SAR ESSENTIALS TUTORIAL:
GETTING STARTED



October 2026

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TABLE OF CONTENTS

1. Introduction 3
2. SAR Essentials installation 3
3. Preferences 5
   3.1. ENVI Preferences 5
   3.2. SAR Essentials preferences 6
4. SAR Essentials tools 8
   4.1. Standart tools 8
   4.2. Interactive tools 9
5. SAR Essentials output files 9
6. SAR Compatibility Check 11
   6.1. Settings 12
   6.2. Report and results 14

1. INTRODUCTION

This tutorial introduces the environment and the manner of working with the *SAR Essentials* module. It presents the following main topics, by step-by-step examples:

- Installing *SAR Essentials*
- Setting ***ENVI Preferences***
- Setting *SAR Essentials preferences* through the ***SAR Essentials Management*** tool.
  Note: *Preferences* should be set before using any SAR Essentials tool.
- Using ***SAR Compatibility Check*** tool.

> ✍ Paragraphs like this one, showing a hand on the left side, indicate a practical step that the user should perform to proceed with the tutorial.

The examples in this tutorial use SAR Essentials version 1.2.0, running under ENVI 6.3 on a Windows 11 (64-bit) system.

2. SAR ESSENTIALS INSTALLATION

SAR Essentials 1.2.0 requires ENVI version 6.1 or higher.

> ✍ Before installing SAR Essentials, make sure you are logged in Windows as an Administrator and that you have at least 1.65 GB of free disk space on your C:\ drive.
>
> ✍ In Windows Explorer, do a right click on **.exe* installation file and select *Run as Administrator*. The *SAR Essentials Setup Wizard* will guide you through the installation steps (Figure 1, left). Get familiar with and click *Next* to accept the License Agreement. Set the destination folder.
>
> ✍ On the "Select Additional Tasks" step (Figure 1, right), select *Install Intel OpenCL CPU-only runtime* if you do not have OpenCL CPU driver. Otherwise, proceed directly with the installation.

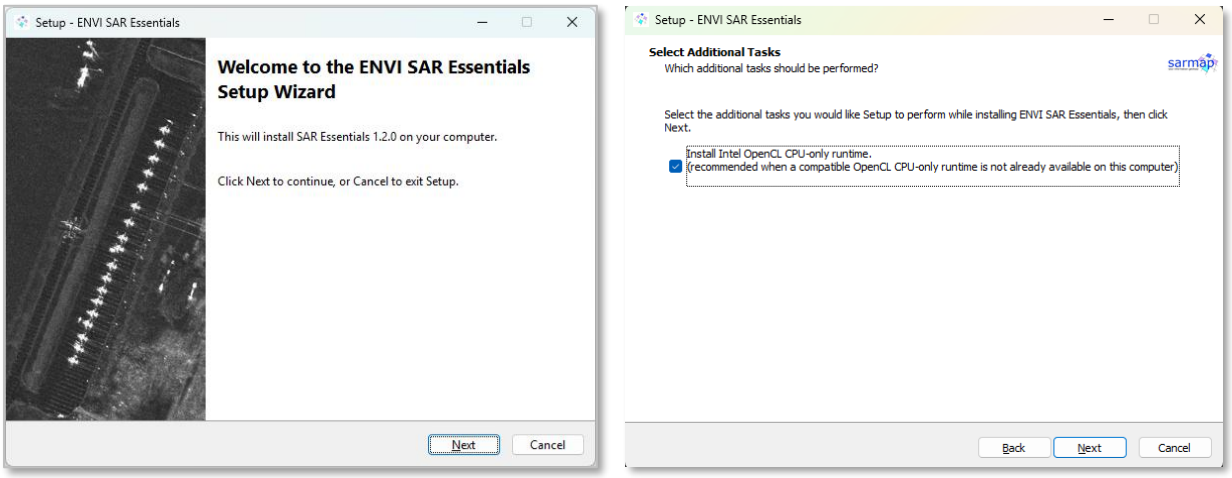


Figure 1. SAR Essentials installation wizard

To optimise the performance, SAR Essentials adopts the Open Computing Language (OpenCL) framework, which allows parallel computing across heterogeneous platforms. The CPU-only implementation can exploit the computational power provided by the available CPU using the OpenCL service. If *Intel OpenCL CPU-only runtime* option is selected, another installation wizard window

appears where the OpenCL installation settings can be customised (Figure 2). For further information, please refer to the *SAR_Essentials_OpenCL_Installation_Guide_120.pdf* document, located in the SAR Essentials installation "doc" folder.



Figure 2. Installation of CPU-only runtime for OpenCL

For Linux installation of the OpenCL CPU-only runtime follow the instructions provided here: https://www.intel.com/content/www/us/en/developer/tools/oneapi/base-toolkit-download.html. Choose the proper installation package for your Linux system distribution and follow the corresponding installation instructions. For details, consult the *SAR_Essentials_OpenCL_Installation_Guide_120.pdf* document that can be found in the SAR Essentials installation "doc" folder.

After the installation, a "SAR Essentials" folder appears in the ENVI Toolbox (Figure 3).

