

InSAR Processing

Sentinel 1 data

Case study of subsidence in Mexico city

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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, G; 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**".

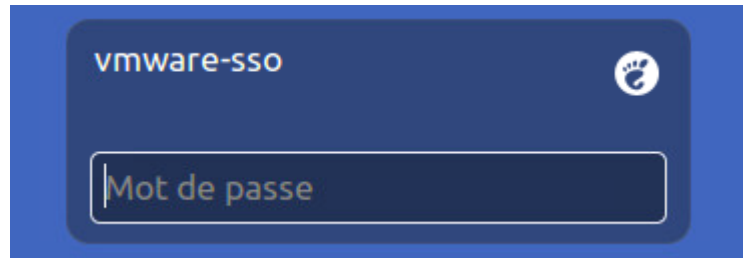
On the new screen "client VMWARE Horizon" click twice on **sciportail.dsi.uca.fr**

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 visualization tool

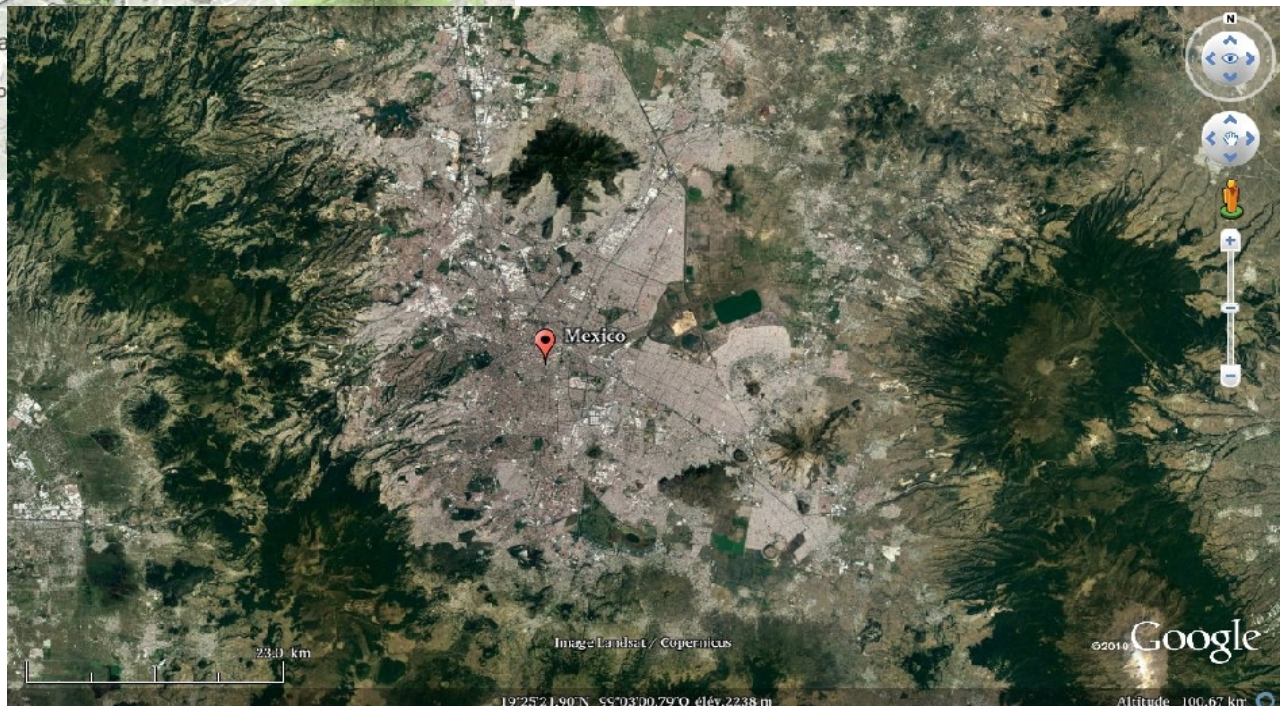
gthumb (to view jpg/png) / evince (to view pdf)



Study site

Topo
+
Landsat

googlemap



Interferograms processing: case 1: etalab

Data : downloaded using the etalab web service

Here descending track

Relative orbit number : 143



ACCUEIL

DONNEES

A PROPOS

AIDE

MON PANIER

SE CONNECTER

S'ENREGISTRER

TRAITEMENTS



Interferograms processing: case 1: etalab

Data : downloaded using the etalab web service

Here descending track

Relative orbit number : 143



Recherches sauvegardées

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S'ENREGISTRER

Collection: S1

Localisation: NORTH-AMERICA

Pays : MEXICO

Date :

2016-04-07T00:25:31.822Z

Sens de l'orbite: descending

Instrument : SAR-C SAR

Plateforme : S1A

Résolution :

polarisation : VV

Taille de l'image :

2.538795033 Go

TRAITEMENTS



Numéro d'orbite: 10715

Niveau de traitement :

LEVEL1

Mode du capteur : IW

Type de produit : SLC

IMAGE MISE DANS
VOTRE PANIER !

Collection : S1

Localisation: NORTH-AMERICA

Pays : MEXICO

Date :

2016-03-31T00:33:36.103Z

Sens de l'orbite: descending

Instrument : SAR-C SAR

Plateforme : S1A

Résolution :

polarisation : VV

Taille de l'image :

2.530584772 Go

Numéro d'orbite : 10613

Niveau de traitement :

LEVEL1

Mode du capteur : IW

Type de produit : SLC

Ajouter au panier

Collection : S1

Localisation: NORTH-AMERICA

Pays : MEXICO

Date :

2016-03-26T00:25:31.048Z

Instrument : SAR-C SAR

Plateforme : S1A

Résolution :

polarisation : VV

Taille de l'image :

Numéro d'orbite : 10540

Niveau de traitement :

LEVEL1

Mode du capteur : IW

Type de produit : SLC

IMAGE MISE DANS
VOTRE PANIER !

Interferograms processing: case 1: etalab

Data : downloaded using the etalab web service

Here descending track

Relative orbit number : 143



Mon Panier

ACCUEIL

DONNEES

A PROPOS

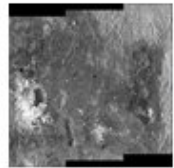
AIDE

MON PANIER

SE CONNECTER

S'ENREGISTRER

TRAITEMENTS ▾



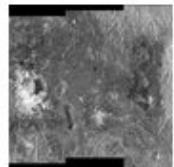
1

COLLECTION: S1
LOCALISATION: MEXICO
DATE :
2016-03-26T00:25:31.822Z
TAILLE DE L'IMAGE
: 2.173920388 Go

Calcul MNT
Description de la chaine NSBAS
ACCES CHAINE NSBAS

INSTRUMENT: SAR-CSAR
NUMERO D'ORBITE :
10540
NIVEAU DE TRAITEMENT :
LEVEL1
MODE DU CAPTEUR :
IW
TYPE DE PRODUIT :
SLC

Retirer du panier



2

COLLECTION: S1
LOCALISATION: Mexico
DATE :
2016-04-07T00:25:31.822Z
TAILLE DE L'IMAGE
: 2.538795033 Go

INSTRUMENT: SAR-C SAR
PLATEFORME: S1A
RESOLUTION : null

NUMERO D'ORBITE :
10715
NIVEAU DE TRAITEMENT :
LEVEL1
MODE DU CAPTEUR :
IW
TYPE DE PRODUIT :
SLC

Retirer du panier

Interferograms processing: case 1: etalab

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



The screenshot shows the ForMater website interface. At the top, there is a navigation bar with the following links: ACCUEIL, DONNEES, A PROPOS, AIDE, MON PANIER (with a shopping cart icon), SE CONNECTER, and S'ENREGISTRER. Below this, there is a search bar with the text TRAITEMENTS and a magnifying glass icon. The main heading is "CALCUL DE L'INTERFEROGRAMME". Below the heading, there are three input fields: "Produits sélectionnés dans le panier:" with the value "b61d0a68-65fb-58e4-8ae3-32d365c6880e;34d35fc", "Jeton:" with the value "f0319571-bfa4-41d5-b471-3e4d352013d9", and "Fauchée:" with the value "1". Below these fields is a large button labeled "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”

ForM@Ter

ACCUEIL DONNEES A PROPOS AIDE MON PANIER SE CONNECTER S'ENREGISTRER TRAITEMENTS

CALCUL DE L'INTERFEROGRAMME

Produits sélectionnés dans le panier:

Jeton:

Fauchée:

Lancer le calcul

Télécharger le résultat

Info

```
{
  "StatusInfo": {
    "JobID": 3607988,
    "Progress": 50,
    "Retcode": "0",
    "Status": "Terminated",
    "processToken": "f0319571-bfa4-41d5-b471-3e4d352013d9"
  }
}
```

Dlnd Sar img (-) Dlnd Dem (- 10 mn) mk work dir (5 sec) build list interf (- 3h) compute interf (- 3h) stmo corr (- 3h) unwrap (sh) geocode (Xmn)

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

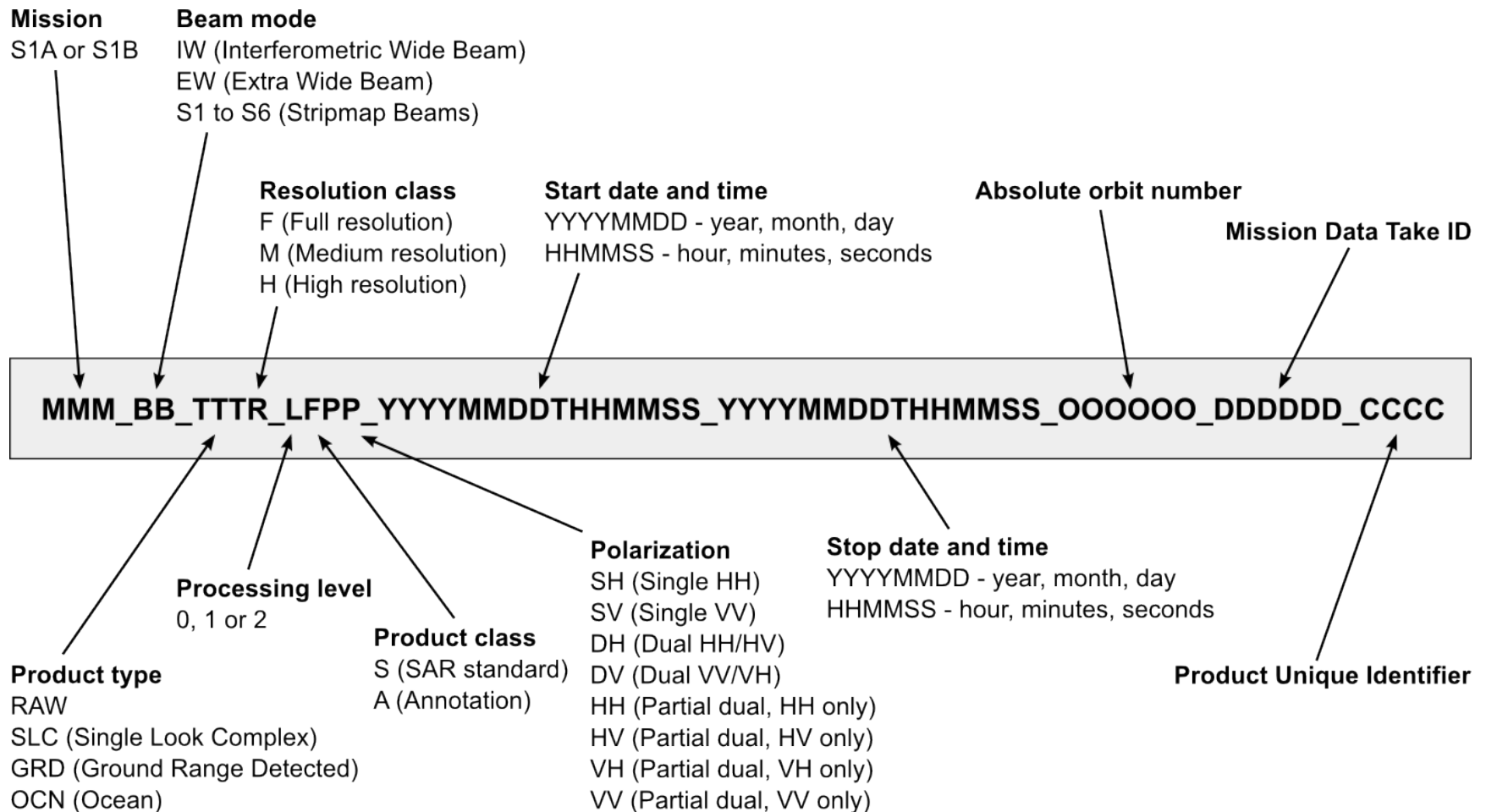
ls /nsbas/MEXICO/RAW

ls /nsbas/MEXICO/RAW/*SAFE :

