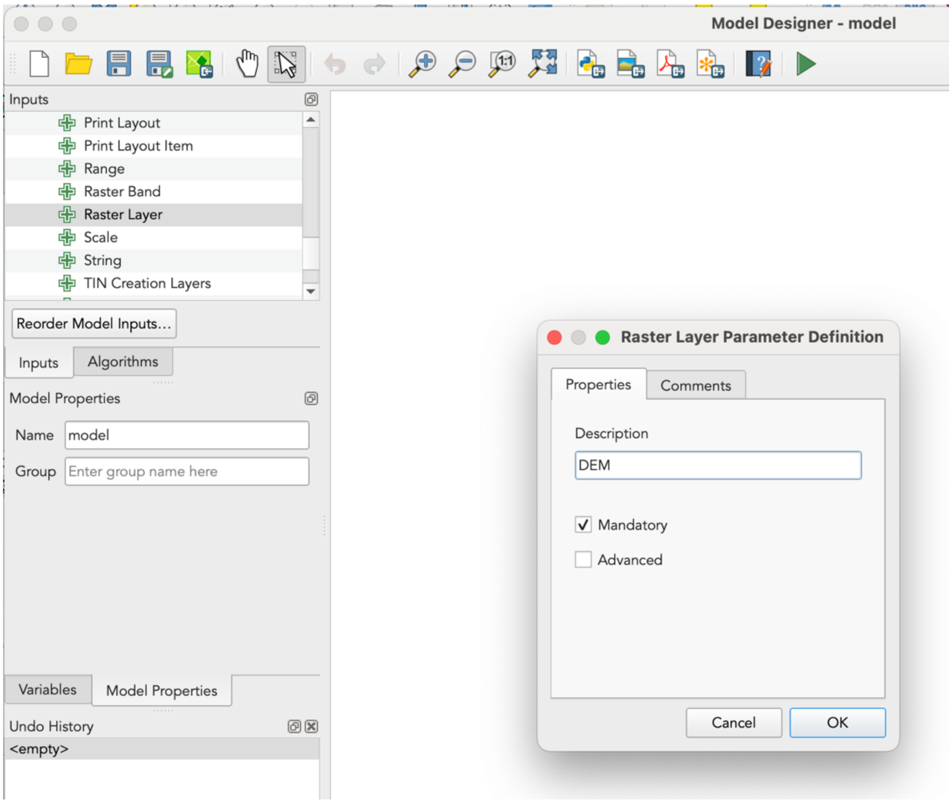
    *A * 0.0715*

    to assign convert degree to radians
  - Name the new output '*slope_rad*'

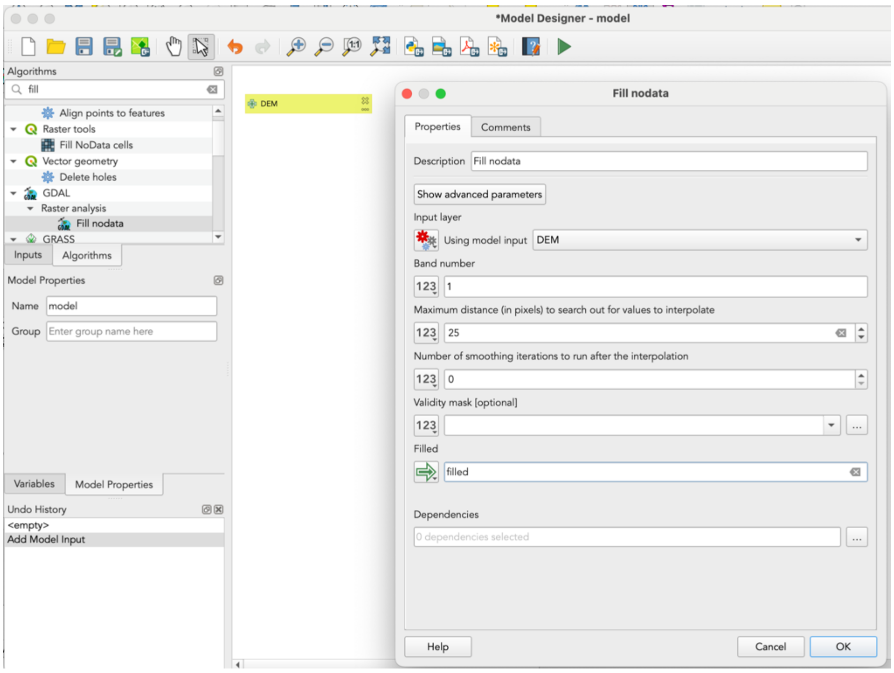
- Now calculate the flow accumulation based on the filled DEM (Fig.):
  - Find the '*GRASS/Raster -> r.watershed*' tool and select the '*filled*' layer as input
  - Set 'Max. size of exterior watershed …' to '500' (cells), check 'Enable Single Flow Direction (D8) …' and check 'Beautify flat areas'
  - Leave everything else default and, if wanted, name the output '*Number of drain …*' '*accumulation*'; we won't use the others, you're of course free to output them all
- Eventually, the TWI can now be computed:
  - Again, use the '*Raster calculator'* to apply the above-mentioned equation by using the generated layers and the cell size (here 100m). Note that 'A' refers to the drainage layer and 'B' to the slope in radians. We further need to add a small value to the slope to avoid zeroes in the denominator:

    *"log ((abs(A) * 100 * 100) / tan (B + 0.000001))"*

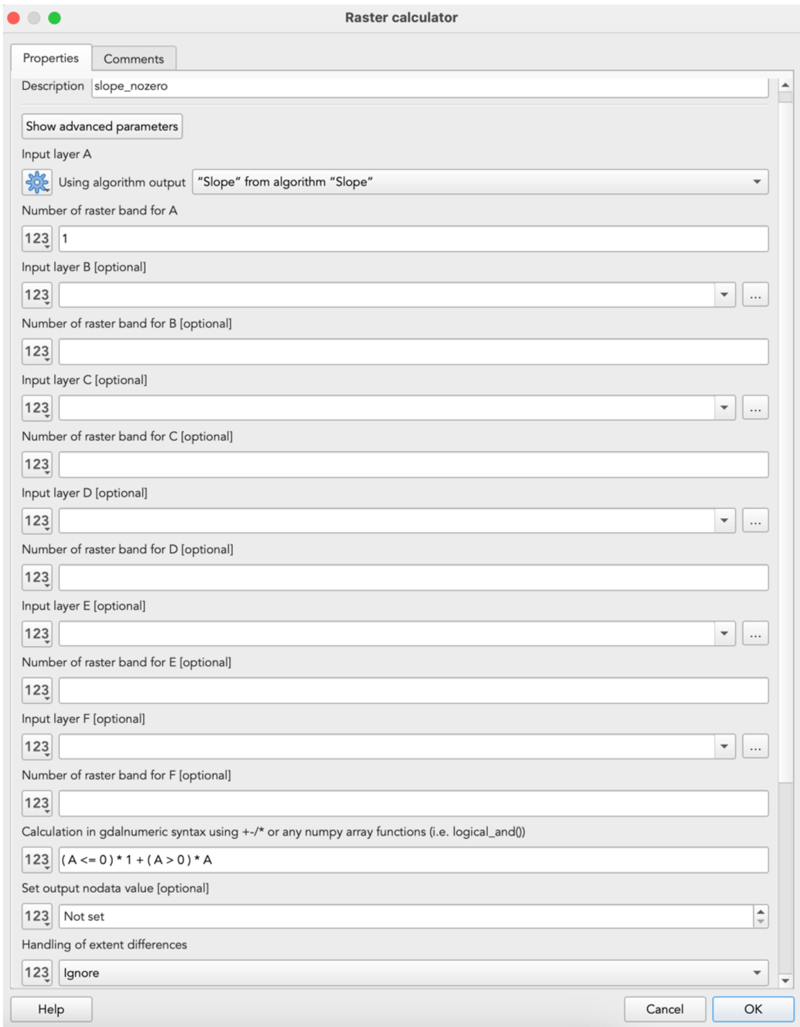
The model should now look somewhat like Fig.
. Now all you have to do is press the '*Play*' button in the upper right and select your input DEM. You can switch on and off the output layers if you don't need to see them all. The rest should run automatically! Another very cool thing about the model builder is that it let's you export the entire model as a **python script** which you can import to any python codebase. Just press the '*Export as Scrip Algorithm*' button in the upper panel of the model builder.



