

→ 3rd ADVANCED COURSE ON RADAR POLARIMETRY

# Polarimetric SAR Tomography Practical session

*Polarimetric SAR interferometry (PolInSAR)*

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Stefano Tebaldini, Politecnico di Milano, Italy

Eric Pottier, University of Rennes 1, France

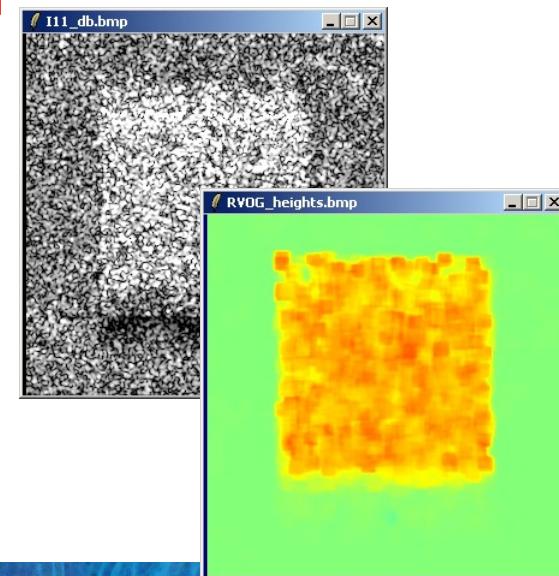
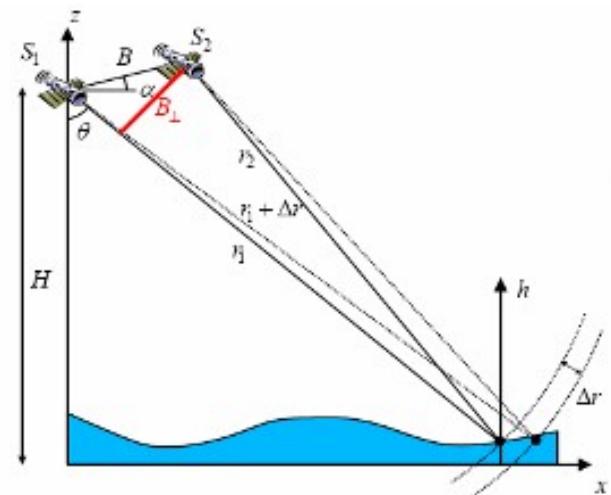


# POLsarPRO

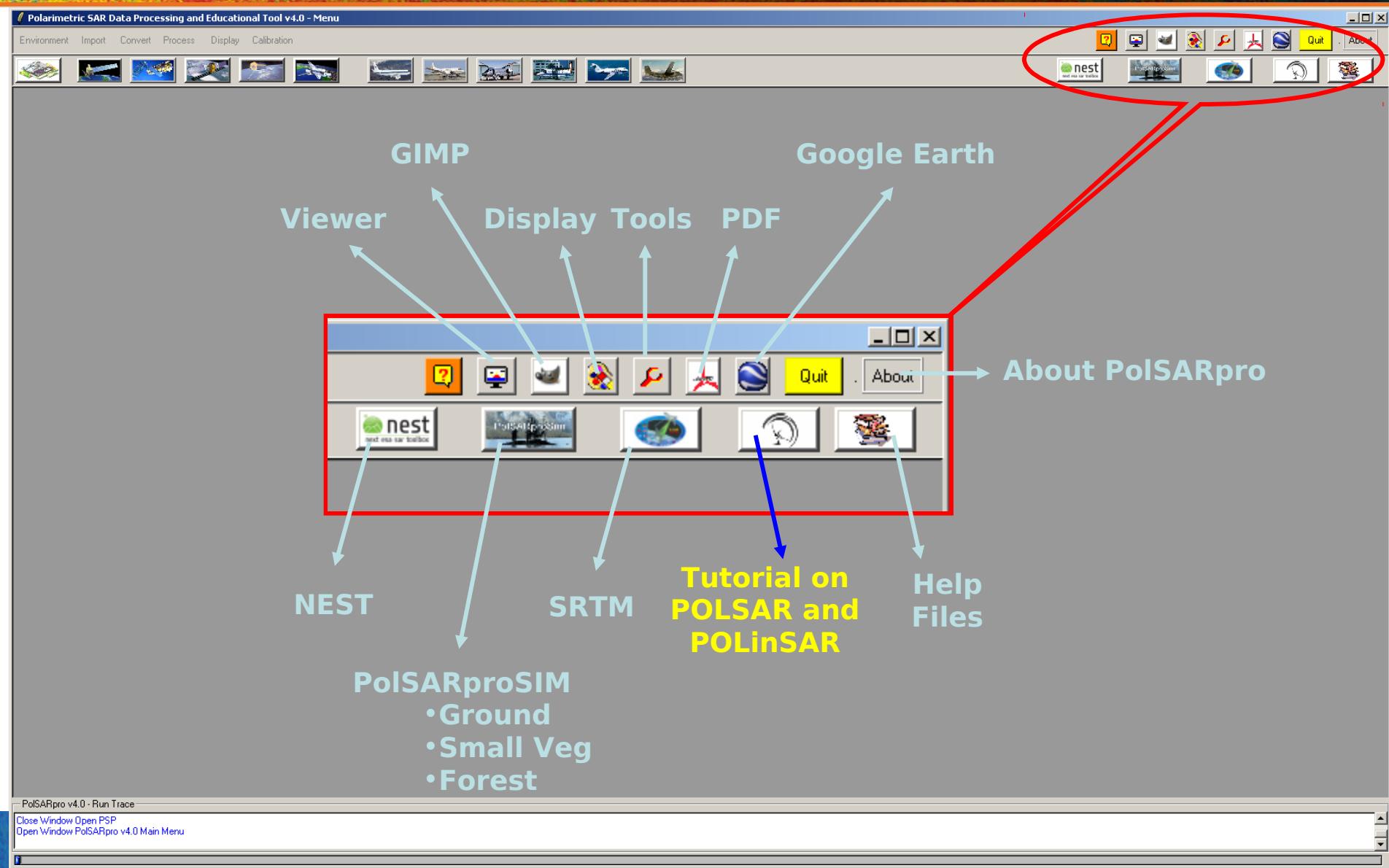
POLarimetric SAR data PROcessor



## Pol-InSAR Tutorial Forest Application



# PolSARpro v4.0 SOFTWARE



# Lecture Notes

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

Environment Import Convert Process Display Calibration

Adobe Acrobat Standard - [1\_Pol-InSAR\_Training\_Course.pdf]

Fichier Edition Affichage Document Commentaires Outils Options avancées Fenêtre ?

Création d'un fichier PDF

Sélectionner

Signets Signatures Calques Pages Pièces jointes Commentaires

**POL-InSAR TRAINING COURSE**

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Close Window Open Window PolS...

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nest  
Paris Agglo

Quitter About

Tutorial Slides Lectures Notes PolSARpro Simulator

Recent Advances

Basic Concepts

Advanced Concepts

Pol-InSAR Training Course

Polarization Coherence Tomography (PCT) Training Course

- 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

Do It Yourself 7

**POLinSAR Training Course**

**1 Objectives**

To provide a self taught introduction to POLinSAR coherence 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 in 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**

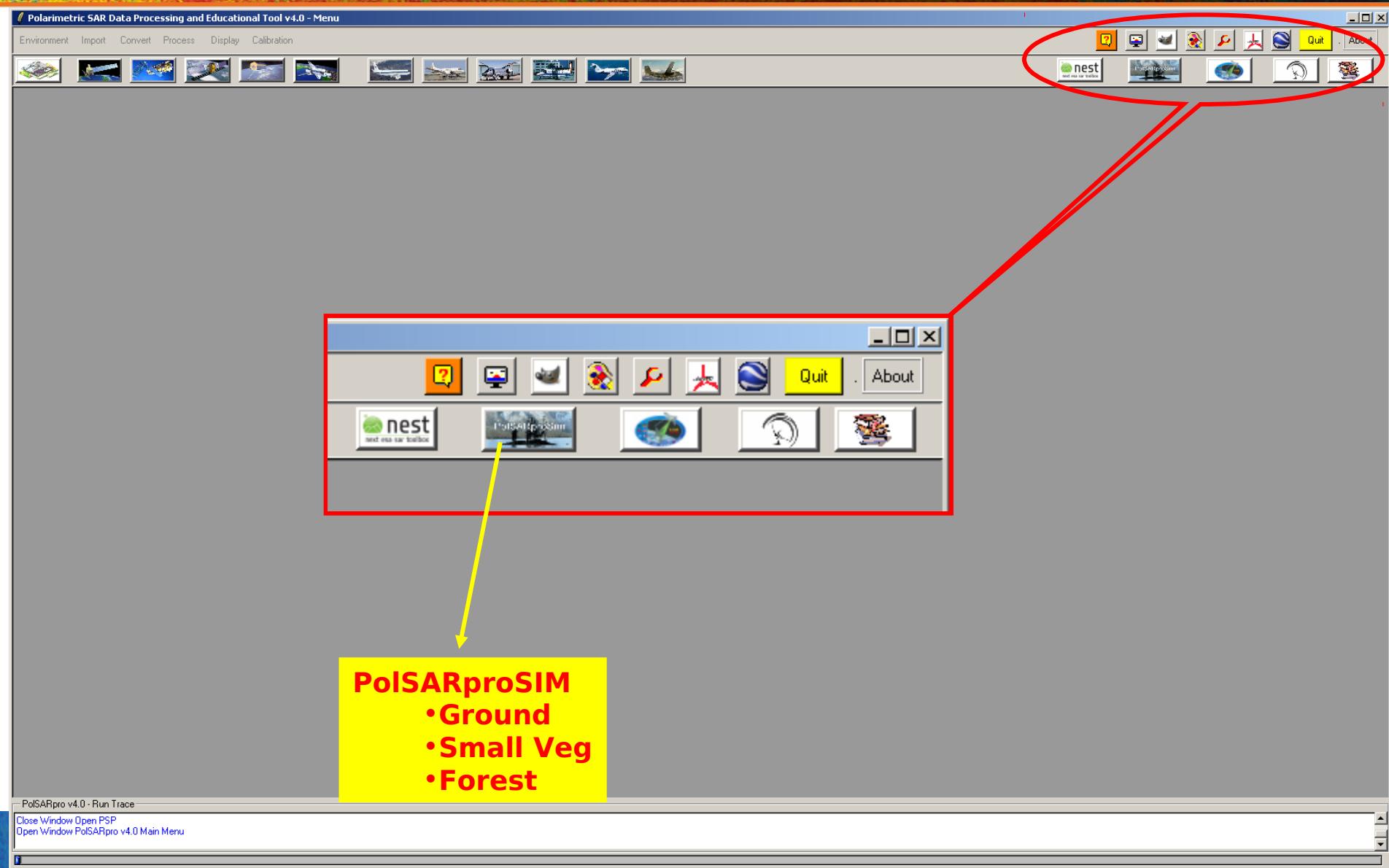
The screenshot shows the PolSARpro Simulator interface with various configuration parameters for a simulation.

Part VI : Do It Yourself

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

Do It Yourself

# PolSARpro v4.0 SOFTWARE



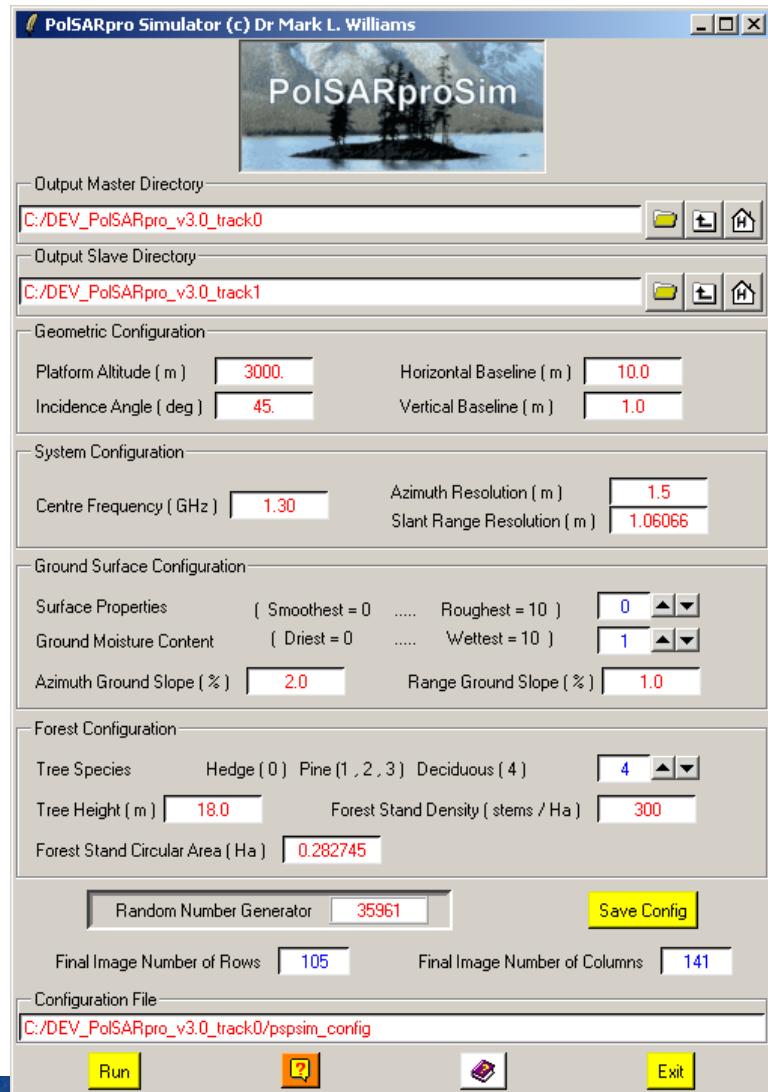
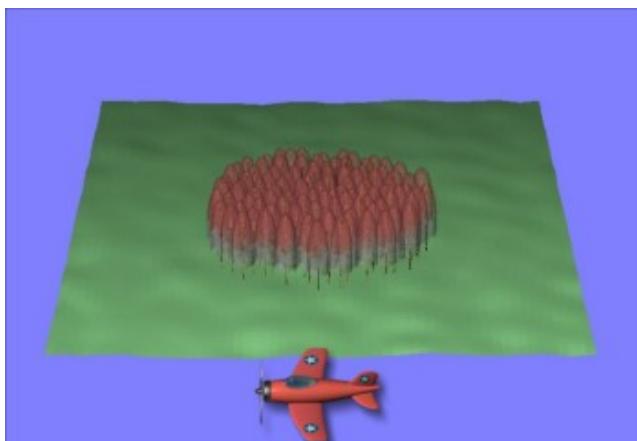
# PolSARpro v3.31 SOFTWARE



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



Mark Williams



# PolSARpro - SIM

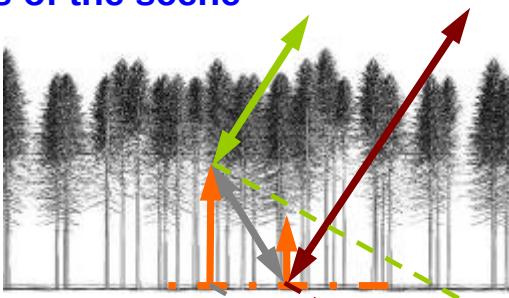
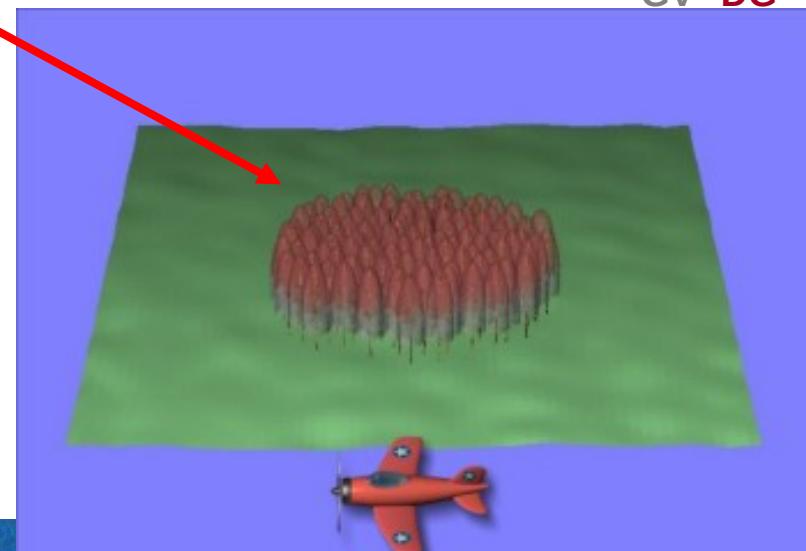
The SAR image is evaluated as a coherent sum of scattering events from small elements of the scene



PINE



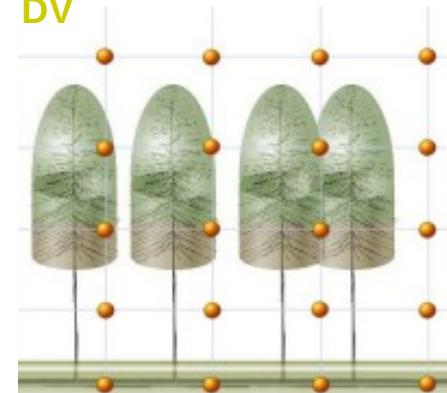
RANDOM HEDGE



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



DV



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

# PolSARpro Simulators

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

Environment Import Convert Process Display Calibration

PolSARpro Ground + Small vegetation Simulator

Output Master Directory: C:/DEV\_PoSARpro\_v4.0/track\_master

Output Slave Directory: C:/DEV\_PoSARpro\_v4.0/track\_slave

Geometric Configuration:

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

System Configuration:

Centre Frequency (GHz): 1.30

Ground Surface Config:

Surface Properties: ( Smoothest = 0 ..... Roughest = 10 ) 0

Ground Moisture Content: ( Driest = 0 ..... Wettest = 10 ) 1

Azimuth Ground Slope (%): 2.0

Ground Surface Square Area (Ha): 1.0

Random Number Generator: 34492

Run

PolSARpro Forest Simulator (c) Dr Mark L. Williams

Output Master Directory: C:/DEV\_PoSARpro\_v4.0/track\_master

Output Slave Directory: C:/DEV\_PoSARpro\_v4.0/track\_slave

Geometric Configuration:

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

System Configuration:

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

Ground Surface Configuration:

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

Forest Configuration:

- Tree Species: Hedge (0) Pine (1, 2, 3) Deciduous (4) 4
- Tree Height (m): 18.0
- Forest Stand Density (stems / Ha): 300
- Forest Stand Circular Area (Ha): 0.28745

Random Number Generator: 34492

Save Config

Final Image Number of Rows: 34492

Final Image Number of Columns: 34492

Configuration File:

Run

PolSARpro SIM

nest and nest-like toolkits

Ground

Ground + Small Vegetation

Forest

Run

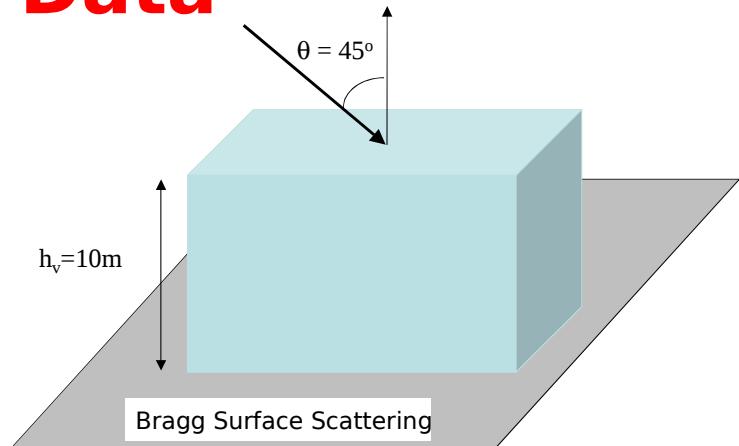
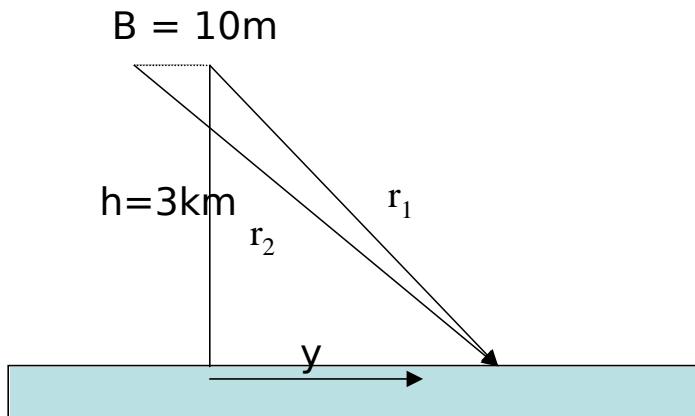
Exit

PolSARpro v4.0 - Run Trace

Open Window PolSARpro Ground + Small Vegetation Simulator

Open Window PolSARpro Forest Simulator

## Pol-InSAR Data



### Geometric configuration

Platform altitude : 3000m  
 Incidence angle:  $45^\circ$   
 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

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

Environment Import Convert Process Display Calibration

PolSARpro Simulator (c) Dr Mark L. Williams

Output Master Directory: C:/DEV\_PoSARpro\_v3.0\_track0

Output Slave Directory: C:/DEV\_PoSARpro\_v3.0\_track1

Geometric Configuration:

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

System Configuration:

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

Ground Surface Configuration:

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

Forest Configuration:

- Tree Species: Hedge (0), Pine (1, 2, 3), Deciduous (4)
- Tree Height (m): 18.0
- Forest Stand Density (stems / Ha): 300
- Forest Stand Circular Area (Ha): 0.282745

Random Number Generator: 35961

Save Config

Final Image Number of Rows: 105

Final Image Number of Columns: 141

Configuration File: C:/DEV\_PoSARpro\_v3.0\_track0/pspsim\_config

Run | Exit

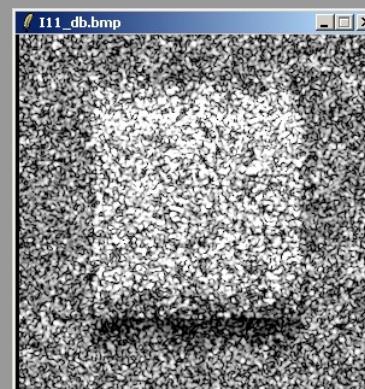
**DATA\_MASTERDIR**

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

**DATA\_SLAVE\_DIR**

- config.txt
- s11.bin, s12.bin  
s21.bin, s22.bin
- flat\_earth.bin
- kz.bin

**111\_db.bmp**



PolSARpro v4.0 - Run Trace

Close Window Open PSP  
Open Window PolSARpro v4.0 Main Menu

# PolSARpro v4.0 SOFTWARE



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

Environment Import Convert Process Display Calibration

nest and esa tools

PolSARpro

About

PolSAR Full Software

- Single Data Set
- Multi Data Sets**

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

Environnement Import Convert Process Display Calibration

Spaceborne Sensors:  
ALOS, ENVISAT  
RADARSAT2, TerraSar, SIR-C

Airborne Sensors:  
AIRSAR, Convair, EMISAR  
ESAR, PISAR, RAMSES

**PolSARpro - Multi Data Sets package**

PolSARpro v4.0 - Run Trace

Close Window Open PSP  
Open Window PolSARpro v4.0 Main Menu

SAR ADVANCED COURSE ON RADAR POLARIMETRY

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European Space Agency

# MAIN MENU



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

Environment Import Convert Process Display Calibration

nest

Quit About

Single Data Set

Multi Data Sets ▶ Dual Pol-InSAR Data Sets

Multi Time / Freq Data Sets

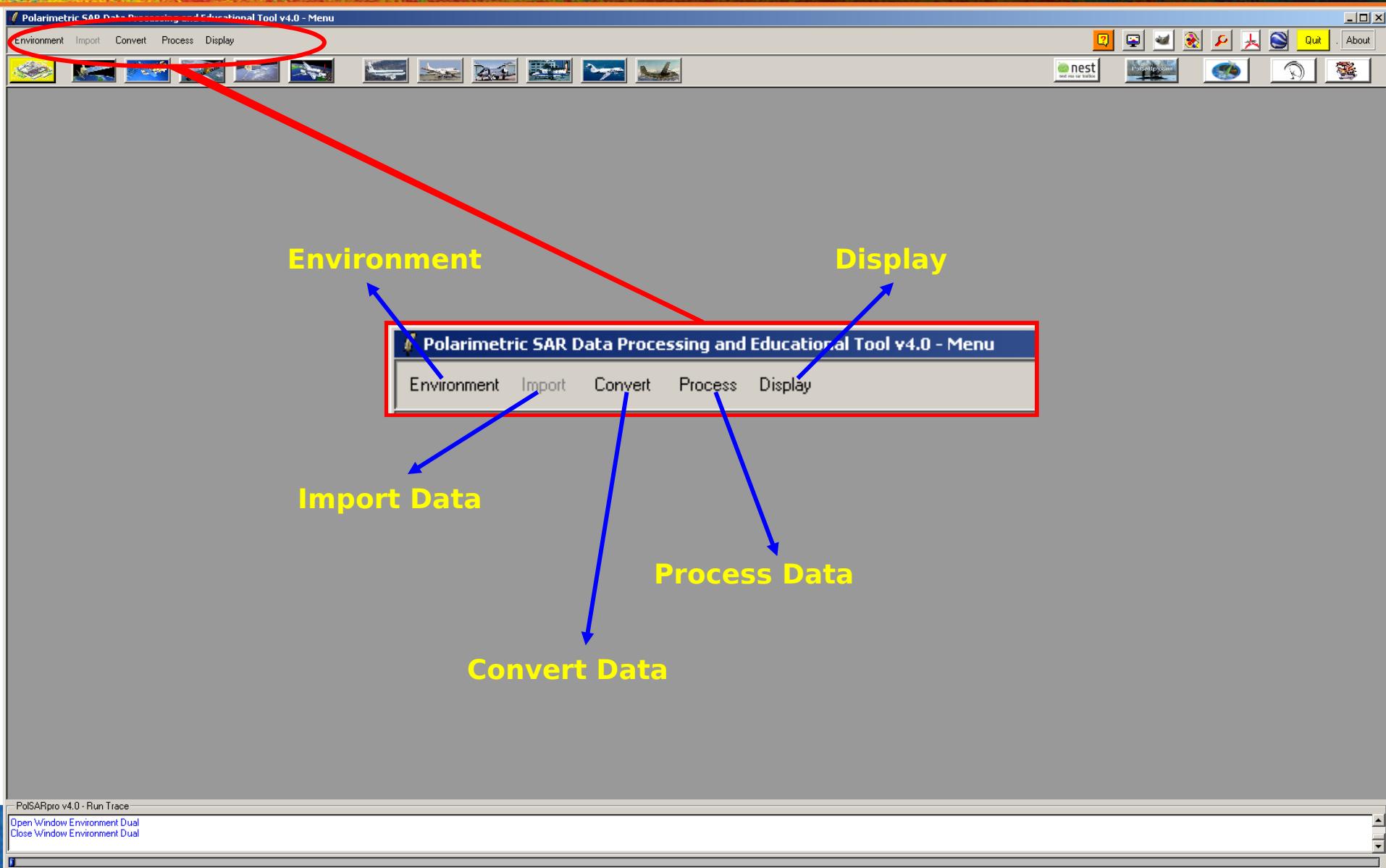
PolSARpro v4.0 - Run Trace

[Close Window](#) [Open PSP](#)  
[Open Window](#) [PolSARpro v4.0 Main Menu](#)

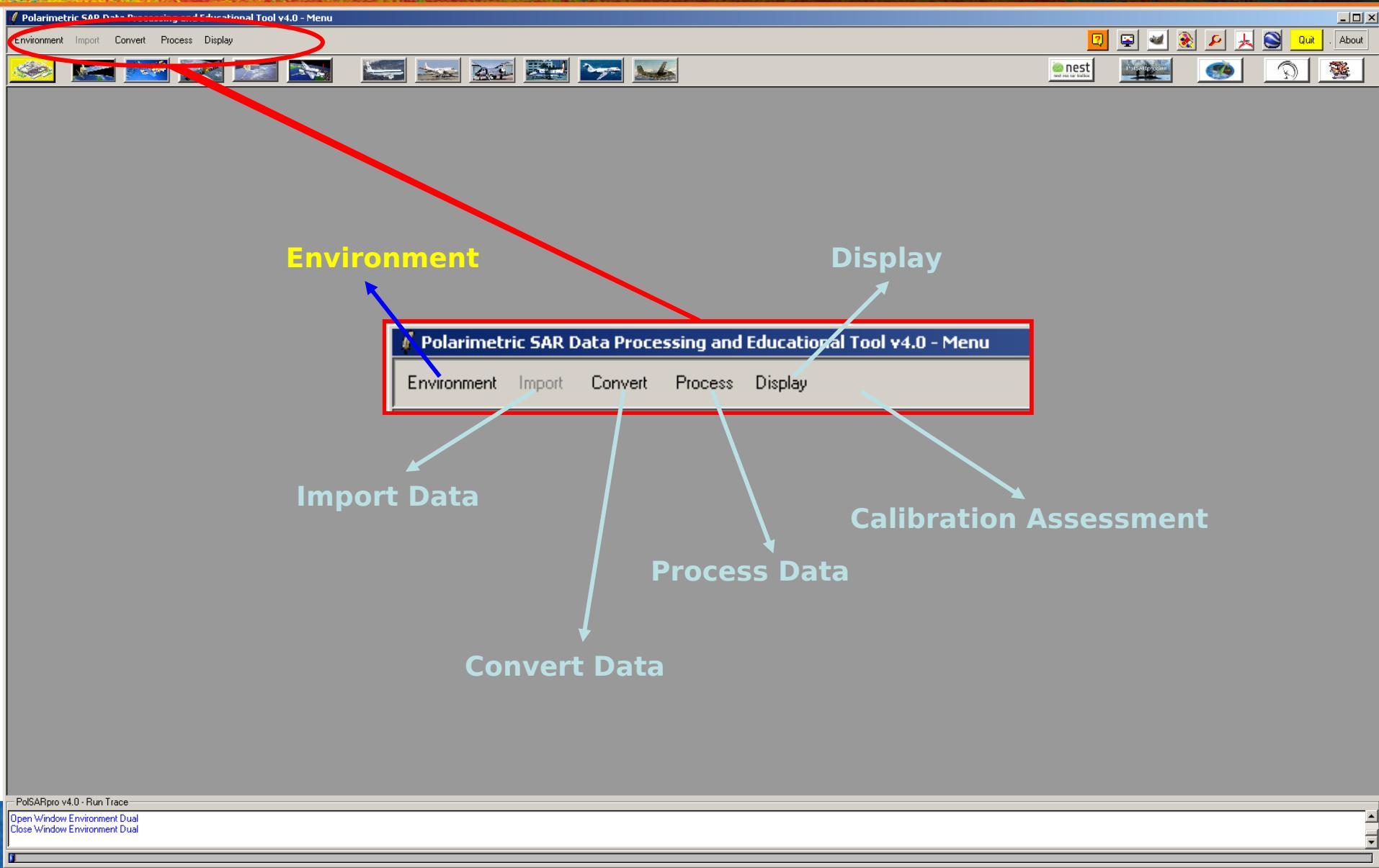
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The screenshot shows the PolSARpro v4.0 software interface. At the top is a blue header bar with the title 'Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu' and various menu items: Environment, Import, Convert, Process, Display, Calibration, and a set of icons. Below the header is a toolbar with icons for different data types. A red circle highlights the first icon in the toolbar. A red box encloses a sub-menu window titled 'Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu' which contains the following items: Environment, Import, Convert, Process, Display, Calibration, and three buttons: 'Single Data Set', 'Multi Data Sets ▶' (which is highlighted in blue), and 'Dual Pol-InSAR Data Sets'. Another red box encloses a second sub-menu window titled 'Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu' containing the same set of menu items and icons as the main header. A red circle highlights the first icon in this second toolbar. At the bottom left is a status bar with the text 'PolSARpro v4.0 - Run Trace' and links to 'Close Window', 'Open PSP', 'Open Window', and 'PolSARpro v4.0 Main Menu'. The bottom right corner features the ESA logo.

