Interferometric processing of TandemX with ISP/DIFF&GEO/LAT

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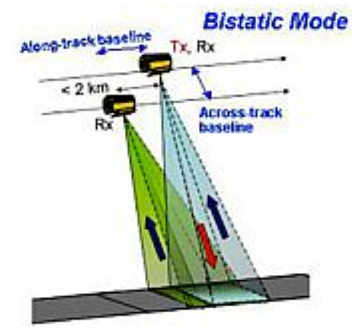
Tandem-X

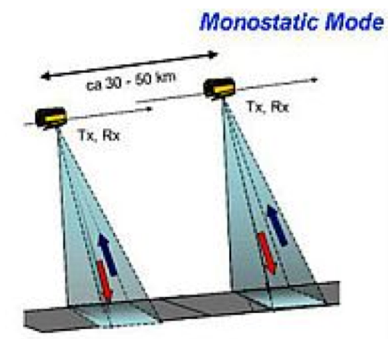
Bi-static Mode

Operational DEM generation will be performed using bi-static mode (see figure below left). Its principle is characterized by the simultaneous measurement of the same scene and identical Doppler spectrum with 2 receivers, avoiding temporal decorrelation. To provide sufficient overlap of the Doppler spectrum, along-track baselines < 2 km are required while the effective across-track baselines for high resolution DEM's have to be in the order of 1 km. PRF synchronization and relative phase referencing between the satellit are mandatory.



Pursuit Mono-static Mode

A secondary DEM generation mode is the pursuit mono-static mode, where two satellites are operated independently, avoiding the need for synchronization. The along-track distance is 30-50 km. The temporal decorrelation is still small for most terrain types with exception of ocean surface and vegetation in the case of moderate to high wind speeds. The interferometric height sensitivity is doubled with respect to bi-static operation, meaning that the baseline determination has to be more accurate.



Along-track Interferometry, ATI Mode

Along-track interferometry will enable accurate velocity measurements e.g. for monitoring ocean currents, sea ice drift and traffic. The required along-track baselines range from several hundred meters to several kilometers. The ATI mode benefits greatly from the 2x2 phase centers to resolve ambiguities in the velocity measurement, thereby providing a unique MTI system for accurate velocity measurements on a large scale.

Experimental Modes

Numerous experimental modes, mainly exploiting the bi-static measurement configuration and the polarimetric capabilities, are considered. Some of them could evolve during the mission from an experimental to an operational mode. A very promising candidate is polarimetric interferometry. Another is super resolution, an elegant way toimprove spatial resolution by a factor 2.

From: http://www.dlr.de/hr/en/desktopdefault.aspx/tabid-2317/3669_read-5497/

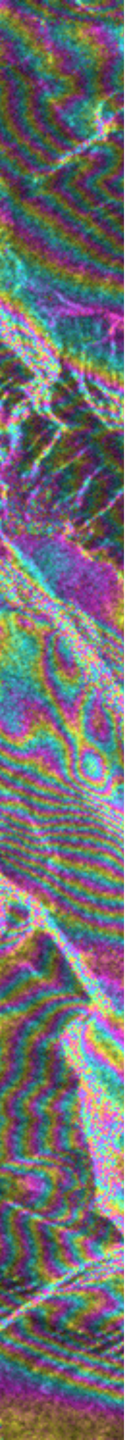
Overview

How to process:

- Interferogram (Tandem-X bistatic case)
- Differential Phase
- Coherence

Analyze phase and coherence as function of forest properties

Gamma Interferometric SAR Processor (ISP) - Image Parameter File



title: C132_N146_A_SM_stripFar_012_R_2011-06-04T16:45:34.621341Z
sensor: TDX-1
date: 2011 6 4 16 45 34.6213
start_time: 60334.621341 s
center_time: 60337.120836 s
end_time: 60339.620331 s
azimuth_line_time: 3.2615582e-04 s
line_header_size: 0
range_samples: 12424
azimuth_lines: 15328
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: 58.4578095 degrees
center_longitude: 13.6280264 degrees
heading: 349.7340309 degrees
range_pixel_spacing: 0.909403 m 1.4 m ground range
azimuth_pixel_spacing: 2.295737 m
near_range_slc: 665435.2094 m
center_range_slc: 671083.9687 m
far_range_slc: 676732.7280 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: 41.4657 degrees
azimuth_deskew: ON
azimuth_angle: 90.0000 degrees
radar_frequency: 9.6500000e+09 Hz
adc_sampling_rate: 1.6482919e+08 Hz
chirp_bandwidth: 1.5000000e+08 Hz
prf: 3066.019196 Hz
azimuth_proc_bandwidth: 2438.16454 Hz
doppler_polynomial: 17.58359 7.28112e-05 0.00000e+00 0.00000e+00 Hz Hz/m Hz/m^2 Hz/m^3
doppler_poly_dot: -1.40803e+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: 15.5500 dB
calibration_gain: 57.0598 dB
sar_to_earth_center: 6880238.6653 m
earth_radius_below_sensor: 6362840.2292 m
earth_semi_major_axis: 6378137.0000 m
earth_semi_minor_axis: 6356752.3141 m
number_of_state_vectors: 16
time_of_first_state_vector: 60330.000000 s
state_vector_interval: 1.000000 s
state_vector_position_1: 3717031.0595 461229.6025 5771431.9336 m m m
state_vector_velocity_1: -5901.04930 -2833.84030 4017.25490 m/s m/s m/s
state_vector_position_2: 3711127.5474 458395.9127 5775445.6587 m m m
state_vector_velocity_2: -5905.97230 -2833.53780 4010.19430 m/s m/s m/s
state_vector_position_3: 3705219.1198 455562.5295 5779452.3181 m m m
state_vector_velocity_3: -5910.88800 -2833.23110 4003.12880 m/s m/s m/s

