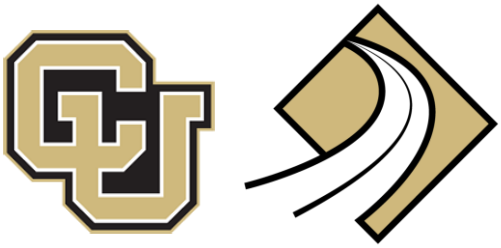
SAR-C User Manual

Version: 3.0

Mohammad Bashar

Cristina Torres-Machi



Innovation for Resilient Infrastructure

University of Colorado Boulder

Boulder, CO 80309

Contents

List of Tables

List of Figures

Chapter 1. Quick Start Tutorial

1.1 Introduction

Synthetic Aperture Radar based Condition (SAR-C) is an intelligent platform that applies deep learning to Synthetic Aperture Radar (SAR) imagery to estimate pavement condition. The software is developed by the Innovation for Resilient Infrastructure (IRI) lab at the University of Colorado Boulder. This manual introduces the software and describes the step-by-step process of pre-processing SAR imagery, preparing pavement features dataset, and running the model to estimate road condition.

1.2 Install SAR-C

Double click on the *SAR-C Setup.exe* file and follow the on-screen prompts (Figure 1-1) to install the software. The software requires about 775 MB of free space for installation.

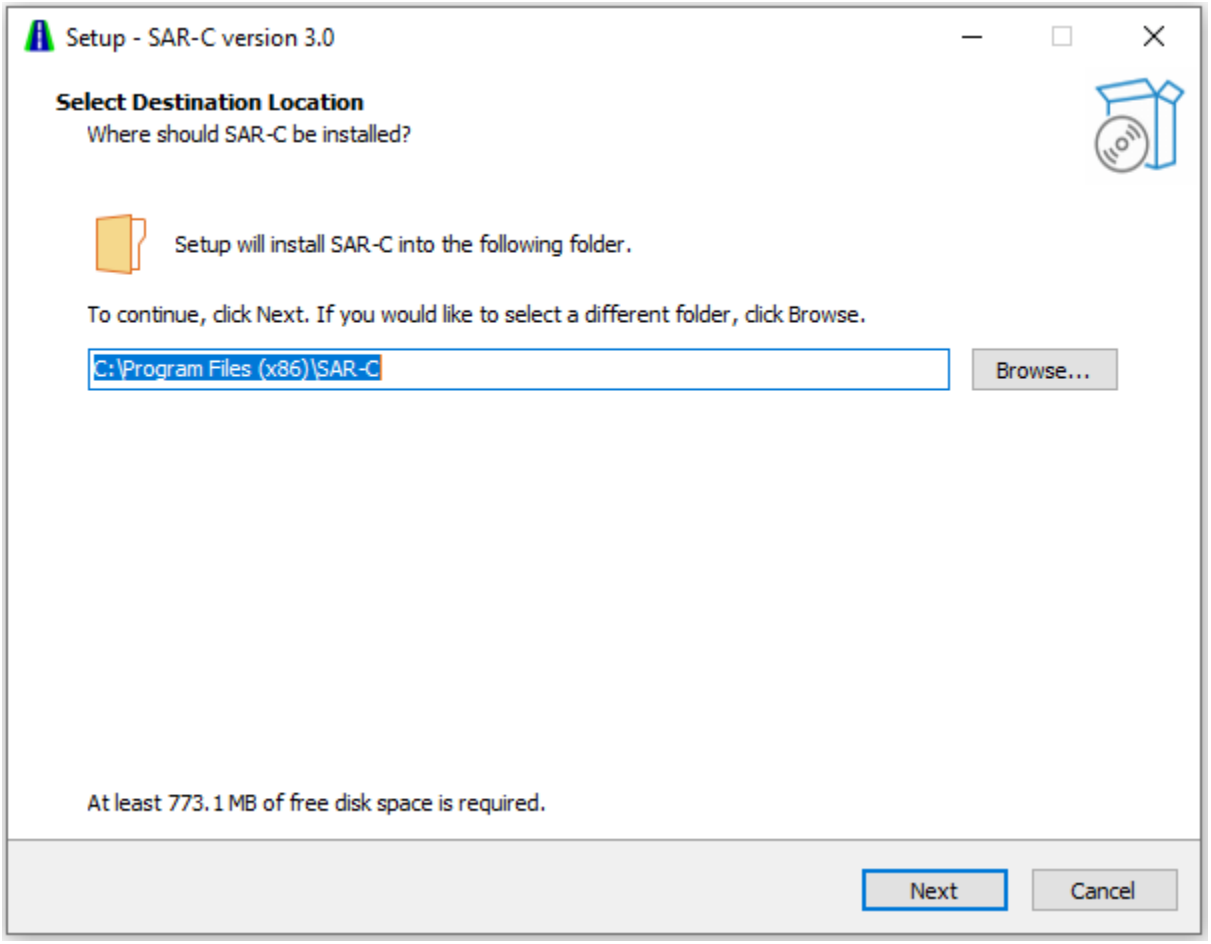


Figure 1-1: SAR-C Setup window.

After successful installation of the program, go to the installation directory (alternatively your start menu or desktop) and double click on the SAR-C ( ) icon to run the program. Depending on the configuration of the computer it may take a few seconds to run. Please note, if the program is installed in a directory that requires administrative right (e.g., C:\) to save files there, SAR-C will

require administrative right to properly function. If that is the case, right click on the SAR-C icon and select *Run as administrator*.

1.3 Minimum System Requirements

The minimum recommended system configuration for the program and its dependencies to successfully run are as follows:

- Processor (CPU): Intel Core i5 or equivalent
- Operating system: Windows 10
- Memory: 16 GB RAM (32 GB Recommended)
- Storage: 1 GB of SSD to install the programs and 20 GB of SSD to process and store SAR imagery.

1.4 User Interface

Figure 1-2 shows the user interface of the software. The menu bar offers the following options:

- *File* > *New* will reset the software for a new run.
- *File* > *Quit* will exit the program.
- *Help* > *User Manual* will open the appropriate version of the user manual associated with the software.
- *Help* > *About* will open a window displaying the version and relevant information about the software.

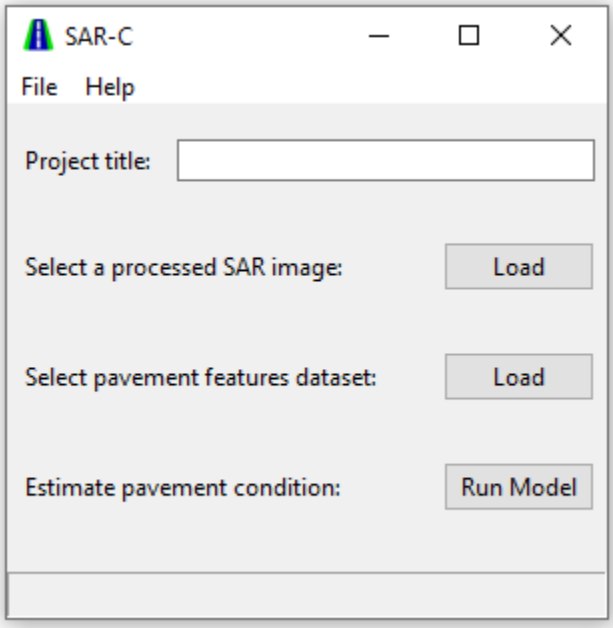


Figure 1-2: SAR-C user interface.

The bottom part of the interface is a status bar. As the user loads data in the program or runs the model, the status bar will display if the software was able to successfully complete the step.

1.5 Steps in Using SAR-C

The user is required to set a title for the project. The project title is associated with the name of the file the software generates after running the model. Then the user needs to load a SAR image in the software. The details of downloading and processing a SAR image is described in Chapter 2 of this manual. The user then loads a pavement features dataset in the software. Chapter 3 describes the specific process of preparing the dataset for the model to run properly. After all the required files have been loaded in the software, the user needs to click on the *Run Model* button to estimate pavement condition using SAR-C. Chapter 4 of this manual shows an example with sample files describing each of these steps in more detail.

