InSAR Processing

Sentinel 1 data
Case study of subsidence in Mexico city

Marie-Pierre Doin, Cécile Lasserre, Raphaël Grandin, Erwan Pathier

NSBAS processing chain (based on ROI_PAC):

ROI-PAC: Rosen et al., 2004

(Rosen, P. A., S. Hensley, G. Peltzer, and M. Simons, Updated Repeat Orbit Interferometry Package released, Eos, 85, p. 47, 2004)

NSBAS: Doin et al. 2011

(Presentation Of The Small Baseline NSBAS Processing Chain On A Case Example: The ETNA Deformation Monitoring From 2003 to 2010 Using ENVISAT Data
Doin, M.-P.; Lodge, F; Guillaso, S; Jolivet, R; Lasserre, C; Ducret, Gl; Grandin, R., Pathier, E; Pinel, V, Proceeding of Fringe 2011)

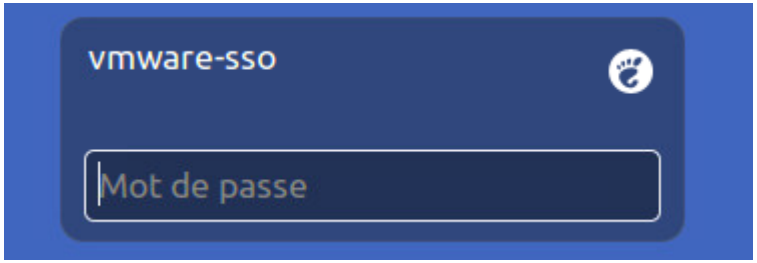
Sentinel-1: Grandin 2015

(Interferometric Processing of SLC Sentinel-1 TOPS Data,DOI: 10.5270/Fringe2015.pp116)

Démarrage du TP:

On the screen, choose **"02-Portail Pédagogique VM"**.
On the new screen "client VMWARE Horizon" click twice on **sciportail.dsi.uca.fr**
Then click on connexion
Login and passwd : tmp.nsbasXX et nsbasXXXX,
Click on NSBAS

Then appears :



NO PASSWORD, JUST TYPE ENTER!!

Open a terminal with:
Applications ---> Accessoires ---> Terminal
Open a second terminal : Fichier → Ouvrir un terminal

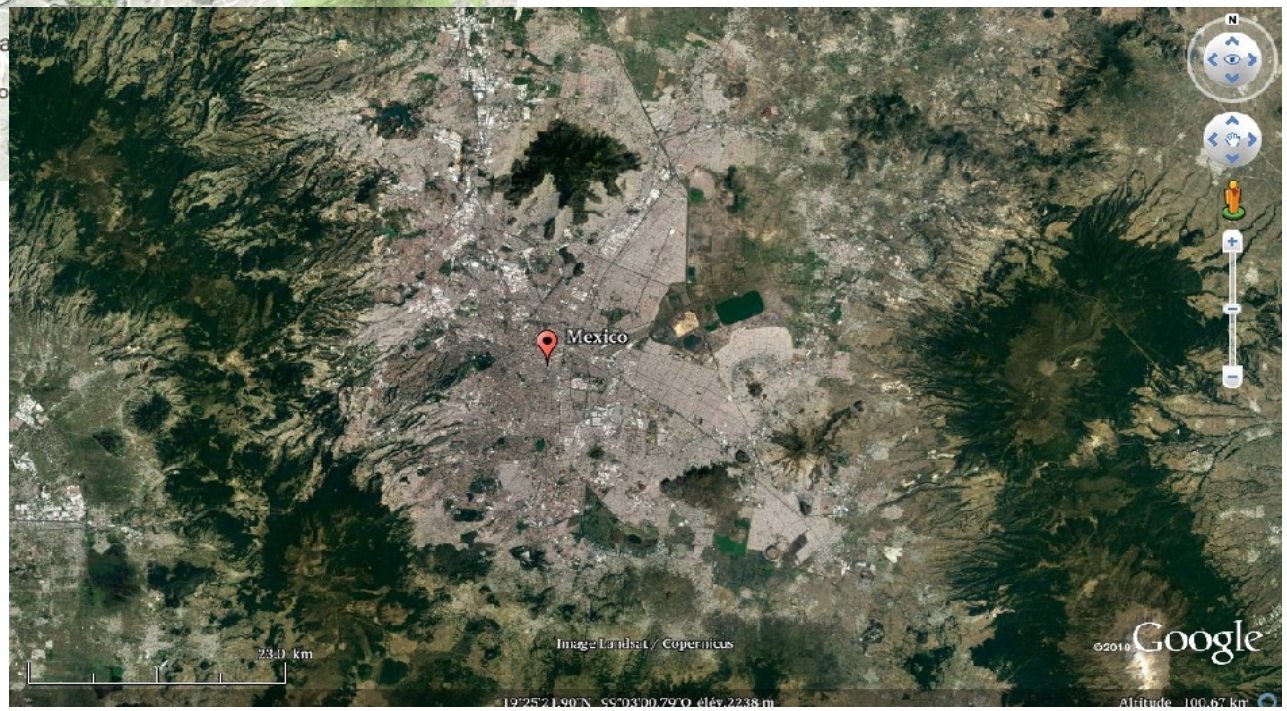
A few commands :

cd : change directory
ls : list content of a directory
pwd : where you are
googleearth
/nsbas/MDX/mdx.pl : launch vizualisation tool
gthumb (to view jpg/png) / evince (to view pdf)

Study site

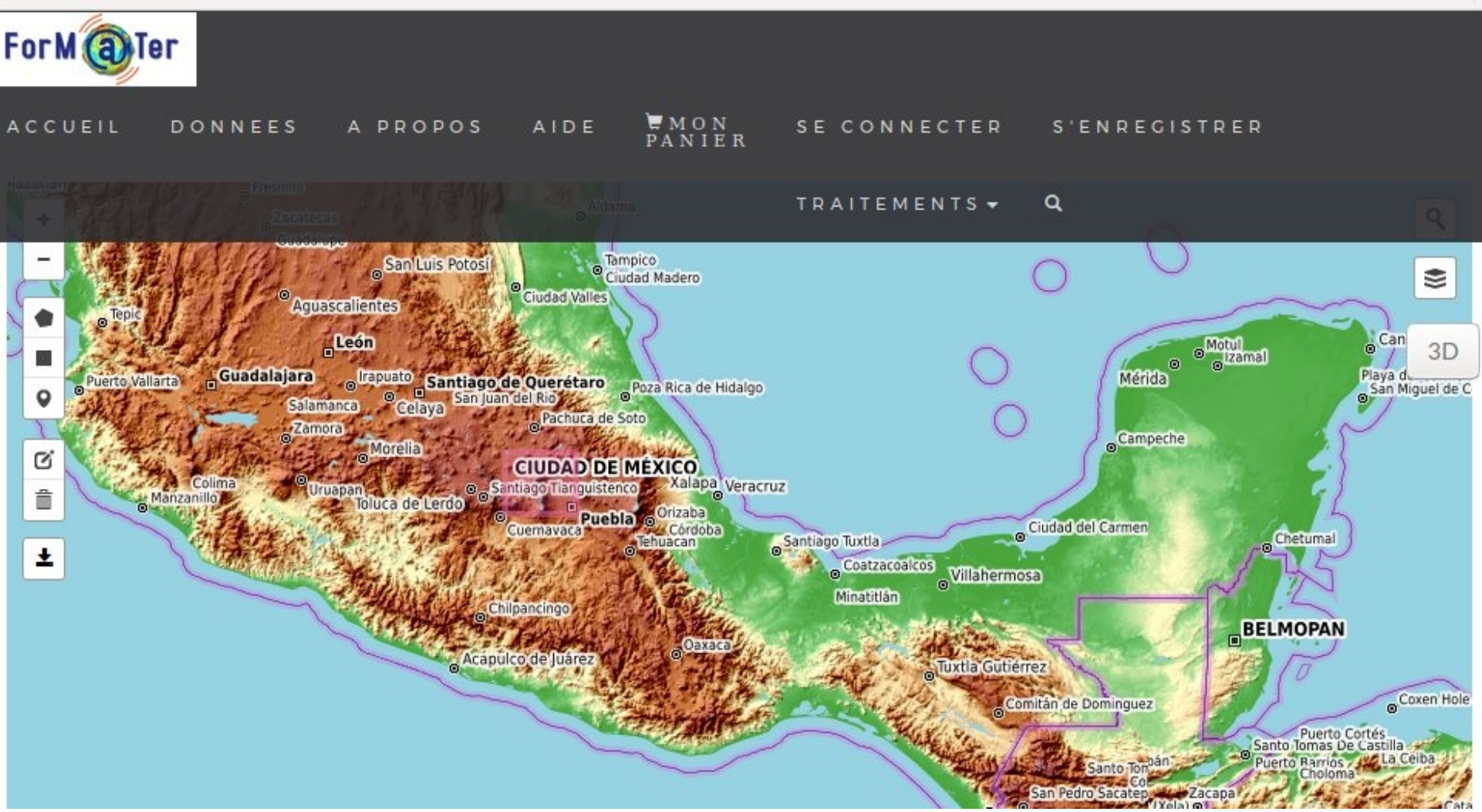
Topo
+
Landsat

googlemap



Interferograms processing: case 1: etalab

Data : downloaded using the etalab web service
Here descending track
Relative orbit number : 143



Interferograms processing: case 1: etalab

Data : downloaded using the etalab web service
Here descending track
Relative orbit number : 143

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Here descending track
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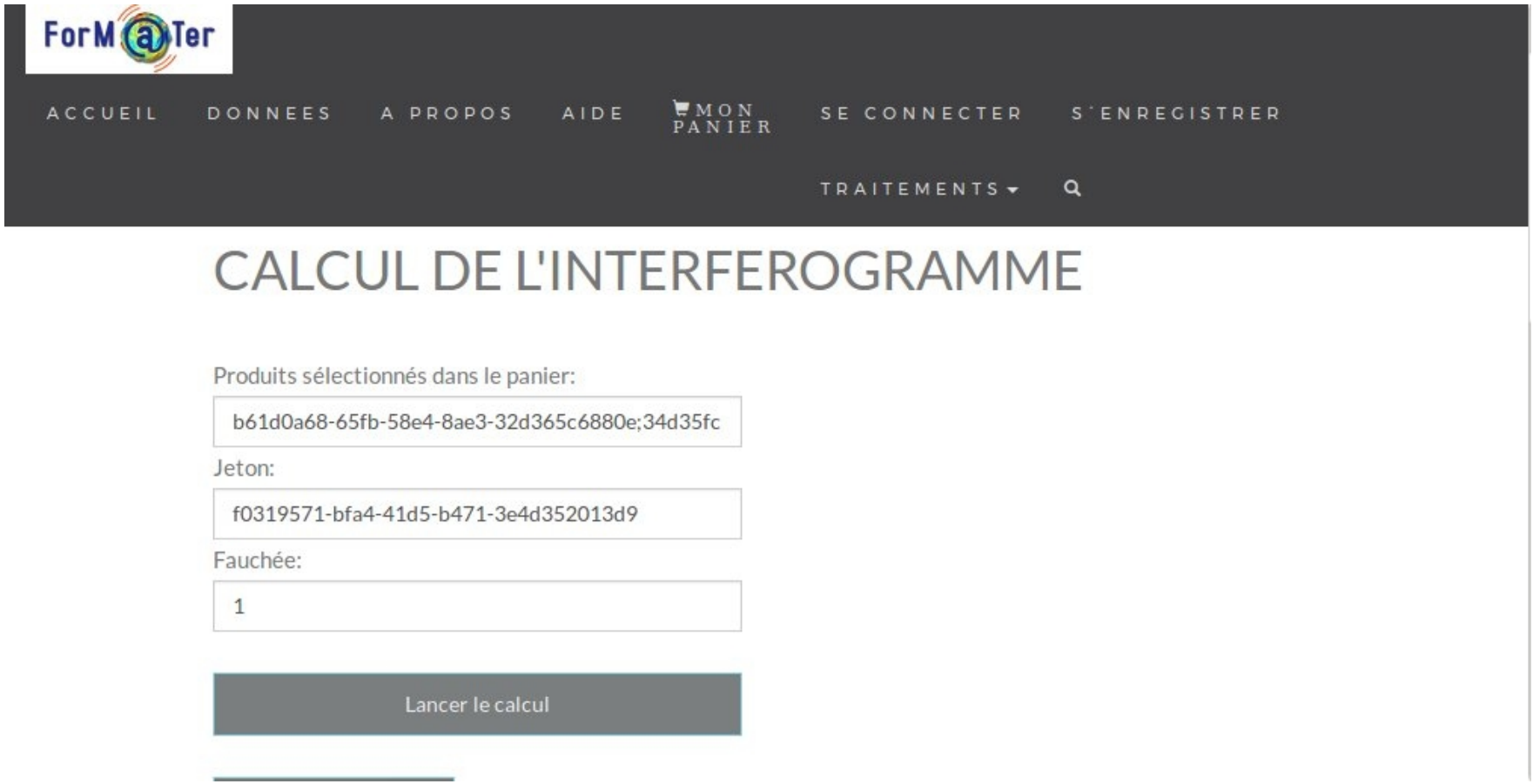
Interferograms processing: case 1: etalab