Multi-looking

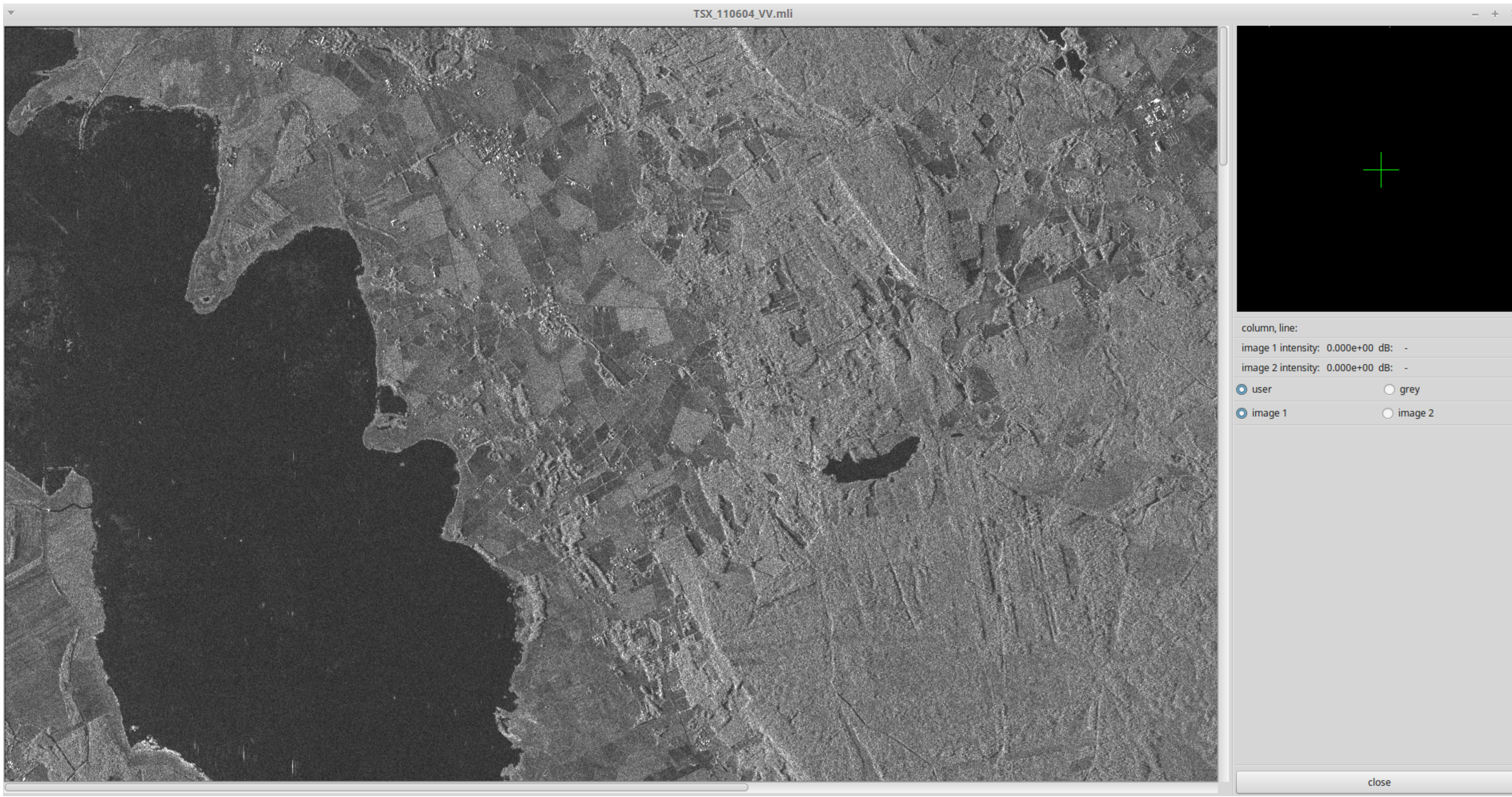
ml_rg=5
ml_az=3

multi_look TSX_110604_VV.slc TSX_110604_VV.slc.par TSX_110604_VV.mli TSX_110604_VV.mli.par $ml_rg $ml_az

multi_look TDX_110604_VV.slc TDX_110604_VV.slc.par TDX_110604_VV.mli TDX_110604_VV.mli.par $ml_rg $ml_az

mli_width=$(cat TDX_110604_VV.mli.par | grep range_samples | awk -F ':' '{ print $2 }')
mli_lines=$(cat TDX_110604_VV.mli.par | grep azimuth_lines | awk -F ':' '{ print $2 }')

dis2pwr TSX_110604_VV.mli TDX_110604_VV.mli $mli_width $mli_width



Calibration

TerraSAR-X and TanDEM-XDdata in SSC, MGD and EEC format are already relatively calibrated. Absolute calibration is done automatically by the corresponding programs for the generation of the ISP SLC parameter file (**par_TX_SLC**), which add the calibration constant found in the xml annotation file. For TerraSAR-X data acquired during the commissioning phase (before 7 January 2008) an additional offset of 56 dB needs to be added. This can be done for example with radcal_MLI or radcal_SLC.

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par_TX_SLC

*** Generate SLC parameter file and SLC image from a Terrasar-X SSC data set ***

*** Copyright 2014, Gamma Remote Sensing, v1.6 17-Oct-2014 awi/clw ***

usage: par_TX_SLC <annotation_XML> <COSAR> <SLC_par> <SLC> [pol]

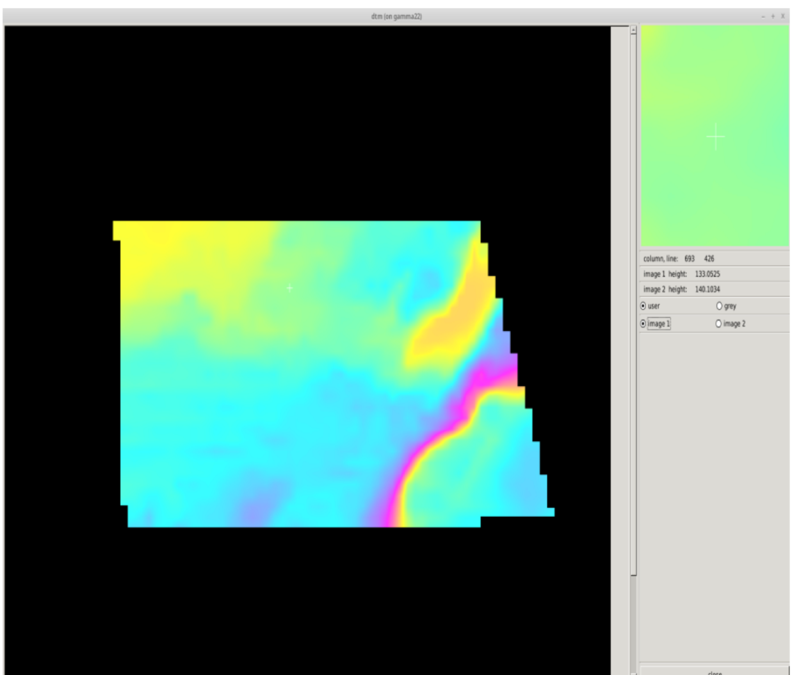
Import DEMs

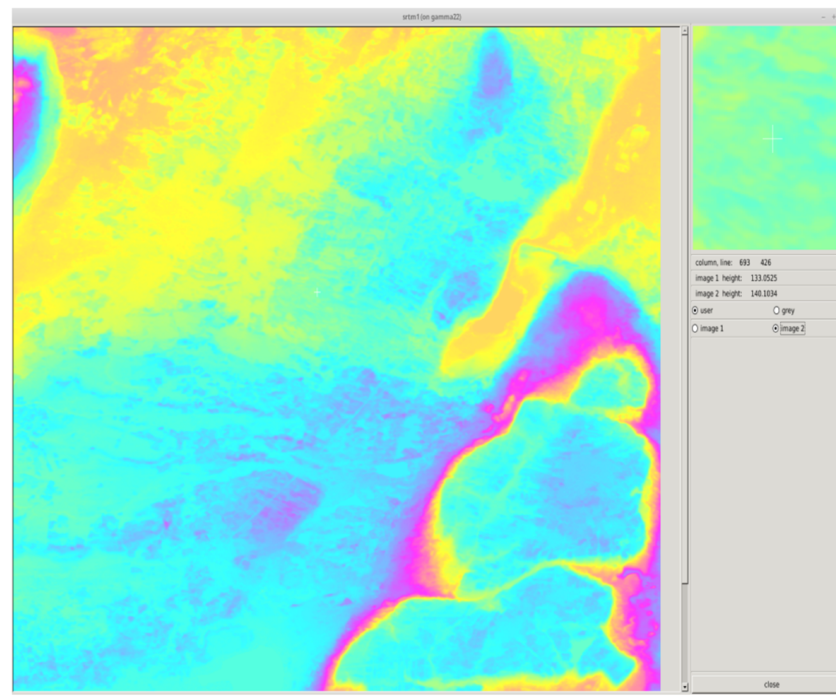
SRTM 1 arcsec DEM to be used for geocoding
Offset between WGS84 and geoid is added

