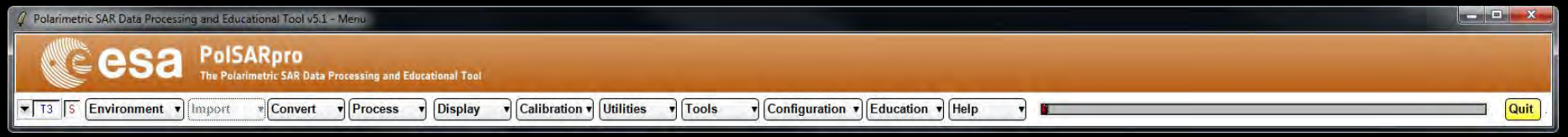
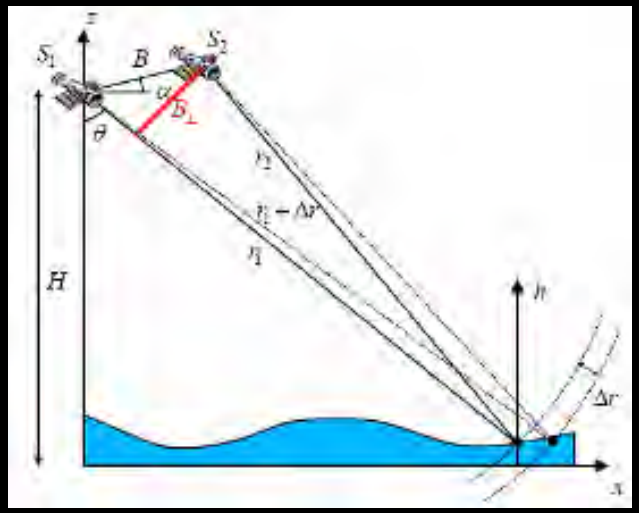
Forest Retrievals using SAR Polarimetry (Practical Session D3P2a)

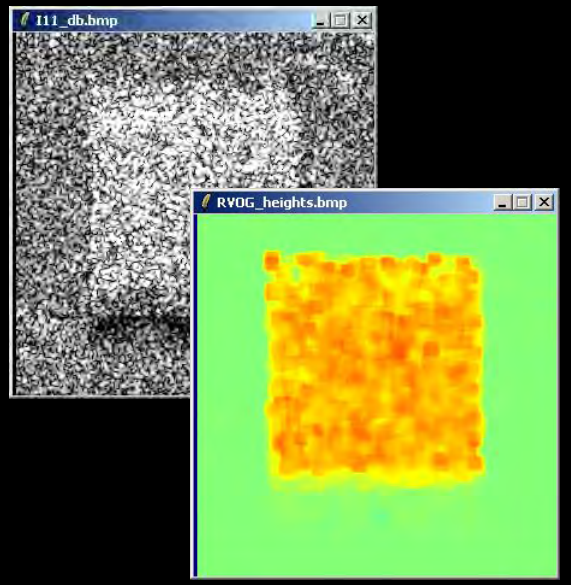
Laurent FERRO-FAMIL - Eric POTTIER

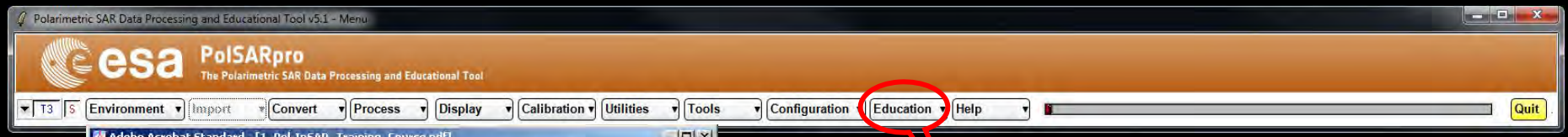
University of Rennes 1

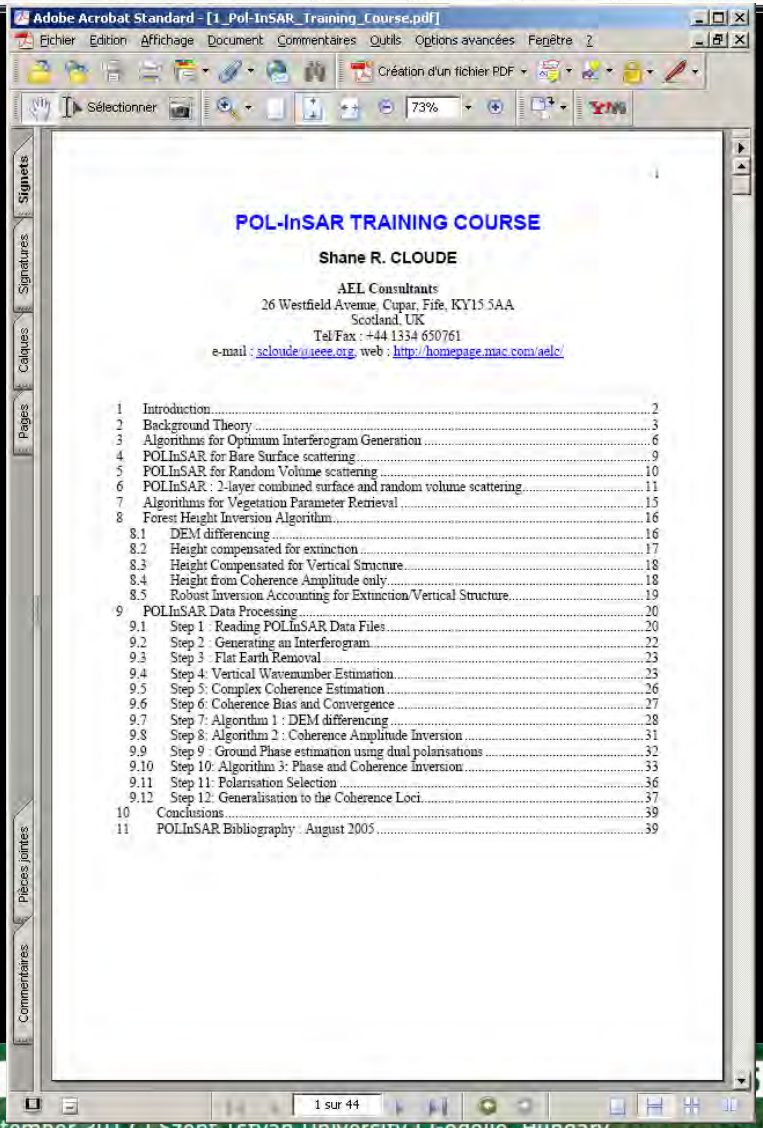


Pol-InSAR Practical
Forest Application







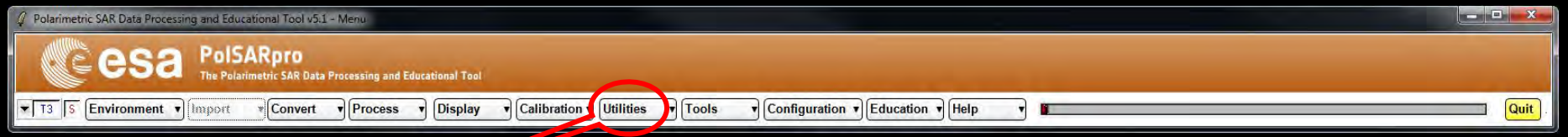


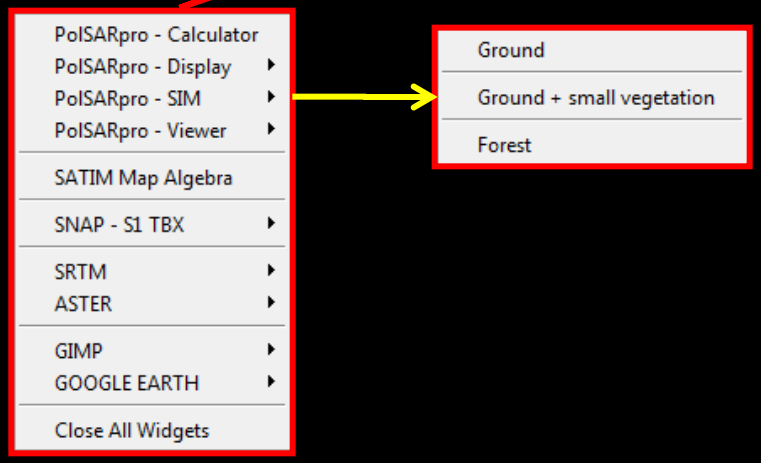
PolSARap Tutorial (C. Lopez - E. Pottier) ▸
PolSARap Showcases
Lectures Notes ▸

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) ▸

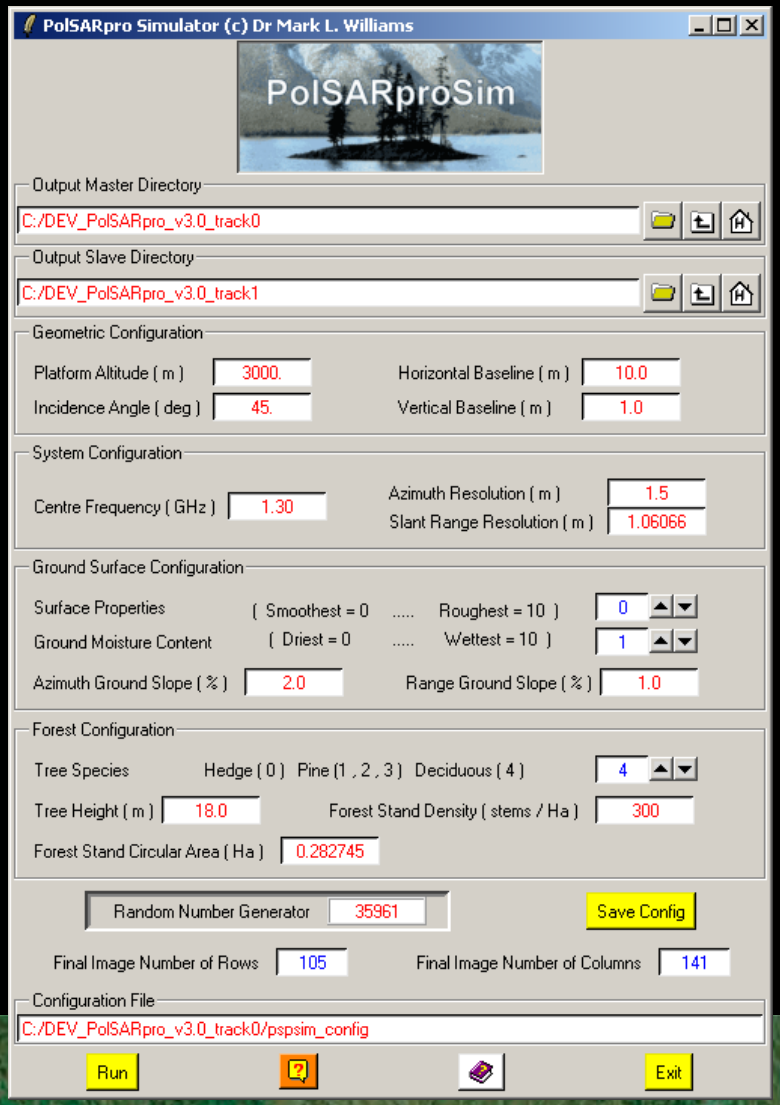
Single vs multi polarization interferometry
Pol-InSAR (Training Course)
Polarization Coherence Tomography (Training Course)

PolSARpro – SIM





PolSARproSim is a rapid, coherent, fully polarimetric and interferometric SAR simulation of forest.

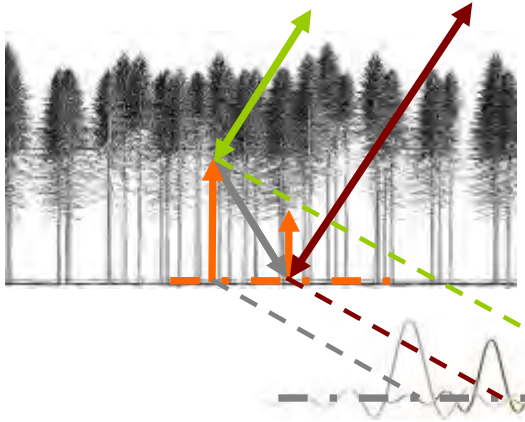


PolSARpro – SIM

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

PINE

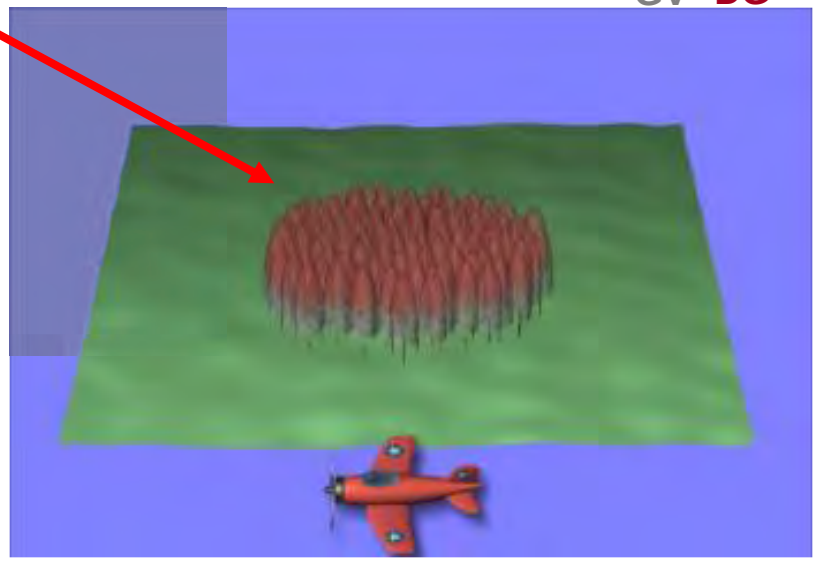
DECIDUOUS



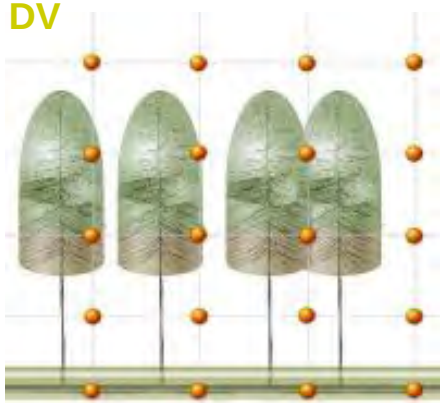
Direct-Ground, Direct-Volume and Ground-Volume contributions are included, with both trees and short vegetation comprising Volume terms.

RANDOM HEDGE

GV DG



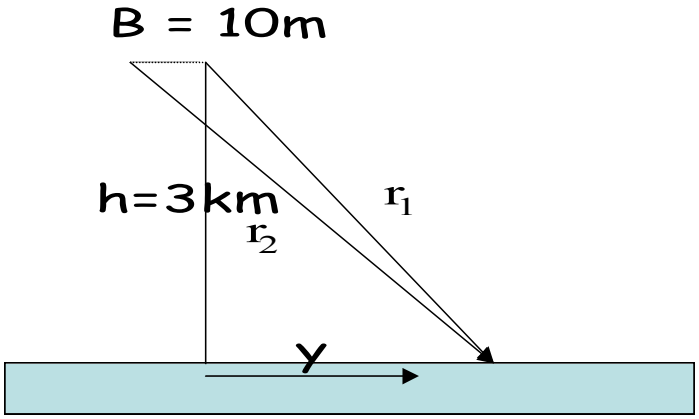
DV

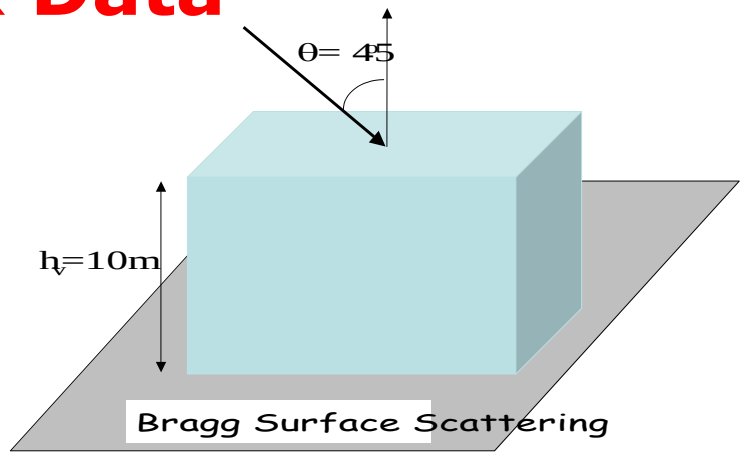


Given the map of tree locations and dimensions a grid of points is used to sample the attenuation of the coherent wave in 3D

PolSARpro – SIM

Pol-InSAR Data





Geometric configuration

Platform altitude :	3000m
Incidence angle:	45°
Horizontal Baseline :	10m
Vertical Baseline :	0m

System Configuration

Frequency :	1.5 GHz
Azimuth resolution :	1.3811 m
Range resolution :	0.6905 m

Ground Surface Configuration

Surface properties :	0 (smoothest)
Ground moisture Content :	0 (driest)
Azimuth / Range ground slope :	0 %

Forest configuration

Tree Species :	0 (hedge)
Tree Height:	10m
Forest stand density :	0.2
Forest Stand Circular Area :	1 Ha

PolSARpro – SIM

Polarimetric SAR Data Processing and Educational Tool v5.1 - Menu

PolSARpro
The Polarimetric SAR Data Processing and Educational Tool

T3 | S | Environment | Import | Convert | Process | Display | Calibration | Utilities | Tools | Configuration | Education | Help | Quit

PolSARpro Simulator (c) Dr Mark L. Williams

PolSARproSim

Output Master Directory: C:/DEV_PolSARpro_v3.0_track0

Output Slave Directory: C:/DEV_PolSARpro_v3.0_track1

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): 0.282745

Random Number Generator: 35961

Save Config

Final Image Number of Rows: 105

Final Image Number of Columns: 141

Configuration File: C:/DEV_PolSARpro_v3.0_track0/pspsim_config

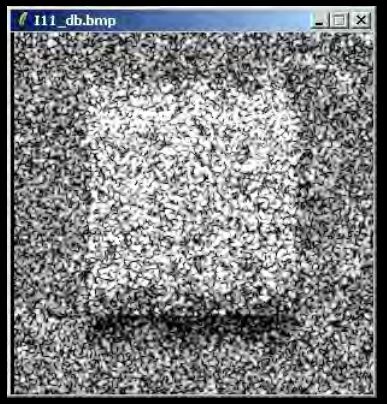
Run | Exit

DATA_MASTERDIR

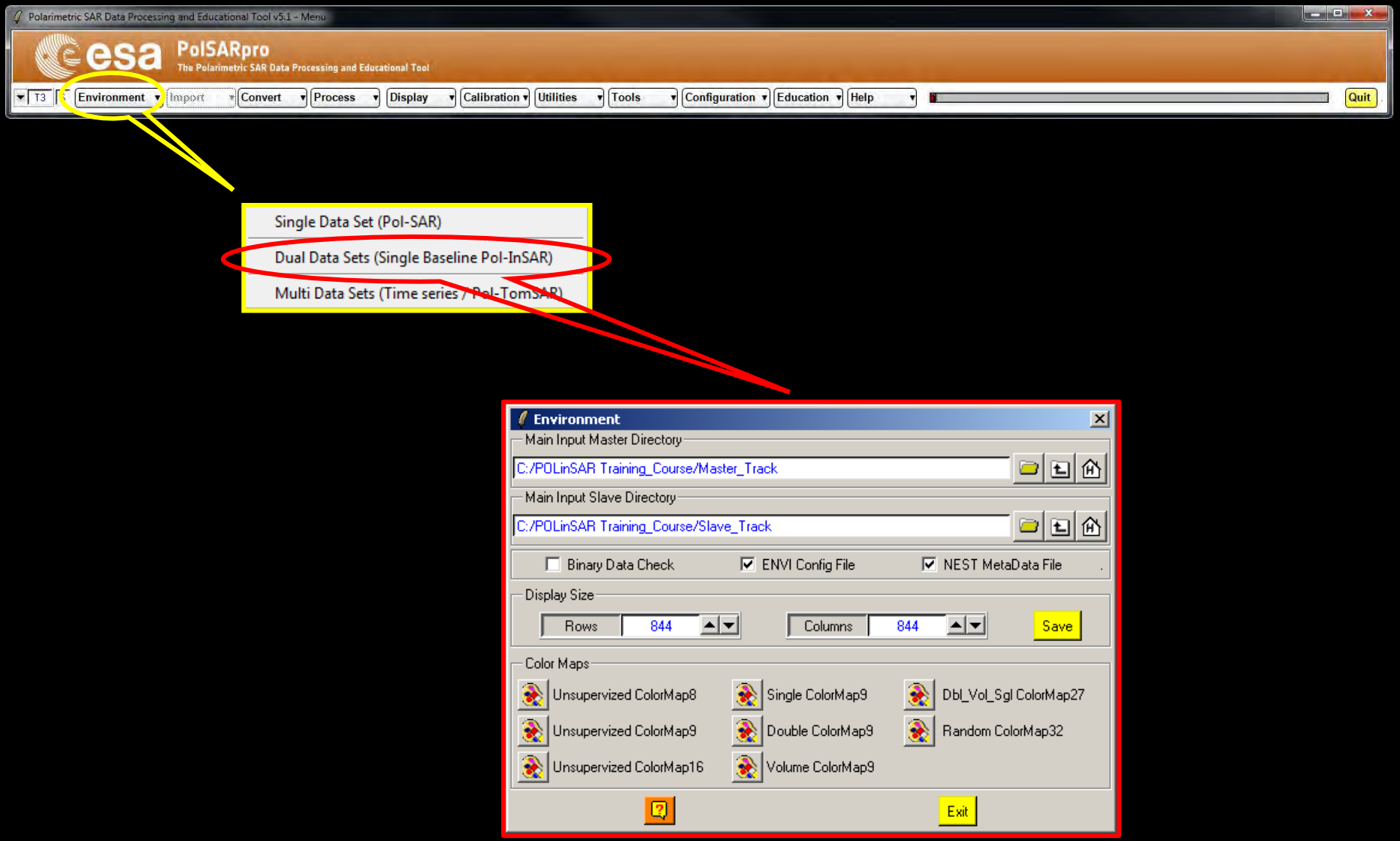
- config.txt
- s11.bin, s12.bin
  s21.bin, s22.bin

DATA_SLAVEDIR

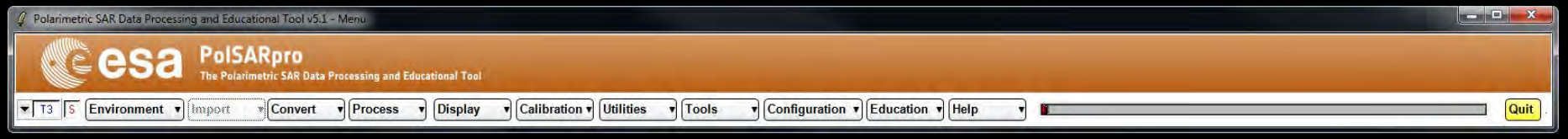
- config.txt
- s11.bin, s12.bin
  s21.bin, s22.bin
- flat_earth.bin
- kz.bin



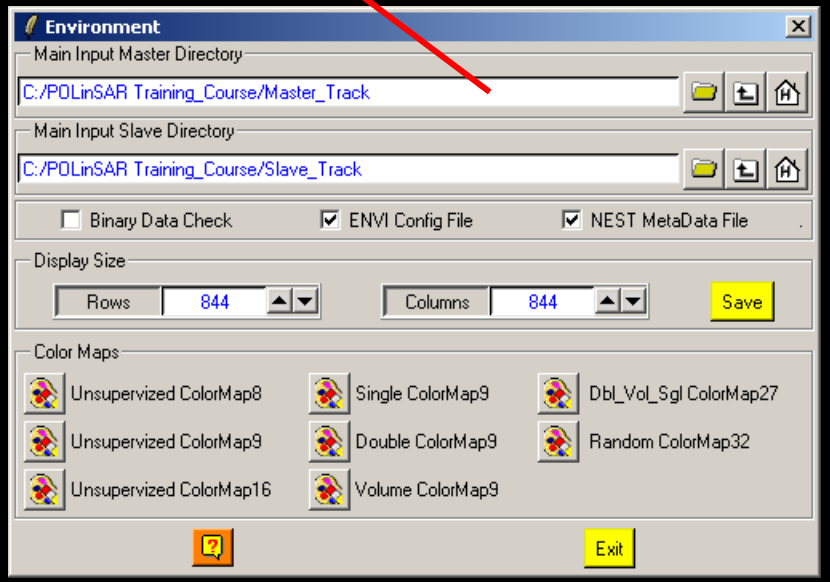
MAIN MENU


Polarimetric SAR Data Processing and Educational Tool v5.1 - Menu
esa PolSARpro
The Polarimetric SAR Data Processing and Educational Tool
T3
Environment
Import
Convert
Process
Display
Calibration
Utilities
Tools
Configuration
Education
Help
Quit
Single Data Set (Pol-SAR)
Dual Data Sets (Single Baseline Pol-InSAR)
Multi Data Sets (Time series / Pol-TomSAR)
Environment
Main Input Master Directory
C:/POLinSAR Training_Course/Master_Track
Main Input Slave Directory
C:/POLinSAR Training_Course/Slave_Track
Binary Data Check
ENVI Config File
NEST MetaData File
Display Size
Rows
844
Columns
844
Save
Color Maps
Unsupervized ColorMap8
Single ColorMap9
Dbl_Vol_Sgl ColorMap27
Unsupervized ColorMap9
Double ColorMap9
Random ColorMap32
Unsupervized ColorMap16
Volume ColorMap9
Exit

ENVIRONMENT



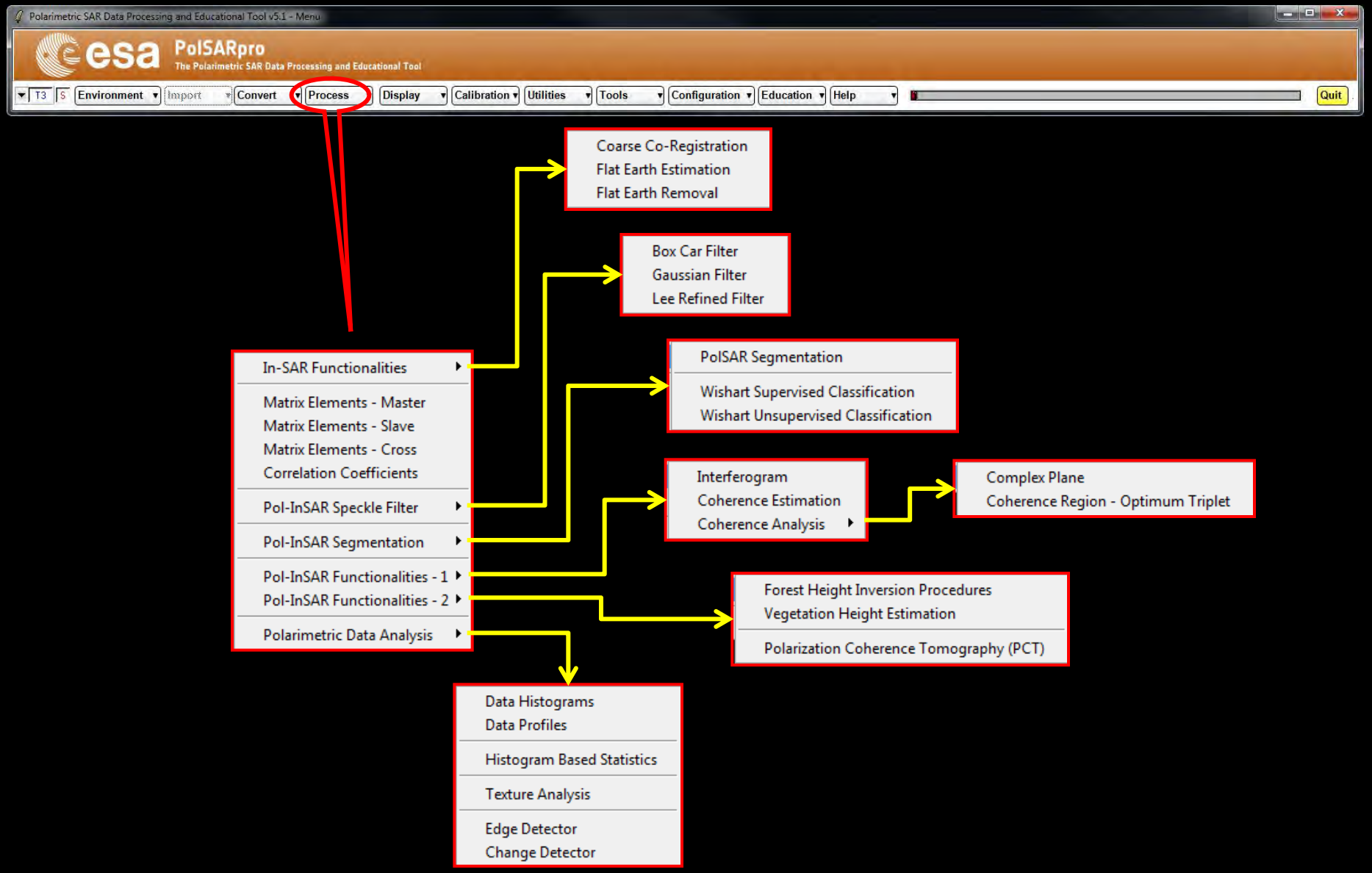
Configure Data Main Directories location



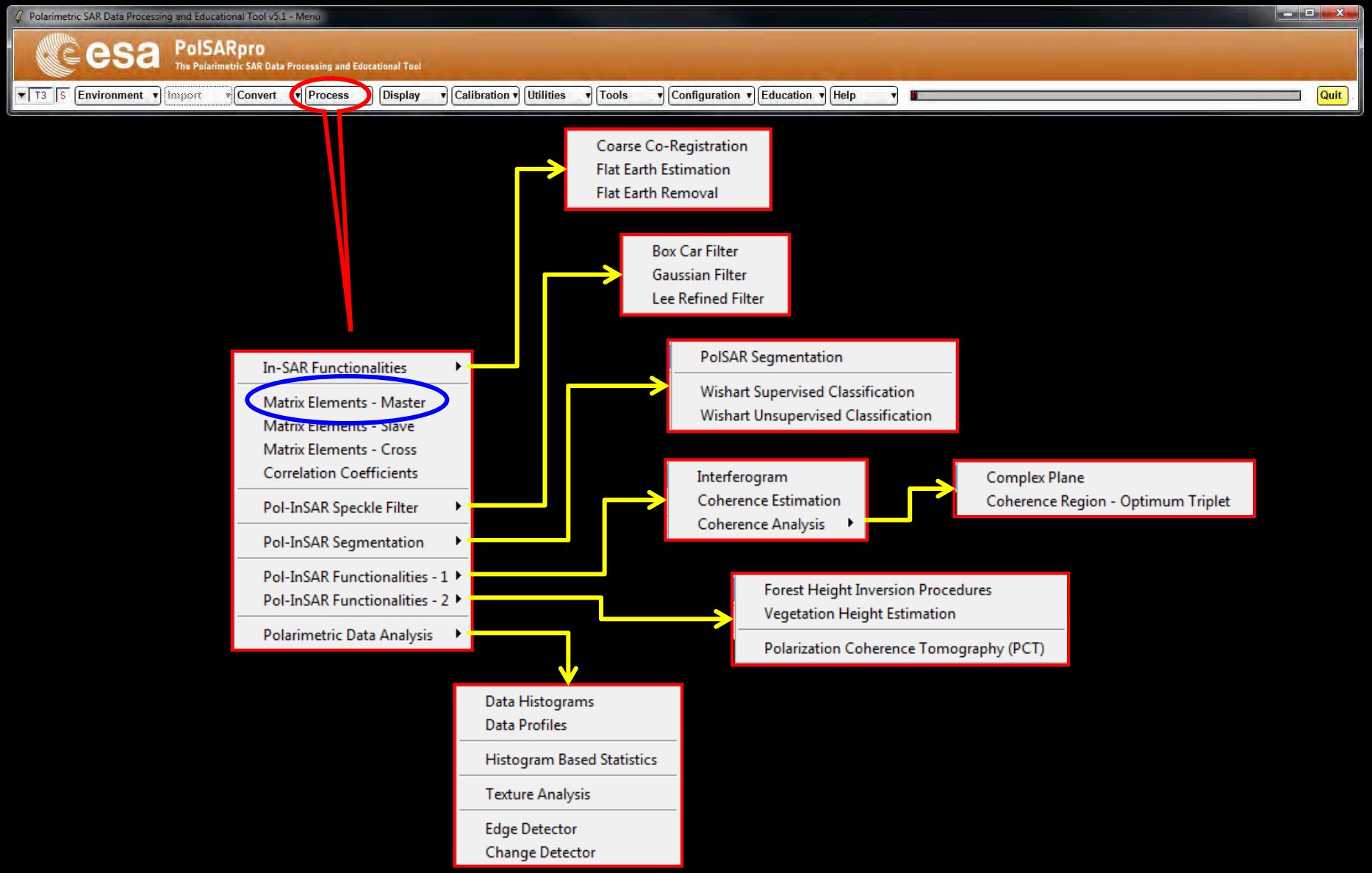
Input Master Directory: C:/Pol-InSAR_Training_Course/Master_Track