Chapter 2. Download and Process SAR Imagery

2.1 Access SAR Data

To access and download Sentinel-1 SAR imagery, a NASA Earthdata account is required. Go to the following link to create a new user account. Skip this step if you already have an account.

https://urs.earthdata.nasa.gov/users/new

2.2 Download SAR Imagery

Sentinel-1 SAR data is available through Alaska Satellite Facility (ASF) Vertex. Go to the following link and sign in using the account created in previous step:

https://search.asf.alaska.edu/

This will open the ASF Vertex page. For 'Search Type', select 'Geographic. For 'Dataset', select 'Sentinel-1'. Use the *Area of Interest* tool to select the area for which the user is planning to use SAR-C. Then define a start and end date for the analysis. An example of these steps is shown in Figure 2-1.

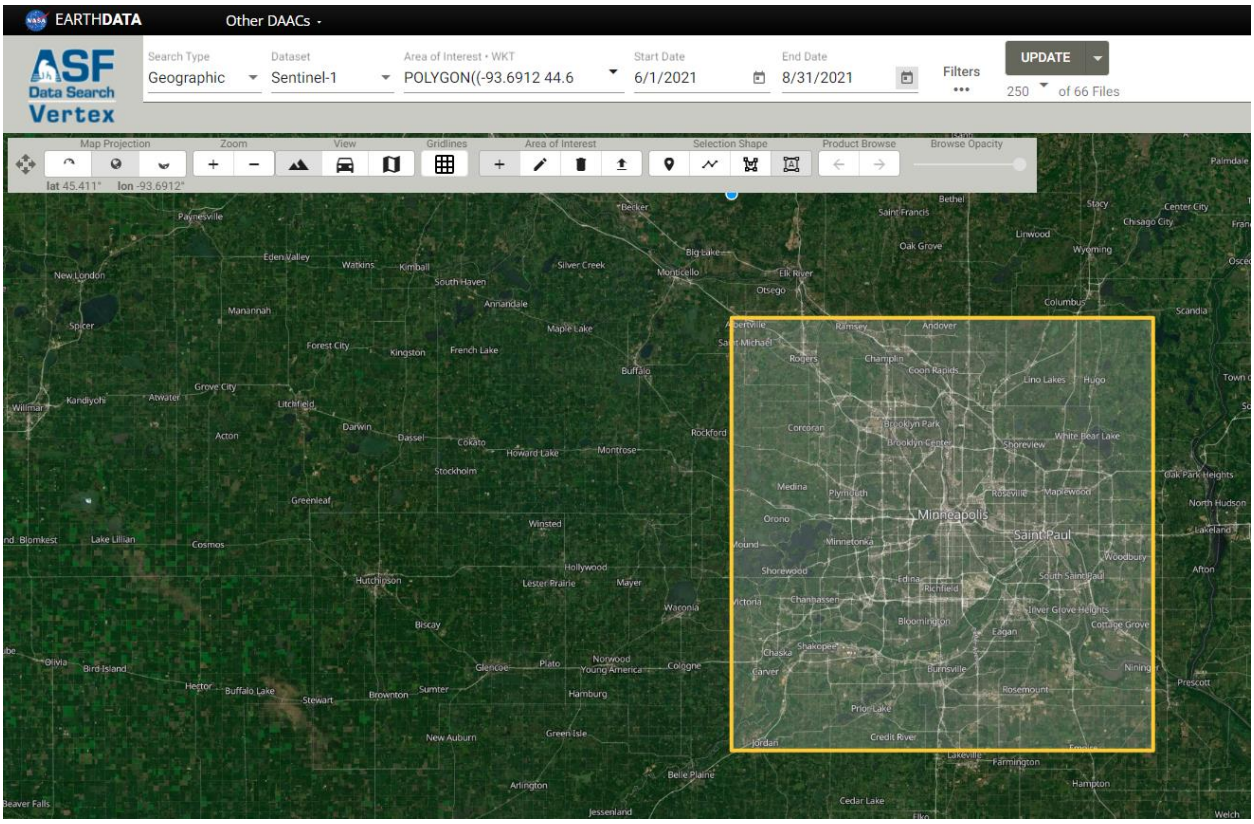


Figure 2-1: Selecting area of interest in ASF Vertex.

Then click on the *Filters* option to set additional settings. Choose 'L1 Detected High-Res Dual-Pol (GRD-HD) for the File type, 'IW' for Beam Mode, Polarization 'VV+VH', and 'Ascending' as Direction (Figure 2-2). Then click on the *Search* button to see the results.

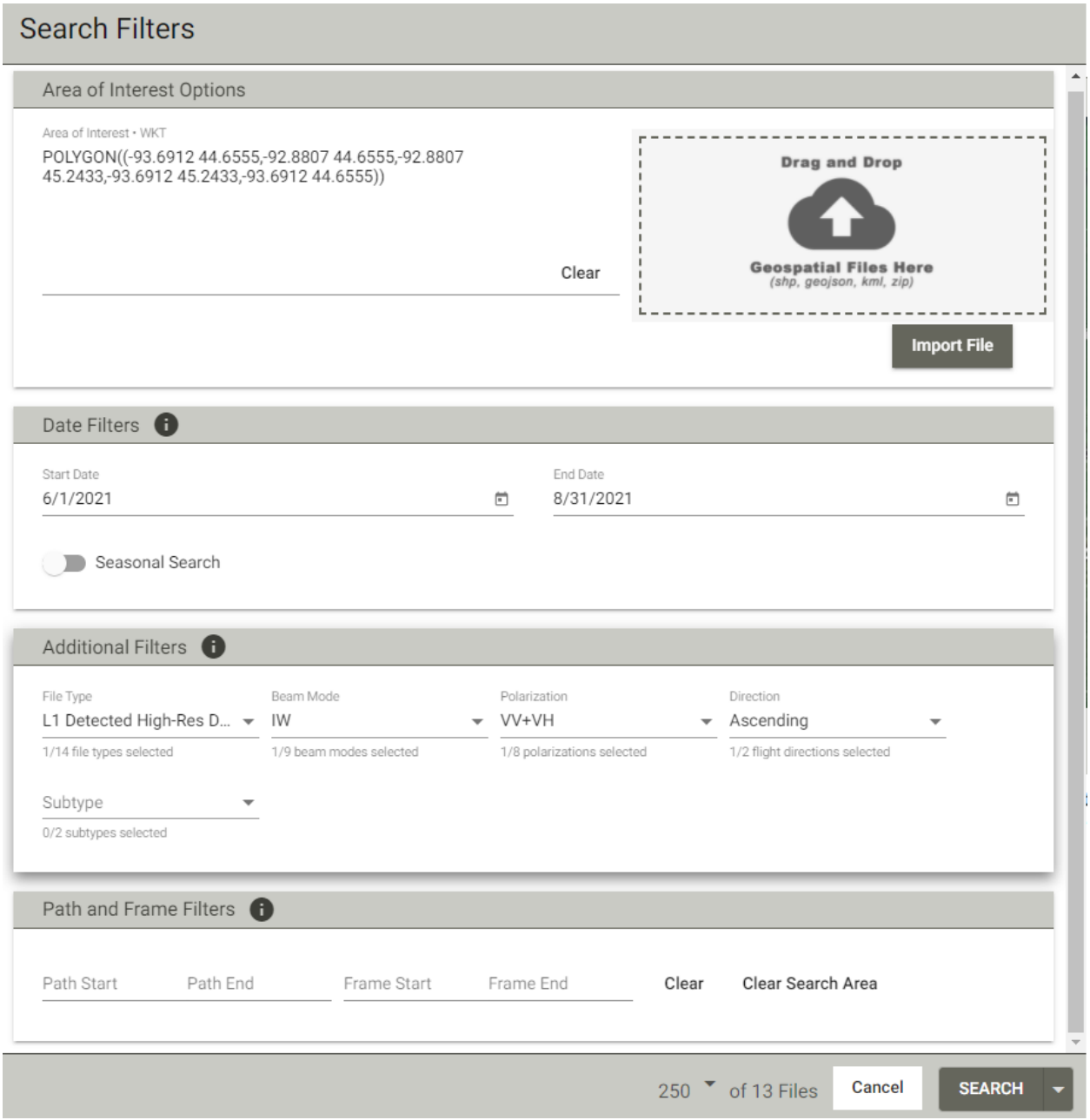
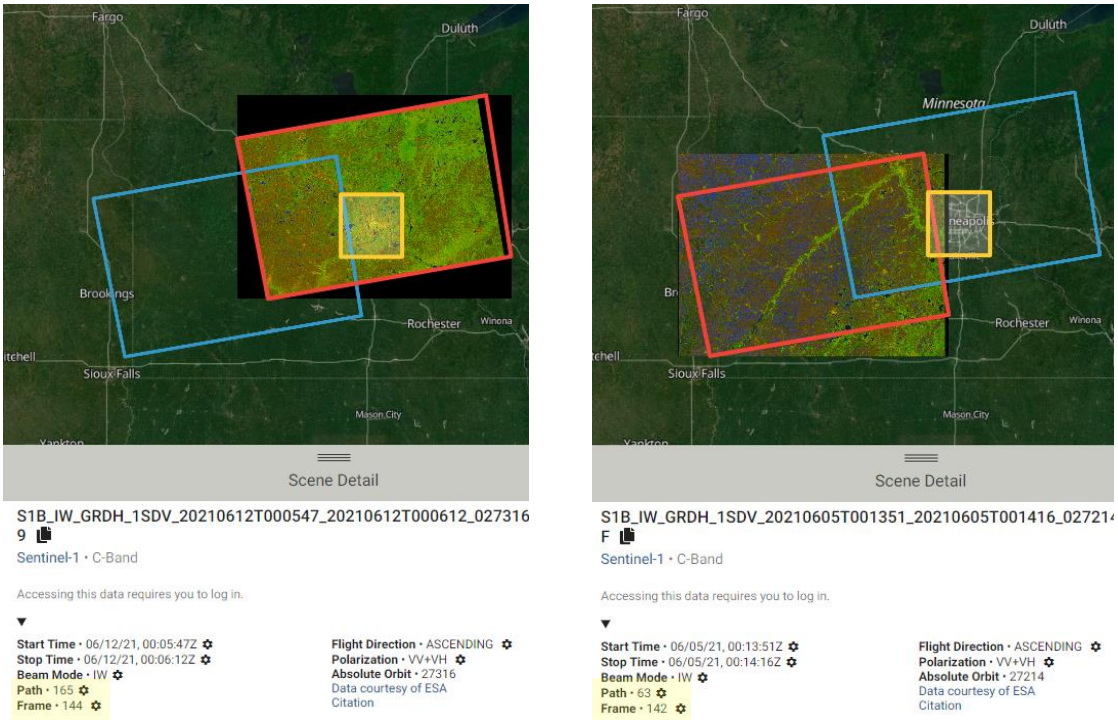


