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Cover image: *Forest height, Dr. H. Skriver et al.*

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CONTENTS

Session 1. Studies on Polarimetry/Interferometry

Chairs: S. Cloude, D. Corr, H. Skriver & J.C. Souyris

Session 2. Land-Agriculture Applications

Chair: J. S. Lee & S. Quegan

Crop Classification with Multitemporal Polarimetric SAR Data
S. Quegan, T. Le Toan, H. Skriver, J. Gomez-Dans, M. Carmen Gonzalez-Sampedro & D. H. Hoekman

Land Cover Classification using Polarimetric SAR Data
A. Rodrigues, D.G. Corr, E. Pottier, L. Ferro-Famil & D. Hoekman

A New Polarimetric Classification Approach Evaluated for Agricultural Crops
D. Hoekman

Polarimetric Indices for Crop Monitoring Based on Model Simulations and Satellite Observations
X. Blaes, P. Defourny & A. Guissard

A Comparison of Statistical Segmentation Techniques for Multifrequency Polarimetric SAR: Region Growing versus Simulated Annealing
T. Macrì Pellizzeri, P. Lombardo, C. J. Oliver, M. Sciotti, M. Meloni & I. McConnell

Model-based Segmentation Techniques for Multifrequency Polarimetric SAR
P. Lombardo, M. Sciotti, T. Macrì Pellizzeri & M. Meloni

Statistical Segmentation of Polarimetric SAR Data
L. Ferro-Famil, E. Pottier,,D. Corr & A. Rodrigues

Session 3. Sea Ice

Chair: W. Dierking & M. Drinkwater

Radar Polarimetry of Sea Ice
M. Drinkwater

Unsupervised Wishart Classifications of Sea-Ice using Entropy, Alpha and Anisotropy Decompositions
A. Rodrigues, D. Corr, K. Partington, E. Pottier & L. Ferro-Famil

SAR Polarimetry for Sea Ice Classification
W. Dierking, H. Skriver & P.Gudmandsen

Preliminary Classification Results of Simulated RADARSAT-2 Polarimetric Sea Ice Data
B. Scheuchl, D. Flett, G. Staples, G. Davidson & I. Cumming

Session 4. Forestry

Chair: C. Schmullius & D. Hoekman

Tropical Forest Mapping using Multiband Interferometric and Polarimetric SAR Data
K. Prakoso

Evaluating POLinSAR Tree Height and Topography Retrievals in Glen Affric
I. H. Woodhouse, S. Cloude, K. Papathanassiou & C. , Hutchinson

Vegetation Parameters using TOPSAR and GeoSAR Systems
S. Hensley, E. Chapin, T. Michel, E. Rodriguez, M. Simard & P. Siqueira

Forest Biomass Estimation using Polarimetric SAR Interferometry
T. Mette, K.P. Papathanassiou, I. Hajnsek & R. Zimmermann

Session 5. Other Applications Development

Chair: K. Czuchlewski & W. Kuehbauch

Assessing Natural Disaster Impacts and Recovery Using Multifrequency, Fully-Polarimetric Synthetic Aperture Radar (SAR)
K. R. Czuchlewski, Y. Kim & J. K. Weissel

Remote Sensing - A Future Technology in Precision Farming
W. Kühbauch & S. Hawlitschka

Multitemporal and/or Polarimetric SAR Characterization of Urban Areas
F. Dell'Acqua & P. Gamba

Improved Oil Slick Detection and Classification with Polarimetric SAR
J. Fortuny-Guasch

Session 6. SAR Polarimetric Interferometry (POLinSAR)

Chair: E. Pottier & K. Papathanassiou

Tree-height Retrieval Using Single Baseline Polarimetric Interferometry
S. R. Cloude & D. Corr

Model Based Forest Height Estimation from Single Baseline POLinSAR Data: The Fichtelgebirge Test Case
K. P. Papathanassiou, T. Mette & I. Hajnsek

The CORSAR project: Can Polarimetric SAR Interferometry improve Forest Biomass Estimation?
C. Rowland, H. Balzter, R. Cox, P. Saich & O. Stebler

Using POLinSAR at X-Band: Preliminary Observations
P. Dubois-Fernandez, X. Dupuis, F. Garestier & P. Paillou

Polarimetric Interferometric SAR Data Analysis Based on ESPRIT/MUSIC Methods
S. Guillaso, L. Ferro-Famil, A. Reigber & E. Pottier

Session 7. Spaceborne SAR

Chair: A. Moreira & Y.-L. Desnos

RADARSAT-2 Mission Update and Applications Overview
G. Staples

TerraSar-X Upgrade to a Fully Polarimetric Imaging Mode
A. Moreira

COSMO-SkyMed: Mission Definition and Main Applications and Products
G. Rum

ENVISAR Mission Results Update
H. Laur

L-Band SAR SAOCOM Mission and SIASGE System. Some Applications
L. Frulla

Session 8. Theoretical Modelling

Chairs: T. Le Toan & P. Saich

Digital Elevation Model (DEM) Generation from SAR Interferometry
M. Kamaruddin, J.R. Abdul Hamid, P.M. Mather & H. Balzter

Modelling of the Scattering by a Smooth Dielectric Cylinder: Study of the Complex Scattering Matrix using Two Different Models
L. Thirion, C. Dahon, A. Lefevre, I. Chenerie, L. Ferro-Famil & C. Titin-Schnaider

On the Physical Modelling of Polarimetric Parameters of Forests
T. Le Toan, G. Picard & S. Quegan

Physical Interpretation of the Sensitivity of Polarisation Coherence to Soil Surface Roughness
F. Mattia & T. Le Toan

Poster Papers

Chairs: P. Lombardo & S. Quegan

Ground Surface Deformation around Tehran due to Groundwater Recharge: InSAR Monitoring.
N. Gourmelen, M. Peyret, J.F. Fritz & J. Cherry

Assessment of Crop Discrimination using Polarimetric C-band SAR Data
M. Gonzalez-Sampedro, T. Le Toan, J. l. Gomez-Dans, S. Quegan, H. Skriver & D. Hoekman

Analytical Solution for a Polarimetric Surface Scattering Model
A. Breuer & I. Hajnsek

Multifrequency SAR Speckle Noise Model Validation
C. López-Martínez & X. Fabregas

Model based SAR Polarimetric Speckle Noise Filter
C. López-Martínez

Entropy-Alpha Classification Alternative for Polarimetric SAR Image
J. Praks & M. Hallikainen

Interpretation of Polarisation Behaviour of Radar Waves Transmitted through Antarctic Ice Shelves
C. Doake, H. F. J. Corr, A. Jenkins, K. W. Nicholls & C. Stewart

InSAR and POLinSAR for Land Subsidence Monitoring - A User Perspective
Z. Perski

Soil Water Assessment Using a P-band Scatterometer and ERS-2 SAR
D. Blumberg, J. Ben-Asher, G. Ronen, M. Sprintsin, V. Freilikher, L. Volfson & A. Kotlyar

Soil Moisture, Crop and Vegetation Study Using AirSAR Data
F. Hilario & J. Mangera

Forest Canopy Height Mapping from Dual-Wavelength SAR Interferometry
H. Balzter, R. Cox, C. Rowland & P. Saich

Modelled Polarimetric Backscattering Response from Single Pine Trees and Pine Canopies
J. Praks, P. Ahtonen, M. Engdahl, M. Hallikainen

Semi-Empirical Approach and Radar Polarimetry for Vegetation Observation
D. Singh, K. P. Papathanassiou & I. Hajnsek

Forest Monitoring by using Polarimetric SAR: A Preliminary Result
B. Trisasongko & M. Raimadoya

SAR Surface Ice Cover Discrimination Using Distribution Matching
R.S. Gill

SAR Ice Classification Using Fuzzy Screening Method
R.S. Gill

Classification Strategies for Polarimetric SAR Sea Ice Data
B. Scheuchl, I. Hajnsek & Ian Cumming

Radar Method for Sea Waves Intensity Determination Using the Crossed Polarization Components of Reflected Signal
S. Pereslegin

Oceanic Variables Extracted from Along-Track Interferometric SAR Data
D-J. Kim & W. M. Moon

Measuring Surface Roughness on Base of the Circular Polarization Coherence as an Input for a Simple Inversion of the IEM Model
C. Thiel

The Pyla 2001 Experiment: Evaluation of Polarimetric Radar Capabilities over a Forested Area
M. Dechambre, S. Le Hégarat, S. Cavelier, P. Dreuillet & I. Champion

STORM: A New Airborne Polarimetric Real-Aperture Radar for Earth Observations
D. Hauser. T. Podvin, M. Dechambre, R. Valentin, G. Caudal & J-F Daloze

Polarimetric Measurements Over the Sea-Surface with the Airborne STORM Radar in the Context of the Geophysical Validation of the ENVISAT ASAR
D. Hauser. T. Podvin, M. Dechambre, R. Valentin, G. Caudal, J-F Daloze & A. Mouche

Operational Application of Envisat ASAR in Tropical Production Forest
M. Raimadoya & B. Trisasongko

A Tomographic Approach to Multi-Pass SAR Imaging
R. Pierri, G. Leone, A. Liseno & R. Solimene

Abstract Book and Final Programme

POLinSAR Workshop

14-16 January 2003
ESA-ESRIN
Frascati
Italy

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Organiser

Yves-Louis Desnos (ESA/ESRIN)
Directorate of Earth Observation Programmes

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The POLinSARWorkshop

Background

The European Space Agency has awarded, in the framework of the General Studies Programme, two studies on the benefits of SAR Polarimetry and Polarimetric Interferometry (POL-inSAR) for applications development. The successful launch of the Envisat ASAR in March 2002 demonstrates the interest of multipolarisation for new applications development. Furthermore in 2003 ESA is intending to initiate a follow-up study on POLinSAR, taking into consideration the workshop conclusions and recommendations.

Objectives

The main objectives of the workshop are to:

- Provide a forum for scientific exchange
- Present new results from European studies in the field
- Present the geophysical parameters that can be retrieved and their accuracy
- Assess the available POL-inSAR tools and data sets
- Demonstrate the latest techniques
- Assess the state of the art in the field
- Make recommendations for algorithm development and new products
- Formulate recommendations for future missions and applications

Participation

The Workshop is open to ESA Principal Investigators and Scientists working in the field of SAR Polarimetry and Polarimetric Interferometry (POL-inSAR), and to representatives from national, European and international space agencies

Organisation

The Workshop is organised around:

- *Papers/Posters selected by the Scientific Committee*
- *Invited papers (ESA studies)*
- *Round table discussion with questions prepared by the Scientific Committee and ESA*
- *Demonstration of Software tools*

Themes

The Event will comprise the following sessions:

- *Studies on Polarimetry/interferometry*
- *Land-Agriculture Applications*
- *Sea Ice*
- *Forestry*
- *Other Applications Development*
- *SAR Polarimetric Interferometry (Polinsar)*
- *Spaceborne SAR*
- *Theoretical Modelling*
- *Poster Session*

POLinSAR Workshop - Preliminary Programme

Day 1, Tuesday 14 January

8:30	Registration	
9:00	Official ESA Welcome	
9:10	Workshop Organization	**Y.L. Desnos**
9:20-10:40	**Studies on Polarimetry/Interferometry**	**Chair:** ***H. Skriver/D.Corr***
9:20	A Review of the Applications of SAR Polarimetry and Polarimetric Interferometry – an ESA-funded study	Douglas Corr
9:40	Applications of Synthetic Aperture Radar Polarimetry	Henning Skriver
10:00	A Review of Polarization Orientation Estimation from Polarimetric SAR Data	Jong-Sen Lee
10:20	Surface Parameter Estimation Using Interferometric Coherences between Different Polarisations	Irena Hajnsek
10:40	Coffee Break	
11:00-12:40	**Studies on Polarimetry/Interferometry**	**Chair:** ***S.Cloude/J.C. Souyris***
11:00	What can be learnt from an 'half-polarimetric' SAR?	Jean-Claude Souyris
11:20	Why We Do Need To Place Multi-Band Single And Multiple Pass Polinsar Monitoring Platforms Into Space	Wolfgang-Martin Boerner
11:40	Polarimetric SAR interferometry classification, resolution estimation and comparison with optical images in Glenaffric radar project.	Parivash Lumsdon
12:00	Analysis Of Sar Response Anisotropic Behavior Using Sub-Aperture Polarimetric Data	Laurent Ferro-Famil
12:20	Round Table	
13:00	Lunch	
14:00-15:40	**Land-Agriculture Applications**	**Chair:** ***J. S. Lee/S. Quegan***
14:00	Crop classification with multitemporal polarimetric SAR data	Shaun Quegan
14:20	Assessing the benefit of SAR Polarimetry for Land Cover Classification	Alex Rodrigues
14:40	A new polarimetric classification approach evaluated for agricultural crops	Dirk Hoekman
15:00	Polarimetric indices for crop monitoring based on model simulations and satellite observations	Xavier Blaes
15:20	A comparison of statistical segmentation techniques for multifrequency polarimetric SAR: region growing versus simulated annealing	Tiziana Macrì Pellizzeri
15:40	Coffee Break	

16:00-17:00	**Land-Agriculture Applications**	**Chair:** ***J. S. Lee/S. Quegan***
16:00	Model-based segmentation techniques for multifrequency Polarimetric SAR	Pierfrancesco Lombardo
16:20	Statistical Segmentation of Polarimetric Sara Data	Laurent Ferro-Famil
16:40	Round Table	
17:20-18:40	**Theoretical Modelling**	**Chair:** ***Le Toan/P. Saich***
17:20	Modelling of the scattering by a smooth dielectric cylinder: study of the complex scattering matrix using two different models	Laetitia Thirion
17:40	On the physical modelling of polarimetric parameters of forests	Thuy Le Toan
18:00	Physical interpretation of the sensitivity of polarisation coherence to soil surface roughness	Francesco Mattia
18:20	Round Table	
18:40-20:00	Welcome Cocktail	

Day Two, Wednesday 15 January

8:30-9:00	Registration	
9:00-10:40	**Forestry (Parallel Session)**	**Chair:** ***D. Hoekman/T.Mette***
9:00	Tropical Forest Mapping using Multiband Interferometric and Polarimetric SAR Data	Kemal Unggul Prakoso
9:20	Evaluating PolInSAR Tree Height and Topography Retrievals in Glen Affric	Iain Woodhouse
9:40	Vegetation Parameters using TOPSAR and GeoSAR Systems	Scott Hensley
10:00	Above Ground Forest Biomass Estimation using Fully Polarimetric / Interferometric Radar Data	Tobias Mette
10:20	Round Table	
9:00-10:40	**Sea Ice (Parallel Session)**	**Chair:** ***W Dierking/M Drinkwater***
09:00	Radar Polarimetry of Sea Ice	Mark Drinkwater
09:20	Unsupervised Wishart Classifications of Sea-Ice using Entropy, Alpha and Anisotropy decompositions	Alex Rodrigues
09:40	SAR Polarimetry for Sea Ice Monitoring	Wolfgang Dierking
10:00	Classification strategies for fully polarimetric SAR data of sea ice	Speaker: Gordon Staples (for Bernd Scheuchl)
10:20	Round Table	
10:40	Coffee Break	

