Documentation – User's Guide

ASAR ScanSAR interferometry with ISP and DIFF&GEO

GAMMA REMOTE SENSING

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GAMMA *Remote Sensing AG, Worbstrasse 225, CH-3073 Gümligen, Switzerland*
tel: +41-31-951 70 05, fax: +41-31-951 70 08, email: gamma@gamma-rs.ch

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List of acronyms

ASAR	Advanced Synthetic Aperture Radar
DEM	Digital Elevation Model
DIFF&GEO	Differential Interferometry And Geocoding Software
ENVISAT	ENVIronmental SATellite
ESA	European Space Agency
ESRIN	European Space Research Institute
FFT	Fast Fourier Transform
ISP	Interferometric SAR Processor
MLI	Multi-Look Intensity
SAR	Synthetic Aperture Radar
SLC	Single Look Complex
SRTM	Shuttle Radar Topography Mission
WSS	Wide Swath SLC

1. Introduction

Interferometry with ScanSAR data has significant potential to make a significant contribution for many interferometric applications because of the increased area coverage. Ideally the sensor must be in the same geometry when acquiring ScanSAR data during successive tracks such that there is no loss of common azimuth spectrum.

The only standard ScanSAR product currently available for SAR interferometry is the ENVISAT ASAR Wide-Swath SLC data provided by ESA. Currently the use of ScanSAR data is limited because of the requirement for burst alignment between tracks. Efforts are underway for the ENVISAT ASAR system to assure burst synchronization.

The ASAR Wide Swath SLC (WSS) data are in the form of SLC bursts with each burst consisting of 48 image lines spaced at 80 meters along-track. Each line also contains 24 bytes of time annotation. During ASAR SCANSAR operation each point on the ground is imaged 3 times by the sensor, i.e. is imaged in 3 bursts.

ScanSAR interferometric processing consists of reading in and generating for each of the 5 sub-swaths a SLC dataset. In an interferometric ScanSAR image pair each dataset of one image is then resampled to match with the corresponding dataset of the reference image. Processing then continues as for normal interferograms. Since there is a large difference in the single-look range and azimuth pixel spacing (20 vs. 80 meters), it is advantageous for interpretation that the results are terrain geocoded.

An example of ASAR ScanSAR differential interferometry is illustrated in Figure 1.

In Sections 2 to 5 we illustrate the programs that are specifically designed for ScanSAR interferometry. Depending on their function, they belong to the ISP or the DIFF&GEO module. WSS interferometric programs are provided in the DIFF&GEO module. The program to generate a MLI image from a WSS SLC is provided in the ISP module. In two examples we demonstrate how to generate a differential interferogram for a pair of ASAR Wide Swath SLC data. Example A illustrates the generation of the interferogram based on the co-registration between the two SLC images using a lookup table procedure. This approach requires the availability of a DEM. Example B deals with the same interferogram where this time the co-registration between the SLCs is based on the traditional cross-correlation intensity algorithm. The first approach is recommended.

2. Generation of WS MLI image from WSS

To calculate an MLI image from an ASAR Wide-Swath SLC the program ***multi_SLC_WSS*** shall be used. This program is part of the ISP module. The program reads the complex-valued input ASAR WSS SLC image and generates a real-valued MLI image. A new ISP parameter file is also generated. This program is necessary in the process of generating an interferogram from WSS data, since MLI images are used for estimation of the offsets between the SLC images and for calculation of the interferometric coherence.

