GAMMA REMOTE SENSING

Interferometric processing of SENTINEL-1 with ISP/DIFF&GEO/LAT

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SENTINEL-1

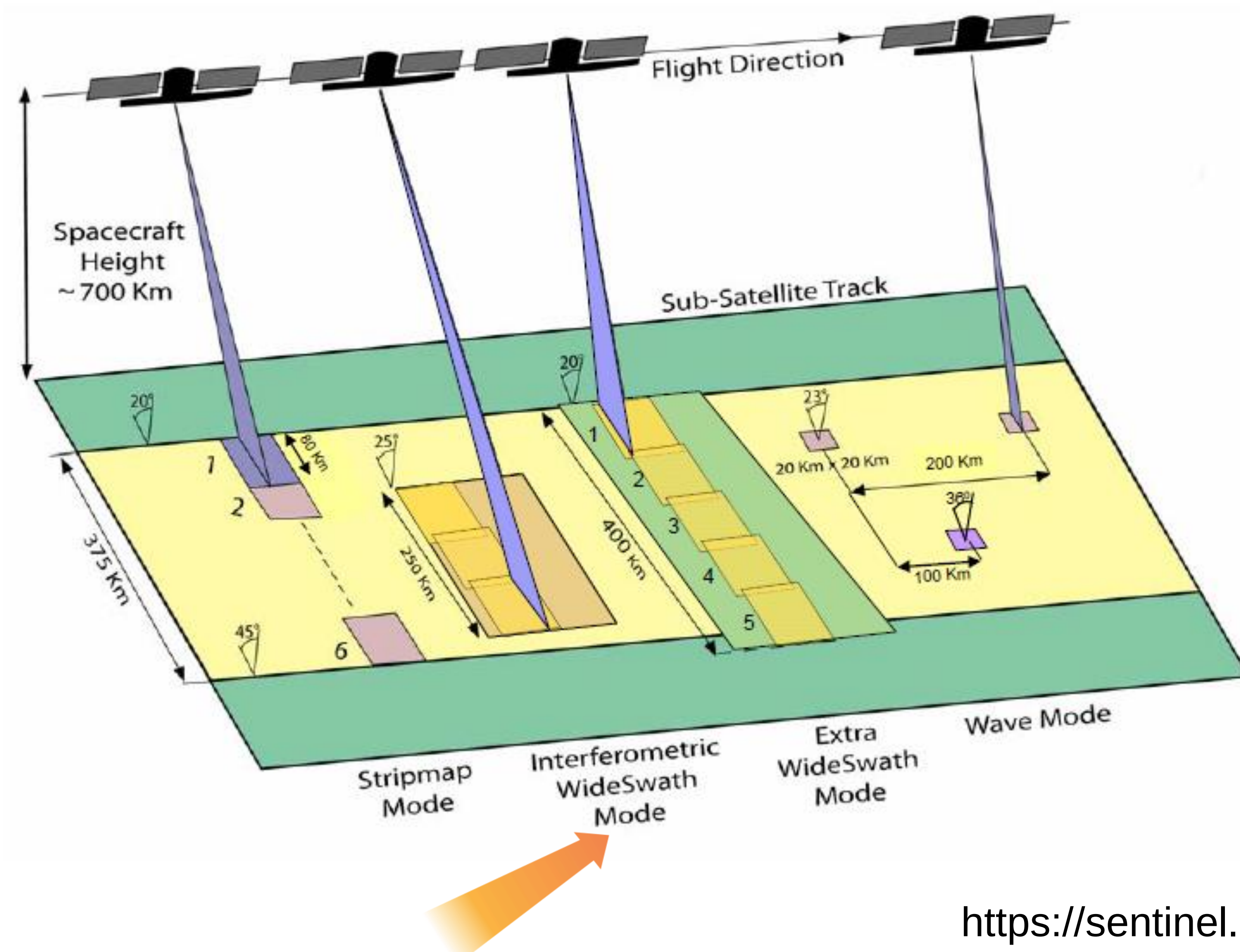
Launch Dates:
Sentinel-1A - 03 April 2014
Sentinel-1B - Scheduled for 2016
Operational lifespan: 7 years (With consumables for 12)

Mission Objectives:
Land monitoring of forests, water, soil and agriculture
Emergency mapping support in the event of natural disasters
Marine monitoring of the maritime environment
Sea ice observations and iceberg monitoring
Production of high resolution ice charts
Forecasting ice conditions at sea
Mapping oil spills
Sea vessel detection
Climate change monitoring

Mission Orbit:
Orbit Type: Sun-synchronous, near-polar, circular
Orbit Height: 693 km
Inclination: 98.18°
Repeat Cycle: 175 orbits in 12 days

Payload:
C-SAR (C-band Synthetic Aperture Radar)
Resolution and Swath Width (Four modes):
Strip Map Mode: 80 km Swath, 5 x 5 m spatial resolution
Interferometric Wide Swath: 250 km Swath, 5x20 m spatial resolution
Extra-Wide Swath Mode: 400 km Swath, 25 x 100 m spatial resolution
Wave-Mode: 20 km x 20 km, 5 x 20 m spatial resolution

SENTINEL-1



https://sentinel.esa.int/

Overview

Today we will:

- calculate differerential interferogram and displacement maps from 12-day repeat-pass S1 IW TOPS data

- calculate coherence

- produce fully calibrated and topographically corrected backscatter intensity images

Remarks:

The general workflow for interferometric processing remains the same:

SLC Import, co-registration, differential interferogram generation, coherence calculation, displacement map generation, calibration, geocoding, etc.

For TOPS mode imagery, there are however differences, which require a different set of programs lls -lahs

```
total 16G
4.0K drwxrwxrwx  2 oliver gamma  4.0K Apr  9 13:35 .
 12K drwxrwxr-x 28 oliver oliver  12K Apr  9 13:35 ..
2.4G -rwxrwxr-x  1 oliver gamma  2.4G Apr  9 12:04 20160202_iw1_slc
4.0K -rwxrwxr-x  1 oliver gamma  3.6K Apr  9 12:04 20160202_iw1_slc.par
612K -rwxrwxr-x  1 oliver gamma  610K Apr  9 12:05 20160202_iw1.slc.ras
 12K -rwxrwxr-x  1 oliver gamma  9.2K Apr  9 12:04 20160202_iw1_slc.tops_par
2.8G -rwxrwxr-x  1 oliver gamma  2.8G Apr  9 12:04 20160202_iw2_slc
4.0K -rwxrwxr-x  1 oliver gamma  3.6K Apr  9 12:05 20160202_iw2_slc.par
 12K -rwxrwxr-x  1 oliver gamma  9.2K Apr  9 12:05 20160202_iw2_slc.tops_par
2.3G -rwxrwxr-x  1 oliver gamma  2.3G Apr  9 12:05 20160214_iw1_slc
4.0K -rwxrwxr-x  1 oliver gamma  3.8K Apr  9 12:05 20160214_iw1_slc.par
 12K -rwxrwxr-x  1 oliver gamma  9.2K Apr  9 12:05 20160214_iw1_slc.tops_par
2.8G -rwxrwxr-x  1 oliver gamma  2.8G Apr  9 12:04 20160214_iw2_slc
4.0K -rwxrwxr-x  1 oliver gamma  3.8K Apr  9 12:05 20160214_iw2_slc.par
 12K -rwxrwxr-x  1 oliver gamma  9.2K Apr  9 12:05 20160214_iw2_slc.tops_par
```

Import of SLCs: (already done)

