



# **QGreenland Documentation**

***Release v3.0.0***

**National Snow and Ice Data Center**

**Aug 31, 2023**

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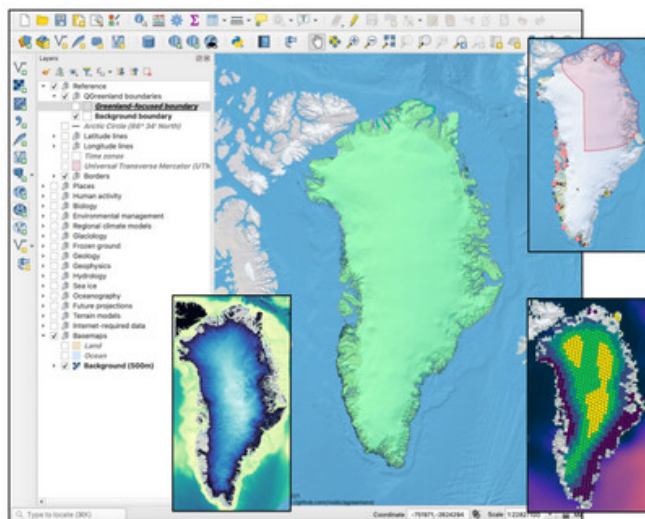
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## **Part I**

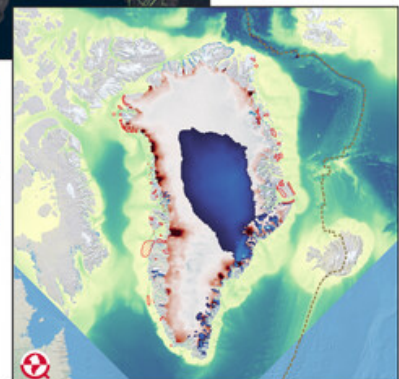
# **Introduction**

## WHAT IS QGREENLAND?

An interdisciplinary environment...



...with local  
detail and  
island-wide  
data.



QGreenland is a free and open-source Greenland-focused GIS environment for data analysis and viewing, powered by QGIS<sup>1</sup>. QGreenland is delivered as a Zip package containing a core set of data curated to serve a broad user base. This package is referred to as **QGreenland Core**.

See our tutorial on how to get started with QGreenland Core [here](#) (page 16)!

**Attention:** The QGIS Plugin **QGreenland Custom<sup>2</sup> (beta)** is no longer supported. This was an experiment, and we decided to go in a different direction. It should not be expected to work.

Visit the [QGreenland website<sup>3</sup>](#)

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<sup>1</sup> <https://qgis.org>

<sup>2</sup> <https://plugins.qgis.org/plugins/qgreenland/>

<sup>3</sup> <https://qgreenland.org>

## 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. Please see our [\*Disclaimer\*](#) (page 10).

## 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](https://www.npolar.no/en/quantarctica/)<sup>4</sup> GIS data package for Antarctica.

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<sup>4</sup> <https://www.npolar.no/en/quantarctica/>



## QGREENLAND CORE DOWNLOAD PACKAGE

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

- Folders containing data layers organized by topic. Each data layer is represented as a GeoTIFF or GeoPackage.
- **qgreenland.qgz** - The main QGreenland project file for QGIS
- **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. The QGreenland Core v3.0.0 download package was released in August 2023. Development versions along the way will continue to be available via the [website](http://qgreenland.org)<sup>5</sup>, with code fully documented on [GitHub](https://github.com/nsidc/qgreenland)<sup>6</sup>.

Although the v3.0.0 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.

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<sup>5</sup> <http://qgreenland.org>

<sup>6</sup> <https://github.com/nsidc/qgreenland>

## 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](https://github.com/nsidc/qgreenland)<sup>7</sup>. 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.

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

Users should note that published works produced using QGreenland are required to cite each dataset used in the work. QGreenland provides all dataset citation information in each layer’s metadata in QGIS (see the *Layer Properties section in the Interacting with Geospatial Data tutorial* (page 25) 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

Please note that QGreenland currently has two citable components:

- The QGreenland QGIS data package is cited as [dataset] and used by researchers and educators.
- The software used to generate the QGIS data package from source data is cited as [software] and used by software developers.

Please choose the appropriate citation depending on which you use.

An asterisk (\*) indicates co-equal lead authorship (listed alphabetically).

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<sup>7</sup> <https://github.com/nsidc/qgreenland>

### 5.1.1 Latest version: v3.0.0

Moon, T. A., M. Fisher, T. Stafford, and A. Thurber (2023). QGreenland (v3.0.0) [dataset], [National Snow and Ice Data Center](#)<sup>8</sup>.

\*Fisher, M., \*Stafford, T., T. Moon, and A. Thurber (2023). QGreenland (v3.0.0) [software], [National Snow and Ice Data Center](#)<sup>9</sup>

### 5.1.2 Version 3

Moon, T. A., M. Fisher, T. Stafford, and A. Thurber (2023). QGreenland (v3) [dataset], [National Snow and Ice Data Center](#)<sup>10</sup>.

\*Fisher, M., \*Stafford, T., T. Moon, and A. Thurber (2023). QGreenland (v3) [software], [National Snow and Ice Data Center](#)<sup>11</sup>

### 5.1.3 Version 2

Moon, T., Fisher, M., Harden, L., Simonoko, H., and T. Stafford (2022). QGreenland (v2) [dataset], [National Snow and Ice Data Center](#)<sup>12</sup>.

\*Fisher, M., \*Stafford, T., Moon, T., Harden, L., and H. Simonoko (2022). QGreenland (v2) [software], [National Snow and Ice Data Center](#)<sup>13</sup>

### 5.1.4 Version 1

Moon, T., Fisher, M., Harden, L., and T. Stafford (2021). QGreenland (v1) [dataset], [National Snow and Ice Data Center](#)<sup>14</sup>.

\*Fisher, M., \*Stafford, T., Moon, T., and L. Harden (2021). QGreenland (v1) [software], [National Snow and Ice Data Center](#)<sup>15</sup>

## 5.2 Acknowledgement

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

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<sup>8</sup> <https://qgreenland.org/>

<sup>9</sup> <https://github.com/nsidc/qgreenland>

<sup>10</sup> <https://qgreenland.org/>

<sup>11</sup> <https://github.com/nsidc/qgreenland>

<sup>12</sup> <https://qgreenland.org/>

<sup>13</sup> <https://github.com/nsidc/qgreenland>

<sup>14</sup> <https://qgreenland.org/>

<sup>15</sup> <https://github.com/nsidc/qgreenland>

## 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](#)<sup>16</sup> 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](#)<sup>17</sup> funded the development of QGreenland versions 1.x, 2.x, and 3.x. Thank you!

### 6.3 Editorial board

The [QGreenland Editorial Board](#)<sup>18</sup> 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 one of the environments described in the [GitHub: environments/README.md](#)<sup>19</sup> file, thank you!

- [QGIS](#)<sup>20</sup>
- [cmocean](#)<sup>21</sup>
- [Python](#)<sup>22</sup>

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<sup>16</sup> <https://www.npolar.no/en/quantarctica/>

<sup>17</sup> [https://nsf.gov/awardsearch/showAward?AWD\\_ID=1928393](https://nsf.gov/awardsearch/showAward?AWD_ID=1928393)

<sup>18</sup> <https://qgreenland.org/our-team>

<sup>19</sup> <https://github.com/nsidc/qgreenland/tree/main/environments/README.md>

<sup>20</sup> <https://www.qgis.org/>

<sup>21</sup> <https://github.com/matplotlib/cmocean>

<sup>22</sup> <https://www.python.org>

- Luigi<sup>23</sup>
- GDAL<sup>24</sup>
- Docker<sup>25</sup>

## 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>.

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<sup>23</sup> <https://github.com/spotify/luigi>

<sup>24</sup> <https://gdal.org>

<sup>25</sup> <https://www.docker.com/>

## DISCLAIMER

QGreenland should not be used as a sole navigational aid while performing remote research activities in Greenland or elsewhere. Always bring appropriate safety and navigational aids (including hard-copies of topographic maps) when visiting the field.

QGreenland is a data-viewing and analysis platform, and the QGreenland Team does not create new data. QGreenland's layers may contain errors from the original data providers. QGreenland makes no guarantees about the accuracy and validity of data contained in QGreenland. Limited notes on known data issues have been added to the 'Populated places' layer metadata. Also, some layers may not perfectly align with each other due to unidentified georeferencing issues with the original data. We recommend using the 'Greenland coastlines 2017' layer as the best approximation reference layer for geolocating Greenland's coastline.

Note that some data were transformed from their native data formats, projections, and resolutions for inclusion within QGreenland. The included metadata (**Layer Properties -> Metadata -> History**) contains provenance information on any transformations. All QGreenland GeoPackages and GeoTIFFs are projected in EPSG:3413.

## TROUBLESHOOTING

### Contents

- *Difficulty opening the project* (page 12)
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- *I am having other problems. How do I contact the QGreenland team?* (page 14)

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### Get more help

This page is a compilation of some common pitfalls and issues users have encountered. If your problem isn't documented here, please join us on [GitHub Discussions](https://github.com/nsidc/qgreenland/discussions)<sup>26</sup> to get more help!

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<sup>26</sup> <https://github.com/nsidc/qgreenland/discussions/>

## 8.1 Difficulty opening the project

If you are having trouble opening the project, first ensure you are 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.

