# POLSARPRO & Land retrievals using SAR Polarimetry

# (Practical Session)

**Eric POTTIER**

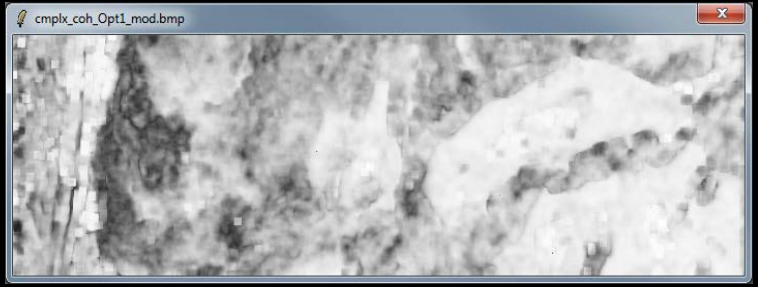
**University of Rennes 1**

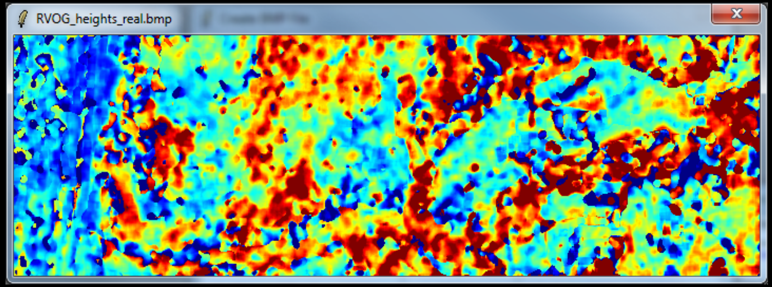
**Erxue Chen**

**Chinese Academy of forestry**

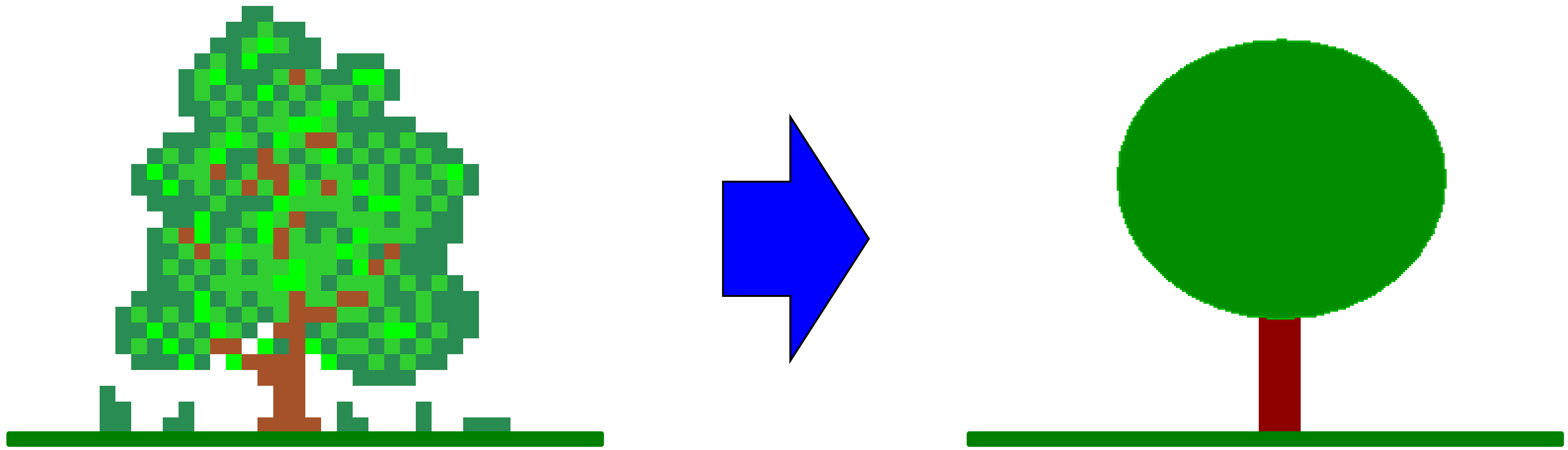

# Pol-InSAR Practical
# Forest Application



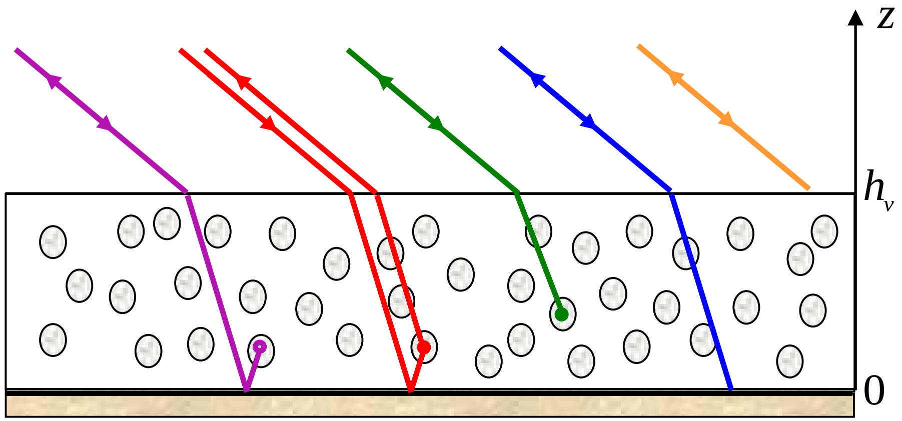


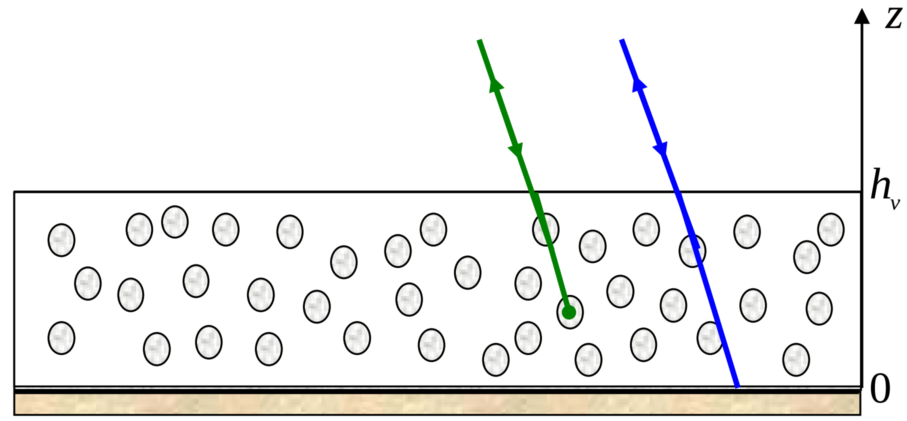



# VOLUME COHERENCE MODEL



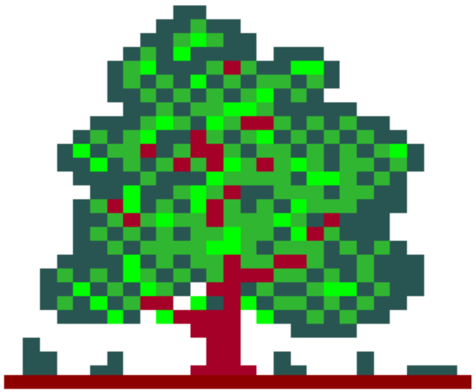
**Modeling** | **Parameter Estimation**

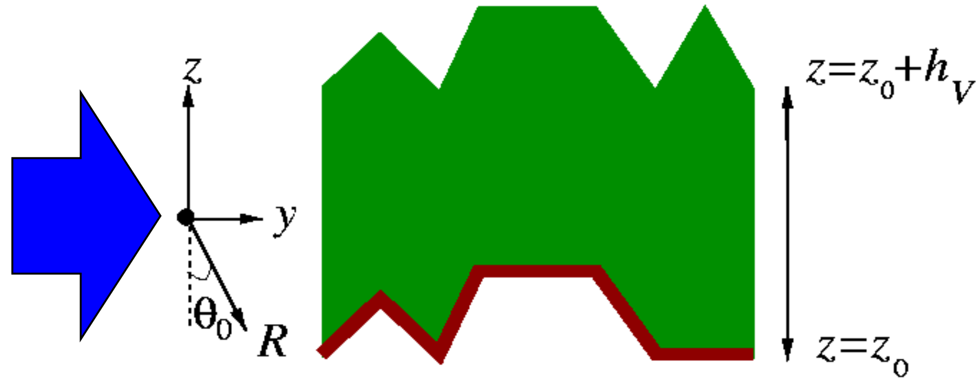



Simplifications : Only 2 significant mechanisms – Low density medium ⇨ No refraction

# VOLUME COHERENCE MODEL






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

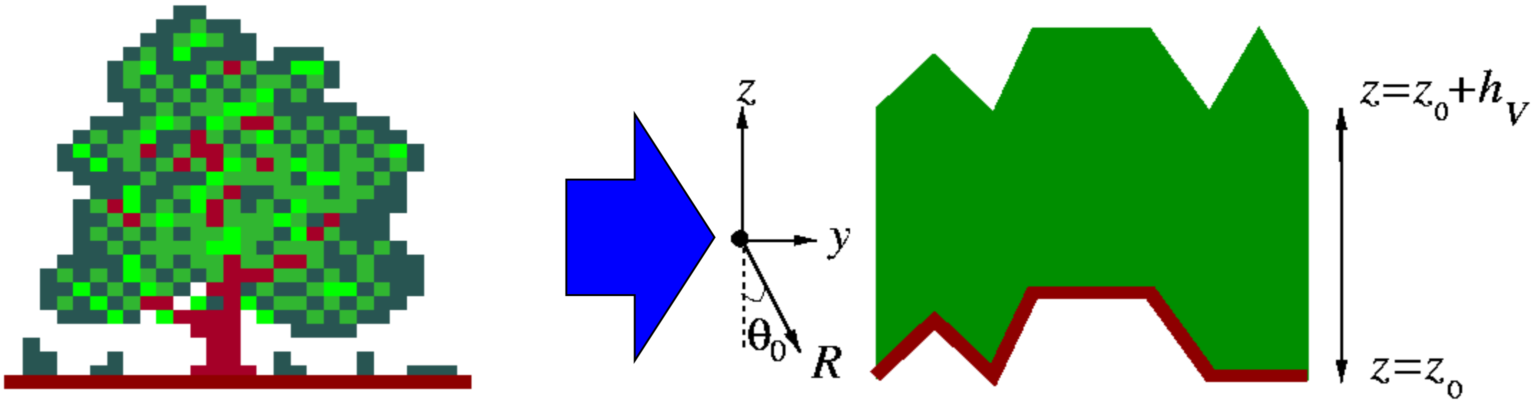
$\phi_0$ **Topographic Phase**

$$k_z = \frac{4\pi\Delta\theta}{\lambda \sin(\theta_0)}$$

**Vertical Wavenumber**

**POLARIZATION INDEPENDENT**

# VOLUME COHERENCE MODEL




**Vertical Structure function**

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

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

**Case of Uniform Random Layer**

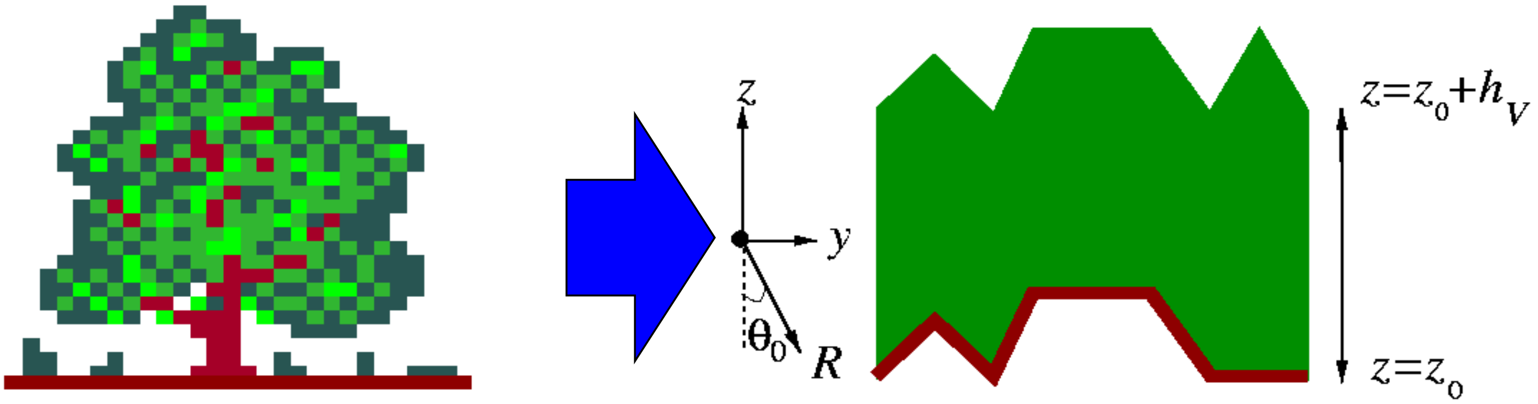
$\theta_0$ **Incidence Angle**

$\sigma$ **Extinction Coefficient**

**POLARIZATION INDEPENDENT**

# RVOG COHERENCE MODEL

## RVOG = Random Volume Over Ground




## 2 Layer Combined Surface and random Volume Scattering

$$\gamma(\underline{w}) = e^{j\phi_0}\frac{\gamma_{VOL} + \mu(\underline{w})}{1+\mu(\underline{w})}$$

$$\mu(\underline{w}) = \frac{\text{Surface Scattering Contribution}}{\text{Volume Scattering Contribution}}$$ G / V ratio

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

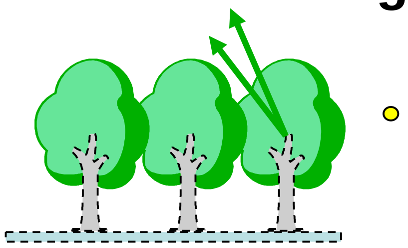
**POLARIZATION DEPENDENT**

# FOREST HEIGHT ESTIMATION

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

$$\gamma(\underline{w}_v) \underset{\mu\mapsto 0}{\mapsto} = e^{j\phi_0}\gamma_{VOL}$$

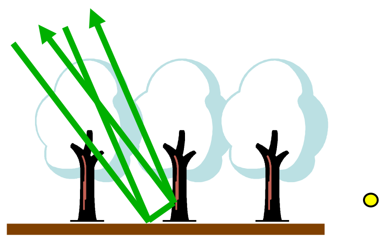
2HV



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

$$\gamma(\underline{w}_s) = e^{j\phi_0}\frac{\gamma_{VOL}+\mu(\underline{w}_s)}{1+\mu(\underline{w}_s)} \underset{\mu\mapsto\infty}{\mapsto} e^{j\phi_0}$$

HH-VV



# FOREST HEIGHT ESTIMATION

$$\left.\begin{aligned}\gamma(\underline{w}_v) &= e^{j\phi_0}\gamma_{VOL}\\ \gamma(\underline{w}_s) &= e^{j\phi_0}\frac{\gamma_{VOL}+\mu(\underline{w}_s)}{1+\mu(\underline{w}_s)}\end{aligned}\right\}\mapsto \begin{bmatrix}\phi_0\\ h_v\\ \sigma\\ \mu\end{bmatrix} = [Model]^{-1}\begin{bmatrix}\gamma(\underline{w}_v)\\ \gamma(\underline{w}_s)\end{bmatrix}$$

**4 Parameters** **4 Observables**

**INVERSION**

## DEM Differencing Algorithm

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

$$\Downarrow$$

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

## 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

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

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

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

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

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

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

# 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 !**

$$h_v \approx \frac{arg[\gamma(\underline{w}_v)] - \hat{\phi}_0}{k_z} + \varepsilon \frac{2\,sinc^{-1}(|\gamma(\underline{w}_v)|)}{k_z}$$