srtm2dem srtm1.tif srtm1 srtm1.par 2 -

Airborne laser scanner DTM to be used for simulating ground phase

srtm2dem dtm.tif dtm dtm.par 2 –



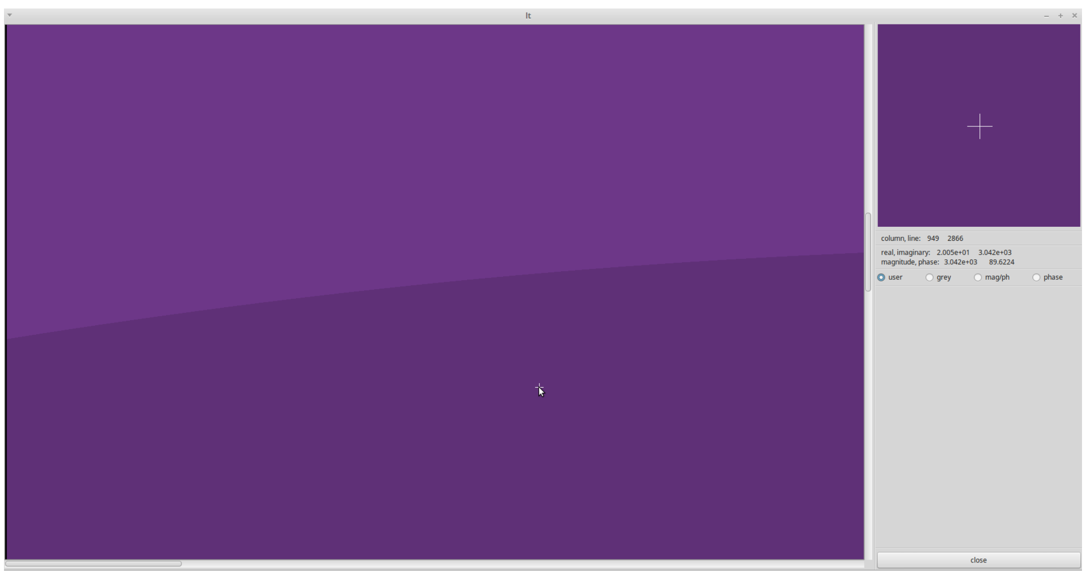


Geocoding with SRTM

gc_map TDX_110604_VV.mli.par – dtm.par dtm gc_dem.par gc_dem lt 3 3- slp - inc - - ls_map - 2 -

map_width=$(cat gc_dem.par | grep width | awk -F ':' '{ print $2 }')

dismph lt $map_width



Resample DTM to slant range geometry

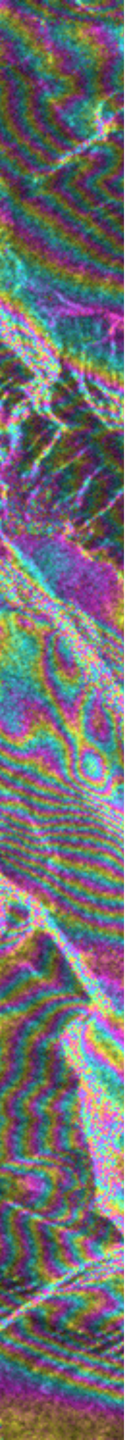
geocode lt gc_dem $map_width dtm.rdc $mli_width $mli_lines

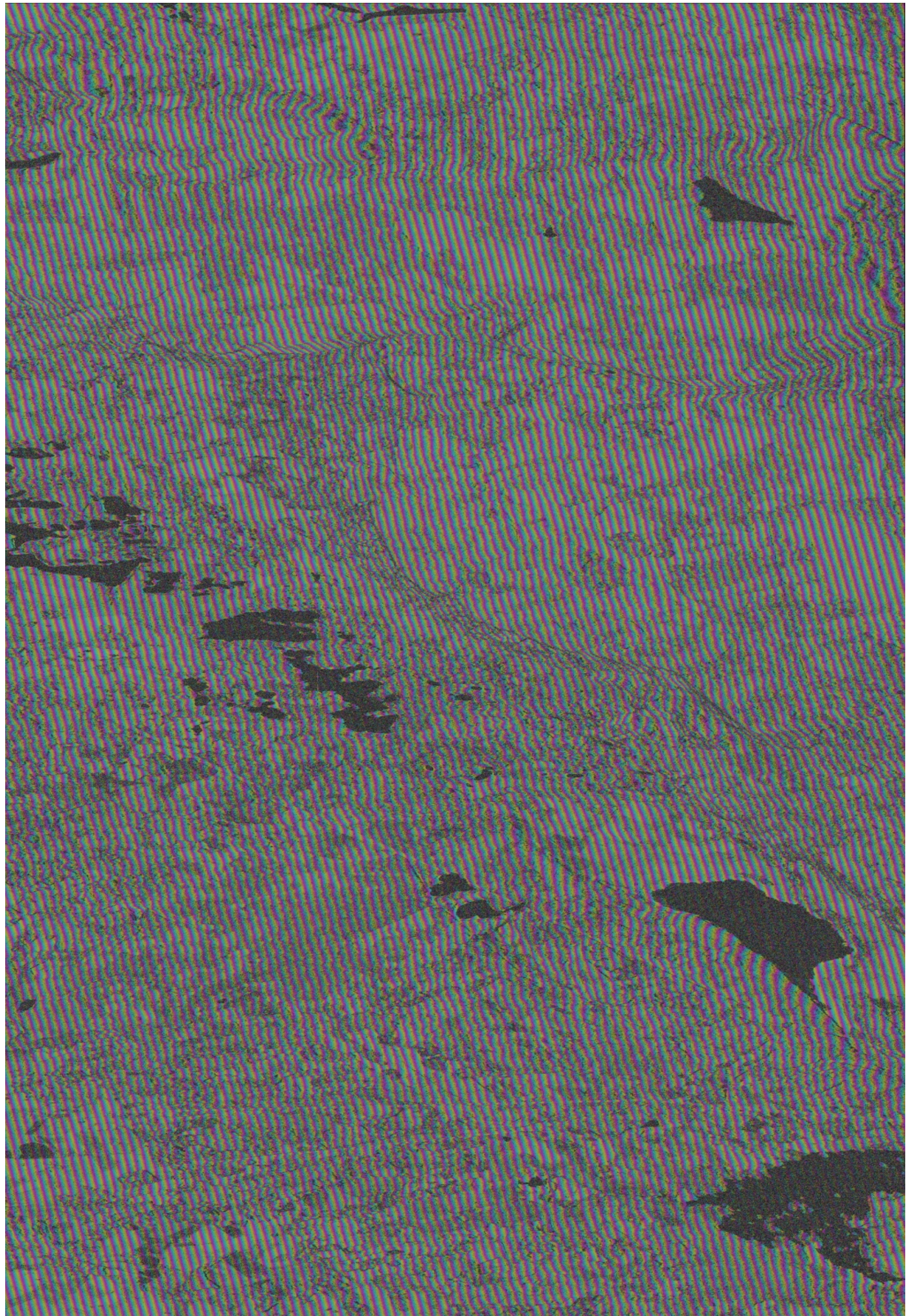
Interferogram

create_offset TDX_110604_VV.slc.par TSX_110604_VV.slc.par off_par 1 1 1 0

SLC_intf TDX_110604_VV.slc TSX_110604_VV.slc TSX_110604_VV.slc.par TDX_110604_VV.slc.par off_par TSX_TDX_110604_int $ml_rg $ml_az

rasmph TSX_TDX_110604_int $mli_width - - - - - - - TSX_TDX_110604_int.bmp 0





What's the baseline?

base_init TDX_110604_VV.slc.par TSX_110604_VV.slc.par off_par TSX_TDX_110604_int base_orb 2

→**baseline perpendicular component (m): 141**

Phase to height relationship:

$$\phi = -\frac{4\pi}{\lambda} R + \boxed{\frac{\mathbf{2}\pi B_n}{\lambda R \sin\theta}} z + \frac{4\pi}{\lambda}\eta + \frac{4\pi}{\lambda}\rho + \phi_{noise} + n \cdot 2\pi$$

