# Sentinel-1 InSAR Phase Unwrapping using S1TBX and SNAPHU

Adapted from the European Space Agency's STEP community platform

## In this document you will find:



## A) System Requirements

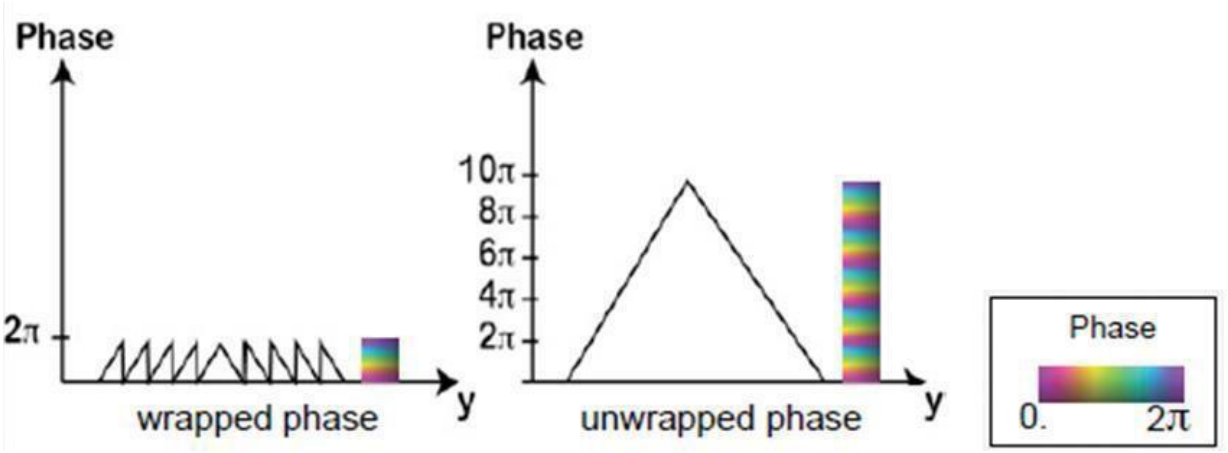
Many of the steps take a very long time to process. We recommend the following:

- 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 generated in that recipe, which in turn allows height values to be derived from the product. Phase unwrapping is the most complicated stage of interferometric data processing.

Here, we will be 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 2π. 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 2π 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 2π phase cycles), the phase variation between two points on the flattened interferogram provides a measurement of the actual altitude variation.

## C) Materials List

- Linux Virtual Machine

  Windows users have several options to access a Linux machine:

  - Download a virtual machine (VM) software such as VirtualBox or VMware.
  - Download a Operating System such as LinuxMint.
  - Launching an Amazon EC2 Linux Instance through Amazon Web Services (AWS).
- Sentinel-1 Toolbox (S1TBX).
- SNAPHU Algorithm for Phase Unwrapping (See Step 3)
- InSAR Data (continuation from the InSAR data recipe), including the coherence band for your interferogram.

# D) Pre-Unwrapping Steps

This data recipe assumes that you have already generated an interferogram, if not the graph below shows the pre-unwrapping steps.

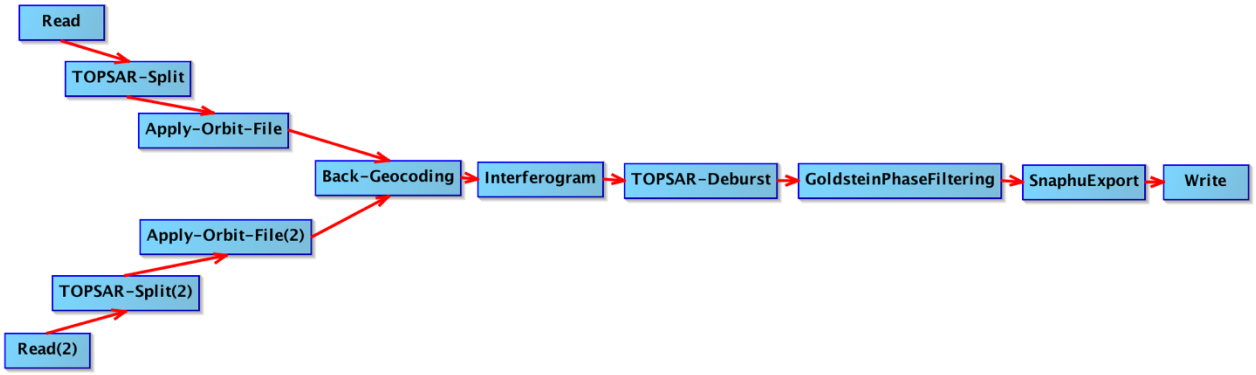



*Figure 1: **Pre-unwrapping** Interferogram Formation steps.*

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. **Note that when performing the multi-look process for data that will be used for phase unwrapping, the coherence band (coh) must be included along with the "i" and "q" bands.**

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

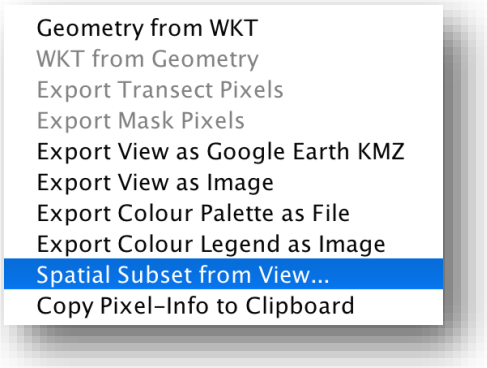
## Step 1 - Open Your Interferogram in S1TBX

- 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 (Figure 2).

