

Pol-InSAR Exercises with PolSARpro – Biomass Edition v1.0.0

Irena Hajnsek

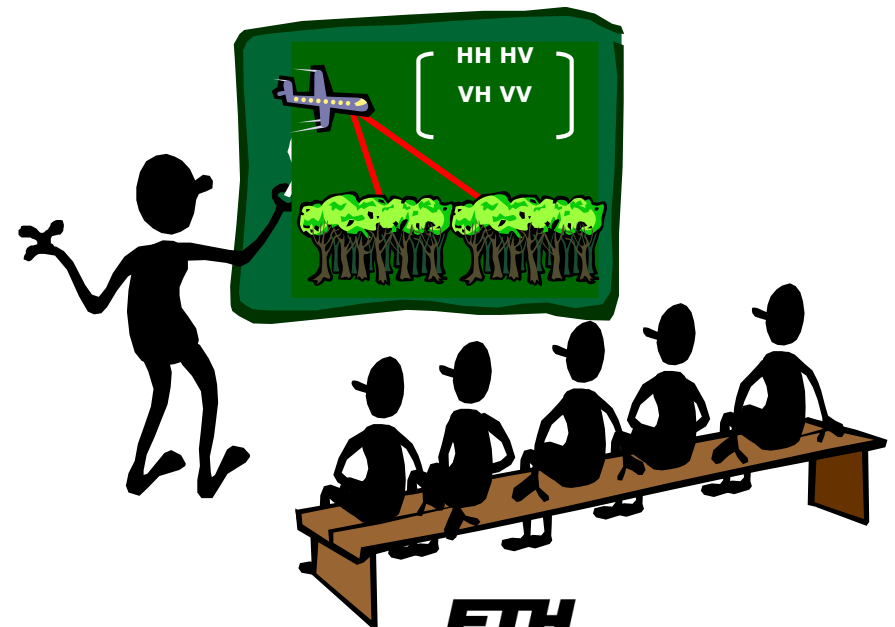
*Earth Observation and Remote Sensing,
Institute of Environmental Engineering, ETH Zürich

*Microwaves and Radar Institut,
German Aerospace Center, Oberpfaffenhofen

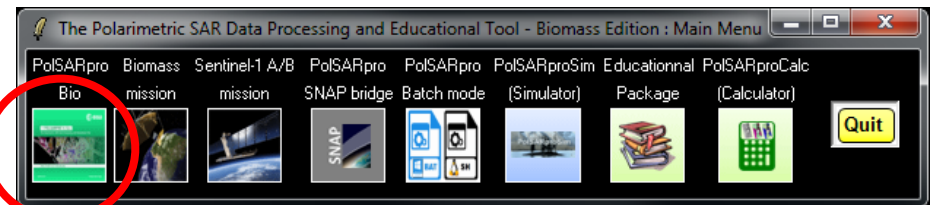
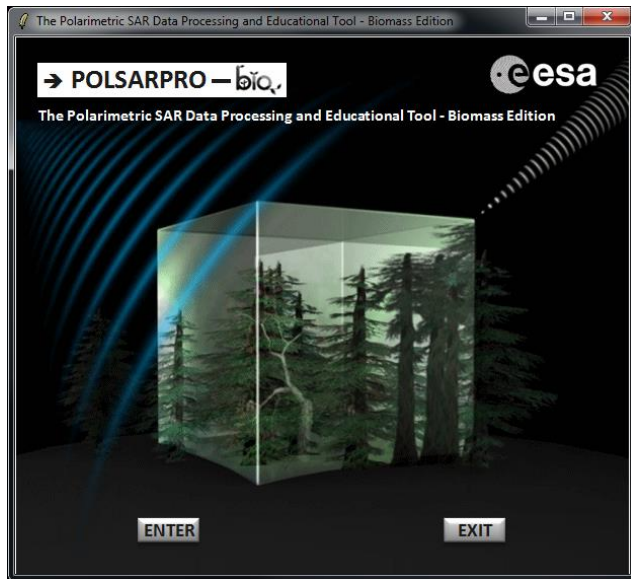


Outline – Polarimetric SAR Interferometry

- Generation of an Interferometric and Polarimetric simulated data set
 - Deciduous Forest @ PolSAR Pro SIM
- Generation of the Complex Coherence
 - Display and interpretation
- Flat Earth removal & renew generation of complex coherence
 - Display and interpretation
- Interferometric Coherence generation @ diff polarisations
 - Linear polarisation coherences
 - Optimisation of coherences
 - Display and interpretation
- Volume height derivation
 - Interferometric phase
 - Coherence phase
 - Analysis and interpretation
 - Statistical Analysis

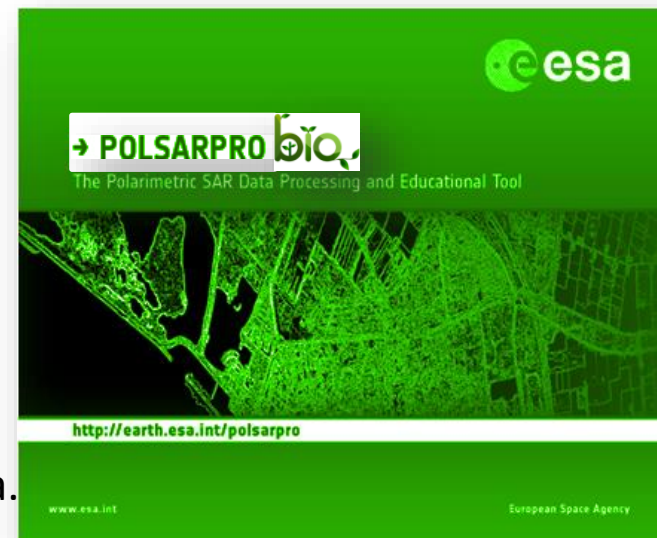


PolSARpro-Biomass Edition V1.0.0 (January 2019)



PolSARpro - Bio SOFTWARE

WEB-LINK: <http://earth.esa.int/polsarpro>



Adobe Acrobat Standard - [1_Pol-InSAR_Training_Course.pdf]

Fichier Edition Affichage Document Commentaires Outils Options avancées Fenêtre ?

Création d'un fichier PDF

Sélectionner 73%

POL-InSAR TRAINING COURSE

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PoISARap Tutorial (C. Lopez - E. Pottier) ▶

PoISARap Showcases

Lectures Notes ▶

Recent Advances (W.M. Boerner)

Basic Concepts (W.M. Boerner)

Advanced Concepts (E. Pottier, J.S. Lee, L. Ferro-Famil)

Polarimetric SAR Interferometry (S.R. Cloude, K. Papathanassiou) ▶

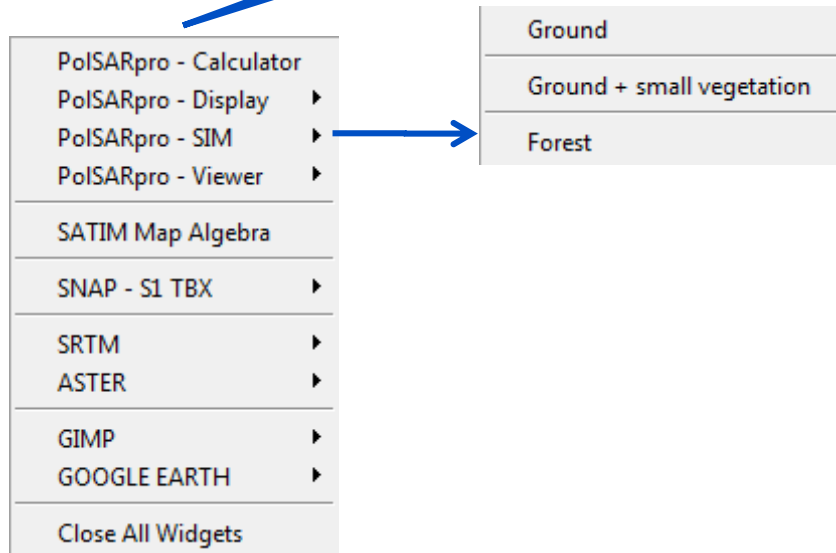
Surface Parameter Retrieval (I. Hajnsek, K. Papathanassiou) ▶

Single vs multi polarization interferometry

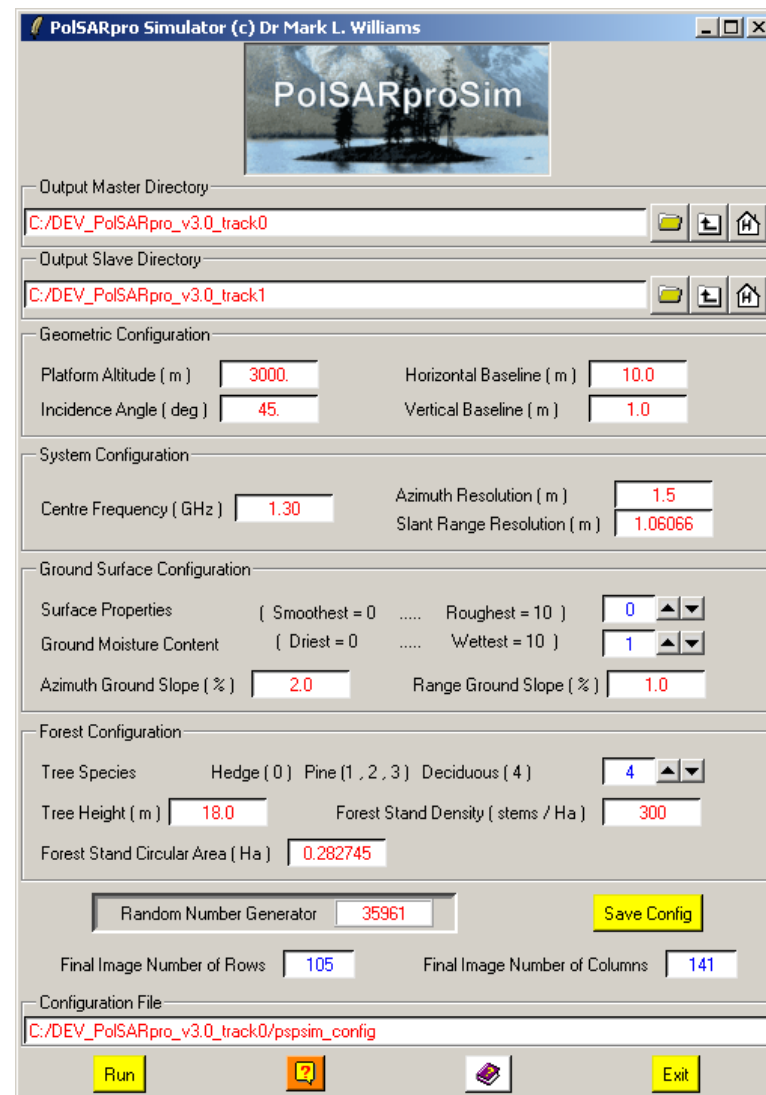
Pol-InSAR (Training Course)

Polarization Coherence Tomography (Training Course)



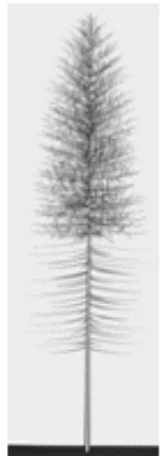


PoISARproSim
 rapid, coherent, fully
 polarimetric and
 interferometric SAR
 simulation of forest.



PolSARpro – SIM

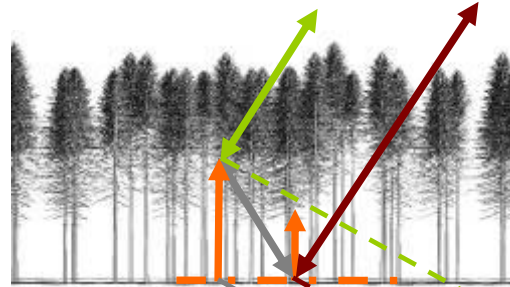
The SAR image is evaluated as a coherent sum of scattering events from small elements of the scene



PINE



DECIDUOUS



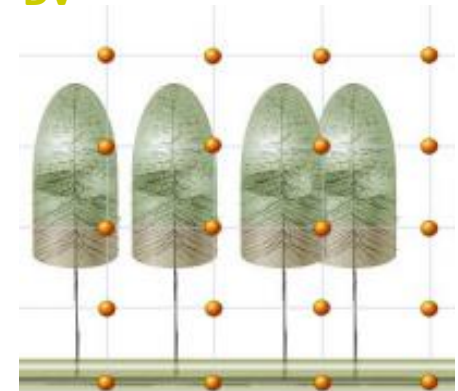
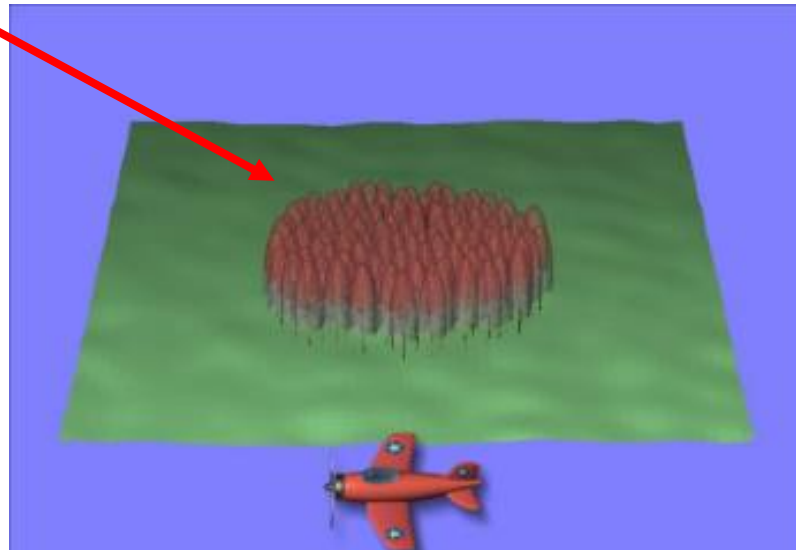
Direct-Ground, Direct-Volume and Ground-Volume contributions are included, with both trees and short vegetation comprising Volume terms.

GV DG

DV



RANDOM HEDGE




Given the map of tree locations and dimensions a grid of points is used to sample the attenuation of the coherent wave in 3D

Simulation of a Deciduous Forest Stand

Parameter space:

- Baseline (horizontal) 10 m
- Flight height 3 km
- AOI 45 degree
- Forest type: deciduous
- Forest height 18 m
- Density (stems/ha) 300
- Smooth surface
- Low soil moisture
- Spatial resolution 1.5 x 1.06 m

PolSARpro Forest Simulator (c) Dr Mark L. Williams



Output Master Directory
C:/Programme/PolSARpro v4.0/track_master

Output Slave Directory
C:/Programme/PolSARpro v4.0/track_slave

Geometric Configuration

Platform Altitude (m)	3000.	Horizontal Baseline (m)	10.0
Incidence Angle (deg)	45.	Vertical Baseline (m)	1.0

System Configuration

Centre Frequency (GHz)	1.30	Azimuth Resolution (m)	1.5
		Slant Range Resolution (m)	1.06066

Ground Surface Configuration

Surface Properties	(Smoothest = 0 Roughest = 10)	0	
Ground Moisture Content	(Driest = 0 Wettest = 10)	1	
Azimuth Ground Slope (%)	2.0	Range Ground Slope (%)	1.0

Forest Configuration

Tree Species	Hedge (0) Pine (1 , 2 , 3) Deciduous (4)	4	
Tree Height (m)	18.0	Forest Stand Density (stems / Ha)	300
Forest Stand Circular Area (Ha)	2827.45		

