Introduction to

PolSARpro Toolbox

ESA-MOST Dragon 4 Cooperation

ADVANCED LAND REMOTE SENSING
INTERNATIONAL TRAINING COURSE

“龙计划4”高级陆地遥感国际培训班

Eric POTTIER

University of Rennes 1 - France

20-25 November 2017 | Yunnan Normal University
Kunming, Yunnan Province, P.R. China

2017年11月20日——11月25日
云南师范大学，中国, 昆明

A Bit Of History

CONTEXT

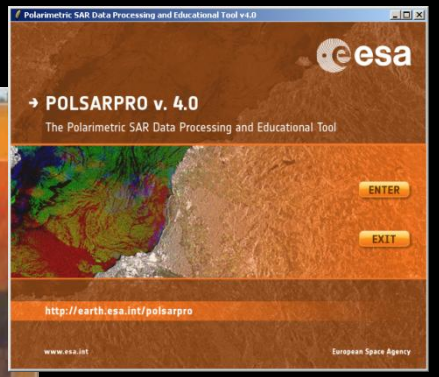
The initiative development of PolSARpro Software is a direct result of recommendations made during the POLinSAR 2003 Workshop held at ESA-ESRIN in January 2003.

2003

2004

2005

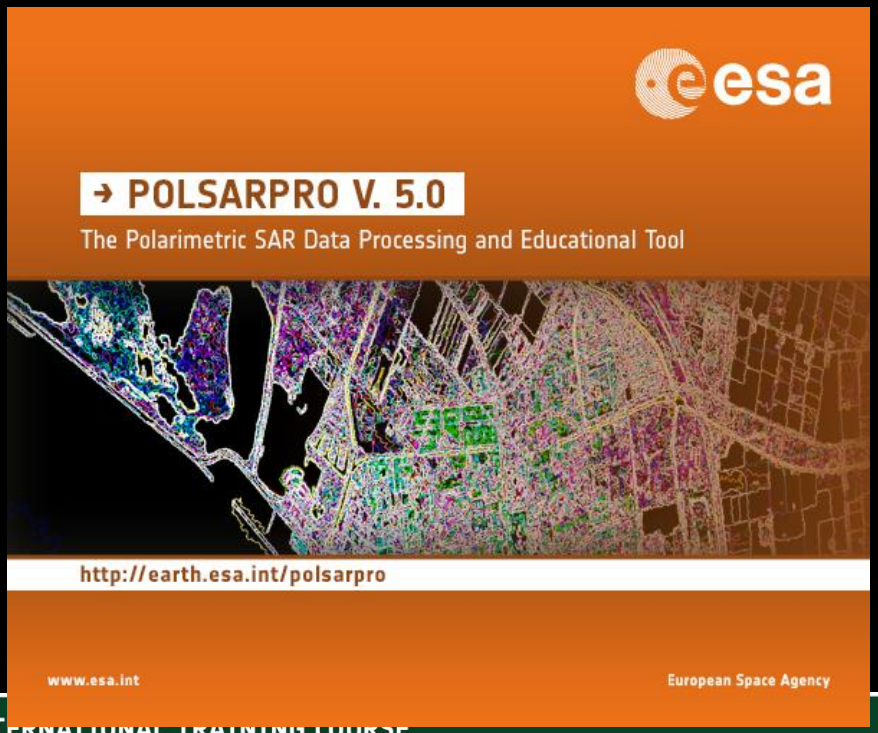
2007



2009

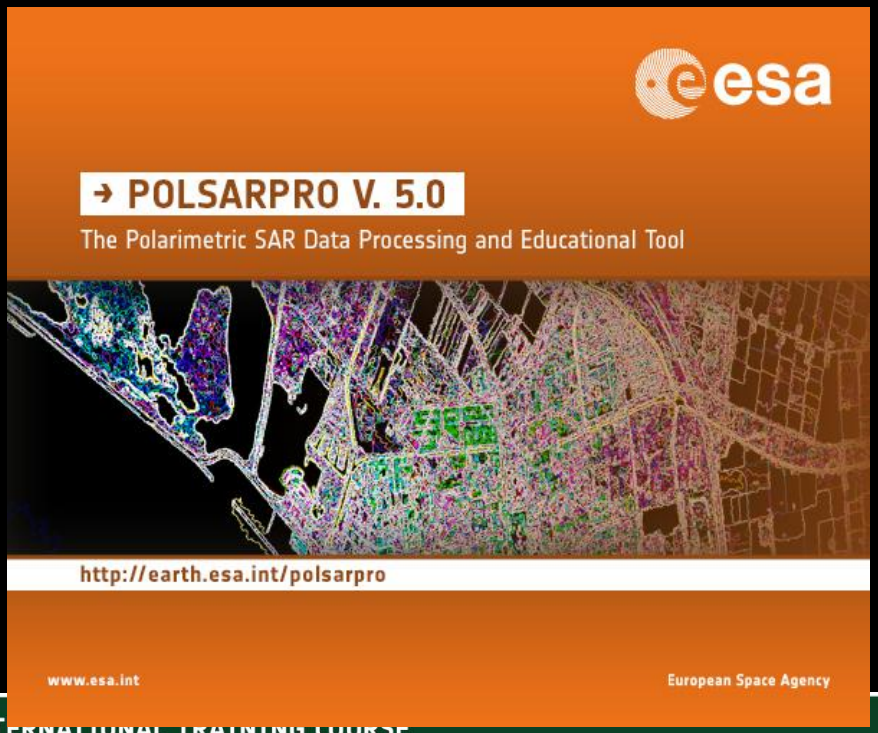
PolSARpro v5.1 SOFTWARE

Tool specifically designed to handle :
Polarimetric data
and
Polarimetric Interferometric data.



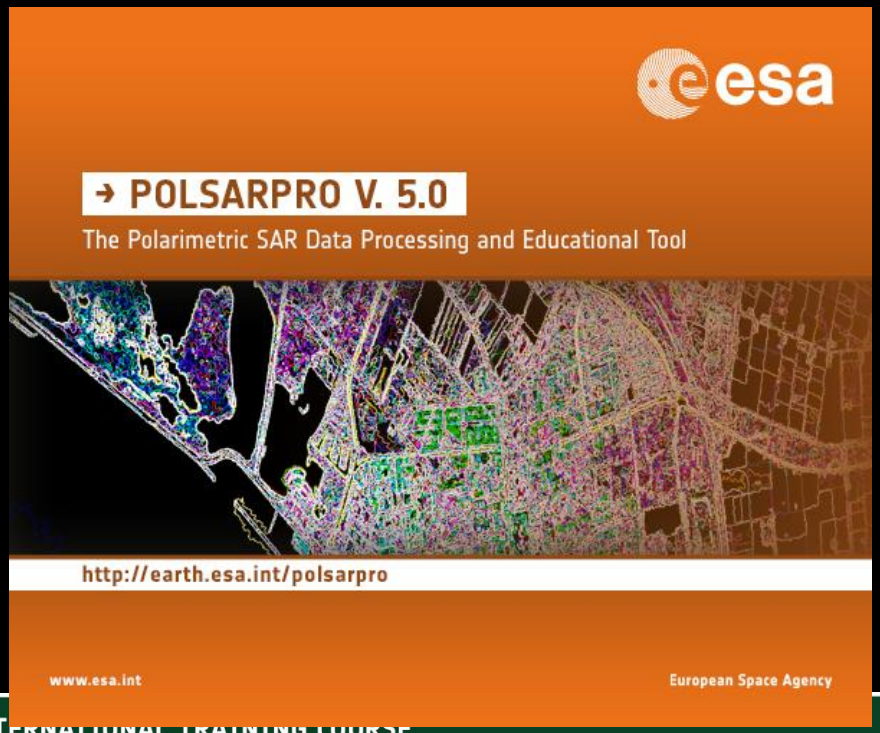
PolSARpro v5.1 SOFTWARE

Educational Software offering a tool for **self-education** in the field of **POLSAR** and **POL-InSAR** data processing and analysis.



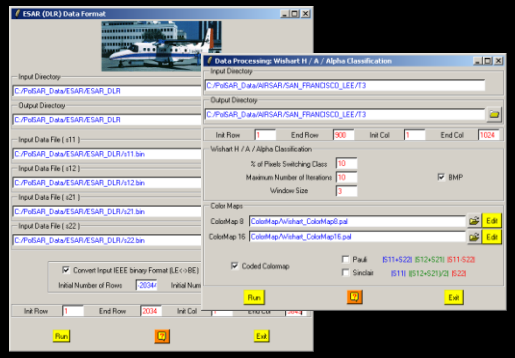
PolSARpro v5.1 SOFTWARE

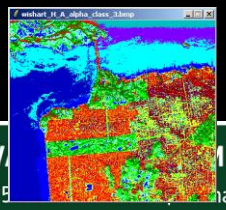
Developed to be accessible to :
a wide range of users
from novices to experts
in the field of POLSAR and POL-InSAR.



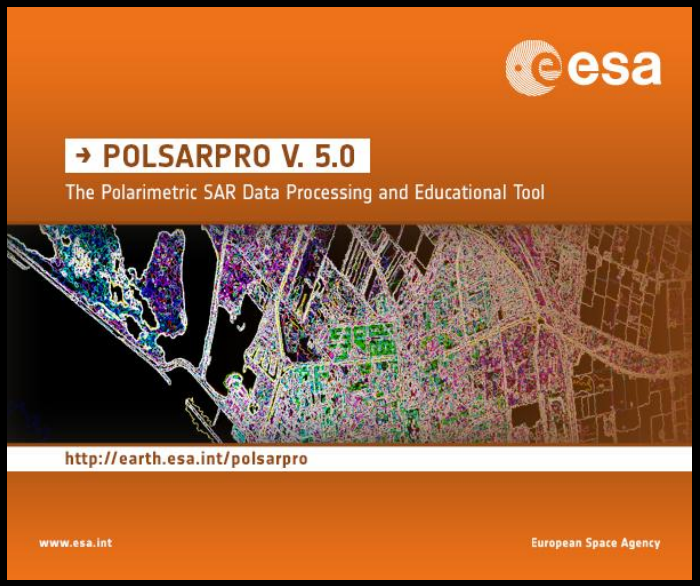
PolSARpro v5.1 SOFTWARE

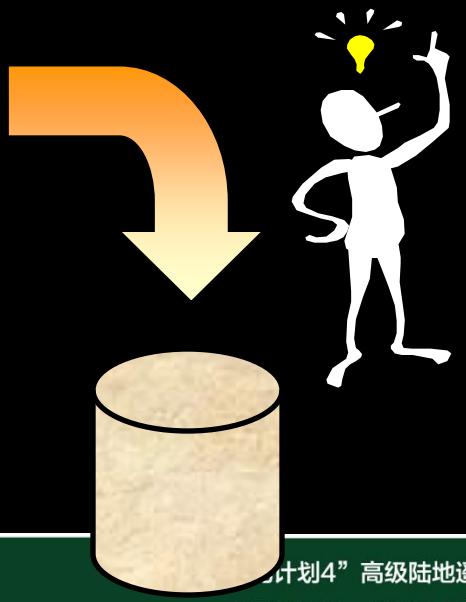
MODULAR STRUCTURE



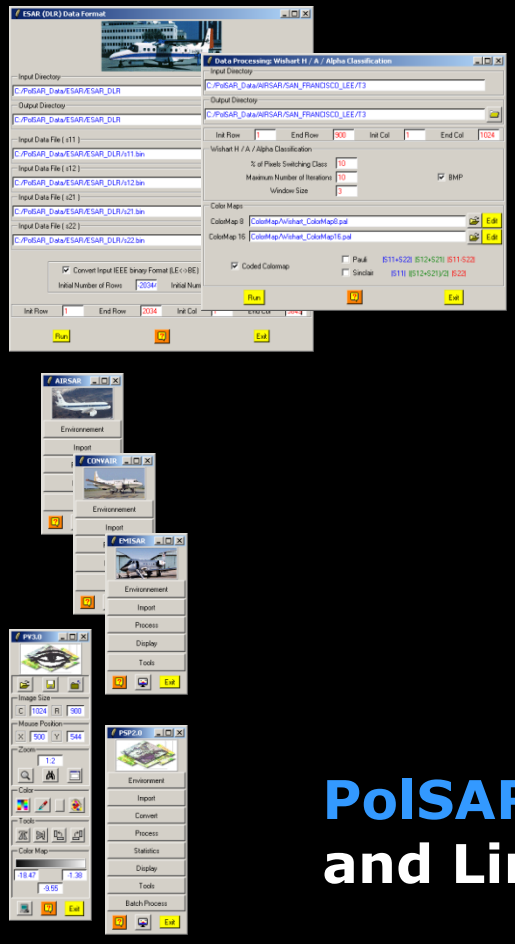


Each element of the Software (a function) can be extracted and incorporated individually into users' own processing software.





PolSARpro v5.1 SOFTWARE



OPEN SOURCE DEVELOPMENT

PolSARpro v5.1 Software is made available following the:

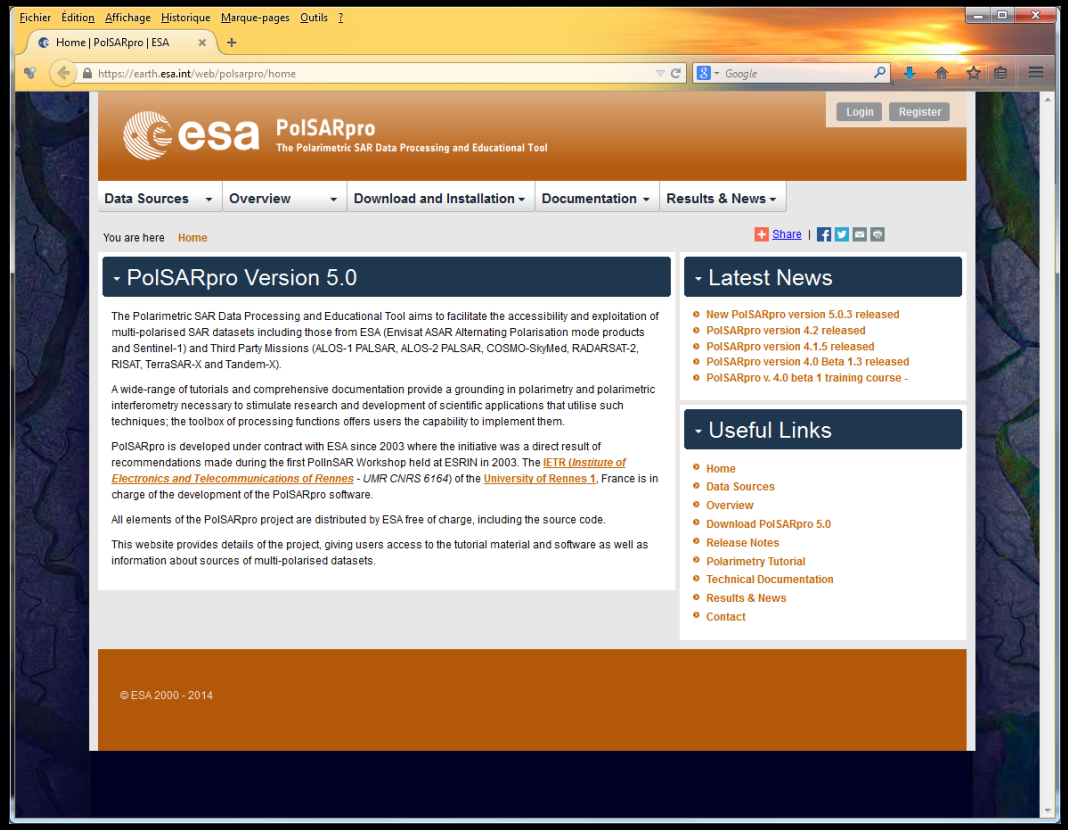
Open Source Software Development (OSSD) approach, and follows the:

GNU General Public License v2 – June 1991.

PolSARpro v5.1 Software runs today on Windows and Linux platforms

PolSARpro v5.1 SOFTWARE

http://earth.esa.int/web/polsarpro/home



The Web Site provides

- Details of the project
- Access to the tutorial and software
- Information about status of the development
- Demonstration Sample Datasets

New! **v5.1 (January 2017)**

Team & Contributors

International Collaborative Project

14 Universities

14 Research Centers

4 Space Agencies

Team & Contributors

Tsinghua University China

National Space Science Center, CAS, China

University of Mining and Technology, China

Fudan University, China

Wuhan University, China

Studies in Resources Engineering Indian Institute of Technology

Satellite Surveying and Mapping Application Center, China

Universidade Federal de Alagoas Brazil

Xidian University, China

University of Science and Technology, Poland

Harbin Institute of Technology China

University of Tehran, School of Surveying and Geospatial Engineering, Iran

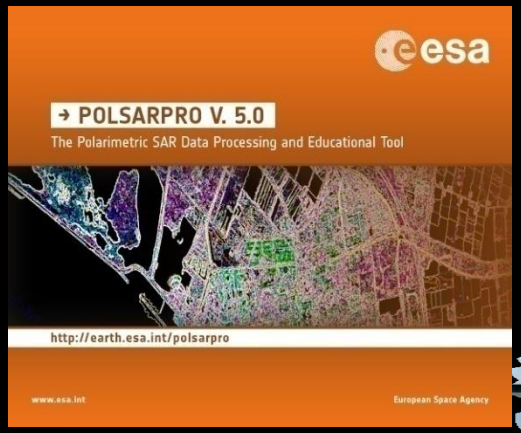
Key Lab of Microwave Remote Sensing, CAS, China

Khajeh Nasir Toosi University of Technology, Iran

PolSARpro v5.1 SOFTWARE

Dual-Pol / Quad-Pol Sensors

PolSARpro v5.1 SOFTWARE



AIRSAR

SETHI

DCRS

EMISAR

PISAR

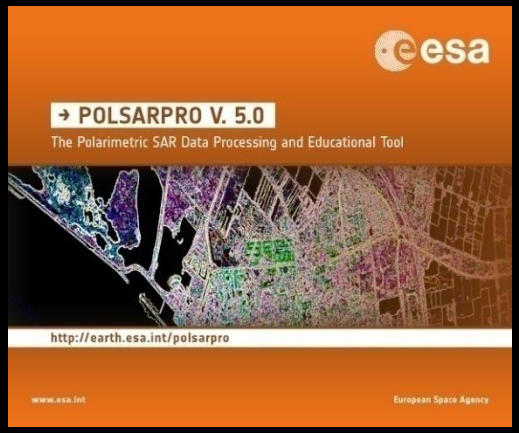
ESAR - FSAR

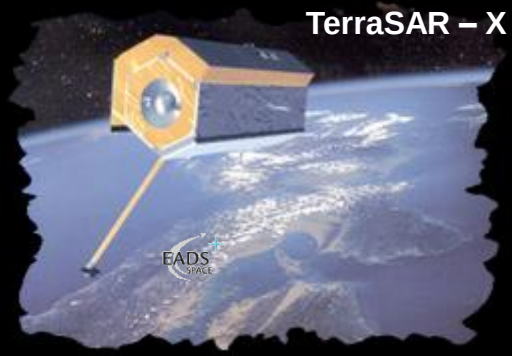
CONVAIR

UAV-SAR

PolSARpro v5.1 Software offers the possibility to handle and convert polarimetric data from a range of well established polarimetric airborne platforms.

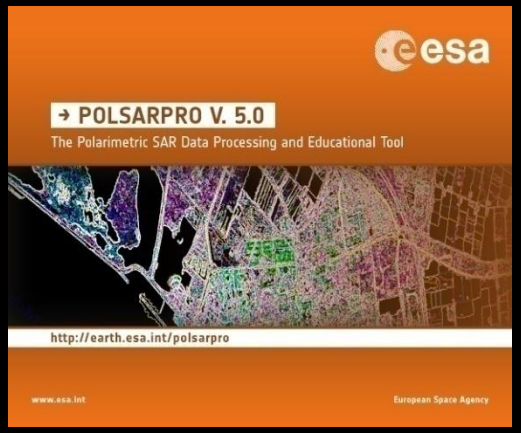
PolSARpro v5.1 SOFTWARE



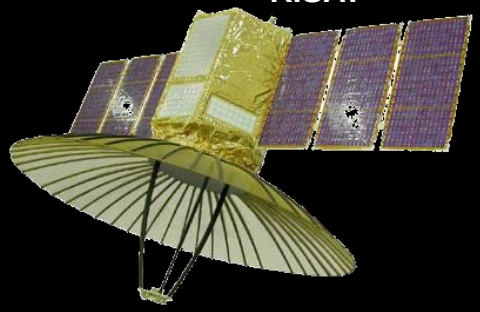


PolSARpro v5.1 Software offers the possibility to handle and convert polarimetric data from a range of well established polarimetric spaceborne platforms.

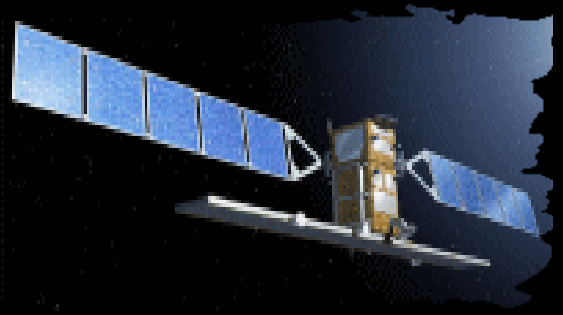
PolSARpro v5.1 SOFTWARE



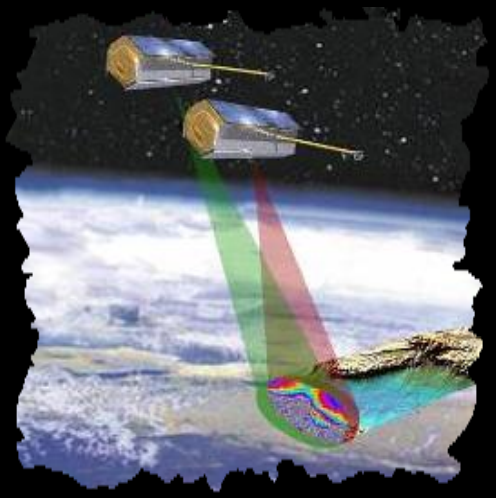
RISAT



SENTINEL 1A

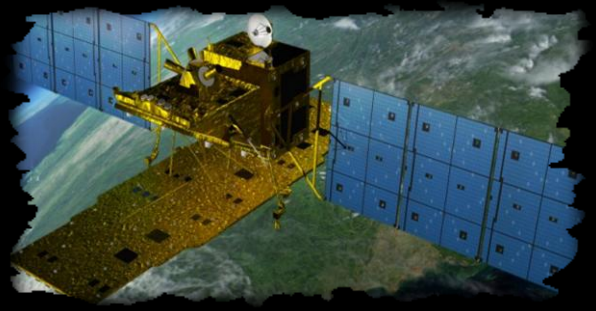


TANDEM-X



COSMO - SKYMED

ALOS-2 – PALSAR



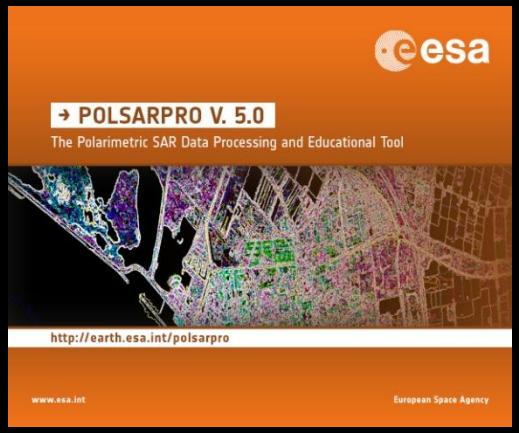
PolSARpro v5.1 Software offers the possibility to handle and convert polarimetric data from a range of well established polarimetric spaceborne platforms.

PolSARpro v5.1 SOFTWARE

External Softwares

PolSARpro v5.1 SOFTWARE

ESA - SNAP



Polariametric Data Processing

- S1 toolbox (split, deburst, merge …)
- Geocoding toolbox
- Interferometric toolbox
  (co-registration, flat Earth estimation …

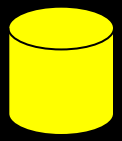
PolSARpro v5.1 SOFTWARE

ESA - SNAP

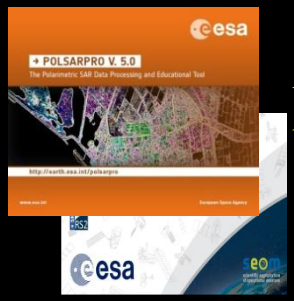
Pre-Processing
Data Extract

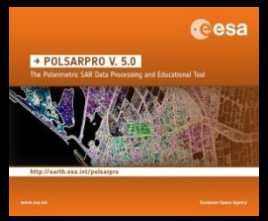
Post-Processing

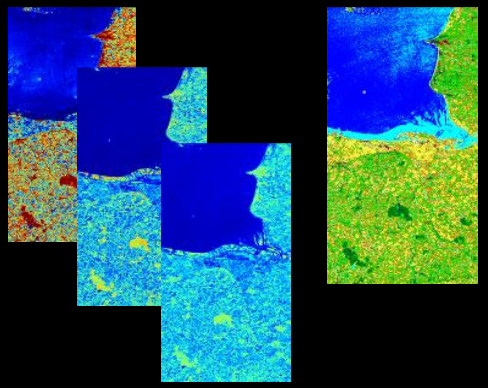
Geo-Coding



POLARIMETRIC DATA SETS

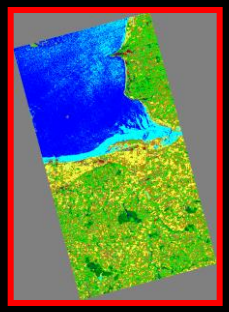






Speckle Filtering
Polar. Decomposition
Unsupervised Segmentation

Terrain Correct
UTM Projection



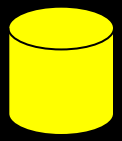
KML File generation

ESA - SNAP

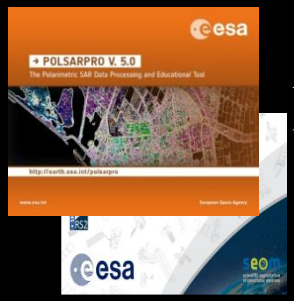
Pre-Processing
Data Extract

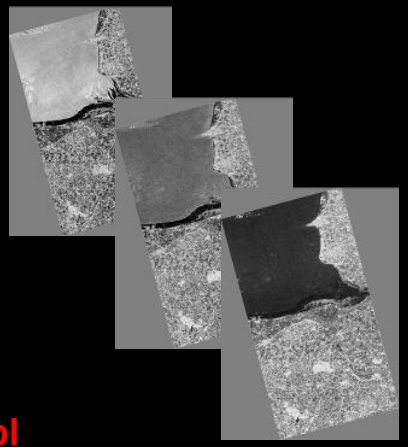
Geo-Coding
Terrain Correct - UTM Proj.

Post - Processing

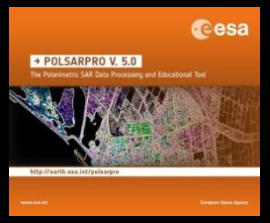


POLARIMETRIC DATA SETS





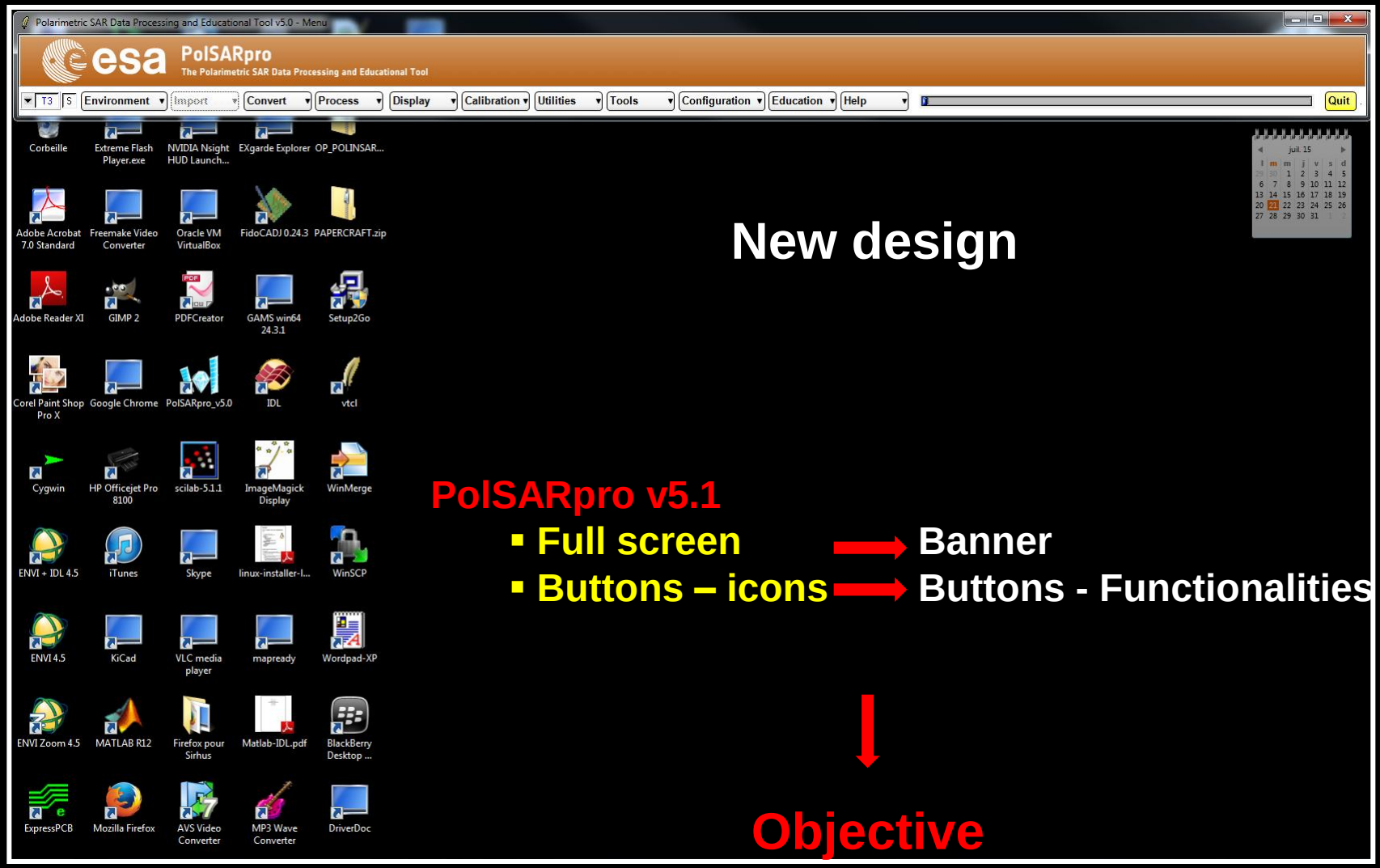
Only valid for:
[C2] matrix: Dual-Pol
[T3] matrix: Quad-Pol



KML File generation

Software – General Presentation

PolSARpro v5.1 SOFTWARE



New design

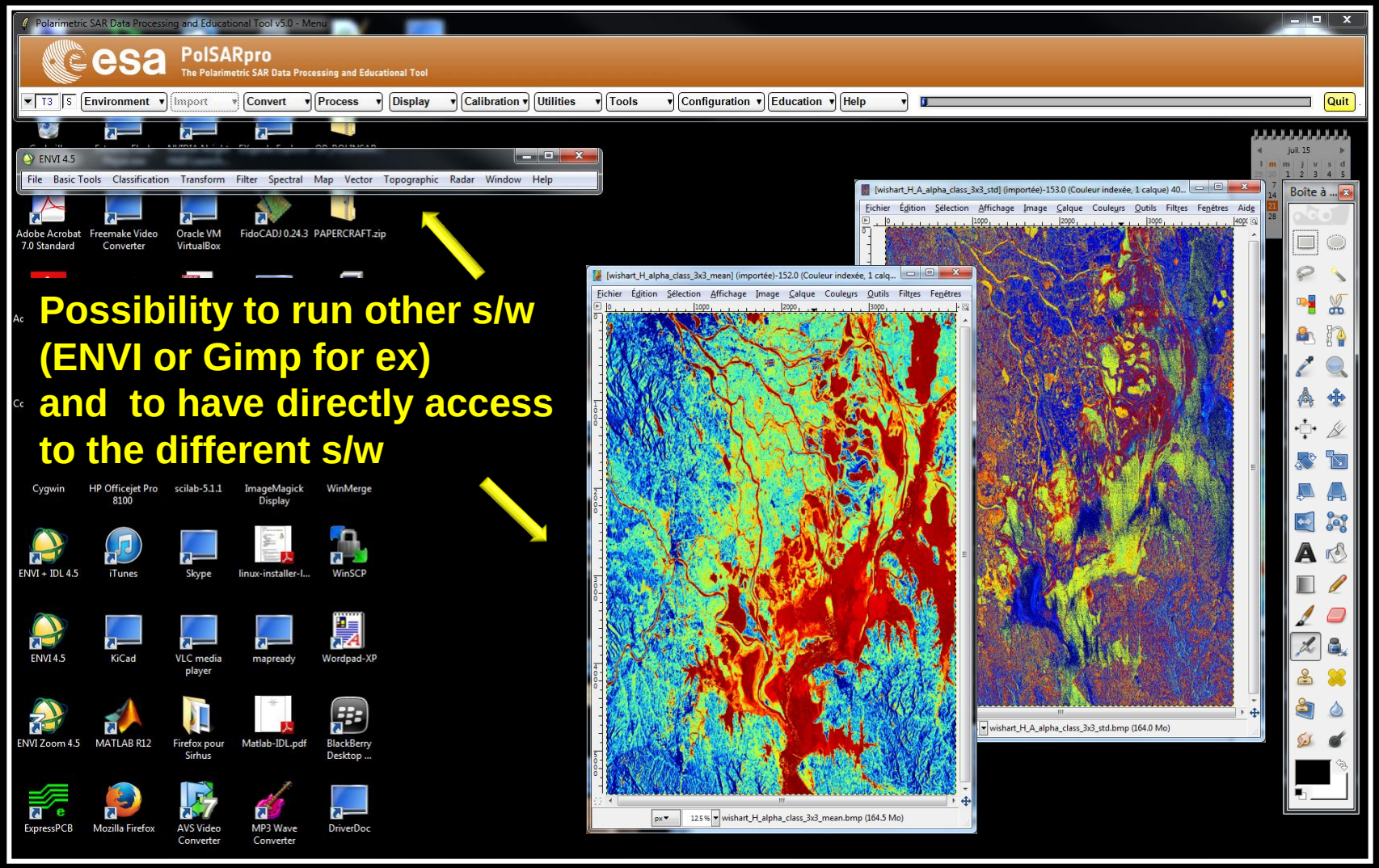
PolSARpro v5.1

- **Full screen** → **Banner**
- **Buttons – icons** → **Buttons - Functionalities**

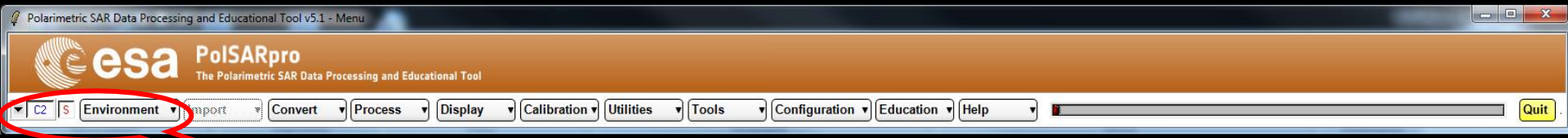
Objective

To minimize the data flow towards a Virtual Machine (ex ESA - GPOD)

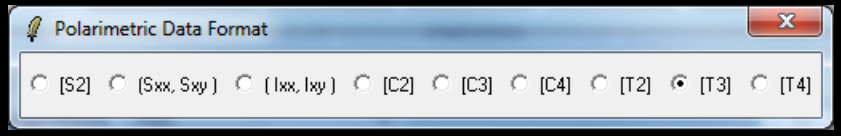
PolSARpro v5.1 SOFTWARE



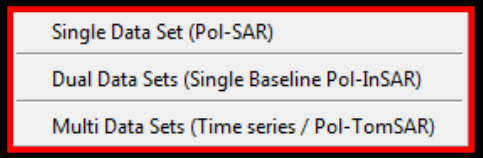
PolSARpro v5.1 SOFTWARE



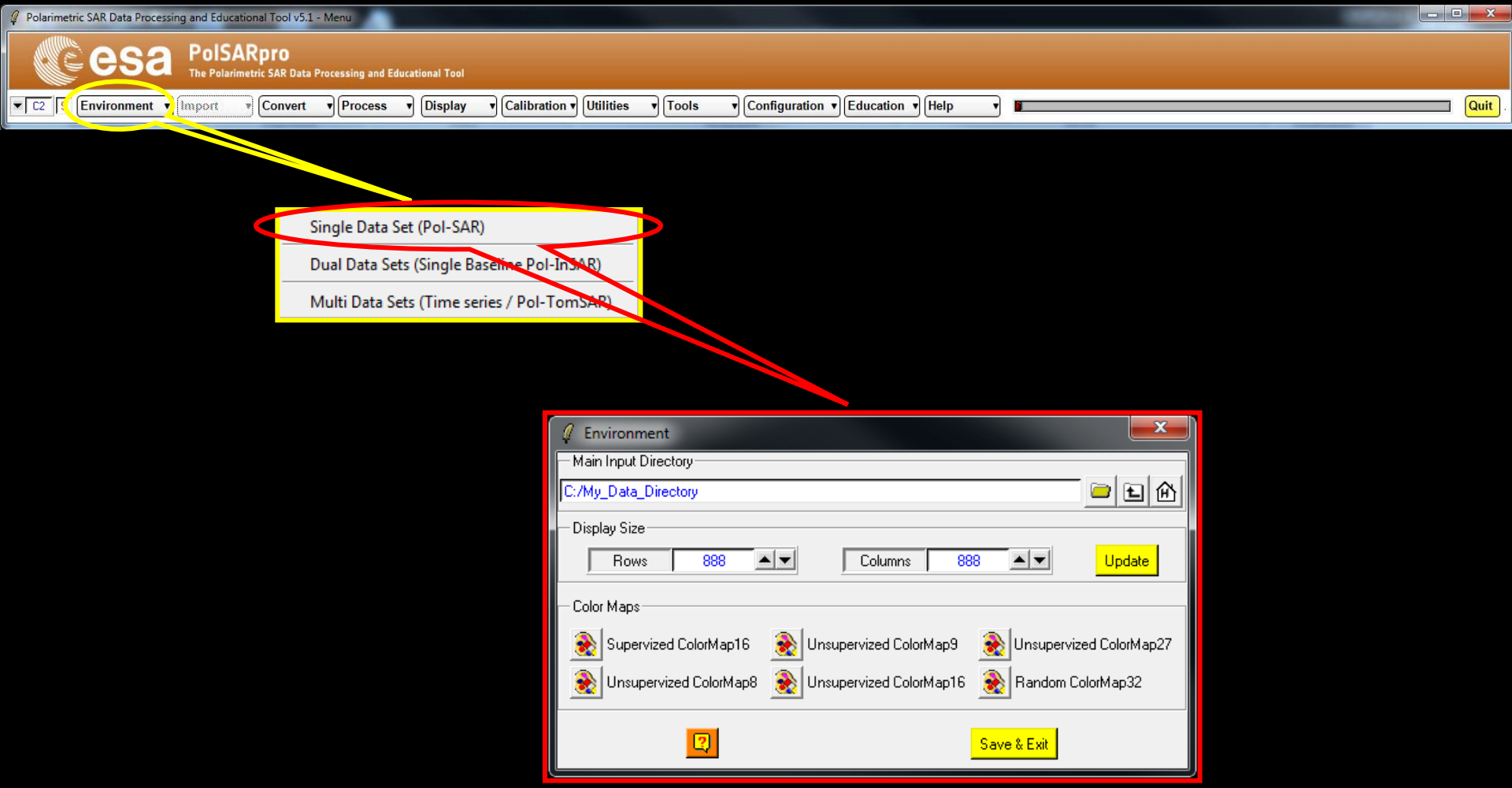
Polarimetric Data Format



DataSet Type



PolSARpro v5.1 SOFTWARE



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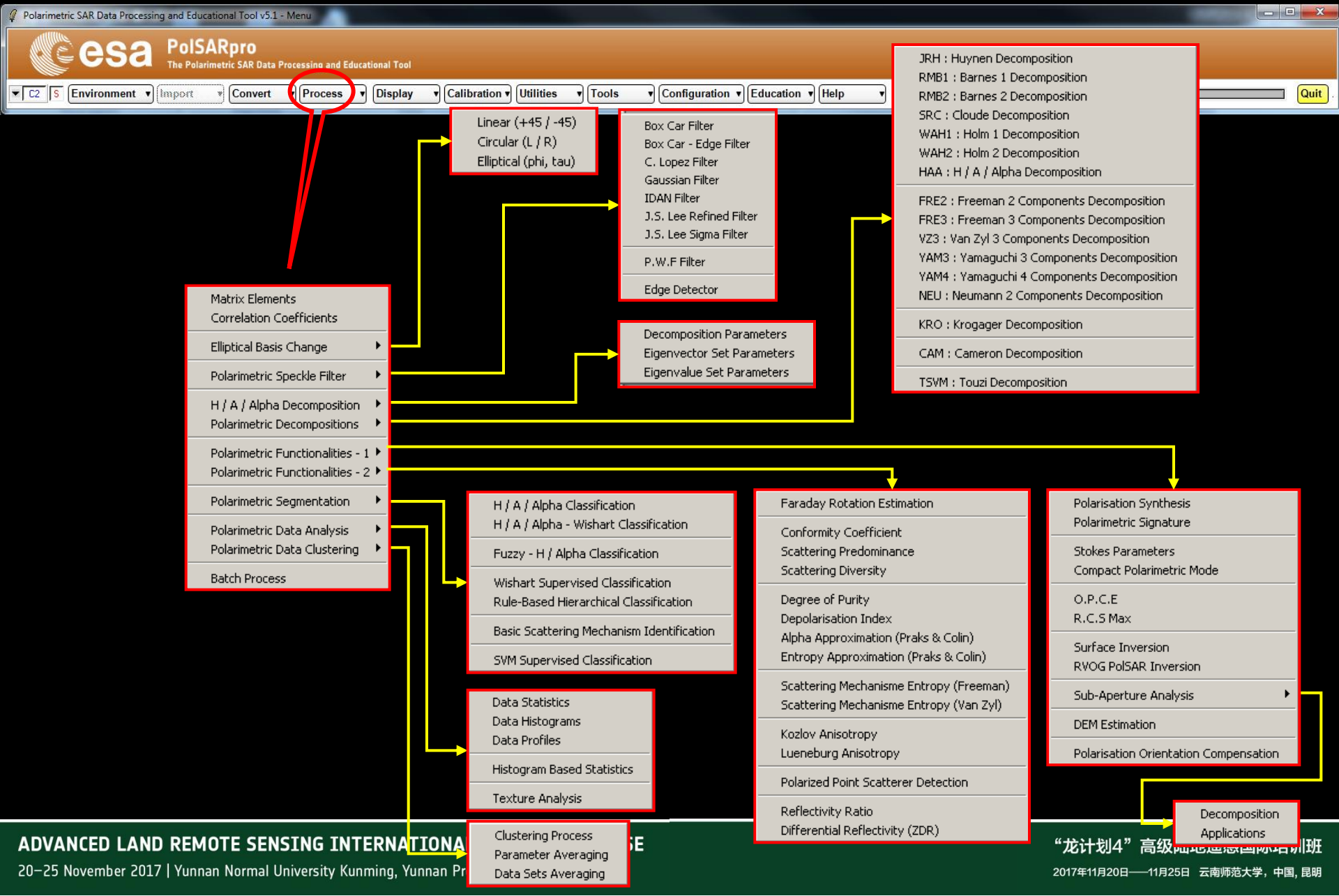

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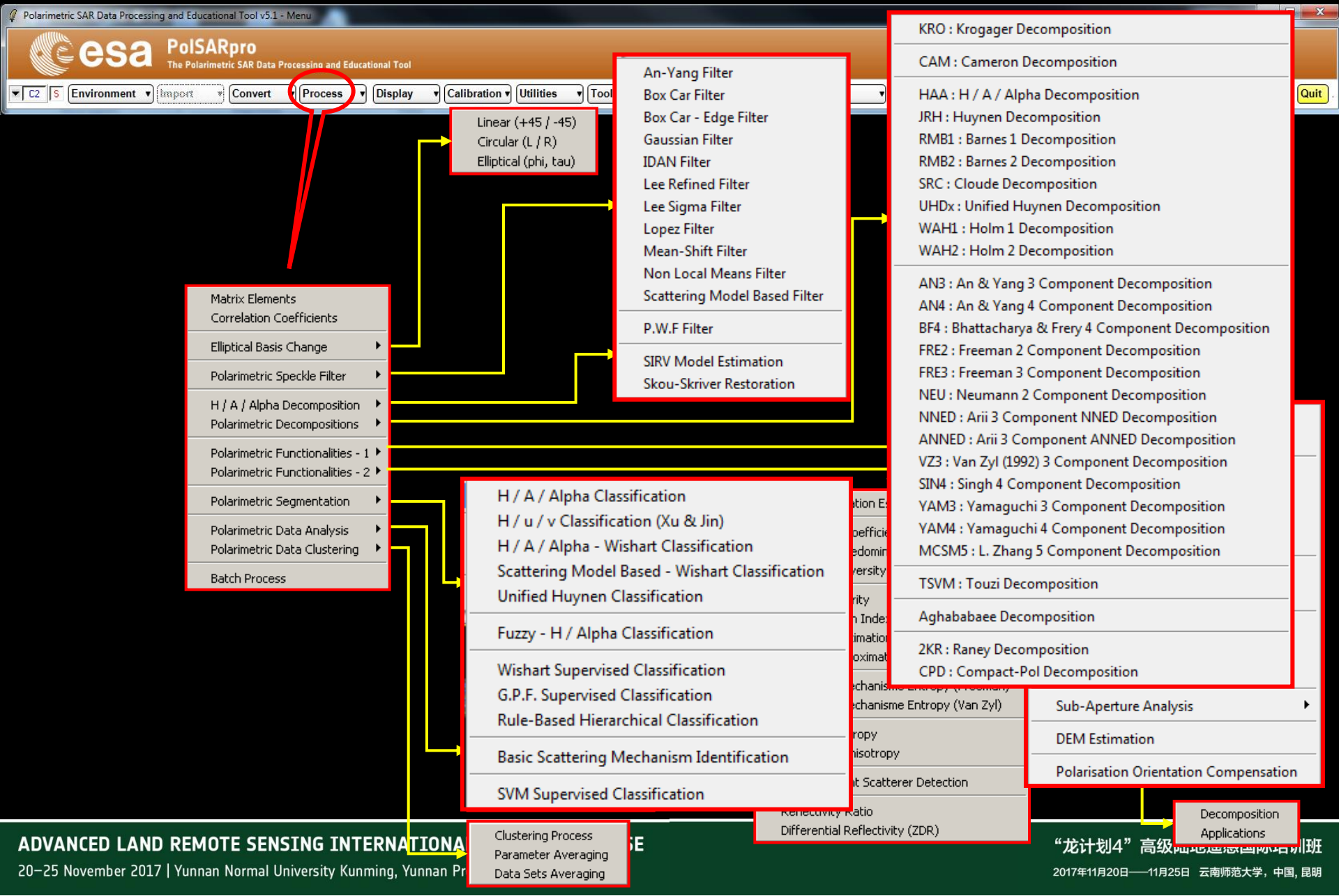

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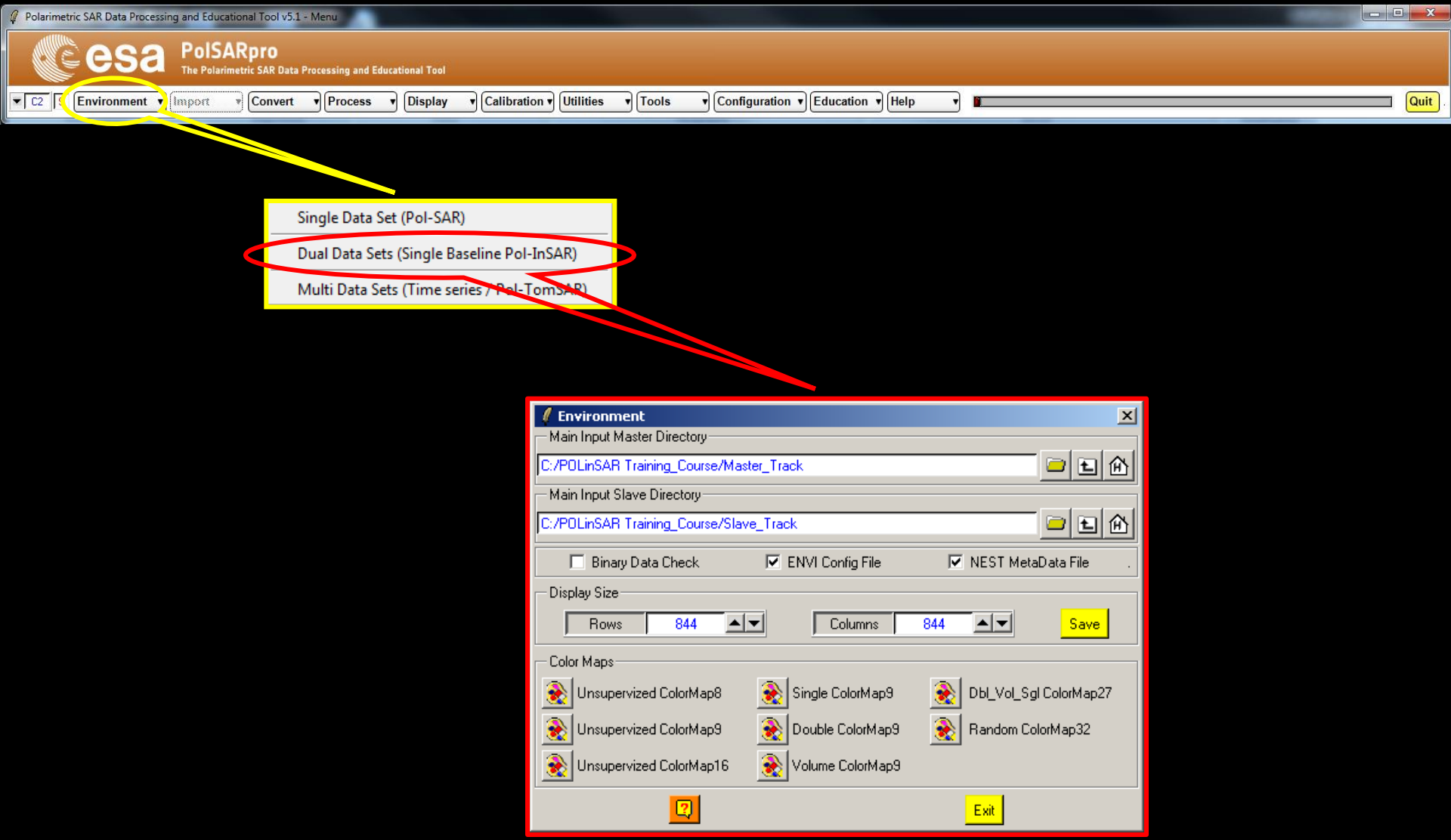

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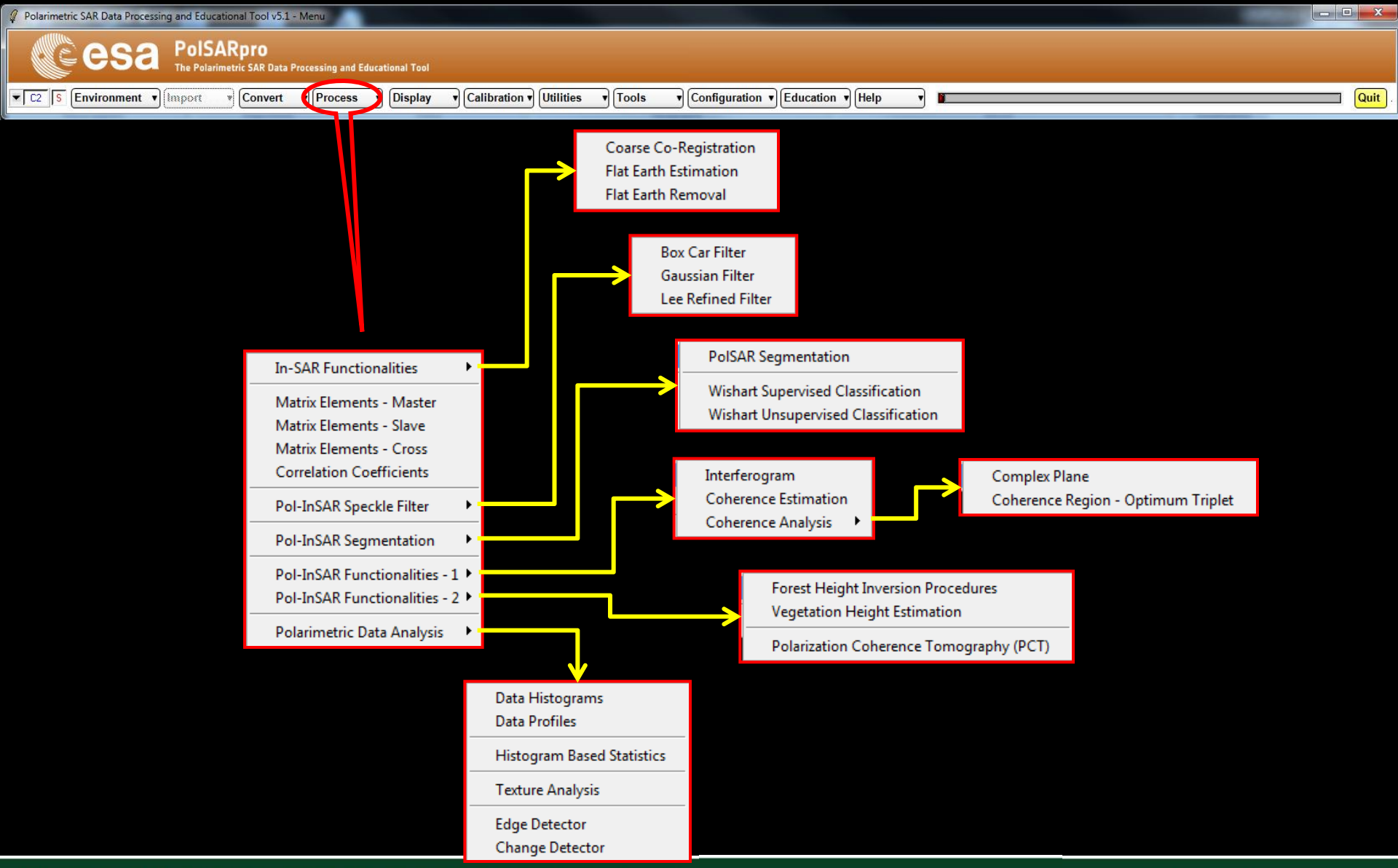
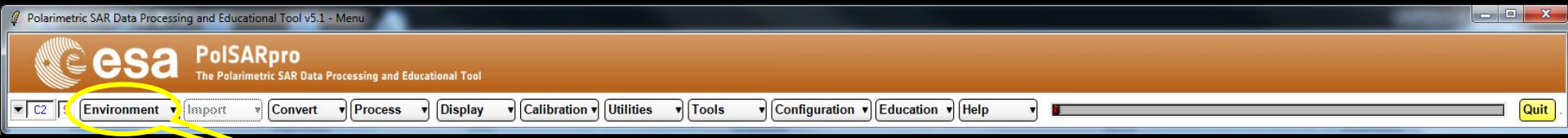
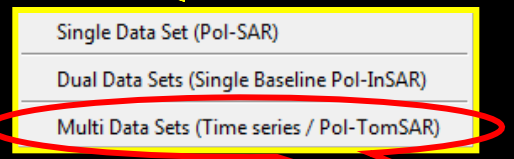
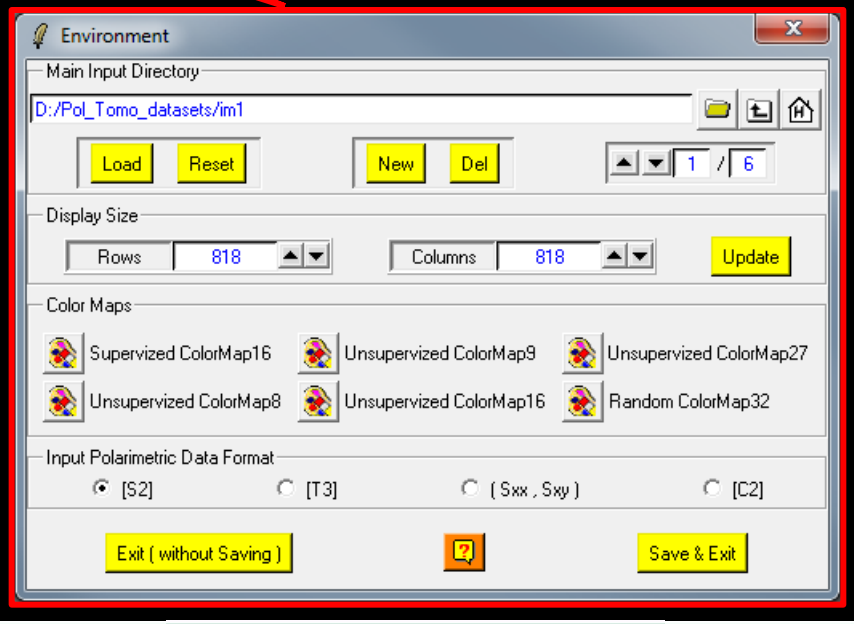


