PARTNERSHIP FOR LAND USE SCIENCE (FOREST-PLUS)

Training Manual for the SAR Technical Protocol for Forest Monitoring

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INTRODUCTION

BRIEF BACKGROUND OF FOREST-PLUS

The Partnership of Land Use Science (Forest-PLUS) program is a five year initiative between USAID/India and Government of India (GOI). Forest-PLUS contributes to USAID/India's Development Objective of accelerating India's transition to a low emissions economy by encouraging REDD+ spread widely as an approach to forest management. Forest-PLUS demonstrates how improved conservation and management of forest ecosystems can reduce emissions from deforestation, and forest degradation, and to sequester atmospheric carbon. By mapping and preserving limited forested resources, this will have the added benefit of i.) enhancing biodiversity health, ii.) improving environmental services, iii.) mapping forest-based livelihoods and iv.) maintaining forest-based social uses. Forest-PLUS achieves these objectives by developing better tools, techniques, and methods for forest ecosystem management. The tools presented here provide a background for scientific data acquisition and analysis, increasing individual and institutional capacities and improving public awareness and environmental education. Forest-PLUS demonstrates this integrated approach in four pilot landscapes that represent a diversity of India's forest types, coordinating its efforts with the Ministry of Environment Forest and Climate Change (MoEFCC), the REDD+ cell, State Forest Department and the Green India Mission (GIM).

TRAINING WORKSHOP CONCEPT

To address the challenges in the forestry sector, the design component of the program focuses on the US-India collaborative scientific research exchanges that explore methods and approaches to implement improved forest management. This will be vital for India's own program and will further demonstrate India's advances in science and technology to develop lessons that may be applied across the globe.

Institutional capacity building is important within forestry institutions at both the state and local levels where carbon and ecosystem service data will be collected and fed to the national level. Highly trained human resources are also required.

The SAR Task Group India with the assistance of the University of Massachusetts has developed protocol for using Synthetic Aperture Radar (SAR) data for mapping forest biomass at landscape level. These protocols are described in the "SAR Protocol" document provided as supporting material. Forest-PLUS has developed a training module that includes brief theory and hands-on work on SAR data for end-to-end processing of data and produces a biomass maps. It is with regard to these training modules that the following materials are provided.

OBJECTIVES

1. To build capacity of SFD technical staff to pre-process the microwave remote sensing (SAR) data for generation of backscatter image using open source software.

2. To build proficiency of SFD technical staff in converting backscatter data to biomass maps at landscape level with the help of field sampled locations using open source software.

DATA SETS

Data sets include SAR remote sensing satellite data, optical remote sensing satellite data, GIS data and forest plot inventory data.

HIMACHAL PRADESH

Sensor/Source	Sensor Type	Product Level	Date	Filename	Path/Frame	Original Projection
ALOS PALSAR	L-band	RTC	8/10/07	AP_08222_FBD_F0610_RT2	P524 F610	UTM 43N
ALOS PALSAR	L-band	Level 1.5 GRD	8/10/07	ALPSRP082220610-L1.5	P524 F610	UTM 43N
ALOS PALSAR	L-band	Level 1.5 GRD	8/18/10	ALPSRP243260610-L1.5	P524 F610	UTM 43N
ALOS PALSAR	L-band	SLC	8/18/10	ALPSRP243260610-L1.1	P524 F610	slant range
Sentinel-1A	C-band	GRD	3/8/15	S1A_IW_GRDH_1SDV_20150308T0		
Sentinel-1A	C-band	GRD	10/28/16	S1A_IW_GRDH_1SDV_20161028T0		
Sentinel-1A	C-band	SLC	10/28/16	S1A_IW_SLC__1SDV_20161028T0		
Landsat 8 OLI/TIRS	optical	Level 1	Oct-16	x4	p146r38, p146r39, p147r38, p147r39	
SRTM 30m	DEM			x4	n30e77, n31e76, n31e77, n31e78	
Anup Das	plot boundary			Rampur-Shimla.shp		custom WGS84

KARNATAKA

Sensor/Source	Sensor Type	Product Level	Date	Filename	Path/Frame	Orig Projection
ALOS PALSAR	L-band	RTC	7/27/07	AP_08018_FBD_F0260_RT2	P534 F260	UTM 43N
ALOS PALSAR	L-band	Level 1.5 GRD	7/27/07	ALPSRP080180260-L1.5	P534 F260	UTM 43N
ALOS PALSAR	L-band	SLC	7/27/07	ALPSRP080180260-L1.1	P534 F260	slant range
Sentinel-1A	C-band	GRD	3/3/15	S1A_IW_GRDH_1SDV_20150303T004731_2015(		
Sentinel-1A	C-band	GRD	10/23/16	S1A_IW_GRDH_1SDV_20161023T004738_20161		
Sentinel-1A	C-band	SLC	10/23/16	S1A_IW_SLC__1SDV_20161023T004737_20161(		
Landsat 8 OLI/TIRS	optical	Level 1	Oct-16	x4	p146r51, p146r50, p145r51, p145r50	
SRTM 30m	DEM			x4	n13e75, n14e75, n14e74, n13e74	
Anup Das	plot boundary			Shimoga.shp		custom WGS84

MADHYA PRADESH

Sensor/Source	Sensor Type	Product Level	Date	Filename	Path/Frame	Orig Projection
ALOS PALSAR	L-band	RTC	6/13/07	AP_07376_FBD_F0440_RT2	P526 F440	UTM 43N
ALOS PALSAR	L-band	Level 1.5 GRD	6/13/07	ALPSRP073760440-L1.5	P526 F440	UTM 43N
ALOS PALSAR	L-band	SLC	6/13/07	ALPSRP073760440-L1.1	P526 F440	slant range
ALOS PALSAR - from Paul	L-band	Level 1.5 GRD	6/13/07		P526 F???	
ALOS PALSAR - from Paul	L-band	Level 1.5 GRD	8/6/10		P526 F???	
Sentinel-1A	C-band	GRD	3/3/15	S1A_IW_GRDH_1SDV_20150303T004501_2015(		
Sentinel-1A	C-band	GRD	10/23/16	S1A_IW_GRDH_1SDV_20161023T004533_20161		
Sentinel-1A	C-band	SLC	10/23/16	S1A_IW_SLC__1SDV_20161023T004533_20161(		
Landsat 8 OLI/TIRS	optical	Level 1	Oct-16	x5	p144r45, p144r44, p146r44, p145r45, p145r44	
SRTM 30m	DEM			x2	n22e77, n22e78	
Anup Das	plot boundary			Hoshangabad.shp		custom WGS84

SIKKIM

Sensor/Source	Sensor Type	Product Level	Date	Filename	Path/Frame	Orig Projection
ALOS PALSAR	L-band	RTC	6/7/07	AP_07288_FBD_F0530_RT2	P504 F530	UTM 45N
ALOS PALSAR	L-band	RTC	6/12/09	AP_18024_FBD_F0530_RT2	P504 F530	UTM 45N
ALOS PALSAR	L-band	Level 1.5 GRD	6/7/07	ALPSRP072880530-L1.5	P504 F530	UTM 45N
ALOS PALSAR	L-band	Level 1.5 GRD	6/12/09	ALPSRP180240530-L1.5	P504 F530	UTM 45N
ALOS PALSAR	L-band	SLC	6/7/07	D26010_2_A3_7288	P504 F530	slant range
ALOS PALSAR	L-band	SLC	6/12/09	D26010_1_A3_18024	P504 F530	slant range
Sentinel-1A	C-band	GRD	3/2/15	S1A_IW_GRDH_1SDV_20150302T0002		
Sentinel-1A	C-band	GRD	10/22/16	S1A_IW_GRDH_1SDV_20161022T0002		
Sentinel-1A	C-band	SLC	10/22/16	S1A_IW_SLC__1SDV_20161022T00024		
Landsat 8 OLI/TIRS	optical	Level 1	Oct-16	LC81390412016301LGN00	p139r41	
SRTM 30m	DEM			n27_e088_1arc_v3.tif	n27e88	
Anup Das	plot boundary			East_sikkim.shp		custom WGS84
Uttara Pandey	biomass ground truth			AGB_Plots_Sikkim.csv		lat/long, EPSG:4326
Alternate ALOS images						
ALOS PALSAR	L-band	RTC	6/7/07	AP_07288_FBD_F0540_RT2	P504 F540	UTM 45N
ALOS PALSAR	L-band	RTC	6/12/09	AP_18024_FBD_F0540_RT2	P504 F540	UTM 45N
ALOS PALSAR	L-band	RTC	6/26/08	AP_12904_FBD_F0530_RT2	P505 F530	UTM 45N

*note: Alternate ALOS images indicates those images that cover a wider geographic region in the area. These regions contain additional ground validation resources.

DEHRADUN

Sensor/Source	Sensor Type	Product Level	Date	Filename	Path/Frame	Orig Projection
ALOS PALSAR	L-band	RTC	7/24/16	AP_07974_FBD_F0590_RT2	P523 F590	
ALOS PALSAR	L-band	Level 1.5 GRD	7/24/16	ALPSRP079740590-L1.5	P523 F590	
ALOS PALSAR	L-band	Level 1.5 GRD	8/1/10	ALPSRP240780590-L1.5	P523 F590	
ALOS PALSAR	L-band	SLC	8/1/10	ALPSRP240780590-L1.1	P523 F590	slant range
Sentinel-1A	C-band	GRD	10/28/16	S1A_IW_GRDH_1SDV_20161028T005126_20161		
Sentinel-1A	C-band	SLC	10/28/16	S1A_IW_SLC__1SDV_20161028T005126_20161(		
Landsat 8 OLI/TIRS	optical	Level 1	Oct-16	LC81460392016302LGN00	p146r39	
SRTM 30m	DEM			x2	n30e77, n30e78	
	plot boundary					
	biomass ground truth					

HOW TO ACQUIRE SAR DATA

Listed below are three providers of SAR and other remote sensing data, the European Space Agency (ESA), Alaska Satellite Facility (ASF), and the United States Geological Survey (USGS). There is some overlap in the data sets provided, and there are other providers not listed of the same or related data. All three of these sites provide free data but require the user to create an account with them prior to downloading data.

European Space Agency (ESA):
Website: scihub.copernicus.eu/dhus/#/home
Data sets: Sentinel data (all mission satellites)

Alaska Satellite Facility (ASF):
Website: vertex.daac.asf.alaska.edu
Data sets: ALOS 1, limited Sentinel, other SAR data

United States Geological Survey (USGS):
Website: http://earthexplorer.usgs.gov/
Data sets: SRTM DEM, Landsat, assortment of other data sets (optical, thermal, etc.)

SOFTWARE REQUIREMENTS

For this training material, there are two fundamental pieces of software that the user should make themselves familiar with. These are:

1. SNAP

2. QGIS

Details on how to install these programs onto your computer are given in Appendix A, located at the end of this document.

Additionally, for the more advanced user, experience with the Python programming language is helpful, as would be the software package known as PolSARPro. Here, Python would be used to automate tasks that can be executed by the QGIS package. PolSARPro, similar to SNAP, can perform advanced processing techniques for reducing speckle and analysing polarimetric SAR data.

WORKING WITH SAR DATA

SAR DATA PRE-PROCESSING

Data acquired by the air-borne and space-borne SAR sensors contain uncertainties due to variations in altitude, velocity of the sensor platform, relief displacement and non-linarites in sweep of a sensor's instantaneous field of view (IFOV). The datasets need to be properly calibrated/pre-processed to use it for desired applications. Pre-processing involves following steps:

(i) Slant to ground range conversion and multi-looking
(ii) Speckle filtering
(iii) Generation of amplitude image
(iv) Data conversion from Amplitude image to Power Image
(v) Linear backscatter image generation from Power image
(vi) Linear to decibel conversion
(vii) Geocoding, terrain correction using appropriate external DEM data
(viii) Correction of backscatter for local incidence angle effects

In what follows are step by step instructions for implementing these steps.

SOFTWARE MODULE: SLANT TO GROUND RANGE CONVERSION AND MULTI-LOOKING

***Data Input*:** Input data for this module is slant range data. It may however be noted that ground range amplitude data also can be used.

***Output Product*:** Output product for this step will be the slant to ground range converted and multi-looked product

Steps

1. **Open SNAP Software**
2. **Go to Radar Module**
3. **Geometric**
4. **Slant to Ground Range Conversion**
5. **Select .xml file** (This file will be sensor specific, extension will vary sensor to sensor)
6. **Define target location**
7. **Select required file format**

8. **Define directory**
9. **Run the module**
10. **Go to Radar Module**
11. **Multilooking**
12. **In the place of source file select the ground range converted product**
13. **Define Directory**
14. **Go to Processing Parameters**
15. **If you wish you can change number of looks otherwise keep it default**
16. **Run the module**

Figure 1 below depicts the process of multilooking and Figure 2 depicts the output as ground range converted multilooked product.

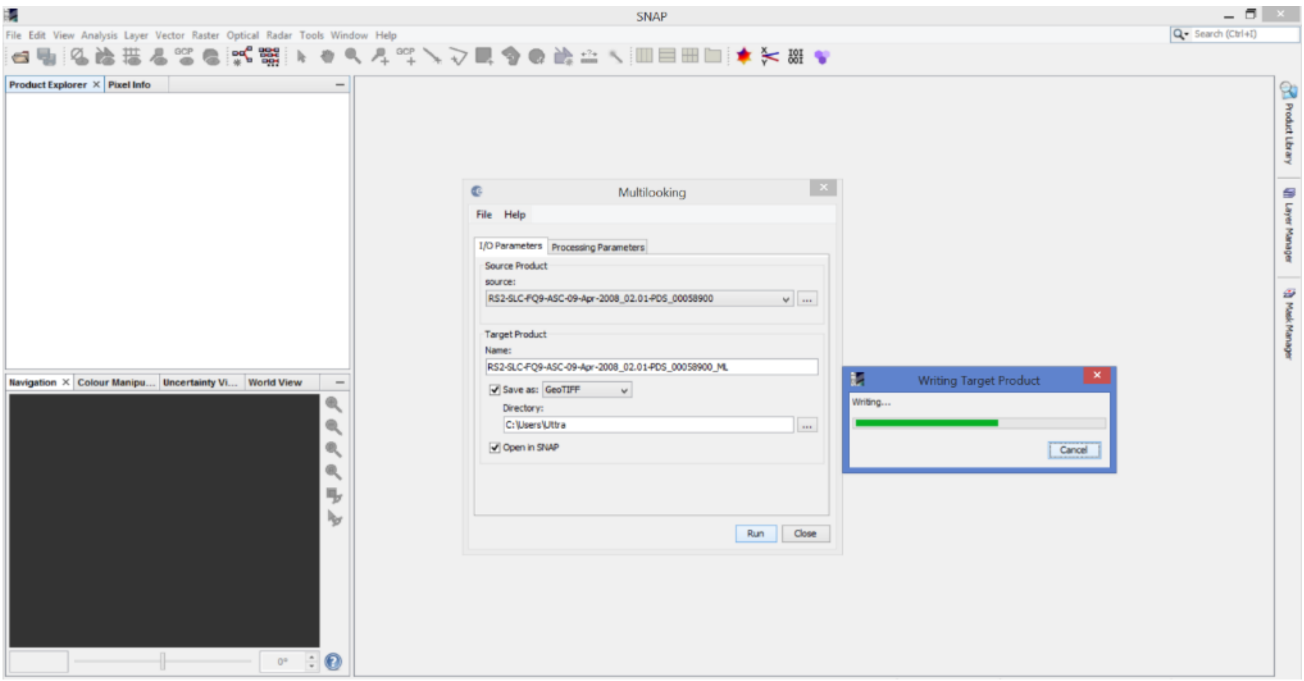


Fig 1. Screenshot of multilooking process.

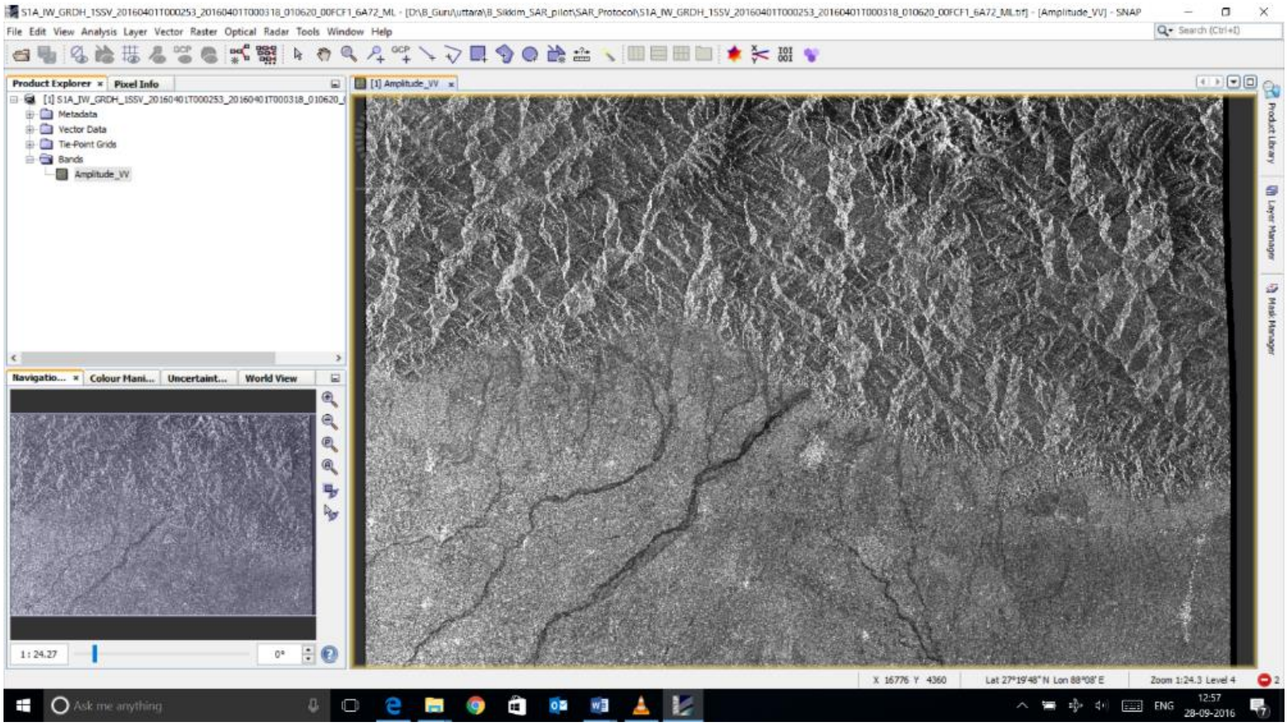


Fig 2. Ground range converted multilooked product (Sentinel-1_VV_Sikkim).

