User Manual

For

INSAR Data-Analysis & Usage Software (INDUS)

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Document Control & Data Sheet

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Contents

1 Introduction

This user manual provides instructions for effectively using the Graphical User Interface (GUI) of the software named *INDUS* (INSAR Data-Analysis & Usage Software) designed for generating interferograms and related output from SAR Interferometric pair datasets. It encompasses the information regarding mission, type of products, DEM usage, processing parameters, multilooking information, geolocation improvement, registration parameters, InSAR filtering parameters, phase unwrapping, geocoding etc. supported by the software. It also provides the information regarding various intermediate files that are generated as part of interferometric processing. Additionally, this document also discusses about display of various outputs generated during processing.

Section 2 of this document discusses about the Graphical User Interface detailing about various functionalities provided in the tool. Details regarding the processing and various intermediate and output files are discussed in section 3. Hardware and software details required for execution of the software is detailed in section 4.

2 Graphical User Interface

Home panel of the Interferometric SAR Processing Tool mainly contains two menus in menu bar namely *Files* & *Help* and four tabs namely *Product*, *Processing*, *Parameters* & *Output*. Details of menus and tabs are given in subsequent subsections.

2.1 Menus

i. Files

a) **Home:** It brings the control to the home panel.
b) **Restore Defaults:** It restores all the default values of the parameter.
c) **Exit (Ctrl + Q):** It exits the GUI.

ii. Help

a) **Shortcuts Summary:** It provides information about the available shortcuts.
b) **User Manual:** It shows the user manual for INDUS software.
c) **About:** Contact information about the developer and other information.

2.2 Tabs

i. Product

Basic information regarding interferometric pair to be used for processing is provided in this tab/panel. User has to provide the path of the Primary and Secondary products to be used as Interferometric pair during processing. Software assumes that both Primary and Secondary Products are Single Look Complex (SLC) products in Range Doppler domain. Here, path refers to the path upto product directory. Currently, software supports EOS-04 datasets only for both CEOS and GeoTiFF format. In subsequent versions of INDUS, support for SAR datasets from other missions will be added. Additionally, user has to select the polarization to be used during interferometric processing as shown in Panel in figure 1. A file dialog box “Output Path” is provided in this panel to get the path for generating "intermediate" and "output" files. This tab/panel also provides three buttons namely "Show Reference", "Show Repeat" and "Next".

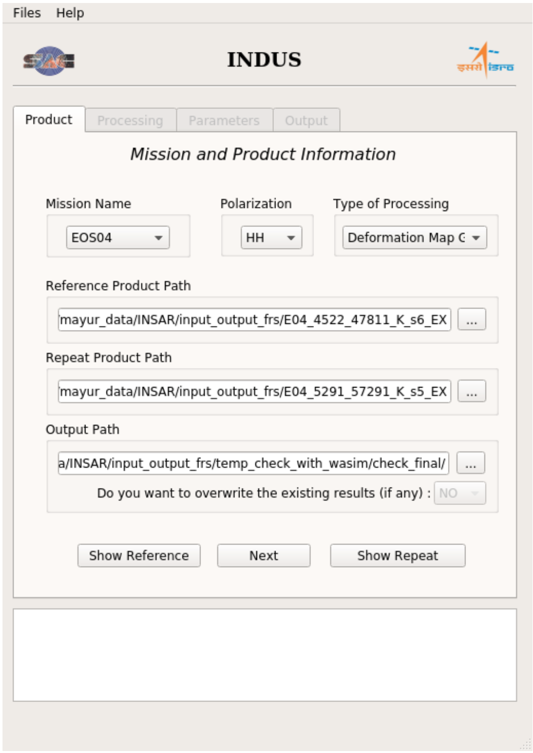

Figure 1 : Interferometric SAR Data Analysis & Usage Software (INDUS) GUI Home Panel