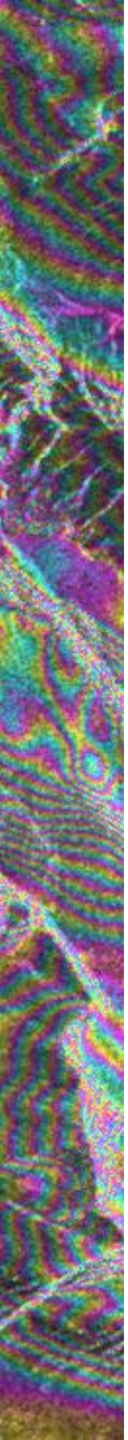
par_S1_SLC

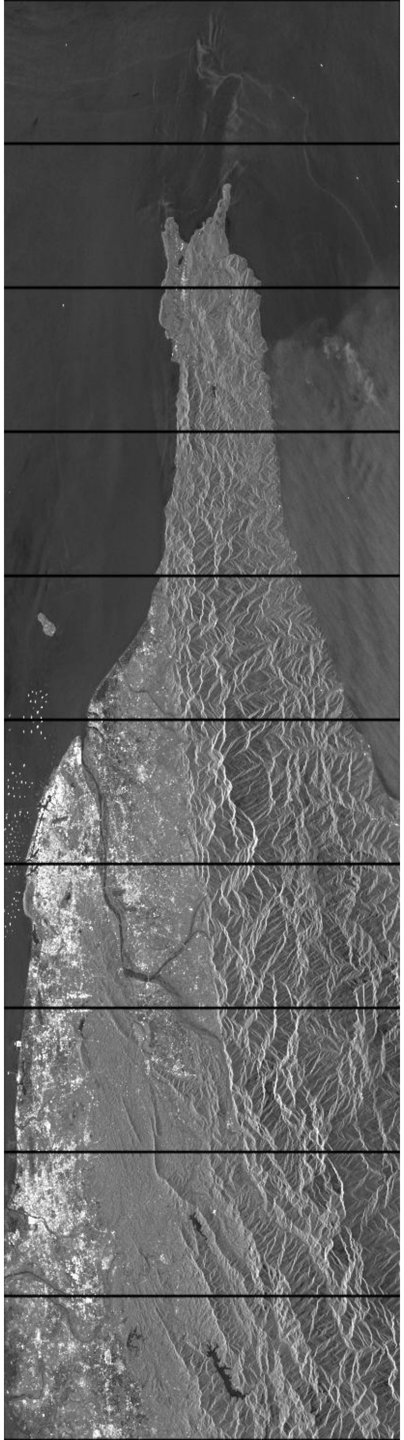
*** Generate SLC parameter and image files for Sentinel-1 SLC data ***
*** Copyright 2015, Gamma Remote Sensing, v2.8 10-Jun-2015 awi/clw ***

usage: par_S1_SLC <GeoTIFF> <annotation_XML> <calibration_XML> <noise_XML> <SLC_par> <SLC> [TOPS_par] [dtype] [sc_dB]

input parameters:
  GeoTIFF   (input) image data file in GeoTIFF format (*.tiff)
  annotation_XML (input) Sentinel-1 L1 XML annotation file
  calibration_XML (input) Sentinel-1 L1 radiometric calibration XML file (enter - for no radiometric calibration)
  noise_XML   (input) Sentinel-1 L1 noise XML file (enter - to not subtract thermal noise power level)
  SLC_par   (output) ISP SLC parameter file (example: yyyymmdd_iw1_vv.slc.par)
  SLC   (output) SLC data file (example: yyyymmdd_iw1_vv.slc)
  TOPS_par   (output) SLC burst annotation file, TOPS and EW SLC data only (enter - for none, example: yyyymmdd_iw1_vv.tops_par)
  dtype   output data type:
                 0: FCOMPLEX (default)
                 1: SCOMPLEX
  sc_dB   scale factor for FCOMPLEX -> SCOMPLEX, default HH,VV (dB): 60.0000, VH,HV: 70.0000

→ par_SLC_SLC already applies absolute calibration to sigma nought !!!





Each Sub-Swath comprises about 10 bursts, separated by a number of no data lines

more 20160202_iw2_slc.par

```
Gamma Interferometric SAR Processor (ISP) - Image Parameter File

title:     s1a-iw2-slc-vv-20160202t100020-20160202t100048-009766-00e469-005.tiff S1A-IW-IW2-VV-9766 (software: Sentinel-1 IPF 002.60)
sensor:    S1A IW IW2 VV
date:      2016 2 2 10 0 20.6366
start_time:             36020.636642   s
center_time:            36034.590786   s
end_time:               36048.544930   s
azimuth_line_time:     2.0555563e-03   s
line_header_size:                  0
range_samples:                 24857
azimuth_lines:                 15030
range_looks:                       1
azimuth_looks:                     1
image_format:               FCOMPLEX
image_geometry:             SLANT_RANGE
range_scale_factor:     1.0000000e+00
azimuth_scale_factor:   1.0000000e+00
center_latitude:          22.7143014   degrees
center_longitude:        121.4920756   degrees
heading:                 -12.3212623   degrees
range_pixel_spacing:        2.329562   m
azimuth_pixel_spacing:     13.977030   m
near_range_slc:          845699.8379  m
center_range_slc:        874651.6345  m
far_range_slc:           903603.4310  m
first_slant_range_polynomial:        0.00000      0.00000  0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  s m 1 m^-1 m^-2 m^-3
center_slant_range_polynomial:       0.00000      0.00000  0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  s m 1 m^-1 m^-2 m^-3
last_slant_range_polynomial:         0.00000      0.00000  0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  s m 1 m^-1 m^-2 m^-3
incidence_angle:              39.3278   degrees
azimuth_deskew:          ON
azimuth_angle:                90.0000   degrees
radar_frequency:        5.4050005e+09  Hz
adc_sampling_rate:      6.4345241e+07  Hz
chirp_bandwidth:        4.8300000e+07  Hz
prf:                     486.4863103  Hz
azimuth_proc_bandwidth:     313.00000  Hz
doppler_polynomial:         14.32080 -8.15365e-05  6.61585e-10  0.00000e+00  Hz     Hz/m     Hz/m^2     Hz/m^3
doppler_poly_dot:        0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  Hz/s   Hz/s/m   Hz/s/m^2   Hz/s/m^3
doppler_poly_ddot:       0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  Hz/s^2 Hz/s^2/m Hz/s^2/m^2 Hz/s^2/m^3
receiver_gain:                0.0000  dB
calibration_gain:             0.0000  dB
```

```
…

calibration_gain:            0.0000  dB
sar_to_earth_center:           7073395.8696   m
earth_radius_below_sensor:      6375071.2260   m
earth_semi_major_axis:          6378137.0000   m
earth_semi_minor_axis:          6356752.3141   m
number_of_state_vectors:                  6
time_of_first_state_vector:      36013.982969   s
state_vector_interval:              10.000000   s
state_vector_position_1:  -3011581.7435    5903990.7259    2471688.8617   m   m   m
state_vector_velocity_1:     2628.92701     -1581.27462      6950.40614   m/s m/s m/s
state_vector_position_2:  -2985135.8071    5887827.9741    2541051.9899   m   m   m
state_vector_velocity_2:     2660.19383     -1651.25310      6922.08892   m/s m/s m/s
state_vector_position_3:  -2958379.2018    5870966.1308    2610128.0337   m   m   m
state_vector_velocity_3:     2691.06025     -1721.09150      6892.98979   m/s m/s m/s
state_vector_position_4:  -2931315.9478    5853406.6392    2678909.1904   m   m   m
state_vector_velocity_4:     2721.52300     -1790.78134      6863.11209   m/s m/s m/s
state_vector_position_5:  -2903950.0983    5835151.0274    2747387.6915   m   m   m
state_vector_velocity_5:     2751.57885     -1860.31415      6832.45921   m/s m/s m/s
state_vector_position_6:  -2876285.7379    5816200.9079    2815555.8025   m   m   m
state_vector_velocity_6:     2781.22464     -1929.68147      6801.03467   m/s m/s m/s
```