SOFTWARE MODULE: SPECKLE FILTERING

***Data Input*:** Input data for this module is ground range converted multilooked SAR data

***Output Product*:** Speckle suppressed product

Steps

1. **Open SNAP Software**
2. **Go to Radar Module**
3. **Go to Speckle Filtering**
4. **Select Single Product Speckle Filter**
5. **Select Multilooked ML file**
6. **Define Target Location**
7. **Select Required File Format**
8. **Define Directory**
9. **Go to Processing Parameters**
10. **Select Band**
11. **Define Filter**

The edge threshold will automatically be selected from the header file.

12. **Run the module**

Fig. 3 depicts the process of speckle filtering and Fig. 4 depicts the Lee-fileted product.

Selection of Appropriate Filter:

The speckle filter is chosen after analysing all filtered images visually and also statistically by calculating Speckle Suppression Index (SSI) and Speckle Suppression and Mean Preservation Index (SMPI) for filtered images as follows (Eq. 1):

$$\text{Speckle suppression index, } SSI = \frac{\sqrt{\text{var}(I_f)}}{mean(I_f)} x \frac{mean(I_0)}{\sqrt{\text{var}(I_0)}} - \quad (1)$$

where If = filtered image; Io = noisy image

This index tends to be less than 1 if the filter performance is efficient in reducing the speckle noise.

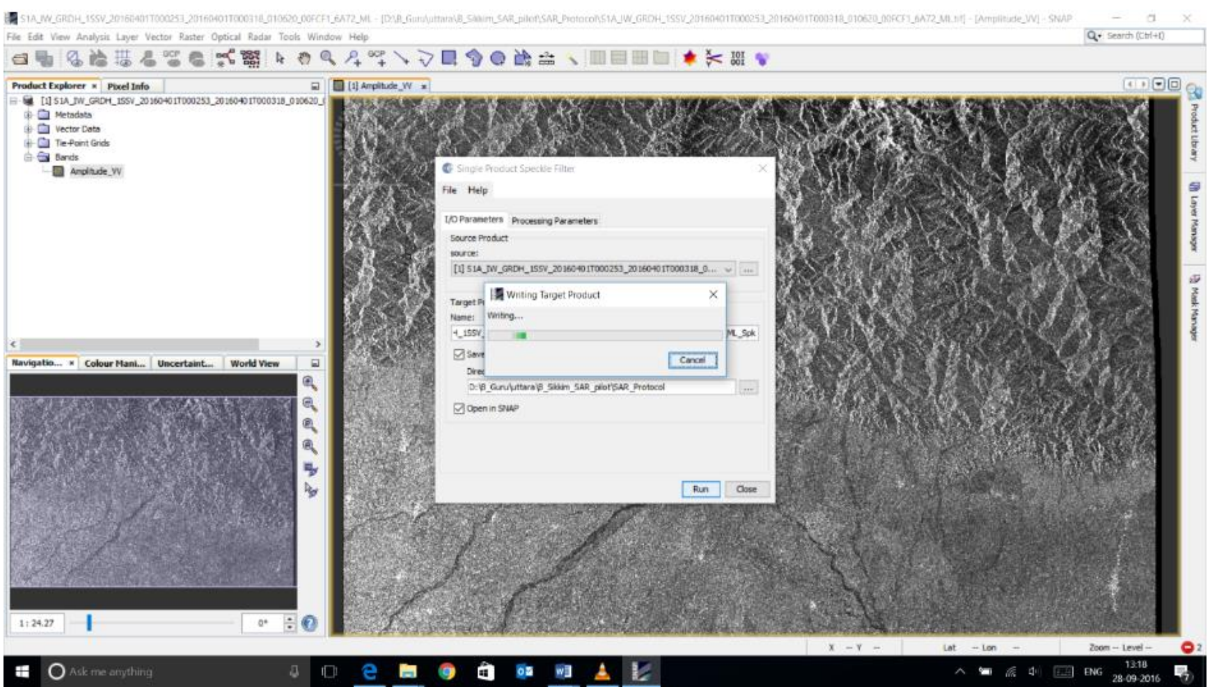


Fig 3. Screen shot of speckle filtering process.

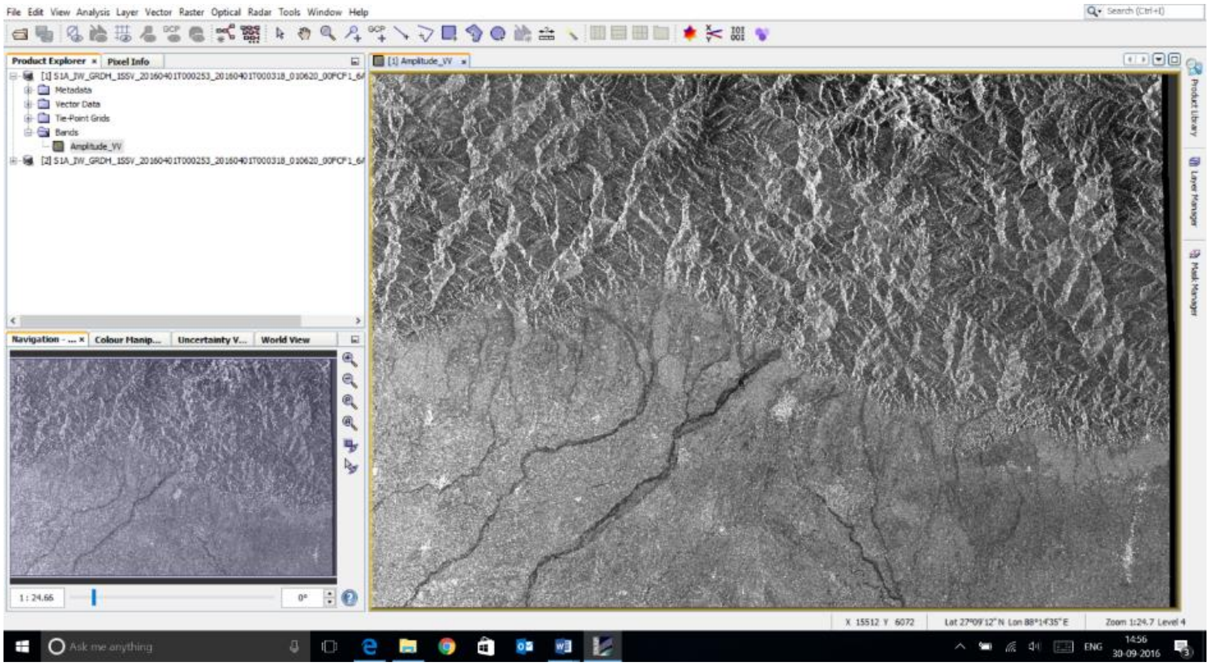


Fig 4. Speckle filtered product (Sentinel-1_VV_Sikkim_Lee_Filtered).

SOFTWARE MODULE: SIGMA NOUGHT GENERATION IN DECIBEL SCALE

***Data Input*:** Input data for this module is ground range converted multilooked and speckle filtered data

***Output Product*:** Calibrated sigma naught image in decibel scale

Steps

1. **Open SNAP Software**
2. **Go to Radar Module**
3. **Radiometric**
4. **Calibrate**
5. **Select ground range converted multilooked and speckle filtered data as a source file**
6. **Define directory**
7. **Open Processing Parameters**
8. **Select save in dB**
9. **Run the Module** (Fig. 5 depicts sigma naught image in decibel scale)

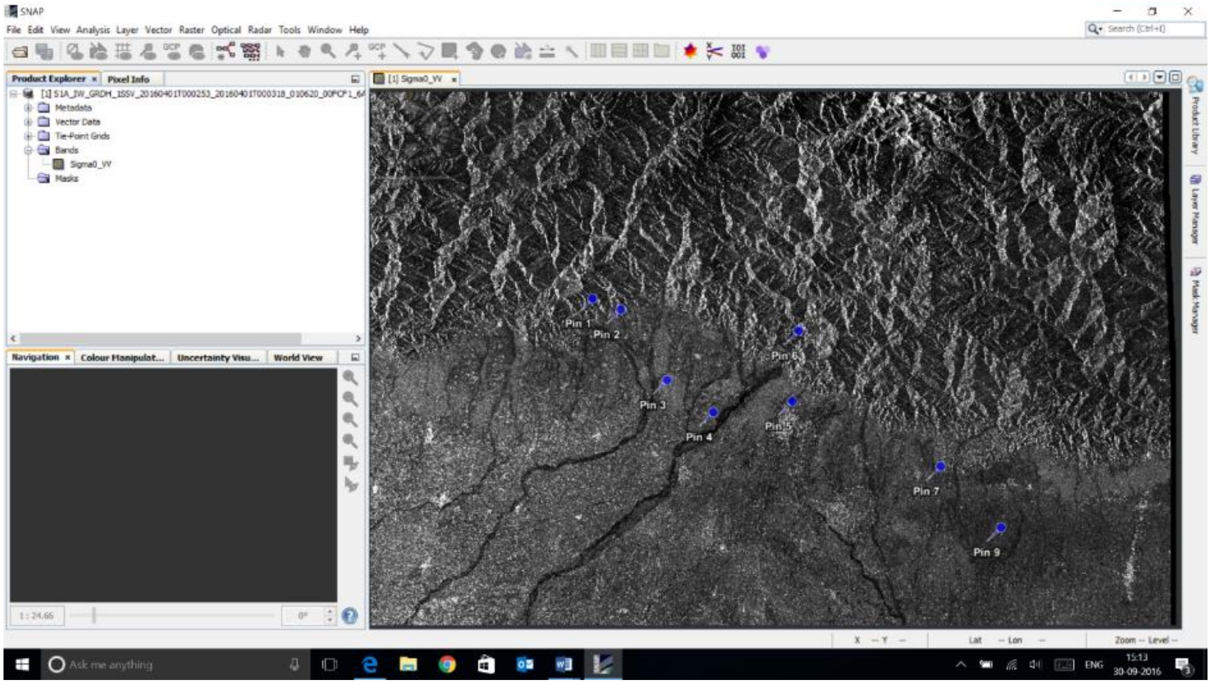


Fig 5. Sigma Nought product (Sentinel-1_VV_Sikkim).

SOFTWARE MODULE: GEOCODING AND LOCAL INCIDENCE ANGLE CORRECTION

***Data Input*:** Input data for this module is calibrated SAR backscatter

***Output Product*:** Terrain corrected SAR backscatter

Steps

1. **Open SNAP Software**
2. **Go to Radar Module**
3. **Geometric**
4. **Terrain Correction**
5. **Range Doppler Terrain Correction**
6. **Select calibrated SAR backscatter as source file**
7. **Define directory**
8. **Open Processing Parameters**
9. **Select the required DEM from the drop down menu (you can select any external DEM as well)**
10. **Define Map Projection**
11. **Select the output bands which you require**
12. **Rest of the parameters can be default**
13. **Run the Module** (Fig. 6,7 & 8 depicts the process of terrain corrected SAR backscatter generation)

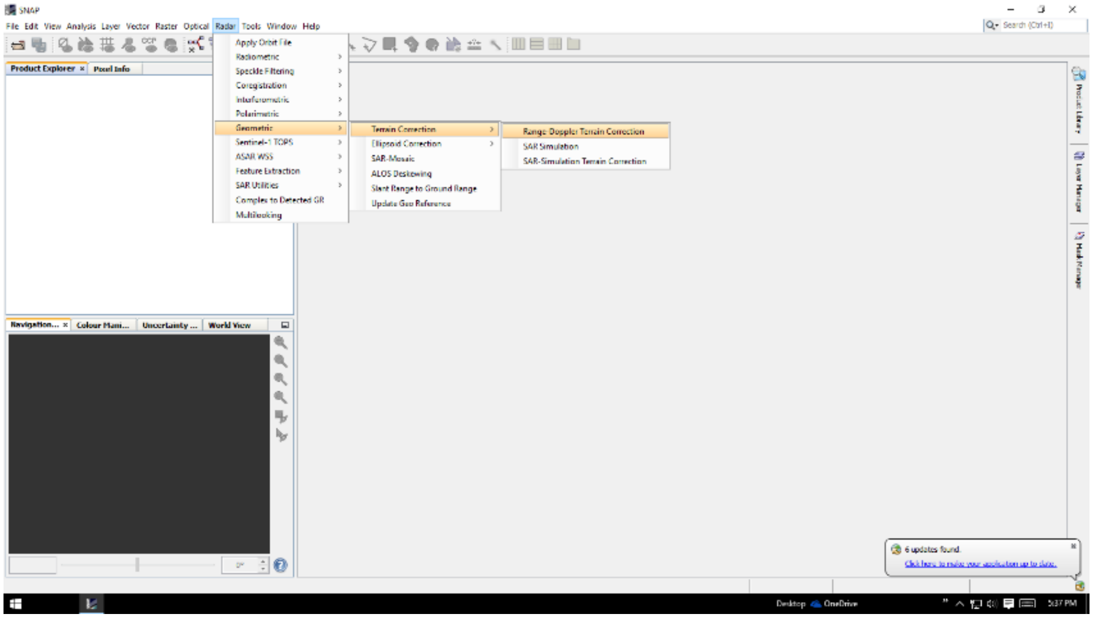


Fig 6. Terrain Corrected Sigma Nought product (Sentinel-1_VV_Sikkim).

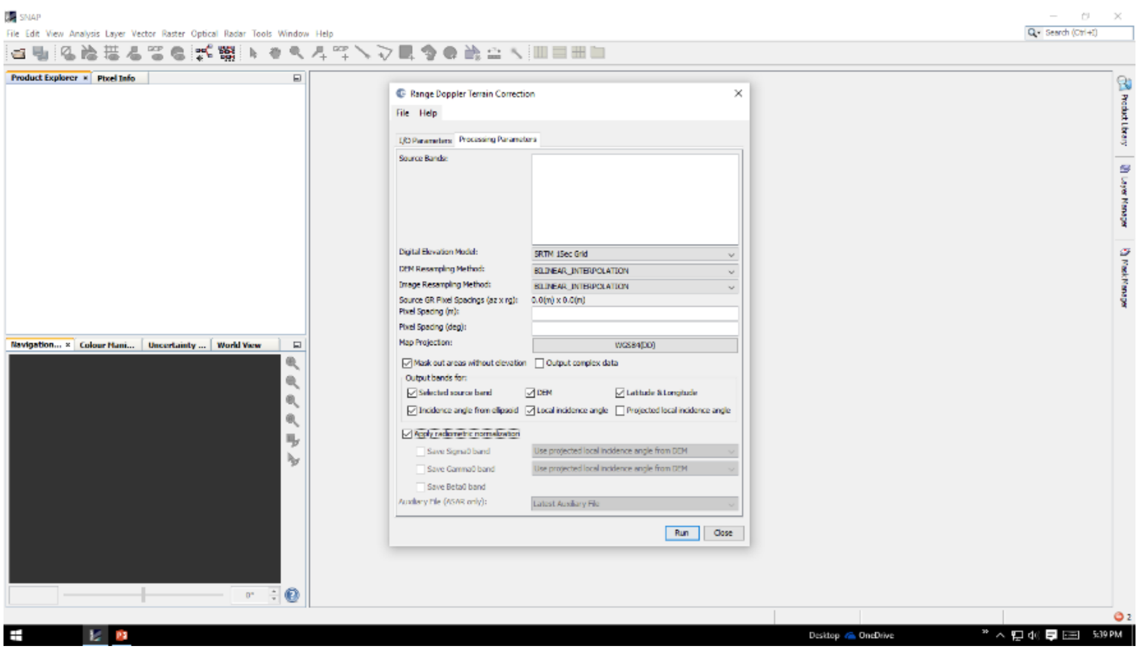


Fig 7. Terrain Corrected Sigma Nought product (Sentinel-1_VV_Sikkim).

