QGreenland Documentation

Release v2.0.0

Twila Moon, Matt Fisher, Hope Simonoko, Trey Stafford

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CONTENTS

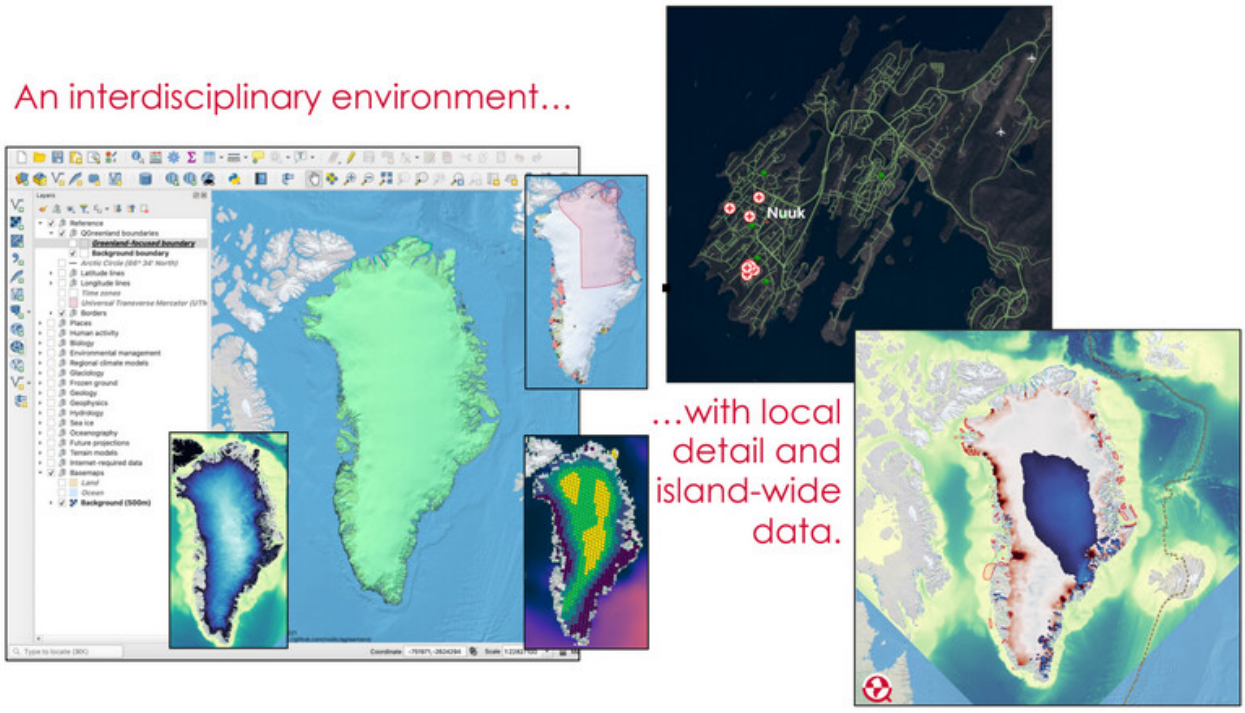
Part I

Introduction

CHAPTER

ONE

WHAT IS QGREENLAND?



QGreenland is a free and open-source Greenland-focused GIS environment for data analysis and viewing, powered by QGIS[1]. QGreenland is delivered in two ways:

1. **QGreenland Core**: a large Zip package containing a core set of data curated to serve the majority of users. This documentation page is about QGreenland Core.
2. **QGreenland Custom (beta)**: a QGIS plugin for downloading a custom set of data, including data which is not part of the QGreenland Core zip package (for example, due to filesize constraints). QGreenland Custom has its own documentation[2].

Return to QGreenland website[3]

[1] https://qgis.org
[2] https://qgreenland-plugin.readthedocs.io
[3] https://qgreenland.org

CHAPTER

TWO

WHAT QGREENLAND *IS NOT*

- The QGreenland project is not a data-production project. While we do process existing data, it is only to enable efficient and effective viewing in the QGreenland QGIS environment.
- QGreenland is not a navigational aid.

CHAPTER

THREE

ABOUT QGIS

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[4] GIS data package for Antarctica.

[4] https://www.npolar.no/en/quantarctica/

CHAPTER

FOUR

QGREENLAND CORE DOWNLOAD PACKAGE

You will find the following files in the v2.0.0 QGreenland Core 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 Core 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 Core User Guide
- **QuickStartGuide.pdf** - A one-page overview guide for experienced QGIS users on how to download the QGreenland Core data package and other information
- **STYLE.txt** - Guidelines and standards for QGreenland data layer styling
- **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 Core v1.0.0 is the first stable public release version from this project. The QGreenland Core v2.0.0 download package was released in March 2022. Development versions along the way will continue to be available via the website[5], with code fully documented on GitHub[6].

Although the v2.0.0 download package contains a full User Guide, updates and additions are constantly being made to our documentation as we continue to develop QGreenland. The most recent version of QGreenland documentation will always be available here on Read the Docs.

[5] http://qgreenland.org
[6] https://github.com/nsidc/qgreenland

CHAPTER

FIVE

CITING QGREENLAND CORE AND CUSTOM

We request that the QGreenland project be cited or acknowledged when publishing a QGreenland-made image or map.

QGreenland development is open source and available on GitHub[7]. 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 Contributor How-to section on Readthedocs.

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 the Layer Properties section in the Interacting with Geospatial Data tutorial 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.

5.1 Citation

Suggested citations for QGreenland:

Version 1.0: Moon, T., Fisher, M., Harden, L., and T. Stafford (2021). QGreenland (v1.0.0) [software], National Snow and Ice Data Center[8].

Version 2.0: Moon, T., Fisher, M., Harden, L., Simonoko, H., and T. Stafford (2022). QGreenland (v2.0.0) [software], National Snow and Ice Data Center[9].

[7] https://github.com/nsidc/qgreenland
[8] https://qgreenland.org/
[9] https://qgreenland.org/

5.2 Acknowledgement

We acknowledge the National Snow and Ice Data Center QGreenland package.

CHAPTER

SIX

ACKNOWLEDGEMENTS

The QGreenland project team acknowledges the following people, organizations, and projects for making our work possible and enjoyable.

6.1 Prior art

The Quantarctica[10] project inspired QGreenland. Our innovation on this prior work is open-source and reproducible package creation. Thank you!

6.2 Funding

The U.S. National Science Foundation grant #1928393[11] funded the development of QGreenland versions `1.x` and `2.x`. Thank you!

6.3 Editorial board

The QGreenland Editorial Board[12] made it possible for QGreenland to cover a wide variety of scientific disciplines at high quality. Thank you!

6.4 Open-source software

QGreenland would not have been possible without the following open-source projects. This is not an exhaustive list – if your project is listed in our `environment-lock.yml` file, thank you!

- QGIS[13]
- cmocean[14]
- Python[15]
- Luigi[16]

[10] https://www.npolar.no/en/quantarctica/
[11] https://nsf.gov/awardsearch/showAward?AWD_ID=1928393
[12] https://qgreenland.org/our-team
[13] https://www.qgis.org/
[14] https://github.com/matplotlib/cmocean
[15] https://www.python.org
[16] https://github.com/spotify/luigi

- GDAL[17]
- Docker[18]

6.5 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.

[17] https://gdal.org
[18] https://www.docker.com/

Part II

Tutorials

CHAPTER

SEVEN

GET STARTED WITH QGREENLAND CORE

By completing this tutorial, the user will install QGIS, download and open the QGreenland Core data package, become familiar with the QGIS interface, and browse some data included in QGreenland.

7.1 System Requirements

Before downloading the QGreenland Core 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 3.16 is the oldest version supported by QGreenland.

7.2 1) Download and Install QGIS

Go to qgis.org[19] and download the free QGIS software, available on Windows, macOS, Linux and Android. It is recommended to download the long term release (3.16 or later) version.

7.3 2) Download and open the QGreenland Core package

Download the QGreenland Core data package (v2.0.0) at https://qgreenland.org/download.

Save the zip package to a location of your choice and unzip it. Open the `qgreenland.qgs` file in the data package folder by double-clicking it. QGIS will open automatically and display the QGreenland Core data environment.

Note: Depending on your version of QGreenland Core, the package may be a `.qgs` or a `.qgz` file. They should function the same as long as you have a compatible version of QGIS.

Note: If QGIS is already open, one can open the `qgreenland.qgs` project file within QGIS by navigating to the **"Project >Open..."** option in the menu bar and selecting the `qgreenland.qgs` file from its saved location.

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[19] https://qgis.org

7.4 3) Get to know the QGIS Interface

In this user guide you will see various screenshots of the QGreenland Core and QGIS interface. The screenshots in this guide were generated from QGIS version 3.16 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 **Map view**, **Status bar**, **Layers panel**, **Toolbars**, and the **Menu bar**.

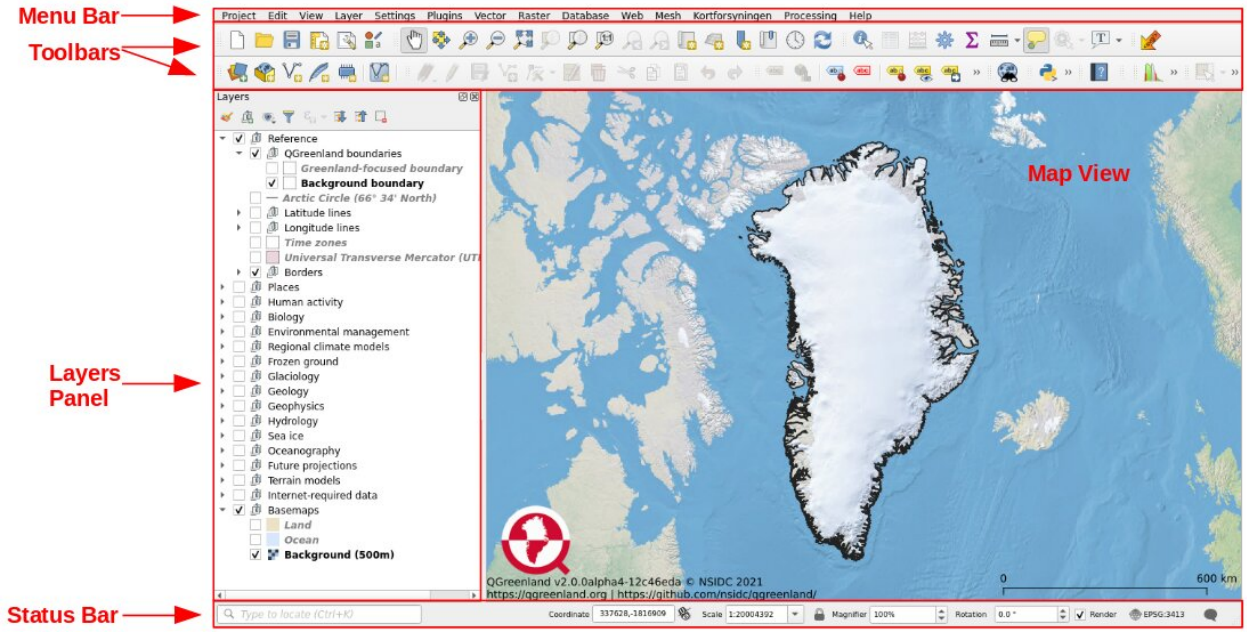


Fig. 1: Main components of the QGIS/QGreenland interface

The **Map View** is the main part of the QGIS/QGreenland Core 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.

The **Status bar** is the bar at the bottom of the QGIS window that shows the current coordinate reference system of the **Map View**, any available plugin updates, and the **Map view scale**. Also included in the **Status bar** is a quick search bar and a button to open a **Log Messages** window to view log messages.

The **Layers Panel** is where all data layers in the current project are listed. Layers can be toggled on or off, which will control whether or not they show up in the **Map View**. Layers are listed in the order in which they show up in the **Map View** - layers at the top of the list show up on top in the **Map View**, and vice versa. Layers can be manually moved around in the **Layers Panel** to change the order in which they show up. **Panels** and **Toolbars** can also be manually moved around the QGIS interface to fit the user's preferences.

When you first open the QGreenland Core 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.

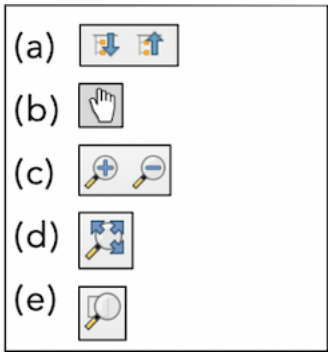


Fig. 2: (a) Buttons above **Layers Panel** to expand or collapse layers; (b) hand button to grab and drag the map view; (c) magnifying glass buttons to zoom in or out in map view; (d) Zoom Full button to bring all visible layers into **Map View**; (d) Zoom to Layer button to bring a desired layer into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

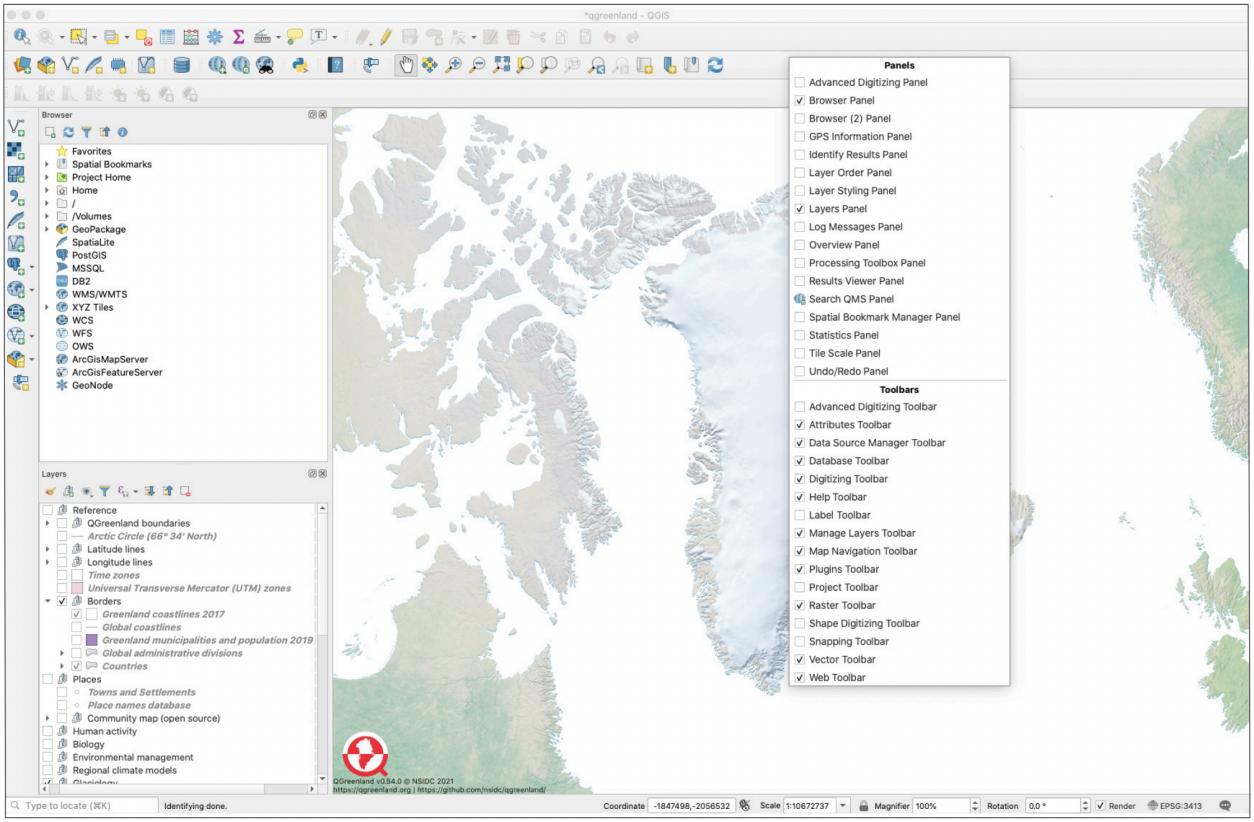


Fig. 3: **Toolbars** can be added or removed by right clicking on the toolbar area and checking/unchecking boxes.