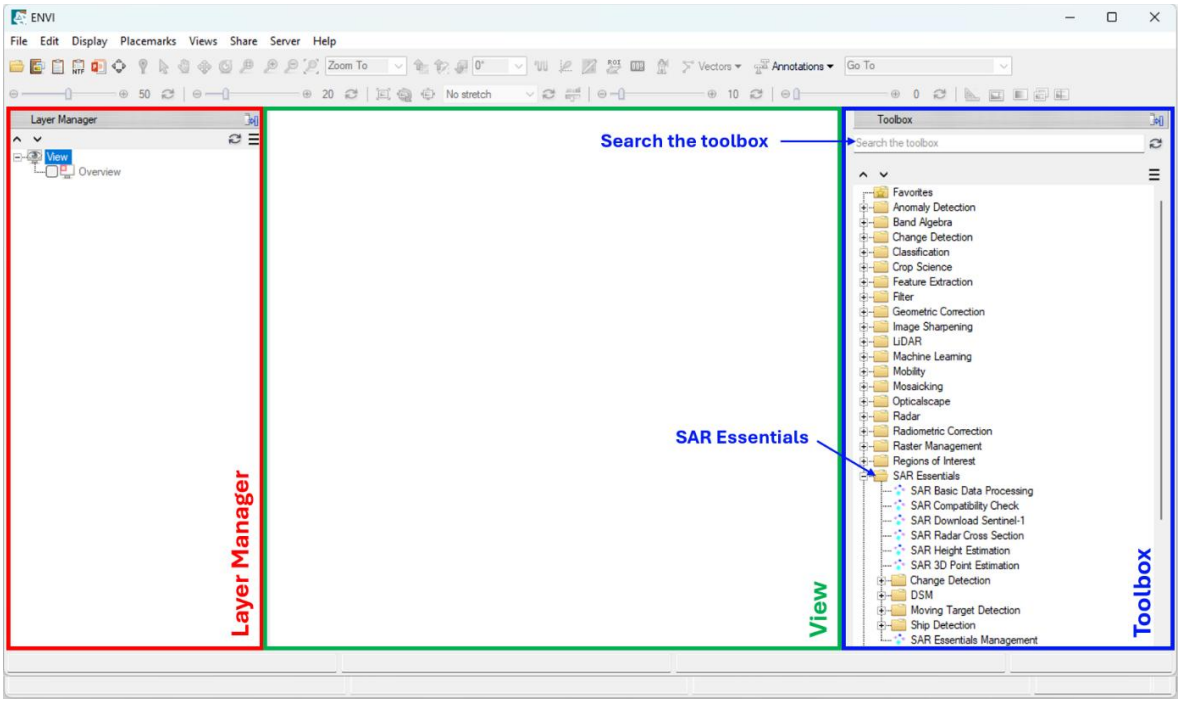


Figure 3. SAR Essentials in the ENVI Toolbox

The ENVI standard interface is divided into three parts (Figure 3):

- **Layer Manager (left):** It shows all the current loaded layers. It is possible to check/uncheck each layer to make it visible/hidden.
- **View (centre):** It shows the active layers in the *Layer Manager*. In the *View* panel it is possible to pan and zoom into/out from the shown layers.
  Note: *View* can be split into several views using ENVI *Views* menu.
- **Toolbox (right):** It contains all ENVI tools divided in folders. Here also all SAR Essentials tools and workflows are grouped into SAR Essentials folder.

3. PREFERENCES

It is recommended to validate and configure the preferences of ENVI and SAR Essentials before starting any processing session. This involves choosing directories associated for the current working session, setting credentials to access online repositories, and defining requested outputs and annotation settings.

3.1. ENVI PREFERENCES

To facilitate the work, it is recommended initially to set paths to the *Input*, *Output* and *Temporary Directories* which will be used for accessing the data during the processing.

From the ENVI menu bar select *File* and then *Preferences* from the drop-down menu (Figure 4, left). Select *Directories* item on the left side of the dialog window (Figure 4, right) and modify the *Input Directory*, *Output Directory*, and *Temporary Directory* as needed.

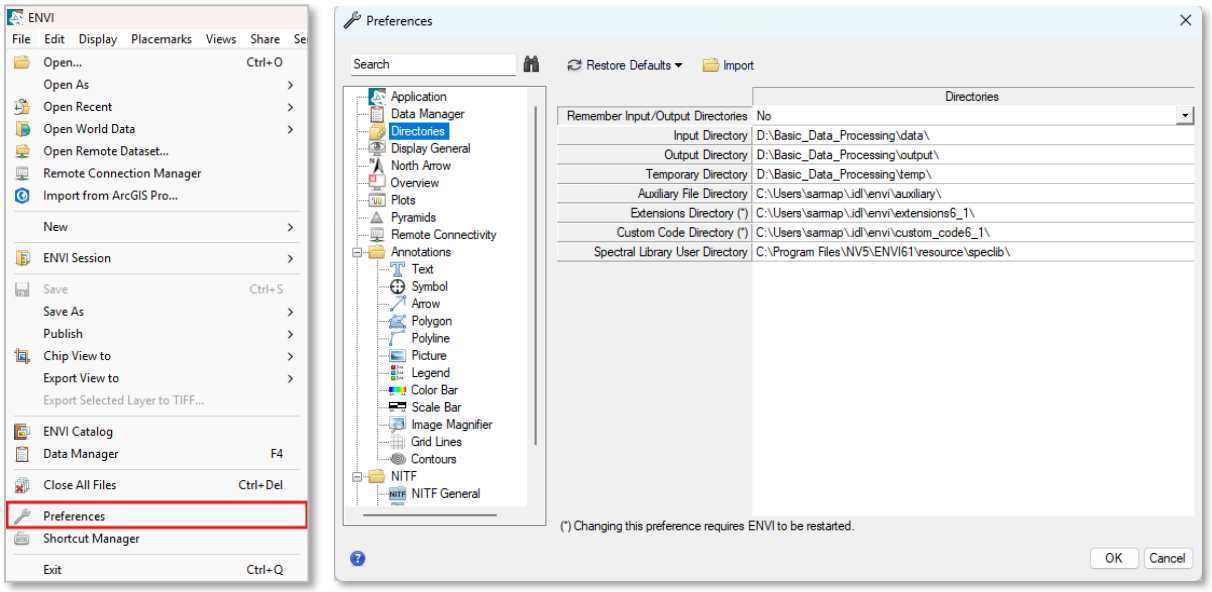


Figure 4. ENVI Preferences – panel Directories for setting Input/Output and Temporary Directory