# MAIN MENU



# ENVIRONNEMENT



# ENVIRONNEMENT



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

Environment Import Convert Process Display

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:

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

?

Exit

Configure Data Main Directories location

?

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:

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

?

Exit

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

15 January 2015 | ESA ESRIN | Frascati (Rome), Italy

# ENVIRONNEMENT



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

Environment Import Convert Process Display

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:

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

?

Exit

## Configure Data Main Directory location

Automatic Data Check (Null or NaN)

Configuration File (ENVI)

Image Display Size setting

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:

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

?

Exit

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# ENVIRONNEMENT



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

Environment Import Convert Process Display

nest and more tools

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

Color Palette Edition & Modification

Choose a color

Couleurs de base :

Couleurs personnalisées :

Définir les couleurs personnalisées >>

OK Annuler Ajouter aux couleurs personnalisées

Le site de l'ESA

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Rows 844 Columns 844 Save

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

Color Maps

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

?

Exit

Rows 844 Columns 844 Save

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

Color Maps

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

?

Exit

# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

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# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
**[S2] Elements**  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave

Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

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# ELEMENTS



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

Environment Import Convert Process Display

Help Home Help Contents Help Index Help Topics Help About

Icons: Polarimetric SAR, Environment, Import, Convert, Process, Display, Help, Home, Help Contents, Help Index, Help Topics, Help About.

Data Processing: Sinclair Elements

Input Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Output Directory: C:/POLinSAR\_Training\_Course/Master\_Track

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

S11:  A11  I11  A11 (dB) = I11 (dB)  Phase  BMP

S21:  A21  I21  A21 (dB) = I21 (dB)  Phase  BMP

S12:  A12  I12  A12 (dB) = I12 (dB)  Phase  BMP

S22:  A22  I22  A22 (dB) = I22 (dB)  Phase  BMP

Span:  Linear  Decibel =  $10\log(\text{Span})$   BMP

Buttons: Run, Reset, Exit

Data Processing: Sinclair Elements

Input Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Output Directory: C:/POLinSAR\_Training\_Course/Master\_Track

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

S11:  A11  I11  A11 (dB) = I11 (dB)  Phase  BMP

S21:  A21  I21  A21 (dB) = I21 (dB)  Phase  BMP

S12:  A12  I12  A12 (dB) = I12 (dB)  Phase  BMP

S22:  A22  I22  A22 (dB) = I22 (dB)  Phase  BMP

Span:  Linear  Decibel =  $10\log(\text{Span})$   BMP

Buttons: Run, Reset, Exit

## 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

nest and more tools Polyphase sum

QUIT About

DATA\_MASTERDIR

config.txt

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

Axy.bin, Ixy.bin  
Ixy\_db.bin  
sxy\_phा. bin

Axy.bmp, Ixy.bmp  
Ixy\_db.bmp  
sxy\_phा. bmp

111\_db.bmp

s11\_phा.bmp

PV3.0

Image Size C 301 R 301

Mouse Position X Y

Zoom 1:1

Color

Tools

Color Map

-180.00 180.00

Exit

PolSARpro v4.0 - Run Trace

Open Window Environment Dual

Close Window Environment Dual

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# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
**Interferogram**  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

```
graph TD; S2[Process Data - [S2] - MENU] --> S2Sub[S2]; S2Sub --> S2Items[Coarse Co-Registration, Flat Earth Estimation, Flat Earth Removal, S2Elements[Elements], Speckle Filter, Interferogram, Coherences Estimation, Coherences Analysis, Height Estimation, PCT, Segmentation, Segmentation, DataAnalysis[Data Analysis]]]; S2Items --> S2SubSub[Spectral Estimation, Baseline Estimation, MasterSlave[Master Slave], BoxCarFilter[Box Car Filter, Gaussian Filter, JSLeeRefinedFilter[J.S. Lee Refined Filter], JSLeeSigmaFilter[J.S. Lee Sigma Filter], EdgeDetector[Edge Detector]], ComplexPlane[Complex Plane, CoherenceRegion[Coherence Region - Optimum Triplet]], InversionProcedures[Inversion Procedures, VegetationHeightEstimation[Vegetation Height Estimation]], WishartSupervised[Wishart Supervised Classification, WishartUnsupervised[Wishart Unsupervised Classification]], DataHistograms[Data Histograms, DataProfiles[Data Profiles], CoeffVariation[Coeff of Variation]]];
```

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# RAW INTERFEROGRAM



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

Environment Import Convert Process Display

Interferogram Estimation

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track

Output Master-Slave Directory: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track

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

Image 1: HV

Image 2: HV

Averaging: Row: [ ] Col: [ ]

Run ? Exit

Interferogram Estimation

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track

Output Master-Slave Directory: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track

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

Image 1: HV

Image 2: HV

Averaging: Row: [ ] Col: [ ]

Run ? Exit

## 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



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

Environment Import Convert Process Display

nest

DATA\_MASTERDIR\_SLAVEDIR

config.txt

interferogram\_XX\_XX.bin

interferogram\_XX\_XX.bmp

Interferogram\_HV\_HV.bmp

PV3.0

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

15-16 January 2015 | ESA LSkin | Frascati (Rome), Italy

The screenshot shows the PolSARpro v4.0 software interface. At the top, there's a menu bar with options like Environment, Import, Convert, Process, and Display. Below the menu is a toolbar with various icons. A red arrow points from the 'Display' icon in the toolbar to a floating window titled 'PV3.0' on the right. This window contains a color-coded interferogram visualization and various controls for image processing, including 'Image Size' (set to C 301 R 301), 'Zoom' (set to 1:1), and a 'Color Map' slider ranging from -180.00 to 180.00. On the left side of the main workspace, there's a folder structure labeled 'DATA\_MASTERDIR\_SLAVEDIR' containing files: 'config.txt', 'interferogram\_XX\_XX.bin', and 'interferogram\_XX\_XX.bmp'. To the right of this folder structure is a preview window titled 'Interferogram\_HV\_HV.bmp' showing a colorful, speckled pattern. At the bottom of the screen, there's a status bar with the text 'PolSARpro v4.0 - Run Trace' and buttons for 'Open Window Environment Dual' and 'Close Window Environment Dual'. The bottom-most bar also includes the date and location: '15-16 January 2015 | ESA LSkin | Frascati (Rome), Italy'.

# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
**Flat Earth Removal**  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

19-25 January 2017 | ESA-TSRIN | Frascati (Rome), Italy

# FLAT EARTH REMOVAL



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

Environment Import Convert Process Display

Help File Contents Print Exit About

**POLinSAR Flat Earth Removal**

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track

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

2D Flat Earth File: C:/POLinSAR\_Training\_Course/Slave\_Track/flat\_earth.bin

Symmetrisation  Conjugate

Output Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Output Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track\_FER

Run Exit

**POLinSAR Flat Earth Removal**

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track

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

2D Flat Earth File: C:/POLinSAR\_Training\_Course/Slave\_Track/flat\_earth.bin

Symmetrisation  Conjugate

Output Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Output Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track\_FER

Run Exit

**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



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

Environment Import Convert Process Display

Environment Import Convert Process Display

POLinSAR Flat Earth Removal

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track

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

2D Flat Earth File: C:/POLinSAR\_Training\_Course/Slave\_Track/flat\_earth.bin

Symmetrisation Conjugate

Output Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Output Slave Directory: C:/POLinSAR\_Training\_Course/Slave\_Track\_FER

Run

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

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

15-16 January 2015 | ESA LSARIN | Frascati (Rome), Italy

# RAW INTERFEROGRAM



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

Environment Import Convert Process Display

Interferogram Estimation

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/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

Image 1: HV

Image 2: HV

Averaging: Row: [ ] Col: [ ]

Run ? Exit

Interferogram Estimation

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/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

Image 1: HV

Image 2: HV

Averaging: Row: [ ] Col: [ ]

Run ? Exit

## 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**

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

15-16 January 2015 | ESA LSINN | Frascati (Rome), Italy

# RAW INTERFEROGRAM



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

Environment Import Convert Process Display

nest

DATA\_MASTERDIR\_SLAVEDIR\_FER

config.txt

interferogram\_XX\_XX.bin

interferogram\_XX\_XX.bmp

Interferogram\_HV\_HV.bmp

PV3.0

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

15-16 January 2015 | ESA LSkin | Frascati (Rome), Italy

The screenshot shows the PolSARpro v4.0 software interface. At the top, there's a menu bar with options like 'Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu', 'Environment', 'Import', 'Convert', 'Process', 'Display', and 'About'. Below the menu is a toolbar with various icons. A red arrow points from the 'nest' icon in the toolbar to a floating window titled 'PV3.0' on the right. This window contains a 3D visualization of the interferogram data, along with various controls for image size (C: 301, R: 301), mouse position, zoom (1:1), color, tools, and a color map ranging from -180.00 to 180.00. In the center, there's a main workspace with a yellow header labeled 'DATA\_MASTERDIR\_SLAVEDIR\_FER'. Inside this workspace, there are three items: 'config.txt' (represented by a blue folder icon), 'interferogram\_XX\_XX.bin' (represented by a blue folder icon), and 'interferogram\_XX\_XX.bmp' (represented by a yellow folder icon). To the right of the workspace is a preview window titled 'Interferogram\_HV\_HV.bmp' showing a green background with a yellow speckled pattern. At the bottom, there's a status bar with the text 'PolSARpro v4.0 - Run Trace' and buttons for 'Open Window Environment Dual' and 'Close Window Environment Dual'. The footer of the slide indicates the date and location: '15-16 January 2015 | ESA LSkin | Frascati (Rome), Italy'.

# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
**Coherences Estimation** (circled in blue)  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

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# COHERENCE ESTIMATION



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

Environment Import Convert Process Display

Help File Contents Print Exit About

Complex Coherence Estimation

Input Master Directory: C:/POLinSAR Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR Training\_Course/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

Complex Coherences:

Linear: HH, HV, VH, WV, Pauli, HH + WV, HH - WV, HV + VH  
Circular: LL, LR, RR, Optimal, SVD, PD, NR, L. MinMax, L. Diff

Numerical Radius: Theta1, Theta3, Num Points

Box Car Window: Row 7, Col 7, BMP, Averaging

Run, Hist, Help, Exit

Complex Coherence Estimation

Input Master Directory: C:/POLinSAR Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR Training\_Course/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

Complex Coherences:

Linear: HH, HV, VH, WV, Pauli, HH + WV, HH - WV, HV + VH  
Circular: LL, LR, RR, Optimal, SVD, PD, NR, L. MinMax, L. Diff

Numerical Radius: Theta1, Theta3, Num Points

Box Car Window: Row 7, Col 7, BMP, Averaging

Run, Hist, Help, Exit

**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



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

Environment Import Convert Process Display

nest

DATA\_MASTERDIR\_SLAVE\_DIR\_FER

config.txt

cmplx\_coh\_XX.bin

cmplx\_coh\_XX\_mod.bmp  
cmplx\_coh\_XX\_phा.bmp

coh\_psoilt\_mod.bmp

coh\_lrlr\_phा.bmp

coh\_vvvv\_mod.bmp

PV3.0

Image Size C 301 R 301

Mouse Position X Y

Zoom 1:1

Color

Tools

Color Map

-180.00 180.00

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

15 January 2015 | ESA LSkin | Frascati (Rome), Italy

The screenshot shows the PolSARpro v4.0 software interface. At the top, there's a menu bar with 'Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu' and sub-options like Environment, Import, Convert, Process, Display. Below the menu is a toolbar with various icons. A red arrow points from the 'nest' icon in the toolbar to a PV3.0 viewer window on the right. The main workspace contains several windows: one titled 'DATA\_MASTERDIR\_SLAVE\_DIR\_FER' showing a file tree with 'config.txt', 'cmplx\_coh\_XX.bin', and two image files ('cmplx\_coh\_XX\_mod.bmp' and 'cmplx\_coh\_XX\_phा.bmp'); three image preview windows ('coh\_psoilt\_mod.bmp', 'coh\_lrlr\_phा.bmp', and 'coh\_vvvv\_mod.bmp'); and a PV3.0 viewer window with various controls for image size, zoom, color, and tools. The bottom of the screen has a run trace window and a footer with the date and location.

# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
**Height Estimation** (circled)  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

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# HEIGHT ESTIMATION INVERSION PROCEDURES

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

Environment Import Convert Process Display

Help File Print Exit 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

Polarimetric Phase Centre Height Estimation      Polarimetric Channel: HH

DEM Differencing Algorithm

Coherence Amplitude Inversion Procedure

Ground Phase Estimation and RVOG Inversion Procedure

Median Window Size: 11      Weighting Coherence Fraction Factor: 0.5

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

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

Run Hist ? Exit

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

Polarimetric Phase Centre Height Estimation      Polarimetric Channel: HH

DEM Differencing Algorithm

Coherence Amplitude Inversion Procedure

Ground Phase Estimation and RVOG Inversion Procedure

Median Window Size: 11      Weighting Coherence Fraction Factor: 0.5

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

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

Run Hist ? Exit

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# HEIGHT ESTIMATION INVERSION PROCEDURES



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

Environment Import Convert Process Display

Help Home nest 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

DEM Differencing Algorithm

Coherence Amplitude Inversion Procedure

Ground Phase Estimation and RVOG Inversion Procedure

Median Window Size: 11      Weighting Coherence Fraction Factor: 0.5

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

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

Run Hist Help Exit

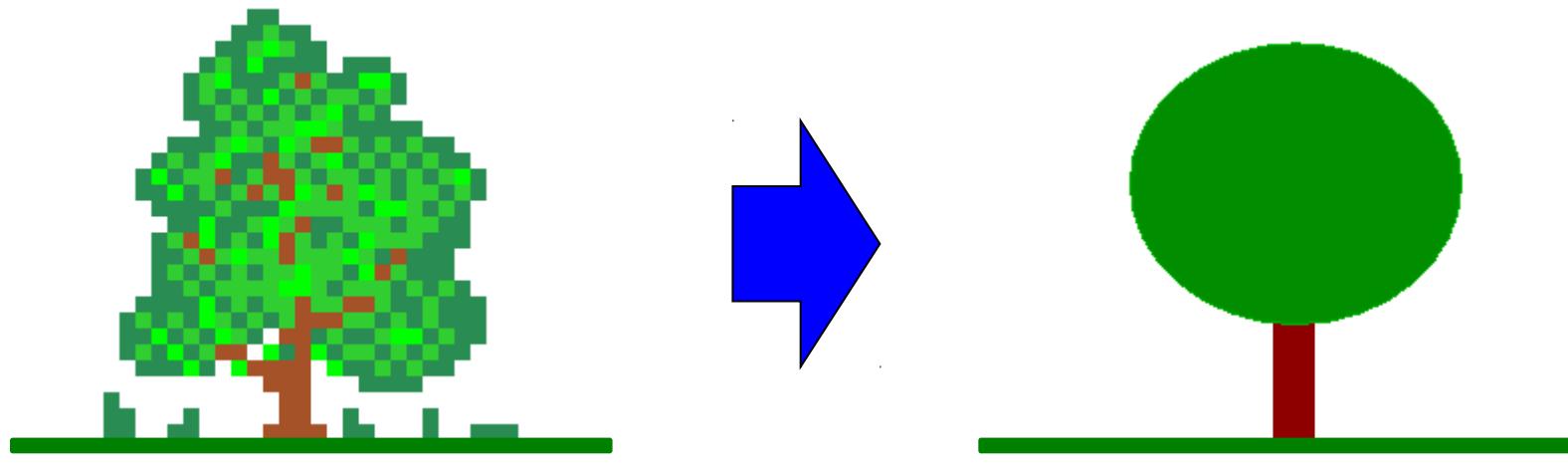
PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

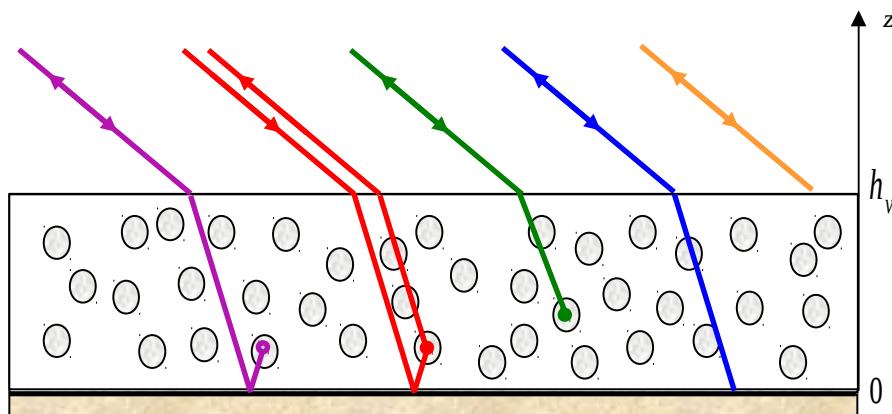
## INVERSION PROCEDURES

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

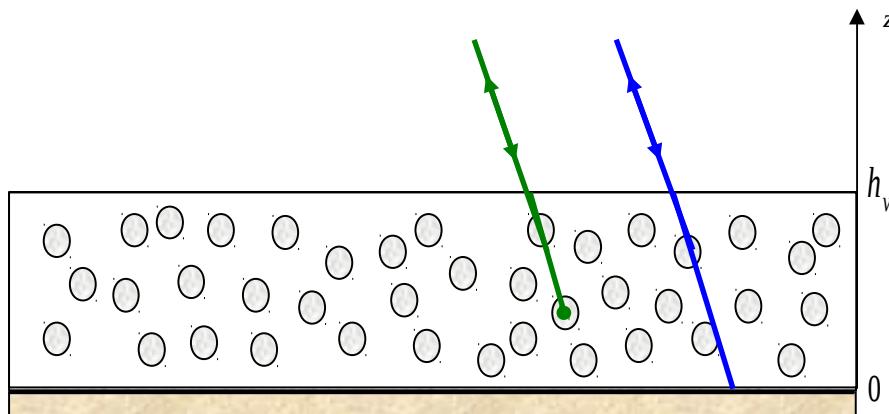
# VOLUME COHERENCE MODEL



Modeling

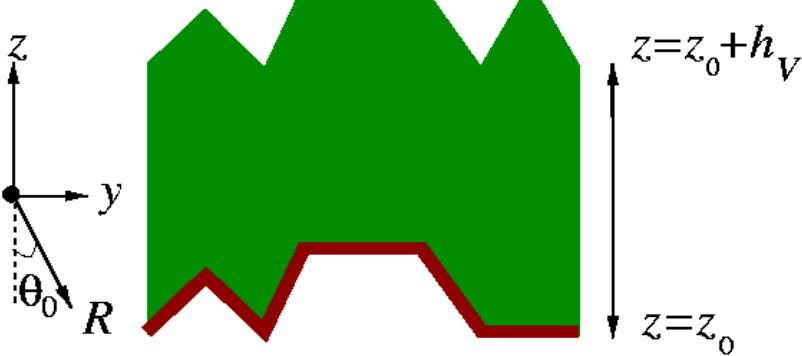
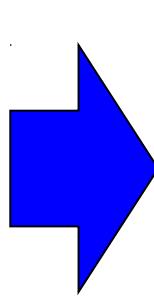
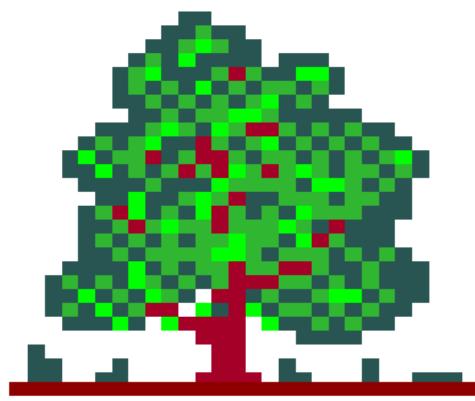


Parameter Estimation



Simplifications : Only 2 significant mechanisms – Low density medium  $\Rightarrow$  No refraction

# VOLUME COHERENCE MODEL



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

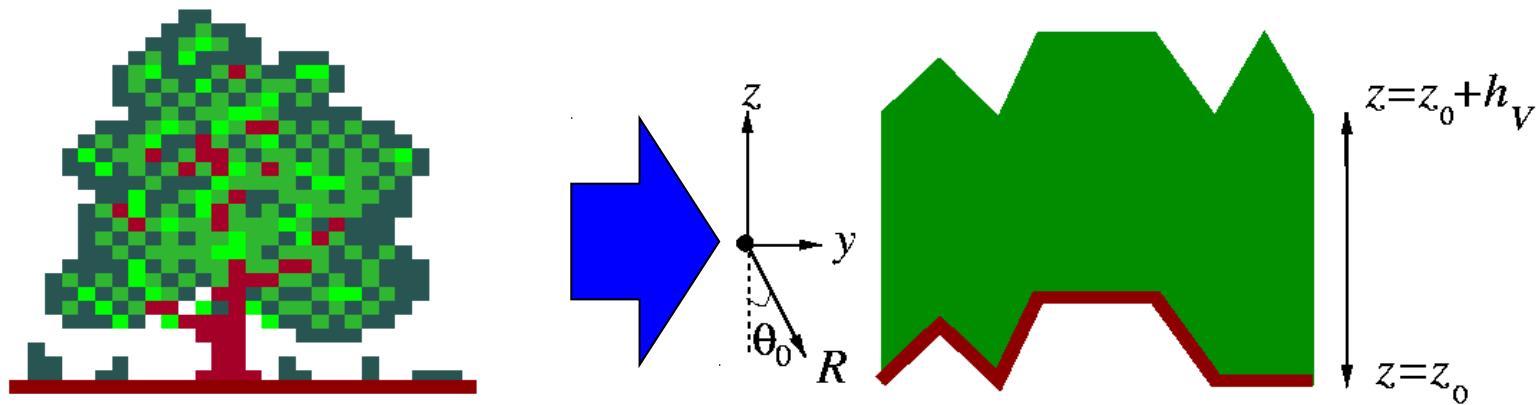
$\phi_0$  Topographic Phase

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

Vertical Wavenumber

POLARIZATION INDEPENDENT

# VOLUME COHERENCE MODEL



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

**Vertical Structure function**

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

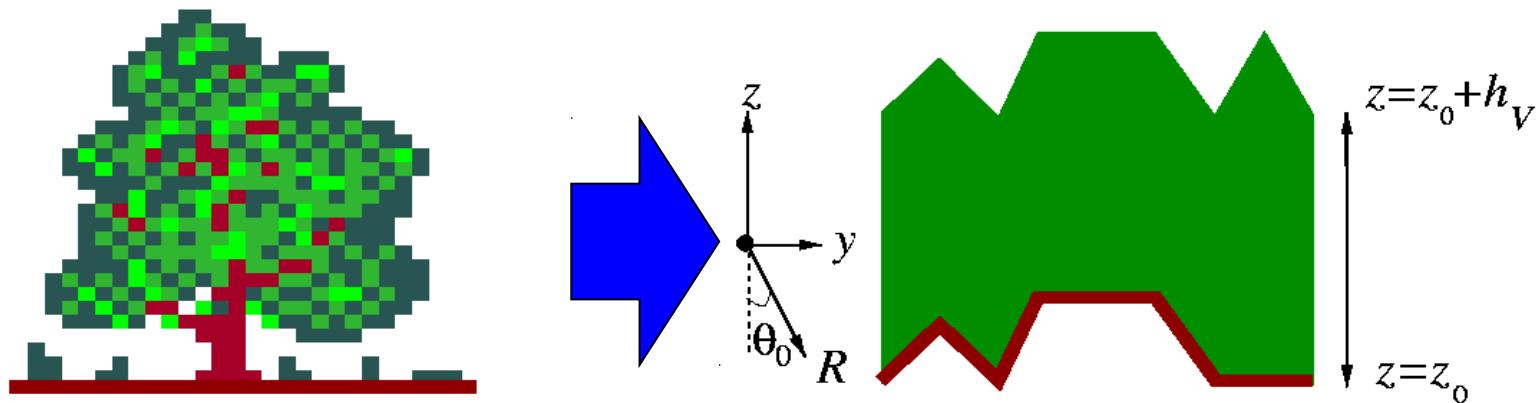
**Case of Uniform Random Layer**

$\theta_0$  **Incidence Angle**

$\sigma$  **Extinction Coefficient**

**POLARIZATION INDEPENDENT**

# RVOG COHERENCE MODEL (Random Volume Over Ground)



## 2 Layer Combined Surface and random Volume Scattering

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

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

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

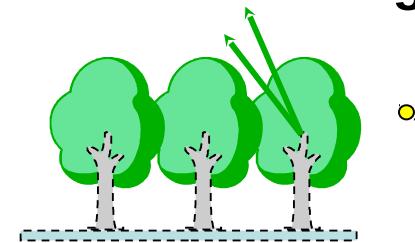
POLARIZATION DEPENDENT

$\underline{w}_v$

## Polarisation Channel corresponding to Volume Scattering

$$\gamma(\underline{w}_v) \xrightarrow[\mu \mapsto 0]{} = e^{j\varphi_0} \gamma_{VOL}$$

2HV

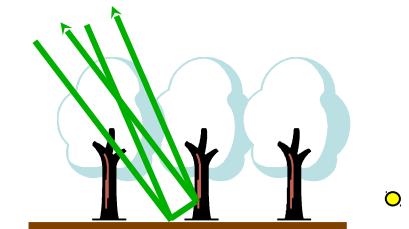


$\underline{w}_s$

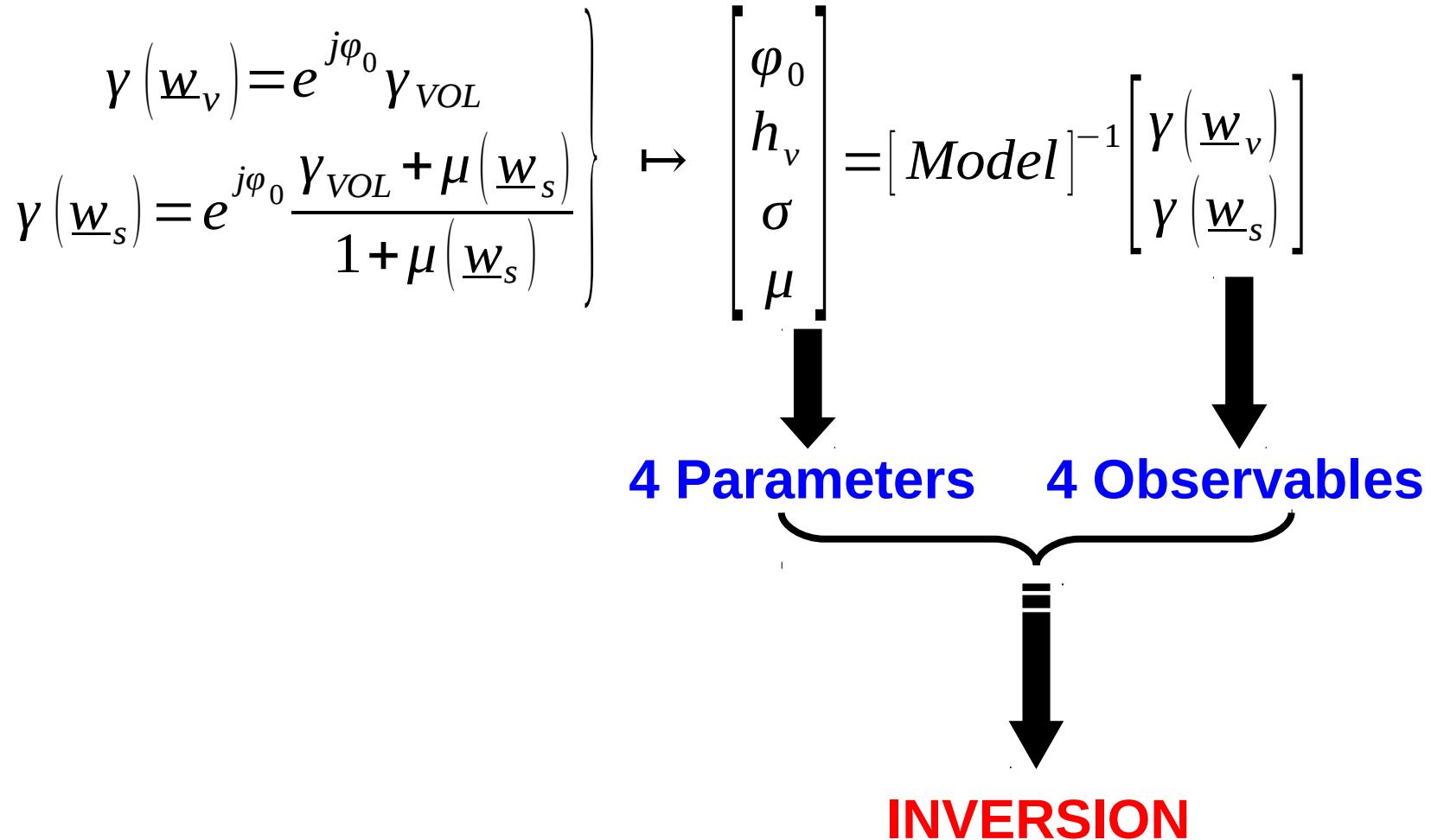
## Polarisation Channel corresponding to Surface Scattering

$$\gamma(\underline{w}_s) = e^{j\varphi_0} \frac{\gamma_{VOL} + \mu(\underline{w}_s)}{1 + \mu(\underline{w}_s)} \xrightarrow[\mu \mapsto \infty]{} e^{j\varphi_0}$$

HH-VV



# FOREST HEIGHT ESTIMATION



# HEIGHT ESTIMATION INVERSION PROCEDURES



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

Environment Import Convert Process Display

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

DEM Differencing Algorithm

Coherence Amplitude Inversion Procedure

Ground Phase Estimation and RVOG Inversion Procedure

Median Window Size: 11 Weighting Coherence Fraction Factor: 0.5

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

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kzbin

Run Hist Help 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

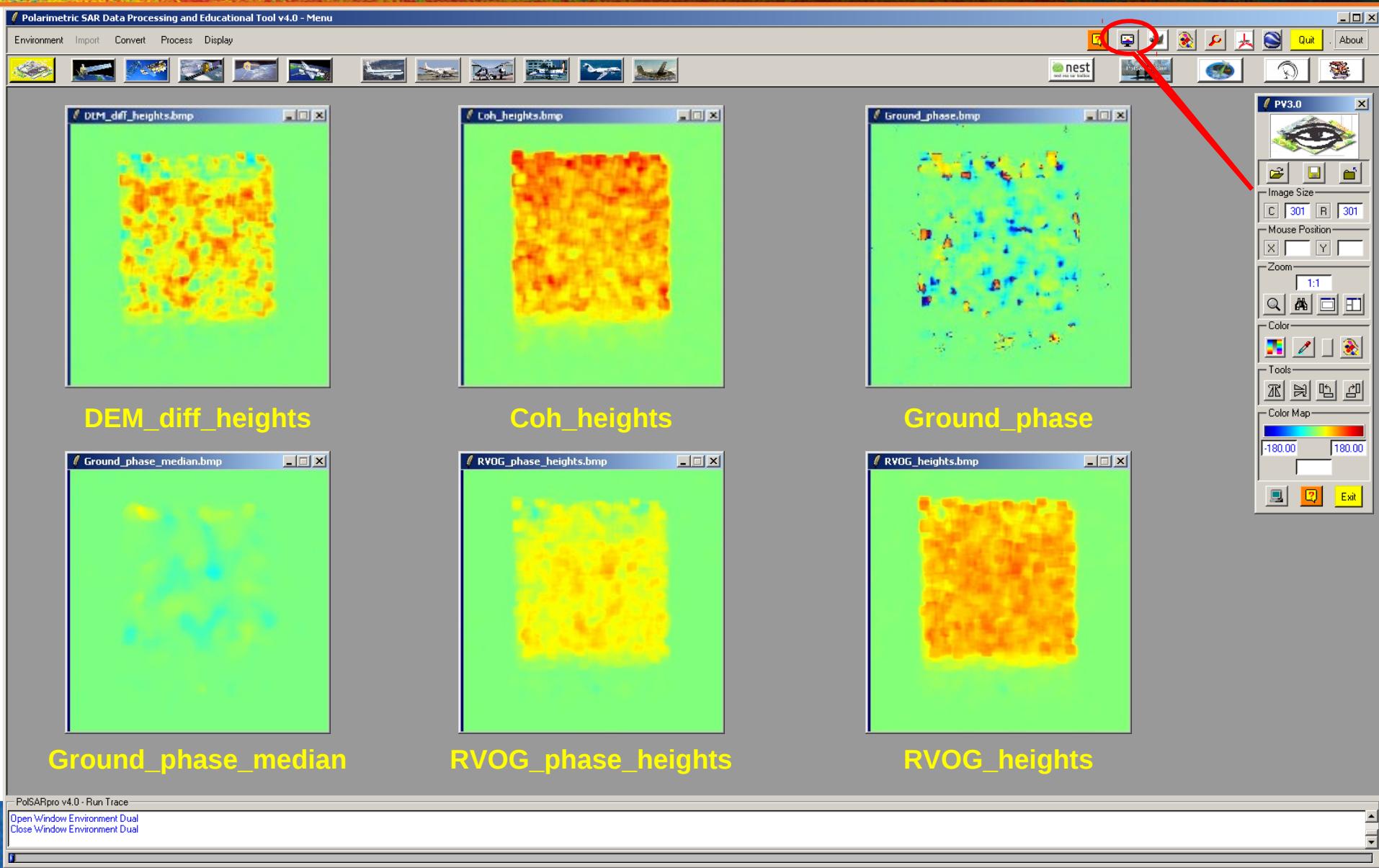
Do it Yourself:  
Set the parameters (Median Size = 21,  
Factor = 0.4)  
and view the corresponding BMP files.

