**Automated Sentinel-1A/B InSAR Processing Using GMT5SAR on the Summit Supercomputer and GIAnT for Time-Series**

**Set up a directory tree as follows on Summit: (Use same capitalization)**

* When you log on to Summit, make sure you **ssh scompile** and source your main directory **(/bin/tcsh**)

$Region

base

Sentinel\_Path\_$PathNumber\_Frame\_$FrameNumber\_gmtsar

Sentinel\_Path\_$PathNumber\_Frame\_$FrameNumber

orbits

DEM

SAFE

\*This will be copied over and will contain all of the scripts to run processing.

**We will first focus on setting up the directories contained within the green box above:**

1. Download data from Vertex (<https://search.asf.alaska.edu/#/?flightDirs=>) and unzip to get SAFE directories. Put all SAFE files into the SAFE directory above.

2. Download a DEM that covers the entire SAR scene and place in the DEM directory above.

* It must be in GMT-compatible grid format and called “dem.grd”
* 30-m resolution SRTM and ASTER may be downloaded from here: <https://topex.ucsd.edu/gmtsar/demgen/>

3. Download all necessary orbit files from <https://qc.sentinel1.eo.esa.int/aux_poeorb/> and place them in the orbits directory above.

4. Under the [Sentinel\_Path\_$PathNumber\_Frame\_$FrameNumber] Directory (where DEM, SAFE, and orbits are) make a file that lists each SAR scene acquisition date by typing the following command:

*ls -d SAFE/\* | awk '{print substr($1,23,8)}' > list\_of\_acquisitions*

5. Copy the contents of the base directory into your [Sentinel\_Path\_$PathNumber\_Frame\_$FrameNumber\_gmtsar] directory. This should contain the following:

* 00\_preproc\_to\_merge\_parallel.csh
* 00\_select\_master.csh
* 011\_F1\_intf\_stage2.csh
* 012\_break.csh
* 021\_F2\_intf\_stage2.csh
* 022\_break.csh
* 031\_F3\_intf\_stage2.csh
* 032\_break.csh
* 04\_merge\_unwrap\_parallel.csh
* batch\_tops.config
* batch\_tops\_stage1.config
* batch\_tops\_stage2.config
* kk\_intf\_tops.csh
* kk\_preproc\_batch\_tops.csh
* make\_ifg\_list
* merge\_batch.csh
* process\_all.csh
* update\_PRM.csh

Processing steps on SUMMIT supercomputer:

6. Go into your gmtsar directory and type the following command:

*sbatch ./00\_select\_master.csh $Path $Frame*

* This first part of the code will set up the proper directory tree within your gmtsar directory, copies the dem to appropriate places, creates the “data.in” input file for the next step in the process (step 7), and then creates the “baseline.ps” plots for each swath in the F1, F2, and F3 directories.
* Open the baseline plots to select the best master date. (Should be a centered data point labeled as S1A$yyyymmdd\_ALL\_F$ )

7. After selecting your master date from the baseline plot, return to in the main Sentinel\_gmtsar directory again and type the following command:

*sbatch ./00\_preproc\_to\_merge\_parallel.csh $Master $AllowedDays*

* The first argument ($Master) comes from your choice of date in the previous step based off of the baseline.ps plot. The format should be as follows: YYYYMMDD ex: 20170923
* The second argument ($AllowedDays) stands for the number of days you will allow between image pairs. This is typically about 50 days but you can use the baseline.ps plot to decide.
* This step can take approximately 4 hours to process.

Processing steps on local TiampoStorage:

8. Once 00\_preproc is done running, copy make\_ifg\_list into gmtsar directory and run the script.

* The output is a file called ifg\_list. Open the file and remove any unnecessary lines, including the any of the dates within the merge directory that do not contain unwrap\_ll files.
* Then copy the merge directory and the ifg\_list to your local (TiampoStorage) drive under a directory called Sentinel\_Path\_$PathNumber\_Frame\_$FrameNumber. The file structure should look as follows:

TiampoStorage Directory Pathway

Sentinel\_Path\_$PathNumber\_Frame\_$FrameNumber

DEM

giant

MSBAS

merge

GPS

giant\_GACOS

* DEM will have your DEM (same one used on summit)
* The giant directory will have all your base scripts and files (different from the base directory on summit)
  + - change\_version.csh
    - create\_latlon\_giant.m
    - for\_google\_earth.kml
    - grdwrite2.m
    - output\_time\_series.py
    - save\_no\_border.py
    - subtracting\_slices.py
    - userfn.py
* The giant\_GACOS directory is where you will download files for the atmospheric correction using GACOS
* GPS is where you will gather GPS station positions. The time series for these stations will integrate with your InSAR time series.
* The merge directory is directly copied over from summit and holds all of the directories labeled as dates from possible image pairs that hold your unwrapped interferograms (unwrap\_ll.grd files).
* MSBAS is where you will perform MSBAS processing.
* Make sure all of the x\_min and y\_min values of all the unwrap\_ll.grd files within the merge directory are the same:

*grdinfo merge/$YYYY\*/unwrap\_ll.grd | grep x\_min*

*grdinfo merge/$YYYY\*/unwrap\_ll.grd | grep y\_min*

* If they are not the same, you can use the script called “change\_version.csh” to crop all files to the smaller size. You can also use the same script to change the format to classic, or to change NAN values to zeros. (You need zero values and not NAN values for MSBAS processing). Just make sure that moving forward, you use the new file names produced by this script in the following steps: for example, use “unwrap\_ll\_cut.grd” instead of “unwrap\_ll.grd”.

9. Copy dem.grd into dem\_orig.grd. Then create a file called dem\_orig.grd.rsc and copy and paste the following:

WIDTH <x\_nx>

FILE\_LENGTH <y\_nx>

AZIMUTH\_PIXEL\_SIZE <x\_inc converted to meters>

RANGE\_PIXEL\_SIZE <y\_inc converted to meters>

LAT\_REF1 <lat coordinate of upper left corner of box around region of interest>

LON\_REF1 <lon coordinate of upper left corner of box around region of interest>

LAT\_REF2 <lat coordinate of upper right corner of box around region of interest>

LONG\_REF2 <lon coordinate of upper right corner of box around region of interest>

LAT\_REF3 <lat coordinate of lower right corner of box around region of interest>

LON\_REF3 <lon coordinate of lower right corner of box around region of interest>

LAT\_REF4 <lat coordinate of lower left corner of box around region of interest>

LON\_REF4 <lon coordinate of lower left corner of box around region of interest>

* <x\_nx> and <y\_nx> values come from *grdinfo dem.grd*
* <x\_inc> and <y\_inc> also come from *grdinfo dem.grd*, but pixel size needs to be converted from degrees to meters. *[(Length of a degree at a particular lat/lon) \* x/y\_inc = Pixel Size]* You can also use this website to calculate the conversion: <https://msi.nga.mil/msisitecontent/staticfiles/calculators/degree.html>
* Lat and lon coordinates should make a box around a region that you think may be a good reference area. This area should remain stable through the time series. You may need to play around with this a little based on your results. A [0.5 degree by 0.5 degree] box is typical but may vary.

10. Open Matlab and make sure create\_latlon\_giant.m is in your working directory.

* Edit the matlab script and fill in the appropriate data for xmin, xmax, ymin, ymax, xinc, and yinc (values come from gdalinfo dem\_orig.grd.
* Run the script. Outputs should be: lat\_orig.grd and lon\_orig.grd
* Copy dem\_orig.grd.rsc (from step 9) into lat\_orig.grd.rsc and lon\_orig.grd.rsc
* Double check that all nx and ny (width and length values) are the same in all rsc files.

11. Use any of the unwrap\_ll.grd files from within the merge directory, (or if you used change\_version.csh in step 8, use one of those edited files), and copy it into a file called exampleimage.grd:

*cp ../merge/$20170304\_20170316/unwrap\_ll.grd exampleimage.grd*

* From the same directory you used above, use the PRM file to create/copy into image.PRM:

*cp ../merge/$20170304\_20170316/$S1A20170304.PRM image.grd*

12. Edit the script called userfn.py:

* Change dirname to the proper pathway
* If you used change\_version.csh in step 8, also edit iname and cname to the proper files

13. Edit prepxml\_SBAS.py:

* Change reference region: rxlim, rylim with ranges of pixels (should be between 0 and values of width/length) where the ground is stable or unmoving.
* Change inc by taking the average inc value from within the SAFE directories on summit. You can get these values when you enter:

*grep inc SAFE/annotation/\**

* Make sure your email/Key are set up in the atm correction section, and it will pull your profile from the script. You will also have to make sure that Key + Email are set in model.cfg (or edit model.cfg.template). This is will come in handy when the GACOS instructions are explained later… If you haven’t already set up an email/key combination with ECMWF, you will need to create a login from ECMWF, which is where you get the "Key".
* When those changes are made, you may run the prepxml\_SBAS.py script: (outputs will be data.xml and sbas.xml)

