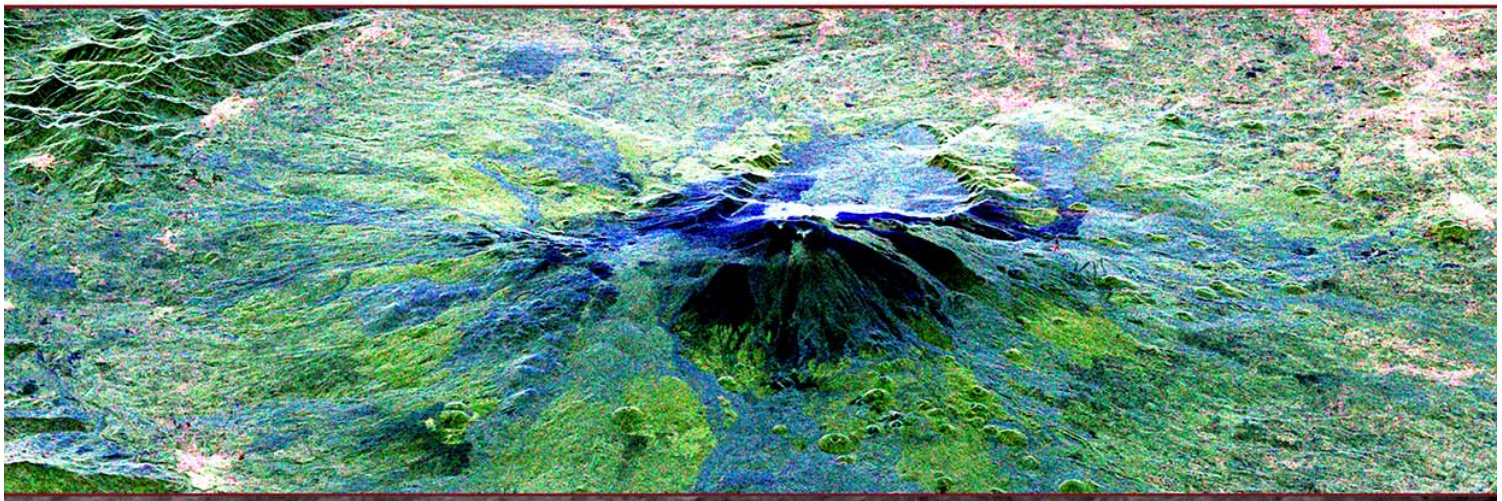
→ POLINSAR 2013

The 6th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry



PROGRAMME & ABSTRACT BOOK

28 January - 1 February 2013 | ESA-ESRIN | Frascati (Rome), Italy

Programme & Abstract Book

POLinSAR 2013

6th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry

28 January through 01 February 2013
ESA-ESRIN,
Frascati (IT)

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Prof. Dr. Yoshio Yamaguchi - Niigata University,Japan

Dr. J. J. Zhang - IECAS; University of Chinese Academy of Sciences, China

Programme

Day 1, Monday 28 January 2013

8:30 9:30 Workshop Registration

Session – Opening

Chairs: Y.-L. Desnos,

9:30 - 9:40 **Opening welcome**
M. Borgeaud (European Space Agency)

9:40 - 10:00 **POLinSAR Achievements and Plans**
Y.L. Desnos
ESA, IT

10:00 - 10:20 **ESA's Biomass Mission Candidate: System and Payload Overview**
Scipal, K; Arcioni, M; Fois, F; Lin, C
ESA, NL

10:20 - 10:40 **Sentinel 1 System overview**
Dirk Geudtner
ESA, NL

10:40 - 11:00 **Sentinel 1 Mission Operation Concepts**
P. Potin
ESA, IT

11:00 - 11:30 COFFEE BREAK

11:30 - 11:50 **PolSAR-Ap: Exploitation of Fully Polarimetric SAR Data for Application Demonstration**
Hajnsek, I.[1]; Pardini, M.[1]; Papathanassiou, K.[1]; Ballester-Berman, J.D.[2]; Cloude, S.[3]; Colin-Koniguer, E.[4]; Desnos, Y-L[5]; Lopez-Martinez, C.[6]; Lopez-Sanchez, J.M.[2]; Migliaccio, M.[7]; Minchella, A.[8]; Nunziata, F.[7]; Pottier, E.[9]; Trouve, N.[4]
[1]German Aerospace Center (DLR), DE; [2]Universidad de Alicante, ES; [3]AEL Consultants, UK; [4]ONERA, FR; [5]ESA-ESRIN, IT; [6]Universitat Politecnica de Catalunya (UPC), ES; [7]Universitá di Napoli "Parthenope", IT; [8]RSCA c/o ESA-ESRIN, IT; [9]Université de Rennes I, FR;

11:50 - 12:10 **Round Table – Opening**

Session - Methods & Theoretical Modelling

Chairs: I. Hajnsek, R.K. Raney

12:10 - 12:30 **Evaluation of the Decomposition Method based on Second- and Third-Order Statistics**
Kojima, SK[1]; Hensley, SH[2]
[1]National Institute of Information and Communications Technology, JP;
[2]Jet Propulsion Laboratory, NASA, USA

12:30 - 12:50 **M−CHI Decompensation of Iperfect Hybrid Dal-Plarimetric Data**
Raney, R. K.
Johns Hopkins University, USA

12:50 - 13:10 **Study of the Speckle Noise Effects Over the Eigen Decomposition of Polarimetric SAR Data: A Review**
López-Martínez, C.; Alonso-Gonzalez, A.
Universitat Politècnica de Catalunya, ES;

13:10 - 13:30 **Schatten Matrix Norm based Polarimetric SAR Data Regularization Application over Chamonix Mont-Blanc**
Le, T. T.; Atto, A. M.; Trouve, E.
University of Savoie, Polytech Annecy – Chambéry, FR

13:30 – 13:50 **Compact Versus Full Polarimetric SAR for Optimum Target Polarization Information Extraction**
Touzi, R.
Canada Centre for Remote Sensing, CA;

13:50 - 15:00 LUNCH

15:00 - 15:20	**Poincare Sphere Representation of Independent Scattering Sources: Application on Distributed Targets** *Besic, N.[1]; Vasile, G.[1]; Chanussot, J.[1]; Stankovic, S.[2]* *[1]Gipsa-lab, FR; [2]University of Montenegro, ME;*
15:20 - 15:40	**Wave Propagation Model for Polarimetric Scattering in Mangroves** *Atwood, D. K.[1]; Matthiss, B.[2]; Jenkins, L.[3]; Wdowinski, S.[4]; Hong, S-H[5]* *[1]University of Alaska Fairbanks, USA; [2]Karlsruhe University, DE; [3]Michigan Tech Research Institute, USA; [4]University of Miami, USA; [5]Korea Aerospace Research Institute, KR*
15:40 -16:00	***PolSAR Time Series Processing and Analysis based on Binary Partition Trees*** *Alonso-Gonzalez, A.; López-Martínez, C.; Salembier, P.* *Universitat Politècnica de Catalunya (UPC), ES;*
16:00 - 16:20	**The Theoretical Problem of Partial Coherence and Partial Polarization in PolSAR and PolInSAR.** *Alvarez-Perez, JL* *Universidad de Alcalá, ES;*
16:20 -16:40	**Scientist's Idealism versus User's Realism for Ortho-Rectifying Full/Compact Polarimetric Data of Radarsat-2/RCM** *Toutin, Th.[1]; Wang, H.[2]; Charbonneau, F.[2]; Pottier, E.[3]* *[1]Natural Resources Canada, CA; [2]Canada Centre for Remote Sensing, CA; [3]Institut d'Électronique et de Télécommunications de Rennes, FR;*
16:40 - 17:10	COFFEE BREAK
17:10 - 17:30	**On the Accuracy and Conditioning of Polarimetric Calibration Methods** *Villa, AV[1]; Iannini, LI[2]; Giudici, DG[3]; Monti-Guarnieri, AMG[2]; Tebaldini, ST[2]* *[1]Aresys / Politecnico di Milano, IT; [2]Politecnico di Milano, IT; [3]Aresys, IT;*
17:30 - 17:50	**SNR and Noise Variance Estimation in Polarimetric SAR Data** *Villano, M; Papathanassiou, K. P.* *German Aerospace Center (DLR), DE;*
17:50 - 18:30	**Round Table - Methods & Theoretical Modelling**
18:30 - 19:40	WELCOME DRINK

Day 2, Tuesday 29 January 2013

Session - Polarimetric SAR Interferometry (Pol-InSAR)

Chairs: S. Hensley, A. Reigber

9:00 - 9:20 **Interpretation of Single-Pass Pol-InSAR Vegetation Signatures at X-Band: Dual- vs. Quad-Pol Case**
Joerg, HJ[1]; Jagdhuber, TJ[1]; Kugler, KF[1]; Hajnsek, Irena[2]
[1]German Aerospace Center, DE; [2]ETH Zürich, CH; (German Aerospace Center - DLR)

9:20 - 9:40 **Tackling temporal Decorrelation with the RMOG Model**
Lavalle, M.[1]; Khun, K.[2]; Neumann, M.[1]; Ahmed, R.[1]; Simard, M.[1]; Hensley, S.[1]
[1]Jet Propulsion Laboratory, USA, California Institute of Technology, USA; [2]University of Montreal, CA

9:40 - 10:00 **Tandem-L for Vertical Forest Structure Monitoring From Multibaseline Multipolarimetric L-Band SAR Data**
Pardini, M.; Kugler, F.; Torano-Caicoya, A.; Hajnsek, I.; Papathanassiou, K.
German Aerospace Center (DLR), DE;

10:00 - 10:20 **Polarimetric-Interferometric Studies at La Amistad International Park**
Hensley, S.[1]; Neumann, M.[1]; Lavalle, M.[1]; Michel, T.[1]; Simard, M.,[1]; Chapman, B.[1]; Ahmed, R.[1]
[1]Jet Propulsion Laboratory, USA;

10:20 - 10:40 **PolInSAR and Multifrequency Image Acquisition with the F-SAR Airborne SAR Instrument**
Reigber, A.; Papathanassiou, K.; Jäger, M.
DLR, DE;

10:40 - 11:10 COFFEE BREAK

Session - Polarimetric SAR Interferometry (Pol-InSAR): Forest

Chairs: K. Papathanassiou, P. Dubois-Fernandez

11:10 - 11:30 **Assessment of Single Baseline PolInSAR in Tropical Context for Vegetation Characterisation**
Dubois-Fernandez, P[1]; Arnaubec, A[2]; Dupuis, X[1]
[1]ONERA, FR; [2]ONERA - Institue Fresnel, FR;

11:30 - 11:50 **Impact of Geophysical Changes on the Pol-InSAR Phase Center of Tropical Dense Forests**
Hamadi, AH[1]; Villard, LV[1]; Borderies, PB[2]; Le Toan, TLT[1]; Koleck, TK[1]
[1]CESBIO, FR; [2]ONERA, FR;

11:50 - 12:10 **PolInSAR Techniques for Forest Characterization with TanDEM-X**
Kugler, F.[1]; Hajnsek, I.[2]; Papathanassiou, K.[3]
[1]Microwave an Radar Institute / German Aerospace Centre (DLR-HR), DE; [2]ETH Zürich, CH; [3]German Aerospace Centre (DLR), DE;

12:10 - 12:30 **A Maximum Likelihood Analysis of the RVoG Model for Forestry Studies in Polarimetric SAR Interferometry**
López-Martínez, C.; Alonso-Gonzalez, A.
Universitat Politècnica de Catalunya, ES;

12:30 - 12:50 **First PolInSAR Forest Height Inversion by means of L-band F-SAR Data**
Lee, S-.K.; Kugler, F.; Papathanassiou, K.; Hajnsek, I.
DLR, DE;

12:50 - 13:10 **Estimation of Canopy Height using UAVSAR Data in the Réserve Faunique des Laurentides and Penobscott Forests.**
Simard, M.[1]; Lavalle, M.[1]; Pinto, N.[1]; Hensley, S.[1]; Michel, T.[1]; Brolly, M.[1]; Dubayah, R.[2]
[1]NASA Jet Propulsion Laboratory, USA; [2]University of Maryland, USA;

13:10 - 13:30 **A Study of Tandem-X PolInSAR Variation over a Forested Area**
Solberg, S.[1]; Weydahl, PhD[2]
[1]Norwegian Forest and landscape Institute, NO; [2]Norwegian Defense Research Institute, NO;

13:30 - 13:50 **Investigation of the Capability of Compact Polarimetric SAR Interferometry to Estimate Forest Height**
Zhang, H.[1]; Zhang, B.[1]; Xie, L.[1]
[1]Center for Earth Observation and Digital Earth Observation, CAS, CN

13:50 - 15:00 LUNCH

15:00 - 15:20 **MRV System Development for REDD+ in Indonesia: Pol-SAR Application**
Raimadoya, M[1]; Gunawan, A[2]
[1]Bogor Agricultural University, ID; [2]Sinarmas Forestry, ID;

15:20 - 15:40 **Boreal Forest Biomass Classification with TanDEM-X**
Toraño Caicoya, A.[1]; Kugler, F.[1]; Papathanassiou, K.[1]; Hajnsek, I.[2]
[1]German Aerospace Center (DLR), DE; [2]ETH Zürich, CH;

15:40 - 16:20 **Status of the Retrieval Algorithms of the Biomass mission**
Le Toan, T.[1]; Ulander, L.[2]; Papathanassiou, K.[3]; Rocca, F.[4]; Saatchi, S.[5]; Quegan, S.[6]; Scipal, K.[7]
[1]CESBIO, FR; [2]FOI, SE; [3]DLR, DE; [4]PoliMi, IT; [5]JPL, USA; [6]University Sheffield, UK; [7]ESA-ESTEC, NL;

16:20 - 17:00 **Joint Round Table - Sessions about Pol-InSAR**

17:00 - 17:30 COFFEE BREAK

Session - Polarimetry & DInSAR, Polarimetry & PSI

Chairs: A. Montiguarnieri, C.Lopez-Martinez

17:30 - 17:50 **Assimilation of Distributed Targets and PS Information for a Scene-Based Monitoring of the Polarimetric Data Distortion**
Iannini, L.; Monti Guarnieri, A.; Tebaldini, S.
Politecnico di Milano, IT;

17:50 - 18:10 **Performance Comparison between Dual Polarimetric and Fully Polarimetric Data for DInSAR Subsidence Monitoring**
Monells, D.; Iglesias, R.; Mallorqui, J. J.
Universitat Politecnica de Catalunya, ES;

18:10 - 18:30 **Polarimetric adaptative Speckle Filtering driven by temporal Statistics for PSI Applications**
Navarro-Sanchez, V. D.; Lopez-Sanchez, J. M.
University of Alicante, ES;

18:30 - 18:50 **Phase Quality Optimization Techniques and Limitations in Polarimetric Differential SAR Interferometry**
Iglesias, R.; Monells, D.; Fabregas, X.; Mallorquí, J. J.; Aguasca, A.; López-Martínez, Carlos
Universitat Politècnica de Catalunya (UPC), ES;

18:50 - 19:10 **Round Table - Polarimetry & DInSAR, Polarimetry & PSI**

Day 3, Wednesday 30 January 2013

Session - Polarimetry and Tomography

Chairs: S. Tebaldini, L. Ferro-Famil

9:00 - 9:20 **Towards Forest Vertical Structure Monitoring From Space: First Experiments With Multi-Baseline TanDEM-X Data**
Pardini, M.; Kugler, F.; Papathanassiou, K.
German Aerospace Center (DLR), DE;

9:20 - 9:40 **P-Band Tomography Imaging of Tropical Forest at 6 MHz Bandwidth: Capabilities for Forest Biomass Estimation**
Ho Tong Minh, D.[1]; Tebaldini, S.[1]; Rocca, F.[1]; Le Toan, T.[2]
[1]Politecnico di Milano, IT; [2]CESBIO, FR;

9:40 - 10:00 **ML Tomography based on the MB RVoG Model: Optimal Estimation of a Covariance Matrix as a Sum of two Kronecker Products**
Ferro-Famil, L.[1]; Tebaldini, S.[2]
[1]University of Rennes 1, FR; [2]Politecnico Milano, IT;

10:00 - 10:20 **Wavelet-based Compressed Sensing for Polarimetric SAR Tomography**
Aguilera, E; Nannini, M; Reigber, A
DLR (German Aerospace Center), DE;

10:20 - 10:40 **Dual-baseline Polarimetric SAR Tomography for Tree Height Estimation Using Single-Pass L-Band PolInSAR Data**
Huang, Y.[1]; Zhang, Q.[1]; Schwaebisch, M.[1]; Wei, M.[1]; Mercer, B.[2]
[1]Intermap Technologies Corp., CZ; [2]University of Calgary, CA

10:40 - 11:00 **Diff-Tomo Separation of Temporal Decorrelation Mechanisms in Forest Multi-Pol Airborne Data**
Lombardini, F.[1]; Viviani, F.[1]; Cai, F.[2]
[1]University of Pisa / CNIT-RaSS, IT; [2]University of Pisa, IT;

11:00 - 11:30 COFFEE BREAK

11:30 - 11:50 **Round Table - Polarimetry and Tomography**

Session – Applications on Ocean & Cryosphere

Chairs: T. Eltoft, M. Migliaccio

11:50 - 12:10 **Polarimetric Decomposition Analysis of Sea Ice Data**
Eltoft, T.[1]; Moen, M.-A.[1]; Ferro-Famil, L.[2]; Doulgeris, A. P.[1]; Anfinsen, S. N.[1]; Gerland, S. N.[3]
[1]University of Tromsø, NO; [2]University of Rennes 1, FR; [3]Norwegian Polar Institute, NO;

12:10 - 12:30 **On the Interpretation of L- and P-Band PolSAR Signatures of Polithermal Glaciers**
Parrella, G.[1]; Hajnsek, I.[2]; Papathanassiou, K.[1]
[1]German Aerospace Center (DLR), DE;
[2]ETH Zurich - Institute of Environmental Engineering, CH;

12:30 - 12:50 **Snow Property Extraction based on Polarimetry and Differential SAR Interferometry**
Leinss, S; Hajnsek, I
ETH Zürich, CH;

12:50 - 13:10 **On Dual-Polarized SAR Measurements of the Ocean Surface**
Myasoedov, A.[1]; Kudryavtsev, V.[1]; Chapron, B.[2]; Collard, F.[3]; Johannessen, J.[4]
[1]RSHU, RU; [2]IFREMER, FR; [3]CLS, FR; [4]NERSC, NO;

13:10 - 13:30 **Marine Bacteria Monitoring via Polarimetric SAR**
Migliaccio, M[1]; Nunziata, F[1]; Kurata, N[2]; Vella, K[2]; Matt, S[2]; Soloviev, A[2]; Perrie, W[3]
[1]Università di Napoli Parthenope, IT; [2]NOVA Southeastern University,USA; [3]Dalhousie University,CA;

13:30 - 13:50 **Round Table - Applications on Ocean & Cryosphere**

13:50 - 15:00 LUNCH

Session - Applications on Ocean Pollution monitoring & target detection

Chairs: C. Brekke, F. Nunziata

15:00 - 15:20 **Polsar-AP:Exploitation if fully Polarimetric SAR Data for Oil and Target at Sea Monitoring**
Nunziata, F.; Migliaccio, M
Università di Napoli Parthenope, IT;

15:20 - 15:40 **Evaluation of RCM Compact Polarimetry for Ship Detection**
Liu, C.; Vachon, P.W.
Defence R&D Canada – Ottawa, CA;

15:40 - 16:00 **Combining Polarimetric Channels for better Ship Detection Results**
Hannevik, T.N.A.
Norwegian Defence Research Establishment, NO;

16:00 - 16:20 **Ship Detection using Polarimetric Radarsat-2 Data and Multi-Dimensional Coherent Time-Frequency Analysis**
Hu, C.[1]; Ferro-Famil, .[2]; Brekke, C.[3]; Anfinsen, S. N.[3]
[1]National University of Defense Technology, School of Electronic Science and Engineering, CN; [2]University of Rennes 1, Institute of Electronics and Telecommunications of Rennes,SAPHIR team, FR; [3]University of Tromsø, Department of Physics and Technology, NO;

16:20 - 6:40 **Towards Oil Slick Monitoring in the Arctic Environment**
Brekke, C.[1]; Holt, B.[2]; Jones, C.[2]
[1]University of Tromsø, NO; [2]Jet Propulsion Laboratory, USA;

16:40 - 17:00 **A Robust Symmetry-based Approach to Exploit TerraSAR-X Dual-pol Data for Targets at Sea Observation**
Velotto, D.[1]; Nunziata, F.[2]; Migliaccio, M.[2]; Lehner, S.[1]
[1]German Aerospace Center (DLR), DE; [2]Università degli Studi di Napoli, IT;

17:00 - 17:20 **Round Table - Applications on Ocean Pollution monitoring & target detection**

17:20 – 19:30 POSTER SESSION with refreshment

Day 4, Thursday 31 January 2013

Session – Applications of SAR Polarimetry on Land: Agriculture, Urban, Archeology

Chairs: E. Koeniguer, J.M. Lopez-Sanchez

9:00 - 9:20 **Time Series Decomposition Analysis for Compact Polarimetry**
Cloude, S.R.[1]; Goodenough, D.G.[2]; Chen, H.[3]
[1]AEL Consultants, UK; [2]University of Victoria, CA; [3]Natural Resources Canada, CA;

