Generating a Radiometrically Terrain Corrected (RTC) Image using the Sentinel-1 Toolbox (S1TBX)

This data recipe is for users who wish to generate an RTC image from Sentinel-1 data using easy-to-follow instructions in a graphical user interface (GUI).

Document Contents:

A) Background

Distortions in SAR imagery are induced by the side-looking nature of SAR sensors and are compounded by rugged terrain. Terrain correction corrects geometric distortions that lead to geolocation errors by moving image pixels into the proper spatial relationship with each other based on a Digital Elevation Model (DEM). Radiometric correction removes the misleading influence of topography on backscatter values. Radiometric Terrain Correction (RTC) combines both corrections to produce a superior product for science applications.

B) Materials List

1. Sentinel-1 Toolbox (S1TBX)

   S1TBX is integrated in ESA's Sentinel Application Platform software.

   a. Download the Sentinel Toolboxes installer for your Operating System.

   b. Run the installer and follow the prompts to install the software.

2. Sentinel-1 data granule

   a. You may download this sample granule, or find a different Sentinel-1 GRD granule on ASF's Vertex data portal. A NASA Earthdata login is required.

C) Preparing Software and Workspace

1. Open S1TBX by double-clicking the software's desktop icon or searching for SNAP Desktop software among your computer programs. The .exe file is saved in the bin folder in the snap folder in your directory of program files. For Mac OSX users, this will be in the *User/Applications/snap/bin* folder.

   a. Make sure that any available updates have been applied. A message will usually display in the bottom right corner when updates are available, but you can also check by selecting Check for Updates from the Help menu.

2. Create a new folder (i.e. Sentinel_RTC_S1TBX) to contain the files for this recipe and move the downloaded Sentinel-1 GRD granule into this new folder.

   a. **Do not unzip** the GRD granule. S1TBX uses the .zip file structure and will not recognize the extracted .SAFE directory.

D) Steps for Generating an RTC Image

Open the GRD granule in S1TBX

1. Open S1TBX (See Section C).
2. From the File menu, select Open Product or click the Open Product icon (Figure 1).
3. Browse to the folder that contains your Sentinel-1 data, and double-click the .zip file (or highlight the file and click Open).

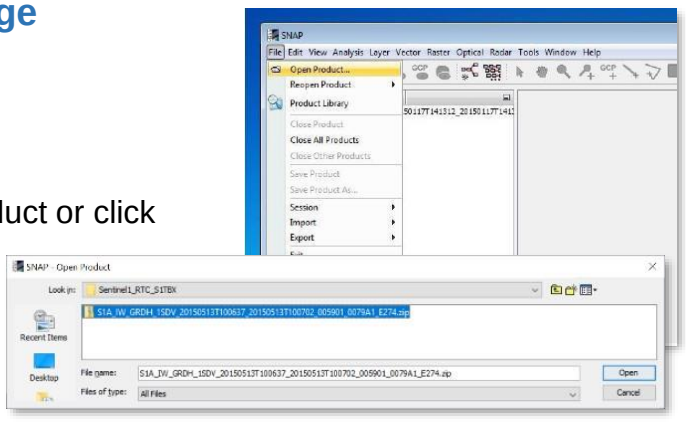

Figure 1: Open GRD Product in the S1TBX

a. If you get an error that no appropriate product reader was found, make sure that all updates have been applied (Section C), restart S1TBX, and re-download the GRD granule; the zip file contents may have been corrupted.

4. Note that as new products are generated during S1TBX processing, they will be displayed in the Product Explorer window numbered sequentially (in square brackets) in the order in which they were generated (Figure 5).

Apply Radiometric Terrain Correction

1. Apply Orbit File

   a. Highlight the GRD granule in the Product Explorer pane by clicking it once, then select Apply Orbit File from the Radar menu (Figure 2).

      i. In the I/O Parameters tab, set the Directory path to the same folder that contains your .zip file, and verify that the source is the correct granule (Figure 3).