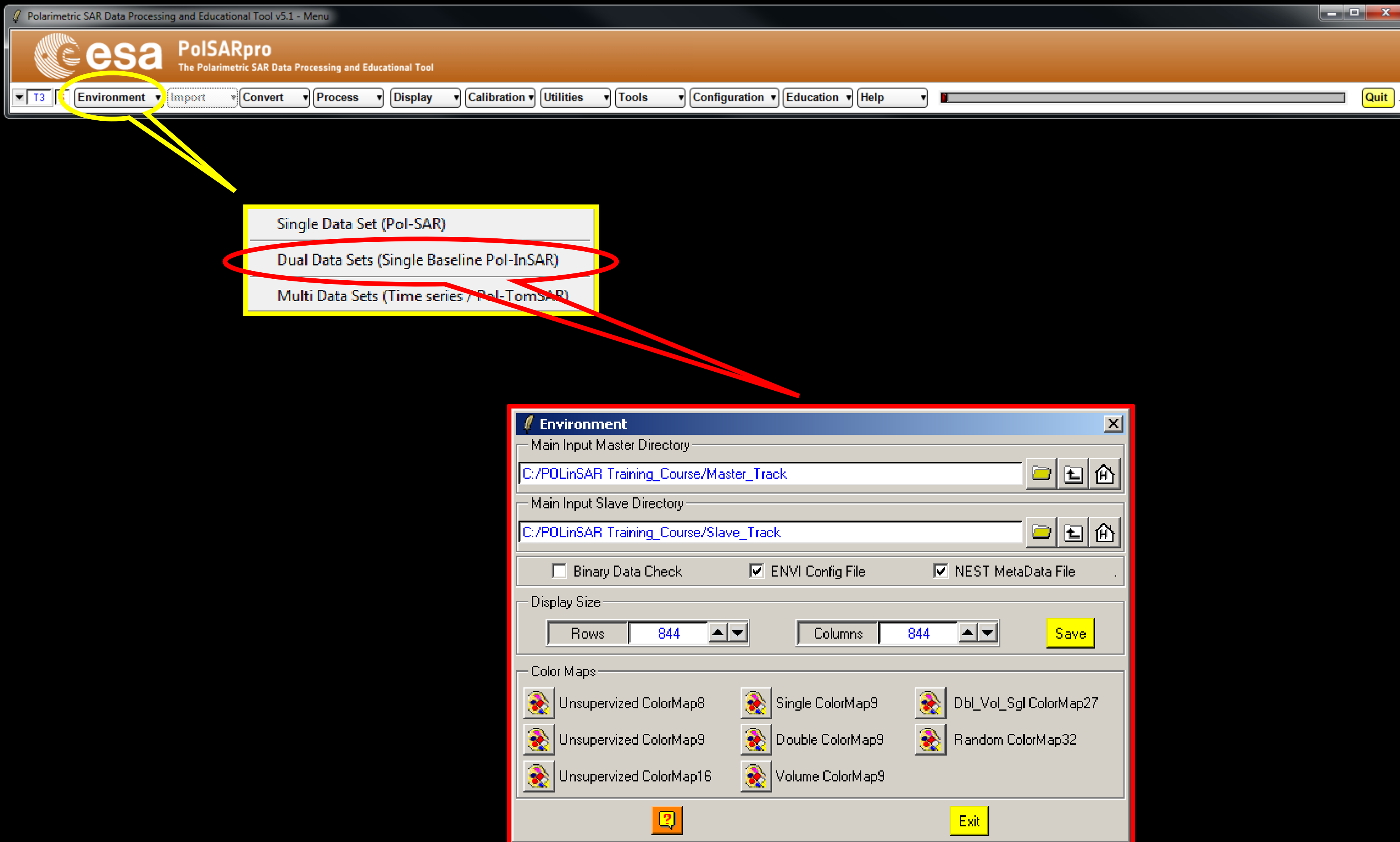
$0.3 \leq \varepsilon \leq 0.5$

**Suitable Compromise**

**DEM Differencing Inversion**

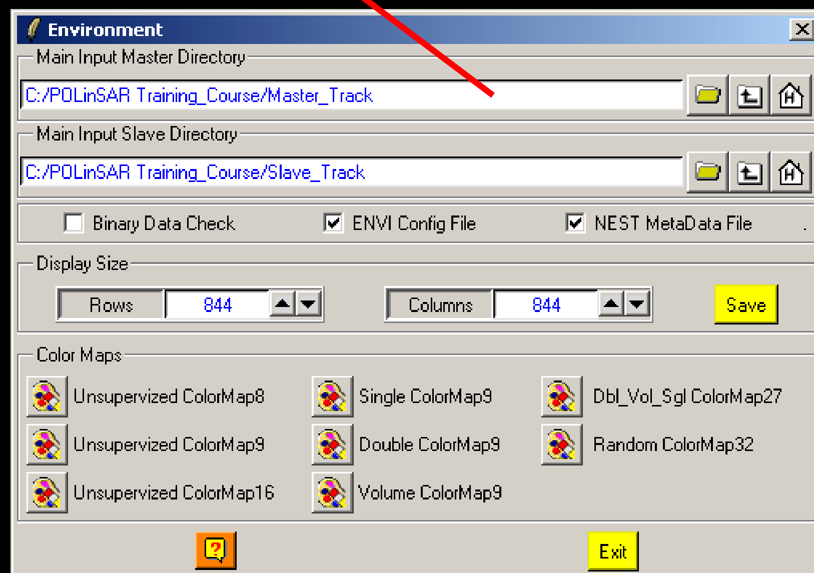
**Coherence Amplitude Inversion**

# 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

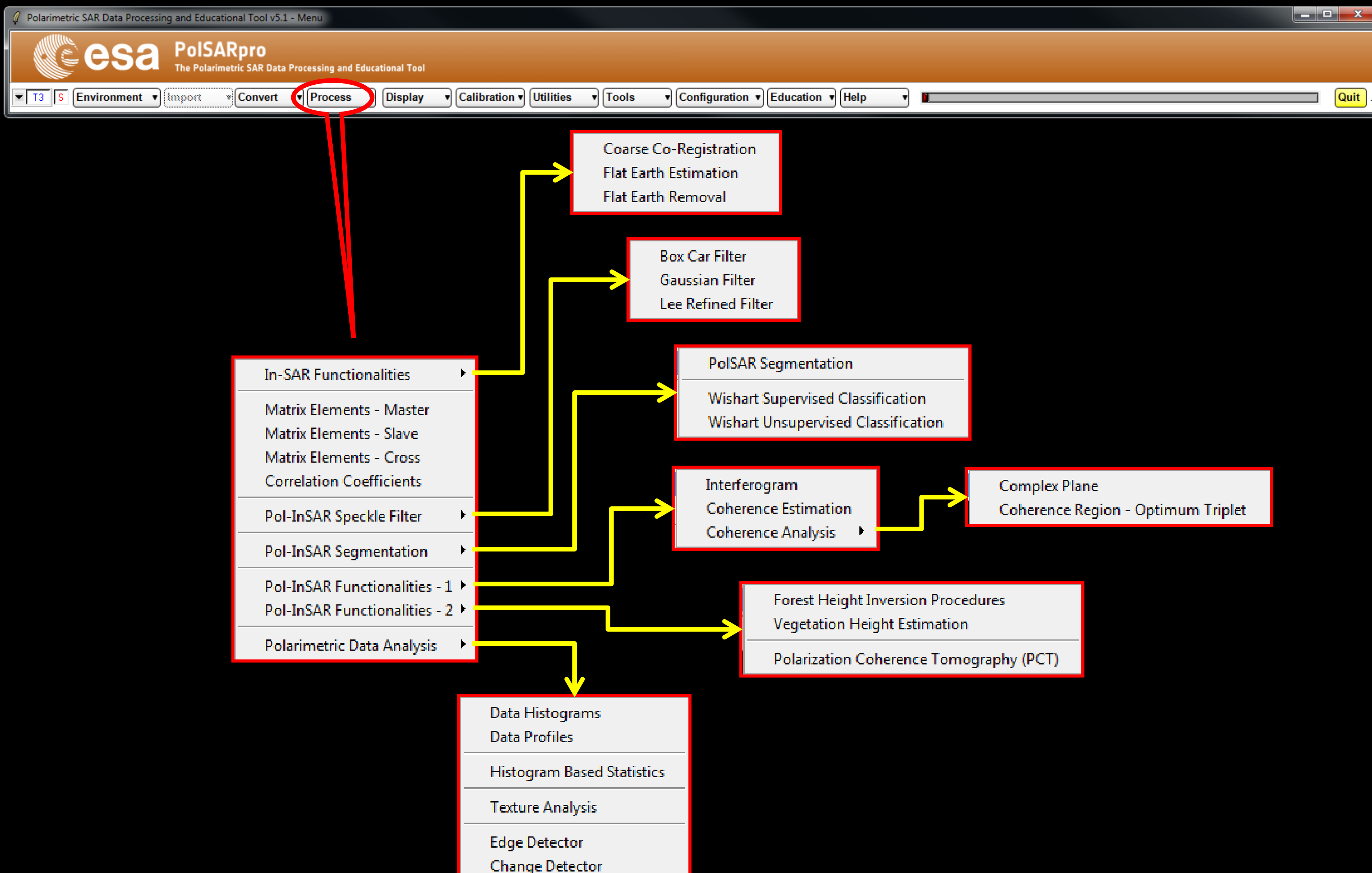

**Configure Data Main Directories location**



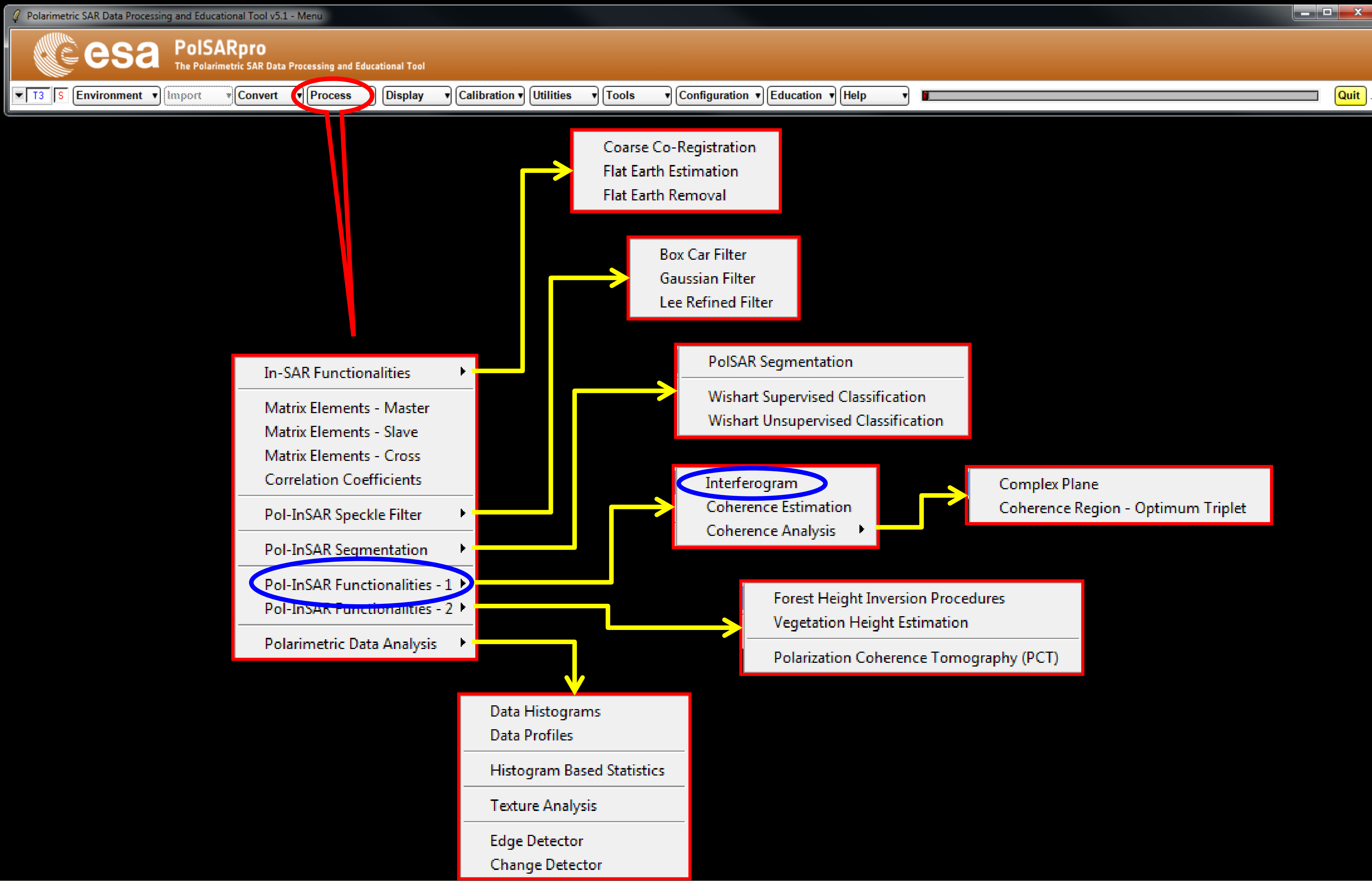

**Input Master Directory: C:/Taunstein_ESAR/master_slc**

**Input Slave Directory: C:/Traunstein_ESAR/slave_slc**

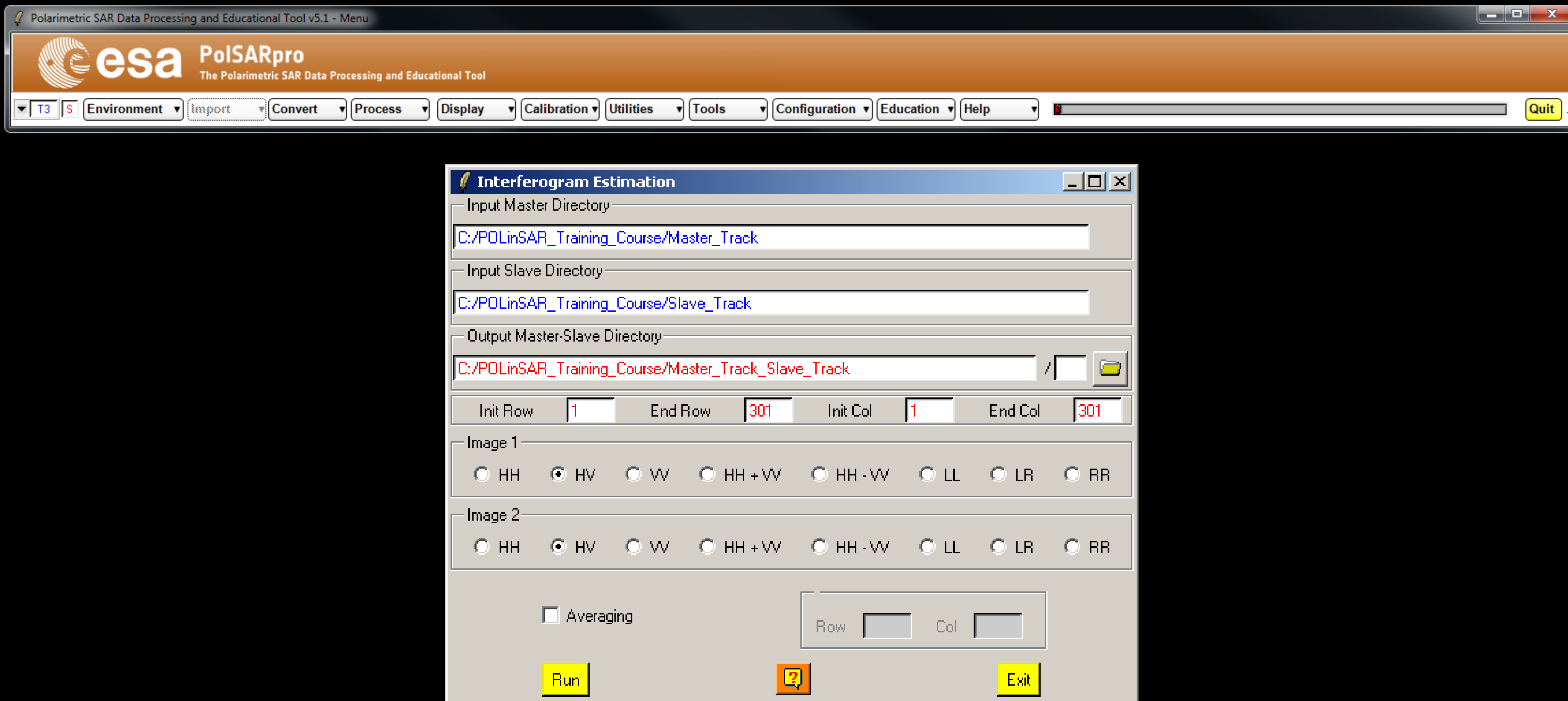
# PROCESS DATA



# PROCESS DATA



# RAW INTERFEROGRAM



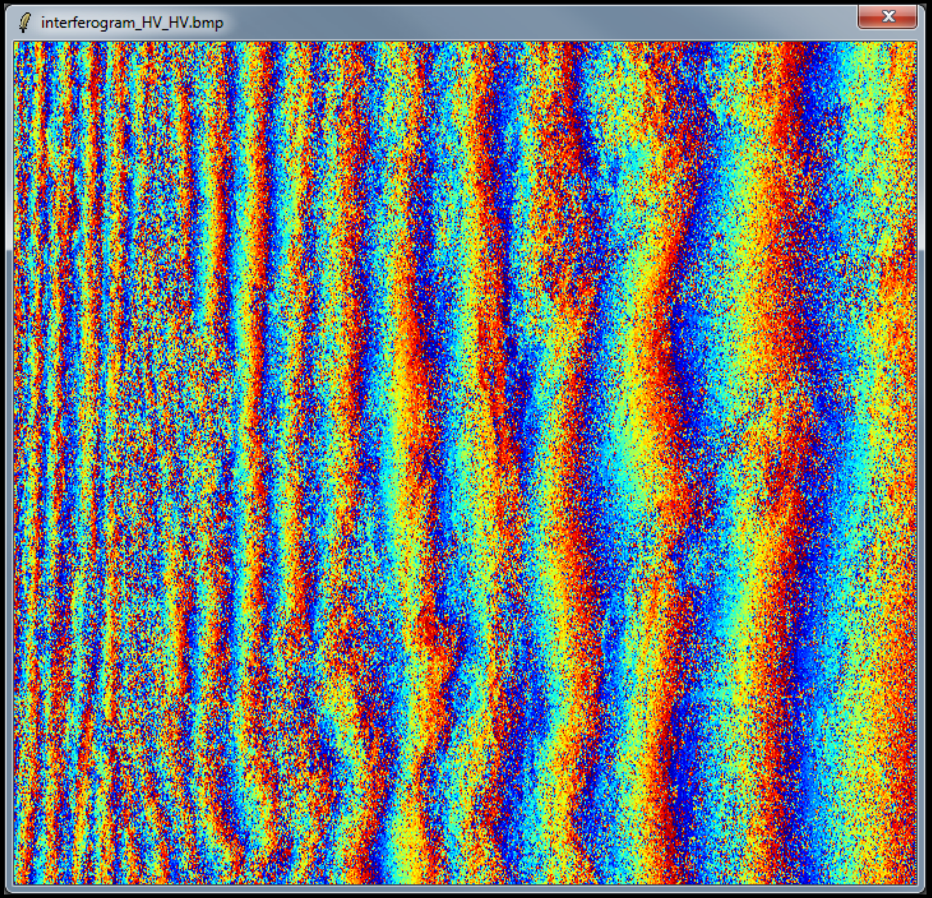

**Do it Yourself:**
**Select polarization channels, set the parameters and view the corresponding BMP files.**

**Note:**
**The Output Directory is automatically set to: MasterDir_SlaveDir**

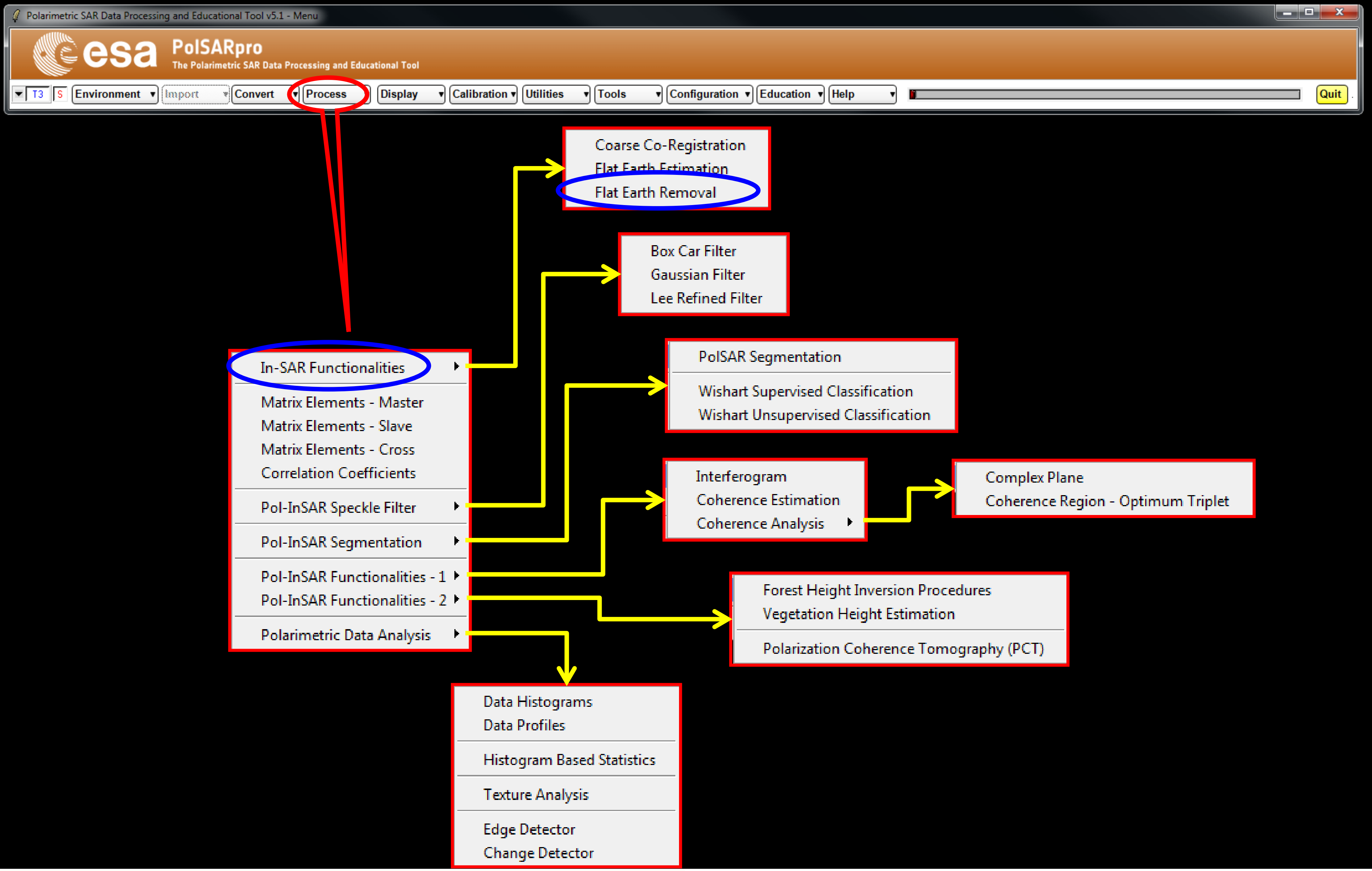