Figure 2-2: Additional filters for searching SAR images.

For this search, 13 images were found. However, these images were taken along two different paths (e.g., 165 and 63) as can be observed from Figure 2-3. SAR-C requires the images to be captured along the same path and on the same location. Pay close attention to the highlighted Path and Frame number on Figure 2-3. Since our area of interest has a better match with Path 165 and Frame 144, we will update the filters accordingly.



(a) (b)

Figure 2-3: Viewing the search results.

Click on the *Filters* option again to set the best path and frame numbers based on your judgment. In the example shown in this manual, path 63 and frame 142 is the one offering a better coverage of the area of analysis. Therefore, the images captured at this location will be used for the analysis. Put the same path and frame number on start and end fields as shown in Figure 2-4. Click on the search button to update the results.

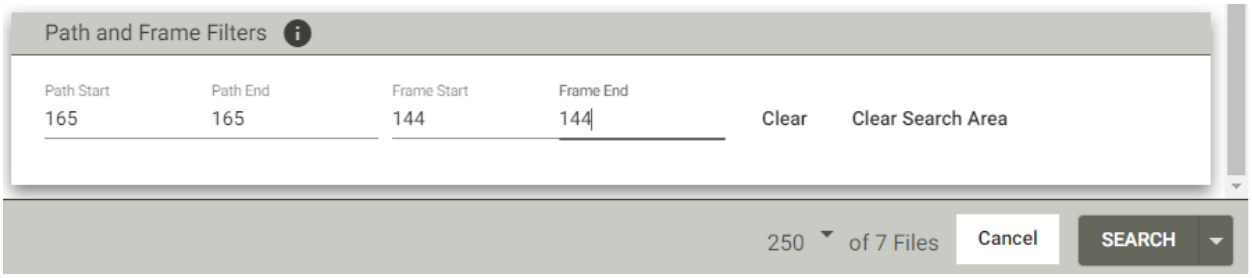


Figure 2-4: Updating the path and frame filters.

As shown in Figure 2-5, this time the system found 7 images matching our selection. Click on the *Queue* button ( ) to add all the results to downloads list. Then click on the *Downloads* button ( ) on the upper right corner of the screen to see the list of all the files and the Downloads window will appear (Figure 2-6). Click on the download icon ( ) beside filenames to download the files and each of the files will be downloaded in a **.zip* file.

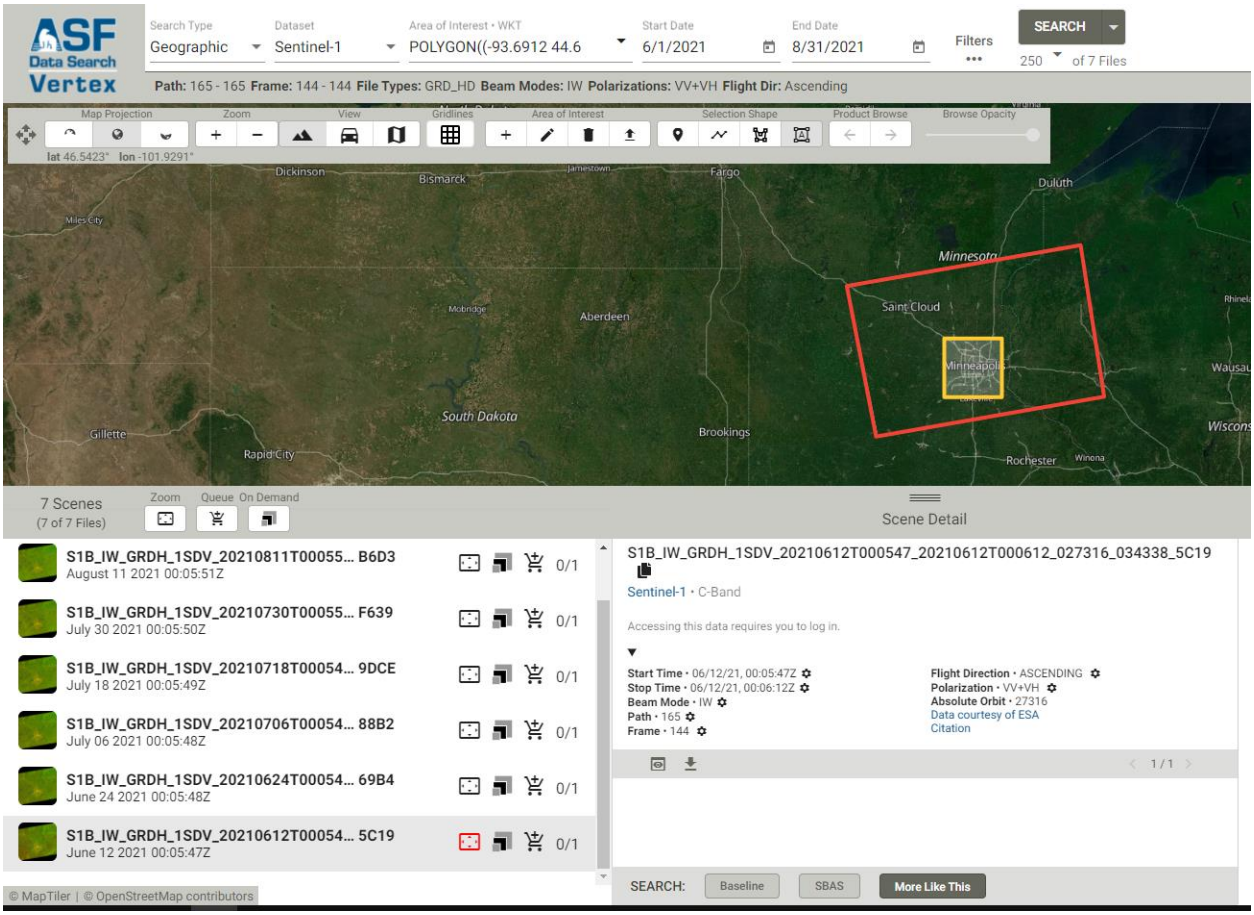


Figure 2-5: Viewing the updated search results.