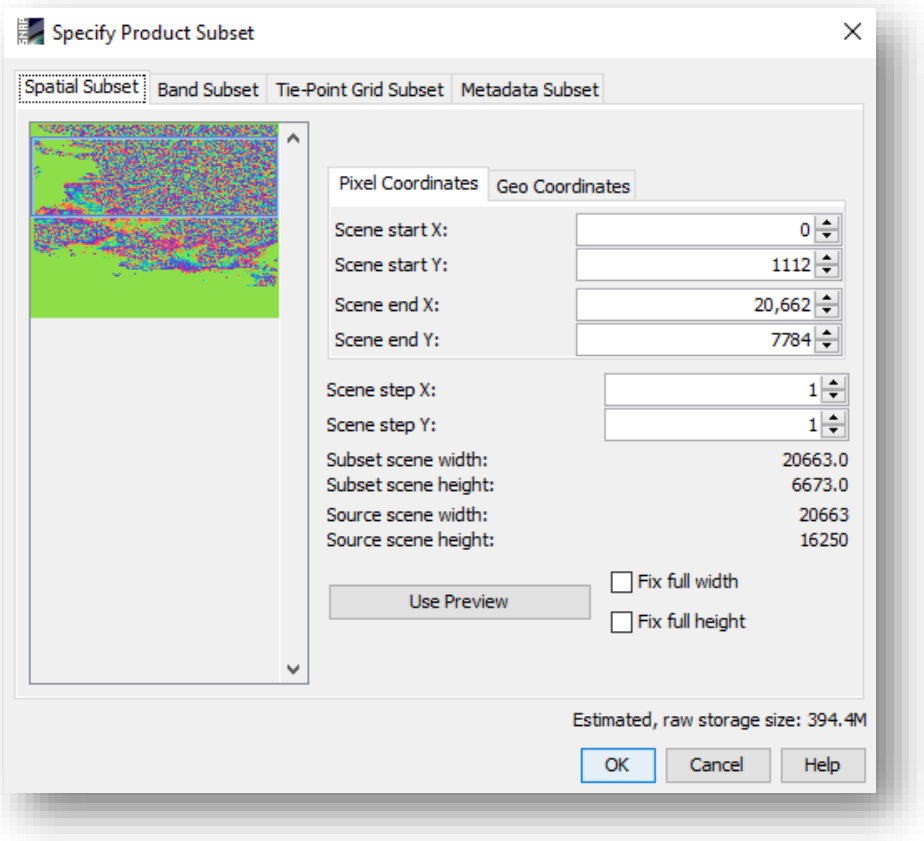



***Figure 2: Specifying a Product Subset***

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.

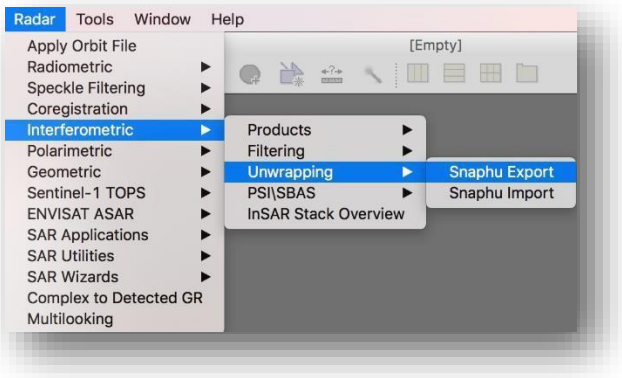
When the new subset product appears in the products view:

- 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 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
  - 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

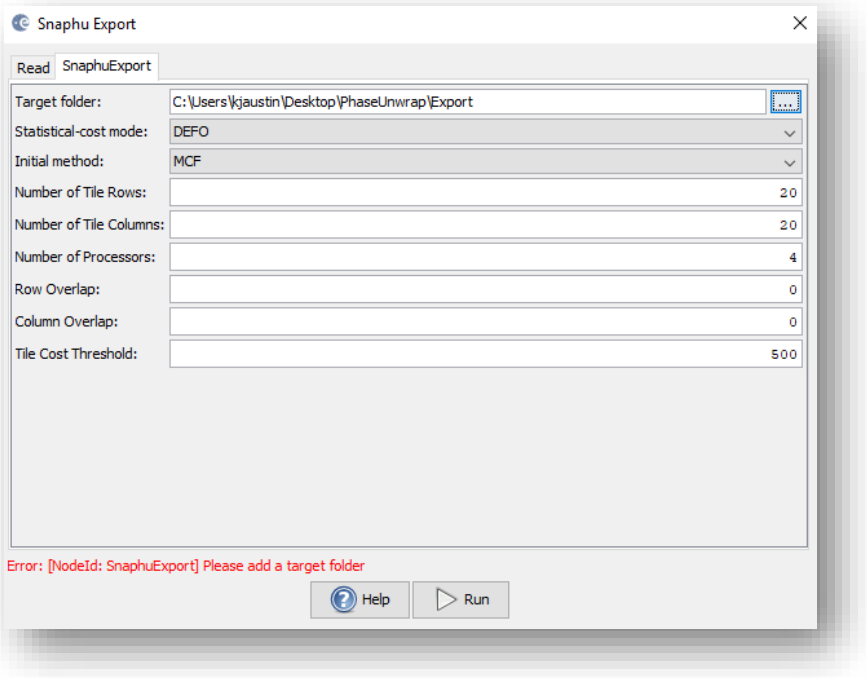



***Figure 3: SNAPHU Export***

# E) Install and open a Virtual Machine (VM)

## Step 4 - Install and open a Linux VM

If you do not have a Linux OS, you will need to install a Linux VM to operate SNAPHU (see Section C: Materials List).

## Step 5 - Transfer in the SNAPHU Export files

Zip the newly generated SNAPHU Export files and move them to a shared folder so it is accessible in your VM for unwrapping. Approaches include:

- Place files in Google Drive or Dropbox on your PC, and download them in your VM.
- Email the files to yourself and retrieve them in your VM.

