An Overview of the PolSARpro v3.0 Software
The Educational Toolbox for Polarimetric and Interferometric Polarimetric SAR Data Processing

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The development of PolSARpro was initialized in 2001, in the frame of the ESA-ESRIN funded study, entitled “Applications of Synthetic Aperture Radar (SAR) Polarimetry” (AO/1-3949/01/I-LG).

This initiative is a direct result of recommendations made at the POLinSAR Workshop held at ESA - ESRIN in January 2003.
PolSARpro v2.0 – Beta 8

DEVELOPMENT OF A POLARIMETRIC SAR IMAGE ANALYSIS TOOL
(ESA – ESRIN Contract n° 17863 / 03 / I – LG)

2003

CONSORTIUM

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Pr Shane Cloude

2003

2005
CONTINUED DEVELOPMENT OF PolSARpro
(ESA – ESRIN SOW TPME-DTEX-EOPS-SW-06-0001 )

CONSORTIUM

Dr Sophie Allain, Dr Laurent Ferro-Famil, Pr Eric Pottier
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Pr Shane Cloude
Dr Mark Williams
A REVIEW OF THE EXISTING PolSARpro v3.0 SOFTWARE
PolSARpro v3.0 Software:

**Tool** specifically designed to handle Polarimetric data.

**Educational Software** offering a tool for self-education in the field of Polarimetric SAR and Interferometric Polarimetric SAR data processing and analysis.

Developed to be accessible to a wide range of users, from **novices** to **experts** in the field of Polarimetry.
PolSARpro v3.0 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:
- 263369 lines managing 154 widget windows
- 681 C routines (279839 lines) performing well-established algorithms in the field of Polarimetry.

PolSARpro v3.0 Software is made available following the Open Source Software Development (OSSD) approach, and follows the GNU General Public License v2 – June 1991.


The Tool is free download on the Internet from the ESA Web Portal (Earthnet) at http://earth.esa.int/polsarpro:
Main Objectives of the Tool:

• Act as a Tutorial for the exploitation of SAR Polarimetry techniques at University levels

• Provide a substantial and balanced introduction to the basic theory, scattering concepts, systems and advanced concepts and applications typical to SAR Polarimetry (PolSAR) and SAR Polarimetric Interferometry (PolInSAR)

• Offer a self-education as a low level teaching aid in the field of Polarimetry illustrated with application examples showing the full range of functions that the Tool offers (Do it yourself sections)
Provide a grounding in SAR Polarimetry (POLSAR) and SAR Polarimetric Interferometry (POLinSAR)

Direct access to the Tutorial while using PolSARpro facilities
The Tutorial is made available in PDF format.
Provide a grounding in SAR Polarimetry (POLSAR) and SAR Polarimetric Interferometry (POLinSAR)

Direct access to the Tutorial while using PolSARpro facilities
The Tutorial is made available in PDF format.
Provide a grounding in SAR Polarimetry (POLSAR) and SAR Polarimetric Interferometry (POLinSAR).

Recent Advances in Radar Polarimetry and Polarimetric SAR interferometry

W.M. Boerner – 31 pages

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The Tutorial is made available in PDF format.
Provide a grounding in SAR Polarimetry (POLSAR) and SAR Polarimetric Interferometry (POLinSAR)

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Provide a grounding in SAR Polarimetry (POLSAR) and SAR Polarimetric Interferometry (POLinSAR)

Advanced Concepts
E. Pottier, J.S. Lee, L. Ferro-Famil – 65 pages

Direct access to the Tutorial while using PolSARpro facilities
The Tutorial is made available in PDF format.
Series of concatenated sub-sections of the User Manual, containing all
the individual pages necessary for a specific interface (Tech Doc).

228 Tcl-Tk Widget description files
526 C Routine description files

Direct access to the Technical Documentation while using PolSARpro facilities
The Technical Documentation is made available in PDF format.
PolSARpro v3.0 Software is accompanied by a comprehensive set of 228 Help Files for each individual function.

Individual Help Files are accessible from within the software by clicking on the help icon present in the relevant dialogue box.

User Manual is made available in PDF format.
PolSARpro v3.0 SOFTWARE

PolSARpro v3.0 Full Software
- Single Data Set
- Multi Data Sets

PolSARpro v3.0 Full Software
Version for the E.O Scientific Investigator

IETR

SAPHIR
PolSARpro v3.0 SOFTWARE offers the possibility to handle and convert polarimetric data from a range of well established polarimetric airborne platforms.