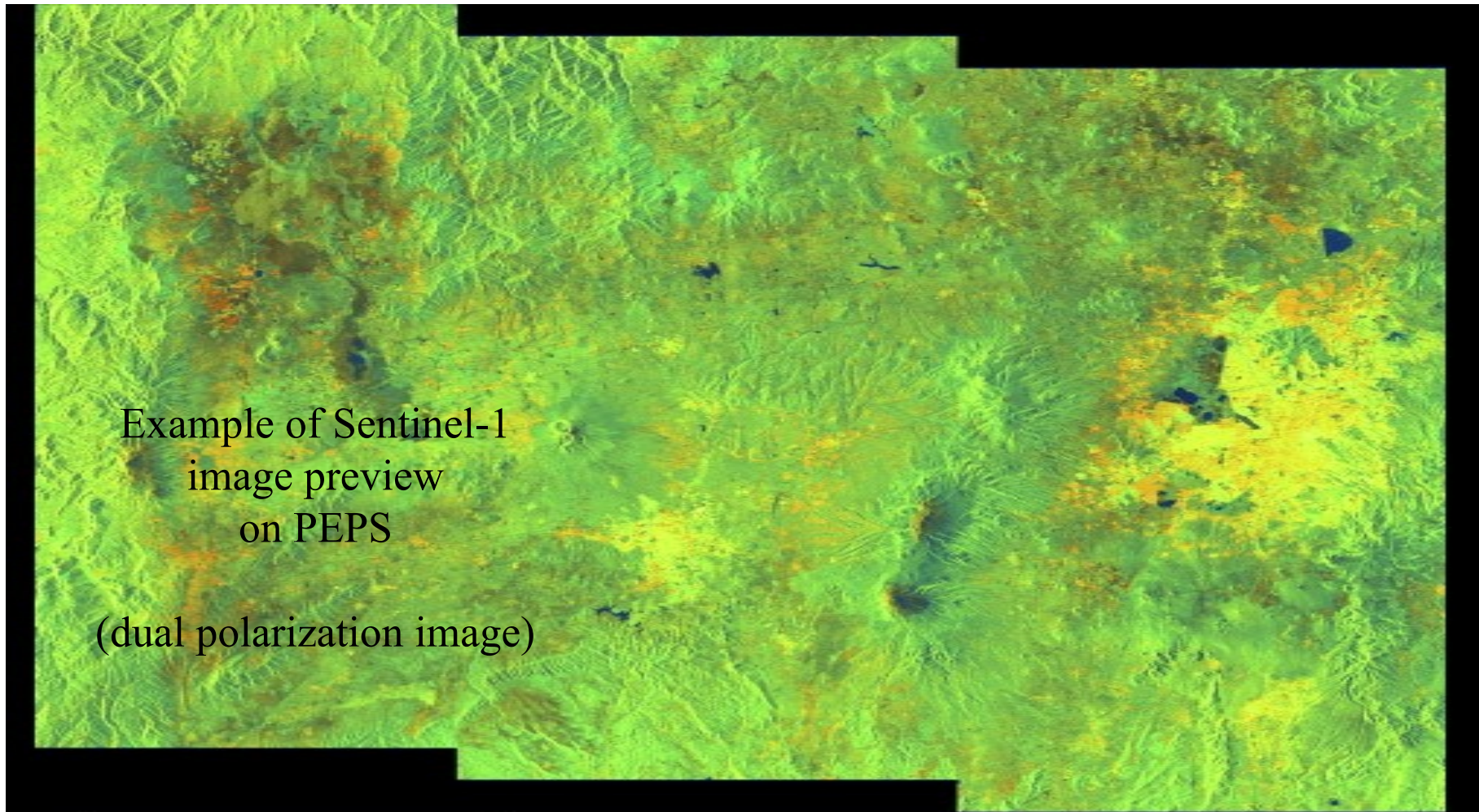
manifest.safe: general information

annotation: xml description of data

measurement : data on iw1/iw2/iw3



Data download from PEPS

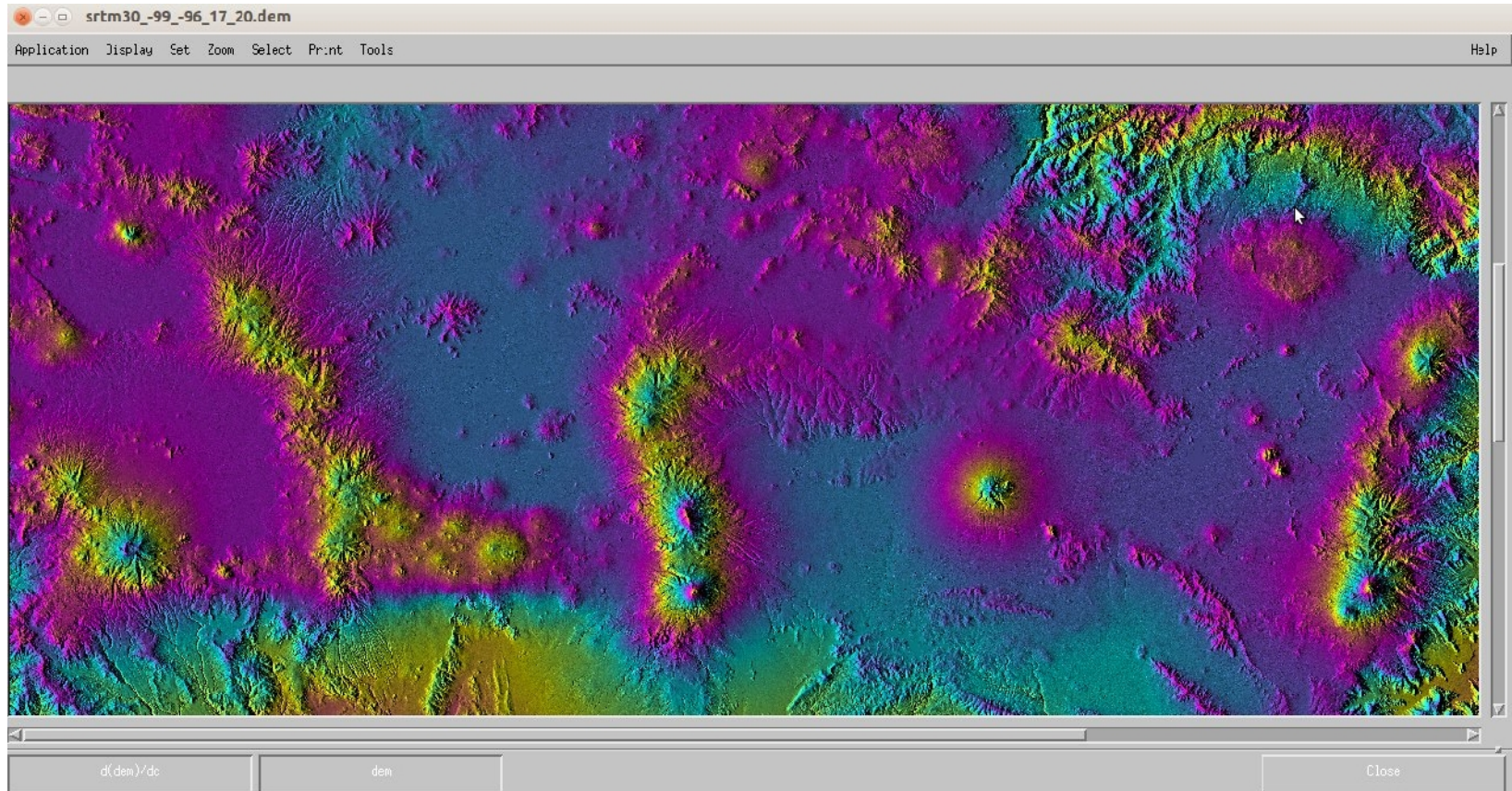


```
$ gthumb /nsbas/MEXICO/RAW/*SAFE/preview/quick-look.png  
here we choose iw3
```

Other preliminary step : DEM download

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

Geoid EGM96 added



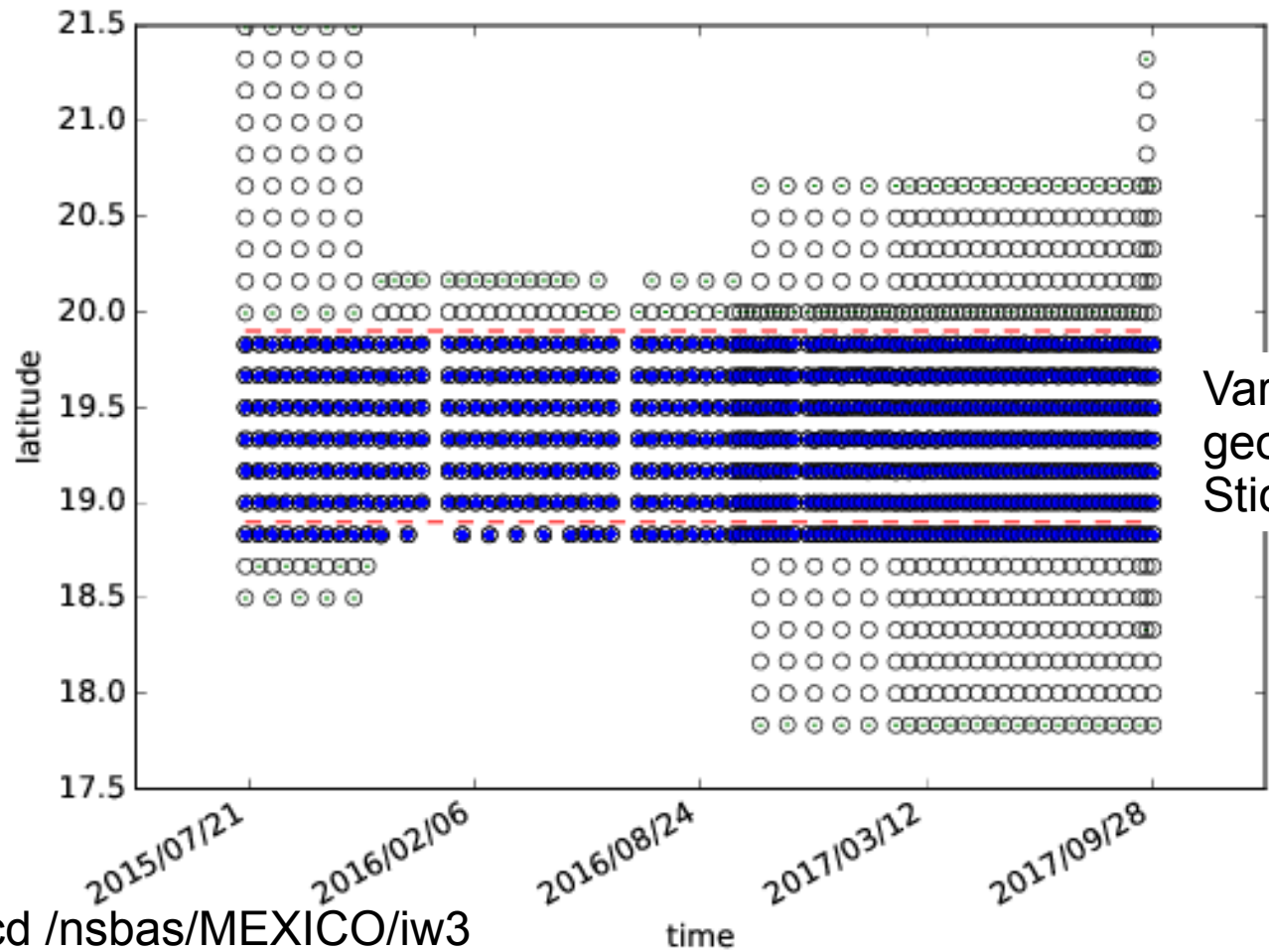
```
$ /nsbas/MDX/mdx.pl /nsbas/MEXICO/DEM/srtm30_-99_-96_17_20.dem -z -8 -wrap 200
```