Lastly, the **Menu bar** and **Toolbars** are different ways to access most QGIS functions, such as opening or saving a

project or analyzing the data using geoprocessing tools. **Panels** are another way for users to interact with data layers and functions in QGIS. 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.

Note: The QGIS User Manual[20] provides a detailed and comprehensive overview of QGIS' core features. Users who are new to Geographic Information Systems may also benefit from reviewing QGIS's Gentle Introduction to GIS[21]

7.5 4) Browse data in the QGreenland project

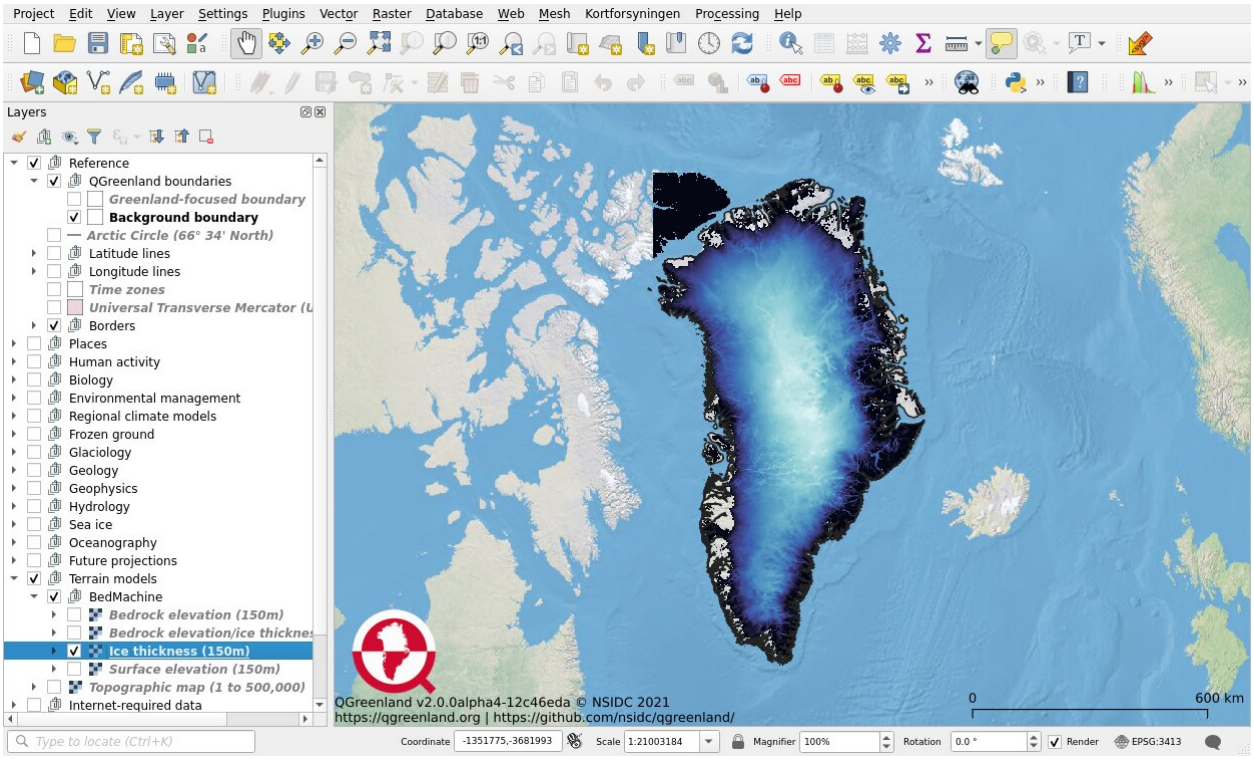
Layers in QGreenland Core are organized into groups by category. For example, the "Background boundary" layer is "QGreenland boundaries" group, which is itself inside of the "Reference" group ("Background boundary/Reference").

7.5.1 Toggle layer visibility

Some layers are turned on by default when opening the QGreenland Core project. In order to visualize another data layer (or remove an existing one), toggle the checkbox next to the layer in the **Layers panel**.

Toggle on the "Ice thickness (150m)" layer, which is in the "Terrain models/Bedmachine" group. The **Map view** should now include a visualization of Ice thickness at a 150m spatial resolution.

[20] https://docs.qgis.org/3.16/en/docs/user_manual/index.html
[21] https://docs.qgis.org/3.16/en/docs/gentle_gis_introduction/index.html



Note: The search bar, located in the **Status bar**, can also be used to find layers in the **Layers panel**.

7.5.2 Navigate the Map View

The **Map view** can be interacted with using a combination of the mouse and the **Map Navigation Toolbar**

By default, the **Pan Map** tool is selected  . This tool allows the user to click and drag on the map view to change the extent. Try using this tool to pan around the map and explore the geography surrounding Greenland.

The zoom tools  can be used to zoom in and out of the map view. Select the **Zoom In** tool and use it to draw a box around southern Greenland to get a better look at the "Ice thickness (150m)" layer in that part of Greenland. Now select the **Pan Map** tool again and explore the layer in detail.

Note: The scroll wheel on your mouse or track pad can also be used to zoom in and out in the **Map view**

Hovering over the other map navigation tool icons will provide a tool tip indicating what the tool is used for. Try hovering over some of the other icons in the **Map Navigation Toolbar** to read their tooltips. Try out some of these other tools to explore the map and QGreenland's various data layers. See the QGIS documentation on zooming and panning[22] for more detailed information on how to effectively navigate the **Map View**.

7.6 5) Summary

In completing this tutorial, the user has installed QGIS, downloaded and opened the QGreenland Core data package, and learned about the fundamentals of using QGIS to explore QGreenland. Having accomplished this, the user is prepared to explore the many data layers included with QGreenland Core. The user is now ready to approach more advanced topics such as performing geospatial analyses and preparing publication-quality maps with the data in QGreenland Core.

[22] https://docs.qgis.org/3.16/en/docs/user_manual/introduction/general_tools.html#zooming-and-panning

CHAPTER

EIGHT

CALCULATE THE VOLUME OF THE GREENLAND ICE SHEET

The **Processing Toolbox** in QGIS provides a collection of tools and pre-written algorithms that allow the user to perform a wide variety of raster and vector data analyses. See the QGIS manual[23] for complete documentation on the **Processing Toolbox**.

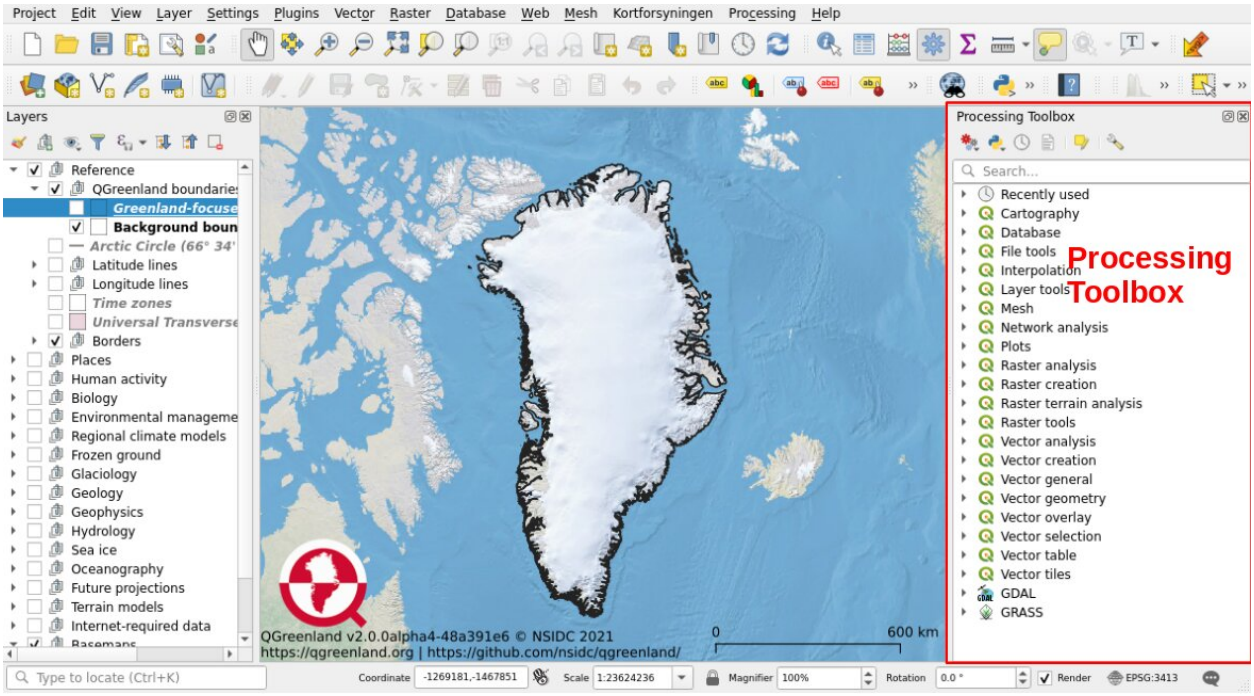
In this tutorial, the user will utilize the **Processing Toolbox** with data in QGreenland to calculate the Greenland ice sheet's volume. In doing so, the user will become familiar with the how to use the **Processing Toolbox** to perform geospatial analysis.

Warning: This tutorial assumes the user has a basic understanding of GIS and geospatial data models (e.g., the difference between raster and vector data). If one if new to GIS, it is reccomended to review QGIS' Gentle Introduction to GIS[24] first

8.1 Open the Processing Toolbox

The **Processing Toolbox** can be opened from the menu bar by selecting **"View>Panels>Processing Toolbox"**. This will open a new panel with a variety of processing tools organized into groups.

[23] https://docs.qgis.org/3.16/en/docs/user_manual/processing/toolbox.html
[24] https://docs.qgis.org/3.16/en/docs/gentle_gis_introduction/index.html



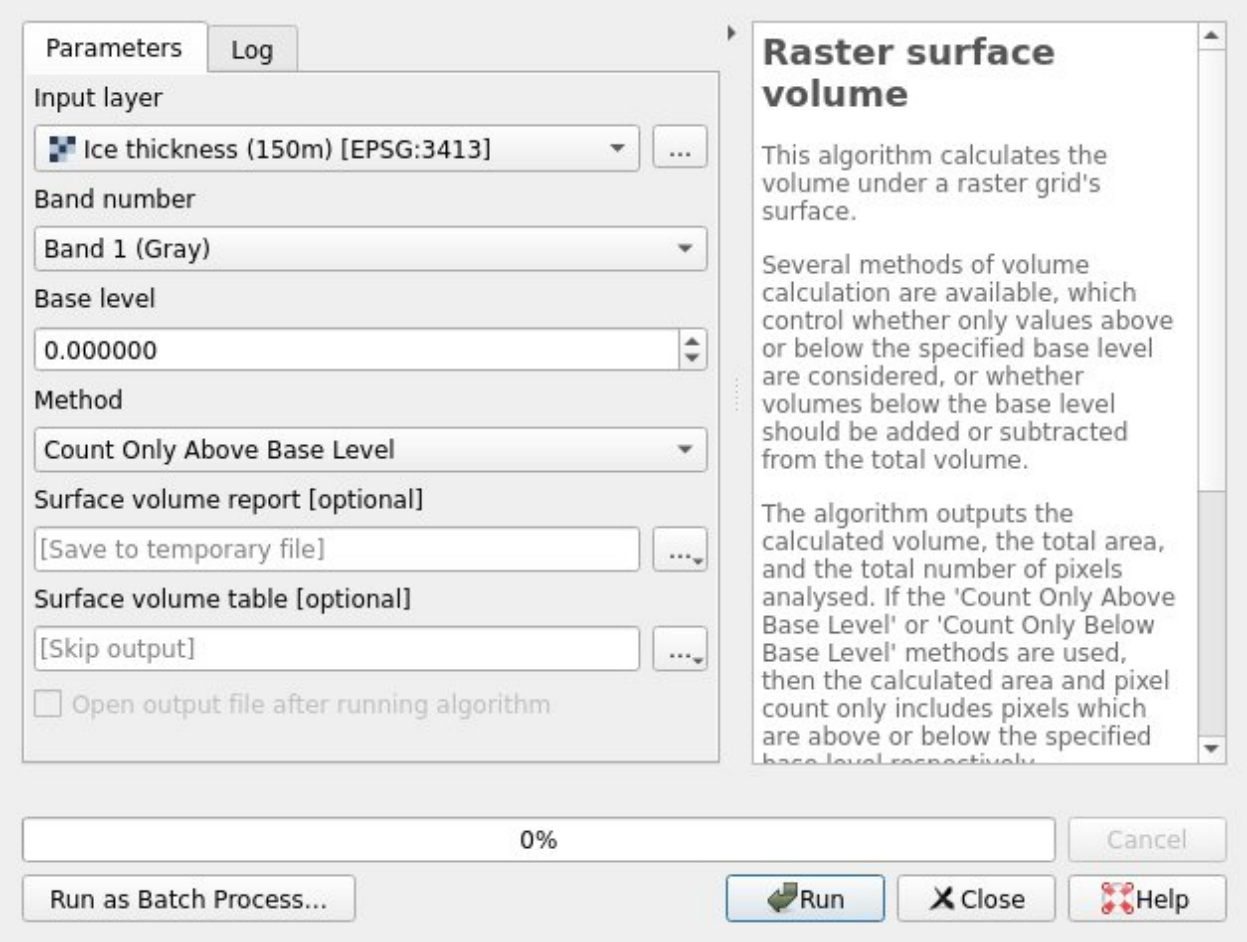
Note: The **Processing Toolbox** can also be opened by clicking on the gear  icon in the **Attributes Toolbar**

.

