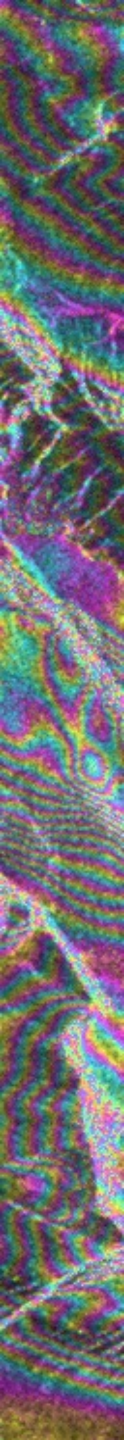


GAMMA REMOTE SENSING

Offset Tracking for mapping Glacier motion with SENTINEL-1

Gamma Remote Sensing AG

Worbstrasse 225

3073 Gümligen

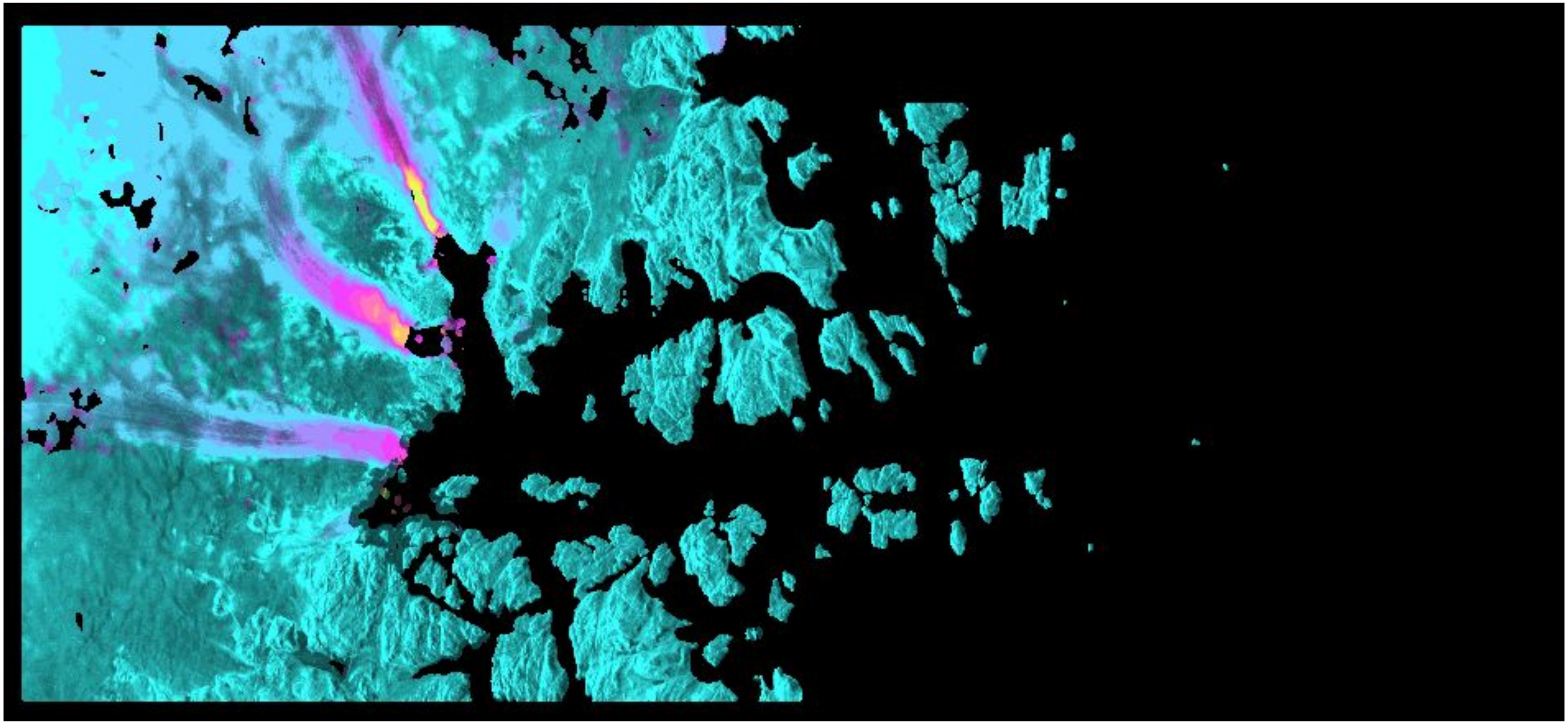
Switzerland

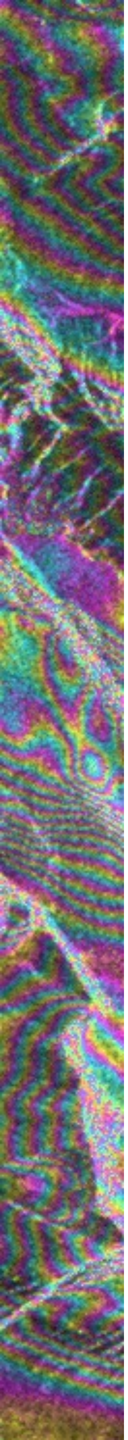
http://www.gamma-rs.ch

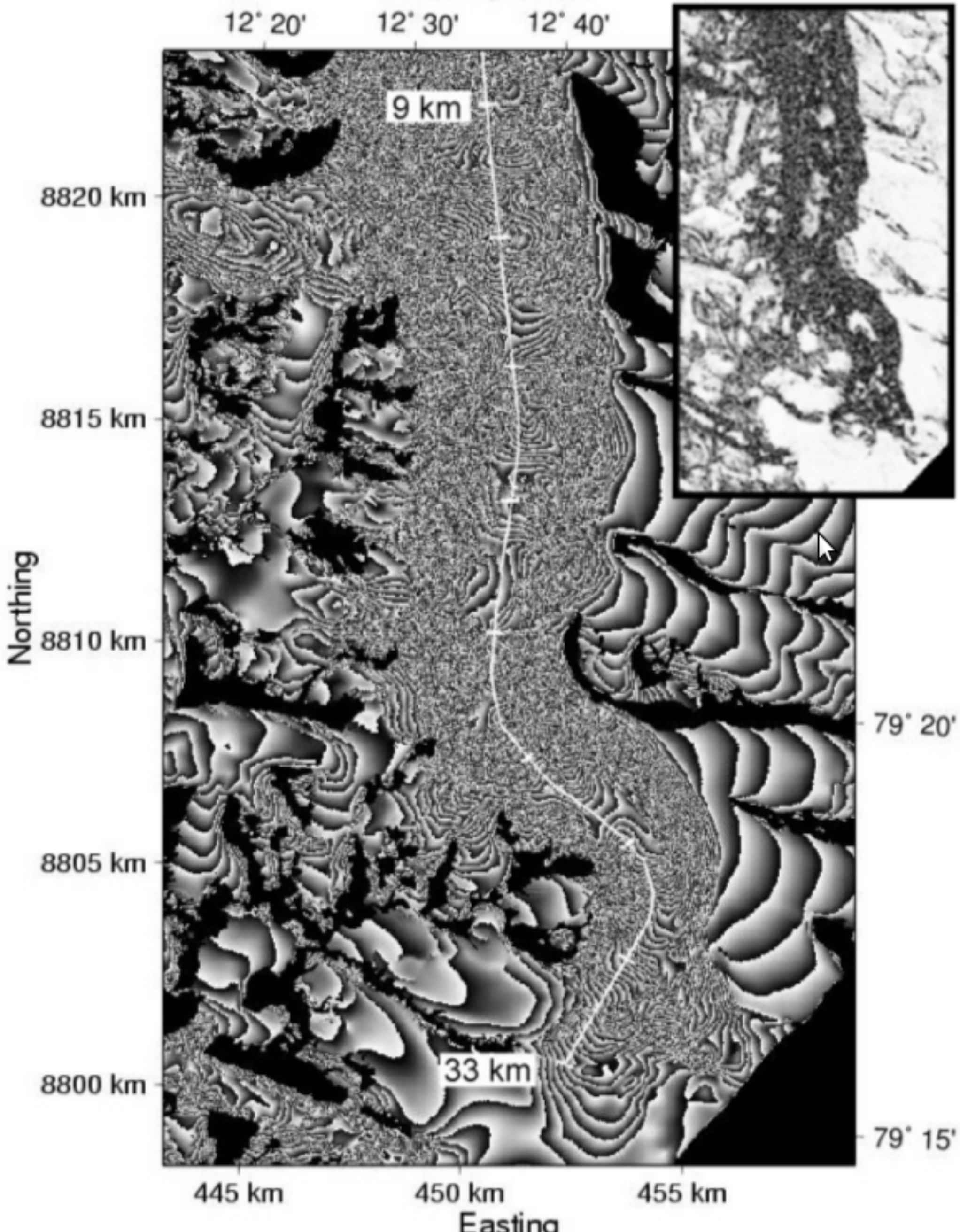
Offset Tracking

Glacier motion is determined by means of intensity cross-correlation

A major advantage over differential interferometry is that it can be applied also in case coherence is lost due to rapid and incoherent flow,large repeat intervals, glacier surface changes (snowfall, snow/ice melt, snow redistribution due to wind, etc.)







Surface motion of Monacobreen Glacier in Svalbard as seen by an interferoemtric image pair acquired by ERS-1.

Monacobreen glacier exhibits surge-type behavior with long periods (20-200 years) of slow flow with short periods of fast flow.

Strozzi et al. (2002)

SENTINEL-1

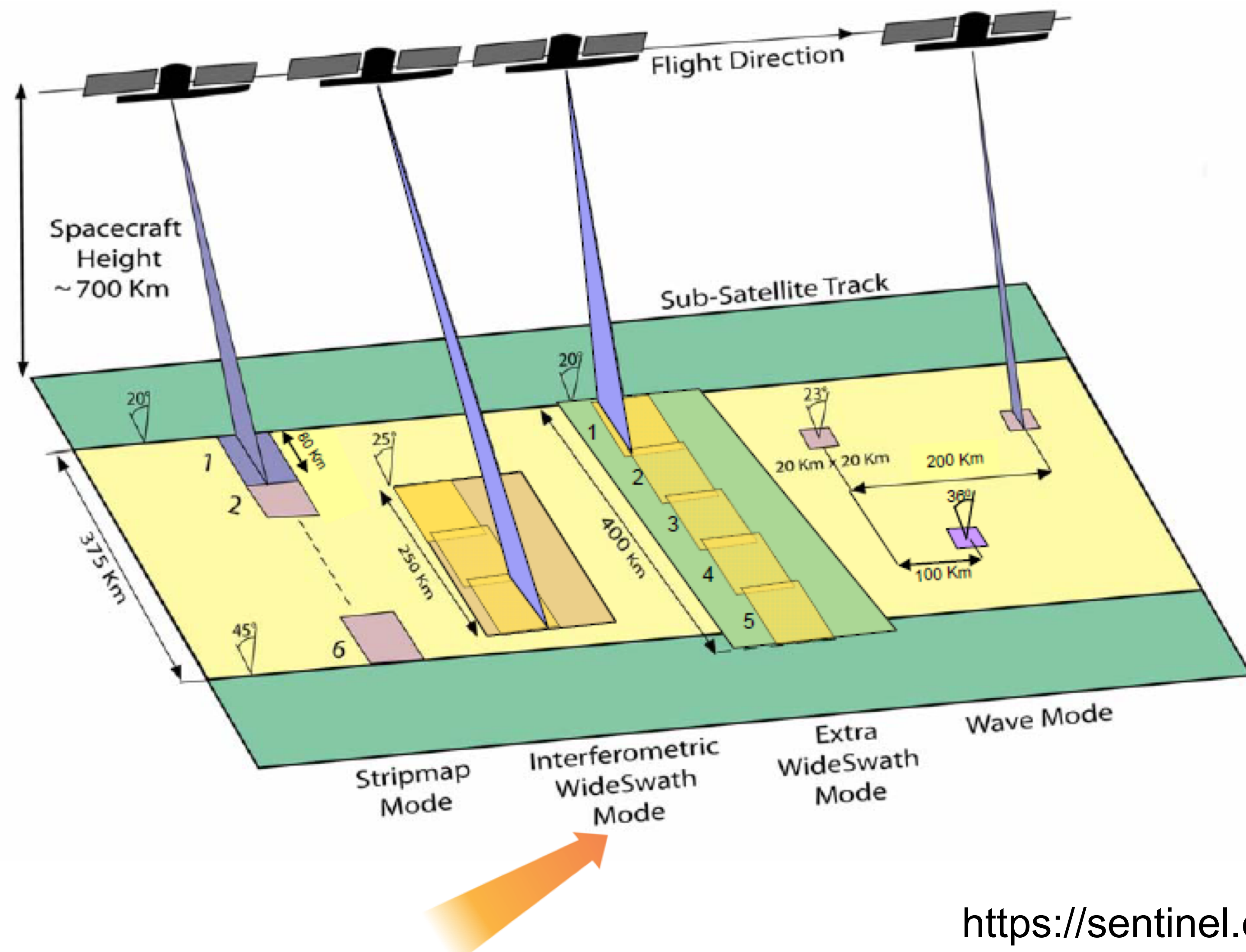
Launch Dates:
Sentinel-1A - 03 April 2014
Sentinel-1B - Scheduled for 2016
Operational lifespan: 7 years (With consumables for 12)