### 8.1.1 QGIS will not 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’

### 8.1.2 ‘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.qgz
```

### 8.1.3 No layers are present in the Layers Panel

If you do not 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.

## 8.2 Difficulty using the project

### 8.2.1 After opening QGreenland, I only see blue ocean

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

If you experience this issue, please [contact us](#)<sup>27</sup> 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.

<sup>27</sup> [qgreenland.info@gmail.com](mailto:qgreenland.info@gmail.com)



## 8.2.2 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.

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

We do not think this is an issue. This started happening when we switched to GeoPackages for vector data, but we have observed no negative impact of this error message.

## 8.2.4 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**.

## 8.2.5 I cannot see a layer in the Map View even though it is turned on and I have 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 (page 26)* for more information). Try zooming in.

### 8.2.6 When I open QGreenland, I get the warning Font "Helvetica" not available on system

Please upgrade to QGreenland v3 and a supported version of QGIS ( $\geq 3.28$ ).

For more context, see the [GitHub issue](#)<sup>28</sup>.

### 8.2.7 When I open QGreenland, I get the warning This project file was created by a newer version of QGIS

For example:

This project file was created by a newer version of QGIS (3.28.8-Firenze) and could not be completely loaded.

We have not observed any adverse effects from this warning. If you want to get rid of the message permanently, update to the latest release of a supported QGIS version.

### 8.2.8 Navigating QGIS errors

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

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

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

## 8.3 I am having other problems. How do I contact the QGreenland team?

If you have feedback or questions about the QGreenland data package, or want to contribute datasets to future QGreenland releases, please participate in our [GitHub Discussions](#)<sup>29</sup> space. If you're uncomfortable with or otherwise can not participate there, please contact us directly at [qgreenland.info@gmail.com](mailto:qgreenland.info@gmail.com).

<sup>28</sup> <https://github.com/nsidc/qgreenland/issues/515>

<sup>29</sup> <https://github.com/nsidc/qgreenland/discussions/>

# **Part II**

## **Tutorials**

## TUTORIALS

## 9.1 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.

### 9.1.1 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.

As of this writing, the oldest version of QGIS we support for the QGreenland release series are:

- QGreenland 1.x: QGIS 3.16.x LTR
- QGreenland 2.x: QGIS 3.16.x LTR
- QGreenland 3.x: QGIS 3.28.x LTR

### 9.1.2 1) Download and Install QGIS

Go to [qgis.org](https://qgis.org)<sup>30</sup> 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.

### 9.1.3 2) Download and open the QGreenland Core package

Download the QGreenland Core data package (v3.0.0) at <https://qgreenland.org/download>.

Save the zip package to a location of your choice and unzip it.

**Warning:** Ensure QGreenland is *actually* unzipped; some operating systems will only “explore” a zip file when you double-click it without actually extracting it to disk. In Windows, please right-click and select **Extract all**.  
...

Open the `qgreenland.qgz` file in the data package folder by double-clicking it. QGIS will open automatically and display the QGreenland Core data environment.

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<sup>30</sup> <https://qgis.org>

**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.qgz project file within QGIS by navigating to the **Project -> Open...** option in the menu bar and selecting the qgreenland.qgz file from its saved location.

### 9.1.4 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**.

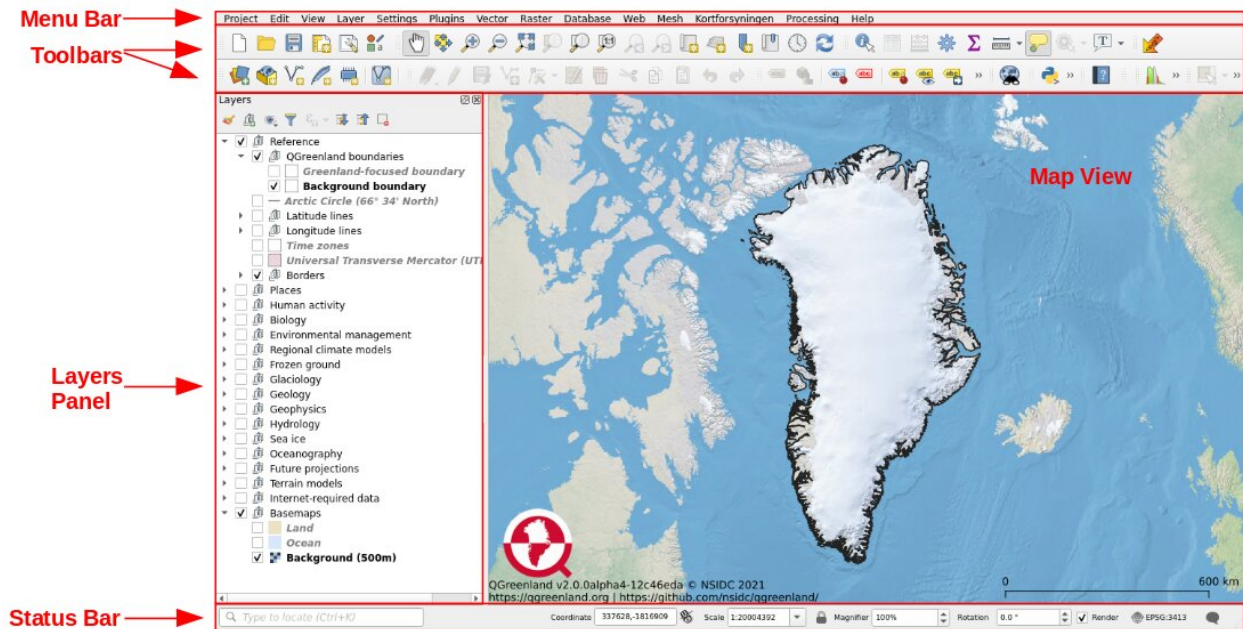


Fig. 9.1: Main components of the QGIS/QGreenland interface.

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. 9.2 (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.

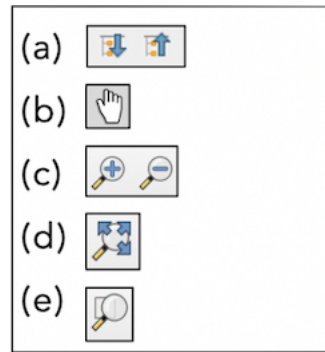


Fig. 9.2: (a) **Expand All** and **Collapse All** buttons at the top of the **Layers Panel** to expand or collapse layers; (b) **Pan Map** button in the **Map Navigation Toolbar** to grab and drag the map view; (c) **Zoom In** and **Zoom Out** buttons in the **Map Navigation Toolbar** to zoom in or out in map view; (d) **Zoom Full** button in the **Map Navigation Toolbar** to bring all visible layers into the **Map View**; (e) **Zoom to Layer** button in the **Map Navigation Toolbar** to bring a desired layer into view.

The **Toolbars** contain buttons that allow the user to interact with the **Map View**. For example, the **Pan Map** button (Fig. 9.2 (b)) in the **Map Navigation Toolbar** lets the user grab and drag the map view around. The magnifying glass buttons (Fig. 9.2 (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, simply right click on a toolbar and check or uncheck the desired boxes (Fig. 9.3).

If data layers are toggled on but not visible in the map view, the magnifying glass with three arrows (**Zoom Full**) button (Fig. 9.2 (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. 9.2 (e)) in the **Map Navigation Toolbar** will also bring a desired layer into view in the **Map View**.