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
```

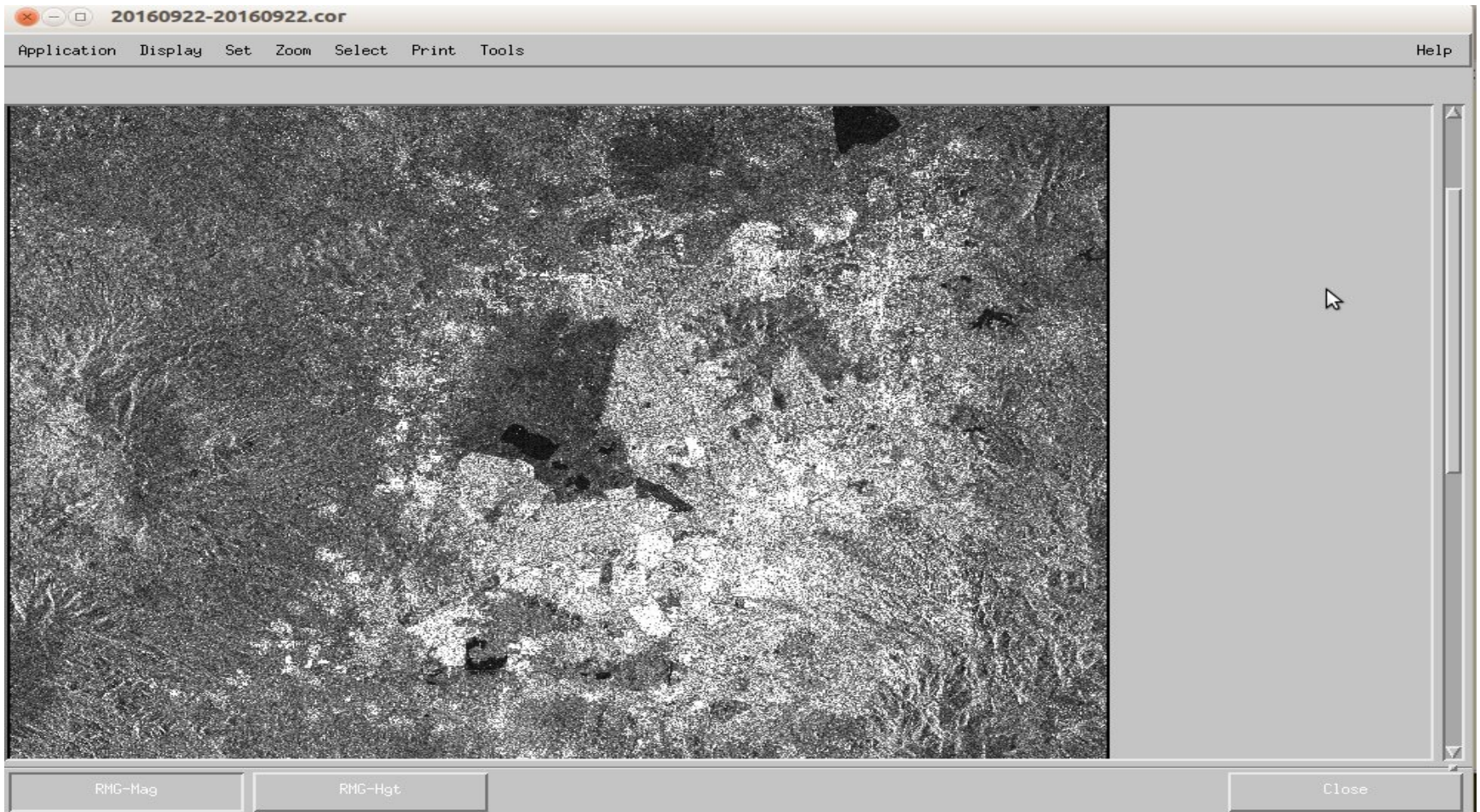
Here, we select bursts between 18.8 and 19.8, and acquisitions complete for these bursts.

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

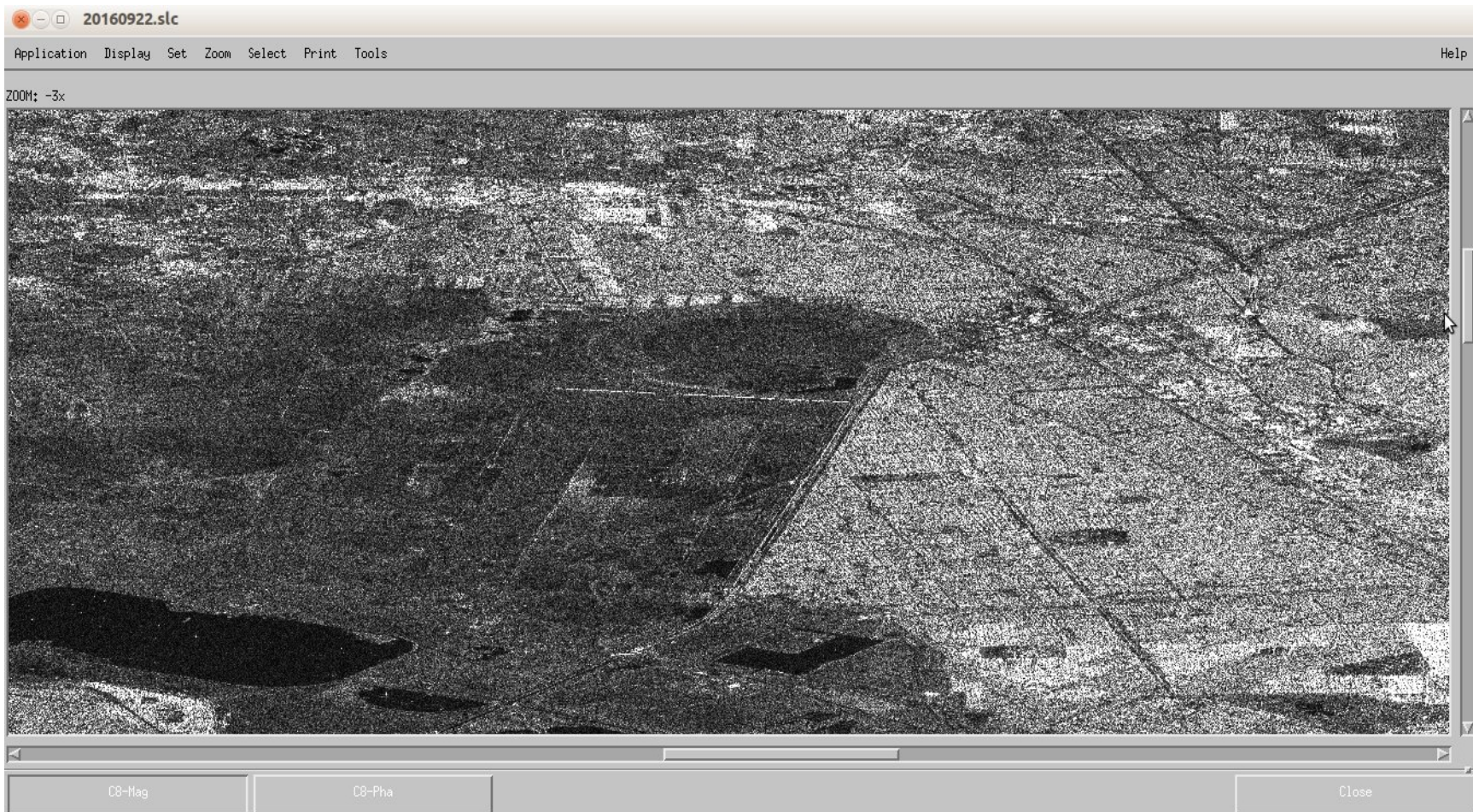



```
$ /nsbas/MDX/mdx.pl 20160922/20160922.slc -z -8
```

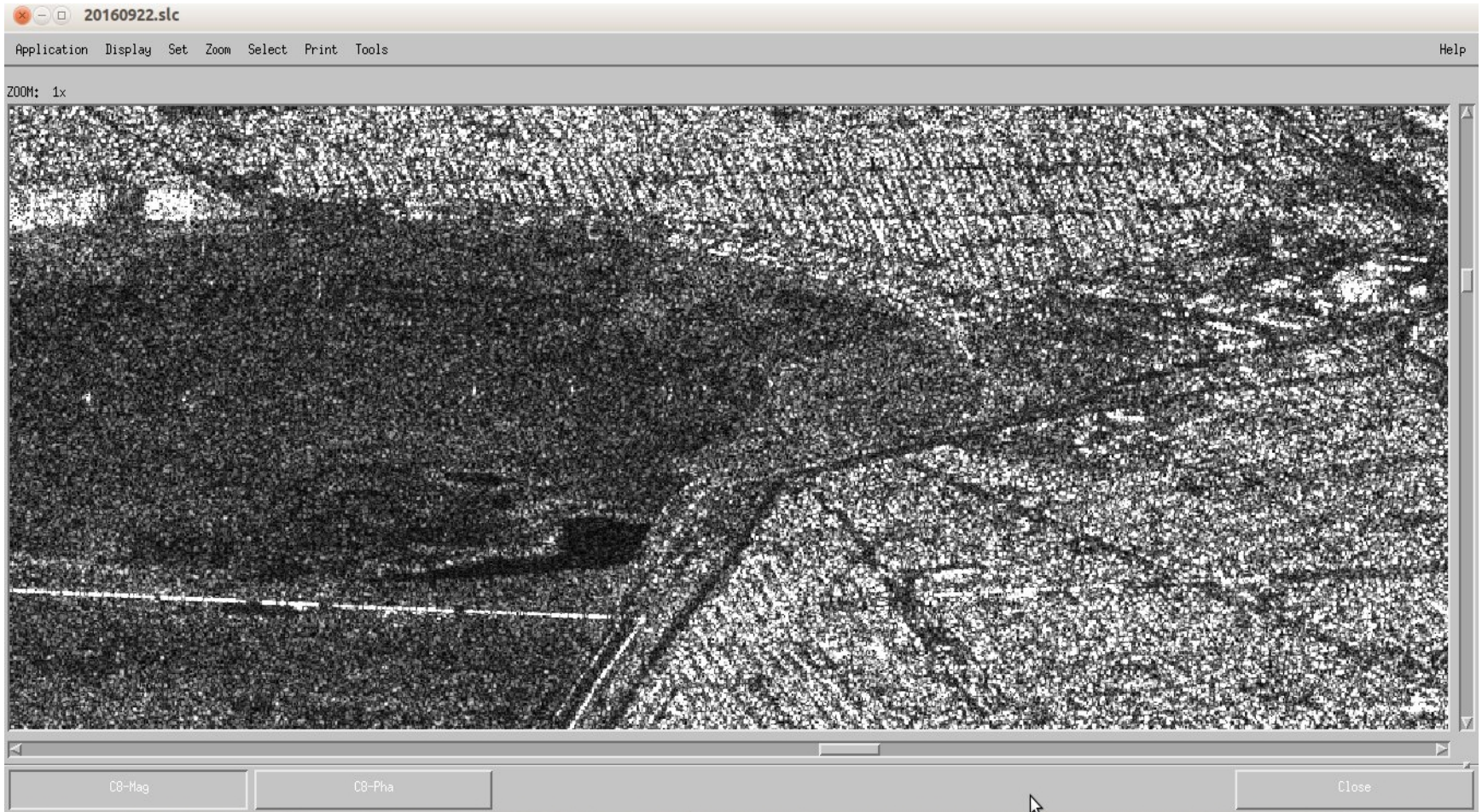
Zoom in /out

You can compare with googleearth /googlemap, see target response to illuminating radar waves in streets or on vegetation

Zoom 1 (Master)



Zoom 2 (Master)

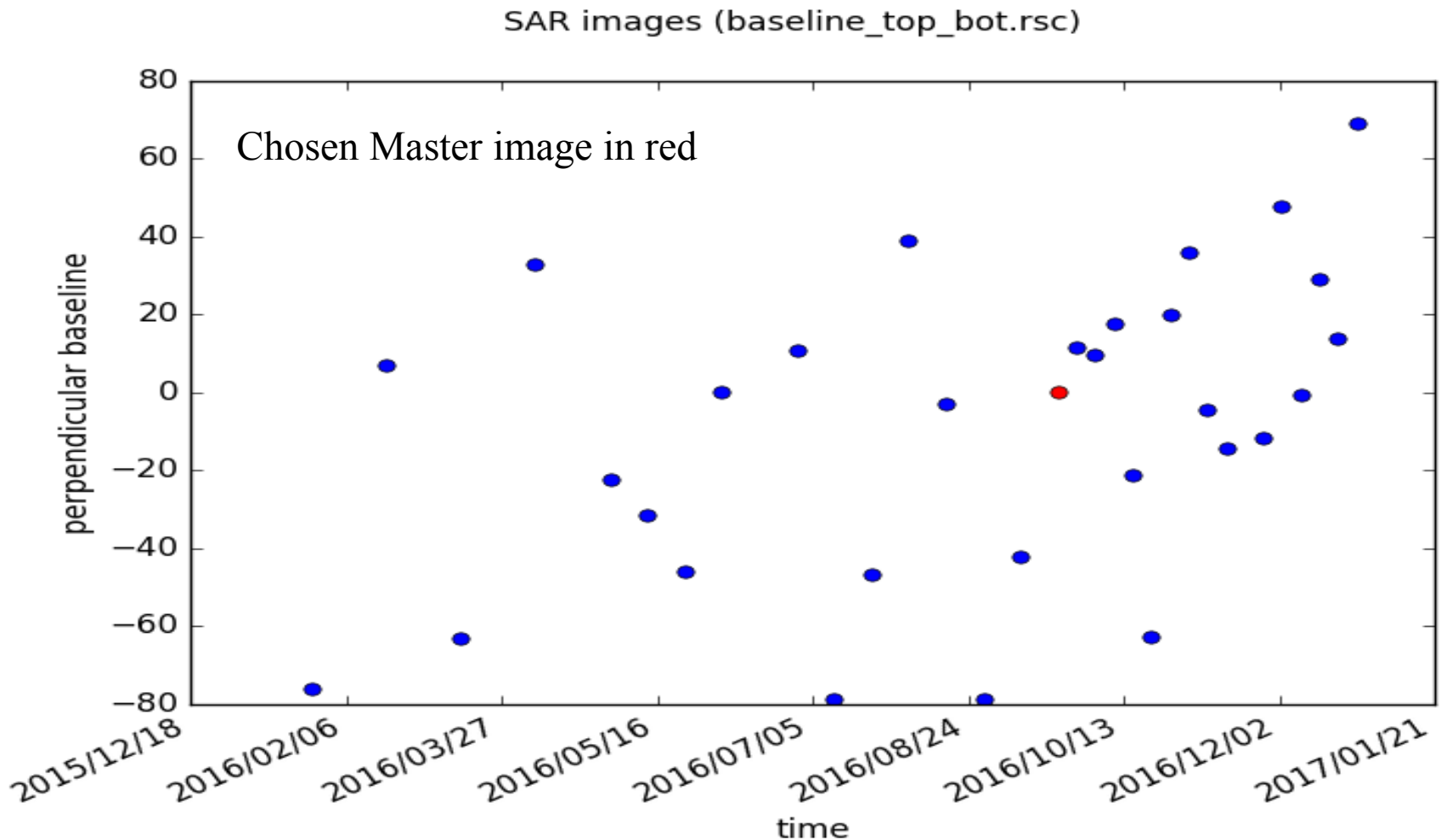


Step 3: compute perpendicular baseline

Small orbital tube + large bandwidth: little geometrical decorrelation, and little sensitivity to topography