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/

Steps of processing

1) Generation of an S1 TOPS SLC and an S1 TOPS MLI mosaic

2) Geocoding of the S1 TOPS data

3) Co-registration of a pair of S1 TOPS SLC

4) Calculation of a S1 TOPS offset field

5) Post-processing of offset field

6) Geocoding of the result

Dataset

Input data (as found in the directory inputs):

20141022.IW2.slc	S1 sub-swath 3 burst SLC data (SCOMPLEX format)
20141022.IW2.slc.par	SLC parameter file of S1 sub-swath 2 burst SLC data
20141022.IW2.slc.TOPS_par	SLC parameter file of S1 sub-swath 2 burst SLC data
20141022.IW3.slc	S1 sub-swath 2 burst SLC data (SCOMPLEX format
20141022.IW3.slc.par	SLC parameter file of S1 sub-swath 2 burst SLC data
20141022.IW3.slc.TOPS_par	SLC parameter file of S1 sub-swath 2 burst SLC data
20141103.IW2.slc	S1 sub-swath 3 burst SLC data (SCOMPLEX format
20141103.IW2.slc.par	SLC parameter file of S1 sub-swath 2 burst SLC data
20141103.IW2.slc.TOPS_par	SLC parameter file of S1 sub-swath 2 burst SLC data
20141103.IW3.slc	S1 sub-swath 2 burst SLC data (SCOMPLEX format
20141103.IW3.slc.par	SLC parameter file of S1 sub-swath 2 burst SLC data
20141103.IW3.slc.TOPS_par	SLC parameter file of S1 sub-swath 2 burst SLC data
SRTM.dem	SRTM DEM over the area of the S1 data
SRTM.dem_par	DEM parameter file of the SRTM DEM over the area of the S1 data
20141022.SLC_tab	SLC_tab file for reference burst SLC
20141103.SLC_tab	SLC_tab file for slave burst SLC
20141022.poly1	polygon file for rock area

Dataset

Remarks:

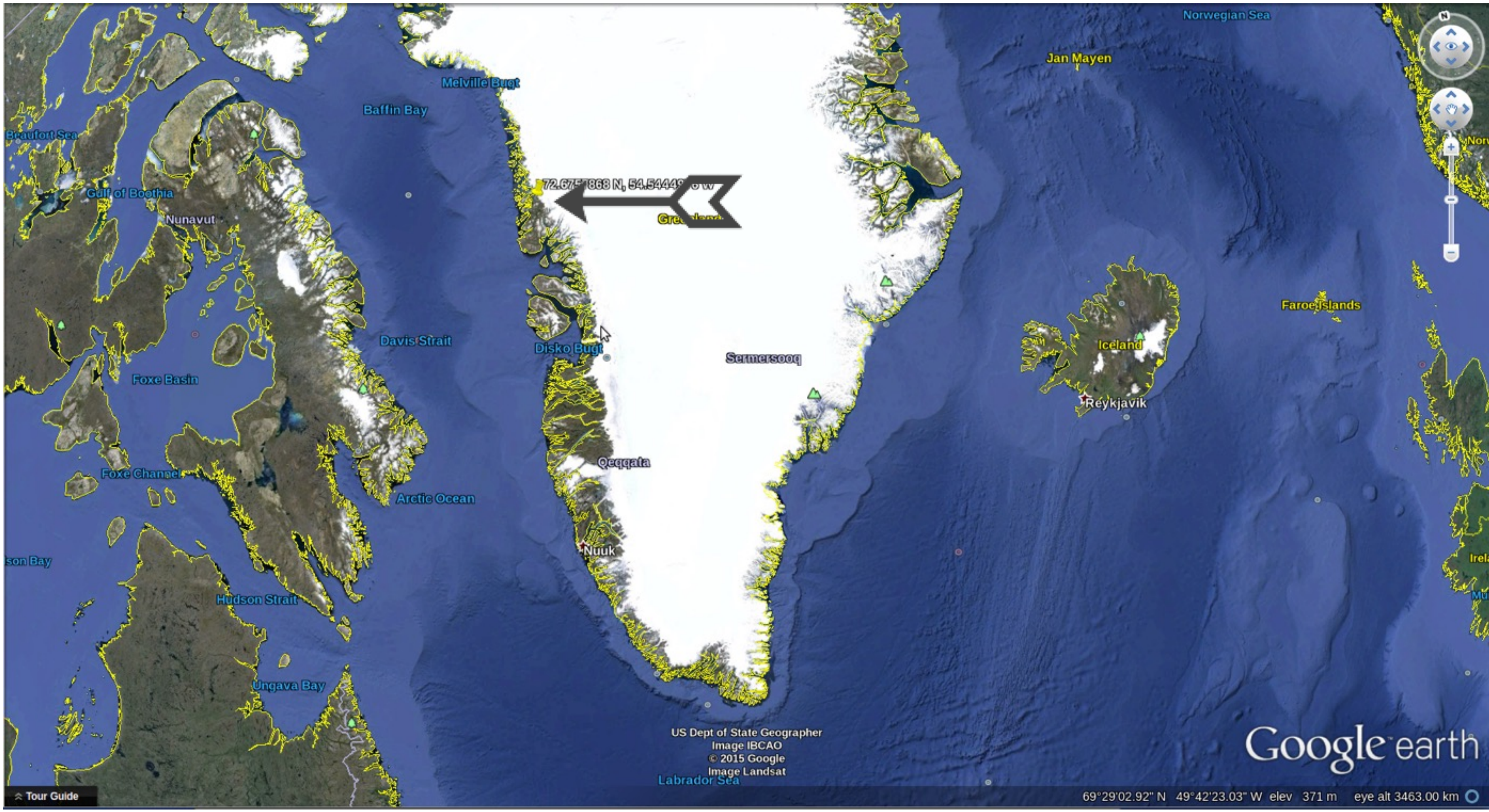
- just two subswaths (IW2, IW3) were selected for the two dates;
  the IWS2 data provided include only 3 bursts each;
  the IWS3 data provided include only 2 bursts each;

- the heights in the SRTM file are WGS84 heights (and not heights
  over the geoid)

- the S1 data are copyright ESA

- jpg files of intermediate and final results are provided for
  comparison in the directory results

- some other files are also copied to the results directory
  (for comparison of the determined offsets)


Norwegian Sea
Jan Mayen
Melville Bugt
Baffin Bay
Beaufort Sea
Gulf of Boothia
Nunavut
Davis Strait
Disko Bugt
Sermersooq
Faroe Islands
Iceland
Reykjavik
Foxe Basin
Foxe Channel
Qeqqata
Arctic Ocean
Nuuk
Hudson Strait
Ungava Bay
US Dept of State Geographer
Image IBCAO
© 2015 Google
Image Landsat
Labrador Sea
Tour Guide
69°29'02.92" N 49°42'23.03" W elev 371 m eye alt 3463.00 km
Google earth

Prepare data

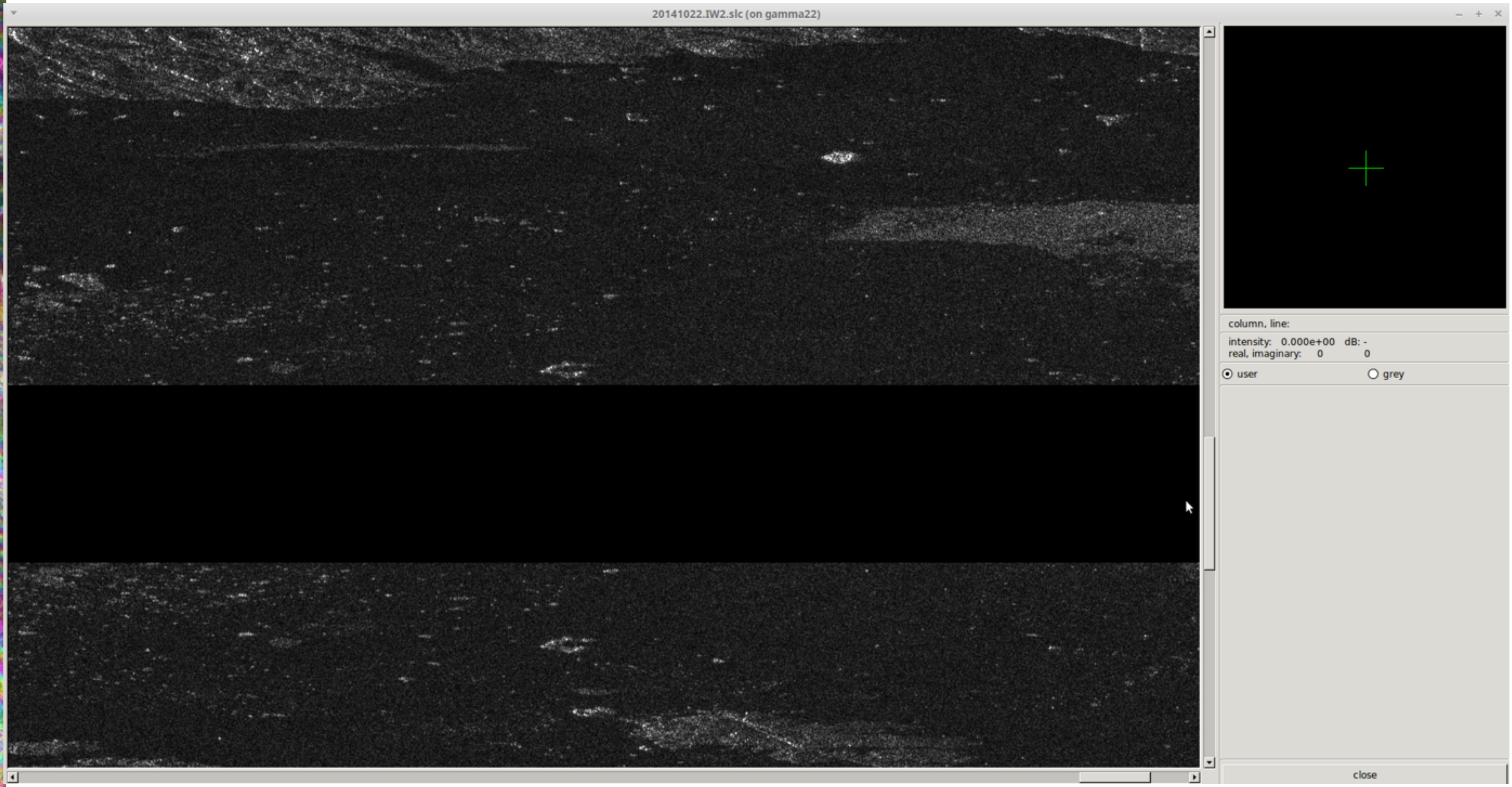
```
cd ./S1_Greenland_tracking_demo

# copy inputs into working directory

/bin/cp inputs/* .
```