# RAW INTERFEROGRAM


**DATA_MASTERDIR_SLAVEDIR**

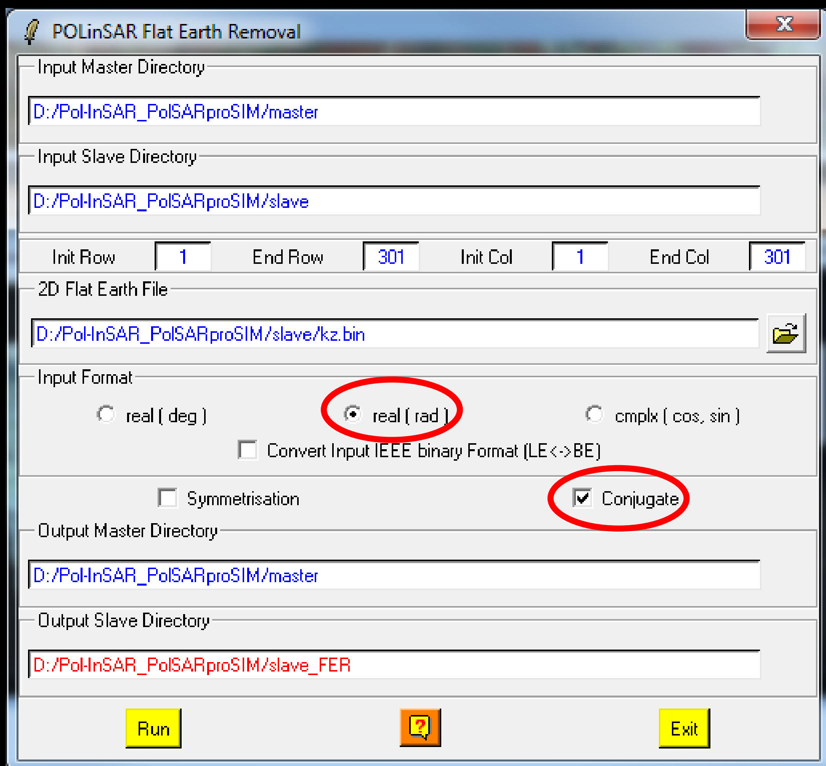
- config.txt
- interferogram_XX_XX.bin
- interferogram_XX_XX.bmp

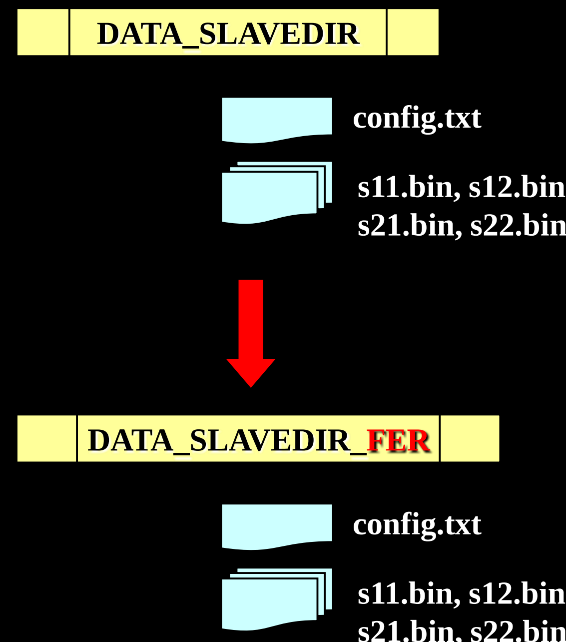


# PROCESS DATA



# FLAT EARTH REMOVAL

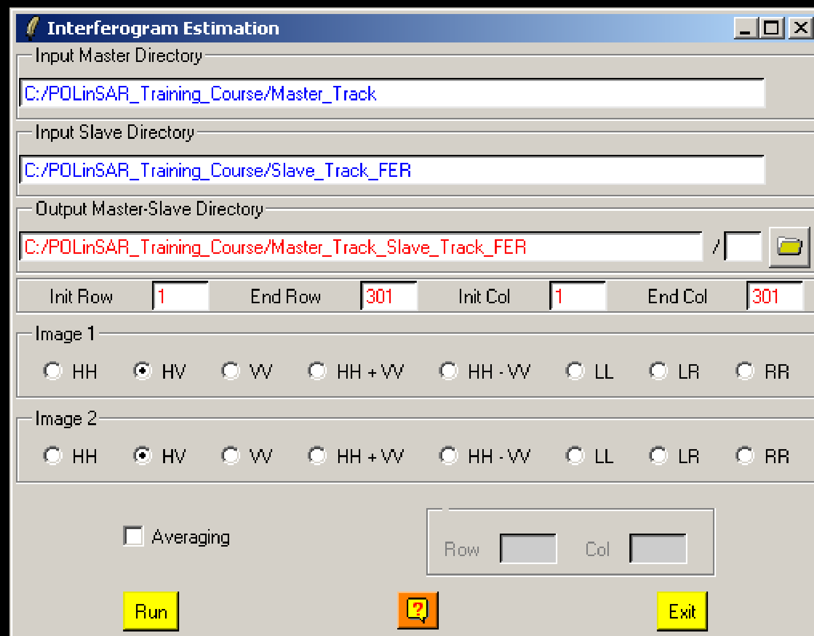




**Do it Yourself:**
**Enter Flat Earth file name, set the parameters and run the function.**

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

# RAW INTERFEROGRAM

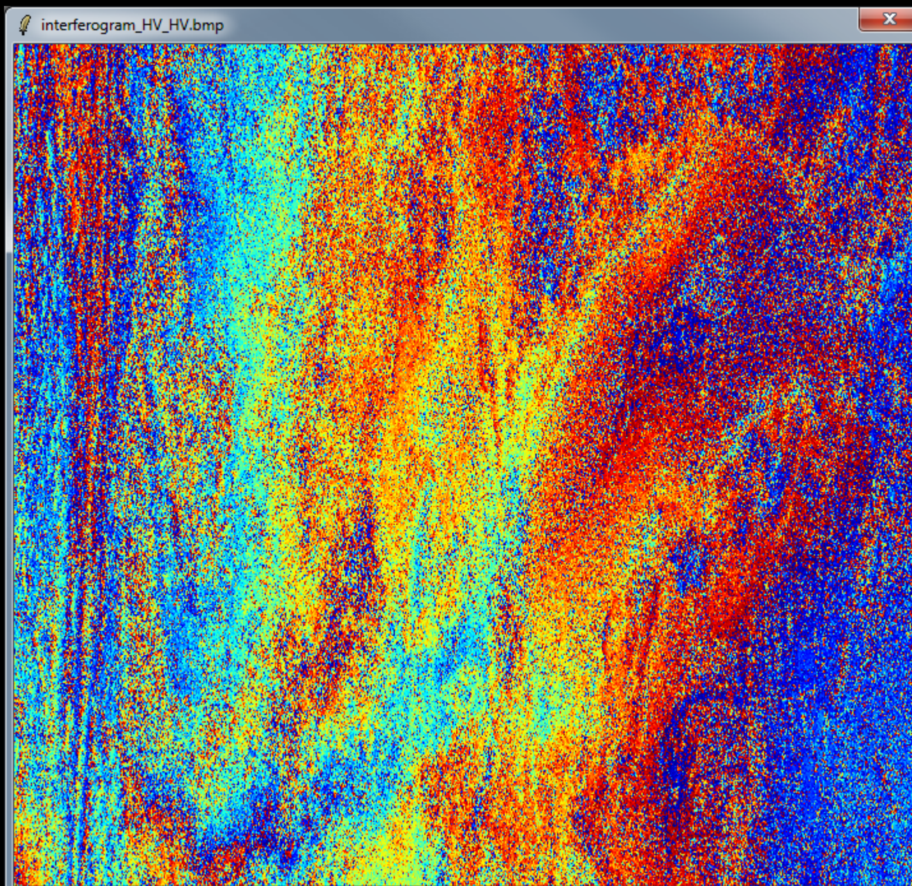

**Do it Yourself:**
**Select polarization channels, set the parameters and view the corresponding BMP files.**

**Note:**
**The Output Directory is automatically set to: MasterDir_SlaveDir_FER**

# RAW INTERFEROGRAM

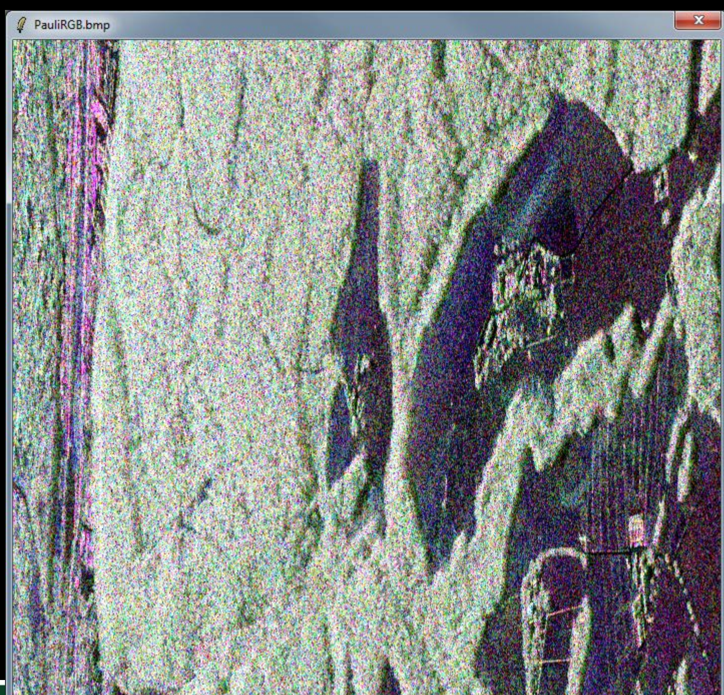

DATA_MASTERDIR_SLAVEDIR_**FER**

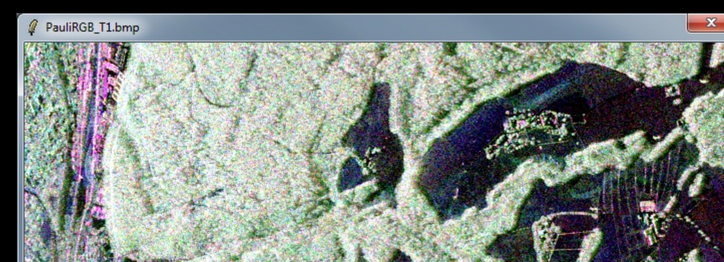
- config.txt
- interferogram_XX_XX.bin
- interferogram_XX_XX.bmp



