→ 6th ESA ADVANCED TRAINING COURSE ON LAND REMOTE SENSING

SAR Polarimetry

eesa

Eric POTTIER

14-18 September 2015 | University of Agronomic Science and Veterinary Medicine Bucharest | Bucharest, Romania





Eric POTTIER eric.pottier@univ-rennes1.fr



I.E.T.R. - UMR CNRS 6164 Université de Rennes I - Campus de Beaulieu Pôle Micro Ondes Radar - Bat 11D 263 Avenue Général Leclerc CS 74205 - 35042 Rennes Cedex – France





SAR POLARIMETRIE HOLOGRAPHIE INTERFEROMETRIE RADARGRAMMETRIE







Rennes - Britanny





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RADAR POLARIMETRY

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Objective



To provide

the minimum, but necessary, amount of knowledge required to understand scientific works on **SAR Polarimetry (PolSAR)**





RADAR POLARIMETRY



- A bit of History
- Airborne and Space-borne Polarimetric SAR Sensors
- Software / Toolbox
- Learning / Training / Results



Radar Polarimetry



Radar Polarimetry (Polar : polarisation Metry: measure) is the science of acquiring, processing and analysing the polarization state of an electromagnetic field

Radar Polarimetry deals with the full vector nature of polarized electromagnetic waves

Radar Polarimetry

The POLARISATION information Contained in the waves backscattered from a given medium is highly related to:

its geometrical structure reflectivity, shape and orientation

its geophysical properties such as humidity, roughness

SAR Polarimetry Applications



Forest Vegetation

- Forest Height
- Forest Biomass
- Forest Structure
- Canopy Extinction
- Underlying Topography

- Forest Ecology
- Forest Management
- Ecosystem Change
- Carbon Cycle

- Soil Moisture Content
- Soil roughness
- Height of Vegetation Layer
- Extinction of Vegetation Layer
- Moisture of Vegetation Layer
- Farming Management
- Water Cycle
- Desretification

Agriculture

Snow and Ice

Urban Areas

- Topography
- Penetration Depth / Density
- Snow Ice Layer
- Snow Ice Extinction
- Water Equivalent

- Ecosystem Change
- Water Cycle
- Water Management

Geometric PropertiesDielectric Properties



Courtesy of Dr. I. Hajnsek

Urban Monitoring

A Bit Of History



Radar Polarimetry



Discovery of the Phenomena of Polarized Electromagnetic Energy















Polarimetric SAR





San Francisco Bay





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



San Francisco Bay

Google Earth <u>Fichier</u> Édition Affichage <u>O</u>utils <u>Ajouter</u> <u>Aide</u> Q 🔲 🛠 🖉 💐 🐼 🥥 🛎 📿 📗 🖂 🖺 📧 Se connecter Google earth Image Landsat Data SIO, NOAA, U S, Navy, NGA, GEBCO Data MBARI Data CSUMB SFML, CA OPC Date des images satellite : 10/4/2013 37º44'56.15"N 122º28'01.94"O élév: 47 m altitude 135.90 km 🔿 Visite guide



SEASAT NASA/JPL (USA) L-Band, 1978



ERS-1 European Space Agency (ESA) C-Band, 1991-2000



J-ERS-1 Japanese Space Agency (NASDA) L-Band, 1992-1998



SIR-C/X-SAR NASA/JPL, L- and C-Band (quad) DLR / ASI, X-band April and October 1994



RadarSAT-1 Canadian Space Agency (CSA) C-Band, 1995-today



ERS-2 European Space Agency (ESA) C-Band, 1995-today



Shuttle Radar Topography Mission (SRTM) NASA/JPL (C-Band), DLR (X-Band) February 2000



ENVISAT / ASAR European Space Agency (ESA) C-Band (dual), 2002-today



ALOS / PALSAR TerraSAR-X Japanese Space Agency (JAXA) German Aerospace Center (DLR) / Astirum L-Band (quad), 2006 X-Band (dual), 2007