33: Define model input

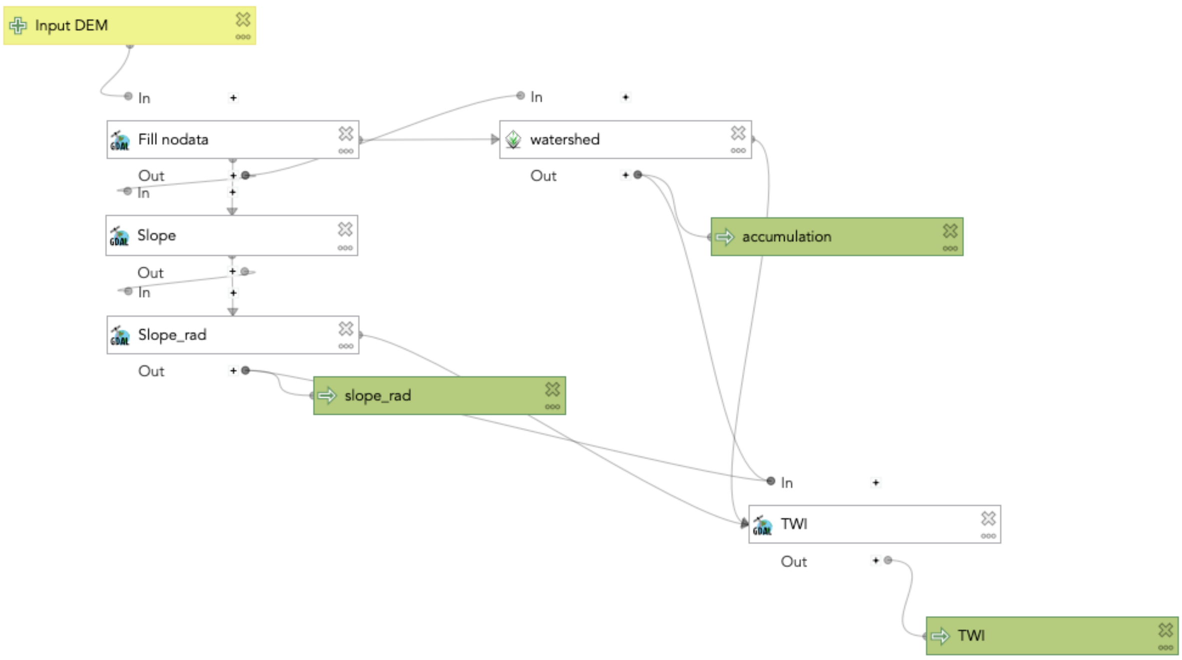


34: Model Builder add function



35: GDAL Raster Calculator inside model builder

36: GRASS watershed tool



37: Final Model

Web Services

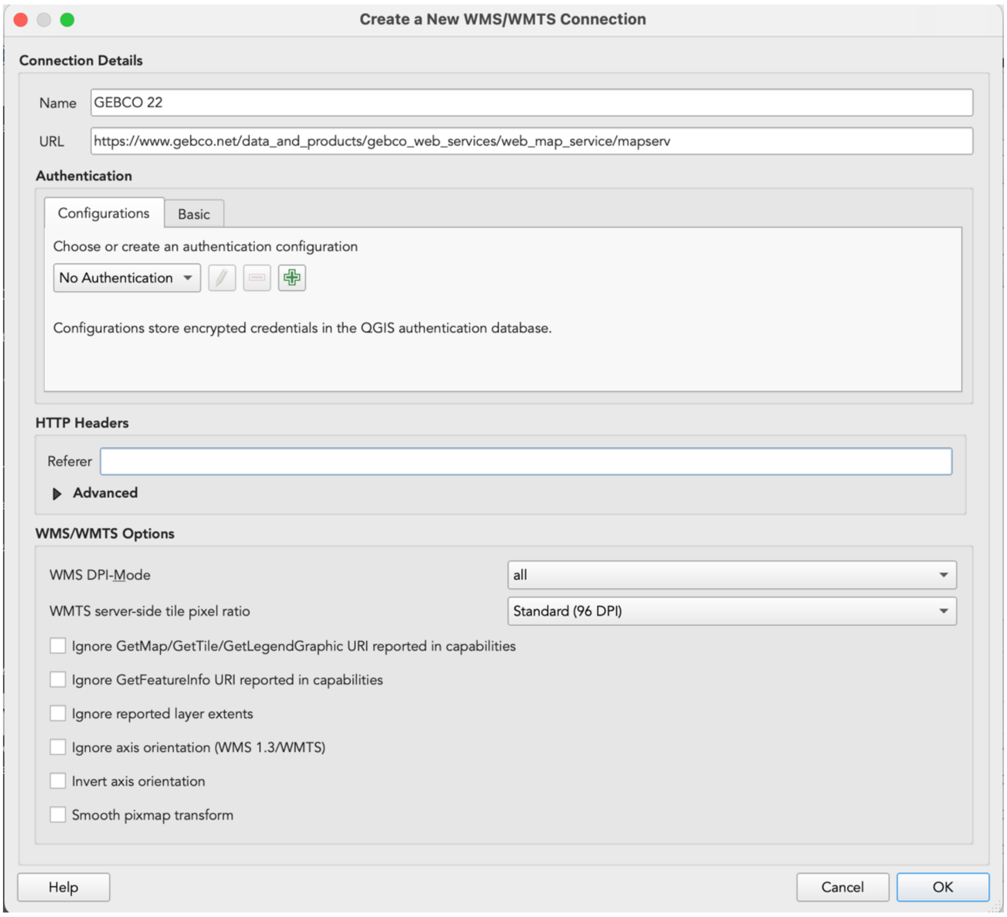
You can also load a broad variety of maps and datasets using **W**eb **M**apping **S**ervices (**WMS**). These services are standardised by the Open Geospatial Consortium (OGC) and are hosted on public servers accessible via specific protocols on the internet. [Here](#) is a good overview about the available protocols, below is a short intro:

- **WMS** (**W**eb **M**ap **S**ervice): Provides general GIS data and maps in image form via web along with basic options like zooming and panning
- **WMTS** (**W**eb **M**ap **T**ile **S**ervice): Provides pre-rendered and georeferenced map tiles
- **WFS** (**W**eb **F**eature **S**ervice): Provides geospatial features and extended manipulation options on vector data via web, such as deleting/creating features or enhanced query options
- **WCS** (**W**eb **C**overage **S**ervice): Provides multi-dimensional raster data, such as satellite imagery or sensor data
- **WPS** (**W**eb **P**rocessing **S**ervice): Provides remote usage of geoprocessing tools via web
- **WCPS** (**W**eb **C**overage **P**rocessing **S**ervice): Provides enhanced processing options for WCS (e.g. remote sensing/satellite data)

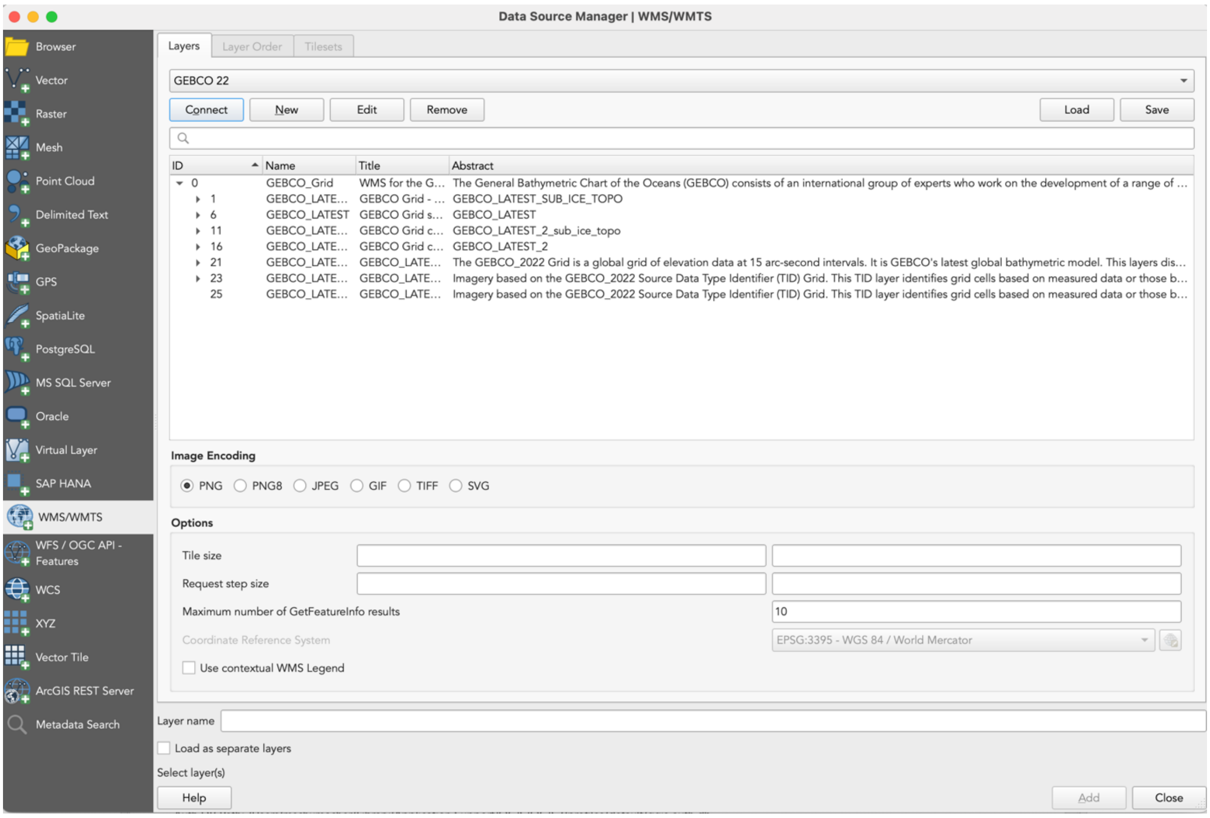
Add WXS layers

All mentioned services can be incorporated into GIS using URLs. There are basically two methods how to do so and here comes a short description using GEBCO 2022 WMS as an example (a more detailed tutorial can be found [here](#)):