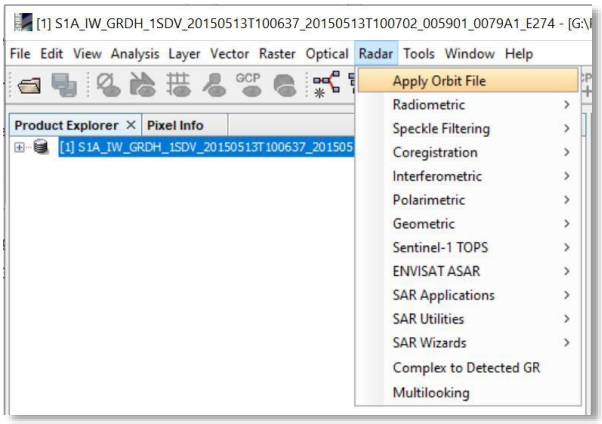

Figure 4: Apply Orbit File in Radar Menu

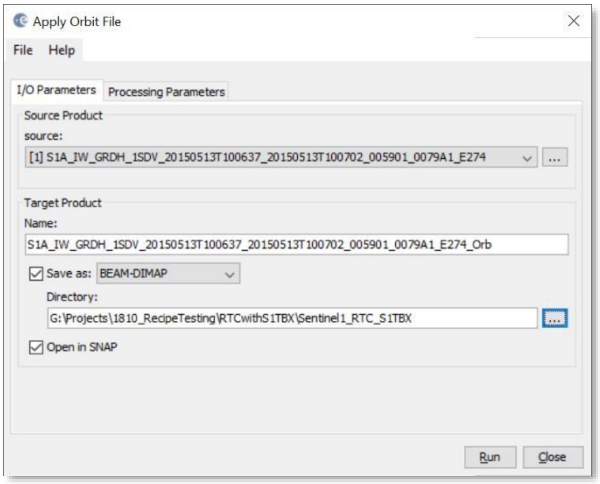

Figure 3: Apply Orbit File - I/O Parameters

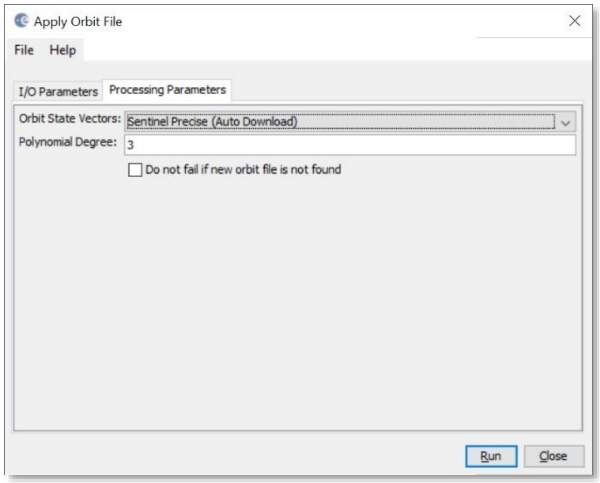

Figure 2: Apply Orbit File - Processing Parameters

   ii. In the Processing Parameters tab, verify that Orbit State Vectors is set to Sentinel Precise (Auto Download). This will automatically find

the appropriate Orbit file from the ESA website (Figure 4).

iii. Click Run. A Writing Target Product popup shows your progress.

b. The output from the Apply Orbit File process now appears as the second product in the Product Explorer pane, with a _Orb tag on the filename and prefixed with [2] (Figure 5).