Input Slave Directory: C:/Pol-InSAR_Training_Course/Slave_Track

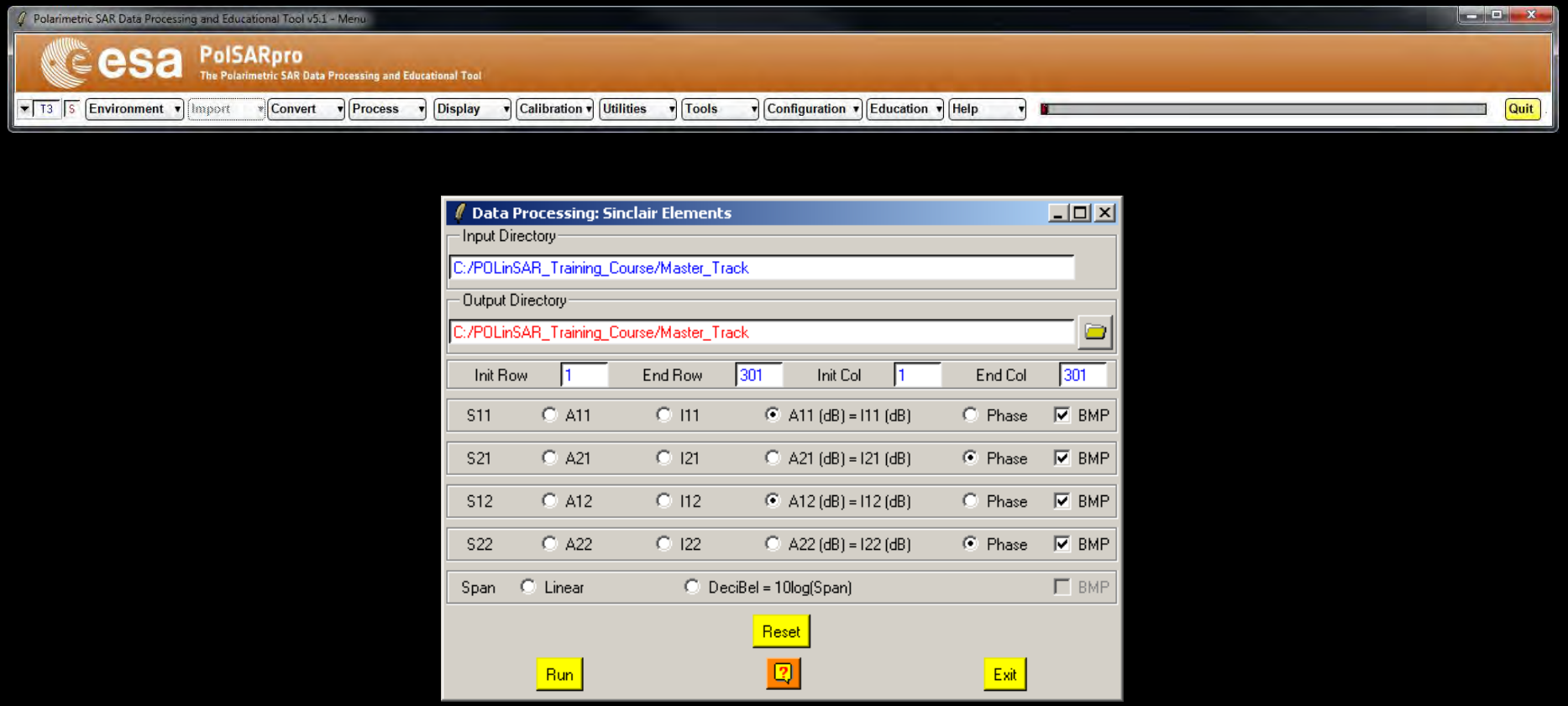
PROCESS DATA



PROCESS DATA

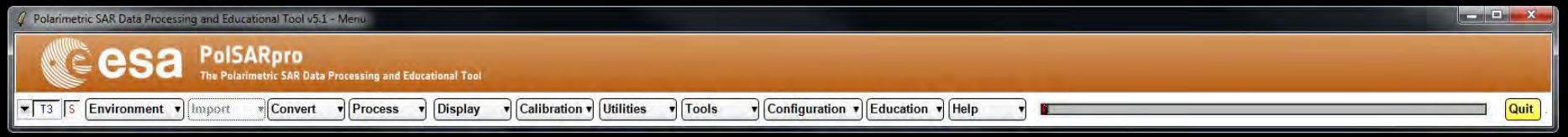


ELEMENTS



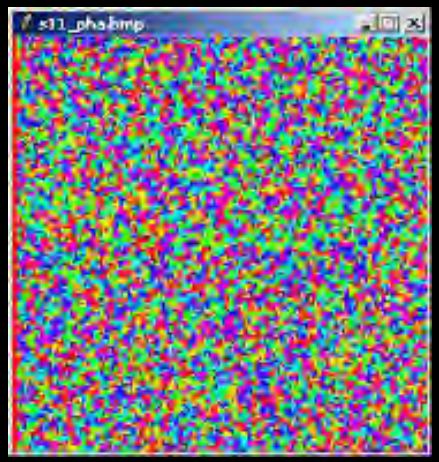
Do it Yourself:
Select some elements, set the parameters and view the corresponding BMP files (select BMP).

ELEMENTS

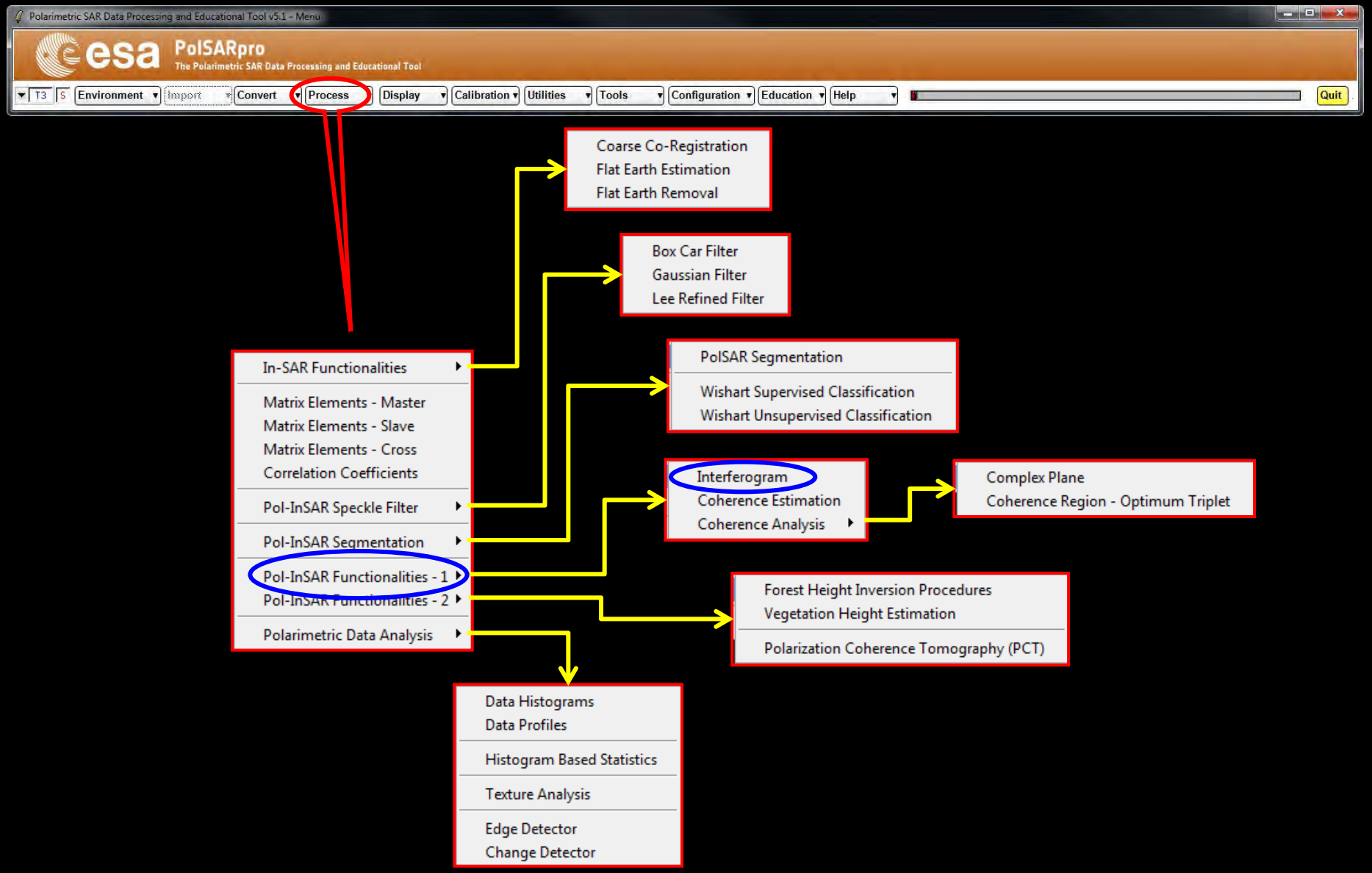


DATA_MASTERDIR

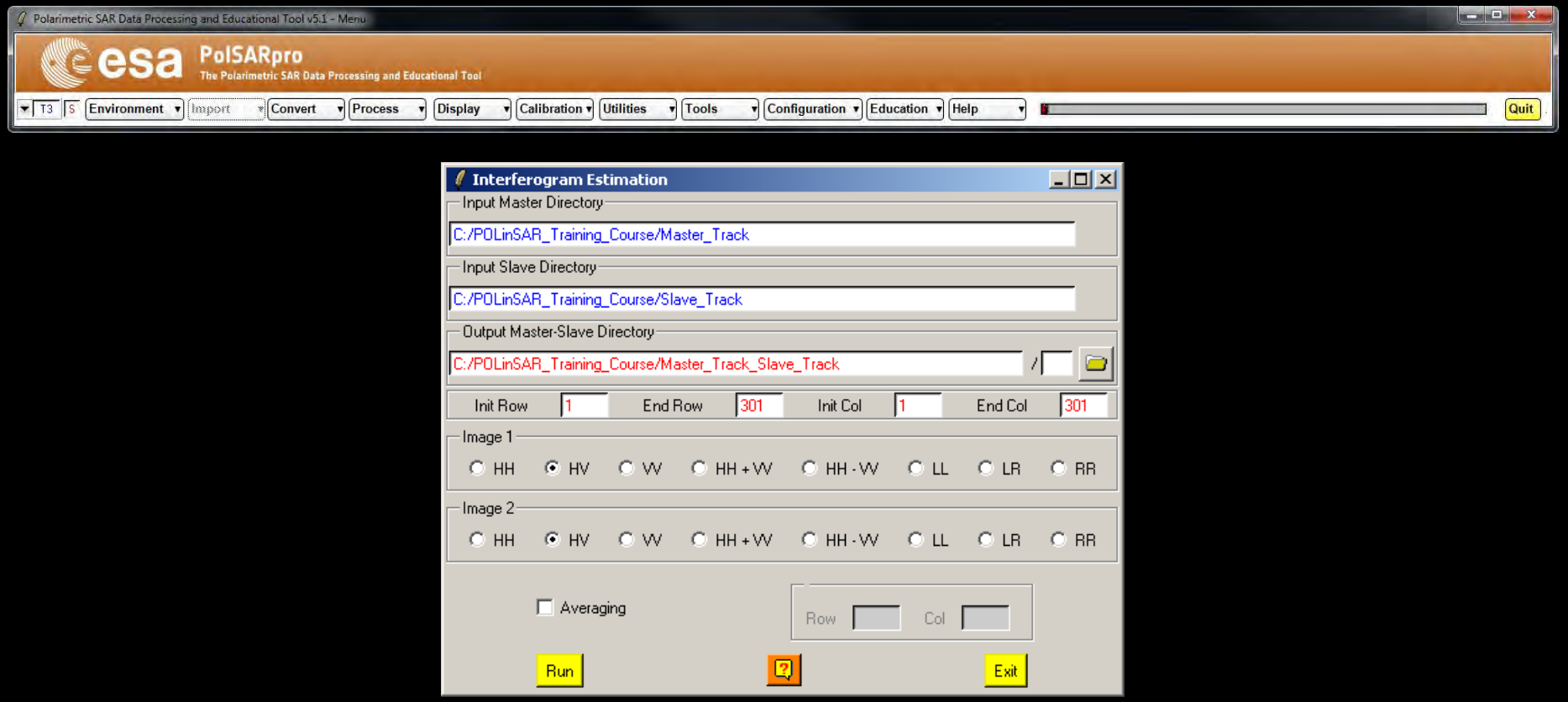
- config.txt
- s11.bin, s12.bin
  s21.bin, s22.bin
- Axy.bin, Ixy.bin
  Ixy_db.bin
  sxy_pha.bin
- Axy.bmp, Ixy.bmp
  Ixy_db.bmp
  sxy_pha.bmp



PROCESS DATA



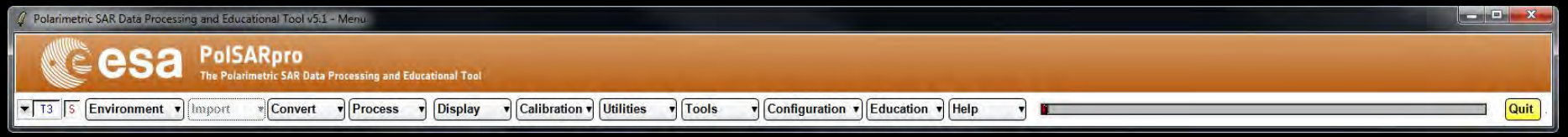
RAW INTERFEROGRAM



Do it Yourself:
Select polarization channels, set the parameters and view the corresponding BMP files.

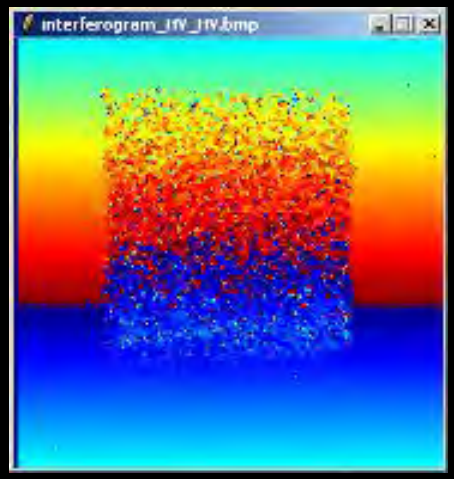
Note:
The Output Directory is automatically set to: MasterDir_SlaveDir

RAW INTERFEROGRAM

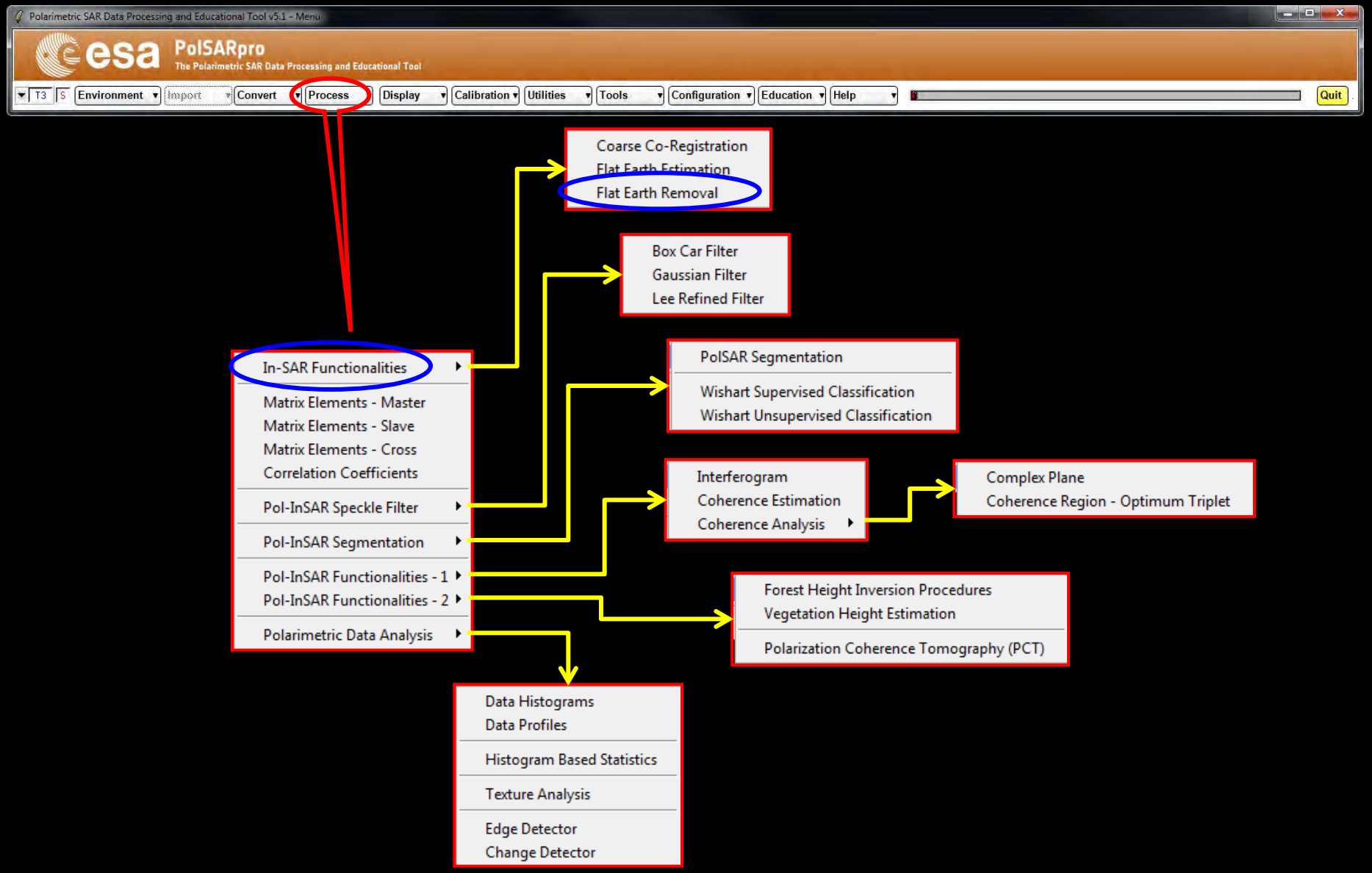


DATA_MASTERDIR_SLAVEDIR

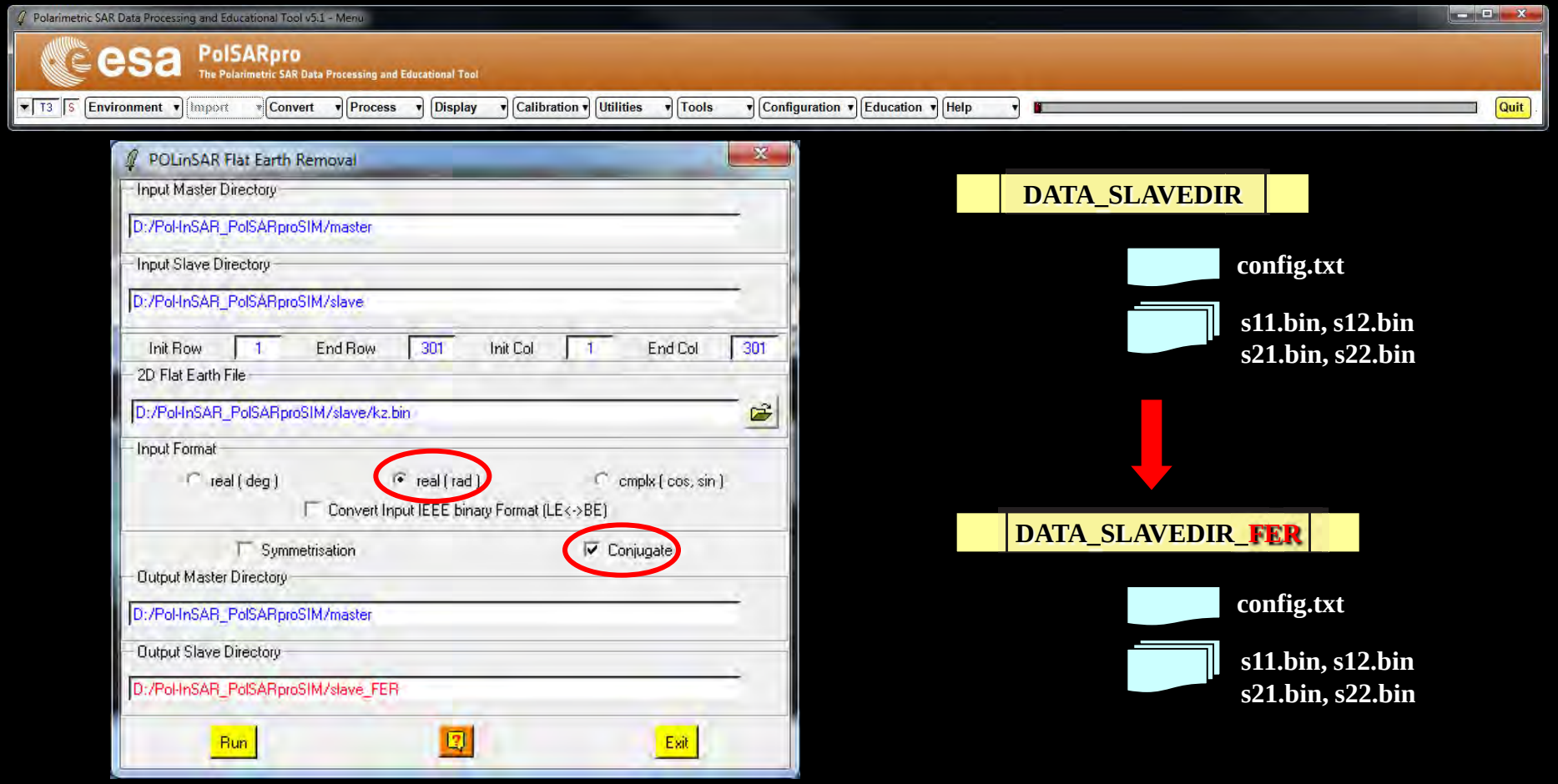
- **config.txt**
- **interferogram_XX_XX.bin**
- **interferogram_XX_XX.bmp**



PROCESS DATA



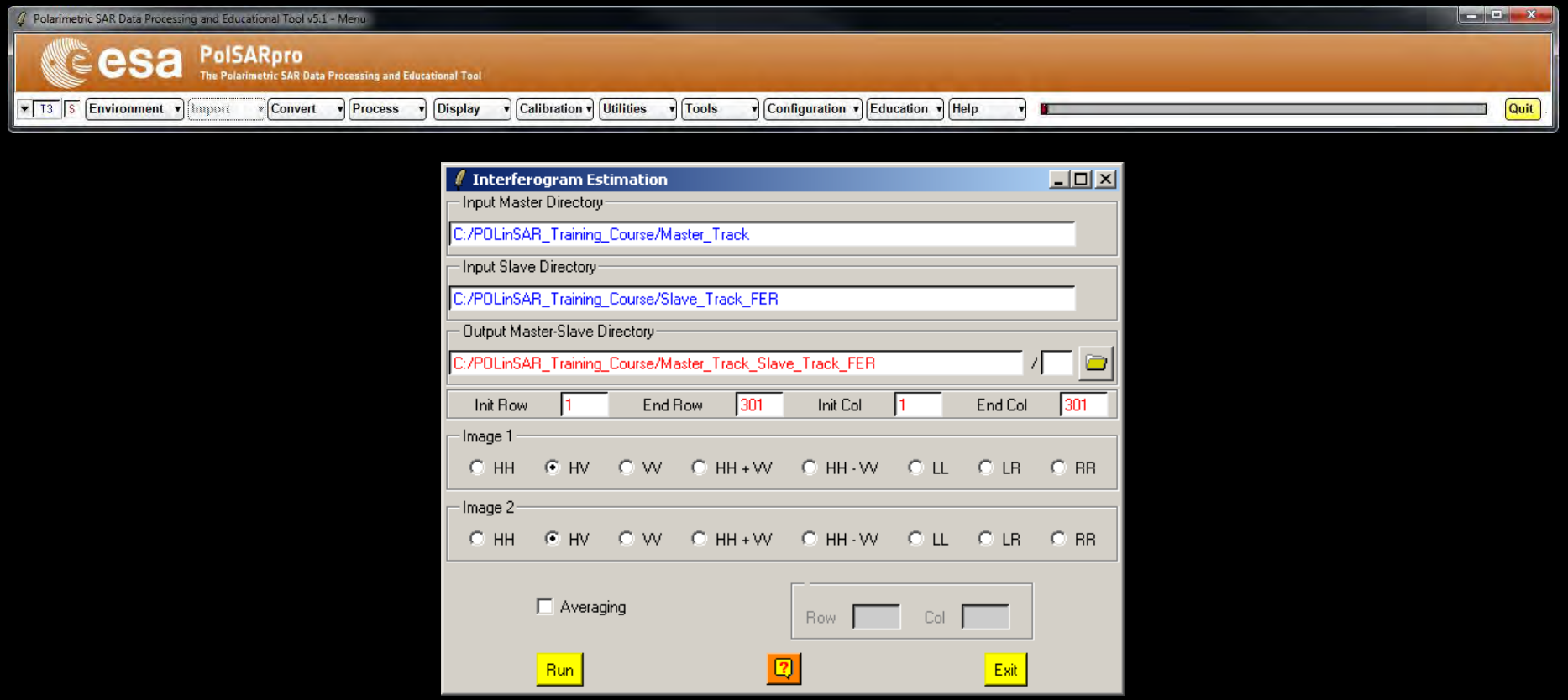
FLAT EARTH REMOVAL



Do it Yourself:
Enter Flat Earth file name, set the parameters and run the function.

Note:
The Input Slave Directory is automatically set to: SlaveDir_FER

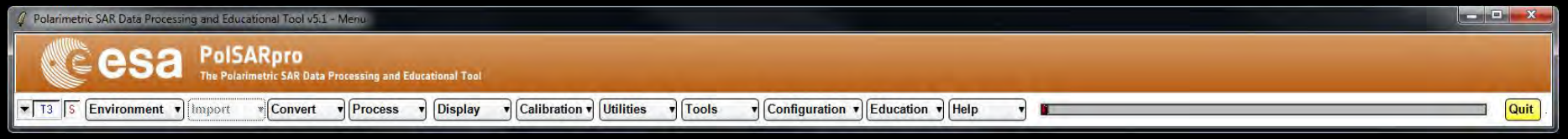
RAW INTERFEROGRAM



Do it Yourself:
Select polarization channels, set the parameters and view the corresponding BMP files.

