How to create a DEM from Sentinel-1 Data

Source: Adapted from the STEP Community Forum and ASF staff data recipes

In this document you will find:

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A) Background

This recipe allows the user to create a Digital Elevation Model (DEM) product from two Sentinel-1 SLC scenes. The user first creates an interferogram, and completes the appropriate phase unwrapping steps, then creates the DEM.

Pair Selection for DEMs

ASF's baseline tool may be used to select a pair of Sentinel images to create the DEM. The baseline tool can be accessed as a stand-alone tool, or via a Vertex search. The optimum pair for DEM creation would have a large perpendicular baseline and a small temporal baseline.

More details for pair selection

Overlap is required. Pairs must be of the same path number and must cover the same area. Images with different flight directions (ascending vs descending) cannot serve as pairs for interferometry.

Coherence is key. You need to pick a pair that has the least temporal baseline possible. This not only minimizes the coherence loss, it also minimizes any potential ground motion. The longer the time between images the higher the decorrelation.

Baseline cannot be ignored. Interferogram sensitivity to the perpendicular baseline is such that a large baseline improves the InSAR's sensitivity to height variations. So, from that perspective larger baselines are better than smaller. However, as the baseline increases, the coherence decreases. Image alignment is problematic if the perpendicular baseline between images is greater than about 3/4 of the critical baseline because the images will be baseline decorrelated. The critical baseline for S1A is about 5 KM.

Tradeoffs of DEMs created with Sentinel's C-Band

On the down side, C-band doesn't penetrate vegetation. This means that DEMs derived from C-band don't actually measure the earth's surface, rather they show the top of the canopy. In contrast, an L-band radar with a long wavelength as found on ALOS, can penetrate vegetation. L-band radar receives a reflected wave from the ground and is coherent even in a forest area. C-band has lower coherence than L band because of the vegetative decorrelation. These effects make it more difficult to make accurate DEMs from Sentinel-1's C-band than from ALOS's L-Band.

On the other hand, Sentinel has excellent temporal coverage, meaning that the temporal decorrelation is lower than with previous sensors. Sentinel should be excellent for creating DEMs of barren land or urban areas. However, beware of DEMs created over vegetated areas, especially in the spring during blooming season.

B) Materials List

A. Sentinel-1 Toolbox (S1TBX v6.0.0)
B. Snaphu (SNAPHU v1.4.2)
C. ASF's **Generate InSAR Processing with Sentinel-1 Toolbox** data recipe
D. ASF's **InSAR Phase Unwrapping** data recipe
E. Linux –
   Windows users can:
   a. Download a Linux virtual machine (VM) or
   b. Use an Amazon EC2 Linux Instance
F. Sample granules
   a. S1A_IW_SLC__1SDV_20150720T203442_20150720T203512_006899_009522_4E7A
   b. S1A_IW_SLC__1SDV_20150801T203443_20150801T203513_007074_009A02_3CD7

C) Steps

1. **Follow steps below from the "Sentinel-1 InSAR Processing using the Sentinel-1 Toolbox" Recipe**

   Note that Steps 7 & 8 are deliberately omitted.

   Step 1 – Open the Products
   Step 2 – View Products
   Step 3 – View a Band
   Step 4 – Co-register the images
   Step 5 – Form the Interferogram
   Step 6 – TOPS Deburst
   Step 9 – Phase Filtering

2. **Follow the steps below from the "Sentinel-1 InSAR Phase Unwrapping using S1TBX and SNAPHU" Recipe**

Step 1- Open your Interferogram in S1TBX

Open the wrapped interferogram file. Use the file ending Orb_Stack_ifg_deb_flt.dim.