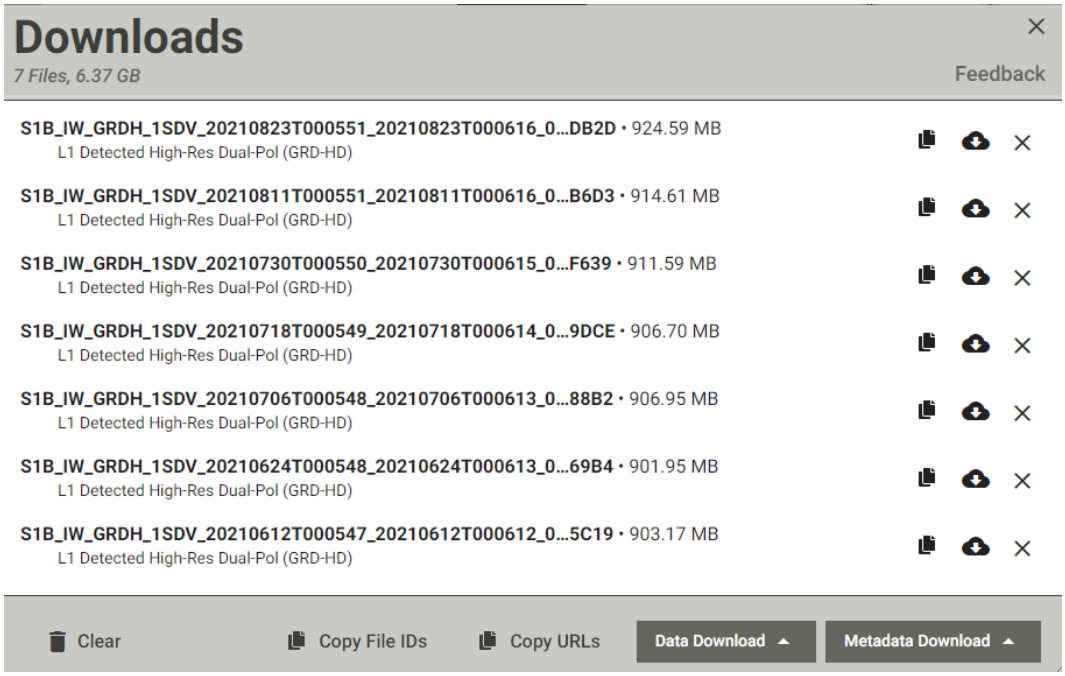


Figure 2-6: Selected files for downloading.

2.3 Process SAR data

Sentinel-1 SAR imagery requires a series of corrections before they can be used for a specific purpose. The Sentinel Application Platform (SNAP) provides a user-friendly environment to process SAR imagery and it available for free from the European Space Agency (ESA).

2.3.1 Install SNAP

Go to the following address to download the latest version of the program:

https://step.esa.int/main/download/snap-download/

From the "All Toolboxes" option, download the appropriate windows version of the software for user computer. Double Click on the downloaded file and follow the on-screen prompts to install the software. To check if the program was successfully installed on the machine, run "SNAP Desktop" app from your start menu and the following window should appear.

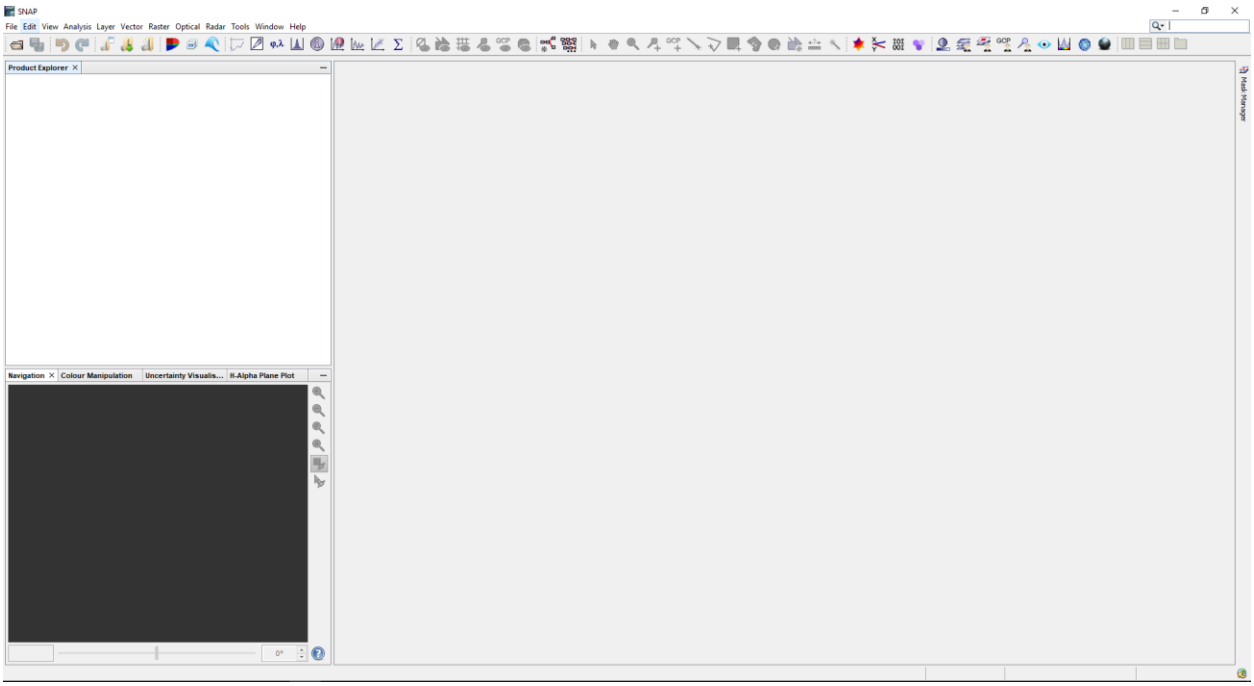


Figure 2-7: SANP user interface.

2.3.2 Open Files

Go to *File > Open Product* to load the downloaded SAR images in **.zip* format. Once the files are opened, they will appear in the Product Explorer tab as shown in the following figure.

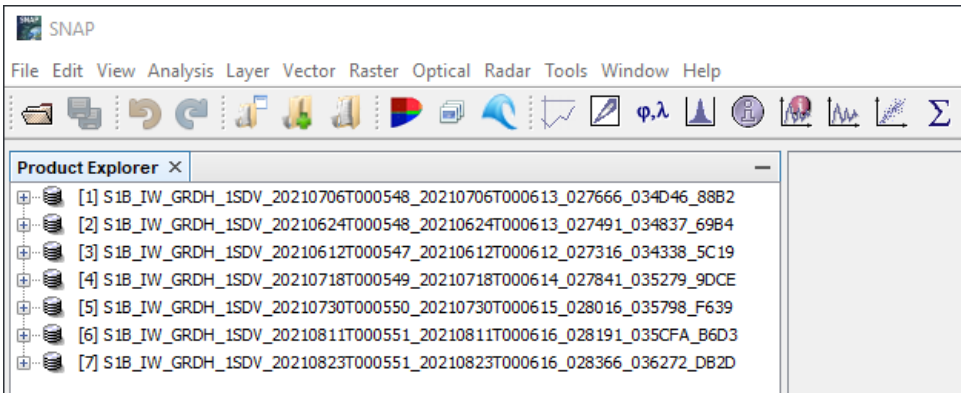


Figure 2-8: Opened SAR data in SNAP.

2.3.3 Batch Process

The SAR data files require precise orbit files, radiometric calibration, speckle filters, terrain flattening, and terrain corrections so that they can function properly in the pavement condition evaluation process. To apply all these corrections to the loaded SAR files, go *Tools* > *Batch Processing* and the following window (Figure 2-9) will show up. Click on the second icon ( ) on the right panel to load all the SAR files opened in the previous step.

