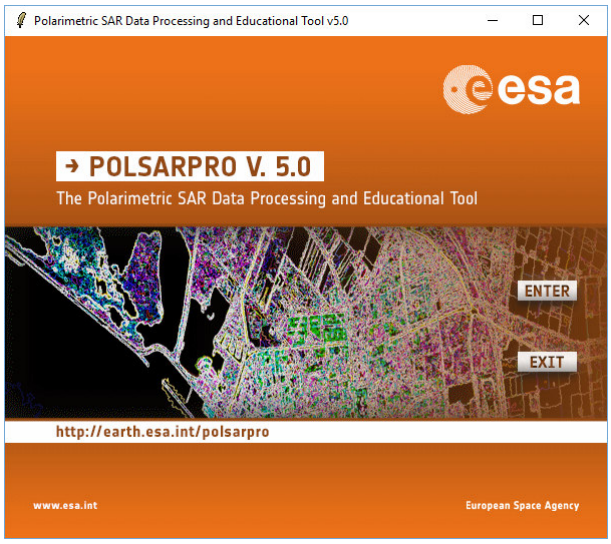
PolSARpro Tutorial

Part 1:
- Introduction
- Hands on Experience
  - Data Import, Image Extraction
  - Matrix Conversion
  - Polarimetric Speckle Filtering

Part 2:
- Polarimetric Decomposition Theorems
- Hands on Experience
  - Matrix Decomposition
  - Land Use Classification

Software Tool
PolSARpro v5.0

The Polarimetric SAR Data Processing



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Please note that the following slide are based on PolSARpro v4.2

The GUI structure and main functions in v5.0 are basically the same with only minor changes in the arrangement of the icons, etc.

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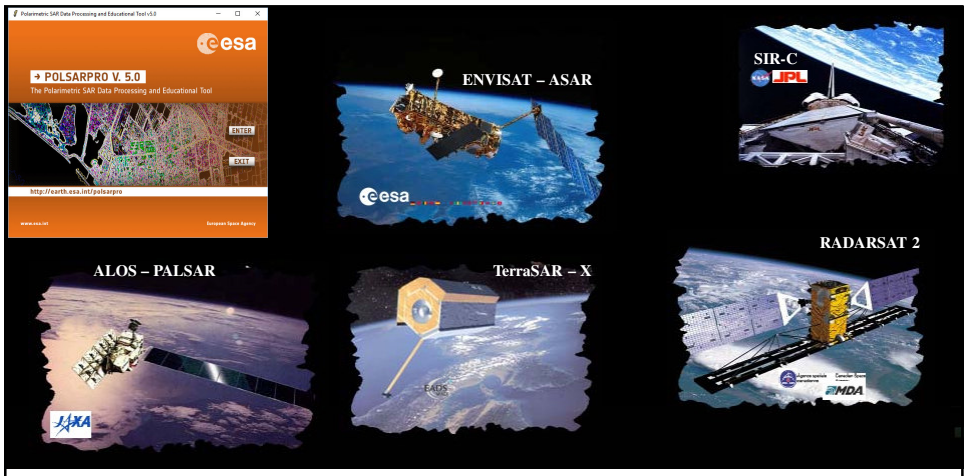
PolSARpro v5.0 Software offers the possibility to handle and convert polarimetric data from a range of well established polarimetric airborne platforms.



PolSARpro v5.0 Software offers the possibility to handle and convert polarimetric data from a range of well established polarimetric airborne platforms.


POLinSAR 2003
Workshop on Applications of SAR Polarimetry and Polarimetric Interferometry
ESA-ESRIN Frascati, Italy
14-16 January 2003
The initiative development of PolSARpro Software is a direct result of recommendations made during the POLinSAR 2003 Workshop held at ESA-ESRIN in January 2003.
POLSARPRO v2.0
PolSARpro v2.0
POLSARPRO
POLSARPRO
2003
2004
2005
2007
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EOPI
Earth
Observation
Principal
Investigator
Portal
http://eopi.esa.int
http://earth.esa.int/gut
http://earth.esa.int/polsarpro
http://earth.esa.int/nest
http://earth.esa.int/beam
http://earth.esa.int/beat
http://earth.esa.int/brat
GUT
POLSARPRO
NEST
BEAM
BEAT
BRAT
ESA free TOOLBOXES to exploit ESA & ESA TPM data available at http://earth.esa.int/resources/softwaretools/
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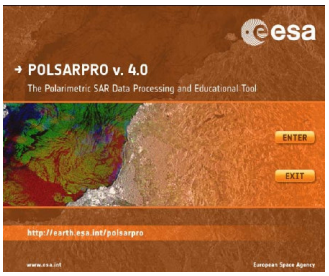
Tool specifically designed to handle :
Polarimetric data
and
Polarimetric Interferometric data.

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



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PolSARpro TEAM

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USER INTERFACE

PolSARpro Software is conceived as a flexible environment, with a friendly and intuitive Graphical User Interface GUI

The graphical user interface (GUI) is written in Tcl-Tk

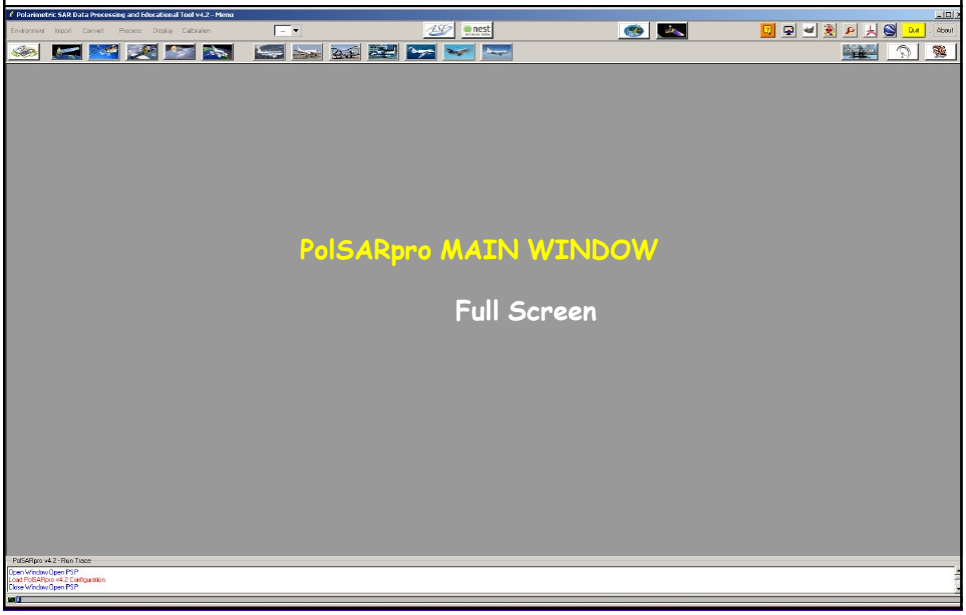
331185 lines managing 189 widget windows

1078 C routines (464803 lines) performing well-established algorithms in the field of POLSAR and POL-InSAR.

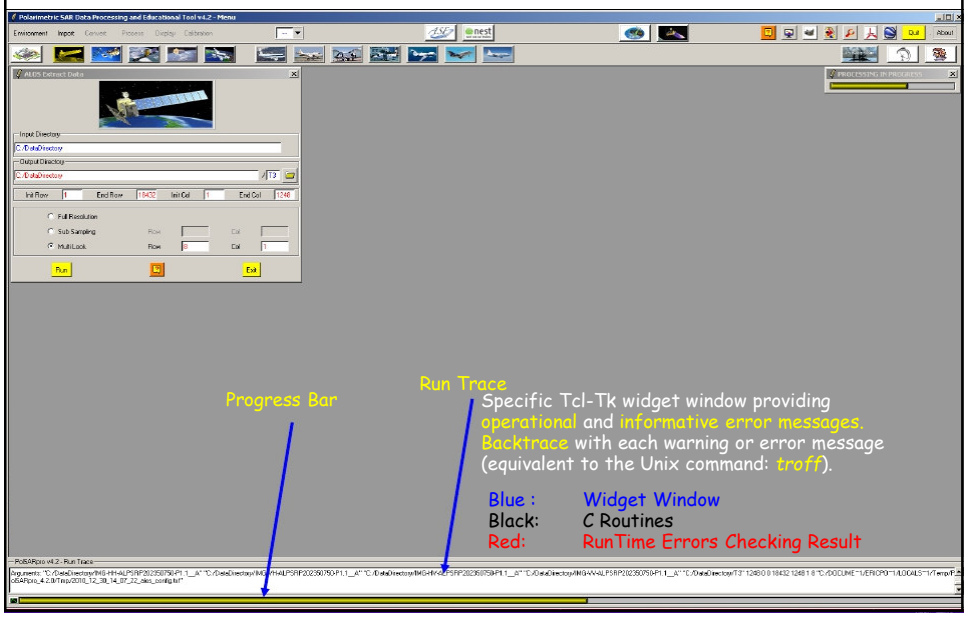
MODULAR STRUCTURE

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

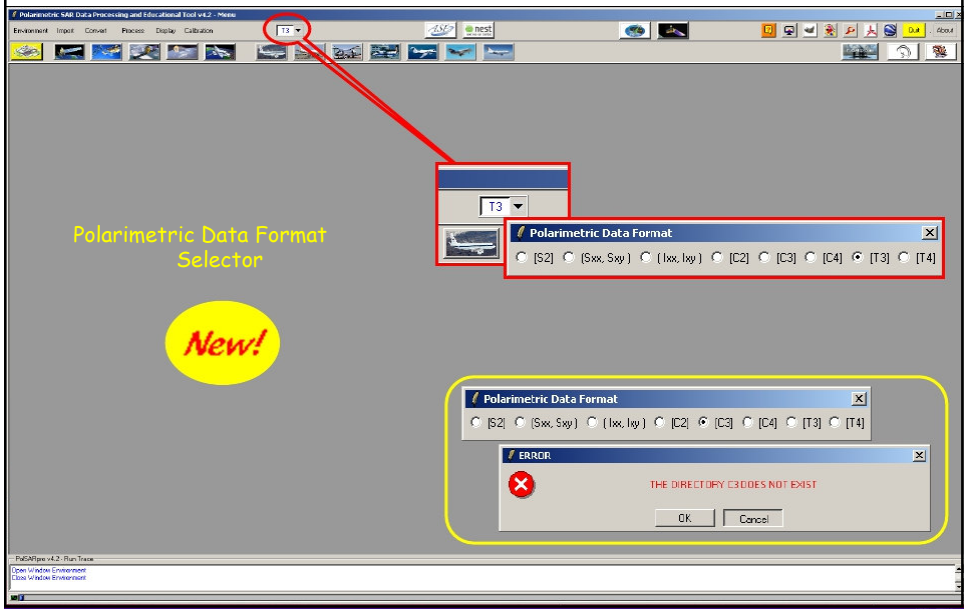
PolSARpro SOFTWARE



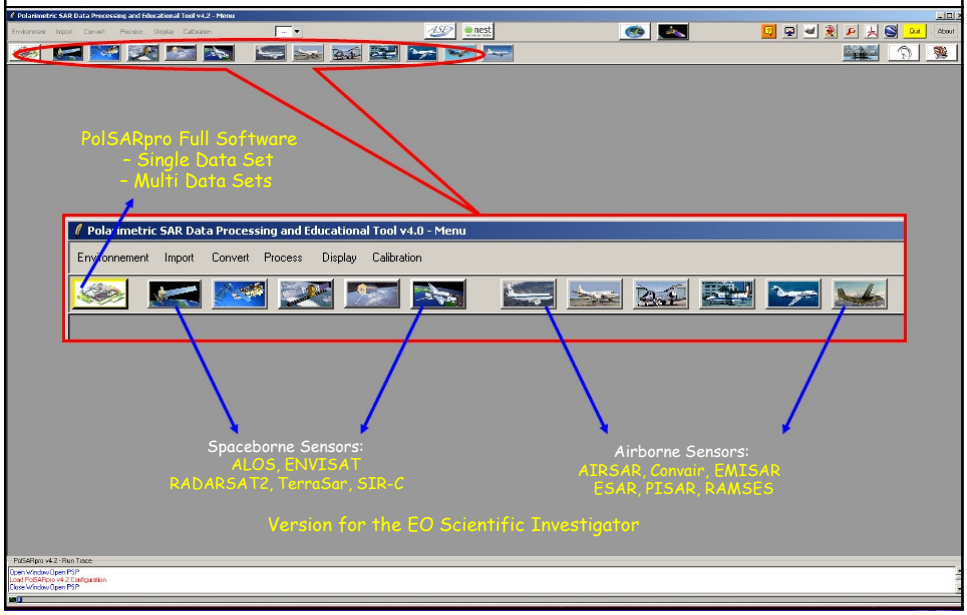
PolSARpro SOFTWARE



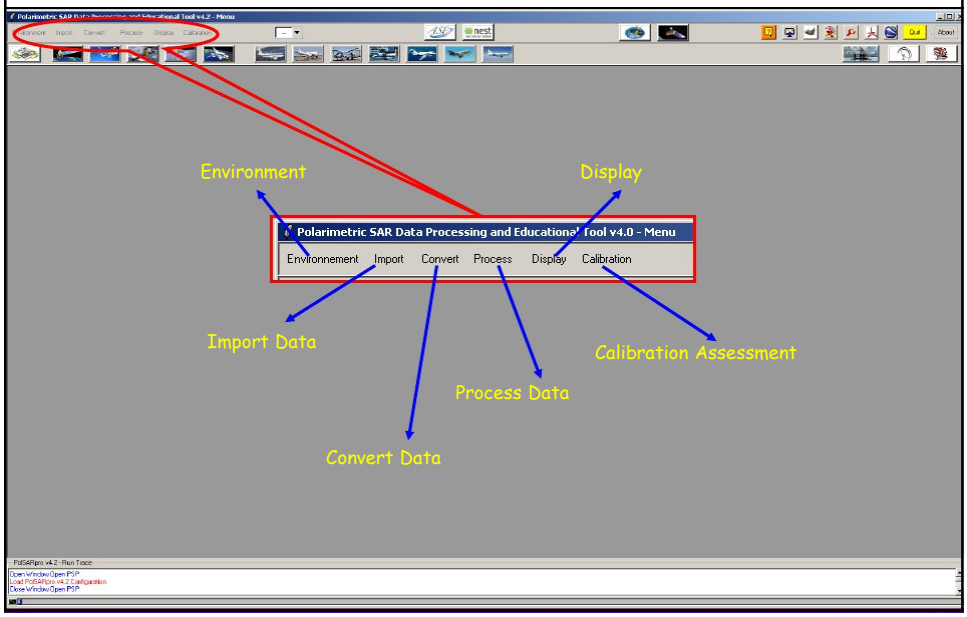
PolSARpro SOFTWARE



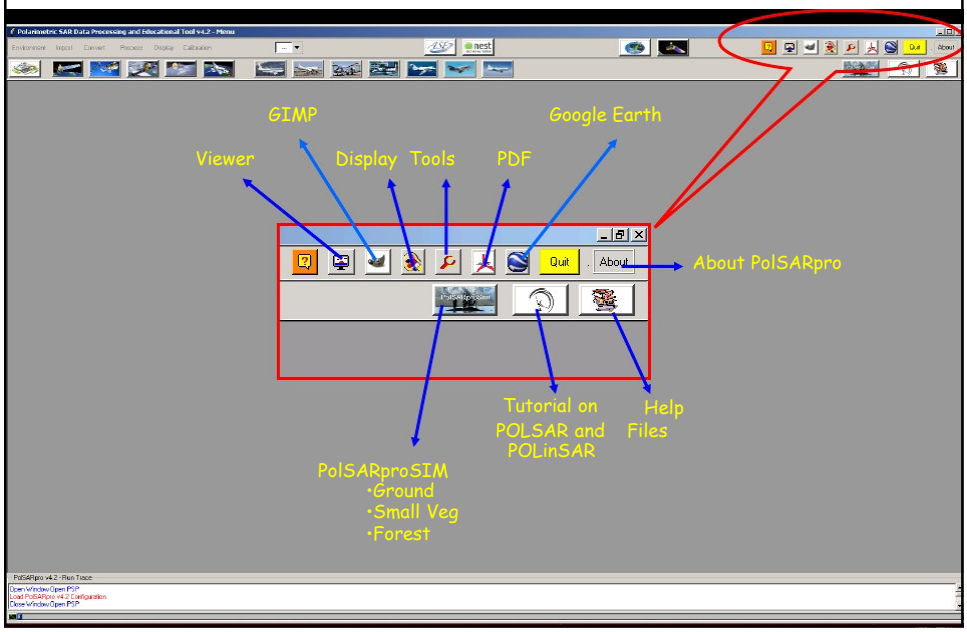
PolSARpro SOFTWARE



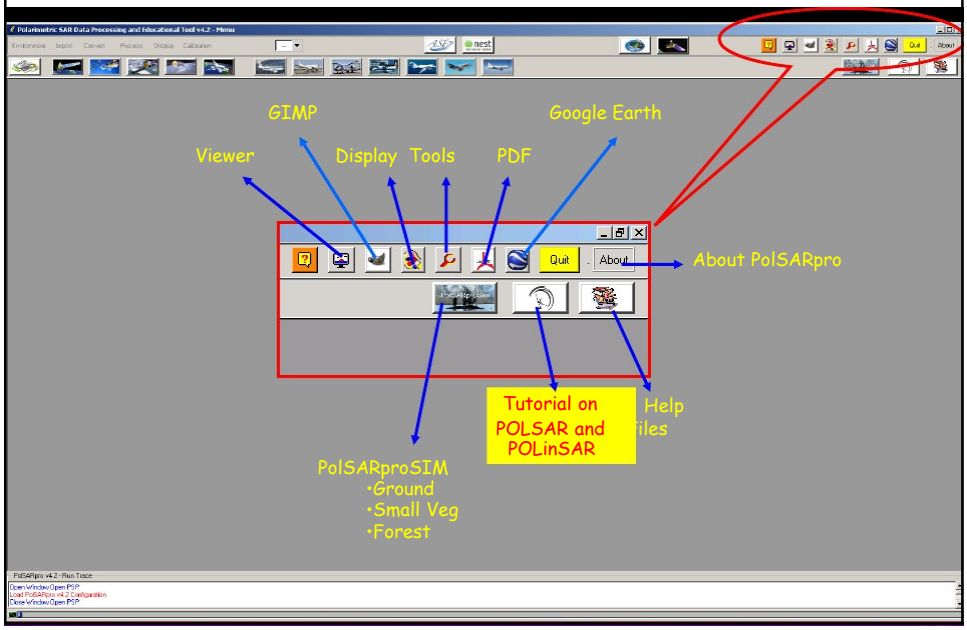
PolSARpro SOFTWARE



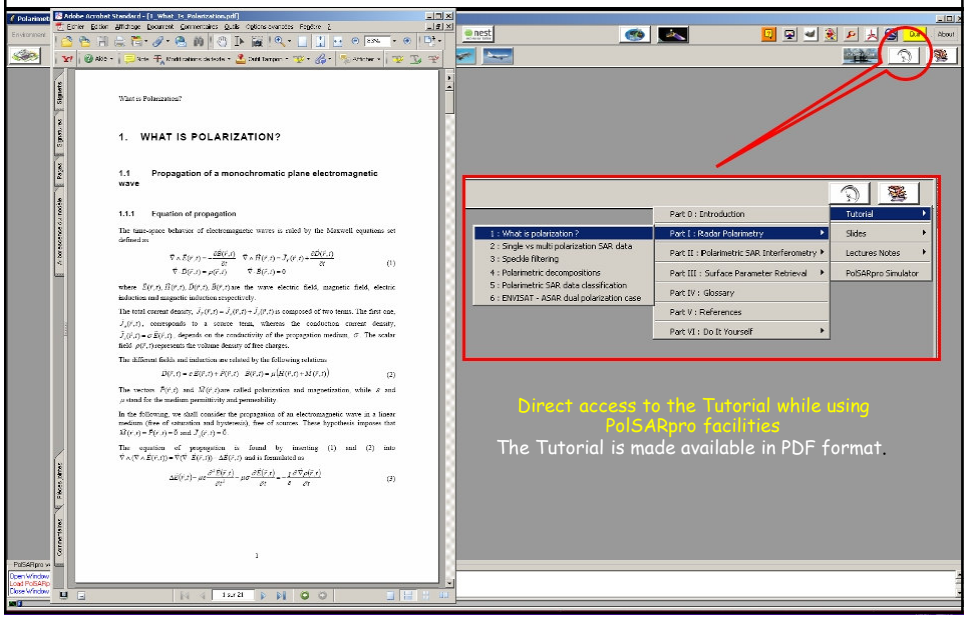
PolSARpro SOFTWARE



PolSARpro SOFTWARE



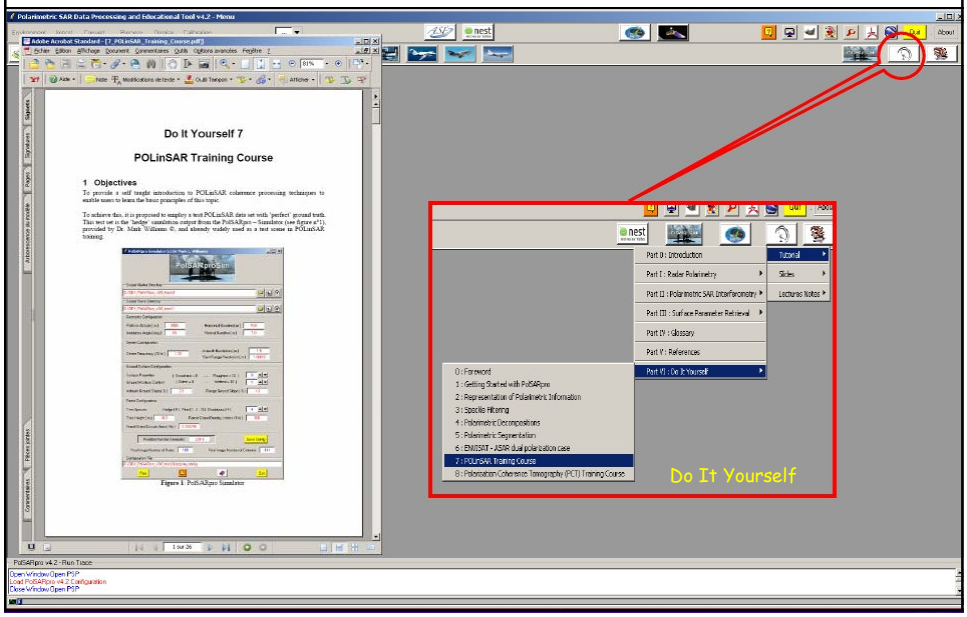
Tutorial Notes



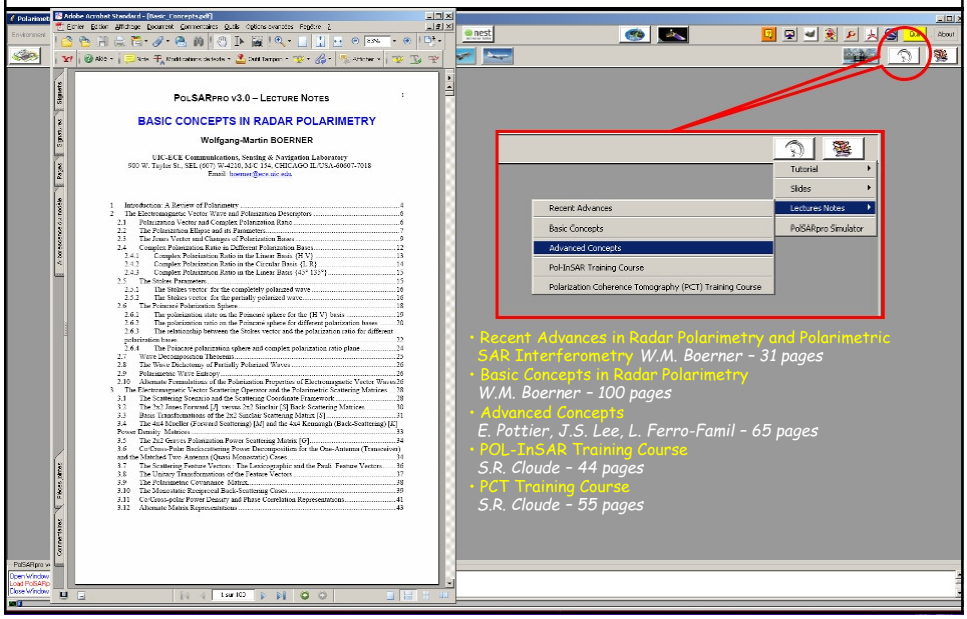
Direct access to the Tutorial while using PolSARpro facilities

The Tutorial is made available in PDF format.

