→ 3rd ADVANCED COURSE ON RADAR POLARIMETRY

Polarimetric SAR Tomography Practical session

Polarimetric SAR interferometry (PolinSAR)

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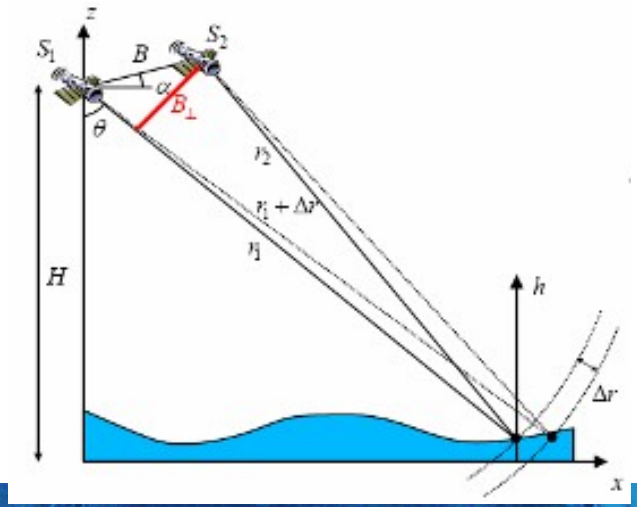
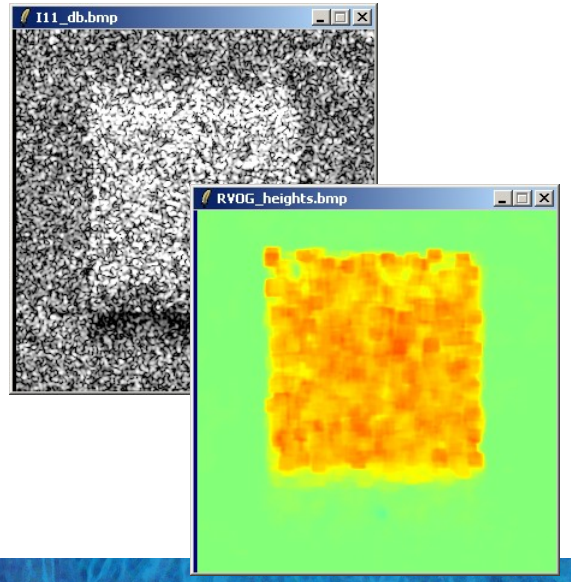
European Space Agency

POLSARPRO

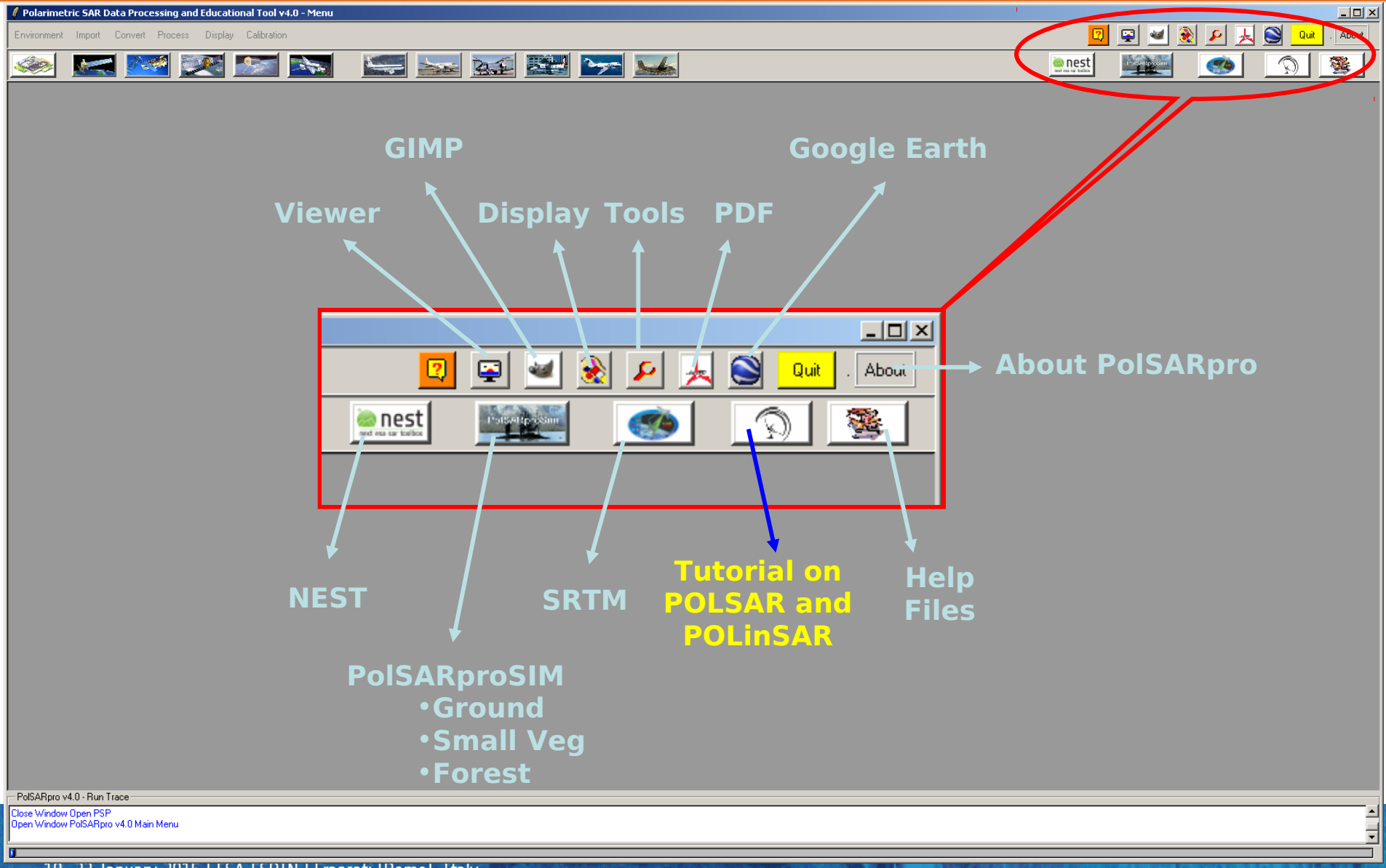
POLarimetric SAR data PROcessor

Pol-InSAR Tutorial
Forest Application

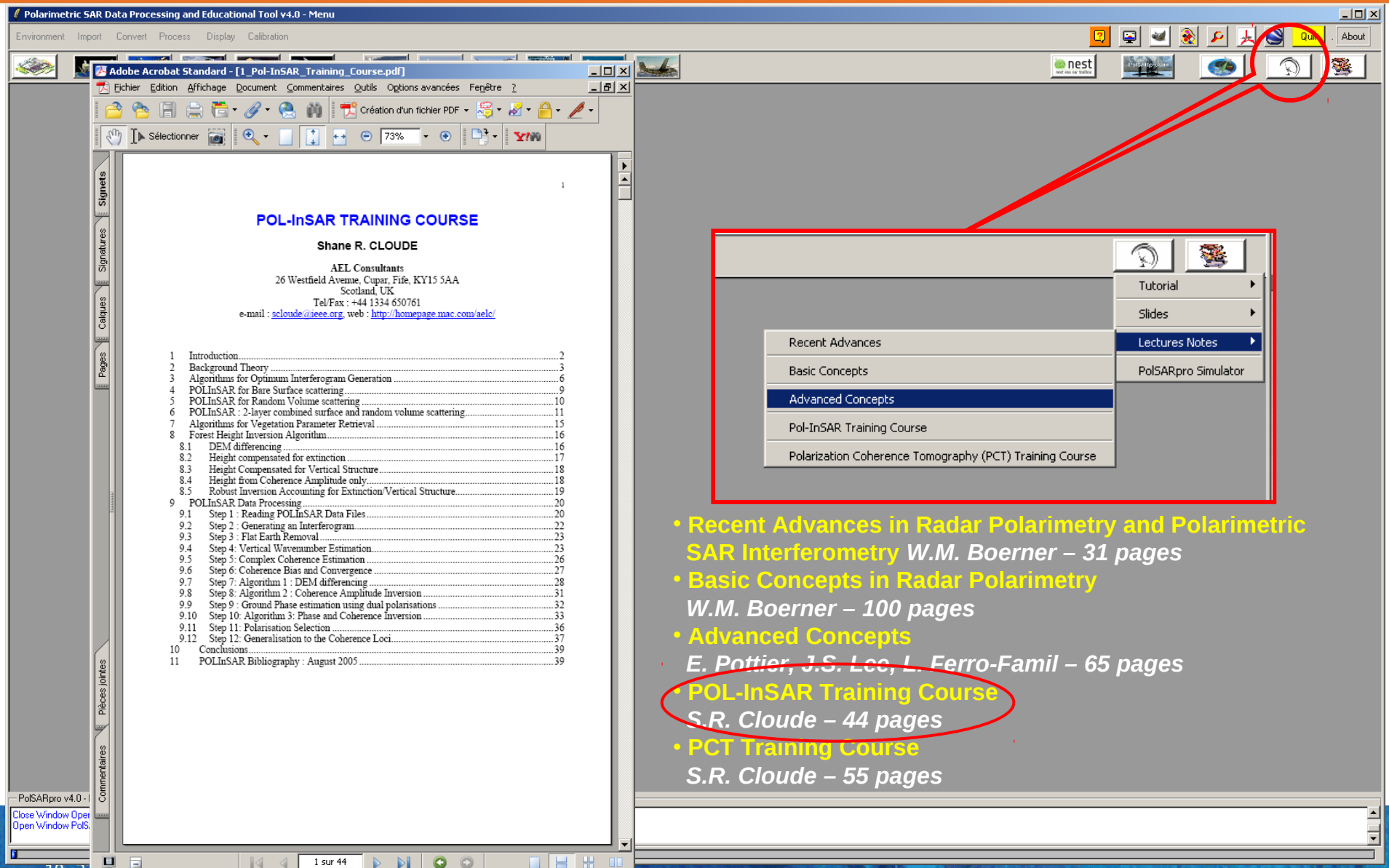




PolSARpro v4.0 SOFTWARE

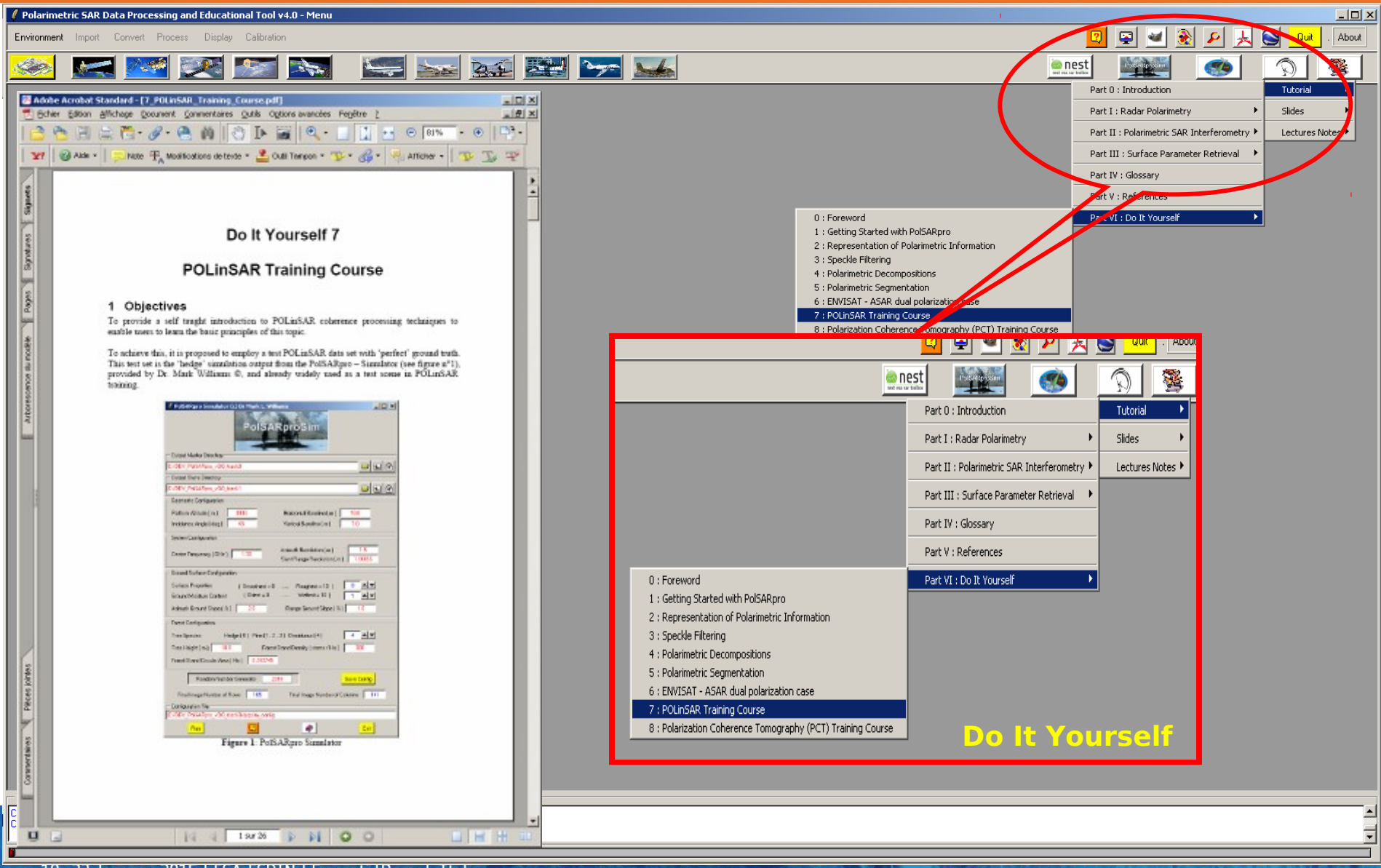


Lecture Notes

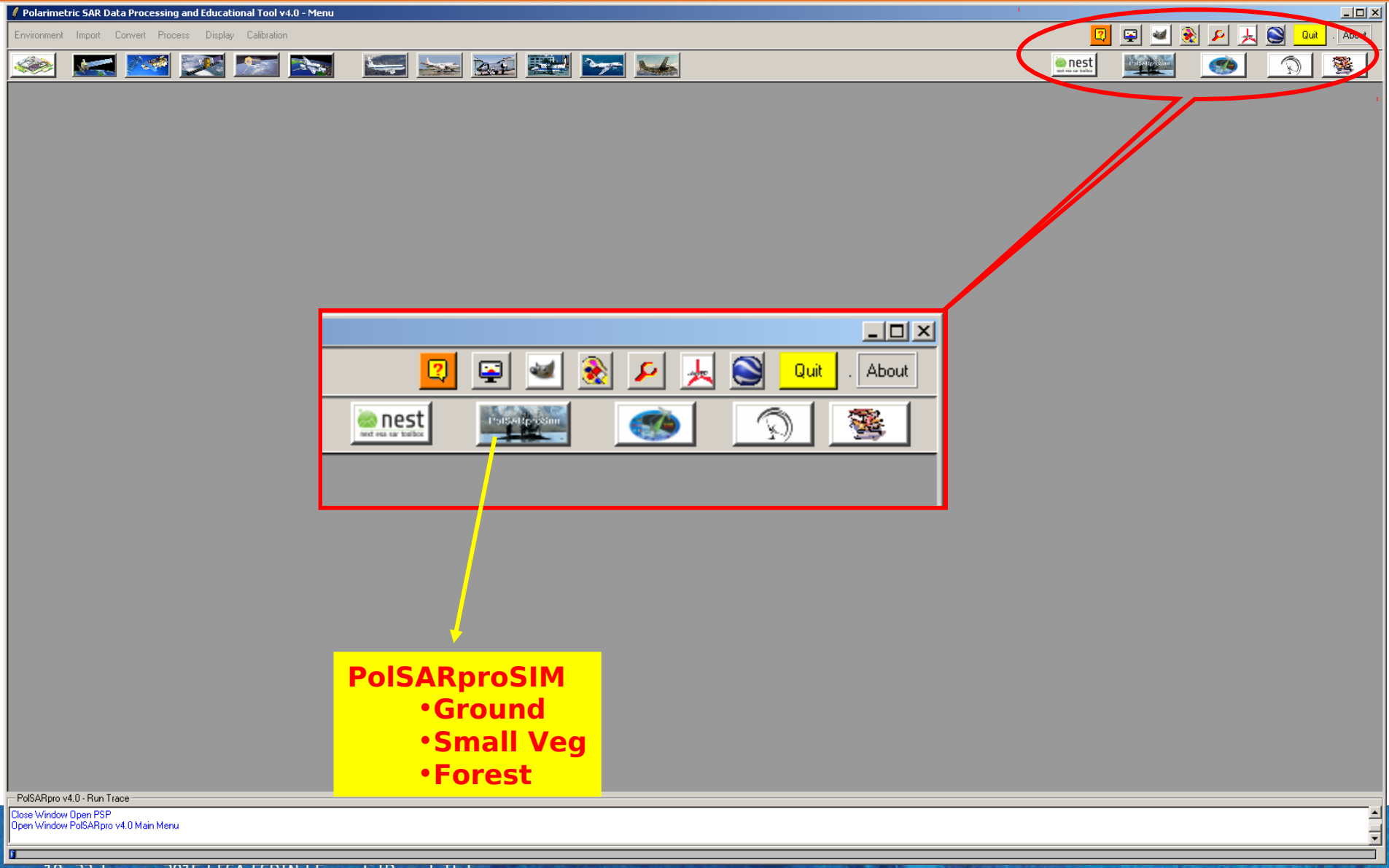


- **Recent Advances in Radar Polarimetry and Polarimetric SAR Interferometry** *W.M. Boerner – 31 pages*
- **Basic Concepts in Radar Polarimetry** *W.M. Boerner – 100 pages*
- **Advanced Concepts** *E. Pottier, J.S. Lee, L. Ferro-Famil – 65 pages*
- **POL-InSAR Training Course** *S.R. Cloude – 44 pages*
- **PCT Training Course** *S.R. Cloude – 55 pages*

Do It Yourself



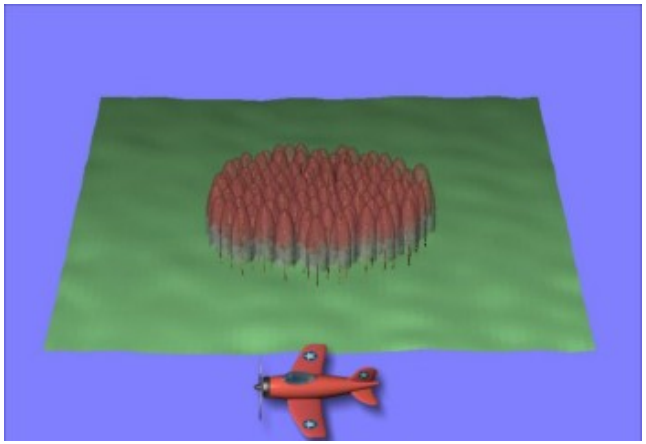
PolSARpro v4.0 SOFTWARE

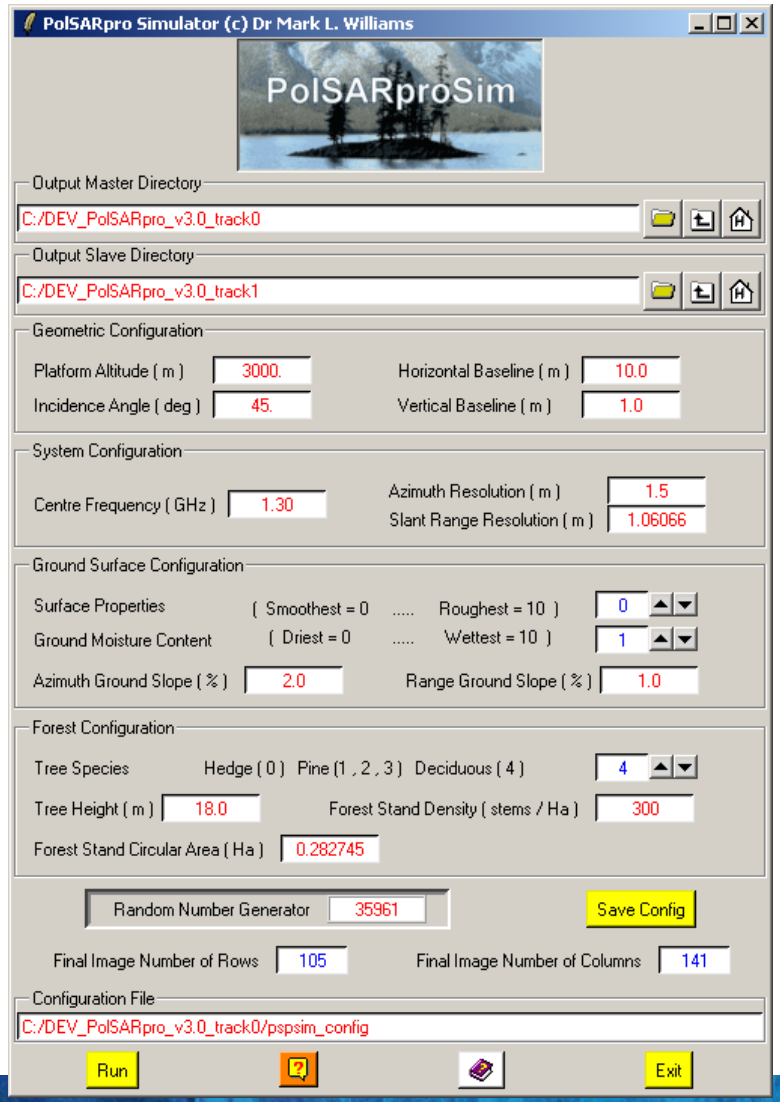


PolSARproSIM
- **Ground**
- **Small Veg**
- **Forest**

PolSARpro v3.31 SOFTWARE

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



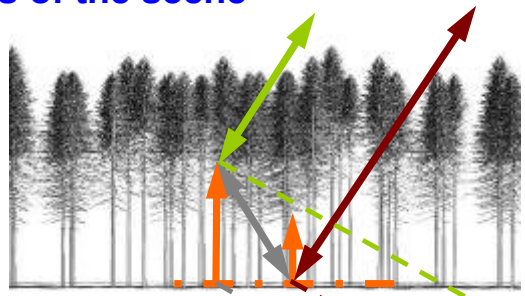


PolSARpro – SIM

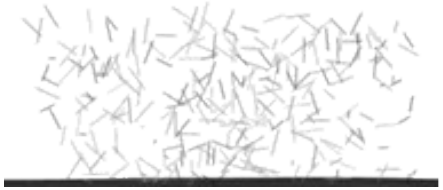
The SAR image is evaluated as a coherent sum of scattering events from small elements of the scene

PINE

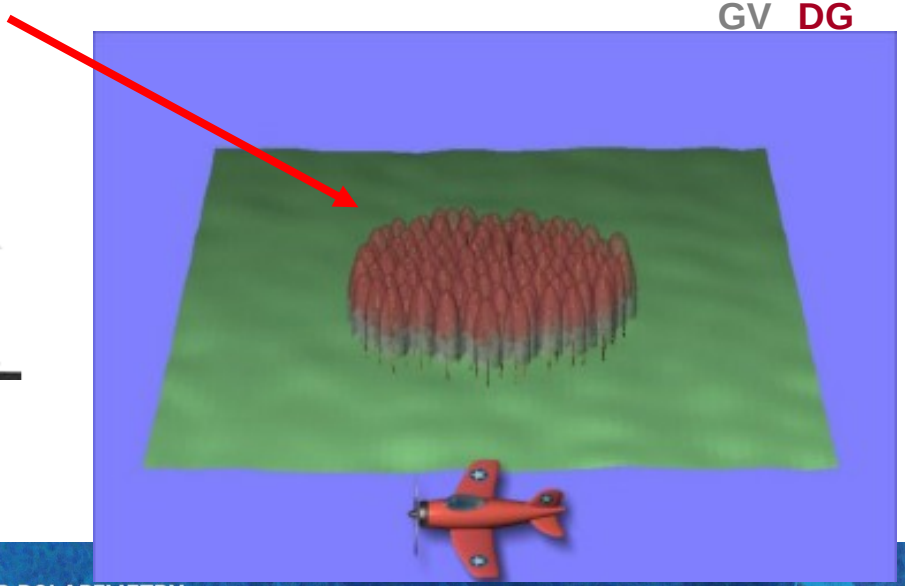
DECIDUOUS

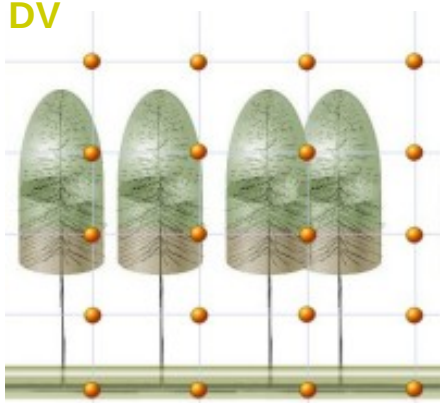


Direct-Ground, Direct-Volume and Ground-Volume contributions are included, with both trees and short vegetation comprising Volume terms.



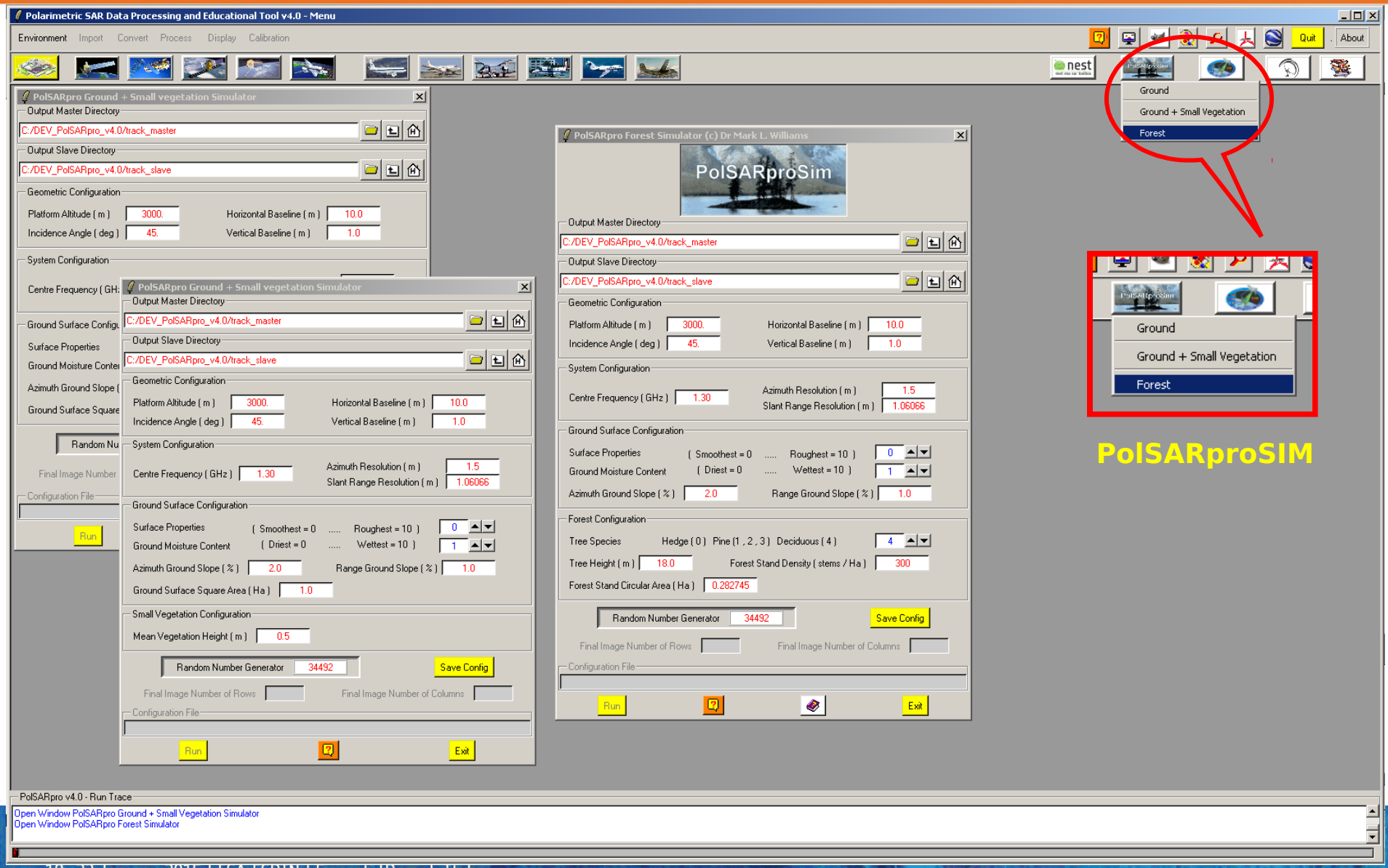
RANDOM HEDGE





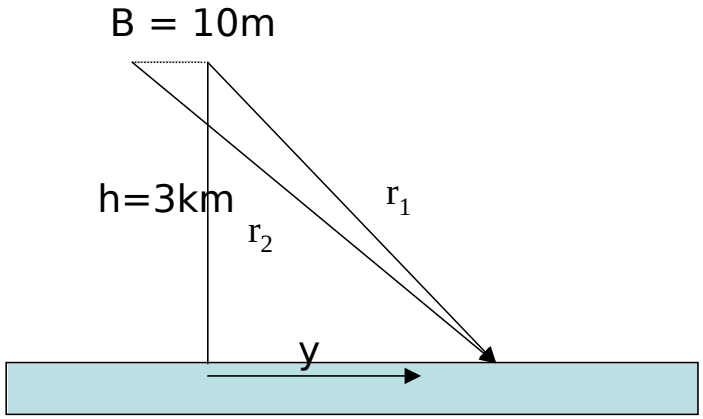
Given the map of tree locations and dimensions a grid of points is used to sample the attenuation of the coherent wave in 3D

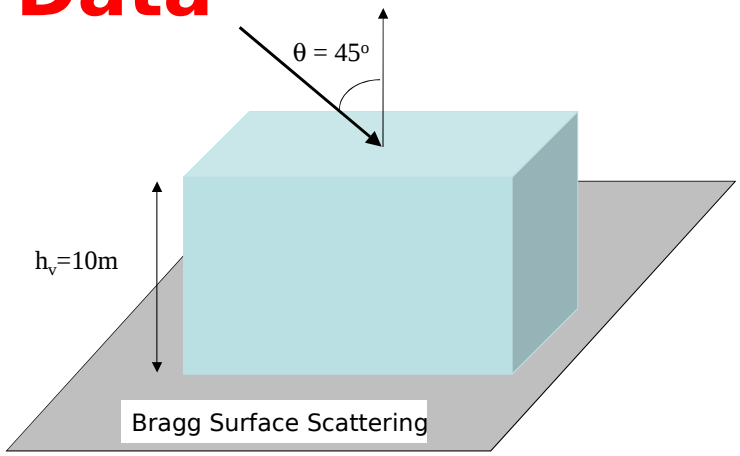
PolSARpro Simulators



PolSARproSIM

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

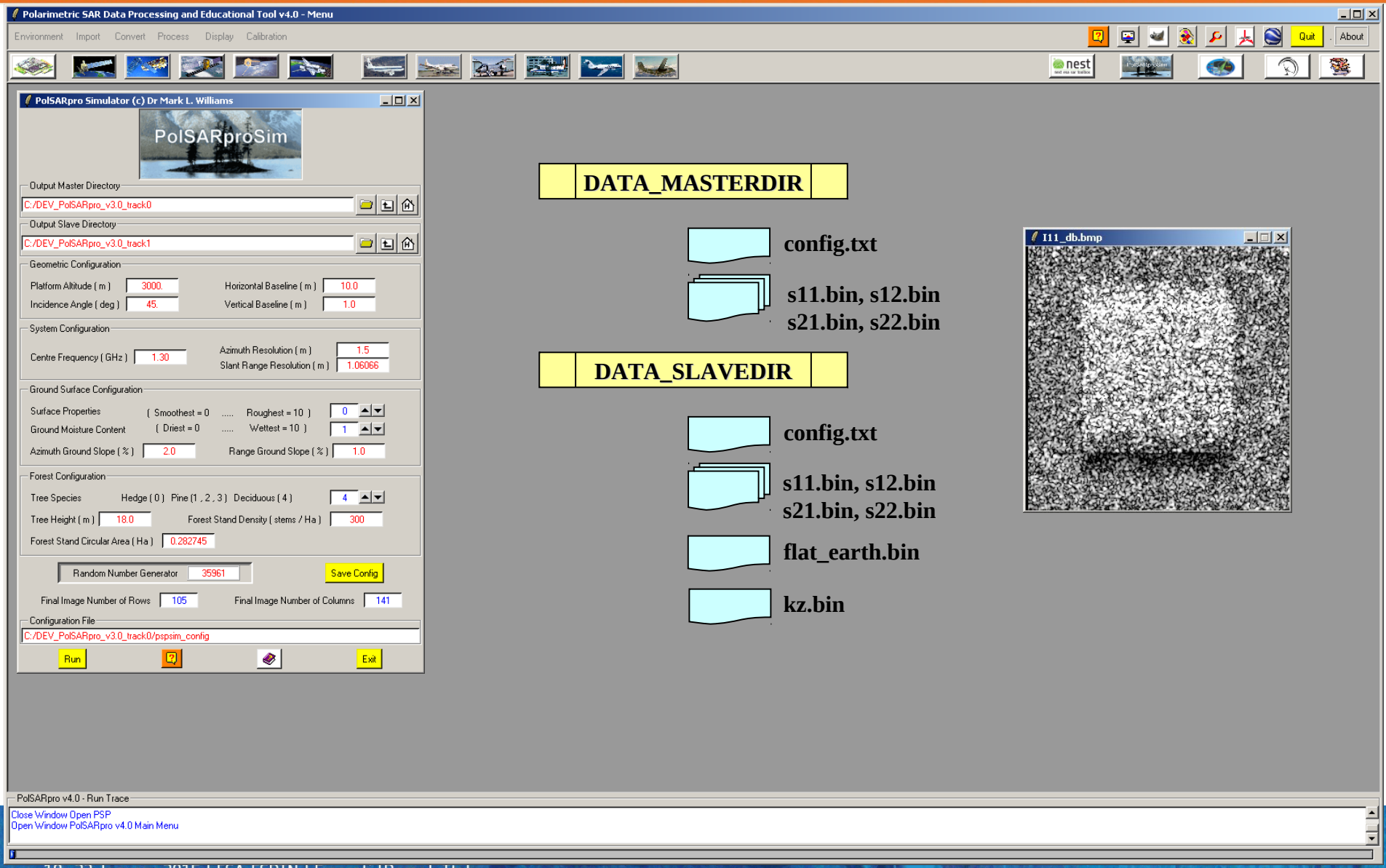
Surface properties : 0 (smoothest)
Ground moisture Content : 0 (driest)
Azimuth / Range ground slope : 0 %

Forest configuration

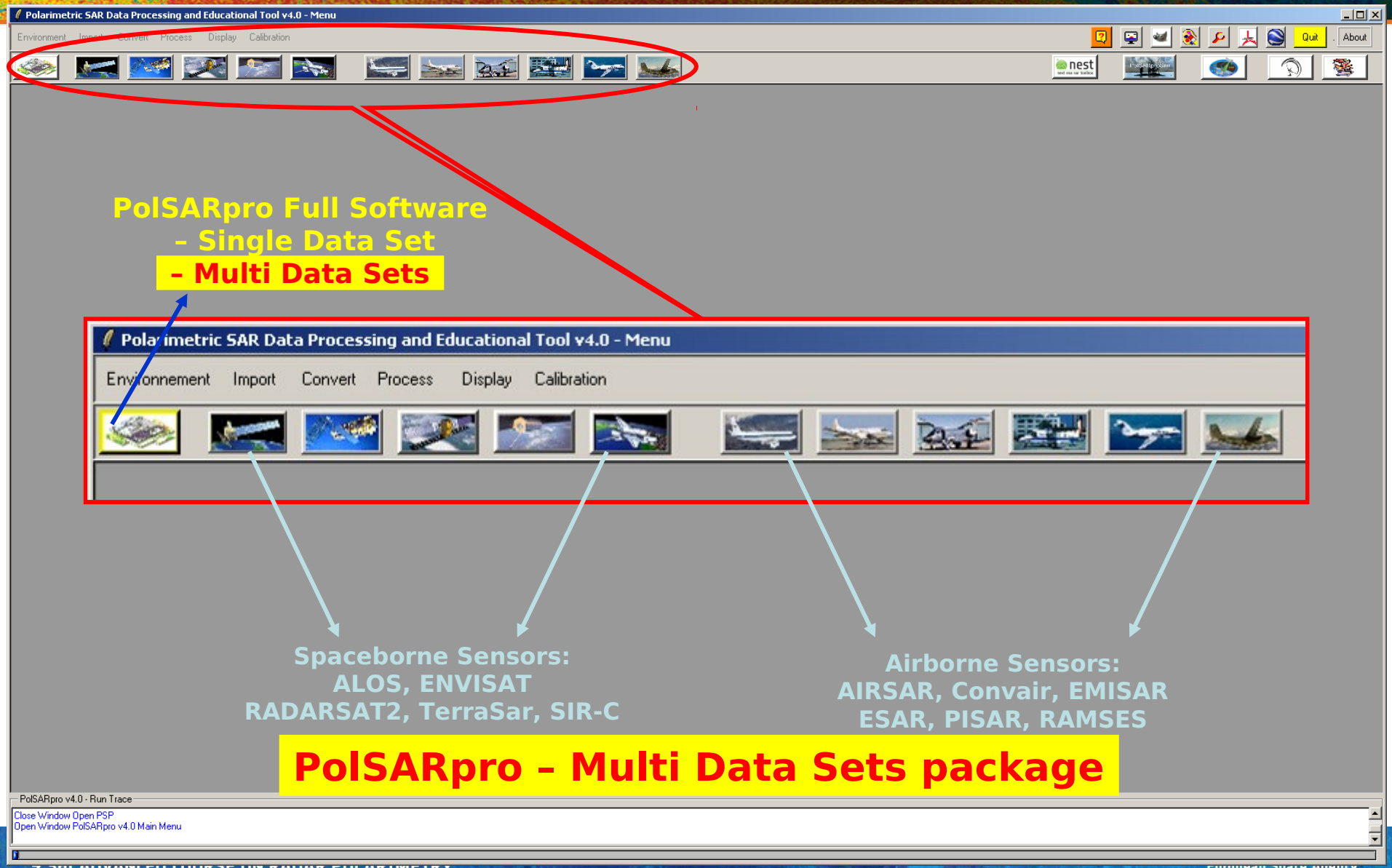
Tree Species :	0 (hedge)
Tree Height:	10m
Forest stand density :	0.2

Forest Stand Circular Area : 1 Ha

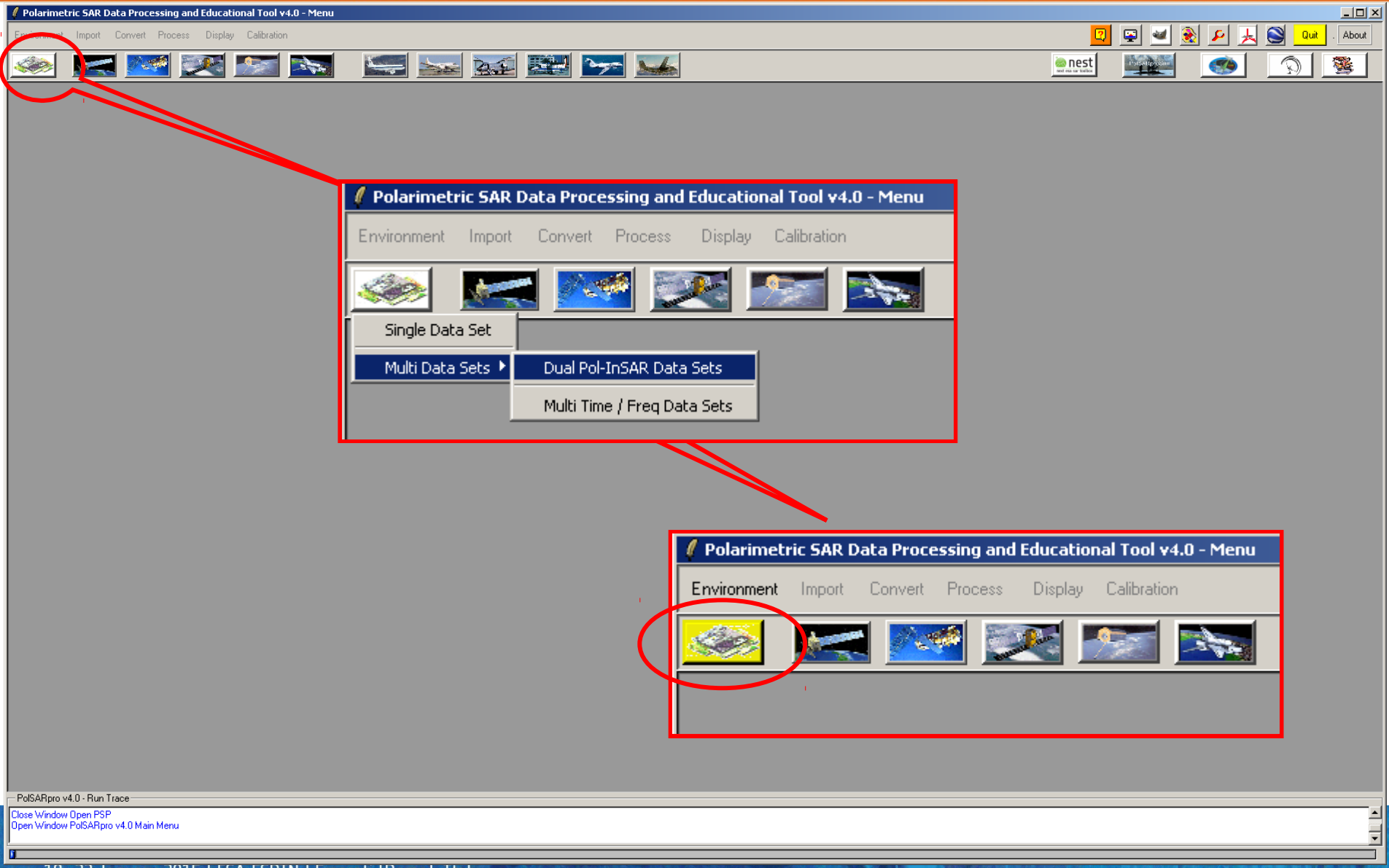
PolSARpro Simulators



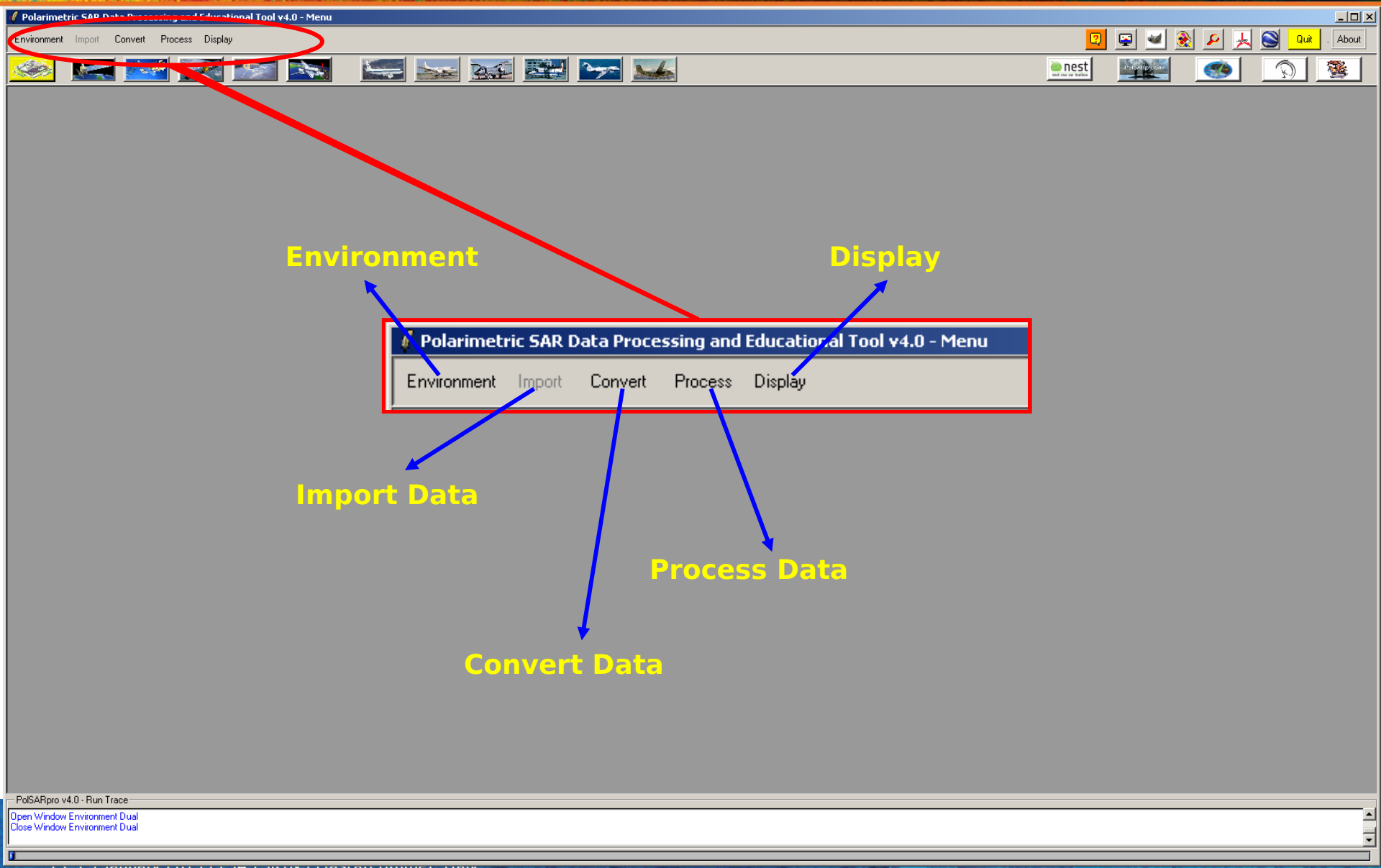
PolSARpro v4.0 SOFTWARE



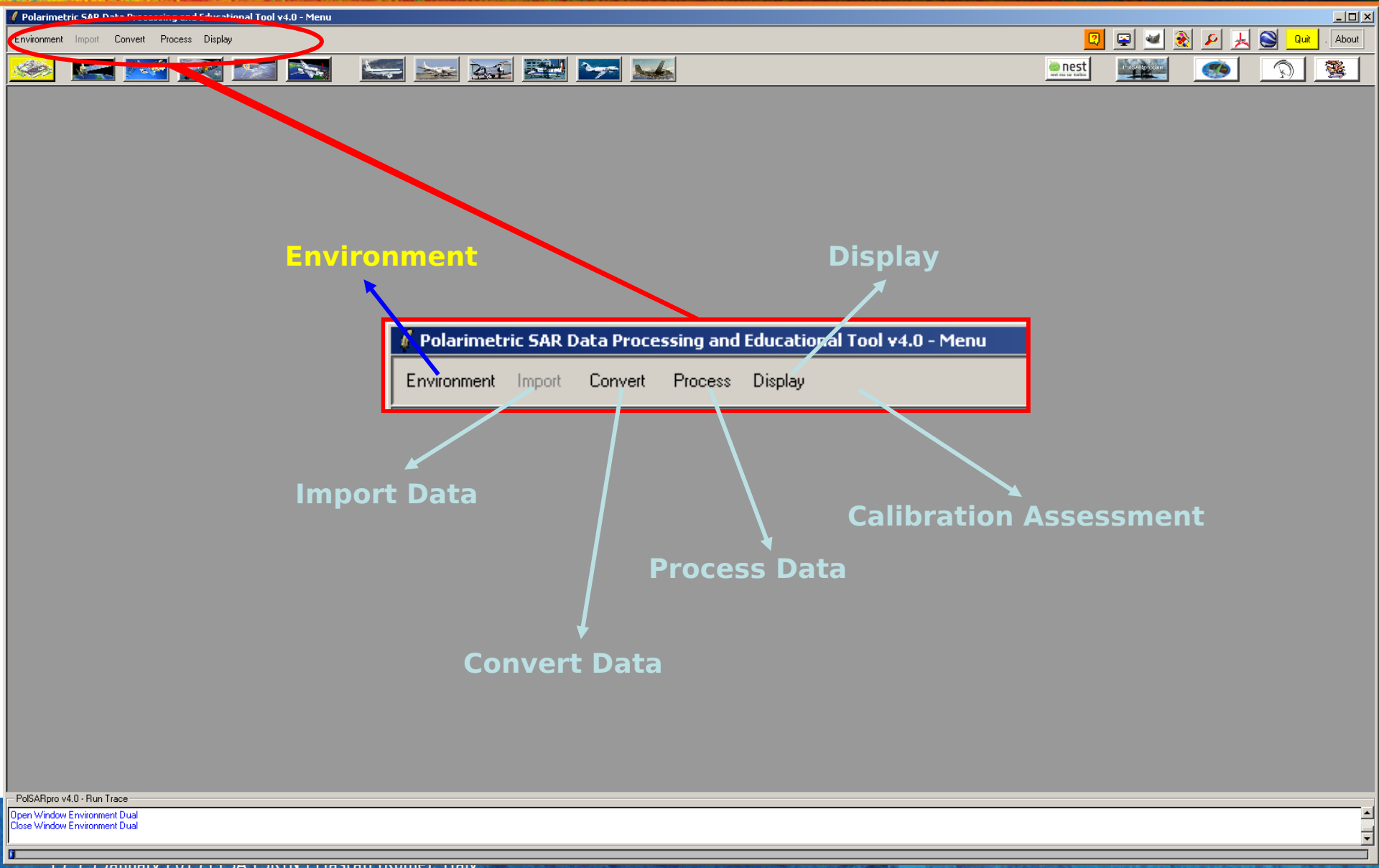
MAIN MENU


Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Import
Convert
Process
Display
Calibration
Quit
About
nest
Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Calibration
Single Data Set
Multi Data Sets
Dual Pol-InSAR Data Sets
Multi Time / Freq Data Sets
Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Calibration
PolSARpro v4.0 - Run Trace
Close Window Open PSP
Open Window PolSARpro v4.0 Main Menu

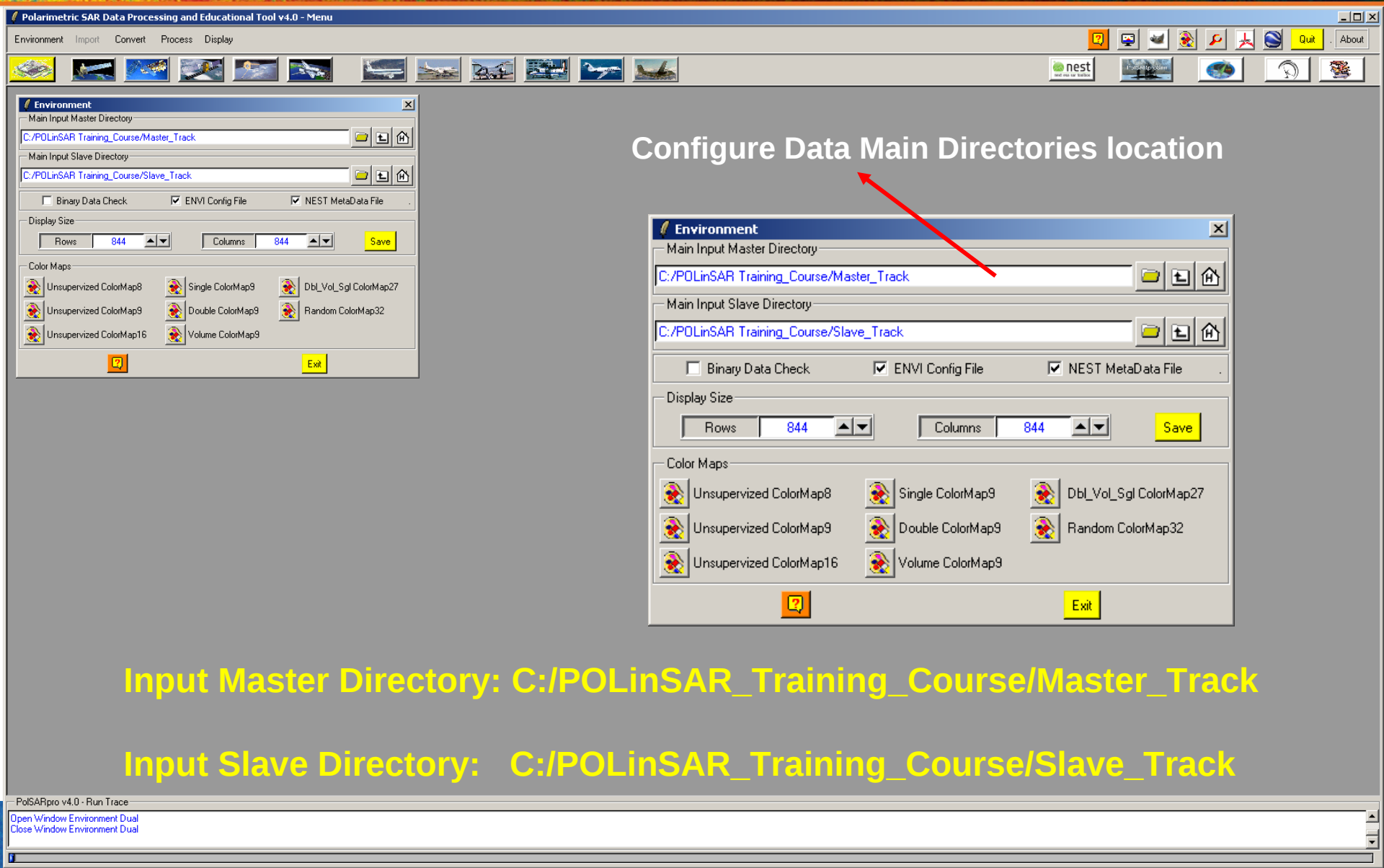
MAIN MENU


Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Quit
About
Environment
Display
Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Import Data
Process Data
Convert Data
PolSARpro v4.0 - Run Trace
Open Window Environment Dual
Close Window Environment Dual

