Sentinel-1 InSAR Phase Unwrapping using S1TBX and SNAPHU
Adapted from the European Space Agency’s STEP community platform

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A) System Requirements
Many of the steps take a very long time to process. We recommend the following:

- At least 16GB memory (RAM)
- Close other applications if possible while using S1TBX
- Do not use the computer while a product is being processed

B) Background
This data recipe is a continuation from ASF’s Sentinel-1 InSAR Processing recipe. It provides the ‘unwrapping’ of the interferogram, which in turn allows height values to be derived from the product. Phase unwrapping is the most complicated stage of interferometric data processing.

For this data recipe, we are using SNAPHU, which is a two-dimensional phase unwrapping algorithm proposed by Chen and Zebker (see Section H). The software is written in C and should run on most Unix/Linux platforms, and it is freely available to the public.
The interferometric phase is ambiguous and only known within $2\pi$. In order to be able to relate the interferometric phase to the topographic height, the phase must first be unwrapped. The altitude of ambiguity $h_a$ is defined as the altitude difference that generates an interferometric phase change of $2\pi$ after interferogram flattening.

Phase unwrapping solves this ambiguity by integrating phase difference between neighboring pixels. After deleting any integer number of altitudes of ambiguity (equivalent to an integer number of $2\pi$ phase cycles), the phase variation between two points on the flattened interferogram provides a measurement of the actual altitude variation.

C) Materials List

1) Linux or Unix

Windows users have several options to access a Linux machine:

- Download a Linux virtual machine (VM) and use it to unwrap the phase [https://www.virtualbox.org/](https://www.virtualbox.org/) , [https://www.vmware.com/](https://www.vmware.com/)


2) Sentinel-1 Toolbox version 5.0.0 (S1TBX)

3) SNAPHU Algorithm for Phase Unwrapping (See Step 3)

4) InSAR Data (continuation from InSAR data recipe)
D) Pre-Unwrapping Steps

This data recipe assumes that you have already generated your interferogram using the Sentinel-1 Toolbox as shown below and would like to follow the unwrapping process.

![Interferogram Formation (without Terrain Correction)](image)

For optimal unwrapping results it is recommended to multi-look (i.e., square) and phase-filter (i.e., increase signal-to-noise and smooth) the interferogram.

The quality and reliability of unwrapped results strongly depends on the input coherence. Reliable results can only be expected in areas with high coherence.

**Step 1 - Open Your Interferogram in S1TBX**

- Use the **Open Product** button to open your interferogram
- You will see the opened product in the **Product Explorer**
- Double-click on the opened product to view the product bands
- Double-click on the **Phase** band to view your interferogram
- Zoom in using the mouse wheel and dragging the left mouse button

**Step 2 – Create a Subset (Optional)**

To reduce the amount of processing needed, you may create a subset of the particular area in which you are interested.

Once you have zoomed and panned to your area of interest, right click on the image and select **Spatial Subset from View** in the context menu.
The subset dialog box will automatically select the area you were viewing. To adjust the extent of your subset image, you may drag the bounding box, enter the pixel coordinates, or add geo coordinates. See Figure 2.

![Subset dialog box](image)

**Figure 2: Specifying a Product Subset**

Press **OK** to create the subset.

**Note:** By default, all bands will be included in the subset. For phase unwrapping, it is required that you keep both the **phase** and **coherence** bands.

When the new subset product appears in the products view:

- Right-click on the product
- Select **Save Product** in the context menu
- Select **Yes** to convert the product to the **BEAM-DIMAP** format
Step 3 – Export to SNAPHU

Export your interferogram to SNAPHU from S1TBX

- Select the product from the Product Explorer tab
- Navigate to: Radar > Interferometric > Unwrapping > SNAPHU Export
- In the SNAPHU Export tab type in the folder directory in the Target Folder box
  i) We recommend creating a separate folder for this step (Figure 3)

- Select DEFO for deformation mapping
- To speed up the unwrapping process, you may increase the number of processors (this depends on the CPU you have)
- Click Run to create SNAPHU export folder