# F) Unwrapping with SNAPHU

SNAPHU is a Statistical-cost, Network-flow Algorithm for Phase Unwrapping developed at Stanford University by Curtis Chen and Howard Zebker, and is available for Linux only. VM users need to start their Linux VM and open the command line in that environment. Linux users simply need to open a command line and follow the steps. Run the following commands from each step:

## Step 6 - Install SNAPHU

Install the software by typing the following command in the command line and hit Enter:

```
apt-get install snaphu
```

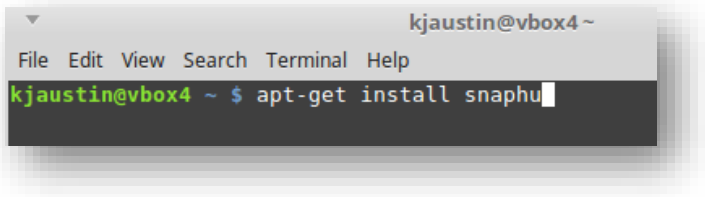



***Figure 4. At the Linux command line, install SNAPHU.***

If a user is not granted root access (the *install snaphu* command results in an Access error), use the following command, which will then prompt for the user's password for Linux (or the Linux VM) and allow the user the elevated privileges required for installing the software:

```
sudo apt-get install snaphu
```

## Step 7 - Display the SNAPHU config file

**Make sure you are in the same directory as the 'snaphu.conf' file**

- Open or **<cd>** to the SNAPHU Export data folder 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
```

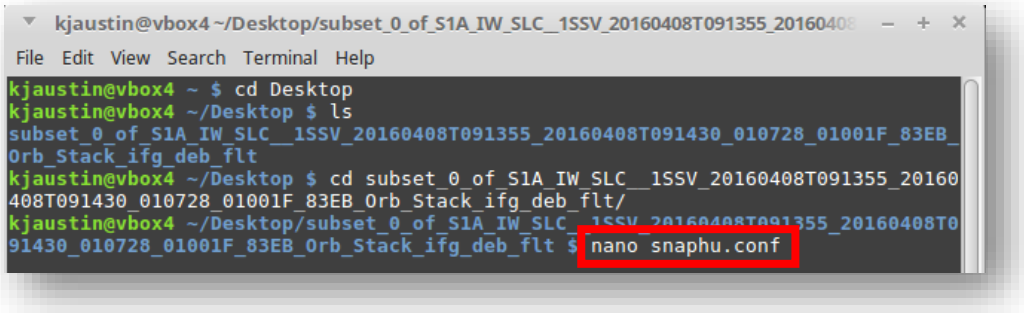



***Figure 5. Display the SNAHPU config file***

## Step 8 – Obtain the *Call to Command SNAHPU* within the config file

Highlight and copy the *Command to call snaphu*, to exit the config file type **CrtlˆX**