11:00-13:00	**SAR Polarimetric Interferometry (Polinsar)**	**Chair:** ***E.Pottier/K Papathanassiou***
11:00	Tree-height retrieval using Single Baseline Polarimetric Interferometry	Shane Cloude
11:20	Model Based Forest Parameter Estimation	Kostas Papathanassiou
11:40	The CORSAR project: Can polarimetric SAR interferometry improve forest biomass estimation?	Clare Rowland
12:00	Using POL-INSAR at X-Band: observations	Pascale Dubois-Fernandez
12:20	Polarimetric Interferometric SAR Data Analysis Based on ESPRIT/MUSIC Methods	Stephane Guillaso
12:40	Round Table	
13:00-14:00	Lunch	
14:00-16:15	**Poster Session**	**Chair:** ***P. Lombardo/S. Quegan***
14:02	Ground surface deformation around Tehran due to groundwater recharge: InSAR monitoring**.**	Michel Peyret
14:04	Assessment of crop discrimination using polarimetric C-band SAR data	Thuy Le Toan
14:08	Fully versus Partial Polarimetry for quantitative surface parameter estimation	Axel Breuer
14:10	Multifrequency SAR polarimetric noise model validation	Carlos López Martínez
14:12	Model based SAR polarimetric speckle noise filter	Carlos López-Martínez
14:14	Entropy-Alpha classification alternative for polarimetric SAR image	Jaan Praks
14:16	Interpretation of polarimetric radar waves transmitted through Antarctic ice shelves	Speaker: Hugh Corr (for Christopher Doake)
14:18	InSAR and POLInSAR for land subsidence monitoring - a user perspective	Zbigniew Perski
14:20	Soil water assessement using a P-band Scatterometer and ERS-SAR	Dan Blumberg
14:22	Soil Moisture, Crop and Vegetation Study Using AirSAR Data	Flaviana Hilario
14:24	Forest canopy height mapping from dual-wavelength SAR interferometry	Heiko Balzter
14:26	Modelled polarimetric backscattering response from single pine trees and pine canopies	Jaan Praks
14:28	Semi-Empirical Approach and Radar Polarimetry for Vegetation Observation	Dhamendra Singh
14:30	Forest monitoring by using polarimetric sar: a preliminary result	Bambang Trisasongko
14:32	SAR surface ice cover discrimination using distribution matching	Rashpal S. Gill
14:34	SAR Ice Classification using Fuzzy Screening Method	Rashpal S. Gill
14:36	Polarimetric data of sea ice in preparation for RADARSAT-2	Speaker Gordon Staples (for Bernd Scheuchl)
14:38	Radar method for sea waves intensity determination using the crossed polarisation components of reflected signal	Sergei Pereslegin

14:40	Oceanic Variables extracted from Along-Track Interferometric SAR data	Duk-jin Kim
14:42	Measuring Surface Roughness on Base of the Circular Polarization Coherence as an Input for a Simple Inversion of the IEM Model	Christian Thiel
14:44	The Pyla 2001 experiment: polarimetric radar observations over a forested area Evaluation of polarimetric radar capabilities over a forest	Monique Dechambre
14:46	STORM: A new airborne polarimetric real-aperture radar for earth observations	Daniele Hauser
14:48	Polarimetric measurements over the sea-surface with the airborne STORM radar in the context of the geophysical validation of the ENVISAT ASAR	Daniele Hauser
14:50	Operational Application of Envisat ASAR in tropical production forest:	Mahmud Raimadoya
14:52	A Tomohgraphic Approach to Multi-Pass SAR Imaging	Rocco Pierri
14:54	ENVISAT ASAR images over Malbork agricultural area (Poland)	Marek Mroz
14:56	Use of ERS-1 and Landsat TM images for geological and mineral exploration of Sol Hamid area	Talaat Ramadan
14:58	On the selection of the best polarization to detect buried objects by means of POLINSAR	Juan M Lopez-Sanchez
15:00	Electric Field ratio Formalism in Radar Polarimetry	Teemu Tares
15:02	Polarimetric SAR interferometry for vegetable vertical structure parameters extraction	Hong Zhang
15:04	Effect of Dew and Interception on the Backscattering Behaviour of Crops	Tanja Riedel
15:06	Speckle Filtering of Polarimetric SAR Interferometry Data	Jong-Sen Lee
15:08	Environmental database and geographic information system for social economic planning	Olakunle Francis Omidiora
15:10	Investigation on different interferometric coherence optimization methods	Elise Colin
15:15	Free Poster Session	
16:15	Coffee Break	
16:30-18:50	**Round Table Session**	
16:30	Polarimetry-Interferometry Studies	
16:50	Land-Agriculture Classification	
17:10	Theoretical Modelling	
17:30	Forestry	
17:50	Sea Ice	
18:10	SAR Polarimetric Interferometry (Polinsar)	
18:30	Poster Session	
19:00-21:30	Reception	

Day Three, Thursday 16 January

09:00-10:40	**Other Applications Development**	***Chairman:*** **K Czuchlewski./W. Kuehbauch.**
09:00	Assessing Natural Disaster Impacts and Recovery Using Airborne, Multifrequency Synthetic Aperture Radar (SAR) Polarimetry	Czuchlewski K.
09:20	Remote Sensing - A Future Technology in Precision Farming	Kuehbauch W.
09:40	Multitemporal And/Or Polarimetric Sar Characterization Of Urban Areas	Dell'Acqua F.
10:00	Improved oil slick detection and classification with polarimetric SAR	Joaquim Fortuny-Guasch
10:20	Round Table	
10:40	Coffee Break	
11:00-12:40	**Spaceborne Sar**	**Chairman:** ***A.Moreira Y-L.Desnos***
11:00	RADARSAT-2 Mission Update and Applications Overview	Staples G.
11:20	TerraSAR-X Upgrade to a Fully Polarimetric Imaging Mode	Moreira A.
11:40	COSMO-SkyMed: Mission definition and main applications and products	Giovanni Rum
12:00	ENVISAT mission results update	Henri Laur
12:20	Round Table	
13.00 - 1400	Lunch	
14.00-16:00	**Workshop Closing Session**	**Chairman:** ***Y-L.Desnos***
14:00	Polarimetry/Interferometry studies	
14:15	Methods - Theoretical Modelling	
14:30	Land - Agriculture applications	
14:45	Forestry	
15:00	Sea-Ice	
15:15	SAR Polarimetric Interferometry (Polinsar)	
15:30	Applications Development	
15:45	Spaceborne Sar	
16:00 –16.15	**Workshop Conclusions & Recommendations**	
16:15	Coffee Break	
16: 30–17:30	**Tour of Esrin**	

Studies on Polarimetry/Interferometry

A REVIEW OF THE APPLICATIONS OF SAR POLARIMETRY AND POLARIMETRIC INTERFEROMETRY - AN ESA-FUNDED STUDY

Dr Douglas Corr [1], Dr Shane Cloude[2] , Dr Laurent Ferro-Famil[3] , Dr Dirk Hoekman[4] , Dr Kim Partington[5] , Prof Eric Pottier[3] , and Alex Rodrigues[1]

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Abstract

In this paper we present an overview of an ESA ESRIN-funded study entitled Applications of SAR Polarimetry. The study was jointly conducted by QinetiQ, AELc, University of Rennes 1, SarVision and Vexcel UK. The aim was to review, assess and validate the benefits of using polarimetry for Land-Cover classification and Sea-Ice classification. The potential of Polarimetric Interferometry for vegetation parameter retrieval was also reviewed, assessed and demonstrated. A literature review was undertaken to choose the most promising techniques prior to their evaluation. This paper summarises the objectives, key conclusions and recommendations of the study.

APPLICATIONS OF SYNTHETIC APERTURE RADAR POLARIMETRY

Dr Henning Skriver [1], Dr. Wolfgang Dierking[2], Dr. Preben Gudmandsen[1] , Dr Thuy Le Toan[3] , Alberto Moreira[4] , Dr Kostas Papathanassiou[4], and Dr. Shaun Quegan[5]

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Abstract

The presentation will contain an overview of the results of an ESA study on applications of synthetic aperture radar polarimtry. In particular, results will be presented on methods and accuracies for agriculture and land-cover classification using polarimetric SAR, methods and accuracies for sea ice classification using polarimetric SAR, and methods and accuracies for retrieval of vegetation parameters from polarimetric interferometry.

A REVIEW OF POLARIZATION ORIENTATION ESTIMATION FROM POLARIMETRIC SAR DATA

Dr. Jong-Sen Lee [(1)], Mr. Thomas L. Ainsworth[(1)] , and Mr. Dale L. Schuler[(1)]

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Abstract

In recent studies, Schuler et al. applied polarimetric SAR derived orientation angles to measure topography, and Lee et al. used orientation angles for polarimetric SAR data compensation. The results from this technique generally agree well with the DEM map. However, the accuracy is not as good as that from SAR interferometry. Accurate estimation of geophysical parameters, such as soil moisture, surface roughness, snow depth, etc requires polarimetric SAR data to be compensated for terrain slope variations. Many different techniques [1-4] for the estimation of orientation angles have been proposed. However, in these studies, inconsistency in the estimation of orientation angles was encountered in several areas, introducing noisy and erroneous results. To support these applications, it is important to accurately estimate shifts in orientation angles induced by the azimuth slope variations. However, in many cases, inconsistency in the estimation of orientation angle shifts was encountered in several areas, introducing noisy and erroneous results. In this paper, we review estimation algorithms and applications of polarization orientation angle induced by terrain slopes. We develop a unified analysis of estimation algorithms based on the circular polarization covariance matrix. The concept of reflection symmetry is used to explain the soundness of the circular polarization method, and to show problems associated with other algorithms. The relationship between several algorithms will also be explored from different viewpoints, and a theoretical model will be used to explain the results. The effect of radar frequency, scattering media, and polarimetric calibration will also be discussed. SIR-C, and JPL AIRSAR L- band and P-band polarimetric SAR images are used for demonstration.

References:

[1] J.S. Lee, D.L. Schuler and T.L. Ainsworth, "Polarimetric SAR Data Compensation for Terrain Azimuth Slope Variation," IEEE Transactions on Geoscience and Remote Sensing, vol. 38, no. 5, 2153-2163, September 2000.

[2] D.L. Schuler, J.S. Lee, G. De Grandi, "Measurement of Topography using Polarimetric SAR Images," IEEE Trans. on Geoscience and Remote Sensing, no.5, pp. 1266- 1277, 1996.

[3] D.L. Schuler, J.S. Lee, T.L. Ainsworth, and M.R. Grunes, "Terrain Topography Measurement Using Multipass Polarimetric Synthetic Aperture Radar Data," Radio Science, vol. 35, no.3, 813- 832, May-June 2000.

[4] E. Pottier, D.L. Schuler, J.S. Lee and T.L. Ainsworth, "Estimation of the Terrain Surface Azimuthal/Range Slopes Using Polarimetric Decomposition of POLSAR Data," Proceedings of IGARSS"99, 2212-2214, July 1999

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SURFACE PARAMETER ESTIMATION USING INTERFEROMETRIC COHERENCES BETWEEN DIFFERENT POLARISATIONS

Irena Hajnsek [(1)], Prof Shane Cloude[(2)] , Alberto Moreira[(1)] , and Kostas Papathanassiou[(1)]

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Abstract

In this work the potential of using the interferometric coherence at different polarisations over surface scatterers in order to extract information about surface parameters is investigated. The sensitivity of the individual coherence contributions to surface roughness and moisture conditions is discussed and simulated using a polarimetric surface scattering model. Polarimetry plays an important role in the estimation of surface parameter, as it allows a direct or indirect separation of roughness, rms height s, and moisture mv [vol. %] induced effects on the backscattered signal. Several algorithms have been proposed in the literature for the retrieval of surface parameters from polarimetric SAR data. Most of them are based on the evaluation of the backscattering amplitudes. However, there are several works addressing the evaluation of second order statistical parameters (correlation coefficients between different polarisations) with respect to surface parameter estimation. The polarimetric coherence can be regarded as a zero baseline interferometric coherence between different polarisations. Introducing a spatial baseline and conventional interferometric coherence is obtained. In this work the information content of an interferometric coherence with respect to surface parameter estimation is investigated and the essential contribution are critical discussed. One important task of this work is to figure out the applicability of using the interferometric coherence between different polarisations in order to increase the estimation accuracy of surface parameters in a general SAR remote sensing scenario. Finally, experimental airborne SAR data are used to demonstrate the discussed effects.

WHAT CAN BE LEARNT FROM A HALF-POLARIMETRIC SAR?

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Abstract

The overall objective of this study has been to assess various designs of partial polarimetry (*pp*) architectures that could be implemented on space segments at a reduced cost, and compliant with micro-satellite platforms (≤100 to 120 kg class). The performance assessment concerns both the level of information preserved in comparison with full polarimetry *(fp)*, and the concurrent space segment complexity, in terms of PRF, processed swath, and down link features.

In previous studies, two *pp* options were investigated. The first one is limited to a unique linear polarization in transmission (e.g. horizontal), while receiving on both co- and cross-polarized channels (h and v). This option is based on a simple design, thanks to the polarisation uniqueness in transmission. However, it led to poor classification performances [1]. The second option considers two interleaved polarizations in transmission (h and v), the reception being restricted to co-polarized channels (i.e. hh and vv). The polarimetric information is much better preserved than in the previous case [1], [2], and the power budget is more comfortable (hv term which is now left out is usually 7 to 10 dB below hh and vv). However, the main drawback is linked to the need for transmitting two polarizations: in comparison with a standard SAR, the PRF has to be doubled, and the swath halved, in order to maintain immunity from range ambiguities.

The framework of this study is consequently to restrict *pp* architectures to the polarization uniqueness in transmission, combined with the polarization duality in reception. Such a configuration justifies the denomination of *'half polarimetry'*. In this context, in order to overcome the drawbacks of the (hh+hv) architecture (critical loss of information), we focus on a configuration where the two linear receiving polarizations are oriented at π/4 of each side of the unique transmitted linear polarization. A procedure to estimate a *full polarimetric* (*fp*) information over extended targets from this design (hereafter called the π/4 *mode*) is proposed, when the nullity of complex correlation between co- and x-polarized terms is assumed. The behaviour of point targets is also considered.

As already mentioned, the polarization uniqueness of the π/4 mode in transmission permits to maintain the PRF at the same value as for a standard SAR. For a given swath, the down-link features are reduced by a factor of 2, in comparison with *fp*. The power balance of the π/4 *mode* is far better than for (hh+hv), for which the two receiving channels are affected by critically different Signal to Noise Ratio (SNR), *X* being typically *7* to *10 dB* below *H* and *V*. However, a drawback of the π/4 mode is related to the non-parallelism of transmitted and received fields, leading to a loss of 3 dB on the power link. At the image level, the Noise Equivalent σ^0 (NEσ^0) increases by 3 dB, transforming a typical value of *-25 dBm_/m_* to *-22 dBm_/m_*. Further studies must be conducted to evaluate the real impact of this loss. At the time of the presentation, the assessment of the π/4*mode* will be discussed for its crop classification capability using L and C band images acquired over the Flevoland area by JPL AIRSAR. In order to assess the performances of the various *pp* architectures (including the π/4mode) in comparison with *fp*, the response of π/4 mode is simulated using the fully polarimetric SAR data of Flevoland. Quantitative comparisons of classification accuracies between *fp, pp* and the π/4 mode are evaluated based on the maximum likelihood Wishart classification. In our initial study, the π/4classification accuracy is comparable to that of the *fp* and the (hh+vv) mode, and is much better than the (hh+hv) mode.