RadarSAT-II Canadian Space Agency (CSA) C-Band (quad), 2007



COSMO-SkyMed Italian Space Agency (ASI) X-Band, 2007











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ALOS / PALSAR TerraSAR-X Japanese Space Agency (JAXA) German Aerospace Center (DLR) / Astirum L-Band (quad), 2006 X-Band (dual), 2007



RadarSAT-II Canadian Space Agency (CSA) C-Band (quad), 2007



COSMO-SkyMed Italian Space Agency (ASI) X-Band, 2007









Space-borne PolSAR Sensors



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J-ERS-1 Japanese Space Agency (NASDA) L-Band, 1992-1998



SIR-C/X-SAR NASA/JPL, L- and C-Band (quad) DLR / ASI, X-band April and October 1994



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ALOS / PALSAR Japanese Space Agency (JAXA) L-Band (quad), 2006



TerraSAR-X German Aerospace Center (DLR) / Astirum X-Band (dual), 2007



RadarSAT-II Canadian Space Agency (CSA) C-Band (quad), 2007



COSMO-SkyMed Italian Space Agency (ASI) X-Band, 2007



Scattering Polarimetry



Space-borne PolSAR Sensors



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J-ERS-1 Japanese Space Agency (NASDA) L-Band, 1992-1998



SIR-C/X-SAR NASA/JPL, L- and C-Band (quad) DLR / ASI, X-band April and October 1994



RadarSAT-1 Canadian Space Agency (CSA) C-Band, 1995-today



ERS-2 European Space Agency (ESA) C-Band, 1995-today



Shuttle Radar Topography Mission (SRTM) NASA/JPL (C-Band), DLR (X-Band) February 2000



ENVISAT / ASAR European Space Agency (ESA) C-Band (dual), 2002-today



ALOS / PALSAR L-Band (quad), 2006



TerraSAR-X Japanese Space Agency (JAXA) German Aerospace Center (DLR) / Astirum X-Band (quad), 2007



RadarSAT-II Canadian Space Agency (CSA) C-Band (quad), 2007



COSMO-SkyMed Italian Space Agency (ASI) X-Band, 2007











Space-borne PolSAR Sensors

ALOS - PALSAR

January 2006 L-Band (Sngl / Twin / Quad)





ALOS : Advanced Land Observing Satellite PALSAR : Phase Array L-Band SAR
Space-borne PolSAR Sensors

TerraSAR - X

June 2007 X-Band (Sngl / Twin / Quad ?)



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Space-borne PolSAR Sensors

RADARSAT - 2



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Space-borne Sensors



Space-borne Sensors



What About The Future ?



From Tomorrow ...



New and Future Space-Borne PolSAR Pol-InSAR Sensors



Space-borne PolSAR Sensors

SENTINEL – 1A



April 2014 C-Band (Dual)



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Space-borne PolSAR Sensors

ALOS - 2



L-Band (Quad)



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Software / Toolbox ?



PolSARpro v5.0

The Polarimetric SAR Data Processing and Educational Tool v5.0

PolSARpro v5.0

OPEN SOURCE DEVELOPMENT

The Tool is free download on the Internet from the ESA Web Portal (Earthnet) at : https://earth.esa.int/web/polsarpro