more 20141103.IW2.slc.par

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

title:     s1a-iw2-slc-hh-20141103t102338-20141103t102406-003116-00393b-002.tiff
sensor:    S1A IW IW2 HH
date:      2014 11 03 10 23 43.65799
start_time:             37423.657993   s
center_time:            37428.154522   s
end_time:               37432.651052   s
azimuth_line_time:     2.0555563e-03   s
line_header_size:                  0
range_samples:                 24713
azimuth_lines:                  5076
range_looks:                       1
azimuth_looks:                     1
image_format:               SCOMPLEX
image_geometry:             SLANT_RANGE
range_scale_factor:     1.0000000e+00
azimuth_scale_factor:   1.0000000e+00
center_latitude:          72.6757868   degrees
center_longitude:        -54.5444976   degrees
heading:                -153.0671876   degrees
range_pixel_spacing:        2.329562   m
azimuth_pixel_spacing:     13.852310   m
near_range_slc:          850532.4463  m
center_range_slc:        879316.5144  m
far_range_slc:           908100.5825  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:              38.7360   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:                      486.4863149  Hz
azimuth_proc_bandwidth:     313.00000  Hz
doppler_polynomial:           1.00776 -1.45352e-04 -3.55178e-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:             60.0000  dB
sar_to_earth_center:             7066117.2061   m
earth_radius_below_sensor:       6358763.0967   m
earth_semi_major_axis:           6378137.0000   m
earth_semi_minor_axis:           6356752.3141   m
number_of_state_vectors:                   32
time_of_first_state_vector:        37416.519000   s
state_vector_interval:                 1.000000   s
state_vector_position_1:   1693331.5507   -1407971.2412    6714112.3581   m   m   m
state_vector_velocity_1:      2585.48565     -6820.12745     -2077.89706   m/s m/s m/s
state_vector_position_2:   1695915.5912   -1414790.7686    6712030.6759   m   m   m
--More--(34%)
```

Display SLCs

disSLC 20141022.IW2.slc 24713



Generation of an S1 TOPS SLC and an S1 TOPS MLI mosaic

20141022: this scene will be used as reference for the geocoding and as master for the co-registration and interferogram generation

prepare SLC_tab for the first scene: 3 filenames (SLC SLC_par TOPS_par)

echo "20141022.IW2.slc 20141022.IW2.slc.par 20141022.IW2.slc.TOPS_par" > 20141022.SLC_tab

echo "20141022.IW3.slc 20141022.IW3.slc.par 20141022.IW3.slc.TOPS_par" >> 20141022.SLC_tab

more 20141022.SLC_tab

-->

20141022.IW2.slc 20141022.IW2.slc.par 20141022.IW2.slc.TOPS_par
20141022.IW3.slc 20141022.IW3.slc.par 20141022.IW3.slc.TOPS_par

Generation of an S1 TOPS SLC and an S1 TOPS MLI mosaic

Generate the SLC mosaic for the first scene. The number of range looks (10) and azimuth looks (2) is used to assure that the cutting between bursts and sub-swaths is done such that multi-looking will not mix pixels from different subswaths or bursts

SLC_mosaic_S1_TOPS 20141022.SLC_tab 20141022.slc 20141022.slc.par 10 2

multi_look 20141022.slc 20141022.slc.par 20141022.slc.mli 20141022.slc.mli.par 10 2

Generate MLI from this mosaic and visualize using a SUN rasterfile

raspwr 20141022.slc.mli 4752 1 0 1 1 1. .35 1 20141022.slc.mli.ras

eog 20141022.slc.mli.ras &

-->
20141022.slc 20141022.slc.par
20141022.slc.mli 20141022.slc.mli.par

Generation of an S1 TOPS SLC and an S1 TOPS MLI mosaic

Now for the second image:

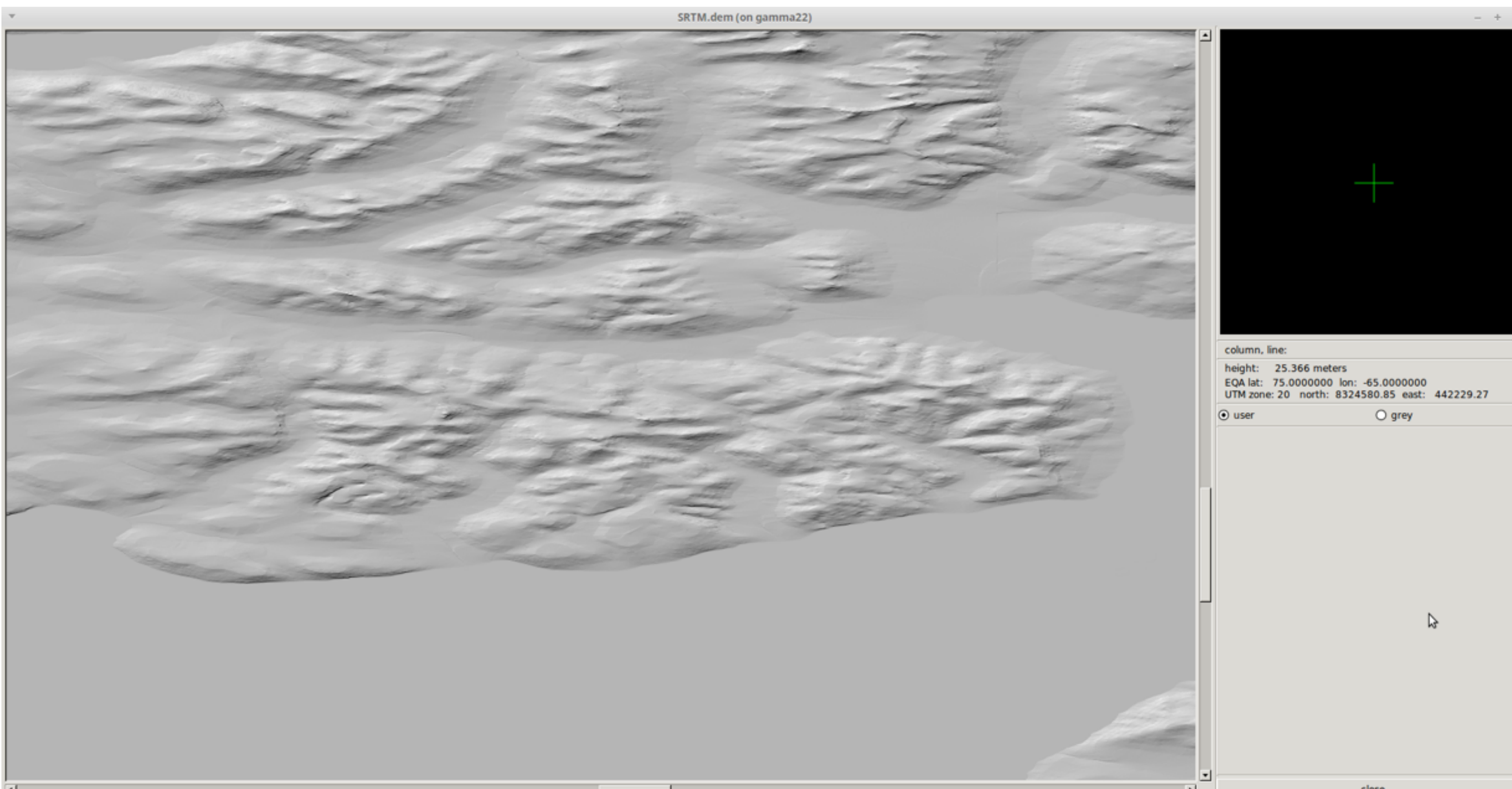
```
echo "20141103.IW2.slc 20141103.IW2.slc.par 20141103.IW2.slc.TOPS_par" > 20141103.SLC_tab

echo "20141103.IW3.slc 20141103.IW3.slc.par 20141103.IW3.slc.TOPS_par" >> 20141103.SLC_tab

SLC_mosaic_S1_TOPS 20141103.SLC_tab 20141103.slc  20141103.slc.par 10 2

multi_look 20141103.slc  20141103.slc.par 20141103.slc.mli  20141103.slc.mli.par 10 2

raspwr 20141103.slc.mli 4752 1 0 1 1 1. .35

eog 20141103.slc.mli.ras &
```

Geocoding of S1 TOPS data

DEM used here is based on Russian Topographic Maps (corrected to WGS84 heights).

SRTM.dem
SRTM.dem_par

disdem_par SRTM.dem SRTM.dem_par



Geocoding of S1 TOPS data

gc_map 20141022.slc.mli.par - SRTM.dem_par SRTM.dem EQA.dem_par EQA.dem 20141022.lt 3 1 20141022.sim_sar u v inc psi pix ls_map 8 2

DEM oversampling factors: 3 in lat 1 in lon (--> about 30m)

Output:

EQA.dem_par	- parameter file for oversampled DEM subset
EQA.dem	- oversampled DEM subset
20141022.lt	- geocoding look-up table
20141022.sim_sar	- simulated radar image
U	- slope
V	- aspect
Inc	- local incidence angle
Psi	- projection angle
Pix	- pixel area normalization factor
ls_map	- layover/shadow mask

cat EQA.dem_par

```
Gamma DIFF&GEO DEM/MAP parameter file
title: N74W065.hgt
DEM_projection:     EQA
data_format:        REAL*4
DEM_hgt_offset:          0.00000
DEM_scale:               1.00000
width:                   6520
nlines:                  3201
corner_lat:     73.4308340  decimal degrees
corner_lon:    -58.1683361  decimal degrees
post_lat:   -2.7777767e-04  decimal degrees
post_lon:    8.3333300e-04  decimal degrees

ellipsoid_name: WGS 84
ellipsoid_ra:        6378137.000   m
ellipsoid_reciprocal_flattening:  298.2572236