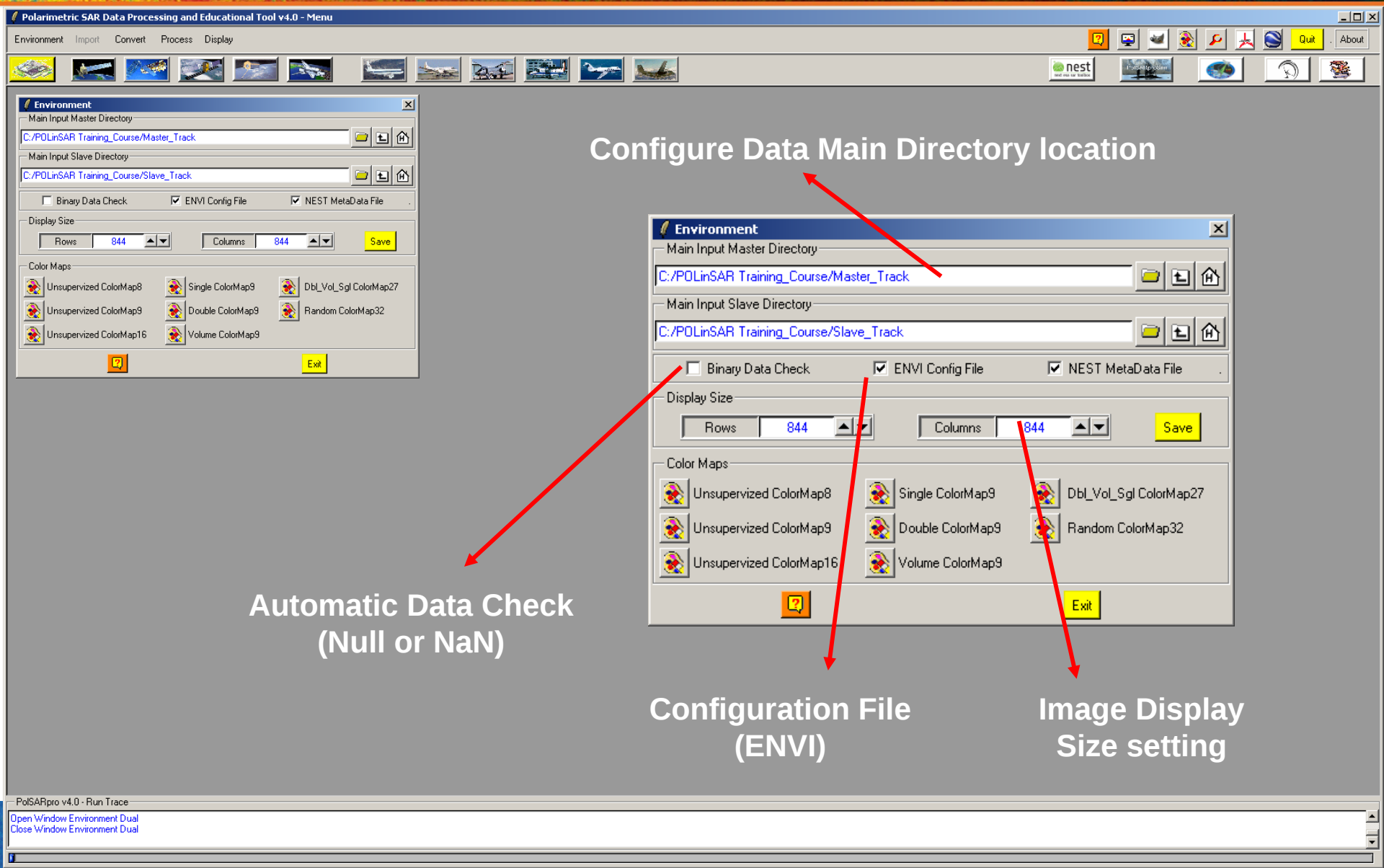
ENVIRONNEMENT

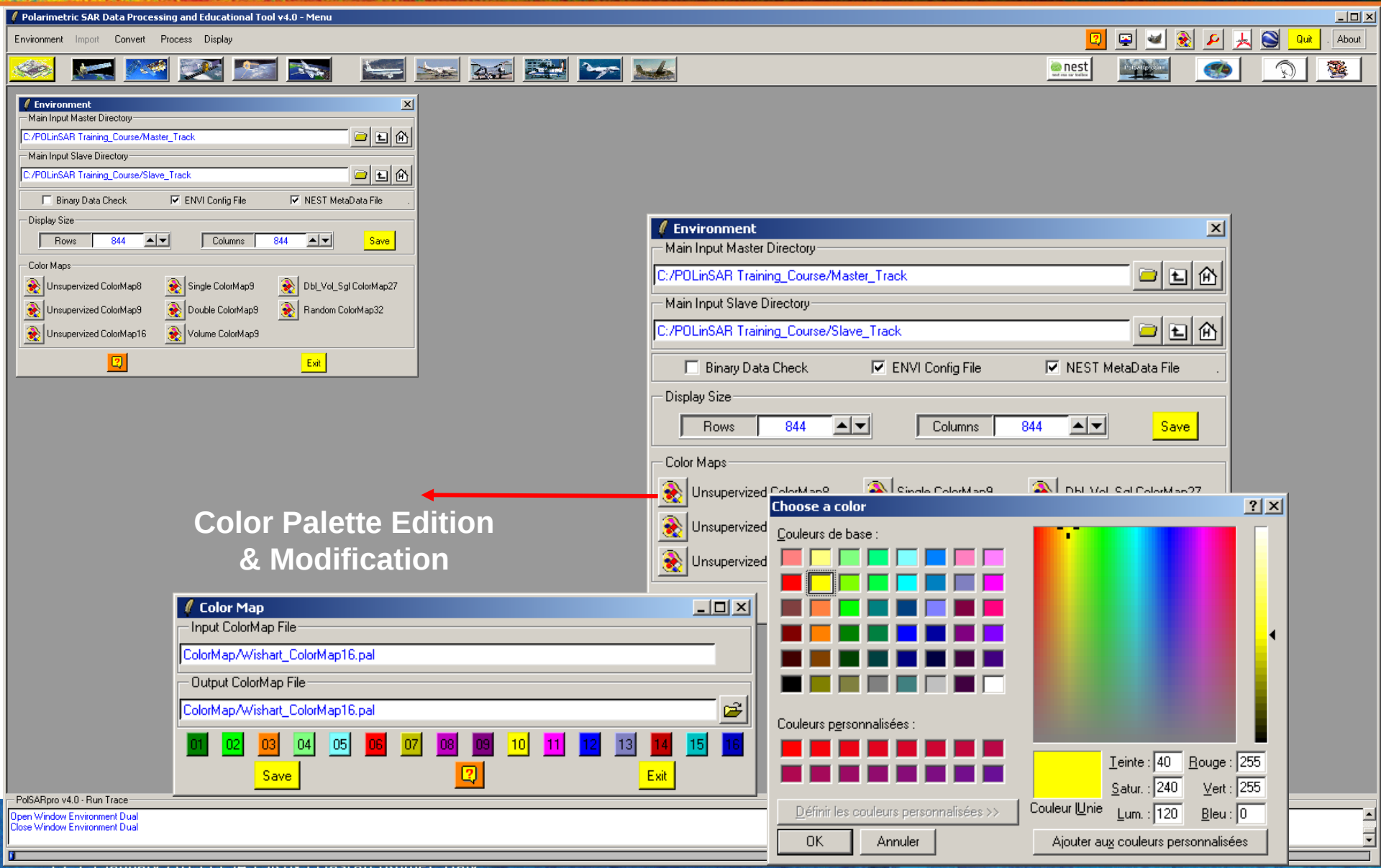


ENVIRONNEMENT

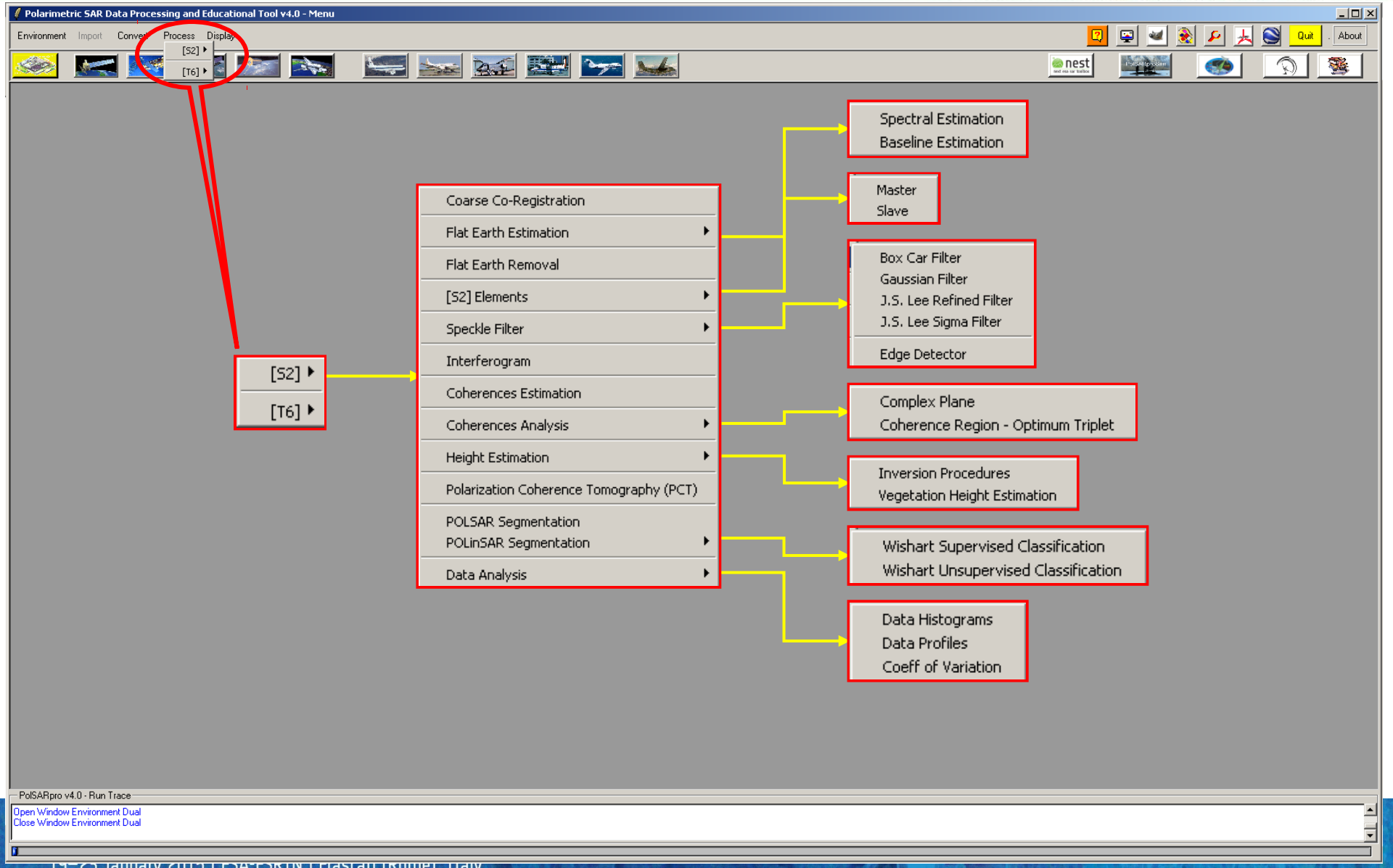


ENVIRONNEMENT

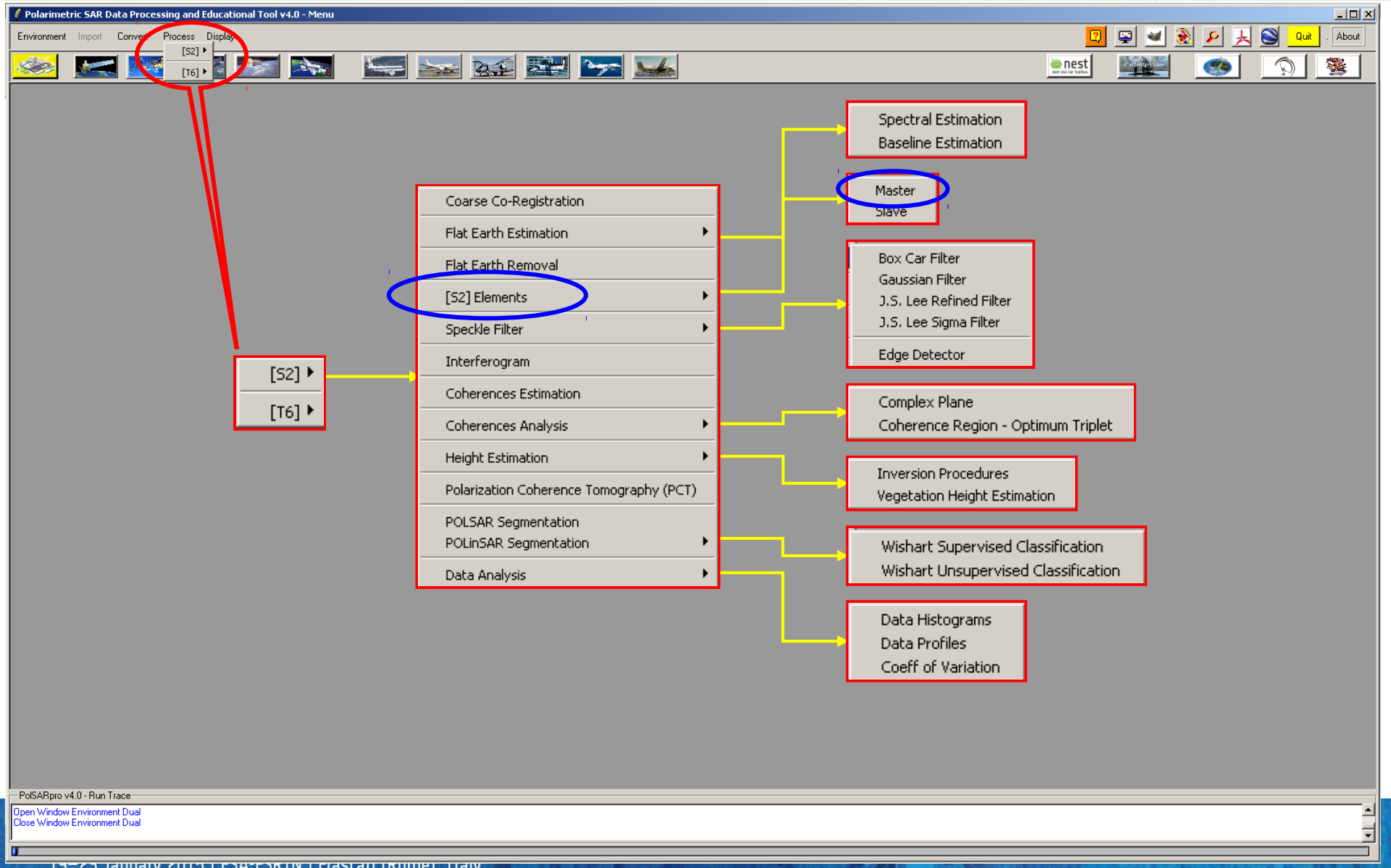



Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Quit
About
Environment
Main Input Master Directory
C:/POLinSAR Training_Course/Master_Track
Main Input Slave Directory
C:/POLinSAR Training_Course/Slave_Track
Binary Data Check
ENVI Config File
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
Color Palette Edition & Modification
Color Map
Input ColorMap File
ColorMap/Wishart_ColorMap16.pal
Output ColorMap File
ColorMap/Wishart_ColorMap16.pal
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
Save
Exit
Choose a color
Couleurs de base :
Couleurs personnalisées :
Définir les couleurs personnalisées >>
OK
Annuler
Couleur Unie
Teinte : 40
Satur. : 240
Lum. : 120
Rouge : 255
Vert : 255
Bleu : 0
Ajouter aux couleurs personnalisées
PolSARpro v4.0 - Run Trace
Open Window Environment Dual
Close Window Environment Dual

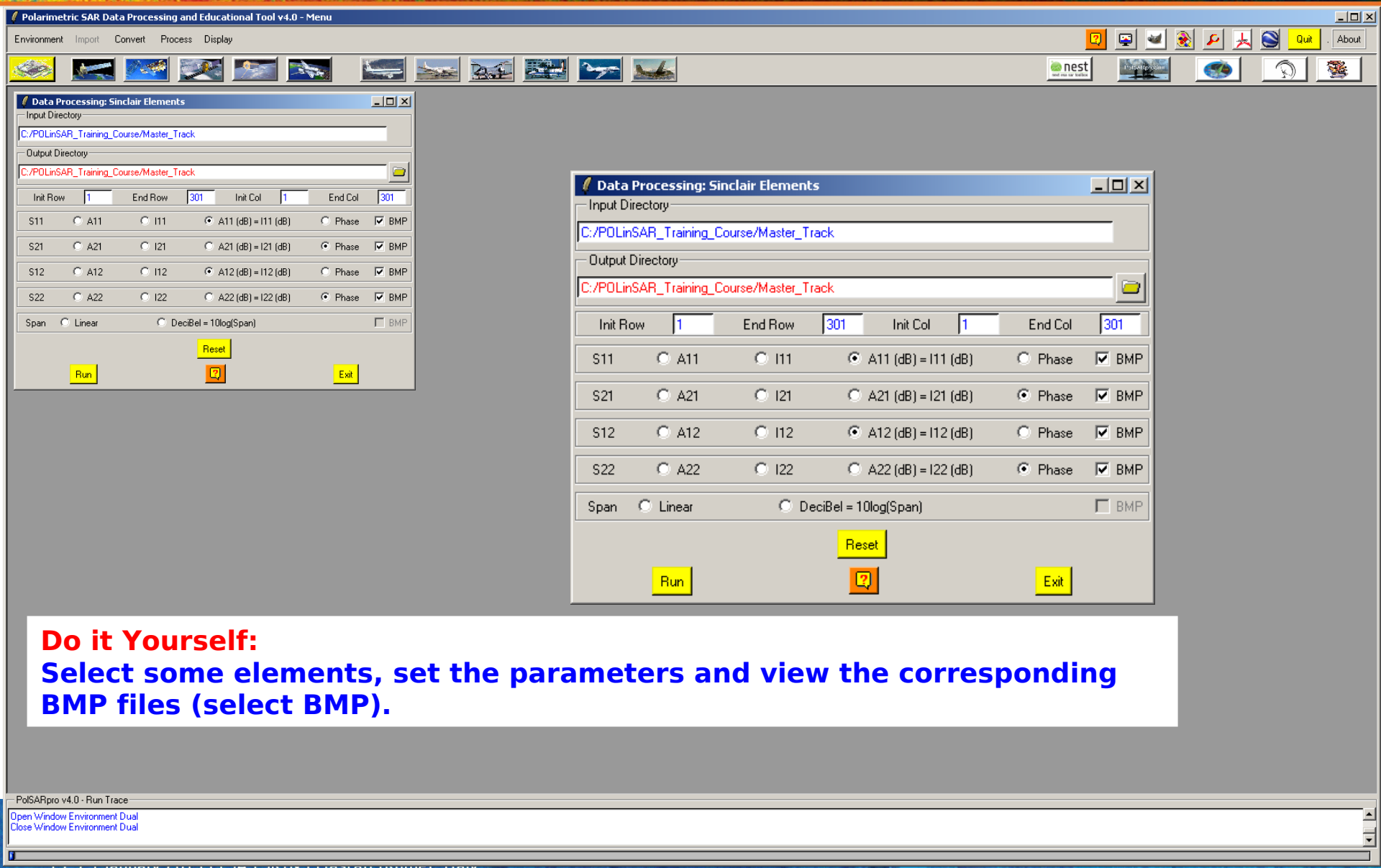
PROCESS DATA - [S2] - MENU



PROCESS DATA - [S2] - MENU



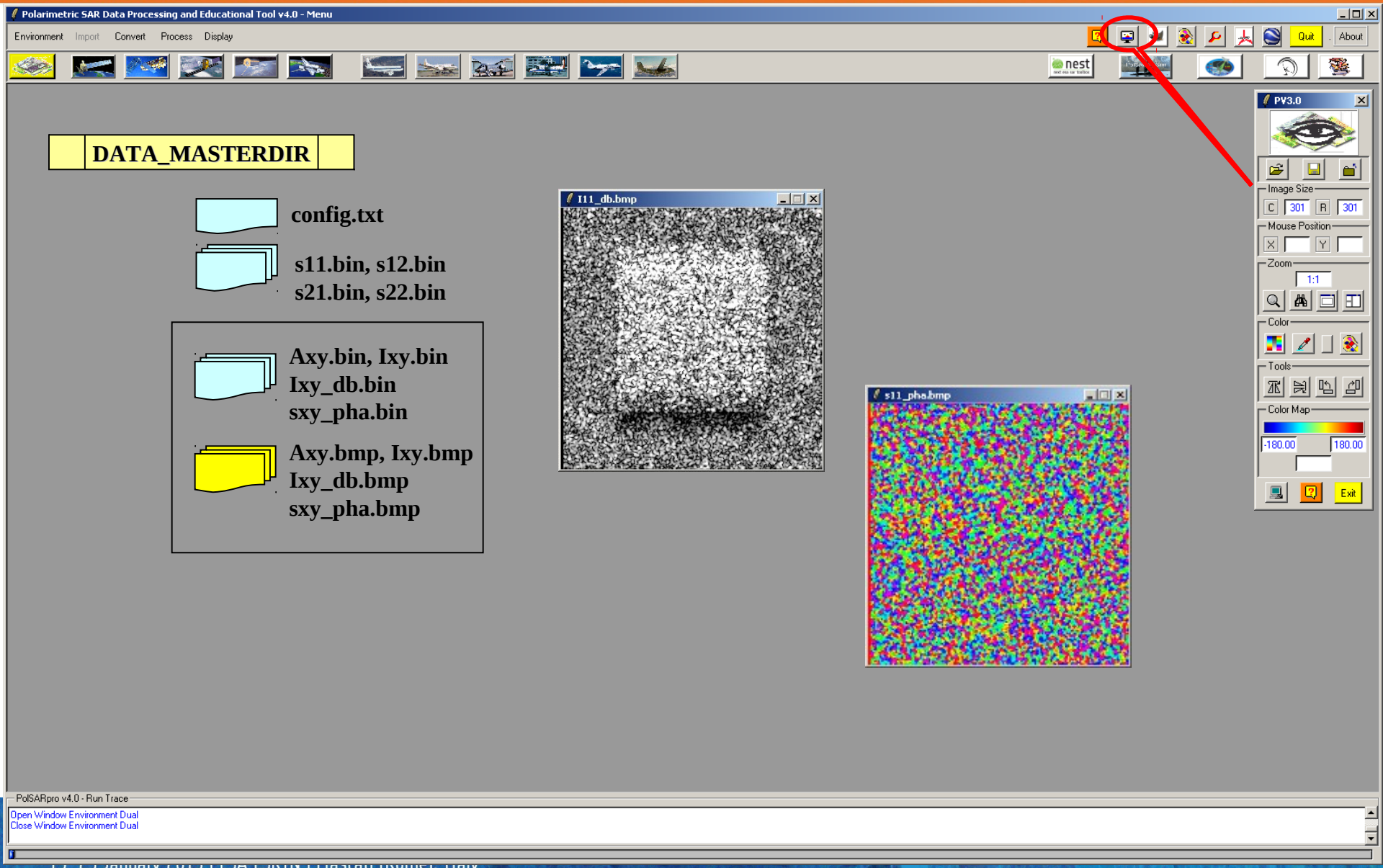
ELEMENTS



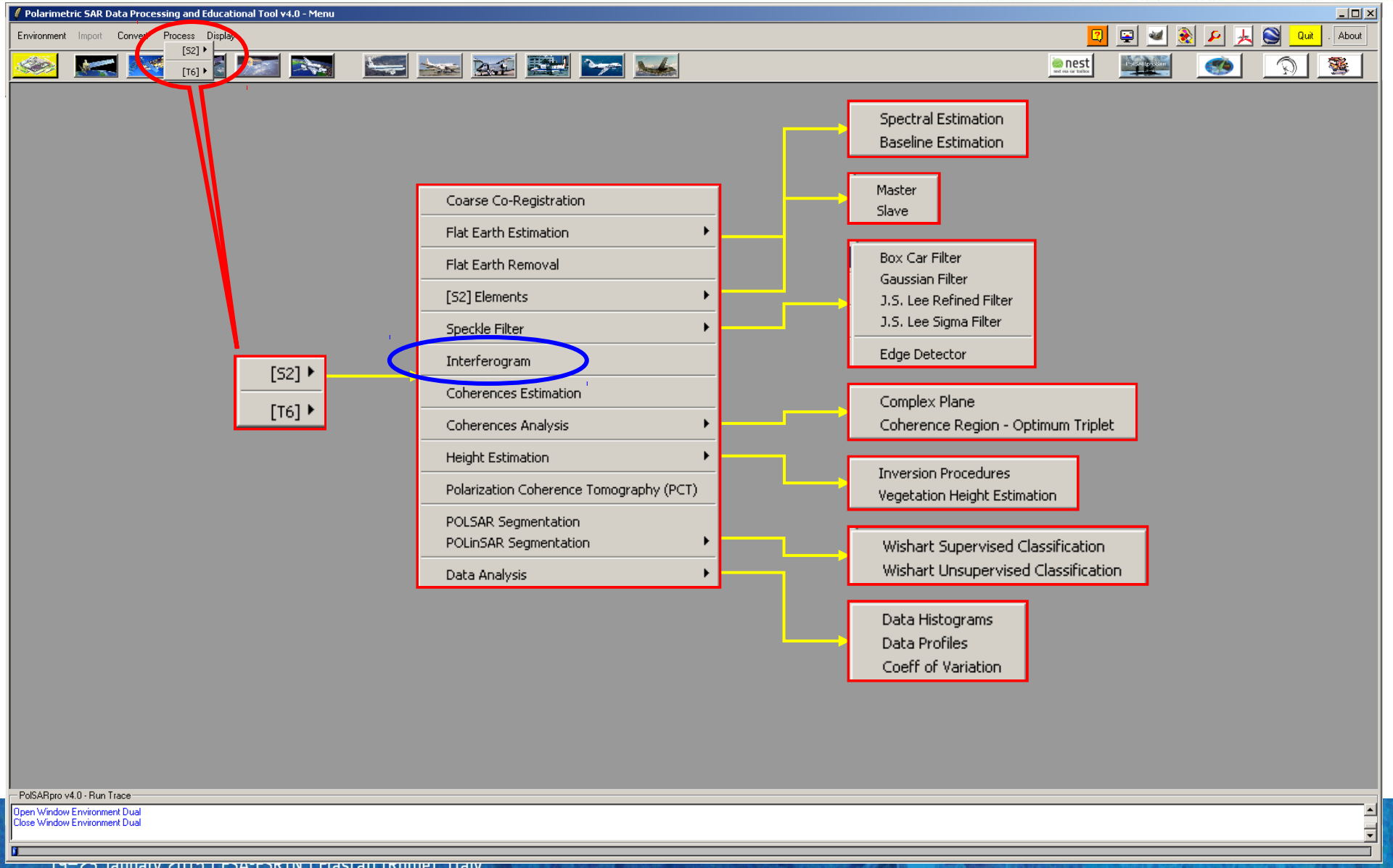
Do it Yourself:

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

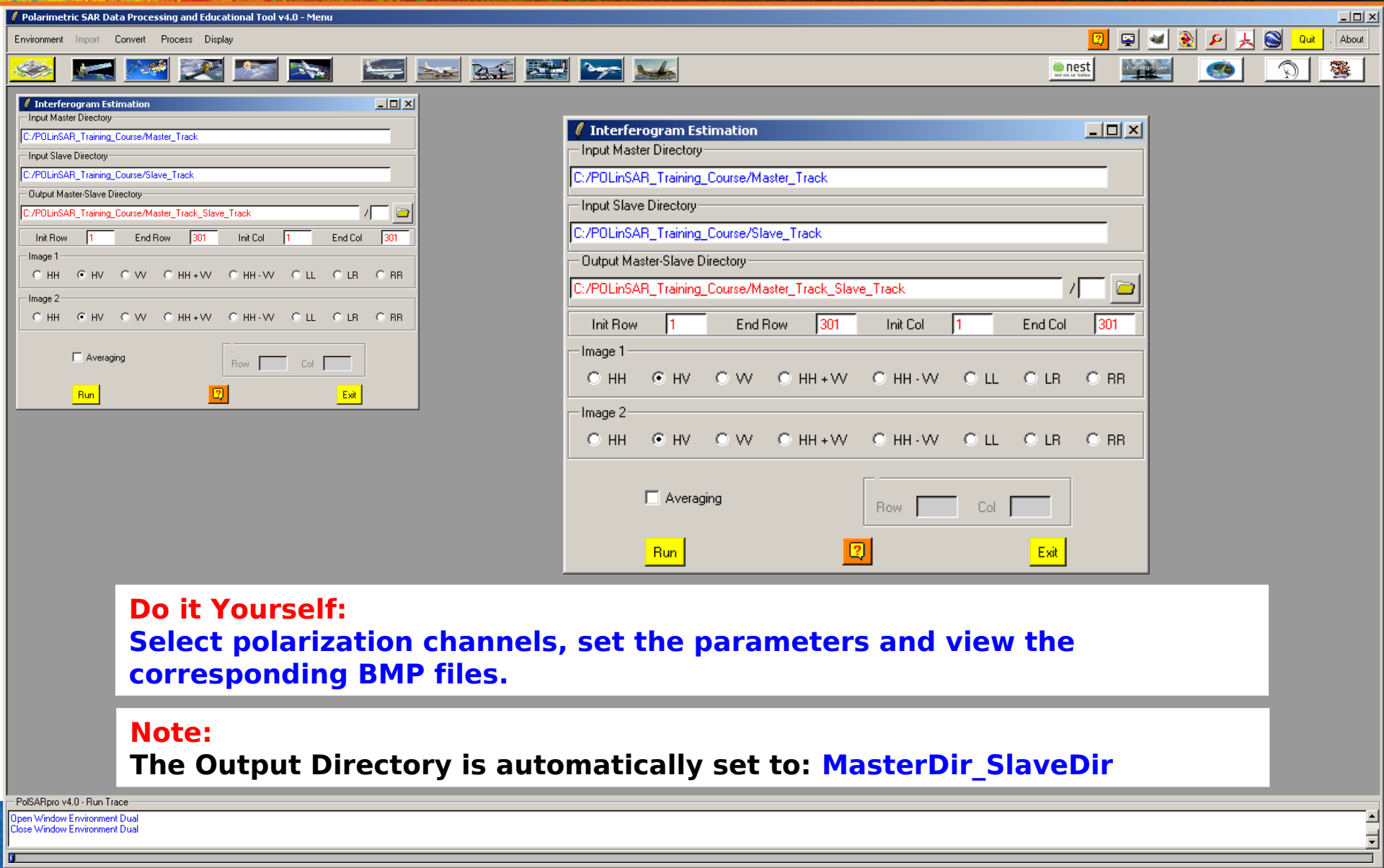
ELEMENTS


Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Quit
About
nest
PV3.0
Image Size
C
301
R
301
Mouse Position
X
Y
Zoom
1:1
Color
Tools
Color Map
-180.00
180.00
Exit
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
I11_db.bmp
s11_pha.bmp
PolSARpro v4.0 - Run Trace
Open Window Environment Dual
Close Window Environment Dual

PROCESS DATA - [S2] - MENU



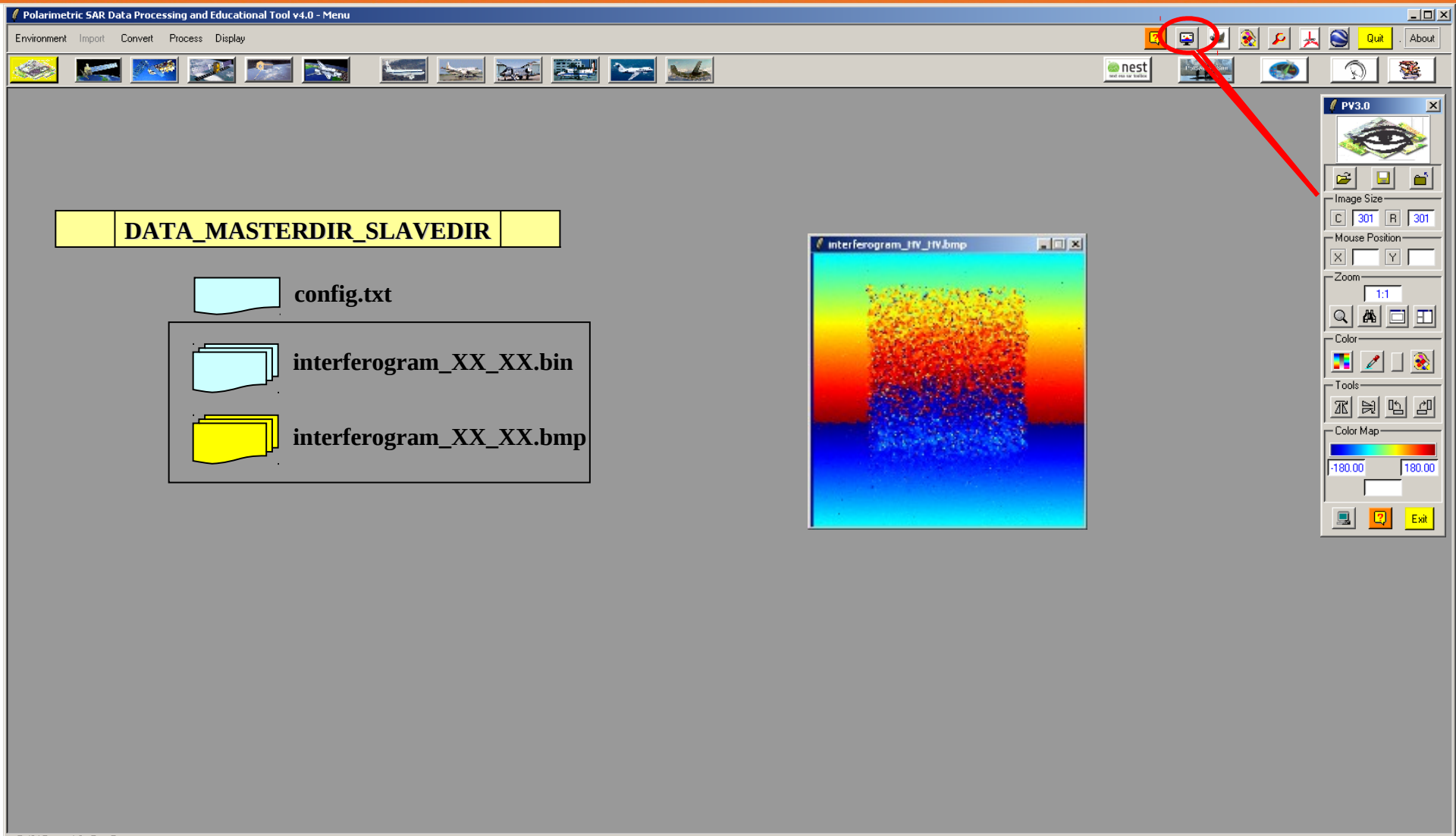
RAW INTERFEROGRAM



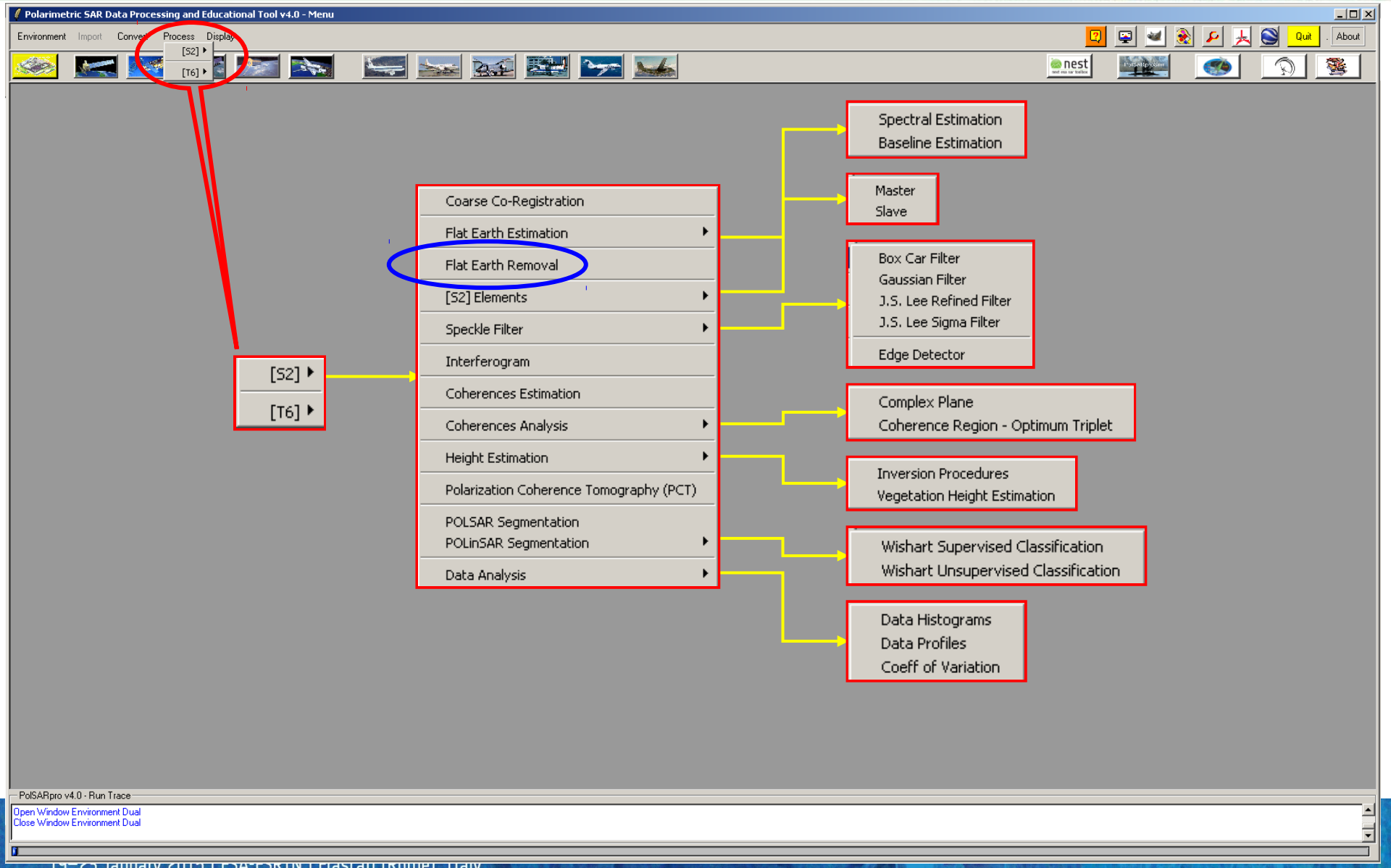
Do it Yourself:
Select polarization channels, set the parameters and view the corresponding BMP files.

Note:
The Output Directory is automatically set to: MasterDir_SlaveDir

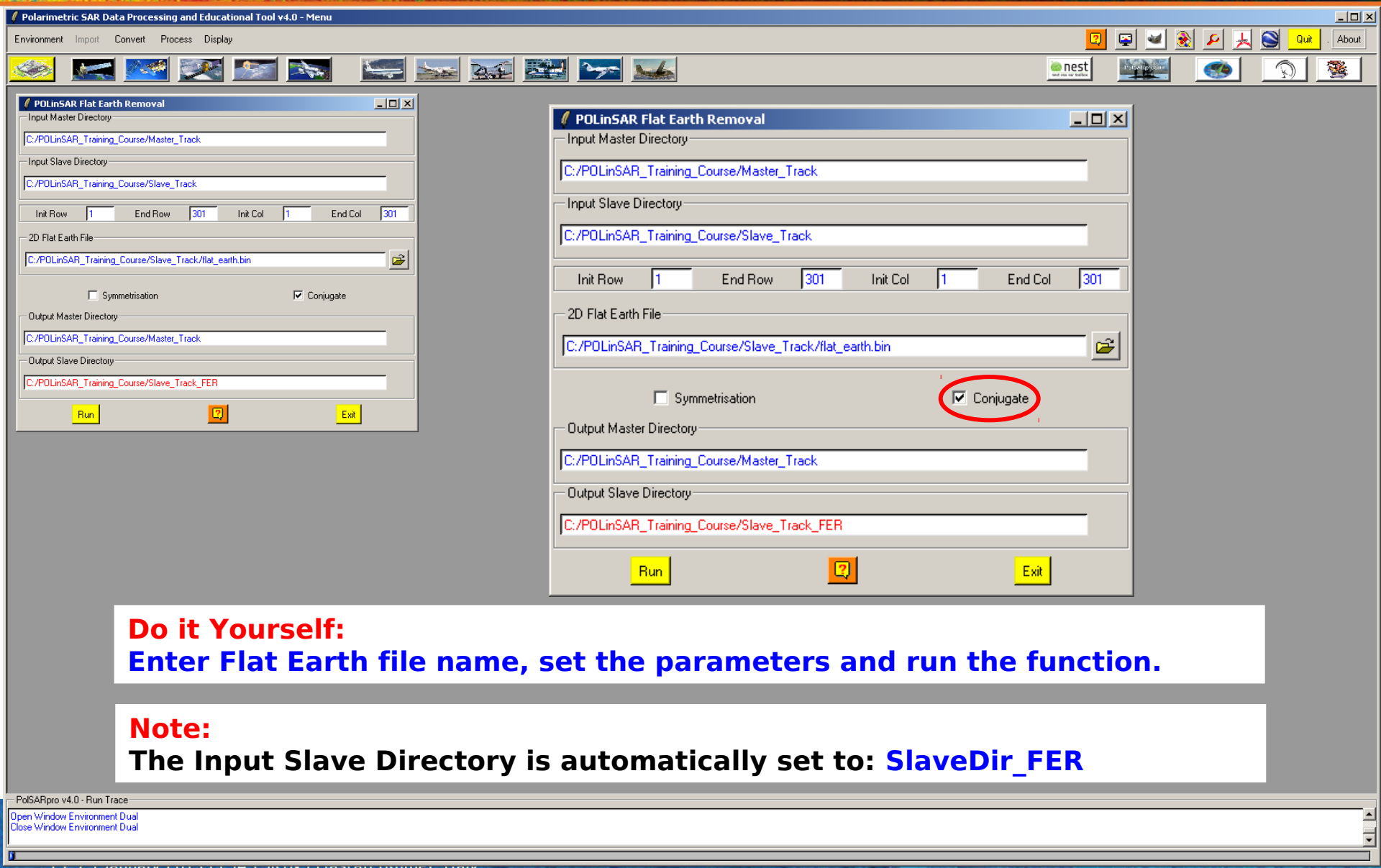
RAW INTERFEROGRAM



PROCESS DATA - [S2] - MENU



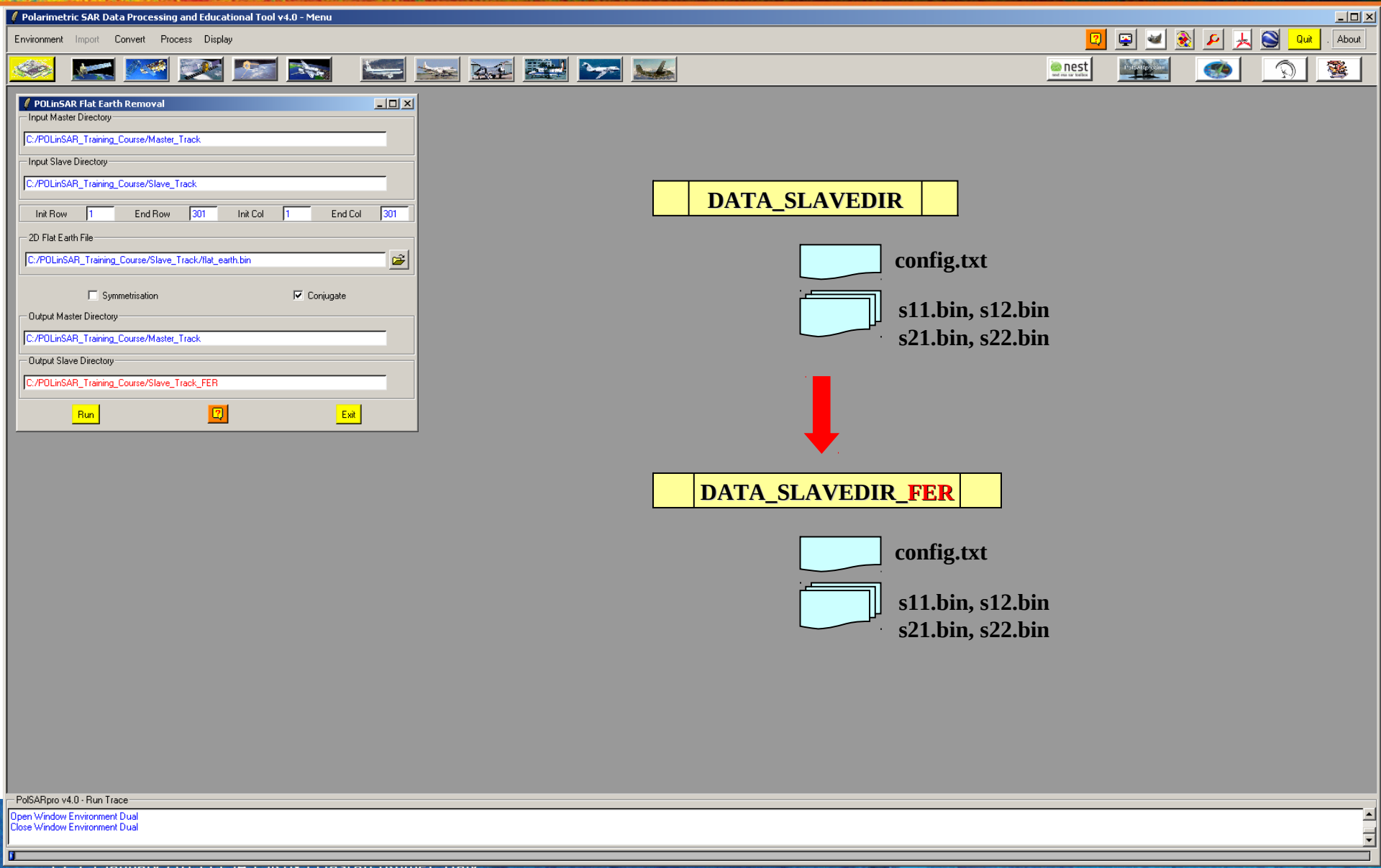
FLAT EARTH REMOVAL



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

FLAT EARTH REMOVAL



DATA_SLAVEDIR

config.txt

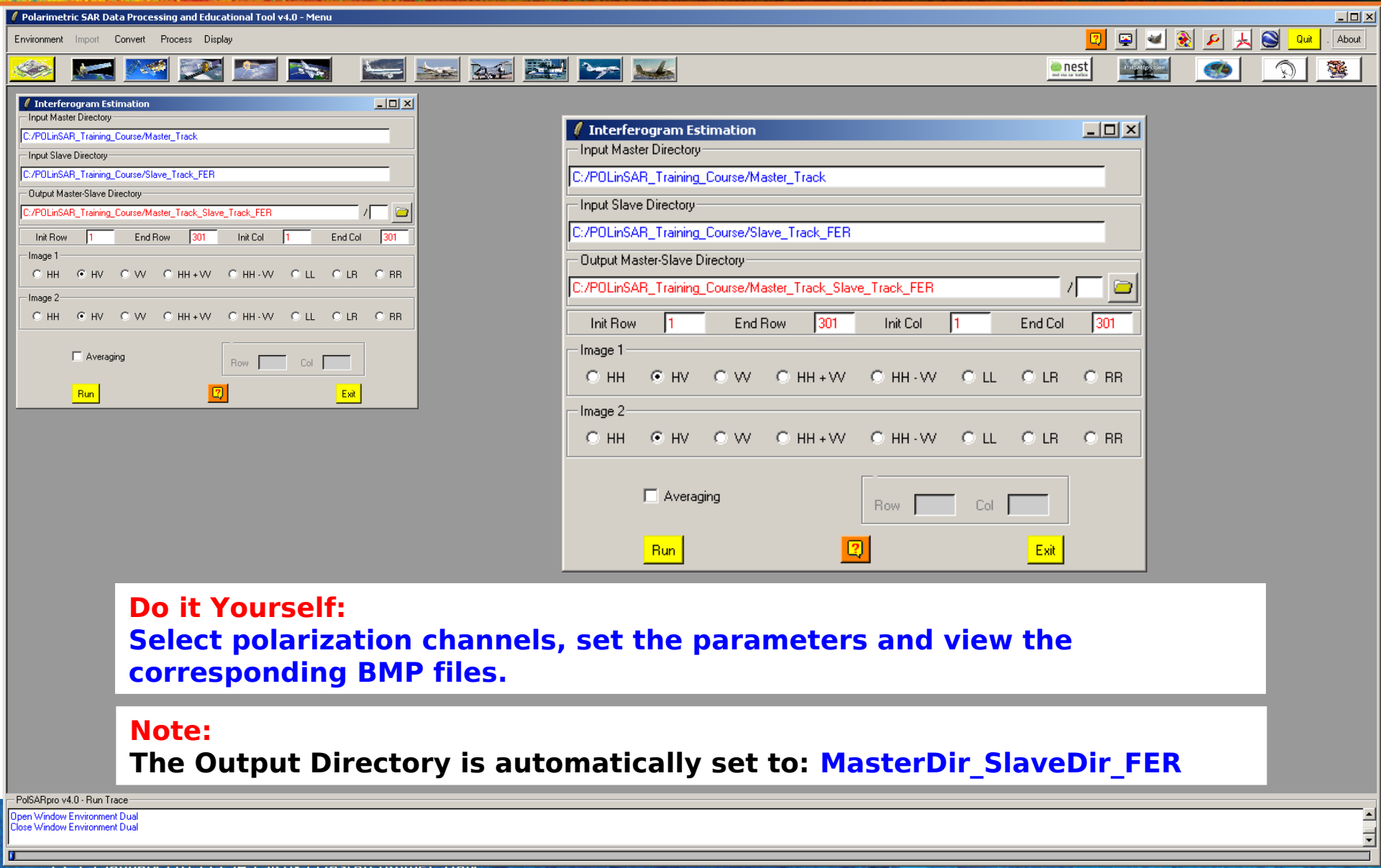
s11.bin, s12.bin
s21.bin, s22.bin

DATA_SLAVEDIR_FER

config.txt

s11.bin, s12.bin
s21.bin, s22.bin

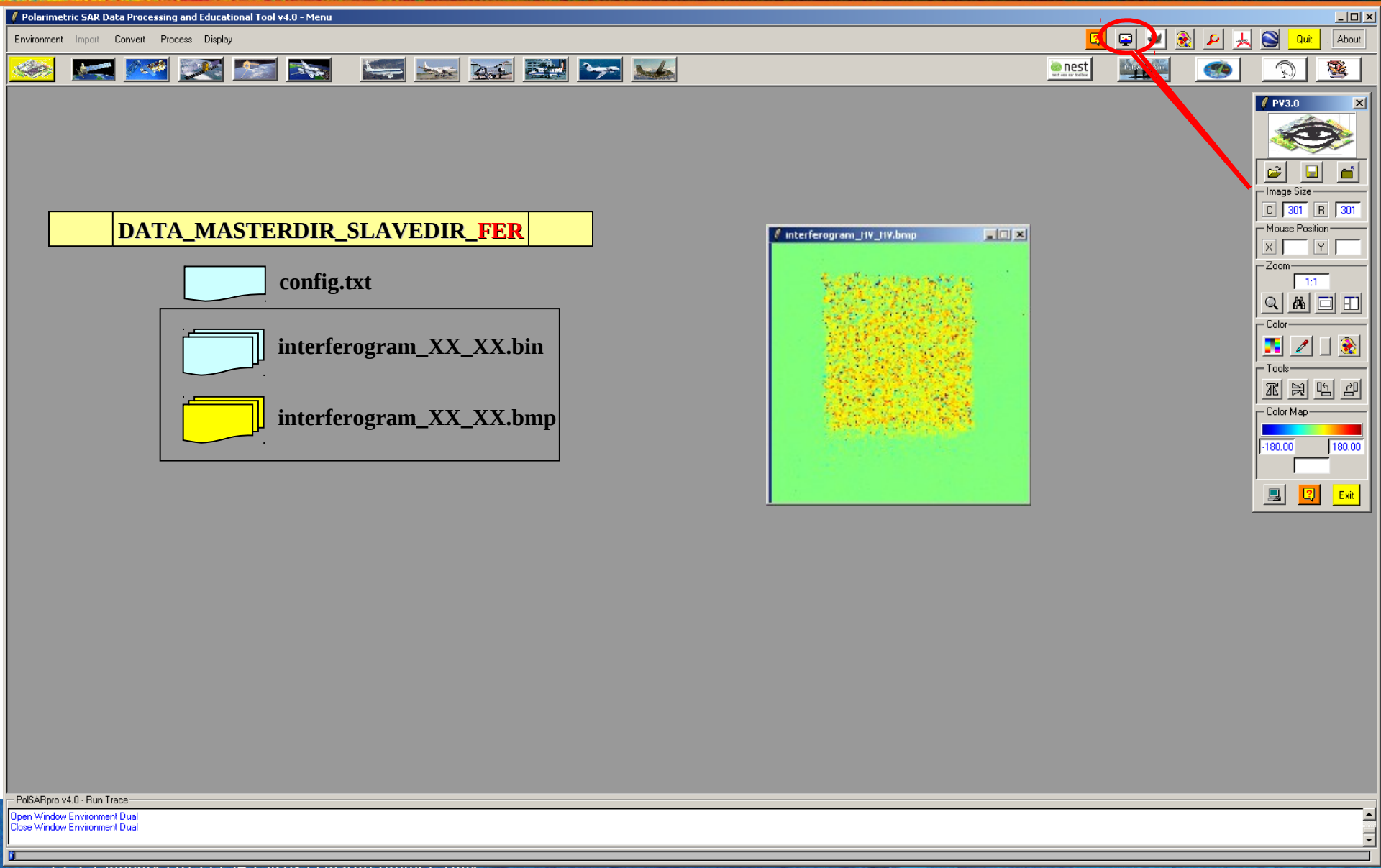
RAW INTERFEROGRAM



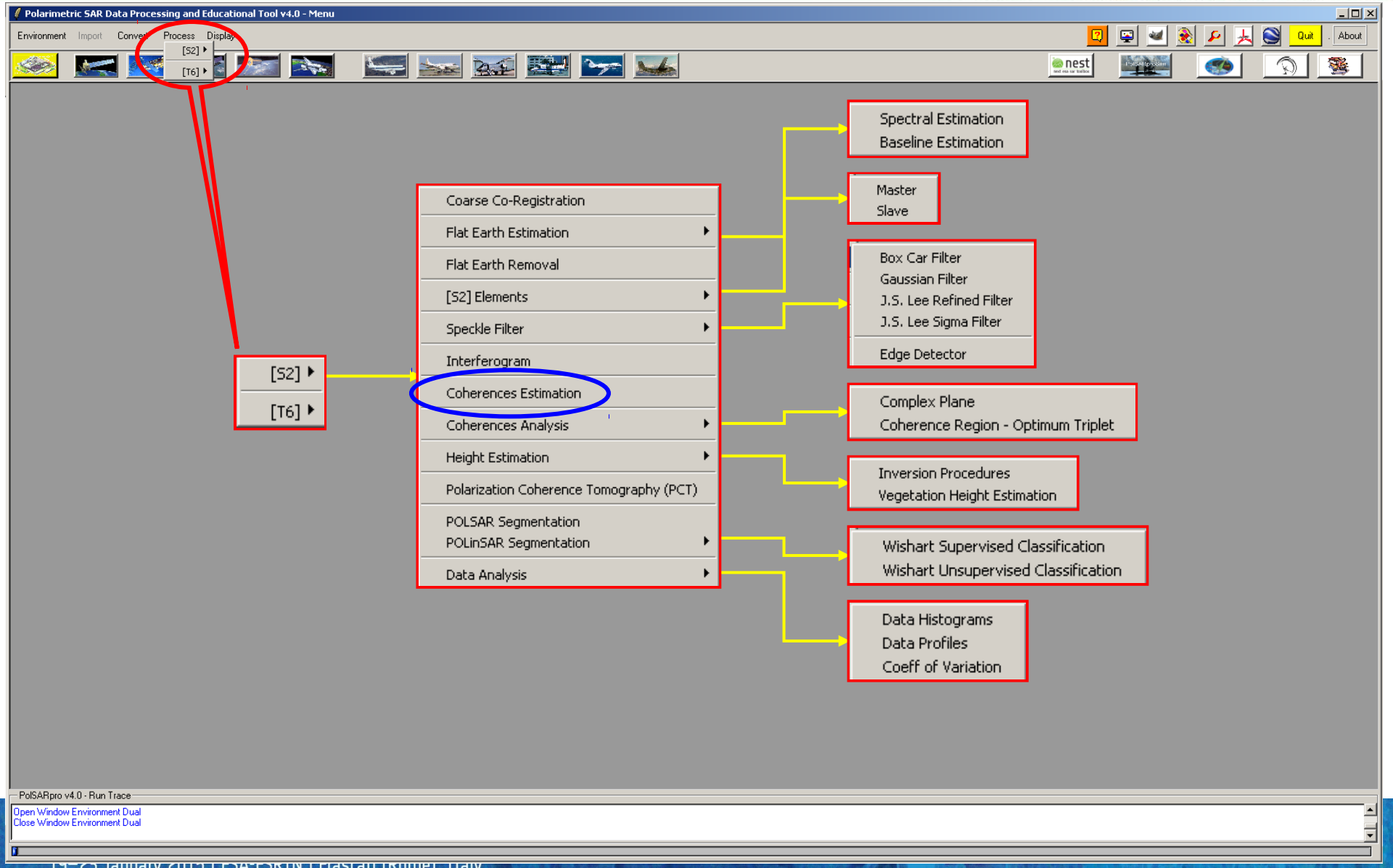
Do it Yourself:
Select polarization channels, set the parameters and view the corresponding BMP files.

