QGreenland

A Free GIS Package for Greenland

User Guide

Version 1.0.0

QGreenland is a free mapping tool to support interdisciplinary Greenland-focused research, teaching, decision making, and collaboration. This project is funded by the U.S. National Science Foundation EarthCube program under grant #1928393.

https://qgreenland.org | https://github.com/nsidc/qgreenland

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1. Introduction to QGreenland

Welcome to QGreenland! We hope this project is useful to you, whatever your goals and purposes. This User Guide is designed to orient the novice QGIS user to the basics of the QGIS interface and functionality, from data analysis to map making, using the QGreenland data package. It is not meant to be a complete and advanced guide to QGIS, thus there are many functionalities within the software that are not covered here but that can be found in more comprehensive online QGIS manuals. There are a number of online resources to explore to learn more about QGIS and its functionality, including:

- QGIS User Guide: https://docs.qgis.org/3.10/en/docs/user_manual/
- QGIS Training Manual: https://docs.qgis.org/3.10/en/docs/training_manual/
- QGIS Tutorials and Tips: https://www.qgistutorials.com/en/
- More advanced trainings and topics: https://courses.spatialthoughts.com

Additional QGreenland-specific how-to video tutorials are available on the QGreenland YouTube channel: https://www.youtube.com/channel/UCjWae_Jrbognx2ju_SHBZ2A

1.1 About the Project

QGreenland (https://qgreenland.org) is a free mapping tool to support interdisciplinary Greenland-focused research, advanced secondary or post-secondary teaching, decision making, and collaboration. QGreenland consists of a curated collection of geospatial datasets for Greenland that is hosted on the QGIS platform (www.qgis.org). QGIS is a free and open source Geographic Information System (GIS) licensed under the GNU General Public License. QGreenland is designed to be used by a diverse user group, from scientists to planners and policymakers to educators, and more. QGreenland users are able to produce high-quality mapping products to meet their unique needs. And because the QGreenland data package is downloaded right onto the user's computer, QGreenland can be used in the field and in remote places without Internet access. Some additional larger datasets (e.g., satellite imagery) not included with the main QGreenland download package are available through online access when connected. QGreenland was inspired by the free and open source Quantarctica GIS data package for Antarctica (https://www.npolar.no/en/quantarctica/).

1.1.1 What is in the v. 1.0.0 QGreenland Download Package?

You will find the following files in the QGreenland data package:

- Folders containing data layers organized by topic
- The main ***qgreenland.qgs*** project file
- ***qgreenland.png*** - The official QGreenland logo
- ***layer_list.csv*** - A complete list of all the data layers in the QGreenland download package, including information about each (data source, file size, etc.). This file can be opened with Microsoft Excel, LibreOffice Calc, a text editor, or a similar program.
- ***UserGuide.pdf*** - The full QGreenland User Guide
- ***QuickStartGuide.pdf*** - A one-page overview guide for experienced QGIS users on how to download the QGreenland data package and other information
- ***MakingDataQGRCompatible.pdf*** - A short guide on how to make your datasets compatible with QGreenland
- ***STYLE.txt*** - Guidelines and standards for QGreenland data layer styling
- ***CONTRIBUTING.txt*** - Instructions on how to contribute to the QGreenland project
- ***README.txt*** - Brief description of the QGreenland data package

- ***CHANGELOG.txt*** - A log of changes made to the QGreenland data package

Please note that QGreenland v1.0.0 is the first stable public release version from this project. QGreenland version 1.0.0 will not be the final version of the QGreenland download package. There will be a version 2.0.0 released some time in 2022 that may include new and updated layers. Development versions along the way will continue to be available via the website (http://qgreenland.org), with code fully documented on GitHub (https://github.com/nsidc/qgreenland).

1.2 Licensing, Citing, and Contributing

QGreenland development is open source and available on GitHub at github.com/nsidc/qgreenland. This means that users are free to create their own customized QGreenland package with different and new styles, layers, and data. Users who wish to contribute to the QGreenland project will find instructions on how to do this in the ***CONTRIBUTING.txt*** file included in the download package and in ***CONTRIBUTING.MD*** on GitHub.

QGreenland is licensed under an MIT license:
Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions: The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.

Users should note that published works produced using QGreenland are required to cite each dataset used in the work. QGreenland provides all dataset citation information in each layer's metadata in QGIS (see section 4.3: Layer Properties for instructions on how to access a layer's metadata) and in the layer catalog provided with the QGreenland download package, ***layer_list.csv***. You are also required to acknowledge or cite QGreenland and the National Snow and Ice Data Center in your work.

Suggested citation for QGreenland:
Moon, T., Fisher, M., Harden, L., and T. Stafford (2021). QGreenland (v1.0.0) [software], National Snow and Ice Data Center Available from https://qgreenland.org/.

1.3 Project Collaborators

QGreenland is developed by researchers, software developers, and education specialists at the National Snow and Ice Data Center and Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder. The QGreenland project is funded by the U.S. National Science Foundation EarthCube program under grant #1928393. The QGreenland project is advised by an Editorial Board consisting of international content experts in remote sensing and GIS, cryospheric and geologic sciences, ecology, climate modeling, and more. Other project collaborators include: The Geological Survey of Denmark and Greenland (De Nationale Geologiske Undersøgelser for Danmark og Grønland), Technical University of Denmark (Dansmarks Tekniske Universitet), Danish Meteorological Institute (Dansmarks Meteorologiske Institut), Asiaq - Greenland Survey, Norwegian Polar Institute (Norsk Polarinstitutt), Arctic Data Committee, International Arctic Science Committee, WWF-Danmark, U.S. Polar Geospatial Center, Greenland Ice Sheet Ocean Science Network, N.S.F. Polar Computing RCN, and Isaafik. More information about the QGreenland team and collaborators is available at the website (http://qgreenland.org).

2. Getting Started

2.1 System Requirements

Before downloading the QGreenland data package, be sure that QGIS is installed on your computer: https://www.qgis.org/en/site/forusers/download.html. QGIS is available on Windows, macOS, Linux and Android. Note that QGIS version 3.10 is the oldest version supported by QGreenland.

2.2 Downloading and Installing QGreenland

The QGreenland data package is available for download at https://qgreenland.org/download. After downloading, unzip and save the folder in a location of your choice. Select the ***qgreenland.qgs*** file to open the full QGreenland data package. Files with a '.qgs' or '.qgz' extension are QGIS project files. When you open ***qgreenland.qgs***, QGIS will open automatically and display the QGreenland data environment. Alternatively, you can open the QGIS software first, then go to 'Project' -> 'Open' and navigate to the ***qgreenland.qgs*** project file on your computer.

Note: Any changes that are made to the *qgreenland.qgs* project that are saved will overwrite the original file; therefore, it is recommended that you save each QGreenland project that you work on with a new and unique filename ('File' -> 'Save as...').

3. Tour the Interface

In this user guide you will see various screenshots of the QGreenland and QGIS interface. The screenshots in this guide were generated from QGIS version 3.10 running on a macOS Catalina operating system; thus, depending on the operating system and QGIS version you are using, your QGIS interface may look slightly different.