Tip: The ENVI *Temporary Directory* is where intermediate files are stored during SAR Essentials processes. Assigning an easily reachable location for *Temporary Directory* allows quick access to the intermediate results of the SAR Essentials processing. Due to the size of the intermediate files, the *Temporary Directory* must be set up accordingly. Here are some recommendations:

- If *Delete processing data* is set to *No* in the *SAR Essentials Management* tool (see section 3.2), the content of the *Temporary Directory* is moved to the *Output Directory*.

- **It is strongly recommended to do not use USB or external drives for the *Input/Output* or *Temporary Directory*, due to the large amount of data transfer.**
- It is recommended to keep the flag for *Remember Input/Output Directories* to *No*. Otherwise, the data will be saved in the *Output Directory*. Alternatively, a unique *Output Directory* can be specified for each process within the SAR Essentials workflow window.

Important: **Make sure that you have read/write privileges for your selected directories.**

Tip: For better SAR image visualisation, set *ENVI Preferences -> Display General -> Zoom Interpolation Method* to ***Nearest Neighbour***. This preserves the original pixel values and provides a sharper display of the SAR imagery.

3.2. SAR ESSENTIALS PREFERENCES

Before running any SAR Essentials processing tool, it is required to set the SAR Essentials preferences in the *SAR Essentials Management* tool. It gives an opportunity to set credentials to access and download some Synthetic Aperture Radar (SAR) data (e.g. Sentinel-1 – consult the dedicated tutorial), proxy credentials, a path to the repository folder for external Digital Elevation Models (DEMs) and other ancillary files. Also, options for processing and working files can be set, as well as annotation preferences, defining custom format for Automatic Identification System (AIS) template files (see *SAR Essentials tutorial: Ship Detection and AIS Matching* for details).

Note: If the preferences have been changed, these changes are not applied to the open tools. These tools must be closed and re-opened to let the changes take place.

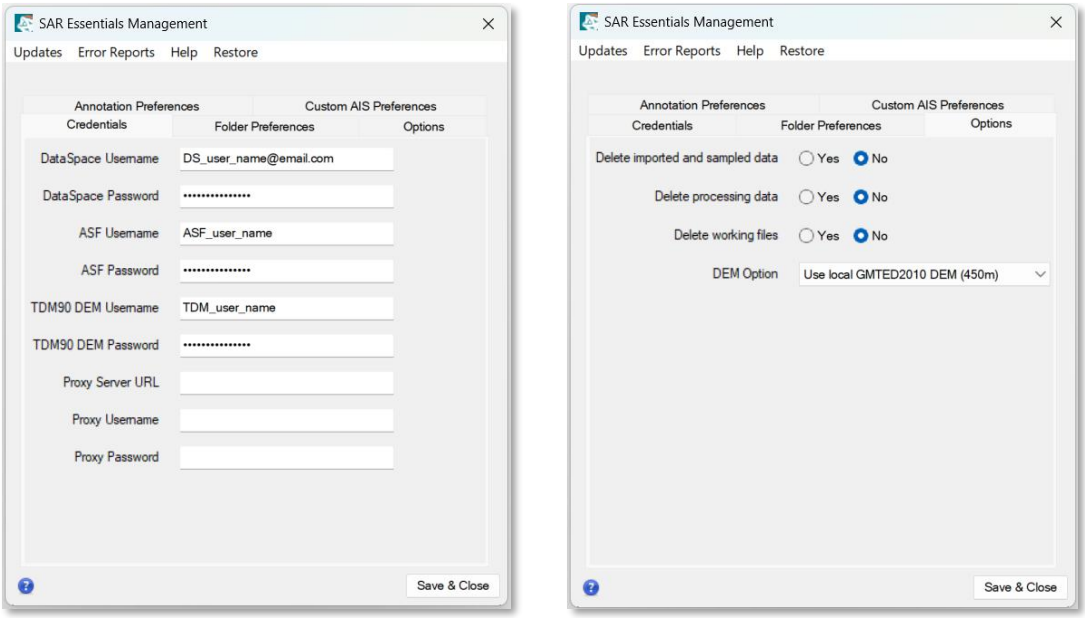


Figure 5. SAR Essentials Management tool: Panel for setting user credentials for online data repositories (left), and panel for optionally saving the imported, sampled, processing and/or working files (right)

Note: The *Data Space* and *Alaska Satellite Facility* (ASF) Sentinel-1 SAR data providers require at least one special character in the password. SAR Essentials supports the following characters:

$ + @ & ! #

The *Options* tab contains a *DEM Option* field where an optional DEM can be selected for subsequent processing in any SAR Essentials tool. Alternatively, *DEM Option* can be set in each tool individually.

As mentioned in Section 3.1, intermediate processing files are stored in the directory specified in the ENVI *Output Directory* preference. Alternatively, the *Output Directory* can be set for each process individually.

The *SAR Essentials Management* tool provides quick access to ***Updates***, ***Error Reports***, and ***Help*** menu, and an option for *restoring* the initial SAR Essentials preferences.

The *Updates* tab gives access to the latest software updates through *Check for SAR Essentials Patches* (Figure 6, left). It opens a web page with a list of fixed bugs and new features, as well as a link to download the latest SAR Essentials patch in case a patch exists. Otherwise, a message "Your software is up to date!" is visualised (Figure 6, right).