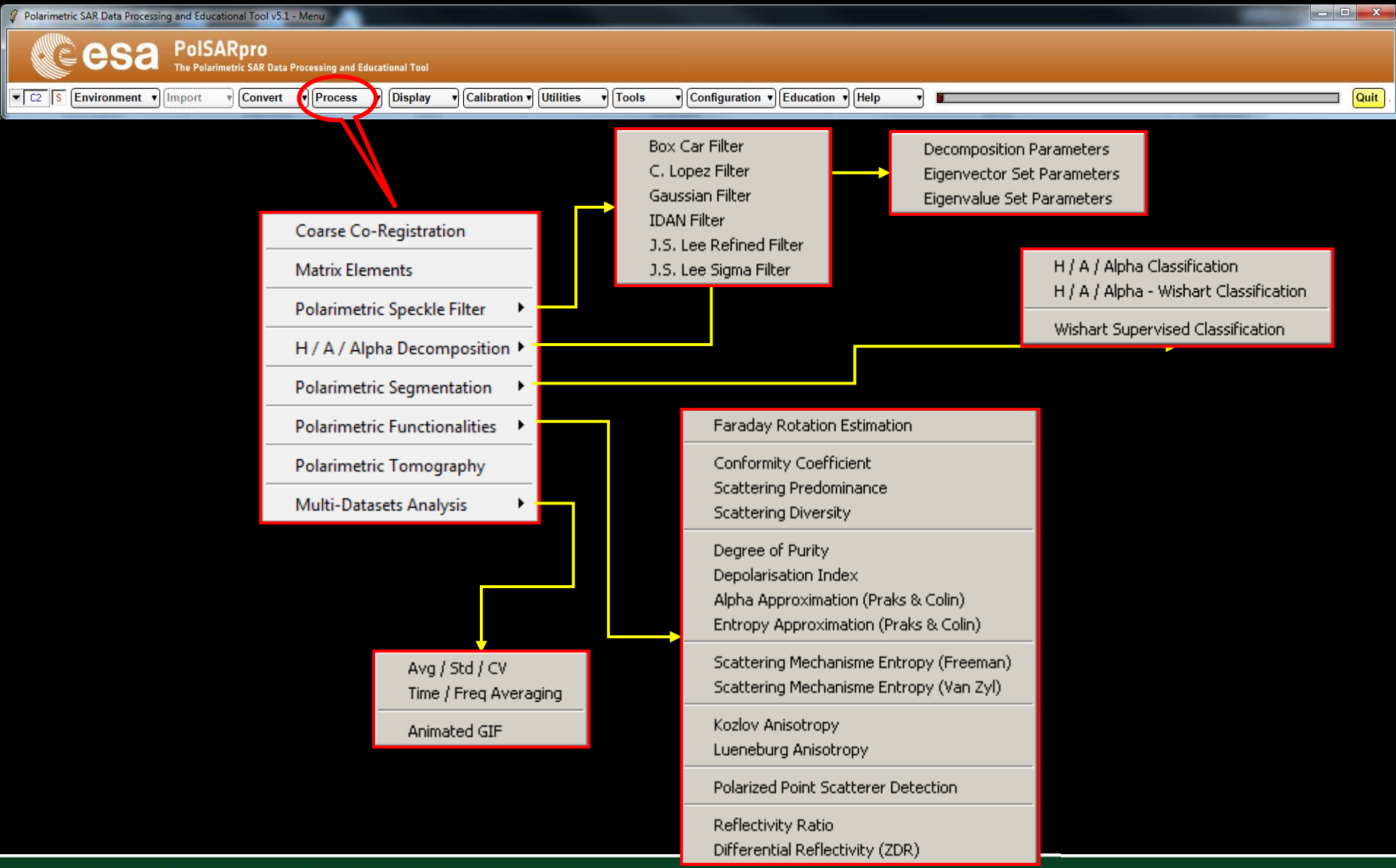
PolSARpro v5.1 SOFTWARE



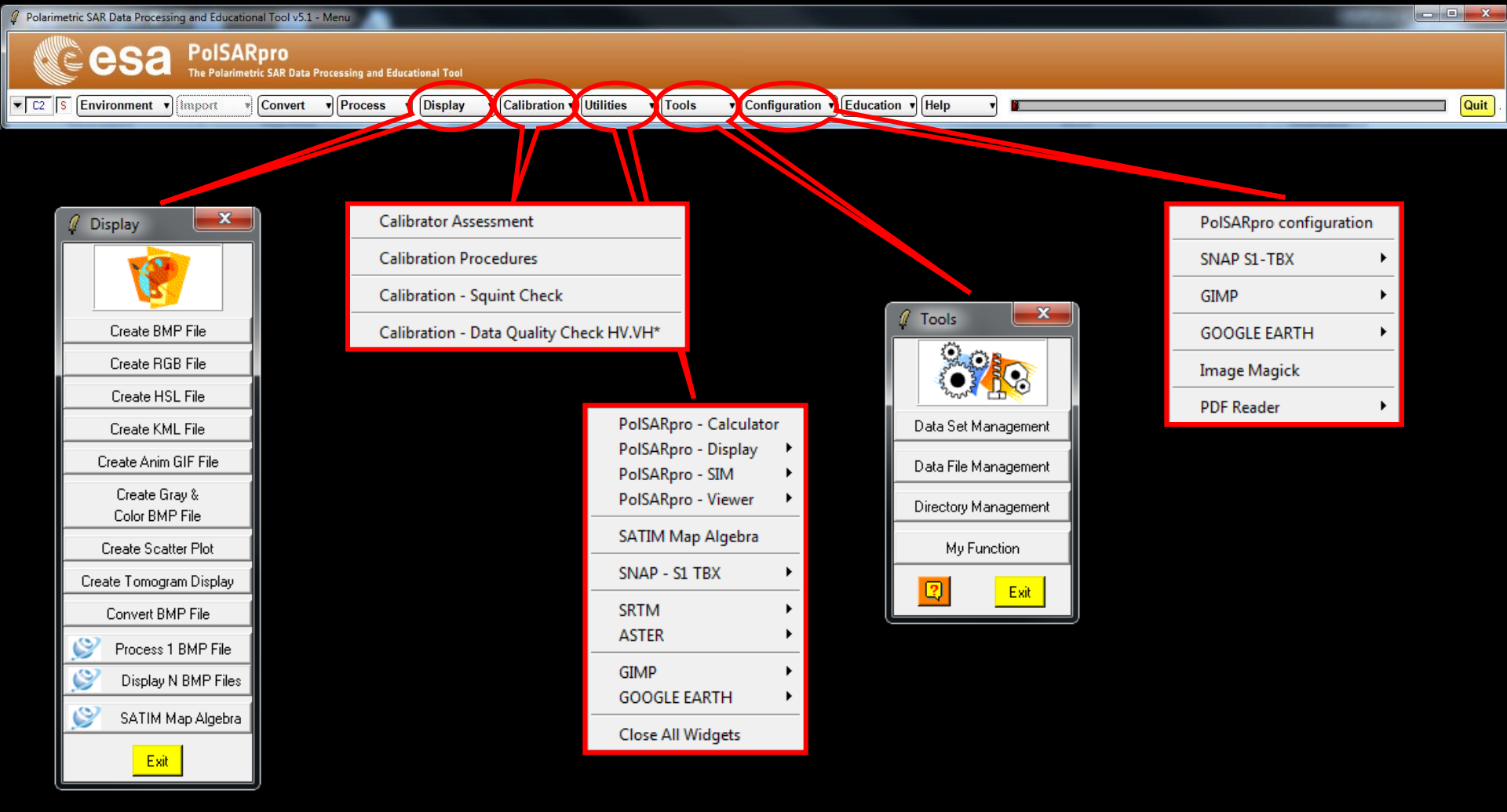




PolSARpro v5.1 SOFTWARE



PolSARpro v5.1 SOFTWARE



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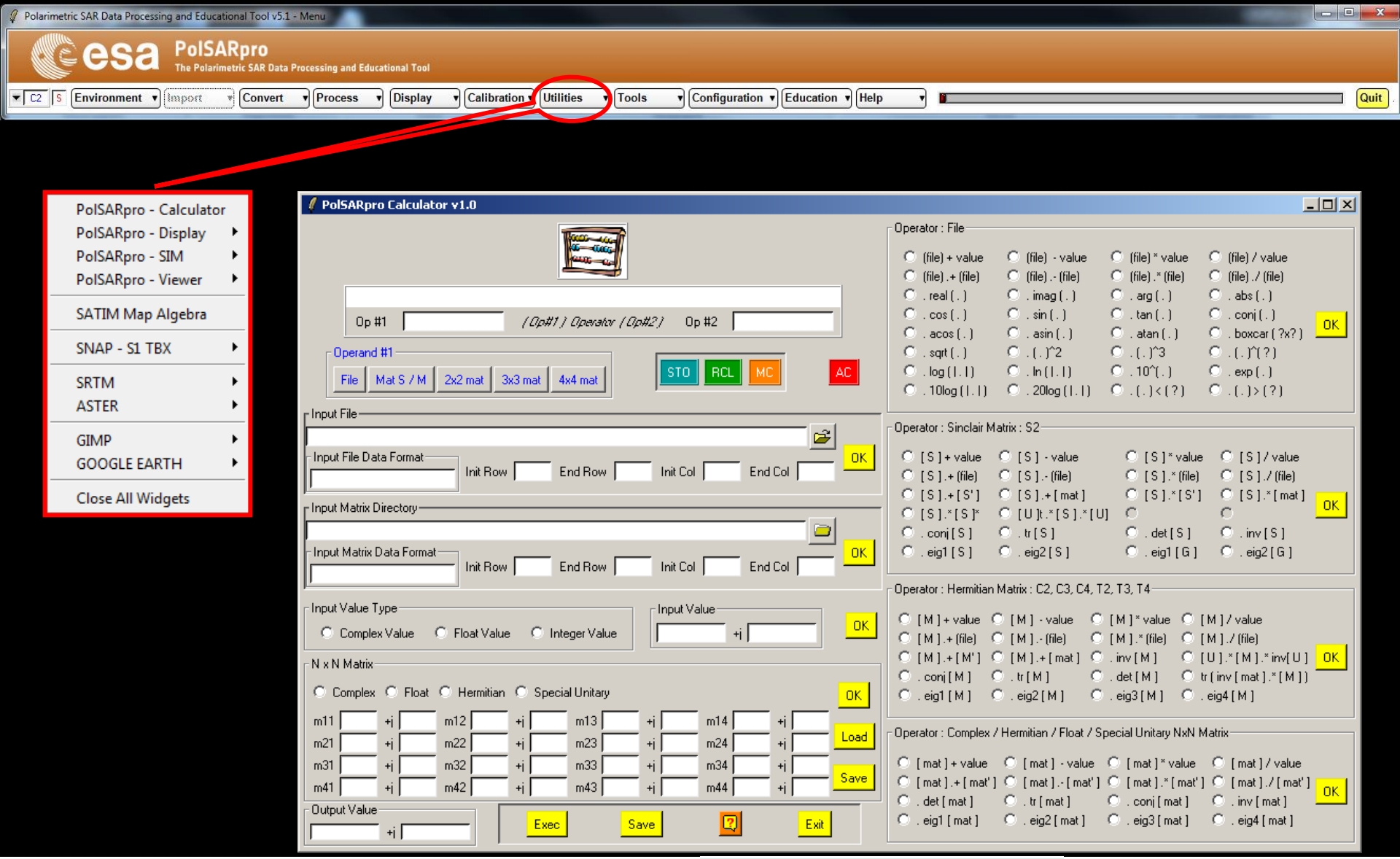

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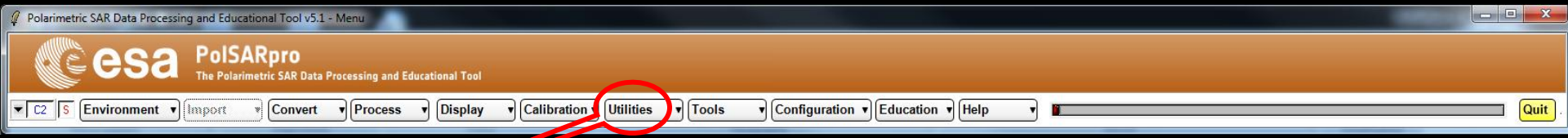
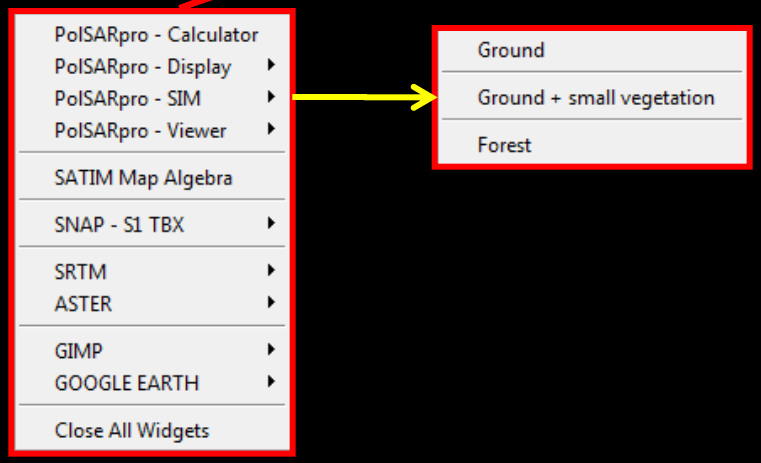
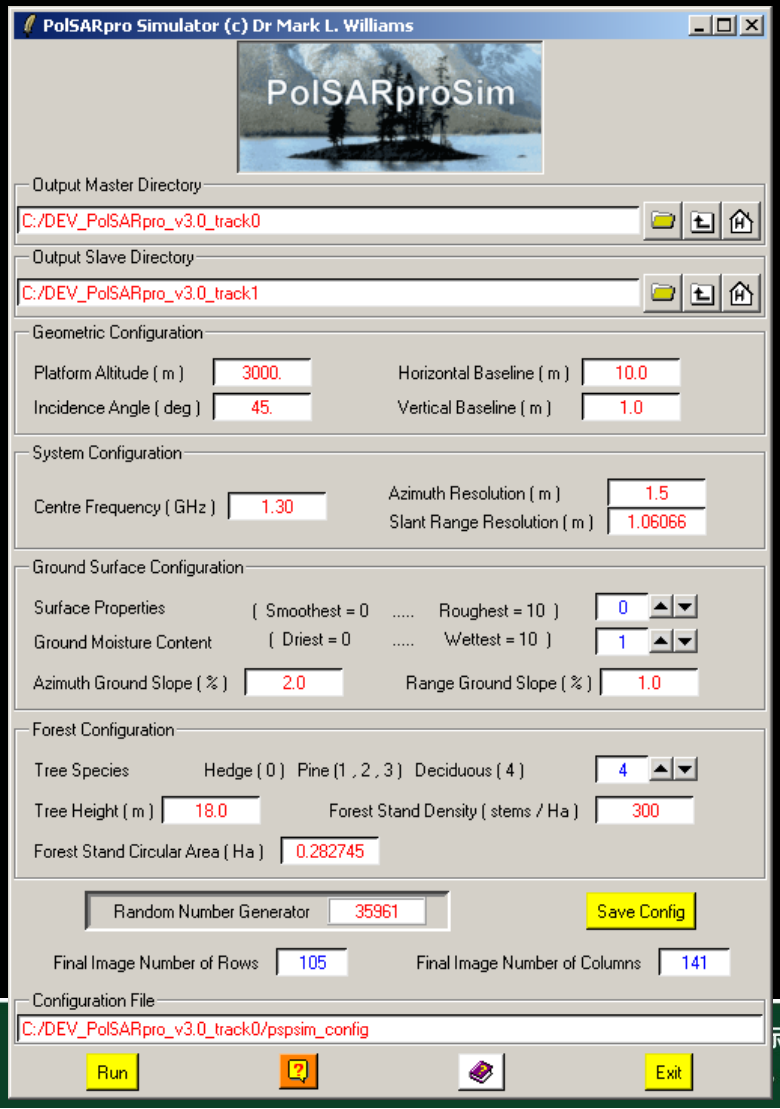
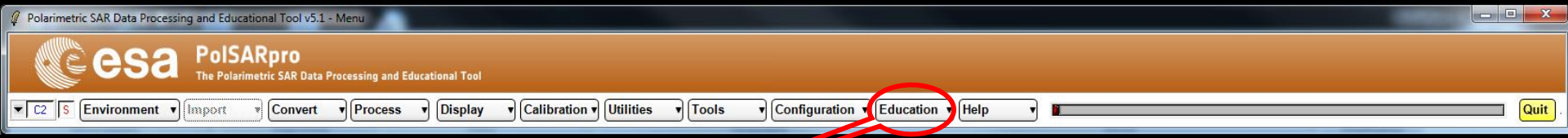


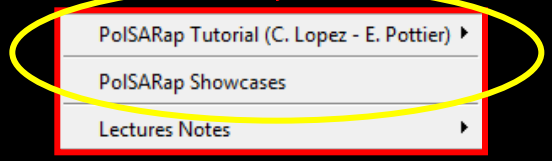


PolSARproSim is a rapid, coherent, fully polarimetric and interferometric SAR simulation of forest.



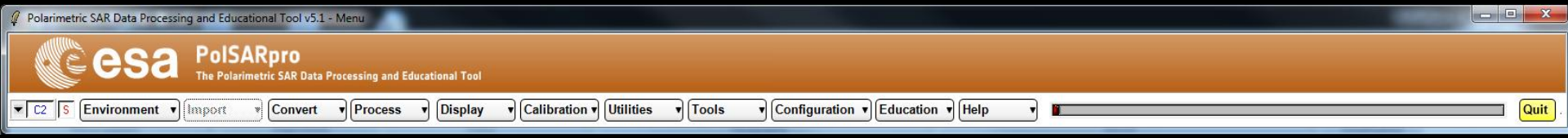
PolSARpro v5.1 SOFTWARE





Learning / Training Next P.I Generations

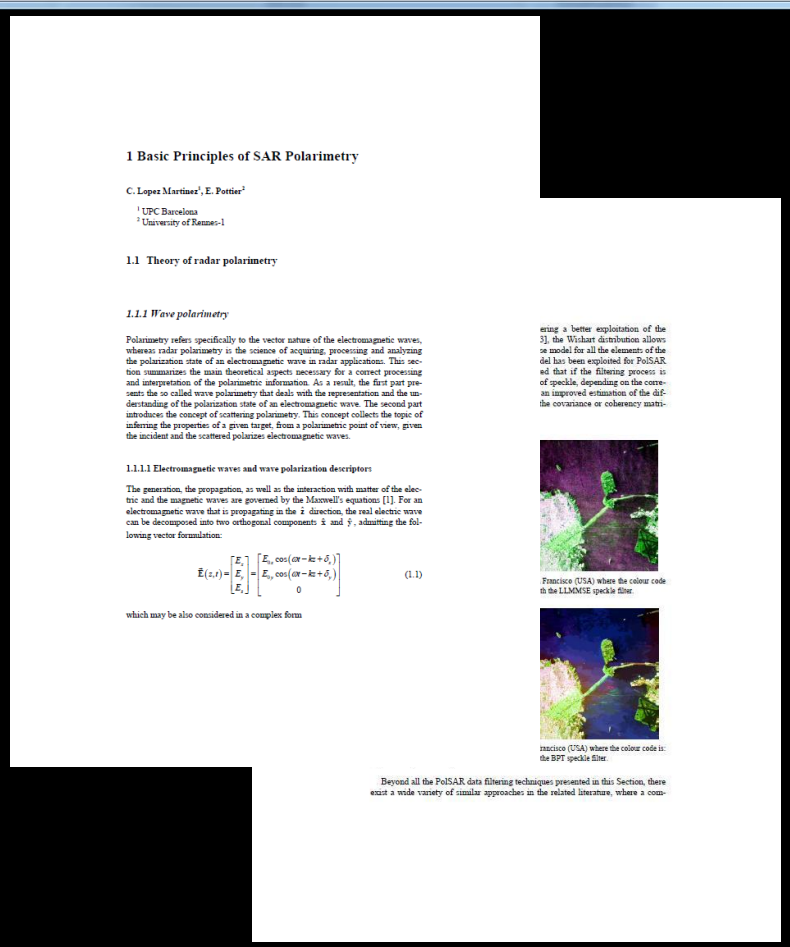
EDUCATIONAL TOOLS



PolSAR-Ap Project

WP360 : Review and update of the Basic Principles and Applications

(E. Pottier, C. Lopez Martinez)



1 Basic Principles of SAR Polarimetry

C. Lopez Martinez[1], E. Pottier[2]

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1.1 Theory of radar polarimetry

1.1.1 Wave polarimetry

Polarimetry refers specifically to the vector nature of the electromagnetic waves, whereas radar polarimetry is the science of acquiring, processing and analyzing the polarization state of an electromagnetic wave in radar applications. This section summarizes the main theoretical aspects necessary for a correct processing and interpretation of the polarimetric information. As a result, the first part presents the so called wave polarimetry that deals with the representation and the understanding of the polarization state of an electromagnetic wave. The second part introduces the concept of scattering polarimetry. This concept collects the topic of inferring the properties of a given target, from a polarimetric point of view, given the incident and the scattered polarizes electromagnetic waves.

1.1.1.1 Electromagnetic waves and wave polarization descriptors

The generation, the propagation, as well as the interaction with matter of the electric and the magnetic waves are governed by the Maxwell's equations [1]. For an electromagnetic wave that is propagating in the $\hat{z}$ direction, the real electric wave can be decomposed into two orthogonal components $\hat{x}$ and $\hat{y}$, admitting the following vector formulation:

$$\vec{E}(z,t) = \begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix} = \begin{bmatrix} E_{0x}\cos(\omega t - kz + \delta_x) \\ E_{0y}\cos(\omega t - kz + \delta_y) \\ 0 \end{bmatrix} \quad (1.1)$$

which may be also considered in a complex form

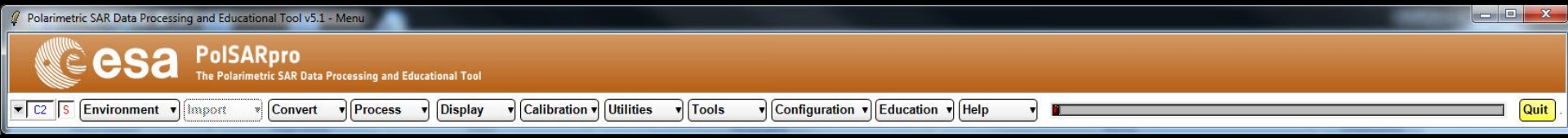
ering a better exploitation of the 3], the Wishart distribution allows se model for all the elements of the del has been exploited for PolSAR ed that if the filtering process is of speckle, depending on the corre- an improved estimation of the dif- the covariance or coherency matri-

Francisco (USA) where the colour code th the LLMMSE speckle filter.

rancisco (USA) where the colour code is: the BPT speckle filter.

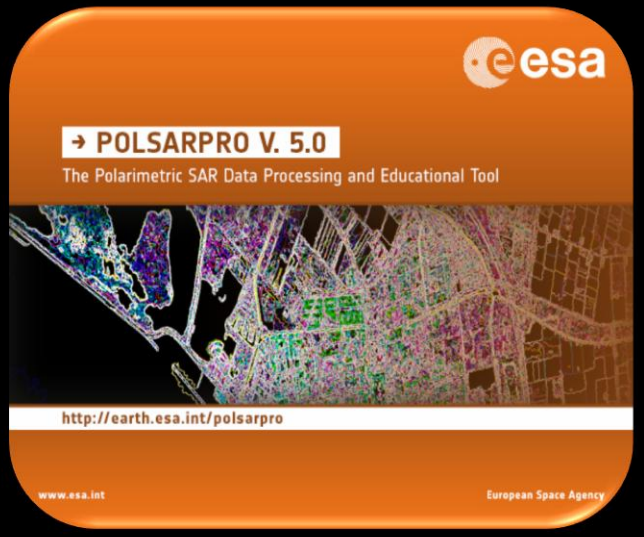
Beyond all the PolSAR data filtering techniques presented in this Section, there exist a wide variety of similar approaches in the related literature, where a com-

EDUCATIONAL TOOLS

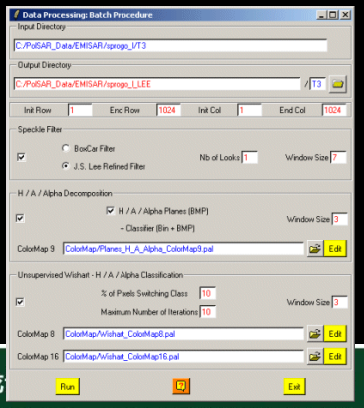


PolSAR-Ap Project

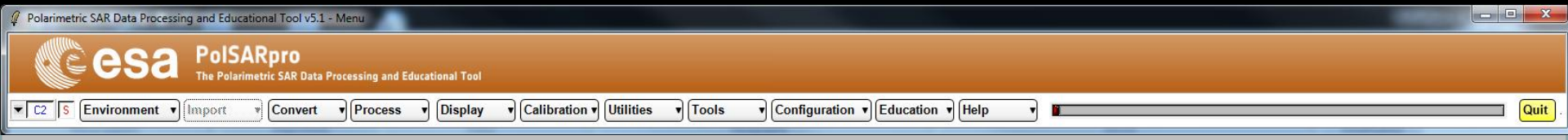
Expert



WP260 : Implementation of Selected Applications
(E. Pottier)



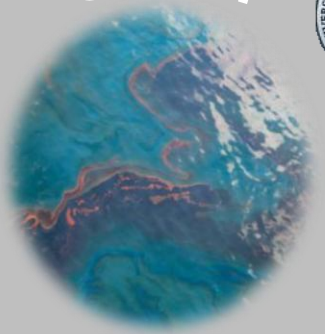
EDUCATIONAL TOOLS

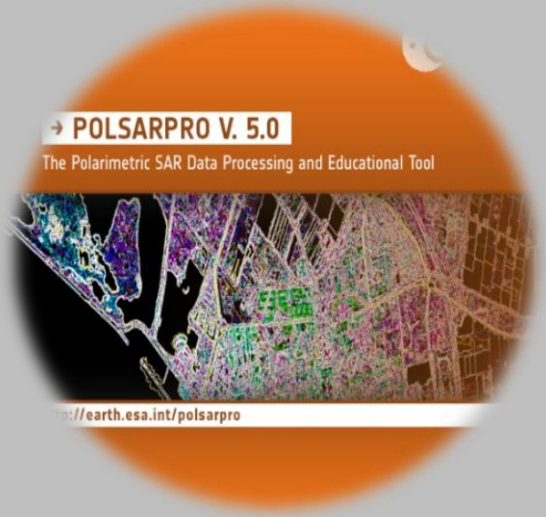


Forest

Agriculture

Ocean

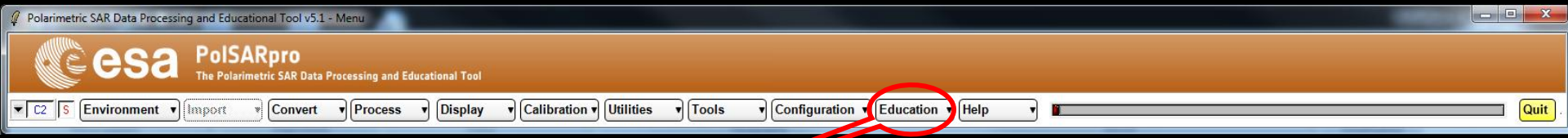


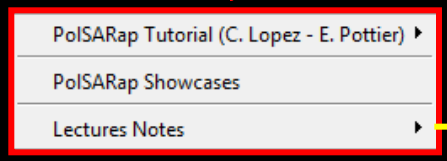


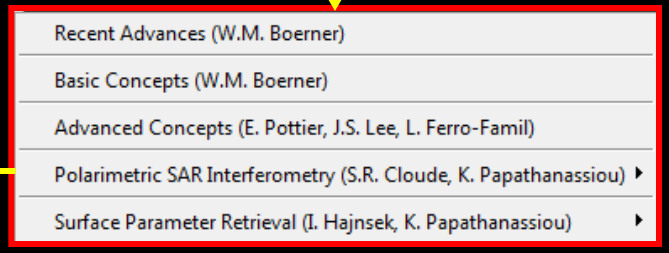
Urban

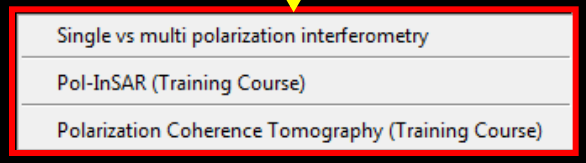
Cryosphere

PolSARpro v5.1 SOFTWARE









Learning / Training Next P.I Generations

PolSARpro v5.1 SOFTWARE

http://earth.esa.int/polsarpro/home

Web Site provides

f the project

e tutorial

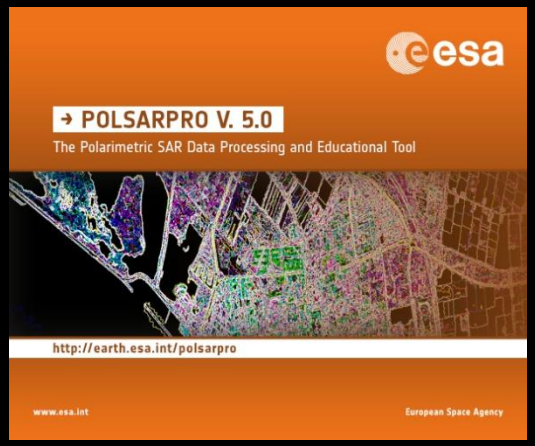
ion about status development

emonstration Sample Datasets

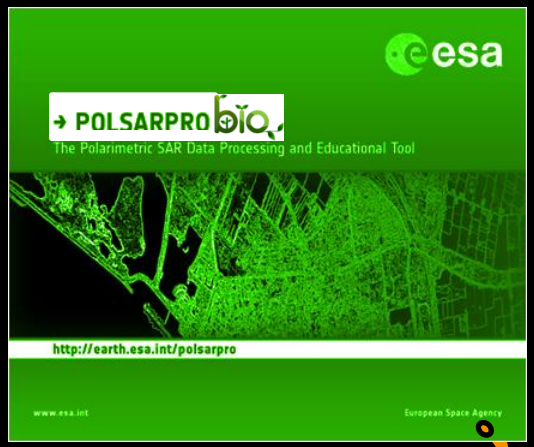
New! **V5.1 (January 2017)**

PolSARpro - Bio SOFTWARE

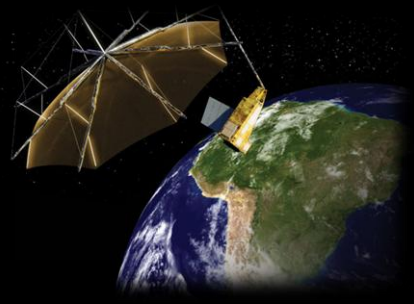
ESA & third party fully polarimetric SAR missions (PolSARpro-Bio)



ESA RFP - 2017

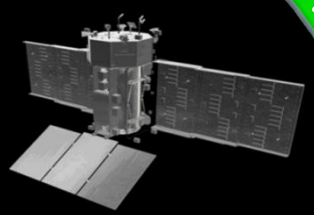


Future spaceborne sensors



BIOMASS

R.C.M



SAOCOM-CS

New functionalities : Pol-SAR, Pol-TomSAR and Pol-TimeSAR / Cloud-based infrastructure SNAP / PolSARproSIM++ / QGIS Plug-in…

PolSARpro v5.1 Software
Practical session

- **Installation procedure**
  - **Configuration of the PolSARpro v5.1 Software**
  - **Test the configuration**

- **Practical**
  - **Basis session**
  - **Advanced session**

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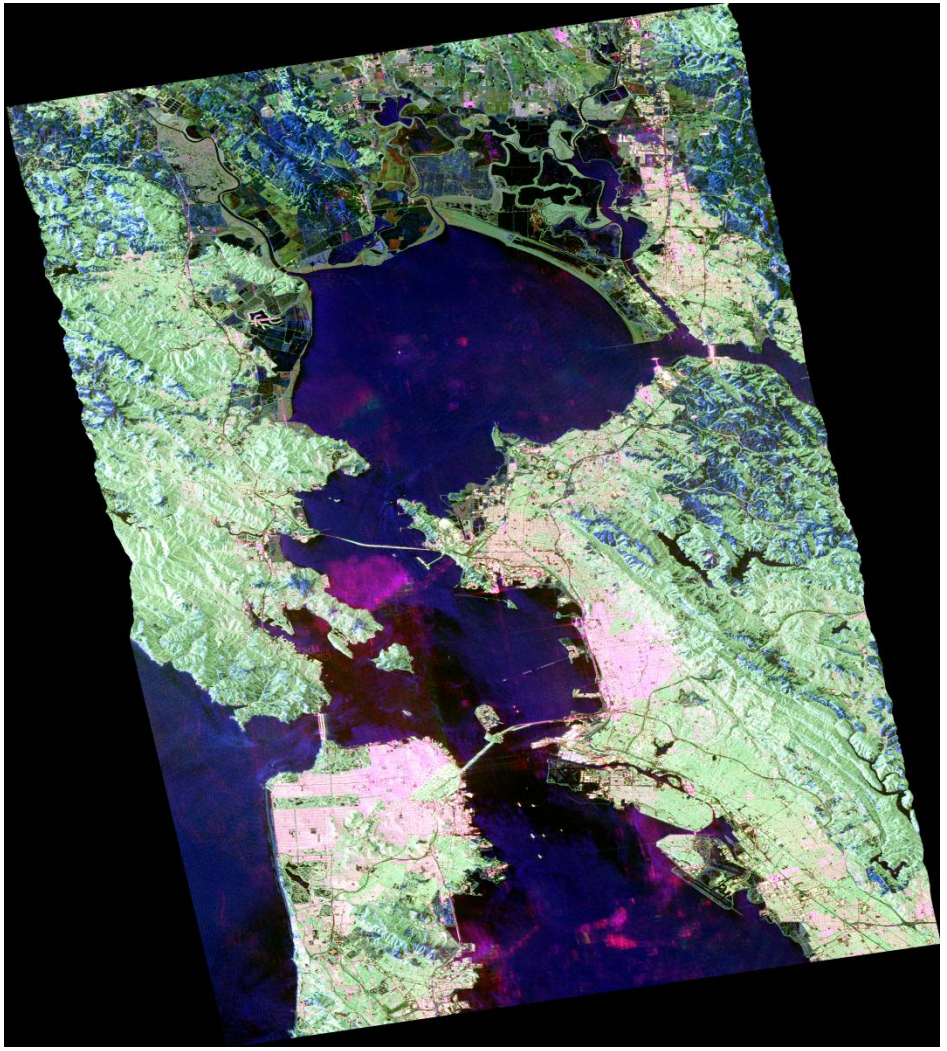
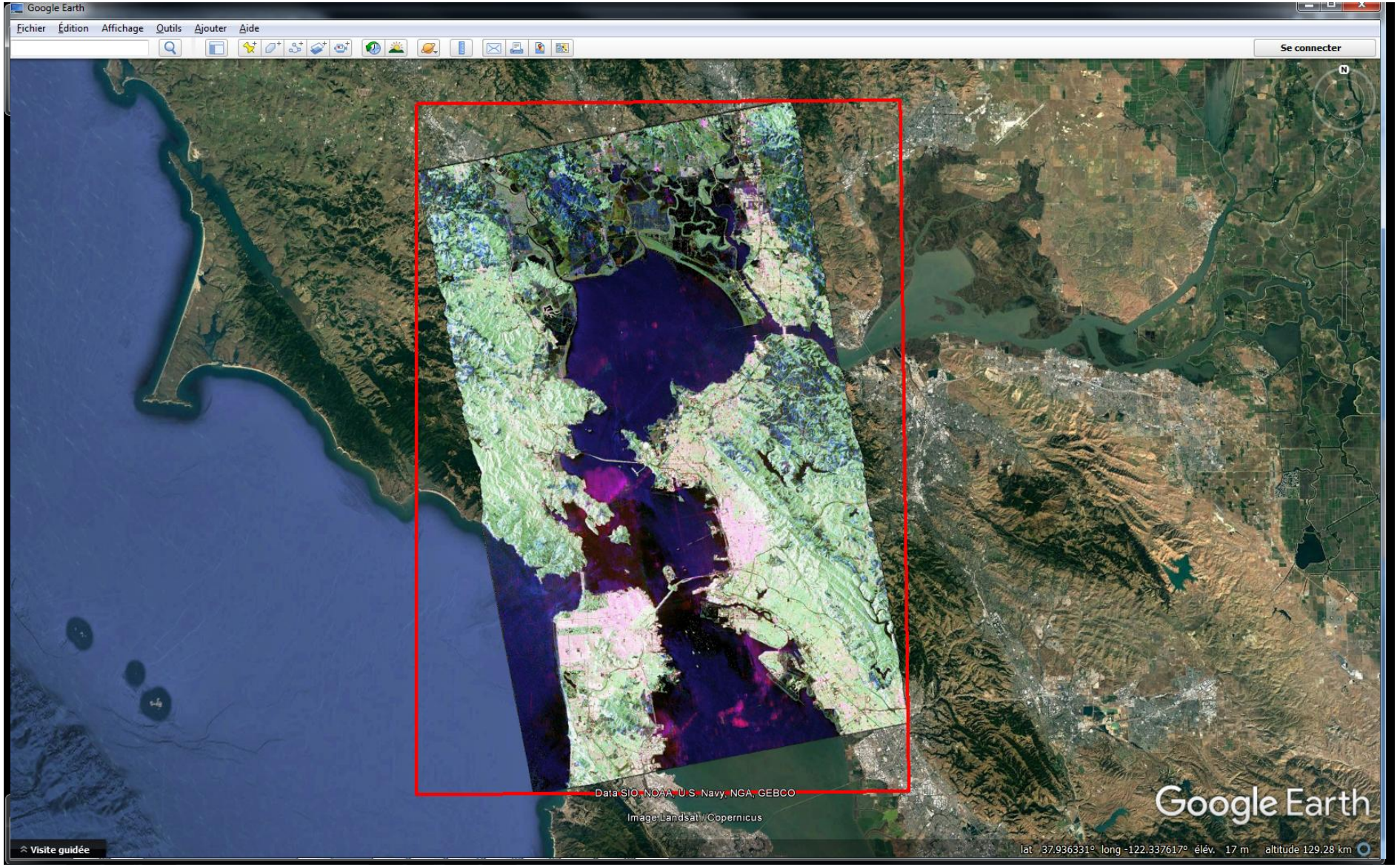
  - **Advanced session**

ALOS
Advanced Land Observing Satellite



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

PolSARpro v5.1 SOFTWARE

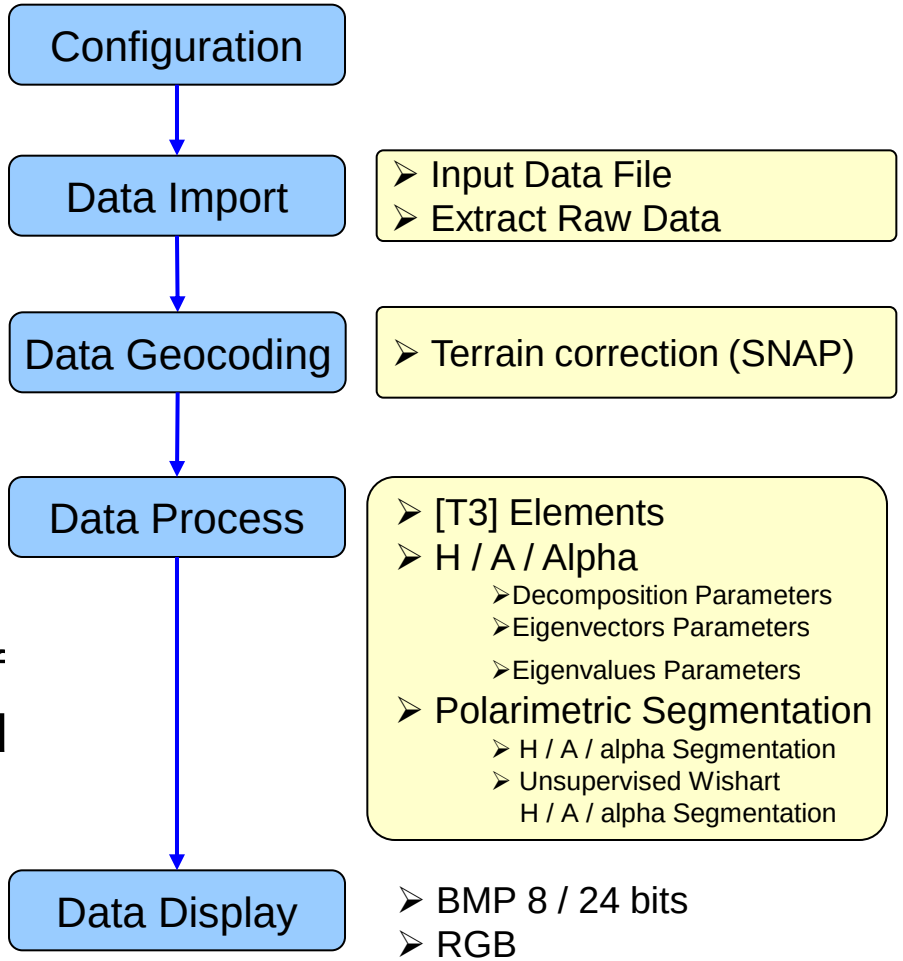


PROCESSING CHAIN

PolSARpro v5.1 Software performs complete end-to-end processing without the need for any other software.

Data Processing Approach along a '**recommended**' and easy processing chain

Provide a **First Qualitative Analysis** of the fully polarimetric data set processed



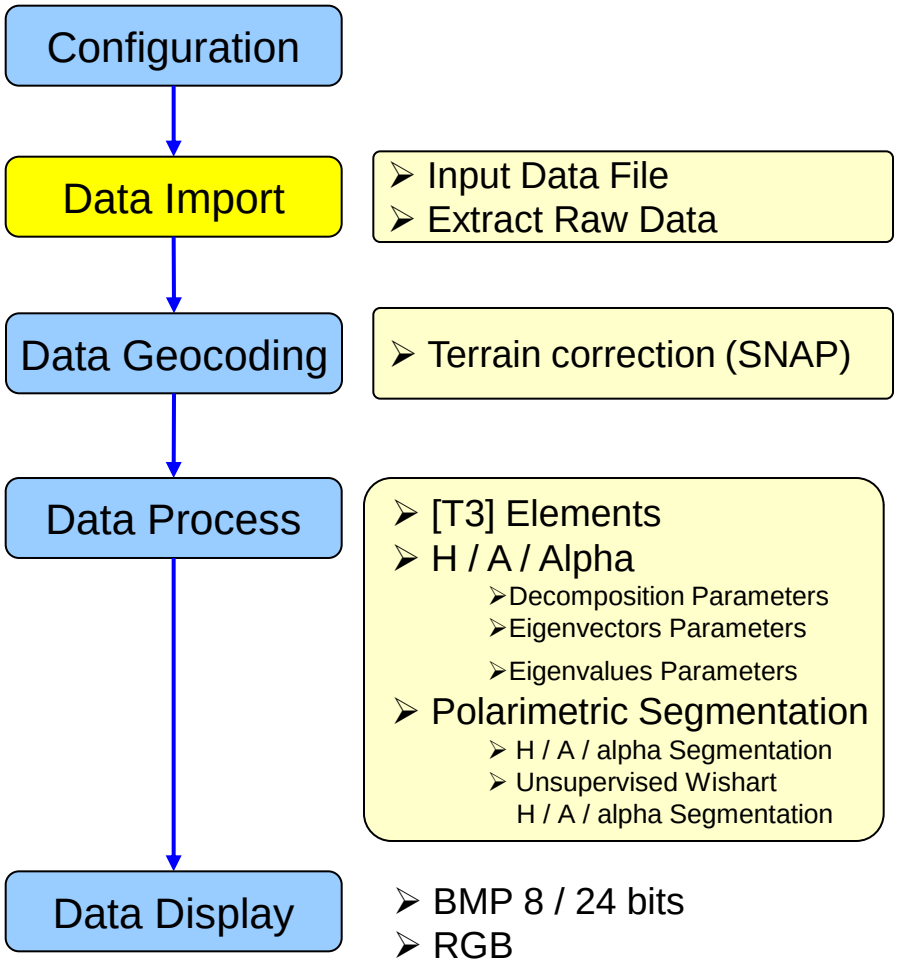
PROCESSING CHAIN

20mn

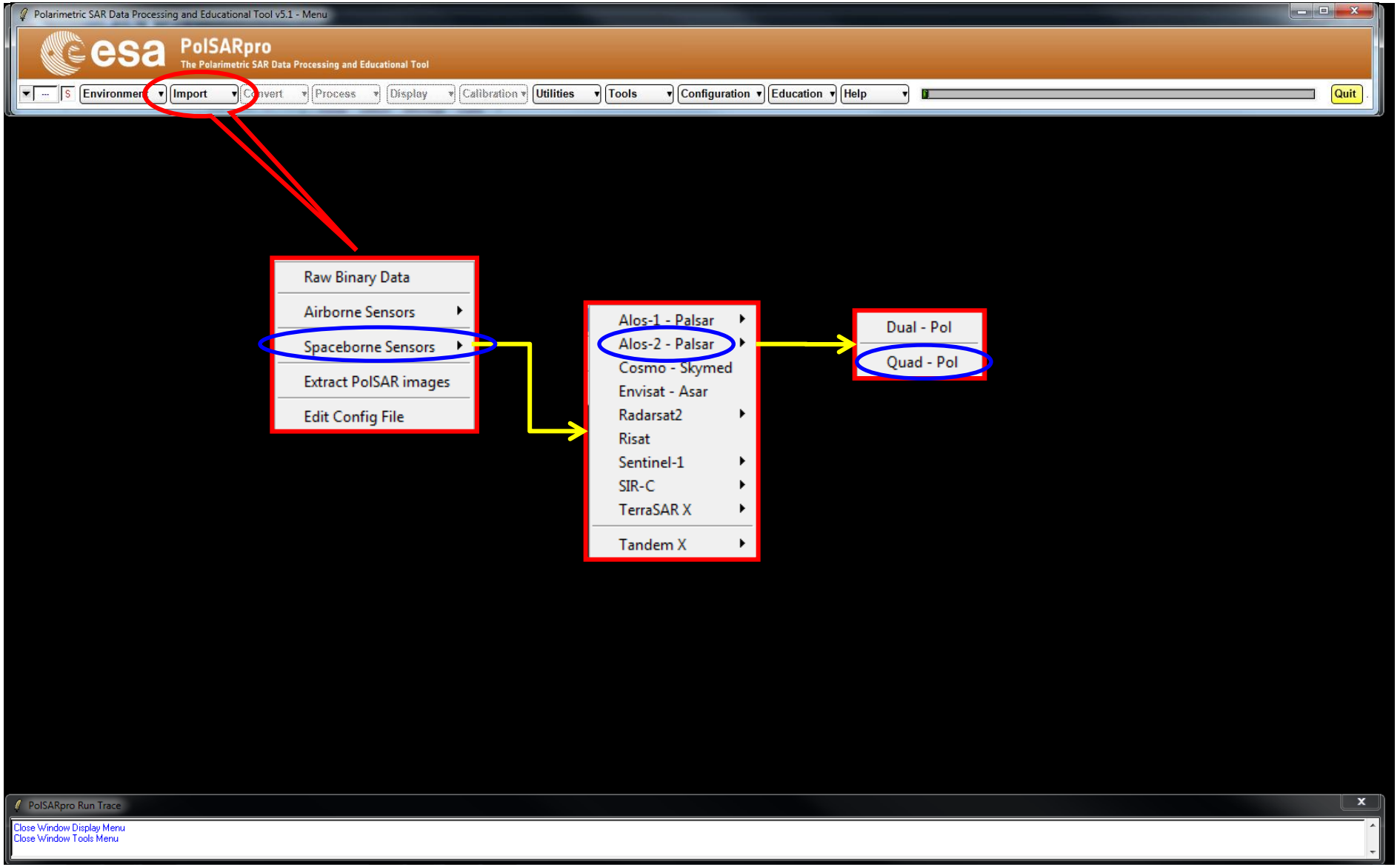
18mn

- **Configuration**
- **Data Import**
  - Input Data File
  - Extract Raw Data
- **Data Geocoding**
  - Terrain correction (SNAP)
- **Data Process**
  - [T3] Elements
  - H / A / Alpha
    - Decomposition Parameters
    - Eigenvectors Parameters
    - Eigenvalues Parameters
  - Polarimetric Segmentation
    - H / A / alpha Segmentation
    - Unsupervised Wishart H / A / alpha Segmentation
- **Data Display**
  - BMP 8 / 24 bits
  - RGB

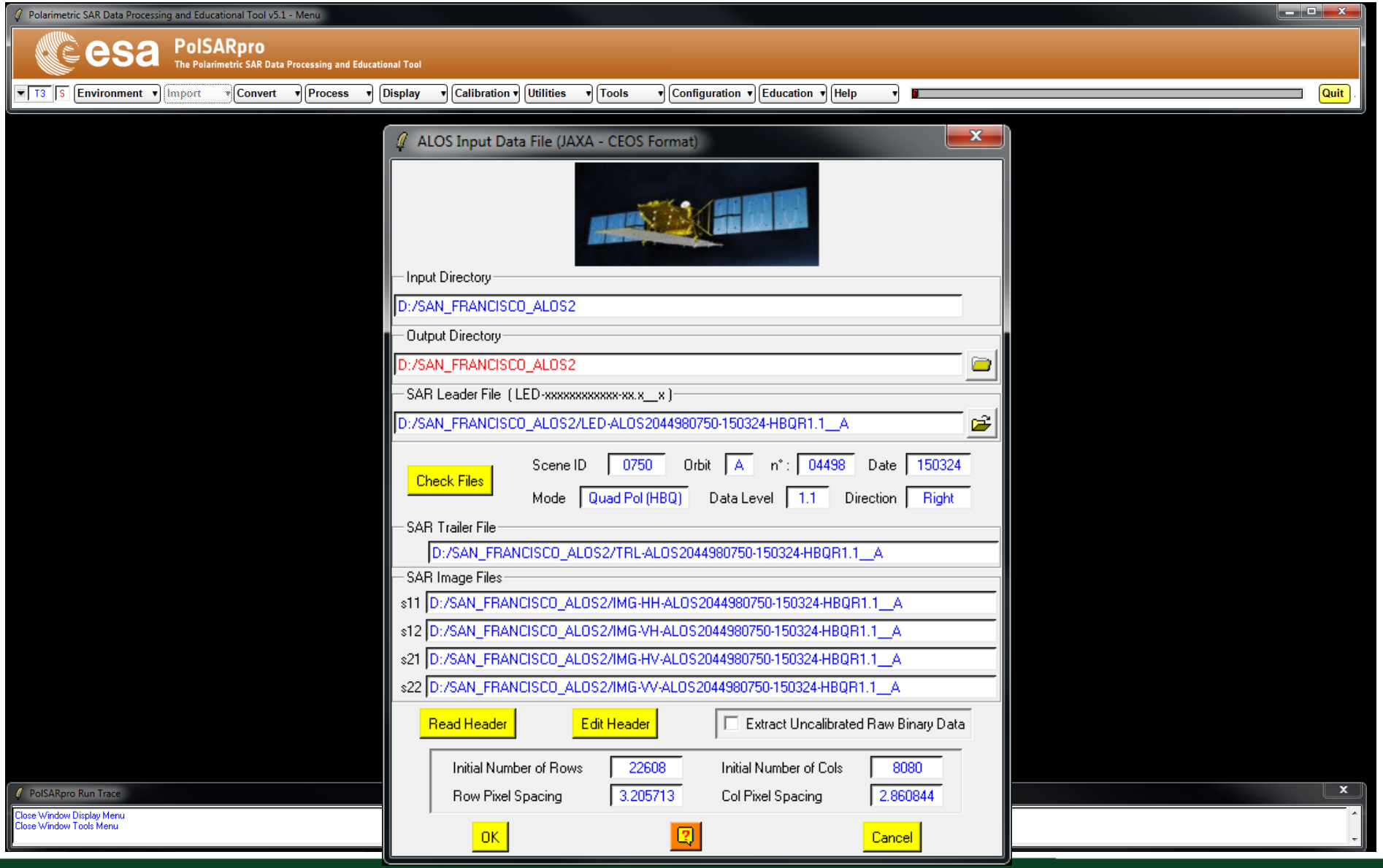
PROCESSING CHAIN



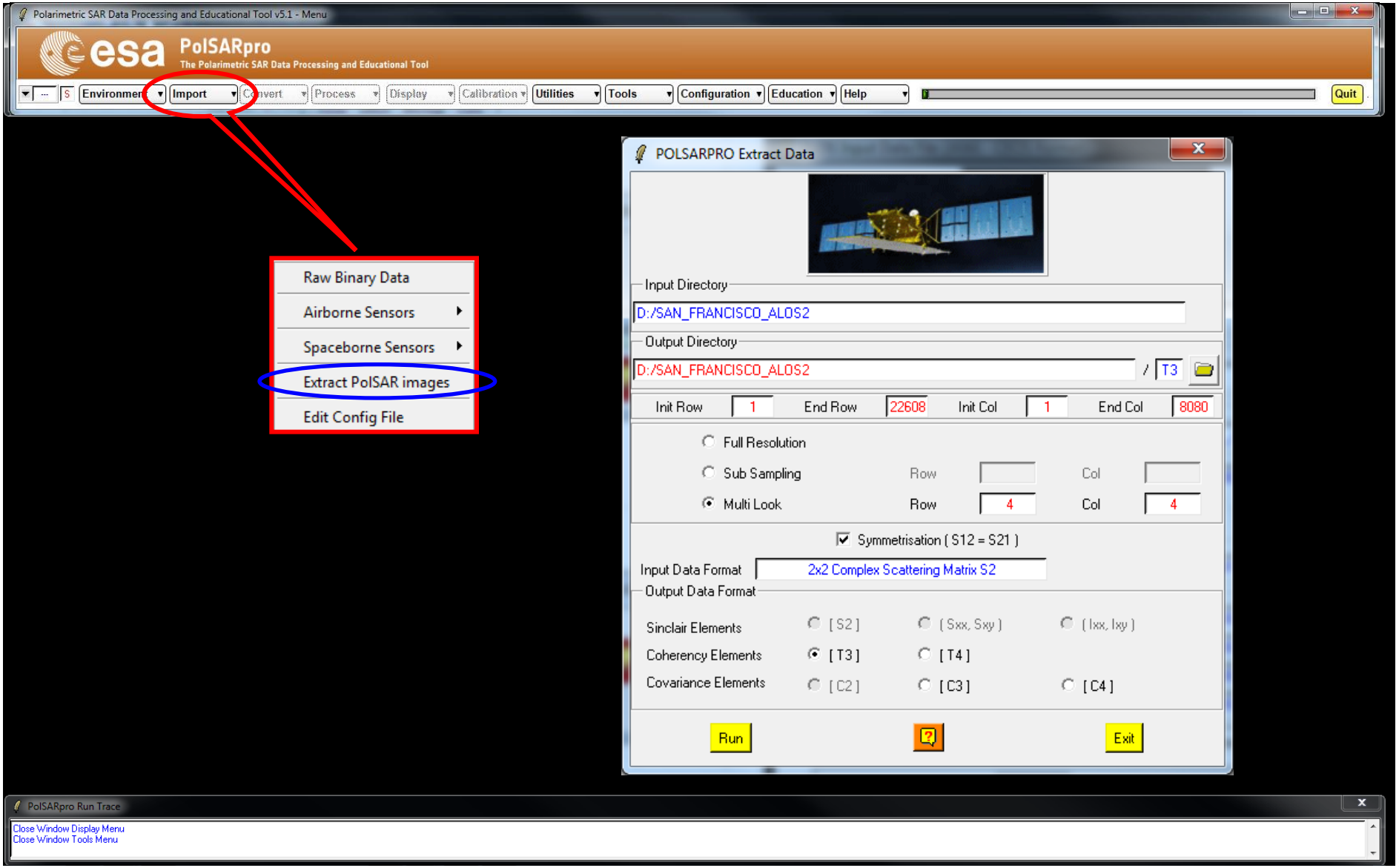
ENVIRONNEMENT



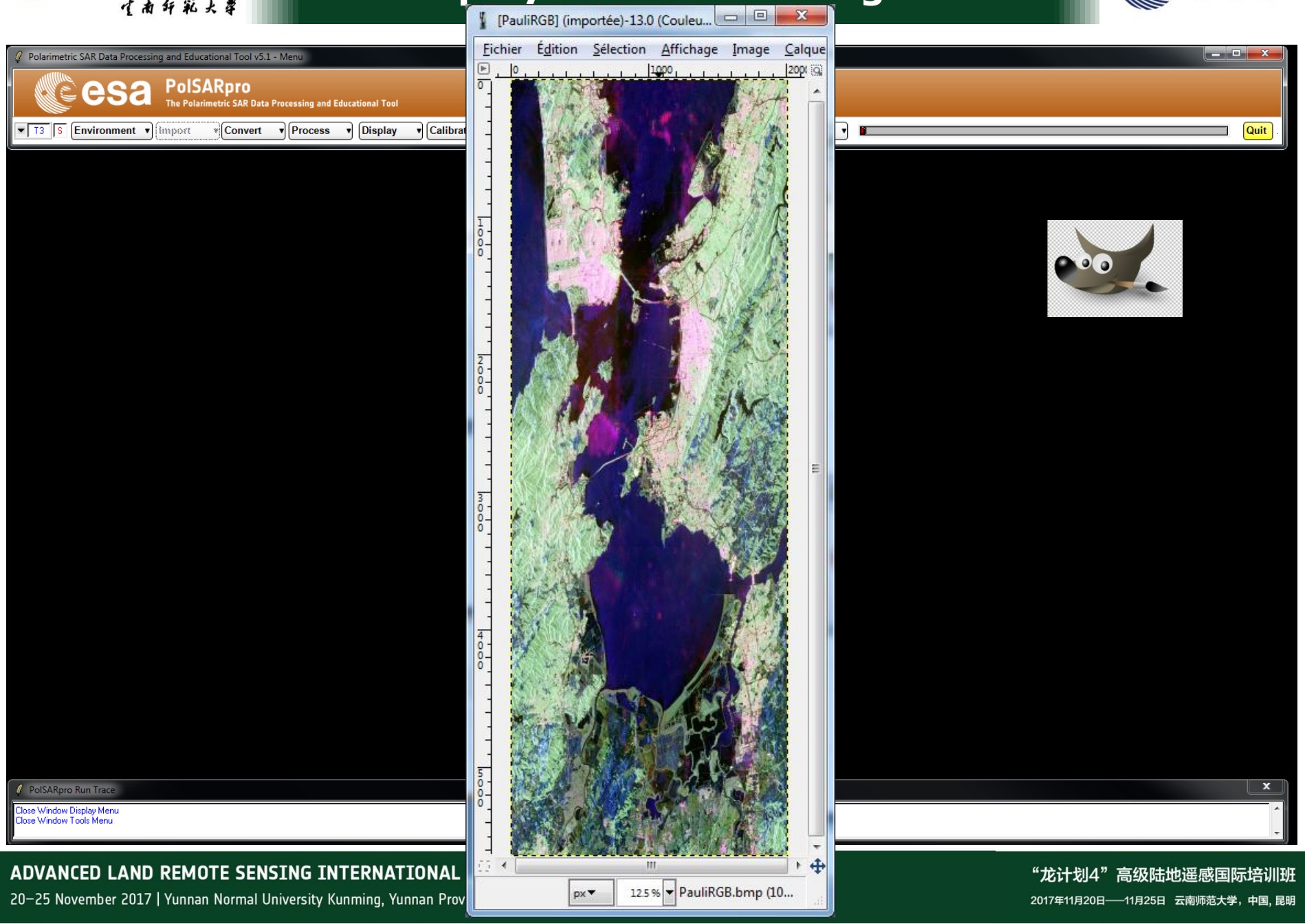
Data IMPORT – Input Data File



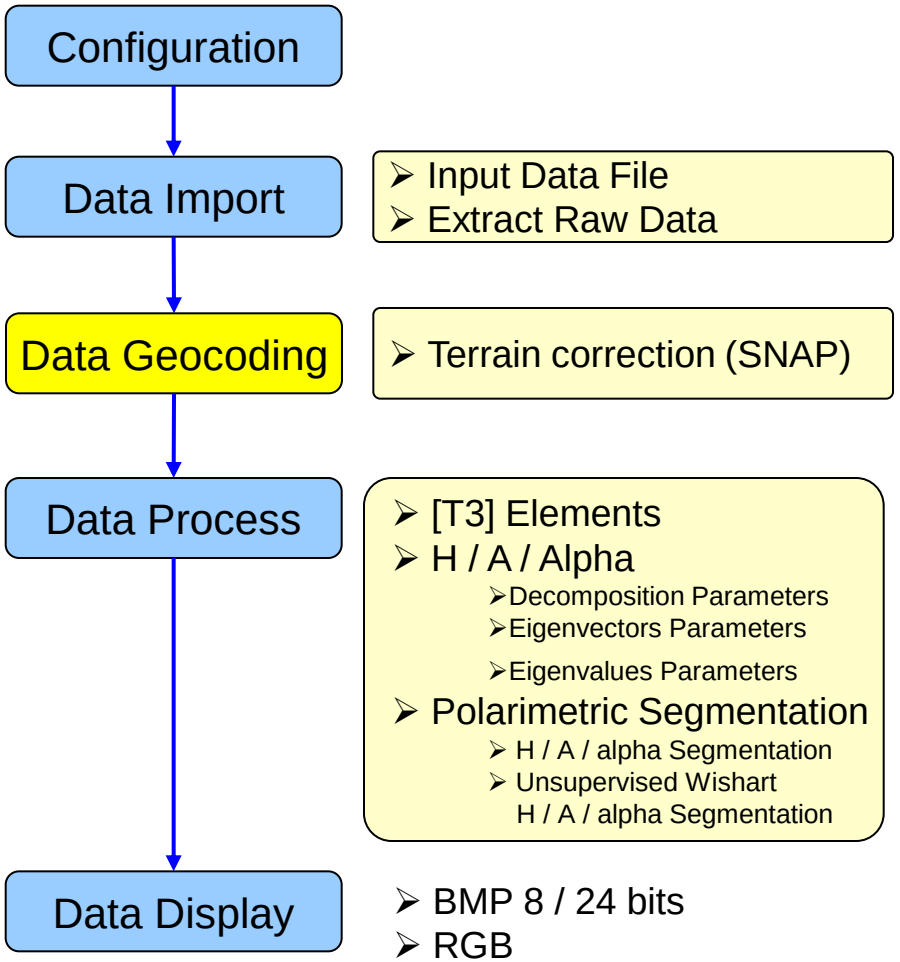
ENVIRONNEMENT



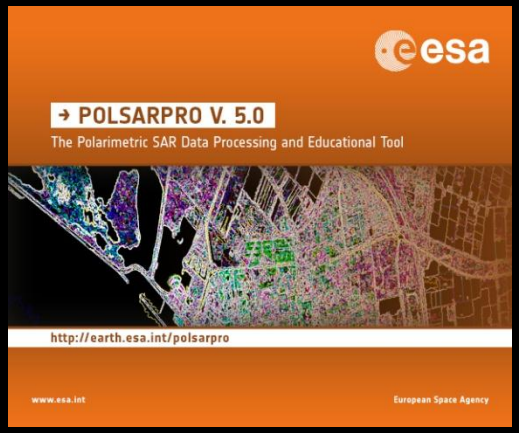
Display Pauli-RGB Image



PROCESSING CHAIN



ESA - SNAP



Polariametric Data Processing

- **S1 toolbox (split, deburst, merge …)**
- **Geocoding toolbox**
- **Interferometric toolbox**
  (co-registration, flat Earth estimation …

PolSARpro v5.1 SOFTWARE

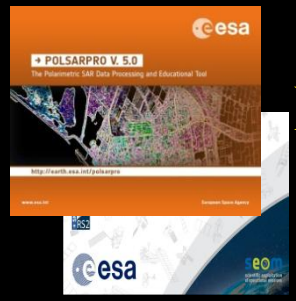
ESA - SNAP

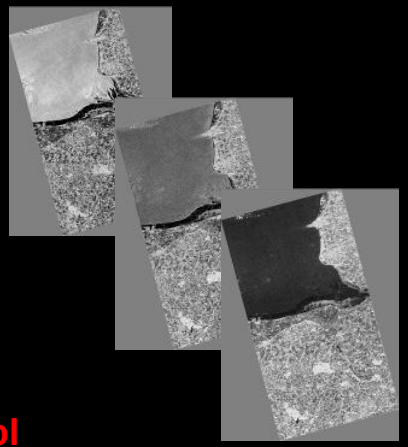
Pre-Processing
Data Extract

Geo-Coding
Terrain Correct - UTM Proj.