9:20 - 9:40 **Polarimetric Response of Rice Fields at C-Band:Analysis and Applications**
Lopez-Sanchez, J. M.[1]; Vicente, F.[1]; Ballester-Berman, J. D.[1]; Cloude, S. R.[2]
[1]University of Alicante, ES; [2]AEL Consultants, UK;

9:40 - 10:00 **Scattering Mechanism Analysis Using Multi-Angular Polarimetric Radarsat-2 Datasets**
Wang, H.[1]; Allain, S.[2]; Meric, S.[1]; Pottier, E.[2]
[1]Institut National des Sciences Appliquees de Rennes, FR; [2]Universite de Rennes 1, FR;

10:00 - 10:20 **POLSARap: Investigating the Benefits of Polarimetry for Urban Applications using X-Band SAR Images.**
Koeniguer, E.; Trouve, N.
ONERA, FR;

10:20 - 10:40 **Multitemporal RADARSAR-2 fine-beam Polarimetric SAR Data for Urban Land Cover Mapping**
Ban, Y.; Niu, X.
KTH Royal Institute of Technology, SE;

10:40 - 11:00 **Hybrid PolInSAR: Combining a HR single Image and a full Polarimetric Image in a lower Resolution - Example on Urban**
Trouve, N.; Koeniguer, E.
Onera, FR

11:00 - 11:30 COFFEE BREAK

11:30 - 11:50 **A Multi Frequency Polarimetric SAR Sensors Analysis over the Archaeological Area of Djebel Barkal (Suadan)**
Patruno, J.; Dore, N.; Pottier, E.; Crespi, M.
[1]University of Rennes 1, FR; [2]University of Rome "Sapienza", IT;

11:50 - 12:10 **Radarsat-2 Polarimetric multi incidence Angle Analysis over the ancient City of Husn Al-Qadisiyya (Iraq)**
Dore, N.[1]; Patruno, J.[1]; Pottier, E.[1]; Crespi, M.[2]
[1]University of Rennes 1', FR; [2]University of Rome Sapienza, IT;

12:10 - 12:30 **Round Table - Applications of SAR Polarimetry on Land: Agriculture, Urban, Archeology**

Session - Applications of SAR Polarimetry on Land: Soil Moisture and Wetlands

Chairs: R. Touzi, S. Cloude

12:30 - 12:50 **Polarimetric Decompositions for Soil Moisture Retrieval from Vegetated Soils in TERENO Observatories**
Jagdhuber, T.; Hajnsek, I.; Papathanassiou, K.P.
German Aerospace Center, DE;

12:50 - 13:10 **RCM Compact Polarimetry Applied to Watershed Study**
Charbonneau, F.J.[1]; Zidane, S.-E.[1]; McNairn, H.[2]; Merzouki, A.[2]
[1]Natural Resources Canada, CA; [2]Agriculture and Agri-Food Canada, CA;

13:10 - 13:30 **Soil Moisture Retrieval via a Polarimetric Two-Scale and Two-Component Scattering Model**
Natale, A.[1]; Iodice, A.[2]; Riccio, D.[2]
[1]IREA – CNR, IT; [2]Università degli Studi di Napoli Federico II, IT;

13:30 - 13:50 **The Chott El Jerid, Tunisia: Observation and Interpretation of a SAR Phase Signature over Evaporitic Soils.**
Paillou, Ph.[1]; Sufyar, S.[1]; Sayah, N.[2]; Frison, P-L.[3]
[1]University Bordeaux, FR; [2]Centre National de Télédétection, TN; [3]University Paris-Est, FR;

13:50 - 15:00 LUNCH

15:00 - 15:20 **Polarimetric L-band ALOS and C-band RADARSAT2 for Sub-Arctic Peatland Characterization and Monitoring**
Touzi, R.; Gosselin, G.
Canada Centre for Remote Sensing, CA;

15:20 - 15:50 **Round Table - Applications of SAR Polarimetry on Land: Soil Moisture and Wetlands**

Session - Applications of SAR Polarimetry: Other

Chairs: E. Pottier, J.J. Zhang

15:50 - 16:10 **2003-2013 : 10 Years of the PolSARpro v5.0 Software. New uUdates and its Link with the ESA POLSAR-Ap Project.**
Pottier, E.[1]; Lopez Martinez, C.[2]
[1]IETR - UMR 6164, FR; [2]UPC Barcelona, ES;

16:10 - 16:30 **CFAR Test for a Change Detector based on an optimized Power Ratio**
Marino, A.[1]; Hajnsek, I[2]
[1]ETH Zurich, CH; [2]ETH Zurich & DLR, CH&DE;

16:30 - 16:50 **Change Detection Analysis for under-cover Detection in L and UHF Band**
Oriot, H
ONERA, FR;

16:50 - 17:20 COFFEE BREAK

17:20 - 17:40 **Unsupervised Classification Based on Seven Scattering Categories Segmentation**
Zhang, J.J.[1]; Li, Y.[1]; Yin, Q.[2]; Hong, W. (Presenting)[2]
[1]Science and Technology on Microwave Imaging Laboratory, IECAS; University of Chinese Academy of Sciences, CN; [2]Science and Technology on Microwave Imaging Laboratory, IECAS, CN;

17:40 - 18:00 **A Simple and Extendable Segmentation Method for multi-polarisation SAR Images**
Doulgeris, A. P.
University of Tromso, NO;

18:00 - 18:20 **Interpretation of an Insar Image using Geometric Codes**
Mokadem, A.[1]; Thirion Lefevre, L.[1]; Colin Koeniguer, E.[2]
[1]Supelec, FR; [2]Onera, FR;

18:20 - 18:40 **A Modified Wishart Distance Measure and Its Application to PolSAR Change Detection**
Liu, M.; Zhang, H.; Wang, C.
Center for Earth Observation and Digital Earth, CAS, CN;

18:40 - 19:00 **Round Table - Applications of SAR Polarimetry: Other**

Day 5, Friday 01 February 2013

Sessions Summaries

Chairs: Y-L. Desnos

9:00 - 9:20	Methods & Theoretical Modelling
9:20 - 9:40	Polarimetric SAR Interferometry (Pol-InSAR)
9:40 - 10:00	Polarimetric SAR Interferometry (Pol-InSAR): Forest
10:00 - 10:20	Polarimetry & DInSAR, Polarimetry & PSI
10:20 - 10:40	Polarimetry and Tomography
10:40 - 11:00	Applications on Ocean & Cryosphere
11:00 - 11:30	COFFEE BREAK
11:30 - 11:50	Applications on Ocean Pollution monitoring & target detection
11:50 - 12:10	Applications of SAR Polarimetry on Land: Agriculture, Urban, Archeology
12:10 - 12:30	Applications of SAR Polarimetry on Land: Soil Moisture and Wetlands
12:30 - 12:50	Session - Applications of SAR Polarimetry: Other
12:50 - 13:10	Closing

Day 1, Monday 28 January 2013

Session: Opening

ESA's Biomass Mission Candidate: System and Payload Overview

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The European Space Agency (ESA) is preparing candidates for the next Earth Explorer Core mission with the aim to select the 7th Earth Explorer mission to be launched towards the end of this decade. Earth Explorers are the backbone of the science and research element of ESA's Living Planet Programme, providing an important contribution to the global endeavour of understanding Earth's System, particularly in view of global climate change.

In the so-called Phase 0 (assessment phase), six candidate mission concepts were selected and further investigated. A down-selection was made after the User Consultation Meeting held in Lisbon, Portugal in January 2009. Three candidate mission concepts are now being further investigated in the feasibility and consolidation phase (Phase A), after which the new Earth Explorer will be selected, implemented and launched. The candidate missions under consideration are:

- Biomass: Global measurements of forest biomass and extent,
- CoReH2O: Detailed observations of key snow, ice and water cycle characteristics,
- PREMIER: Understanding the processes that link trace gases, radiation, chemistry and climate in the atmosphere.

This presentation will give an overview of the observation requirements, satellite system and payload descriptions, supporting scientific activities and general status of the Biomass mission. The primary scientific objectives of the Biomass mission are to determine the distribution of aboveground biomass in the world forests and to measure annual changes in this stock over the period of the mission to greatly enhance our understanding of the land carbon cycle. To achieve these objectives, the Biomass space segment will consist of a P-band (435 MHz) Synthetic Aperture Radar (SAR) in side-looking geometry with full polarimetric and interferometric capabilities. Secondary objectives of the mission are linked to the fact that Biomass would provide the first opportunity to acquire P-Band SAR images from space. New information is expected in mapping ice structure and ice velocities in Polar Regions, subsurface geomorphology in arid areas and sub-forest canopy Digital Elevation Model.

The technical description of the Biomass mission is derived from the preparatory activities at Phase A level and it shows how candidate implementation concepts can respond to the scientific mission requirements. The system description is mainly based on the results of the work performed during parallel Phase A system studies by two industrial consortia. Two implementation concepts are described, which provide viable options capable of meeting the mission requirements. The Biomass space segment comprises a single low Earth orbit satellite platform carrying a fully polarimetric P-band SAR instrument. The SAR antenna is based on a large deployable reflector (12 m circular projected aperture) with an offset feed array. The Biomass mission will operate in a dawn-dusk, sun-synchronous orbit with a mean altitude of about 660 km and a local time of 6:00. A 17 day repeat cycle orbit has been selected in order to minimise the temporal de-correlation in the data between successive cycles for the interferometric product generation. Strategies to reduce the repeat cycle to 4 days are currently investigated. The SAR operates in stripmap mode with a 6 MHz bandwidth and a 200/300 W peak transmitted power. Since the swath width produced by the instrument is not sufficient to provide global coverage within one repeat cycle, the spacecraft performs a small roll manoeuvre to enable successively access to the second and third swath regions each time after two to three repeat cycles. This allows global coverage to be achieved within the required 6 months.

After an overview of the mission architecture and the proposed orbit, the space segment is described in detail followed by the launcher, the ground segment and operations concepts.

PolSAR-Ap: Exploitation of Fully Polarimetric SAR Data for Application Demonstration

Hajnsek, I.[1]; Pardini, M.[1]; Papathanassiou, K.[1]; Ballester-Berman, J.D.[2]; Cloude, S.[3]; Colin-Koniguer, E.[4]; Desnos, Y-L[5]; Lopez-Martinez, C.[6]; Lopez-Sanchez, J.M.[2]; Migliaccio, M.[7]; Minchella, A.[8]; Nunziata, F.[7]; Pottier, E.[9]; Trouve, N.[4]

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In the last decade, a number of SAR satellites operating with polarimetric capability at different frequencies have been launched. The Japanese ALOS/PalSAR operating at L-band, the Canadian Radarsat-2 operating at C-band and the German TerraSAR-X operating at X-band made the access to individual polarimetric data sets rather easy. As a consequence, the wider distribution of polarimetric data sets across the remote sensing community boosted activity and development in polarimetric SAR applications, also in the light of future missions (e.g. ALOS-2) and mission proposals under study (e.g. Tandem-L). This is manifested in the increased number of scientific publications related to SAR polarimetry in the last years and in the increased number of topics and contributions presented in ESA's bi-annual POLinSAR workshops. In this framework, the PolSAR-Ap project, supported by the European Space Agency and coordinated by the German Aerospace Center, is aimed at evaluating and demonstrating the importance and the unique benefits of quad-polarimetric SAR data for a wide range of remote sensing applications [1].

In order to cover the whole range of remote sensing applications, the project is organised into five thematic domains: Forest, Agriculture, Cryosphere, Urban and Ocean. Hazard applications are treated as well. More in detail, for each thematic domain two main objectives are followed:

1. Identification of applications for which the availability of quad-polarimetric SAR data brings unique benefits and/or significant performance improvements when compared to single- or dual-polarimetric data;
2. Demonstration of the benefits / improvements induced by polarimetry by implementing the applications, applying them on suitable, if possible space-borne, SAR data and validating their performance against reference data available for each case.

Important components of the project are the integration of the implemented applications in the ESA software PolSARpro and the generation of the appropriate demonstration examples for demonstration and educational purposes. Finally, the evaluated applications, the implemented applications and the generated showcases will be integrated in ESA's TM publication "Principles and Applications of Pol-InSAR".

In the presentation, an overview of the project at the current status will be given. The test sites and data sets selected for the evaluations will be presented, together with first results and comparisons for each thematic domain.

References:

[1] Project proposal "Exploitation of Fully Polarimetric SAR Data for Application Demonstration", ESRIN contract no. 4000104595/11/I/NB

NOTES:

Day 1, Monday 28 January 2013

Session: Methods & Theoretical Modelling

Evaluation of the Decomposition Method based on Second- and Third-Order Statistics

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1.Introduction and Purpose

There are many papers concerning the research of the decomposition of polerimetric SAR imagery. Most of them are based on second-order statistics analysis that Freeman and Durden suggested for the reflection symmetry condition that implies that the co-polarization and cross-polarization correlations are close to zero. Since then a number of improvements and enhancements have been proposed to better understand the underlying backscattering mechanisms present in polarimetric SAR images. For example, Yamaguchi et al. added the helix component into Freeman fs model and developed a 4 component scattering model for the non-reflection symmetry condition. In addition, Arii et al. developed an adaptive model-based decomposition method that could estimate both the mean orientation angle and a degree of randomness for the canopy scattering for each pixel in a SAR image without the reflection symmetry condition.

This purpose of this research is to develop a new decomposition method based on second- and third-order statistics analysis to estimate the surface, dihedral, volume and helix scattering components from polarimetric SAR images without the specific assumptions concerning the model for the volume scattering. In addition, we evaluate this method by using both simulation and real UAVSAR data and compare this method with other methods.

2. Decomposition method based on second- and third-order statistics analysis

We express the volume scattering component using the wire formula and formulate the relationship equation between backscattering echo and each component such as the surface, dihedral, volume and helix via linearization based on second- and third-order statistics. In third-order statistics, we calculate the correlation of the correlation coefficients for each polerimetric data and get one new relationship equation to estimate each polarization component such as HH, VV and VH for the volume.

As a result, the equation for the helix component in this method is the same formula as one in Yamaguchi fs method. However, the equation for the volume component is different from other methods. This method can estimate each polarization component for the volume without specific a priori volume scattering assumptions.

3. Evaluation

To evaluate this estimation method, we simulate polerimetric SAR images as the summation of surface, dihedral, volume and helix scattering and decompose these polerimetric images into the surface, dihedral, volume and helix using the proposed method. In addition, we compare these results with ones estimated by Freeman fs method and Yamaguchi fs method and remark on the merits and limitations for each method.

The surface and dihedral scattering estimated by Freeman fs and Yamaguchi fs method are larger than simulated truth data and the estimated volume scattering is smaller. This is especially the case when surface scattering occurs simultaneously with volume scattering (e.g., the forested area) that results in an overestimation.

On the other hand, the proposed method gives an overestimation for volume scattering, however this method does estimate the surface and dihedral scattering with high accuracy.

Finally, we analyze polarimetric SAR images using the proposed method and compare with Freeman fs and Yamaguchi fs method. The decomposition result in the proposed method is different from Yamaguchi fs method in the vegetated terrain which is especially apparent in the large field.

4. Conclusion

We proposed a new decomposition method based on second- and third-order statistics analysis and clarified its merits and limitations including the estimation accuracy by analyzing both real and simulated data. The proposed method is able to estimate the surface and dihedral scattering more accurately than other methods we compared Further research and fieldwork are needed to better quantify and understand these results fully.

M−CHI Decompensation of Iperfect Hybrid Dal-Plarimetric Data

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If the field transmitted by a hybrid dual-polarimetric (CL) radar is not perfectly circularly polarized, then certain decomposition techniques, including especially the older *m-delta* method, will lead to ambiguous results. This paper describes the *m-chi* analysis methodology, which has proven to be robust when applied to backscatter generated by elliptically-polarized transmitted fields from two radars: Mini-RF aboard NASA's Lunar Reconnaissance Orbiter (2009-), and its precursor, Mini-SAR on India's lunar Chandrayaan-1 satellite (2008-9). These instruments, the first orbital compact-polarimetric radars, were characterized by transmitted axial ratios on the order of 2 [1], for which decomposition of the resulting "CL" data has proven to be challenging.

The degree of polarization *m* is a natural choice for the first decomposition variable. The Poincaré ellipticity parameter *chi* is an obvious and the most robust choice for the second decomposition variable. It is one of the three classical principal components (*m*, *chi*, *psi*) that are necessary and sufficient to describe the polarized portion of a partially-polarized quasi-monochromatic EM field of average strength S1. Further, the sign of *chi* is an unambiguous indicator of even versus odd bounce backscatter, even when the radiated EM field is not perfectly circularly polarized. In this paper the underlying theory is briefly summarized. Examples from lunar data illustrate the benefits of the *m-chi* approach in contrast to *m-delta* [2]. A color wheel is introduced that provides additional clarity to aid classification and interpretation. The results further suggest that an *m-chi-psi* three-component decomposition strategy could provide additional backscatter analysis finesse. These methods are directly applicable to data anticipated from Earth-observing compact-polarimetric radars.

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Study of the Speckle Noise Effects Over the Eigen Decomposition of Polarimetric SAR Data: A Review

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Polarimetric Synthetic Aperture Radar (PolSAR) is nowadays an important observation technique of the Earth surface. The correct interpretation of data, especially from a physical point of view, needs to consider the use of physical models, which exploitation may be performed in two different ways. The first option considers a model for the complete polarimetric measurement, i.e., the covariance or coherency matrices. Nevertheless, polarimetric measurements result from the combination of different scattering mechanisms within the same resolution cell. Hence, the second option consists on applying physical models to the different parts of the signal, aiming to analyze them separately. This second option has attracted much attention, as it allows analyzing the inherent complexity of the polarimetric return by decomposing it into more simple building blocks. Collectively, these techniques are known as target decomposition (TD) theorems.

Among the different alternatives, it is important to highlight the eigenvector-based TD theorems, based on the eigendecomposition of the covariance or coherency matrices. Under this approach, these matrices are first decomposed through the eigendecomposition and then, the eigenvalues and the eigenvectors are interpreted physically [1][2]. Considering this approach, Cloude and Pottier [2] introduced the parameters Entropy (H), Anisotropy (A) and mean Alpha angle.

The previous TD theorem is essentially considered in the analysis of distributed scatterers. Since PolSAR data are affected by speckle noise, the interpretation of the decomposition results, as well as the retrieved physical information, must take into account this component. A first study of the speckle noise effects on this TD theorem was already presented in the PolInSAR 2005 conference [3] and complemented in [4], where it was demonstrated that the estimated eigenvalues are asymptotically non-biased with respect to the actual ones. Indeed the first eigenvalue results always overestimated, the third always underestimated and the second one can be over or underestimated, depending on the underlying scattering mechanism. Finally, an analytical expression for the sample eigenvalues was derived. From the study of the sample eigenvalues, it was shown that the Entropy is underestimated and the Anisotropy can be over or underestimated, but no analytical expressions for them were obtained. The technique employed in [3][4] prevented to derive any information

related with the eigenvectors and the alpha angles. This limitation was partially overcome in [5], where some information was derived for the mean alpha angle based on the use of simulated data. Precisely, the use of this type of data limited the scope of the study, as it was not possible to obtain any information about the behavior of the sample alpha and mean alpha angles, beyond the fact that they seem to be asymptotically non biased.

The objective of the work to be presented in this contribution is to complement the previous approaches based on a perturbation analysis of the eigendecomposition of the coherency matrix that allows the study of both, the eigenvalues and the eigenvectors. As it will be shown, this type of study is able to overcome the limitations of all the techniques presented up to now, allowing to obtain analytical expressions for the mean and the variance of the eigenvalues, the mean and the covariance matrix of the sample eigenvectors, as well as the analytical expressions for the Entropy, the Anisotropy, the mean Alpha angle, and the individual alpha angles. The amplitude of this study allows also an in-depth analysis of these parameters making possible, for instance, to determine the dependency of the over or underestimation nature w.r.t. the underlying scattering mechanism. As this study is analytical, there are no restrictions with respect to the type of scatterer that can be analyzed. Finally, the analytical expressions shall be compared against simulated as well as real PolSAR data to show their accuracy.

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Schatten Matrix Norm based Polarimetric SAR Data Regularization Application over Chamonix Mont-Blanc

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The paper addresses the filtering of Polarimetry Synthetic Aperture Radar (PolSAR) images. The filtering strategy is based on a regularizing cost function associated with a matrix norm called the Schatten norm. This norm applies on matrix singular values. The proposed approach is illustrated on RADARSAT-2 PolSAR image over the Chamonix Mont-Blanc test site.

1. INTRODUCTION

Since the launch of SAR satellites offering full polarization (ALOS, RADASAT-2 and TERRASAR-X, in L band, C band and X band respectively), the use of PolSAR imagery has been studied extensively in many fields, such as biomass and forest height estimation, snow cover mapping, glacier monitoring, damage assessment.... The intrinsic difficulty on using these data is the so-called speckle noise involved in coherent acquisition systems. There are many approaches for speckle filtering in single polarization channel and multi-channel extensions investigated in the PolSAR literature. This paper presents an original method for filtering multi-channel complex SAR images based on regularization cost functions that apply in the matrix domain.