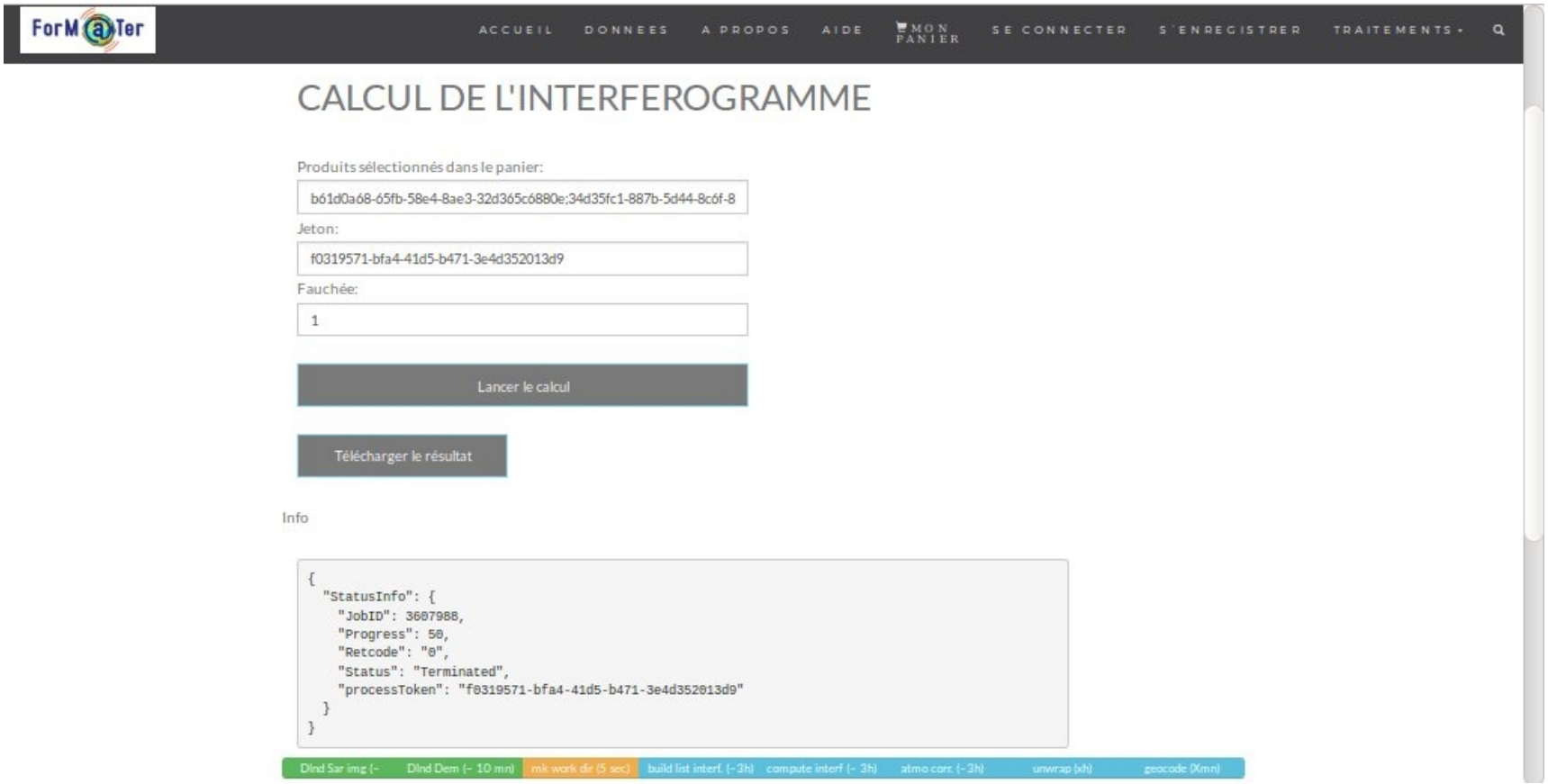
Processing based on NSBAS chain (Doin et al., 2011, Grandin 2016)
"lancer le calcul"



Results : only major outputs of NSBAS will be available to download

Interferograms processing: case 1: etalab

Processing based on NSBAS chain (Doin et al., 2011, Grandin 2016)
“lancer le calcul”



Results : only major outputs of NSBAS will be available to download

Interferograms processing:
case 2: nsbas

Now, let us look at the results of the process

$ cd /nsbas/MEXICO
$ ls
DEM iw3 RAW
$ cd RAW
$ ls
List of data to download on descending track 143
$ gedit mexico_D143.json

Example of a SAFE directory

Data download from PEPS

Example of .json original input file to prepare for automatic data download

```
{
    "aral": {
        "box": "-99.5,19,-98.5,20",
        "comment": "Mexico City",
        "download": "no",
        "end_date": "2017-09-30",
        "manager": {
            "email": "                                                    ",
            "name": "
        },
        "missing": [],
        "polarisation": [
            "VV",
            "VV VH"
        ],
        "productType": "SLC",
        "quota": "500T",
        "relativeOrbitNumber": [
            "D143"
        ],
        "start-date": "2012-08-01",
        "urls": {
        },
        "urls_size": "468.6 GB",
        "working_dir": "/cycle_scratch/doin/MEXICO/D143/raw_data"
    }
}
```

Polarisation : either VV or VV+VH

D: descending
143: relative orbit number

Data download from PEPS

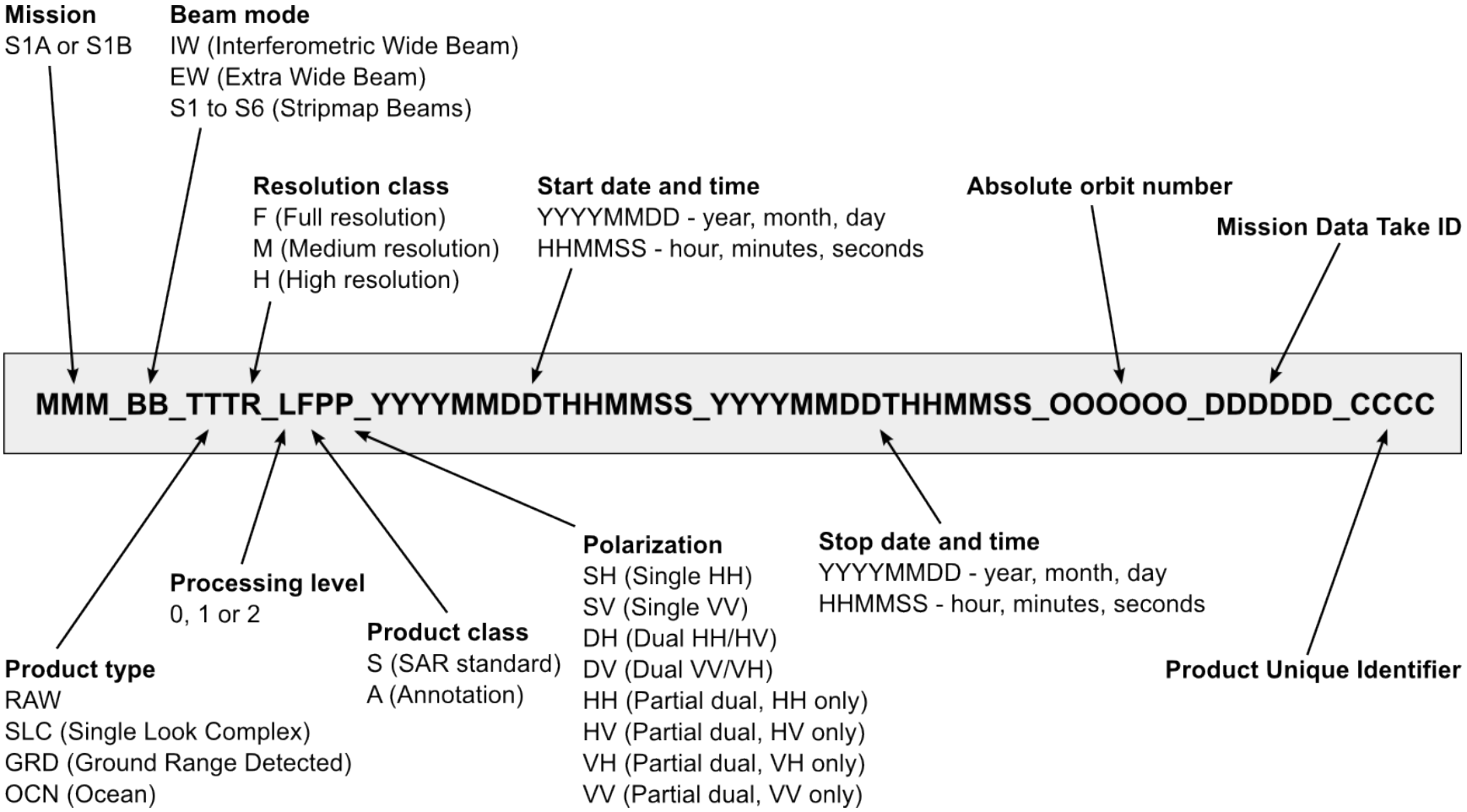
Example of .json after exploring PEPS archive with previous selection parameters. A list of images to download appears.


```
],
"start-date": "2012-08-01",
"urls": {
    "S1A_IW_SLC__1SDV_20170225T122529_20170225T122556_015440_019589_15D7": [
        "64c2da20-e418-540a-b3aa-09b458ae6795",
        4641137494,
        "2017-02-28T00:18:12.648Z",
        "disk"
    ],
    "S1A_IW_SLC__1SDV_20170225T122554_20170225T122620_015440_019589_8457": [
        "5e0260fd-479c-578f-b55e-9336116668d7",
        4753055802,
        "2017-03-02T21:06:05.502Z",
        "disk"
    ],
    "S1A_IW_SLC__1SDV_20170309T122529_20170309T122556_015615_019AD5_4767": [
        "864c6742-4fa6-5c20-bb29-195c4928b2a7",
        4689505710,
        "2017-03-12T00:46:14.309Z",
        "tape"
    ],
    "S1A_IW_SLC__1SDV_20170309T122554_20170309T122621_015615_019AD5_488D": [
        "68788abe-b6b0-5ebc-84bc-5bf91b06171c",
        4758821859,
        "2017-03-12T00:44:14.401Z",
        "tape"
    ],
    "S1A_IW_SLC__1SDV_20170321T122529_20170321T122556_015790_01A00C_76C7": [
        "0cde1343-1116-597a-8ba7-1573d8146549",
        4647995057,
        "2017-03-21T15:43:12.148Z",
        "tape"
    ],
```

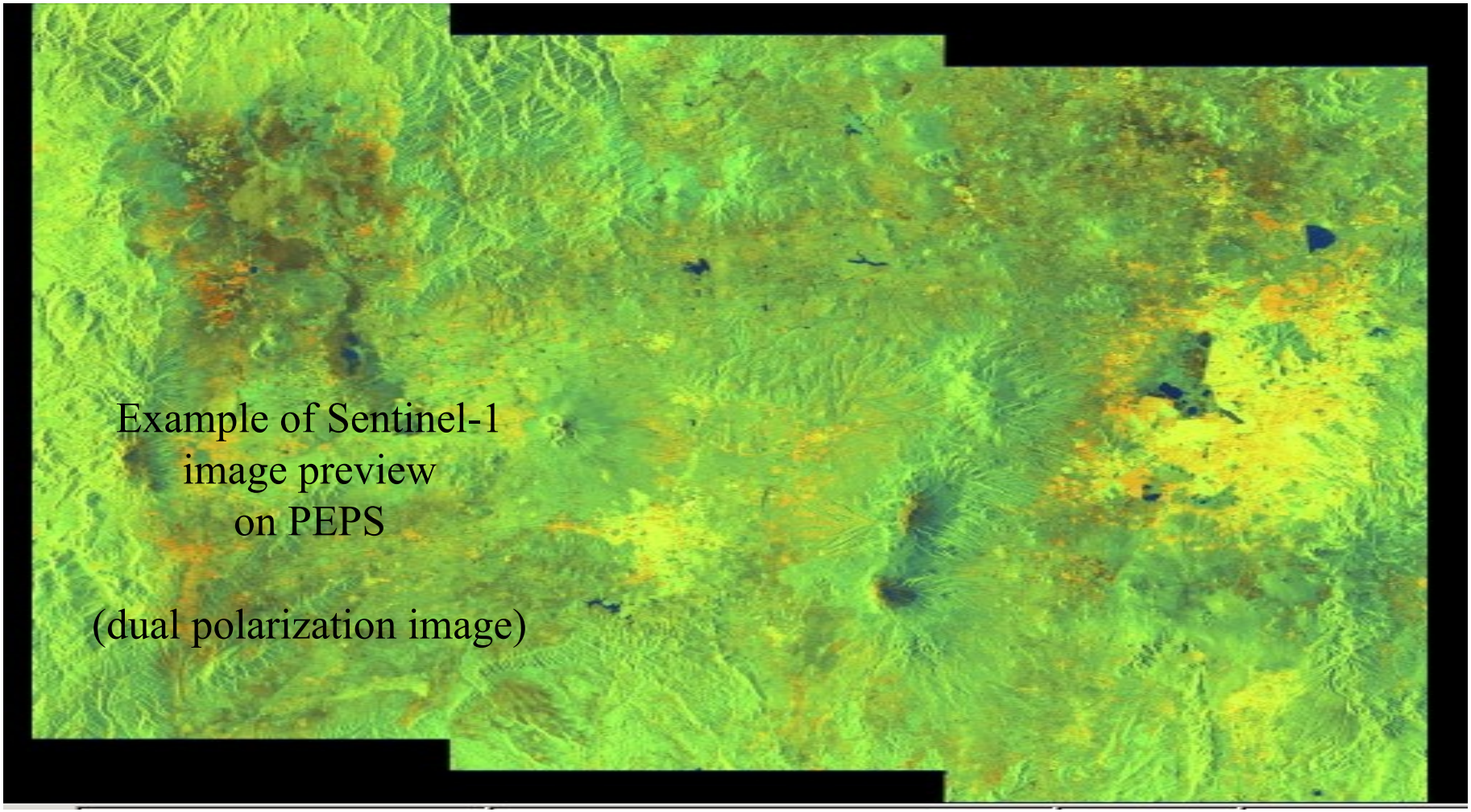
SAFE name

ls /nsbas/MEXICO/RAW
ls /nsbas/MEXICO/RAW/*SAFE :

manifest.safe: general information
annotation: xml description of data
measurement : data on iw1/iw2/iw3