Do It Yourself

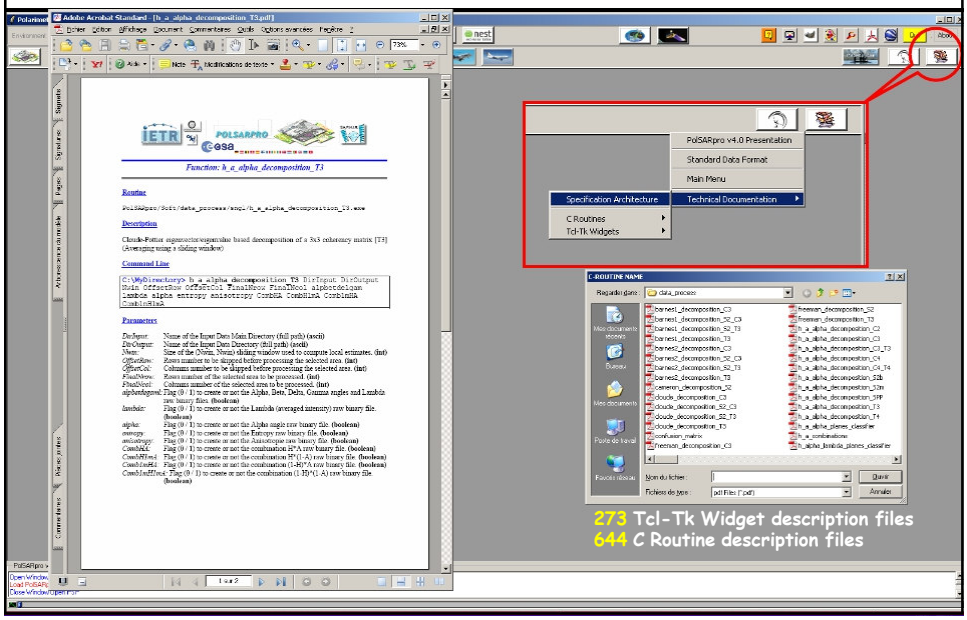


Lecture Notes



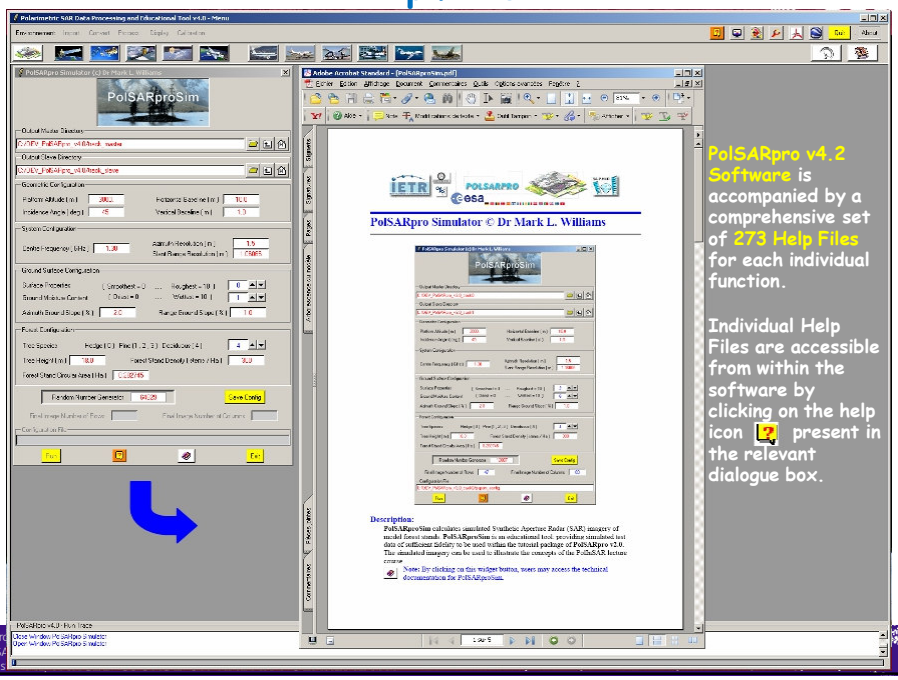
- Recent Advances in Radar Polarimetry and Polarimetric SAR Interferometry W.M. Boerner – 31 pages
- Basic Concepts in Radar Polarimetry W.M. Boerner – 100 pages
- Advanced Concepts E. Pottier, J.S. Lee, L. Ferro-Famil – 65 pages
- POL-InSAR Training Course S.R. Cloude – 44 pages
- PCT Training Course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

Technical Documentation

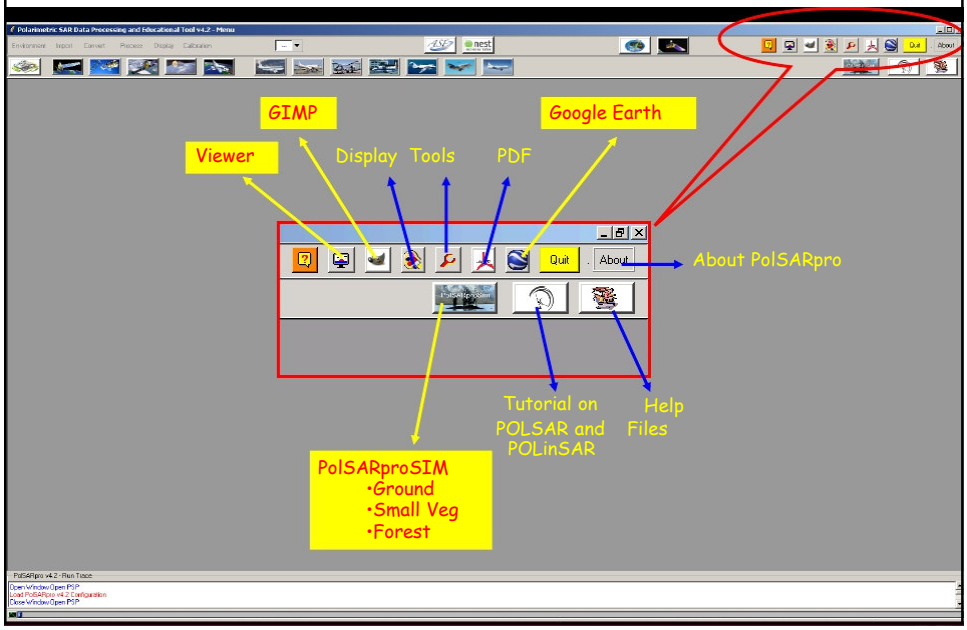


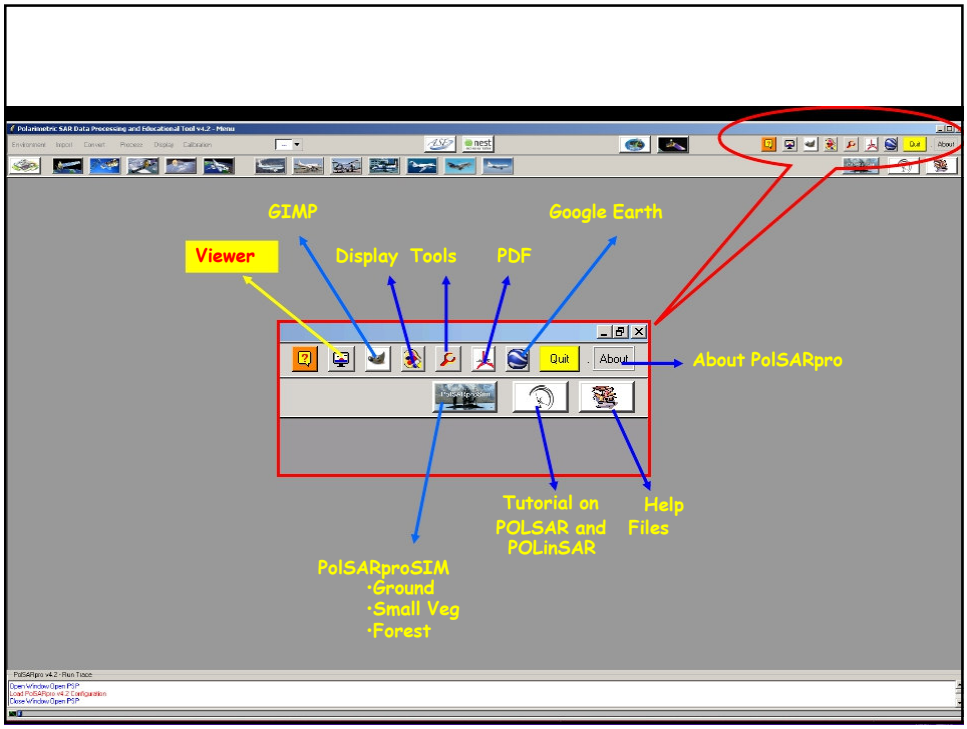
273 Tcl-Tk Widget description files
644 C Routine description files

Help Files

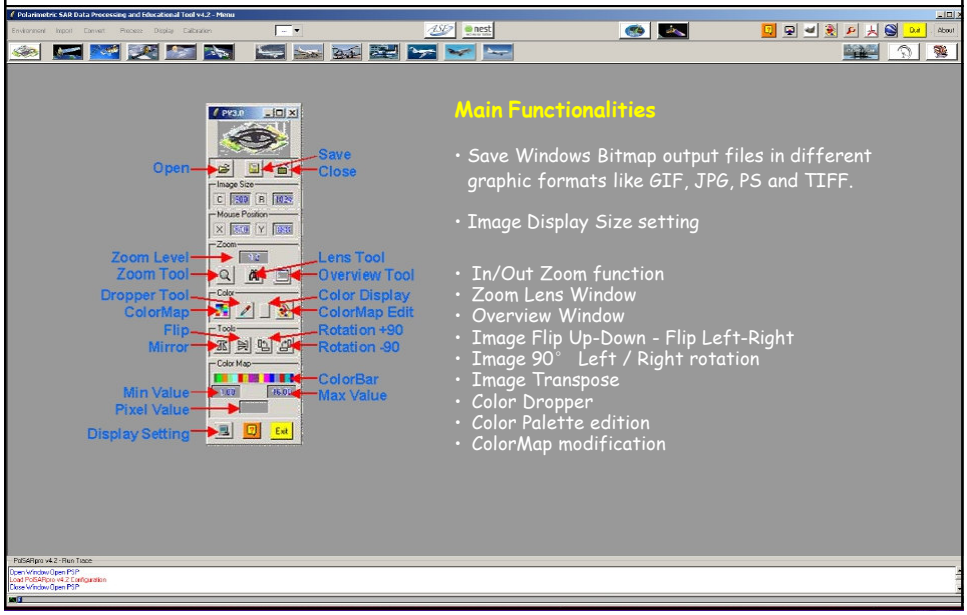


PolSARpro v4.2 SOFTWARE





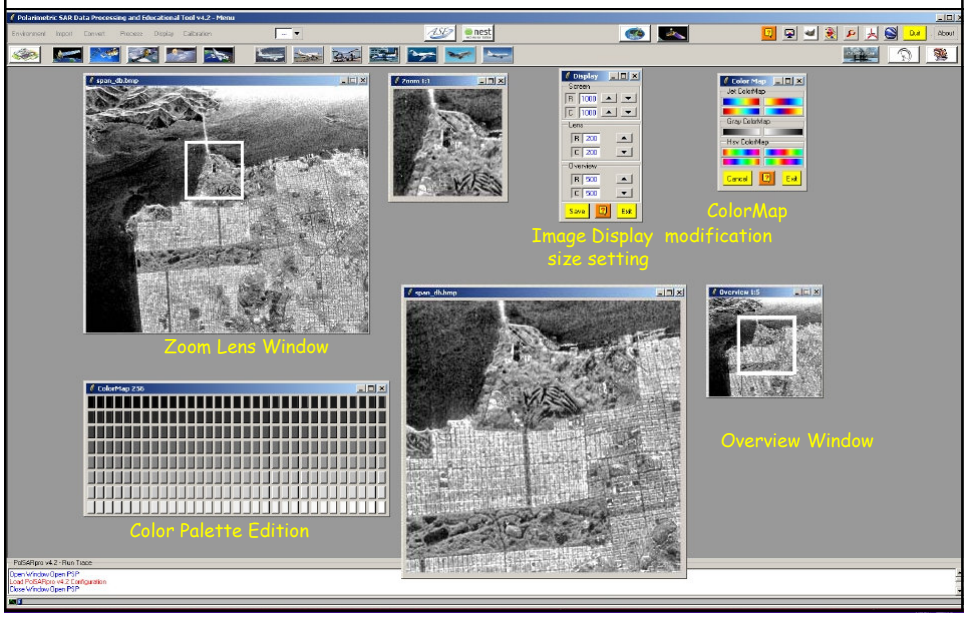
PolSARpro VIEWER (PV3.0)



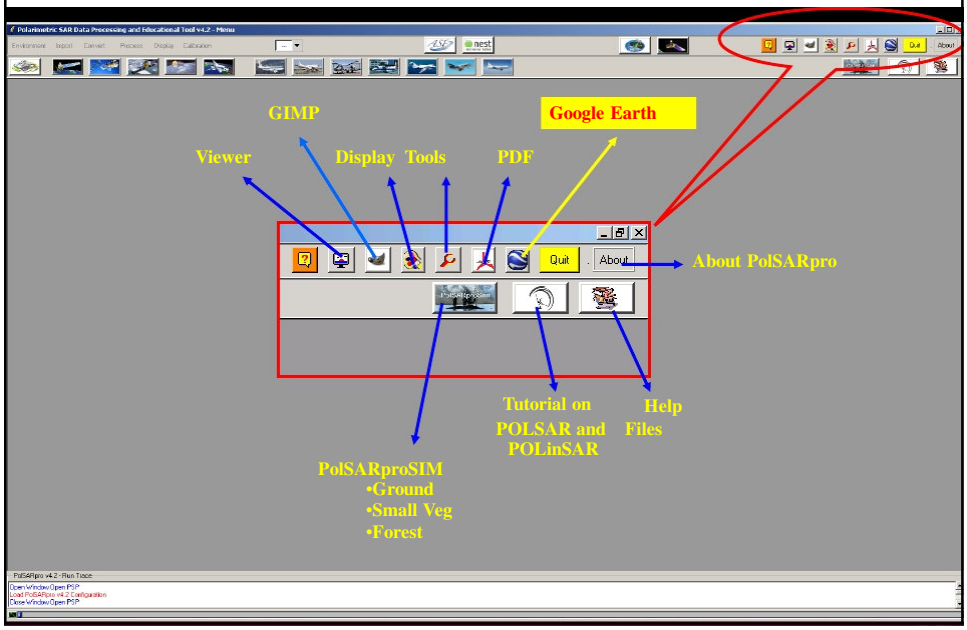
Main Functionalities

- Save Windows Bitmap output files in different graphic formats like GIF, JPG, PS and TIFF.
- Image Display Size setting
- In/Out Zoom function
- Zoom Lens Window
- Overview Window
- Image Flip Up-Down - Flip Left-Right
- Image 90° Left / Right rotation
- Image Transpose
- Color Dropper
- Color Palette edition
- ColorMap modification

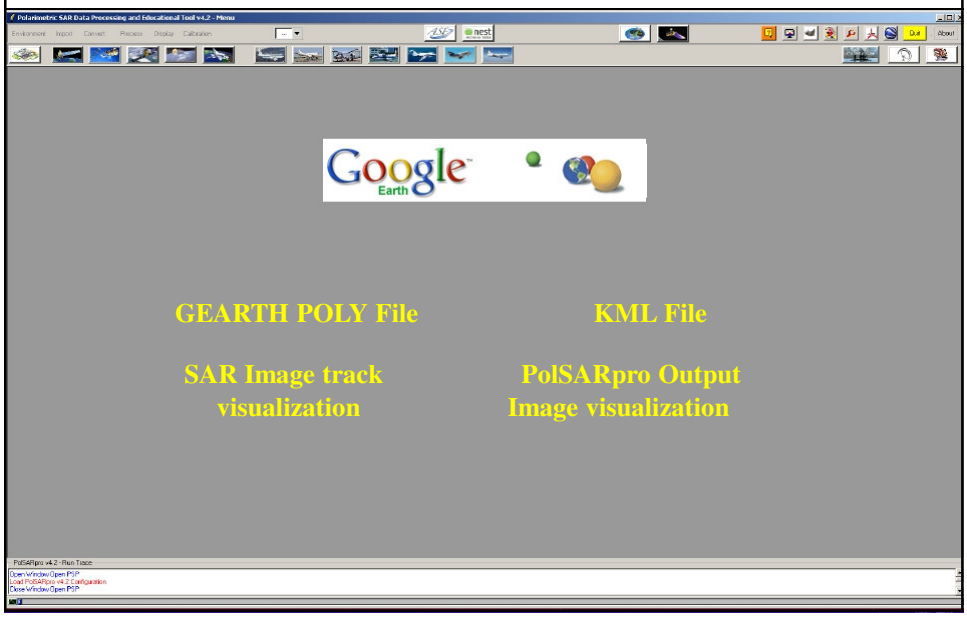
PolSARpro VIEWER (PV3.0)



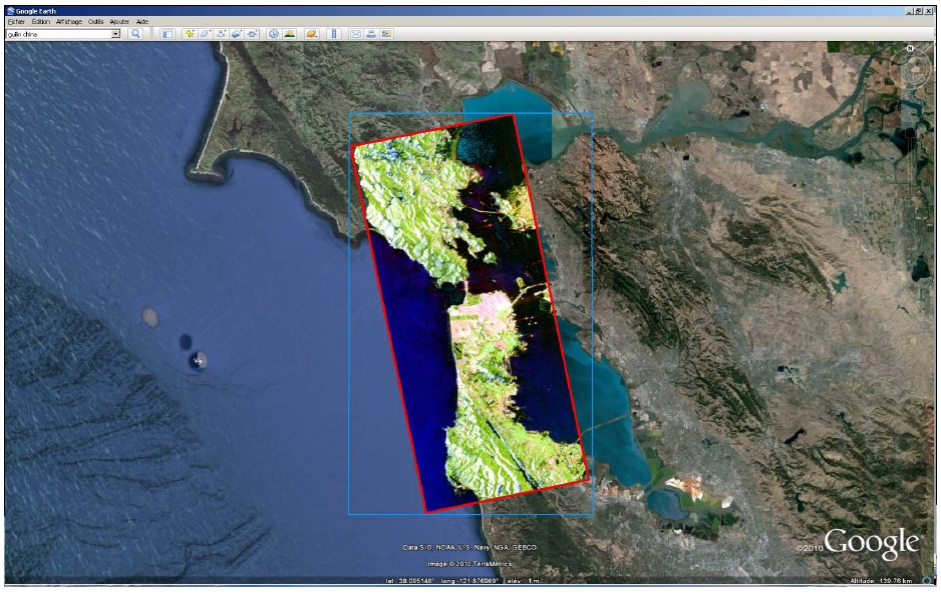
PolSARpro v4.2 SOFTWARE



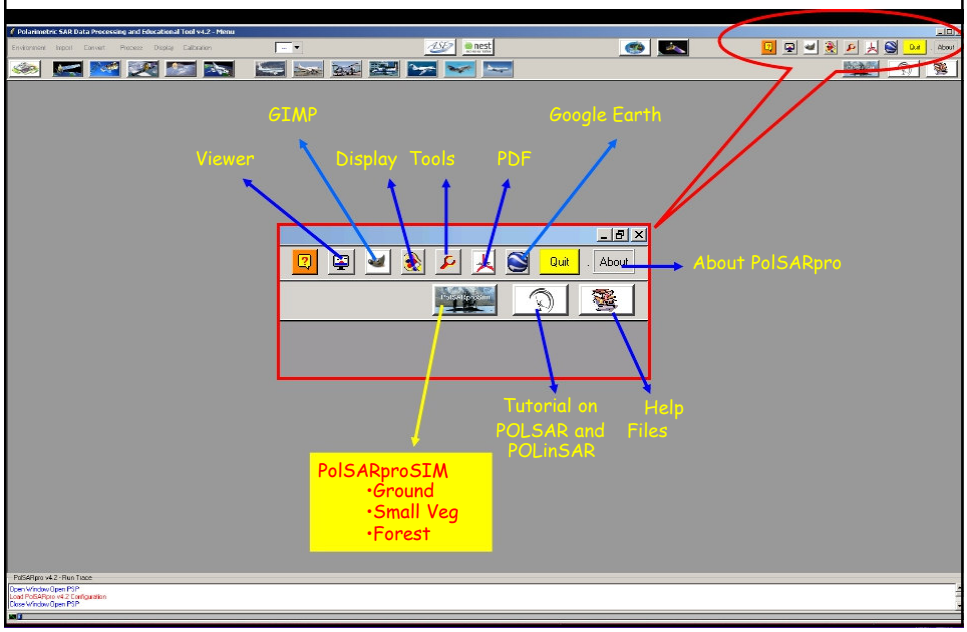
PolSARpro v4.2 SOFTWARE



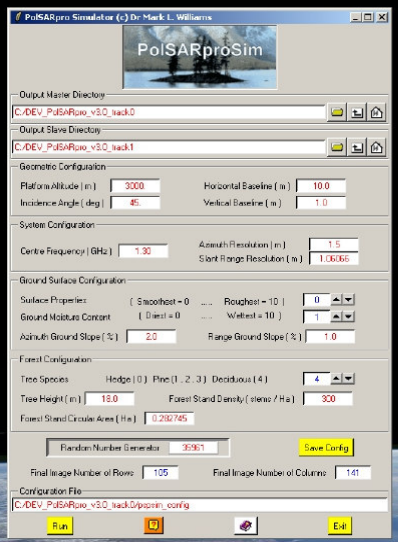
PolSARpro v4.2 SOFTWARE



PolSARpro v4.2 SOFTWARE



PolSARpro – SIM



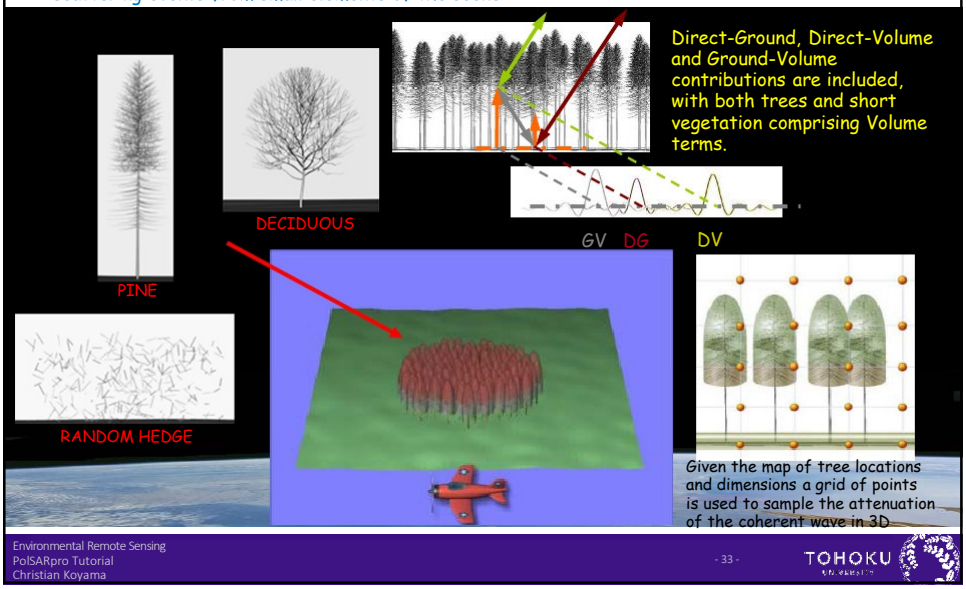
PolSARpro v3.31 SOFTWARE


Mark Williams

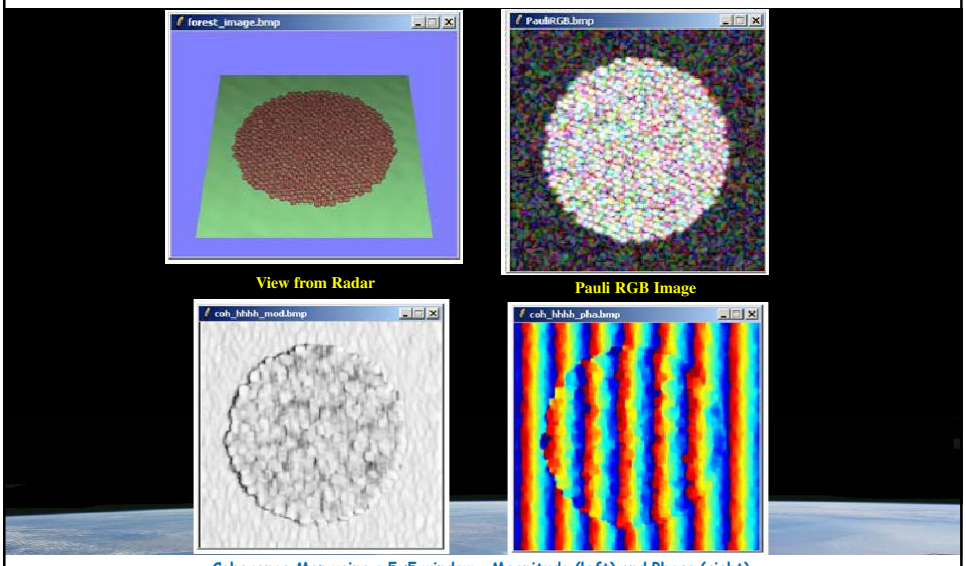
- PolSARproSim is a rapid, coherent, fully polarimetric SAR simulation of forest for demonstrating POLinSAR techniques within PolSARpro Software v3.31.
- PolSARproSim generates simulated interferometric SAR images of artificial forest scenes that may be analysed as real SAR imagery.
- SAR properties and imaging geometry are obtained from the user who specifies centre frequency, azimuth and slant range resolutions, along with platform altitude, incidence angle and horizontal and vertical interferometric baselines.
- Ground surface generation is controlled by specifying the surface properties slope, roughness and wetness (on simple sliding scales) and forest properties (species, height, stand density and stand area).

PolSARpro – SIM

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

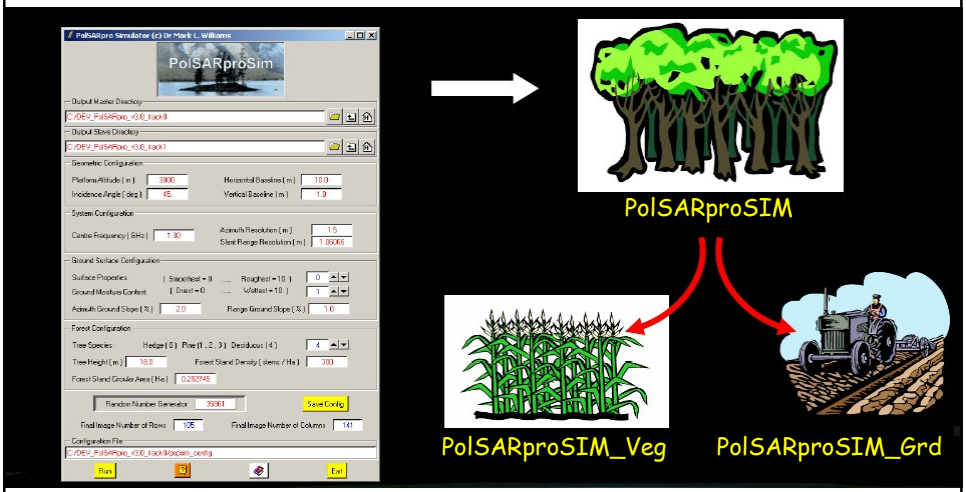


PolSARpro – SIM



Coherence Map using a 5x5 window – Magnitude (left) and Phase (right)

PolSARpro – SIM



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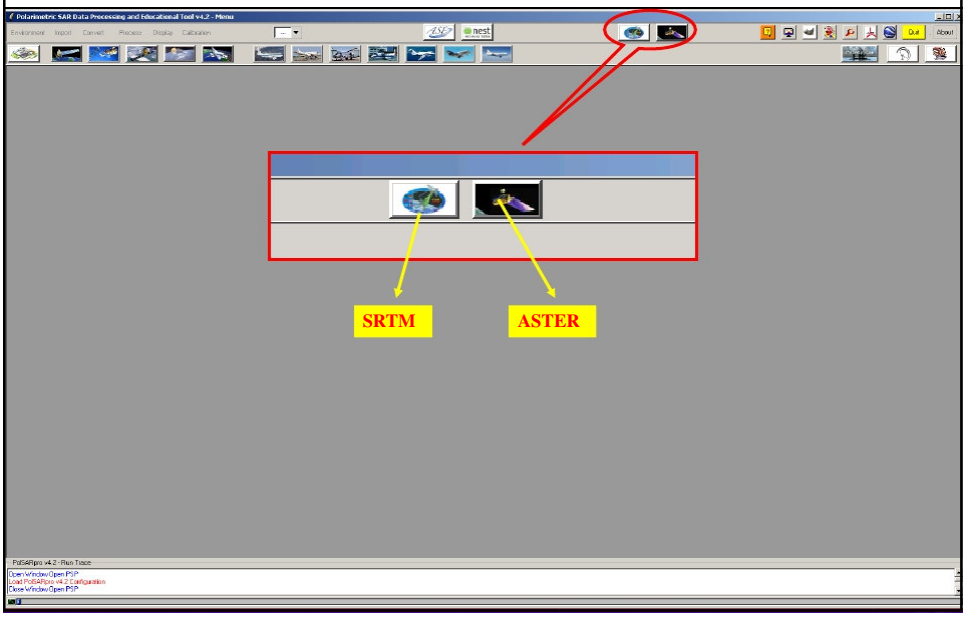
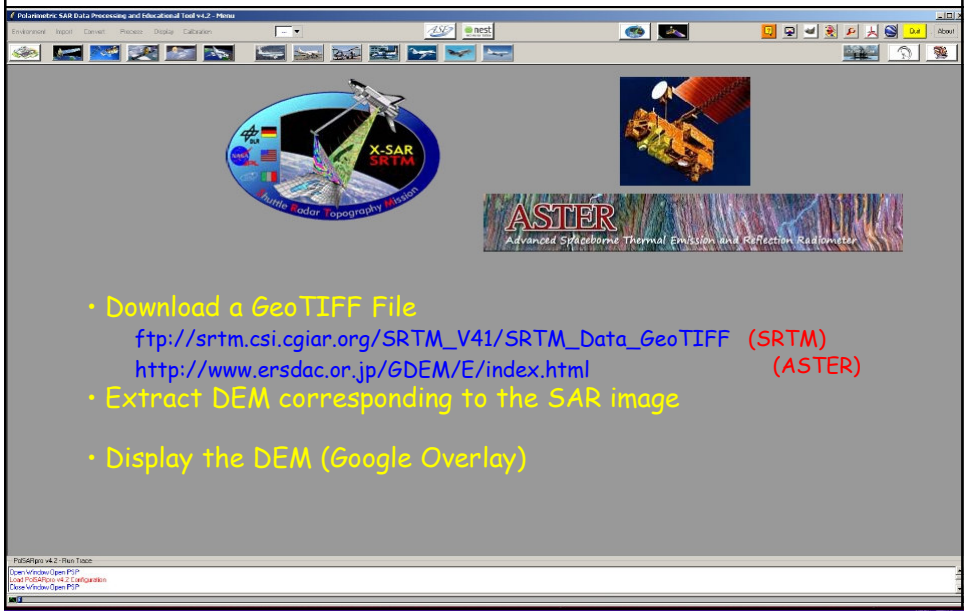
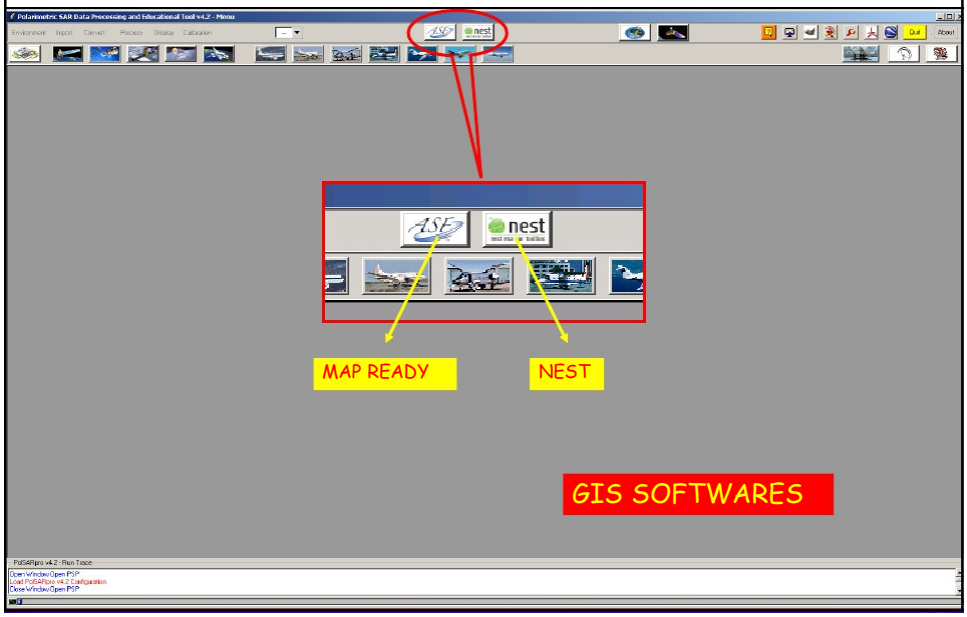