```
snaphu –f snaphu.conf YOUR_PHASE_BAND.snaphu.img XXXX
```

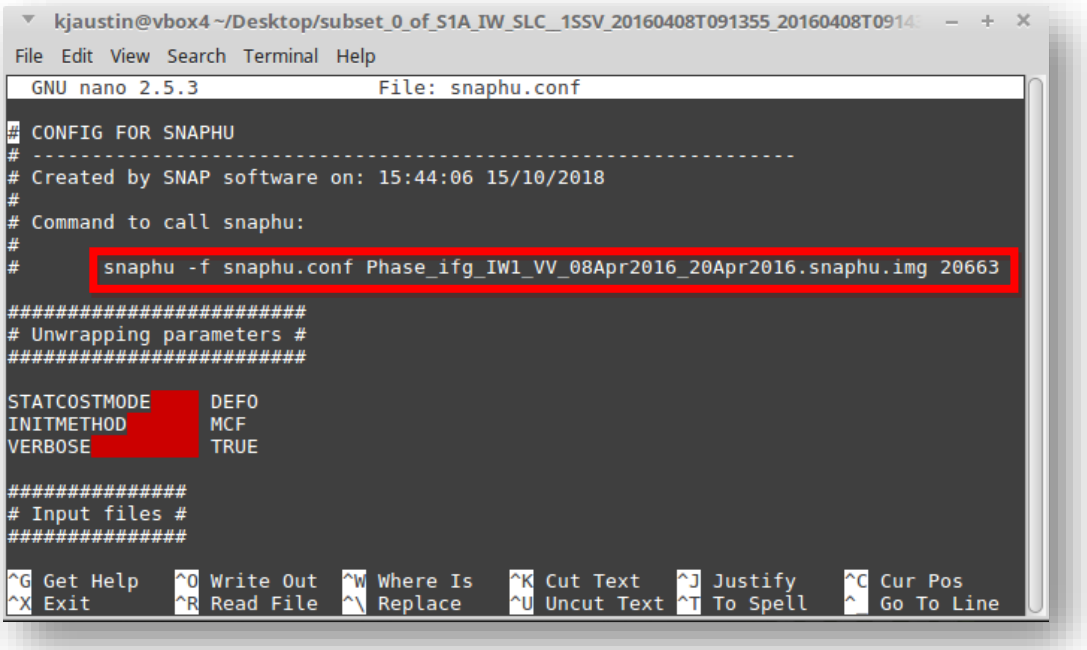



***Figure 6: SNAPHU Configuration File Contents***

## Step 9 - Run the Command:

**Paste** the command into the command terminal and hit **Enter:**

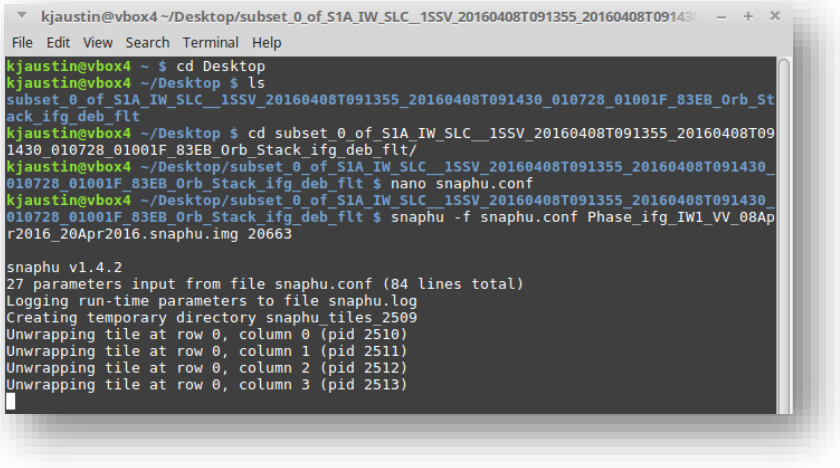



***Figure 7: SNAPHU Output***

**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.

## Step 10 – Make output files available to S1TBX

Zip and move the files from the VM to your PC, then download them so they are accessible to S1TBX.

- On your desktop, check the .hdr and .img filenames for a possible mismatch
    - A bug may cause a filename and contents mismatch between the .hdr and .img files
    - Mismatched filenames and contents will cause recipe failure
    - If this happens see the Defect Warning and Work around section below

## Optional - Defect Warning and Work around

**Work around:** If the polarization in the .hdr filename does not match the .img filename, edit the .hdr filename and contents to match the .img filename and contents polarization. Example below:

- **Edit the .hdr filename** polarization to match the .img filename polarization:

UnwPhase_ifg_IW1_VH_20Jul2015_01Aug2015.snaphu.hdr

- **To match** the .img file name:

  UnwPhase_ifg_IW1_VV_20Jul2015_01Aug2015.snaphu.img

- **To get this:**

  UnwPhase_ifg_IW1_VV_20Jul2015_01Aug2015.snaphu.hdr

- **Edit the .hdr contents** polarization to match the polarization of the .img file.

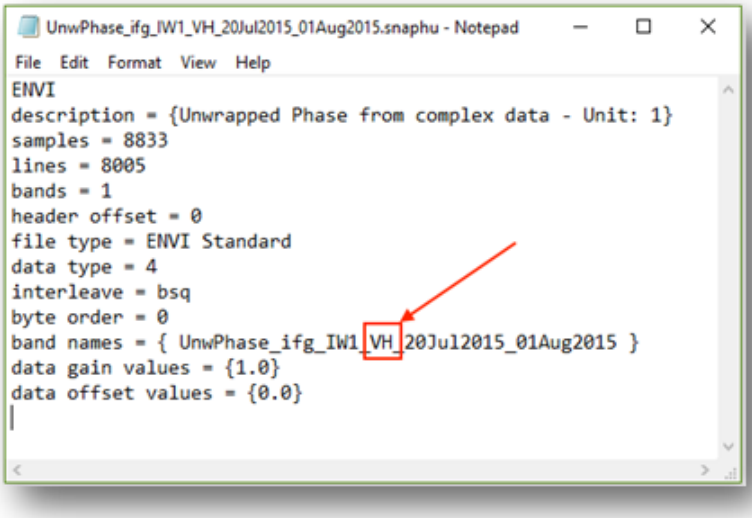
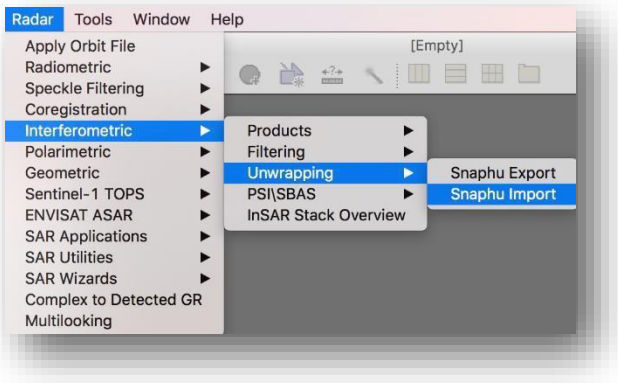



***Figure 8. Edit the .hdr file polarization (VH) to match the .img polarization (VV).***

# G) 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 11 – 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

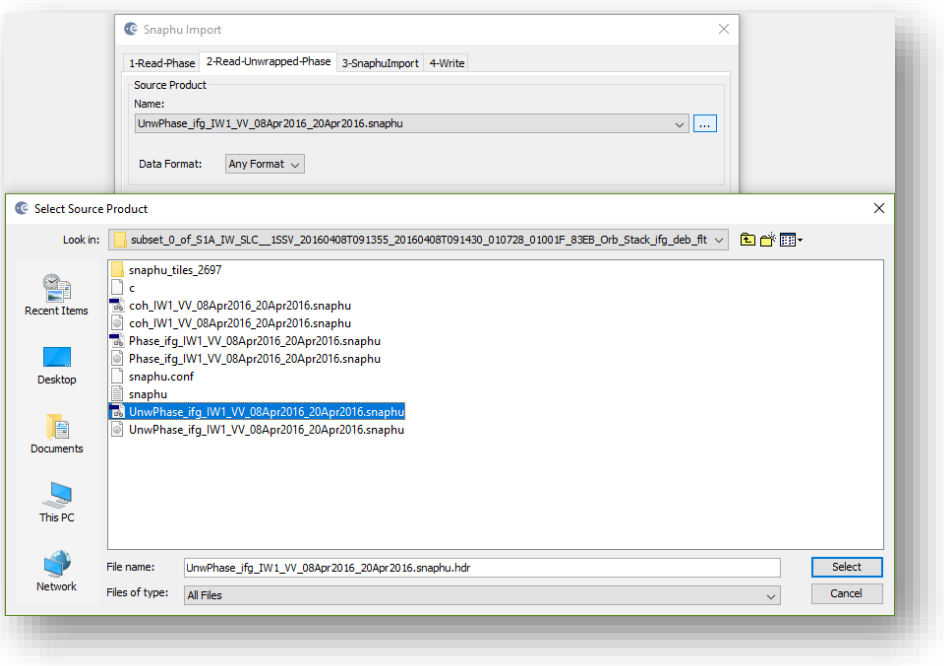



***Figure 9: SNAPHU Import –Select Unwrapped Phase Product***

## Step 12 – Geocoding

At this point, you may view your Unwrapped Phase product (Figure 10). 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.

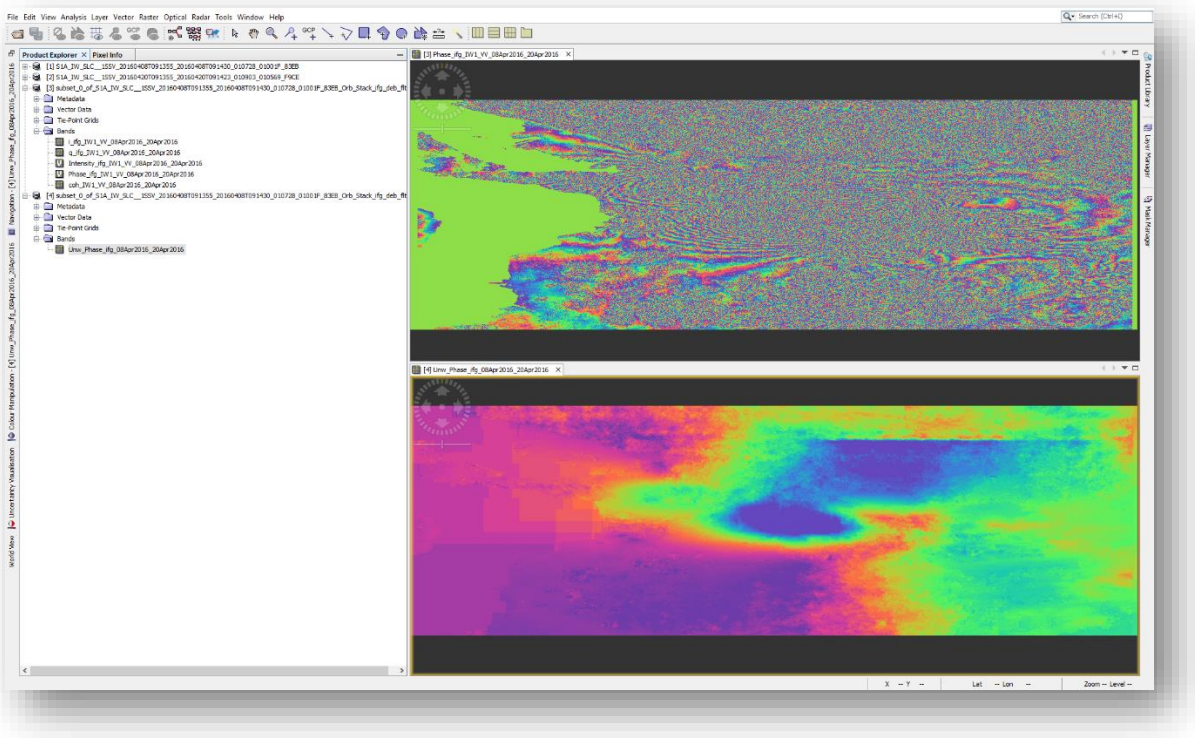
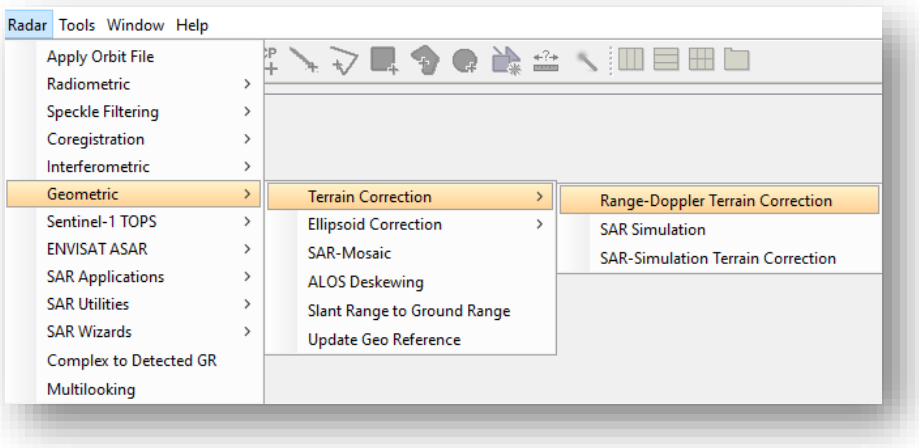