Note:
The Output Directory is automatically set to: MasterDir_SlaveDir_FER

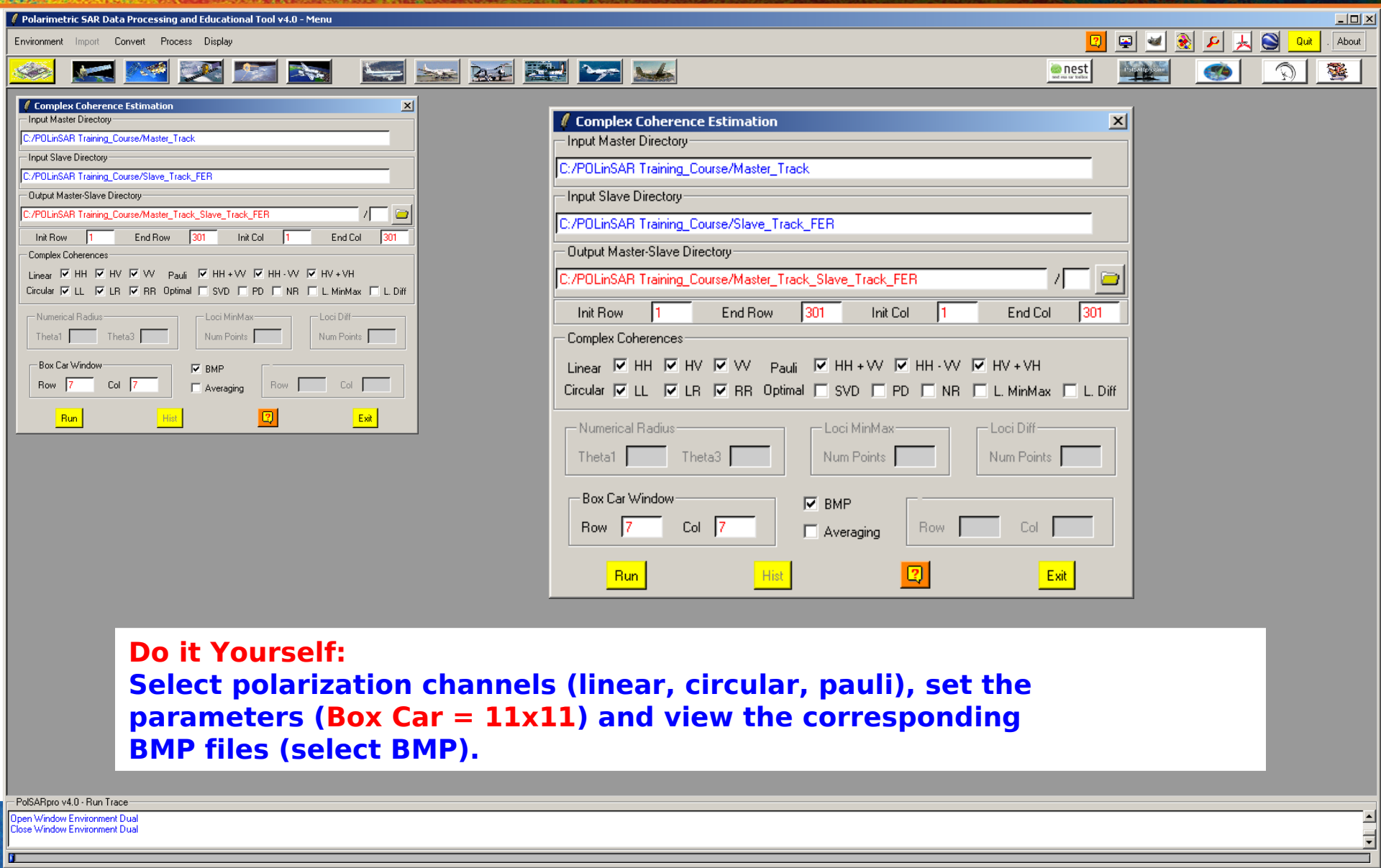
RAW INTERFEROGRAM



PROCESS DATA - [S2] - MENU

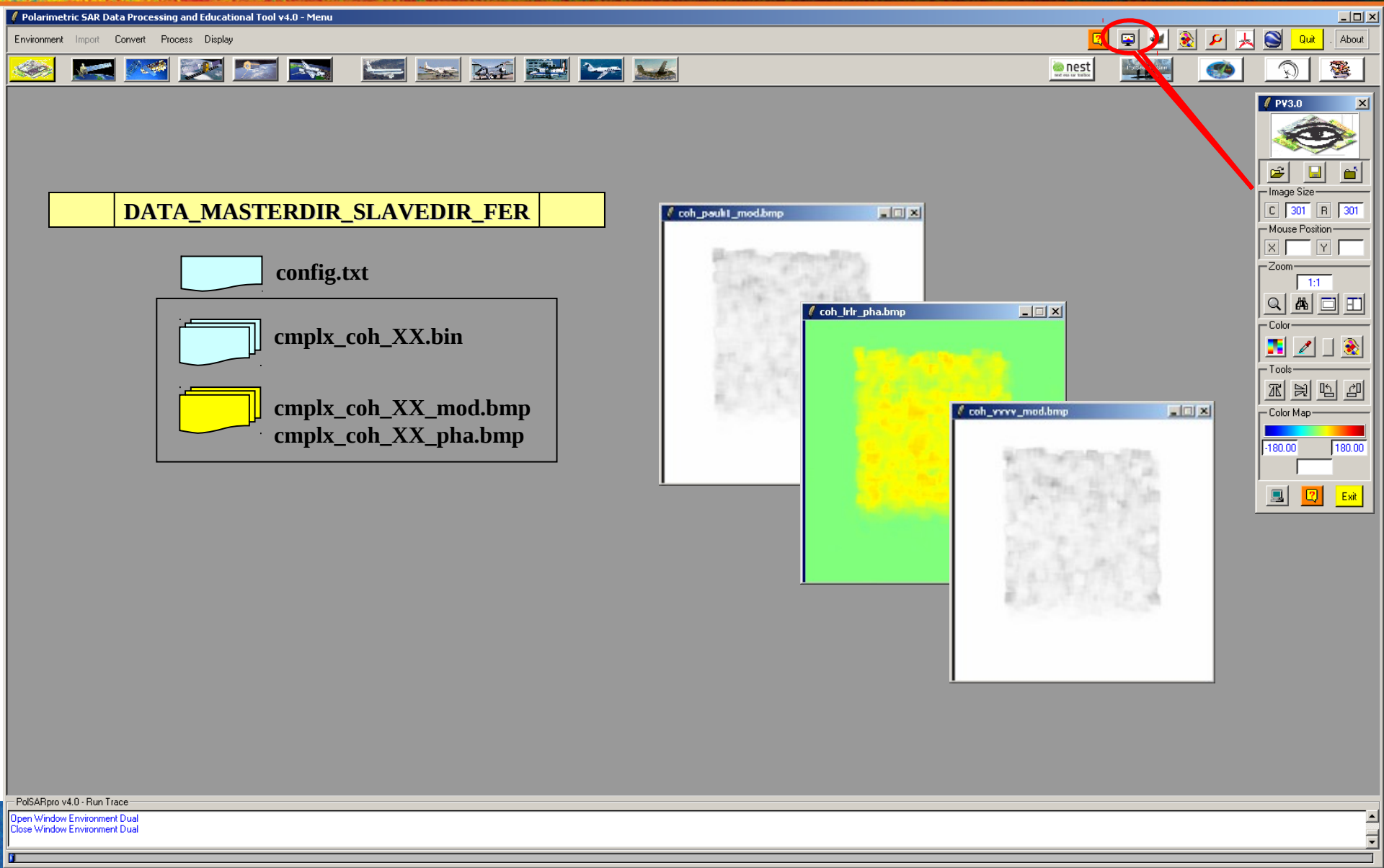


COHERENCE ESTIMATION

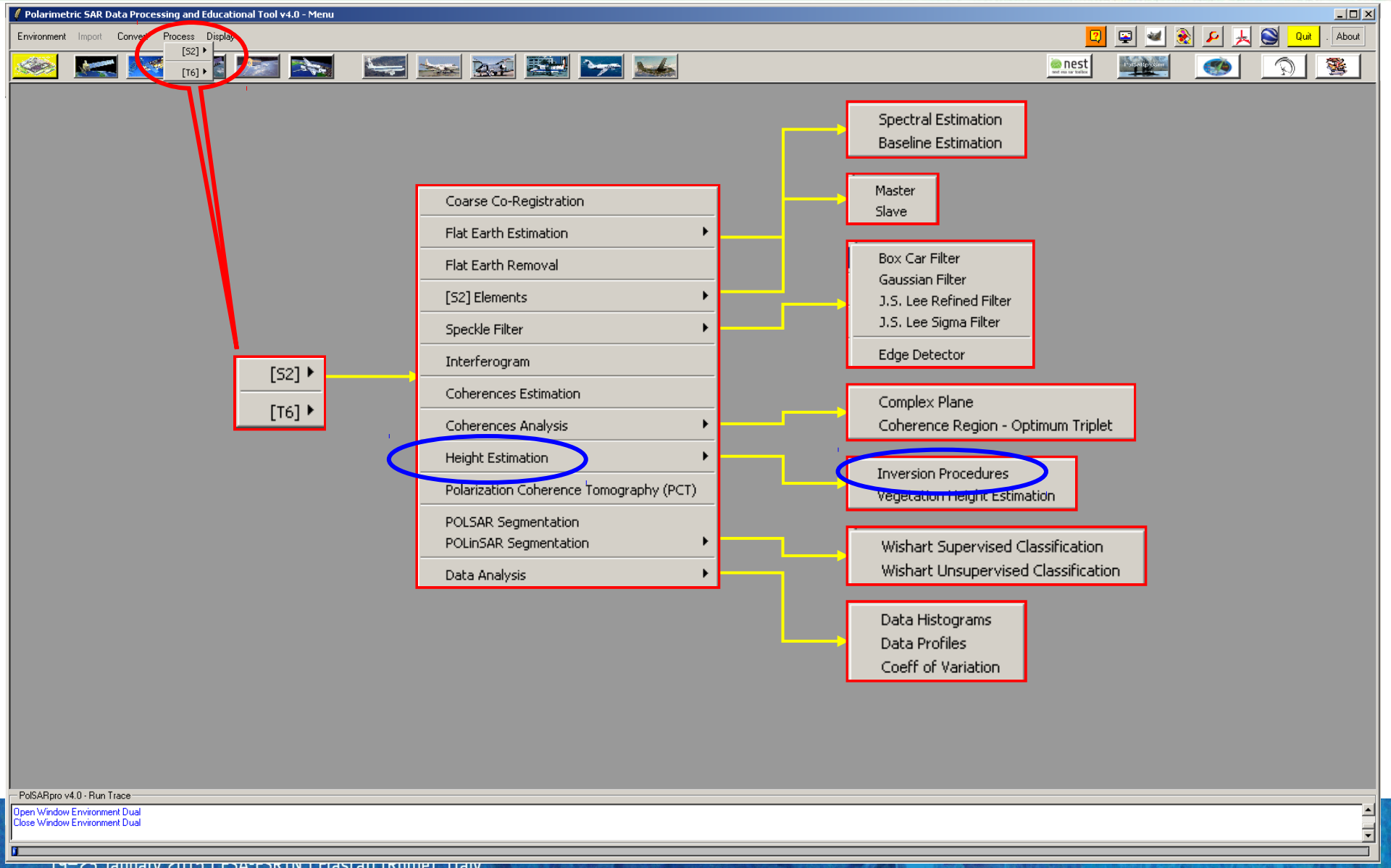


Do it Yourself:
Select polarization channels (linear, circular, pauli), set the parameters (Box Car = 11x11) and view the corresponding BMP files (select BMP).

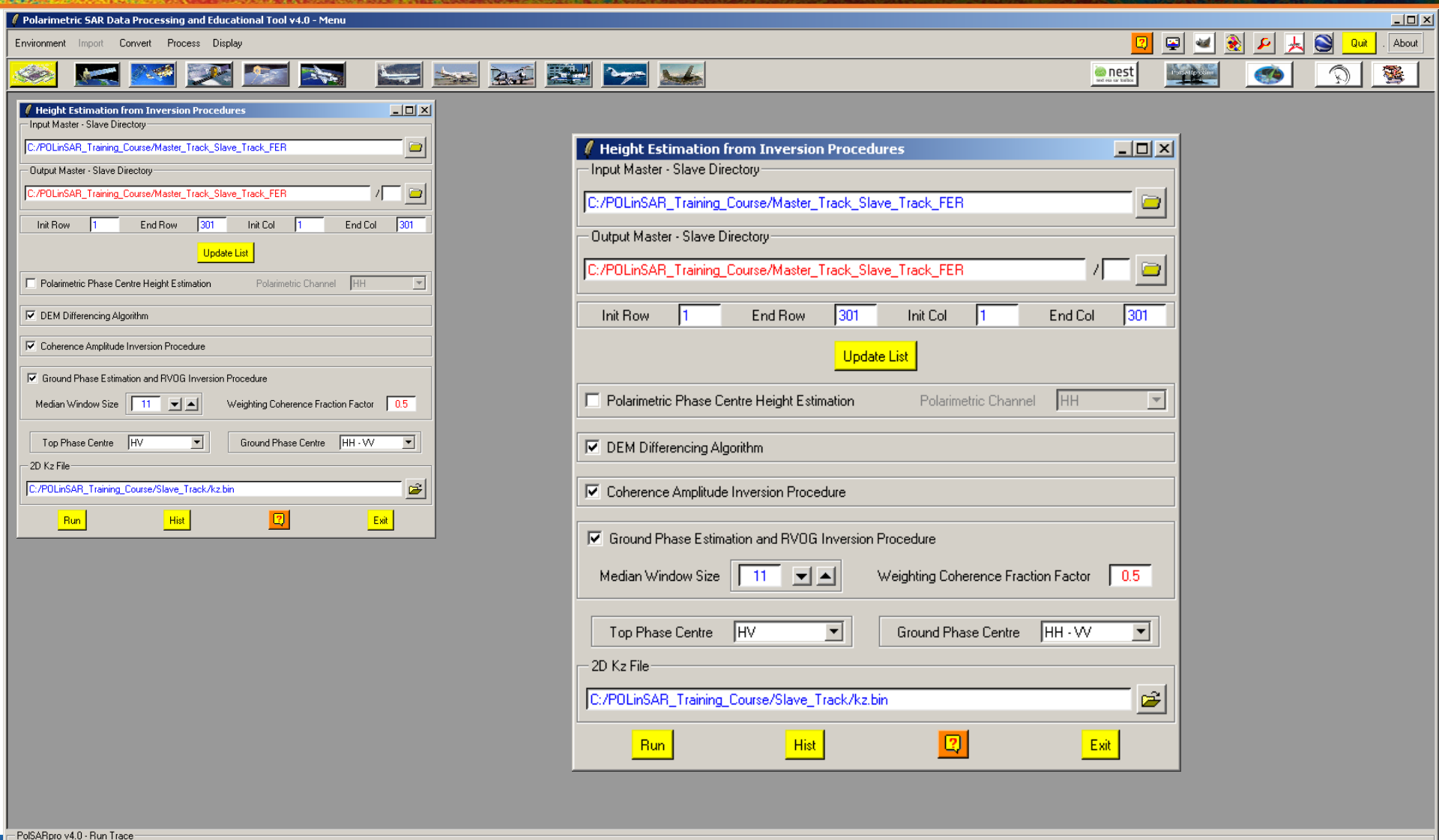
COHERENCE ESTIMATION



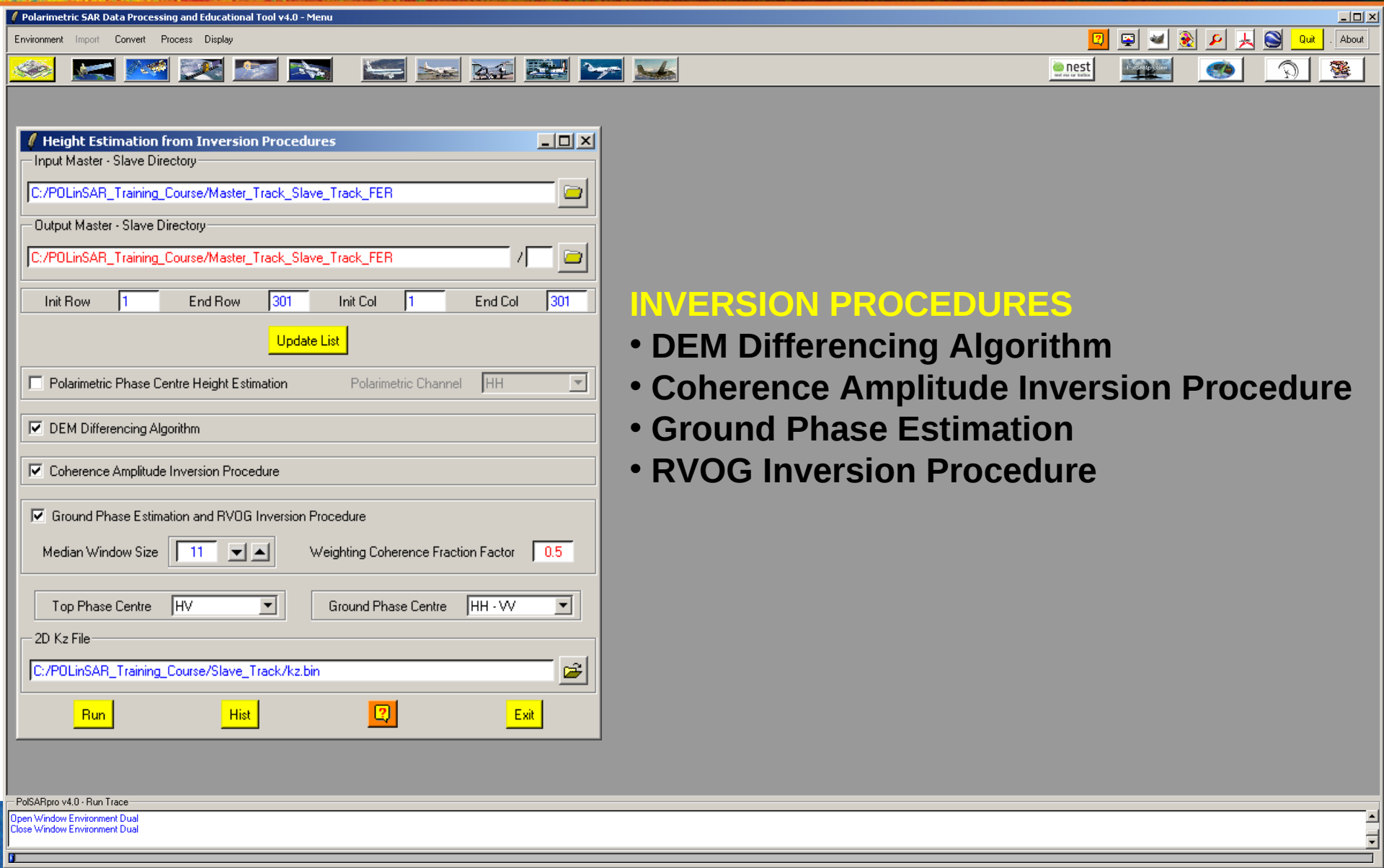
PROCESS DATA - [S2] - MENU



HEIGHT ESTIMATION INVERSION PROCEDURES



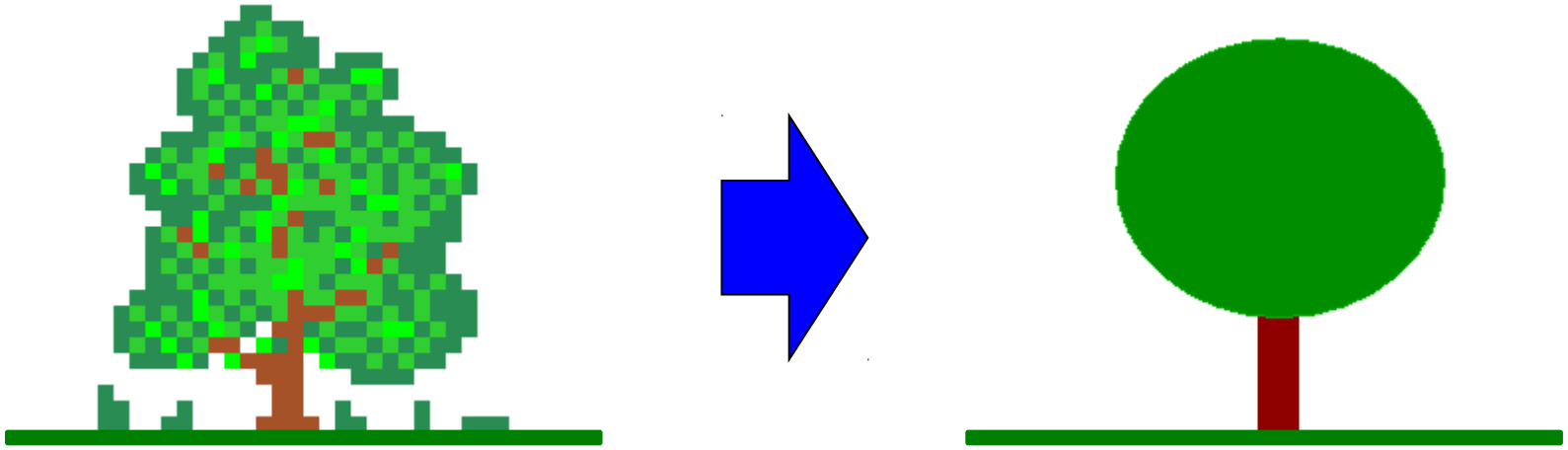
HEIGHT ESTIMATION INVERSION PROCEDURES



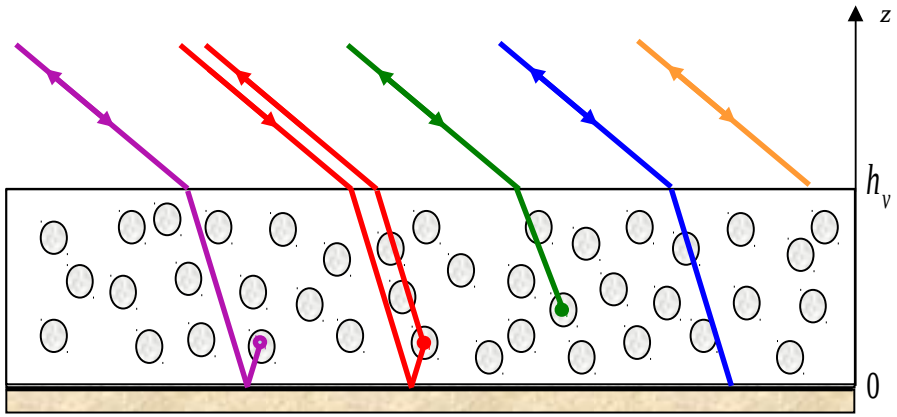
INVERSION PROCEDURES

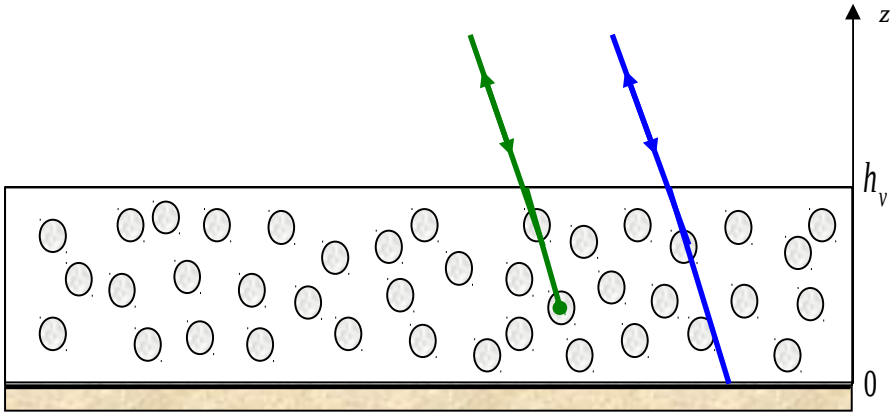
- DEM Differencing Algorithm
- Coherence Amplitude Inversion Procedure
- Ground Phase Estimation
- RVOG Inversion Procedure

VOLUME COHERENCE MODEL

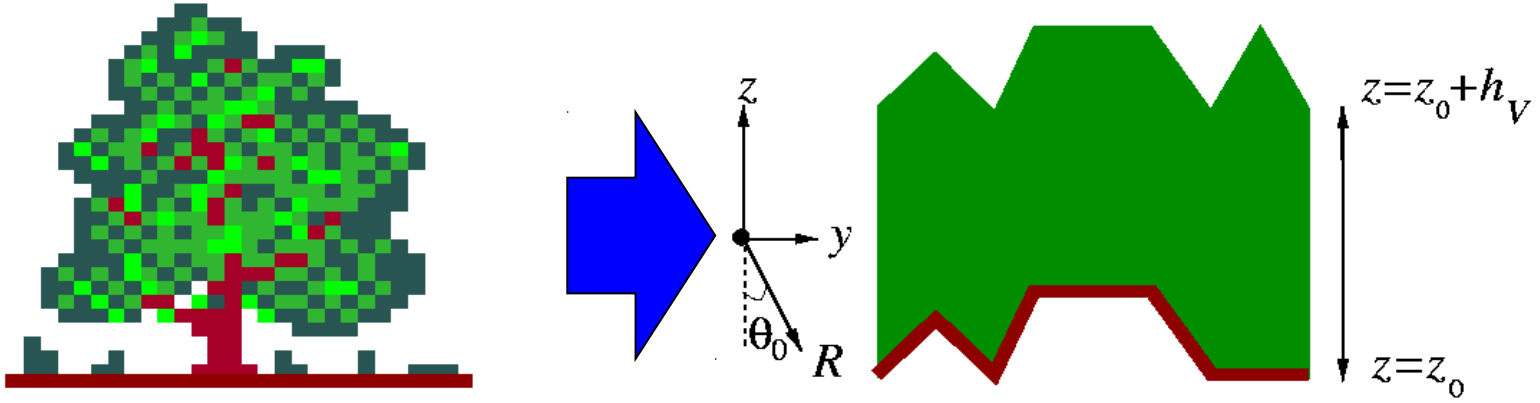


Modeling **Parameter Estimation**





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



$$\gamma_{VOL} = e^{j\varphi_0} \frac{\int_0^{h_v} f(z) e^{jk_z z} dz}{\int_0^{h_v} f(z) dz}$$

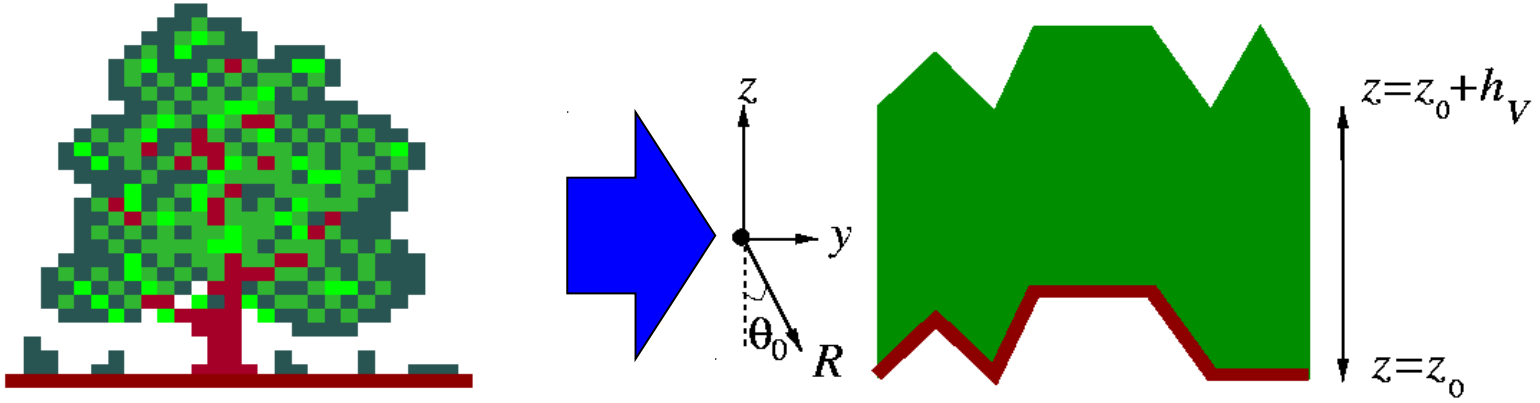
φ_0 **Topographic Phase**

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

Vertical Wavenumber

POLARIZATION INDEPENDENT

VOLUME COHERENCE MODEL



$$\gamma_{VOL} = e^{j\varphi_0} \frac{\int_0^{h_v} f(z) e^{jk_z z} dz}{\int_0^{h_v} f(z) dz}$$

Vertical Structure function

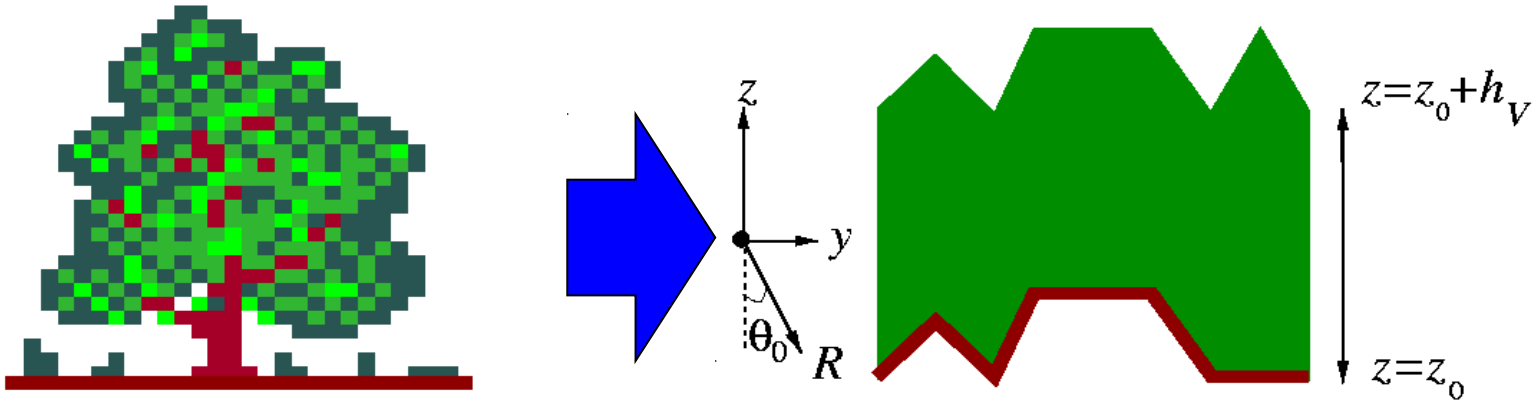
$$f(z) = e^{\frac{\sigma z}{\cos(\theta_0)}}$$

Case of Uniform Random Layer

θ_0 **Incidence Angle**

σ **Extinction Coefficient**

POLARIZATION INDEPENDENT



2 Layer Combined Surface and random Volume Scattering

$$\gamma(\underline{w}) = e^{j\varphi_0}\frac{\gamma_{VOL} + \mu(\underline{w})}{1 + \mu(\underline{w})}$$

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

G / V ratio

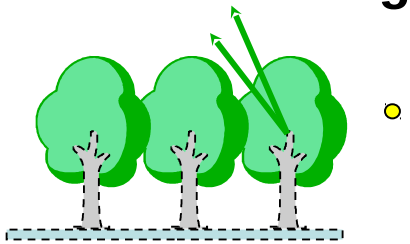
B. Treuhaft (2000), S.R. Cloude (2003)

POLARIZATION DEPENDENT

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

$$\gamma\left(\underline{w}_v\right) \underset{\mu \mapsto 0}{\mapsto} = e^{j\varphi_0}\gamma_{VOL}$$

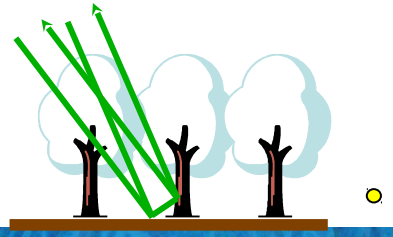
2HV



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

$$\gamma\left(\underline{w}_s\right) = e^{j\varphi_0}\frac{\gamma_{VOL} + \mu\left(\underline{w}_s\right)}{1 + \mu\left(\underline{w}_s\right)} \underset{\mu \mapsto \infty}{\mapsto} e^{j\varphi_0}$$

HH-VV



$$\left.\begin{aligned}\gamma\left(\underline{w}_v\right) &= e^{j\varphi_0}\gamma_{VOL} \\ \gamma\left(\underline{w}_s\right) &= e^{j\varphi_0}\frac{\gamma_{VOL}+\mu\left(\underline{w}_s\right)}{1+\mu\left(\underline{w}_s\right)}\end{aligned}\right\} \mapsto \begin{bmatrix}\varphi_0 \\ h_v \\ \sigma \\ \mu\end{bmatrix} = \left[Model\right]^{-1}\begin{bmatrix}\gamma\left(\underline{w}_v\right) \\ \gamma\left(\underline{w}_s\right)\end{bmatrix}$$

4 Parameters **4 Observables**

INVERSION

HEIGHT ESTIMATION INVERSION PROCEDURES

Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu

Environment | Import | Convert | Process | Display | Quit | About

Height Estimation from Inversion Procedures

Input Master - Slave Directory: C:/POLinSAR_Training_Course/Master_Track_Slave_Track_FER

Output Master - Slave Directory: C:/POLinSAR_Training_Course/Master_Track_Slave_Track_FER

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

Update List

- [ ] Polarimetric Phase Centre Height Estimation — Polarimetric Channel: HH
- [x] DEM Differencing Algorithm
- [x] Coherence Amplitude Inversion Procedure
- [x] 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:/POLinSAR_Training_Course/Slave_Track/kz.bin

Run | Hist | Exit

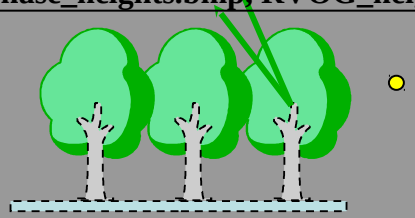
DATA_MASTERDIR_SLAVEDIR_FER

config.txt

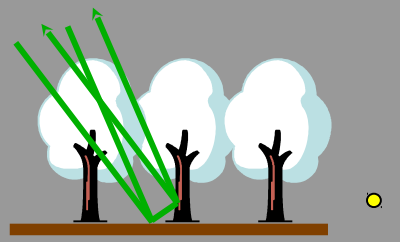
DEM_diff_heights.bin, Coh_heights.bin
Ground_phase.bin, Ground_phase_median.bin
RVOG_phase_heights.bin, RVOG_heights.bin

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

2HV



HH-VV

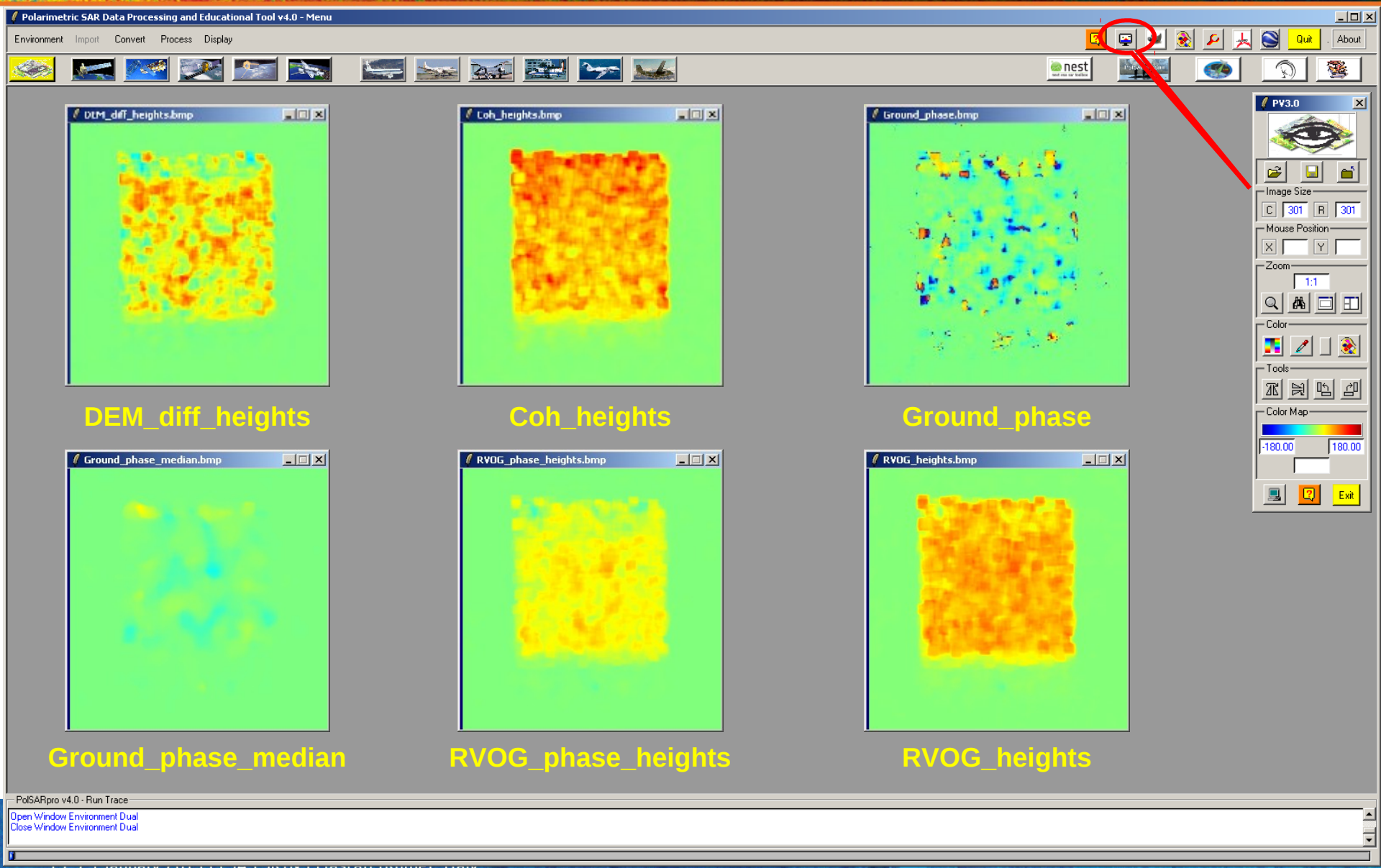


Do it Yourself:
Set the parameters (Median Size = 21, Factor = 0.4)
and view the corresponding BMP files.