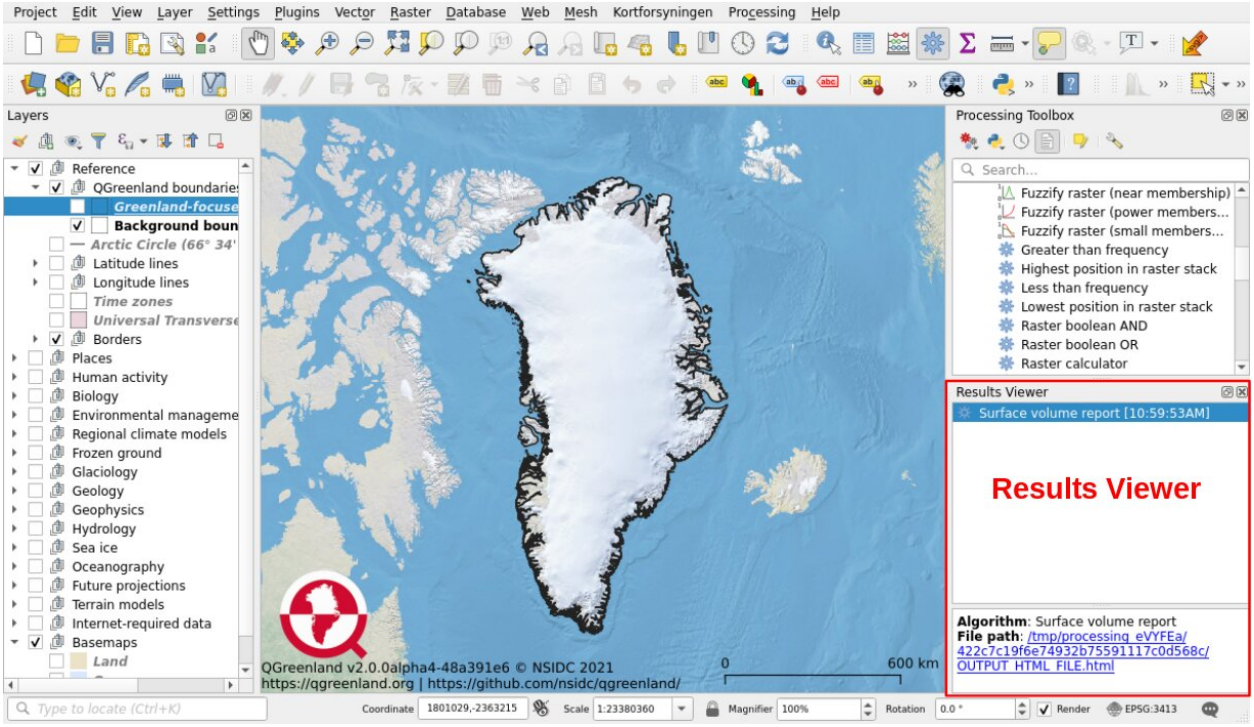
8.2 Use the Raster Surface Volume tool

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. Double-click **"Raster surface volume"** to open the tool's window, and enter the following parameters:

- **Input layer** = Ice thickness (150 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 one's computer.



Click "Run" and wait for the analysis to finish. The window will switch to the "Log" tab, which shows log messages and results for the run. A **Results Viewer** panel should open in a panel underneath the **Processing Toolbox**. Close the Raster surface volume tool's window and click on the "Surface volume report" entry in the **Results Viewer**. This will show a link to a results HTML page that can be opened in your broswer. Open this file and review the results.



The **results file** will contain information from the run, including which file was analyzed, the calculated volume, pixel count, and total area. If one has succuessfully run the analysis, the results should show that the Greenland ice sheet has a volume of 2,942,360,633,311,806 m3, or about 2.9 million km3.

8.3 Summary

In completing this tutorial, the user has become familar with the **Processing Toolbox** and has successfully utilized the Raster Surface Volume tool with ice sheet thickness data included in the QGreenland core package to calculate the volume of the Greenland ice sheet. Having accomplished this, the user is now ready to explore other geospatial processing tools included in the **Processing Toolbox** to further analyze other QGreenland data.

CHAPTER

NINE

CREATE A LAYOUT FOR PRINT OR PUBLICATION

QGIS is a powerful data viewing and analysis platform, but it is also capable of creating publication-quality maps for print or publiction. This tutorial covers the basics of creating a new print layout in QGIS, adding a map and map elements to that layout, and exporting the resulting layout as an image.

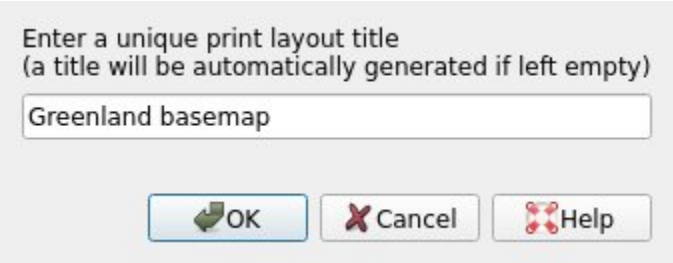
See the QGIS manual[25] for complete documentation on print layouts in QGIS.

9.1 Creating a new print layout

Once one has created a map in the **QGIS map display** that one would like to print or publish, one needs to switch to the **QGIS print layout**. Select **"Print Layout"** from the "Project" menu.

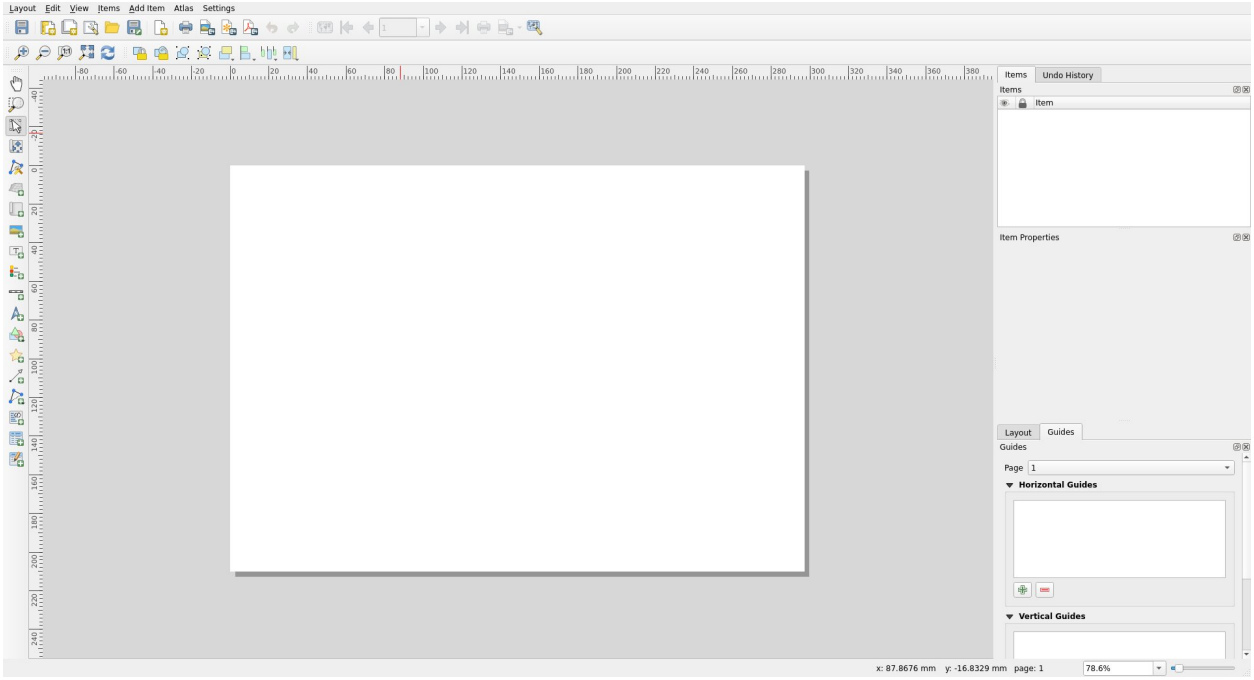
Note: The **Project Toolbar**  also contains a button () that creates a new **Print Layout**.

First, name the new print layout after the figure you plan to create and click **"OK"**.



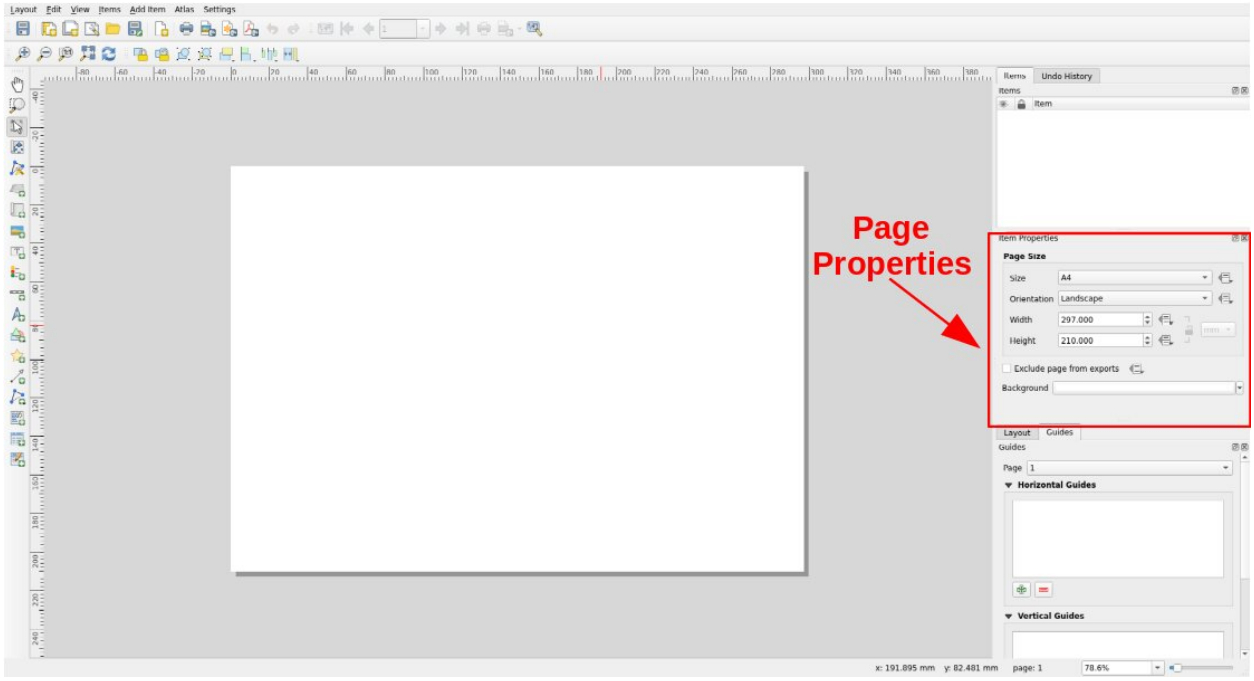
When the print layout window opens, it will be initially blank.

[25] https://docs.qgis.org/3.16/en/docs/training_manual/map_composer/map_composer.html



9.2 Changing the print layout's properties

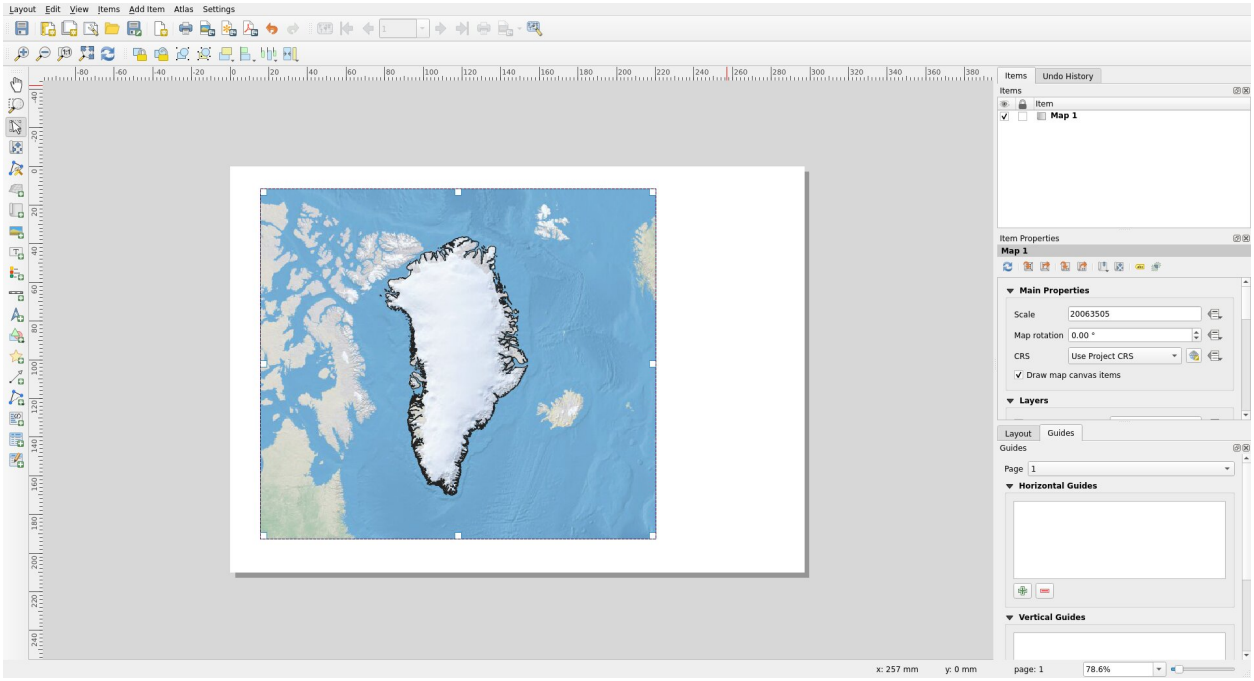
To change the size and orientation of your print layout, right click in the map area and choose **"Page Properties"**. This will add page size options to the **Item Properties** panel on the right side of the screen.