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# HEIGHT ESTIMATION INVERSION PROCEDURES



# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLInSAR Segmentation  
POLInSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

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# HEIGHT ESTIMATION INVERSION PROCEDURES

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

Environment Import Convert Process Display

File Open Save Print Exit

Data Analysis : Statistics - Histogram

Input Data File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/phase\_center\_height\_HV.bin

Input Data Format:  Complex  Float  Integer

Show:  Modulus  10log(Mod)  20log(Mod)  Phase  Real  Imag

Histogram Title: HISTOGRAM Histogram Label: Label

Minimum / Maximum Values:  Automatic Min Auto Max Auto MinMax

Plot:  line  box  Close

Clear Save Exit

Data Analysis : Statistics - Histogram

Input Data File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/phase\_center\_height\_HV.bin

Input Data Format:  Complex  Float  Integer

Show:  Modulus  10log(Mod)  20log(Mod)  Phase  Real  Imag

Histogram Title: HISTOGRAM Histogram Label: Label

Minimum / Maximum Values:  Automatic Min Auto Max Auto MinMax

Plot:  line  box  Close

Clear Save Exit

pv3.0

Image Size: C 301 R 301

Mouse Position: X Y

Zoom: 1:1

Color:

Tools:

Color Map: -180.00 180.00

phase\_center\_height\_hvhv.bmp

gnuplot graph

HISTOGRAM

Nb of Samples: 300 250 200 150 100 50 0

Value: -6 -4 -2 0 2 4 6 8 10 12 14 16

-9.30000, -47.3684

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

# HEIGHT ESTIMATION INVERSION PROCEDURES

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

Environment Import Convert Process Display

File Open Save Print Exit Help About

Image Tools Color Map

Data Analysis : Statistics - Histogram

Input Data File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/phase\_center\_height\_HV.bin

Input Data Format:  Complex  Float  Integer

Show:  Modulus  10log(Mod)  20log(Mod)  Phase  Real  Imag

Histogram Title: HISTOGRAM Histogram Label: Label

Minimum / Maximum Values:  Automatic Min Auto Max Auto MinMax

Plot:  line  box Close

Clear Save Plot Exit

phase\_center\_height\_hvhv.bmp

gnuplot graph

HISTOGRAM

Nb of Samples

Value

Label

DEM\_diff\_heights

gnuplot graph

HISTOGRAM

Nb of Samples

Value

-5.79870, 810.526

Label

Coh\_heights

gnuplot graph

HISTOGRAM

Nb of Samples

Value

-9.30000, -126.316

Label

RVOG\_heights

PV3.0

Image Size: C 301 R 301

Mouse Position: X Y

Zoom: 1:1

Color:

Tools:

Color Map: -180.00 180.00

Open Window Environment Dual Close Window Environment Dual

PolSARpro v4.0 - Run Trace

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# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

19-25 January 2012 | ESA-TSRIN | Frascati (Rome), Italy

# HEIGHT ESTIMATION INVERSION PROCEDURES

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

Environment Import Convert Process Display

File Open Save Save As Print Preview Exit About

Image Tools Color Map Plot 3D View Help

**Data Analysis : Value - Profile**

Input Data File: C:/POLInSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/DEM\_diff\_heights.bin

Input Data Format:  Complex  Float  Integer

Pixel Values: X 152 Y 131 Value 2.385493

Show:  Modulus  10log(Mod)  20log(Mod)  
 Phase  Real Part  Imag part

Range Length (pix) 200 Value 2.385493

Representation:  X Range  Y Range  (X,Y) Range  
 Mesh  Surface  Mesh C  Mesh S

Minimum / Maximum Values:  Auto Min 0 Max 15 MinMax

Profile Title: RANGE PROFILE

Plot Close ? Exit

**phase\_center\_height\_hhv.bmp**

**Data Analysis : Value - Profile**

Input Data File: C:/POLInSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/DEM\_diff\_heights.bin

Input Data Format:  Complex  Float  Integer

Pixel Values: X 152 Y 131 Value 2.385493

Show:  Modulus  10log(Mod)  20log(Mod)  
 Phase  Real Part  Imag part

Range Length (pix) 200 Value 2.385493

Representation:  X Range  Y Range  (X,Y) Range  
 Mesh  Surface  Mesh C  Mesh S

Minimum / Maximum Values:  Auto Min 0 Max 15 MinMax

Profile Title: RANGE PROFILE

Plot Close ? Exit

**PV3.0**

Image Size: C 301 R 301

Mouse Position: X Y

Zoom: 1:1

Color:

Tools:

Color Map: -180.00 180.00

Close Window Environment Dual

0

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# HEIGHT ESTIMATION INVERSION PROCEDURES



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

Environment Import Convert Process Display

File Open Save Exit

Data Analysis : Value - Profile

Input Data File: C:/POLInSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/DEM\_diff\_heights.bin

Input Data Format:  Float  Integer

Pixel Values: X 152 Y 131 2.385493

Show: Modulus  10log(Mod)  20log(Mod)  
Phase  Real Part  Imag part

Range Length (pix): 200 Value: 2.385493

Representation: X Range  Y Range  (X,Y) Range  
Mesh  Surface  Mesh C  Mesh S

Minimum / Maximum Values: Auto Min 0 Max 15 MinMax

Profile Title: RANGE PROFILE

Plot Close

phase\_center\_height\_hvhv.bmp

gnplot graph

RANGE PROFILE

-18.5380, -2.36842 X Range

DEM\_diff\_heights

gnplot graph

RANGE PROFILE

-6.38427, 17.2961 X Range

Coh\_heights

gnplot graph

RANGE PROFILE

-13.9130, 17.3684 X Range

RVOG\_heights

PV3.0

nest and nasa tools

File Open Save Exit

Image Size C 301 R 301

Mouse Position X Y

Zoom 1:1

Color

Tools

Color Map -180.00 180.00

Plot Close

Open Window Environment Dual

Close Window Environment Dual

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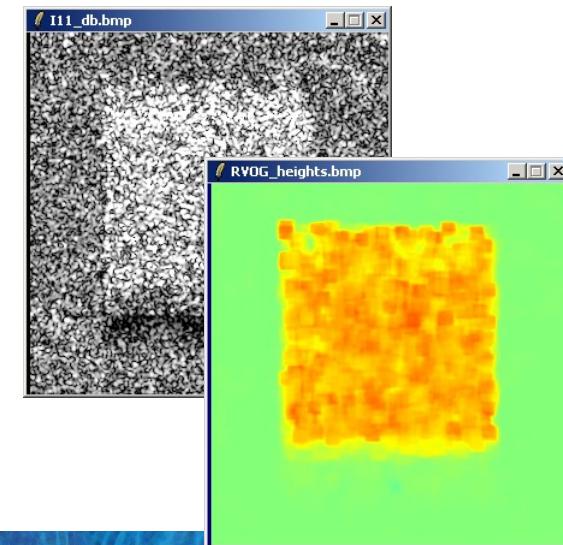
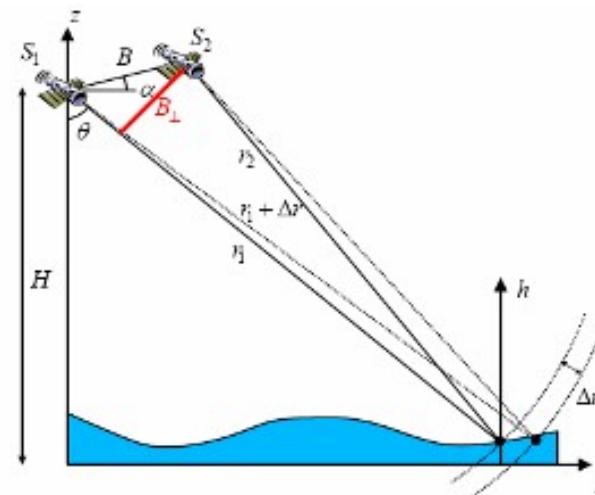


# POLSARPRO

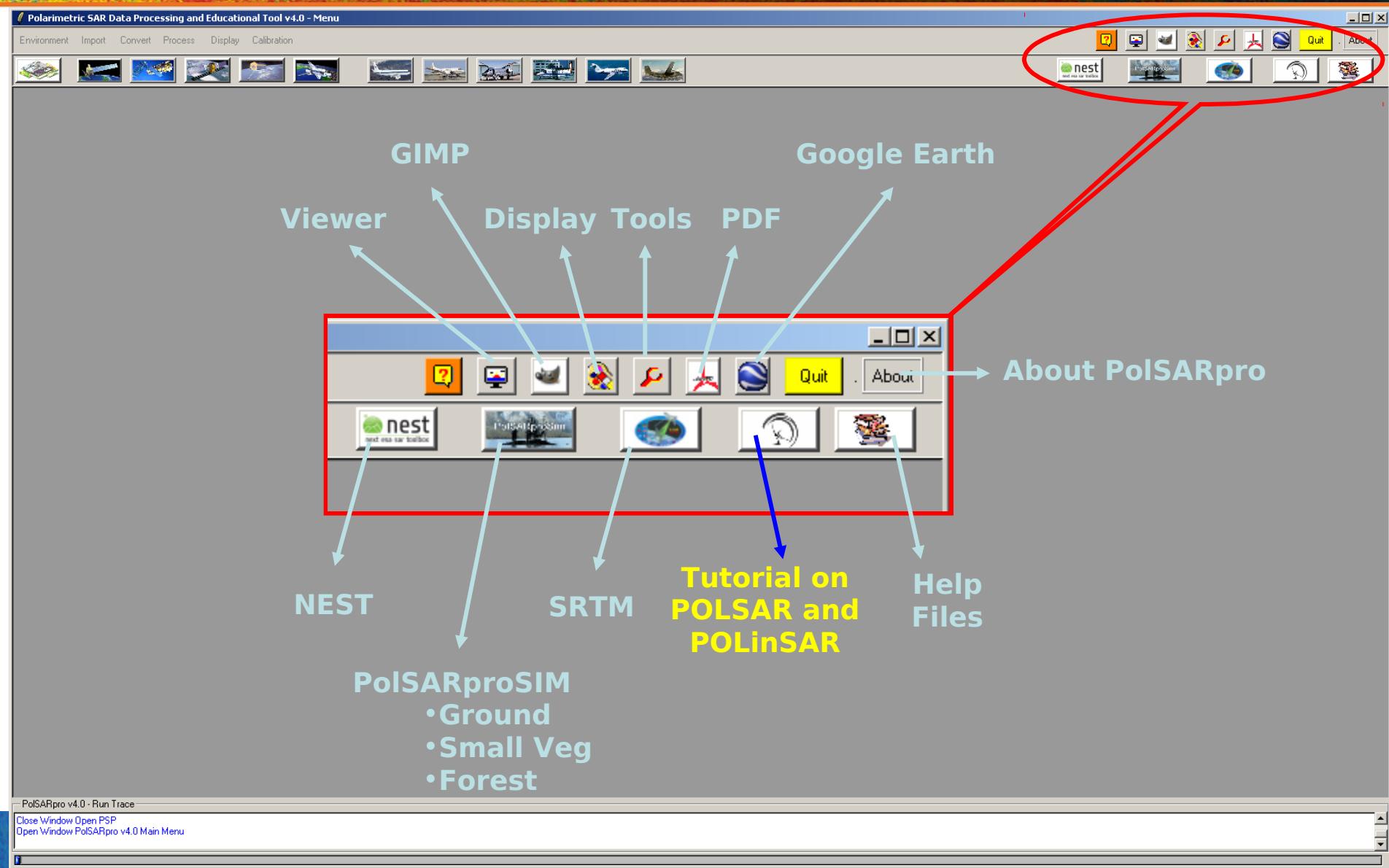
POLarimetric SAR data PROcessor



# Polarization Coherence Tomography Tutorial



# PolSARpro v4.0 SOFTWARE



# Lecture Notes

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

Environment Import Convert Process Display Calibration

Adobe Acrobat Standard (3\_PCT\_Training\_Course.pdf)

Fichier Édition Affichage Document Commentaires Outils Options avancées Fermer

Sélectionner

Création d'un fichier PDF Conserves et annotations

nest

PolSARpro Simulator

Segments

Pages

Affichages du modèle

Annotations de modèle

Police police

Commentaires

Close Window Open Window

**POLARIZATION COHERENCE TOMOGRAPHY (PCT):  
A TUTORIAL INTRODUCTION**

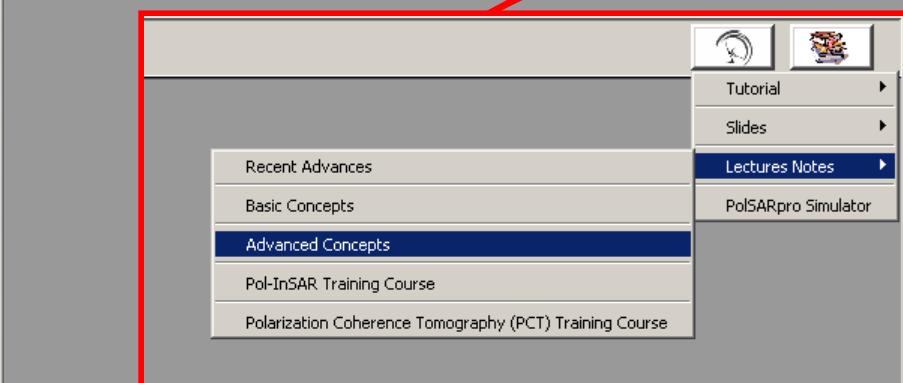
By

Shane R. Cloude  
AEL Consultants  
26 Westfield Avenue  
Cupar, Fife, Scotland UK  
Tel/fax : +44 1334 650761  
e-mail : [scl@mac.com](mailto:scl@mac.com)  
web : <http://web.mac.com/scl/>

Polarization Coherence Tomography (PCT):  
A Tutorial Introduction.....1  
1.1 Introduction.....1  
1.2 PCT Background Theory.....3  
1.2.1 Relating Radar Interferometry to Radar Polarimetry.....3  
1.2.2 Range Spectral Filtering and Critical Baseline.....6  
1.2.3 Volume Deconvolution and Vertical Structure.....8  
1.2.4 Special Case 1: The Uniform Profile.....13  
1.2.5 Special Case 2: The Exponential Profile.....14  
1.2.6 Generalised Structure Functions.....18  
1.3 Polarization Coherence Tomography (PCT).....19  
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1.4 Parameter Estimation for PCT.....28  
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1.4.2 Height Estimation Algorithms for PCT.....33  
1.4.3 Inclusion of temporal and SNR decorrelation effects in PCT.....37  
1.5 Summary Algorithm for Polarization Coherence Tomography (PCT).....39  
1.6 Case Study : PCT from L-band POLInSAR Simulations.....41  
1.6.1 Evaluation of the Legendre Spectrum for arbitrary polarization w....45  
1.6.2 3-D Imaging Results.....49  
1.7 Conclusions.....54  
1.8 References.....55

1.1 Introduction

Information about vertical structure (i.e. the variation of scattering in the vertical or z-direction) can be considered the missing component in synthetic aperture radar imagery (SAR). SAR is inherently a two-dimensional imaging process, with along-track or azimuth resolution given by one half the real antenna size and slant range resolution determined by the inverse of unmodulated bandwidth. However the radar



- 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

Adobe Acrobat Standard - [E\_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 truths. 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**

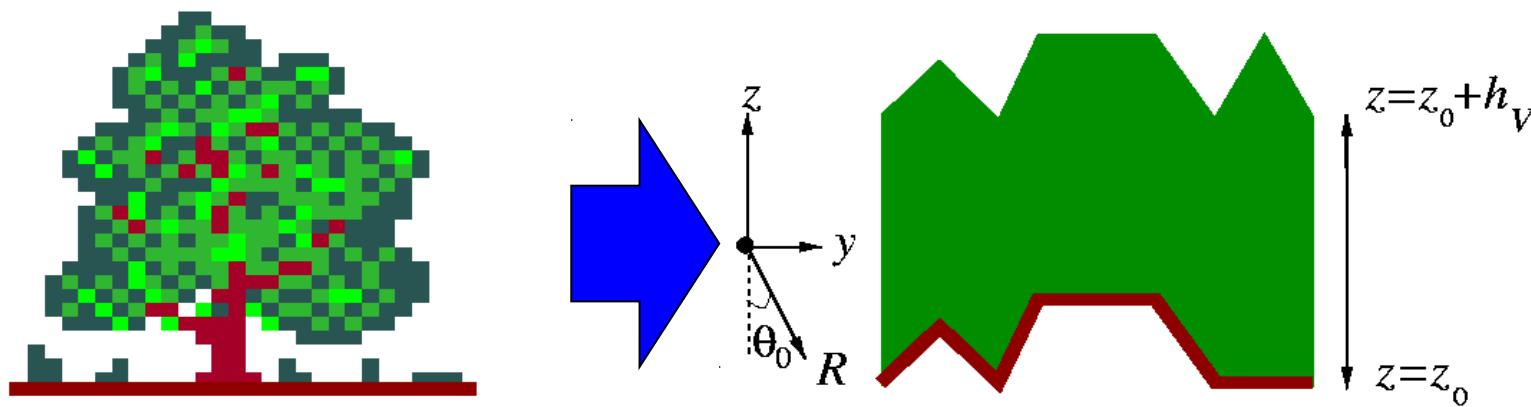
The screenshot shows the PolSARpro Simulator interface with various configuration parameters for a PCT training course.

Part VI : Do It Yourself

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

Do It Yourself

# VOLUME COHERENCE MODEL



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

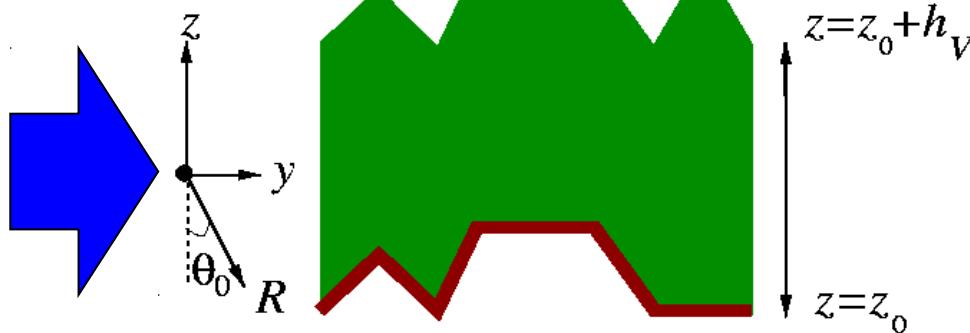
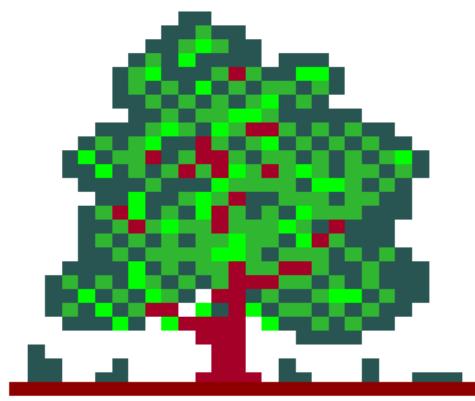
## Vertical Structure function

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

**Case of Uniform Random Layer**

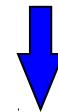
$\theta_0$  **Incidence Angle**

$\sigma$  **Extinction Coefficient**



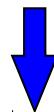
$$\gamma_{VOL} = e^{j\phi_0} \frac{\int_0^{h_v} f(z) e^{jk_z z} dz}{\int_0^{h_v} f(z) dz}$$

Assuming we know the estimates of:  
 $\phi_0$  (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

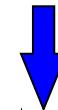


$a_n$

## Calculate Legendre Spectrum for polarization w

Select an arbitrary polarization scattering mechanisms: w

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



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

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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
**Polarization Coherence Tomography (PCT)** (highlighted)  
POLsar Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

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# POLARIMETRIC COHERENCE TOMOGRAPHY

## PCT Parameters Estimation



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

Environment Import Convert Process Display

Help Nest Project Home About

Polarization Coherence Tomography (P.C.T)

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/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

P.C.T Parameters Estimation:

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

Window Size: 11 Epsilon: 0.8 Run

P.C.T Engine:

2D Kz File

2D PCT Topographic Phase File

2D PCT Estimated Height File

2D PCT Kv File

Polarimetric Channel: Update List Pixel Spacing: Row: Col: Run

Hist Display PCT ? Exit

Polarization Coherence Tomography (P.C.T)

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/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

P.C.T Parameters Estimation:

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

Window Size: 11 Epsilon: 0.8 Run

P.C.T Engine:

2D Kz File

2D PCT Topographic Phase File

2D PCT Estimated Height File

2D PCT Kv File

Polarimetric Channel: Update List Pixel Spacing: Row: Col: Run

Hist Display PCT ? Exit

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

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

# POLARIMETRIC COHERENCE TOMOGRAPHY

## PCT Parameters Estimation



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

Environment Import Convert Process Display

Help Home nest EarthView Plugins About

Polarization Coherence Tomography (P.C.T)

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/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

P.C.T Parameters Estimation

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin  
Window Size: 11 Epsilon: 0.8 Run

P.C.T Engine

2D Kz File  
2D PCT Topographic Phase File  
2D PCT Estimated Height File  
2D PCT Kv File  
Polarimetric Channel: Update List! Pixel Spacing: Row: Col: Run

Buttons: Hist, Display PCT, Exit

**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\_phd.bmp,  
cmplx\_coh\_PCTgamLo\_mod.bmp,  
cmplx\_coh\_PCTgamLo\_phd.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.**

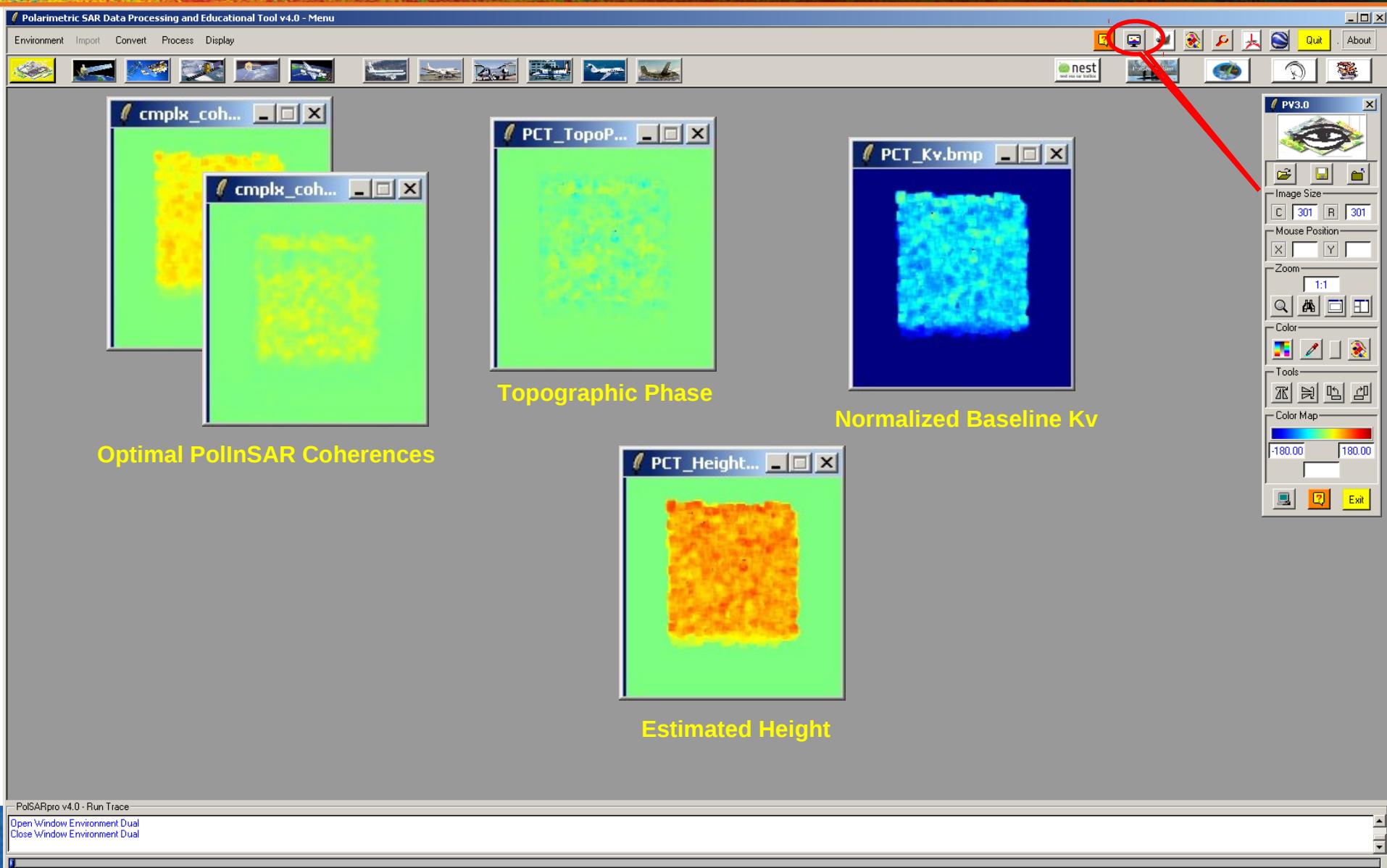
PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# POLARIMETRIC COHERENCE TOMOGRAPHY

## PCT Parameters Estimation



# POLARIMETRIC COHERENCE TOMOGRAPHY

## PCT Engine



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

Environment Import Convert Process Display

File Edit View Tools Help

Icons: Polarimetric SAR, Environment, Import, Convert, Process, Display, Help, About, nest, Python, Plugins, Scripts, Tools, Quit

**Polarization Coherence Tomography (P.C.T.)**

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/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

P.C.T Parameters Estimation:

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

Window Size: 11 Epsilon: 0.8 Run

P.C.T Engine:

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

2D PCT Topographic Phase File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_TopoPhase.b

2D PCT Estimated Height File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_Height.bin

2D PCT Kv File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_Kv.bin

Polarimetric Channel: PCT GamHi Update List Pixel Spacing: Row: 1.0 Col: 1.0 Run

Hist Display PCT Exit

**Polarization Coherence Tomography (P.C.T.)**

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/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

P.C.T Parameters Estimation:

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

Window Size: 11 Epsilon: 0.8 Run

P.C.T Engine:

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

2D PCT Topographic Phase File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_TopoPhase.b

2D PCT Estimated Height File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_Height.bin

2D PCT Kv File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_Kv.bin

Polarimetric Channel: PCT GamHi Update List Pixel Spacing: Row: 1.0 Col: 1.0 Run

Hist Display PCT Exit

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

PolSARpro v4.0 - Run Trace

Open Window Environment Dual Close Window Environment Dual

# POLARIMETRIC COHERENCE TOMOGRAPHY

## PCT Engine



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

Environment Import Convert Process Display

DATA\_MASTERDIR\_SLAVEDIR\_FER

config.txt

PCT\_f0.bin, PCT\_f1.bin, PCT\_f2.bin, PCT\_a10.bin, PCT\_a20.bin

PCT\_a10.bmp, PCT\_a20.bmp

**PCT\_a10.b...** **PCT\_a20.b...**

Legendre Coefficients a10 and a20

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# POLARIMETRIC COHERENCE TOMOGRAPHY

## PCT Engine



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

Environment Import Convert Process Display

Polarization Coherence Tomography (P.C.T)

Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

Input Slave Directory: C:/POLinSAR\_Training\_Course/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

P.C.T Parameters Estimation:

- 2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin
- Window Size: 11 Epsilon: 0.8 Run

P.C.T Engine:

- 2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin
- 2D PCT Topographic Phase File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_TopoPhase.b
- 2D PCT Estimated Height File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_Height.bin
- 2D PCT Kv File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_Kv.bin
- Polarimetric Channel: PCT GamHi Update List Row: 1.0 Col: 1.0 Run
- Hist** (highlighted with a red circle)
- Display PCT
- Exit

Data Processing : Statistics - Histogram

Input Data File: C:/POLinSAR\_Training/Master\_Slave\_FER/coh\_hvhv.bin

Input Data Format: Complex (selected)

Show: Modulus (selected)

Histogram Title: Coherence Histogram with Window Size

Histogram Label: Nwin = 11

Minimum / Maximum Values: Min: 0.7 Max: 1 MinMax

Plot Options: line (selected), box, Close

Buttons: Run, Clear, Save, Plot, Exit, ?

gnuplot graph

Phase Center Heights in Canopy Region

Nb of Samples vs Value (blue line plot)

gnuplot graph

Legendre Coherence function : 10

Nb of Samples vs Value (blue line plot)

gnuplot graph

Legendre Coherence function : 11

Nb of Samples vs Value (blue line plot)

gnuplot graph

Legendre Coherence function : 12

Nb of Samples vs Value (blue line plot)

Do it Yourself:  
Select the Hist function

Legendre Functions f0, f1 and f2

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

# POLARIMETRIC COHERENCE TOMOGRAPHY PCT Engine



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

Environment Import Convert Process Display

File Edit View Tools Help

Toolbar icons: Open, Save, Print, Zoom, etc.