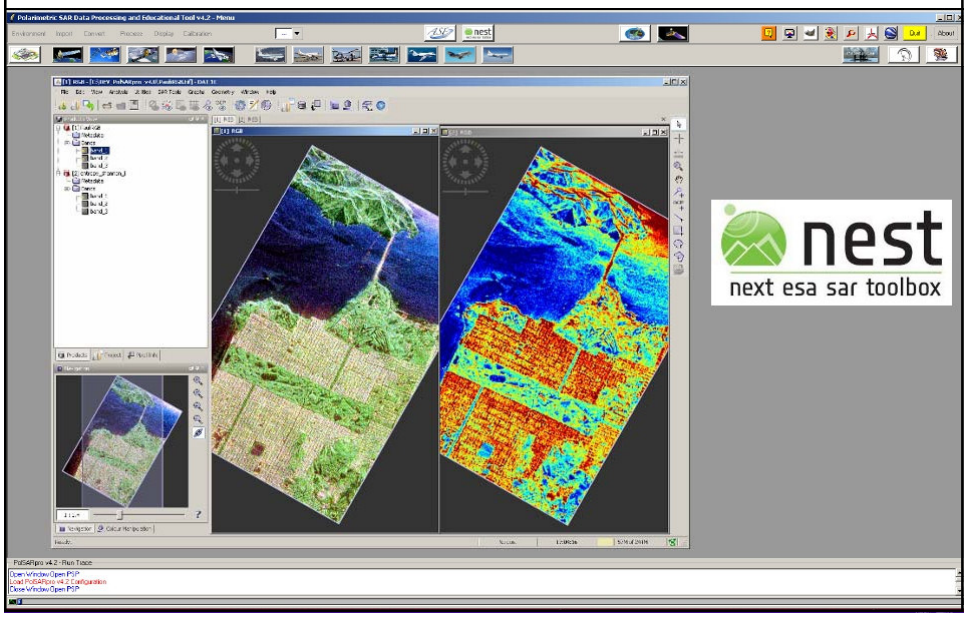
S.R.T.M - ASTER



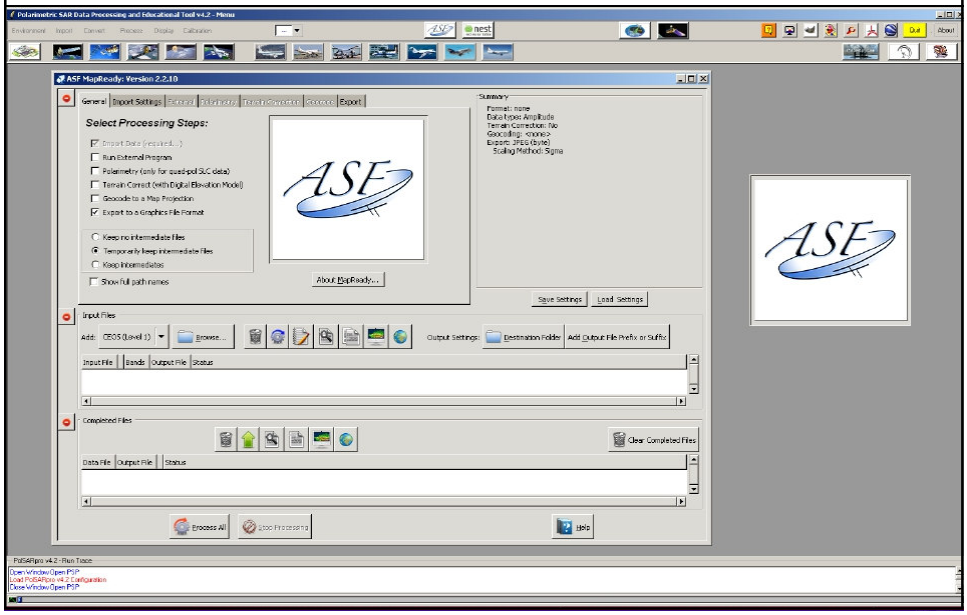
Auxiliary Software in PolSARpro



N.E.S.T



MAP READY

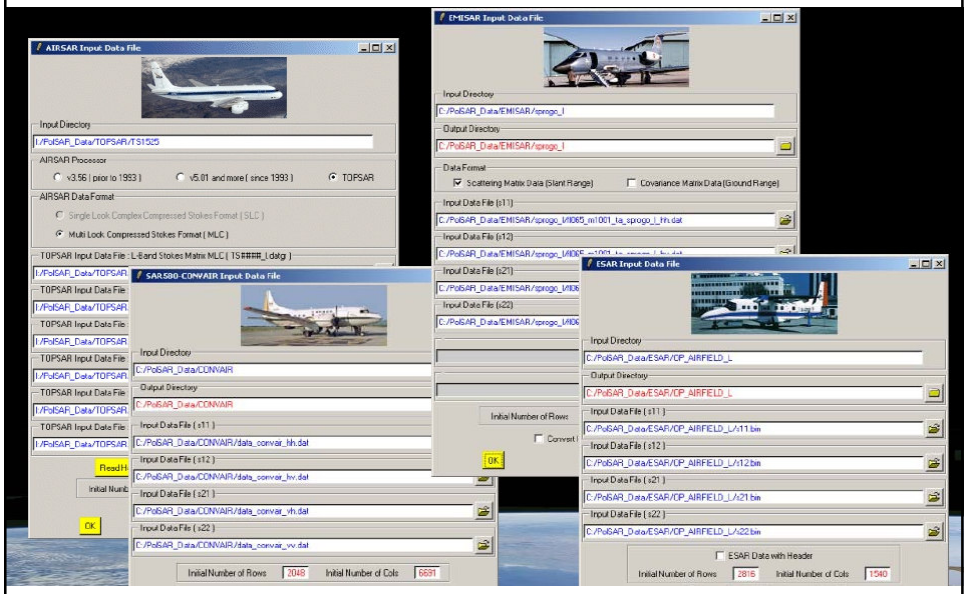


PolSARpro SOFTWARE

PolSAR Sensors Data Import

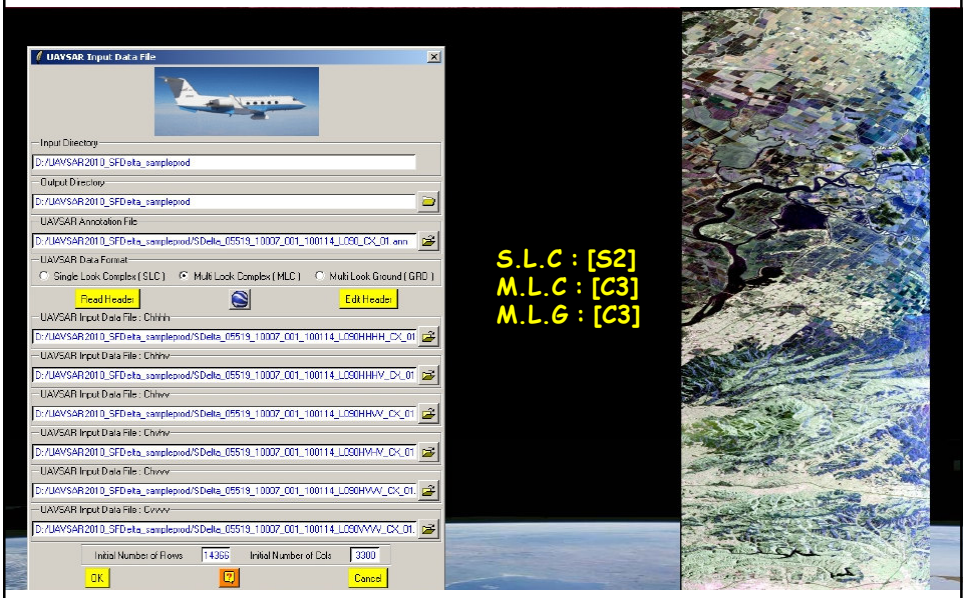
PolSARpro v5.0 Software offers the possibility to handle and convert polarimetric data from a range of well established polarimetric airborne platforms.

PolSARpro v4.2 SOFTWARE



PolSARpro v4.2 SOFTWARE

PolSARpro v4.2 SOFTWARE



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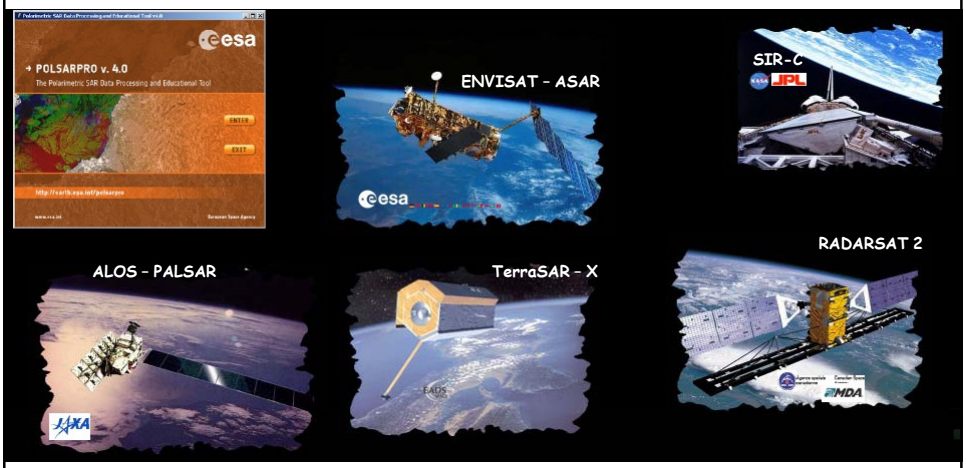
PolSARpro v4.2 SOFTWARE



PolSARpro v4.2 Software offers the possibility to handle and convert polarimetric data from a range of well established polarimetric spaceborne platforms.

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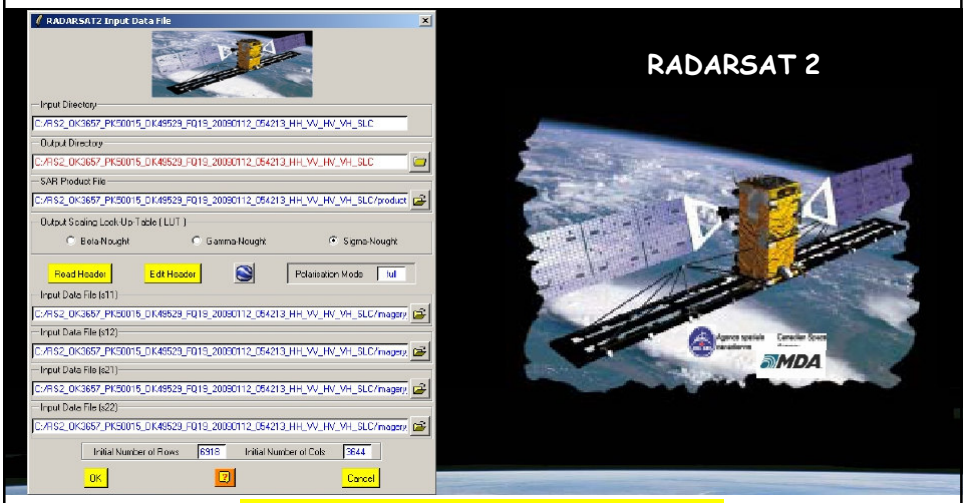
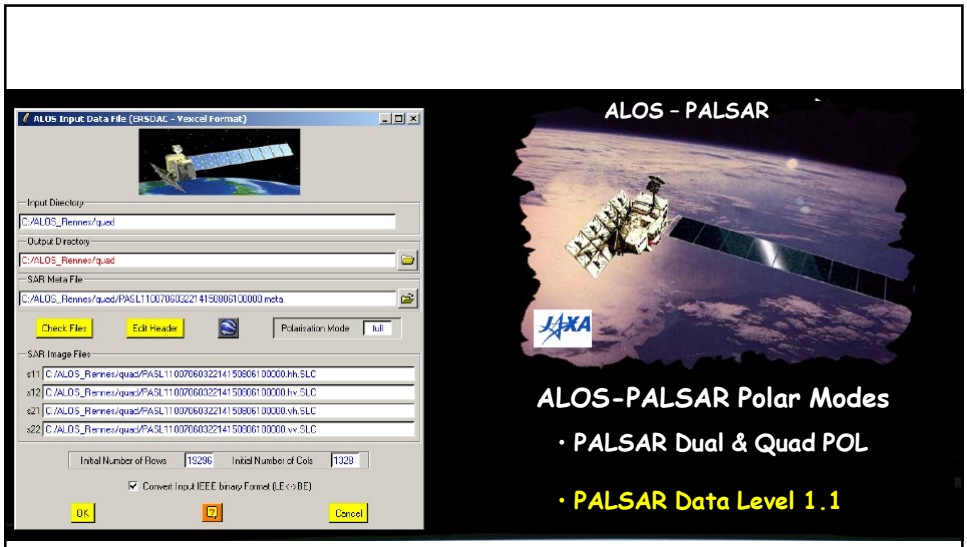
PolSARpro v4.2 SOFTWARE

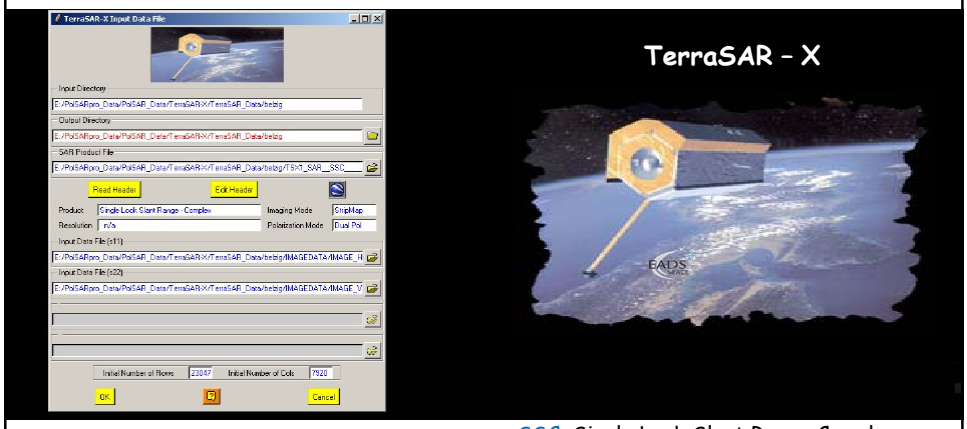


- RADARSAT-2 Dual & Quad POL
- RADARSAT-2 Fine and Standard Mode

JAXA - CEOS Data Format

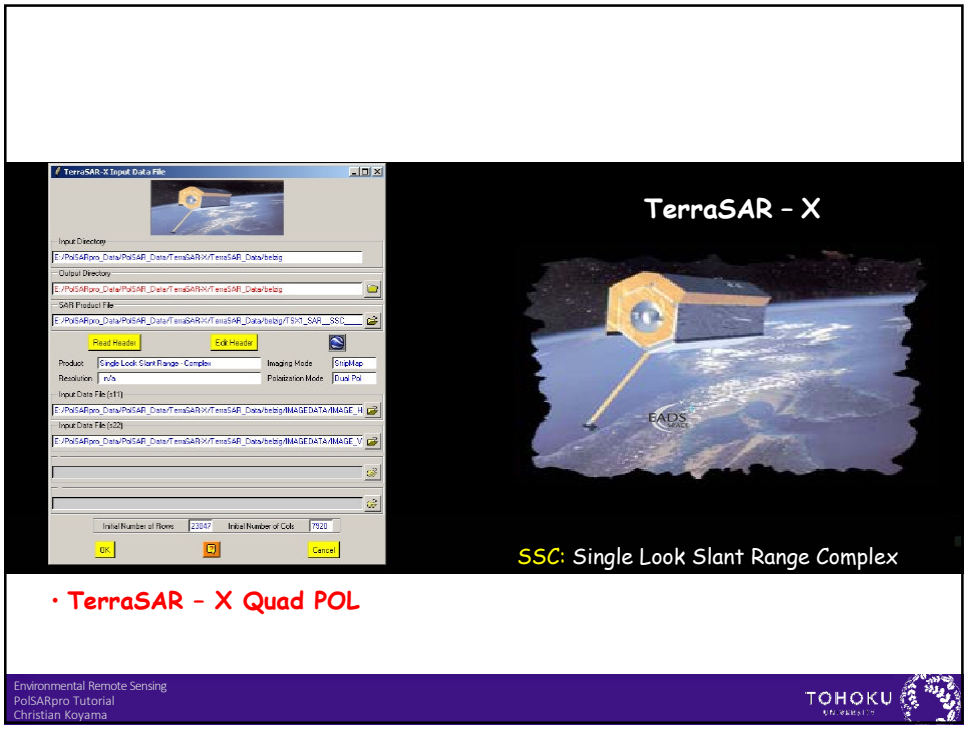


ERSDAC - Vexcel Data Format



• TerraSAR - X Dual POL

SSC: Single Look Slant Range Complex
EEC: Enhanced Ellipsoid Corrected
GEC: Geocoded Ellipsoid Corrected
MGD: Multi-Look Ground Range


TerraSAR-X Input Data File
Input Directory
Output Directory
SAR Product File
Read Header
Edit Header
Product
Single Look Slant Range - Complex
Imaging Mode
StripMap
Resolution
n/a
Polarization Mode
Dual Pol
Input Data File (s11)
Input Data File (s22)
Initial Number of Rows
23047
Initial Number of Cols
7920
OK
Cancel
TerraSAR - X
EADS
SSC: Single Look Slant Range Complex
• TerraSAR - X Quad POL
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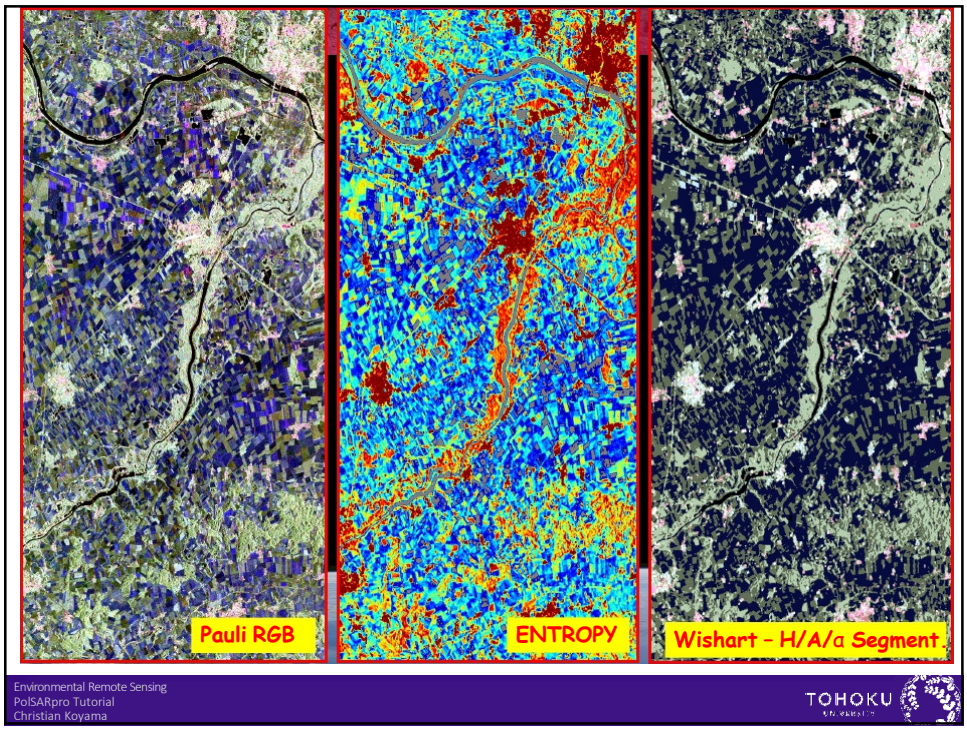
Pauli RGB
ENTROPY
Wishart - H/A/α Segment
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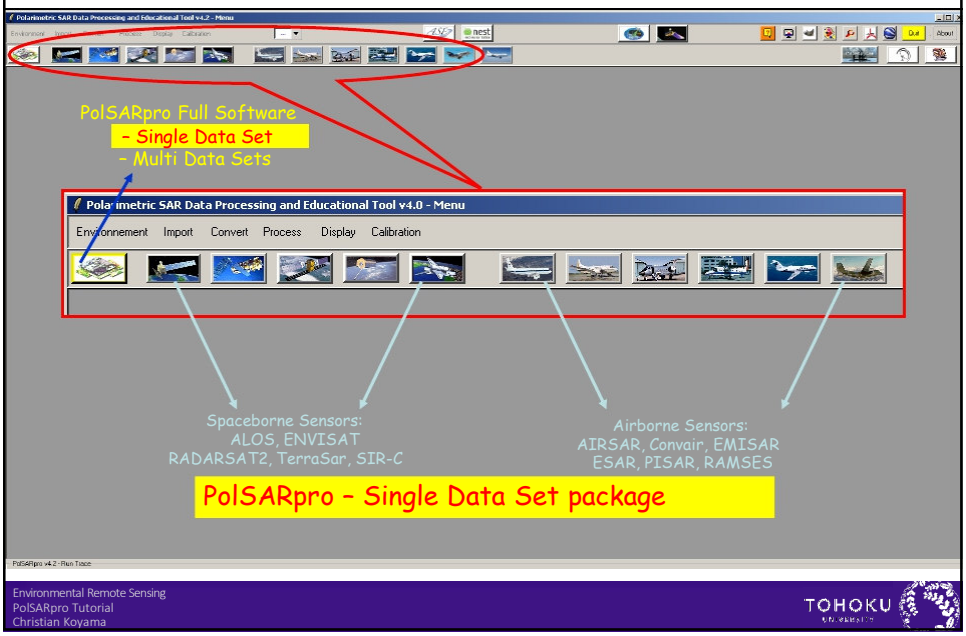
PolSARpro v4.2 SOFTWARE

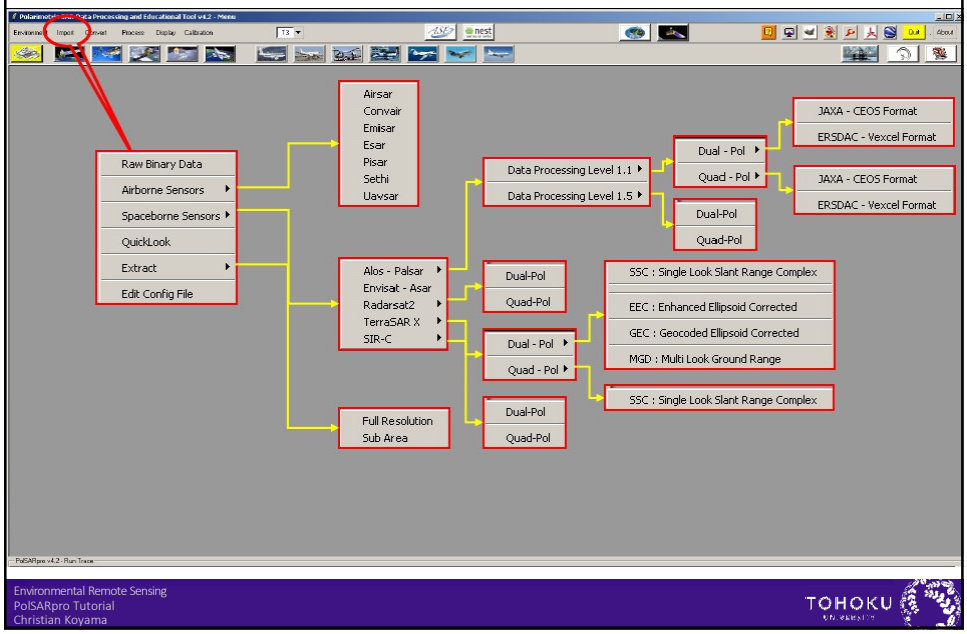
Single Data Set Package - PolSAR

Note: This is the most commonly used import routine.