more 20160214_iw1_slc.tops_par

```
Gamma Interferometric SAR Processor (ISP) - TOPS IW and EW Mode SLC Parameter File
number_of_bursts:    10
lines_per_burst:   1490
az_steering_rate: -1.590368784  (deg/s)
burst_date_1:          2016-02-14T10:00:19.426905
burst_start_time_1:    36019.426905   s
sensing_date_1:        2016-02-14T10:00:20.551704
sensing_start_time_1:  36020.551704   s
burst_boffset_1:       0
doppler_date_1:        2016-02-14T10:00:21.912322
doppler_time_1:        36021.912322   s
doppler_srdelay_1:      5.33168e-03   s
doppler_polynomial_1:    -5.21190   38708.04000  -1.78131e+07   0.00000e+00   0.00000e+00
az_fmrate_date_1:      2016-02-14T10:00:20.949582
az_fmrate_time_1:      36020.949582   s
az_fmrate_srdelay_1:    5.33179e-03   s
az_fmrate_polynomial_1: -2336.50578  448908.86395  -7.83457e+07
first_valid_sample_1:       0         samples
last_valid_sample_1:    20453         samples
first_valid_line_1:       19         lines
last_valid_line_1:      1473         lines
burst_win_1:      0.00000       0.00000       0.000000       0.000000      0      0      0      0

burst_date_2:          2016-02-14T10:00:22.193684
burst_start_time_2:    36022.193684   s
sensing_date_2:        2016-02-14T10:00:23.309981
sensing_start_time_2:  36023.309981   s
burst_boffset_2:       244777200
doppler_date_2:        2016-02-14T10:00:24.670599
doppler_time_2:        36024.670599   s
doppler_srdelay_2:      5.33168e-03   s
doppler_polynomial_2:    13.24827   33941.80000  -3.14286e+07   0.00000e+00   0.00000e+00
az_fmrate_date_2:      2016-02-14T10:00:23.707859
az_fmrate_time_2:      36023.707859   s
az_fmrate_srdelay_2:    5.33179e-03   s
az_fmrate_polynomial_2: -2336.43885  448935.09867  -7.83589e+07
first_valid_sample_2:       0         samples
last_valid_sample_2:    20453         samples
first_valid_line_2:       18         lines
last_valid_line_2:      1472         lines
burst_win_2:      0.00000       0.00000       0.000000       0.000000      0      0      0      0

--More--(21%)
```

Extract bursts from swath SLCs:

date1=20160202
date2=20160214

SLC_burst_corners ${date1}_iw1_slc.par ${date1}_iw1_slc.tops_par

```
*** Print corner coordinates of Sentinel-1 TOPS SLC bursts ***
*** Copyright 2015, Gamma Remote Sensing, v0.1 13-Oct-2015 awi/rc ***

TOPS SLC parameter file: 20160202-iw1.slc.par
TOPS SLC TOPS_PAR annotation file: 20160202-iw1.slc.tops_par
SLC title: s1a-iw1-slc-vv-20160202t100019-20160202t100047-009766-00e469-004.tiff S1A-IW-IW1-VV-9766 (software: Sentinel-1 IPF 002.60)
SLC radar sensor: S1A IW IW1 VV
S1 TOPS total number of bursts: 10


LATITUDE_CALC BEGINNING:     22.59706118
Burst:   1    21.74515040 120.39757126    21.92591450 120.35940353    22.07260937 121.17521114    21.89193174 121.21229008
Burst:   2    21.91174462 120.36239670    22.09250275 120.32419815    22.23911861 121.14101946    22.05844624 121.17811855
Burst:   3    22.07833333 120.32719376    22.25896129 120.28899011    22.40549886 121.10683424    22.22495589 121.14392846
Burst:   4    22.24491649 120.29196194    22.42553836 120.25372643    22.57199824 121.07260408    22.39146064 121.10971938
Burst:   5    22.41136990 120.25672704    22.59210976 120.21843286    22.73849263 121.03835401    22.55783636 121.07551639
Burst:   6    22.57830182 120.22271135    22.75891125 120.18441235    22.90523160 121.00550664    22.72470507 121.04266357
Burst:   7    22.74474377 120.18741798    22.92547108 120.14905921    23.07171568 120.97121726    22.89107060 121.00842225
Burst:   8    22.91130409 120.15206748    23.09202510 120.11367470    23.23819462 120.93690666    23.05755511 120.97413466
Burst:   9    23.07785861 120.11668566    23.25857324 120.07825832    23.40472083 120.90287510    23.22408699 120.94012617
Burst:  10     23.24453137 120.08124561    23.42523959 120.04278314    23.57131337 120.86849549    23.39068521 120.90577056

Max_Lat:     23.57131337
Min_Lat:     21.74515040
Max_Lon:     121.21229008
Min_Lon:     120.04278314
```

Create file lists

```
echo "${date1}_iw1_slc ${date1}_iw1_slc.par ${date1}_iw1_slc.tops_par" > slc1_tab
echo "${date1}_iw2_slc ${date1}_iw2_slc.par ${date1}_iw2_slc.tops_par" >> slc1_tab

echo "${date2}_iw1_slc ${date2}_iw1_slc.par ${date2}_iw1_slc.tops_par" > slc2_tab
echo "${date2}_iw2_slc ${date2}_iw2_slc.par ${date2}_iw2_slc.tops_par" >> slc2_tab
```

Create SLC mosaic for reference image

```
ml_rg=18
ml_az=4
SLC_mosaic_S1_TOPS slc1_tab ${date1}.slc  ${date1}.slc.par $ml_rg $ml_az
```

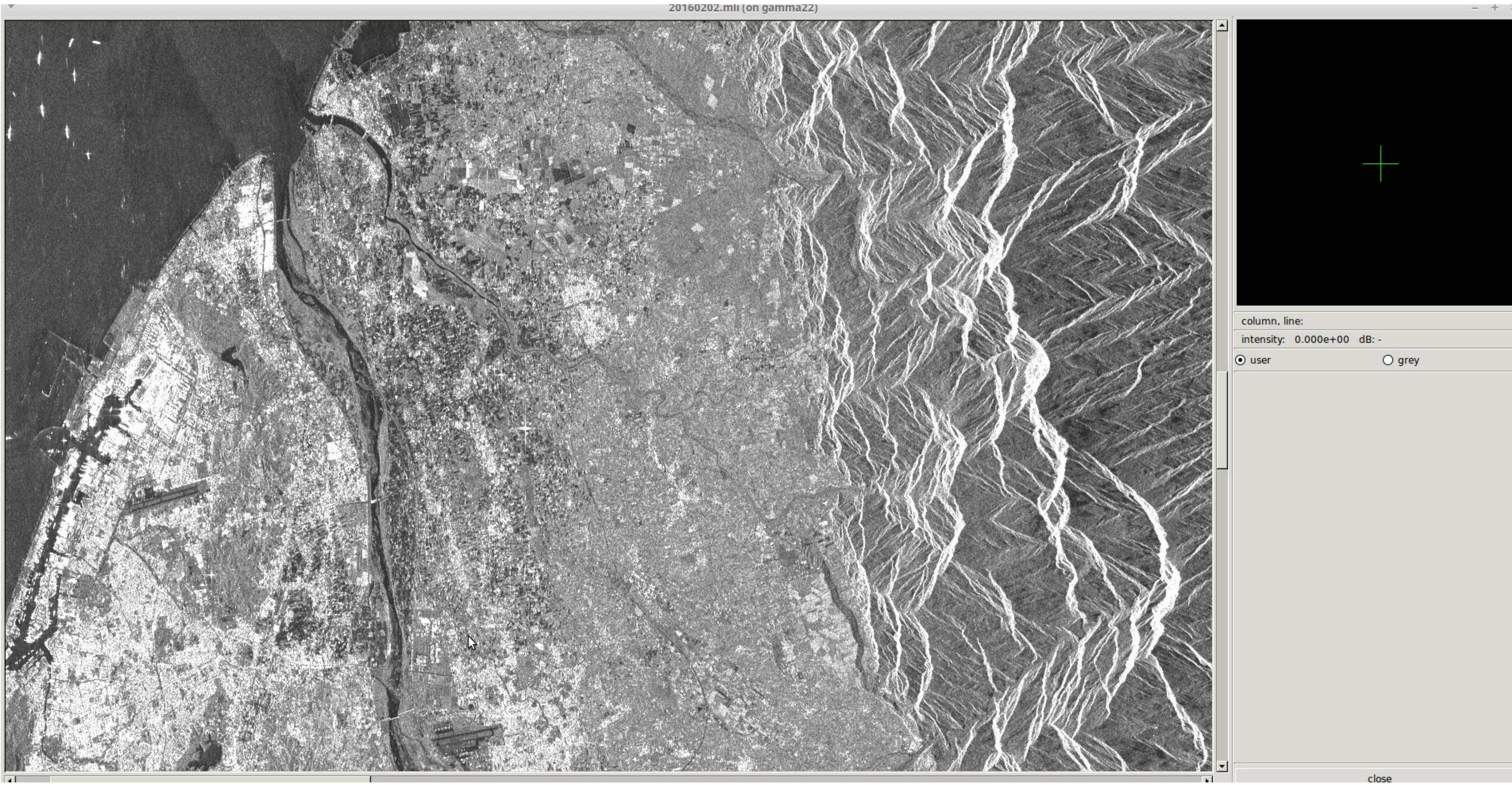
Multi-looking

```
multi_look ${date1}.slc  ${date1}.slc.par ${date1}.mli ${date1}.mli.par $ml_rg $ml_az
```