2. METHODOLOGY

We consider PolSAR characterization by using coherency matrices of the PolSAR data. This matrix is still corrupted by speckle noise. Assume that we wish to replace this matrix by an arbitrary matrix M. The error cost function associated with matrix M can then be defined as the norm of the difference between matrix M and the above PolSAR matrix. There exist many matrix norms. Among these norms, we consider the Schatten-norm which relates to the sum of the singular values of the difference matrix in our regularization cost function. The filtering strategy then consists in selecting the best matrix M that minimizes the above cost function from neighborhood consideration: in practice, we apply the above pixelwise cost function on pixel neighborhoods and we seek for the matrix M that minimizes the sum of pixelwise cost functions, the pixel under consideration pertaining to the pixel neighborhood. The filtering strategy also uses a recursive Peano-based scan for 2D datasets in order to avoid discontinuities involved in line-per-line scanning.

3. APPLICATION

The filtering strategy can be applied to full polarization SAR images. The data used in this paper is a RADARSAT2 image acquired on January 14, 2010, over Chamonix Mont-Blanc test-site. This testimage is the subimage over Argentière glacier. The considered matrix is the covariance matrix formed from the HH, HV and VV channels or the coherency matrix formed from the 3 channels of the Pauli basis. The p value of p-norm which we have used is 1. The proposed approach is compared to conventional strategies for filtering PolSAR data.

Compact Versus Full Polarimetric SAR for Optimum Target Polarization Information Extraction

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Radar polarimetry has finally reached its golden age with the recent launch of fully polarimetric satellite SARs; TerraSAR and ALOS PASAR with experimental modes, and more recently RADARAT2 with operational polarimetric modes at various incidence angles (between 20 and 50) and fine and standard 9 and 24 m resolution. This stage has been reached thanks to a big effort in research and development being invested since the release of the first polarimetric radar concepts in the 1950th. Recently, the compact mode concept firstly suggested in the 1970th has been resuscitated [1, 2, 10]. Basically, the Compact SAR transmits at a polarization that is a combination of equally weighted horizontal and vertical polarizations (at 45 degree or shifted in phase by 90 degree for a circular polarization). Souyris et al [1] have shown that the compact SAR provides information similar to the one provided by fully polarimetric SAR for azimuthally symmetric targets. They showed that it is possible to reconstruct $\alpha$from the Compact SAR measurements equivalent to the Cloude-Pottier parameters , H, combined with the Wishart distribution lead$\alpha$and H [3]. The reconstructed to a classification of agriculture fields and forested areas similar to the one obtained with a fully polarimetric SAR. Similar conclusions were reached by Raney [2, 6, 10], who promotes particularly the hybrid SAR (transmitting at circular-polarization and receiving at horizontal and vertical polarization) of architecture much simpler than conventional circularly polarized SAR. Other investigations have been conducted since [7-10], and led to the conclusions that "hybrid Compact polarimetric data always approach – and occasionally are comparable to analyzes of quad-pol data [10]". A ranking of the polarization single, dual- , and quad-pol modes was conducted in [9, 10]. Hybrid compact is ranked as the best dual-polarization mode. It was also claimed that it has performance superior to cross-pol HV. As a result, the Compact mode was recommended for the P-band biomass mission as an essential mode that permits accurate biomass estimation while optimizing the swath and data volume. Even though it was not the intention of the Compact initiators [1, 2], all these recent polarimetric-compact comparative studies have raised a big confusion in the SAR community, and there is an immediate need for a fair comparison of quad-pol and compact in terms of key SAR applications, and polarization synthesis accuracy (i.e. signal to noise ratio). In this study, the optimal polarization theory is first reconsidered. The dynamic range of the degree of polarization first used in [11] permits a quantitative evaluation of the information loss related to the dual-polarization compact mode in comparison with quad- pol. Demonstration is conducted using Radarsat2, ALOS, and the CCRS Convair 580 polarimetric SAR to show the significant added value of polarimetric SAR (with reference to compact) for ship detection [12] and forest species discrimination [13]. Recently, we have shown [4] that the target scattering cannot be unambiguously characterized by a real entity, as it is currently done with the Cloude-Pottier decomposition [15]. A new decomposition, the Touzi decomposition [4], was introduced to characterize uniquely target scattering s and phase$\alpha$with a complex entity, the symmetric scattering type of magnitude s is$\alpha\phi$s and the target helicity. It was shown that target scattering phase $\alpha\phi$ αs (equivalent to Cloude αmuch more powerful than scattering type of magnitude for target of symmetric scattering) for wetland classification [6] . In contrast s separate well conifers from deciduous trees during leafy$\alpha\phi$), αs (and $\alpha$to s separates also well poor fens from bogs, two classes that cannot$\alpha\phi$conditions. , and theαs, αbe discriminated using the radiometric information provided by multi-polarization HH-HV and VV [6]. The equivalent parameters reconstructed from Compact polarimetry are generated. It is shown that the Compact parameters lead to a poor classification in comparison with the ones obtained with fully polarimetric information when the polarimetric scattering phase information is fully exploited. The reconstructed Compact parameters from the ALOS data collected over a subarctic peatland on the Wapusk National park are not sensitive to peatland subsurface water in contrast to the original polarimetric data [14]. Finally, compact SAR is compared with conventional single- and dual polarization HH-HV and implications for the design of new missions are considered. References: [1] J.-C. 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Poincare Sphere Representation of Independent Scattering Sources: Application on Distributed Targets

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I Introduction

Blind Source Separation (BSS) aims to recover source signals from their mixture without having any physical knowledge of the mixing process. The linear mixing model assumes that a space dependent vector, representing a certain stochastic process, can be expressed as the product of a vector consisting of the one-dimensional sources and a mixing matrix, that provides the contribution of each source. If the mixing matrix is derived using only second-order statistics to discriminate between sources, they are considered as statistically uncorrelated - Principal Component Analysis (PCA). Otherwise, in case of using higher order statistics, the sources are mutually independent - Independent Component Analysis (ICA).

Most of the existing Incoherent Target Decompositions (Touzi, Cloude and Pottier etc.) rely on eigenvector decomposition of the space averaged coherency matrix. Each eigenvector represents the target vector of a dominant single scatterer, while the corresponding eigenvalue defines its contribution to the total scattering. The eigenvector parameterisation using target scattering vector model (TSVM) ensures roll-invariance in case of both symmetric and non-symmetric targets. Using these parameters, it is possible to represent the dominant single scatterer on the Poincaré sphere. Its physical properties can be inferred based on its position on the sphere.

II ICA in the Incoherent Target Decomposition

The eigenvector decomposition of the scattering coherency matrix could be, with certain constraints, considered as equivalent to the normalized PCA. Namely, by choosing eigenvectors multiplied with the square roots of their corresponding eigenvalues as the columns of the mixing matrix, it is possible to ensure the decorrelation between the sources. The scattering components target vectors are mutually orthogonal in this case.

When dealing with distributed targets, it is necessary to identify integrated scattering mechanisms showing particular electromagnetic behaviour rather than single scatterers present in the scene. Therefore, the idea is to generalise eigenvector decomposition to the level of linear BSS techniques by showing that the proposed TSVM parameterisation could be also applied to the target vectors of statistically independent components, which are not necessarily orthogonal. Through the analysis of both real and synthetic data sets, we show that the application of ICA on the target vector results in different TSVM parameters and it provides a possibility of identifying the most dominant scattering mechanisms even though they are not orthogonal.

Briefly, the proposed method steps are the following:

- Performing appropriate classification and choosing representative target vectors for each class (assuring stationarity);
- Applying ICA (FastICA algorithm) on the selected target vectors;
- TVSM parameterization of the independent scattering mechanism;

Columns of the obtained mixing matrix are considered as statistically independent target vectors, while the corresponding one-dimensional sources provide their weight. The issue to be resolved, whose deliberation starts with this article, is the TVSM parameters roll-invariance property in the case of non-orthogonal vectors. In this context, the ICA derived one-dimensional sources, which are replacing the PCA eigenvalues, have been particularly considered.

III Poincaré sphere representation

As suggested by Touzi, the roll-invaraint TVSM parameters allow orthogonal single scatterers representation on Poincaré spheres. The poles and the characteristic points of the equator on the sphere are defined as orthogonal elementary reflectors (dihedral, thiredral, dipole etc.). The single scatterer positioning on this sphere makes its physical interpretation straightforward.

In this article, the same step is performed but with non-orthogonal, independent scattering mechanisms. That kind of a scattering process, with the dominant components not being orthogonal but independent, can be found in case of a distributed targets in non-urban areas. In our case, the distributed target of interest is the Alpine snow cover. The goal is to identify the characteristic points or areas on the Poincaré sphere, in terms of snow cover and underlying ground physical properties. This is archieved empirically, using quad-pol ALOS L-band and RADARSAT-2 C-band data and appropriate ground thruth data. By this, we are characterizing the physical nature of the target component based on the TVSM parameters.

The long term goal is to use the sphere representation of independent sources to solve the problem of extracting distributed target physical parameters from POLSAR data. Identifying independent scattering components, in terms of their physical properties, could result in having less target parameters affecting the particular component target vector and therefore better estimation.

Wave Propagation Model for Polarimetric Scattering in Mangroves

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Coherent backscatter from mangroves and marshlands has permitted the use of Differential InSAR for determining changes in standing water level. Hong et al. have shown that low temporal decorrelation exists for X., C-, and L-band SAR over multiple revisit periods, where interferograms of high coherence can be produced for HH, VV, and HV polarizations. While providing an extremely useful operational tool for understanding the hydrology of the Everglades, these results pose numerous questions in terms of inconsistencies with respect to polarimetric decomposition, uncharacteristically low temporal decorrelation, and coherency of the HV polarization.

The presumed scattering mechanism for mangroves and marshlands is double bounce between the vegetation and the water. In most polarimetric decompositions, this scattering mechanisms is strongly associated with the T22 element of the coherency matrix, (HH-VV). While Pauli images of the Everglades do show a high T22 element for freshwater sawgrass, T22 is exceedingly low for mangroves. Decomposition would suggest that mangrove scattering is dominated by surface bounce and volume scattering. Thus any model proposing double bounce requires additional scrutiny.

Typically, temporal decorrelation poses problems for interferograms of vegetation. Plant growth, wind, and environmental change serve to severely limit the time period over which interferograms can be generated. Yet despite this, the mangroves and sawgrass of the Everglades exhibit good InSAR coherence over periods as long as 33 days for X-band, 72 days for C-band, and more than four months for L-band. Conventional explanations would seem to necessitate a remarkable amount of stationarity for the structurally-frail vegetation of the Everglades.

Last, HV polarization is usually associated with incoherent volume scattering. Although the observed HV coherence is less than that for HH or VV, its very existence is surprising. Recently, Hong and Wdowinski proposed a rotated dihedral scattering model to explain the scattering conversion. To explain HV InSAR, this paper proposes an alternative mechanism by which Horizontal and Vertical polarizations undergo a coherent rotation.

To address the above challenges, a new model for the interaction of microwaves with the vegetation of the Everglades is proposed. A wave propagation model is introduced that produces coherent backscatter in HH, VV, and HV, thereby explaining the current ability to produce interferograms. A key element of this theory is that it does not require stationarity in the wetland vegetation; a necessary condition for explaining the low temporal decorrelation. Last, by introducing scattering mechanisms that cannot be modeled in the conventional Surface/Double/Volume manner, the theory is able to explain the anomalous polarimetric properties of mangroves. Application of this theory to other as-yet-unexplained scattering scenarios will be discussed as well.

PolSAR Time Series Processing and Analysis based on Binary Partition Trees

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In the last years, the presence of space-borne SAR sensors has empowered the construction of temporal series datasets of SAR images. These datasets consist of a number of acquisitions of the same scene at different times. Moreover, the currently planned SAR missions for the next years, including, for instance, the ESA Sentinel-1 mission, are focused also in building time series datasets. The main advantage of these datasets is the information contained within the temporal dimension, indicating the scene evolution and dynamics during the acquisition time.

We propose to employ the Binary Partition Tree (BPT) [1] data abstraction in order to analyze PolSAR time series. The BPT is a region-based and multi-scale data representation. Recently, it has been adapted to process PolSAR images [2][3][6], demonstrating its usefulness to detect homogeneous regions of the scene. Since it is a multi-scale representation, it may obtain large regions over homogeneous areas while also preserving small spatial details of the image. The BPT may be constructed through iterative merging of neighboring regions. The resulting representation is attractive for a wide range of applications, including filtering, classification, segmentation and object detection. The BPT structure has also been extended, through different approaches, to process PolSAR time series datasets in [4][5].

In this work, two different alternatives to process the temporal dimension of the data will be studied in detail. Basically, the two approaches differ in the temporal characterization of the targets, leading to completely different data representations, having distinct strengths and limitations that will be studied. One the one hand, a space-time data representation is proposed, considering the data within a three-dimensional space-time domain, and, consequently, grouping pixels possibly of different acquisitions with similar polarimetric response. On the other hand, it may be assumed that a target is characterized by a specific temporal evolution of the polarimetric response, leading to a spatial segmentation grouping pixels that follow a similar polarimetric evolution among all the acquisitions.

Additionally, a more detailed analysis will be presented focusing on the temporal evolution of the polarimetric information when employing these BPT data representations. One of the applications that naturally arises when processing time series datasets is change detection. With the proposed technique, scene change maps may be generated indicating the number of changes or their relevance. Moreover, the proposed technique is also able to characterize the detected changes, being able to extract the evolution of the fully polarimetric information in order to interpret the dynamics of the detected changes.

The proposed technique has already been employed to process a real fully polarimetric RADARSAT-2 dataset corresponding to the city of Barcelona, Spain. The obtained results reveal the ability of the BPT to adapt to the temporal dimension and to detect changes in the scene. Furthermore, the obtained change detection and characterization results have been confronted with some on-ground information, as a ground truth, in order to validate them. The scene changes are detected by the technique, especially those related with human activity, including industrial areas and transportation. For instance, the results over the city harbor and the airport will be analyzed in detail. Additionally, the scene changes produced due to construction of buildings are also detected, as will be shown with some photographies of the studied areas. Finally, the ability to detect very localized changes will be also examined.

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The Theoretical Problem of Partial Coherence and Partial Polarization in PolSAR and PolInSAR.

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The difference between partial coherence of an electromagnetic beam versus its partial polarization state has been an issue that has aroused interest again in the last decade [1], after a period in which this question had been assumed as settled, and, in the area of radar remote sensing, has been the subject of study by the author of this paper in [2]. In the latter work, this distinction, together with the analysis of the meaning of statistical independence of different scatterers in a SAR image resolution cell, was used to assess the well-known polarimetric theory (PolSAR) developed by Cloude and Pottier. In the present contribution, this subject is presented with the help of some numerical experiments of scattering phenomena both in the shape of rough surfaces and volume scatterer distributions.

We also turn our attention to the consequences of these developments in polarimetric SAR interferometry (PolInSAR). This is an important question, since both coherence and statistical independence between scatterers or scattering clusters can be based on the information gathered at two or more different points, whereas correlations at a single point of the different vector components account for estimating the degree of polarization. Therefore, it is plausible that PolInSAR be suitable to describe coherence, at least in Wolf's sense [2]. In particular, the ability of the SVD-based decomposition in PolInSAR is studied at the light of Refregier and Goudail's work on the definition of polarization-invariant degrees of coherence. Since coherence is a good indicator of statistical independence, this decomposition would seem as an adequate estimator of the presence of different scattering mechanisms and their mutual phase relationships. However, we demonstrate that PolInSAR methods as presented in [3] are potentially hindered by the inherent Hilbert-Schmidt orthonormalization process.

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Scientist's Idealism versus User's Realism for Ortho-Rectifying Full/Compact Polarimetric Data of Radarsat-2/RCM

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The user's realism in extracting thematic information of EO data required to perform the geometric processing before the radiometric processing. On the other hand, the scientist's idealism required to perform the radiometric processing in the original slant-range geometry before the geometric processing because resampling the complex data can corrupt the polarimetric phase. Therefore, the user's realism by ortho-rectifying the polarimetric SAR complex data cannot be performed without a lost of the polarimetric information and any derived parameter and data. However, some major disadvantages of the scientist's idealism for the users are: if the analyzed results in the GIS are not satisfactory for any reason, such as an error or an inappropriate parameterization of the large number of varying parameters in the polarimetric processing, the full method (polarimetric and ortho processing) has to be performed again, resulting in an inefficient practice of the polarimetry for the users. It could largely refrain the operational use and applications of polarimetric data.

To close-up these two viewpoints (scientist versus user), this presentation will compare the two methods with different full polarimetric data of Radarsat2 (R2) and simulated compact polarimetric data of the next Radar Constellation Mission (RCM). The presentation evaluates the variations in the polarimetric information, if any, and the conditions of variations as a function of different geometric and radiometric parameters, such as the multilooking, the look angles, the terrain slopes and the DEM accuracy. A roll-invariant polarimetric scattering parameter, the entropy, sensitive to variations of the polarimetric information is used for the comparison of the two methods. The entropy H, which defines the degree of statistical disorder of each distinct scatter type within the ensemble, provides thus an efficient and suitable basis-invariant parameter.

Global error statistics of relative differences ¥ÄH was first computed over the full images to describe the difference over the study site. While there is no written consensus in the polarimetric community about any significant threshold in the entropy variation, the user's community of polarimetry seems to accept that 10% relative sensitivity in H is not significant for the post-processing and polarimetric classification, which are largely satisfied with 90% accuracy due to different issues in accuracy assessment. While this threshold can be further discussed, the results were thus evaluated as a function of the relative ¥ÄH larger than 10% as a function of terrain slopes and land cover.

The tests over three fine quad polarimetric R2 data demonstrated that the user's realism and method can generate some entropy errors resulting in small loss in polarimetric information, which are correlated with the look angles, the preprocessing (single-look vs. multi-look), the terrain slopes and the accuracy of the DSM. In general, (i) the shallower is the look angle, the smaller is the lost of polarimetric information; (ii) the multilook preprocessing largely reduced the global errors to a non-significant level (2% to 1% with decreasing look angles); and (iii) the loss in polarimetric information is correlated with the DEM accuracy and the slopes. For FQ SL data the global error percentage climbs to 8% to 4% in the same acquisition conditions than (ii). On the other hand, only the ter-rain slopes larger than 22¨¬ and steep SAR look angles could result in local errors higher than 10%, especially with low-accurate DEM, certainly due to the layover. This potential layover problem should thus be verified with shallower look angles over steeper relief. If the original hypothesis of "10% error does not impact the post-processing and classification of polarimetric data" is valid and acceptable, the user's realism and method can be safely applied to polarimetric data, whatever the SAR look angles, the DEM accuracy (better than 10 m) and the terrain slopes, as soon as they were preprocessed as multilook. In these conditions, 98-99% of ML data will not have errors larger than 10%. Nonetheless, there are some few limitations of the user's realism and method using the single-look data at the layover limit and especially with low-accurate DEM. The scientist's idealism and method should thus be preferred with such data set combination.

The tests over three simulated RCM very-high-resolution compact polarimetric data in single look demonstrated that the user's realism and method cannot be used due to large losses in compact polarimetric information whatever look angles and terrain slopes. Both the large noise (-17dB) and the oversampling (from 8 m to 3 m) of simulated compact polarimetric data largely contributed to more than 95% in these polarimetric losses. The scientist's idealism and method should thus be preferred with such RCM singlelook data.

On the Accuracy and Conditioning of Polarimetric Calibration Methods

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Polarimetric SAR data is receiving continuously growing attention in the last years, thanks to the benefits provided with respect to traditional single-channel acquisitions. In order to preserve of the real characteristic of the observed data, the distortions introduced by the system and the propagation medium should be removed. Traditionally, the interest is both in calibrating the data and in estimating the distortions (or calibration) parameters, that are useful to monitor the acquisition system itself. By this point of view, the accurate calibration of Polarimetric SAR data is not trivial task, and there are cases for which data can be calibrated but calibration parameters cannot be retrieved without ambiguity. The number of parameters which has to be estimated and the non-linearity of the solving equations make difficult the correct estimation of such unknowns without the use of suitable assumptions. The use of some assumptions is therefore needed, in order to provide a prior conditioning of the problem.

A number of approaches have been proposed in the last two decades for accurate Polarimetric SAR data calibration, based either on the use of Distributed Target alone and on the use of Distributed Target jointly with a target with known radar cross section, such as a trihedral Corner Reflector. All these approaches make explicit assumptions on the target symmetry (equal contribution of the cross-polarized channels), on the system distortion configuration (symmetric cross-talk) or on the atmospheric condition (absence of Faraday Rotation).

In this paper, two main contributions are proposed. Firstly, an accurate study of the problem is conducted from the theoretical point of view. A feasibility analysis is conducted over some realistic scenario aimed to assessing the conditioning of the solution for retrieving calibration parameters under the assumption of small errors. This assumption allows us to linearize the equations close to the optimum. The possibility to solve the problem in the parameters' space close to the correct configuration is investigated, along with the prior conditioning needed to have a well-posed problem.

Then, if prior information about the distortion parameters is retrieved, a numerical solver can be used to obtain a correct estimation of the unknowns. This is the second contribution proposed in this work. The proposed optimization exploits the relationship between the distorted data covariance matrix and the covariance matrix of the original data, weighted by the distortion parameters.

Several tests have been conducted considering both synthetic data and real L-band airborne data. The proposed methodology gave very encouraging results in terms of accuracy in comparison to the traditional approaches, with a computational time in the order of seconds.