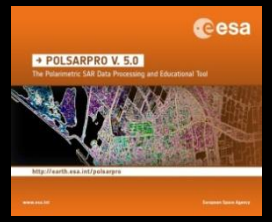
Post - Processing

POLARIMETRIC DATA SETS

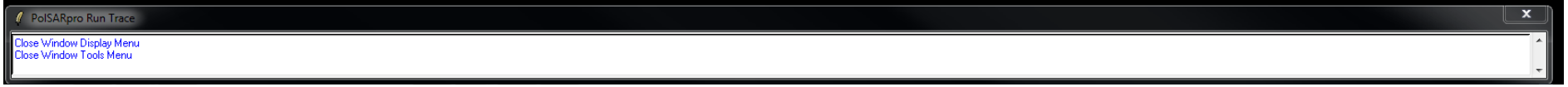




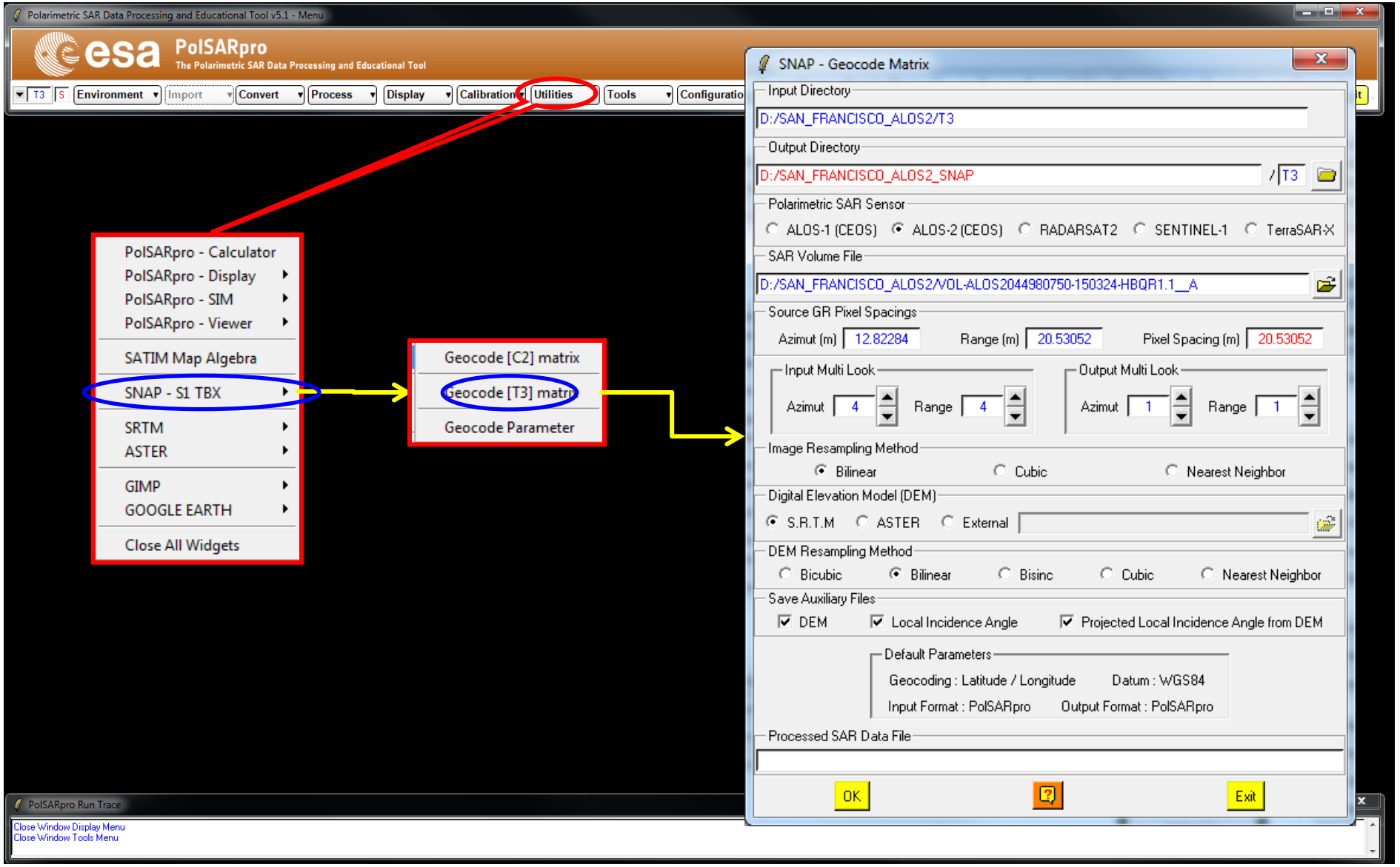
Only valid for:
[C2] matrix: Dual-Pol
[T3] matrix: Quad-Pol



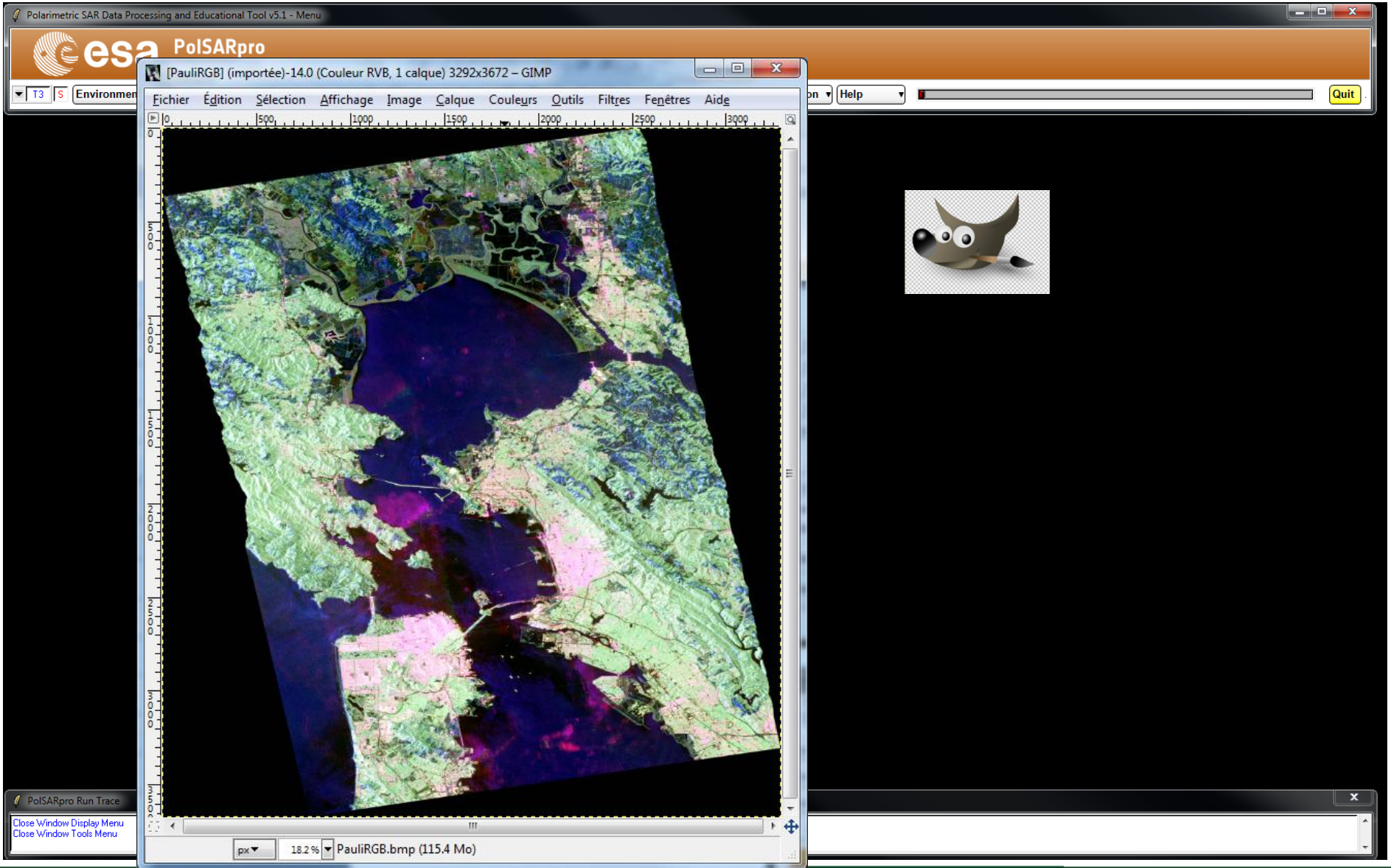
KML File generation



PolSARpro v5.1 SOFTWARE



Display Pauli-RGB Image



PROCESSING CHAIN

20mn

18mn

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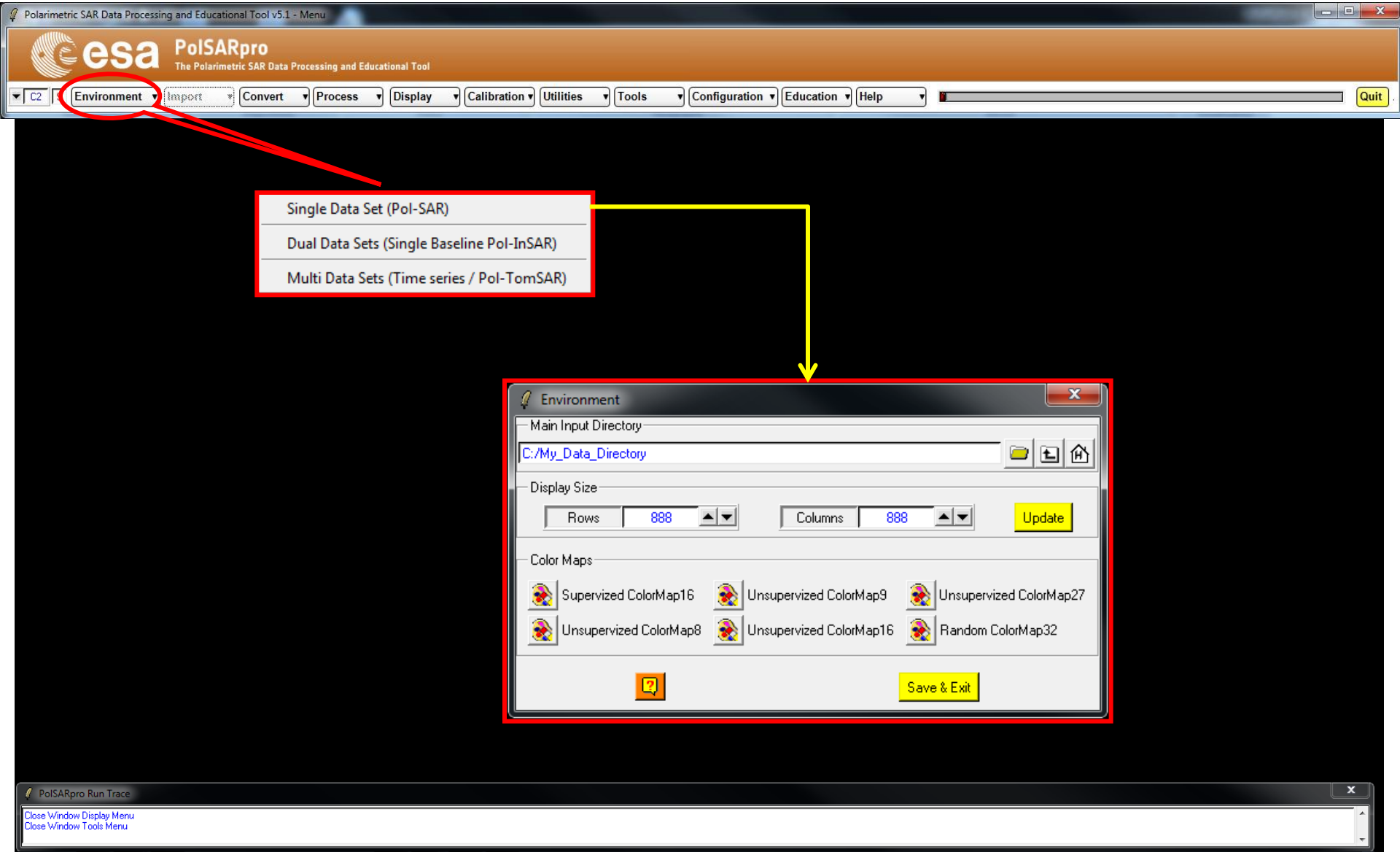
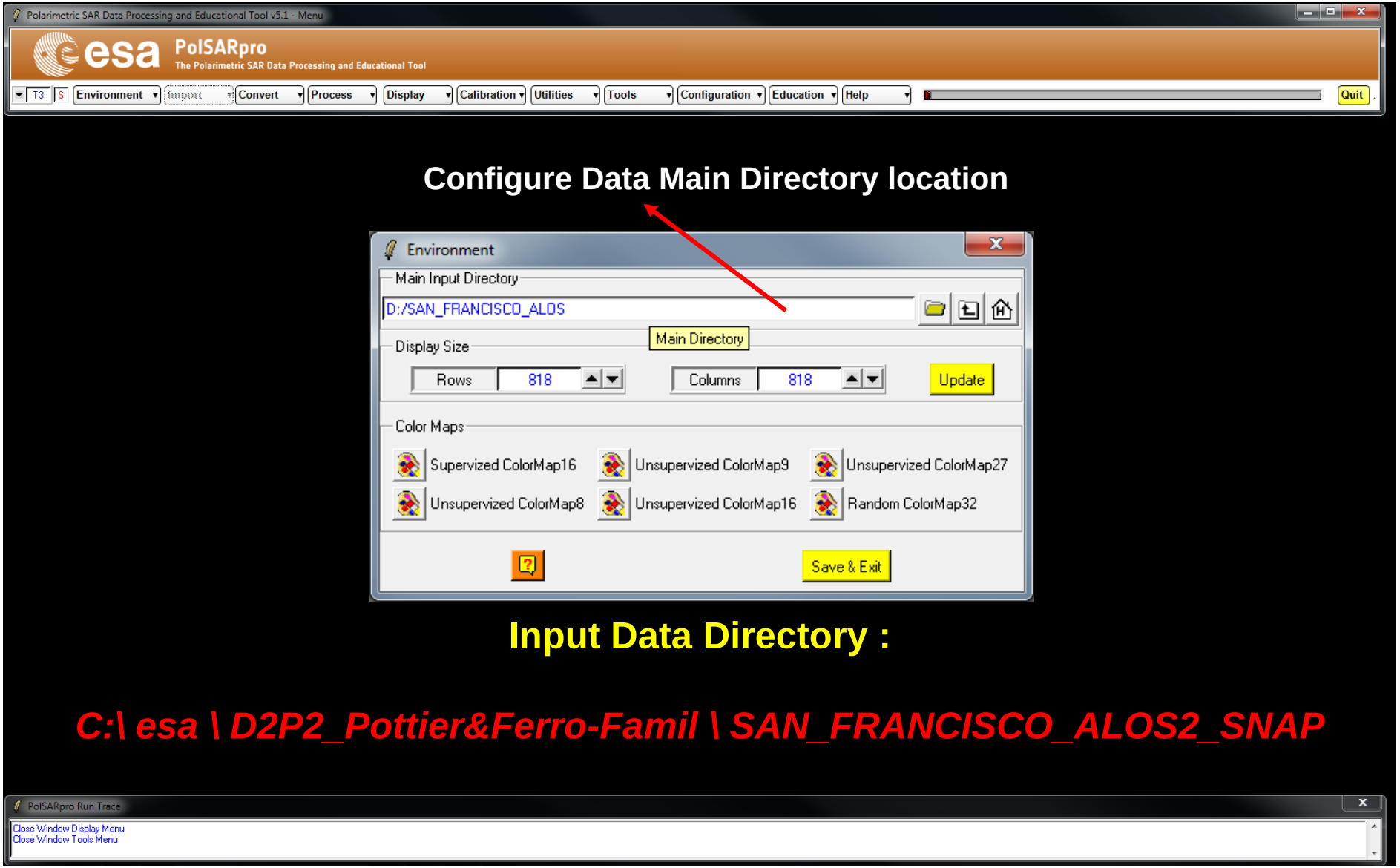
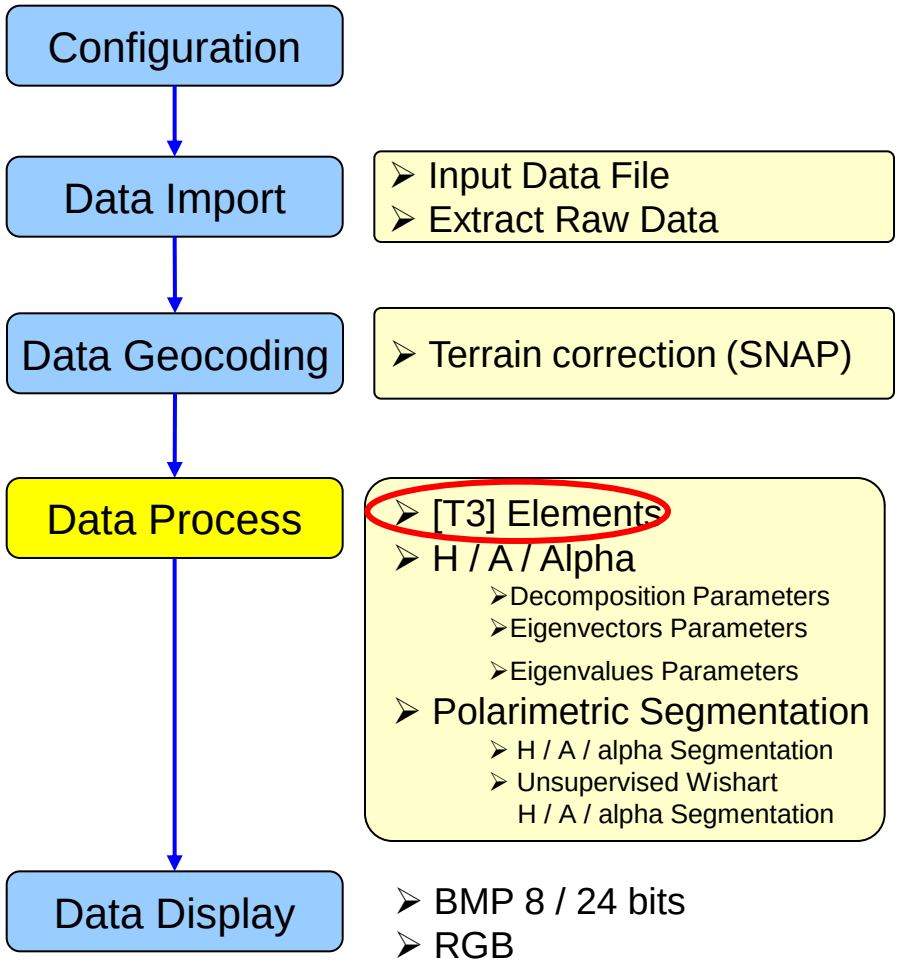
PolSARpro v5.1 SOFTWARE

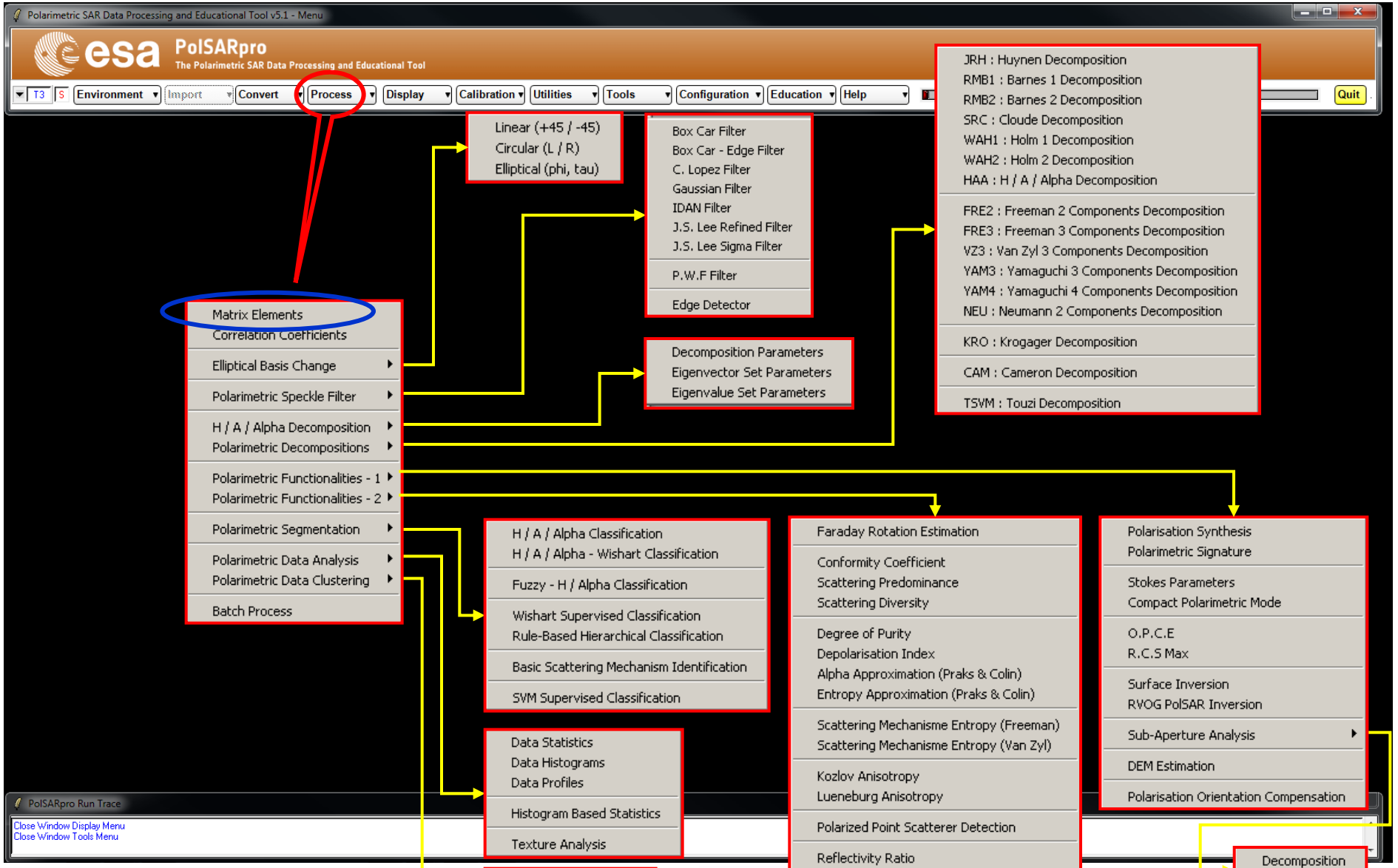



Polarimetric SAR Data Processing and Educational Tool v5.1 - Menu
PolSARpro
The Polarimetric SAR Data Processing and Educational Tool
T3
S
Environment
Import
Convert
Process
Display
Calibration
Utilities
Tools
Configuration
Education
Help
Quit
Configure Data Main Directory location
Environment
Main Input Directory
D:/SAN_FRANCISCO_ALOS
Main Directory
Display Size
Rows
818
Columns
818
Update
Color Maps
Supervized ColorMap16
Unsupervized ColorMap9
Unsupervized ColorMap27
Unsupervized ColorMap8
Unsupervized ColorMap16
Random ColorMap32
Save & Exit
Input Data Directory :
C:\ esa \ D2P2_Pottier&Ferro-Famil \ SAN_FRANCISCO_ALOS2_SNAP
PolSARpro Run Trace
Close Window Display Menu
Close Window Tools Menu

PROCESSING CHAIN



PolSARpro v5.1 SOFTWARE



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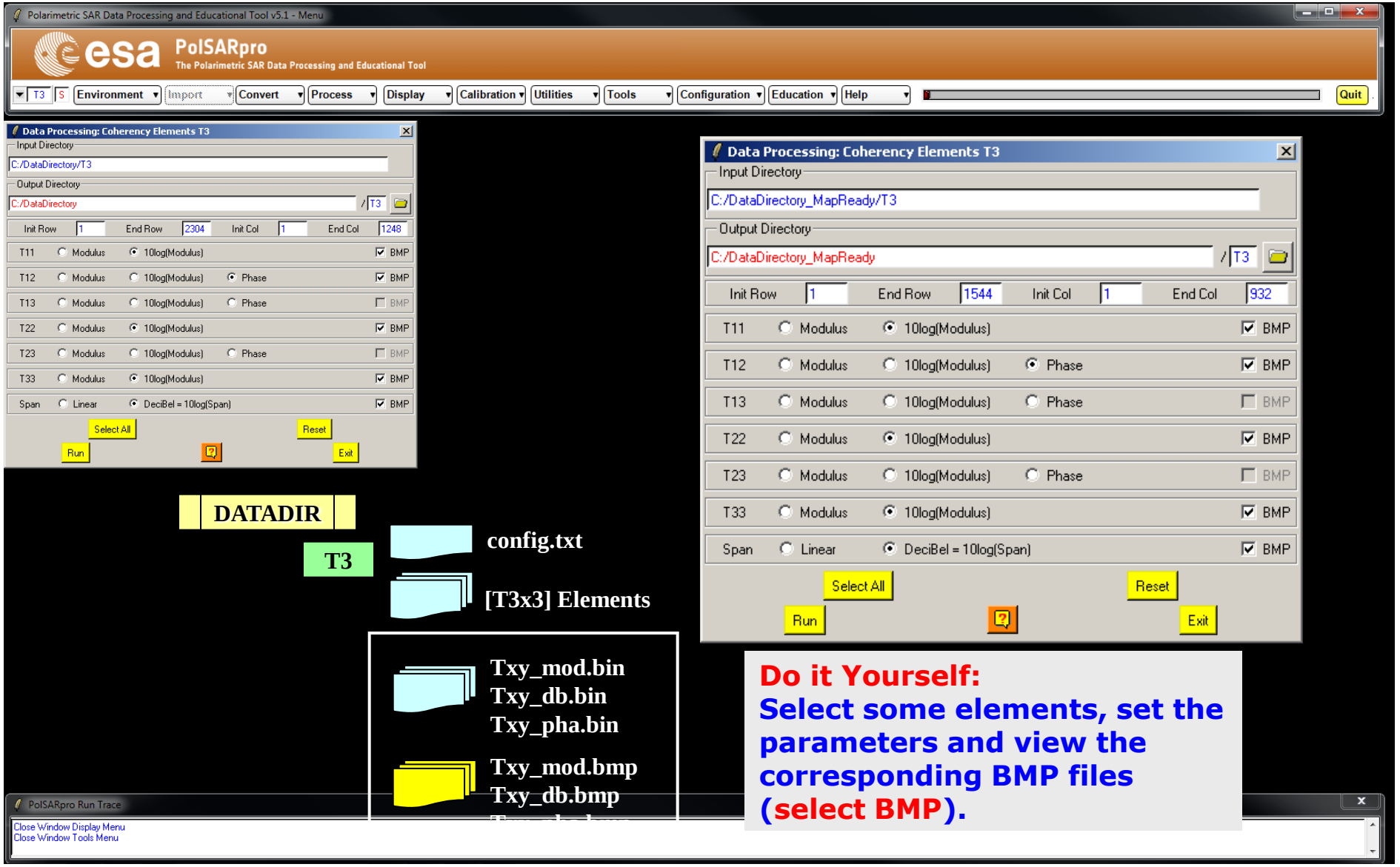
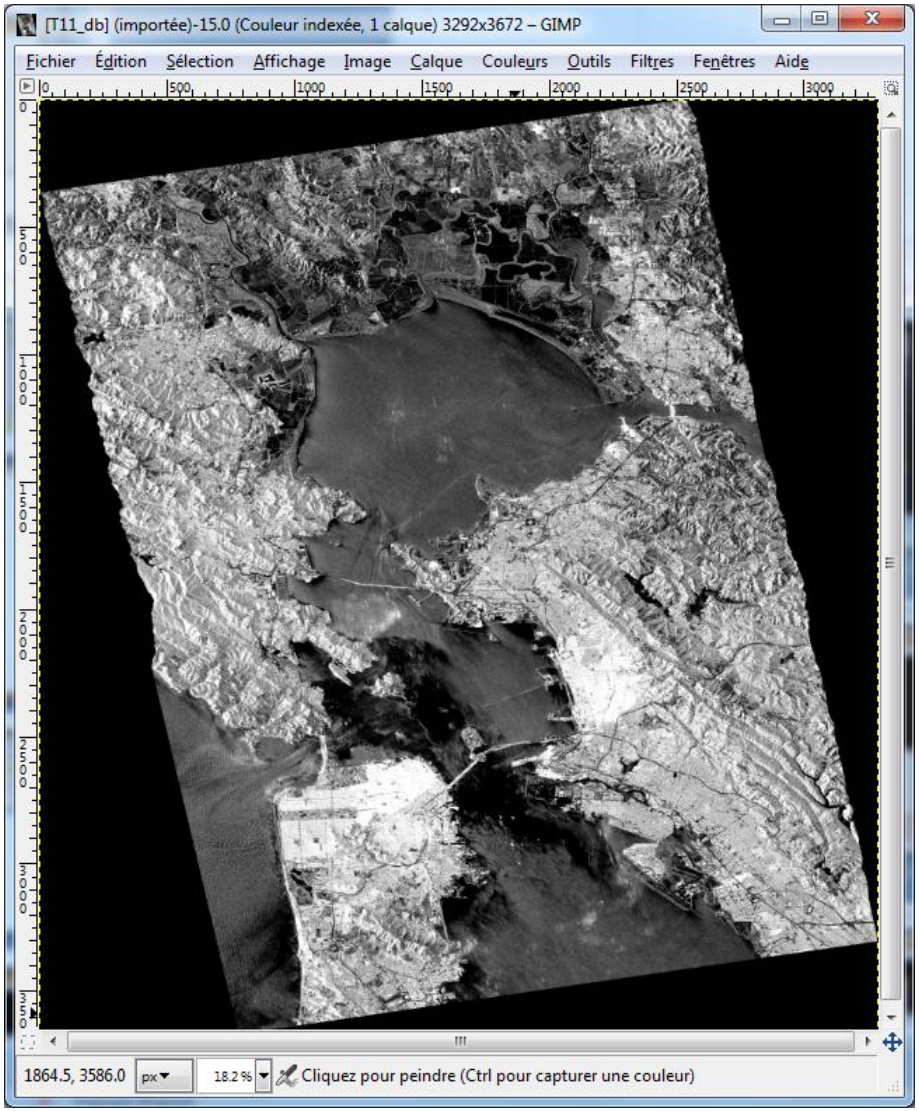


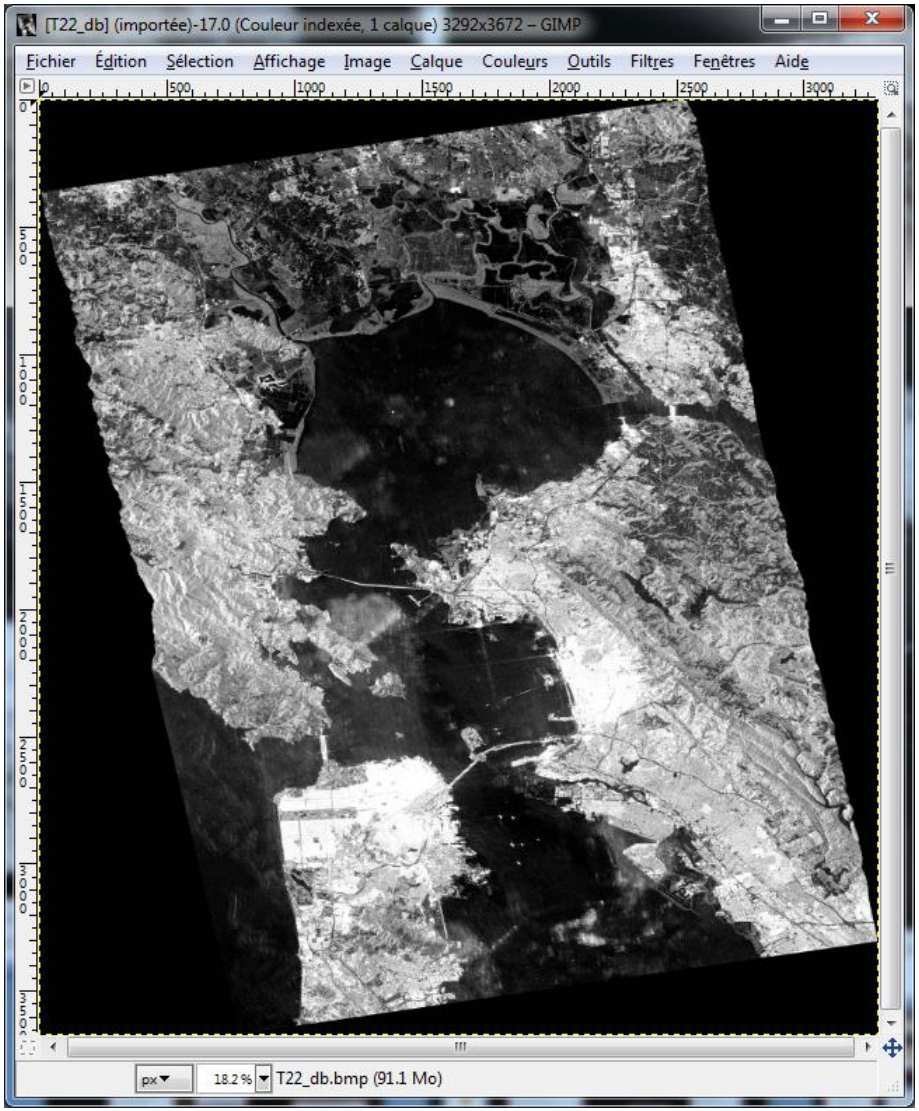
Do it Yourself:
Select some elements, set the parameters and view the corresponding BMP files (select BMP).