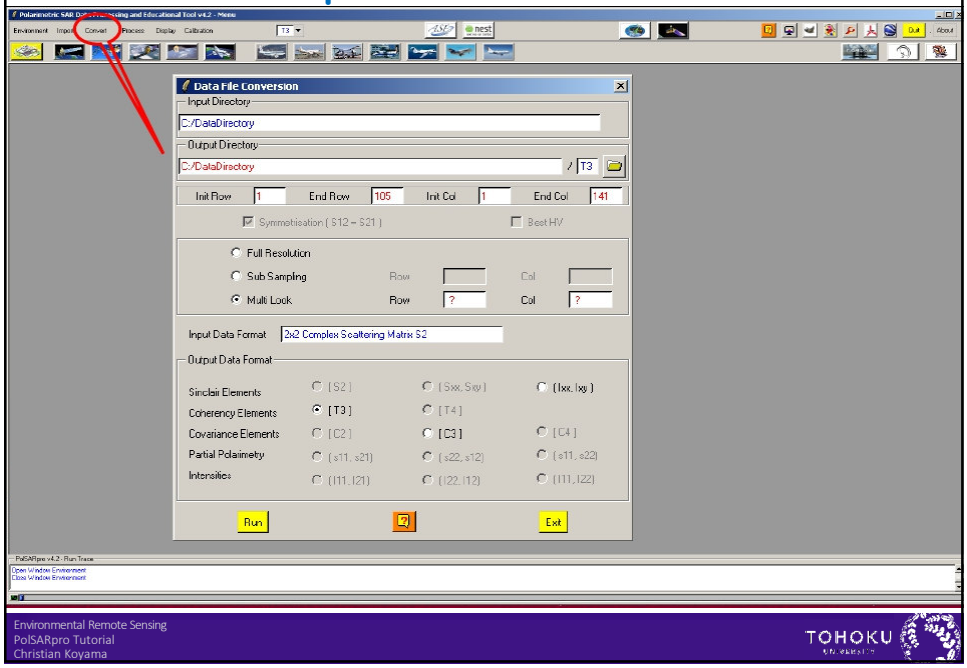
PolSARpro v4.2 SOFTWARE

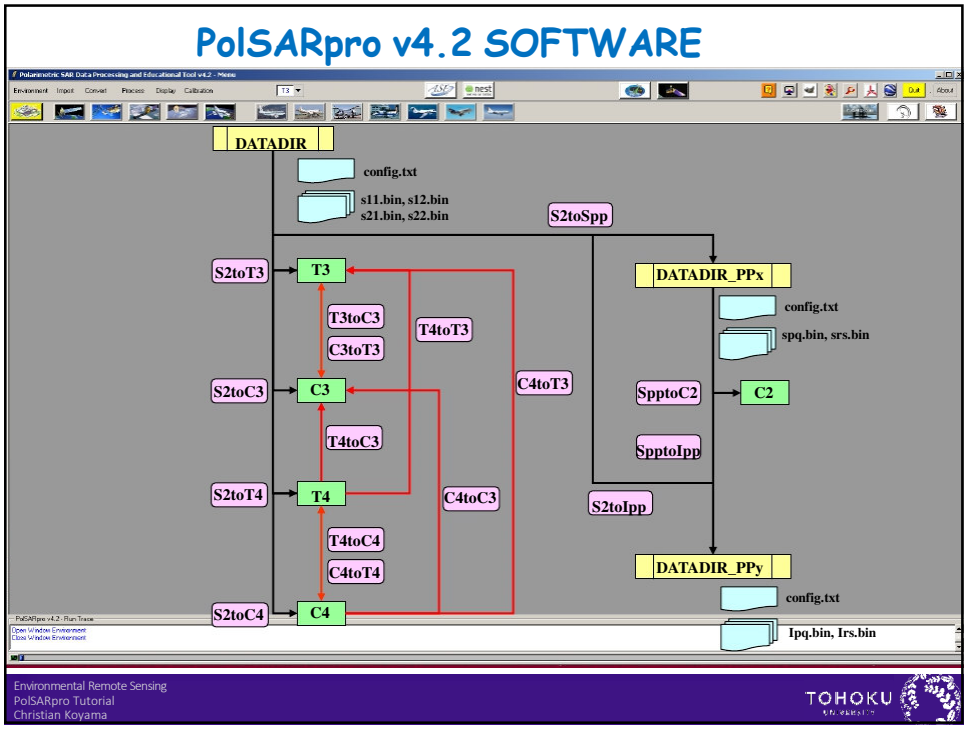


PolSARpro v4.2 SOFTWARE



PolSARpro v4.2 SOFTWARE




PolSARpro v4.2 SOFTWARE
DATADIR
config.txt
s11.bin, s12.bin
s21.bin, s22.bin
S2toSpp
S2toT3
T3
T3toC3
C3toT3
T4toT3
C4toT3
DATADIR_PPx
config.txt
spq.bin, srs.bin
S2toC3
C3
SpptoC2
C2
T4toC3
SpptoIpp
S2toT4
T4
C4toC3
S2toIpp
T4toC4
C4toT4
DATADIR_PPy
config.txt
S2toC4
C4
Ipq.bin, Irs.bin
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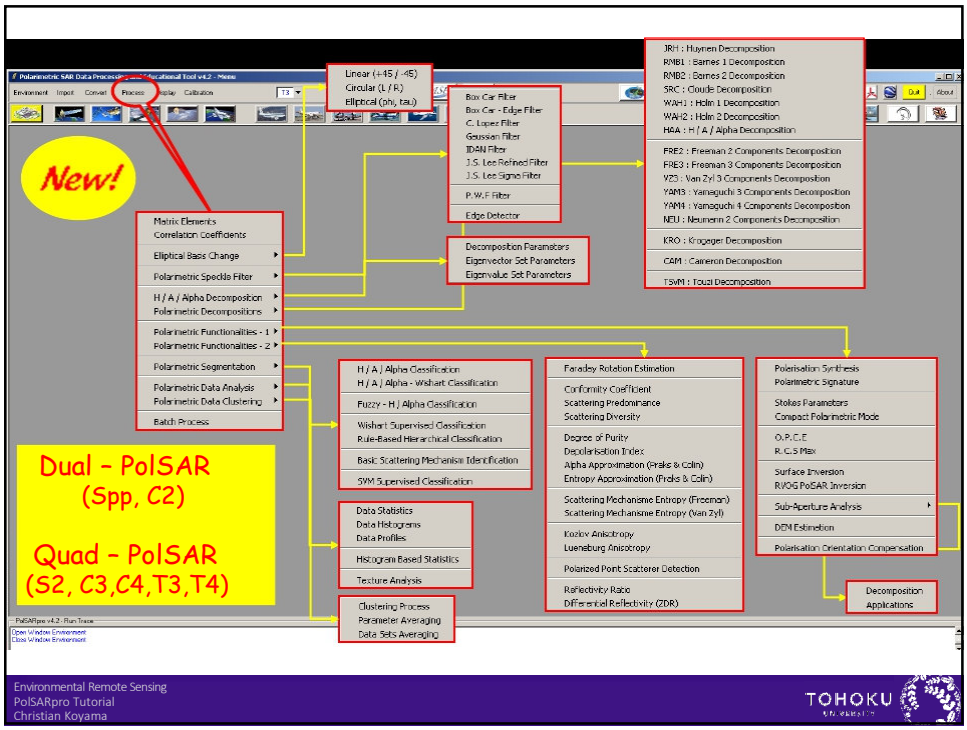
New!
Dual - PolSAR
(Spp, C2)
Quad - PolSAR
(S2, C3,C4,T3,T4)
Environmental Remote Sensing
PolSARpro Tutorial
Christian Koyama
TOHOKU

PolSARpro v4.2 SOFTWARE

Questions?

Ok, let's start!

Environmental Remote Sensing
PolSARpro Tutorial
Christian Koyama

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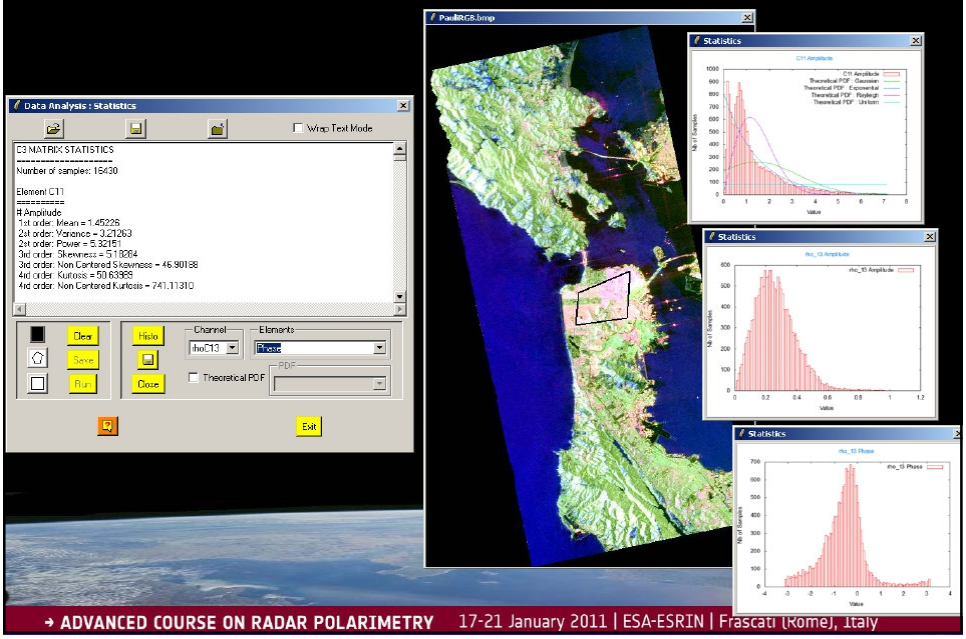
Data Analysis – Statistics

esa



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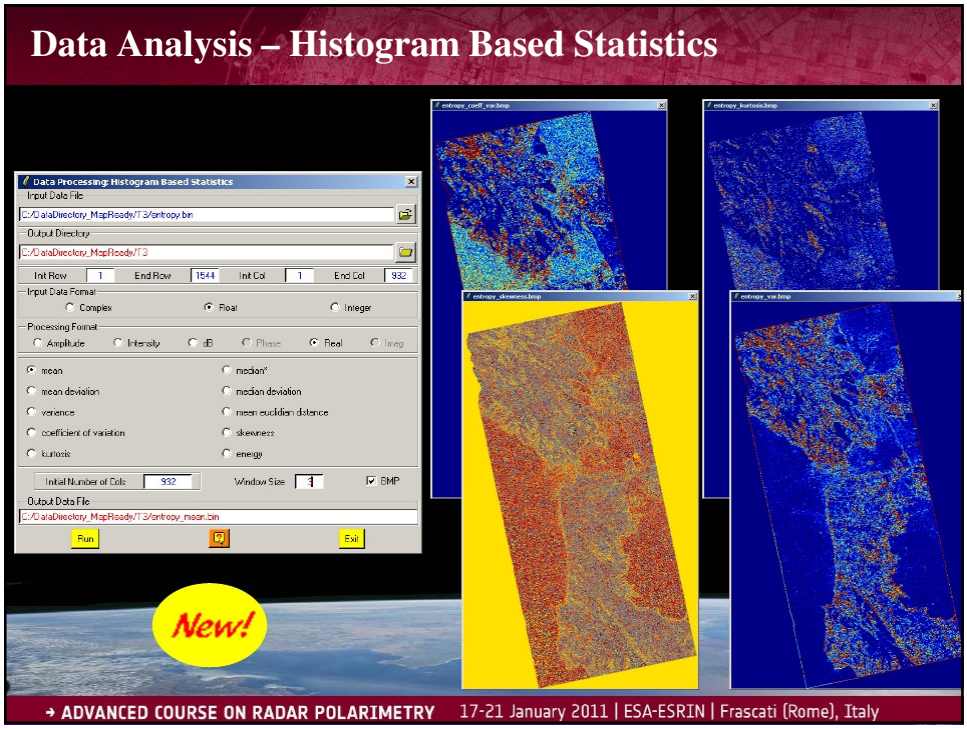
Data Analysis – Histogram Based Statistics
Data Processing: Histogram Based Statistics
Input Data File
Output Directory
Input Data Format
Processing Format
mean
mean deviation
variance
coefficient of variation
kurtosis
median*
median deviation
mean euclidien distance
skewness
energy
Output Data File
Run
Exit
New!
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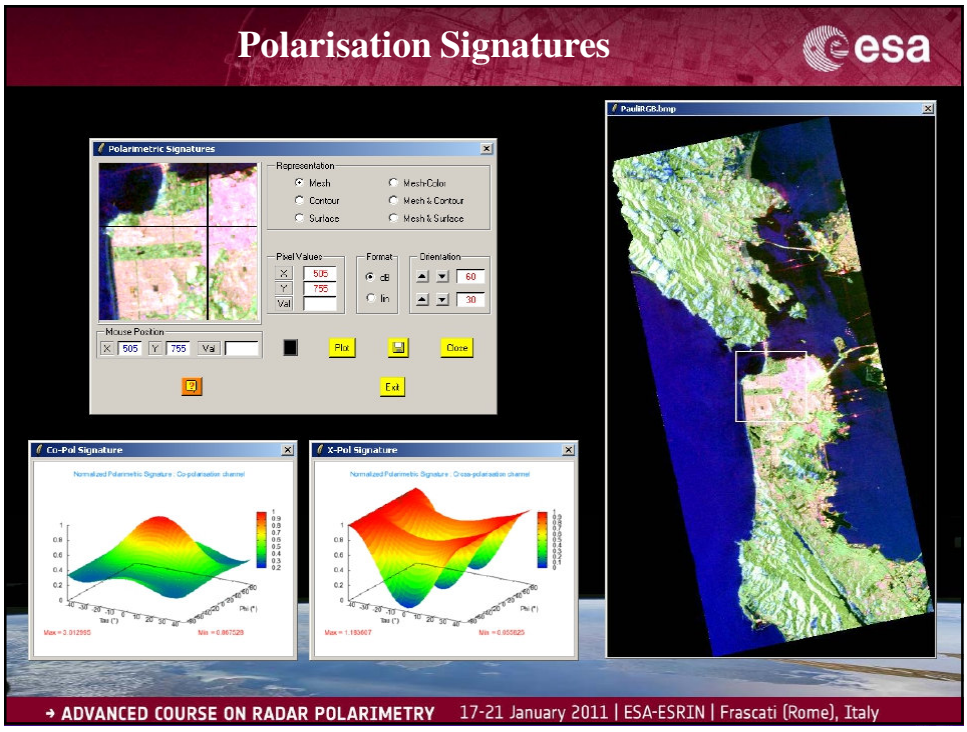
Polarisation Signatures
esa
Polarimetric Signatures
Representation
Mesh
Contour
Surface
Mesh+Color
Mesh & Contour
Mesh & Surface
Pixel Values
Format
Orientation
Mouse Position
Plot
Clone
Exit
Co-Pol Signature
X-Pol Signature
PauliRGB.bmp
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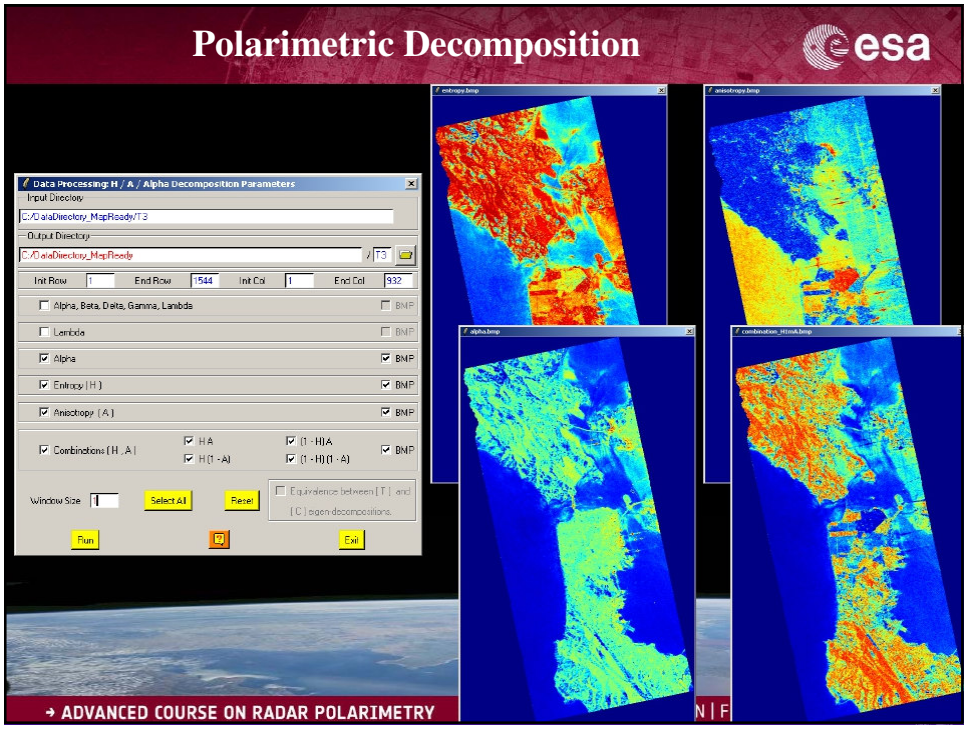
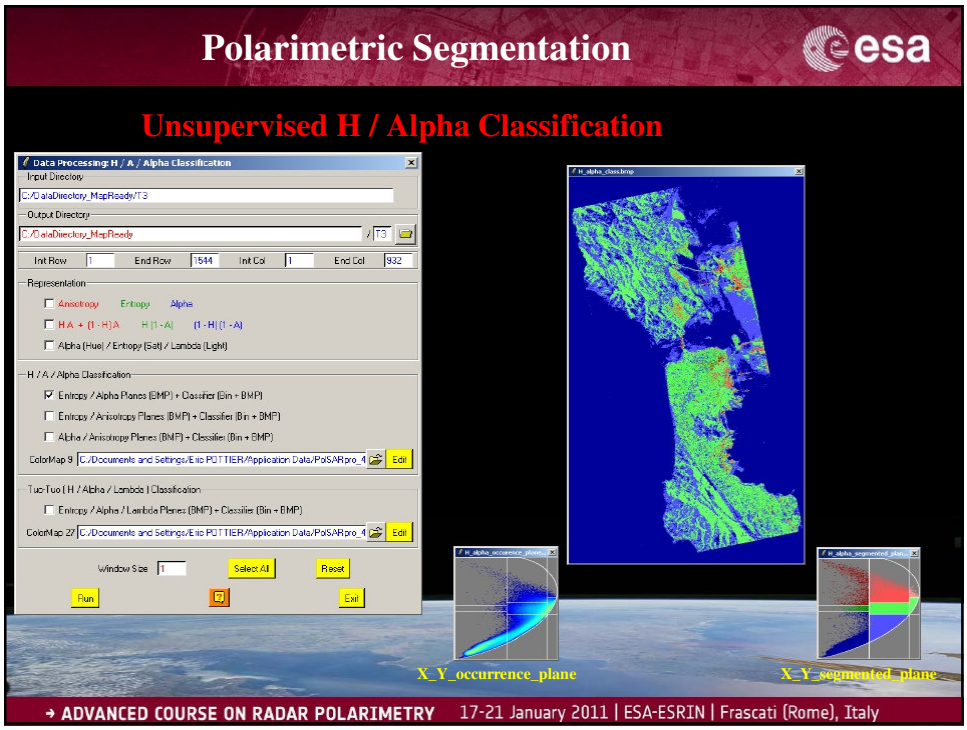

Polarimetric Decomposition
esa
Data Processing: H / A / Alpha Decomposition Parameters
Input Directory
Output Directory
Init Row
End Row
Init Col
End Col
Alpha, Beta, Delta, Gamma, Lambda
Lambda
Alpha
Entropy (H)
Anisotropy (A)
Combinations (H , A)
Window Size
Select All
Reset
Run
Exit
ADVANCED COURSE ON RADAR POLARIMETRY


Polarimetric Segmentation
esa
Unsupervised H / Alpha Classification
Data Processing: H / A / Alpha Classification
Input Directory
Output Directory
Init Row
End Row
Init Col
End Col
Representation
Anisotropy
Entropy
Alpha
H / A / Alpha Classification
Entropy / Alpha Planes (BMP) + Classifier (Bin + BMP)
Entropy / Anisotropy Planes (BMP) + Classifier (Bin + BMP)
Alpha / Anisotropy Planes (BMP) + Classifier (Bin + BMP)
Edit
Window Size
Select All
Reset
Run
Exit
X_Y_occurrence_plane
X_Y_segmented_plane
ADVANCED COURSE ON RADAR POLARIMETRY
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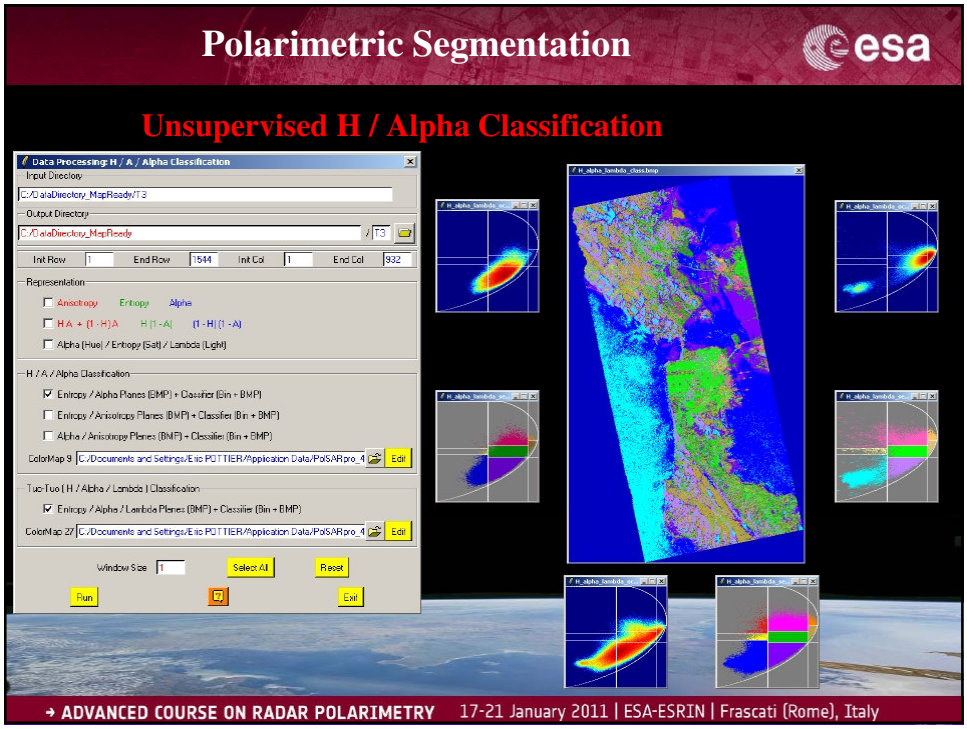
Polarimetric Segmentation
esa
Unsupervised H / Alpha Classification
Data Processing: H / A / Alpha Classification
Input Directory
Output Directory
Init Row
End Row
Init Col
End Col
Representation
Anisotropy
Entropy
Alpha
H A + (1 - H) A
H (1 - A)
(1 - H) (1 - A)
Alpha (Hue) / Entropy (Sat) / Lambda (Light)
H / A / Alpha Classification
Entropy / Alpha Planes (BMP) + Classifier (Bin + BMP)
Entropy / Anisotropy Planes (BMP) + Classifier (Bin + BMP)
Alpha / Anisotropy Planes (BMP) + Classifier (Bin + BMP)
ColorMap 8
Edit
Two-Two (H / Alpha / Lambda) Classification
Entropy / Alpha / Lambda Planes (BMP) + Classifier (Bin + BMP)
ColorMap 27
Window Size
Select All
Reset
Run
Exit
ADVANCED COURSE ON RADAR POLARIMETRY
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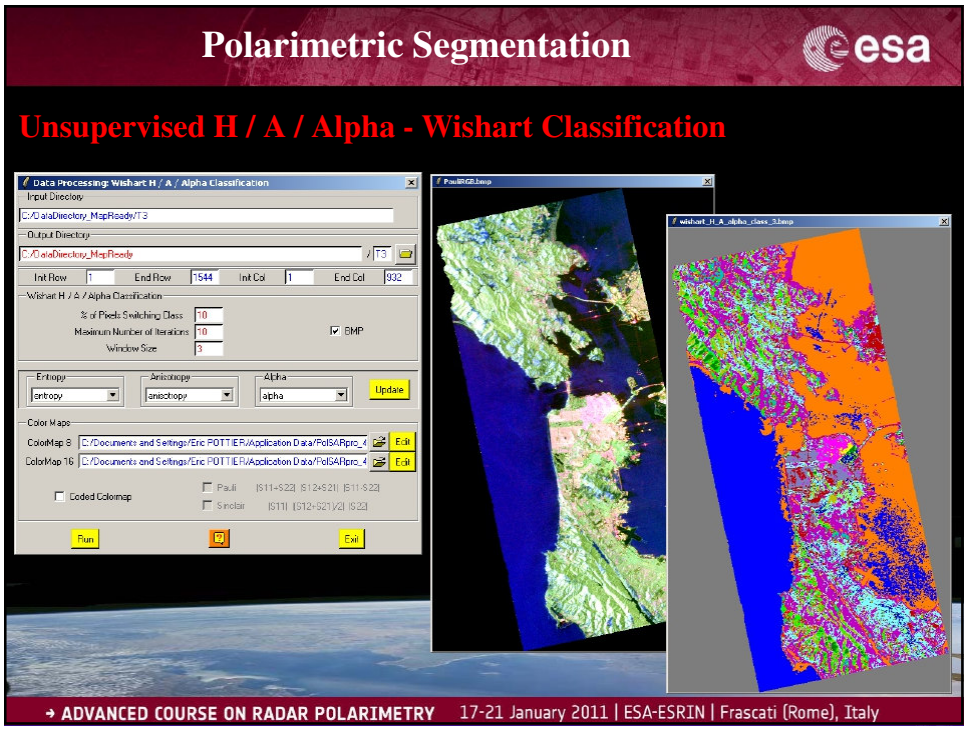
Polarimetric Segmentation
esa
Unsupervised H / A / Alpha - Wishart Classification
Data Processing: Wishart H / A / Alpha Classification
Input Directory
Output Directory
Init Row
End Row
Init Col
End Col
Wishart H / A / Alpha Classification
% of Pixels Switching Class
Maximum Number of Iterations
Window Size
BMP
Entropy
Anisotropy
Alpha
Update
Color Maps
ColorMap 8
ColorMap 16
Edit
Coded Colormap
Pauli
Sinclair
Run
Exit
ADVANCED COURSE ON RADAR POLARIMETRY
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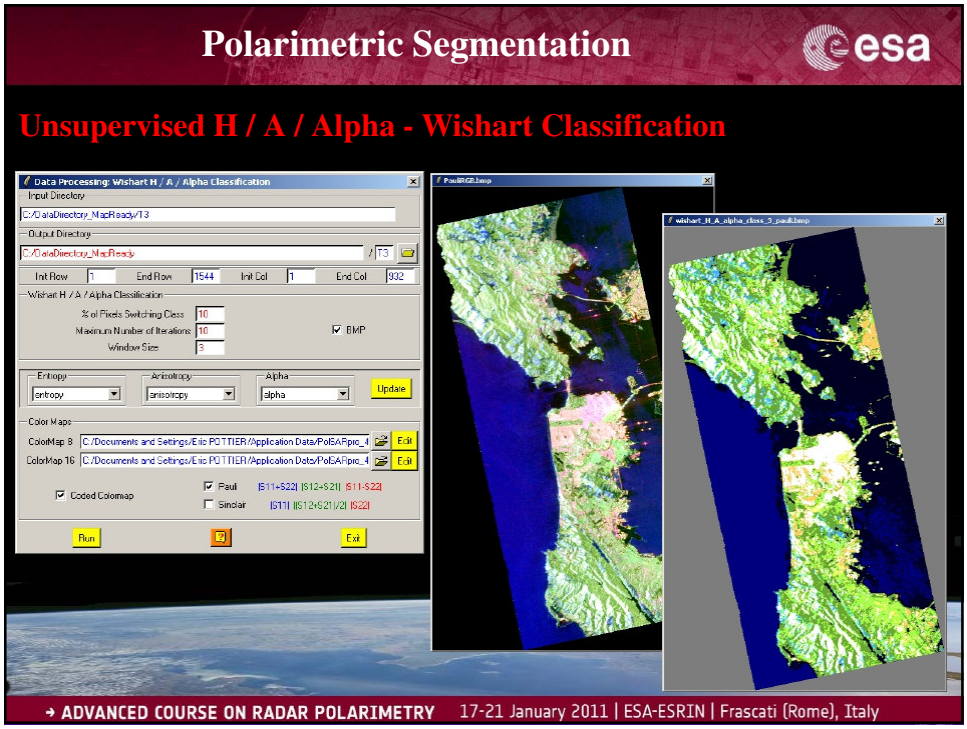
Polarimetric Segmentation
esa
Unsupervised H / A / Alpha - Wishart Classification
Data Processing: Wishart H / A / Alpha Classification
Input Directory
Output Directory
Wishart H / A / Alpha Classification
Update
Color Maps
Run
Exit
ADVANCED COURSE ON RADAR POLARIMETRY
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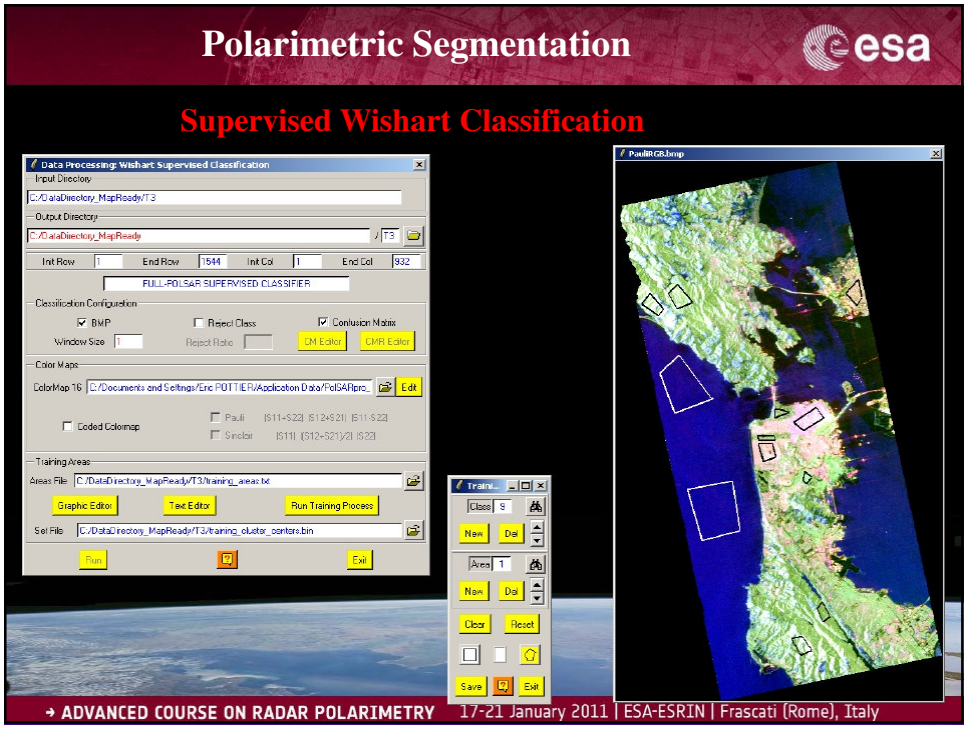
Polarimetric Segmentation
esa
Supervised Wishart Classification
Data Processing: Wishart Supervised Classification
Input Directory
Output Directory
FULL-POLSAR SUPERVISED CLASSIFIER
Classification Configuration
Color Maps
Training Areas
Graphic Editor
Text Editor
Run Training Process
Run
Exit
ADVANCED COURSE ON RADAR POLARIMETRY
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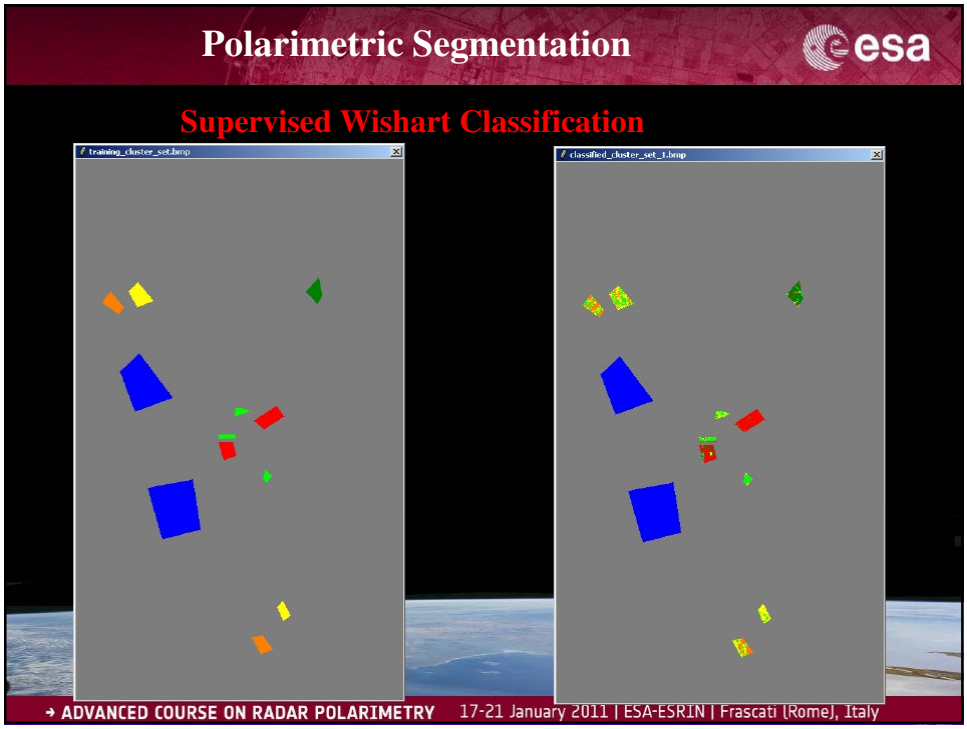
Polarimetric Segmentation
esa
Supervised Wishart Classification
training_cluster_set.bmp
classified_cluster_set_1.bmp
ADVANCED COURSE ON RADAR POLARIMETRY
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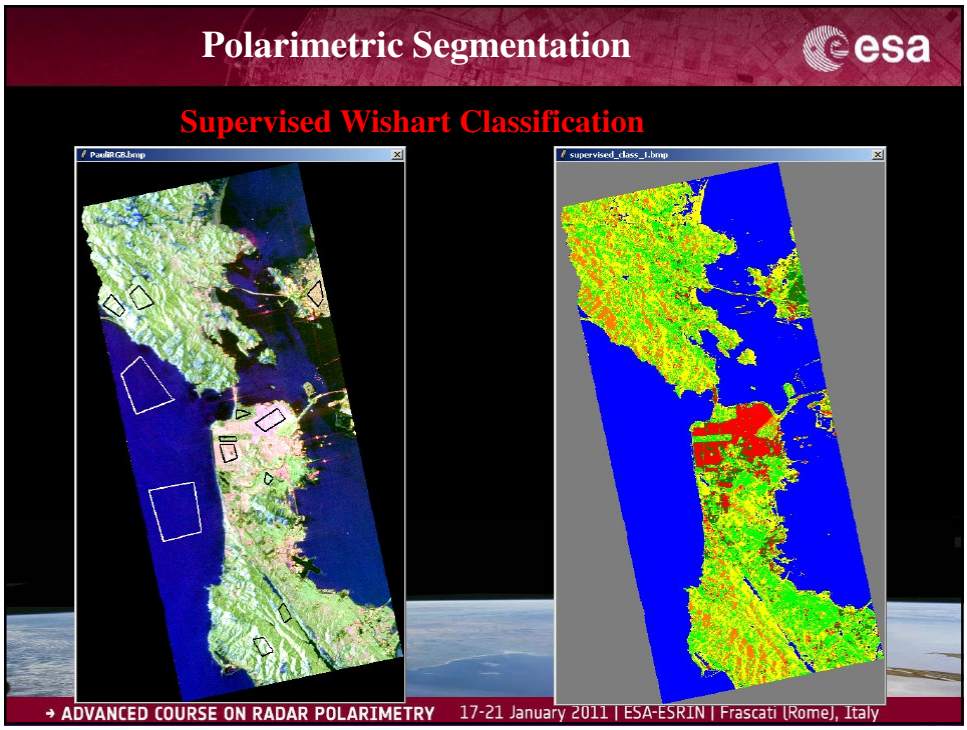
Polarimetric Segmentation
esa
Supervised Wishart Classification
PauliRGB.bmp
supervised_class_1.bmp
ADVANCED COURSE ON RADAR POLARIMETRY
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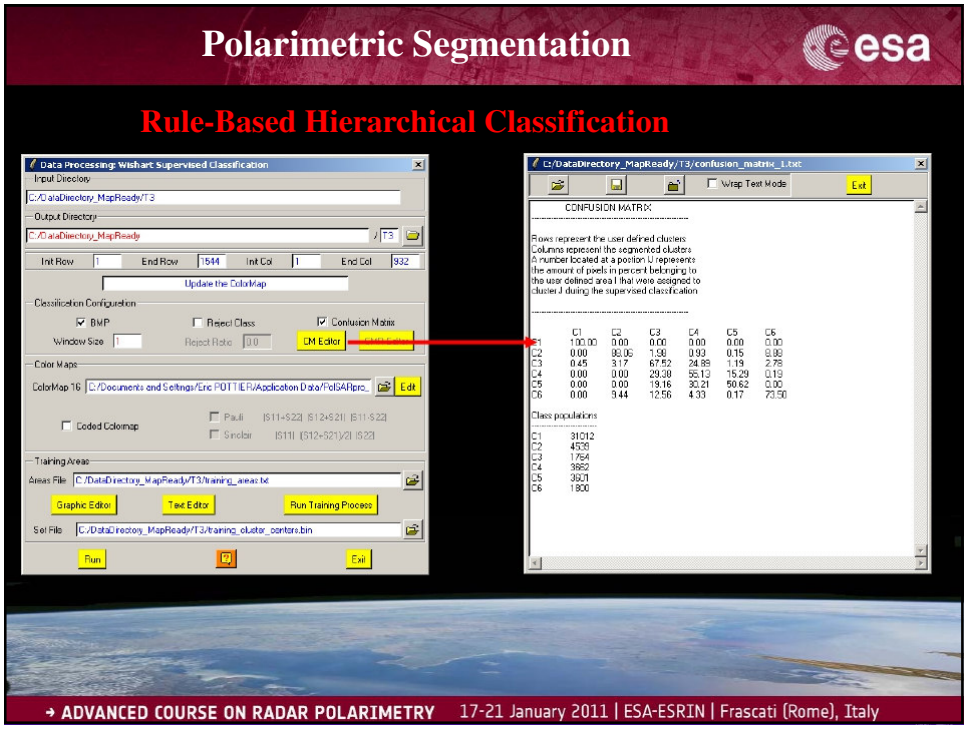
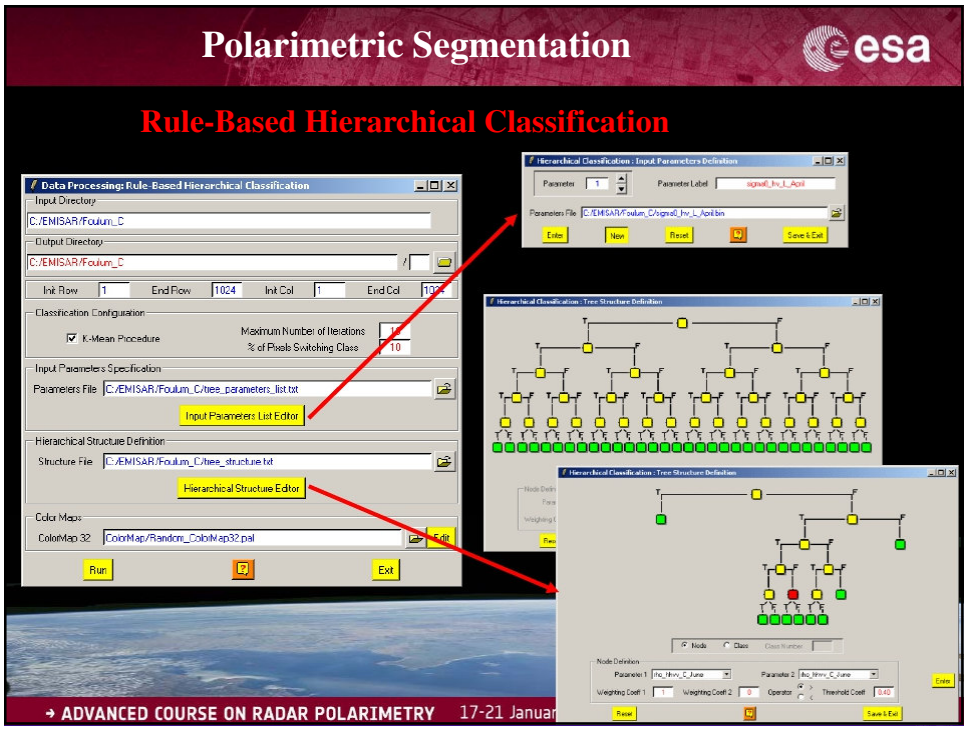
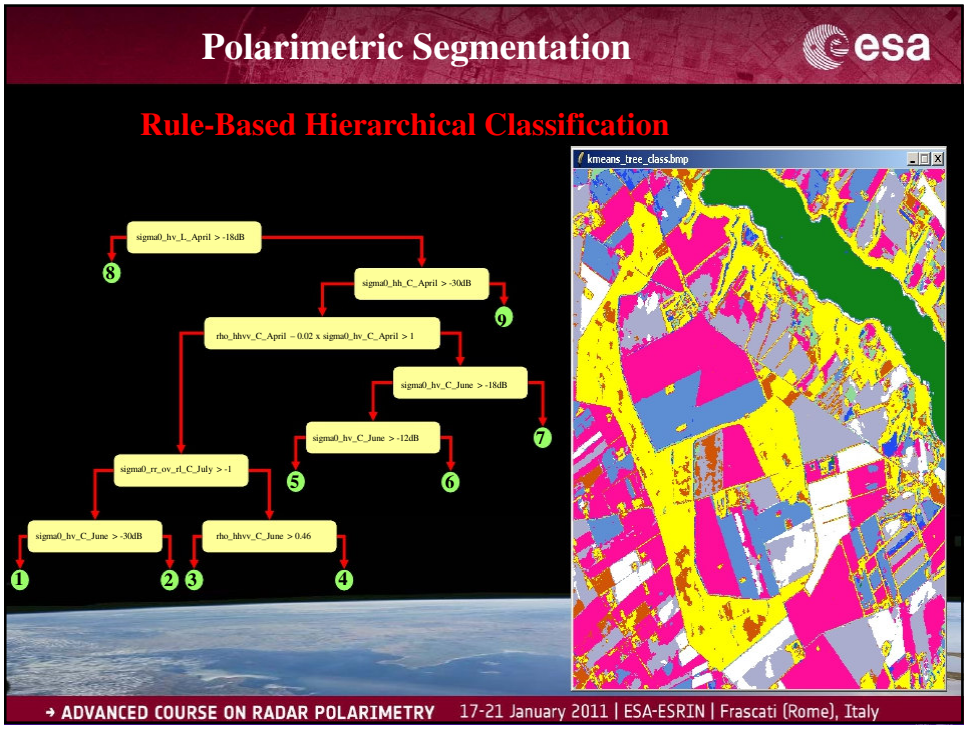