SNR and Noise Variance Estimation in Polarimetric SAR Data

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The problem of estimating the signal-to-noise ratio (SNR) of the cross-polarised channels and the noise variance in polarimetric synthetic aperture radar (SAR) data is dealt with. The Cramer-Rao Lower Bound (CRLB) is evaluated and a maximum likelihood (ML) estimator is derived, which jointly estimates the SNR of the cross-polarised channels and the noise variance. The performance of the joint estimator is assessed and a comparison with a coherence-based (CB) SNR estimator and an eigenvalue-based (EB) noise variance estimator is carried out. As far as the SNR estimation is concerned, both the ML and the CB estimator are biased, but the bias of the ML estimator is smaller than the bias of the CB estimator, while the accuracies are very similar. As far as the noise variance estimation is concerned, the ML estimator is unbiased and its variance is equal to the CRLB, while the EB estimator is biased. The difference in the biases is also shown using TerraSAR-X fully-polarimetric data, acquired during the Dual Receive Antenna (DRA) campaign.

NOTES:

Day 2, Tuesday 29 January 2013

Session - Polarimetric SAR Interferometry (Pol-InSAR)

Interpretation of Single-Pass Pol-InSAR Vegetation Signatures at X-Band: Dual- vs. Quad-Pol Case

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The analysis of the phase centre locations in early airborne high-resolution single-pass (Pol)-InSAR at X-Band indicated - in contrast to what was "believed" at this time - significant penetration depths not only into sparse but even in medium and dense vegetation. This new understanding triggered a number of case studies for the estimation of vegetation parameters from single- or dual-Pol-InSAR airborne measurements at X-band with surprisingly successful results indicating the potential of Pol-InSAR techniques at X-band [1, 2]. However, the lack of quad-pol and multi-baseline data sets and/or the presence of temporal decorrelation left many questions open as for example which mechanism causes volume decorrelation: Is it penetration meaning a continuous volume case or the presence of forest gaps referring to a discrete volume case associated to the high spatial resolution of the sensors?

TanDEM-X is the first space-borne single-pass Pol-InSAR instrument operating in dual-pol mode. Since 2010, it acquires data primarily for generating a global DEM with high accuracy. Indeed TanDEM-X allows investigating the performance of forest height inversion by means of the Random Volume over Ground model (RVoG) in a large number of sites [3, 4] but did not allow a direct validity assessment of the used inversion models. The validation of the RVoG model in terms of the shape of the coherence region is possible only when quad-pol data are available. In the two-dimensional case the coherence region is always elliptic.

DLR's F-SAR is the first operational single-pass quad-Pol-InSAR airborne instrument for X-Band. It operates in a single-pass quad-Pol-InSAR mode with a spatial baseline of about 1.6 m at a bandwidth up to 800 MHz. F-SAR data allows for the first time to investigate the three-dimensional coherence region and to draw conclusions about the validity of the different Pol-InSAR inversion models. In this paper we investigate scattering and propagation characteristics at X-band using single-pass quad-Pol-InSAR data over different test sites. We interpret quad-pol coherence regions over vegetation scatterers and draw conclusions about the validity and constraints of different Pol-InSAR inversion models for a variety of vegetation conditions. Individual scattering mechanisms are interpreted in terms of the polarimetric scattering angle alpha and associated to their location within the vegetation i.e. the associated penetration depth.

In a second step we compare the quad-Pol-InSAR (F-SAR) signatures against dual-Pol-InSAR (TanDEM-X) signatures and discuss the effect of the differences in acquisition geometry and system specifications (e.g. NESZ). Based on this we are able to understand the information content and potential of Tandem-X data in a better way. Finally, we generalise the quad- vs dual-Pol-InSAR discussion evaluating optimised dual-pol configurations and comparing them to the quad-pol case.

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Tackling temporal Decorrelation with the RMOG Model

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In this paper we present our latest developments and experiments with the random-motion-over-ground (RMoG) model [1, 2] used to extract canopy height and other important forest parameters from repeat-pass polarimetric-interferometric SAR (Pol-InSAR) data. More specifically, we summarize the key features of the RMoG model in contrast with the random-volume-over-ground (RVoG) model [3], describe in detail a possible inversion scheme for the RMoG model and illustrate the results of the RMoG inversion using airborne data collected by the Jet Propulsion Laboratory (JPL) and the European Space Agency (ESA).

The success of Pol-InSAR in monitoring forests using repeat-pass radar data is predicated on understanding temporal decorrelation and having robust algorithms that compensate for its effects. Users of forthcoming radar missions, such as ALOS-2, and proposed missions, such as BIOMASS and DESDynI, will face the problem of temporal decorrelation inevitably. This motivated us to investigate the potentials and limitations of the RMoG model and to design an algorithm that helps the ecosystem science community to monitor forests at regional and global scales using Pol-InSAR technique and radar technology.

Canopy height has been traditionally extracted from measures of volumetric coherence [3]. In a repeat-pass scenario, however, the radar collects data at different times, and the dynamic changes occurring in the forest corrupt the coherence resulting in large errors when forest parameters are estimated. In previous approaches, temporal decorrelation was estimated from external data (e.g. zero-baseline data) and then removed from long-baseline data to isolate volumetric decorrelation. This approach has two major limitations. First, temporal decorrelation is not a systematic effect, therefore the level of temporal decorrelation estimated from one dataset is not necessarily applicable to other datasets. Secondly, temporal decorrelation is considered a real-valued number, which does not compensate for complex phenomena, leaving the estimates with large uncertainty.

In the proposed approach, we do not try to remove temporal decorrelation from the data. Instead, we model temporal decorrelation and extract the canopy height from measures of temporal-volumetric coherence. The extraction is based on the RMoG model, which relates a small number of forest parameters to the temporal-volumetric coherence. In the RMoG model the vegetation is idealized as a two-layer scenario constituted by a penetrable layer of randomly oriented scattering elements (i.e., the canopy layer) above a dielectric rough surface (i.e., the ground layer).

The scattering formulation of the RMoG model is based on the RVoG model, which was designed to predict the volume coherence in single-pass interferometry [3]. To extend the model to repeat-pass interferometry and account for temporal decorrelation, we assume the temporal changes in the canopy layer and on the ground surface to be caused by a Gaussian-statistic motion of the scattering elements. The RMoG model is derived considering the first-order expansion of the function that defines the motion along the vertical direction in the canopy layer. The assumption of first-order Gaussian-statistic motion has been validated with zero-baseline Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) data [1].

In the RMoG model the polarimetric-interferometric coherence is predicted by 6 real parameters: the ground topography, the canopy height, the mean wave extinction, the ground-to-volume scattering ratio, the motion variance of the scattering elements at ground level and the motion variance of the scattering elements at a reference height in the canopy layer. The key feature of the RMoG model is the dependence of temporal decorrelation on polarization and on vegetation structure. This feature makes the model attractive for the inverse problem.

We designed a possible RMoG inversion scheme using a least-square optimization approach based on the interior-point algorithm. Tests of the inversion algorithm were conducted on numerical simulations and actual L-band UAVSAR data collected over Harvard Forest in Massachusetts (United States) [2]. We have also obtained data from the BIOSAR campaign series and TROPISAR campaign and we plan to test our RMoG model-based algorithms on these data. We will illustrate the outcome of these additional experiments and discuss the implications for the exploitation of forthcoming satellite radar data.

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Tandem-L for Vertical Forest Structure Monitoring From Multibaseline Multipolarimetric L-Band SAR Data

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Tandem-L is a German mission proposal for an innovative interferometric L-band radar mission that enables the systematic monitoring of dynamic Earth processes using advanced techniques and technologies. The mission is science driven aiming to provide a unique data set for climate and environmental research, geodynamics, hydrology and oceanography. Important application examples are global forest height and biomass inventories, measurements of Earth deformation due to tectonic processes and/or anthropogenic factors, observations of ice/glacier velocity field and 3-D structure changes, and the monitoring of ocean surface currents. The Tandem-L mission concept consists of two cooperating satellites flying in close formation. The Pol-InSAR and repeat-pass acquisition modes provide a unique data source to observe, analyse and quantify a wide range of mutually interacting processes in the bio-, litho-, hydro- and cryosphere. The systematic observation of these processes benefits from the high data acquisition capacity and the novel high-resolution wide-swath SAR imaging modes that combine digital beamforming with a large reflector antenna [1].

In particular, the monitoring of forest vertical structure is one of Tandem-L objectives. Indeed, vertical structure is widely recognized to be an indicator of the above ground biomass, whose knowledge is very important to understand the global carbon cycle. Moreover, vertical structure allows the characterization of the state of a forest ecosystem in terms of biodiversity, degradation and regeneration. Within this framework, the employment of space borne synthetic aperture radar (SAR) systems results to be particularly suitable as they can acquire data continuously with large coverage, beside the possibility to reach areas in which extensive and continuous ground measurement are difficult, if not impossible. In addition, L-band radar signals are a rich source of information given their penetration capability. Although the application of multibaseline-multipolarimetric SAR tomographic techniques to the estimation of forest structure is rather new and still in an early development stage, many analyses have been carried out to understand pros and cons of each method [2]-[8]. In general, the goodness of the results (in terms of vertical resolution, stability and robustness) depends critically on the number of images available.

This work, after a review of the Tandem-L mission concept and study at their present status, further evaluates the capabilities in the monitoring of forest vertical structures offered by multipolarimetric SAR data acquisitions with a low number of baselines. In particular, the role of polarimetry is further evaluated as concerns structure interpretation, which is still an underdeveloped element. The potentials will also be addressed of parameterizing the vertical structure function using a limited number of parameters, a challenging step when accounting for the complexity of forest structures. Beyond classification purposes, such a structure parameterization could also have applications in the monitoring of biomass dynamics in time. Experimental results will be shown by processing multibaseline fully polarimetric data acquired by the DLR airborne platform E-SAR in the frame of relevant campaigns over different forest scenarios.

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Polarimetric-Interferometric Studies at La Amistad International Park

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La Amistad International Park is a World Heritage Site and a Transboundary Protected Area in Latin America jointly managed by Costa Rica and Panama. The park covers 401,000 ha of tropical forest and is the largest nature reserve in Central America. The area with a 15 km buffer zone represents a major biodiversity resource at both regional and global levels. On February 8, 2010 UAVSAR collected a series of repeat pass lines with a variety of physical baselines. Baseline lengths varied from 20 m to 1000 m with temporal baselines from 40 minutes to several hours. Data were collected on flight lines that extended from the Pacific coast to the Atlantic coast across Central America to cover a wide range of biomes and terrains. Data were also collected on opposite headings for look direction diversity particularly useful in the high relief regions in the central portion of the flight lines. We have processed a combination of both short and long baseline pairs for analysis that show interesting temporal correlation behavior as well as illustrating PolinSAR techniques through a variety of biomes. Comparisons with IceSAT tree height data will be presented.

This research was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Polinsar and Multifrequency Image Acquisition with the F-SAR Airborne SAR Instrument

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The F-SAR airborne SAR instrument represents the successor of the E-SAR system of the German Aerospace Center (DLR), which has been extensively used in the last three decades. Its development was triggered by the current demand for data being simultaneously acquired at different wavelengths and polarisations, as well as by the demand for very high resolution in the order of decimetres. F-SAR is a modular development utilising the most modern hardware and commercial off the shelf components. With the recently completed X-band single-pass interferometer and the P-band subsystem, F-SAR is now ready for operational purposes.

F-SAR is designed to operate fully polarimetrically at X-, C-, S-, L- and P-bands and provides single-pass polarimetric interferometric capabilities in X- and S-bands. Additionally, up to four bands can be acquired simultaneously, with some limitations even in polarimetric acquisition modes. For regular Earth observation purposes the radar covers an off-nadir angle range of 25 to 60 degrees at altitudes between 3000 and 6000m above sea level, which is the maximum operating altitude of the utilised DO228 aircraft. For special purpose, other off-nadir angle can be realised technically.

This paper aims to present first results of single-pass polarimetric interferometry at X-band. The X-band across-track interferometer of F-SAR has a mechanical baseline of approx. 1.60m and offers spatial resolution of up to 25cm in both range and azimuth. In 2012, several data sets have been acquired over the test-sites of Kaufbeuren, Traunstein and Juist (Germany), possessing various vegetation types from low bush land to dense forests. Up to now, the potential of X-band PolInSAR for vegetation height estimation remained unknown due to the limited penetration capabilities at X-band; the analyses in this paper offer some first insights about realistic limits and potential at this frequency.

A second objective of this paper is to present results of simultaneous multi-frequency image acquisitions with F-SAR. Basically, two different data sets have been analysed: simultaneously acquired X/S-band fully polarimetric data, as well as simultaneously acquired X/C/L-band at different polarimetric modes. This allows a direct comparison of the polarimetric signature of a wide range of natural scatterers at different frequencies. This is of special interest at S-band which is in practice an unexplored frequency band. In this sense, the polarimetric signatures at S-band are compared and discussed against the ones in the other frequency bands and used also to draw conclusions about potential PolInSAR performances.

NOTES:

Day 2, Tuesday 29 January 2013

Session - Polarimetric SAR Interferometry (Pol-InSAR): Forest

Assessment of single baseline PolInSAR in tropical Context for Vegetation Characterisation

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The TropiSAR campaign was conducted in French Guiana in the summer 2009 in the framework of the Phase A studies pertaining to the BIOMASS mission, one of the three for Earth Explorer candidates with the SETHI radar operated by ONERA. The inversion techniques, proposed for BIOMASS include radiometric inversion to access biomass level and polarimetric interferometric (PolInSAR) approach to evaluate the vegetation height.

In this paper we concentrate on the PolInSAR inversion addressing two main issues.

The first one concerns the temporal stability of the polarimetric response. This is a crucial aspect as the interferometric processing requires two acquisitions which will happen in two successive cycles for BIOMASS. Several studies have shown that at C and L band over forests the interferometric coherences are strongly affected by the temporal baseline. The consequence being that at these frequencies, only a single pass system could be used with a zero temporal baseline. At P band, this study needs to be conducted over tropical forest and the TropiSAR dataset is used to that purpose.

The second aspect is to assess the precision of the estimation on the vegetation parameters from single baseline PolInSAR data in this tropical context. The estimation quality is assessed by comparing the output of the inversion to lidar data. The influence of the acquisition geometry on the estimation precision is discussed both for the undercanopy terrain height and the vegetation height. Several studied have suggested that the interferometric height measured with the HH polarisation channel is close to the ground and can be used in some cases to provide a meaningful terrain elevation model. This will be discussed in the presentation and measured with different interferometric configurations. Based on the PolInSAR inverstion, we can separate the ground and volume backscatter contributions. These contributions have a polarimetric signature which allows us to explore further the wave interaction with the forest. The analysis will be presented and will point how topography influences the ground response. Finally, the last point to be addressed in this paper is the effect of resolution. BIOMASS has a low resolution resulting from the limited frequency allocation of 6MHz at 335MHz. The TropiSAR bandwidth is 150MHz; the resulting resolution being 25 time finer that the BIOMASS resolution. We will discuss how this loss of resolution can affect the inversion results.

Impact of Geophysical Changes on the Pol-InSAR Phase Center of Tropical Dense Forests

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To estimate forest height, Pol-InSAR retrieval is based on the measurement of the complex polarimetric and interferometric coherences which can be described as a function of the medium extinction, the ratios between scattering mechanisms, the ambiguity height and forest height.

In the case of multi-pass configuration, the Pol-InSAR coherences are also impacted by temporal decorrelation due to changes of the forest between the two or several acquisitions. To account for temporal decorrelation, it is often assumed, that only the amplitude of the coherence is affected.

Nevertheless, the phase center is likely to be also impacted, as pointed out in this paper. Considering geophysical changes in terms of permittivity values and wind displacements of the scatterers, electromagnetic (em) simulations using MIPERS -- Multistatic Interferometric Polarimetric model for Remote Sensing -- have been performed in order to assess quantitatively the temporal decorrelation, and its consequence on the phase center. The analysis of the scattering contributions participating to the backscatter shows that the phase center variations lie in the fact that all the scatterers are not similarly impacted by the geophysical changes and that the resulting complex coherences are governed by the most stables among them.

These simulations have been conducted to interpret the results of the Tropiscat experiment, a low frequency scatterometer (P to L-band with Pol-InSAR and tomographic capabilities) installed on the top of the Guyaflux tower, overlooking the Paracou forest in French Guiana. This experiment is operating since August 2011 to study how forest scattering evolved with time, and thus to study temporal decorrelation. As a matter of fact, the effects of diurnal changes (related to dielectric properties, temperature and wind disturbance) on the complex coherences have been pointed out. Along with our em simulation results, this analysis shows that geophysical changes can significantly impact the magnitude but also the phase of the Pol-InSAR coherences and explains the resulting error in the retrieved height. Following this analysis, further work will be carried out for the design of Pol-InSAR acquisition campaigns and for Pol-InSAR height indicator reducing these temporal changes.

Pol-InSAR Techniques for Forest Characterization with TanDEM-X

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Pol-InSAR techniques have been successfully applied to TanDEM-X (TDX) data as described in [5] and [6] using different interferometric acquisition modes. The TanDEM-X mission provides three interferometric acquisition modes [7]:

- Monostatic Mode: In the very early mission time satellites were flown in a loose formation with a 20km along track separation that corresponds to a 3sec temporal baseline. So each satellite can operate on its own. In this mode temporal decorrelation effects may appear even for temporal baselines in the order of seconds. This mode offers single pol as well as dual pol acquisitions in the standard operation mode of the mission
- Bistatic Mode: The satellites fly in a close formation. In this mode one satellite transmits and both satellites receive allowing single pol as well as dual pol acquisitions.
- Alternating Bistatic Mode: In this mode the satellites alternate with the signal transmit. This means: the first satellite transmits a signal, both satellites receive the signal then the second satellite transmits and both satellites receive again the signal and so on. This provides four acquisitions of a scene which can be combined to two (by a factor of two) different interferomtric baselines. Alternating bistatic acquisition providing two interferometric baselines can be only acquired in a single polarization.

So far TDX data for forest applications have been only analyzed for the monostatic and the bistatic mode. [5] describes the effects of temporal decorrelation on TDX monostatic data and in [6] a first analysis of TDX bistatic data is presented. Both articles demonstrate Pol-InSAR height inversion [4] for a boreal forest test site (Krycklan in northern Sweden) using either a dual pol acquisition or a single pol acquisition in combination with an external terrain DEM [5].

In this paper the potential of TanDEM-X for forest applications with data acquired in the alternating bistatic mode should be investigated. For this several alternating bistatic acquisitions in HH as well as in VV polarization for different test sites are analyzed for their suitability on forest parameter estimation. It is also planned to develop a single-pol dual-baseline height inversion algorithm [1][3][4].

Analysis of several acquisitions over the same test site revealed different scattering behavior for different seasons. Scattering behavior is best described by the penetration depth or the polarimetric distance i.e. the maximized interferometric distance between two polarizations. Strongest differences in the seasonal scattering behavior were detected between summer and winter in the case of boreal forests and between wet season and dry season in the case of tropical forest systems.

Investigations on seasonal changes in scattering are ongoing. Different forest systems (from boreal to tropics) will be analyzed and results will be presented in this paper. This includes also the detection of changes (manmade or natural disturbances) in forest systems with TanDEM-X. [1] R.N. Treuhaft, S.N. Madsen, M. Moghaddam, and J.J. van Zyl, "Vegetation Characteristics and Underlying Topography from Interferometric Data", Radio Science, vol. 31, pp. 1449-1495, 1996.

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A Maximum Likelihood Analysis of the RVoG Model for Forestry Studies in Polarimetric SAR Interferometry

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Forests study and characterization is a crucial field of research, as well as a generator of economical activity in a wide range of applications, as for instance, forest management and conservation, biomass estimation, illegal logging, disaster and fire management or stand delineation. Taking into account that forest areas cover approximately 30% of the Earth's solid surface, any attempt to provide forest information beyond a local scale, needs to consider remote sensing techniques based on airborne or spaceborne platforms. Due to the capability of microwaves to penetrate vegetation, radar, and specially Synthetic Aperture Radar (SAR), represents nowadays an established technology to provide quantitative information about forests.

Polarimetric SAR Interferometry (PolInSAR) has been demonstrated to be a convenient remote sensing technique for the study and characterization of the three dimensional forest structure, making possible, for instance, to estimate forest height or to estimate the complete three dimensional scattering profile. The potential of PolInSAR to perform quantitative remote sensing in forest areas has been already demonstrated, experimentally, based on airborne SAR data at a regional scale. Nevertheless, with the objective to perform global forest mapping, space PolInSAR measurements are necessary. Currently, the Tandem-X mission presents a PolInSAR experimental mode at X-band that makes it possible this analysis. There exist also future mission concepts like Biomass (P-band) and Tandem-L (L-band) that focus specifically on the study of forests by means of PolInSAR data.

The quantitative estimation of forest parameters needs to be based on the inversion of coherent scattering models. The use of these models, focused on a simplification of the forest scattering process, makes it possible to fit the number of parameters to be estimated to the limited number of radar observables. In microwave forest scattering, a particularly useful model, named Random Volume over Ground (RVoG), was introduced in [1], considering PolInSAR data. This model was employed later on for the quantitative estimation of forest parameters as the forest height [2], based on the linear behavior of the complex interferometric coherence as a function of polarimetry.