ta Sources • Overview • Download and Installation • Documentation •	Results & News +
are here Home	🚹 Share 🗗 💟 🖾 💿
PolSARpro Version 4.2	- Latest News
ne Polarimetric SAR Data Processing and Educational Tool aims to facilitate the accessibility and exploitation of uult-polarised SAR datasets including those from ESA Third Party Missions (ALOS PALSAR), Envisat ASAR Iternating Polarisation mode products, RADARSAT-2 and TerraSAR-X.	New PolSARpro version 4.2 released New PolSARpro version 4.0 Beta 1.3 released New PolSARpro version 4.0 Beta 1.3 released
wide-range of tutorials and comprehensive documentation provide a grounding in polarimetry and polarimetric iterferometry necessary to stimulate research and development of scientific applications that utilise such chniques; the toolbox of processing functions offers users the capability to implement them.	PolsARpro V. 4.0 beta 1 training course - PolSARpro version 4.0 beta 1 released for
oISARpro is developed under contract with ESA, a consortium I <u>ETR (<i>Institut d'électronique et de</i> l<u>'écommunications de Rennes</u>) in conjunction with the <u>University of Rennes 1, DLR Microwaves and Radar</u> stitute (HR) of DLR and AEL Consultants, together with Dr Mark Williams. The initiative is a direct result of</u>	- Useful Links
commendations made at the POLINSAR Workshops held at ESRIN since January 2003.	Data Sources
I elements of the PolSARpro project are distributed by ESA free of charge, including the source code.	Overview
his website provides details of the project, giving users access to the tutorial material and software, information	Download PolSARpro 4.2
bout sources of multi-polarised data and recently obtained results of POLInSAR studies. Navigate between anes using the menu on the left	Release notes Delarimetry Tutorial
ages doing the monte of the for.	Technical Documentation
	Results & News
	0 Contract

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PolSARpro v5.0

http://earth.esa.int/web/polsarpro The Web Site provides

		Download and installation +	Documentation +	Results & News -
are here Home				🛨 Share 🗗 💟 📼 💿
PolSARp	oro Version 4	.2		- Latest News
ne Polarimetric SAR utti-polarised SAR ternating Polarisati wide-range of tutori terferometry necess chniques; the toolb	Data Processing and Ex datasets including those on mode products, RADA als and comprehensive sary to stimulate research ox of processing function	sucational Tool aims to facilitate the acce from ESA Third Party Missions (ALOS PA RSAT-2 and TerraSAR-X. focumentation provide a grounding in po and development of scientific applicatio s offers users the capability to implemen	ssibility and exploitation of LSAR), Envisat ASAR larimetry and polarimetric ns that utilise such t them.	Hew PolSARpro version 4.2 released New PolSARpro version 4.1.5 released New PolSARpro version 4.0 beta 1.3 released PolSARpro v. 4.0 beta 1 training course - PolSARpro version 4.0 beta 1 released for
olSARpro is develop	ed under contract with E	SA, a consortium <u>IETR (Institut d'électron</u> n with the University of Rennes 1. D. R. M	ique et de icrowaves and Radar	- Useful Links
Iécommunications : stitute (HR) of DLR commendations m I elements of the Pro	and AEL Consultants, to ade at the <u>POLINSAR Wo</u> DISARpro project are dist	gether with Dr Mark Williams. The initiativ rkshops held at ESRIN since January 20 ibuted by ESA free of charge, including th	e is a direct result of 03. Ie source code.	 Home Data Sources Overview

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

Demonstration Sample Datasets

Learning / Training

Next P.I Generations

Books On Polarimetric Radar SAR, Polarimetric Interferometry

Polarimetric Radar Imaging: From basics to applications Jong-Sen LEE – Eric POTTIER CRC Press; 1st ed., February 2009, pp 422 ISBN: 978-1420054972

Polarisation: Applications in Remote Sensing Shane R. CLOUDE Oxford University Press, October 2009, pp 352 ISBN: 978-0199569731

WAVE POLARIMETRY

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POLARISATION ELLIPSE

THE REAL ELECTRIC FIELD VECTOR MOVES IN TIME ALONG AN ELLIPSE

$$\left(\frac{E_x}{E_{\theta x}}\right)^2 - 2\frac{E_x E_y}{E_{\theta x} E_{\theta y}} \cos(\delta) + \left(\frac{E_y}{E_{\theta y}}\right)^2 = \sin^2(\delta)$$