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WHY WE DO NEED TO PLACE MULTI-BAND SINGLE AND MULTIPLE PASS POLINSAR MONITORING PLATFORMS INTO SPACE

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Abstract

The ESA POLinSAR Workshop on "Applications of SAR Polarimetry and Polarimetric SAR Interferometry" is arranged at the ideal time for developing this urgently required technology for environmental stress-change and local-to-global conflict monitoring in air and specifically in space. In this overview, reasons are provided on why we do need to place multi-modal, multi-band single and multiple pass POLinSAR monitoring platforms into space. The questions "on what POLinSAR monitoring can provide that POL-SAR and IN-SAR by themselves cannot accomplish" is assessed; whereupon facts and justifications on placing POL-IN-BISAR satellite clusters into space are presented. Reasons for this technology becoming a basic requirement for current, near-future and much more so for future all-day & night year-round monitoring of the terrestrial covers are analyzed in view of the un-abating and uncontrollable terrestrial population explosion. The pertinent questions on how to reduce the exorbitant cost for initiating this "home-globe security protection" technology are also broached, and the expected benefits are laid out in detail. The pertinent National and International airborne and space borne multi-modal, multi-band SAR remote sensing and security conflict surveillance support agencies are herewith invited for co-sponsoring our proposal, which is timely and POLinSAR platforms are urgently required to be placed into space.

Outline

I. Background with developmental technology history

1.1. POLinSAR theory and algorithm development has been accomplished and is verified.

1.2. POLinSAR image data takes were acquired with space borne SIR-C/X-SAR and with several POLinSAR airborne platforms like the DLR-OP-IHR E-SAR, the DCRS EMI-SAR, the CRL PiSAR, the ONERA RAMSES-SAR and the NASA-JPL AIRSAR.

1.3. POLinSAR image feature sorting and identification algorithms have been tested and are available as was demonstrated by Cloude and Papathanassiou beyond doubt.

1.4. Cost reduction with the aid of bistatic cartwheel POL-SAR imaging platforms in air and space have been and/or are being demonstrated currently in North America and Europe.

II. From airborne to space borne POLinSAR platform deployment

2.1 Not withstanding space borne applications, airborne multi-modal, multi-band POLinSAR test platform development is essential, must go on for years to come in order to support basic technology advancement and algorithms verification

2.2 Airborne POL-inSAR platform deployment, while truly imperative for technology development, is too expensive for wide area conflict monitoring, and need be replaced by "Unmanned Automated Vehicle: UAV" POLinSAR platforms at the same time during which the entire air and space borne technology is being developed

2.3 While both airborne and UAV multi-modal, multi-band POLinSAR platform deployment is very essential for localized, regional and mission-oriented flight-path imaging; global terrestrial and future planetary remote sensing and

surveillance require the urgent and rapid development of space borne multi-modal, multi-band single and multiple pass POLinSAR monitoring platforms

2.4 Global worldwide monitoring of the terrestrial hydro-sphere and biosphere together with a more accurate acquisition of more precise biomass estimation require single and distributed multi-modal, multi-band POLinSAR monitoring platform deployment. This technology will become all the more relevant for effective global conflict surveillance

III. Applications and improvement on terrestrial biomass estimation

3.1 POL-SAR imaging platform deployment enabled the development of highly improved supervised and unsupervised image feature sorting and interpretation algorithms including soil moisture and roughness parameter estimation, which are far superior to those of mono/multiple-polarization-amplitude SAR and/or passive lidar sensing.

3.2 IN-SAR can provide only average-in-altitude "Digital Elevation Maps: DEM" and it is not able to discern canopy cover versus under-store, versus vegetated ground and/or multilayered under burden returns.

3.3 Although for rather specific limited cases multiple complex amplitude-only (HH, HH + VV, HH + HV, VV + VH) quasi-polarimetric SAR may provide may provide improved "specific scenario-dependent" information on vegetation cover above that of amplitude- only SAR, it is not sufficient for precise biomass estimation of densely vegetated and especially forested regions; whereas INSAR does not help at all to acquire 3-D forest canopy versus forest under-store, versus vegetated ground und multi-layered under-burden differentiation, which only and only multi-band single and multiple pass POLinSAR and POL-TOMO-SAR can accomplish. This applies especially to soil moisture and roughness estimation as well as to the mapping of flooded regions.

IV. Cost reduction via POLin BISAR cartwheel clusters in space

4.1 It is a well known fact that any novel advanced forefront imaging technique whether in non-destructive testing, medical radiology, sub-aquatic sonar imaging, and/or Radar/SAR remote sensing and conflict surveillance - is exorbitantly costly during its infant stages; and these relatively high cost factors cannot and must not be considered a deterrent factor, hampering the steady and urgent advancement of POLinSAR technology.

4.2 Multi-modal multi-band polarimetric SAR deployment was proven a viable novel imaging technology hitherto not surpassed or even closely competing with existing SAR imaging technology. In fact, it was demonstrated beyond doubt that fully polarimetric POL-SAR outperforms conventional mono/multiple-polarization-amplitude- only SAR by a factor of 12 15 dB in general.

4.3 Airborne and space borne POLinSAR imaging & sensing platform deployment was successfully demonstrated with the SIR-C/X-SAR missions 1 & 2, which were complemented more recently by the DLR-OP-IHR multi-pass E-SAR POL-TOMO-SAR experiments, providing the first true 3-D image-reconstructions of volumetric vegetation scatter, which when extended to the multi-band microwave POLinSAR image data take acquisition will enable the isolation of compact (point) targets in a 3-D forest and vegetated or urban environment being of essential relevance to `National home-land' and even more so to `International home-globe' security conflict surveillance missions

4.4 The first steps in developing airborne and space borne clusters of partially and fully polarimetric bistatic cartwheel SAR imaging deployment are well under way both in Europe and North-America and, a fully polarimetric Cartwheel SAR Cluster deployment was proven to be feasible - at least on the drawing boards. The costs are only slightly above those of purely amplitude-only systems, and the truly impressive improvements obtained in deploying bistatic POLinSAR cartwheel clusters for a highly more accurate and close-to-reality biomass estimation justify the costs.

V. Benefits for highly improved and more accurate biomass estimation, and for the ` homeland' plus `home-globe' security conflict mitigation missions

5.1 Near future and future environmental stress-change remote sensing and localized to wide area security conflict surveillance requires monitoring technologies which are being advanced towards the limits of physical realizability like POLinSAR is

5.2 The entire field of local to global biomass estimation of multi-modal, multi-band microwave POLinSAR imaging in concert with advanced passive and active polarimetric EO sensing will be advanced most actively and will become quantitatively accessible.

5.3 The initial exorbitant cost factors are being addressed and shown to be not as drastic - with the introduction of multi-static cartwheel clusters of multi-band POL-SAR, i.e., POL-IN-BISAR systems - as previously estimated, which will pave the way to "all-day & night year-round" 3-D monitoring of the terrestrial covers.

5.4 Similar to placing the equidistantly spaced fleet of orbiting GPS satellites into space, we are herewith developing the complementary set of equidistantly spaced orbiting clusters of multi-modal, multi-band microwave POL-IN-BISAR monitoring satellites for space deployment, which will provide day and night, hourly stress-change and security conflict indicators. These all-important indicators are required already now, and much more so are in desperate need in the nearer and distant future for protecting "Mother Earth = our home-globe" suffering from an un-abating population explosion and therewith an ever increasing number of future environmental stress-change and political security conflicts.

POLARIMETRIC SAR INTERFEROMETRY CLASSIFICATION, RESOLUTION ESTIMATION AND COMPARISON WITH OPTICAL IMAGES IN GLENAFFRIC RADAR PROJECT.

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Abstract

In this paper we summarise our recent studies on the Polarimetric SAR Interferometric classification of the data for the Glenaffric radar project. With a focus on the vegetation height estimation, DEM, and error measurement due to the presence of speckles and Phase unwrapping errors. The SAR image resolution is further compared with the optical image resolution and classification of the same area.

ANALYSIS OF SAR RESPONSE ANISOTROPIC BEHAVIOUR USING SUB-APERTURE POLARIMETRIC DATA

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Abstract

In synthetic aperture radar (SAR) polarimetry, the measured polarimetric signatures are used to analyse physical scattering properties of the imaged objects. It is thereby generally assumed, that the sensor has a fixed orientation with respect to the objects. But SAR sensors operating at lower frequencies, like L- and P-band, have a wide antenna characteristic in azimuth; i.e. during the formation of the synthetic aperture, multiple squint angles are integrated to form the full-resolution SAR image. Possible changes in the polarimetric backscattering characteristics during this change of the look-angle remain unconsidered. In this paper a fully polarimetric sub-aperture analysis method is introduced. Using deconvolution, synthesized SAR images are decomposed into sub-aperture data sets, which correspond to the scene responses under different azimuthal look angles. A statistical analysis of the polarimetric data permits to clearly discriminate the media showing a varying behaviour during the SAR integration. This analysis is based on test statistics applied to R sub-aperture images and uses the Wishart pdf of a coherency matrix. This test permits to discriminate, for each pixel, the range of azimuth observation angles corresponding to an anisotropic behaviour. Some plowed surfaces show, for some particular observation angle, a resonant behaviour, which has a significant influence on pertinent polarimetric indicators. Certain surface parameters of such areas may be estimated, using the subaperture approach, which are not observable in the full-resolution data. Finally, a method is proposed in this paper, which eliminates the influence of azimutal backscattering variations in conventional polarimetric SAR data analysis. The effectiveness of the new methods is demonstrated on fully polarimetric SAR data, acquired by the DLR s airborne experimental SAR sensor (E-SAR) in L-band.

Land-Agriculture Applications

CROP CLASSIFICATION WITH MULTITEMPORAL POLARIMETRIC SAR DATA

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Abstract

Multitemporal measurements gathered by EMISAR over the Foulum (Jutland) test site and AirSAR over the Wageningen test site provide an unrivalled opportunity to examine the factors affecting classification of northern European agricultural crops using both polarimetric and multitemporal information. Data analysis, guided by physical principles, has been used to investigate those polarimetric features most adapted to separating different classes of crops (with the emphasis on C band data). This has led to a hierarchical approach in which broad classes (spring vs winter crops) are successively subdivided into more specific classes using the most appropriate polarimetric features. While the overall ordering and rationale of the hierarchy is determined by the physics, hence is inherently transferable between different regions, the scheme increasingly relies on statistical methods to fix the decision boundaries, thus allowing adaptivity to local conditions. Because an underlying principle is exploitation of the prevalent scattering mechanisms, the behaviour and structure of the scheme is very dependent on the temporal evolution of the crop state. The performance of the approach will be demonstrated using both of the airborne datasets.

ASSESSING THE BENEFIT OF SAR POLARIMETRY FOR LAND COVER CLASSIFICATION

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Abstract

In this paper we demonstrate and validate the benefit of polarimetry for land cover classification. The performance of a number of supervised and unsupervised algorithms are presented. Two data sources are used: DLR -ESAR P and L-Band data of Alling, Germany and JPL AIRSAR P, L and C Band data of Flevoland, The Netherlands. Both datasets have comprehensive ground truth and this is used as validation. In addition to full polarimetry, the performance of L and C Band partial polarimetry (HH-HV and HH-VV combinations) is also assessed. Confusion matrices are presented for each algorithm and conclusions about the best frequency and polarisation combinations to use are drawn.

A NEW POLARIMETRIC CLASSIFICATION APPROACH EVALUATED FOR AGRICULTURAL CROPS

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Abstract

A new polarimetric classification approach evaluated for agricultural crops Dirk H. Hoekman Wageningen University Dept. of Environmental Sciences Nieuwe Kanaal 11, 6709 PA Wageningen, The Netherlands tel:+31-317-482894, fax:+31-317-484885, email: Dirk.Hoekman@wur.nl ABSTRACT Statistical properties of the polarimetric backscatter behaviour for a single homogeneous area are described by the Wishart distribution or its marginal distributions. These distributions do not necessarily well describe the statistics for a collection of homogeneous areas of the same class because of variation in, for example, biophysical parameters, which often is reflected in variation in the mean backscatter values. Using Kolmogorov-Smirnov (K-S) tests of fit it will be shown that, for example, the Beta distribution is a better descriptor for the coherence magnitude, and the log-normal distribution for the backscatter level. This will be evaluated for a number of agricultural crop classes, grasslands and fruit tree plantations at the Flevoland test site, using AirSAR (C-, L- and P-band polarimetric) data. Classification improvements will be quantified. Also the effect of azimuthal asymmetric backscatter behaviour on the classification results will be discussed. A new reversible transform of the covariance matrix will be introduced in order to describe the full polarimetric target properties in a mathematically simpler way, allowing even simpler statistical descriptions. It will be shown that this transform yields versatile and robust classification approaches and gives new insight in polarimetric decomposition. A comparison of results for the various classification methods will be given, using several (combinations) of frequency bands. To support generalisation of the results the physical relation between vegetation structure and backscatter mechanisms will be discussed explicitly.

POLARIMETRIC INDICES FOR CROP MONITORING BASED ON MODEL SIMULATIONS AND SATELLITE OBSERVATIONS

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Abstract

A polarimetric radiative transfer model has been developed at UCL for the simulation of polarimetric radar observation of rough soils and vegetated areas. The so called Polscat model is a fully polarimetric model and allows to compute the complete Mueller matrix from which the backscattering coefficients in various polarization's can be obtained. For the soil, the Integral Equation Method (IEM) has been implemented. This surface scattering model requires as input the dielectric properties of the soil and the geometric properties of the surface (i.e. rms height and slopes). For the vegetation, the volume electromagnetic scattering model is based on the radiative transfer theory. It includes size distributions, it accounts for the reciprocity effect, it allows vertical distributions within the canopy and provides a precise description of the vegetation component. The soil parameters measurements are widely discussed in the literature. The rms height and the correlation length are commonly measured using linear profilometer. In our study, the 3-D geometry of the soil surface is determined using stereoscopic pairs of photographs acquired at 4- meter high over 2 crop types (i.e. sugar beet and spring barley) along the first stage of the growing period (when the soil is sparsely covered by the vegetation). From the modelled soil surfaces, 2-D profiles are generated in various directions (relative to the crop row orientation), positions and using different sampling distances. The roughness parameters are deduced from this different configurations and the corresponding co-polarized (HH and VV) signals are modelled. The effects of the sampling distance, the profile length and the roughness anisotropy on the output simulated signal are systematically investigated. In a second part, the partial validation of the surface scattering model is presented. This was made using simultaneous SAR images acquisitions (ERS, RADARSAT and JERS) and fields measurements from the 1995 to the 2000 growing seasons over sugar beet and cereal fields. Simulations were made for each configuration of mentioned sensors and compared to the recorded co-polarized signal. Based on the simulations in C-band, polarimetric indices are proposed to separate soil and vegetation effects from the backscattered signal. Temporal signal variation and the anisotripic effect of row orientation thanks to the satellite look direction are also presented

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A COMPARISON OF STATISTICAL SEGMENTATION TECHNIQUES FOR MULTIFREQUENCY POLARIMETRIC SAR: REGION GROWING VERSUS SIMULATED ANNEALING

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Abstract

Two polarimetric segmentation techniques have been devised and implemented by the authors, starting from the generalised maximum likelihood approach with a Wishart distribution: a region growing approach (POL MUM) and global likelihood approach (POLSEGANN) based on the simulated annealing. Both techniques exploit the properties of the covariance matrix of the data, but they proceed with very different approaches to identify the widest possible homogeneous segments. A number of different sets of simulated images with known segments and polarimetric characteristics are used to compare the segmentation performance of the different techniques. Different measures are introduced to compare the achieved segments, among which the probability of correct classification and the fractional overlap between segments that belong to the same region. The comparative performance of the two techniques on a set of SIRC polarimetric images are also discussed.