Despite forest height inversion has been demonstrated for different types of forests and different frequencies, a question that remains unanswered is the validity of the RVoG model. Indeed, the estimation of the forest height, as mentioned above, has been employed as an indirect demonstration of the validity of the RVoG model assumption. Nevertheless, the lack of a direct mechanism to prove the validity of this assumption prevents from an accurate analysis of the forest scattering process.

Recently, the authors have derived the Maximum Likelihood Estimator (MLE) of the RVoG model, under the assumption of PolInSAR data to be distributed according to the zero-mean complex Gaussian distribution [3]. This maximum likelihood study makes possible to derive two important results. First, to derive the MLE of the 6x6 coherency matrix T under the assumption of the RVoG model, so the estimated coherences through this model describe a line in the complex plane. In addition, two Maximum Likelihood Ratio Tests have been derived that allow testing the validity of the hypothesis of the RVoG directly from the measured data. The objective of this contribution is twofold. First, to detail the basics of this analysis and especially to continue the study of the different tests and filters to show how their use may improve the estimation of different forest parameters. The second objective, and representing contribution of this work, shall be to apply the RVoG model validity tests to different type of forests and data sets to determine the validity of the RVoG as a function of frequency, incidence, angle forest type, etc...

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First Pol-InSAR Forest Height Inversion by means of L-band F-SAR Data

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Polarimetric Synthetic Aperture Radar Interferometry (Pol-InSAR) has been developed to a powerful technique for quantitative forest applications, based on the combination of two important SAR measurements: Interferometry and Polarimetry. The coherent combination of polarimetric and interferometric information provides the separation and the identification of different scattering contributions within the resolution cell. In last decade, a variety of quantitative models for the estimation of forest parameters from Pol-InSAR data, as the Random Volume over Ground (RVoG) model, have been developed and demonstrated mostly using airborne SAR systems.

The F-SAR sensor is the next generation of the well-known DLR's E-SAR system and provides higher resolution, fully polarimetric and interferometric SAR data in multi-frequencies (X-, C-, S-, L- and P-band). Currently, the repeat-pass L-band F-SAR system was completed. The fully polarimetric and interferometric SAR data were acquired over the Traunstein in the southeast of Germany in 2011. The Traunstein has been the test site for previous E-SAR campaigns: TreeSAR 2003 and TempoSAR 2008 and 2009. In this sense, F-SAR system allows the successive forest monitoring, application, validation and development of the Pol-InSAR techniques.

In this paper, first the actual status of multi-baseline Pol-InSAR techniques is reviewed and then the potential of the new F-SAR system for Pol-InSAR forest applications is discussed. This study is supported and validated by using fully polarimetric and interferometric data sets acquired by repeat-pass L-band E-SAR and F-SAR systems.

Estimation of Canopy Height using UAVSAR Data in the Réserve Faunique des Laurentides and Penobscott Forests.

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We demonstrate the use of the polarimetric interferometric synthetic aperture radar (polinSAR) technique to estimate forest canopy height with the new Uninhabited Airborne Vehicle Synthetic Aperture Radar (UAVSAR) system over temperate and boreal forests of Maine and Québec to obtain canopy height. The UAVSAR is an L-band fully polarimetric airborne radar system that enables repeat-pass interferometry, flying at an altitude of 12.5km and within 5m of the planned flight tracks. Data were collected in August 2009 in temperate and boreal forests in the state of Maine and province of Québec.

The Réserve Faunique des Laurentides is characterized by a 1000 m altitudinal gradient and exhibits a smooth transition from mixed deciduous temperate to boreal coniferous forests. Forest composition is typical of the boreal mixed wood zone. We focused on a study site with elevations ranging from 700 to nearly 1000m. The Réserve Faunique des Laurentides is also the first of a set of active sensor calibration super sites. On the other hand, the Penobscot region of Maine is dominated by mixed conifers but is more diverse than forest farther north. While the Penobscott experimental forest is protected, the surrounding region contains small-plantations, multi-generation clearings as well as large natural stands. This study site exhibits a relatively smooth topography (<60m).

We validated the polinSAR model inversion of canopy height using field measurements of canopy height collected with a clinometer. In addition, we used data from the Laser Vegetation Imaging Sensor (LVIS) airborne system. LVIS records the full waveform over a footprint of 20m and we use the relative height of the 100th percentile energy (RH100) to represent the top canopy height. We compared the field measurements with the tallest LVIS shot and UAVSAR polinSAR point within an arbitrary 20 meters radius to account for field geolocation errors. We found least square linear fits with correlation coefficients of 0.94 and 0.93 for the closest and tallest neighborhood RH100 estimate respectively. For the polinSAR height, we found correlations of 0.88 and 0.94 for center and neighborhood maximum respectively. The root mean square (rms) errors are respectively 2.0, 2.4, 2.2 and 1.8 meters. The accuracies for both RH100 and polinSAR are close to the field measurement error for a single tree which we estimate to be 10% of the height with a clinometer, i.e. from 1 to 2.5 meters.

The UAVSAR system is a NASA facility instrument that routinely collects data, generally to study ground deformation. We demonstrated the potential of UAVSAR fast repeat-pass interferometry to accurately map forest canopy height at the landscape scale through polinSAR. It is expected the results presented in this paper will significantly improve estimates of biomass at the landscape scale. These results also open a new field of applications in terrestrial ecology and biodiversity in North America.

A Study of Tandem-X PolInSAR Variation over a Forested Area

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The hypothesis for this study was that a co-pol InSAR DEM will be lower than a cross-pol InSAR DEM over forested areas, because the co-pol is more influenced by the terrain and the tree stems, while the cross-pol is dominated by foliar scatterers such as leaves and branches. If this is the case, PolInSAR would have a potential for forest monitoring, including forest health monitoring because the height separation between co- and cross-pol DEMs would decrease with increasing crown defoliation. A bi-static, dual-pol (HH+HV) acquisition by Tandem-X was carried out over a forested area in Norway summer 2011. The HH and HV channels are processed separately into two DEMs using the interferomtric processing tool in ENVI/Sarscape. A high quality DTM generated from airborne laser scanning (ALS) was subtracted from the co- and crosspol DEMs, resulting in two data sets of InSAR height (IH_HH and IH_HV), i.e. the height above ground of the co- and cross-pol backscatter centers. We have studied the height separation between the cross- and co-pol DEMs, as well as how both InSAR heights vary with forest biomass and tree height. The results show that InSAR heights in general correspond well with forest variables like biomass and height. The HH DEM was in general lower than the HV. This was pronounced in in topography related low backscatter - low coherence areas in forests, i.e. in hillsides facing away from the SAR sensor. The height separation was minor in high coherence agricultural areas. This shows that the artefact effects of topography, backscatter intensity and coherence seems to dominate the height separation. In the continuation of this work we will remove the artefact effects and re-estimate the relationship with variables like canopy height and canopy density (leaf area index).

Investigation of the Capability of Compact Polarimetric SAR Interferometry to Estimate Forest Height

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Full Polarimetry(FP) has explored a more novel method and idea in target detection, natural surface parameters estimation, topographic measurement, and analysis; it has advantages that a single polarimetry cannot provide. However, this mode increases the complexity, cost, mass, and data rate of the SAR system, the image swaths decrease to half, resulting in reduced coverage and a degraded revisiting time. Compact polarimetric (CP) synthetic aperture radar (SAR) system, which transmits only one polarized wave and receives two orthogonal backscatter waves, overcomes those drawbacks of fully polarimetric SAR systems, effective CP modes, i.e., CTLR mode which transmits circularly-polarized wave while both H and V polarization waves are coherently received, have been proposed.

Several preliminary experiments used polarimetric data at L-band or P-band have been performed to investigate the potential of CP Interferometric SAR(C-PolInSAR) to estimate forest height; one of the most widely used methods is based on the reconstruction of F-PolInSAR covariance matrix C6 from C-PolInSAR covariance matrix J4. Souyris et al. have confirmed the ability of CP mode data to reconstruct FP covariance based on the assumption of medium symmetry. M.Lavalle et al. have derived the expression of the reconstructed covariance matrix C6 from compact covariance matrix J4. In this paper, two refined algorithms based on matrix C6 are introduced to estimate forest height.

First, we will revisit the reconstruction algorithm proposed by M.Lavalle, and derive the detailed expression of matrix C6. Then two forest algorithms will be applied, respectively.

Although the covariance matrix C6 has been obtained, the three-stage algorithm cannot be used straightforwardly, because targets in forest may not always hold the symmetry hypothesis, this uncertainty will leads the coherence exceed 1 in some circumstances, then the algorithm fails. A refined experimental scheme will be proposed to deal with this uncertainty. To obtain a more accurate ground scatter phase, a total least square (TLS) line fit algorithm will replace the conventional least square line fit algorithm in the ground scatter phase estimation step, the TLS algorithm takes error of real part and imaginary part take into consideration and has more fitting precision. The inversion forest height show a good fit with the ground test and confirm the capability of the refined algorithm.

Another method in this paper is hybrid algorithm, this algorithm combines ESPRIT and three-stage algorithm together. The existence of depolarized components seriously influences the retrieval accuracy of conventional Esprit algorithm, a refined algorithm will be introduced and improve the performance. The canopy scattering phase ¦µv is firstly estimated using ESPRIT algorithm, the ground scattering phase ¦µg can be obtained via refined three-stage algorithm, the forest height can then be estimated.

The experimental data used is fully polarimetric data at X-band of Lingshui Li Minority Autonomous County, Hainan province, China; it is the Chinese first dual-antenna polarimetric data, as the data was acquired in a single-pass mode, the temporal decorrelation can be neglected. The same algorithms can also be used on L-

band simulated data, results of the two inversion algorithms show a good fit with ground test and confirm the potential of C-PolInSAR in forest height inversion.

MRV System Development for REDD+ in Indonesia: Pol-SAR Application

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An important and critical requirement for the implementation of REDD-Indonesia (REDD-I) will be the establishment of an independent MRV (Monitoring, Reporting, and Verification) procedure. This procedure is consisted of Public MRV (national and provincial level) and Corporate MRV (at Forest Management Unit level). REDD-I has completed the Readiness Phase and now in the Implementation Phase. The study was designed within the context of REDD+P (REDD+ Partnership) approach, which the involvement of ABG (Academic, Bussiness and Government) parties: IPB/AIPEX (ALOS-Indonesia Pol-InSAR Experiment), Sinarmas Forestry and Ministry of Forestry

This paper presents the progress in the etablishment of a model for Corporate MRV of forest plantation (HTI) in Indonesia. The objectives of the study are: (1) to observe the impact of HTI on the degraded peat land; (2) to initiate MRV procedure standardized to 2006 IPCC Guidelines (AFOLU Sector); and (3) to explore PALSAR application for MRV. The total area of the targeted HTI test site is 585,305 Ha, located in Ogan Komering Ilir (OKI) District of South Sumatera Province, where the first planting operation was started on 2004-2005. The study involved multi-temporal and multi-mission image archives of 15 years period (1995-2009). Detailed study was implemented on the four selected imageries: Landsat-ETM (1995 & 2000), SPOT-4 (2004) and ALOS/PALSAR (2009).

The result of the study on HTI impact was presented in terms of carbon stock and carbon stock change (Tier-1) on the four selected imageries, with 1995 image archive as the baseline. HTI (2009) showed a positive impact with carbon stock increase of 24% compared to 1995. While the other two showed carbon stock decrease of -18% (2000) due to 1998 forest fire, and -8% (2004) due to natural forest recovery.

Boreal Forest Biomass Classification with TanDEM-X

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Boreal forests contain roughly 1/3 of the total Earth's forest biomass. Due to the vastness and remoteness of this area, satellite imagery is needed to extend and update boreal forest biomass data. The main existing Remote Sensing data are based on optical systems which are limited to qualitative classifications and generally result in an insufficient number of forest classes (mainly distinguishing between Forest and Non Forest). Quantitative classifications of the boreal forest biomass are necessary to estimate global carbon rates and dynamics. In the SIBERIA project [1], a radar approach, based on ERS/JERS backscattering and ERS interferometric coherence, was used to generate a land cover classification with three forest biomass classes (sensitive up to 81 Mg/ha) showing the potential of synthetic aperture radar (SAR) to map boreal forest biomass.

Now, the TanDEM-X (TDX) mission offers again interferometric coherence measurements. X-band interferometric coherence is sensitive to forest structures and therefore can be used to improve and extend boreal forest biomass classifications. The TDX mission provides a global acquisition in the operational DEM generation mode covering the entire boreal region, although only in one polarization (HH) [2].

Forest height can be estimated from the interferometric coherence (using the Random Volume over Ground model (RVoG)) [3]. The interferometric coherence, in case of TDX, comprises two main decorrelation contributions, volume and noise decorrelations (in the operational bistatic mode the temporal decorrelation can be assumed equal to 1) [2]. Noise decorrelation is calculated from the antenna pattern and corrected from the data. Thus, volume coherence can be assumed to be the only contribution to the interferometric coherence and forest height can be directly estimated from it. With one polarization only a simplified height estimation is possible under the assumption of an exponential backscattering function with a constant shape factor. A performance analysis will show the impact of this assumption on the biomass classification.

Forest biomass is estimated from forest height using a height-to-biomass allometric equation. The accuracy of the allometric function is maximum for forests characterized by homogenous structural conditions, like in the boreal region, but it is reduced for forests with highly diverse structures, or forests affected by disturbances. The impact of the height-to-biomass allometry accuracy in the biomass classification performance will be also analyzed. Two test-sites have been evaluated in this study: Krycklan located in middle Sweden, a boreal forest site with a hilly topography; and Remningstorp in southern Sweden, a hemi-boreal forest over a rather flat terrain. High resolution LiDAR data, acquired in 2007 over these sites, are used to validate the biomass classification results and the European thematic classification CORINE is used to illustrate the potential of biomass classifications for the improvement of existing thematic classifications.

The boreal forest biomass classification obtained from TDX DEM standard acquisition data shows a good agreement with the validation biomass maps. A performance analysis accounting for both sources of deviation (height and allometry induced errors) shows an optimum number of 4 biomass classes with a confidence interval of 95%. In our test sites the defined four biomass classes result in the following ranges: <10, 10-50, 50-150, >150 Mg/ha. The height estimation accuracy lies within a range of +/- 10% and a shows correlation factor of 70%, allowing biomass estimations within a range of +/- 25% and a correlation of 54%. Finally, it will be shown that the obtained biomass classification maps can improve thematic mapping in forested areas, like CORINE, and is able to discriminate between different biomass levels within defined CORINE classes in the boreal forests.

The improvement of the biomass classification after combining acquisitions with different baseline configurations (more and narrower biomass classes) and the influence of seasonality in the classification performance will be discussed.

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Status of the Retrieval Algorithms of the BIOMASS Mission

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The BIOMASS mission is designed to map the full range of the world's above-ground forest biomass, and to quantify biomass changes during the mission lifetime, with accuracy and spatial resolution compatible with the needs of national scale inventory and global carbon flux calculations. This objective is achieved with advanced P-band SAR techniques. The P-band biomass measurement concept is based on previous work over the past two decades. During the preparatory phase, six new campaigns have been conducted to address remaining questions on the biomass retrieval algorithms, mainly over tropical and boreal forests. The collected datasets comprise the most accurate and complete sets of in situ data and P-band SAR data in different modes currently available (Polarimetry, Pol-InSAR and Tomography).

The BIOMASS mission itself and the inversion algorithms used to recover biomass and height have been designed to mitigate or correct for a range of disturbing effects, including ionospheric perturbations of the signal, temporal decorrelation and its effects on Pol-InSAR, and environmental effects such as topography and soil moisture variations.

The required accuracy for biomass measurements is ±20% for forest with biomass in excess of 50 t ha-1. Using campaign data, it was demonstrated that the BIOMASS mission should be able to achieve such accuracy by combining estimates from the covariance data and from height derived using Pol-InSAR techniques. Analysis has been carried out to simulate performance in spaceborne conditions (including resolution, radiometric stability, ambiguity & ionospheric effects). The paper will summarise the status and the results of the retrieval algorithms.

NOTES:

Day 2, Tuesday 29 January 2013

Session - Polarimetry & DInSAR, Polarimetry & PSI

Assimilation of Distributed Targets and PS Information for a Scene-Based Monitoring of the Polarimetric Data Distortion

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So far, the calibration of full-polarimetric SAR systems mostly relies on ad-hoc ground installations of calibrated active (transponders) or passive (corner reflectors) targets. It is although evident that part of the system health information can also be retrieved from other natural features which are intrinsic to the illuminated scene. In particular, noteworthy efforts have been spent through the years , [1-2] to name a few, on investigating the potential of Distributed Target (DT) areas with relation to the distortion estimation. It was shown that, by reducing the problem complexity in the distortion model (null Faraday and/or symmetric cross-talks) and in DT model (reflection symmetry), effective information on the system cross-talks and on the channel imbalance ratio can be extracted from the scene. It can be verified, though, that in a generic scenario the DT must be nevertheless complemented by a calibrated reflector in order to accomplish a full polarimetric monitoring (the topic will better outlined in a companion paper dedicated to evaluating the accuracy and the conditioning of the polarimetric calibration methods).

An alternative calibration approach, recently investigated in [3], consists in taking advantage of multiple image datasets collected over the same area. Whereas the DT-based approach made assumptions on the ensemble spatial statistics of the target (orientation symmetry), this latter makes explicit exploitation of the Permanent Scatterer (PS) temporal stability, in both its radiometric and polarimetric behavior. When a sufficient density of PSs can be found within the selected image frame (urban scenarios are in particular suited), the PS based technique, namely PolPSCal, offers a reliable relative calibration solution. More specifically it returns the differential distortion information with respect to a master image of the stack, which in [3] was supposed to be ideally calibrated (or whose distortion is perfectly known).

The present paper proposes an encompassing framework for polarimetric system monitoring based on both the spatial and the temporal exploitation of the natural targets. The solution relies exclusively on the in-scene information, and thus it's independent from calibrated reflectors. A generic distortion model has been conceived, so that the approach can be readily tailored to different sensor scenarios, ranging from higher-frequency SARs to lower-frequency acquisitions affected by Faraday rotations. The DT estimates are indeed integrated with the PS differential distortion in order to achieve (up to an absolute radiometric scale factor) an unambiguous temporal monitoring of the system distortion, and therefore a consistent data calibration within the image stack. The performance has been assessed through synthetic simulations and validated on a Fine Quad-Pol Radarsat-2 dataset which comprises 26 images over the Barcelona area, returning an accuracy on the channel imbalance stability below 0.2 dB and on the cross-talk level <-35 dB.

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Performance Comparison between Dual Polarimetric and Fully Polarimetric Data for DInSAR Subsidence Monitoring

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Differential SAR Interferometry (DInSAR) is an established technique, able to detect changes on the Earth surface during long periods of time, such as subsidence, landslides or volcanic activity [1][2][3]. The proliferation of satellites with polarimetric capabilities, such as ALOS, Radarsat-2 and TerraSAR-X has provided the community with lots of opportunities to exploit this Polarimetric data in many applications. Among them, the phase quality optimization techniques [4][5][6] are playing an important role lately in the DInSAR framework. This approach has been applied in several works, using both Dual Polarimetric (Dual-Pol) [7] and Fully Polarimetric (Quad-Pol) data [8][10], providing a clear improvement of the DInSAR results from the Single Polarimetric case.

As stated before, both Full-Pol and Dual-Pol data are suitable for the application of phase quality optimization techniques. The former covers the whole polarimetric space, and so the optimum value of the phase quality can be achieved. The latter consists of only two channels, so the result will be suboptimum; however the complexity of the problem is significantly reduced. The objective of this study is to determine when the use of Full-Pol provides a significant advantage respect to the Dual-Pol SAR data case in the phase quality optimization framework and when not. Dual-Pol acquisitions can double the swath of Full-Pol ones making it more efficient in terms of coverage.

In order to assess the study, a set of 40 Radarsat-2 Fine Quad-Pol acquisitions around the city of Barcelona in Spain will be used, acquired in the scope of the project SOAR-EU 6779. The area covers several kinds of terrain, from urban to rural, which will provide several scenarios to test the performance of each kind of data. Barcelona is affected by the construction of new underground infrastructures, generating subsidence phenomena in several urban areas.

This work will consider two phase quality estimators, the interferometric coherence [9] and the amplitude dispersion stability [3]. In order to simulate the different Dual-Pol products usually provided in the current sensors, the Full-Pol data will be narrowed down, selecting either the two direct channels (HH/VV) or a direct channel and a cross-polar channel (HH/HV or VV/VH). The quality of the results will be analyzed considering different points of view, such as the pixel density, the quality of the data or the computational cost. It will also be considered different scenarios with different characteristics, in order to distinguish possible different behaviors depending on the characteristics of the scatters.

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Polarimetric adaptative Speckle Filtering driven by temporal Statistics for PSI Applications

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One of the major sources of error inherent to any SAR system is the speckle noise, produced by the mutual interference of coherent electromagnetic waves when reflected by a different elements contained in the resolution cell. Speckle behaves as granular random noise and it is generally reduced by using spatial filtering. However, spatial filtering comes at the cost of resolution loss, plus the conventional fixed-size sliding window filters may not be suitable for heterogeneous areas, such as urban environments, where preserving the maximum level of detail is desirable.