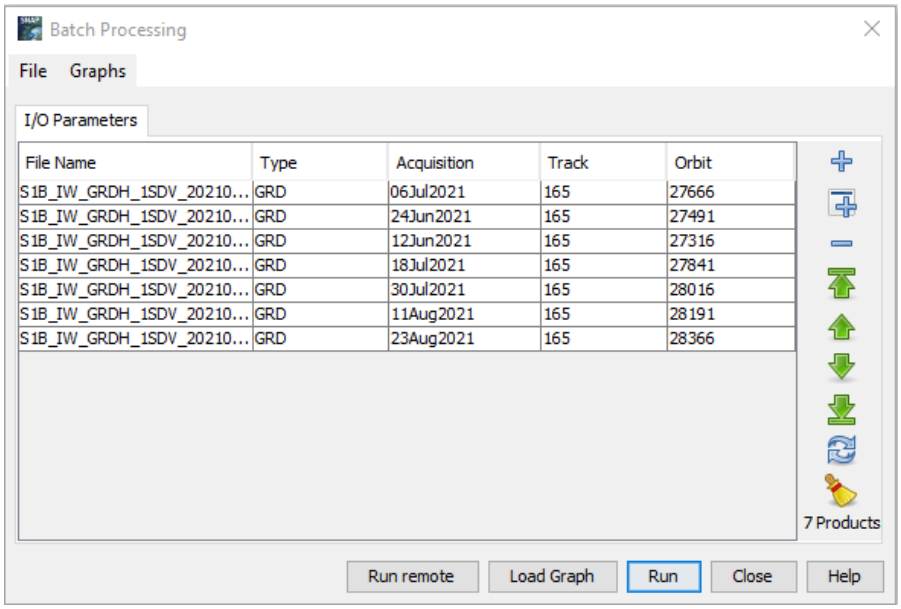


Figure 2-9: Loading files to batch process SAR images.

After the files have been loaded, click on the *Load Graph* button and select the '*RTC calibration graph'* file from '*SNAP files*' folder in the SAR-C installation directory (Figure 2-10). This file contains all the commands to automate the SAR data correction process. Once the graph file is successfully loaded, additional tabs will show up on the 'Batch Processing' window as shown in Figure 2-11. Go to the 'Write' tab and set an appropriate directory on the user computer where the processed files will be saved.

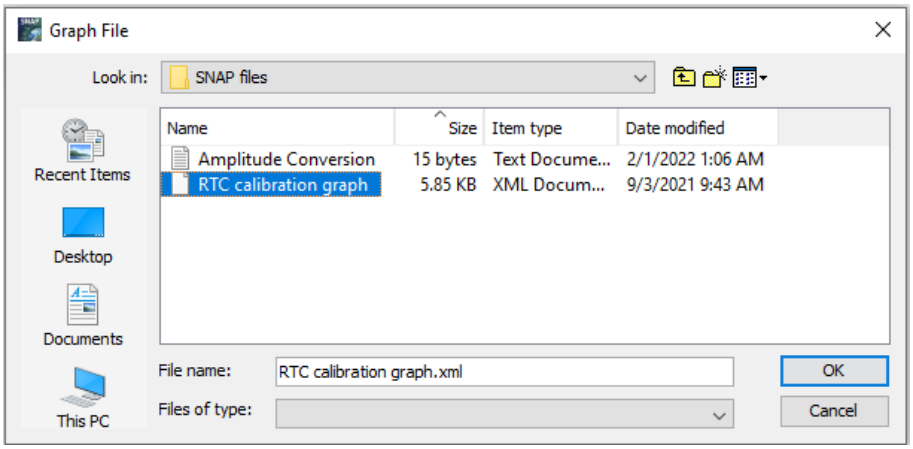


Figure 2-10: Loading batch processing graph file.

Figure 2-11: Graph loaded to batch process the SAR data.

Once the graph has been loaded, click on the *Run* button to start batch processing the data. This is a very computationally demanding process and can take hours to complete depending on the processing power of the computer and the number of files selected for batch processing. Upon completion of the process, the corrected SAR files will show up on the product explorer (Figure 2-12) with 'Orb_Cal_Spk_TF_TC' at the end of their original file names. These letters represent the processes they have been through during the batch processing.

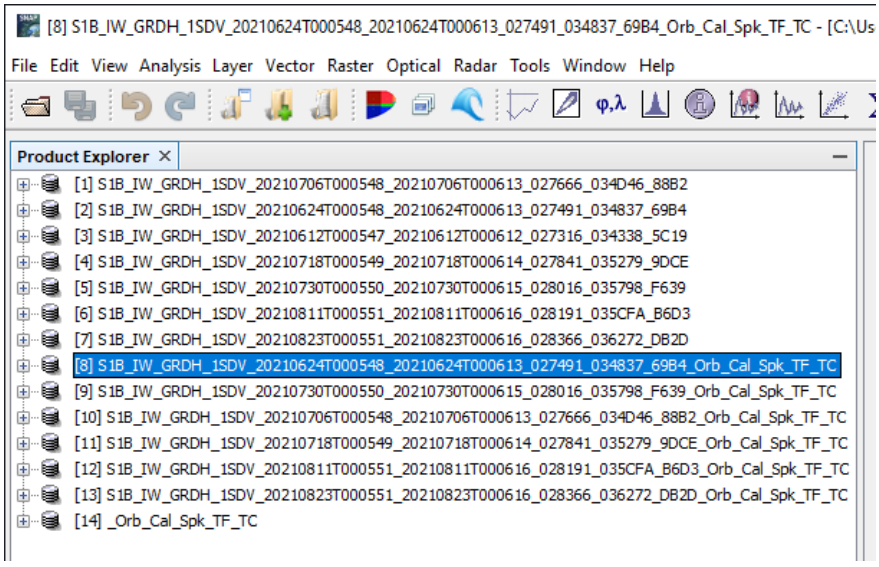


Figure 2-12: SAR files after the completion of batch processing.

2.3.4 Stacking

The corrected SAR files will be stacked together in a single file in this step. To create a stack, go to *Radar* > *Coregistration* > *Stack Tools* > *Create Stack* and the following window (Figure 2-13) will pop up. Use the  button to load all the processed SAR files for stacking as shown in Figure 2-13.