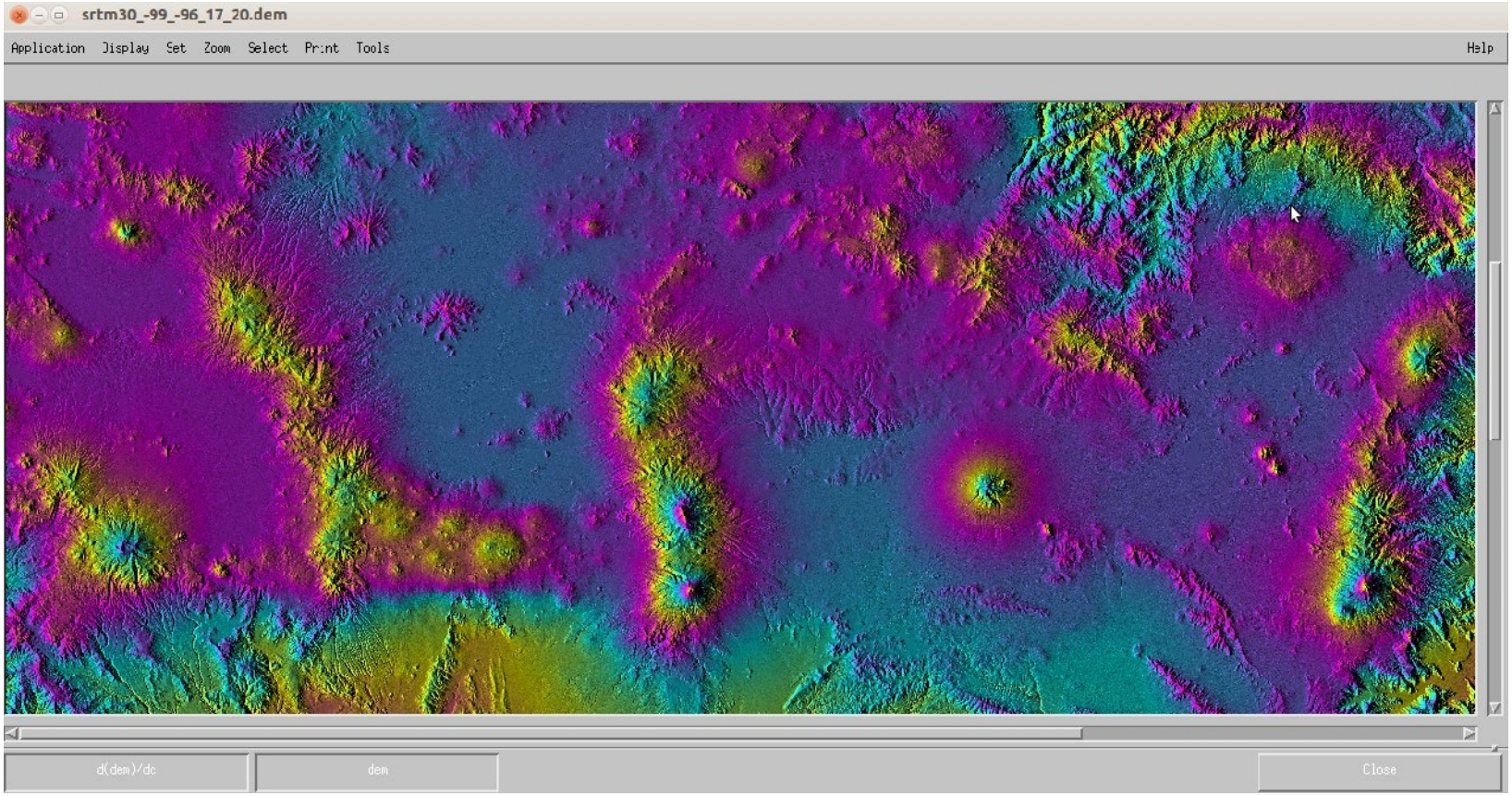
Data download from PEPS



$ gthumb /nsbas/MEXICO/RAW/*SAFE/preview/quick-look.png
here we choose iw3

Other preliminary step : DEM download

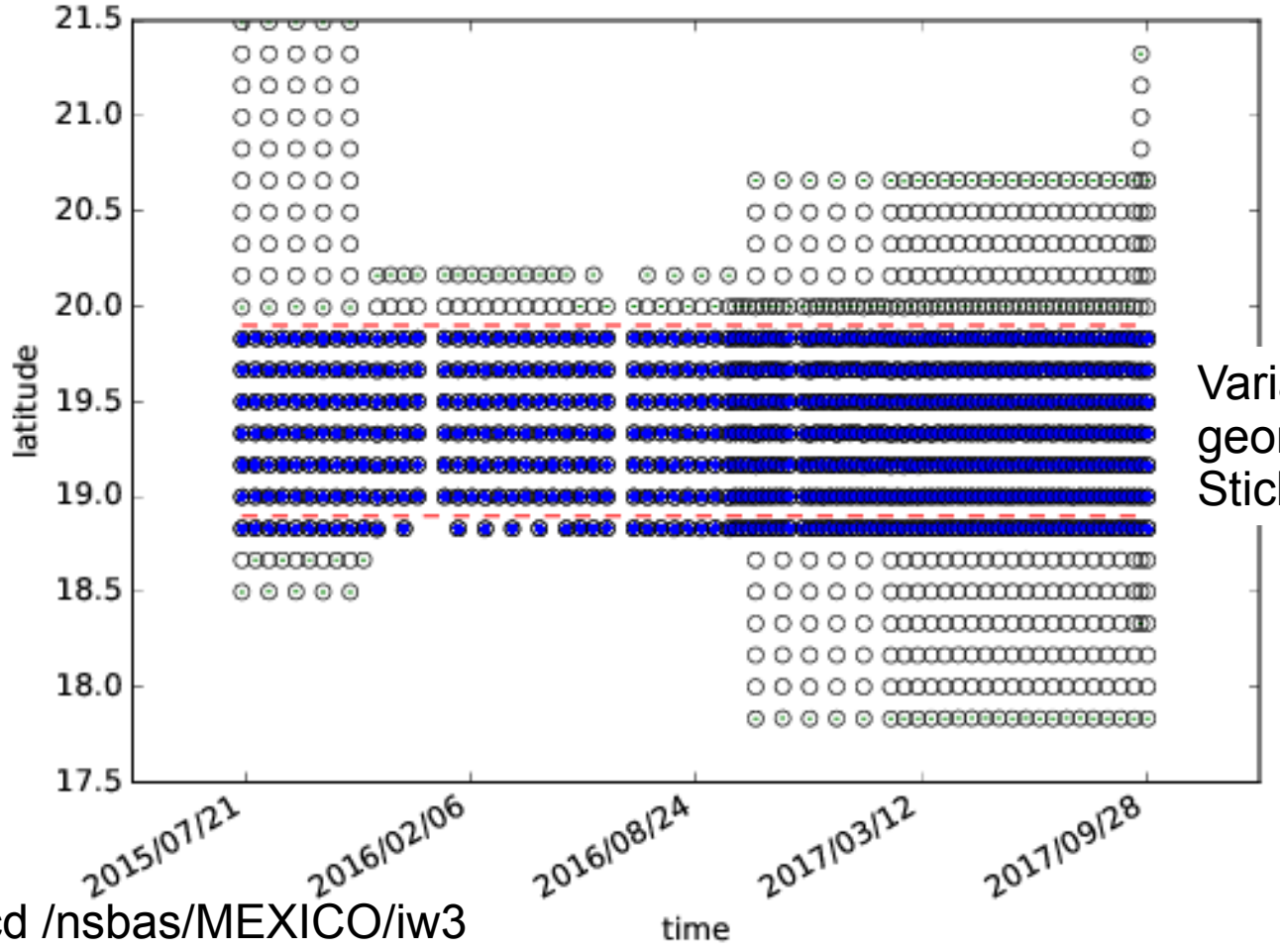
Automatic ftp of SRTM 30 m from USGS, englobing all downloaded Sentinel-1 frames
Geoid EGM96 added



$ /nsbas/MDX/mdx.pl /nsbas/MEXICO/DEM/srtm30_-99_-96_17_20.dem -z -8 -wrap 200
Right click on button : change color scale
Middle click on other button : but amplitude + color

Step 1: create working space, make links extract metadata, and bursts limits

Common bursts selection before SLC processing



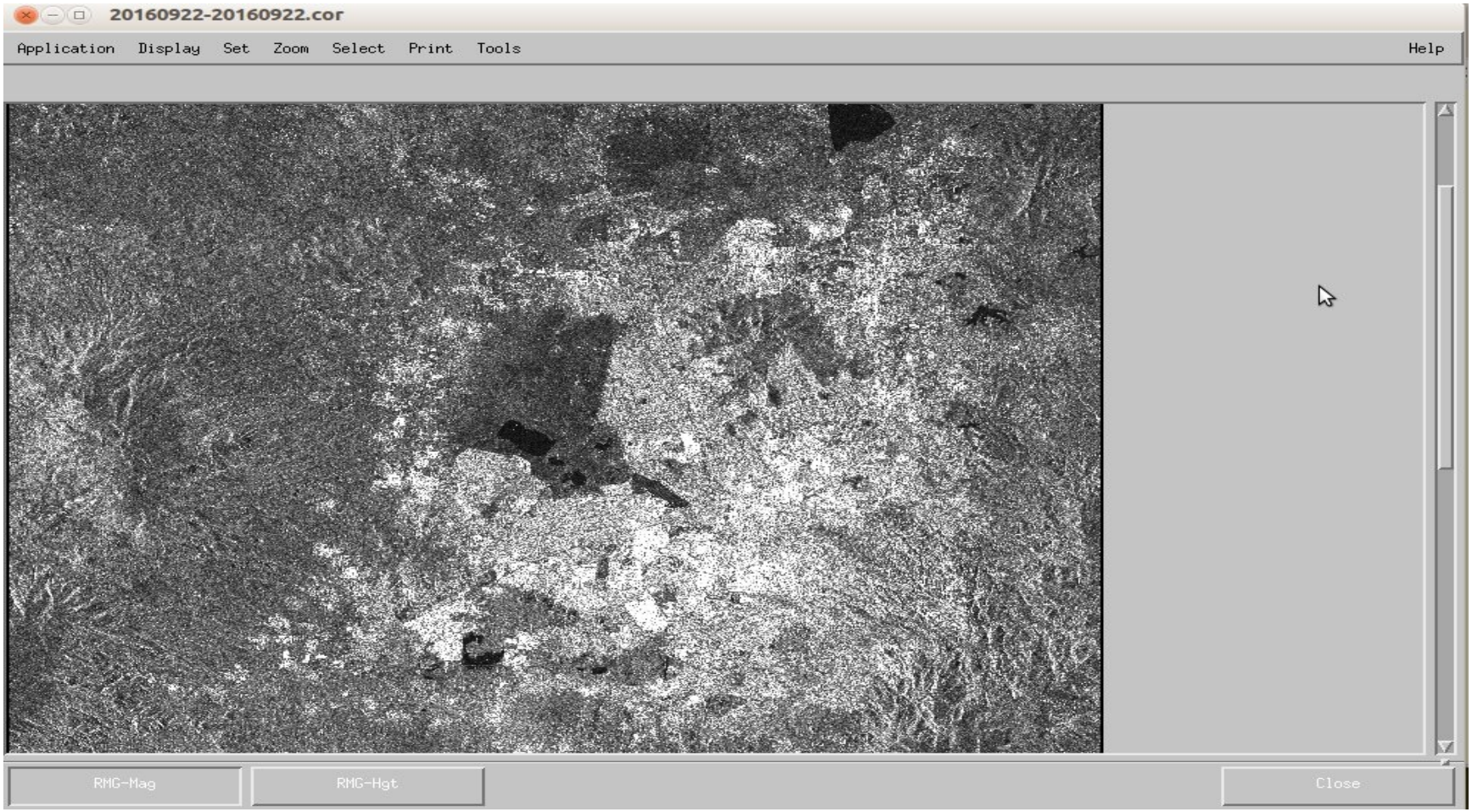
Variable slices geometry along track: Stiching / Cut

$ cd /nsbas/MEXICO/iw3
$ evince plot_time_lat.pdf

Here, we select bursts between 18.8 and 19.8, and acquisitions complete for these bursts.

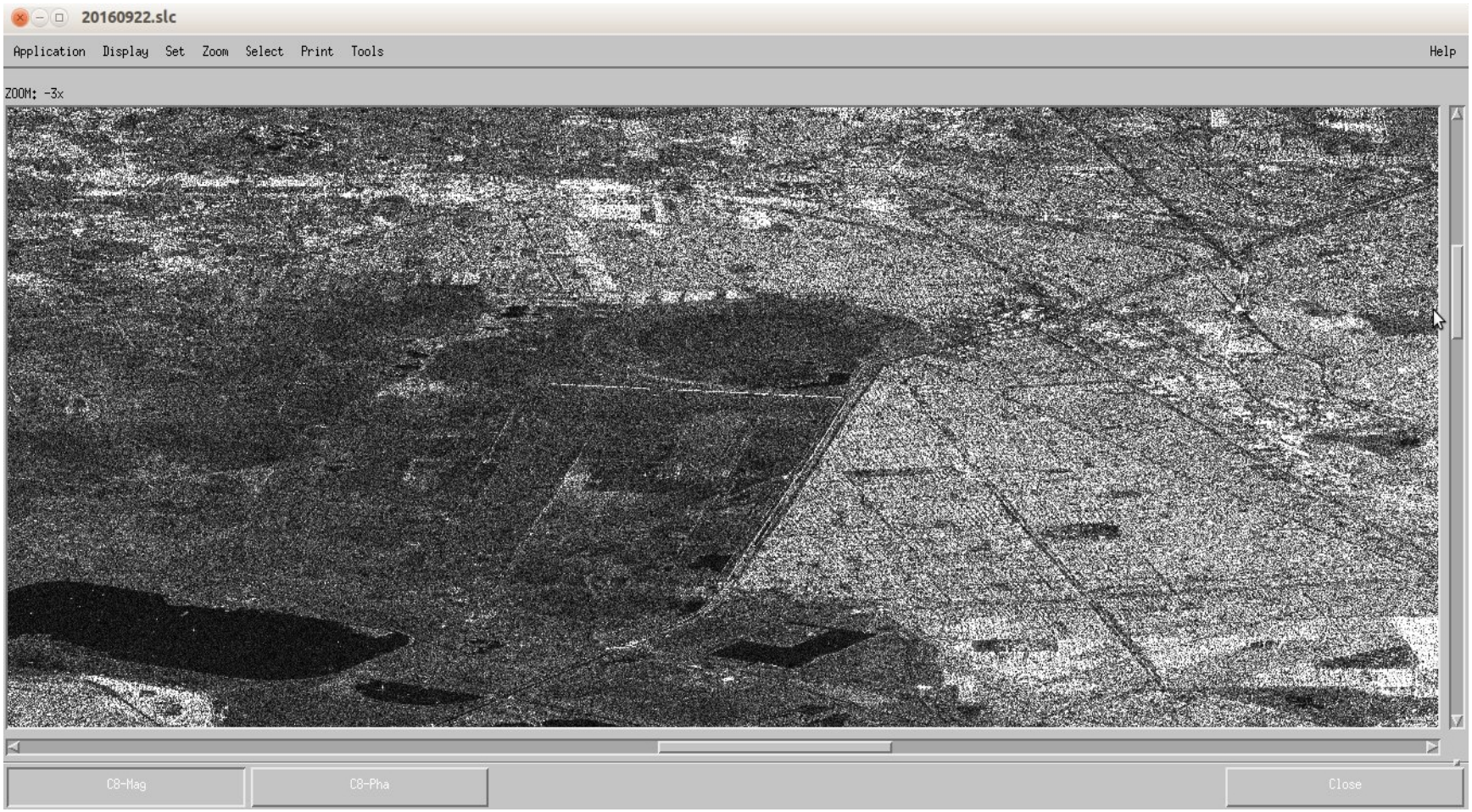
Step 2: SLC formation

Stitch all bursts in a single image cutting overlap in the middle
$ /nsbas/MDX/mdx.pl 20160922/20160922.slc -z -8
Zoom in /out