- Under '*Layer*' -> '*Add Layer*' you can find all the above mentioned services in the lower third of the dropdown menu.
- If you click e.g. '*WMS/WMTS*' a window will open.
- Click '*New*' to establish a connection to a geodata host
- Now enter a reasonable name (e.g. GEBCO 22) in the name field of the new window and the respective service address in die field below. For GEBCO, this URL is: https://www.gebco.net/data_and_products/gebco_web_services/web_map_service/mapserv?SERVICE=WMS&REQUEST=GetCapabilities
- Then click '*OK*' and '*Connect*'
- You will see a list of available layers. Select one or more and click '*Add*'
- You should now see the selected layer on the map canvas



38: Create connection to WMS/WMTS service



39: WMS/WMTS layer dialogue

The procedure described above is very similar for the other web services like WFS, WCS or XYZ. The latter is similar to WMTS and also lets you load raster tiles, but is not standardised by OGC. The use XYZ vs. WMTS etc. really depends on the purpose and the services provided.

Useful WMS/WMTS URLs:
Quick Map Service Catalogue: https://qms.nextgis.com/
NASA Earth Observation Catalogue: https://neo.gsfc.nasa.gov/wms/wms?version=1.3.0

If you're looking for more or more specific services, ask Google or ChatGPT (:
If you know what you're looking for, you can also use specified search engines to find WXS services:

Spatineo: https://directory.spatineo.com/
GeoSeer: https://www.geoseer.net/
List of **XYZ tile** services: https://xyzservices.readthedocs.io/en/stable/introduction.html

A quick access list of the most basic available web service URLs for XYZ tiles is here:

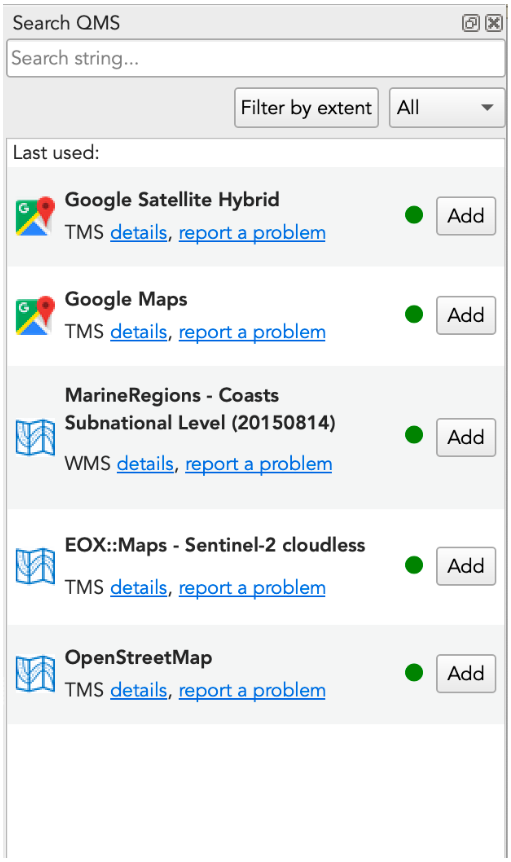
Google Maps: https://mt1.google.com/vt/lyrs=r&x={x}&y={y}&z={z}
Google Satellite: https://www.google.cn/maps/vt?lyrs=s@189&gl=cn&x={x}&y={y}&z={z}
Google Satellite Hybrid: https://mt1.google.com/vt/lyrs=y&x={x}&y={y}&z={z}
Google Terrain: https://mt1.google.com/vt/lyrs=t&x={x}&y={y}&z={z}
Google Roads: https://mt1.google.com/vt/lyrs=h&x={x}&y={y}&z={z}

Open Street Map (OSM): https://tile.openstreetmap.org/{z}/{x}/{y}.png
Open Weather: http://{s}.tile.openweathermap.org/map/{variant}/{z}/{x}/{y}.png?appid={apiKey}%0A

Search QMS

A second (easier (:) method to look for web-based data is to use the '*Quick Map Services (QMS)*' plugin. It's based on the Quick Map Service catalogue (see above). With this you don't have to care about what type os service protocol is used, you just click the desired layer and add it:

- If not yet done, activate the plugin under '*Plugins*' -> '*Manage and install plugins*' and under '*Installed*', check the box next to '*QuickMapServices*'
- You should then be able to see the '*Search QMS*' dialogue and type anything you like in the search bar



40: Quick Map Services

Tiling

Representing and visualising large datasets can be a very CPU-intensive task. Online map services like Google therefore came up with the idea of tiling – dividing a map into (mostly) squares to be able to load them faster. This requires the map to be projected and most commonly, Mercator projections are used here, such like Pseudo- or Spherical Mercator (EPSG:3857). Raster tiling then works by calculating pixel coordinates at defined zoom levels. Multiple distinct zoom level then form a pyramid with the top zoom level (zoom=0) that represents 256x256 pixels (one tile), 512x512 at zoom=1 (four tiles), 1024x1024 at zoom=2 (16 tiles) etc. The resolutions for the first 5 zoom levels are listed below. A full list of zoom levels as well as more information on tiling here.

41: Tiling pyramids. Source: maptiler.com

Table 1: Zom level. For map tiling. Source: maptiler.com

Zoom level	Resolution (meters / pixel)	Map Scale (at 96 dpi)	Width and Height of map (pixels)
0	156543.0339	1 : 591 658 710.90	512
1	78271.51696	1 : 295 829 355.45	1024
2	39135.75848	1 : 147 914 677.73	2048
3	19567.87924	1 : 73 957 338.86	4096
4	9783.939620	1 : 36978669.43	8,192
5	4891.969810	1 : 18489334.72	16,384

Vector tiling works similar, except that there are no pixels, hence no resolution or distinct zoom levels. Instead, vector tiles contain geometries and metadata that have been clipped to the tile area and are rendered and styled on the fly during loading (a website or else). Most web services use vector tiling nowadays.