Random Number Generator 6392

Save Config

Final Image Number of Rows 105

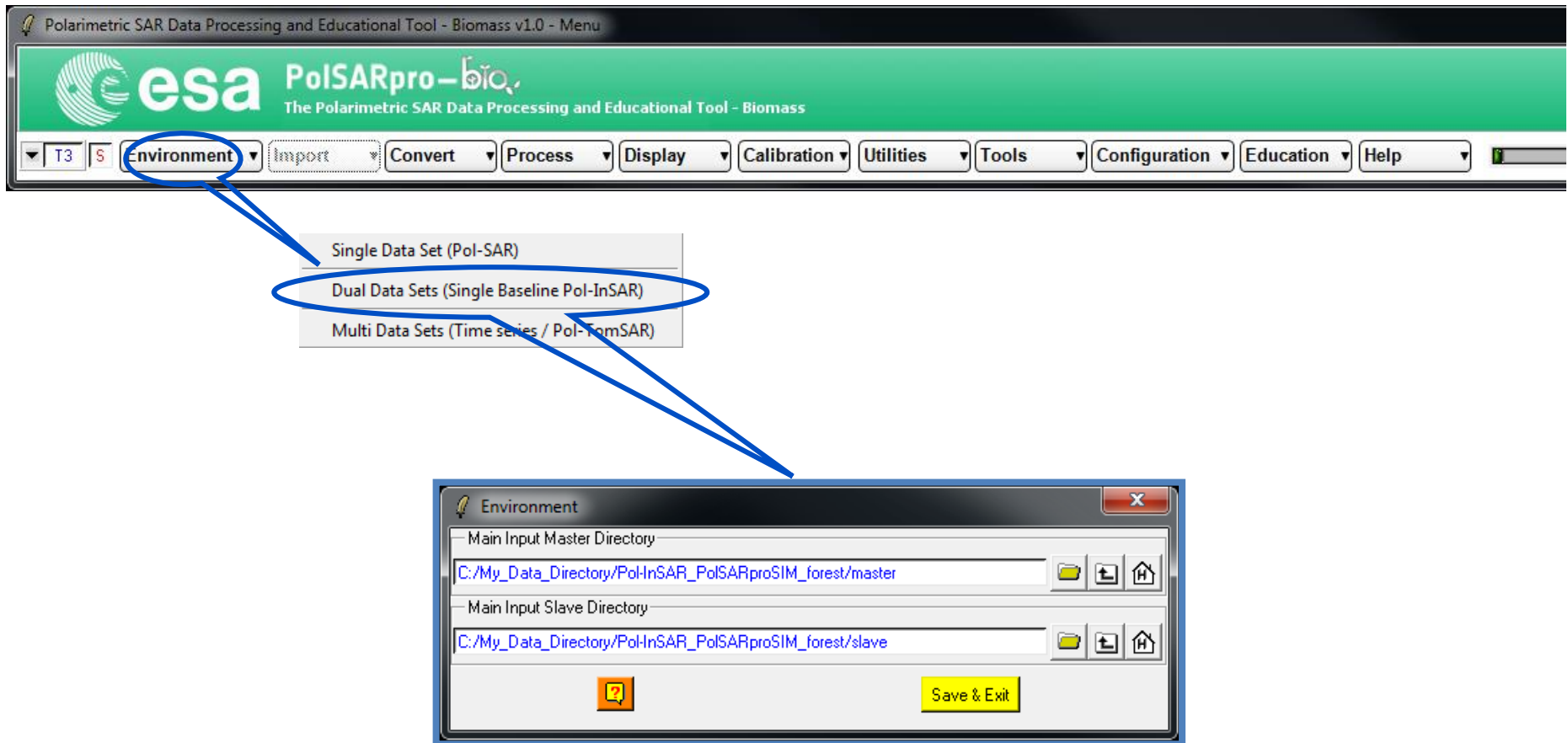
Final Image Number of Columns 141

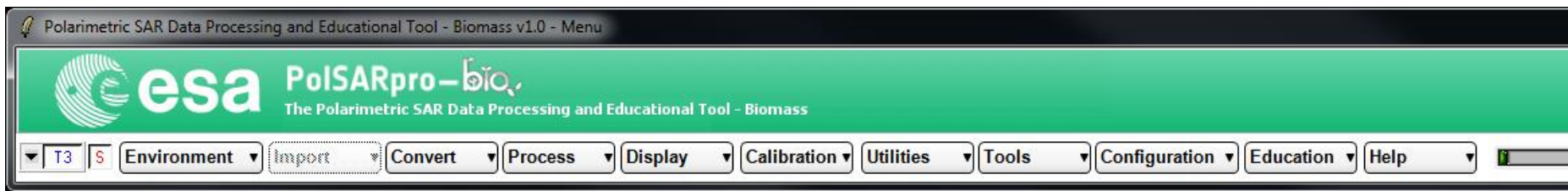
Configuration File
C:/Programme/PolSARpro v4.0/track_master/pspsim_config

Run ? [Icon] Exit

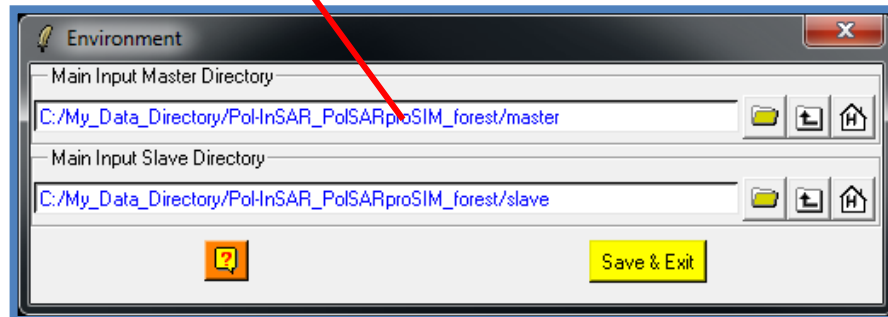


Process the Data Interferometrically



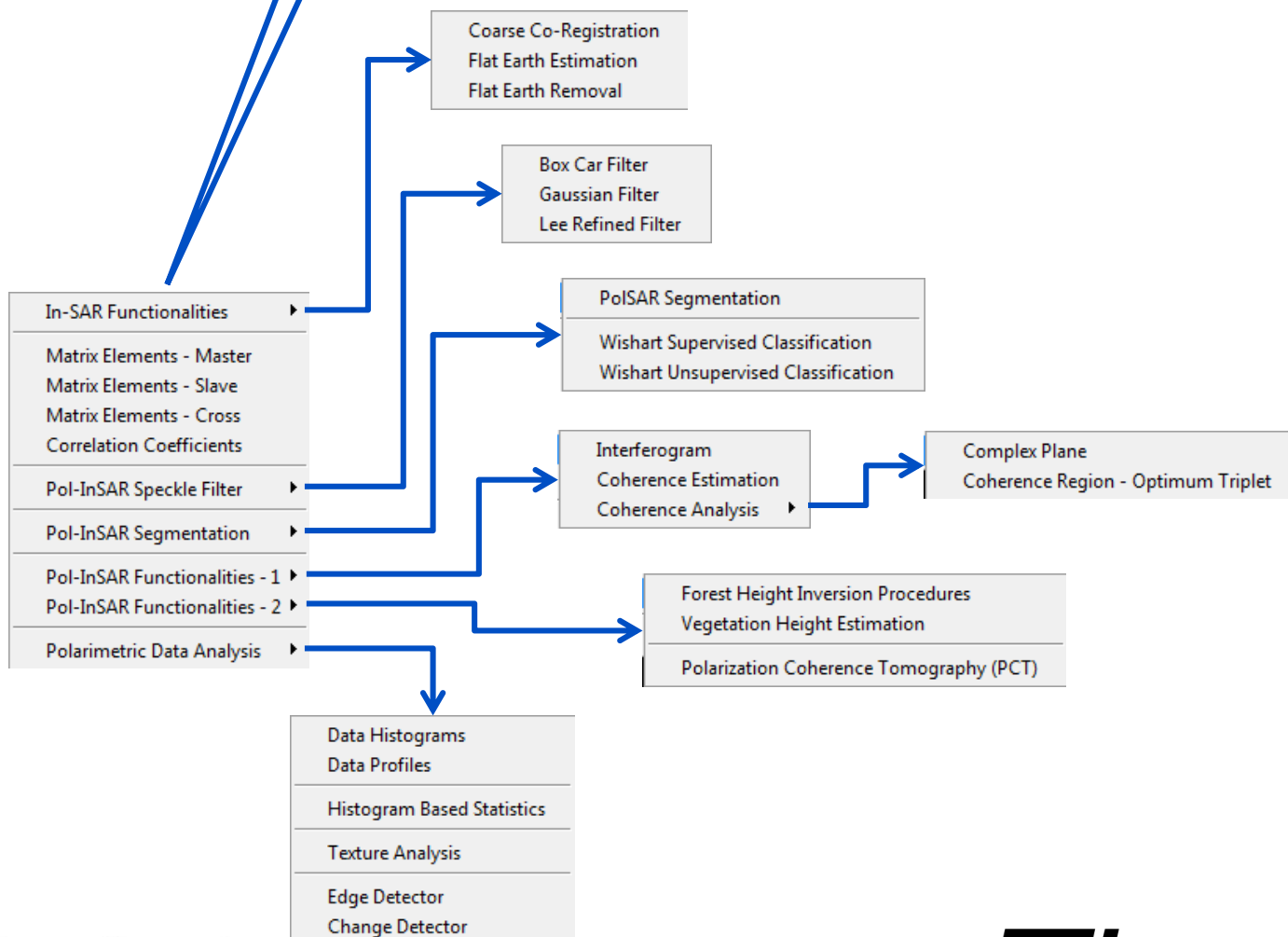


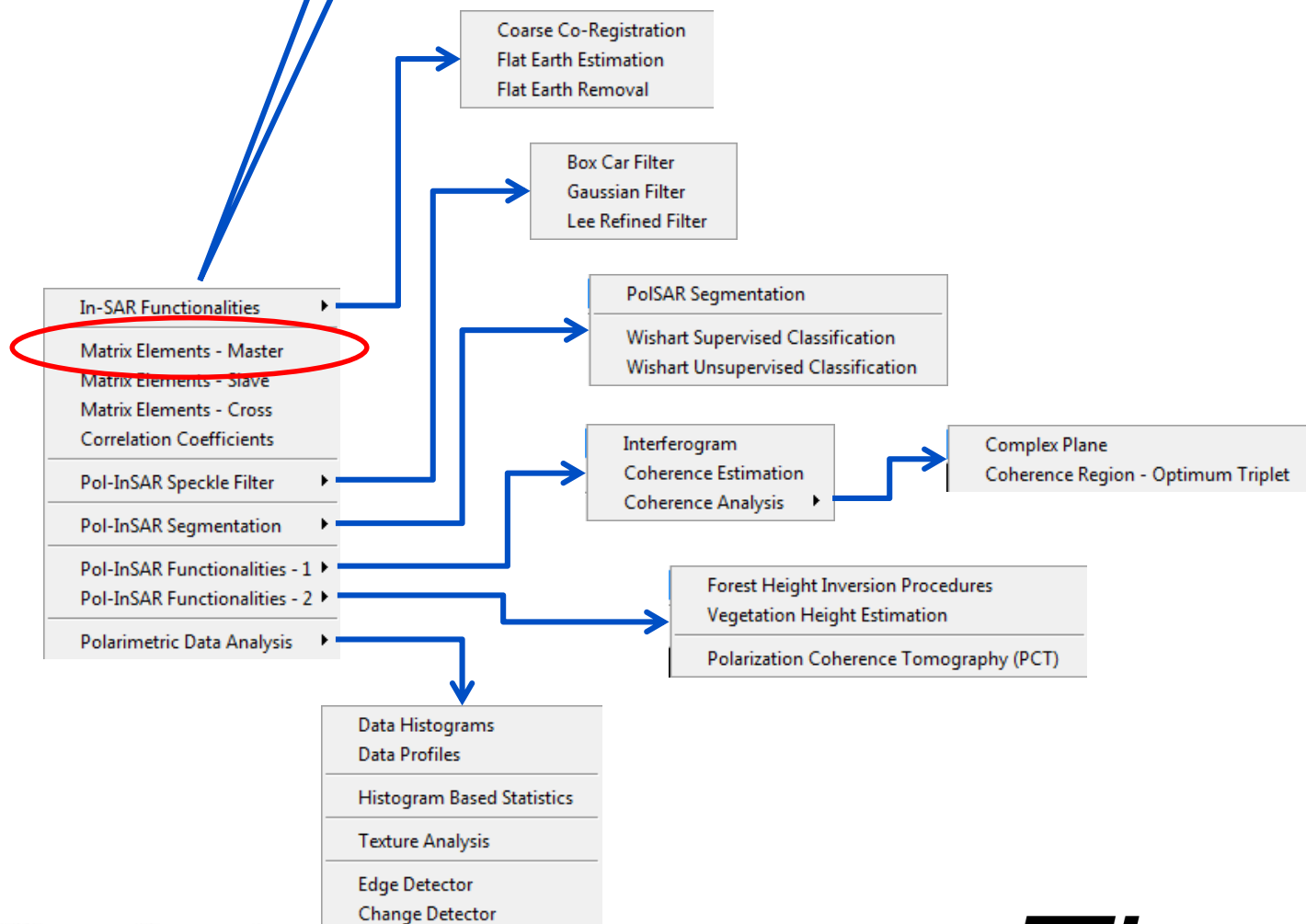
Configure Data Main Directories location



Input Master Directory: C:/... /Pol-InSAR_datasets/master

Input Slave Directory: C:/... /Pol-InSAR_datasets/slave





Generate the Scattering Matrix of the Master

- Processes to BMP File

Data Processing: Sinclair Elements


Input Directory
C:/My_Data_Directory/Pol-InSAR_PolSARproSIM_forest/master

Output Directory
C:/My_Data_Directory/Pol-InSAR_PolSARproSIM_forest/master

Init Row: 1 End Row: 301 Init Col: 1 End Col: 301

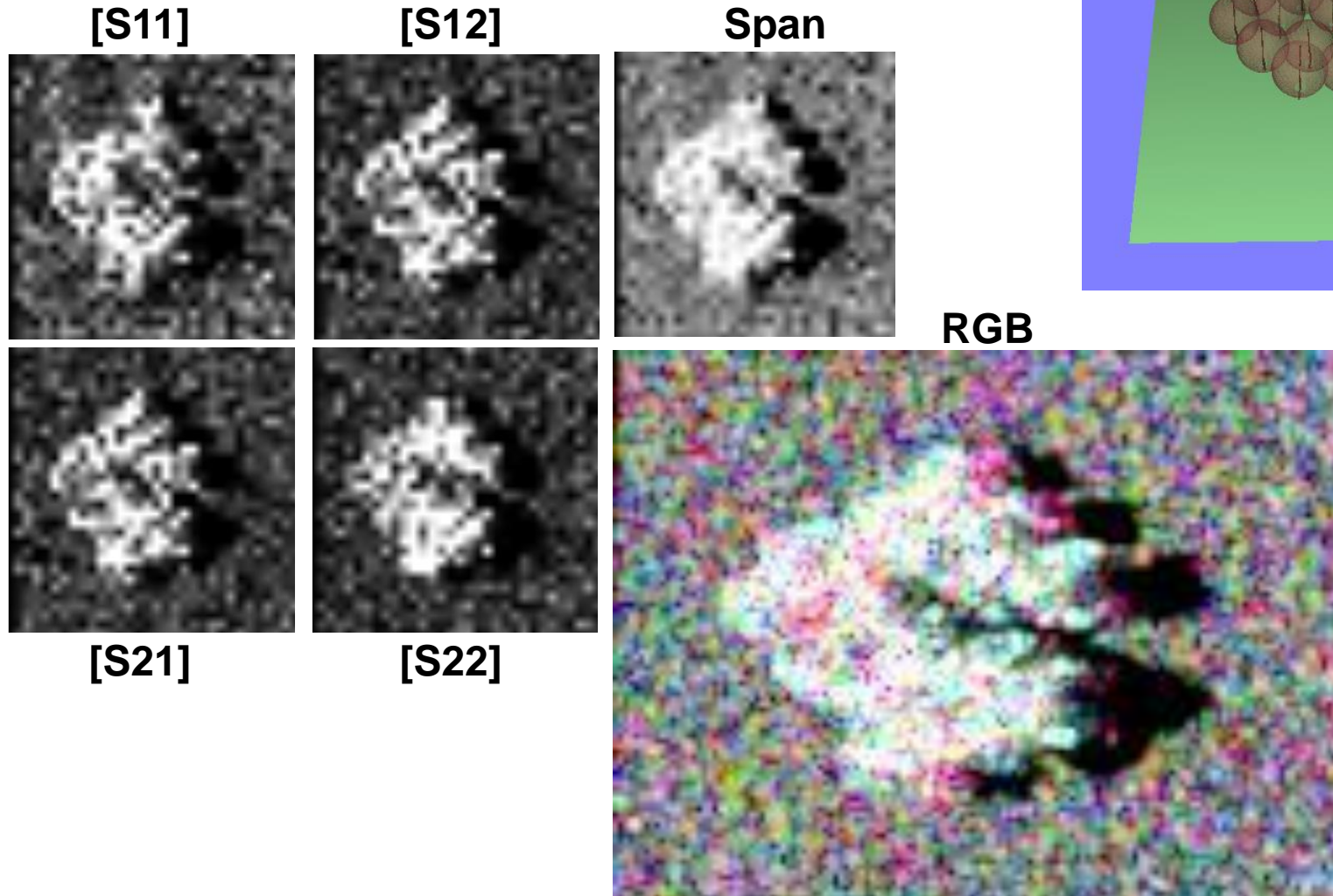
S11	<input type="radio"/> A11	<input type="radio"/> I11	<input checked="" type="radio"/> A11 (dB) = I11 (dB)	<input type="radio"/> Phase	<input checked="" type="checkbox"/> BMP
S21	<input type="radio"/> A21	<input type="radio"/> I21	<input type="radio"/> A21 (dB) = I21 (dB)	<input checked="" type="radio"/> Phase	<input checked="" type="checkbox"/> BMP
S12	<input type="radio"/> A12	<input type="radio"/> I12	<input checked="" type="radio"/> A12 (dB) = I12 (dB)	<input type="radio"/> Phase	<input checked="" type="checkbox"/> BMP
S22	<input type="radio"/> A22	<input type="radio"/> I22	<input type="radio"/> A22 (dB) = I22 (dB)	<input checked="" type="radio"/> Phase	<input checked="" type="checkbox"/> BMP
Pauli	<input type="radio"/> Cmplx	<input type="radio"/> Mod	<input checked="" type="radio"/> 20log10(Mod) (dB)	<input type="radio"/> Phase	<input checked="" type="checkbox"/> BMP
Span	<input type="radio"/> Linear	<input checked="" type="radio"/> DeciBel = 10log(Span)			<input checked="" type="checkbox"/> BMP