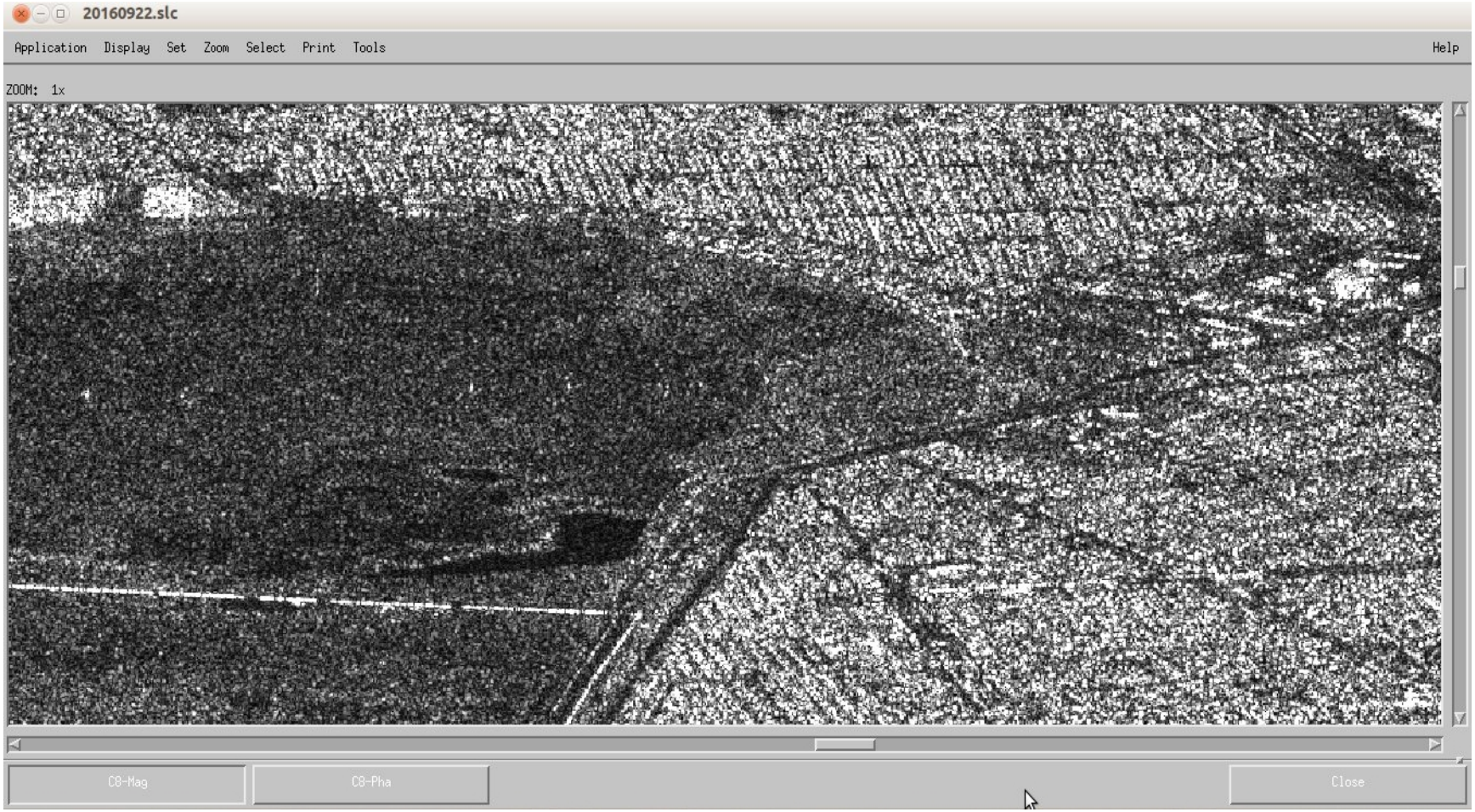


$ /nsbas/MDX/mdx.pl 20160922/20160922.slc -z -8
Zoom in /out
You can compare with googleearth /googlemap, see target response to illuminating radar waves in streets or on vegetation

Zoom 1 (Master)

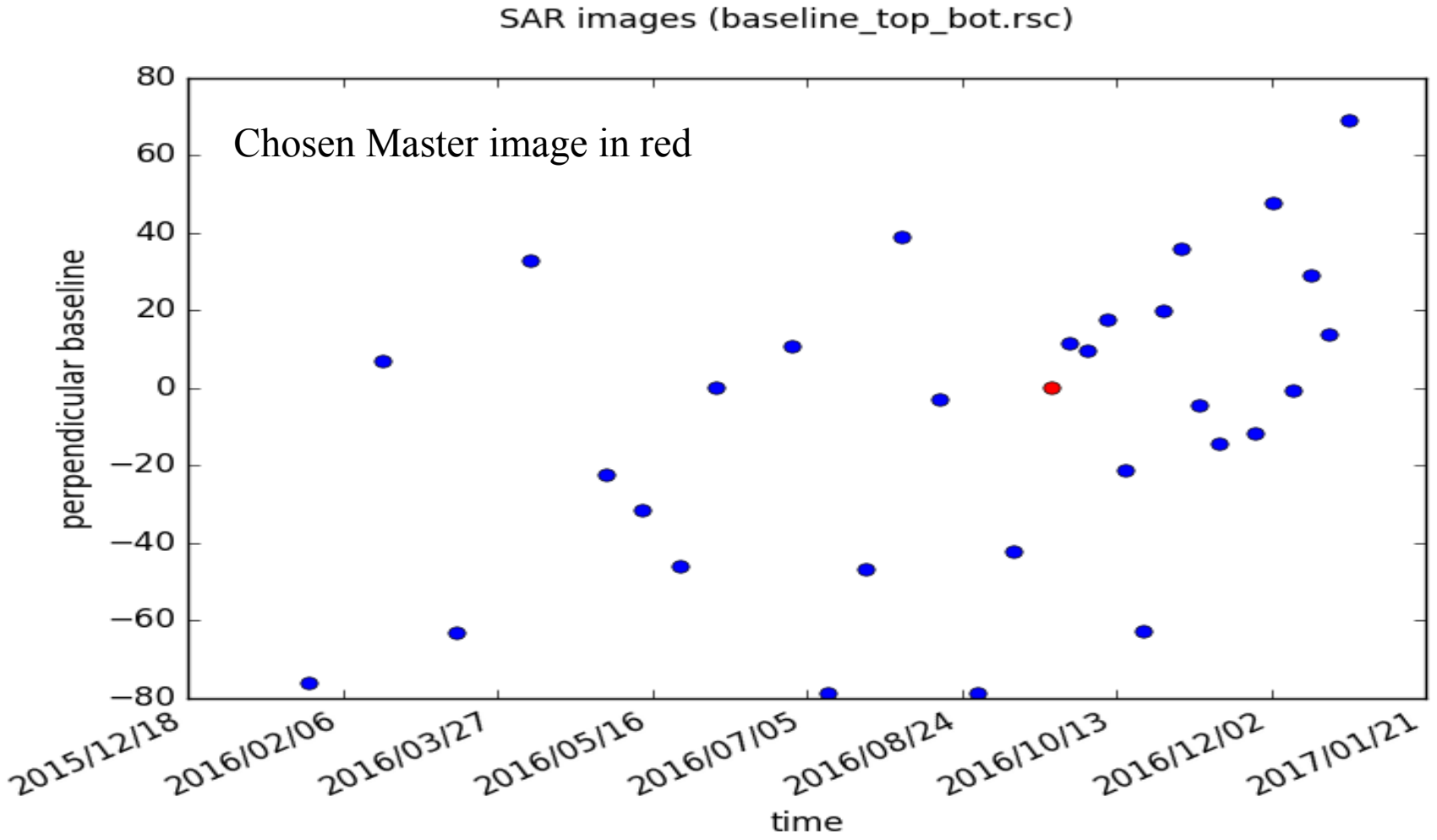


Zoom 2 (Master)



Step 3: compute perpendicular baseline

Small orbital tube + large bandwidth: little geometrical decorrelation, and little sensitivity to topography
$ gthumb plot_baseline_top_bot.png
$ gedit baseline.rsc

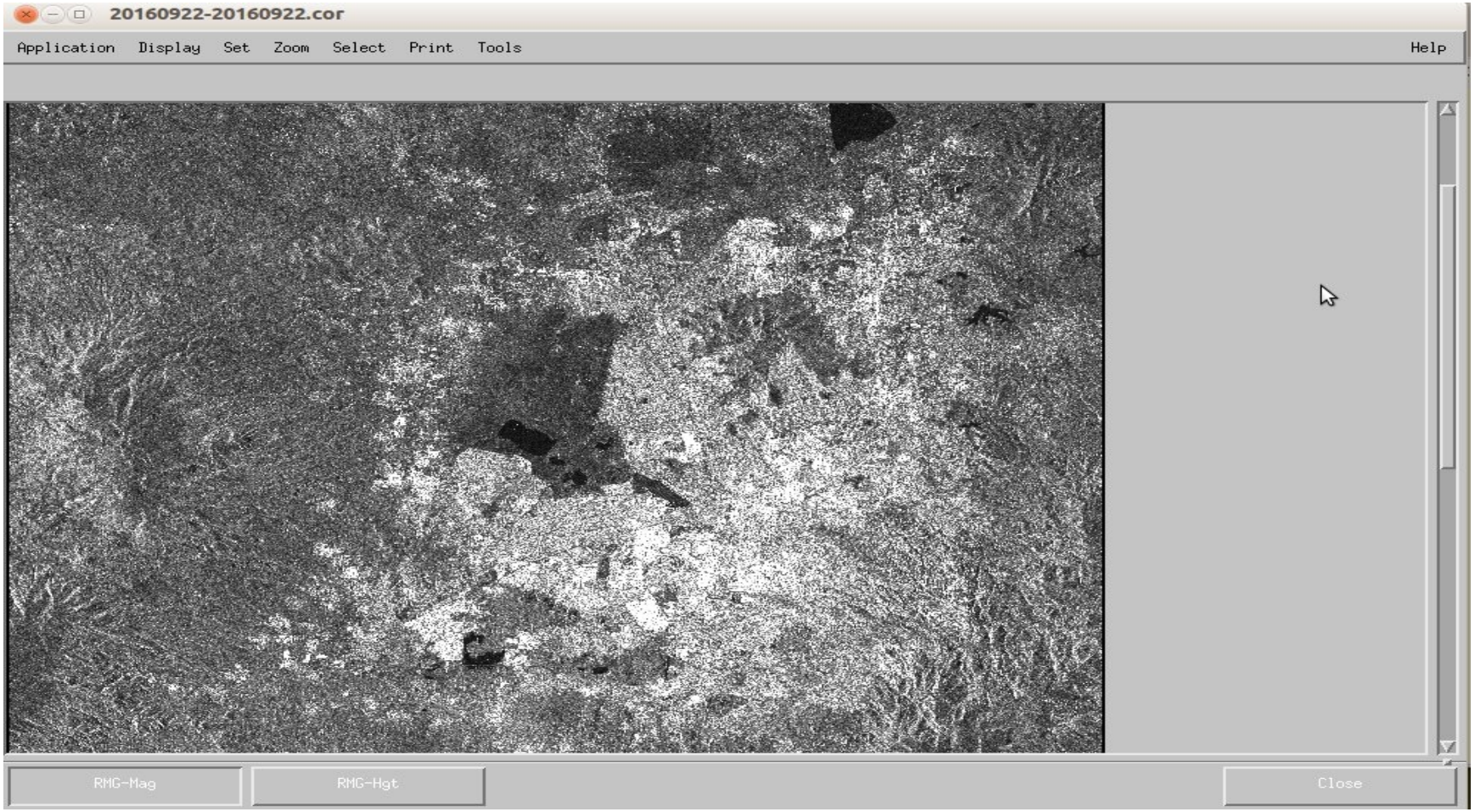


Step 4: DEM simulation in Master data radar geometry

We compare simulated amplitude image and radar amplitude image to place DEM exactly in SAR geometry. Look similarities / discrepancies between both images:

$ /nsbas/MDX/mdx.pl 20160922/SIM_20160922.hgt -z -8

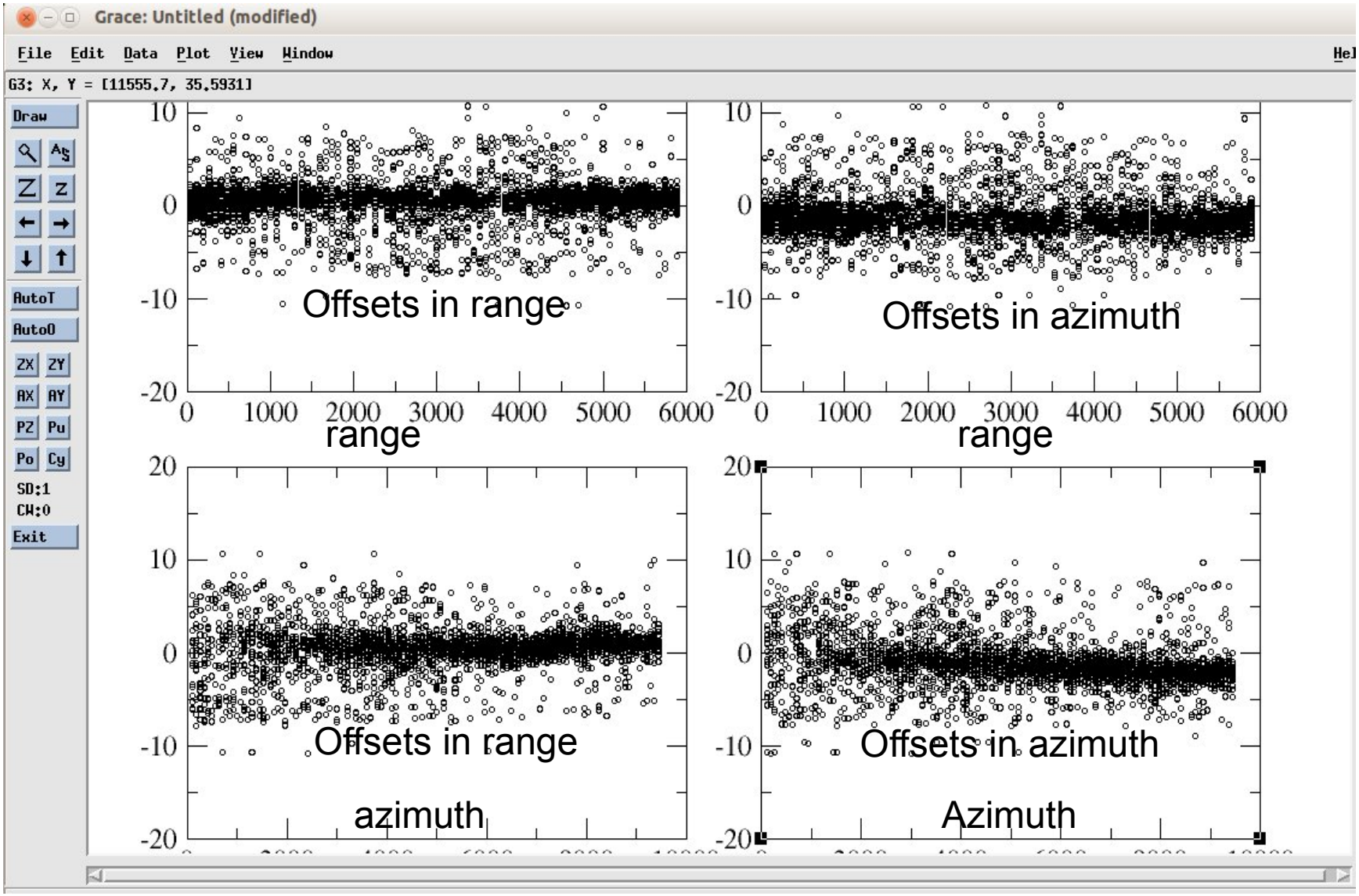
$ /nsbas/MDX/mdx.pl 20160922-20160922.cor -z -8



Simulation-Master coregistration

Automatic offset detection by image correlation. If fails, zero offset assumed.

