

OVERVIEW OF THE POLSARPRO V4.0 SOFTWARE. THE OPEN SOURCE TOOLBOX FOR POLARIMETRIC AND INTERFEROMETRIC POLARIMETRIC SAR DATA PROCESSING.

Eric Pottier⁽¹⁾, Laurent Ferro-Famil⁽¹⁾, Sophie Allain⁽¹⁾, Shane Cloude⁽²⁾, Irena Hajnsek⁽³⁾, Kostas Papathanassiou⁽³⁾, Alberto Moreira⁽³⁾, Mark Williams⁽⁴⁾, Andrea Minchella⁽⁵⁾, Marco Lavallo⁽⁵⁾, Yves-Louis Desnos⁽⁵⁾

⁽¹⁾ IETR, UMR CNRS- 6164, SAPHIR Team, Université de Rennes 1, Campus de Beaulieu, Bat-11D, 263 Avenue Général Leclerc, F-35042 Rennes Cedex, France

⁽²⁾ AEL Consultants, 26 Westfield Avenue, KY15 5AA Cupar, United Kingdom

⁽³⁾ DLR (German Aerospace Centre), Oberpfaffenhofen, Postfach 11 16, D-82230 Wessling, Germany

⁽⁴⁾ Mark L. Williams, 6 Bayview Parade, Gulfview Heights, Adelaide, SA 5096, Australia

⁽⁵⁾ ESA - ESRIN, Science and Applications Dept, Via Galileo Galilei, CP64, 00044 Frascati, Italy

ABSTRACT.

The objective of this paper is to make a review of the current status of the PolSARpro v4.0 Software (Polarimetric SAR Data Processing and Educational Toolbox), developed under contract to ESA by a consortium comprising I.E.T.R at the University of Rennes 1, AELc, DLR-HR and Dr mark Williams from Adelaide. The objective of this current project is to provide Educational Software that offers a tool for self-education in the field of Polarimetric SAR data analysis at University level and a comprehensive suite of functions for the scientific exploitation of fully and partially polarimetric multi-data sets and the development of applications for such data. The PolSARpro v4.0 Software establishes a foundation for the exploitation of Polarimetric techniques for scientific developments and stimulates research and applications developments using PolSAR and PolInSAR data..

1. INTRODUCTION

SAR remote sensing allows all weather, global scale imaging and estimation of important bio and geophysical parameters about the Earth's surface. It is achieved by sensing scattered electromagnetic fields reflected from the Earth surface when emitted by an electromagnetic energy source situated on an aircraft, spacecraft or satellite outside of the Earth's atmosphere. The development of multi-parameter SAR techniques such as Polarimetric SAR (POLSAR) and Polarimetric Interferometric SAR (POLInSAR) is advancing rapidly, and these novel radar technologies are constantly extending decisively the range of applications of radar in remote sensing. Due to the polarimetric radar sensors (ENVISAT ASAR, ALOS-PALSAR, TerraSAR-X and RADARSAT-2), it is now shown that the accelerated advancement of POLSAR techniques is of direct relevance and of priority to local-to-global environmental ground-truth measurement and validation, stress assessment, and stress-change

monitoring of the terrestrial and planetary covers. POLSAR and POLINSAR remote sensing techniques offer efficient and reliable means of collecting information required to extract biophysical and geophysical parameters about the Earth's surface and have found successful applications in crop monitoring and damage assessment, in forestry clear cut mapping, deforestation and burn mapping, in land surface structure (geology) land cover (biomass) and land use, in hydrology (soil moisture, flood delineation), in sea ice monitoring, in oceans and coastal monitoring (oil spill detection) etc ...

2. CONTEXT AND PRINCIPAL OBJECTIVES

Due to, both, the ESA's desire to augment his collection of software packages, known as the Envisat Toolboxes, and the feedback from the Workshop on "Applications of SAR Polarimetry and Polarimetric Interferometry", held at ESA-ESRIN, Frascati, Italy, on 14-16 January 2003, it was proposed to expand the existing PolSARpro software to handle data from current and future spaceborne missions (in addition to those airborne missions already supported), thus providing a comprehensive suite of functions for the scientific exploitation of fully and partially polarimetric data and the development of applications for such data.

PolSARpro v2.0 was developed under contract to ESA ("Development of a Polarimetric SAR Image Analysis Tool", ESA-ESRIN Contract n° 17863/03/I-LG). Today a new version of the software (PolSARpro v4.0) is continued to be developed under contract to ESA ("Continued Development of PolSARpro Software", C.C.N to ESA-ESRIN Contract n° 17863/03/I-LG) by a consortium comprising I.E.T.R at the University of Rennes 1, DLR-HR, AELc and Dr Mark L. Williams.