R: 671082.1473m
λ: 0.0311 m
ϑ: 41.4657 degrees

Height of ambiguity=~98m

phase_sim_orb

*** Simulate unwrapped interferometric phase using DEM height and deformation rate using orbit state vectors ***

usage: phase_sim_orb <SLC1_par> <SLC2R_par> <OFF_par> <hgt> <sim_unw> [SLC_ref_par] [def] [delta_t] [int_mode] [ph_mode]

input parameters:

```
  SLC1_par    (input) SLC parameter file of reference SLC-1
  SLC2R_par   (input) SLC parameter file of resampled SLC-2
  OFF_par     (input) ISP offset/interferogram parameter file
  hgt         (input) height map in the same geometry as the interferogram (meters, float, enter - for none)
  sim_unw     (output) simulated unwrapped interferometric phase
  SLC_ref_par (input) SLC parameter file of the image used for geometric coregistration (enter - for none)
  def         (input) LOS deformation rate map (meters/yr, float, enter - for none)
  delta_t     (input) interferogram time interval (days, required for deformation modeling, enter - for none)
  int_mode    (input) interferometric acquisition mode:
              0: single-pass mode (Tandem-X)
              1: repeat-pass mode (default)
  ph_mode     phase offset mode:
              0: absolute phase (default)
              1: subtract phase offset that is a multiple of 2PI to improve precision
```

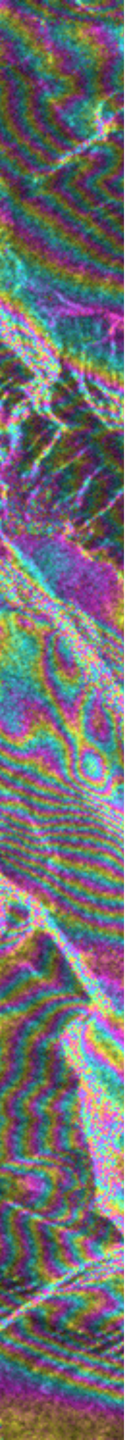
Simulating phase with DTM

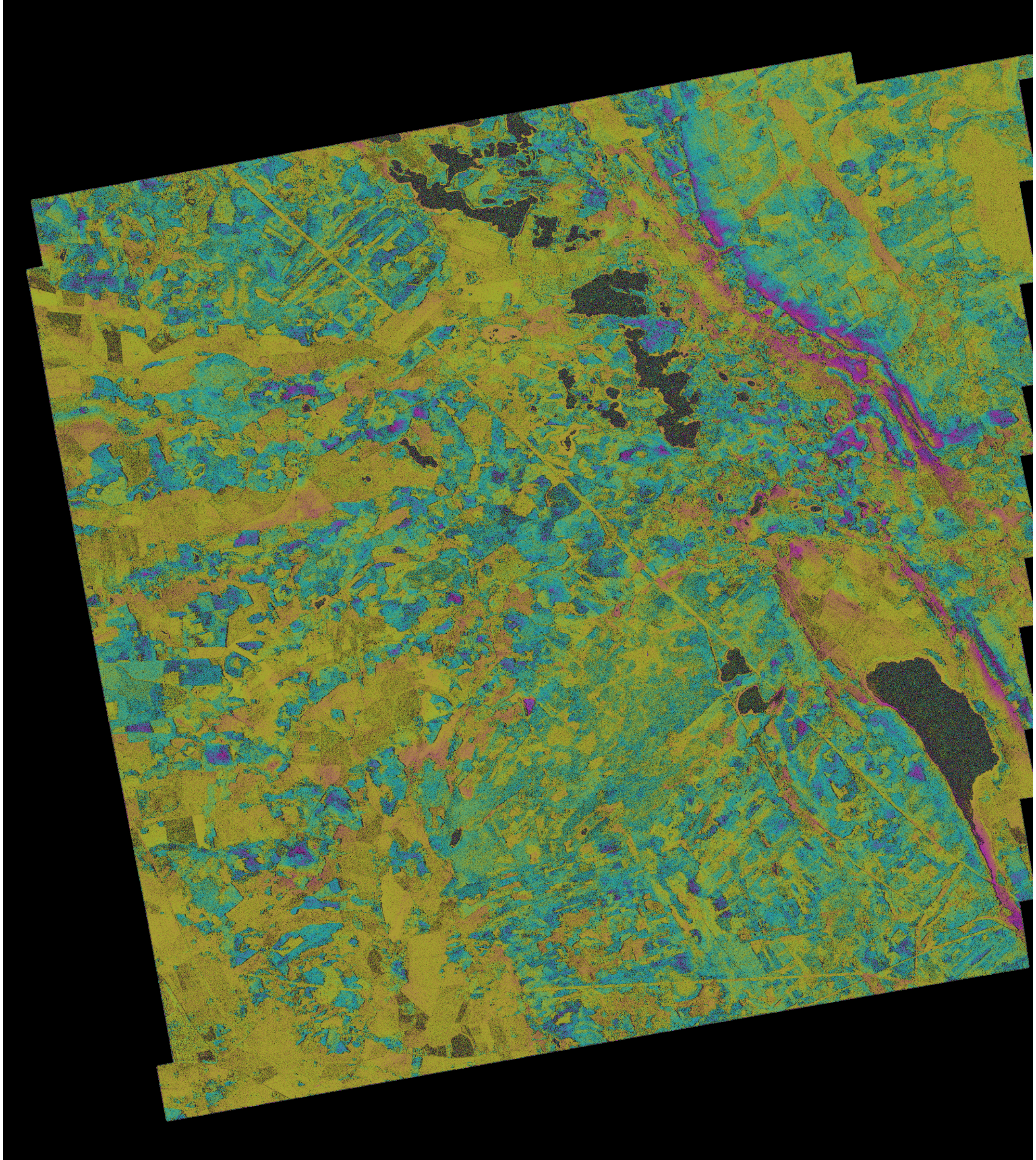
phase_sim_orb TDX_110604_VV.slc.par TSX_110604_VV.slc.par off_par dtm.rdc TSX_TDX_110604_sim_unw_phase - - - 0 0

create_diff_par off_par off_par diff_par 0 0

SLC_diff_intf TDX_110604_VV.slc TSX_110604_VV.slc TDX_110604_VV.slc.par TSX_110604_VV.slc.par off_par TSX_TDX_110604_sim_unw_phase TSX_TDX_110604_diff $ml_rg $ml_az