Note:
The Output Directory is automatically set to: MasterDir_SlaveDir_FER

RAW INTERFEROGRAM

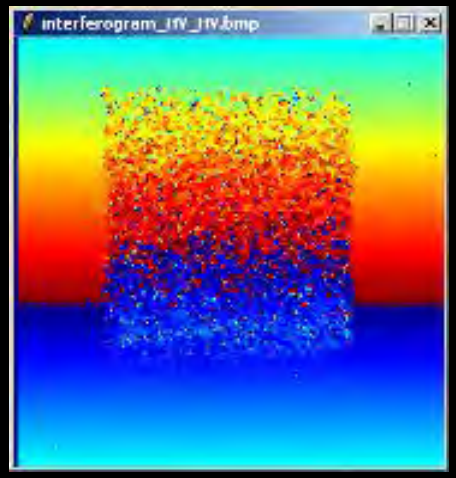


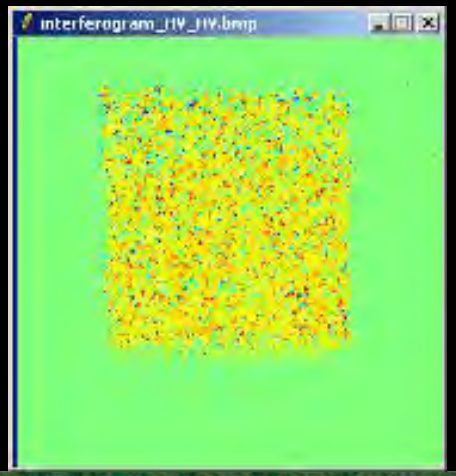
DATA_MASTERDIR_SLAVEDIR_FER

config.txt

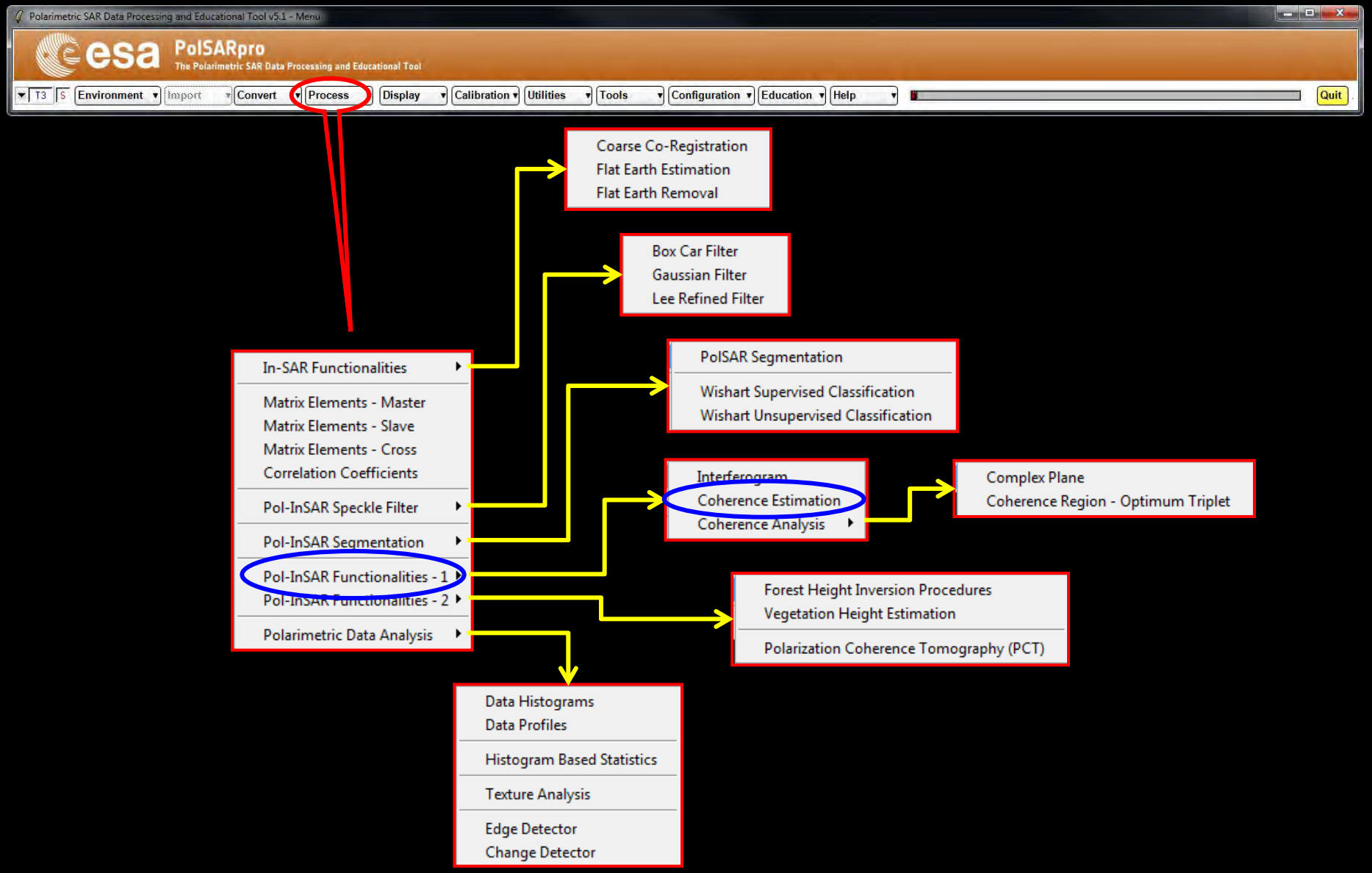
interferogram_XX_XX.bin

interferogram_XX_XX.bmp

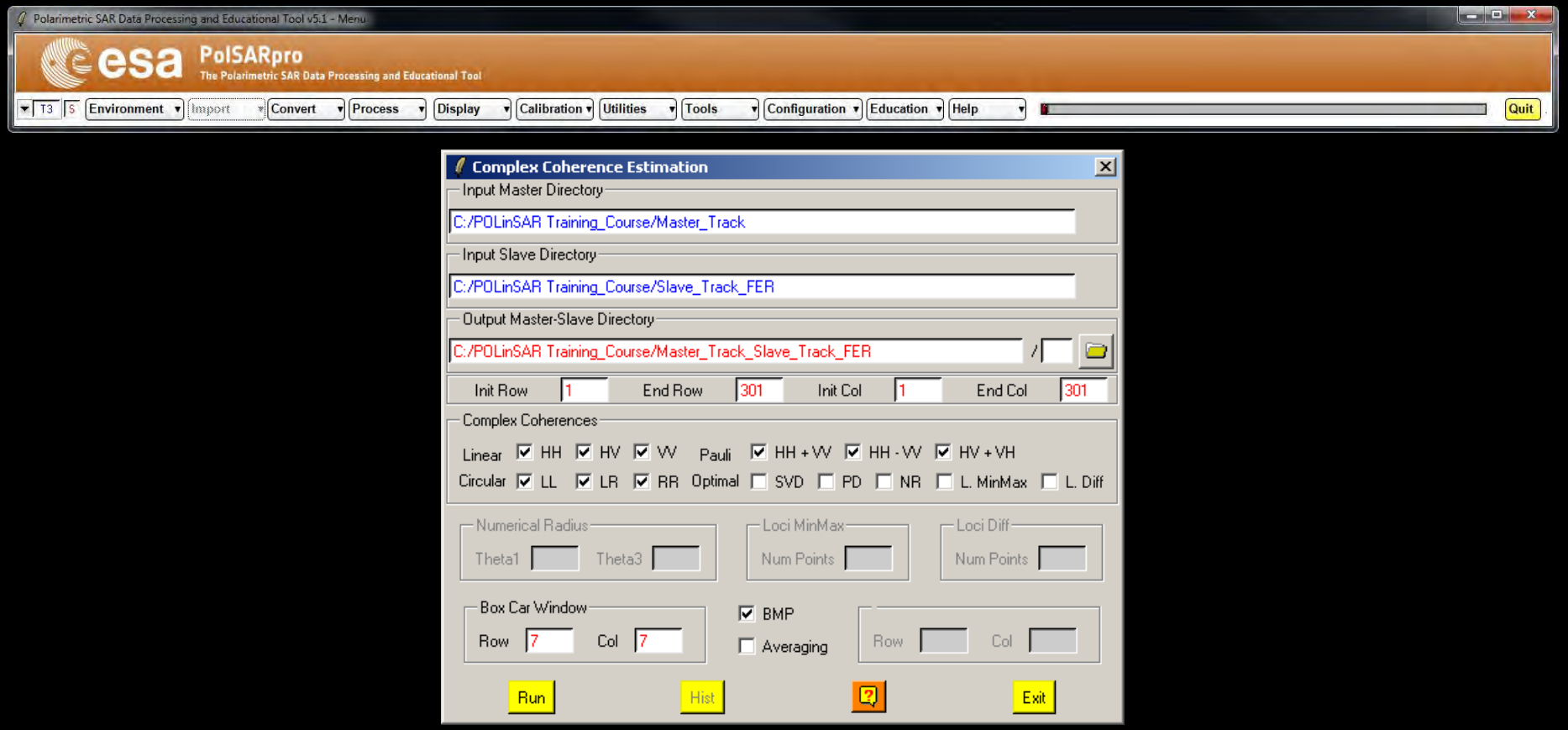




PROCESS DATA

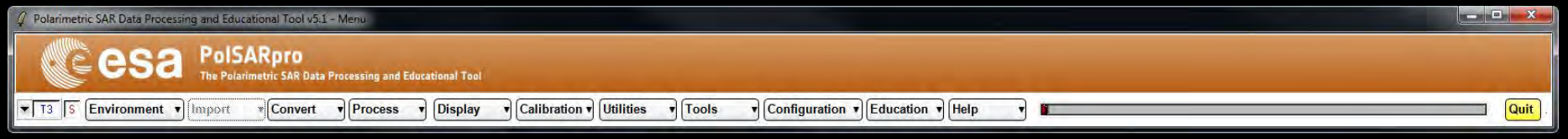


COHERENCE ESTIMATION



Do it Yourself:
Select polarization channels (linear, circular, pauli), set the parameters (Box Car = 11x11) and view the corresponding BMP files (select BMP).

COHERENCE ESTIMATION

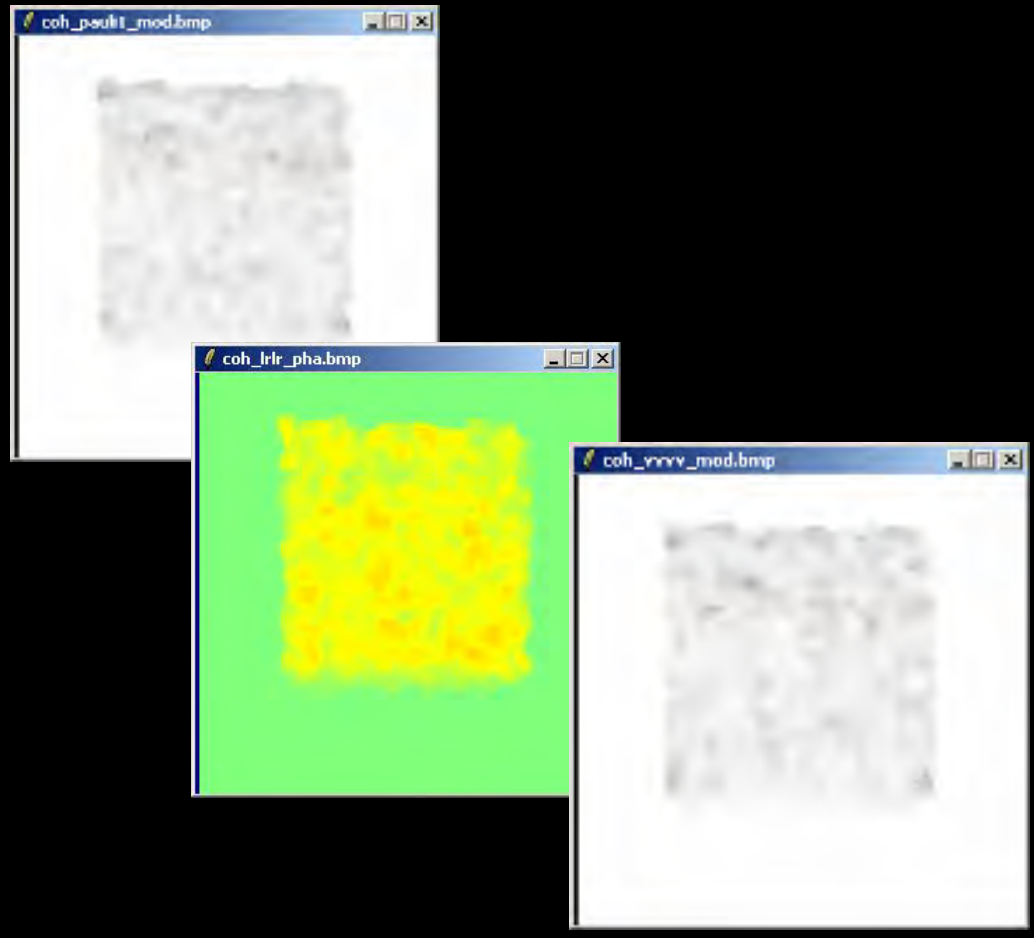


DATA_MASTERDIR_SLAVEDIR_FER

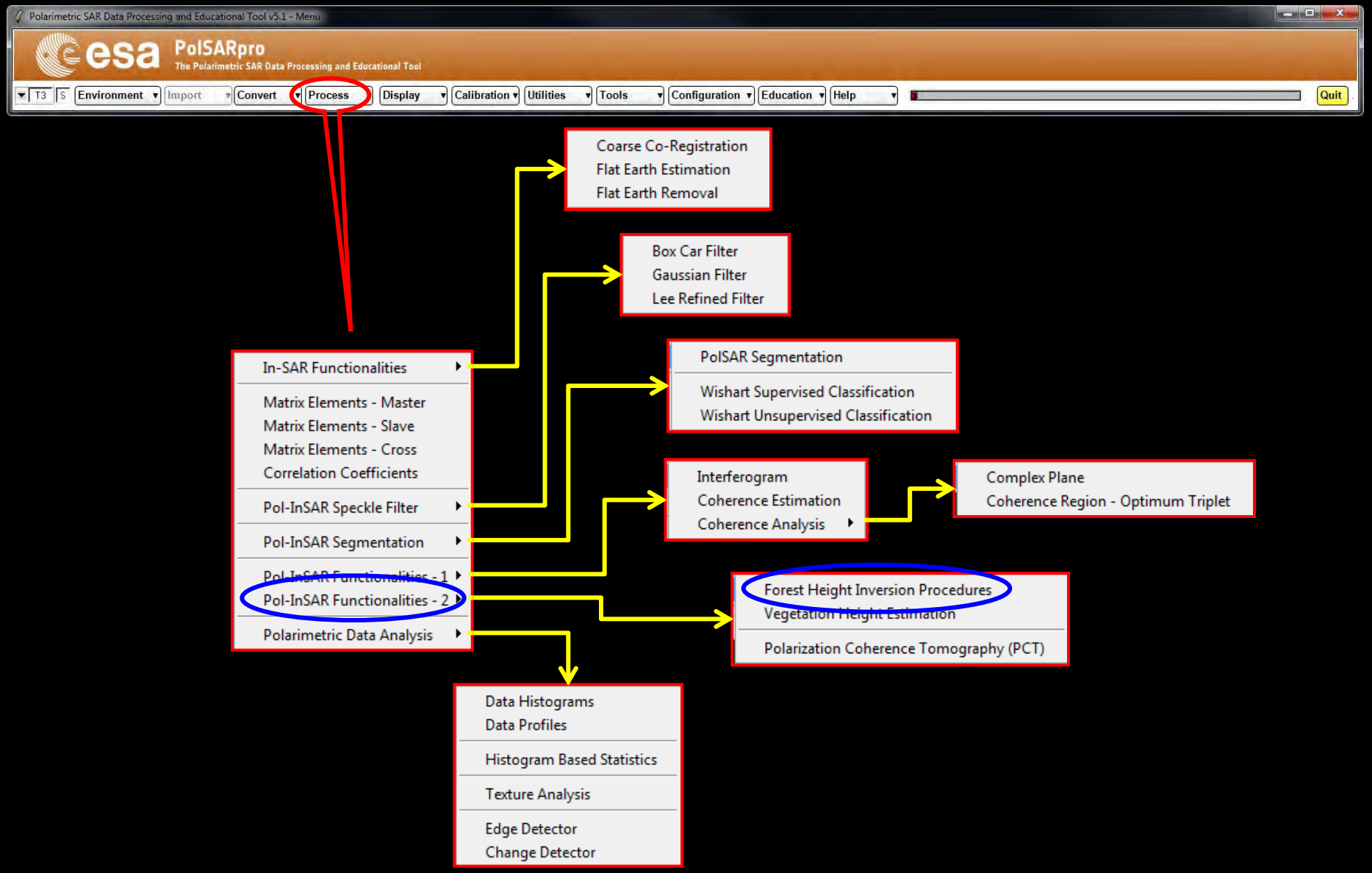
config.txt

cmplx_coh_XX.bin

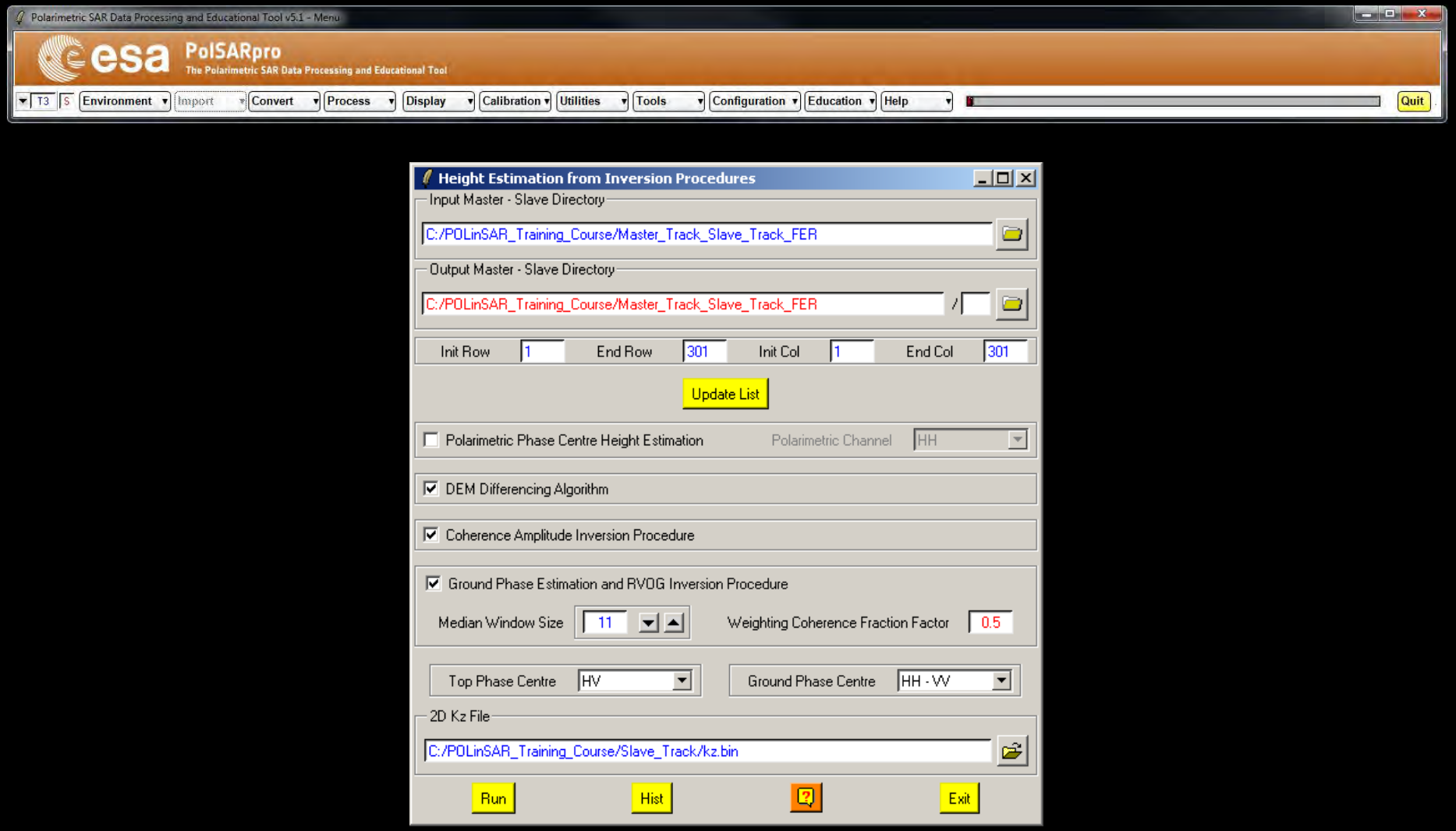
cmplx_coh_XX_mod.bmp
cmplx_coh_XX_pha.bmp



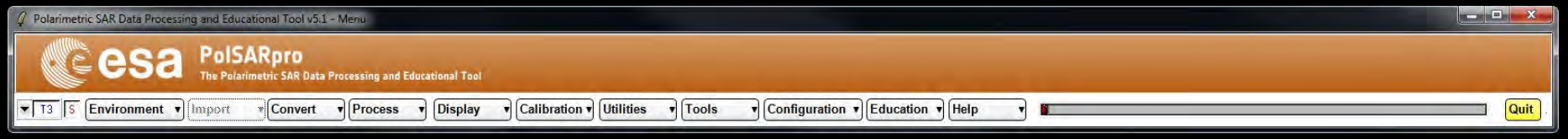
PROCESS DATA

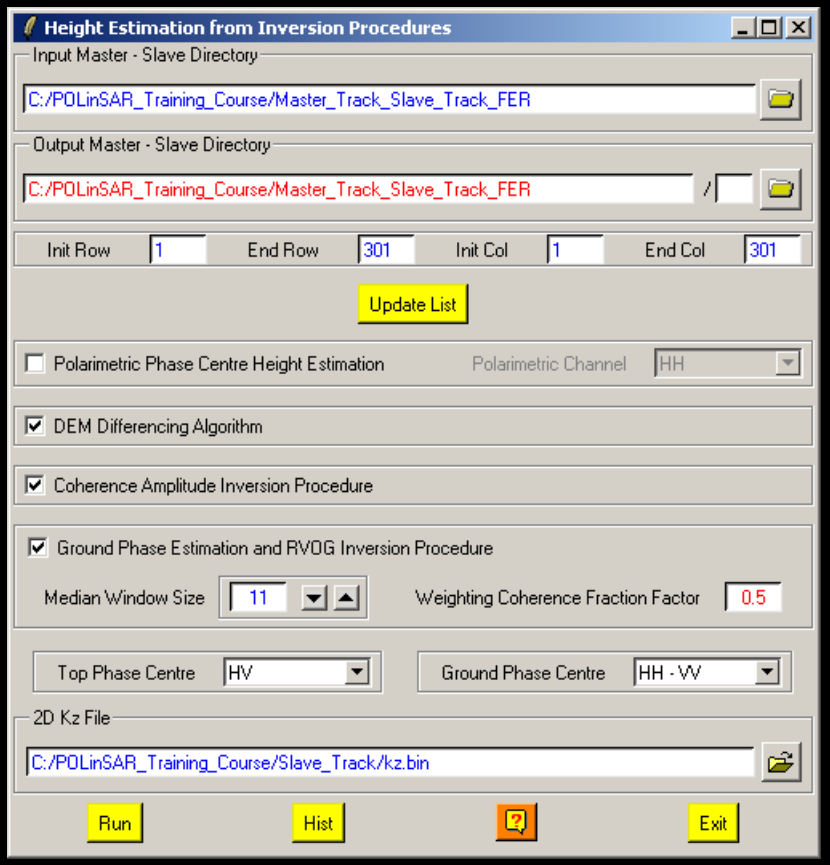


HEIGHT ESTIMATION



HEIGHT ESTIMATION

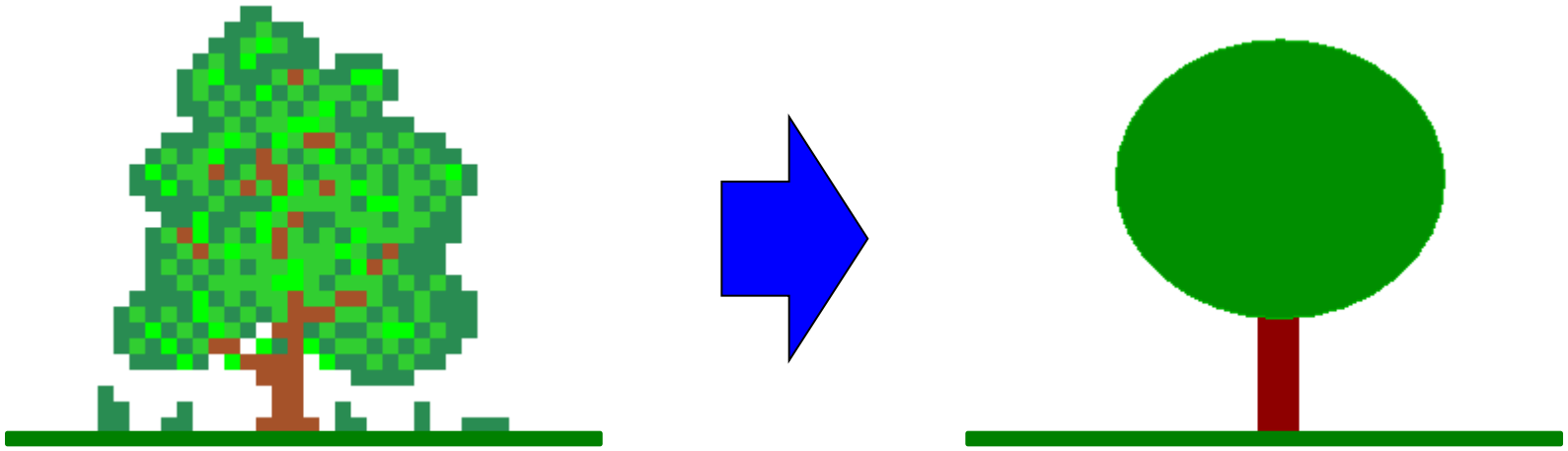




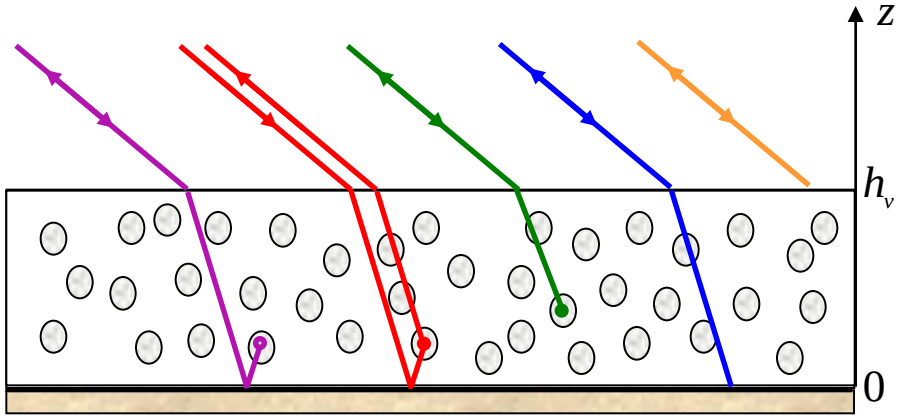
INVERSION PROCEDURES

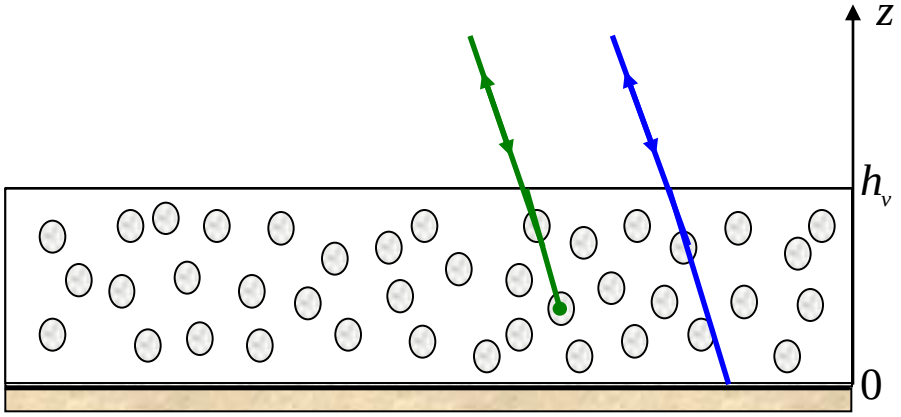
- DEM Differencing Algorithm
- Coherence Amplitude Inversion Procedure
- Ground Phase Estimation
- RVOG Inversion Procedure

VOLUME COHERENCE MODEL



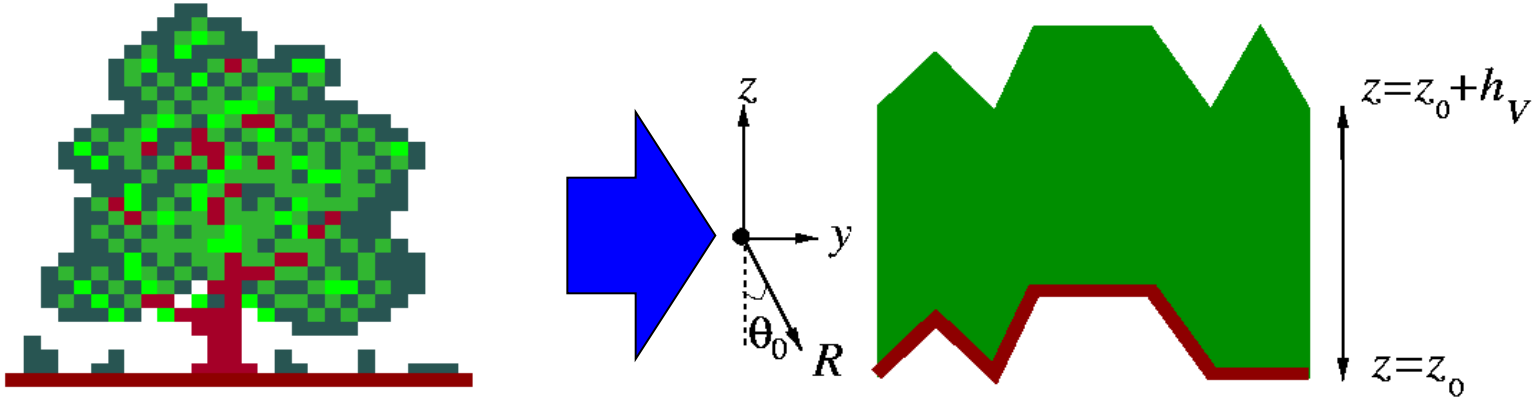
Modeling **Parameter Estimation**





Simplifications : Only 2 significant mechanisms – Low density medium ⇨ No refraction

VOLUME COHERENCE MODEL



$$\gamma_{VOL} = e^{j\phi_0} \frac{\int_0^{h_v} f(z) e^{jk_z z} dz}{\int_0^{h_v} f(z) dz}$$

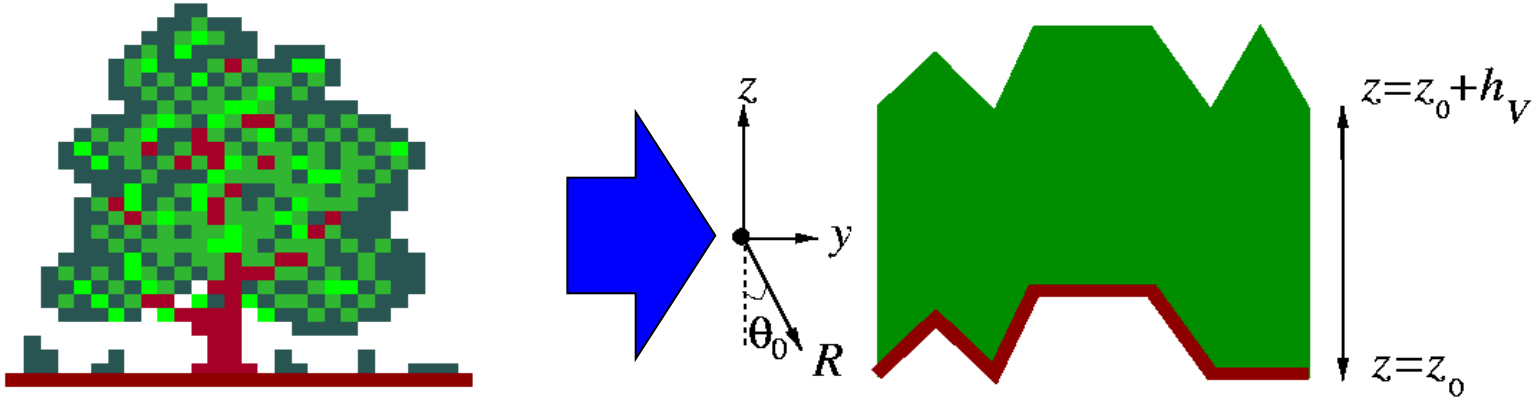
ϕ_0 **Topographic Phase**

$$k_z = \frac{4\pi}{\lambda} \sin(\theta_0 - \alpha)$$

Vertical Wavenumber

POLARIZATION INDEPENDENT

VOLUME COHERENCE MODEL



$$\gamma_{VOL} = e^{j\phi_0} \frac{\int_0^{h_v} f(z) e^{jkz} dz}{\int_0^{h_v} f(z) dz}$$

Vertical Structure function

$$f(z) = e^{\frac{\alpha z}{\cos\theta_0}}$$

Case of Uniform Random Layer

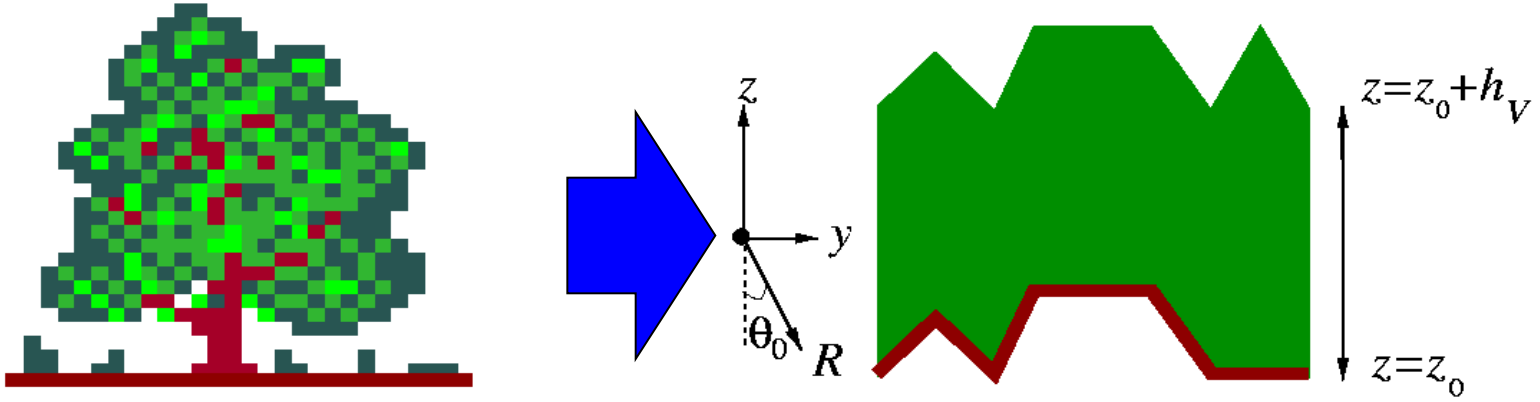
θ_0 **Incidence Angle**

σ **Extinction Coefficient**

POLARIZATION INDEPENDENT

RVOG COHERENCE MODEL

RVOG = Random Volume Over Ground



2 Layer Combined Surface and random Volume Scattering

$$\mu(w) = \frac{\text{Surface Scattering Contribution}}{\text{Volume Scattering Contribution}}$$

G / V ratio

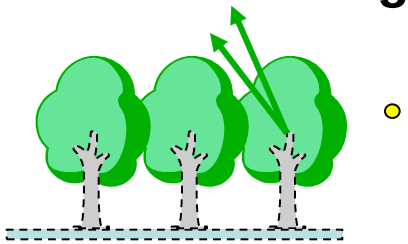
B. Treuhaft (2000), S.R. Cloude (2003)