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MODEL-BASED SEGMENTATION TECHNIQUES FOR MULTIFREQUENCY POLARIMETRIC SAR

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Abstract

A new technique, named DPOL MUM, is proposed for the segmentation of multifrequency polarimetric SAR images, that exploits the characteristic block diagonal structure of their covariance matrix. This technique is based on the newly introduced split-merge test, that has a reduced fluctuation error than the straight extension of the polarimetric test (POL MUM) and is shown to yield a more accurate segmentation on simulated SAR images. DPOL-MUM is especially useful in the extraction of information from urban areas that are characterised by the presence of different spectral and polarimetric characteristics. Its effectiveness is demonstrated by applying it to segment a set of polarimetric SIR-C images of the town of Pavia. The classification of the image segmented with DPOL MUM shows higher probability of correct classification compared to POL MUM and to a similar technique that does not use the correlation properties (MT MUM).

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STATISTICAL SEGMENTATION OF POLARIMETRIC SAR DATA

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Abstract

The polarimetric response of a medium is highly related to intrinsic parameters (such as its geometrical structure, its dielectric properties etc.) and observation parameters (such as incidence angle, centre frequency etc.). Segmentation techniques in polarimetric applications have significantly improved the interpretation of the scattering from natural media. However, a wide number of schemes have been proposed, each having particular advantages and disadvantages. Maximum Likelihood k-mean clustering procedures using the coherency matrix and Wishart statistics were proposed by Lee and Cloude (Wishart H-alpha classifier) and Pottier and Lee (Wishart H-alpha-A classifier). These procedures are initialised using the data distribution in the H-alpha plane (Cloude and Pottier). They have the advantage of being highly related to a physical interpretation of the scattering phenomenon. However, they are limited by the high sensitivity of the k-mean procedure to the number of classes and to the initial distribution of the pixels into these classes. To overcome these limitations, Lee et al. proposed an initialisation scheme with a large number of classes followed by a reduction procedure that preserves the scattering mechanisms. This approach used a decomposition theorem (Freeman et al.) that presents an under-determination and is not roll invariant. Skriver et al. also proposed a class number reduction procedure, uniquely based on a Wishart test. Schou et al. proposed a classification scheme using Gaussian Hidden Markov Random Fields (HMRF) while D'hondt, Ferro-Famil and Pottier introduced a less restrictive HMRF classifier using Potts model and Wishart statistics. The main limitation of these classification schemes is high computing time. We propose a classification procedure that gathers the main advantages of all of these approaches. A large number of initial classes is obtained from the H-alpha-A domain and the polarimetric span. The number of classes is then is reduced to a value defined by the data by using test statistics. Finally, the clusters are identified using a Freeman decomposition (Lee et al.) or a H-alpha -A decomposition (Ferro-Famil et al.)

Theoretical Modelling

MODELLING OF THE SCATTERING BY A SMOOTH DIELECTRIC CYLINDER: STUDY OF THE COMPLEX SCATTERING MATRIX USING TWO DIFFERENT MODELS

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Abstract

Forested areas and more generally natural scenes are widely studied due to economical but also ecological interests at stake. Such areas may be surveyed using SAR measurements. The interpretation of SAR data remains particularly difficult in the case of forests. Actually these natural scenes are complex multi-scale media, where the scattering mechanisms are numerous and the contribution of interactions between forest elements may be very important. Interferometric or/and polarimetric studies may enable us to retrieve some characteristics of the forest and identify the relevant scattering mechanisms involved in the global scattering phenomenon. However, the complex nature of the scene makes the use of simulations very helpful. Thus, a lot of models have been developed to make the retrieval easier. Both interferometry and polarimetry require a good knowledge of the phase of the scattering matrix elements, which are studied here for a single scatterer with a focussing on trunks, branches and needles, which are generally modelled by cylinders. The polarimetric behavior of a cylinder is simulated with two different commonly used models, based on the infinite cylinder approximation. The complex scattering matrix is computed for several local mechanisms involved in the global scattering by forested areas, that are: back, forward and specular scattering. Significantly different results are found, pointing out that it is necessary to determine criteria which enable to choose the physically adapted modelling of the scatterers, when phase information is required.

ON THE PHYSICAL MODELLING OF POLARIMETRIC PARAMETERS OF FORESTS

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Abstract

With the increasing availability of polarimetric and inteferometic polarimetric data from airborne SARs as well as data from the forthcoming spaceborne systems such as ALOS/PALSAR, there is a clear need to improve our understanding of the physical content of polarimetric data.

In the recent years, polarimetric parameters have been proposed to classify surface covers or to retrieve surface bio-geophysical characteristics. Many of them are derived from algebraic concepts and may in general not be adequate to describe the physical information content. More recently, parameters based on physical modelling have been developed, especially for polarimetric interferometry. However, the approach used which relies on simplified description of the physical mechanisms may not be applicable to a large range of observation conditions. Meantime, more complex backscatter models have been developed in the last decade to interpret backscatter intensity data. Although these models are able to simulate polarimetric data, in general, they do not include all the relevant electromagnetic interactions.

This paper will deal with the physical modelling of polarimetric features of forest covers. In a first step, modelling of the polarimetric phase is addressed. A higher order model coupled with a realistic description of the cover is developed and the model results are compared with polarimetric coherence data. In a second step, requirements for polarimetric interferometry modelling is given in the light of observations in interferometry and polarimetry on different forest covers.

PHYSICAL INTERPRETATION OF THE SENSITIVITY OF POLARISATION COHERENCE TO SOIL SURFACE ROUGHNESS

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Abstract

Surface roughness is an important geo-physical parameter required for numerous applications such as agronomy, geology, risk assessment, etc. In addition, the estimate of soil roughness may provide valuable a priori information to simplify the problem of soil moisture retrieval from SAR data.

In the past, roughness discriminators based on the ratio between soil backscatter at different polarisations (i.e. $sigma_{HH}$/ $sigma_{VV}$) and on the correlation coefficient between *HH* and *VV* channels (i.e. rho_{HHVV}) have been suggested. More recently, the potential of the correlation coefficient between co-polarised channels (i.e. polarisation coherence) in an arbitrary state of polarisation has been investigated. In particular, the correlation coefficient between co-polarised channels at circular polarisation (i.e. rho_{RRLL}) has been found extremely sensitive to surface roughness and weakly sensitive to soil moisture content. However, notwithstanding these observations have been confirmed by several experimental studies a complete physical understanding of the phenomenon is still missing, at least in the remote sensing community.

One of the main reasons for this lack of understanding is that in general, only lowest order approximations of theoretical surface scattering models are exploited in remote sensing applications. These approximations do not include the effect of multiple reflections. They cannot therefore predict accurately the whole covariance matrix often required to synthesise roughness discriminators, such as rho_{RRLL}. In this respect, despite the fact that higher order approximations of theoretical surface scattering models are mathematically very complex, they are necessary to give indications to understand the phenomenon and they can provide physical guidelines to develop semi-empirical approaches.

In this context, the objective of this paper is to present a simple physical framework to interpret the sensitivity of different roughness discriminators to soil roughness. The adopted interpretation scheme is based on indications provided by 2nd order approximations of surface scattering models, such as Small Perturbation Method (SPM), Small Slope Approximation (SSA) and Kirchhoff approximation (KA).

Finally, limits and perspectives of using ASAR and the forthcoming PALSAR data to retrieve surface roughness is discussed.

Forestry (Parallel Session)

TROPICAL FOREST MAPPING USING MULTIBAND INTERFEROMETRIC AND POLARIMETRIC SAR DATA

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Abstract

The potential of the combined use of multi-band interferometric and multi-band polarimetric airborne SAR for tropical forest mapping are discussed using the NASA/JPL AirSAR data from the PacRim-2 2000 campaign in Indonesia. Through orthorectification of the C-, L- and P-band fully polarimetric images, an accurate geometrically registration to the C- and L-band VV-polarisation interferometric images was achieved. This fusion allows to account for the disturbing effects of relief on the backscatter level in the fully polarimetric classification procedure applied. It will be shown that many land cover and forests types, and the effects of forest fire, thus can be accurately mapped, even in hilly terrain. This will be demonstrated by the analysis of two large, independently acquired, ground truth data sets of land cover observations. In addition biomass and vegetation height data were collected for a large number of forest transects and several non-forest plots. Empirical relations with L- and P-band backscatter, and C- and L-band interferometric coherence, will be presented.

EVALUATING POLINSAR TREE HEIGHT AND TOPOGRAPHY RETRIEVALS IN GLEN AFFRIC

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Abstract

In this paper we present new results evaluating the retrieval of tree height and bald earth topography from polarimetric interferometry. We present a comparison of results from L-band repeat pass SAR imagery with detailed in-situ measurements of forest height and ground topography across the test site. The data was acquired over Glen Affric in Northern Scotland as part of the NERC/BNSC SAR and Hyperspectral Airborne Campaign (SHAC) in June 2000. The DLR E-SAR data comprises fully polarimetric L-band SAR data in repeat-pass interferometry mode with two baselines, and two look directions. The Glen Affric data set is unique within the UK in that it contains polarimetric and multi-baseline interferometric L-band data in an area of varied topography and heterogeneous landscape. This paper will comprise a description of recent field measurements that include a detailed survey of almost 400 trees, and a quantitative comparison between this survey data and retrieved parameters. The paper will assess both the accuracy of tree height retrievals derived from single baseline polarimetric interferometry, and surface topography derived from dual-baseline PolInSAR using coherence optimisation. Within certain limits of canopy geometry and topography the tree height derivation has proven to be more successful than expected in areas of heterogeneous forest cover. A RMS error of 6m was found when comparing the trend between retrieved and field survey topography, despite canopy heights of 20m or more. As expected, the greatest errors are mainly in areas of high canopy density.

VEGETATION PARAMETERS USING TOPSAR AND GeoSAR SYSTEMS

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Abstract

This paper will present quantitative results of vegetation parameter extraction using inteferometric data collected using the TOPSAR and GeoSAR mapping instruments. These radar operate interferometrically at an range of frequencies from X-band to P-band. Radar data derived vegetation parameters are compared to LIDAR data and in situ measurements for a variety of canopy and terrain types. Comparison of how the different frequencies interact with the vegetation as a function of tree height, and incidence angle and canopy parameters will be presented.

ABOVE GROUND FOREST BIOMASS ESTIMATION USING FULLY POLARIMETRIC / INTERFEROMETRIC RADAR DATA

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Abstract

The assessment of above ground forest biomass is one of the most demanded parameters for global carbon stock modelling. Its estimation on a global scale is a big challenge for radar remote sensing. Unfortunately, conventional radar remote sensing techniques based on backscattering amplitude evaluation cannot estimate accurately forest biomass above a level of 120 tons/hectare. In this poster presentation we address an alternative methodology for estimating forest biomass from remote sensing data based on primary forest parameter estimates from single frequency polarimetric-interferometric radar data. As already demonstrated in the last years, single baseline polarimetric interferometry allows accurate quantitative estimation of key forest parameters as forest height mean forest extinction and underlying terrain topography. Based on these primary forest parameters an above ground biomass estimation methodology - that potentially allows the estimation of biomass levels up to 400 tons/hectare - is addressed and discussed. The proposed methodology is applied on fully polarimetric repeat pass interferometric data acquired with DLR's experimental airborne system at L- and P-band over the Fichtelgebirge test area in Germany. The estimation performance is tested against accurate and detailed ground measurements. Finally, advantages and limitations with respect to local and global scale biomass estimation are critically discussed.

Sea Ice (Parallel Session)

RADAR POLARIMETRY OF SEA ICE

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Abstract

Dating back to 1988, polarimetric SAR imaging has been demonstrated from a variety of airborne platforms but in only a relatively limited variety of polar sea ice locations. Data were first acquired by NASA-JPL in the context of the SSMI calibration and validation campaign using the C-, L-, and P-band AIRSAR system. These flights were performed in the Beaufort, Chukchi and Bering Seas. Subsequently, data were acquired by the Danish EMISAR airborne system in the Greenland and Baltic Seas. To-date, however, the only spaceborne polarimetric sea-ice data have been acquired from the Space Shuttle, in the Weddell Sea, Antarctica during the SIR-C mission. These limited cases are currently being supplemented by ASAR alternating polarisation acquisitions from Envisat, thus helping to broaden our knowledge on the discriminatory capability of C-band. This presentation will review the historical background to polarimetric remote sensing of sea ice, together with the regional characteristics of the sea-ice data from these different experiments. Examples of lessons learned will be provided from previous attempts to classify sea ice, and illustrated with examples from microwave polarimetric and multi-frequency data from the above cases.

UNSUPERVISED WISHART CLASSIFICATIONS OF SEA-ICE USING ENTROPY, ALPHA AND ANISOTROPY DECOMPOSITIONS

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Abstract

Sea-ice classification based on scattering mechanisms is investigated using the Unsupervised Wishart Classification with Entropy, Alpha and Anisotropy decomposition parameters. L and C Band JPL AIRSAR fully polarimetric data from the Beaufort Sea during winter/freeze conditions are used for testing the algorithm. Initial results show that, within specified ranges of incidence angles, there is good discrimination between the major ice classes, with L-Band generating better results in general than C band.

SAR POLARIMETRY FOR SEA ICE MONITORING

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Abstract

Polarimetric SAR imaging has shown a promising potential for the classification of sea ice types. However, from the last decade only a few studies are available, each of them focussing on one particular SAR sensor (mostly airborne) and certain polar ocean regions. In 2001, a project was initiated by the European Space Agency, which deals with the application of polarimetric radar in various geo- and biophysical studies and data surveys. The goal is to quantify the improvement of information gathering gained by utilizing polarimetric systems instead of the single-polarization SAR instruments, which are part of recent remote sensing satellite missions. In the project, polarimetric classification methods had to be investigated with regard to their accuracy and their robustness in operational use. To this end, different already existing data sets had to be combined For our sea ice study, test sites were selected in different ice regimes (Greenland Sea, Baltic Sea, and Beaufort Sea). For these test sites, at least a minimum of complementary data about the state of the ice and about the environmental conditions are available. The polarimetric data were acquired by the Danish EMISAR and the US AIRSAR which both are airborne systems. In our study, we focus on the use of C- and L-band data. Because of its robustness, a knowledge-based classification is regarded optimal. The potential of a number of polarimetric parameters for ice type discrimination is assessed. On the basis of this assessment, a classification scheme is devised and tested. In our presentation, we will compare the classification accuracies of polarimetric and single-polarization SAR modes for the different ice regimes. The merits of a polarimetric SAR for the discrimination of sea ice types will be discussed.

CLASSIFICATION STRATEGIES FOR FULLY POLARIMETRIC SAR DATA OF SEA ICE

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Abstract

The potential of polarimetric SAR data for classification purposes is widely recognised. More information on scattering mechanisms is now available and models have been developed to estimate contributions of these mechanisms to the total backscatter. In this paper we investigate the separation of scattering mechanisms for the classification of sea ice. Airborne data from the JPL AIRSAR as well as from the Canadian CV-580 is used. Based on the eigenvector decomposition of the coherency matrix, we sort the three resulting rank-one coherency matrices by the alpha angle estimate of the eigenvectors (as opposed to sorting by their corresponding eigenvalues). This sorting allows an interpretation of the scattering mechanism involved, a concept first introduced in [1]. In a multi-stage approach, we first focus on surface scattering, the main factor for first year ice (FYI), and investigate how other contributions (i.e. volume scattering and double bounce) can then best be used to refine the classification result. The multi-stage classifier results are compared to single-stage classification results. Our main objective is the classification of C-band polarimetric data, to develop RADARSAT-2 applications. But as AIRSAR data are available in C-, L-, and P- band, a multi-frequency approach will also be discussed and will be used as reference result.

References:

[1] Scheuchl B., I. Hajnsek, and I. Cumming, 'Model based Sea Ice Classification Using Polarimetric SAR Data,' Proc. IGARSS 02, Toronto, 2002.