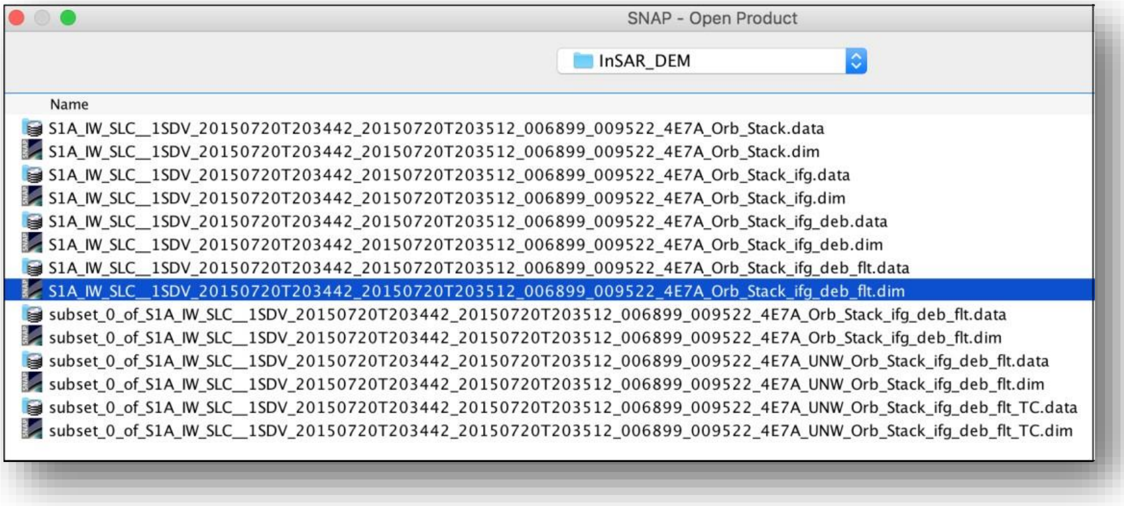

Figure 1. Open the file ending Orb_Stack_ifg_deb_flt.dim.

Step 2 – Create a Subset (Optional)

Creating a subset can significantly speed up processing.

3. **Export to SNAPHU**

Export your interferogram or your subset interferogram from S1TBX to SNAPHU

a. In S1TBX navigate to Radar/Interferometric/Unwrapping/Snaphu Export

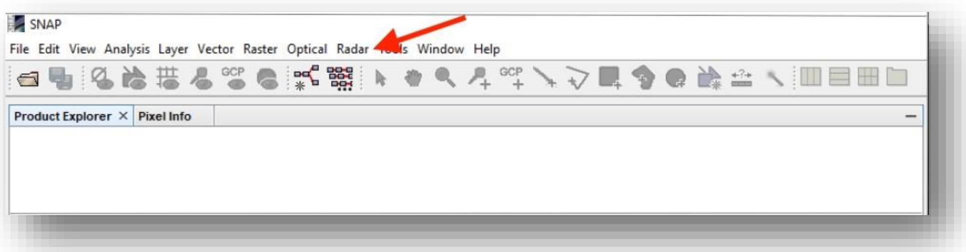

Figure 2. In S1TBX, select Radar.

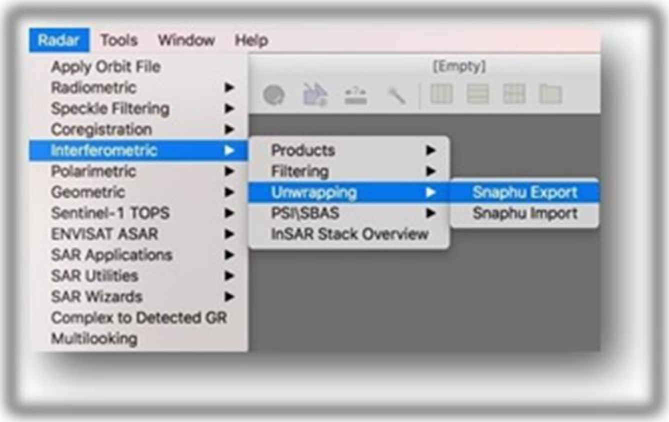

Figure 3. Select Interferometric/Unwrapping/Snaphu Export.

In the Snaphu Export window (Figure 4):

b. Create a new folder for this step by entering a path and new folder name
   i. Type the folder directory in the Target Folder box.
   ii. This recipe will call the folder *SNAPHU_Export*
c. Select **TOPO** mode for DEM generation
d. Select **MCF**
e. Change the values of **Tile Rows** and **Tile Columns** to 20
f. Click **Run** to create the *SNAPHU_Export* folder
   a. The folder now holds files used for phase unwrapping