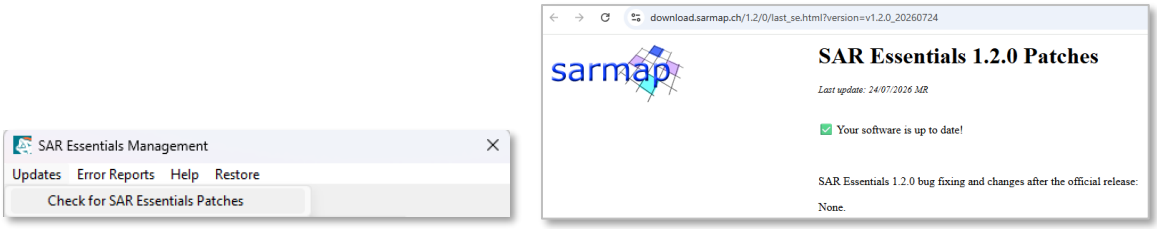


Figure 6. Access to the SAR Essentials patches

The main option under *Help* tab is SAR Essentials Help. It leads to a window which contains the synthesised supporting information (Figure 7, left). By clicking "*Read more…*" a detailed help page is open in the default internet browser (Figure 7, right). On the left side of the page a full Help table of content can be found by expanding the folders.

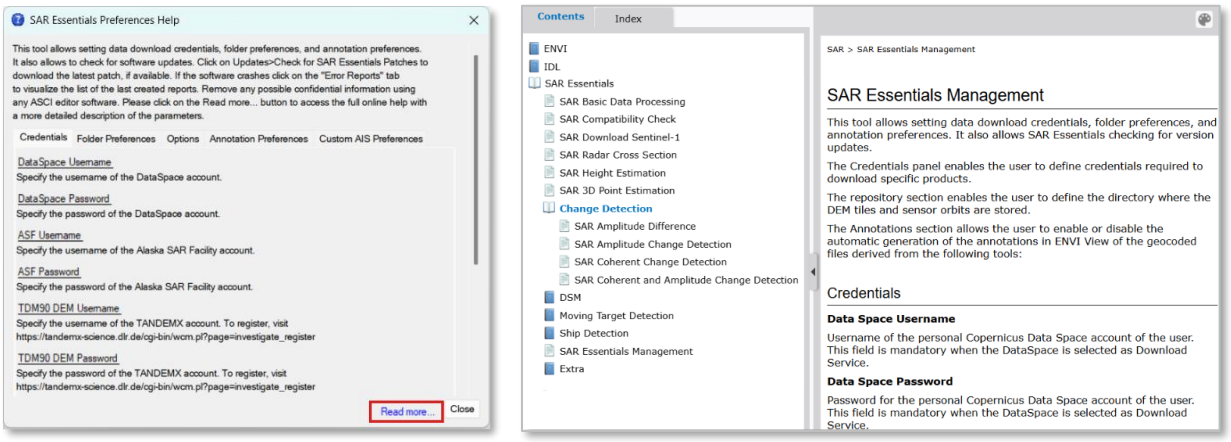


Figure 7. Access to the SAR Essentials patches

Each SAR Essentials tool has a direct link to its help information through the question mark icon which opens the corresponding for this tool help page – first a short explanation, and possibility to open detailed page by "Read more…" button as in Figure 7.

Information about the currently installed version can be displayed via the *Help -> About SAR Essentials tool* menu (Figure 8).

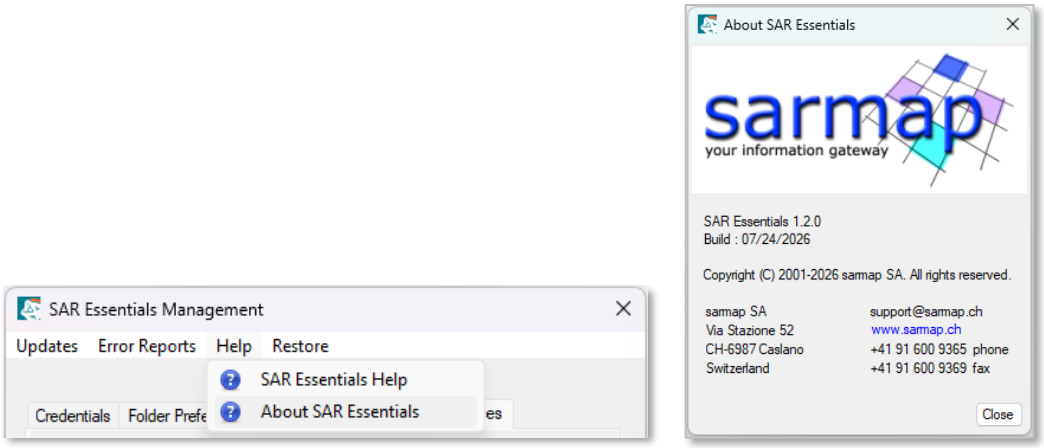


Figure 8. About SAR Essentials and Help

The *Error Reports* tab provides access to the *SAR Essentials Error Report Viewer* (Figure 9), which lists errors, if any, and provides a link to the separate Error Report, named *SE_report_error_YYYY-MM-DD_HHMMSS.txt* file (YYYY-MM-DD_HHMMSS referes to Year-Month-Date_HourMinutesSeconds).