PolSARpro v3.0 Software accepts today the following input specific formats:

- AIRSAR
- CONVAIR
- EMISAR
- ESAR
- PISAR
- RAMSES
PoISARpro v3.0 SOFTWARE

AIRSAR Sensor

- AIRSAR data prior to 1993
  (AIRSAR processor v3.56)

- AIRSAR data since 1993
  (AIRSAR processor v5.01 and v6.01)

- TOPSAR data since 1993
  (AIRSAR processor v5.01 and v6.01)

New AIRSAR Configuration widget
PoISARpro v3.0 SOFTWARE
AIRSAR – TOPSAR Sensor

New AIRSAR – TOPSAR Configuration widget

Tubuai Island
TOPSAR Polarimetric and Auxiliary data sets
(TOPSAR – 00/08/06)

Thanks to Pr J.P Rudant (U.M.L.V) for providing TOPSAR test data
PolSARpro v3.0 SOFTWARE

RAMSES Sensor

Updated RAMSES Configuration widget

RAMSES SAR Bande X
ONERA – DEMR
(DVDROM X-1/05/001)
Demonstration CD ROM

Freely Available from:
ONERA
DEMR – RIM
Guichet RAMSES
Chemin de la Huniere
91761 Palaiseau Cedex
Fax: +33 (0) 169 93 62 69
Em: guichet.ramses@onera.fr
PolSARpro v3.0 SOFTWARE handles and converts polarimetric data from a range of future and planned spaceborne missions.

PolSARpro v3.0 Software is flexible to accommodate data from the following current and future missions:

- ALOS - PALSAR
- ENVISAT - ASAR
- RADARSAT 2
- TerraSAR X
- SIR-C
PolSARpro v3.0 SOFTWARE
ALOS - PALSAR Sensor

LEADER FILE

TRAILER FILE

• PALSAR Dual & Quad POL
• PALSAR Data Level 1.1 and 1.5
PolSARpro v3.0 SOFTWARE

ALOS - PALSAR Sensor

Quick Look Image BMP File

- PALSAR Dual & Quad POL
- PALSAR Data Level 1.1 and 1.5
PoISARpro v3.0 SOFTWARE
RADARSAT - 2 Sensor

Getting ready for RADARSAT 2
Pre-launch Products and Activities

Daniel De Lisle
(Canadian Space Agency)

• RADARSAT-2 Dual & Quad POL
PoISARpro v3.0 SOFTWARE
RADARSAT - 2 Sensor

• RADARSAT-2 Dual & Quad POL
Request from B. Chapman (J.P.L)

Thanks to T. Ainsworth (N.R.L) for providing some parts of the CEOS Source Code written in 1993 and no more available
PolSARpro v3.0 SOFTWARE

SIR-C Sensor

Quick Look Image BMP File

• Request from B. Chapman (J.P.L)

• Thanks to T. Ainsworth (N.R.L) for providing some parts of the CEOS Source Code written in 1993 and no more available
PolSARpro v3.0 SOFTWARE

**PROCESSING CHAIN**

- **Configuration**
  - Input Data File
  - QuickLook
  - Extract Raw Data
  - [T3] Elements

- **Data Import**
  - Speckle Filtering
    - Box Car
    - Gaussian
    - Lee Refined
  - H / A / Alpha
    - Decomposition Parameters
    - Eigenvectors Parameters
    - Eigenvalues Parameters

- **Data Process**
  - Polarimetric Segmentation
    - H / A / alpha Segmentation
    - Unsupervised Wishart
    - Supervised Wishart

- **Data Display**
  - BMP 8 / 24 bits
  - RGB

- **Batch Process**
  - Speckle Filtering
  - H / A / alpha Decomposition
  - Unsupervised Wishart
    - H / A / alpha Segmentation

**Airborne Sensors Quad-Pol**
**Spaceborne Sensors Quad-Pol**

Interface guides an E.O investigator along a ‘recommended’ and easy processing chain using only essential Polarimetric functionalities.