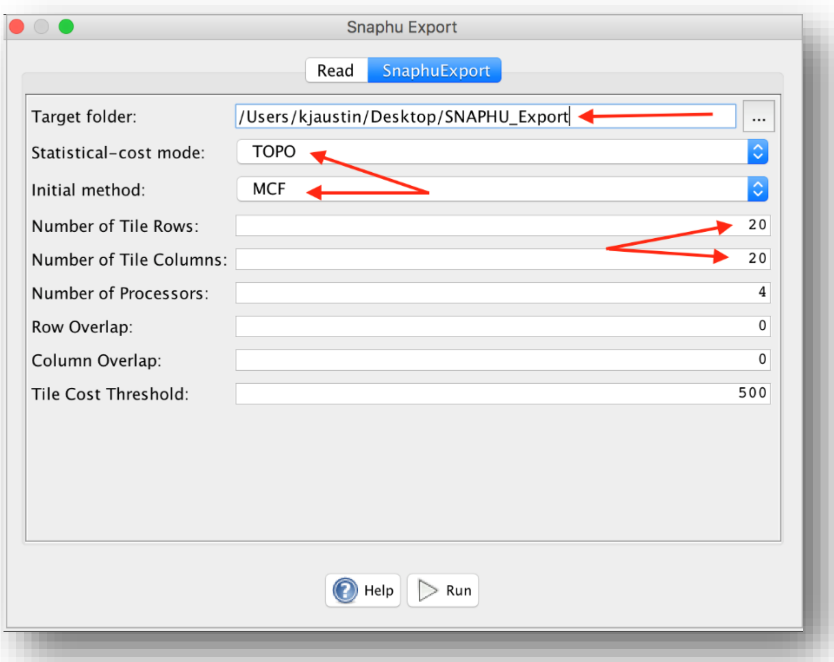

Figure 4. Enter folder name, TOPO, MCF, and change row and column values to 20.

4. **Install a [Linux VM](#) so you have a place to put the SNAPHU Export folder files in Step 6a. below.**

5. **Zip and move SNAPHU Export files to make them accessible to SNAPHU software on Linux**
   a. One way is to place files in Google Drive and download them to Linux
   b. Another method is to email them to yourself and retrieve in Linux.

6. **Unwrap Interferogram with SNAPHU**

   SNAPHU is the 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 Linux only. The user needs to install SNAPHU on the [Linux VM](#).

   a. **Install SNAPHU**

   At the Linux command line, install SNAPHU:

   ```
   $ apt-get install snaphu
   ```

   ```
   [jlaurenc@gwa ~]$
   [jlaurenc@gwa ~]$
   [jlaurenc@gwa ~]$
   [jlaurenc@gwa ~]$
   [jlaurenc@gwa ~]$ apt-get install snaphu
   ```

   Figure 5. At the Linux command line, install SNAPHU.

   b. **Display the SNAPHU config file**

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

   At the Linux command line, display snaphu.conf by pasting the below command

   ```
   $ nano snaphu.conf
   ```

   ```
   [jlaurenc@gwa ~]$
   [jlaurenc@gwa ~]$
   [jlaurenc@gwa ~]$
   [jlaurenc@gwa ~]$
   [jlaurenc@gwa ~]$ nano snaphu.conf
   ```

   Figure 6. Display the SNAPHU configuration file

c. **Copy the command from the config file**

```
 GNU nano 2.5.3                File: snaphu.conf

# CONFIG FOR SNAPHU
# ------------------------------------------------------------------
# Created by SNAP software on: 16:49:42 08/08/2017
#
# Command to call snaphu:
#
#       snaphu -f snaphu.conf Phase_ifg_VV_08Apr2016_20Apr2016.snaphu.img 6887

#########################
# Unwrapping parameters #
#########################

STATCOSTMODE      DEFO
INITMETHOD        MCF
VERBOSE           TRUE

###############
# Input files #
###############

CORRFILE                coh_IW1_VV_08Apr2016_20Apr2016.snaphu.img

################
# Output files #
################

OUTFILE                 UnwPhase_ifg_VV_08Apr2016_20Apr2016.snaphu.img
LOGFILE                 snaphu.log

^G Get Help  ^O Write Out ^W Where Is  ^K Cut Text  ^J Justify   ^C Cur Pos
^X Exit      ^R Read File ^\ Replace   ^U Uncut Text^T To Spell  ^_ Go To Line
```

Figure 7. Copy the command in the red box. Ctrl + X to exit the config file.

d. **Use Ctrl + X to exit the config file**

e. **Run the command you copied to unwrap your interferogram**

In the same directory, paste the command at the Linux command line and Enter.

```
ubuntu@ip-172-31-4-255:~$ snaphu -f snaphu.conf Phase_ifg_VV_08Apr2016_20Apr2016
.snaphu.img 6887

snaphu v1.4.2
27 parameters input from file snaphu.conf (84 lines total)
Logging run-time parameters to file snaphu.log
Creating temporary directory snaphu_tiles_8349
Unwrapping tile at row 0, column 0 (pid 8351)
Unwrapping tile at row 0, column 1 (pid 8352)
Unwrapping tile at row 0, column 3 (pid 8354)
Unwrapping tile at row 0, column 2 (pid 8353)
```

Figure 8. Paste the command and hit Enter.

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 of the InSAR Phase Unwrapping data recipe and try again).

f. Zip and move the files from the VM to your PC or Mac, so they are accessible to S1TBX

g. On your desktop, check your .hdr and .img filenames for a possible mismatch

a. A bug may cause a filename and contents mismatch between the .hdr and .img files
b. Mismatched filenames and contents will cause recipe failure
c. If this happens see the **Defect Warning and Workaround** section below

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Defect Warning and Workaround

Workaround: 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.