Polarimetric Segmentation
esa
Rule-Based Hierarchical Classification
Data Processing: Wishart Supervised Classification
C:/DataDirectory_MapReady/T3/confusion_matrix_1.txt
CONFUSION MATRIX
ADVANCED COURSE ON RADAR POLARIMETRY 17-21 January 2011 | ESA-ESRIN | Frascati (Rome), Italy


Polarimetric Segmentation
esa
Rule-Based Hierarchical Classification
Data Processing: Rule-Based Hierarchical Classification
Hierarchical Classification : Input Parameters Definition
Hierarchical Classification : Tree Structure Definition
ADVANCED COURSE ON RADAR POLARIMETRY 17-21 Januar


Polarimetric Segmentation
esa
Rule-Based Hierarchical Classification
sigma0_hv_L_April > -18dB
sigma0_hh_C_April > -30dB
rho_hhvv_C_April – 0.02 x sigma0_hv_C_April > 1
sigma0_hv_C_June > -18dB
sigma0_hv_C_June > -12dB
sigma0_rr_ov_rl_C_July > -1
sigma0_hv_C_June > -30dB
rho_hhvv_C_June > 0.46
1
2
3
4
5
6
7
8
9
kmeans_tree_class.bmp
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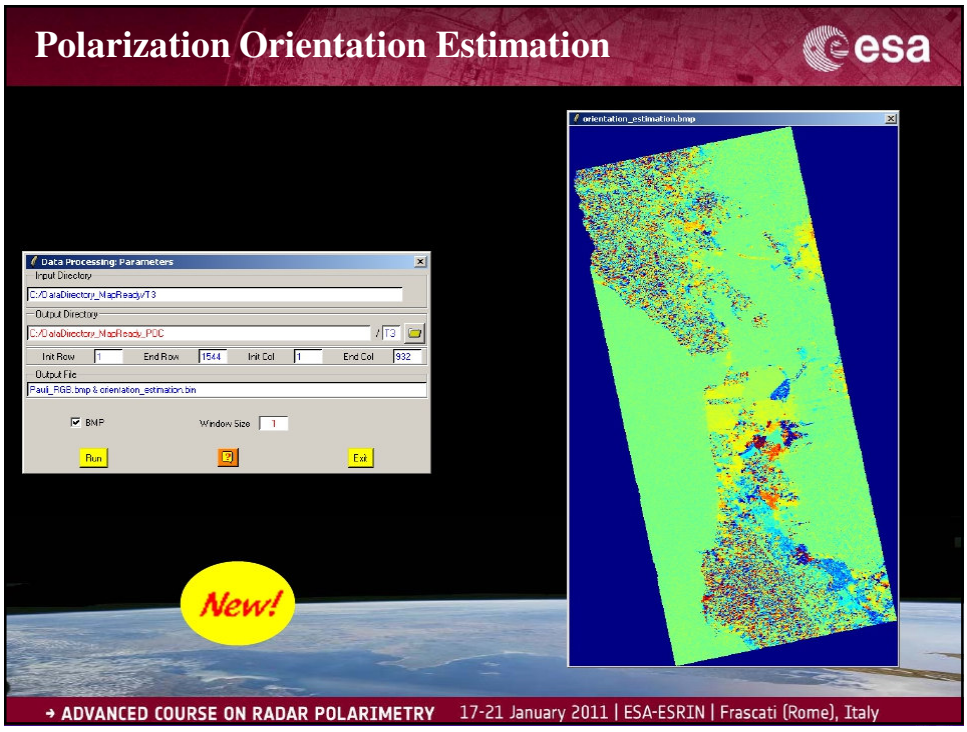
Polarization Orientation Estimation
esa
Data Processing: Parameters
Input Directory
C:/DataDirectory_MapReady/T3
Output Directory
C:/DataDirectory_MapReady_PDC
/T3
Init Row
1
End Row
1544
Init Col
1
End Col
932
Output File
Pauli_RGB.bmp & orientation_estimation.bin
BMP
Window Size
1
Run
Exit
New!
orientation_estimation.bmp
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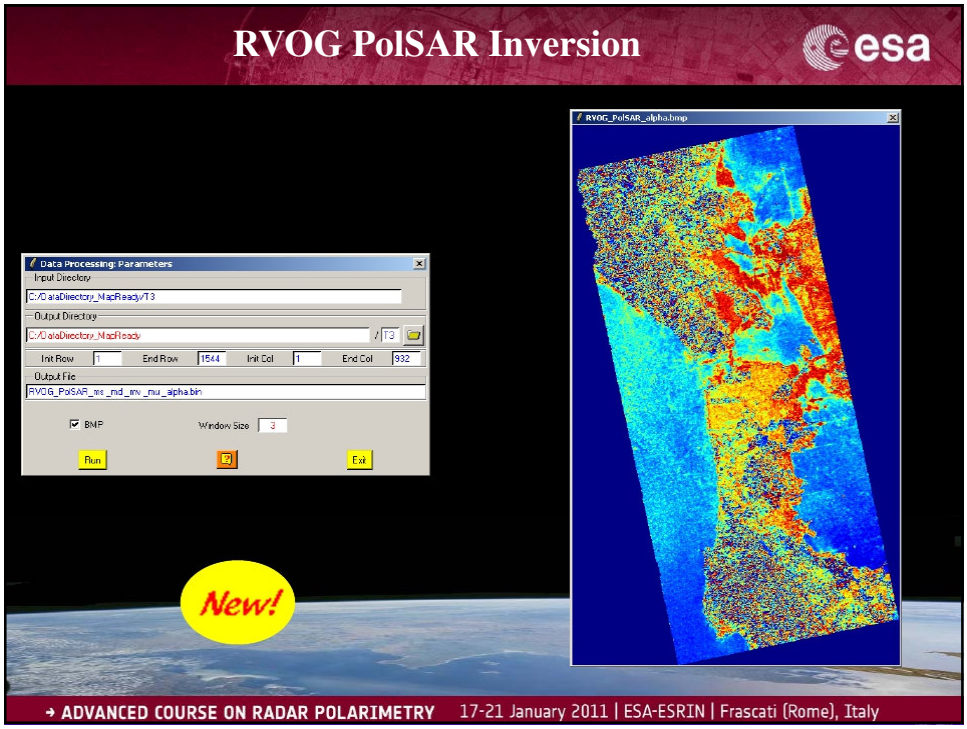
RVOG PolSAR Inversion
esa
Data Processing: Parameters
Input Directory
Output Directory
Init Row
End Row
Init Col
End Col
Output File
BMP
Window Size
Run
Exit
New!
ADVANCED COURSE ON RADAR POLARIMETRY
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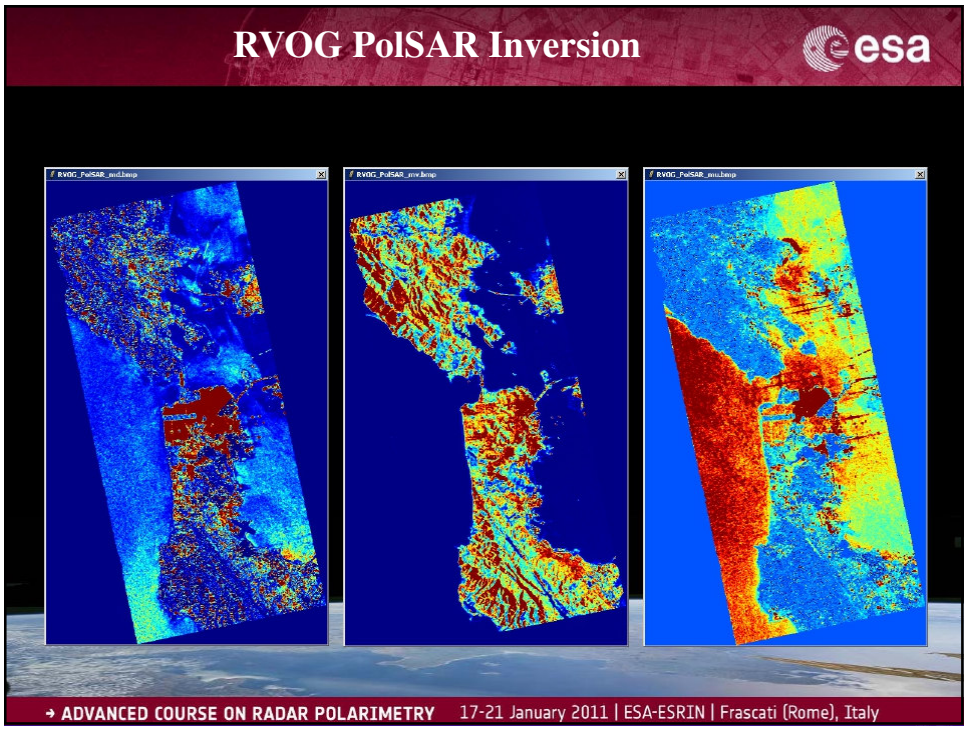
RVOG PolSAR Inversion
esa
ADVANCED COURSE ON RADAR POLARIMETRY
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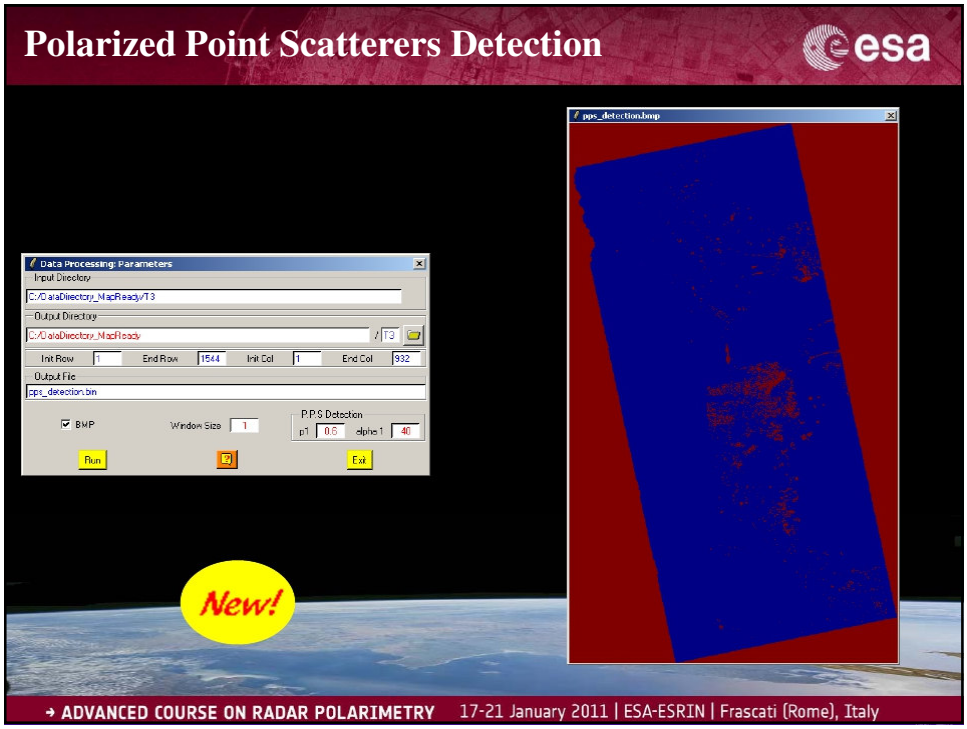
Polarized Point Scatterers Detection
esa
pps_detection.bmp
Data Processing: Parameters
Input Directory
Output Directory
Output File
pps_detection.bin
BMP
Window Size
P.P.S Detection
Run
Exit
New!
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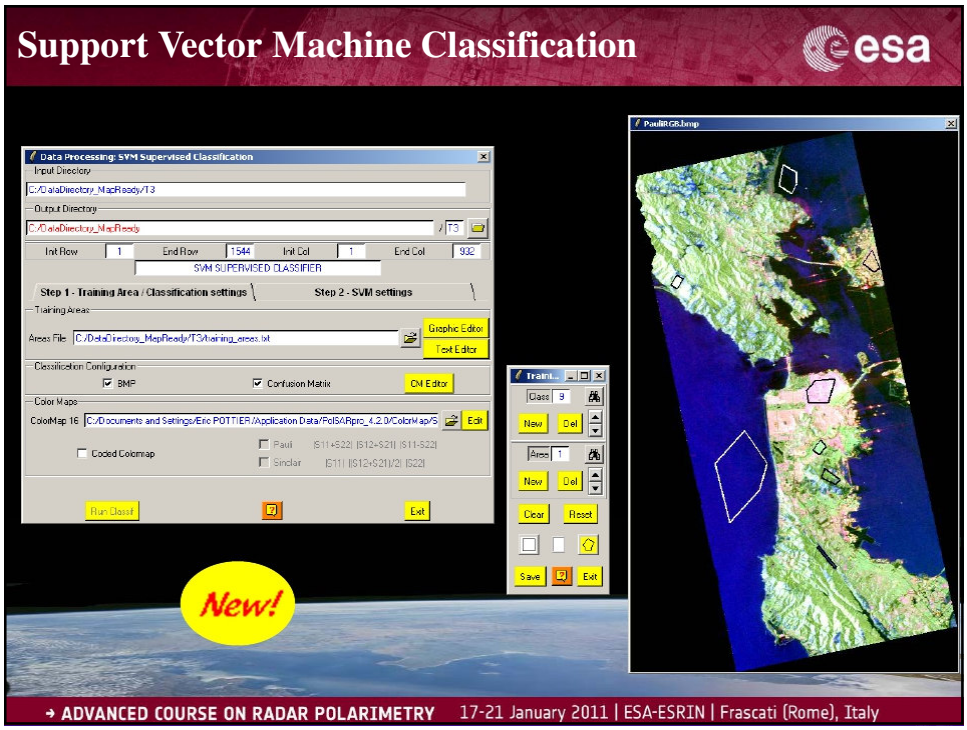
Support Vector Machine Classification
esa
PauliRGB.bmp
Data Processing: SVM Supervised Classification
Input Directory
Output Directory
SVM SUPERVISED CLASSIFIER
Step 1 - Training Area / Classification settings
Step 2 - SVM settings
Training Areas
Graphic Editor
Text Editor
Classification Configuration
BMP
Confusion Matrix
CM Editor
Color Maps
Coded Colormap
Run Classif
Exit
New!
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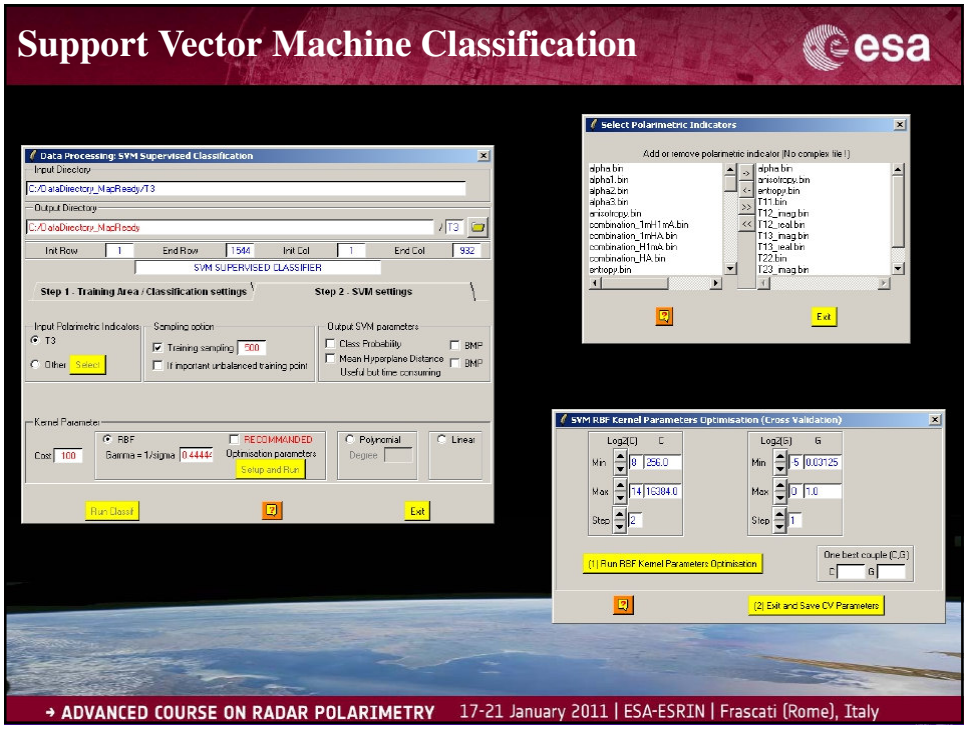
Support Vector Machine Classification
esa
Data Processing: SVM Supervised Classification
Select Polarimetric Indicators
SVM RBF Kernel Parameters Optimisation (Cross Validation)
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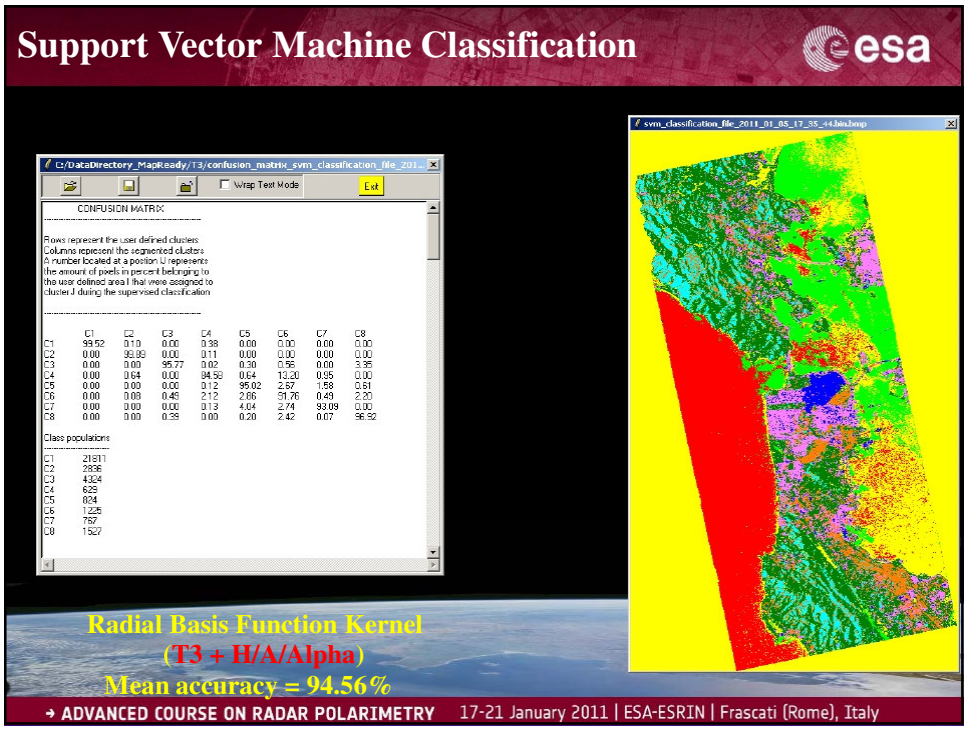
Support Vector Machine Classification
esa
CONFUSION MATRIX
Radial Basis Function Kernel
(T3 + H/A/Alpha)
Mean accuracy = 94.56%
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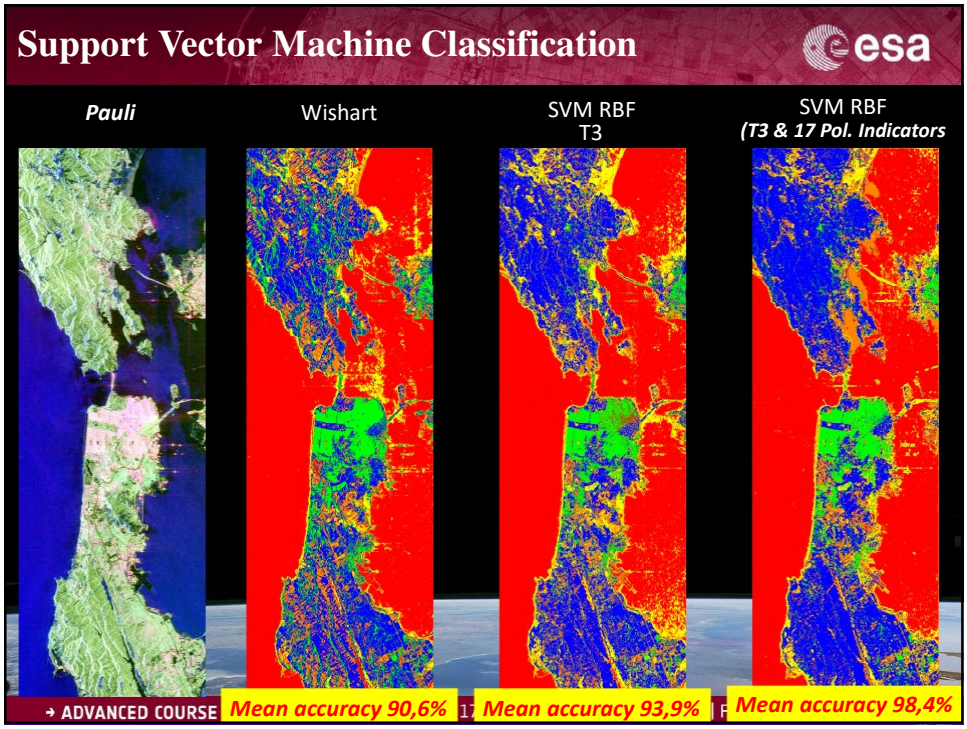
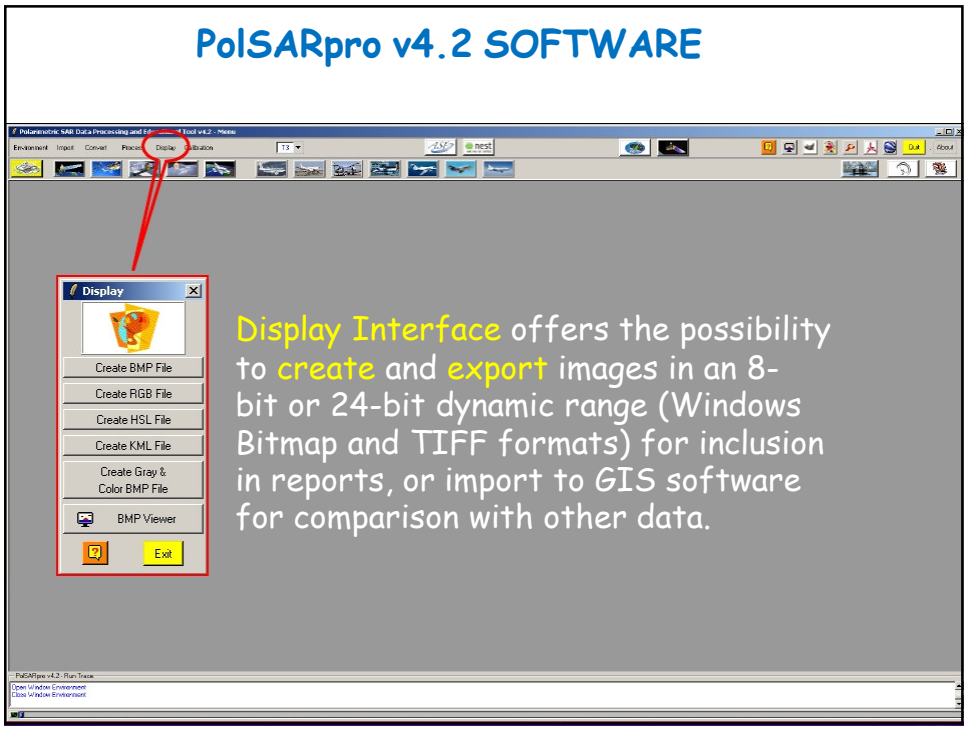
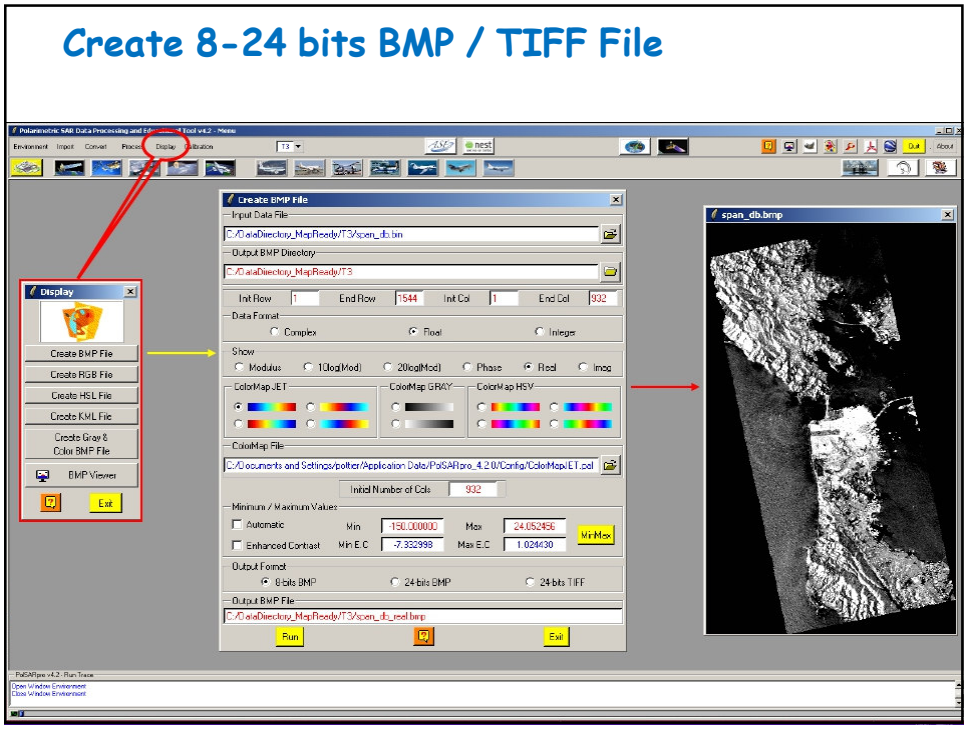
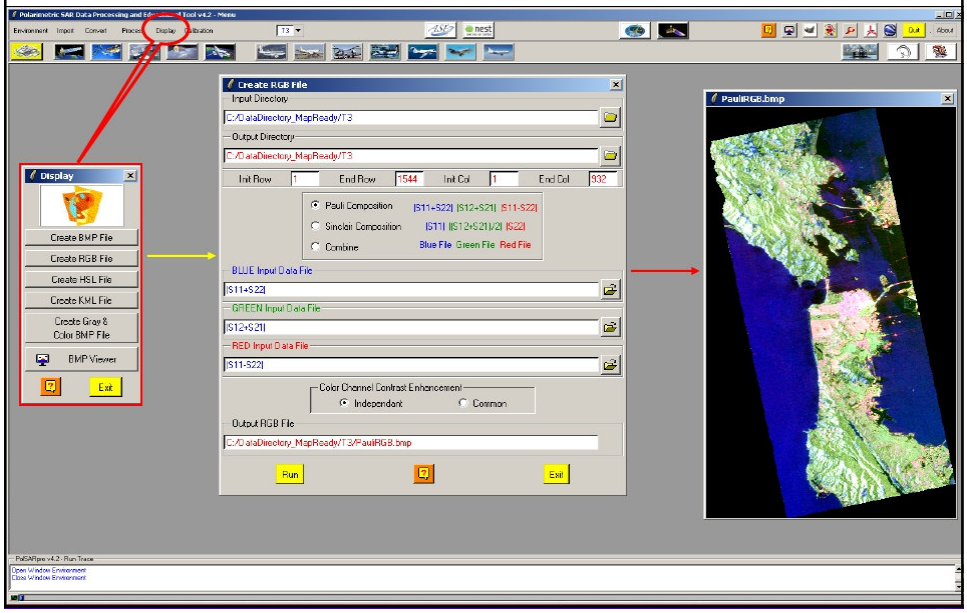