Provide a First Qualitative Analysis of the fully polarimetric data set processed.
PolSARpro v3.0 SOFTWARE

PROCESSING CHAIN

- Configuration
- Data Import
- Data Process
- Data Display

- Input Data File
- QuickLook
- Extract Raw Data (Mode PP1, PP2, PP3)

- [C2] Elements
- [C2] Correlation Coefficients
- Stokes Parameters
- Speckle Filtering
  - Box Car
  - Gaussian
  - Lee Refined
- H / A / Alpha Wave Decomposition
- Supervised Wishart
- H / A / alpha Segmentation

- BMP 8 / 24 bits
- RGB

- Spaceborne Sensors Dual-Pol
  - ALOS-PALSAR
  - RADARSAT2
  - TerraSAR-X

- Interface guides an E.O investigator along a ‘recommended’ and easy processing chain using only essential Polarimetric functionalities

- Provide a First Qualitative Analysis of the fully polarimetric data set processed
PolSARpro v3.0 SOFTWARE

PROCESSING CHAIN

Configuration

Data Import

- Input Data File
- QuickLook
- Extract Raw Data (Mode PP5, PP6, PP7)

Data Process

- (Ixx, Ixy) Elements
- (Ixx, Ixy) Multi looking
- Speckle Filtering
  - Box Car
  - Gaussian
  - Lee Refined
- Supervised Wishart
  - H / A / alpha Segmentation

New!

Data Display

- BMP 8 / 24 bits
- RGB

- Spaceborne Sensors Dual-Pol Georef.
  - ENVISAT-ASAR Mode APP, APG
  - ALOS-PALSAR Data Level 1.5

Interface guides an E.O investigator along a ‘recommended’ and easy processing chain using only essential Polarimetric functionalities

Provide a First Qualitative Analysis of the fully polarimetric data set processed
PolSARpro V3.0 Software provides a comprehensive suite of functions for the scientific exploitation of fully and partially polarimetric data, and is aimed at radar experts and post-graduate level students.

PolSARpro V3.0 Software performs complete end-to-end processing without the need for other software.

PolSARpro V3.0 Software is accompanied by in-depth documentation permitting self-education to a high level.
PolSARpro v3.0 SOFTWARE

MAIN PROCESSING FUNCTIONALITIES

Data conversion:

• Decode AIRSAR, EMISAR, E-SAR, PISAR, Convair SAR580, RAMSES and ALOS-PALSAR, ENVISAT-ASAR, RADARSAT 2, SIR-C SLC and MLC data

• Fully Polarimetric Data Format Conversion
  • From Sinclair Matrix (S2) to Coherency Matrix (T3 or T4) or Covariance Matrix (C3 or C4)
  • From Coherency Matrix (T3 or T4) to Covariance Matrix (C3 or C4)
  • From Covariance Matrix (C3 or C4) to Coherency Matrix (T3 or T4)

• Fully Polarimetric Data to Partial Polarimetry Data

Calibration Assessment:

New! • SAR device impulse response analysis (3D) and characteristics metrics (PSLR, ISLR, phase stability …)

New! • Calibration Procedures for Cross-Talk removal: Quegan, Papathanassiou, Ainsworth
MAIN PROCESSING FUNCTIONALITIES

Data processing:

• Sinclair (S2), Coherency (T3 or T4) or Covariance (C3 or C4) parameters processing, correlation coefficients

• Stokes Parameters, Wave analysis

• Elliptical Basis Change: From (H-V) polarisation basis to pre-defined polarisation basis (+/- 45°, Left-Right Circular basis).

• Polarimetric Whitening Filter (P.W.F), Optimal Polarimetric Contrast Enhancement (O.P.C.E), Maximum Radar Cross Section (R.C.S)

• Polarisation Synthesis, Polarimetric Signatures

• Polarimetric Decompositions (Huynen, Barnes, Holm, Cloude, Krogager, Freeman, Cameron …)

• H / A / α decomposition (Decomposition parameters, Eigenvectors Set parameters, Eigenvalues Set parameters)
PolSARpro v3.0 SOFTWARE

MAIN PROCESSING FUNCTIONALITIES

Data processing:

• Polarimetric Segmentation
  • Supervised Wishart classification
  • Unsupervised (H / α), (A / α), (H/A) classifications
  • Unsupervised Wishart - H / A / α classification

New! • Rule-Based Hierarchical classification
New! • Basic scattering mechanisms identification