With: $\delta = \delta_y - \delta_x$

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POLARISATION ELLIPSE

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POLARISATION HANDENESS

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ROTATION SENSE: LOOKING INTO THE DIRECTION OF THE WAVE PROPAGATION

SAN FRANCISCO BAY

DC8 P, L, C-Band (Quad)

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|HV|_{dB} -15dB -30dB 0dB

|VV|_{dB}

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SCATTERING POLARIMETRY

Sinclair Color Coding

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SINCLAIR MATRIX

TRANSMITTER:H & VRECEIVERS:H & V

POLARIMETRIC DESCRIPTORS

- [S] SINCLAIR Matrix $[S] = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}$
- <u>k</u> Target Vector
- [T] 3x3 COHERENCY Matrix

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TARGET VECTOR

VECTORIZATION OF [S]

$$[S] = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{HV} & S_{VV} \end{bmatrix} \implies \underline{k} = V([S]) = \frac{1}{2}Trace([S][\psi])$$

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COHERENCY MATRIX

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TARGET VECTOR **k**

$$\underline{k} = \frac{1}{\sqrt{2}} \begin{bmatrix} S_{HH} + S_{VV} & S_{HH} - S_{VV} & 2S_{HV} \end{bmatrix}^T$$

COHERENCY MATRIX [7]

$$\begin{bmatrix} T \end{bmatrix} = \underline{k} \cdot \underline{k}^{*T} = \begin{bmatrix} 2A_0 & C - jD & H + jG \\ C + jD & B_0 + B & E + jF \\ H - jG & E - jF & B_0 - B \end{bmatrix}$$

HERMITIAN MATRIX - RANK 1

A0, B0+B, B0-B : HUYNEN TARGET GENERATORS

[7] is closer related to Physical and Geometrical Properties of the Scattering Process, and thus allows a better and direct physical interpretation

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PHYSICAL INTERPRETATION

 $T_{11} = 2A_0 = |S_{XX} + S_{YY}|^2$ $T_{33} = B_0 - B = 2|S_{XY}|^2$

$$T_{22} = B_0 + B = |S_{XX} - S_{YY}|^2$$

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TARGET GENERATORS

(H,V) POLARISATION BASIS

|HV |

|HH+VV|

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$$\left[S_{(B,B_{\perp})}\right] = \left[U_{(A,A_{\perp})\mapsto(B,B_{\perp})}\right]^{T} \left[S_{(A,A_{\perp})}\right] \left[U_{(A,A_{\perp})\mapsto(B,B_{\perp})}\right]$$

CON-SIMILARITY TRANSFORMATION

$$\begin{bmatrix} U_{(A,A_{\perp})\to(\underline{B},\underline{B}_{\perp})} \end{bmatrix} = \begin{bmatrix} U(\phi,\tau,\alpha) \end{bmatrix}^{-1} \\ = \begin{bmatrix} e^{j\alpha} & 0 \\ 0 & e^{-j\alpha} \end{bmatrix} \begin{bmatrix} \cos(\tau) & -j\sin(\tau) \\ -j\sin(\tau) & \cos(\tau) \end{bmatrix} \begin{bmatrix} \cos(\phi) & \sin(\phi) \\ -\sin(\phi) & \cos(\phi) \end{bmatrix} \\ \begin{bmatrix} U_{2}(-\alpha) \end{bmatrix} & \begin{bmatrix} U_{2}(-\tau) \end{bmatrix} \begin{bmatrix} U_{2}(-\phi) \end{bmatrix}$$

|HH+VV|

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|HH-VV|

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|HV |

(+45°,-45°) POLARISATION BASIS

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(LC,RC) POLARISATION BASIS

|LL+RR| |LR | LL-RR

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ELLIPTICAL BASIS TRANSFORMATION
SINCLAIR MATRIX

$$\underline{E}_{(A,A_{\perp})}^{s} = [S_{(A,A_{\perp})}] \underline{E}_{(A,A_{\perp})}^{i} \qquad \underline{E}_{(B,B_{\perp})}^{s} = [S_{(B,B_{\perp})}] \underline{E}_{(B,B_{\perp})}^{i} \\ [S_{(B,B_{\perp})}] = [U_{(A,A_{\perp}) \mapsto (B,B_{\perp})}]^{T} [S_{(A,A_{\perp})}] [U_{(A,A_{\perp}) \mapsto (B,B_{\perp})}]$$
CON-SIMILARITY TRANSFORMATION