[T3] ELEMENTS

T11_dB

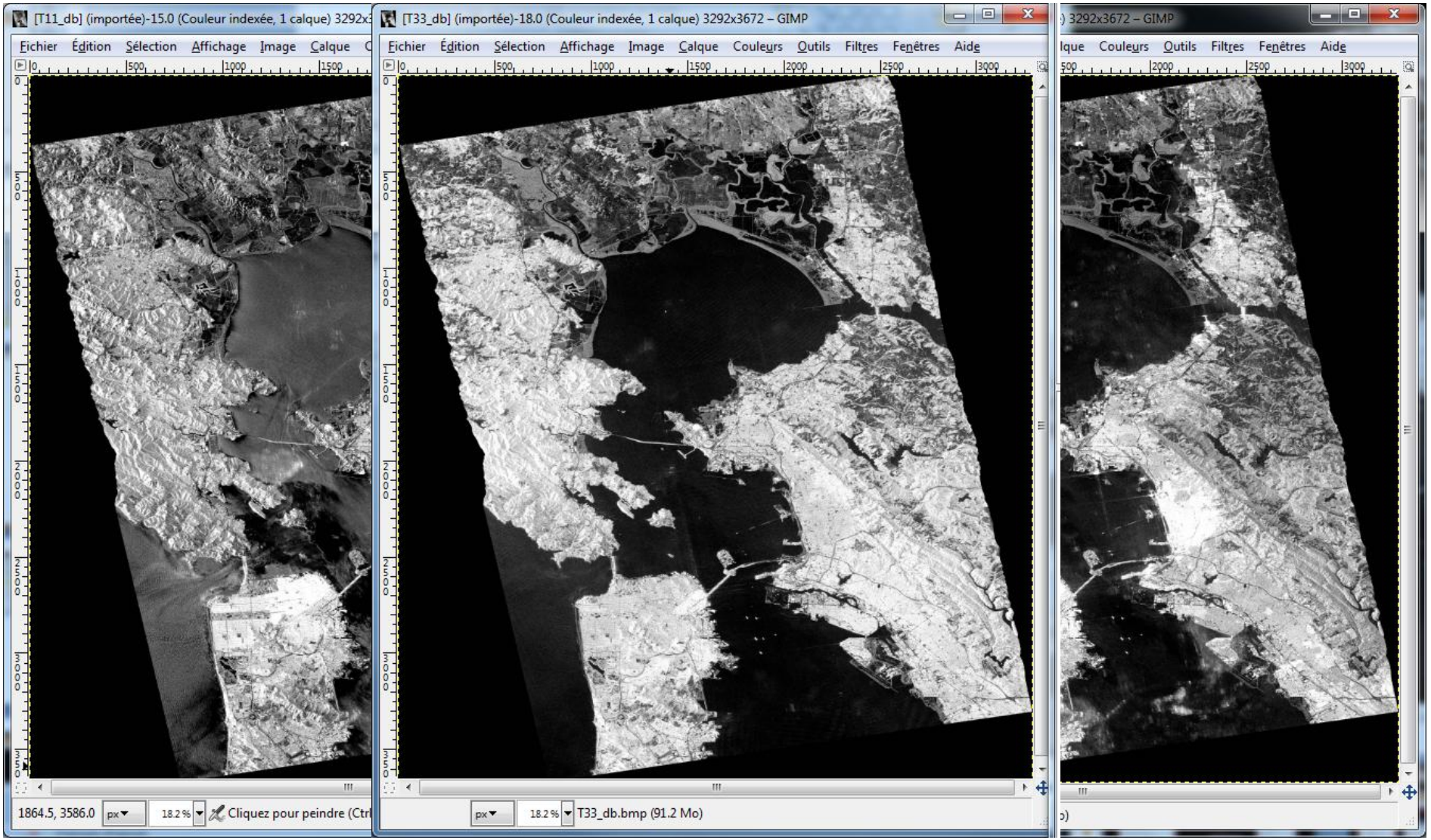


T22_dB



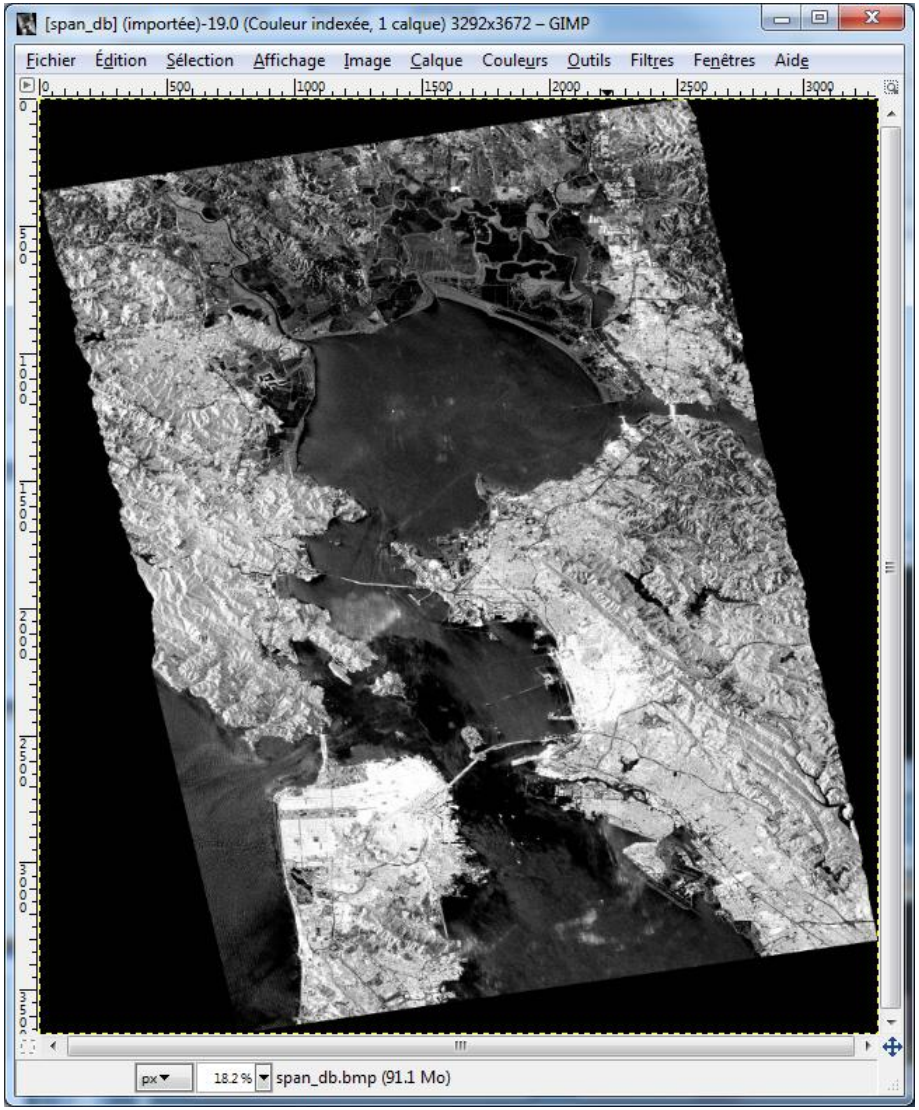
[T3] ELEMENTS

T11_dB **T33_dB** **T22_dB**

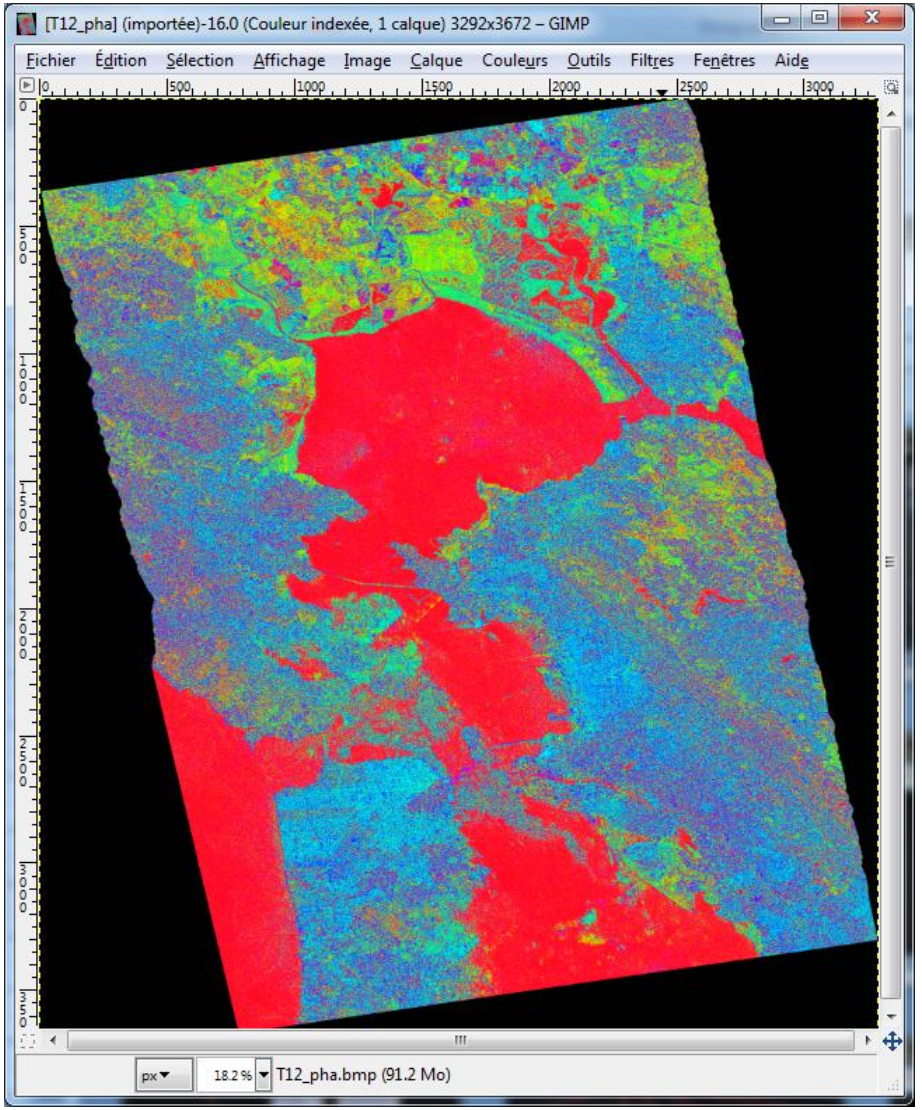


[T3] ELEMENTS

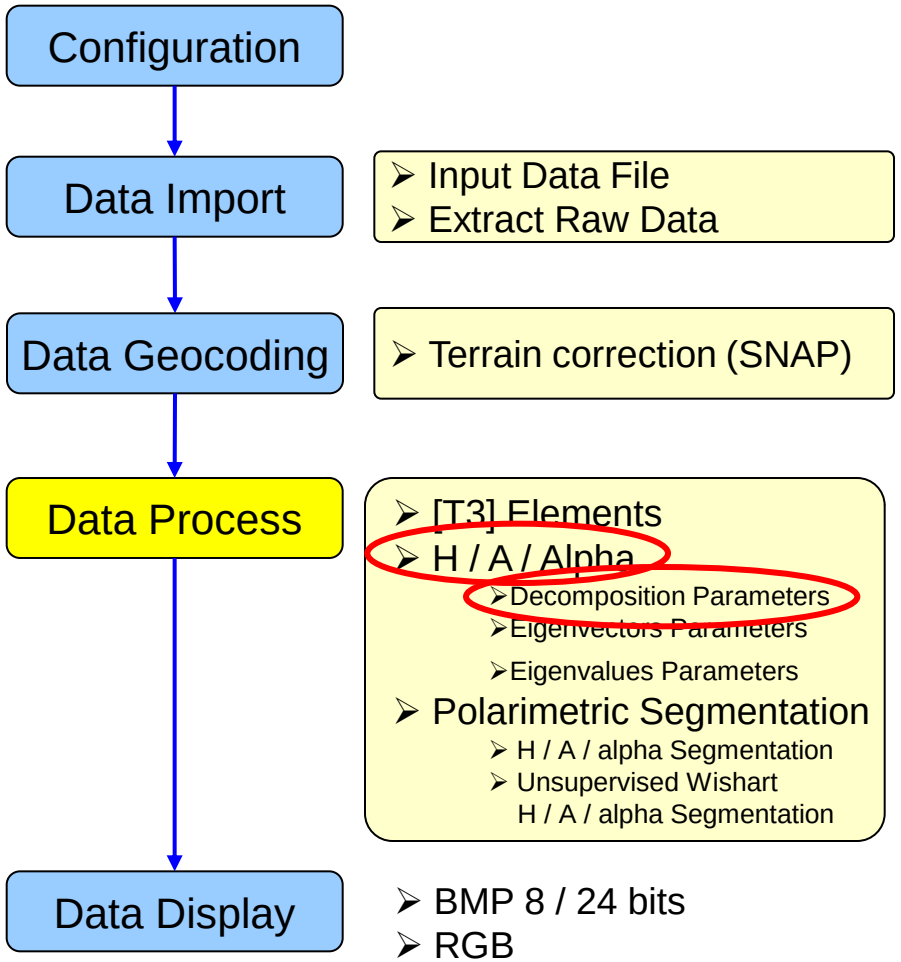
span_dB



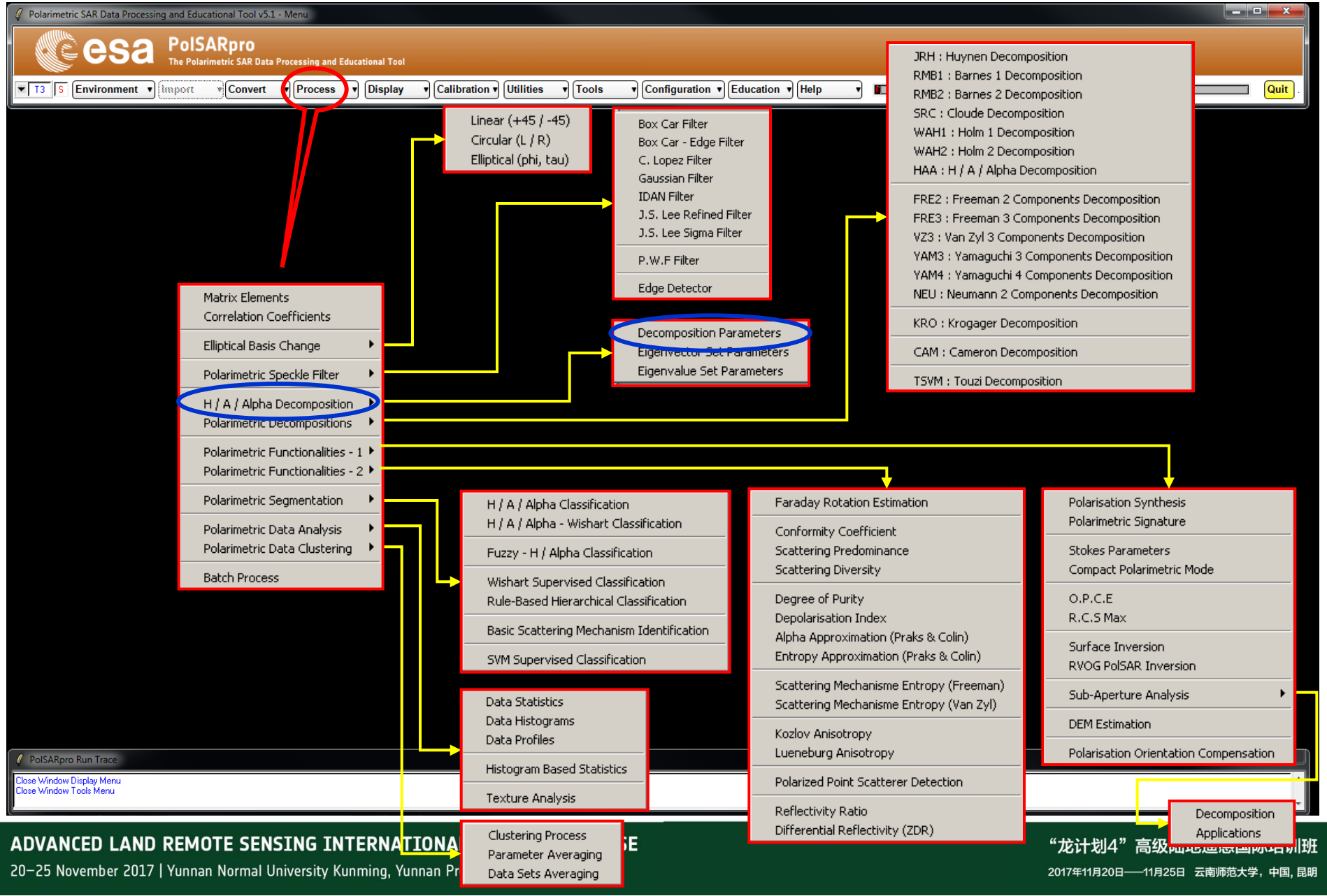
T12_pha



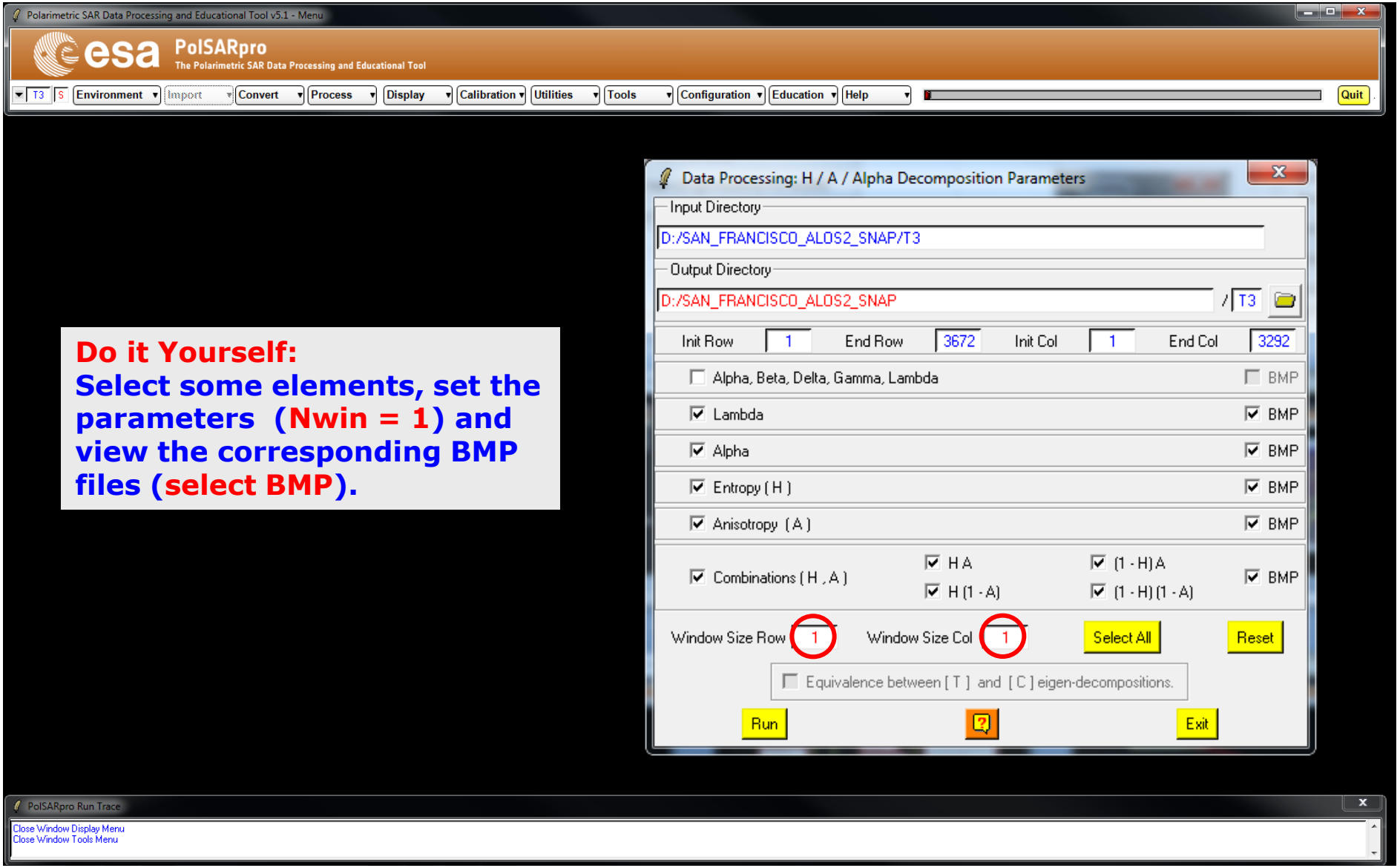
PROCESSING CHAIN



PolSARpro v5.1 SOFTWARE



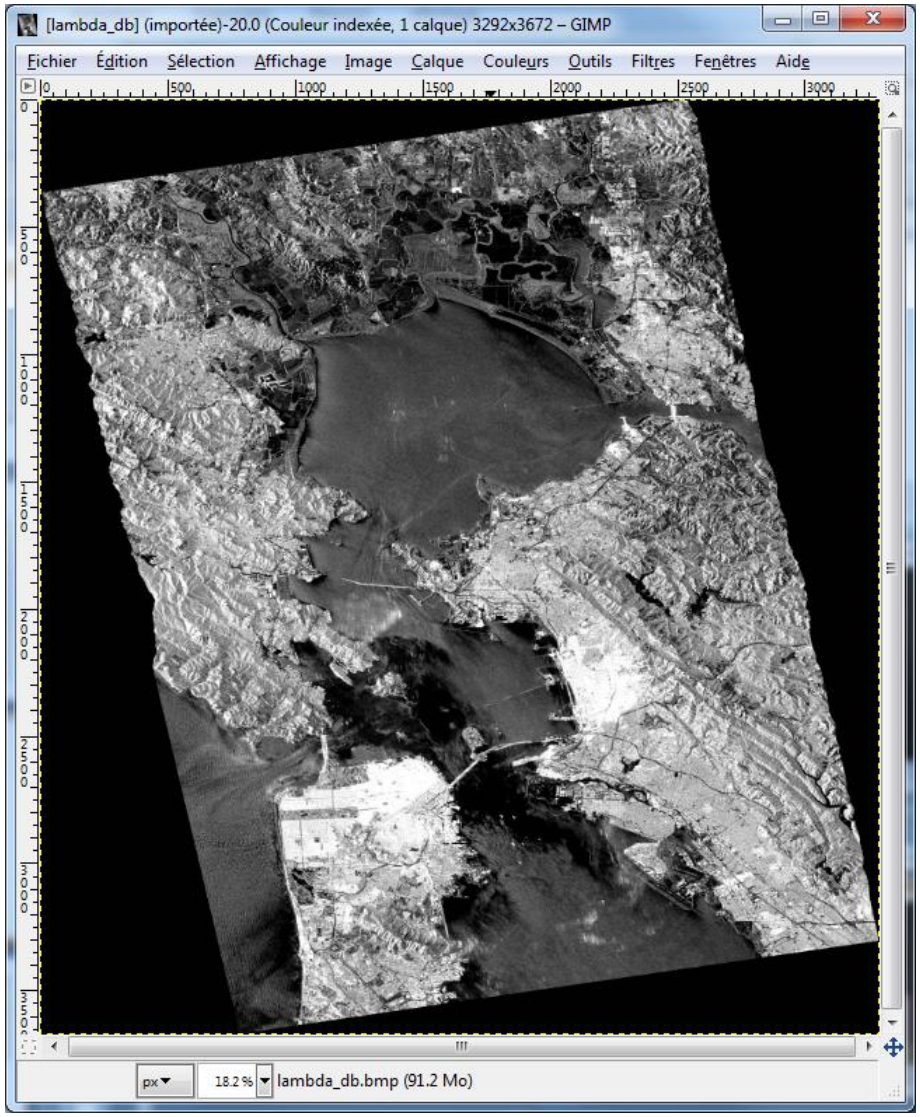
DECOMPOSITION PARAMETERS



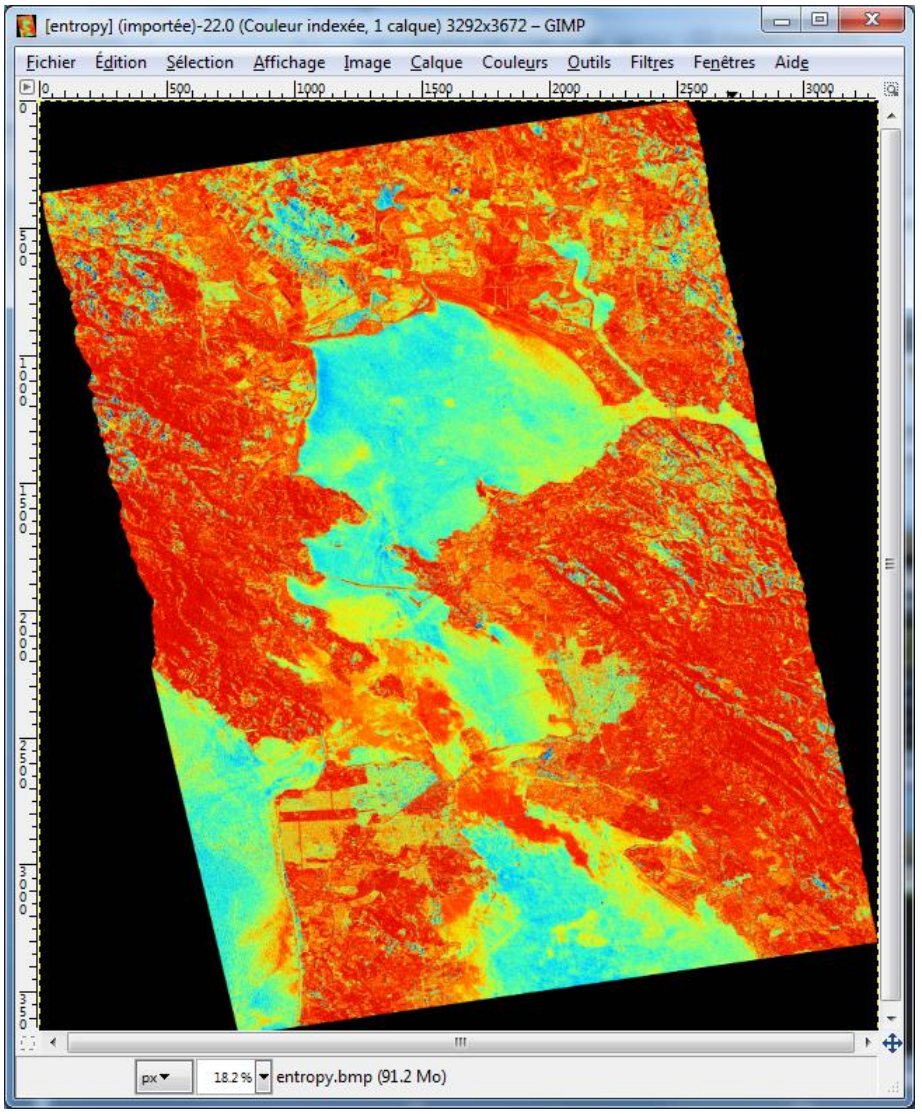
Do it Yourself:
Select some elements, set the parameters (Nwin = 1) and view the corresponding BMP files (select BMP).

DECOMPOSITION PARAMETERS

Lambda

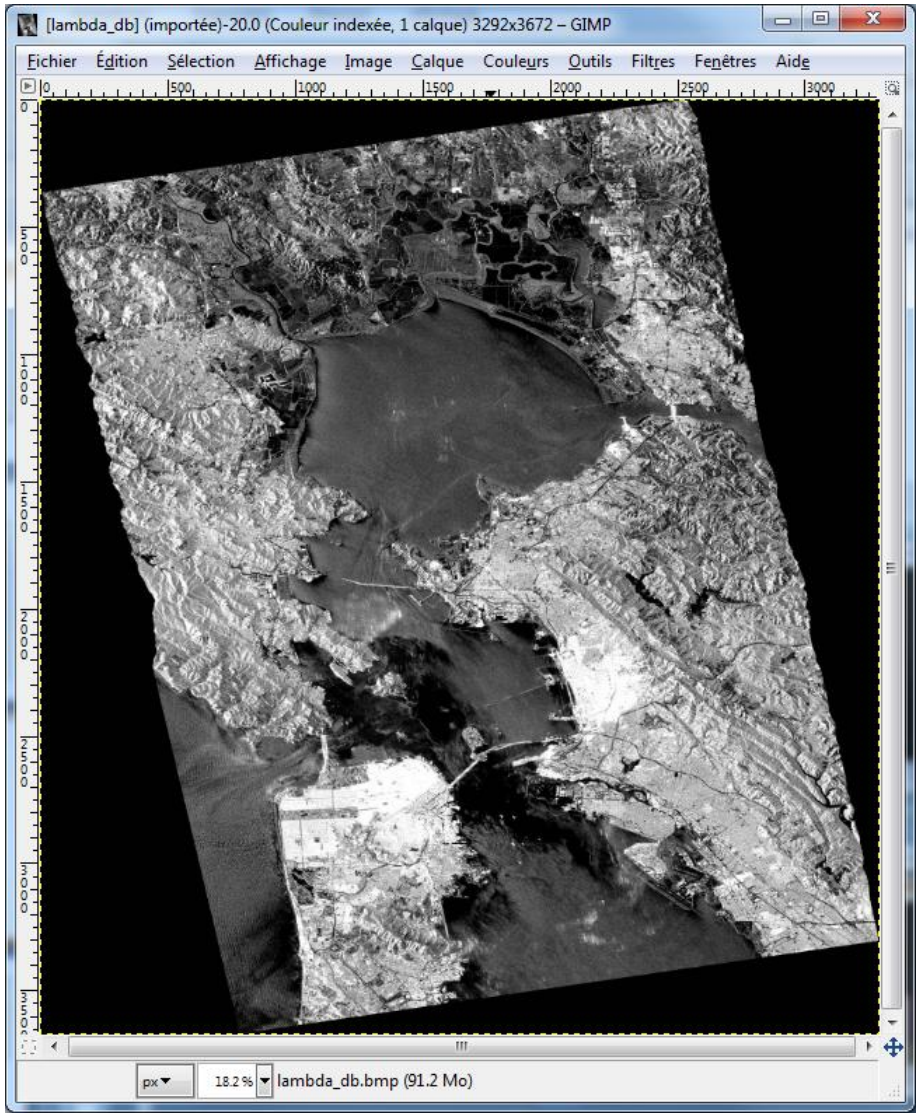


Entropy

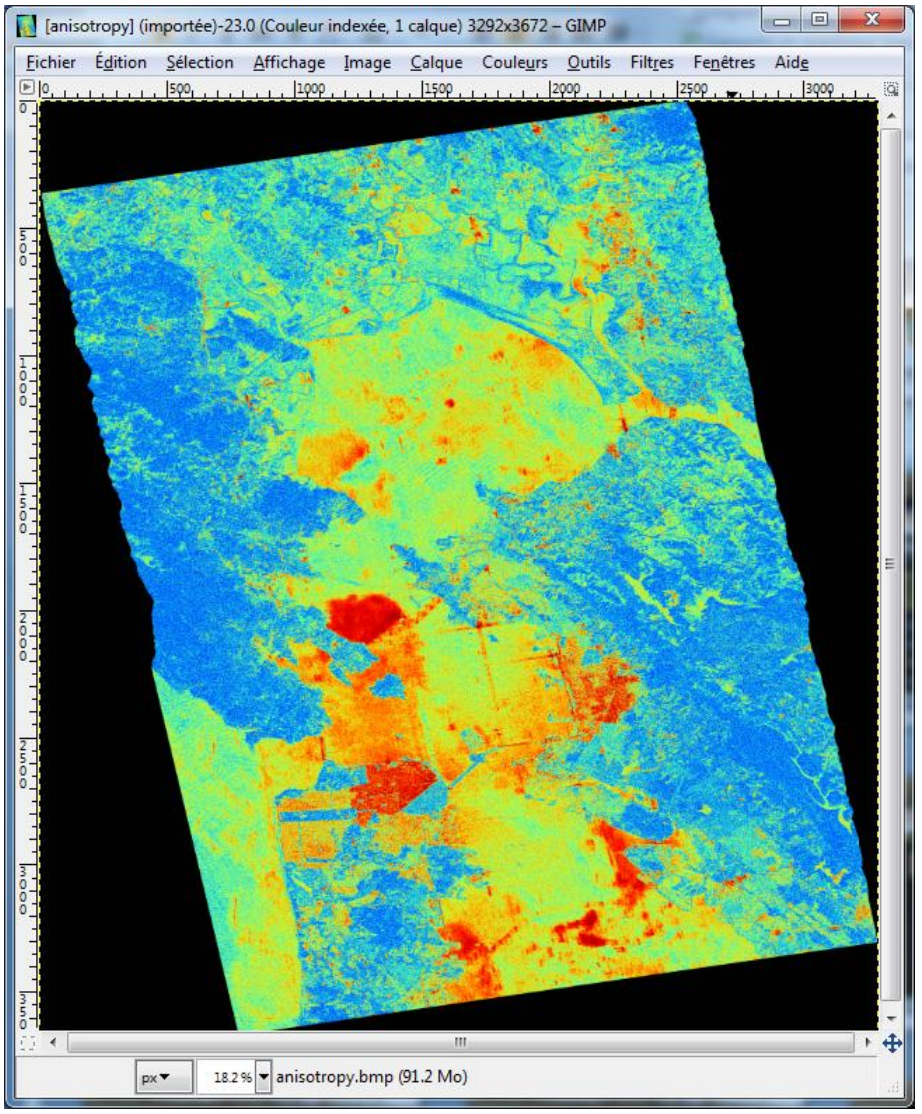


DECOMPOSITION PARAMETERS

Lambda

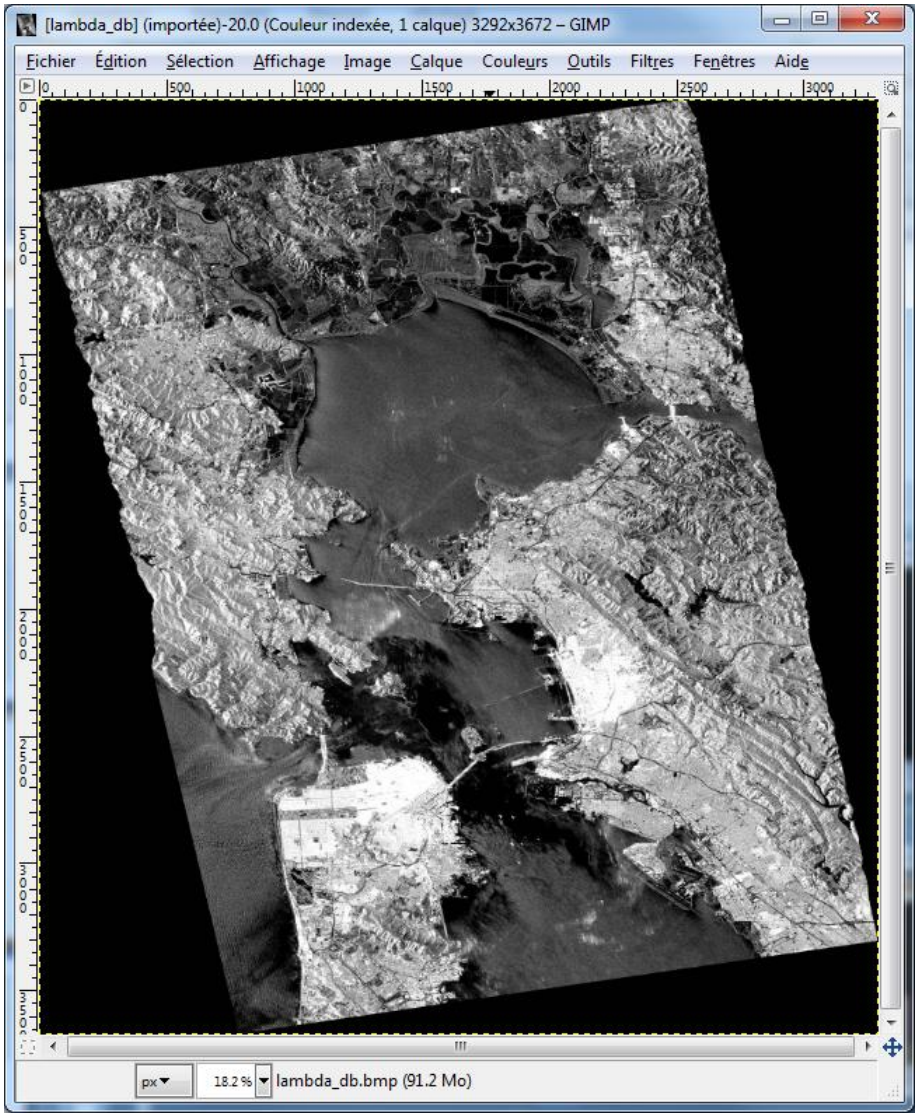


Anisotropy

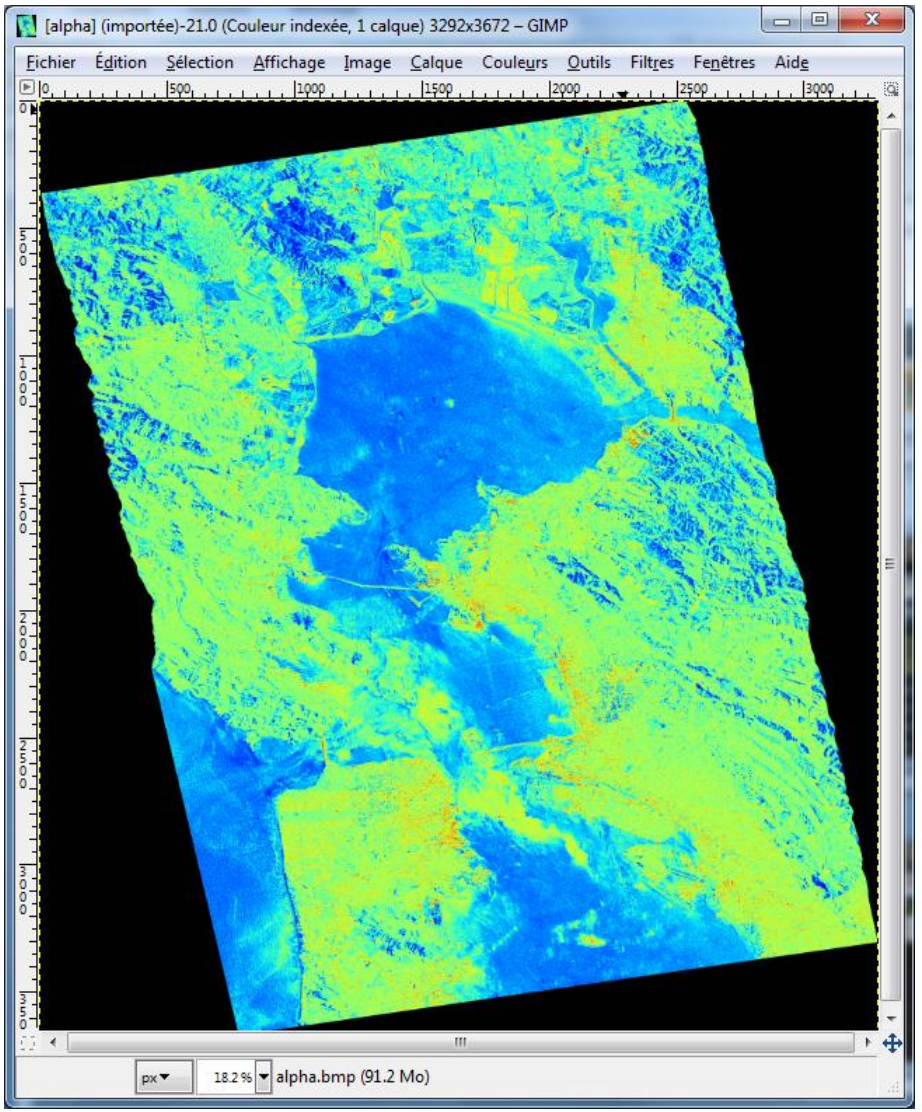


DECOMPOSITION PARAMETERS

Lambda

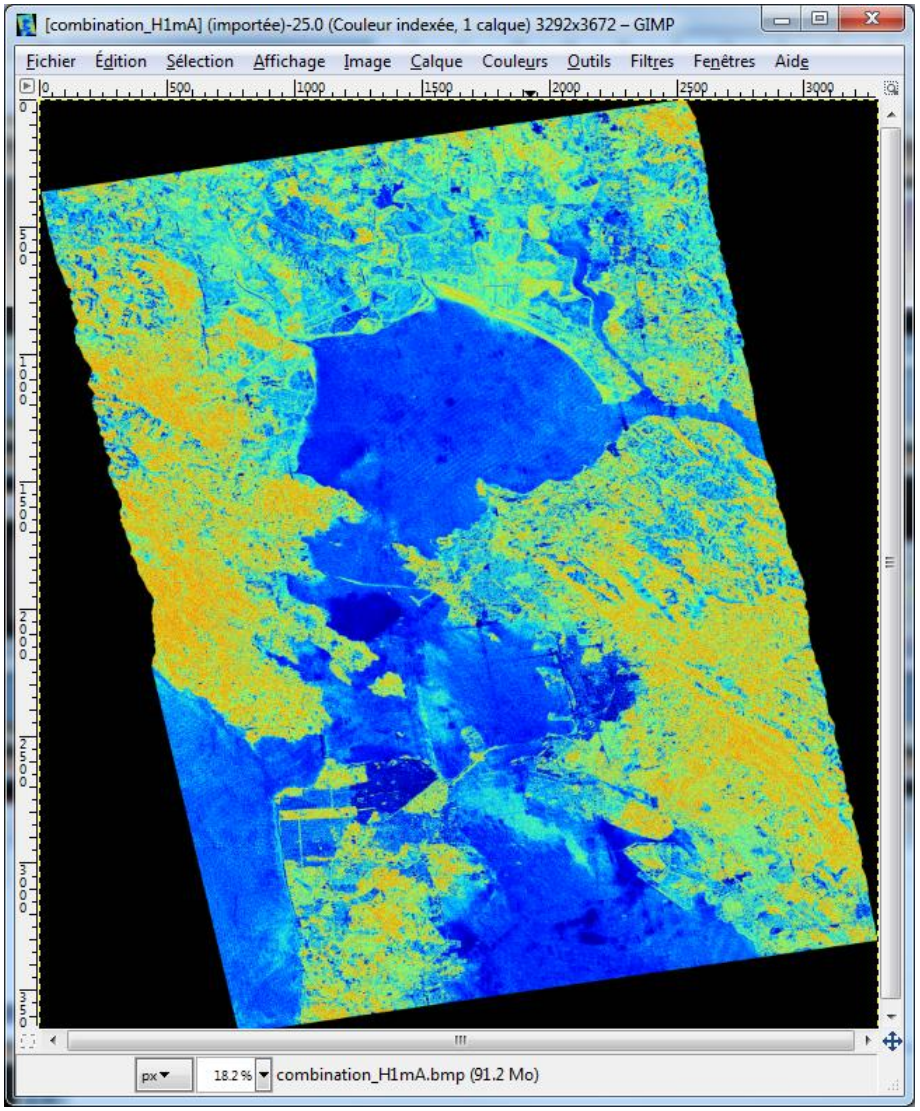


Alpha

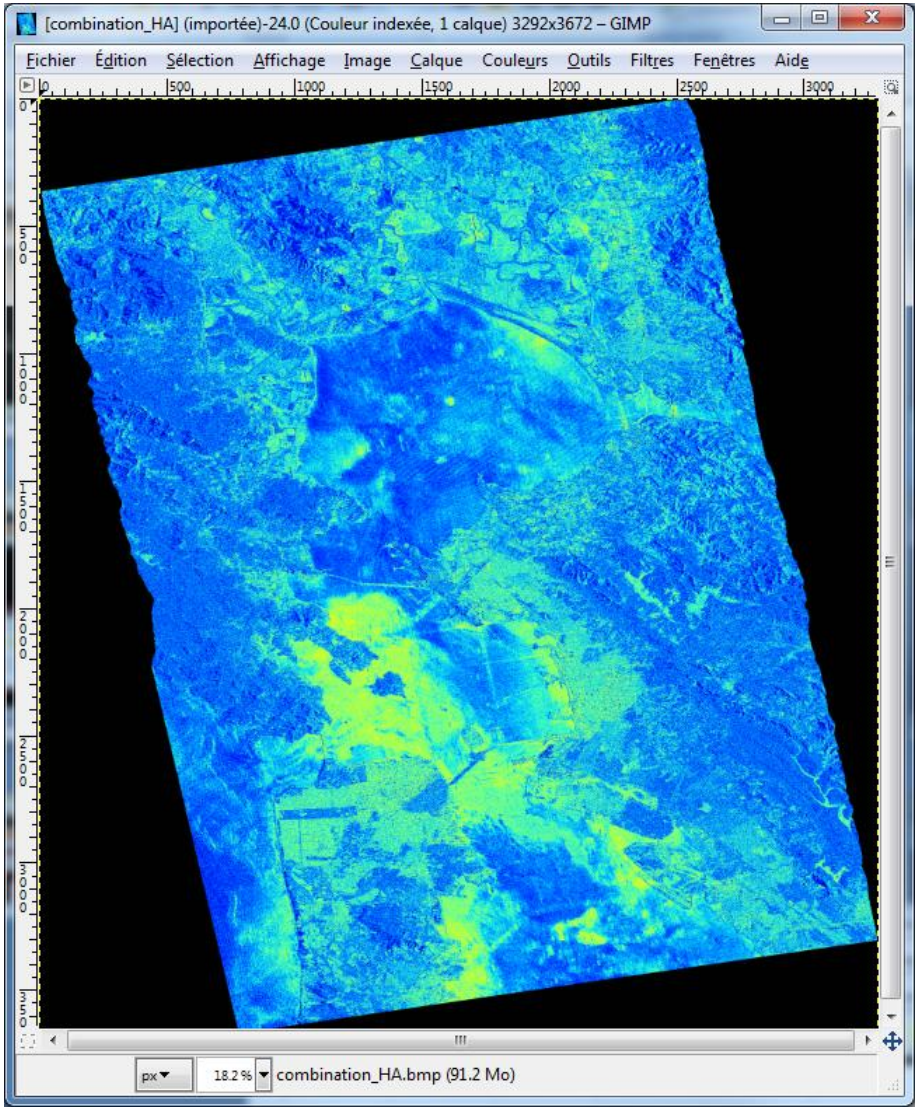


DECOMPOSITION PARAMETERS

H (1-A)

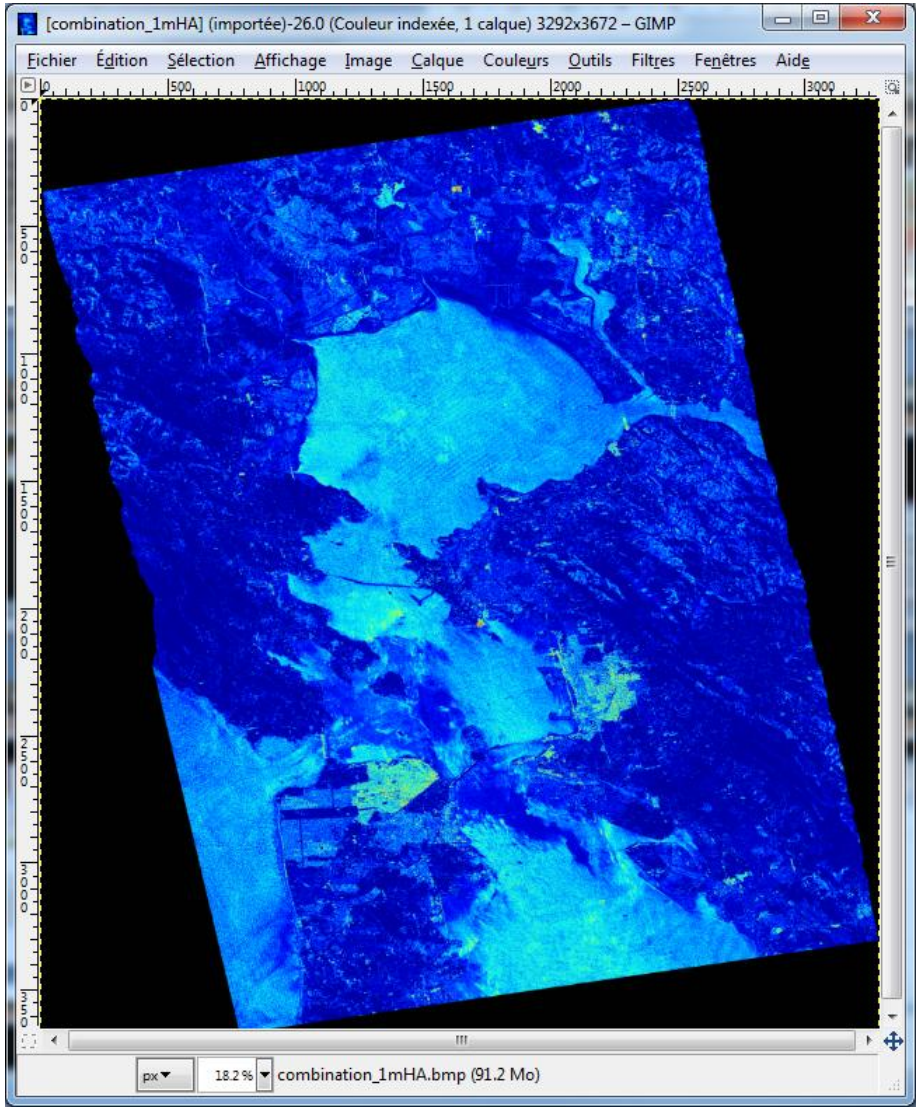


HA

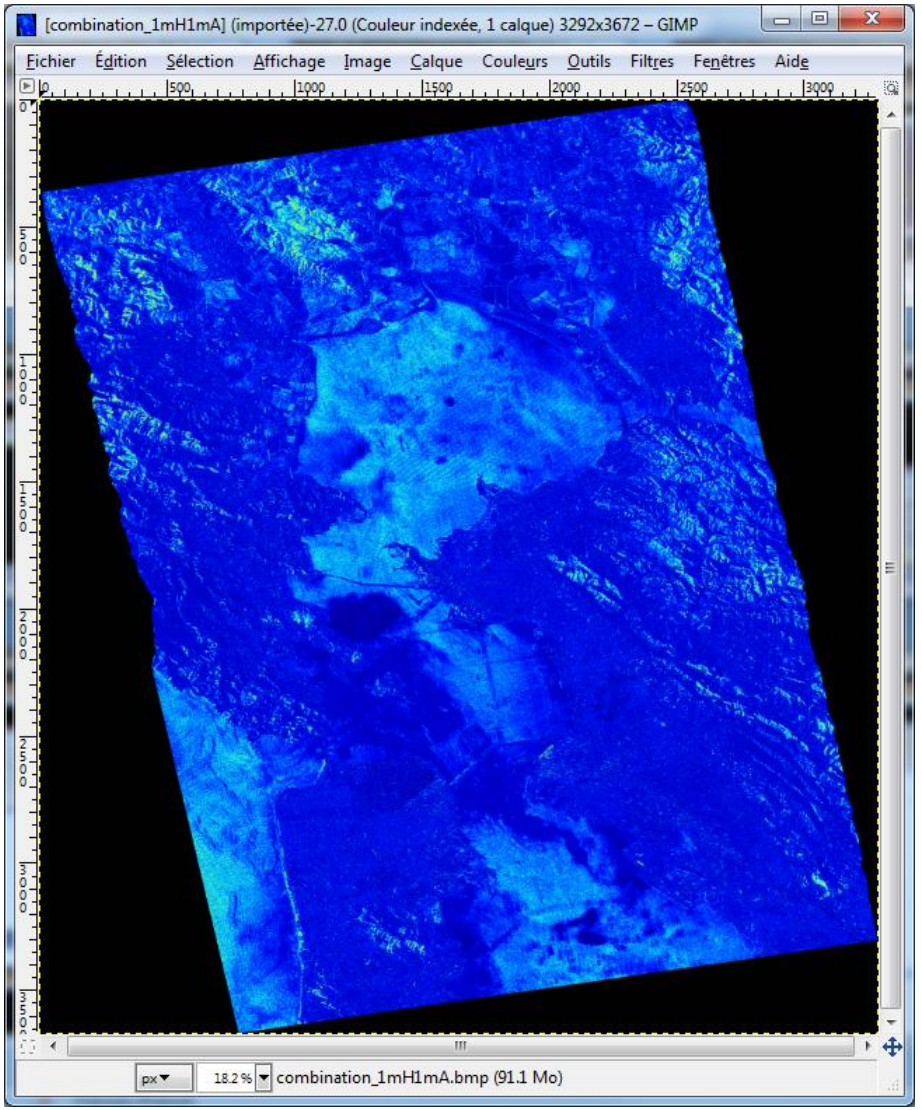


DECOMPOSITION PARAMETERS

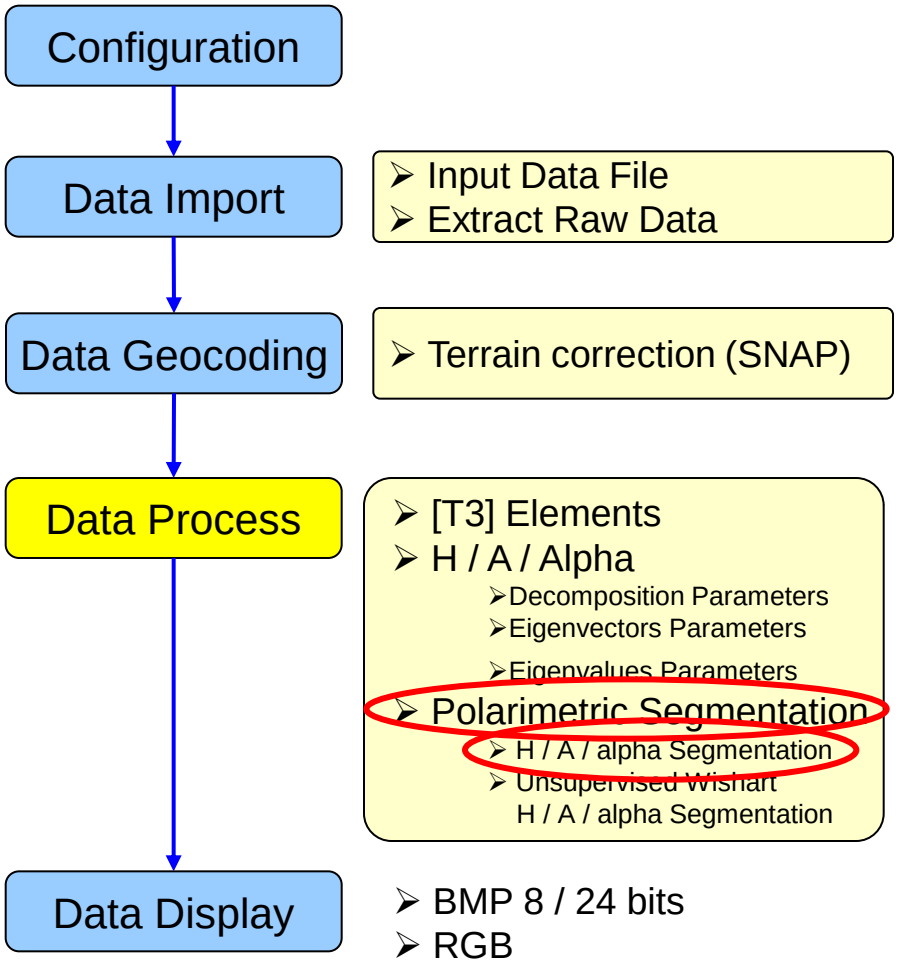
(1–H) A



(1-H) (1-A)



PROCESSING CHAIN



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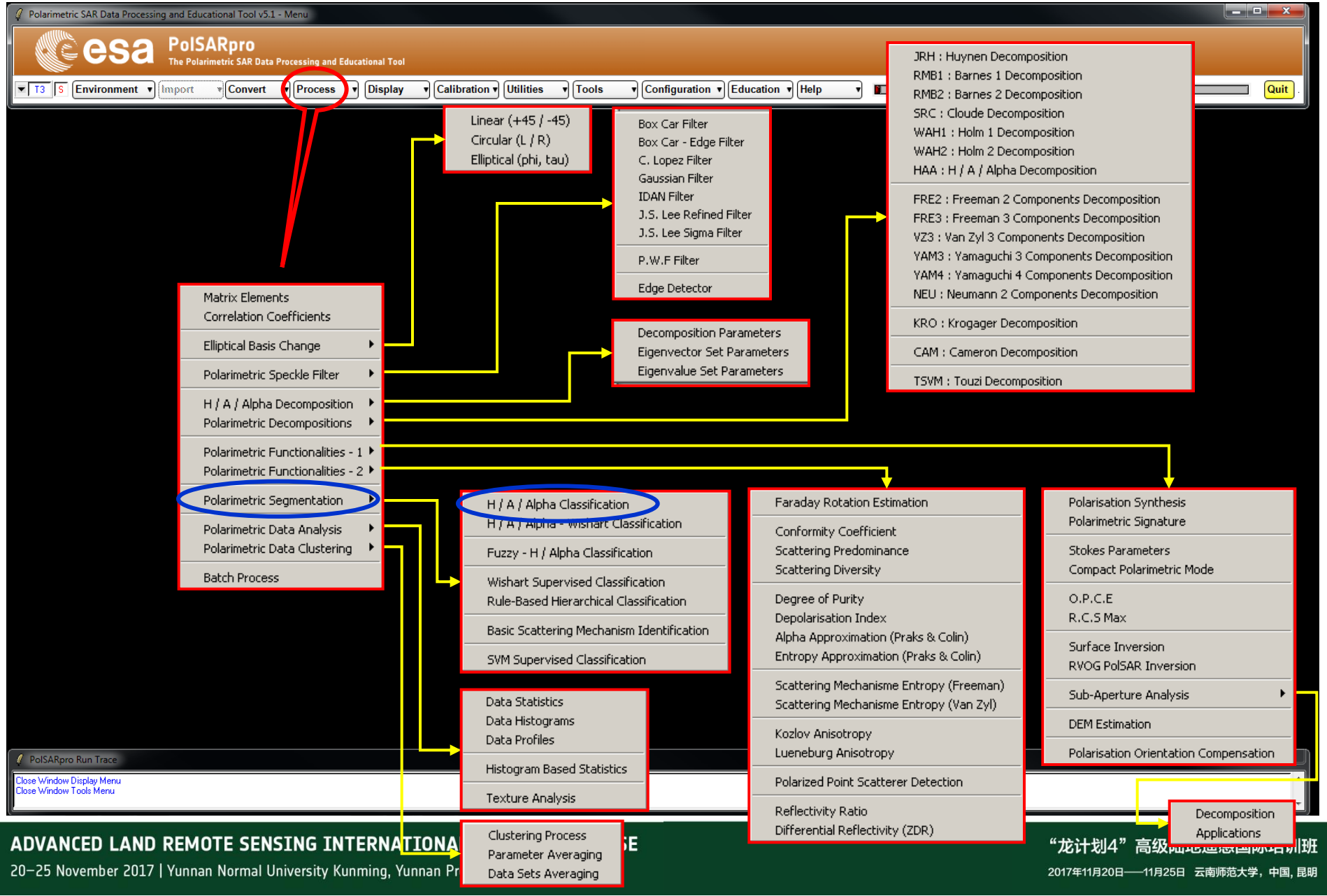
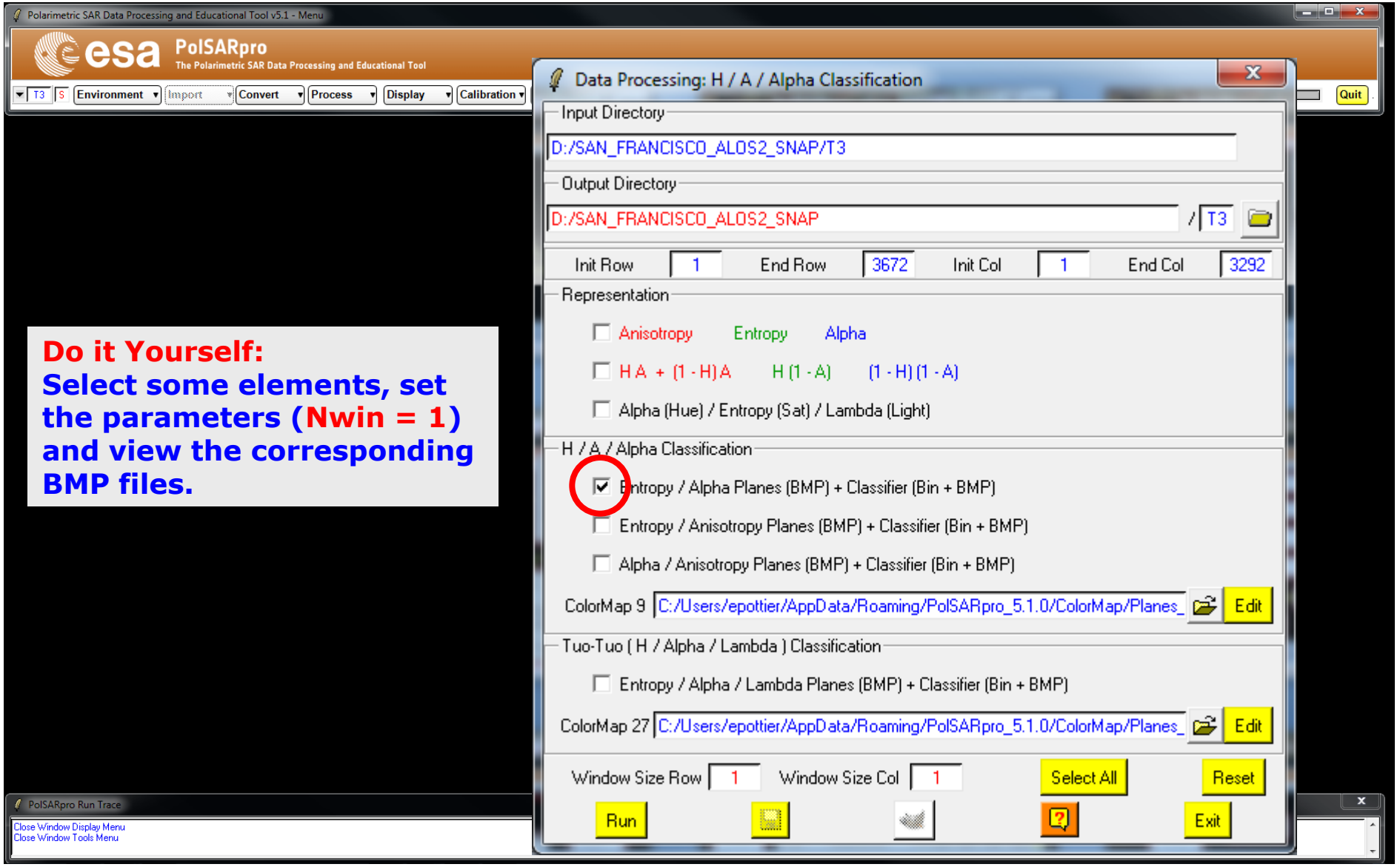
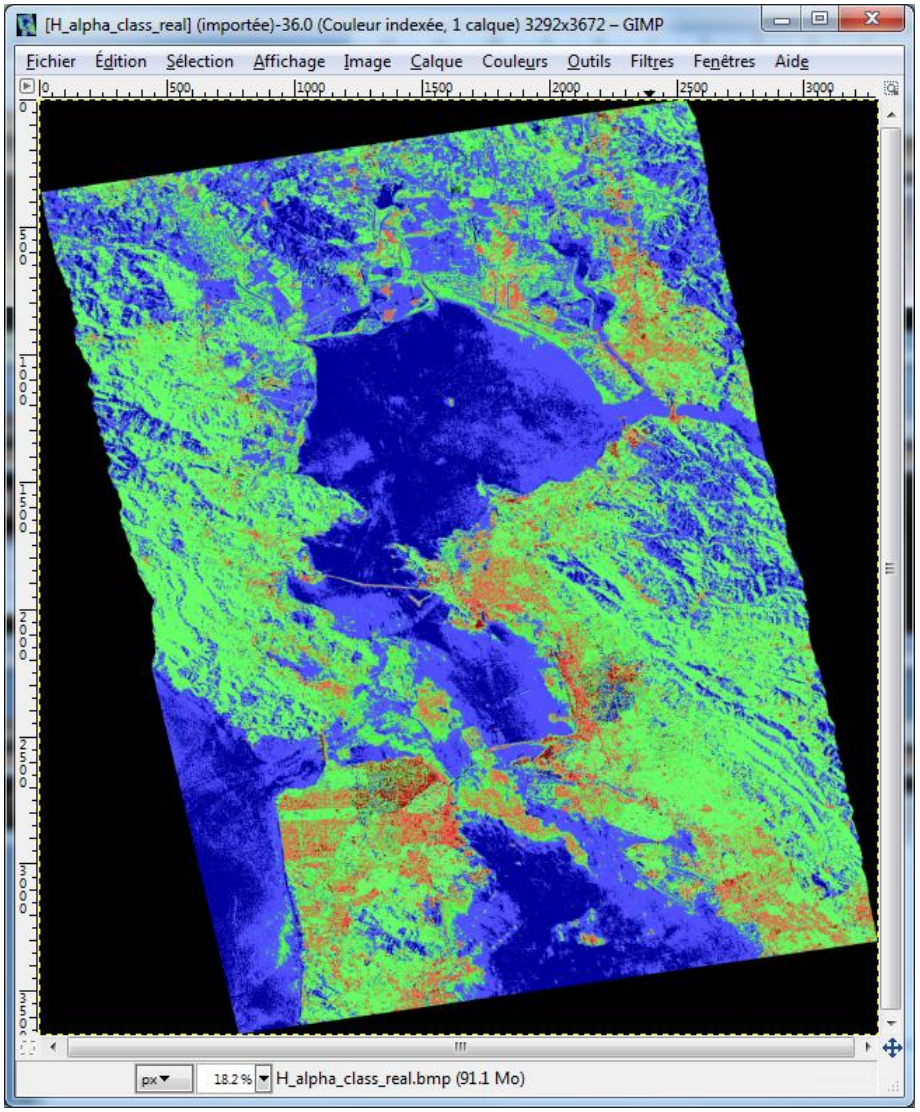


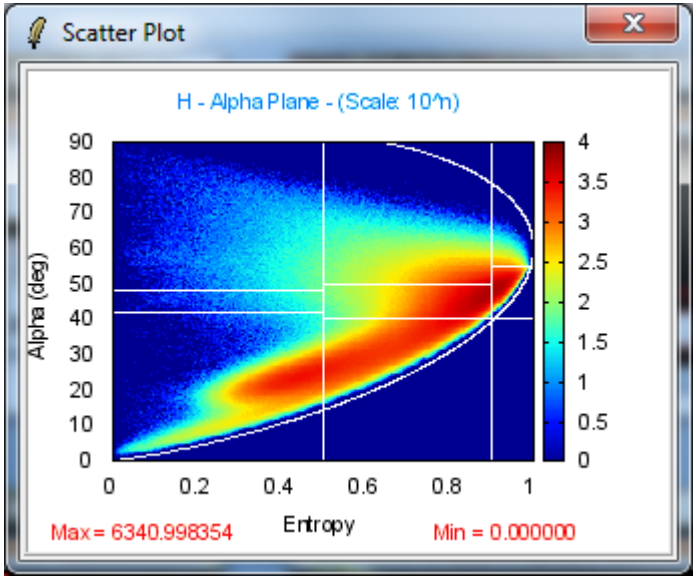
H / A / alpha CLASSIFICATION



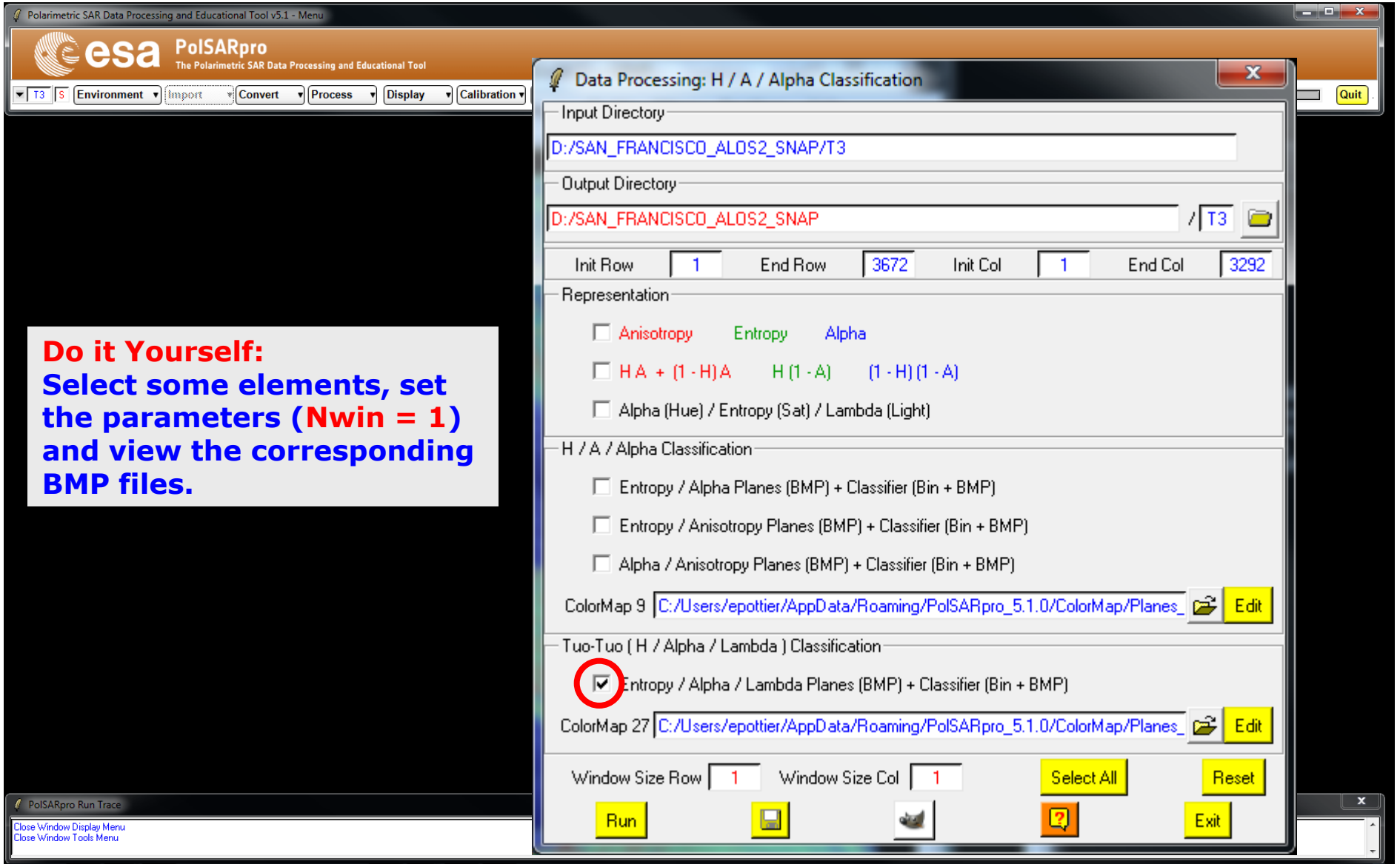
Do it Yourself:
Select some elements, set the parameters (Nwin = 1) and view the corresponding BMP files.