9.3 Adding a map and other elements

The print layout will allow you to add features to your map such as a title, legend, north arrow, scale bar, pictures, etc by interacting with the buttons in the **Toolbar** on the left of the screen.

To add a map to your layout, click on the **Add Map** button  . Click and drag to create a box where the map will appear on the print layout display.



To zoom into the region shown in the map or change the extent, click on the **Move Item Content** button  , which will make it possible to manipulate the map area within the box.

Now explore some of the other buttons included in the map layout Toolbar. Add a north arrow and scale bar. Finally, once one is happy with the layout, try exporting the layout as an image by opening the **"Layout"** menu and selecting **"Export as Image"**.

9.4 Summary

In completing this tutorial, the user has created a new print layout, added a map and other elements to the layout, and exported the layout as an image. This image can now be utilized in publications or printed to physical media (e.g., a poster).

CHAPTER

TEN

INTERACTING WITH GEOSPATIAL DATA IN QGREENLAND CORE

10.1 Spatial Data Overview

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

10.1.1 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.

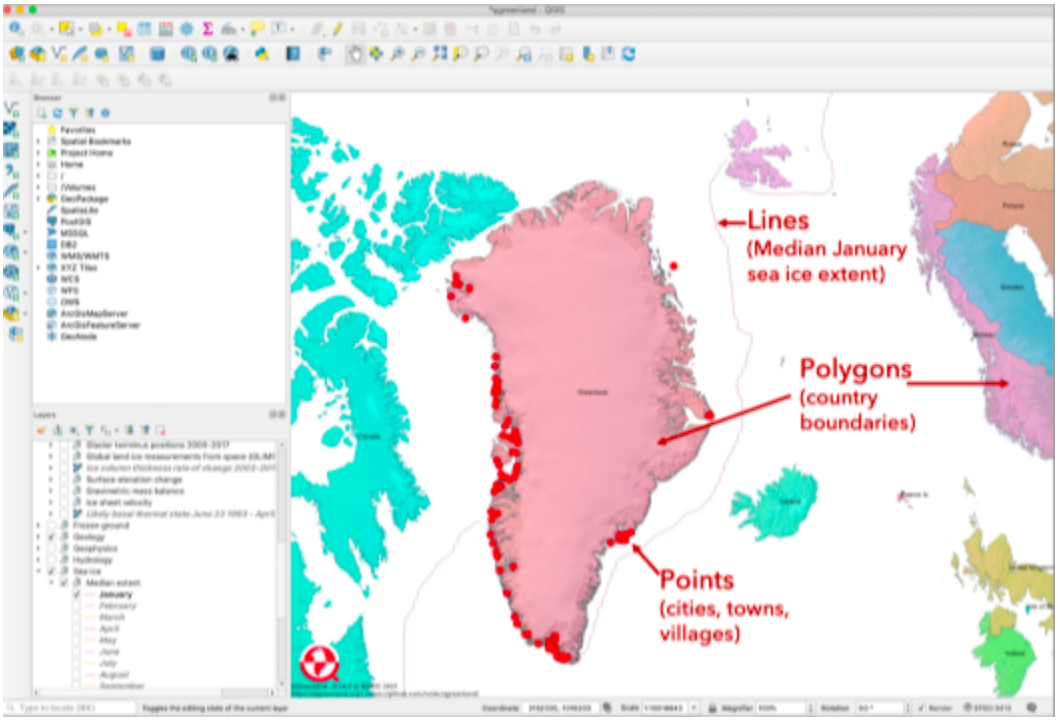


Fig. 4: Examples of **Vector** data layers in QGreenland Core: Points (towns and settlements), lines (median January sea ice extent), and polygons (country boundaries).

10.1.2 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'.

10.1.3 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.

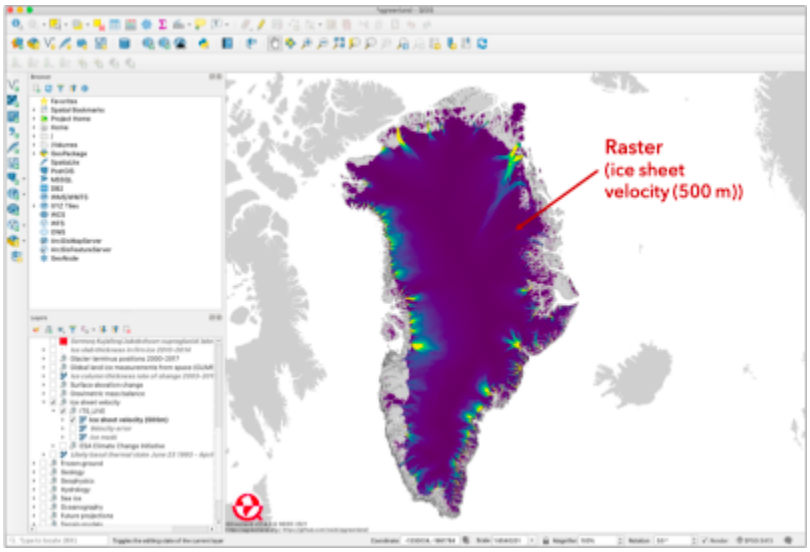


Fig. 5: Example of a **Raster** data layer in QGreenland, ice sheet velocity, where each grid cell in the raster is 500 m x 500 m and is color-coded by a velocity

10.2 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 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.

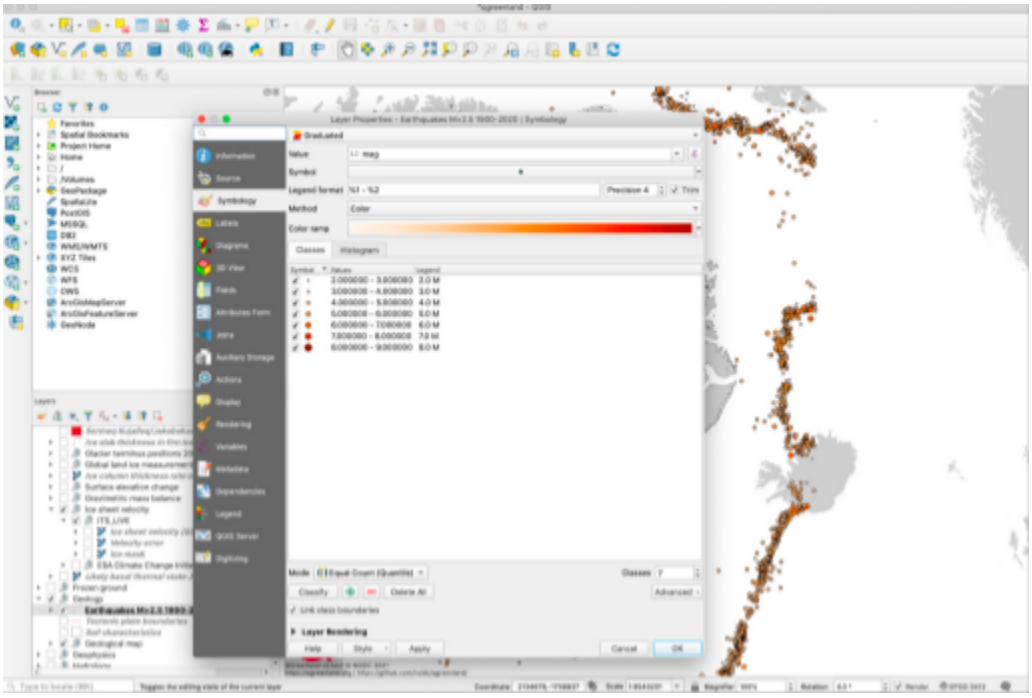


Fig. 6: The **Layer Properties** dialog window for the QGreenland 'Earthquakes' data layer

10.3 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 underlying data, though QGIS will do on-the-fly reprojection of layers not in the selected CRS. 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.

10.3.1 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**.

10.3.2 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.

10.4 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**.

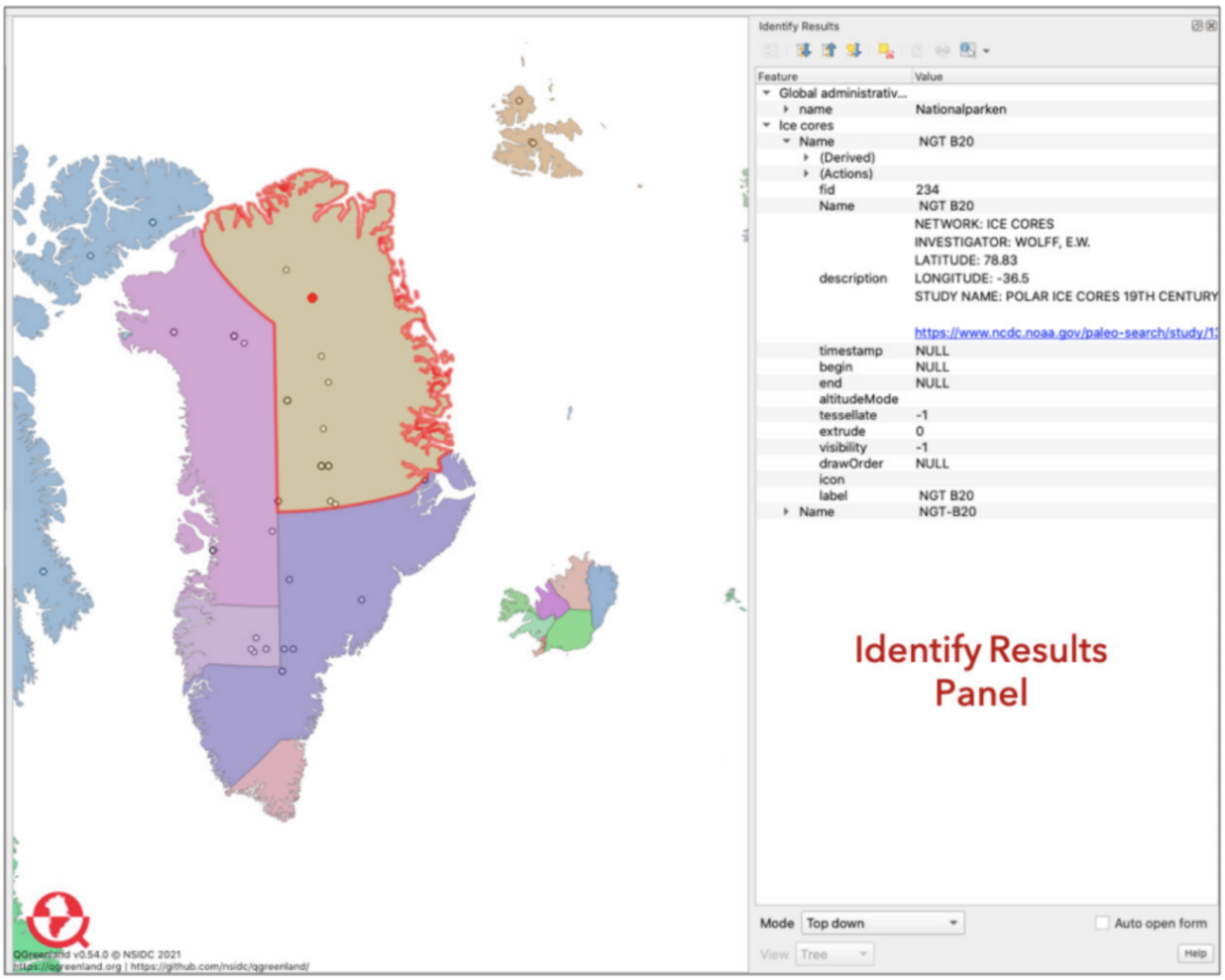


Fig. 7: The **Identify Results Panel** that shows results from the **Identify Features** tool.

10.5 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.

10.6 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**.

10.7 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.

10.8 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 the QGIS User Manual[26]

[26] https://docs.qgis.org/3.16/en/docs/user_manual/processing/toolbox.html

10.9 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**.

10.9.1 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**.

10.9.2 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).

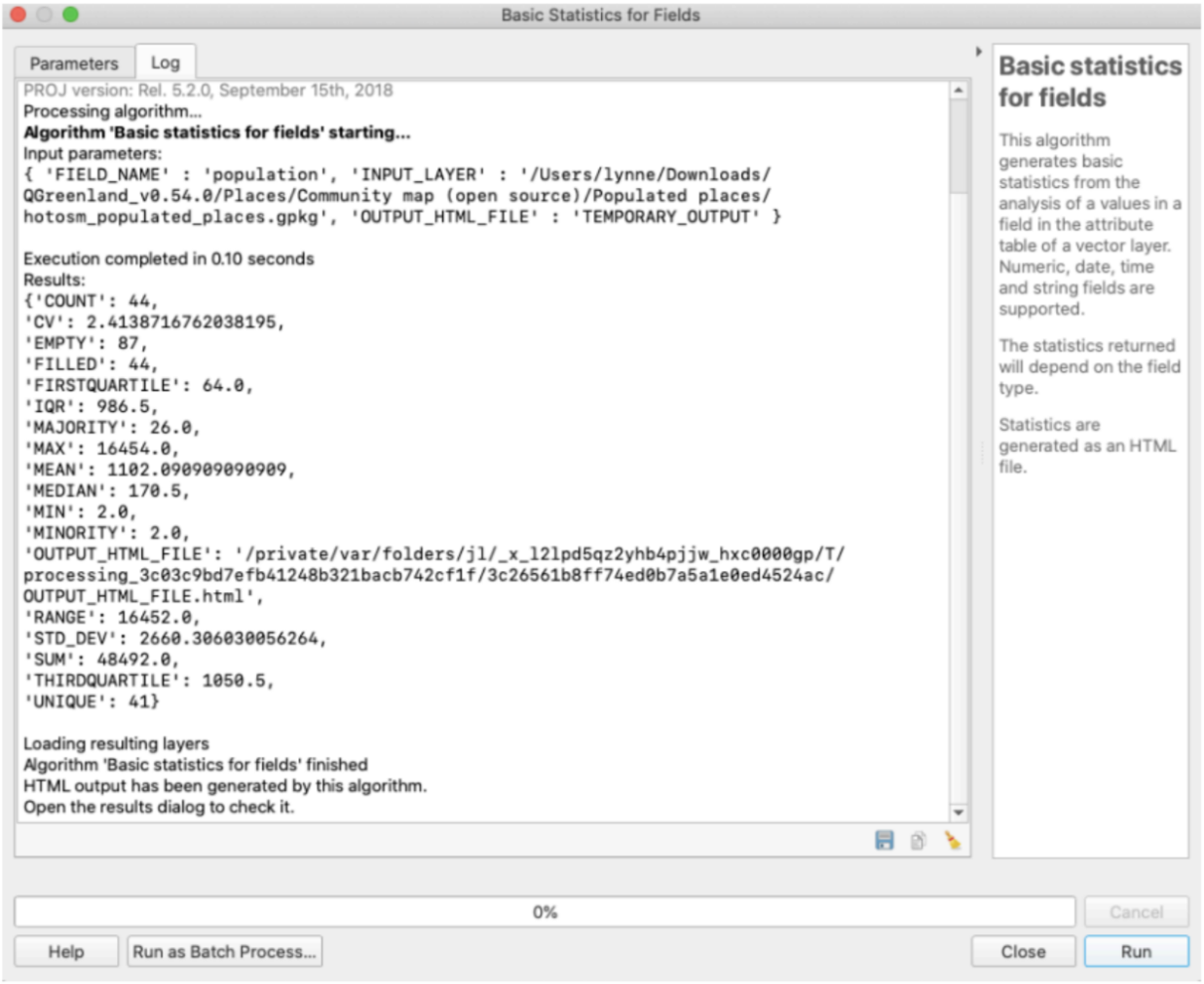


Fig. 8: Results of Example 2: Vector Layer Statistics

10.9.3 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 (150 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 m3. The results should show that the Green- land ice sheet has a volume of 2,942,360,633,311,806 m3, or about 2.9 million km3.