COHERENCY MATRIX

$$[T_{(B,B_{\perp})}] = [U_{3(A,A_{\perp})\mapsto(B,B_{\perp})}][T_{(A,A_{\perp})}][U_{3(A,A_{\perp})\mapsto(B,B_{\perp})}]^{-1}$$

SIMILARITY TRANSFORMATION

 $\begin{bmatrix} U_{3(A,A_{\perp})\mapsto(B,B_{\perp})} \end{bmatrix} \qquad \begin{array}{c} U(3) \text{ SPECIAL UNITARY ELLIPTICAL} \\ \text{BASIS TRANSFORMATION MATRIX} \end{array}$

100 11





POLARIMETRIC GOLDEN NUMBER

POLARIMETRIC TARGET DIMENSION



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TARGET EQUATIONS

PURE TARGET – MONOSTATIC CASE

$$\begin{bmatrix} T \end{bmatrix} = \underline{k} \cdot \underline{k}^{*T} = \begin{bmatrix} 2A_0 & C - jD & H + jG \\ C + jD & B_0 + B & E + jF \\ H - jG & E - jF & B_0 - B \end{bmatrix}$$

3x3 HERMITIAN MATRIX - RANK 1

$$2A_{0}(B_{0} + B) - C^{2} - D^{2} = 0 \qquad 2A_{0}(B_{0} - B) - G^{2} - H^{2} = 0$$

$$-2A_{0}E + CH - DG = 0 \qquad B_{0}^{2} - B^{2} - E^{2} - F^{2} = 0$$

$$C(B_{0} - B) - EH - GF = 0 \qquad -D(B_{0} - B) + FH - GE = 0$$

$$2A_{0}F - CG - DH = 0 \qquad -G(B_{0} + B) + FC - ED = 0$$

$$H(B_{0} + B) - CE - DF = 0$$

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POLARIMETRIC REMOTE SENSING









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SURFACE ROUGHNESS WAVELENGTH

SCATTERING FROM DISTRIBUTED SCATTERERS

COHERENT INTERFERENCES OF WAVES SCATTERED FROM MANY RANDOMLY DISTRIBUTED ELEMENTARY SCATTERERS INSIDE THE RESOLUTION CELL

GRANULAR NOISE

SPECKLE PHENOMENON



SPECKLE FILTERING

HENIOMEN

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(SPATIAL RESOLUTION)

DISTORTION OF THE INTERPRETATION



(RADIOMETRIC RESOLUTION)

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BoxCar Filter

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J.S. Lee, M.R. Grunes and G. De Grandi, "Polarimetric SAR Speckle Filtering and Its Impact on Terrain Classification" *IEEE TGRS*, September 1999

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J.S. Lee, D.L. Schuler, T.L. Ainsworth, M.R. Grunes, E Pottier, L. Ferro-Famil, "Scattering Model Based Speckle Filetring of Polarimetric SAR Data" IEEE – TGRS, vol 1, January 2006

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J.S. Lee, J.H Wen, T.L. Ainsworth, K.S. Chen, A.J. Chen, "*Improved Sigma Filter for Speckle Filtering of SAR Imagery*" IEEE – TGRS, vol 1, January 2009

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THE H/A/ α POLARIMETRIC TARGET DECOMPOSITION THEOREM













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S.R. CLOUDE - E. POTTIER (1995 - 1996)