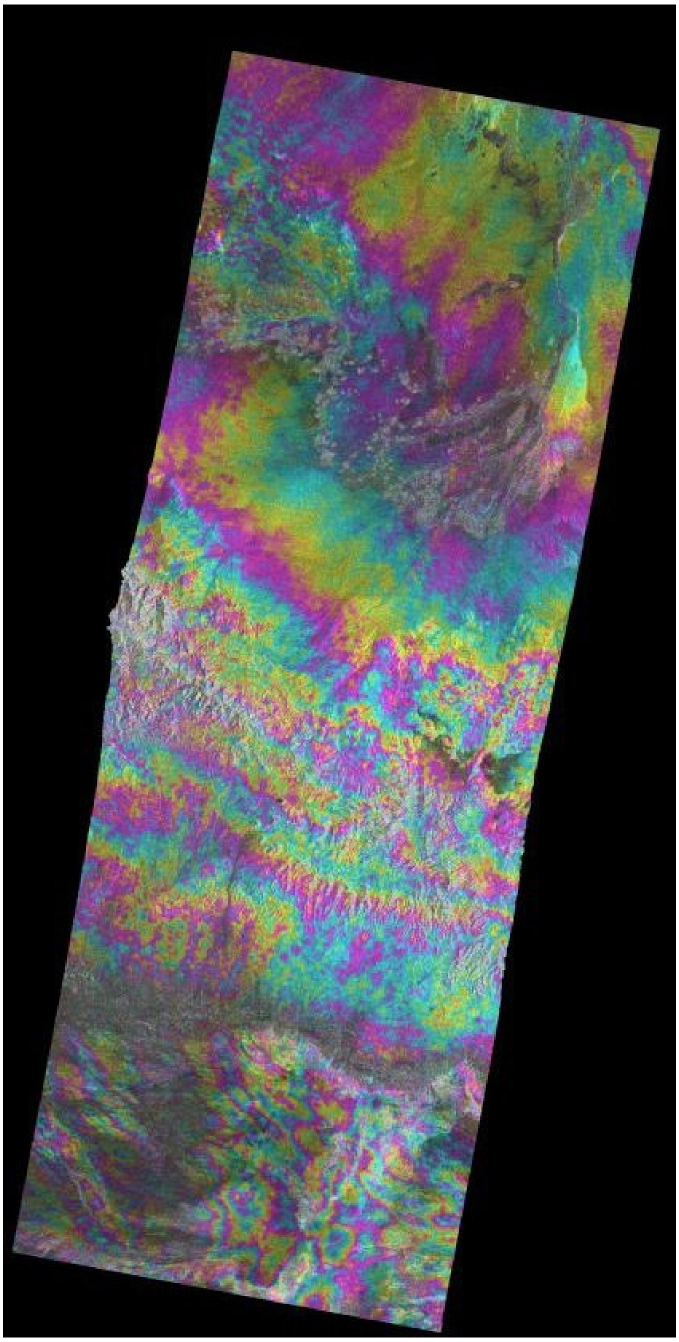

Figure 1. ScanSAR differential interferogram of the area of Bam, Iran, from 20030921-20040208 geocoded to UTM projection. The image corresponds to the swath IS2 and covers approximately 300 km along-track with a range swath width of 100 km.

3. Co-registration of WSS SLCs

For ASAR Wide-Swath SLC complex image resampling the DIFF&GEO module offers two programs depending on which resampling algorithm shall be applied.

The program ***WSS_interp*** uses an offset polynomial model and 2-D SINC interpolation for the resampling. In order to obtain the offset polynomial, the MLI images must be obtained from the SLC data as described in Section 2 and the offsets must be estimated using the procedure described in the DIFF&GEO User's Guide on Geocoding and Image Registration. The programs to be used are ***create_diff_par*** to generate a DIFF_par file in which the offsets will be stored, ***offset_pwrm*** and ***offset_fitm***. It should be noticed that the resampling polynomial between SLCs is determined based on the MLI images. For more details it is referred to the ***WSS_interp*** entry in the DIFF&GEO Reference Manual. The processing steps for this type of resampling are described in Example B.

The program ***WSS_interp_lt*** does the resampling using a lookup table and 2-D SINC interpolation. The lookup table is generated using the DIFF&GEO program ***rdc_trans***. The lookup table describes the correspondence between the geometries of the two SLC images. To obtain the lookup table the MLI images must be obtained as described in Section 2 and a DEM has to be transformed from map to the geometry of the reference MLI image. This has been described in the DIFF&GEO User's Guide on Geocoding and Image Registration. The lookup table can be refined by using the procedure for image registration described in the DIFF&GEO User's Guide on Geocoding and Image Registration. For more details on the individual processing steps it is referred to the ***WSS_interp_lt*** entry in the DIFF&GEO Reference Manual. The processing steps for this type of resampling are described in Example A.