QGIS has built-in functions for tiling raster and vector data. An example of tiling the contents of your current map canvas is given here:

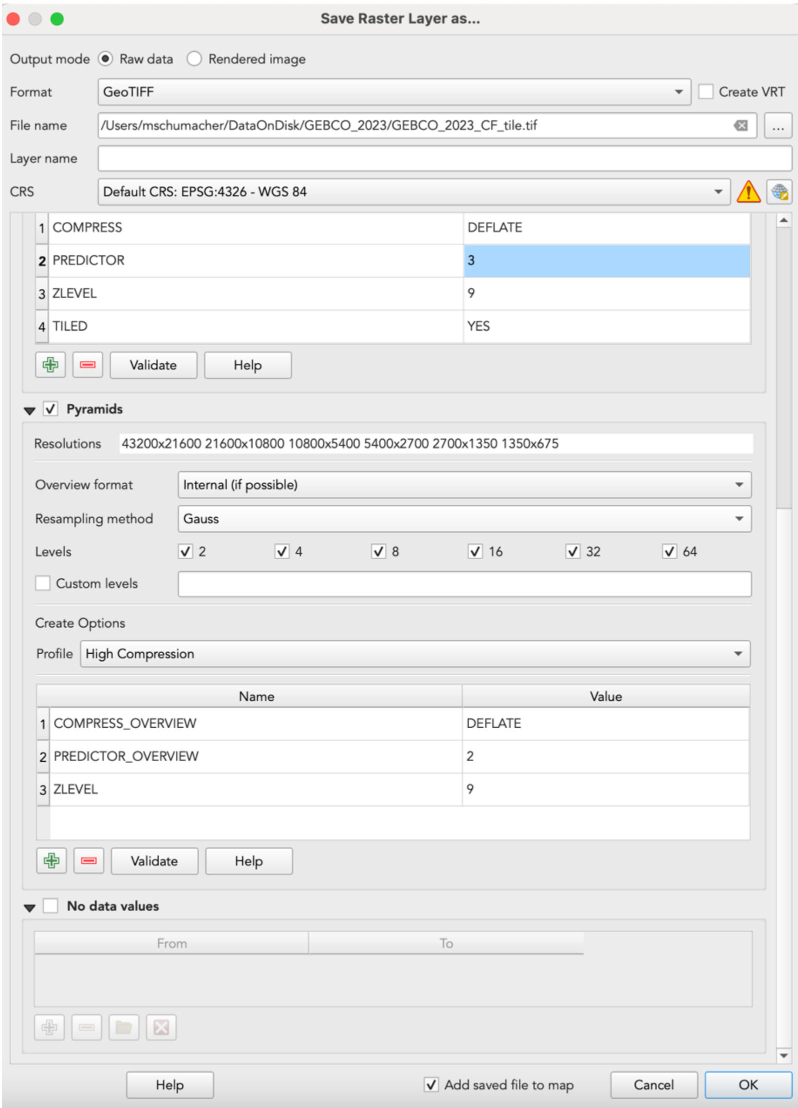
- In the Processing Toolbox, find '*Generate XYZ Tiles (MBTiles/Directory)*' MBTiles: Images are saved into one database file (preferred); Directory: Images are saved individually
- Define the extent (leave empty if global/full extent)
- Define min/max zoom level (Careful – many and higher zoom levels require a lot of time & CPU)

- Select output directory and give a reasonable name

You can use the tool/s '*Write vector tiles (MBTiles/XYZ)* similar to the example above ' to create tile for single vector layers.

Tiling and pyramids building can also be achieved within the export dialogue of a .tiff. It then works on a layer basis and is recommended if you want to save large raster layers into smaller pieces. To do so:

- Right-click on the raster you want to export, select 'GeoTIFF' as export format and enter a path to the directory
- Under '*Profile*', select '*High Compression*'
- You should see the table below populated with '*COMPRESS*', '*PREDICTOR*' and '*ZLEVEL*'.
- Leave them as is but with the *'+'* sign, create a new entry named '*TILED'* and enter '*YES'* as a value
- Now under '*Pyramids*', select '*Internal (if possible)*' as overview format to avoid creating a separate pyramid file and '*Gauss*' as resampling method.
- Check all level (=Zoom-level) boxes to cover all possible resolutions. You can also add custom levels if you like
- And again, under '*Profile*', select '*High Compression*' (this is for the Pyramids file only)
- Click '*OK*' – **Note**: Depending on the size of your raster and the number of zoom levels, this can take a while!



42: Tiling raster layer

Expressions

QGIS Expressions are a built-in tool which is very powerful and can be used on any vector layer to do almost anything you want such like filtering, selecting, visualising, labelling etc.. It can e.g. be opened via the '*Field Calculator*' in the '*Processing Toolbox*' or in the properties of vector layers or within the attribute table of a (vector) layer etc. Whenever you spot a symbol like these: , it's the '*Expression builder*' behind it.
'*Expression builder*' uses a SQL-like QGIS proprietary script language which basically calls a function first that embraces some variables and methods. Some of the most practical expressions are introduced below, although it shall be pointed out that there are a lot more useful expressions.

Aggregate Function

The aggregate function can be used to combine attribute values from other layers to the working layer. Imagine for example you have a point vector file containing seamount positions and a polygon file with a swath coverage of a multibeam, that you would like to sum up all the seamounts within an area that intersects with the swath coverage. You can do so using aggregate:

- Right-click the swath coverage layer to open its attribute table
- Toggle editing mode
- Open the field calculator
- Depending on whether you want to use an existing column or not, let the box '*Create a new field'* checked or uncheck it and check '*Update existing field*'
- Give reasonable formatting (e.g. integer or decimal for calculations)
- Enter the following expression (make sure you adapt 'layer' and 'expression' according to your layers and naming):

```
aggregate(
layer:='all_seamounts — all',
aggregate:='count',
expression:="field_5",
filter:=intersects(@geometry, geometry(@parent))
)
```

Note: In the above function, '*layer*' refers to the layer that contains the information that you want to aggregate, '*aggregate*' is the aggregation method, '*expression'* refers to the field in the '*layer*' that you want to aggregate and under '*filter*', you can add the method how the actual layer and the aggregation layer should relate (i.e. aggregate where they intersect etc.). In the case of using '*count'* as aggregation method it doesn't matter what field you enter next to '*expression'* because it's just a feature counter and you need to enter something here. If you use a different aggregation method, e.g. '*sum'*, '*min'* or '*max'* you need to enter the field containing the values you want to sum here. Imagine you want to know the seamount with the least depth, the expression would be like below (because '*field_5*' contains the depth values of the seamounts):