For example:

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

UnwPhase_ifg_IW1_VH_20Jul2015_01Aug2015.snaphu.hdr

To match .img filename

UnwPhase_ifg_IW1_VV_20Jul2015_01Aug2015.snaphu.img

To get this

UnwPhase_ifg_IW1_VV_20Jul2015_01Aug2015.snaphu.hdr

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

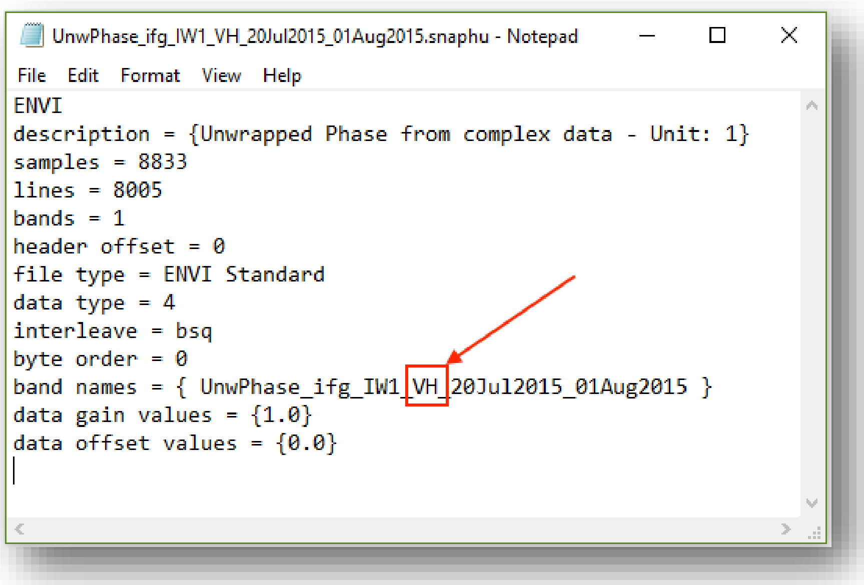

Figure 9. Edit the .hdr file polarization(VH) to match the .img polarization (VV).

7. **Open the files in S1TBX**

   Import your wrapped and unwrapped interferograms into S1TBX

   a. **In S1TBX, navigate to Radar/Interferometric/Unwrapping/Snaphu Import**

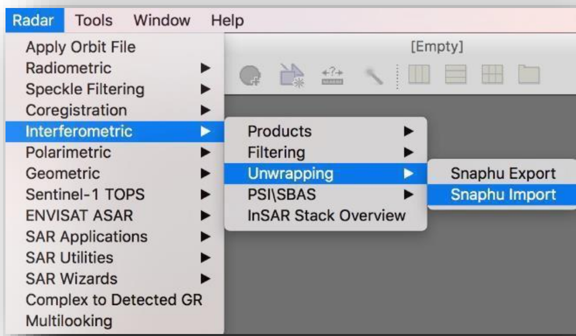

Figure 10. Navigate to Snaphu Import.

   b. In the **1-Read-Phase tab**, select your **wrapped** interferogram product. This is the same file you exported to SNAPHU. Filename will end in Orb_Stack_ifg_deb_flt.dim. If you subset, it will also start with 'subset'.

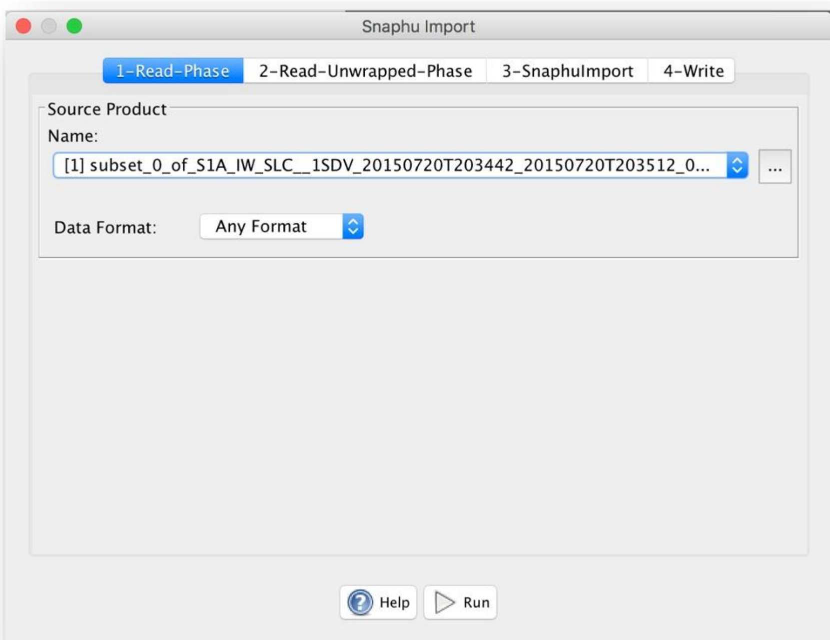

Figure 11. Browse to your wrapped interferogram and select it. File name will end in Orb_Stack_ifg_deb_flt.dim*.*