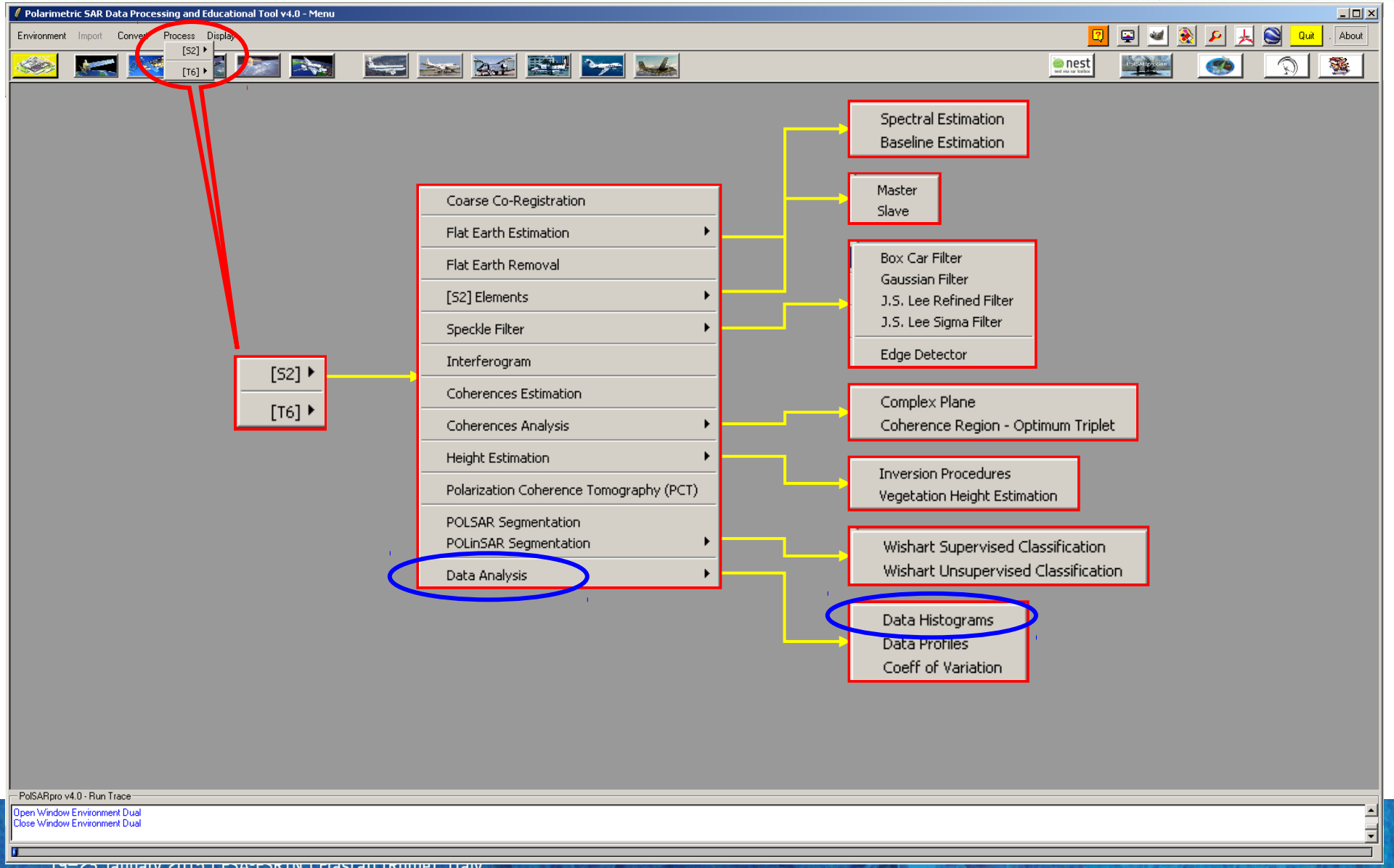
PolSARpro v4.0 - Run Trace

Open Window Environment Dual
Close Window Environment Dual

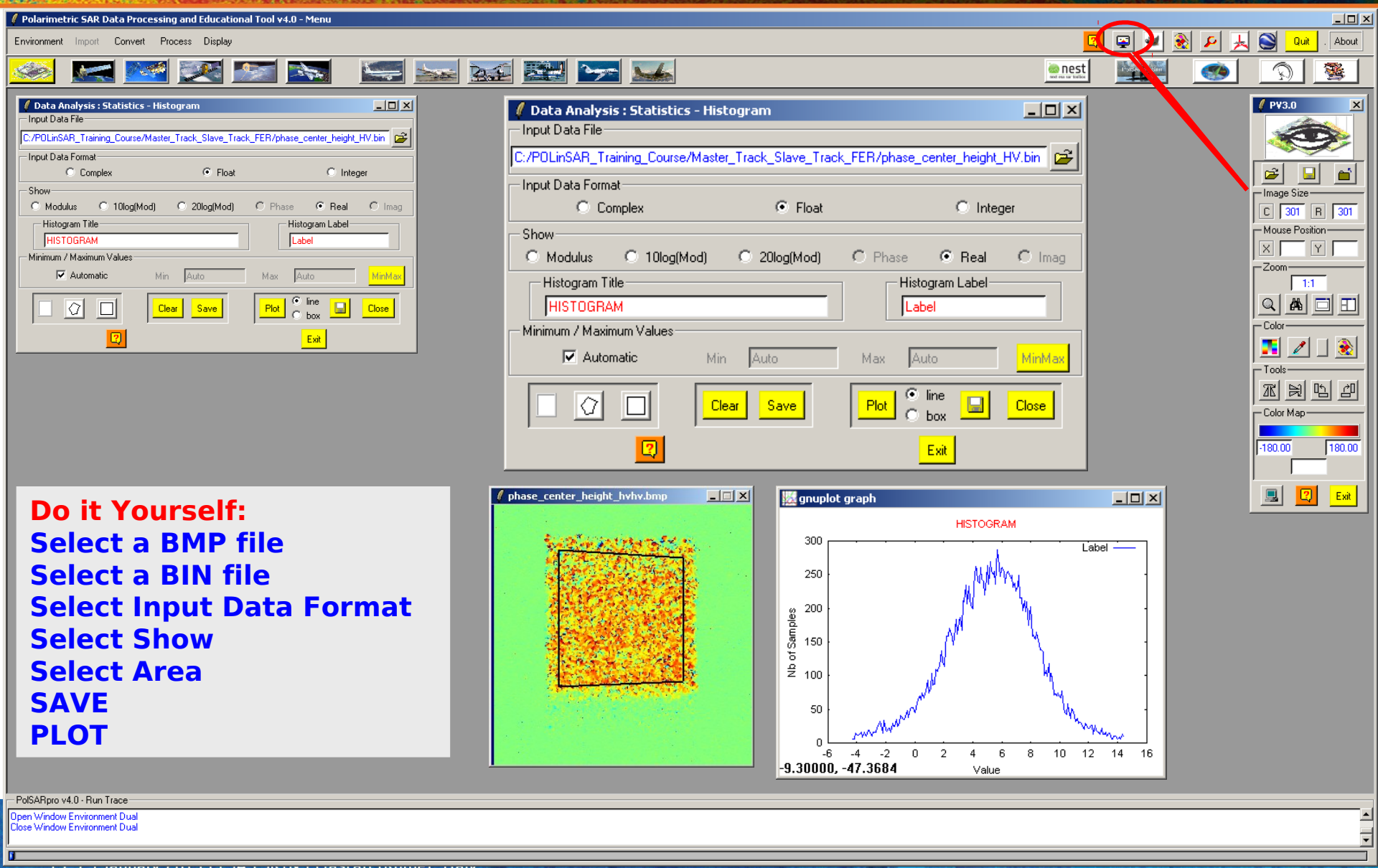
HEIGHT ESTIMATION INVERSION PROCEDURES



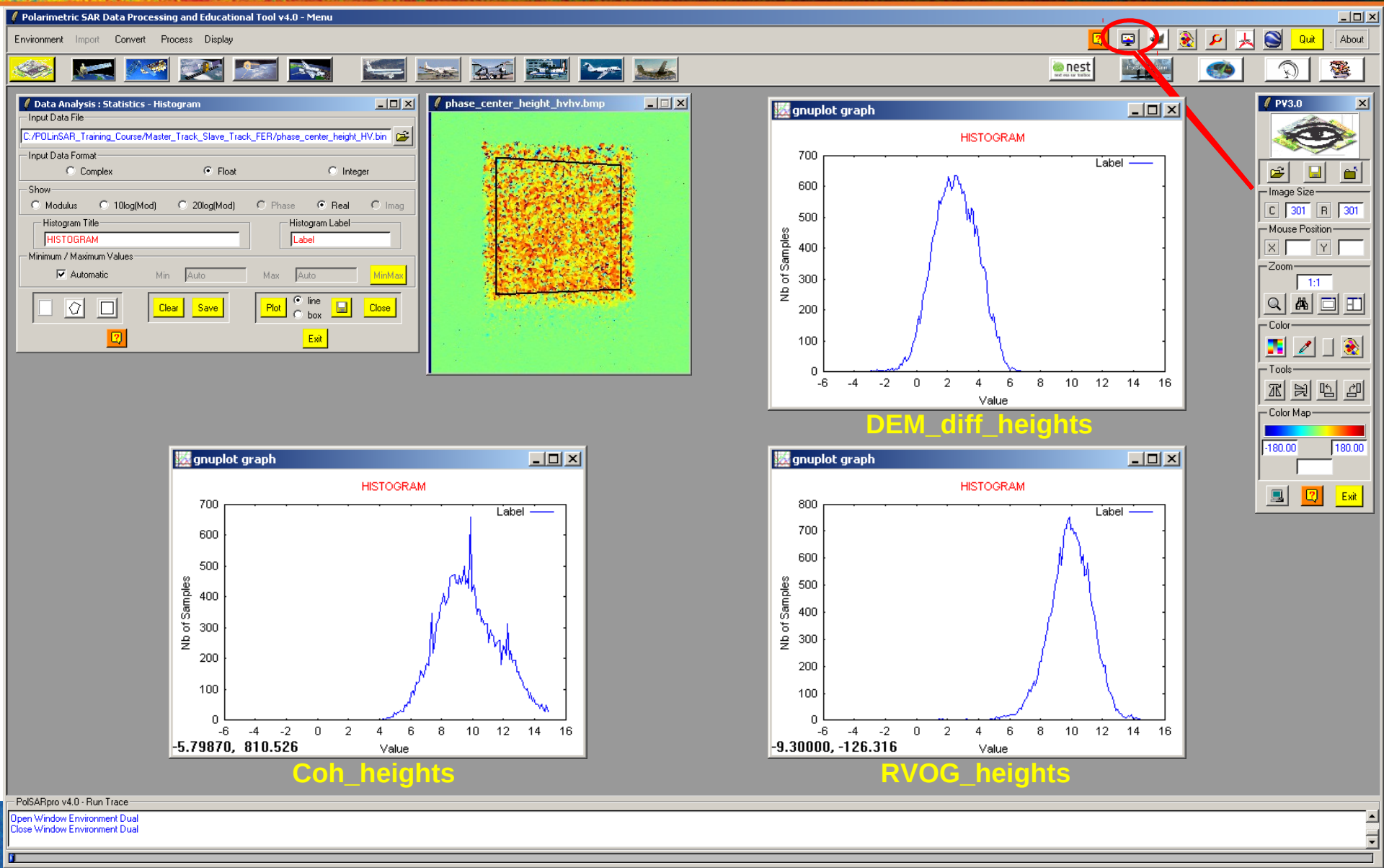
PROCESS DATA - [S2] - MENU



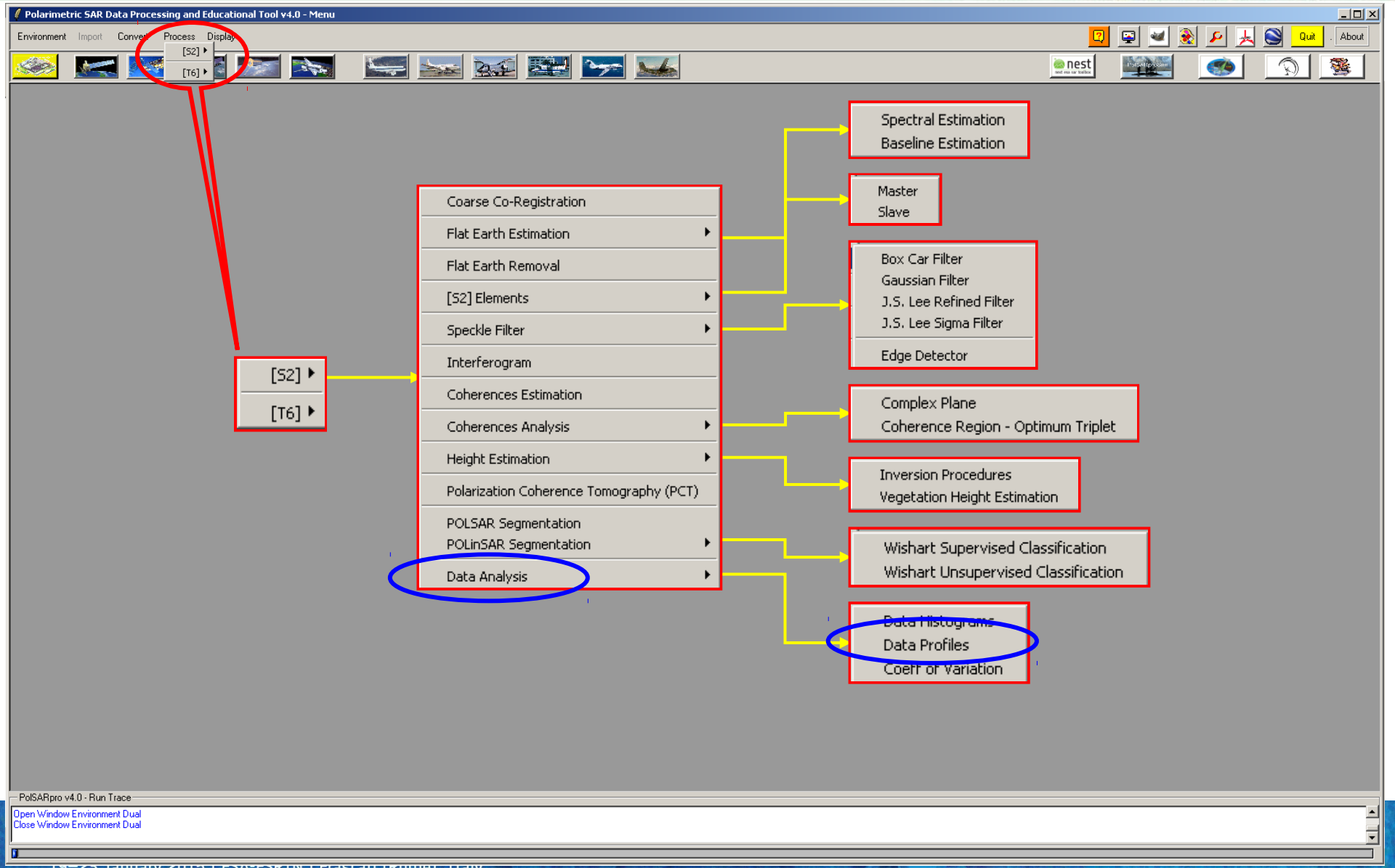
HEIGHT ESTIMATION INVERSION PROCEDURES



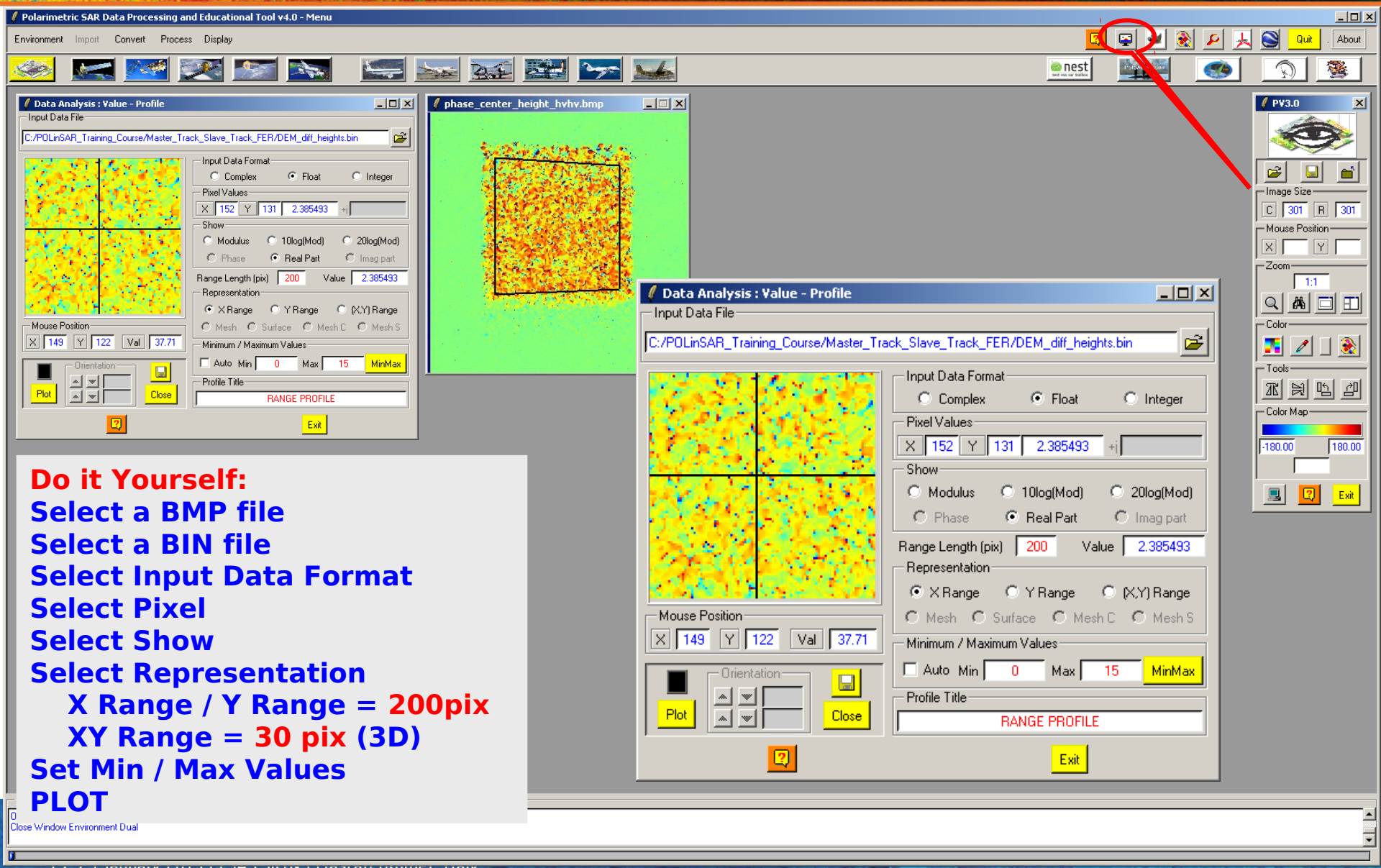
HEIGHT ESTIMATION INVERSION PROCEDURES



PROCESS DATA - [S2] - MENU



HEIGHT ESTIMATION INVERSION PROCEDURES



Do it Yourself:

Select a BMP file

Select a BIN file

Select Input Data Format

Select Pixel

Select Show

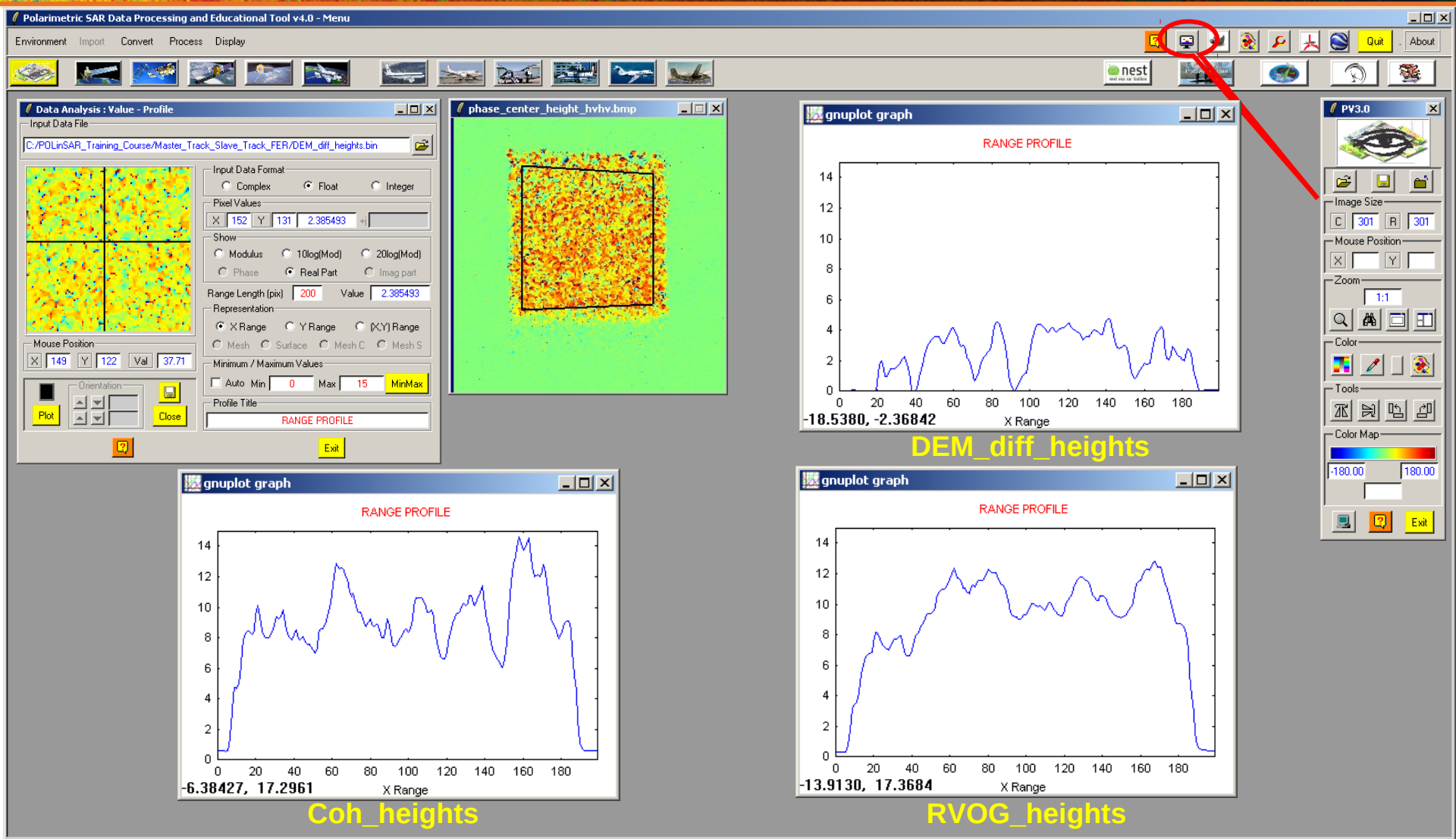
Select Representation

- **X Range / Y Range = 200pix**
- **XY Range = 30 pix (3D)**

Set Min / Max Values

PLOT

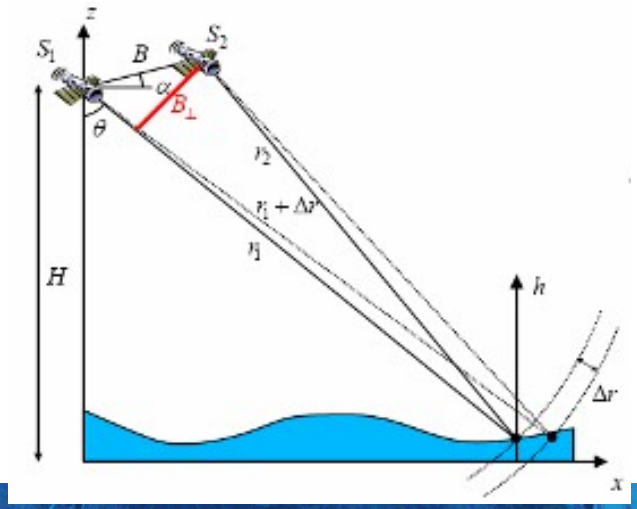
HEIGHT ESTIMATION INVERSION PROCEDURES

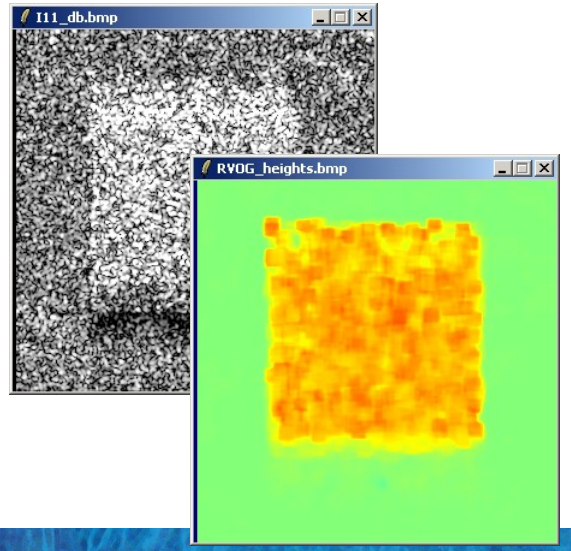


POLSARPRO

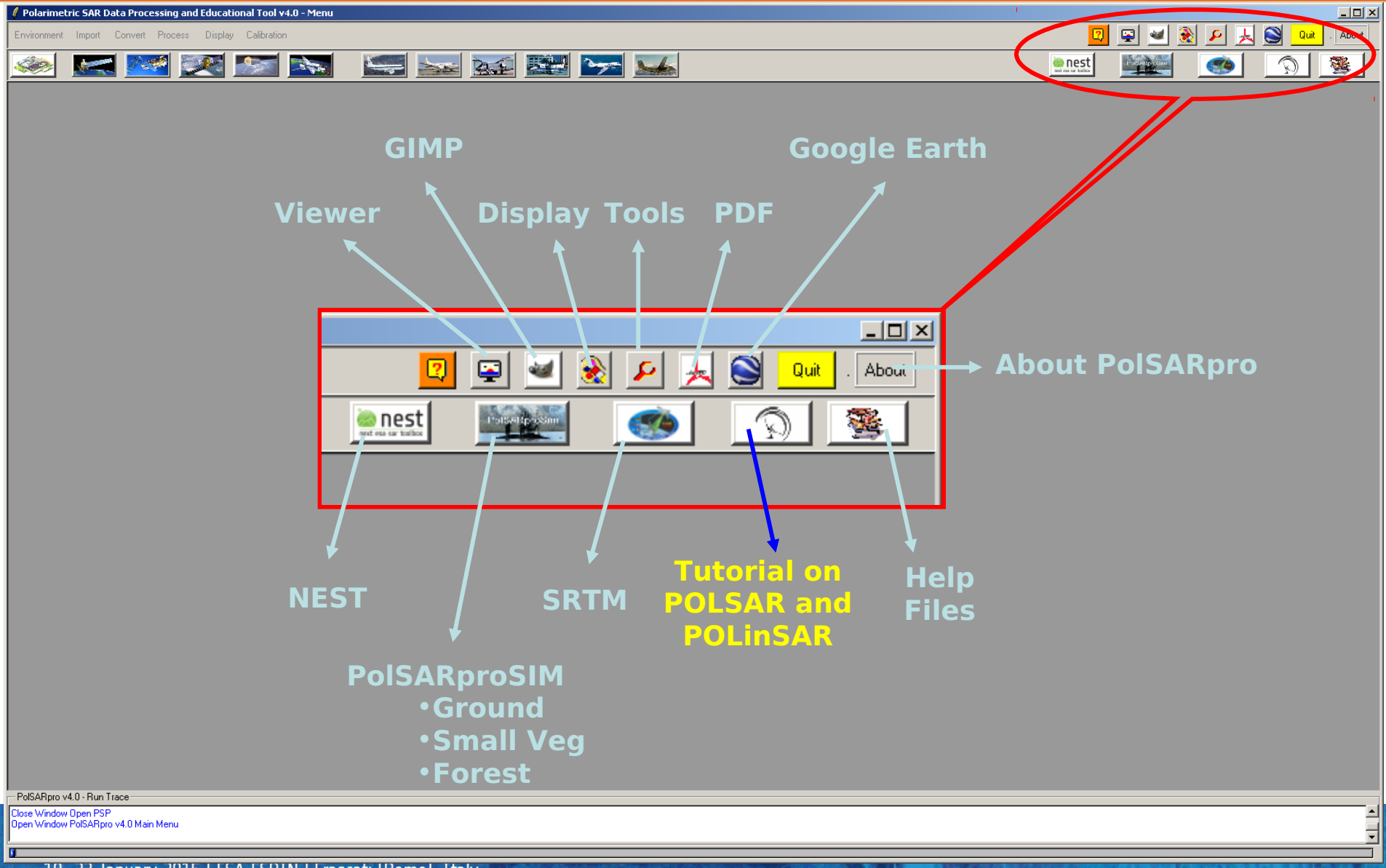
POLarimetric SAR data PROcessor

Polarization Coherence Tomography Tutorial

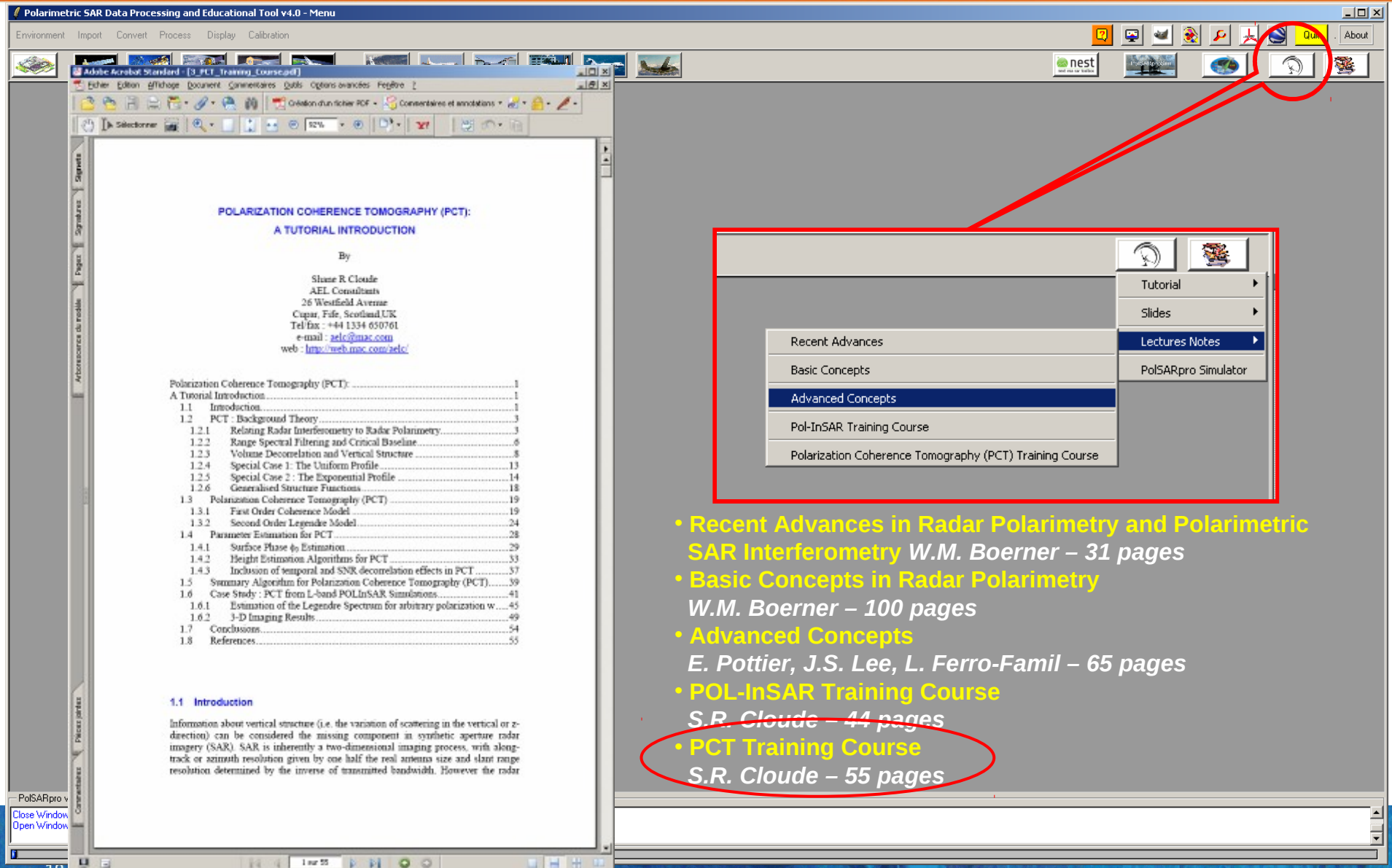




PolSARpro v4.0 SOFTWARE



Lecture Notes



- **Recent Advances in Radar Polarimetry and Polarimetric SAR Interferometry** *W.M. Boerner – 31 pages*
- **Basic Concepts in Radar Polarimetry** *W.M. Boerner – 100 pages*
- **Advanced Concepts** *E. Pottier, J.S. Lee, L. Ferro-Famil – 65 pages*
- **POL-InSAR Training Course** *S.R. Cloude – 44 pages*
- **PCT Training Course** *S.R. Cloude – 55 pages*

Do It Yourself

Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu

Environment Import Convert Process Display Calibration Quit About

Part 0 : Introduction
Part I : Radar Polarimetry
Part II : Polarimetric SAR Interferometry
Part III : Surface Parameter Retrieval
Part IV : Glossary
Part V : References
Part VI : Do It Yourself

Tutorial
Slides
Lectures Notes

0 : Foreword
1 : Getting Started with PolSARpro
2 : Representation of Polarimetric Information
3 : Speckle Filtering
4 : Polarimetric Decompositions
5 : Polarimetric Segmentation
6 : ENVISAT - ASAR dual polarization case
7 : POLinSAR Training Course
8 : Polarization Coherence Tomography (PCT) Training Course

Adobe Acrobat Standard - [8_PCT_Training_Course.pdf]

Do It Yourself 8

Polarization Coherence Tomography (P.C.T) Training Course

1 Objectives

To provide a self taught introduction to Polarization Coherence Tomography (PCT) processing techniques to enable users to learn the basic principles of this topic.

To achieve this, it is proposed to employ a test POLinSAR data set with 'perfect' ground truth. This test set is the 'hedge' simulation output from the PolSARpro – Simulator (see figure n°1), provided by Dr. Mark Williams ©, and already widely used as a test scene in POLinSAR training.

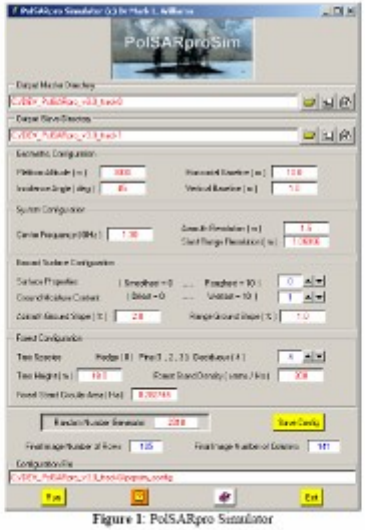
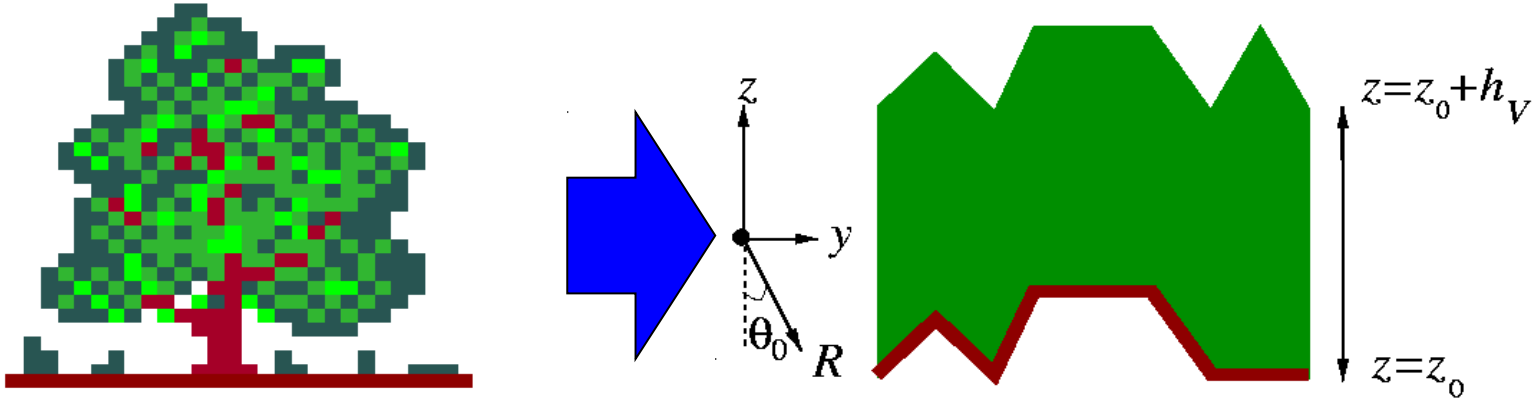


Figure 1: PolSARpro Simulator

Do It Yourself



$$\gamma_{VOL} = e^{j\varphi_0} \frac{\int_0^{h_v} f(z) e^{jk_z z} dz}{\int_0^{h_v} f(z) dz}$$

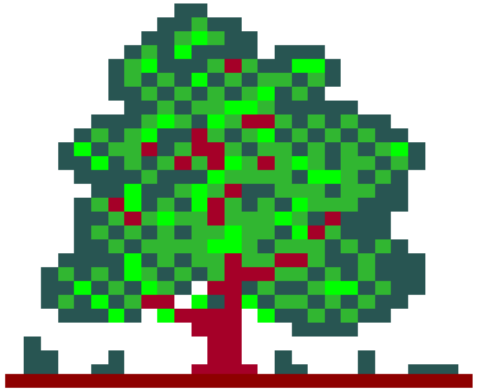
Vertical Structure function

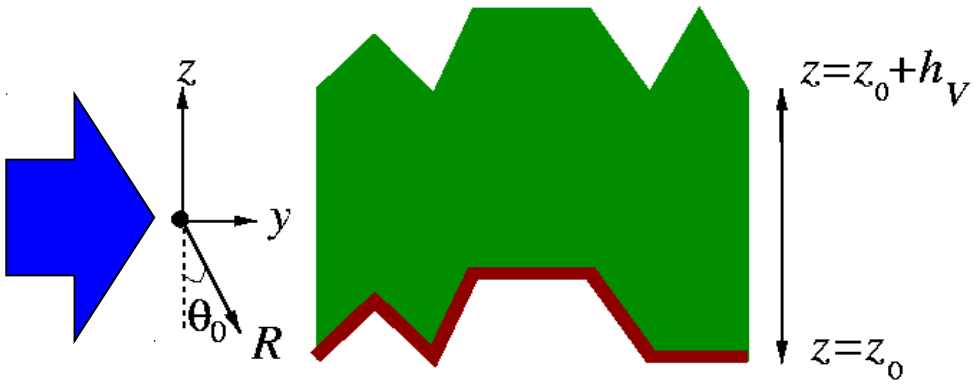
$$f(z) = e^{\frac{\sigma z}{\cos(\theta_0)}}$$

Case of Uniform Random Layer

θ_0 **Incidence Angle**

σ **Extinction Coefficient**





$$\gamma_{VOL} = e^{j\varphi_0} \frac{\int_0^{h_v} f(z) e^{jk_z z} dz}{\int_0^{h_v} f(z) dz}$$

Assuming we know the estimates of:

φ_0 **(topographic phase) and** h_v **(height)**

Techniques for the reconstruction of:

$f(z)$ **(Vertical Structure Function)**

Develop $f(z_L)$ in a Fourier-Legendre series on [-1 , +1]

$$f(z_L) = \sum_n a_n P_n(z_L)$$

$$a_n = \frac{2n+1}{2} \int_{-1}^{1} f(z_L) P_n(z_L) dz_L$$

$P_n(z_L)$ **Legendre Polynomials**

a_n

Calculate Legendre Spectrum for polarization $\underline{w}$

Select an arbitrary polarization scattering mechanisms: $\underline{W}$

$$\underline{w} \Rightarrow \gamma(\underline{w}) \Rightarrow \tilde{\gamma} = \gamma(\underline{w}) e^{-j\hat{\varphi}_0} e^{-j\hat{k}_v}$$

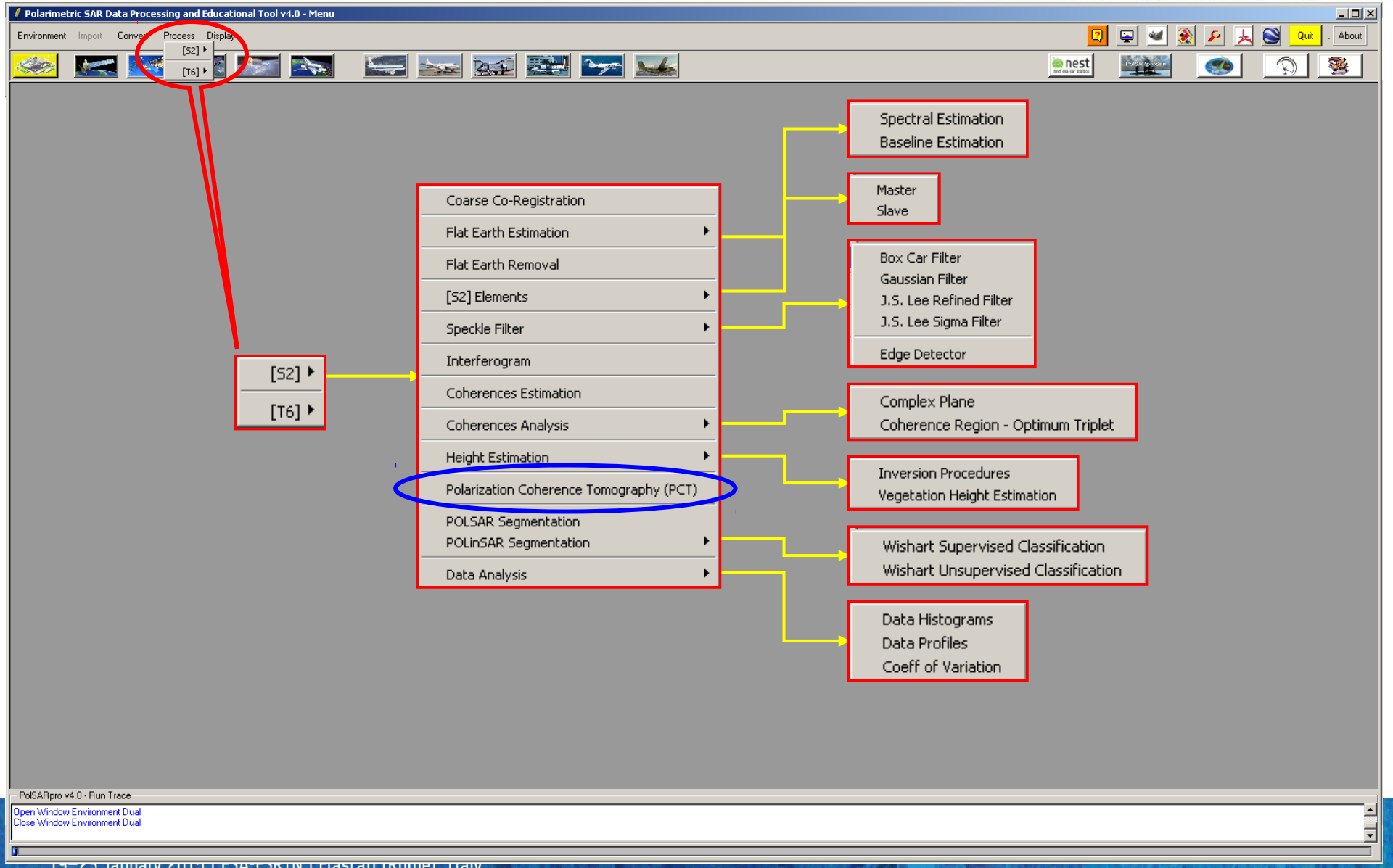
$$\begin{cases} \mathrm{Re}(\tilde{\gamma}) - f_0 = a_{20} f_2 \\ \mathrm{Im}(\tilde{\gamma}) = -j a_{10} f_1 \end{cases} \Rightarrow \begin{cases} \hat{a}_{20} = \dfrac{\mathrm{Re}(\tilde{\gamma}) - f_0}{f_2} \\ \hat{a}_{10} = j\dfrac{\mathrm{Im}(\tilde{\gamma})}{f_1} \end{cases}$$

Reconstruct normalized vertical structure

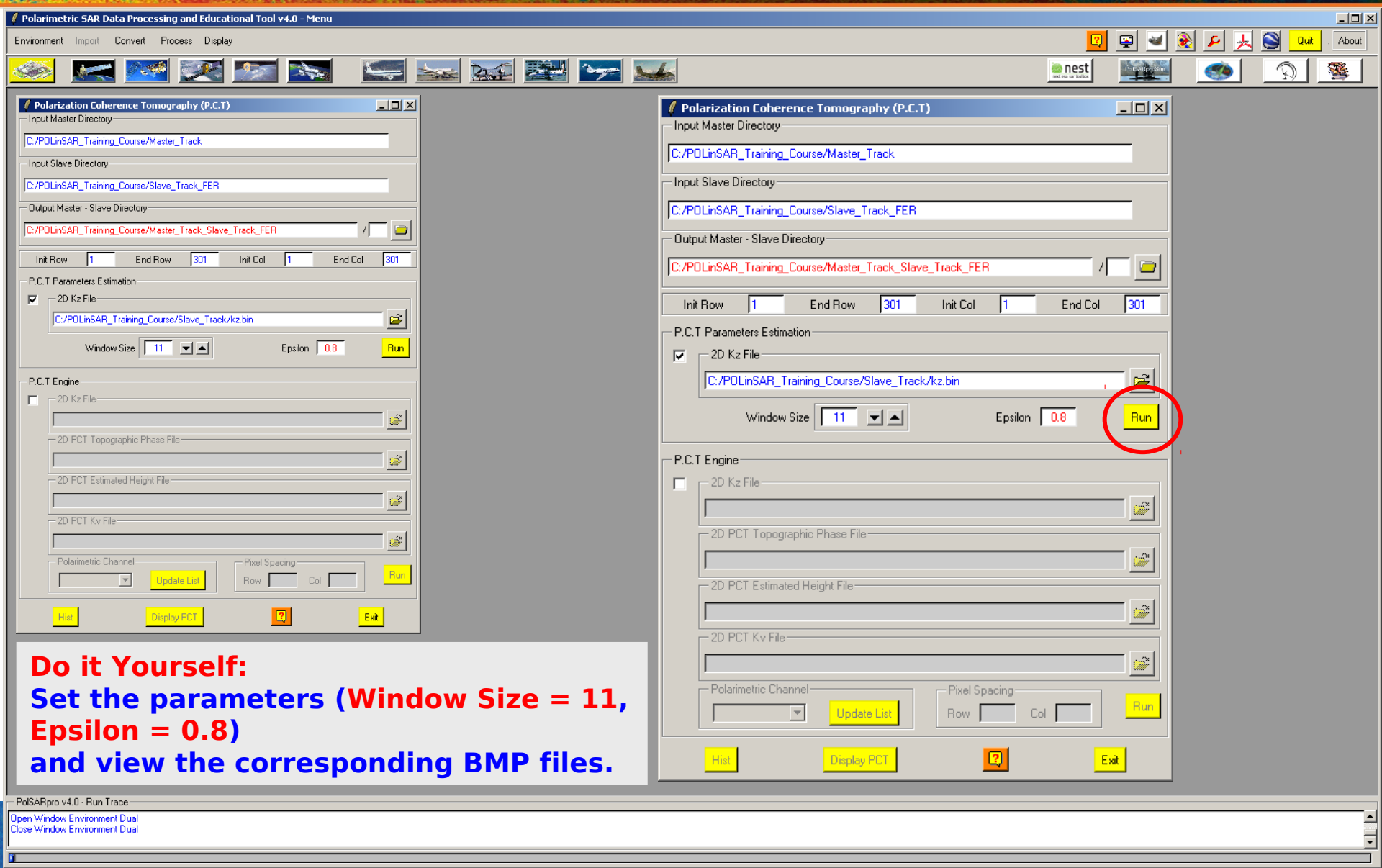
$$\hat{f}(\underline{w}, z) = \frac{1}{\hat{h}_v}\left\{\left(1 - \hat{a}_{10}(\underline{w})\right) + 2\frac{\hat{a}_{20}(\underline{w})}{\hat{h}_v} z\right\}$$

With: $0 < z < \hat{h}_v$

PROCESS DATA - [S2] - MENU

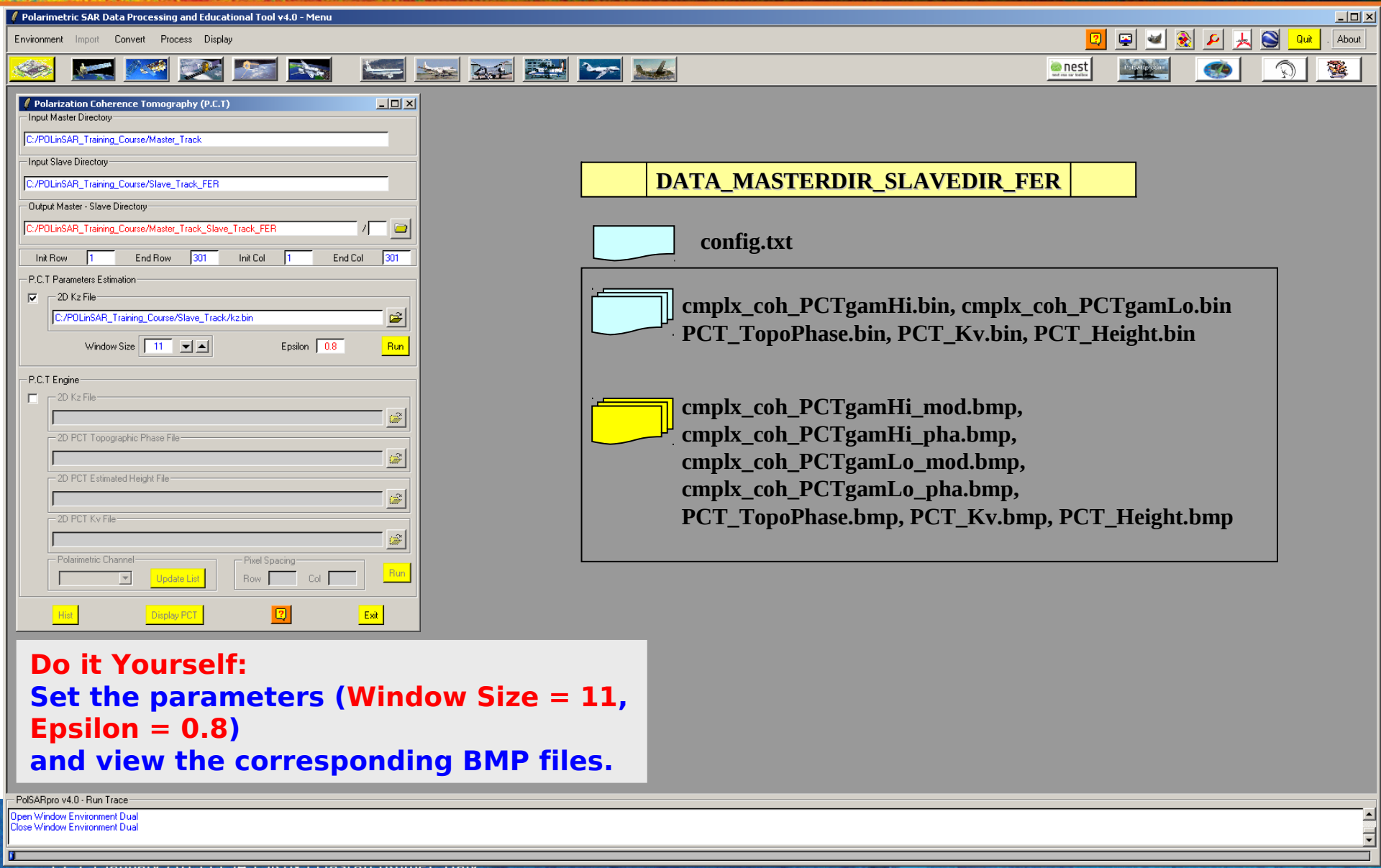


POLARIMETRIC COHERENCE TOMOGRAPHY
PCT Parameters Estimation



Do it Yourself:
Set the parameters (Window Size = 11, Epsilon = 0.8)
and view the corresponding BMP files.

POLARIMETRIC COHERENCE TOMOGRAPHY
PCT Parameters Estimation



DATA_MASTERDIR_SLAVEDIR_FER

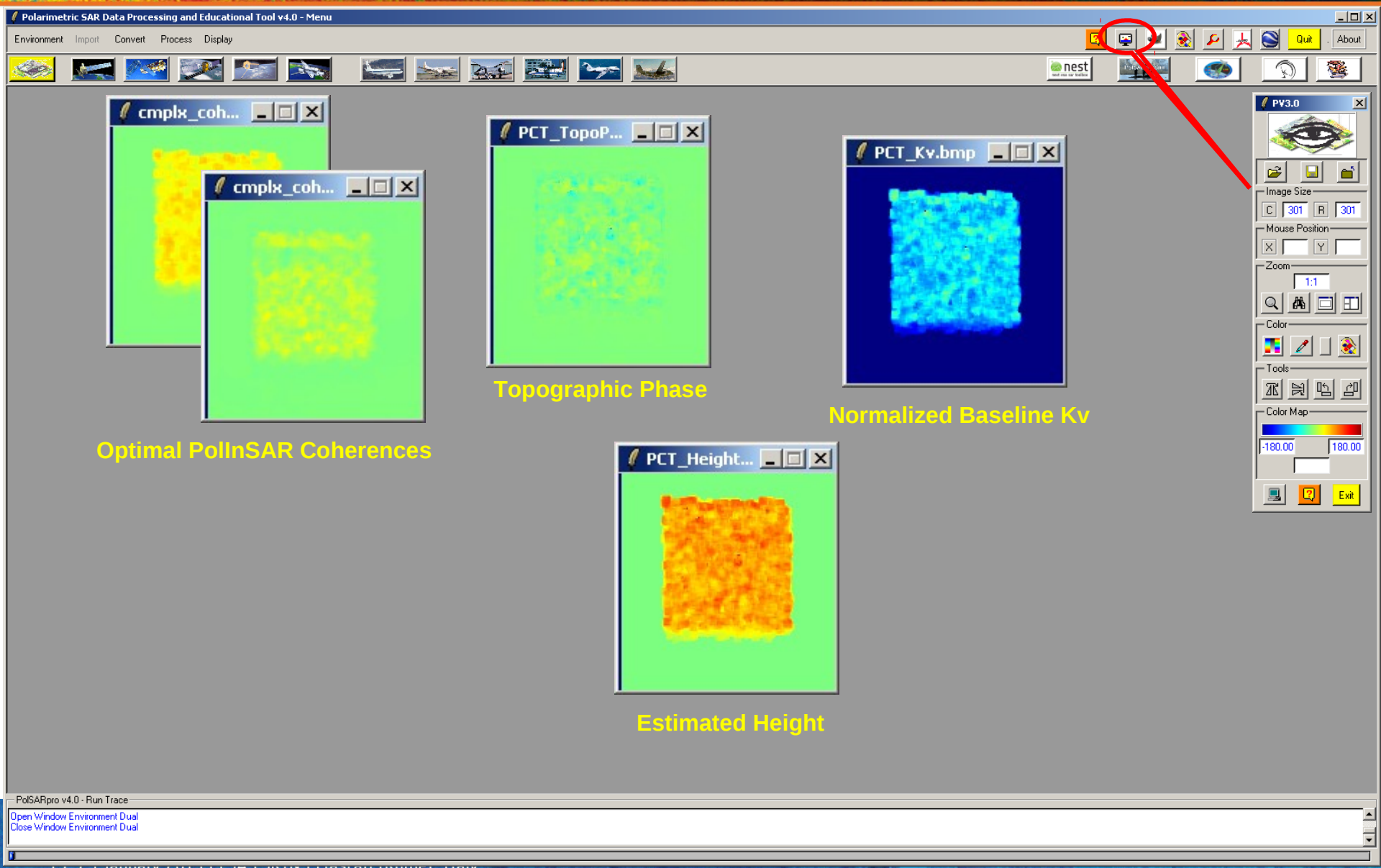
config.txt

cmplx_coh_PCTgamHi.bin, cmplx_coh_PCTgamLo.bin
PCT_TopoPhase.bin, PCT_Kv.bin, PCT_Height.bin

cmplx_coh_PCTgamHi_mod.bmp,
cmplx_coh_PCTgamHi_pha.bmp,
cmplx_coh_PCTgamLo_mod.bmp,
cmplx_coh_PCTgamLo_pha.bmp,
PCT_TopoPhase.bmp, PCT_Kv.bmp, PCT_Height.bmp

Do it Yourself:
Set the parameters (Window Size = 11, Epsilon = 0.8)
and view the corresponding BMP files.

POLARIMETRIC COHERENCE TOMOGRAPHY
PCT Parameters Estimation



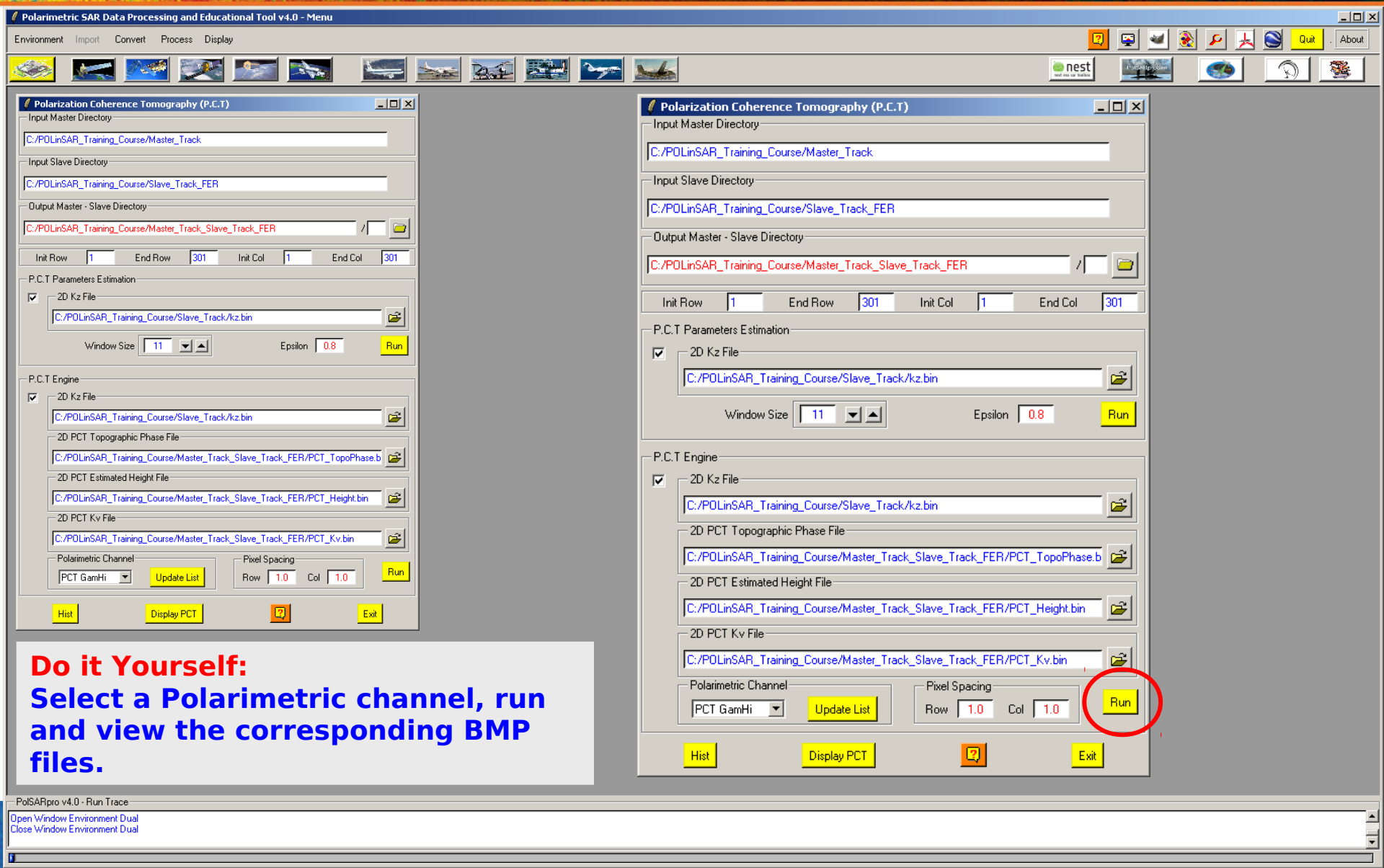
Optimal PolInSAR Coherences

Topographic Phase

Normalized Baseline Kv

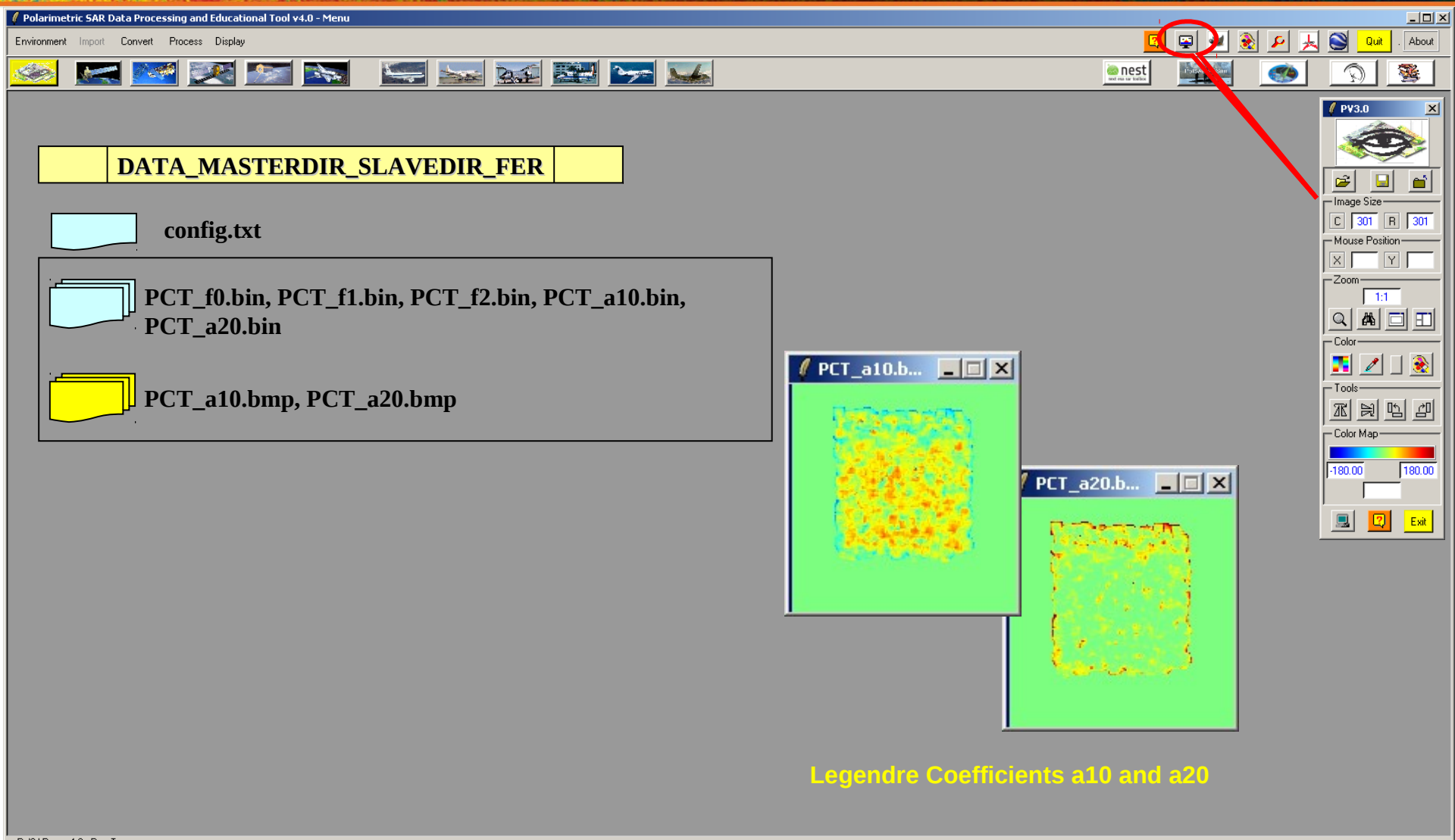
Estimated Height

POLARIMETRIC COHERENCE TOMOGRAPHY
PCT Engine



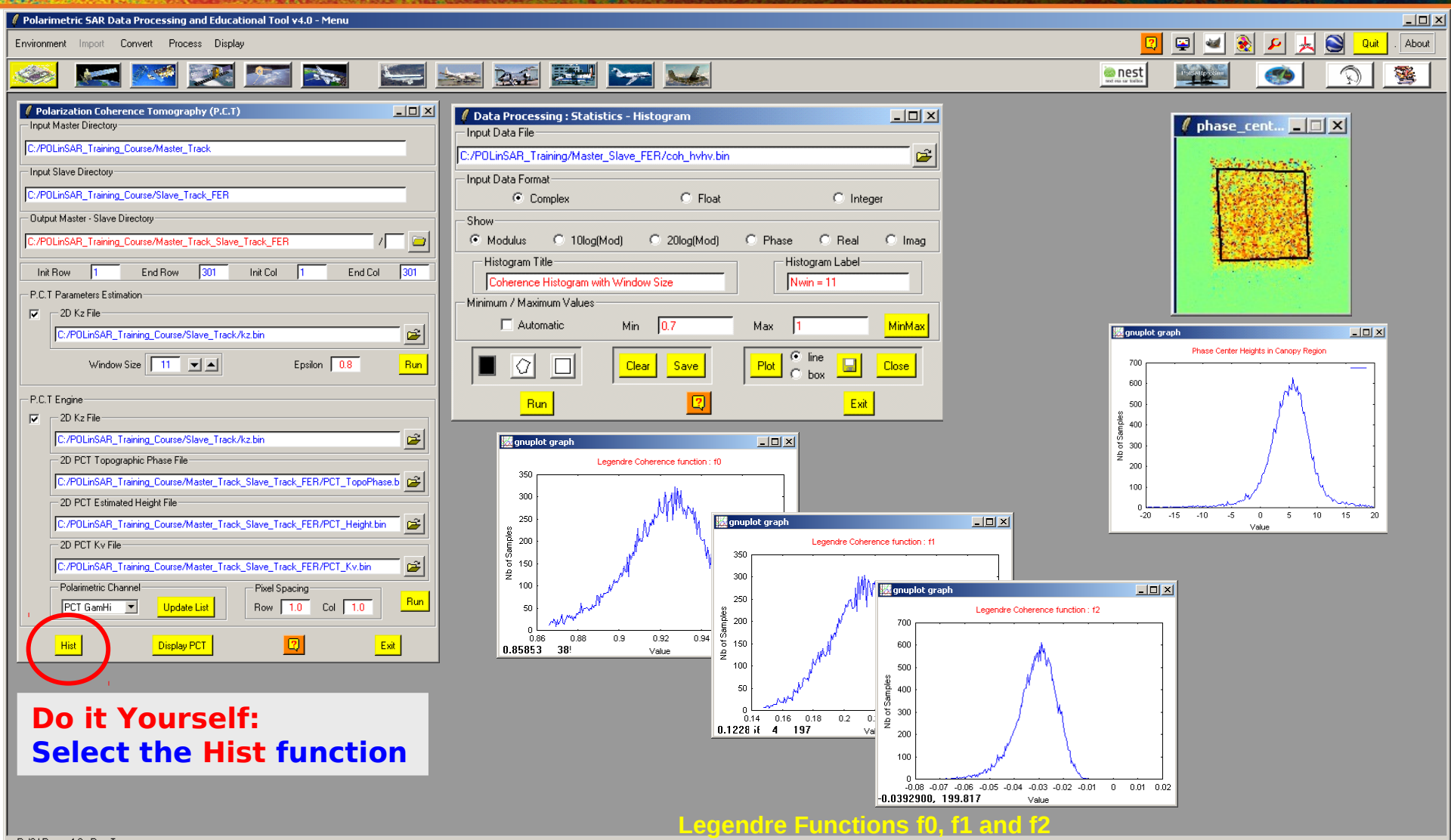
Do it Yourself:
Select a Polarimetric channel, run and view the corresponding BMP files.