Get MLI image dimensions

```
mli1_width=$(cat ${date1}.mli.par | grep "range_samples:" | awk -F ':' '{ print $2 }')
mli1_lines=$(cat ${date1}.mli.par | grep "azimuth_lines:" | awk -F ':' '{ print $2 }')
```

dispwr 20160202.mli $mli1_width → to look at multilooked pwr image



Geocoding

Create geocoding look-up table:

```
gc_map ${date1}.mli.par - srtm.dem_par srtm EQA.dem_par EQA.dem ${date1}.lt 0.5 0.5 - - - ${date1}.inc - - ${date1}.ls_map 8 2
```

Save pixel dimensions of DEM as variables:

```
dem_width=$(cat EQA.dem_par | grep "width:" | awk -F ':' '{ print $2 }')
dem_lines=$(cat EQA.dem_par | grep "nlines:" | awk -F ':' '{ print $2 }')
```

Estimate pixel scattering area:

```
pixel_area ${date1}.mli.par EQA.dem_par EQA.dem ${date1}.lt ${date1}.ls_map ${date1}.inc pix_sigma0 - - - pix
```

Co-registration and calculation of differential interferogram

Resample DEM to RDC geometry:

```
geocode ${date1}.lt EQA.dem ${dem_width} ${date1}.hgt ${mli1_width} ${mli1_lines} 2 0
```

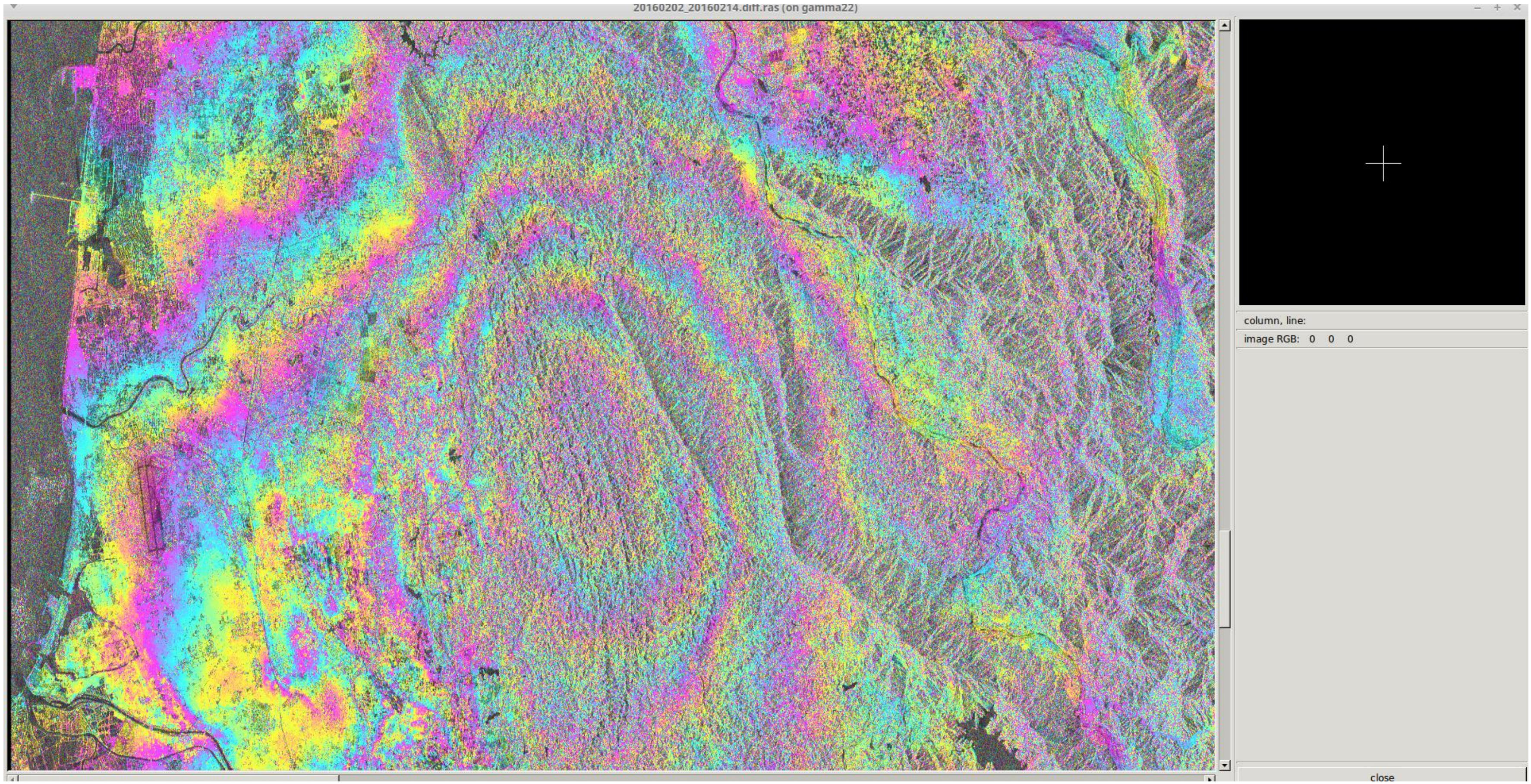
Co-registration and calculation of differential interferogram:

```
echo "${date2}_iw1_rslc ${date2}_iw1_rslc.par ${date2}_iw1_rslc.tops_par" > slc3_tab
echo "${date2}_iw2_rslc ${date2}_iw2_rslc.par ${date2}_iw2_rslc.tops_par" >> slc3_tab

S1_coreg_TOPS slc1_tab ${date1} slc2_tab ${date2} slc3_tab ${date1}.hgt ${ml_rg}
${ml_az} - - 0.8 0.01 0.8 1
```

Output: Co-registered secondary SLC, differential interferogram (optional)