The main components of the QGIS interface are the menu bar, toolbars, panels, status bar, and map view (Fig. 1):

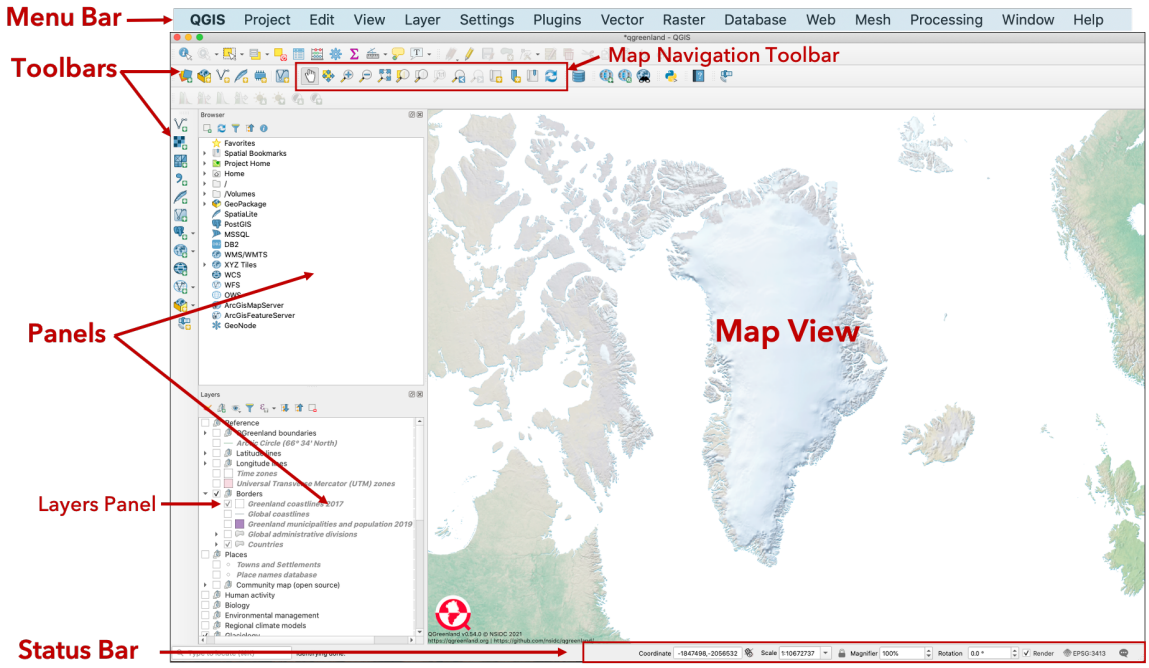

Fig. 1: Main components of the QGIS/QGreenland interface

The **MAP VIEW** is the main part of the QGIS/QGreenland interface where the data layers are displayed. A GIS 'layer' refers to a geospatial dataset along with the symbols and labels used to portray it in a GIS environment. Information about the map view such as its coordinate reference system, scale, and the coordinates of your cursor's location as you move it around the map view are indicated in the **STATUS BAR**.

The data layers in the current project are listed in the **LAYERS PANEL**, and, when checked 'on', are displayed in the map view in the order that they are listed in the Layers panel (the layer listed first in the Layers panel is the topmost layer in the map view). If you downloaded the full QGreenland data package, the Layers panel will show all of the data layers included in the package. A complete list of all data layers in QGreenland can also be found in the ***layer_list.csv*** file included in the download package. Layers and layer groups (a collection of related layers nested within a broader group) can be toggled on and off by checking or unchecking boxes in the Layers panel. When you first open the QGreenland data package, two reference layers will be automatically toggled on: *Greenland coastlines 2017* and the QGreenland Basemap. Layers can be rearranged by clicking and dragging up or down. Layer groups can be expanded or collapsed by clicking on the arrow to the left of the checkbox. To expand or collapse all layers at once, click on the respective buttons (Fig. 2 (a)) right above the layers list in the Layers panel. In addition to the Layers panel, there are a variety of other panels that can be displayed on the QGIS interface. For example, the Browser panel provides a shortcut for

accessing other data layers or project files on your computer or another location. Panels can be moved around the interface by clicking and dragging, and can be removed by clicking on the 'X' box in the upper righthand corner.

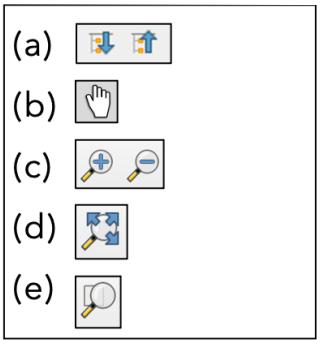

Fig. 2: (a) Buttons above Layers panel to expand or collapse layers; (b) hand button to grab and drag the map view; (c) magnifying glass buttons to zoom in or out in map view; (d) Zoom Full button to bring all visible layers into map view; (d) Zoom to Layer button to bring a desired layer into view.

The **TOOLBARS** contain buttons that allow the user to interact with the map view. For example, the hand button (Fig. 2 (b)) in the Map Navigation toolbar lets the user grab and drag the map view around. The magnifying glass buttons (Fig. 2 (c)) allow the user to zoom in and out or to a particular feature or selection in the map view. More information about a toolbar button's function can be obtained by hovering one's mouse over the button. Toolbars can be moved around the QGIS workspace by clicking and dragging. To toggle a toolbar on or off, simple right click on a toolbar and check or uncheck the desired boxes. (Fig. 3).

If data layers are toggled on but not visible in the map view, the magnifying glass with three arrows ('Zoom Full') button (Fig. 2 (d)) will bring all visible layers back into the map view. Right clicking on a layer in the Layers panel and selecting 'Zoom to Layer' or clicking on the magnifying glass over a square button (Fig. 2 (e)) in the Map Navigation toolbar will also bring a desired layer into view in the map view.

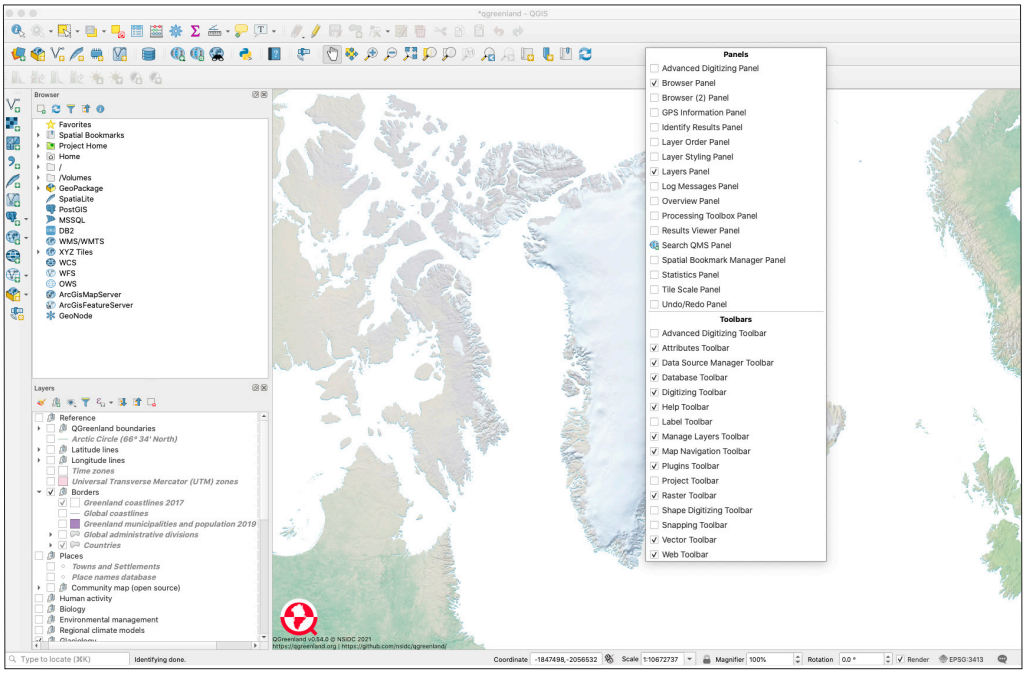

Fig. 3: Toolbars can be added or removed by right clicking on the toolbar area and checking/unchecking boxes.