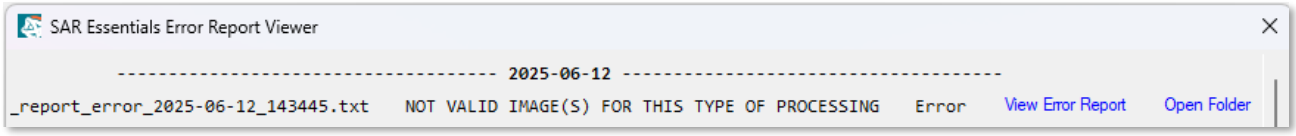


Figure 9. SAR Essentials Error Report Viewer

4. SAR ESSENTIALS TOOLS

The "SAR Essentials" folder of the ENVI Toolbox contains all SAR Essentials tools (Figure 3). The subfolders and tools are accessible by choosing the plus (+) symbol next to "SAR Essentials" folder.

SAR Essentials tools are defined by two interface types – standard and interactive.

4.1. STANDART TOOLS

The standard tools contain *Input* and *Export* tabs, and for some tools also an *Optional* tab (Figure 10). Depending on the functionality of the tool, the *Input* tab may ingest one, two or more input datasets. Optionally, an external file that defines the extent of a spatial subset can be loaded. This can be a Google Earth KML/KMZ file or a vector shapefile in geographic coordinates.

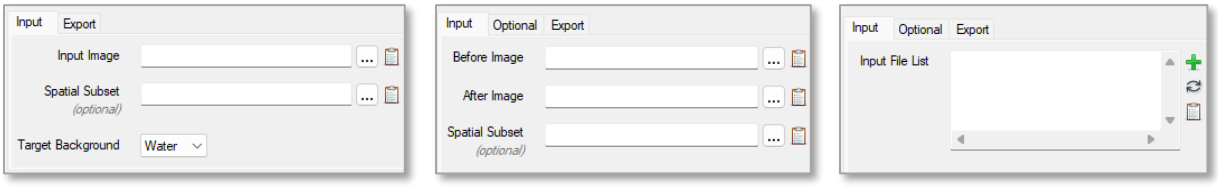


Figure 10. Examples of the standard tabs in SAR Essentials tools

The *Export* tab is used to indicate optional output parameters. The examples in Figure 11 include *Generated Products*, *Output Folder* locations and *Grid Size*. Some tools provide an option to apply mandatory parameters for the output results, e.g. application of precise geocoding to the result.



Figure 11. Examples of Export tabs in SAR Essentials tools

Processing pipeline with specific processing steps is placed on the bottom of the standard tool windows (Figure 12).

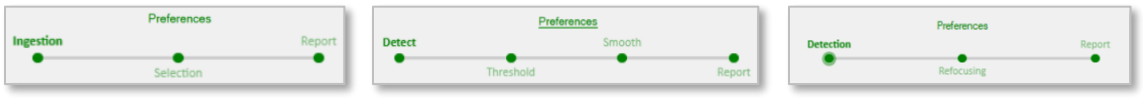


Figure 12. Examples of Processing pipeline in SAR Essentials tools

The intermediate steps of the SARscape workflow can be skipped, and the processing can be passed to the final step by selecting **Report** from the processing pipeline (Figure 12). The parameters for these intermediate steps will be taken by default. Otherwise, the process can be done step-by-step by the button **Next>>.** There is a possibility to go back one step by clicking **<< Back** button.

Alternatively, the process can be passed to a selected step, without stopping on all the steps in between by clicking on the step name. The same can be done backwards selecting any processing step from the pipeline.

An additional button called "Preferences" (Figure 12) gives a direct access to the SAR Essentials Management tool where the basic SAR Essentials preferences can be modified (see section 3.2).

4.2. INTERACTIVE TOOLS

The interactive tools contain *Open*, *Annotation*s and *Help* menus. Some include additional menu options such as *Mode* and *Units* (Figure 13).

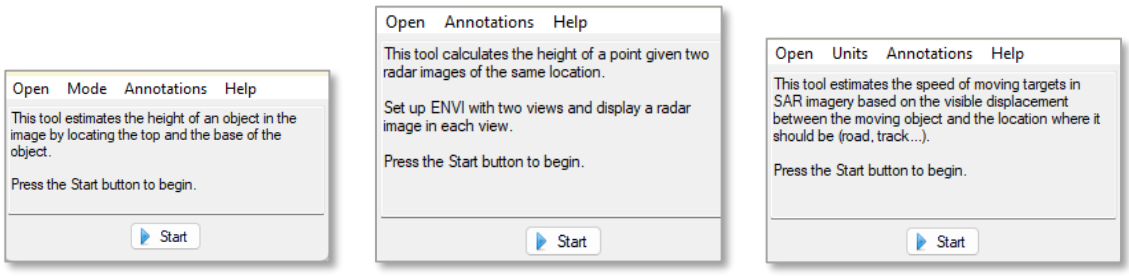


Figure 13. Examples of SAR Essentials interactive tools

5. SAR ESSENTIALS OUTPUT FILES

SAR Essentials creates a set of the following three output files:

- **binary data** – raster data matrix (usually float, complex and byte)
- ***.sml** – SAR Essentials ASCII header file containing all mandatory information for the data processing
- ***.hdr** – ENVI header file for compatibility with ENVI tools

The binary data (raster matrix), with or without file extension, is classified by the operational system (OS) simply as "File" (Figure 14). The complete file description is contained in the *.sml file associated with the binary file. In addition to the main SAR Essentials files some processes also create shapefiles (*.shp), together with their auxiliaries (*.dbf, *.prj, *.shx), as well as Google Earth *.kml files.

For the examples below the files in ***SAR_Essentials_dataset/Getting_started*** folder are used.