H / A / alpha CLASSIFICATION



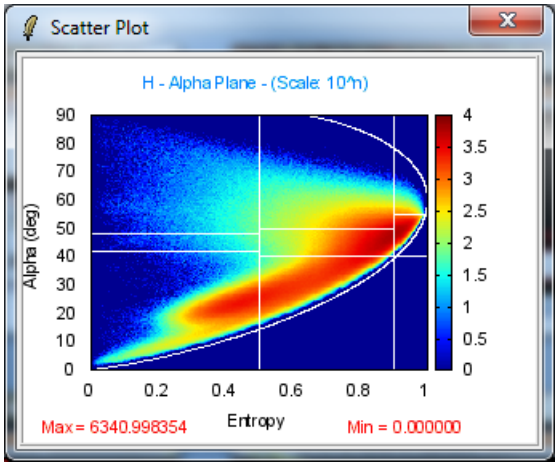


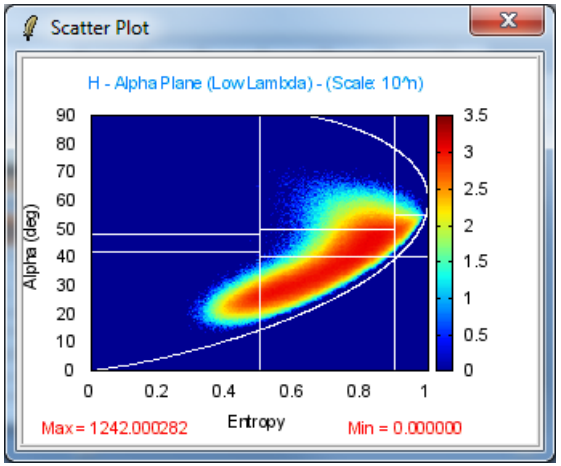
H / A / alpha CLASSIFICATION



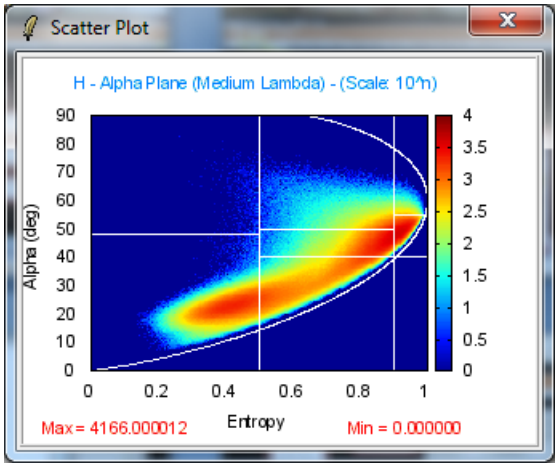
Do it Yourself:
Select some elements, set the parameters (Nwin = 1) and view the corresponding BMP files.

H / A / alpha CLASSIFICATION

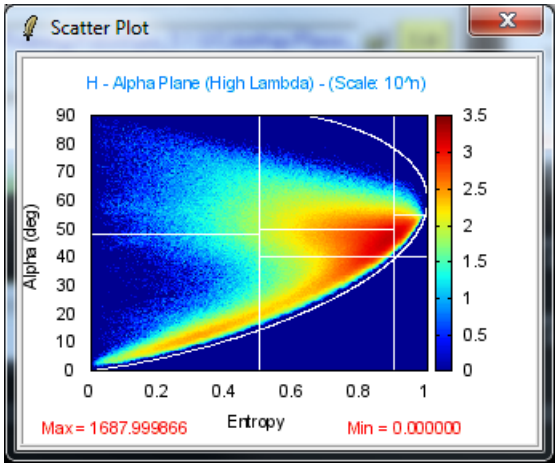




Low λ

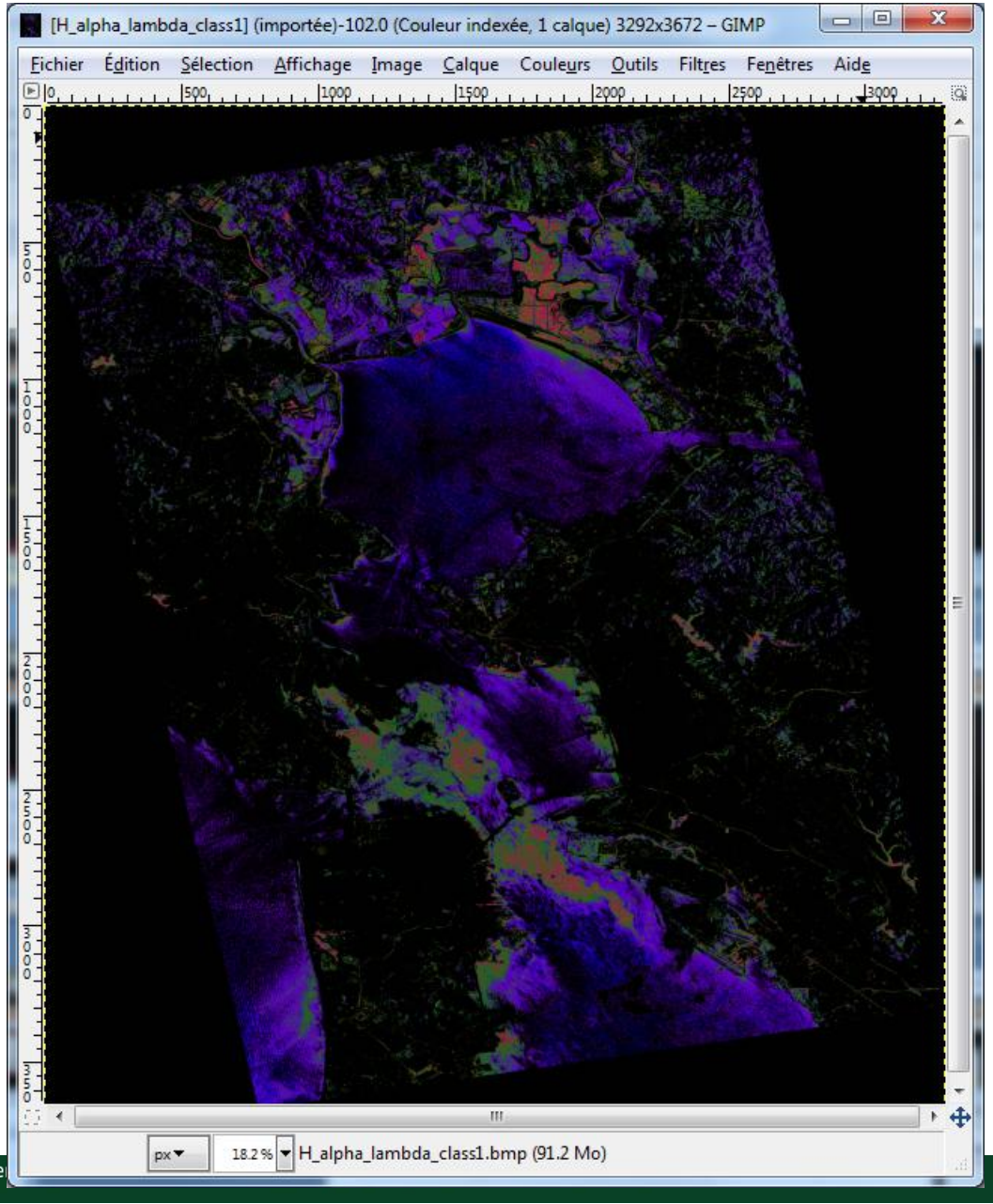


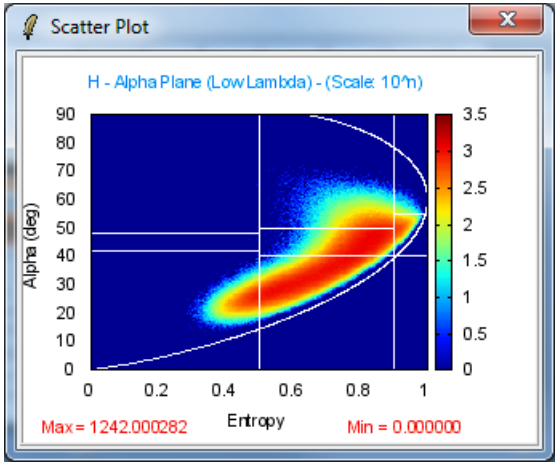
Medium λ



High λ

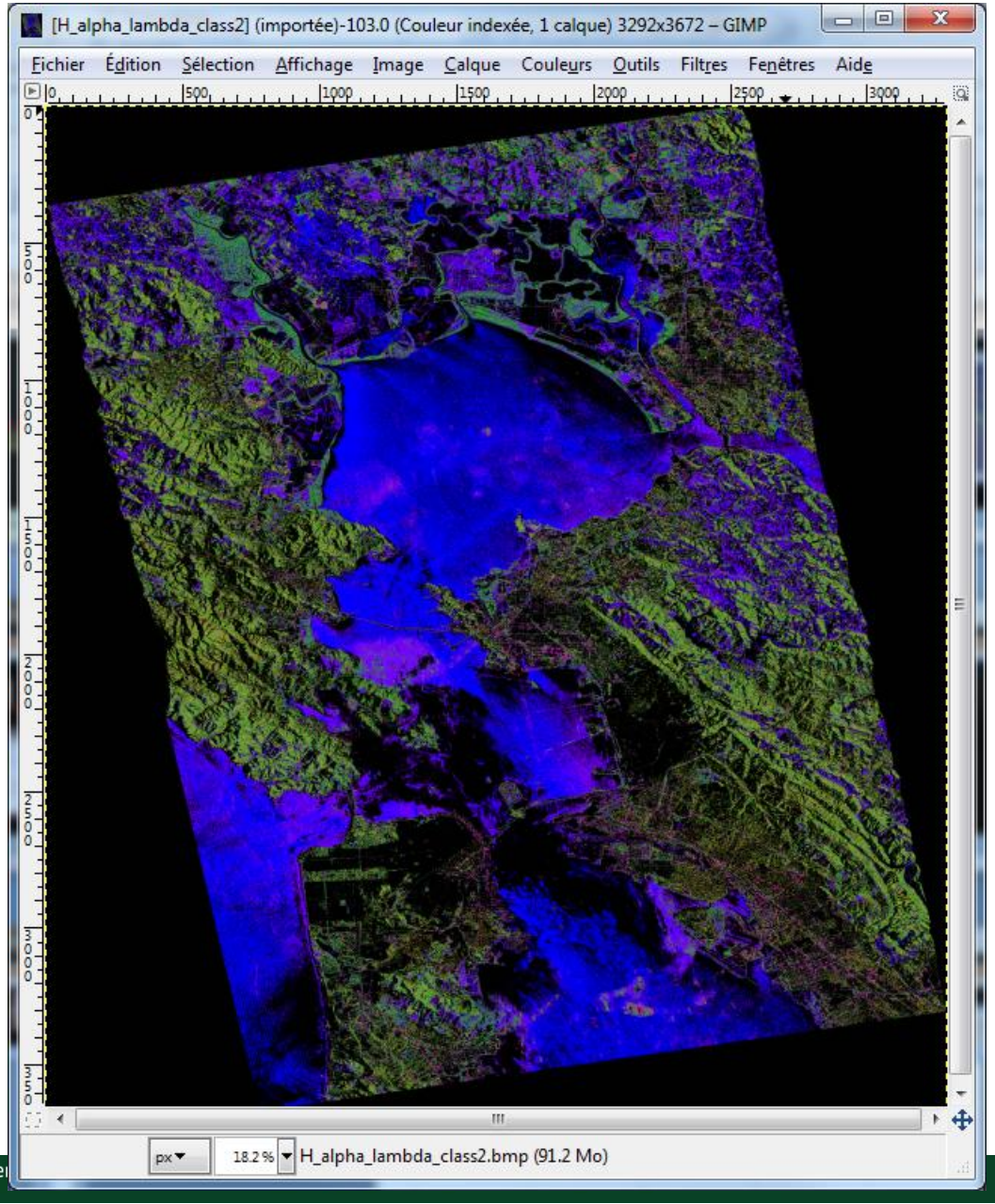
H / A / alpha CLASSIFICATION

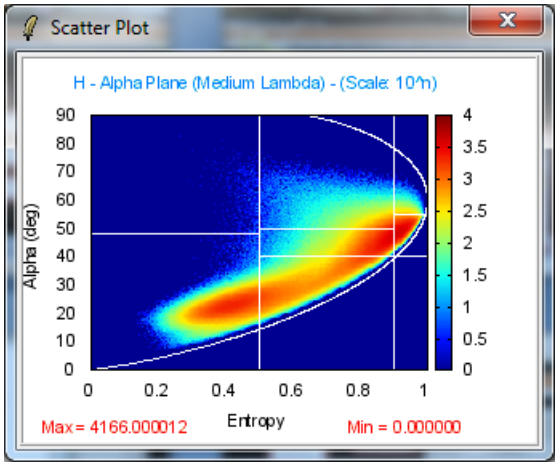




Low λ

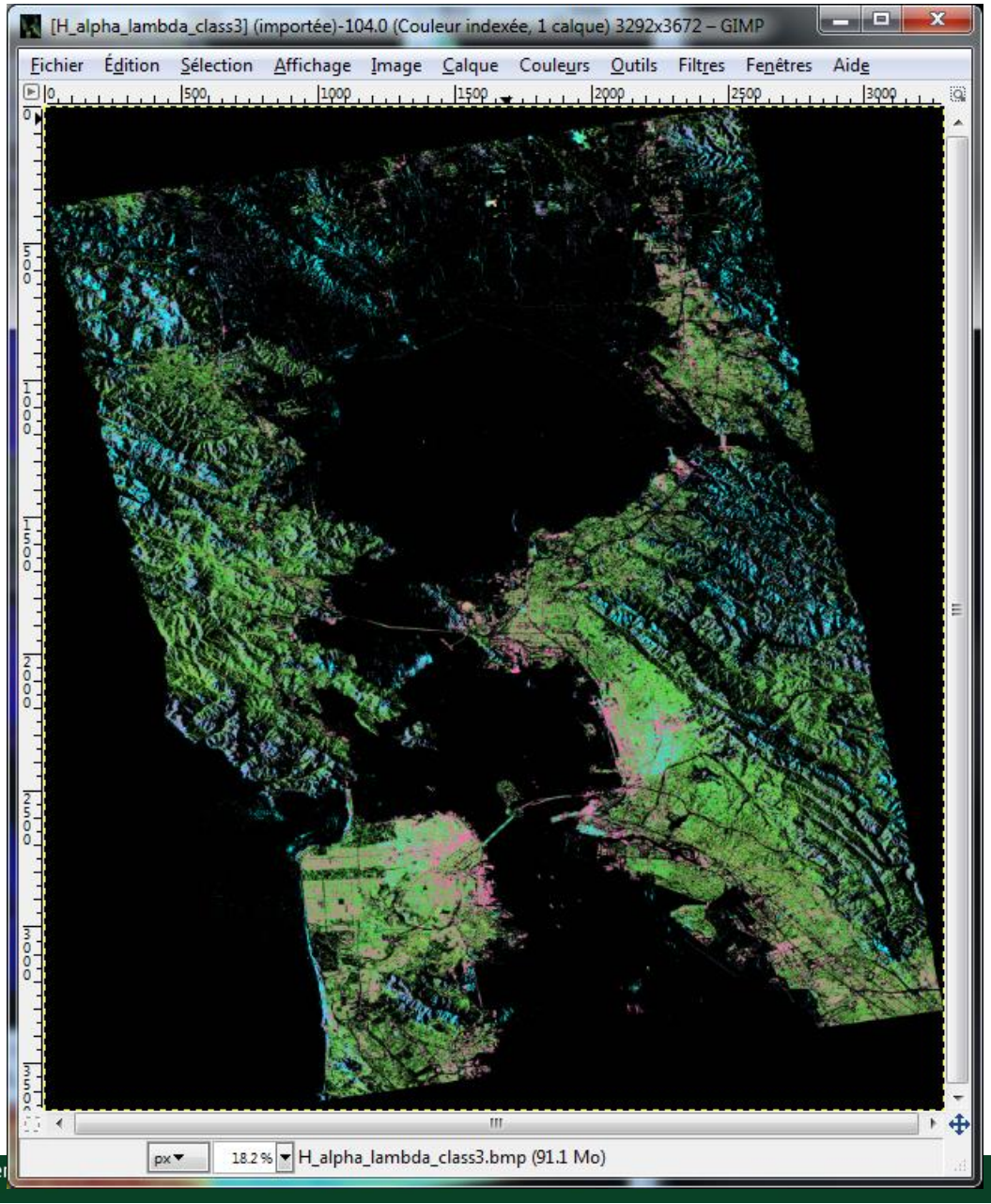
H / A / alpha CLASSIFICATION

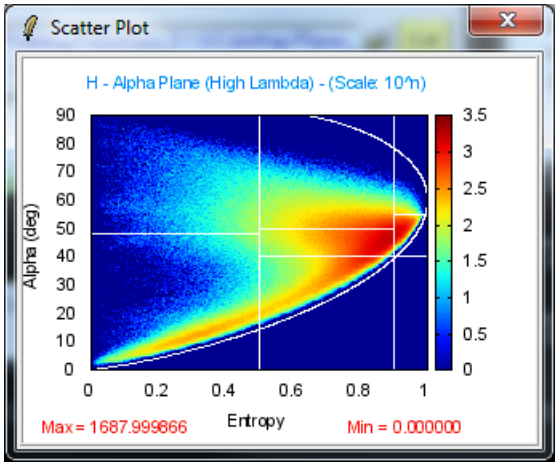




Medium λ

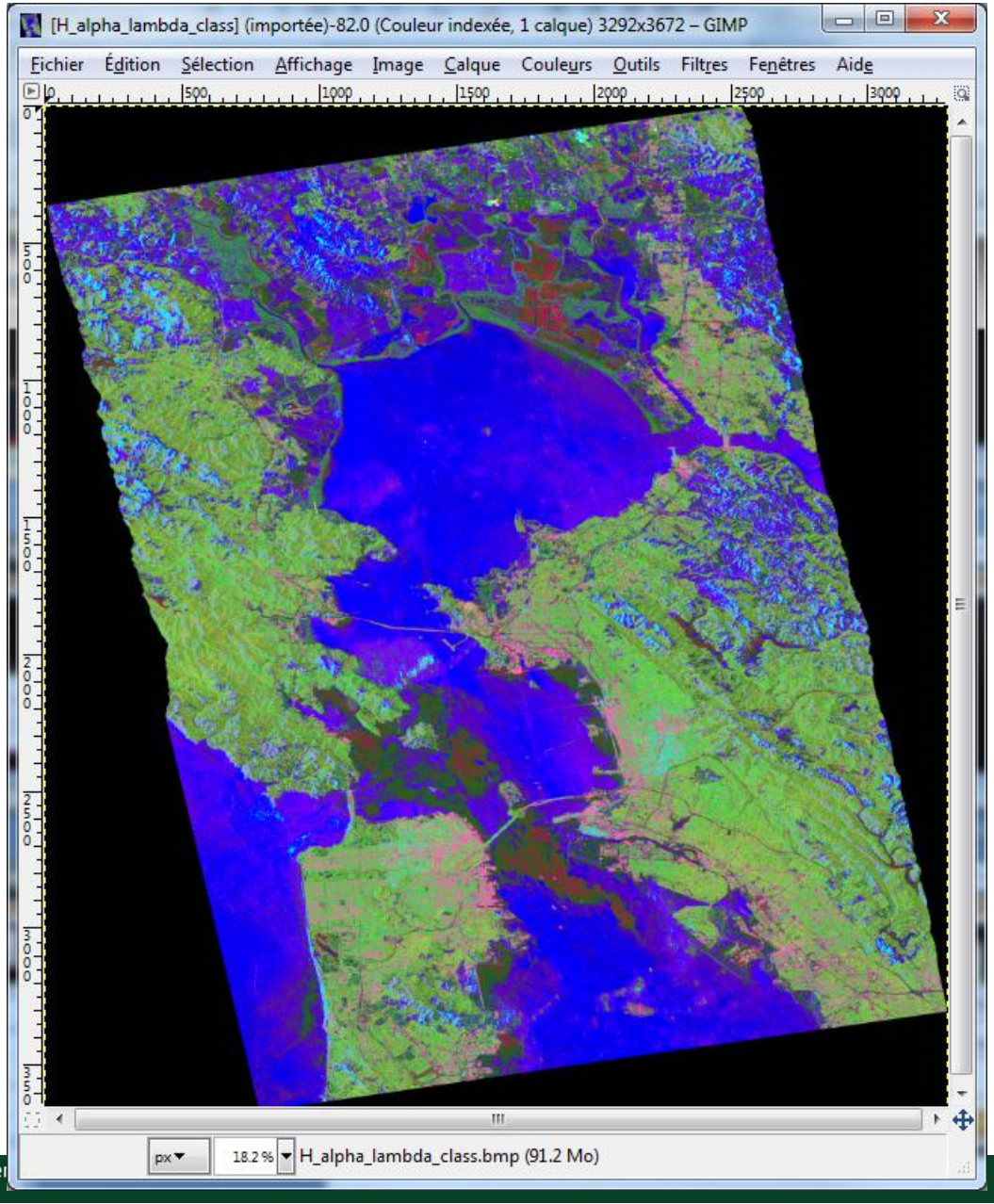
H / A / alpha CLASSIFICATION

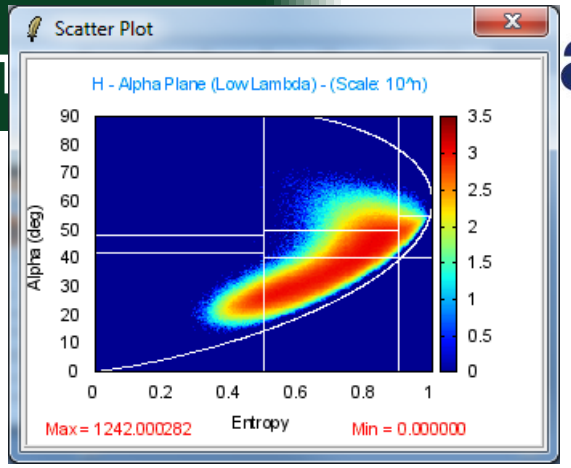


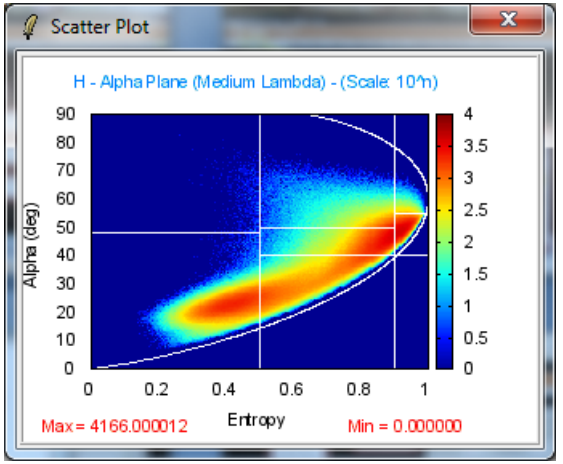


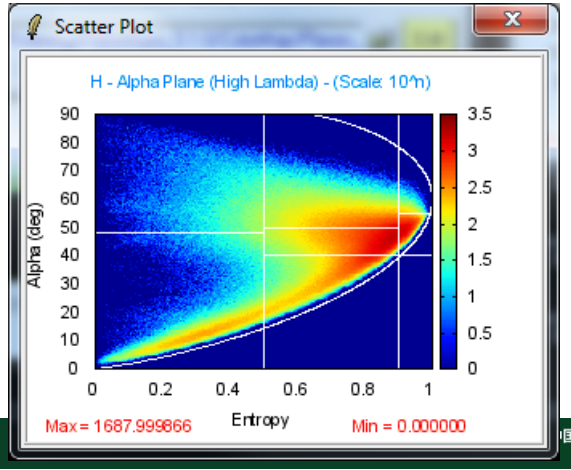
High λ

H / A / alpha CLASSIFICAT

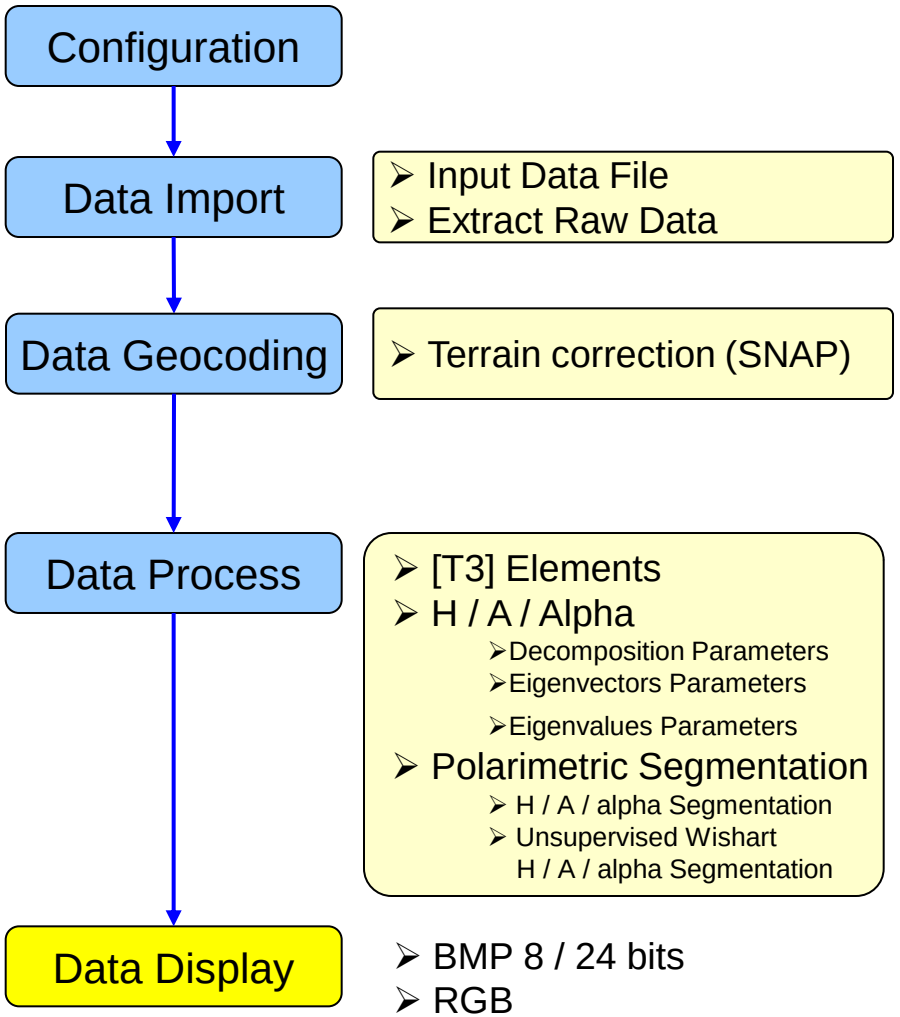




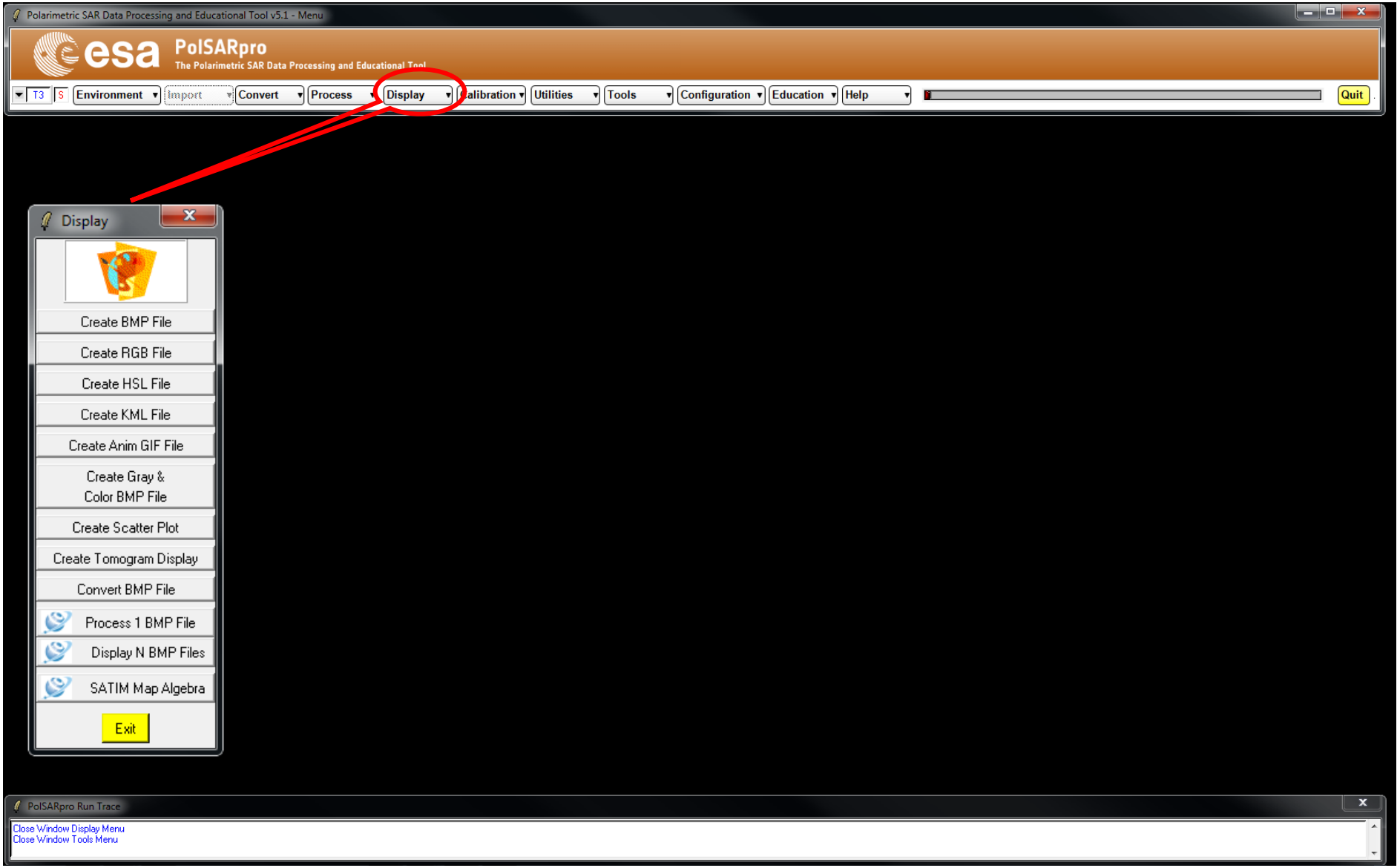




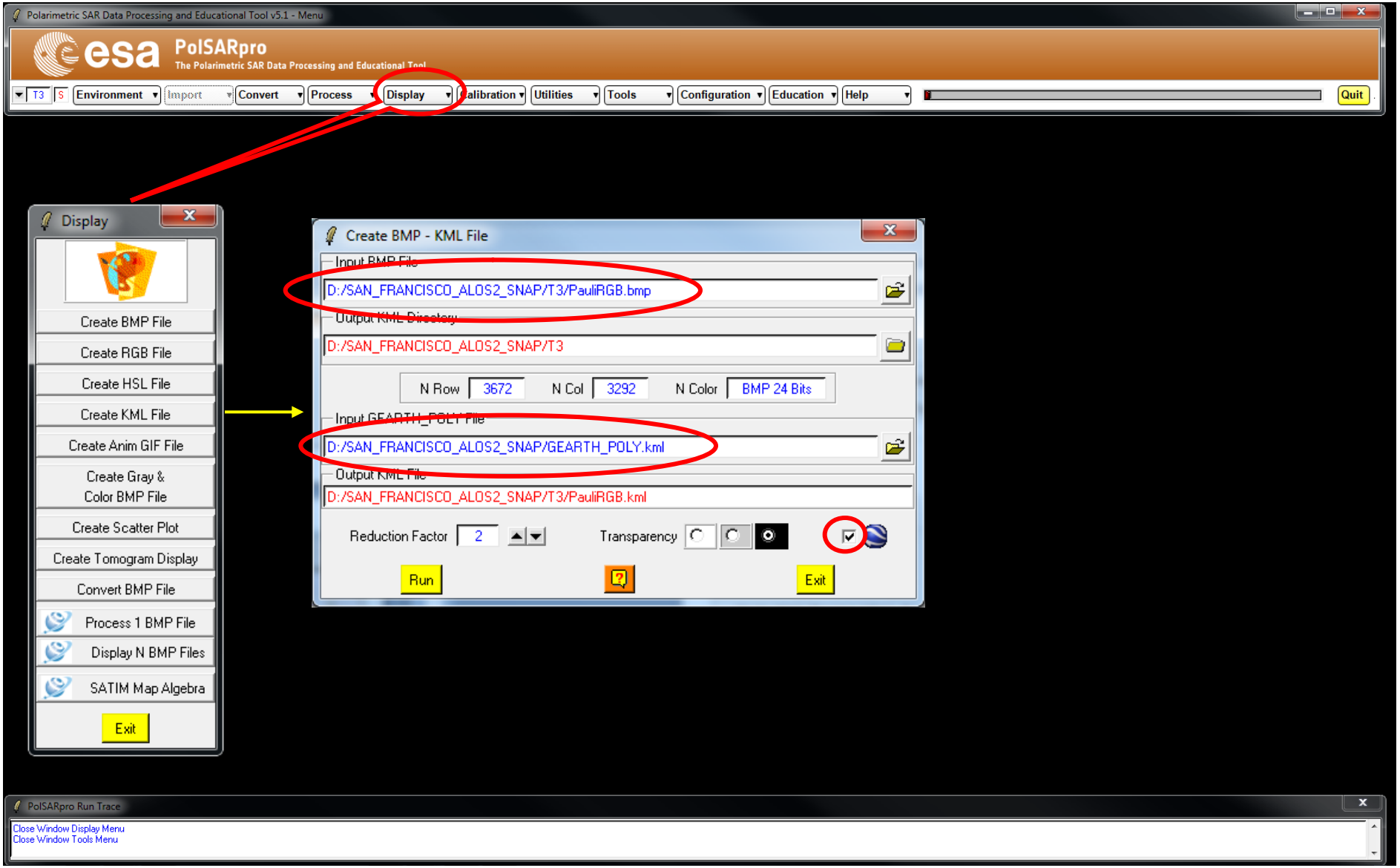
PROCESSING CHAIN



Display Main Menu



Create Pauli-RGB to KML Image



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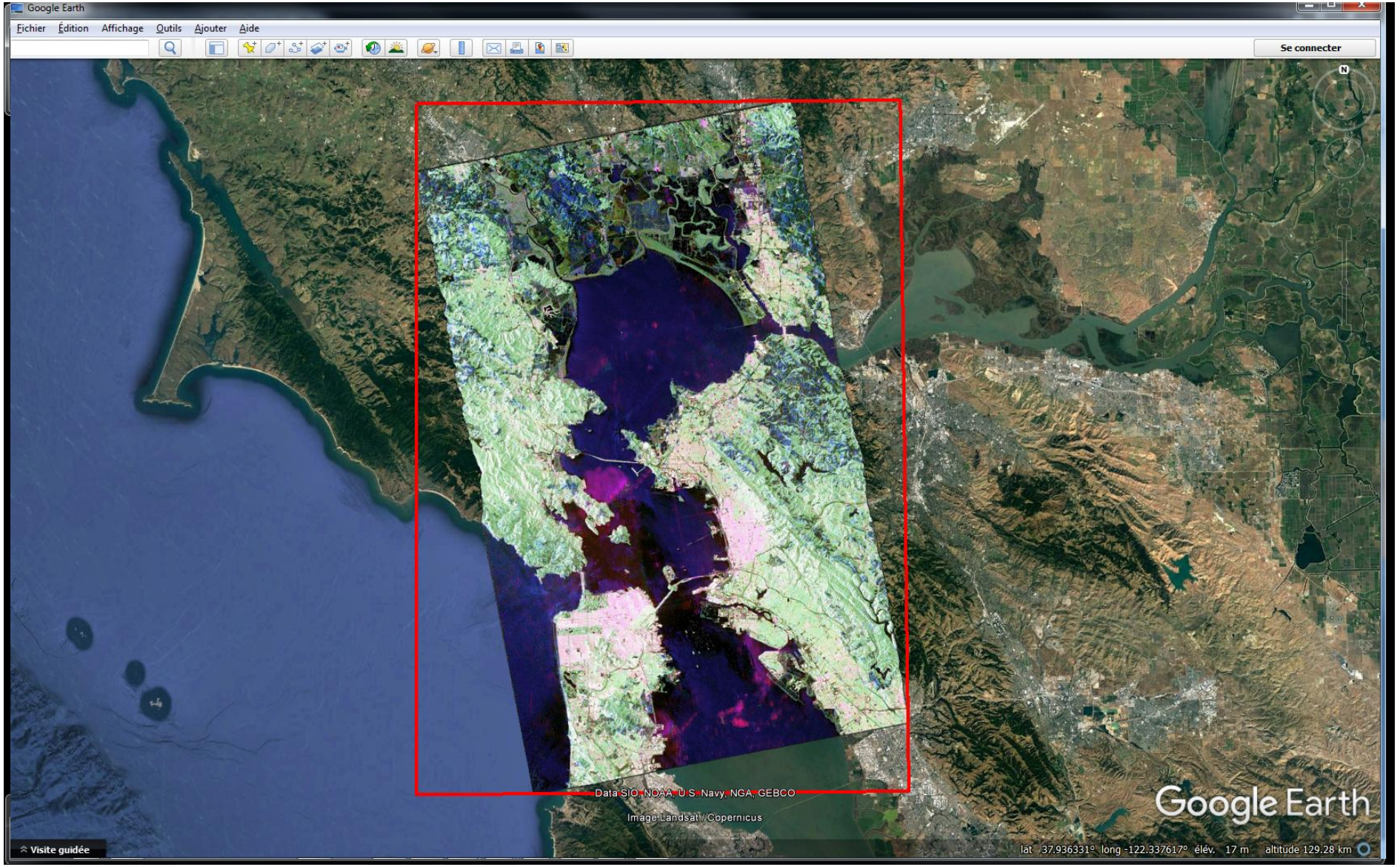
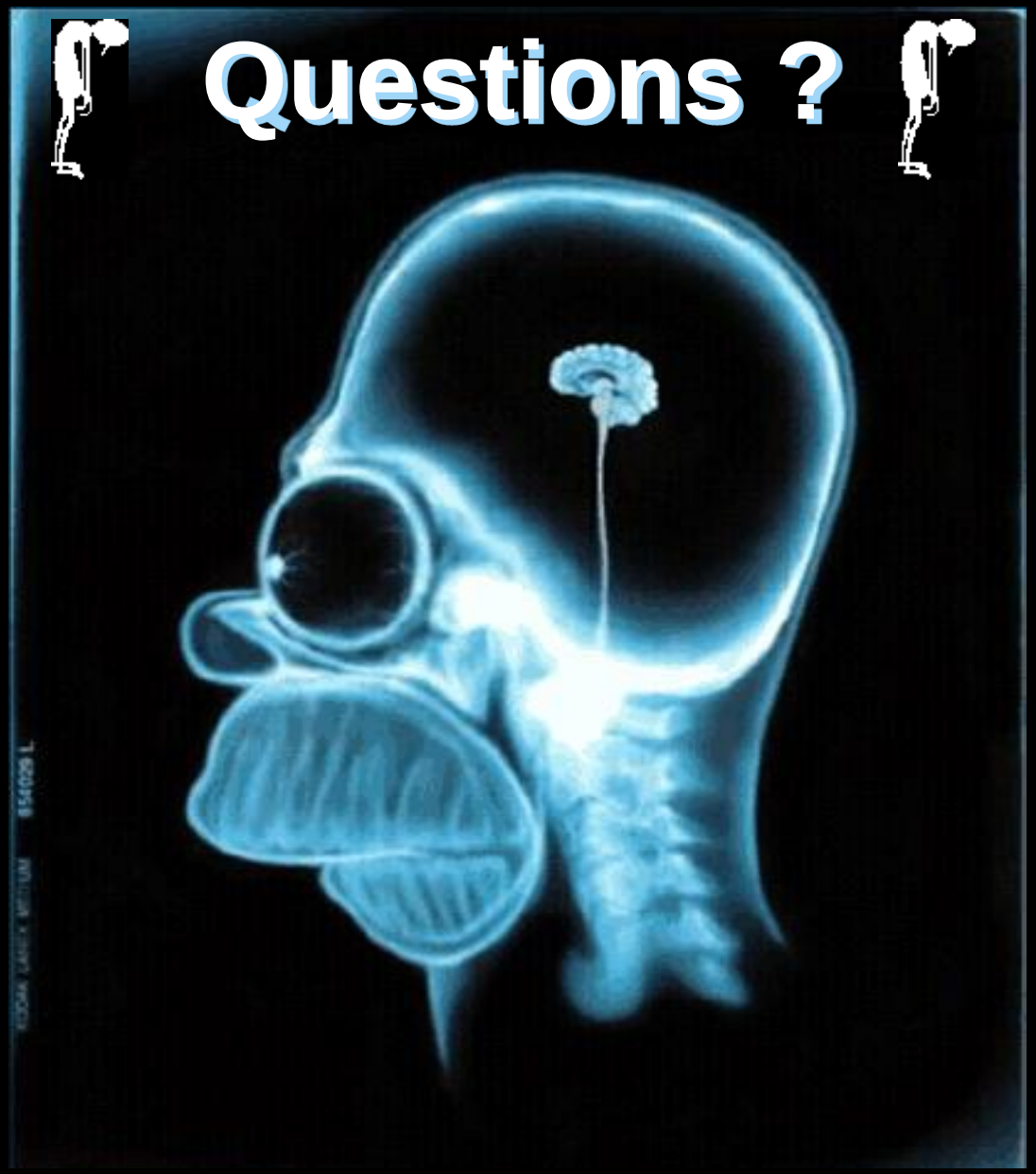
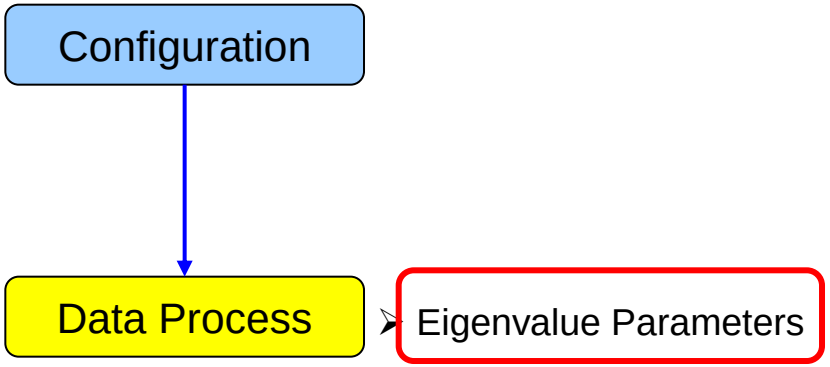


Questions ?



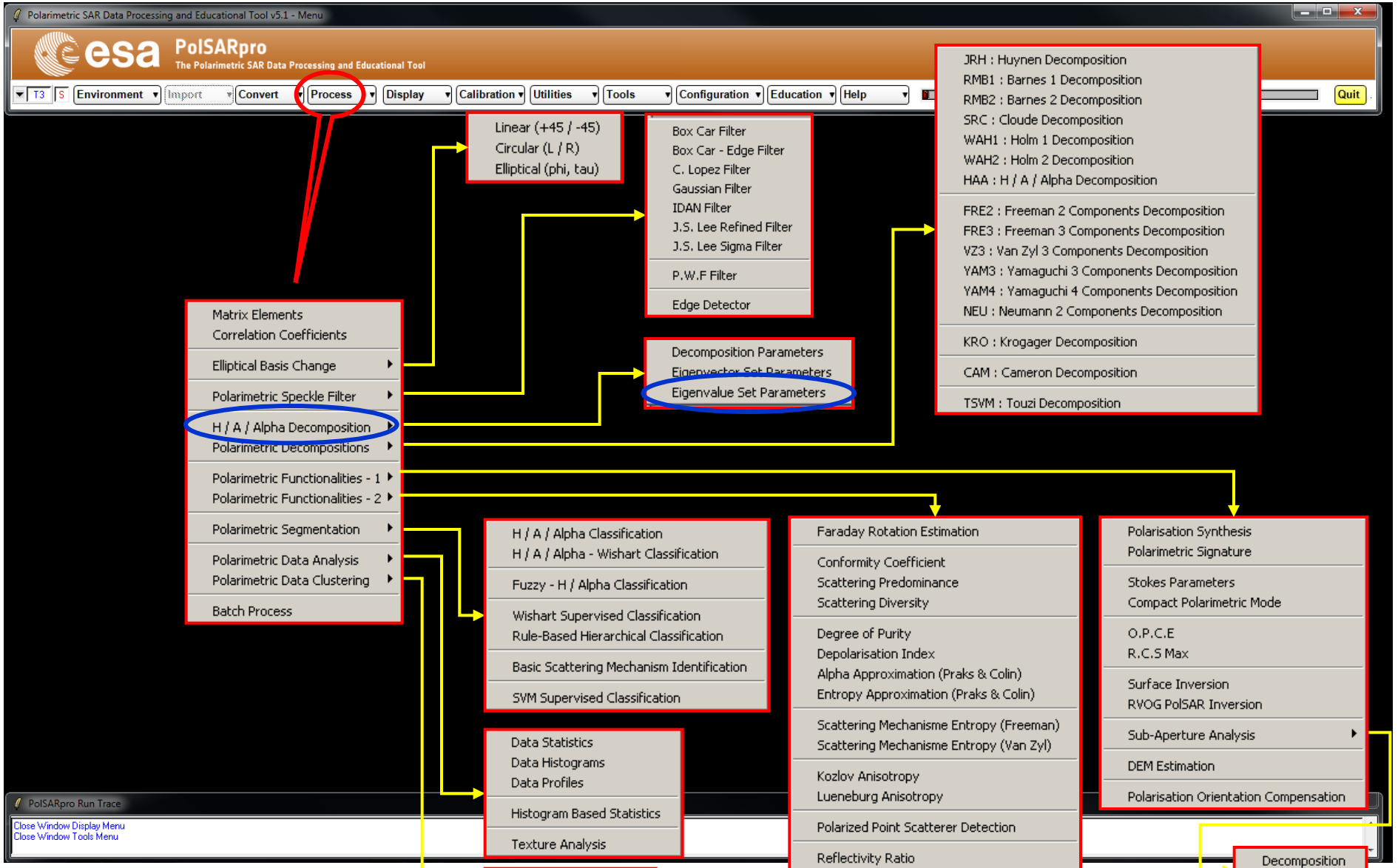
PolSARpro v5.1 Software
Practical advanced session

PROCESSING CHAIN

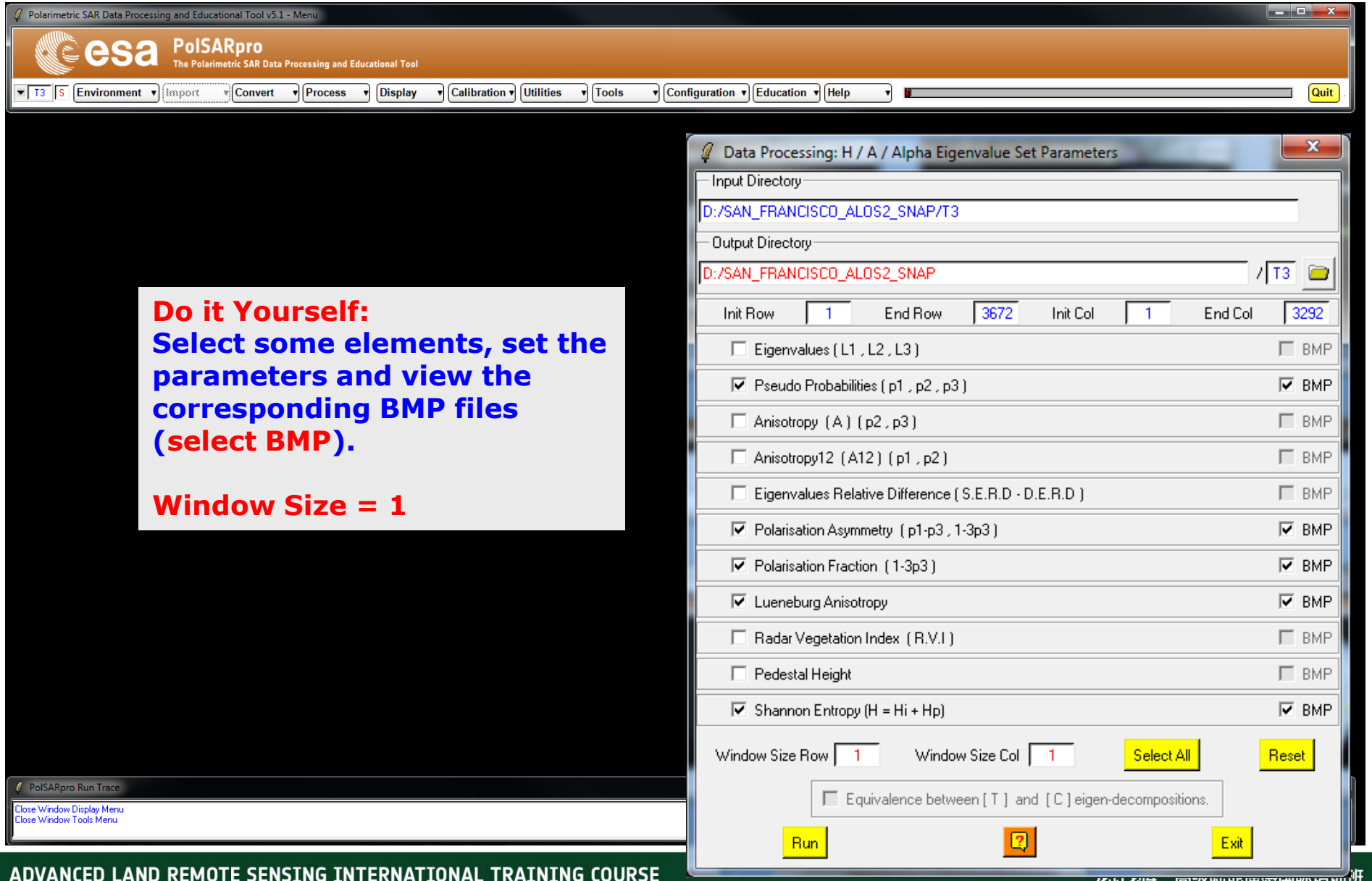


- Eigenvalue Parameters
- Polarimetric Decomposition
- Polarimetric Segmentation
  - Wishart - H / A / alpha classification
  - Supervised Wishart classification
  - Support Vector Machine Classification

PolSARpro v5.1 SOFTWARE



EIGENVALUE SET PARAMETERS

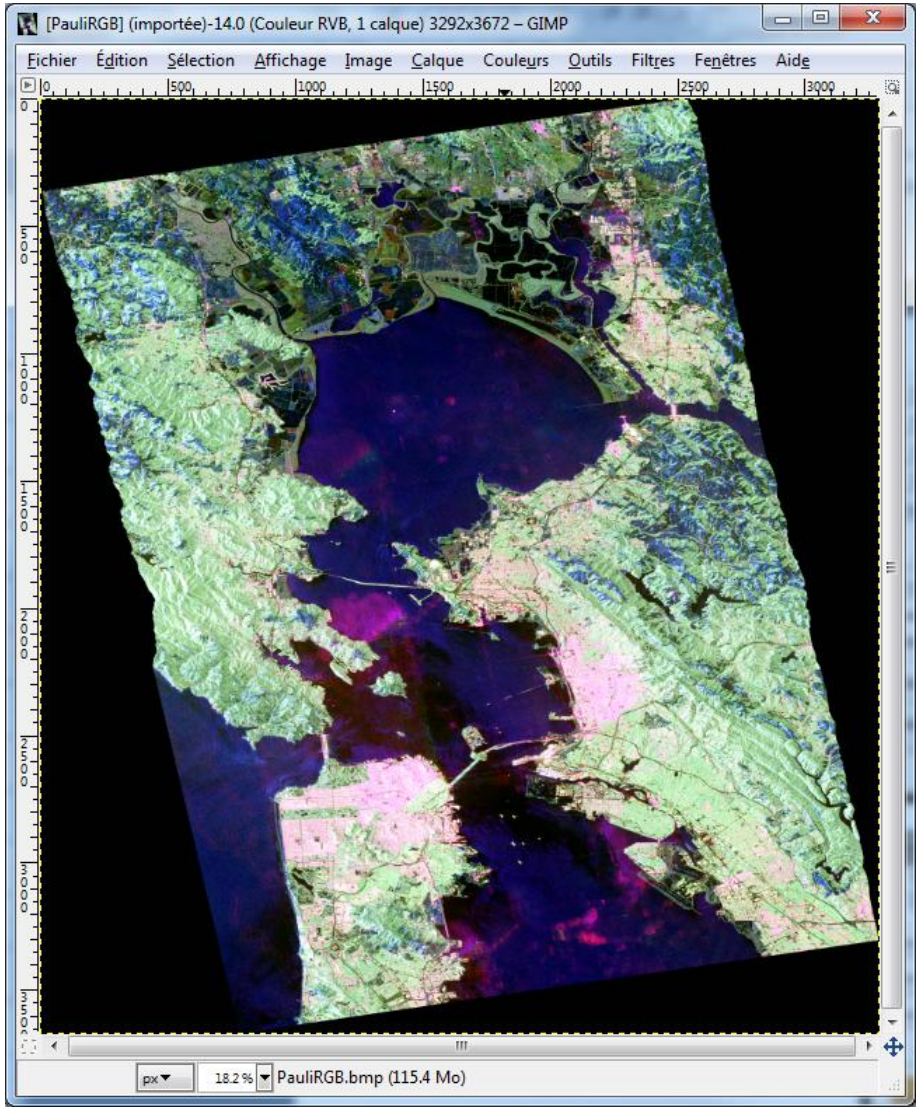


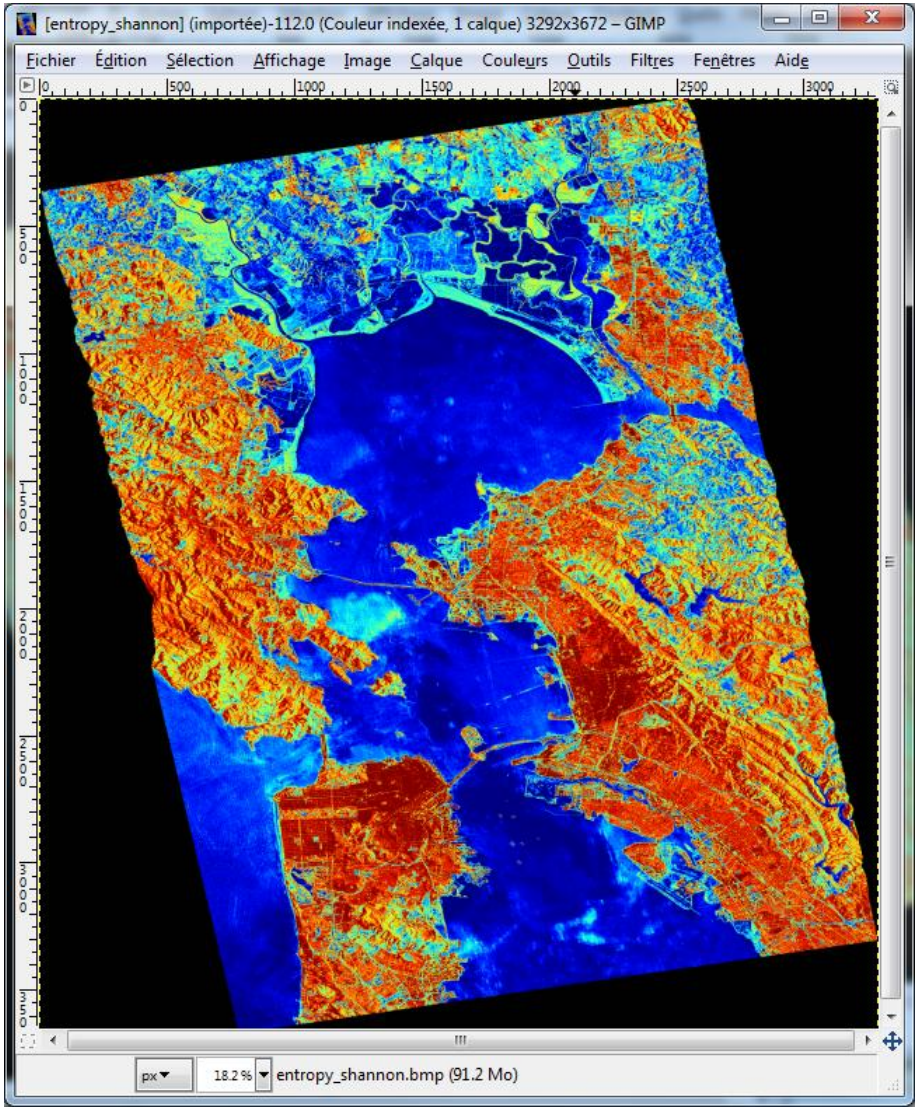
Do it Yourself:
Select some elements, set the parameters and view the corresponding BMP files (select BMP).