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](https://docs.qgis.org/3.28/en/docs/user_manual/index.html)<sup>31</sup> 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](https://docs.qgis.org/3.28/en/docs/gentle_gis_introduction/index.html)<sup>32</sup>

<sup>31</sup> [https://docs.qgis.org/3.28/en/docs/user\\_manual/index.html](https://docs.qgis.org/3.28/en/docs/user_manual/index.html)

<sup>32</sup> [https://docs.qgis.org/3.28/en/docs/gentle\\_gis\\_introduction/index.html](https://docs.qgis.org/3.28/en/docs/gentle_gis_introduction/index.html)

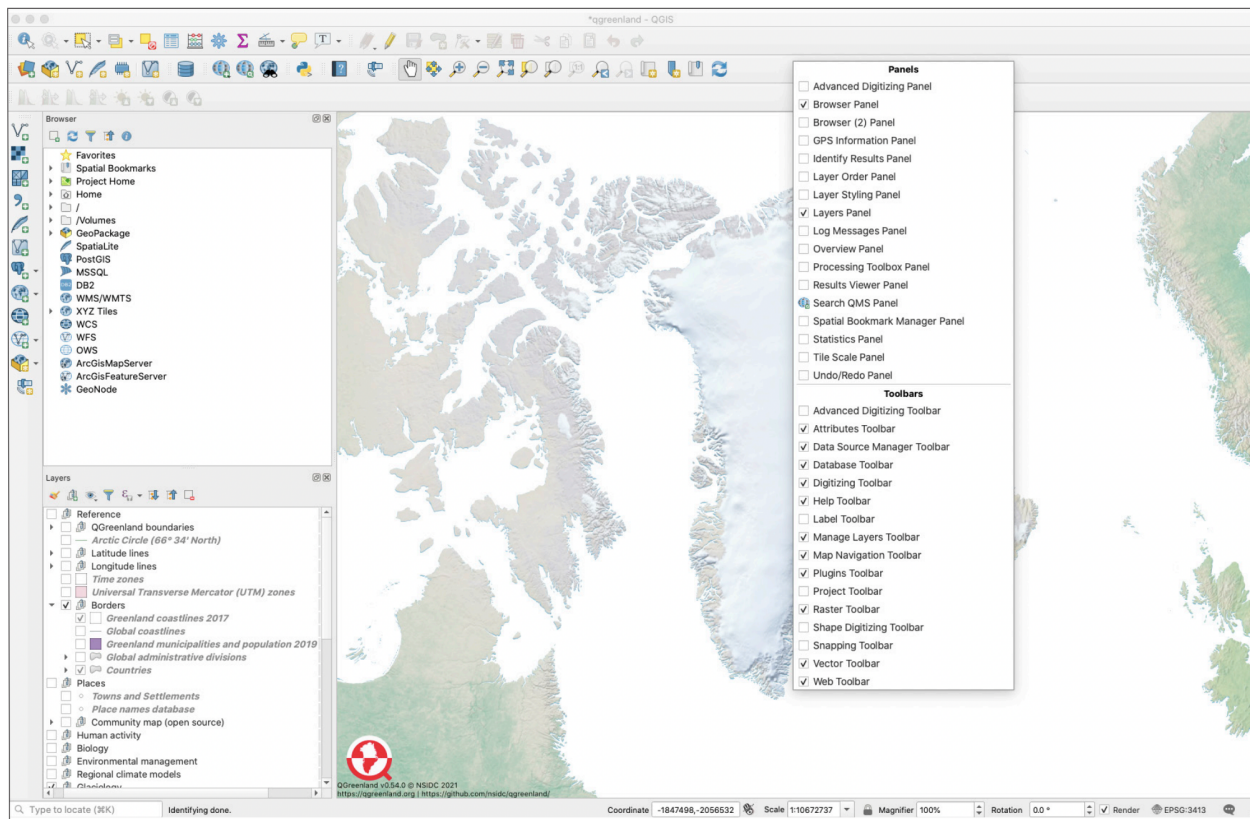


Fig. 9.3: Toolbars can be added or removed by right clicking on the toolbar area and checking/unchecking boxes.



### 9.1.5 4) Browse data in the QGreenland project

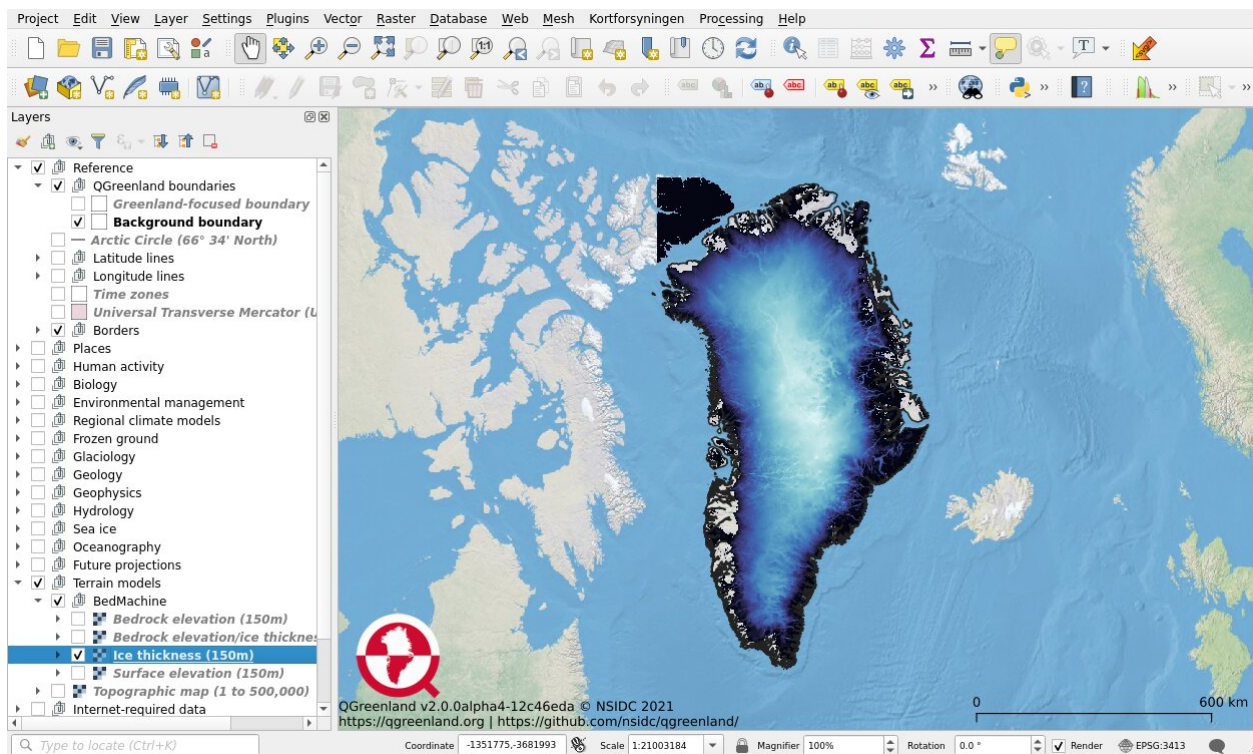
Layers in QGreenland Core are organized into groups by category. For example, the “Background boundary” layer is “QGreenland boundaries” group, which is itself inside of the “Reference” group (“Reference/QGreenland boundaries/Background boundary”).



#### 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 v5” group. The **Map view** should now include a visualization of Ice thickness at a 150m spatial resolution.



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



## Project Layers


- ☒ Ice thickness (150m)
- ☒ Ice thickness contours
- ☒ Ice slab thickness in firm ice 2010-2014
- ☒ Bedrock elevation/ice thickness error (150m)
- ☒ Ice column thickness rate of change 2003-2...



## 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](https://docs.qgis.org/3.28/en/docs/user_manual/introduction/general_tools.html#zooming-and-panning)<sup>33</sup> for more detailed information on how to effectively navigate the **Map View**.

<sup>33</sup> [https://docs.qgis.org/3.28/en/docs/user\\_manual/introduction/general\\_tools.html#zooming-and-panning](https://docs.qgis.org/3.28/en/docs/user_manual/introduction/general_tools.html#zooming-and-panning)

### 9.1.6 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.

## 9.2 Beginner Video Series

### 9.2.1 Overview

In this video series, you will become familiar with QGIS, learn how to download and browse the QGreenland Core data package, and explore the basic geospatial data analysis tools that make QGreenland a powerful tool for research, education, and local decision making. The video tutorial series contains 7 short video sessions.

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#### Goals

- Learn what data is included in the QGreenland Core Package
- Analyze Greenland data using geoprocessing tools
- Find analysis tools and data relevant to you or your classes

Total Time: 1 hour

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In order to get the most out of this series, we recommend the following:

- Install QGIS on your computer. Go to [qgis.org](https://qgis.org)<sup>34</sup> and download the free QGIS software. QGIS version 3.16 is the oldest version supported by QGreenland
- Download the QGreenland Core data package at <https://qgreenland.org/download>
- When watching the videos, click on the settings icon to adjust the subtitles (in English or other languages) and adjust the playback speed
- Take time to engage in the practice tasks and take notes

#### Session 1: Introduction to QGreenland<sup>35</sup>

- This video will introduce you to geographic information systems (GIS) and what it can be used for.

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<sup>34</sup> <https://www.qgis.org/>

<sup>35</sup> <https://www.youtube.com/watch?v=gD0vkP5JUmA&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=1>

**Session 2: Introduction to QGIS and QGreenland Core Package**<sup>Page 23, 36</sup>

- How to download QGIS and QGreenland Core package
- Obtain a general understanding of what GIS and QGreenland are
- Explore the QGreenland Core package folders

**Session 3: Navigating the Core package**<sup>37</sup>

- Navigate the QGIS interface
- Toggle panels on and off
- Turn toolbars on and off

**Session 4: Layers and Properties**<sup>38</sup>

- Access properties, attributes, and metadata of layers
- Know the difference between vector and raster layers
- Identify different layer types in Layers Panel
- Change display or symbology of layers

**Session 5: Processing Toolbox and Data Analysis**<sup>39</sup>

- Locate and open the processing toolbox
- Select by attribute in a vector layer
- Run basic statistics on a vector attribute field including sum, mean, and range
- Calculate the surface volume area of a raster layer

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**Note:** The “Populated places” layer referred to in this video has been updated and moved from “Places/Community map (crowd-sourced)” to the root of the “Places/” layer group in QGreenland v3.

This updated “Populated places” layer has a “Population 2016” attribute that should be used instead of the “population” attribute indicated in the video.

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<sup>36</sup> <https://www.youtube.com/watch?v=u8exrxhwme4&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=2>

<sup>37</sup> <https://www.youtube.com/watch?v=WhboP5u5HqE&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=3>

<sup>38</sup> [https://www.youtube.com/watch?v=hAMw-\\_dFWng&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=4](https://www.youtube.com/watch?v=hAMw-_dFWng&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=4)