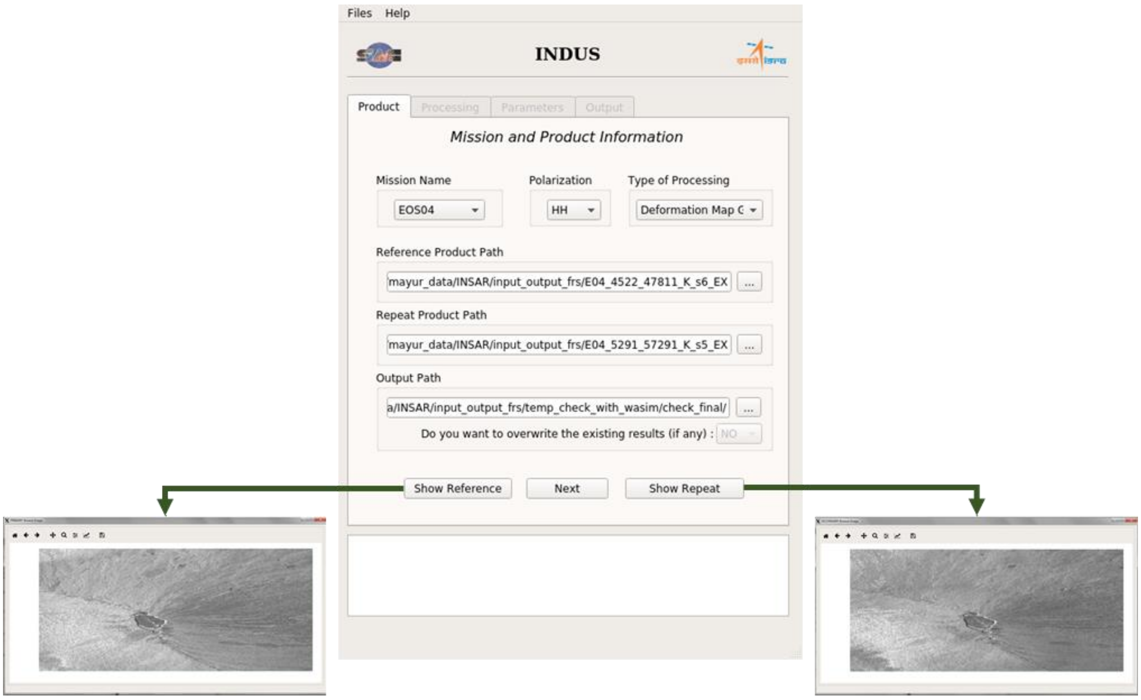

Figure 2 : Browse images can be displayed by clicking "Show Primary" & "Show Secondary" button

User can use "Show Reference" and "Show Repeat" buttons to have a quick look onto the selected data products. Fig. 2 depicts the GUI with browse images. Reference and Repeat is used interchangeably with Primary and Secondary respectively. Once user is satisfied with the information provided, he/she can click the "Next" to go onto the next tab. If any of the provided path is invalid, text box will display the error message. Upon correction in the provided path, error message will disappear. Additionally, if user provides the invalid "Polarization", an error message will be displayed on clicking the "Next" button. It is to be noted that if any of the provided path is not found then user will not be able to press "Next" Button and components of the GUI on other tabs will not be accessible. It is true even when the user provides same path for primary and secondary product. On clicking the "Next" button, background process will be triggered for computing the baseline and DEM information to be used during processing. Any action is disabled until the background process execution completes. Afterwards, "Processing" tab alongwith all it's elements gets enabled.

ii. Processing

Processing tab contains various sub-panels capturing different kind of information like processing stage selection, number of cores to be used in processing, DEM Information, and Geolocation refinement. A picture of Processing Tab is shown in Fig. 3. Details regarding the sub-panels is discussed as below:

Processing Stage Selection

Interferometric processing involves many different processing stages to produce meaningful interferometric results. The complete list of stages is given in Table 1. This tool provides the option for "Default" or "Custom" processing under "Processing Stage Selection".

a. ***Default*** – Runs the processing from the scratch till the end.
b. ***Custom*** – User can select different starting and end stage based upon the process which they want to run.

Table 1 : Processing Stages

i.	Start InSAR Processing	vii.	Earth Flattening
ii.	POS Grid Generation	viii.	InSAR MultiLooking
iii.	Offset Map Generation	ix.	InSAR Filtering
iv.	Geometrical Registration	x.	Phase Unwrapping
v.	Registration Error Generation	xi.	Height Conversion
vi.	Fine Resampling	xii.	Geocoding

However, while we start from any given stage in the chain, previous stages must have been completed. Additionally, intermediate information from previous stages must be lying at its respective locations. Stop stage should always be after the start stage. This particular feature aids the user in analyzing the output of various stages during Interferometric processing.

Geolocation Refinement

Interferometric processing is highly dependent on the geolocation accuracy. Hence, a feature for "Geolocation Refinement" have been provided in the tool. In this, both "Primary" and

"Secondary" datasets are registered with DEM and a mean geolocation error in terms of "Range" and "Time" is computed. This particular feature is beneficial in cases where inherent geolocation accuracy of the "Primary" and "Secondary" products is not good. Usage of these errors in the interferometric processing results in improved quality for interferograms.