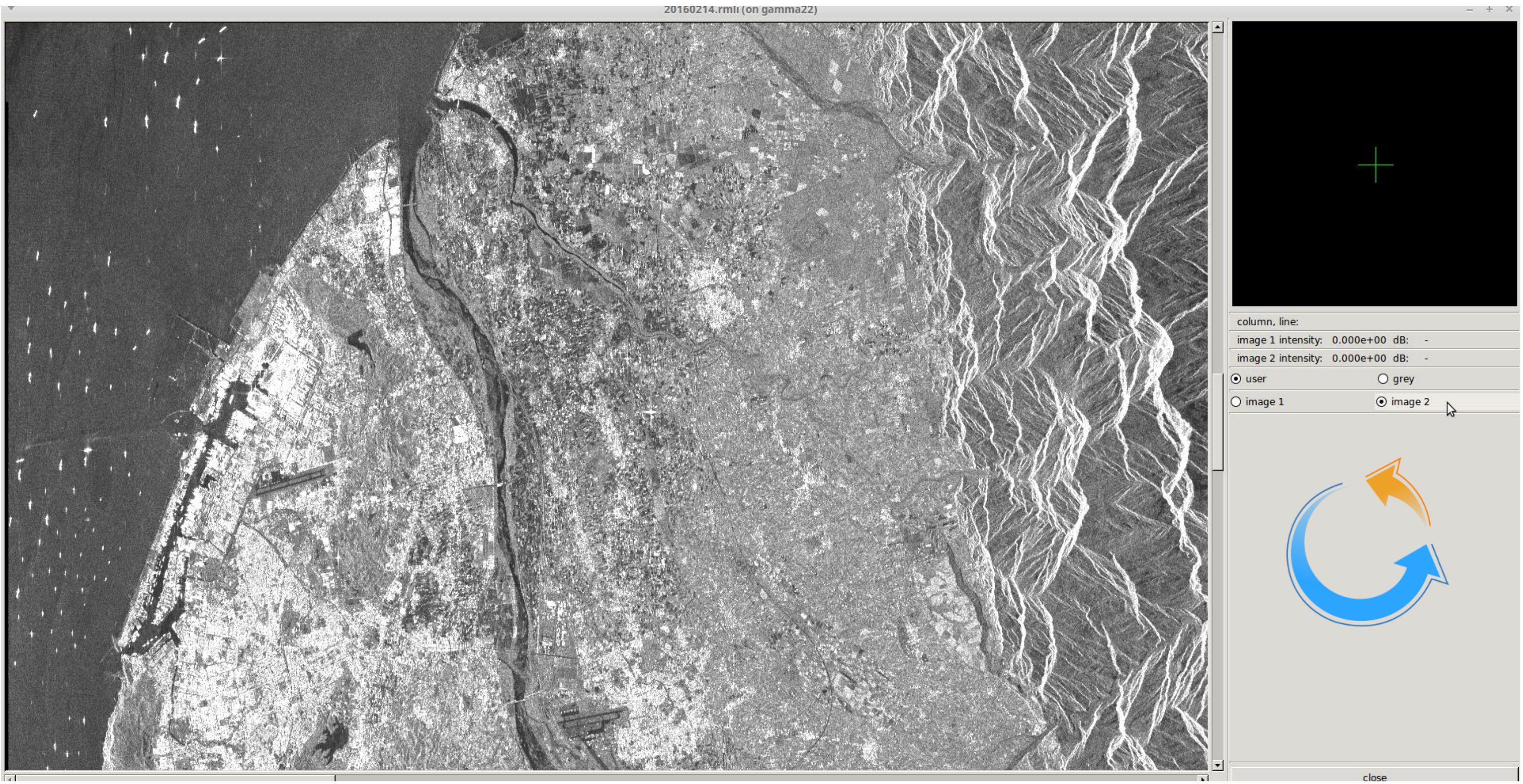
disras 20160202_20160214.diff.ras



Mosaic resampled burst SLC

multi_look ${date2}.rslc ${date2}.rslc.par ${date2}.rmli ${date2}.rmli.par $ml_rg $ml_az

dis2pwr 20160202.mli 20160214.rmli ${mli1_width} ${mli1_width}



Check Co-registration accuracy

more 20160202_20160214.coreg_quality

look for line:

azimuth_pixel_offset -0.000001 [azimuth SLC pixel]

Remark:

- co-registration accuracies in azimuth need to be of the order of few thousands of a pixel

- Because of the steep spectral ramp of the doppler centroid, mis-registrations above that will lead to phase jumps between bursts

Estimate baseline

base_orbit ${date1}.slc.par ${date2}.rslc.par ${date1}_${date2}.base > baseline.txt

*** Estimate baseline from orbit state vectors ***
*** Copyright 2015, Gamma Remote Sensing, v4.1 clw 18-Apr-2015 ***
nominal azimuth angle (deg.): 90.0000 (right-looking)

CENTER TIME FOR ORBIT 1: 36034.120
state vector data start (s): 36008.33972 end: 36068.33972
bracket times for the solution (s): 36018.43573 36049.28545
S/C position vector center scene: -2.95801024e+06 5.87073011e+06 2.61107299e+06
estimated error: : 7.30995621e-07 -2.28437210e-07 -9.13741836e-08
S/C velocity vector center scene: 2.69148061e+03 -1.72204793e+03 6.89258544e+03
estimated error: 1.37061806e-08 -2.31220605e-18 3.65498118e-08
unit vel. vector center scene (x,y,z): 3.54273311e-01 -2.26669150e-01 9.07254935e-01

…

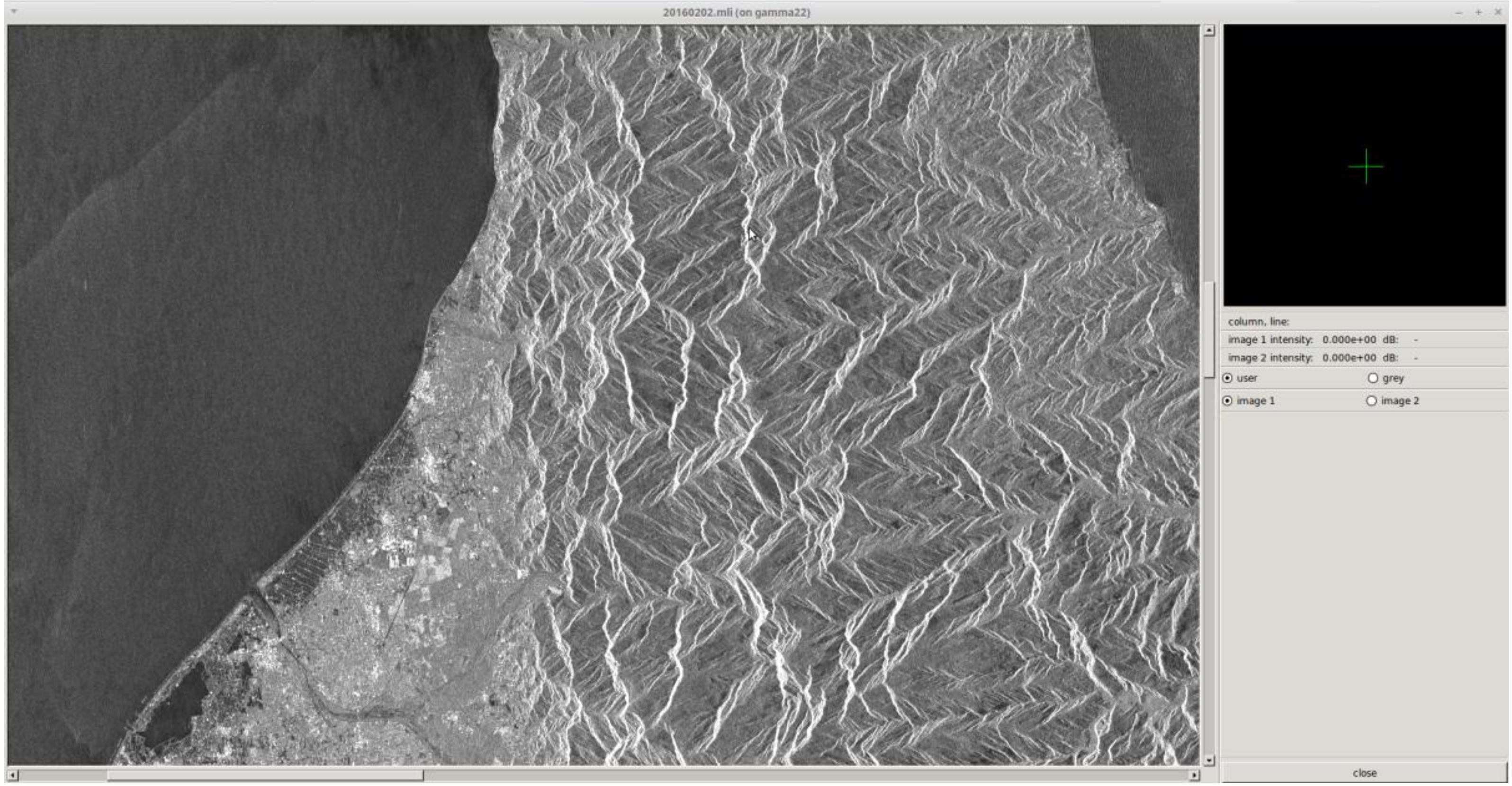
baseline parallel component (m): **-14.8749**
baseline perpendicular component (m): **-24.9985**
estimated range offset slope (pixels/pixel): 3.89171e-05
writing baseline file: 20160202_20160214.base