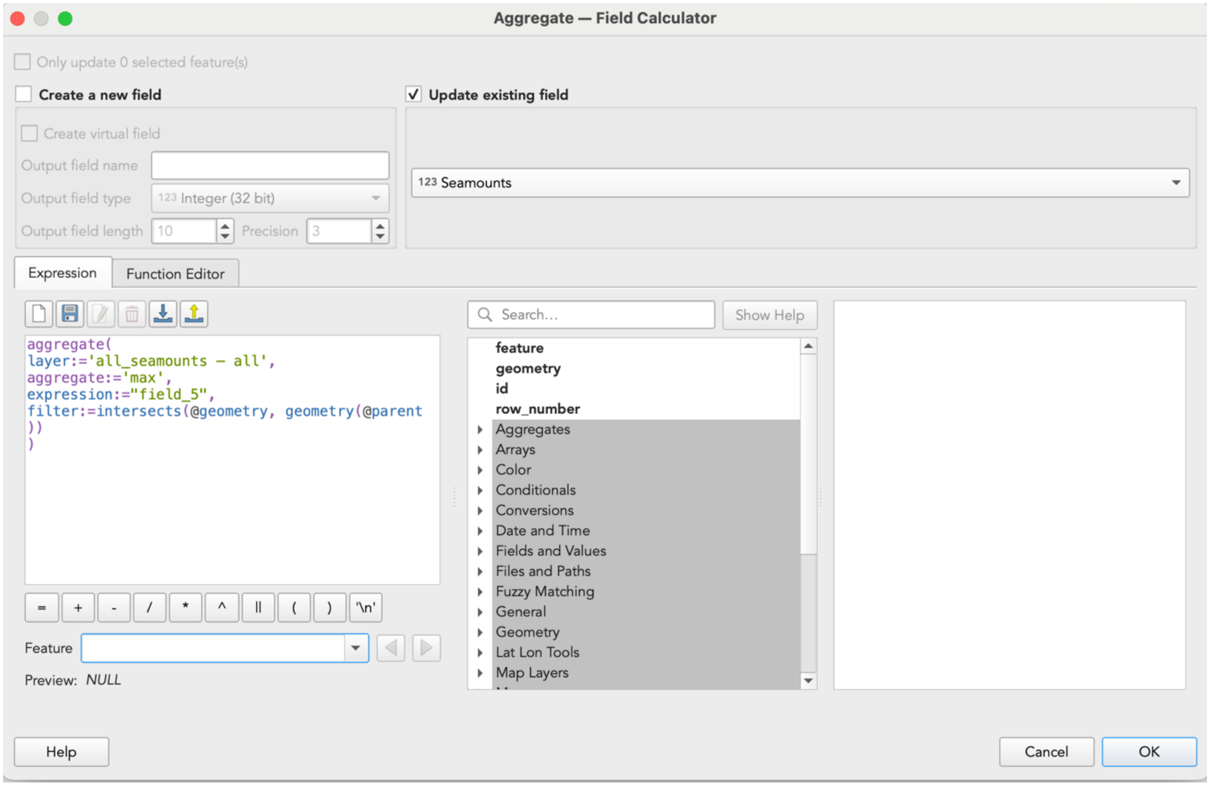
```
aggregate(
layer:='all_seamounts — all',
aggregate:='min',
expression:="field_5",
filter:=intersects(@geometry, geometry(@parent))
)
```

The new field should be filled with the sum of all seamounts within the coverage for each feature. You can also use this expression to e.g. set a **default value for a field**. To do so:

- Double-click the vector layer to open its properties
- Go to 'Attribute form' and find your field under 'Available Widgets'

- On the right, under *'Default'*, hit the *'sum'* button
- The next steps should be familiar, they are the same as above: Like before, enter the expression in the expression field and click *'ok'*
- Check the box 'Apply default value on update'

Now if you add a new polygon, the field should be automatically filled with the sum of all seamounts within the polygon area.
There are of course more useful aggregation functions like e.g. average, min, max (numerical) or concatenations for string analyses. Go try them out!



Categorising with CASE … WHEN Expression

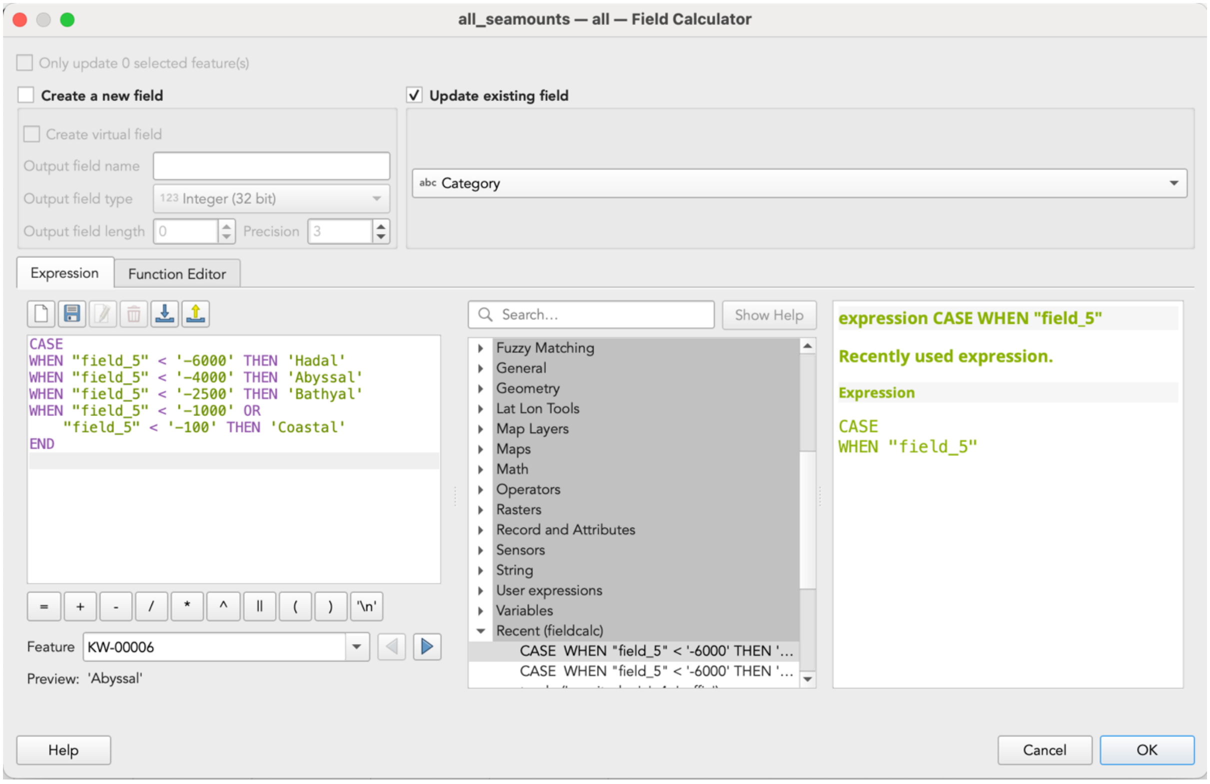
Imagine a shapefile having multiple features with different value for an attribute. Take for example the seamount shapefile that contains charted and uncharted seamounts with given depth along with more information. Now we want to roughly categorise them into the depth boundaries hadal, bathyal, etc… - here is how it can be done:

- Open the attribute table of the seamounts layer and make it edible
- Open the field calculator and add a new field (e.g. '*Category*'), select '*Text*' as output format and set the output field length to '*20*'
- Now enter the following logic in the expression field (here, "field_5" contains depth values):

  CASE
  WHEN "field_5" < '-6000' THEN 'Hadal'
  WHEN "field_5" < '-4000' THEN 'Abyssal'

WHEN "field_5" < '-2500' THEN 'Bathyal'
WHEN "field_5" < '-1000' OR
"field_5" < '-100' THEN 'Coastal'
END

- If you are a little familiar with coding, this is nothing else than an if-else loop: If below or between certain depth values, set the category to the appropriate value
- **Note:** Make sure that "*field_5*" contains valid depth values



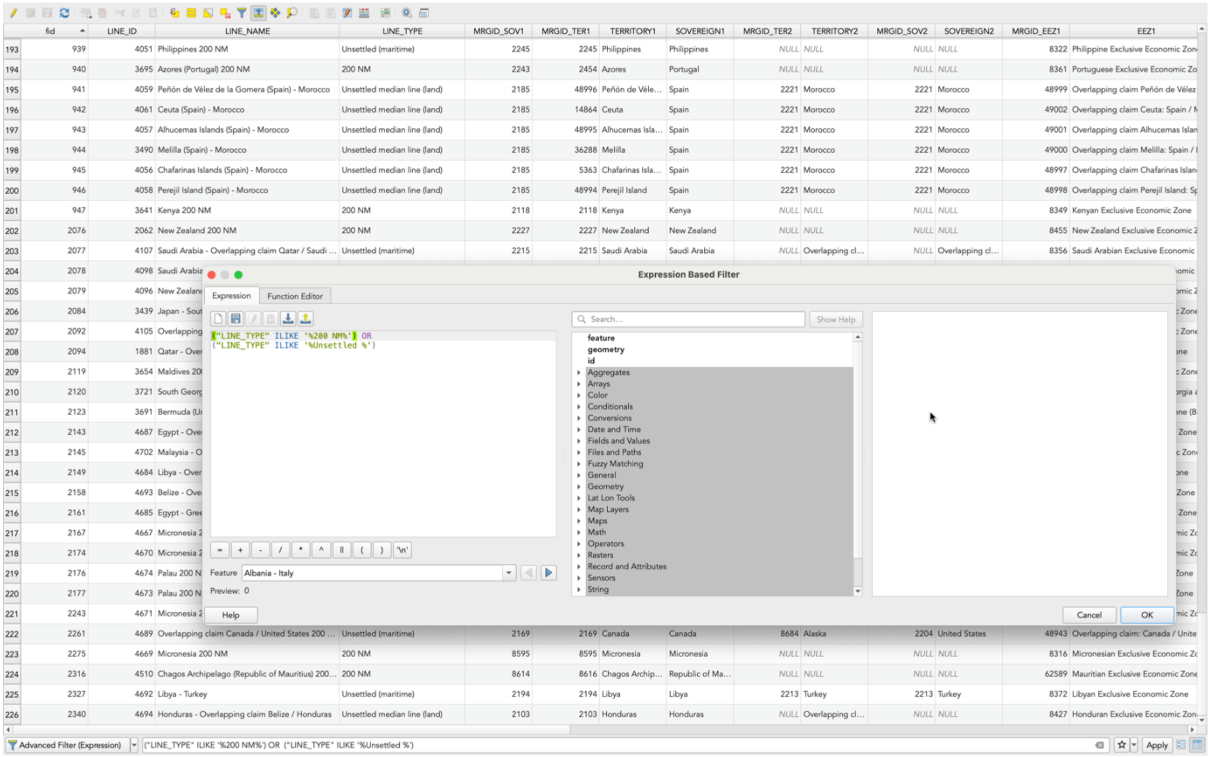
43: CASE/WHEN (if-else) logic

Advanced Filtering using Expressions

Recall from the Feature Selection/Filtering section how to select features using the attribute table. What happens in the background when using the '*Select/filter features using form*' is that from the stuff you type in the values field, QGIS builds expressions. Now guess what – you can build these expressions yourself to filter and/or select features! Here is how:

- Repeat steps 1-5 from the Feature Selection/Filtering section
- Now instead of clicking the '*Select features*' button, press '*Filter Features*' next to it.
- You should see a field at the bottom of the windows showing something like '*("LINE_TYPE" ILIKE '%200 NM%')*' – translated, this means nothing else than before: '*Filter features whose LINE_TYPE attribute contains 200 NM*' and is the QGIS expression for this operation. '*ILIKE*' means something like '*contains*' and is a logical operator (just like '=').
- Press '*Apply*'
- You should now only see the filtered features in the attribute table (Note they are not highlighted like when selecting stuff!)