Window Size = 1

EIGENVALUE SET PARAMETERS

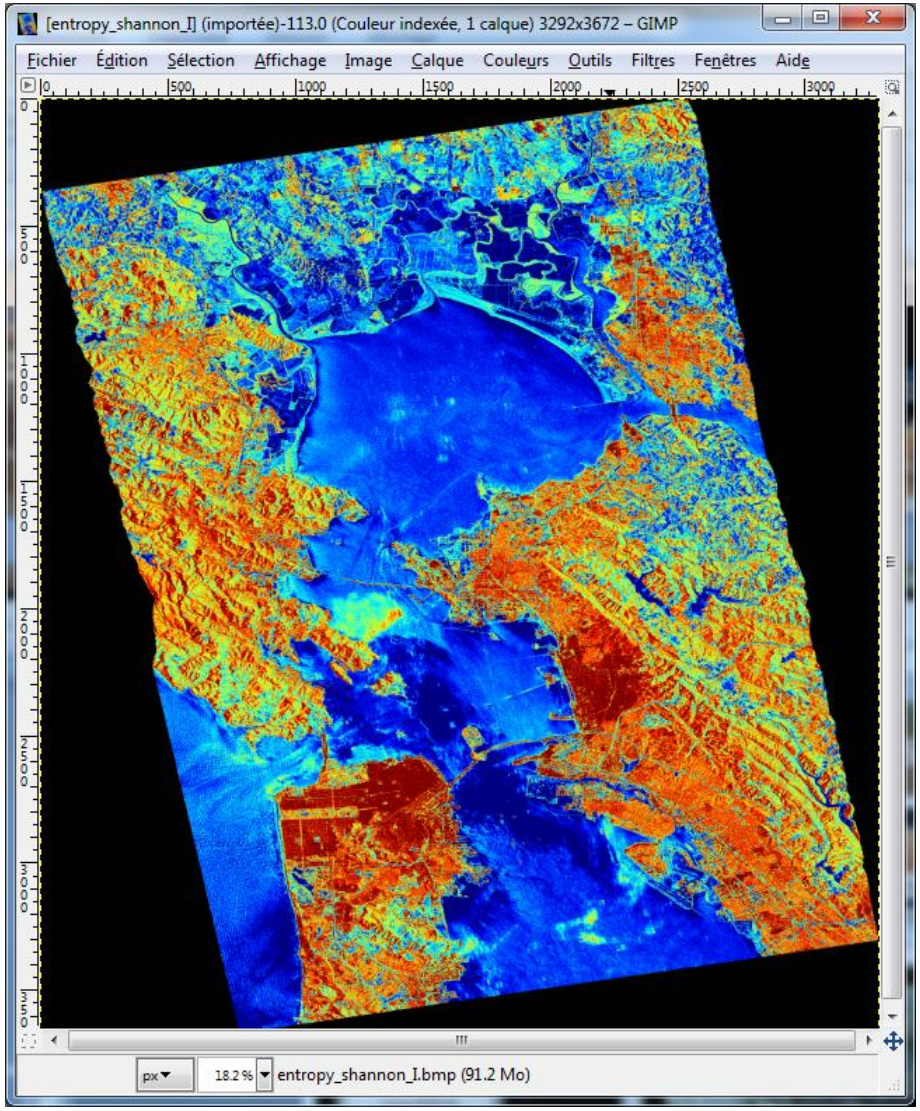
Entropy Shannon



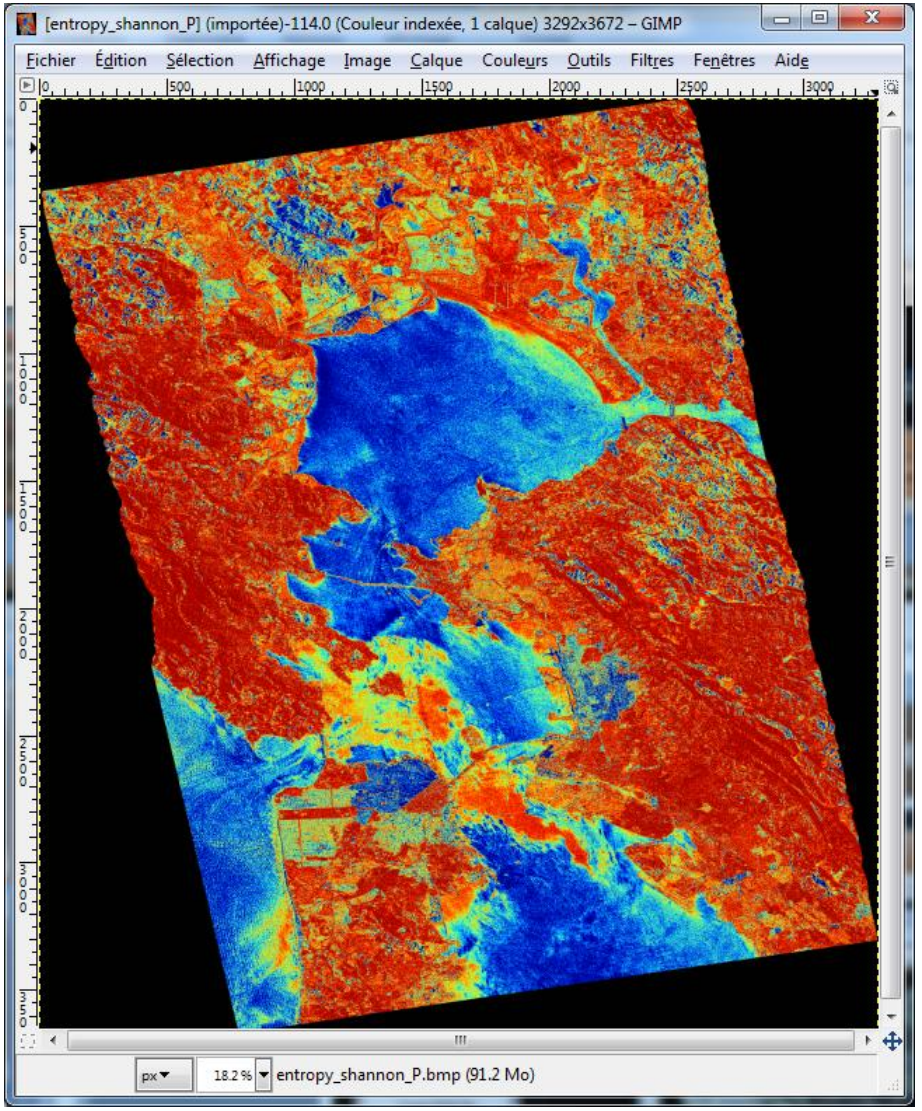


EIGENVALUE SET PARAMETERS

Entropy I

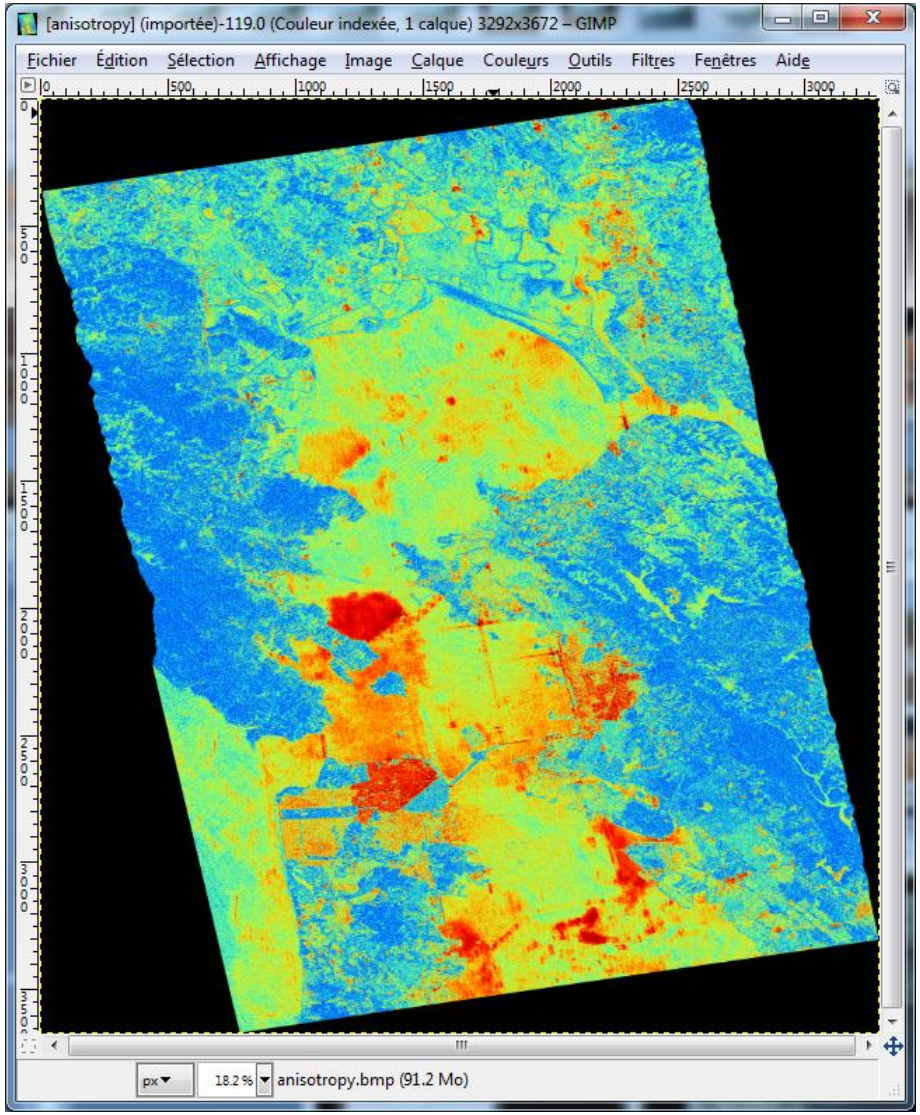


Entropy P

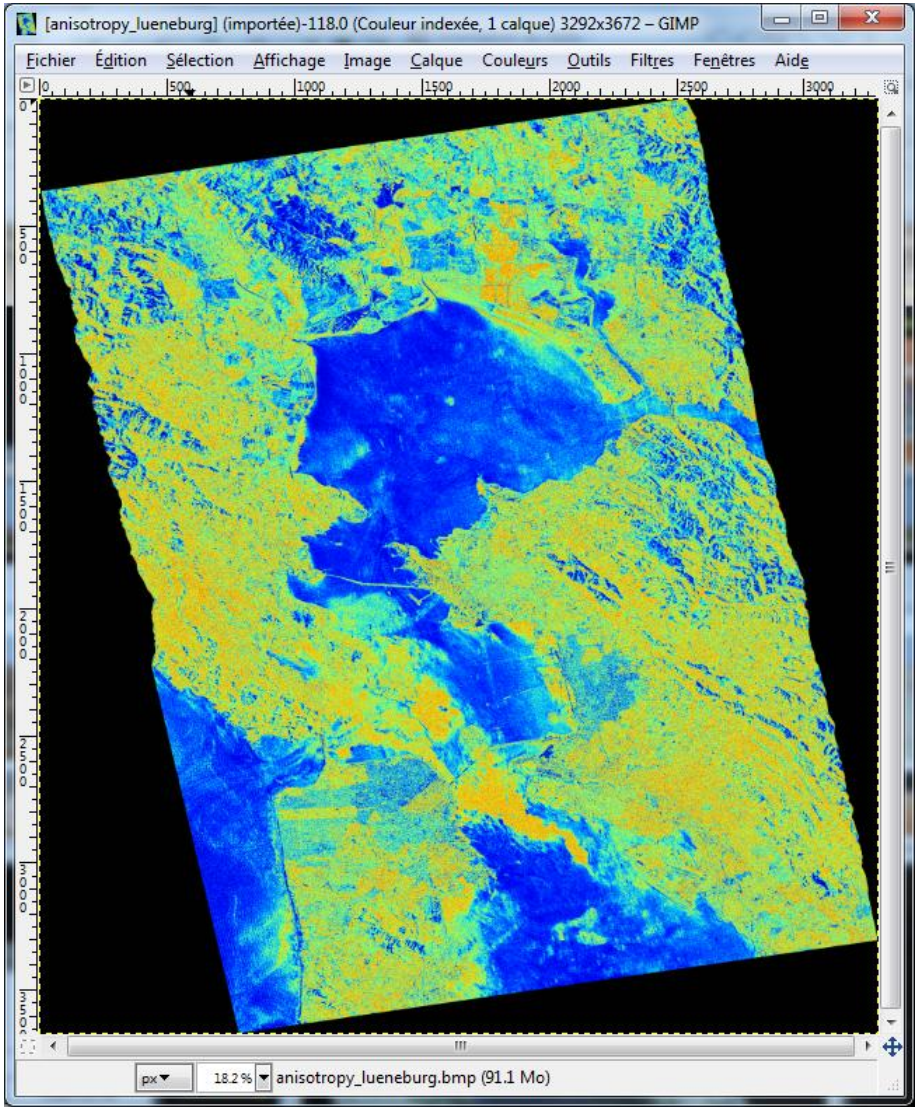


EIGENVALUE SET PARAMETERS

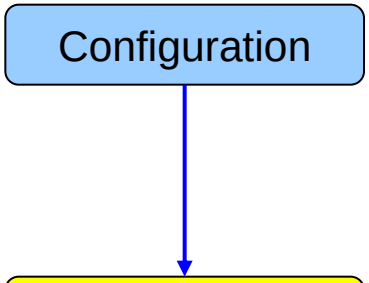
Anisotropy



Lueneburg Anisotropy



PROCESSING CHAIN



- Eigenvalue Parameters
- Polarimetric Decomposition
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  - Wishart - H / A / alpha classification
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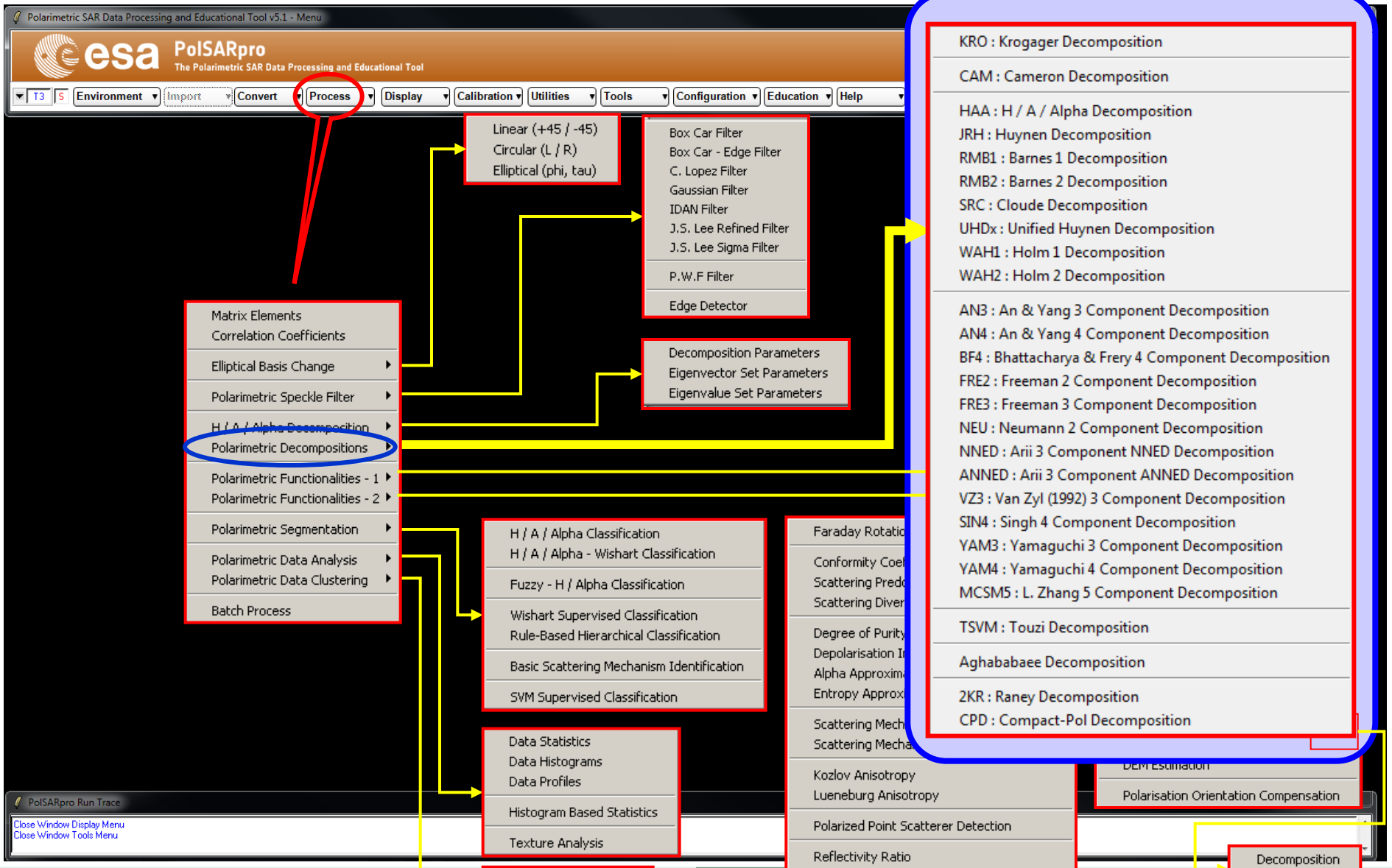
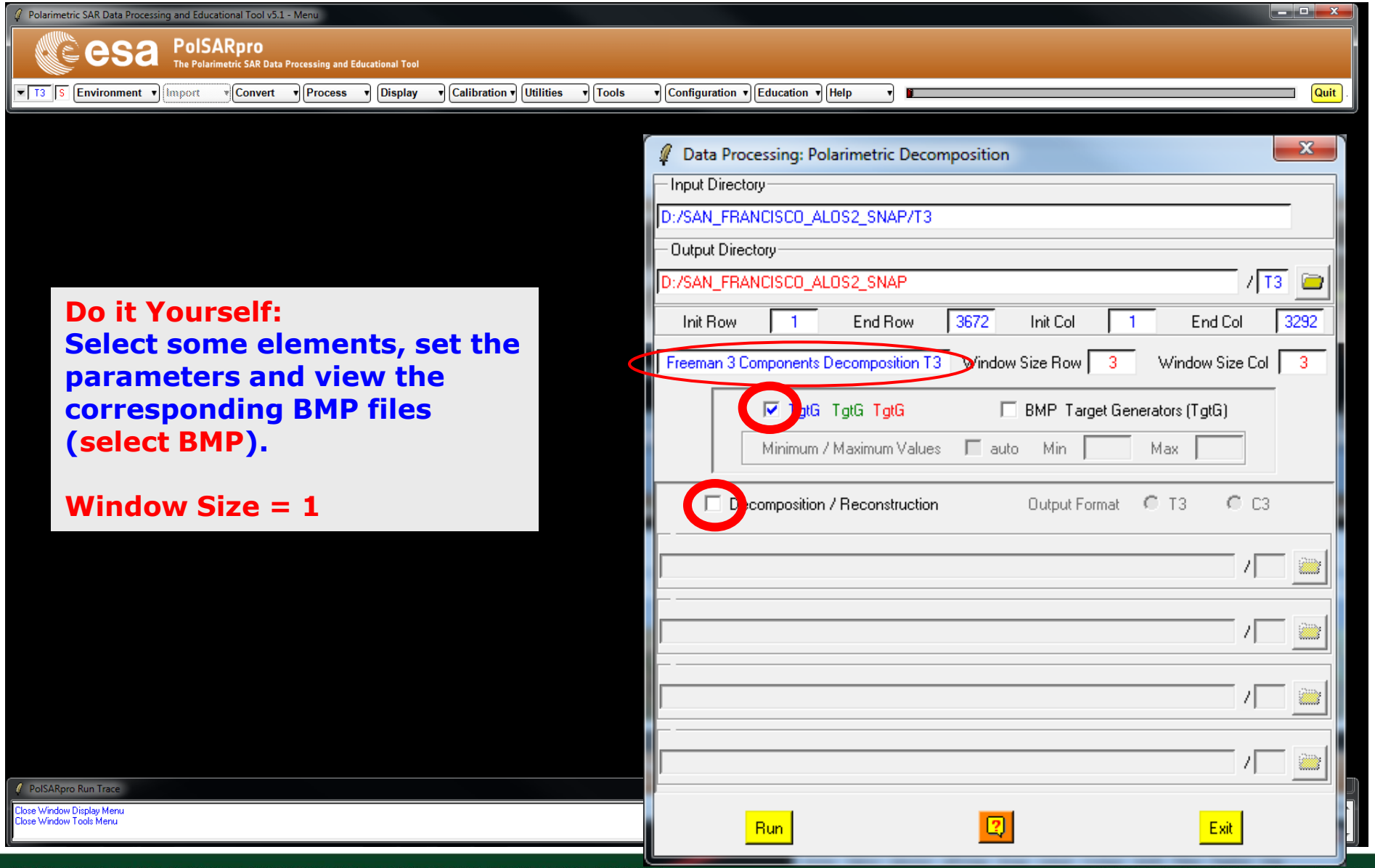
PolSARpro v5.1 SOFTWARE



POLARIMETRIC DECOMPOSITION

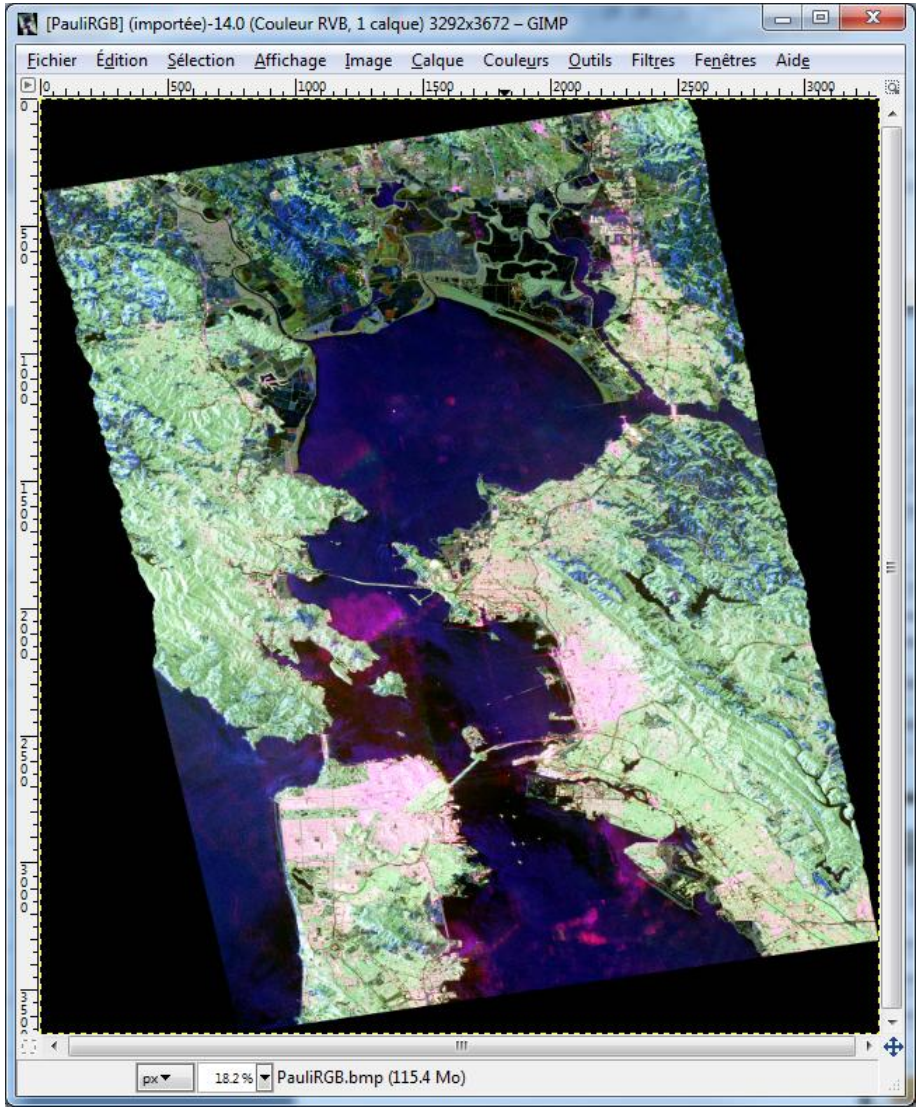


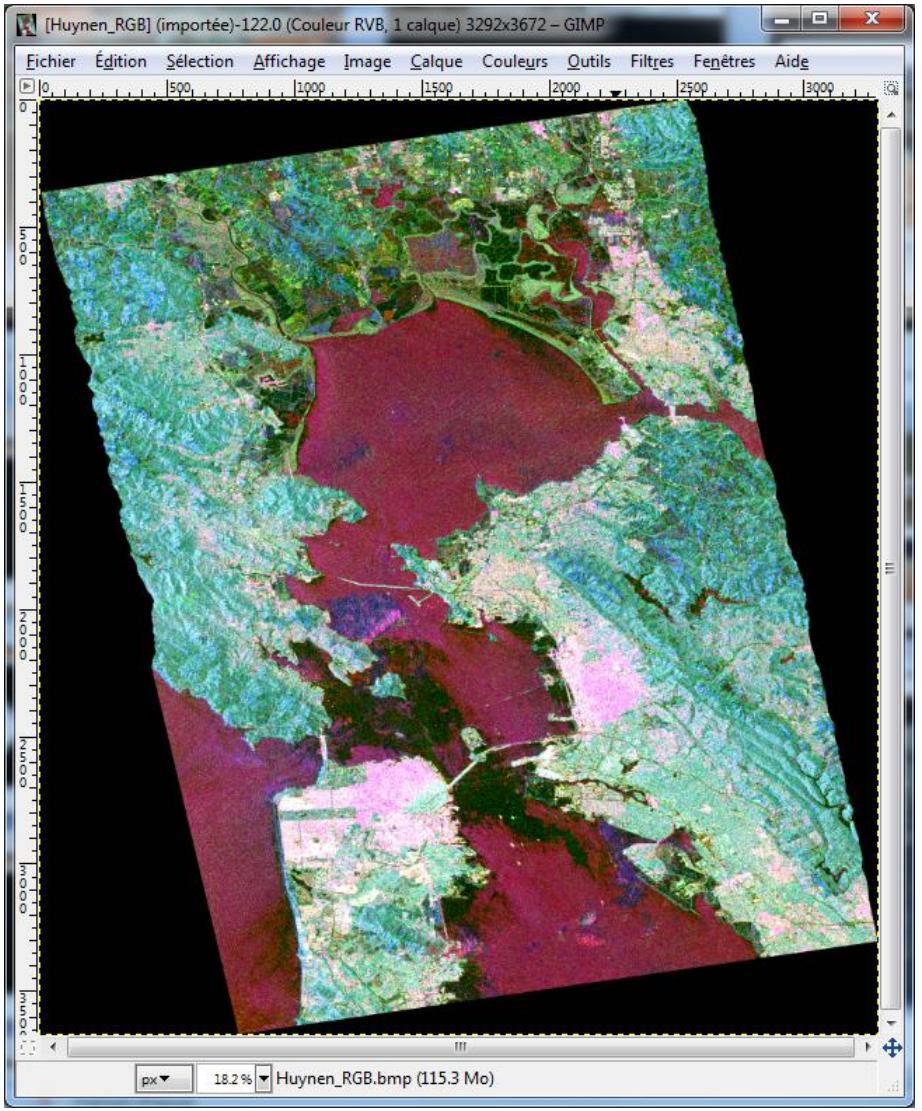
Do it Yourself:
Select some elements, set the parameters and view the corresponding BMP files (select BMP).

Window Size = 1

POLARIMETRIC DECOMPOSITION

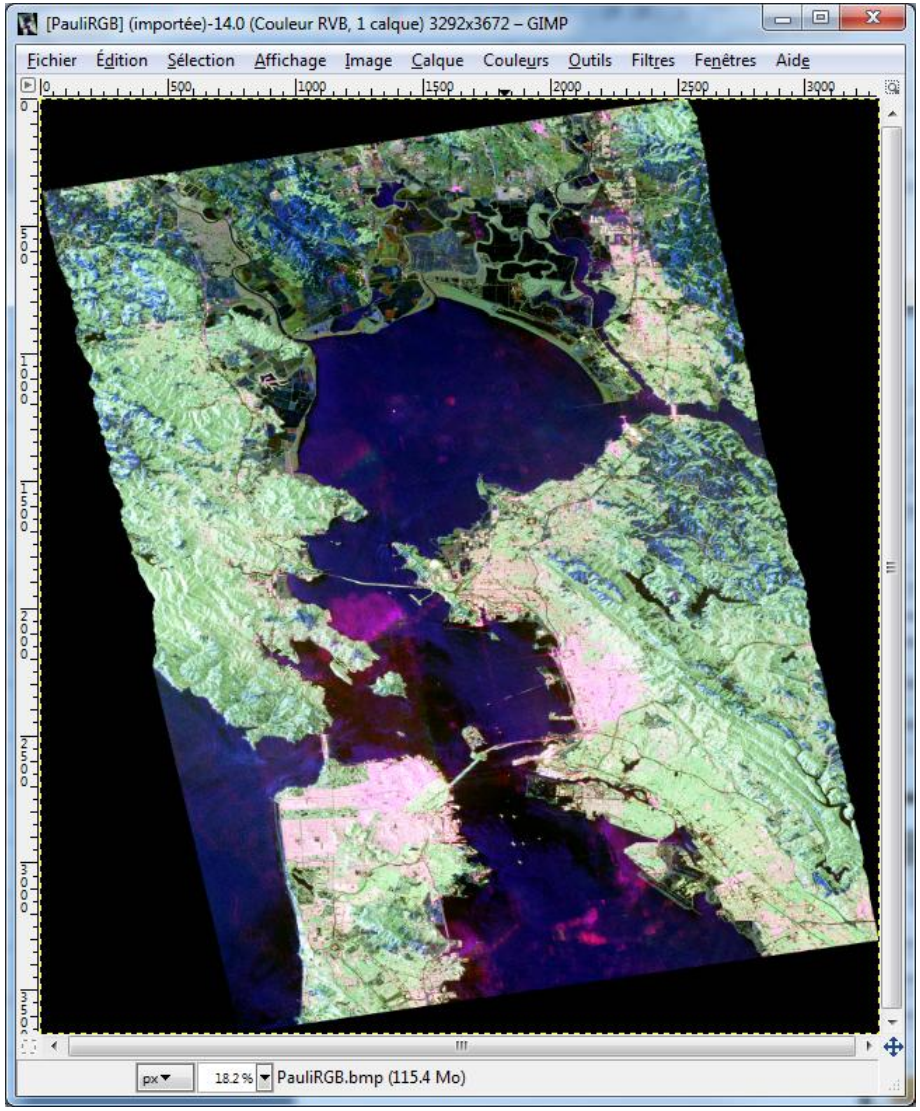
Pauli Huynen

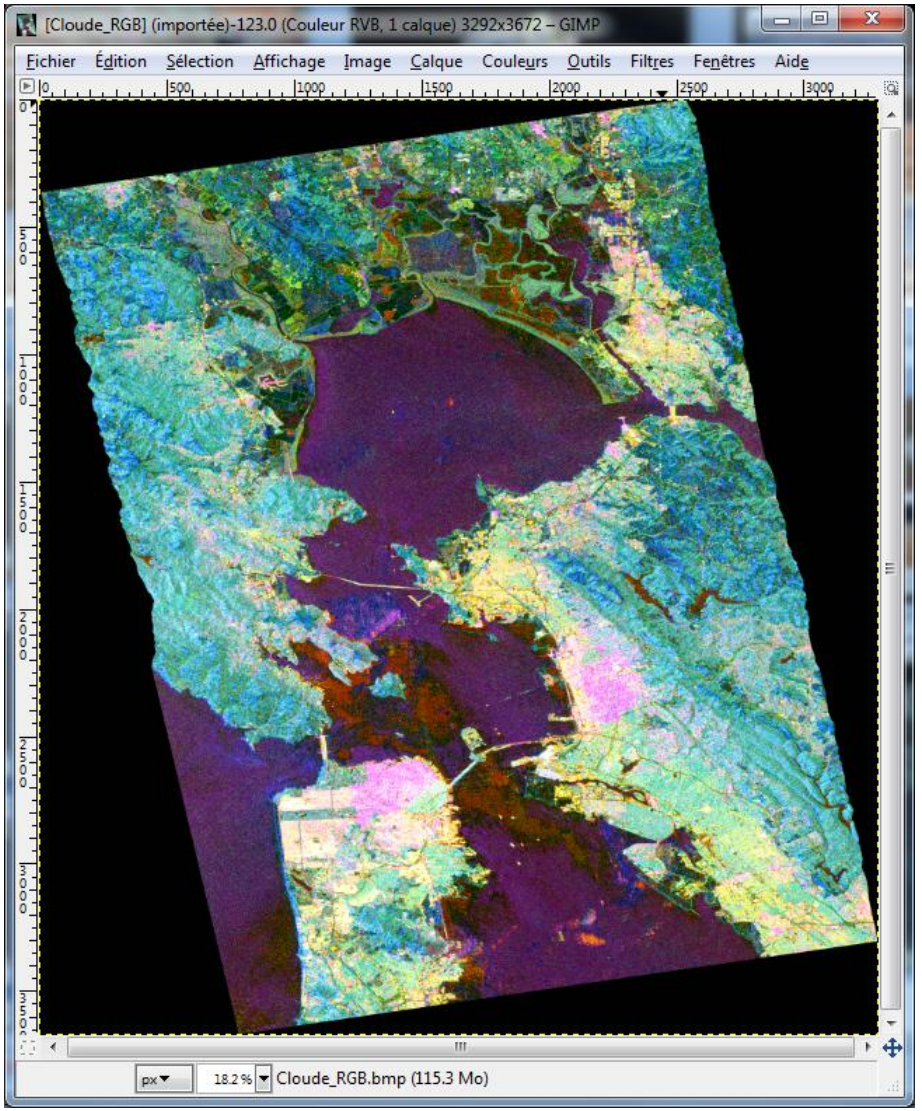




POLARIMETRIC DECOMPOSITION

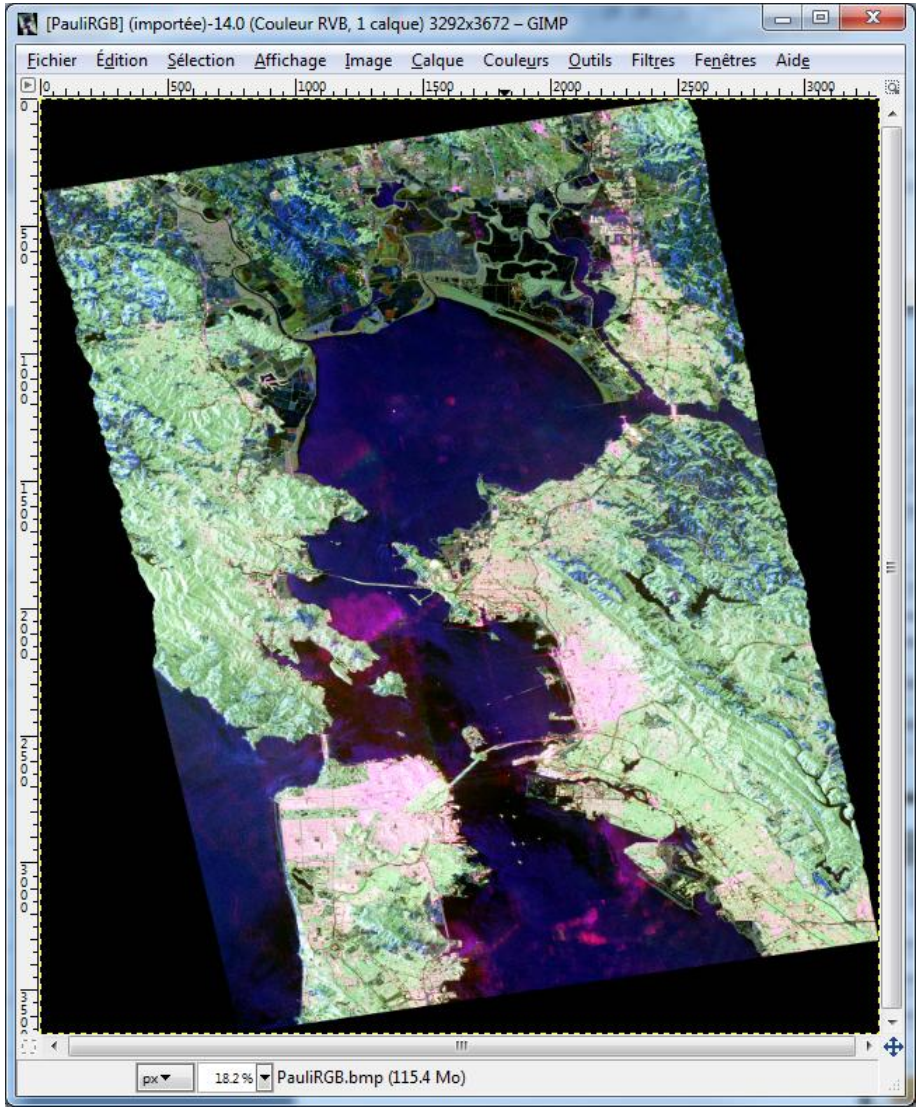
Pauli Cloude

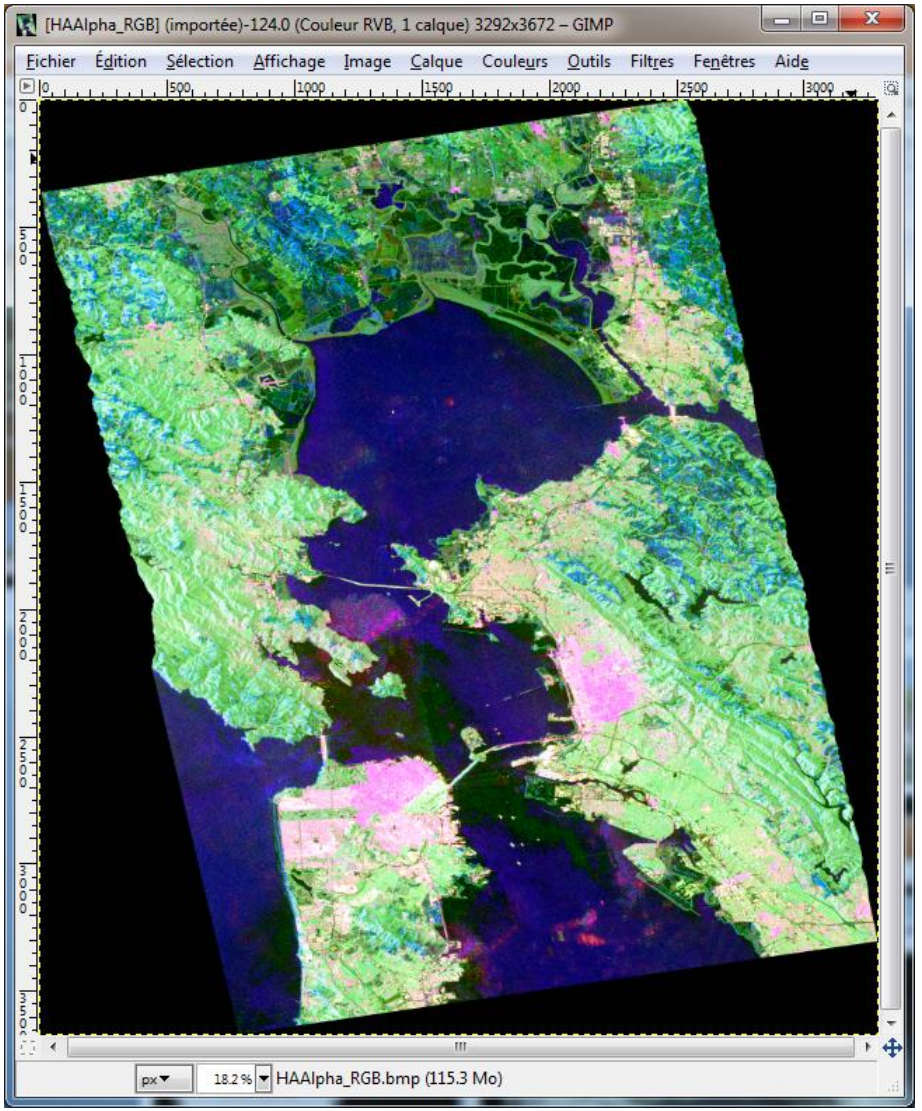




POLARIMETRIC DECOMPOSITION

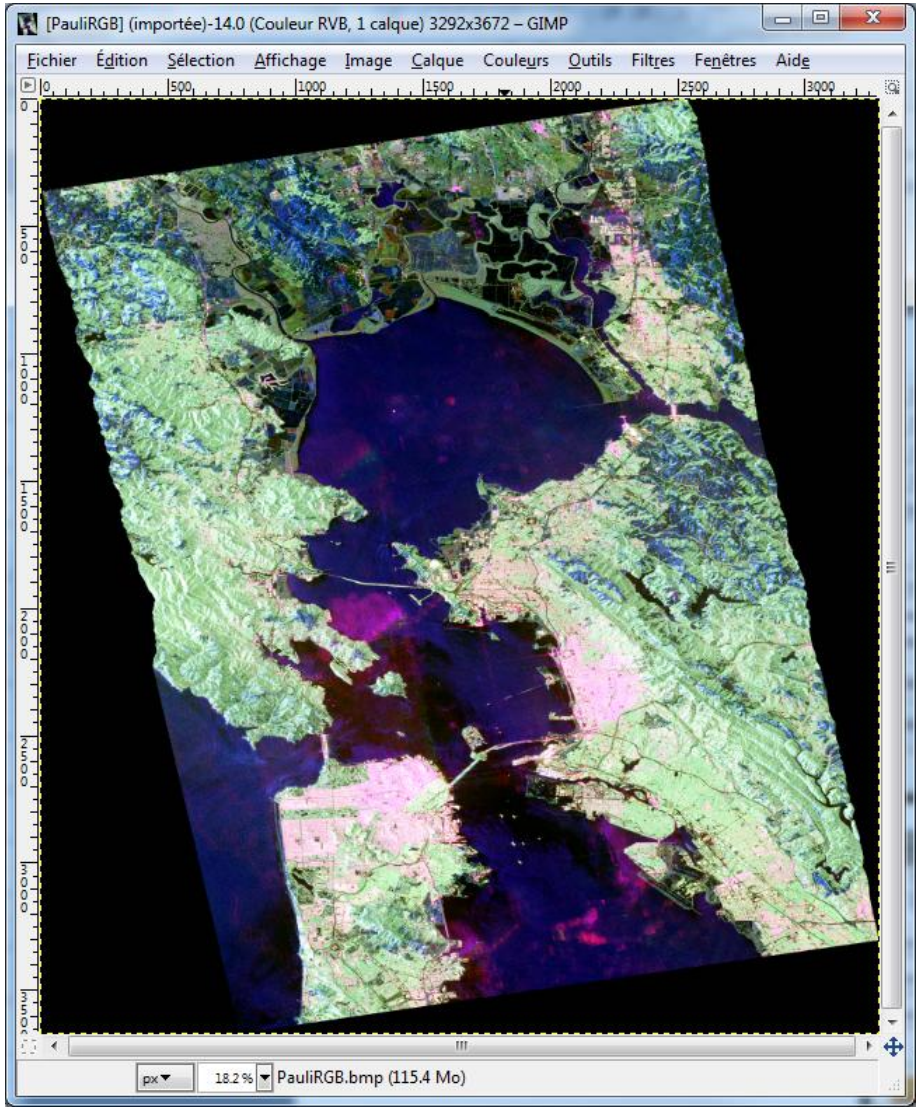
Pauli H-A-Alpha

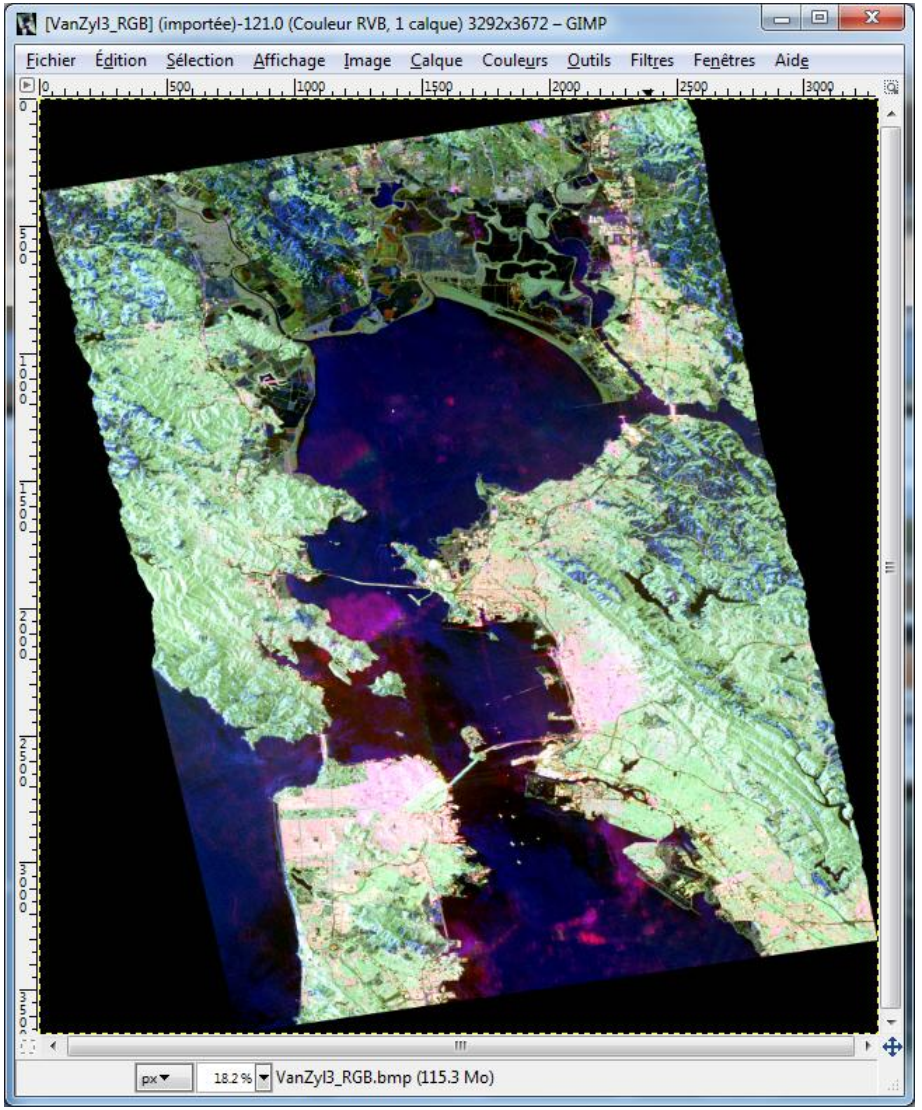




POLARIMETRIC DECOMPOSITION

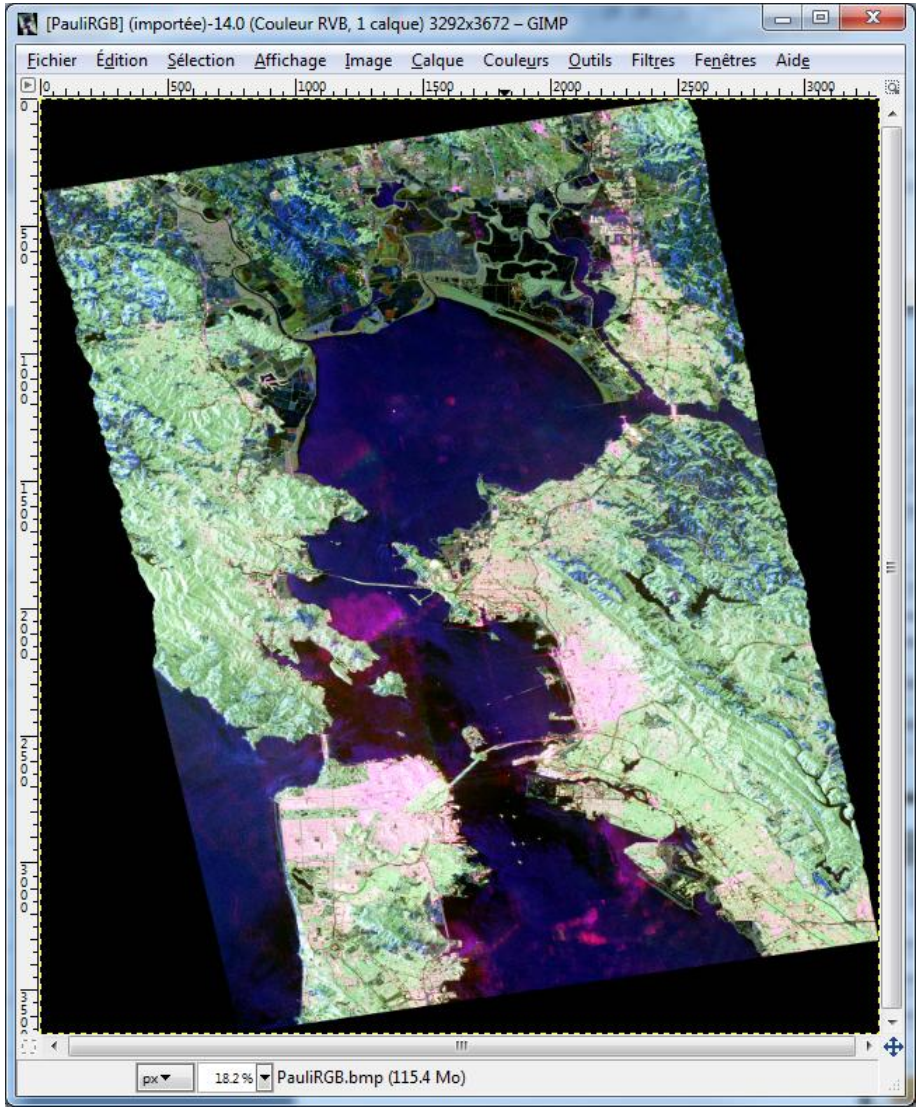
Pauli Van Zyl 3

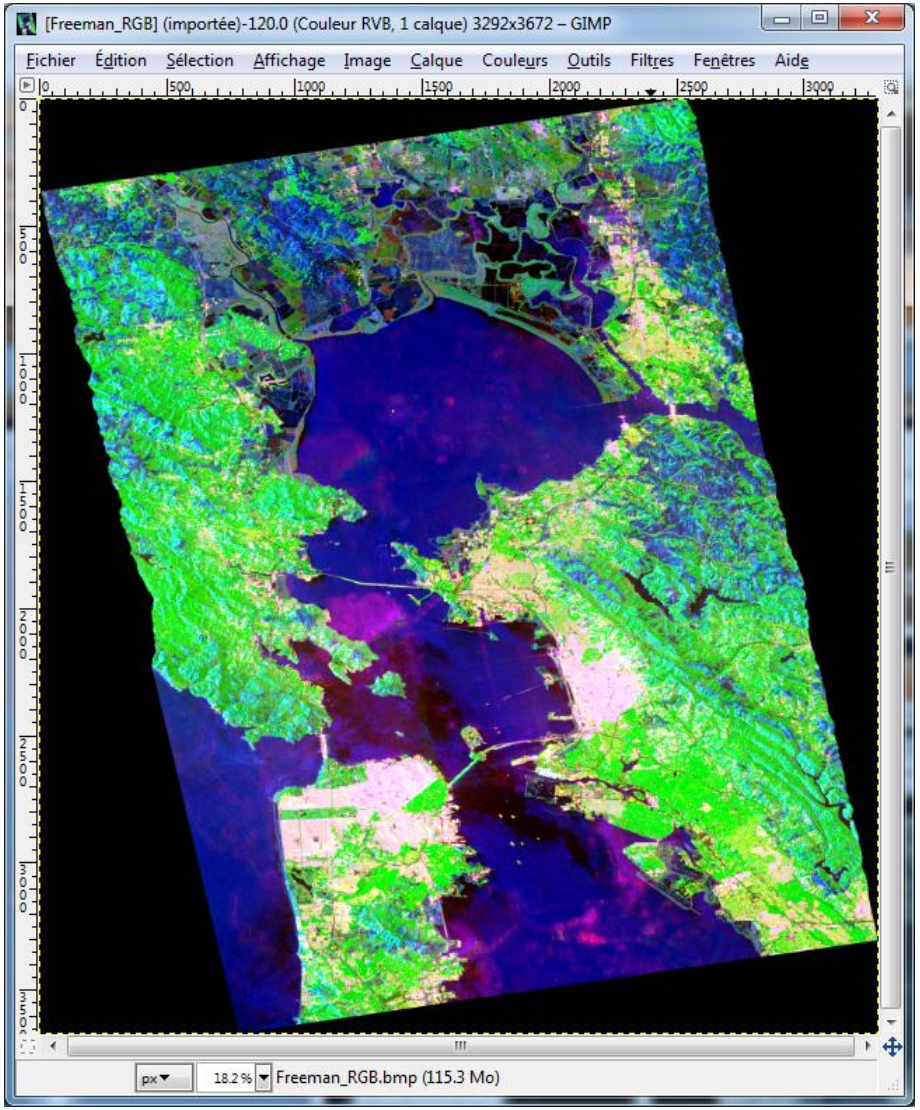




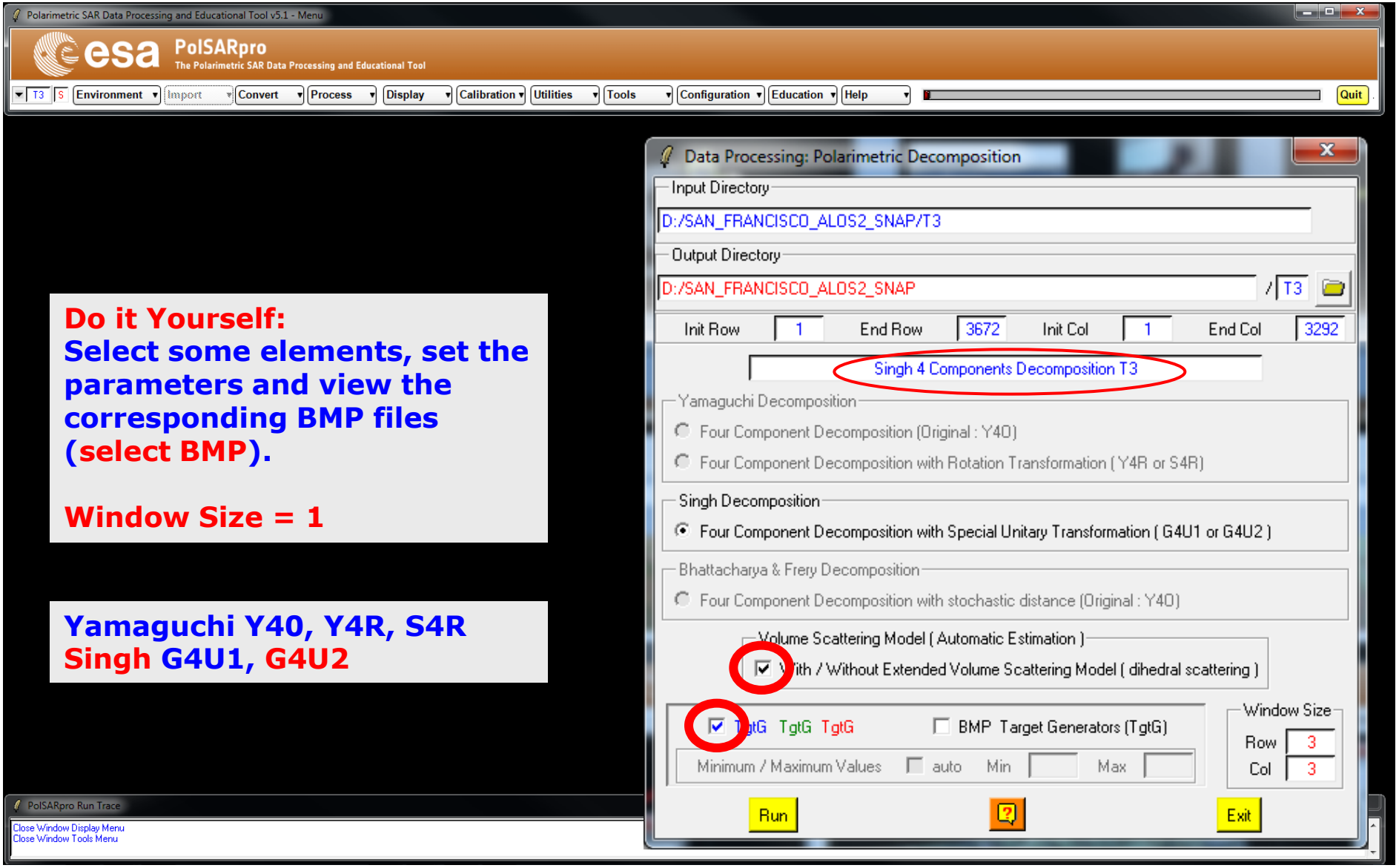
POLARIMETRIC DECOMPOSITION

Pauli Freeman 3





POLARIMETRIC DECOMPOSITION



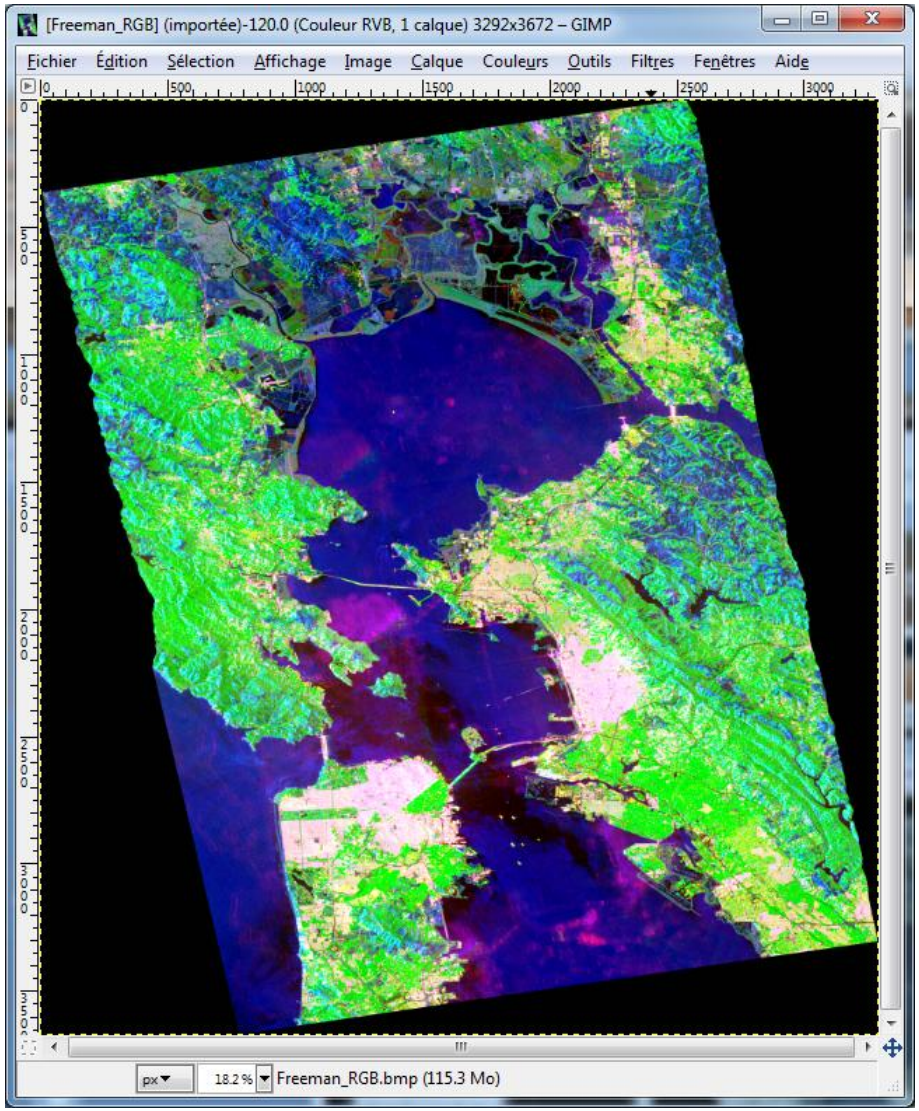
Do it Yourself:
Select some elements, set the parameters and view the corresponding BMP files (select BMP).