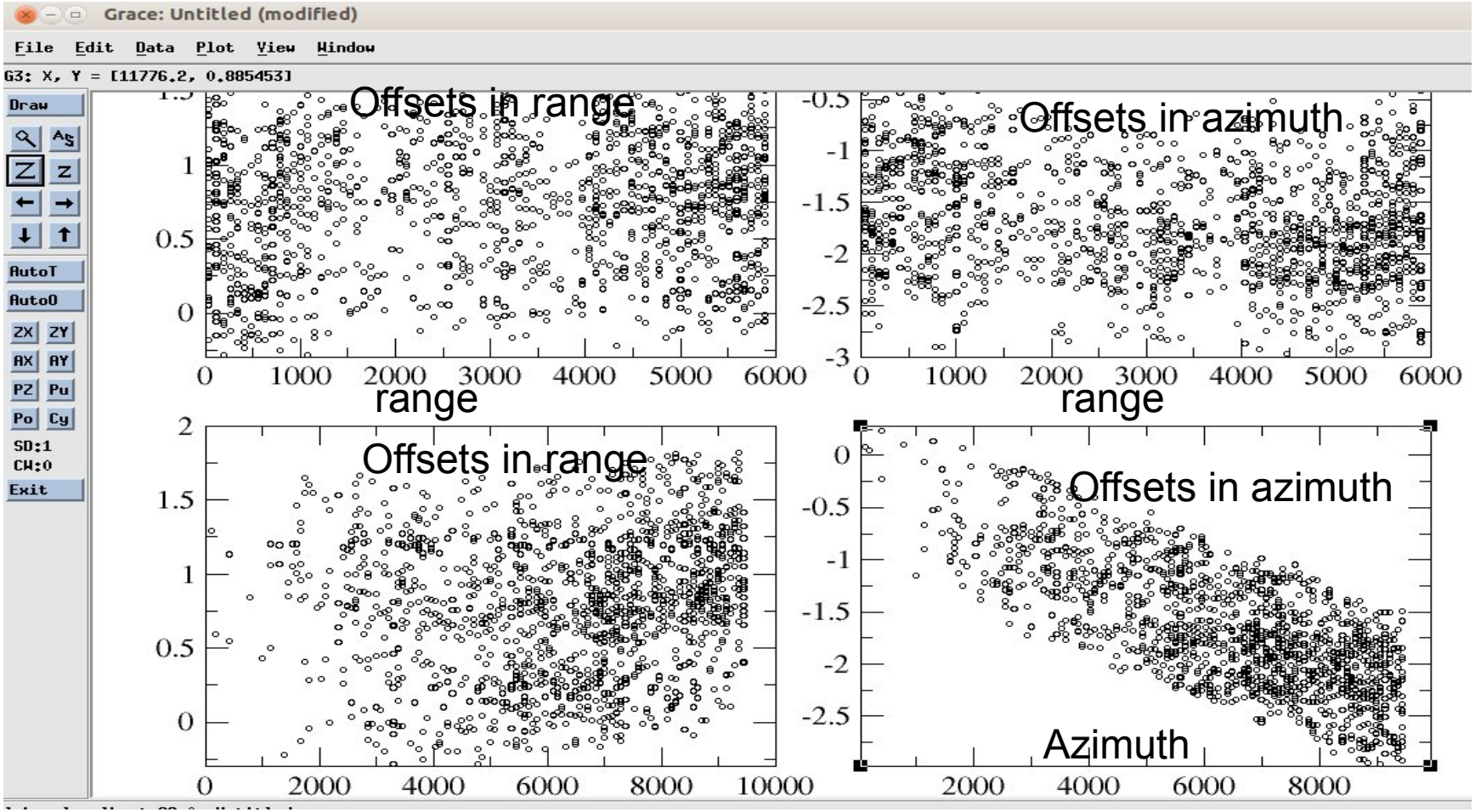
$ /nsbas/MDX/PlotOffset.pl 20160922/ampmag.off



Simulation-Master coregistration

$ /nsbas/MDX/PlotOffset.pl 20160922/ampmag_cull.off

Zoom, After iteratively removing all outliers : it defines a distortion function



Simulation-Master coregistration

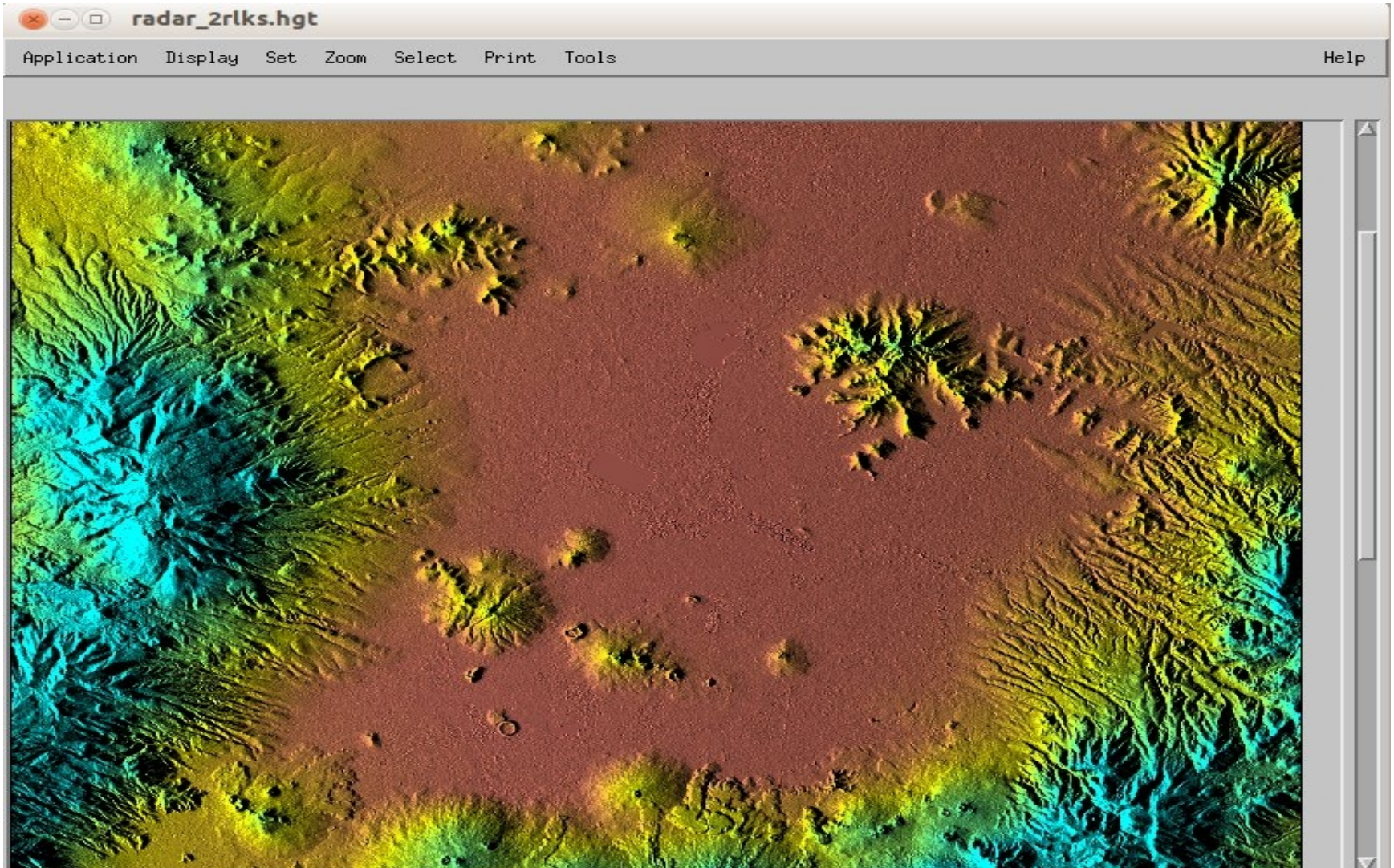
Distortion affine function
$ gedit 20160922/cull.out

Estimated parameters for coregistration

```
     << Fitoff Program >>

 Number of points remaining =        1413

 RMS in X =   0.463464680005555        RMS in Y =   0.394896903859968

       Matrix  Analysis

  Affine Matrix

    1.0000146293    0.0000246219
   -0.0000247180    0.9997935588

 Translation Vector

       0.602      -0.266

  Rotation Matrix

    0.9999999997    0.0000247176
   -0.0000247176    0.9999999997

 Rotation Angle (deg) =  -1.416214325846281E-003

  Axis Scale Factors

   1.0000146   0.9997936

"20160922/cull.out" 35L, 566C
```

DEM simulation in Master data radar geometry

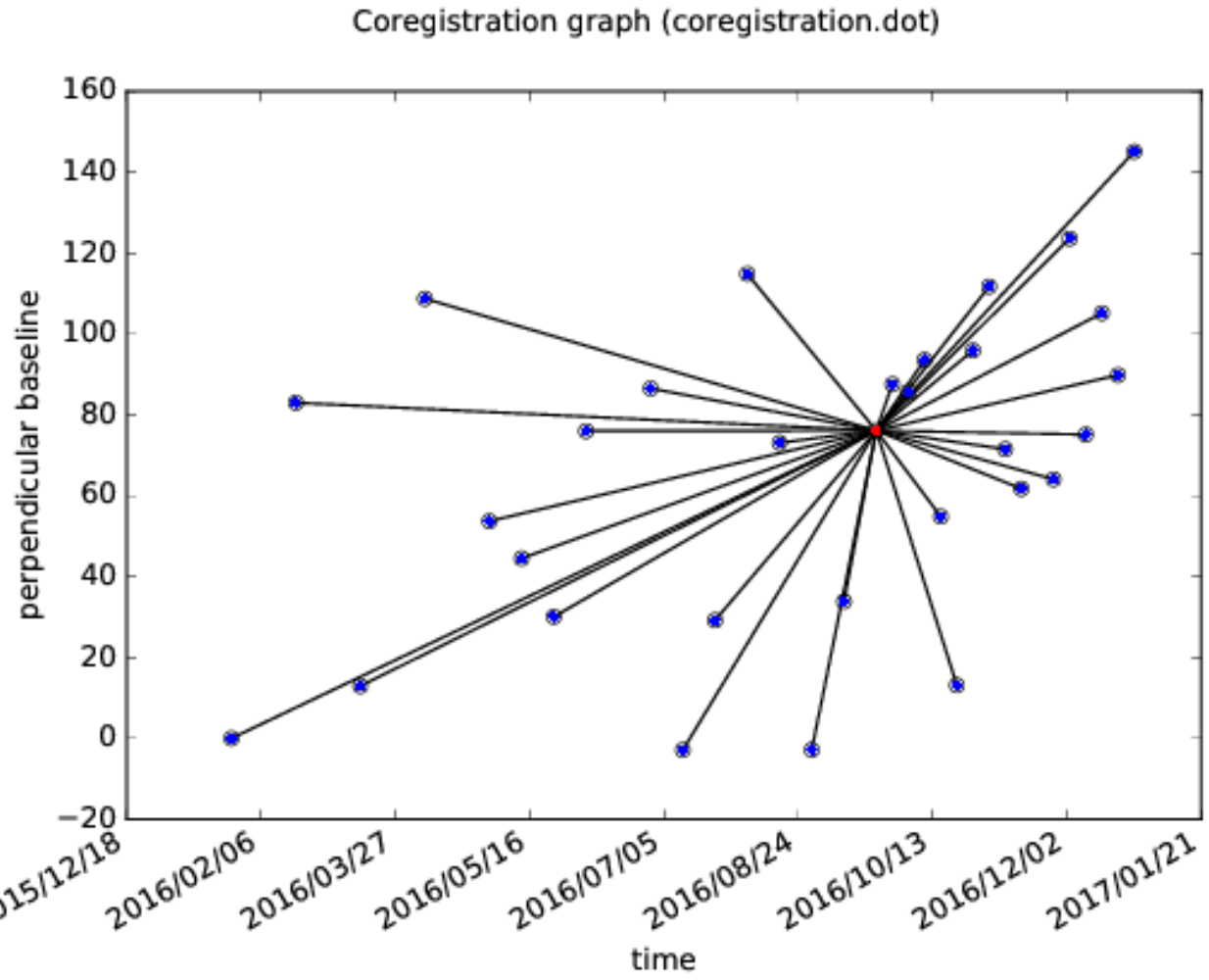
Final DEM in radar geometry
$ /nsbas/MDX/mdx.pl 20160922/radar_2rlks.hgt -z -4