```
$ gthumb plot_baseline_top_bot.png
```

```
$ gedit baseline.rsc
```

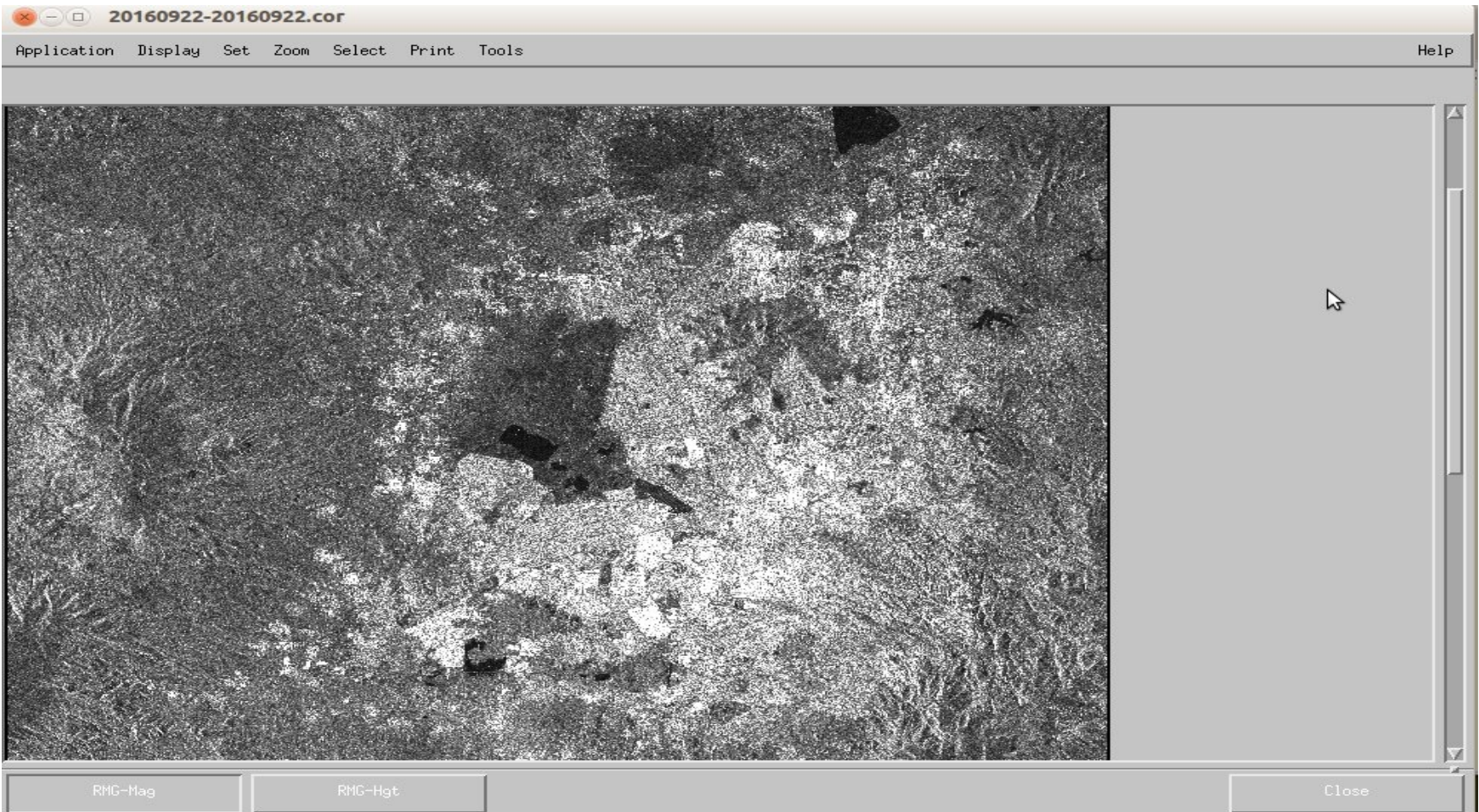


Step 4: DEM simulation in Master data radar geometry

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
```

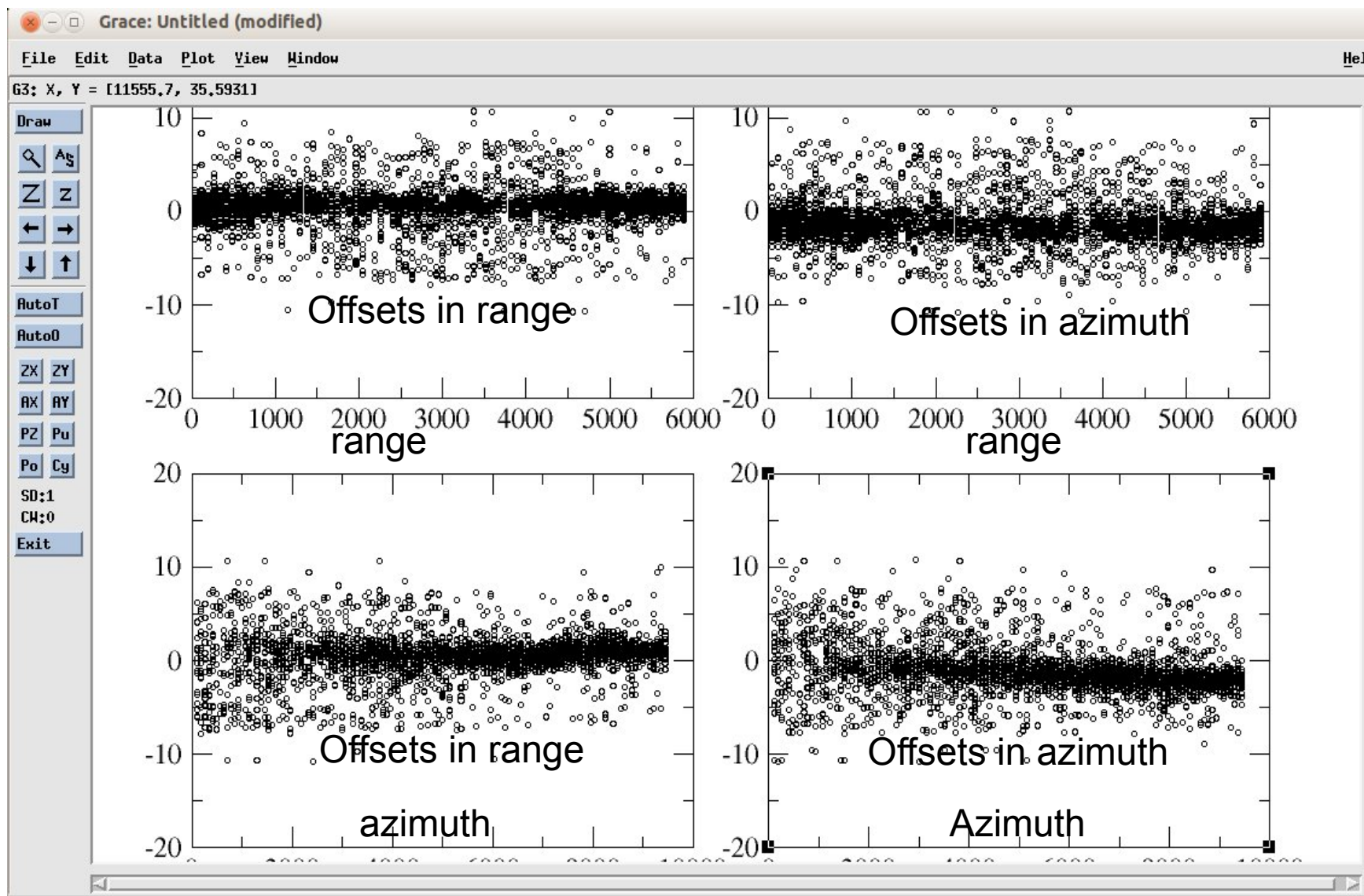
```
$ /nsbas/MDX/mdx.pl 20160922-20160922.cor -z -8
```



Simulation-Master coregistration

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

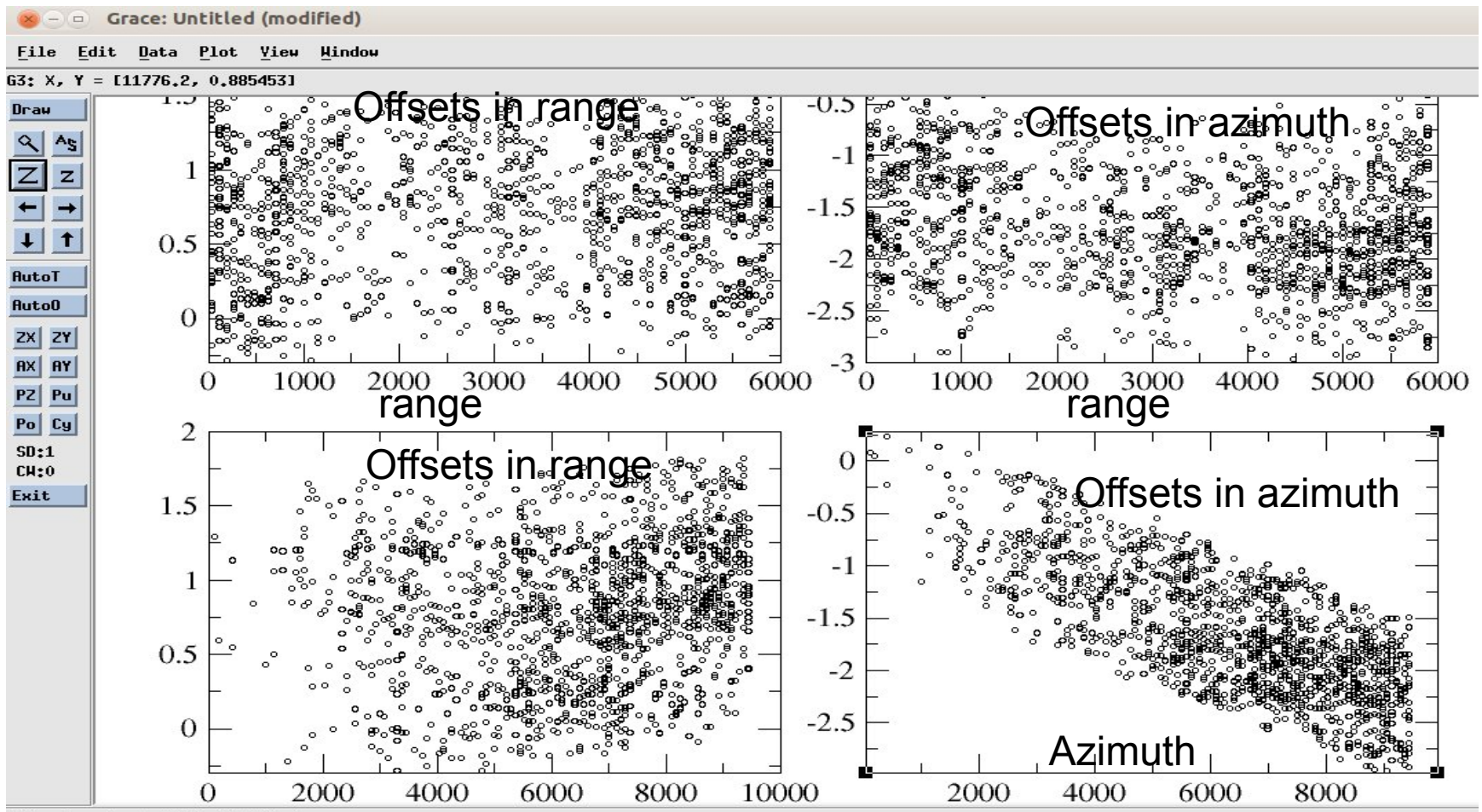
```
$ /nsbas/MDX/PlotOffset.pl 20160922/ampmag.off
```