Window Size = 1

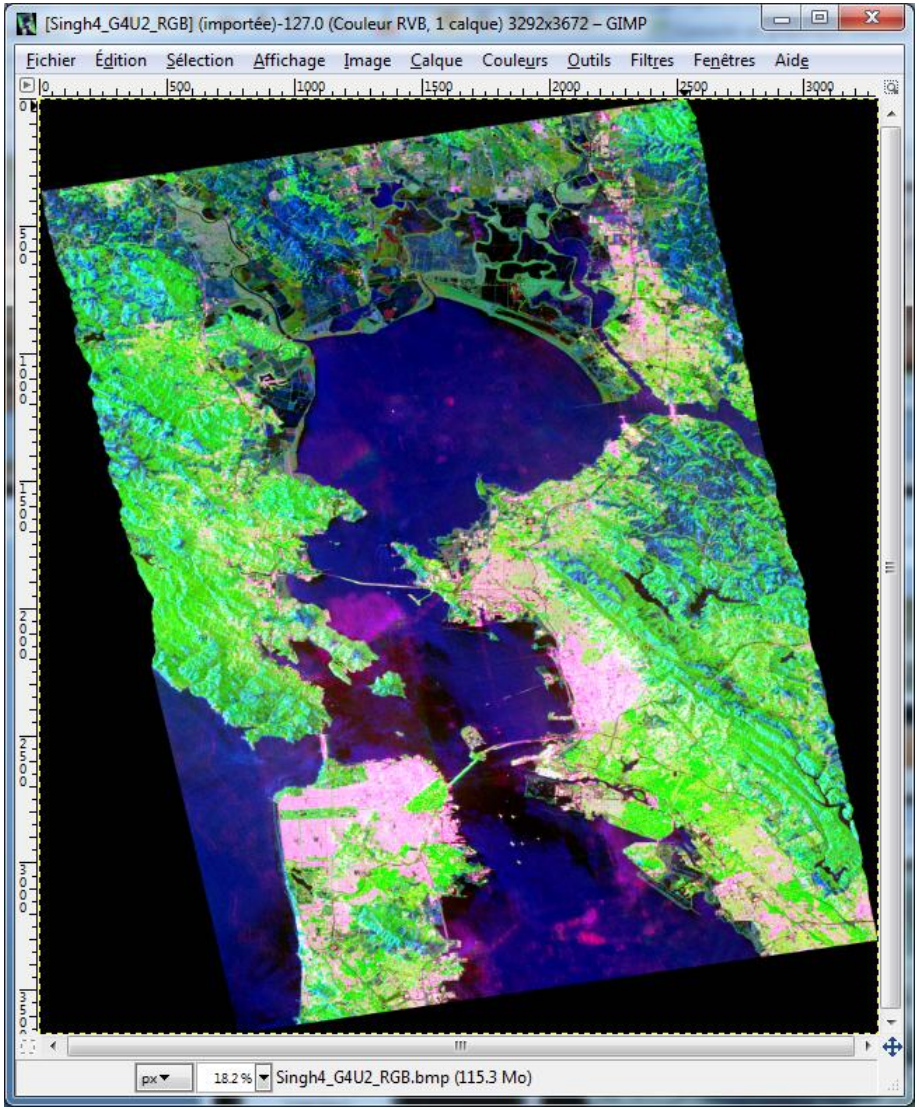
Yamaguchi Y40, Y4R, S4R
Singh G4U1, G4U2

POLARIMETRIC DECOMPOSITION

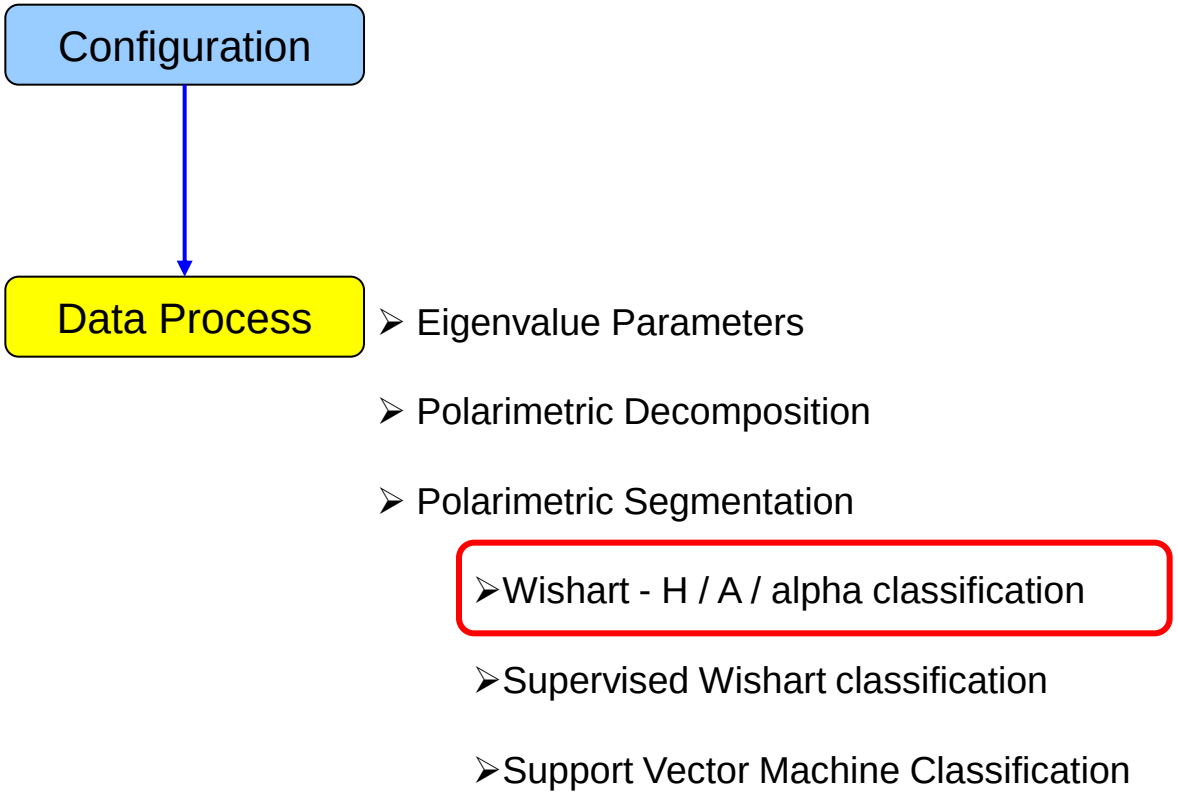
Pauli Freeman 3



Pauli Singh - Yamaguchi G4U2



PROCESSING CHAIN



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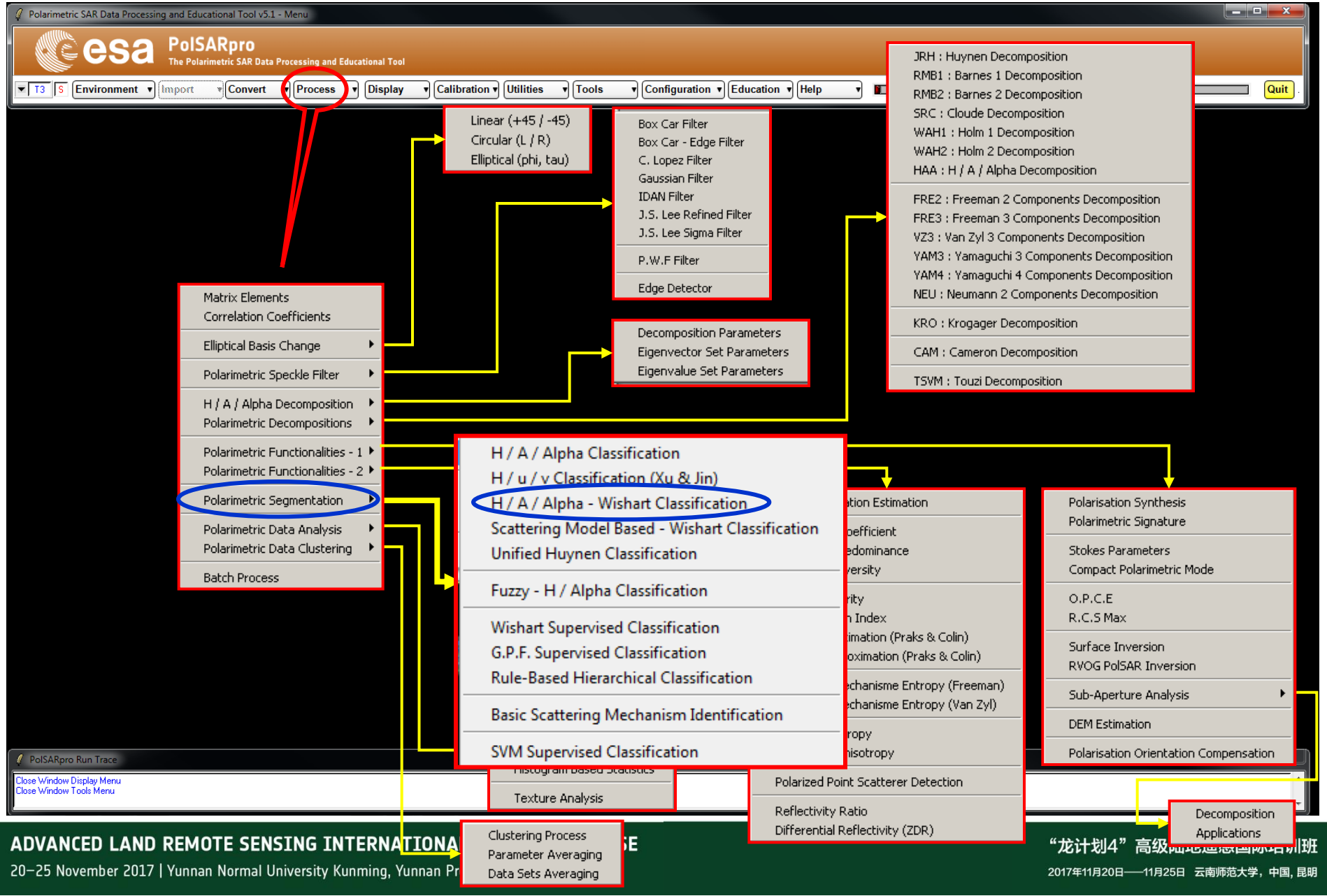
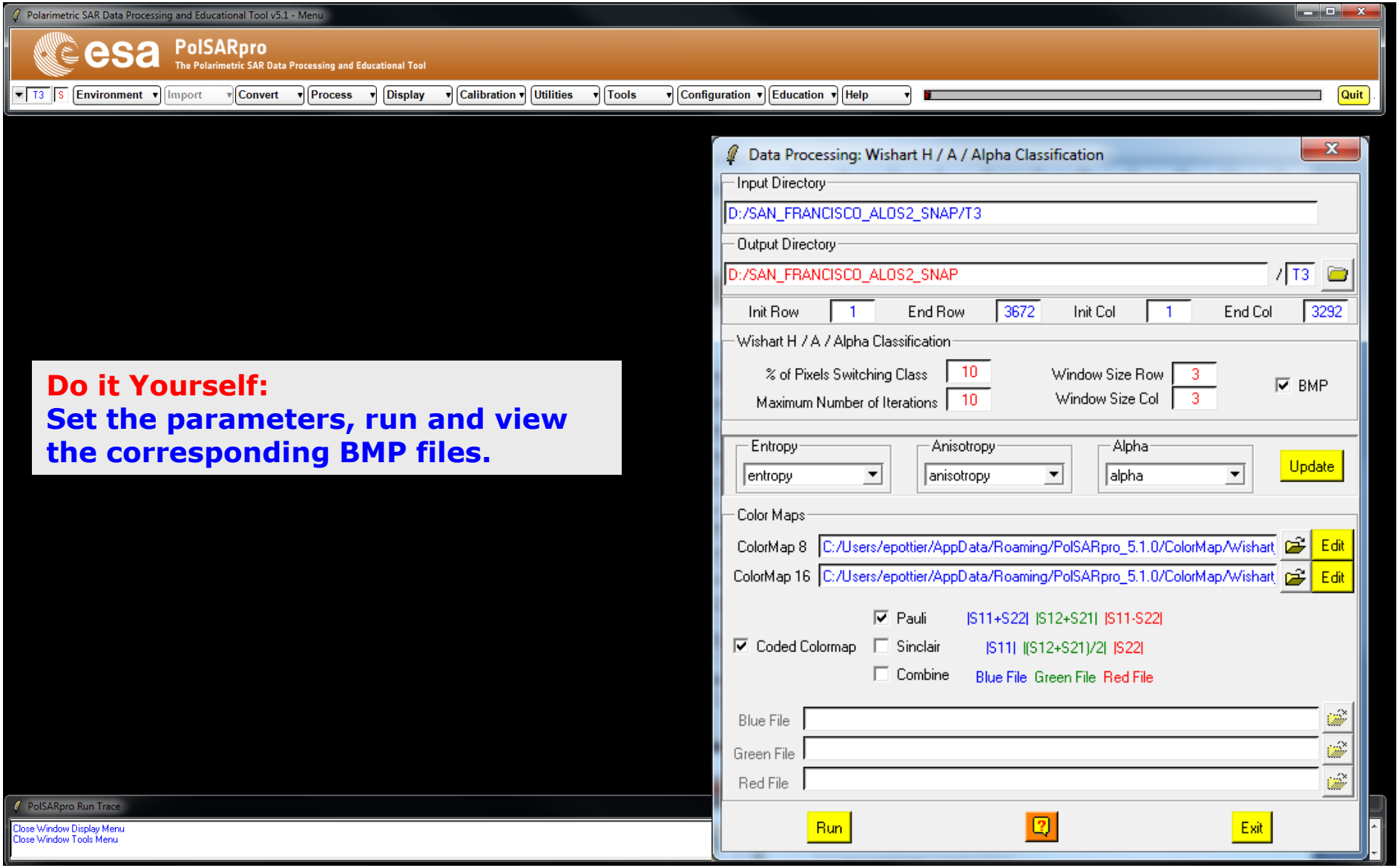
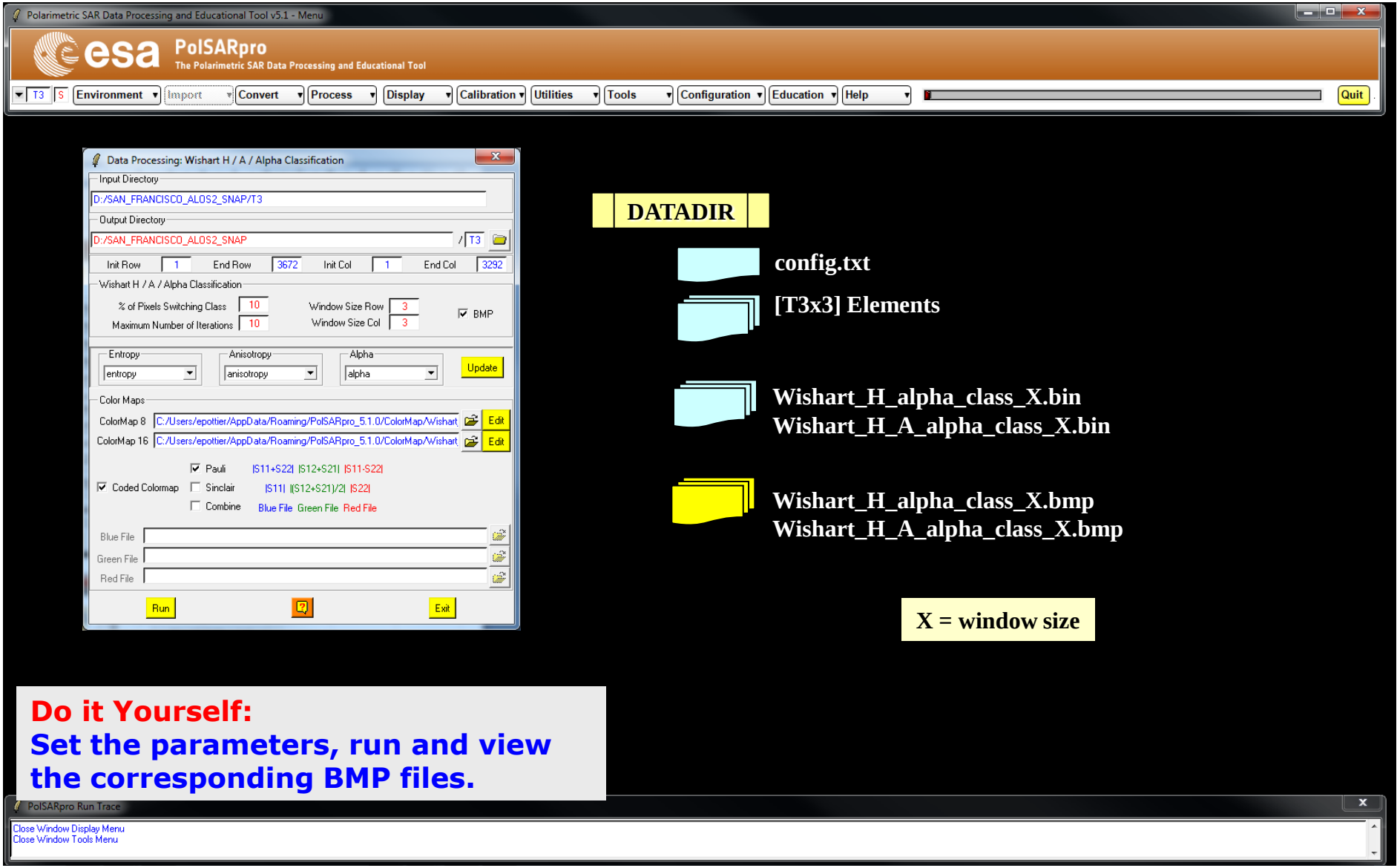


WISHART - H/A/alpha CLASSIFICATION



Do it Yourself:
Set the parameters, run and view the corresponding BMP files.

WISHART - H/A/alpha CLASSIFICATION



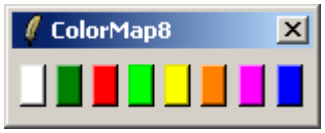
DATADIR

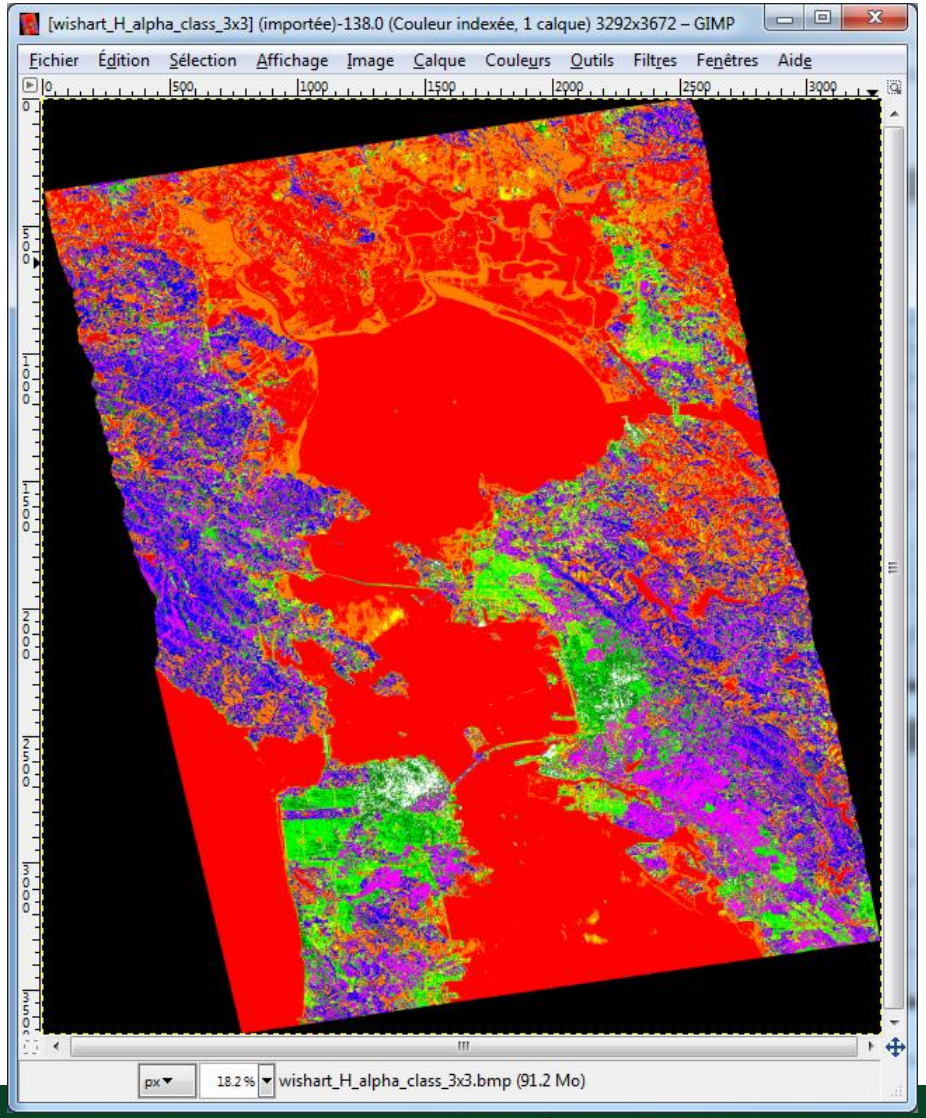
- config.txt
- [T3x3] Elements
- Wishart_H_alpha_class_X.bin
  Wishart_H_A_alpha_class_X.bin
- Wishart_H_alpha_class_X.bmp
  Wishart_H_A_alpha_class_X.bmp

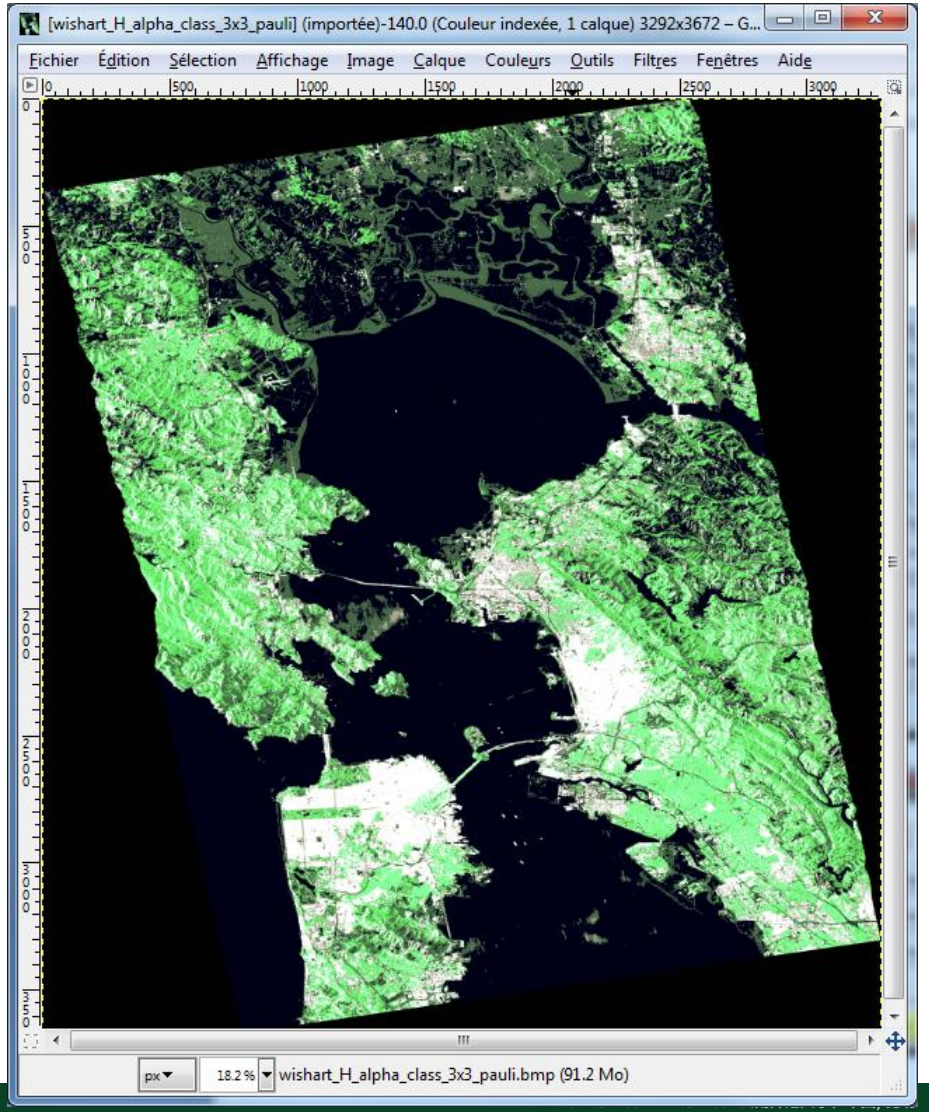
X = window size

Do it Yourself:
Set the parameters, run and view the corresponding BMP files.

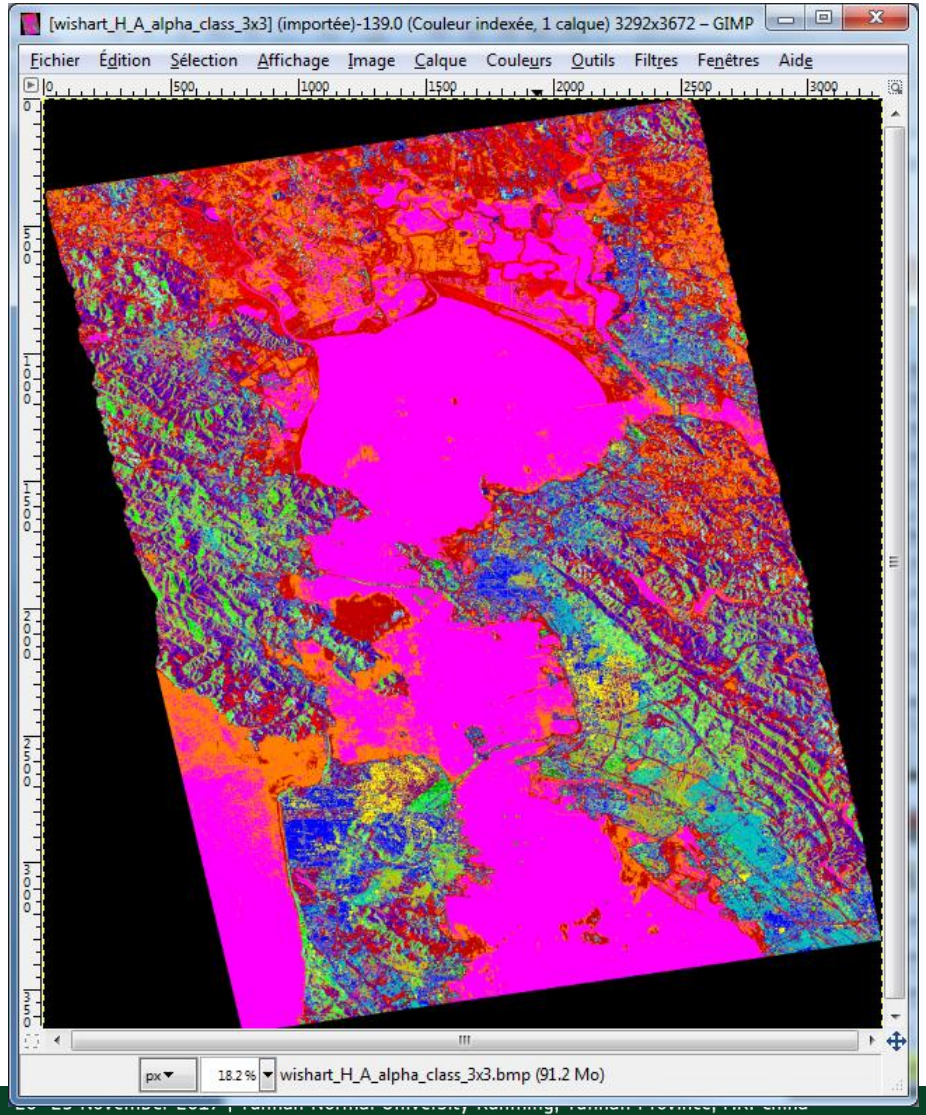
WISHART - H/A/alpha CLASSIFICATION

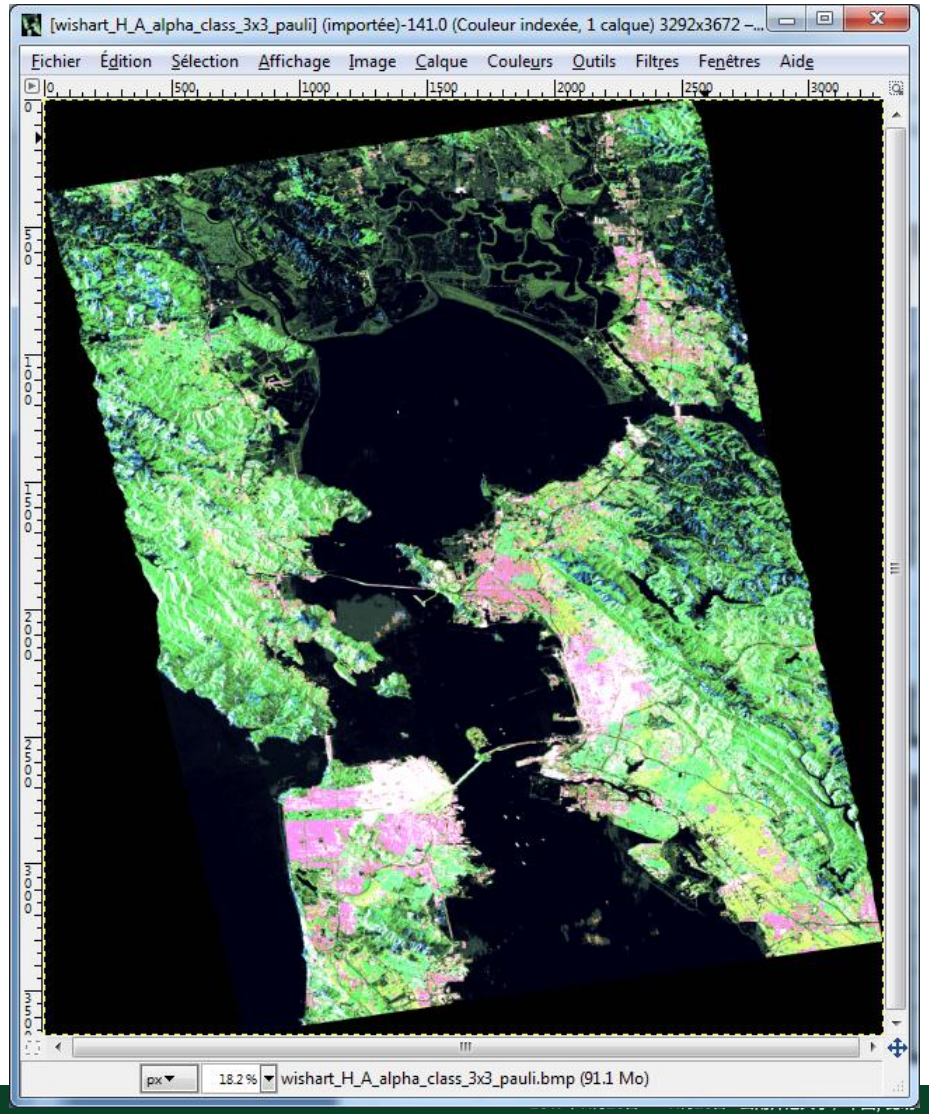




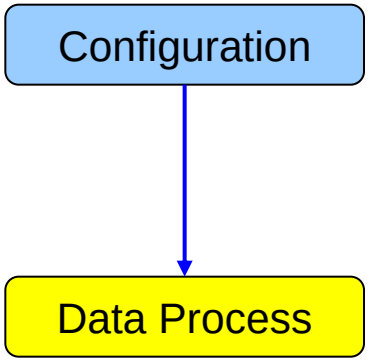


WISHART - H/A/alpha CLASSIFICATION



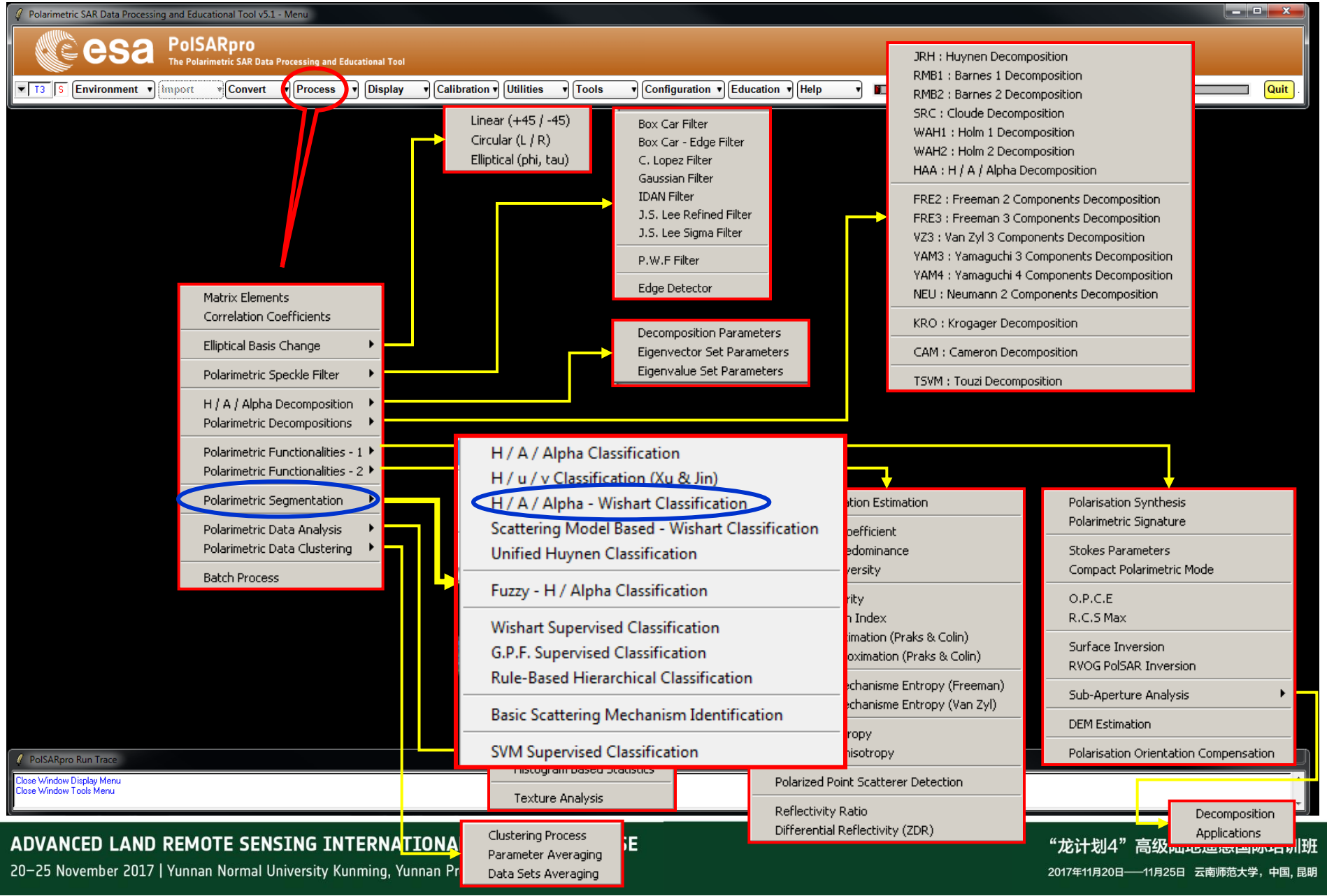


PROCESSING CHAIN

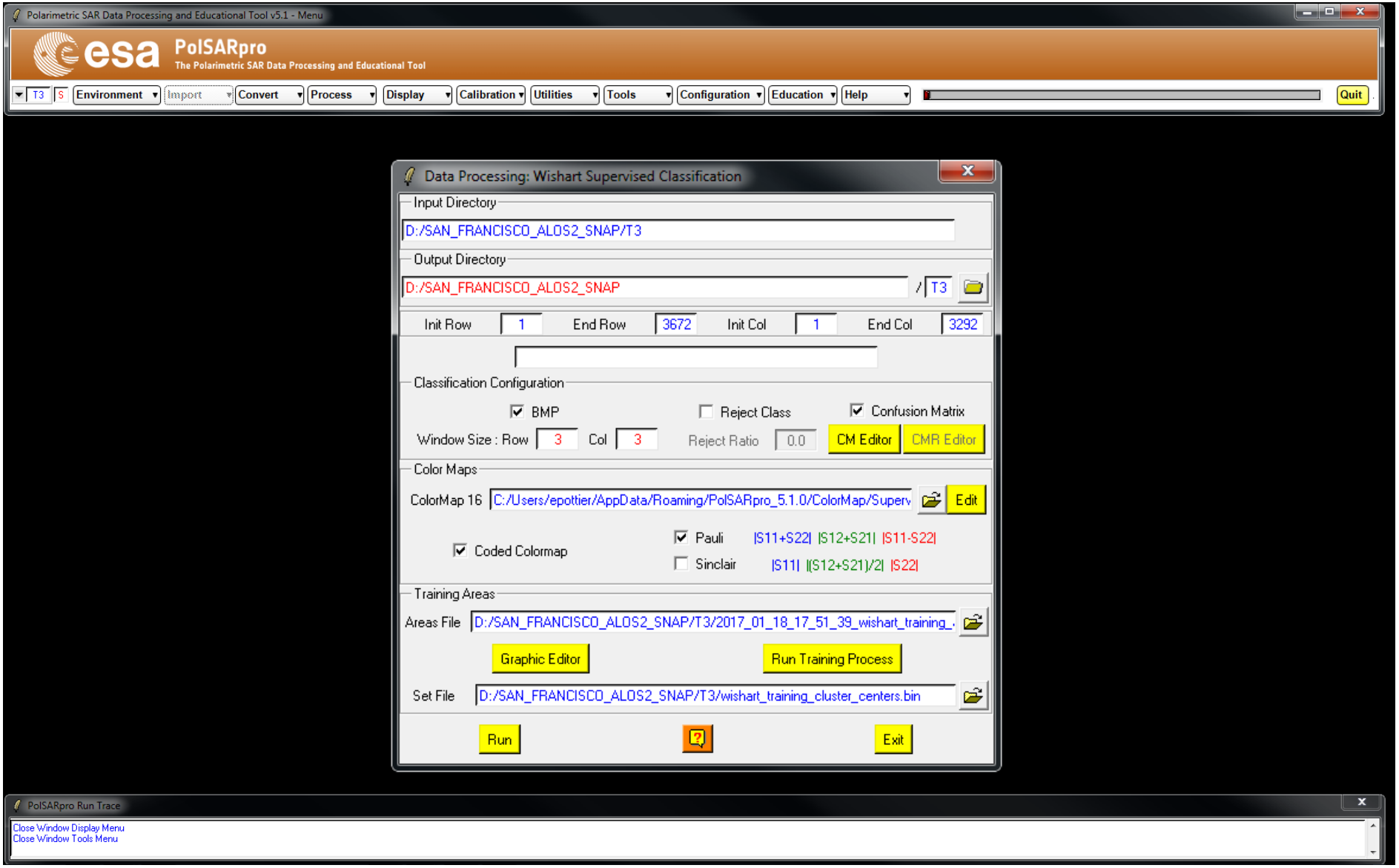


- Eigenvalue Parameters
- Polarimetric Decomposition
- Polarimetric Segmentation
  - Wishart - H / A / alpha classification
  - Supervised Wishart classification
  - Support Vector Machine Classification

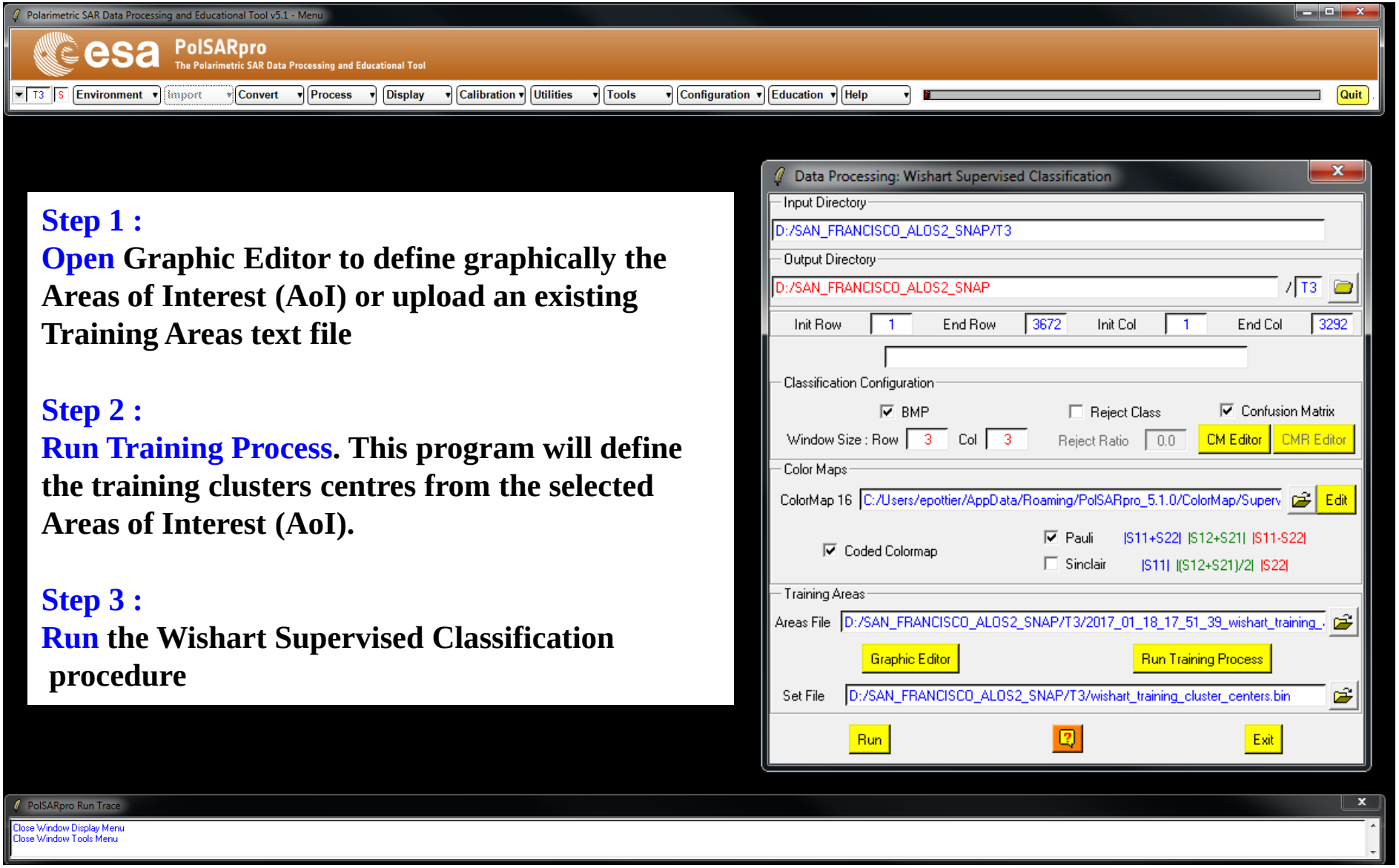
PolSARpro v5.1 SOFTWARE



SUPERVISED CLASSIFICATION



SUPERVISED CLASSIFICATION



Step 1 :

Open Graphic Editor to define graphically the Areas of Interest (AoI) or upload an existing Training Areas text file

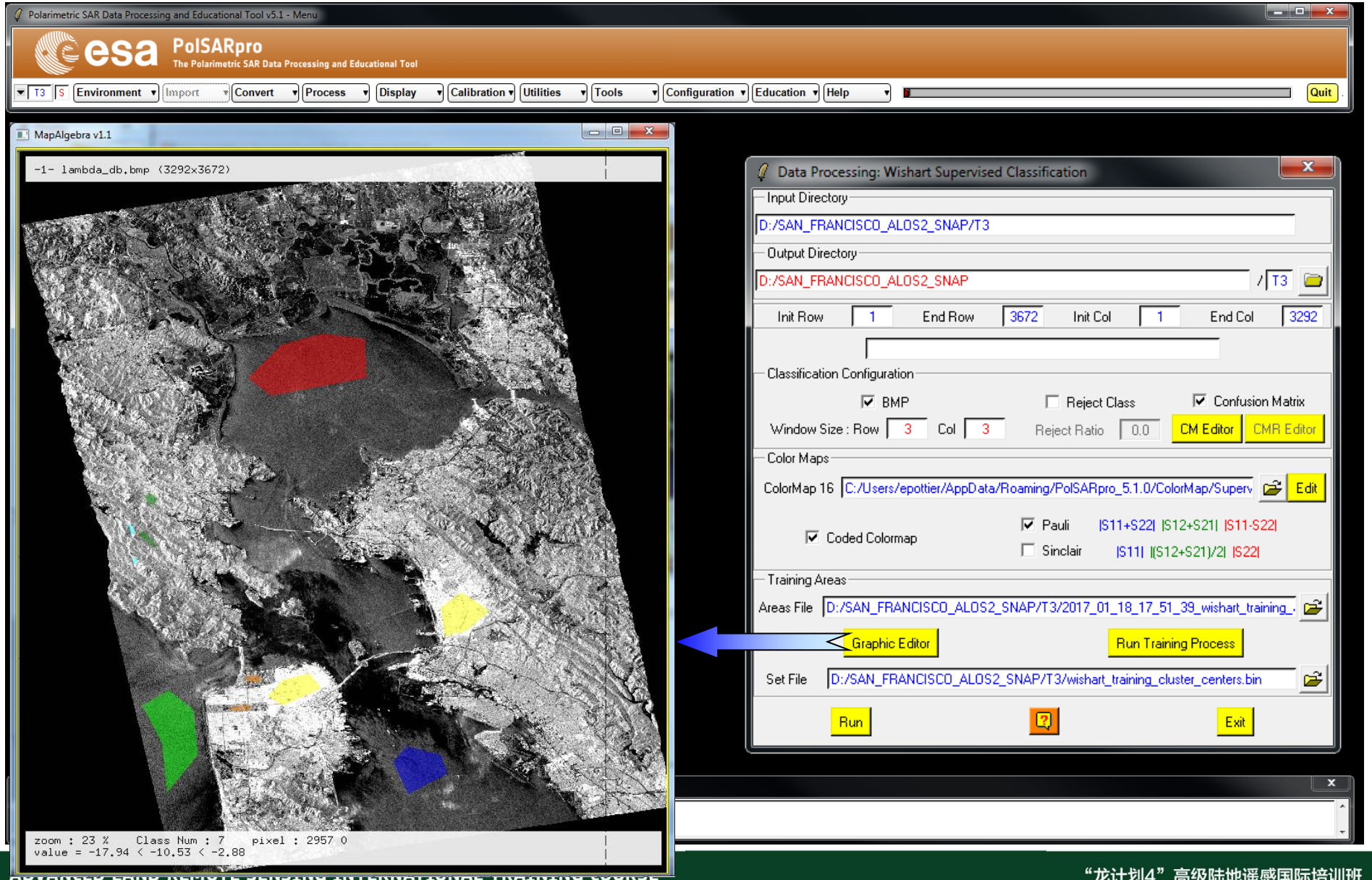
Step 2 :

Run Training Process. This program will define the training clusters centres from the selected Areas of Interest (AoI).

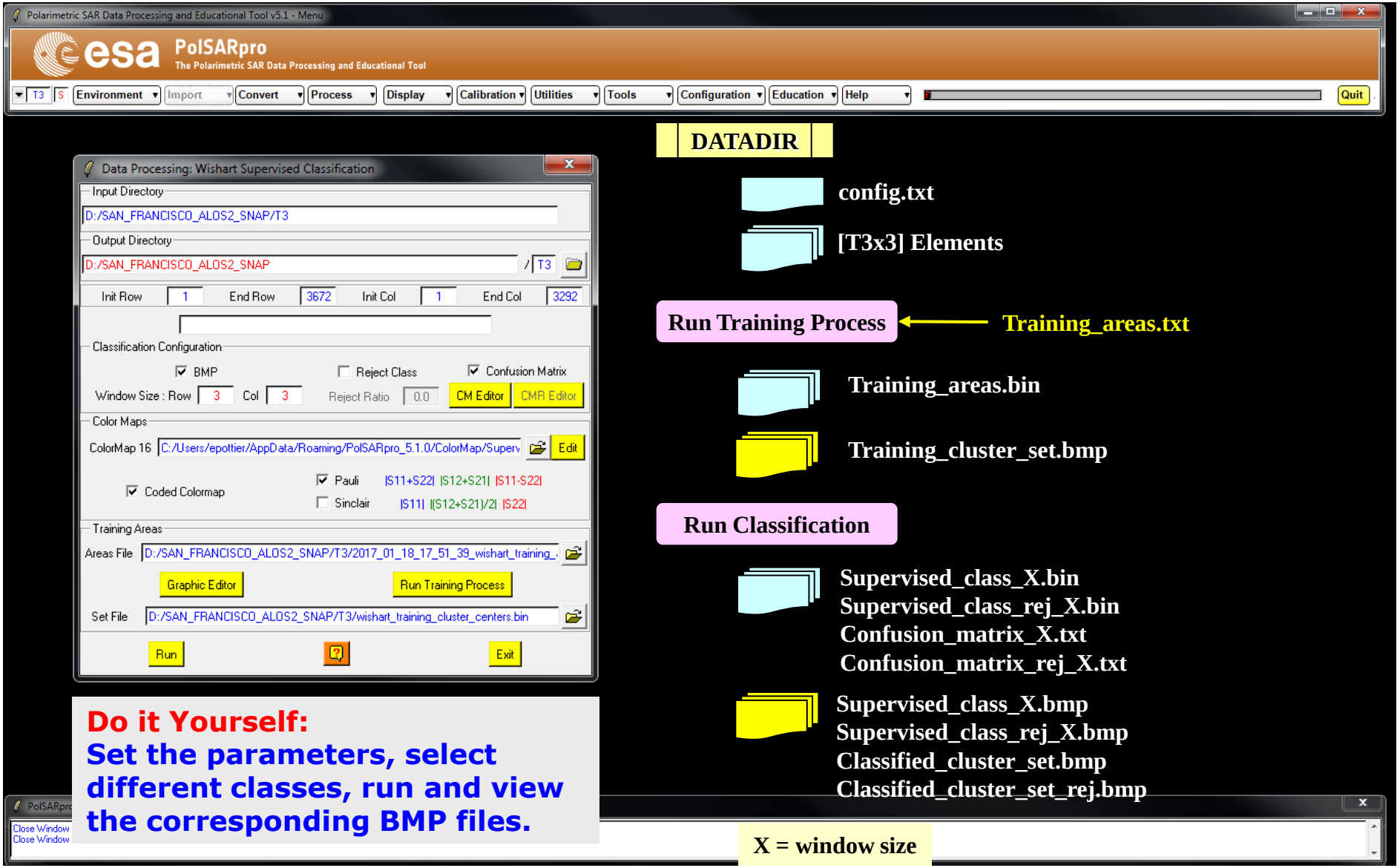
Step 3 :

Run the Wishart Supervised Classification procedure

SUPERVISED CLASSIFICATION



SUPERVISED CLASSIFICATION



DATADIR

- config.txt
- [T3x3] Elements

Run Training Process ← Training_areas.txt

- Training_areas.bin
- Training_cluster_set.bmp

Run Classification

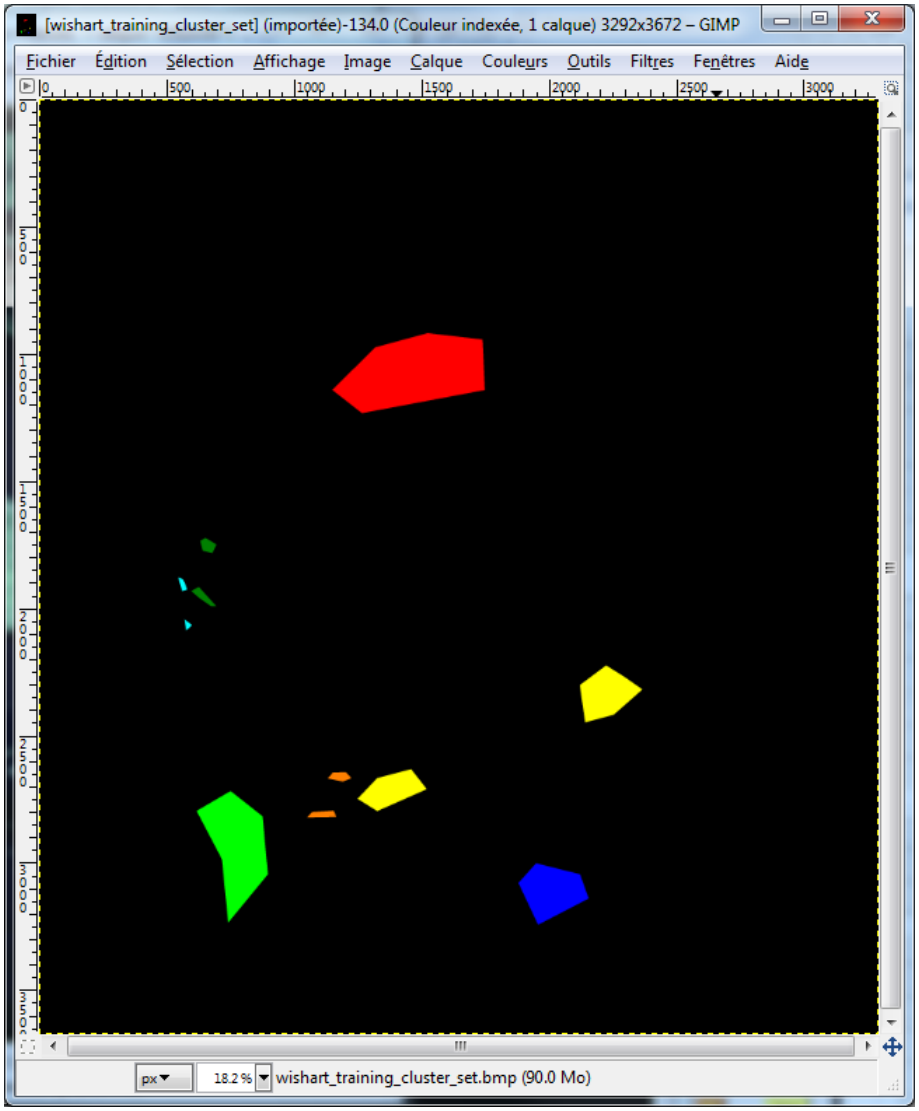
- Supervised_class_X.bin
- Supervised_class_rej_X.bin
- Confusion_matrix_X.txt
- Confusion_matrix_rej_X.txt

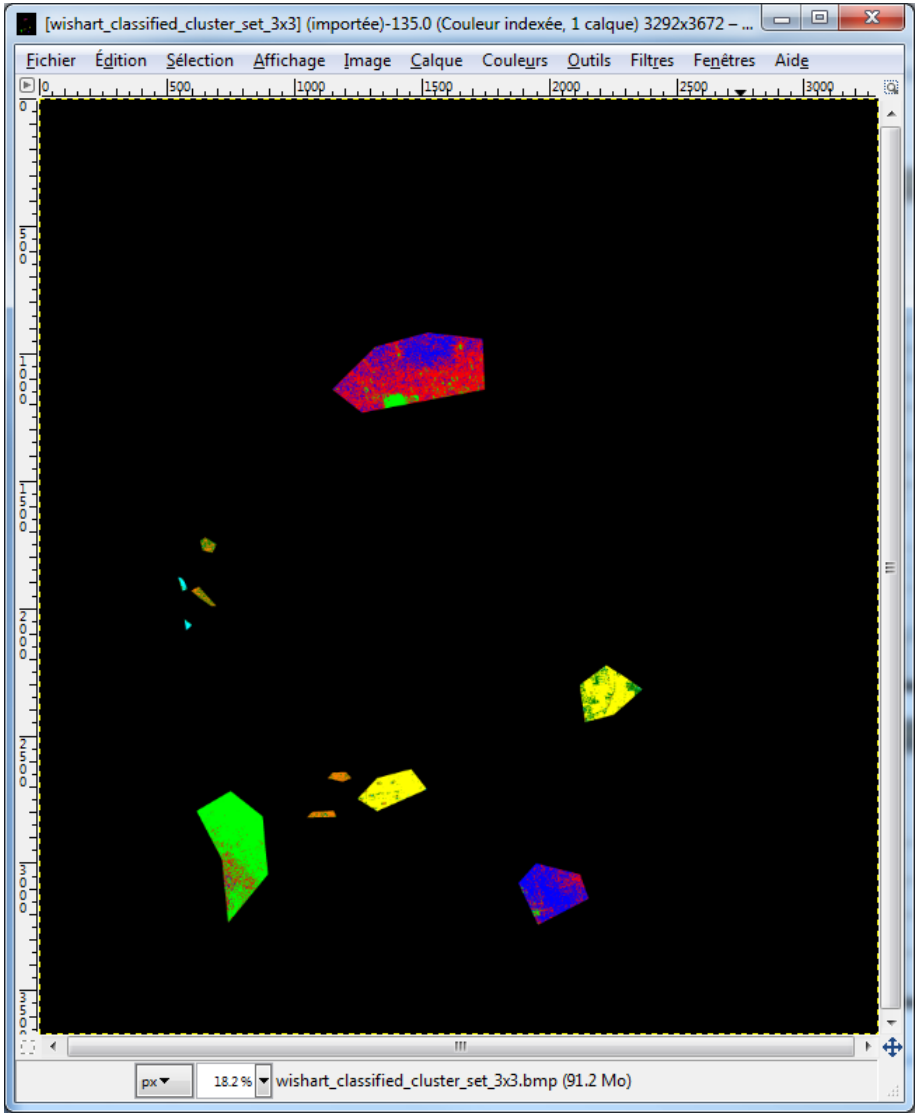
- Supervised_class_X.bmp
- Supervised_class_rej_X.bmp
- Classified_cluster_set.bmp
- Classified_cluster_set_rej.bmp

Do it Yourself:
Set the parameters, select different classes, run and view the corresponding BMP files.