Step 5: Coregistration slaves to master

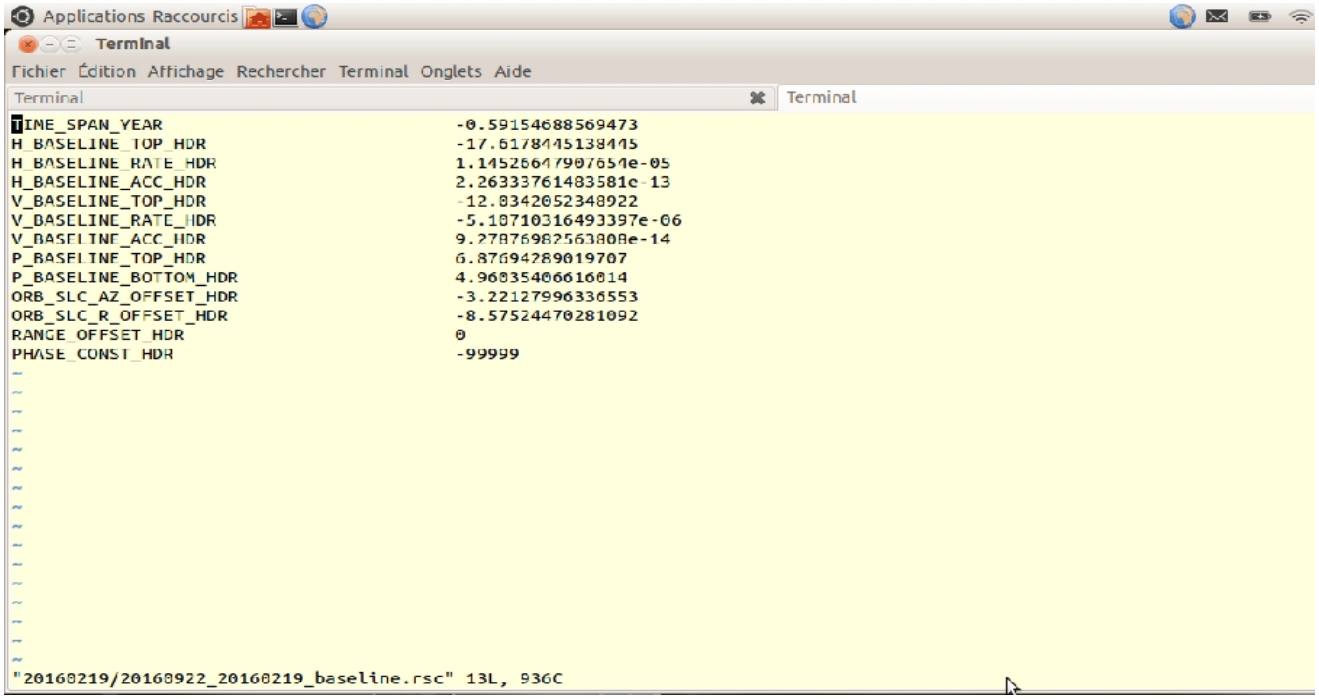
All slcs from “slave” acquisitions should be resampled in master geometry. Step based on orbit and image correlation

$ evince plot_coregistration.pdf



Baseline information for one selected pair of images

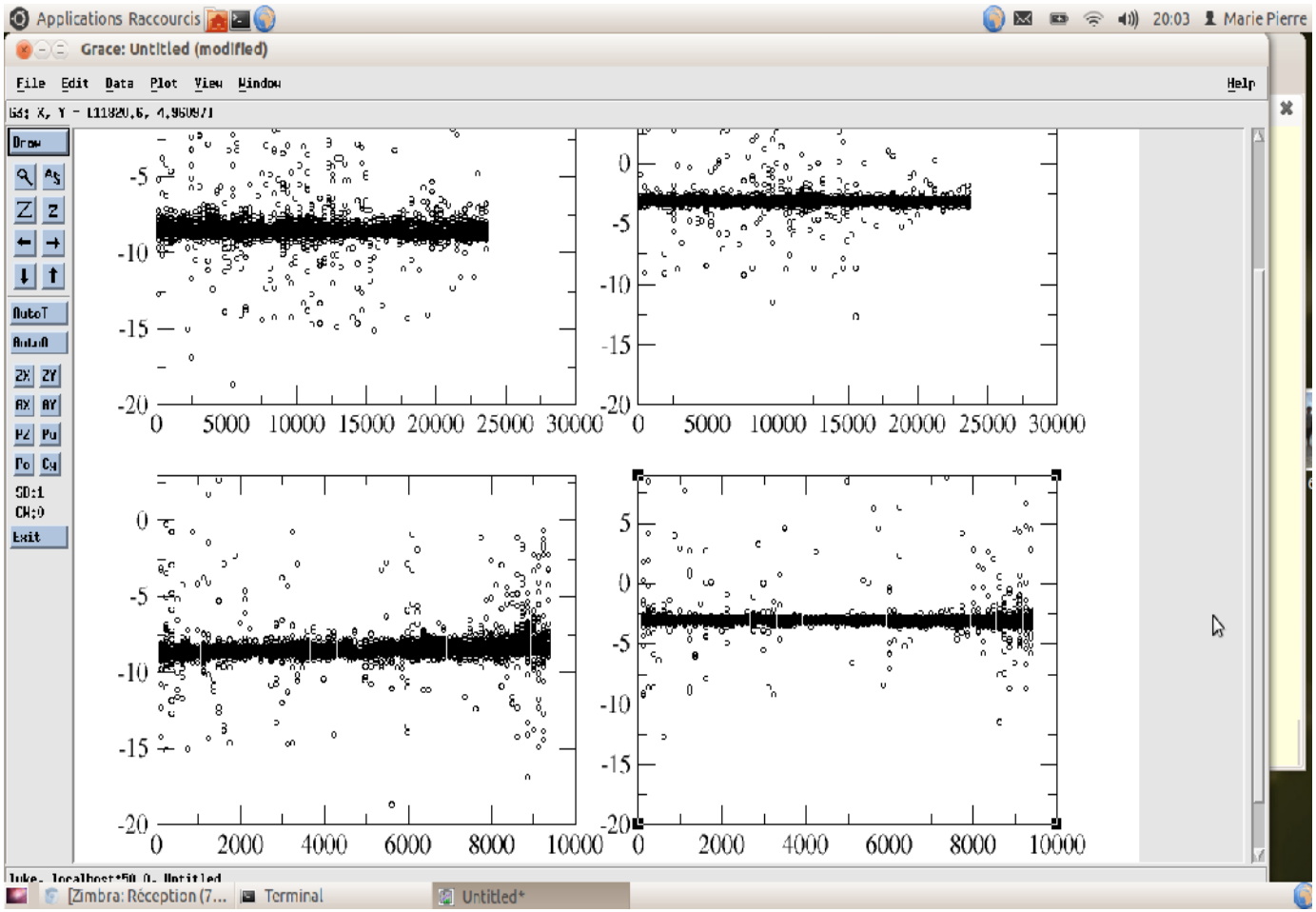
To view a priori offset file :
$ gedit 20160219/20160922_20160219_baseline.rsc



Slave-Master coregistration

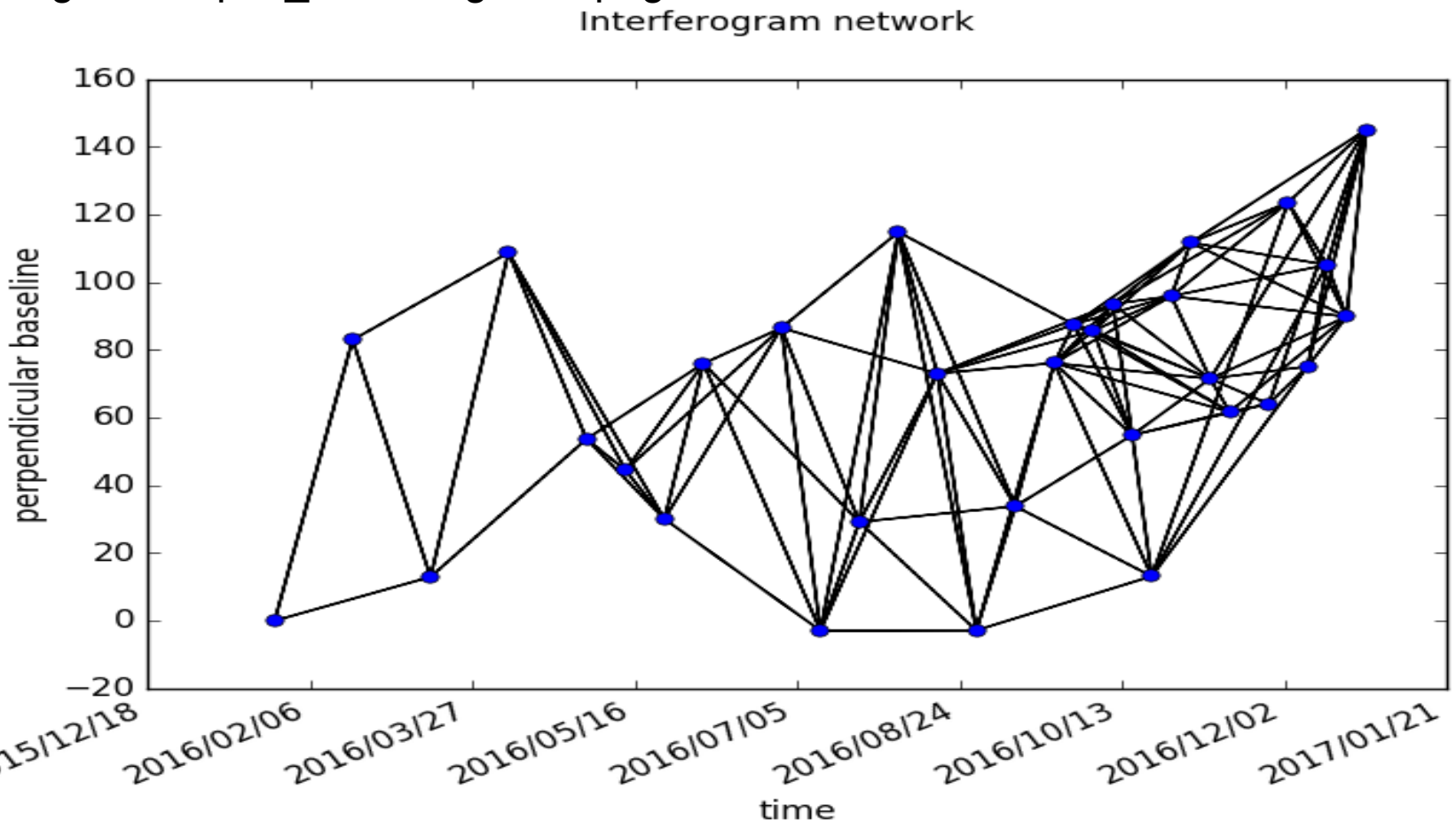
To plot estimated offset between slave and master:
Should be accurate to 1/100th of pixel !!!
$ /nsbas/MDX/PlotOffset.pl 20160219/20160922-20160219_ampcor.off
$ /nsabs/MDX/mdx.pl 20160219/20160219_coreg.slc -z -8

Example for one pair

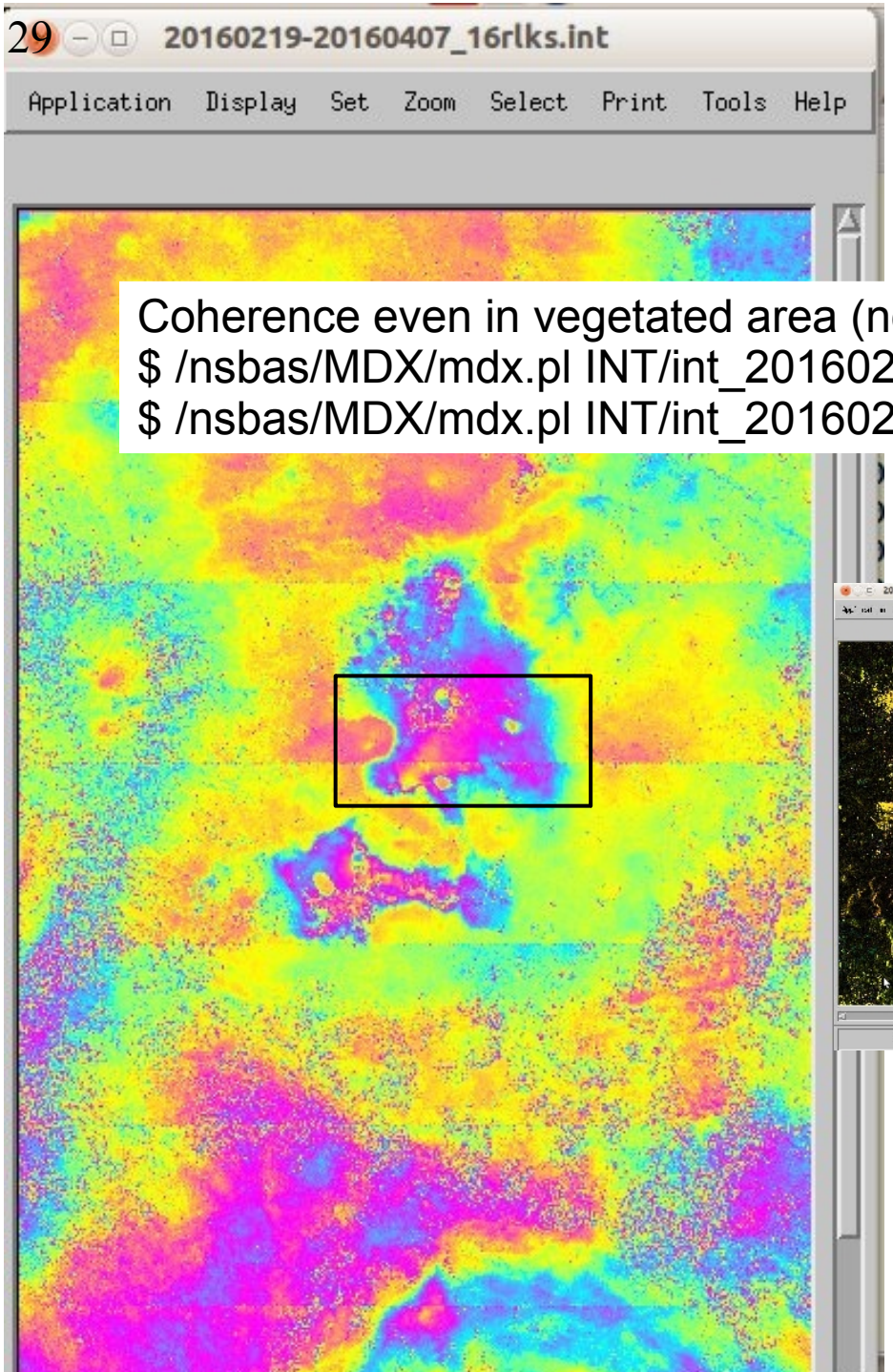


Step 6: Interferogram computation

Interferograms for temporal baseline < 0.16 years : preserve coherence
$ gthumb plot_interferograms.png