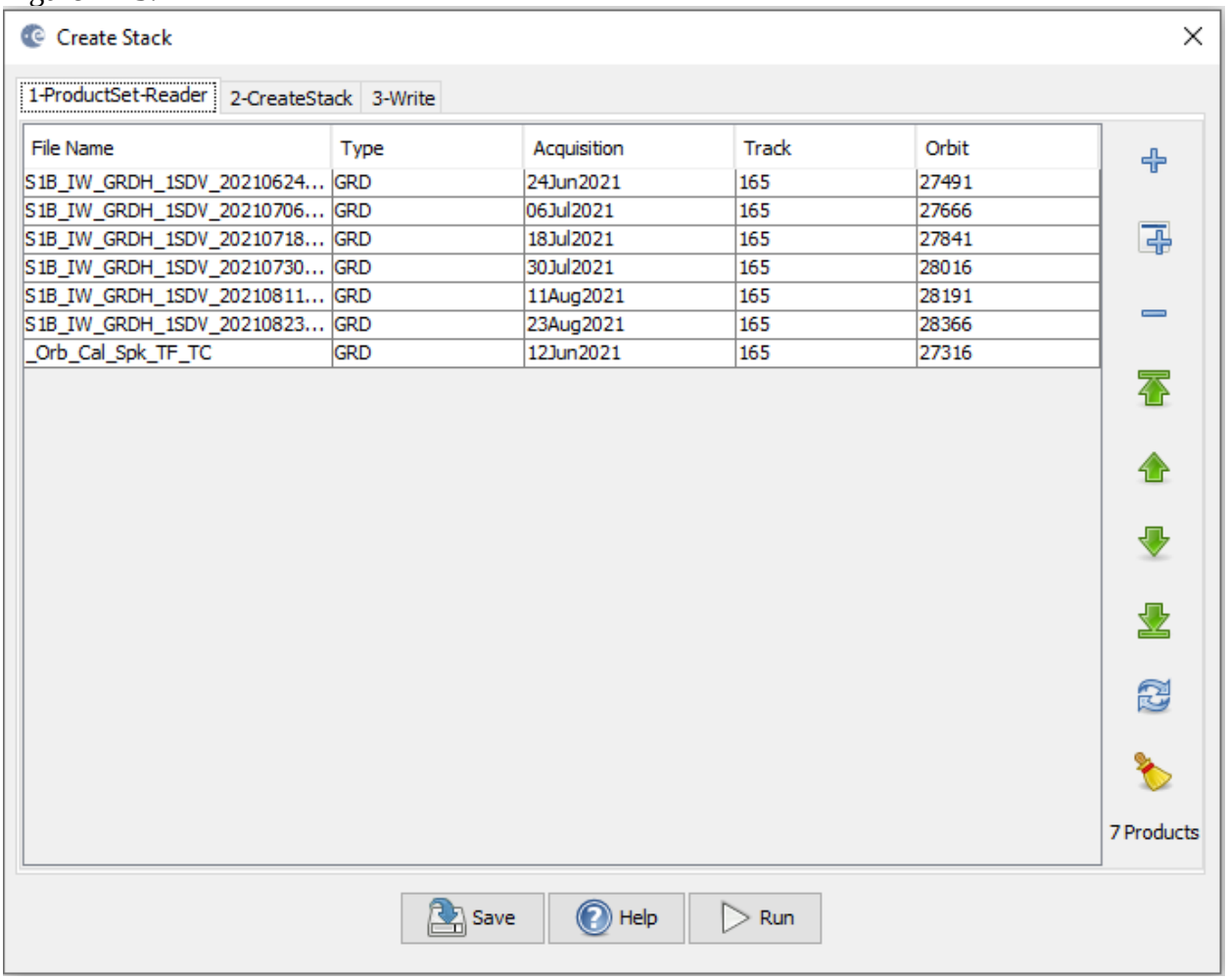


Figure 2-13: Stacking all the processed SAR files.

After all the files have been successfully loaded, go to the *Create Stack* Tab and select the options as shown in Figure 2-14. Set Initial Offset Method as Product Geolocation and output extents as Master. Then click on the *Find Optimal Master* Button and SNAP will select a file as the master for the stack.

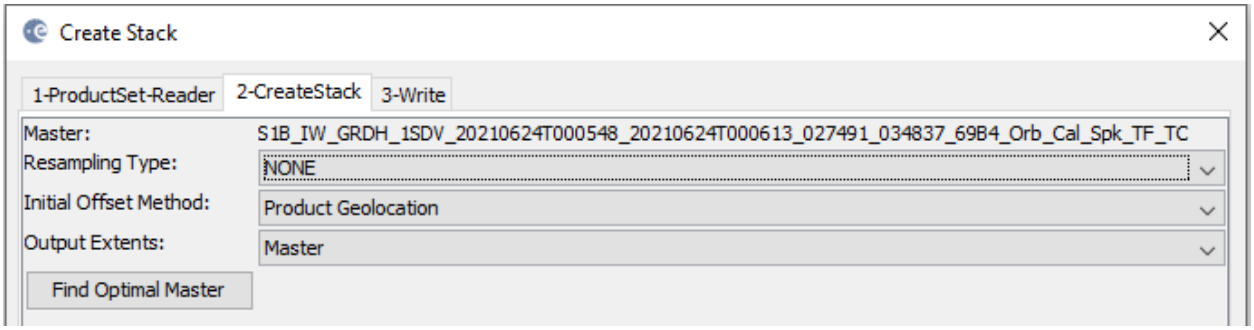


Figure 2-14: Options for creating stacks.

Once all the options are properly set, click on the *Run* button to initiate the stacking process. Upon completion of the stacking process, the output file will show up on the product explorer (Figure 2-15) with '_Stack' at the end of the filename.

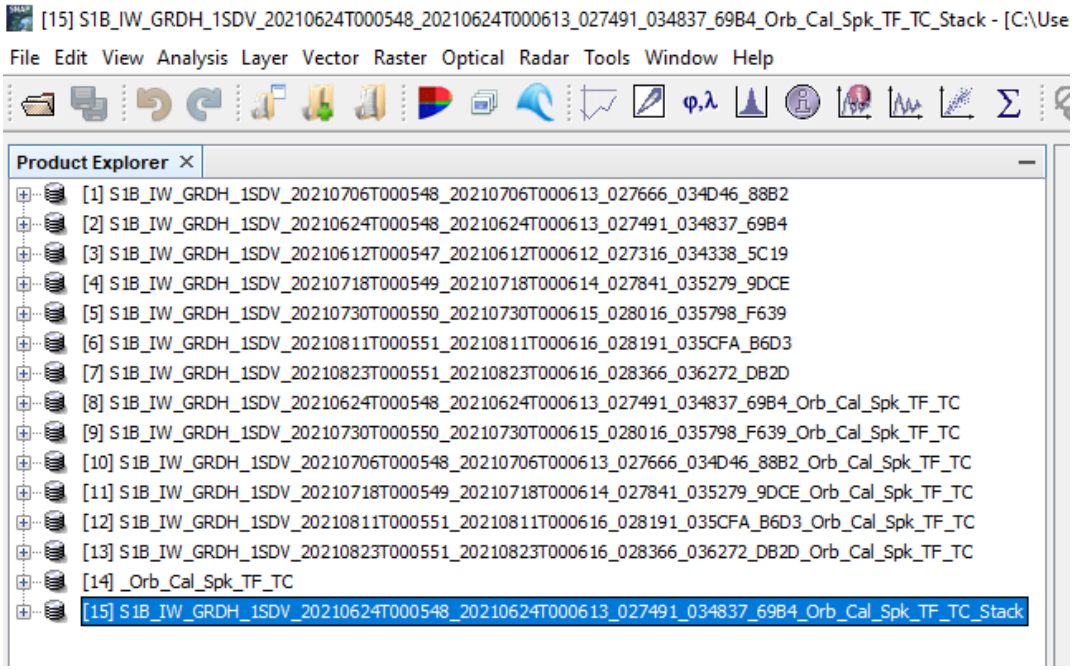


Figure 2-15: Output file from the stacking process.

2.3.5 Create a Stack Average

To create a minimum image based on the stack created on the previous step, go to: *Radar* > *Coregistration* > *Stack Tools* > *Stack Averaging* and the following window will show up (Figure 2-16). Select the stack created in previous step as the source product. Then go to the 'Processing Parameters' tab and choose 'Minimum' from the drop-down menu as the Statistic parameter (Figure 2-17). After all the options are properly set, hit the *Run* button to create a stack average.

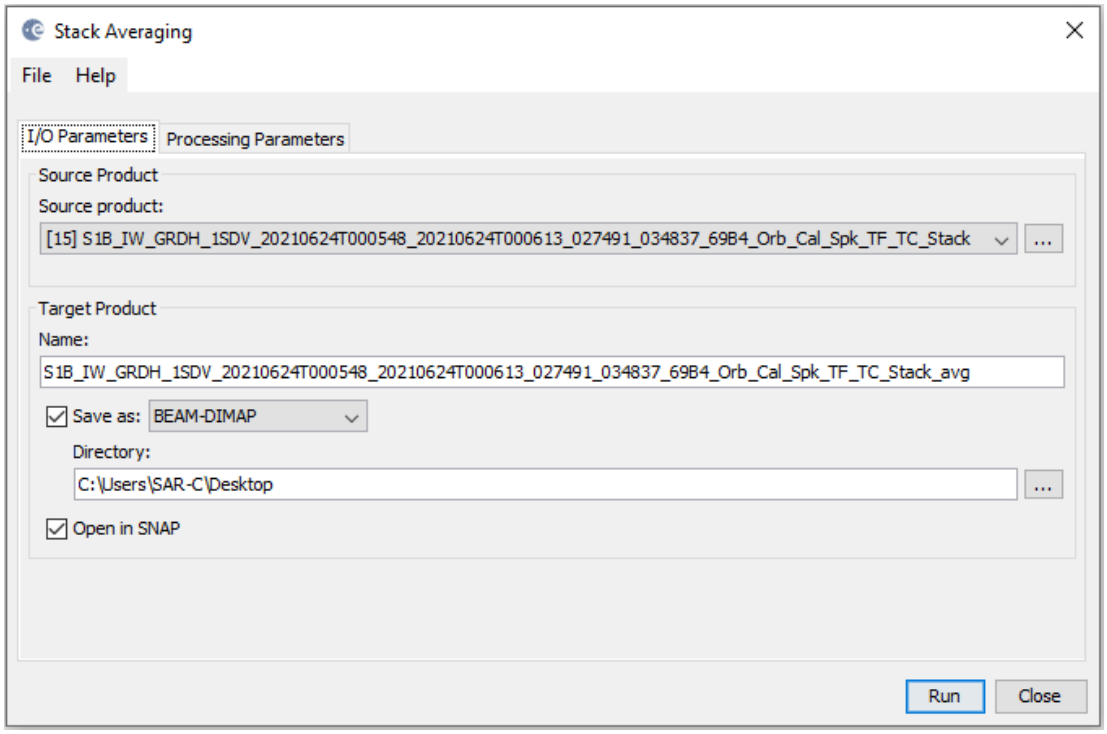


Figure 2-16: Creating a stack average image.