c. In the **2-Read-Unwrapped-Phase** tab

Navigate to your SNAPHU Export folder and browse to the **UnwPhase……..hdr file.** See **Defect and Workaround** below in case of an error.

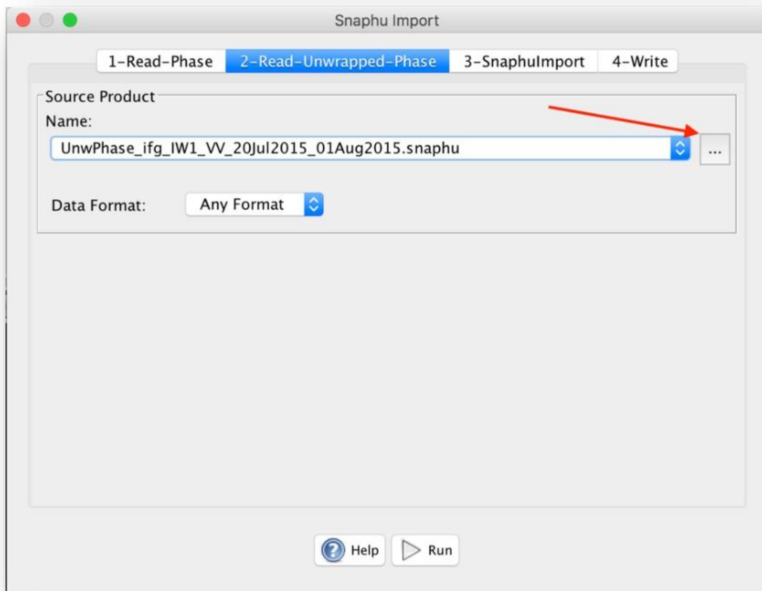

Figure 12. Browse to your ***unwrapped*** *.hdr file.*
Note the .hdr extension will not be displayed in this window after selection.

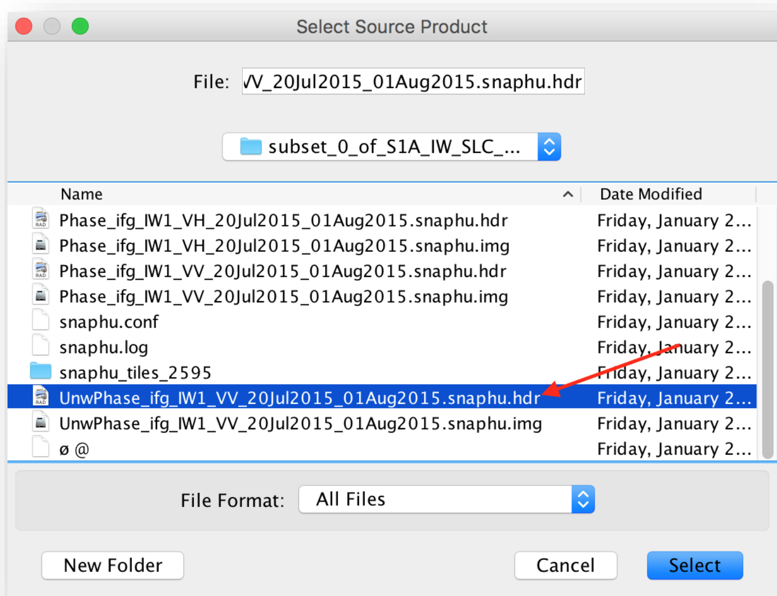

Figure 13. Select the UnwPhase…hdr file.

In Case of Error Message

Error messages: “No matching Envi image for header file.” Or “Header file could not be read.”

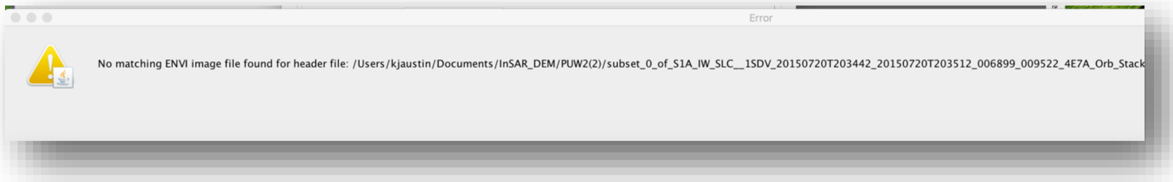

Figure 14. Error message that is thrown if file names or contents are mismatched.