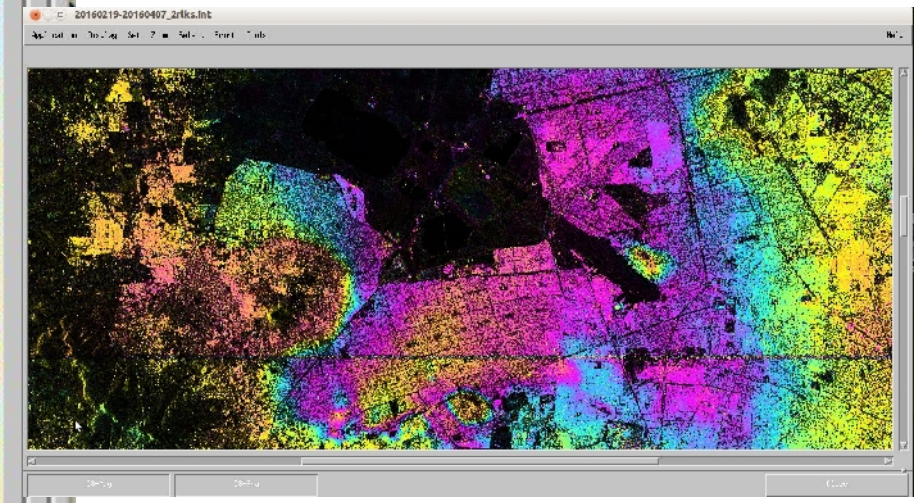
Interferogram computation



Coherence even in vegetated area (noisier)

$ /nsbas/MDX/mdx.pl INT/int_20160219_20160407/20160219-20160407_2rlks.int

$ /nsbas/MDX/mdx.pl INT/int_20160219_20160407/20160219-20160407_16rlks.int

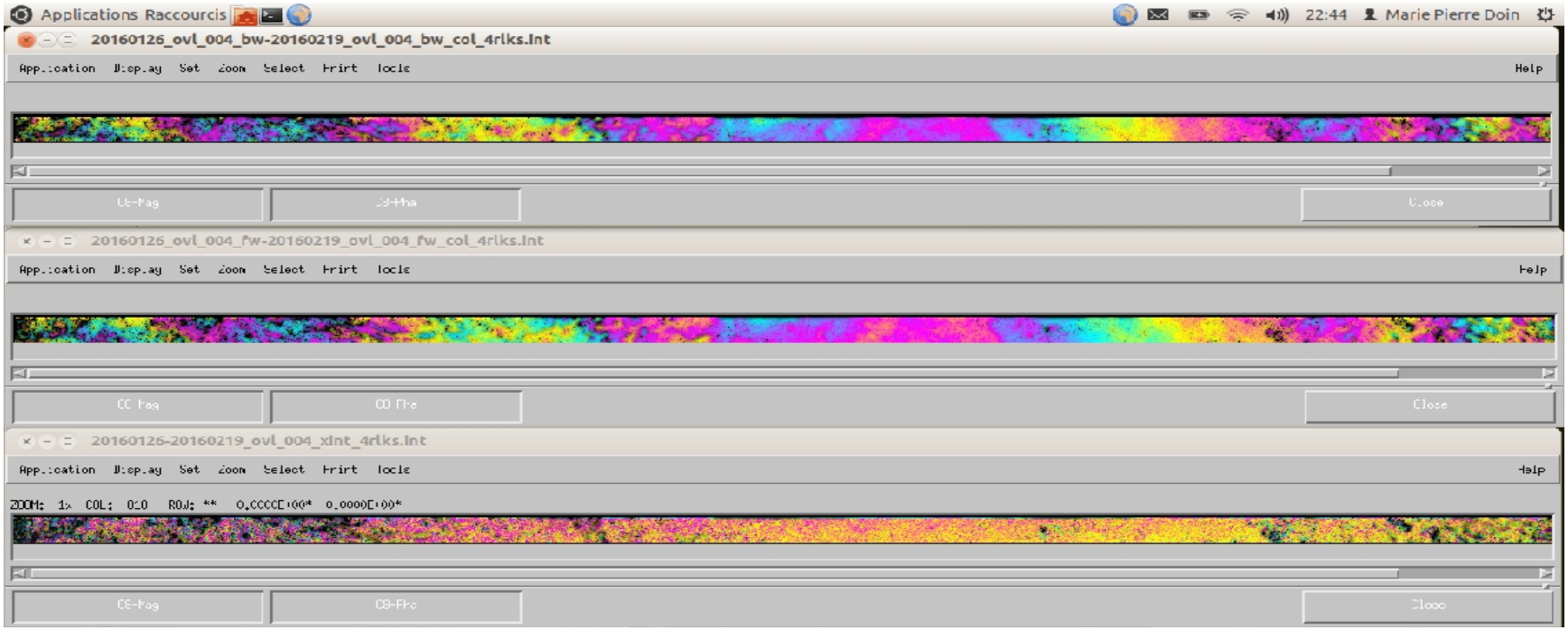


Step 7: Spectral diversity correction step

$/nsbas/MDX/mdx.pl INT_sd/int_20160126_20160219/20160126_ovl_004_bw-20160219_ovl_004_bw_col_4rlks.in
$ /nsbas/MDX/mdx.pl INT_sd/int_20160126_20160219/20160126_ovl_004_fw-20160219_ovl_004_fw_col_4rlks.int

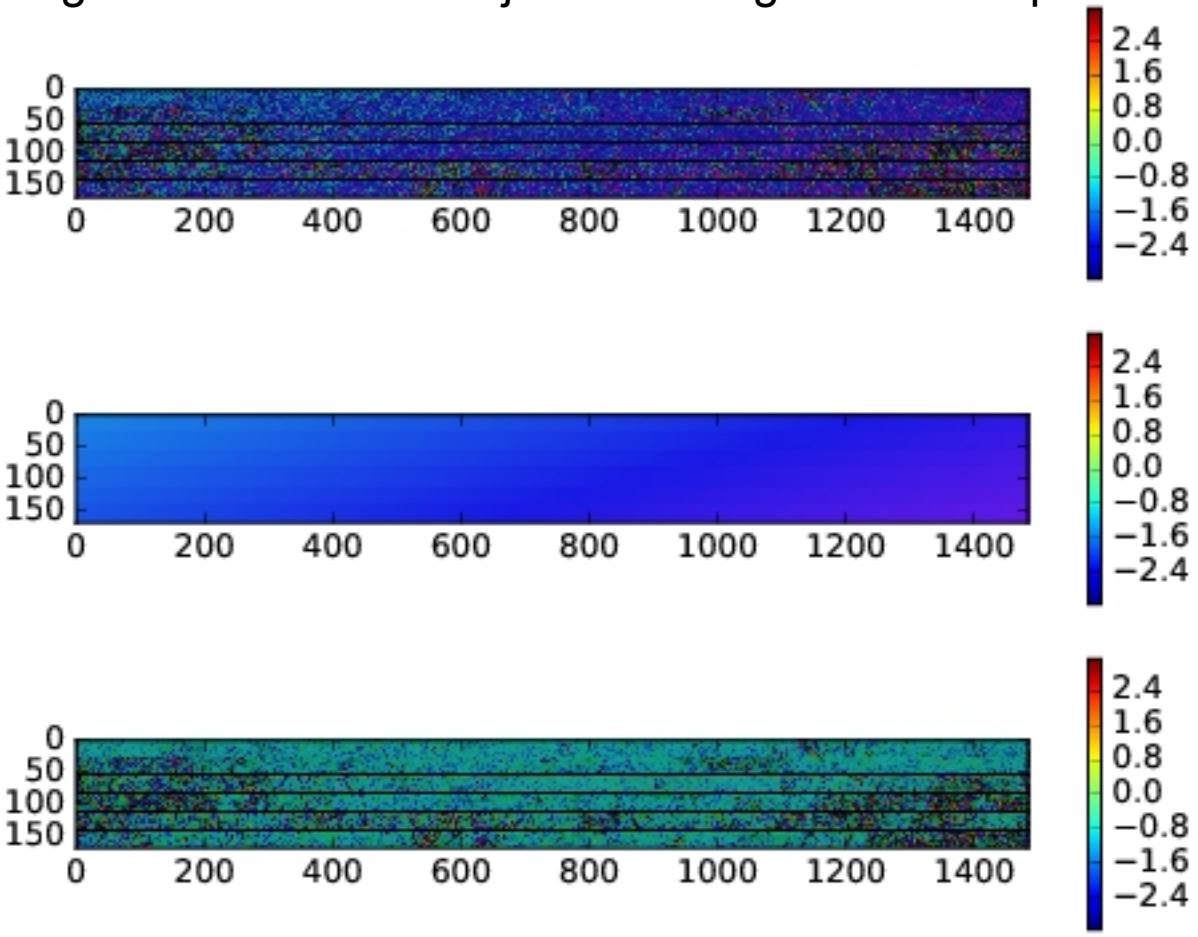
$ /nsbas/MDXmdx.pl INT_sd/int_20160126_20160219/20160126-20160219_ovl_004_xint_4rlks.int

Forward and Backward interferograms in bursts overlap.
Their difference contains the residual mis-registration term between master and slave and has to be estimated for correction of interferograms



The spectral diversity phase is plotted for all overlaps :
$ evince
INT_sd/int_20160126_20160219/20160126_coreg_Overlap_20160219_coreg_Overlap_sdFit.pdf
See all in INT_sd/all_sdFit with gthumb

An affine function of range and azimuth is adjusted through these SD phase measurements.

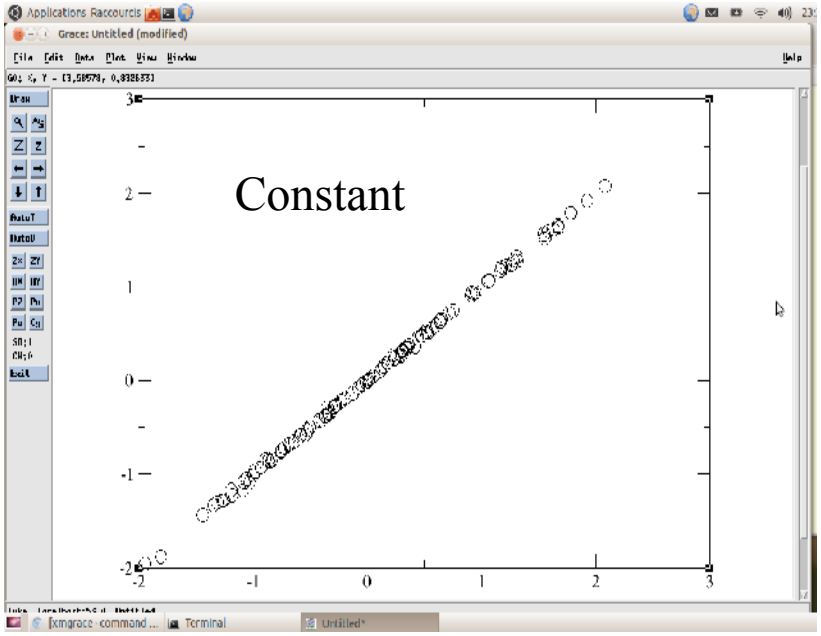


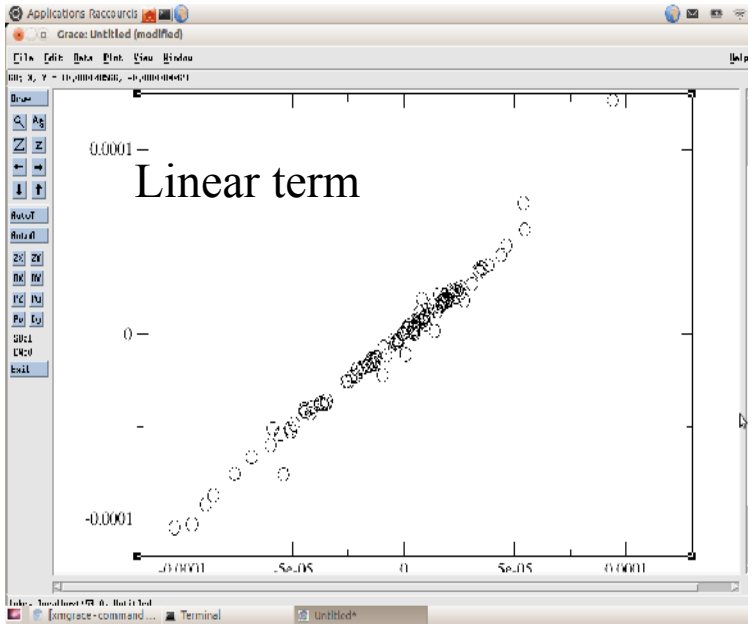
Inversion of spectral diversity affine functions
ΔΦ Fw-Bw = a + by + cz

Quality check after inversion of residual mis-registration ramps
estimated for all interferograms in bursts overlap (small baseline inversion procedure)

```
$ xmgrace -block invers_sd_int/inverted_cst_interf -bxy 3:4
$ xmgrace -block invers_sd_int/inverted_lin_interf -bxy 3:4
$ xmgrace -block invers_sd_int/inverted_quad_interf -bxy 3:4
```