<sup>39</sup> <https://www.youtube.com/watch?v=znKeiV3-Amo&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=5>

**Session 6: Editing Existing and New Layers**<sup>Page 24, 40</sup>

- Edit existing layers in the QGreenland Core Package
- Create a new Vector layer
- Manage layer locations and removal of layers

**Session 7: Preparing Map for Export and Publication**<sup>41</sup>

- Export a QGreenland Map for publication

## 9.3 Interacting with Geospatial Data in QGreenland Core

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**Note:** QGreenland users will learn through experience that there is very often more than one way to complete a desired task in the QGIS platform

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### 9.3.1 Spatial Data Overview

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

#### 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. 9.4). All of the vector layers in QGreenland are GeoPackage (.gpkg) files. A GeoPackage is just a platform-independent file type for storing geospatial data.

#### 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**.

<sup>40</sup> <https://www.youtube.com/watch?v=98nF6YJAnns&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=6>

<sup>41</sup> [https://www.youtube.com/watch?v=6YG\\_Jc7HcOo&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=7](https://www.youtube.com/watch?v=6YG_Jc7HcOo&list=PLSRiyMridUCwyu-vqpAFtm8bVERgTvs7q&index=7)

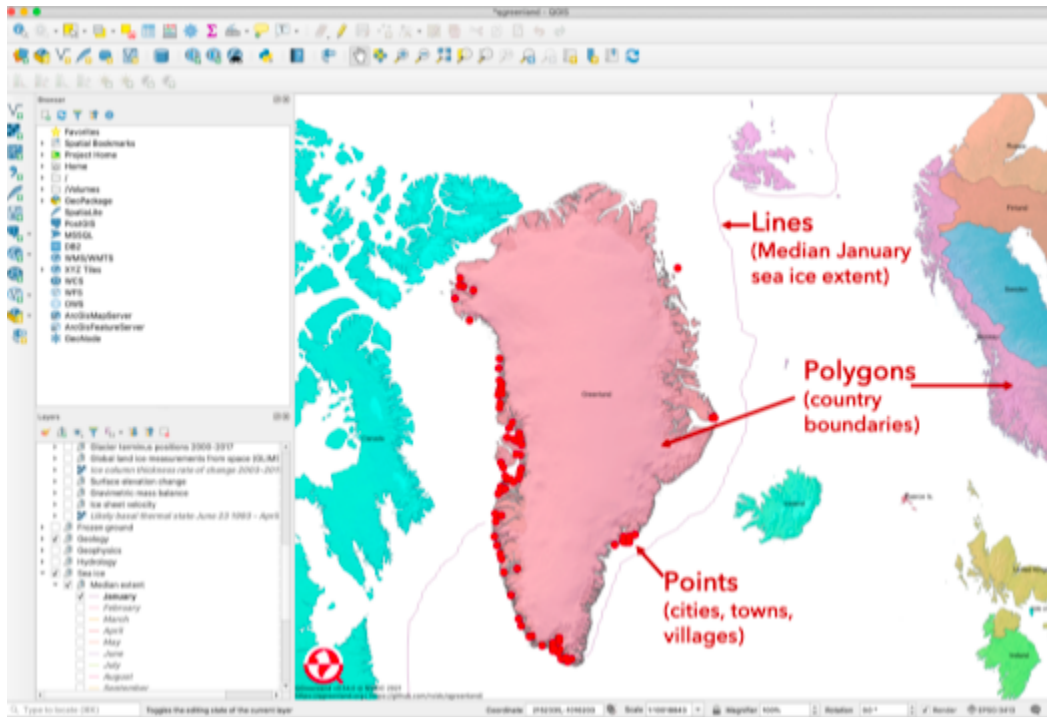


Fig. 9.4: Examples of vector data layers in QGreenland Core: points (towns and settlements), lines (median January sea ice extent), and polygons (country boundaries).

## 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. 9.5). 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.

### 9.3.2 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. 9.6). 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

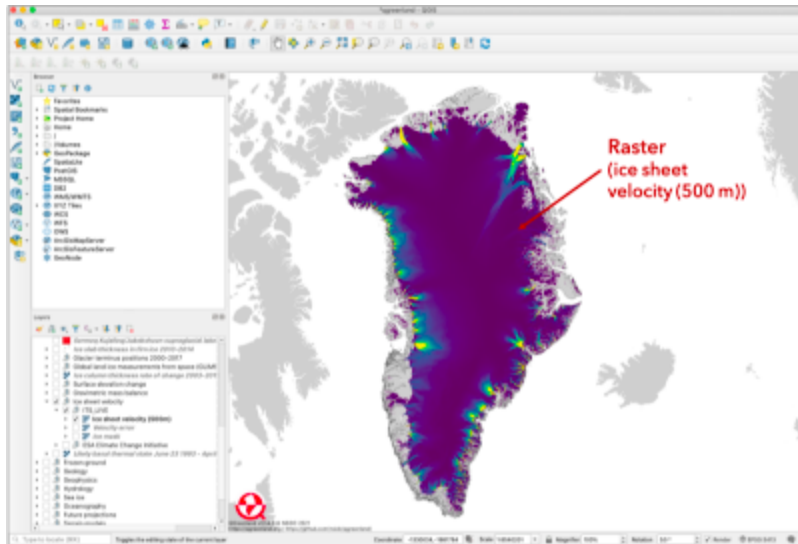


Fig. 9.5: Example of a Raster data layer in QGreenland, ice sheet velocity, where each grid cell in the raster is 500 m x 500 m and is color-coded by a velocity

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 'Populated places' layer. Regardless, QGreenland makes no guarantees about the accuracy and validity of data contained in QGreenland. See our [Disclaimer](#) (page 10) for more information.

### 9.3.3 Coordinate Reference System (CRS)

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.

### 9.3.4 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**.

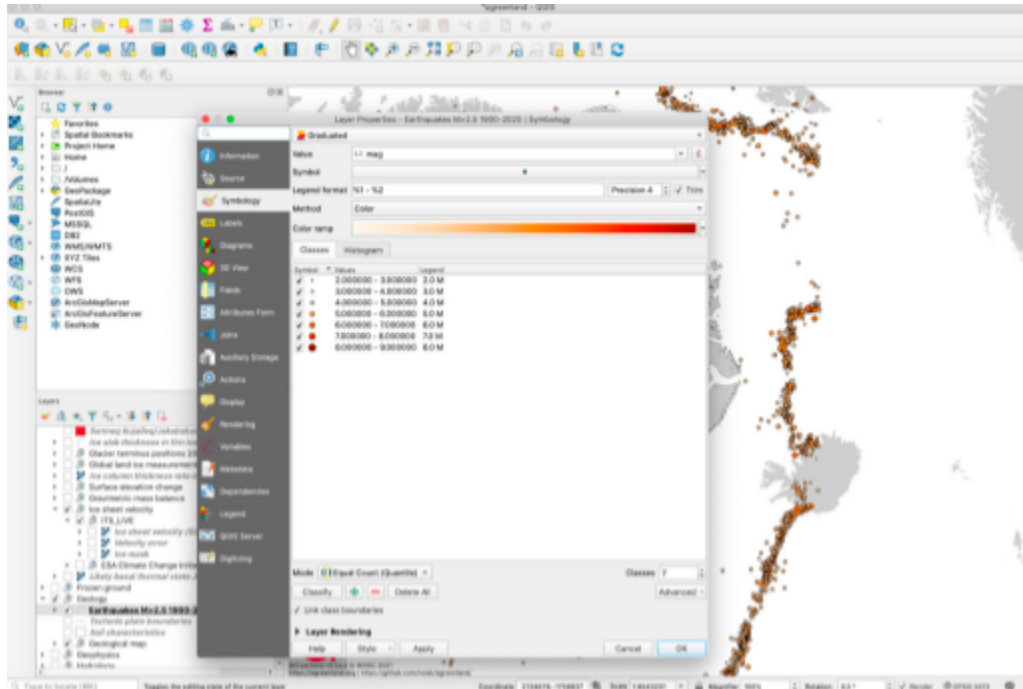


Fig. 9.6: The **Layer Properties** dialog window for the QGreenland ‘Earthquakes’ data layer.

### 9.3.5 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.

### 9.3.6 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 the **Identify Features** 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. 9.7).
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**.

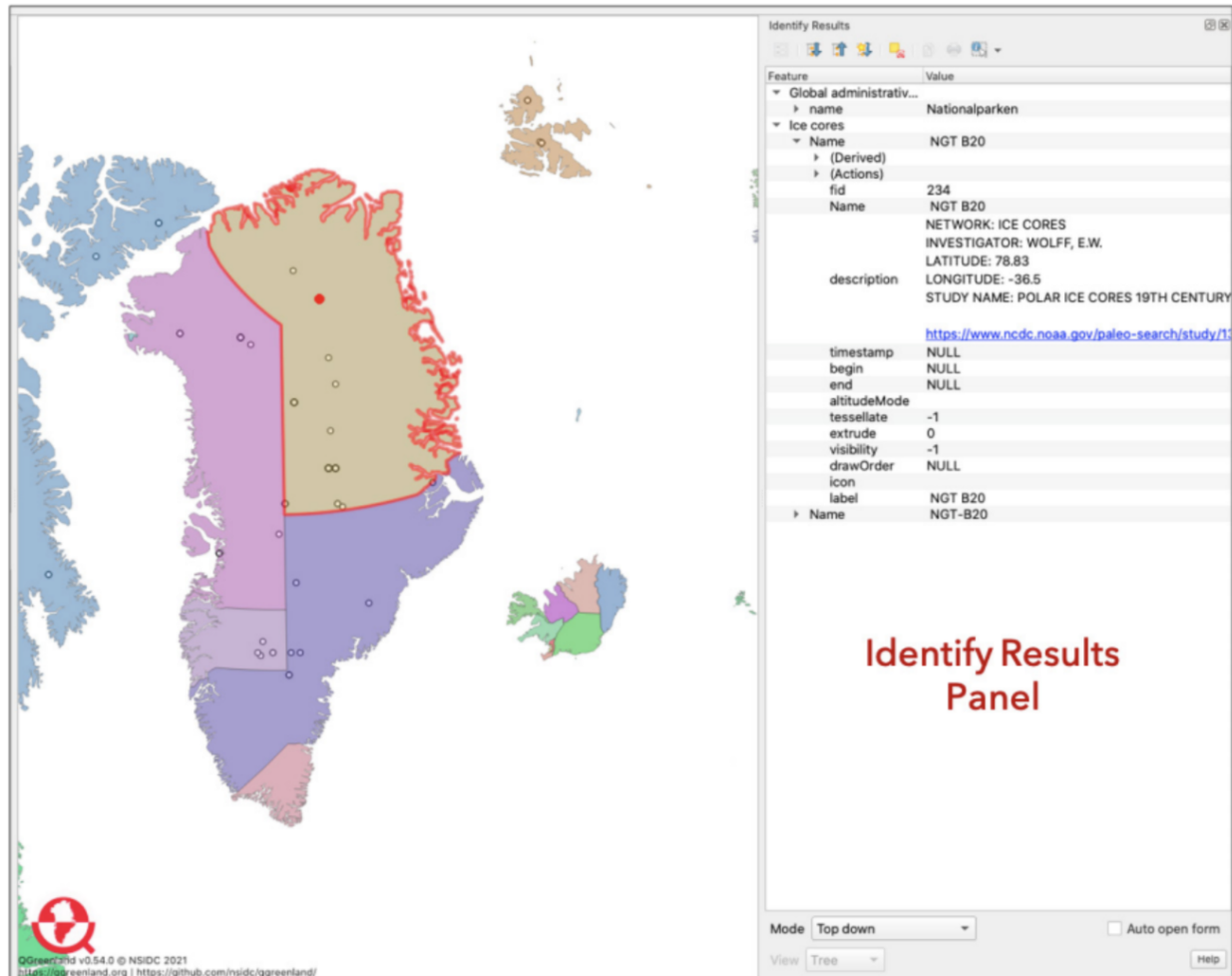


Fig. 9.7: The **Identify Results Panel** that shows results from the **Identify Features** tool.



### 9.3.7 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.

### 9.3.8 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 are 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**.

### 9.3.9 Editing Layer Symbolology

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.

### 9.3.10 Processing Toolbox

The **Processing Toolbox** is what makes the QGIS platform a powerful spatial data analysis tool. The **Processing 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](#)<sup>42</sup>

Examples of using the **Processing Toolbox** with QGreenland data are given below.

#### 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 2016 -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**. Close the window 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 2016 > 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**.

#### 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 2016 -Statistics = Save to temporary file (or whatever your preference is)
3. Click **Run**.

The **Basic statistics for fields** window should automatically switch to a view of the Log where you will see the results for the population basic statistics (Fig. 9.8). The value 'MEAN' will tell you the average size of Greenland's populated places (702 people). The value 'SUM' will tell you the total number of people in Greenland's metropolitan areas (55,494 people).

<sup>42</sup> [https://docs.qgis.org/3.28/en/docs/user\\_manual/processing/toolbox.html](https://docs.qgis.org/3.28/en/docs/user_manual/processing/toolbox.html)

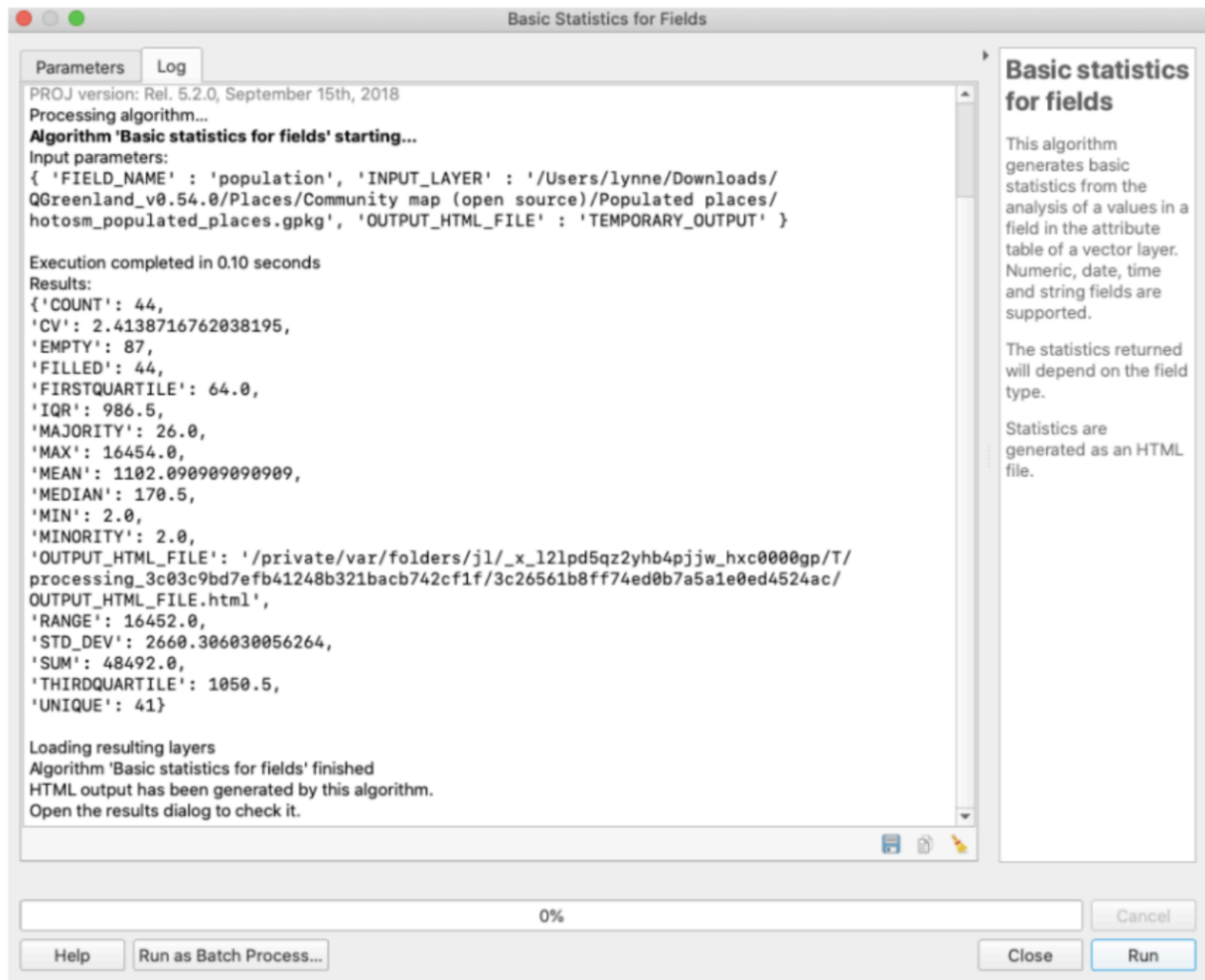


Fig. 9.8: Results of Example 2: Vector Layer Statistics

### Example 3: Simple Raster Analysis

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

See the *Calculate the volume of the Greenland ice sheet* (page 32) tutorial for an example of how to utilize the **Raster Surface Volume** tool.

### Example 4: Using the Raster Calculator

How does the maximum sea ice concentration (%) around Greenland and the surrounding land masses in 2021 compare to the maximum sea ice concentration a decade earlier (2011)?

The **Raster Calculator** is a tool that allows you to perform calculations on one or more raster layers. For example, if you wanted to convert a raster layer that is in km<sup>2</sup> to mi<sup>2</sup>, you could use the raster calculator. In this example, we are 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 **March2021@1** layer (this is the layer for the NSIDC's sea ice concentration data from March 2021). 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 **March2011@1** layer. It should show up after the minus sign, again in quotations (Fig. 9.10). 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.