Pixel area normalization of MLI images

Apply "pix"-correction

product ${date1}.mli pix ${date1}.cmli $mli1_width 1 1 0
product ${date2}.rmli pix ${date2}.crmli $mli1_width 1 1 0

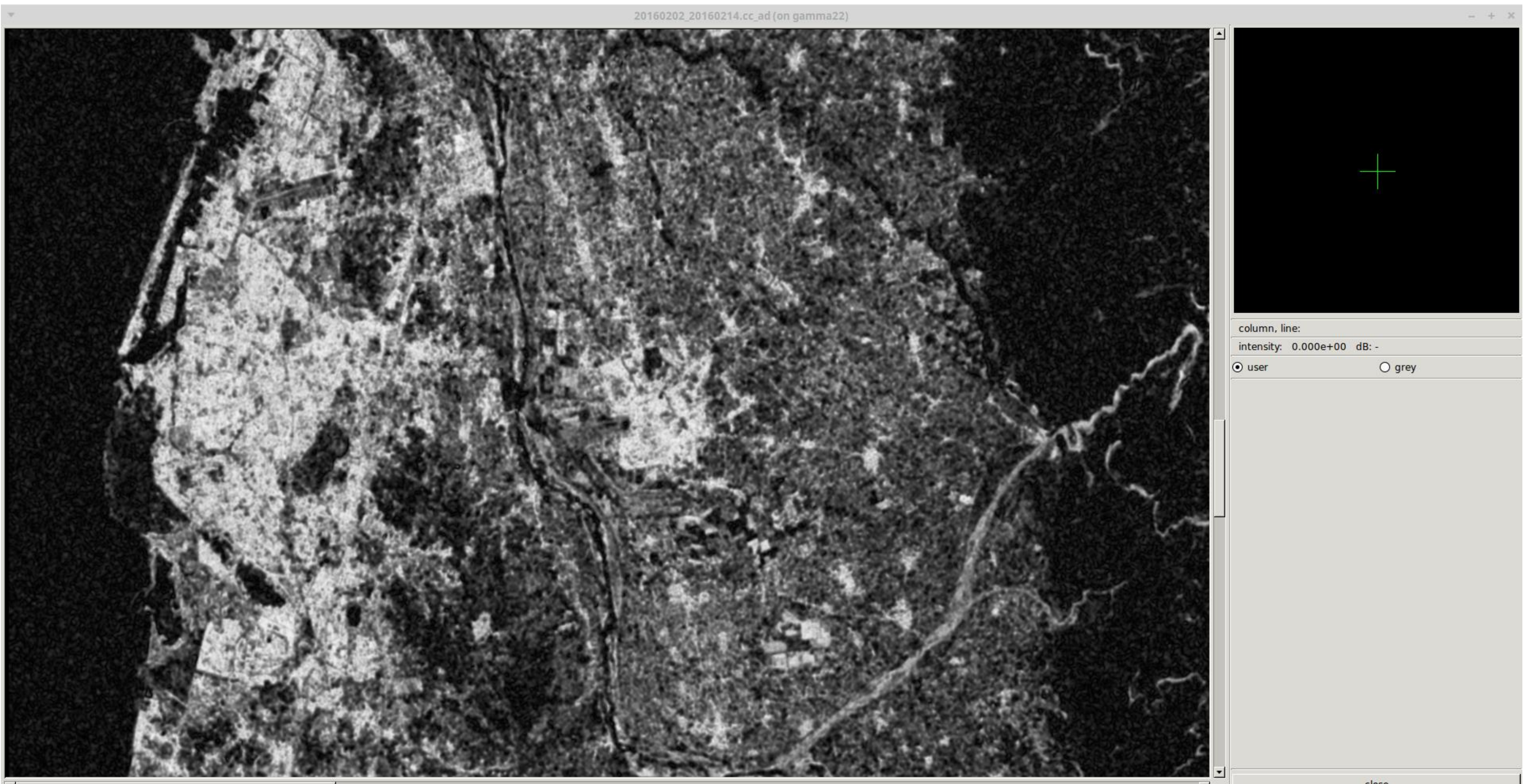
dis2pwr 20160202.mli 20160202.cmli ${mli1_width} ${mli1_width)



Estimate coherence

cc_ad ${date1}_${date2}.diff ${date1}.cmli - - - ${date1}_${date2}.cc_ad ${mli1_width} 3 7 1

dis_linear ${date1}_${date2}.cc_ad ${mli1_width}



Adaptive filtering of interferogram

To filter the inteferogram in our example we use the program adf as follows

adf ${date1}_${date2}.diff ${date1}_${date2}.diff_sm ${date1}_${date2}.diff_smcc $mli1_width 0.5 64 7 8 0 0 0.25

The program generates:

- filtered differential interferogram: *.diff_sm

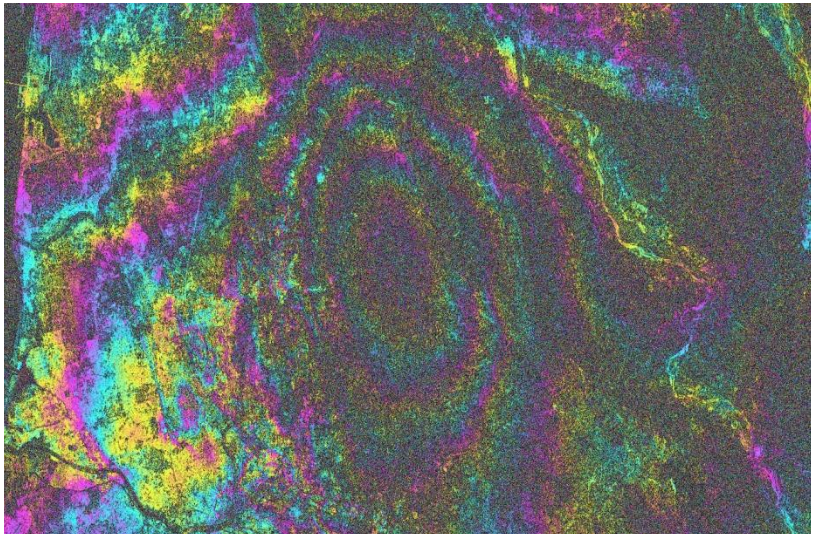
- filtered correlation of interferogram: *.diff_smcc