Finally, the **MENU BAR** across the top of the QGIS interface provides the user with access to most QGIS functions, including many that can also be accessed in the toolbars: opening new or saved projects, saving a current project, adding or creating data layers, analyzing layers, etc. You can fully customize the look and layout of your QGIS interface by going to 'View' in the menu bar and selecting the panels, toolbars, etc. that you would like visible.

4. Spatial Data Overview

There are two main basic kinds of GIS data layers: vector and raster.

4.1 Vector Data

Vector data are composed of points, lines, and polygons and represent discrete features. Examples of vector data are cities (points), roads and highways (lines), and geographic boundaries like country borders (polygons) (Fig. 4). All of the vector layers in QGreenland are *GeoPackage* (.gpkg) files. A GeoPackage is just a platform-independent file type for storing geospatial data.

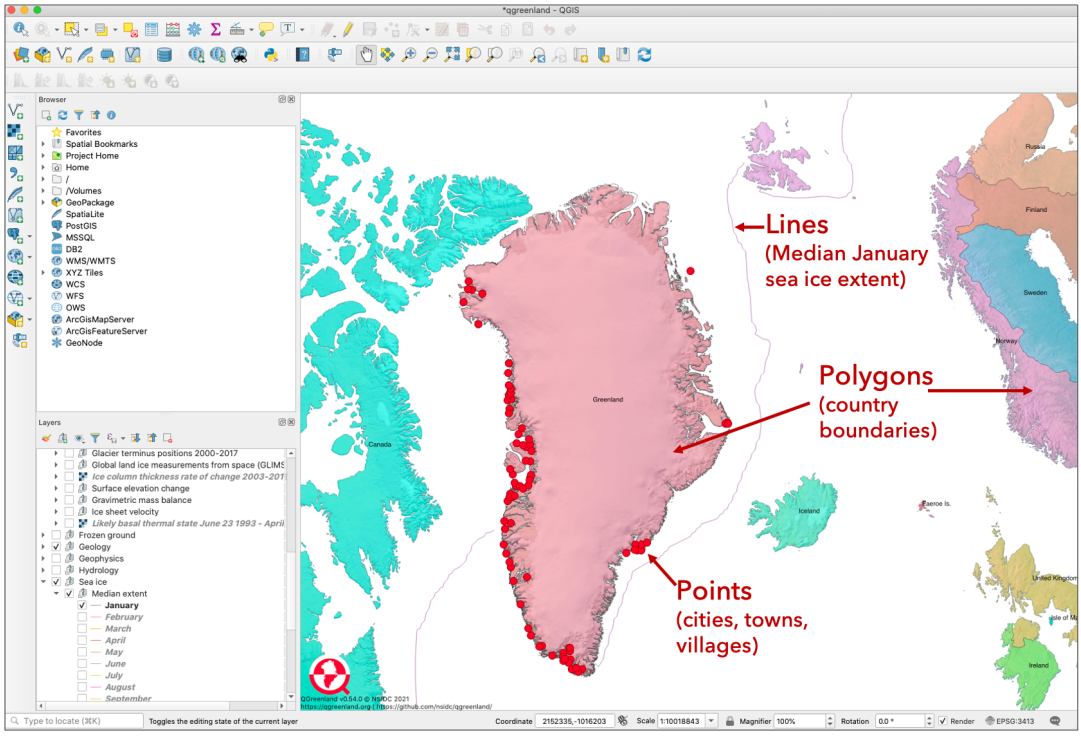

Fig. 4: Examples of vector data layers in QGreenland: Points (towns and settlements), lines (median January sea ice extent), and polygons (country boundaries).

4.1.1 Vector Data Attributes

All QGIS vector data layers have associated attributes, or characteristics of the discrete features. Attributes can be almost anything: city name, road type (highway, paved, unpaved, etc.), land elevation value, population density, date, etc. The attributes of a data layer can be viewed in tabular form by right clicking on the layer in the Layers panel and selecting 'Open Attribute Table' from the menu options, or by clicking on the layer in the Layers panel and then clicking on the Open Attribute Table button  in the Attributes toolbar. This opens up an Attribute Table, where the columns are the various fields, or attributes, and the rows are individual features. Clicking on and highlighting records in the Attribute Table will also highlight those specific points, lines, or polygons in the map view. Right-click any cell to 'Zoom to feature', 'Pan to feature', or 'Flash feature'.

4.2 Raster Data

Raster data are composed of grid cells or pixels, where each grid cell has its own value. Rasters represent continuous data, such as land elevation, surface temperature, land cover, etc. (Fig. 5). The resolution, which is the length of the grid cell sides of each raster dataset in QGreenland, is indicated in the name of the dataset, e.g.: "Ice Sheet Velocity (500 m)". Raster layers in QGreenland are all GeoTIFF files, which are images with geographic features, such as geospatial metadata and overviews/tile pyramids.

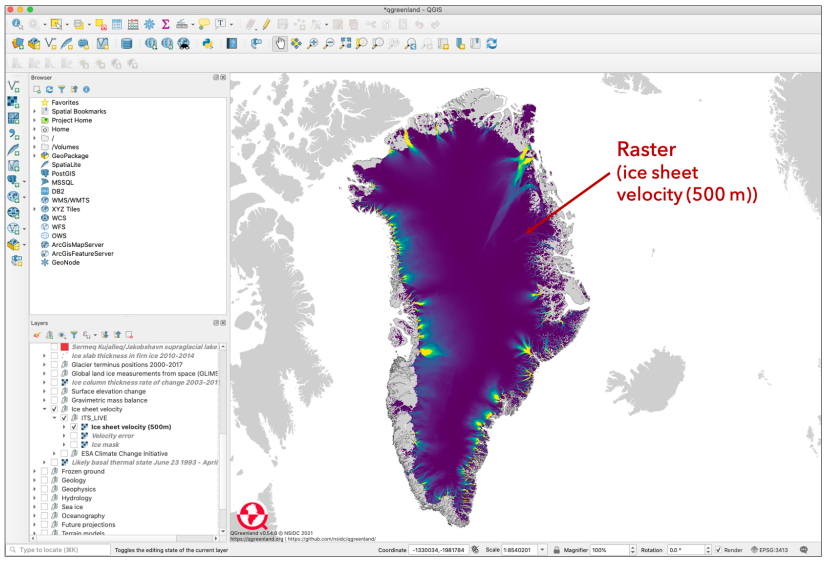

Fig. 5: Example of a raster data layer in QGreenland, ice sheet velocity, where each grid cell in the raster is 500 m x 500 m and is color-coded by a velocity