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 2011 and 2021, where positive values indicate an increase between 2011 and 2021 (endmember = +80%), and negative values indicate a decrease (endmember = -95%).

## 9.4 Calculate the volume of the Greenland ice sheet

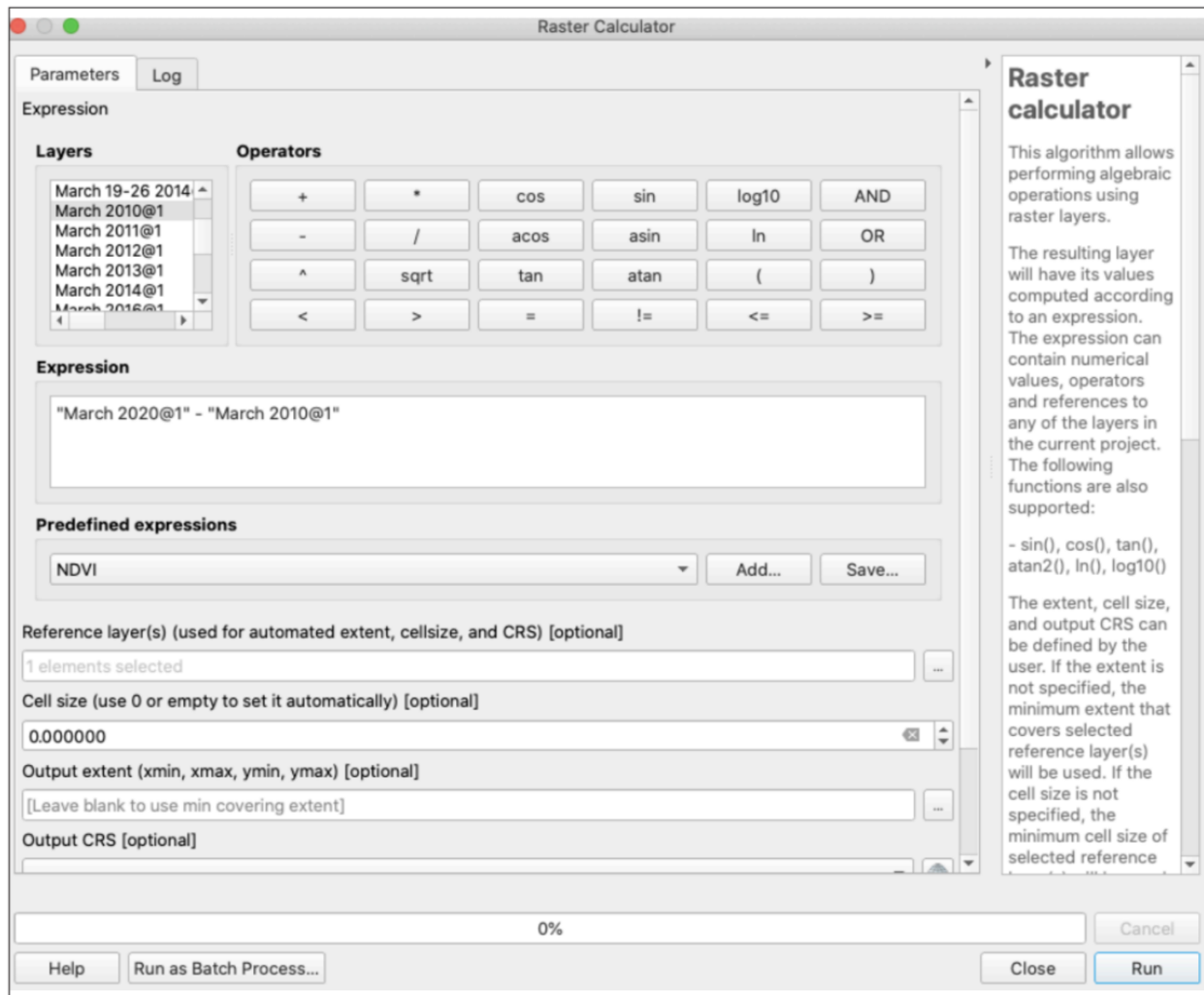
The **Processing Toolbox** in QGIS provides a collection of tools and pre-written algorithms that allow the user to perform a wide variety of raster and vector data analyses. See the [QGIS manual](#)<sup>43</sup> for complete documentation on the **Processing Toolbox**.

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 is new to GIS, it is recommended to review QGIS' [Gentle Introduction to GIS](#)<sup>44</sup> first

<sup>43</sup> [https://docs.qgis.org/3.28/en/docs/user\\_manual/processing/toolbox.html](https://docs.qgis.org/3.28/en/docs/user_manual/processing/toolbox.html)

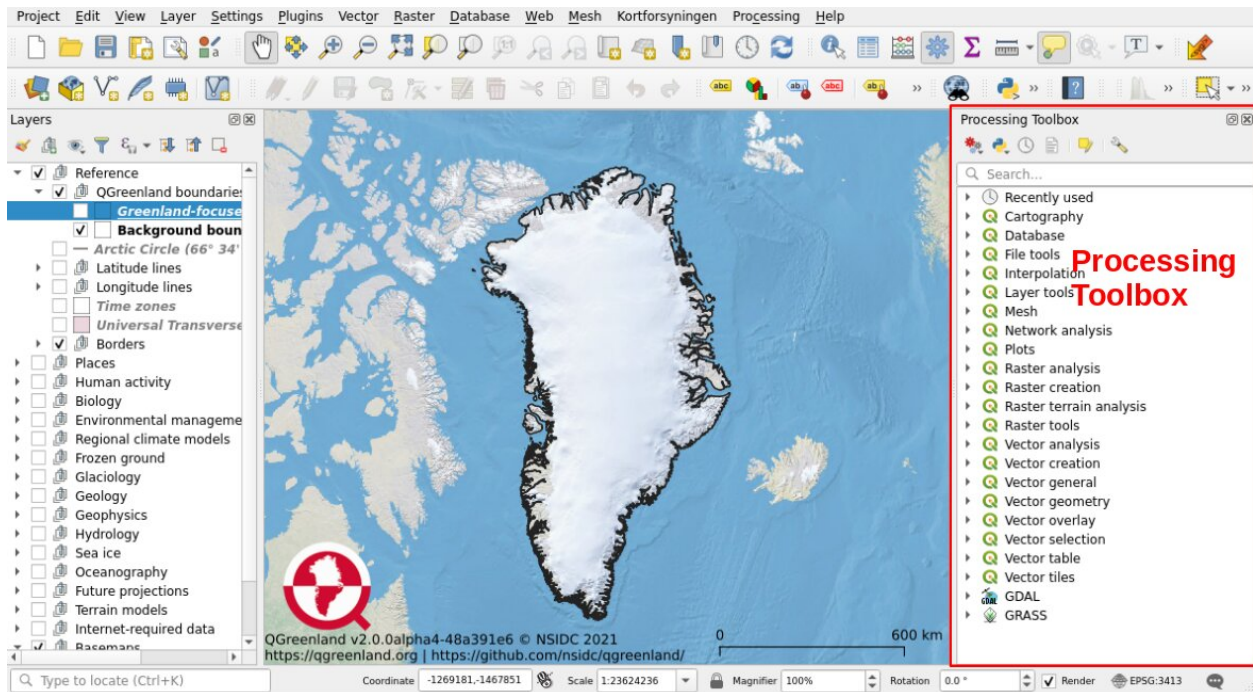
#### 9.4. Calculate the volume of the Greenland ice sheet

Fig. 9.10: The **Raster Calculator** expression for Example 4.



### 9.4.1 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.



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

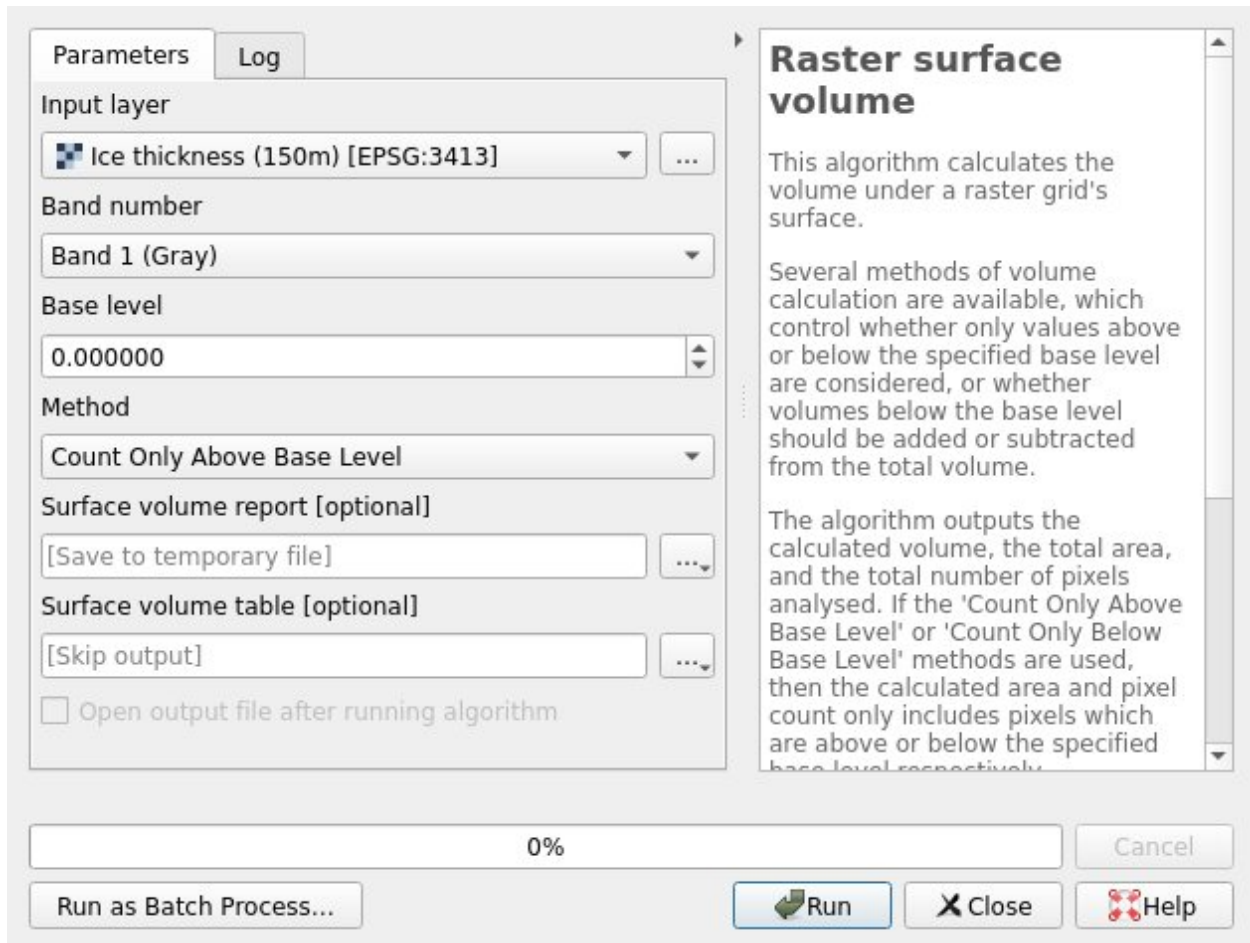


### 9.4.2 Use the Raster Surface Volume tool

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:

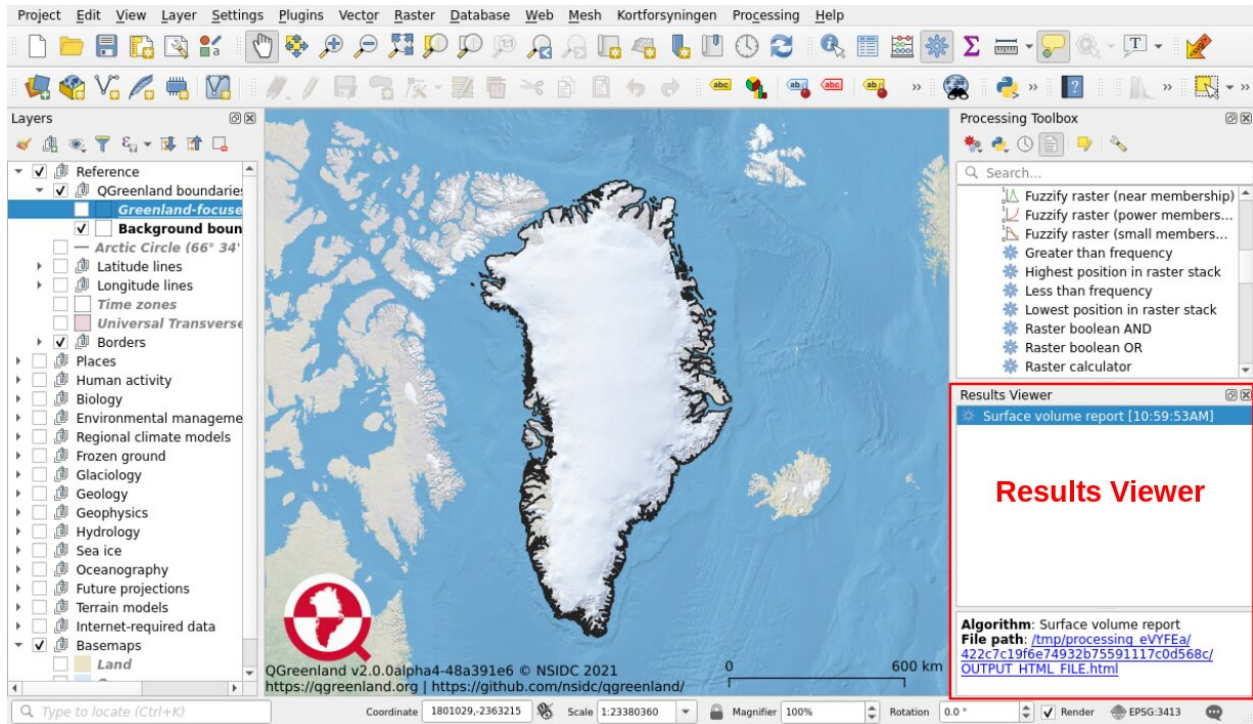
- **Input layer** = Ice thickness (150 m)
- There will only be one option for **Band number**
- **Base level** = should already be set to 0. This is the minimum pixel value in the Ice thickness layer.
- **Method** = Count only above base level (since we are interested in ice thickness values greater 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.

<sup>44</sup> [https://docs.qgis.org/3.28/en/docs/gentle\\_gis\\_introduction/index.html](https://docs.qgis.org/3.28/en/docs/gentle_gis_introduction/index.html)



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 browser. 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 successfully run the analysis, the results should show that the Greenland ice sheet has a volume of 2,965,561,810,382,715 m<sup>3</sup>, or about 3 million km<sup>3</sup>.

### 9.4.3 Summary

In completing this tutorial, the user has become familiar 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.

## 9.5 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 publication. 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.

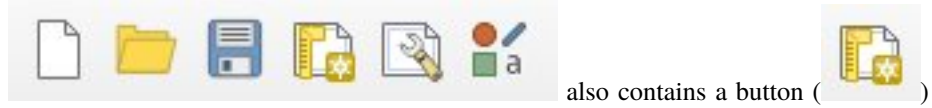
See the [QGIS manual](#)<sup>45</sup> for complete documentation on print layouts in QGIS.


<sup>45</sup> [https://docs.qgis.org/3.28/en/docs/training\\_manual/map\\_composer/map\\_composer.html](https://docs.qgis.org/3.28/en/docs/training_manual/map_composer/map_composer.html)

## 9.5.1 Creating a new print layout

Once one has created a map in the QGIS **Map View** that one would like to print or publish, one needs to switch to the QGIS **Print Layout**. From the menu bar, select **Project -> Print Layout**.

**Note:** The **Project Toolbar** that creates a new **Print Layout**.






also contains a button (  )

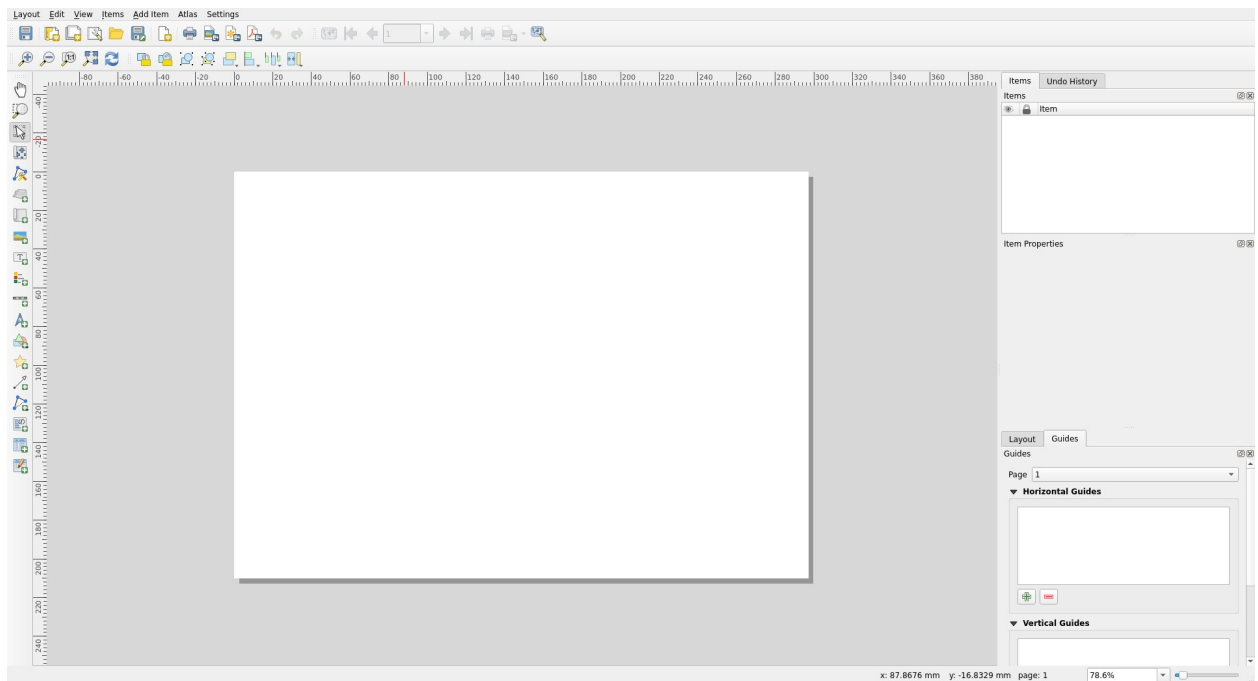
First, name the new print layout after the figure you plan to create and click **OK**.

Enter a unique print layout title  
(a title will be automatically generated if left empty)

Greenland basemap

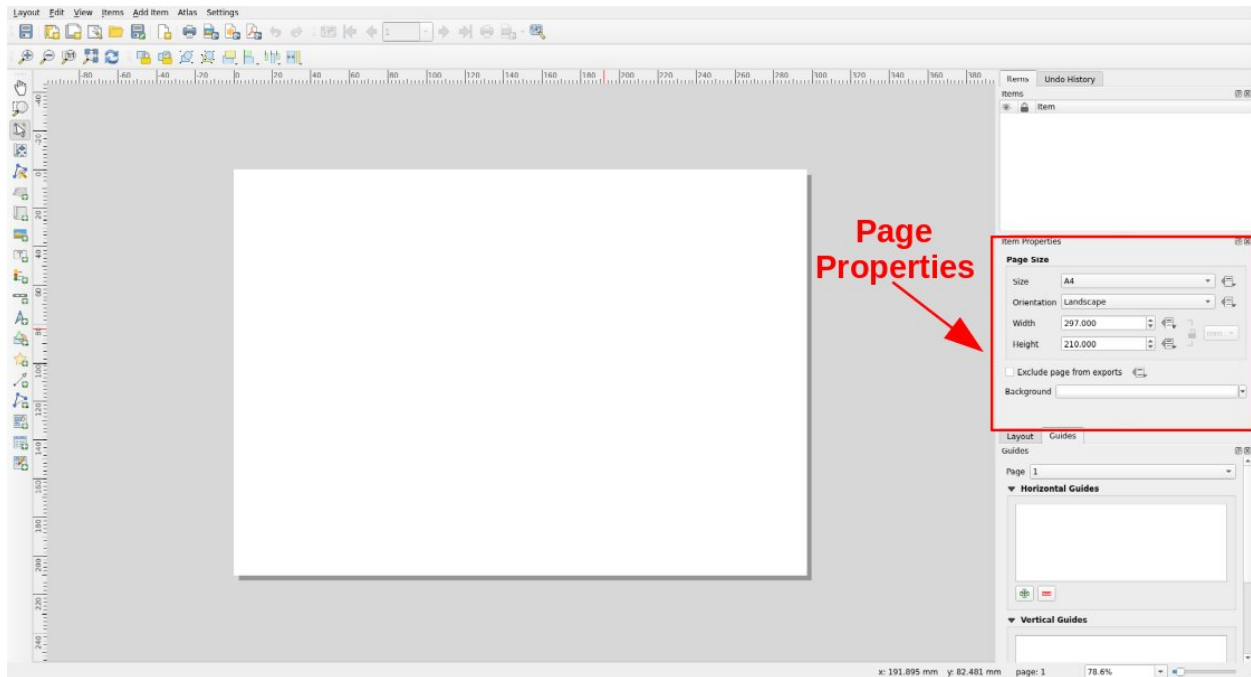
  

When the print layout window opens, it will be initially blank.



### 9.5.2 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.

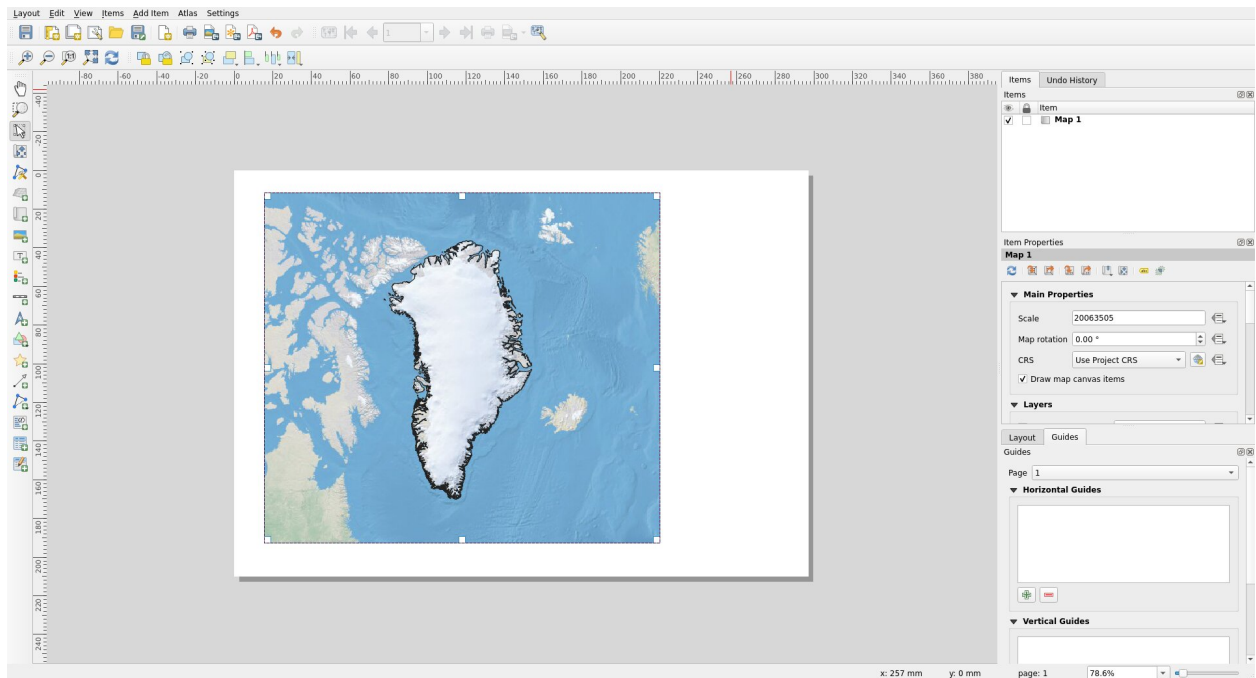



### 9.5.3 Adding a map and other elements

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**.

### 9.5.4 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).

## **Part III**

## **How-to**

## HOW-TO GUIDES

### 10.1 Adding New Datasets to QGreenland

Once the QGreenland Core package is downloaded and extracted 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.qgz` project file. If you do not 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.

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**Note:** The QGreenland project uses the EPSG:3413 coordinate reference system (CRS) and all pre-loaded layers are either GeoTIFF (raster) or GeoPackage (vector) files. Datasets in different CRSs or data formats can still be added to QGreenland, but may undergo “on the fly reprojection”<sup>46</sup>.

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#### 10.1.1 Adding New Layers in QGIS

To add new data layers to QGreenland in QGIS:

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**.

To learn about adding online-access layers (e.g, WMS, WFS, WCS), see our documentaiton on *How to add an online layer to QGIS* (page 48).

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<sup>46</sup> [https://docs.qgis.org/3.28/en/docs/training\\_manual/vector\\_analysis/reproject\\_transform.html#basic-fa-on-the-fly-reprojection](https://docs.qgis.org/3.28/en/docs/training_manual/vector_analysis/reproject_transform.html#basic-fa-on-the-fly-reprojection)