4. Generation of WS interferogram

To generate the multi-look interferogram from ASAR Wide-Swath SLC images the program ***WSS_intf*** shall be used. The program reads the two co-registered ASAR Wide-Swath SLC SAR images, the corresponding SLC parameter files and computes the multi-look interferogram. The interferogram parameters are written to the output ISP offset (interferogram) parameter file. Wide-Swath SLC data are special in that each point on the ground is observed in nominally 3 bursts. Hence the number of interferometric looks is at 3 times the number of interferometric range looks. More details on the program can be found in the DIFF&GEO Reference Manual.

5. Mosaicing of WSS products

With the program ***WSS_mosaic*** it is possible to mosaic the sub-swaths of MLI images and interferograms produced from Wide-Swath SLC products. The WSS products are generated such that the output SLC samples are on a 0-Doppler grid. This has the consequence that the images and interferograms from each of the sub-swaths can be exactly mosaiced using nearest-neighbor resampling. The processing sequence to produce a mosaiced WSS interferogram is described in more detail in the DIFF&GEO Reference Manual.

Example of ASAR ScanSAR Interferometry

ScanSAR Interferometry is currently supported by the GAMMA Software for ENVISAT ASAR Wide-Swath SLC (WSS) data. In the following Examples the initial inputs are 2 ESA processed Wide Swath ASAR SLCs and a DEM in the desired projection such as UTM. Data in the example are from region near Bam, Iran, site where a devastating M6.6 earthquake took place on 2003-12-26. Data were acquired on 2003-09-21 and 2004-02-08, thus covering the event. The first SLC dataset will be referred to as SLC-1, the second as SLC-2. Example A shows how to generate the interferogram using the resampling approach based on the lookup table described in Section 4. Example B shows for the same interferogram generation procedure the co-registration step using the cross-correlation intensity algorithm described in Section 3.

A. ASAR Wide Swath interferogram generation using a lookup-table

A.1. Extraction of Wide Swath SLC sub-swaths

The first step consists in extracting the five sub-swaths forming a WS image. The program ***par_ASAR*** has been adapted to also process data from ESA ASAR WSS products. The data from each of the 5 sub-swaths is extracted from the data WSS data set. An ISP image parameter file is also generated from the ASAR meta-data. The command lines for the two SLCs look as follows:

```
par_ASAR ASA_WSS_1PXPDE20030921_060659_000000602020_00077_08147_0011.N1 20030921

par_ASAR ASA_WSS_1PXPDE20040208_060718_000000492024_00077_10151_0012.N1 20040208
```

The output files are:

20030921.VV.IS1.SLC 20030921.VV.IS1.SLC.par
20030921.VV.IS2.SLC 20030921.VV.IS2.SLC.par
20030921.VV.IS3.SLC 20030921.VV.IS3.SLC.par
20030921.VV.IS4.SLC 20030921.VV.IS4.SLC.par
20030921.VV.IS5.SLC 20030921.VV.IS5.SLC.par

20040208.VV.IS1.SLC 20040208.VV.IS1.SLC.par
20040208.VV.IS2.SLC 20040208.VV.IS2.SLC.par
20040208.VV.IS3.SLC 20040208.VV.IS3.SLC.par
20040208.VV.IS4.SLC 20040208.VV.IS4.SLC.par
20040208.VV.IS5.SLC 20040208.VV.IS5.SLC.par

Note the WSS related parameters at the bottom of the parameter files.

From now onwards the processing steps will be given for the IS2 dataset.

A.2. Replacement of state vectors with DORIS precision state vectors

The next step is to replace the single state vector provided with the SLC data with precision state vectors from the DORIS instrument on-board ENVISAT. These state vectors can be downloaded from ESA from a web server. Contact the ESA ESRIN helpdesk to get access to the DORIS data products. See information in the ISP on the program ***DORIS_vec*** further information on access and use of the DORIS state vectors:

```
DORIS_vec 20030921.VV.IS2.SLC.par DOR_VOR_AXVF-P20031128_150100_20030920_215528_20030922_002328 15

DORIS_vec 20040208.VV.IS2.SLC.par DOR_VOR_AXVF-P20040402_140900_20040207_215528_20040209_002328 15
```