SAR Polarimetric Interferometry (Polinsar)

TREE-HEIGHT RETRIEVAL USING SINGLE BASELINE POLARIMETRIC INTERFEROMETRY

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Abstract

Polarimetric single-baseline interferometric techniques have recently been developed for the measurement of forest height (Papathanassiou, IEEE Trans GRS, Nov. 2001). In this paper, three techniques are described: DEM differences, Vegetation Bias Removal and Full Model Inversion. The choice of technique depends on the quality of the coherence data. The techniques are illustrated and validated using two sources of data: coherent SAR simulations for canopy scattering and experimental repeat-pass L-Band airborne SAR data of mature forest. The simulated data is L-Band and has baselines of 10 and 20 metres. The airborne SAR data is also L-Band, acquired with a temporal separation of 1 hour and a horizontal baseline of 20 metres. This work was performed as part of an ESA ESRIN project entitled, "Applications of SAR Polarimetry", which acts as a basis for this workshop.

MODEL BASED FOREST PARAMETER ESTIMATION

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Abstract

Polarimetric Synthetic Aperture Radar (SAR) interferometry is a recently developed radar remote sensing technique, based on the coherent combination of radar interferometry and polarimetry. On the one hand side, SAR interferometry is a well-established SAR technique to estimate the height location of the effective scattering center in each resolution cell through the phase difference in images acquired from spatially separated antennas. The sensitivity of the interferometric phase and coherence to spatial variability of height and density of vegetation make the estimation of structural vegetation parameters from interferometric measurements a challenge. On the other hand, scattering polarimetry is sensitive to the shape, orientation and dielectric properties of scatterers. This allows the identification and separation of different scattering mechanisms occurring inside the resolution cell of natural media by employing differences in the polarization signature. In polarimetric interferometry both techniques are coherently combined to provide sensitivity to the vertical distribution of different scattering processes and make the investigation of volume scatterers a challenge. Indeed, in the last years, quantitative model based estimation of forest parameters - based on a single frequency, fully polarimetric, single baseline configuration - has been demonstrated using space- and airborne repeat pass fully polarimetric interferometry at C-, L-, and P-band. These experiments demonstrated the potential of this new technology to estimate with high accuracy key forest parameters like tree height, stand and/or canopy density, and forest ground topography. In this paper we present work performed in the frame of the ESA project on Polarimetric SAR Applications. We review the actual status of Polarimetric SAR Interferometry, and point out potential and limitations of this technique with respect to quantitative model based forest parameter inversion using several experimental Air- and Space-borne data sets.

THE CORSAR PROJECT: CAN POLARIMETRIC SAR INTERFEROMETRY IMPROVE FOREST BIOMASS ESTIMATION?

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Abstract

The main limitation in the application of spaceborne SAR to large-scale forest biomass mapping is the variability in canopy structure and vegetation density. It causes signal saturation and a large residual error in the parameter estimates. A problem in defining retrieval algorithms for forest biomass is that microwaves respond to the shapes, sizes, orientations and dielectric properties of all the illuminated scatterers including the ground. Microwave backscatter models have revealed that the effect of variation in canopy structure on the signal can be higher than the effect of biomass. Polarimetric SAR interferometry potentially offers a means of improving SAR-based estimates of forest biomass by quantifying canopy structural variability. The polarisation information is dependent on the scattering mechanisms, and the interferometric information can be used to determine the vertical location of these scattering events in the canopy. The CORSAR project (Carbon Observation and Retrieval from SAR), which is supported by the UK Natural Environment Research Council (NERC), has the objective to examine polarimetric decomposition and polarimetric SAR interferometry methods for estimating the effects of canopy structure in biomass-backscatter relationships. We present results of the polarimetric coherence optimisation of L-band E-SAR data acquired during the SAR and Hyperspectral Airborne Campaign (SHAC 2000), and compare the InSAR DEM's with a LIDAR derived DEM that was acquired concurrently. The effect of polarisation on the height estimation is discussed, and illustrated by coherent microwave modelling results from the model CASM. The expected rmse of the interferometric phase is modelled and its implications for defining useful sensor configurations discussed.

USING POL-INSAR AT X-BAND: OBSERVATIONS

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Abstract

The ONERA RAMSES system (Radar Aéroporté Multi-spectral d'Etude des Signatures) is a flexible SAR system in constant evolution developed mainly as a test bench for new technologies and to provide specific data for TDRI (Target Detection, Recognition and Identification) algorithm evaluation. It is flown on a Transall C160 platform operated by the CEV (Centre d'Essais en Vol). Recently a POL-INSAR mode has been added where the system is able to acquire simultaneous interferometric polarimetric data in X band. This paper presents an on-going research effort to analyze the influence of the system parameters (frequency, noise , resolution) on the characterization provided by POLINSAR technics. .It relies on the analysis of data acquired over Martigues, and Avignon in Southern France. The polarimetry associated with interferometry provides the necessary elements for understanding the different scattering mechanisms. However, the high frequency linked to reduced penetration is simplifying the modeling of electromagnetic interactions. Volume scattering is not as important in X-Band as with the lower frequencies and decorrelation effect (apart from system noise) can be attributed mainly to mixed contribution linked to elements at different heights inside each pixel.

POLARIMETRIC INTERFEROMETRIC SAR DATA ANALYSIS BASED ON ESPRIT/MUSIC METHODS

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Abstract

Interferometric SAR provides a two-dimensional image of elevation angle related to the scatterer height. By construction, SAR imaging is a projection of a volume response onto a plane. Thus, scattering points are distributed over a two-dimensional surface. The retrieval of the scatterer height assumes that only one scattering mechanism is present in each resolution cell. Unfortunately, this assumption is invalid in the sense that multiple scatterers, with distinct elevation angles, arise in a single resolution cell. This effect introduces artefacts during the projection under the form of a phase centre bias. To improve the interferometric phase estimation, it is thus necessary to discriminate the different scattering mechanisms arising over man-made or volumetric targets, like urban area or forest, but also to filter artefacts related to the SAR device, like noise. Recently, many studies have been proposed to estimate the interferometric phase over forest areas. One of them is based on the ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques) algorithm, often employed for Direction-Of-Arrival estimation using antenna arrays. For volume areas, this algorithm can directly retrieve the interferometric phases of the ground and the canopy. Man-made targets are constituted of different kinds of scatterer and the interferometric phase estimation becomes complex. This paper addresses a polarimetric approach based on ESPRIT/MUSIC algorithm, using multibaseline fully polarimetric SAR images. A polarimetric interferometric speckle using segmented data is presented. This allows to filter cells showing same behaviour. The different scattering mechanisms may be separated using ESPRIT/MUSIC algorithms, A polarimetric technique based on an eigenvalue spectral analysis is applied. This principle, used over forested area, is extended over man-made targets in order to separate different kinds of scatterers. It allows the estimation of the polarisation states of the dominant scatterers, in H and V polarisations, based on Jones vector polarisation ratio retrieval. Finally, this paper introduces a multibaseline analysis using a scattering model. The efficiency of this polarimetric interferometric SAR data analysis is demonstrated using fully polarimetric multibaseline SAR images, obtained from DLR-ESAR airborne sensor in L-band repeat-pass mode.

Poster Session

GROUND SURFACE DEFORMATION AROUND TEHRAN DUE TO GROUNDWATER RECHARGE: INSAR MONITORING.

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Abstract

Tehran is located on an active tectonic and seismic zone. The surface deformation monitoring provides a powerful tool for getting a better understanding of faults kinematics and mechanisms. Used in conjunction with GPS networks, InSAR (Interferometric Synthetic Aperture Radar) provides dense and precise deformation measurements which are essential for mapping complex heterogeneous deformation fields. Moreover, urban and arid areas preserve interferometric phase coherence. The archived acquisitions of ERS that span 9 months between September 1998 and June 1999 reveal wide areas of surface uplift (by as much as 9 cm). This vertical deformation (gradual in time) has probably no tectonic meaning but is rather the ground response to ground water recharge. These zones are all located dowstream of large alluvial fans like the one of Karaj. The variation of effective stress caused by intersticial water draining could explain such surface deformation. It can also be noticed that some faults act as boundary for these deformation zones and fluid motion. The understanding of this deformation is relevant for groundwater monitoring and urban developement management. It is also necessary for discriminating it from tectonic deformation that also occurs on this zone. Due to the lack of attitude control of satellite ERS-2 since February 2001, the last images acquired could not be combined with the former acquisitions. Nevertheless, we expect to be able to enrich our set of images in order to map tectonic deformation on a longer period and to monitor in a more continuous way the deformation due to groundwater evolution. This would allow to quantify the permanent and reversible part of this signal

ASSESSMENT OF CROP DISCRIMINATION USING POLARIMETRIC C-BAND SAR DATA

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Abstract

In the frame of the POLSAR project, multi-temporal C-band polarimetric SAR data over Flevoland (NL) have been analysed, aiming at selecting optimum parameters for crop classification.

The dataset, held in the European ERA-ORA database, contains a large amount of measurements derived from AIRSAR data, acquired on June 15, and July 3, 12 and 28, 1991.

The data analysis shows very strong temporal variation in the intensity and polarimetric measurements during June and July. Relatively invariant features for different dates in July appear to be the RR/RL ratio to discriminate crops with vertical from those with random structure, the correlation between HH and VV to separate structure in sugarbeet and potatoes, HV to separate crops with different biomass levels, and the HH/HV ratio to separate vegetation from bare soil (or harvested fields).

Different classification schemes have been applied to the filtered image data, in particular hierarchical classification using the optimum features, ISODATA clustering followed by classification, and WISHART classification. The results are compared and interpreted, and conclusions are given on the most effective use of polarimetric SAR data for crop classification.

FULLY VERSUS PARTIAL POLARIMETRY FOR QUANTITATIVE SURFACE PARAMETER ESTIMATION

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Abstract

Surface parameters are important for applications such as hydrological processes forcasting, agricultural activities management and climatic models validation. Polarimetric SAR data analysis is a promising technique for estimating quantitatively surface parameters on extended areas. For that purpouse, fully polarimetric inversion algorithms are under development. The aim of the poster is to briefly present a direct fully polarimetric model, the recent F-Bragg Model [1], and to focus on its inversion abilities. This is dons by comparing the estimated soil moisture and surface roughness to in-situ measurements. In the second step the potential of using partial polarimetric information inside the developed F-Bragg model is investigated.

References:

[1] A. Breuer, I. Hajnsek, S. Allain, L. Ferro-Famil, E. Pottier, J. Bruniquel, 'Polarimetric Surface scattering model for Surface Parameter Inversion', Proc. of SPIE 9th international Symposium on Remote Sensing, 2002.

MULTIFREQUENCY SAR POLARIMETRIC NOISE MODEL VALIDATION

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Abstract

SAR polarimetry is a well-established technique to gather information about the earth's surface. Most of the earth's surface scatterers can be considered as distributed scatterers, being modelled as a set of randomly located point scatterers. When a SAR system illuminates such a scatterer, the recovered complex signal can be modelled as the coherent addition of the scattered signals by each one of the point scatterers. The main consequence of this coherent nature is that the recovered signal is affected by speckle. Despite speckle is a deterministic effect, due to the complexity involved within the scattering process it can be only statistically analysed. Therefore, speckle is considered as a source of noise. The speckle problem has been already solved for the case of single-channel SAR systems. The speckle can be considered as a multiplicative noise term for the amplitude and additive for the phase. For the case of multi-channel SAR systems as a polarimetric SAR systems, the speckle problem is more complex due to the fact that the SAR channels present a non-zero correlation, which also contains information about the scattering process. In a general case, polarimetric SAR data are described by the covariance matrix. Recently, the authors presented, by the first time, a speckle noise model for all the elements of the covariance matrix. In this paper, the authors will present a validation of this new polarimetric speckle noise model for three SAR polarimetric datasets in L- C- and P-band. The aim of this paper is to show the validity of the noise model for all the frequency range and to show possible frequency effects within this noise model. The paper shall be divided in two parts. A short presentation on the polarimetric speckle noise model shall be given. The second part shall be devoted to present the study of the polarimetric speckle noise model for all the three datasets. Finally, some conclusion shall be presented.

MODEL BASED SAR POLARIMETRIC SPECKLE NOISE FILTER

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Abstract

Speckle noise is the most important problem for a correct interpretation of polarimetric SAR data. Polarimetric SAR data are described by the complex hermitian covariance matrix. For the backscattering case, this matrix has 3 by 3 elements. The diagonal elements contain intensity information, where speckle noise follows a multiplicative noise model. Up to now, speckle was assumed also multiplicative within the off-diagonal elements. The authors have recently proved that speckle noise presents a multiplicative as well as an additive behaviour within the off-diagonal elements, by presenting a complete speckle noise model for the covariance matrix. Noise reduction techniques that are based on assuming only a multiplicative speckle noise model for all the covariance matrix elements shall reduce speckle in a non-optimum form. Based on the new speckle noise model, the authors shall present in this paper a new technique to optimally reduce speckle noise for all the covariance matrix elements. Results of this new polarimetric speckle noise reduction technique shall be presented by employing real polarimetric SAR data. The paper shall be divided in two main parts. The first part shall be devoted to present the theoretical background as well as the implementation of the polarimetric speckle noise reduction technique. The second part shall show different results of applying the speckle noise reduction technique to real polarimetric SAR data.

ENTROPY-ALPHA CLASSIFICATION ALTERNATIVE FOR POLARIMETRIC SAR IMAGE

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Abstract

In this work we describe how coherency matrix simple invariants can be used to create similar classification parameter space to the well-known Entropy-Alpha classification. Proposed parameter pair is very simple and fast to calculate with almost any remote sensing oriented image- processing software if polarimetric data is given in covariance matrix (or comparable) format. Calculations employ only linear combinations of absolute values of the coherency matrix elements. Proposed parameters are related to entropy and alpha with some ambiguity and classification results differ slightly from entropy-alpha classification. Classification results between entropy-alpha and proposed scheme differ only for 3% of an example image pixels. As an example, NASA/JPL AIRSAR L-Band image for the San Francisco bay was classified with both algorithms. Size of the used image was 224 x 256 pixels. Both algorithms classified 97 % of pixels into corresponding classes. Highest misclassification rates are for high entropy classes. Method is suitable for using as fast approximation for the entropy-alpha classification or independent classification scheme.

INTERPRETATION OF POLARIMETRIC RADAR WAVES TRANSMITTED THROUGH ANTARCTIC ICE SHELVES

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(2)

Abstract

A network analyser has been operated on the surface of several Antarctic ice shelves as a step-frequency ice penetrating radar. Being a wideband phase sensitive instrument, the radar is capable of allowing the vectorial nature of the interaction between radio waves and the ice and reflecting surface to be explored. Using separate linearly polarised dipole antenna for transmitting and receiving, four independent measurements with parallel and orthogonal orientations allow the (Sinclair) scattering matrix to be determined. Single crystals of ice are birefringent at radar frequencies, so in an ice sheet the crystal orientation fabric determines the overall level of birefringence. The polarisation of radio waves is changed not only by the birefringent nature of the ice but also by the reflecting surface, whether an internal layer or the basal boundary. Thus, the scattering matrix is modelled by a part depending on the birefringence and a part depending on the reflecting surface. Parameters related to the orientation of the effective optic axis, the overall birefringence and the reflection coefficients in orthogonal directions can be found by a semi-analytic method. An additional advantage of the network analyser is that its wide bandwidth allows the frequency dependence of the polarisation behaviour to be explored. Separating out the contributions made by the ice and the reflection process to the depolarisation behaviour is an inverse problem with a non-unique answer. However, comparison of the results from different ice shelf environments allows some broad principles to be established. Where there is a 'smooth' isotropic reflecting surface the effective birefringence of the ice sheet can be readily determined, while a highly anisotropic reflecting surface, such as regular grooves that might be formed by sub-ice shelf currents, can dominate the polarisation behaviour. Analysis of data from two sites on Ronne Ice Shelf, one near the grounding line of Rutford Ice Stream and the other close to the shear margin with Korff Ice Rise, shows the fluted type of reflecting surface seen on George VI Ice Shelf but not on Brunt Ice Shelf.