POLARIZATION DEPENDENT

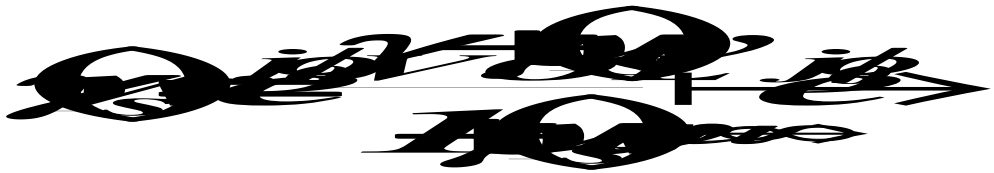
FOREST HEIGHT ESTIMATION

$\underline{w}_v$ **Polarisation Channel corresponding to Volume Scattering**

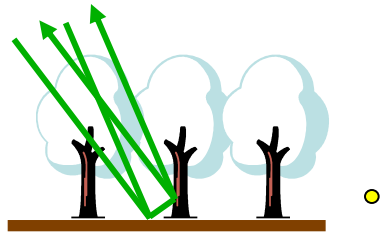
2HV



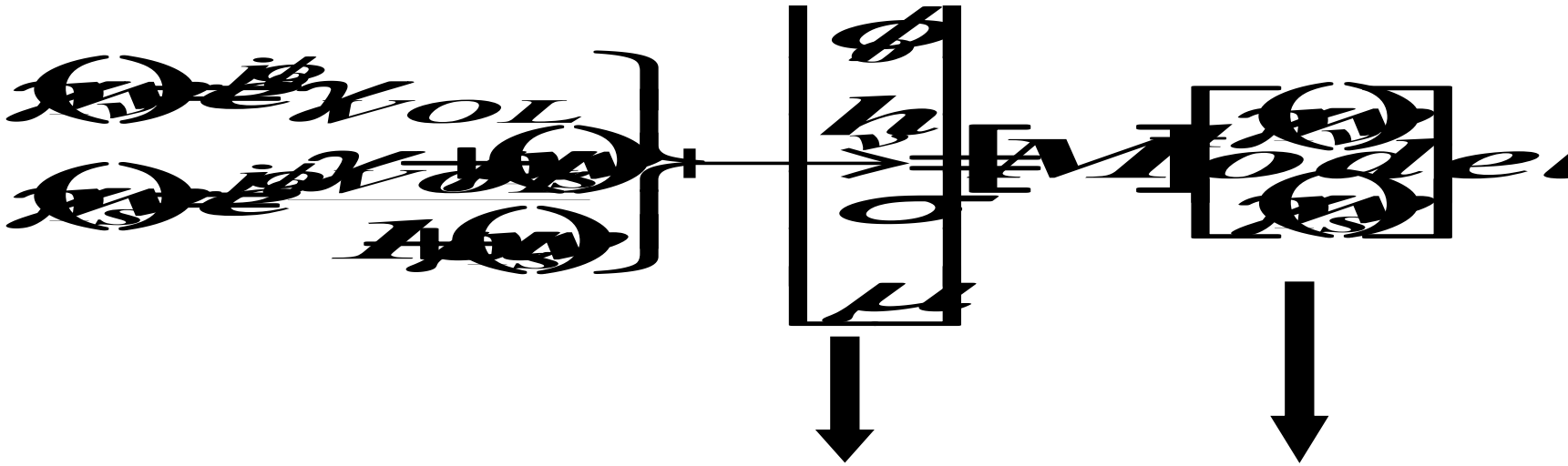
$\underline{w}_s$ **Polarisation Channel corresponding to Surface Scattering**



HH-VV



FOREST HEIGHT ESTIMATION



4 Parameters 4 Observables

INVERSION

DEM Differencing Algorithm

$$\left.\begin{aligned}\gamma(\underline{w}_v) &= e^{j\phi_0}\gamma_{VOL}\\ \gamma(\underline{w}_s) &\mapsto e^{j\phi_0}\end{aligned}\right\} \quad \mapsto \quad \gamma(\underline{w}_v) = \gamma(\underline{w}_s)\gamma_{VOL} \approx \gamma(\underline{w}_s)\alpha e^{jk_z h_v}$$

$$h_v \approx \frac{arg[\gamma(\underline{w}_v)] - arg[\gamma(\underline{w}_s)]}{k_z}$$

Coherence Amplitude Inversion Procedure

Assumption: Only Volume Scattering is present

$$\gamma(\underline{w}_v) = e^{j\phi_0}\gamma_{VOL} \quad \mapsto \quad |\gamma(\underline{w}_v)| = |\gamma_{VOL}|$$

$$\min_{h_v} \left\| |\gamma(\underline{w}_v)| - \left| \frac{p}{p_1} \frac{e^{p_1 h_v} - 1}{e^{p h_v} - 1} \right| \right\|$$

1-D Search Procedure
Look Up Table (LUT)

Topographic Phase Estimation

$$\left.\begin{aligned}\gamma(\underline{w}_v) &= e^{j\phi_0}\gamma_{VOL}\\ \gamma(\underline{w}_s) &= e^{j\phi_0}\frac{\gamma_{VOL}+\mu(\underline{w}_s)}{1+\mu(\underline{w}_s)}\end{aligned}\right\} \mapsto \quad e^{j\phi_0} = \frac{\gamma(\underline{w}_s)-\gamma(\underline{w}_v)(1-L)}{L}$$

$$\hat{\phi}_0 = arg\left[\gamma(\underline{w}_s)-\gamma(\underline{w}_v)(1-L)\right]$$

With: $L = \dfrac{\mu(\underline{w}_s)}{1+\mu(\underline{w}_s)}$

Estimation of L $\left|\dfrac{\gamma(\underline{w}_s)-\gamma(\underline{w}_v)(1-L)}{L}\right|^2 = 1 \Rightarrow AL^2+BL+C=0$

$$A = |\gamma(\underline{w}_v)|^2 - 1 \quad B = 2\Re\left[(\gamma(\underline{w}_s)-\gamma(\underline{w}_v))\gamma^*(\underline{w}_s)\right] \quad C = |\gamma(\underline{w}_s)-\gamma(\underline{w}_v)|^2$$

$$L = \frac{-B-\sqrt{B^2-4AC}}{2A}$$

FOREST HEIGHT ESTIMATION

RVOG Inversion Procedure

$$\min_{h_v,\sigma} \left\| \gamma(\underline{w}_v) - e^{j\hat{\phi}_0} \frac{p}{p_1} \frac{e^{p_1 h_v} - 1}{e^{p h_v} - 1} \right\|$$

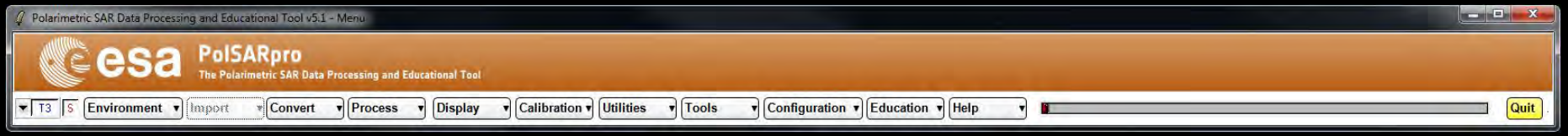
Expensive 2-D Search Procedure !

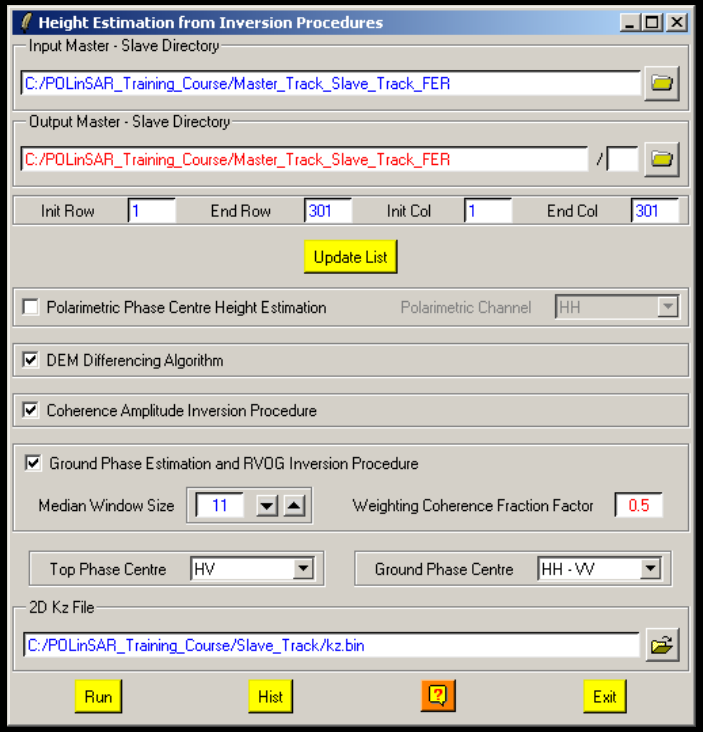
$$h_v \approx \underbrace{\frac{\arg[\gamma(\underline{w}_v)] - \hat{\phi}_0}{k_z}}_{\text{DEM Differencing Inversion}} + \varepsilon \underbrace{\frac{2\,\mathrm{sinc}^{-1}(|\gamma(\underline{w}_v)|)}{k_z}}_{\text{Coherence Amplitude Inversion}}$$

$0.3 \le \varepsilon \le 0.5$

Suitable Compromise

HEIGHT ESTIMATION





Do it Yourself:
Set the parameters (Median Size = 21, Factor = 0.4)
and view the corresponding BMP files.

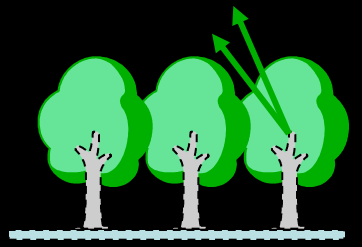
DATA_MASTERDIR_SLAVEDIR_FER

config.txt

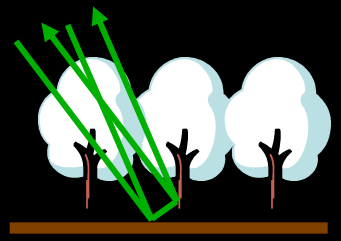
DEM_diff_heights.bin, Coh_heights.bin
Ground_phase.bin, Ground_phase_median.bin
RVOG_phase_heights.bin, RVOG_heights.bin

DEM_diff_heights.bmp, Coh_heights.bmp
Ground_phase.bmp, Ground_phase_median.bmp
RVOG_phase_heights.bmp, RVOG_heights.bmp

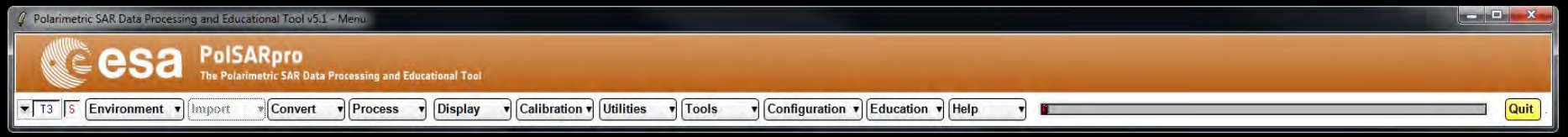
2HV

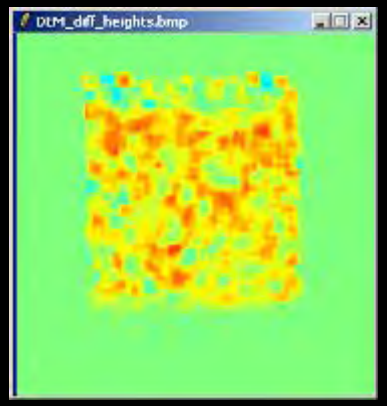


HH-VV

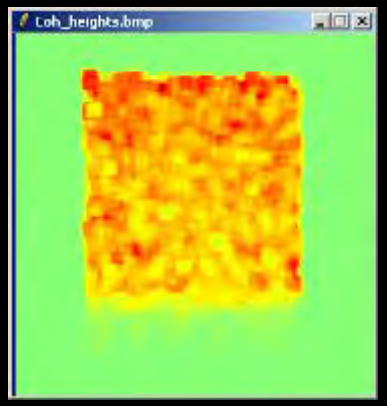


HEIGHT ESTIMATION

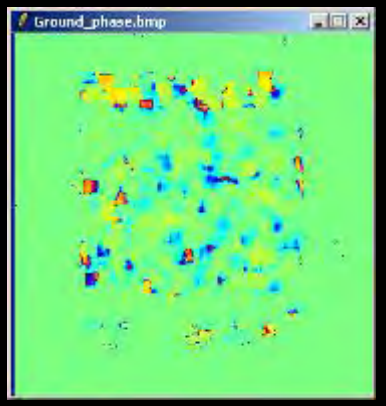




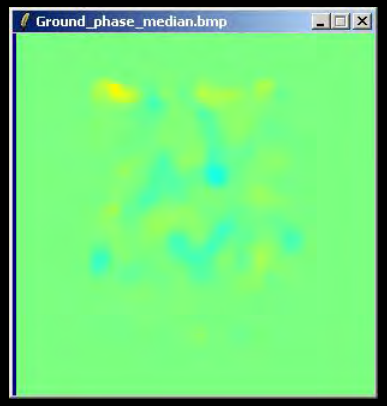
DEM_diff_heights



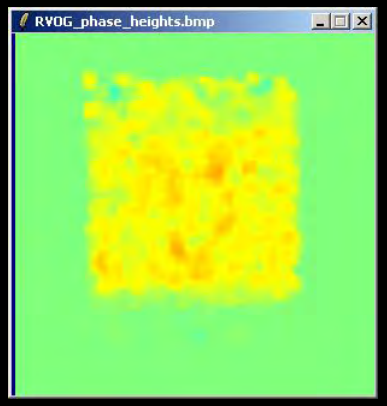
Coh_heights



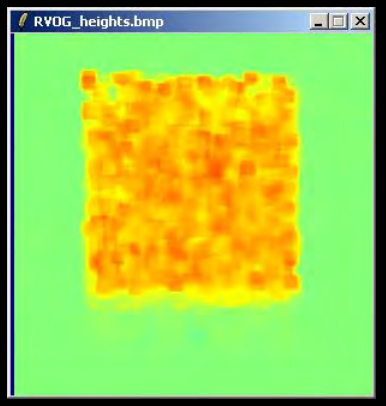
Ground_phase



Ground_phase_median

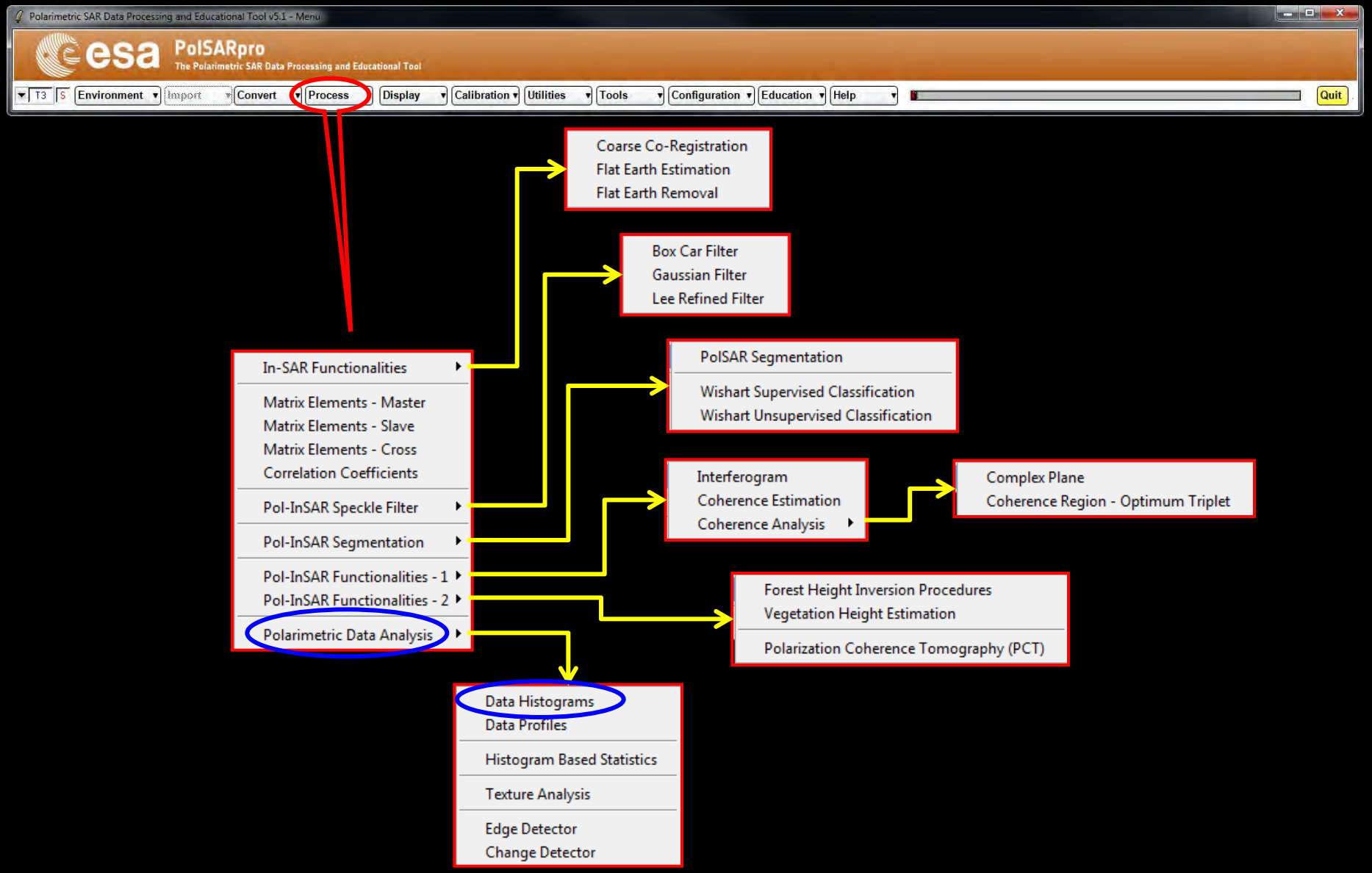


RVOG_phase_heights

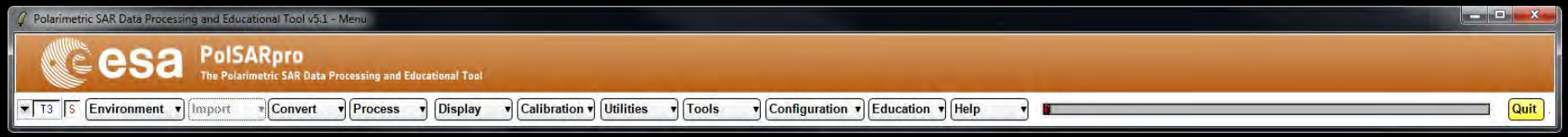


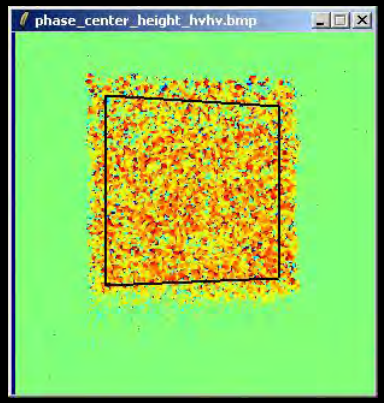
RVOG_heights

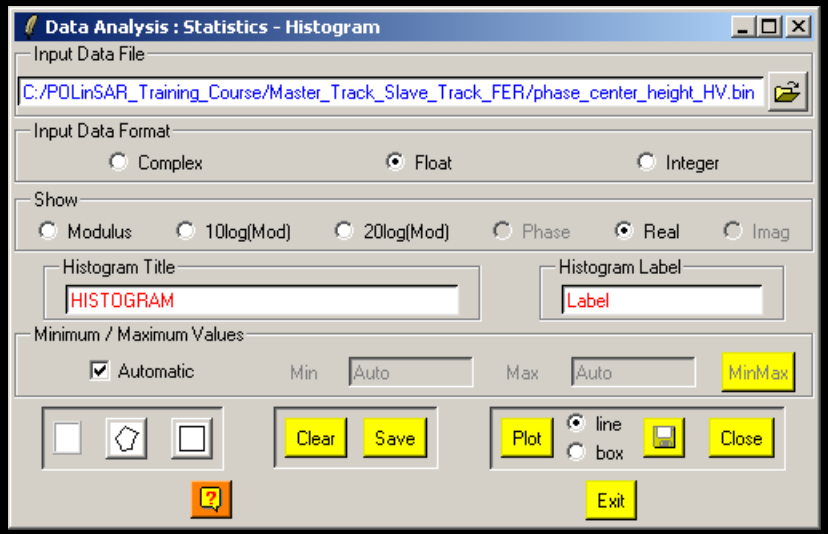
PROCESS DATA

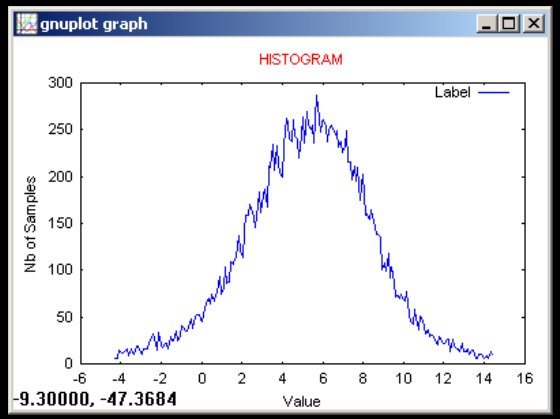


HEIGHT ESTIMATION





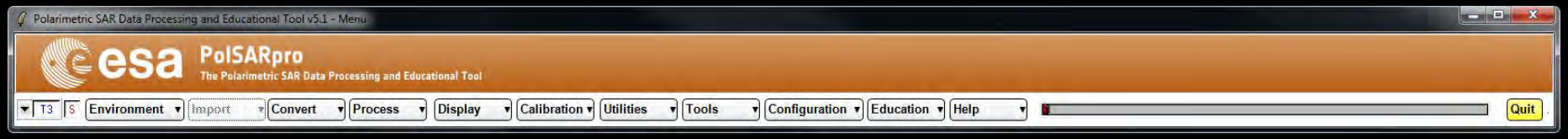


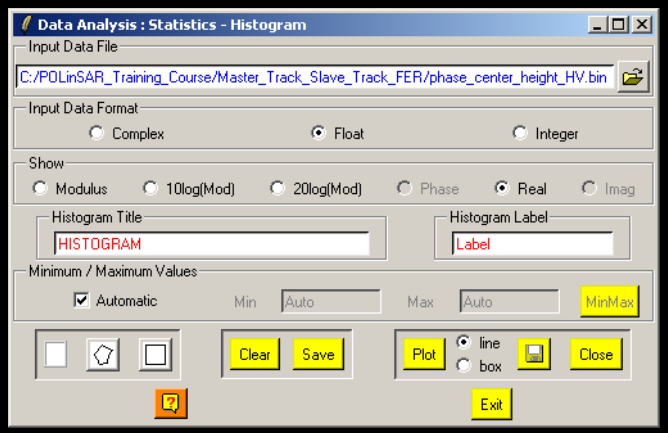


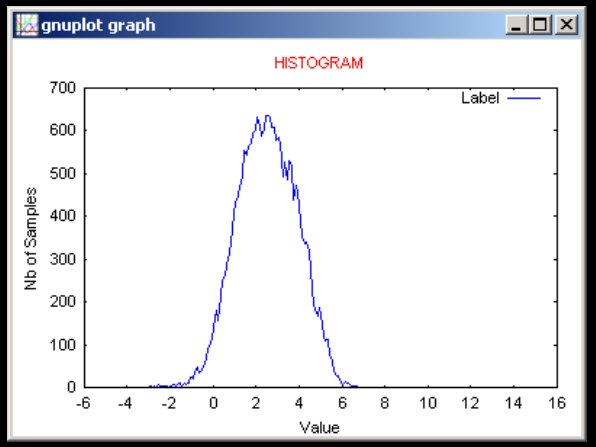
Do it Yourself:

Select a BMP file
Select a BIN file
Select Input Data Format
Select Show
Select Area (line or rect)
SAVE
PLOT

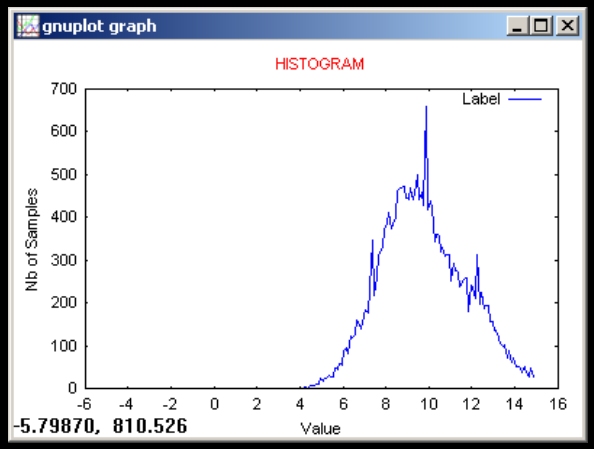
HEIGHT ESTIMATION



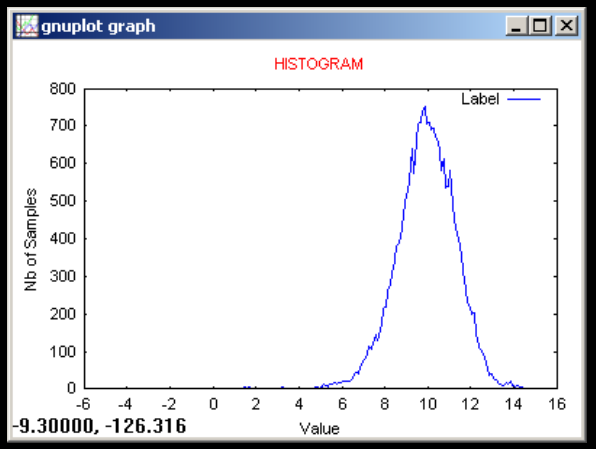




DEM_diff_heights

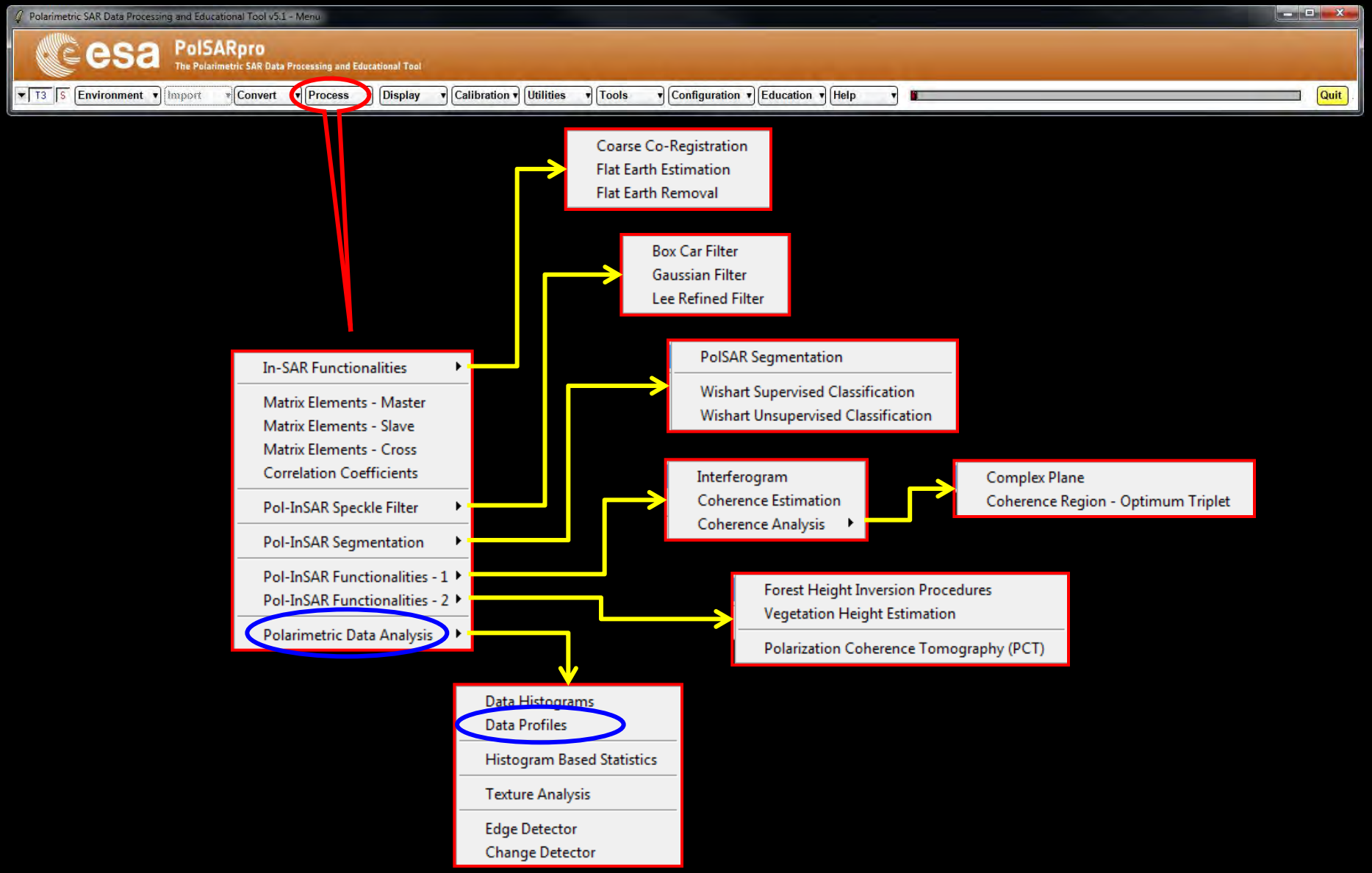


Coh_heights

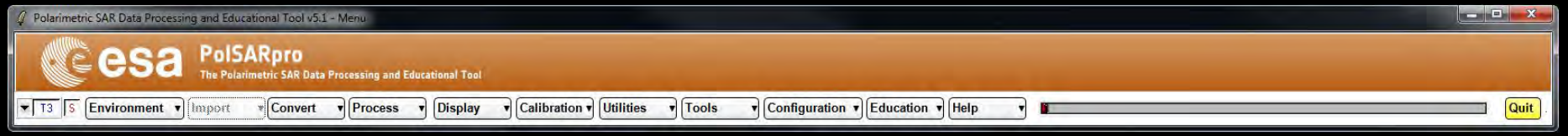


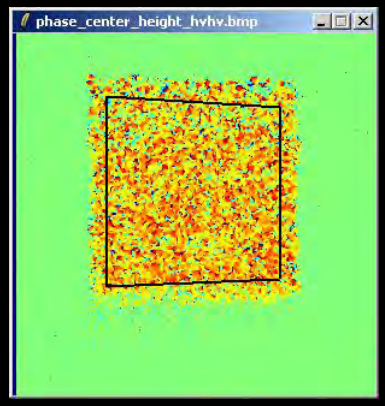
RVOG_heights

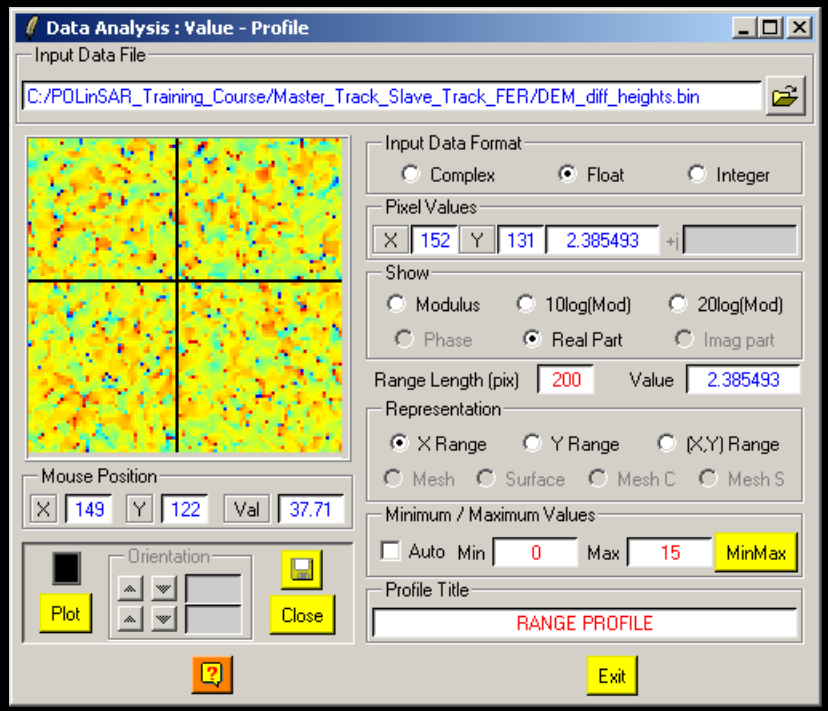
PROCESS DATA



HEIGHT ESTIMATION





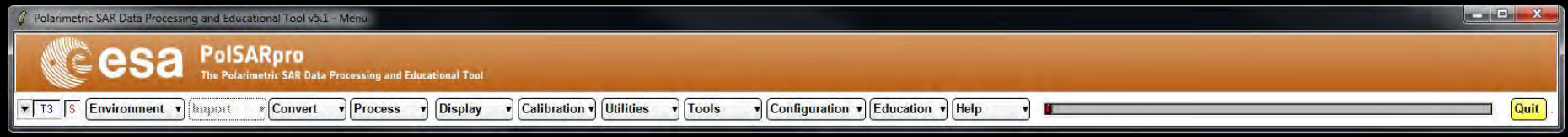


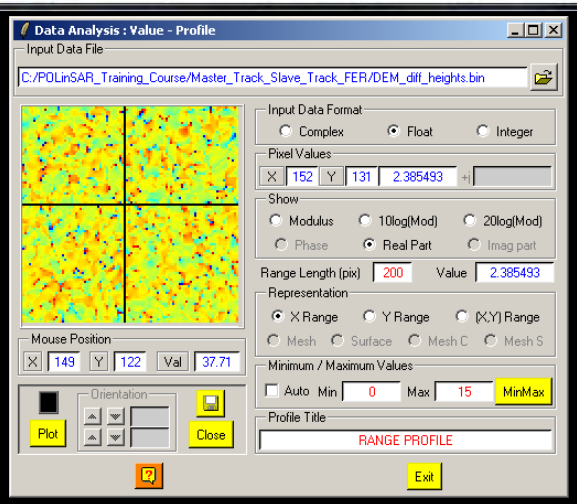
Do it Yourself:

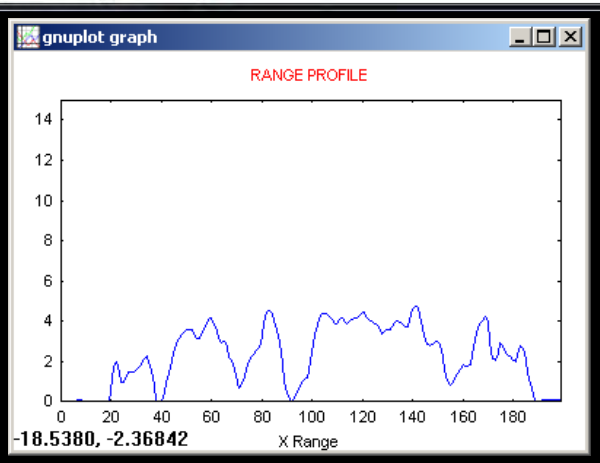
Select a BMP file
Select a BIN file
Select Input Data Format
Select Pixel
Select Show
Select Representation
- **X Range / Y Range = 200pix**
- **XY Range = 30 pix (3D)**

Set Min / Max Values
PLOT

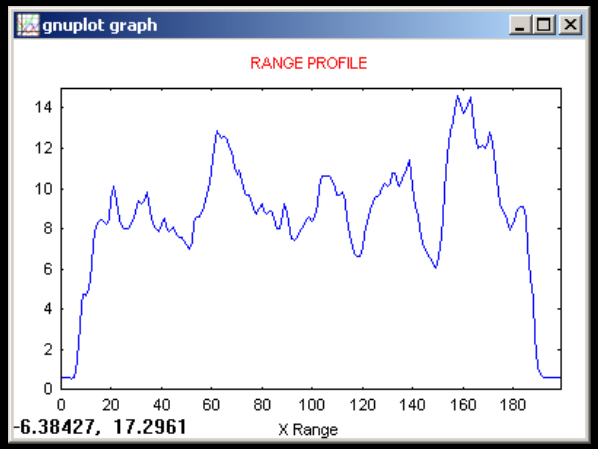
HEIGHT ESTIMATION



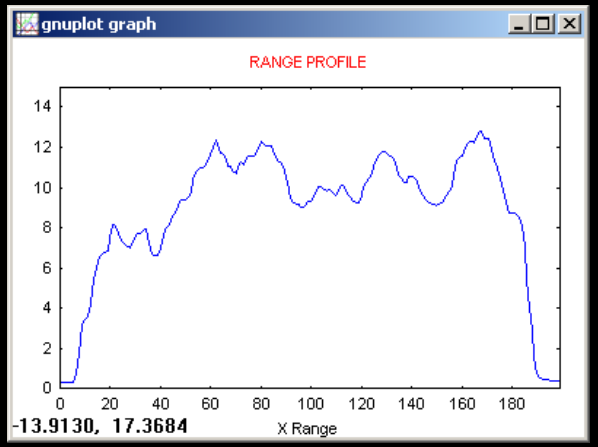




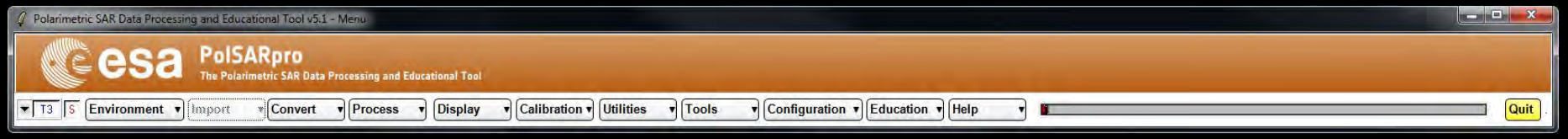
DEM_diff_heights



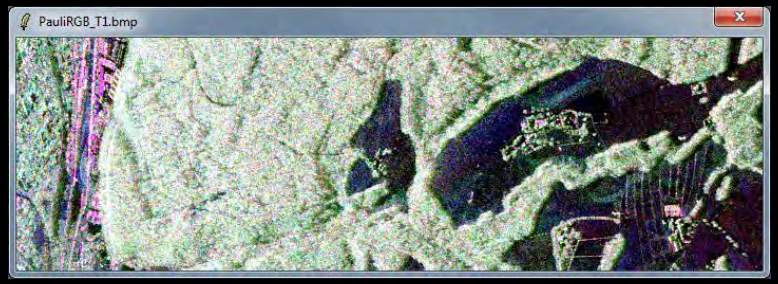
Coh_heights

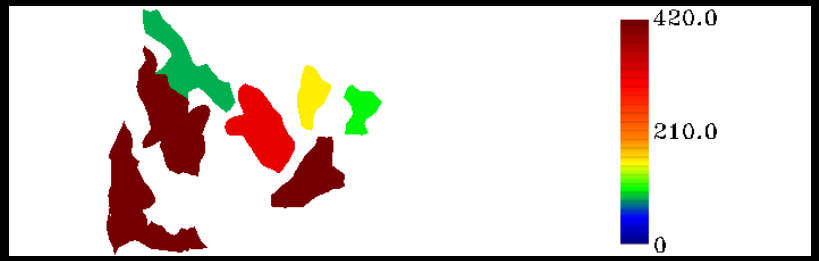


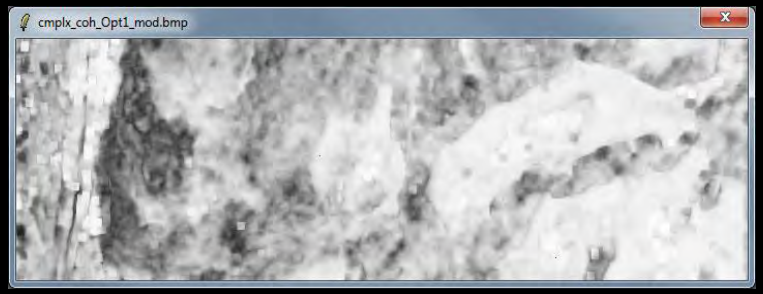
RVOG_heights

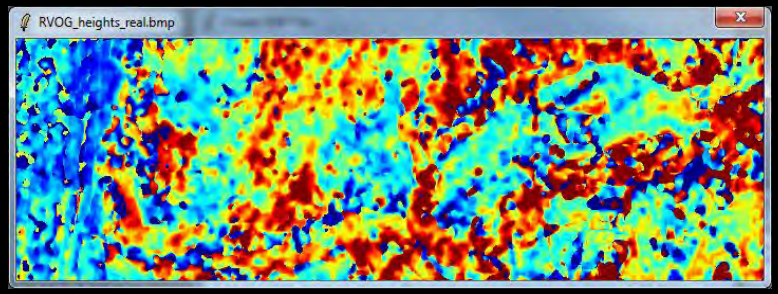


Pol-InSAR Practical
Forest Application

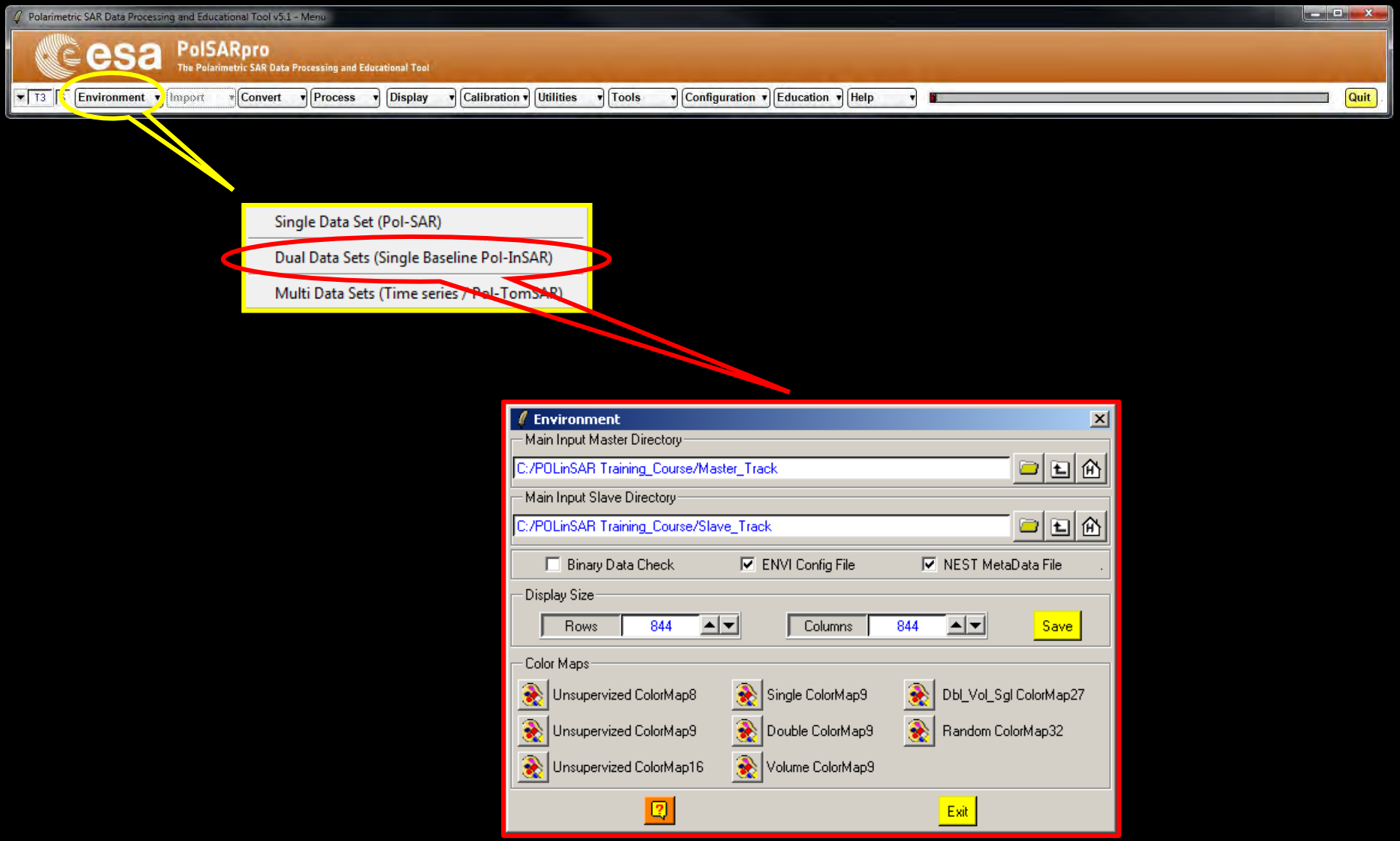




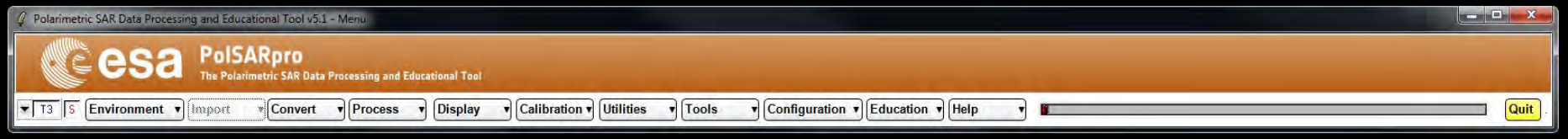




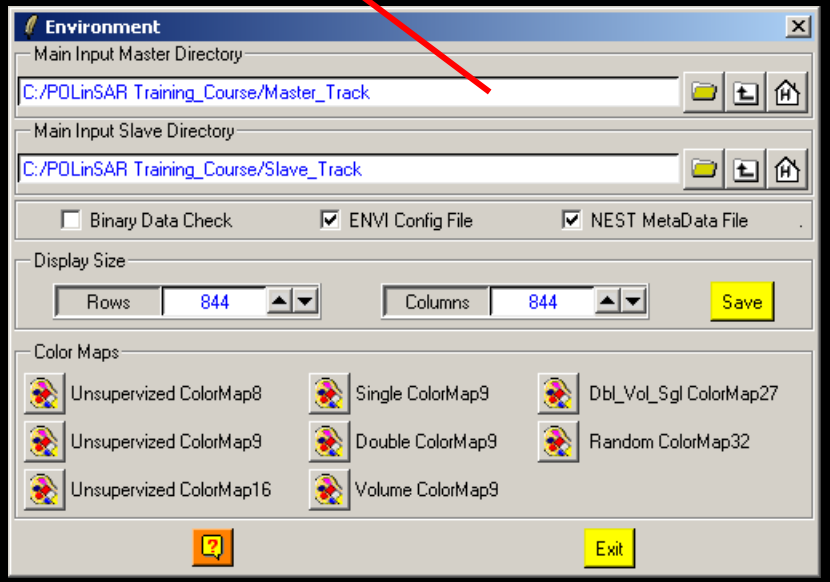
MAIN MENU


Polarimetric SAR Data Processing and Educational Tool v5.1 - Menu
esa PolSARpro
The Polarimetric SAR Data Processing and Educational Tool
T3
Environment
Import
Convert
Process
Display
Calibration
Utilities
Tools
Configuration
Education
Help
Quit
Single Data Set (Pol-SAR)
Dual Data Sets (Single Baseline Pol-InSAR)
Multi Data Sets (Time series / Pol-TomSAR)
Environment
Main Input Master Directory
C:/POLinSAR Training_Course/Master_Track
Main Input Slave Directory
C:/POLinSAR Training_Course/Slave_Track
Binary Data Check
ENVI Config File
NEST MetaData File
Display Size
Rows
844
Columns
844
Save
Color Maps
Unsupervized ColorMap8
Single ColorMap9
Dbl_Vol_Sgl ColorMap27
Unsupervized ColorMap9
Double ColorMap9
Random ColorMap32
Unsupervized ColorMap16
Volume ColorMap9
Exit

ENVIRONMENT



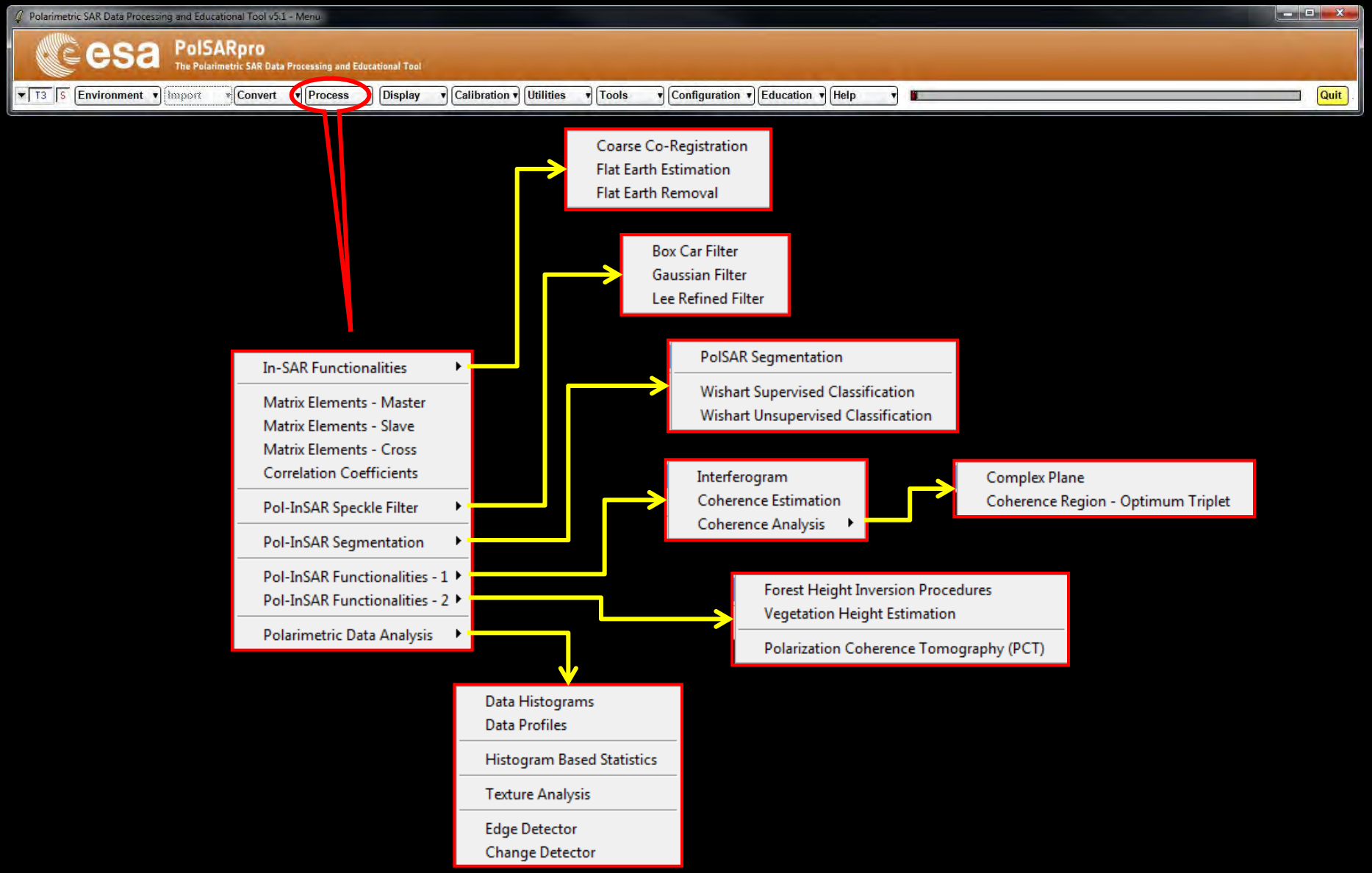
Configure Data Main Directories location



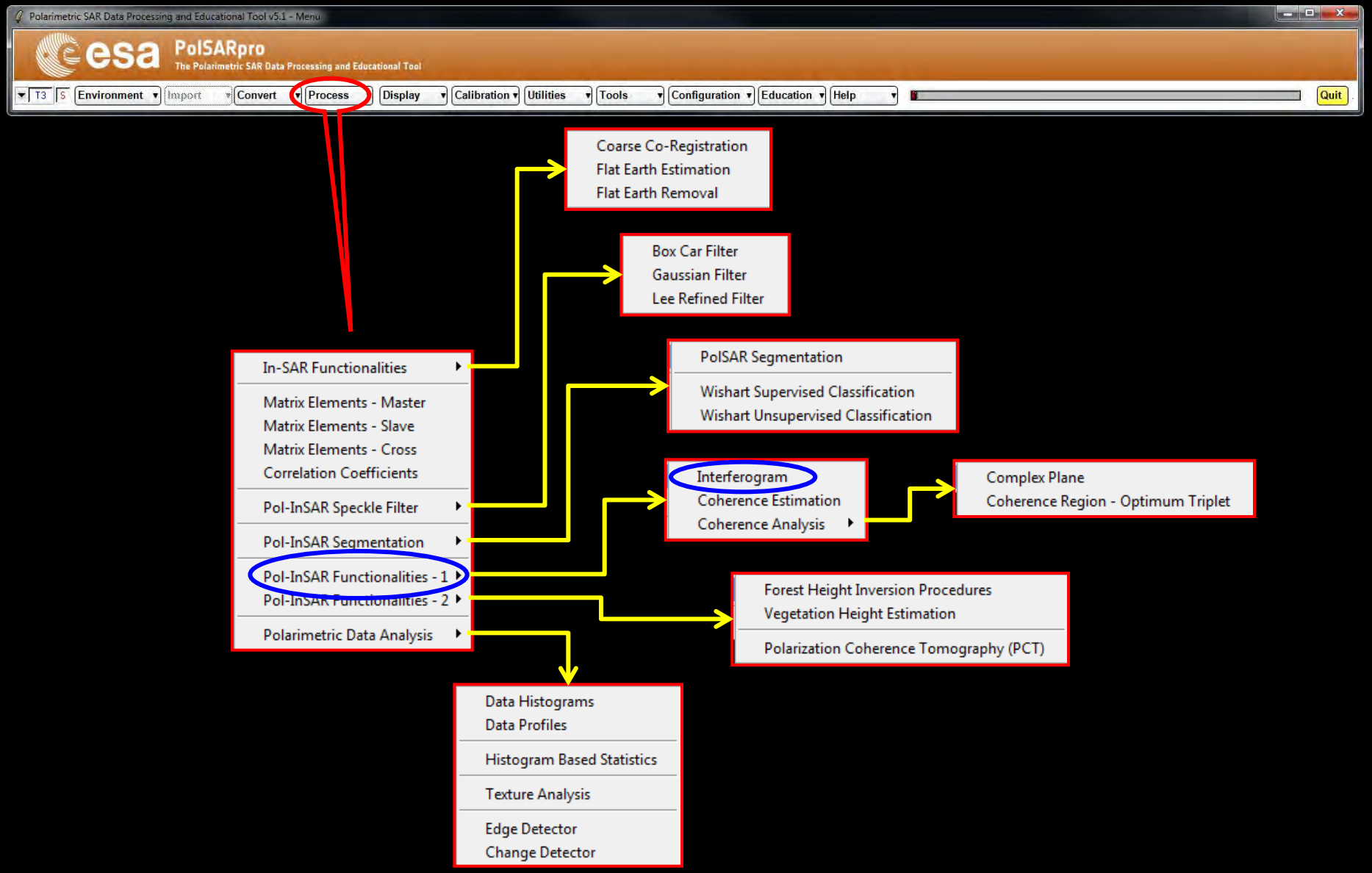
Input Master Directory: C:/Taunstein_ESAR/master_slc

Input Slave Directory: C:/Traunstein_ESAR/slave_slc

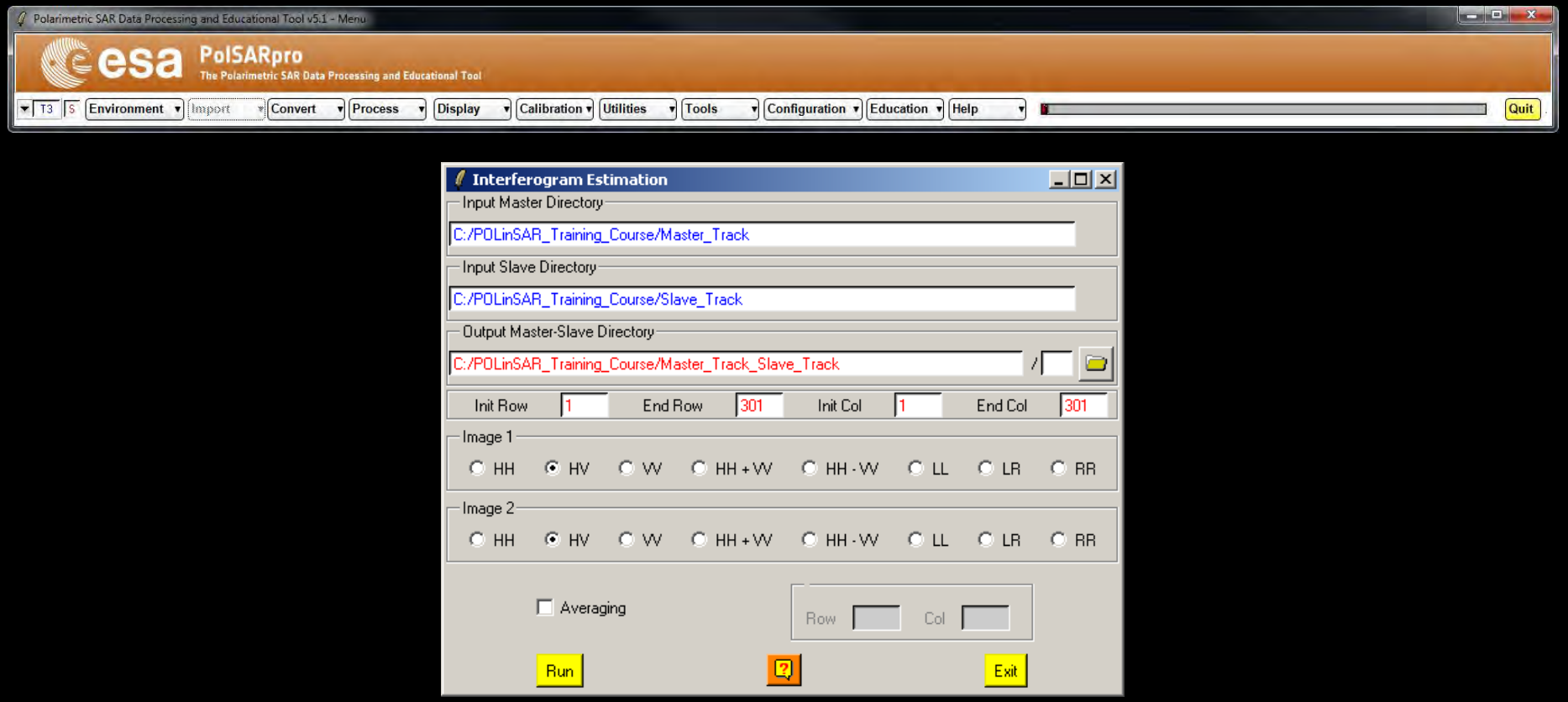
PROCESS DATA



PROCESS DATA



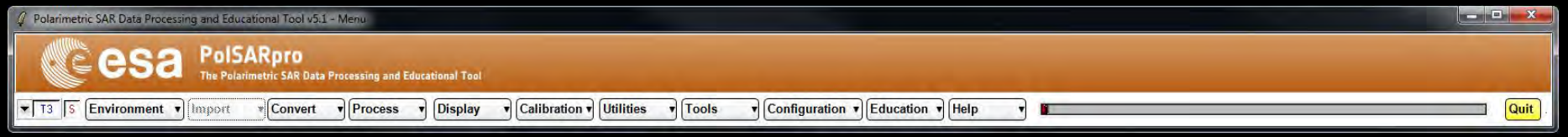
RAW INTERFEROGRAM



Do it Yourself:
Select polarization channels, set the parameters and view the corresponding BMP files.