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H/A/<u>α</u> DECOMPOSITION

TARGET VECTOR
$$\underline{k} = \frac{1}{\sqrt{2}} \begin{bmatrix} S_{XX} + S_{YY} & S_{XX} - S_{YY} & 2S_{XY} \end{bmatrix}^T$$

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

$$\langle [T] \rangle = [U_3] [\Sigma] [U_3]^{-1} = \begin{bmatrix} u_1 & u_2 & u_3 \end{bmatrix} \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \begin{bmatrix} u_1 & u_2 & u_3 \end{bmatrix}^{*T}$$

$$\begin{array}{c} \text{ORTHOGONAL} \\ \text{EIGENVECTORS} \end{array} \xrightarrow{\text{REAL EIGENVALUES} \\ \lambda_1 > \lambda_2 > \lambda_3 \end{array}$$

$$\begin{array}{c} P_i = \frac{\lambda_i}{\sum \lambda_k} \end{array}$$

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 $H/A/\alpha$ DECOMPOSITION

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MEAN SCATTERING MECHANISM



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$H/A/\alpha$ DECOMPOSITION

ROLL INVARIANCE PROPERTY

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

ORIENTED ($\boldsymbol{\theta}$) COHERENCY MATRIX

SU(3) UNITARY ROTATION MATRIX ($\boldsymbol{\theta}$)

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

$$\begin{bmatrix} U_R(\theta) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 2\theta & \sin 2\theta \\ 0 & -\sin 2\theta & \cos 2\theta \end{bmatrix}$$

EIGENVECTORS / EIGENVALUES ANALYSIS $\langle [T(\theta)] \rangle = [U_3(\theta)] [\mathcal{L}] [U_3(\theta)]^{-1}$

EIGENVALUES
$$\lambda_1^{}$$
 $\lambda_2^{}$ $\lambda_3^{}$: ROLL INVARIANT

PROBABILITIES P_1 P_2 P_3 : ROLL INVARIANT

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H/A/ α DECOMPOSITION Cesa

EIGENVECTORS UNITARY MATRIX

 $[\boldsymbol{U}_{3}(\boldsymbol{\theta})] = [\boldsymbol{U}_{R}(\boldsymbol{\theta})][\boldsymbol{U}_{3}]$

PARAMETERIZATION OF THE UNITARY MATRIX



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

PHYSICAL INTERPRETATION

 $H/A/\alpha$ DECOMPOSITION

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$\underline{\alpha}$ PHYSICAL INTERPRETATION



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DIFFICULT MECHANISM DISCRIMINATION WHEN : H > 0.7

ANISOTROPY (EIGENVALUES SPECTRUM)



- COMPLEMENTARY TO ENTROPY
- ► DISCRIMINATION WHEN H > 0.7









POLARIMETRIC REMOTE SENSING esa OSa **POL-SAR PROCESSING** PHENOMENOLOGIC **QUALITATIVE ANALYSIS** XY XX **POLARIMETRIC POLARIMETRIC** POLARIMETRIC

POLARIMETRIC SPECKLE FILTERING POLARIMETRIC TARGET DECOMPOSITION

POLARIMETRIC CLASSIFICATION MONO/DUAL CHANNELS

H/α CLASSIFICATION

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H/α CLASSIFICATION

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SEGMENTATION OF THE H / $\underline{\alpha}$ SPACE









WISHART CLASSIFIER

Target Vector

$$\underline{X} = \begin{bmatrix} S_{HH} & \sqrt{2}S_{HV} & S_{VV} \end{bmatrix}^T \qquad P(\underline{X}) = \frac{1}{\pi^3 |[C]|} e^{-\underline{X}^{*T} [C]^{-1} \underline{X}}$$

$$\underline{k} = \frac{1}{\sqrt{2}} \begin{bmatrix} S_{HH} + S_{VV} & S_{HH} - S_{VV} & 2S_{HV} \end{bmatrix}^T \qquad P(\underline{k}) = \frac{1}{\pi^3 |[T]|} e^{-\underline{k}^{*T} [T]^{-1} \underline{k}}$$