datum_name: WGS 1984
datum_shift_dx:              0.000   m
datum_shift_dy:              0.000   m
datum_shift_dz:              0.000   m
datum_scale_m:         0.00000e+00
datum_rotation_alpha:  0.00000e+00   arc-sec
datum_rotation_beta:   0.00000e+00   arc-sec
datum_rotation_gamma:  0.00000e+00   arc-sec
datum_country_list: Global Definition, WGS84, World
```

Geocoding of S1 TOPS data – Refinement of Look-up table

Generate simulated radar image based on DEM and resample to radar geometry.

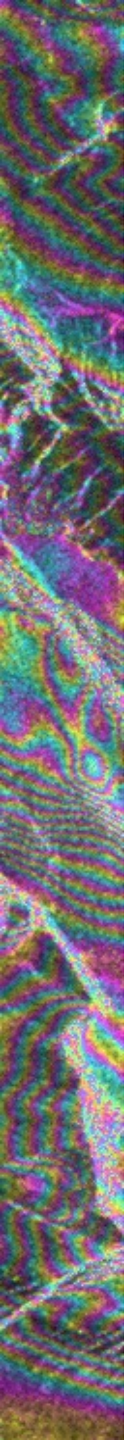
pixel_area 20141022.slc.mli.par EQA.dem_par EQA.dem 20141022.lt ls_map inc pix_sigma0 pix_gamma0 20

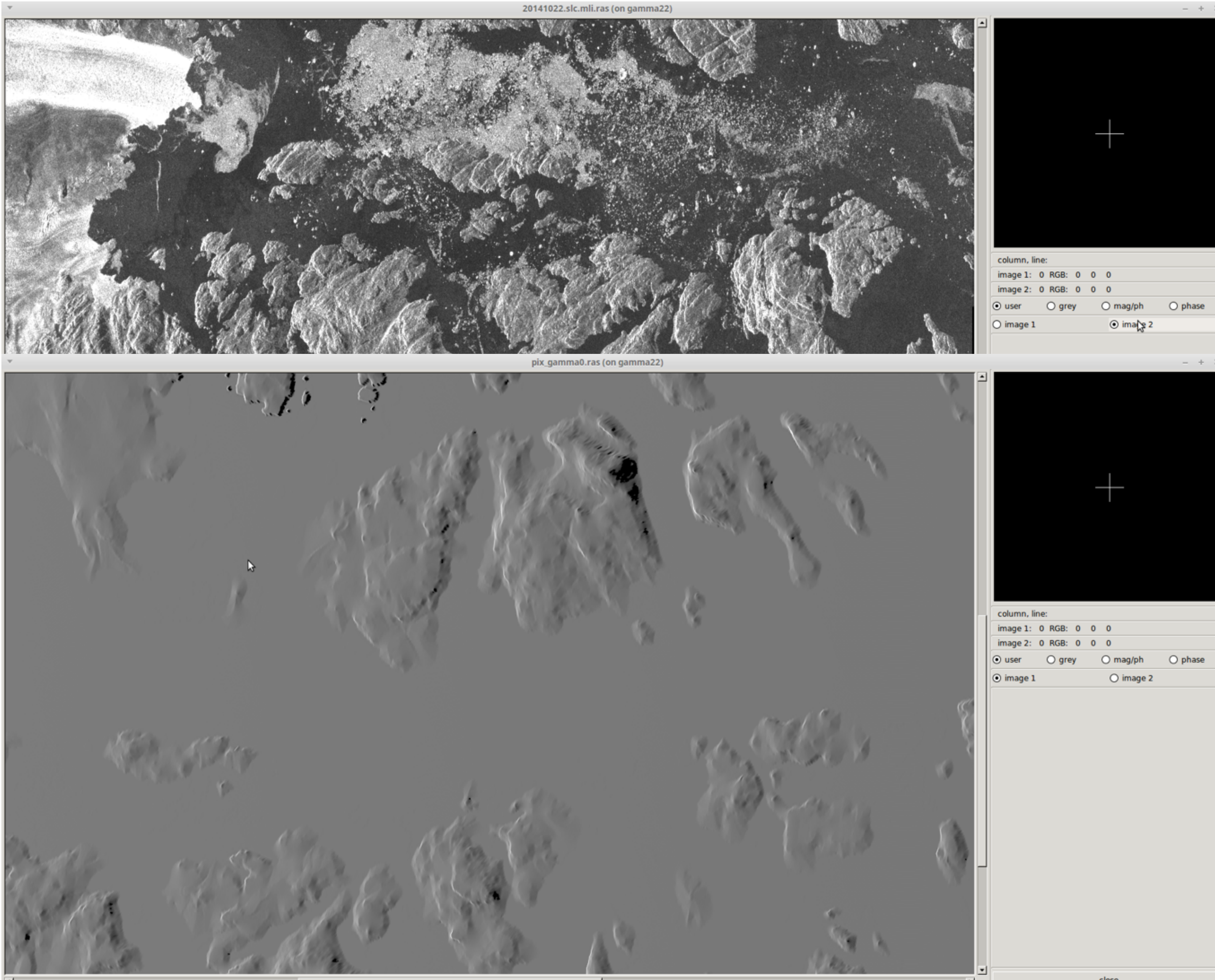
Compare real and simulated radar image

raspwr pix_gamma0 4752 1 0 1 1 1. .35 1 pix_gamma0.ras

dis2ras pix_gamma0.ras 20141022.slc.mli.ras &

→ simulated backscatter well suited to determine a refinement





20141022.slc.mli.ras (on gamma22)
column, line:
image 1: 0 RGB: 0 0 0
image 2: 0 RGB: 0 0 0
user
grey
mag/ph
phase
image 1
image 2
pix_gamma0.ras (on gamma22)
column, line:
image 1: 0 RGB: 0 0 0
image 2: 0 RGB: 0 0 0
user
grey
mag/ph
phase
image 1
image 2
close

Geocoding of S1 TOPS data – Refinement of Look-up table

create_diff_par 20141022.slc.mli.par - 20141022.diff_par 1 0

offset_pwrm pix_sigma0 20141022.slc.mli 20141022.diff_par 20141022.offs 20141022.ccp 128 128 offsets 2 64 32 0.25 4 0 0

→

number of offsets above correlation threshold: 388 of 2048
output binary offset data file: 20141022.offs
output binary cross-correlation data (ccp) file: 20141022.ccp
number of offsets range: 64   azimuth: 32
MLI offset search window size range: 128 azimuth: 128
output DIFF/GEO parameter file: 20141022.diff_par

offset_fitm 20141022.offs 20141022.ccp 20141022.diff_par coffs coffsets 0.35 1

→

final solution: 226 offset estimates accepted out of 2048 samples

final range offset poly. coeff.:   0.83347
final azimuth offset poly. coeff.:   -0.62781

final range offset poly. coeff. errors: 2.00323e-01
final azimuth offset poly. coeff. errors: 2.23004e-01
final model fit std. dev. (samples) range: 1.3504   azimuth: 1.5033

Geocoding of S1 TOPS data – Refinement of Look-up table

Remarks:

1) correcting only an offset is sufficient
2) estimated refinement offset is small
3) not correcting the geocoding may also be an adequate alternative
(i.e. fully trusting the orbit geometry)

Refine geocoding lookup table

gc_map_fine 20141022.lt 6520 20141022.diff_par 20141022.lt_fine 1

Geocoding of S1 TOPS data – Refinement of Look-up table

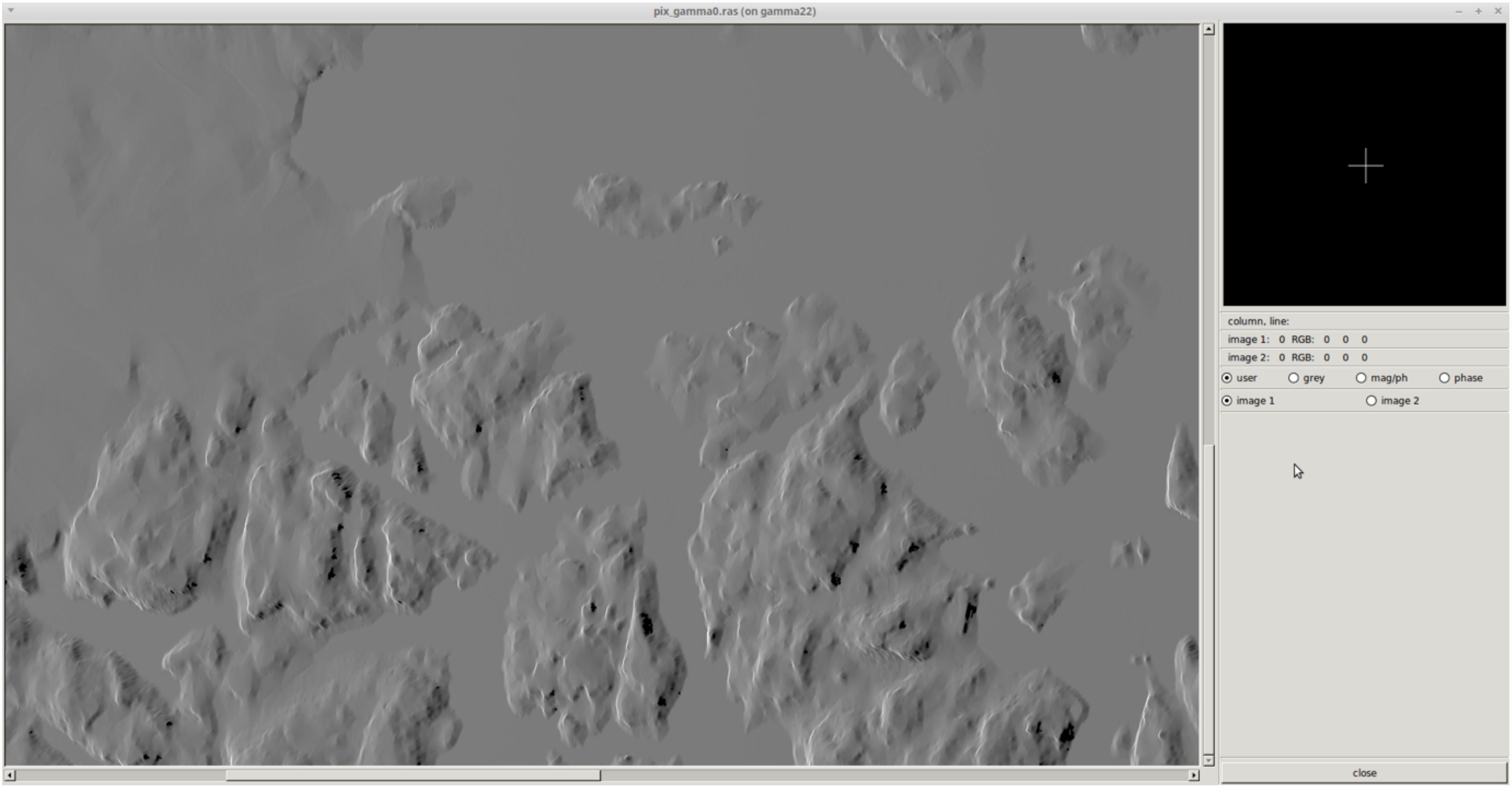
Apply again pixel_area using the refined lookup table to assure that the simulated image uses the refined geometry

pixel_area 20141022.slc.mli.par EQA.dem_par EQA.dem 20141022.lt_fine ls_map inc pix_sigma0 pix_gamma0 20

raspwr pix_gamma0 4752 1 0 1 1 1. .35 1 pix_gamma0.ras

dis2ras pix_gamma0.ras 20141022.slc.mli.ras &

Geocoding of S1 TOPS data – Refinement of Look-up table



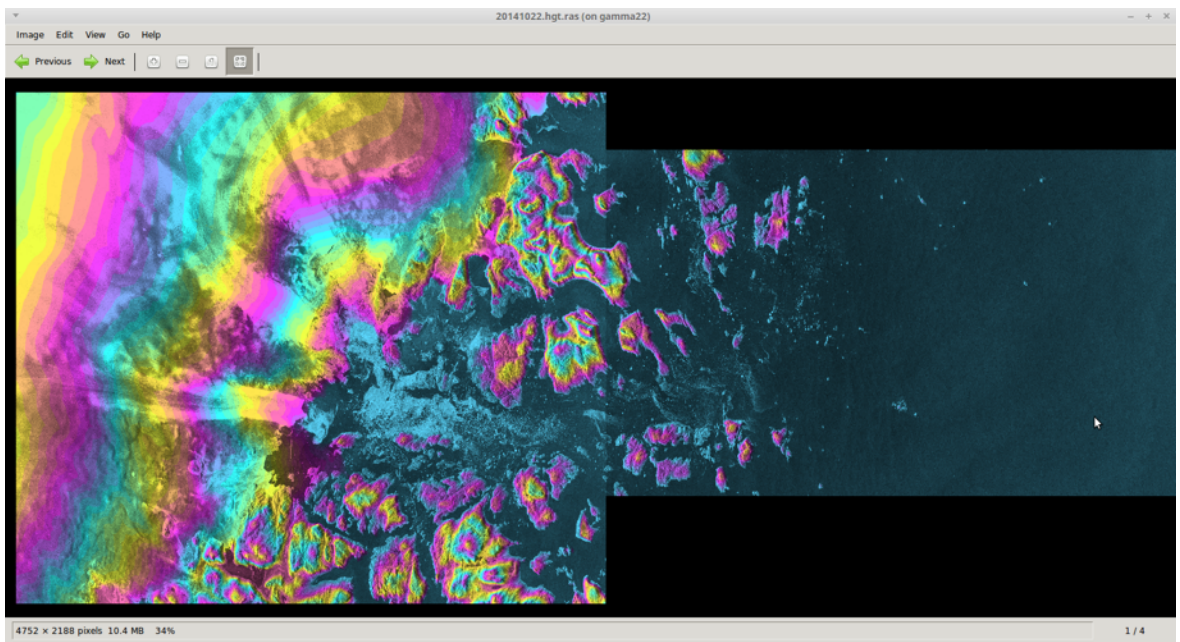
Resample the DEM heights to the slant range MLI geometry

geocode 20141022.lt_fine EQA.dem 6520 20141022.hgt 4752 2188 2 0

rashgt 20141022.hgt 20141022.slc.mli 4752 1 1 0 1 1 500. 1. .35 1 20141022.hgt.ras

eog 20141022.hgt.ras &

--> geocoding lookup table (20141022.lt_fine), geocoded backscatter image (EQA.20141022.slc.mli),and heights in slant range geoemtry (20141022.hgt).



Co-registration of a pair of S1 TOPS SLC

Processing strategy:

A) Advanced co-registration procedure for Interferometry considering refinements using matching and spectral diversity for the burst overlap regions. A polygon area (covering the stable rock areas) is used to optimize the method. The procedure is supported by the script S1_coreg_TOPS

B) Use simple method without refinement just based on the available orbit data and assuming a constant terrain height

Co-registration of a pair of S1 TOPS SLC – Strategy A

The script S1_coreg_TOPS is used for the co-registration

S1_coreg_TOPS automates a co-registration sequence that turned out to be often applicable

S1_coreg_TOPS calculates the co-registration lookup table and refines it iteratively, first by estimating offsets using matching and then the spectral diversity method for the burst overlap areas.

Quality information is written out to a quality file

The differential interferogram is calculated

Co-registration of a pair of S1 TOPS SLC – Strategy A

create_offset 20141022.slc.par 20141103.slc.par 20141022_20141103.off 1 10 2 0

echo "20141022.IW2.slc 20141022.IW2.slc.par 20141022.IW2.slc.TOPS_par" > 20141022.SLC_tab
echo "20141022.IW3.slc 20141022.IW3.slc.par 20141022.IW3.slc.TOPS_par" >> 20141022.SLC_tab

echo "20141103.IW2.slc 20141103.IW2.slc.par 20141103.IW2.slc.TOPS_par" > 20141103.SLC_tab
echo "20141103.IW3.slc 20141103.IW3.slc.par 20141103.IW3.slc.TOPS_par" >> 20141103.SLC_tab

For co-registered SLC

echo "20141103.IW2.rslc 20141103.IW2.rslc.par 20141103.IW2.rslc.TOPS_par" >
20141103.RSLC_tab

echo "20141103.IW3.rslc 20141103.IW3.rslc.par 20141103.IW3.rslc.TOPS_par" >>
20141103.RSLC_tab

Co-registration of a pair of S1 TOPS SLC – Strategy A

S1_coreg_TOPS: Script to coregister a Sentinel-1 TOPS mode burst SLC to a reference burst SLC v1.1 23-Nov-2015 uw