- If you want to filter by multiple values, you can chain selections using '*OR*':
- ("LINE_TYPE" ILIKE '%200 NM%') OR ("LINE_TYPE" ILIKE '%Unsettled (land)%')
- **Note:** It might be better to use the '*Expression builder*' here: Next to the field on the left windows side, find the '*Advanced Filter (Expression)*' button and open the '*Expression builder*'. You should see your query already in here.



44: Filter by Expression

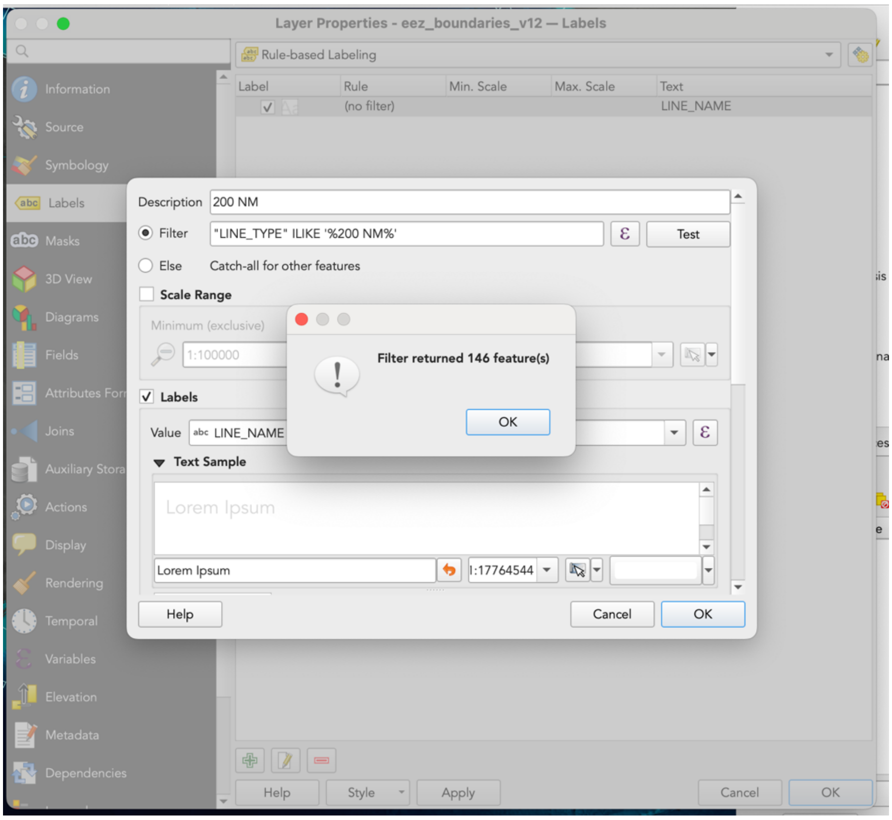
Labelling using Expressions

If you don't want to have label on each feature of your layer, you can smart label by using expressions and/or rule-based labelling:

- In the layer's properties, open the '*Label*' tab
- Select 'Rule-based' labelling
- **Example**: For the EEZ layer, add a rule by clicking the '+' sign and click the '*Edit Rule*' button. In the 'Filter' field, add e.g. *"LINE_TYPE" ILIKE '%200 NM%*' and click '*Test*'. You should see a windows saying '*XX Features found*'. If you apply this rule, only features matching this filter should appear as labels.

Symbology using Expressions

Analogous to the labelling, you can apply rule-based symbology by simply entering the same rules like above in the '*Symbology*' of the layer properties. You should see only features matching the filter/s on the map canvas.



45: Rule-based Labelling/Symbology

Editor's choice: More Tools from the Processing Toolbox

- '*GDAL Warp (reproject)*': Reproject raster layer (change geometry to different projection)
- *'Reproject layer'*: Reproject raster layer (change geometry to different projection)
- *'Heatmap (Kernel Density Estimation)'*: Create density (heatmap) raster of input point vector layer using kernel density estimation.
- *'Points to Path'*: Connects points with lines (useful for survey planning)
- *'Extract vertices'*: Opposite of *'Points to Path'*: Extracts the vertices as points from a line or a polygon layer. Also useful for survey planning.
- '*Array of offset parallel lines*': Creates copies of line of a layer, by creating multiple offset versions of each feature with preset distance. Useful for survey planning.
- '*GDAL: Polygonize (raster to vector)*': creates features for each colour in raster. Useful if you e.g. have a raster file with different classes and want to convert it to vector.
- *'Select/Extract by xx'*: Select or extract features from vector data based on area, attributes, expression or location.

- *'Fix geometries':* Attempts to create a valid version of a given vector file with invalid geometry without losing any of the input data. Useful if you work on vector data that have missing or broken geometries (like e.g. ring enclosures etc.). If a corrupt shapefile doesn't let you do anything with it, this tool helps!
- *'Buffer'*: Computes a buffer area for all the features in an input layer, using fixed or dynamic distance. There are multiple buffer tool out there, check them out! Useful e.g. to estimate multibeam coverage. Note that this tool needs a projected input layer (UTM is most accurate at small areas) if distances are given in metric units (meters, km etc.)
- *'Dissolve Features'*: Merges multiple features of a vector file based on attribute selection. Useful if you e.g. have a line file with many pieces that belong to the same line and you want to make it one line.

Editor's choice: More Plugins

The below list doesn't claim to be exhaustive. You can find all top rated plugins here.

- *'Value Tool'*: Display values when hovering over map from all layers in project. Handy e.g. during cruise when you want to know about your surroundings.
- '*Point Sampling Tool*': Collect attributes (polygon) and/or values (raster) from multiple layers at specific sampling points.
- *'Cruise Tools'*: An entire workbench for cruise planning written by AWI. Contains several stand-alone tools. Handy if you would like to plan survey exactly like the tool proposes.
- *'Lat Lon Tool'*: Basically can do anything concerning coordinates: Capture coordinates, zoom to coordinates, add points based on given coordinates, conversion etc. Useful for a lot of stuff.
- *'Quick Map Services NextGIS'*: Provides a list of (web)services and lets you search for datasets and base maps. These can be added to the map canvas.

Congratulations, you made it! This is

------------------------------------ THE END --