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

$$P(\langle [T] \rangle / [T_{m}]) = \frac{L^{Lp} |\langle [T] \rangle|^{L-p} e^{-LTr([T_{m}]^{-1} \langle [T] \rangle)}}{\pi^{\frac{p(p-1)}{2}} \Gamma(L) ... \Gamma(L-p+1) [T_{m}]^{L}}$$
COMPLEX WISHART DISTRIBUTION
$$L: \text{ Number of Look} \quad p: \text{ Polarimetric Dimension}$$

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$$WISHART CLASSIFIER$$

$$P(\langle [T] \rangle / [T_m]) = \frac{L^{L_p} |\langle [T] \rangle|^{L_{-p}} e^{-LTr([T_m]^{-1}\langle [T] \rangle)}}{\pi^{\frac{p(p-1)}{2}} \Gamma(L)...\Gamma(L-p+1) [T_m]^L}$$

BAYES MAXIMUM LIKELIHOOD CLASSIFICATION PROCEDURE $\langle [T] \rangle \in [T_m] \quad if \quad P([T_m]/\langle [T] \rangle) \geq P([T_j]/\langle [T] \rangle) \quad \forall \ j \neq m$

Applying Bayes rule
$$P([T_m]/\langle [T] \rangle) = \frac{P(\langle [T] \rangle / [T_m])}{P(\langle [T] \rangle)} P([T_m])$$

It follows

 $\langle [T] \rangle \in [T_m] \quad if \quad P(\langle [T] \rangle / [T_m]) P([T_m]) \ge P(\langle [T] \rangle / [T_j]) P([T_j]) \quad \forall j \neq m$

[*T*_m] : Cluster Center of the class *m*

WISHART CLASSIFIER

$$P(\langle [T] \rangle / [T_m]) = \frac{L^{Lp} |\langle [T] \rangle|^{L-p} e^{-LTr([T_m]^{-1}\langle [T] \rangle)}}{\pi^{\frac{p(p-1)}{2}} \Gamma(L) \dots \Gamma(L-p+1) [T_m]^L}$$

BAYES MAXIMUM LIKELIHOOD CLASSIFICATION PROCEDURE

$$\langle [T] \rangle \in [T_m] \quad if \quad d_m(\langle [T] \rangle) < d_j(\langle [T] \rangle) \quad \forall j \neq m$$

with

$$d_m(\langle [T] \rangle) = LTr([T_m]^{-1}\langle [T] \rangle) + L\ln([T_m]) - \ln(P([T_m])) + K$$

[*T*_m] : Cluster Center of the class *m*

rosa

H / $\underline{\alpha}$ - WISHART CLASSIFIER

esa

k - mean CLASSIFICATION PROCEDURE





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POLSAR DATA DISTRIBUTION IN THE H / A / $\underline{\alpha}$ SPACE





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2 Successive k - mean Classification procedures



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 $2A_0 \qquad B_0 + B \qquad B_0 - B$









 $2A_0 \qquad B_0 + B \qquad B_0 - B$





TRAUNSTEIN - ESAR L-band

C1 C2 C3 C4 C5 C6 C7 C8

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

C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16

H/A/ α and WISHART CLASSIFIER





DERFFAFFENHOFEN - ESAR L-Dand



 $2A_0 \qquad B_0 + B \qquad B_0 - B$



H/A/ C and WISHART CLASSIFIER

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H/A/ α and WISHART CLASSIFIER









PolSARpro v5.0 SOFTWARE



PolSARpro v5.0 Software Training Course

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SAN FRANCISCO BAY





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





SAN FRANCISCO BAY

Eichier Édition Affichage Outils Ajouter Aide

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