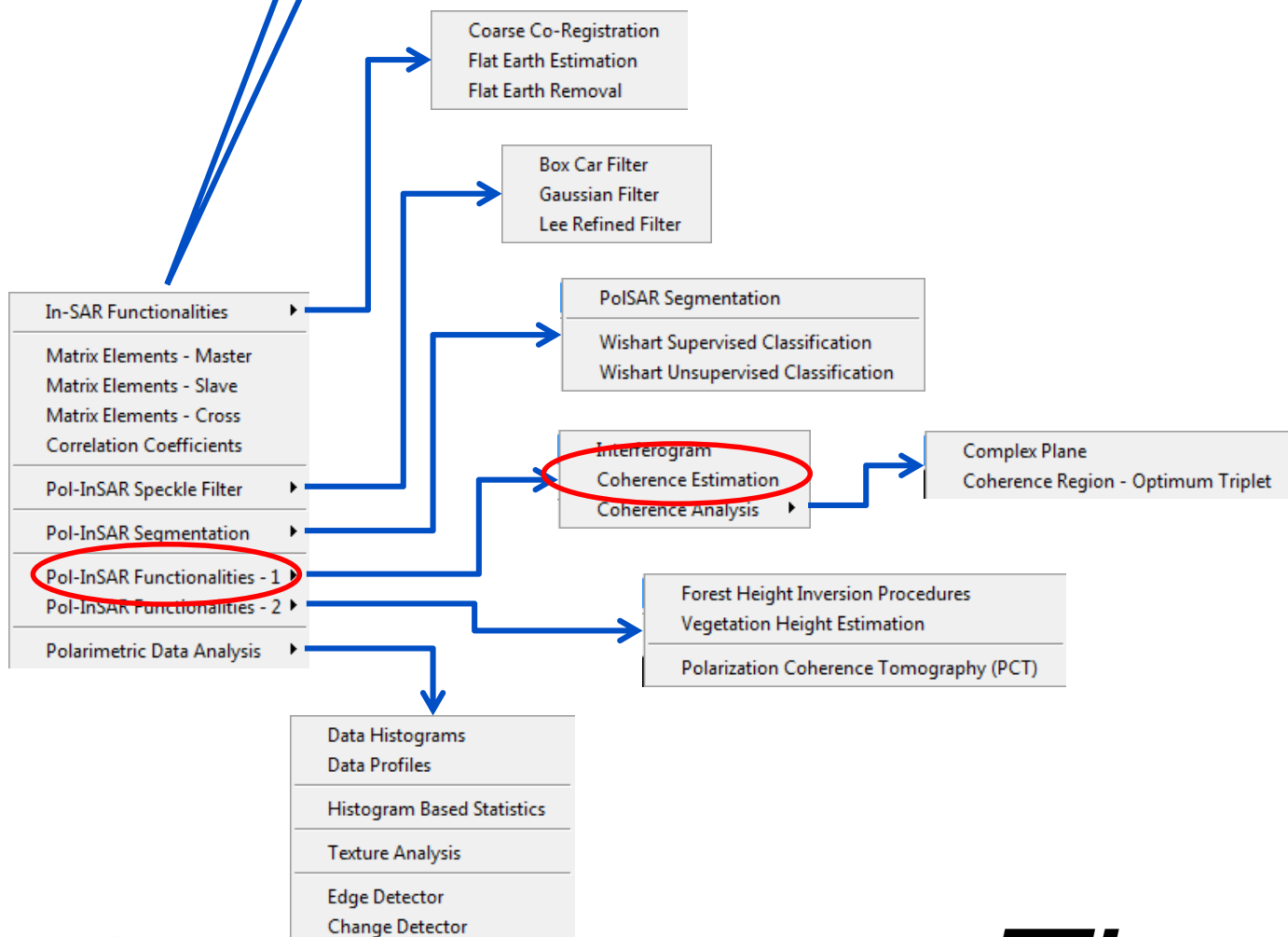
Select All Reset

Run  Exit

Display Master Files with GIMP

Forest Simulation





Generation of the Complex Coherence

- Go to Process
 - Coherence Estimation

Note:

The Output Directory is automatically set to:
master_slave

Complex Coherence Estimation

Input Master Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR

Input Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR

Output Master-Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/P /

Init Row 1 End Row 105 Init Col 1 End Col 141

Complex Coherences

Linear
☒ HH
☒ HV
☒ W

Circular
☒ LL
☒ LR
☒ RR

Pauli
☐ HH + WV ☐ HV + VH
☒ HH - WV ☐ HH.WV*

Optimal
☒ SVD ☐ L. MinMax
☒ PD ☐ L. Diff
☒ NR

Numerical Radius
Theta1 Theta3

Loci MinMax
Num Points

Loci Diff
Num Points

Box Car Window
Row 7 Col 7

☒ BMP
☐ Averaging

Row Col

Run Hist ? Exit

Display Complex Coherences with GIMP

Coherence
Magnitude

γ_{HH}



γ_{VV}



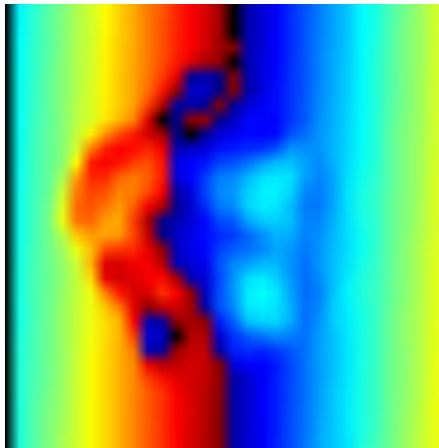
γ_{HV}



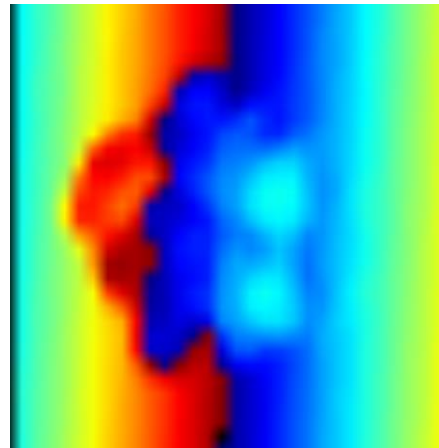
0  1

Coherence
Phase ~
Inter-
ferometric
Phase

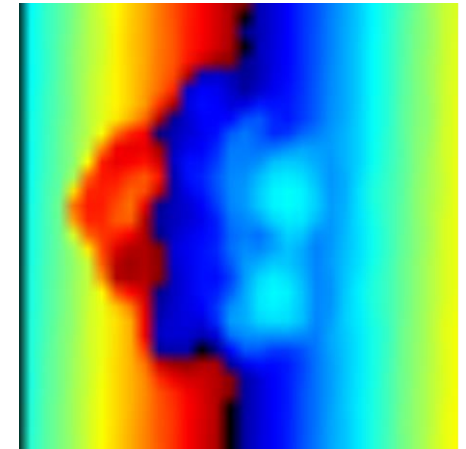
Φ_{HH}



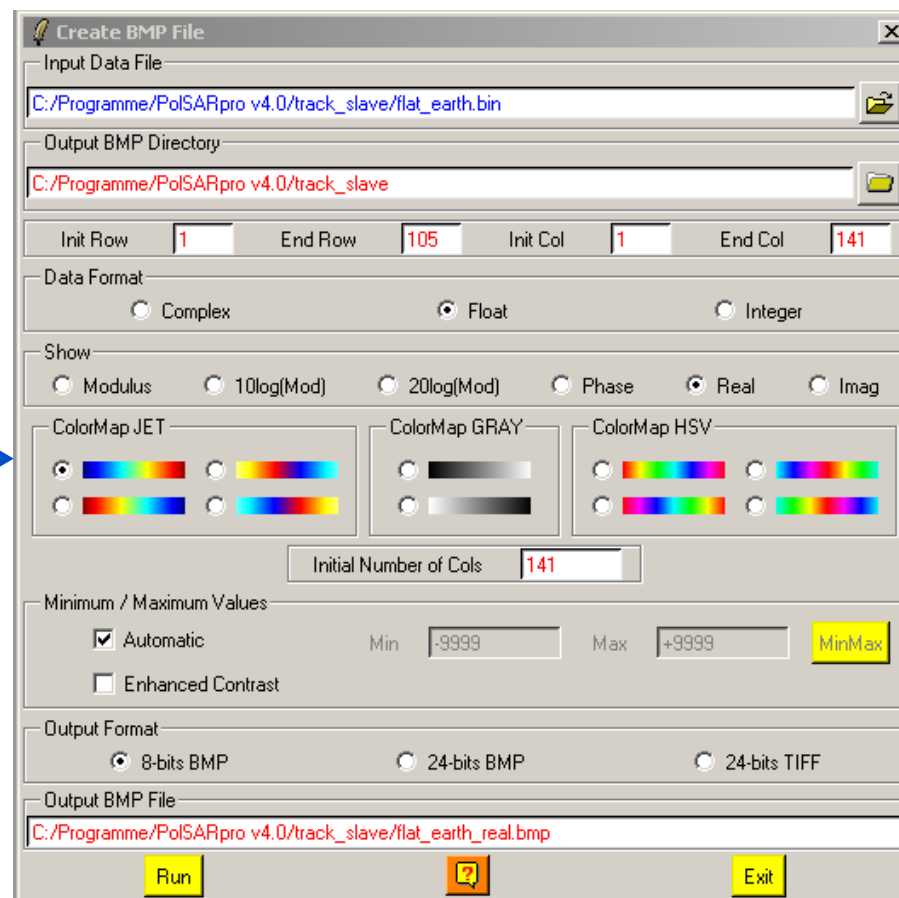
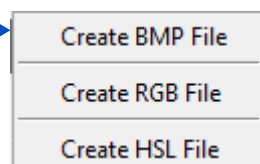
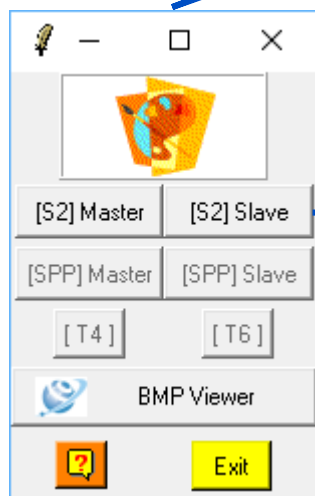
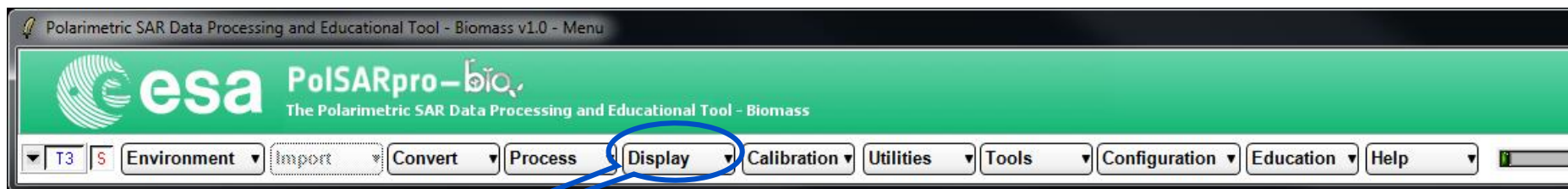
Φ_{VV}



Φ_{HV}



-180°  +180°



Display Flat Earth

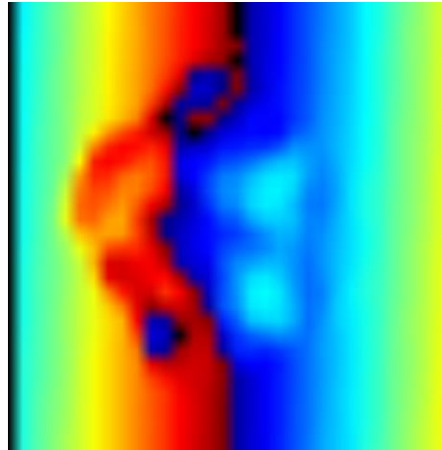
- The flat earth is the dominant frequency component due to the side looking geometry (range direction)
- Flat Earth for the simulation data were already estimated during the PolSARPro Sim
- Go to Display and create a .bmp file

The screenshot shows the 'Create BMP File' dialog box in PolSARPro v4.0. The 'Input Data File' is set to 'C:/Programme/PolSARpro v4.0/track_slave/flat_earth.bin'. The 'Output BMP Directory' is 'C:/Programme/PolSARpro v4.0/track_slave'. The 'Init Row' is 1, 'End Row' is 105, 'Init Col' is 1, and 'End Col' is 141. The 'Data Format' is set to 'Float'. The 'Show' section has 'Real' selected. The 'ColorMap JET' section has the first color bar selected. The 'ColorMap GRAY' section has the first grayscale bar selected. The 'ColorMap HSV' section has the first color bar selected. The 'Initial Number of Cols' is 141. The 'Minimum / Maximum Values' section has 'Automatic' checked, with 'Min' at -9999 and 'Max' at +9999. The 'Output Format' is set to '8-bits BMP'. The 'Output BMP File' is 'C:/Programme/PolSARpro v4.0/track_slave/flat_earth_real.bmp'. At the bottom are 'Run', 'Help' (with a question mark icon), and 'Exit' buttons.

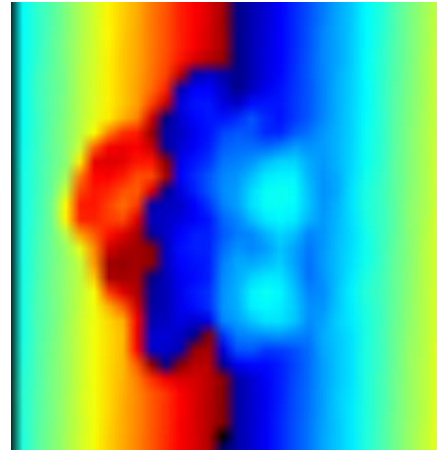
Display Flat Earth Earth & Store as .bmp