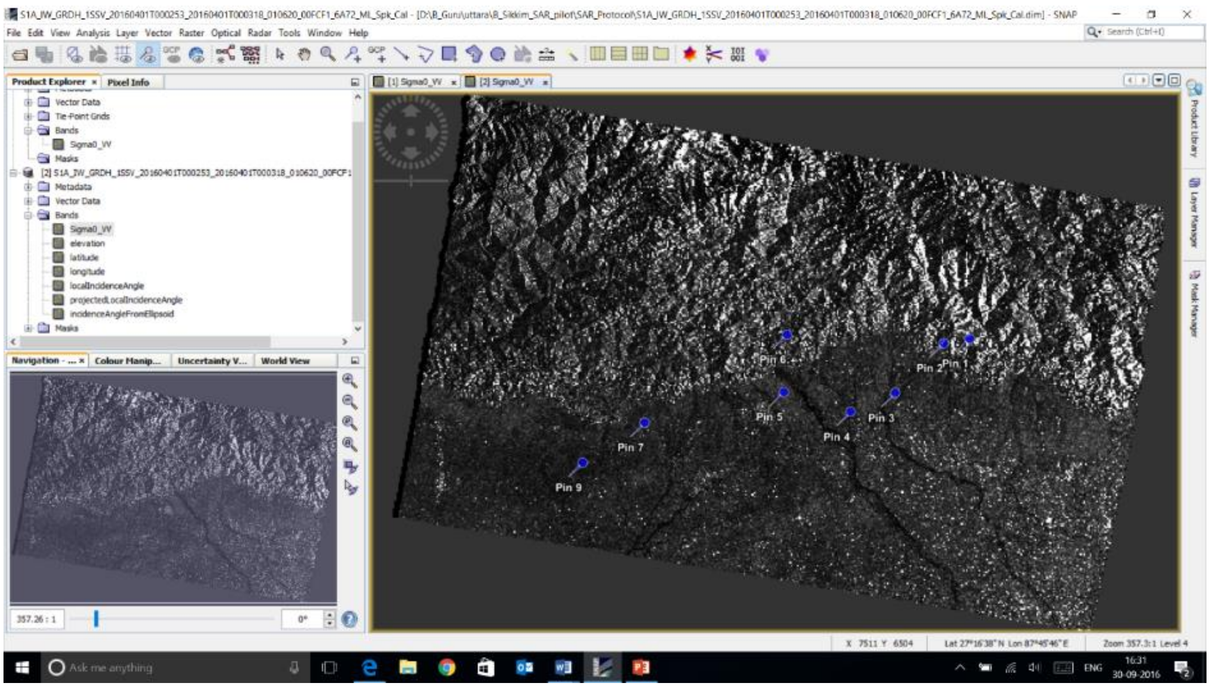


Fig 8. Terrain Corrected Sigma Nought product (Sentinel-1_VV_Sikkim).

PROTOCOL MODELS

INTRODUCTION

The tools that are introduced in the following sections have been developed using the QGIS Processing framework to estimate aboveground biomass from synthetic aperture radar (SAR) backscatter and to monitor land cover change in forested areas. As a part of this framework the scripts are open source and written in python.

Among the Backscatter to Biomass Tools the main steps are the Backscatter to Biomass Regression, and then Apply Estimated Biomass. First, the Backscatter to Biomass Regression tool uses ground truth data and the associated backscatter values to calculate a best fit regression line based on the equation, "backscatter = A(1 – e^-Bb) + C," where A, B, and C are constants, and b is biomass. If the input values and starting constants are poorly related the script may be unable to fit this equation to the data, in which case it will instead produce a linear regression fit. In either case the constants (A, B, and C or slope and intercept) will be outputted. Second, the Apply Estimated Biomass tool takes in the constants along with the backscatter image and applies an estimated biomass calculation to that image. Depending on the results of part one there are two different versions of Apply Estimated Biomass, one using the curve fit and the other using the linear fit. The remaining graphing and ground truth data format modifying tools are supplementary tools to the main backscatter to biomass process. The two graphing tools, one for curve fit and one for linear regression can be run as a standalone tools as well as being built into Backscatter to Biomass Regression. They graph the ground truth-backscatter pairs against either the best fit curve line or the linear regression, outputting the resultant graph as an image. The two ground truth (either CSV or point) to polygon tools are there to convert ground truth data stored as either a point vector file or as a comma separated value (CSV) table into the polygon vector format required by the Backscatter to Biomass Regression tool.

The Forest Change Tools comprises of a forest/non-forest (FNF) classification and forest land cover change tool. The FNF classification takes user inputted upper and lower thresholds to define a range of SAR backscatter values to be classified as forest. The forest change tool takes two FNF classified images of the same location at different times and detects where the classification has or has not shifted between the two dates. It outputs a layer with four classifications; unchanged forest, unchanged non-forest, forest degraded to non-forest, and non-forest regrown to forest.

PROTOCOL TOOLS INTRODUCTION

This section includes descriptions on the inputs and outputs for each tool, the basic processing involved, and a screenshot of the tool input window.

BACKSCATTER TO BIOMASS TOOL INTRODUCTION

This tool uses ground truth biomass measurements and SAR backscatter values to create a best fit curve line of estimated aboveground biomass. The regression uses the equation, "backscatter = A(1 – e^-Bb) + C," where A, B, and C are constants, and b is biomass. To aid in the curve fitting the user has the option of entering starting values for A, B, and C. A default set of values are used if the user does not given input. If input backscatter-biomass pairs and starting constants are poorly matched and the script is unable to fit the curve equation to the data it will instead run a linear regression on the data. If the ground truth data and backscatter image are not in the same projection, a reprojected version of the ground truth data will be automatically created in the same projection as the backscatter image and used for further processing. The script also outputs a layer comprising of the original ground truth layer with an additional attribute table column containing the average backscatter within each ground truth plot. A text file is produced at the end of the script containing either the best fit A, B, and C constants or the slope and intercept of the linear regression.

- Input Data:
  - Backscatter image (raster)
  - Ground truth (polygon vectors) – must have an attribute table column containing biomass
  - Biomass (attribute column of ground truth layer)
  - Starting A, B, C constants (float, default given)
- Output files (file names need to be inputted):
  - Ground truth with backscatter output (polygon vector) – copy of the ground truth file with a new attribute column for mean backscatter based on the backscatter raster values
  - output text file (text file) – text file containing the values for best fit A, B, and C constants or the slope and intercept of the linear regression
  - graph (graphic window that can be saved by the user) – graph showing the backscatter-ground truth data points graphed with either the best fit curve line or the linear regression

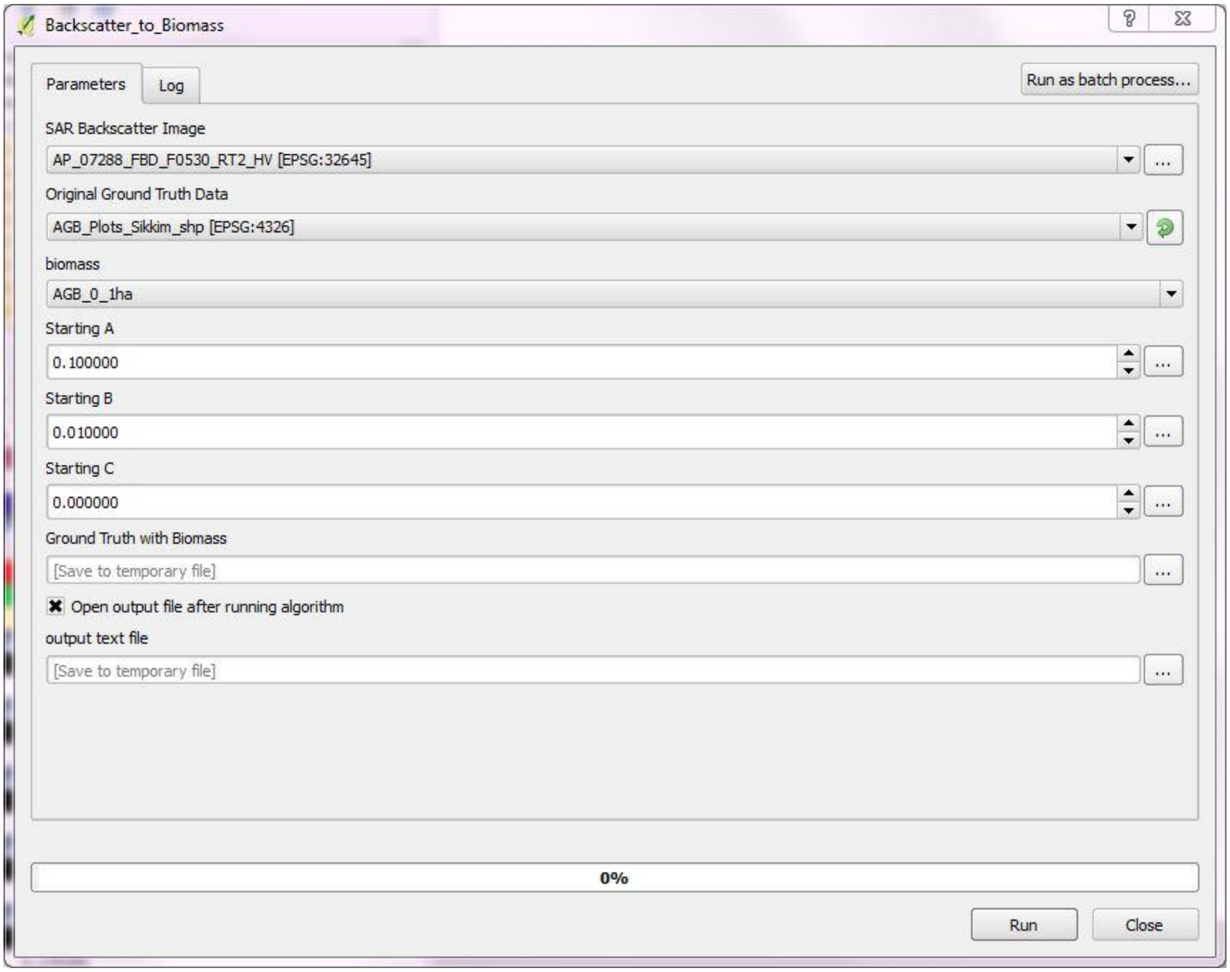


Fig 9. Backscatter to Biomass Tool.

APPLY ESTIMATED BIOMASS CURVE

This tool uses the inputted A, B, and C constants in the aforementioned biomass equation to produce an estimated biomass layer. The equation is adjusted to solve for biomass instead of backscatter, taking the form, “biomass = ln(1 – ((backscatter – C)/A)) / -B”. The default constants are A=0.1, B=0.01, C=0. A threshold for the maximum biomass in this area is also inputted. Any equation-made biomass values above the threshold are reset to the threshold to prevent nonsensically high biomass values.

- Input Data:
  - SAR backscatter image (raster)
  - A, B, C constants (float)
  - Max biomass (float) – threshold to use as a maximum biomass for this area.
- Output files (file names need to be inputted):
  - Estimated biomass layer (raster)

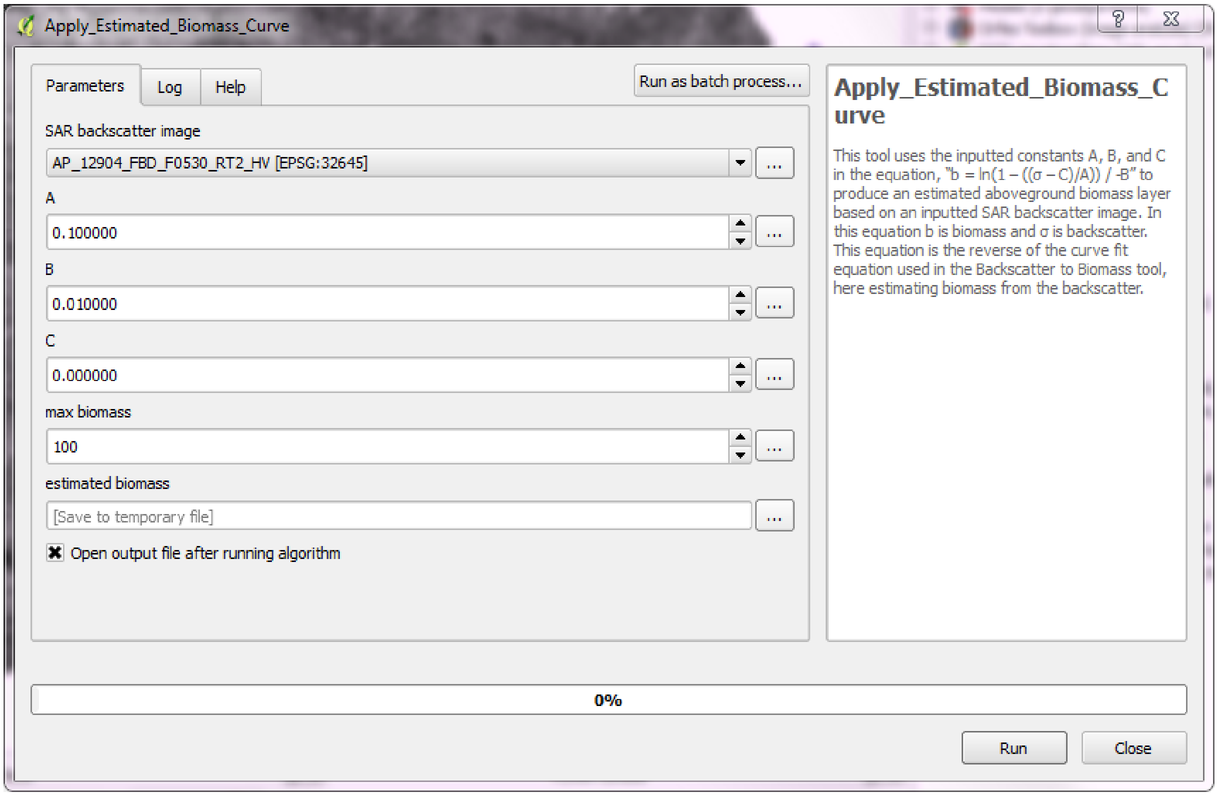


Fig 10. Apply Estimated Biomass Curve Tool.

APPLY ESTIMATED BIOMASS LINEAR

This tool applies the linear regression estimate of biomass, taking the form backscatter = slope*biomass + intercept. To calculate estimated biomass (instead of backscatter) the equation is inversed to biomass = (backscatter – intercept) / slope. The default slope and intercept are slope=0.00005 and intercept=0.5. A threshold for the maximum biomass in this area is also inputted. Any equation-made biomass values above the threshold are reset to the threshold to prevent nonsensically high biomass values.

- Input Data:
  - Backscatter image (raster)
  - Slope and intercept values (float)
  - Max biomass (float) – threshold to use as a maximum biomass for this area.
- Output files (file names need to be inputted):
  - Estimated biomass layer (raster)

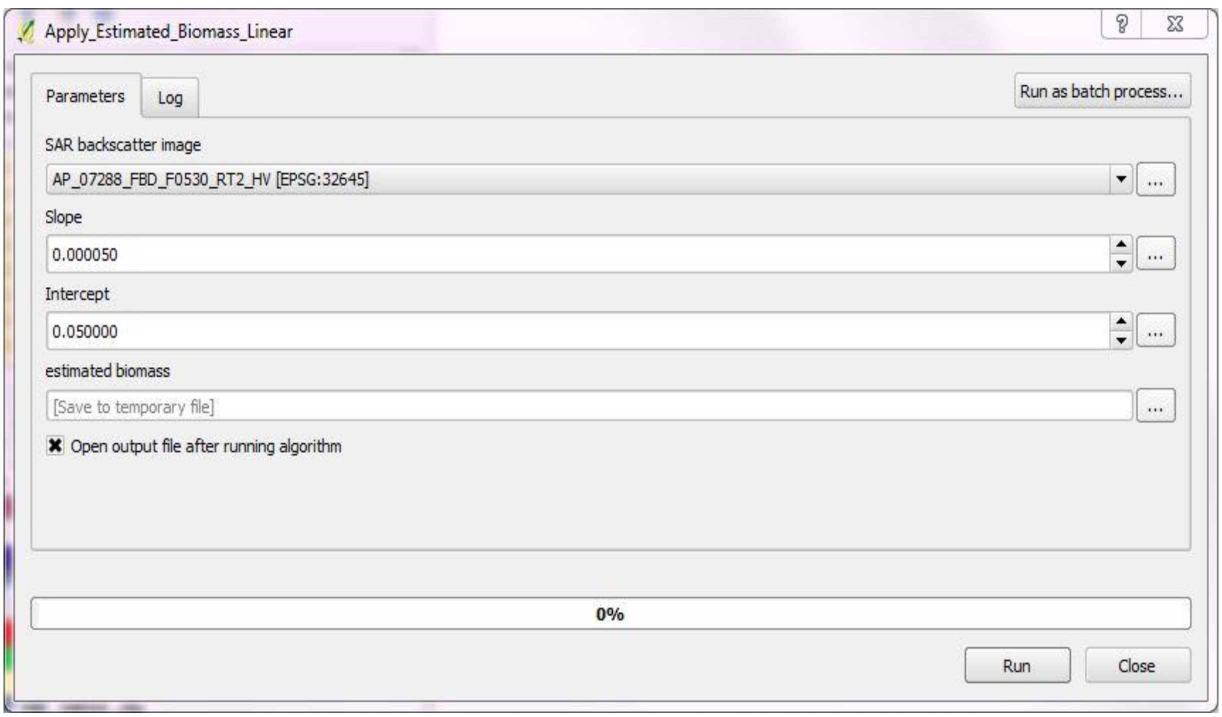


Fig 11. Apply Estimated Biomass Linear Tool.

GRAPH CURVE FIT

This tool is called as part of the Backscatter to Biomass Regression tool if curve fitting is successful, as well as being available as a standalone entity. It graphs the ground truth and backscatter information against the curve line formed by the inputted A, B, and C values, allowing the user to examine how well the line fits the data. The default constants are A=0.1, B=0.01, C=0. The graph is outputted as a pop-up window that gives the user the option to save to a variety of file types.