POLARIMETRIC COHERENCE TOMOGRAPHY
PCT Engine



Legendre Coefficients a10 and a20

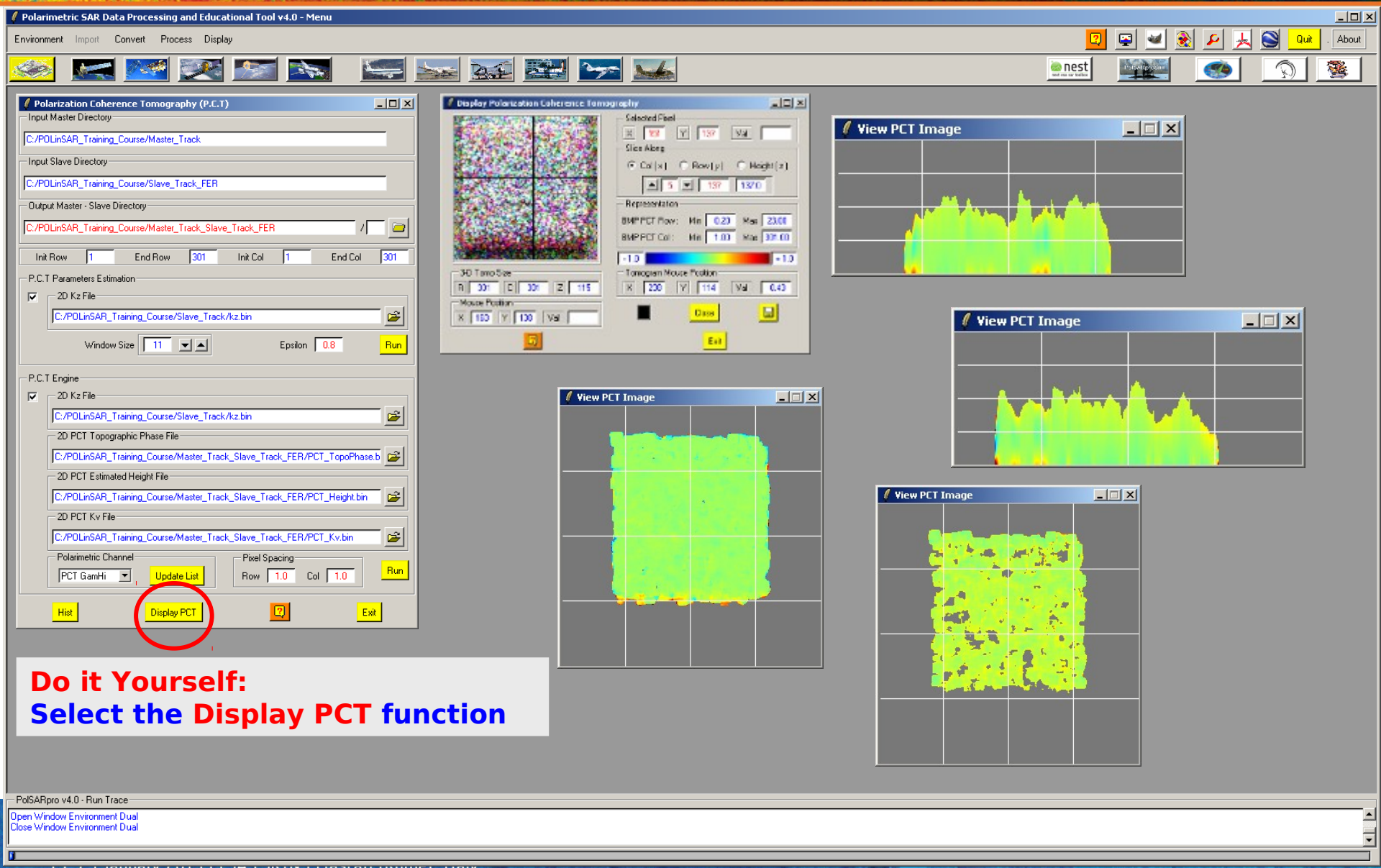
POLARIMETRIC COHERENCE TOMOGRAPHY
PCT Engine



Do it Yourself:
Select the Hist function

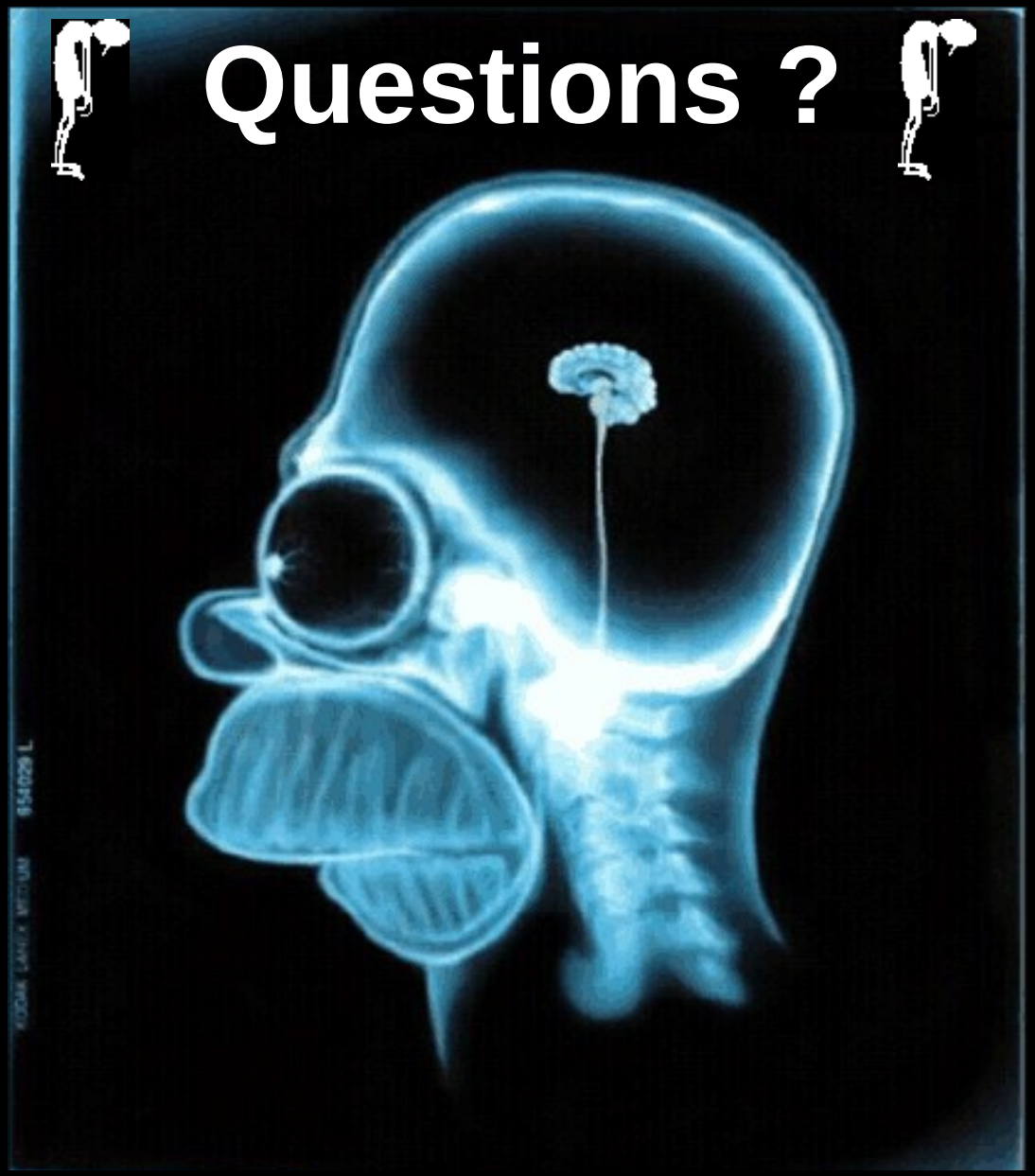
Legendre Functions f0, f1 and f2

POLARIMETRIC COHERENCE TOMOGRAPHY
PCT Engine



Do it Yourself:
Select the Display PCT function

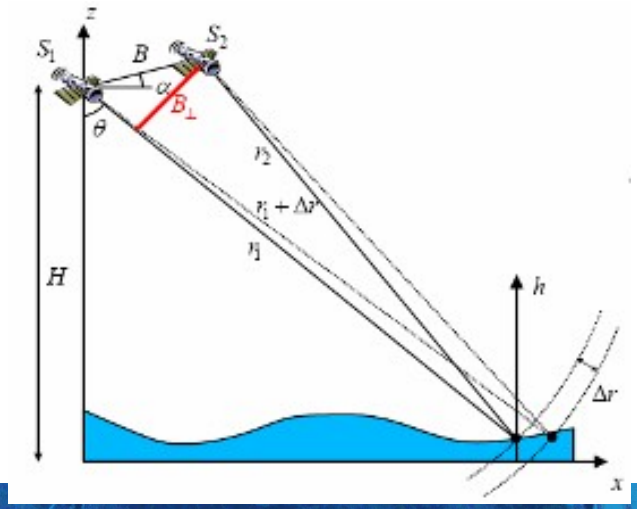
Questions ?

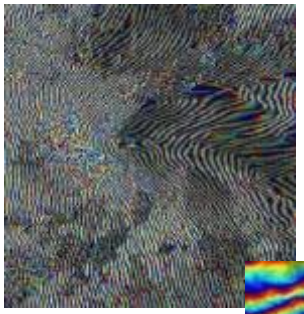


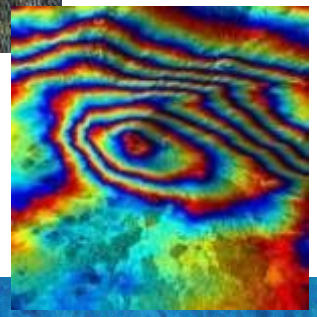
POLSARPRO

POLarimetric SAR data PROcessor

ALOS / PALSAR Pol-InSAR DataSets



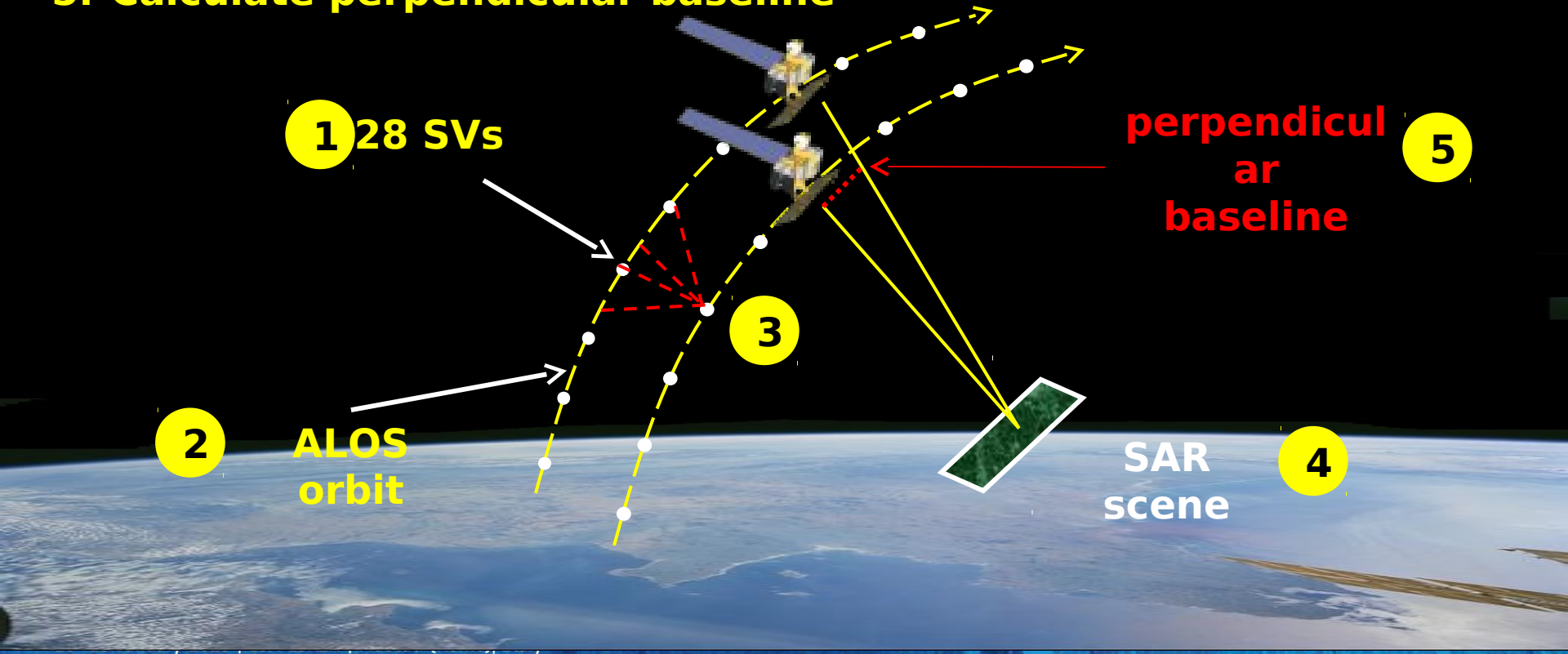




BASELINE CALCULATOR TOOL

PALSAR Data Level 1.1

1. Read orbit Position and Velocity vectors (28 SVs) from L1.1 product header
2. Interpolate the 2 ALOS orbits
3. Align the time reference between the orbits
4. Read timing and geometry information from the SAR scene
5. Calculate perpendicular baseline

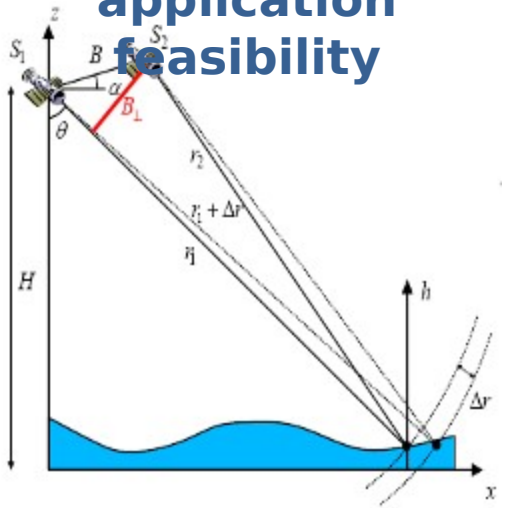


BASELINE CALCULATOR TOOL

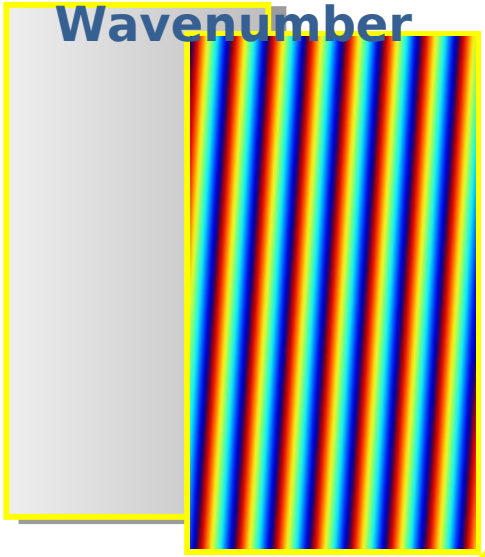
PALSAR Data Level 1.1

INTERFEROMETRIC BASELINE TOOL

Check the Pol-InSAR application feasibility



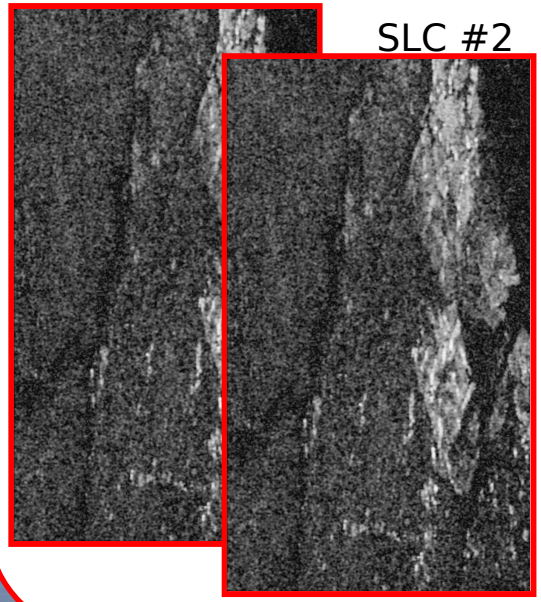
Generate Flat-Earth and Vertical Wavenumber

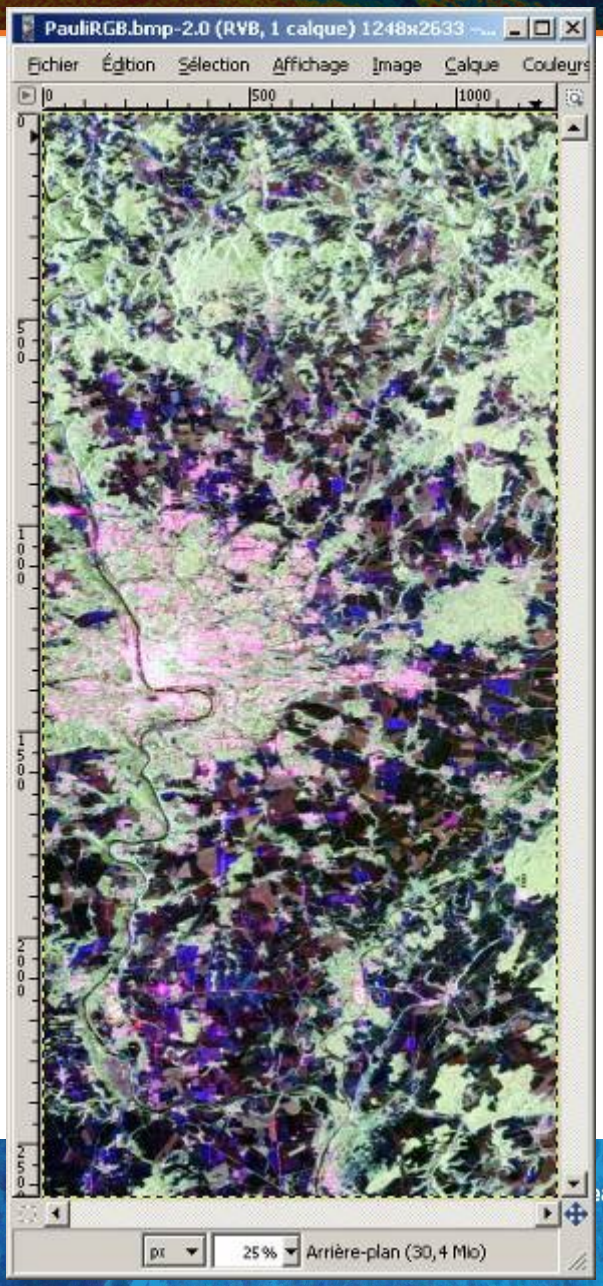


Provide coarse co-registration

SLC #1

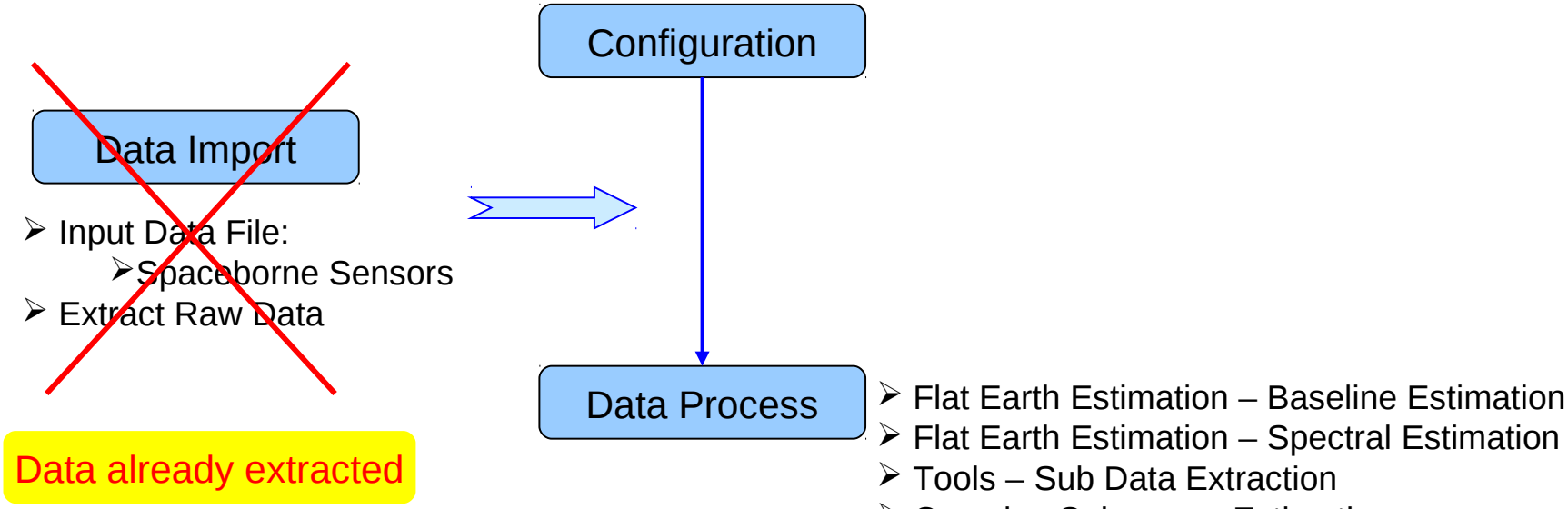
SLC #2



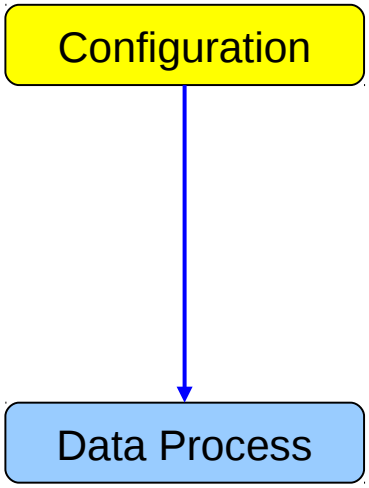


ALOS : Advanced Land Observing Satellite
PALSAR : Phase Array L-Band SAR

PROCESSING CHAIN

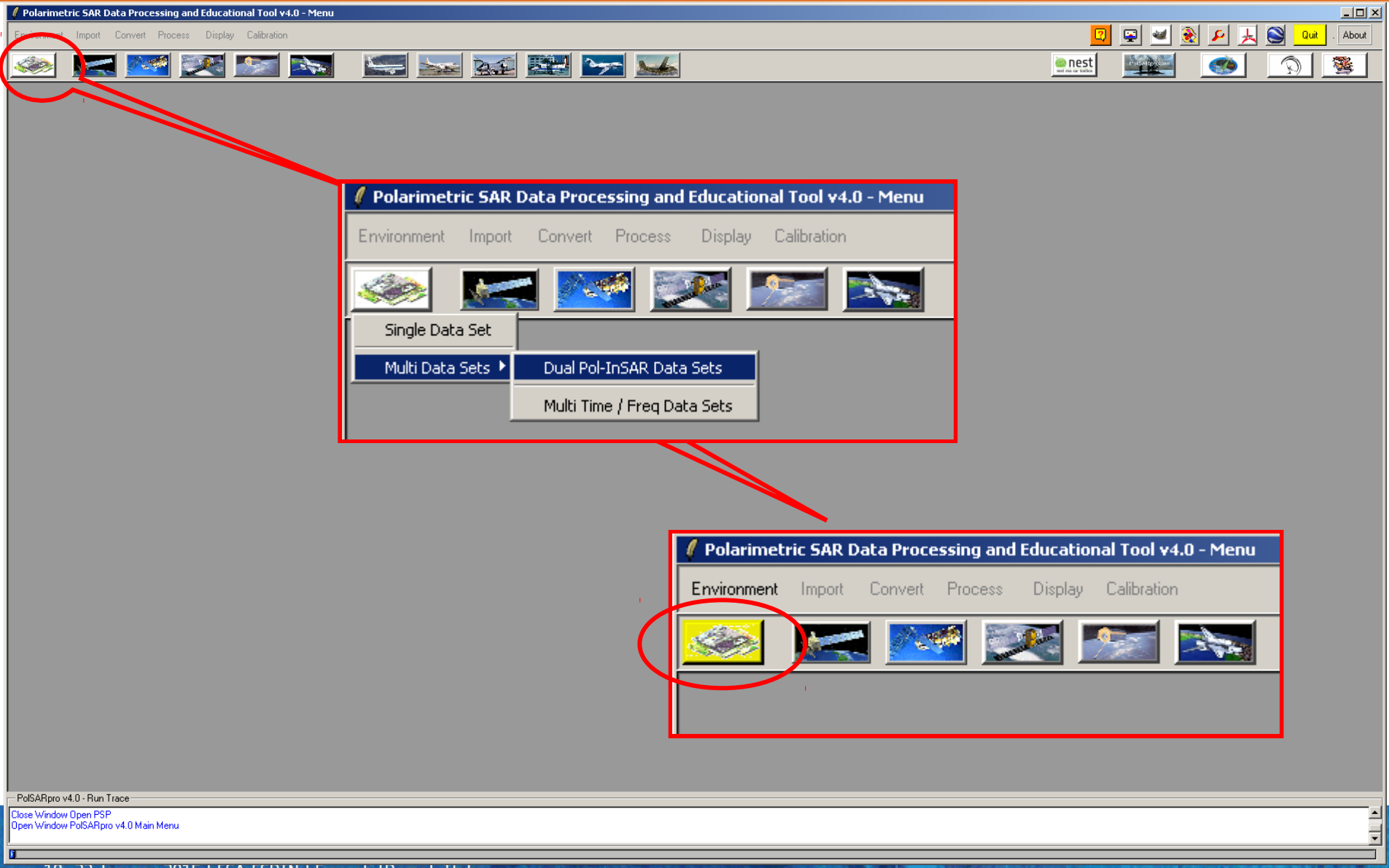


PROCESSING CHAIN

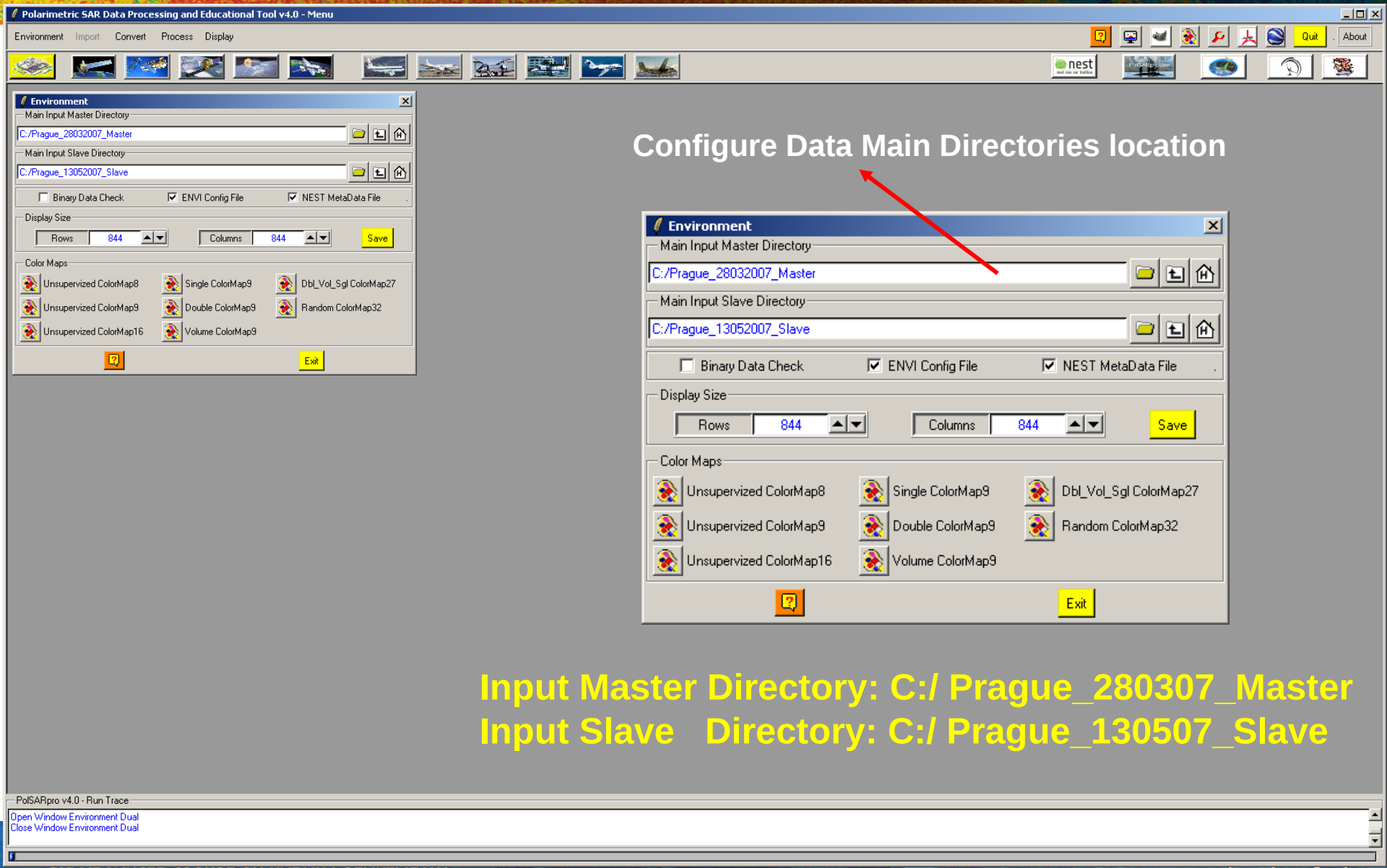


- Flat Earth Estimation – Baseline Estimation
- Flat Earth Estimation – Spectral Estimation
- Tools – Sub Data Extraction
- Complex Coherence Estimation
- Coarse Co-Registration
- Flat Earth Estimation – Spectral Estimation
- Complex Coherence Estimation
- Flat Earth Removal
- Complex Coherence Estimation

MAIN MENU


Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Import
Convert
Process
Display
Calibration
Quit
About
nest
Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Calibration
Single Data Set
Multi Data Sets
Dual Pol-InSAR Data Sets
Multi Time / Freq Data Sets
Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Calibration
PolSARpro v4.0 - Run Trace
Close Window Open PSP
Open Window PolSARpro v4.0 Main Menu

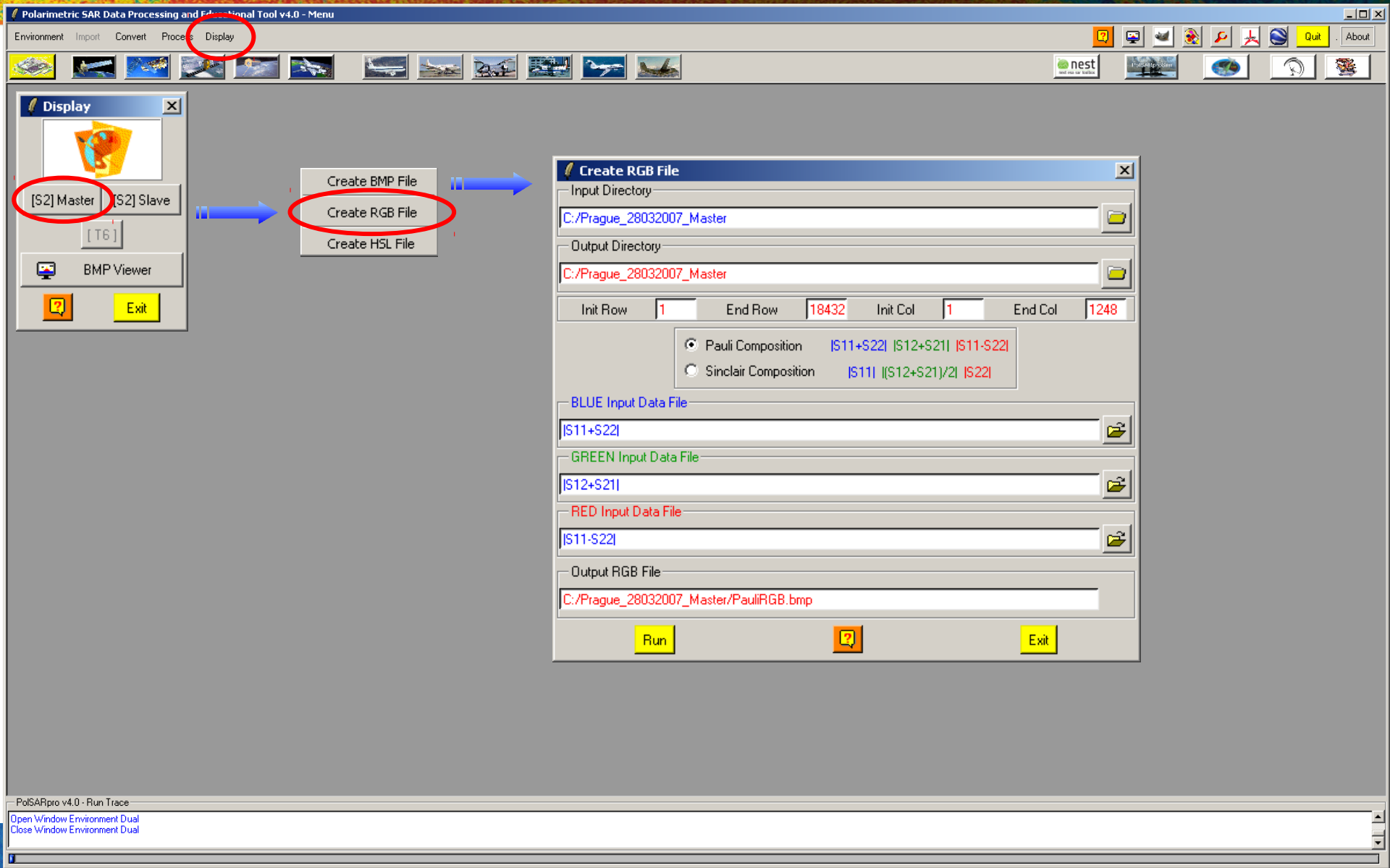
ENVIRONNEMENT



Configure Data Main Directories location

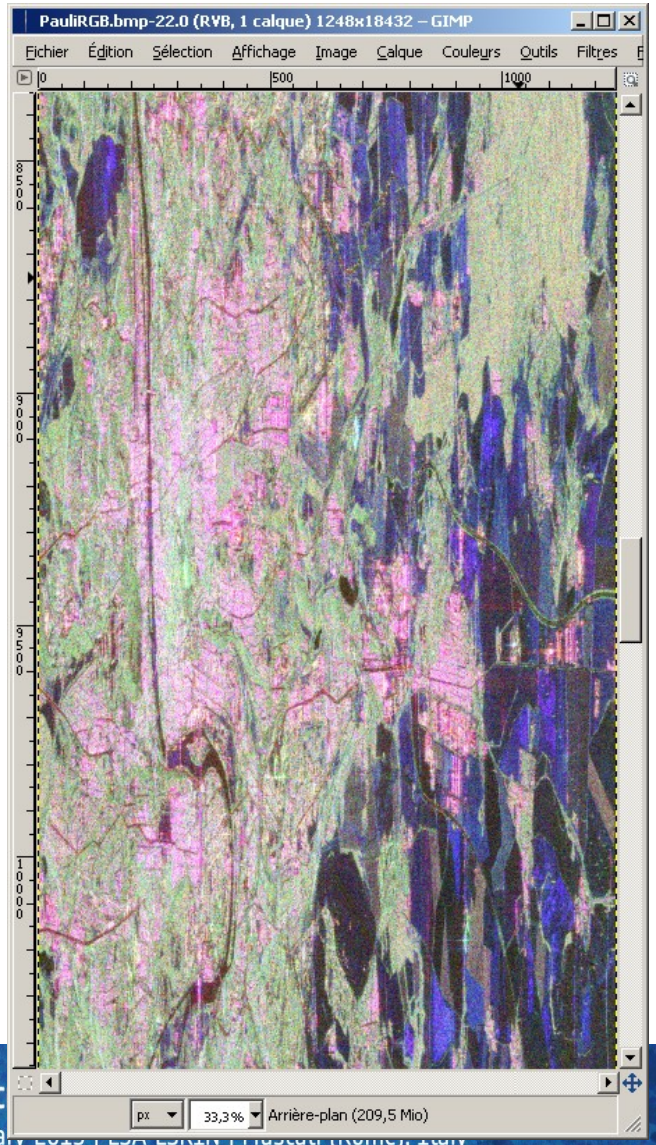
Input Master Directory: C:/ Prague_280307_Master
Input Slave Directory: C:/ Prague_130507_Slave

DISPLAY

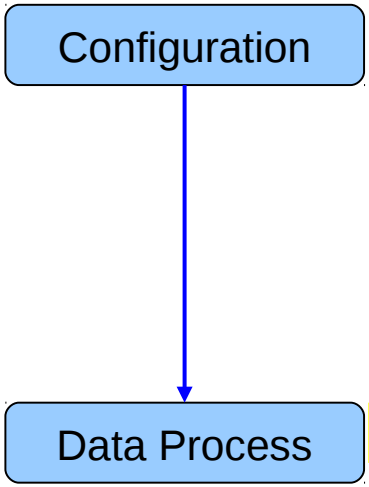

Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Quit
About
Display
[S2] Master
[S2] Slave
[T6]
BMP Viewer
Exit
Create BMP File
Create RGB File
Create HSL File
Create RGB File
Input Directory
C:/Prague_28032007_Master
Output Directory
C:/Prague_28032007_Master
Init Row
1
End Row
18432
Init Col
1
End Col
1248
Pauli Composition
|S11+S22| |S12+S21| |S11-S22|
Sinclair Composition
|S11| |(S12+S21)/2| |S22|
BLUE Input Data File
|S11+S22|
GREEN Input Data File
|S12+S21|
RED Input Data File
|S11-S22|
Output RGB File
C:/Prague_28032007_Master/PauliRGB.bmp
Run
Exit
PolSARpro v4.0 - Run Trace
Open Window Environment Dual
Close Window Environment Dual

DISPLAY

Master Pauli Image



Slave Pauli Image



- Flat Earth Estimation – Baseline Estimation
- Flat Earth Estimation – Spectral Estimation
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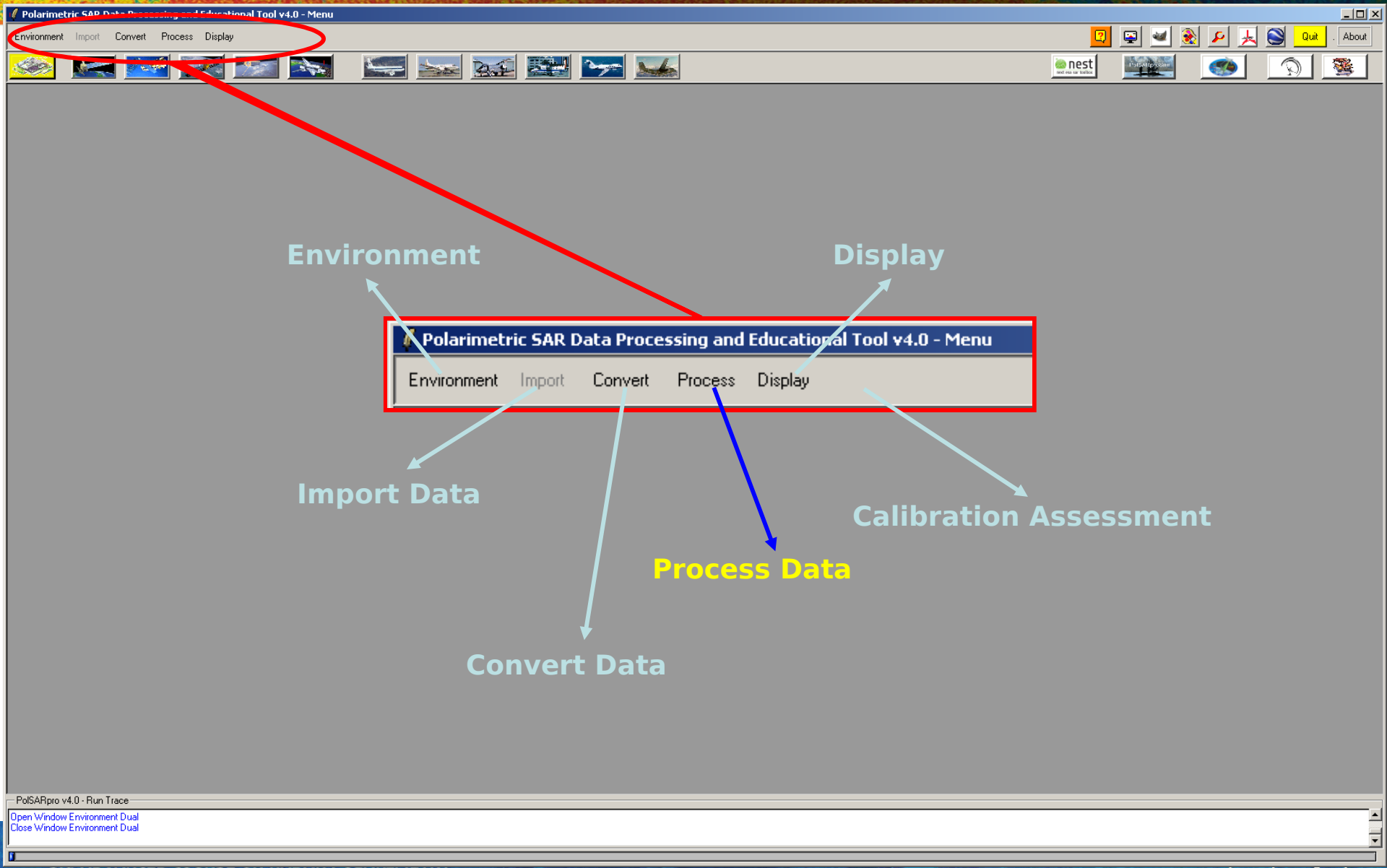
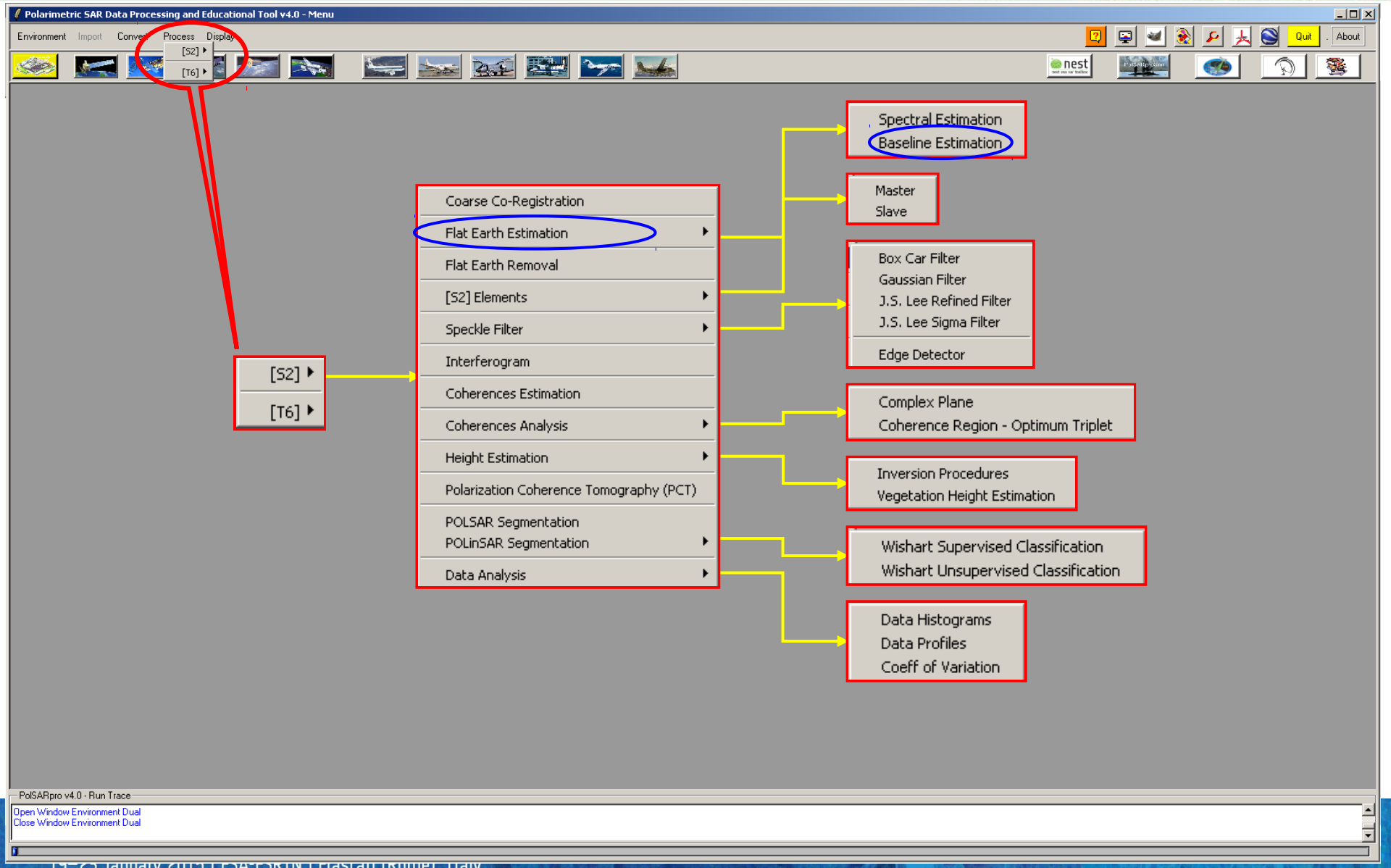
- Complex Coherence Estimation
- Coarse Co-Registration
- Flat Earth Estimation – Spectral Estimation
- Complex Coherence Estimation
- Flat Earth Removal
- Complex Coherence Estimation