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

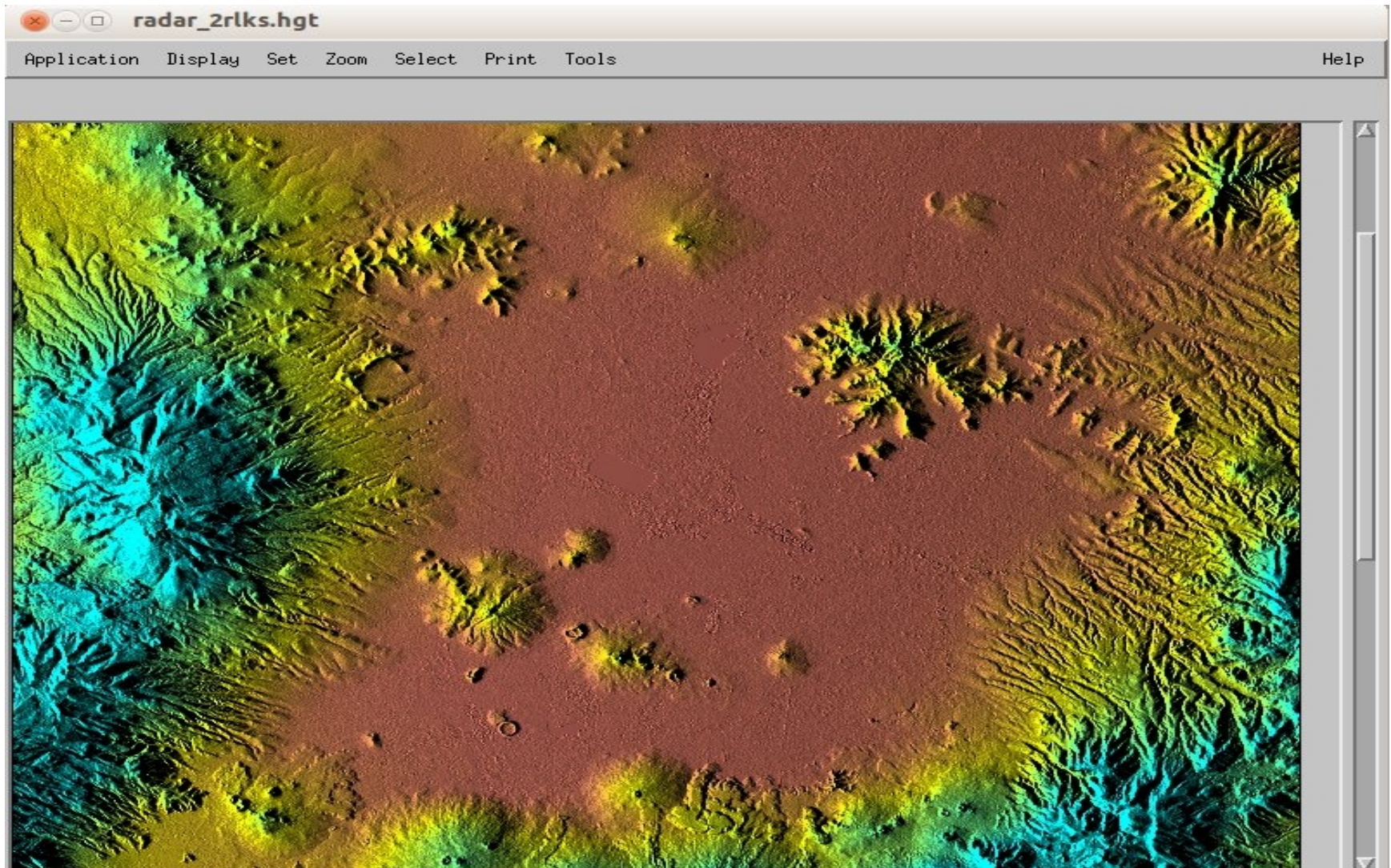
      1.0000146      0.9997936

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

DEM simulation in Master data radar geometry

Final DEM in radar geometry

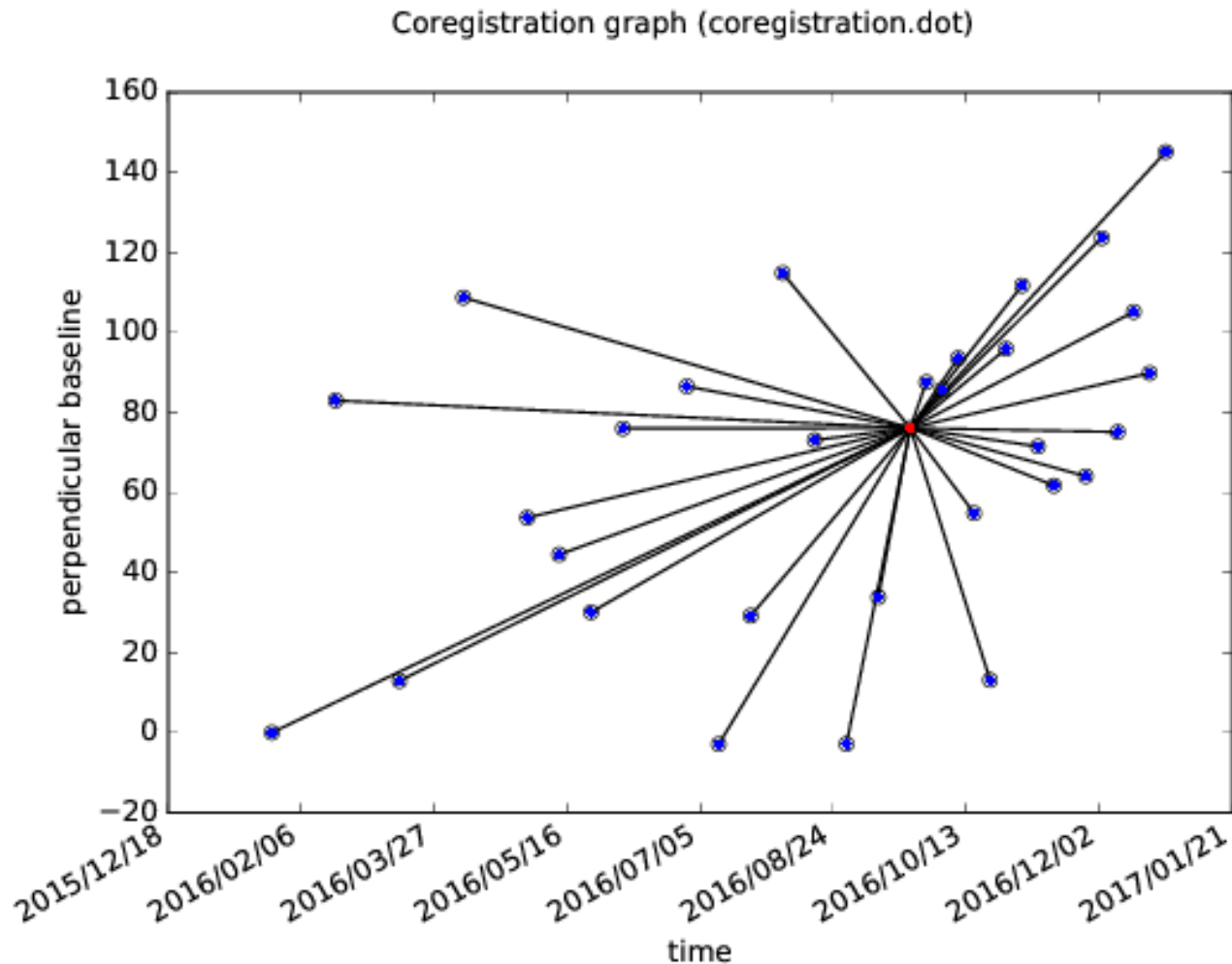
```
$ /nsbas/MDX/mdx.pl 20160922/radar_2rlks.hgt -z -4
```



Step 5: Coregistration slaves to master

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

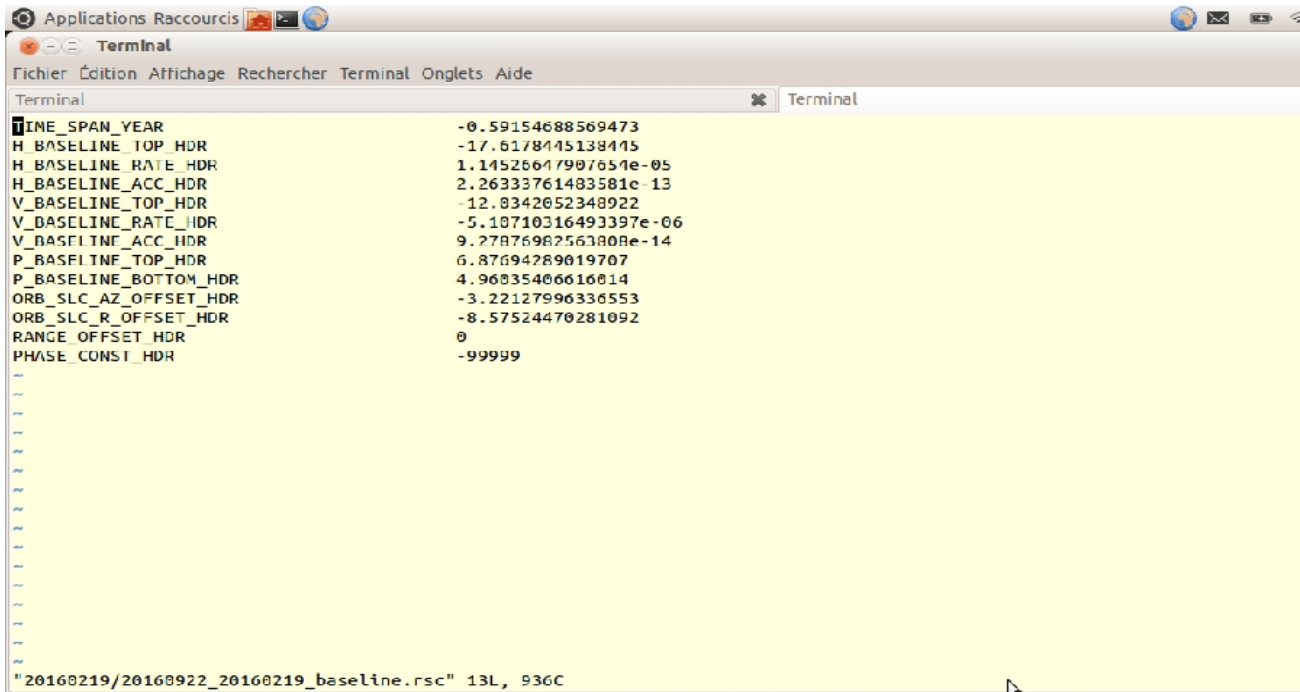
\$ evince plot_coregistration.pdf



Baseline information for one selected pair of images

To view a priori offset file :

```
$ gedit 20160219/20160922_20160219_baseline.rsc
```



The image shows a terminal window titled "Terminal" with a menu bar containing "Fichier", "Édition", "Affichage", "Rechercher", "Terminal", "Onglets", and "Aide". The terminal displays the contents of the file "20160219/20160922_20160219_baseline.rsc". The output is a list of parameters and their values, with some values in scientific notation. The parameters listed are:

LINE_SPAN_YEAR	-0.59154688569473
H_BASELINE_TOP_HDR	-17.6178445138445
H_BASELINE_RATE_HDR	1.14526647907654e-05
H_BASELINE_ACC_HDR	2.26333761483581e-13
V_BASELINE_TOP_HDR	-12.8342652348922
V_BASELINE_RATE_HDR	-5.10710316493397e-06
V_BASELINE_ACC_HDR	9.27876962563808e-14
P_BASELINE_TOP_HDR	6.87694289019707
P_BASELINE_BOTTOM_HDR	4.96035406616014
ORB_SLC_AZ_OFFSET_HDR	-3.22127996336553
ORB_SLC_R_OFFSET_HDR	-8.57524470281092
RANGE_OFFSET_HDR	0
PHASE_CONST_HDR	-99999

Below the list, there are several tilde (~) characters. At the bottom of the terminal, the status bar shows: "20160219/20160922_20160219_baseline.rsc" 13L, 936C.