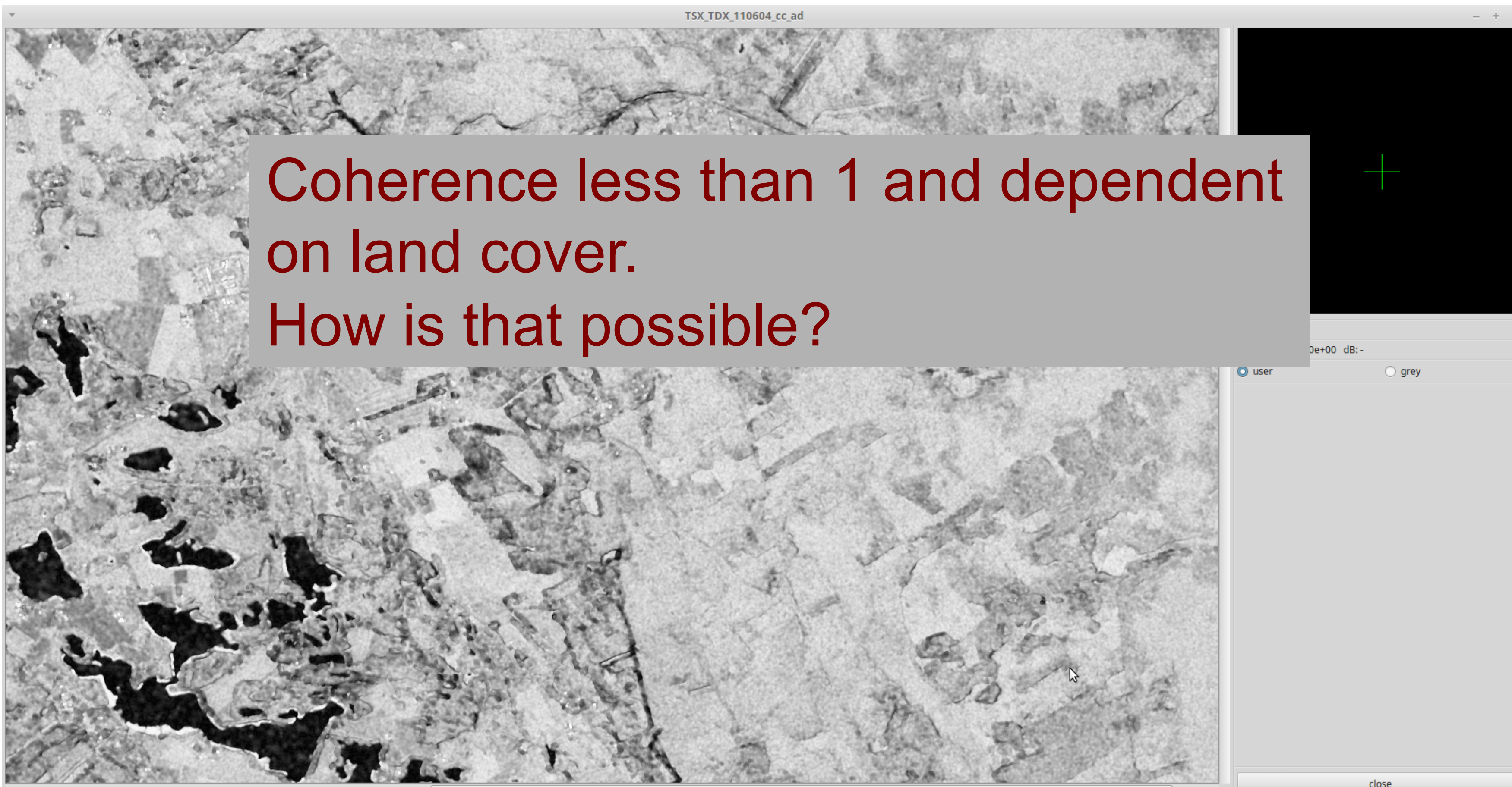
rasmph TSX_TDX_110604_diff $mli_width - - - - - - - TSX_TDX_110604_diff.bmp 0





cc_ad TSX_TDX_110604_diff TSX_110604_VV.mli TDX_110604_VV.mli - - TSX_TDX_110604_cc_ad $mli_width 3 9

dis_linear TSX_TDX_110604_cc_ad $mli_width

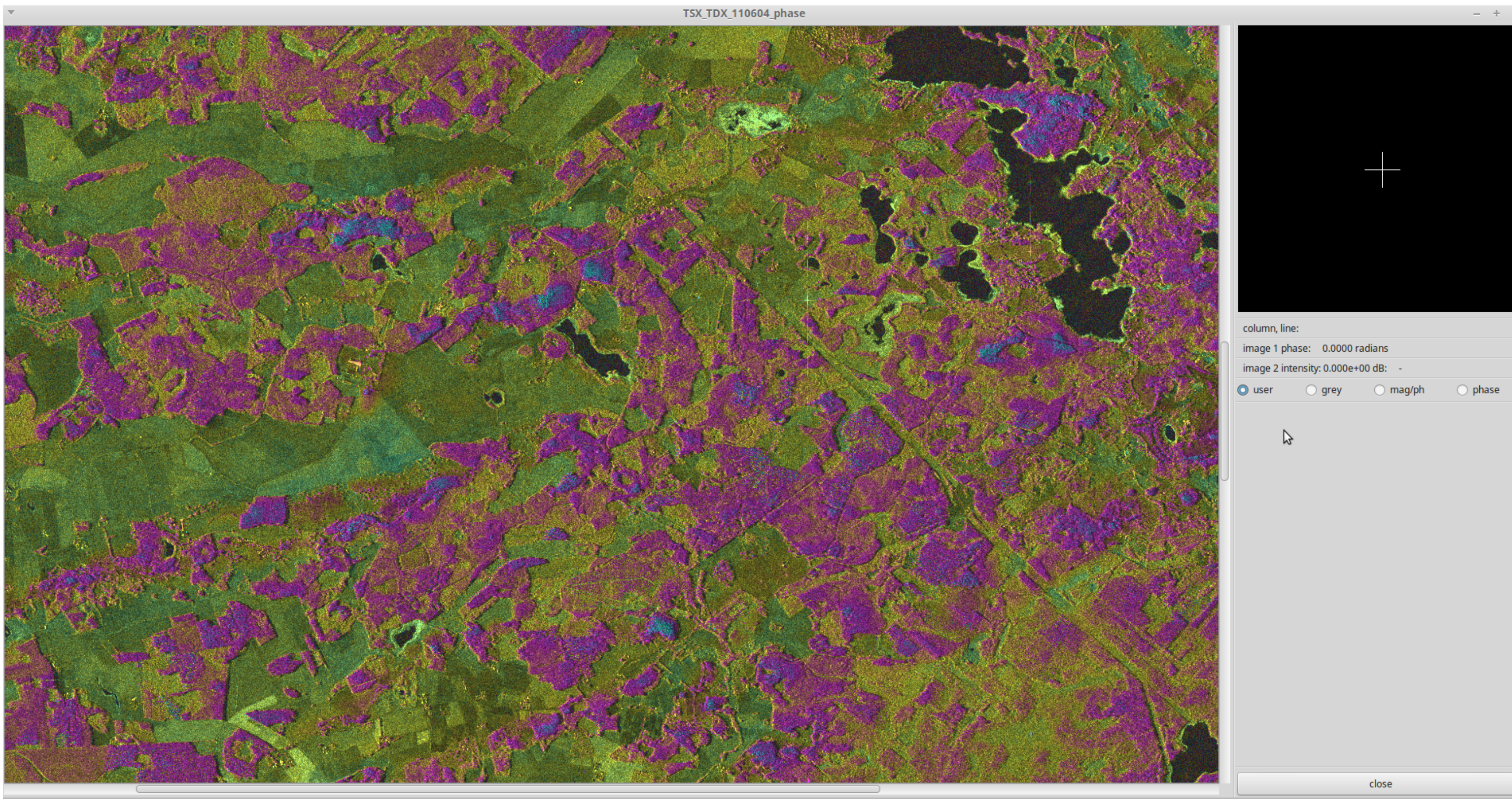


Coherence less than 1 and dependent on land cover.
How is that possible?