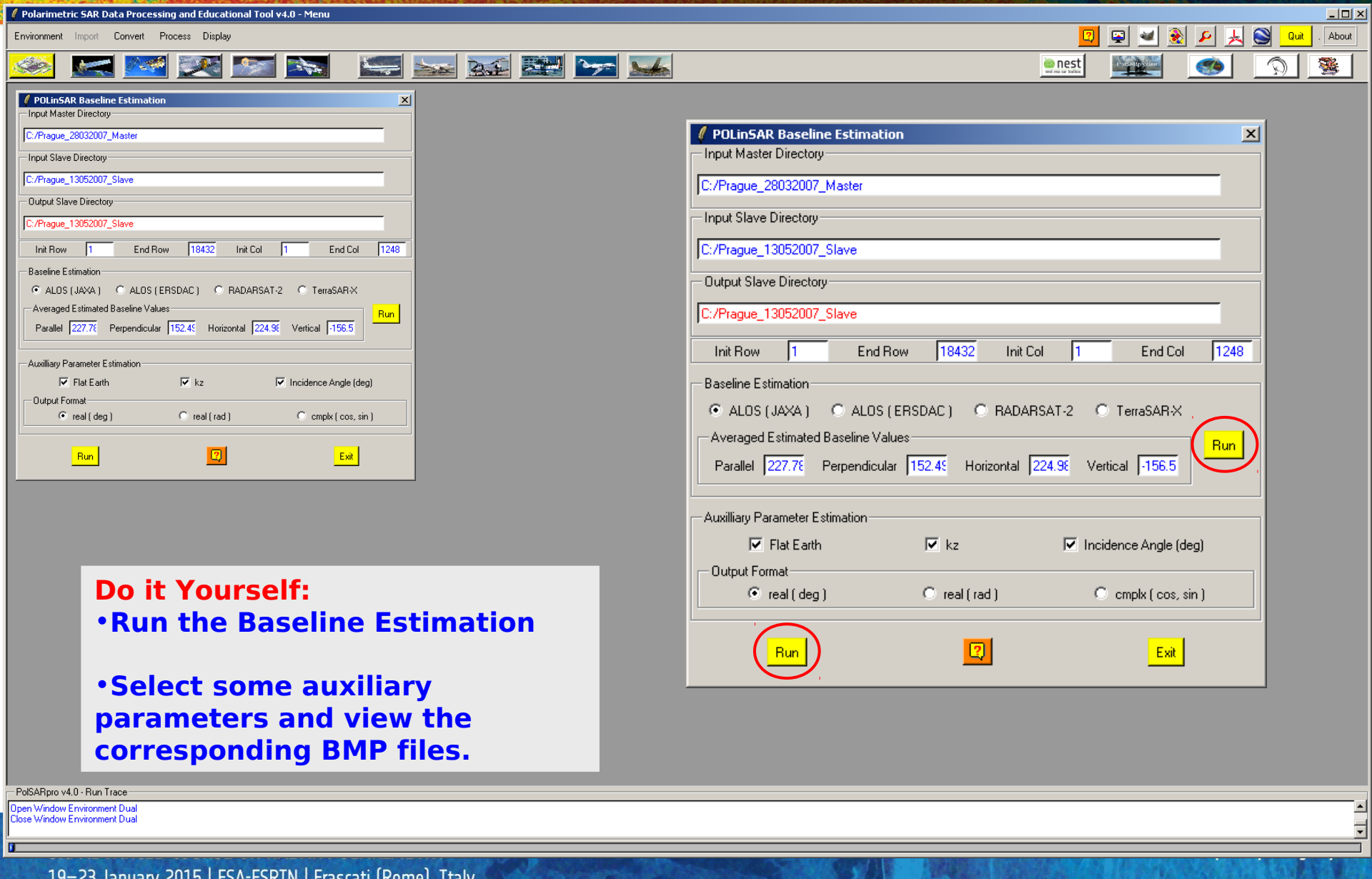
PROCESS DATA



PROCESS DATA - [S2] - MENU



BASELINE ESTIMATION



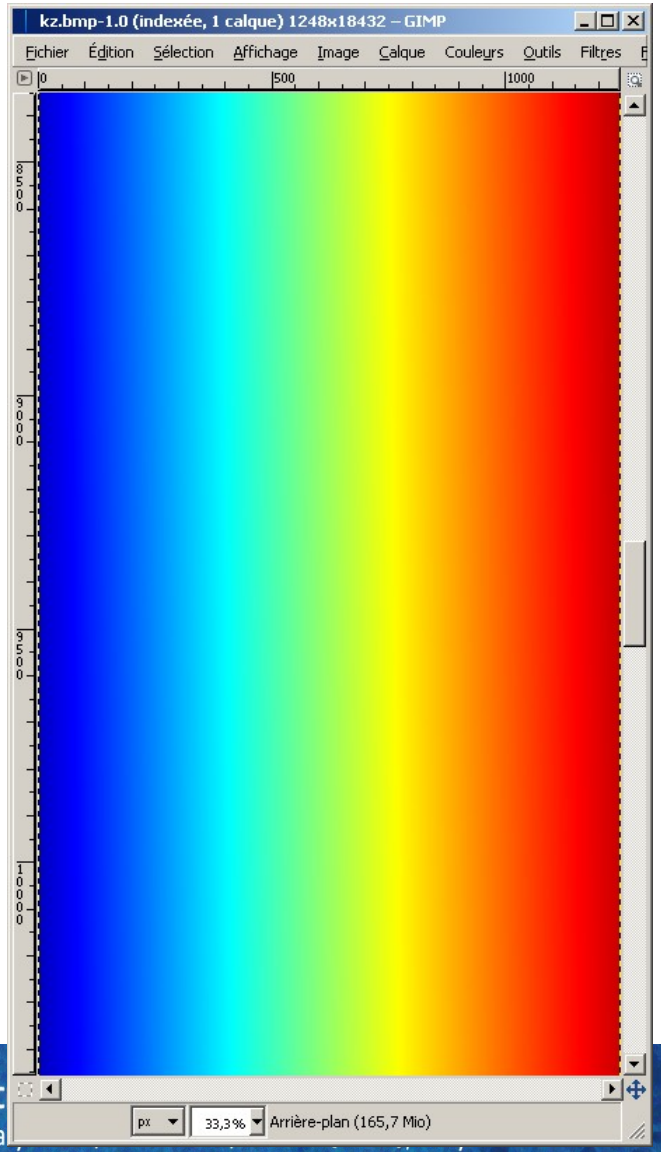
Do it Yourself:

- **Run the Baseline Estimation**
- **Select some auxiliary parameters and view the corresponding BMP files.**

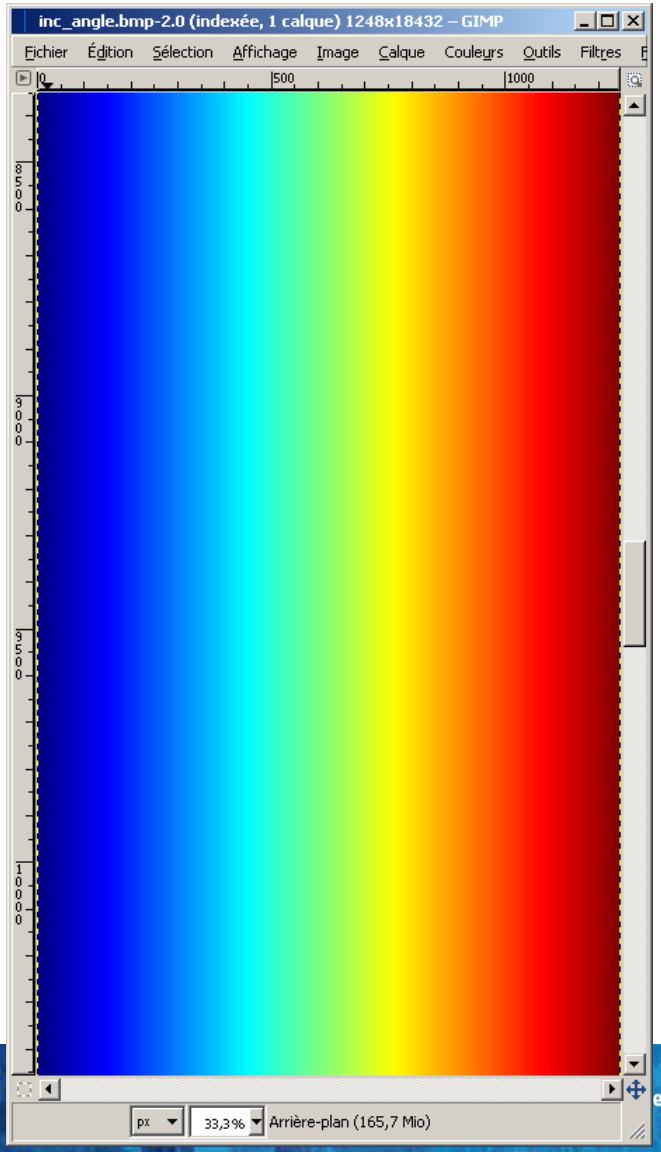
BASELINE ESTIMATION

kz

kz



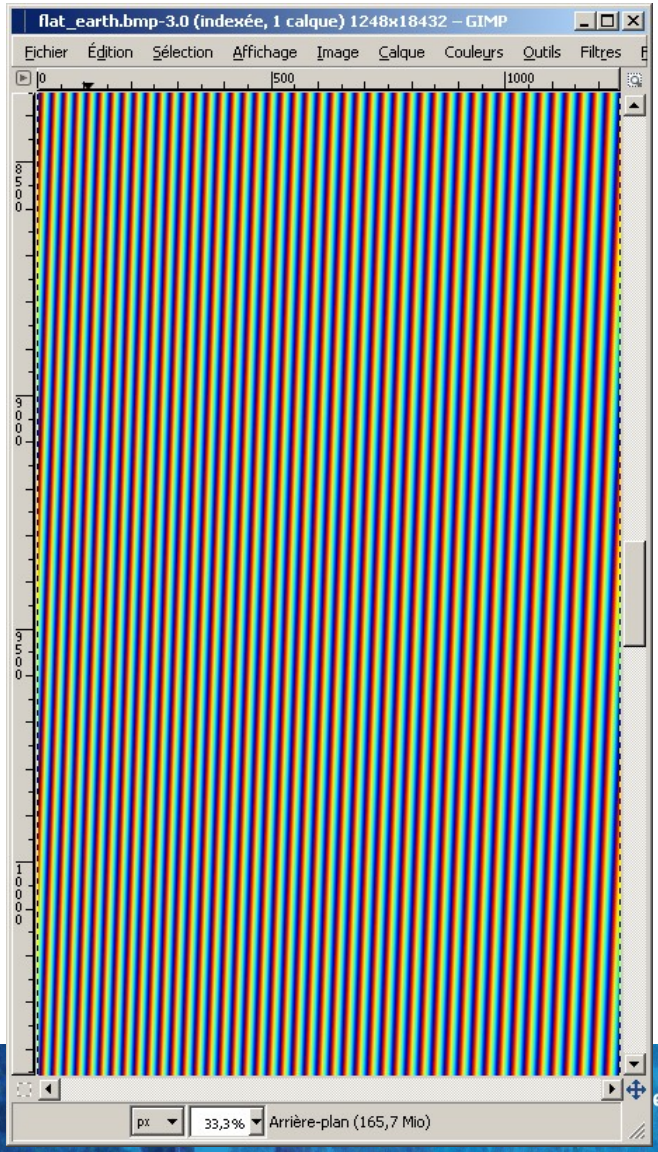
Radar Incidence Angle

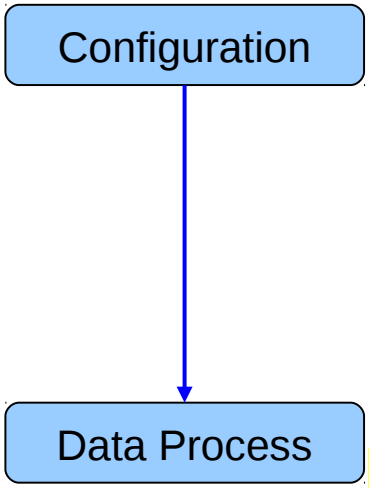


BASELINE ESTIMATION

Master Pauli Image

Flat Earth





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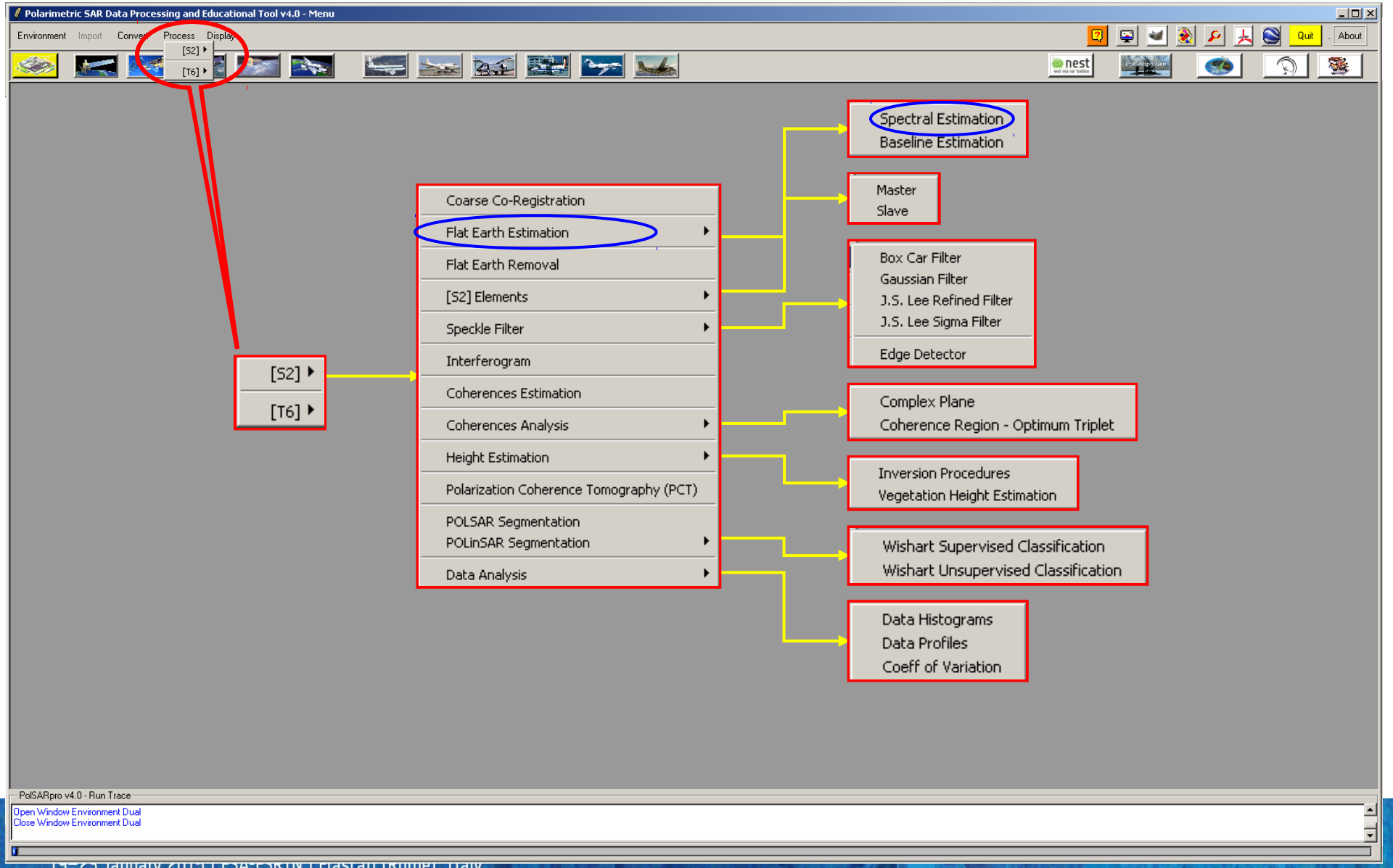
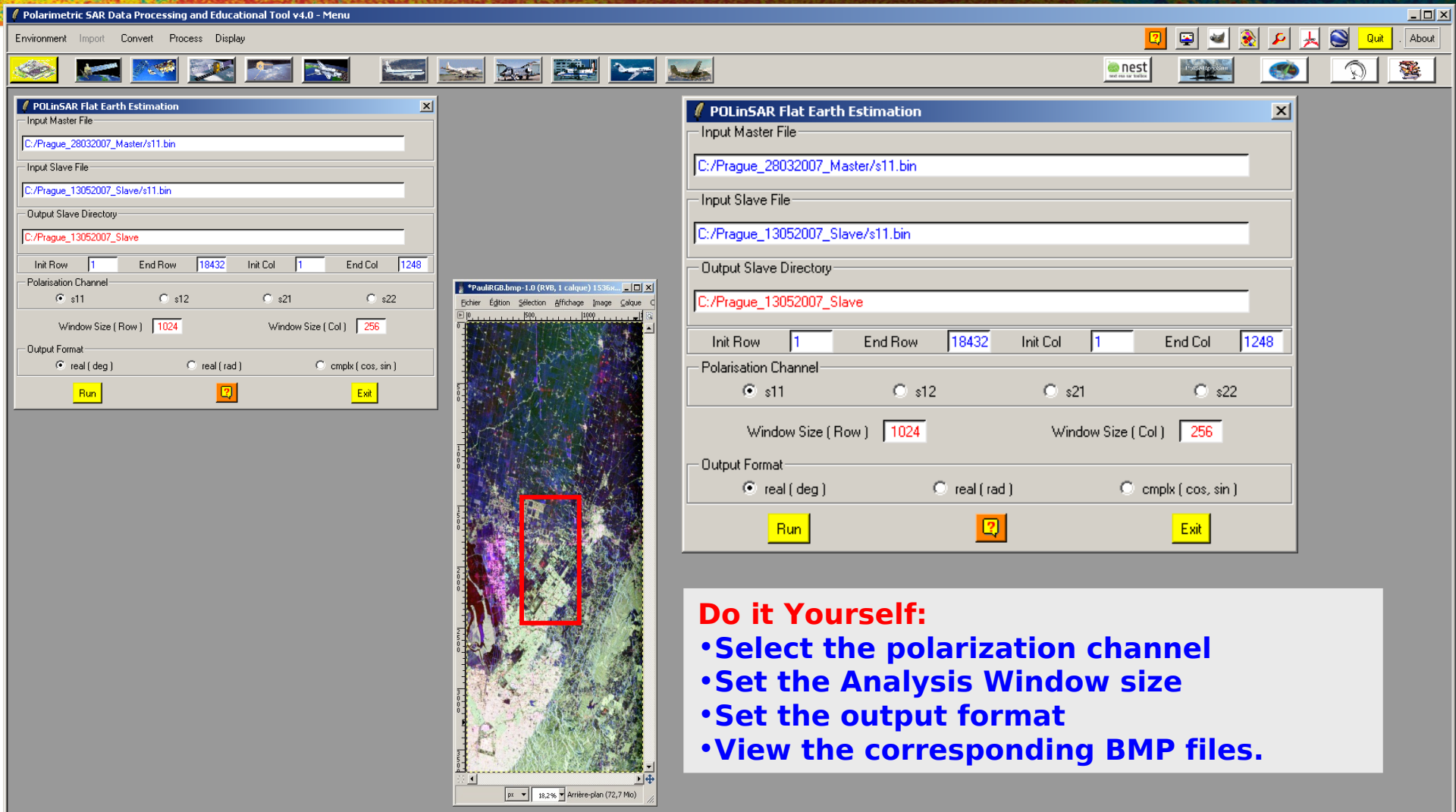
- Flat Earth Estimation – Spectral Estimation
- Complex Coherence Estimation
- Flat Earth Removal
- Complex Coherence Estimation

PROCESS DATA - [S2] - MENU



SPECTRAL ESTIMATION

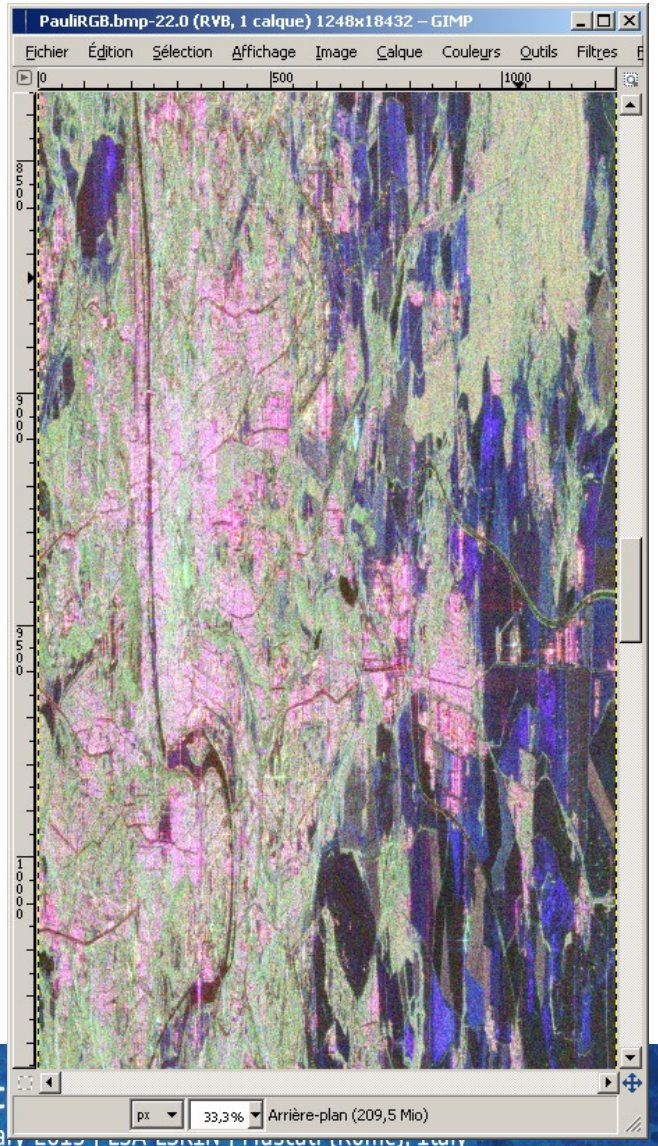


Do it Yourself:

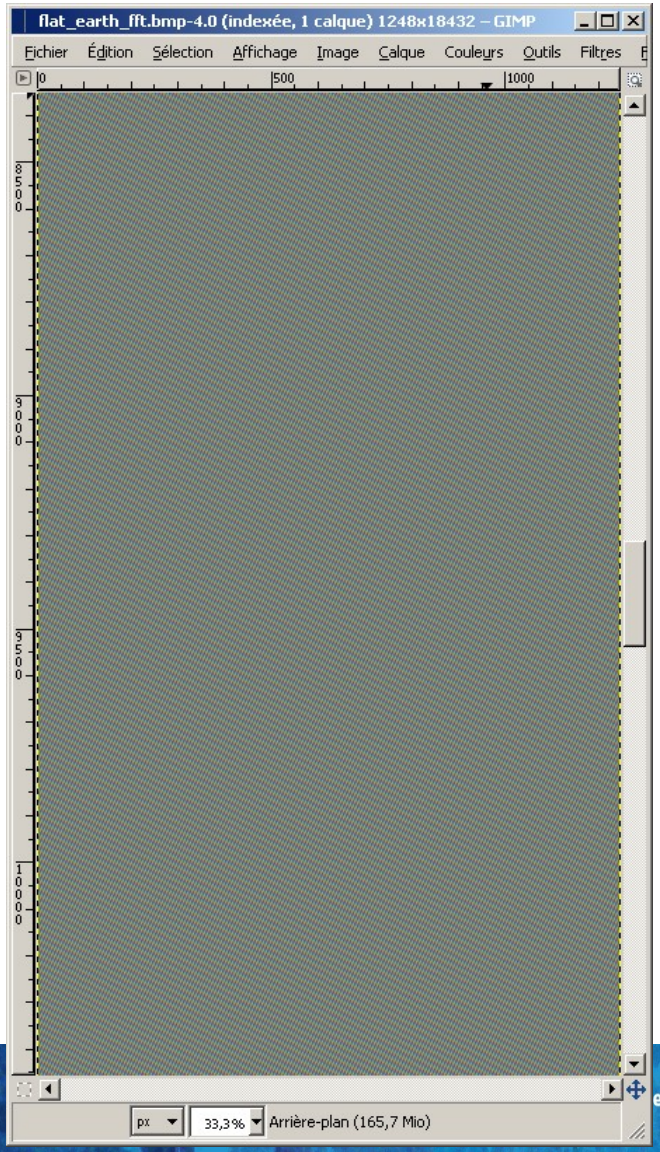
- **Select the polarization channel**
- **Set the Analysis Window size**
- **Set the output format**
- **View the corresponding BMP files.**

SPECTRAL ESTIMATION

Master Pauli Image

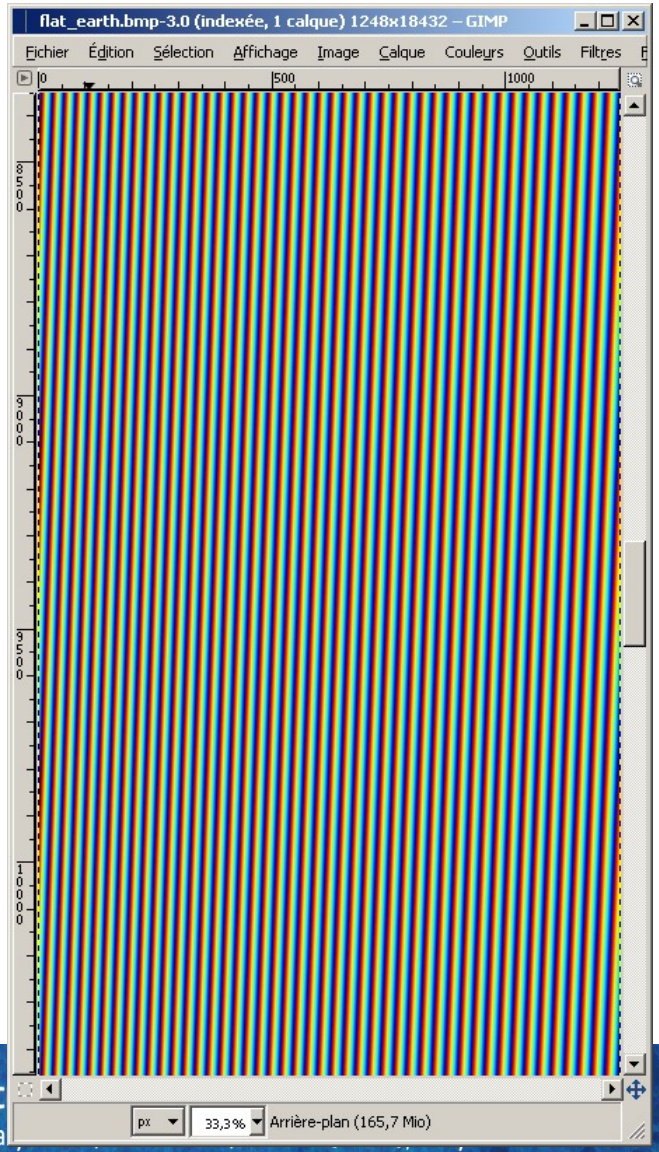


Flat Earth FFT

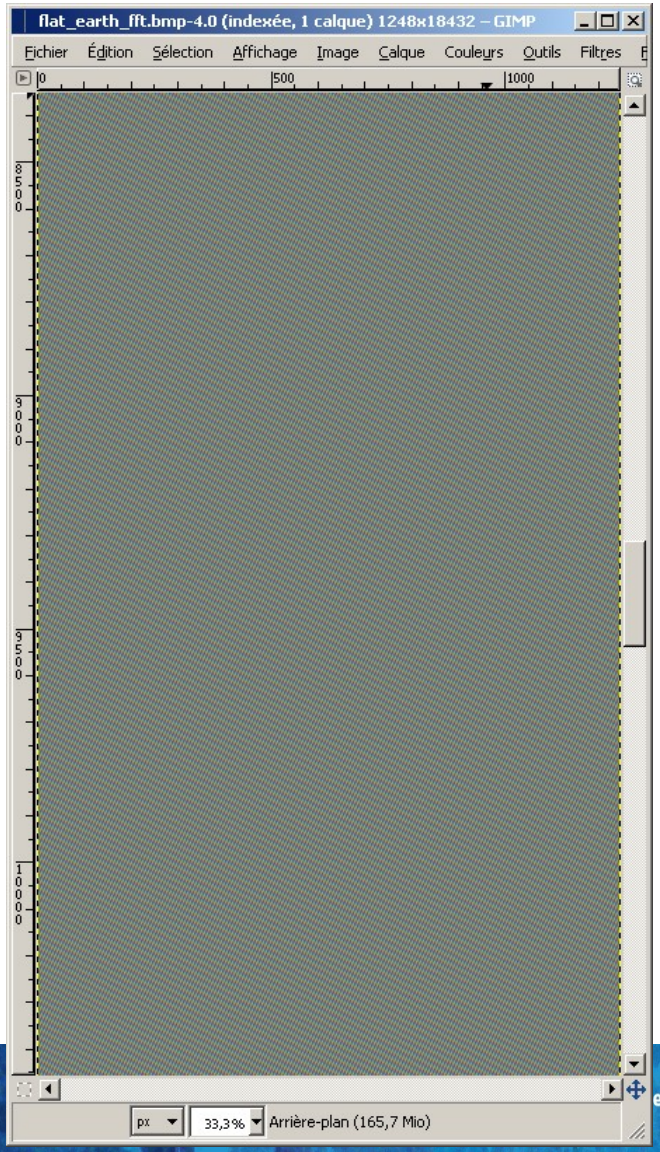


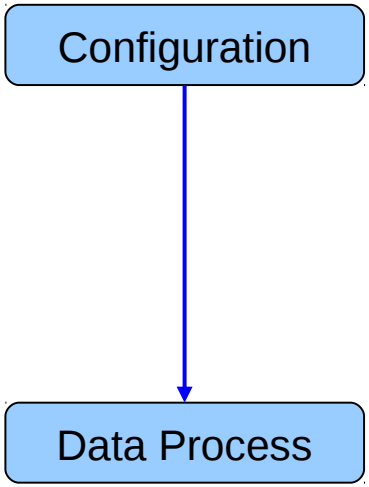
SPECTRAL ESTIMATION

Flat Earth



Flat Earth FFT





- Flat Earth Estimation – Baseline Estimation
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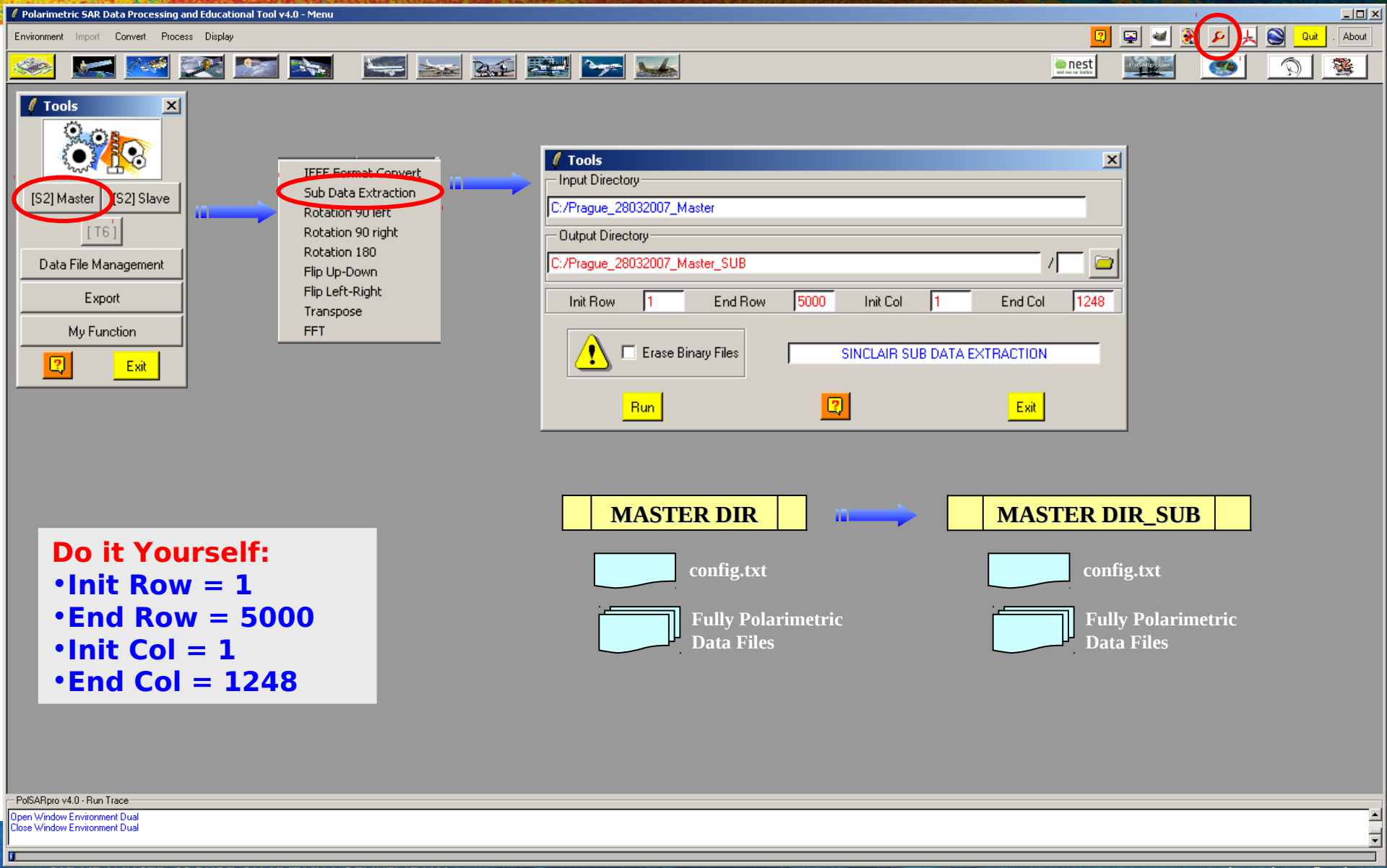
- Complex Coherence Estimation
- Coarse Co-Registration
- Flat Earth Estimation – Spectral Estimation
- Complex Coherence Estimation
- Flat Earth Removal
- Complex Coherence Estimation

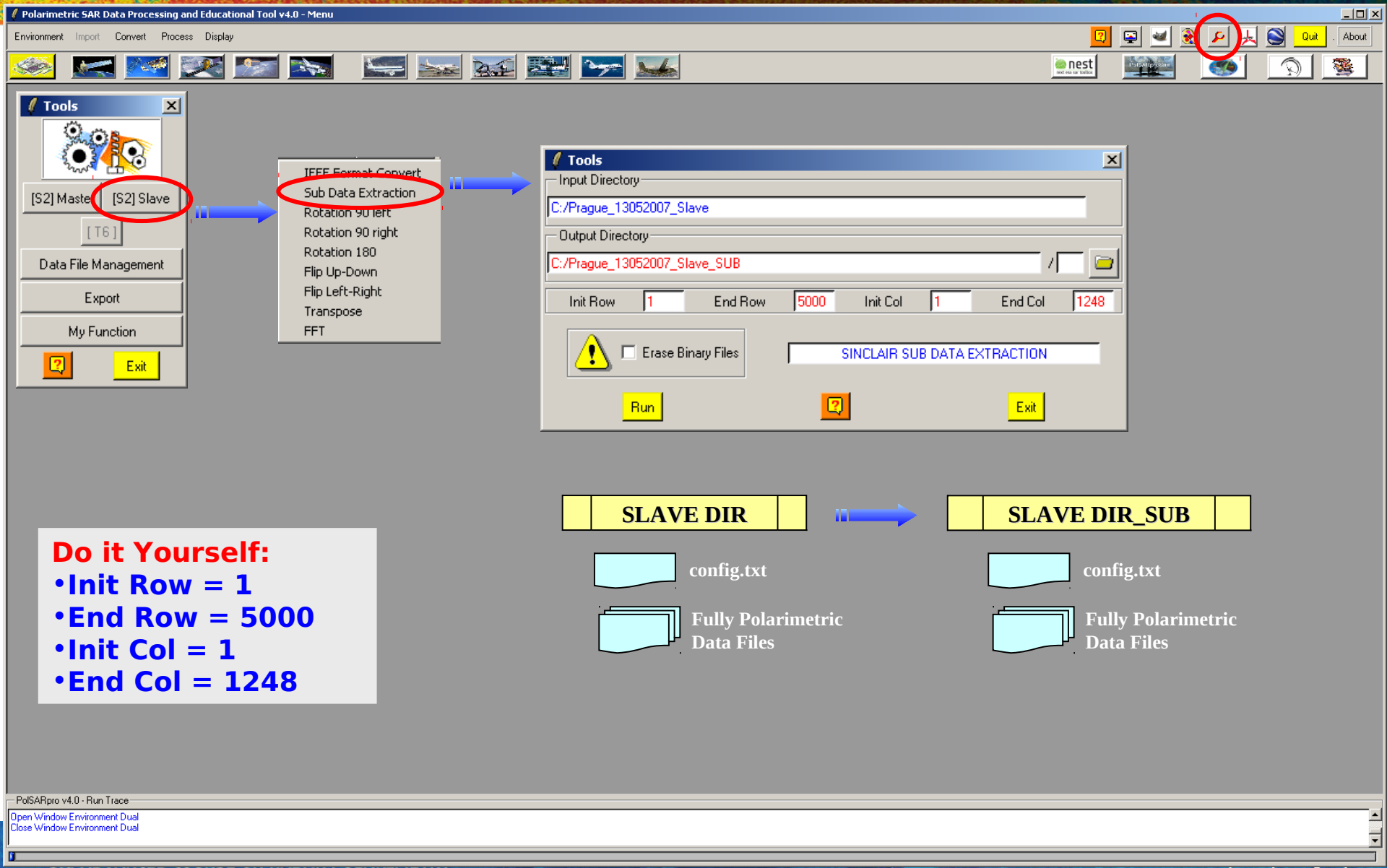
TOOLS



Do it Yourself:

- **Init Row = 1**
- **End Row = 5000**
- **Init Col = 1**
- **End Col = 1248**

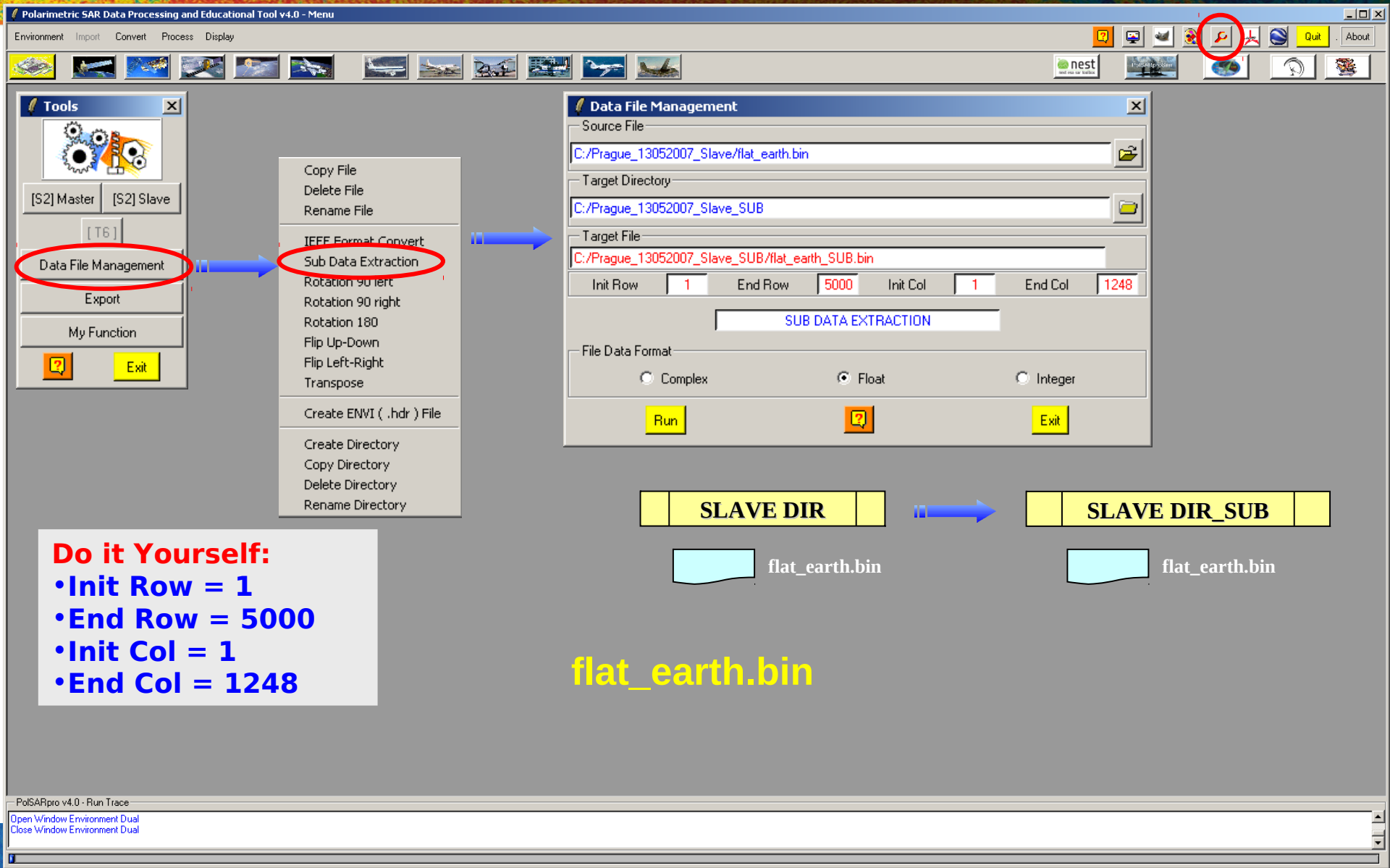
TOOLS



Do it Yourself:

- **Init Row = 1**
- **End Row = 5000**
- **Init Col = 1**
- **End Col = 1248**

TOOLS

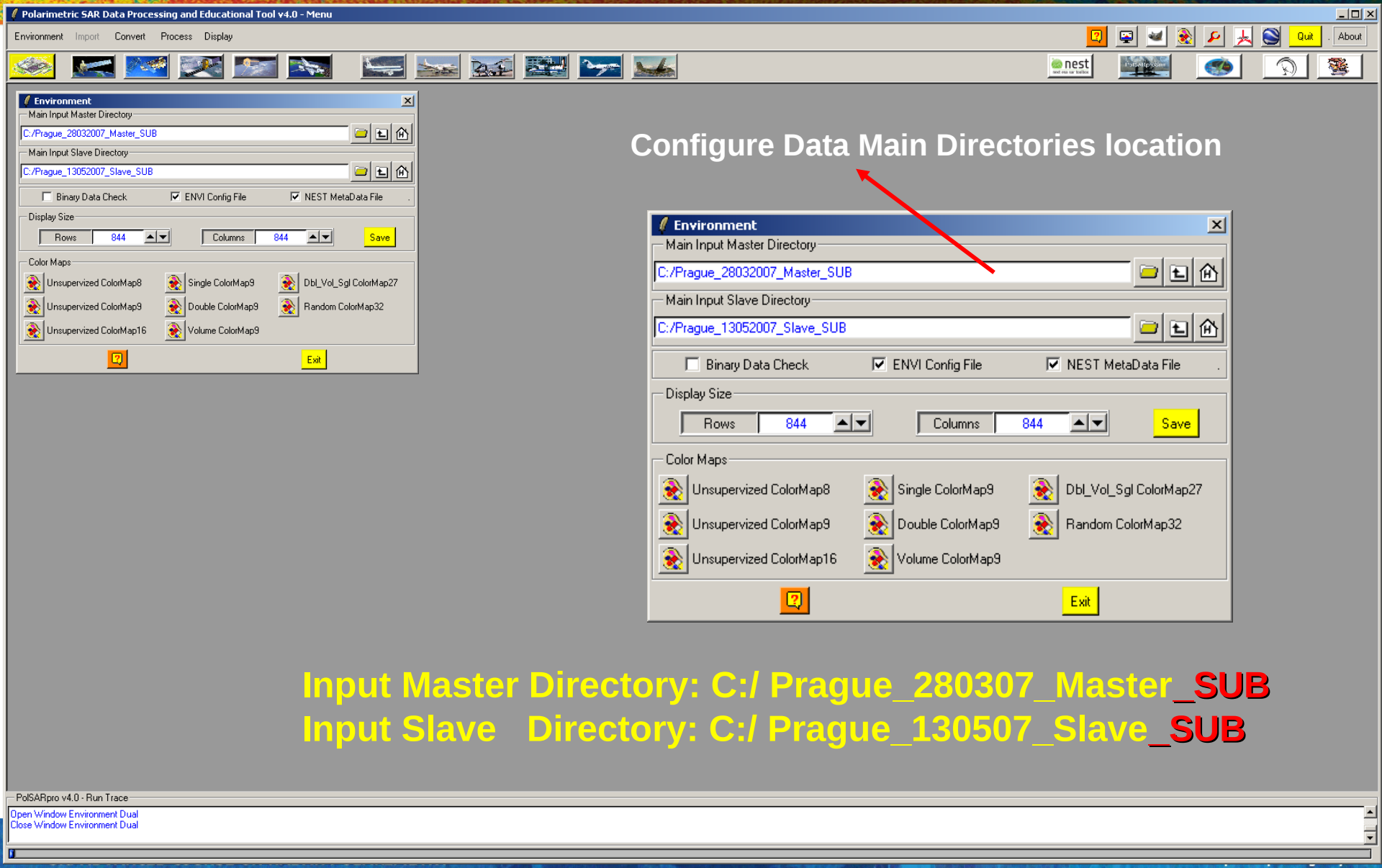


Do it Yourself:

- **Init Row = 1**
- **End Row = 5000**
- **Init Col = 1**
- **End Col = 1248**

flat_earth.bin

ENVIRONNEMENT

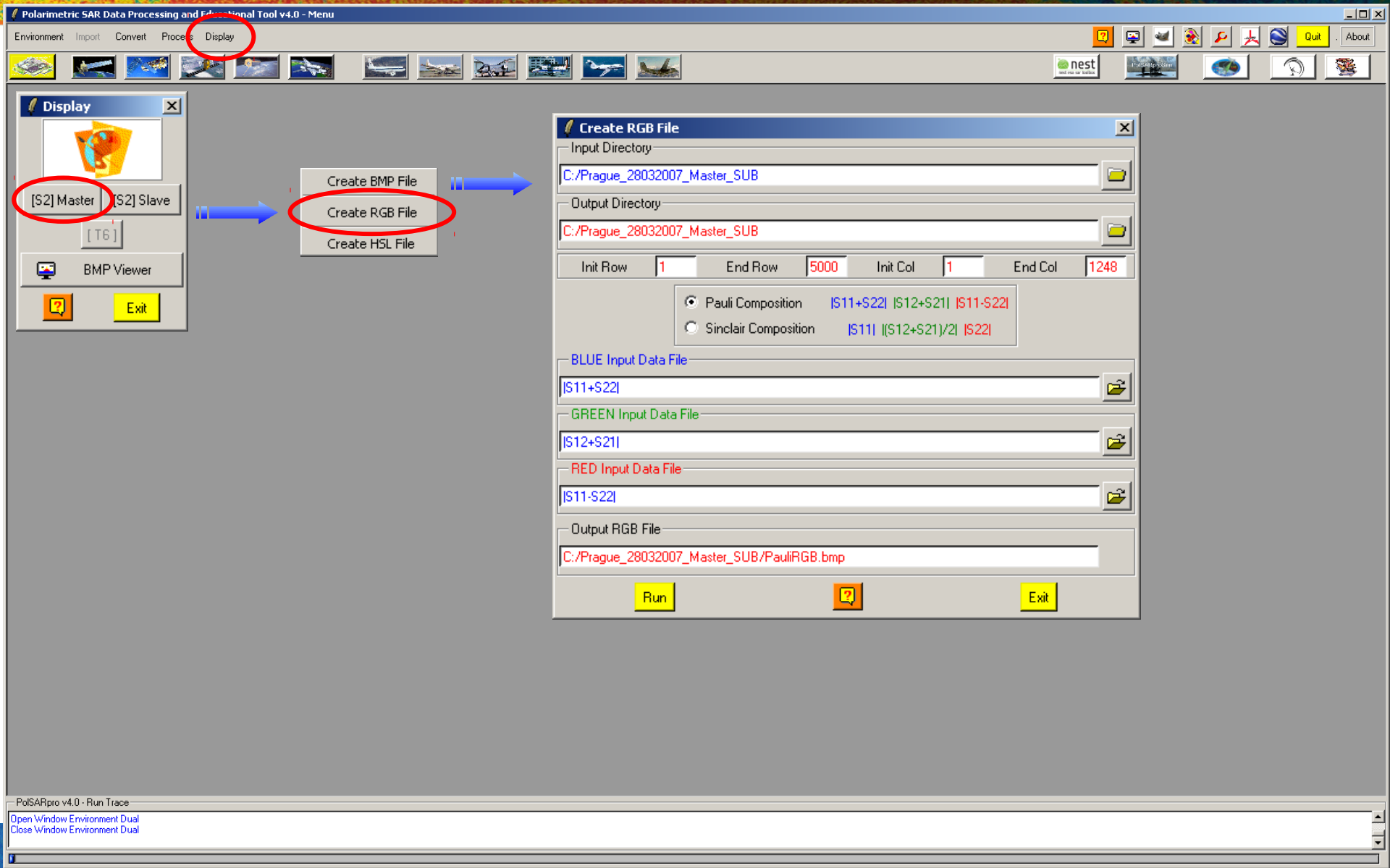


Configure Data Main Directories location

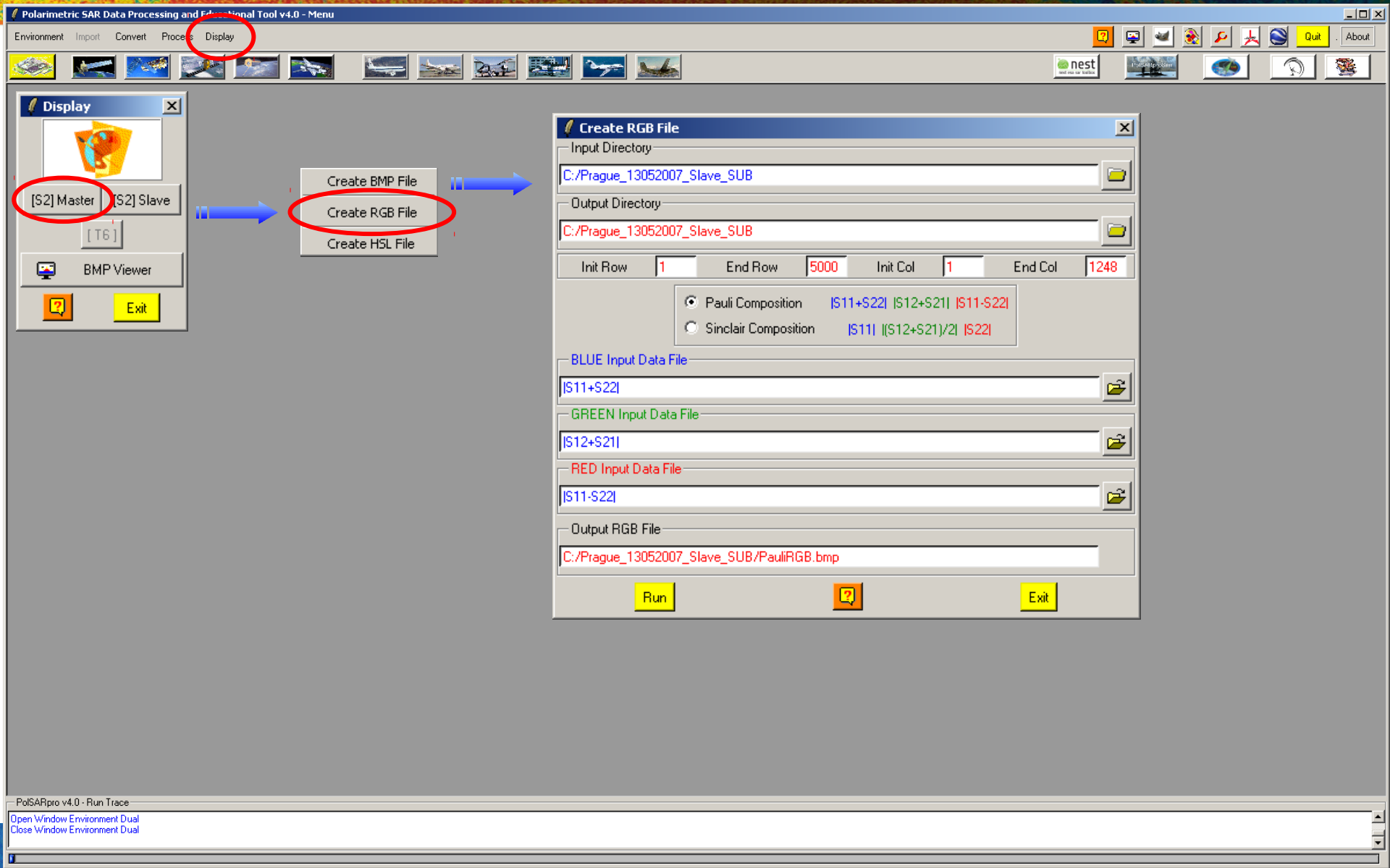
Input Master Directory: C:/ Prague_280307_Master_SUB

Input Slave Directory: C:/ Prague_130507_Slave_SUB

DISPLAY

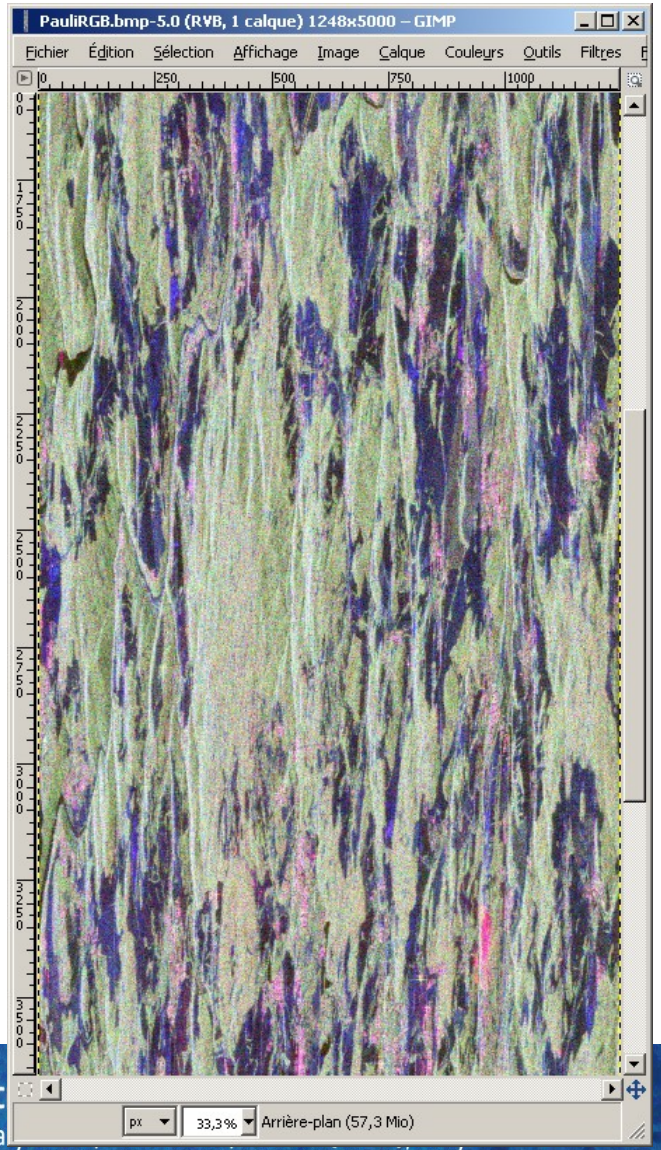

Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Quit
About
Display
[S2] Master
[S2] Slave
[T6]
BMP Viewer
Exit
Create BMP File
Create RGB File
Create HSL File
Create RGB File
Input Directory
C:/Prague_28032007_Master_SUB
Output Directory
C:/Prague_28032007_Master_SUB
Init Row
1
End Row
5000
Init Col
1
End Col
1248
Pauli Composition
|S11+S22| |S12+S21| |S11-S22|
Sinclair Composition
|S11| |(S12+S21)/2| |S22|
BLUE Input Data File
|S11+S22|
GREEN Input Data File
|S12+S21|
RED Input Data File
|S11-S22|
Output RGB File
C:/Prague_28032007_Master_SUB/PauliRGB.bmp
Run
Exit
PolSARpro v4.0 - Run Trace
Open Window Environment Dual
Close Window Environment Dual