Figure n°1 proposes the PolSARpro v4.0 Main Entry Screen in its actual version (January 2009).

The objective of the current project is to provide an Educational Software that offers a tool for self-education in the field of Polarimetric SAR data analysis at University level and a comprehensive suite of functions for the scientific exploitation of fully and partially polarimetric multi-data sets and the development of applications for such data.

The PolSARpro v4.0 Software establishes a foundation for the exploitation of Polarimetric techniques for scientific developments and stimulate research and applications developments using PolSAR and PolInSAR data.

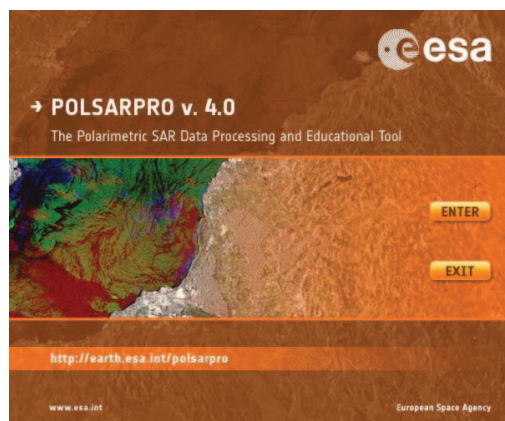


Figure n°1 : PolSARpro v4.0 Main Entry Screen

3. SOFTWARE PORTABILITY AND DEVELOPMENT LANGUAGE

PolSARpro v4.0 Software is developed to be accessible to a wide range of users, from novices (in terms of training) to experts in the field of Polarimetry and Interferometric Polarimetric SAR data processing. For this, the tool is conceived as a flexible environment, proposing a friendly and intuitive graphical user interface (GUI), enabling the user to select a function, set its parameters and run the software. The PolSARPro v4.0 software is a complementary Toolbox to existing commercial SAR image processing packages (ENVI, PCI ...) and must be considered as a Polarimetric SAR data processing software which proposes well-established algorithms in the field of polarimetric and polarimetric-interferometric radar signal processing with high-level functionalities for in-depth analysis and for the scientific exploitation of fully and partially polarimetric data to the development of the corresponding remote sensing applications.

The PolSARPro v4.0 software proposes a graphical user interface (GUI) written in Tcl-Tk (more than 331185 lines managing 189 widget windows) and contains today around 1078 C routines (464803 lines) which perform the different processing functions. All the development languages and compilers used in PolSARpro are open source and completely free. There is no use of any 4th generation programming languages (such as IDL or MATLAB) thus avoiding any licensing problem and associated cost.

The PolSARPro v4.0 software runs today on the following platforms: Windows 98+, Windows 2000, Windows NT 4.0, Windows XP, Linux I386, Unix-Solaris and on Macintosh OS (using Parallels).

As the software is made available following the Open Source Software Development (OSSD) approach, where the source code of the C Routines are made available for free download on the Internet, it is thus possible for the users to develop additional new modules following the flexible structure of the environment. Users can easily understand how modules can be extracted from the Tool, modified and / or incorporated into their own systems. As it can be seen, the proposed open software environment approach enables the user to select a function, set its parameters and run the routine on his own system, independently of the PolSARPro environment. This approach can also encourage users to modify the routines to meet their individual requirements, and then to share the fruits of their work with other users.

4. PolSARpro v4.0 MAIN MENU

The PolSARpro v4.0 Software offers the possibility to handle and convert polarimetric data from a range of well established polarimetric airborne platforms and spaceborne missions.

The PolSARpro v4.0 proposes different specific interfaces, with identical functionalities, dedicated to different Polarimetric Spaceborne Sensors (ALOS-PALSAR, ENVISAT-ASAR, RADARSAT2, TerraSAR X, SIRc) and Airborne Sensors (AIRSAR, TOPSAR, Convair, EMISAR, ESAR, PISAR, RAMSES) data processing selectable from the main menu..