Support Vector Machine Classification
esa
Pauli
Wishart
SVM RBF
T3
SVM RBF
(T3 & 17 Pol. Indicators
ADVANCED COURSE
Mean accuracy 90,6%
Mean accuracy 93,9%
Mean accuracy 98,4%


PolSARpro v4.2 SOFTWARE
Display
Create BMP File
Create RGB File
Create HSL File
Create KML File
Create Gray & Color BMP File
BMP Viewer
Exit
Display Interface offers the possibility to create and export images in an 8-bit or 24-bit dynamic range (Windows Bitmap and TIFF formats) for inclusion in reports, or import to GIS software for comparison with other data.

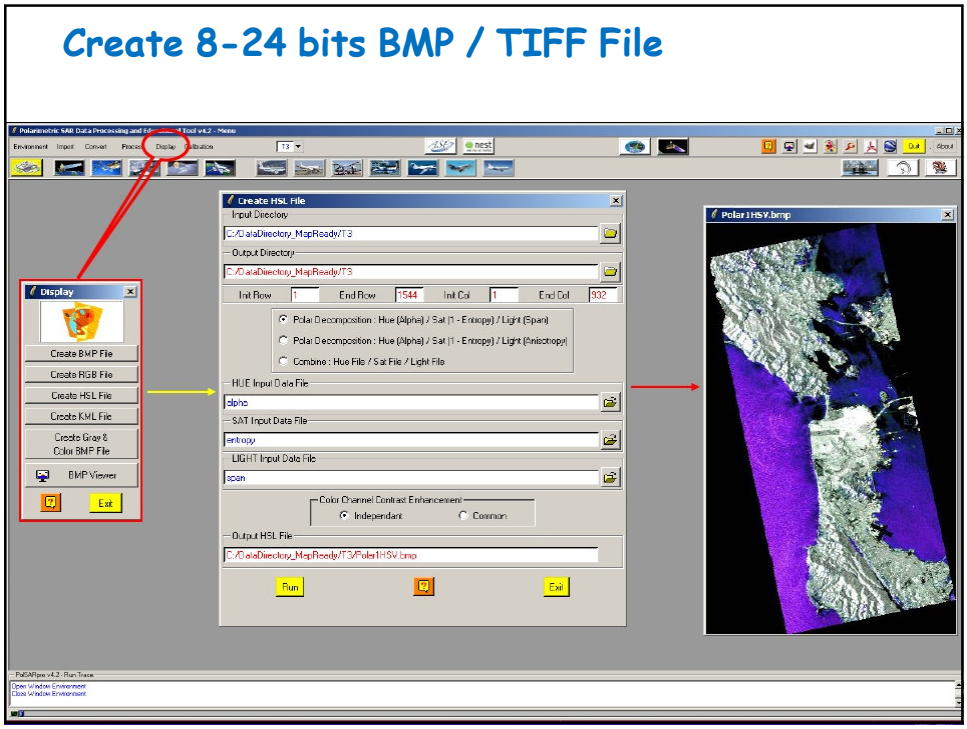
Create 8-24 bits BMP / TIFF File



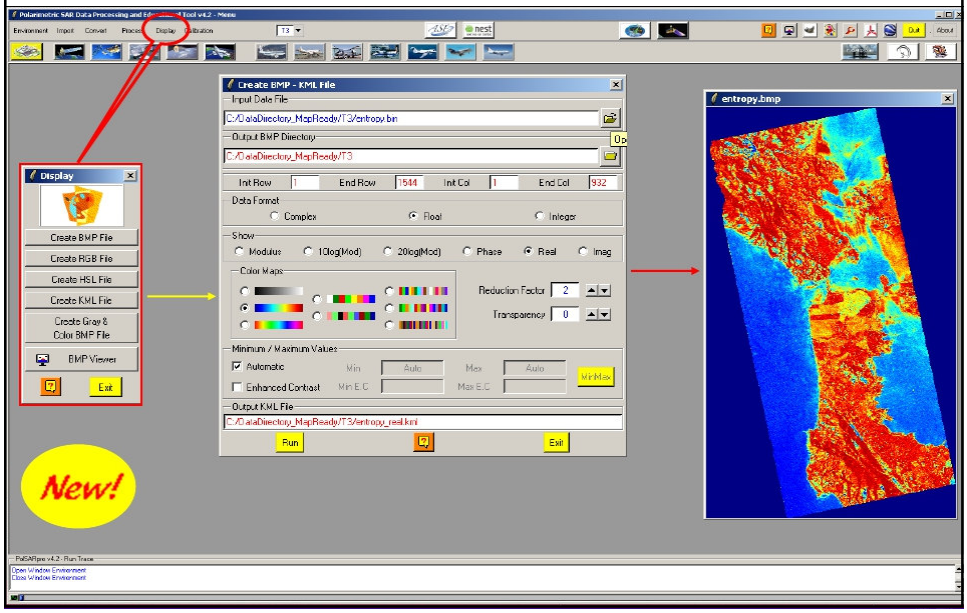
Create 8-24 bits BMP / TIFF File



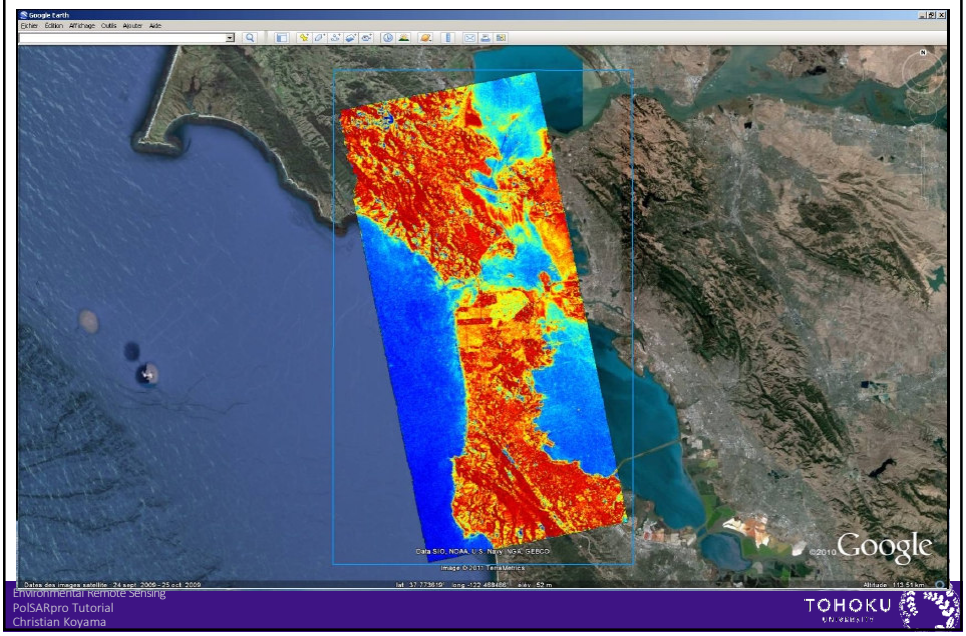
Create 8-24 bits BMP / TIFF File



Create BMP to KML File



GOOGLE EARTH



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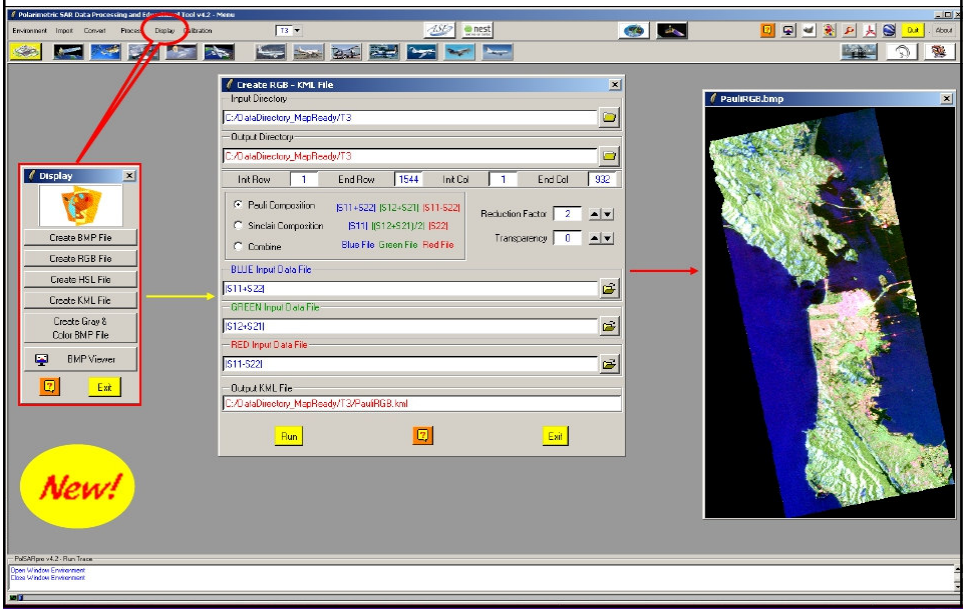
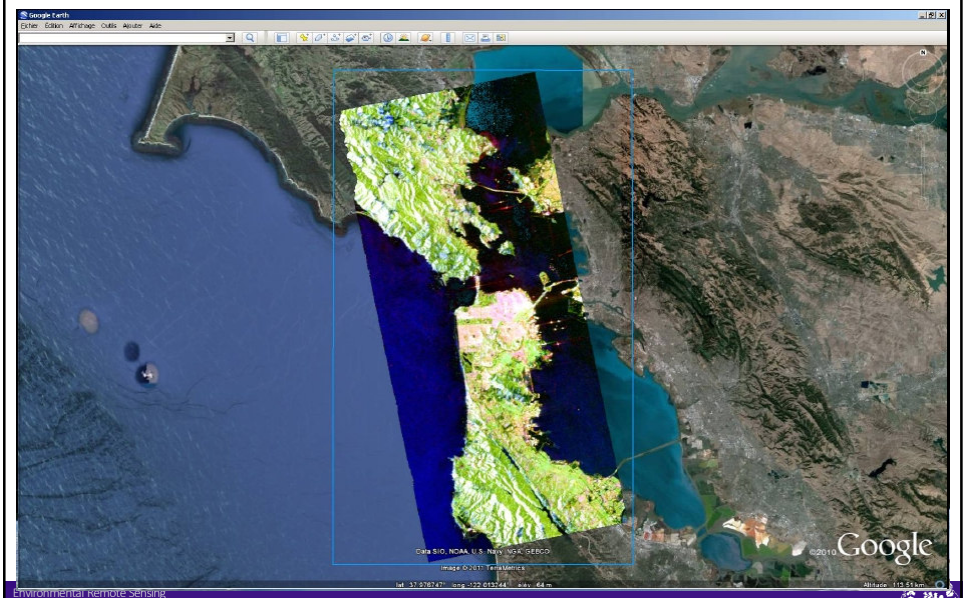
Create RGB to KML File



GOOGLE EARTH



PolSARpro Tutorial

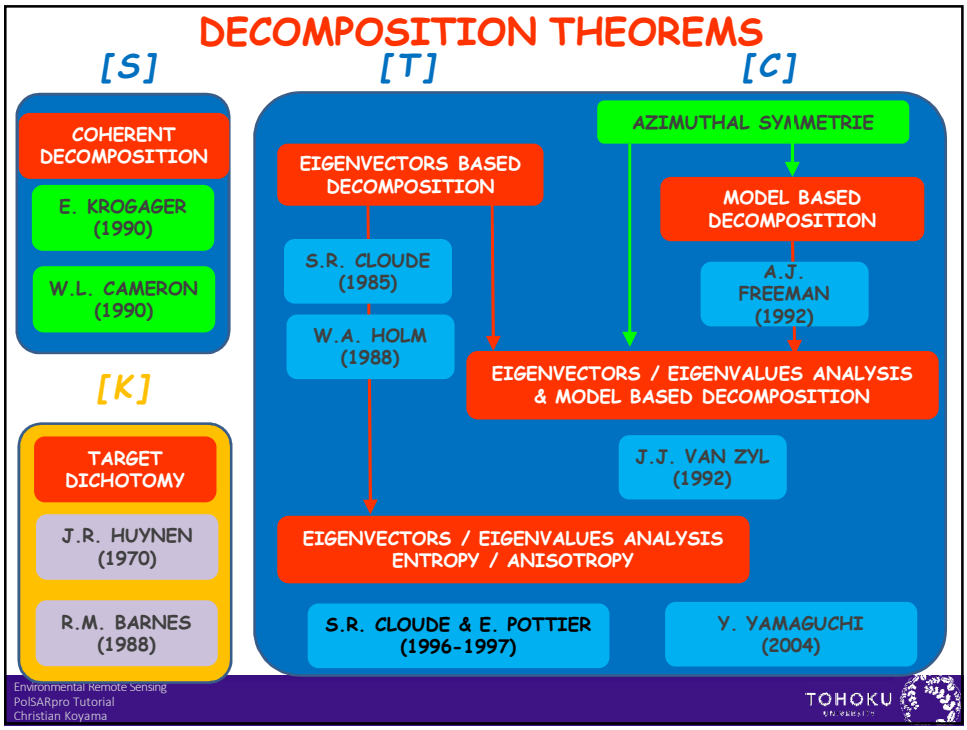
Day 1:

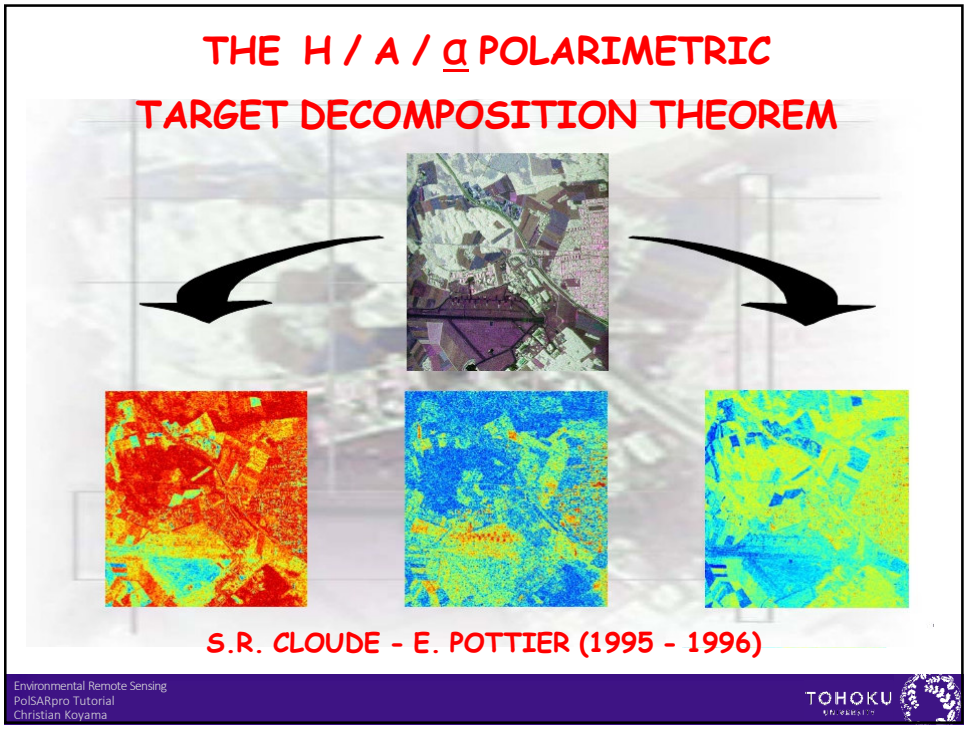
- Introduction
- Hands on Experience
  - Data Import, Image Extraction
  - Matrix Conversion
  - Polarimetric Speckle Filtering

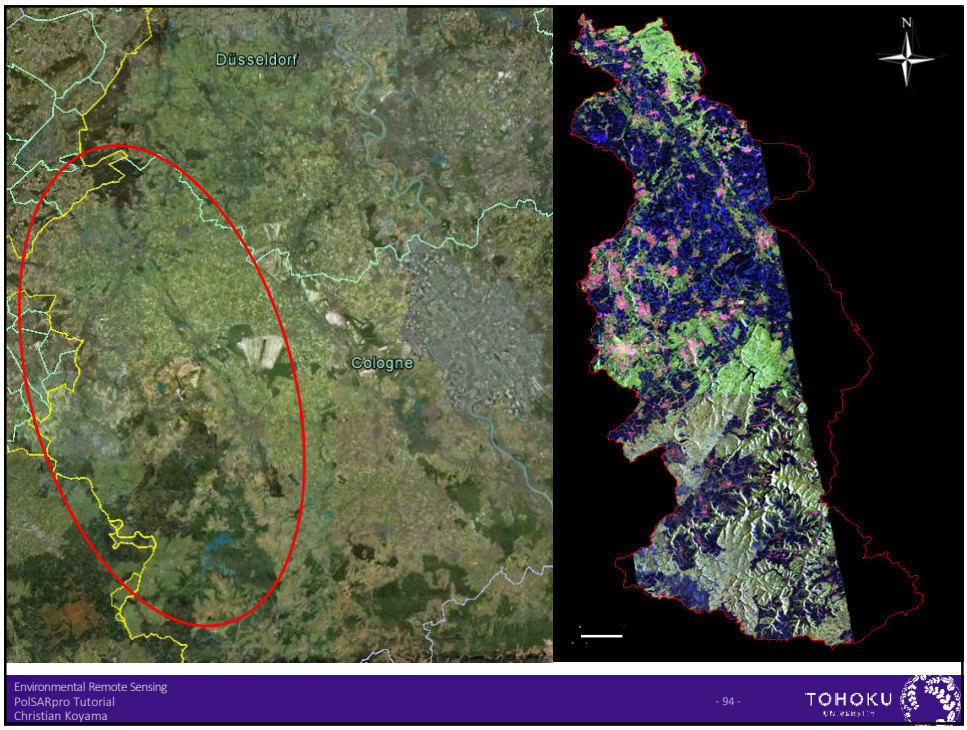
Day 2:

- Polarimetric Decomposition Theorems
- Hands on Experience
  - Polarimetric Decomposition
  - Land Use Classification

Polarimetric Decomposition




THE H / A / α POLARIMETRIC
TARGET DECOMPOSITION THEOREM
S.R. CLOUDE - E. POTTIER (1995 - 1996)
Environmental Remote Sensing
PolSARpro Tutorial
Christian Koyama
TOHOKU


Düsseldorf
Cologne
N
Environmental Remote Sensing
PolSARpro Tutorial
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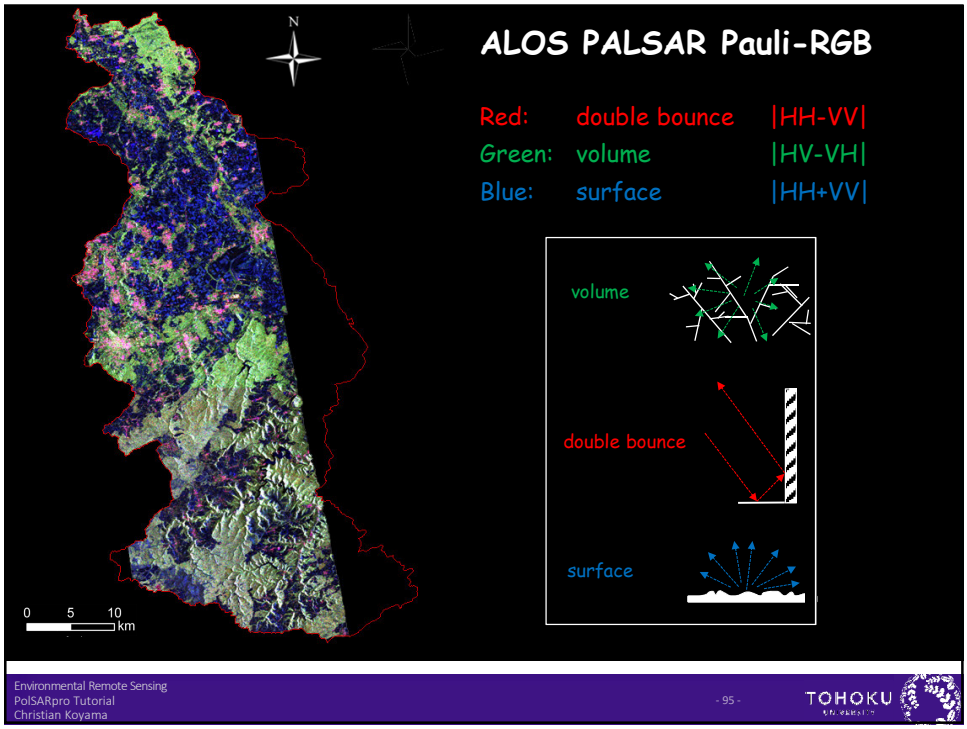
- 94 -
TOHOKU


ALOS PALSAR Pauli-RGB
Red: double bounce |HH-VV|
Green: volume |HV-VH|
Blue: surface |HH+VV|
volume
double bounce
surface
N
0 5 10 km
Environmental Remote Sensing
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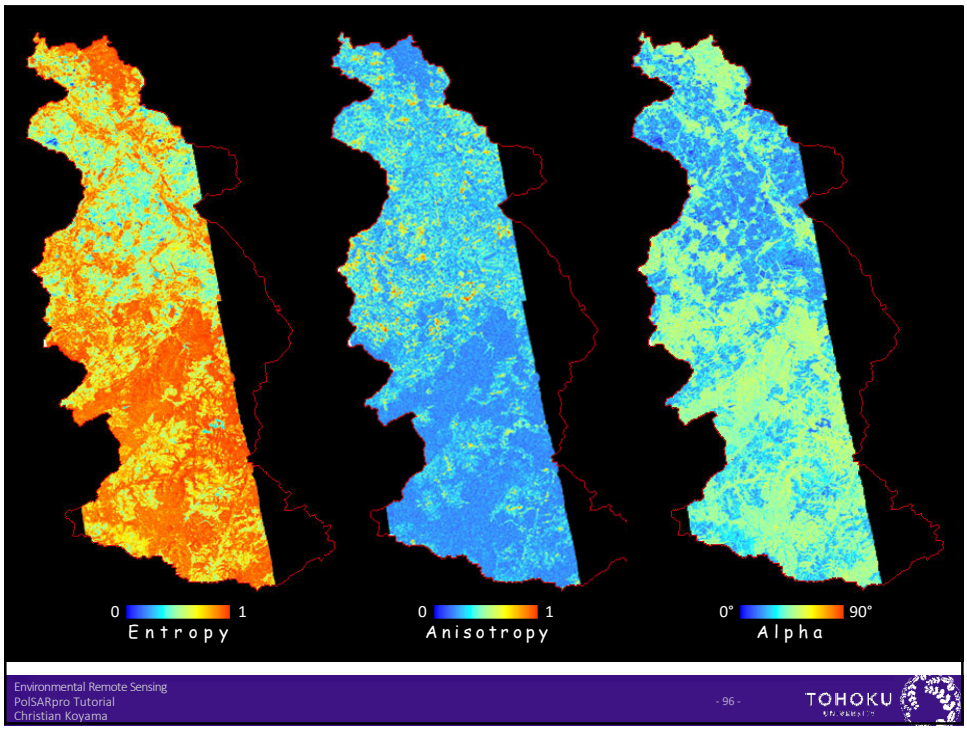
TOHOKU


0 1
Entropy
0 1
Anisotropy
0° 90°
Alpha
Environmental Remote Sensing
PolSARpro Tutorial
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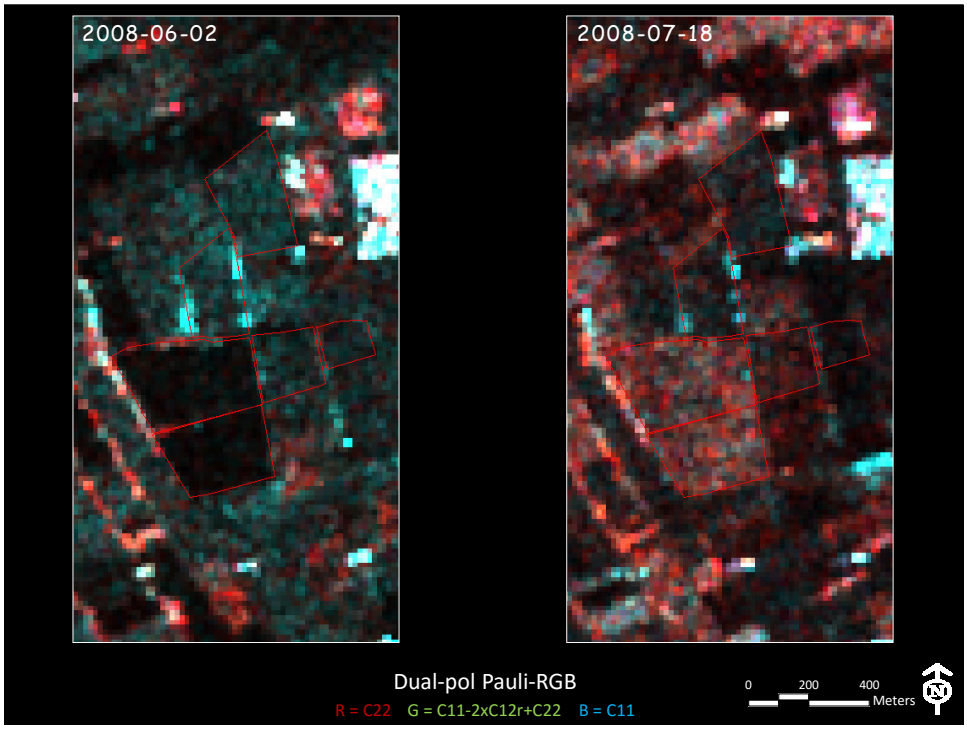
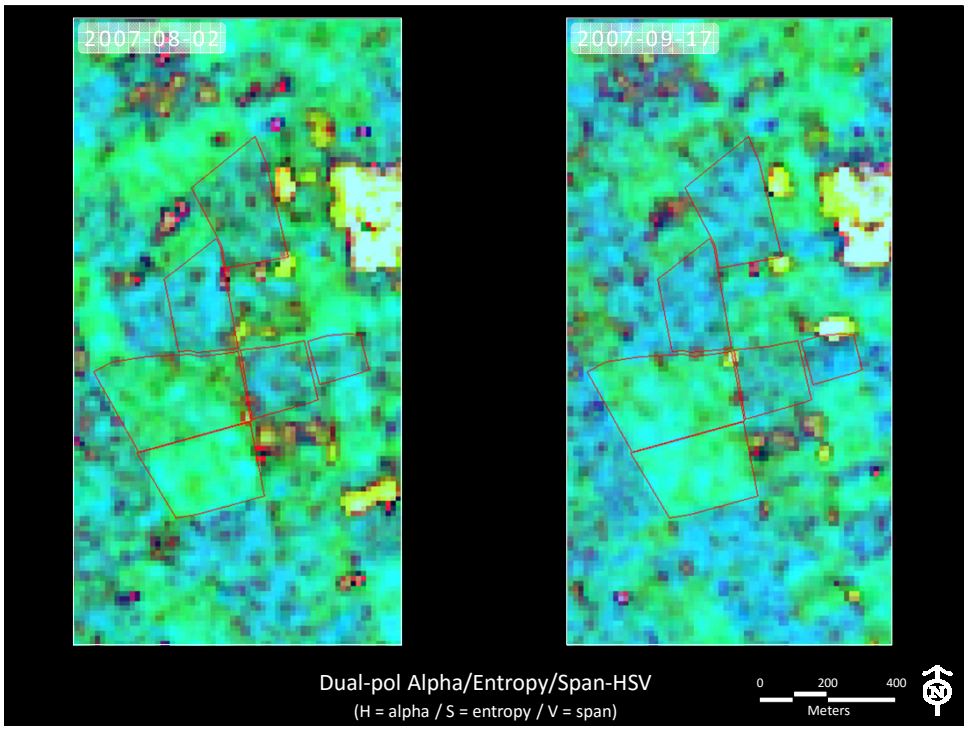

2008-06-02
2008-07-18
Dual-pol Pauli-RGB
R = C22 G = C11-2xC12r+C22 B = C11
0 200 400
Meters
N


2007-08-02
2007-09-17
Dual-pol Alpha/Entropy/Span-HSV
(H = alpha / S = entropy / V = span)
0 200 400
Meters
N

H / A / α DECOMPOSITION

TARGET VECTOR

$$\underline{k} = \frac{1}{\sqrt{2}}\left[S_{XX} + S_{YY} \quad S_{XX} - S_{YY} \quad 2S_{XY}\right]^T$$

LOCAL ESTIMATE OF THE COHERENCY MATRIX

$$\langle [T] \rangle = \frac{1}{N}\sum_{i=1}^{N} \underline{k}_i \cdot \underline{k}_i^{*T} = \frac{1}{N}\sum_{i=1}^{N} [T_i]$$

EIGENVECTORS / EIGENVALUES ANALYSIS

$$\langle [T] \rangle = [U_3][\Sigma][U_3]^{-1} = \begin{bmatrix} \underline{u}_1 & \underline{u}_2 & \underline{u}_3 \end{bmatrix} \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \begin{bmatrix} \underline{u}_1 & \underline{u}_2 & \underline{u}_3 \end{bmatrix}^{*T}$$

ORTHOGONAL EIGENVECTORS

REAL EIGENVALUES
λ1 > λ 2 > λ3

$$P_i = \frac{\lambda_i}{\sum_{k=1}^{3} \lambda_k}$$

H / A / α DECOMPOSITION

$$\langle [T] \rangle = [U_3][\Sigma][U_3]^{-1} = \begin{bmatrix} \underline{u}_1 & \underline{u}_2 & \underline{u}_3 \end{bmatrix} \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \begin{bmatrix} \underline{u}_1 & \underline{u}_2 & \underline{u}_3 \end{bmatrix}^{*T}$$

ORTHOGONAL EIGENVECTORS

REAL EIGENVALUES
λ1 > λ2 > λ3

PARAMETERISATION OF THE SU(3) UNITARY MATRIX

$$[U_3] = \begin{bmatrix} \cos(\alpha_1) & \cos(\alpha_2) & \cos(\alpha_3) \\ \sin(\alpha_1)\cos(\beta_1)e^{j\delta_1} & \sin(\alpha_2)\cos(\beta_2)e^{j\delta_2} & \sin(\alpha_3)\cos(\beta_3)e^{j\delta_3} \\ \sin(\alpha_1)\sin(\beta_1)e^{j\gamma_1} & \sin(\alpha_2)\sin(\beta_2)e^{j\gamma_2} & \sin(\alpha_3)\sin(\beta_3)e^{j\gamma_3} \end{bmatrix}$$

TARGET 1 TARGET 2 TARGET 3

H / A / $\underline{\alpha}$ DECOMPOSITION

PROBABILITIES

$$P_i = \frac{\lambda_i}{\sum_{k=1}^{3} \lambda_k}$$

AVERAGED PARAMETERS

$$\underline{\alpha} = P_1\alpha_1 + P_2\alpha_2 + P_3\alpha_3 \quad \underline{\beta} = P_1\beta_1 + P_2\beta_2 + P_3\beta_3$$
$$\underline{\gamma} = P_1\gamma_1 + P_2\gamma_2 + P_3\gamma_3 \quad \underline{\delta} = P_1\delta_1 + P_2\delta_2 + P_3\delta_3$$

UNITARY TARGET VECTOR ($\underline{u_0}$) OF THE MEAN DOMINANT MECHANISM

$$\underline{u_0} = \left[\cos(\underline{\alpha}) \quad \sin(\underline{\alpha})\cos(\underline{\beta})\, e^{j\underline{\delta}} \quad \sin(\underline{\alpha})\sin(\underline{\beta})\, e^{j\underline{\gamma}}\right]^T$$

H / A / $\underline{\alpha}$ DECOMPOSITION

MEAN SCATTERING MECHANISM

UNITARY VECTOR $\underline{u_0}$

$$\underline{u_0} = \begin{bmatrix} \cos(\underline{\alpha}) \\ \sin(\underline{\alpha})\cos(\underline{\beta})e^{j\underline{\delta}} \\ \sin(\underline{\alpha})\sin(\underline{\beta})e^{j\underline{\gamma}} \end{bmatrix}$$

TARGET MAGNITUDE

$$\underline{\lambda} = P_1\lambda_1 + P_2\lambda_2 + P_3\lambda_3 = \frac{\sum_{i=1}^{3} \lambda_i^2}{\sum_{k=1}^{3} \lambda_k}$$

TARGET VECTOR $\underline{k_0}$

$$\underline{k_0} = \sqrt{\underline{\lambda}} \begin{bmatrix} \cos(\underline{\alpha}) \\ \sin(\underline{\alpha})\cos(\underline{\beta})e^{j\underline{\delta}} \\ \sin(\underline{\alpha})\sin(\underline{\beta})e^{j\underline{\gamma}} \end{bmatrix}$$

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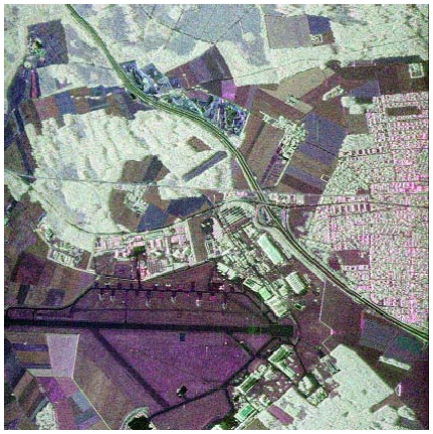
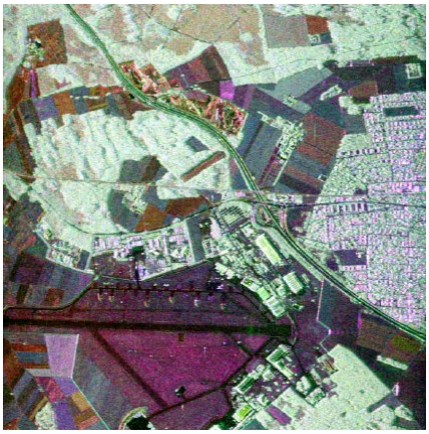
H / A / α DECOMPOSITION



$2A_0$ $B_0 + B$ $B_0 - B$



$\sqrt{\lambda}\cos(\alpha)$ $\sqrt{\lambda}\sin(\alpha)\cos(\beta)$
$\sqrt{\lambda}\sin(\alpha)\sin(\beta)$

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H / A / α DECOMPOSITION

$2A_0$ $B_0 + B$ $B_0 - B$

$\sqrt{\lambda}\cos(\alpha)$ $\sqrt{\lambda}\sin(\alpha)\cos(\beta)$
$\sqrt{\lambda}\sin(\alpha)\sin(\beta)$

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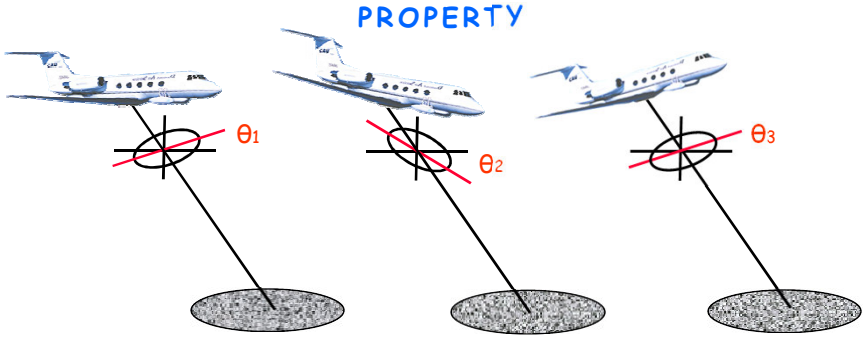
H / A / α DECOMPOSITION

ROLL INVARIANCE PROPERTY



SAME PHYSICAL PHENOMENOUS WHATEVER THE ANTENNA *ORIENTATION ANGLE* AROUND THE *RADAR LINE OF SIGHT*

H / A / α DECOMPOSITION

ROLL INVARIANCE PROPERTY

T(3) ORIENTED (θ) COHERENCY MATRIX SU(3) UNITARY ROTATION MATRIX(θ)

$$\langle [T(\theta)] \rangle = [U_R(\theta)] \langle [T] \rangle [U_R(\theta)]^{-1} \qquad [U_R(\theta)] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 2\theta & \sin 2\theta \\ 0 & -\sin 2\theta & \cos 2\theta \end{bmatrix}$$

EIGENVECTORS / EIGENVALUES ANALYSIS

$$\langle [T(\theta)] \rangle = [U_3(\theta)][\Sigma][U_3(\theta)]^{-1}$$

EIGENVALUES λ_1 λ_2 λ_3: ROLL INVARIANT

PROBABILITIES P_1 P_2 P_3: ROLL INVARIANT

H / A / $\underline{\alpha}$ DECOMPOSITION

EIGENVECTORS UNITARY MATRIX

$$[U_3(\theta)] = [U_R(\theta)][U_3]$$

PARAMETERIZATION OF THE UNITARY MATRIX

$$[U_3] = \begin{bmatrix} \cos(\alpha_1) & \cos(\alpha_2) & \cos(\alpha_3) \\ \sin(\alpha_1)\cos(\beta'_1)e^{j\delta'_1} & \sin(\alpha_2)\cos(\beta'_2)e^{j\delta'_2} & \sin(\alpha_3)\cos(\beta'_3)e^{j\delta'_3} \\ \sin(\alpha_1)\sin(\beta'_1)e^{j\gamma'_1} & \sin(\alpha_2)\sin(\beta'_2)e^{j\gamma'_2} & \sin(\alpha_3)\sin(\beta'_3)e^{j\gamma'_3} \end{bmatrix}$$

$$\underline{\alpha} = P_1\alpha_1 + P_2\alpha_2 + P_3\alpha_3$$: ROLL INVARIANT

PHYSICAL INTERPRETATION

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ANISOTROPIC PARTICLES CLOUD

$$[S] = \begin{bmatrix} a & 0 \\ 0 & b \end{bmatrix} \Rightarrow [T] = \begin{bmatrix} \varepsilon & \mu & 0 \\ \mu^* & \nu & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$\langle [T(\theta)] \rangle_\theta = \frac{1}{2}\begin{bmatrix} 2\varepsilon & 0 & 0 \\ 0 & \nu & 0 \\ 0 & 0 & \nu \end{bmatrix}$$

AVERAGING OVER ALL ORIENTATION ANGLES WITH : $P(\theta) = \frac{1}{2\pi}$

$$\lambda_1 = \varepsilon \Rightarrow P_1 = \frac{\varepsilon}{(\varepsilon+\nu)}$$

$$\lambda_2 = \lambda_3 = \frac{\nu}{2} \Rightarrow P_2 = P_3 = \frac{\nu}{2(\varepsilon+\nu)}$$

$$[U_3] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \Rightarrow \alpha_1 = 0, \quad \alpha_2 = \alpha_3 = \frac{\pi}{2}$$

$$\underline{\alpha} = \alpha_1 P_1 + \alpha_2 P_2 + \alpha_3 P_3 = \frac{\pi}{2}(P_2 + P_3)$$

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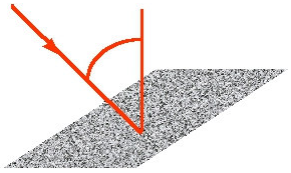
H / A / α DECOMPOSITION

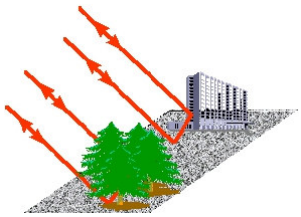
ALPHA PHYSICAL INTERPRETATION

SINGLE BOUNCE SCATTERING
(ROUGH SURFACE)



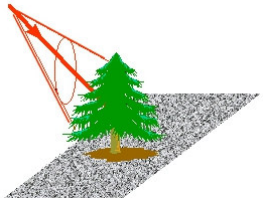
$$a \mapsto b \Rightarrow \nu \mapsto 0 \Downarrow \alpha \mapsto 0$$

DOUBLE BOUNCE SCATTERING



$$a \mapsto -b \Rightarrow \varepsilon \mapsto 0 \Downarrow \alpha \mapsto \frac{\pi}{2}$$

VOLUME SCATTERING



$$a >> b \Rightarrow \varepsilon \approx \nu \Downarrow \alpha \mapsto \frac{\pi}{4}$$

H / A / α DECOMPOSITION

EIGENVALUES λ_1 λ_2 λ_3: ROLL INVARIANT

PROBABILITIES P_1 P_2 P_3: ROLL INVARIANT

ENTROPY

(DEGREE OF RANDOMNESS
STATISTICAL DISORDER)

$$H = -\sum_{i=1}^{3} P_i \log_3(P_i)$$

PURE TARGET

$\lambda_1 = SPAN \quad \lambda_2 = 0 \quad \lambda_3 = 0$

$H = 0$

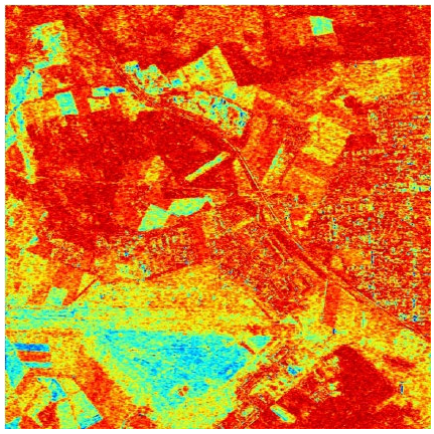
DISTRIBUTED TARGET

$\lambda_1 = \lambda_2 = \lambda_3 = SPAN / 3$

$H = 1$

H / A / α DECOMPOSITION

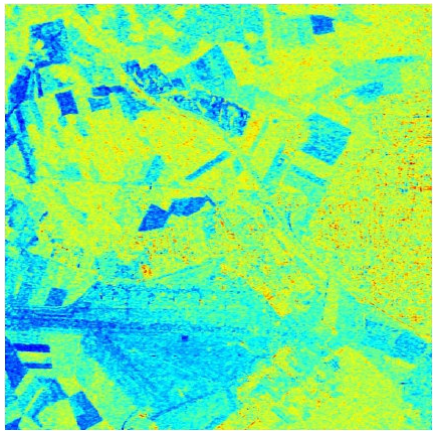
$2A_0$ $B_0 + B$ $B_0 - B$



ENTROPY (H)