DISPLAY

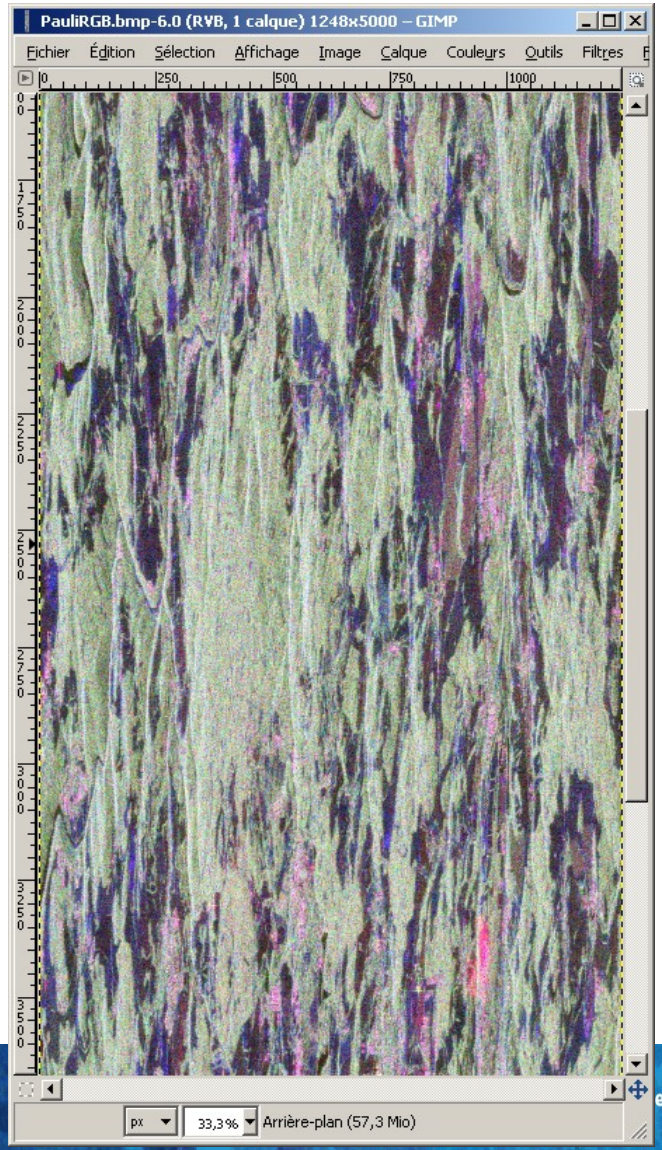

Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu
Environment
Import
Convert
Process
Display
Quit
About
Display
[S2] Master
[S2] Slave
[T6]
BMP Viewer
Exit
Create BMP File
Create RGB File
Create HSL File
Create RGB File
Input Directory
C:/Prague_13052007_Slave_SUB
Output Directory
C:/Prague_13052007_Slave_SUB
Init Row
1
End Row
5000
Init Col
1
End Col
1248
Pauli Composition
|S11+S22| |S12+S21| |S11-S22|
Sinclair Composition
|S11| |(S12+S21)/2| |S22|
BLUE Input Data File
|S11+S22|
GREEN Input Data File
|S12+S21|
RED Input Data File
|S11-S22|
Output RGB File
C:/Prague_13052007_Slave_SUB/PauliRGB.bmp
Run
Exit
PolSARpro v4.0 - Run Trace
Open Window Environment Dual
Close Window Environment Dual

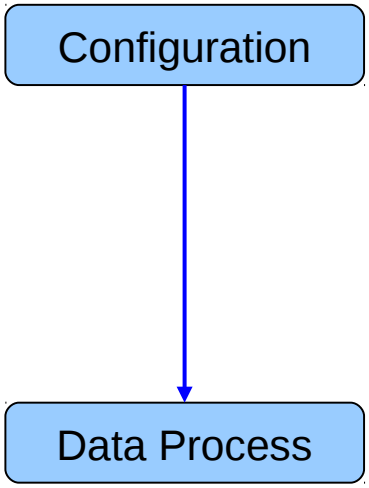
DISPLAY

Master Pauli Image



Slave Pauli Image





- Flat Earth Estimation – Baseline Estimation
- Flat Earth Estimation – Spectral Estimation
- Tools – Sub Data Extraction
- Complex Coherence Estimation
- Coarse Co-Registration
- Flat Earth Estimation – Spectral Estimation
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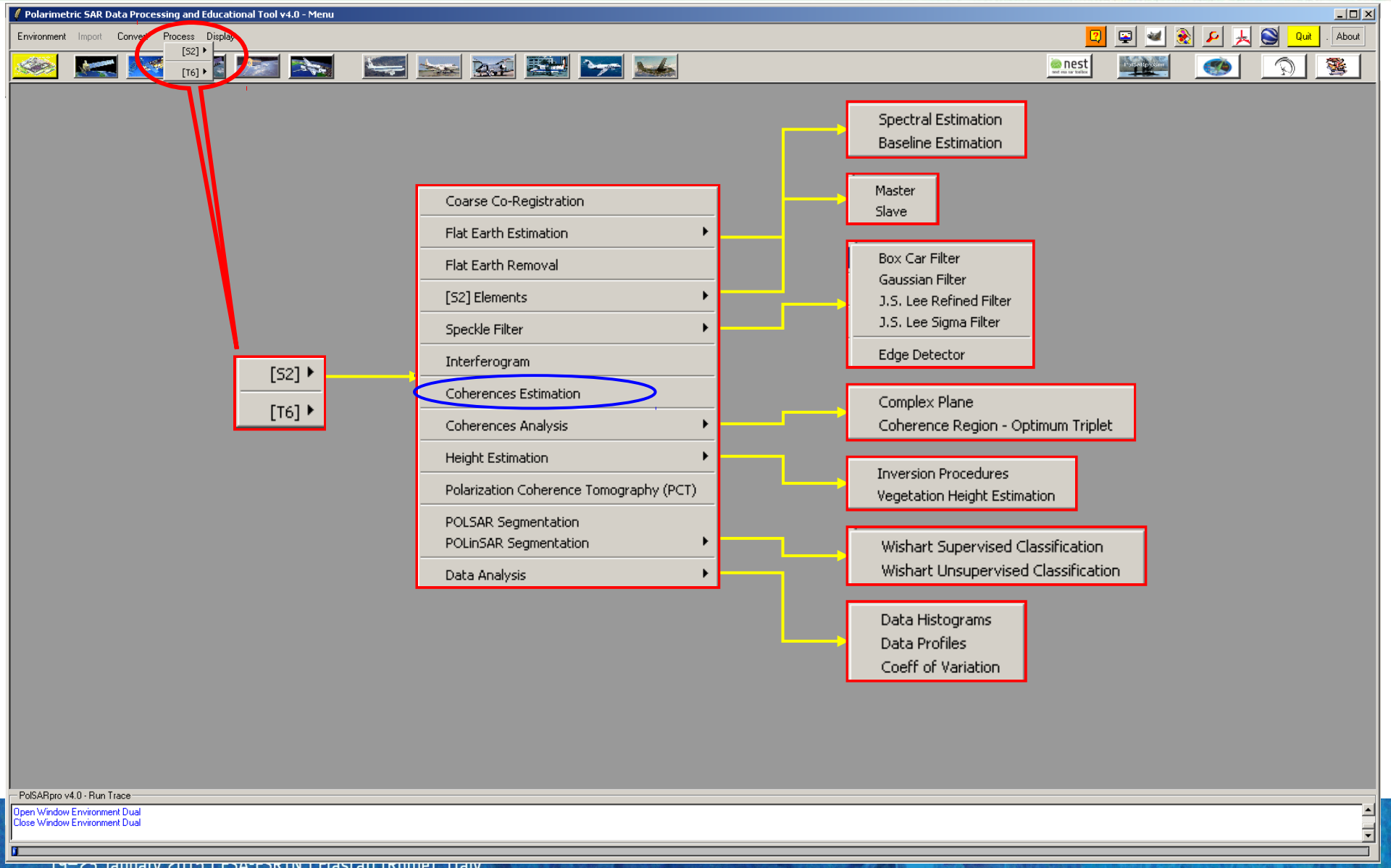
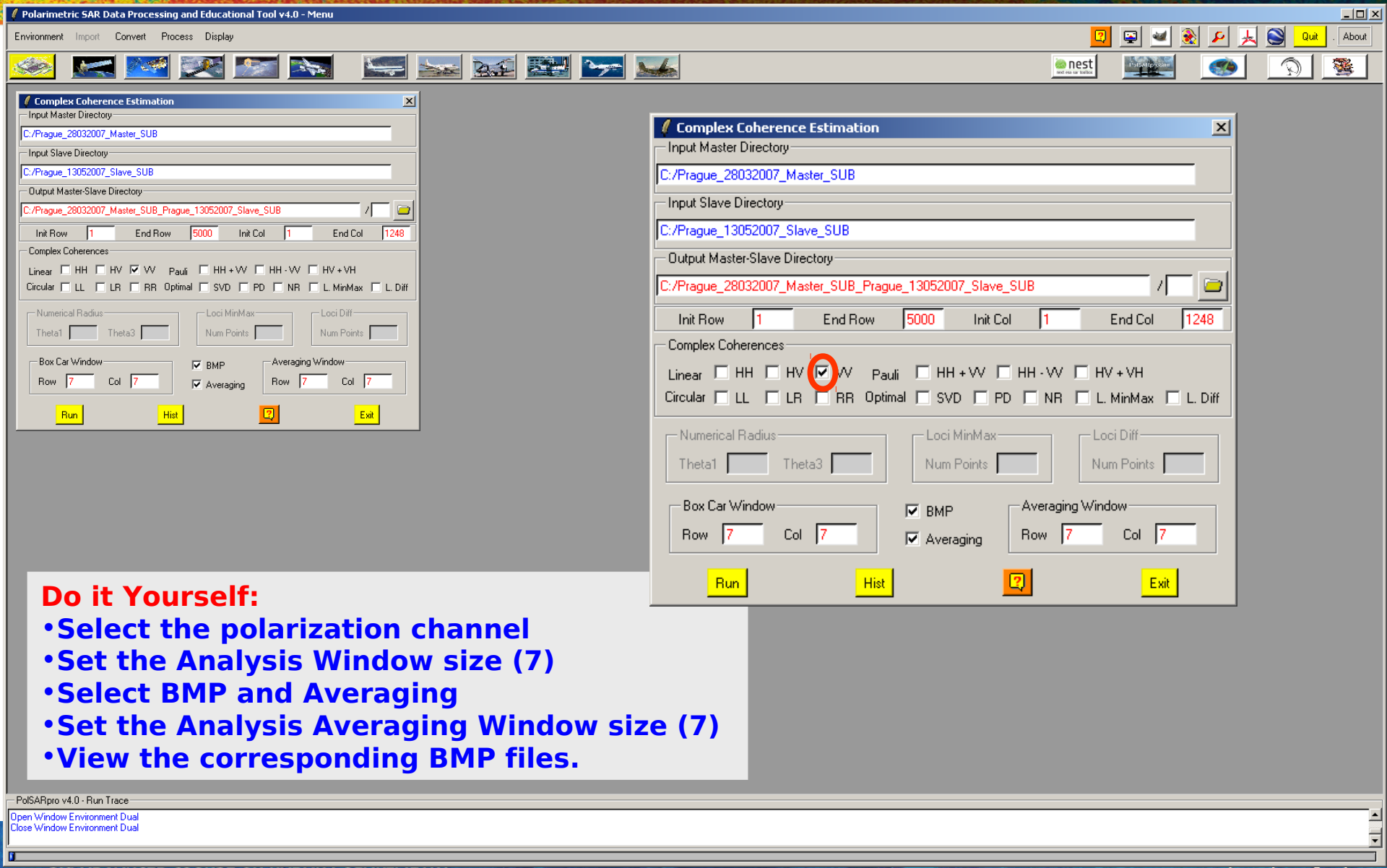
- Flat Earth Removal
- Complex Coherence Estimation

PROCESS DATA - [S2] - MENU



COMPLEX COHERENCE ESTIMATION

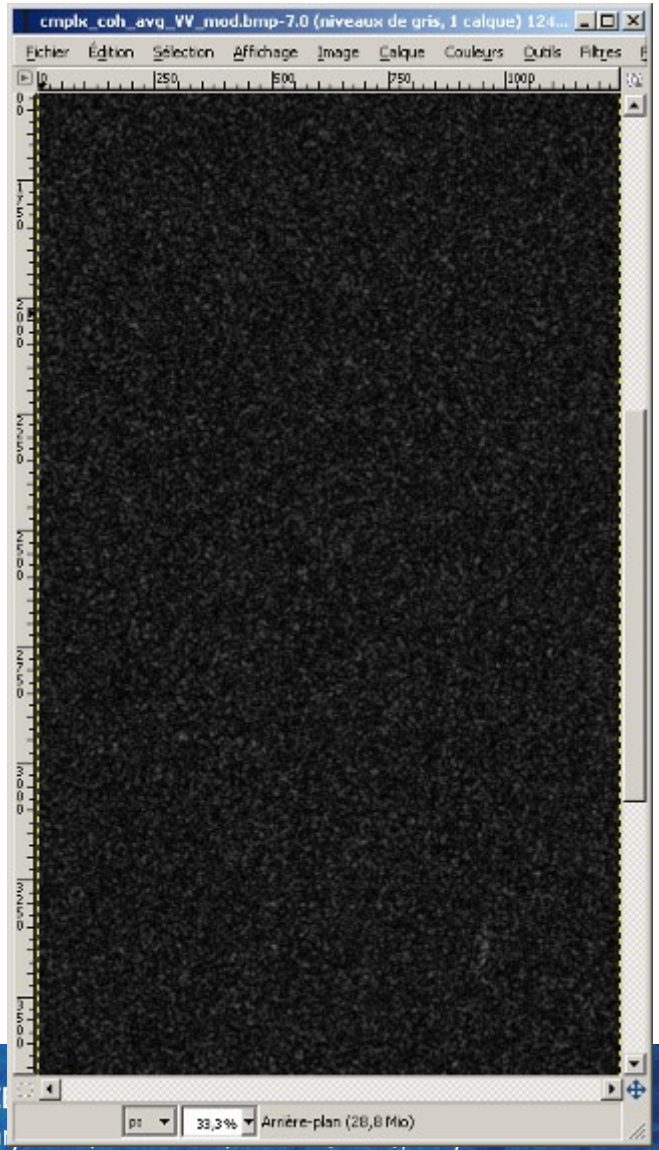


Do it Yourself:

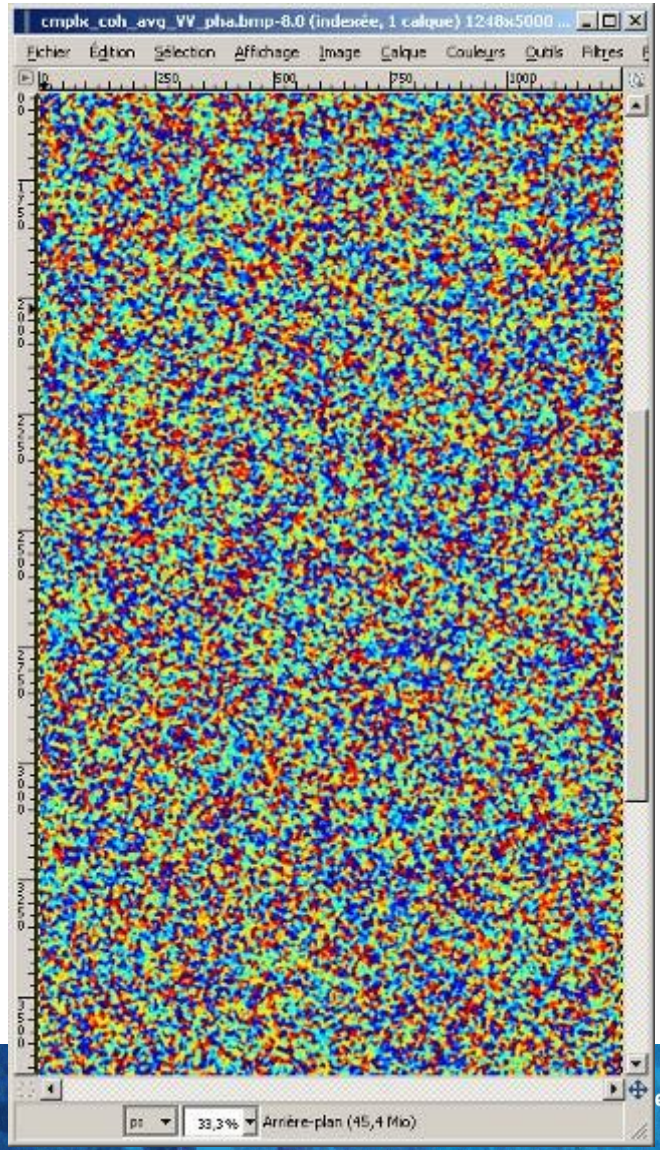
- **Select the polarization channel**
- **Set the Analysis Window size (7)**
- **Select BMP and Averaging**
- **Set the Analysis Averaging Window size (7)**
- **View the corresponding BMP files.**

COMPLEX COHERENCE ESTIMATION

cmplx_coh_avg_VV_mod

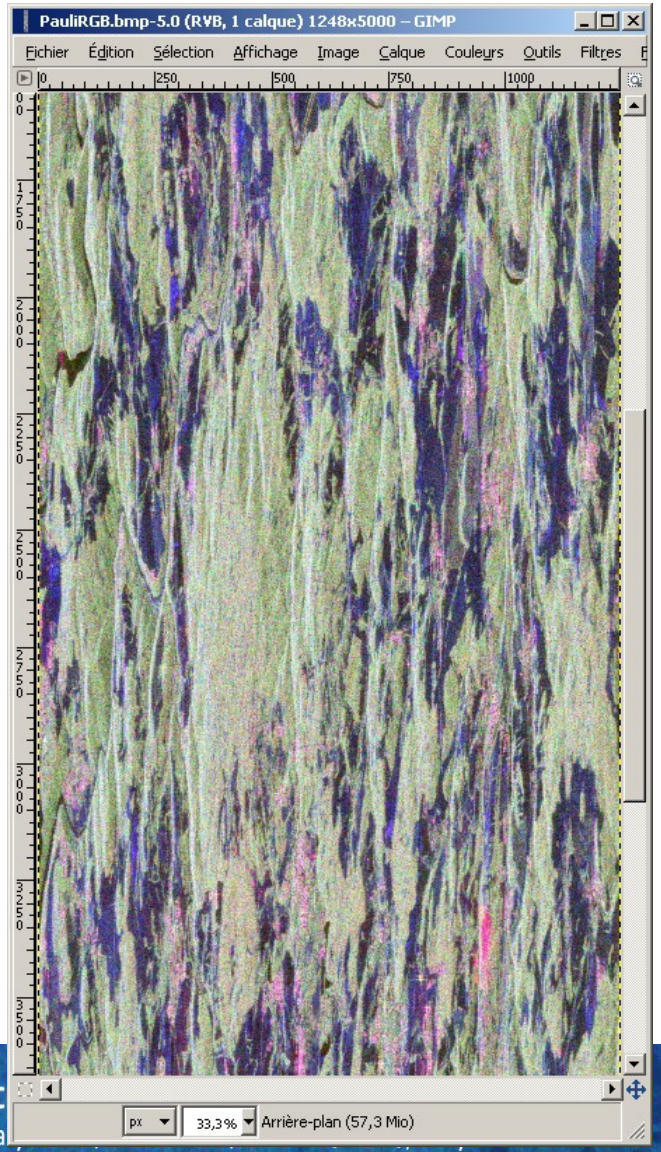


cmplx_coh_avg_VV_pha

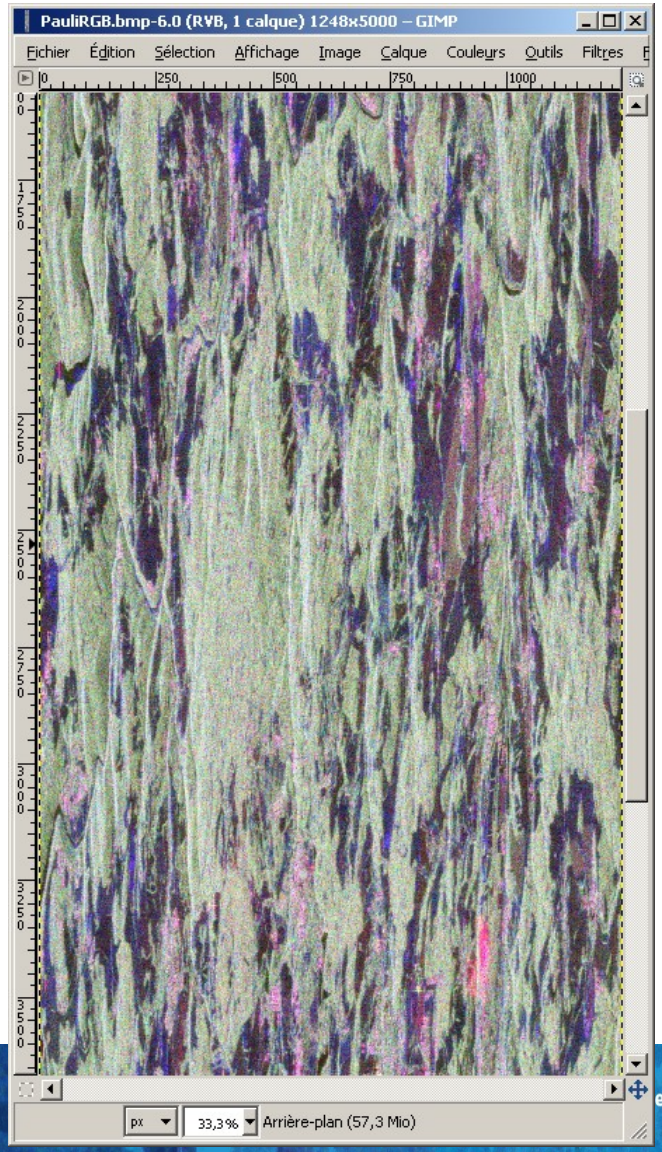


COMPLEX COHERENCE ESTIMATION

Master Pauli Image

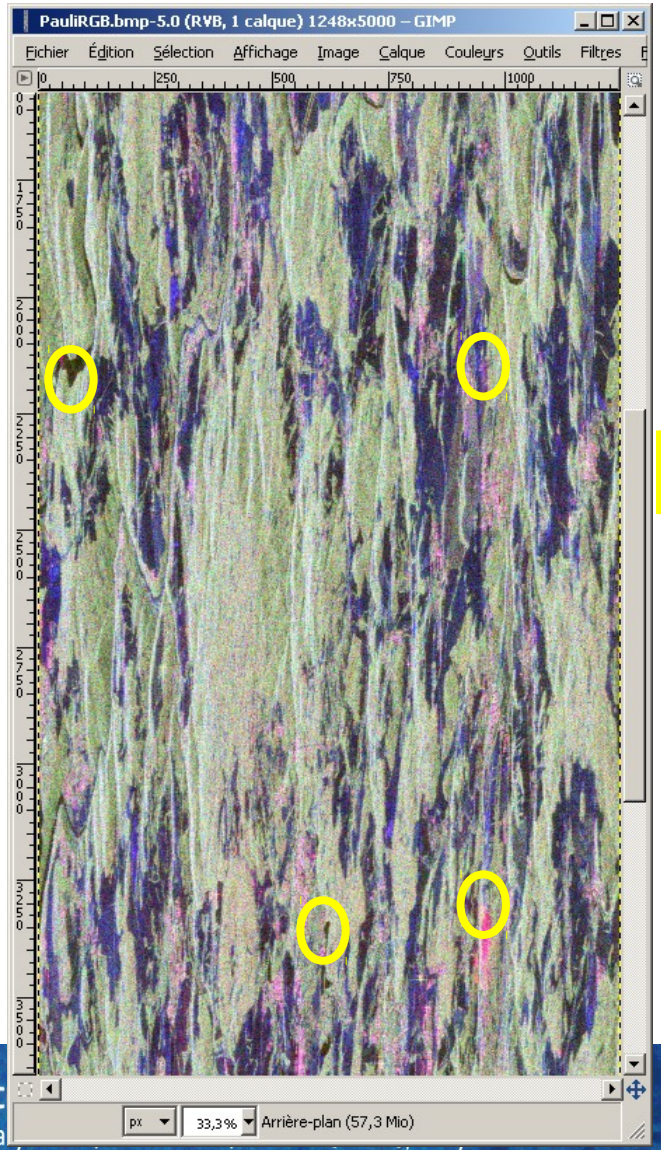


Slave Pauli Image



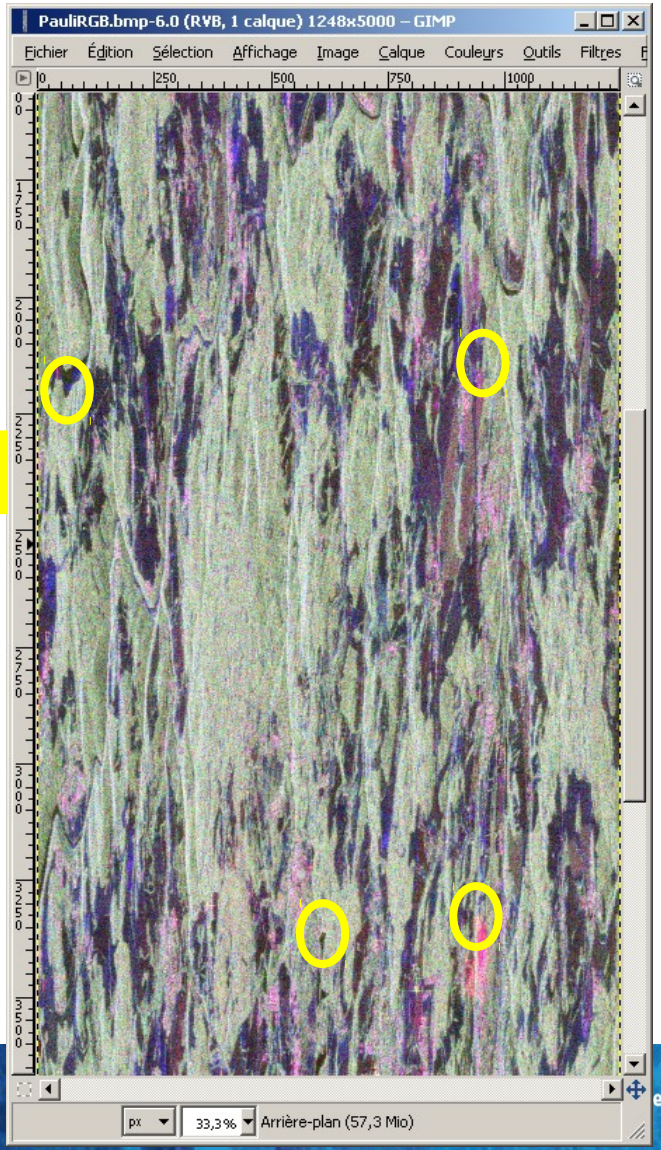
COMPLEX COHERENCE ESTIMATION

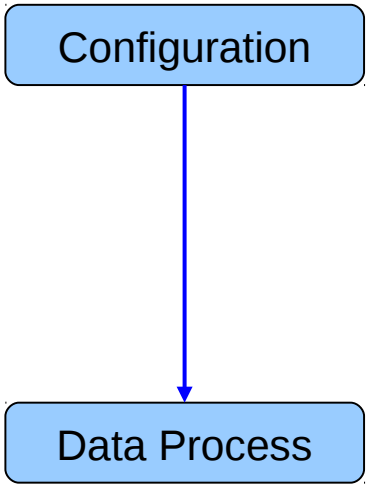
Master Pauli Image



SHIFT

Slave Pauli Image





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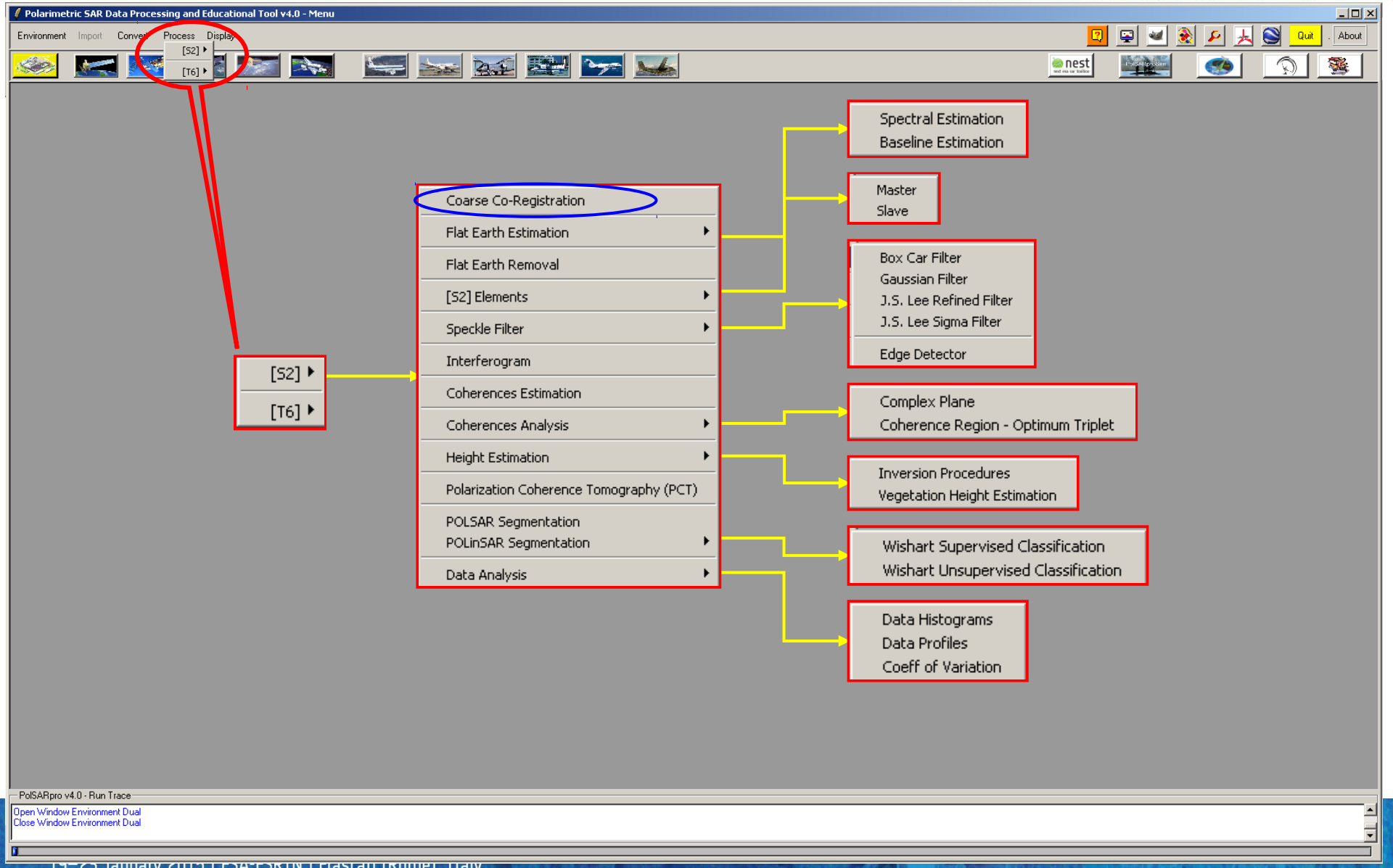
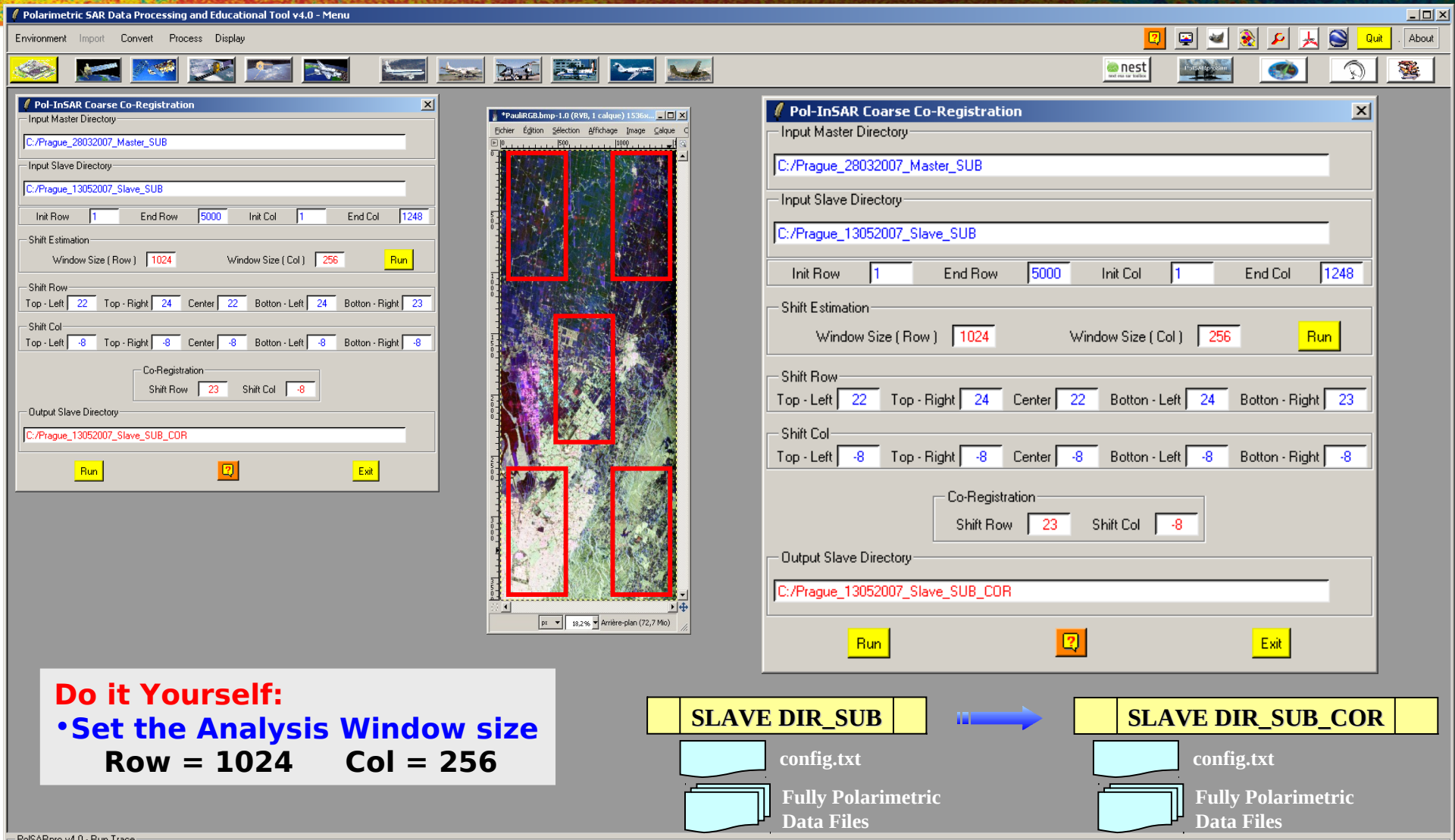
- Flat Earth Removal
- Complex Coherence Estimation

PROCESS DATA - [S2] - MENU



BASIC COARSE COREGISTRATION



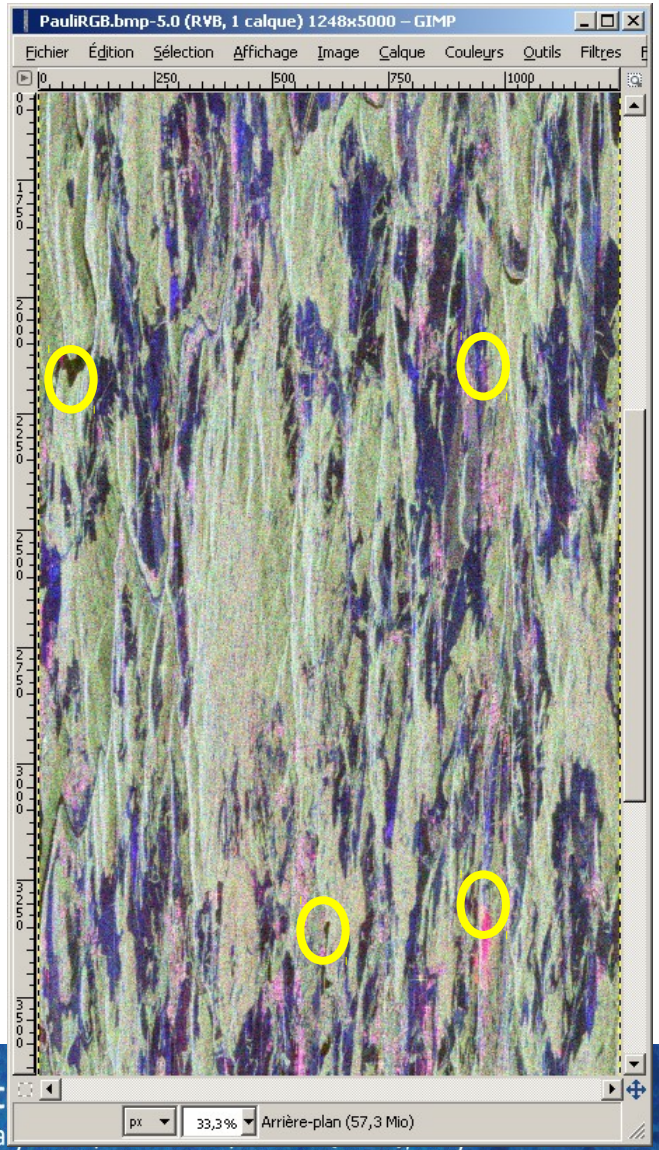
Do it Yourself:

- **Set the Analysis Window size**

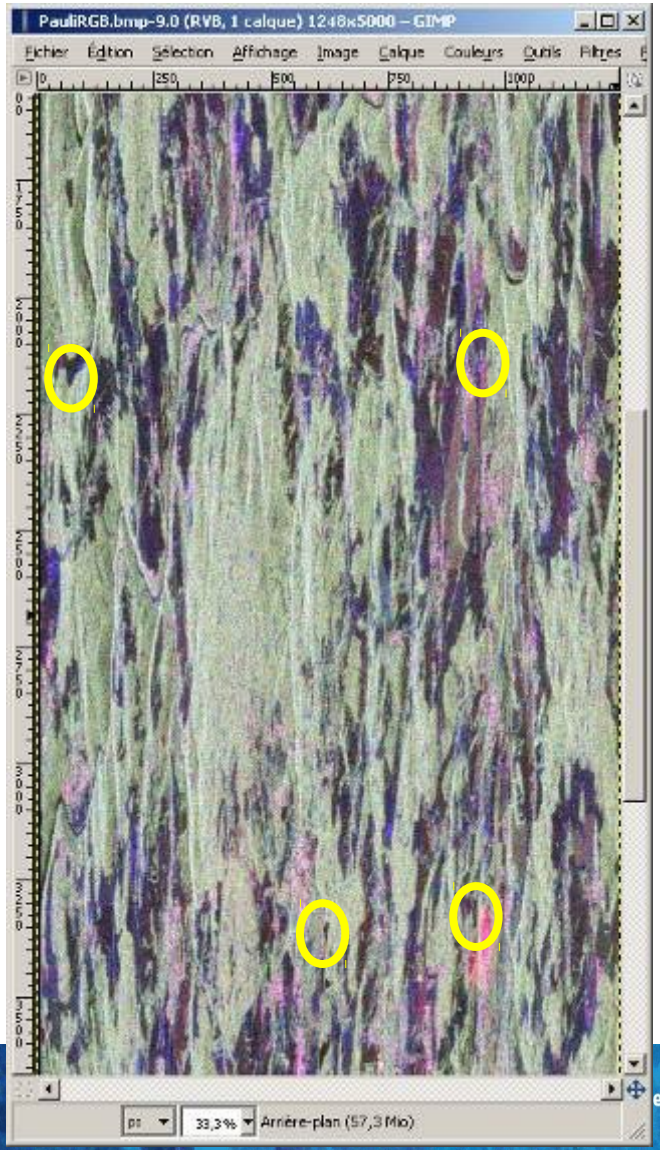
  Row = 1024 Col = 256

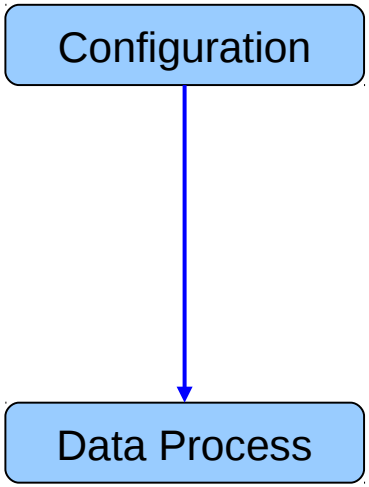
BASIC COARSE COREGISTRATION

Master Pauli Image



Slave Pauli Image





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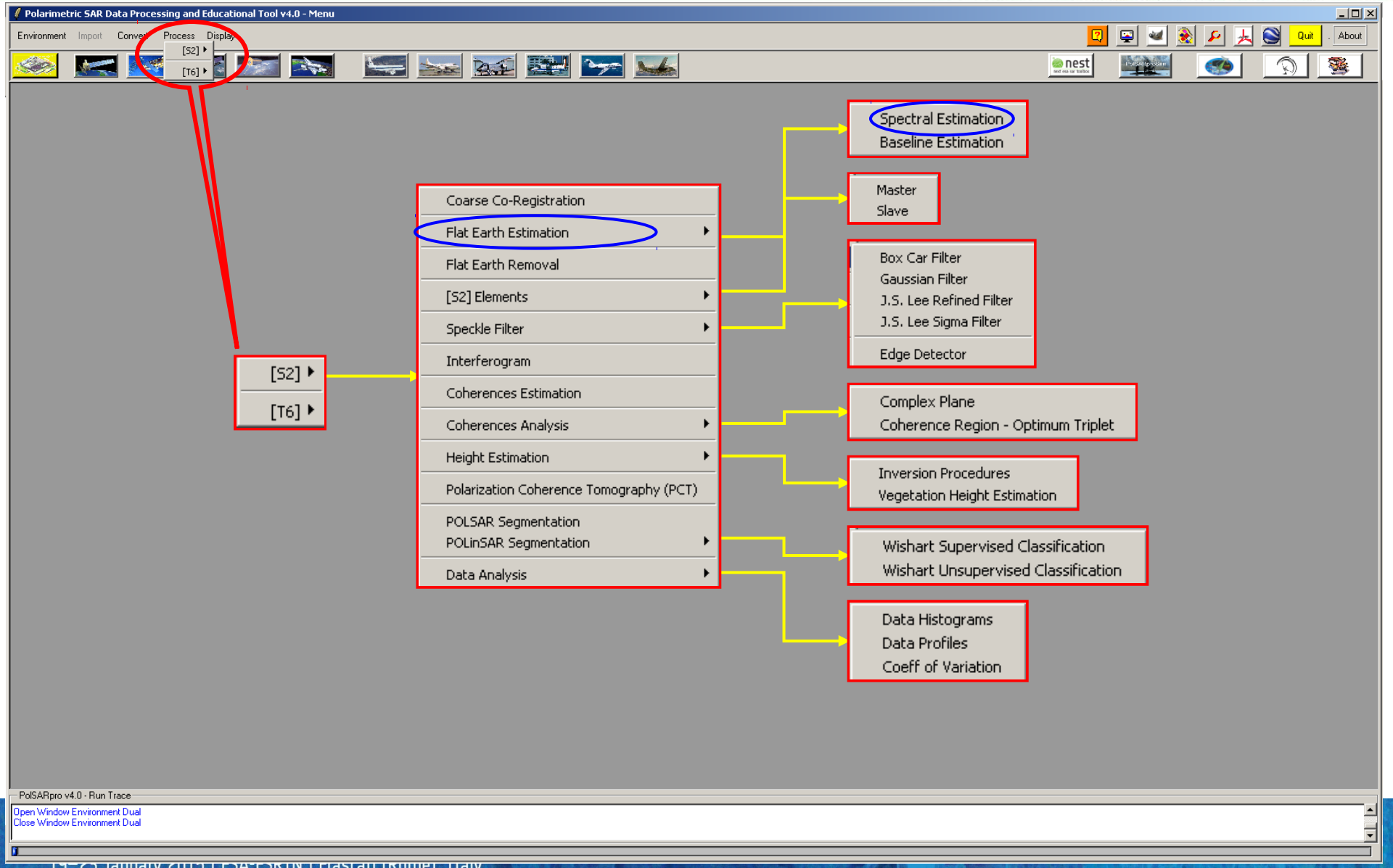
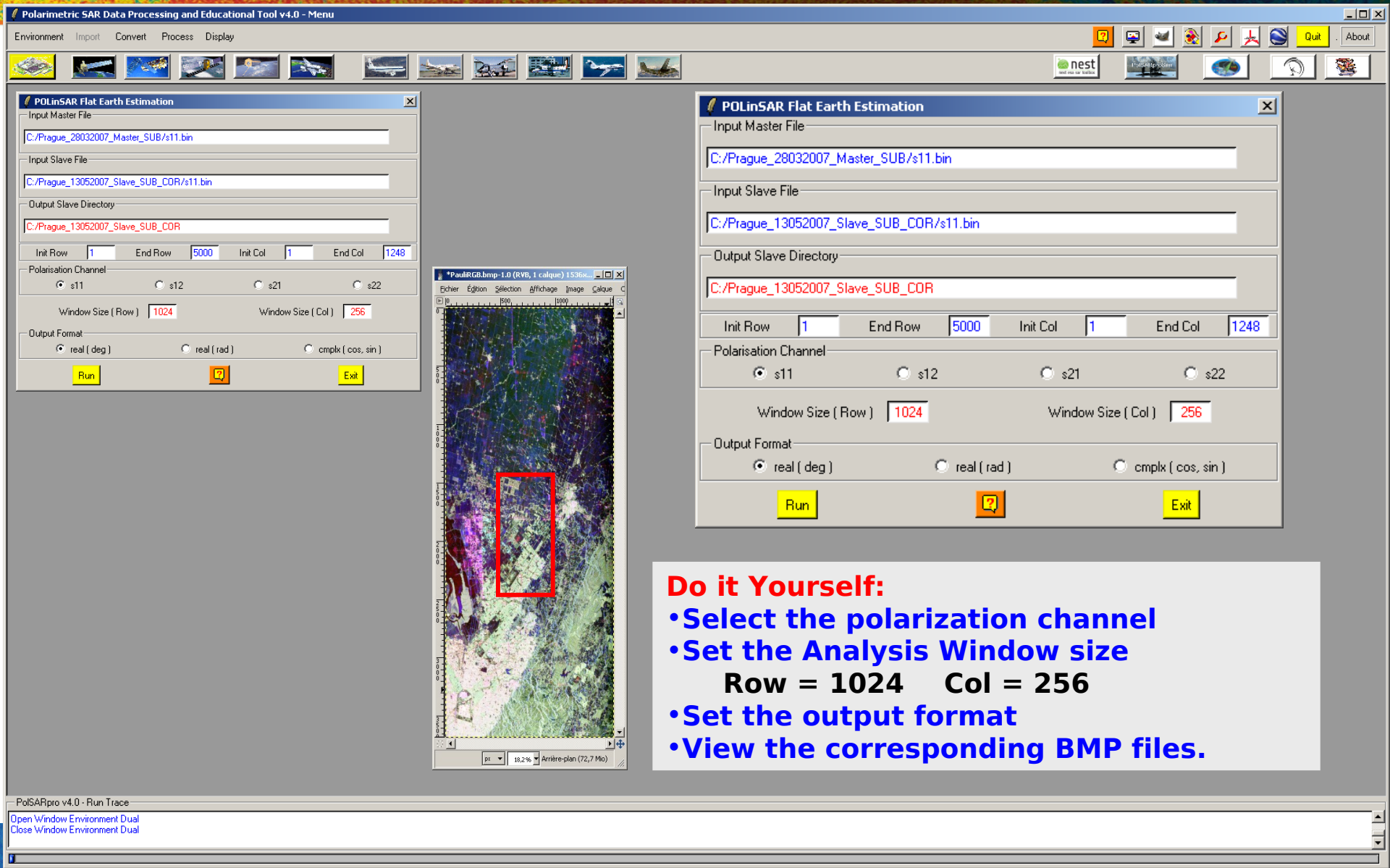
- Complex Coherence Estimation

PROCESS DATA - [S2] - MENU



SPECTRAL ESTIMATION

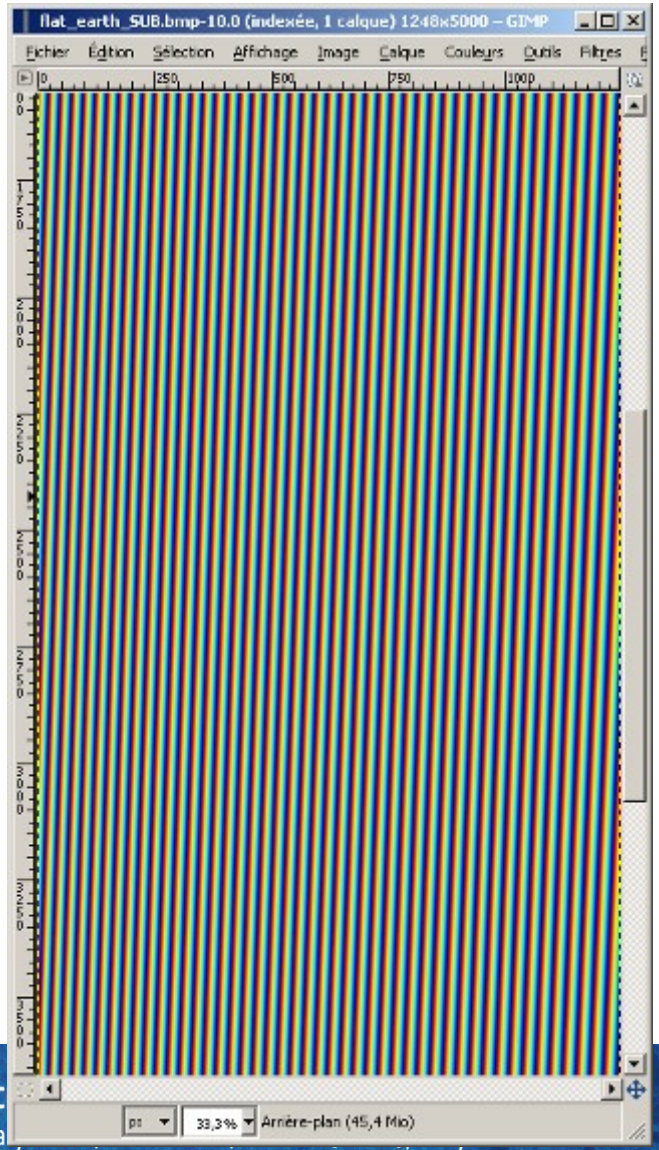


Do it Yourself:

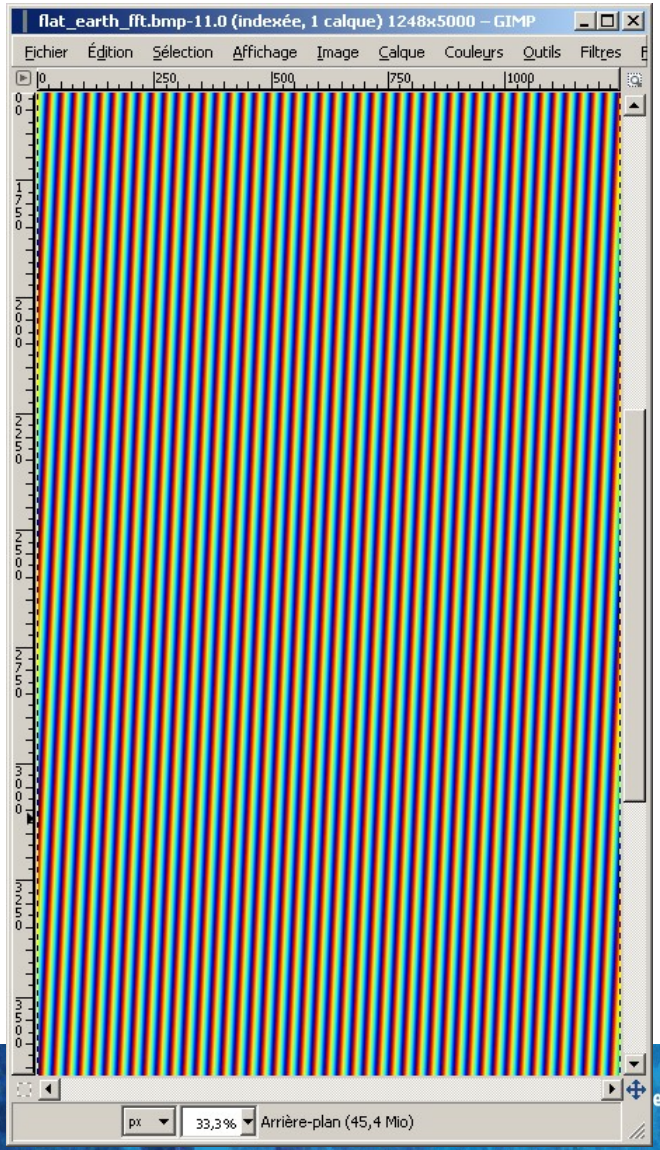
- **Select the polarization channel**
- **Set the Analysis Window size**
  Row = 1024 Col = 256
- **Set the output format**
- **View the corresponding BMP files.**