4.3 Layer Properties

Right clicking on a data layer in the Layers panel and selecting 'Properties', or simply double clicking on a layer in the Layers panel will bring up the Layer Properties dialog window, which contains a variety of information about a layer (Fig. 6). The information is organized into sections (or tabs) that can be accessed by clicking on an individual tab (e.g., Symbology) in the left sidebar of the window. The tabs listed in a vector Layer Properties dialog window differ slightly from those listed for a raster layer. The tabs most relevant to a novice QGIS user and that exist for both vector and raster layers are:

- **Information:** This section summarizes information about a layer, including its name, coordinate reference system, spatial extent (geographic boundaries), description (abstract), and more.
- **Symbology:** Every QGreenland data layer has a predefined symbology, or visual representation in the map view. See section 5.4: Editing Layer Symbology for instructions on how to modify or customize a layer's symbology.
- **Metadata:** Metadata is essentially "data about data". In QGIS, layer metadata is information about the data in the layer, including its name, description, citation, and link to the source that the data was retrieved from. As outlined in section 1.2: Licensing, Citing, and Contributing, published works produced using QGreenland are required to cite each dataset used in the work. Users can thus simply copy a layer's citation directly from its metadata. An abbreviated version of a layer's metadata can also be viewed by selecting a layer in the Layers panel and hovering your mouse over the layer name.

Note: The QGreenland team has in a few instances included comments on 'Noted Data Issues'. Read about 'Noted Data Issues' in the layer metadata. These are currently noted for the 'Towns and settlements' and the 'Community map (crowdsourced)' layers. Regardless, QGreenland makes no guarantees about the accuracy and validity of data contained in QGreenland.

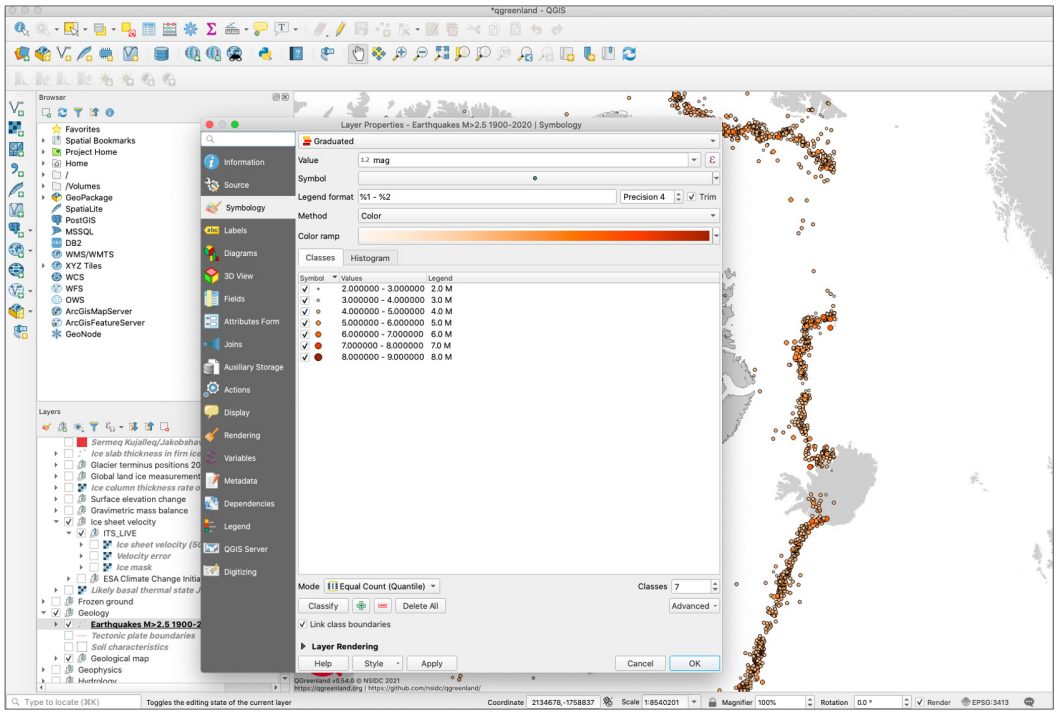

Fig. 6: The Layer Properties dialog window for the QGreenland 'Earthquakes' data layer

4.3.1 Data Projections

Data projections, or Coordinate Reference Systems (CRS), define the coordinate system for a QGIS project and data layers. The CRS for the current map view is indicated on the right side of the QGIS status bar. For QGreenland, the current CRS should be identified as 'EPSG: 3413,' which is the identifier for the NSIDC Sea Ice Polar Stereographic North on a WGS 84 Ellipsoid CRS. Changing the CRS of the map view will not change the source CRS of data layers in the project (called 'reprojection'). It is possible to reproject a layer into a new CRS; however, this transforms the data and can introduce artifacts. Therefore, it is recommended that to reproject data, the user do so from the source data and not the data contained in the QGreenland package.

4.3.2 Scale-Dependent Rendering

Scale-dependent rendering refers to the scale at which a particular data layer will be visible in the QGIS map display. This can make it easier to zoom in and out for certain data layers. The user can turn on scale-dependent rendering for any layer by going to the layer 'Properties' -> 'Rendering', checking the box for Scale Dependent Visibility, and then setting the minimum and maximum scale dependent visibility. For scale reference, refer to the scale indicated at the bottom of the QGIS interface in the Status Bar.

4.4 QGreenland Data Layers

A complete list of all QGreenland data layers and their metadata, including information about their original data source, can be found in the ***layer_list.csv*** file included in the QGreenland download package.

5. Interacting with Geospatial Data in QGreenland

5.1 Identifying Features in Layers

One of the most basic ways to interact with data in QGIS is to use the Identify Features button in the Attributes toolbar to quickly view the attributes of an individual record (i.e., a single point, line, or polygon in a vector layer or a single cell in a raster layer). **Note:** If you do not see this button in any of your toolbars, then you need to toggle on the Attributes toolbar. Either right click anywhere in the toolbar area and check the box next to 'Attributes toolbar', or go to 'View' -> 'Toolbars' in the menu bar.

To use the Identify Features button:

1. First, make sure that the layer (not just layer group) that you are interested in is toggled on and selected (click on it so that the layer is highlighted) in the Layers panel.
2. Click on the Identify Features button in the Attributes toolbar.
3. Click on the individual point, line, polygon, or raster cell of interest in the map view. The record for the object selected will show up in a new Identify Results panel to the right of the map display (Fig. 7).
4. You can choose what information the Identify tool is showing you and how it is displayed by toggling the Mode and View options at the bottom of the Identify Results panel.