usage: S1_coreg_TOPS <SLC1_tab> <SLC1_ID> <SLC2_tab> <SLC2_ID> <RSLC2_tab> [hgt] [RLK] [AZLK] [poly1] [poly2] [cc_thresh] [fraction_thresh] [ph_stdev_thresh] [cleaning] [flag1] [RSLC3_tab]

- SLC1_tab (input) SLC_tab of S1 TOPS burst SLC reference (e.g. 20141015.SLC_tab)
- SLC1_ID (input) ID for reference files (e.g. 20141015)
- SLC2_tab (input) SLC_tab of S1 TOPS burst SLC slave (e.g. 20141027.SLC_tab)
- SLC2_ID (input) ID for slave files (e.g. 20141027)
- RSLC2_tab (input) SLC_tab of co-registered S1 TOPS burst SLC slave (e.g. 20141027.RSLC_tab)
- hgt (input) height map in RDC of MLI-1 mosaic (float, or constant height value; default=0.1)
- RLK number of range looks in the output MLI image (default=10)
- AZLK number of azimuth looks in the output MLI image (default=2)
- poly1 polygon file indicating area used for matching (relative to MLI reference to reduce area used for matching)
- poly2 polygon file indicating area used for spectral diversity (relative to MLI reference to reduce area used for matching)
- cc_thresh coherence threshold used (default = 0.8)
- fraction_thresh minimum valid fraction of unwrapped phase values used (default = 0.01)
- ph_stdev_thresh phase standard deviation threshold (default = 0.8)
- cleaning flag to indicate if intermediate files are deleted (default = 1 --> deleted, 0: not deleted)
- flag1 flag to indicate if existing intermediate files are used (default = 0 --> not used, 1: used)
- RSLC3_tab (input) 3 column list of already available co-registered TOPS slave image to use for overlap interferograms
- RSLC3_ID (input) ID for already available co-registered TOPS slave; if indicated then the differential interferogram between RSLC3 and RSLC2 is calculated

Co-registration of a pair of S1 TOPS SLC – Strategy A

Determine 20141022.poly1 as an area to be used for the matching refinement
--> do not select water area (incoherent) and ice area (may have velocity)

polyras 20141022.slc.mli.ras > 20141022.poly1 ### you don't have to do this as the polygons are provided

Here we select an area including most rock areas

S1_coreg_TOPS 20141022.SLC_tab 20141022 20141103.SLC_tab 20141103 20141103.RSLC_tab 20141022.hgt 10 2 20141022.poly1 20141022.poly1 0.8 0.01 0.8 1 0

Alternatively the S1_coreg_TOPS can be run without indicating polygon areas:

S1_coreg_TOPS 20141022.SLC_tab 20141022 20141103.SLC_tab 20141103 20141103.RSLC_tab 20141022.hgt 10 2 - - 0.8 0.01 0.8 1 0

--> quality file 20141022_20141103.coreg_quality

reference: 20141022 20141022.rslc 20141022.rslc.par 20141022.SLC_tab
slave: 20141103 20141103.slc 20141103.slc.par 20141103.SLC_tab
coregistered_slave: 20141103 20141103.rslc 20141103.rslc.par 20141103.RSLC_tab
reference for spectral diversity refinement: 20141022.SLC_tab
polygon used for matching (poly1): 20141022.poly1
polygon used for spectral diversity (poly2): 20141022.poly1

Iterative improvement of refinement offset using matching:
matching_iteration_1: -0.01787 0.01917 -0.008935 0.001917 (daz dr daz_mli dr_mli)
matching_iteration_stdev_1: 0.0479 0.0444 (azimuth_stdev range_stdev)
matching_iteration_2: -0.00527 0.00559 -0.002635 0.000559 (daz dr daz_mli dr_mli)
matching_iteration_stdev_2: 0.0453 0.0441 (azimuth_stdev range_stdev)

Iterative improvement of refinement offset azimuth overlap regions:
az_ovr_iteration_1: -0.016359 (daz in SLC pixel)
20141022_20141103.results
thresholds applied: cc_thresh: 0.8, ph_fraction_thresh: 0.01, ph_stdev_thresh (rad): 0.8

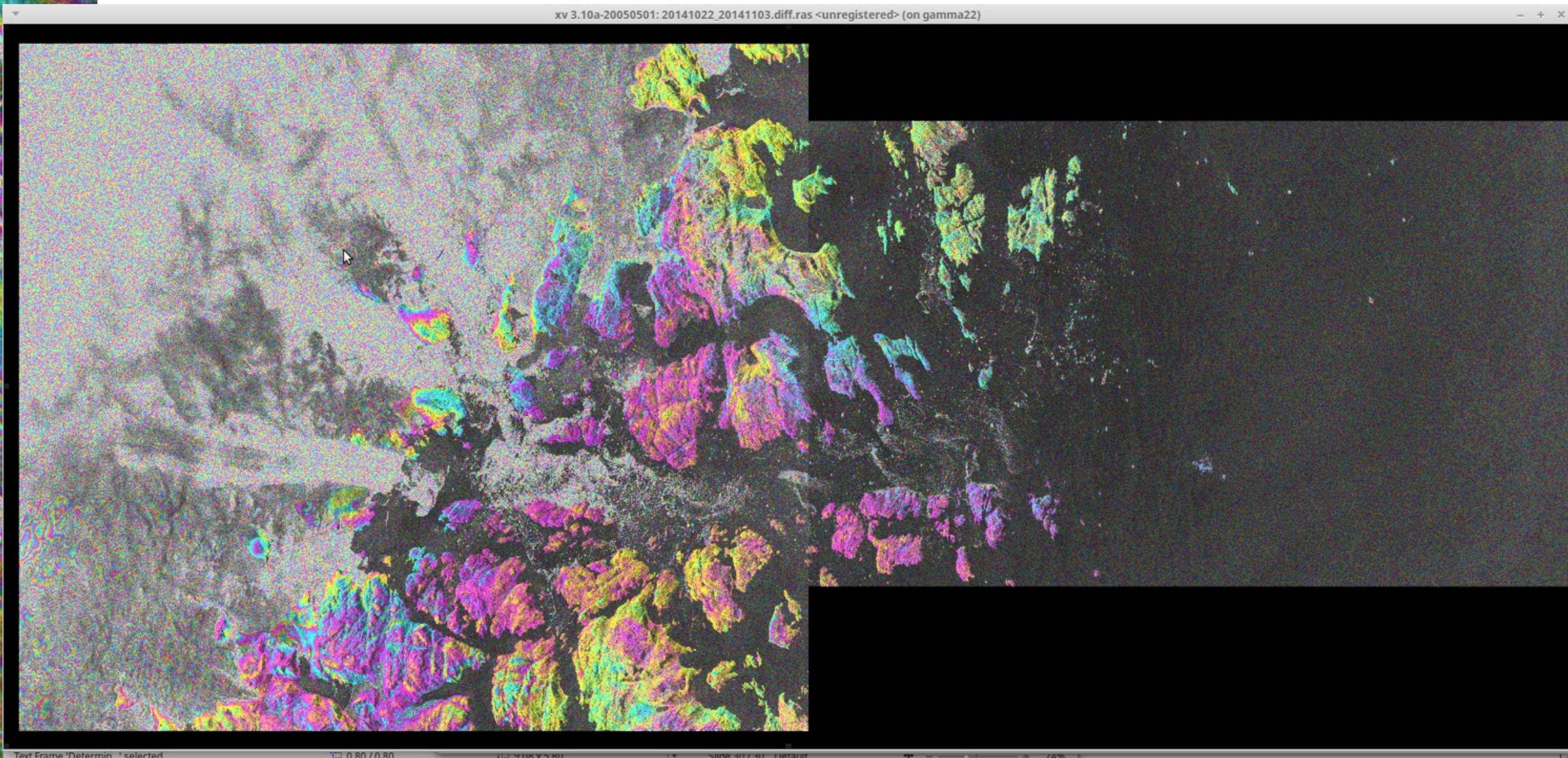
IW overlap ph_mean ph_stdev ph_fraction (cc_mean cc_stdev cc_fraction) weight
IW1 1 8.705652e-01 4.344030e-02 0.023082 (6.863320e-01 5.494430e-02 0.054761) 1.121840
IW1 2 0.00000 0.00000 0.00000 (0.000000e+00 0.000000e+00 0.000000) 0.000000
IW1 0.870548
IW2 1 1.252086e+00 7.437441e-02 0.014706 (6.559770e-01 4.291626e-02 0.046858) 0.483648
IW2 1.252074
all 1.019027
azimuth_pixel_offset -0.016359 [azimuth SLC pixel]

az_ovr_iteration 2:

az_ovr_iteration_3: -0.000259 (daz in SLC pixel)

azimuth_pixel_offset -0.000460 [azimuth SLC pixel]

Co-registration of a pair of S1 TOPS SLC – Strategy A



Differential interferogram

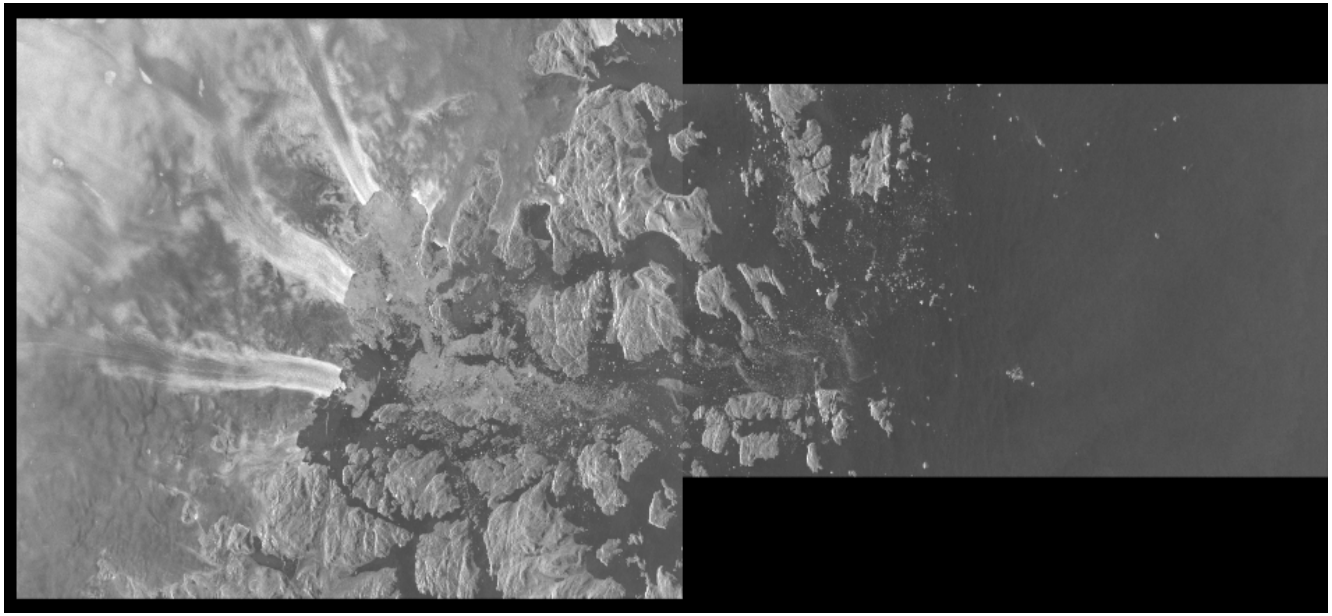
Offset Tracking

Prepare MLI in the geometry of the offset estimates

multi_look 20141022.slc 20141022.slc.par 20141022.mli5 20141022.mli5.par 50 10 0 -

raspwr 20141022.mli5 950 1 0 1 1 1. .2 1 20141022.mli5.ras

eog 20141022.mli5.ras



Offset Tracking

Estimate offset field: window size (256x64) step (50,10)

offset_pwr_tracking 20141022.slc 20141103.rslc 20141022.slc.par 20141103.rslc.par 20141022_20141103.off 20141022_20141103.offs 20141022_20141103.ccp 256 64 - 1 0.05 50 10 - - - - 4 0 0

Low correlation threshold

number of offsets above SNR threshold: 194666 of 415150
output binary offset file: 20141022_20141103.offs
output binary cross-correlation peak data (ccp) file: 20141022_20141103.ccp
number of offsets range : 950   azimuth: 437
SLC offset search window size range: 256 azimuth: 64
writing ISP OFF_par file: 20141022_20141103.off

Offset Tracking

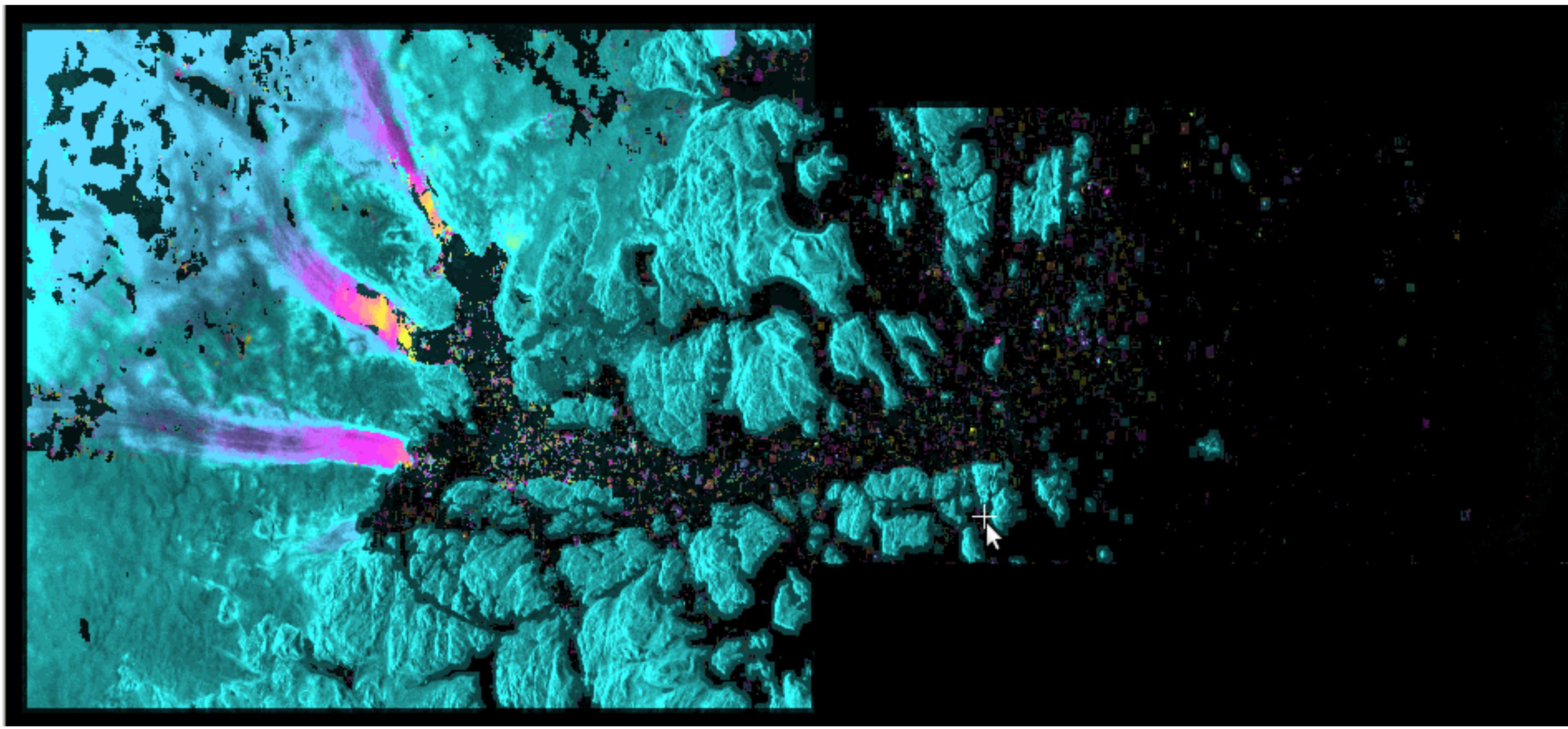
Offsets are given in pixels (complex numbers)