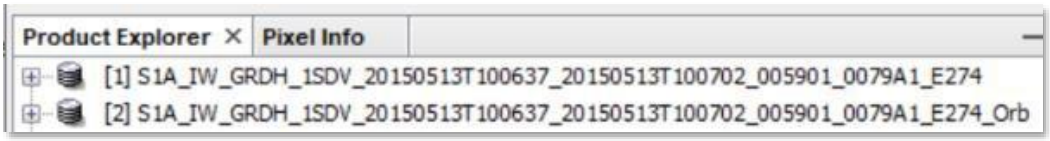

Figure 5: Naming and numbering convention in the Product Explorer

NOTE: *Depending on the computing power of your machine, this process can take from less than a minute to several minutes to complete.*

NOTE: If the Writing Target Product popup window does NOT appear, the software may be having difficulty locating the orbit files, and a window may eventually display directing you to download the orbit file manually (Figure 6). If this happens, follow the directions. Make sure to type in the https:// before the website address. Click on the POD Precise Orbit Ephemerides link and use the filters in the Validity Start section of the panel on the right side of the webpage to browse to an orbit file that includes the necessary date. You may need to add additional folders to the destination directory in order to match the destination path required by S1TBX.

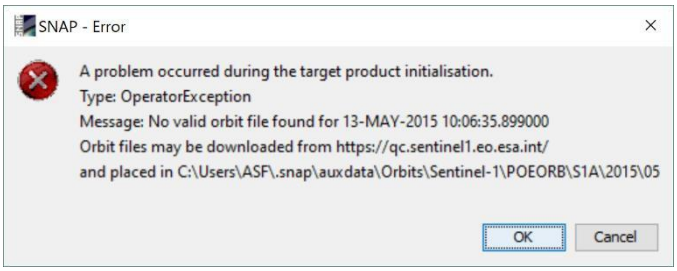

Figure 6: Error message when Orbit File is not found.

2. Calibrate Data

   a. Single-click the _Orb file in the Product Explorer pane.

   b. In the Radar menu, select Radiometric > Calibrate (Figure 7).

   c. In the Calibration dialog box, verify that the source is the _Orb product, and that the directory is the same output folder.

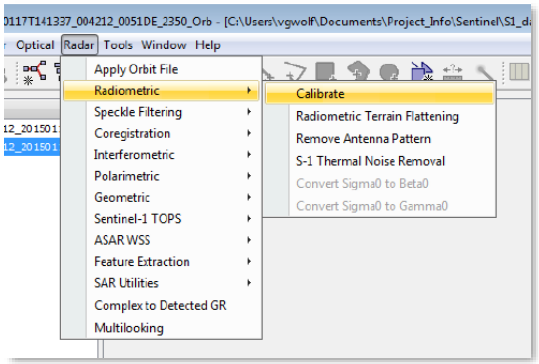

Figure 7: Selecting the Calibrate function in the Radiometric group of the Radar menu

d. Under the Processing Parameters tab, select Output beta0 band (the next step requires a beta0 output), and remove the check from any of the other output options (Figure 8).

    i. Your granule may have multiple polarizations listed, which is fine.

e. Click the Run button.

f. The output will have a _Cal tag at the end of the filename (product [3]).

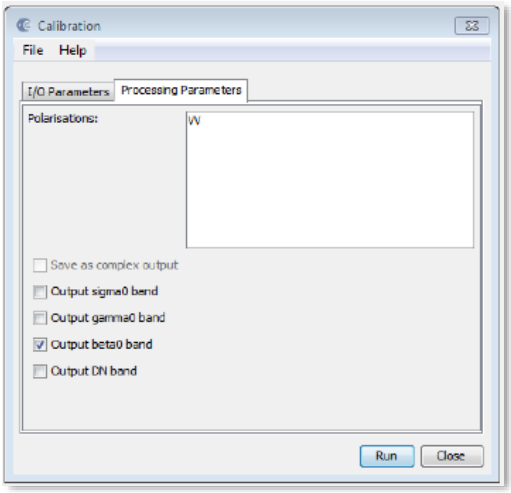

Figure 8: Calibration Processing Parameters

3. Flatten Terrain Radiometrically

a. Single-click the _Orb_Cal product in the Product Explorer pane.

b. In the Radar menu, select Radiometric > Radiometric Terrain Flattening (Figure 9).

c. Verify that the source is the _Orb_Cal product, and that the output directory is correct.

d. In the Processing Parameters tab, the Digital Elevation Model is already listed; it is selected automatically to match the geolocation of the GRD granule and downloaded from ESA.

e. Click the Run button. *This step may take upwards of an hour to complete.*

f. The output will have a _TF tag at the end of the filename (product [4]).