Following option is provided in the feature for usage purpose:

a) *Yes* If inherent geolocation accuracy of products is not good.
**** COPERNICUS DEM SHOULD BE USED FOR THIS ****

b) *No* If user is wants to use inherent geolocation accuracy of the products.

This error is used during interferometric processing if usage of "Geolocation Refinement" is enabled in the selection box.

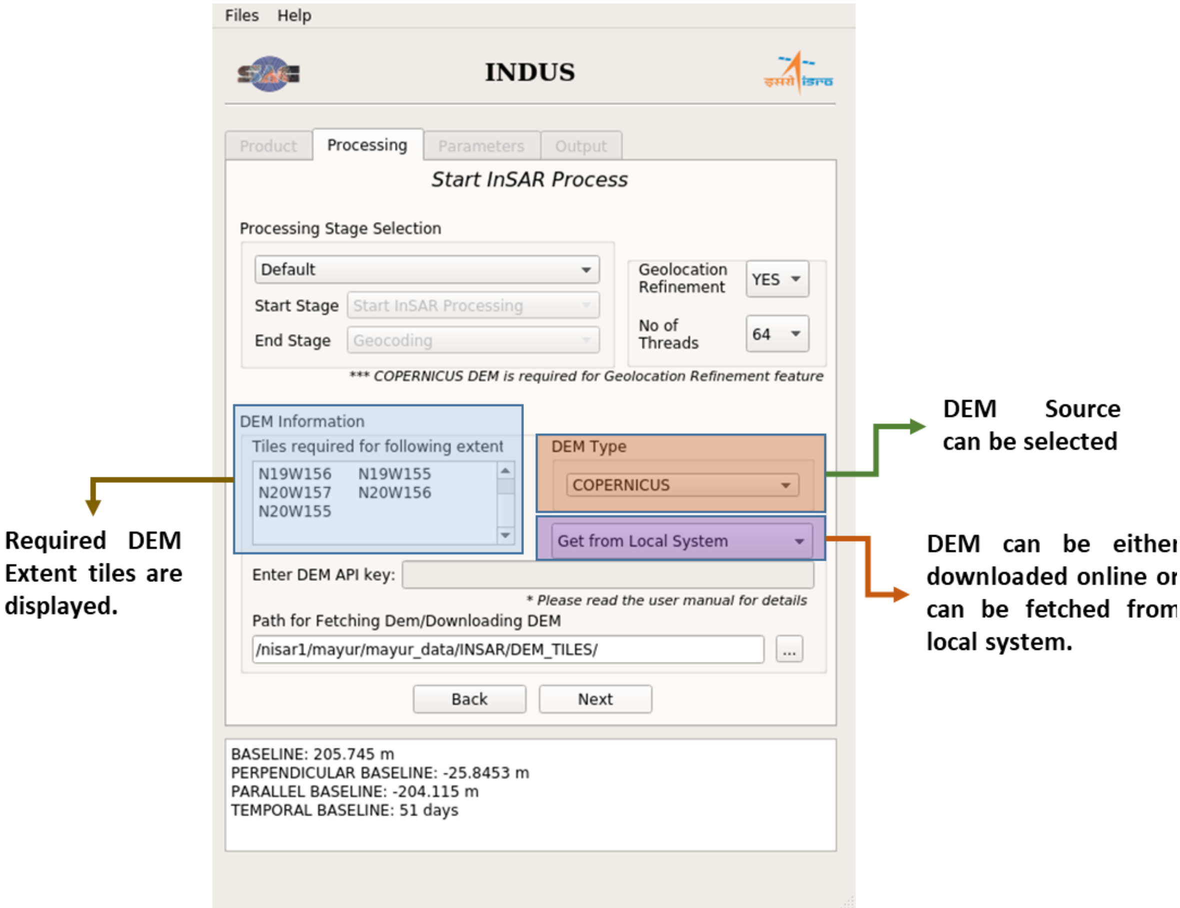

Figure 3 : Processing Information Panel

No of Threads

Interferometric processing is a compute intensive process. Hence, the interferometric software has been designed to use compute resources available with this system. By default, it shows the maximum number of threads that the software can use on the targetted system. User can also specify the number of threads that should be used during processing. However, software will not allow to specify more number threads than the maximum allowable limit defined by the system configuration.

DEM Information:

This subpanel is all about the DEM Information to be used during interferometric processing. It captures various DEM Information like DEM Extent, DEM Type and Location of DEM as follows:

- ***a) DEM Extent*** — DEM Tiles required for processing are displayed in this box.
- ***b) DEM Type*** — Software supports for mainly three type of DEM.
  - "COPERNICUS"
  - "SRTM"
  - "NASADEM".