10.9.4 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 km2 to mi2, 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.

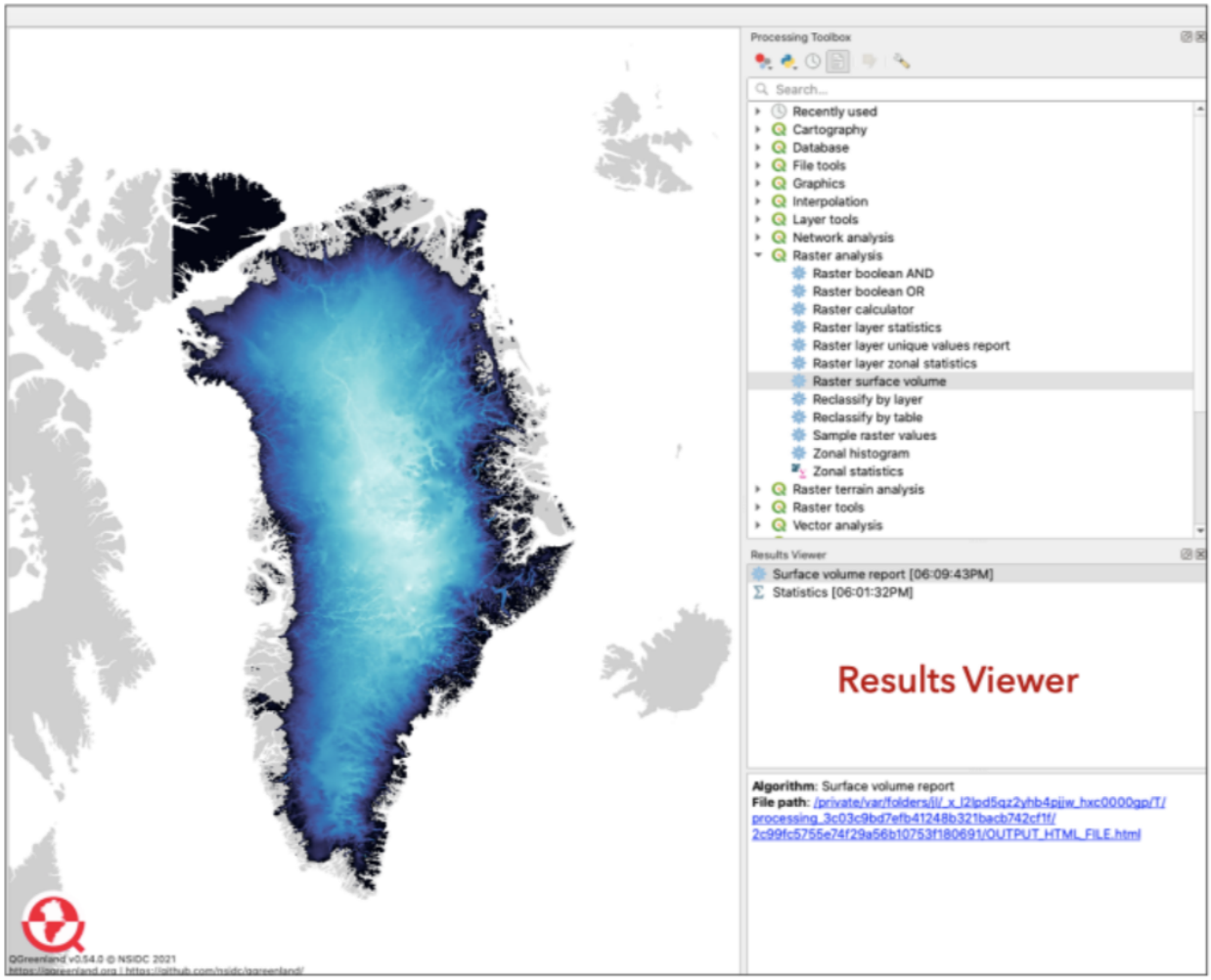


Fig. 9: To view the results of the **Raster** surface volume analysis, click on the link next to 'File path' in the **Results**

Viewer Panel below the **Processing Toolbox**.

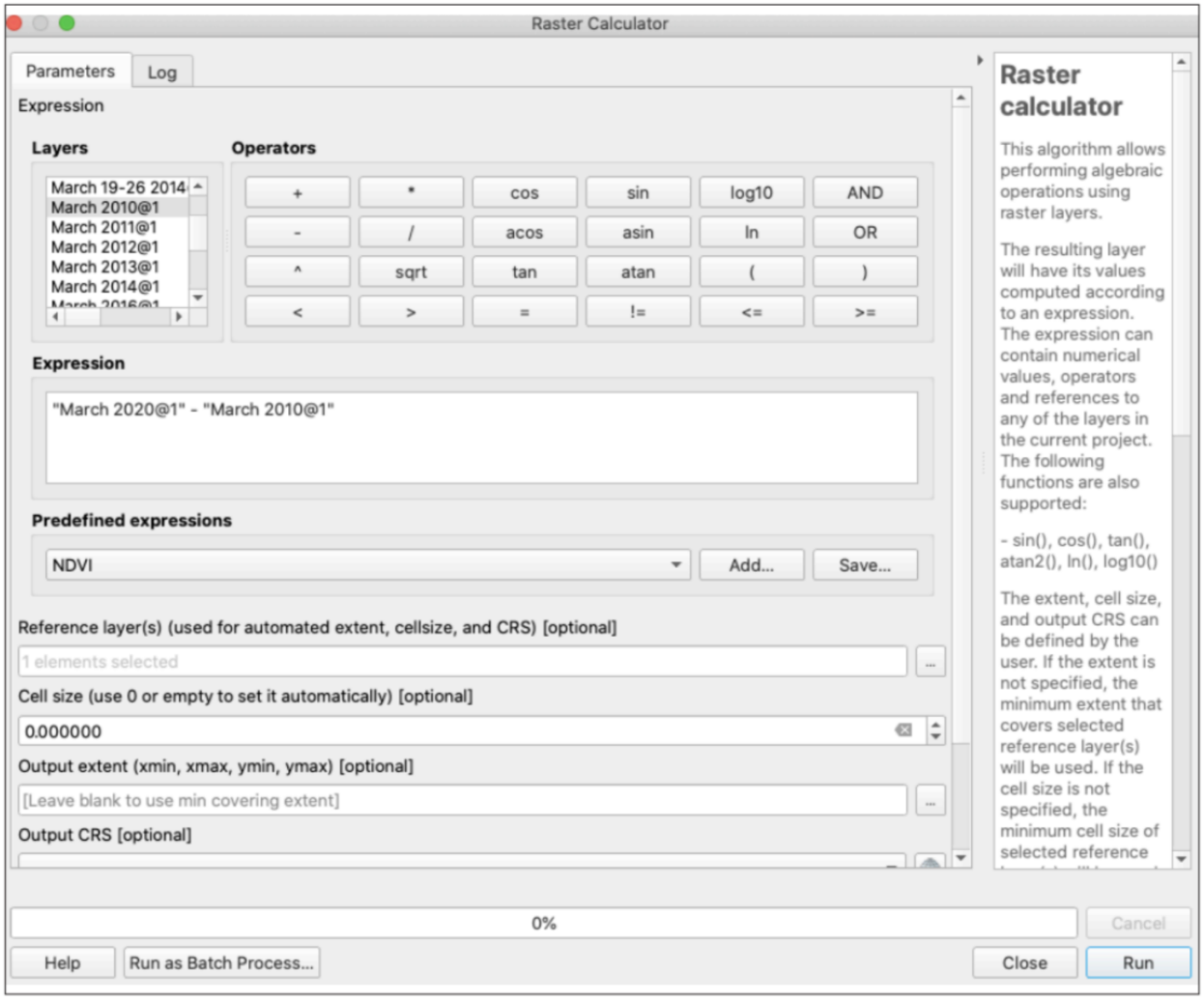


Fig. 10: The **Raster Calculator** expression for Example 4.

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%).

CHAPTER

ELEVEN

INSTALL AND USE QGREENLAND CUSTOM

For a full tutorial on how to install and use the QGreenland QGIS plugin, QGreenland Custom, visit the QGreenland Custom documentation here[27].

[27] https://qgreenland-plugin.readthedocs.io/en/latest/plugin-how-to.html

Part III

How-to

CHAPTER

TWELVE

USER HOW-TO GUIDES

12.1 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.

12.1.1 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**.

12.1.2 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**.

12.1.3 Creating a Custom Clipping Boundary Polygon

You can create your own custom boundary polygon layer to extract features from. Follow the instructions in section, **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.

12.1.4 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.

12.1.5 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 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 **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 the **Reference** tab.

12.1.6 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 section 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.
    - 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.
    - If you want to import data directly from a GPS device, click on the **Download from GPS** tab. Select the GPS device you are importing from, the port the device is connected to, and what feature types you want to download. Give the data a layer name, which is what it will show up as in the **Layers Panel**. 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**.
    - 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.

12.2 How to add an online layer to QGIS

When access to the internet is available, QGIS is capable of connecting to various online map services that can provide access to additional geospatial data that compliments QGreenland. Common map services include:

- Web Map Service (WMS)[28]: Provides image representations of geospatial data.
- Web Coverage Service (WCS)[29]: Provides access to raster data
- Web Feature Service (WFS)[30]: Provides access to vector data

This how-to guide covers creating a new connection to a WMS and adding a layer from that service. WCS, WFS, and other online services can be interacted with in a similar way.

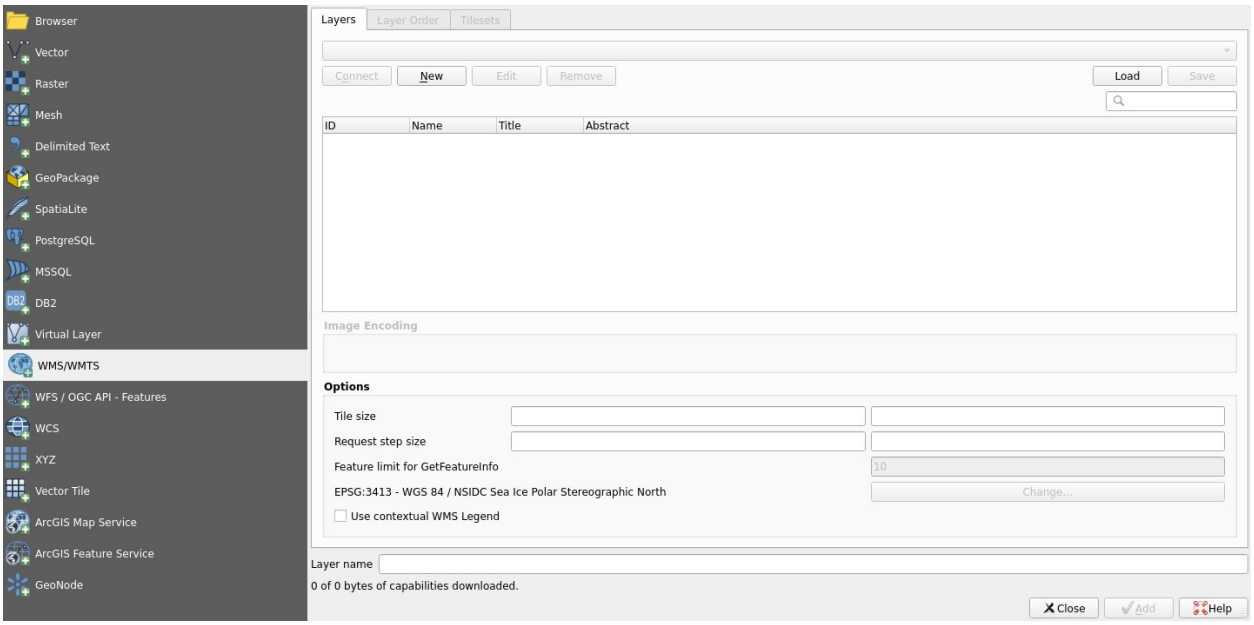
For more information about adding online layers, see the following resources from QGIS:

- Online resources tutorial[31]
- OGC web services user manual[32]

12.2.1 Add a WMS Layer

First, open the "Data Source Manager" from the top **Menu Bar (Layer >Data Source Manager)** and select the "WMS/WMTS" option.