Coherence
Phase ~
Inter-
ferometric
Phase

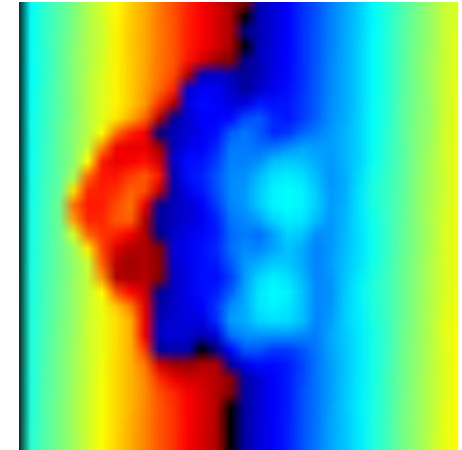
Φ_{HH}



Φ_{VV}

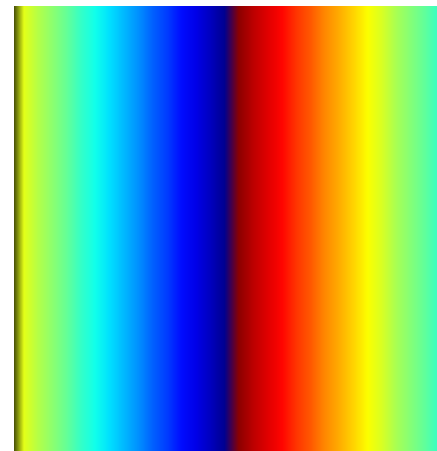


Φ_{HV}



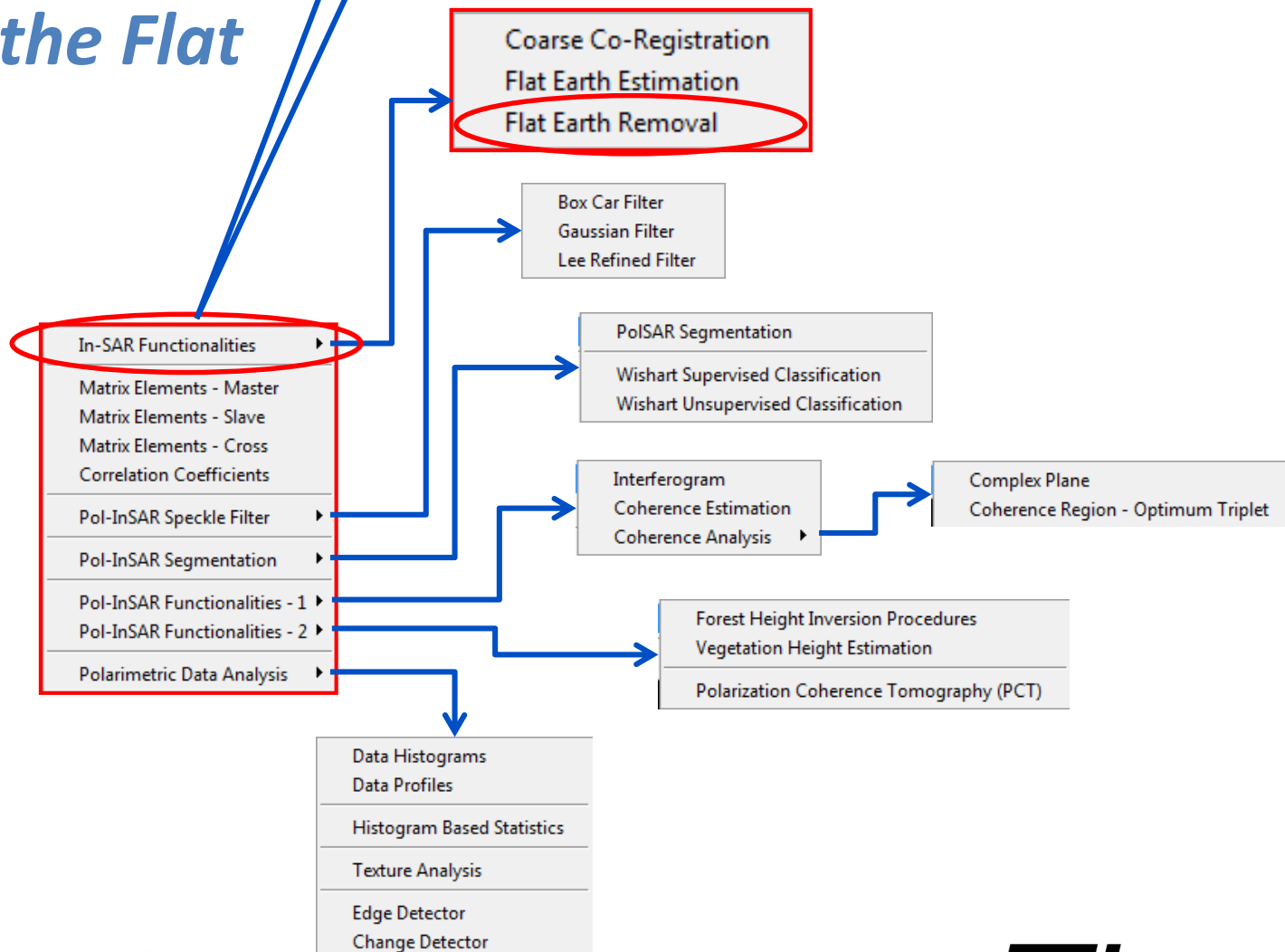
-180°  +180°

Flat Earth:
regular fringe
pattern in range



-180°  +180°

Correct the Flat Earth



Correct the Flat Earth

- Go to Processes
 - Flat Earth Removal

Note:

The Output Directory is automatically set to:
slave_FER

POLinSAR Flat Earth Removal

Input Master Directory
C:/My_Data_Directory/Pol-InSAR_PolSARproSIM_forest/master

Input Slave Directory
C:/My_Data_Directory/Pol-InSAR_PolSARproSIM_forest/slave

Init Row 1 End Row 301 Init Col 1 End Col 301

2D Flat Earth File
C:/My_Data_Directory/Pol-InSAR_PolSARproSIM_forest/slave/flat_earth.bin

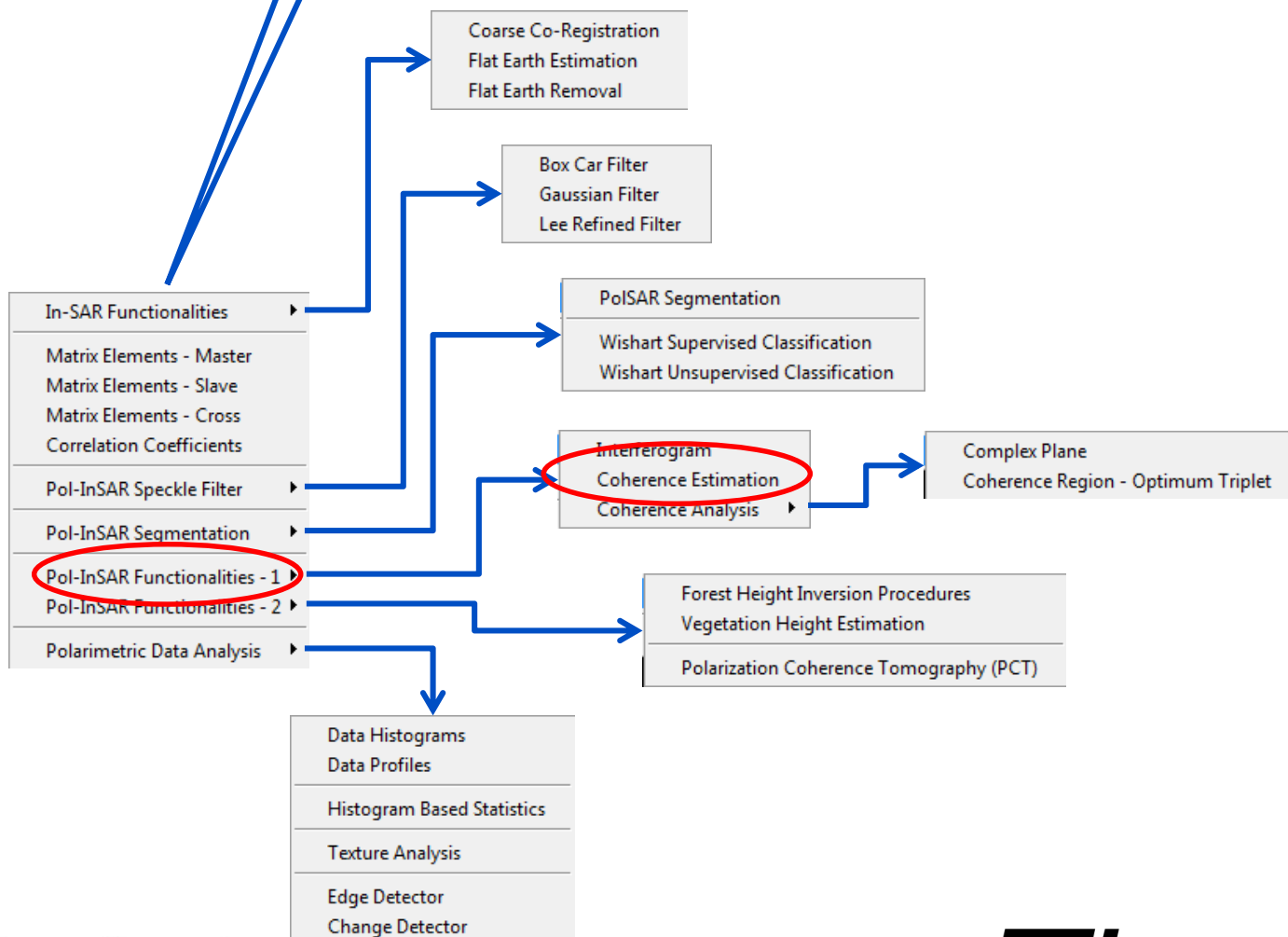
Input Format
☐ real (deg) ☒ real (rad) ☐ cmplx (cos, sin)
☐ Convert Input IEEE binary Format (LE<->BE)

☐ Symmetrisation ☐ Conjugate

Output Master Directory
C:/My_Data_Directory/Pol-InSAR_PolSARproSIM_forest/master

Output Slave Directory
C:/My_Data_Directory/Pol-InSAR_PolSARproSIM_forest/slave_FER

Run [?] Exit



Run again the Coherence Estimation

- Go to Process
 - Coherence Estimation

Complex Coherence Estimation

Input Master Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR

Input Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR

Output Master-Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR

Init Row 1 End Row 105 Init Col 1 End Col 141

Complex Coherences

Linear
☒ HH
☒ HV
☒ VW

Circular
☒ LL
☒ LR
☒ RR

Pauli
☒ HH + WV
☒ HH - WV
☒ HV + VH
☐ HH.VW*

Optimal
☒ SVD
☐ L. MinMax
☐ PD
☐ L. Diff
☐ NR

Numerical Radius
Theta1 Theta3

Loci MinMax
Num Points

Loci Diff
Num Points

Box Car Window
Row 7 Col 7

☒ BMP
☐ Averaging

Row Col

Run Hist ? Exit

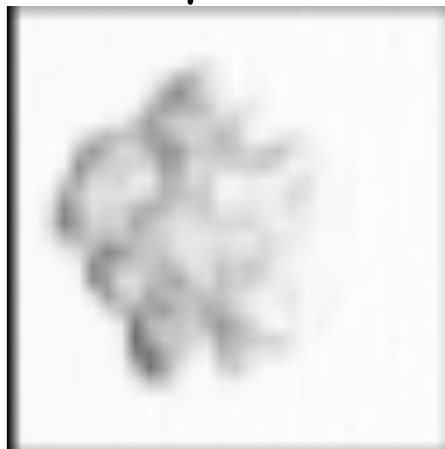
Note:

The Output Directory is
automatically set to:
[master_slave_FER](#)

Display Complex Coherences with GIMP – After FE Correction

Coherence
Magnitude

γ_{HH}



γ_{VV}



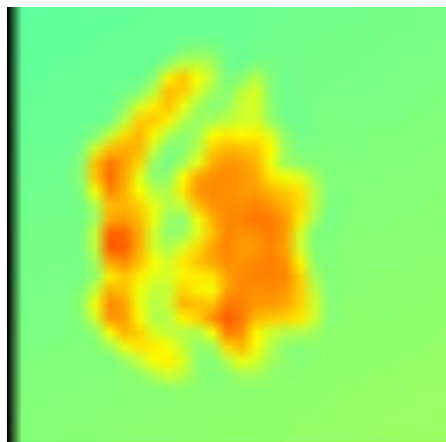
γ_{HV}



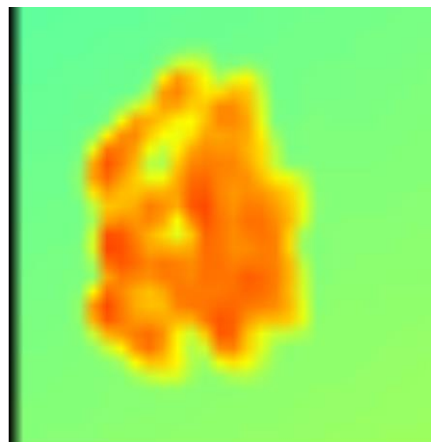
0  1

Coherence
Phase ~
Inter-
ferometric
Phase

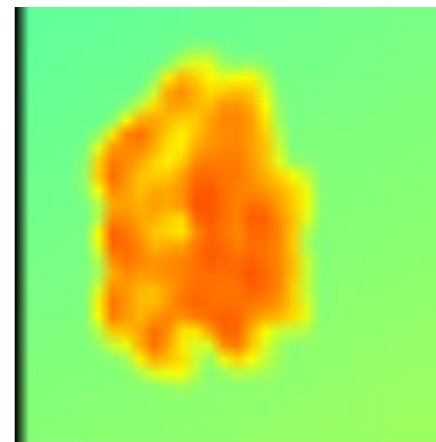
Φ_{HH}



Φ_{VV}



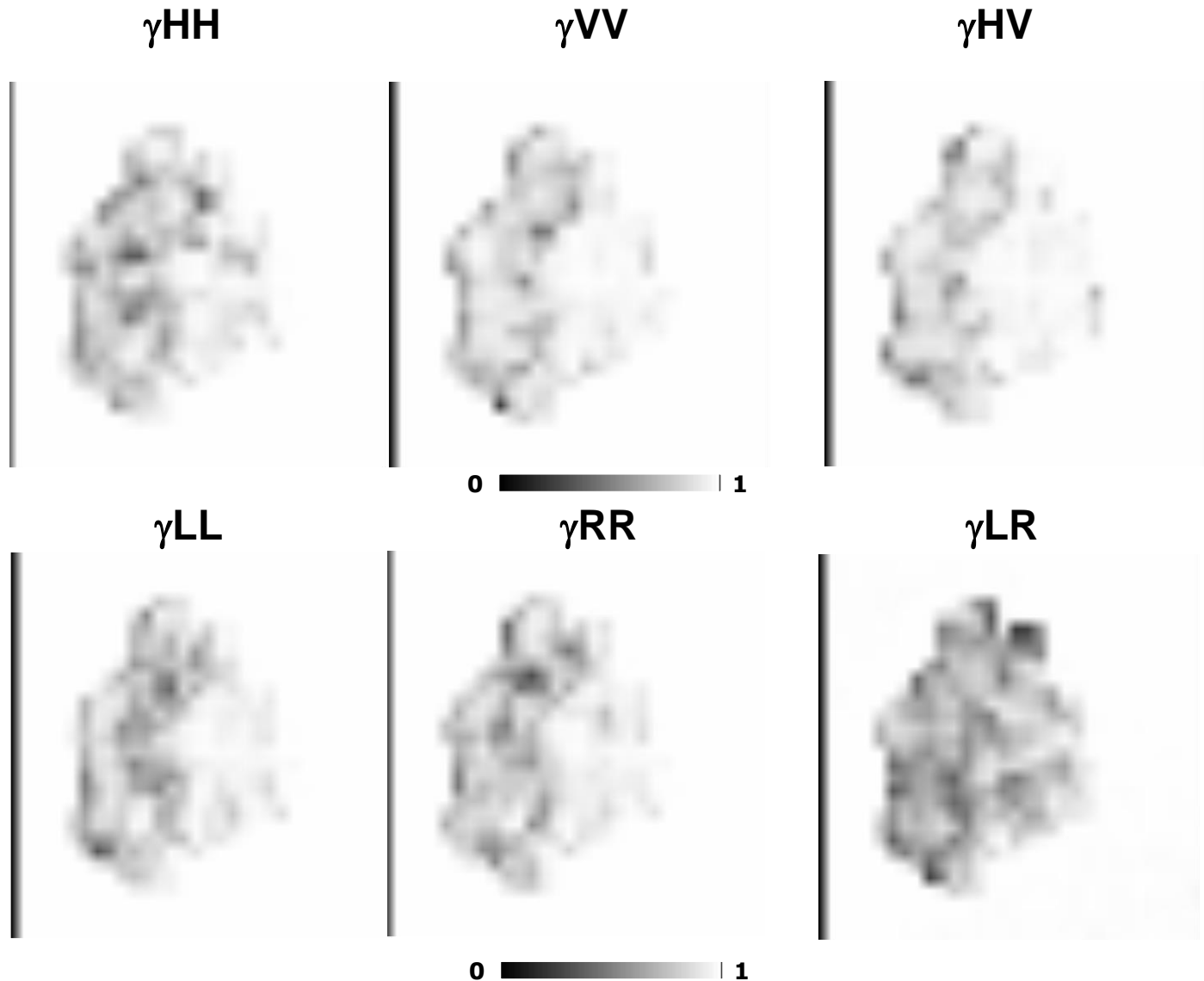
Φ_{HV}



-180°  +180°

Display Complex Coherences with GIMP – After FE Correction

Coherence
Magnitude



Earth Observation and
Remote Sensing

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- 25

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Display Complex Coherences with GIMP – After FE Correction