- Input Data:
  - Ground truth (polygon vectors) – must have an attribute table columns for backscatter and biomass, such as the output file from Backscatter to Biomass
  - Backscatter (attribute column of ground truth layer)
  - Biomass (attribute column of ground truth layer)
  - A, B, C constants (float)
- Output:
  - graph (graphic window that can be saved by the user) – graph showing the backscatter-ground truth data points graphed with either the best fit curve line

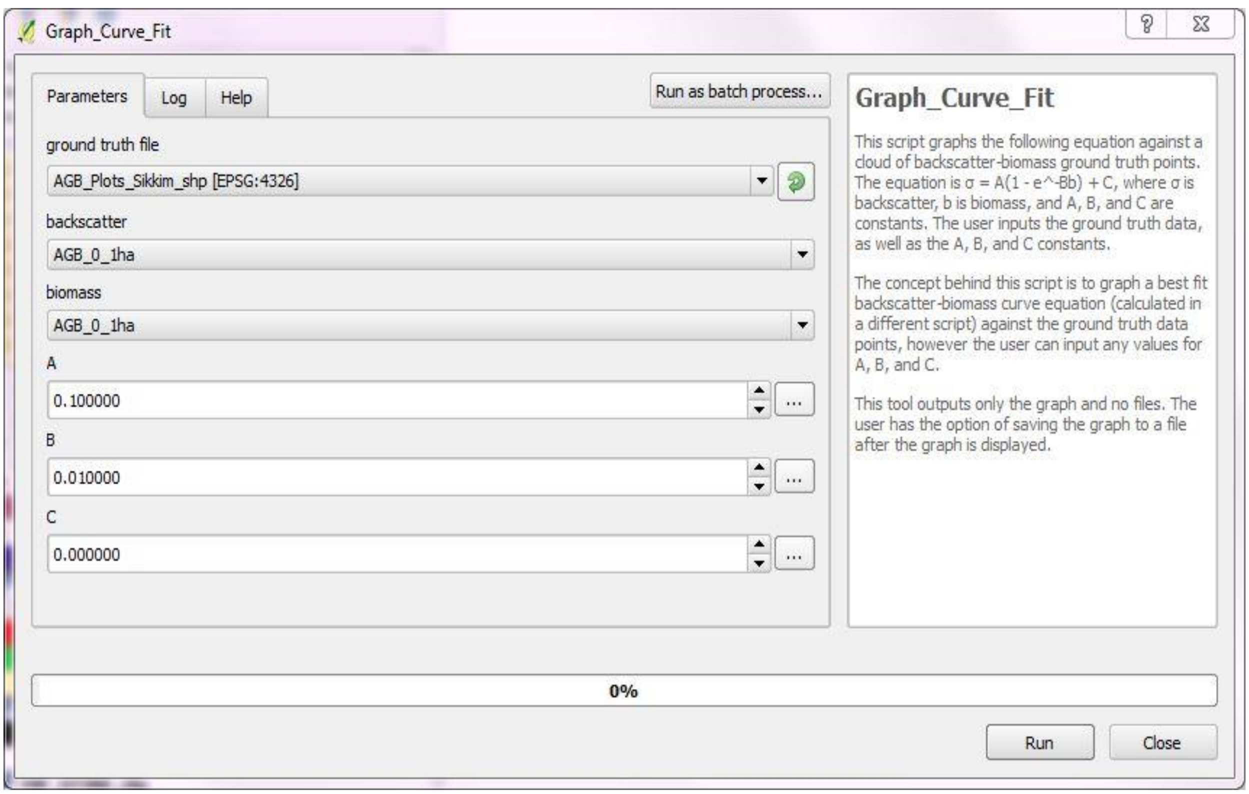


Fig 12. Graph Curve Fit Tool.

GRAPH LINEAR REGRESSION

This tool is called as part of the Backscatter to Biomass Regression tool if linear regression is calculated, as well as being available as a standalone entity. It graphs the ground truth and backscatter information against the linear equation formed by the inputted slope and intercept values, allowing the user to examine how well the line fits the data. The default values are slope=0.00005 and intercept=0.5. The graph is outputted as a pop-up window that gives the user the option to save to a variety of file types.

- Input Data:
    - Ground truth (polygon vectors) – must have an attribute table columns for backscatter and biomass, such as the output file from Backscatter to Biomass
    - Backscatter (attribute column of ground truth layer)
    - Biomass (attribute column of ground truth layer)
    - Slope and intercept values (float)
- Output:
    - graph (graphic window that can be saved by the user) – graph showing the backscatter-ground truth data points graphed with either the best fit curve line

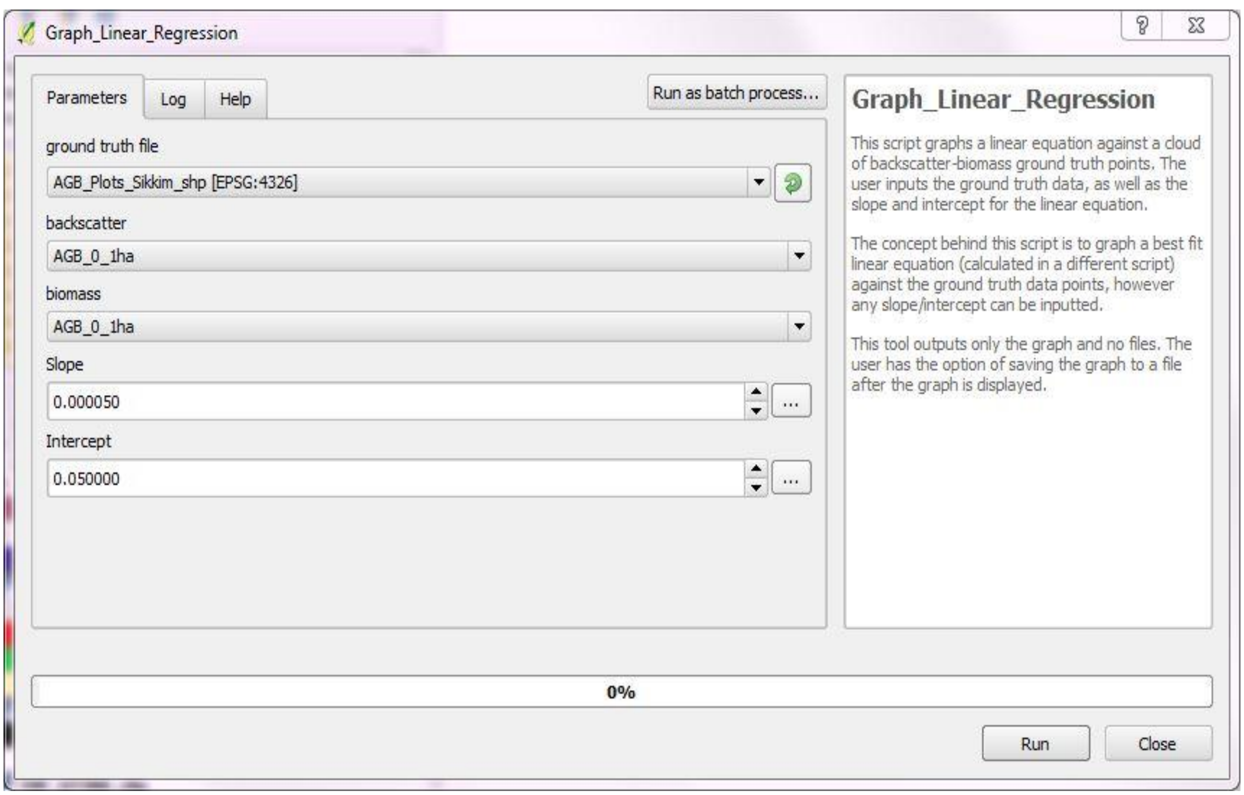


Fig 13. Graph Linear Regression Tool.

GROUND TRUTH CSV TO POLYGON

This tool is a helper method to convert ground truth data stored as a CSV table into the polygon vector format needed by the Backscatter to Biomass Regression tool. The CSV file needs to have at a minimum the coordinates of each ground truth data point and the associated biomass values. The user also needs to provide the coordinate system in use. The script transforms the CSV data from a point listed as a coordinate pair into either square or circular polygons with user-inputted dimensions given in the same units as the projection (i.e. if coordinates are in latitude and longitude then the plot size must be given in degrees). This dimension is listed in map units instead of meters because there are many options for projection units (meters, degrees, feet, etc.), and they do not all had a set conversion rate (for example meters per degree varies depending on latitude).

- Input Data:
  - Ground truth (CSV table file) – must have table columns containing location coordinates
  - X Coordinate Field (attribute column of ground truth layer)
  - Y Coordinate Field (attribute column of ground truth layer)
  - Coordinate System (coordinate reference system (CRS) value)
  - Plot diameter (float – in map units)
  - Plot shape (drop down menu – square or circle)
- Output:
  - Ground truth (polygon vectors)

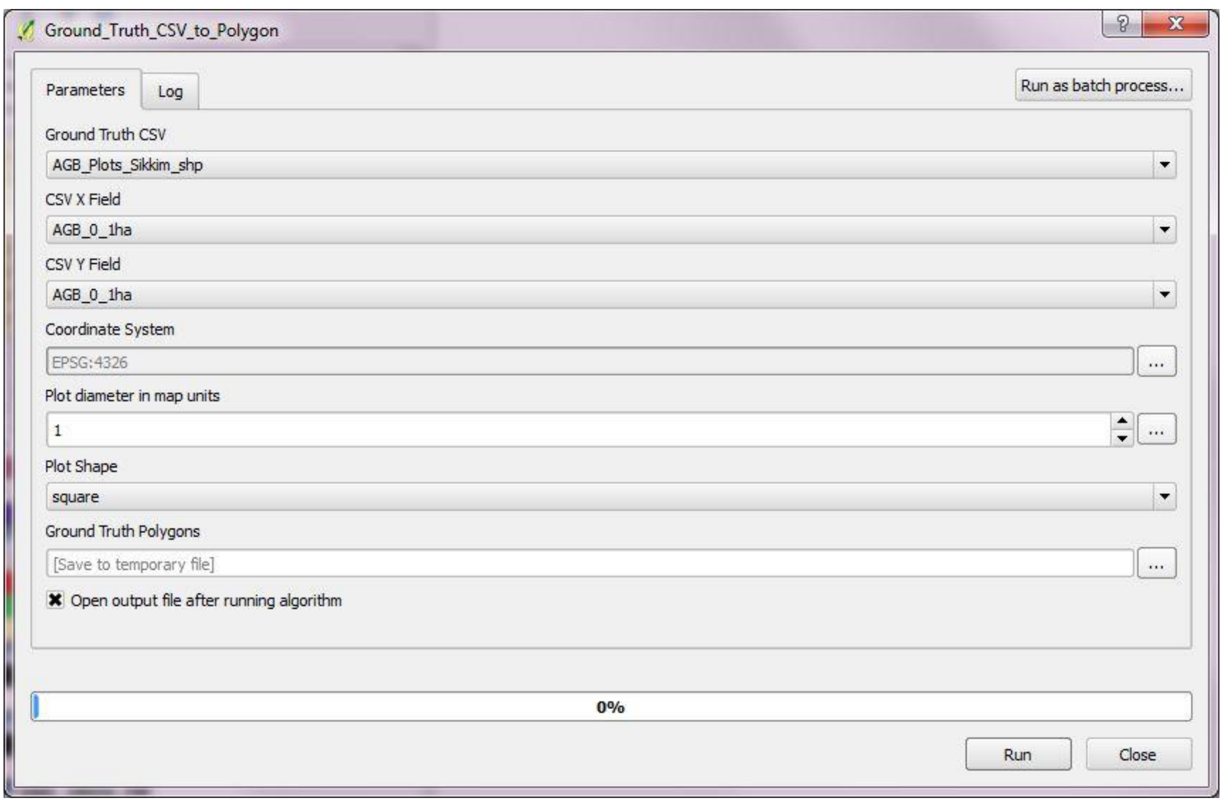


Fig 14. Ground Truth CSV to Polygon Tool.

GROUND TRUTH POINT TO POLYGON

This tool is a helper method to convert ground truth data stored as points into the polygon vector format needed by the Backscatter to Biomass Regression tool. The script transforms the ground truth data from points into either square or circular polygons with user-inputted dimensions given in the same units as the projection (i.e. if coordinates are in latitude and longitude then the plot size must be given in degrees). This dimension is listed in map units instead of meters because there are many options for projection units (meters, degrees, feet, etc.), and they do not all had a set conversion rate (for example meters per degree varies depending on latitude).

- Input Data:
  - Ground truth (point vectors)
  - Plot diameter (float – in map units)
  - Plot shape (drop down menu – square or circle)
- Output:
  - Ground truth (polygon vectors)

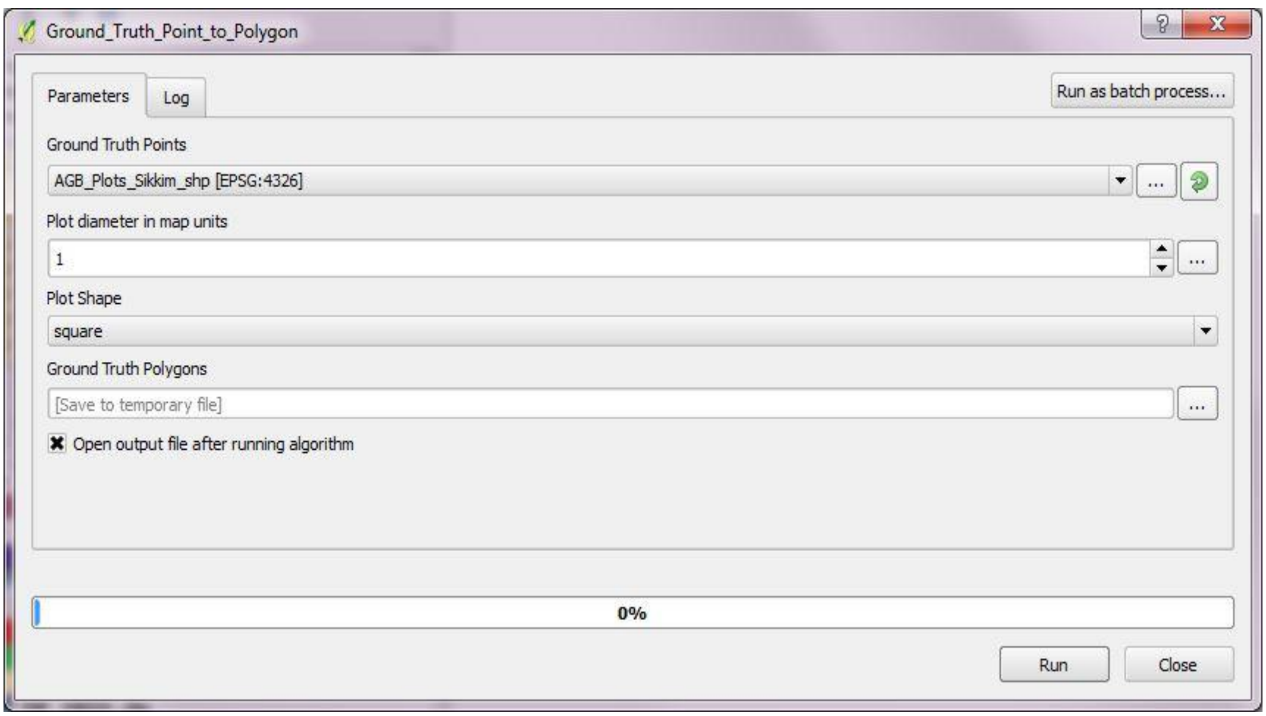


Fig 15. Ground Truth Point to Polygon.

FOREST CHANGE TOOLS

FOREST NON-FOREST (FNF) CLASSIFICATION

This tool creates a forest non-forest classification of a SAR backscatter image based on an upper and lower threshold inputted by the user. Values between the two thresholds are classified as forest, while values lower or higher than this range are classified as non-forest.

- Input Data:
  - Backscatter image (raster)
  - Lower threshold (float)
  - Upper threshold (float)
- Output:
  - Forest non-forest classification (raster)

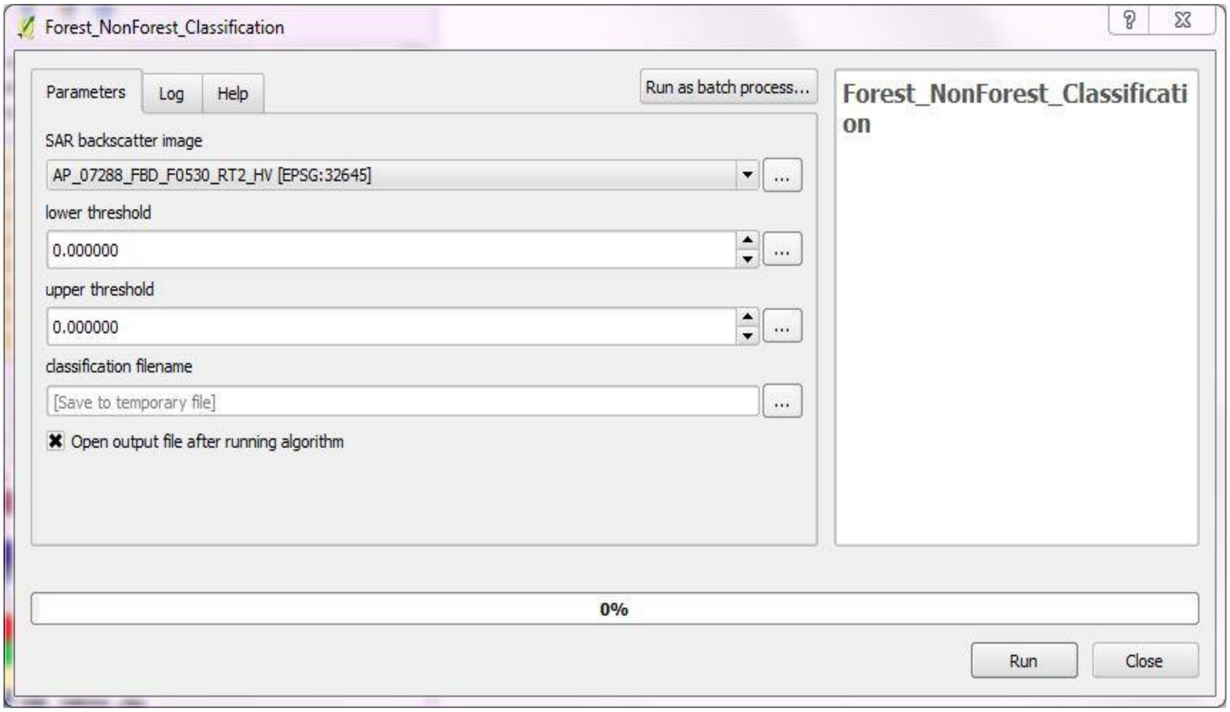


Fig 16. Forest Non-Forest Classification Tool.