Persistent Scatterers Interferometry (PSI) techniques are extensively used for subsidence monitoring of urban areas. They are based in the analysis of the interferometric phase of pixels that satisfy some quality requirements, namely Persistent Scatterers Candidates (PSC). Whilst speckle filtering can contribute to better estimate quality indicators of distributed scatterers, too aggressive filtering strategies may lead to the loss of information on point-like scatterers. Consequently, an adaptative filtering approach is the option of choice for PSI, given the heterogeneity that characterizes urban environments.

So far, a number of speckle filtering approaches have been proposed in the literature [1, 2] that use spatial statistics to adapt the shape and size of the sliding window, so that only homogeneous, connected areas are averaged. Main drawback of these techniques is that each pixel spatial statistics are estimated from a population of samples extracted from a predefined neighborhood of nearby pixels, so still some high contrast details are lost. In order to avoid resolution loss when multi-temporal data is available, adaptative speckle filtering approaches based on the analysis of temporal statistics have been successfully applied in the framework of single-pol PSI [3].

Motivated by the recent launch of satellite sensors able to provide polarimetric data with reasonable revisit times, in previous works we presented a general framework to improve PSI performance when polarimetric data were available [4, 5]. Similarly, in this work we extend the use of adaptative speckle filtering driven by temporal statistics to fully-polarimetric satellite data, for its use in polarimetric PSI. This is expected to translate into a more accurate PSC selection, increasing the number of reliable pixels and thus improving deformation estimates, as well as the identification of dominant polarimetric mechanisms.

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Phase Quality Optimization Techniques and Limitations in Polarimetric Differential SAR Interferometry

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In this paper, the use of polarimetric optimization techniques in the frame of Differential SAR Interferometry (DInSAR) is put forward using the two main criteria available in the literature for the estimation of the pixel's phase quality: the coherence stability [1] and the amplitude dispersion [2]. The main advantages and drawbacks of each optimization method are carefully analyzed, especially when polarimetric stability does not apply. To overcome this problem the use of similarity measures between T matrices problem it is proposed in order to detect these problematic points and thus avoiding the optimization process may lead to an erroneous phase. The fully-polarimetric joint DInSAR processing is also presented. With these optimization techniques it has been achieved up to a twofold increase of the pixel candidates in the coherence case and a threefold increase in the amplitude dispersion case.

Owning to the lack of long-time polarimetric SAR (PolSAR) data, the development of DInSAR techniques has been limited to the single-polarization case. These last years, the launch of several satellites with polarimetric capabilities has allowed extending interferometric techniques in order to improve the quality and thus, the density of the final DInSAR results.

The methods available in the literature [3][4][5][6] referred in this paper as Best, Double Scattering Mechanism and Equal Scattering Mechanism are reviewed and carefully analyzed in terms of pixels' density and phase quality for DInSAR applications. With the aim to solve some of the optimization problems found in the existing methods, the use of the method proposed in [7], referred as Sub-Optimum Scattering Mechanism (SOM), is proposed in the frame of polarimetric optimization for DInSAR purposes. The adaptation to the PSI approach, by means of amplitude-based dispersion index DA optimization [8], is also presented to the fully-polarimetric data case [9].

Finally, it is analyzed how most of the optimization methods present some restrictions since not all the points could be optimized to PolDInSAR applications. Most of existing algorithms are only valid under the hypothesis of polarimetric stationary, i.e., T11 and T22 are similar. When this hypothesis does not apply, the optimized differential phase may be affected by this difference and the optimization process may have no sense. To overcome this problem a similarity measure to evaluate the polarimetric stability is proposed with the aim of evaluating the difference between the T matrices from acquisitions and thus detecting these conflicting points.

The relationship between the polarimetric optimized coherences or amplitude dispersion maps and its corresponding phase quality will be carefully analyzed using both orbital (RADARSAT-2) and Ground-Based SAR fully-polarimetric data.

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NOTES:

Day 3, Wednesday 30 January 2013

Session - Polarimetry and Tomography

Towards Forest Vertical Structure Monitoring From Space: First Experiments With Multi-Baseline TanDEM-X Data

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The estimation of the vertical structure of forests from multibaseline SAR data becomes particularly challenging when addressed in terms of a space borne mission implementation. In particular, the lack of multiple space borne SAR configurations able to perform simultaneous acquisitions, combined with (temporal) scene decorrelation, reduce the number of suitable acquisitions in a realistic space borne scenario drastically. The acquisition and analysis of Pol-InSAR data without the disturbing effect of temporal decorrelation on a global scale is now possible by means of the TanDEM-X mission [1], which provides for the first time single pass (single- and dual-) polarimetric interferometric data from space. After two years of mission, first time series with variable baseline over the same forest site are available, allowing to (1) explore their information content, (2) assess penetration capabilities, (2) asses scattering model assumptions, and (4) estimate vertical structure and monitor its dynamics.

Particularly crucial is the penetration of the X-band electromagnetic waves into the forest layers. This aspect was evaluated in [2] by analysing dual-pol data and by calculating the phase difference between the polarization with lowest and highest ground contributions. Beyond heterogeneity of forest stands and seasonal effects (e.g. leaf fall, freezing conditions ...), results demonstrated enough penetration capabilities at X-band to allow Pol-InSAR inversion.

Given these penetration potentials at X-band, time has come to evaluate in more detail the tomographic capabilities offered by a set of tandem acquisitions with variable baseline. As a set of temporal decorrelation-free coherences corresponding to different vertical wavenumbers are available for processing, the estimation of the vertical profile can be recast in the framework of coherence tomography [3]. The simplest way to obtain the vertical profiles consists in calculating the Fourier transform of the available coherence set. However, the Fourier imaging suffers from inflated (positive and negative) sidelobes due to the non-uniformity of the coherence samples in the wavenumber domain. As a consequence, different algorithms should be set up in order to obtain an imaging with higher constrast and height resolution. For instance, the vertical structure could be either extracted by model based inversion from the interferometric coherences [4]-[5] or by approximating the structure function through a weighted sum of a series of (orthogonal) basis functions, as in the Polarization Coherence Tomography (PCT) [3]. Alternatively, one could also apply deconvolution-based algorithms like the one in [6], which do not need to assume particular scattering models.

This work is focused on the derivation of vertical vegetation profiles from TanDEM-X data. First of all, a performance comparison of different coherence tomography algorithms (model-based and not) will be carried out, and pros and cons evaluated. Furthermore, the obtained tomograms will be analysed in order to derive first insights about further potentials of the TanDEM-X mission for the characterization of the 3-D structure of forests.

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P-Band Tomography Imaging of Tropical Forest at 6 MHz Bandwidth: Capabilities for Forest Biomass Estimation

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The candidate Earth Explorer mission BIOMASS mission has been selected for Phase A, which is a feasibility and consolidation phase. The satellite will be operated in two different observation phases, a short experimental tomographic phase and the nominal phase implemented with a drifting orbit to allow acquisition of interferometric image pairs [1]. SAR Tomography (TomoSAR) imaging allows to retrieve the vertical structure of the vegetation, which would be one of the key elements for the assessment of the forest biomass [2]. However, a major contributor to the error budget is the limited bandwidth allowed for the BIOMASS system by ITU regulations to 6 MHz [3]. Bandwidth reduction causes the SAR resolution cell to spread along the Line of Sight (LOS). At the proposed incidence angle of 23° this translates into an appreciable resolution loss not only in the ground range direction, but in the vertical direction a well [4]. As a result, BIOMASS tomography is hindered by two different factors compared to airborne tomography, that is:

i) A significant reduction of the number of looks to be used for coherence evaluation
ii) A significant vertical resolution loss.

The objective of this paper is to provide a better understanding of BIOMASS capabilities concerning the estimation of forest biomass and height by means of tomographic techniques. The analysis presented in this paper is carried out on airborne data acquired by ONERA over the site of Paracou, French Guyana, during the ESA campaign TropiSAR [5]. Those data have been reprocessed in order to generate a new data stack consistent with BIOMASS as for bandwidth and carrier frequency. To do this, two different processing approaches have been considered. One consisted in degrading the resolution of airborne data through linear filtering. This approach has the main advantage of being fast, although it does not allow to have the same LOS as the emulated spaceborne system along the whole imaged swath. The other approach consisted in recovering the 3D distribution of the scatterers at high resolution, which was then reprojected onto BIOMASS geometry accounting for the available radiofrequency bandwidth. This procedure allows to obtain a data stack that is consistent with BIOMASS concerning not only spatial resolution, but also geometrical features, i.e.: system LOS. Accordingly, the data stack obtained by reprojection exhibits the same vertical resolution along the swath, resulting in a faithful emulation of BIOMASS imaging capabilities. The connection to forest biomass has been examined in both cases, by investigating the correlation between backscattered power at different forest heights and above ground biomass (AGB) values from in-situ data. As expected, the reduction of system bandwidth to 6 MHz resulted in significant vertical resolution losses compared to the original airborne data (125 MHz). Nevertheless, it was possible to retrieve forest height to within an accuracy of less than 4 m, whereas the backscattered power at volume height (say 30 m above the ground) exhibited a correlation higher than 0.7 with in-situ data and no bias phenomena over AGB values ranging from 250 t/ha to 450 t/ha.

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ML Tomography based on the MB RVoG Model: Optimal Estimation of a Covariance Matrix as a Sum of two Kronecker Products

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The Random Volume over Ground model, introduced by S. Cloude and K. Papathanassiou, has been widely used for the characterization of vegetated environments using polarimetric and interferometric SAR measurements. The RVoG approach considers a natural environment as a layer of randomly oriented particles, representing vegetation, lying over a ground, accounting for surface scattering and scattering from the ground level.

Using different assumptions on the interferometric and polarimetric properties of the ground and volume components, Cloude and Papathanassiou showed that interferometric coherences obtained for different polarizations with the RvoG model were located over a line segment in the complex plane and could be used to estimate some of the properties of the observed environment. In 2009 and 2010, L. Ferro-Famil et al. proposed and analytical Least-Square (LS) estimator of the segment from the POL-inSAR covariance matrix and proposed an extension to the Multi-Baseline (MB) case using polarimetric whitening and the joint diagonalization of the different normalized cross-correlation matrices with a special unitary transformation. Recently C. Lopez-Martinez used this LS approach to perform a test of validity of the RVoG model. In Flynn et al. and Roueff et al. are reported some results on the Maximum Likelihood (ML) estimation of the RVoG model in the single-baseline case. In various publications, S. Tebaldini introduced a new and more general formalism for the RVoG model in the MB case by showing that the ground and volume contributions could be modeled as Kronecker products between interferometric and polarimetric covariance matrices. The resulting Sum of 2 Kronecker Products (SKP-2) was then solved in the LS sense using the SVD decomposition of a modified MB-POL-inSAR covariance matrix.

This paper presents a Maximum Likelihood estimator of the MB polarimetric RVoG model, whose objectives are:

- A significant gain of performance compared to the LS method introduced by Tebaldini, in terms of variance, accuracy of the medium characterization in the polarimetric or tomographic domains, and positiveness of the estimated covariance matrices of the different components.
- A computational complexity maintained to a level comparable to the LS estimation one

The LS estimation of the SKP-2, based on the minimization of the L2 distance between a sample covariance matrix and a model, may show a lack of accuracy, in particular for a low number of looks. The optimization of an ML criterion accounts more properly for the intrinsic variability of the observed data, and generally provides much better estimates when few looks are employed. The ML estimation of a covariance matrix structured as a sum of several Kronecker products (SKP-N) is still an open problem, mainly due to the fact that the inverse of a SKP-N matrix is not bound to have the same structure. Nevertheless, we will show in this paper the SKP-2 case can be treated, thus providing a ML solution for MB PolInSAR.

Our demonstration is based on the following facts:

(1) two hermitian matrices, and hence their sum, can always be jointly diagonalized by hermitian similarity

(2) as shown by Phan, an arbitrary matrix may be diagonalized according to an ML-like criterion

Fact (1) may is used to represent and SKP-2 covariance matrix as the hermitian similarity transformation of a diagonal term by an operator formed of a Kronecker product. Inserting this formalism inside the MB-POLinSAR log-likelihood function, one obtains a complex non-linear optimization problem. This problem is solved by applying fact (2) alternatively on the interferometric and polarimetric components of the diagonalizing operator using a flip-flop iterative scheme. The estimation converges after a few (typ. 4) loops. The ground and volume components are then identified as proposed by Tebaldini. Simulations reveal that the estimation variance is considerably reduced with respect to the LS case and gets close to the CRLB. For a low number of looks, the estimated volume and ground phase centers are closer to the true ones and are much more stable. Over real data, the ML approach shows a better performance, and an improved conditioning of the RVoG parameter estimation.

Wavelet-based Compressed Sensing for Polarimetric SAR Tomography

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Multibaseline polarimetric measurements allow us to resolve a vertical structure via well-established synthetic aperture radar (SAR) imaging principles. Also, they provide an additional dimension to further describe the response of illuminated objects, which, in the case of partial scatterers, is commonly captured in the form of a polarimetric covariance matrix. However, the achievable resolution of conventional estimators is highly dependent on the extension of the elevation aperture. Moreover, the sampling rate dictated by the well-known Nyquist frequency imposes an additional requirement, namely, dense regular sampling [1].

Recently, alternative sparsity-driven nonlinear reconstruction algorithms have been put forward in order to attain low sidelobe and ambiguity levels with a reduced number of irregular passes. In particular, the authors in [2] extended the work in [3] and [4] and proposed a compressed sensing-based joint reconstruction technique that takes advantage of possible intersignal structural correlations between neighboring azimuth–range pixels, as well as between polarimetric channels. Also, a single-channel covariance fitting methodology was introduced in [5], which employs sparse representations of the vertical backscattered power in the wavelet domain. In this paper, we combine all these lines of research and extend them so as to take advantage of the fact that polarimetric signatures, as characterized by the so-called coherency/covariance matrix [6], can be approximated in a low-dimensional subspace [7]. For this purpose, we form a data-adaptive orthonormal basis that spans the space of polarimetric signatures.

First, we formulate the inverse problem from a multibaseline polarimetric covariance matrix perspective in such a way that we are able to decouple the structures of scattering mechanisms from their polarimetric signatures. Subsequently, we revisit the concept of joint sparse reconstruction. Then, we cast the covariance fitting problem as an instance thereof and reformulate it so as to be able to restrict the polarimetric signatures to lie in a low-dimensional subspace. Finally, we present results obtained using fully polarimetric L-band data acquired by one of the airborne sensors of the German Aerospace Center (DLR), namely, E-SAR.

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Dual-baseline Polarimetric SAR Tomography for Tree Height Estimation Using Single-Pass L-Band PolInSAR Data

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SAR tomography (SARTOM) is the extension of conventional two-dimensional SAR imaging principle to three dimensions [Reigber and Moreira, 2000]. A real 3D imaging of a scene is achieved by the formation of an additional synthetic aperture in elevation and the coherent combination of images acquired from several parallel flight tracks. This imaging technique allows a direct localization of multiple scattering contributions in a same resolution cell, leading to a refined analysis of volume structures, like forests. Forests play a crucial role in Earth's carbon cycle by absorbing carbon from the atmosphere and storing it in its biomass. Remote sensing techniques may be capable of providing accurate and reliable information about forest parameters on a global scale with a suitable temporal and spatial resolution. The potential of Polarimetric SAR Interferometry (PolInSAR), together with an appropriate model such as the Random Volume Over Ground (RVOG) model [Treuhaft and Siqueira 2000], [Papathanassiou and Cloude 2001], has demonstrated significant success for the recovery of canopy height and ground elevation beneath canopy as documented in the literature.

In 2007 and 2008, Intermap developed an experimental single-pass L-Band PolInSAR system operated at a relatively lower altitude (~1000m) with a physical baseline around 3.5m. The design philosophy was driven by the desire to demonstrate relatively quickly and inexpensively, the capabilities and issues associated with tree height and Digital Terrain Model (DTM) generation using L-Band PolInSAR technology. The single-pass configuration allowed us to assess performance in forest conditions in the absence of temporal de-correlation and residual motion issues. In [Mercer et al, 2009], we have reported our RVOG Model inversion results from the single-baseline datasets initially on DTM extraction and then on forest height generation in an area that was largely populated by pine stands of heights ranging to 30 meters. Those results suggested that tree height accuracies (relative to Lidar-derived heights) in sampled subsets were better than 10% of tree height, while the DTM showed biases that were typically 2-3 meters above the true ground elevation. In this paper, we broaden the effort and show our forest parameters retrieval results from the dual-baseline configuration using SAR tomography.

In our experimental L-Band system, a single transmitter and receiver chain provides fully polarimetric data through a switching network that allowed pulses to be recorded in both ping-pong and non ping-pong modes simultaneously. Therefore a total of 12 active channels were recorded on a pulse-sequential basis [Mercer et al, 2009]. The ping-pong and non ping-pong modes provided three independent antenna phase center positions (noted as NN-NF-FF) in a single flight. Therefore dual-baseline datasets are available for each acquisition. Various tomographic estimators described in [Ferro-Famil et al, 2011], [Huang et al, 2011] are applied to our single-pass dual-baseline PolInSAR data for the purpose of forest height estimation and DTM generation. The results will be compared with those based on RVOG line model using single-baseline PolInSAR data. Moreover, the quality of SAR focusing imposes undeniable influences on the PolInSAR performance [Schwaebisch et al,10]. Therefore, SAR focusing algorithms also lead to some impacts of SAR tomography, such as tomographic defocusing, mislocalization of scatterers, etc. In this paper, the tomographic techniques will be both applied to data obtained by using frequency-domain algorithm like Omega-k and time-domain algorithm like back projection algorithm. Moreover, some tomgraphic caibration algorithms will be considered in the processing to futher improve the tomographic focusing quality. Through tomographic techniques, the ground elevation and canopy heights over our test sites will be estimated and validated against Lidar data.

Diff-Tomo Separation of Temporal Decorrelation Mechanisms in Forest Multi-Pol Airborne Data

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3D SAR Tomography (Tomo-SAR) exploiting multibaseline data [1,2] is an important evolution of SAR Interferometry, to sense complex scenarios with multiple scatterers mapped in the SAR cell. Recently, this concept has been integrated with multipass Differential Interferometry [3], producing the Differential Tomography (Diff-Tomo, "4D") mode which furnishes "space-time" signatures of multiple dynamic scatterers [4]. Diff-Tomo has been usefully applied to subsidence monitoring in garbled layover urban areas (see [5]). Other emerging interferometric and tomographic remote sensing applications regard forest scenarios. However, these are characterized by a temporal decorrelating canopy scatterer, and an open problem exist of possible accuracy losses and height blurring for Pol-InSAR and Tomo-SAR techniques to be applied to biomass inventory and monitoring [6,7].

In this work, to deal with such issues, experimental advances are presented of the original extension of Diff-Tomo methods for analyzing vegetated scenarios [8,9] to extract both geometric and dynamic information of forest layers. In particular, the Diff-Tomo enabled developing functionalities for vegetated scenarios are 3D Tomography robust to temporal decorrelation [9,10], possible sub-canopy subsidence monitoring [8,9], and separation in the height dimension of different temporal coherence levels that are mixed (undiscriminated) in the classical (overall) coherence analysis [8,11,12].

Here, with regard to the temporal coherence separation functionality, the concept of space-time signatures of temporal decorrelation [8,9] - a new vision in SAR Interferometry - is recalled and deeper illustrated, and it is confirmed with non-parametric Diff-Tomo analysis of BioSAR-1 ESA campaign P-band forest data with 2 months time span, acquired by an airborne platform (DLR's E-SAR), over a boreal region (Sweden). Also, the first large-scale P-band separation of height-varying temporal coherences (average HV pol. canopy and ground coherence times of 5.6 and 13.2 months, respectively) [10,11,12], is expanded to some hectares of the boreal area airborne data. This extended analysis is obtained with the new semi-parametric (AR model) [11] unique Diff-Tomo functionality of separation of temporal decorrelation mechanisms of canopy and ground employed in [10,11,12]. Moreover, the Diff-Tomo separation of temporal coherences is extended to multiple polarizations, corresponding first results are shown, and a phenomenological interpretation is discussed which is consistent with the typical scattering mechanisms, first cut estimates yielding average separated ground coherence time about three-fold rising in HH pol.

These Diff-Tomo phenomenological investigations, that can be employed to characterize the effect of temporal decorrelation on Pol-InSAR and Tomo-SAR [9] methods, as well as robust Tomography through Diff-Tomo [8,9,11], can be useful in the framework of developments of spaceborne forest Pol-InSAR and Tomo-SAR remote sensing [6,7].

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Session - Applications on Ocean & Cryosphere

Polarimetric Decomposition Analysis of Sea Ice Data

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Sea ice is a random, dynamic surface made up of a mixture snow, ice, water, salt and air, resulting in radar signals that typically are complex combinations of several scattering mechanisms. The interpretation of SAR images of sea ice requires a thorough understanding of the interaction of electromagnetic radiation with the snow and ice layers, and of how this interaction depends on both surface properties, such as sea ice thickness, concentration, roughness and salinity, and imaging parameters such as frequency, incidence angle, and polarization. The availability of dual-polarization and fully polarimetric (quad-pol) space-borne SAR systems give prospects for enhancement in the amount of information about target surface properties that can be obtained from satellite borne sensors. In this regard, polarimetric decomposition represents a powerful tool for information extraction. Polarimetric decomposition refers to an analysis strategy in which the polarimetric scattering matrix or the average covariance matrix is decomposed into different scattering components to isolate the contribution from a specific scattering mechanism.