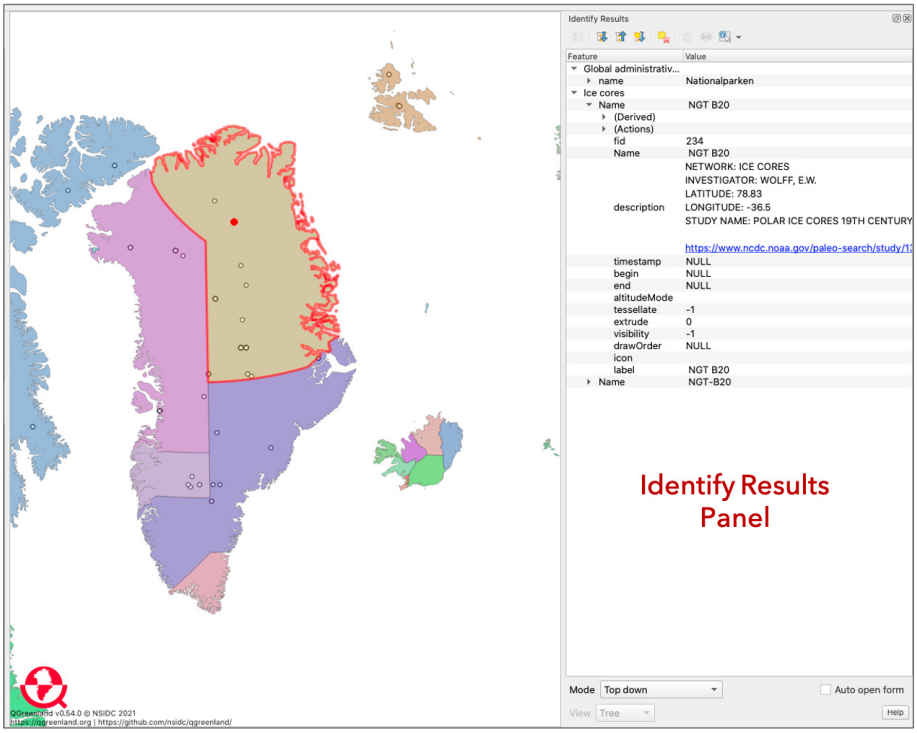

Fig. 7: The Identify Results panel that shows results from the Identify Features tool.

5.2 Measuring Distances, Areas, and Angles

Another useful basic tool in the Attributes toolbar is the measuring tool  . The measuring tool is a quick and easy way to measure distances between two points or along a line, area of a polygon, or angles between geographic features or locations.

To use the measuring tool:

1. Click on the arrow to the right of the measuring tool button and choose if you want to measure a line, area, or angle. Regardless of which one you choose, a small window will appear.
2. If you are measuring a line distance, first choose your desired units (e.g. kilometers). Ellipsoidal measurements take into account the spherical shape of the earth and the project's coordinate reference system. Cartesian measurements assume a flat Earth. For small distances, these numbers will be very similar, but for very large distances they can be very different.
3. Clicking first on one point on the map and then another will draw a line segment whose length will be indicated in the 'Segments' box. You can draw and measure multiple line segments.
4. To clear the segments you've drawn, click on 'New'.
5. To measure an area instead of a line with the measuring tool, you will follow essentially the same steps for measuring a line distance, except you will click and map out an area on the map instead of drawing line segments.
6. To measure the angle created by three points on the map, click on each of the three points to draw the angle. The second point you click on will serve as the angle's vertex.

5.3 Adding Text Annotations to the Map View

You can add a text annotation anywhere in the map view using the text annotation tool  in the Attributes toolbar.

To use the text annotation tool:

1. Click on the text annotation button in the Attributes toolbar.
2. Click on the place on the map where you want the text annotation to go. A small white box will appear.
3. Double click on the box to open a new window where you can write your annotation and choose the font you want to use, among other things (e.g., you can link the annotation to a specific layer).
4. When you're done, click 'Apply' and then 'Ok' to close the window.
5. To delete an annotation, double click on it to open the dialog window, then click 'Delete'.

5.4 Editing Layer Symbology

Each QGreenland data layer comes with a predefined symbology (how the layer is visualized in the map view).

To modify a layer's symbology:

1. Open the Layer Properties dialog window for the layer you want to edit.
2. Go to the 'Symbology' section and modify the layer symbology as desired.

   a) For a vector layer, you can choose from a built-in set of QGIS symbols, and/or can change individual characteristics of the layer's symbology such as symbol shape, weight, color, size, opacity, and more.

   b) For a raster layer, you can change the color properties of the grid cells, as well as characteristics like brightness and contrast. The opacity/transparency of a raster layer can be changed in the Transparency tab of the Layer Properties dialog window.

5.5 Processing Toolbox

The Processing Toolbox is what makes the QGIS platform a powerful spatial data analysis tool. The Toolbox is a collection of tools and prewritten algorithms that allow the user to perform a wide variety of raster and vector data analyses. For example, the Processing Toolbox contains tools for identifying features in a vector layer that fulfill certain criteria, extracting selected features from a vector layer and saving them as a new layer, and calculating vector and raster layer statistics. The Processing Toolbox can be opened in a new panel to the right of the map view by clicking on the gear icon  in the Attributes toolbar or by going to 'View' -> 'Panels' -> 'Processing Toolbox Panel' in the menu bar.

For more in-depth information about the Processing Toolbox see: https://docs.qgis.org/3.10/en/docs/user_manual/processing/toolbox.html

5.6 Spatial Querying

Spatial querying allows the user to select specific layer features based on desired parameters, or compare features from one layer with features from another layer based on their spatial relationships or common parameters. Below we describe a specific set of steps for completing various example query and analysis tasks; however, the QGreenland user will learn through experience that there is very often more than one way to complete a desired task in the QGIS platform. We will describe several query and analysis methodologies that use the QGIS Processing Toolbox.

5.7 Examples of Simple Querying

5.7.1 Example 1: Selecting from Vector Layers for Specific Features

Which populated regions in Greenland have more than 5000 people?

1. Open the Processing Toolbox and go to 'Vector selection' -> 'Select by attribute'.

2. Fill in the following parameters:
   -Input layer = *Populated places*
   -Selection attribute = *population*
   -Operator = '>'
   -Value = type in '5000'
   -Modify current selection by = *creating new selection*
   These parameters are telling the program to identify all of the populated places in Greenland that have a population greater than 5000.

3. Click on 'Run'. The window will automatically close when processing is complete.

There are a couple of ways to view the selected data points, populated places in Greenland with more than 5000 people. First, you should see the places that meet this parameter highlighted in the map view (make sure the Populated places layer is toggled on). You can also open the Populated places layer Attribute Table and select 'Show Selected Features' in the bottom left corner. This will hide all records in the layer Attribute Table except for the ones you selected, the locations with populations greater than 5000 people.

If you want to create an entirely new layer based on this feature selection (population>5000), you can do so by either 1) right-clicking on the layer you have just selected from and choosing 'Export' -> 'Save selected features as…', or by 2) selecting 'Extract by attribute' under 'Vector selection' in the Processing Toolbox.

5.7.2 Example 2: Vector Layer Statistics

What is the total number of people in Greenland's populated areas?
What is the average size of Greenland's populated areas?

1. Open the Processing Toolbox and go to 'Vector analysis' -> 'Basic statistics for fields'.

2. Fill in the following parameters:
   -Input layer = *Populated places*
   -Field to calculate statistics on = *population*
   -Statistics = *Save to temporary file* (or whatever your preference is)

3. Click 'Run'.

The vector analysis window should automatically switch to a view of the Log where you will see the results for the population basic statistics (Fig. 8). The value 'MEAN' will tell you the average size of Greenland's populated places (1102 people). The value 'SUM' will tell you the total number of people in Greenland's metropolitan areas (48,492 people).