γ_{HH}

γ_{VV}

γ_{HV}

Coherence
Magnitude

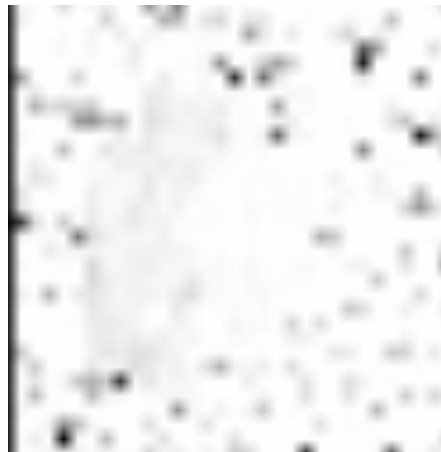


0 | 1

γ_{opt1}

γ_{opt2}

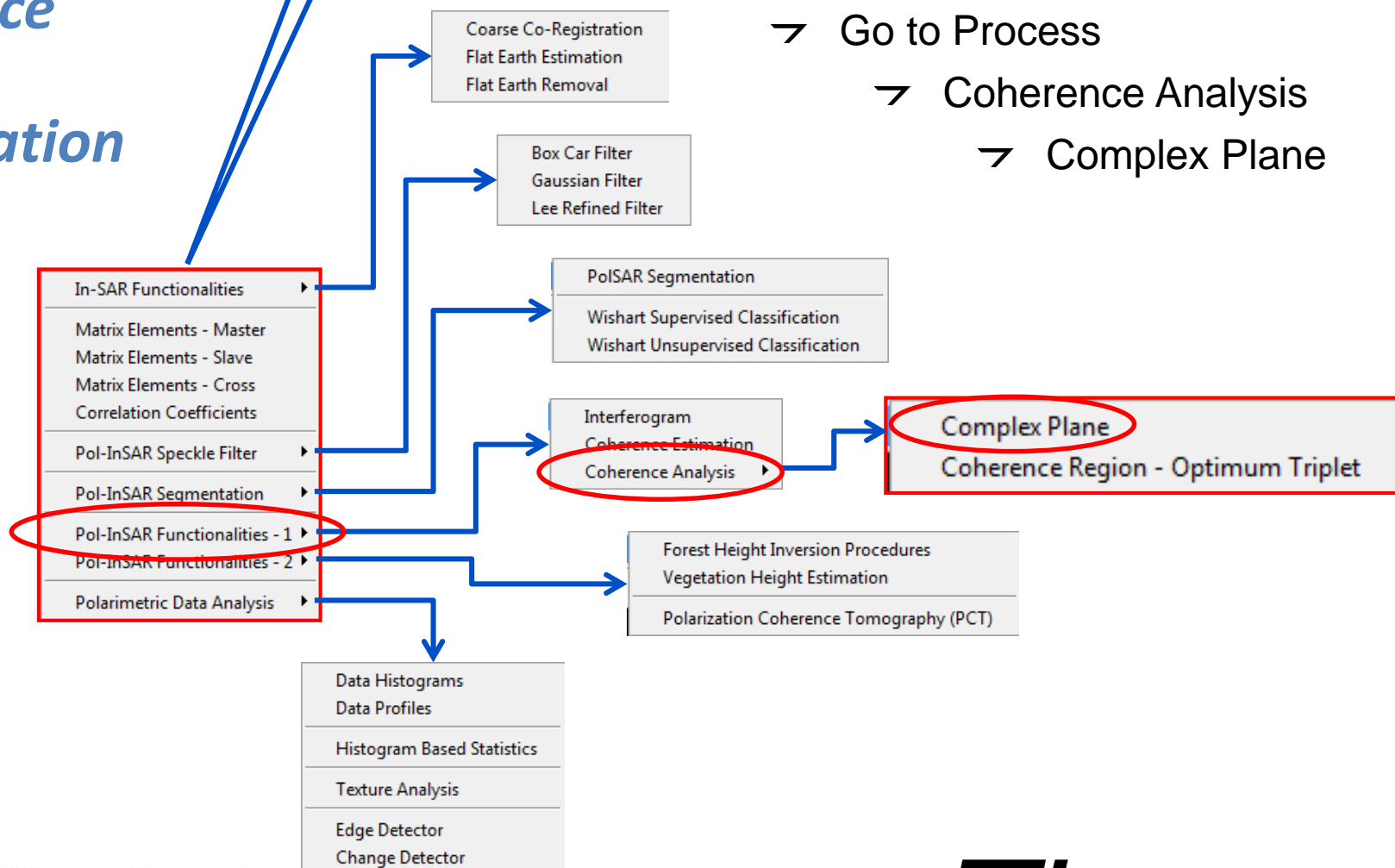
γ_{opt3}



0 | 1



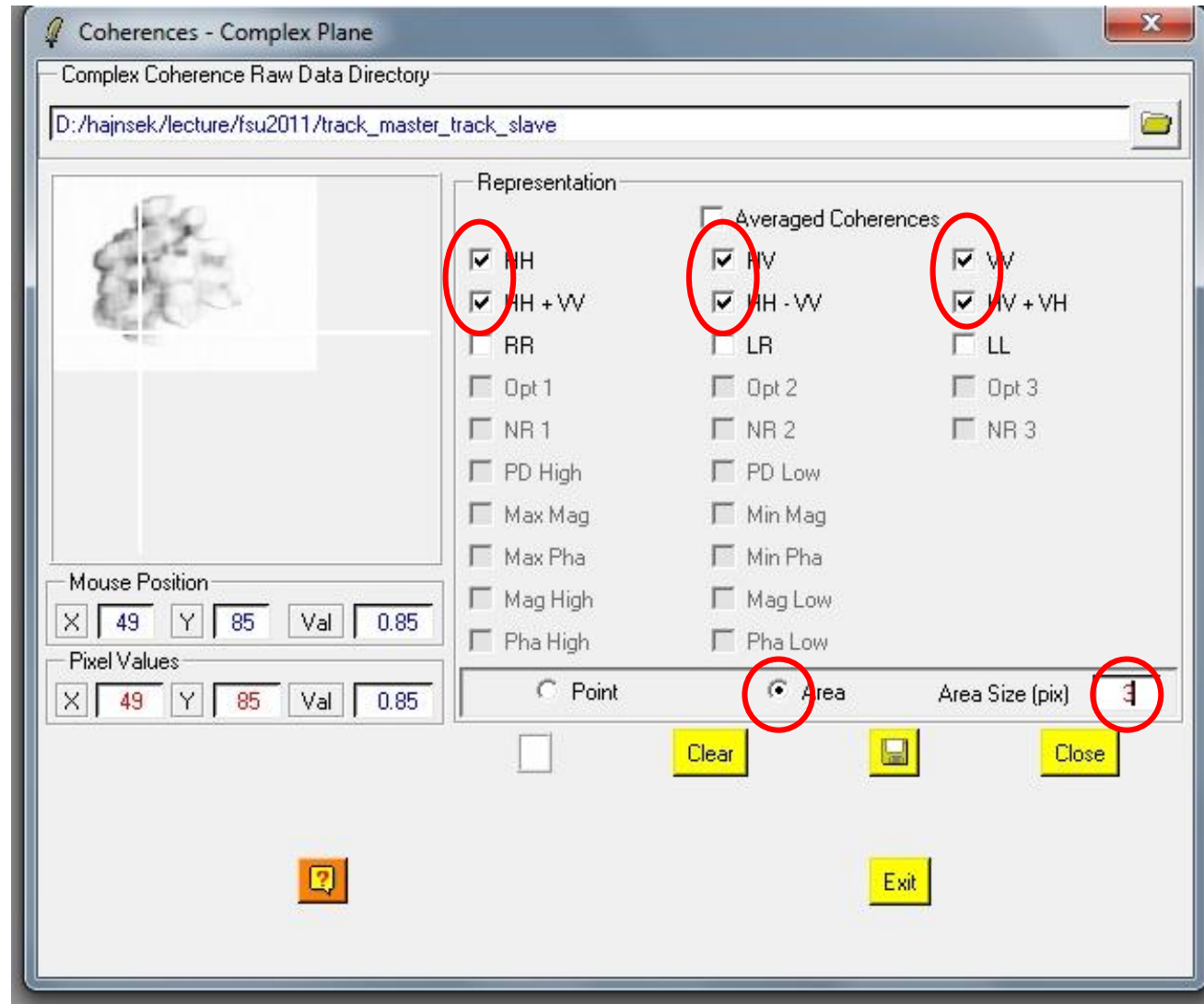
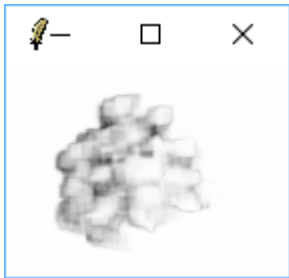
Coherence Plane Investigation



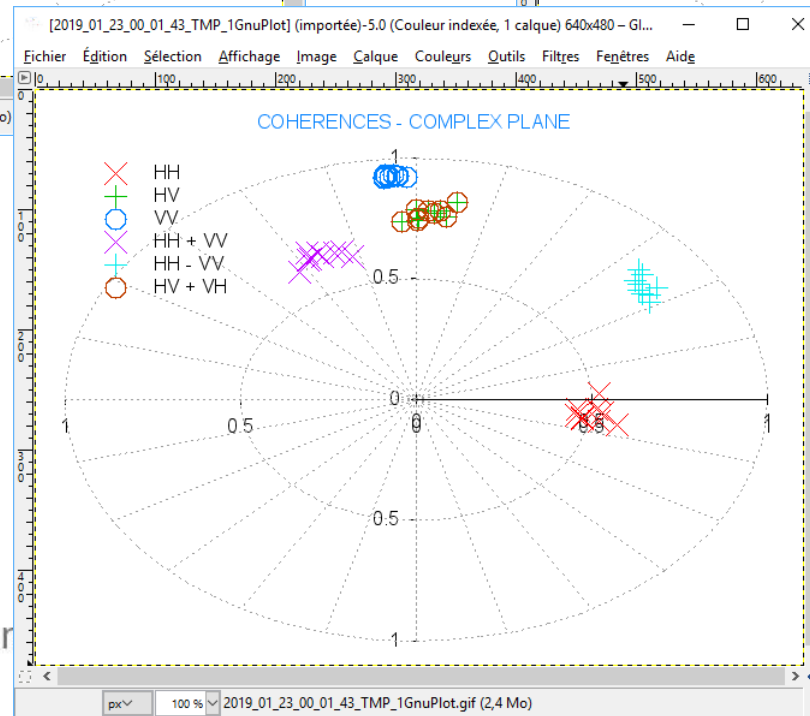
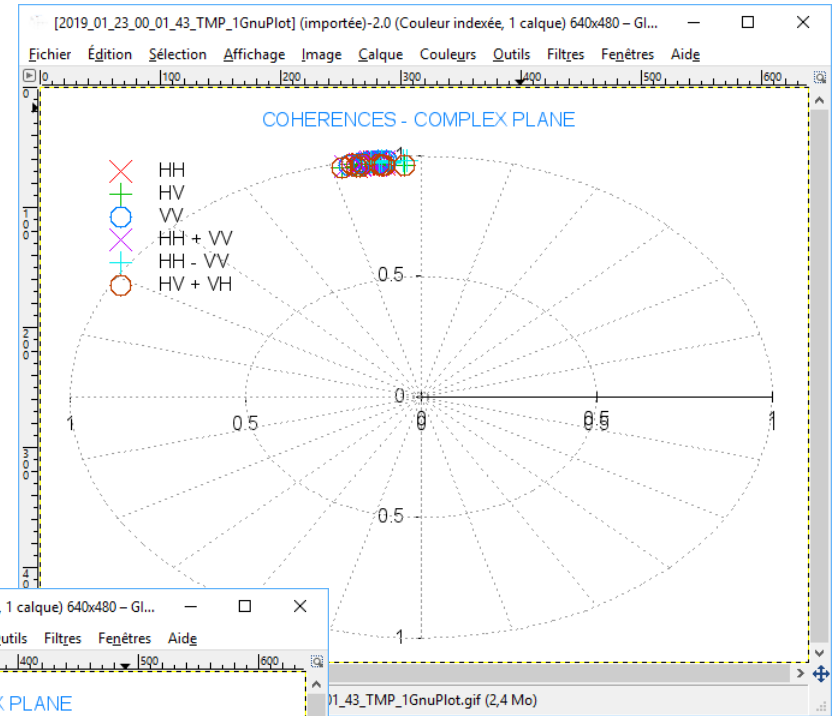
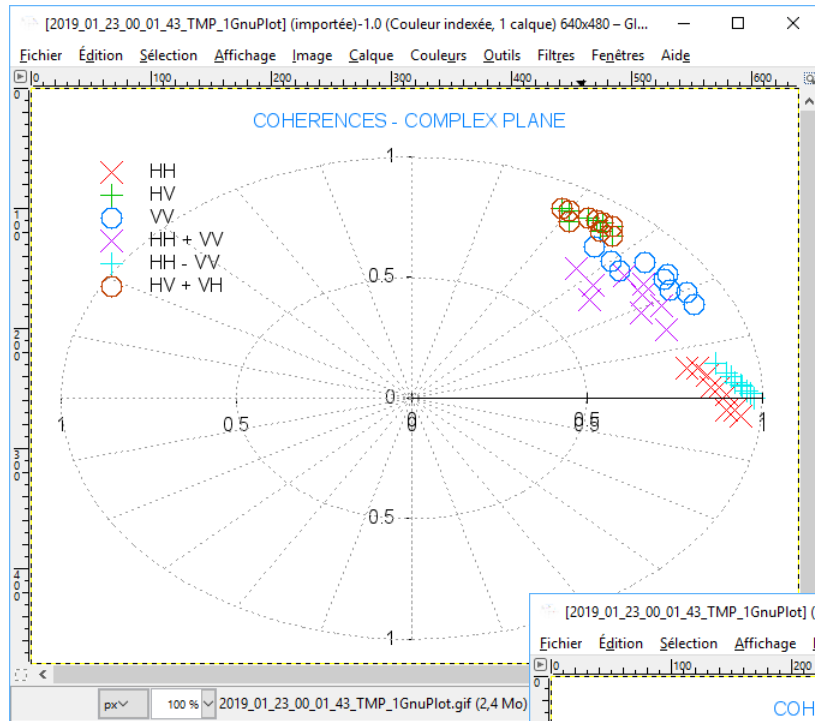
- Go to Process
- Coherence Analysis
- Complex Plane

Coherence Plane Investigation

- Select an area
- Save the plot with the complex circle

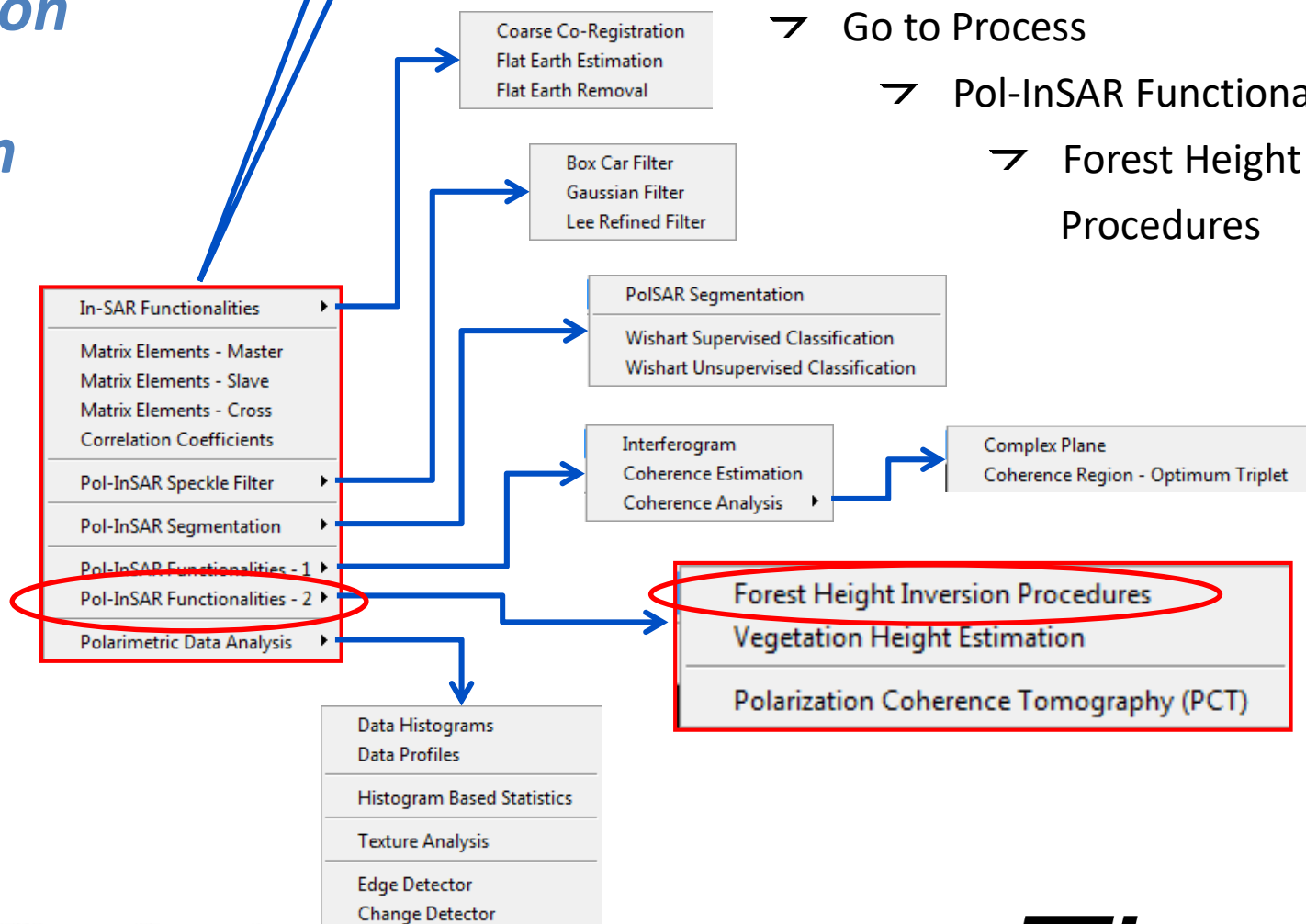


Complex Unit Circle





Vegetation Height Inversion Using K_z



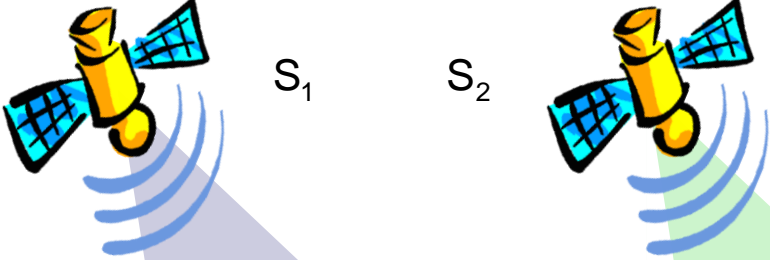
➤ Go to Process

➤ Pol-InSAR Functionalities -2

➤ Forest Height Inversion Procedures

Height Inversion using different Methods

- RVoG Inversion
 - 2-Layer inversion model (standard):
Parameter space: ground/volume ratio, underlying topography, height, extinction
- Coherence Height
 - Amplitude inversion, assumption only volume scattering is present, procedure uses coherence to kz (0 s) inversion according to a sinc function
- Phase Center Heights (HH)
 - Based on the inversion of the scattering phase centers – simple conversion into height
- DEM Difference Heights
 - Based on the difference of two polarisation channels (phase location between volume and ground)