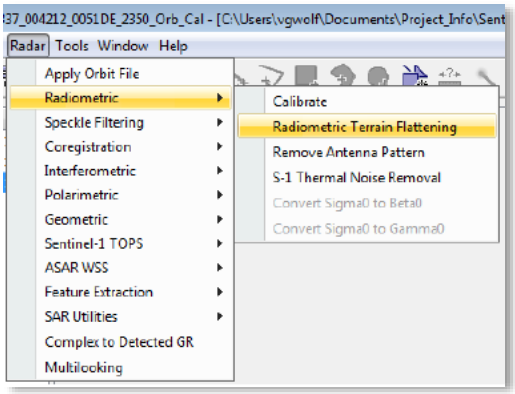

Figure 9: Radiometric Terrain function in the Radiometric group of the Radar menu

4. Apply Geometric Terrain Correction

   a. Single-click the _Orb_Cal_TF product in the Product Explorer pane.
   b. In the Radar menu, select Geometric > Terrain Correction > Range- Doppler Terrain Correction (Figure 10).

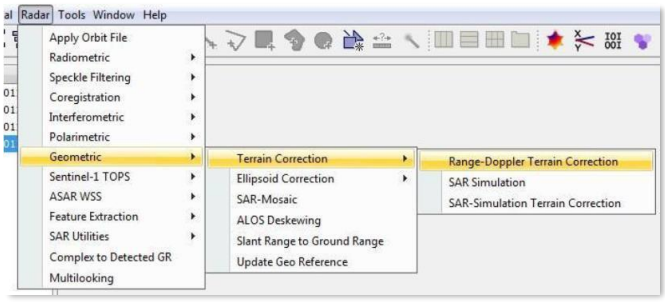

Figure 10: Range-Doppler Terrain Correction (in the Radar menu)

   c. Verify that the source is _Orb_Cal_TF product, and that the output directory is correct.

   d. In the Processing Parameters tab, change the following settings (Figure 11):

      i. Click the button next to Map Projection. Select “UTM / WGS 84 (Automatic)” from the Projection dropdown menu and click OK. The correct UTM zone will be automatically selected based on the granule location and displayed for the Map Projection.

      ii. If desired, you may set the pixel spacing to a value other than the source pixel spacing.

      iii. Note that if you had multiple polarizations in previous steps, there will be multiple Source Bands listed.

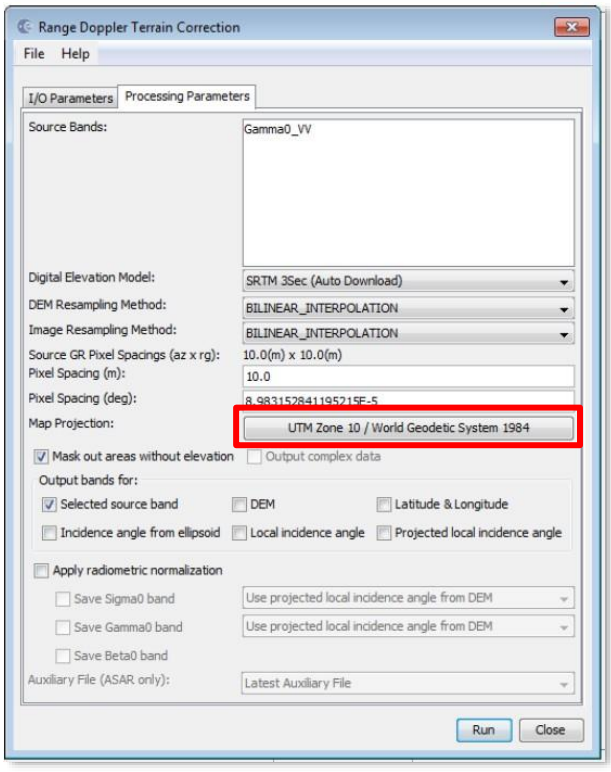

Figure 11: Range Doppler Terrain Correction Processing Parameters

iv. Leave all remaining settings as default, unless you would like to output additional products, such as the DEM or incidence angle bands.

e. Click the Run button. *This step may take on the order of 30 minutes to complete.*

f. The output will have a _TC tag at the end of the filename (product [5]).