Extract phase from differential interferograms

cpx_to_real TSX_TDX_110604_diff TSX_TDX_110604_phase $mli_width 4

disrmg TSX_TDX_110604_phase TDX_110604_VV.mli $mli_width 1 1 - 1



Differential height

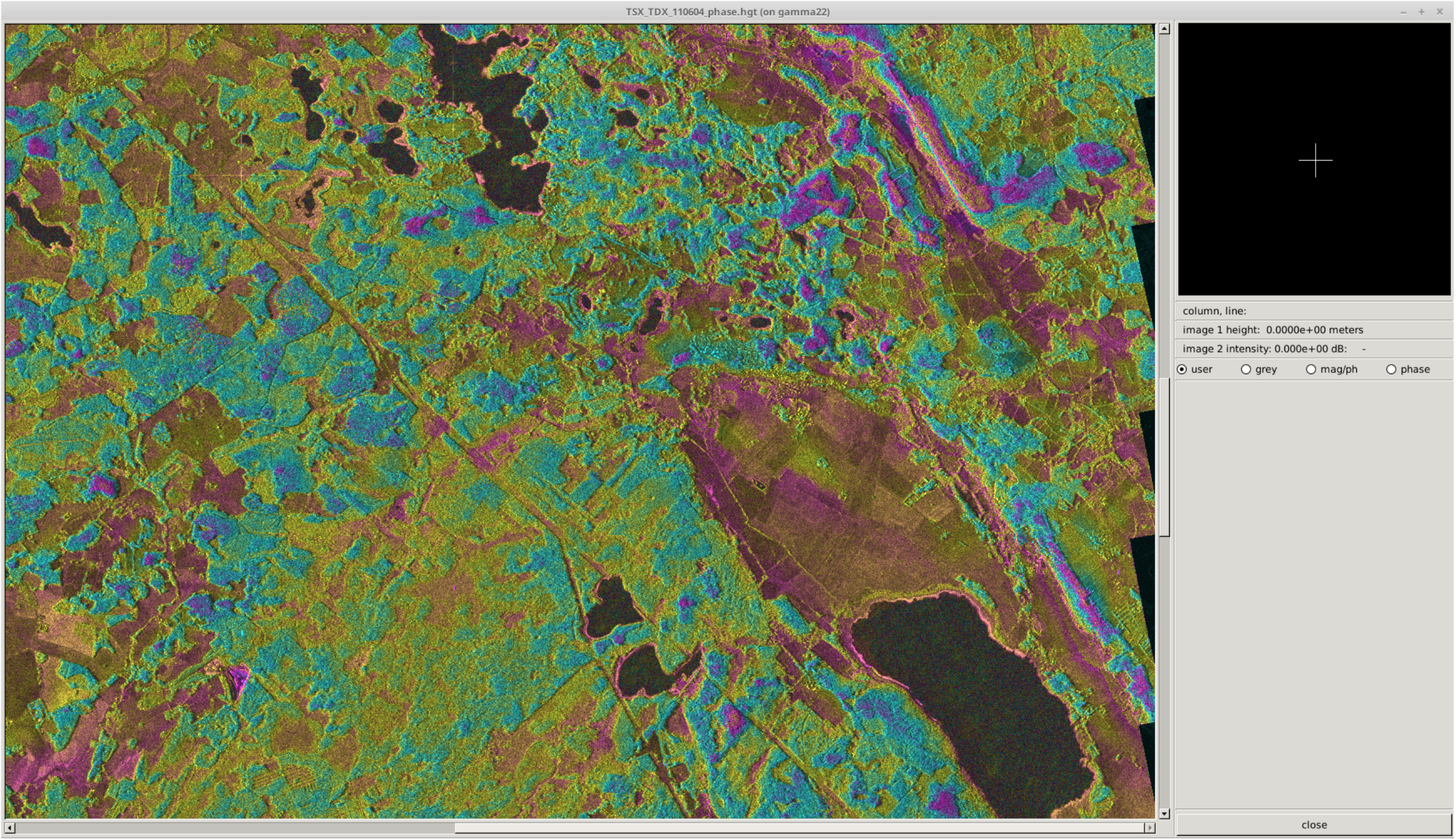
Extract Phase:
cpx_to_real TSX_TDX_110604_diff TSX_TDX_110604_phase $mli_width 4

Correct for height offset: (Reference window around point 947 3609):
float_math TSX_TDX_110604_phase - TSX_TDX_110604_phasec $mli_width 1 947 3609 - -

Convert to height:
dh_map_orb TDX_110604_VV.slc.par TSX_110604_VV.slc.par off_par dtm.rdc TSX_TDX_110604_phasec - TSX_TDX_110604_phase.hgt TDX_110604_VV.slc.par 0

dishgt TSX_TDX_110604_phase.hgt TSX_110604_VV.mli $mli_width - - - 40

disrmg TSX_TDX_110604_phase TDX_110604_VV.mli $mli_width 1 1 - 1



Remark: Zero tree height ~ -18 m → offset must be accounted for, e.g., when unwrapping by defining reference point

Geocode images with LUT

geocode_back TSX_TDX_110604_cc_ad $mli_width lt TSX_TDX_110604_geo_cc_ad $map_width - - 0

geocode_back TSX_TDX_110604_phase $mli_width lt TSX_TDX_110604_geo_phase $map_width - - 0

geocode_back TSX_110604_VV.mli $mli_width lt TSX_110604_geo_mli $map_width - - 0

geocode_back TSX_TDX_110604_phase.hgt $mli_width lt TSX_TDX_110604_geo_hgt $map_width - - 0

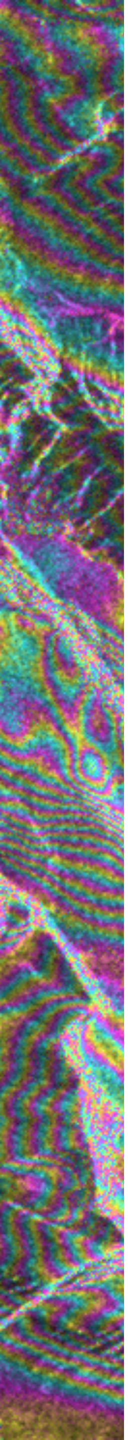
Create GeoTiffs

data2geotiff gc_dem.par TSX_TDX_110604_geo_cc_ad 2 TSX_TDX_110604_geo_cc_ad.tif

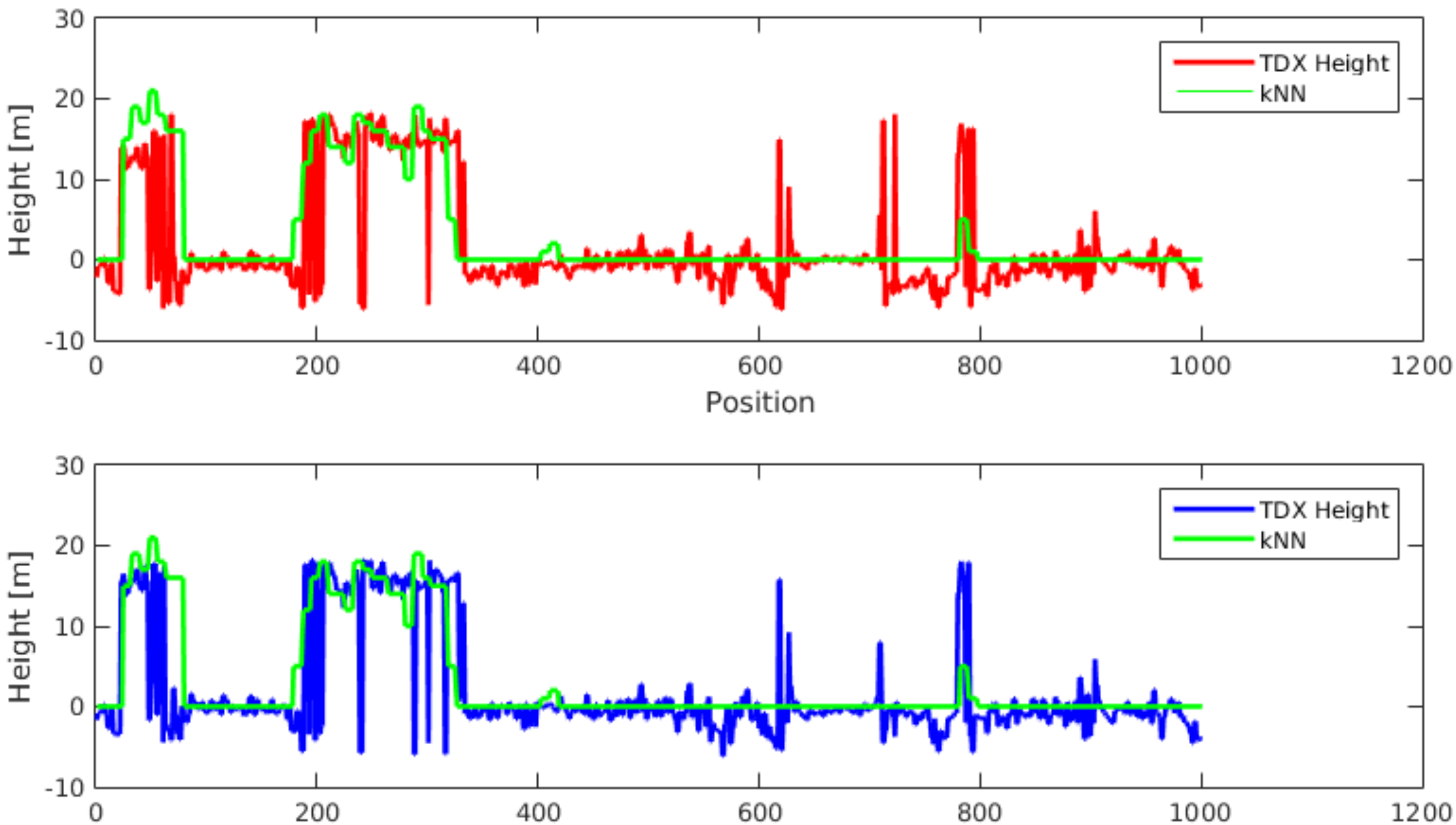
data2geotiff gc_dem.par TSX_TDX_110604_geo_phase 2 TSX_TDX_110604_geo_phase.tif