  Any one of the DEM can be selected in this selection box.
- ***c) DEM Availability*** — software supports following two options for DEM usage:

  1.1) Get from Local System: If DEM tiles are available locally

  1.2) Path: Enter the path where the Tiles are located.

  2.1) Download from internet: If not available locally

  2.2) Enter DEM API Key: Provide DEM API key for downloading DEM from the internet.

  2.3) Path: Enter the path where the downloaded tiles will be kept.

Once all the inputs are given user can proceed further by pressing the "**Next**" Button. It will go to **"Parameters"** tab. Upon providing the invalid path or the DEM API key, an error message will be shown in the display area. A facility to go back to previous panel is provided through a "Back" button for user's convenience. Additionally, out of DEM Extent, if any of the tile is not available, software will not work.

iii. Parameters

This particular panel contains various subpanels corresponding to various sub-stages of interferometric processing. Any given subpanel is enabled only when the corresponding sub-stage of interferometric processing is within the processing stages selected in the previous tab/panel. Each sub-panel captures various configurable parameters required for executing the corresponding sub-stage. The default values of all the parameters is prefilled. A snapshot of Parameters panel is exhibited in Fig. 4. Different subpanels corresponding to various stages are as follows:

Registration Parameters

The parameters required at this stage are meant for generating sub-pixel level offset between Primary and Secondary products. Sub-pixel level offset is computed using amplitude correlation. Parameters required during the amplitude correlation are as follows:

- ***a) Template Window*** — size of template window (x,y)
- ***b) Search Radii*** — Size of search radii kernel (x, y)
- ***c) Stride*** — Size of stride (x, y)

During amplitude correlation, template window is taken from the Primary product/image and searched in the Secondary product/image. For a template window size of MxN and search radii of PxQ, search space will be (M+2*P) x (N+2*Q) resulting in a correlation matrix of (2*P+1)*(2*Q+1). The correlation matrix is upsampled by a factor of 128 to get offset accuracy at 1/128th sub-pixel level. Stride defines the density of the offset map. Smaller stride corresponds to more dense offset map and hence takes more time in computation. For flatter terrains and nominal deformation scenarios, larger stride can be kept for reducing the turn around time.