```
cpx_to_real 20141022_20141103.offs 20141022_20141103.offs.real 950 0
cpx_to_real 20141022_20141103.offs 20141022_20141103.offs.imag 950 1
```

Offset Tracking

dishgt 20141022_20141103.offs.real 20141022.mli5 950 1 1 0 50. 1. .35

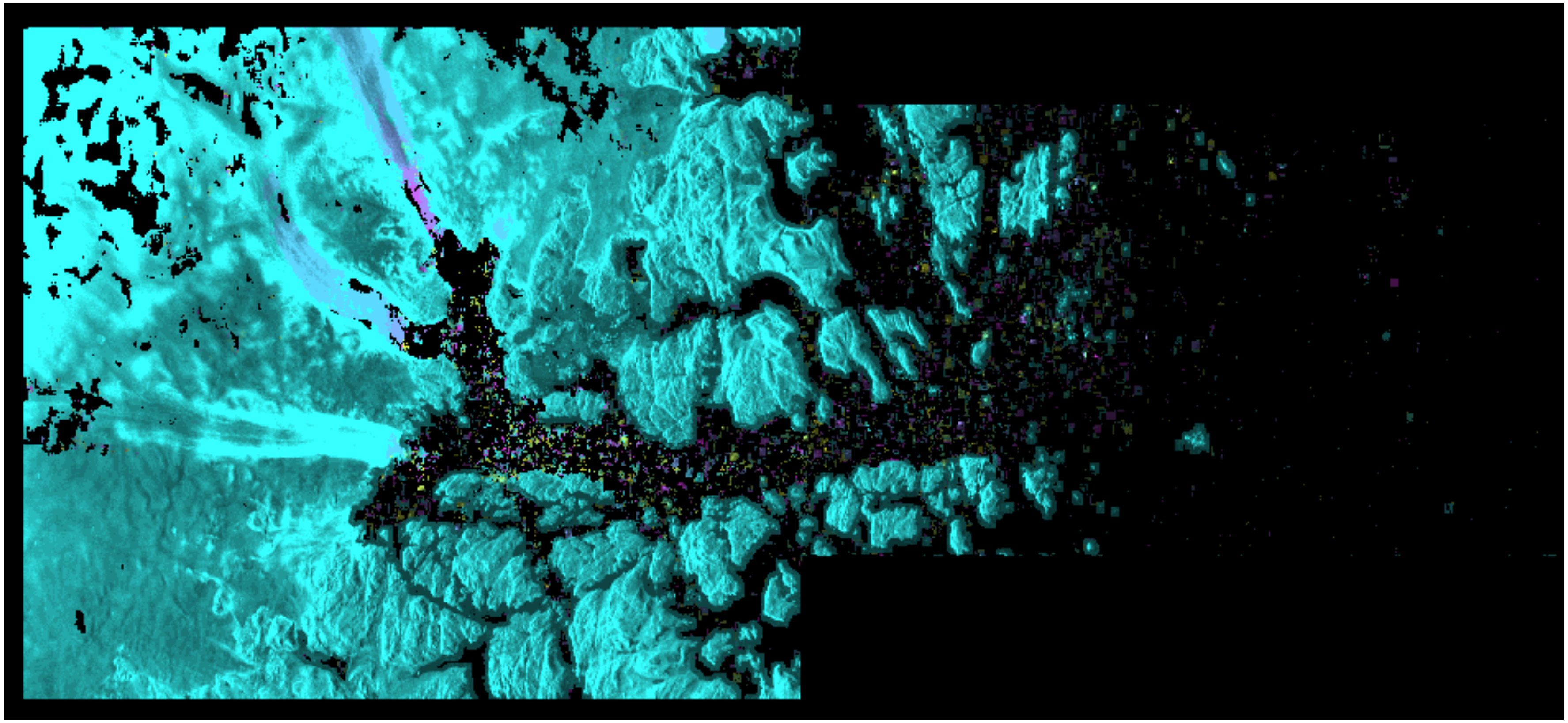
rashgt 20141022_20141103.offs.real 20141022.mli5 950 1 1 0 1 1 50. 1. .35



Offset Tracking

dishgt 20141022_20141103.offs.imag 20141022.mli5 950 1 1 0 50. 1. .35

rashgt 20141022_20141103.offs.imag 20141022.mli5 950 1 1 0 1 1 50. 1. .35



Post-processing

Convert pixel offsets to displacement map (ground-range and azimuth)

offset_tracking 20141022_20141103.offs 20141022_20141103.ccp 20141022.slc.par 20141022_20141103.off 20141022_20141103.disp_map - 2 0.05 0

cpx_to_real 20141022_20141103.disp_map 20141022_20141103.disp_map.real 950 0

cpx_to_real 20141022_20141103.disp_map 20141022_20141103.disp_map.imag 950 1

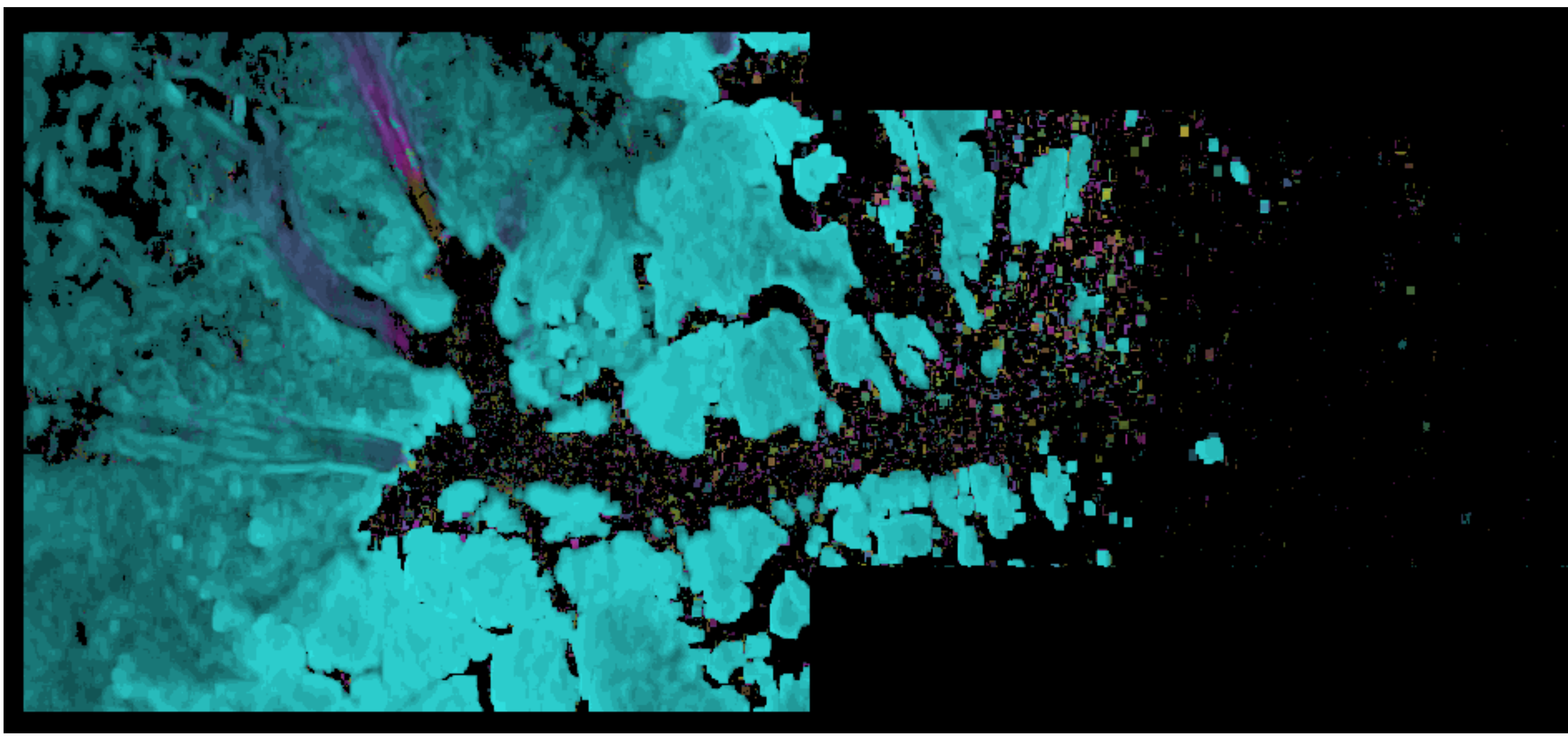
cpx_to_real 20141022_20141103.disp_map 20141022_20141103.disp_map.mag 950 3

rashgt 20141022_20141103.disp_map.real 20141022_20141103.ccp 950 1 1 0 1 1 250. 1. .35
rashgt 20141022_20141103.disp_map.imag 20141022_20141103.ccp 950 1 1 0 1 1 250. 1. .35
rashgt 20141022_20141103.disp_map.mag 20141022_20141103.ccp 950 1 1 0 1 1 250. 1. .35

dishgt 20141022_20141103.disp_map.real 20141022.mli5 950 1 1 0 250. 1. .35

dishgt 20141022_20141103.disp_map.imag 20141022.mli5 950 1 1 0 250. 1. .35

dishgt 20141022_20141103.disp_map.mag 20141022.mli5 950 1 1 0 250. 1. .35



Post-processing

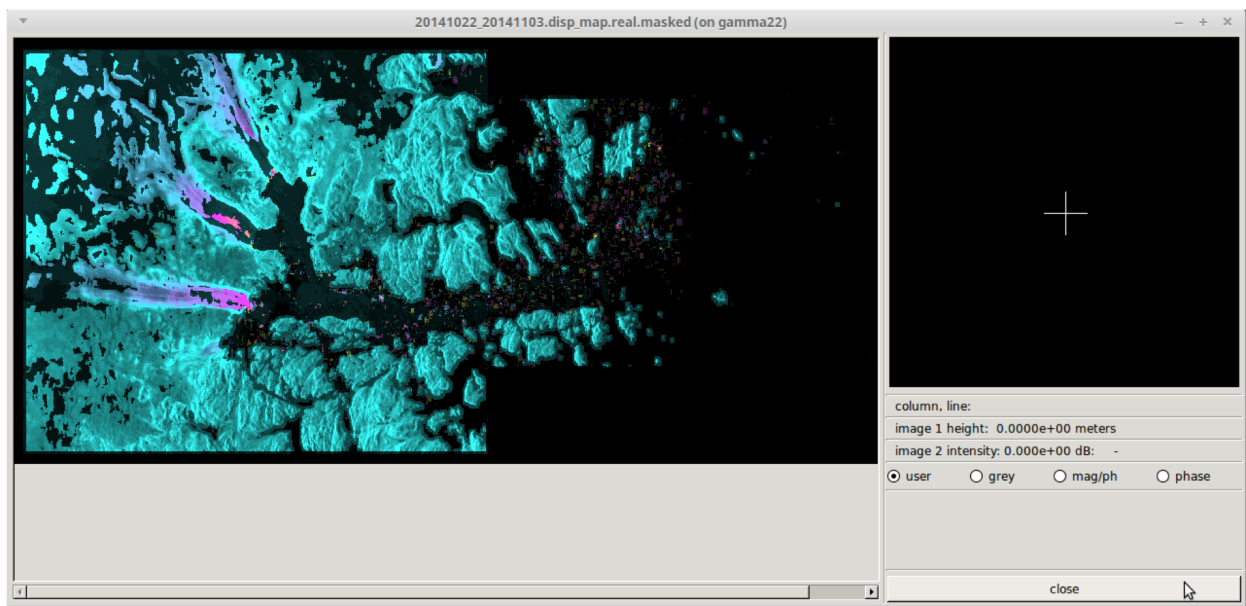
Generate a mask using a snr threshold: e.g. 0.1

rascc_mask 20141022_20141103.ccp 20141022.mli5 950 1 1 0 1 1 0.1 0.0 0.0 1.0 1. .2 1 20141022_20141103.ccp_mask.ras

mask_class 20141022_20141103.ccp_mask.ras 20141022_20141103.disp_map.real 20141022_20141103.disp_map.real.masked 0 1 1 1 0 0.0

dishgt 20141022_20141103.disp_map.real.masked 20141022.mli5 950 1 1 0 250. 1. .35

--> noisy parts are strongly reduced but also "good values" are lost



Post-processing

Generate a mask based on the deviation relative to a filtered solution:

Range:

fspf 20141022_20141103.disp_map.real 20141022_20141103.disp_map.real.fspf 950 2 7 4

dishgt 20141022_20141103.disp_map.real.fspf 20141022.mli5 950 1 1 0 250. 1. .35

lin_comb 2 20141022_20141103.disp_map.real 20141022_20141103.disp_map.real.fspf 0. 1. -1. 20141022_20141103.disp_map.dreal 950 1 0 1 1

dishgt 20141022_20141103.disp_map.dreal 20141022.mli5 950 1 1 0 250. 1. .35

Post-processing

Azimuth

fspf 20141022_20141103.disp_map.imag 20141022_20141103.disp_map.imag.fspf 950 2 7 4

dishgt 20141022_20141103.disp_map.imag.fspf 20141022.mli5 950 1 1 0 250. 1. .35

lin_comb 2 20141022_20141103.disp_map.imag 20141022_20141103.disp_map.imag.fspf 0. 1. -1. 20141022_20141103.disp_map.dimag 950 1 0 1 1

dishgt 20141022_20141103.disp_map.dimag 20141022.mli5 950 1 1 0 250. 1. .35