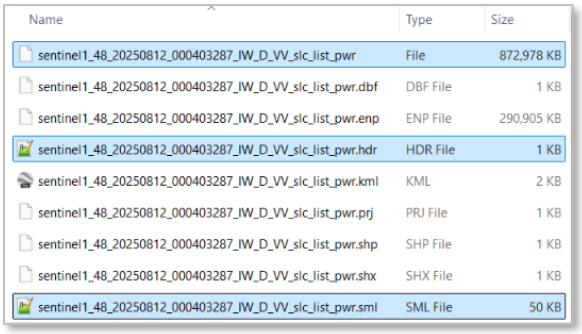


*Figure 14. SAR Essentials output files. The three main outputs are the marked in blue: *_slc, recognised by the OS as "File", *.hdr is the ENVI header file, *.sml is the SAR Essentials header file.*

Once SAR Essentials has processed data, it adds extensions using the underscore symbol and a suffix indicating the file content, e.g. _slc (single look complex), _pwr (power), _geo (geocoded). This nomenclature helps to quickly locate a file of a certain type when a filter in the file browser is active.

SAR Essentials uses **filters** in its file browser windows to help selecting the correct binary files (ancillary files cannot be selected) for the chosen process. In the general case the browsing window for file selection displays possible file input among a set of default extensions (Figure 15), depending on the requirements for the process. Only the files with the listed extensions will be shown in the list of files.

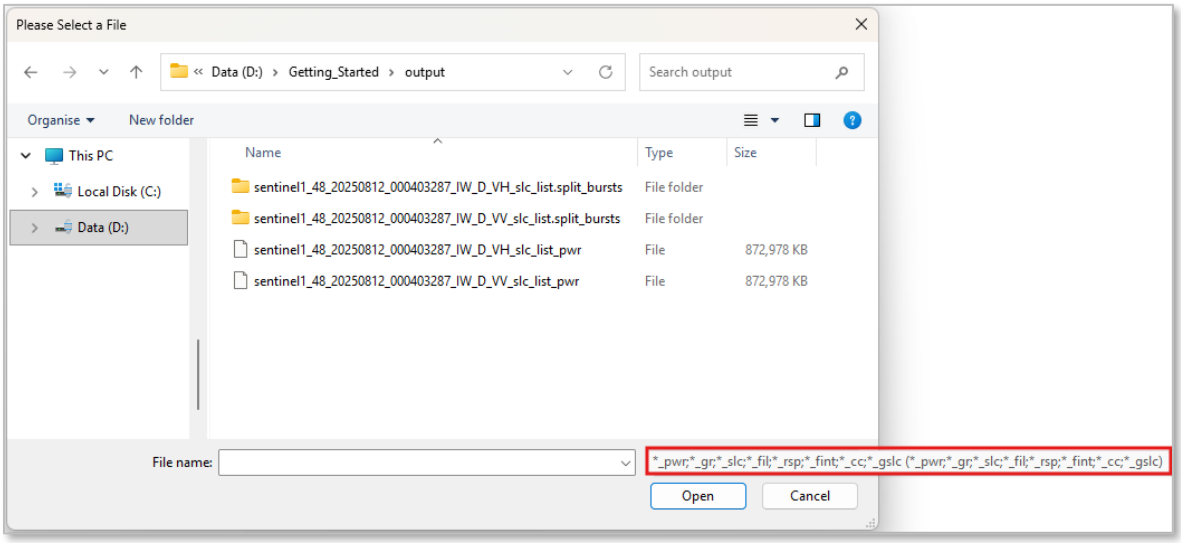


Figure 15. Filter with predefined file extensions in SAR Essentials data selection browsing window (example with Geocoding and Radiometric Calibration tool)

The filter can be turned off by changing the file name extension indicator from the drop-down arrow to *.* (Figure 16). In this way all the files in the directory will be shown.



Figure 16. Turned off filter for data selection browsing window

The data selection filter can be customised by the User. In this case, the star symbol is used as a wildcard with the following interpretation:

- when the star is at the beginning of the filter text (*filtertext, Figure 17), only the files with the filename ending with the filter text are shown:

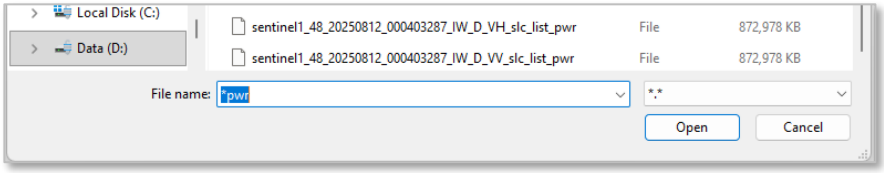


*Figure 17. Filter with keeping end part of a file name (*filtertext)*

- when the star is at the beginning and at the end of the filter text (*filtertext*, Figure 18), only the files with the filter text inside the filename are shown:

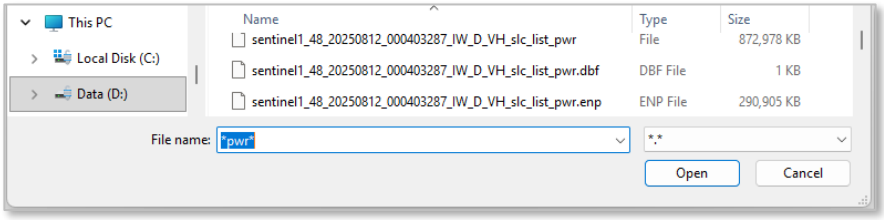


*Figure 18. Filter with keeping middle part of a file name (*filtertext*)*

- when the star is at the end of the filter text (filtertext*), only the files with the filename beginning with the filter text are shown.