Display of differential interferogram before and after adf

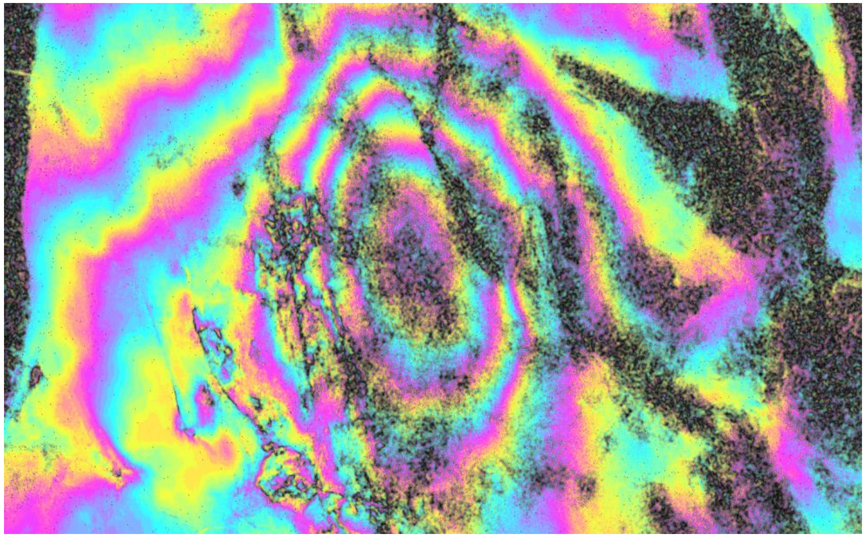
The differential interferogram before and after filtering can be displayed with the program dis2mph of the DISP module

dis2mph ${date1}_${date2}.diff ${date1}_${date2}.diff_sm $mli1_width $mli1_width

Interferogram BEFORE filtering



Interferogram AFTER filtering



Phase unwrapping

The GAMMA software provides programs for two algorithms of phase unwrapping. Here we use the program supporting the Minimum Cost Flow (MCF) algorithm. For phase unwrapping, we therefore use the program mcf

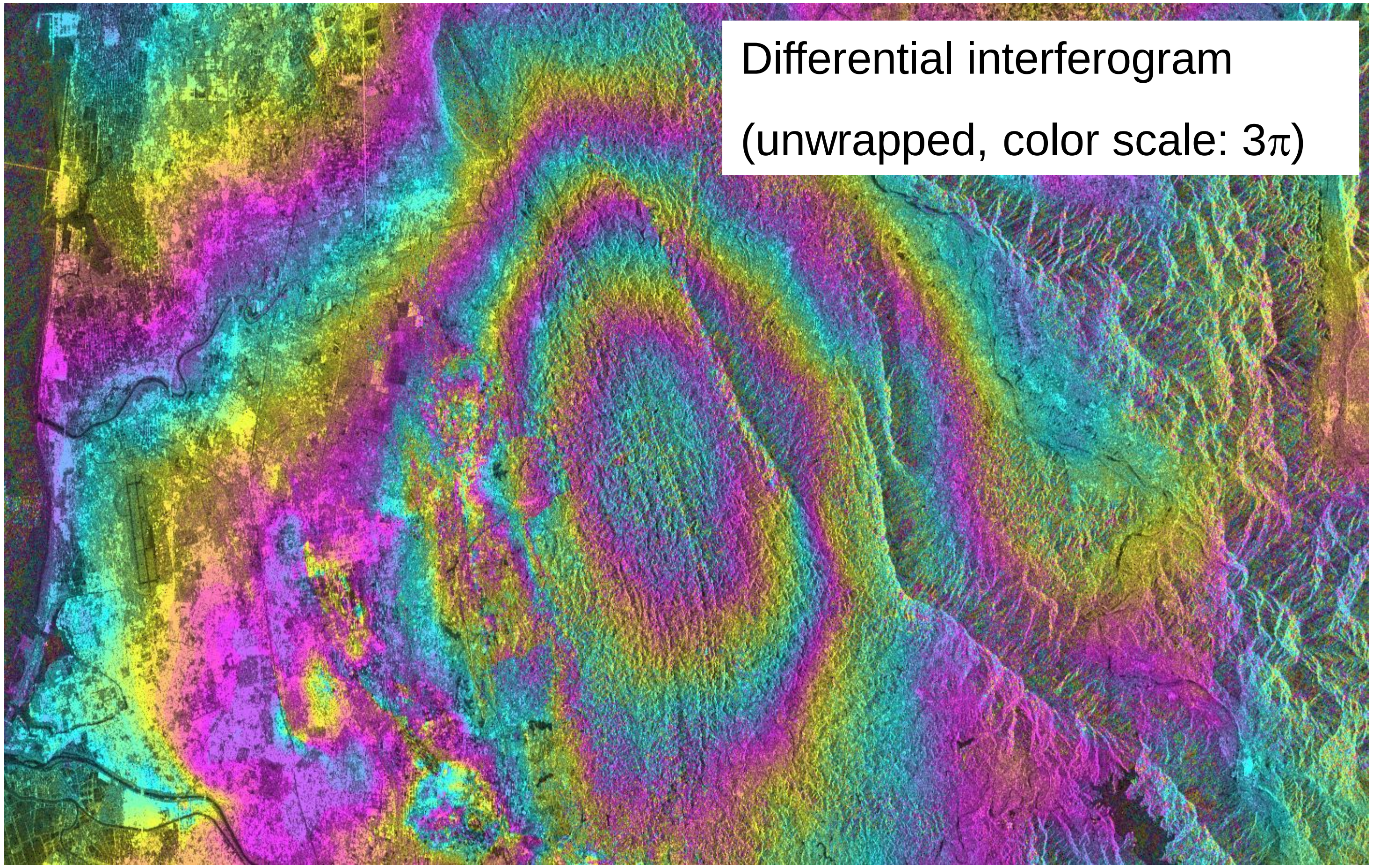
```
mcf ${date1}_${date2}.diff_sm ${date1}_${date2}.cc_ad - ${date1}_${date2}.diff_sm.unw $mli1_width 0 0 0 - - 1 1 512 180 2046  1
```

- Input are the flattened interferogram and the coherence image
- The phase is unwrapped by considering the lowest costs, which are determined by the coherence image
- Output is the unwrapped phase
- The program has several parameters one can play with. Here, we
  - used a Delaunay Triangulation,
  - considered the whole image
  - used 1 patch (use more if data file is big -> causing memory allocation problems)
  - used as starting point for unwrapping the position 200,750 i.e. a stable point with high coherence and clear phase.

Display of unwrapped interferogram

We can display the unwrapped differential interferogram with the intensity information in the background with the program **disrmg** of the DISP module.

disrmg ${date1}_${date2}.diff_sm.unw ${date1}.mli ${mli1_width} 1 1 0 0.66667



Computation of displacements

To determine the displacement from the unwrapped differential interferogram we use the program dispmap

dispmap ${date1}_${date2}.diff_sm.unw ${date1}.hgt ${date1}.slc.par ${date1}_${date2}.off ${date1}_${date2}.disp 0

Input

- the unwrapped differential interferogram (*.diff0_sm.unw)
- the height map (*.hgt)
- the parameter files of the reference image (*.slc.par) and of the interferogram (*.off)

Output

- the displacement map (*.disp)

The differential interferometric phase corresponds to the displacement along the SAR look vector. As a consequence the 3-dimensional displacement of a surface element cannot be completely described.

To let dispmap show in a clear way displacements the user can select the value of the “mode” flag on the command line.

Use of dispmap and interpretation of displacement map

Under the assumption of a predefined surface displacement direction a conversion to vertical or horizontal displacement is possible by setting the „mode“ flag as follows

0: conversion to displacement along the look vector in meters

+ signs correspond to displacement towards the sensor

For this conversion no specific assumption on the surface deformation is necessary.

1: conversion to vertical displacement in meters

+ signs correspond to increasing surface height

- signs correspond to subsidence

Vertical displacement can often be assumed in the case of subsidence

2: conversion to horizontal displacement component in ground range direction in meters

+ corresponds to decreasing ground range

Display of displacement map

To display the displacement map together with the intensity MLI in the background, we use the program disdt_pwr24 of the DISP module:

disdt_pwr24 ${date1}_${date2}.disp ${date1}.mli ${mli1_width} - - - 0.05

• A color cycle of 1 meter is used.