May resolve 2pi error in spectral diversity phase estimation



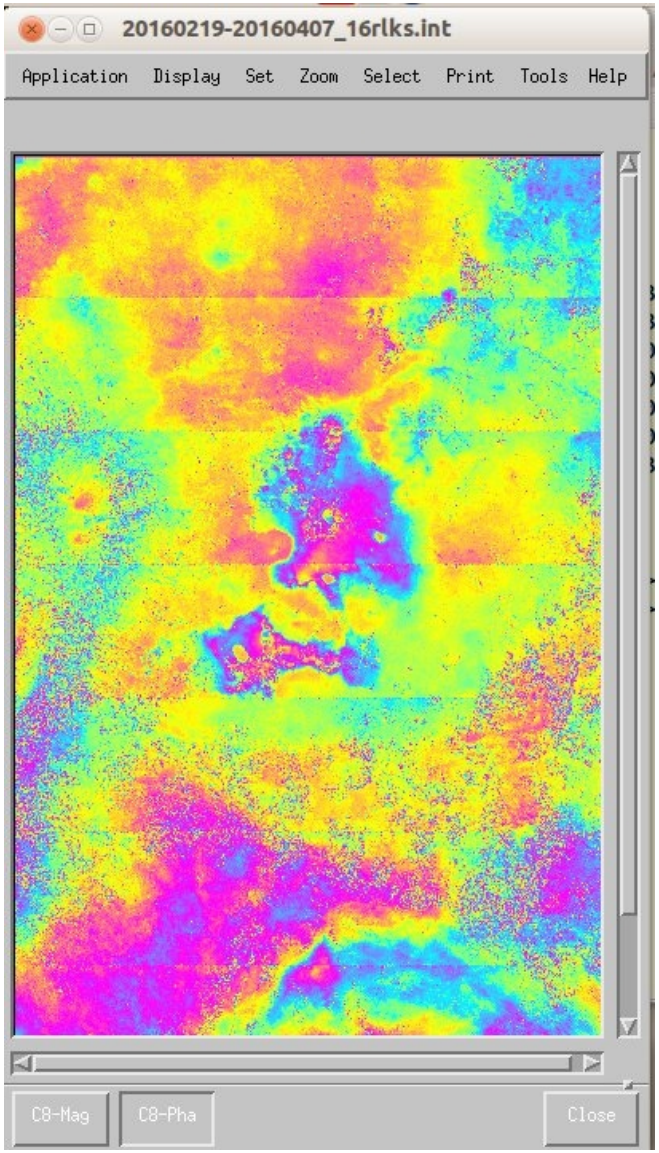


Observed spectral diversity (X-axis) versus Inversed spectral diversity (Y-axis)

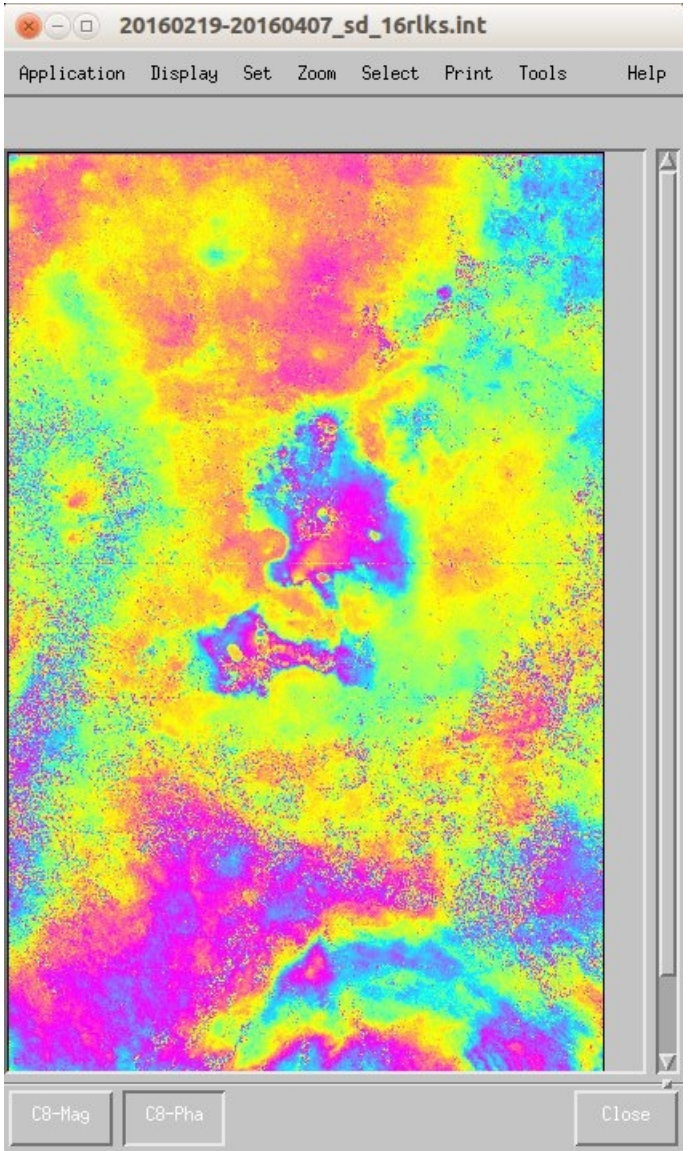
Spectral diversity correction

$ /nsbas/MDX/mdx.pl INT/int_20160219_20160407/20160219-20160407_16rlks.int
$ /nsbas/MDX/mdx.pl INT/int_20160219_20160407/20160219-20160407_sd_16rlks.int

Before correction



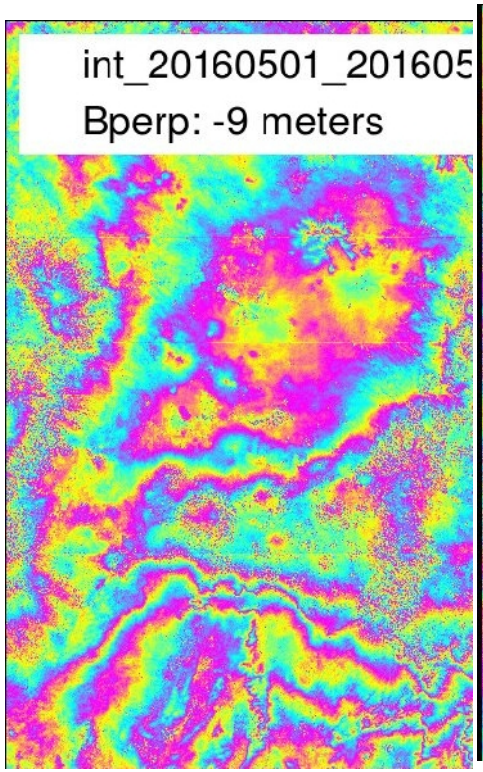
After correction

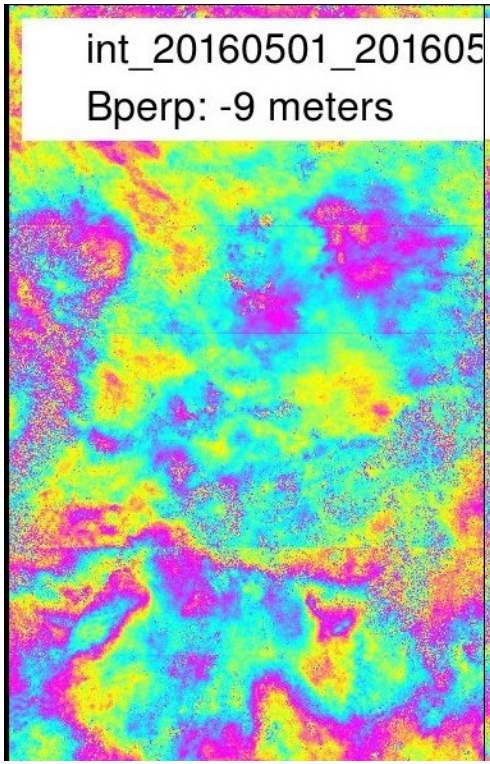


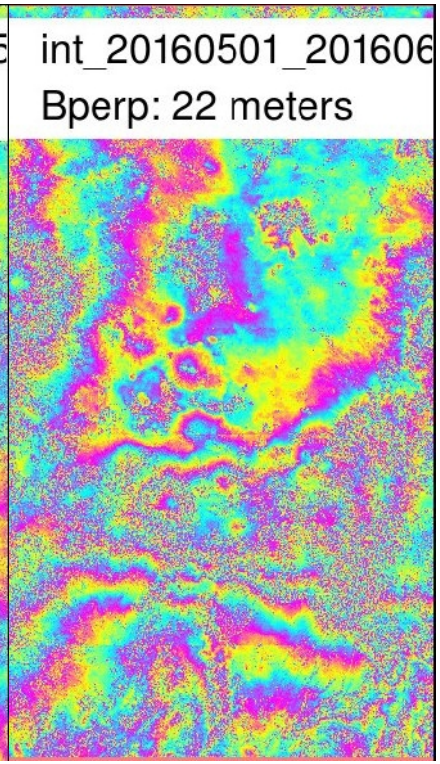
Step 8: Correction of stratified atmospheric delay

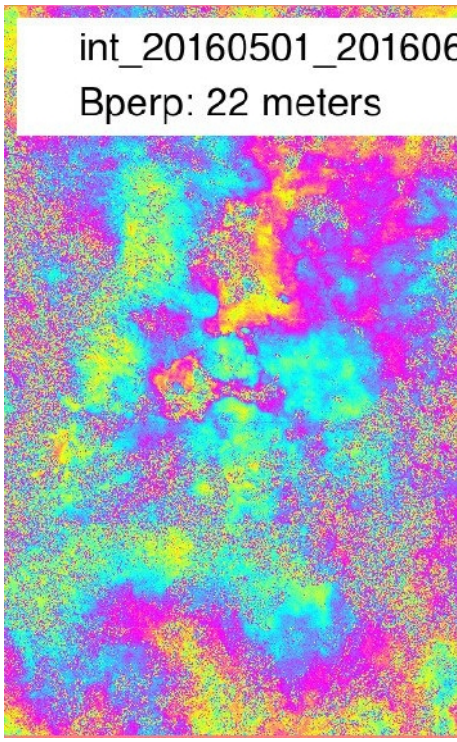
Example of dry delay vertical profile
$ xmgrace ERA/96_348_12h/*del
$ /nsbas/MDX/mdx.pl ERA/20161022_mdel_2rlks.unw

$ gthumb INT/int_JPG/20160501-20160513_sd_16rlks.int.jpg
$ gthumb INT/int_JPG/20160501-20160513_sd_era_16rlks.int.jpg
$ gthumb INT/int_JPG/20160501-20160606_sd_16rlks.int.jpg
$ gthumb INT/int_JPG/20160501-20160606_sd_era_16rlks.int.jpg





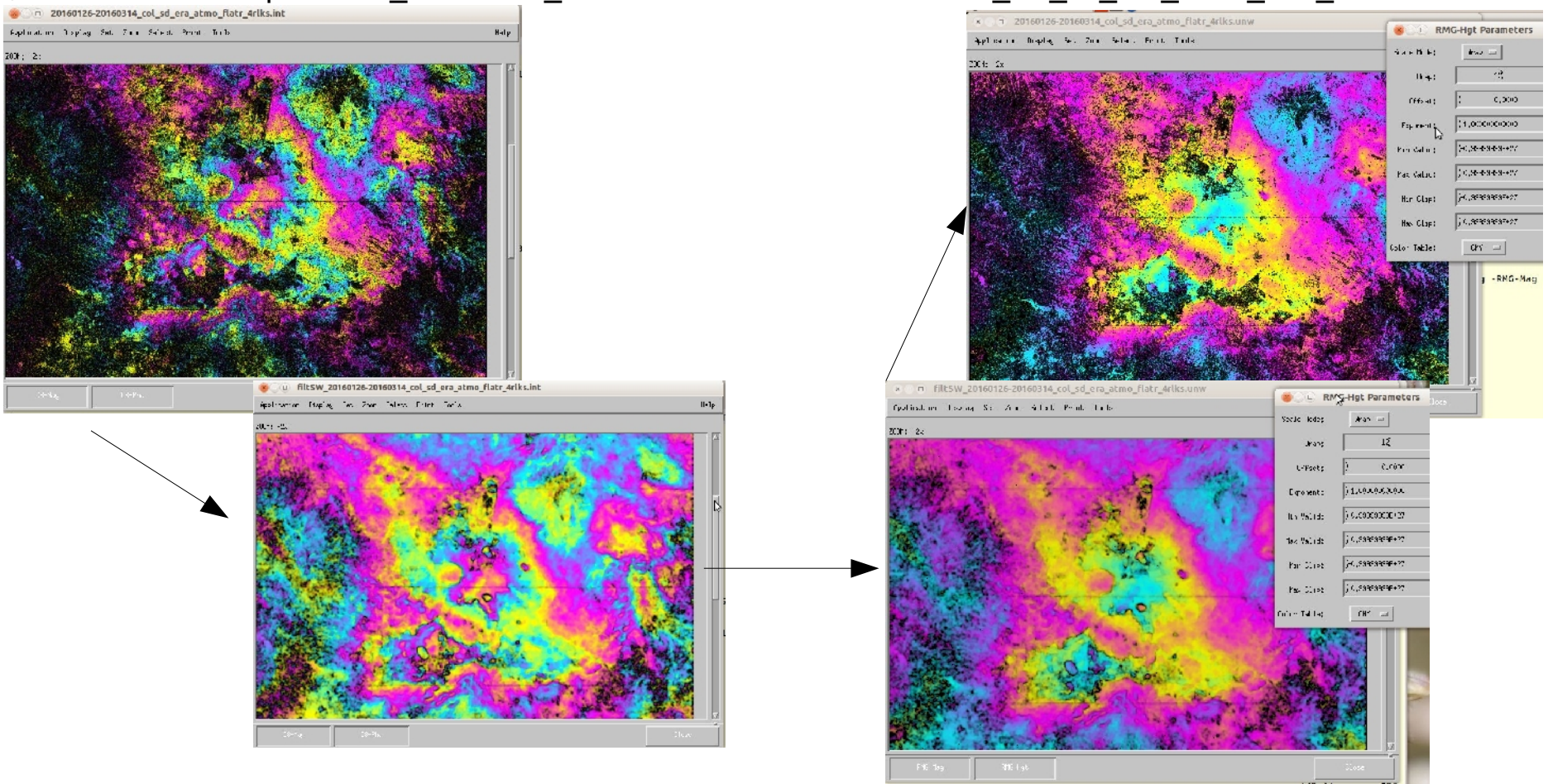




Step 9 : Interferogram filtering and unwraping

Multilooking, filtering
$ cd INT
$ /nsbas/MDX/mdx.pl INT/int_20160126_20160314/20160126-20160314_col_sd_era_atmo_flatr_4rlks.int
$ /nsbas/MDX/mdx.pl INT/int_20160126_20160314/filtSW_20160126-20160314_col_sd_era_atmo_flatr_4rlks.int

Unwrapping
$/nsbas/MDX/mdx.pl INT/int_20160126_20160314/filtSW_20160126-20160314_col_sd_era_atmo_flatr_4rlks.unw
$/nsbas/MDX/mdx.pl INT/int_20160126_20160314/20160126-20160314_col_sd_era_atmo_flatr_4rlks.unw



Step 10 : Geocoding

Interferogramme en géométrie radar:
$ /nsbas/MDX/mdx.pl int_20160501_20160606/geo_20160501-20160606_col_sd_era_atmo_flatr_4rlks.unw

$ googleearth → load
int_20160501_20160606/geo_20160501-20160606_col_sd_era_atmo_flatr_4rlks.unw.jpg.kml