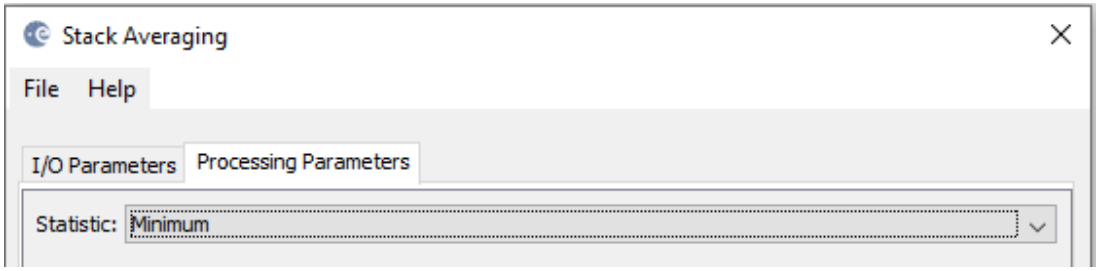


Figure 2-17: Processing parameters for stack averaging.

Upon completion of the averaging process, the output image will show up on the Product Explorer (Figure 2-18) with '_avg' at the end of the filename. The output image can be viewed by double clicking on the filename, then 'Bands' and 'Gamma0_VV', see Figure 2-18.

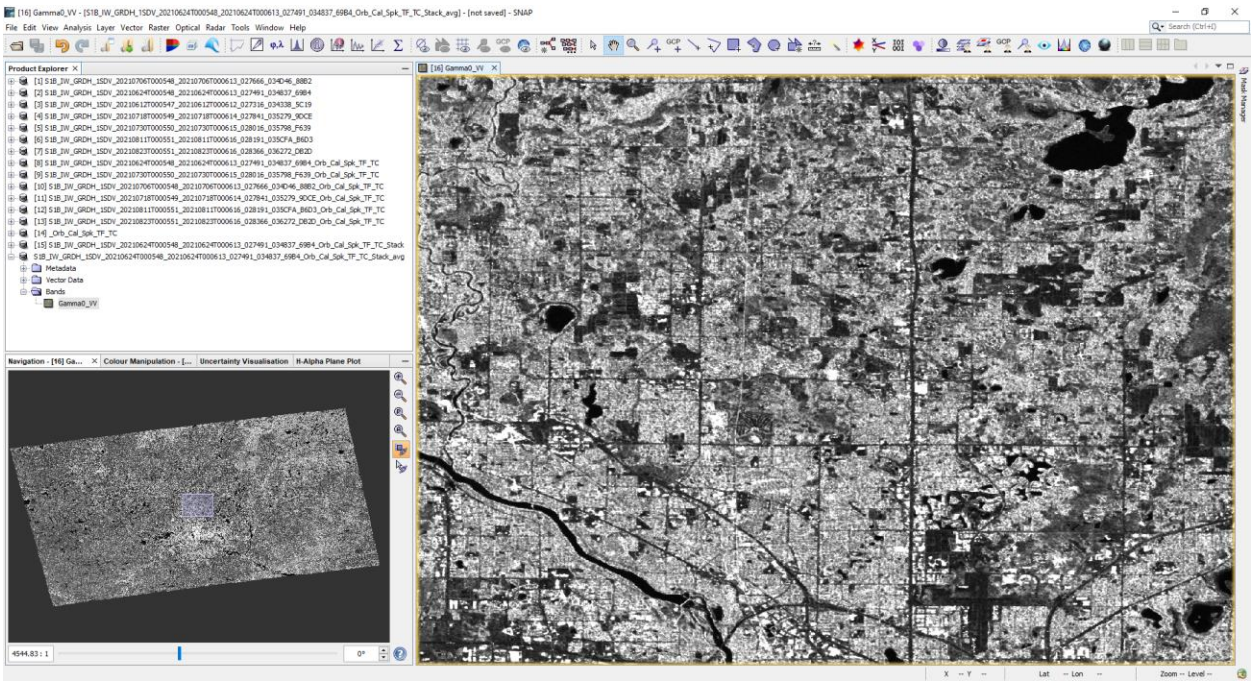


Figure 2-18: Viewing the output image from the stack averaging process.

2.3.6 Export the Image

To export the image, select the image file (Gamma0_VV) and go to *File > Export > GeoTIFF* and export the image as a **.tif* file, as shown in Figure 2-19.

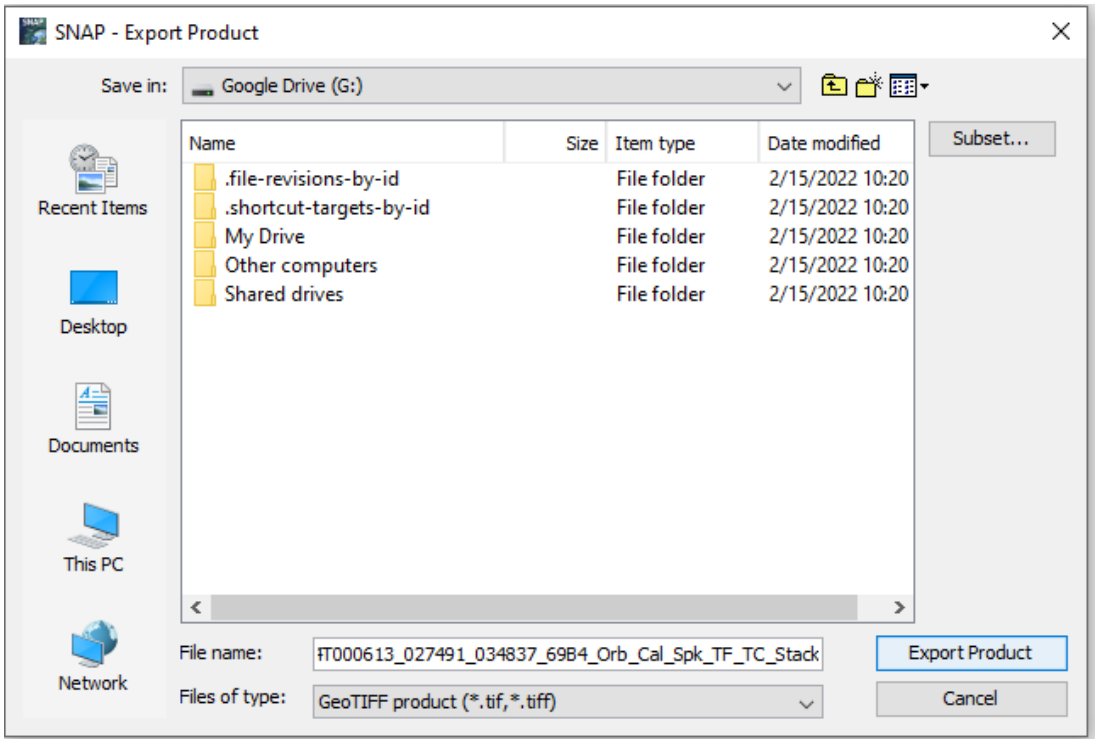


Figure 2-19: Exporting the processed SAR image.

Chapter 3. Prepare Pavement Features Dataset

3.1 Preparing the Data

In addition to the SAR imagery, SAR-C requires several pavement related information such as the location, type and age of the pavements, layer thicknesses, and traffic information to estimate pavement condition at those locations. This dataset needs to be prepared in a specific format so that the model can run properly.

The dataset can be prepared in any spreadsheet program, and it needs to be saved as a **.csv* file. The header of the spreadsheet needs to be *exactly the same* as shown in Table 3-1.

Table 3-1: Header of the pavement features dataset.