Slave-Master coregistration

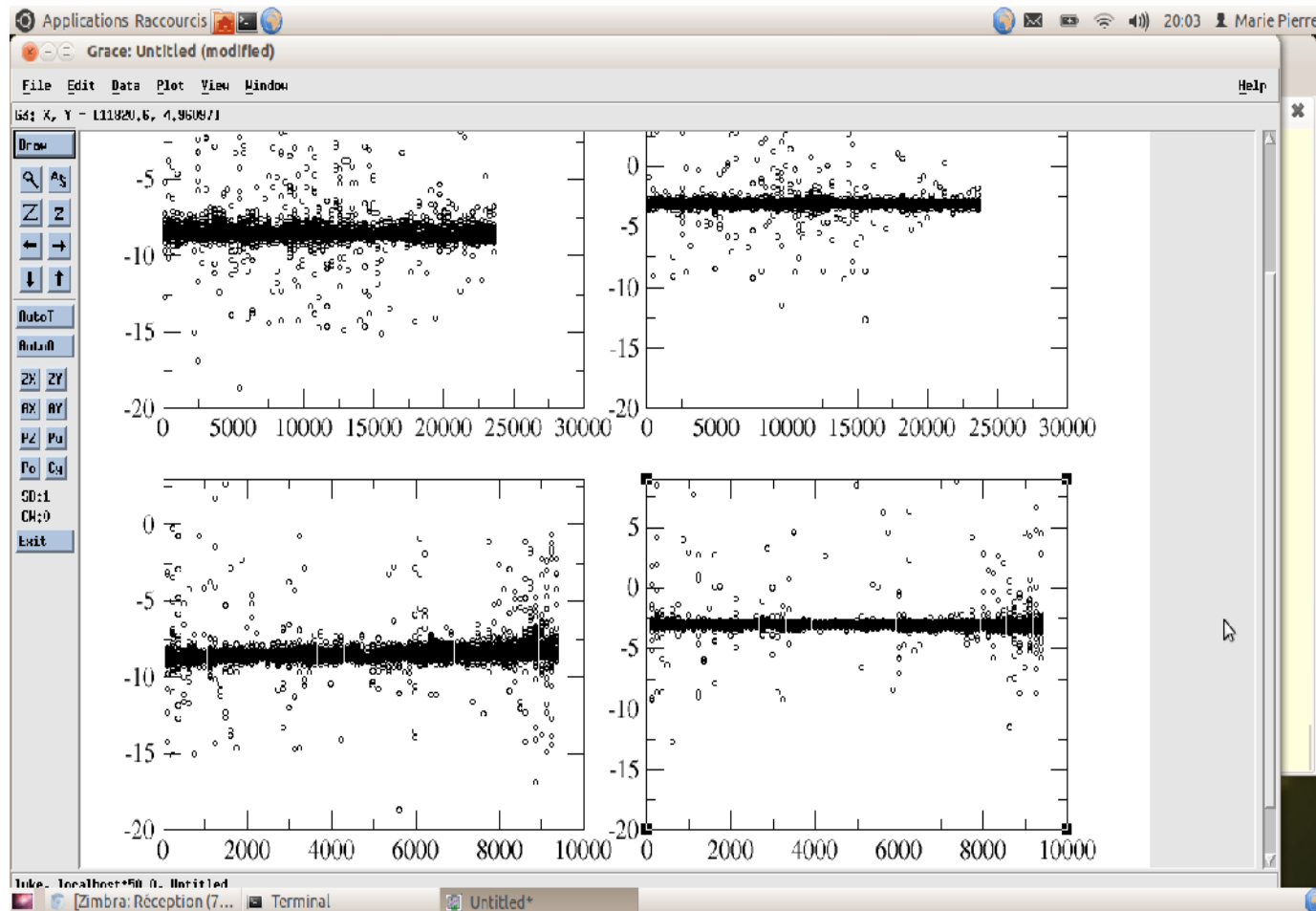
To plot estimated offset between slave and master:

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

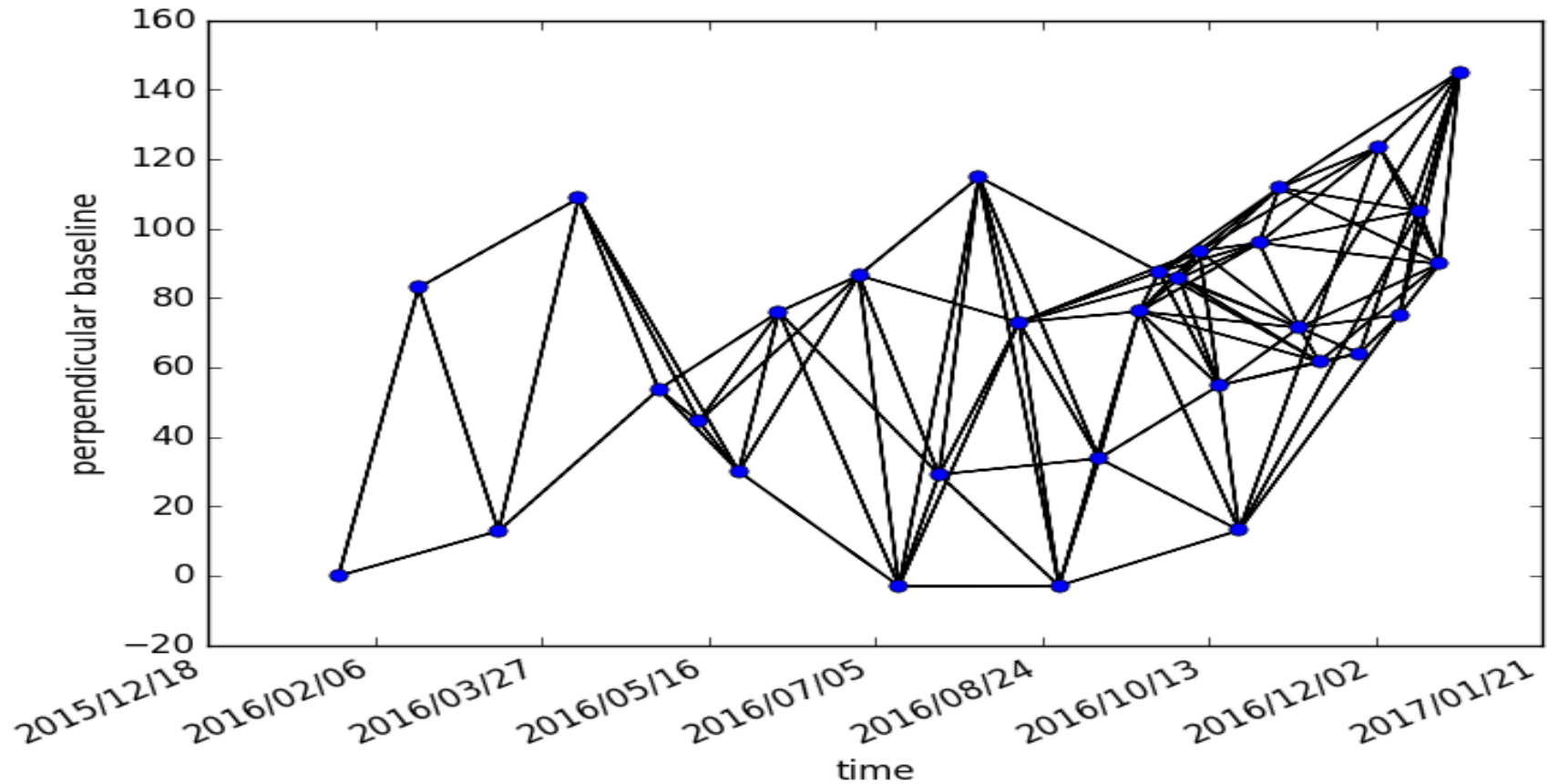


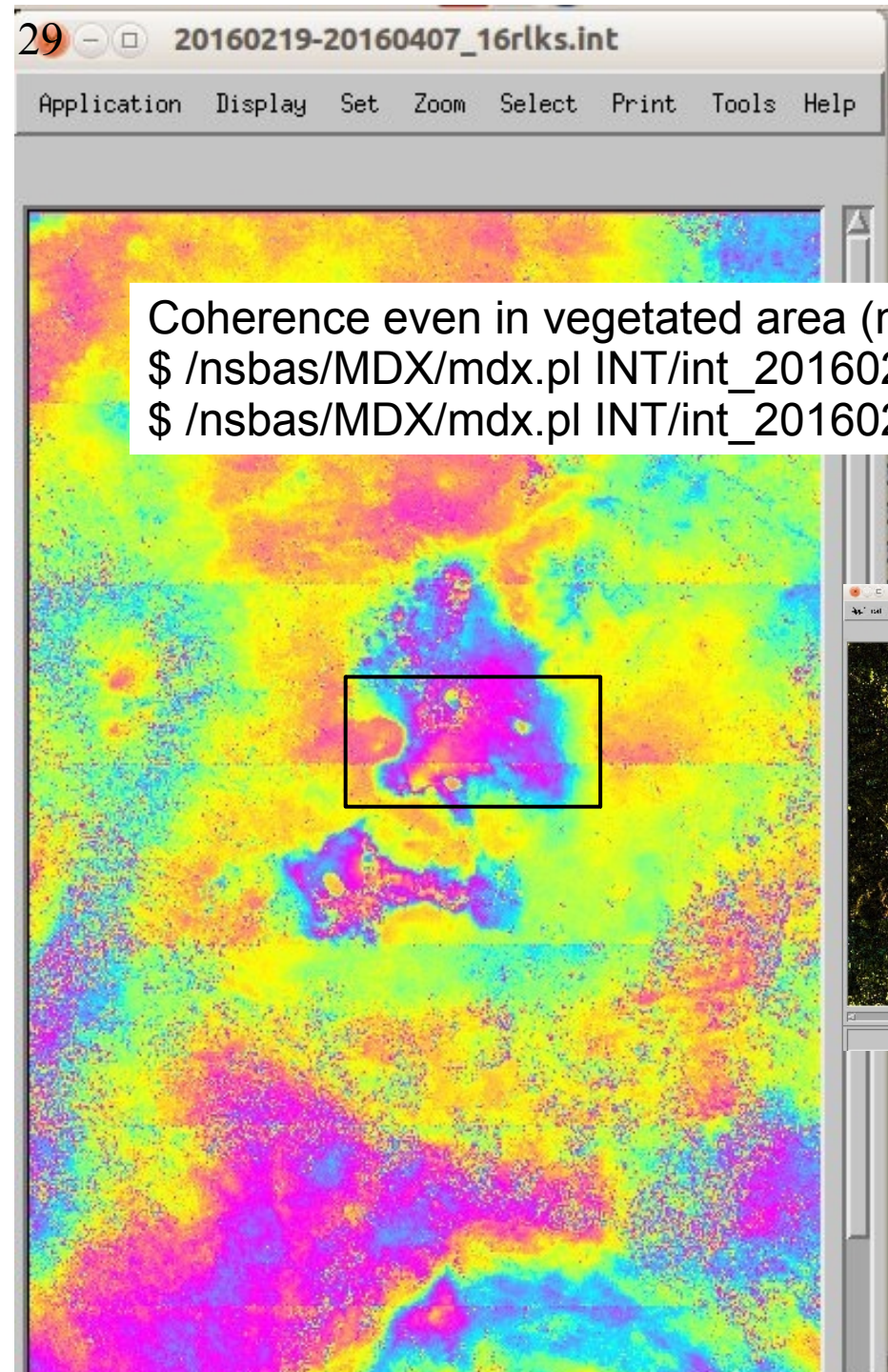
Step 6: Interferogram computation

Interferograms for temporal baseline < 0.16 years : preserve coherence

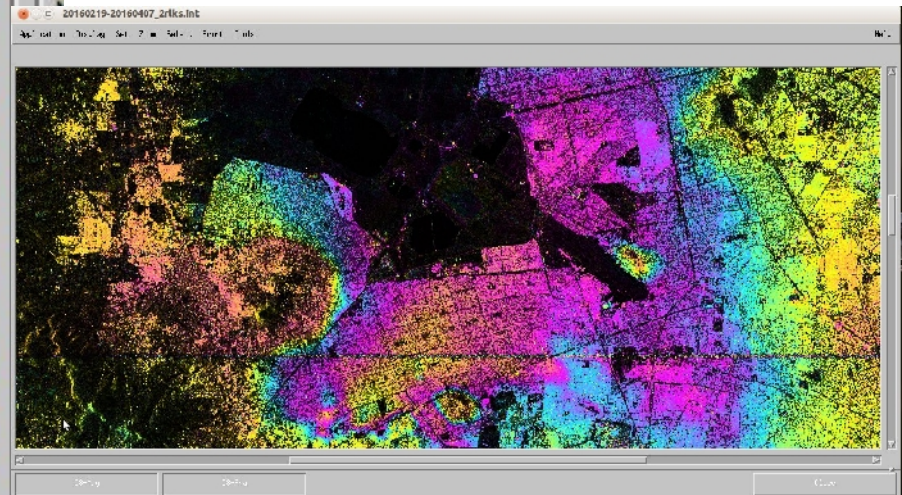
\$ gthumb plot_interferograms.png

Interferogram network





Interferogram computation



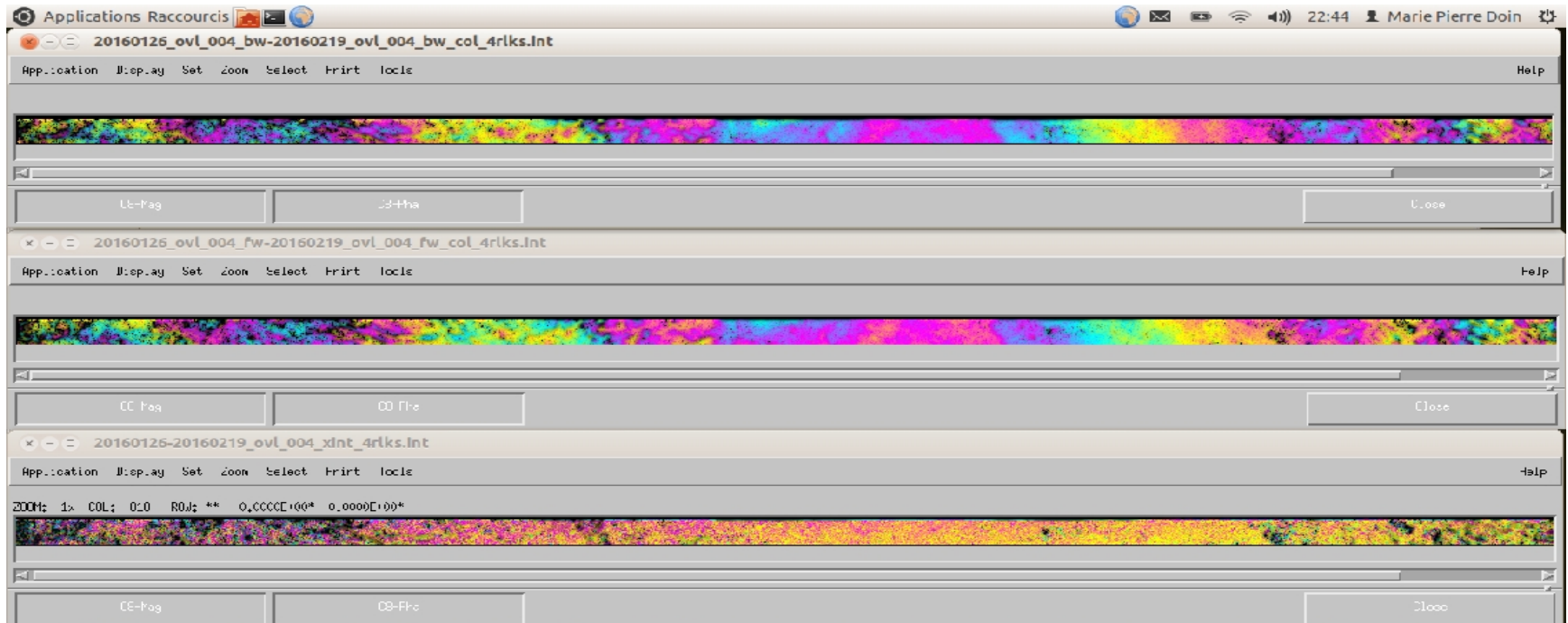
Step 7: Spectral diversity correction step

```
$ /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.in
```

```
$ /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



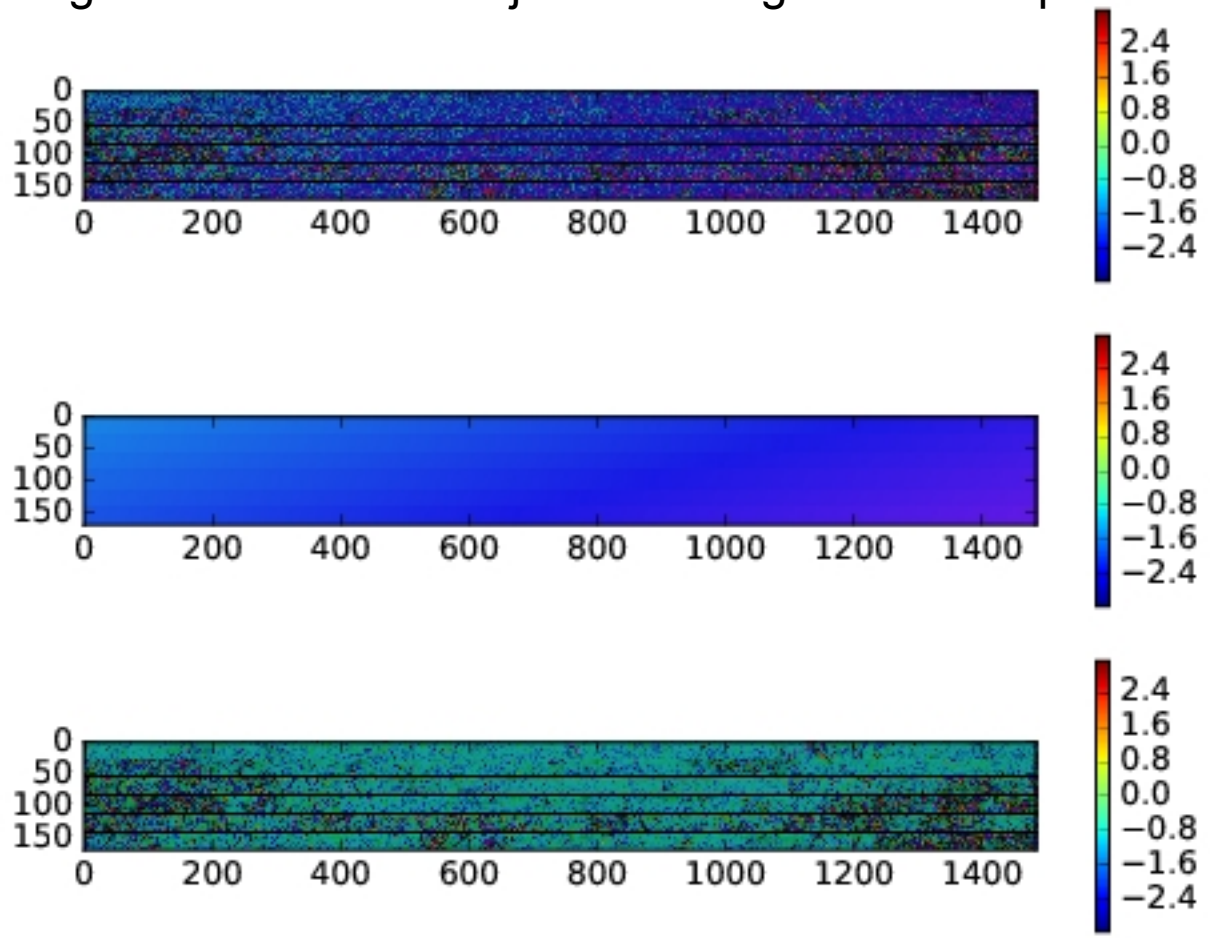
The spectral diversity phase is plotted for all overlaps :

\$ 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

$$\Delta\Phi Fw-Bw = a + by + cz$$

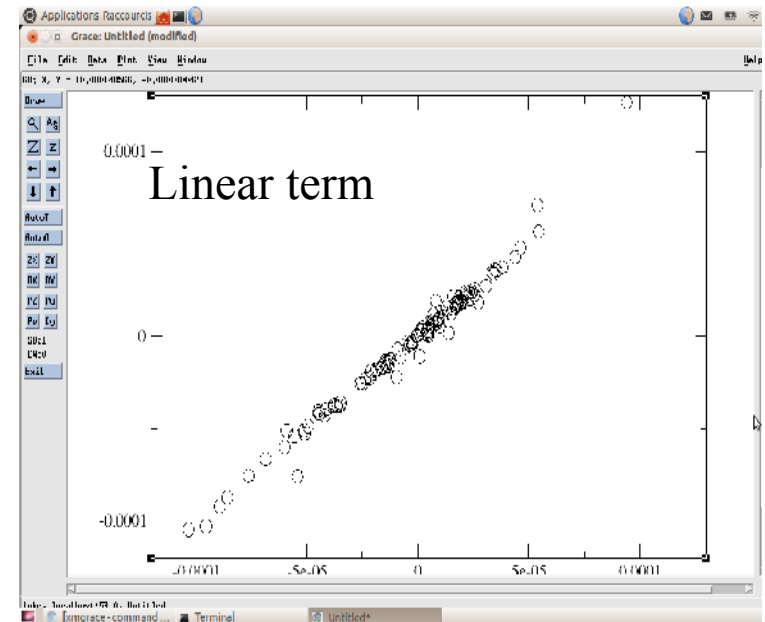
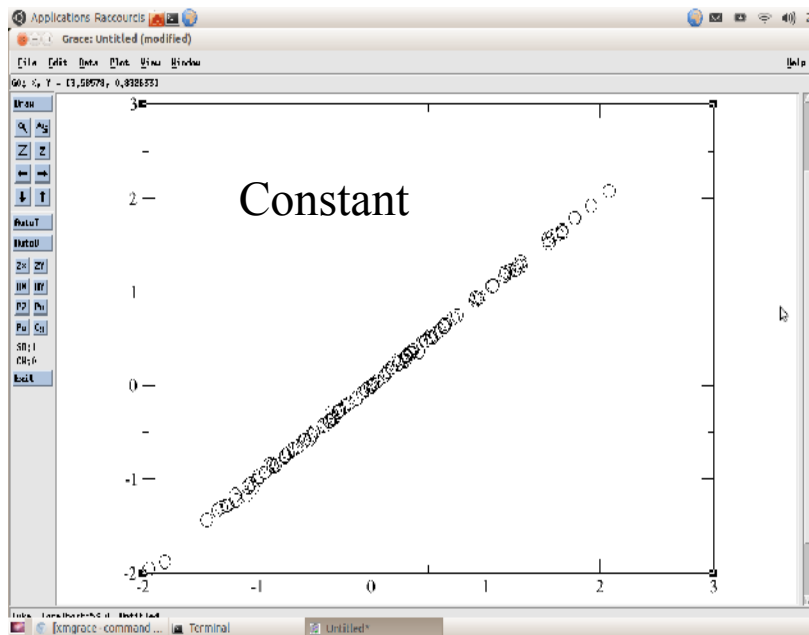
Quality check after inversion of residual mis-registration ramps
estimated for all interferograms in bursts overlap (small baseline inversion procedure)