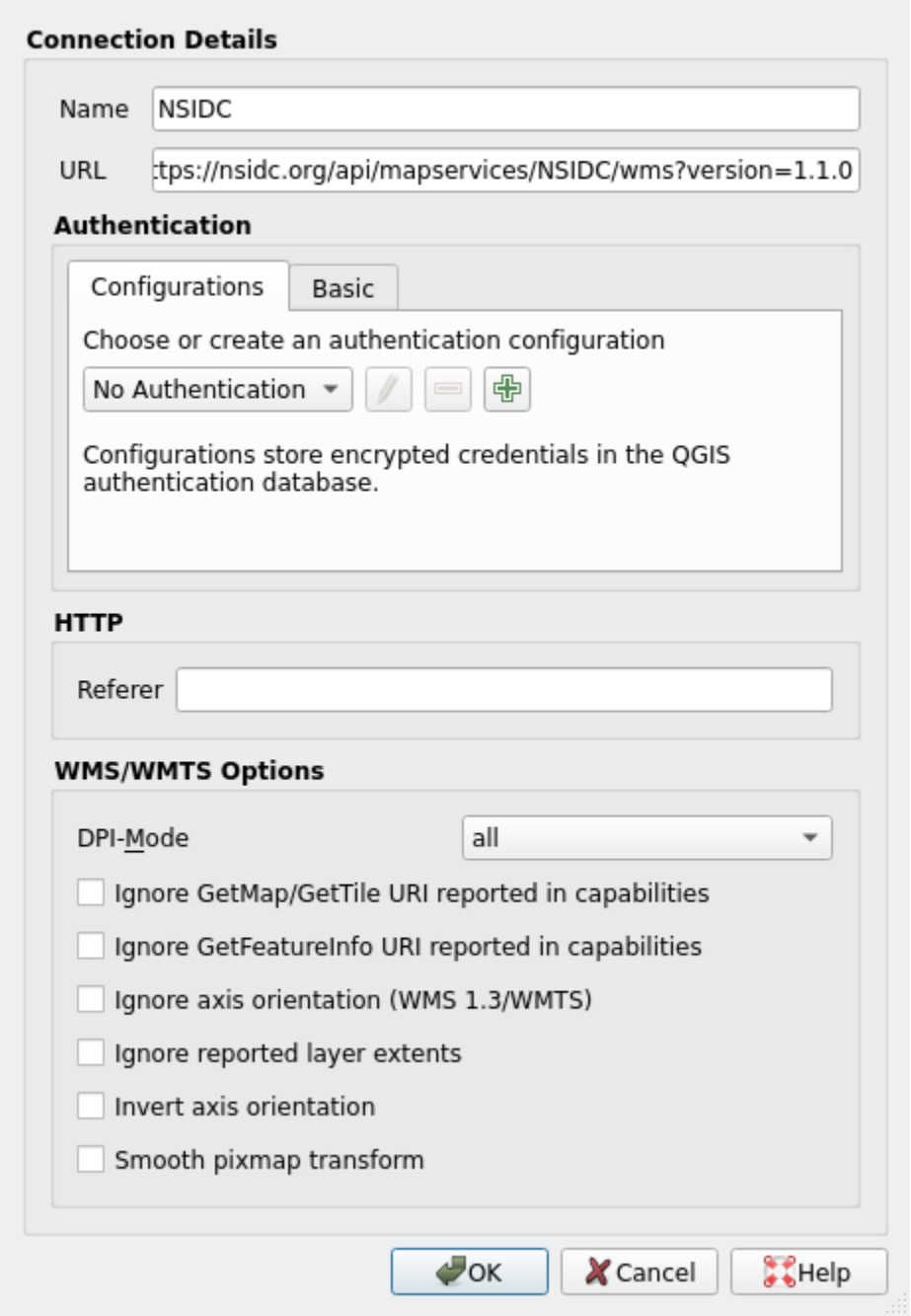
[28] https://www.ogc.org/standards/wms
[29] https://www.ogc.org/standards/wcs
[30] https://www.ogc.org/standards/wfs
[31] https://docs.qgis.org/3.16/en/docs/training_manual/online_resources/index.html
[32] https://docs.qgis.org/3.16/en/docs/user_manual/working_with_ogc/ogc_client_support.html



Click "New" to add a new connection to a WMS server. In this example, we will be using the National Snow and Ice Data Center's (NSIDC). Add a descriptive name (e.g., 'NSIDC') and add the following URL to the "URL" field: `https://nsidc.org/api/mapservices/NSIDC/wms?version=1.1.0`.

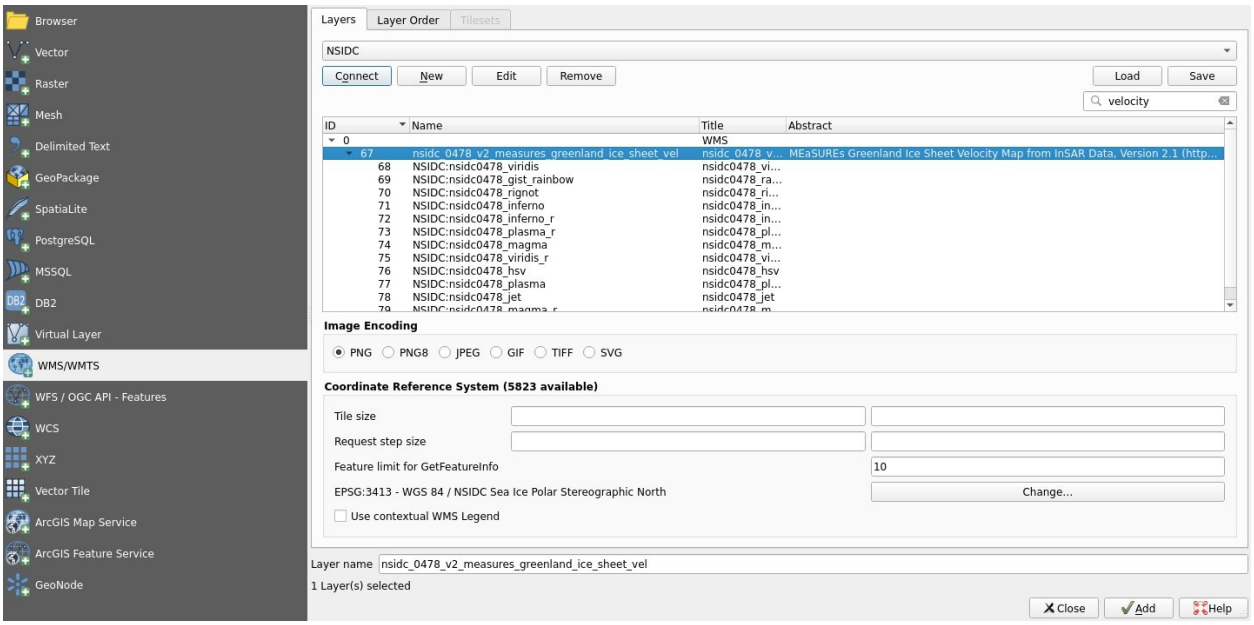
Note: Additional information about NSIDC's web map services is available here: https://nsidc.org/map-services/geospatial-map-services.

For additional online resources, see the *Online layers reference* (page 61) page.



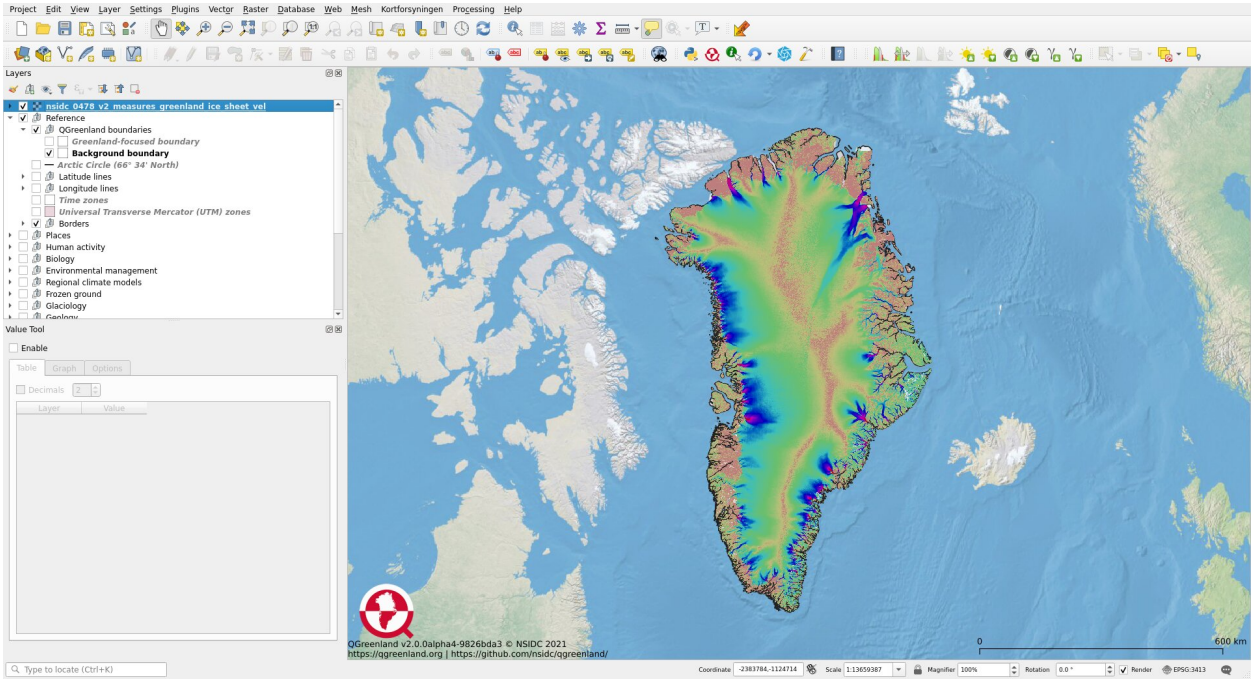
Click “OK”. This will create and select a new server connection to NSIDC’s WMS that can be re-used between sessions of QGIS.

Click “Connect”. This will populate a list of available layers for the currently selected server.



Use the search bar or scroll to the `nsidc_0478_v2_measures_greenland_ice_sheet_vel` layer and select it. This layer provides a visualization of Greenland ice sheet velocity. See NSIDC's documentation for this dataset for more information: https://nsidc.org/data/nsidc-0478.

Finally, click "Add". The layer will be added to the **Layers Panel** in QGIS.



Warning: The added layer will be inserted below whatever layer was previously selected in the **Layers Panel**. This may mean that the layer is covered by other layers above it. If the layer does not show up within a few seconds, check which layers are above the inserted layer and reorder as needed.

Note: Some online layers are a timeseries. QGIS will automatically detect layers with a time component and identify them as such with a clock icon next to the layer name in the **Layers Panel**.

Temporal Layers can be interacted with using the Temporal Controller. See the qgistutorials.com[33] tutorial on animating timeseries data for more information on how to use the Temporal Controller.

12.3 Troubleshooting

Contents

[33] https://www.qgistutorials.com/en/docs/3/animating_time_series.html

12.3.1 Difficulty opening the project

If you're having trouble opening the project, first ensure you're using QGIS 3.16 LTR or greater. If you want to move QGreenland to a different location on your filesystem, move the entire directory; do not attempt to move only the `.qgs/.qgz` project file.

QGIS won't start on OSX Catalina

QGIS is currently not 'notarized' for Mac OSX. If you receive `The developer of this app needs to update it to work with this version of macOS. Contact the developer for more information.`, then, in your OSX menus, try:

- 'Security and Privacy'
- 'Allow apps downloaded from…'
- 'App Store and identified developers'
- Locate QGIS here and select 'Open anyway'

'Unable to open' from QGIS when opening project

If you opened QGreenland from the command line, ensure you got the project name correct. E.g., from inside the unzipped QGreenland directory:

```
qgis qgreenland.qgs
```

No layers are present in the Layers Panel

If you don't see layers in the **Layers Panel**, you have not correctly opened a project. Click **Project** in the **Menu Bar**, then select **Add Project**, then navigate to your QGreenland directory, wherever you saved it, and open the `.qgs/.qgz` file inside.

12.3.2 Difficulty using the project

After opening QGreenland, I only see blue ocean

Right click on a layer in the **Layers Panel** that you'd like to view, and select **Zoom to Layer**.

If you experience this issue, please contact us[34] with information about your Operating System and QGIS version. A small number of users have reported this issue, but we haven't been able to identify the cause thus far.

[34] qgreenland.info@gmail.com

`Too many open files` on Linux

Your system may have multiple ways of limiting open files in different contexts. To check your limits:

```
ulimit -Sn  # soft limit
ulimit -Hn  # hard limit
```

Edit the `/etc/security/limits.conf` to add or update rules that apply to your user. If there are no rules, you can try adding:

```
* soft nofile 20480
* hard nofile 1048576
```

If your system uses `systemd`, also edit the `/etc/systemd/system.conf` and `/etc/systemd/user.conf` files to ensure the following variable is set to a large value in *both* files:

```
DefaultLimitNOFILE=20480
```

After applying these changes, you may find that new terminal windows are not affected. Reboot your computer to make the changes permanent.

I see `ERROR: Too many connections: max 64` in my terminal

We don't think this is an issue. This started happening when we switched to GeoPackages for vector data, but we've observed no negative impact of this error message.

The QGIS interface has no buttons or toolbars

Right-click 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**.

I can't see a layer in the Map View even though it's turned on and I've zoomed to it

Double-check that there is not another layer overlaying and thus obscuring the layer you want to see in the **Map View**. Remember that layer are displayed in the **Map View** in the same order that they are listed in the **Layers Panel - layers** listed at the top of the **Layers Panel** show up on top on 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 re-arrange the order of layers by clicking and dragging them up or down in the **Layers Panel**.

Some QGreenland data layers are only visible at a specific map scale (see *QGreenland User Guide section 4.3.1: Scale-dependent rendering* for more information). Try zooming in.

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.

12.3.3 I'm having other problems. How do I contact the QGreenland team?

If you have feedback on or questions about the QGreenland data package, or want to contribute datasets to future QGreenland releases, please contact us at mailto:qgreenland.info@gmail.com[35].

[35] qgreenland.info@gmail.com

CHAPTER

THIRTEEN

CONTRIBUTOR HOW-TO GUIDES

13.1 How to contribute new layers

It's recommended to use the CLI to create a dataset and/or layer template to help you along. In the below commands, replace filenames, paths, and ids with real ones. NOTE: When generating templates, but *not* when fetching, you can use `./scripts/experimental/local_cli.sh config-template <dataset|layer>` in place of the `cli.sh` commands.

13.1.1 Add a dataset

If the layer does not use an existing dataset, start with a new dataset.

```
./scripts/cli.sh config-template dataset > \
  qgreenland/config/datasets/new_dataset.py
```

After running the command above, a new_dataset.py file will be populated with dataset information that is needed to create a layer. Make sure that the abstract and title are filled out.

13.1.2 Fetch the data

Once you are finished filling in the dataset information, you can try testing the dataset by fetching the data:

```
./scripts/cli.sh fetch new_dataset_id
```

Note: If your fetch command results in an error, there may be issues with the entry of your dataset. Go back to your dataset.py file and make sure that all fields are filled in (abstract, title, etc.) to avoid linting errors.

13.1.3 Create new layer

The next step is to create the new data layer. To do this, create new layer directories as needed, and then define your new layer in a Python file with a descriptive name within the appropriate layer group.

You can do this by running this command:

```
./scripts/cli.sh config-template layer > \
  qgreenland/config/layers/Group/Subgroup/new_layer.py
```

The above command generates a new_layer.py file. Once you see this file, follow the documentation within the file to fill out your layer configuration.

Note: If the group directory where you have created your layer file has a **settings**.py file, you must add your new group to the 'order' list of this file. Make sure it is spelled exactly the same as in your file structure.