A.3. Generation of multi-look (MLI) images from WSS data

Once the ASAR WSS SLC data have been extracted from the ESA product, MLI images must be produced. The ISP program ***multi_SLC_WSS*** adds the looks from multiple bursts and produces a floating point MLI file and ISP image parameter. These MLI files will be used for terrain geocoding and estimation of the offsets between the images.

```
multi_SLC_WSS 20030921.VV.IS2.SLC 20030921.VV.IS2.SLC.par 20030921.VV.IS2.mli 20030921.VV.IS2.mli.par
```

```
multi_SLC_WSS 20040208.VV.IS2.SLC 20040208.VV.IS2.SLC.par 20040208.VV.IS2.mli 20040208.VV.IS2.mli.par
```

To display the images, note that the image width will vary for the different swaths. The width of the image can be determined from the image parameter files. In this case IS2 of 20030921 has a width of 5143 samples whereas 20040208 has a width of 5123 samples.

```
raspwr 20030921.VV.IS2.mli 5143 1 0 3 1

raspwr 20040208.VV.IS2.mli 5123 1 0 3 1

dis2ras 20030921.VV.IS2.mli.ras 20040208.VV.IS2.mli.ras
```

A.4. Terrain geocoding of MLI-1 reference image

Terrain geocoding of the image is required to resample corresponding pairs to the reference SLC geometry. Use of the lookup-table based resampling is preferred to the polynomial offset model approach for WSS interferograms. It can also be used to later mosaic the different sub-swath images in map geometry. The procedure for terrain geocoding of the reference MLI image from the WSS data is the same as for strip-map derived MLI images. The input DEM has been derived from the SRTM DEM using the DIFF&GEO program ***dem_trans***. A DEM in the geometry of the reference MLI image must also be calculated using the geocoding lookup table.

For this example the command lines look as follows

Create directory for output

```
mk_dir geo_is2
```

Create initial geocoding lookup-table and display simulated image (it is here assumed that the DEM and the DEM parameter file are located in a “SRTM_DEM” sub-directory)

```
gc_map 20030921.VV.IS2.mli.par - SRTM_DEM/Bam_WSS_utm.dem_par SRTM_DEM/Bam_WSS_utm.dem SRTM_DEM/Bam_WSS_utm_is2_seg.dem_par SRTM_DEM/Bam_WSS_utm_is2_seg.dem geo_is2/bam_0.map_to_rdc 2 2 geo_is2/bam_0.sim - - - - - - 8 2 2

raspwr geo_is2/bam_0.sim_rdc 5143 1 0 1 1
```

Generate the DIFF_par parameter file for geocoding refinement

```
create_diff_par 20030921.VV.IS2.mli.par - geo_is2/bam.diff 1
```

Geocode simulated SAR image from map into SLC geometry

```
geocode geo_is2/bam_0.map_to_rdc geo_is2/bam_0.sim 3098
geo_is2/bam_0.sim_rdc 5143 - 2 0 1 1 2 8
```

Measure initial offset and measure offsets between the simulated SAR image geo_is2/bam_0.sim_rdc and the data SAR image 20030921.VV.IS2.mli, and calculate the range and azimuth polynomial offset model based on the offsets:

```
init_offsetm geo_is2/bam_0.sim_rdc 20030921.VV.IS2.mli geo_is2/bam.diff 1 1
2571.5 2474 0 0 10 - 1

offset_pwrm geo_is2/bam_0.sim_rdc 20030921.VV.IS2.mli geo_is2/bam.diff
geo_is2/bam.offs geo_is2/bam.snr

offset_fitm geo_is2/bam.offs geo_is2/bam.snr geo_is2/bam.diff
geo_is2/bam.coffs - 10 3
```

Update the lookup table with the corrections from the polynomial offset model, and regenerate the simulated SAR image for comparison with the original SAR image

```
gc_map_fine geo_is2/bam_0.map_to_rdc 3098 geo_is2/bam.diff
geo_is2/bam_1.map_to_rdc 1

geocode geo_is2/bam_1.map_to_rdc geo_is2/bam_0.sim 3098
geo_is2/bam_1.sim_rdc 5143 4948 2 0 1 1 2 8

raspwr geo_is2/bam_1.sim_rdc 5143 1 0 1 1

dis2pwr geo_is2/bam_1.sim_rdc 20030921.VV.IS2.mli.ras
```