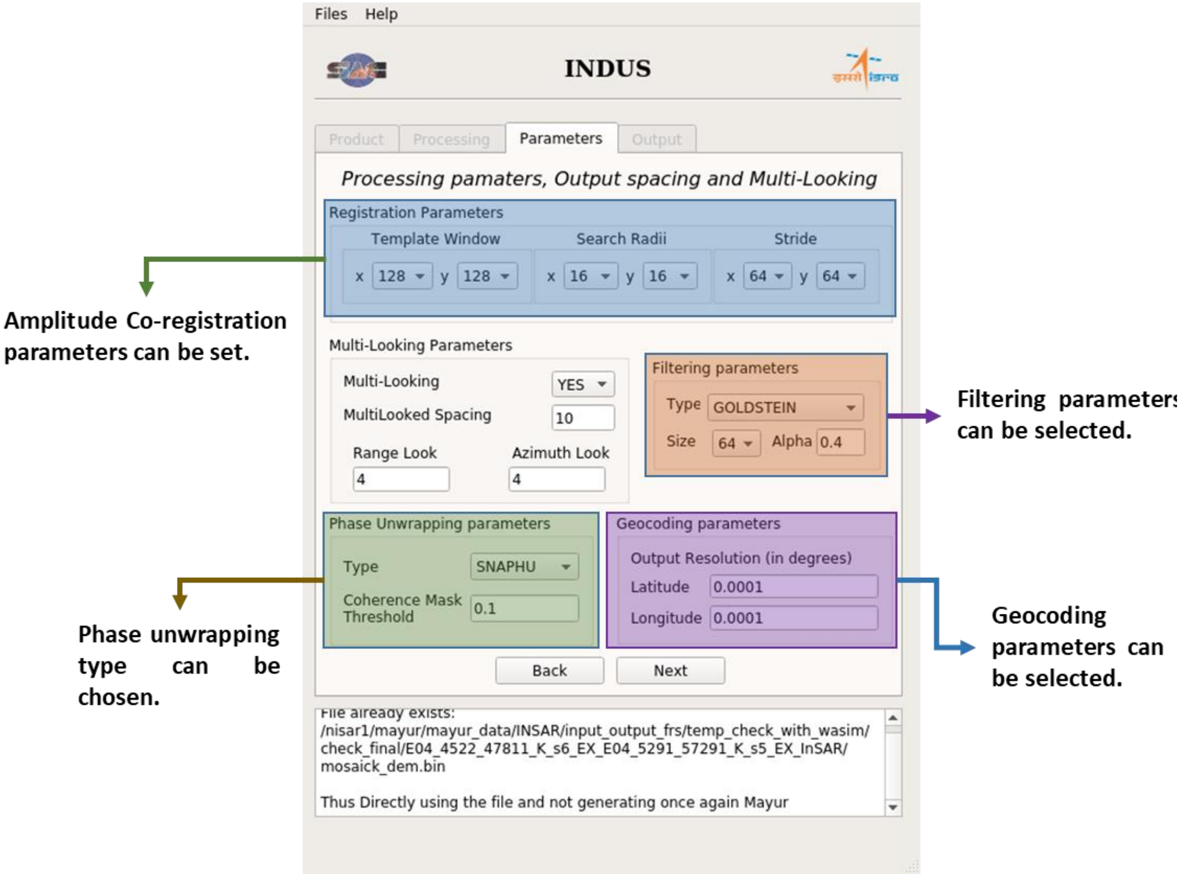

Figure 4 : Parameters Required for Interferometric Processing

Multi-Looking Parameters

Raw interferograms are generally very noisy. In order to reduce the noise in interferograms, multilooking is performed. Multilooking is performed in range as well as in azimuth direction. Additionally, as a rule, multilooking factor should correspond to same pixel size in range and azimuth direction. Hence, this sub-panel captures the pixel size as follows:

- ***a) Multi-Looking*** Multilooking is enabled by selecting "YES" in selection box.
- ***b) Multilook Spacing*** It captures the pixel size for multilooking in both range and azimuth direction.

Multilook spacing is used internally to compute the approximate number of looks in range & azimuth direction and are displayed in this sub-panel. Change in pixel size will result in updation of range & azimuth looks to be used during processing. User can not update range look and azimuth look directly. Multilook spacing can be provided as an input only when multilooking proess is enabled by selecting “YES” in selection box. The number of range looks and azimuth looks are used in multilooking of raw interferogram as well as in coherence map generation. For cases, where multilooking is disabled, no multilooking is applied on raw interferogram. However, a 3x3 moving window is used for generating the coherence map.

InSAR Filtering

Interferograms are representative of phase difference due to path delay differences between primary and secondary images for each of the target within the primary image. Various factors like temporal decorrelation, spatial decorrelation, thermal noise, baseline decorrelation etc. affect interferograms such that even after multilooking, these remains noisy. Thus, filters specific to interferometric processing, which preserves the edges/discontinuities, are required. Information regarding the filters that can be used during InSAR filtering is captured as follows:

a)	***Type***	Defines the type of InSAR specific filter to be used. User can choose out of following three available filters: ➢ GOLDSTEIN ➢ ADAPTIVE_GOLDSTEIN ➢ BOXCAR BOXCAR is provided for completeness sake.
b)	***Size***	Size of filter (Same in both (x,y) direction)
c)	***Alpha***	If **GOLDSTEIN** filter is selected, the value of Alpha is used in filtering process. Value of alpha should be between 0 and 1 where “0” represents the minimum filtering while “1” represents the maximum filtering.

Phase Unwrapping Parameters

Various type of unwrapping algorithms exist for interferogram unwrapping. Algorithm suppoprted for unwrapping the interferogram are as follows:

a)	***Type***	Following type of algorithm are available for phase unwrapping. ➢ SNAPHU ➢ ICU
b)	***Coherence Mask Threshold***	Value of the threshold for coherence mask. It is used during the phase unwrapping process.

Geocoding Parameters

Interferometric processing is performed on range doppler products and all the intermediate results are generated in Range Doppler domain only. A facility for geocoding all the intermediate layers is provided in the software. This panel captures the output spacing in geographical coordinate system as follows:

a)	***Latitude***	Output latitude resolution in degrees

b) Longitude Output longitude resolution in degrees

Once user provides all the inputs can click on “Next” button to go onto next tab “Output”. All the input parameters for various sub-stages are validated against the reference values. Clicking of “Next” button triggers the interferometric processing. All actions are disabled until background process execution is complete. “Output” panel show up after completion of the interferometric processing. Like other panels, this panel also contains “Back” button to facilitate the user to go to the previous tab allowing users to verify & correct the inputs.

iv. Output

This tab is meant for displaying various outputs and statistics. It has further 6 tabs inside it namely Primary, Secondary, Coherence Map, Flattened, Filtered and Deformation/Elevation as shown in Fig. 5. All the tabs have two buttons namely Display Statistics and Show Full Resolution.