FOREST CHANGE

This tool uses two FNF classifications of the same location from different dates and evaluates whether or not a pixel has changed land cover type between the two dates. Using two FNF layers from the previous tool (where values are only forest or non-forest) the output is a layer with four potential classifications; unchanged forest, unchanged non-forest, forest degraded to non-forest, and non-forest regrown to forest. If the inputs contain more landcover classes, such as water or no data the output will have additional corresponding outputs, for example forest to water. In order to find the differences between the two FNF images they must be of exactly the same dimensions. In order to ensure this the user inputs a clipping mask, and within the script both input FNF images are clipped to identical dimensions. If the two inputs have varying pixel sizes the "After" image is clipped to match the "Before" image. This tool can also be used to compare FNF layers produced by two different sources, such as a ground truth versus a newer estimation.

- Input Data:
    - Before FNF image (raster)
    - After FNF image (raster)
    - Clipping mask (polygon vector)
- Output:
    - Forest change classification (raster)

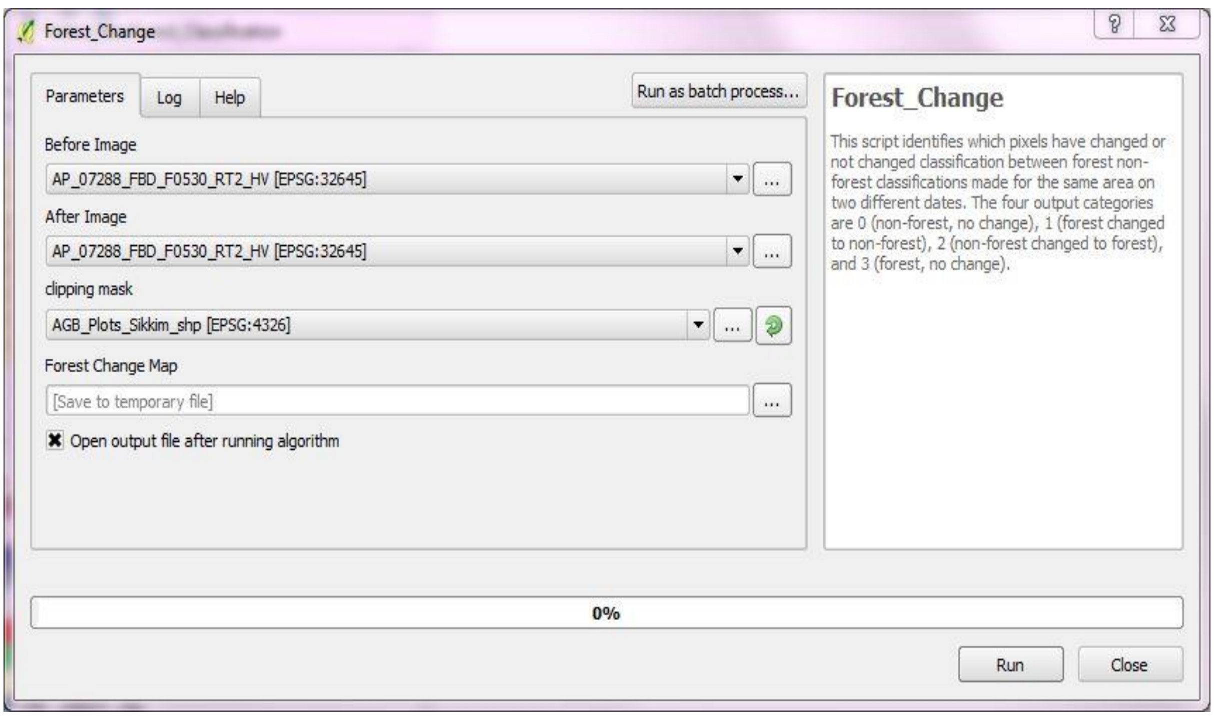


Fig 17. Forest Change Tool.

APPENDIX A: SOFTWARE INSTALLATION INSTRUCTIONS

A.1: INTRODUCTION

There are two software programs being used in this training course; SNAP and QGIS. SNAP is available from the European Space Agency (ESA), and QGIS is available from the QGIS Project website. Both of them are free and open source, and are available for Windows, Mac, and Linux platforms. Below are instructions for downloading and installing each program so that they can do all the functions taught in this training course.

A.2: QGIS

1. Download from http://www.qgis.org/en/site/forusers/download.html. Under the Windows tab select either the 32-bit or 64-bit version of the OSGeo4W Network Installer. We are using the OSGEO4W installation version instead of the standalone QGIS installer to enable some of the more advanced QGIS functions that this training course will be using. (Figure A.1)
2. Confirm that you really do want to let this downloaded .exe install software on your computer. (Figure A.2)
3. Select Advanced Install and click Next. (Figure A.3)
4. Keep the default Install from Internet and click Next. (Figure A.4)
5. Choose where to install the root directory (default is normally fine), and select which users to install for, and where to add icons. Click Next. (Figure A.5)
6. Select the local package directory and start menu name (default is fine) and click Next. (Figure A.6)
7. Keep the default of using direct internet connection and click Next. (Figure A.7)
8. Choose a download site (it should be http://download.osgeo.org) and click Next. (Figure A.8)
9. Select the following packages to install, using the most recent version. To select an entry click where it says Skip under the New column to change versions. Packages already installed will say Keep or have a new version number instead of saying Skip. Click Next to install the packages. (Figure A.9)
    a. Desktop:
        i. qgis-ltr (QGIS Desktop long term release)
        ii. grass (GRASS GIS – stable release)
        iii. otb-monteverdi (Monteverdi – Desktop application based on Orfeo Toolbox)
        iv. saga (SAGA System for Automated Geographical Analyses)
    b. Libs:
        i. gdal (The GDAL/OGR library and commandline tools)
        ii. gdal-python (The GDAL/OGR Python Bindings and Scripts)

iii. python-numpy
iv. python-scipy

10. QGIS will ask if it can install other packages required by those you have selected. Say yes to all of these. (Figure A.10)
11. Agree to license agreements for some of the dependent packages and click Next. (Figure A.11)
12. Click Finish to finish the installation. (Figure A.12)
13. When you first open QGIS Desktop check to make sure that the Processing output folder is set to the same location as the local package directory set in the installation. (Figures A.13a and A.13b)

A.3: SNAP

1. Download installer from: http://step.esa.int/main/download/. Select the Sentinel Toolboxes download link that is appropriate to your operating system. (Figure A.14)
2. When it has finished downloading double click on the .exe file to run it, and select "Run" when it asks for confirmation that you would like to run this downloaded file. (Figure A.15)
3. Confirm that you really do want to let this downloaded .exe install software on your computer. (Figure A.16)
4. Accept the license agreement and click Next (Figure A.17)
5. Select which toolboxes you would like to install and click Next. For this training course we need to install SNAP and the Sentinel-1 Toolbox. The Sentinel-2, Sentinel-3, and Radarsat-2 toolboxes are optional, and can be installed at a later date by running this same .exe file. (Figure A.18)
6. Configure SNAP to work with Python, and give the location of where Python is stored on your computer. Click Next. If you don't already have python installed it should have been installed as part of QGIS, and will be located in C:\OSGeo4W64\bin (or in the bin folder of wherever you have OSGeo4W installed). (Figure A.19)
7. Keep the default file associations and click Next. (Figure A.20)
8. Complete the ESA SNAP Setup Wizard. Keep the default selections of extending the PATH variable and running SNAP checked. Creating a desktop icon is at the user's discretion. Click Finish. (Figure A.21)

A.4 QGIS IMAGES

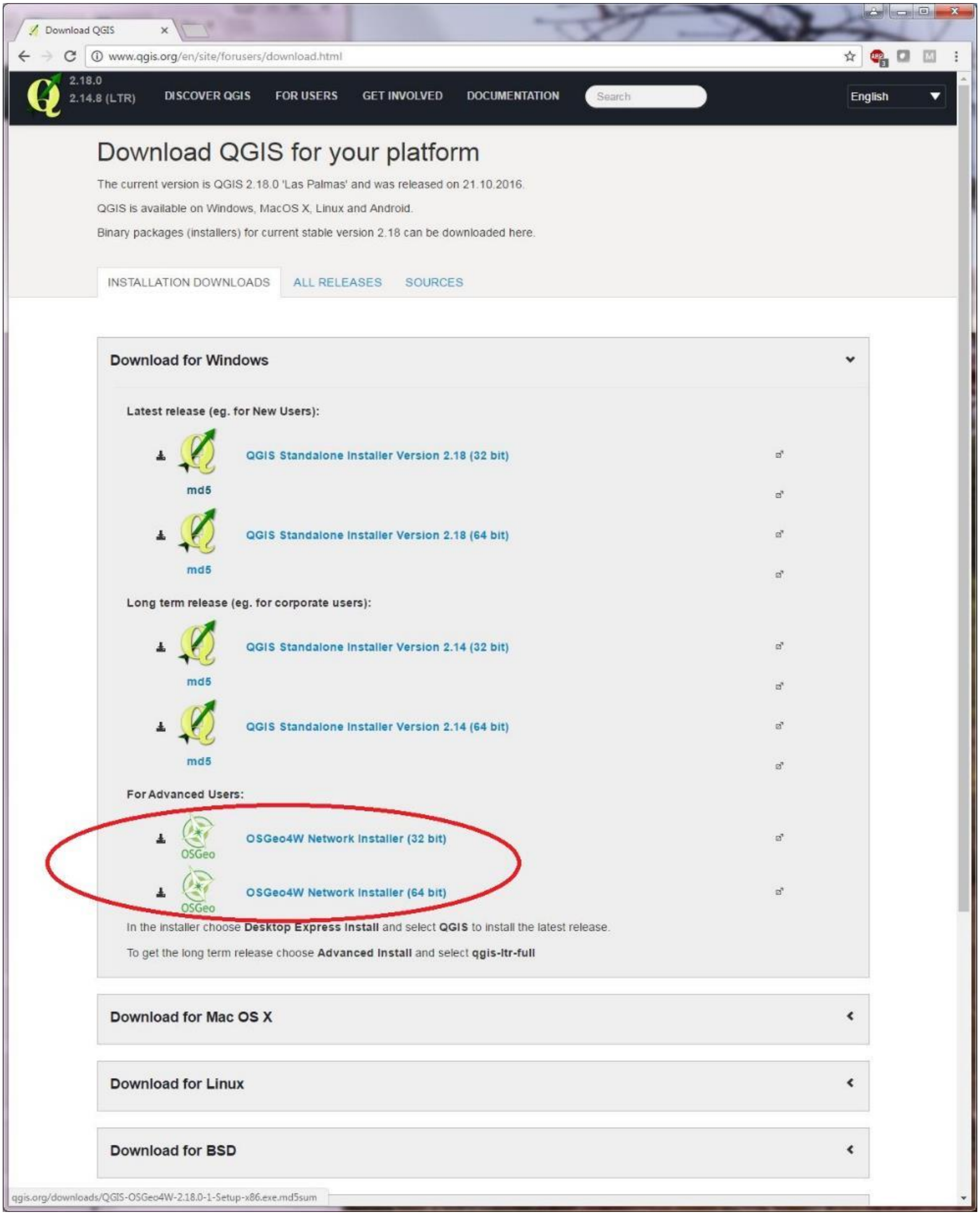


Fig. A.1

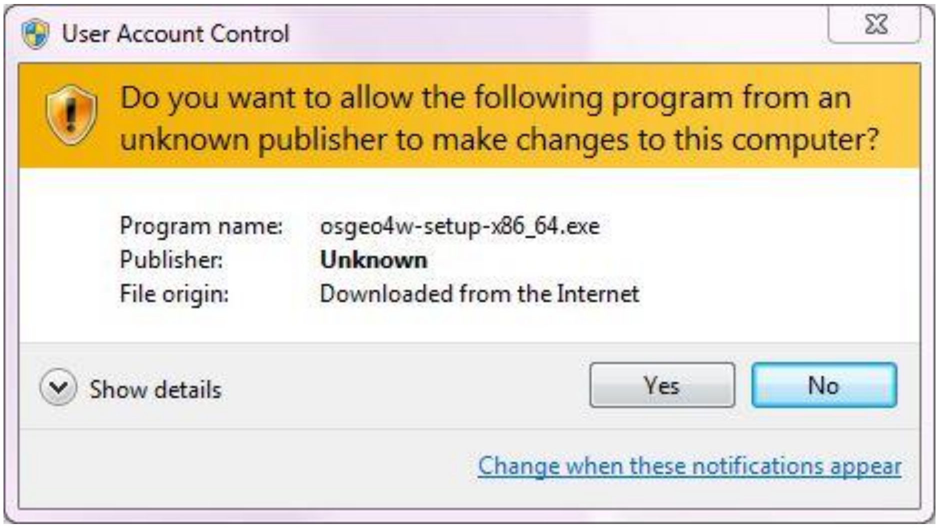


Fig. A.2

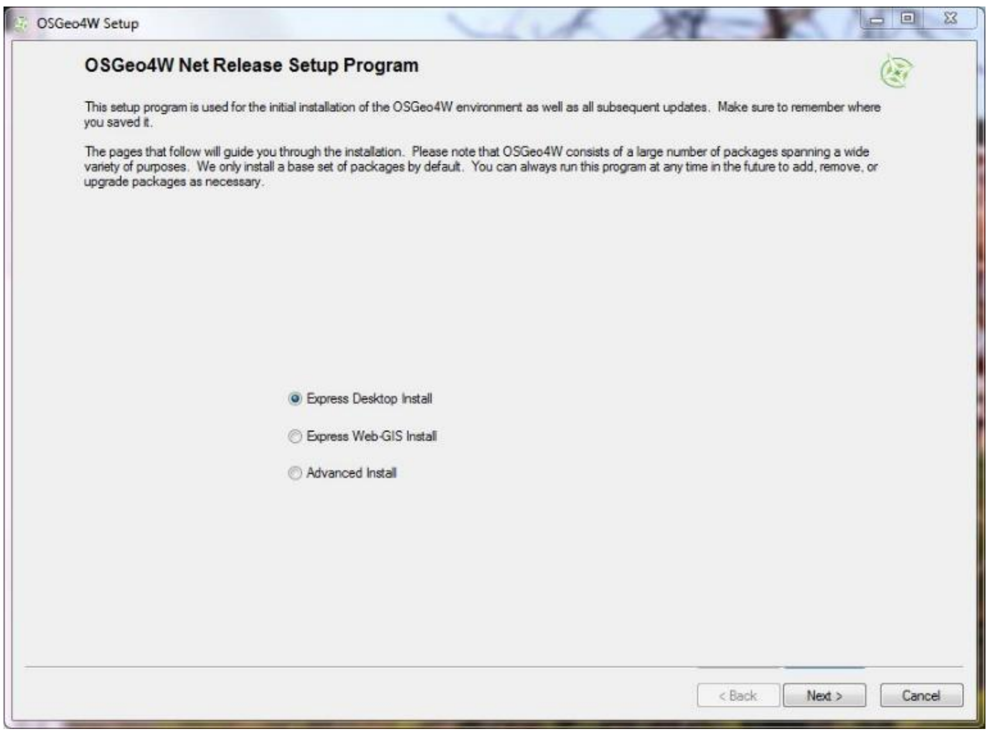


Fig. A.3

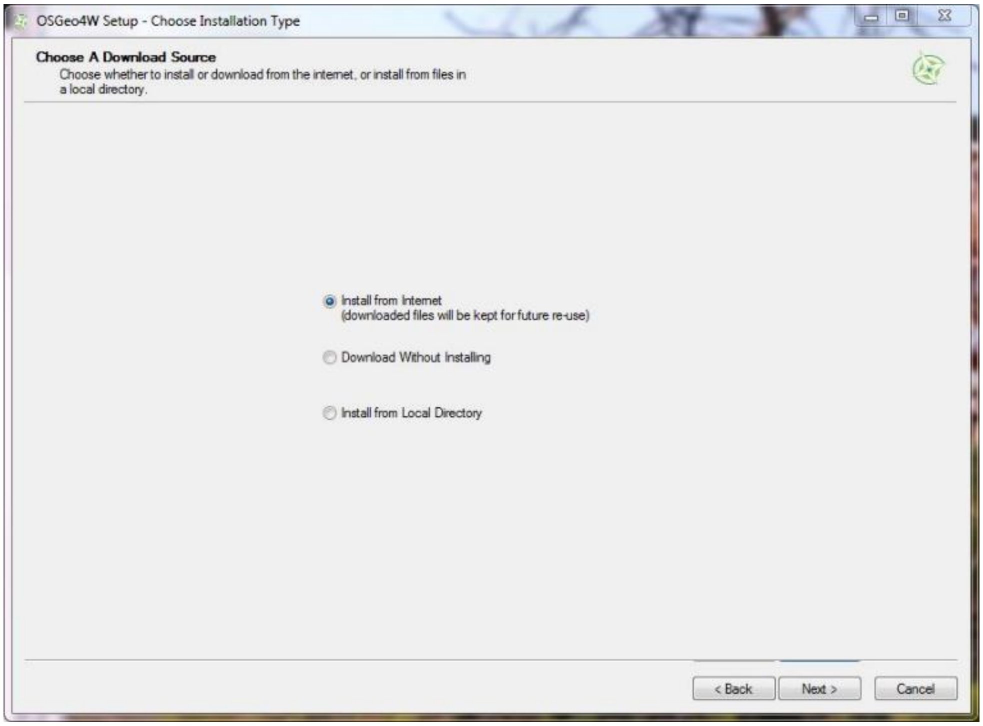

OSGeo4W Setup - Choose Installation Type
Choose A Download Source
Choose whether to install or download from the internet, or install from files in a local directory.
Install from Internet
(downloaded files will be kept for future re-use)
Download Without Installing
Install from Local Directory
< Back
Next >
Cancel