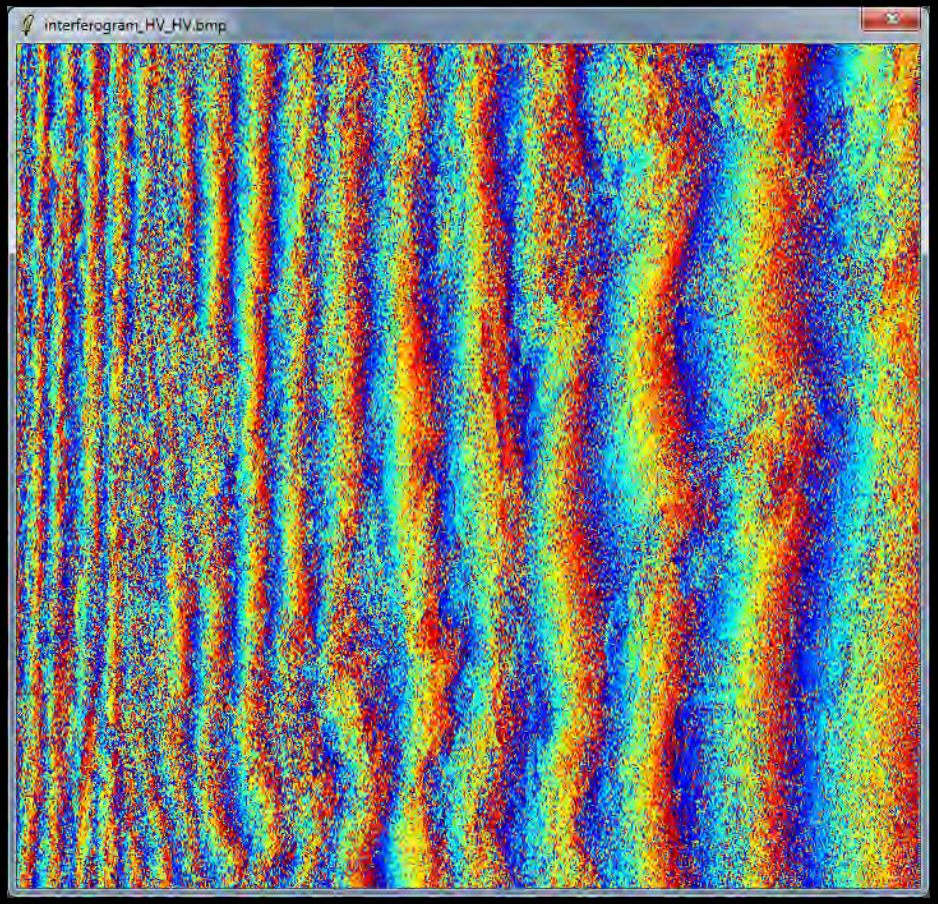
Note:
The Output Directory is automatically set to: MasterDir_SlaveDir

RAW INTERFEROGRAM

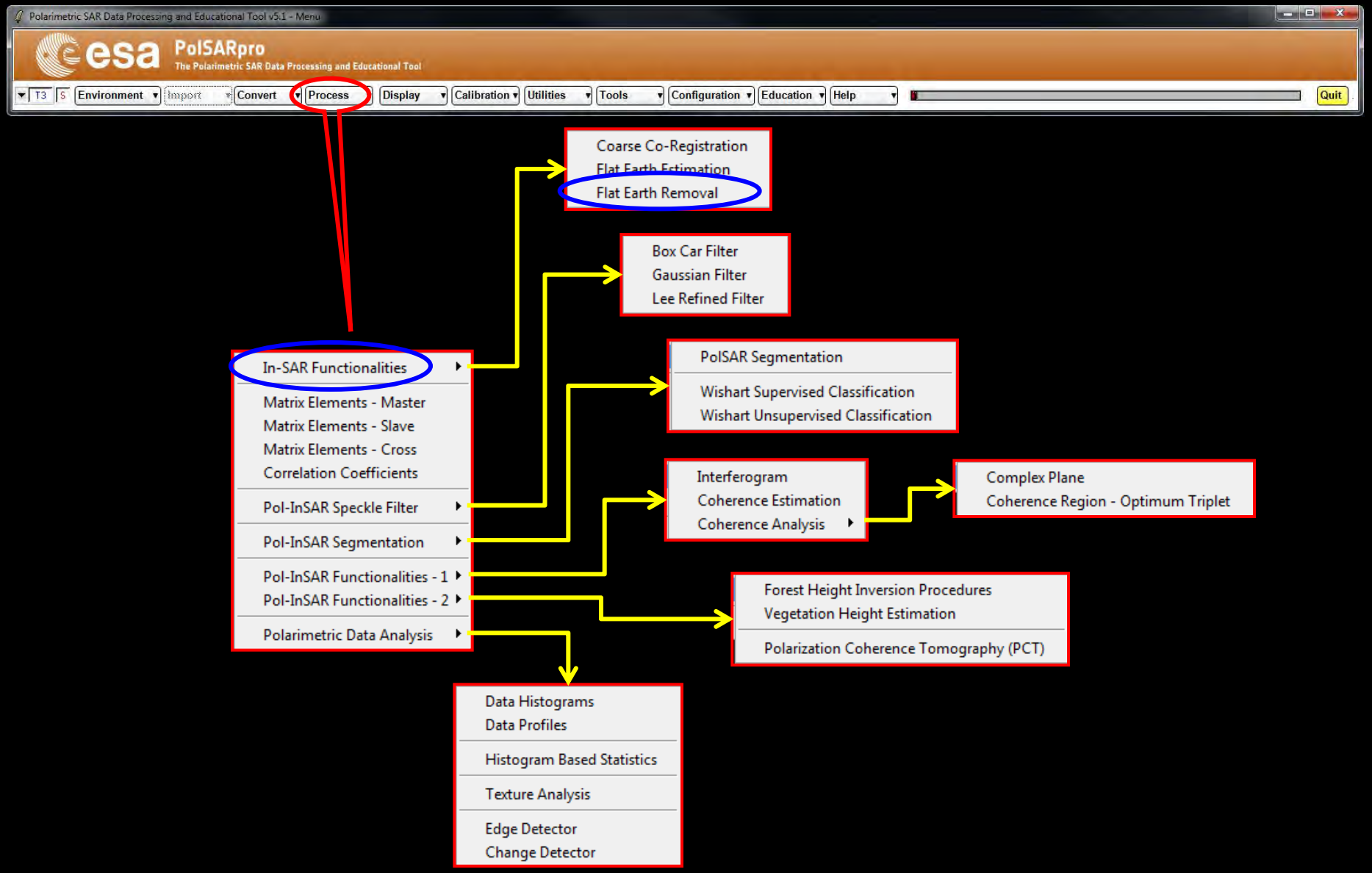


DATA_MASTERDIR_SLAVEDIR

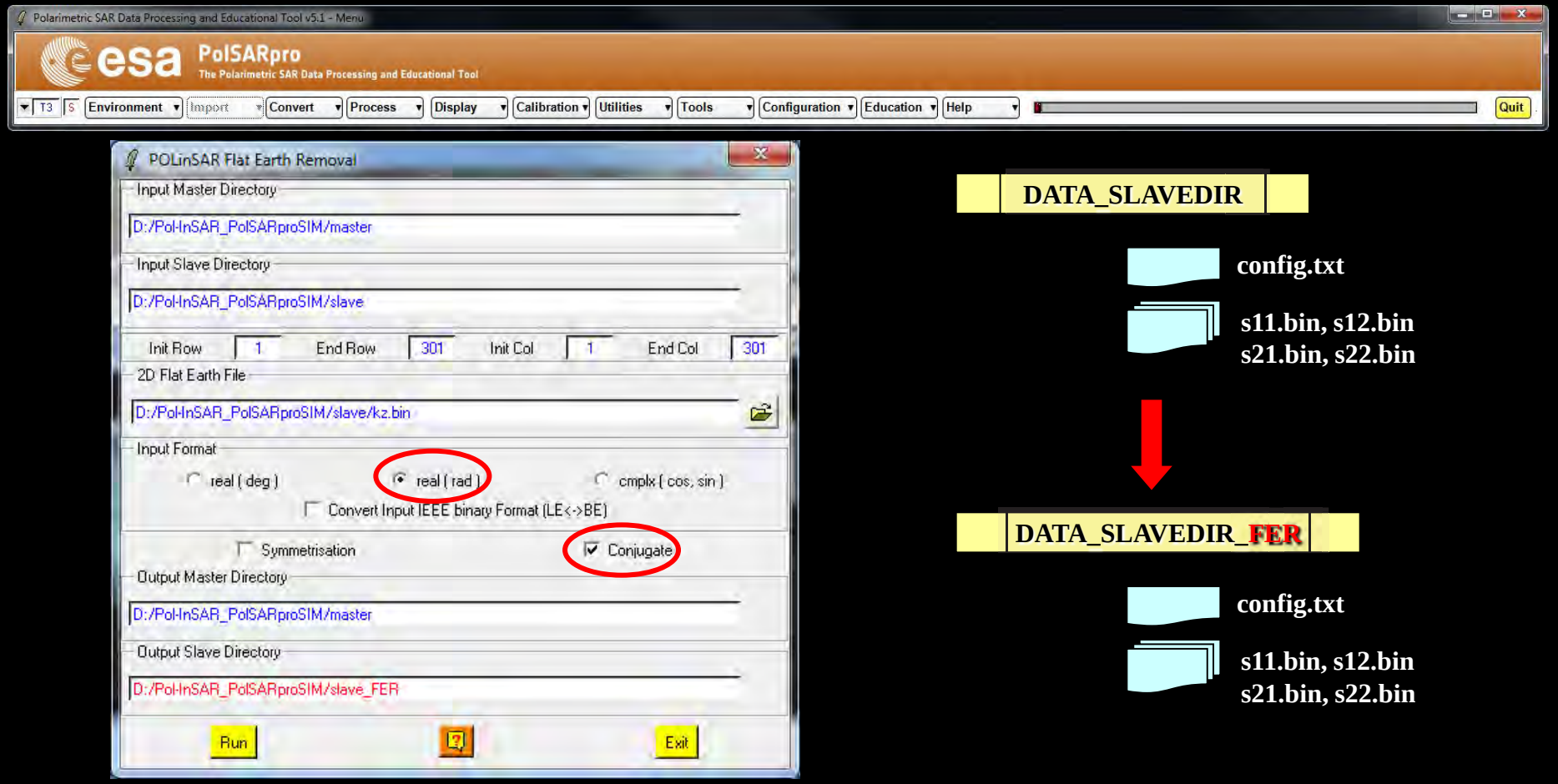
- **config.txt**
- **interferogram_XX_XX.bin**
- **interferogram_XX_XX.bmp**



PROCESS DATA



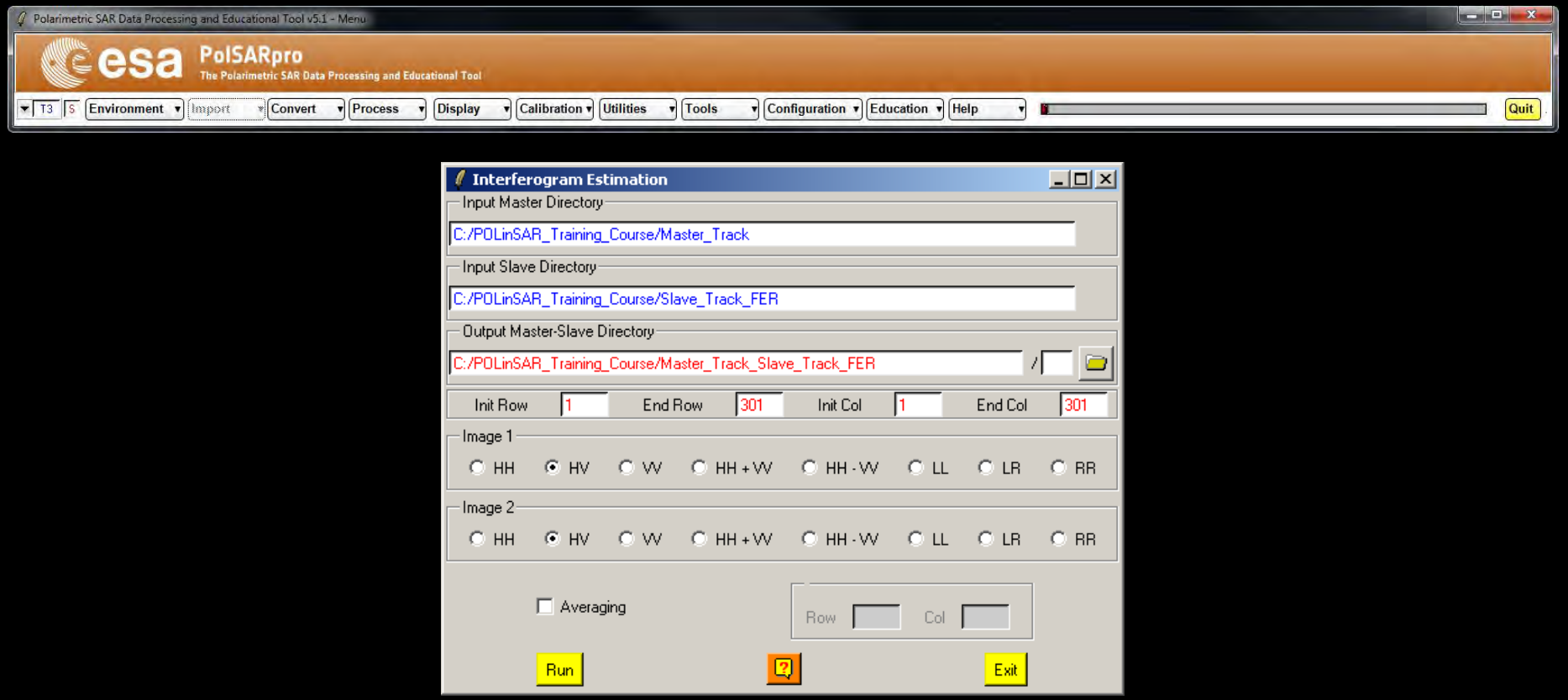
FLAT EARTH REMOVAL



Do it Yourself:
Enter Flat Earth file name, set the parameters and run the function.

Note:
The Input Slave Directory is automatically set to: SlaveDir_FER

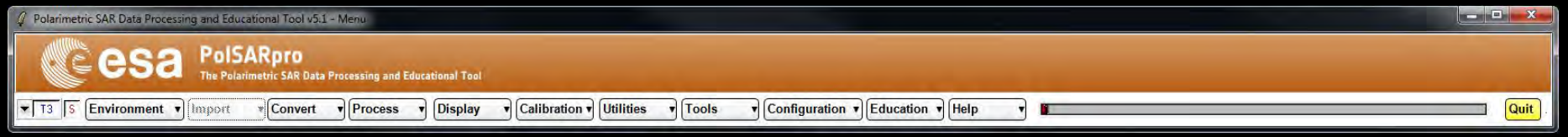
RAW INTERFEROGRAM



Do it Yourself:
Select polarization channels, set the parameters and view the corresponding BMP files.

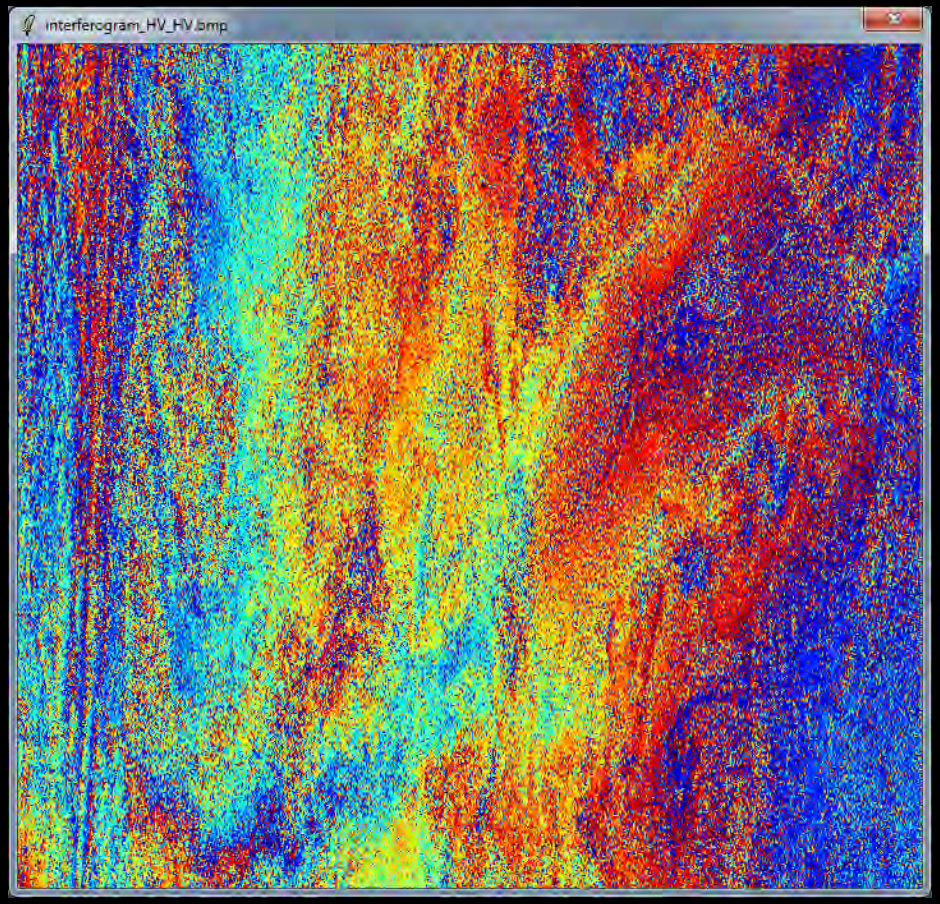
Note:
The Output Directory is automatically set to: MasterDir_SlaveDir_FER

RAW INTERFEROGRAM

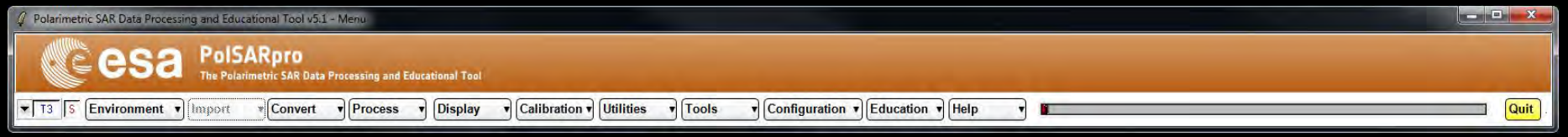


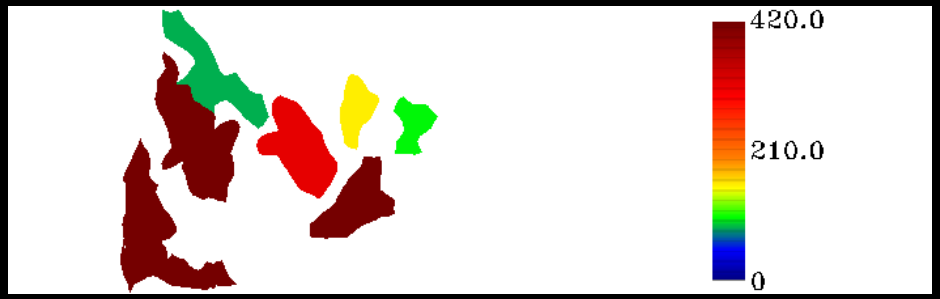
DATA_MASTERDIR_SLAVEDIR_FER

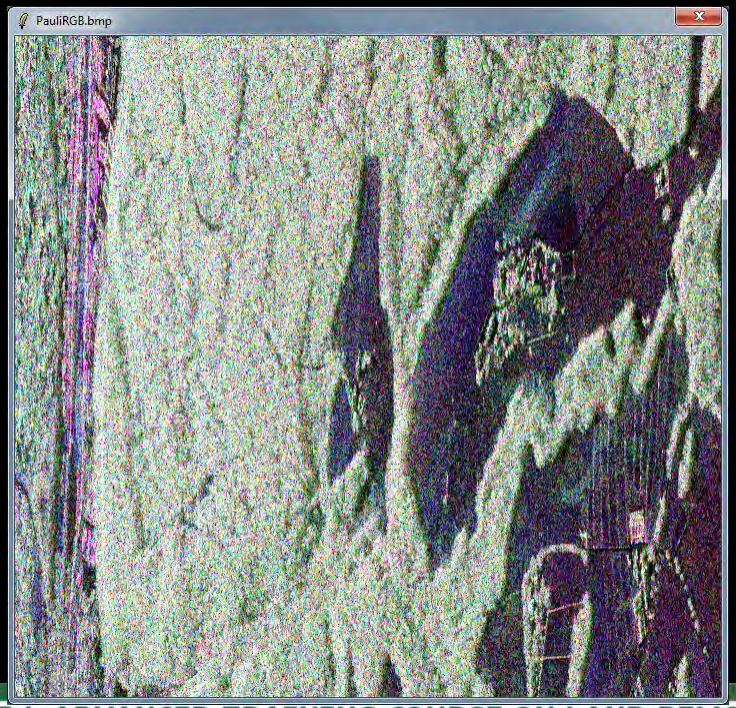
- config.txt
- interferogram_XX_XX.bin
- interferogram_XX_XX.bmp



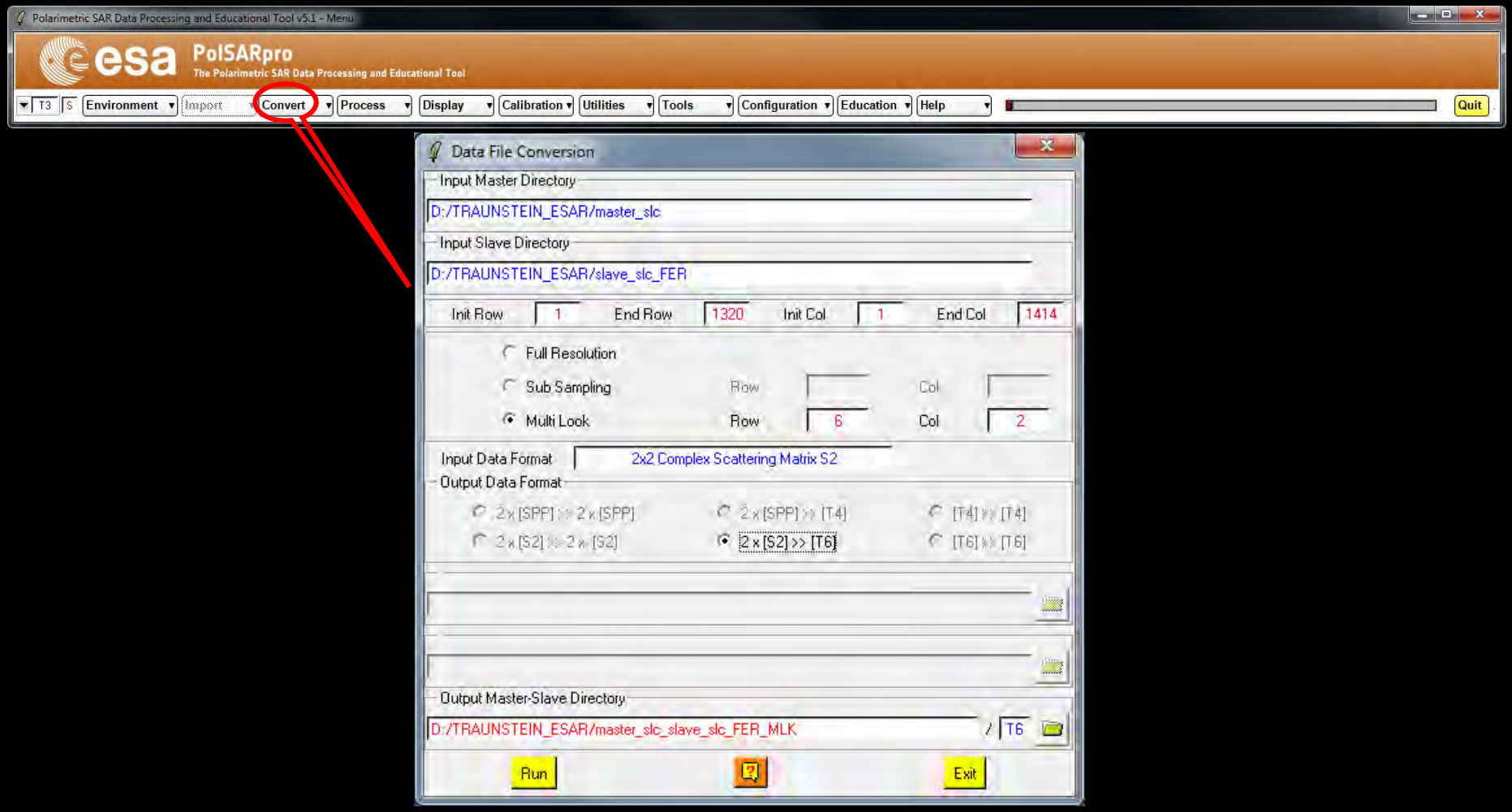
Convert S2 - T6 : Multilook







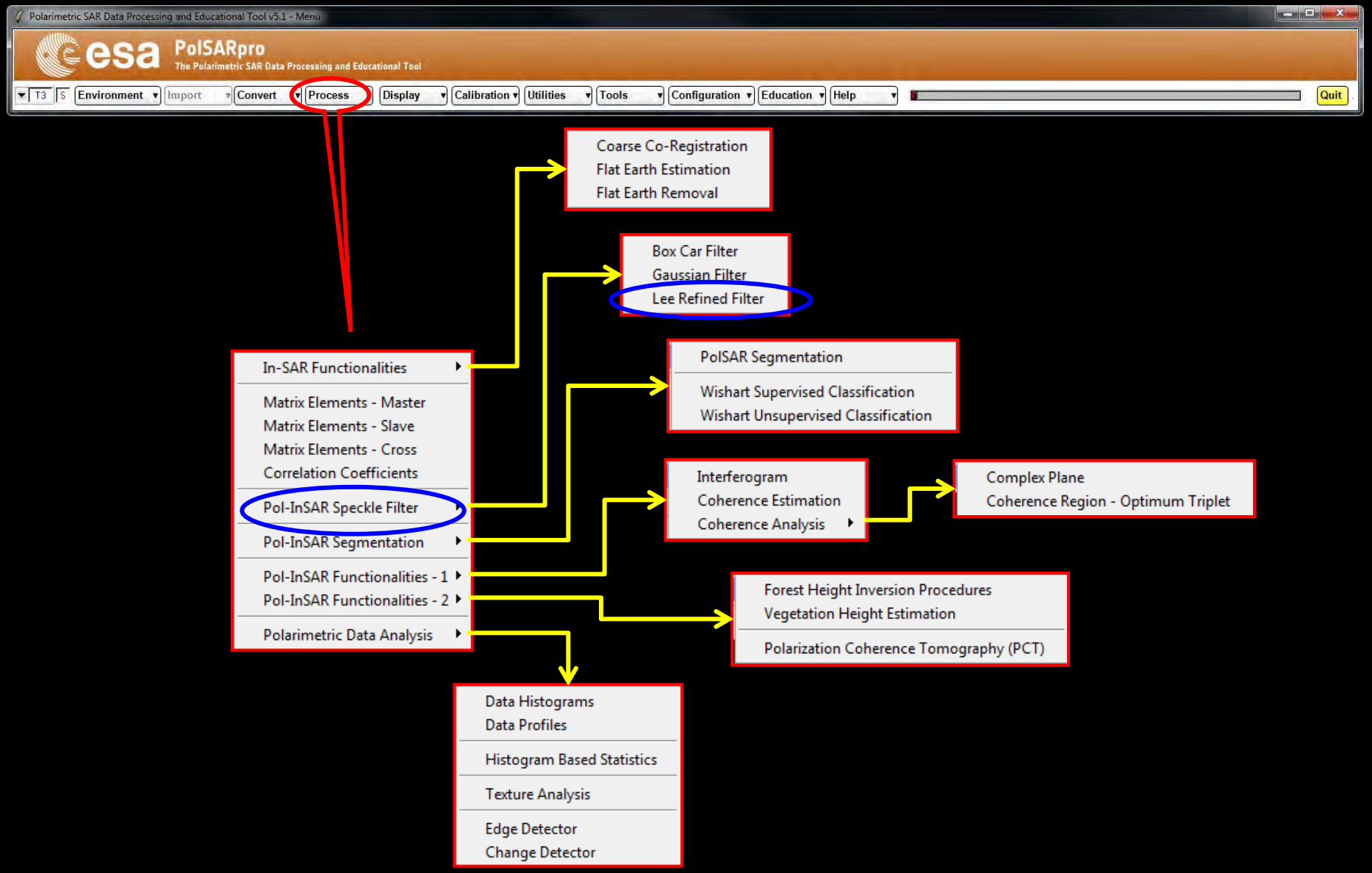
Convert S2 - T6 : Multilook



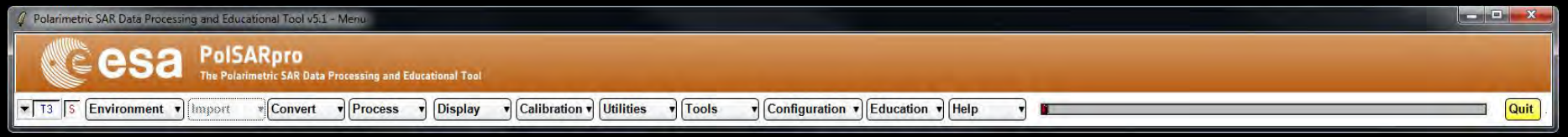
Do it Yourself:
Select Multi Look : Row = 6 and Col = 2
Select Output Data Format : 2 x [S2] >> [T6]

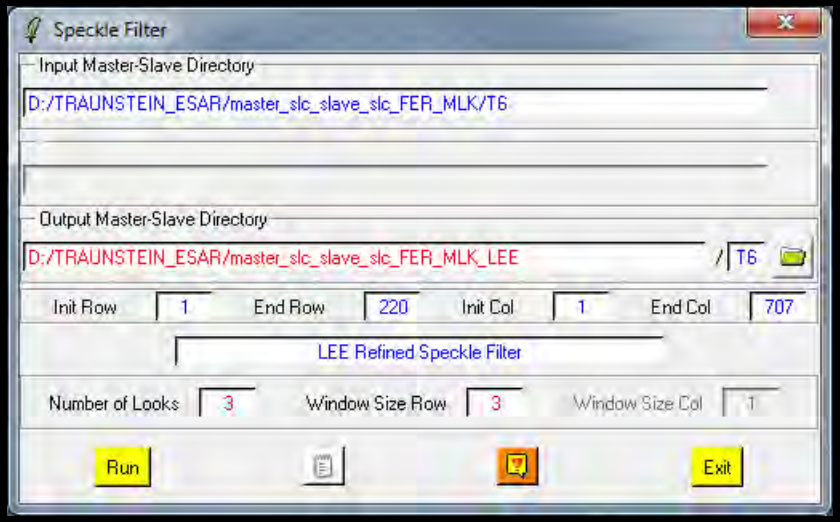
Note:
The Output Directory is automatically set to: MasterDir_SlaveDir_FER_MLK

PROCESS DATA



PROCESS DATA

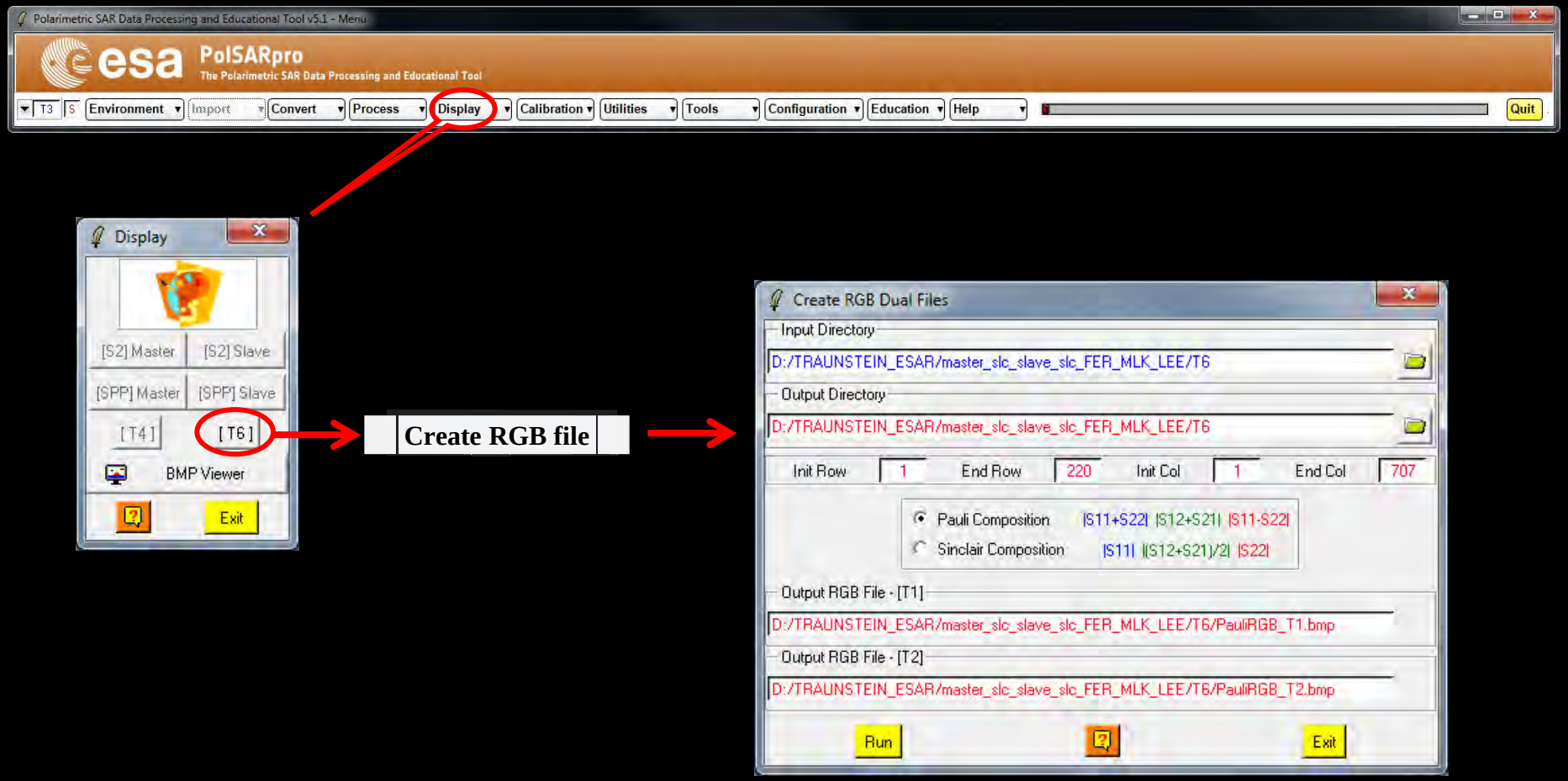




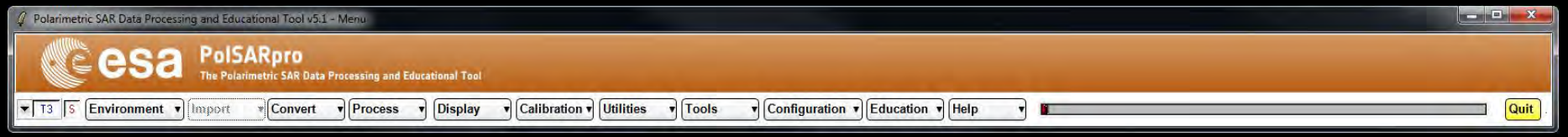
Do it Yourself:
Set the parameters : Num Looks = 3 ; Window Size = 3.