Generate the geocoded SAR intensity image using the updated lookup table

```
geocode_back 20030921.VV.IS2.mli 5143 geo_is2/bam_1.map_to_rdc
geo_is2/bam_map.mli 3098 8134 1 0

raspwr geo_is2/bam_map.mli 3098 1 0 1 1
```

Generate the DEM in SAR coordinates

```
geocode geo_is2/bam_1.map_to_rdc SRTM_DEM/Bam_WSS_utm_is2_seg.dem 3098
geo_is2/bam_dem.rdc 5143 4948 2 0 1 1 2 8
```

A.5. Generation of lookup table of MLI-2 to MLI-1

To resample MLI-2 into the geometry of MLI-1 a lookup table is generated. This lookup table can also be used to resample SLC-2 into the geometry of SLC-1. The look up table is obtained with the program ***rdc_trans*** as follows

```
rdc_trans 20030921.VV.IS2.mli.par geo_is2/bam_dem.rdc
20040208.VV.IS2.mli.par 20030921_20040228.VV.IS2.lt
```

A.6. Interpolate MLI-2 into the geometry of MLI-1

To resample MLI-2 to the geometry of the reference MLI-1 image the program ***MLI_interp_lt*** shall be used. The resampled MLI-2 image will be hereafter referred to as MLI-2R.

```
MLI_interp_lt 20040208.VV.IS2.mli 20030921.VV.IS2.mli.par
20040208.VV.IS2.mli.par 20030921_20040228.VV.IS2.lt 20030921.VV.IS2.mli.par
20040208.VV.IS2.mli.par - 20040208.VV.IS2.rmli 20040208.VV.IS2.rmli.par
```

```
raspwr 20040208.VV.IS2.rmli 5143
```

```
dis2pwr 20030921.VV.IS2.mli 20040208.VV.IS2.rmli 5143 5143
```

A.7. Generation of offset model from MLI-2 to MLI-1

Residual offsets between the resampled MLI-2R image and MLI-1 can be measured and a polynomial model derived. This polynomial model can then be applied to improve the resampling. The processing steps are as follows

Create a DIFF_par parameter file from the image parameter files

```
create_diff_par 20030921.VV.IS2.mli.par 20040208.VV.IS2.rmli.par
is2.diff_par 1
```

Set initial azimuth further to the center of the valid region in 20040208.rmli because of the large initial offset

```
init_offsetm 20030921.VV.IS2.mli 20040208.VV.IS2.rmli is2.diff_par 1 1 -
3500
```

The results of offset estimate are rather good. The initial offset estimates are for range -0.011 and for azimuth 0.009 with correlation SNR of 20.459.

Measure offsets

```
offset_pwrm 20030921.VV.IS2.mli 20040208.VV.IS2.rmli is2.diff_par is2.offs
is2.snr
```

Generate offset model (using single constant offset)

```
offset_fitm is2.offs is2.snr is2.diff_par i2s.coffs - - 1
```

These are the results
Final range offset poly. coeff.: -0.01905
Final range offset poly. coeff. errors: 1.57182e-05
Final azimuth offset poly. coeff: 0.00838
Final azimuth offset poly. coeff. errors: 1.36799e-05
Final model fit std. dev. (samples) range: 0.0123 azimuth: 0.0107

This residual offset model is then included in the resampling

```
MLI_interp_lt 20040208.VV.IS2.mli 20030921.VV.IS2.mli.par
20040208.VV.IS2.mli.par 20030921_20040228.VV.IS2.lt 20030921.VV.IS2.mli.par
20040208.VV.IS2.mli.par is2.diff_par 20040208.VV.IS2.rmli
20040208.VV.IS2.rmli.par
```

Display reference and resampled MLI images

```
raspwr 20040208.VV.IS2.rmli 5143
```

```
dis2pwr 20030921.VV.IS2.mli.ras 20040208.VV.IS2.rmli.ras
```

A.8. Resampling using a lookup table

At this point in the processing the individual bursts of SLC-2 are resampled into the geometry of SLC-1. An important aspect of Wide-Swath ScanSAR interferometry is the percentage overlap between bursts. During the run of ***WSS_interp_lt*** (same for ***WSS_interp***) the local burst offset is displayed on the screen. Offsets greater than about 30 percent (12 lines) will lead to serious degradation of the multi-look interferogram because an increasingly large fraction of the interferogram will only be single look. In the example shown here, the azimuth offset varies between 1 and 2 lines.