This paper presents a detailed study of decomposition strategies for decomposing the covariance matrix associated with dual and quad polarization SAR scenes of Arctic sea ice. These techniques are called incoherent decompositions, and can generally be placed into two main categories;

- The first class is based on an eigenvector-based decomposition introduced by Cloude in the context of radar imaging [1].
- The second major class is model-based decomposition, as, for example, proposed by Freeman and Durden [2].

The analysis of the data conducted here is performed in several steps. Initially, the SAR images are segmented into distinct classes using an unsupervised classification algorithm, which incorporates both polarimetric and statistical signal features. The algorithm has built in contextual information through Markov Random Field modeling. The resulting classes are separated using statistical and polarimetric properties representative of different sea ice types, but are unlabeled. In the second step, the image segments are classified into ice types using in-situ information, such as optical images and electromagnetic measurements of thickness from helicopter,in addition to expert inputs from sea ice analysts.

The segmented images are used to mask out areas associated with various ice types. In the quad-pol case, and by assuming reciprocity and reflection symmetry, the volume scattering component can be decoupled from the surface scattering contributions in the polarimetric coherency matrix, and the characteristics of each component depend on hypothesis made on the polarimetric structure of the volume or surface terms. The further analysis evaluates which polarimetric decompositions are most useful for characterizing the scattering mechanism of various sea ice types, and which polarimetric features are informative for sea ice monitoring. In the dual-pol case, we show that the coherency matrix can be decomposed as a rank-1 surface term plus a volume component that can be used to characterize such an environment. The TerraSAR-X scenes include the HH-VV combinations, and hence the data set allow for inter-comparisons of C- and X-band.

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On the Interpretation of L- and P-Band PolSAR Signatures of Polithermal Glaciers

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Monitoring polar glaciers and ice sheets is a primary task to understand and quantify climate change. In situ activities (e.g. ice cores drilling, ground based sensing) provide, in terms of spatial and temporal coverage, rather limited information. At the same time there is a growing need of information on larger scales for a better understanding of the ongoing processes. The inaccessibility of Polar Regions promotes remote sensing techniques for glaciological applications.

Long-wavelength (e.g. P- and L- band) SAR systems can penetrate tens of meters deep into ice bodies. Hence, they are sensitive to the ice surface as well as to sub-surface (volume) ice structures. Both contributions are present in the SAR signature that has to be interpreted accordingly. For this, significant attention has been given to model-based decomposition techniques of polarimetric SAR (PolSAR) data. Recently, Sharma, et al. [1] proposed a first model-based decomposition for glacier ice, with three main scattering components: the firn-ice interface, a volume of ice particles (modeled as a cloud of dipoles) and an oriented wind-induced sastrugi field. While this model is able to explain a wide range of characteristics observed in the data, it is still not capable to describe the complete set of experimental observations. Moreover, it represents only a first order approach with (over-)simplified scattering components.

In this sense, this paper extends and investigates in detail the modeling of potential scattering contributions with the attempt to explain long-wavelength PolSAR signatures of subpolar glacier ice. The main effort is the development of an extended volume scattering component; different kinds of inclusions typically present in glacier ice (e.g. air bubbles, oriented crystals fabrics, etc.) [2] are modeled by particle clouds with variable particle shape as well as main orientation direction and degree of randomness in a three dimensional space. For the case of oriented particles, the volume anisotropy induces differential propagation effects. The associated differential propagation velocities (phase differences) and losses are accounted for the different polarimetric channels. The volume component is finally completed by including the incidence angle dependency and a variable vertical structure.

Beside the already discussed first order volume scattering component, second order mechanisms generated from the interaction between adjacent particles or internal ice layers might play a relevant role. For instance, double reflections can cause significant co-polarization phase difference as well as increase in entropy (in the far range), despite their very low scattering amplitude.

Finally, the model can be completed with a surface scattering contribution, coming from the air/ice interface at the glacier surface. This component is modeled using the X-Bragg scattering formulation in order to account for depolarization effects of surface roughness.

Covariance matrices of the above mentioned contributions are modeled and incoherently combined. Different possible scenarios are then simulated and analyzed by acting on the free parameters of the model (particle shape and orientation, inclusions nature and volume fraction, distribution of power contributions, etc...). Finally, a performance assessment is conducted by comparing modeled PolSAR signature to fully polarimetric SAR data at L- and P-band acquired by DLR's E-SAR system within the ICESAR 2007 campaign, over the Austfonna ice-cap, in the Svalbard archipelago, Norway.

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Snow Property Extraction based on Polarimetry and Differential SAR Interferometry

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Currently the determination of snow water equivalent (SWE) and other snow parameters rely on a network of weather stations, and air- and space borne missions with resolutions on the km-scale. High resolution weather and precipitation models will depend on high resolution input data. Active radar systems, especially SAR-systems can provide high resolution datasets independent of daylight. For a sufficient interaction of microwave radiation with the snow cover, high radar frequencies are needed. The satellite formation TerraSAR-X and TanDEM-X build for the generation of a high resolution globe-covering digital elevation model (DEM) (Krieger 2007) provides X-band data at 9.65 GHz with a resolution on the meter scale. Every time, flying over a certain area two acquisitions are taken which allow a DEM-generation for each pass (single pass interferometry). Differential interferometry (D-InSAR) is possible between acquisitions of different passes and polarimetric analysis is possible when the acquisitions are taken in different polarization. Here, an overview over results for snow height and snow water equivalent determination by using differential SAR interferometry of multi-pass and single-pass acquisitions will be presented. D-InSAR is a known method to detect height changes (Gabriel, 1989) on the wavelength-scale (lambda = 3 cm) by comparing the measured phase with a reference, here a synthetically calculated phase, based on the best available digital elevation model (DEM). Atmospheric disturbances cancel out in single-pass interferograms, but remain visible as long-range phase patterns in multi-pass interferograms. Still, they cannot explain small scale phase patterns, which correlate with local topographic features. These phase patterns are caused by the changing penetration depth of microwaves but also height deformations, both resulting in different location of scattering centers. Various properties of the cryosphere change over time and affect the location of scattering centers. Soil freezing, water content of snow, snow height and snow water equivalent but also vegetation cover are discussed to explain the detected phase patterns. Further, the interferometric coherence, which measures changes between two acquisitions, allows the detection of snowfall and melting periods.

In single pass interferometry, due to zero temporal difference between the two acquisitions, the bistatic mode of the TanDEM-X formation provides a very high coherence and phase accuracy. Therefore, elevation changes on the sub-meter scale can be detected, by comparing two obtained DEMs. This might not work in early winter when the snow layer is very cold (not conducting) and thin, but with some content of liquid water in the snow, a height difference should be possible to detect.

Polarimetric phase differences between HH and VV polarization are detectable and change over the winter season.
For validation, ground measurements are essential and have been acquired. The test sites Sodankylae in northern Finland and Churchill in Canada, MB, have been chosen as already intensive ground measurements were done there within the framework of the CoreH2O mission (Rott, 2010). Snow height, snow water equivalent, air temperature, soil moisture, wind speed and even snow profile data are available. For both test-sites exists a set of 20 - 25 TerraSAR-X multi-pass acquisitions and 6, resp. 8 single-pass TanDEM-X acquisitions during the winter 2011/2012.

On Dual-Polarized SAR Measurements of the Ocean Surface

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Previous analysis of satellite Synthetic Aperture Radar (SAR) complex signals already demonstrated very valuable sources of high resolution information to derive both kinematic and dynamic properties of the moving ocean surface roughness. Applied to a RADARSAT-2 quad-polarization ocean SAR scene, an investigation is further carried out to provide a simple and very effective methodology to help the interpretation of various detected surface features. As demonstrated using the complex radar signals, both the polarized Doppler and complex scattering amplitude information can advantageously be combined to efficiently discriminate different scattering mechanisms. This approach, in turn, supports further interpretation and quantification of wind direction changes and signatures of surface wave-current interactions with very local ocean surface roughness modulations, as well as oil-spill manifestations.

The goal of this study is to promote a very effective methodology using satellite high resolution polarized information to interpret and quantitatively assess various surface ocean phenomena. In particular, the proposed methodology helps to better understand, discriminate and quantify the different scattering mechanisms responsible for the manifestation of surface currents, slicks and wind field features in SAR images.

Marine Bacteria Monitoring via Polarimetric SAR

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Marine surface bacteria exist at the uppermost 1mm of the ocean. Although a number of studies have suggested the peculiarities of such marine ecosystems little detailed information is currently available. First and controlled in situ experiments have been conceived and implemented by the NOVA Southeastern University Oceanographic Center in the Strait of Florida (USA). Analysis of the in situ data involves a careful sampling strategy and DNA characterization of the marine bacteria in the sea surface microlayer marine through analyses the 16S rRNA genes.

In this paper a complementary remote sensing visibility analysis of the marine surface microlayer is accomplished. The quad-pol RADARSAT 2 and dual-pol COSMO SkyMed SAR data and the Co-Polarized Phase difference (CPD) algorithms are used to monitor from space the microlayer. Results show how polarimetric SAR can assist oceanographic researchers to detect the surfactant transforming marine bacteria within the sea surface microlayer.

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Day 3, Wednesday 30 January 2013

Session - Applications on Ocean Pollution monitoring & target detection

Polsar-AP:Exploitation if fully Polarimetric SAR Data for Oil and Target at Sea Monitoring

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Oil-at-sea monitoring and man-made metallic target observation are very important issues; they represent two complex activities that cannot be solved just by means of conventional observation techniques, i.e., coast guard ships and aerial observation. Within such a framework, synthetic aperture radar (SAR) plays a fundamental role since it allows overcoming the constraints of in situ techniques and ensures improved spatial/temporal coverage. However, observing oil slicks and man-made metallic targets at sea by means of single-polarization SAR is not an easy task due to both technical, e.g., false alarms, speckle, etc., and technological, e.g., spatial resolution, spatial and/or temporal coverage, etc. In the last decade, a number of SAR satellites operating with polarimetric capability at different frequencies have been launched, e.g. the L-band ALOS/PalSAR, the C-band Radarsat-2, the X-band TerraSAR-X and the X-band COSMO-SkyMed. As a consequence, the wider distribution of polarimetric data sets across the remote sensing community boosted activity and development in polarimetric SAR applications. In this framework, the PolSAR-Ap project, supported by the European Space Agency and coordinated by the German Aerospace Center, is aimed at evaluating and demonstrating the importance and the unique benefits of quad-polarimetric SAR data for a wide range of remote sensing applications [1]. In order to cover the whole range of remote sensing applications, the project is organised into five thematic domains: Forest, Agriculture, Cryosphere, Urban and Ocean.
In this study, the activities carried on the unit of Universita di Napoli Parthenope are summarized. They relate to the Ocean application and deal with polSAR observation of oil and targets at sea. Several approaches are reviewed and their performance are compared using actual RADARSAT-2 full-polarimetric SAR data collected in Gulf of Mexico in order to demonstrate the unique benefit of fully-polarimetric SAR data.
In the presentation, an overview of the project at the current status will be given. The test sites and data sets selected for the evaluations will be presented, together with first results and comparisons for the Ocean thematic domain.

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Evaluation of RCM Compact Polarimetry for Ship Detection

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The RADARSAT Constellation Mission (RCM) will provide compact polarimetry (CP) for nearly all of its acquisition modes. A CP SAR is a single polarization transmit and dual-channel receive system that preserves phase information between the two channels, providing some target polarization information across a wide image swath. CP is expected to improve ship detection when compared to single-polarization (single-pol) and conventional dual linear polarization (dual-pol).

This paper investigates the RCM ship detection mode, which can be acquired with CP. The ship detection mode will provide similar swath widths and coverage as the ScanSAR Narrow mode of RADARSAT-2 (R-2), which is already widely used for ship detection. The CP products for this study were simulated from R-2 Fine Quad (FQ) data using a CP simulator with the expected RCM system configuration of right-circular transmit and two orthogonal linear polarization receive channels (i.e., RH+RV). The simulator was developed by the Canada Centre for Remote Sensing (CCRS).

The R-2 data used in this study were acquired over the Strait of Gibraltar and contain known ships imaged under various conditions, including SAR incidence angle, wind speed, and ship velocity.

Shore-based Automatic Identification System (AIS) data were acquired along with the RADARSAT-2 data and were used to identify the ship targets considered in this study.

A ship detection methodology based on the Maximum Likelihood Ratio was applied to the simulated RCM ship detection mode data acquired with various polarization configurations, including CP. The ship detection performance was evaluated using receiver operating characteristic (ROC) curves, along with analysis of ship and ocean intensities, and target-to-clutter ratios. The results demonstrate that CP dual-pol (RH+RV) data provides better detection than other single-pol (HH, HV, RH, RV) and conventional dual-pol (HH+HV) scenarios, all else held constant. In particular, a benefit of using CP dual-pol system arises under higher sea state (i.e., stronger wind) conditions demonstrating a larger improvement in relative performance under these conditions.

The role of the CP m-chi decomposition, where m is the degree of depolarization and chi is the Poincaré ellipticity parameter was also studied for the maritime environment. It was found that potential ship targets can be readily distinguished from the ocean background using the m-chi decomposition. Wind speed effects on the characteristic of the ocean backscatter are also clearly observed; for high wind speed, a strong double bounce scattering from the ocean is observed as the cross-pol component increases, while at low wind speed, the scattering is dominated by single bounce.

Combining Polarimetric Channels for better Ship Detection Results

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Extensive research has been done, throughout the years, on the use of radar satellites for ship detection. Earlier advice has been to use large incidence angels and HH-polarisation to detect ships. The ocean backscatter is decreasing with increasing incidence angels for co-polarisation, thus making it easier to detect ships at lager incidence angles. ENVISAT opened up the possibility to do research on cross-polarised data. It has been shown that cross-polarised data can be used for ship detection at low incidence angels. Research has also indicated that it is easier to estimate more accurate ship lengths in cross-polarised data compared to co-polarised data.

The information content in multi-polarised SAR (Synthetic Aperture Radar) data is superior to the more traditional single-polarised SAR data from ERS, ENVISAT and RADARSAT-1. Several systems now in orbit (RADARSAT-2, TerraSAR-X and Cosmo-SkyMed) can now provide dual-polarised data. Significant improvements may be made in using the co- and cross-polarised channels of SAR data to detect and ship wakes. Ocean backscatter in co-polarised data is dependent on imaging geometry and wind conditions. Co-polarised data is suitable for detecting vessels at large incidence angles, when ship to sea contrast is maximised, and detecting features on the ocean surface, such as ship wakes. Ocean backscatter in cross-polarised data is much weaker than in co-polarised data, and is observed to be much less dependent on imaging geometry and wind conditions. Ship signatures are also weaker, but the reduction is not as significant as for the ocean surface backscatter. This means that ship detection can be done at smaller incidence angles than in the co-polarised case.

Dual-polarised data are in the combination HH/VV, HH/HV or VV/VH. The information in these data sets is not as complete as in fully polarimetric data sets, so it is not possible to do a full decomposition into the different scattering types. On the upside, dual-polarised data may be better for operational use, since the data are available in wider swaths. Using only two polarisations give some enhancements compared with single polarisation. With two polarisations it is possible to get information by looking at the channels separately and also by combining the two channels by multiplying the amplitude of the two channels and dividing by the average sea clutter around the vessel. Examples of the combination will be shown in the paper.

When quad-polarisation data are used, additional opportunities to extract more information unveils. How to optimize the use of different polarisations, and how to best combine these to achieve the best ship detection results will be shown. It is possible to get more complete information when fully polarimetric data is available. The scattering matrix from a vessel can be decomposed in many different ways when fully polarimetric data is available. One well known decomposition method is the Pauli decomposition, which gives components of surface scattering (|HH+VV|), volume scattering (|HV| or |VH|) and double bounce (|HH-VV|). Another decomposition method is the Circular Basis decomposition. Using this method gives the elements SRL, SLR and SLL. The SRL (Right-Left) and SLR (Left-Right) elements contain the double bounce |HH-VV| and the sum of the volume scattering |HV+VH|. The SRR and SLL elements contain surface scattering |HH+VV|. It is expected that the ocean surface scattering is suppressed in the double bounce case. In the surface scattering channels, we expect to see more surface waves, oceanographic phenomena and ship wakes. Combining the double bounce and the volume scattering ((HH-VV)*HV) will give even stronger contrast between ship and sea. The Krogager and Yamaguchi decomposition methods will also be explored and the ship detection results will be compared for all the different combinations. This will be done for different vessel sizes.

Spaceborne and land-based AIS (Automatic Identification System) will be used to verify and identify the vessels in the SAR image. Norwegian defence Research Establishment (FFI) is developing capabilities using space borne sensors for monitoring ship traffic in the open ocean. Norway and FFI has also launched an AIS transponder on AISSat-1 on July 12th 2010 to receive AIS signals in space. AISSat-1 is a demonstration mission focusing on vessel detection in waters north of the Arctic Circle. Operationally, vessel tracking based on SAR and AIS will give a picture of all vessels in the area. Ship detection in SAR imagery and tracking based on AIS reports are complementary. SAR and AIS can be combined for surveillance in remote areas. AIS information can identify vessels detected in SAR images, while SAR can be used to detect vessels not reporting through AIS. The combination of sources gives the opportunity to unveil vessels that don't send mandatory AIS reports.

Ship Detection using Polarimetric Radarsat-2 Data and Multi-Dimensional Coherent Time-Frequency Analysis

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1. INTRODUCTION

Ship detection using Synthetic Aperture Radar(SAR) has been a topic of considerable interest in the recent years, and the increased availability of multi-polarimetric high resolution SAR data has favored the emergence of new techniques for this application. Among many polarimetric detectors proposed in the literature, Constant False Alarm Rate (CFAR) detection schemes have been broadly developed and applied[1]. However, when making use of these methods, some difficulties may be encountered as it is hard to find a suitable statistical distribution model for highly complicated and non-homogenous background clutter .

In order to overcome these problems due to the complex scenario, Time-Frequency(TF) techniques have been introduced to analyze the characteristic of target behavior in SAR images. In [2], a fully polarimetric subaperture analysis method was presented to describe the features of the scene backscattering response under different azimuthal look angles. In [3], Arnaud proposed a new concept based on SAR interferometry and coherent techniques to detect boat by analyzing spectral correlation in azimuth direction. In [4][5][6], two-dimensional spectral analysis, i.e in range and azimuth, has been depicted for target detection. For remote sensing of urban areas, Schneider et al. [7] and Ferro-Famil et al. [8] characterized target polarimetric behaviors in different single direction, range and azimuth respectively.

In this paper, we apply a polarimetric coherent TF decomposition approach to the analysis of RADARSAT-2 data and show the TF behaviors of ships with different background scenes. The PolSAR data are decomposed in azimuth direction, range direction only and in both directions. Two statistical descriptors [8], i.e polarimetric TF stationarity and coherence indicators, are applied to detect ships. Their individual performance is assessed. The corresponding results of the three decomposition modes are compared with each other. The polarimetric indicator of the nature of the scattering mechanism, i.e á_TF parameter, is extracted from the detected ship and can show some special relevant information compared to the original full resolution á parameter [9].

The data used to process Time-Frequency analysis for ship detection is acquired by RADARSAT-2 in Fine Quad Mode. Two different scenes are investigated. The first test scene of the Vancouver city contains harbour and some ships in the sea, as well as some "ghosts" in the range direction. "Ghosts" are due to the payload performance for high resolution modes [10] and may influence detection result as false alarms.The other test site is ice sea near the Svalbard archipelago in the Arctic. The whole scene is frozen and includes some isolated icebergs and a scientific expedition ship that can hardly be discriminated from other objects by visual inspection.Preliminary results demonstrate the efficiency of the method in terms of ship detection.

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Towards Oil Slick Monitoring in the Arctic Environment

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The melting of the Arctic sea ice makes new shipping routes and natural resources more easily accessible at high latitudes. Increased activity is expected in the Arctic regions from the international maritime industry and the oil and gas sector in the coming years. New knowledge on and development of technology for oil spill remote sensing in Arctic conditions are requested. To the authors' knowledge, there are few existing publications on this topic (Praks et al. (2004), Bradford et al. (2010)).

This study is at its preliminary stage, and the focus is currently on thin sea ice features (new lead ice, grease ice and thin first year ice), appearing as dark in synthetic aperture radar (SAR) imagery. Thin sea ice, low wind regions and biogenic slicks are examples of low backscattering phenomena that could resemble oil slicks in the marginal ice zone, and hence cause false oil spill alarms in SAR measurements. We aim at investigating the potential in multi-polarization and multi-frequency SAR data for the purpose of discriminating look-alikes from theoretical oil spills in icy waters. We pursue this by comparing actual detected oil spills (e.g. in the Gulf of Mexico and the North Sea) with available collections of sea ice data from the Arctic region.

The JPL/NASA AIRSAR system operated in fully polarimetric mode at P-, L- and C-band simultaneously. The system became operational in 1987 and a polarimetric mode was available since 1989 (Lou, (2002)). In this study, we analyze six AIRSAR scenes recorded from the Baufort Sea in 2004, containing multiple recently frozen sea ice leads. A preliminary analysis show a benefit of combining multi-polarization and multi-frequency measurements for discrimination of various newly frozen sea ice classes. State-of-the-art knowledge on oil slick characterization by current polarimetric radar systems, such as UAVSAR, Radarsat-2, and TerraSAR-X is used as a reference in this work (Minchew (2012), Skrunes et al. (2012a), Skrunes et al. (2012b)).