### 10.1.2 Selecting for Greenland-Specific Vector 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 for data inside 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**.

### 10.1.3 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 are done making edits.
6. When you're finished, click on the **Toggle Editing** button again in the toolbar to disable editing.

### 10.1.4 Creating New Vector Layers from Scratch

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

To draw a new vector layer from scratch, use the **Layer -> Create Layer** menu and select one of the following options:

- New GeoPackage Layer (reccomended)
- New Shapefile Layer (not reccomended, see [switchfromshapefile.org](http://switchfromshapefile.org)<sup>47</sup>).
- New Spatiallite Layer
- New Temporary Scratch Layer (will not persist data to disk!)

In the new window that opens after selecting one of these options, fill out the given options (each will be slightly different). For detailed instructions on how to add vector layers, see the [QGIS documentation](#)<sup>48</sup>.

#### Creating a 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**<sup>49</sup> 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.

### 10.1.5 Creating a Custom Clipping Boundary Polygon

You can create your own custom boundary polygon layer to extract features from. Follow the instructions above on *Creating New Vector Layers from Scratch* (page 44) to draw a polygon layer from scratch. Then, follow the instructions on *Selecting for Greenland-Specific Vector Data* (page 43) to extract features from vector layers using the custom polygon boundary layer instead of the “Greenland coastlines 2017” layer.

<sup>47</sup> <http://switchfromshapefile.org/>

<sup>48</sup> [https://docs.qgis.org/3.28/en/docs/user\\_manual/managing\\_data\\_source/create\\_layers.html#creating-new-vector-layers](https://docs.qgis.org/3.28/en/docs/user_manual/managing_data_source/create_layers.html#creating-new-vector-layers)

<sup>49</sup> <http://www.geopackage.org/>



### 10.1.6 Importing GPS and other GNSS Data

QGIS supports importing Global Positioning System (GPS) and other Global Navigation Satellite System (GNSS) data from GPS Exchange Format (GPX) datasets. In the **Menu Bar**, go to **Layer -> Add Layer -> Add GPX Layer**.

QGIS can also interface with a GPS device to download data directly and provide live tracking.

Please see the QGIS documentation on [Working with GPS Data](https://docs.qgis.org/3.28/en/docs/user_manual/working_with_gps/index.html)<sup>50</sup> for more information.

## 10.2 How to Locate Layer Metadata

Metadata refers to the general information about a data file, and the metadata for QGreenland layers can be accessed in two ways.

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**Note:** For more information on layer properties and metadata, see our Tutorial on *Interacting with Geospatial Data in QGreenland Core* (page 24).

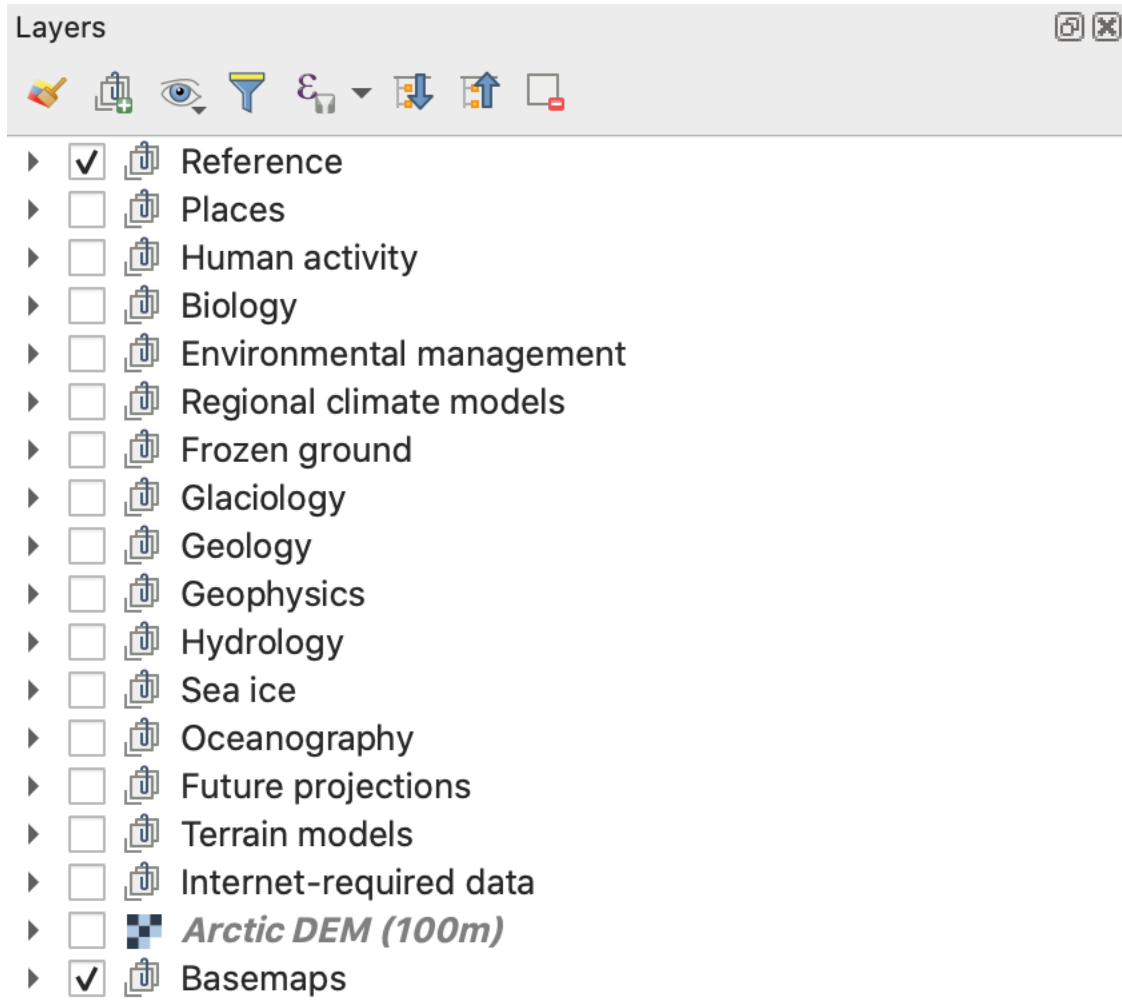
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### 10.2.1 Via QGIS Layer Properties

If you have the QGreenland Core base package downloaded, you can easily locate and view layer metadata within QGIS. First, open the `qgreenland.qgz` QGIS project file that was included in the QGreenland Core download package. Next, locate your layer of interest in the **Layer Panel**. The **Layer Panel** is a panel on the left side of the **Map View** containing a list of layers that are in your QGIS project.

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<sup>50</sup> [https://docs.qgis.org/3.28/en/docs/user\\_manual/working\\_with\\_gps/index.html](https://docs.qgis.org/3.28/en/docs/user_manual/working_with_gps/index.html)



Right click on the layer and select the **Properties** option. This will open the Layer Properties window. Next, find the metadata tab on the left side window panel. This will show any available information that is associated with the data layer, including the title and abstract.

Identification | Categories | Keywords | Access | Extent | Contact | Links | History | Validation

This page describes the basic attribution of the dataset. Please use the tooltips for more information.

Parent identifier

Identifier

Title

Depth contours

Type

Language

Abstract

This dataset includes linear features that represent bathymetric contours recorded in metres, derived from the International Bathymetric Chart of the Arctic Ocean.

=== Original Data Source ===

Geological map of the Arctic / Carte gologique de l'Arctique

As part of the International Polar Year (IPY) 2007-08 and 2008-09 activities, and related objectives of the Commission for the Geological Map of the World (CGMW), nations of the circumpolar Arctic have co-operated to produce a new bedrock geology map and related digital map database at a scale of 1:5 000 000. The map, released in north polar stereographic projection using the World Geodetic System (WGS) 84 datum, includes complete geological and physiographic coverage of all onshore and offshore bedrock areas north of latitude 60 degrees north.

Citation:

Harrison, J.C., St-Onge, M.R., Petrov, O.V., Strelnikov, S.I., Lopatin, B.G., Wilson, F.H., Tella, S., Paul, D., Lynds, T., Shokalsky, S.P., Hults, C.K., Bergman, S., Jepsen, H.F., and Solli, A., 2011. Geological map of the Arctic / Carte gologique de l'Arctique; Geological Survey of Canada, Map 2159A, scale 1:5 000 000.

Citation URL:

<https://doi.org/10.4095/287868>

Help | Metadata | Apply | Cancel | OK

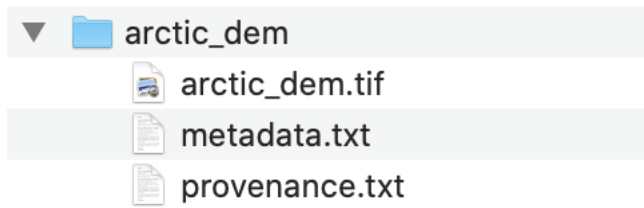
Information about the layer's coordinate reference system and spatial extent can be found in the **Information** tab.