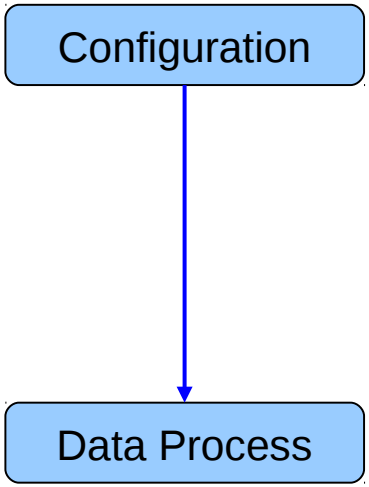
SPECTRAL ESTIMATION

Flat Earth



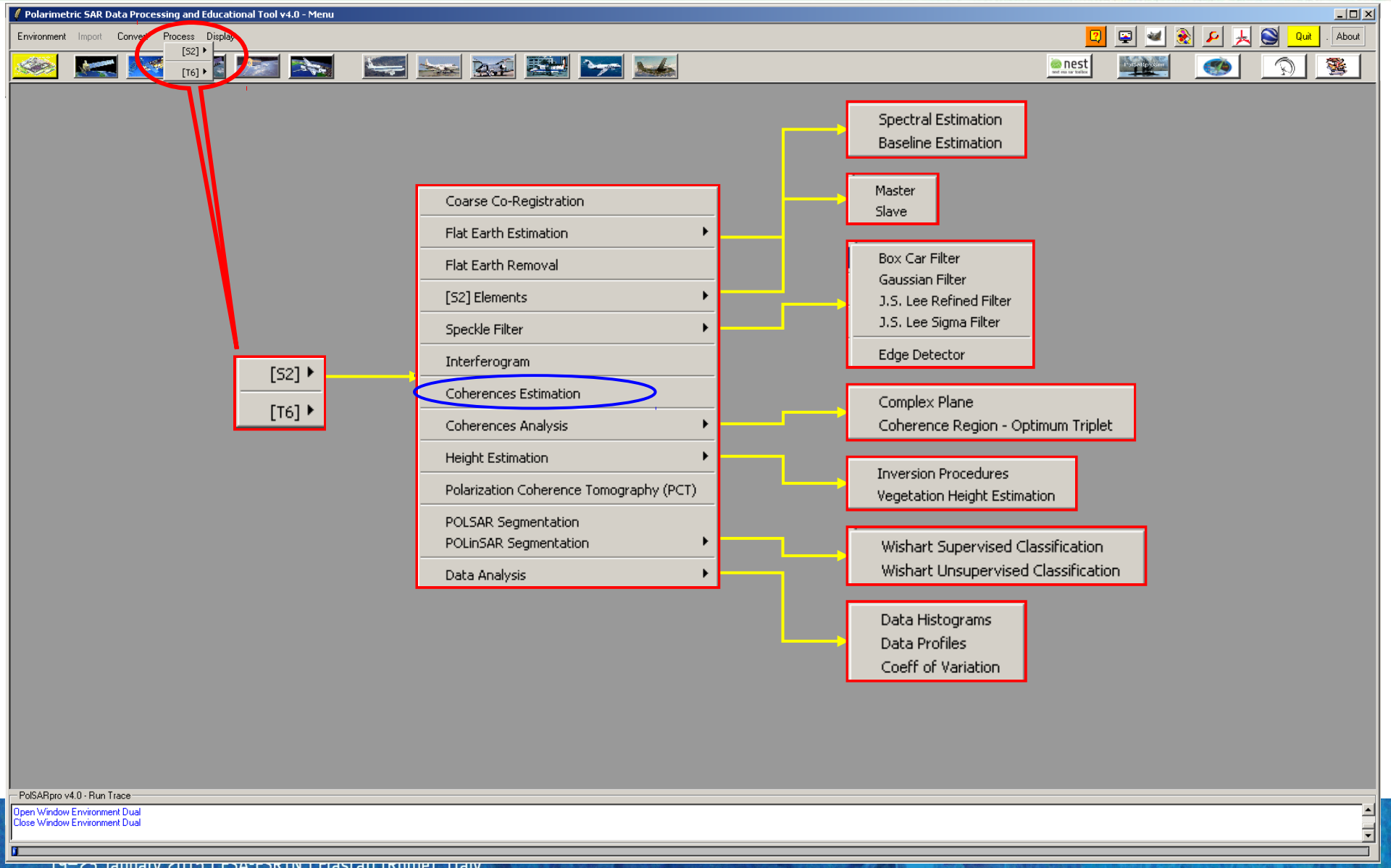
Flat Earth FFT



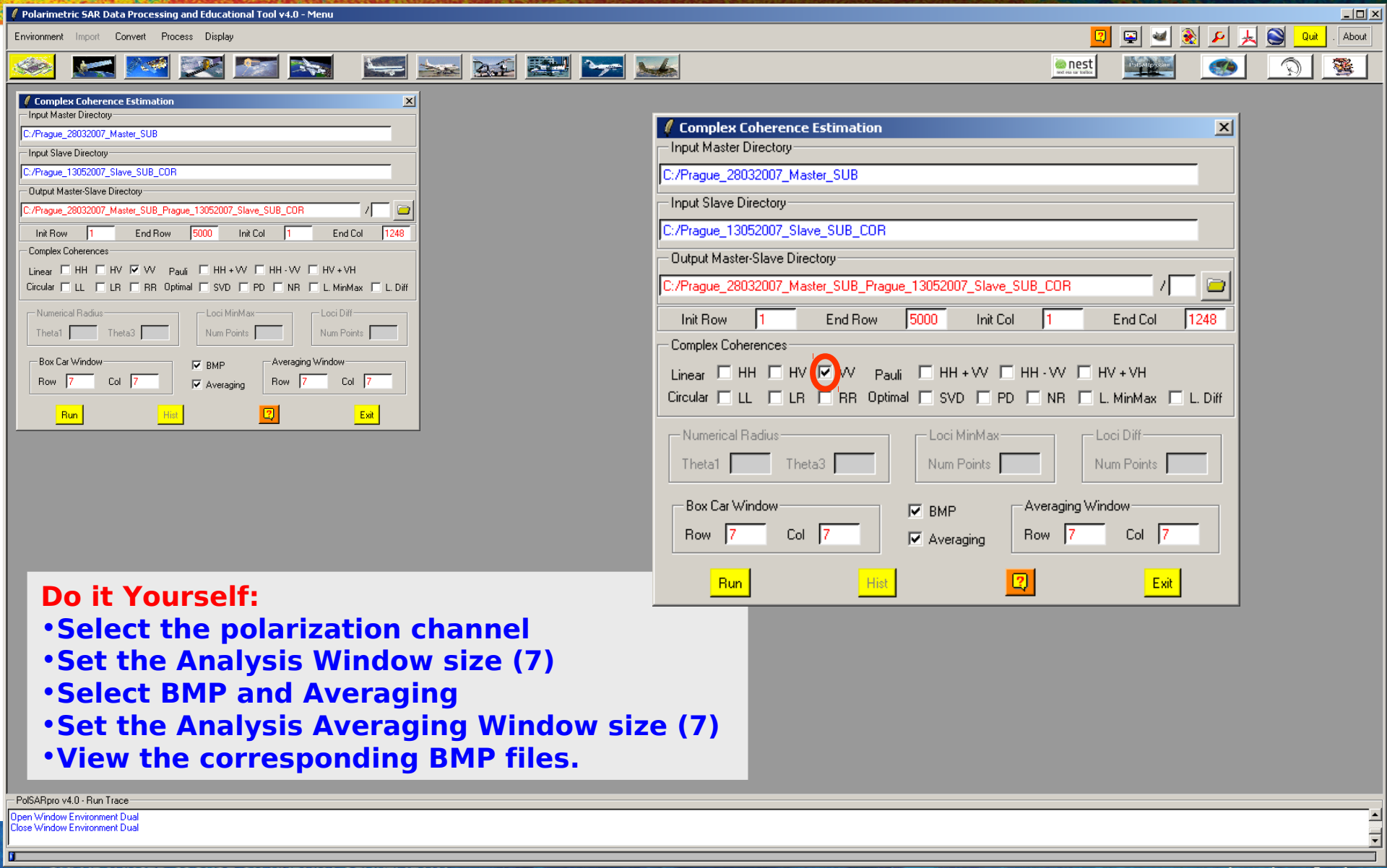


- Flat Earth Estimation – Baseline Estimation
- Flat Earth Estimation – Spectral Estimation
- Tools – Sub Data Extraction
- Complex Coherence Estimation
- Coarse Co-Registration
- Flat Earth Estimation – Spectral Estimation
- Complex Coherence Estimation
- Flat Earth Removal
- Complex Coherence Estimation

PROCESS DATA - [S2] - MENU



COMPLEX COHERENCE ESTIMATION



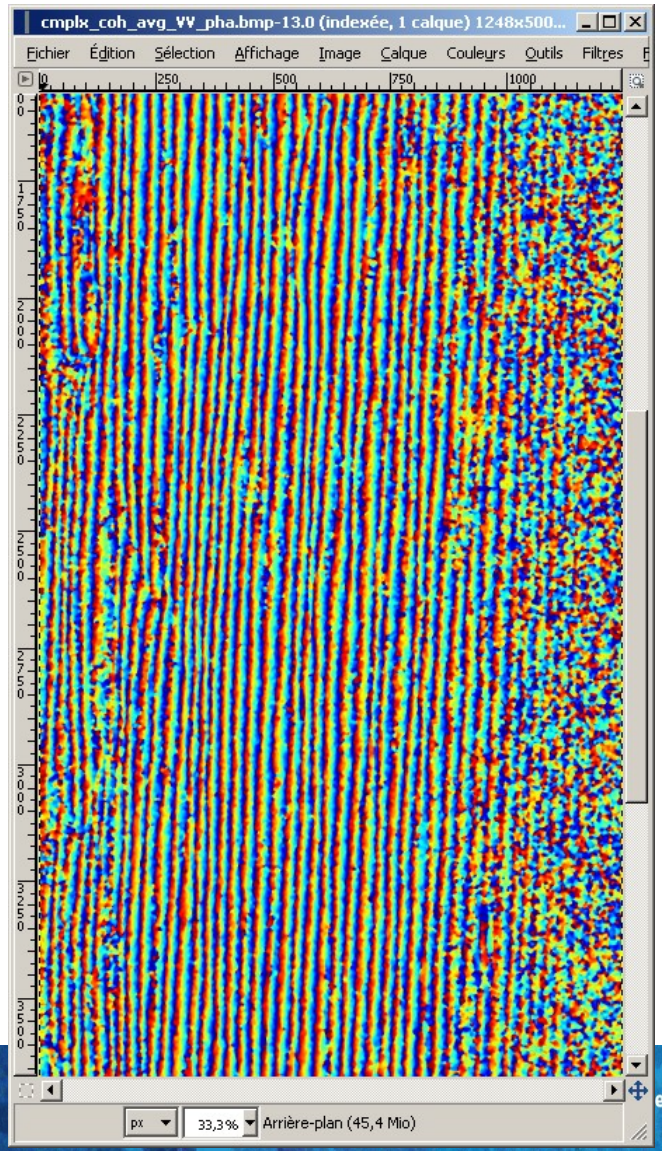
Do it Yourself:

- **Select the polarization channel**
- **Set the Analysis Window size (7)**
- **Select BMP and Averaging**
- **Set the Analysis Averaging Window size (7)**
- **View the corresponding BMP files.**

COMPLEX COHERENCE ESTIMATION

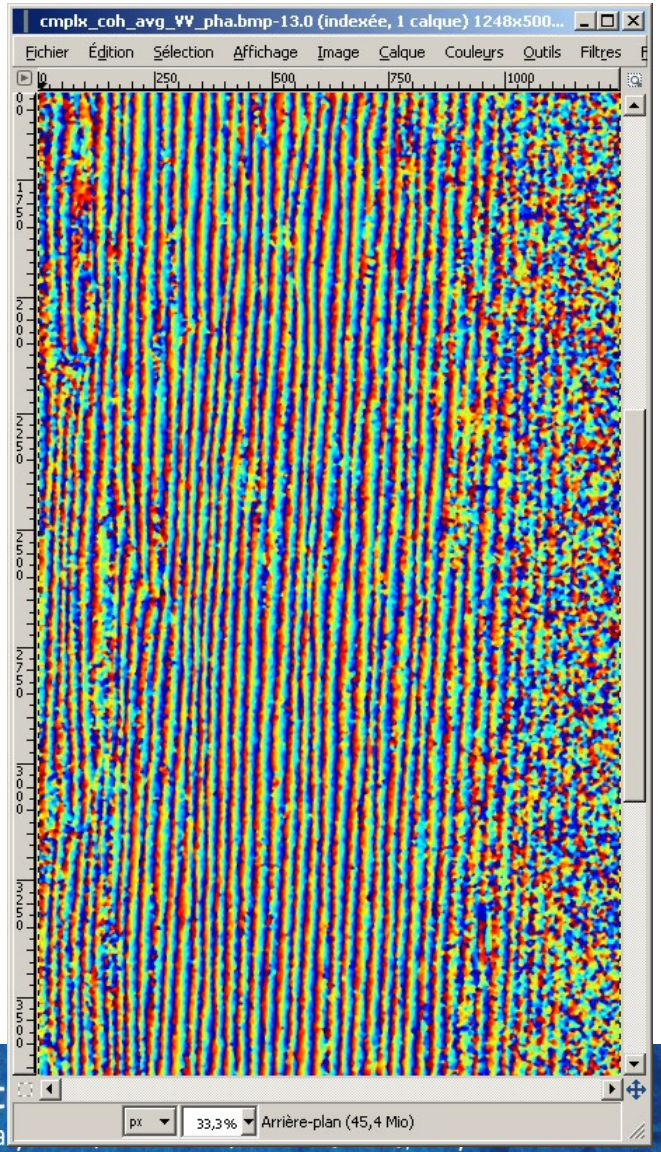
cmplx_coh_avg_VV_mod

cmplx_coh_avg_VV_pha

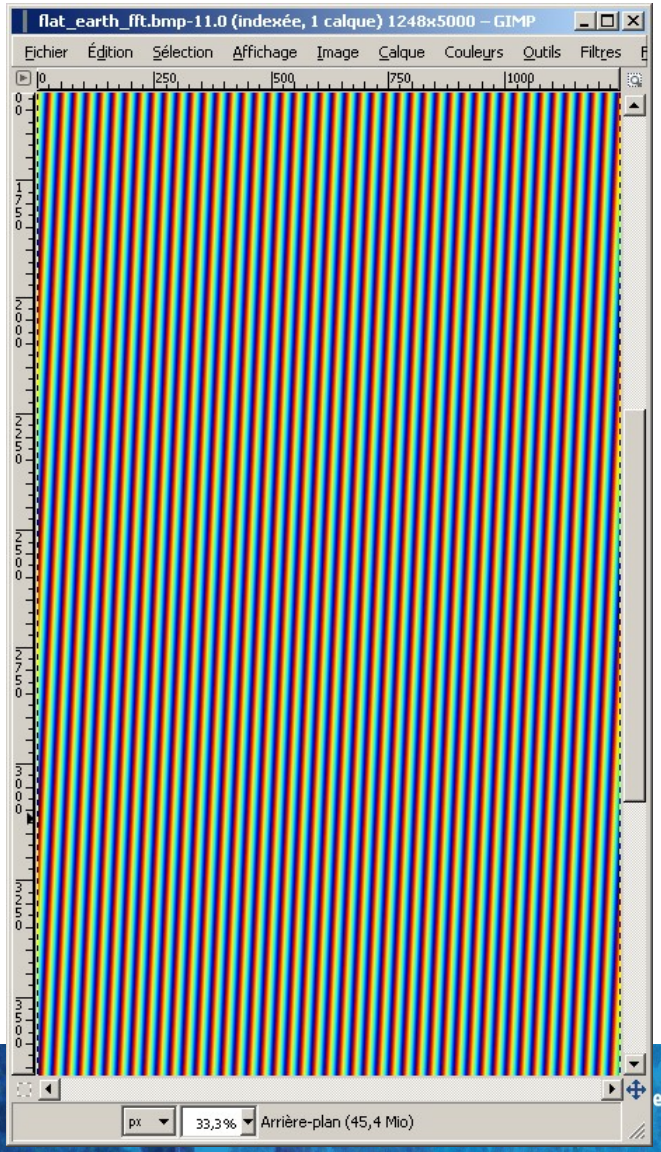


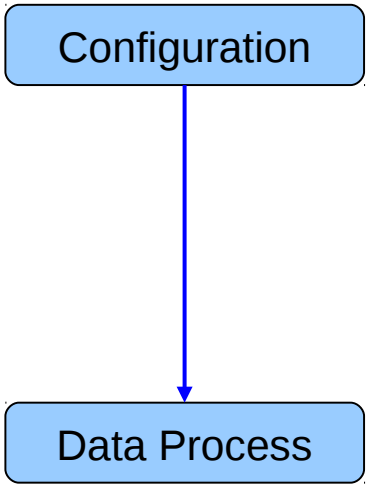
COMPLEX COHERENCE ESTIMATION

cmplx_coh_avg_VV_pha



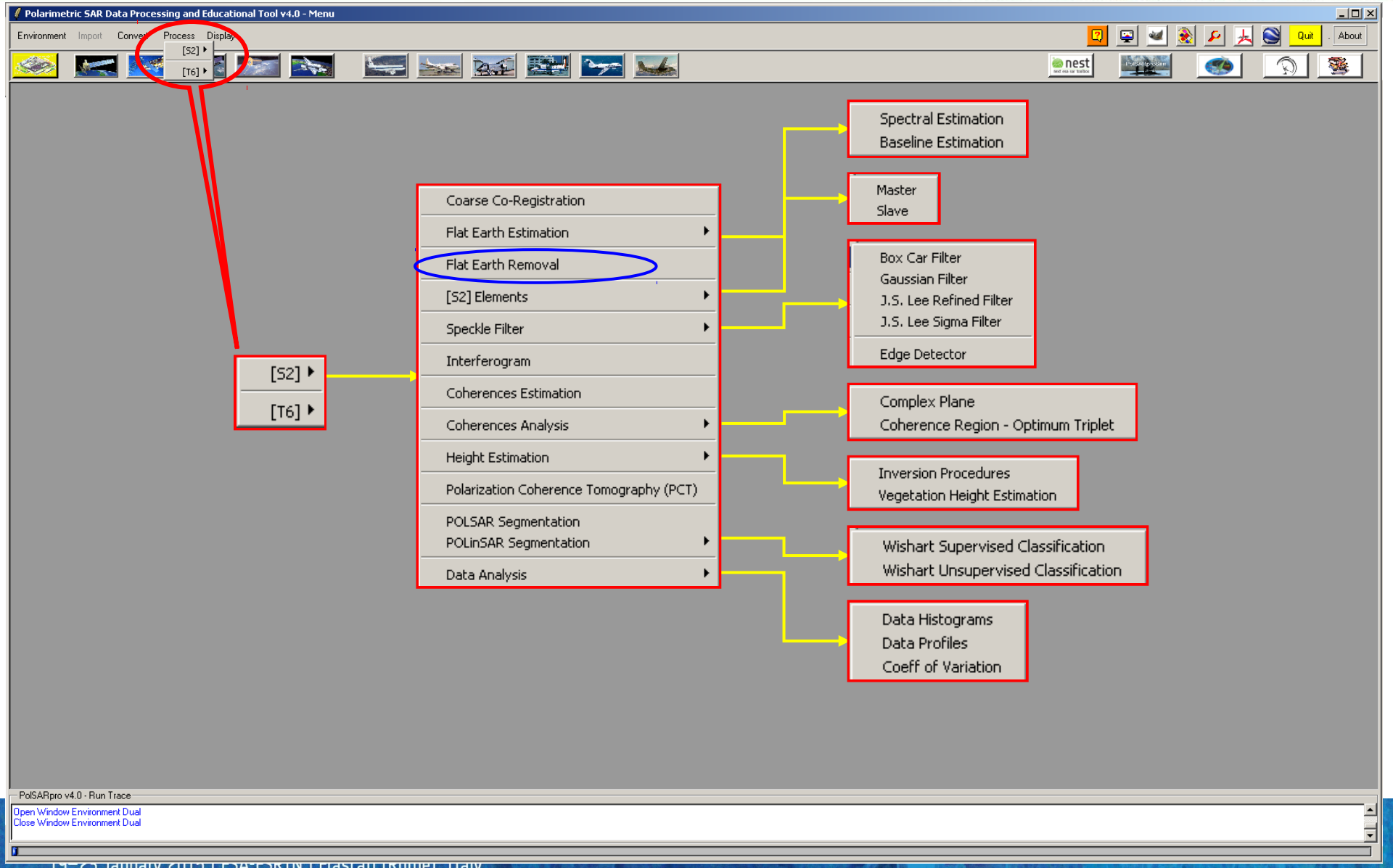
Flat Earth FFT



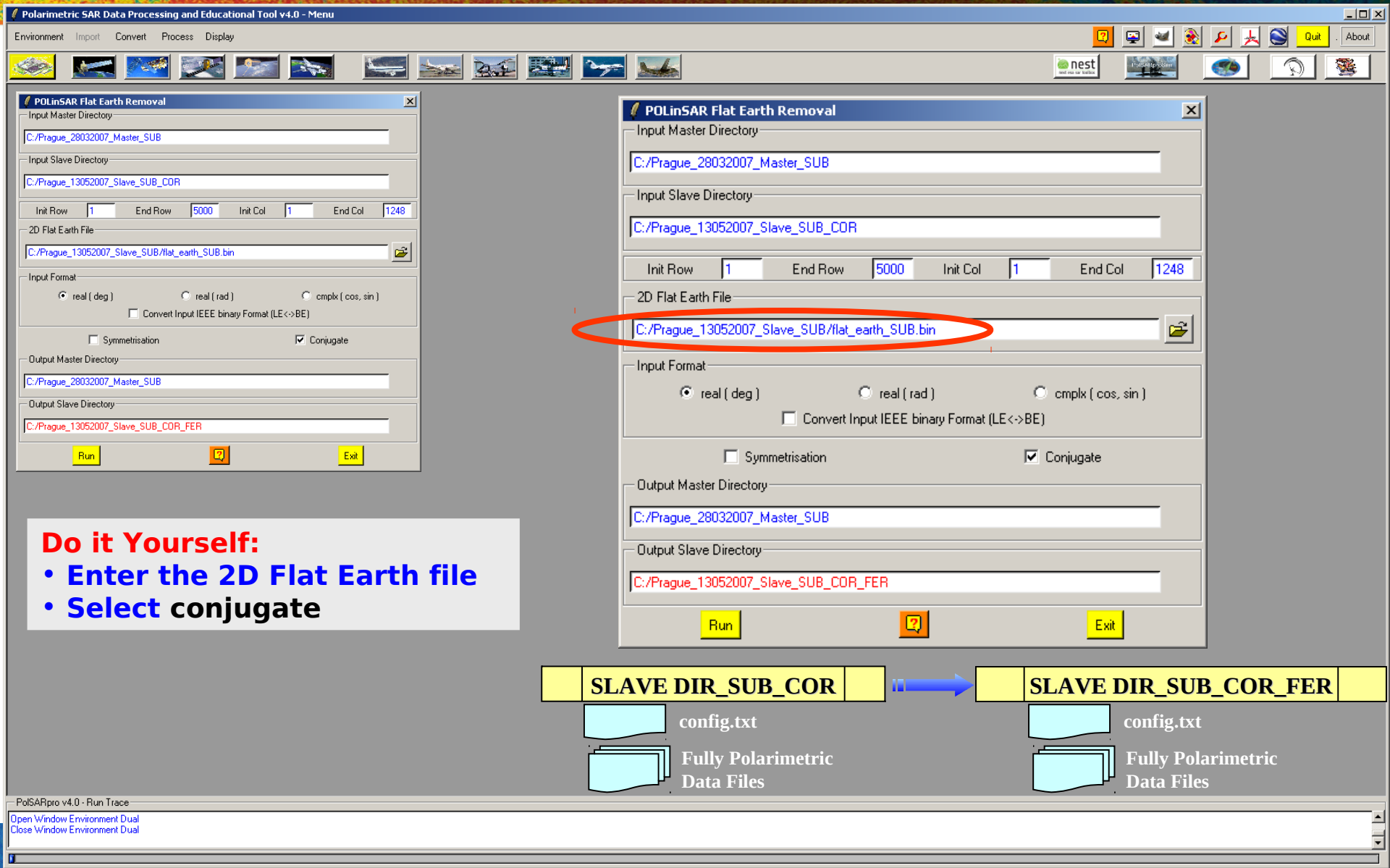


- Flat Earth Estimation – Baseline Estimation
- Flat Earth Estimation – Spectral Estimation
- Tools – Sub Data Extraction
- Complex Coherence Estimation
- Coarse Co-Registration
- Flat Earth Estimation – Spectral Estimation
- Complex Coherence Estimation
- Flat Earth Removal
- Complex Coherence Estimation

PROCESS DATA - [S2] - MENU



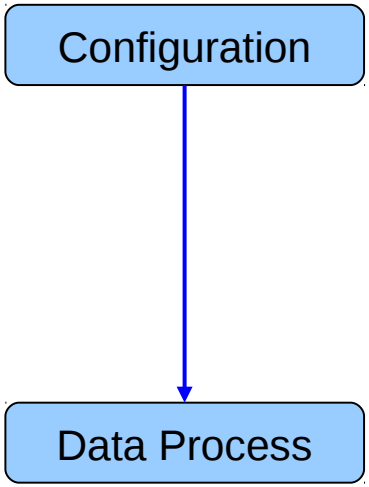
FLAT EARTH REMOVAL



Do it Yourself:

- **Enter the 2D Flat Earth file**
- **Select conjugate**

PROCESSING CHAIN



- Flat Earth Estimation – Baseline Estimation
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- Complex Coherence Estimation
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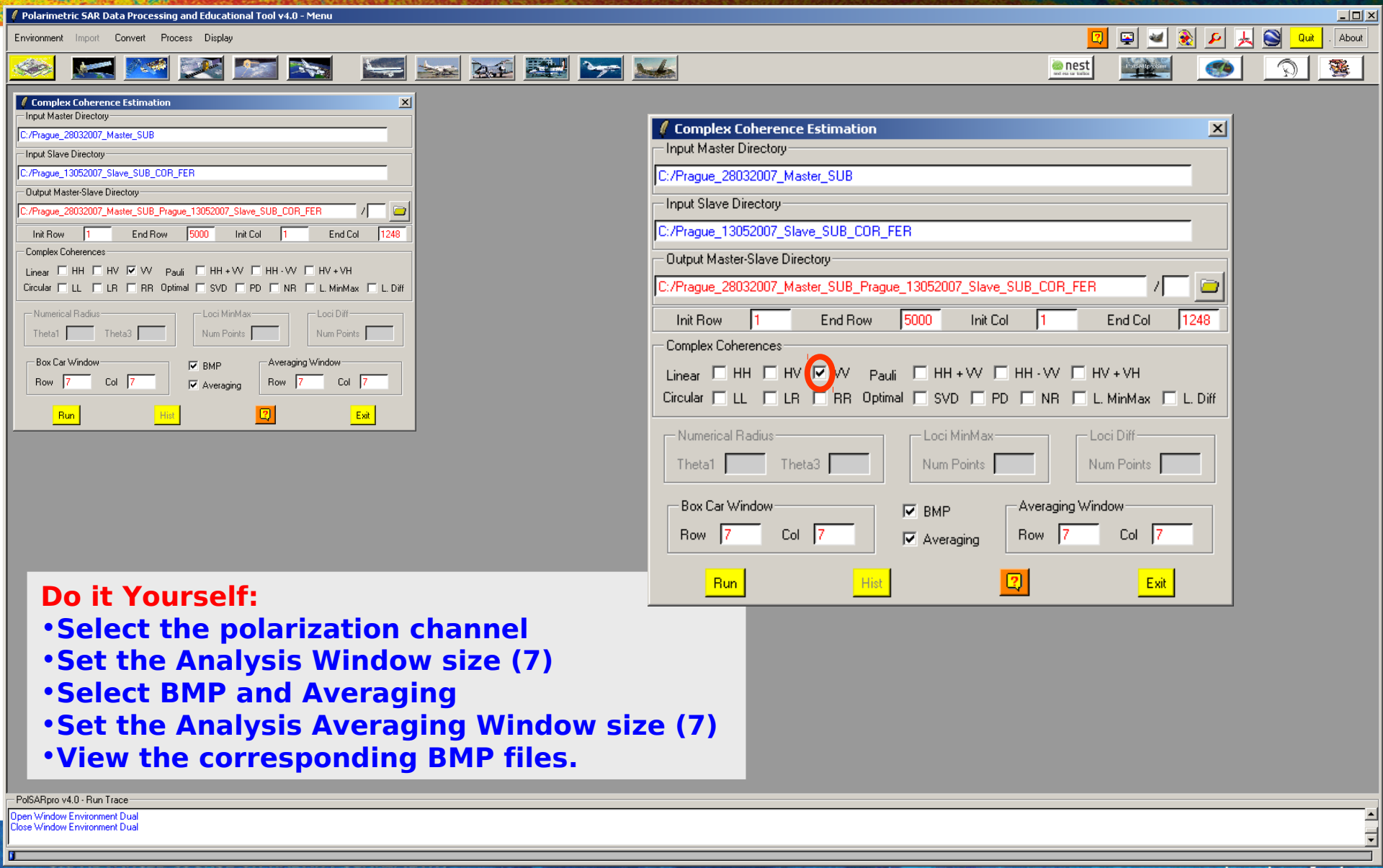
- Flat Earth Estimation – Spectral Estimation
- Complex Coherence Estimation
- Flat Earth Removal
- Complex Coherence Estimation

COMPLEX COHERENCE ESTIMATION



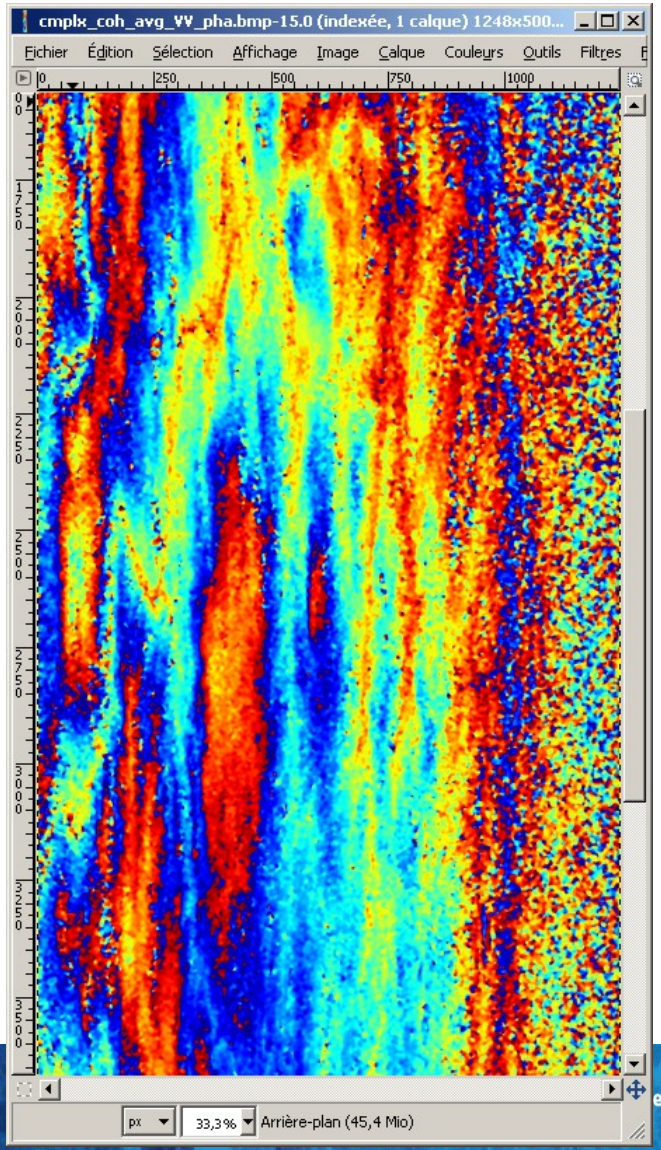
Do it Yourself:

- **Select the polarization channel**
- **Set the Analysis Window size (7)**
- **Select BMP and Averaging**
- **Set the Analysis Averaging Window size (7)**
- **View the corresponding BMP files.**

COMPLEX COHERENCE ESTIMATION

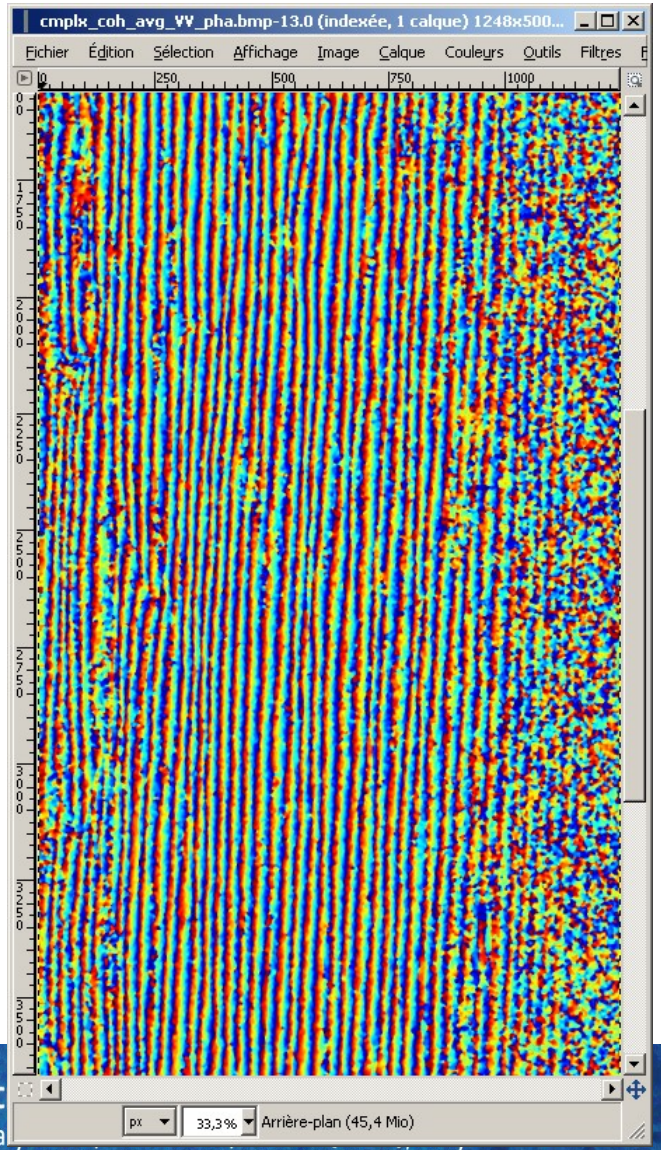
cmplx_coh_avg_VV_mod

cmplx_coh_avg_VV_pha

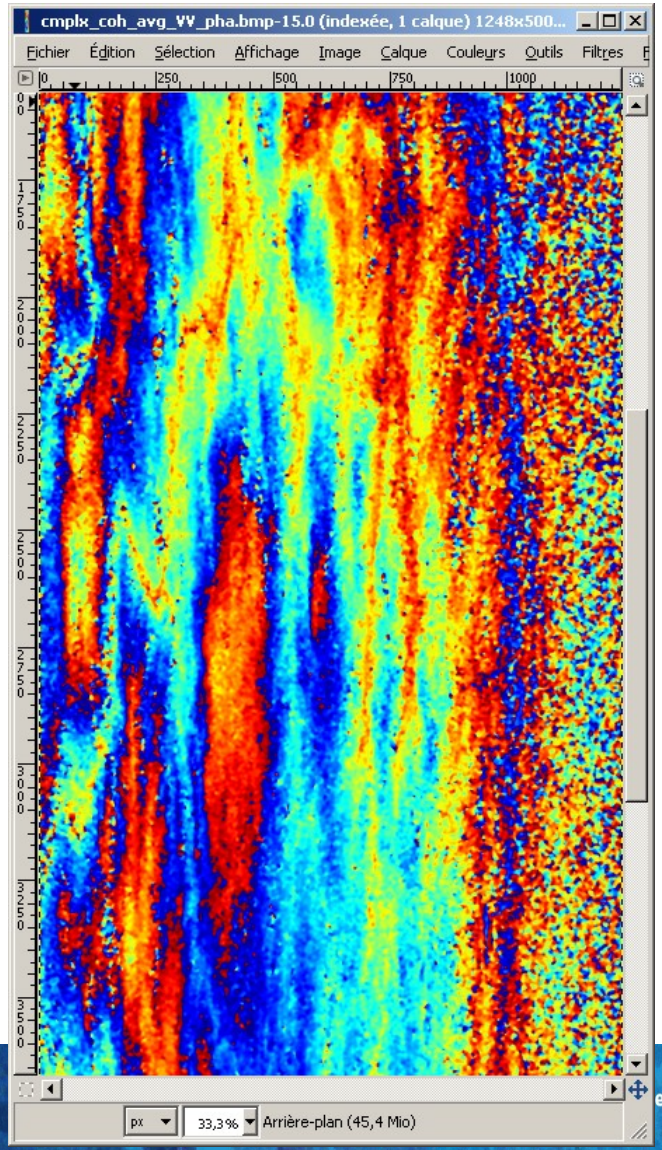


COMPLEX COHERENCE ESTIMATION

cmplx_coh_avg_VV_pha

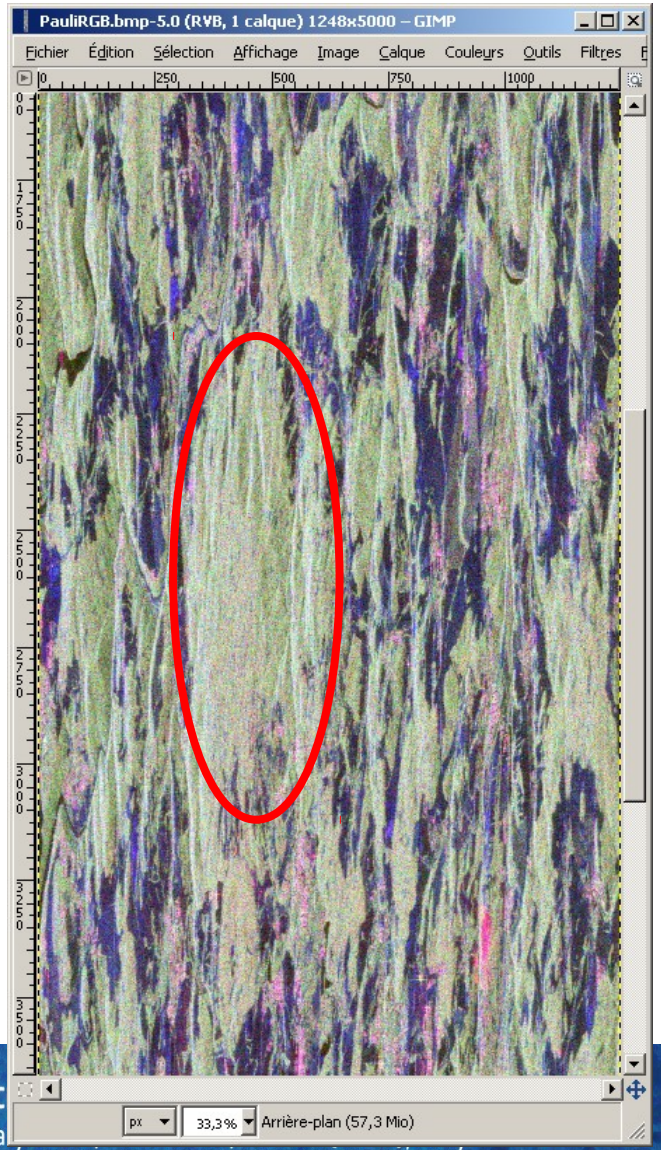


cmplx_coh_avg_VV_pha



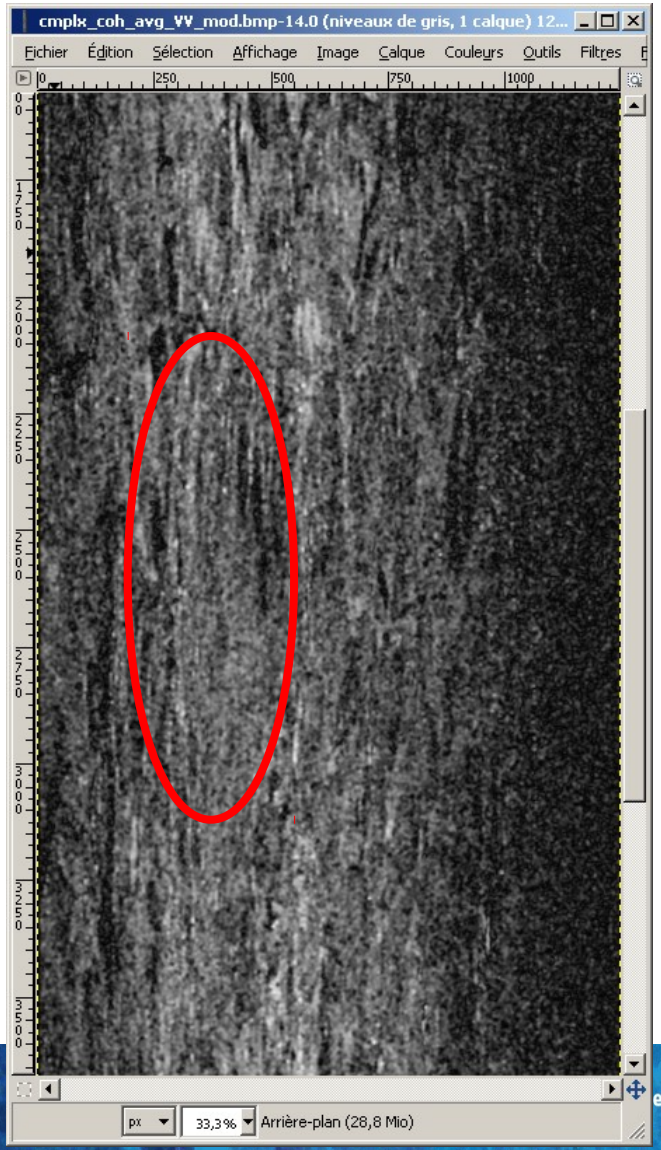
CONCLUSION

Master Pauli Image



?

cmplx_coh_avg_VV_mod



POLSAR IMAGES $I_1 = \underline{w}_1^{T*} \cdot \underline{k}_1$ **and** $I_2 = \underline{w}_2^{T*} \cdot \underline{k}_2$

With: $(\underline{w}_1, \underline{w}_2)$ **Complex Unitary Vectors**

$$\underline{w}_1^{T*} [\Omega_{12}] \underline{w}_2$$

$$\underline{w}_2^{T*} [T_2] \underline{w}_2$$

$$\underline{w}_1^{T*} [T_1] \underline{w}_1$$

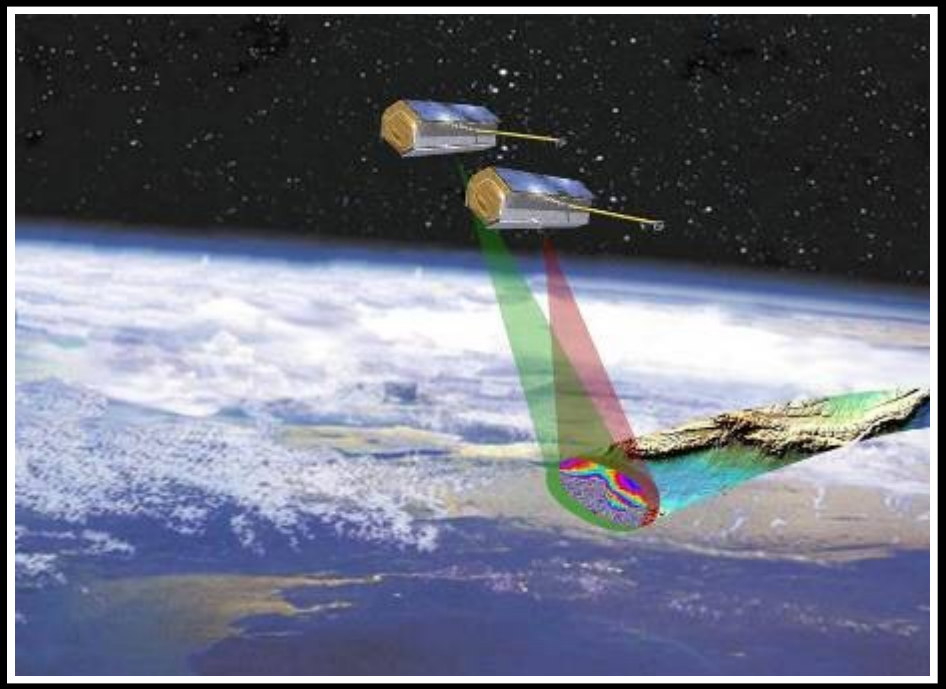
$$\gamma(\underline{w}_1, \underline{w}_2) = \frac{\langle I_1 I_2^* \rangle}{\sqrt{\langle I_1 I_1^* \rangle \langle I_2 I_2^* \rangle}} = |\gamma|$$

COMPLEX POLARIMETRIC INTERFEROMETRIC COHERENCE

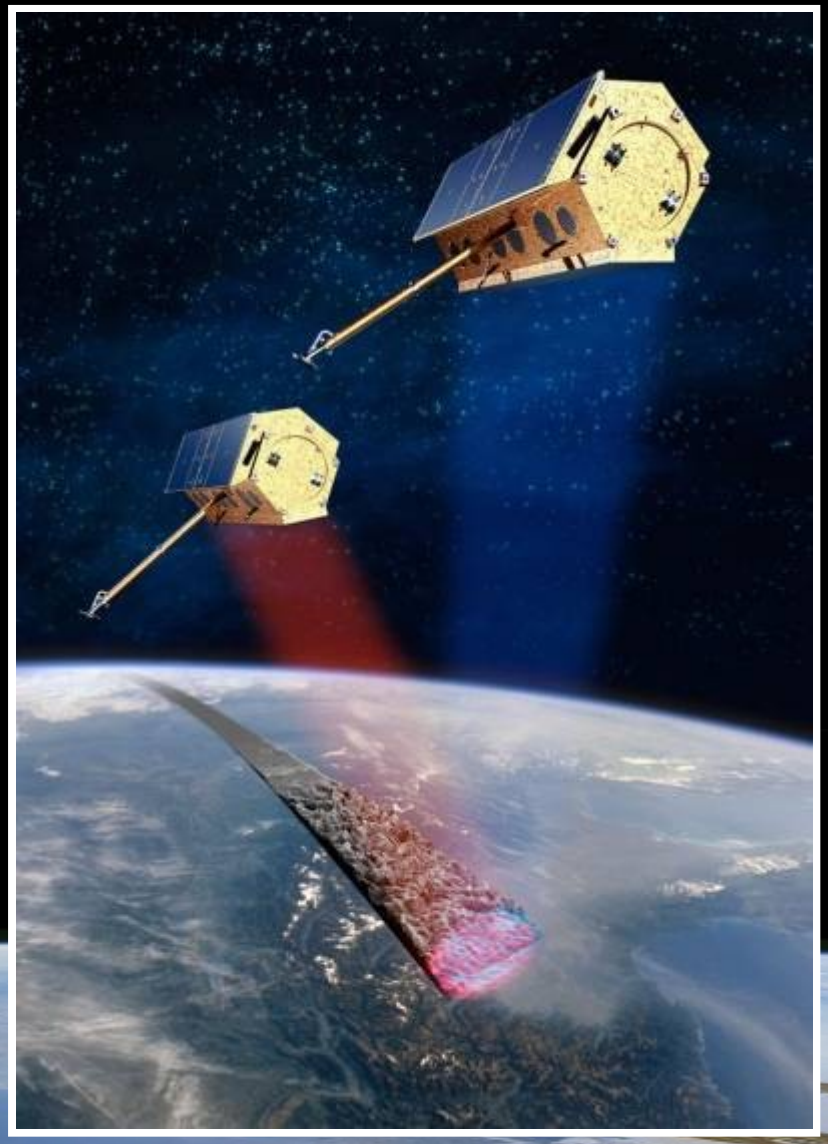
$$\gamma = \gamma_{SNR} \cdot \gamma_{spatial} \cdot \gamma_{temporal} \cdot \gamma_{polar}$$

46 days

TanDEM-X

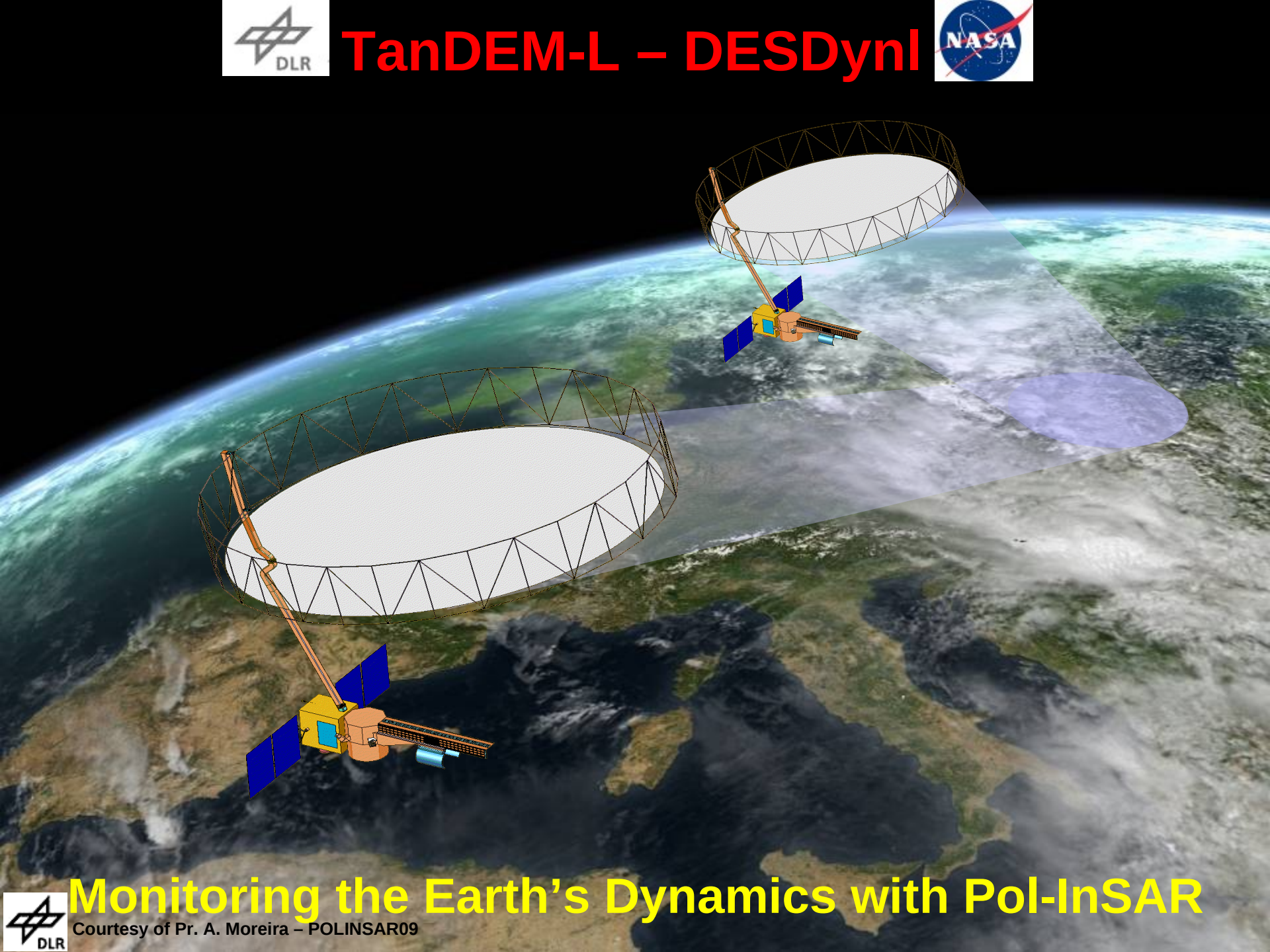


TerraSAR – X (1 & 2)
(2010)



Pol – InSAR Sensors

TanDEM-L – DESDynI



Monitoring the Earth's Dynamics with Pol-InSAR

Courtesy of Pr. A. Moreira – POLINSAR09

Questions ?