13.1.4 Dataset requirements

In order for a new dataset to be added to QGreenland, we strongly encourage public archival with OGC-compliant metadata. If data is not publicly archived or stored in a non-standard format, maintenance of that layer takes an order of magnitude more effort and therefore we are unable to promise permanent inclusion of such data. File formats that are particularly challenging include: raw binary grids, Excel files, Word documents. We prefer GeoTIFFs or NetCDFs for raster data, and GeoPackages or shapefiles for vector data.

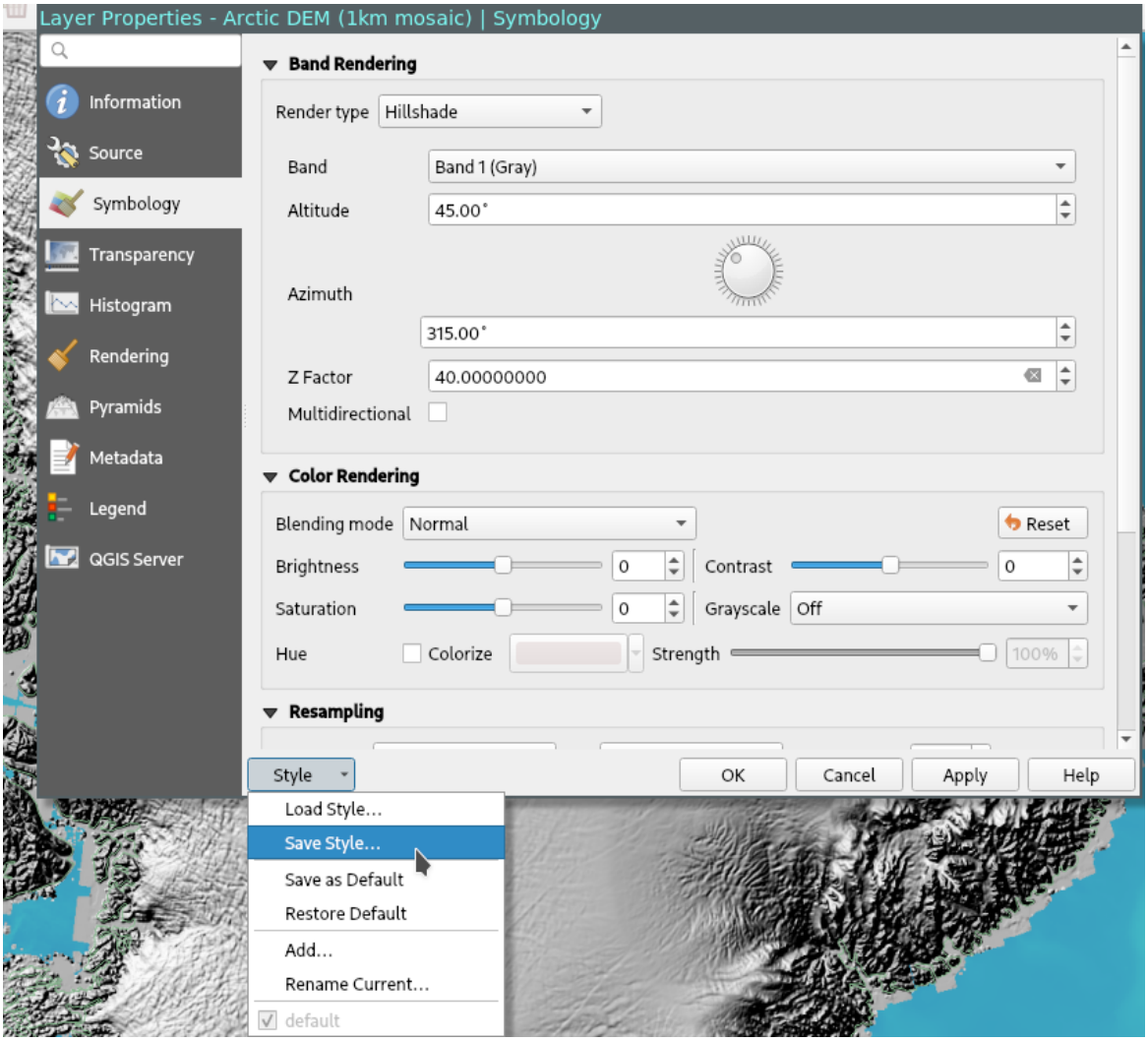
A correct QGreenland data pipeline will output data that:

- Is in EPSG:3413. This is to reduce load on QGIS caused by on-the-fly reprojection. Some exceptions may exist in the current code as a workaround, but they are bugs.
- Is subset to one of the defined layer boundaries in `config/project.py`. Existing layer tasks can do this for vector or raster data.
- For raster data:
  - In GeoTIFF (`.tif`) format.
  - Includes overviews, for raster data. This improves QGIS performance.
  - Is losslessly compressed using the DEFLATE algorithm.
- For vector data:
  - In GeoPackage (`.gpkg`) format.
  - Uses the `label` attribute name for pre-calculated labels when using generic styles with labels, for example `labeled_point.qml`

13.2 How to contribute styles

You can contribute style changes without editing any Python code using the following process:

- Download (or build) and open the most recent version of the project in QGIS.
- In the 'Layers' menu, double click on the layer you wish to edit.
- Open the 'symbology' tab.
- Make your desired style changes.
- In the lower-left corner, click the 'Style' dropdown.
- In this menu, select 'Save Style…'



- At this point, if you're uncomfortable with Git and GitHub, you can email us your style file at qgreenland.info@gmail.com. Otherwise, continue on…
- Save the style to `qgreenland/assets/styles/<name>.qml` directory of this repository or your fork. Keep in mind that styles can be shared between layers, so give the style a generic name instead of a layer-specific name where possible.
- Edit the relevant layer configuration file in `qgreenland/config/layers` and find the layer(s) you wish to apply this style to. Populate the `style` attribute for each layer with the name of the `.qml` file you saved in the previous step, excluding the file extension. For example, if you saved `foo.qml`, then populate `style='foo'`.

13.3 How to install QGreenland Custom as a developer

QGreenland Custom is a QGIS plugin for downloading a custom set of data, including data which is not part of the QGreenland Core zip package. This how-to guide walks through how to install the plugin as a developer.

First, clone the QGreenland Custom repo from Faunalia:

```
git clone https://github.com/faunalia/qgreenland-plugin.git
```

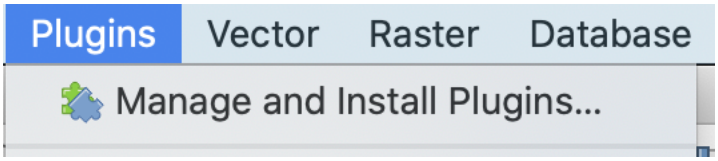
Use the QGIS GUI to locate the QGreenland Custom directory by going to **Settings -> User Profiles -> Open Active Profile Folder**. Then, navigate to the /.python/plugins directory, echo $PWD and copy the full filepath.

Next symlink the plugin repo to the plugin directory using the filepath from the previous step:

```
ln -s $PWD '/filepath'
```

13.3.1 Installing and reloading QGreenland Custom

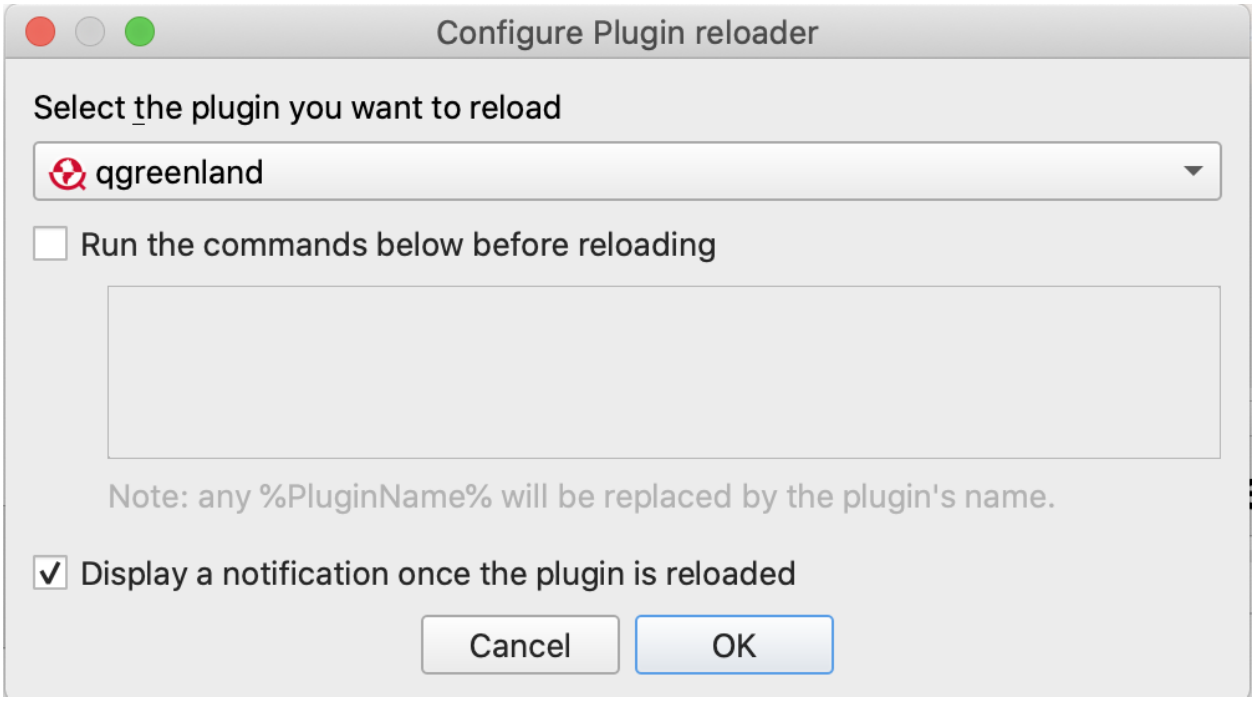
To begin installing QGreenland Custom, access the **Plugin** tab in the top **Menu Bar**, and select **Manage and Install Plugins**.



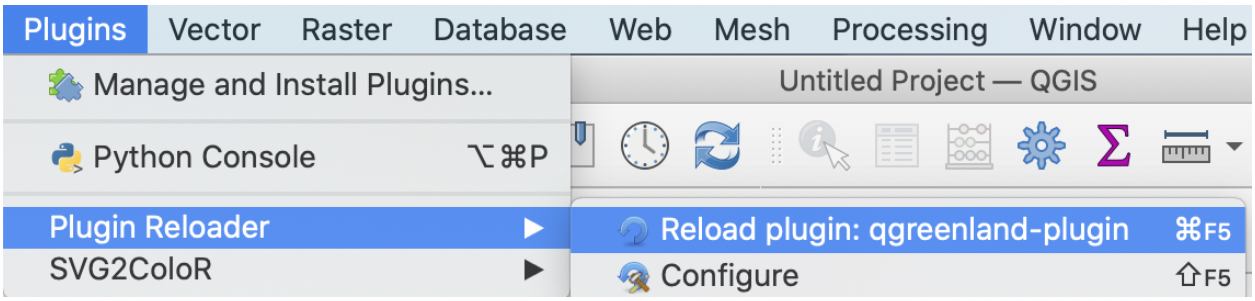
Navigate to the **Installed** tab in the **Plugin** window, and check the box for QGreenland Custom.

Instead of restarting QGIS after installing QGreenland Custom, install the plugin, **Plugin Reloader**. **Plugin Reloader** will allow you to immediately see your changes instead of needing to restart QGIS. You can do this by navigating to **Plugin -> Manage and Install Plugins**, then searching for **Plugin Reloader** in the search bar. Install the plugin then press OK.

To use the plugin, navigate to the **Menu Bar** and select **Plugins -> Plugin Reloader -> Configure**. Select **qgreenland-plugin** in the drop down. Uncheck the **run the commands below before reloading** option. Leave the display option checked, and press OK.



Navigate to **Plugins -> Plugin Reloader -> Reload Plugin: qgreenland-plugin**.



You should receive a message notifying you that the plugin has been reloaded.

After reloading the plugin, you are all set to begin using QGreenland Custom. Reference the user guide, **How to install and use QGreenland Custom**, to get started.

13.4 How to release a new version of QGreenland Core code

Use `bumpversion` to bump the specified part of the version:

```
$ bumpversion --part={major|minor|patch}
```

Versions should be in one of the following forms:

- `vX.Y.ZalphaN`: An alpha pre-release, e.g. `v1.2.3beta2`
- `vX.Y.ZbetaN`: A beta pre-release, e.g. `v1.2.3alpha2`
- `vX.Y.ZrcN`: A release candidate, e.g. `v1.2.3rc3`.
- `vX.Y.Z`: A final release, e.g. `v1.2.3`.

NOTE: When using `bumpversion build`, ensure you've already used `bumpversion prerelease`. Running `bumpversion build` from a final release version number can result in an incorrect patch number, e.g. `v1.2.304`.

Publishing a tag to GitHub will trigger an automated build and publish of the QGreenland Core package to various mirrors.

Creating a "Release" in GitHub will trigger archival of our code in Zenodo and issuance of a new DOI. Do *not* create a "Release" in GitHub until a new version of the package has been successfully built and pushed to mirrors.

13.5 How to run QGreenland Core

This project uses Docker and `docker-compose` to run each of its components as services. See Docker's Getting started guide[36].

The docker-compose stack runs Luigi (with visualizer at port 8082) as a service for running tasks, as well as NGINX (port 80, 443) for hosting outputs.

13.5.1 How to start the service stack

In order to download data behind Earthdata Login, you must `export` the following environment variables on the docker host before starting the stack:

- `EARTHDATA_USERNAME`
- `EARTHDATA_PASSWORD`

Developers at NSIDC may use the values stored in Vault at the following path: `nsidc/apps/qgreenland`. Those outside of NSIDC must use their personal Earthdata Login credentials. New users to Earthdata can register here: https://urs.earthdata.nasa.gov/users/new

Create a docker-compose override[37] file for `./logs` and `./appdata`.

```
ln -s docker-compose.local.yml docker-compose.override.yml
```

WARNING: Docker Desktop for OSX has some "gotchas". Running with "Use gRPC FUSE for file sharing" *enabled* is recommended. You may see indefinite hangs otherwise. Please reference the Docker documentation for more info:

https://docs.docker.com/desktop/mac/

Start the stack with docker-compose:

```
docker-compose up -d
```

13.5.2 How to run processing pipelines with the QGreenland CLI

The primary entrypoint for the CLI is `./scripts/cli.sh`. This runs the CLI program inside the `luigi` container, allowing us to kick off pipelines or cleanup data from standard locations without risking destructive actions on the user's computer.