**Polarization Coherence Tomography (P.C.T.)**

- Input Master Directory: C:/POLinSAR\_Training\_Course/Master\_Track

- Input Slave Directory: C:/POLinSAR\_Training\_Course/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

- P.C.T Parameters Estimation:

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

Window Size: 11 Epsilon: 0.8 Run

- P.C.T Engine:

2D Kz File: C:/POLinSAR\_Training\_Course/Slave\_Track/kz.bin

2D PCT Topographic Phase File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_TopoPhase.b

2D PCT Estimated Height File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_Height.bin

2D PCT Kv File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_Kv.bin

Polarimetric Channel: PCT\_GamHi Update List Row: 1.0 Col: 1.0 Run

Hist Display PCT Exit

**Display Polarization Coherence Tomography**

Selected File: C:/POLinSAR\_Training\_Course/Master\_Track\_Slave\_Track\_FER/PCT\_TopoPhase.b

Slice Along: Col (x) Row (y) Height (z)

3D Tomo Size: 301 301 301

Representation: BMP PCT Row: Min: 0.23 Max: 23.00

BMP PCT Col: Min: 1.03 Max: 30.00

Topogram Mouse Position: X: 100 Y: 100 Val: 0.43

Data Exit

**View PCT Image**

Topographic phase image showing a textured surface with a color scale from red to green.

**View PCT Image**

Estimated height image showing a surface with a color scale from red to green.

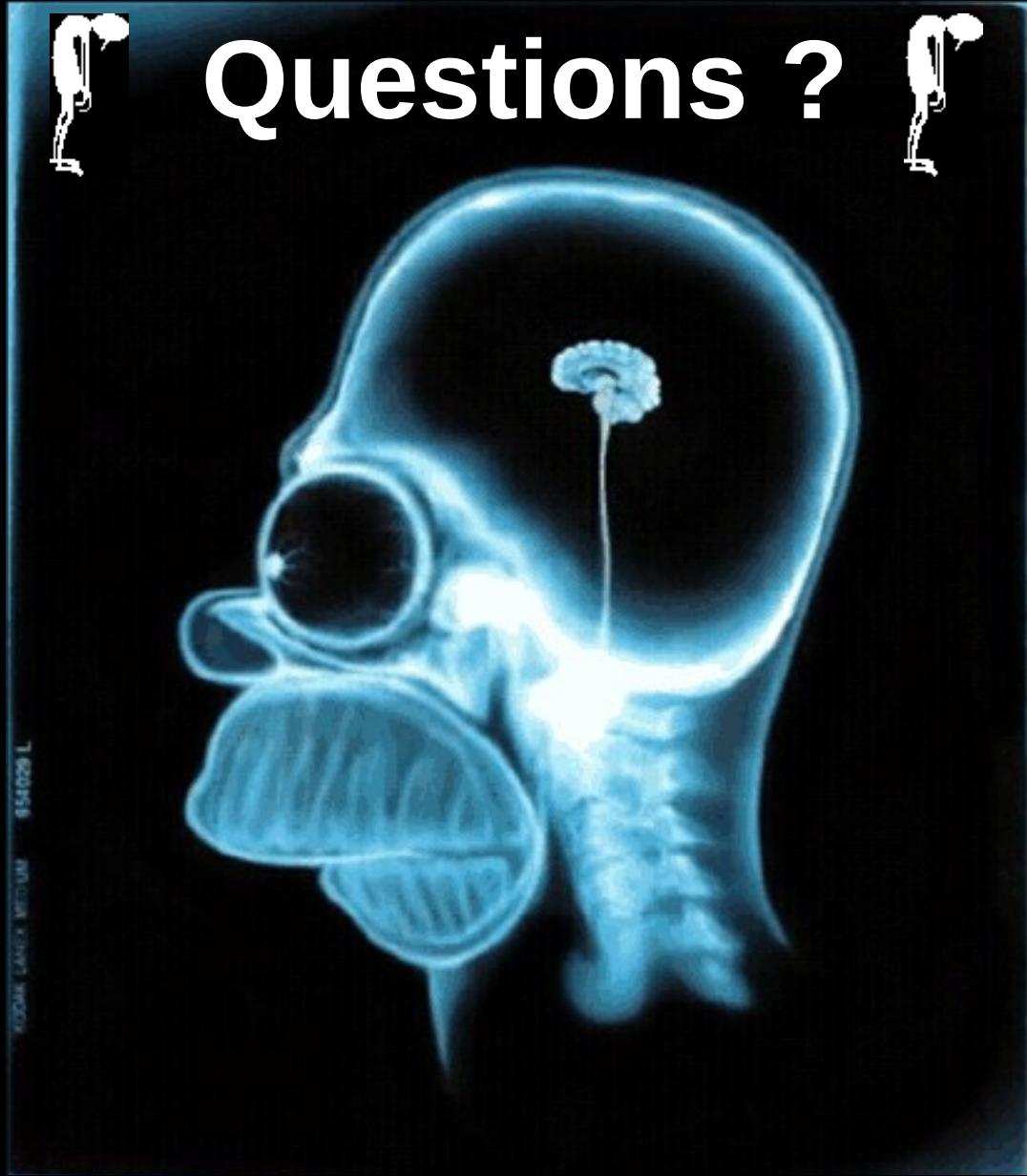
**View PCT Image**

Kv (Coherence) image showing a surface with a color scale from red to green.

**Do it Yourself:  
Select the Display PCT function**

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

# Questions ?



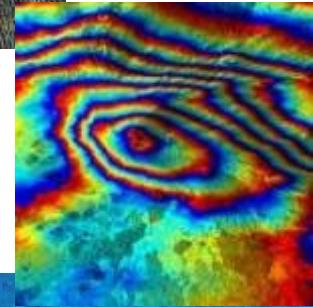
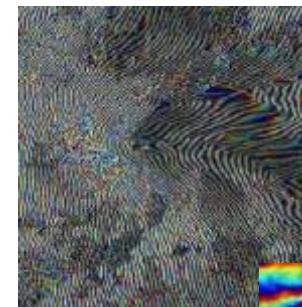
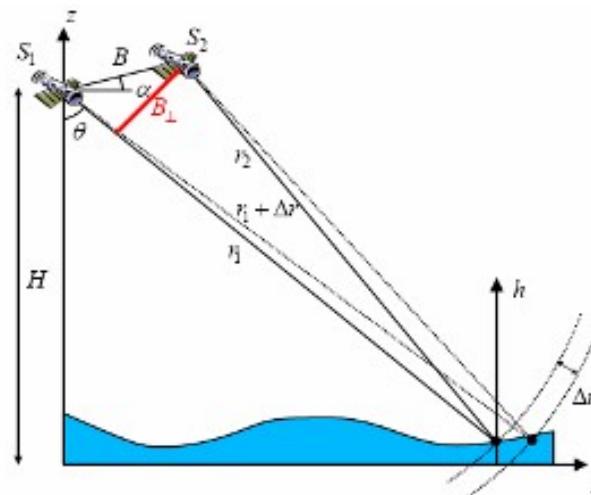


# POLSTARPRO

POLarimetric SAR data PROcessor

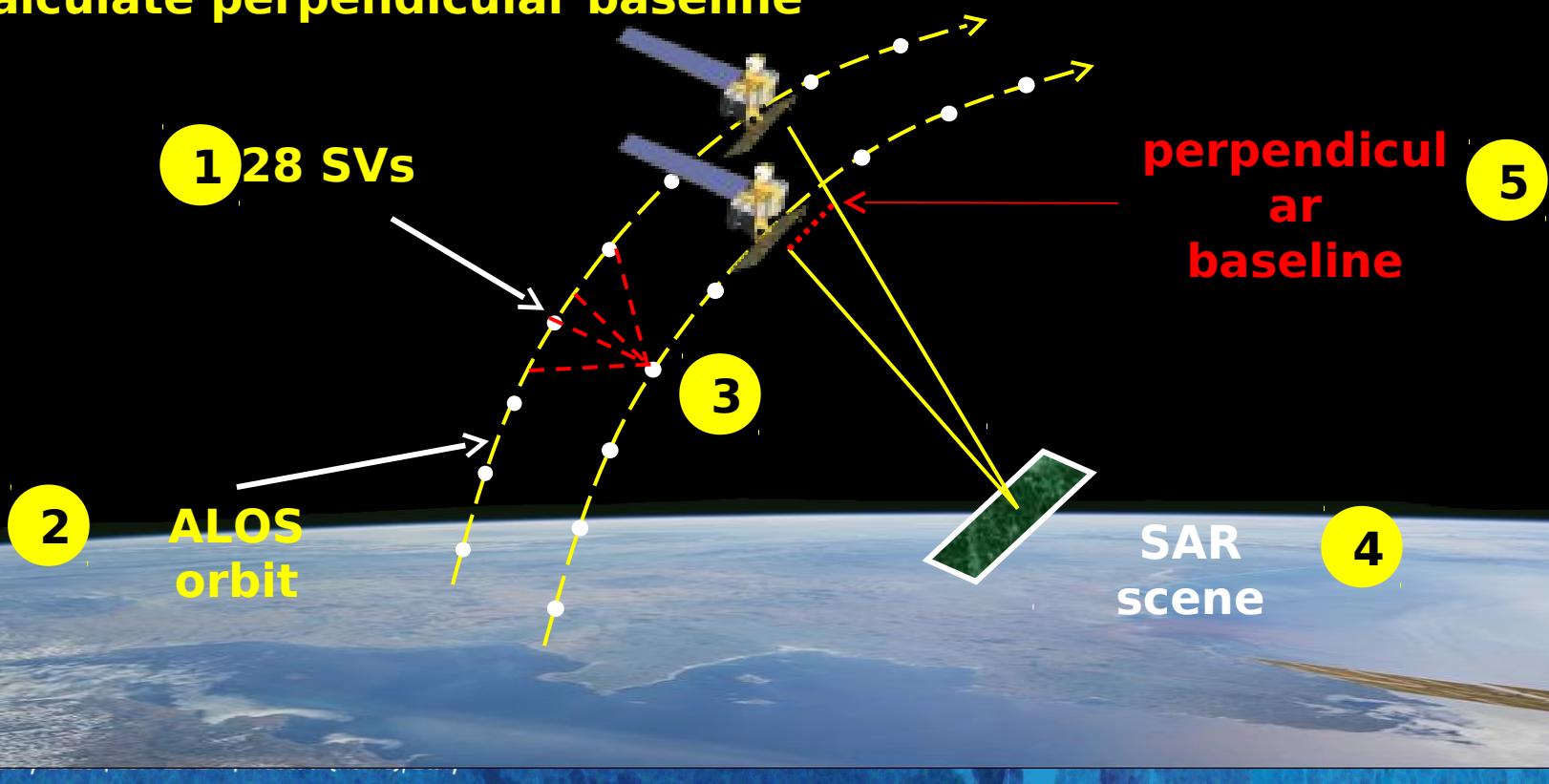


## ALOS / PALSAR Pol-InSAR DataSets



## PALSAR Data Level 1.1

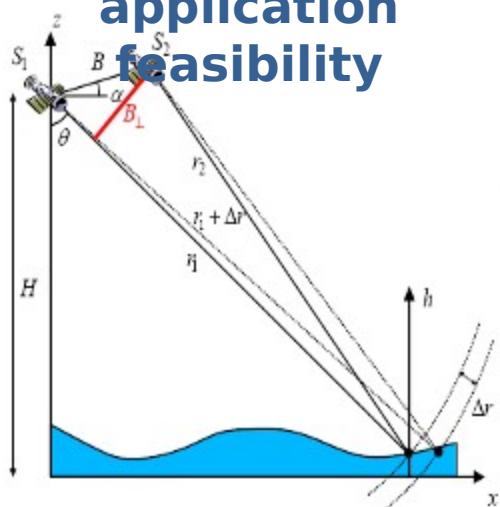
1. Read orbit Position and Velocity vectors (28 SVs) from L1.1 product header
2. Interpolate the 2 ALOS orbits
3. Align the time reference between the orbits
4. Read timing and geometry information from the SAR scene
5. Calculate perpendicular baseline



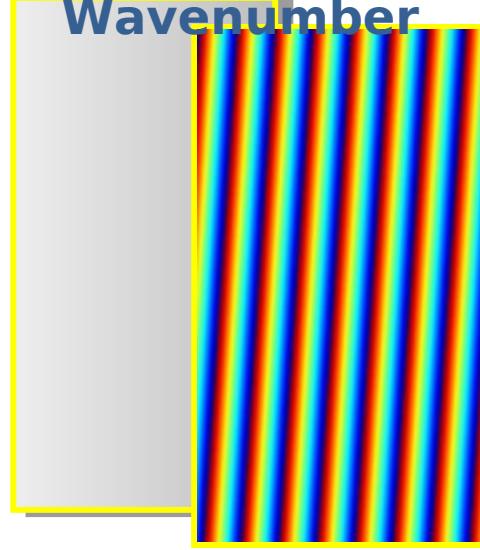
## PALSAR Data Level 1.1

### INTERFEROMETRIC BASELINE TOOL

Check the Pol-InSAR application feasibility



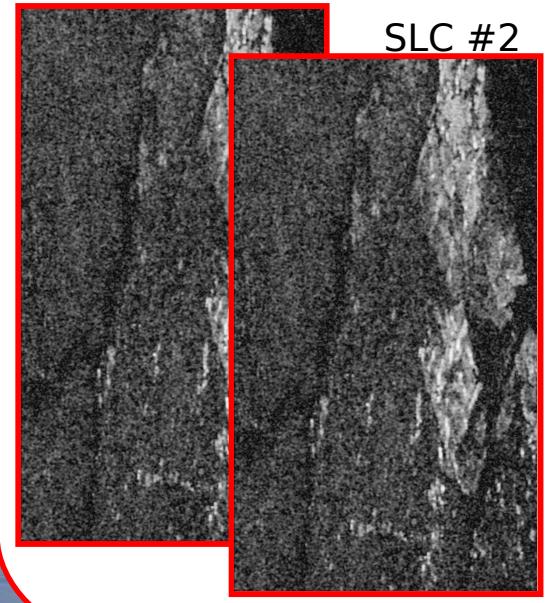
Generate Flat-Earth and Vertical Wavenumber



Provide coarse co-registration

SLC #1

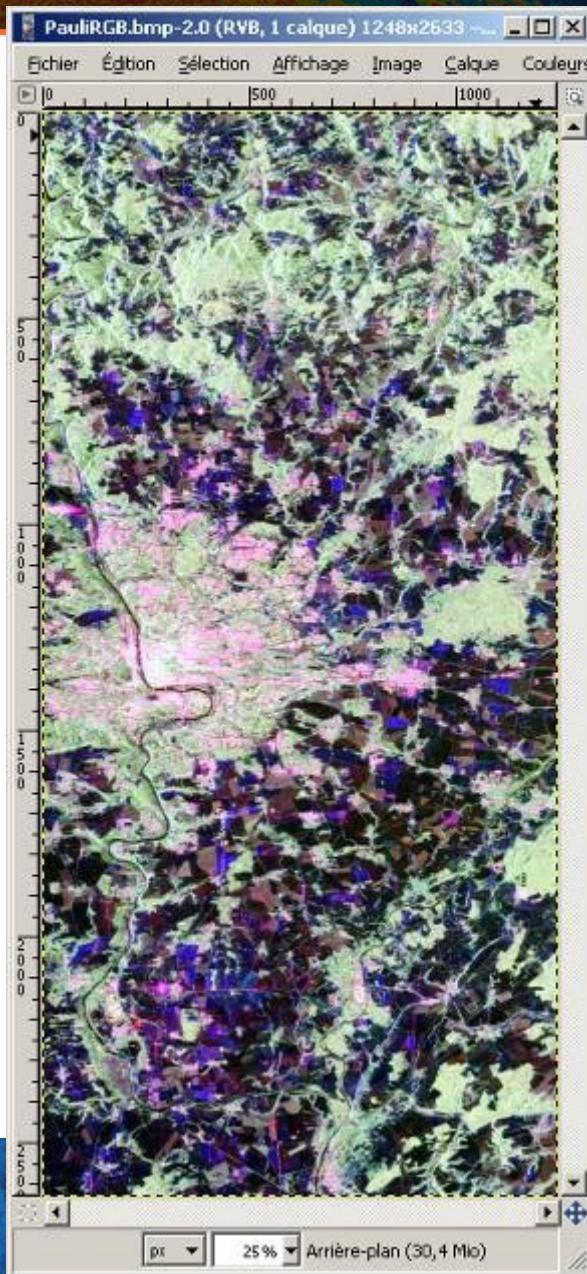
SLC #2



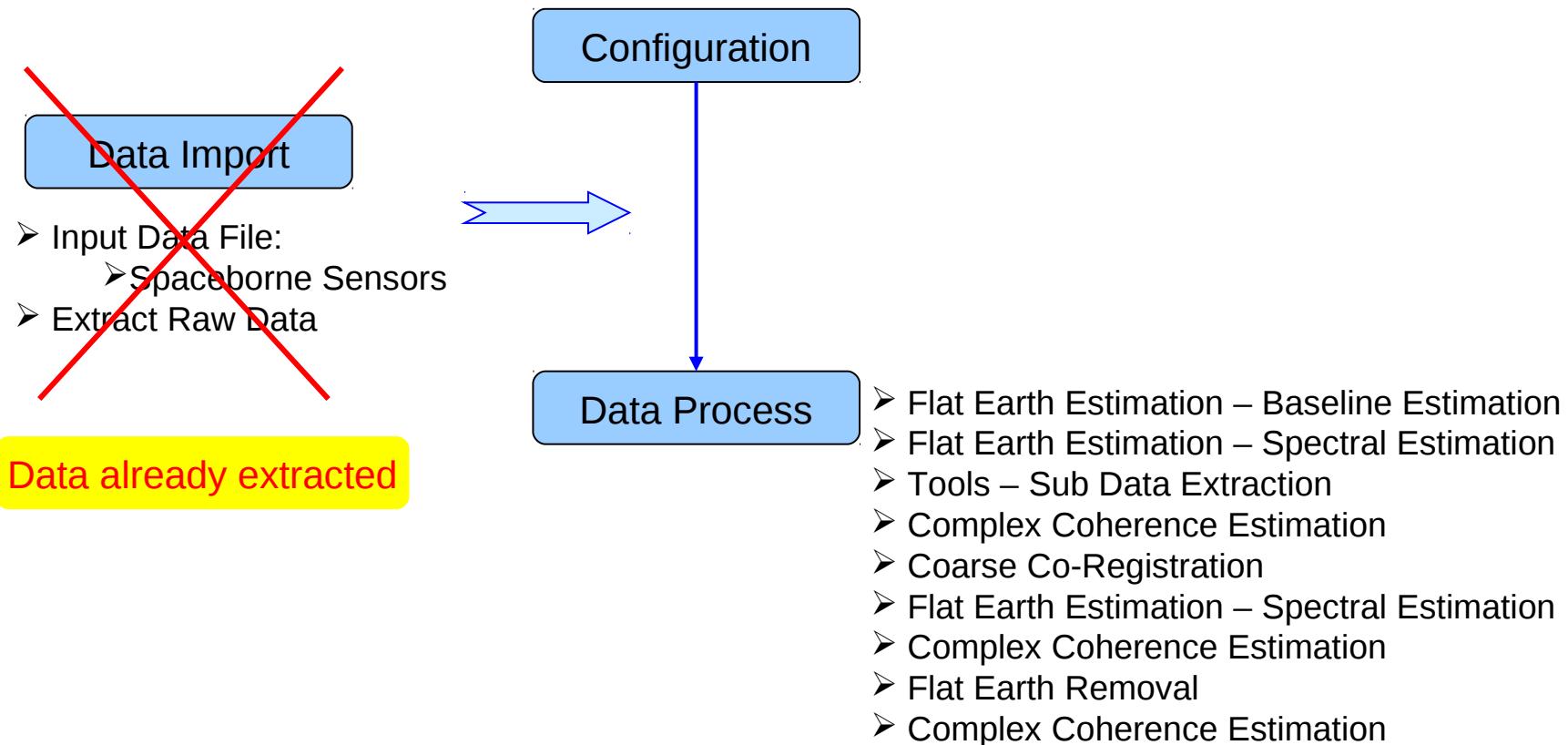
# PoISARpro v4.0 SOFTWARE

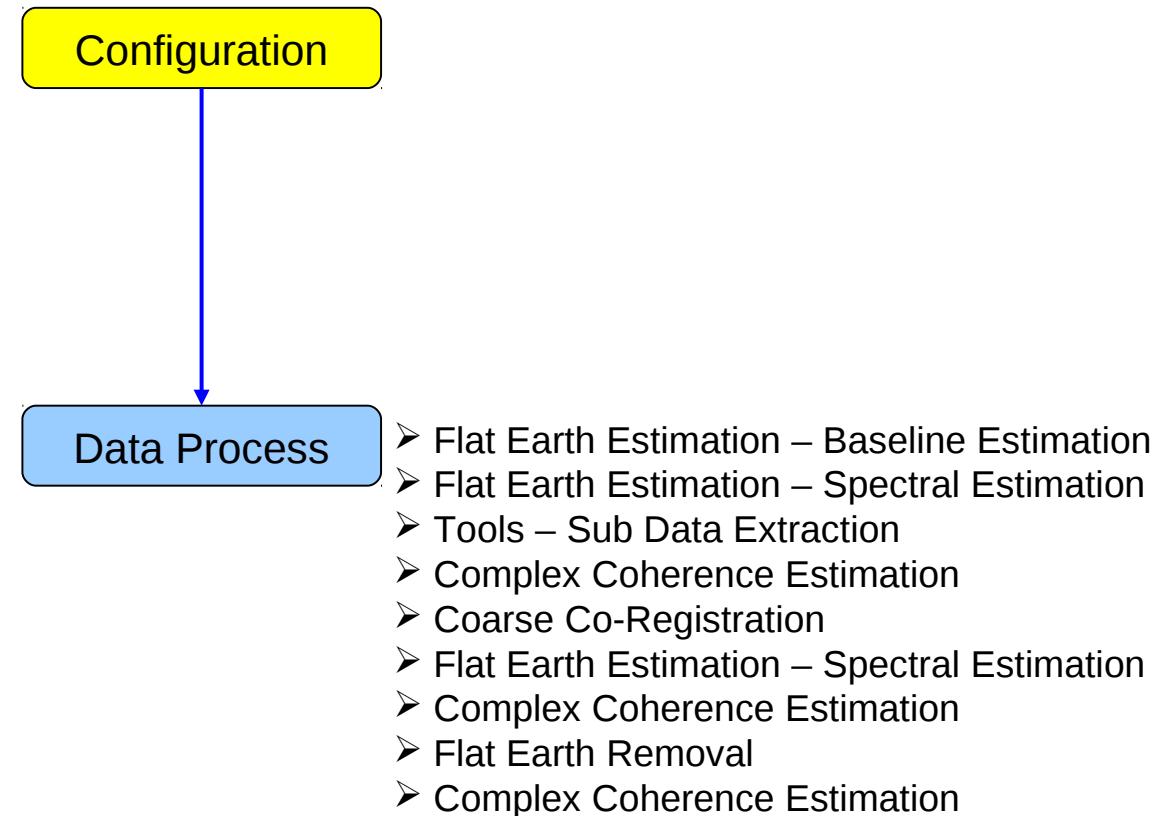


**ALOS : Advanced Land Observing Satellite  
PALSAR : Phase Array L-Band SAR**



# PROCESSING CHAIN





# MAIN MENU



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

Environment Import Convert Process Display Calibration

nest

Quit About

Single Data Set

Multi Data Sets ▶ Dual Pol-InSAR Data Sets

Multi Time / Freq Data Sets

PolSARpro v4.0 - Run Trace

[Close Window](#) [Open PSP](#)  
[Open Window](#) [PolSARpro v4.0 Main Menu](#)

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The screenshot shows the PolSARpro v4.0 software interface. At the top is a blue header bar with the title 'Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu' and various menu items: Environment, Import, Convert, Process, Display, Calibration, and a set of icons. Below the header is a toolbar with icons for different data types. A red circle highlights the first icon in the toolbar. A red box encloses a sub-menu window titled 'Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu' which contains the following items: Environment, Import, Convert, Process, Display, Calibration, and three buttons: 'Single Data Set', 'Multi Data Sets ▶' (which is highlighted in blue), and 'Dual Pol-InSAR Data Sets'. Another red box encloses a second sub-menu window titled 'Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu' containing the same set of menu items and icons as the main header. A red circle highlights the first icon in this second toolbar. At the bottom left is a status bar with the text 'PolSARpro v4.0 - Run Trace' and links to 'Close Window', 'Open PSP', 'Open Window', and 'PolSARpro v4.0 Main Menu'. The bottom right corner features the ESA logo.

# ENVIRONNEMENT



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

Environment Import Convert Process Display

Environment

Main Input Master Directory  
C:/Prague\_28032007\_Master

Main Input Slave Directory  
C:/Prague\_13052007\_Slave

Binary Data Check  ENVI Config File  NEST MetaData File

Display Size  
Rows 844 Columns 844 Save

Color Maps

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

Exit

Configure Data Main Directories location

Environment

Main Input Master Directory  
C:/Prague\_28032007\_Master

Main Input Slave Directory  
C:/Prague\_13052007\_Slave

Binary Data Check  ENVI Config File  NEST MetaData File

Display Size  
Rows 844 Columns 844 Save

Color Maps

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

Exit

Input Master Directory: C:/ Prague\_280307\_Master  
Input Slave Directory: C:/ Prague\_130507\_Slave

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**

[S2] Master [S2] Slave [T6]

BMP Viewer

Exit

Create BMP File

**Create RGB File**

Create HSL 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



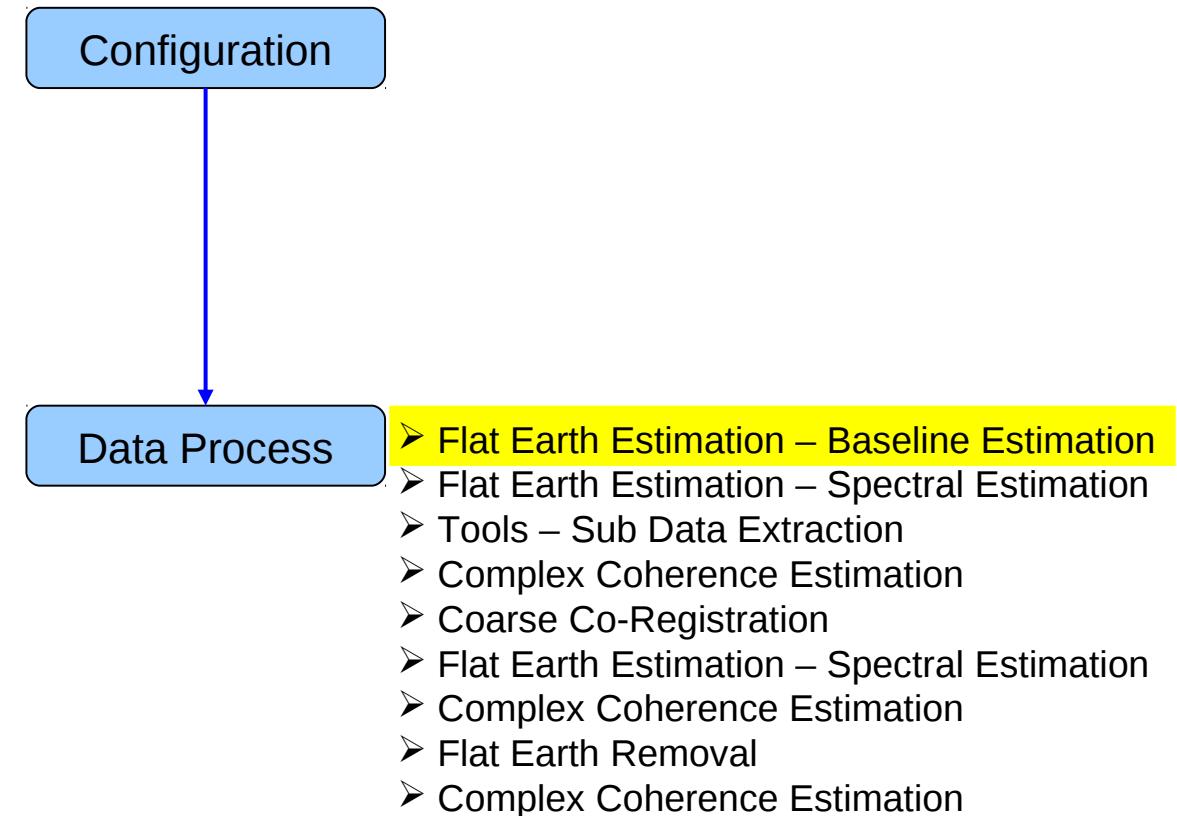
Master Pauli Image



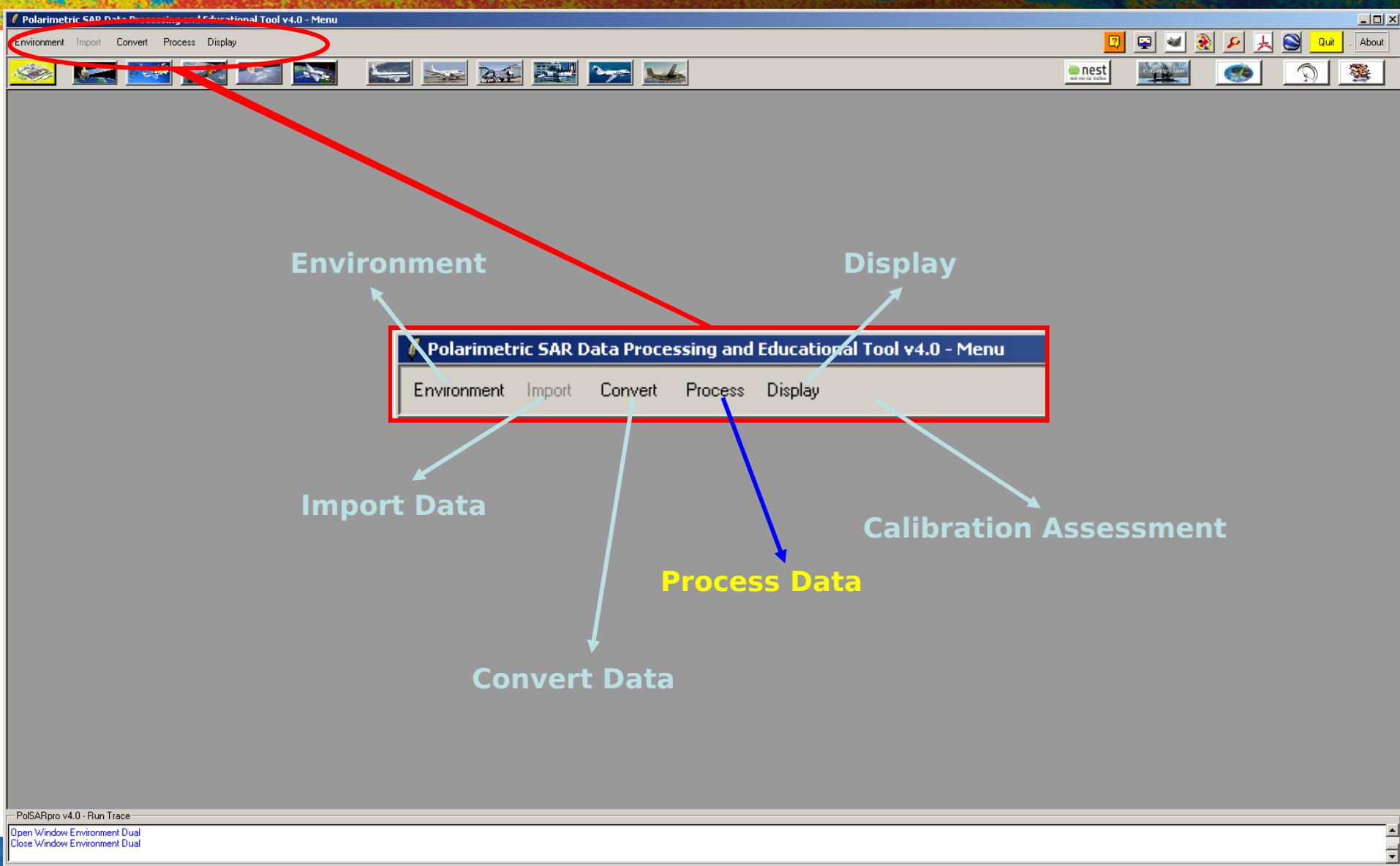
Slave Pauli Image



# PROCESSING CHAIN



# PROCESS DATA



# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] [About] [Quit]