INSAR AND POLINSAR FOR LAND SUBSIDENCE MONITORING - A USER PERSPECTIVE

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Abstract

In this paper the selected interferometric studies of subsidence caused by underground mining are discussed. Despite the common limitations the traditional single-polarization InSAR technique is already proved its high potential in this application. Today, the determination of the areas of affected by terrain deformation risks becomes one of the most promising applications for operational use of SAR data. InSAR monitoring of Upper Silesian Coal Basin in Poland (ESA AO3-127 project) and other studies from Central Europe shows that the interpretation of the fringe pattern is often strongly reduced by low coherence. On the base of these examples this paper aims to discuss a potential advantages of POLInSAR technique in this application.

SOIL WATER ASSESSEMENT USING A P-BAND SCATTEROMETER AND ERS-SAR

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[2] Bar-Ilan University, Ramat Gan, Israel

Abstract

A series of studies utlizing a P-band scatterometer, ERS-2 SAR, and relatively high resolution airborne SAR for assessing soil water content in agricultural fields in the Neegev Desert, Israel will be presented here.

SOIL MOISTURE, CROP AND VEGETATION STUDY USING AIRSAR DATA

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Abstract

The use of remote sensing in monitoring rice production has been extensively done using optical sensors. The Philippines being located in the tropical region is perennially covered with clouds; hence, the use of optical sensors is not practical. The synthetic aperture radar (SAR) with its cloud penetrating capability could be very useful for rice crop monitoring. In November 1996, The DC-8 aircraft which operates in full polarimetric mode at C-band (5.6 cm), L-band (24 cm) and P-band (68 cm) flew over Central Philippines with the AIRSAR system on board with spatial resolution of about 10 meters. The main objective of the study is to determine of the usefulness of radar data in distinguishing the different stages of rice growth in some parts of Iloilo, a major rice growing area in the Visayas. The results of the study showed that the C-, L- and P-band AirSAR images are capable of distinguishing the various stages of rice growth. The use of P-band to determine soil moisture also showed promising results. However, further studies are needed and emphasis must be given on the simultaneous acquisition of ground truth data for quantitative analysis.

FOREST CANOPY HEIGHT MAPPING FROM DUAL-WAVELENGTH SAR INTERFEROMETRY

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Abstract

The CORSAR project (Carbon Observation and Retrieval from SAR), which is supported by the UK Natural Environment Research Council (NERC), has the objective to examine polarimetric decomposition and polarimetric SAR interferometry methods for estimating the effects of canopy structure in biomass-backscatter relationships. Forest canopy height is a useful input parameter to yield models, carbon cycle models, and habitat maps for biodiversity conservation. SAR interferometry can used to produce digital elevation models from the interferometric phase. The penetration of the radiation into the canopy - and thus the height of the effective phase scattering centre - depends on wavelength and polarisation. Multi-wavelength SAR interferometry shows differences of the vertical locations of the effective phase scattering centres. We present a canopy height model derived from airborne X-band VV polarised single-pass SAR interferometry and L-band HH polarised repeat- pass SAR interferometry. The E-SAR data were acquired during the SAR and Hyperspectral Airborne Campaign (SHAC 2000). The accuracy of the SAR derived canopy height model is assessed. The model is compared to a LIDAR derived canopy height model that was acquired at the time of the campaign. The LIDAR model is more accurate and has a higher spatial resolution. However, the significance of a dual-wavelength canopy height product from SAR alone is that it can potentially be delivered from space.

MODELLED POLARIMETRIC BACKSCATTERING RESPONSE FROM SINGLE PINE TREES AND PINE CANOPIES

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Abstract

In this work polarimetric backscattering model has been employed to simulate L-and C-band polarimetric backscattering from single pine tree and pine forest stand. Behaviors of several polarimetric parameters (entropy, alpha angle, covariance matrix elements etc.) are examined as a function of forest and tree geometry parameters (number of branches, stem size, etc.). Also forest interferometric coherence is studied for different polarizations. Lately developed 'Electromagnetic Scattering Model for Forest Remote Sensing', elaborated in Rolf Nevanlinna institute in Finland (L. Zurk et. al. 2002) has been used. The model extends the discrete particle approach to rigorously handle the first order direct scattering, the single and double ground bounce terms, and the first order interaction between the trunk and branches. For the first order interaction between the trunk and branches it is employs computational segmentation and a local plane wave expansion to provide efficient calculation. The model computes fully coherent polarimetric quantities for general bistatic remote sensing of a forested region at microwave frequencies. The model assumes that the trees are made up of cylinders that represent its trunk and branches. Trees for simulations are created with LIGNUM tree growth model. The LIGNUM model is based on extensive studies of tree growth in Finland and it is able to generate photo-realistic trees. Results are discussed and compared with results obtained from SAR images. In comparison EMISAR images from 1995 from Finland are used.

SEMI-EMPIRICAL APPROACH AND RADAR POLARIMETRY FOR VEGETATION OBSERVATION

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Abstract

The health of crop depends on the amount of supplies on one hand and the exhalation of crop specific parameters on other hand. Important parameters in crop development are crop height, leaf area index, crop covered soil moisture etc. Valuating these parameters over large area is difficult physically, but it has its importance in the crop-physiology research and for instant health of a crop. Remote sensing can provide information on the actual status of vegetation. In this direction, radar has proved to have some inherent advantages over optical sensors in crop monitoring due to the ability o microwaves to penetrate into/and through the vegetaton cover. Many studies have been carried out to investigate the sensitivity of microwave sensors to agricultural vegetation parameters and promissing results have been obtained. Until now polarimetric-interferometric approaches have been mainly applyed on forests to assess the tree height and extinction coefficient. This papers highlights the semi-empirical polarimetric / interferometric approach to estimate agricultural vegetation parameters. The effect of crop height on the backscattering coefficient and interferometric observables for various polarizations is analysed as well as the sensitivity to vegetation extinction coefficient. Based on this the potential of polarimetric / interferometric observables for quantitative crop parameter estimation is discussed.

FOREST MONITORING BY USING POLARIMETRIC SAR: A PRELIMINARY RESULT

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Abstract

Global Forest Watch ranks Indonesia as one of the top five tropical forest-rich countries in the world, with more than a hundred million hectares. Rainforestweb.org claimed that Indonesia has already lost an estimated 72 percent of its original frontier forest, and half of what remains is currently threatened. About 21 percent of Indonesia's forests are protected. Since the forest activities are high, comprehensive monitoring should be done in the period of time. Common approaches for forest resources monitoring in Indonesia is by using Landsat TM or SPOT Multispectral data. However, some parts of Sumatra, Borneo and West Papua are almost cloud-covered and it was difficult to find sufficient images. In this situation, SAR has significant advantages to fill gaps on forest resource data. Many SAR data have been tested for forestry application, including STAR-1, ERS-1, JERS-1, Radarsat, and DORSAR. However, very limited application is utilizing polarimetric radar dataset. In this paper, we present preliminary results on current trend on polarimetric SAR classification based on Entropy-Alpha feature space. This activity is managed under Envisat research AO#869 granted to second author.

SAR SURFACE ICE COVER DISCRIMINATION USING DISTRIBUTION MATCHING

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Abstract

Discrimination between open water and sea ice in SAR imagery can still pose a problem to the ice analysts in their daily task of charting the sea ice for safe navigation. To help them in this task, a new algorithm have been tested that rely on a user first manually identifying a particular region in a SAR image (e.g., open water area or sea ice of certain concentration or ice type) then the algorithm will automatically determine similar regions in the remainder of an image. The algorithm is based on matching the statistics of the known and unknown regions using either (a) Kolmogorov-Smirnov (KS), and (b) Chi-Square (CS) distribution matching tests. The main advantage in using these distribution matching tests is that the probability distribution function (pdf) of the known region does not need to be known. Both KS and CS tests determine whether the two data sets belong to the same or different, yet undetermined, distributions. The main difference between KS and CS tests is that they are valid for un-binned and binned data respectively. In this note the relative performance of the KS and CS tests is presented. The tests were carried out using the amplitude SAR image and the image products: (a) Power-to-Mean Ratio (PMR), and (b) Gamma-pdf which are computed from it. The results presented in this report shows that the KS test is reasonably successful at identifying similar surface types. It performed best with the amplitude data and Gamma-pdf while results using the Gamma-pdf and PMR images were prone to ambiguities. The CS test did not perform as well as the KS test. This is because the data first has to be arbitrarily binned which results in some information being lost. It was also found to be many times slower to run on the computer. The information obtained using the KS tests can be considered as the "best statistical guess" during situations when the ice analysts have difficulty in interpreting parts of a SAR image. Keyword: Sea ice, RADARSAT, image interpretation, distribution matching, Kolmogorov-Smirnov test, Chi-Square test, Greenland, Ice Charting.

SAR ICE CLASSIFICATION USING FUZZY SCREENING METHOD

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Abstract

A semi-automatic SAR sea ice classification algorithm is described. It is based on combining the information in the original SAR data with those in the three "image" products derived from it, namely Power-to-Mean Ratio (PMR), the Gamma distribution and the second order texture parameter entropy, respectively. The technique used to fuse the information in these products is the fuzzy screening method called Multi Experts-Multi Criteria Decision Making (ME-MCDK). The Multiple Experts in this case are the above four "image" products. The two criteria used currently for making decisions are the Kolgomorov-Smirnov distribution matching and the mean of float values. The algorithm classifies an image into any number of predefined classes of sea ice and open water. The representative classes of these surface types are manually identified by the user. Further, as SAR signals from sea ice covered regions and open water are ambiguous, it was found that for the ice infested water around Greenland 4 pre-identified surface classes (2 of sea ice and 2 of open water) in the near range and a similar number in the far range are needed to reliably classify an image. Initial results illustrating the potential of this ice classification algorithm using the RADARSAT ScanSAR data will be presented and its possible extension to fuse the information in these data with the ENVISAT ASAR image products will be discussed. Keywords: SAR, KS Distribution Matching, Ice Cover Classification, Fuzzy Rule, ME-MCDK, RADARSAT, ENVISAT ASAR, Greenland.

POLARIMETRIC DATA OF SEA ICE IN PREPARATION FOR RADARSAT-2

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Abstract

RADARSAT-2 will be the first commercial satellite capable of providing polarimetric data on an operational basis. In preparation for this launch the Canadian Space Agency (CSA) has started a variety of initiatives to prepare potential users of RADARSAT-2 data for the new capabilities of the sensor. The activities range from an online tutorial to airborne data acquisition using the Environment Canada operated CV-580 polarimetric SAR. In this CSA funded project we are analysing CV-580 C-band data of sea ice acquired off Prince Edward Island (Canada). Auxiliary data like ice analysis charts from the Canadian Ice Service and temperature information are also available. The SAR data is analysed using a variety of methods, from single parameter analysis to parameter spaces in two and more dimensions and classification using the full polarimetric information. Signature analysis is focussed on parameters and parameter groups recommended for sea ice classification in the literature. The Wishart classifier preceded by an Entropy/Anisotropy/alpha-angle classification is used to classify the scene. Interpretation of this result is still a manual step and we are investigating methods to reduce human interaction. The effect of the incidence angle on signatures and classification results is also analysed. After project completion the Canadian Space Agency will make the data as well as the analysis results available to interested parties. The differences between the airborne data and RADARSAT-2 data are emphasised by providing a simulated product that approximates the spaceborne product.

RADAR METHOD FOR SEA WAVES INTENSITY DETERMINATION USING THE CROSSED POLARISATION COMPONENTS OF REFLECTED SIGNAL

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Abstract

The ENVISAT platform, launched this year, is capable to reproduce simultaneously a crossed polarization components of SAR reflected signal. It may be used for precision construction of sea waves intensity images. On the base of known ideas about small wind waves modulation by large waves, both (parallel and cross) components are calculated for vertically polarizated reflected signal. The value of these components depends on wind waves slops dispersion only. Some errors caused by taken model and others factors are analysed. Applied for high resolution SAR, that gives the possibility to observe a wave structure, the proposed method have certain adventures in comparison with NSCAT or QUIKSCAT scatterometers.

OCEANIC VARIABLES EXTRACTED FROM ALONG-TRACK INTERFEROMETRIC SAR DATA

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Abstract

The Synthetic Aperture Radar (SAR) data contain the greatest amount of information among various microwave techniques developed for measuring ocean variables from aircraft or satellites. They have the potential of measuring wavelength, wave direction and wave height of the ocean waves. But, it is difficult to retrieve ocean wave heights and surface current from conventional SAR data, since the imaging mechanism of ocean waves by the SAR is determined by the three basic modulation processes arise through the tilt modulation, hydrodynamic modulation and velocity bunching, which are poorly known functions. Along- Track Interferometric (ATI) SAR systems can directly detect the Doppler shift associated with each pixel of a SAR image and have been used to estimate wave fields and surface currents. However, the Doppler shift is not simply proportional to the component of the mean surface current. It includes also contributions associated with the phase velocity of the Bragg waves and orbital motions of all ocean waves that are longer than Bragg waves. We have developed a method for extracting the surface current vector from multiple-frequency (L- & C-band) ATI SAR data, and have generated surface wave height.

MEASURING SURFACE ROUGHNESS ON BASE OF THE CIRCULAR POLARIZATION COHERENCE AS AN INPUT FOR A SIMPLE INVERSION OF THE IEM MODEL

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Abstract

In this paper a simple inversion approach is applied to the integral equation method model. The inversion of the radar backscatter into soil moisture was accomplished with an iterative method. To date most inversion approaches with the IEM try to determine both the surface roughness and the soil moisture on base of two copolarized radar channels. Because there are a number of possible combinations of roughness and moisture parameters to reach the same values for the radar backscatter, these approaches always contain a fragment of uncertainty and inaccurateness. Therefore this work follows the idea of arising the number of input variables to reduce the inaccurateness and ambiguity of the inversion results. For this reason the surface roughness parameters are declared as input variables and were calculated external of the IEM. The base for computing the RMS values is the circular polarization coherence of the copolarized channels. The real part of this coherence was found to be a good measure for this surface roughness parameter. For agricultural surfaces the correlation length of the autocorrelation function was found to correlate with the RMS heights. Because of the fact, that the autocorrelation length is not the most deciding parameter, this contiguity was used to calculate the autocorrelation length from the RMS heights. The final result in the form of a soil moisture map seems quite promising. Good correlations between measured and modelled values were realised. The arrangement of the soil moisture outside the test areas are rather real with higher values in depressed areas and lower values on hilltops.