• Sub-Aperture Capability: Scattering behavior variations analysis, sub-images decomposition, non-stationary map, polarimetric parameters variations …

• Surface Inversion (Oh, Dubois)

New! • Data Analysis: Data Statistics, Data Histograms, Data Profiles

Speckle filters:

• Box Car Filter, Refined Lee Filter, Gaussian Filter.
  Speckle Filters can be applied to SLC (S2) data, MLC (T3, T4, C3, or C4) data or Partial Polarimetric data.
PolSARpro v3.0 SOFTWARE

CALIBRATION ASSESSMENT
PoISARpro v3.0 SOFTWARE

CALIBRATION ASSESSMENT

Thanks to Dr. Carlos Lopez-Martinez (U.P.C) for the development of this functionality
PolSARpro v3.0 SOFTWARE

POLARIMETRIC SIGNATURES
Output from the ESA-ESRIN Contract Polarimetric Interferometric Mission and Applicability Study (Contract n° 17893/03/I-LG) and presented during POLINSAR 05 Workshop by Pr. Henning Skriver.

The crop classification algorithm uses a knowledge-based approach in order to define classification rules. Tree Structure definition is performed via a dedicated graphical interface.
RULE-BASED HIERARCHICAL CLASSIFICATION

- Forest: $\sigma_0^L > -15 \text{ dB} \quad \text{L-April}$
- Lake: $\sigma_0^C > -30 \text{ dB} \quad \text{C-April}$
- Spring crops: $\rho_{d,\theta} > 0.02 \sigma_0^C (\text{dB}) > 1 \quad \text{C-April}$
- Winter crops: $\sigma_0^C > -18 \text{ dB} \quad \text{C-June}$
- Small stems: $\sigma_0^T_{n,\theta}/\sigma_0^L (\text{dB}) > -1 \quad \text{C-July}$
- Broad leaves: $\sigma_0^T_{n,\theta} > -18 \text{ dB} \quad \text{C-June}$
- Winter wheat: $\rho_{d,\theta} > 0.46 \quad \text{C-June}$
- Peas, spring barley, beets, potatoes.
Channel: Polarimetric Elements [S2], [T3], [C3], [T4], [C4]

Elements: Real part, Imaginary part, Amplitude, Phase

Theoretical PDF: Gaussian, Exponential, Rayleigh, Uniform

Thanks to Dr. Carlos Lopez-Martinez (U.P.C) for the development of this functionality
PolSARpro V3.0 Software provides a comprehensive suite of functions for the scientific exploitation of fully polarimetric interferometric data, and is aimed at radar experts and post-graduate level students.

PolSARpro V3.0 Software performs complete end-to-end processing without the need for other software.

PolSARpro V3.0 Software includes the functions necessary to perform Single Baseline Polarimetric Interferometry (SBPI).
PolSARpro v3.0 SOFTWARE

MAIN PROCESSING FUNCTIONALITIES

Data conversion:

- **Interferometric Polarimetric** Data Format Conversion
  - From Sinclair Matrix ($S_2$) to Coherency Matrix ($T_6$)
  - From Coherency Matrix ($T_6$) to Coherency Matrix ($T_6$ MLK)

Speckle filters:

- Box Car Filter, Refined Lee Filter, Gaussian Filter.

  *Speckle Filters can be applied to SLC ($S_2$) data or MLC ($T_6$) data.*

Data processing:

- Flat Earth Removal

- Sinclair ($S_2$) or Coherency ($T_6$) parameters processing

- Interferogram generation

- Complex Coherence Estimation (linear, circular and Pauli basis, optimal polarization states)
Data processing:

- POLSAR Segmentation

**New!** POLinSAR Segmentation
- Wishart supervised classification
- Wishart unsupervised classification

**New!** Complex Coherence Analysis
- Complex Plane
- Coherence Region – Optimum Triplet

**New!** Height Estimation
- Phase centre height
- Coherence estimation
- Inversion procedures
- Vegetation height Estimation

**New!** Data Analysis: Data Histograms, Data Profiles
PolSARpro v3.0 SOFTWARE

POLinSAR SEGMENTATION and FOREST HEIGHT ESTIMATION

Outputs from the ESA-ESRIN Contract Polarimetric Interferometric Mission and Applicability Study (Contract n° 17893/03/I-LG) and presented during POLINSAF 05 Workshop by Dr. Laurent Ferro-Famil, Dr. Kostas Papanathanassiou and Pr. Shane Cloude.