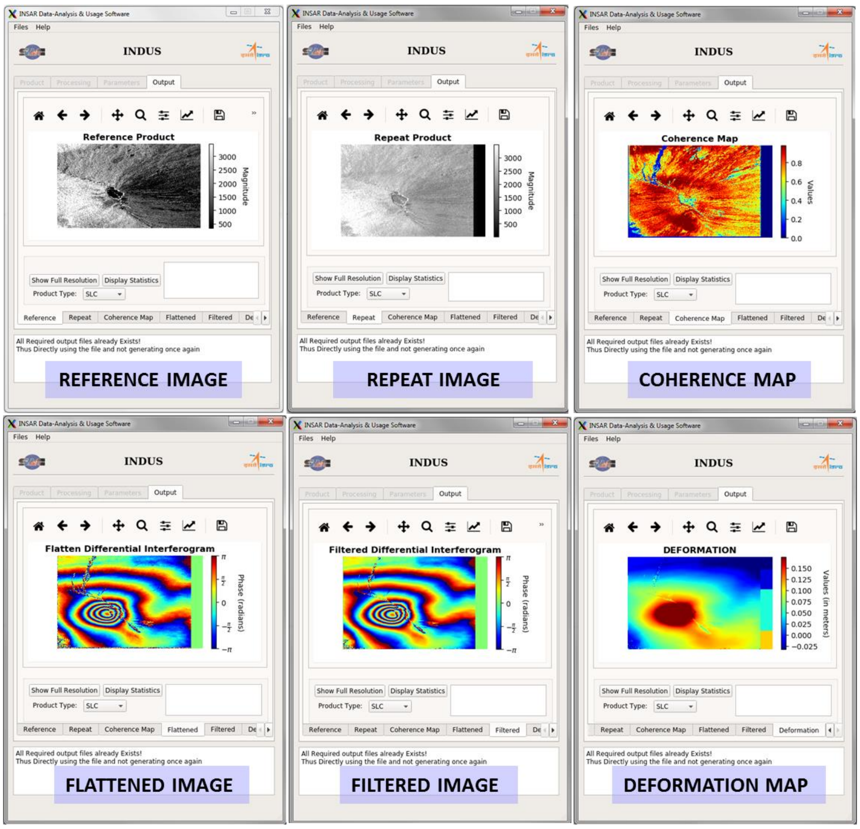

Figure 5 : Output Images of the Interferometric Processing in Range Doppler Domain

Display Statistics

Software display the statistics (Min, Max, Mean, STD) corresponding to the image shown in the GUI (Fig. 6).

Show Full Resolution

It will open another window to display the corresponding product in full resolution as shown in Fig. 6. Image canvas that display full resolution image features buttons for Reset original value, Back to previous view, Forward to next view, Pan, Zoom, Editing axes, and Save.

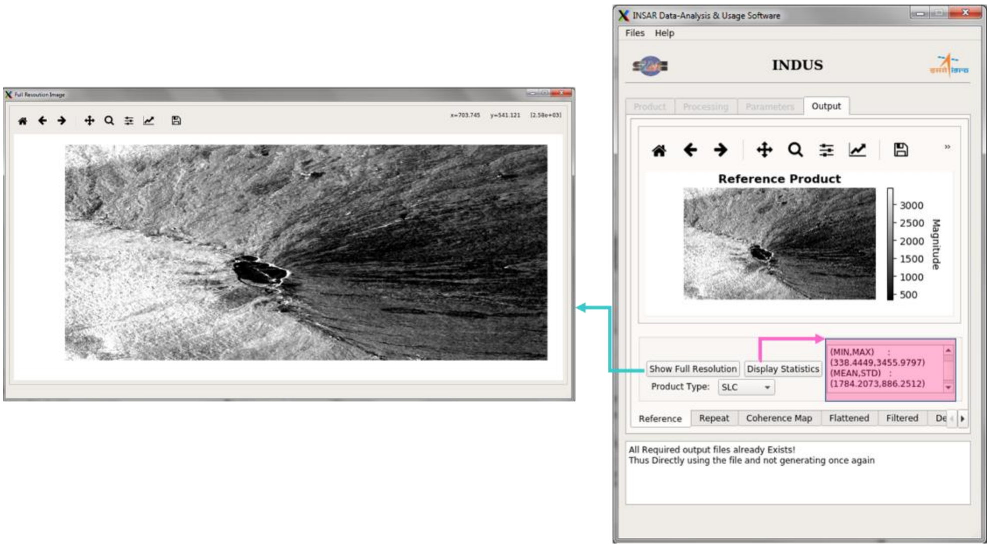

Figure 6 : Statistics can be displayed by clicking "Display Statistics" button. "Show Full Resolution" button can be used to view the images in full resolution having zoom in/zoom out features.