### 10.2.2 Via Text Files in Layer Directories

In each layer directory inside the QGreenland package, you should see 2 text files, one `provenance.txt`, which includes information on how the data is processed, and one `metadata.txt`.

Open up `metadata.txt` to read through the layer metadata including layer description, dataset abstract, and citation information.

Open the `provenance.txt` file to see all of the processing steps applied to the data for QGreenland.



**Note:** To see the layer's geospatial metadata (e.g., the coordinate reference system and spatial extent), we recommend

using *QGIS* (page 45).

## 10.3 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)**<sup>51</sup>: Provides image representations of geospatial data.
- **Web Coverage Service (WCS)**<sup>52</sup>: Provides access to raster data
- **Web Feature Service (WFS)**<sup>53</sup>: Provides access to vector data

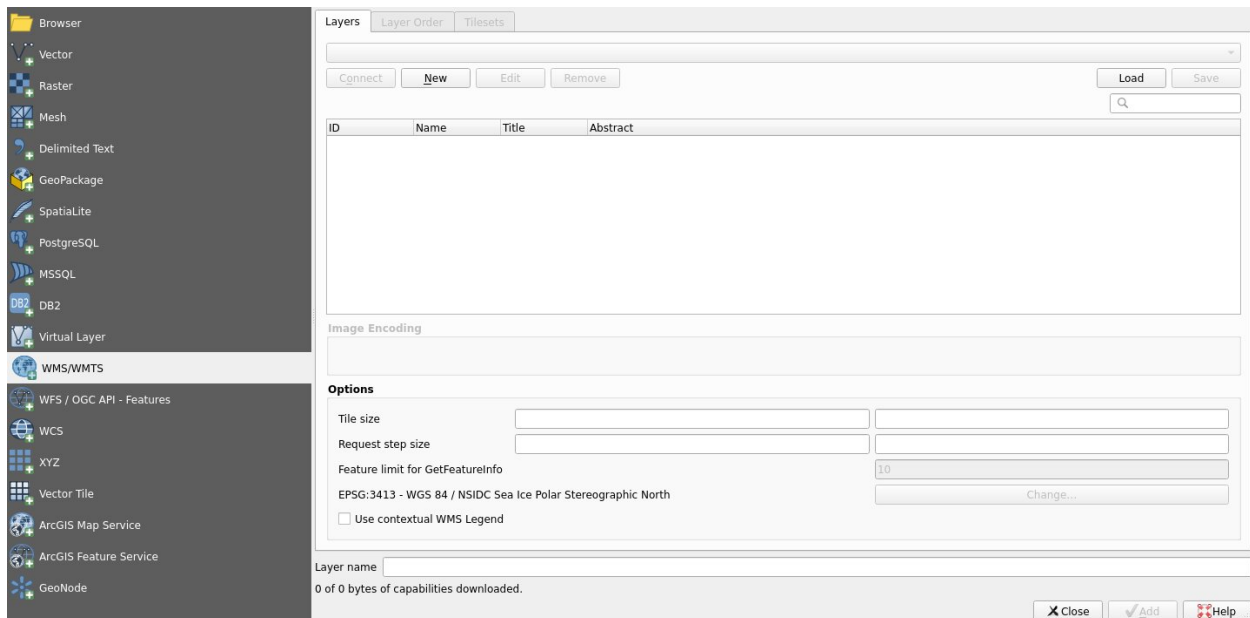
This how-to guide covers creating a new connection to a WMS and adding a layer from that service. WCS, WFS, and other online services can be interacted with in a similar way.

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

- **Online resources tutorial**<sup>54</sup>
- **OGC web services user manual**<sup>55</sup>

### 10.3.1 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.



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>.

<sup>51</sup> <https://www.ogc.org/standards/wms>

<sup>52</sup> <https://www.ogc.org/standards/wcs>

<sup>53</sup> <https://www.ogc.org/standards/wfs>

<sup>54</sup> [https://docs.qgis.org/3.28/en/docs/training\\_manual/online\\_resources/index.html](https://docs.qgis.org/3.28/en/docs/training_manual/online_resources/index.html)

<sup>55</sup> [https://docs.qgis.org/3.28/en/docs/user\\_manual/working\\_with\\_ogc/ogc\\_client\\_support.html](https://docs.qgis.org/3.28/en/docs/user_manual/working_with_ogc/ogc_client_support.html)

**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 54) page.

**Connection Details**

Name

URL

**Authentication**

Configurations Basic

Choose or create an authentication configuration

No Authentication

Configurations store encrypted credentials in the QGIS authentication database.

**HTTP**

Referer

**WMS/WMTS Options**

DPI-Mode

☐ Ignore GetMap/GetTile URI reported in capabilities

☐ Ignore GetFeatureInfo URI reported in capabilities

☐ Ignore axis orientation (WMS 1.3/WMTS)

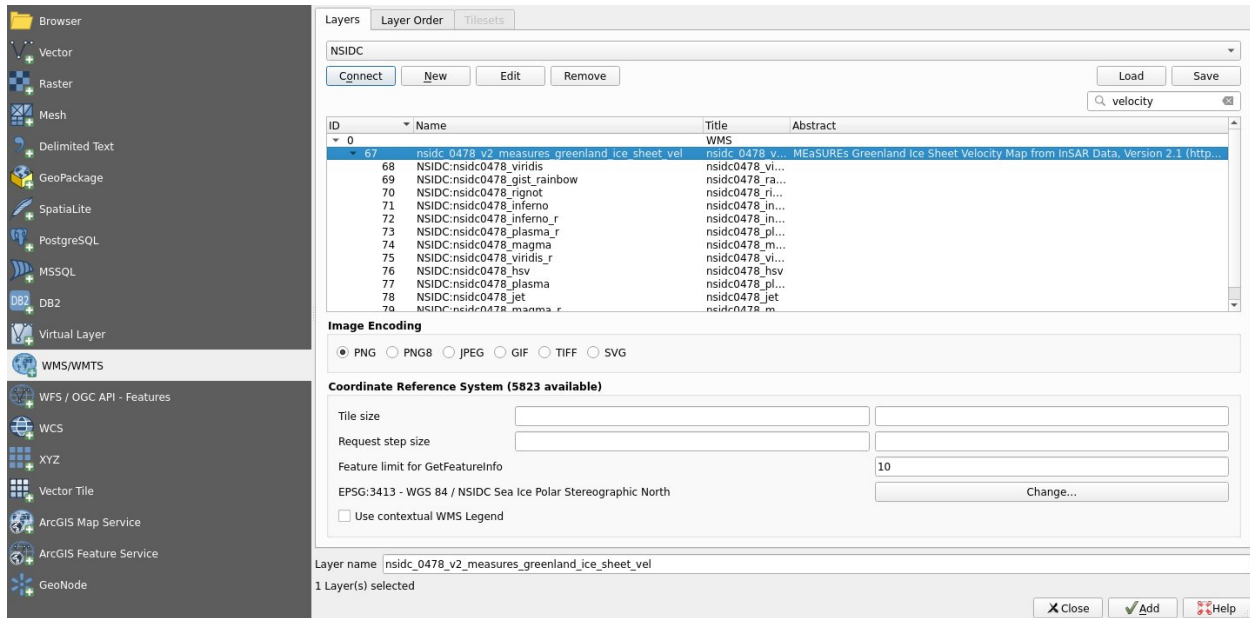
☐ Ignore reported layer extents

☐ Invert axis orientation

☐ Smooth pixmap transform

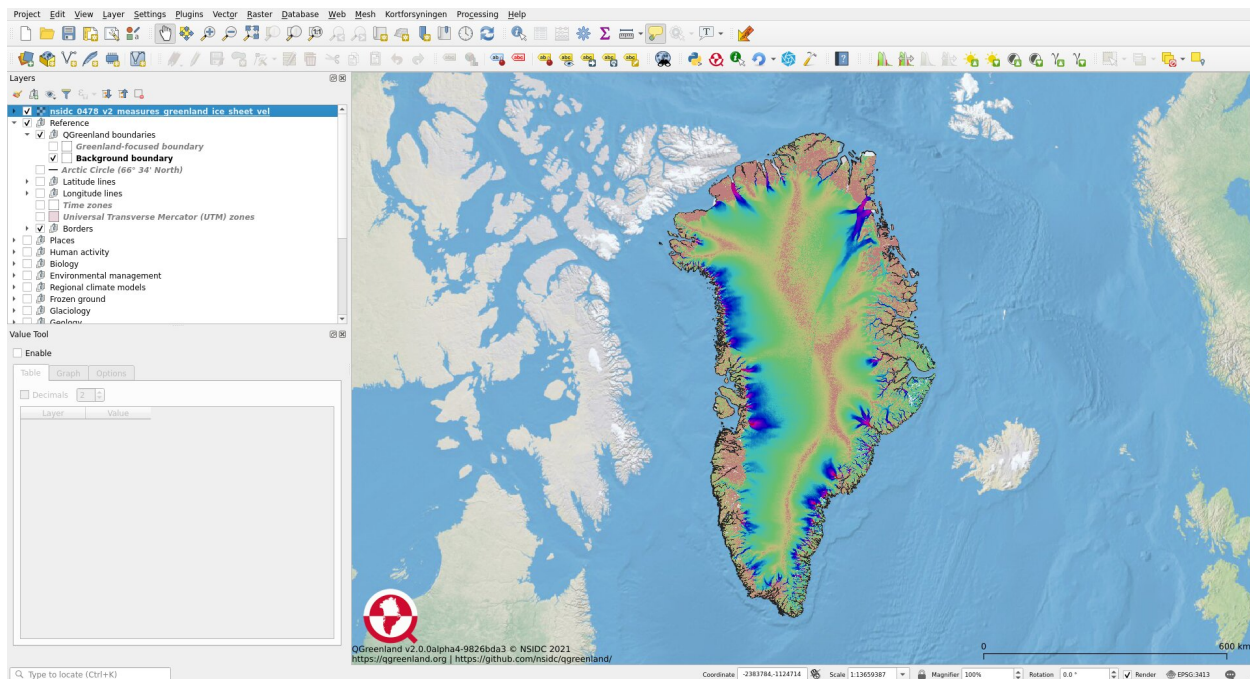
Click “OK”. This will create and select a new server connection to NSIDC’s WMS that can be re-used between sessions of QGIS.

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** panel. See the [QGIS documentation](#)<sup>56</sup> for more information about time-based control of the map canvas.

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<sup>56</sup> [https://docs.qgis.org/3.28/en/docs/user\\_manual/map\\_views/map\\_view.html#maptimecontrol](https://docs.qgis.org/3.28/en/docs/user_manual/map_views/map_view.html#maptimecontrol)

# **Part IV**

## **Reference**



## REFERENCE

### 11.1 Glossary

A “user” is someone who uses QGreenland in QGIS.

#### 11.1.1 QGreenland Core

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

#### 11.1.2 QGreenland Custom

<b>Attention:</b> QGreenland Custom is no longer supported.
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QGreenland Custom is a QGIS plugin that enables users to download and use only the QGreenland layers they are interested in.

#### 11.1.3 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.

#### 11.1.4 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.

## 11.2 Online layers reference

QGreenland can be enriched with layers provided by online services such as [Web Map Service \(WMS\)](#)<sup>57</sup>, [Web Feature Service \(WFS\)](#)<sup>58</sup>, and [Web Coverage Service \(WCS\)](#)<sup>59</sup>. 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 48) page for information on how to utilize these resources.

- The [National Snow and Ice Data Center \(NSIDC\)](#)<sup>60</sup> [WMS, WFS, WCS] provides access to a wide variety of datasets.
- The [Arctic Observing Viewer](#)<sup>61</sup> [WMS, WFS] provides observing sites associated with long-term monitoring activities in the circumarctic.
- The [Arctic Research Mapping Application](#)<sup>62</sup> [WMS, WFS] provides a variety of reference layers such as Arctic cities and an Arctic base map.
- The [Geological Survey of Denmark and Greenland \(GEUS\)](#)<sup>63</sup> [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 \(GIBS\)](#)<sup>64</sup> [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](#)<sup>65</sup>
- The <https://dataforsyningen.dk/data> [WMS, WMTS, WFS, WCS] provides reference data from the Danish Agency for Data Supply and Infrastructure Data Portal (SDFI) and other partner institutions. Users must register an account before accessing data. Note that the website is in Danish and can be translated to English via [Google Translate](#)<sup>66</sup>.

<sup>57</sup> <https://www.ogc.org/standards/wms>

<sup>58</sup> <https://www.ogc.org/standards/wfs>

<sup>59</sup> <https://www.ogc.org/standards/wcs>

<sup>60</sup> <https://nsidc.org/map-services/geospatial-map-services>

<sup>61</sup> <https://arcticobservingviewer.org/web-services/>

<sup>62</sup> <https://armap.org/web-services/>