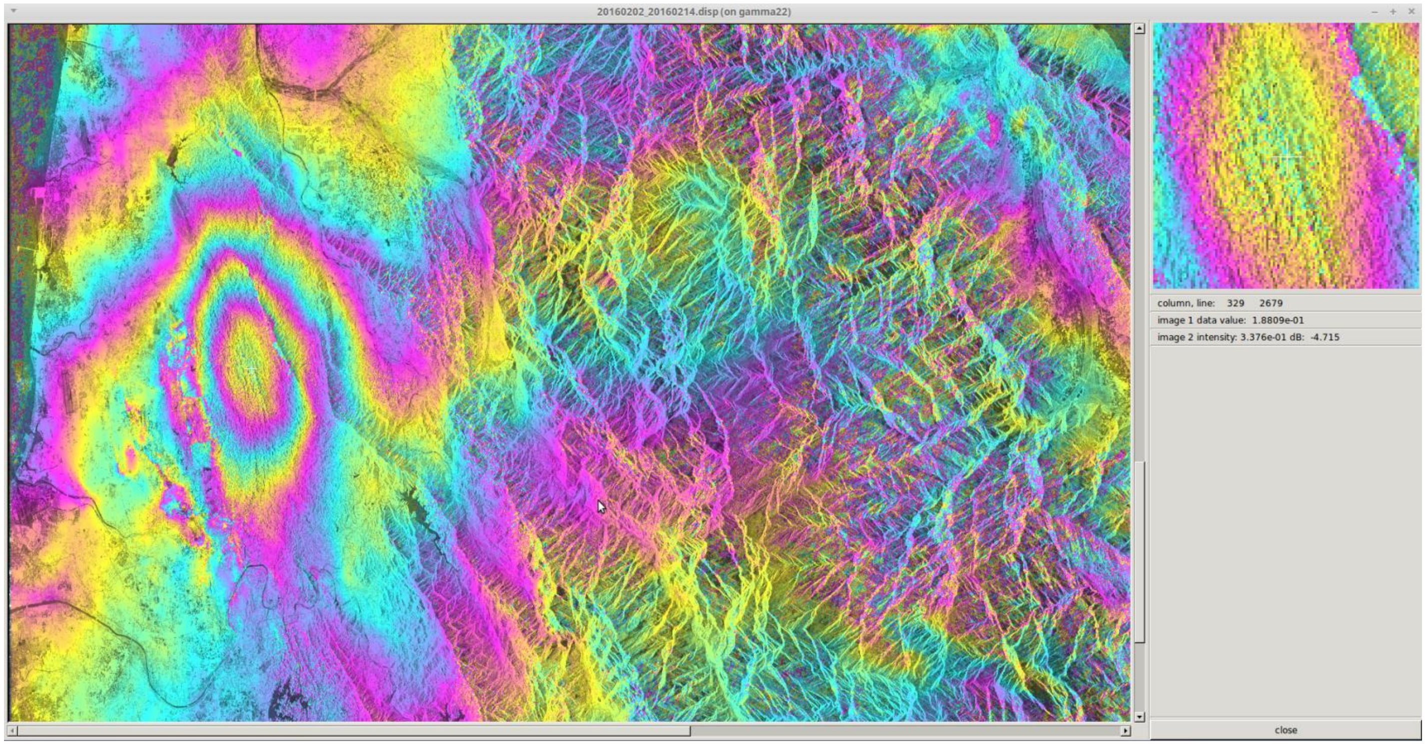
The corresponding color bar can be generated with the program ras8_color_scale of the DISP module

ras8_color_scale colors.ras 0 0. 360. .5 .75

• The color bar is saved to the file colors.ras

• For interferometric products, a double hexagon color model is generally used (parameter value 1).

Displacement map



Displacement map in slant range coordinates, phase-colour-coded with SAR intensity image in the background.

Geocoding

geocode_back ${date1}_${date2}.cc_ad ${mli1_width} ${date1}.lt ${date1}_${date2}.geo.cc_ad ${dem_width}

geocode_back ${date1}.cmli ${mli1_width} ${date1}.lt ${date1}.geo.pwr ${dem_width}

geocode_back ${date2}.crmli ${mli1_width} ${date1}.lt ${date2}.geo.pwr ${dem_width}

geocode_back ${date1}_${date2}.disp ${mli1_width} ${date1}.lt ${date1}_${date2}.geo.disp ${dem_width}

Create GTiff file

```
data2geotiff EQA.dem_par ${date1}_${date2}.geo.cc_ad 2 ${date1}_${date2}_geo_cc_ad.tif

data2geotiff EQA.dem_par ${date1}.geo.pwr 2 ${date1}_geo_s0.tif 0

data2geotiff EQA.dem_par ${date2}.geo.pwr 2 ${date2}_geo_s0.tif 0

data2geotiff EQA.dem_par ${date1}.inc 2 ${date1}_inc.tif 0

data2geotiff EQA.dem_par ${date1}_${date2}.geo.disp 2 ${date1}_${date2}.geo.disp.tif 0
```

Summary:

We have learned how to calculate:

- a differential repeat-pass interferogram
- displacement
- coherence
- backscatter intensity

from a 12-day repeat-pass pair of S1 TOPS IW SLCs

Note: S1 imagery can also be downloaded in detected ground range format, in which case no interferometry is possible. The sequence of programs needed to process GRDs is:

par_S1_GRD

multilook

gc_map_grd

pixel_area

geocode_back

Extract bursts from swath SLCs:

SLC_copy_S1_TOPS

```
*** Copy multiple bursts from a Sentinel-1 TOPS SLC to an output TOPS SLC ***
*** Copyright 2015, Gamma Remote Sensing v1.6 21-Aug-2015 ***

usage: SLC_copy_S1_TOPS <SLC1_tab> <SLC2_tab> <s1> <bn1> <s2> <bn2> [dtype]

input parameters:
  SLC1_tab  (input) 3 column list of TOPS SLC-1 swaths to be copied in row order IW1, IW2, IW3:
          SLC_tab line entries:   SLC    SLC_par   TOPS_par
  SLC2_tab  (input) 3 column list of the output copied SLC-1 TOPS swaths in the order IW1, IW2, IW3
  sw1       index of the swath containing the first burst to copy,    1 -> number of swaths in SLC1_tab
  bn1       burst number of the first burst to copy in SLC swath sw1, 1 -> number of bursts in the swath
  sw2       index of the swath containing the last burst to copy,     1 -> number of swaths in SLC1_tab)
  bn2       burst number of the last burst to copy in SLC swath sw2,  1 -> number of bursts in the swath
          (enter - for default, default: number of bursts in the swath)
  dtype     output data type (default: same as input data):
            0: FCOMPLEX
            1: SCOMPLEX
```

Extract bursts from swath SLCs:

Input files:

```
echo "${date1}_iw1_slc ${date1}_iw1_slc.par ${date1}_iw1_slc.tops_par" > tab11
echo "${date1}_iw2_slc ${date1}_iw2_slc.par ${date1}_iw2_slc.tops_par" >> tab11

echo "${date2}_iw1_slc ${date2}_iw1_slc.par ${date2}_iw1_slc.tops_par" > tab12
echo "${date2}_iw2_slc ${date2}_iw2_slc.par ${date2}_iw2_slc.tops_par" >> tab12
```

Output files:

```
echo "${date1}_iw1_slc2 ${date1}_iw1_slc2.par ${date1}_iw1_slc2.tops_par" > tab21
echo "${date1}_iw2_slc2 ${date1}_iw2_slc2.par ${date1}_iw2_slc2.tops_par" >> tab21

echo "${date2}_iw1_slc2 ${date2}_iw1_slc2.par ${date2}_iw1_slc2.tops_par" > tab22
echo "${date2}_iw2_slc2 ${date2}_iw2_slc2.par ${date2}_iw2_slc2.tops_par" >> tab22
```

Extract bursts from swath SLCs:

```
SLC_copy_S1_TOPS tab11 tab21 1 3 2 8

SLC_copy_S1_TOPS tab12 tab22 1 3 2 8
```

Note: Burst numbers in repeat-pass swath SLCs do not always match !!!

Additonal tools:

S1_coreg_TOPS_burst_selection

S1_import_SLC_from_zipfiles

S1_OPOD_vec

SLC_cat_S1_TOPS