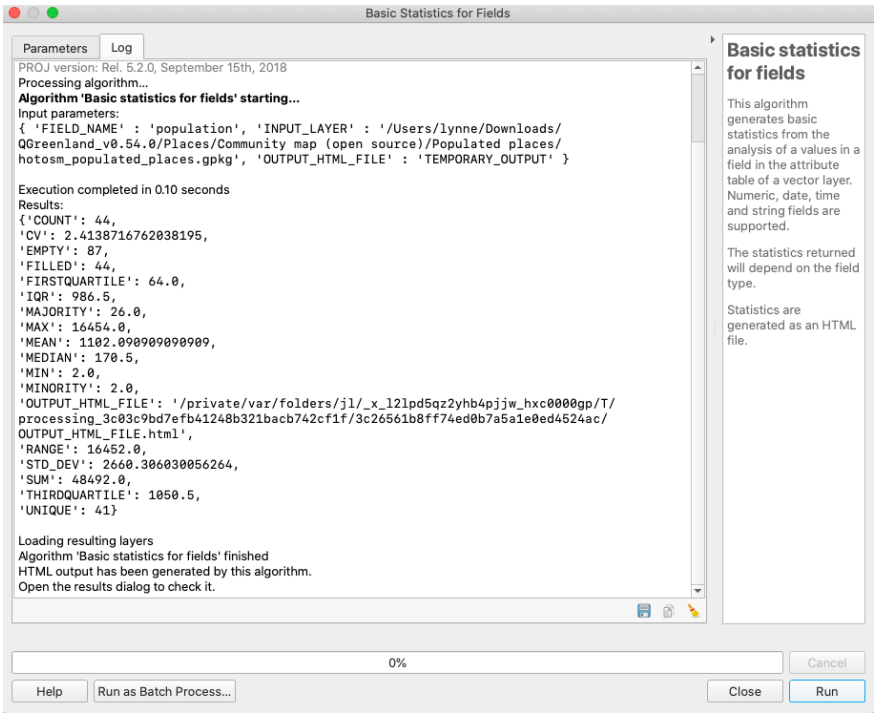

Fig. 8: Results of Example 2: Vector Layer Statistics

5.7.3 Example 3: Simple Raster Analysis

What is a good estimate of the Greenland ice sheet's volume?

1. In the Processing Toolbox, go to 'Raster analysis' -> 'Raster surface volume'. This is an algorithm that calculates the volume under a raster grid's surface.

2. Fill in the following parameters:
   -Input layer = *Ice thickness (500 m)*
   -There will only be one option for Band number
   -Base level = should already be set to 0 This is the minimum pixel value in the Ice thickness layer.
   -Method = *Count only above base level* (since we are interested in ice thickness values greater than zero)
   -Save the *Surface volume report,* the output for this algorithm, in a temporary file or in a desired location on your computer.

3. Click 'Run' and close the Raster surface volume window.

4. You should now see a panel underneath the Processing Toolbox called Results Viewer (Fig. 9), which will direct you to the location of the results html file for this calculation. Open the file.

The results file should contain three numbers: volume, pixel count, and area. The volume is the volume of the Greenland ice sheet in units of m^3. The results should show that the Greenland ice sheet has a volume of 2,947,732,015,000,000 m^3, or about 2.9 million km^3.

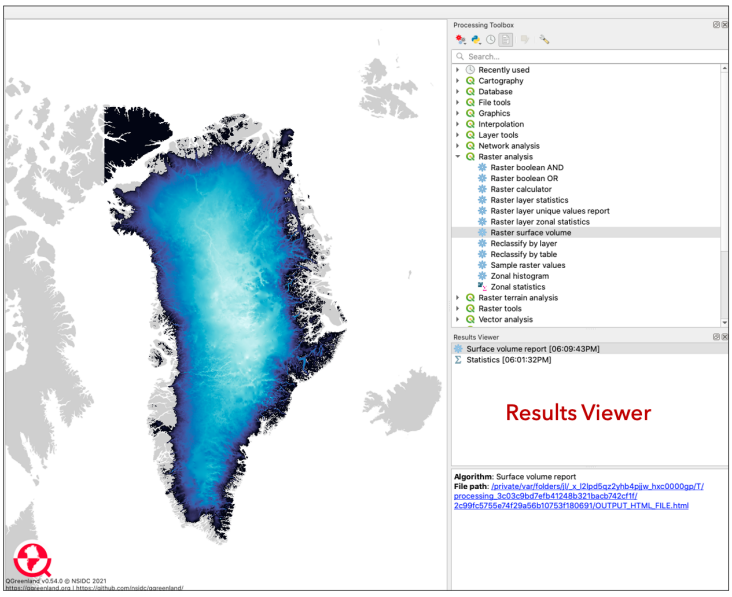

Fig. 9: To view the results of the raster surface volume analysis, click on the link next to 'File path' in the Results Viewer panel below the Processing Toolbox.

5.7.4 Example 4: Using the Raster Calculator

How does the maximum sea ice concentration (%) around Greenland and the surrounding land masses in 2020 compare to the maximum sea ice concentration a decade earlier (2010)?

The raster calculator is a tool that allows you to perform calculations on one or more raster layers. For example, if you wanted to convert a raster layer that is in km^2 to mi^2, you could use the raster calculator. In this example, we're going to use the raster calculator to subtract one layer from another. **Note:** There is a different Raster calculator that can be accessed in the menu bar by going to 'Raster' -> 'Raster calculator'. This calculator is different from the one in the Processing Toolbox used in this example:

1. In the Processing Toolbox, go to 'Raster analysis' -> 'Raster calculator'.

2. In the window that appears, you are going to build a mathematical expression using the layers and operators in the Expression box:

   a) In the Layers box, scroll down and double click on the March2020@1 layer (this is the layer for the NSIDC's sea ice concentration data from March 2020). You should see it show up in the Expression box in quotations (" ").

   b) Either type in the minus (-) symbol or click on it under Operators. It should show up after the layer you just chose.

   c) In the Layers box, scroll to and double click on the March2010@1 layer. It should show up after the minus sign, again in quotations (Fig. 10).

   d) For Reference layer, it's recommended you choose either of the two layers used in the expression. Click on the three dots […] which will open up another window and allow you to choose the reference layer by checking the box next to the layer name.