*python2 prepxml\_SBAS.py*

14. Run PrepIgramStack.py:

*python2 PrepIgramStack.py*

* This uses the ifg.list we created in step 8, data.xml from step 13, and the userfn.py script to create a directory called Stack, which contains the outputs of PrepIgramStack, including RAW-STACK.h5

15. Run ProcessStack.py:

*python2 ProcessStack.py*

* Applies atmospheric correction, deramping, and creates a folder called Figs, which contains images of all the products.
* Outputs PROC-STACK.h5 in the same Stack directory generated in step 14, LS-PARAM.h5, and NSBAS-PARAM.h5

16. There are a couple ways to view the time series:

*python2 NSBASInvert.py* (or SBASInvert.py)

*python2 plotts.py -f Stack/NSBAS-PARAM.h5* (or LS-PARAM.h5)

Incorporate GPS data:

\*You can do this between steps 8/9.

* In your main Sentinel\_gmtsar directory, make a new directory named GPS.
* To view a map of all the available GPS stations, go to the following website:

<https://www.unavco.org/instrumentation/networks/status/all>

* Zoom in on your location and gather the names of stations you want to include in your time series. (For example: AB35)
* **Option 1:** copy the get\_data file into your GPS directory, open the file and copy/paste the appropriate station-codes into your terminal. You will need to edit the dates/times within the code to match your time series.
* **Option 2:** Go to the following web link to download the data

<https://www.unavco.org/data/web-services/documentation/documentation.html#!/gps/getPositionByStationId>

* Enter in the desired Station ID, Start Time, and End Time. Click on “Try it out!” at the bottom of the page. Copy the curl code that is produced and copy/run it in your terminal within the GPS directory.
* Edit the script called make\_no\_header. Change the first line to the proper station ID and run the script.
* You should now have directories and files AB35, AB35\_no\_header, make\_no\_header, filelist, get\_data
* Copy plot\_GPS.m and gps\_insar\_$path\_$frame.m to GPS directory and open matlab
* Edit plot\_GPS.m for the heading (-180 to +180), inc (elevation), and azimuth (0-360 degrees)=(90 degrees – heading), and run when parameters are correct.
  + Plots East/North/Vertical displacements and finds the angle (vector of unit length 1) of the vector in line with the satellite. (East= blue, North= red, Vertical= green, Total Displacement= black)
* Edit gps\_insar\_$path\_$frame.m
  + R= total displacement in LOS
  + Picks the corresponding GPS stating point with the giant data starting points and subtracts the displacement so that the two different time series are aligned. The scripts require you to match giant\_time(1) with time($gps), which you will need to search for. (For example giant\_time(1) may correspond with the GPS start time of time(443) In matlab, you can enter:

*giant\_time(1)* <Tells you when giant data begins>

*time(1)* <Tells you when GPS data begins>

Incorporate Atmospheric Correction files GACOS:

Incorporate multiple SAR scenes from various Path/Frames using MSBAS:

Under your MSBAS directory for each Path and Frame processed, you will need the following files:

* + ifg.list (copied from your merge directory originally created on Summit and copied locally)
  + asc.txt
  + header.txt
  + and par.txt

**Use the msbas\_base directory for reference on these files.**

Copy the script from the base directory called make\_asc.csh and run it: *./make\_asc.csh*

asc.txt will have 4 columns:

* column 1: points to the pathway to all unwrap\_ll.TIFF files
* column 2: copy from column #3 in the ifg.list file
* column 3 and 4: copy from column #1 and #2 in the ifg.list file

For example:

A close up of a newspaper

Description automatically generated

The header.txt file should look as follows:

A screenshot of a cell phone

Description automatically generated

* FORMAT= 2,0 comes from the GMTSAR Manual (Do not need to change for our purposed but you may see the manual for more options)
* You will need to edit the FILE\_SIZE, which comes from *grdinfo exampleimage.grd* (generated in step 11)
* C\_FLAG is a reference region (You can get this stable region for reference if you hover your mouse over the image output from SBAS in step 16)
* R\_ & I\_FLAG are kept the same and also come from the GMTSAR manual
* SET = [TIME] [HEADING] [INCIDENCE]
  + TIME comes from the original SAFE files information
  + HEADING and INCIDENCE will both be an average value from all the original SAFE files. You can get these by typing the following in the Summit directory storing all SAFE files:

*grep Heading ./\*SAFE/annotation\**

*grep incidenceAngle ./\*SAFE/annotation\**