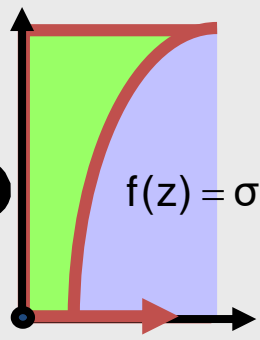
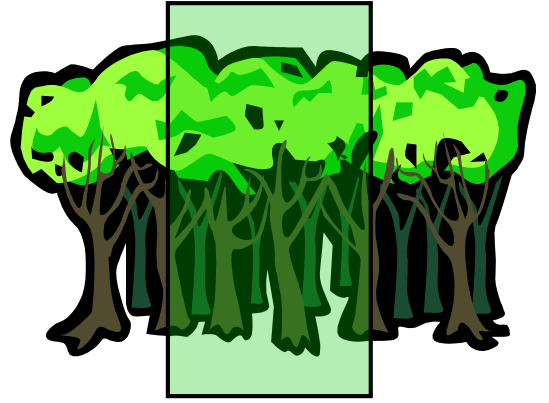
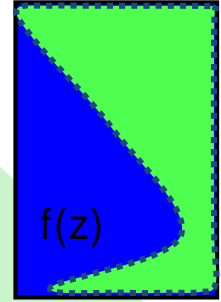


Interferometric
Coherence

$$\tilde{\gamma}(S_1 S_2) = \frac{\langle S_1 S_2^* \rangle}{\sqrt{\langle S_1 S_1^* \rangle \langle S_2 S_2^* \rangle}}$$

Volume
Coherence

$$\tilde{\gamma}_{Vol}(f(z)) = e^{ik_z z_0} \frac{\int_0^{h_v} f(z) e^{ik_z z} dz}{\int_0^{h_v} f(z) dz}$$



2 Layer Scattering Model



$$\tilde{\gamma}(\vec{w}) = \exp(i\varphi_0) \frac{\tilde{\gamma}_V + m(\vec{w})}{1 + m(\vec{w})}$$

Volume
Coherence

$$\tilde{\gamma}_V = \frac{I}{I_0}$$

$$I = \int_0^{h_v} \exp(ik_z z') \exp\left(\frac{2 \sigma z'}{\cos \theta_0}\right) dz'$$

$$I_0 = \int_0^{h_v} \exp\left(\frac{2 \sigma z'}{\cos \theta_0}\right) dz'$$

$$G/V \text{ Ratio: } m(\vec{w}) = \frac{m_G(\vec{w})}{m_V(\vec{w}) I_0}$$

$$\text{Vertical Wavenumber: } k_z = \frac{\kappa \Delta \theta}{\sin(\theta_0)}$$

- Volume Height h_v
- Extinction σ
- Topography φ_0
- G/V Ratio $m(\vec{w})$

Do it yourself!

- Please generate the following products
 - Phase center heights in HH, VV, HV, LL, LR, RR, Opt1, Opt2, Opt3

Height Estimation from Inversion Procedures

Input Master - Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR2019_Datas

Output Master - Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR201 /

Init Row: 1 End Row: 105 Init Col: 1 End Col: 141

Update List

☒ Polarimetric Phase Centre Height Estimation Polarimetric Channel: HH

☐ DEM Differencing Algorithm

☐ Coherence Amplitude Inversion Procedure

☐ Ground Phase Estimation and RVOG Inversion Procedure

Median Window Size: [] [] [] Weighting Coherence Fraction Factor: []

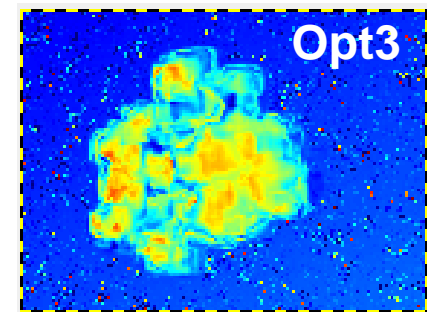
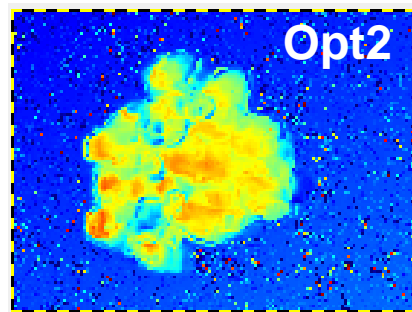
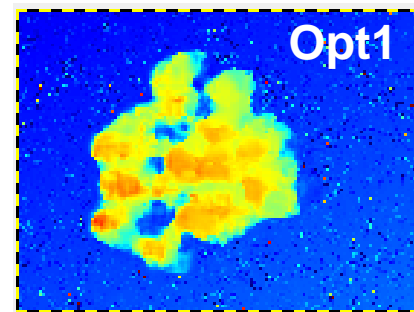
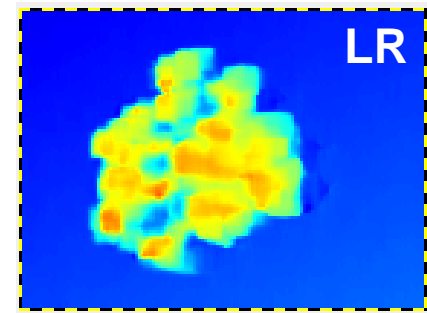
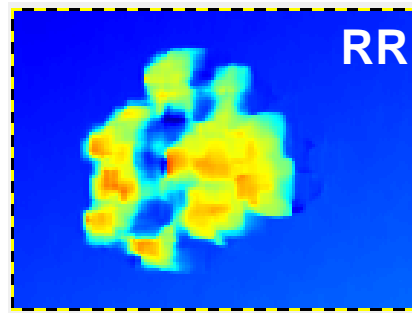
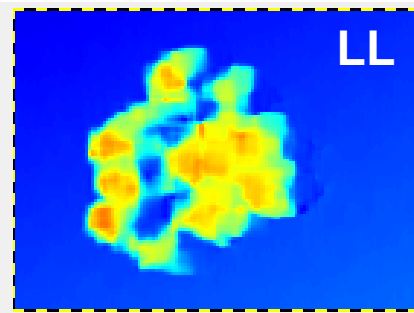
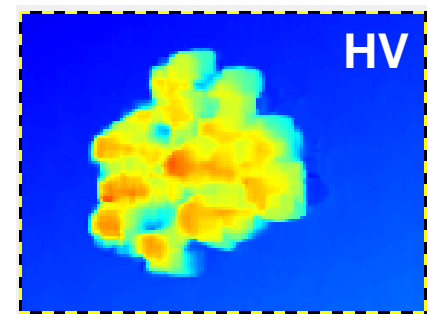
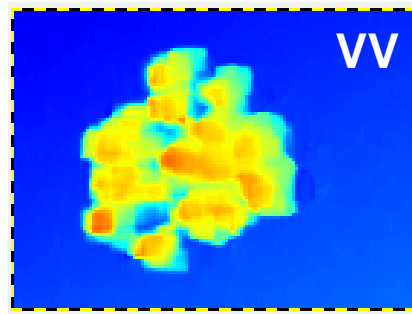
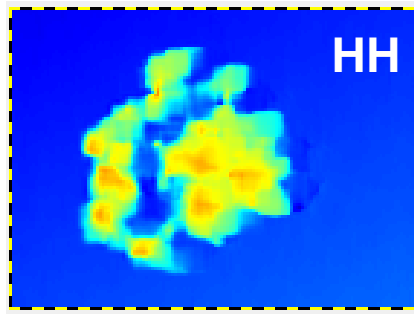
Top Phase Centre: HV Ground Phase Centre: HH + VV

2D Kz File
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR2019_Data

Run Hist [?] Exit

Phase Center Heights [m]

min max
-5 m +25 m



Do it yourself!

- Please generate the following products
 - Compare the different inversion models in terms of height inversion

Height Estimation from Inversion Procedures

Input Master - Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR2019_Datas

Output Master - Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR201 /

Init Row: 1 End Row: 105 Init Col: 1 End Col: 141

Update List

☒ Polarimetric Phase Centre Height Estimation Polarimetric Channel: HH

☒ DEM Differencing Algorithm

☒ Coherence Amplitude Inversion Procedure

☒ Ground Phase Estimation and RVOG Inversion Procedure

Median Window Size: 11 Weighting Coherence Fraction Factor: 0.5

Top Phase Centre: HV Ground Phase Centre: HH + VV

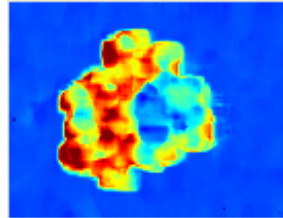
2D Kz File
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR

Run Hist ? Exit

Height Inversion using different Methods

- RVoG Inversion

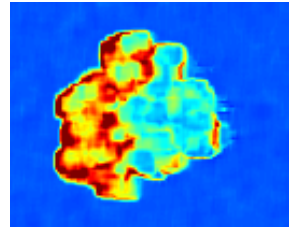
min max
-5 m +25 m



➤ 2-Layer inversion model (standard):
Parameter space: ground/volume ratio,
underlying topography, height,
extinction

- Coherence Height

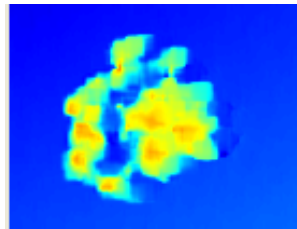
min max
-5 m +25 m



➤ Amplitude inversion, assumption only
volume scattering is present, procedure
uses coherence to RVoG model
predictions (0 s) inversion according to a
sinc function

- Phase Center Heights (HH)

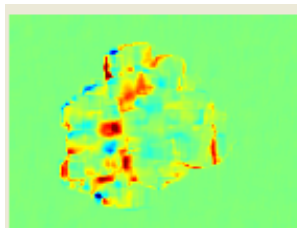
min max
-5 m +25 m



➤ Based on the inversion of the
scattering phase centers – simple
conversion into height

- DEM Difference Heights

min max
-10 m +10 m



➤ Based on the difference of two
polarisation channels (phase location
between volume and ground)

Do it yourself!

- Please generate the following products
 - Compare the phase center heights (statistics)

Height Estimation from Inversion Procedures

Input Master - Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR2019_Datas

Output Master - Slave Directory
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR201 /

Init Row: 1 End Row: 105 Init Col: 1 End Col: 141

Update List

☒ Polarimetric Phase Centre Height Estimation Polarimetric Channel: HH

☒ DEM Differencing Algorithm

☒ Coherence Amplitude Inversion Procedure

☒ Ground Phase Estimation and RVOG Inversion Procedure

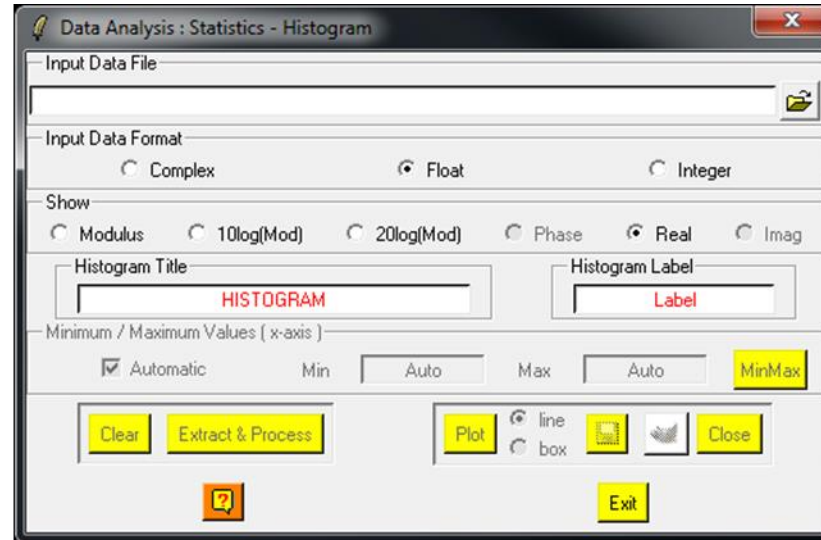
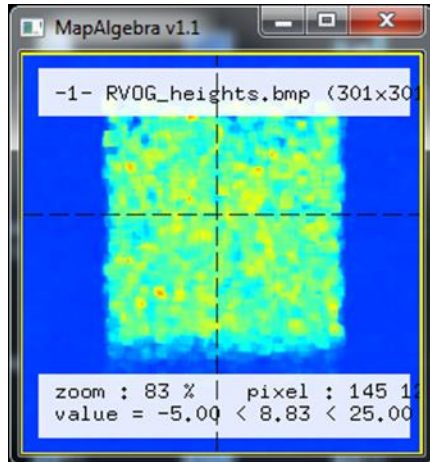
Median Window Size: 11 Weighting Coherence Fraction Factor: 0.5

Top Phase Centre: HV Ground Phase Centre: HH + WV

2D Kz File
C:/POTTIER/RECHERCHE/ESA_Projets/ESA_PolSarPro_2016/ESA_Training_2019/POLINSAR2019_Data

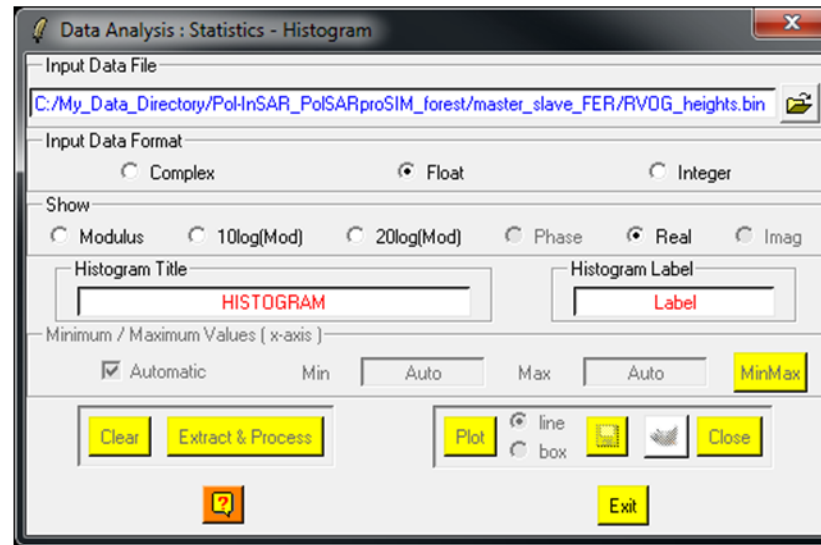
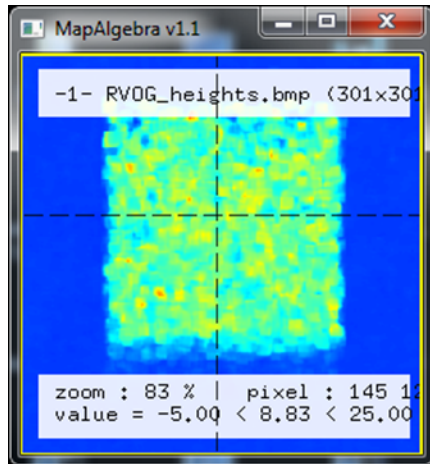
Run Hist ? Exit