5. View the RTC image in S1TBX

a. Double-click the _Orb_Cal_TF_TC product in the Product Explorer pane to expand the product contents.

b. Expand the Bands item.

c. Double-click on the image file named Gamma0_VV. The image will open in the S1TBX interface, and you may use other tools in the interface to interact with the image. You may wish to explore the Tool Windows available in the View menu (Figure 12).

i. The Navigation window allows you to pan and zoom.

ii. The World View window shows where the granule is located on a globe-like view, while World Map shows the granule location on a flattened map of the world.

iii. The Colour Manipulation pane displays the values contained in the image and includes tools for visualizing the image and data values.

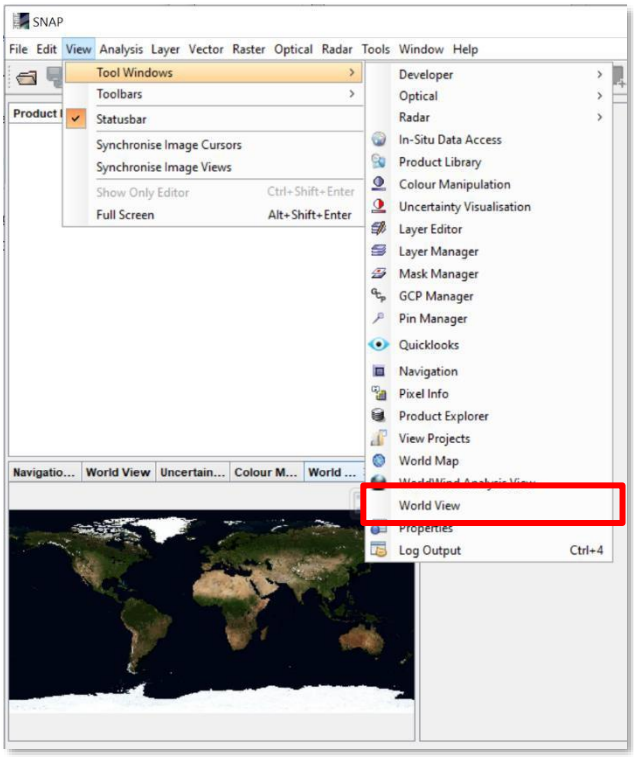

Figure 12: Tool Windows

d. Zooming in on the mountainous regions of the radiometrically terrain corrected product, you may notice patches of missing data. This is a

consequence of the Sentinel-1's look angle and shadows created by high relief topography (Figure 13).