In some cases .hdr filenames and files contain the incorrect polarization. If this happens the import will fail because the .img file will not have a matching .hdr file.

Please scroll up to the **Defect Warning and Workaround** instructions.

d. In the **3-SnaphuImport** tab

Running Snaphu Import will overwrite your file.
To create a new file instead, check the **Do NOT save Wrapped Interferogram in the target product** option.

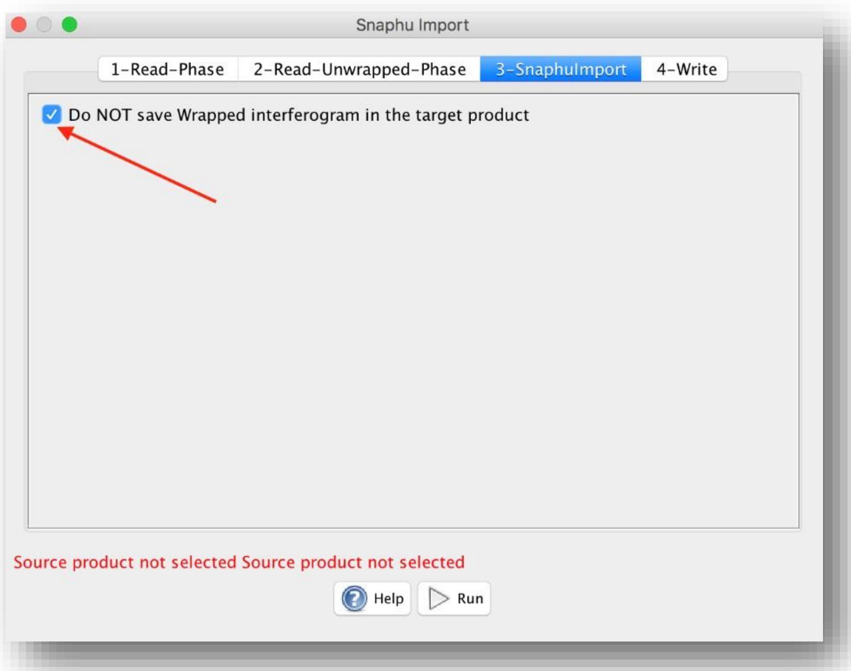

Figure 15. Check the box.

e. In the **4-Write** tab

Values will auto-fill.

Edit (add text) to create a unique file name.

We added 'UNW' to indicate unwrapped.

Click **Run.**

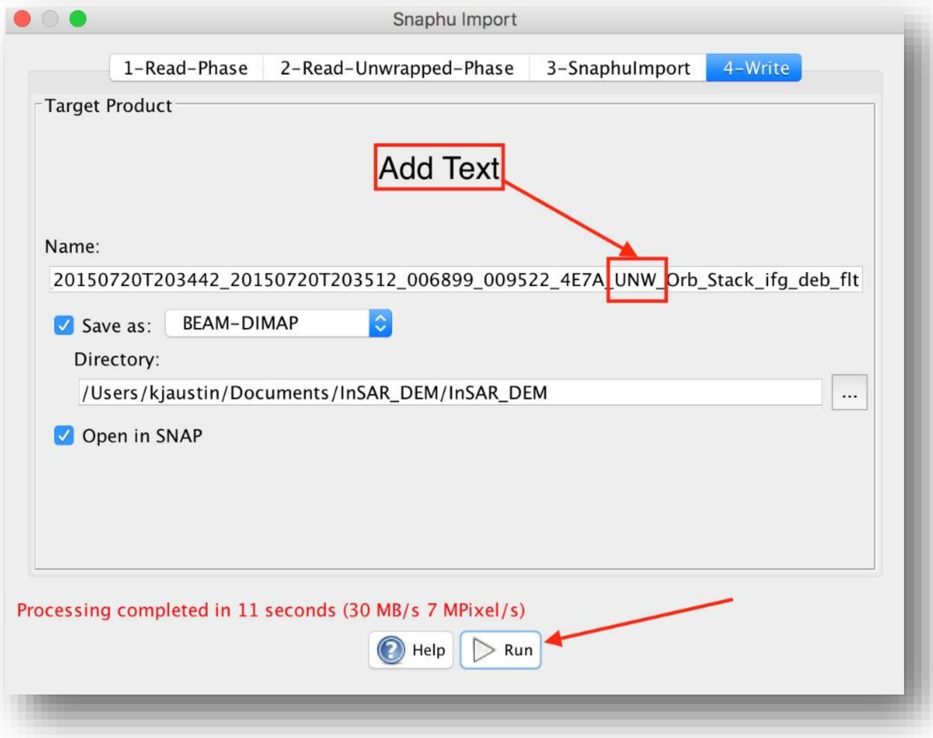

Figure 16. Add text to create a unique file name. Click Run.