Fig A.4

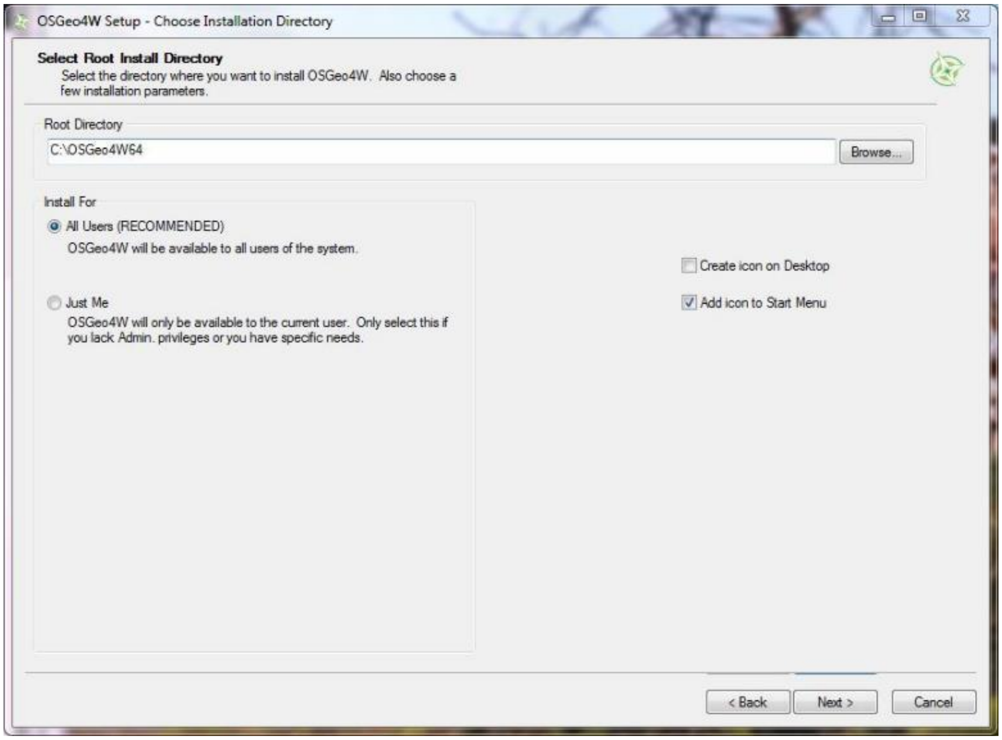

OSGeo4W Setup - Choose Installation Directory
Select Root Install Directory
Select the directory where you want to install OSGeo4W. Also choose a few installation parameters.
Root Directory
C:\OSGeo4W64
Browse...
Install For
All Users (RECOMMENDED)
OSGeo4W will be available to all users of the system.
Just Me
OSGeo4W will only be available to the current user. Only select this if you lack Admin. privileges or you have specific needs.
Create icon on Desktop
Add icon to Start Menu
< Back
Next >
Cancel

Fig A.5

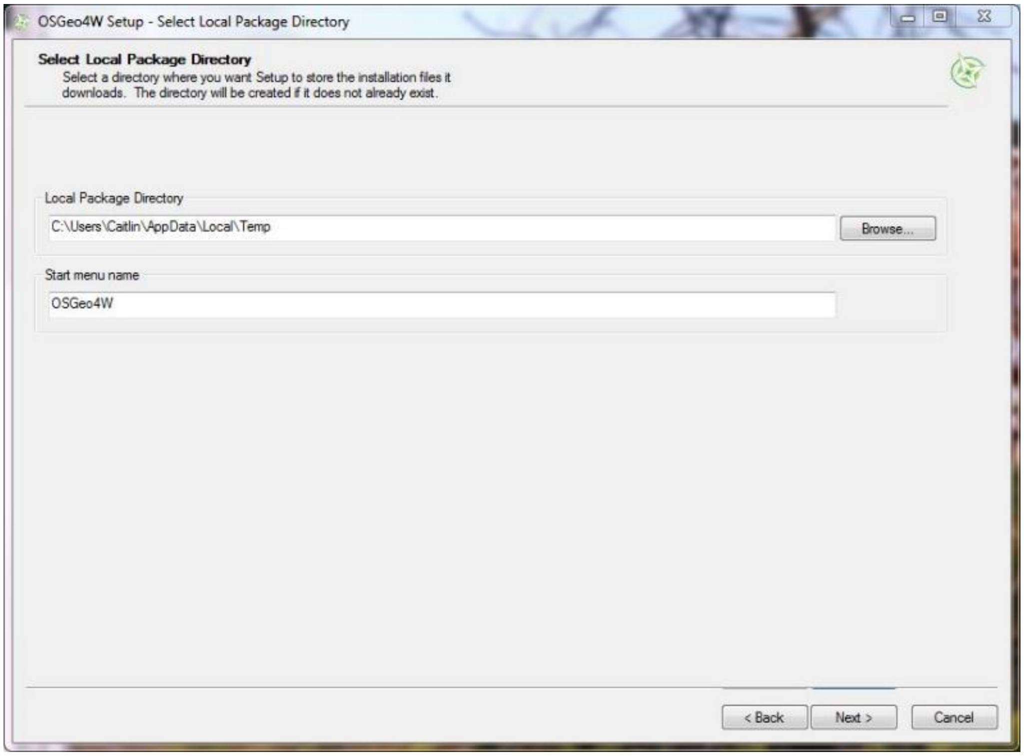

OSGeo4W Setup - Select Local Package Directory
Select Local Package Directory
Select a directory where you want Setup to store the installation files it downloads. The directory will be created if it does not already exist.
Local Package Directory
C:\Users\Caitlin\AppData\Local\Temp
Browse...
Start menu name
OSGeo4W
< Back
Next >
Cancel

Fig A.6

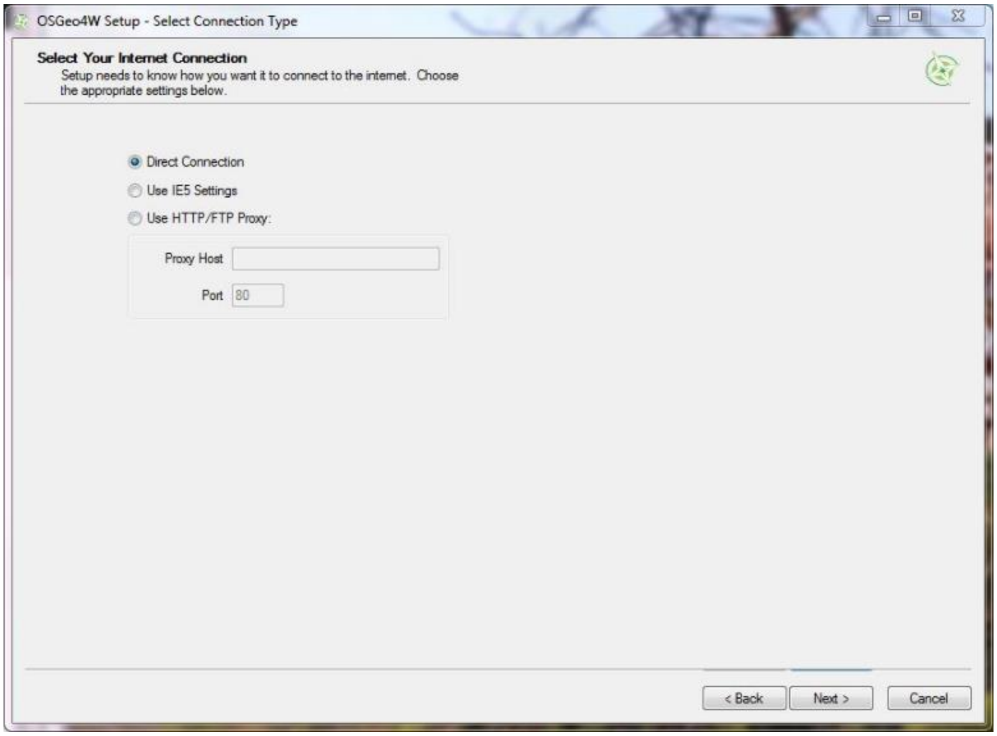

OSGeo4W Setup - Select Connection Type
Select Your Internet Connection
Setup needs to know how you want it to connect to the internet. Choose the appropriate settings below.
Direct Connection
Use IE5 Settings
Use HTTP/FTP Proxy:
Proxy Host
Port
80
< Back
Next >
Cancel

Fig A.7

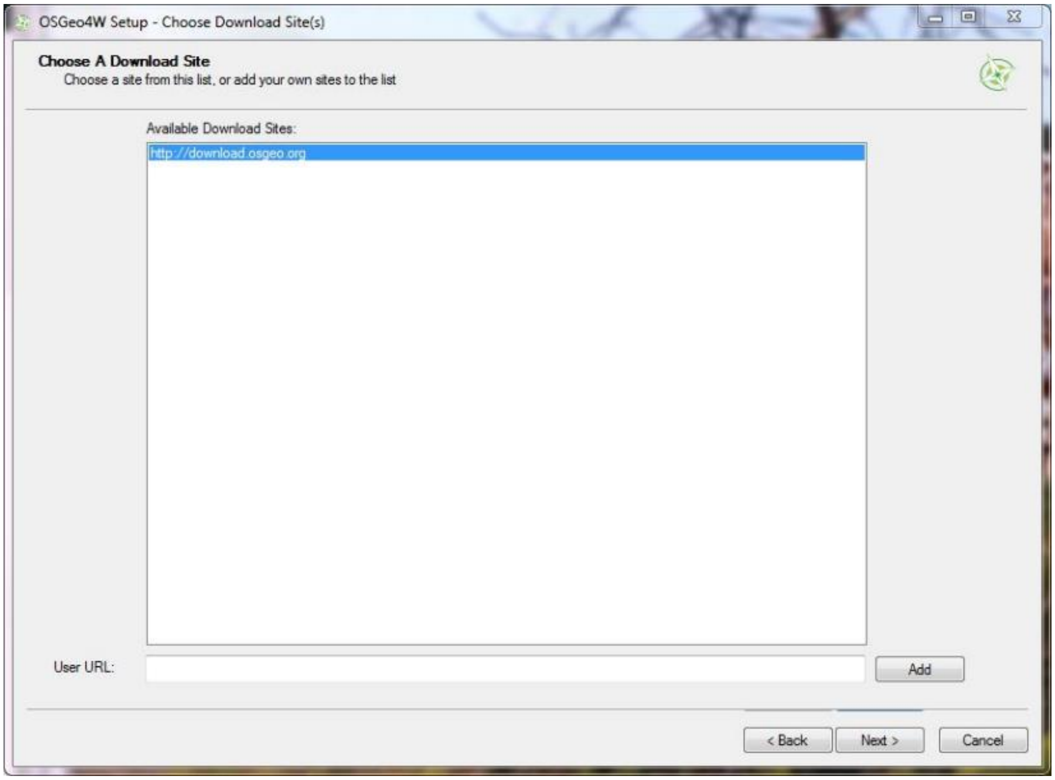

OSGeo4W Setup - Choose Download Site(s)
Choose A Download Site
Choose a site from this list, or add your own sites to the list
Available Download Sites:
http://download.osgeo.org
User URL:
Add
< Back
Next >
Cancel

Fig. A.8

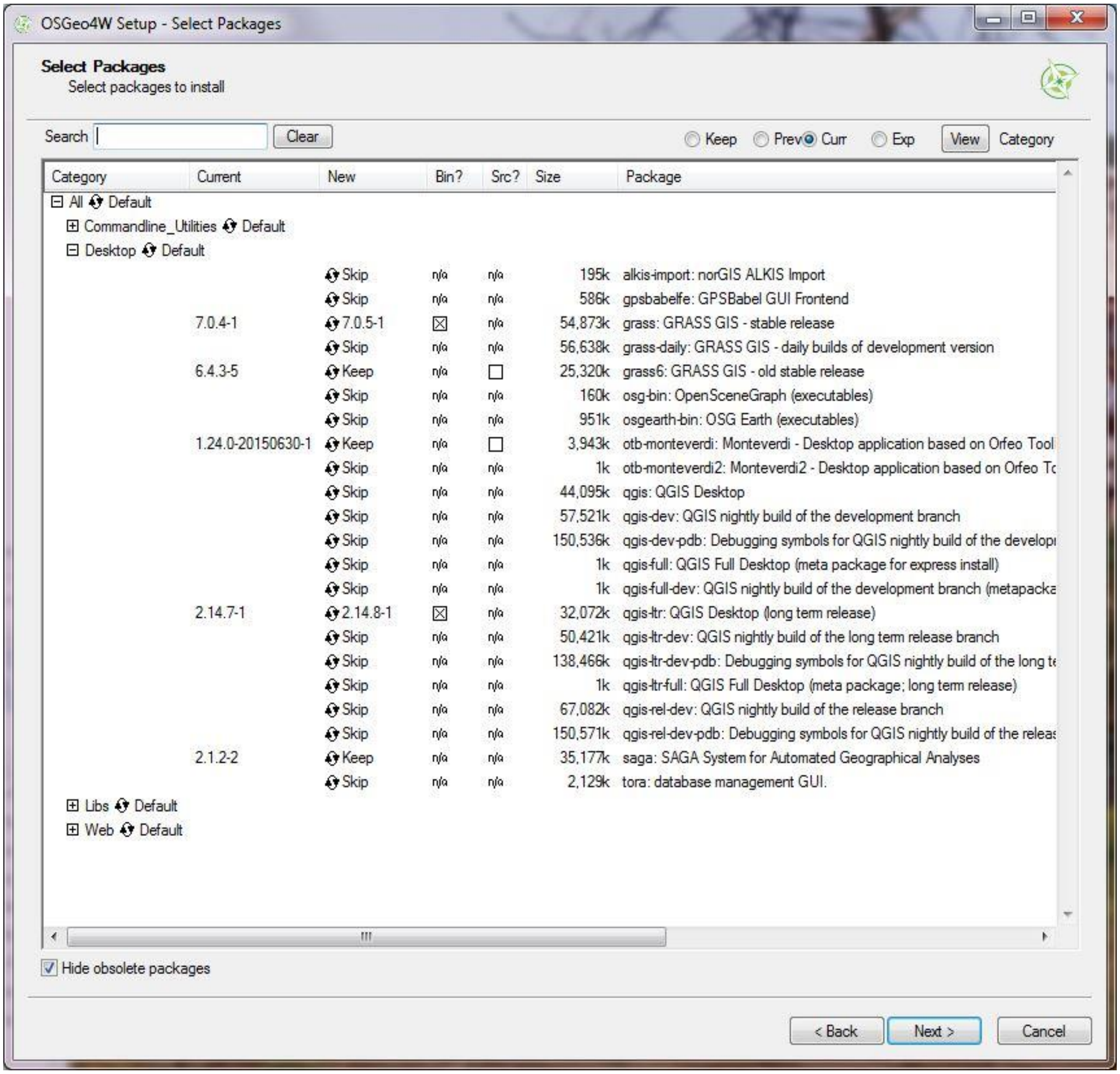

OSGeo4W Setup - Select Packages
Select Packages
Select packages to install
Search
Clear
Keep
Prev
Curr
Exp
View
Category
Category
Current
New
Bin?
Src?
Size
Package
All Default
Commandline_Utilities Default
Desktop Default
Skip n/a n/a 195k alkis-import: norGIS ALKIS Import
Skip n/a n/a 586k gpsbabelfe: GPSBabel GUI Frontend
7.0.4-1 7.0.5-1 n/a 54,873k grass: GRASS GIS - stable release
Skip n/a n/a 56,638k grass-daily: GRASS GIS - daily builds of development version
6.4.3-5 Keep n/a 25,320k grass6: GRASS GIS - old stable release
Skip n/a n/a 160k osg-bin: OpenSceneGraph (executables)
Skip n/a n/a 951k osgearth-bin: OSG Earth (executables)
1.24.0-20150630-1 Keep n/a 3,943k otb-monteverdi: Monteverdi - Desktop application based on Orfeo Tool
Skip n/a n/a 1k otb-monteverdi2: Monteverdi2 - Desktop application based on Orfeo
Skip n/a n/a 44,095k qgis: QGIS Desktop
Skip n/a n/a 57,521k qgis-dev: QGIS nightly build of the development branch
Skip n/a n/a 150,536k qgis-dev-pdb: Debugging symbols for QGIS nightly build of the develop
Skip n/a n/a 1k qgis-full: QGIS Full Desktop (meta package for express install)
Skip n/a n/a 1k qgis-full-dev: QGIS nightly build of the development branch (metapacka
2.14.7-1 2.14.8-1 n/a 32,072k qgis-ltr: QGIS Desktop (long term release)
Skip n/a n/a 50,421k qgis-ltr-dev: QGIS nightly build of the long term release branch
Skip n/a n/a 138,466k qgis-ltr-dev-pdb: Debugging symbols for QGIS nightly build of the long t
Skip n/a n/a 1k qgis-ltr-full: QGIS Full Desktop (meta package; long term release)
Skip n/a n/a 67,082k qgis-rel-dev: QGIS nightly build of the release branch
Skip n/a n/a 150,571k qgis-rel-dev-pdb: Debugging symbols for QGIS nightly build of the releas
2.1.2-2 Keep n/a n/a 35,177k saga: SAGA System for Automated Geographical Analyses
Skip n/a n/a 2,129k tora: database management GUI.
Libs Default
Web Default
Hide obsolete packages
< Back
Next >
Cancel