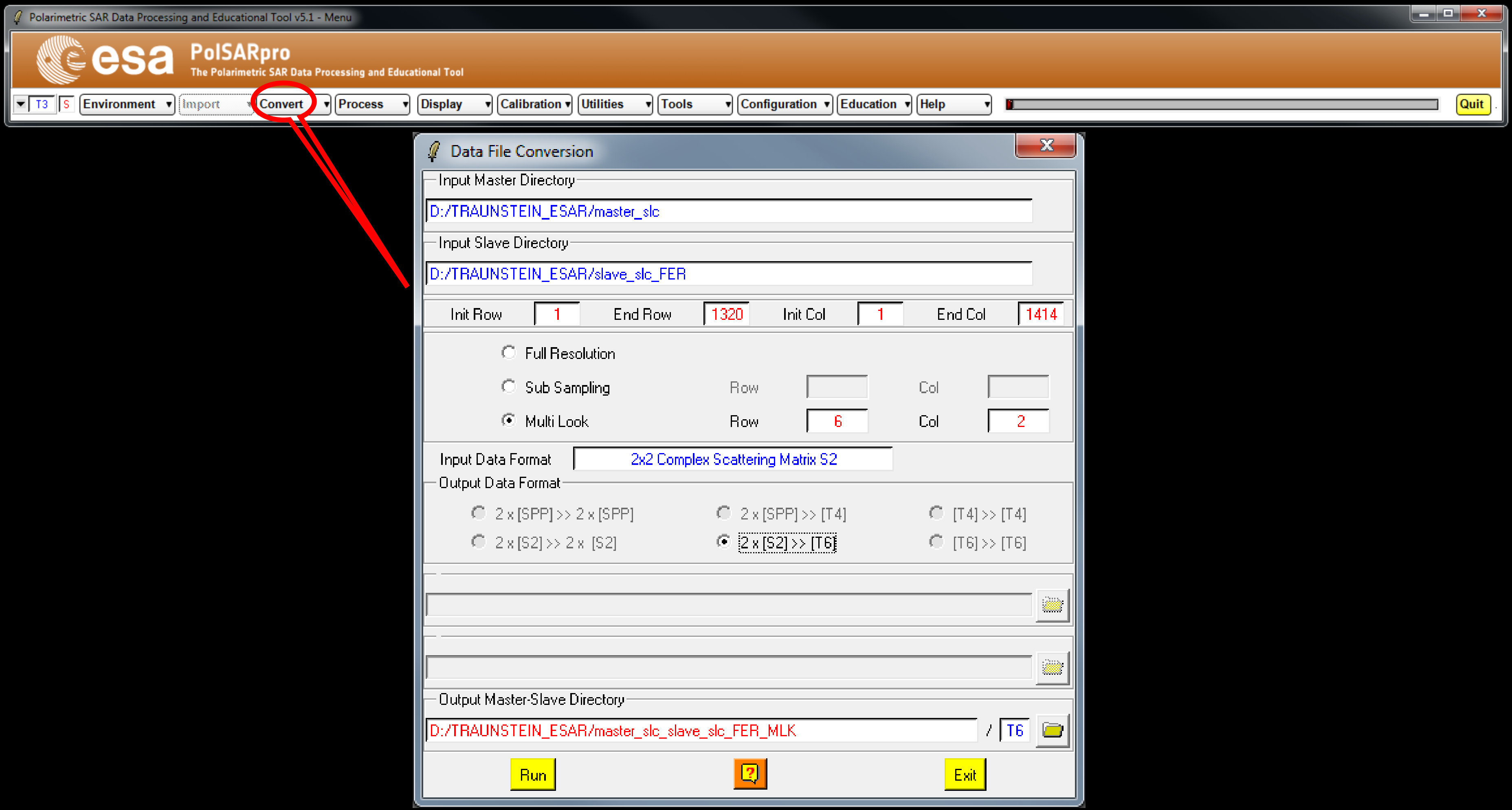
# Convert S2 - T6 : Multilook





# Convert S2 - T6 : Multilook




**Do it Yourself:**

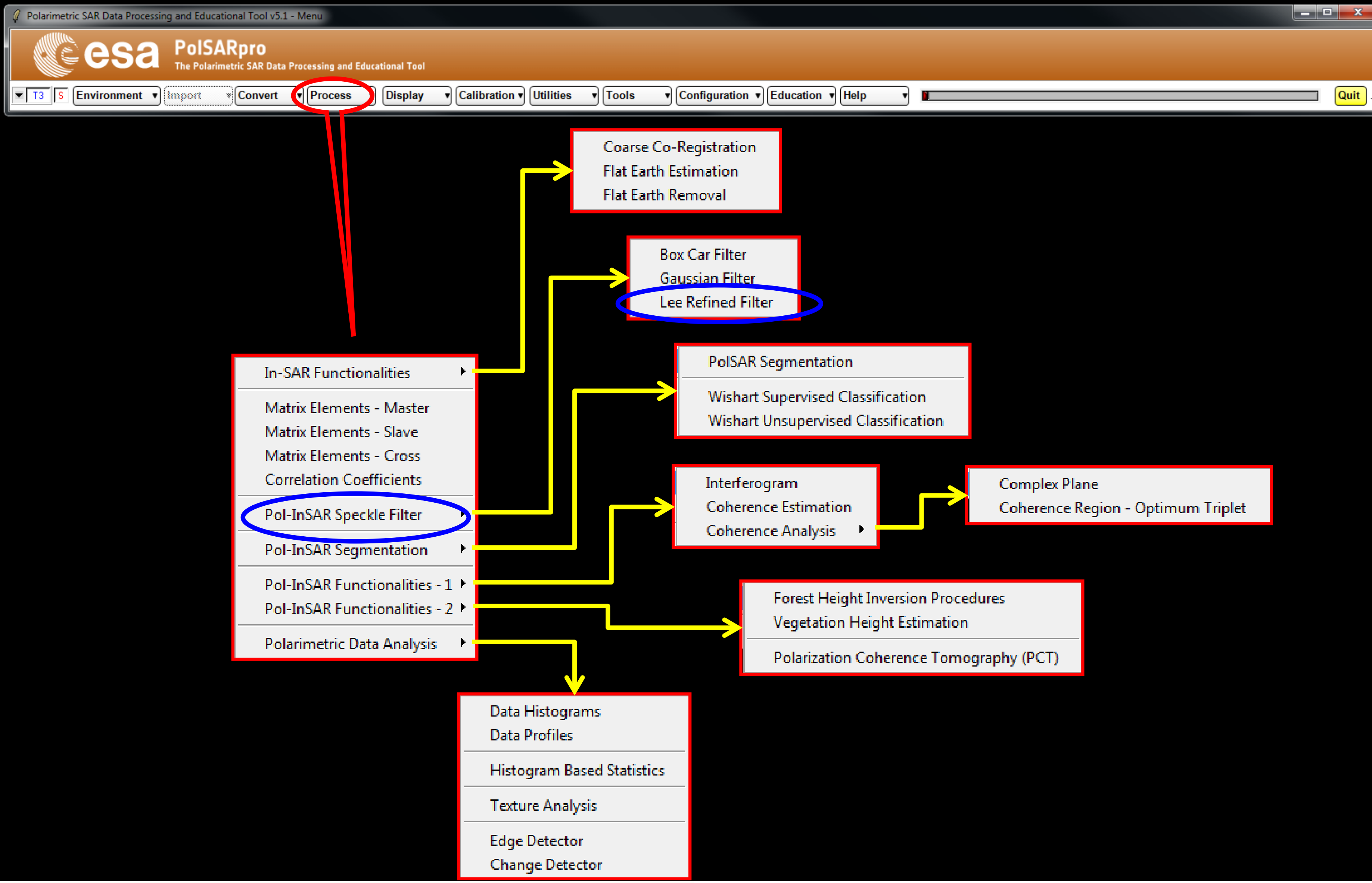
**Select Multi Look : Row = 6 and Col = 2**