Post-processing

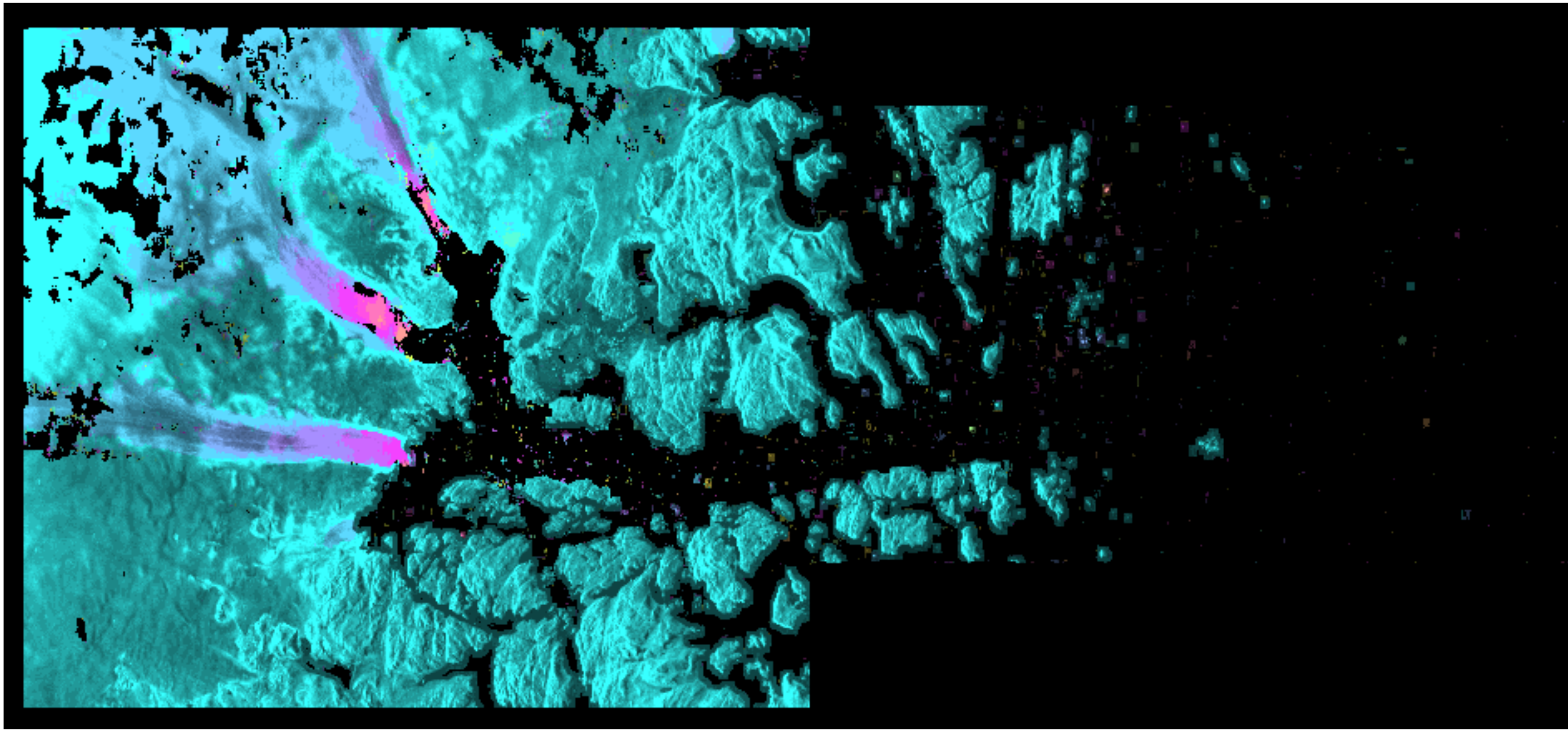
apply thresholds

single_class_mapping 2 20141022_20141103.disp_map.dreal -90. 90. 20141022_20141103.disp_map.dimag -90. 90. 20141022_20141103.mask1.ras 950 1 0 1 1

mask_class 20141022_20141103.mask1.ras 20141022_20141103.disp_map.real 20141022_20141103.disp_map.real.masked 0 1 1 1 0 0.0

dishgt 20141022_20141103.disp_map.real.masked 20141022.mli5 950 1 1 0 250. 1. .35

rashgt 20141022_20141103.disp_map.real.masked 20141022.mli5 950 1 1 0 1 1 250. 1. .35



Post-processing

mask_class 20141022_20141103.mask1.ras 20141022_20141103.disp_map.imag 20141022_20141103.disp_map.imag.masked 0 1 1 1 0 0.0

dishgt 20141022_20141103.disp_map.imag.masked 20141022.mli5 950 1 1 0 250. 1. .35

rashgt 20141022_20141103.disp_map.imag.masked 20141022.mli5 950 1 1 0 1 1 250. 1. .35

mask_class 20141022_20141103.mask1.ras 20141022_20141103.disp_map.mag 20141022_20141103.disp_map.mag.masked 0 1 1 1 0 0.0

dishgt 20141022_20141103.disp_map.mag.masked 20141022.mli5 950 1 1 0 250. 1. .35

rashgt 20141022_20141103.disp_map.mag.masked 20141022.mli5 950 1 1 0 1 1 250. 1. .35

Post-processing

slight interpolation and spatial filtering

interp_ad 20141022_20141103.disp_map.real.masked 20141022_20141103.disp_map.real.masked.interp 950 2 4 16 0 2 0

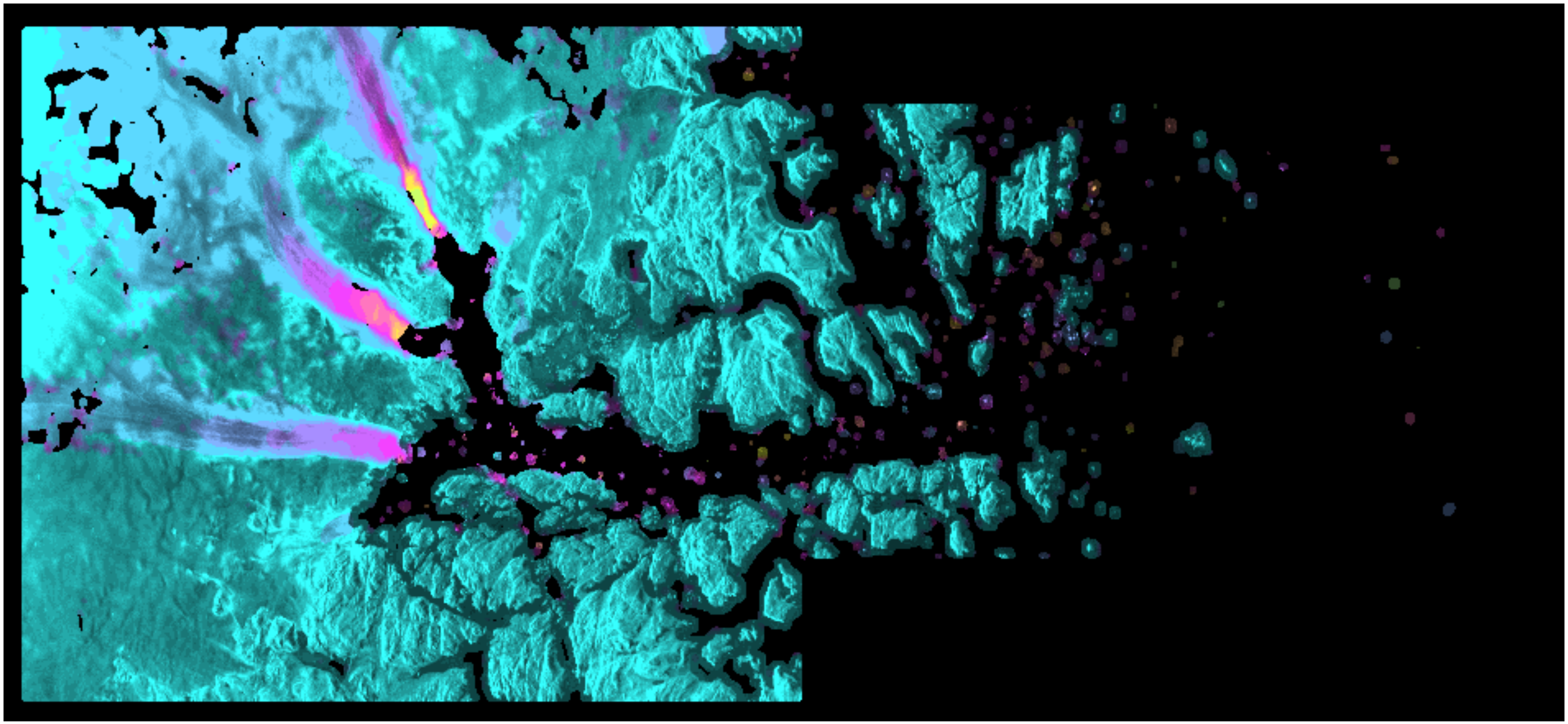
interp_ad 20141022_20141103.disp_map.imag.masked 20141022_20141103.disp_map.imag.masked.interp 950 2 4 16 0 2 0

interp_ad 20141022_20141103.disp_map.mag.masked 20141022_20141103.disp_map.mag.masked.interp 950 2 4 16 0 2 0

dishgt 20141022_20141103.disp_map.mag.masked.interp 20141022.mli5 950 1 1 0 250. 1. .35

rashgt 20141022_20141103.disp_map.mag.masked.interp 20141022.mli5 950 1 1 0 1 1 250. 1. .35

Post-processing

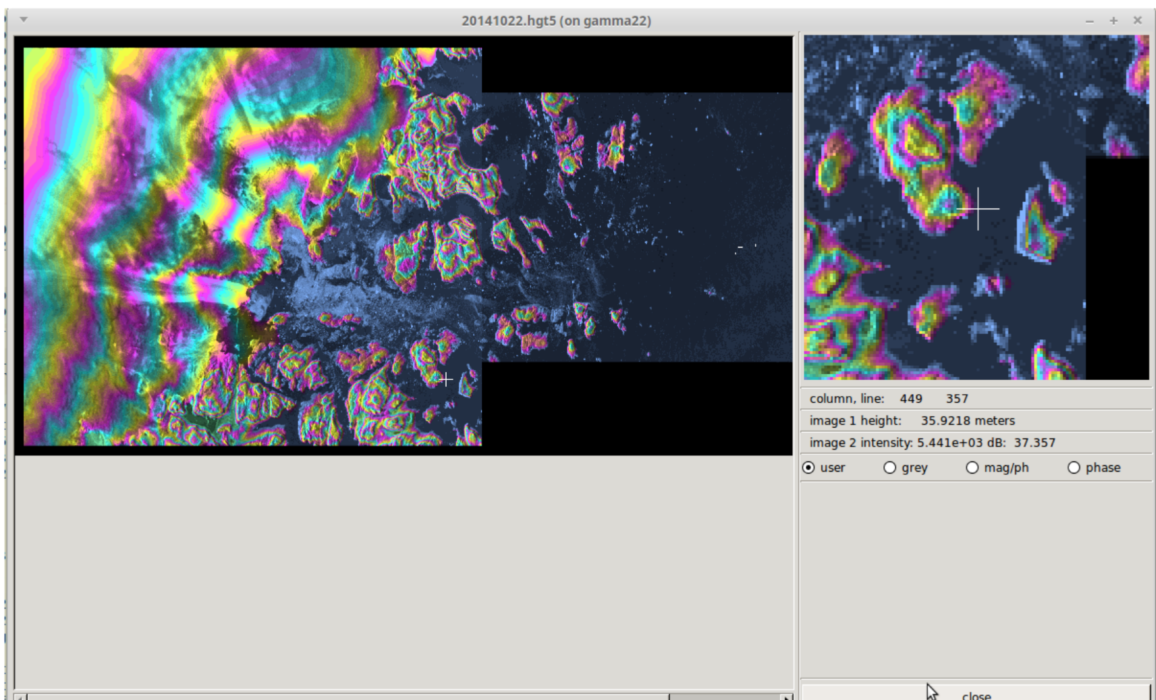


Post-processing

Apply ocean mask (use DEM height with threshold 27.0m to determine ocean mask)

multi_real 20141022.hgt 20141022_20141103.off 20141022.hgt5 20141022_20141103.off5 5 5

dishgt 20141022.hgt5 20141022.mli5 950 1 1 0 250. 1. .35
single_class_mapping 2 20141022.hgt5 27.0 10000. 20141022.mli5 0.000000001 100000000. 20141022_20141103.mask2.ras 950 1 0 1 1



Post-processing

mask_class 20141022_20141103.mask2.ras 20141022_20141103.disp_map.real.masked.interp 20141022_20141103.disp_map.real.final 0 1 1 1 0 0.0

mask_class 20141022_20141103.mask2.ras 20141022_20141103.disp_map.imag.masked.interp 20141022_20141103.disp_map.imag.final 0 1 1 1 0 0.0

mask_class 20141022_20141103.mask2.ras 20141022_20141103.disp_map.mag.masked.interp 20141022_20141103.disp_map.mag.final 0 1 1 1 0 0.0

dishgt 20141022_20141103.disp_map.mag.final 20141022.mli5 950 1 1 0 250. 1. .35

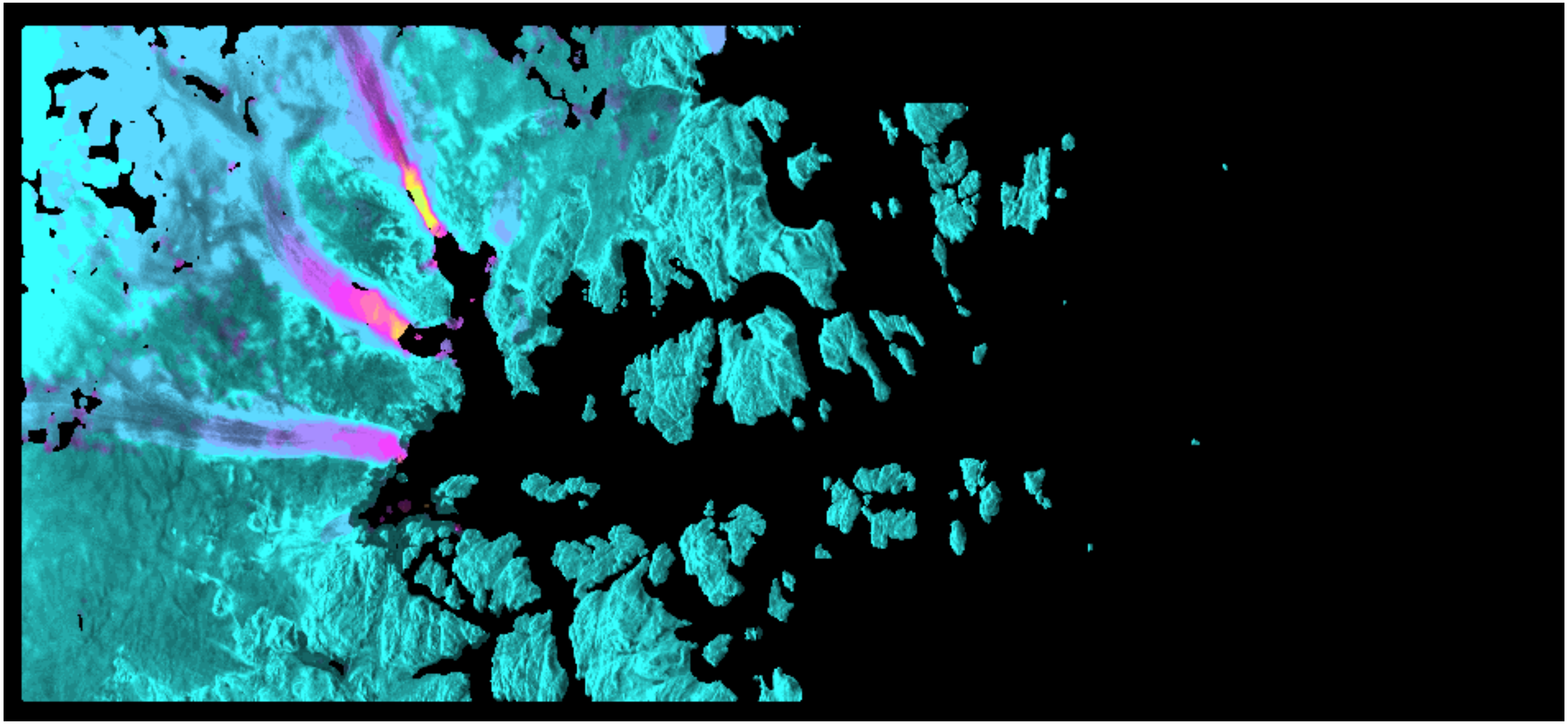
rashgt 20141022_20141103.disp_map.mag.final 20141022.mli5 950 1 1 0 1 1 250. 1. .35

Post-processing