Fig. A.9

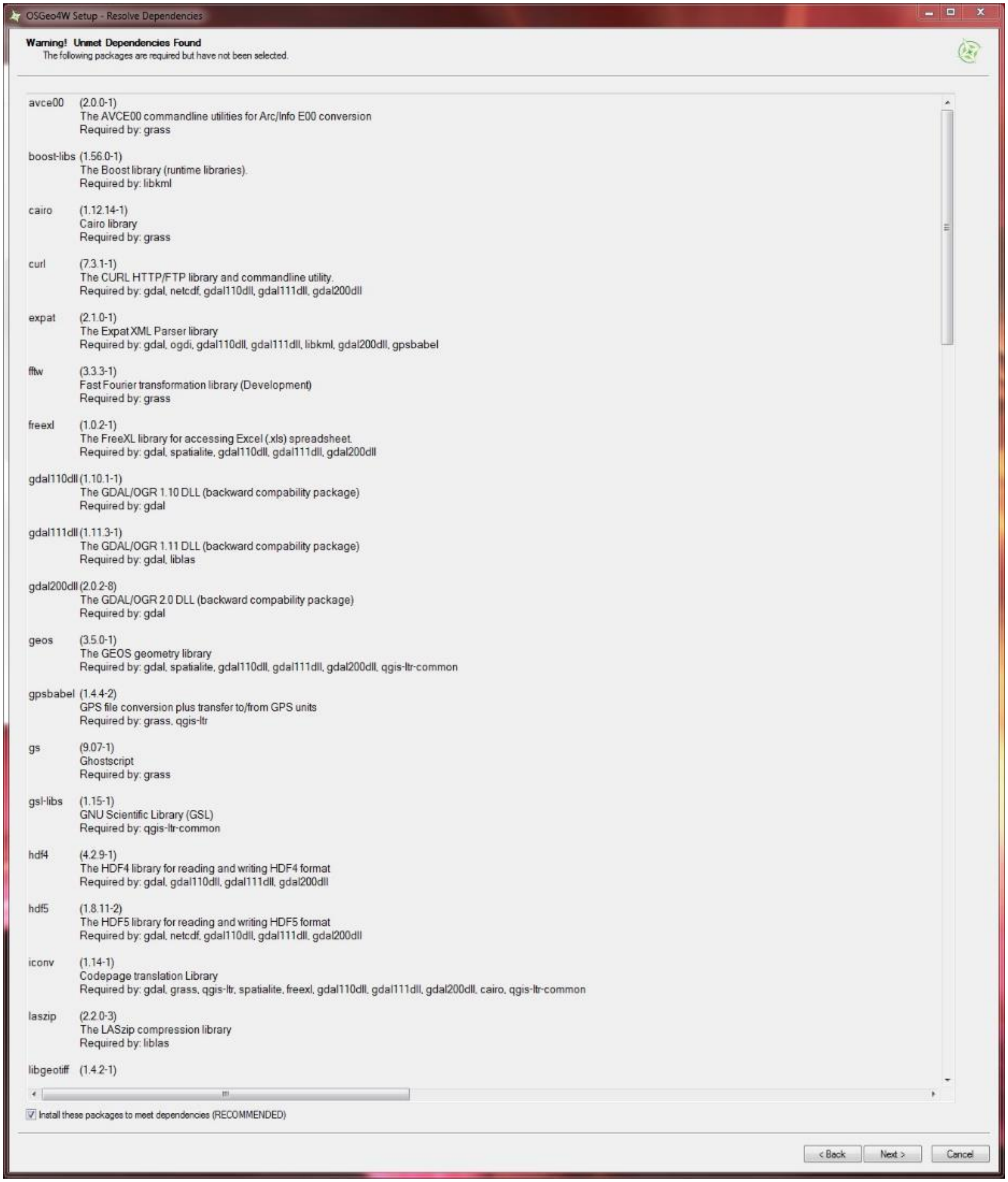

OSGeo4W Setup - Resolve Dependencies
Warning! Unmet Dependencies Found
The following packages are required but have not been selected.
avce00 (2.0.0-1)
The AVCE00 commandline utilities for Arc/Info E00 conversion
Required by: grass
boost-libs (1.56.0-1)
The Boost library (runtime libraries).
Required by: libkml
cairo (1.12.14-1)
Cairo library
Required by: grass
curl (7.3.1-1)
The CURL HTTP/FTP library and commandline utility.
Required by: gdal, netcdf, gdal110dll, gdal111dll, gdal200dll
expat (2.1.0-1)
The Expat XML Parser library
Required by: gdal, ogdi, gdal110dll, gdal111dll, libkml, gdal200dll, gpsbabel
fftw (3.3.3-1)
Fast Fourier transformation library (Development)
Required by: grass
freexl (1.0.2-1)
The FreeXL library for accessing Excel (.xls) spreadsheet.
Required by: gdal, spatialite, gdal110dll, gdal111dll, gdal200dll
gdal110dll (1.10.1-1)
The GDAL/OGR 1.10 DLL (backward compability package)
Required by: gdal
gdal111dll (1.11.3-1)
The GDAL/OGR 1.11 DLL (backward compability package)
Required by: gdal, liblas
gdal200dll (2.0.2-8)
The GDAL/OGR 2.0 DLL (backward compability package)
Required by: gdal
geos (3.5.0-1)
The GEOS geometry library
Required by: gdal, spatialite, gdal110dll, gdal111dll, gdal200dll, qgis-ltr-common
gpsbabel (1.4.4-2)
GPS file conversion plus transfer to/from GPS units
Required by: grass, qgis-ltr
gs (9.07-1)
Ghostscript
Required by: grass
gsl-libs (1.15-1)
GNU Scientific Library (GSL)
Required by: qgis-ltr-common
hdf4 (4.2.9-1)
The HDF4 library for reading and writing HDF4 format
Required by: gdal, gdal110dll, gdal111dll, gdal200dll
hdf5 (1.8.11-2)
The HDF5 library for reading and writing HDF5 format
Required by: gdal, netcdf, gdal110dll, gdal111dll, gdal200dll
iconv (1.14-1)
Codepage translation Library
Required by: gdal, grass, qgis-ltr, spatialite, freexl, gdal110dll, gdal111dll, gdal200dll, cairo, qgis-ltr-common
laszip (2.2.0-3)
The LASzip compression library
Required by: liblas
libgeotiff (1.4.2-1)
Install these packages to meet dependencies (RECOMMENDED)
< Back
Next >
Cancel

Fig. A.10

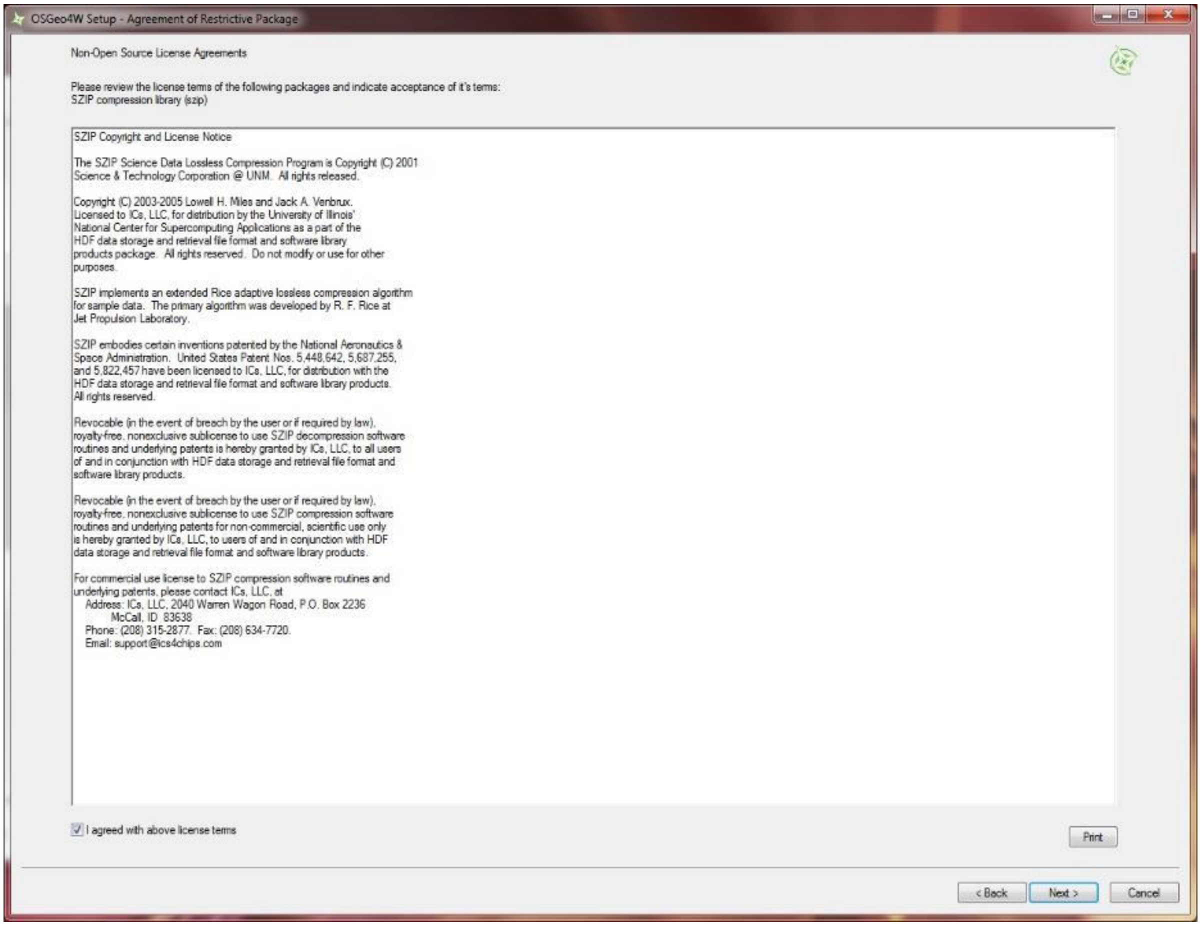

OSGeo4W Setup - Agreement of Restrictive Package
Non-Open Source License Agreements
Please review the license terms of the following packages and indicate acceptance of it's terms:
SZIP compression library (szip)
SZIP Copyright and License Notice
The SZIP Science Data Lossless Compression Program is Copyright (C) 2001 Science & Technology Corporation @ UNM. All rights released.
Copyright (C) 2003-2005 Lowell H. Miles and Jack A. Venbrux. Licensed to ICs, LLC, for distribution by the University of Illinois' National Center for Supercomputing Applications as a part of the HDF data storage and retrieval file format and software library products package. All rights reserved. Do not modify or use for other purposes.
SZIP implements an extended Rice adaptive lossless compression algorithm for sample data. The primary algorithm was developed by R. F. Rice at Jet Propulsion Laboratory.
SZIP embodies certain inventions patented by the National Aeronautics & Space Administration. United States Patent Nos. 5,448,642, 5,687,255, and 5,822,457 have been licensed to ICs, LLC, for distribution with the HDF data storage and retrieval file format and software library products. All rights reserved.
Revocable (in the event of breach by the user or if required by law), royalty-free, nonexclusive sublicense to use SZIP decompression software routines and underlying patents is hereby granted by ICs, LLC, to all users of and in conjunction with HDF data storage and retrieval file format and software library products.
Revocable (in the event of breach by the user or if required by law), royalty-free, nonexclusive sublicense to use SZIP compression software routines and underlying patents for non-commercial, scientific use only is hereby granted by ICs, LLC, to users of and in conjunction with HDF data storage and retrieval file format and software library products.
For commercial use license to SZIP compression software routines and underlying patents, please contact ICs, LLC, at
Address: ICs, LLC, 2040 Warren Wagon Road, P.O. Box 2236
McCall, ID 83638
Phone: (208) 315-2877. Fax: (208) 634-7720.
Email: support@ics4chips.com
I agreed with above license terms
Print
< Back
Next >
Cancel

Fig. A.11

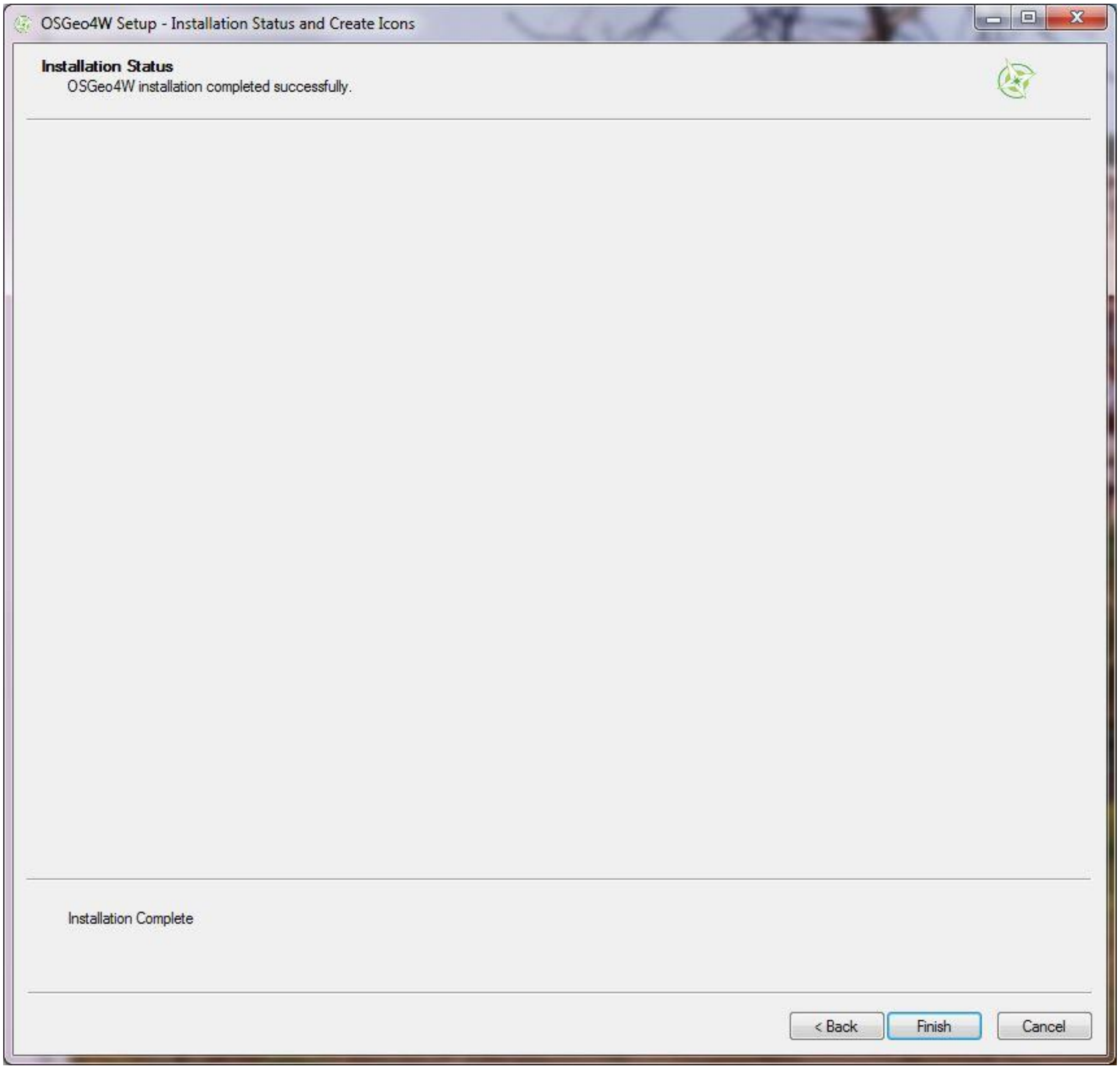

OSGeo4W Setup - Installation Status and Create Icons
Installation Status
OSGeo4W installation completed successfully.
Installation Complete
< Back
Finish
Cancel