**Select Output Data Format : 2 x [S2] >> [T6]**

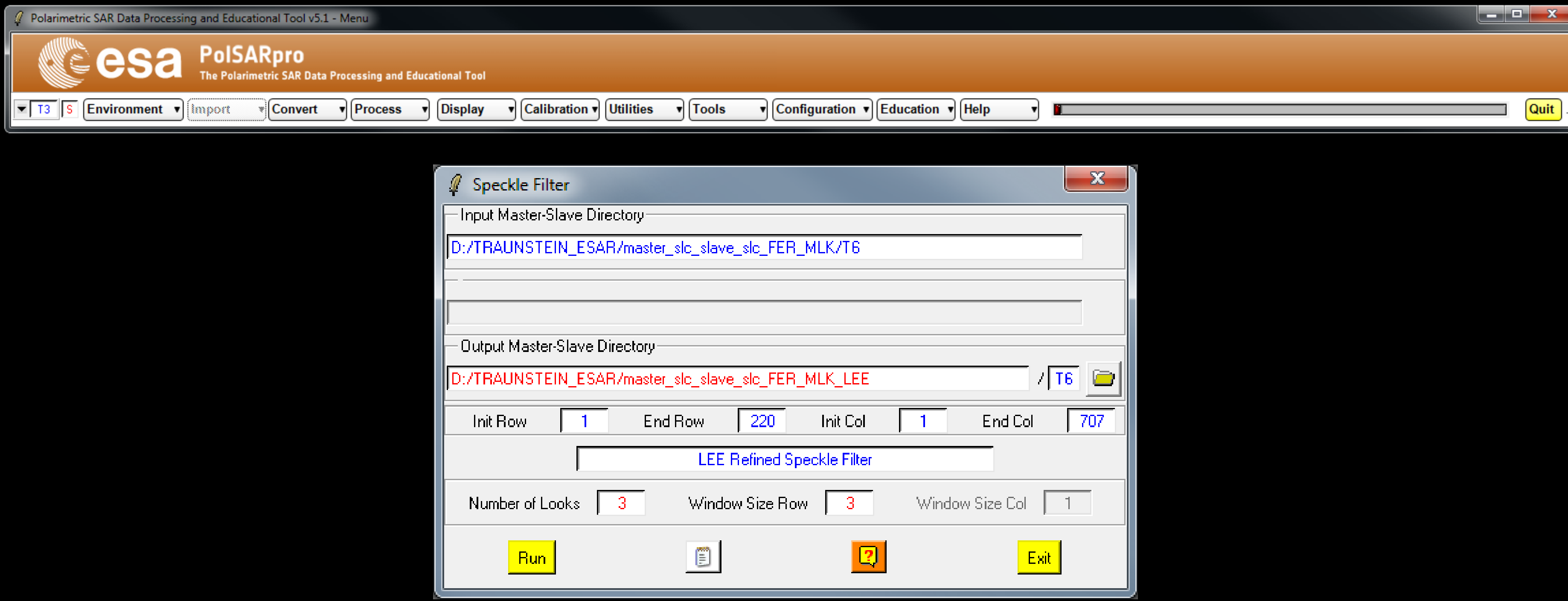
**Note:**

**The Output Directory is automatically set to: MasterDir_SlaveDir_FER_MLK**

# PROCESS DATA



# PROCESS DATA



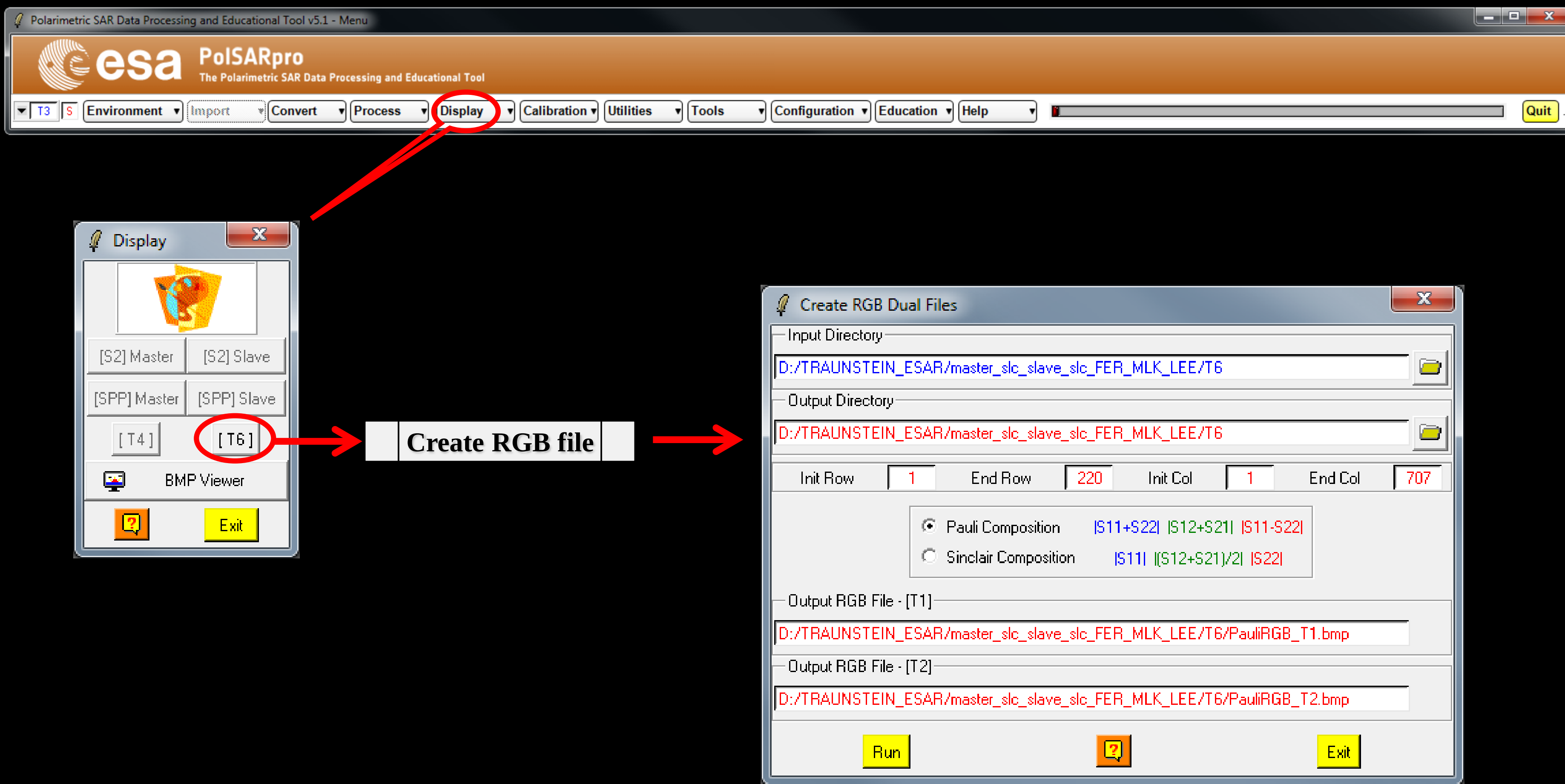

**Do it Yourself:**

**Set the parameters : Num Looks = 3 ; Window Size = 3.**

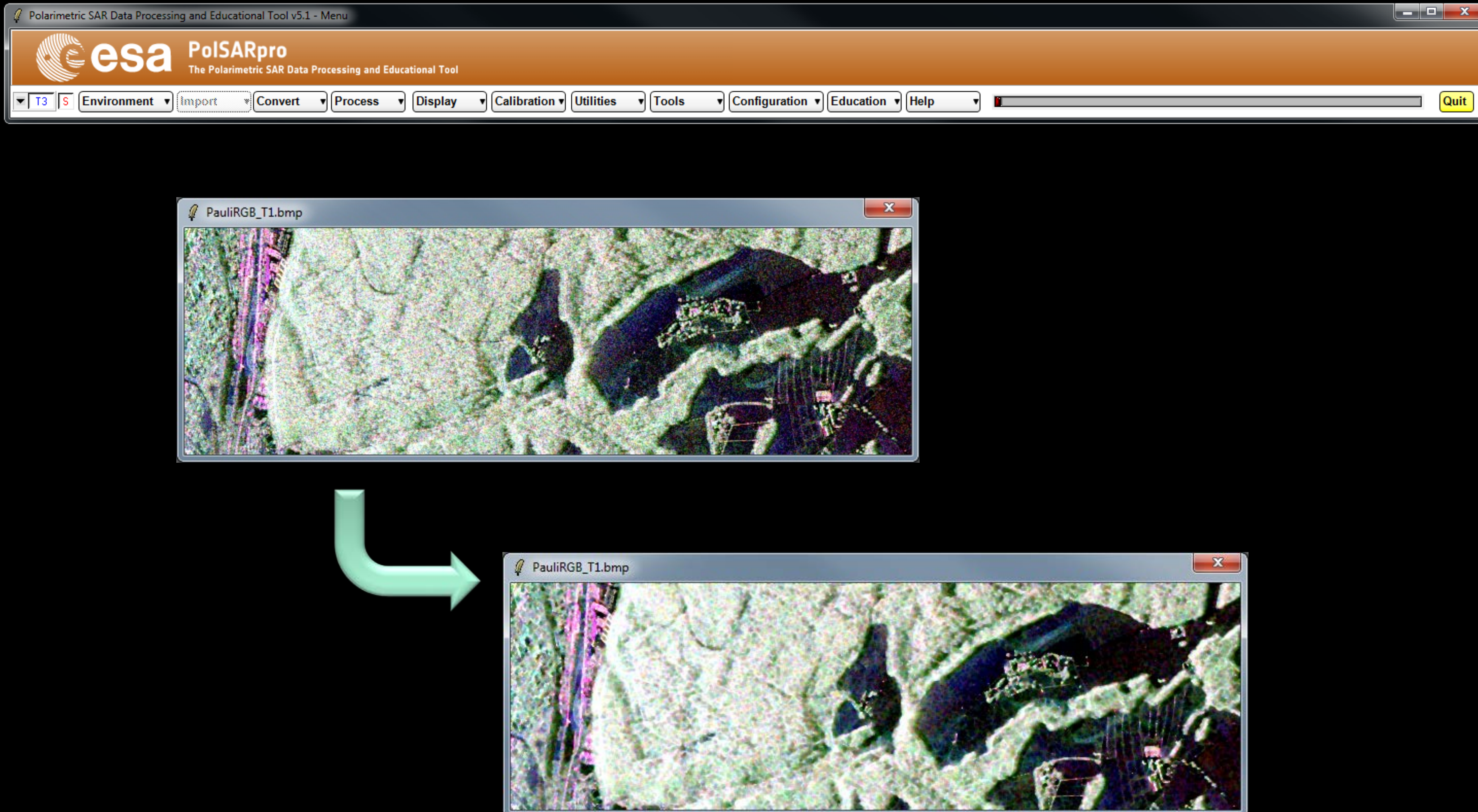
**Note:**

**The Output Directory is automatically set to: MasterDir_SlaveDir_FER_MLK_LEE**

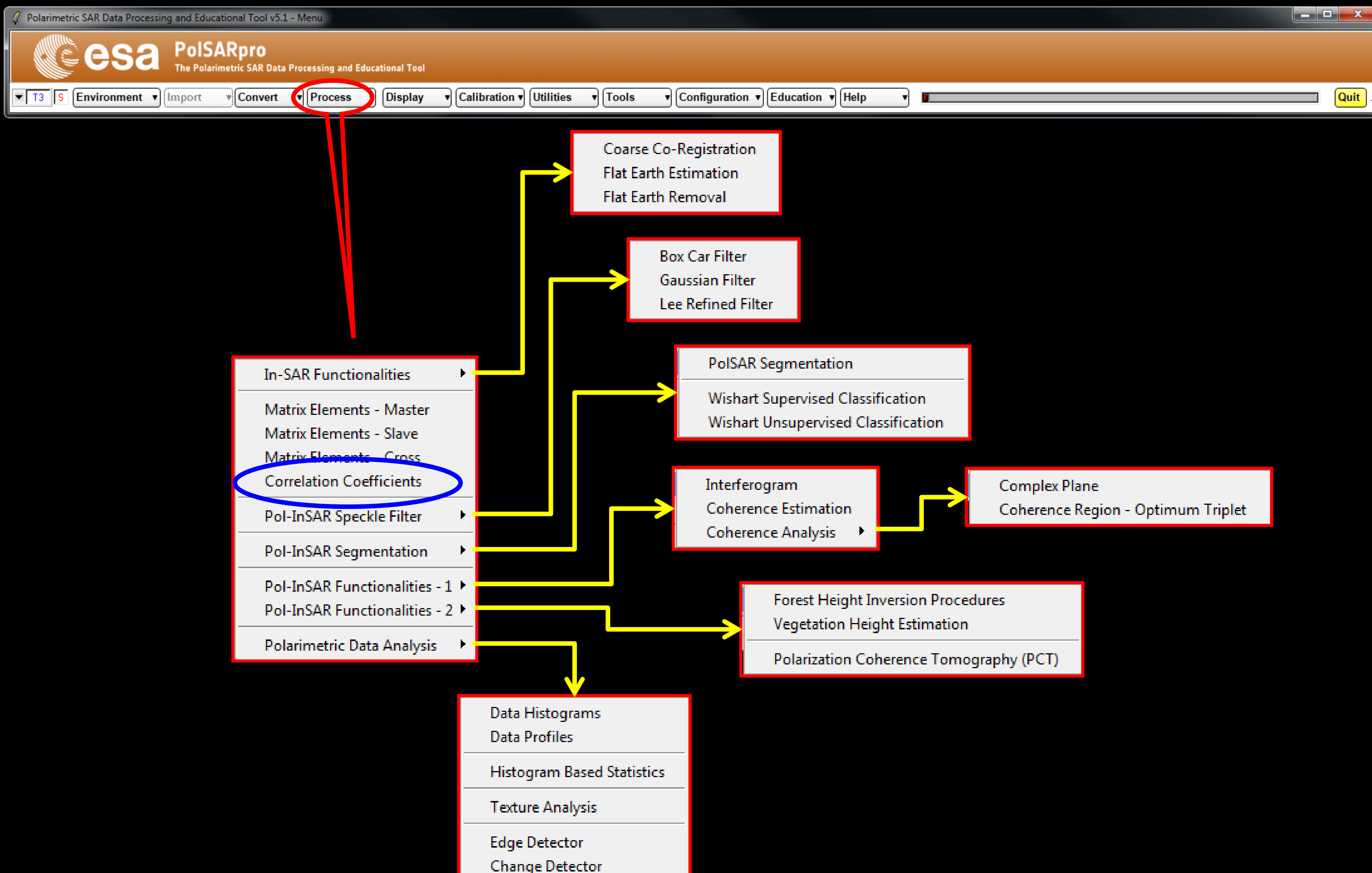