8. **Create the DEM - Convert Phase to Elevation**

This step converts the interferometric phase to a digital elevation map (DEM).

a. In S1TBX, in the Radar tab, select Interferometric/Products/Phase to Elevation.

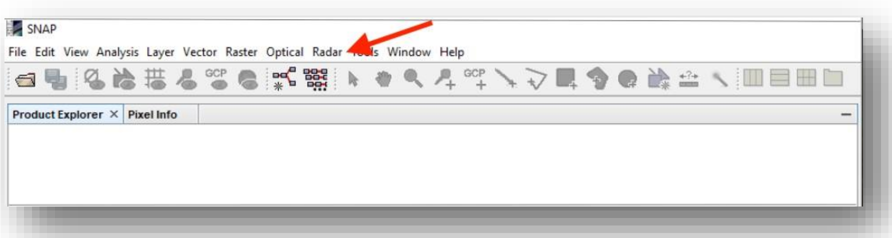

Figure 17. SNAP S1TBX menu. Select Radar.

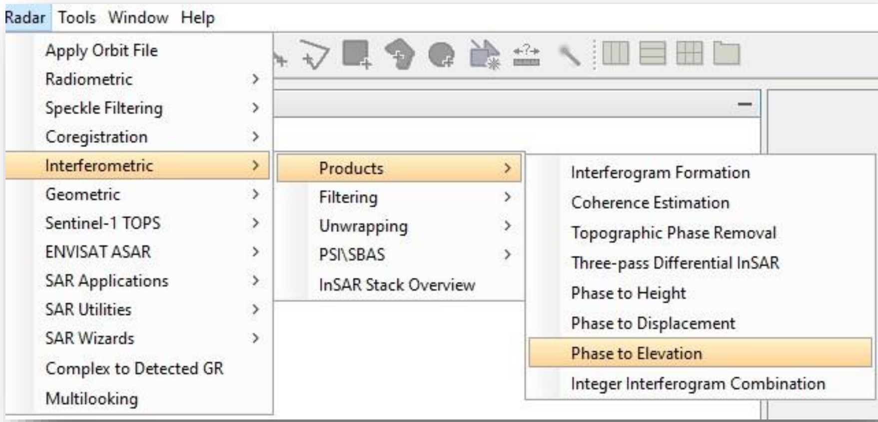

Figure 18. Select Phase to Elevation.

b. Enter the unwrapped interferometric product filename in Source Product, source:

i. Use the file you added the 'UNW' text to in Step 7e. (Figure 19)

ii. The Target Product Name, your DEM final product, will automatically populate

iii. Edit the Directory the product will appear in, if desired.

Figure 19. Select the file you added 'UNW' to, your unwrapped interferogram.

c. Click **Run**

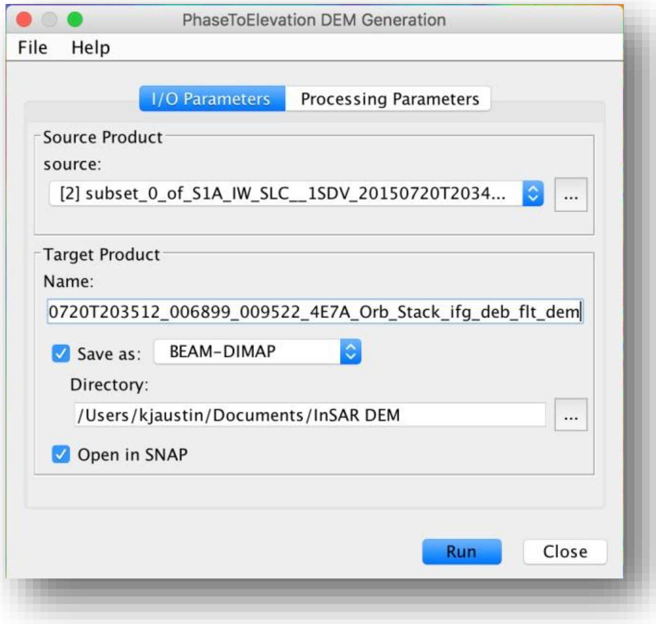

*Figure 20. Click **Run** to create a DEM.*

d. You now have a DEM file called *yoursourcefilename_dem*

9. Geocode the DEM

a. From the Radar menu, select Geometric/Terrain Correction/Range Doppler Terrain Correction.

i. ***Note:*** This correction method uses available orbit state vector information in the metadata, the radar timing annotations, the slant to ground range conversion parameters together with the reference DEM data to derive the precise geolocation information.