Statistics: Histogram for the Vegetation Height



Do it Yourself:
Step 1 : Select a BMP File

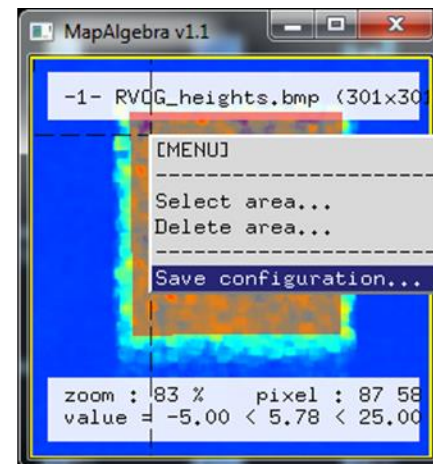
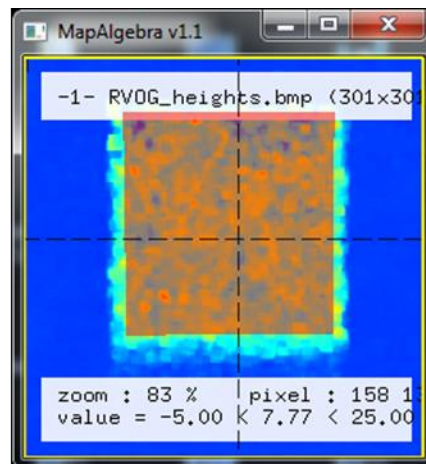
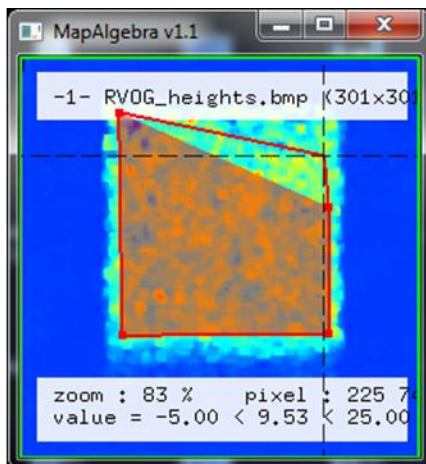
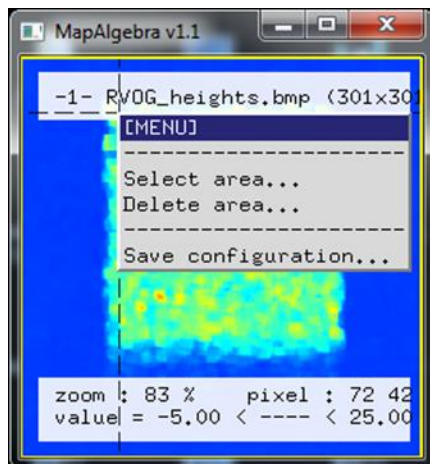
Statistics: Histogram for the Vegetation Height



Do it Yourself:

Step 2 : Select an Input Binary Data File
Select what to *Show*
Enter the *Histogram Title*
Enter the *Histogram Label*

Statistics: Histogram for the Vegetation Height

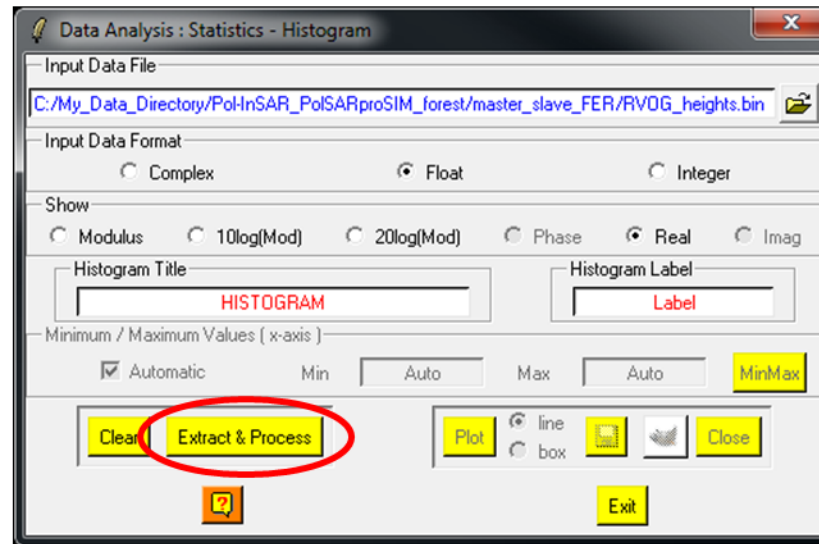
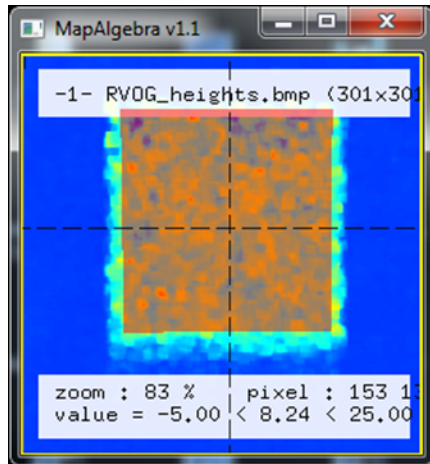


Do it Yourself:

Step 3 : Define the polygon area

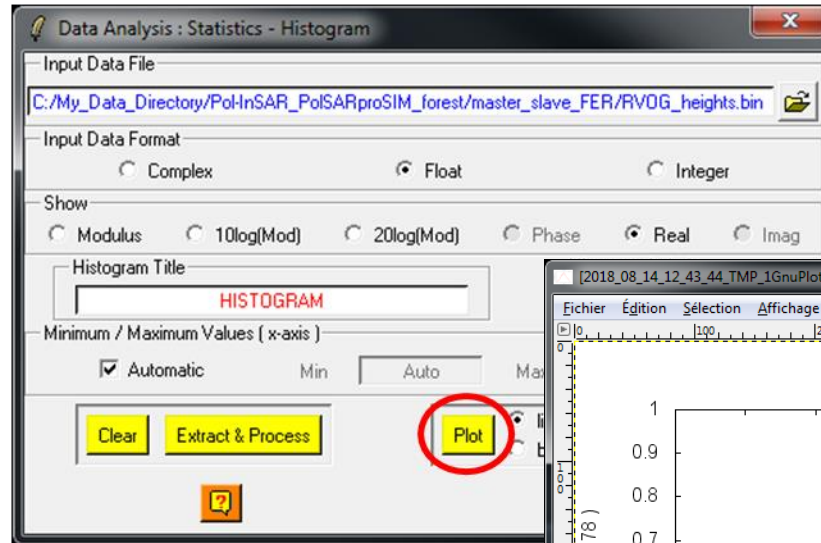
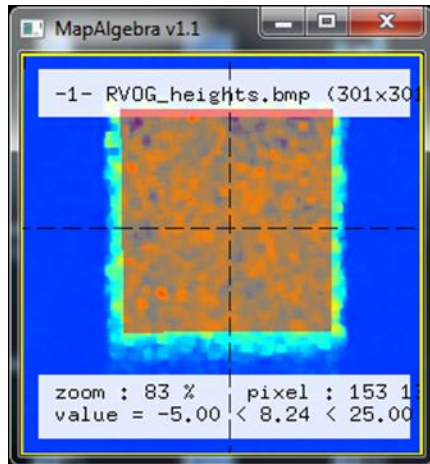
- 1) *Right button* : Select area
- 2) *Left button* : Draw the polygon
- 3) *Enter* : Close the polygon
- 4) *Right button* : Save configuration

Statistics: Histogram for the Vegetation Height

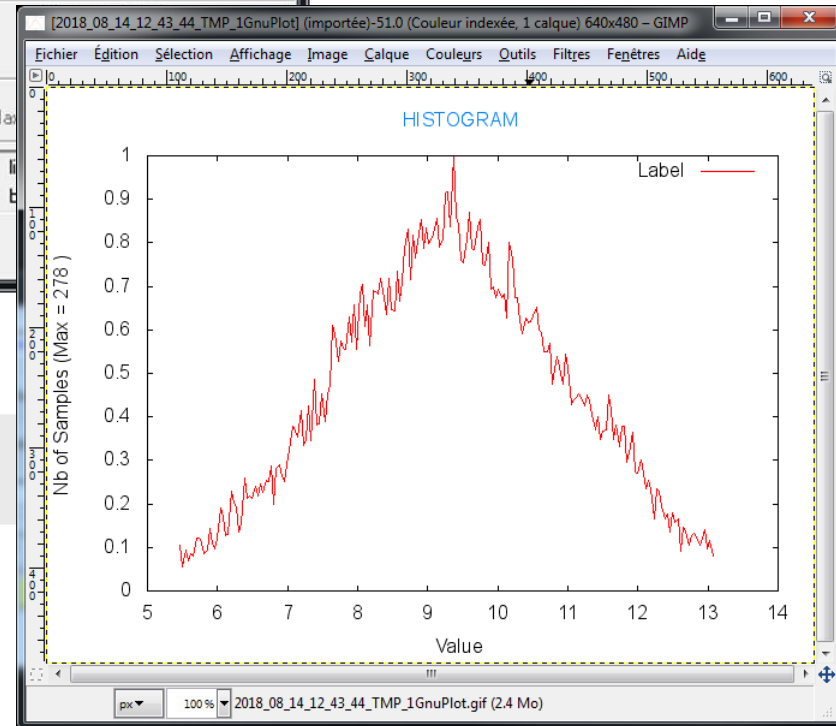


Do it Yourself:
Step 4 : Extract and Process

Statistics: Histogram for the Vegetation Height

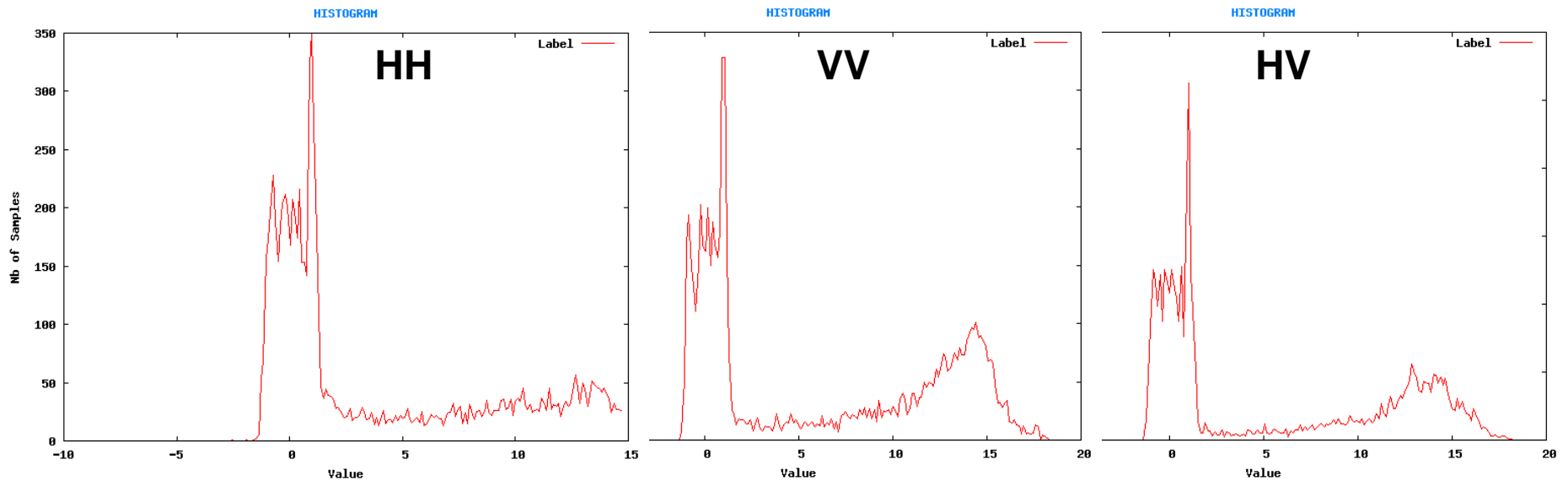
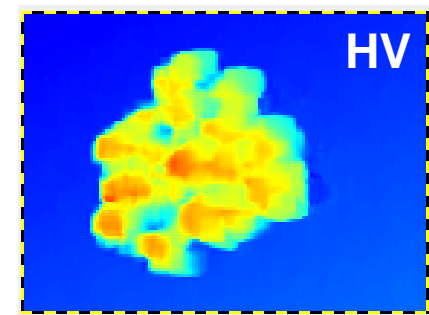
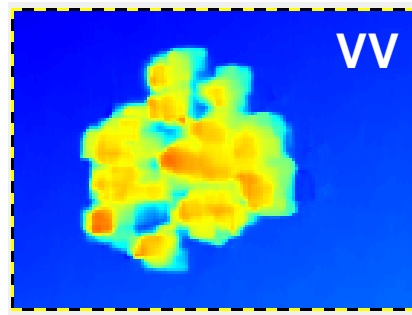
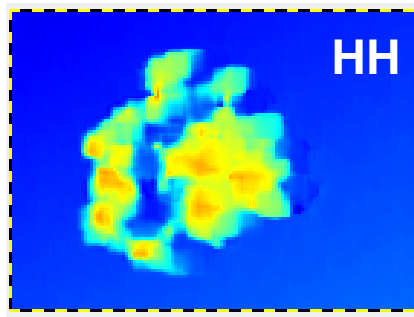


Do it Yourself:
Step 5 : Plot the histogram



Phase Center Heights

min max
-5 m +25 m

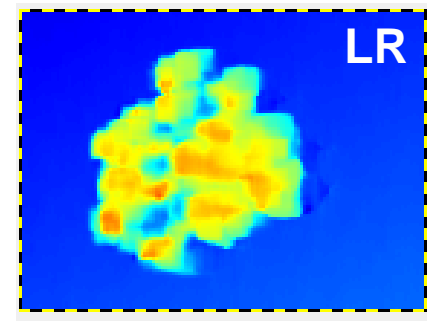
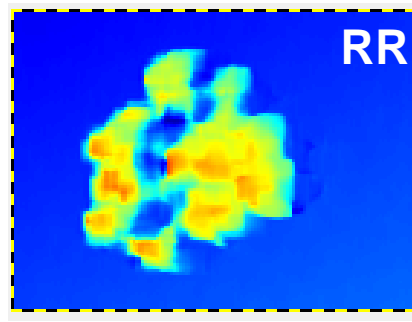
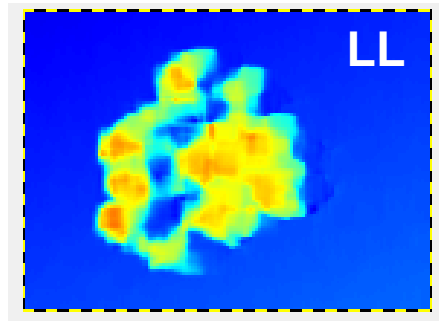