Fig. A.12

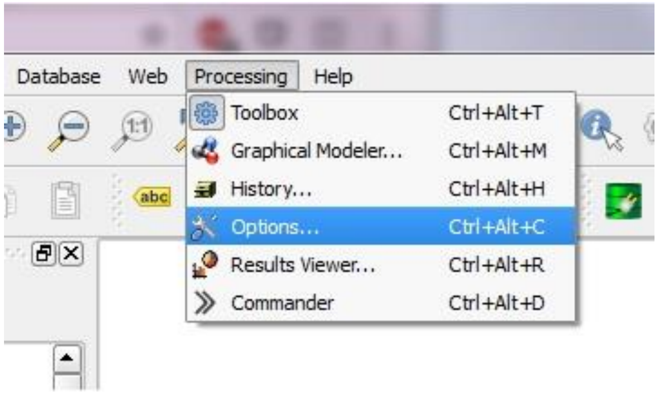


Fig. A.13a

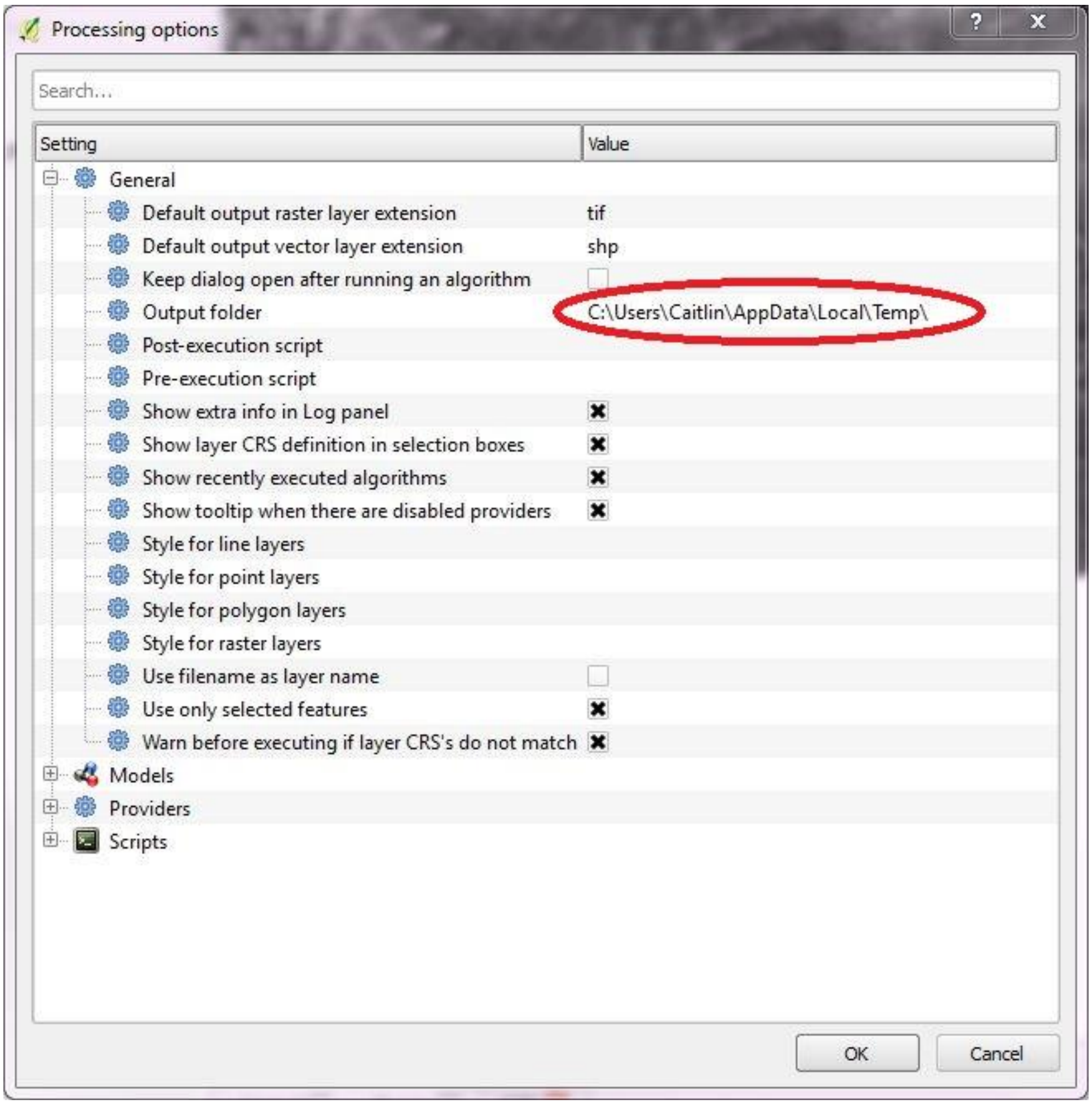


Fig. A.13b

A.5 SNAP IMAGES

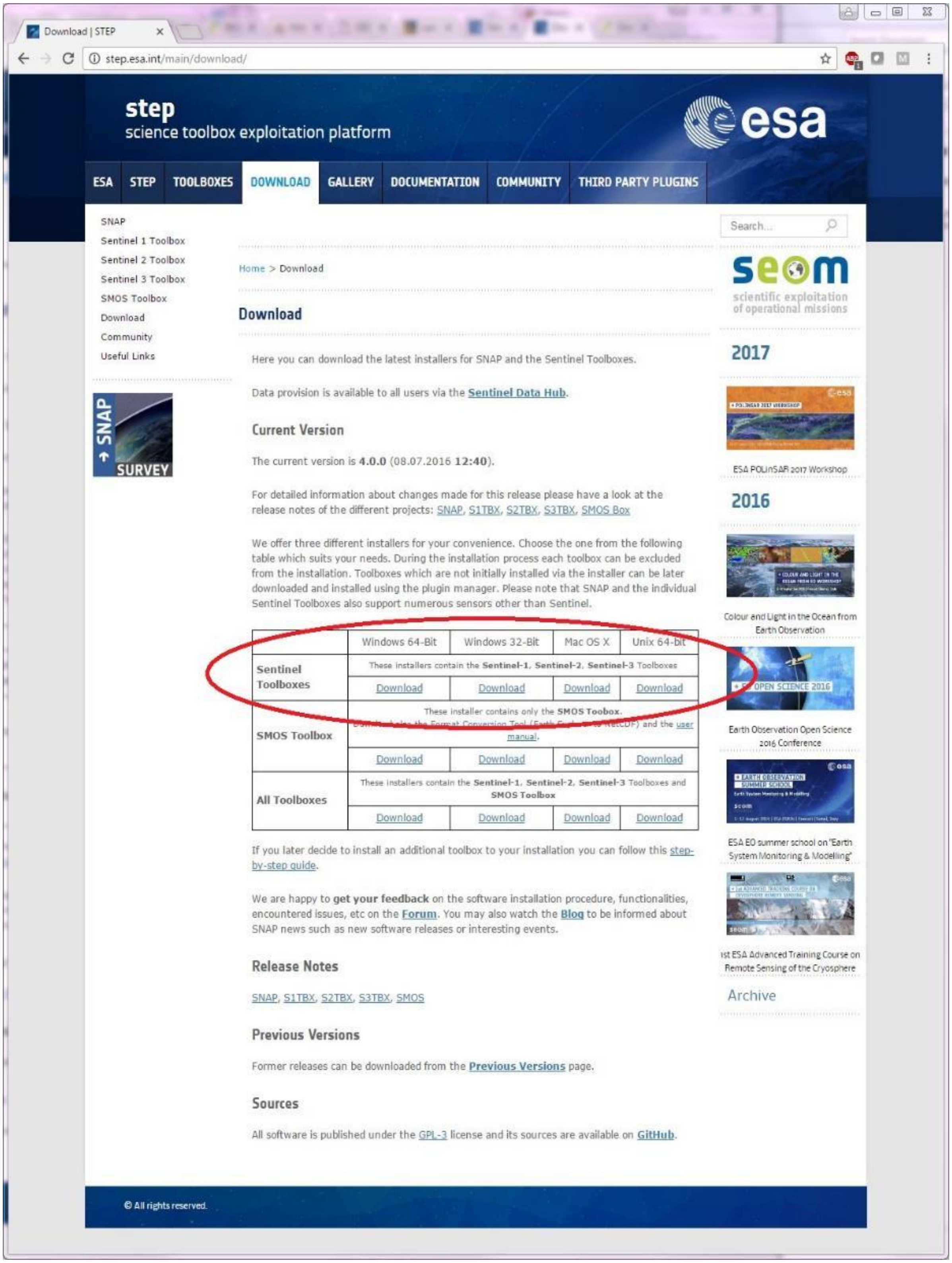


Fig. A.14

Fig. A.15

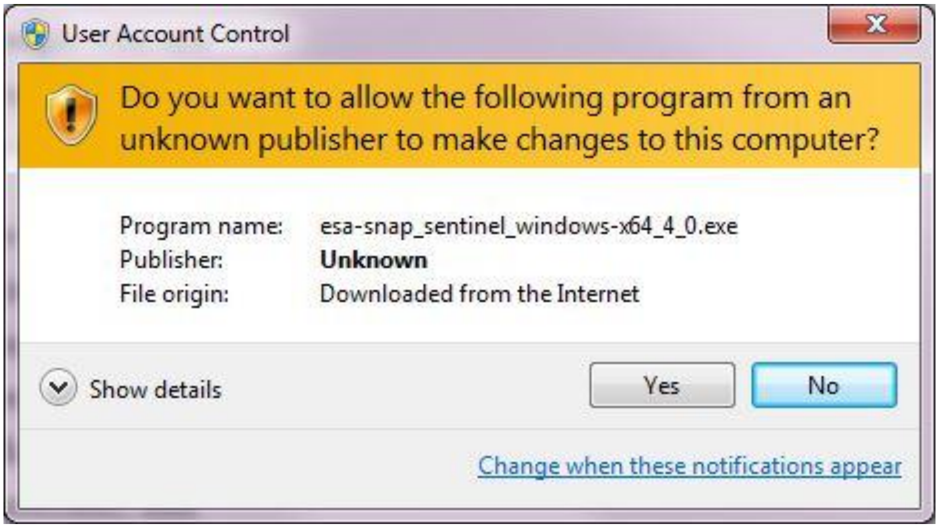


Fig. A.16

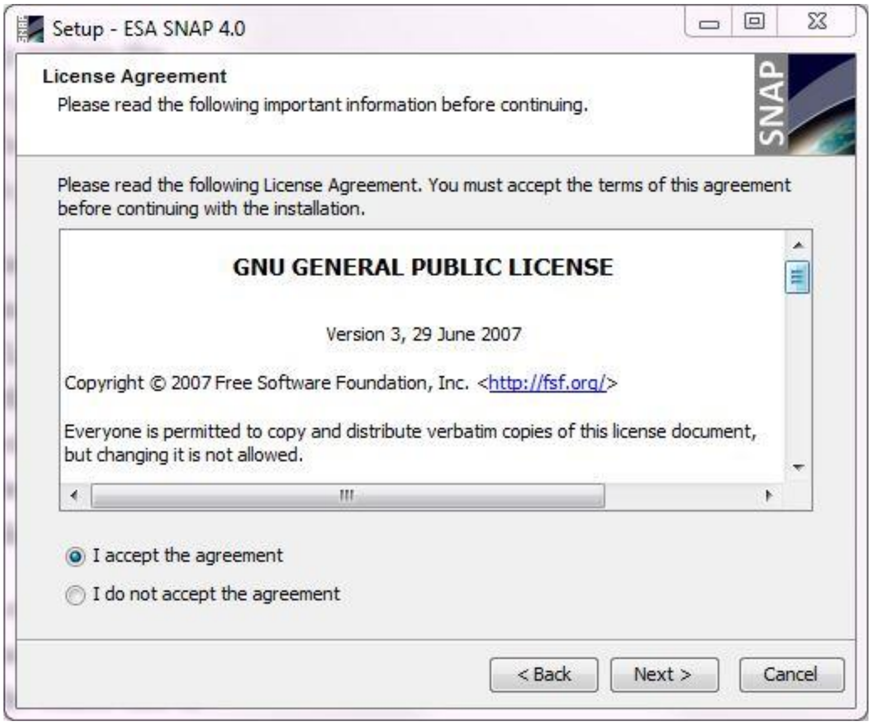


Fig. A.17

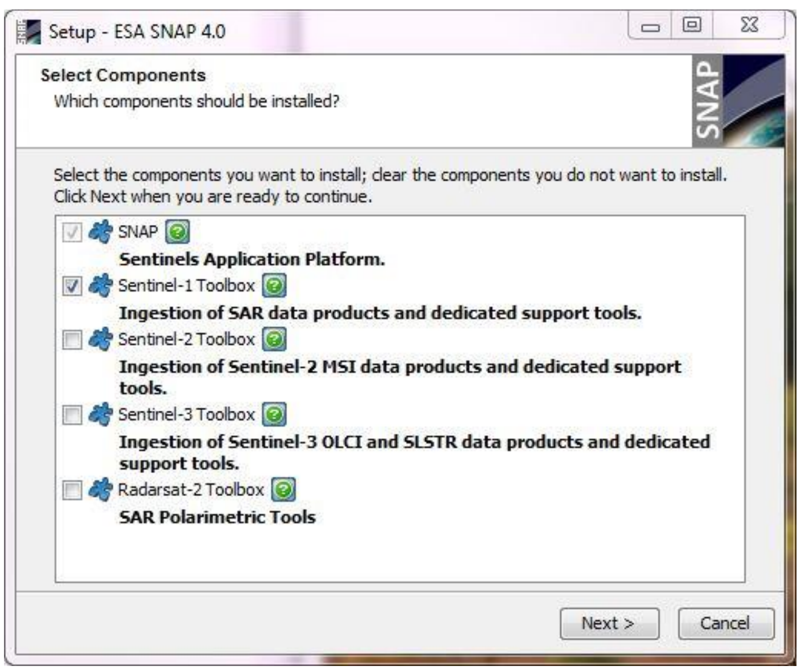


Fig. A.18

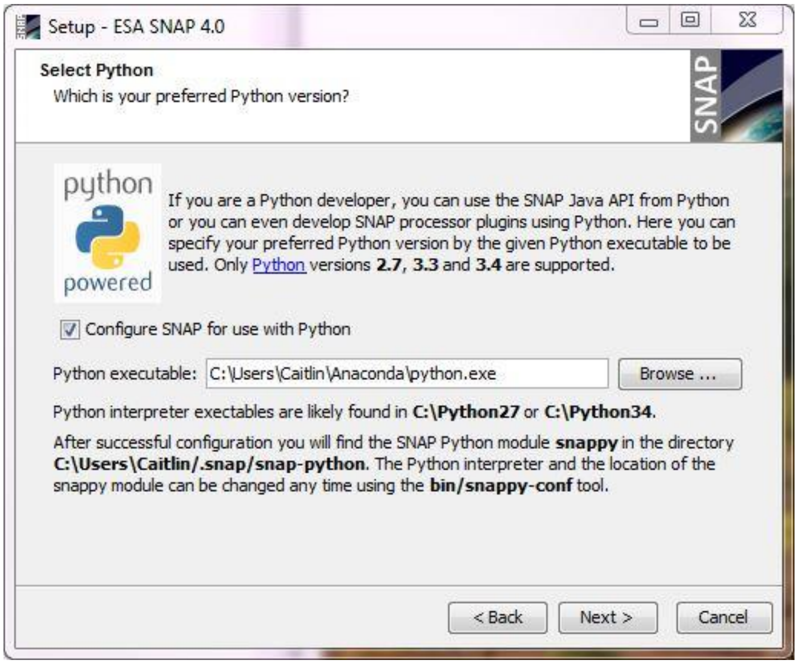
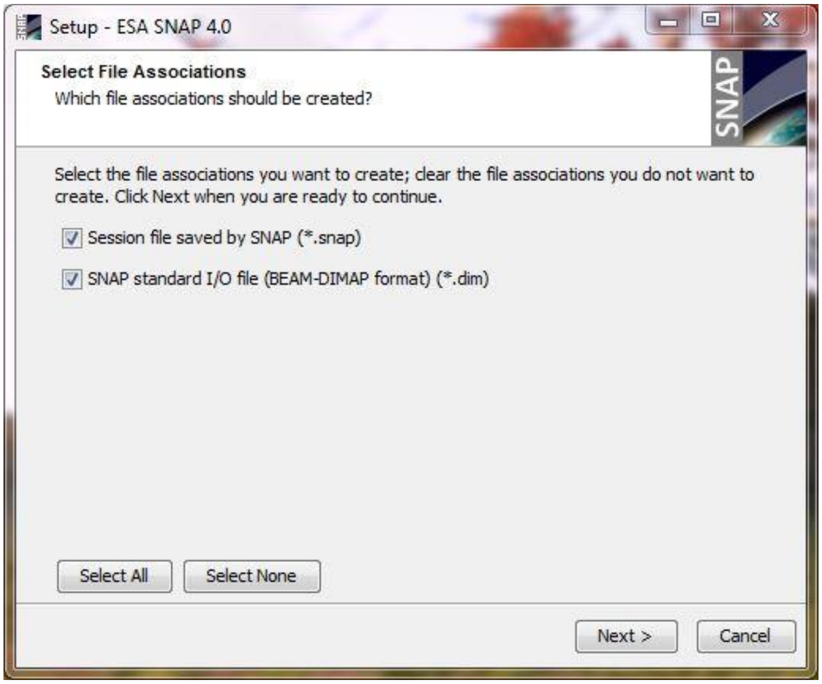

Setup - ESA SNAP 4.0
Select Python
Which is your preferred Python version?
python powered
If you are a Python developer, you can use the SNAP Java API from Python or you can even develop SNAP processor plugins using Python. Here you can specify your preferred Python version by the given Python executable to be used. Only Python versions 2.7, 3.3 and 3.4 are supported.
Configure SNAP for use with Python
Python executable: C:\Users\Caitlin\Anaconda\python.exe
Browse ...
Python interpreter exectables are likely found in C:\Python27 or C:\Python34.
After successful configuration you will find the SNAP Python module snappy in the directory C:\Users\Caitlin/.snap/snap-python. The Python interpreter and the location of the snappy module can be changed any time using the bin/snappy-conf tool.
< Back
Next >
Cancel
SNAP

Fig. A.19


Setup - ESA SNAP 4.0
Select File Associations
Which file associations should be created?
Select the file associations you want to create; clear the file associations you do not want to create. Click Next when you are ready to continue.
Session file saved by SNAP (*.snap)
SNAP standard I/O file (BEAM-DIMAP format) (*.dim)
Select All
Select None
Next >
Cancel
SNAP


Setup - ESA SNAP 4.0
SNAP
Completing the ESA SNAP Setup Wizard
Setup has finished installing ESA SNAP on your computer. The application may be launched by selecting the installed icons.
Click Finish to exit Setup.
Create a desktop icon
Extend my PATH environment variable
Run SNAP Desktop and configure Python
If you don't run SNAP Desktop and the Python configuration now you can run the configuration manually later. This is documented in the SNAP Wiki
Please also consider visiting the STEP website. STEP is the Science Toolbox Exploitation Platform which provides news, documentation, tutorials, and a vibrant user forum for ESA's free open source Earth Observation toolboxes.
esa
seom
scientific exploitation of operational missions
Finish

Fig. A.20

Fig. A.21

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