**[S2] ▶** [T6] ▶

- Coarse Co-Registration
- Flat Earth Estimation
- Flat Earth Removal
- [S2] Elements
- Speckle Filter
- Interferogram
- Coherences Estimation
- Coherences Analysis
- Height Estimation
- Polarization Coherence Tomography (PCT)
- POLInSAR Segmentation
- Data Analysis

- Spectral Estimation
- Baseline Estimation
- Master Slave
- Box Car Filter
- Gaussian Filter
- J.S. Lee Refined Filter
- J.S. Lee Sigma Filter
- Edge Detector
- Complex Plane
- Coherence Region - Optimum Triplet
- Inversion Procedures
- Vegetation Height Estimation
- Wishart Supervised Classification
- Wishart Unsupervised Classification
- Data Histograms
- Data Profiles
- Coeff of Variation

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# BASELINE ESTIMATION



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

Environment Import Convert Process Display

Help Home nest TerraSAR-X SRTM DEM About

**POLinSAR Baseline Estimation**

Input Master Directory: C:/Prague\_28032007\_Master

Input Slave Directory: C:/Prague\_13052007\_Slave

Output Slave Directory: C:/Prague\_13052007\_Slave

Init Row: 1 End Row: 18432 Init Col: 1 End Col: 1248

Baseline Estimation:

ALOS (JAXA)  ALOS (ERSDAC)  RADARSAT-2  TerraSAR-X

Averaged Estimated Baseline Values:

Parallel: 227.76 Perpendicular: 152.49 Horizontal: 224.98 Vertical: -156.5

Run

Auxiliary Parameter Estimation:

Flat Earth  kz  Incidence Angle (deg)

Output Format:

real (deg)  real (rad)  cmplx (cos, sin)

Run Exit

**POLinSAR Baseline Estimation**

Input Master Directory: C:/Prague\_28032007\_Master

Input Slave Directory: C:/Prague\_13052007\_Slave

Output Slave Directory: C:/Prague\_13052007\_Slave

Init Row: 1 End Row: 18432 Init Col: 1 End Col: 1248

Baseline Estimation:

ALOS (JAXA)  ALOS (ERSDAC)  RADARSAT-2  TerraSAR-X

Averaged Estimated Baseline Values:

Parallel: 227.76 Perpendicular: 152.49 Horizontal: 224.98 Vertical: -156.5

Run

Auxiliary Parameter Estimation:

Flat Earth  kz  Incidence Angle (deg)

Output Format:

real (deg)  real (rad)  cmplx (cos, sin)

Run Exit

**Do it Yourself:**

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

PolSARpro v4.0 - Run Trace

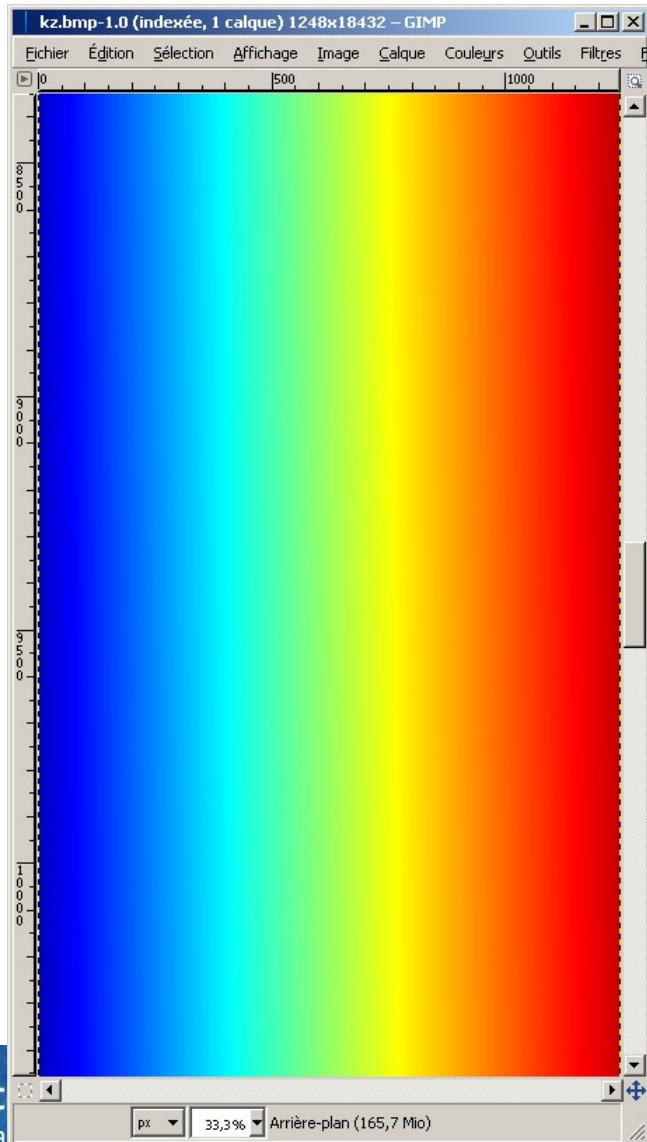
Open Window Environment Dual Close Window Environment Dual

# BASELINE ESTIMATION

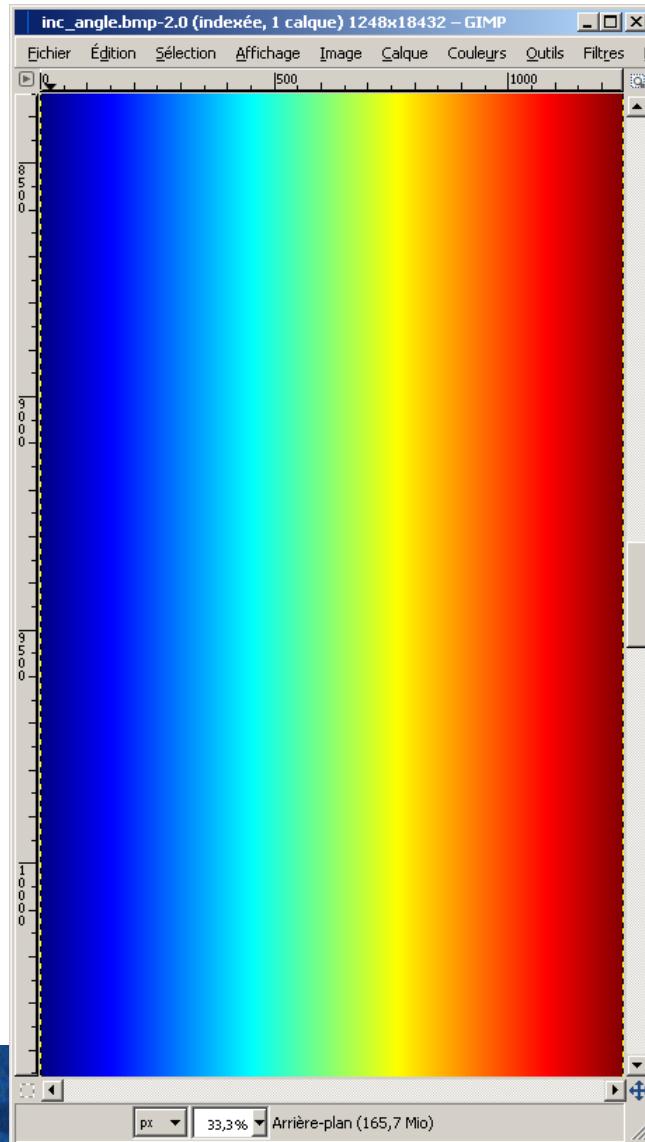


kz

kz



Radar Incidence Angle



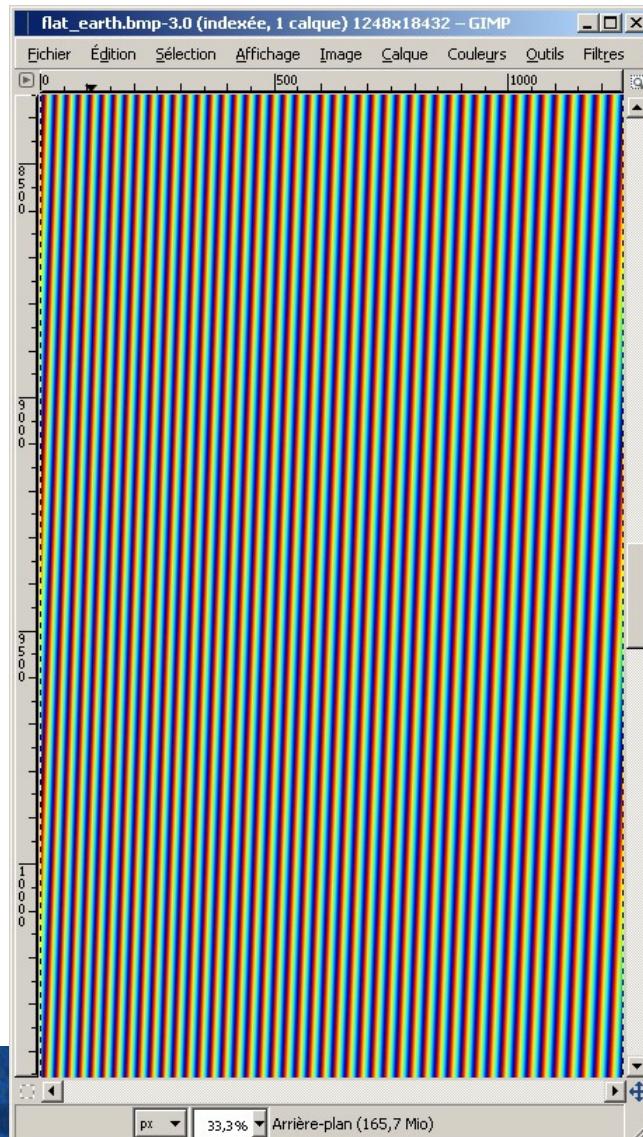
# BASELINE ESTIMATION



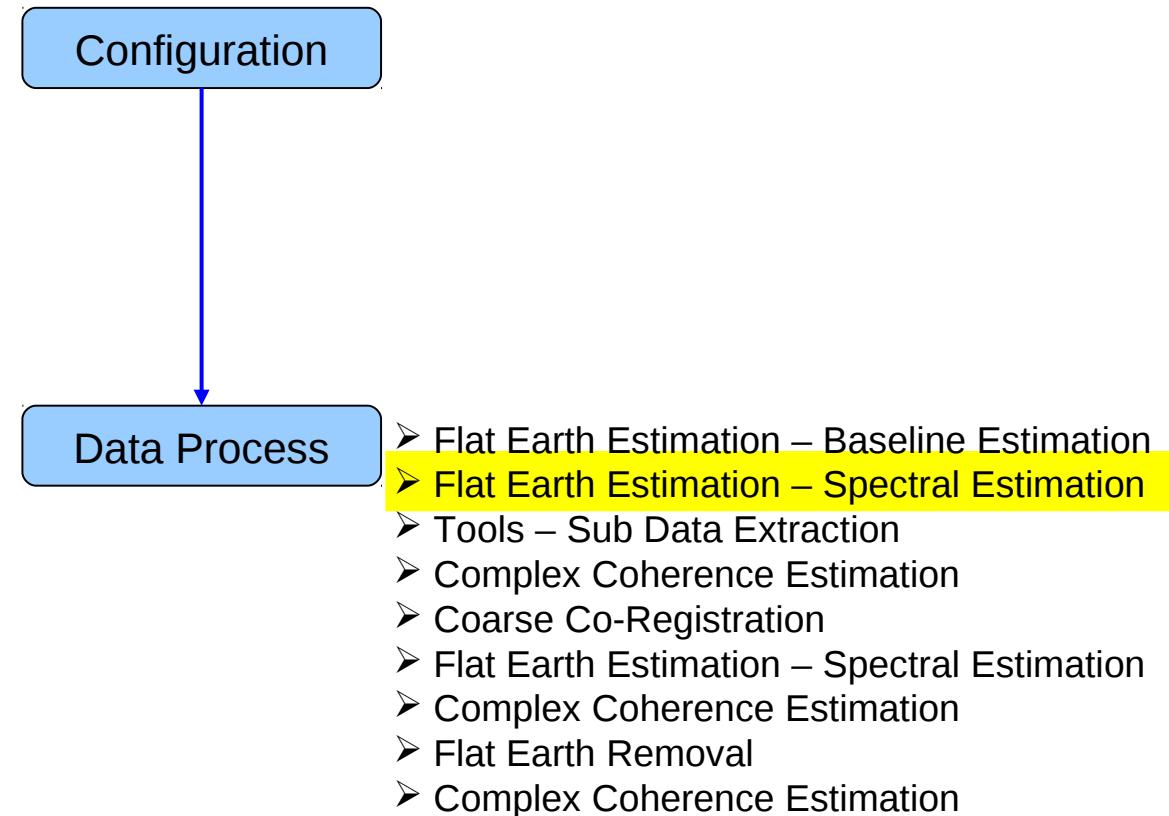
Master Pauli Image



Flat Earth



# PROCESSING CHAIN



# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[S2] [T6]

Spectral Estimation  
Baseline Estimation

Master Slave

Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter

Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# SPECTRAL ESTIMATION



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

Environment Import Convert Process Display

Help Home About

**POLinSAR Flat Earth Estimation**

Input Master File: C:/Prague\_28032007\_Master/s11.bin

Input Slave File: C:/Prague\_13052007\_Slave/s11.bin

Output Slave Directory: C:/Prague\_13052007\_Slave

Init Row: 1 End Row: 18432 Init Col: 1 End Col: 1248

Polarisation Channel:  s11  s12  s21  s22

Window Size (Row): 1024 Window Size (Col): 256

Output Format:  real (deg)  real (rad)  cmplx (cos, sin)

Run ? Exit

**POLinSAR Flat Earth Estimation**

Input Master File: C:/Prague\_28032007\_Master/s11.bin

Input Slave File: C:/Prague\_13052007\_Slave/s11.bin

Output Slave Directory: C:/Prague\_13052007\_Slave

Init Row: 1 End Row: 18432 Init Col: 1 End Col: 1248

Polarisation Channel:  s11  s12  s21  s22

Window Size (Row): 1024 Window Size (Col): 256

Output Format:  real (deg)  real (rad)  cmplx (cos, sin)

Run ? Exit

\*PaulIRGB.bmp - 1.0 (RVB, 1 couleur) 1536x1024

px 18.2% Arrière-plan (72.7 Mo)

PolSARpro v4.0 - Run Trace

Open Window Environment Dual Close Window Environment Dual

## Do it Yourself:

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

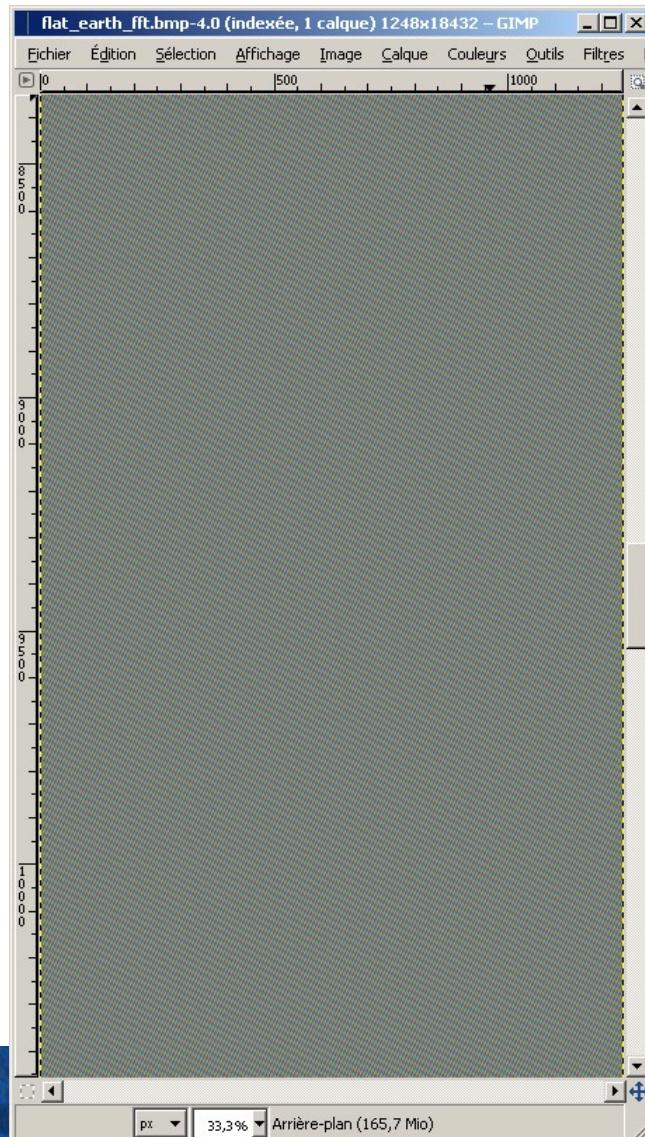
# SPECTRAL ESTIMATION



Master Pauli Image



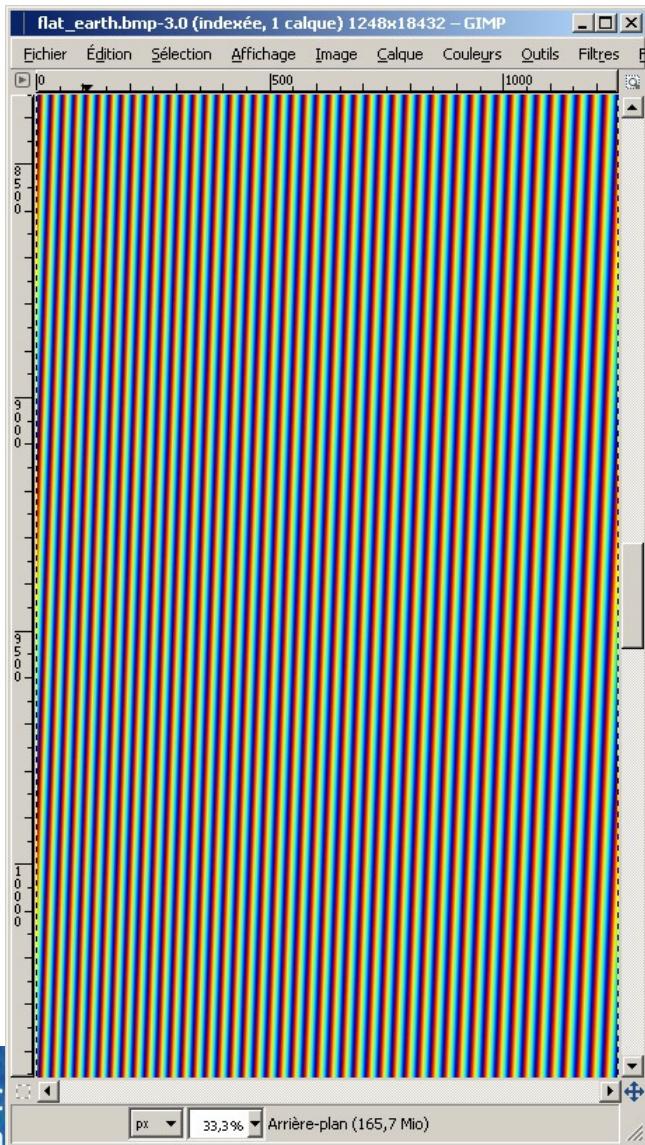
Flat Earth FFT



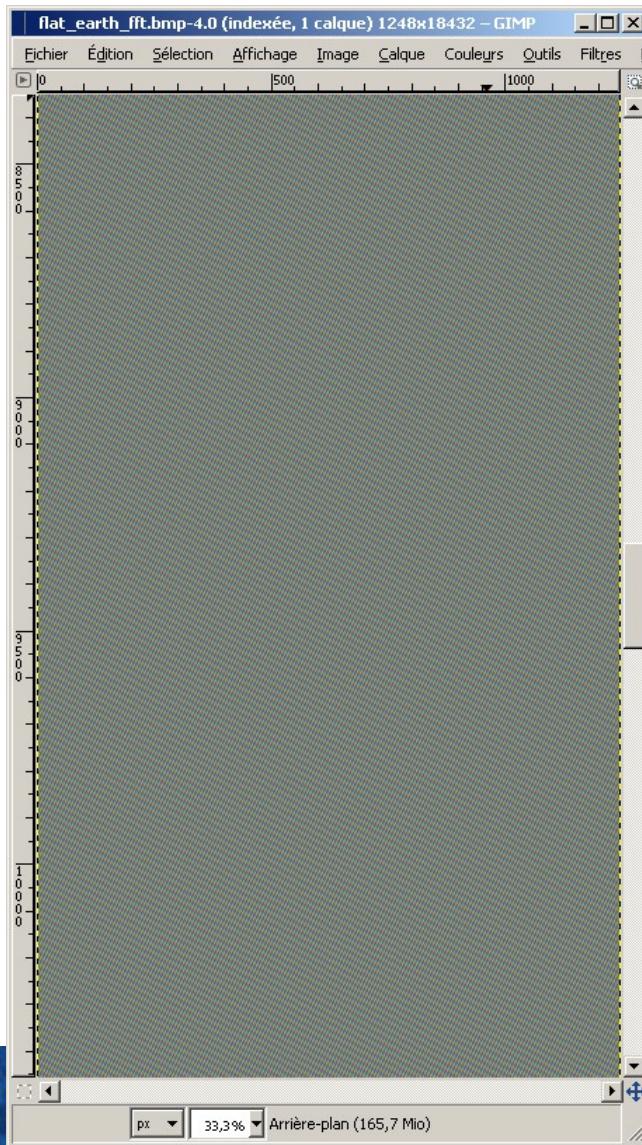
# SPECTRAL ESTIMATION



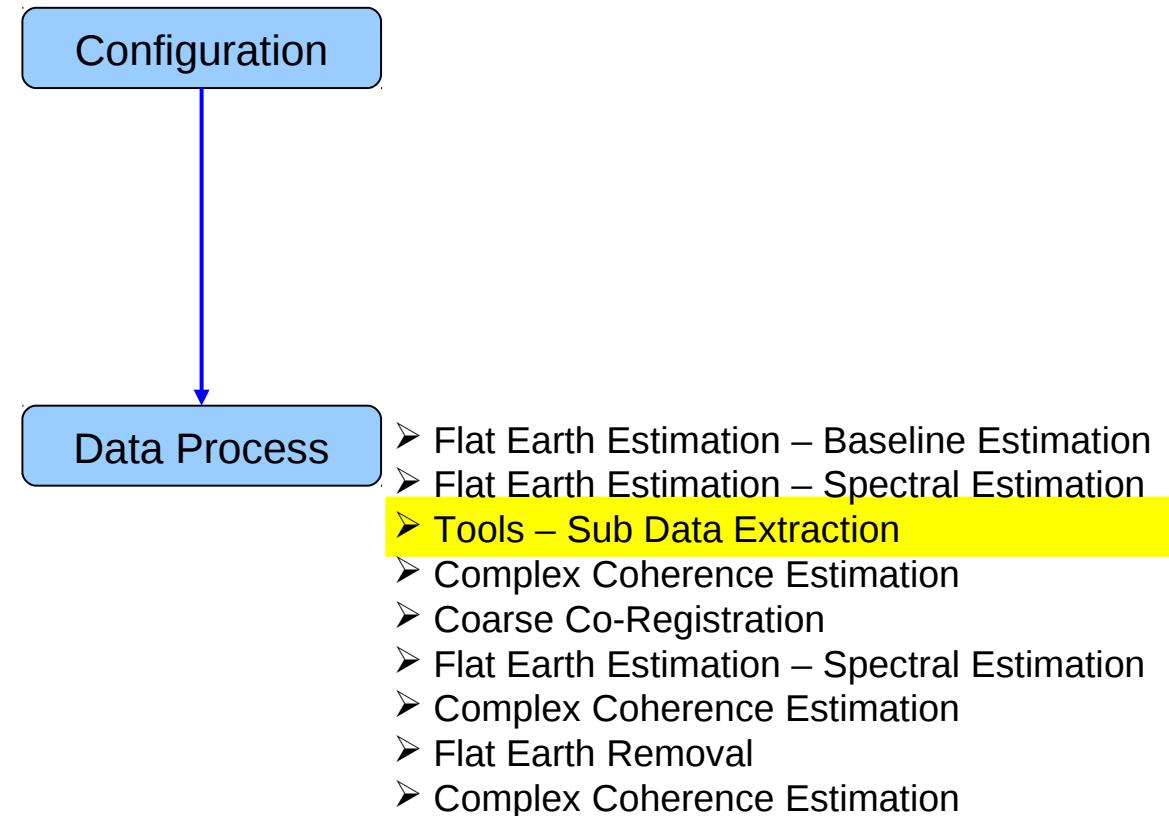
Flat Earth



Flat Earth FFT



# PROCESSING CHAIN



# TOOLS

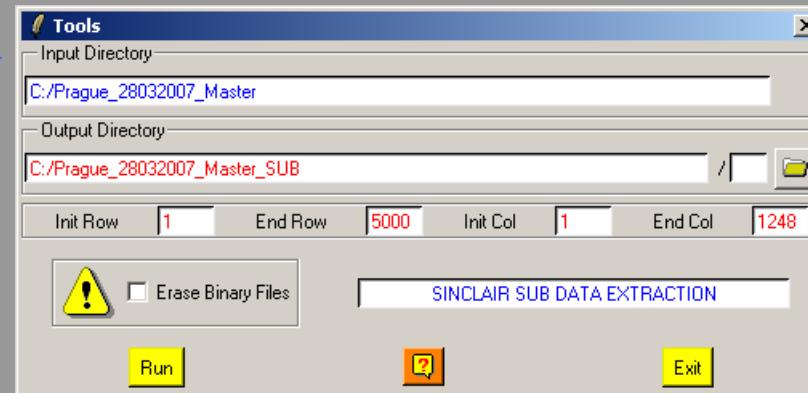


## Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu

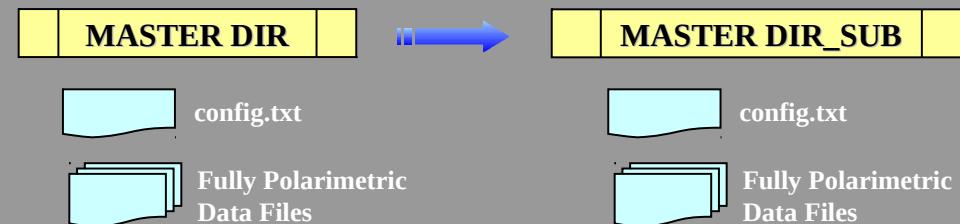
Environment Import Convert Process Display



- IFFE Format Convert
- [S2] Master [S2] Slave
- [T6]
- Sub Data Extraction
- Rotation 90 left
- Rotation 90 right
- Rotation 180
- Flip Up-Down
- Flip Left-Right
- Transpose
- FFT



**Do it Yourself:**  
**•Init Row = 1**  
**•End Row = 5000**  
**•Init Col = 1**  
**•End Col = 1248**



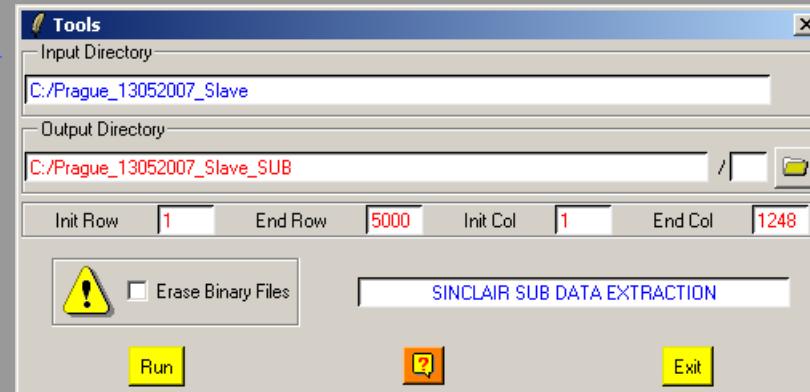
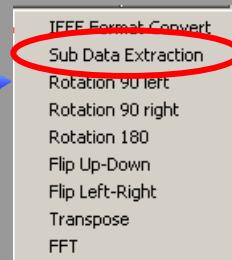
PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

# TOOLS

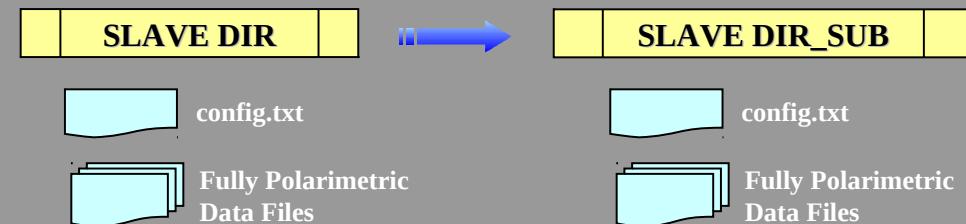


## Polarimetric SAR Data Processing and Educational Tool v4.0 - Menu

Environment Import Convert Process Display



**Do it Yourself:**  
**•Init Row = 1**  
**•End Row = 5000**  
**•Init Col = 1**  
**•End Col = 1248**



PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

# TOOLS



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

Environment Import Convert Process Display

Tools [S2] Master [S2] Slave [T6] Data File Management Export My Function ? Exit

Copy File Delete File Rename File IFF Format Convert Sub Data Extraction Rotation 90 left Rotation 90 right Rotation 180 Flip Up-Down Flip Left-Right Transpose Create ENVI (.hdr) File Create Directory Copy Directory Delete Directory Rename Directory

Data File Management Source File C:/Prague\_13052007\_Slave/flat\_earth.bin Target Directory C:/Prague\_13052007\_Slave\_SUB Target File C:/Prague\_13052007\_Slave\_SUB/flat\_earth\_SUB.bin Init Row 1 End Row 5000 Init Col 1 End Col 1248 SUB DATA EXTRACTION File Data Format Complex (radio button selected) Float Integer Run ? Exit

SLAVE DIR flat\_earth.bin SLAVE DIR\_SUB flat\_earth.bin

Do it Yourself:  
• **Init Row = 1**  
• **End Row = 5000**  
• **Init Col = 1**  
• **End Col = 1248**

flat\_earth.bin

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

# ENVIRONNEMENT



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

Environment Import Convert Process Display

Environment

Main Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Main Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB

Binary Data Check  ENVI Config File  NEST MetaData File

Display Size: Rows 844 Columns 844 Save

Color Maps:

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

Exit

Configure Data Main Directories location

Environment

Main Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Main Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB

Binary Data Check  ENVI Config File  NEST MetaData File

Display Size: Rows 844 Columns 844 Save

Color Maps:

- Unsupervised ColorMap8
- Single ColorMap9
- Dbl\_Vol\_Sgl ColorMap27
- Unsupervised ColorMap9
- Double ColorMap9
- Random ColorMap32
- Unsupervised ColorMap16
- Volume ColorMap9

Exit

Input Master Directory: C:/ Prague\_280307\_Master\_SUB  
Input Slave Directory: C:/ Prague\_130507\_Slave\_SUB

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**

[S2] Master [S2] Slave [T6]

BMP Viewer

Exit

Create BMP File Create RGB File Create HSL 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**

[S2] Master [S2] Slave [T6]

BMP Viewer

Exit

Create BMP File Create RGB File Create HSL 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|

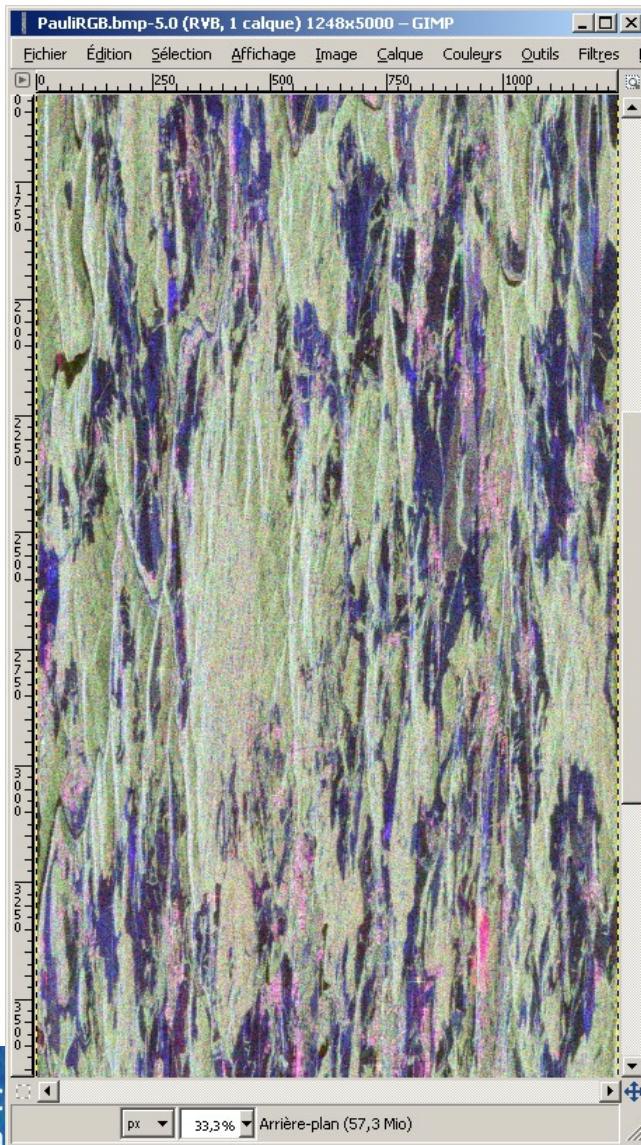
Output RGB File: C:/Prague\_13052007\_Slave\_SUB/PauliRGB.bmp

Run Exit

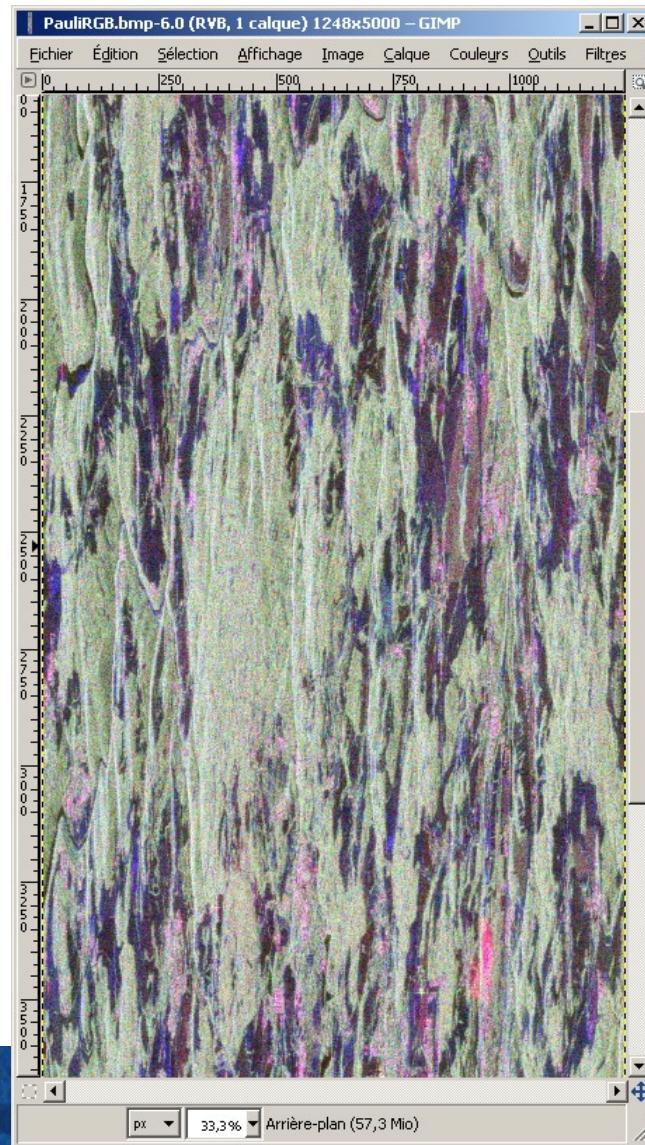
PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

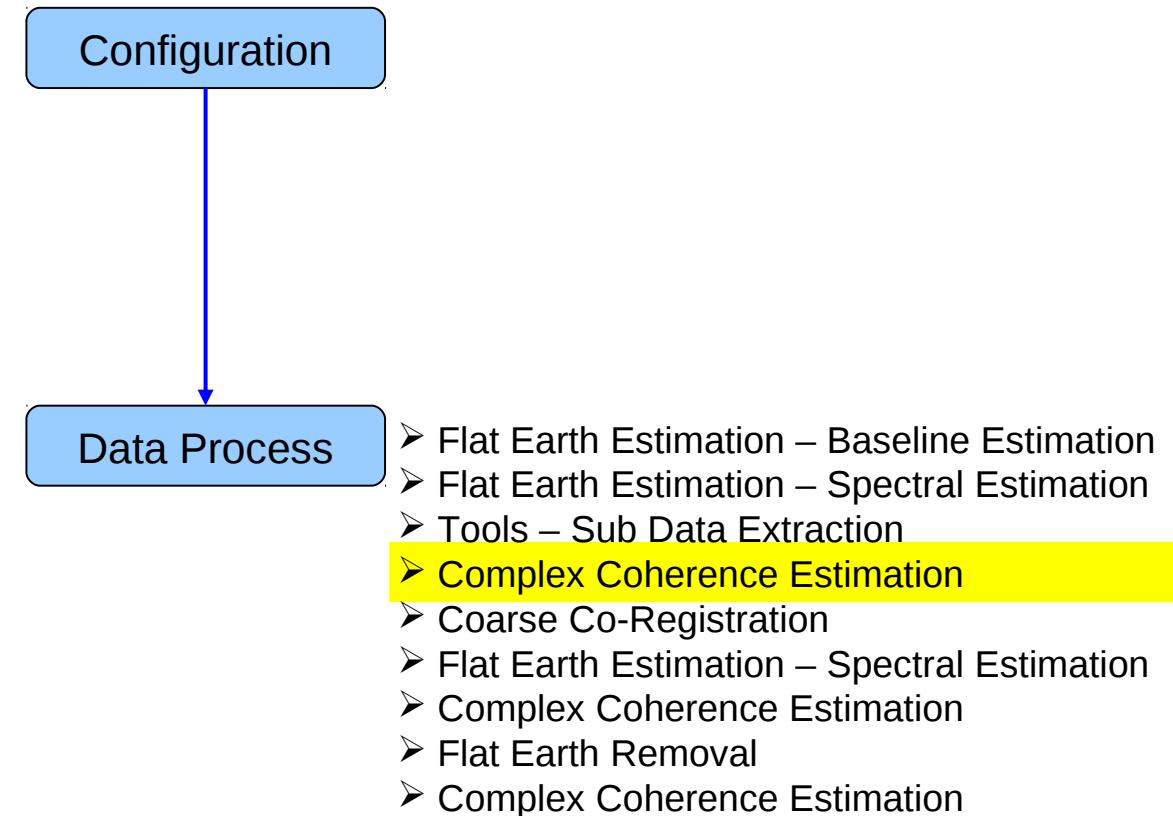
Master Pauli Image



Slave Pauli Image



# PROCESSING CHAIN



# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
**Coherences Estimation** (circled)  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

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# COMPLEX COHERENCE ESTIMATION



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

Environment Import Convert Process Display

Complex Coherence Estimation

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB

Output Master-Slave Directory: C:/Prague\_28032007\_Master\_SUB\_Prague\_13052007\_Slave\_SUB

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Complex Coherences:

Linear: HH, HV, VV, Pauli, HH+VV, HH-VV, HV+VH  
Circular: LL, LR, RR, Optimal, SVD, PD, NR, L. MinMax, L. Diff

Numerical Radius: Theta1, Theta3  
Loci MinMax: Num Points  
Loci Diff: Num Points

Box Car Window: Row 7, Col 7  
Averaging Window: Row 7, Col 7  
BMP: checked  
Averaging: checked

Run Hist Help Exit

Complex Coherence Estimation

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB

Output Master-Slave Directory: C:/Prague\_28032007\_Master\_SUB\_Prague\_13052007\_Slave\_SUB

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Complex Coherences:

Linear: HH, HV, **VV**, Pauli, HH+VV, HH-VV, HV+VH  
Circular: LL, LR, RR, Optimal, SVD, PD, NR, L. MinMax, L. Diff

Numerical Radius: Theta1, Theta3  
Loci MinMax: Num Points  
Loci Diff: Num Points

Box Car Window: Row 7, Col 7  
Averaging Window: Row 7, Col 7  
BMP: checked  
Averaging: checked

Run Hist Help Exit

## 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.

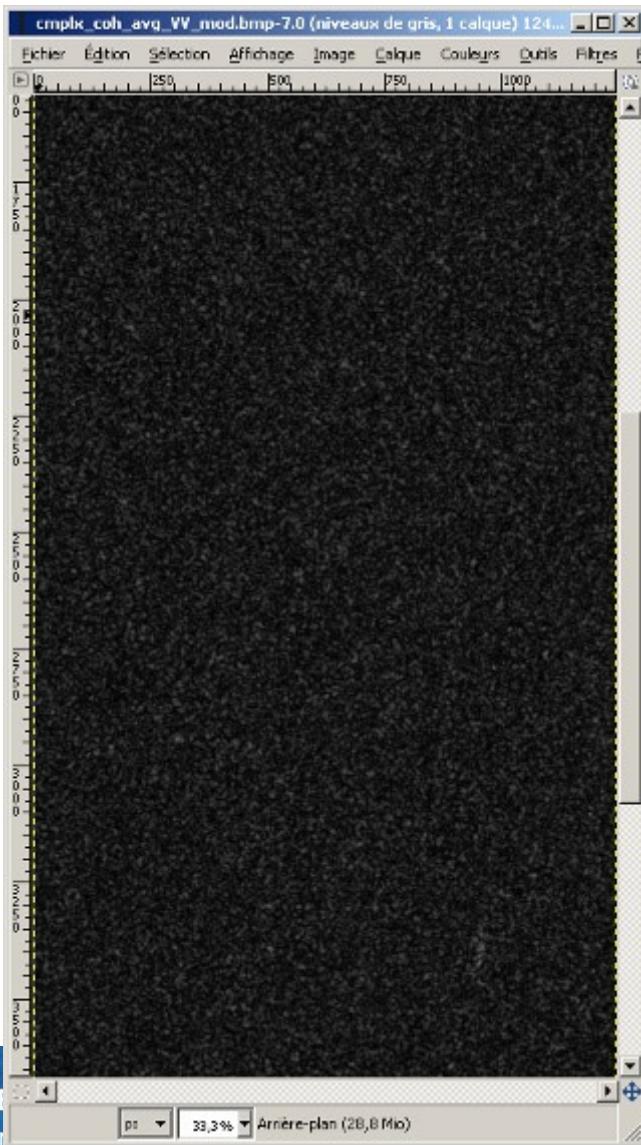
PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

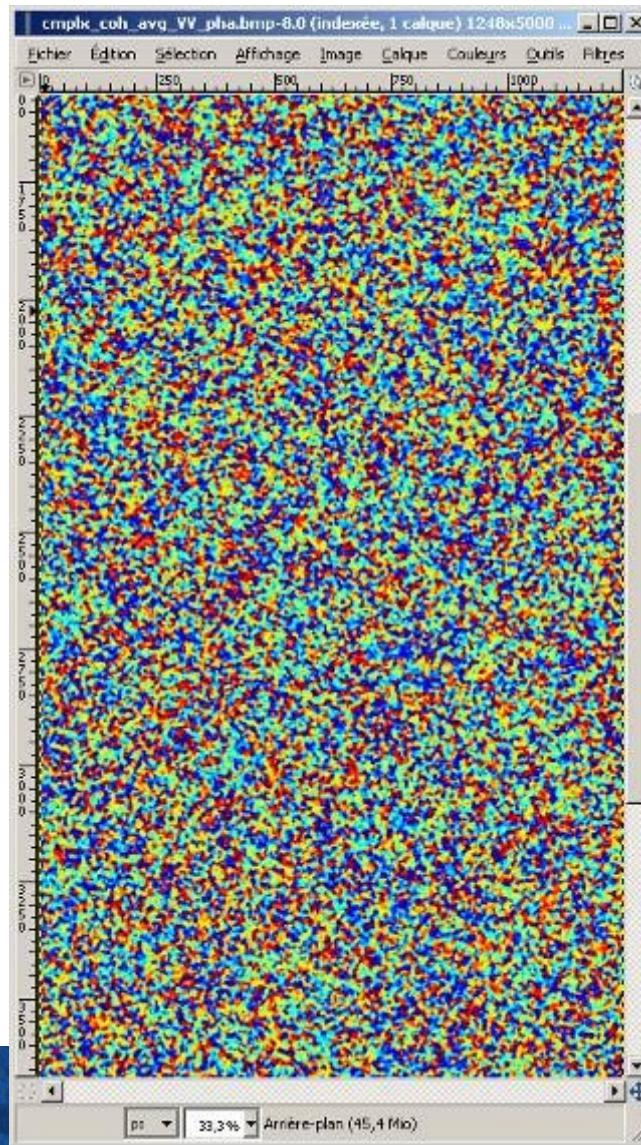
# COMPLEX COHERENCE ESTIMATION



cmplx\_coh\_avg\_VV\_mod

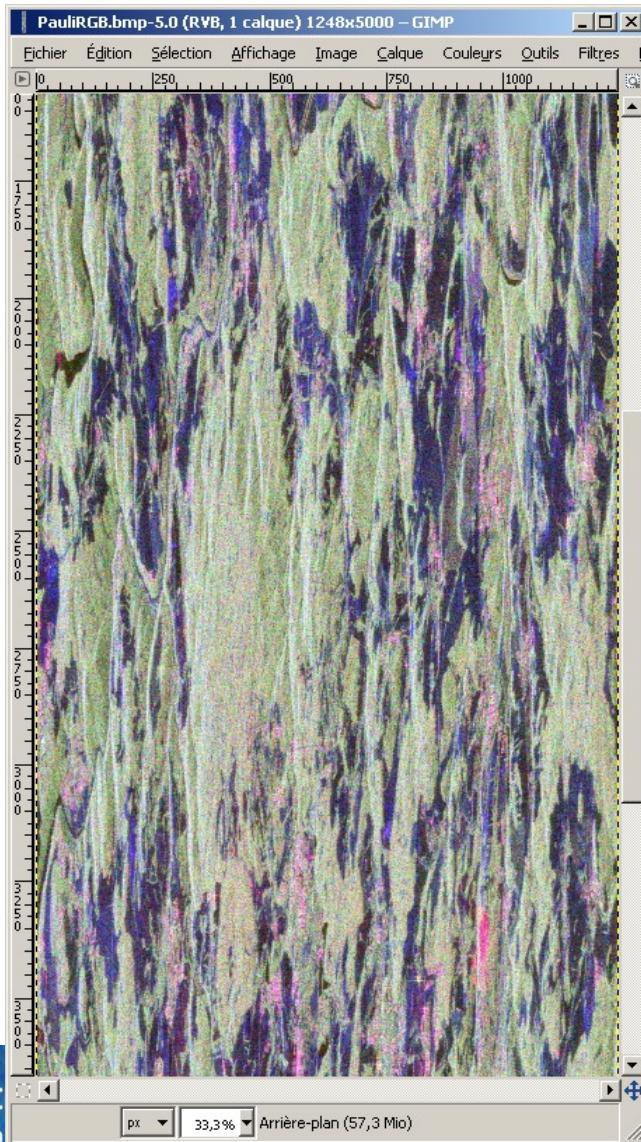


cmplx\_coh\_avg\_VV\_pha

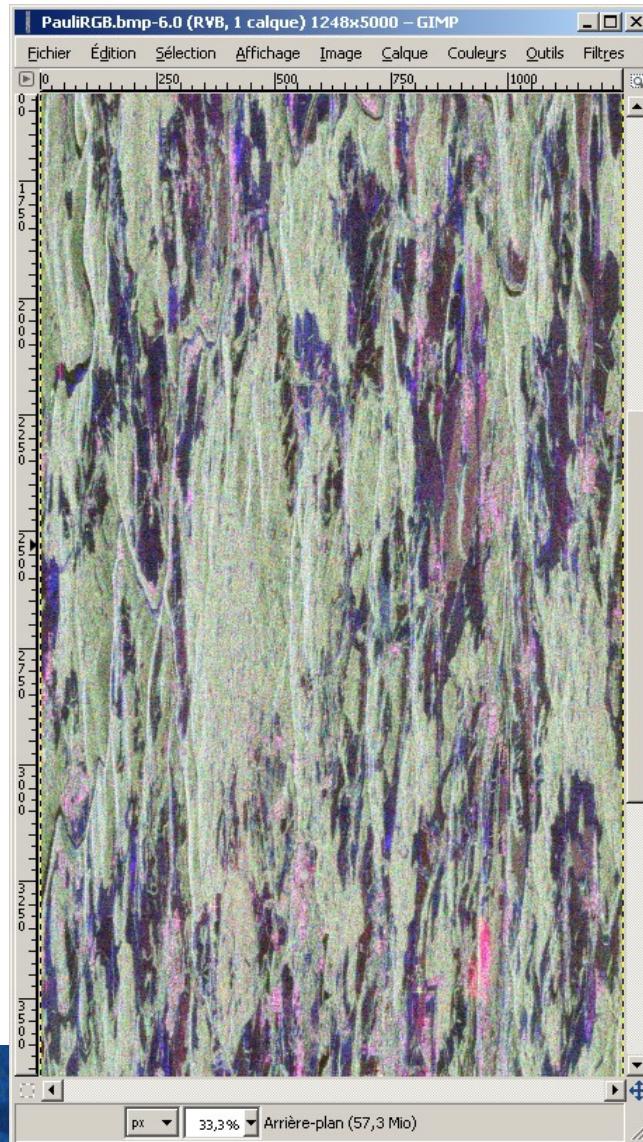


# COMPLEX COHERENCE ESTIMATION

Master Pauli Image

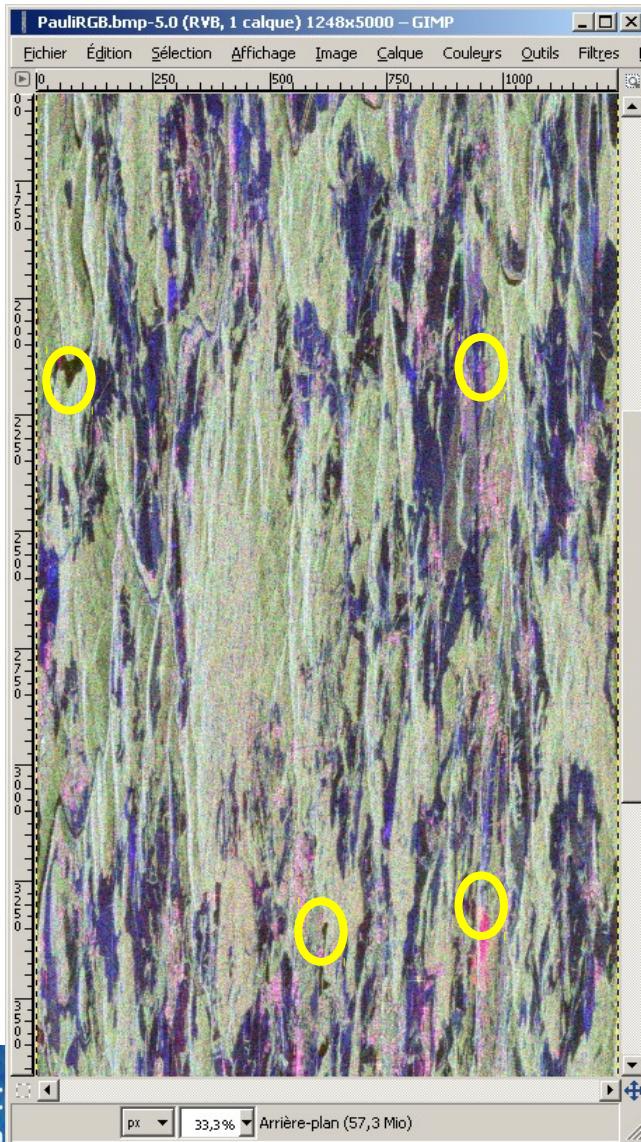


Slave Pauli Image

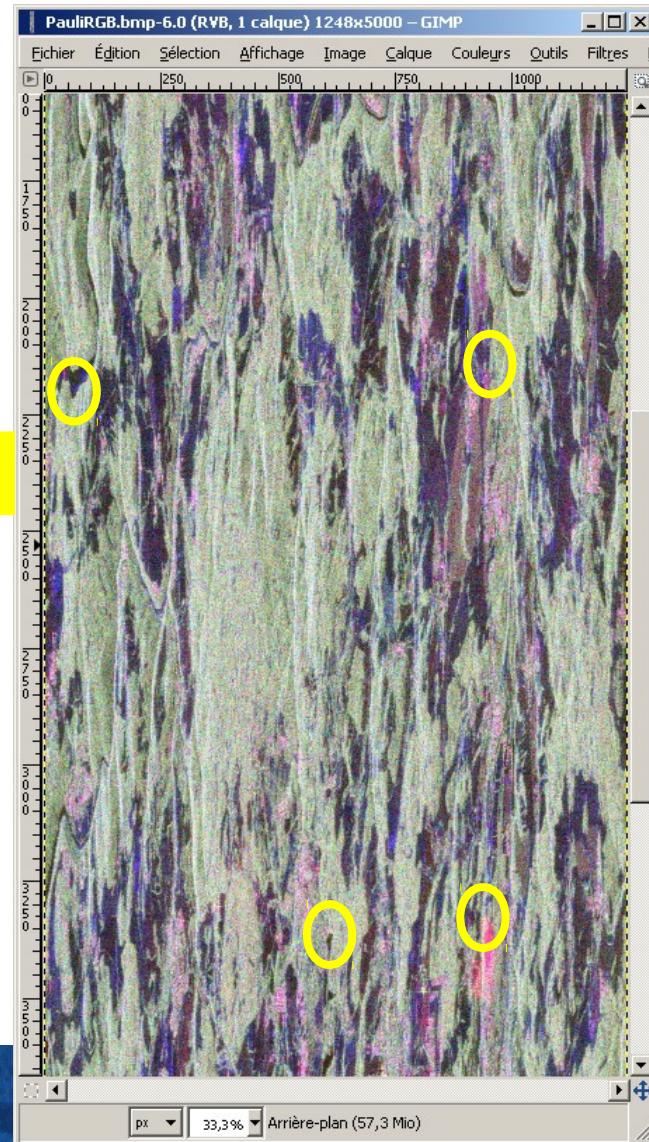


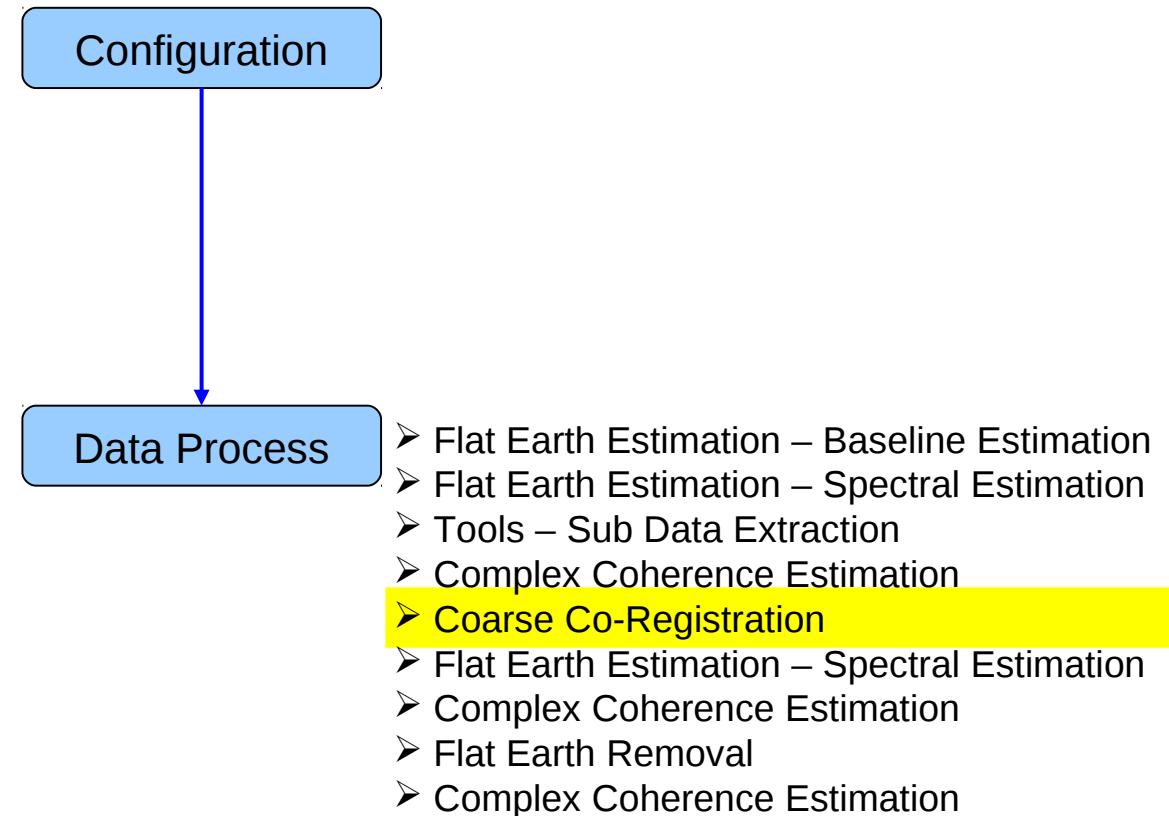
# COMPLEX COHERENCE ESTIMATION

Master Pauli Image



Slave Pauli Image





# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration

Flat Earth Estimation

Flat Earth Removal

[S2] Elements

Speckle Filter

Interferogram

Coherences Estimation

Coherences Analysis

Height Estimation

Polarization Coherence Tomography (PCT)

POLInSAR Segmentation

Data Analysis

Spectral Estimation  
Baseline Estimation

Master  
Slave

Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter

Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# BASIC COARSE COREGISTRATION



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

Environment Import Convert Process Display

Pol-InSAR Coarse Co-Registration

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Shift Estimation: Window Size (Row) 1024 Window Size (Col) 256 Run

Shift Row: Top - Left 22 Top - Right 24 Center 22 Bottom - Left 24 Bottom - Right 23

Shift Col: Top - Left -8 Top - Right -8 Center -8 Bottom - Left -8 Bottom - Right -8

Co-Registration: Shift Row 23 Shift Col -8

Output Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR

Run ? Exit

Pol-InSAR Coarse Co-Registration

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Shift Estimation: Window Size (Row) 1024 Window Size (Col) 256 Run

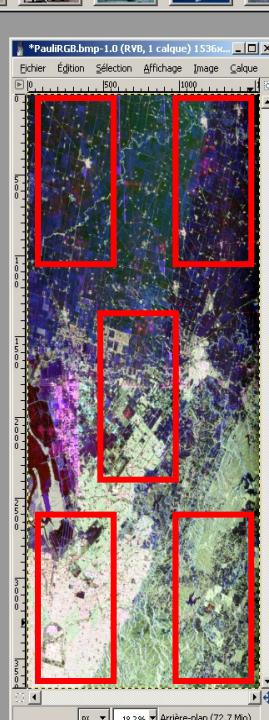
Shift Row: Top - Left 22 Top - Right 24 Center 22 Bottom - Left 24 Bottom - Right 23

Shift Col: Top - Left -8 Top - Right -8 Center -8 Bottom - Left -8 Bottom - Right -8

Co-Registration: Shift Row 23 Shift Col -8

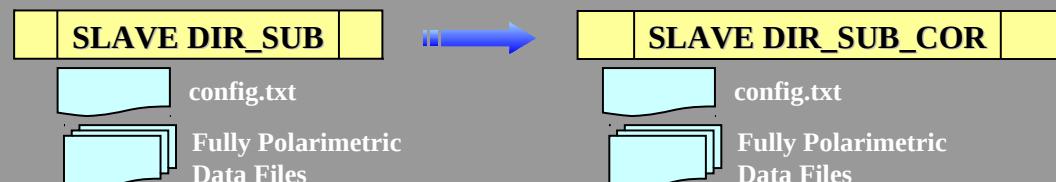
Output Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR

Run ? Exit



## Do it Yourself:

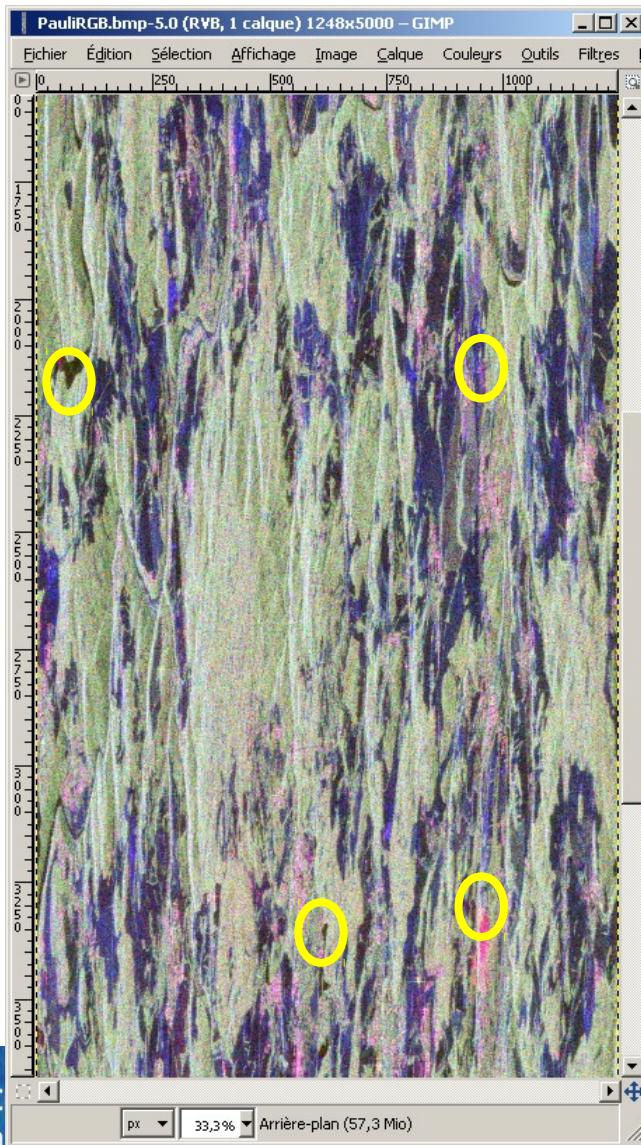
- Set the Analysis Window size  
Row = 1024    Col = 256