# PROCESS DATA



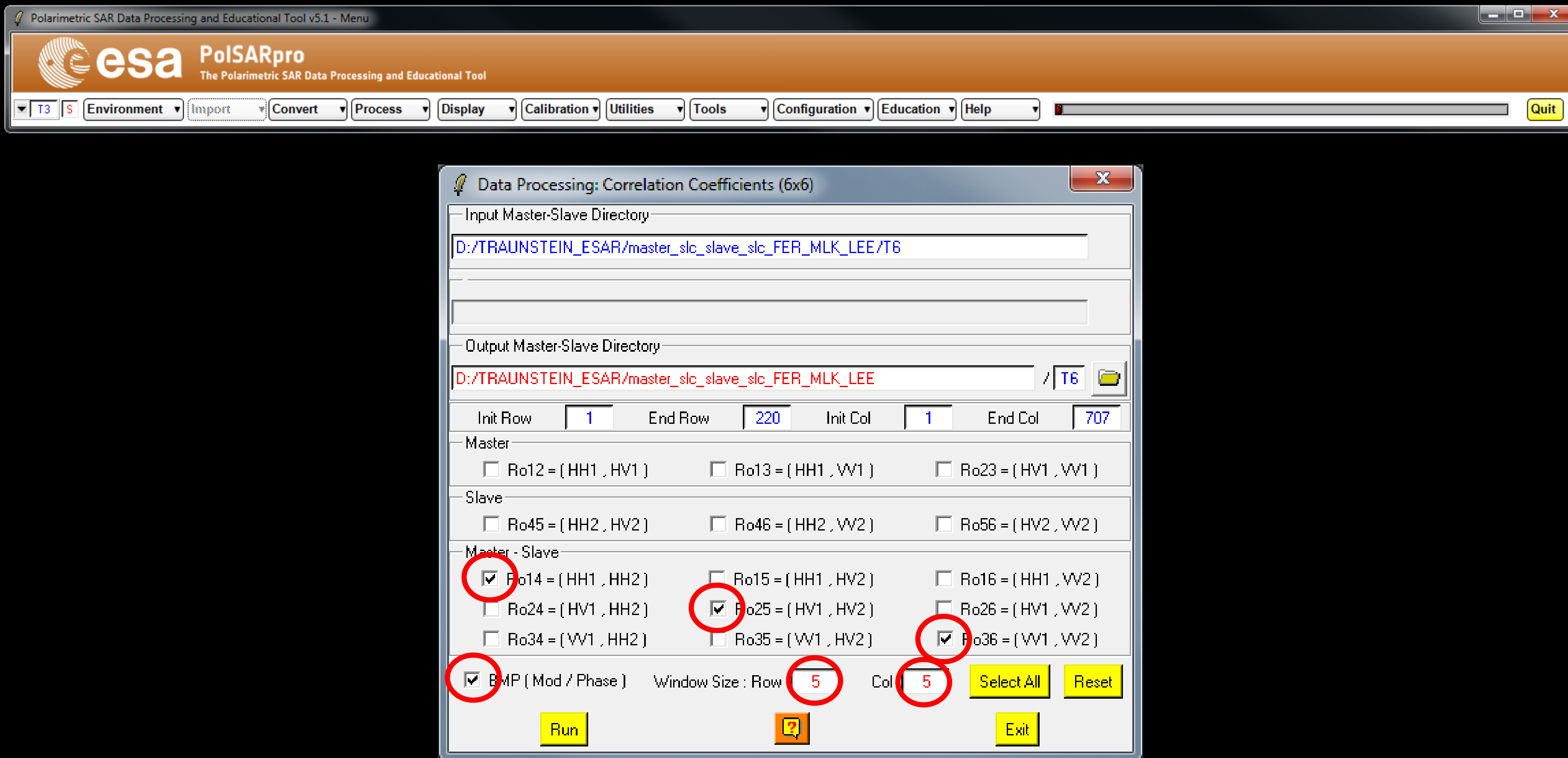
# PROCESS DATA



# PROCESS DATA



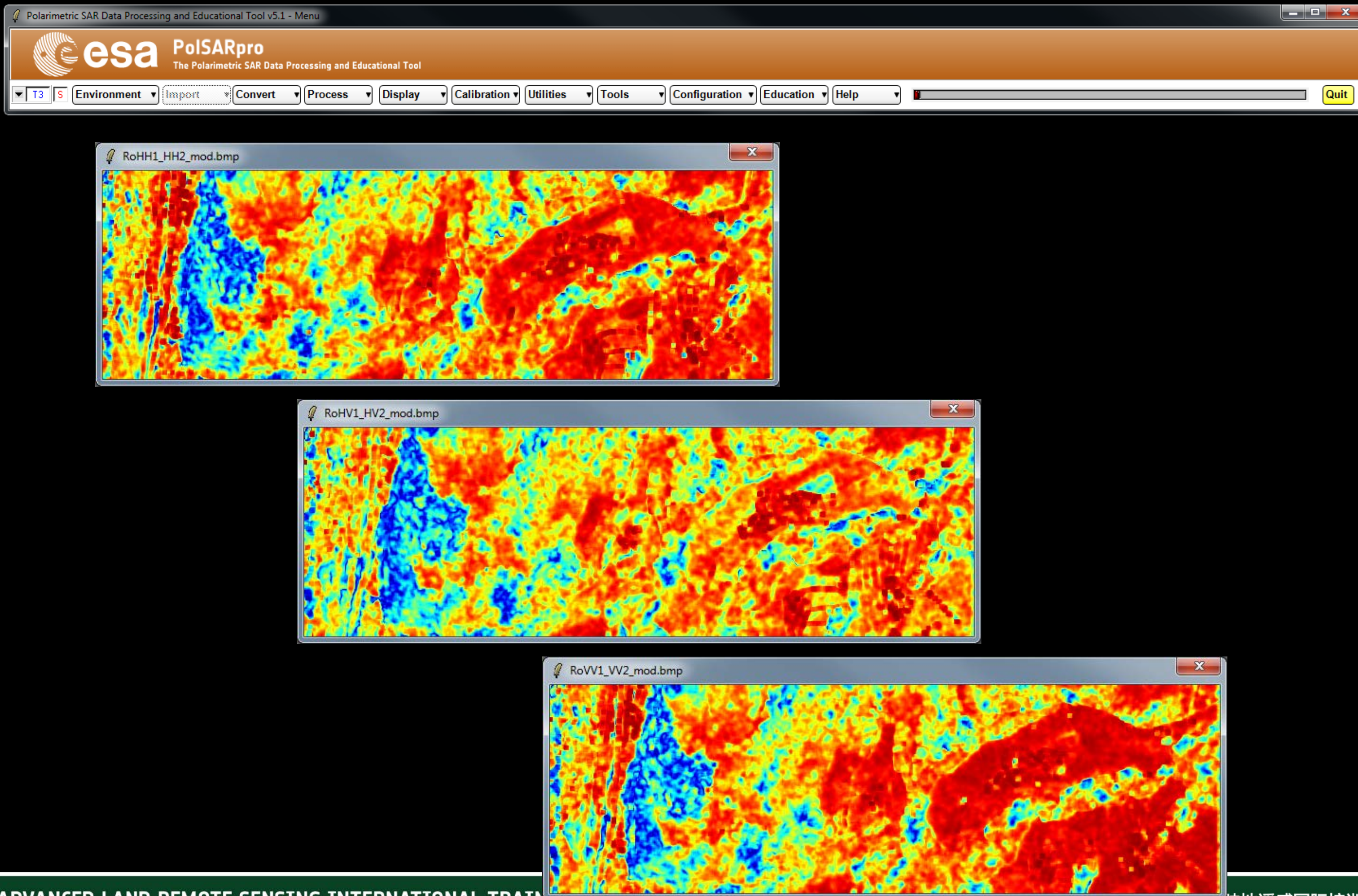
# PROCESS DATA



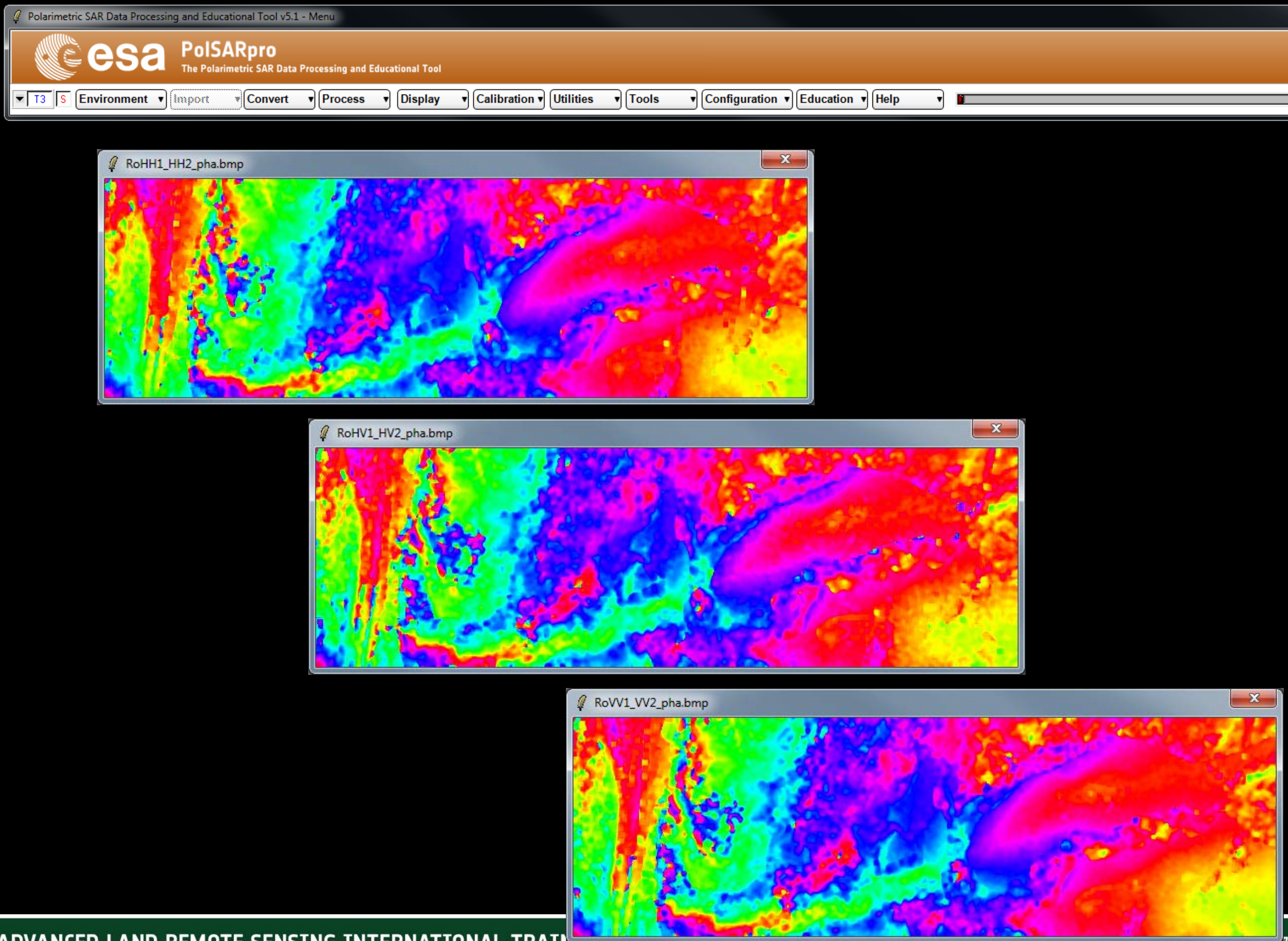

**Do it Yourself:**

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

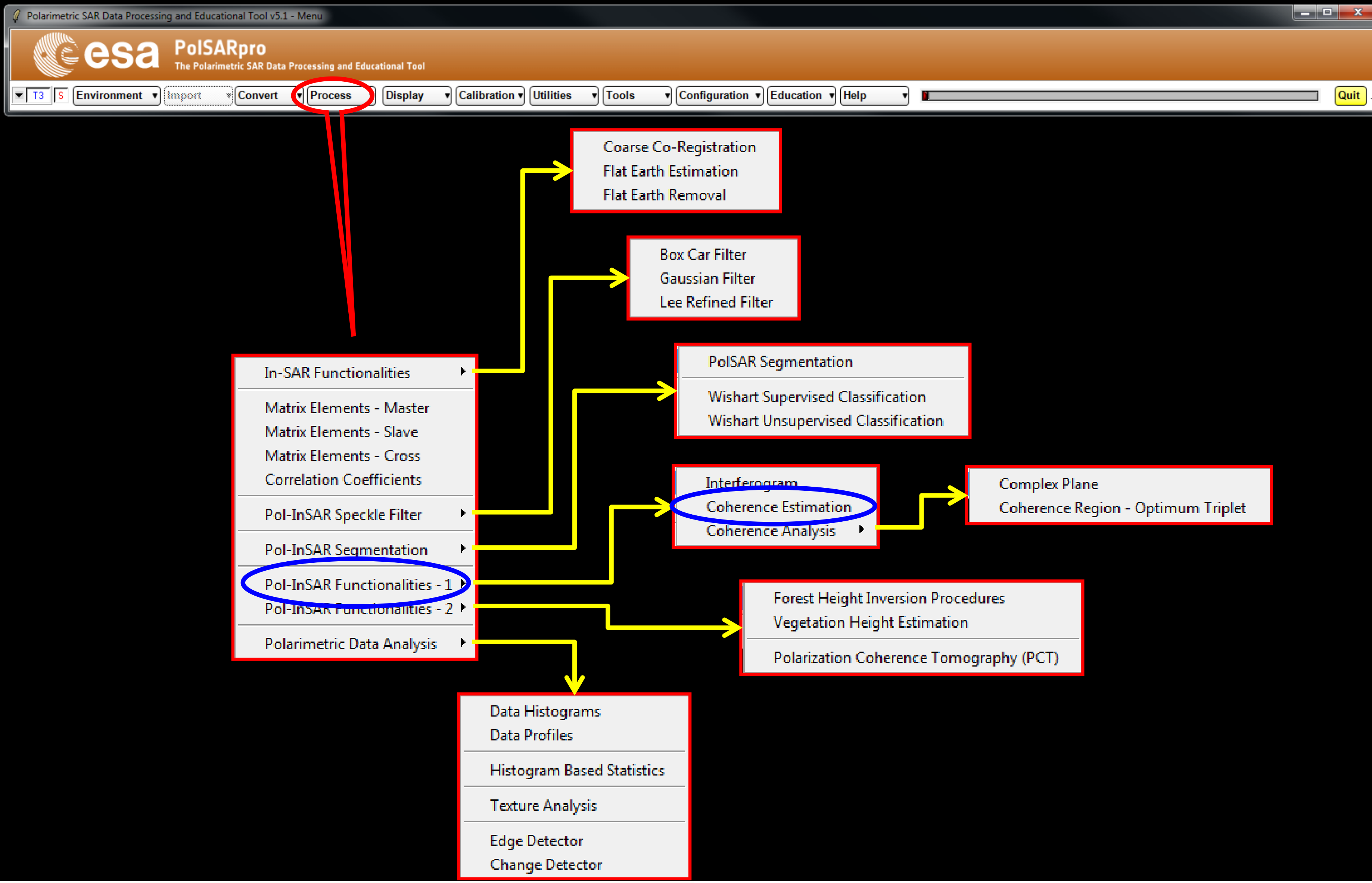
# PROCESS DATA



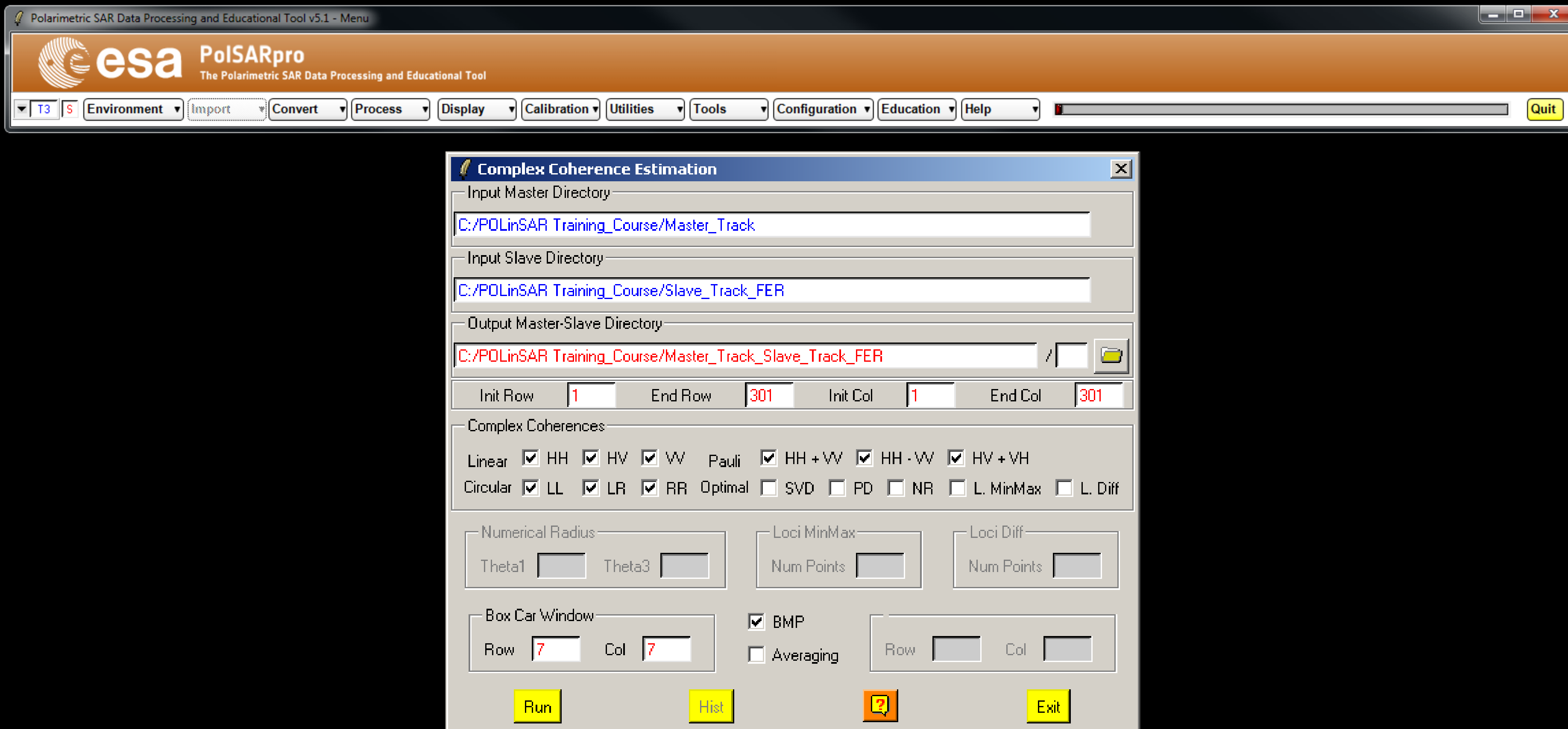
# PROCESS DATA



# PROCESS DATA



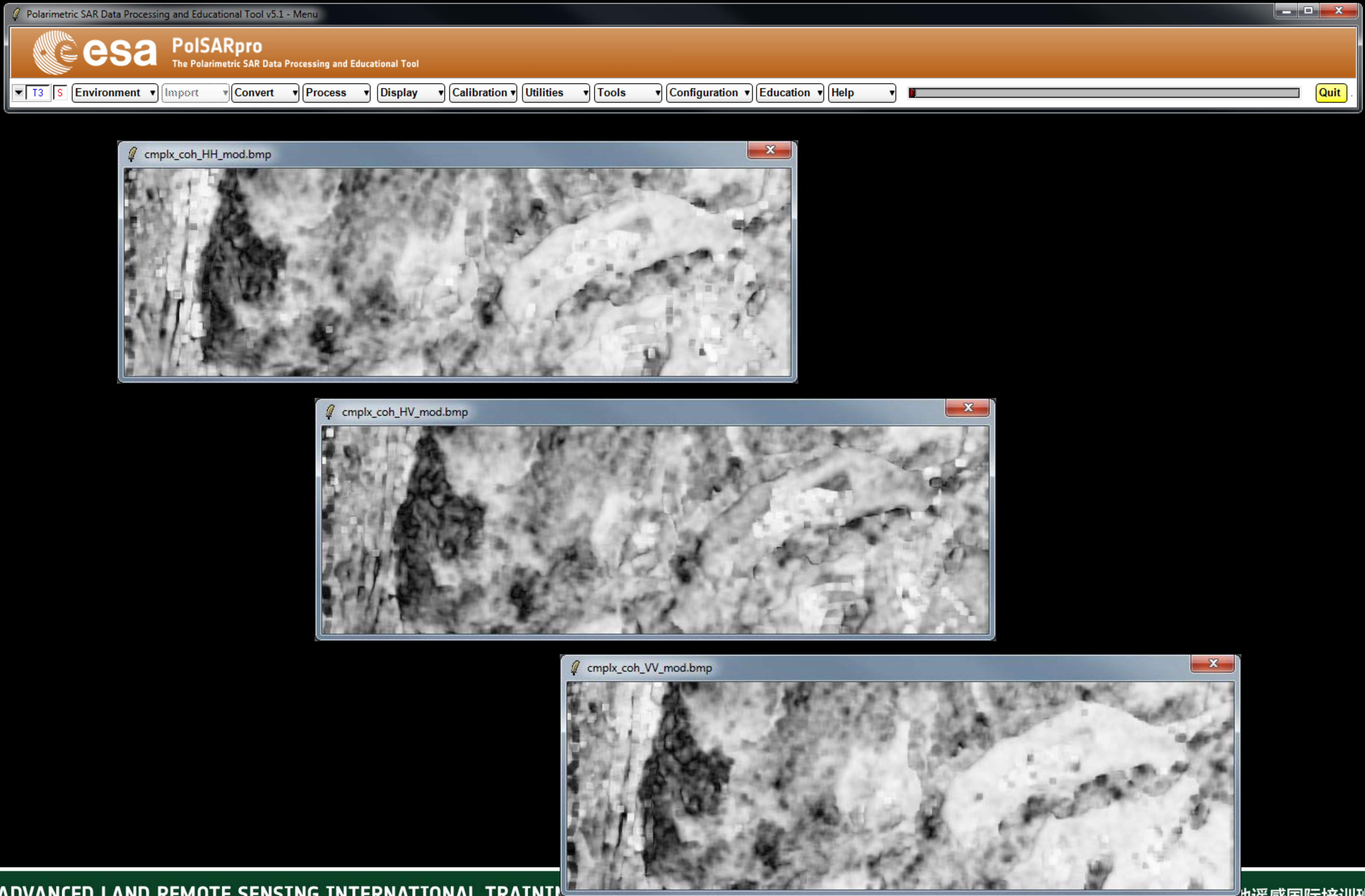
# COHERENCE ESTIMATION



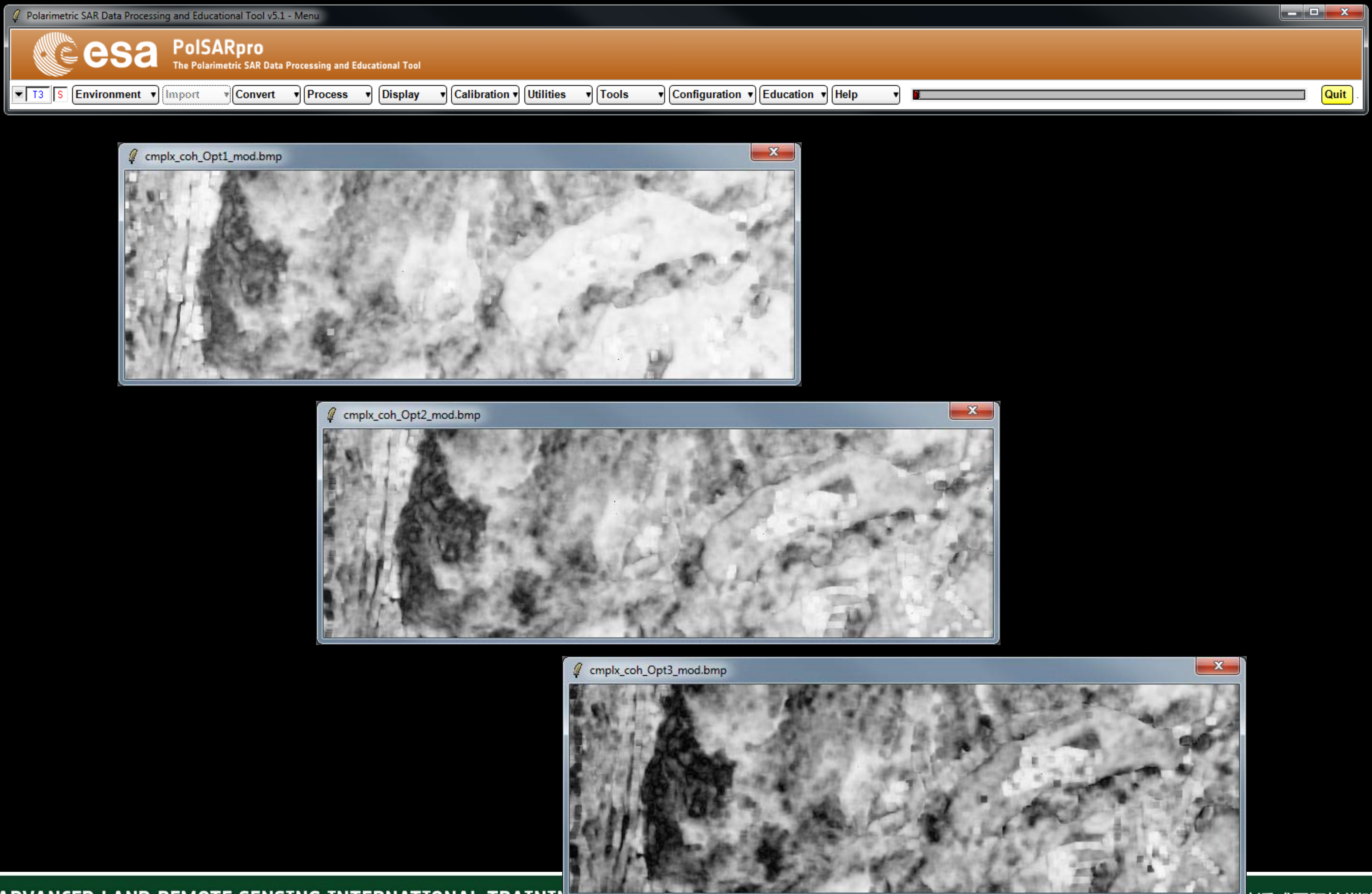