Y	X	surface_type	surface_age	pavement_thickness	base_thickness	AADT

The description of these variables and the process to estimate them are as follows:

- ⇒ *Y* is the latitude of the location in decimal degrees.
- ⇒ *X* is the longitude of the location in decimal degrees.
- ⇒ *surface_type* represents the type of pavements. Assign a value of 1 for asphalt pavements and 0 for concrete pavements.
- ⇒ *surface_age* is the estimated as the minimum of the age of the pavement since construction and the age of the pavement since last major maintenance in years.

$$surface\_age = MIN(age\ since\ constuction, age\ since\ last\ maintenance)$$

- ⇒ *pavement_thickness* is the thickness of the surface layer in inches.
- ⇒ *base_thickness* is the thickness of the base layer in inches.
- ⇒ *AADT* is the Annual Average Daily Traffic.

3.2 Saving the File

A sample pavement features dataset is shown in Figure 3-1. Once the data is ready, save it in **.csv* format with any filename you prefer.

Y	X	surface_type	surface_age	pavement_thickness	base_thickness	AADT
45.00878	-93.099	1	14	4	12	1000
44.81494	-93.3989	1	7	1.5	8	2257
44.81205	-93.399	1	7	1.5	8	2257
44.93553	-93.0727	1	6	4.5	6	4399
44.93683	-93.0744	1	6	4.5	6	4602
44.8135	-93.3989	1	7	1.5	8	2257
44.85886	-93.4044	1	13	8	4	2963

Figure 3-1: Sample pavement features dataset.

Chapter 4. Estimate Pavement Condition

Once the SAR data and the pavement features dataset is ready, follow the following steps to estimate pavement condition using SAR-C. Please note, SAR-C will require administrator rights to properly function if it was installed in a directory (e.g. C:\) that requires administrative permission to save files. If that is the case, right click on the SAR-C icon and run it as administrator.

4.1 Assign a Project Title

Set an appropriate title for the project as shown in Figure 4-1. This title is associated with the file name SAR-C will generate after running the model.

To avoid overwriting files, assign a different project title each time you run the model. You can simply edit the project title if you want to work with the same SAR image and pavement features dataset. But if you want to work with new files, start a new project from *File > New*.

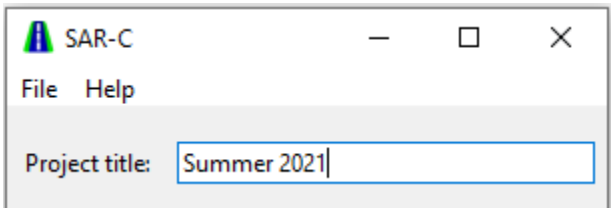


Figure 4-1: Setting a project title.

4.2 Load SAR Data

To load the processed SAR image, simply click on the *Load* button next to 'Select a processed SAR image' label. Once the image has been successfully loaded, the status bar will show the update as shown in Figure 4-2.

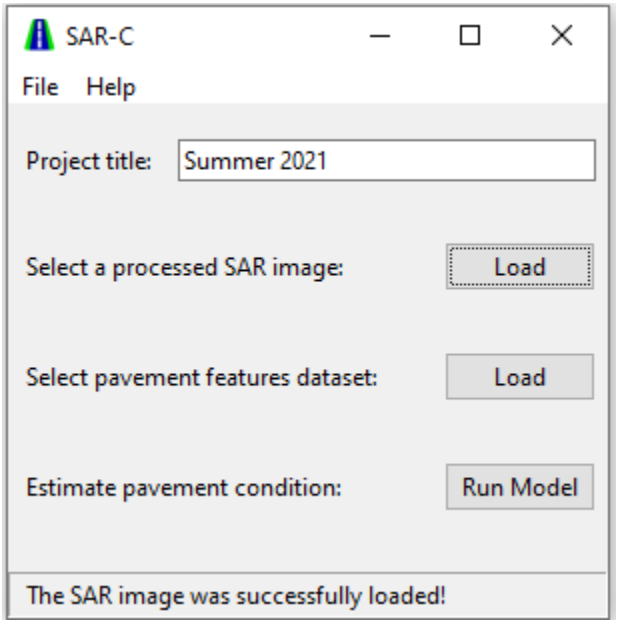


Figure 4-2: Loading a SAR image.

4.3 Load Pavement Features Dataset

To load the pavement features dataset, click on the *Load* button next to 'Select pavement features dataset' label. Upon successful completion of this step, the status bar will display that the pavement features were successfully loaded in the program (Figure 4-3).

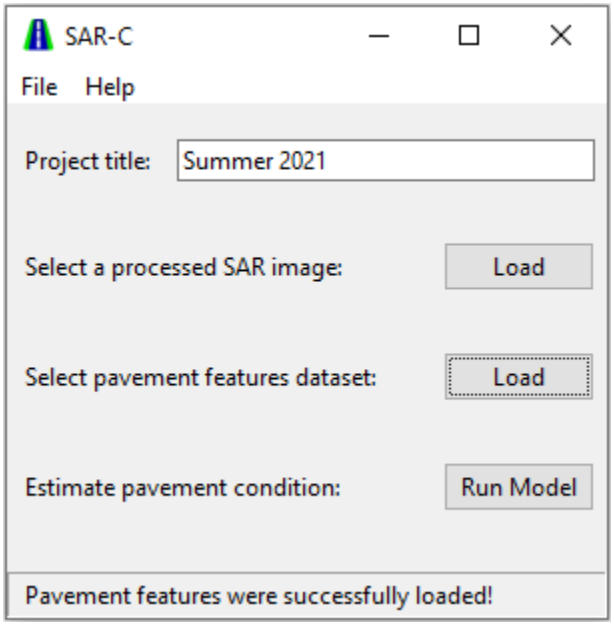


Figure 4-3: Loading the pavement features dataset.

4.4 Run the Model

Once both the data have been loaded in the program, click on the *Run Model* icon to estimate pavement condition. The status bar will notify the user upon completion of the step (Figure 4-4).

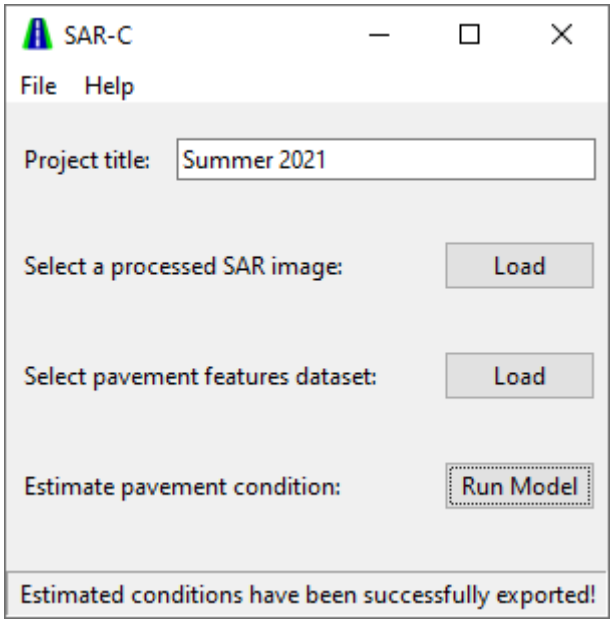


Figure 4-4: Running the model to estimate pavement condition.

4.5 View the Results

The software will export the results in a **.csv* file. The file with can be found in the same directory as the software with the project title in the filename. Use a spreadsheet program or text viewer to open the file. As illustrated in Figure 4-5, the output file contains predicted IRI, associated predicted intervals, and Road Quality Index category for each coordinate. This file can be imported in any mapping platform to visualize the results.

	A	B	C	D	E	F	G
1		X	Y	Predicted IRI	Upper Limit	Lower Limit	RQI Category
2	0	-93.09895229	45.00877567	132.93869	159.8898395	105.9875408	Fair
3	1	-93.39888885	44.81494238	134.62094	157.8517816	111.3901007	Fair
4	2	-93.39898363	44.81205362	139.13907	163.3413271	114.9368101	Fair
5	3	-93.07272519	44.93553332	89.507195	115.8035128	63.21087625	Good
6	4	-93.07442572	44.93682963	84.49443	113.1627008	55.82616029	Good
7	5	-93.398893	44.81350028	145.20619	171.0476786	119.3647055	Fair
8	6	-93.40442383	44.85886308	115.41915	136.6146818	94.22362084	Fair
9	7	-93.40849389	44.85881595	123.926285	147.2206991	100.6318705	Fair
10	8	-93.40322055	44.85884098	90.758316	113.6414801	67.87515195	Good
11	9	-93.20457604	45.00386308	83.30288	106.4312754	60.17448328	Good

Figure 4-5: Viewing the exported results.