3. Click 'Run' and close the window.

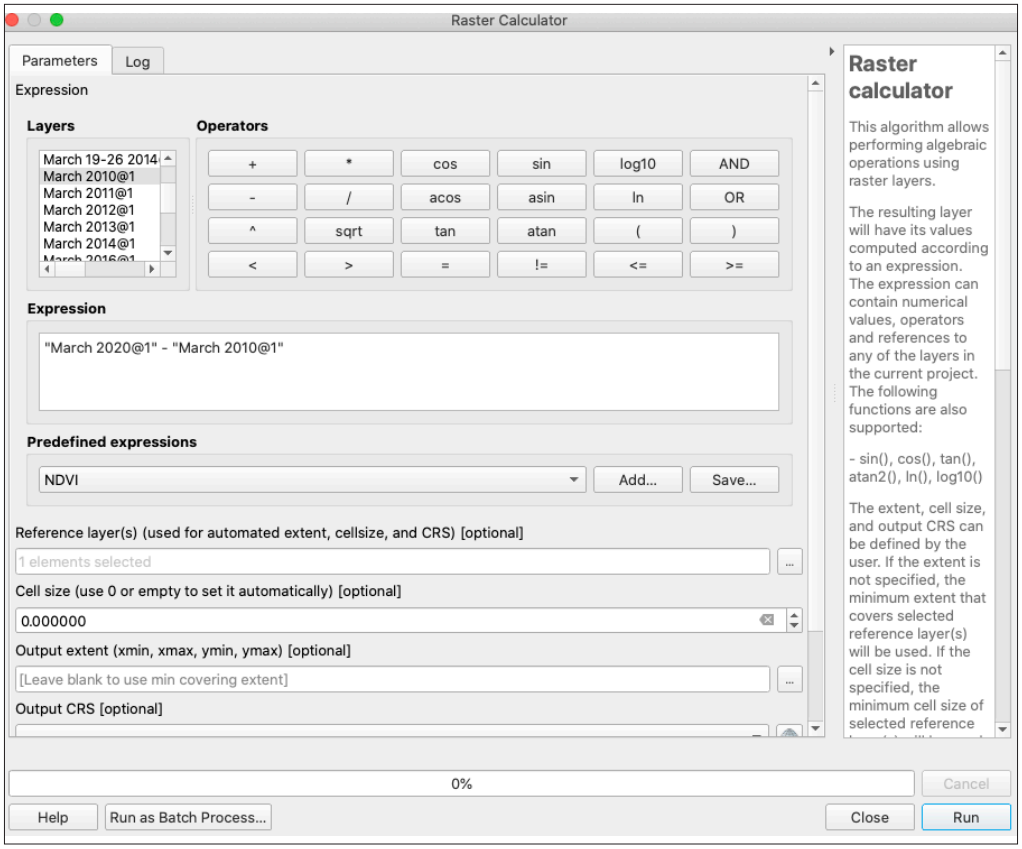

Fig. 10: The Raster calculator expression for Example 4.

The output layer will appear in the layers panel (likely named 'Output'). You can right click on it and rename it if you like. The values next to the colored boxes below the output file (likely black and white boxes) will tell you the minimum and maximum values of the resulting raster layer. In this case, the numbers will be the difference in the maximum sea ice concentration (%) between 2010 and 2020, where positive values indicate an increase between 2010 and 2020 (endmember = +80%), and negative values indicate a decrease (endmember = -95%).

6. Adding New Datasets to QGreenland

Once the QGreenland package is downloaded onto a user's computer, it is fully customizable by the user. One can add new data, delete layers within QGreenland, or make changes. Saving the project will update the ***qgreenland.qgs*** project file. If you don't want to overwrite the original project version, simply save your updated project using a new filename via 'Save As…' You can create as many different projects as you like, adding or removing data from the downloaded QGreenland package or adding data from elsewhere on your computer.

6.1 Uploading New Layers to QGreenland

To add new data layers to QGreenland:

1. In the menu bar, go to 'Layer' -> 'Add Layer', and choose the layer type you want to add. Alternatively, you can either click on the desired add layer button in the toolbar, or click on the Data Source Manager button  in the Data Source Manager toolbar.

2. Any option you choose will open the same Data Source Manager window. On the right side of the window, you can double check that the layer type you want to add is highlighted.

3. Navigate to the data file that you want to add as a layer, then click 'Add.'

6.2 Selecting for Greenland-Specific Data

Because the geographic extent of some QGreenland data layers extends beyond the geographic and political border of Greenland to include the surrounding water bodies and land masses, it might sometimes be necessary to filter out certain data if one is only interested in data within Greenland's geographic boundary. You can do this using the *Greenland coastlines 2017* polygon layer.

To filter out data outside of Greenland:

1. Make sure that the group you want the filtered/extracted data to be added to is selected/highlighted in the Layers panel.

2. Open the Processing Toolbox and go to 'Vector selection' -> 'Extract by location'.

3. Fill in the following parameters:
   -Extract features from = the data layer you want to filter, for example, *Ice cores*
   -Where the features (geometric predicate) = *are within* (you can also check intersect and others to capture data that might be located along the Greenland coastline)
   -By comparing to the features from = *Greenland coastlines 2017*
   -Extracted (location) = You can either save the file output from this as a temporary layer or as a permanent layer somewhere on your computer or within your QGreenland data package. **Note:** If you try to save the file as a GeoPackage layer (GPKG) and receive an error, try again and save it as a Shapefile (SHP) instead.

4. Click 'Run' and close the window.

The filtered data will show up in the Layers panel within the group you had selected and likely named 'Extracted (location)'. You can rename the layer by right clicking on it and selecting 'Rename Layer'.

6.3 Creating a Custom Clipping Boundary Polygon

You can create your own custom boundary polygon layer to extract features from. Follow the instructions in section 6.5: Creating New Shapefiles and GeoPackage Layers from Scratch to draw a polygon layer from scratch. Then, follow the instructions in section 6.2 Selecting for Greenland-Specific Data to extract features from your custom polygon boundary layer; however, instead of comparing features from the *Greenland coastlines 2017* layer, you will instead select the new custom boundary layer.

6.4 Editing Vector Data Layers

How do you add or delete points, line segments, or polygons to/in an existing vector layer in your QGreenland project?

To edit a vector layer:

1. Select the layer you want to edit in the Layers panel (click on it so that it is highlighted).
2. Toggle into editing mode by either right clicking on the vector layer you are editing in the Layers panel and selecting 'Toggle Editing,' or by clicking on the Toggle Editing button  in the Digitizing toolbar.
3. With Editing on, you will have access to new editing buttons in the Digitizing toolbar:
    Add new points to a point vector layer
    Add new lines to a line vector layer
    Add new polygons to a polygon vector layer
4. Whenever you create any new vector feature, you will be prompted to enter attribute information for the new feature for its record in the layer's Attribute Table.
5. If you just want to edit a record in a vector layer's Attribute Table, you can open the Attribute Table and click on the Toggle Editing icon in the table toolbar. Be sure to save the layer edits  after you're done making edits.
6. When you're finished, click on the Toggle Editing button again in the toolbar to disable editing.

6.5 Creating New Shapefiles and GeoPackage Layers from Scratch

In your QGreenland project, you may want to create a new vector layer from scratch, such as a point shapefile of potential study sites for your research in Greenland. To draw a new vector layer from scratch, you can either create a new shapefile or a new GeoPackage.

To create a new shapefile layer:

1. Go to 'Layer' -> 'Create Layer' -> 'New Shapefile Layer' in the menu bar or click on the New Shapefile Layer button  in the Data Source Manager toolbar.

2. In the new window, specify the properties of your new layer, including giving it a name, specifying its geometry (point, line, polygon) and coordinate reference system (the coordinate reference system for all QGreenland data layers is EPSG: 3413).

3. In the same window, create each field for your new layer's Attribute Table under "New Field". You will need to specify whether the new field will contain text data (string), whole number data (integer), decimal number data (real), or a date. When you click "Add to Fields List", the new field will show up in the Field List below.

4. If you have a layer group highlighted in the Layers panel when you create the new layer, the new layer will be automatically nested into the highlighted group. You can move it out of the group by right clicking on the new layer and selecting 'Move Out of Group.'

5. Once the new layer has been created, add new features to it using the processes described in section 6.4: Editing vector data layers.

To create a new GeoPackage layer:

1. In the menu bar, go to 'Layer' -> 'Create Layer' -> 'New GeoPackage Layer' or click on the New GeoPackage Layer button  in the Data Source Manager toolbar.