X = window size

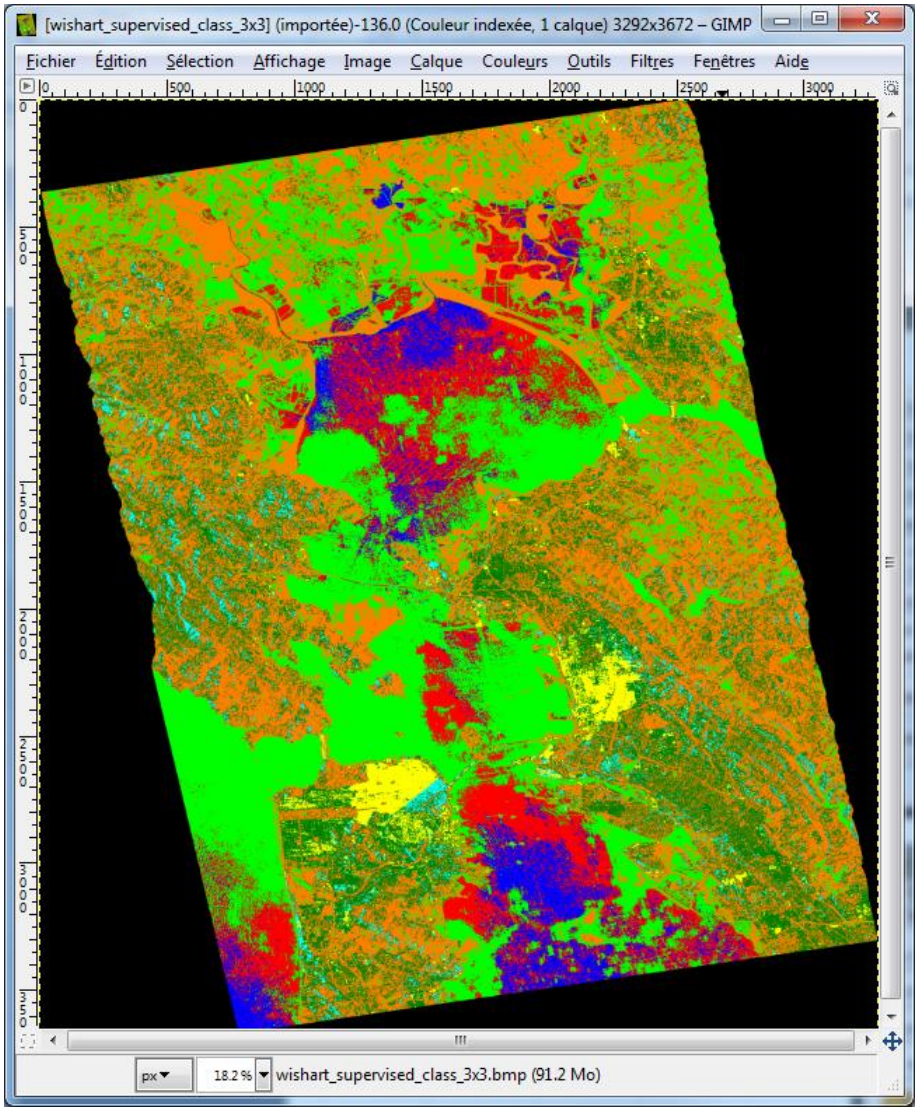
SUPERVISED CLASSIFICATION

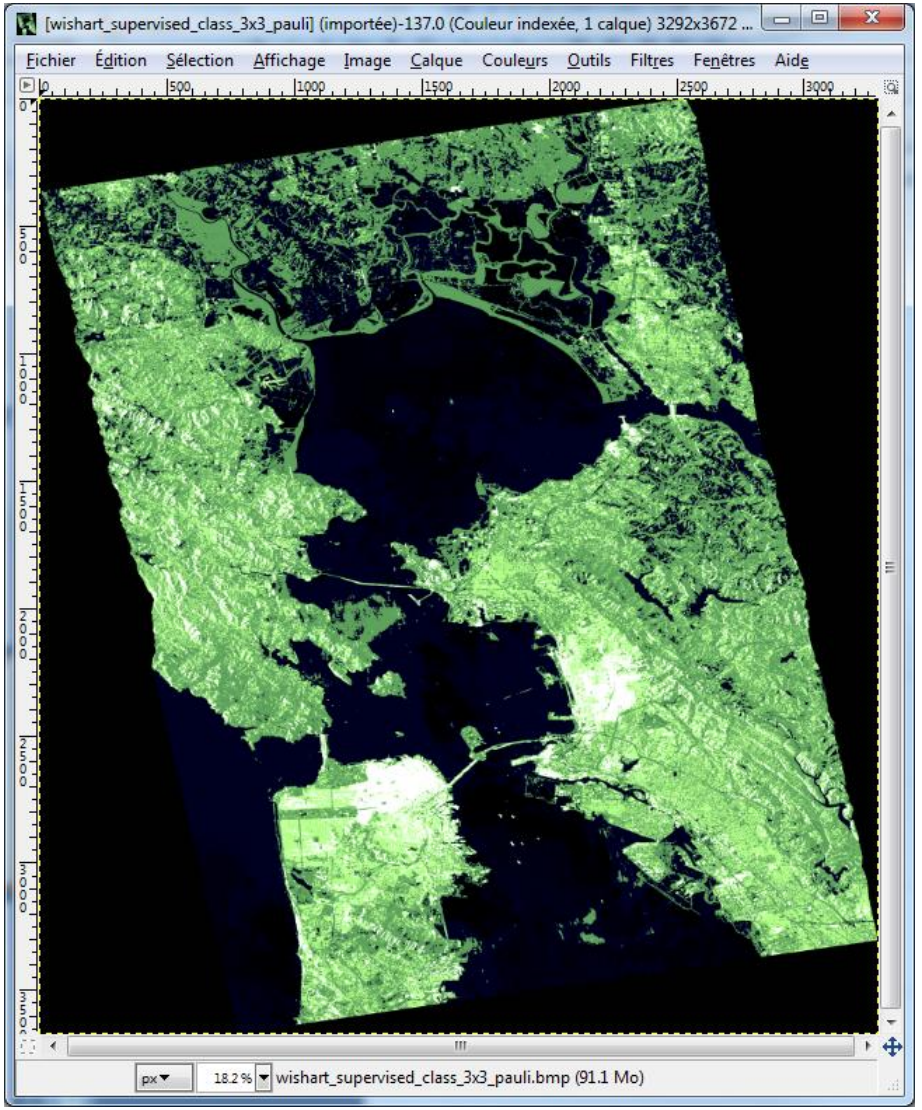




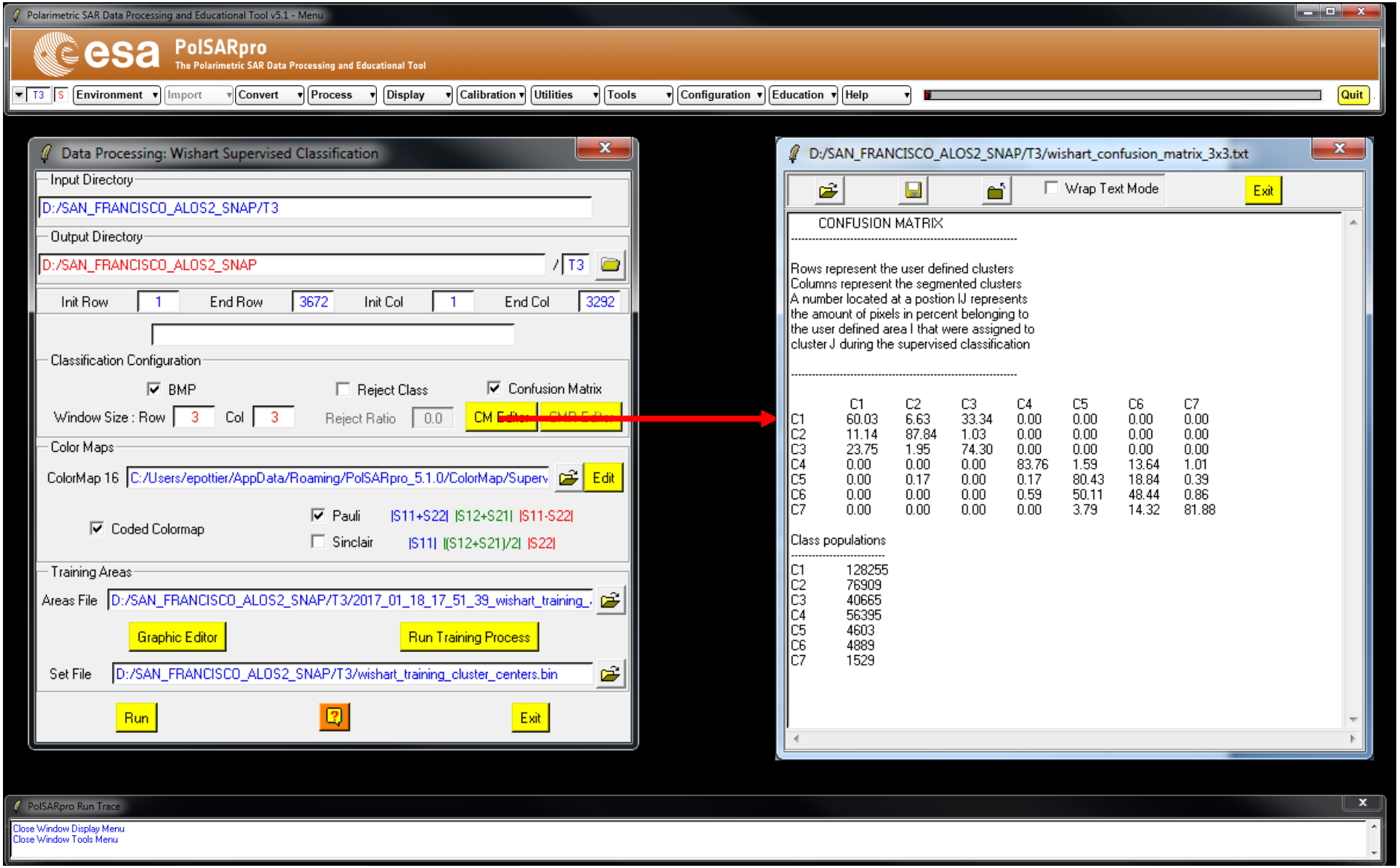
SUPERVISED CLASSIFICATION

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16

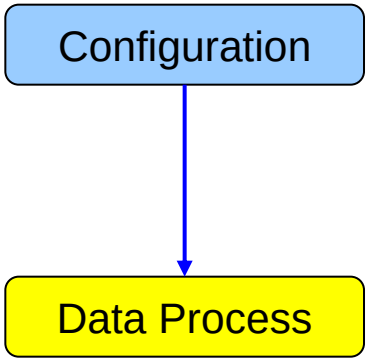




SUPERVISED CLASSIFICATION

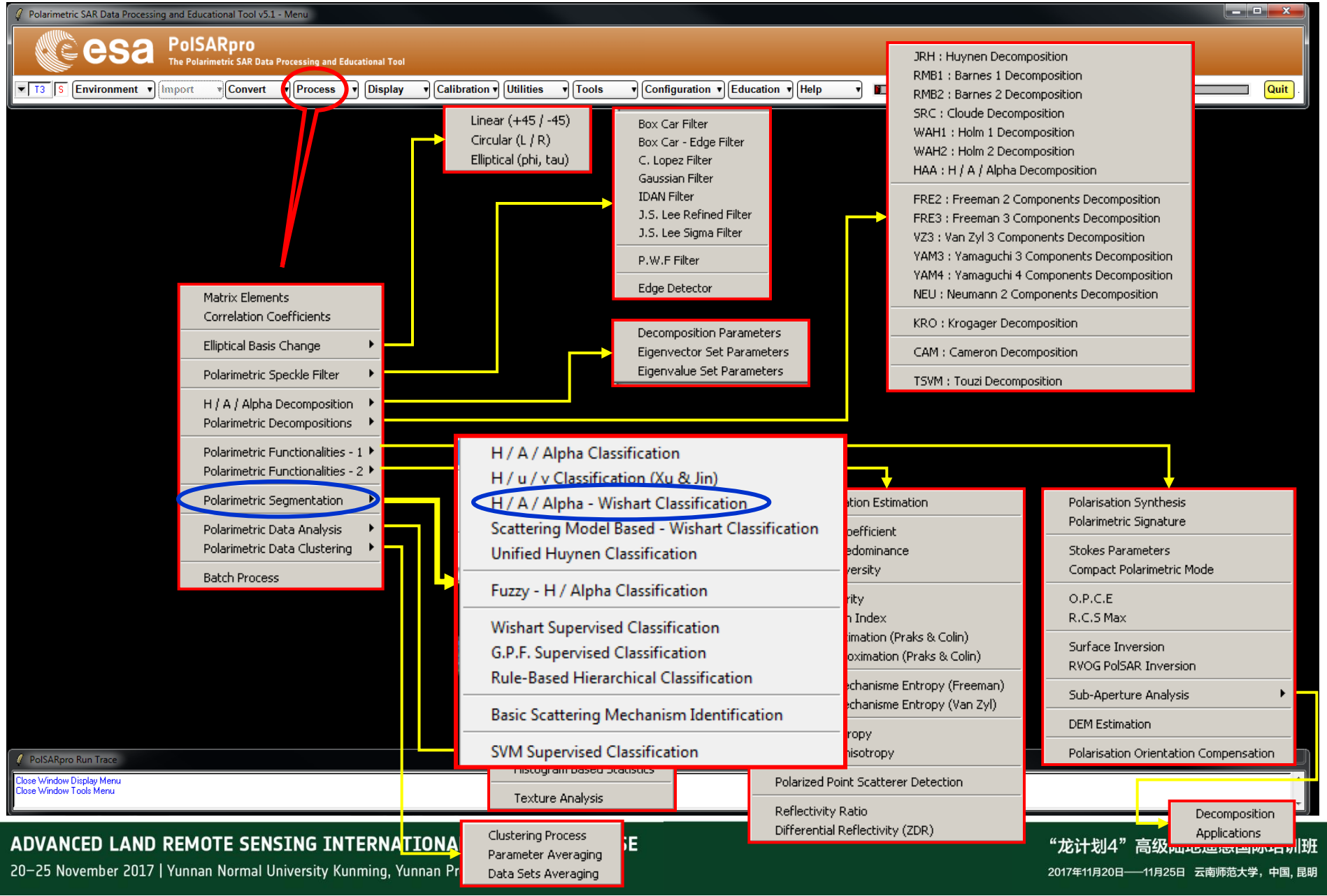


PROCESSING CHAIN

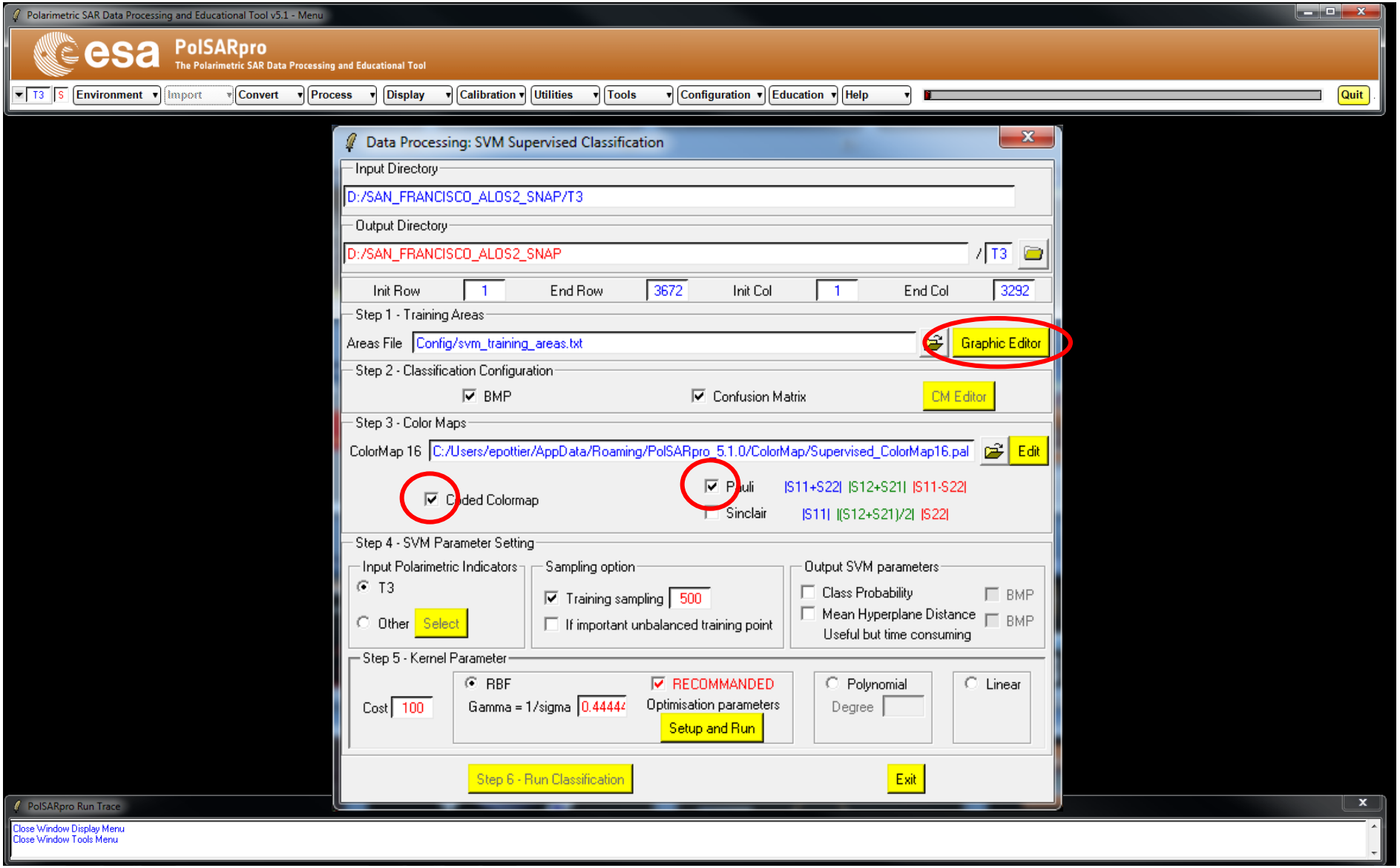


- Eigenvalue Parameters
- Polarimetric Decomposition
- Polarimetric Segmentation
  - Wishart - H / A / alpha classification
  - Supervised Wishart classification
  - Support Vector Machine Classification

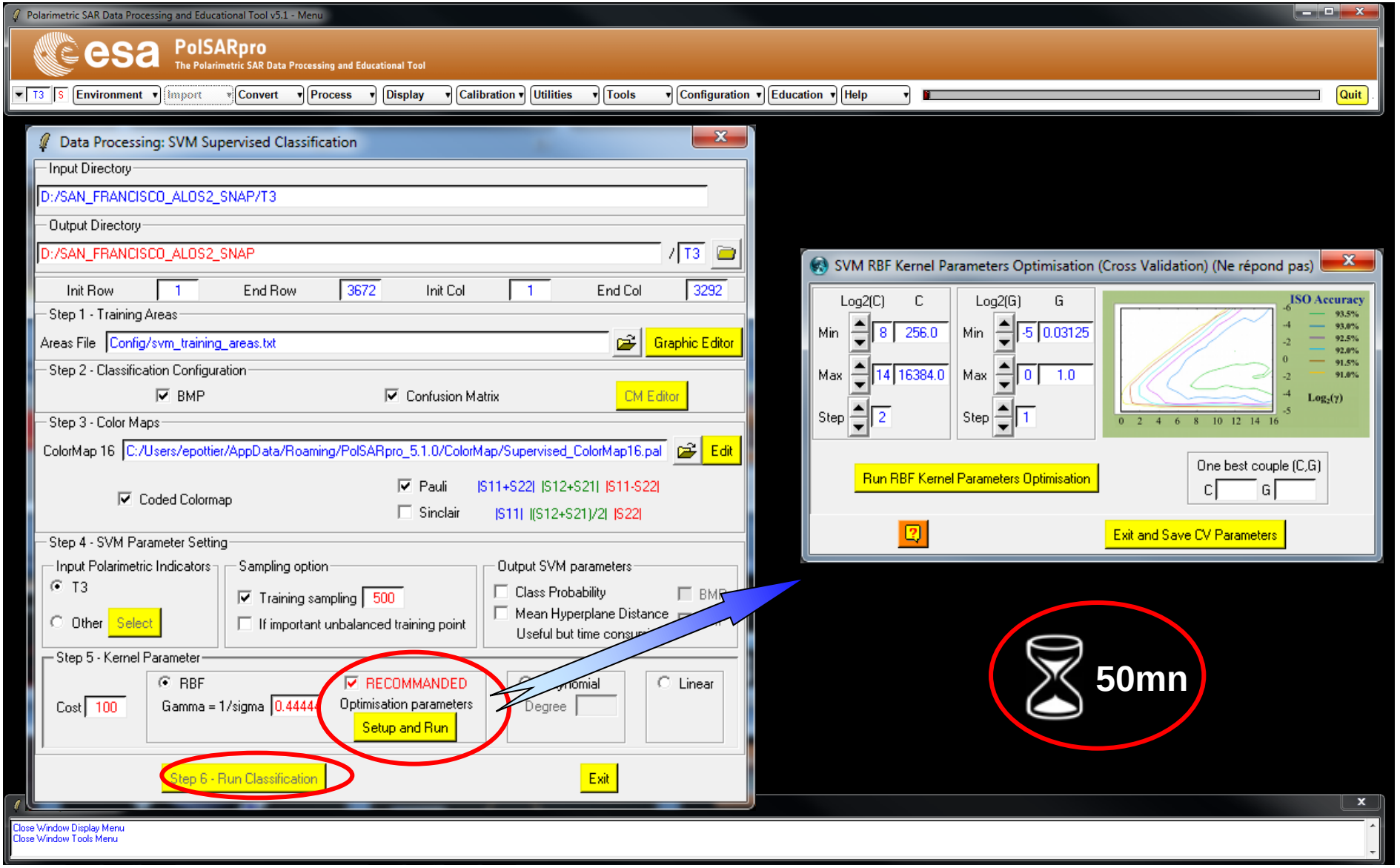
PolSARpro v5.1 SOFTWARE



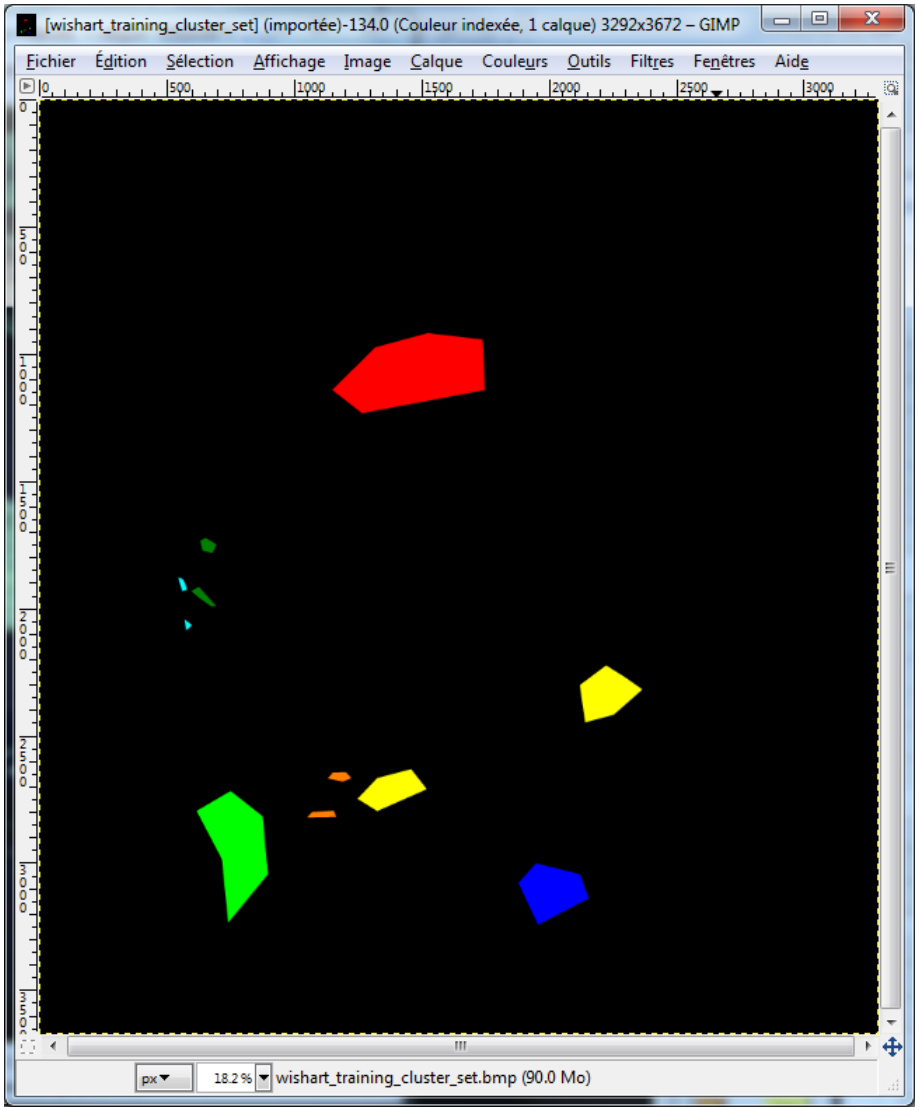
RT VECTOR MACHINE CLASSIFICATION

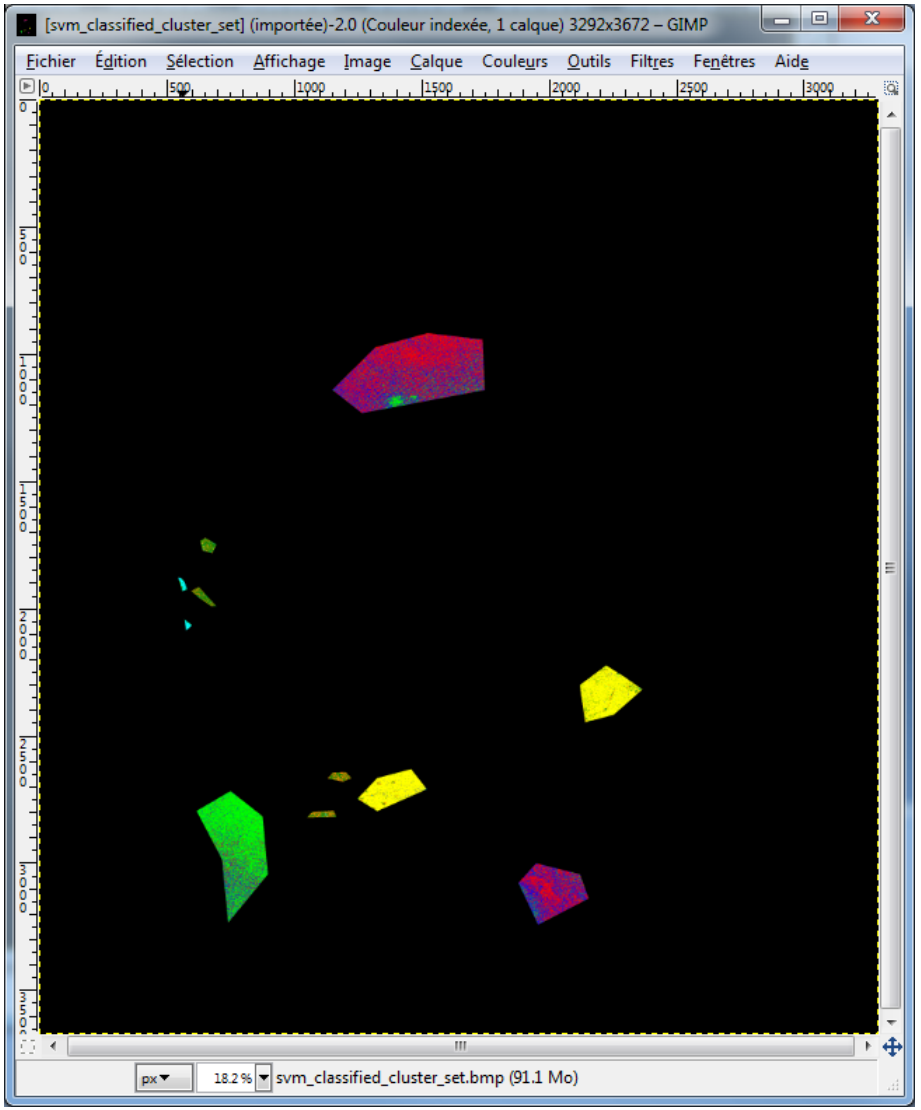


RT VECTOR MACHINE CLASSIFICATION

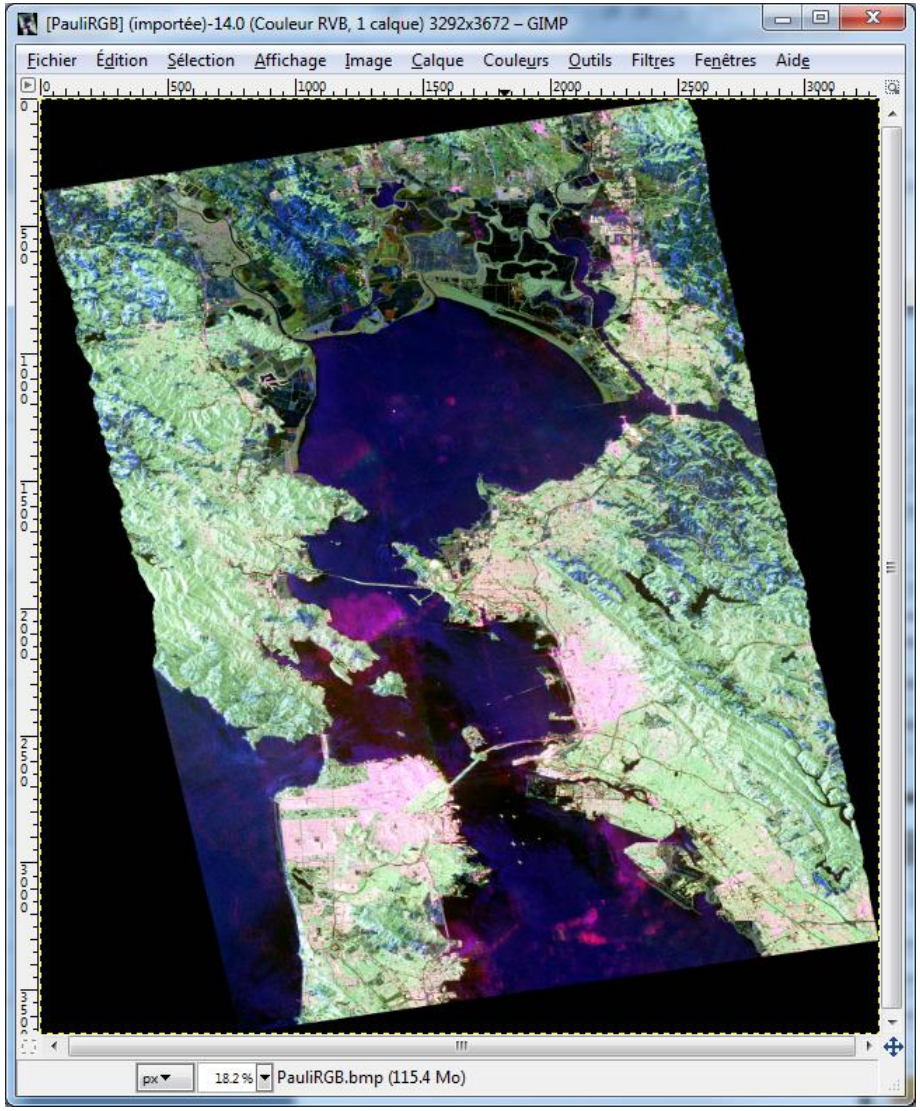


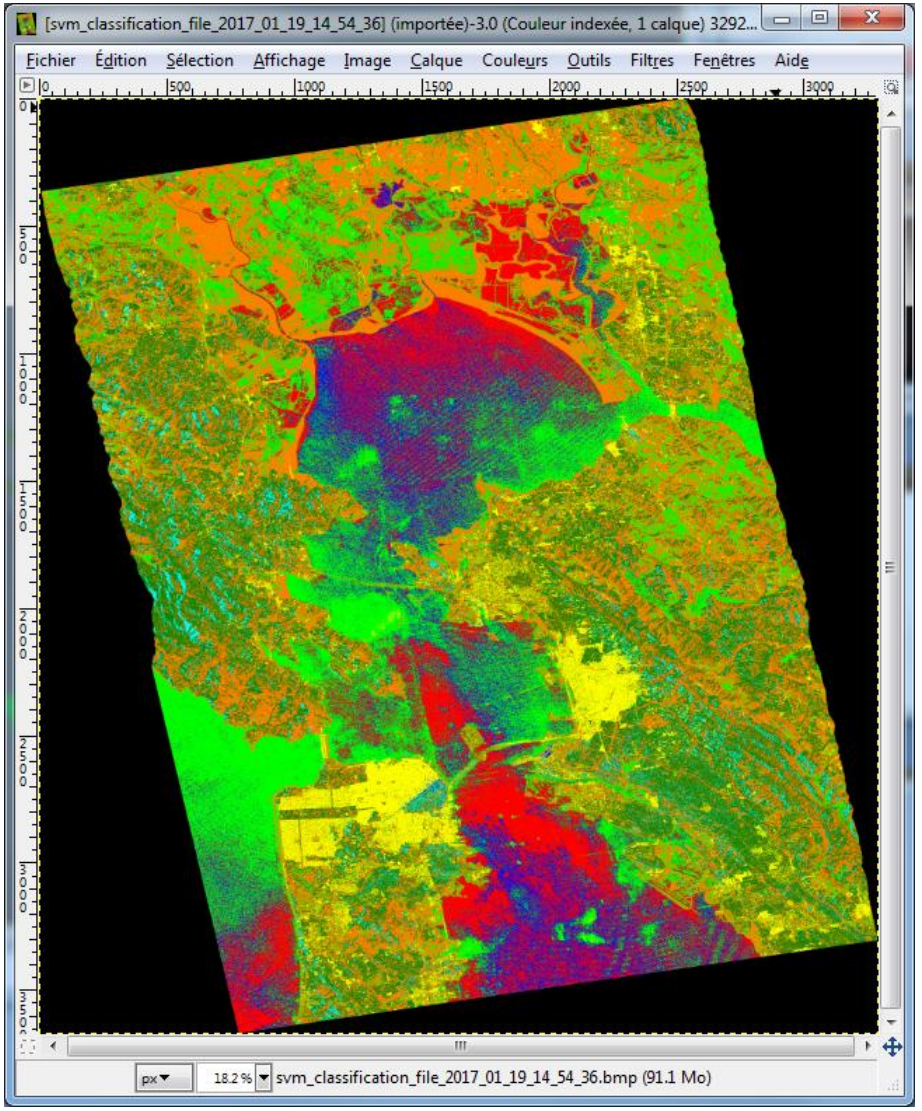
RT VECTOR MACHINE CLASSIFICATION



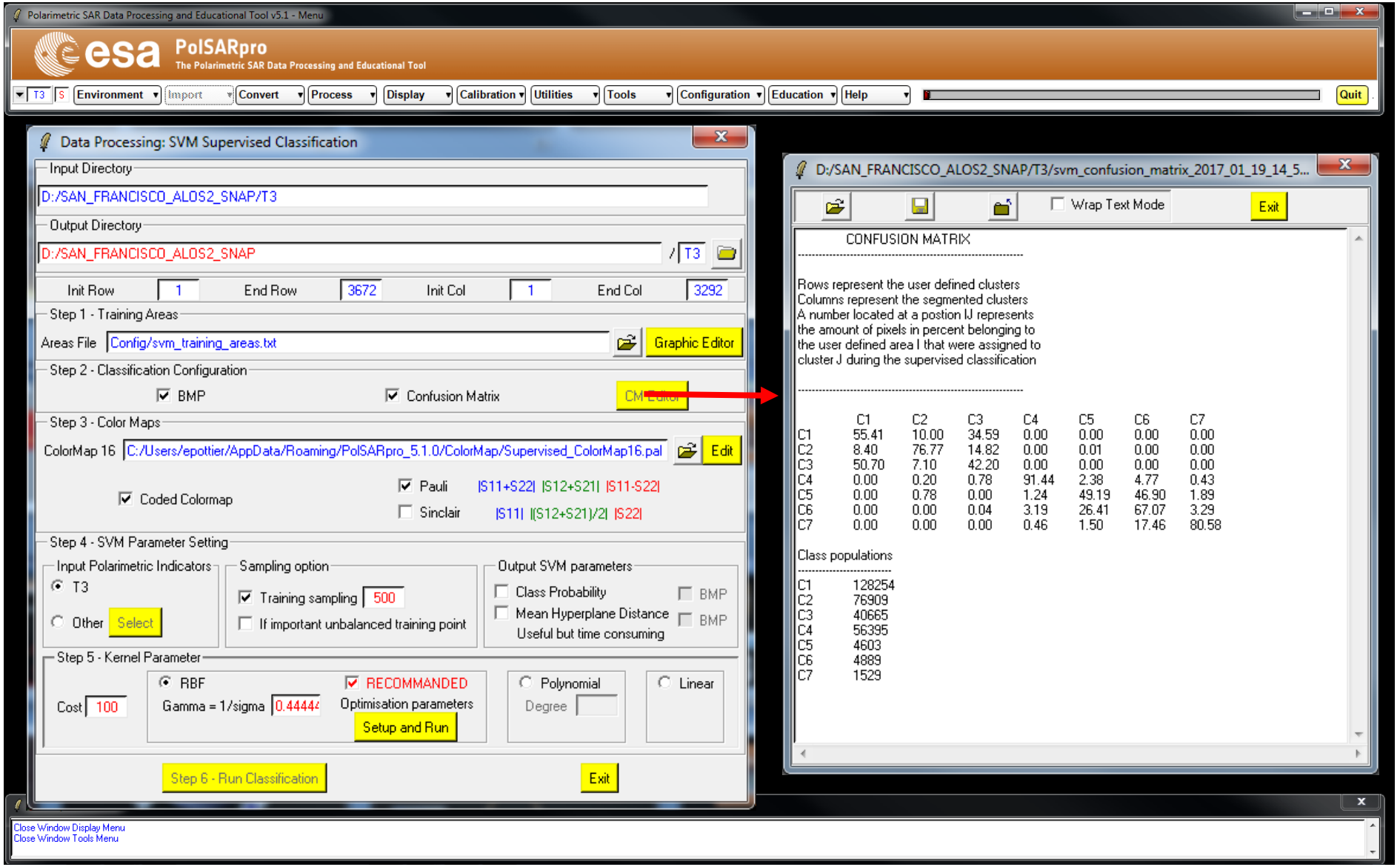


RT VECTOR MACHINE CLASSIFICATION

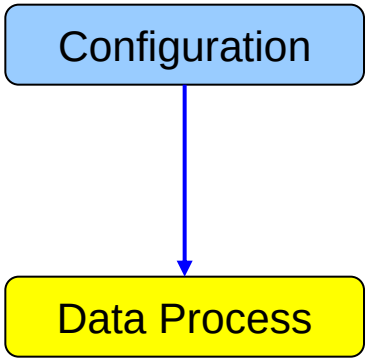




RT VECTOR MACHINE CLASSIFICATION

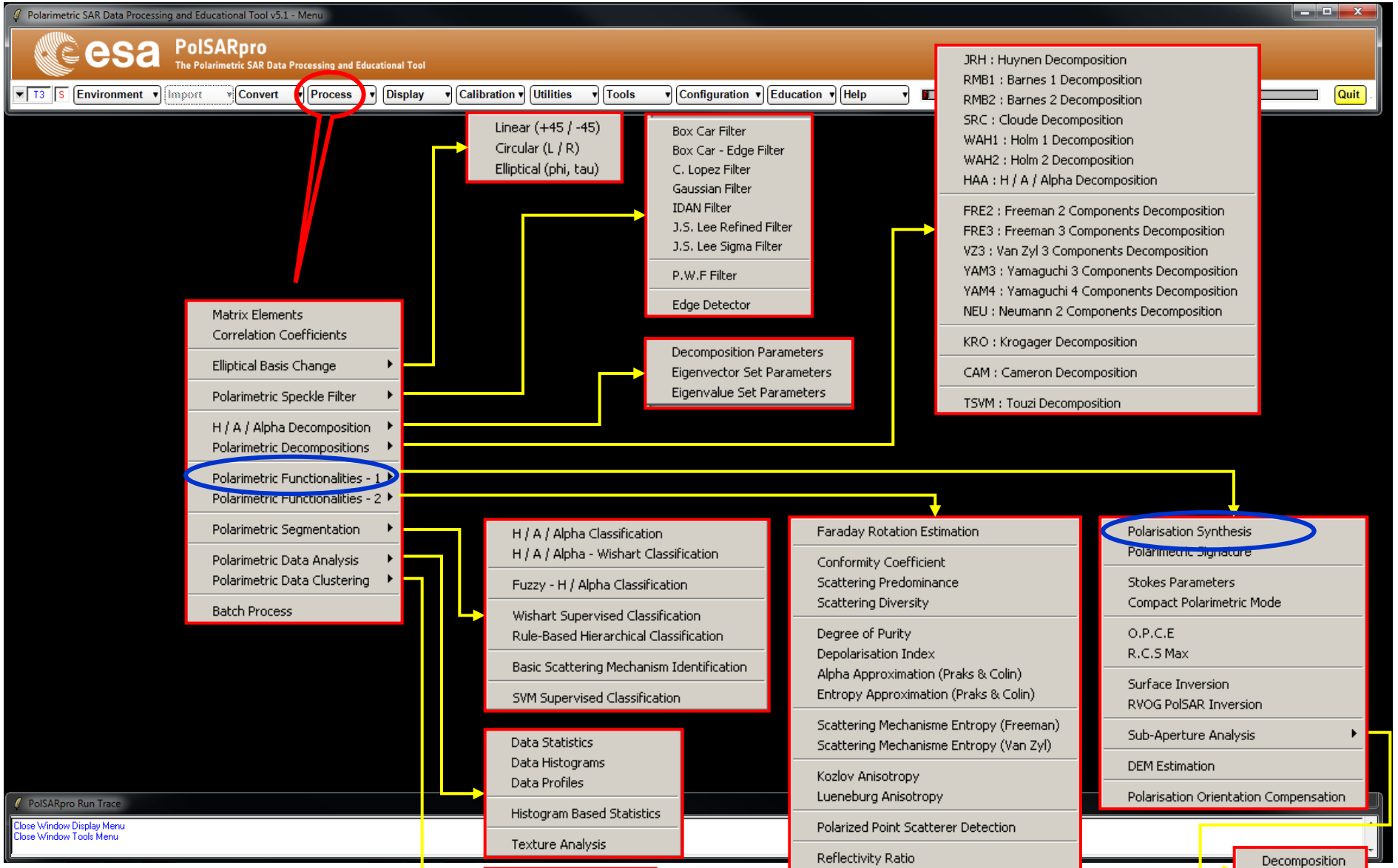


PROCESSING CHAIN

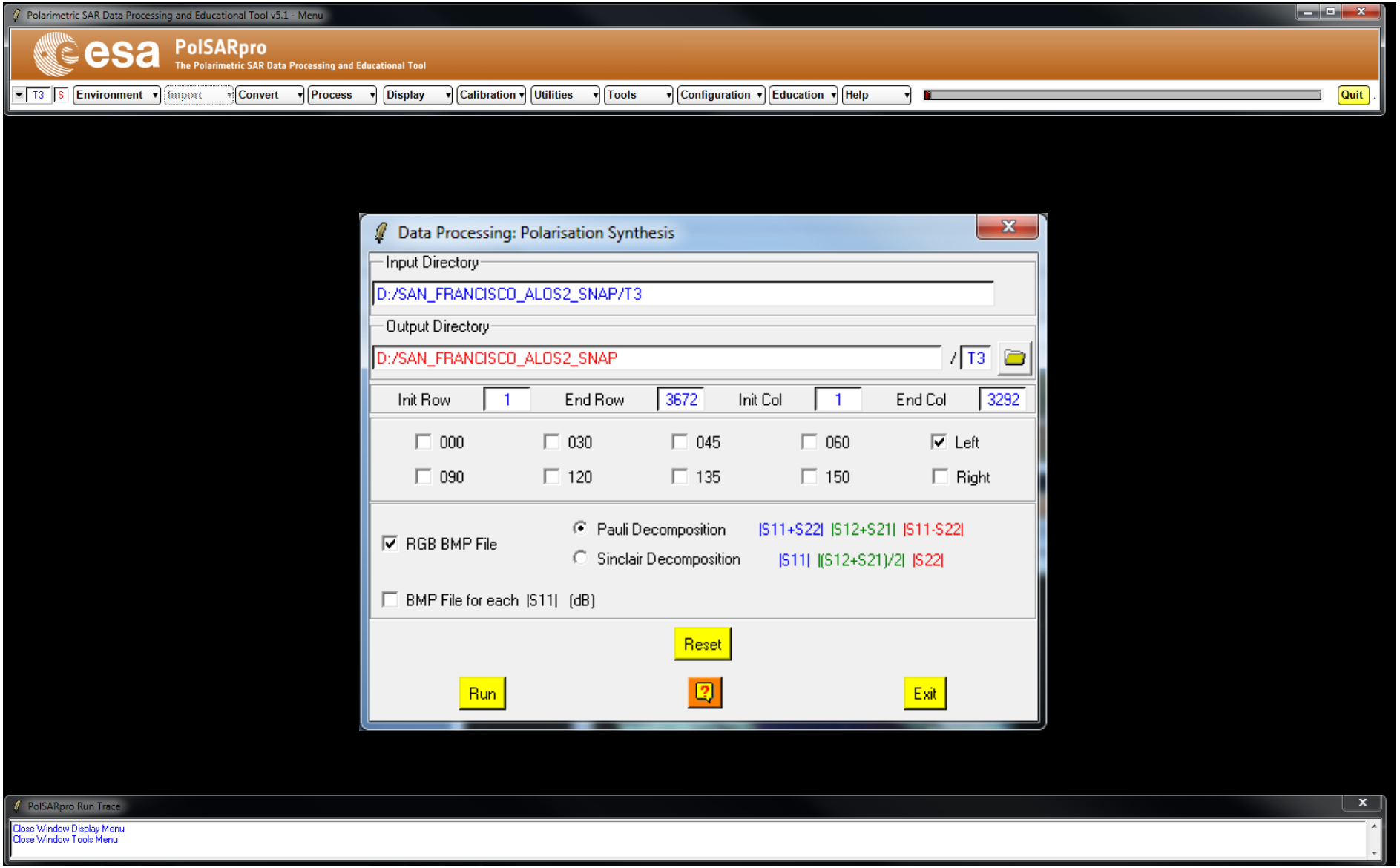


- Eigenvalue Parameters
- Polarimetric Decomposition
- Polarimetric Segmentation
  - Wishart - H / A / alpha classification
  - Supervised Wishart classification
  - Support Vector Machine Classification
- Polarimetric Functionalities
  - Polarimetric synthesis

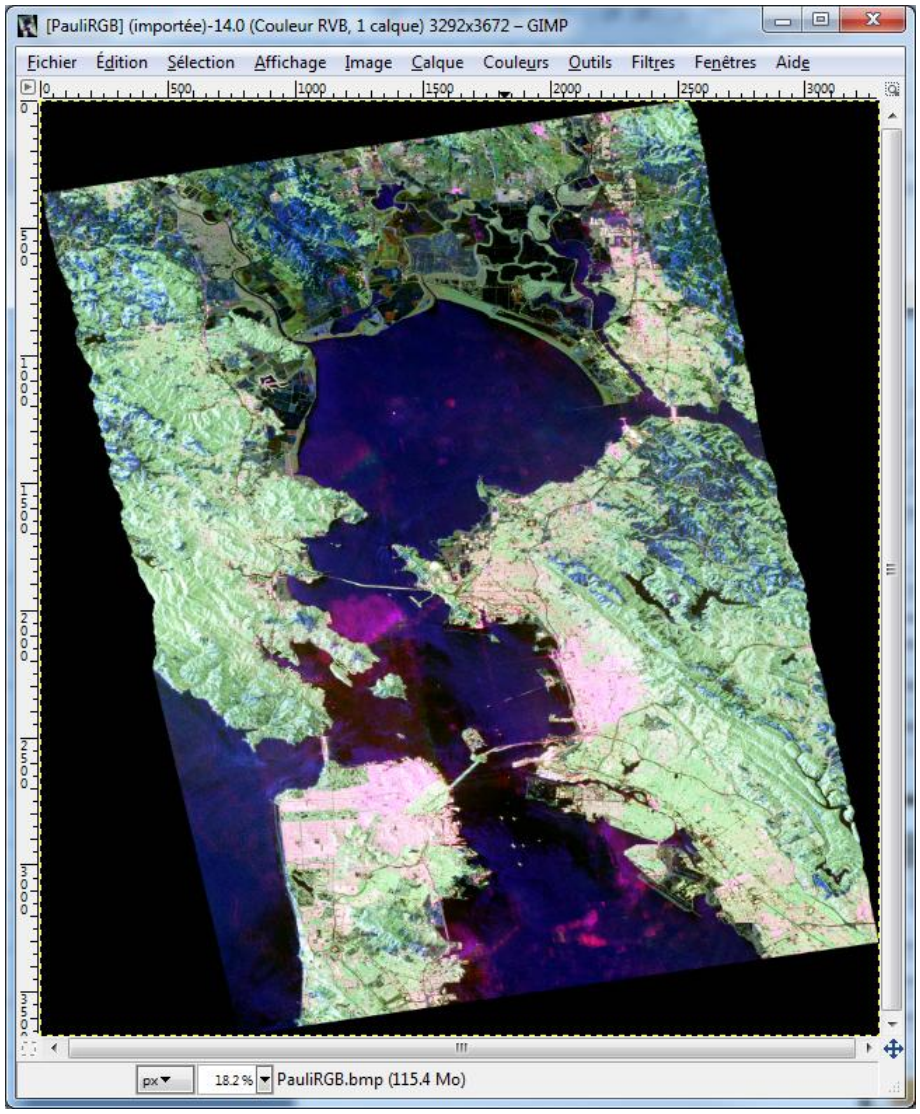
PolSARpro v5.1 SOFTWARE

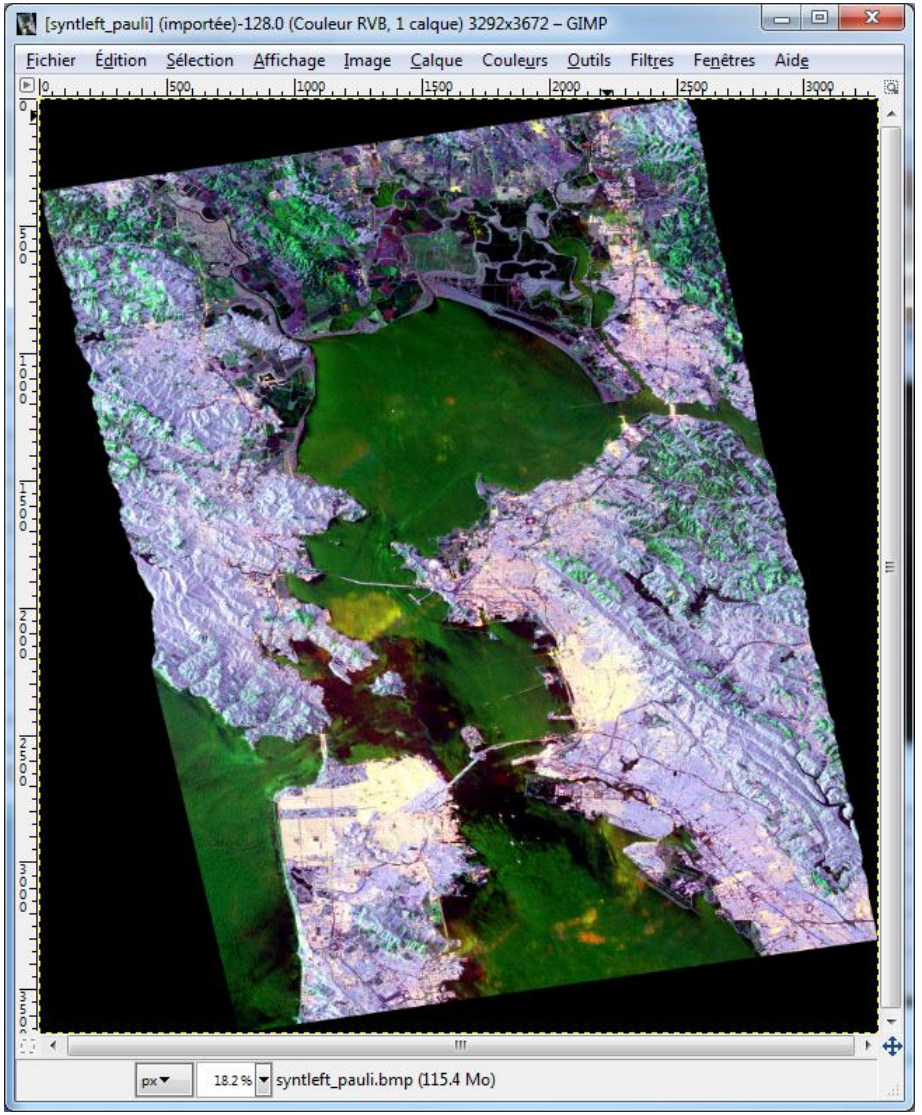


POLARIZATION SYNTHESIS



POLARIZATION SYNTHESIS





Questions ?