To resample the Wide-Swath SLC to the geometry of SLC-1 we use the program ***WSS_interp_lt*** as follows

```
WSS_interp_lt            20030921.VV.IS2.SLC            20040208.VV.IS2.SLC
20030921.VV.IS2.SLC.par  20040208.VV.IS2.SLC.par  20030921_20040228.VV.IS2.lt
20030921.VV.IS2.mli.par         20040208.VV.IS2.mli.par         is2.diff_par
20040208.VV.IS2.rslc 20040208.VV.IS2.rslc.par 1
```

We can compare SCOMPLEX SLC burst data to see if there are residual offsets (add 6 to the image width of 5143 pixels to account for the 24 byte header of each line)

```
dis2SLC 20040208.VV.IS2.rslc 20030921.VV.IS2.SLC 5149 5149
```

Finally we generate the RMLI image from the resampled SLC-2R data and display it

```
multi_SLC_WSS         20040208.VV.IS2.rslc         20040208.VV.IS2.rslc.par
20040208.VV.IS2.rmli 20040208.VV.IS2.rmli.par

raspwr 20040208.VV.IS2.rmli 5143 1 0 4 1

dis2ras 20030921.VV.IS2.mli.ras 20040208.VV.IS2.rmli.ras
```

A.9. Generation of interferogram

Generation of the interferogram requires forming single look interferograms from the individual bursts and summing the bursts. Common band range and azimuth filtering is implemented at this point in the processing. It is recommended that the number of range looks be kept at 1 to maximize the image resolution and maintain the same size as the MLI images used for co-registration. The interferogram is generated with the program ***WSS_intf*** as follows

```
WSS_intf  20030921.VV.IS2.SLC  20040208.VV.IS2.rslc  20030921.VV.IS2.SLC.par
20040208.VV.IS2.rslc.par                       20030921_20040208.VV.IS2.off
20030921_20040208.VV.IS2.int 1 0
```

A.10. Estimation of baseline

Estimation of the interferometric baseline is done using the ISP program ***base_orbit*** and the MLI image parameter files. It is suggested to use the same baseline file for all 5 swaths to facilitate phase continuity across the swaths (take reference *.base file and compute the related initial_baseline (TCN) and initial_baseline_rate for the other subswath *.base files. The shift relative to the subswath center time must be taken from the corresponding *.SLC.par file).

The command lines in this example look as follows

```
base_orbit 20030921.VV.IS2.SLC.par 20040228.VV.IS2.SLC.par 20030921_20040208.base

base_perp 20030921_20040208.base 20030921.VV.IS2.SLC.par 20030921_20040208.VV.IS2.off
```

Output from running ***base_orbit*** gives the baseline model in TCN coordinates and the perpendicular and parallel baseline components. The baseline parameters as obtained from base_orbit are as follows:

initial_baseline(TCN): -1.2899361 -196.8436476 -64.3042274 m m m
initial_baseline_rate: 0.0000000 0.9771933 -0.0155285 m/s m/s m/s
precision_baseline (TCN): 0.0000000 0.0000000 0.0000000 m m m
precision_baseline_rate: 0.0000000 0.0000000 0.0000000 m/s m/s m/s
unwrap_phase_constant: 0.00000 radians

The baseline can be improved by the use of ground control points derived from the DEM in SAR coordinates with the DIFF&GEO program ***base_ls***.