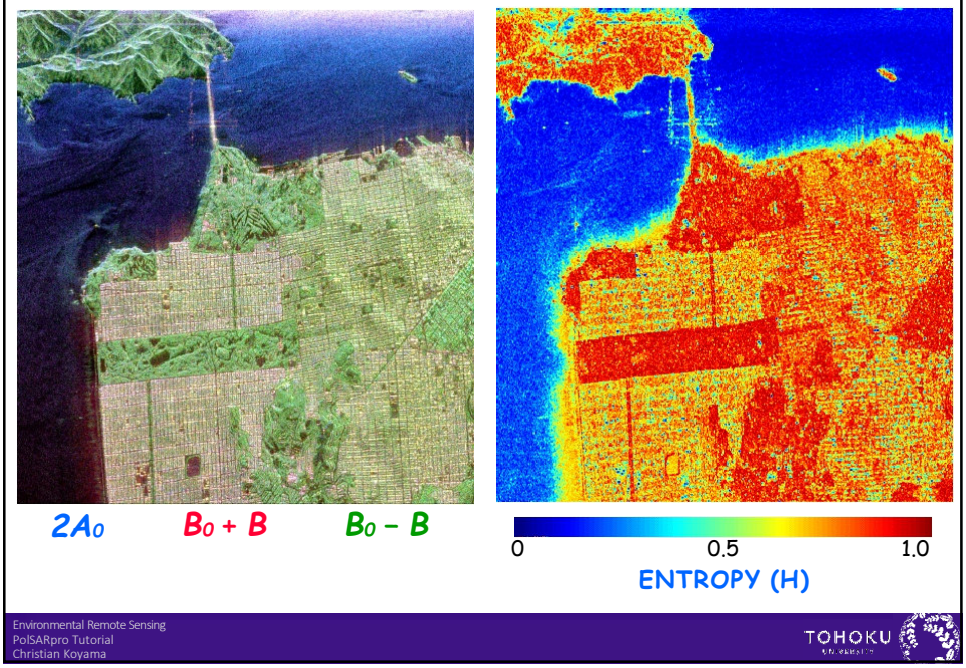
H / A / α DECOMPOSITION

$2A_0$ $B_0 + B$ $B_0 - B$

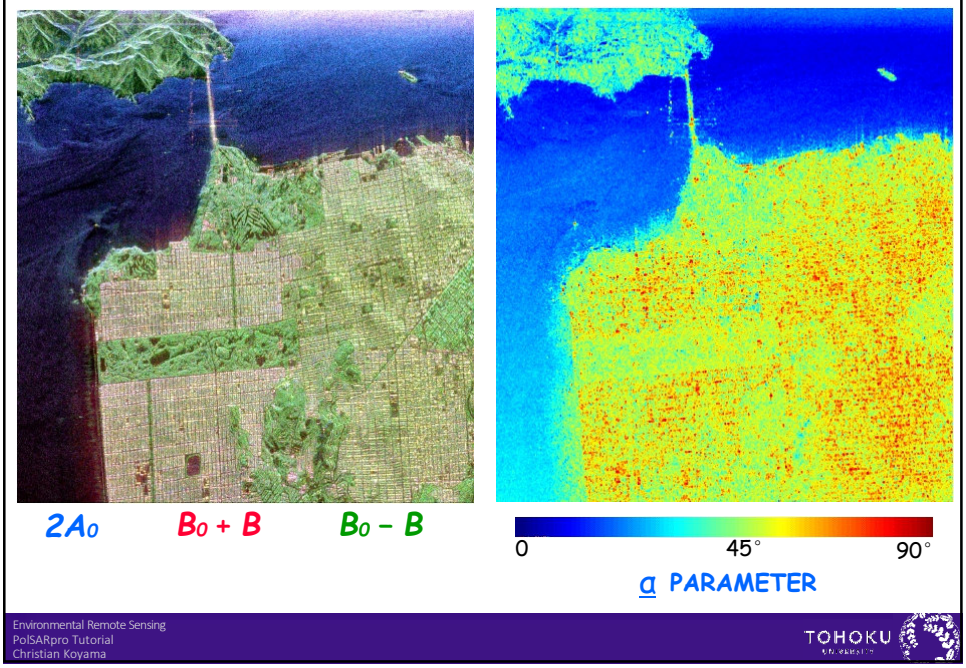


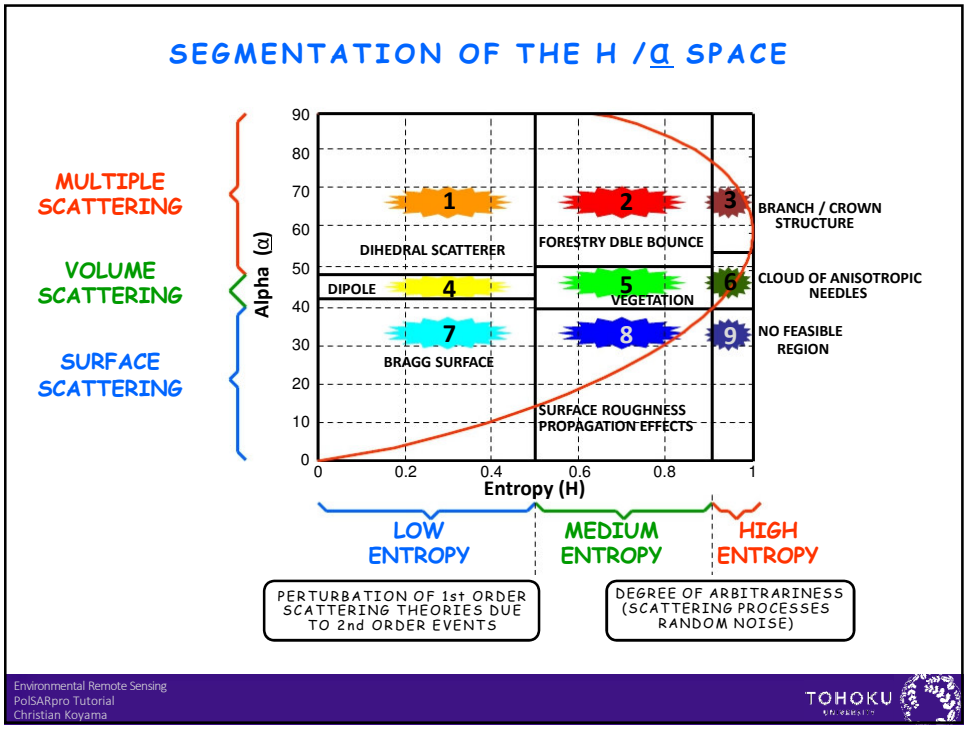
α PARAMETER

H / A / α DECOMPOSITION



H / A / α DECOMPOSITION




SEGMENTATION OF THE H /α SPACE
MULTIPLE SCATTERING
VOLUME SCATTERING
SURFACE SCATTERING
Alpha (α)
Entropy (H)
1
2
3
4
5
6
7
8
9
DIHEDRAL SCATTERER
FORESTRY DBLE BOUNCE
BRANCH / CROWN STRUCTURE
DIPOLE
VEGETATION
CLOUD OF ANISOTROPIC NEEDLES
BRAGG SURFACE
NO FEASIBLE REGION
SURFACE ROUGHNESS PROPAGATION EFFECTS
LOW ENTROPY
MEDIUM ENTROPY
HIGH ENTROPY
PERTURBATION OF 1st ORDER SCATTERING THEORIES DUE TO 2nd ORDER EVENTS
DEGREE OF ARBITRARINESS (SCATTERING PROCESSES RANDOM NOISE)
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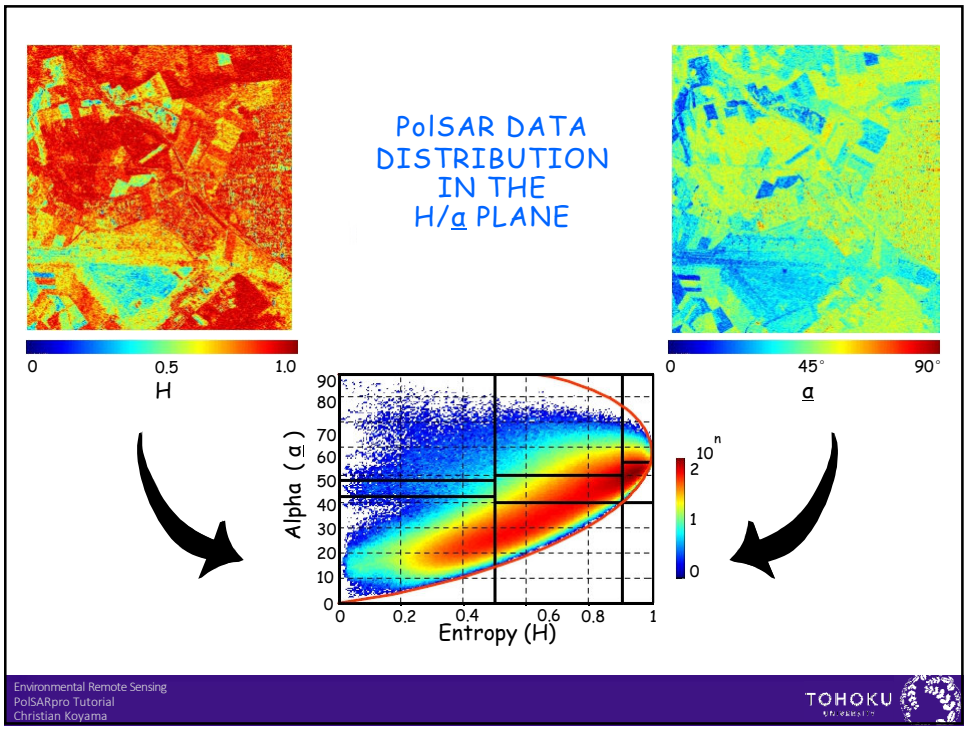
PolSAR DATA DISTRIBUTION IN THE H/α PLANE
H
α
Alpha (α)
Entropy (H)
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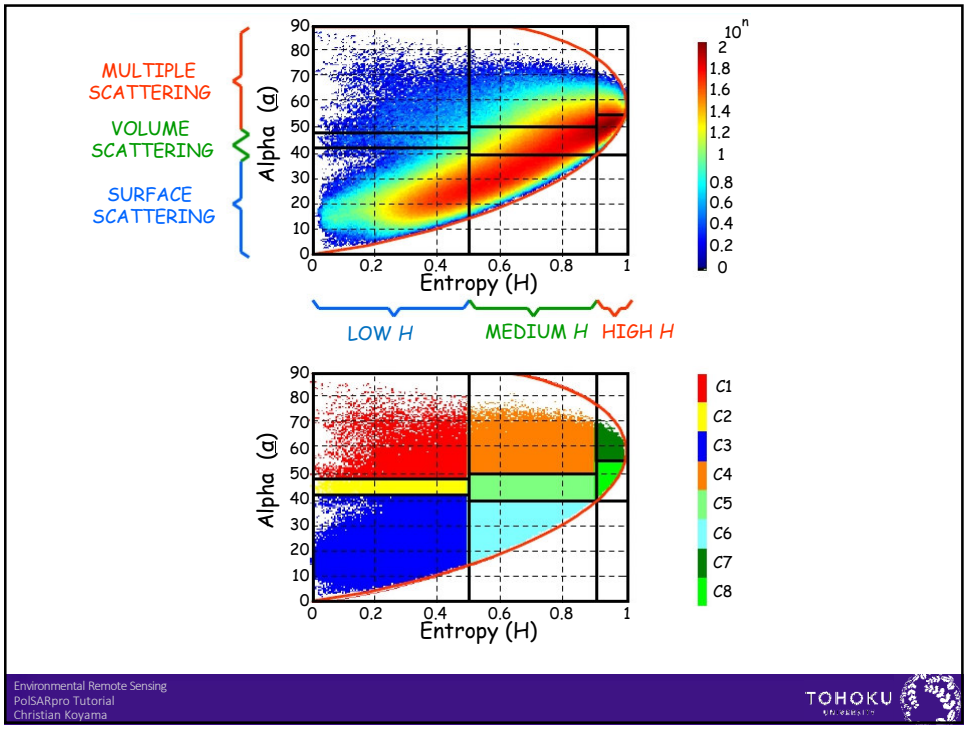
MULTIPLE SCATTERING
VOLUME SCATTERING
SURFACE SCATTERING
Alpha (α)
Entropy (H)
LOW H
MEDIUM H
HIGH H
10^n
C1
C2
C3
C4
C5
C6
C7
C8
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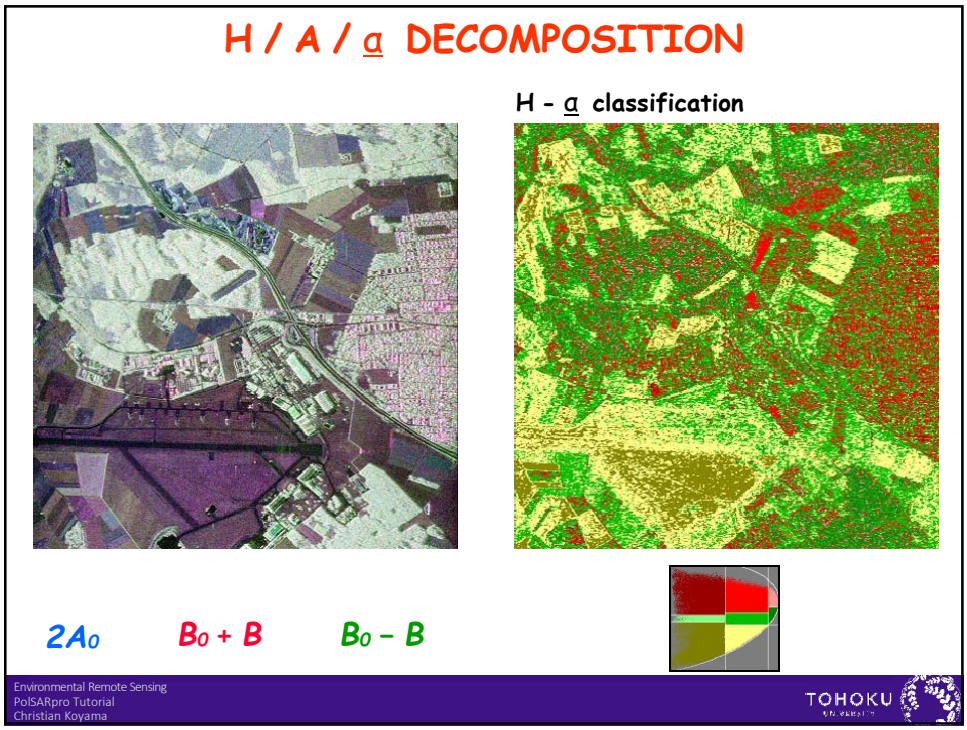
H / A / α DECOMPOSITION
H - α classification
2A0
B0 + B
B0 - B
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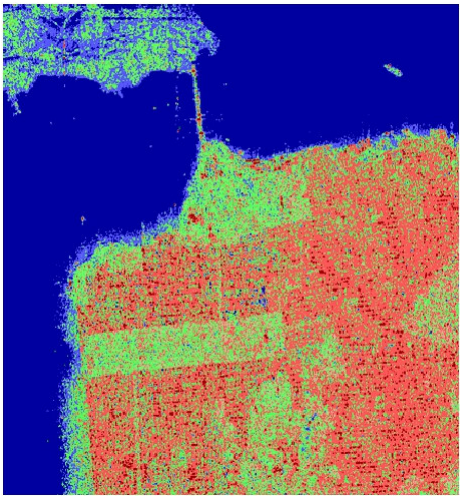
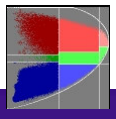
H / A / α DECOMPOSITION

H - α classification



$2A_0$ $B_0 + B$ $B_0 - B$



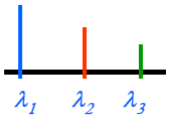
H / A / α DECOMPOSITION

DIFFICULT MECHANISM DISCRIMINATION WHEN: H > 0.7

↓

ANISOTROPY
(EIGENVALUES SPECTRUM)

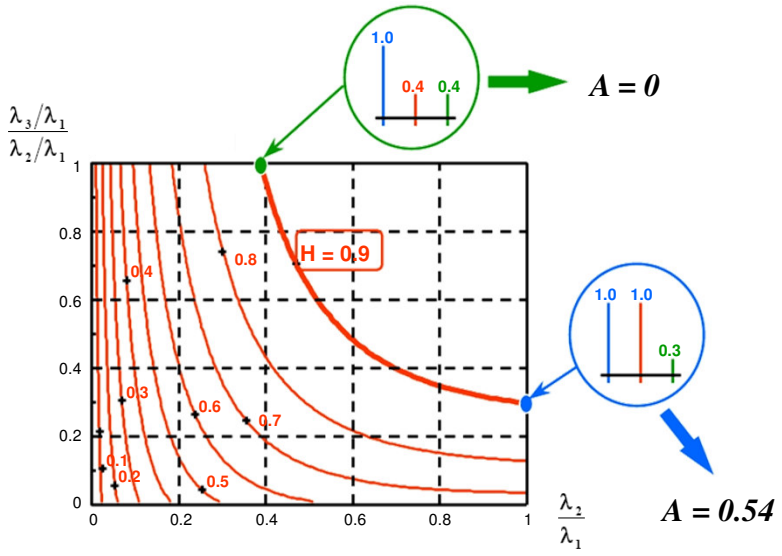
$$A = \frac{\lambda_2 - \lambda_3}{\lambda_2 + \lambda_3}$$



↓

→ COMPLEMENTARY TO ENTROPY
→ DISCRIMINATION WHEN H > 0.7
→ ROLL INVARIANT

H / A / α DECOMPOSITION



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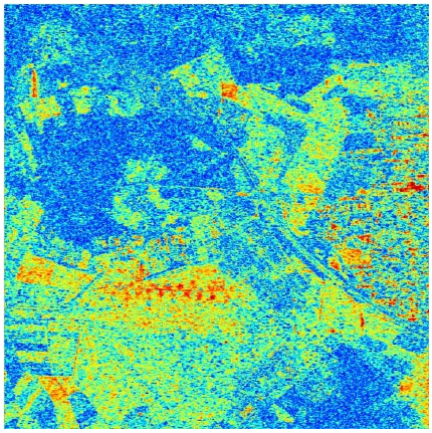
H / A / α DECOMPOSITION



0 0.5 1.0

$2A_0$ $B_0 + B$ $B_0 - B$ ANISOTROPY (A)

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ENTROPY (H)
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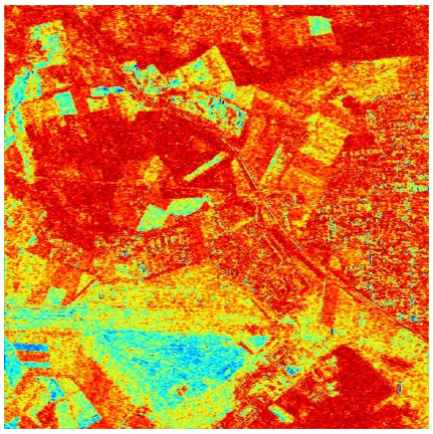
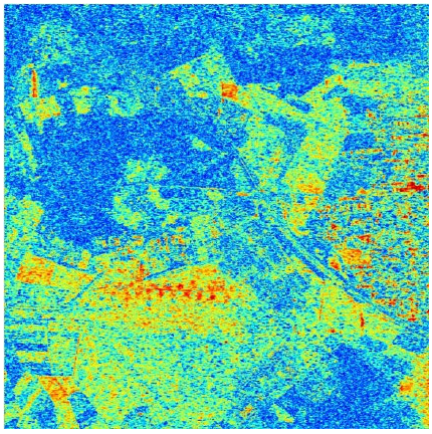
H / A / α DECOMPOSITION





0 0.5 1.0

ENTROPY (H)

0 0.5 1.0

ANISOTROPY (H)

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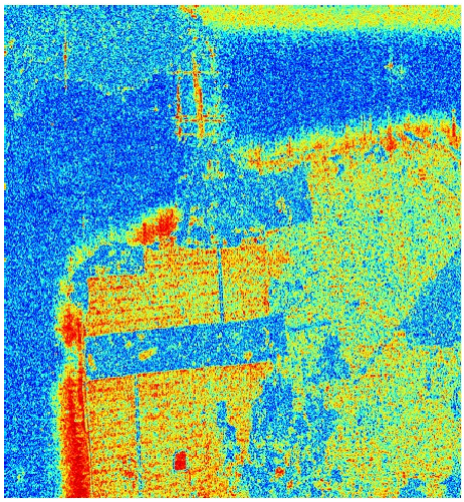
$2A_0$ $B_0 + B$ $B_0 - B$



0 0.5 1.0

ANISOTROPY (H)

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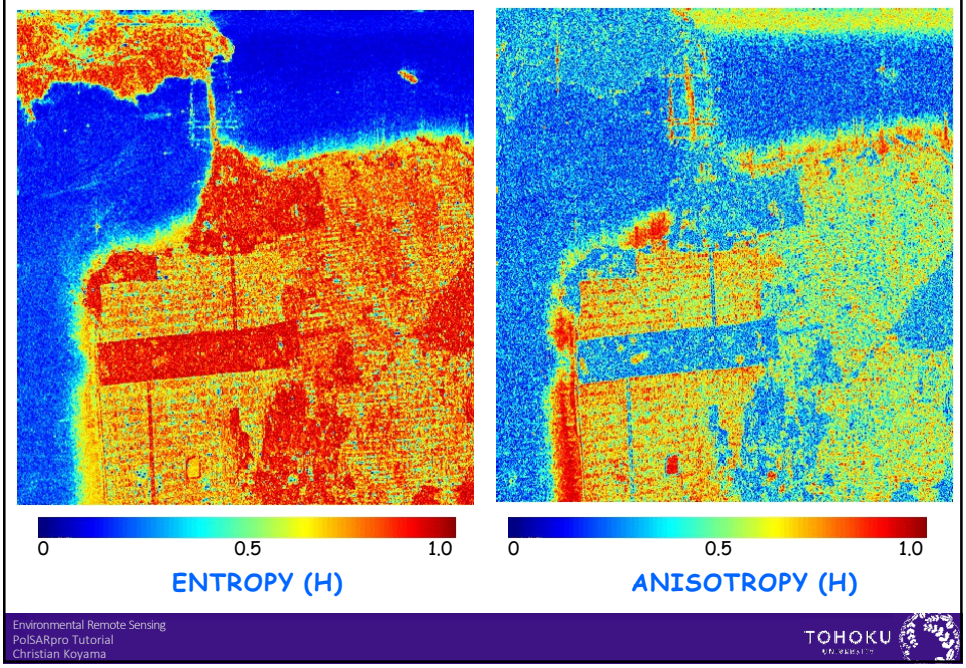
0
0.5
1.0
ENTROPY (H)
0
0.5
1.0
ANISOTROPY (H)
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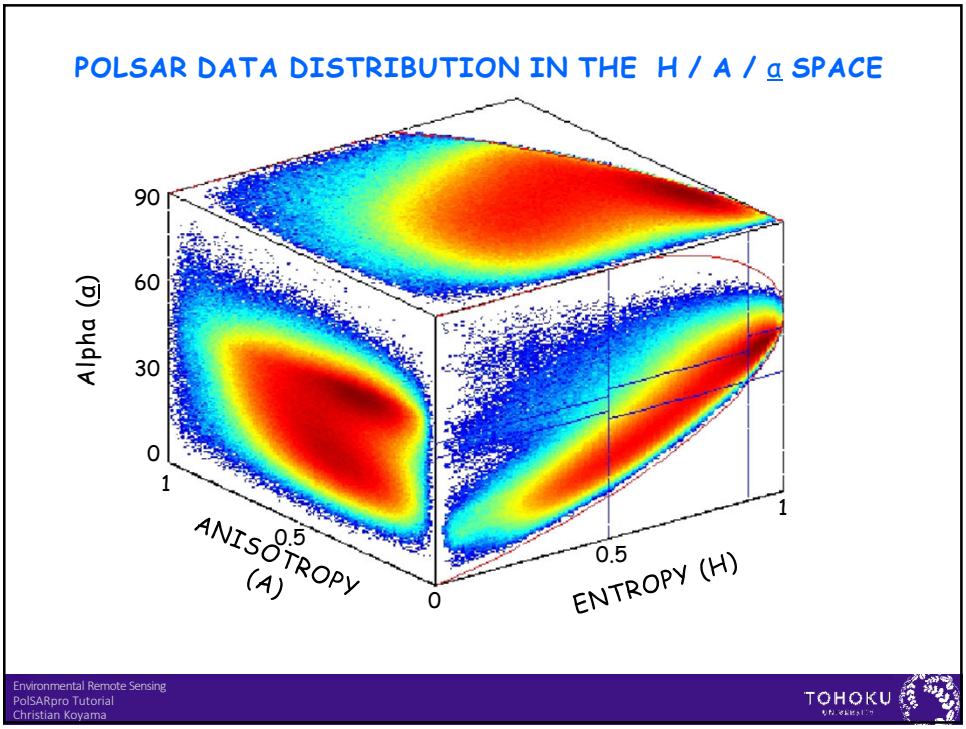
POLSAR DATA DISTRIBUTION IN THE H / A / α SPACE
Alpha (α)
90
60
30
0
1
ANISOTROPY (A)
0.5
0
0.5
1
ENTROPY (H)
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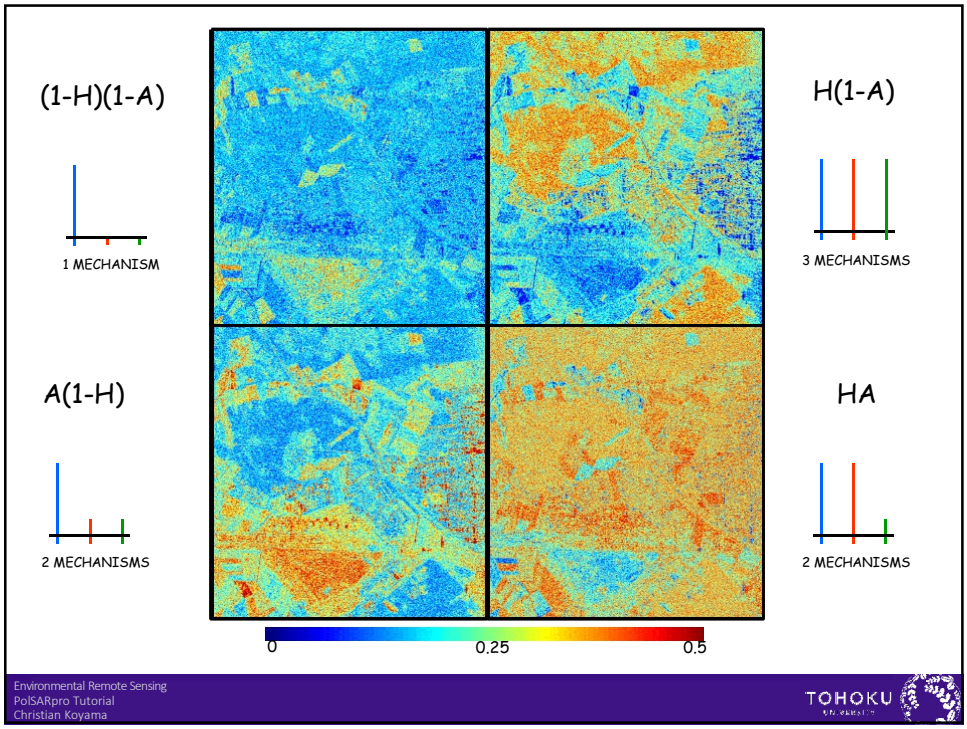
(1-H)(1-A)
1 MECHANISM
H(1-A)
3 MECHANISMS
A(1-H)
2 MECHANISMS
HA
2 MECHANISMS
0
0.25
0.5
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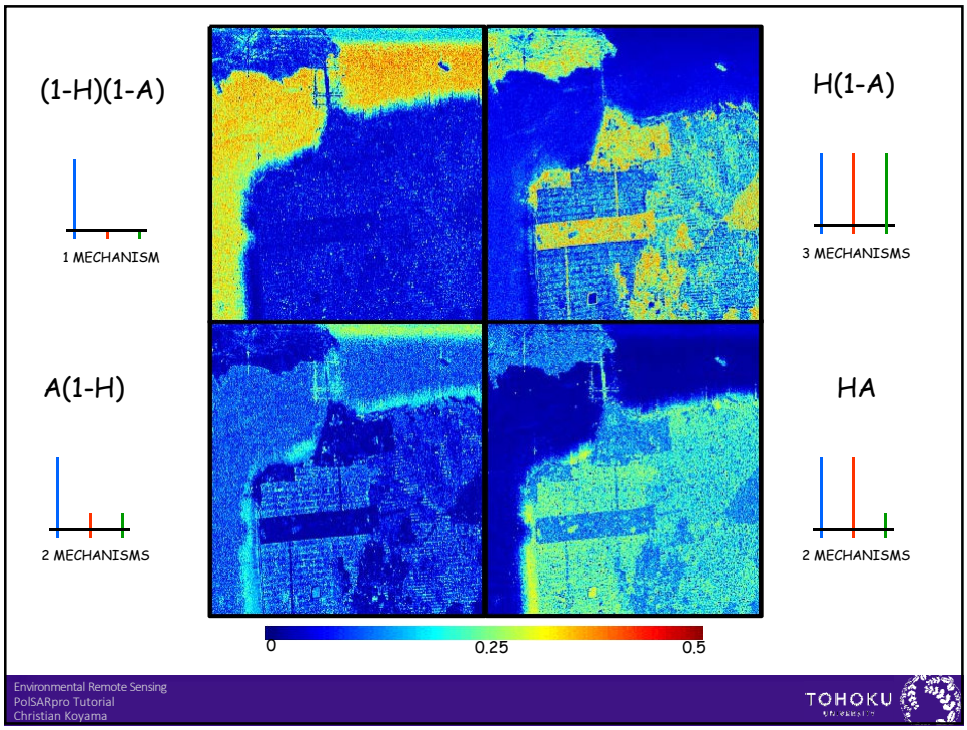
(1-H)(1-A)
1 MECHANISM
H(1-A)
3 MECHANISMS
A(1-H)
2 MECHANISMS
HA
2 MECHANISMS
0
0.25
0.5
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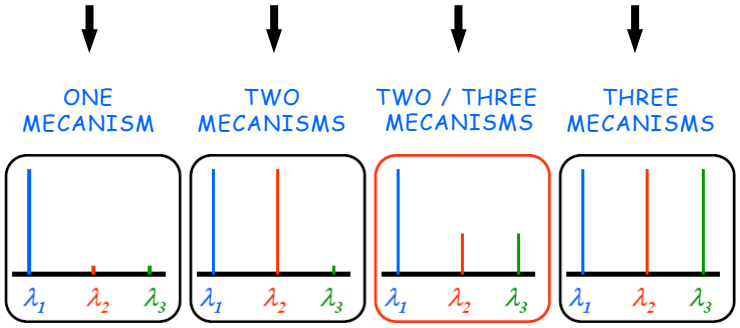
H / A / α DECOMPOSITION

SCATTERED POWER

$$P = P.*(1-H)(1-A) + P.*HA + P.*(1-H)A + P.*H(1-A)$$



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TOHOKU

ENTROPY

$$H = -\sum_{i=1}^{3} P_i log_3(P_i)$$

α PARAMETER

$$\alpha = P_1\alpha_1 + P_2\alpha_2 + P_3\alpha_3$$

ANISOTROPY

$$A = \frac{\lambda_2 - \lambda_3}{\lambda_2 + \lambda_3}$$

3 ROLL INVARIANT PARAMETERS

$$\underline{I} = \begin{bmatrix} \alpha \\ HA \\ H(1-A) \\ (1-H)A \\ (1-H)(1-A) \end{bmatrix}$$

→ PHYSICAL SCATTERING MECHANISM

→ TYPE OF SCATTERING PROCESS

SEGMENTATION / CLASSIFICATION

Environmental Remote Sensing
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Questions?

Ok, let's start!