2. A GeoPackage is a GIS file format that allows you to save multiple layers in one file; thus, you will actually be creating a new GeoPackage database that your new GeoPackage layer will live in. In the new window:

   -Name your new Database
   -Name the new GeoPackage layer you are creating - this is the 'Table name'
   -Specify the geometry of the new GeoPackage layer (point, line, etc.)
   -Specify the layer coordinate reference system
   -Create the fields that will be in the layer's Attribute Table by giving them a name and indicating their type (text data, integer, etc.) under 'New Field'. When you click on 'Add to Fields List', the new field will show up in the Fields List box.

3. Click 'Ok'. Your new layer will appear in the Layers panel. If it is within another Group you do not want it in, right click on it and select 'Move Out of Group.' You can also drag and drop your layer into the location you want it.

In addition to shapefiles and GeoPackages, there are additional new layer types that can be created also, such as SpatialLite Layer and Virtual Layer. Descriptions for all layer types can be found in Appendix A: Defined Terms.

6.6 Importing GPS and other GNSS Data Using the GPS Plugin

Importing GPS (Global Positioning System) or other GNSS (Global Navigation Satellite System) data into QGIS requires an internal plugin. A plugin is just a new feature or function that you can add to QGIS that does something one of the built-in tools doesn't do. Many plugins are 'external' meaning they are not developed and maintained by the QGIS development team. Some plugins, however, are 'core' meaning they are maintained by the QGIS team. The GPS plugin is a core plugin and should already be installed in your version of QGIS.

To turn on the GPS plugin:

1. Go to 'Plugins' -> 'Manage and Install Plugins' in the menu bar.
2. Click on 'Installed' in the left sidebar, then check the box next to 'GPS Tools' in the plugin list. If it is already checked, don't change anything.
3. Click 'Close'.

You can import GPS data either directly from a GPS device that is connected to your computer, or from a file on your computer. Note that QGIS uses the GPX file format for GPS data, although you can import GPS data that is not GPX (see #2c below).

To import GPS or GNSS data using the GPS plugin:

1. Go to 'Vector' -> 'GPS Tools' in the menu bar.
2. In the window that pops up, click on the tab most appropriate for the data you want to import.

   a) If you are importing GPS data from a file on your computer, click on the 'Load GPX file' tab and navigate to the file on your computer. Indicate which feature types you want to load from the file (waypoints, routes or tracks), then click 'Ok'. Each feature type you selected will be loaded in a separate layer.

   b) If you want to import data directly from a GPS device, click on the 'Download from GPS' tab.

      i) Select the GPS device you are importing from, the port the device is connected to, and what feature types you want to download.

      ii) Give the data a layer name, which is what it will show up as in the Layers panel.

      iii) The output file is where the downloaded data from your device will be stored on your computer. Click 'Ok'. The data should appear as a new layer in the Layers panel.

   c) To import GPS data that is not in the GPX file format, click on the 'Import other file' tab and fill in the relevant information.

7. Creating a Map for Print or Publication

7.1 Print Layout

Once you've created a map in the QGIS map view that you would like to print or publish, you need to switch to the QGIS print layout, where you will be able to create and customize your map.

To create a map for print or publication:

1. Go to 'Project' -> 'New Print Layout' or click on the New Print Layout button  in the Project toolbar. You will have the option to name your new print layout.
2. When the print layout window opens, it will be initially blank. To change the size and orientation of your print layout, right click in the layout area and choose 'Page Properties.'
3. To add a map to your layout, click on the Add Map button  and click and drag to create a box where the map will appear on the print layout display. To zoom in on the region shown in the box or change what region is shown, you can click on the Move Item Content button  , which will make it possible to manipulate the map area within the box.
4. Add map components such as a north arrow, scale bar, legend, or image to your print map by either using the appropriate buttons in the Toolbox toolbar or by going to 'Add Item' in the menu bar.

For more detailed information on creating a map for print or publication, see https://docs.qgis.org/3.10/en/docs/training_manual/map_composer/map_composer.html

8. Frequently Asked Questions and Troubleshooting

8.1 What if I can't see any data layers in the map view?

Double check that the layer(s) you wish to view in the map view are checked on in the Layers panel. **Note:** Toggling on a main Layer Group won't necessarily toggle on all individual layers within the group. Right click on a layer you wish to view and select 'Zoom to Layer', or click on the Zoom Full button  in the Map Navigation toolbar to zoom to the full extent of the QGreenland data layer package.

8.2 Why can't I find the buttons or toolbars referred to in the user guide?

Right click on the toolbar area in the QGIS interface and check the toolbars you wish to turn on so that they are displayed. You can also go to 'View' -> 'Toolbars' in the menu bar.

8.3 Why can't I see a layer in the map view even though it is turned on and I've zoomed to the layer?

Double check that there isn't another layer overlaying and thus obscuring the layer you want to see in the map view. Remember that layers are displayed in the map view in the order that they are listed in the Layers panel - layers listed at the top in the Layers panel show up on top in the map view. You can either turn off any layer that might be obscuring the layer you wish to see by unchecking it in the Layers panel, or rearrange the order of layers by clicking and dragging them up or down in the Layers panel.

8.4 Navigating QGIS errors

If you are opening QGIS using a terminal or using the QGIS Python console, it is possible you might see one of a few different error messages while using QGIS that the QGreenland team has determined can be ignored:

Warning: Logged warning: Creating Warped VRT
This error message is likely triggered by a raster layer in the QGreenland project but should not have any impact on the data layers or project usability.

ERROR: Too many connections: max 64
This error is thought to be related to the GeoPackage file format but should not have any impact on the layers themselves or the project usability.

8.5 How do I contact the QGreenland team?

If you have feedback on or questions about the QGreenland data package or want to contribute datasets for future QGreenland releases, you can send an email to: qgreenland.info@gmail.com

Note: This list of QGreenland FAQs will be frequently updated on the QGreenland website - for a more up-to-date list of FAQs, go to https://qgreenland.org.

9. Appendices

9.1 Appendix A: Defined Terms

- **Attribute:** Information about the components of a vector layer listed in tabular form. For example, a possible attribute of a point vector layer of cities is city name or population.
- **Coordinate Reference System (CRS):** The system used to reference the x and y coordinates of a dataset.
- **Layer:** A set of data and its symbology.

  -***GeoPackage Layer***: A collection of one or more data layers, including points, lines, and polygons, that are saved as a single file. A GeoPackage layer is an open format and platform-independent using SQLite.

  -***Shapefile Layer:*** A proprietary vector layer format (points, lines, polygons) developed and regulated by Esri, but usable in QGIS.

  -***SpatialLite Layer***: A way to store an entire spatial database in one file; a spatial extension to SQLite, a relational database management system.

  -***Temporary Scratch Layer:*** A temporary layer formed as a result of a spatial query of analysis that is discarded when QGIS is closed.

  -***Virtual Layer:*** A specific kind of vector layer that results from an SQL query.
- **Layer Group:** A collection of multiple layers that are related to one another.
- **Raster:** A layer type consisting of grid cells or pixels, where each cell has a specified value.
- **Vector:** A layer type consisting of either points, lines, or polygons, where each point, line, or polygon has a unique set of attribute values.