The PolSARpro v4.0 EO Scientific Investigator package has been developed to the support of the following data sources:

Mission	Sensor	Polarimetric Data Type
ALOS - PALSAR	PALSAR (Fine mode, Direct downlink mode)	Dual-Pol
	PALSAR (Polarimetry mode, experimental)	Quad-Pol
ENVISAT - ASAR	ASAR – APS Mode	Dual-Pol
	ASAR – APP Mode	
	ADAR – APG Mode	
TerraSAR - X	TSX-SAR	Dual-Pol
	TSX-SAR (experimental)	Quad-Pol
RADARSAT-2	SAR (selective polarisation)	Dual-Pol
	SAR (Standard Quad polarisation, Fine Quad polarisation)	Quad-Pol

The PolSARpro v4.0 Software proposes a great collection of well-established algorithms and tools designed for the analysis of only Single Data Set, Dual Data Sets (Interferometry) and Multi Time / Freq Data Sets Polarimetric SAR data with specialized functionalities for in-depth analysis of fully and partially polarimetric data and the development of applications for such data. The PolSARpro v4.0 specific

interface performs complete end-to-end processing without the need for other software and is selectable from the main menu.

The PolSARpro v4.0 software can process polarimetric or partially polarimetric data sets under many different formats. The different polarimetric data formats handled by PolSARpro v4.0 are the following: The (2x2) complex Sinclair [S2] matrix, the (3x3) and (4x4) complex Coherency [T3], [T4] or Covariance [C3], [C4] matrices and Partial Polarimetry representation.

5. EDUCATIONAL SOFTWARE

Due to the polarimetric radar sensors (ENVISAT ASAR, ALOS-PALSAR and the future RADARSAT-2 and TerraSAR-X), it is now shown that the accelerated advancement of POLSAR techniques is of direct relevance and of priority to local-to-global environmental ground-truth measurement and validation, stress assessment, and stress-change monitoring of the terrestrial and planetary covers. Scientists and engineers already engaged in the fields of radar remote sensing generally gain their specialist knowledge in polarimetry by working through scientific papers and specialized literature available on the subject. The aim of this Tutorial is to provide a substantial and balanced introduction to the basic theory, scattering concepts, systems and advanced concepts and applications typical to Radar Polarimetry and Interferometry.

This Tutorial on Radar Polarimetry is completed with a review of some important aspects of radar polarimetry and interferometry to learn how to generate multiple polarization interferograms and how to use them with simple inversion models to estimate surface parameters, vegetation height and ground topography. This tutorial can be used as a low level teaching aid for polarimetric SAR processing and is illustrated with application examples showing the full range of functions that the Tool offers (*Do it yourself sections*). The PolSARpro v4.0 software is thus provided with a comprehensive in-depth documentation permitting self-education to a high level (radar experts and post graduate students). User has access to this wide-ranging tutorial, available in PDF format, providing grounding in SAR Polarimetry (PolSAR) and SAR Polarimetric Interferometry (POLinSAR) from the main menu. User have also access to different series of Tutorial Slide Shows, that are made available to support taught courses of for use as part of a self teaching programme.

The PolSARpro v4.0 Software is also accompanied by a detailed set of 228 Help Files, made available in PDF format, for each individual function. The User Manual provides comprehensive documentation of the software. As each new version of the PolSARpro v4.0 software becomes available, extra content are added.

The PolSARpro v4.0 Software is also accompanied by a detailed set of 526 Technical Documentation Files, made available in PDF format, for each individual C Routine in order to provide to users information about

how modules can be extracted from the Tool, modified and / or incorporated into their own systems.

6. POL-InSAR COHERENT SCATTERING AND IMAGING SIMULATOR

The objective of the PolSARpro v4.0 software is to provide, also, a self taught introduction to Pol-InSAR 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. To achieve this, a simulated test Pol-InSAR data set with 'perfect' ground truth is used to illustrate the lecture course. This test set is a simulation output from the Pol-InSAR simulator. The test data set is designed to mimic the same performance of airborne / spaceborne systems, except there are no residual motion, baseline or co-registration errors and no problems associated with temporal and SNR decorrelation sources. In this way the users can get used to Pol-InSAR principles in a controlled environment before applying the techniques to real world data sets. As a secondary objective, the modules generated can also be used for dual polarised Pol-InSAR inversion studies on arbitrary data sets to complement the more robust but complicated multipolarisation algorithm existing in the literature.

The user is provided a dedicated interface that permits the ready description of a realistic forest model and a flexible description of SAR imaging parameters. Having designed the forest and set the imaging scenario the simulation is called from within PolSARpro v4.0 software, and in a reasonable space of time, the user has available simulated polarimetric, interferometric SAR data for the scene of their choice. The PolSARpro v4.0 software user could then proceed to follow the Pol-InSAR tutorial with the data appropriate to the scenario of particular interest to them, and be able to determine that the techniques work well in a realistic situation for the sensor of their choice.