***Figure 10: Unwrapped and Wrapped Phase***

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




In the **Range-Doppler Terrain Correction** window (Figure 11), select the Unwrapped Phase product you just imported from SNAPHU.

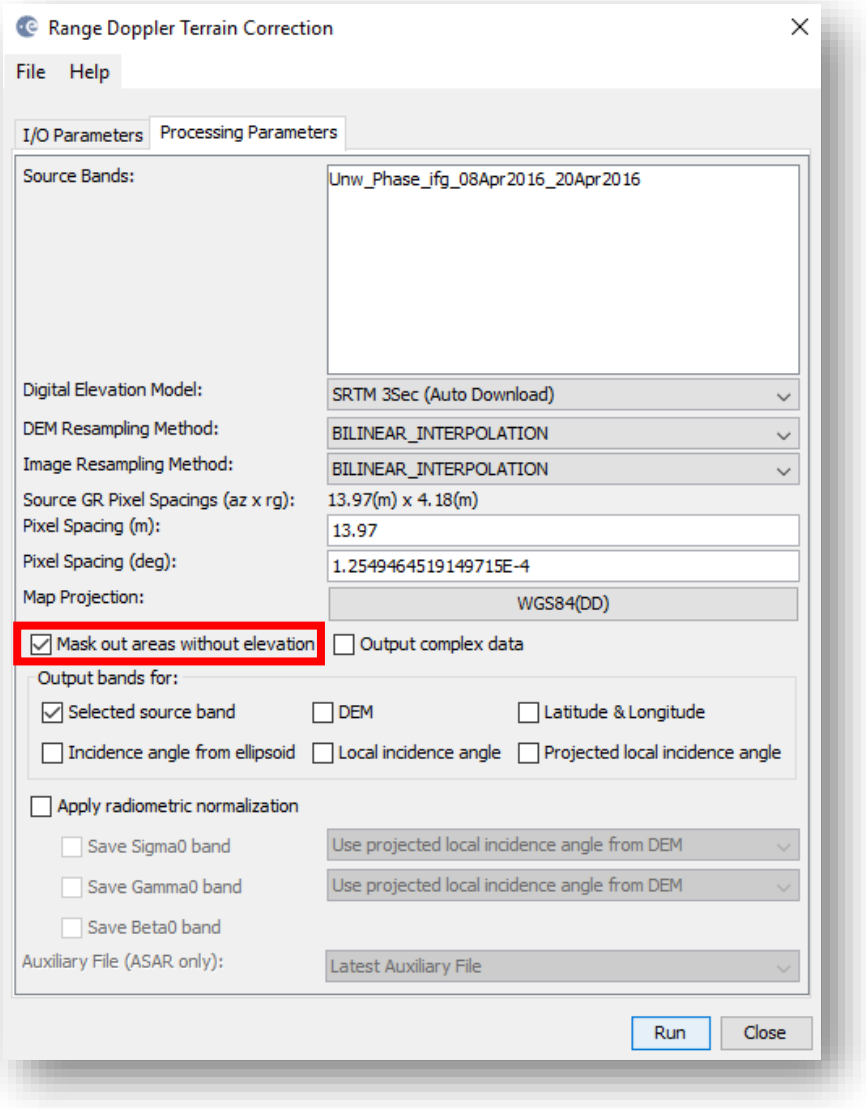



***Figure 11: Range Doppler Terrain Correction***

In the **Processing Parameters** tab:

- Select the option to **Mask out areas with no elevation**, of desired
- Change pixel spacing, if desired
- Leave all other parameters as **default**
- Click **Run** to geocode your data

The resulting product name is appended with _**TC**.

See Figure 12 below for the resulting geocoded wrapped and unwrapped interferograms.

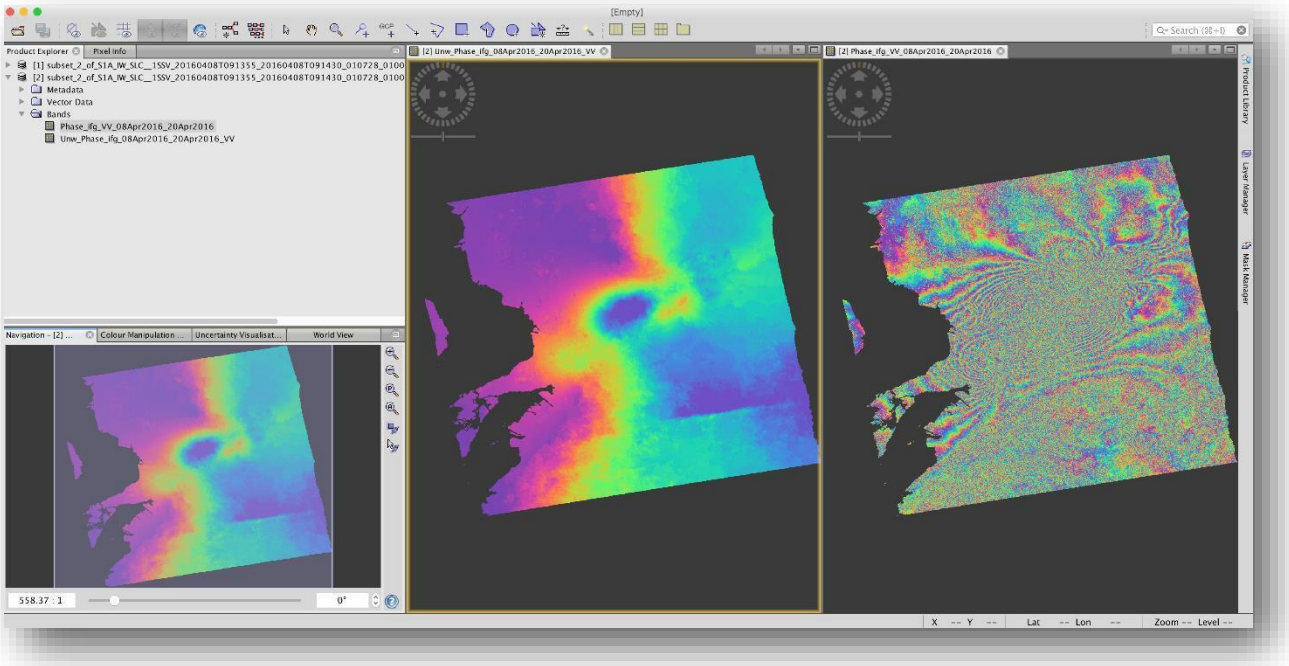


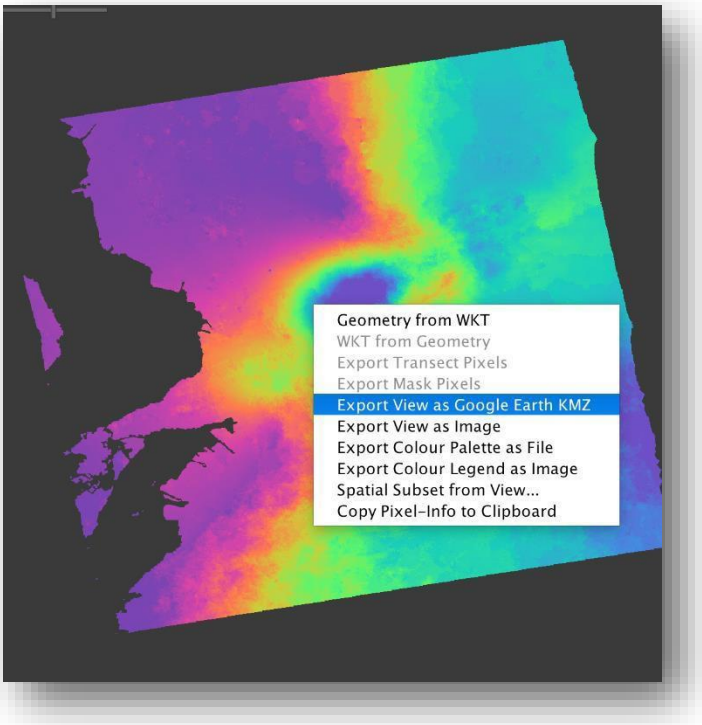
***Figure 12: Geocoded Wrapped and Unwrapped Phase***

## Step 12 – 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 13 shows a KMZ-formatted unwrapped interferogram in Google Earth.



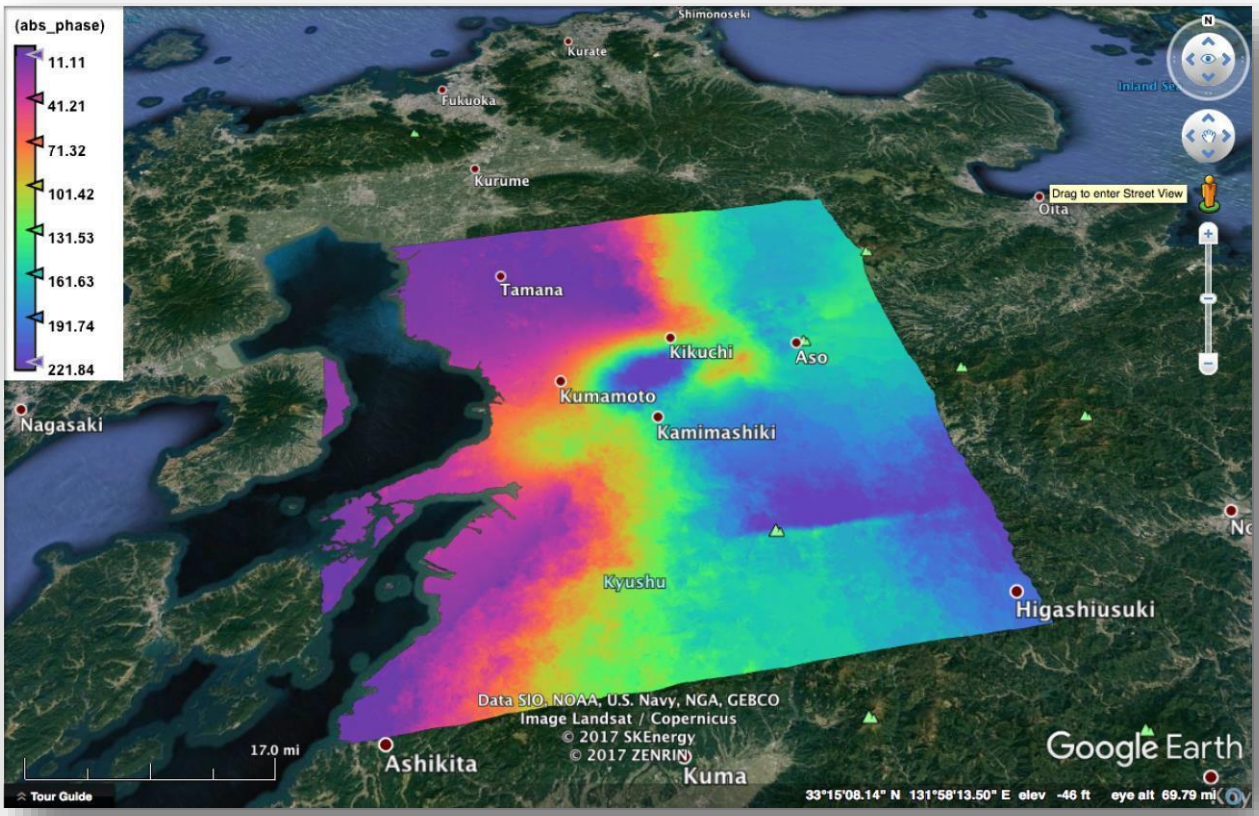