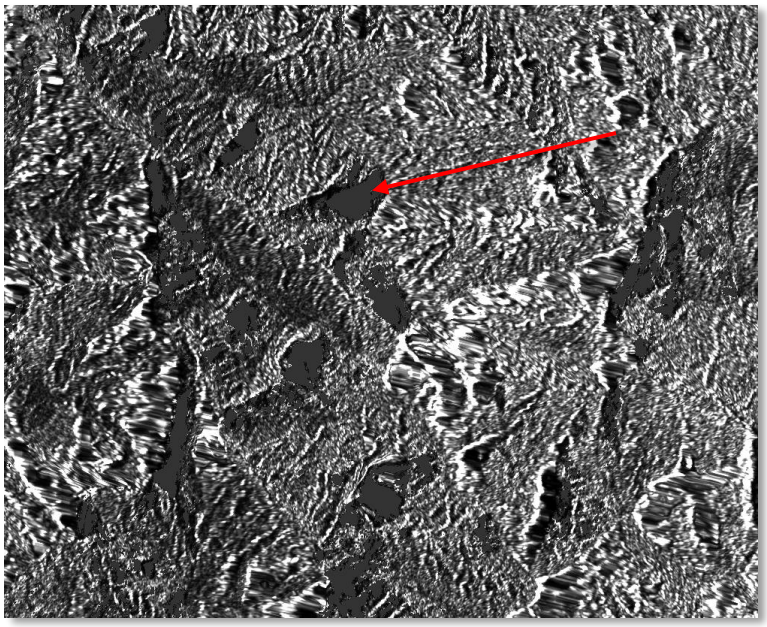

Figure 13: Radar shadows with missing data

6. Save the S1TBX Session
    a. Under the File menu, select Session – Save Session As.
        i. Browse to the directory where you would like to save the session and enter a name for the session file.
    b. Saving a session retains all of the products generated during the RTC process, allowing for easy viewing of the different steps, and amendments to the settings. This is especially useful if you are not able to finish the entire process in one sitting and want to save your work to continue later.
    c. To re-open a session:
        i. Under the File menu, select Session – Open Session.
        ii. Browse to your saved session and double-click to Open.

E) OPTIONAL: View RTC Image in a GIS Program

The TC outputs are in ENVI format, comprised of a header file (.hdr) and an image file (.img). To view the data in a GIS, both files must be present in the same folder. If you have not made any changes to the TC product folder, these files will be stored together, allowing the image to be added easily to either ArcGIS or QGIS.

ArcGIS

Figure 14: Catalog tab in ArcMap

1. Open ArcMap and use the Catalog window to navigate to the folder containing your S1TBX products (See Section C). This is located on the right-hand side of the window (Figure 14).

    a. Right click on “Folder Connections” and select Connect To Folder (Figure 15).

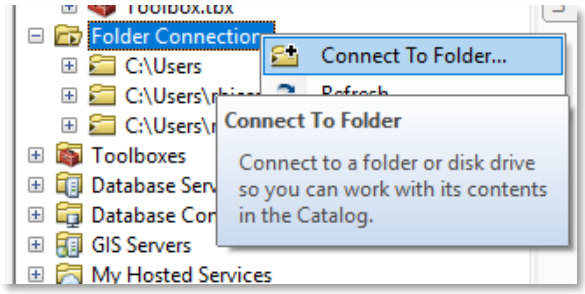

Figure 15: Opening a folder in ArcMap

    b. Navigate to your product’s parent directory.

2. Expand the _Orb_Cal_TF_TC.data folder and drag the Gamma0_VV.img file into your project. Build pyramids if desired (it will take a while).

    a. Note that only the .img file will appear in the Catalog window; the .hdr file is hidden from view, but used by ArcGIS to properly display the .img file.

3. **The image may appear very dark in GIS.** You may change the stretch properties to display the image in a more visually useful way, or refer to the ASF Data Recipes on How to View RTC in GIS for instructions on converting the values from power to another scale (Amplitude or dB) for easier viewing. This second approach creates a new raster with a different value scale, while changing the stretch does not impact the actual power data values.

    a. To simply change the stretch without generating new data:
        i. Right-click on the layer in the Table of Contents, select Properties (Figure 16).
        ii. In the Symbology tab, under the Stretched option, set the Stretch Type to Standard Deviations (the default is Percent Clip).
        iii. The default value for the number of standard deviations is 2.5, which is fine for many RTC images. You may find that a different number works better for your image; try a few others and use the Apply button to find the value that you like best for your dataset. When you’ve decided on a value, click the OK button.

iv. When using the Identify tool on a stretched image, the main Identify window will still display the original power value. The expanded feature properties will display both the Stretched value and the original (power) pixel value.