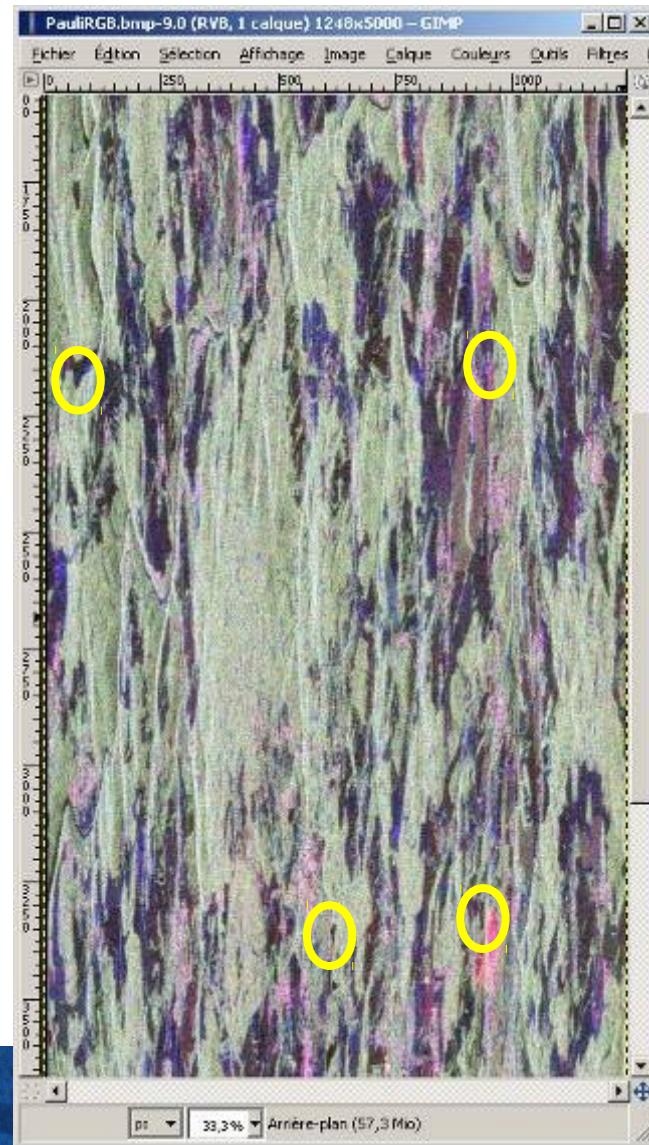
PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

# BASIC COARSE COREGISTRATION

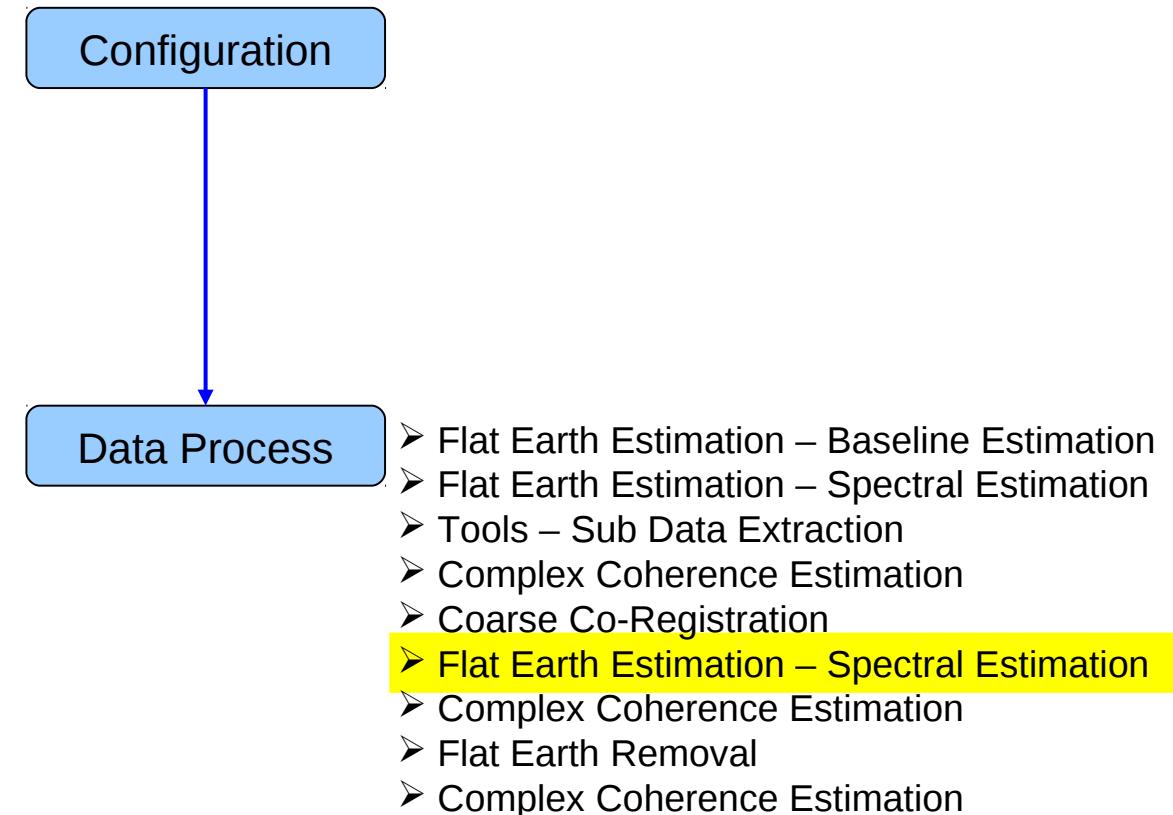
Master Pauli Image



Slave Pauli Image



# PROCESSING CHAIN



# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[S2] [T6]

Spectral Estimation  
Baseline Estimation

Master Slave

Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter

Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

```
graph TD; S2[Process Data - [S2] - MENU] --> S2Button[ ]; S2 --> T6Button[ ]; S2 --> MainMenu[ ]; S2 --> SubMenus[ ]; S2 --> Bottom[ ]; S2Button --> S2List[ ]; S2List --> S2SubMenus[ ]; S2SubMenus --> S2SubSubMenus[ ]; S2SubSubMenus --> S2Bottom[ ]; T6Button --> T6List[ ]; T6List --> T6SubMenus[ ]; T6SubMenus --> T6Bottom[ ]; MainMenu --> Coarse[ ]; MainMenu --> FlatEarth[ ]; MainMenu --> FlatEarthRemoval[ ]; MainMenu --> S2Elements[ ]; MainMenu --> SpeckleFilter[ ]; MainMenu --> Interferogram[ ]; MainMenu --> CoherencesEstimation[ ]; MainMenu --> CoherencesAnalysis[ ]; MainMenu --> HeightEstimation[ ]; MainMenu --> PCT[ ]; MainMenu --> Segmentation[ ]; MainMenu --> DataAnalysis[ ]; Coarse --> S2SubMenus[ ]; FlatEarth --> S2SubMenus[ ]; FlatEarthRemoval --> S2SubMenus[ ]; S2Elements --> S2SubMenus[ ]; SpeckleFilter --> S2SubMenus[ ]; Interferogram --> S2SubMenus[ ]; CoherencesEstimation --> S2SubMenus[ ]; CoherencesAnalysis --> S2SubMenus[ ]; HeightEstimation --> S2SubMenus[ ]; PCT --> S2SubMenus[ ]; Segmentation --> S2SubMenus[ ]; DataAnalysis --> S2SubMenus[ ]; S2SubMenus --> S2SubSubMenus[ ]; S2SubSubMenus --> S2Bottom[ ]; S2SubSubMenus --> T6SubMenus[ ]; S2SubSubMenus --> S2SubSubSubMenus[ ]; S2SubSubSubMenus --> S2Bottom[ ]; T6SubMenus --> T6SubSubMenus[ ]; T6SubSubMenus --> T6Bottom[ ]; S2SubSubSubMenus --> S2Bottom[ ]; S2Bottom --> S2BottomText[ ]; T6Bottom --> T6BottomText[ ]; S2BottomText --> S2BottomText[ ]; T6BottomText --> T6BottomText[ ];
```

nest

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# SPECTRAL ESTIMATION



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

Environment Import Convert Process Display

Help Home About

**POLinSAR Flat Earth Estimation**

Input Master File: C:/Prague\_28032007\_Master\_SUB/s11.bin

Input Slave File: C:/Prague\_13052007\_Slave\_SUB\_COR/s11.bin

Output Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Polarisation Channel:  s11  s12  s21  s22

Window Size (Row): 1024 Window Size (Col): 256

Output Format:  real ( deg )  real ( rad )  cmplx ( cos, sin )

Run ? Exit

**POLinSAR Flat Earth Estimation**

Input Master File: C:/Prague\_28032007\_Master\_SUB/s11.bin

Input Slave File: C:/Prague\_13052007\_Slave\_SUB\_COR/s11.bin

Output Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Polarisation Channel:  s11  s12  s21  s22

Window Size (Row): 1024 Window Size (Col): 256

Output Format:  real ( deg )  real ( rad )  cmplx ( cos, sin )

Run ? Exit

\*PaulIRGB.bmp-1.0 (RVB, 1 couleur) 1536x1024

Image showing a satellite radar image with a red rectangular box highlighting a specific area.

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.

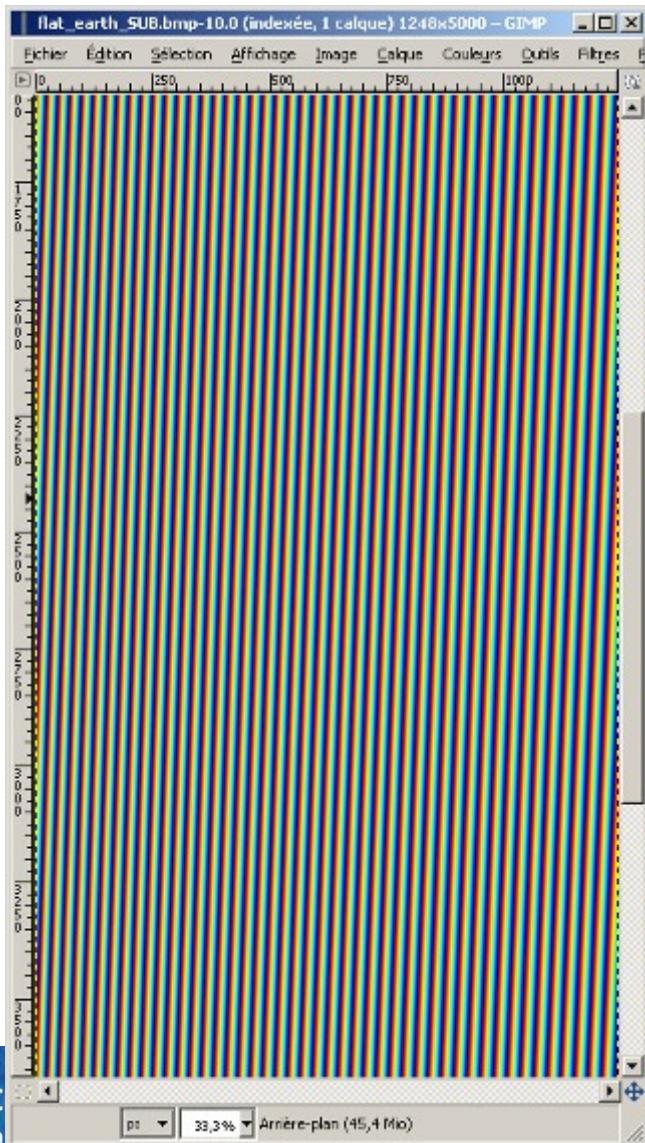
PolSARpro v4.0 - Run Trace

Open Window Environment Dual Close Window Environment Dual

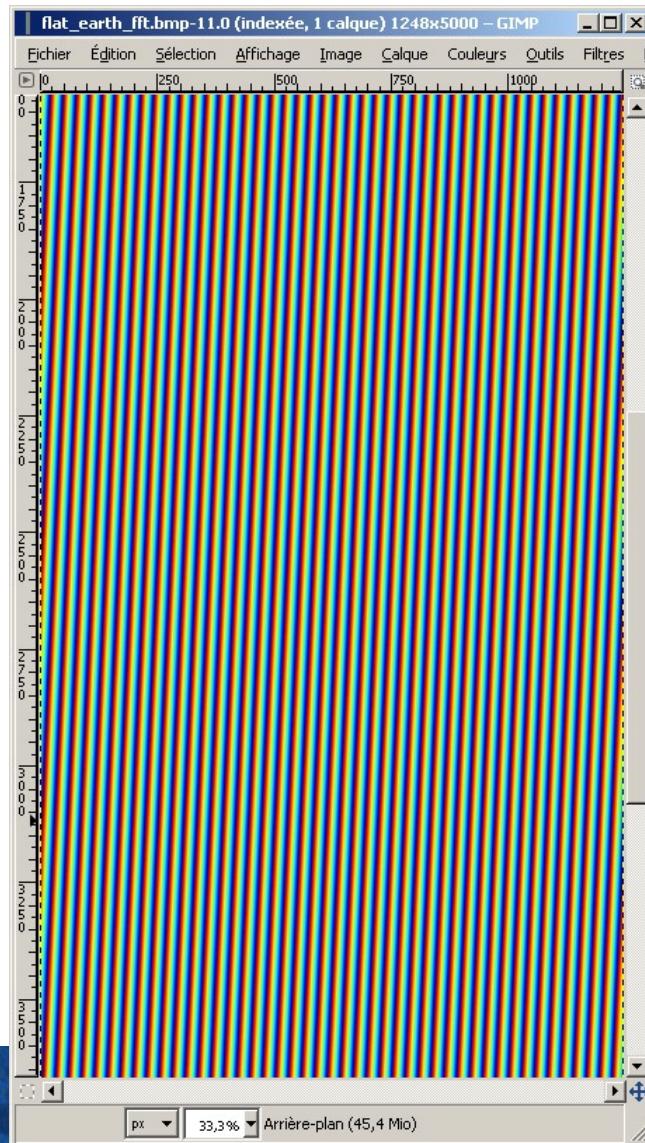
# SPECTRAL ESTIMATION

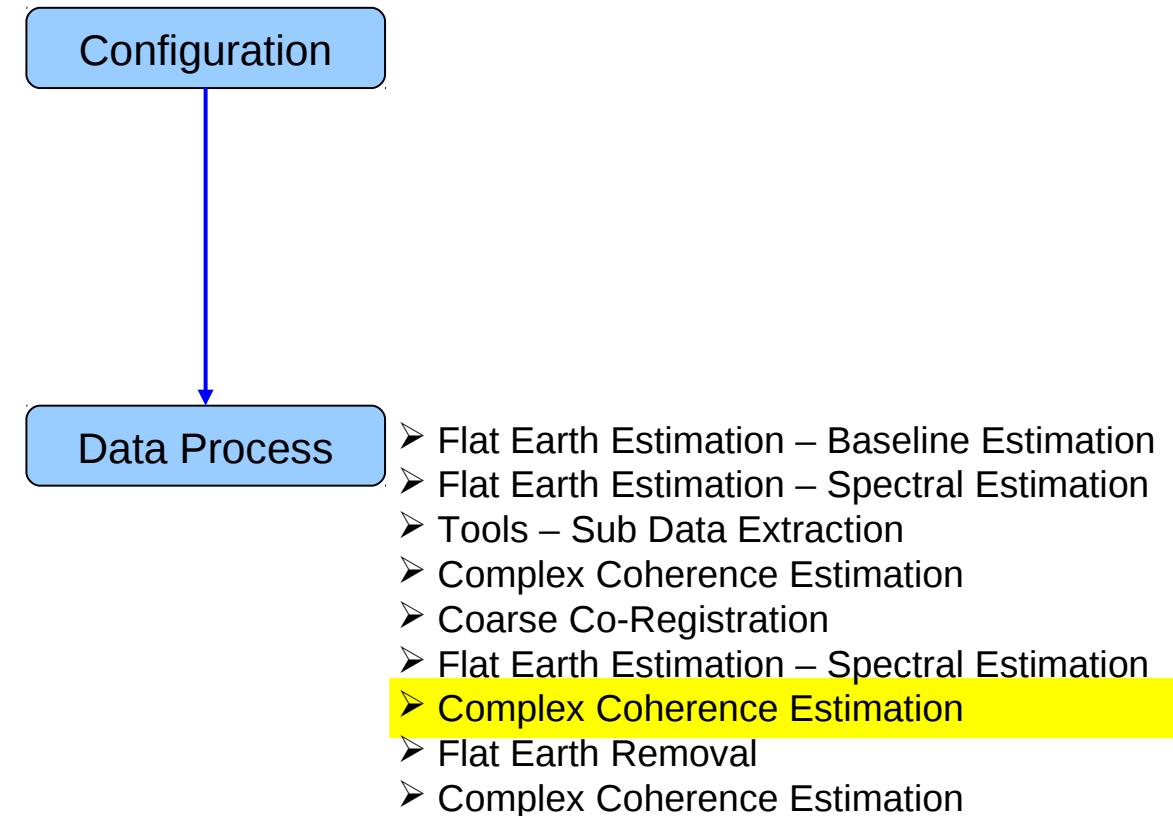


Flat Earth



Flat Earth FFT





# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
Flat Earth Removal  
[S2] Elements  
Speckle Filter  
Interferogram  
**Coherences Estimation** (circled)  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector

Complex Plane  
Coherence Region - Optimum Triplet

Inversion Procedures  
Vegetation Height Estimation

Wishart Supervised Classification  
Wishart Unsupervised Classification

Data Histograms  
Data Profiles  
Coeff of Variation

PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

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# COMPLEX COHERENCE ESTIMATION



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

Environment Import Convert Process Display

Complex Coherence Estimation

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR

Output Master-Slave Directory: C:/Prague\_28032007\_Master\_SUB\_Prague\_13052007\_Slave\_SUB\_COR

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Complex Coherences:

Linear: HH, HV, VV, Pauli, HH+VV, HH·VV, HV+VH  
Circular: LL, LR, RR, Optimal, SVD, PD, NR, L. MinMax, L. Diff

Numerical Radius: Theta1, Theta3  
Loci MinMax: Num Points  
Loci Diff: Num Points

Box Car Window: Row 7, Col 7  
Averaging Window: Row 7, Col 7  
BMP: checked  
Averaging: checked

Run Hist ? Exit

Complex Coherence Estimation

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR

Output Master-Slave Directory: C:/Prague\_28032007\_Master\_SUB\_Prague\_13052007\_Slave\_SUB\_COR

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Complex Coherences:

Linear: HH, HV, VV, Pauli, HH+VV, HH·VV, HV+VH  
Circular: LL, LR, RR, Optimal, SVD, PD, NR, L. MinMax, L. Diff

Numerical Radius: Theta1, Theta3  
Loci MinMax: Num Points  
Loci Diff: Num Points

Box Car Window: Row 7, Col 7  
Averaging Window: Row 7, Col 7  
BMP: checked  
Averaging: checked

Run Hist ? Exit

## 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.

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

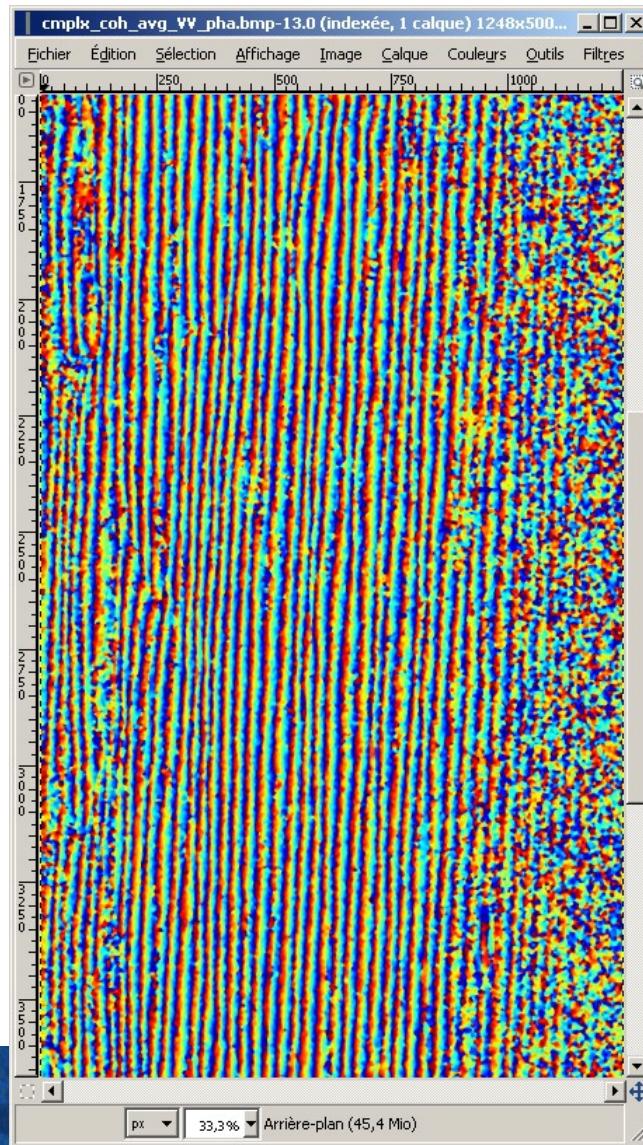
# COMPLEX COHERENCE ESTIMATION



[cmplx\\_coh\\_avg\\_VV\\_mod](#)



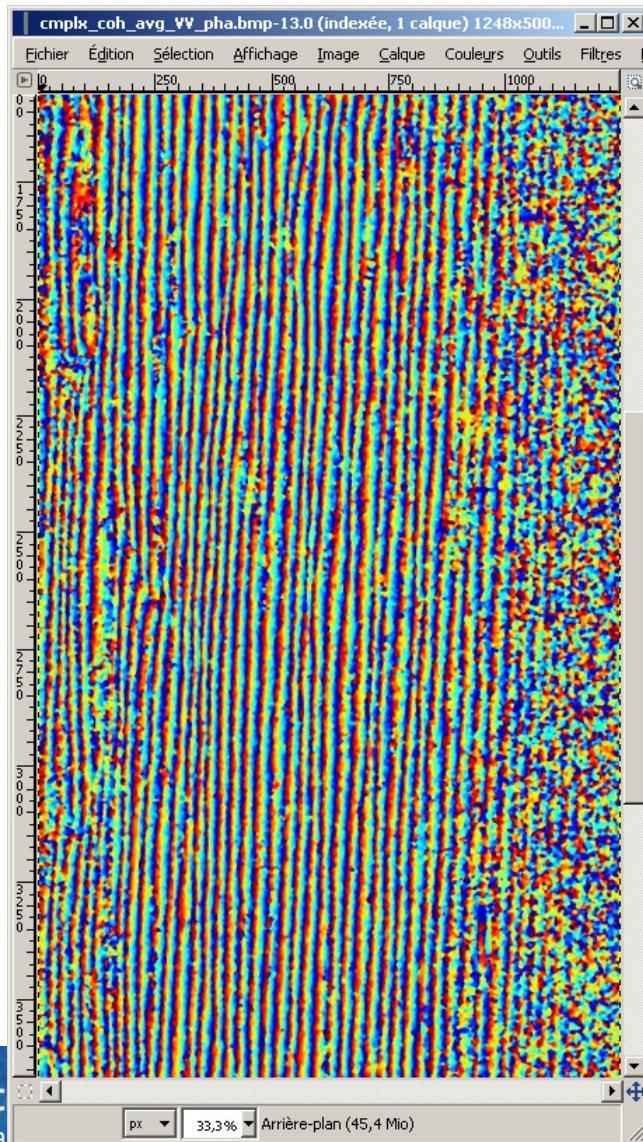
[cmplx\\_coh\\_avg\\_VV\\_phha](#)



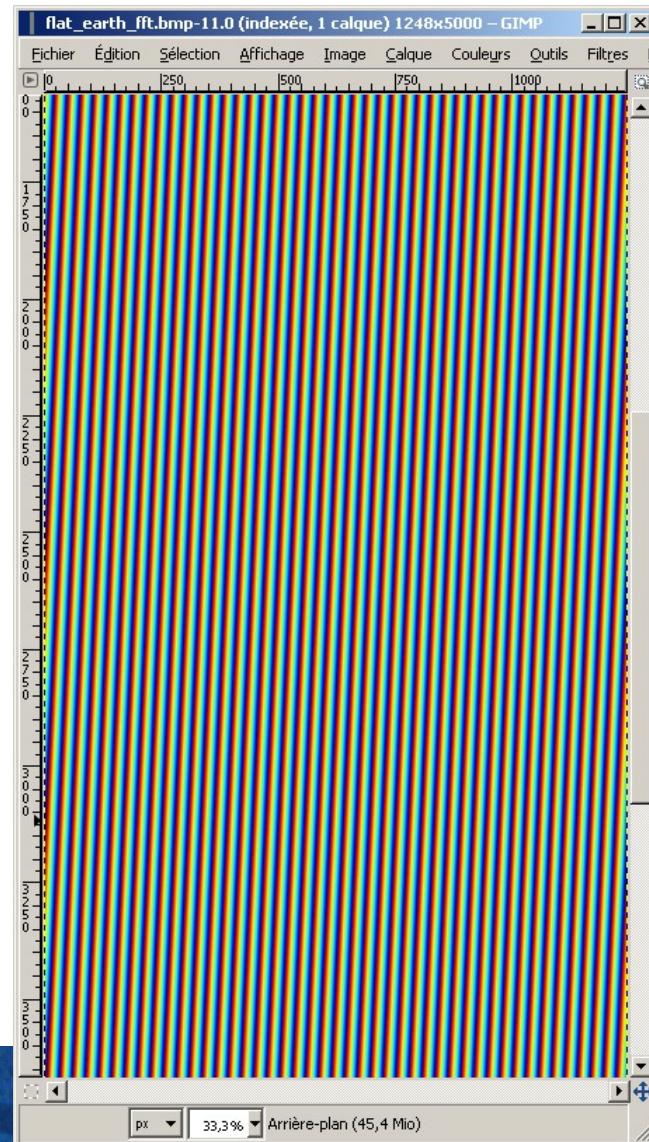
# COMPLEX COHERENCE ESTIMATION



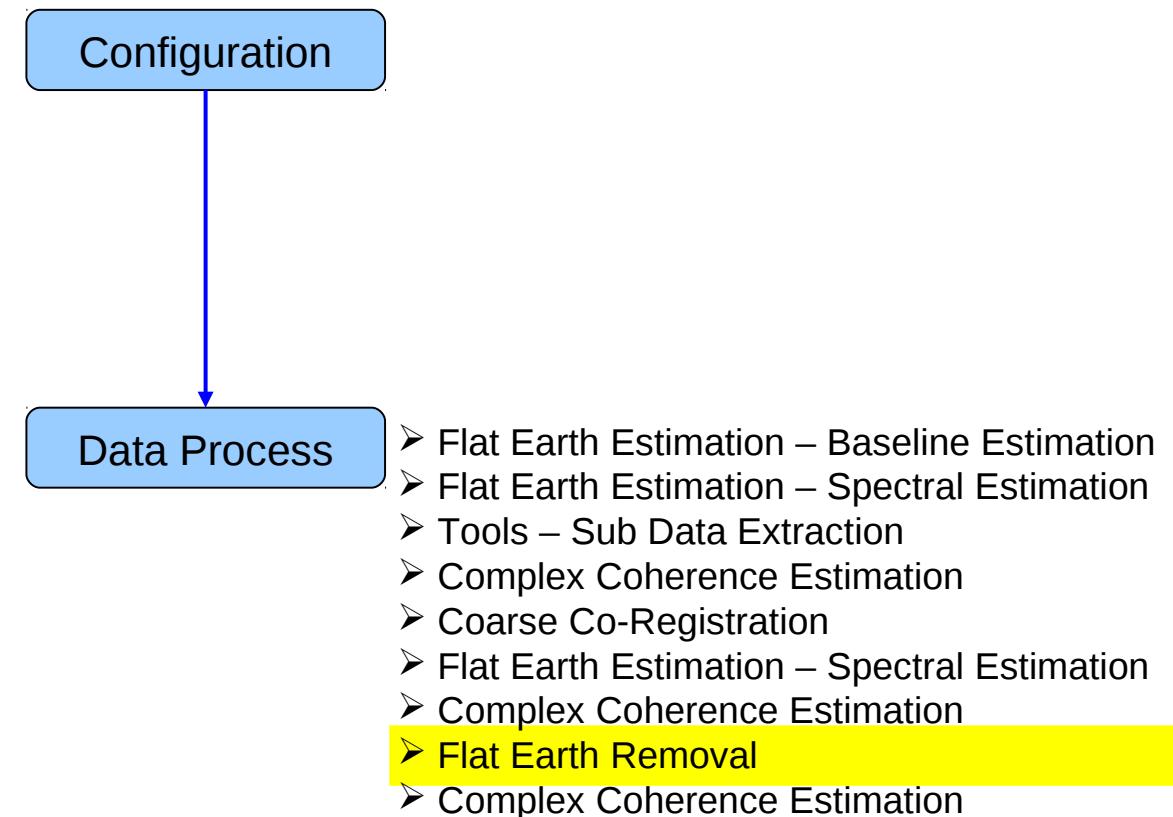
**cmplx\_coh\_avg\_VV\_ph**



**Flat Earth FFT**



# PROCESSING CHAIN



# PROCESS DATA - [S2] - MENU



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

Environment Import Convert Process Display [S2] [T6]

[nest] About

[S2] ► [T6] ►

Coarse Co-Registration  
Flat Earth Estimation  
**Flat Earth Removal**  
[S2] Elements  
Speckle Filter  
Interferogram  
Coherences Estimation  
Coherences Analysis  
Height Estimation  
Polarization Coherence Tomography (PCT)  
POLSAR Segmentation  
POLinSAR Segmentation  
Data Analysis

Spectral Estimation  
Baseline Estimation  
Master Slave  
Box Car Filter  
Gaussian Filter  
J.S. Lee Refined Filter  
J.S. Lee Sigma Filter  
Edge Detector  
Complex Plane  
Coherence Region - Optimum Triplet  
Inversion Procedures  
Vegetation Height Estimation  
Wishart Supervised Classification  
Wishart Unsupervised Classification  
Data Histograms  
Data Profiles  
Coeff of Variation

```
graph TD; S2_main["[S2] ►"] --> S2_submenu["[S2]"]; S2_submenu --> S2_submenu_items["Flat Earth Removal"]; S2_submenu_items --> S2_submenu_items_options["Spectral Estimation / Baseline Estimation / Master Slave / Box Car Filter / Gaussian Filter / J.S. Lee Refined Filter / J.S. Lee Sigma Filter / Edge Detector / Complex Plane / Coherence Region - Optimum Triplet / Inversion Procedures / Vegetation Height Estimation / Wishart Supervised Classification / Wishart Unsupervised Classification / Data Histograms / Data Profiles / Coeff of Variation"];
```