```
mask_class 20141022_20141103.mask2.ras
20141022_20141103.disp_map.real.masked.interp
20141022_20141103.disp_map.real.final 0 1 1 1 0 0.0
mask_class 20141022_20141103.mask2.ras
20141022_20141103.disp_map.imag.masked.interp
20141022_20141103.disp_map.imag.final 0 1 1 1 0 0.0
mask_class 20141022_20141103.mask2.ras
20141022_20141103.disp_map.mag.masked.interp
20141022_20141103.disp_map.mag.final 0 1 1 1 0 0.0
```

dishgt 20141022_20141103.disp_map.mag.final 20141022.mli5 950 1 1 0 250. 1. .35

rashgt 20141022_20141103.disp_map.mag.final 20141022.mli5 950 1 1 0 1 1 250. 1. .35



Geocoding

First we expand the solution to the full resolution mli geometry (20141022.slc.mli.par). Offsets results are in 20141022.mli5.par geometry

Determine lookup table for the transformation

rdc_trans 20141022.slc.mli.par 0.1 20141022.mli5.par mli_to_mli5.lt

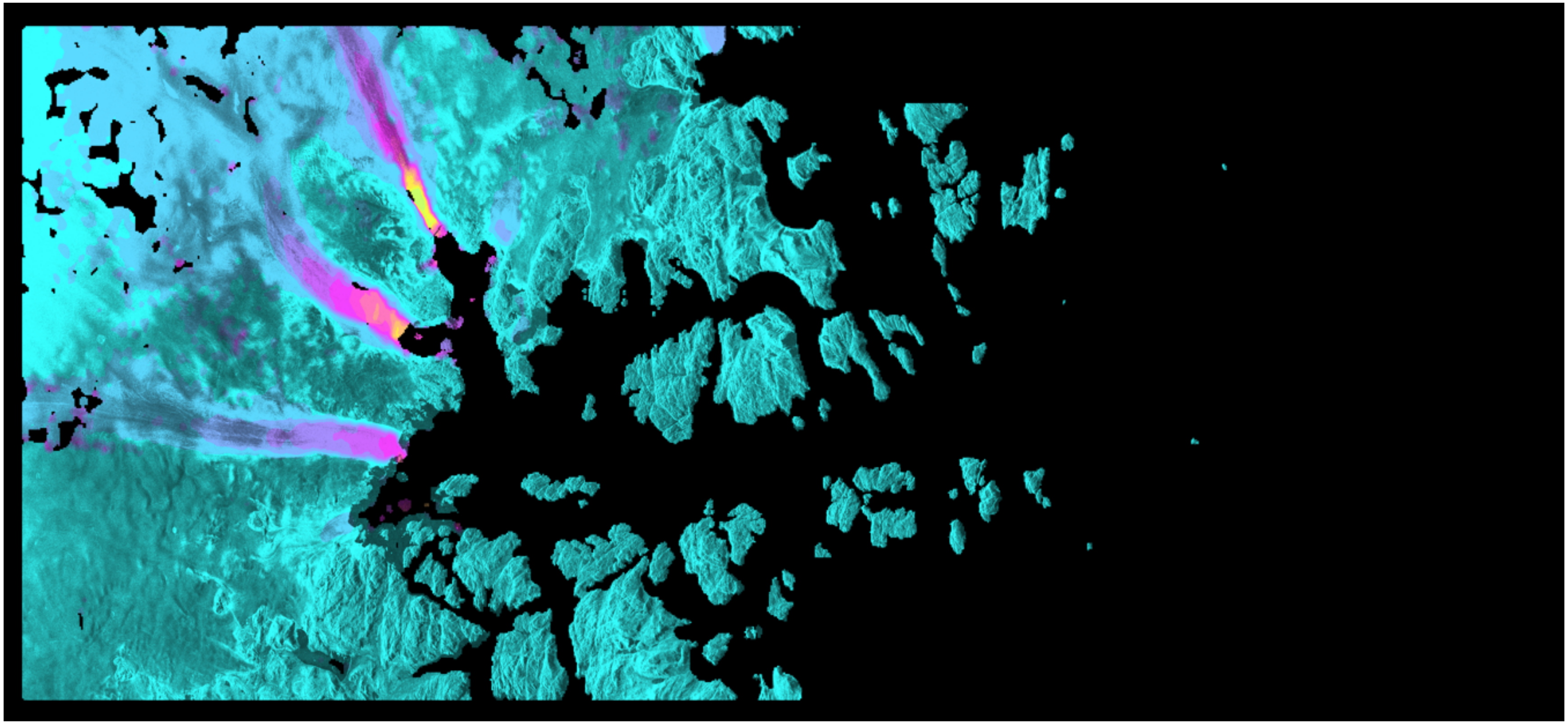
Resample the data

geocode_back 20141022_20141103.disp_map.mag.final 950 mli_to_mli5.lt 20141022_20141103.disp_map.mag.final1 4752 2188 1 0

dishgt 20141022_20141103.disp_map.mag.final1 20141022.slc.mli 4752 1 1 0 250. 1. .35

rashgt 20141022_20141103.disp_map.mag.final1 20141022.slc.mli 4752 1 1 0 1 1 250. 1. .35

Geocoding



eog 20141022_20141103.disp_map.mag.final1.ras

Geocoding

Geocode the expanded solution

geocode_back 20141022_20141103.disp_map.mag.final1 4752 20141022.lt_fine EQA.20141022_20141103.disp_map.mag.final 6520 3201 1 0

geocode_back 20141022.slc.mli 4752 20141022.lt_fine EQA.20141022.slc.mli 6520 3201 1 0

rashgt EQA.20141022_20141103.disp_map.mag.final EQA.20141022.slc.mli 6520 1 1 0 1 1 250. 1. .35

eog **EQA.20141022_20141103.disp_map.mag.final.ras**