Product Type

Software generates each of the output in Range Doppler as well as in geocoded domain and can be selected. Select SLC to visualize the various results in Range Doppler domain and Geocoded to visualize results in geocoded domain.

3 Intermediate & Output Files

Interferogram generation involves various processing stages. It requires various type of information as discussed previously for generating interferograms. Software generates various intermediate results in the processing flow during different stages as following location:

InSAR_Output_Location = "outputpath/ PrimaryJobId_SecondaryJobId_InSAR"

i. Product Decoding

In "Product" tab, on click of "Next" button, both primary and secondary products are decoded and corresponding intermediate files are created within the following path:

"InSAR_Output_Location/PrimaryJobId_scene_Polarization"
"InSAR_Output_Location/SecondaryJobId_scene_Polarization"

Additionally, using product information, software generates the DEM extent required for usage and stores in following location:

"InSAR_Output_Location/DEM_Extent.txt"

ii. Interferometric Processing

Once all inputs upto "Parameters" tab are provided, actual interferometric processing starts as per following steps.

Relevant Information Extraction

Ephemeris and attitude information is modelled and corresponding files alongwith complex Binary files corresponding to Primary and Secondary images are stored as follows:

Ephemeris :

“InSAR_Output_Location/PRIMARY.oatcoeffs”
“InSAR_Output_Location/SECONDARY.oatcoeffs”

Binary Images;

“InSAR_Output_Location/PRIMARY_POLARIZATION.cmplx”
“InSAR_Output_Location/SECONDARY_POLARIZATION.cmplx”

Additionally, a file named “InSAR.info” is also created at this location containing all relevant information about the primary and secondary product that is required for processing.

Geometric Registration

Once, process extracts required information, it generates the geolocation information for each pixel for “Primary” frame using ephemeris from “Primary” product. Afterwards, using “Secondary” product ephemeris, a geometric “OffsetMap” of secondary product with respect to “Primary” product in “Scanline” and “Pixel” offset for each data pixel is computed. “Secondary” image is geometrically registered with “Primary” image using offsetMap. Following output is stored at “InSAR_Output_Location”.

Filename	**Type**	**Datatype**	**Remark**
posgrid.dat	Binary File	Double	Interleaved Latitude, Longitude, Height at each pixel.
primary_secondary_pol.offsetMap	Binary File	Double	Interleaved Scanline, Pixel Offset at each pixel.
SECONDARY_POL_coarse.cmplx	Binary File	Complex (float, float)	Interleaved “Real”, “Imag” at each pixel.

Fine Registration

Primary and geometrically registered Secondary may be mis-registered due to various factors like atmospheric delay, ephemeris inaccuracy, unaccounted processing biases or due to actual temporal deformation. Thus, amplitude correlation is applied between coarsely registered “Seconary” and primary image to generate the residual registration error. This registration error is used further to resample the secondary image to get finely registered secondary image with respect to primary image. Following outputs are stored:

Filename	**Type**	**Datatype**	**Remark**
primary_pol.rdp	Binary File	Structure (Mixed Information)	It contains registration data points for entire image. The number of data points depends on the “Stride” provided in “Parameters” tab as input.

SECONDARY_pol_fine.cmplx	Binary File	Complex (float, float)	Interleaved "Real", "Imag" at each pixel.

Earth Flattening

Fine registered secondary image and primary image are used for earth flattening process. Here, complex conjugate of secondary image is multiplied with the primary image. OffsetMap is used to derive the earth flattening phase and is compensated on the resultant to generate earth flattened raw interferogram output. Following is the output of the same.

Filename	**Type**	**Datatype**	**Remark**
flatten_raw_difg_HH.cmplx	Binary File	Complex (float, float)	Raw interferogram. Interleaved "Real", "Imag" at each pixel.

Filtering

Multilooking is applied on to the raw interferogram generated in the previous step. Looks in range and azimuth direction is computed using the "Multilook Spacing" parameter captured in "Parameters" Tab. Primary and Fine registered Secondary images are also multilooked. Same range and azimuth look values are used for generating the coherence map. Further, InSAR specific filtering chosen by the user is applied onto the multilooked earth flattened interferogram.