![Figure 3: SNAPHU Export](image)
E) Unwrapping with SNAPHU

SNAPHU is a Statistical-cost, Network-flow Algorithm for Phase Unwrapping developed at Stanford University by Curtis Chen and Howard Zebker. 
http://nova.stanford.edu/sar_group/snaphu/

SNAPHU is available for Linux only. Linux users simply need to open a command line and run the following commands from each step:

1) Install SNAPHU
Install the software package by typing in the command line and hit <Enter>:

`apt-get install snaphu`

2) Copy SNAPHU Command
Open or <cd> to the SNAPHU Export data file you created in Step 3
Use the following command or use a text-only editor of your choice to open the configuration file located inside the export folder (snaphu.conf):

`nano snaphu.conf`

![Figure 4: Snaphu Configuration File Contents](image-url)

UAF is an AA/EO employer and educational institution and prohibits illegal discrimination against any individual: www.alaska.edu/nondiscrimination
Copy the SNAPHU command from the configuration file (Figure 4)
To exit type <Ctrl + X>

3) Run the Command:
Paste the command into the command terminal and hit <Enter>:

```
snaphu -f snaphu.conf YOUR_PHASE_BAND.img 99999
```

![SNAPHU Output](image)

Figure 5: SNAPHU Output

Note: Execution time depends on the size of the interferogram. Unwrapping can use a lot of memory. If the unwrapping fails due to insufficient memory, you may wish to create a subset of your area of interest (see Step 2) and try it again.
F) Post-Unwrapping Steps

This section assumes you have your interferogram from Section D, Step 3 still open in S1TBX. If you do not, please open your product before proceeding.

Step 4 – SNAPHU Import

Navigate to Radar > Interferometric > Unwrapping > Snaphu Import

In the SNAPHU Import window (Figure 6):

- In the Read Phase tab: Select the interferogram product
- In the Read Unwrapped Phase tab: Navigate to your SNAPHU export folder and select the UnwPhase.hdr file
- In the SNAPHU Import tab:
  OPTIONAL: To create a separate file, check the Do NOT save Wrapped interferogram in the target product option
- In the Write tab: Click Run

![Figure 6: SNAPHU Import – Select Unwrapped Phase Product](image)
Step 5 – Geocoding

At this point, you may view your Unwrapped Phase product (Figure 7). However, you will notice that areas of no-elevation incorrectly appear as having data in the Unwrapped Phase image. To fix this, we will terrain correct and geocode the data.

![Figure 7: Unwrapped and Wrapped Phase](image)

Navigate to Radar > Geometric > Terrain Correction > Range-Doppler Terrain Correction

In the **Range-Doppler Terrain Correction** window (Figure 8), select the Unwrapped Phase product you just imported from SNAPHU.
Figure 8: Range Doppler Terrain Correction

In the **Processing Parameters** tab:

- Leave all parameters as **default**
- Click **Run** to geocode your data

The resulting product name is appended with **_TC**.

Note the checked box which masks out areas without elevation. See Figure 9 below for the resulting geocoded wrapped and unwrapped interferograms.
Step 6 – Export Data

The final geocoded data can be exported from S1TBX in a variety of formats.

To export you may either **right-click** on your product in the product view or navigate to *File > Export*

In addition to GeoTIFF and HDF5 formats, KMZ and various specialty formats are supported. Figure 10 shows a KMZ-formatted Unwrapped interferogram in Google Earth.
Interferogram Interpretation

The interferometric phase carries a wealth of information about surface deformation (strength and direction of motion) and the location of the surface rupture. The phase map is also a proxy for other earthquake-related parameters such as the energy released during an event and the amount of shaking experienced across the affected area.

Unwrapped results should be interpreted as a relative height/displacement between two pixels. To obtain absolute estimates, a tie point can be used in the unwrapped phase to height operation.

Figure 10: Geocoded Kumamoto Unwrapped Phase projected onto Google Earth. Contains modified Copernicus Sentinel data (2016) processed by ESA
G) Sample Images

Wrapped Phase

Unwrapped Phase
H) Extended Reading List