6. SAR COMPATIBILITY CHECK

SAR Essentials includes *SAR Compatibility Check* tool (Figure 19, left) that verifies whether the input data are compatible with the processing tools in the module.

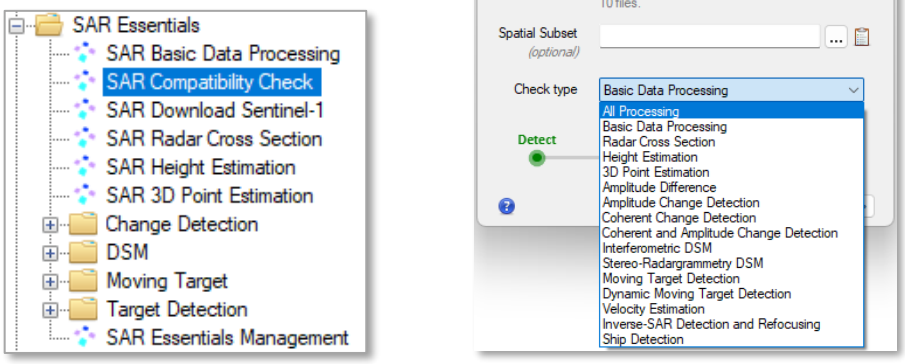


Figure 19. SAR Compatibility Check in SAR Essentials toolbox (left) and tool settings (right)

The validity check can be performed on a list of files, and it will check all possible image combinations (Figure 19, right), including the compatibility of possible combinations of images for the tools that require an input of a pair of images.

Moreover, it can also be verified whether the list of files is compatible with all available tools, eliminating the need to repeat the operation for each tool and dataset individually. During the process, both the data and the metadata of each input file are validated for multiple parameters such as range resolution, data type, acquisition time, line-of-sight incidence angle (ILOS), line-of-sight azimuth angle (ALOS), and other parameters that must be considered for the specific SAR processing.

> A recommended first step before using any SAR Essentials tool is to check whether your input data meets the requirements for the intended SAR processing. Do this by applying *SAR Compatibility Check*.

6.1. SETTINGS

The *SAR Compatibility Check* tool works with original SAR files (e.g. manifest.safe, *.h5, *.xml, *.n1, *.e1, *.e2, IMG*) or with files that were already imported (i.e., _slc.sml). The imported data can come as a result from SAR Essentials software processing or from the SAR Essentials *SAR Basic Data Processing* tool. Importing data allows to reuse the same data in multiple processes.

Original SAR data are typically stored in one of the following standard formats:

- **SLC** – Single Look Complex
- **SICD** – Sensor Independent Complex Data, a standard format for representing complex SAR data
- **SIDD** – Sensor Independent Derived Data
- **NITF** – National Imagery Transmission Format
- **GeoTIFF** – Geographic Tagged Image File Format (GeoTIFF), a standard format based on the TIFF format used for georeferenced raster imagery

Depending on the distributor, they are further delivered in different file formats. Some of them are described below:

- The manifest.safe is an Extensible Markup Language (XML) text file. Each line contains a JavaScript Object Notation (JSON) description that contains information about a single image. “Safe” stands for Standard Archive Format for Europe. This format is used for data from the Sentinel-1 satellite launched by the European Space Agency (ESA). Refer to **SAR Sentinel-1 Data Download tutorial** for more information about the *SAR Download Sentinel-1* tool in SAR Essentials. The Sentinel-1 manifest.safe file is associated with a directory that contains image data in a binary data format and product metadata in XML format, organised in subfolders for each measurement. Data from the RADARSAT Constellation Mission (RCM) from the Canadian Space Agency (CSA) are also distributed in the manifest.safe format.
- The *.h5 format is a version of the Hierarchical Data Format (HDF) for storing large amounts of data, usually remote sensing data. It is used to distribute data from missions such as ICEYE, Cosmo-SkyMed, and NASA-ISRO Synthetic Aperture Radar NISAR.
- Data from some satellite missions, such as the Korean Multipurpose Satellite (Kompsat-5), SAR Observation & Communications (SAOCOM-1) from the Argentinian Space Agency) and more, are delivered as *.xml files that can be read by SAR Essentials.

- Data from the ESA ENVISAT mission are distributed in *.n1 format, while data from the European Remote Sensing satellites ERS-1 and ERS-2 are provided in *.e1 and *.e2 formats, respectively.
- Data from the Phased Array L-band Synthetic Aperture Radar (PALSAR) sensor are distributed in binary format with an IMG* prefix in the image filename. PALSAR is a sensor onboard the Advanced Land Observing Satellite (ALOS), launched by the Japan Aerospace Exploration Agency (JAXA).

Use the *Add file(s)* button next to the *Input File List* field to navigate to the *SAR_Essentials_dataset* folder stored on your computer. Select all files with extensions *.nitf and *.ntf and click *Open*. The filenames are added to the *Input File* List (Figure 19, right).

Optionally, the data can be sampled to a smaller area by using the *Spatial Subset* (Figure 19, right). An external Google Earth KML/KMZ file or a shapefile in geographic coordinates that define the exact area to process can be chosen via *Browse…* button. Alternatively, a vector file that is already open in ENVI Layer Manager can be selected via *Choose from Data Manager* button. This opens an additional window showing the loaded vector files. This button is also available when files are selected in the *Input File List*.

The *Check type* field allows selecting the processing (tool) for which the compatibility of the data needs to be verified. The selection can be applied to a chosen tool or to all tools via *All Processing* option.

Click the *Check type* drop-down list and select *All Processing* (Figure 19, right) and then click *Next*. As you proceed through the workflow, you can click the *Back* button to return to the previous step, if needed.