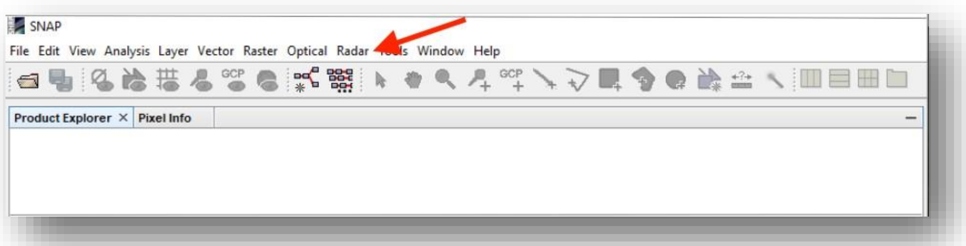

Figure 21. SNAP S1TBX menu. Select Radar.

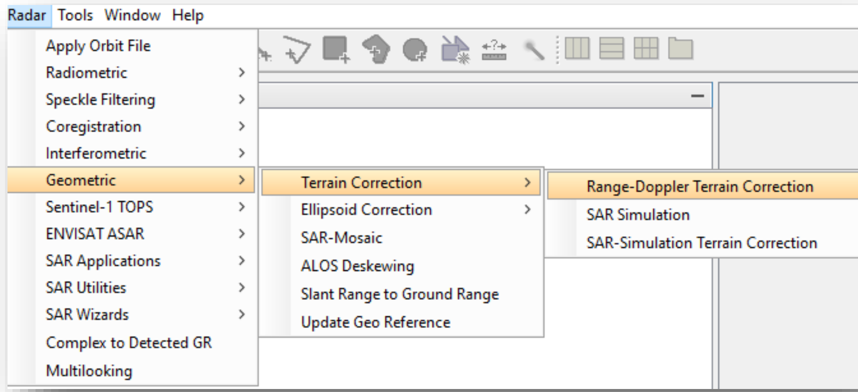

Figure 22. Select Range-Doppler Correction

b. Without changing any values, click **Run**.

Figure 23. Click Run.

D) The DEM product

- Double-click the resulting *_TC* product
  - Double-click on *Bands*
    - Then double-click on the *Unw_Phase_ifg_20Jul2015_01Aug2015_VH* file

The image of your DEM will appear.
You now have a geocoded terrain-corrected DEM called *yoursourcefilename_TC.*

Completed DEM

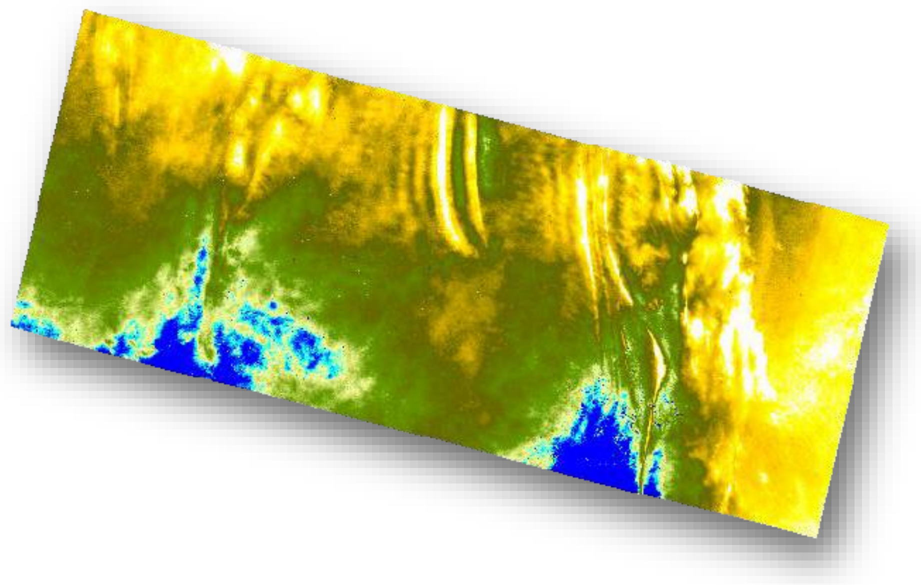

Figure 24. The complete geocoded terrain-corrected Sentinel-1 DEM