A.11. Simulation of interferometric phase

Once the DEM is in SAR coordinates, the unwrapped interferometric phase can be simulated and displayed. This is done with the ISP program ***phase_sim*** as follows:

```
phase_sim 20030921.VV.IS2.mli.par 20030921_20040208.VV.IS2.off 20030921_20040208.base geo_is2/bam_dem.rdc 20030921_20040208.VV.IS2.sim_unw 0 0

disrmg 20030921_20040208.VV.IS2.sim_unw 20030921.VV.IS2.mli 5143
```

A.12. Generation of 2-pass differential interferogram

Forming the differential interferogram requires subtracting the simulated interferometric phase from the multi-look Wide-Swath interferogram. This is done with the program ***sub_phase*** as follows (for display use the program ***rasmph_pwr*** with SAR intensity image in background):

```
sub_phase 20030921_20040208.VV.IS2.int 20030921_20040208.VV.IS2.sim_unw 20030921_20040208.VV.IS2.diff_par 20030921_20040208.VV.IS2.diff 1 0

rasmph_pwr 20030921_20040208.VV.IS2.diff 20030921.VV.IS2.mli 5143
```

The interferogram can now be used in the same way as strip-map interferograms

A.13. Calculation of the correlation map

To calculate the interferometric correlation we can use the program ***cc_wave*** as follows. In this example a 3x3 window is used. The coherence image can be displayed with ***discc*** or saved to SUNraster format with the program ***rascc*** (in this case combined with the SAR intensity image)

```
cc_wave 20030921_20040208.VV.IS2.diff 20030921.VV.IS2.mli
20040208.VV.IS2.rmli 20030921_20040208.VV.IS2.cc 5143 3 3

discc 20030921_20040208.VV.IS2.cc 20030921.VV.IS2.mli 5143

rascc 20030921_20040208.VV.IS2.cc 20030921.VV.IS2.mli 5143 1 1 0 4 4
```

A.14. Mosaicing of the data in SAR geometry

The previous steps needed to be done for all sub-swaths. The data can now be mosaiced in SAR geometry using ***WSS_mosaic*** for further analysis and for geocoding afterwards. The mosaicing in SAR geometry can also be left out and the sub-swath data can first be terrain corrected and geocoded and mosaiced afterwards (Proceed directly with step 15).

The program ***WSS_mosaic*** requires the list of images (and corresponding ISP parameter files) that shall be mosaiced. This list can be generated using the UNIX commands ***ls*** and ***paste***. With the first ls command all file names with extension mli are saved in one column to the text file q1. With the second ls command all file names with extension mli.par are saved in one column to the text file q2. The command paste pastes the files q1 and q2 generating a text file with two columns called mli_tab.

```
ls –1 20030921.VV.IS*.mli > q1

ls –1 20030921.VV.IS*.mli.par > q2

paste q1 q2 > mli_tab
```

The command line to mosaic the individual MLIs of the different sub-swaths is then:

```
WSS_mosaic mli_tab 20030921.mli.par 20030921.mli 0
```

The procedure above can be repeated for all data of interest (interferograms, coherence etc.).

Now it is possible to do data analysis on the full WSS image. To terrain geocode the full swath images a similar procedure as described in Step 4 adapted to the full swath MLI file has to be done.

A.15. Terrain geocoding of differential phase and correlation map

Resampling of the differential interferogram and the correlation map from radar to map geometry is carried out with the program ***geocode_back*** that uses the geocoding lookup table generated at step 4. This is done for each sub-swath. It shall be reminded that the DEM segment has a width of 3098 pixels for IS2.

For the differential interferogram these are the commands for generation of the geocoded product and the display

```
geocode_back 20030921_20040208.VV.IS2.diff 5143 geo_is2/bam_1.map_to_rdc
geo_is2/20030921_20040208_map.VV.IS2_map.diff 3098 8134 1 0

rasmph_pwr geo_is2/20030921_20040208.VV.IS2_map.diff geo_is2/bam_map.mli
3098
```

For the correlation map these are the commands for generation of the geocoded product and the display

```
geocode_back 20030921_20040208.VV.IS2.cc 5143 geo_is2/bam_1.map_to_rdc
geo_is2/20030921_20040208.VV.IS2_map.cc 3098 8134 1 0
```

```
rascc geo_is2/20030921_20040208.VV.IS2_map.cc geo_is2/bam_map.mli 3098 1 1
0
```

The two images can be displayed simultaneously as follows

```
dis2ras geo_is2/20030921_20040208.VV.IS2_map.diff.ras
geo_is2/20030921_20040208.VV.IS2_map.cc.ras
```

B. ASAR Wide Swath interferogram generation without using a lookup-table

Instead of using the procedure based on the lookup table (steps 5 to 8), resampling of the WSS data can also be done using a bilinear polynomial offset model with the model parameters determined from the MLI images. Below we describe the individual processing steps for the IS2 swath. These have to be repeated for all the other scans.