In the new PolSARpro v4.0 Software version, two new simulators on real environments are proposed:

- **PolSARproSIMgr**: for Pol-InSAR ground surface simulation
- **PolSARproSIMgv**: for Pol-InSAR ground + small vegetation simulation

7. PolSARPRO v4.0 NEW FUNCTIONALITIES

A new design

The new version of the PolSARpro v4.0 Software proposes a complete new design of the main interface. In the previous version, the PolSARpro Software was composed of a full collection of independent widgets associated to a given functionality.

In this new version (Version 4.0 Beta 1), all these widgets are now seen as transient windows by the Window Manager and so, are all embedded in only one main window.

Minimizing or maximizing this Master Window will minimize / maximize or iconify all opened transient widgets.

Interface with External Software

The PolSARpro v4.0 Software can now offer the possibility to interface with the following external softwares:

- G.I.M.P (Gnu Image Manipulation Program) : This open source software, under GNU License, can handle and display several BMP images at the same time, thus allowing a better comparison between them.
- Google Earth : Different functionalities are also provide that offer to the user the possibility to visualize on Google Earth the SAR Image Track (Read / Create / Open a GEARTH_POLY file), or overlay and display on Google Earth the PolSARpro output BMP images (Create / Open a KML file).
- S.R.T.M (Shuttle Radar Topographic Mission) : This functionality offers to the user to download from two given ftp sites, the SRTM GeoTIFF file and display and overlay on Google Earth the extracted DEM image corresponding to the SAR image under process.
- N.E.S.T (New ESA Software Tool) : A new link has been implemented in the PolSARpro v4.0 Software to launch directly the ESA-NEST Software, thus proposing to the user all the G.I.S functionalities offered by the NEST Software.

Import dataset

The PolSARpro v4.0 software can now offer the possibility to handle and convert polarimetric data from the **ALOS / PALSAR** Spaceborne Sensor, according to the **ERSDAC (Earth Remote Sensing Data Analysis Center) – Vexcel Format**.

Single Data set - Data Process

Different additional functionalities are proposed in the release Version 4.0 Beta 1.3:

- Box-Car + Edge detectors: This speckle filter uses the outputs of the edge detector functionality, thus preserving linear features or structures during the filtering process.
- C Lopez and Lee-Sigma speckle filters: Two new speckle filters, recently published by C. Lopez and J.S. Lee, are implemented.
- New Polarimetric Parameters:
 - Conformity Coefficient (M.L. Truong Loi)
 - Differential Reflectivity (ZDR)
 - Polarimetric Reflectivity Ratio
 - Scattering Predominance (J. Praks & E. Colin)
 - Degree of Purity (J. Praks & E. Colin)
 - Scattering Diversity (J. Praks & E. Colin)
 - Depolarisation Index (J. Praks & E. Colin)
 - Entropy approximation (J. Praks & E. Colin)
 - Alpha approximation (J. Praks & E. Colin)

- Scattering Mechanism Entropy (A. Freeman)
- Kozlov Anisotropy coefficient
- Faraday Rotation Estimation
- M. Neumann 2-components decomposition
- R. Touzi - TSVM decomposition
- J.J. VanZyl 3-model based components decomposition (published in 2008)
- Unsupervised fuzzy neural segmentation (S.E. Park)
- Algorithms for topography extraction from PolSAR data.
- Surface parameter data inversion: Oh 2004 Model.

Multi Data sets – Dual POLinSAR – Data Process

- Pol-InSAR Coherence Optimisation Methods: New approaches, proposed by M. Lavalley are implemented: Singular Value Decomposition (SVD), Phase Diversity (Tabb), Numerical Radius (E. Colin), Min/Max of Phase / Magnitude over Coherence Boundary and Max Phase / Max Difference over Coherence Boundary.
- Baseline Calculator Tool (M. Lavalley):
 - Estimation of the horizontal, vertical, parallel and perpendicular baselines from the state vectors
 - Coarse Co-Registration of the [S2] SLC PolSAR images
 - Generation and estimation of the Flat Earth map
 - Generation and estimation of the Vertical Wavenumber (kz)

8. OUTLOOK

Currently in its development stage, PolSARpro v4.0 Software (source code and elements software packages) is added gradually throughout 2009 and made publicly available for free download on the Internet from the ESA Web Portal (Earthnet) at:

<http://earth.esa.int/polsarpro>

This 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

The authors would like to thank the following Agencies, Research Institutes and Universities to, freely, provide appropriate sample datasets for demonstration purpose: CSA (Convair and RadarSat2 simulated data sets), CRL-NASDA (PISAR), DLR-HR (ESAR), DTU (EMISAR), ESA (ENVISAT-ASAR, ALOS-PALSAR), NASA – JPL (AIRSAR, SIR-C)