primarily ground contribution

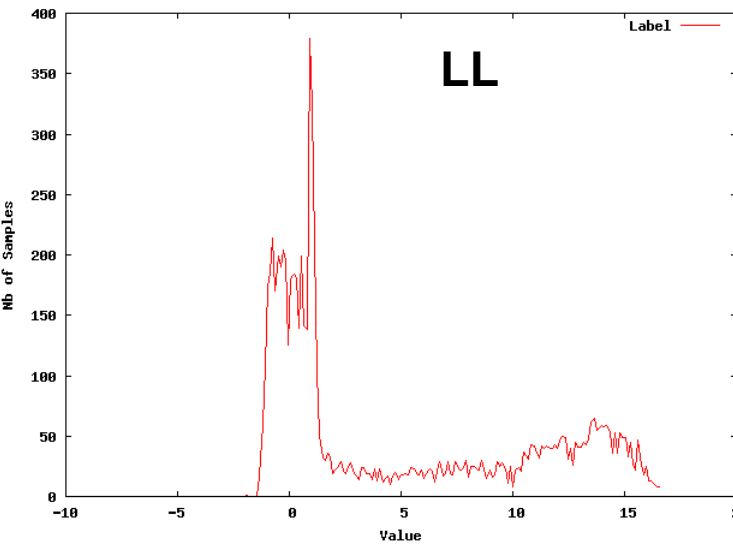
primarily volume contribution

Phase Center Heights

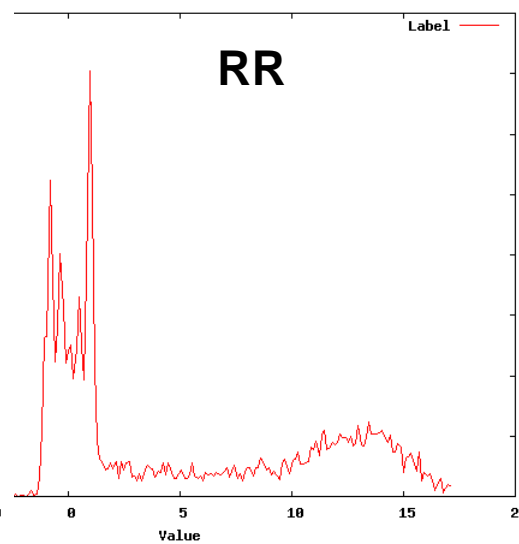
min max
-5 m +25 m



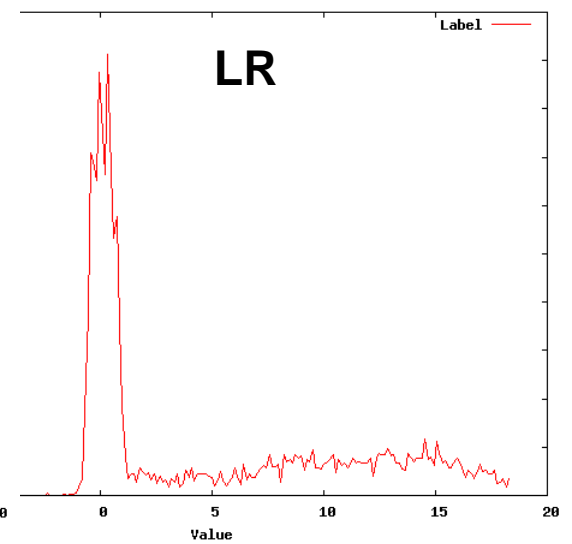
HISTOGRAM



HISTOGRAM

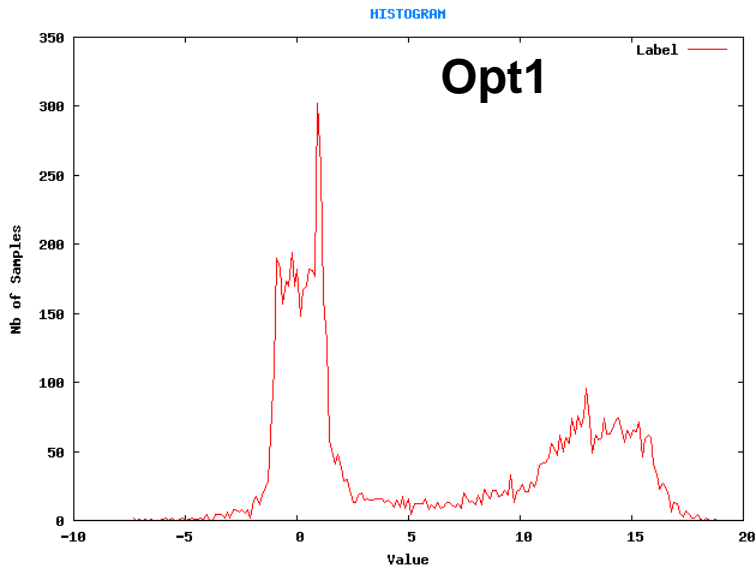
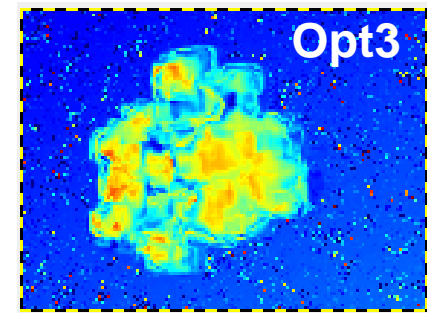
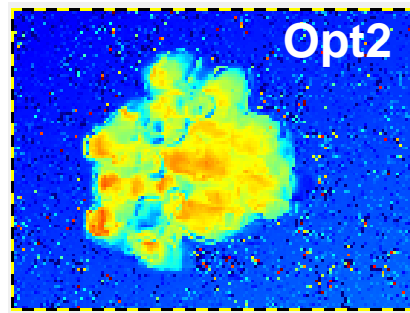
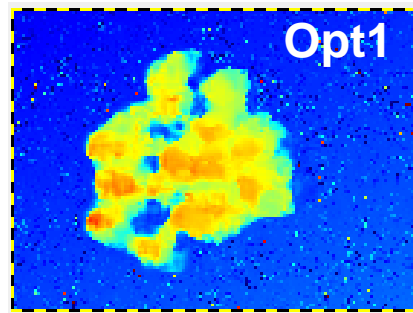


HISTOGRAM

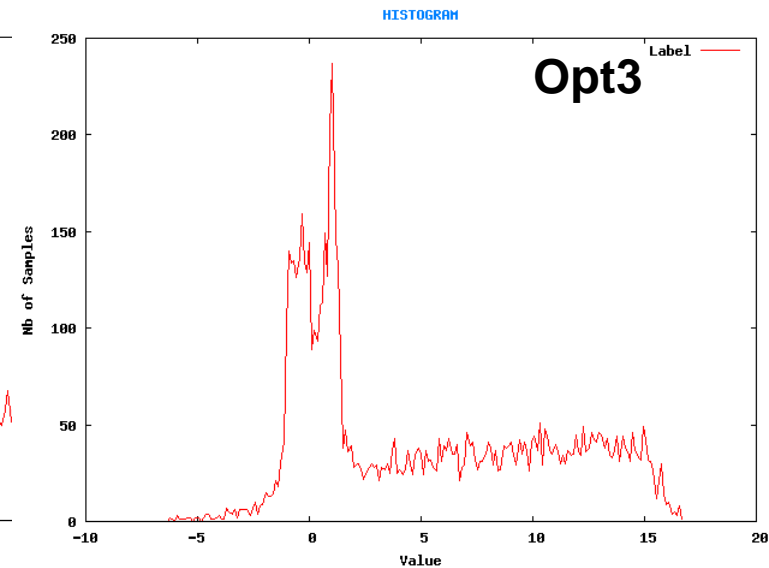
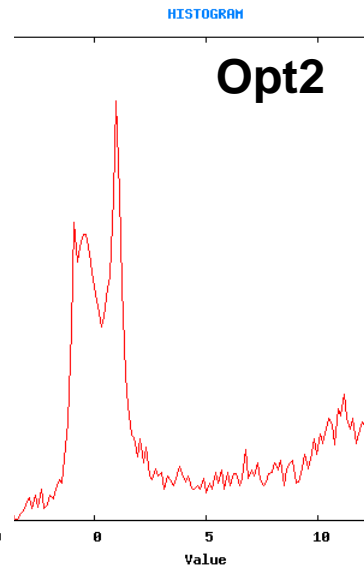


Phase Center Heights

min max
-5 m +25 m



primarily ground contribution

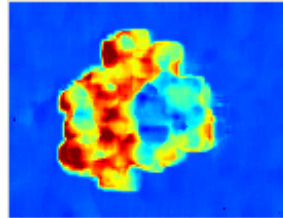


primarily volume contribution

Height Inversion using different Methods

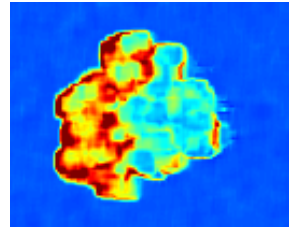
- RVoG Inversion

min max
-5 m -5 m +25 m



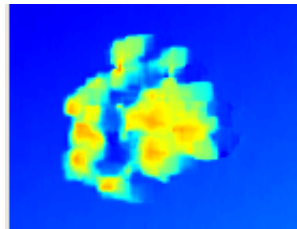
- Coherence Height

min max
-5 m -5 m +25 m



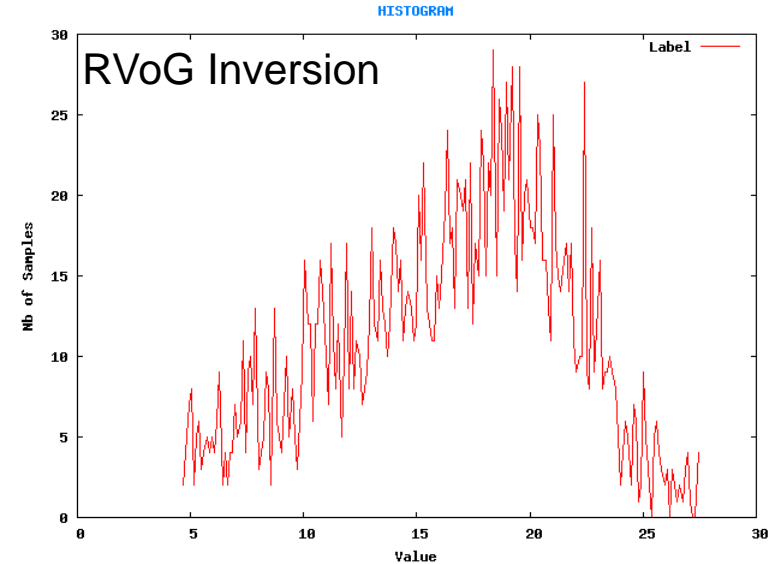
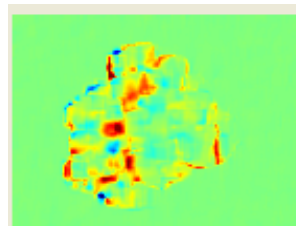
- Phase Center Heights (HH)

min max
-5 m -5 m +25 m



- DEM Difference Heights

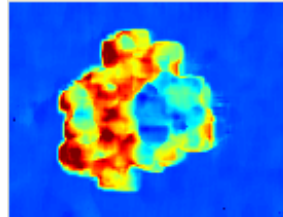
min max
-10 m -10 m +10 m



Height Inversion using different Methods

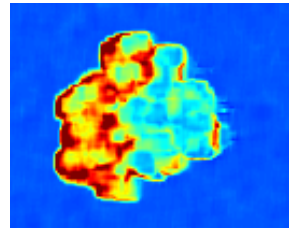
- RVoG Inversion

min max
-5 m +25 m



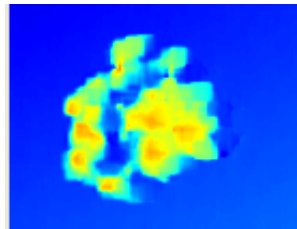
- Coherence Height

min max
-5 m +25 m



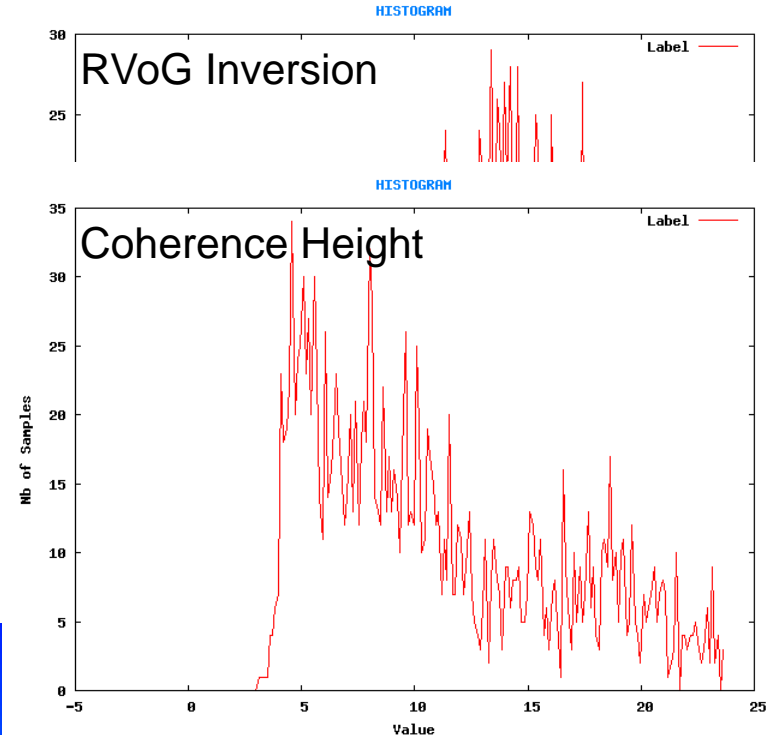
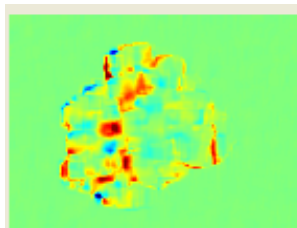
- Phase Center Heights (HH)

min max
-5 m +25 m



- DEM Difference Heights

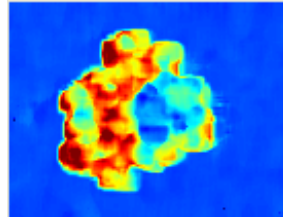
min max
-10 m +10 m



Height Inversion using different Methods

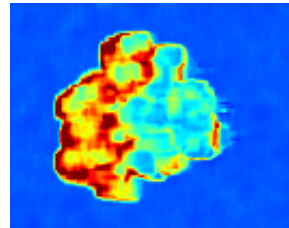
- RVoG Inversion

min max
-5 m +25 m



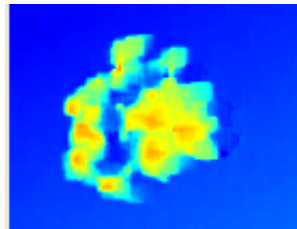
- Coherence Height

min max
-5 m +25 m



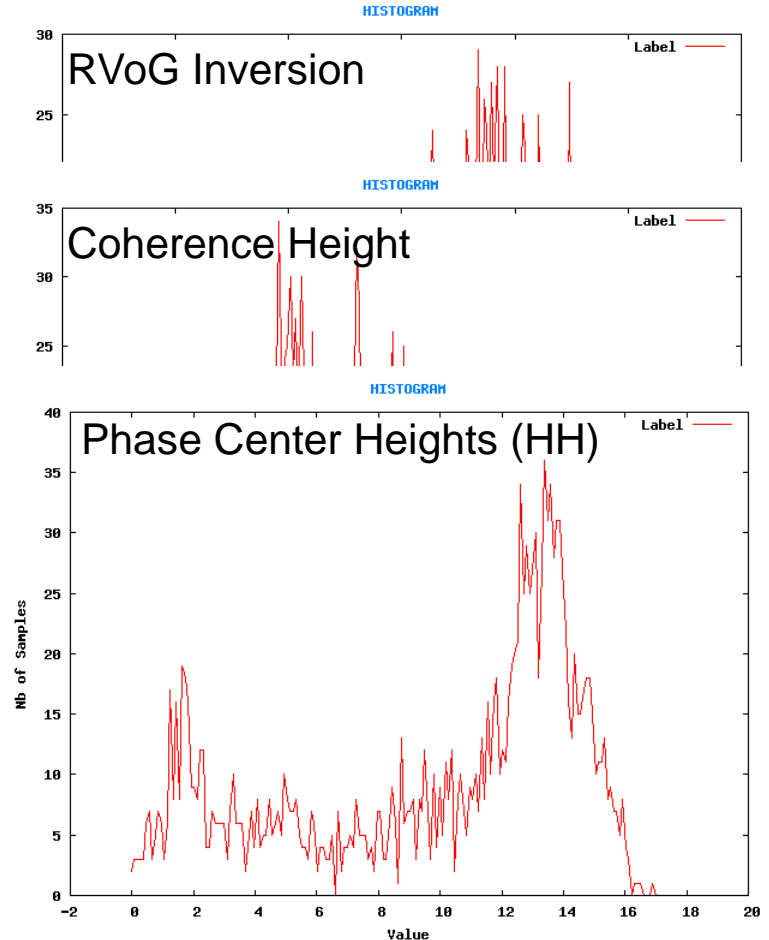
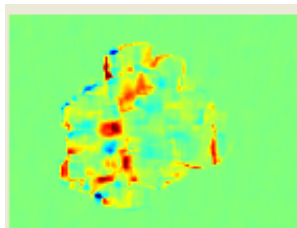
- Phase Center Heights (HH)

min max
-5 m +25 m



- DEM Difference Heights

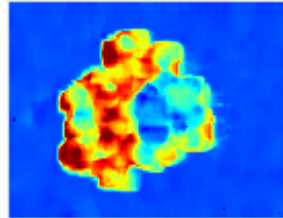
min max
-10 m +10 m



Height Inversion using different Methods

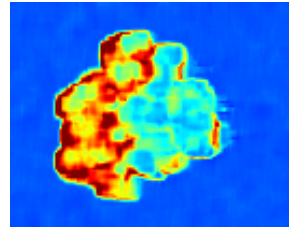
- RVoG Inversion

min max
-5 m +25 m



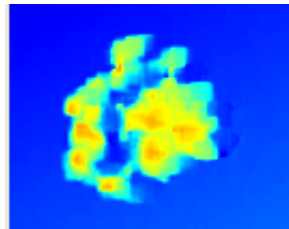
- Coherence Height

min max
-5 m +25 m



- Phase Center Heights (HH)

min max
-5 m +25 m



- DEM Difference Heights

min max
-10 m +10 m