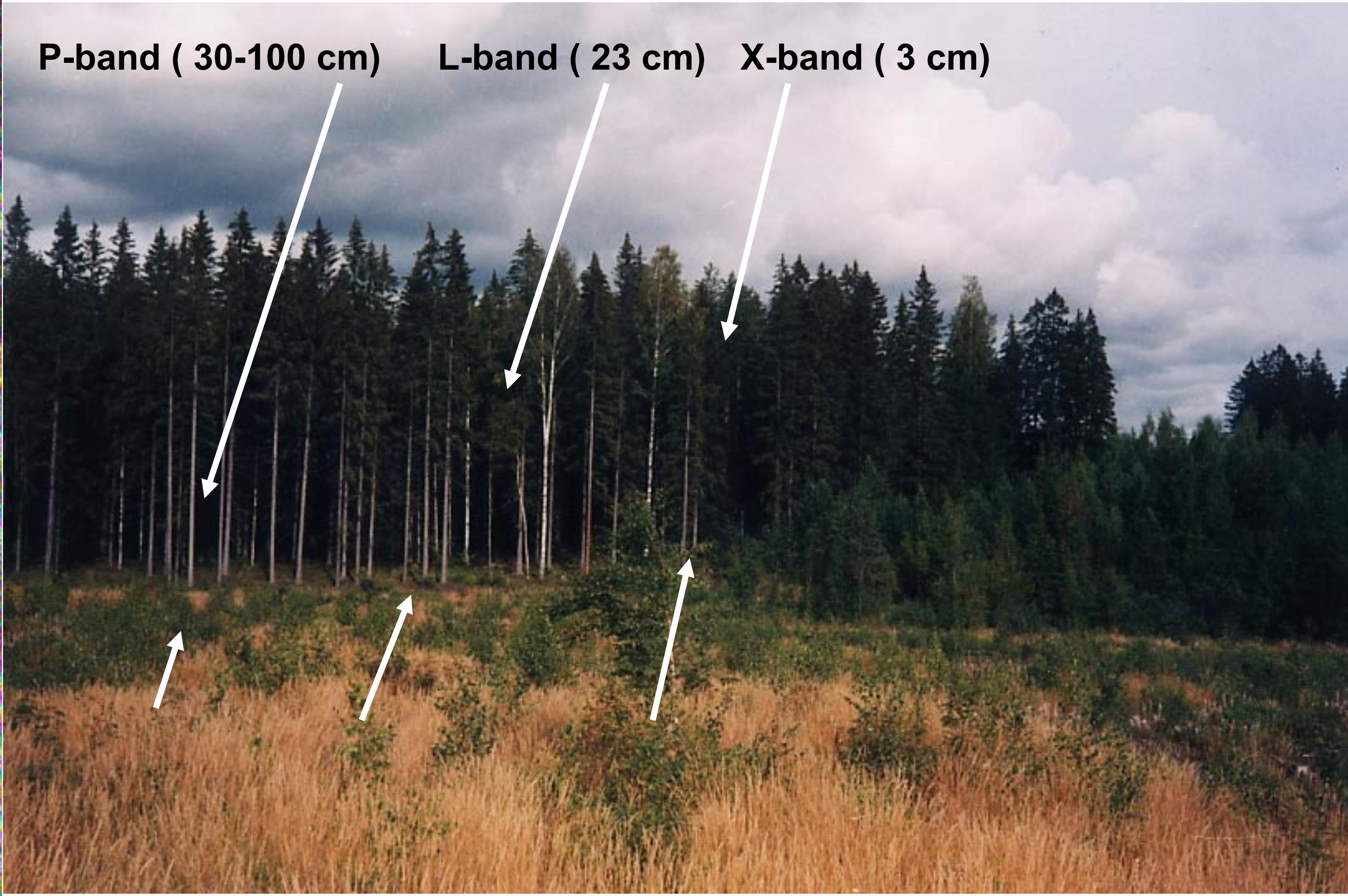
data2geotiff gc_dem.par TSX_TDX_110604_geo_hgt 2 TSX_TDX_110604_geo_hgt.tif

data2geotiff gc_dem.par TSX_110604_geo_mli 2 TSX_110604_geo_mli.tif



$$\phi = -\frac{4\pi}{\lambda}R + \boxed{\frac{2\pi B_n}{\lambda R \sin\theta}}\,z + \frac{4\pi}{\lambda}\eta + \frac{4\pi}{\lambda}\rho + \phi_{noise} + n \cdot 2\pi$$