B.1. Estimation of offset polynomial parameters used for resampling

Measuring the offsets and calculation of the offset model parameters begins by creating an offset parameter file,

```
create_offset 20030921.VV.IS2.mli.par 20040208.VV.IS2.mli.par 20030921_20040208.VV.IS2.off
```

and estimating initial offsets from the orbit data

```
init_offset_orbit 20030921.VV.IS2.mli.par 20040208.VV.IS2.mli.par 20030921_20040208.VV.IS2.off
```

In this example the initial offset in range (samples) is 18 and in azimuth (lines) is -2035. These values are entered as the initial offsets when creating the DIFF_par parameter file that will contain the offset polynomial parameters. Offsets between MLI files are done using programs in the DIFF&GEO package that use the DIFF_par parameter file format.

At first the DIFF_par file is initialized (note that the widths of the 2 MLI images are different!!):

```
create_diff_par 20030921.VV.IS2.mli.par 20040208.VV.IS2.mli.par 20030921_20040208.VV.IS2.diff_par 1
```

Then the offsets between the MLIs are measured

```
offset_pwrm 20030921.VV.IS2.mli 20040208.VV.IS2.mli 20030921_20040208.VV.IS2.diff_par is2.offs is2.snr
```

Then the offset polynomial parameters are calculated

```
offset_fitm is2.offs is2.snr 20030921_20040208.VV.IS2.diff_par - -
```

The results from running the offset program are the following:
final solution: 1729 offset estimates accepted out of 4096 samples
final range offset poly. coeff.: 18.81565 3.49796e-04 -5.60519e-04 -1.73794e-08
final range offset poly. coeff. errors: 5.49097e-04 1.93936e-07 1.56185e-07 5.78430e-11
final azimuth offset poly. coeff.: -2035.61774 2.71893e-05 2.01919e-04 -1.65865e-09
final azimuth offset poly. coeff. errors: 3.74140e-04 1.32143e-07 1.06420e-07 3.94127e-11
final model fit std. dev. (samples) range: 0.0537 azimuth: 0.0366

Note that the residual offsets are not as small as with the lookup-table based resampling approach. This can lead to lower interferometric correlation over parts of the image as has been observed.

B.2. Resampling of WSS data using the polynomial offset models

Next, the range and azimuth offset polynomials are used by the program ***WSS_interp*** to resample the WSS of 20040208 into the geometry of 20030921.

```
WSS_interp 20030921.VV.IS2.SLC 20040208.VV.IS2.SLC 20030921.VV.IS2.SLC.par
20040208.VV.IS2.SLC.par 20030921_20040208.VV.IS2.diff_par
20040208.VV.IS2.rslc 20040208.VV.IS2.rslc.par 0
```

The MLI image can be generated from the resampled SLC and compared to the original MLI image

```
multi_SLC_WSS 20040208.VV.IS2.rslc 20040208.VV.IS2.rslc.par
20040208.VV.IS2.rmli 20040208.VV.IS2.rmli.par

raspwr 20040208.VV.IS2.rmli 5143 1 0 4 1

dis2ras 20030921.VV.IS2.mli.ras 20040208.VV.IS2.rmli.ras
```

To compare bursts the program ***disSLC*** shall be used (note add 6 to the value of the width to take into account the SLC line headers):

```
dis2SLC 20030921.VV.IS2.SLC q.VV.IS2.rslc 5149 5149 8000 1000 0 0 1. .5 1
```

After this proceed as previously using the resample SLC to generate the interferogram using ***WSS_intf*** (restart from step 9).