```
$ 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



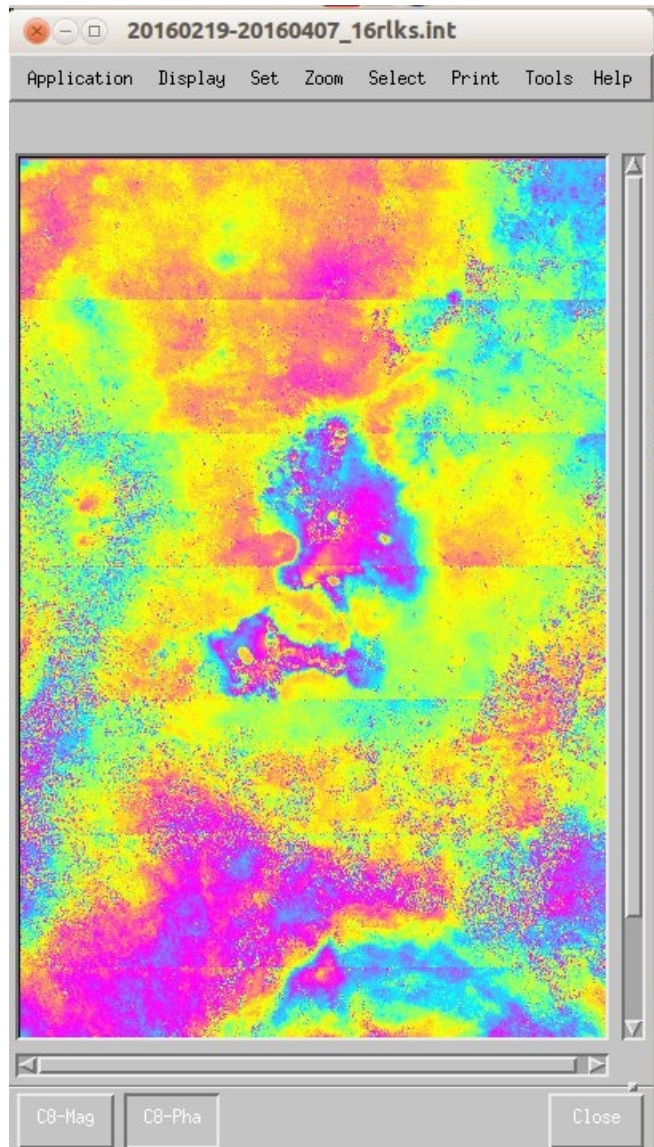
Observed spectral diversity (X-axis) versus Inversed spectral diversity (Y-axis)

Spectral diversity correction

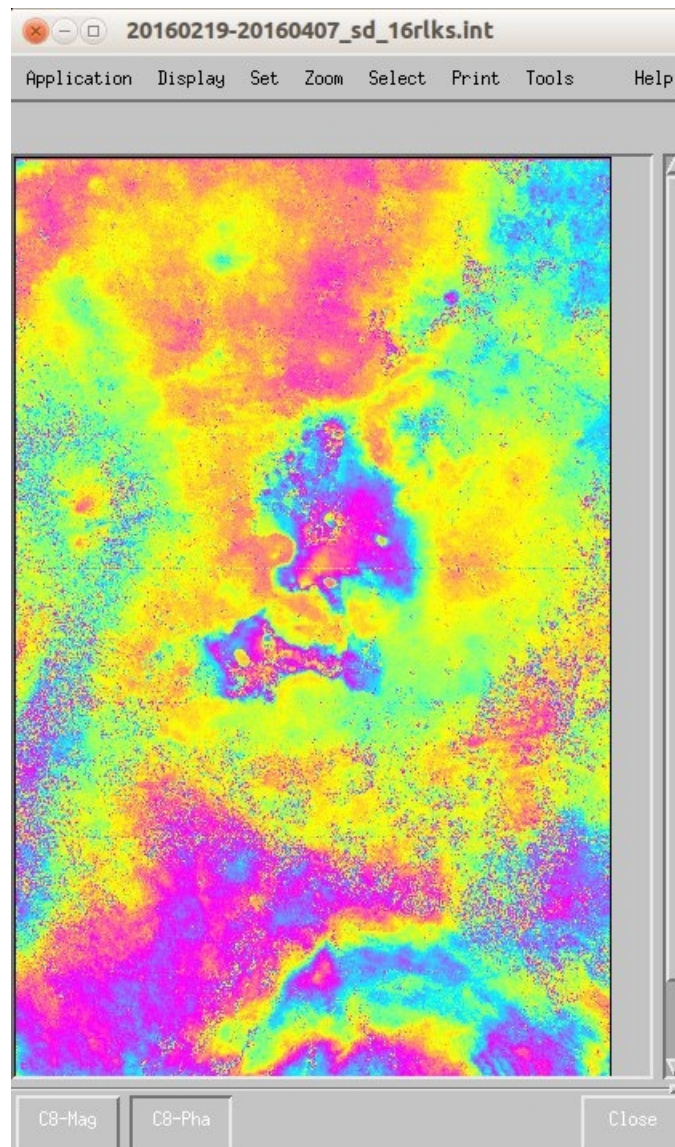
```
$ /nsbas/MDX/mdx.pl INT/int_20160219_20160407/20160219-20160407_16rlks.int
```

```
$ /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
```

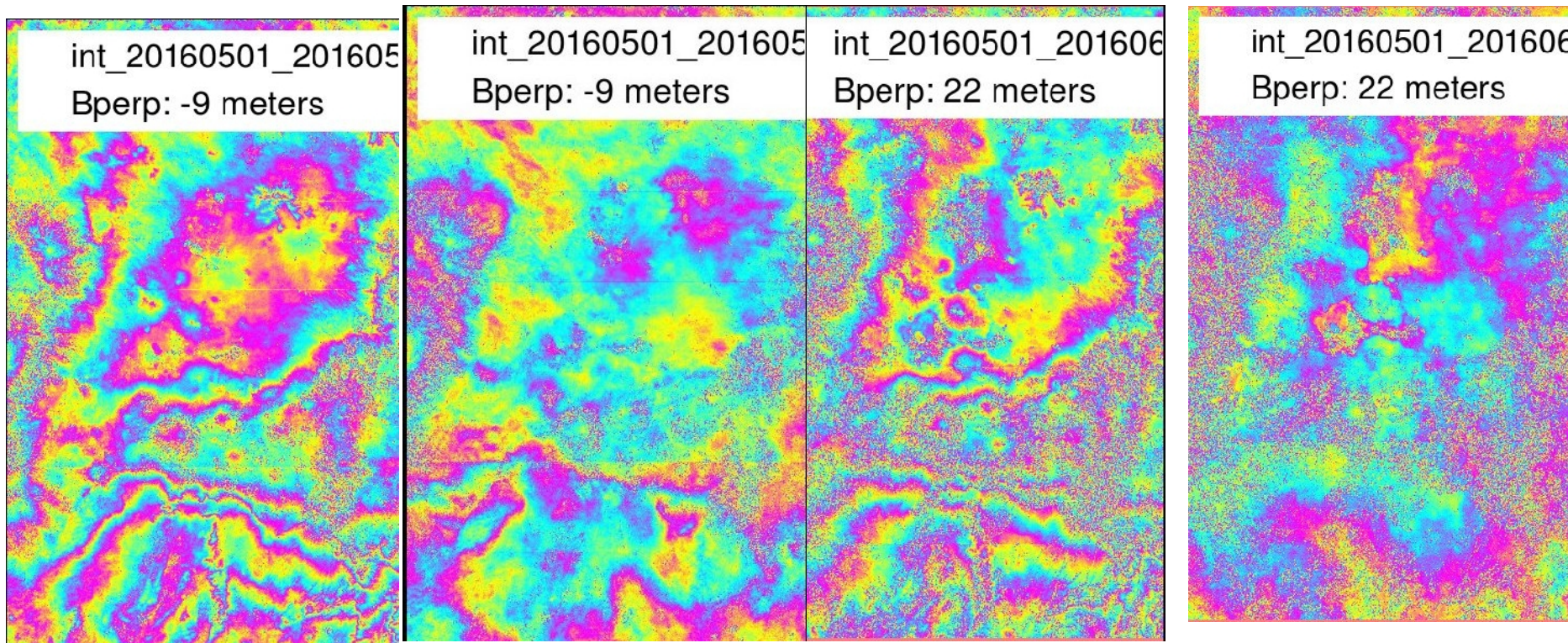
```
$ /nsbas/MDX/mdx.pl ERA/20161022_mdel_2rlks.unw
```

```
$ 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 unwrapping

Multilooking, filtering

```
$ cd INT
```

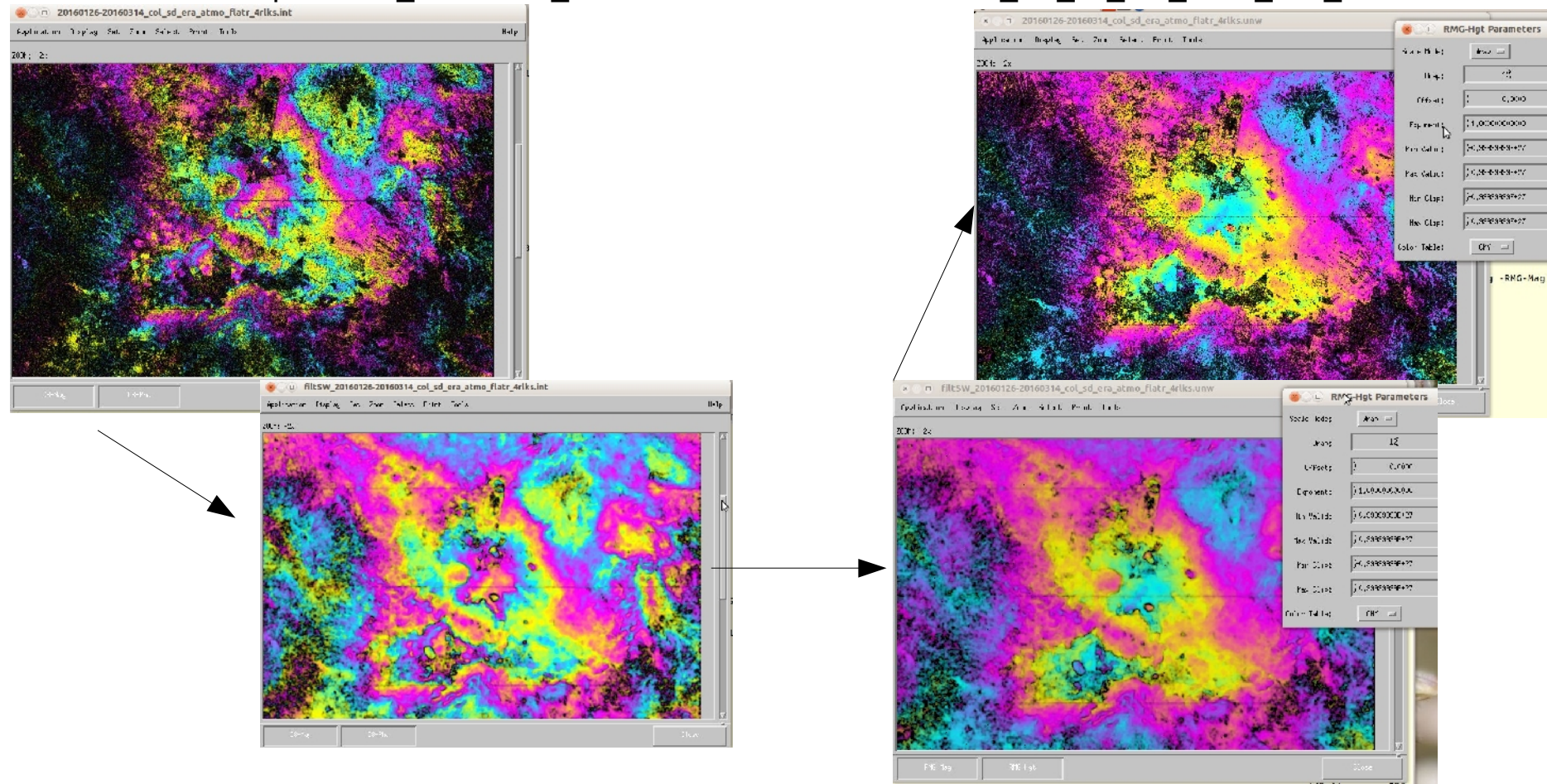
```
$ /nsbas/MDX/mdx.pl INT/int_20160126_20160314/20160126-20160314_col_sd_era_atmo_flatr_4rlks.int
```

```
$ /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
```