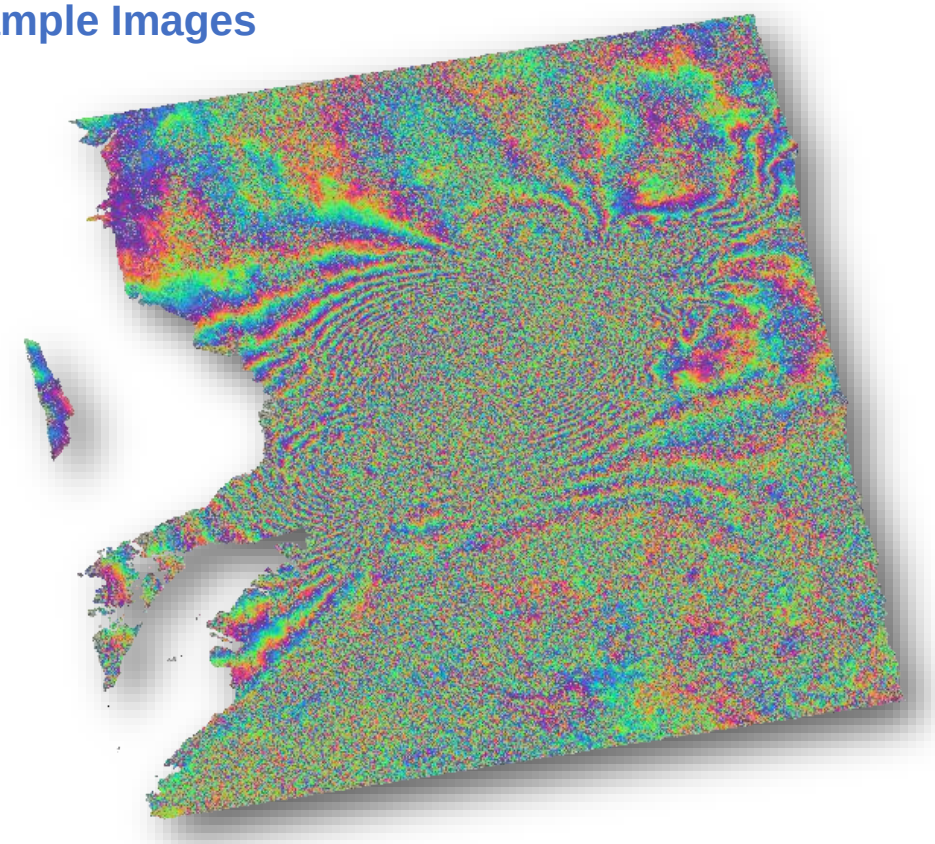

***Figure 13: Geocoded Kumamoto Unwrapped Phase projected onto Google Earth. Contains modified Copernicus Sentinel data (2016) processed by ESA***

## Interferogram Interpretation

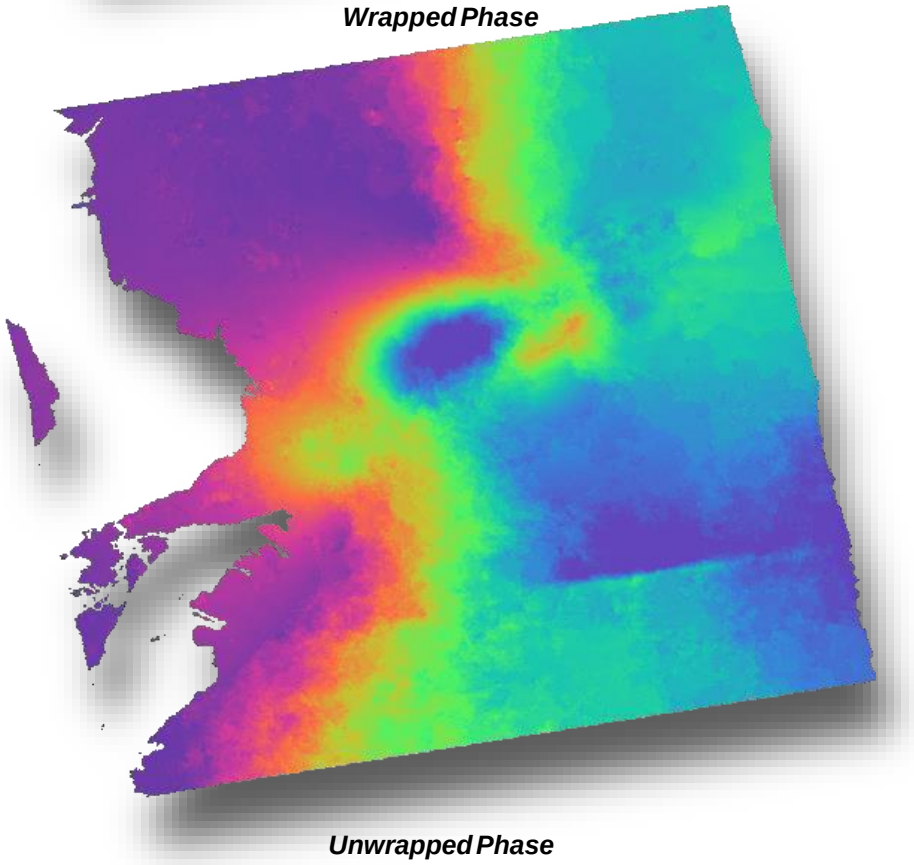
The interferometric phase carries a wealth of information about surface deformation (strength and direction of motion) and the location of the surface rupture. The phase map is also a proxy for other earthquake-related parameters such as the energy released during an event and the amount of shaking experienced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

## H) Sample Images



***Wrapped Phase***



***Unwrapped Phase***

# I) Extended Reading List


Akerson, J. J., Yang, Y. C. E., Hara, Y., Wu, B. I. and Kong, J. A., 2000. Automatic phase unwrapping algorithms in Synthetic Aperture Radar (SAR) Interferometry. *IEICE Transactions on Electronics,* **E83C** (12) :1896-1904.

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Fu, S. H., Long, X. J. and Yang, X., 2010. Coherence estimation method and its application to phase unwrapping. *Journal of Applied Remote Sensing,* **4** (5) .

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Ghiglia, D. C. and Romero, L. A., 1996. Minimum L(p)-norm two-dimensional phase unwrapping. *Journal of The Optical Society of America A-Optics Image Science and Vision,* **13** (10) :1999-2013.

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Goldstein, R. M., Zebker, H. A. and Werner, C. L., 1988. Satellite Radar Interferometry - Two-Dimensional Phase Unwrapping. *Radio Science,* **23** (4) :713-720.

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Wei, Z. Q., Xu, F. and Jin, Y. Q., 2008. Phase unwrapping for SAR interferometry based on an ant colony optimization algorithm. *International Journal of Remote Sensing,* **29** (3) :711-725.

Yang, Lei, Liu, Wei and Zhao, Yong-jun, 2007. Branch - cut strategy analyses in phase unwrapping algorithm for interferometric SAR. *Science of Surveying and Mapping,* **37** (1) :75-7.

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