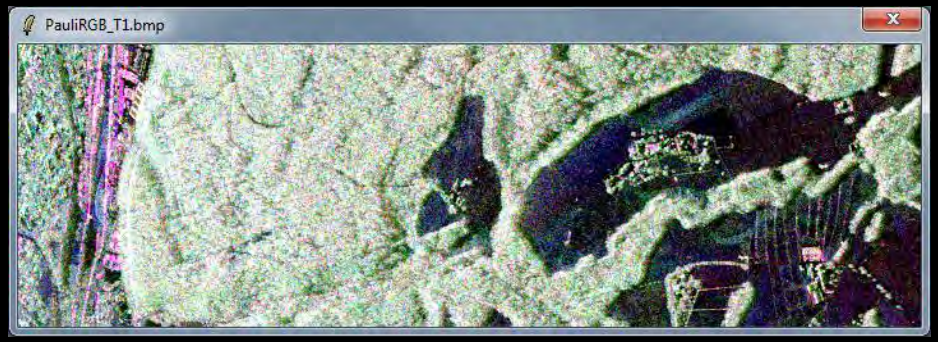
Note:
The Output Directory is automatically set to: MasterDir_SlaveDir_FER_MLK_LEE

PROCESS DATA

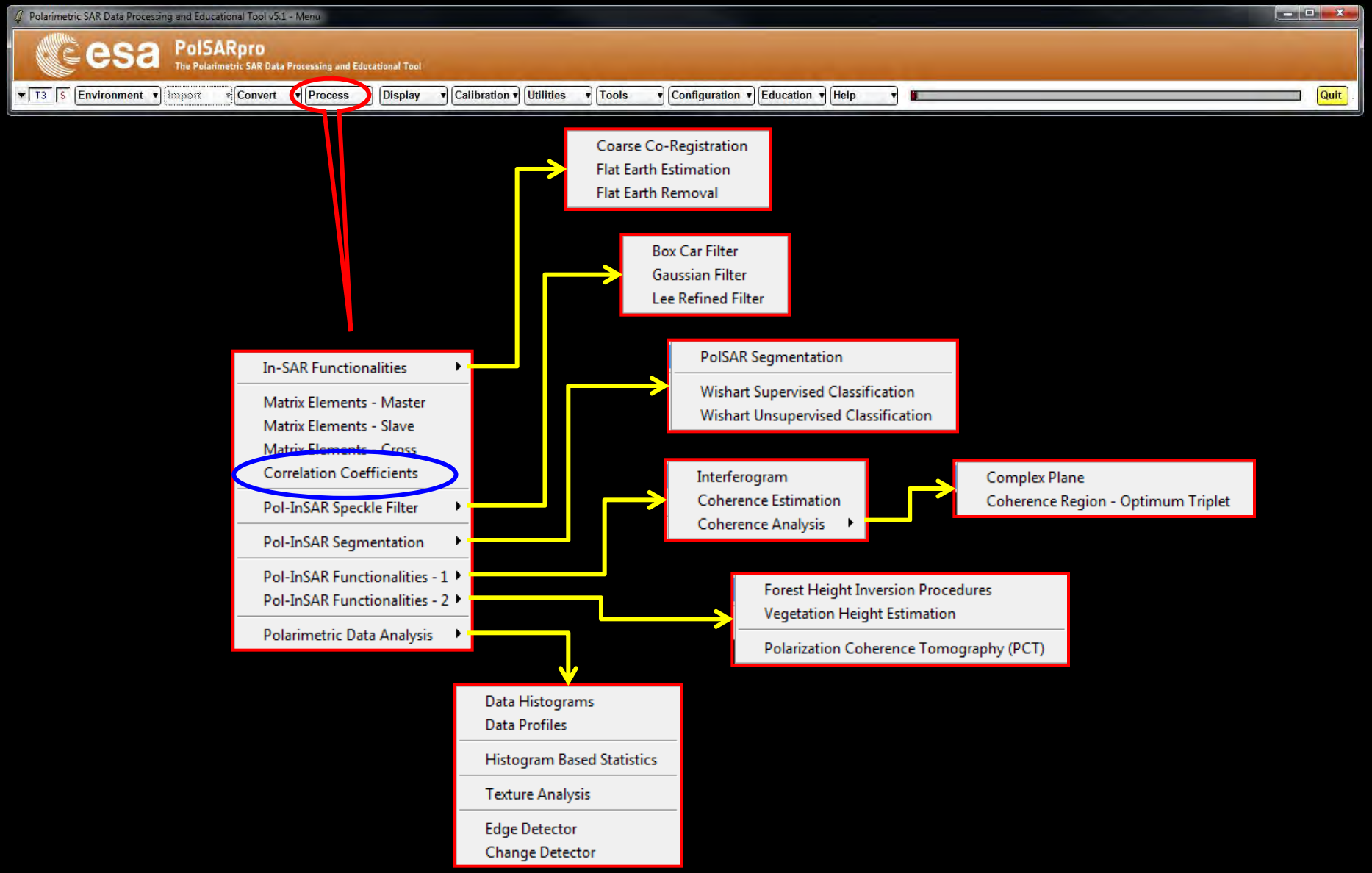


PROCESS DATA

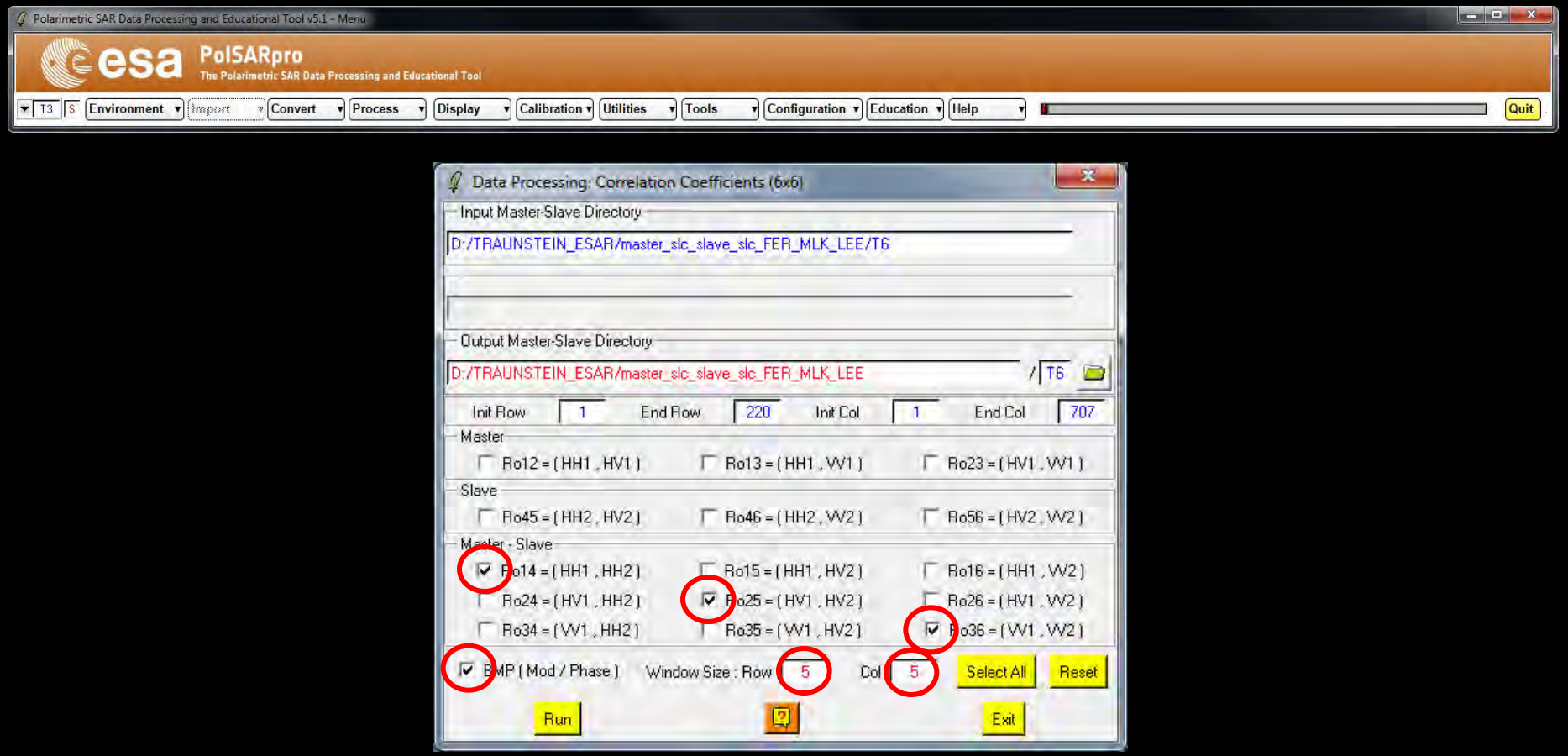




PROCESS DATA

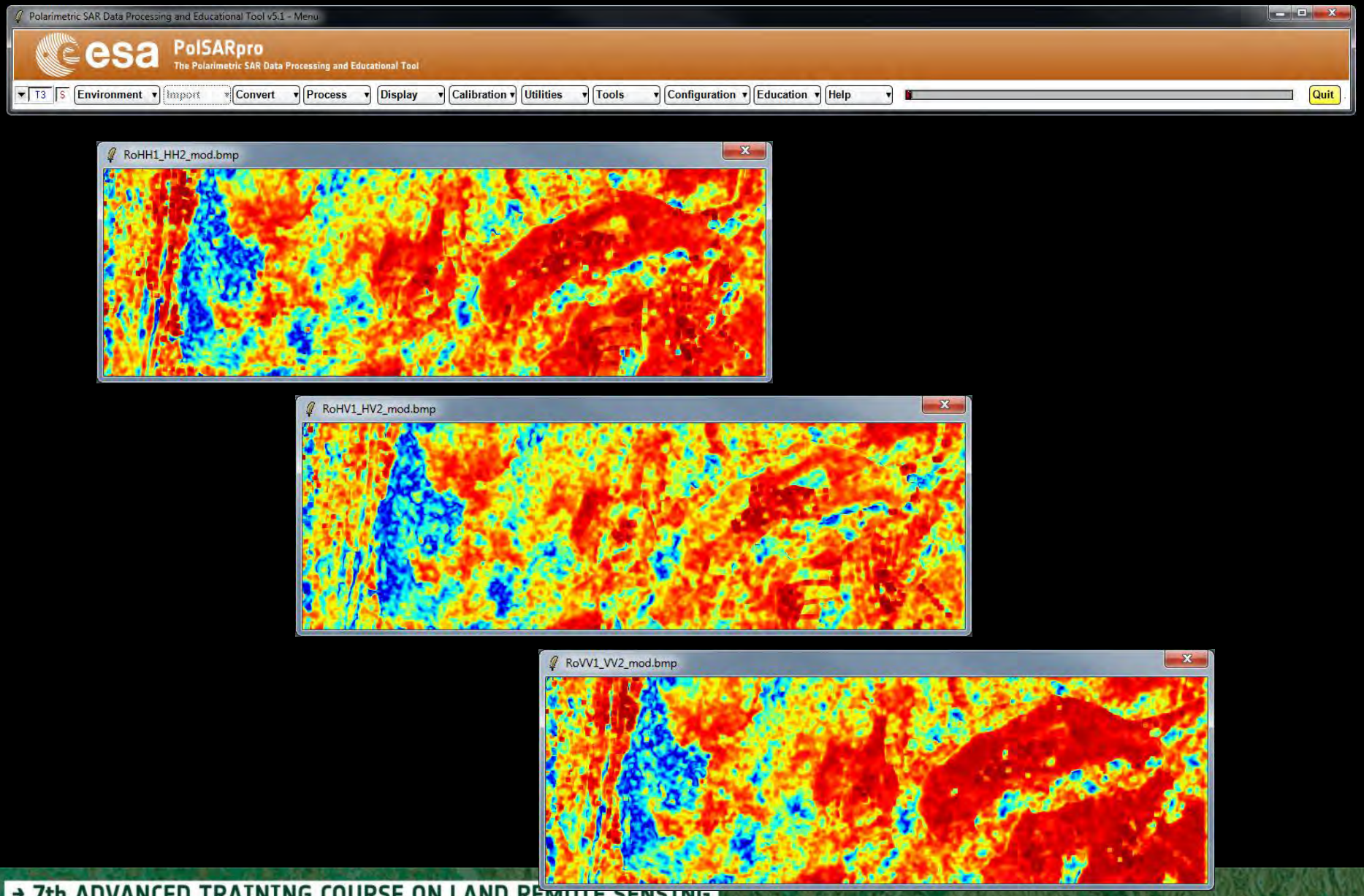


PROCESS DATA

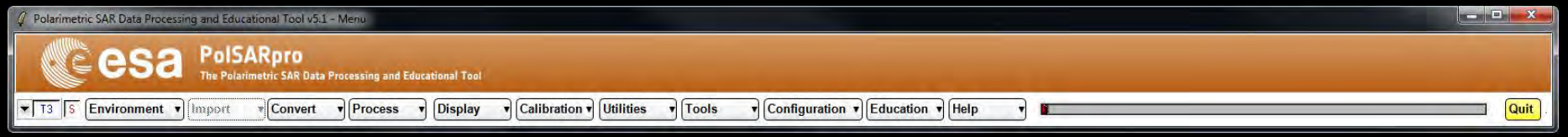


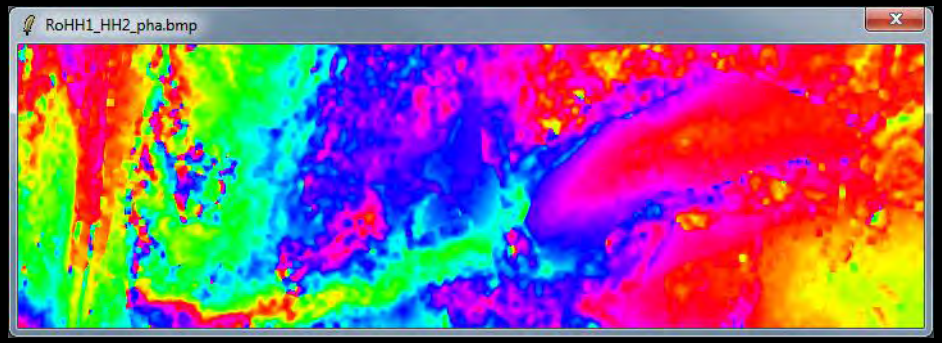
Do it Yourself:
Select the correlation coefficients, set the parameters (Box Car= 5x5) and view the corresponding BMP files.

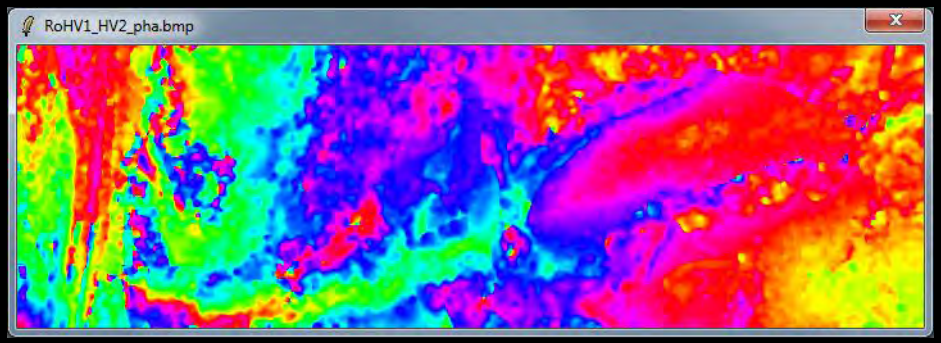
PROCESS DATA

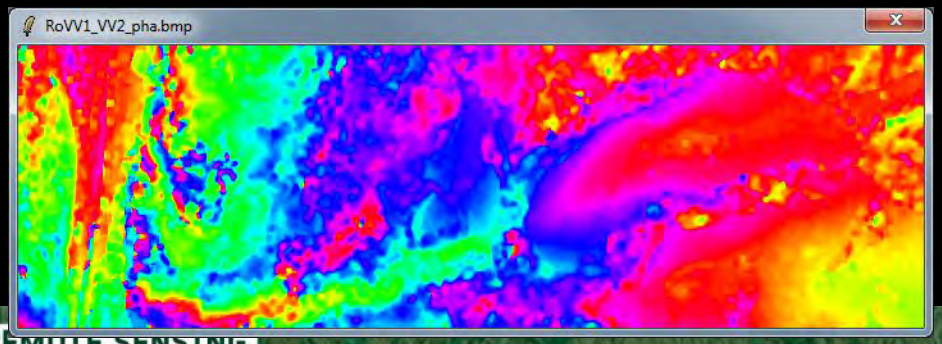


PROCESS DATA

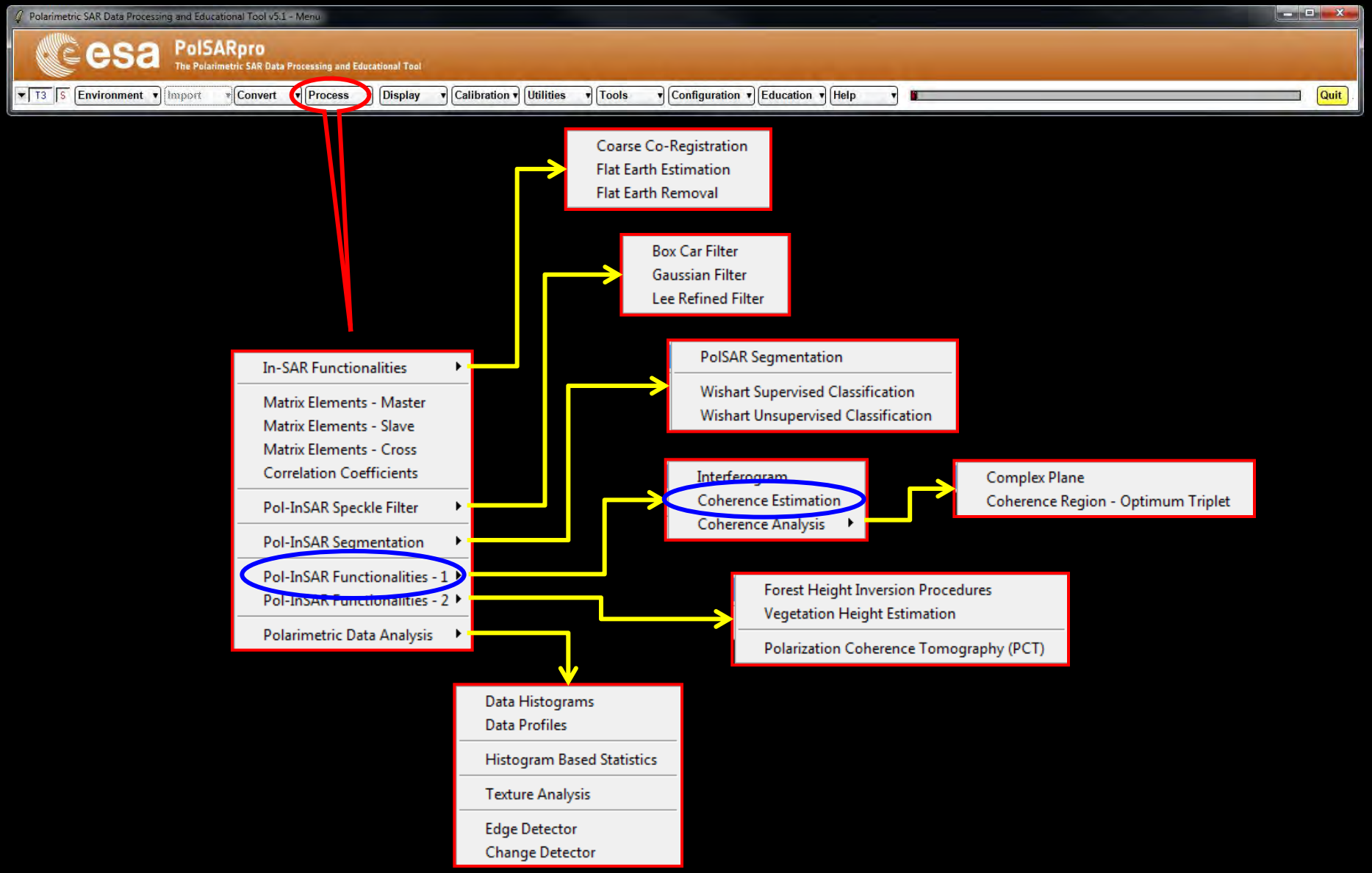




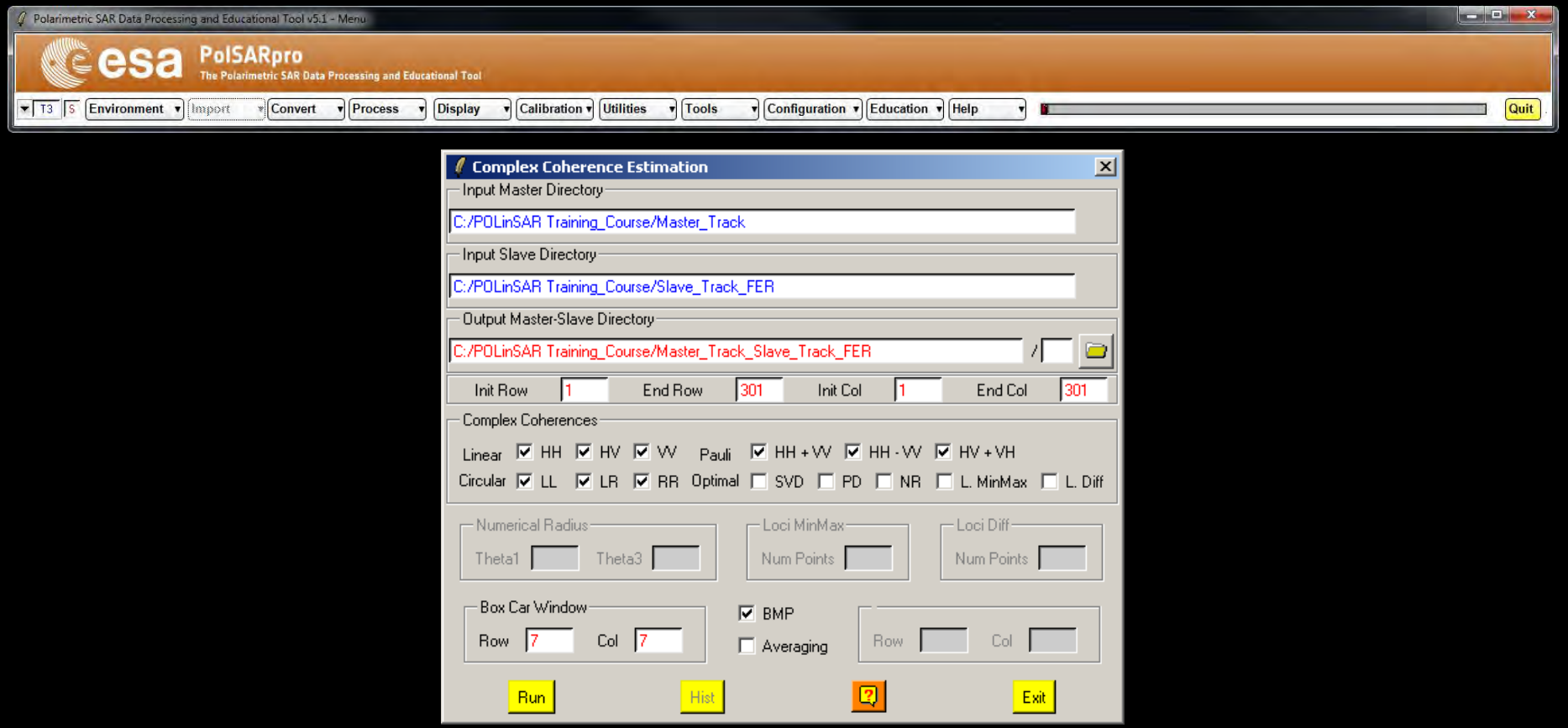




PROCESS DATA

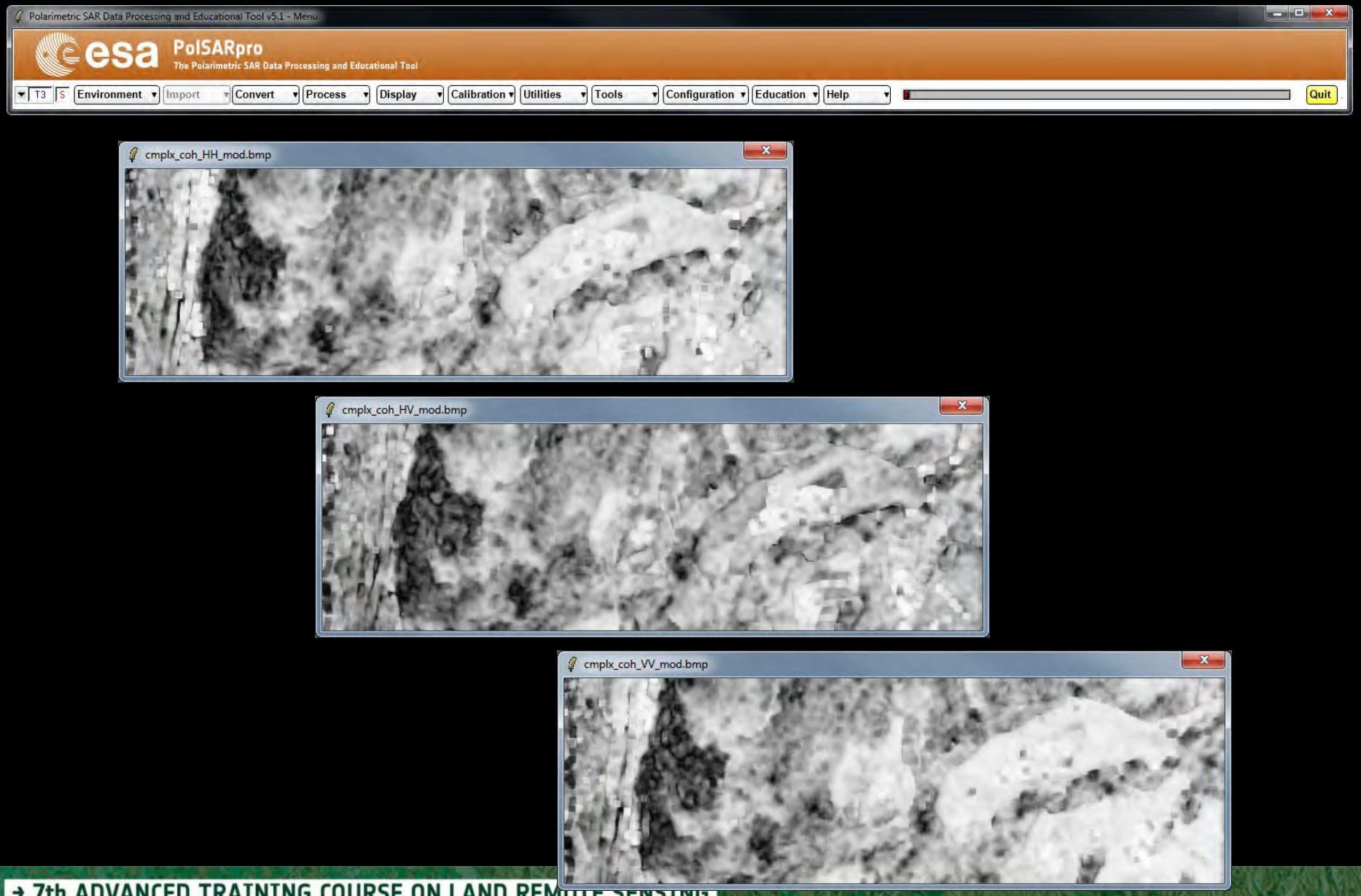


COHERENCE ESTIMATION

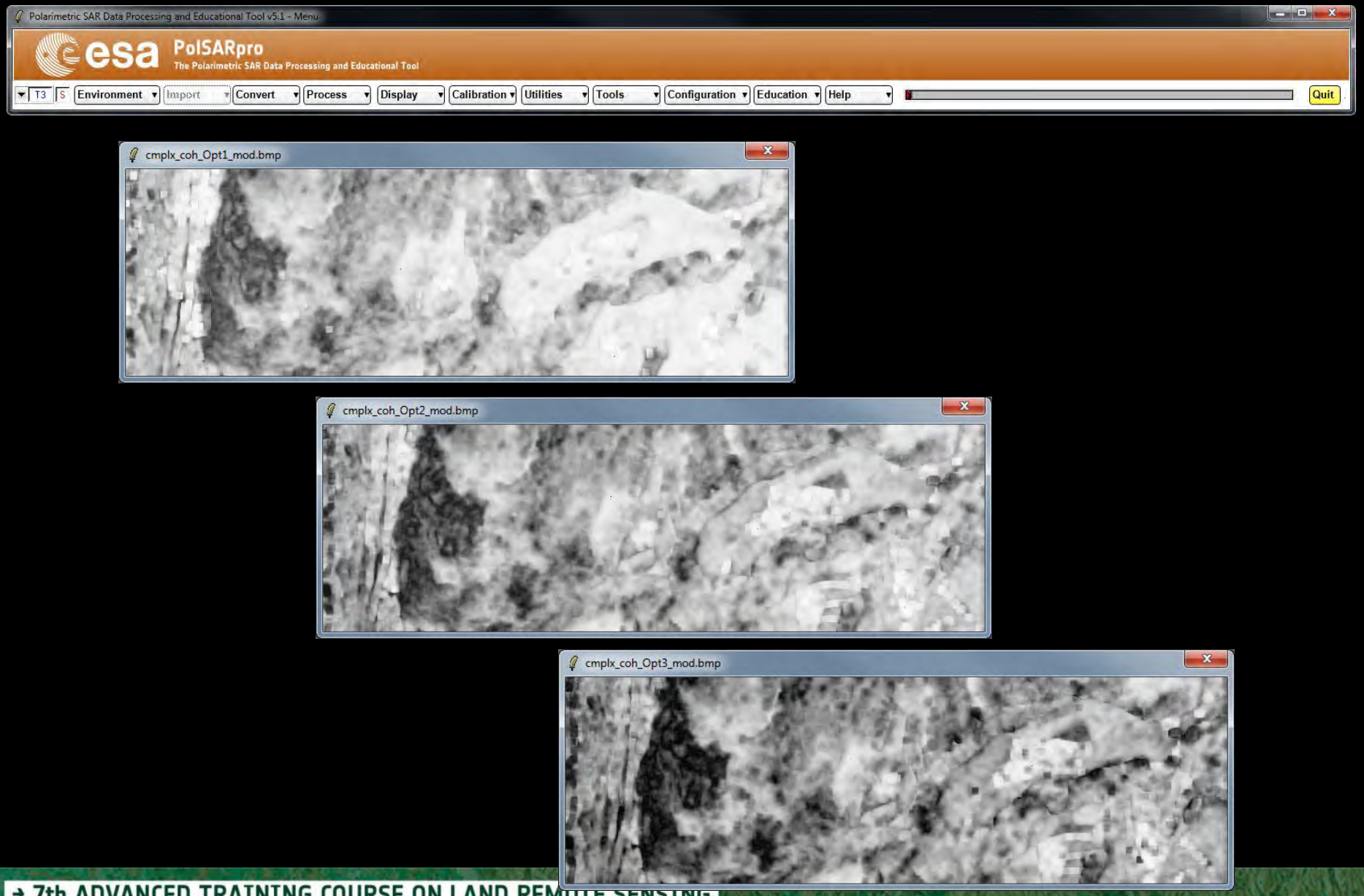


Do it Yourself:
Select polarization channels (linear, circular, pauli), set the parameters (Box Car = 7x7) and view the corresponding BMP files (select BMP).