THE PYLA 2001 EXPERIMENT: POLARIMETRIC RADAR OBSERVATIONS OVER A FORESTED AREA EVALUATION OF POLARIMETRIC RADAR CAPABILITIES OVER A FORESTED AREA

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Abstract

Low frequency SAR (P-band) represents a promising tool for remote sensing, since it allows us to investigate the sub-surface down to several meters under certain circumstances as well as the vegetation cover. On the other hand, polarimetric capabilities of such system bring also new contributions in SAR measurements. ONERA developed a multi-frequency, full polarimetric, high resolution airborne SAR facility named RAMSES which now operates at P-band (435 MHz). An experiment was performed over the Pyla region near Bordeaux, in France during April and May 2001, in order to assess the benefit of low frequency, multi-polarization and polarimetric in interpreting SAR measurements over natural sites. This area was chosen as a suitable laboratory site for fieldwork validation : (1) sub-surface soil moisture detection (Pyla sand dune), (2) biomass evaluation (Nezer forest), (3) mapping of the ocean bathymetry and salinity (basin of Arcachon), and (4) archeology. In addition, a dedicated P-band calibration site was set up in order to fully exploit the polarimetric information as well as ground measurements in order to derive the biophysical and geophysical characteristics of the terrain. During this workshop, firt results of this experiment obtained over the Nezer test site (a forested area located in les Landes) will be investigated. Amplitude and phase distributions of the radar signal derived from several images will be considered in terms of the geometrical tree parameters and the biomass.

STORM: A NEW AIRBORNE POLARIMETRIC REAL-APERTURE RADAR FOR EARTH OBSERVATIONS

Dr Daniele Hauser [(1)], Prof. Gérard Caudal[(2)] , Dr Monique Dechambre[(1)] , Thierry Podvin[(1)] , and René Valentin[(1)]

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Abstract

The successful launch of the Envisat in March 2002 offers new possibilities for estimating geophysical quantities characterizing continental or sea surface using the multi-polarization ASAR. In addition, in the context of the preparation of future missions which will embark polarimetric SAR (e.g. RADARSAT2) it is important to better assess the benefit of multi-polarization or polarimetric SAR systems. Airborne radar systems remain a very useful way to validate satellite measurements and to develop or validate algorithms needed to retrieve geophysical quantities from the radar measurements. CETP has designed and developed a new airborne radar called "STORM" , which has a full polarimetric capability. STORM is derived from two previous versions of airborne radars developed at CETP, namely RESSAC (Hauser et al, JGR 1992) and RENE (Leloch-Duplex et al, Annales of Telecommunications, 1996). STORM is a real-aperture, C-Band system with a FM/CW transmission and with a rotating antenna to explore in azimuth. It offers a polarization diversity, receiving the complex signal in amplitude and phase simultaneously in H and V polarizations, which makes it possible to analyze the radar cross-section in HH, VV, HV, and other cross-polarized terms related to the scattering matrix. The antenna are pointed towards the surface with a mean incidence angle of 20° and a 3-dB aperture of about 30° in elevation and 8° in azimuth. The backscattered signal is analyzed from nadir to about 35° along the look-direction in 1012 range gates every 1.53m. The first tests with this system have been carried out in October 2001 over corner reflectors , over grass and ocean. In this workshop, we will present a validation of this system based on the results obtained with this first data set. In particular, we will present the calibration method of the complex signal (amplitude, phase), and distribution of phase differences (HH/VV, HV/VH) obtained over the different scatters (corner reflectors, grass, ocean). Comparison of results obtained with forward and side looking antenna will be discussed.

POLARIMETRIC MEASUREMENTS OVER THE SEA-SURFACE WITH THE AIRBORNE STORM RADAR IN THE CONTEXT OF THE GEOPHYSICAL VALIDATION OF THE ENVISAT ASAR

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Abstract

Among the new specificities of the ENVISAT/ASAR particular polarization diversity make the instrument very promising, but require complementary studies in addition to those already completed with the ERS data. Moreover, in the context of the preparation of other missions which will embark polarimetric SAR (e.g. RADARSAT2) it is important to better assess the benefit of multi-polarization or polarimetric SAR systems. In particular, over the ocean the question remains open regarding the estimate of wind speed, directional spectra of surface ocean waves and maybe other parameters related to wave breaking. CETP has designed and developed a new airborne radar called "STORM", which has a full polarimetric capability. STORM is a new-version of the RESSAC airborne radar already used in previous experiments (Hauser et al, JGR 1992). STORM is a real-aperture, C-Band system with a FM/CW transmission and with a rotating antenna to explore in azimuth. In addition to RESSAC (which was mono-polarized) it offers a polarization diversity (receiving simultaneously in H and V polarizations) which enables us to analyze the radar cross-section in HH, VV, HV, and other cross-polarized terms related to the scattering matrix. In the context of the validation of the ASAR wave mode of ENVISAT, a field experiment will be carried out in October and November 2002 over the ocean (offshore the coasts of Brittany, France), with "STORM" embarked on the MERLIN-IV aircraft of Meteo-France. We intend to perform about 20 flights under the ENVISAT SAR swath during a one-month experiment, with overpasses over a directional wave buoy also equipped with wind measurements. The ASAR image mode (in HH or VV) or alternating polarization mode will be requested during these flights. STORM will be used in a mode which will permit to measure the full complex scattering matrix over the sea surface at incidence angles ranging from 10 to 35°. In addition to conventional analysis of the radar cross-sections in HH, and VV polarizations to estimate wind speed and directional wave spectra, cross-polarized cross-sections and parameters derived from the full polarimetric matrix will be analyzed to investigate their relation with the environmental conditions (wind, waves), using co-located in situ measurements. With this combination of measurements we will first assess the performance of the ASAR products and inversion scheme to estimate the 2D wave spectra and wind in various configurations of polarization state. In addition, we expect new results on the parameters related to the full polarimetric matrix and their relation with environmental conditions. During this workshop, first results of this experiment will be presented.

OPERATIONAL APPLICATION OF ENVISAT ASAR IN TROPICAL PRODUCTION FOREST.

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Abstract

Operational Application of Envisat ASAR in tropical production forest: Challenges in the Riau Andalan Pulp and Paper, Indonesia Mahmud A. Raimadoya Principal Investigator AO#869. Dept. of Soil Sciences, Bogor Agricultural University, Bogor, INDONESIA E-mail: mud@indo.net.id Ibrahim Hasan Riau Andalan Pulp and Paper, Jakarta, INDONESIA Bambang H. Trisasongko Co-Investigator AO#869. Dept. of Soil Sciences, Bogor Agricultural University, Bogor, INDONESIA Abstract A joint research between European Space Agency (ESA) and Bogor Agricultural University (IPB), Indonesia, has been approved under Envisat AO (AO- ID 869). The research is intended to study the operational application of Advanced Synthetic- Aperture Radar (ASAR) for production forest management in Indonesia. Two test sites in forest plantation area of Riau Andalan Pulp and Paper (RAPP) in Riau Province, Central Sumatera, Indonesia, have been selected recently for the implementation of this joint research. This paper briefs the recent progress of this two- year research (2002-2004) activity. The main objective is to explore the potential of ASAR image analysis application, including POLINSAR, for better and more efficient operational management of tropical plantation forest and its environment. Several interesting operational applications have been identified for the test sites. First application is vegetative cover classification of Acacias, mixed hardwoods, shrubs, oil palms and bare lands. The second is biomass-related application, which study Envisat data on biomass monitoring related to forest plantation. The third is environmental study particularly for site degradation, including issues on water bodies monitoring and burn site.
Keywords: Envisat, Indonesia, Tropical Production Forest.

A TOMOGRAPHIC APPROACH TO MULTI-PASS SAR IMAGING

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Abstract

In this communication we propose the employment of a tomographic technique in the framework of SAR imaging. In particular, for a two-dimensional and scalar geometry we cast the imaging problem as the inversion of the linearized scattering operator. In this way the imaging is achieved discarding the usual techniques of range compression and azimuth focusing. We consider a multi-frequency and multi- monostatic configuration in which the different point of illumination and observation arise from different passes of the SAR sensor. Furthermore, the scenario under test is supposed time- invariant so no de-correlation occurs for the different observations. We also suppose to a priori know that the scattering object is enclosed in square investigation domain and perform the analysis and the inversion by through the Singular Value Decomposition (in short SVD) of the relevant operator. This allows to determine an effective base functions in order to represent in a non- redundant way the unknown scattering object and thus to counteract the instability of reconstructions due to the effect of noise. Moreover, a sampling criterion of the scattered field, that is the number and the positions the sensor has to occupy, and a resolution estimate achievable in the reconstructions, are derived. Finally, we test the proposed approach on a case study by showing the capability of the scheme to localize and reconstruct objects located at different "height" without exploiting interferometric information.

ENVISAT ASAR IMAGES OVER MALBORK AGRICULTURAL AREA (POLAND)

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Abstract

The poster will present the first processed ENVISAT ASAR images taken over test area Malbork in the north of Poland. This test area will be imaged by ASAR several times in the frame of the project ENVISAT-AO 783.

USE OF ERS-1 AND LANDSAT TM IMAGES FOR GEOLOGICAL AND MINERAL EXPLORATION OF SOL HAMID AREA

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Abstract

Use of ERS-1 and Landsat TM images for geological and mineral exploration of Sol Hamid area , South Eastern Desert , Egypt Talaat M. Ramadan and Hoda Onsi National Authority for Remote Sensing and Space Sciences, Egypt ABSTRACT:- This research focuses on the merging of ERS-1 SAR and Landsat TM images for geological mapping and mineral exploration of Sol Hamid area in the South Eastern Desert of Egypt. This area is underlain by the Neoproterozoic rocks of the Sol Hamid suture. They are partly covered by Miocene sediments and recent sand sheets and dunes. The Neoproterozoic rocks include ophiolitic ultramafic to mafic rocks, metavolcano-sedimentary rocks, metavolcanics, gobbro-diorite rocks, granodiorites , biotite granites and alkali granites. Mineral deposits associated with different rock units include magnesite , chromite , iron are deposits , manganese and barite deposits. ERS-1 SAR data enable to obtain an image of Sol Hamid area that reveals fluvial features beneath a surface cover of desert sand. These same features are not observable in Landsart TM images of similar resolution. Principal component analysis technique is used on merged ERS-1 SAR and Landsart TM images for enhancing subsurface structures such as foliation and foaultss that control minerelization of several deposits in the study area. This study in a good example to demonstrate the utility of the used remote sensing technique for finding ore deposits in arid region.

ON THE SELECTION OF THE BEST POLARIZATION TO DETECT BURIED OBJECTS BY MEANS OF POLINSAR

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Abstract

In this work, we analyze some questions about the potential application of polarimetric SAR interferometry (POLINSAR) in ground penetrating radar (GPR) systems. GPR is based on the ability of electromagnetic waves in the microwave region to penetrate the matter. However, the detection performance of these systems is only acceptable when looking for large metallic objects. Buried plastic mines are nearly invisible to the radar and can not be detected due to the low dielectric contrast between the mine and the surrounding soil. The weak signal returned from the mine is normally obscured by the terrain clutter. POLINSAR can be used to combine the three polarimetric channels of two images obtained from different incidence angles, in order to look for coherence peaks in the scene. This technique can retrieve these peaks even if some scattering centers are present in the same resolution cell, or if their backscatter levels are very different. The application of POLINSAR to the detection of buried objects was already introduced in [1] and [2]. The optimization of the interferometric coherence, carried out by POLINSAR at every resolution cell, produces three coherences associated with three scattering mechanisms or polarizations. It was shown in [2] that, in the presence of mines, one of these mechanisms corresponds to the surface clutter and a different one is located at the mine. Each mechanism is identified by a change in the polarization basis, which in turn can be interpreted by projection vectors [3] or by angles in the polarization ellipse [2]. In this work we have reviewed which polarizations are the optimum to detect mines by means of POLINSAR. This preliminary study shows that circular polarizations (or nearly circular) are always useful to discriminate the mine from the clutter. Therefore, instead of carrying out the full POLINSAR optimization, we have proceed to compute coherence maps of the scene by employing this type of polarization. First experimental results with real polarimetric data indicate that the coherence maps exhibit very low values in the positions of the mines, whereas the coherence is quite high in the rest. So, this parameter can be applied to detect mines. A physical interpretation of these results is currently in progress. Moreover, the minimum signal-to-clutter ratio necessary to detect the mine is being investigated.

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ELECTRIC FIELD RATIO FORMALISM IN RADAR POLARIMETRY

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Abstract

Both the polarization state and power of a synthetic aperture radar backscatter vary as a function of the transmit polarization of the radar and environmental properties of the illuminated target. With a polarimetric radar, this variation can be registered and, in the best case, attributed to the target's bio- and geophysical parameters. In spite of the fact, that radar is practically an all-weather instrument, radar imagery may suffer from precipitation and other environmental factors. Moreover, the radar imagery is often noisy and not of visual quality comparable to high- resolution optical imagery. However, radar polarimetry allows us not only to monitor cloud- covered areas day and night, but to enhance the SAR data in order to improve target to background contrast or target to target separation, to diminish unwanted signals like speckle, topographic and scatterer orientation effects, or, to derive more detailed digital elevation models, to mention a few examples. This means better usability for remote sensing. Much effort has been put on developing the theoretical foundations and practical applications for radar polarimetry. Also in this presentation both the theory and applications will be addressed. Traditionally, the polarization response has been represented as a function of both the receiver and transmitter polarization states. This may unnecessarily complicate a fully polarimetric representation. Actually, the properties of a receiving antenna should not be of any interest as soon as the properties of the backscattered wave are known through the available scattering matrix. Thus, a substantially simpler, but nevertheless fully polarimetric polarization response will be discussed. Since the complex-valued scattering matrix contains all the backscattering information of a single target, it would be sufficient to concentrate in studying the properties of this matrix alone. However, polarization is the key term in understanding the scattering matrix and many studies on radar polarimetry are still being done using only the backscattered power at some standard combinations of linear polarizations. Using these standard polarizations is not an optimal approach, because targets are not only horizontally or vertically oriented, for example, which may lead to contradictory research results. A better approach is to use polarization optimization. Evidently, the optimization result will not be invariant - as the nature is not - which means that an optimum polarization cannot be selected in advance, and instead of a single polarization state many more should be used in one image. An approach to polarization optimization using complex scattering matrices will be discussed. To accomplish these tasks, a not so often used theoretical definition for the polarization will be redeveloped. It will be shown, that an Electric Field Ratio representation is not only simple, but substantially better definition for polarization than the commonly used Polarization Ellipse in many types of calculations. In the electric field ratio formalism, the Poincaré sphere will reduce onto a two-dimensional polarization circle, which is a great advantage. Moreover, a quite practical Polarimetric Radar Equation pair can be derived by using this formalism.

POLARIMETRIC SAR INTERFEROMETRY FOR VEGETABLE VERTICAL STRUCTURE PARAMETERS EXTRACTION

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Abstract

Polarimetric SAR interferometry is much more sensitive to the distribution of oriented objects in a vegetated land surface than either polarimetric or interferometry alone. In this paper, we propose a polarimetric SAR interferometry technique for the estimation of parameters characterizing the vertical structure vegetated land surfaces. Based on simple physical model, we use SIR-C/X-SAR full polarimetric data to calculate the optimized interferometric coherences. Test site is Tianshan and its surrounding area, where pine trees are planted and the characteristics are well known. As a result, we could estimate the tree height distribution, and the quantitative evaluation is presented to relate the phase center differences and the tree types and the polarization combinations.