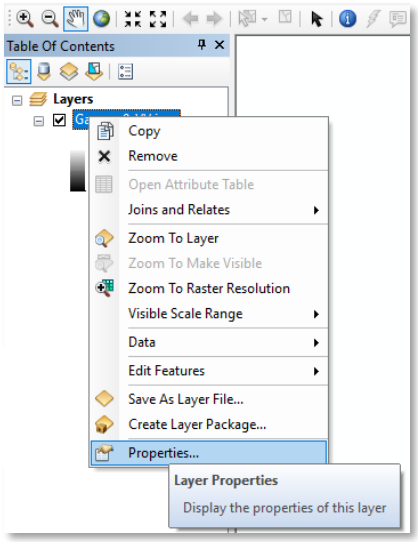

Figure 16: Opening layer properties in ArcMap

QGIS

Open QGIS and use the Browser panel to navigate to your data folder (Figure 17).

b. If your Browser panel is not open, right-click in the open grey area by the toolbars and select Browser Panel from the dropdown list.

2. Expand the _Orb_Cal_TF_TC.data folder and drag the Gamma0_VV.img file into your Layers panel.

a. Unlike ArcGIS, the file structure is transparent, so you can see files in the Browser panel that are not GIS-readable. You can see that each .img file has an associated .hdr file. As in ArcGIS, you only need to add the .img file, and it will recognize the associated .hdr file and use the contents appropriately to display the image.

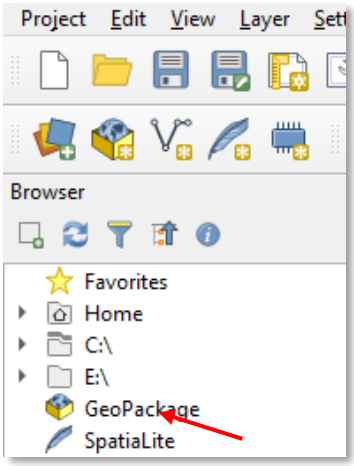

Figure 17: Navigate to your folder under Home using the Browser panel

3. As in ArcGIS, you can adjust the appearance of the image by changing the Stretch settings, or refer to the ASF Data Recipes on How to View RTC in GIS for instructions on converting the values from power to another scale (Amplitude or dB) for easier viewing. This second approach creates a new raster with a different value scale, while changing the stretch does not impact the actual power data values.

   In QGIS 2.18, the default Min/Max stretch value settings defaulted to the "Cumulative count cut" setting, which tends to render RTC images fairly well.

   With the release of QGIS 3.0, the default settings changed so that the stretch Min/Max values match the actual range of data values in the image by default.

This will generally result in a very dark RTC image.

You may adjust the stretch settings in either case, but it will be more necessary in QGIS 3.X.

NOTE: The symbology legend beneath the layer in the Layers panel will display the range of stretched values, but if you use the Identify Features tool (located under the View dropdown), it will only display the original power value.

QGIS 2.18

a. Right-click the Gamma0_VV layer in the Layers panel and select Properties.

b. Under the Style tab, expand the “Load min/max values” section.

    i. The default in 2.18 is the Cumulative count cut option, which generally displays well. You can adjust the values, click the Load button to recalculate the min/max values, and click the Apply button at the bottom of the dialog box to view how the changes impact the image display. Click OK to finish.

    ii. Another approach is to use the Mean +/- standard deviation option. The default of 2 is usually okay, but in some images, you may want to experiment with other values. Click the Load button to calculate changes and use the Apply button if you’d like to test the settings before clicking OK to finish.

QGIS 3.X

a. Right-click the Gamma0_VV layer in the Layers panel and select Properties.

b. Under the Symbology tab, expand the “Min / max values settings” section. The default in 3.X is Min / max, which will tend to display very dark.

    i. To use the same settings as the 2.18 default, select the Cumulative count cut option. The default values are probably appropriate, but you can change the values and use the Apply button to view the effects before clicking OK to close.

    ii. Another approach is to use the Mean +/- standard deviation option. The default of 2 is usually okay, but in some images, you may want to experiment with other values. Use the Apply button to view the effects before clicking OK to close.