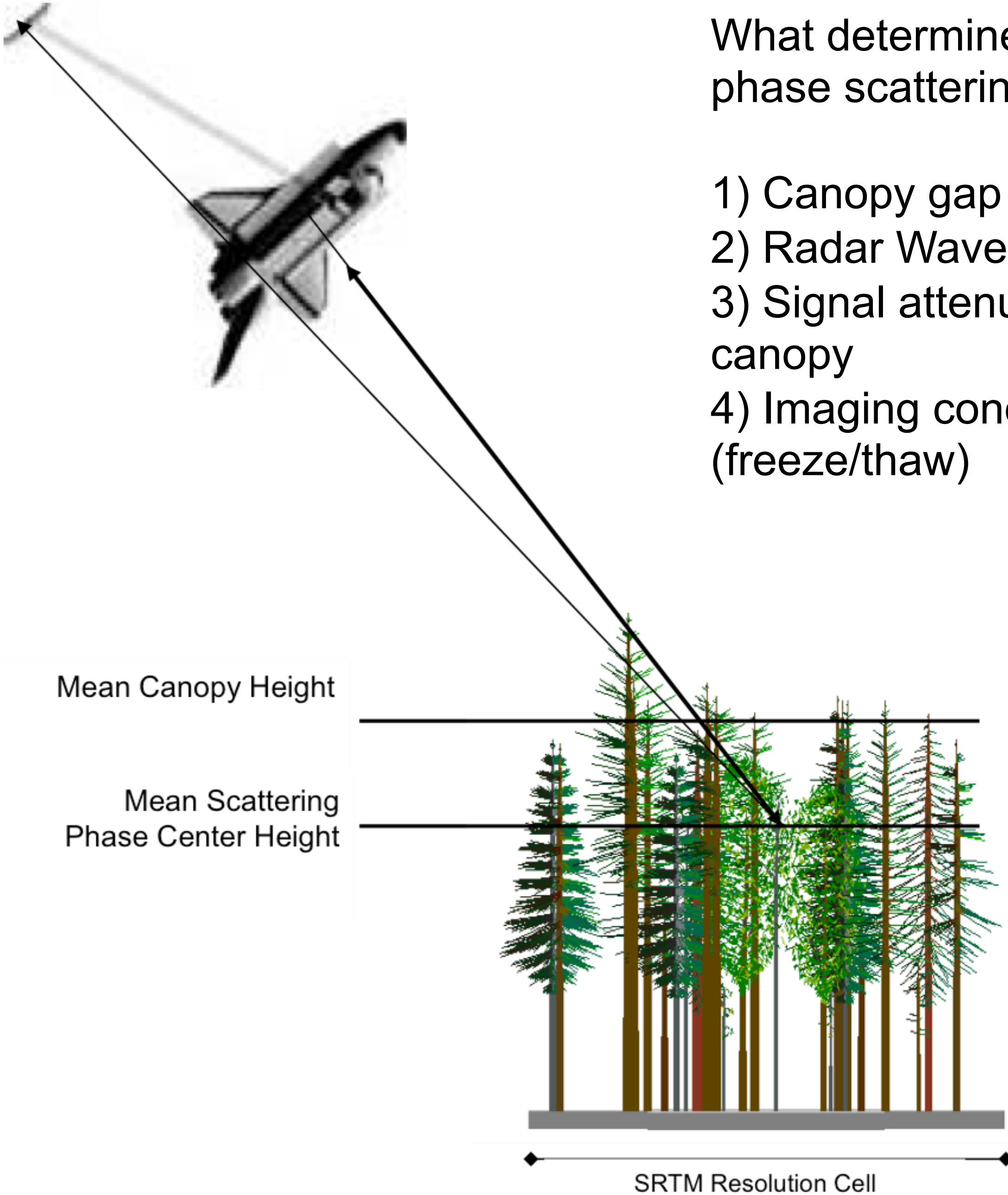




The longer the wavelength, the more the signal senses the vertical structure of forests

What determines the height of the phase scattering center:

1) Canopy gap fraction
2) Radar Wavelength
3) Signal attenuation within canopy
4) Imaging conditions (freeze/thaw)



Now process the TandemX image pair for Kryklan

We have no DTM for this area

Sequence of programs:

multi_look

gc_map

geocode

create_offset

SLC_intf

phase_sim_orb

create_diff_par

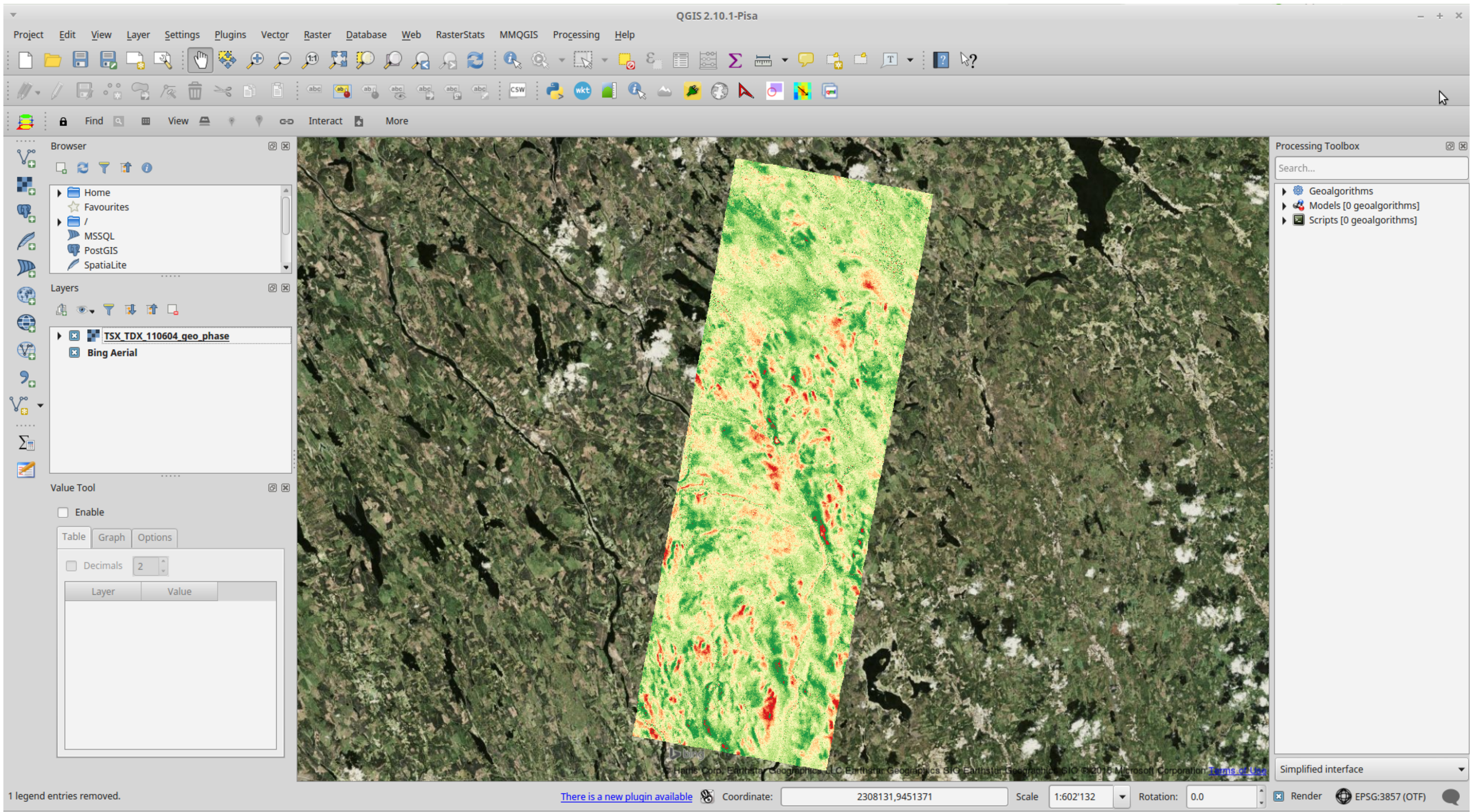
sub_phase

cc_ad

cpx_to_real

geocode_back

data2geotiff


QGIS 2.10.1-Pisa
Project
Edit
View
Layer
Settings
Plugins
Vector
Raster
Database
Web
RasterStats
MMQGIS
Processing
Help
Find
View
Interact
More
Browser
Home
Favourites
/
MSSQL
PostGIS
SpatiaLite
Layers
TSX_TDX_110604_geo_phase
Bing Aerial
Value Tool
Enable
Table
Graph
Options
Decimals
2
Layer
Value
Processing Toolbox
Search...
Geoalgorithms
Models [0 geoalgorithms]
Scripts [0 geoalgorithms]
Simplified interface
1 legend entries removed.
There is a new plugin available
Coordinate:
2308131,9451371
Scale
1:602'132
Rotation:
0.0
Render
EPSG:3857 (OTF)