**Do it Yourself:**

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

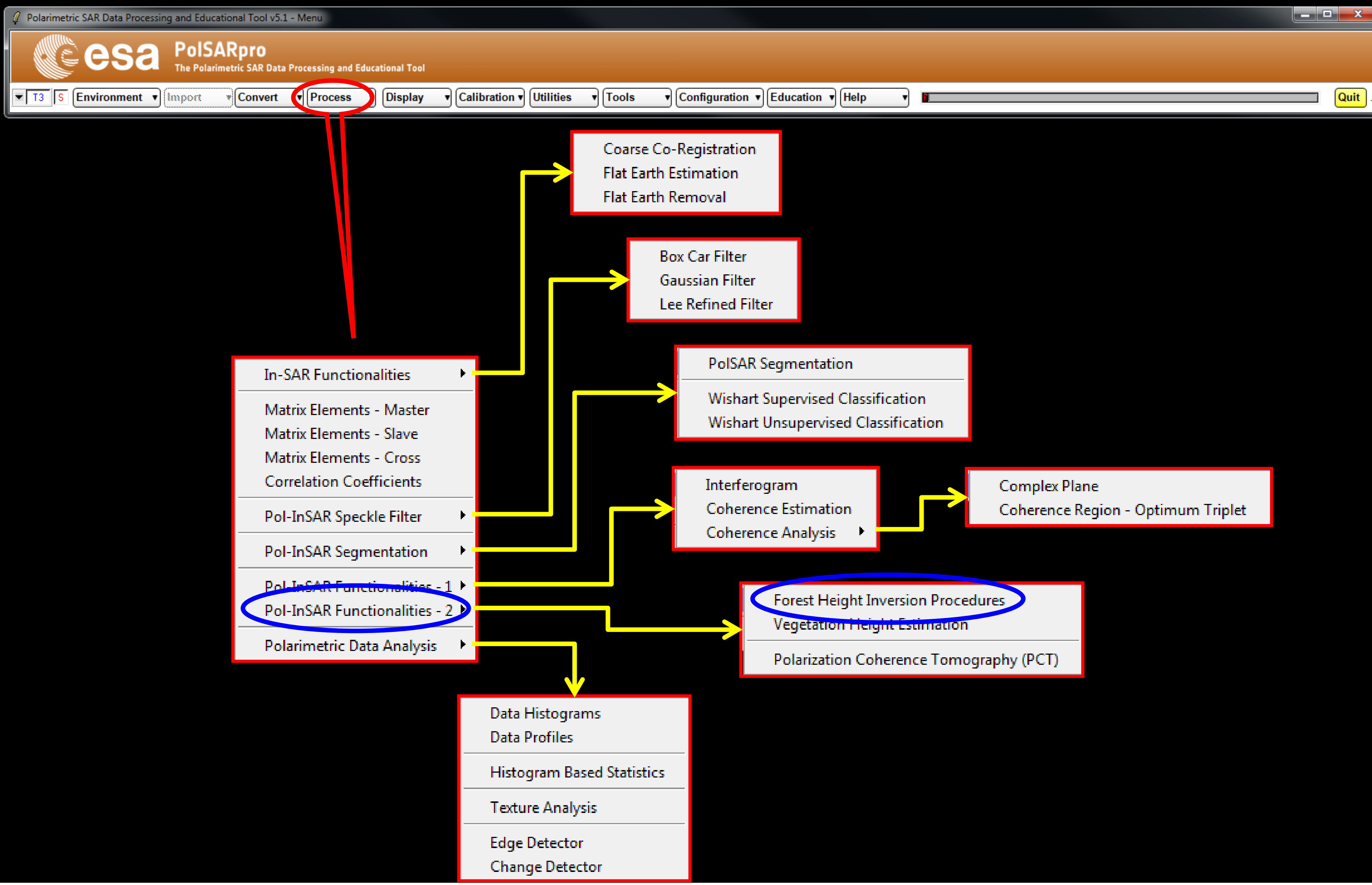
# COHERENCE ESTIMATION



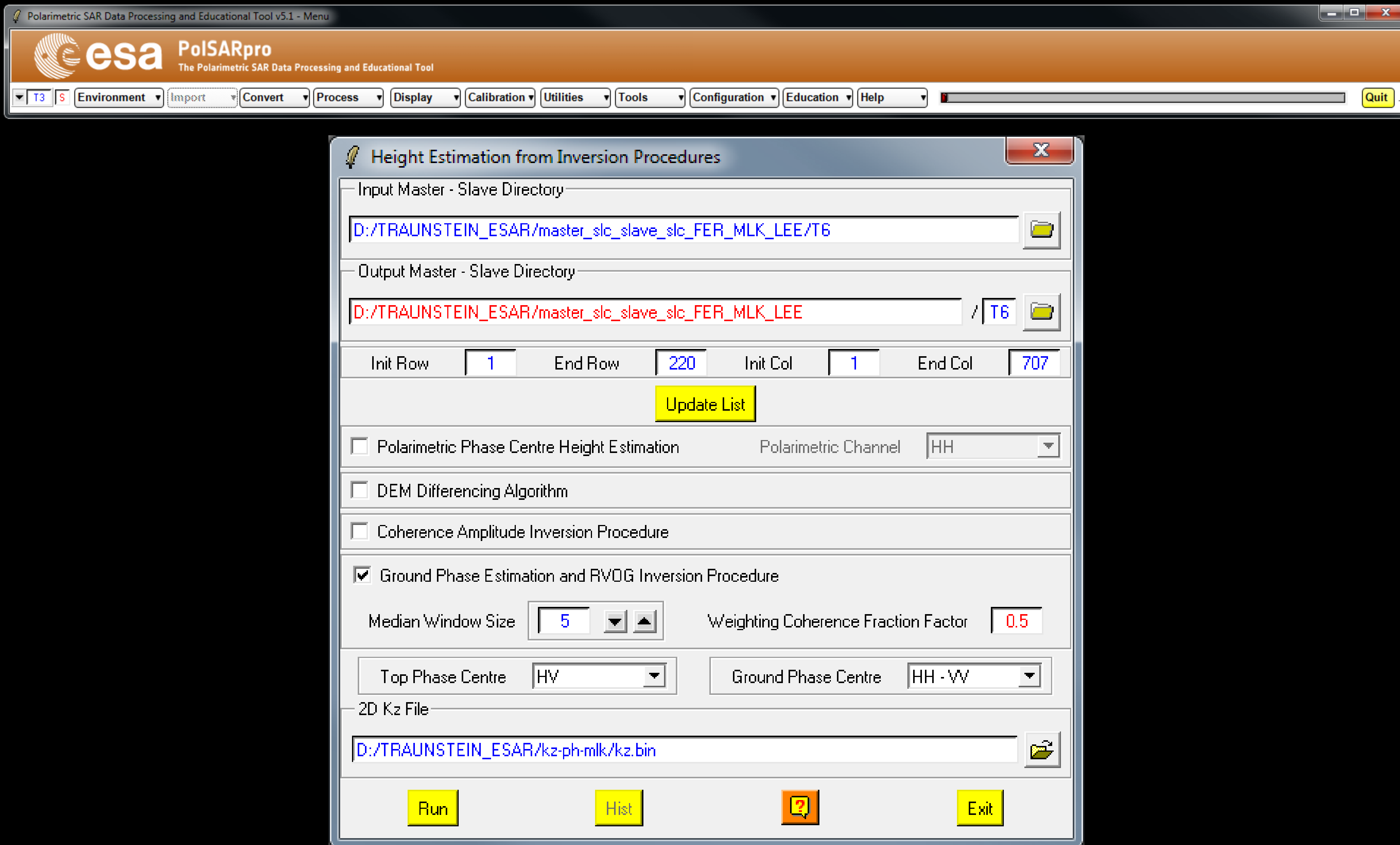
# COHERENCE ESTIMATION



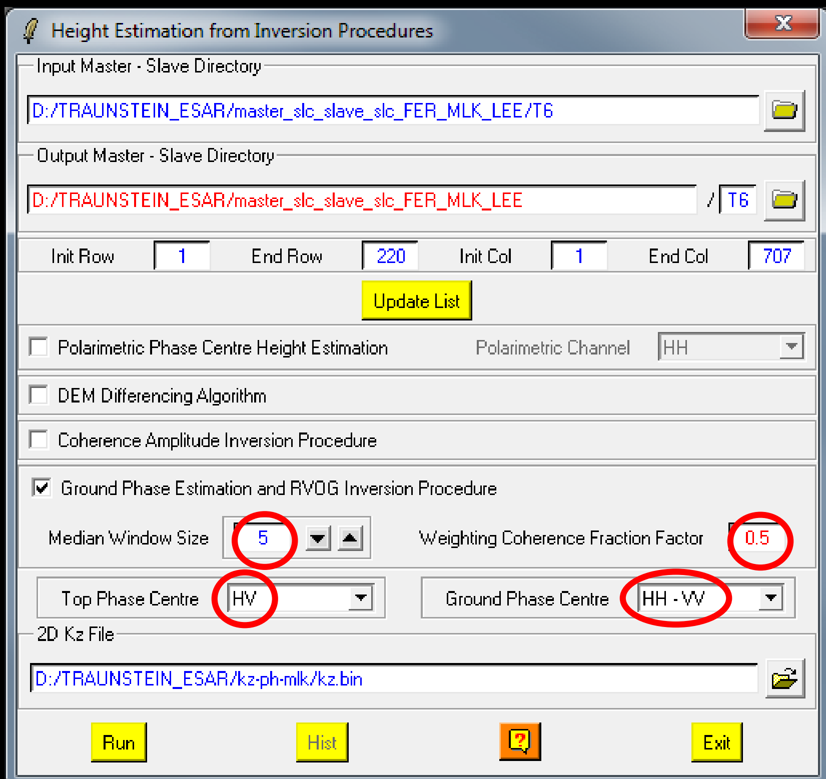
# PROCESS DATA

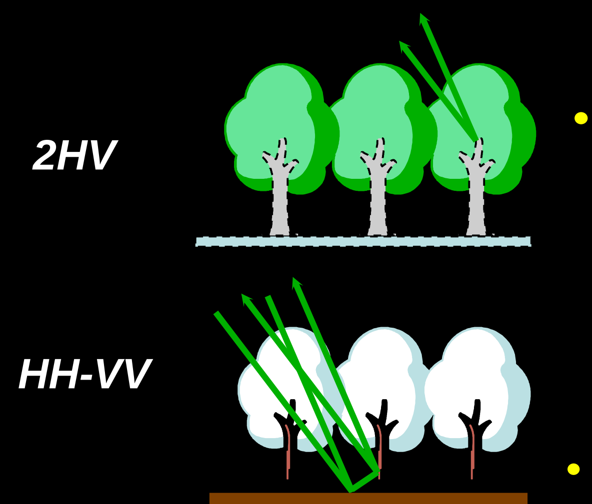


# HEIGHT ESTIMATION



# HEIGHT ESTIMATION

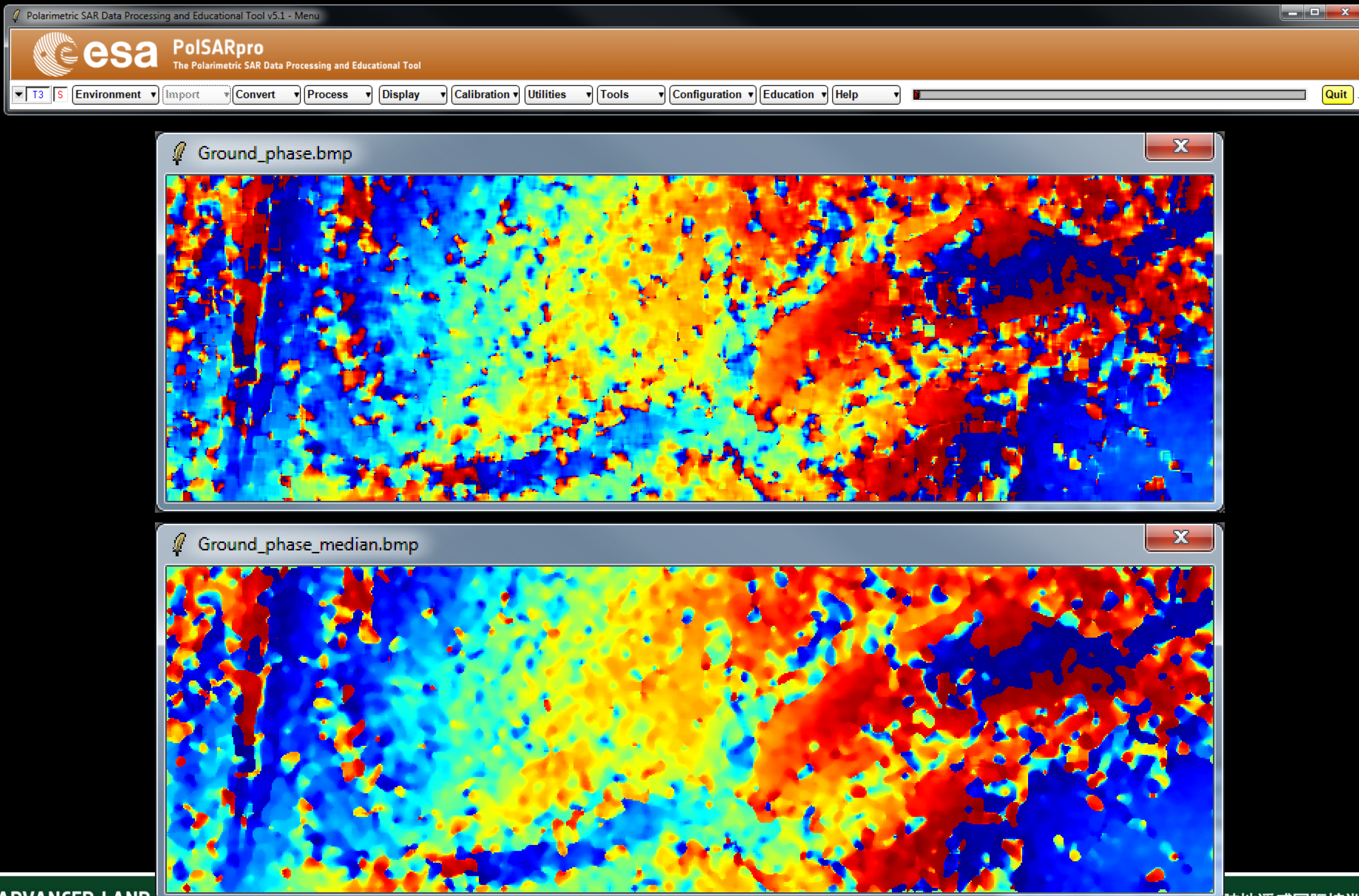




**Do it Yourself:**

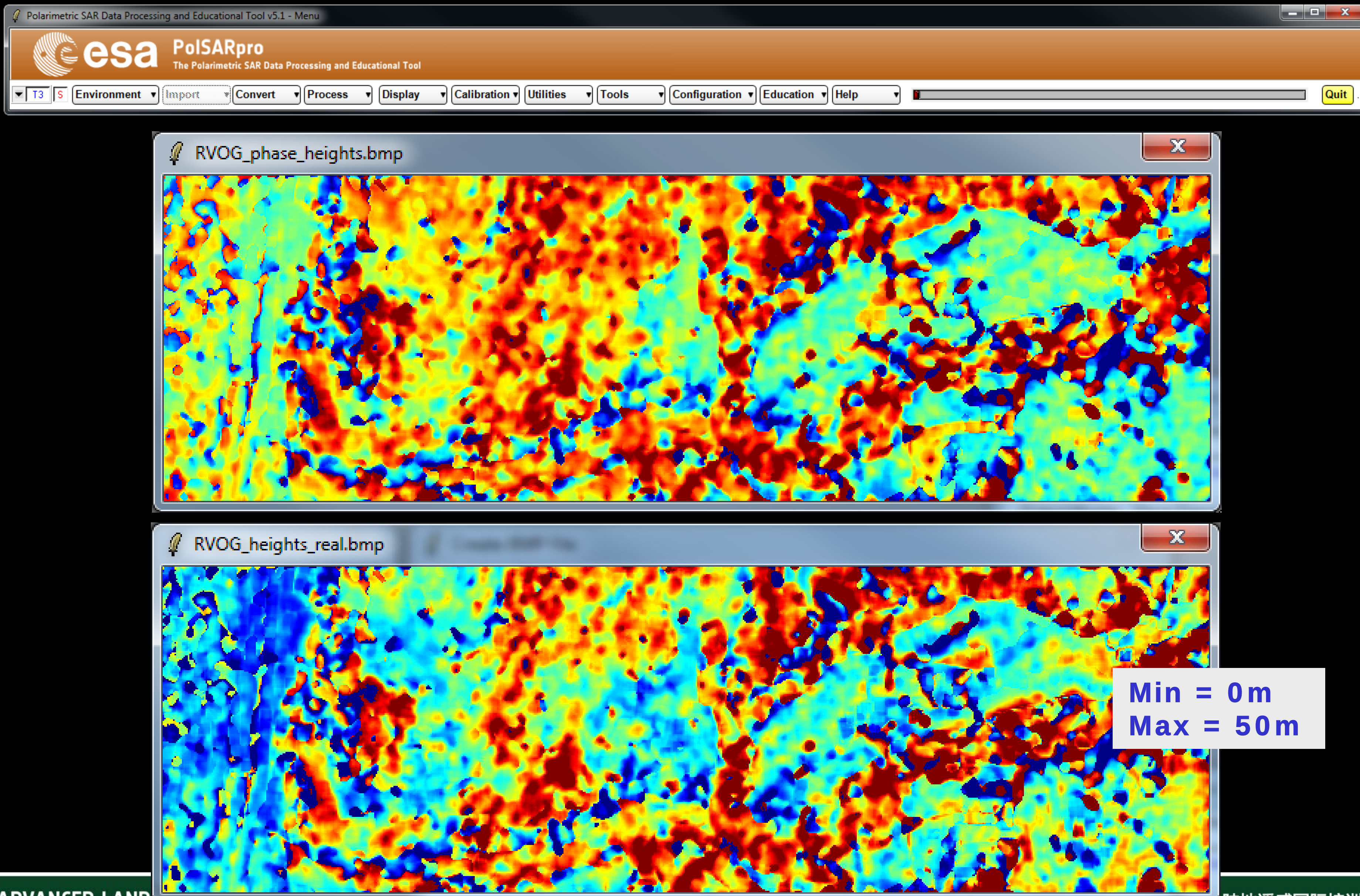
**Set the parameters (Median Size = 21, Factor = 0.4) and view the corresponding BMP files.**