Detailed descriptions about the usage of the SAR Essentials tools are provided in the following tutorials:

Tutorial title	Included tools
• Basic Data Processing	○ Basic Data Processing
• Radar Cross Section	○ Radar Cross Selection
• Estimate Feature Heights – Object Heights and 3D Point Estimations	○ Height Estimation ○ 3D Point Estimation
• Change Detection	○ Amplitude Difference ○ Amplitude Change Detection ○ Coherent Change Detection ○ Coherent and Amplitude Change Detection
• Digital Surface Model (DSM) generation – from Interferometry and Stereo-Radargrammetry	○ Interferometric DSM ○ Stereo-Radargrammetry DSM
• Moving Target Detection	○ Moving Target Detection ○ Dynamic Moving Target detection ○ Velocity Estimation ○ Inverse-SAR Detection and Refocusing
• Ship Detection and AIS Matching	○ Ship Detection

6.2. REPORT AND RESULTS

The *Report* panel of the *SAR Compatibility Check* tool provides a summary of the data verification results (Figure 20). The same information is given in a text file named *processing_report.txt*, which is stored in the specified *Output Directory* (Figure 4), within a subfolder named:

SAR_Compatibility_Check_output_folder_xxxxxxx.

The *Report* panel shows a numbered list of the images included in the check (Figure 20, left) and a summary of the chosen checks with the compatible and incompatible images, as well as image pairs, for those tools that requires two input files (Figure 20, right).

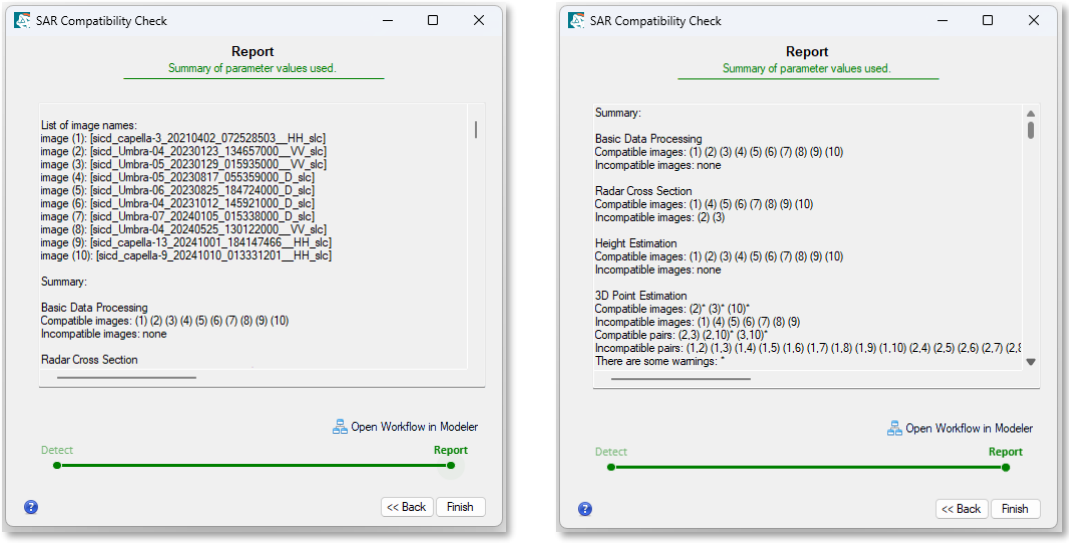


Figure 20. Report showing the general results of the compatibility check

Further, the *Report* panel describes the compatibility of each image or pair of images for each of the chosen tools (Figure 21). The information in the *Report* panel provides guidance on the proper usage of the input data with the SAR Essentials tools.

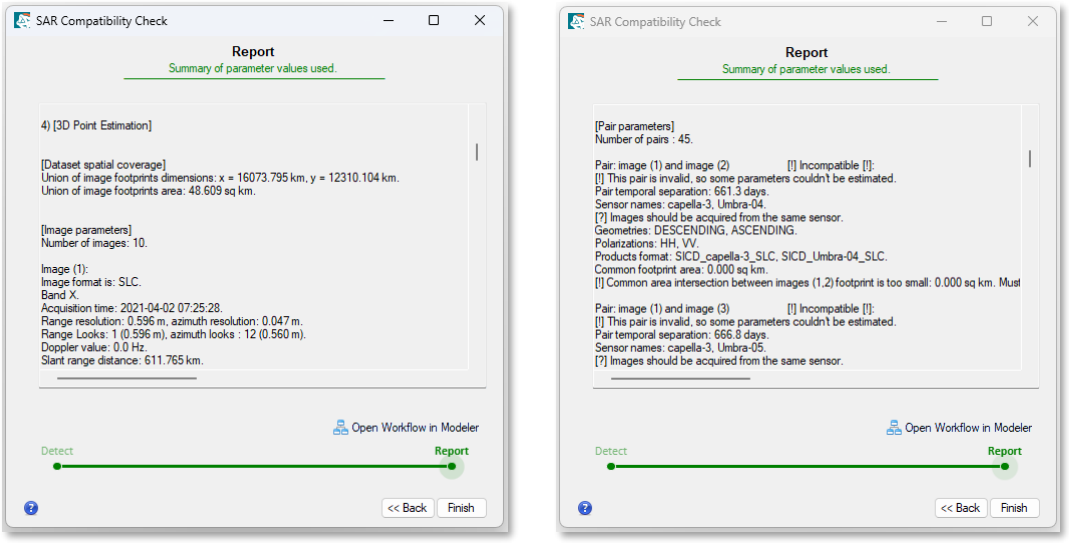


Figure 21. Example Report window of the SAR Compatibility Check tool