<sup>63</sup> [http://maps.greenmin.gl/geusmap/ows/help/?mapname=greenland\\_portal](http://maps.greenmin.gl/geusmap/ows/help/?mapname=greenland_portal)

<sup>64</sup> <https://earthdata.nasa.gov/eosdis/science-system-description/eosdis-components/gibs>

<sup>65</sup> <https://wiki.earthdata.nasa.gov/display/GIBS/Geographic+Information+System+%28GIS%29+Usage#expand-QGIS>

<sup>66</sup> <https://translate.google.com/>

## 11.3 Add-on data

### 11.3.1 ArcticDEM add-on data

The Polar Geospatial Center<sup>67</sup> provides a custom Greenland 32-meter resolution ArcticDEM<sup>68</sup> for users of QGreenland.

Two download packages are provided for the v4.1 ArcticDEM:

- `arcticdem_v4.1_32m_greenland_dem_only.zip`: A ~4.1GB package containing only the 32-m resolution DEM.
- `arcticdem_v4.1_32m_greenland_dem_full.zip`: A ~9.5GB package containing the 32-m resolution DEM and ancillary datasets (e.g., a “count” dataset giving the number of contributing DEMs for each pixel).

Download one of these add-on packages and place it in a suitable location in your filesystem. Unzip the package and then follow the directions in the `README.txt` file included.

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<sup>67</sup> <https://www.pgc.umn.edu/>

<sup>68</sup> <https://data.pgc.umn.edu/gis/packages/qgreenland/packages/addons/>

## **Part V**

# **Discussion topics**

## DISCUSSION

### 12.1 About the QGreenland project

Greenland-focused research, planning, and education crosses disciplinary boundaries. With QGreenland, a free and open data platform, anyone can explore a wide variety of Greenland-focused data identified by an [expert team and Editorial Board](#)<sup>69</sup>.

QGreenland is a United States National Science Foundation EarthCube-funded effort (award #1928393<sup>70</sup>). Project development began in 2019, led by the [National Snow and Ice Data Center](#)<sup>71</sup>, which is a part of the University of Colorado Boulder [Cooperative Institute for Research in Environmental Sciences](#)<sup>72</sup>. In 2023, a second award (#2324765<sup>73</sup>) was granted, enabling continued work on QGreenland. 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](#)<sup>74</sup>. 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 on [GitHub Discussions](#)<sup>75</sup> or by [email](#)<sup>76</sup>.

### 12.2 QGreenland Custom QGIS Plugin

**Attention:** QGreenland Custom is no longer supported.

**QGreenland Custom** was an experimental 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).

The plugin is no longer under active development and should not be expected to work.

See the [QGreenland Custom Documentation](#)<sup>77</sup> for more information.

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<sup>69</sup> <https://qgreenland.org/our-team>

<sup>70</sup> [https://nsf.gov/awardsearch/showAward?AWD\\_ID=1928393&HistoricalAwards=false](https://nsf.gov/awardsearch/showAward?AWD_ID=1928393&HistoricalAwards=false)

<sup>71</sup> <https://nsidc.org/>

<sup>72</sup> <https://cires.colorado.edu/>

<sup>73</sup> [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=2324765](https://www.nsf.gov/awardsearch/showAward?AWD_ID=2324765)

<sup>74</sup> <https://github.com/nsidc/qgreenland>

<sup>75</sup> <https://github.com/nsidc/qgreenland/discussions>

<sup>76</sup> [qgreenland.info@gmail.com](mailto:qgreenland.info@gmail.com)

<sup>77</sup> <https://qgreenland-plugin.readthedocs.io/en/latest/>

## 12.3 What is next for QGreenland?

The release of v3 completes QGreenland’s original grant funding provided by the NSF’s EarthCube program and marks the start of planning for our next award.

### 12.3.1 QGreenland: Enabling Science through GIS<sup>Page 58, 78</sup>

Under this grant, we released QGreenland v1, v2, and v3. The QGreenland team also hosted virtual (e.g., <sup>179</sup>, <sup>280</sup>) and in-person workshops, developed educational materials, and participated in conferences and travel to Denmark and Greenland.

### 12.3.2 QGreenland-Net: Open, connected data infrastructure for Greenland-focused geoscience, and beyond<sup>81</sup>

Under QGreenland’s next award, we will focus on developing community practices for data customization that QGreenland and other communities can leverage to create consistent geospatial data packages. Learn more [here](#)<sup>82</sup>.

If you are interested in contributing data to QGreenland, we have added notes to our dataset compatibility guide about how to prepare for QGreenland-Net.

You can keep up-to-date by:

- Subscribing to the [QGreenland newsletter](#)<sup>83</sup>
- Following our activity in [GitHub](#)<sup>84</sup>, where we do our work in the open. Our [GitHub Discussions](#)<sup>85</sup> space may be of particular interest to follow or participate in discussions about our future direction.

<sup>78</sup> [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=1928393](https://www.nsf.gov/awardsearch/showAward?AWD_ID=1928393)

<sup>79</sup> <https://qgreenland-workshop-2023-researcher.github.io/>

<sup>80</sup> <https://qgreenland-workshop-2023-educator.github.io/>

<sup>81</sup> [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=2324765](https://www.nsf.gov/awardsearch/showAward?AWD_ID=2324765)

<sup>82</sup> [https://www.nsf.gov/awardsearch/showAward?AWD\\_ID=2324765](https://www.nsf.gov/awardsearch/showAward?AWD_ID=2324765)

<sup>83</sup> <http://eepurl.com/gQ7VCr>

<sup>84</sup> <https://github.com/nsidc/qgreenland>

<sup>85</sup> <https://github.com/nsidc/qgreenland/discussions>