EFFECT OF DEW AND INTERCEPTION ON THE BACKSCATTERING BEHAVIOUR OF CROPS

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Abstract

A major application field of radar polarimetry is the interpretation of SAR data from agricultural areas. Of special interest is the understanding of the scattering mechanisms, that contribute to the received radar signal. In recent years many studies have been published investigating the scattering behaviour of crops. Polarimetric parameters such as the phase difference, the correlation coefficient, the circular backscatter and the pedestal height were analysed to derive information about the effective scattering mechanism. Furthermore, scattering models and different target decomposition theorems were applied to improve the understanding about the backscattering from crops. Indeed, until today only few studies have been published analysing the effect of dew and interception on the radar backscatter and on the effective scattering mechanisms. Due to missing experimental data, it is still impossible to draw a general conclusion about this topic. The effect of dew and interception on crop recognition is a crucial issue for orbit planning issues, such as the German TerraSAR Project, and initiated the TerraDew project. The project is funded by the German Ministry of Education and Research (BMBF, FKZ 50EE0035).It aims to quantify and systematically evaluate and model the effects of free vegetation water on multifrequency and polarimetric microwave data for different crop types. The investigations were carried out using polarimetric L-band data from the airborne E-SAR system of the German Aerospace Center (DLR), which were recoded on the 14th and 16th June 2000 at 6, 9 and 12 am. During the flight campaign extensive field data were obtained, i.e. land use, vegetation parameters, soil moisture and micro-climatologic conditions to retrieve e.g. the dew point. Objective of this study is to analyse and interpret the diurnal changes in the backscattering behaviour of crops due to dew and interception. Therefore different target decomposition theorems, i.e. the Pauli, the eigenvector and the model based decomposition approach, were applied to the polarimetric SAR- data at L-band. For each field the mean values were calculated and the diurnal changes of the parameters were analysed and interpreted. First analyses show that the influence of dew and interceptions differ for various crop types. The visual interpretation of the Pauli-decomposition indicates a strong increase in volume scattering processes for some vegetation types, such as barley and grassland. This is in agreement with the results obtained by the model based decomposition approach. Contrary, the polarimetric parameters derived by the eigenvector decomposition show no significant diurnal variations, except the beta-information.

SPECKLE FILTERING OF POLARIMETRIC SAR INTERFEROMETRY DATA

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Abstract

Polarimetric SAR interferometry has generated great interest for forest applications. The complex interferometric coherence from combinations of polarizations is computed to form the 6x6 coherency matrix. This matrix is generally filtered by a boxcar filter to reduce speckle, and then the linear combination of polarizations is optimized producing three optimized coherences and their associated interferometric phases. In earlier work, the maximum phase difference between these three interferometric phases was used to estimate tree heights. Recently, a coherent mixture model of a random volume and ground proposed by Papathanassiou and Cloude [1] has been applied to extract tree heights and the extinction coefficient based on interferometric coherence for polarimetric SAR. In both approaches, the accurate estimation of coherence is critical for tree height estimation. Interferometric coherence is a statistical average. It requires averaging many samples from the same distribution. It has been shown that an insufficient number of samples would produce an overestimate of the true coherence. For example, for 1-look interferometric SAR data, the coherence is at the maximum value of 1. The second problem associated with coherence computation is that the coherence is underestimated when averaging samples from difference distributions. Thus, the commonly used boxcar filter would produce erroneous coherences especially near forest boundaries, or in inhomogeneous vegetated areas. For examples, at forest edges, a 5x5 window would contain samples from two distinct distributions. The indiscriminate average produces a lower coherence at the edges as dark lines (lower coherence) of 3 to 5 pixel wide.. Most forest areas are not homogeneous, such as those in the Glen Affric Project. Better speckle averaging than the boxcar filter is needed. The basic principle in speckle filtering of polarimetric interferometric data is in the selection of pixels of the same scattering characteristics to be included in the average. Polarimetric SAR has the capability of characterizing the scattering mechanism of a medium. The filtering is done on the 6x6 coherency matrix based on the speckle filter that minimize the mean square error [2]. The filtered image successfully corrects the deficiency of the boxcar filter. The problem of dark (low coherence) lines along forest edges is eliminated. Importance in the tree height extractions using the Glen Affric data will be demonstrated.

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ENVIRONMENTAL DATABASE AND GEOGRAPHIC INFORMATION SYSTEM FOR SOCIAL ECONOMIC PLANNING

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Abstract

The use of satellite information in the study of weather and climate variability for social economic planing

Geographic information System has helped in taking Integrated land-resources Inventory data derived from remote sensing imagery with other geo coded statistics: these environmental database and used in detecting some disatser such as Flood, Erosion and Drought. A Gis is designed to accept large volume of spatial data derived from a variety of sources including Remore Sensing Sensor and to effectively store, retrieve Mamipulate, Analysed and Siplay these data according to user defined specification. Planning organizatio need vast ammount of accurate and timely information on physical resources and related socioeconomic factors to helpguide their managment and Planning Decision. Application also include Environmental Plantation, Biomass Production for energetic and industrial uses.

INVESTIGATION ON DIFFERENT INTERFEROMETRIC COHERENCE OPTIMIZATION METHODS

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Abstract

The interferometric coherence optimization methods are based on the definition of so-called projection vectors, which is the way to combine the information occurring from the polarimetric channels of both interferometric images. An important point is the physical interpretation of the projection vectors in terms of scattering characteristics. An optimization algorithm has been first proposed by Cloude and Papathanassiou, based on the selection of the best pair of projection vectors. The C & P algorithm leads to a 3 x 3 complex eigenvector problem, each projection vector representing a selected mechanism for one image. First we prove that the C & P algorithm corresponds mathematically to the most general optimization of the interferometric coherence. This means that the interferograms formed by using these mechanisms have the highest possible coherence. Nevertheless a major drawback of the C& P algorithm is that in neighboring resolution cells the optimal scattering mechanisms can vary significantly, introducing discontinuities into the extracted height differences, Moreover, the C & P algorithm does not fix uniquely the phase difference between the two projection vectors. Although an additional condition can be freely fixed, an attempt to apply the C& P algorithm to a selected set of our data led to an unexploitable height mapping. In this paper an alternative coherence optimization algorithm using the same projection vector for both images is proposed. This method is tested and compared with the first one in terms of physical interpretation and results; the properties of the projection vectors obtained by both methods are discussed. Finally, some tests have been carried out in order to assess the height estimations obtained from both methods.

Other Applications Development

ASSESSING NATURAL DISASTER IMPACTS AND RECOVERY USING AIRBORNE, MULTIFREQUENCY SYNTHETIC APERTURE RADAR (SAR) POLARIMETRY

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Abstract

Many natural disasters involving landslides, volcanic eruptions, fires, or floods entail terrain resurfacing, followed by a period of recovery. Modern satellite and airborne remote sensing technologies, which combine broad spatial coverage and high spatial resolution with time- sequential site revisit capability, can provide important information on the extent and duration of major landscape disturbance. In humid climate settings, these hazards remove or replace a natural vegetation cover temporarily, and in doing so modify the physical properties of the land surface. In optical remote sensing, removal of vegetation alters surface albedo in the visible - near infrared (V-NIR) waveband, particularly the high reflectance from vegetation in the NIR. For SAR remote sensing, removal of vegetation cover causes a change in dominant microwave scattering mechanism for the areas affected. SAR has operational advantages over optical sensors for rapid disaster assessment because of its day/night acquisition capability, the ability to 'see through' smoke, clouds and dust, and the side-looking viewing geometry is an advantage whenever data collection directly above the site would prove dangerous. We show how parameters that reflect scattering mechanism signatures diagnostic of different surface cover types can be derived from multifrequency, fully-polarimetric airborne SAR data. We apply a uniform methodology to map landslides resulting from the 1999 Mw 7.6 Chi-Chi earthquake in Taiwan, volcanic flows from the major 1996 eruption of Manam volcano in Papua New Guinea, and the extent of damage from the summer 2002 Rodeo - Chediski wildfire in Arizona. In addition, earlier work has shown that multifrequency SAR polarimetric backscatter is sensitive to total above-ground biomass. This attribute can be exploited to calculate vegetation loss during a disaster and for assessment of regrowth during the recovery phase.

REMOTE SENSING - A FUTURE TECHNOLOGY IN PRECISION FARMING

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Abstract

The paper briefly reports the opportunities of remote sensing for precision farming, a coming main focus in agriculture. Foreseeable advantages in precision farming that can be achieved by remote sensing are: o tracing target areas with abnormal appearance; early recording of hidden faults in field crops and on site identification of their causes o improved partitioning of fields into zones of uniform crop management o mapping of the spatial expansion of diseases and pests in field crops throughout the growing season; revision and enhancement of measures of pest control o continuous or stage dependent mapping of the crop nutrient demand, e.g. nitrogen; revision and enhancement of measures of fertiliser application o successive control of the effectiveness of crop management actions. In this context polarimetry is powerful to enhance the accuracy of the determination of biophysical parameters of agricultural crops. In a SIR-C/X-SAR study the cross-polarized C-band backscatter value Chv as well as the coefficient Lhh/Lvv could be shown to detect the amount of biomass of cereals very well. In another study conducted earlier in the vegetation period with the airborne E-SAR the coefficient Lhh/Xvv correlated well with the Biomass of winter barley. From that data in the ProSmart project 'Vitalitaet' a map of the variability of the Biomass within fileds could be generated. Successful introduction of remote sensing in precision farming depends on the availability of ready to use products for the farmers. In order to transform remote sensing data in practicable site specific applications, close cooperation between the operators of satellite systems and agro-consultants will be necessary.

MULTITEMPORAL AND/OR POLARIMETRIC SAR CHARACTERIZATION OF URBAN AREAS

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Abstract

Introduction

A few studies have shown that polarimetric SAR data sets may be useful for discriminating different urban environments. In particular, in [1] the AIRSAR data over Sydney have been considered, and the potentials for characterizing different building clusters by extracting single, double and triple bounce effects have been demonstrated. Similarly, in [2] the different statistical properties of built aggregates in a urban area using SIR-C measurements have been discussed in order to provide a basis for an efficient segmentation of polarimetric urban SAR data sets. Finally, the availability of SRL-1, 2 and possibly SRTM mission allows considering multitemporal and multiparametric characterization of urban areas discussing the mutual effects of temporal/polarimetric redundancy [3]. To provide a quantitative discussion on the usefulness and the limits of SAR data sets at the spatial resolution that satellite sensor are currently able to provide, and to further validate these results, a comprehensive study is proposed in this paper using ERS, RADARSAT and SIR-C/X-SAR data over the town of Pavia, northern Italy.

Methodology

Using nine ERS images, 5 SIR-C/X-SAR data sets and one RADARSAT image over the same urban area, many investigations may be produced. The precise knowledge of the site and the availability of a well tested neural classifier allows a quantitative comparison on both the possibility to discriminate among different urban environments (city center vs. residential areas vs. sparse buildings) and among some of the most important land cover/land use classes (built up areas, streets and railways, vegetation, water...). In particular, the neural kernel-based classifier is based on a two-step approach, performing first the image segmentation on a pixel-by-pixel basis. Then, the spatial analysis is carried out by means of a second classification, but using as input vector the percentages of pixels in a window around the current pixel position assigned to each class by the first classifier. These steps are implemented either by an unsupervised neural network (ART-2), followed by a fuzzy clustering using a standard Fuzzy-C-Means (FCM) algorithm [4], or a supervised fuzzy ARTMAP structure [5]. Results and conclusions We compare classification results obtained by using polarimetric, multitemporal or multitemporal/polarimetric data sets, aggregating SAR polarizations or dates and exploring also the interactions among SAR data recorded by different sensors. Since SIR-C/X-SAR data were recorded in April 1994 , they partially overlap with the ERS images, providing a unique set for this kind of analysis. Classifications are obtained also by exploiting texture measures for a better discrimination of urban environments. We want to discuss which are the advantages of a polarimetric data sets, and to evaluate the usefulness, for our purposes, of using more polarizations with respect to a combination of multitemporal single polarization images. This could also be used to determine which of the many functioning modes of the ASAR sensor would be most useful for urban mapping and/or monitoring applications.

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IMPROVED OIL SLICK DETECTION AND CLASSIFICATION WITH POLARIMETRIC SAR

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Abstract

The future advent of polarimetric SAR Earth observation platforms (e.g., Radarsat2, Envisat) poses the question whether there will be any improvement in the performance of the oil slick detection and identification schemes. This is seen as an important issue to be addressed now. The assessment of this potential improvement can be done analyzing some existing polarimetric data sets. As an example, some full polarimetric spaceborne acquisitions over various oil slicks took place in 1994 during the NASA/JPL SIR-C/X-SAR Mission. In this poster, the use of the circular polarization coherence and the polarimetric anisotropy as potential indicators of thickness and/or texture changes of the oil film will be addressed. These two measurables have been recently proposed as estimators of terrain surface roughness, therefore their potential use in an oil slick detection and classification scheme needs to be considered. A total of five images with full polarimetric SAR data acquired are used in this study. The study sites included the North Sea, the English Channel, Northern Germany, and the Pantelleria Island in Southern Italy. Preliminary results indicate that the surface roughness is highly correlated with changes in the thickness and/or the texture of the oil layer.

Spaceborne SAR

RADARSAT-2 MISSION UPDATE AND APPLICATIONS OVERVIEW

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Abstract

RADARSAT-2, planned for a 2004 launch, is an advanced SAR satellite. Key features of RADARSAT-2 are high resolution (3 m), polarimetric modes, enhanced ground system providing rapid satellite tasking and near-real time data processing, improved image location accuracy, and on-board solid state recorders. The focus of this presentation is on the RADARSAT-2 polarimetric capability. RADARSAT-2 offers three polarimetric modes: (1) selective polarization (dual pol) providing one co-pol channel (HH or VV) and the corresponding cross-pol channel (HV); (2) high resolution (3 m) single pol channel (HH or VV); and (3) a fully polarimetric mode (quad pol) providing both amplitude and phase. The fully polarimetric mode is significant since RADARSAT-2 is the first commercial satellite to offer this mode. In conjunction with the Canada Centre for Remote Sensing and MacDonald Dettwiler, RADARSAT International initiated application development projects to understand the potential and limitation of the RADARSAT-2 polarimetric modes. An overview of this development work is presented, including agriculture applications, ship detection, forestry, ocean features, DEM generation, and ice mapping. Results based on CV-580 airborne SAR data and SIR-C are used. Polarimetry, while intrinsically challenging from a scientific perspective, is daunting to the end user. The commercial focus of the RADARSAT-2 mission dictates the development of operational applications, and ultimately the extraction of information from the SAR data. This presentation concludes with an assessment of operational practicality of the RADARSAT-2 polarimetric modes.

TERRASAR-X UPGRADE TO A FULLY POLARIMETRIC IMAGING MODE

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Abstract

TerraSAR-X will be the first German SAR satellite for scientific and commercial applications. The satellite program is being carried out in the scope of a Public Private Partnership between DLR and Astrium. The launch is planed for 2005. While the satellite is being built by Astrium, DLR is responsible for the development of the ground segment (receiving station, operation center, processing and archiving facility) as well as for the system engineering and calibration. The TerraSAR-X program is the result of a successful technology development line in X-band carried out in the scope of the SIR-C/X-SAR missions in 1994 and 2000. Additionally, the TerraSAR-X satellite features an active phased array antenna (4,8 m x 0,7 m) with 384 T/R-modules allowing the radar operation in stripmap, ScanSAR, spotlight and sliding spotlight modes. It will be operated in a dawn-dusk orbit at 515 km height.

The redundancy concept in the TerraSAR-X receiving chain and the front-end design offer the possibility to use the second spare receiving channel in parallel to the main receiving channel. By this means, raw data from the two antenna halves (separated in along track direction) can be acquired independently and simultaneously. This split antenna concept enables several new imaging modes: along-track interferometry, fully polarimetric X-band data acquisition, enhancement of azimuth resolution and additional calibration techniques for the improvement of the standard TerraSAR-X products. The paper will first give an overview of the TerraSAR-X project and will emphasize the new applications to be investigated with the upgrade to a split antenna concept with a fully polarimetric mode.

COSMO-SKYMED : MISSION DEFINITION AND MAIN APPLICATIONS AND PRODUCTS

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