**2D Kz File : DataDirectory / kz-ph-mlk / kz.bin**

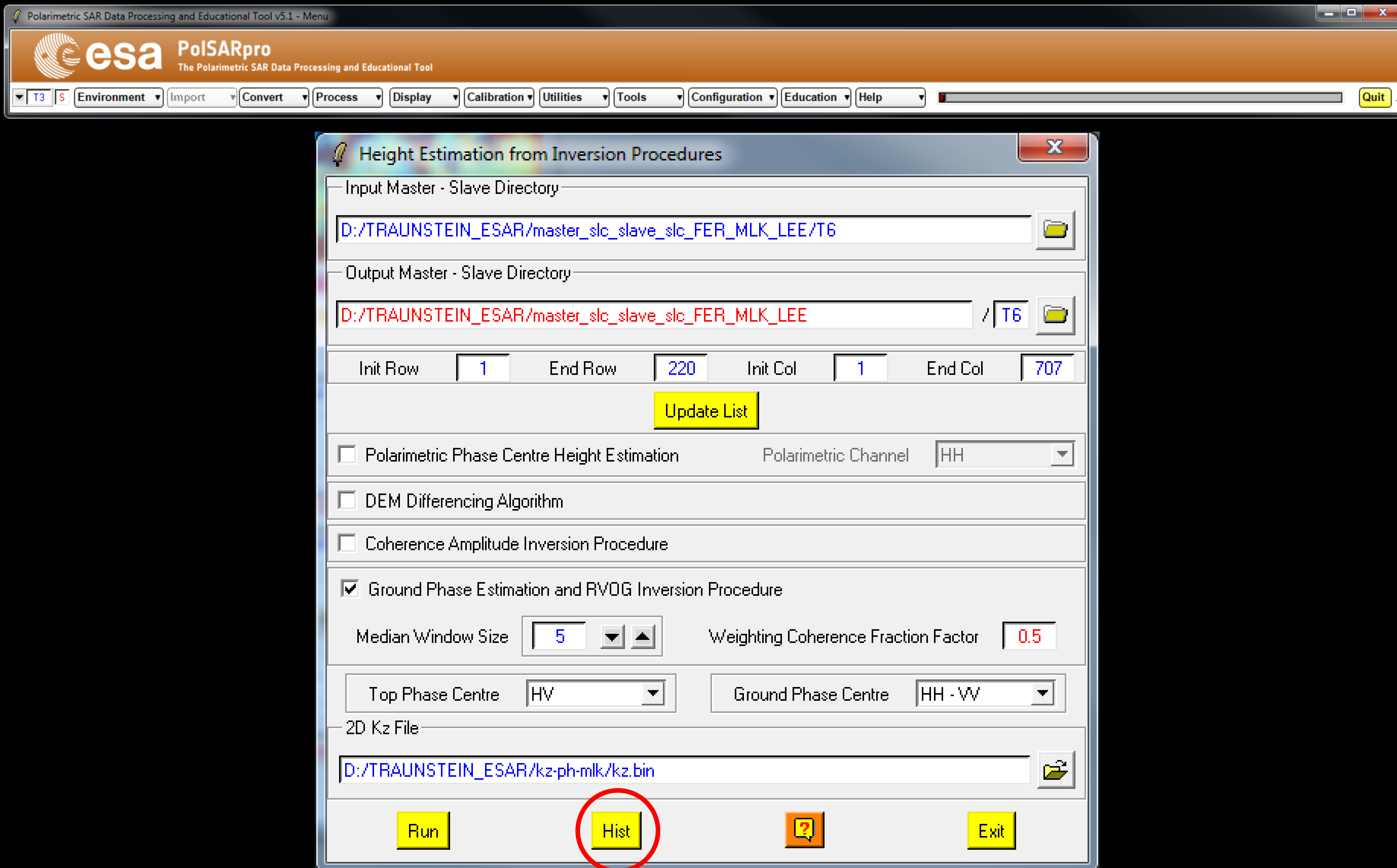
# HEIGHT ESTIMATION



# HEIGHT ESTIMATION

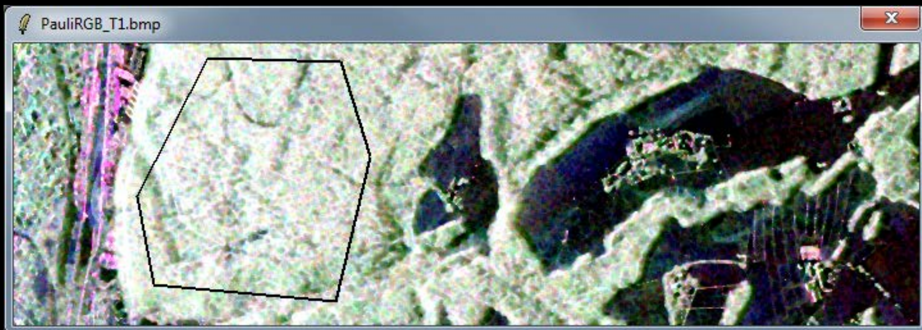


# HEIGHT ESTIMATION




**Data Analysis : Histogram**

# HEIGHT ESTIMATION


**Do it Yourself:**

**Select a BMP file**

**Select a BIN file**

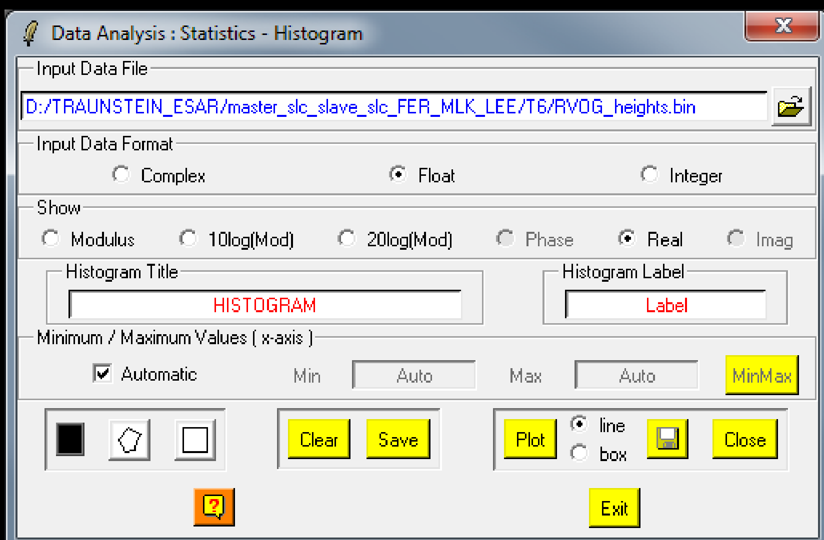
**Select Input Data Format**

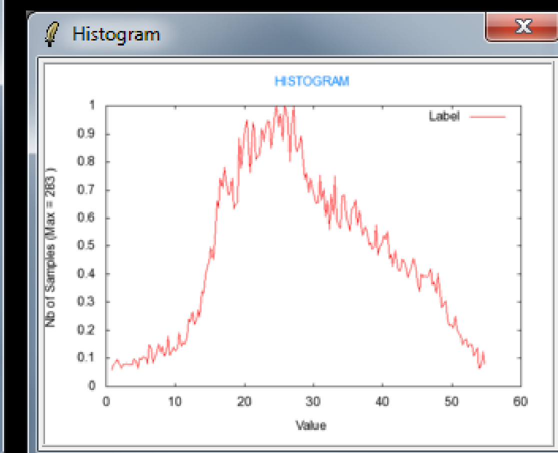
**Select Show**

**Select Area**

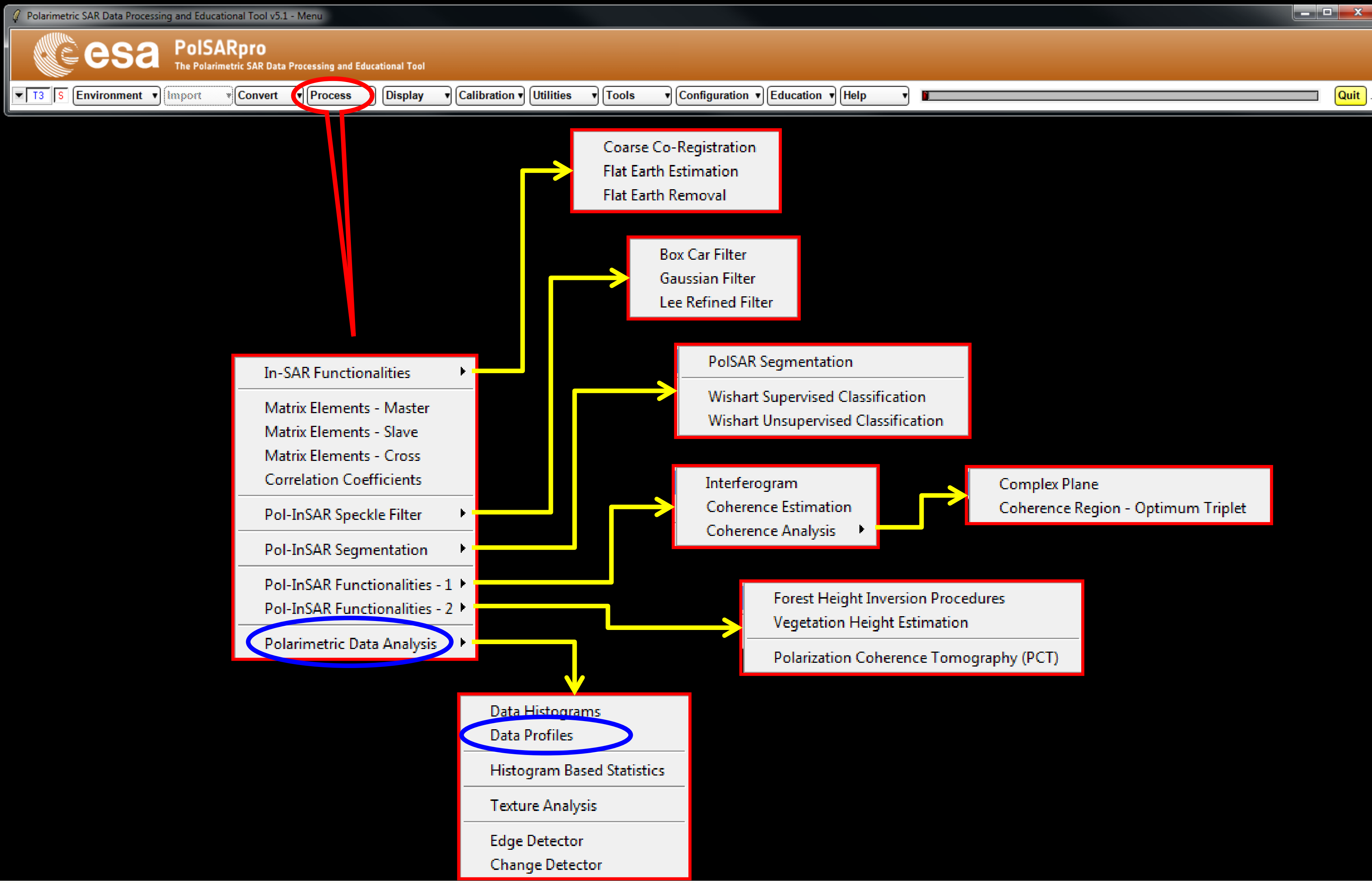
**SAVE**

**PLOT**

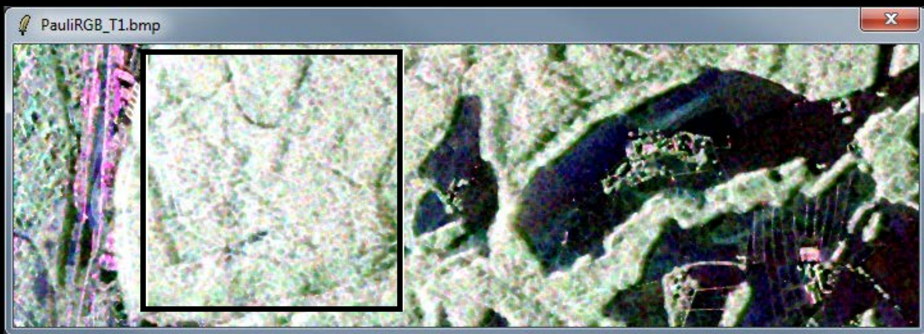


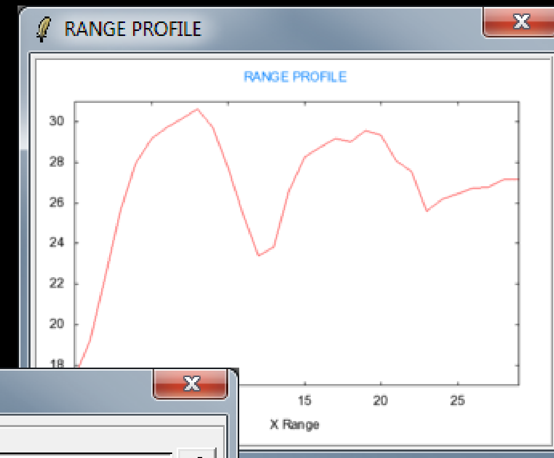



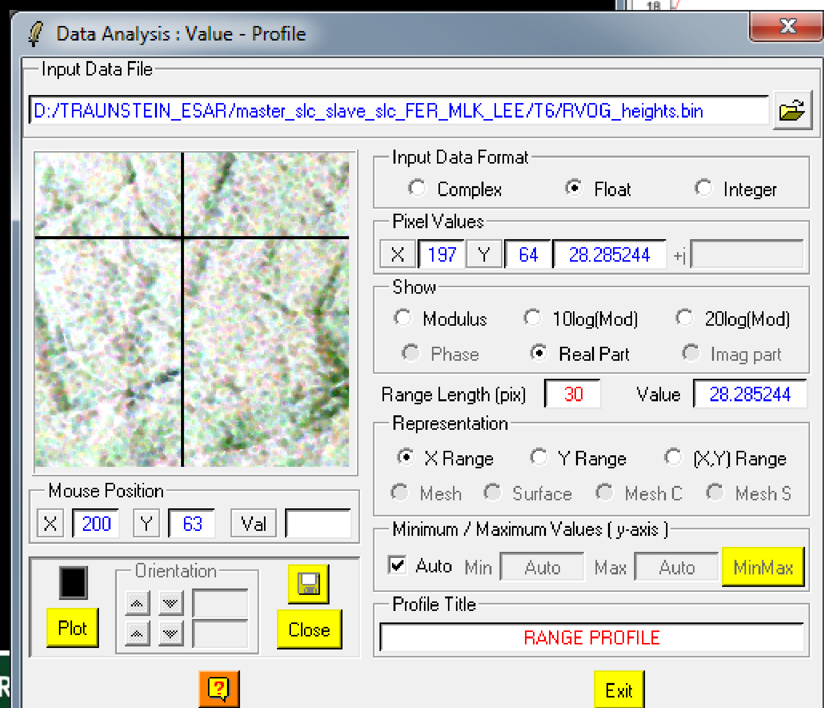
# PROCESS DATA



# 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 ?