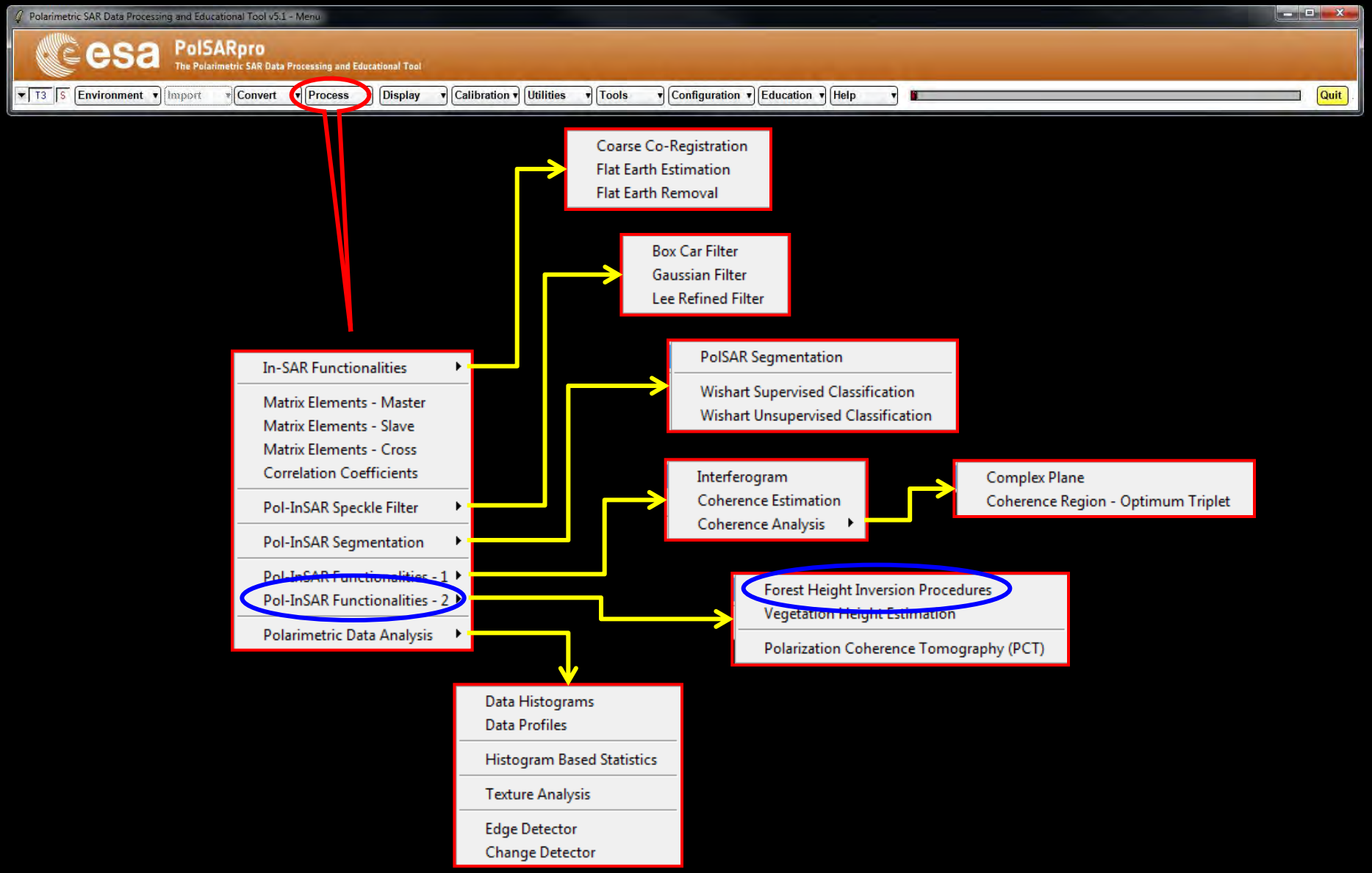
COHERENCE ESTIMATION



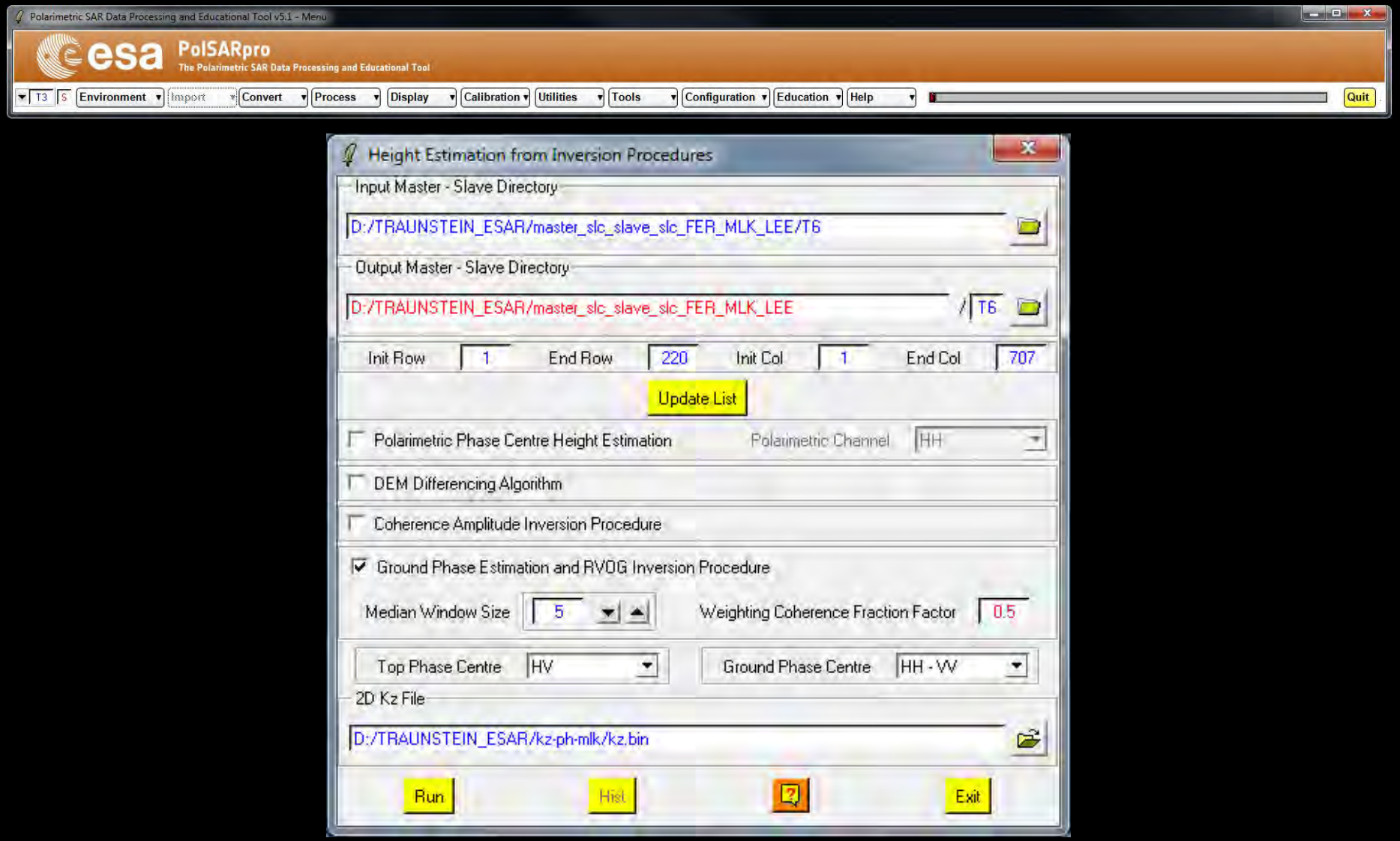
COHERENCE ESTIMATION



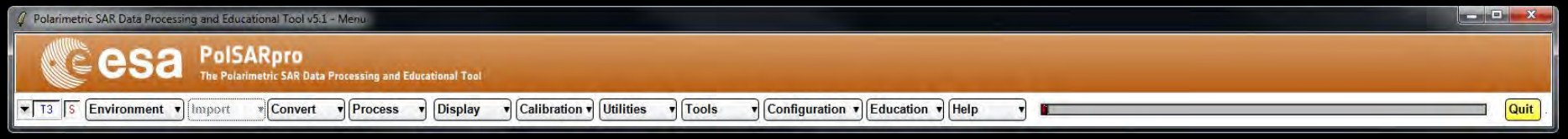
PROCESS DATA

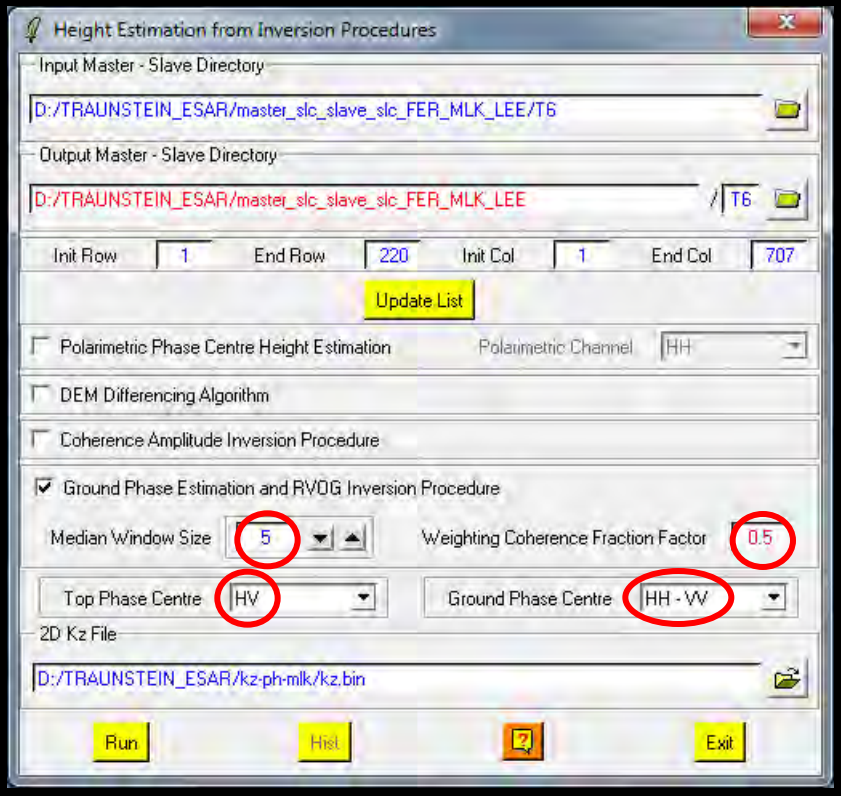


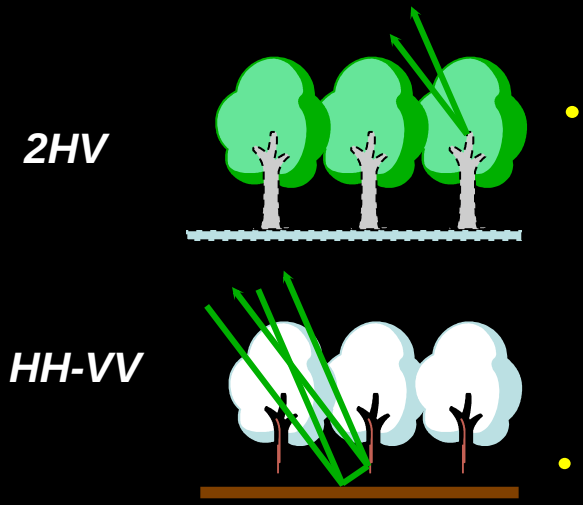
HEIGHT ESTIMATION



HEIGHT ESTIMATION

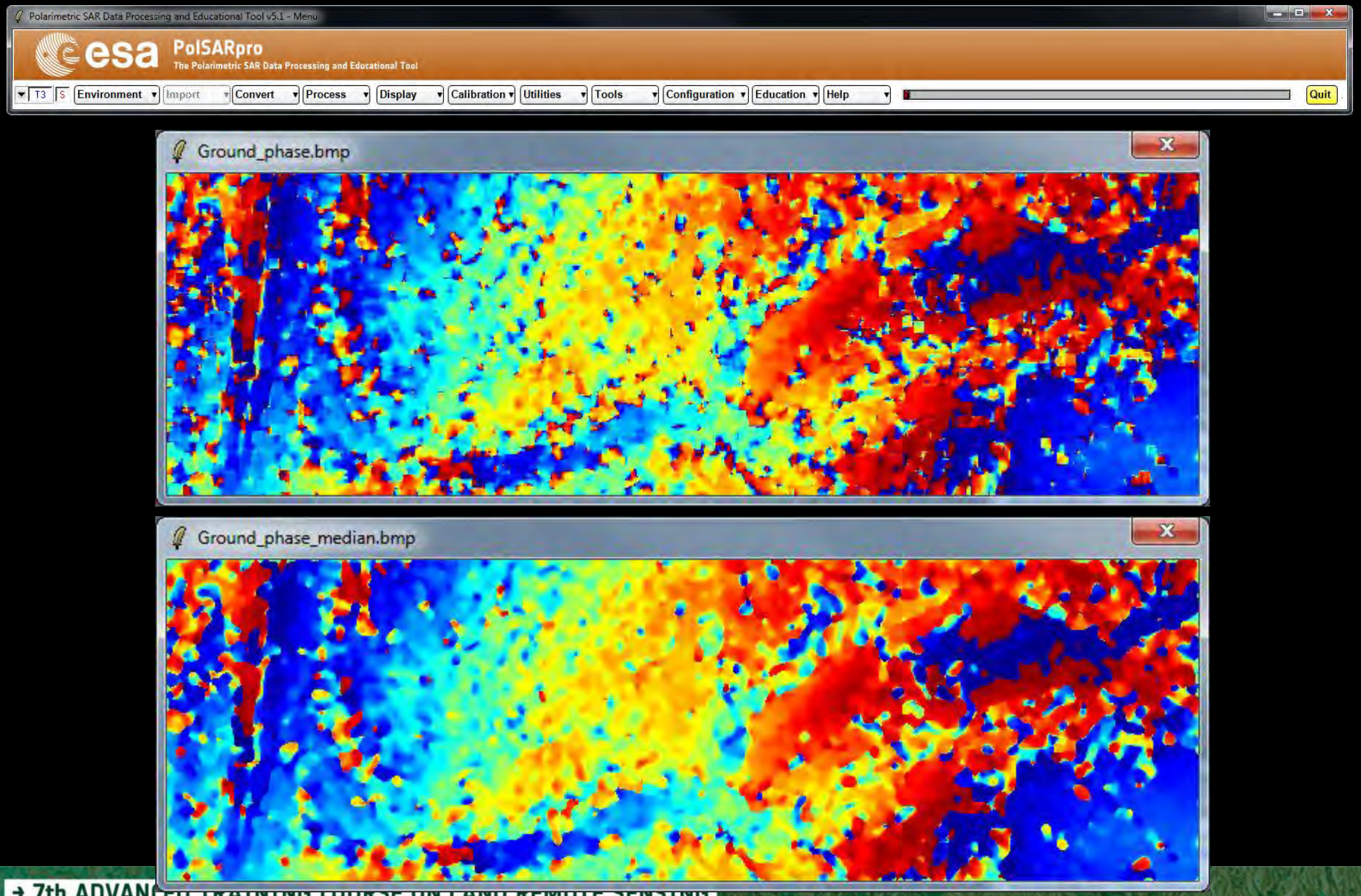




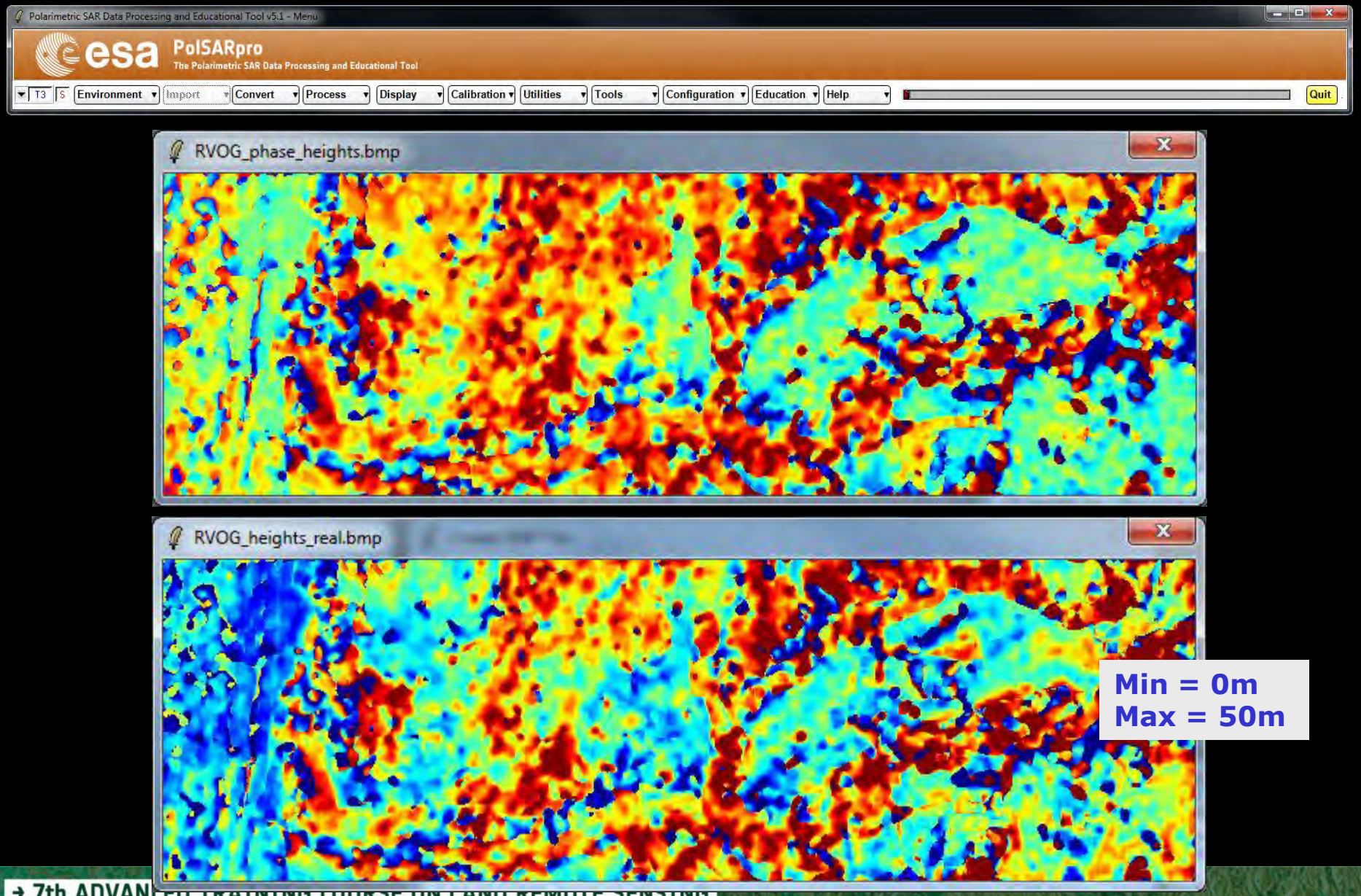


Do it Yourself:
Set the parameters (Median Size = 21, Factor = 0.4) and view the corresponding BMP files.
2D Kz File : DataDirectory / kz-ph-mlk / kz.bin

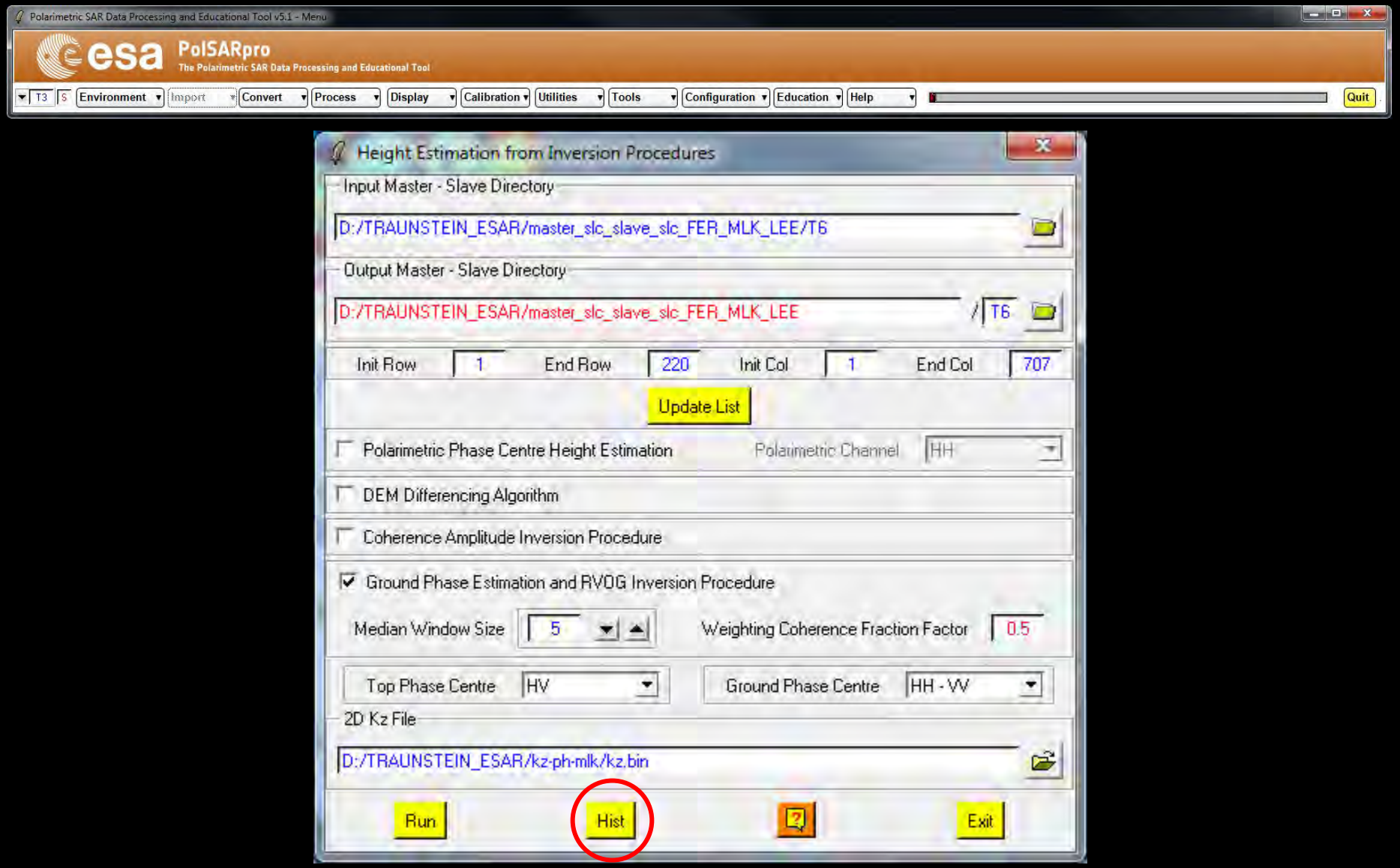
HEIGHT ESTIMATION



HEIGHT ESTIMATION

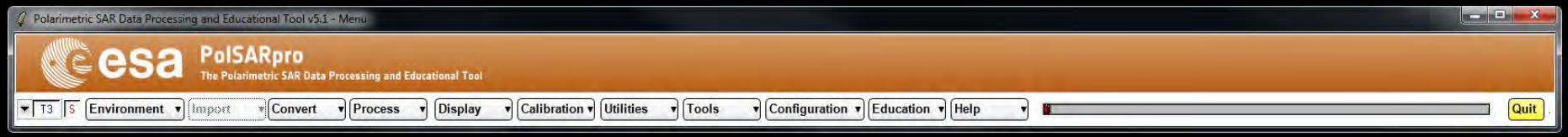


HEIGHT ESTIMATION

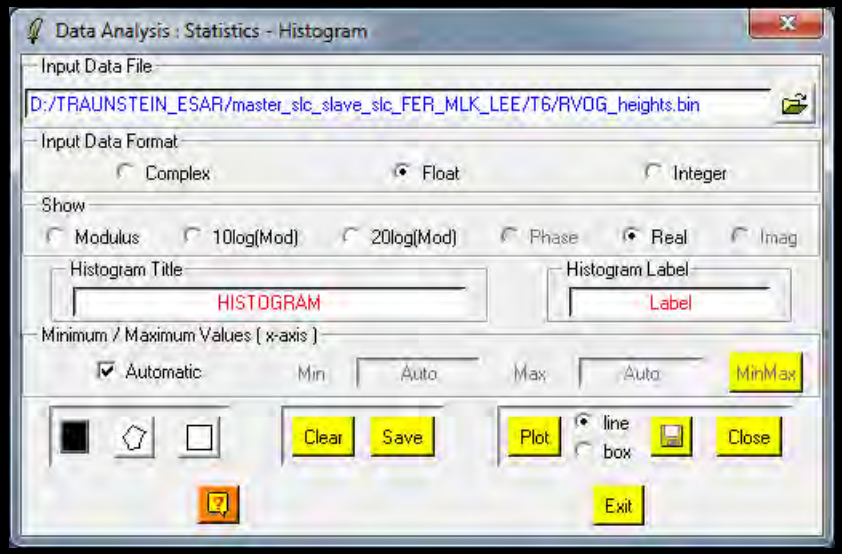


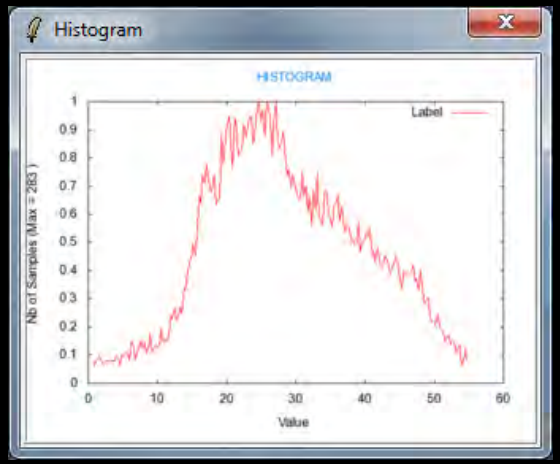
Data Analysis : Histogram

HEIGHT ESTIMATION

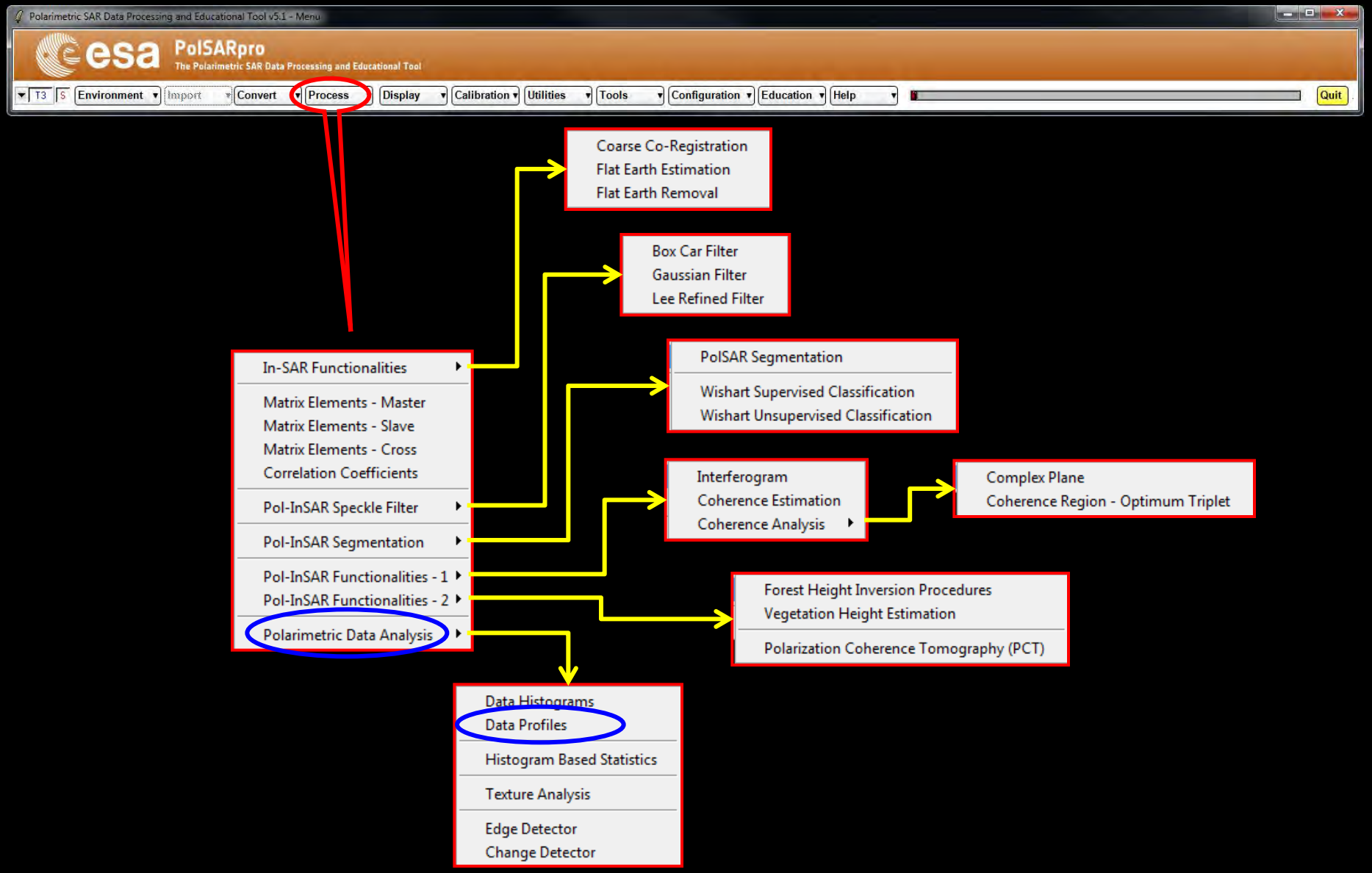


Do it Yourself:
Select a BMP file
Select a BIN file
Select Input Data Format
Select Show
Select Area
SAVE
PLOT

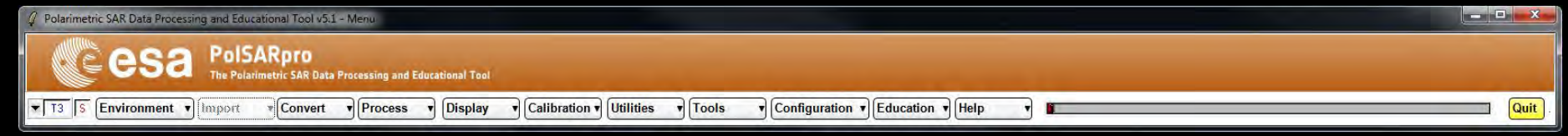


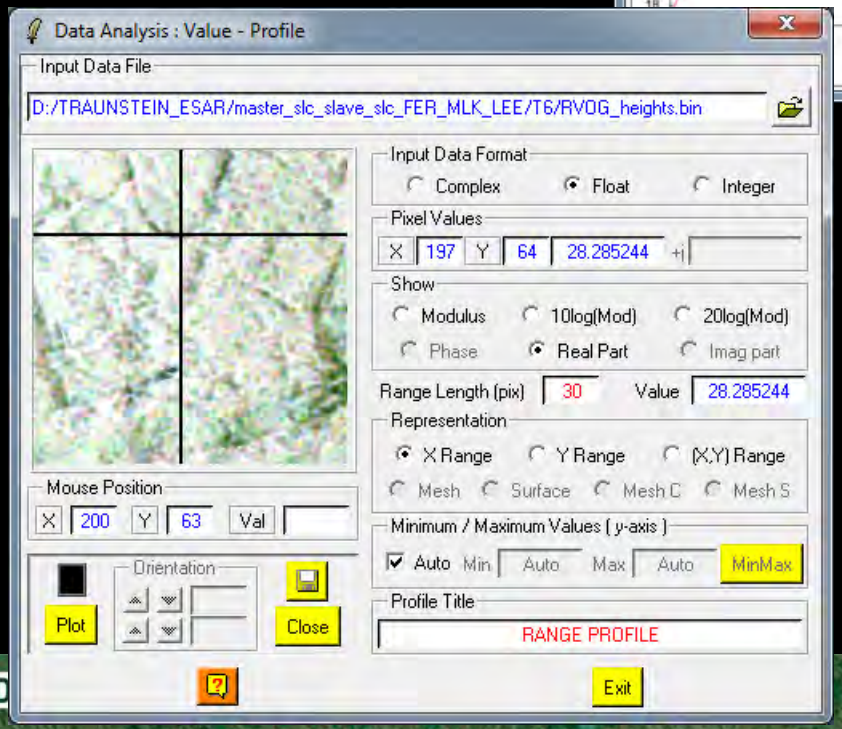


PROCESS DATA



HEIGHT ESTIMATION





Do it Yourself:

Select a BMP file
Select a BIN file
Select Input Data Format
Select Pixel
Select Show
Select Representation
- **X Range / Y Range = 30pix**
- **XY Range = 30 pix (3D)**

Set Min / Max Values
PLOT

Questions ?