PolSARpro v4.0 - Run Trace

Open Window Environment Dual  
Close Window Environment Dual

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# FLAT EARTH REMOVAL



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

Environment Import Convert Process Display

Help Home About

**POLinSAR Flat Earth Removal**

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

2D Flat Earth File: C:/Prague\_13052007\_Slave\_SUB/flat\_earth\_SUB.bin

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

Symmetrisation  Conjugate

Output Master Directory: C:/Prague\_28032007\_Master\_SUB

Output Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR\_FER

Run Exit

**POLinSAR Flat Earth Removal**

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

2D Flat Earth File: **C:/Prague\_13052007\_Slave\_SUB/flat\_earth\_SUB.bin** (highlighted with a red circle)

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

Symmetrisation  Conjugate

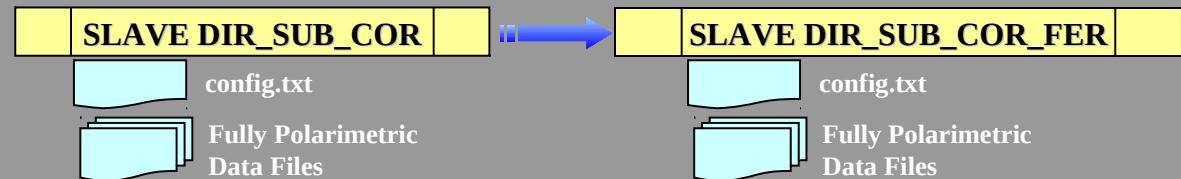
Output Master Directory: C:/Prague\_28032007\_Master\_SUB

Output Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR\_FER

Run Exit

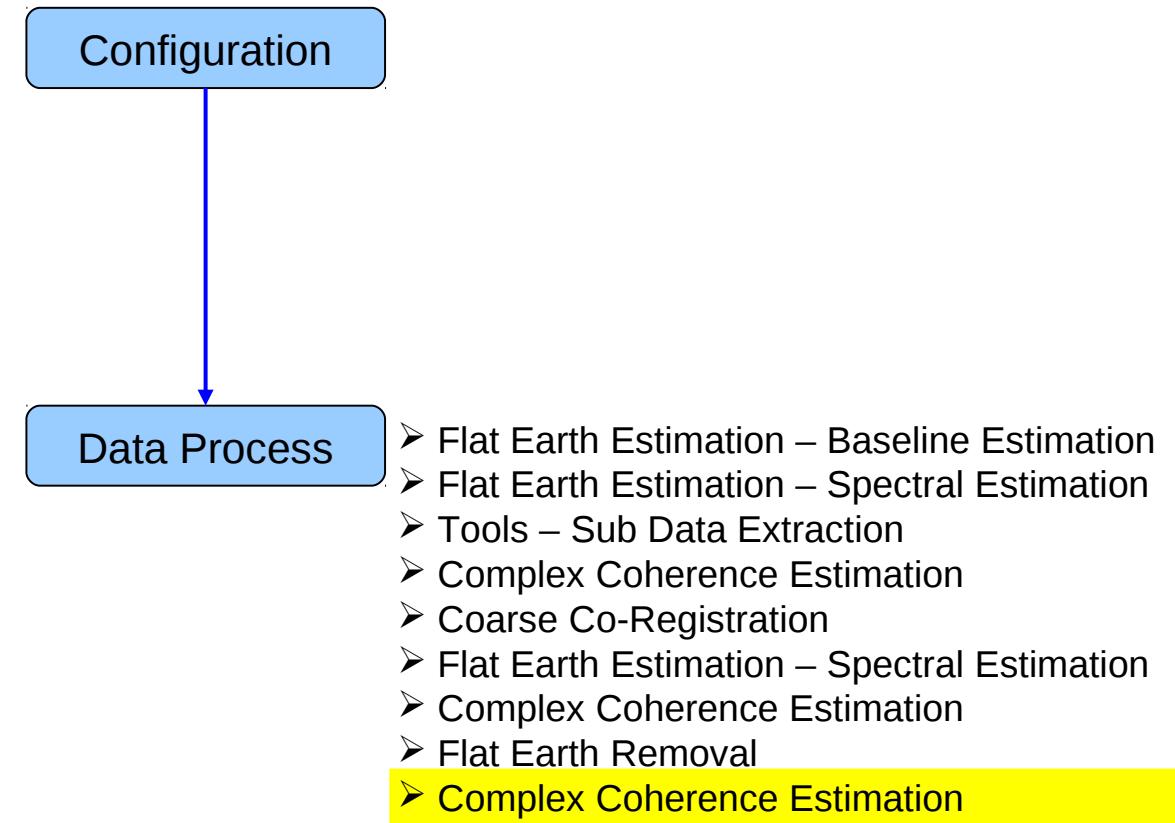
## Do it Yourself:

- Enter the 2D Flat Earth file
- Select conjugate



PolSARpro v4.0 - Run Trace  
Open Window Environment Dual  
Close Window Environment Dual

# PROCESSING CHAIN



# COMPLEX COHERENCE ESTIMATION



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

Environment Import Convert Process Display

Complex Coherence Estimation

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR\_FER

Output Master-Slave Directory: C:/Prague\_28032007\_Master\_SUB\_Prague\_13052007\_Slave\_SUB\_COR\_FER

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Complex Coherences

Linear: HH HV VV Pauli HH + VV HH - VV HV + VH  
Circular: LL LR RR Optimal SVD PD NR L. MinMax L. Diff

Numerical Radius: Theta1 Theta3 Loci MinMax Num Points Loci Diff Num Points

Box Car Window: Row 7 Col 7 BMP Averaging Window: Row 7 Col 7

Run Hist Help Exit

Complex Coherence Estimation

Input Master Directory: C:/Prague\_28032007\_Master\_SUB

Input Slave Directory: C:/Prague\_13052007\_Slave\_SUB\_COR\_FER

Output Master-Slave Directory: C:/Prague\_28032007\_Master\_SUB\_Prague\_13052007\_Slave\_SUB\_COR\_FER

Init Row: 1 End Row: 5000 Init Col: 1 End Col: 1248

Complex Coherences

Linear: HH HV  VV Pauli HH + VV HH - VV HV + VH  
Circular: LL LR RR Optimal SVD PD NR L. MinMax L. Diff

Numerical Radius: Theta1 Theta3 Loci MinMax Num Points Loci Diff Num Points

Box Car Window: Row 7 Col 7 BMP Averaging Window: Row 7 Col 7

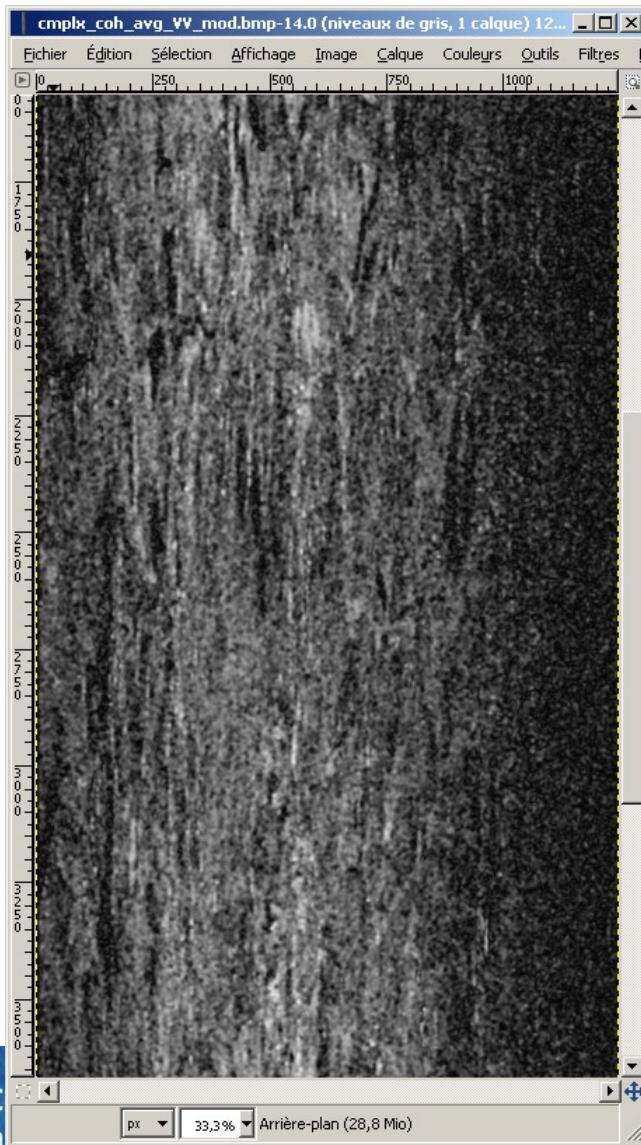
Run Hist Help Exit

## Do it Yourself:

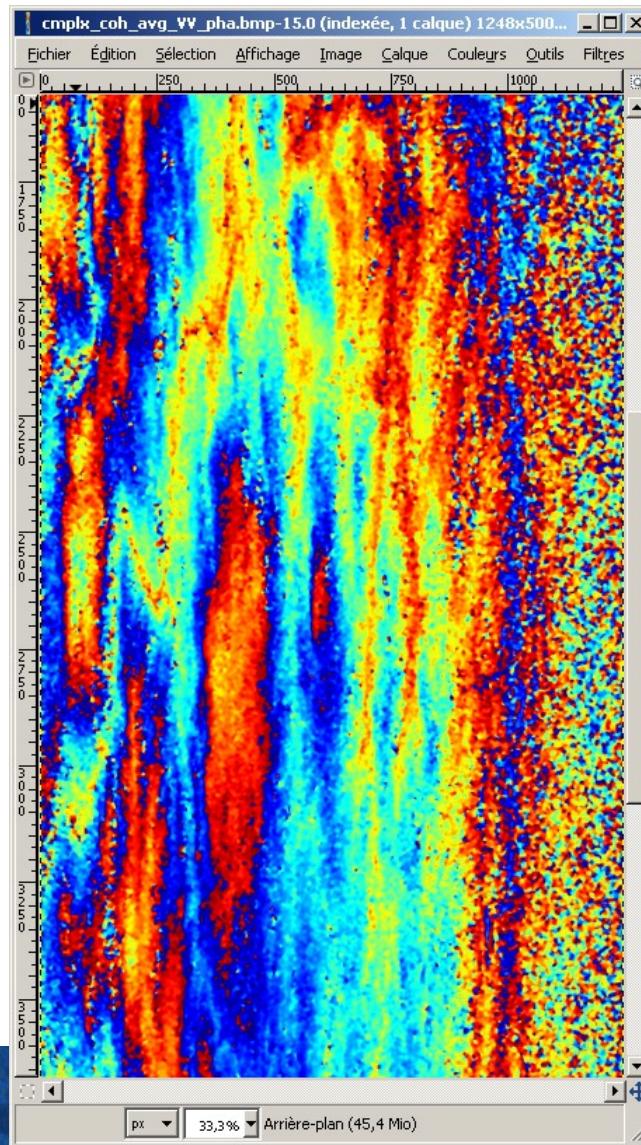
- Select the polarization channel
- Set the Analysis Window size (7)
- Select BMP and Averaging
- Set the Analysis Averaging Window size (7)
- View the corresponding BMP files.

# COMPLEX COHERENCE ESTIMATION

cmplx\_coh\_avg\_VV\_mod



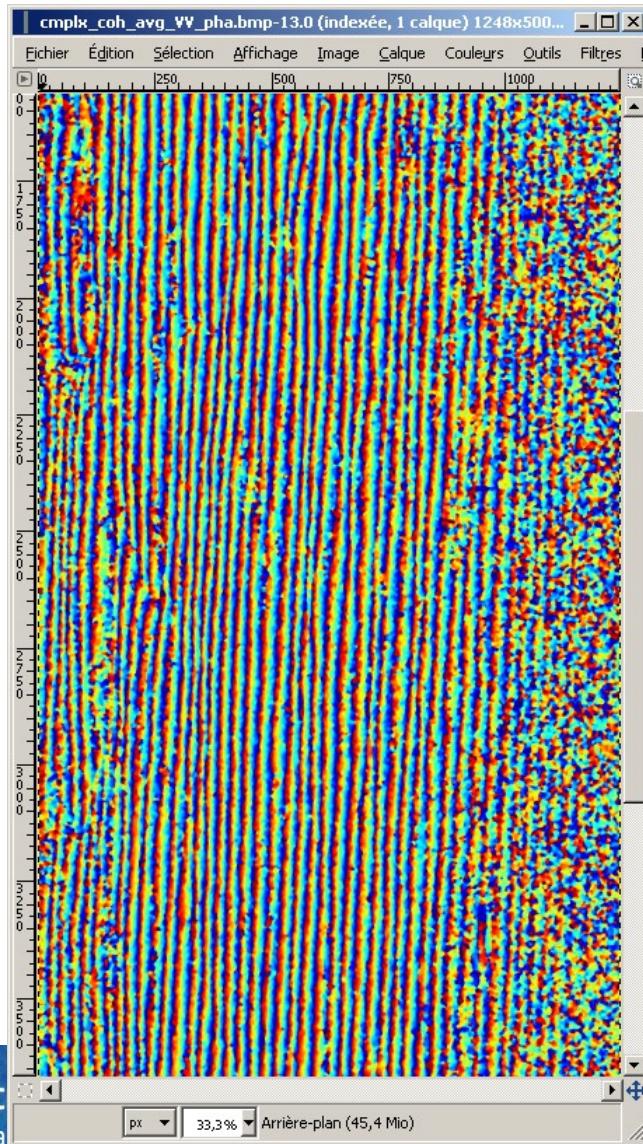
cmplx\_coh\_avg\_VV\_phd



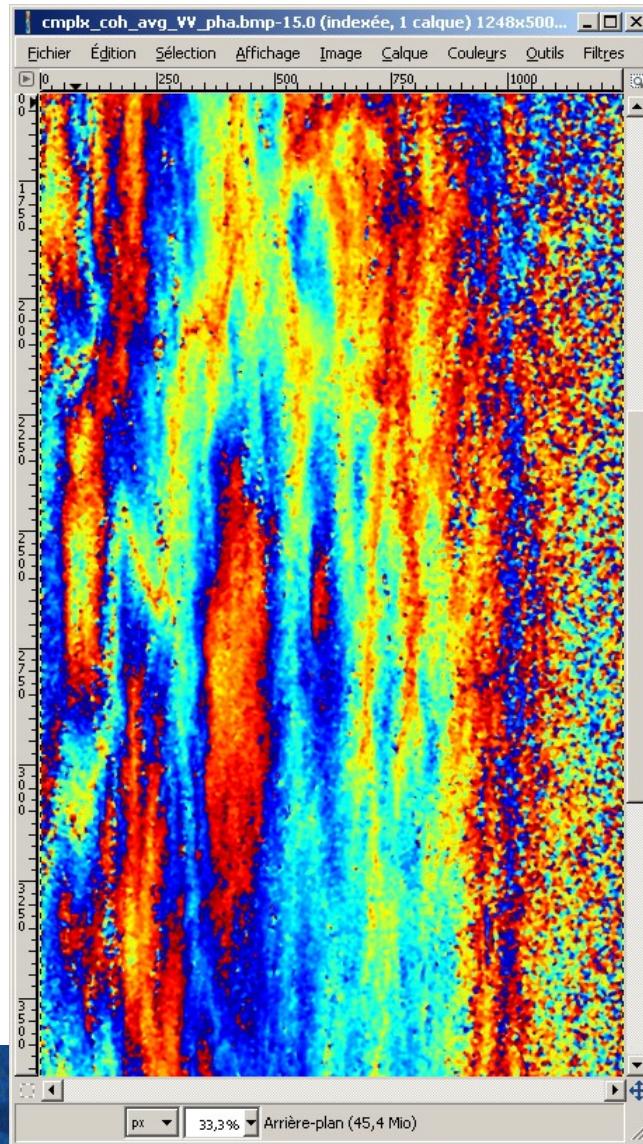
# COMPLEX COHERENCE ESTIMATION



cmplx\_coh\_avg\_VV\_ph



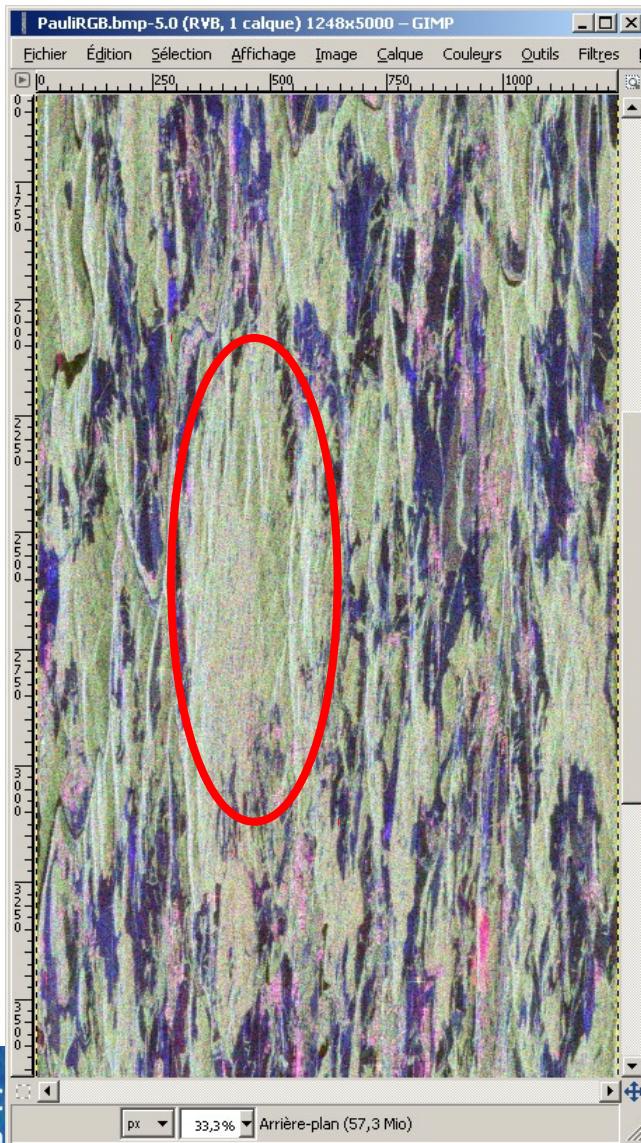
cmplx\_coh\_avg\_VV\_ph



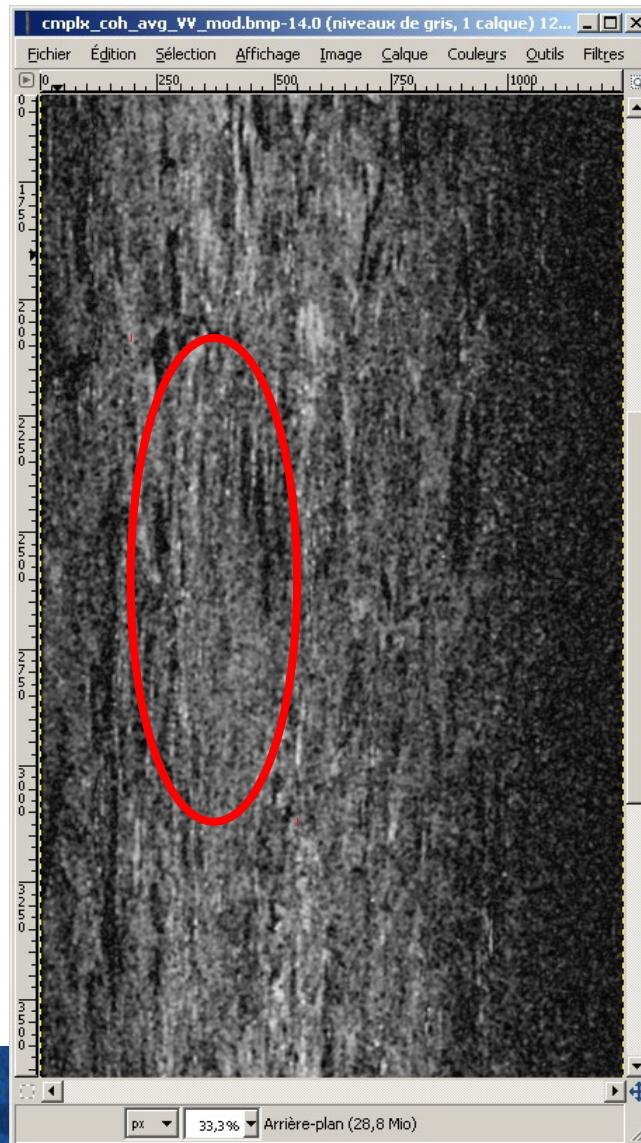
# CONCLUSION



Master Pauli Image



cmplx\_coh\_avg\_VV\_mod



?

# CONCLUSION



POLsar IMAGES

$$I_1 = \frac{\mathbf{w}_1^T * \mathbf{I} \cdot \mathbf{k}_1}{\|\mathbf{w}_1\|} \quad \text{and} \quad I_2 = \frac{\mathbf{w}_2^T * \mathbf{I} \cdot \mathbf{k}_2}{\|\mathbf{w}_2\|}$$

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



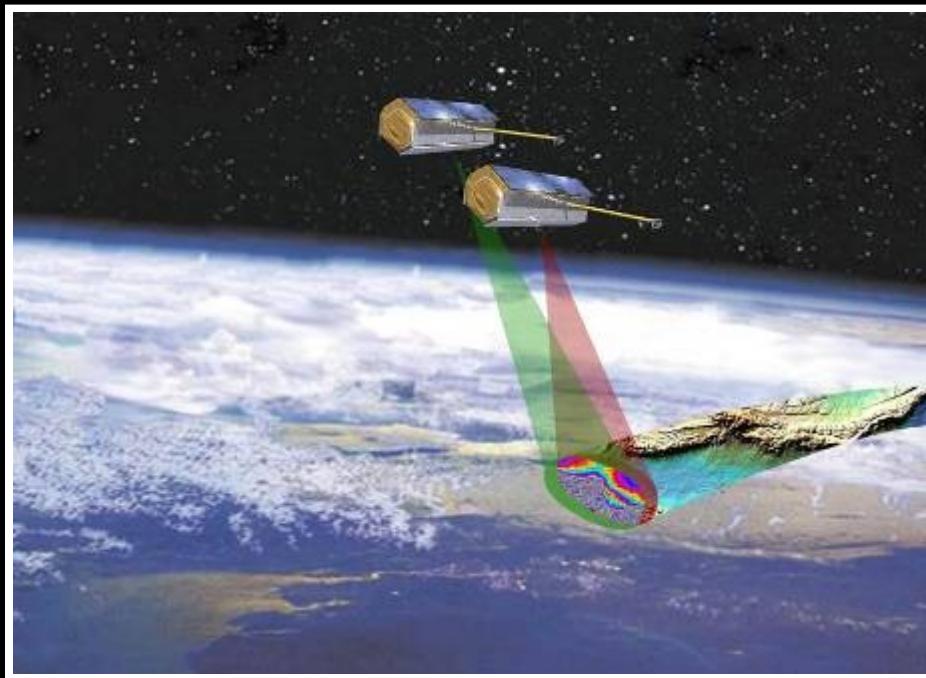
$$\begin{aligned}\mathbf{w}_1^T [\mathbf{T}_1^* \mathbf{T}_2] \mathbf{w}_2 \\ \mathbf{w}_2^T [\mathbf{T}_2^* \mathbf{T}_1] \mathbf{w}_1 \\ \mathbf{w}_1^T [\mathbf{T}_1^* \mathbf{T}_1] \mathbf{w}_1 \\ \mathbf{w}_2^T [\mathbf{T}_2^* \mathbf{T}_2] \mathbf{w}_2\end{aligned}$$
$$Y \langle \mathbf{w}_1, \mathbf{w}_2 \rangle = \frac{\langle I_1, I_2 \rangle}{\sqrt{\langle I_1, I_1 \rangle \langle I_2, I_2 \rangle}} = \epsilon.$$

COMPLEX POLARIMETRIC INTERFEROMETRIC COHERENCE

$$Y = Y_{SNR} \cdot Y_{spatial} \cdot Y_{temporal} \cdot Y_{polar}$$

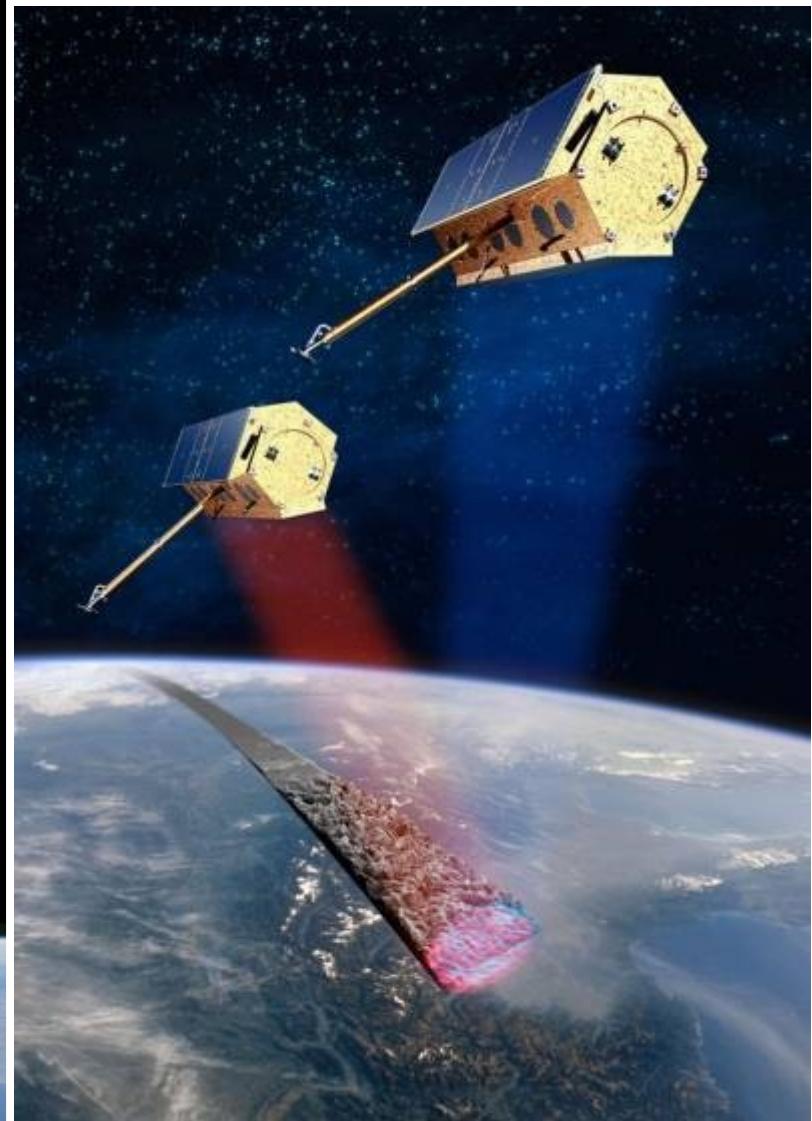
46 days

# TanDEM-X



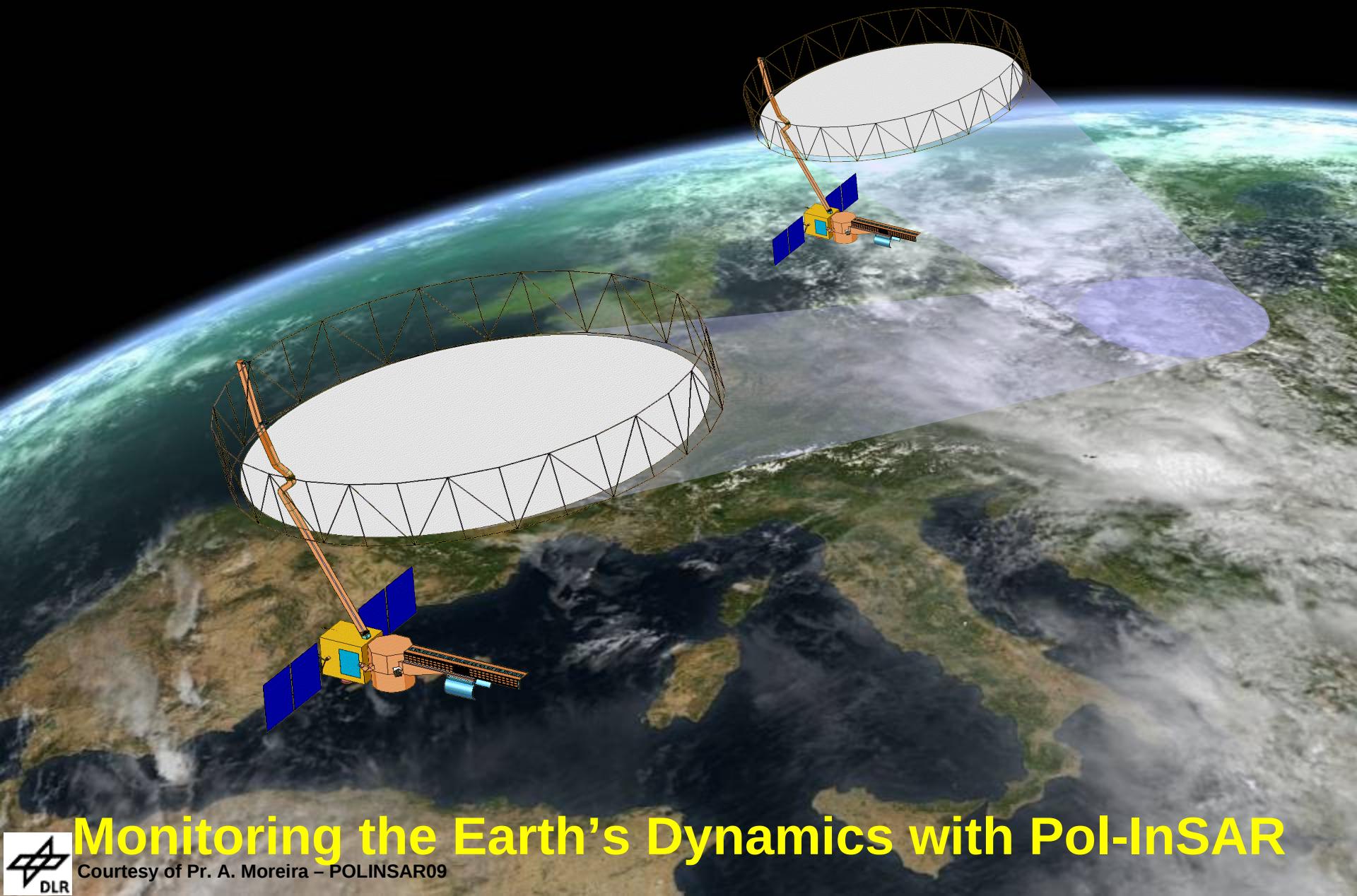
TerraSAR – X (1 & 2)  
(2010)

Pol – InSAR Sensors





# TanDEM-L – DESDynI



**Monitoring the Earth's Dynamics with Pol-InSAR**

Courtesy of Pr. A. Moreira – POLINSAR09

# Questions ?