POLinSAR Unsupervised Segmentation is used for Forest Mapping and consists in delimiting the extent of forest or vegetation area within a SAR image.

POLinSAR Supervised Segmentation is used for Forest Classification and is achieved using a classical two-stage Wishart statistical algorithm.

The Tree Height Estimation package analyses forested terrain using single-baseline polarimeteric SAR interferometry, and from an inversion procedure based on a polarimetric coherent scattering model, estimates forest parameters such as tree height, underlying ground topography and validity map.
PoISARpro v3.0 SOFTWARE

POLinSAR SEGMENTATION
SAPHIR

POLinSAR SEGMENTATION

PolSARpro v3.0 SOFTWARE
PolSARpro v3.0 SOFTWARE

FOREST HEIGHT ESTIMATION

Pauli RGB
Height Forest Height Estimation
Mask Validity Mask
Phi0 Ground Topography
To further develop the educational worth of PolSARpro Software v3.0, more teaching material are added in the form of the POLinSAR Lecture Course proposed by Pr. Shane Cloude, associated to the SAR Coherent Scattering and Imaging Code proposed by Dr. Mark Williams.

1st PART: POLinSAR Lecture Course:

The objective is to provide a self taught introduction to POLinSAR coherence processing techniques to enable users to learn the basic principles of this topic and to enable them to use more confidently and knowledgably airborne and spaceborne POLinSAR processing tools developed under the PolSARpro Software v3.0
PolSARpro v3.0 SOFTWARE

POLinSAR LECTURE COURSE and TRAINING COURSE

POL-inSAR Training Course
S.R. Cloude – 44 pages

Direct access to the Tutorial while using PolSARpro facilities
The Tutorial is made available in PDF format.
PolSARpro v3.0 SOFTWARE

POLinSAR LECTURE COURSE
and TRAINING COURSE

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PolSARpro v3.0 SOFTWARE

POLinSAR LECTURE COURSE
and TRAINING COURSE
PolSARpro v3.0 SOFTWARE

POLinSAR LECTURE COURSE
and TRAINING COURSE
PolSARpro v3.0 SOFTWARE

POLinSAR LECTURE COURSE and TRAINING COURSE
To further develop the educational worth of PolSARpro Software v3.0, more teaching material are added in the form of the POLinSAR Lecture Course proposed by Pr. Shane Cloude, associated to the SAR Coherent Scattering and Imaging Code proposed by Dr. Mark Williams.

2nd PART: SAR Coherent Scattering and Imaging Code (POLinSAR Simulator):

The POLinSAR lecture course is illustrated using a simulated L-Band SAR image of a woody hedge above rough ground.

The data was produced using a high-fidelity SAR coherent scattering and imaging code developed by Dr Mark L. Williams.

The POLinSAR Simulator is included in the PolSARpro Software v3.0 and could be used extensively with detailed forest models to demonstrate the feasibility of many of the techniques that PolSARPro Software v3.0 software seeks to illustrate and teach.
**PoISARpro v3.0 SOFTWARE**

**POLinSAR LECTURE COURSE**
and **TRAINING COURSE**

- **PoISARproSim** is a rapid, coherent, fully polarimetric SAR simulation of forest for demonstrating POLinSAR techniques within PoISARpro Software v3.0.

- **PoISARproSim** 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).
The SAR image is evaluated as a coherent sum of scattering events from small elements of the scene. Direct-Ground, Direct-Volume and Ground-Volume contributions are included, with both trees and short vegetation comprising Volume terms. 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 v3.0 SOFTWARE

POLinSAR LECTURE COURSE and TRAINING COURSE

View from Radar

Pauli RGB Image

Coherence Map using a 5x5 window – Magnitude (left) and Phase (right)
PolSARpro v3.0 SOFTWARE

http://earth.esa.int/polsarpro

The Web Site provides

- Details of the project
- Access to the tutorial and software
- Information about status of the development
- Demonstration Sample Datasets
- Recently obtained results
PolSARpro v3.0 Training Course
Friday Morning

Install PolSARpro V3.0 Software on your laptop before Friday morning. Help can be provided.

Load the different data sets that will be used for training support and illustration.

SEE YOU ON FRIDAY MORNING ...