	Filename	**Type**	**Datatype**	**Remark**
1	flatten_difg_HH_ml_xx.cmplx	Binary File	Complex (float, float)	Multilooked Complex raw interferogram
	flatten_difg_HH_ml_xx.dat	Binary File	float	Phase information of Multilooked Complex interferogram
2	filtered_difg_HH_ml_xx.cmplx	Binary File	Complex (float, float)	Multilooked, Filtered Complex interferogram
	filtered_difg_HH_ml_xx.dat	Binary File	float	Phase information of Multilooked Filtered interferogram
3	cohmap_difg_HH_ml_xx.dat	Binary File	float	Coherence map
4	PRIMARY_HH_ml_xx.dat	Binary File	float	Multilooked power of Primary Image
5	SECONDARY_HH_ml_xx.dat	Binary File	float	Multilooked power of Secondary Image
* Here, "xx" represents the multilook spacing value.				

Apart from these, ".hdr" file is created with each type of output. This file contains all basic information such that corresponding "binary" file can be directly loaded onto "ENVI" or "QGIS" softwares with ".hdr" file's help.

Elevation/Deformation Map Generation

Filtered interferograms are unwrapped using the phase unwrapping algorithm chosen by the user. Further, depending upon the user requirement, unwrapped phase is converted to deformation map or the elevation map. Various output generated are detailed in below table. Additionally, a ".hdr" file is also created for each type of output.

	Filename	**Type**	**Datatype**	**Remark**
1	unwrapped_difg_pol_ml_xx.cmplx	Binary File	Complex (float, float)	Unwrapped complex interferogram. Here, real part represents the phase while "imaginary" part represents the coherence.
	unwrapped_difg_pol_ml_xx.dat	Binary File	float	Unwrapped phase
2	defo_difg_HH_ml_xx.cmplx	Binary File	Complex (float, float)	Deformation map, real part represents the deformation while "imaginary" part represents the coherence.
	defo_difg_HH_ml_xx.dat	Binary File	float	Phase information of Multilooked Filtered interferogram
3	cohmap_difg_HH_ml_xx.dat	Binary File	float	Coherence map
4	PRIMARY_HH_ml_xx.dat	Binary File	float	Multilooked power of Primary Image
5	SECONDARY_HH_ml_xx.dat	Binary File	float	Multilooked power of Secondary Image

Resultant Information

Intermediate results have invalid portions corresponding to non-overlapping portions of primary and secondary images, template window sizes, InSAR filtering sizes etc. These invalid portions are filled with NaN and are stored at following location:

InSAR_Results_Location = "InSAR_Output_Location/results/"

Files corresponding to Primary Image, Secondary Image, multilooked earth flattened interferogram, coherence map, InSAR filtered interferogram, unwrapped interferogram and deformation map/elevation map are generated at above location alongwith ".hdr" files.

Geocoded Output Generation

All the output files discussed till now, are in Range Doppler domain. These files are geocoded and generated in geographical coordinates using "Latitude Resolution" and "Longitude Resolution" provided in in "Parameters" tab. The following table shows the various output generated in this step at "InSAR_Results_Location".
Similar to Range Doppler domain outputs, a ".hdr" file is generated for "Geocoded" output. For elevation map generation option, files starting from prefix as "defo" will be starting with a prefix "height". Additionally, all the files having "difg" in the filename will be having "ifg" in the filename for elevation map generation option.

	Filename	Type	Datatype	Remark
1	PRIMARY_HH_ml_xx_geo.bin	Binary File	float	Geocoded result of Multilooked power of Primary Image
2	SECONDARY_HH_ml_xx_geo.bin	Binary File	float	Geocoded result of Multilooked power of Secondary Image
3	flatten_difg_HH_ml_xx_geo.bin	Binary File	float	Geocoded multilooked differential interferogram
4	filtered_difg_HH_ml_xx_geo.bin	Binary File	float	Geocoded multilooked filtered differential interferogram
5	cohmap_difg_HH_ml_xx_geo.bin	Binary File	float	Geocoded Coherence map
6	unwrapped_difg_HH_ml_xx_geo.bin	Binary File	float	Geocoded multilooked filtered unwrapped interferogram
7	defo_difg_HH_ml_xx_geo.bin	Binary File	float	Geocoded deformation map

4 Hardware & Software Requirements

The software can be downloaded from VEDAS (https://vedas.sac.gov.in) / BHOONIDHI (https://bhoonidhi.nrsc.gov.in) site. For running INDUS, any container running software should be installed in the system i.e. docker /podman.

To run INDUS application, mount your storage where data resides and execute the following command:

docker run -it --rm --name indus -v /tmp/.X11-unix:/tmp/.X11-unix:ro -e DISPLAY=$DISPLAY -v /storage_area_where_data_resides:/data/ localhost/insar_sw:latest

Finally, to launch the INDUS software, run the below command:

python bin_gui/run_gui_insar.py

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