To run the full pipeline:

```
./scripts/cli.sh run
```

[36] https://docs.docker.com/get-started/
[37] https://docs.docker.com/compose/extends/#understanding-multiple-compose-files

To run in parallel:

```
./scripts/cli.sh run --workers=4
```

To run only the layers you care about (plus the background, useful for testing, but the final output will not be zipped):

```
./scripts/cli.sh run \
  --include="background" \
  --include="*my_layerid_mask*"
```

Collaborators outside NSIDC may want to run QGreenland pipeline without "manual access" layers that require difficult or impossible additional steps to prepare input data. See Assets documentation to learn more about "manual access" assets.

```
./scripts/cli.sh run \
  --exclude-manual-assets
```

Inclusion and exclusion flags can be combined arbitrarily. When `--include` and `--exclude` are used together, the final result is the set of layers which are included *or* not excluded. This is different from the set of layers which are included *and* not excluded.

To cleanup outputs while developing a new layer (deletes WIP and released layers matching mask, WIP and released packages; see `--help` for more):

```
./scripts/cli.sh cleanup --dev '*my_layerid_mask*'
```

See the Luigi documentation[38] for more information on running Luigi if you want to do anything not documented here.

How to debug a Luigi pipeline

Simply add `breakpoint()` anywhere in the pipeline code, then run the pipeline with 1 worker (the default) and whichever layer(s) you want to debug.

13.6 How to write documentation

Our documentation is written in reStructuredText[39] and Markdown[40] for the Sphinx[41] documentation generator. The documentation website[42] is built by and hosted on Read the Docs[43].

We follow a conceptual framework called Diátaxis[44] to write high quality, easy-to-use documentation.

We expected Sphinx and reStructuredText to be difficult to learn, but were pleasantly surprised. We hope that you will also find it easy and pleasant to contribute to our documentation. Thank you in advance for your efforts!

[38] https://luigi.readthedocs.io/en/stable/running_luigi.html
[39] https://docutils.sourceforge.io/rst.html
[40] https://daringfireball.net/projects/markdown/
[41] https://www.sphinx-doc.org/en/master/
[42] https://qgreenland.readthedocs.io/
[43] https://readthedocs.org/
[44] https://diataxis.fr/

13.6.1 Background information

Our documentation lives in the `doc/` folder. The documentation-generator config is in `doc/conf.py`. The ReadTheDocs configuration is in `.readthedocs.yml` file at the root of this repository. The main tables of contents are expressed in the `doc/index.rst` file.

Diátaxis

Diátaxis[45] provides a conceptual framework for targeting and organizing information in documentation.

Please familiarize yourself with this framework and help us continually improve the quality of our docs. The best place to start is this video on YouTube[46].

Sphinx

Sphinx reads documentation (written in reStructuredText or, with an extension, Markdown) and other content (including code with `autodoc` or other extensions). It converts this content into many output formats including HTML and PDF.

Sphinx's configuration is kept at `doc/conf.py`.

Read the Docs

Read the Docs is a documentation building and hosting service. It can use Sphinx or MkDocs under the hood, and we chose Sphinx. It runs automatically in response to changes in GitHub. It is configured by `.readthedocs.yml` at the root of this repository.

When Read the Docs builds our documentation, it uses the Python environment defined by `doc/requirements.txt`.

reStructuredText

Start here[47] to learn about writing reStructuredText for Sphinx documentation.

MyST Markdown extension

Start here[48] to learn about writing Markdown for Sphinx documentation. Markdown is supported out of the box by Read the Docs.

13.6.2 How to add a new documentation page

- Is this new content a How To[49], a Tutorial[50], Reference material[51], or a Discussion topic[52]? Ensure your document is in the correct directory and written for the correct audience.
- Write your documentation in Markdown, unless you're writing a page that must be majority reStructuredText, such as an `index.rst` for a new group of pages.

[45] https://diataxis.fr/
[46] https://www.youtube.com/watch?v=t4vKPhjcMZg
[47] https://www.sphinx-doc.org/en/master/usage/restructuredtext/basics.html
[48] https://myst-parser.readthedocs.io
[49] https://diataxis.fr/how-to-guides/
[50] https://diataxis.fr/tutorials/
[51] https://diataxis.fr/reference/
[52] https://diataxis.fr/explanation/

- Ensure your documentation page starts with a top-level header. This is the title of the page.
- Use `inv docs.watch` to build documentation on every edit and view your changes in the browser.
- Create a pull request. GitHub will trigger a build on Read the Docs which you can view by clicking "details" for the Read the Docs check.

13.6.3 How to update an existing documentation page

- Is this new content a How To[53], a Tutorial[54], Reference material[55], or a Discussion topic[56]? Ensure your document is in the correct directory and written for the correct audience.
- Ensure your new content fits appropriately with surrounding content.
- Use `inv docs.watch` to build documentation on every edit and view your changes in the browser.
- Create a pull request. GitHub will trigger a build on Read the Docs which you can view by clicking "details" for the Read the Docs check.

13.6.4 Documentation styles

We have created the following styles to use when referring to QGIS elements and menu paths:

- Any reference to a QGIS user interface element will be bolded. e.g.: "Navigate to **Settings -> User Profiles -> Open Active Profile Folder** to get the directory path" or "Use the **Layers Panel** to change the order of the layers".
- Menu paths are delimited by ->, e.g.: Settings -> User Profiles -> Open Active Profile Folder

[53] https://diataxis.fr/how-to-guides/
[54] https://diataxis.fr/tutorials/
[55] https://diataxis.fr/reference/
[56] https://diataxis.fr/explanation/

Part IV

Reference

CHAPTER

FOURTEEN

GLOSSARY

14.1 User Glossary

A "user" is someone who uses QGreenland in QGIS.

14.1.1 QGreenland Core

QGreenland Core is a large zip package curated to cover a broad variety of disciplines within a reasonable file size.

14.1.2 QGreenland Custom

QGreenland Custom is a QGIS plugin that enables users to download and use only the QGreenland layers they are interested in.

In the future, QGreenland Custom will be capable of downloading "modules".

14.1.3 QGreenland Modules

QGreenland modules are subsets of the QGreenland layers intended for more targeted use. Modules include:

- QGreenland Core: Covers a wide variety of disciplines and scientific needs. Curated to be useful for the largest number of users.
- More coming soon…

14.1.4 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.

14.2 Contributor Glossary

Someone who adds more layers to QGreenland by configuring pipeline(s) to transform source data in to a standard QGreenland specification.

14.2.1 Pipeline

A chain of steps to build a QGIS Layer.

14.2.2 Step

A unit of work for transforming a layer. Must be a Linux shell command (e.g. `gdalwarp` or `ogr2ogr`).

14.2.3 Boundary

Instead of extent, which to some may imply rectangular or lon/lat-based shape, use the term "Boundary".

You can define as many boundaries as you want with arbitrary names, in addition to the required `data` boundary, which is used for defining the initial extent shown when opening QGIS.

CHAPTER

FIFTEEN

QGREENLAND DATASET COMPATIBILITY GUIDE

While QGreenland provides a curated base package of data on a variety of topics, the options for adding additional data are nearly unlimited. We offer different guidelines for data compatibility depending on what your goals are:

1. Guidelines for publishing previously unpublished data so it is compatible with QGreenland:

To ensure that your own original research datasets will be easy to work with in QGreenland, either in your own individual QGreenland project or as an addition to the public QGreenland data package, please note the following:

- Make sure your data are produced in a standard format with appropriate spatial metadata. For example, your dataset should have clearly defined projection metadata (as an EPSG code, proj4 params, OGC-compliant well-known-text, etc.) and should be formatted in a way that gdal/ogr tools can read and understand. Double check that your data can be opened in QGIS and appropriately geolocated.
- If your data are not already in the QGreenland project coordinate reference system (EPSG:3413), that's OK. The QGreenland project includes all the tooling necessary to reproject your data, as long as the data meet the metadata requirements. A contributor to the QGreenland open source project can take it from here to ensure consistent and compatible results (see section 2 below).
- Make sure your data are accompanied by metadata that describe the methods used for producing the data (e.g., scientific paper, document that describes the algorithm/data collection procedures used, etc.).

2. Guidelines for contributing datasets to QGreenland via GitHub for inclusion in future releases:

Follow the instructions found in our contributing guidelines[57]. The QGreenland source code defines "processing pipelines", which, when executed on a server or a user's computer, fetch data from its original source location, transform it (reproject, reformat, subset, resample, etc.) as needed, and finally compile these data into a zipped QGreenland QGIS project. Contributors may customize, re-use, or add to our processing pipelines to support their new layer, and when their changes are ready, submit a Pull Request[58] to contribute valuable changes back to the QGreenland project.

We strive to support extensive customization of the QGreenland processing pipelines without any coding knowledge. As of QGreenland v2.0.0, we support editing of dataset metadata, QGIS styles, and various processing parameters (such as X and Y resolution) via configuration in the YAML configuration language[59], which is simple to learn.

- Ensure that all outputs of QGreenland processing pipelines are in EPSG:3413 coordinate reference system.
- Ensure that all outputs of the QGreenland processing pipelines are in the correct format. We expect one GeoPackage per vector layer and one GeoTIFF per raster layer.
- Fill out all metadata as configuration. This includes abstract, citation, layer description and title, etc. The QGreenland processing pipelines will automatically format this information and add it to the correct interfaces (metadata tab) in QGIS.

3. Guidelines for adding datasets to your QGreenland project for personal use only:

[57] https://qgreenland.readthedocs.io/en/latest/discussion/contributing.html
[58] https://docs.github.com/en/github/collaborating-with-issues-and-pull-requests/about-pull-requests
[59] https://en.wikipedia.org/wiki/YAML

- Refer to the QGreenland User Guide Section 6: Adding New Datasets to QGreenland for instructions on how to add new data layers to your QGreenland project (go to https:// qgreenland.org/learn-and-teach to download the User Guide directly or locate it in the QGreenland download package).
- Note that the QGreenland data package is in the EPSG:3413 coordinate reference system and all pre-loaded layers are either GeoTIFF (raster) or GeoPackage (vector) files.

CHAPTER

SIXTEEN

ONLINE LAYERS REFERENCE

QGreenland can be enriched with layers provided by online services such as Web Map Service (WMS)[60], Web Feature Service (WFS)[61], and Web Coverage Service (WCS)[62]. This document provides a list of potentially useful resources that QGIS can connect to to provide layers via the internet.

See the *How to add an online layer to QGIS* (page 39) page for information on how to utilize these resources.

- The National Snow and Ice Data Center (NSIDC)[63] [WMS, WFS, WCS] provides access to a wide variety of datasets.
- The Arctic Observing Viewer[64] [WMS, WFS] provides observing sites associated with long-term monitoring activities in the circumarctic.
- The Arctic Research Mapping Application[65] [WMS, WFS] provides a variety of reference layers such as Arctic cities and an Arctic base map.
- The Geological Survey of Denmark and Greenland (GEUS)[66] [WMS, WFS] provides various layers including a geological occurrence map. Note that GEUS requests that users of its services provide an email address as part of each request. Results may be limited during peak service hours.
- The National Aeronautics and Space Administration (NASA)'s Global Imagery Browse Service (GIBS)[67] [WMS/WMTS] provides quick access to over 1000 satellite imagery products. For instructions on how to utilize GIBS with QGIS, see the Earthdata Wiki on GIBS[68]

[60] https://www.ogc.org/standards/wms
[61] https://www.ogc.org/standards/wfs
[62] https://www.ogc.org/standards/wcs
[63] https://nsidc.org/map-services/geospatial-map-services
[64] https://arcticobservingviewer.org/web-services/
[65] https://armap.org/web-services/
[66] http://maps.greenmin.gl/geusmap/ows/help/?mapname=greenland_portal
[67] https://earthdata.nasa.gov/eosdis/science-system-description/eosdis-components/gibs
[68] https://wiki.earthdata.nasa.gov/display/GIBS/Geographic+Information+System+%28GIS%29+Usage#expand-QGIS

Part V

Discussion topics

CHAPTER

SEVENTEEN

ABOUT THE QGREENLAND PROJECT

Greenland-focused research, planning, and education crosses disciplinary boundaries. With QGreenland, a free data-viewing platform, anyone can explore a wide variety of Greenland-focused data identified by an expert team and Editorial Board[69].

QGreenland is a United States National Science Foundation EarthCube-funded effort (award #1928393[70]). Project development began in 2019, led by the National Snow and Ice Data Center[71], which is a part of the University of Colorado Boulder Cooperative Institute for Research in Environmental Sciences[72]. The project is made possible through the generous efforts of a wide range of collaborators.

The QGreenland Team believes in open and accessible resources. QGreenland is built using free and open software, with development tools and workflows fully documented on our Github page[73]. We also believe in FAIR (findable, accessible, interoperable, reproducible) data and strive to include clear information about original data sources and complete metadata. To the best of our ability, we aim to include data that are already free and publicly archived.

As QGreenland development continues, we will be expanding our educational resources, increasing optional data download options, and working to be as responsive as possible to user feedback. We look forward to hearing from you[74].

[69] https://qgreenland.org/our-team%3E
[70] https://nsf.gov/awardsearch/showAward?AWD_ID=1928393&HistoricalAwards=false
[71] https://nsidc.org/
[72] https://cires.colorado.edu/
[73] https://github.com/nsidc/qgreenland
[74] qgreenland.info@gmail.com

CHAPTER

EIGHTEEN

CONTRIBUTING

This project is currently undergoing rapid development, so expect change in any release except releases labeled as "stable". Stable releases can be found at https://qgreenland.org/explore!

18.1 The processing pipeline

In general, a data-processing pipeline looks like this:

- Fetch input assets
- Run layer pipelines, writing outputs to final layer hosting locations.
- For layers for which `in_package` is `True`, use hardlinks to link final layer ouputs to a QGreenland package compile location.
- Create QGreenland package QGIS project file and other ancillary package files.
- Zip the QGreenland package.

18.2 Contributing to the project

One of the primary goals of this project is to allow for scientists comfortable with standard GIS command-line tools to contribute new layers with as little friction as possible.

Contributing new datasets and layers requires writing simple Python objects containing the relevant data (metadata, download location, transformation steps) needed to include the layer in QGreenland.

Currently, layer styles can be contributed without any programming knowledge by designing the style in QGIS, saving it as a `.qml`, and committing it to the `qgreenland/ancillary/styles` directory.

You can contribute to this project even if you don't have write access by forking, making your change, making all CI checks pass, then opening a Pull Request. Learn more:

https://docs.github.com/en/github/collaborating-with-issues-and-pull-requests/creating-a-pull-request-from-a-fork