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A Robust Symmetry-based Approach to Exploit TerraSAR-X Dual-pol Data for Targets at Sea Observation

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Target at sea monitoring finds its utmost importance in global monitoring applications, e.g. offshore platform localization and integrity in case of extreme weather event, and environment and security, e.g. automatic ship detection and tracking to contrast illegal activity like pollution, piracy, human traffic etc. A non-cooperative and efficient monitoring tool able to operate 24/7 is therefore preferable.

Metallic targets over the ocean surface, being man-made structures, are usually responsible of a mixture of basic scattering mechanisms: single-bounce returns from surfaces perpendicular to the radar illumination; double-bounce returns due to the dihedral formed by vertical structure over the sea surface; multiple-bounce returns. Synthetic Aperture Radar (SAR) observation of target at sea relies on the fact that the signal return of such objects is usually stronger than the one from the surrounding sea surface. This means that the Normalized Radar Cross Section (NRCS) is quite large and therefore targets can be visually recognized as bright spots over SAR images.

The information content provided by the NRCS collected by a single-polarization SAR (the Horizontal-Horizontal polarization, i.e. HH, is assessed to perform better respect to the Vertical-Vertical, i.e. VV one) is in general quite poor to efficiently observe metallic targets at the sea. The increased interest towards polarimetric SAR (PolSAR) data to fill the lack of information has driven the scientific community to conceive more effective techniques, e.g. Cloude-Pottier decomposition parameters, coherent target decomposition (CTD). Along with this interest, new SAR missions equipped with high resolution X-band sensors, i.e. TerraSAR-X (TS-X), Tandem-X (TD-X) and COSMO-SkyMed (CSK), have been launched recently. As far as target at sea detection is concerned, high resolution SAR images are preferred to medium- or low-resolution SAR images especially if small targets and coastal zones monitoring are of interest. TS-X and TD-X are equipped with coherent SAR sensors capable of acquire dual-pol images (with the following combinations: HH/HV, VH/VV and HH/VV) at the expense of a smaller swath. The coverage of any target monitoring tool is of course of great importance as well as for SAR-based target detection system. To justify the smaller swath of PolSAR data, the benefits of using such data in application like target at sea observation needs to be demonstrated.

In this study we exploit a simple physical property, known as reflection symmetry, that differentiates the objects in the observed scene, i.e. sea surface and metallic targets.

Sea surface being a natural target is expected to follow the reflection symmetry law while targets at sea being man-made structures are expected to break this law. To measure the departure from the reflection symmetry, the magnitude of the correlation between the combinations of cross-polarized channels (HH/HV and VH/VV) has been used. First the reflection symmetry properties are verified against actual SAR images, and then a sensitivity study is performed to show the potential of the proposed method. Direct comparison with classical single-polarization method, demonstrated a great improvement in the Target to Clutter Ratio (TCR), hence suggesting that the correlation between cross-polarized channels improve the detection of targets at sea. As outcome of sensitivity study a simple but very effective filter, that acts as clutter suppression while enhancing targets at sea is developed and a detection method is tuned in order to detect metallic targets at sea in dual-polarimetric X-band SAR data with low false positives.

Experiments undertaken over X-band Single look Slant range Complex (SSC) TerraSAR-X SAR data confirm the soundness of the approach. Peculiarity of X-band SAR data like, internal wave, rain cells, etc., that are often cause of false positives have been taken into account. The filter is tested on both HH/HV and VV/VH dual-polarimetric combinations and the outputs are verified through available ground truth measurements, i.e. Automatic Identification System (AIS) data, oil rigs location and nautical chart.

NOTES:

Day 4, Thursday 31 January 2013

Session - Applications of SAR Polarimetry on Land: Agriculture, Urban, Archeology

Time Series Decomposition Analysis for Compact Polarimetry

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RCM, the proposed Canadian C-Band follow up to the successful Radarsat-2 satellite imaging radar, proposes a new wide-swath polarimetric mode, compact [1], which comprises a hybrid basis, single transmit polarization (circular) and simultaneous coherent orthogonal linear receive. On a single pixel SLC level, the system will then measure only a projection of the complex scattering matrix [S]. The main advantages of such a system are the simpler transmitter architecture requirements, the wider swath capability and lower data rate compared to quadpol. However, it remains to be seen how the loss of information through projection affects the quality of classification products. Here we investigate this for land-use forestry applications using extensive time series of Radarsat-2 data.

In this talk we first highlight a new approach to the analysis of compact polarimetric data [2]. In most analyses of compact polarimetry, interest is centered on the multi-looked 4-element real Stokes vector (SV) of the scattered wave [1]. This is then the basis for one of the most popular compact techniques, the m-ƒÂ classification, investigated for crop time series in [3]. Here we extend the analysis to consider a wider brief, namely how to relate the basic SV observables obtained from compact to classical decomposition methods, as used in full quadpol systems. We outline a new approach to compact analysis based on decomposition theory [2]. We treat both the entropy/alpha and model based decomposition methods before summarizing our proposed new approach to decomposition parameter estimation from compact data. Critically we then apply these decomposition methods to time-series analysis with a view to improving land-use classification algorithms [4].

We employ time series of Radarsat-2 quadpol data acquisitions collected over several years (2008-2012) for two well-calibrated test sites, the first near Hinton in Alberta, Canada, which contains a mixed forest, semi-natural vegetation and mountainous terrain environment. The Hinton data is collected every 24 days (with low conflict) over a full year in the new wide swath quadpol mode FQW of Radarsat-2, which matches the wider range swath capability of any future compact mode. The second test site is near Petawawa, Ontario, and contains a more mixed deciduous/non-deciduous forest as well as urban and open water areas collected in standard FQ mode. This data time sampling is more irregular (due to data conflicts) but covers several seasons, enabling a detailed analysis of time varying decomposition parameters.

The data is first used to simulate compact mode data using circular polarization transmit and dual linear receive and the co-registered multi-temporal stack then employed for time dependent decomposition analysis. We compare the information obtained against a standard dualpol linear transmit and dual linear receive, as proposed in the ESA Sentinel mission, to confirm the utility of using circular polarization for enhanced land-use products.

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Polarimetric Response of Rice Fields at C-Band:Analysis and Applications

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Two series of five quad-pol Radarsat-2 images, acquired over a rice cultivation site in Spain during 2009 and 2010, have been analysed in order to explore the polarimetric response of such an important crop at C-band.

A whole set of polarimetric observables has been studied and related to the phenology of the rice fields and to other physical parameters (vegetation height, plantation density, etc.). An interpretation of the polarimetric response at each phenological stage is provided in terms of the scattering mechanisms present in the scene. This study incorporates also a comparison with other results obtained with dual-pol (HHVV) TerraSAR-X images over the same test area [1]. The influences of the frequency band and of the availability of the cross-polar channel on the physical description of the scene are studied.

As a first application, based on the variation of the polarimetric response during the cultivation cycle, a simple approach for determining the phenological stage from single acquisitions has been proposed and tested.

In second place, a potential application consisting of early detection of cultivation problems (e.g. growth delays due to water salinity, plant diseases due to plagues, etc.) is studied.

Finally, these applications are being evaluated under the conditions of future sensors with reduced polarimetric capabilities, such as Sentinel-1 and the RCM.

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Scattering Mechanism Analysis Using Multi-Angular Polarimetric Radarsat-2 Datasets

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The objective of this study is to analyze scattering mechanisms as a function of incidence angle over agricultural fields. Radarsat-2 datasets acquired at the end of March (October) / beginning of April (November) in 2011 with four different ranges of incidence angle are explored using polarimetric decomposition methodology. Three land cover classes are first considered: bare surface, prairie canopy and wheat canopy. The results show that single scattering is always the dominant scattering mechanism for the three surface types, although single scattering occurs on bare surface is significantly stronger than that occurs in vegetation canopy. For the three land covers, as incidence angle increases, single scattering decreases, double and volumetric scattering increase as expected. Therefore, lower incidence angle acquisition is appropriate to characterize soil moisture over bare surface due to the limited effect of roughness, while higher incidence angle is suitable for surface roughness identification over bare surface and plant height description over vegetation canopy. Nevertheless, as the incidence angle increases, the entropy also increases which restrain the separation abilities of various scattering mechanisms. The IEM simulations also show that entropy increases with incidence angle, but the increase is much stronger than that observed on the Radarsat-2 data. Thus, entropy and high incidence angle should make a compromise for the selection of incidence angle. For agricultural fields, reflection symmetry condition is satisfied and polarimetric parameters SERD, DERD are designed to describe the magnitude differences among three scattering mechanisms. It is observed that SERD decreases slightly with incidence angle while DERD increases slightly as incidence angle increasing over the three land covers. It can be explained by the variation trends of NOS eigenvalues as a function of incidence angle: single scattering eigenvalue decreases with incidence angle while volumetric scattering eigenvalue increases with incidence angle so that their difference (SERD) decreases. In addition, DERD variation trend also indicates that double scattering eigenvalue increases faster than volumetric scattering component as incidence angle increases. The combination of various incidence angles helps us to monitor the types of vegetation and their growth cycle and also to get a better estimation of soil parameters.

POLSARap: Investigating the Benefits of Polarimetry for Urban Applications using X-Band SAR Images.

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There is nowadays a clear need to be able to characterize urban land use/land cover change in a timely and accurate manner, since urban growth and expansion is an ongoing concern for both developed and developing nations. How much of the Earth's landmass is urban, and where are these urbanized areas located? As polarimetry is known to be a valuable tool to discriminate deterministic and non deterministic targets, this paper investigates the capability of using multi temporal and polarimetric SAR imagery for two main applications:

- Urban boundary mapping, using classification between deterministic and non deterministic targets;
- 3D rendering using POLINSAR data.

In the context of classification, polarimetry can be considered as a valuable tool, for example through the use of the entropy parameter. This parameter measures the mixing of different electromagnetic mechanisms (bounces, single scattering, etc.) But unfortunately, at X-band and with current resolutions of several meters, it turns out that entropy is also very high and not discriminating for deterministic targets. The presence of several small elements of a wall or on the roof in the same resolution cell induces an important mixture of different mechanisms. Other polarimetric parameters were investigated and their effectiveness in the context of the issue of classification: Yamaguchi, Freeman Durden, etc.

Here, we propose to use polarimetry in another way: we use the generalized interferometric coherence obtained from multipass acquisitions as a key parameter for the classification. It turns out that the interferometric coherence is one of the most discriminating parameters between deterministic targets and natural targets that have been modified at the scale of the wavelength. We can therefore consider generalize this classification approach to other applications as urban. The benefit of polarimetry is investigated through its contribution for the coherence optimization.

Secondly, we will also investigate the benefits of polarimetry for interferometry, especially for the three dimensional rendering of buildings thanks to coherence optimization algorithms.

Classification and elevation results obtained using single pol, dual pol and full polarization will be compared. Algorithms will be tested on full polarimetric TerraSAR-X images of San Francisco and dual polarimetric TerraSAR-X images of Toulouse (France)

Multitemporal RADARSAR-2 fine-beam Polarimetric SAR Data for Urban Land Cover Mapping

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With half of humanity living in cities today, and increasing number of people are moving to cities, timely and reliable information on urban land use/land cover is required to support sustainable urban planning. The objective of this research is to evaluate multitemporal RADARSAT-2 high-resolution polarimetric SAR (PolSAR) data for urban land cover mapping. Six-date RADARSAT-2 PolSAR data were acquired during the vegetation season of 2008 over the Greater Toronto Area. The major land cover classes include high-density residential areas, low-density residential areas, industrial and commercial areas, construction sites, roads, parks, golf courses, forests, water, pasture and two types of crops. The multitemporal PolSAR data were classified using an object-based SVM and a pixel-based contextual Stochastic Expectation-Maximization algorithm. The preliminary results show that multitemporal RADARSAT-2 PolSAR data are suitable for detailed urban land cover mapping. Both the object-based SVM and the pixel-based SEM can obtain homogenous land cover classification results with good accuracy while preserving shape details in the complex urban environment.

Hybrid PolInSAR: Combining a HR single Image and a full Polarimetric Image in a lower Resolution - Example on Urban

Trouve, N.; Koeniguer, E.
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For the past decade, polarimetry followers have shown and demonstrated numerous applications of SAR polarimetry, from its ability to discriminate targets and natural medium by their scattering mechanisms, to its combination with interferometry named PolInSAR.

Despite an increasing availability of fully polarimetric data, many SAR users are still reluctant to exploit polarimetry because of the lower resolution provided in full polarimetric mode. This psychological barrier is even stronger in the case of urban applications. Single pol SAR systems have reached levels of resolution allowing the users to visually discriminate each building. On the other hand, polarimetric data resolution still remains above that threshold, and so can still only deal with buildings blocks. In this case the debate of polarimetry versus single or dual polarimetry may not be in favor of full polarimetry when a single image in a higher resolution is considered.

But nowadays with the numerous polarimetric spaceborne SAR systems and the incredible quantity of data and coverage they can provide, multiple images of the same scenes can be easily obtained.

When short time-scale change detection is not the main goal, two temporal acquisitions can be used for numbers of civilian applications. When two images are used, the users may consider using polarimetry for both images (that is PolInSAR), single polarization for both (InSAR), or using a hybrid approach (what we will call Hybrid PolInSAR), that would consider the combination of a single polarization high resolution image with a full polarimetric image acquired in a lower resolution.

In this study, we show that it is possible make interferogram with two such images. We then offer clues for the use of this "hybrid pair", for conventional applications related to urban environments: classification, segmentation, coherence optimization, 3D rendering, etc.

Images used in this paper are TerraSAR-X spotlight high resolution images over San Francisco (resolution of 1x1m) and TerraSAR-X full polarimetric images of the same area (resolution 2m x 6m), in a stripmap mode.

A Multi Frequency Polarimetric SAR Sensors Analysis over the Archaeological Area of Djebel Barkal (Suadan)

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Differences in vegetation growth and in soil moisture content generate ground anomalies which can be linked to the presence of subsurface anthropic structures. Such evidences have been studied and observed for a long time by means of aerial photographs, thanks to planned campaigns or through the observation of historical II World War acquisitions first, and thanks to the very high spatial resolution of optical satellites later. The present research constitutes a contribution to the non-invasive archaeological investigation methodology carried out in the last years by several institutions and cultural organizations.

The work aims to exploit the technique of SAR Polarimetry for the detection of surface and subsurface archaeological structures, comparing ALOS PALSAR L-band, with a central frequency of 1.27 GHz, with RADARSAT-2 C-band sensor, whose central frequency is 5.405 GHz. The choice to analyze radar sensors capabilities is based on their 24-hour observations, as they are independent from Sun illumination and meteorological conditions. Moreover, they could provide additional information concerning electromagnetic properties of the target, qualities not derivable from optical images.

A multi frequency comparison between the two SAR sensors has been performed over the Napatan (900-270 BC) Meroitic (270 BC-350 AD) area of Djebel Barkal, located in Sudan and inscribed in the UNESCO World Heritage List since 2003. It constitutes one of the five Napatan and Meroitic archaeological sites stretching over more than 60 km in the Nile valley, in an arid area part of Nubia. The area, not completely excavated, presents thombs, pyramids and sacred palaces.

The dataset we disposed of is composed of two archived ALOS PALSAR polarimetric images and four RADARSAT-2 polarimetric data specifically acquired for the current research. All the products have been then processed and integrated with the available optical data and the cartographic documentation derivable from UNESCO reports over the area. A multitemporal analysis has been also performed thanks to the notable difference in time acquisition between ALOS PALSAR and RADARSAT-2 data.

The possibility of monitoring and observing ancient sites by means of remotely acquired SAR data could be an added value to the archaeological research, especially for those areas in which instable political situations do not allow ground truth and surveys in situ.

The great potential of the two polarimetric instruments with different frequency for the detection of archaeological remains has been demonstrated thanks to the sand penetration capability of both C-band and L-band sensors.

Radarsat-2 Polarimetric multi incidence Angle Analysis over the ancient City of Husn Al-Qadisiyya (Iraq)

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This work has as goal the detection of archaeological buried remains and the monitoring of the external ones. The archaeological site taken into account for this purpose is the area of the ancient octagonal city funded by Harun al-Rashid: al-Qadisiyya. This city, located in the southern part of the Samarra territory (Longitudes 43°45'- 43°51'; Latitudes 34°25'-34°05' for a total extension of 15058 hectares), was abandoned unfinished when the caliph moved to Raqqa (Syria) in 796 A.D. Bigness of the structures and extensive excavation not yet occurred in that zone (as for the remaining 80% of the whole archaeological zone - 41.5km x 8km extension), the unstable political situation and agricultural expansion threats (that let the city of Samarra be inscribed in the UNESO list of sites in danger since 2007) gave us a reason more to investigate this area.

The study was carried out with four fine quad-pol imagery of the Canadian satellite RADARSAT-2, launched in December 2007. The images were scheduled and provided by VigiSat, in the frame of the GIS BRETEL and processed with the PolSARpro software. However C-band lower capability of penetration compared to ALOS PALSAR L-band, the choice of this satellite is due to its higher spatial resolution compared to the PALSAR one, whose datawere employed in a previous study [1]. Thanks to the higher spatial resolution and the location of the site in a semi desert area, we succeeded in balancing a probable lower waves penetration. Our analysis focused on four polarimetric images, two with a 23° incidence angle and two with a 45° incidence angle, acquired in different moments of the year 2012. The difference between the angles was motivated, respectively, by the possibility of a higher penetration of the microwaves in the ground and by the higher possibility of double bounce response in the case of presence of buried structures. The time spacing, on the other hand, allowed a temporal analysis over different months of the same year accompanied by meteorological condition available on the web for the zone.

This type of analysis, however, allowed the identification of the qanat (the underground channel present in the northern part of the octagonal city of al-Qadisiyya) thanks to differences visible in all the products.

The potentiality of this SAR research for archaeology is well known, in particular for those areas of the Globe where surveys in situ are not allowed because of political instability (as in the case of Iraq), or for those zones in which a cloud cover is always present and where optical satellites cannot acquire as radar does in any kind of illumination and in any sky coverage.

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NOTES:

Day 4, Thursday 31 January 2013

Session - Applications of SAR Polarimetry on Land: Soil Moisture and Wetlands

Polarimetric Decompositions for Soil Moisture Retrieval from Vegetated Soils in TERENO Observatories

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Soil moisture under vegetation cover and their spatial and temporal variations from point to catchment scale are crucial for understanding hydrological processes within the vadose zone, for managing irrigation and consequently maximizing yield in the sense of precision farming.

Polarimetric decompositions, as for example proposed in [1], represent valid unmixing techniques to separate different scattering mechanisms within the SAR resolution cell. In this way, the disturbing vegetation volume component can be separated from the soil ground components. In [2] a variety of these polarimetric decompositions were developed and investigated for their estimation performance concerning soil moisture. The best performance was achieved by applying so-called hybrid decompositions for soil moisture retrieval, which are exploiting the advantages of model-based and eigen-based decompositions in a joint manner. This combination together with the implementation of a physically constrained volume intensity component led to very high inversion rates and a promising inversion performance for a variety of agricultural scattering scenarios. However the performance analyses also showed slight range trends within the moisture inversion results. In addition the inversion for strongly oriented vegetation volumes also revealed a distinct deviation of the inverted moisture values from the measured ones. Therefore new investigations on the algorithm were undertaken to tackle the remaining challenges for an improved soil moisture retrieval under vegetation cover.

The developed algorithm is applied on fully-polarimetric L-band data of the TERENO 2012 campaigns conducted in three different TERENO observatories (Ammer, Bode, Uecker). The data were acquired by DLR's novel F-SAR sensor in May 2012, when vegetated soils already prevailed. Moreover, a complete set of in situ measurements comprising soil moisture, and plant parameters were collected and are available for these campaigns.

In a final step, the extracted SAR-based soil moisture values are validated with corresponding ground measurements of the conducted TERENO campaigns for a quality assessment and a discussion on potentials and limitations regarding future space-borne SAR missions like Tandem-L or ALOS-2.

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RCM Compact Polarimetry Applied to Watershed Study

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The RADARSAT Constellation (RCM) is a three-satellite mission that will benefit from two new capabilities: Rapid Revisits and Compact Polarimetry (CP) Mode. The four days InSAR capacity and the complete daily coverage of Canada's land and oceans will fulfill the Rapid Revisits component. CP mode will provide advanced information while maintaining the large spatial coverage key to many operational applications. Both new features will improve the Earth monitoring and bring SAR system usage to operational uses. RCM is designed to meet the Government of Canada's requirements for Ecosystem Monitoring, Disaster Management and Maritime Surveillance.

This presentation discusses the use of CP in the context of watershed management, more specifically soil moisture and vegetation characterization. In order to conduct the study under similar condition to RCM, a tool that simulates all RCM modes, including the new Compact Polarimetric mode has been developed. Simulated products take into account system noise and spatial resolution specific to each beam mode. Results from empirical and semi-empirical modeling of RH, RV, RR and RL function of surface soil moisture and roughness will be presented. In situ data from two seasonal fieldwork campaigns over agriculture fields are used for the model validation. Considering the higher noise floor and the potential circularity stability problem along the large swath, it will be demonstrated that the RL polarization is the most suitable for soil moisture retrieval from one polarization. Regarding the vegetation characterization, CP-InSAR analyses have been done over two horticulture areas (composed of apple, cherry, vineyard, pear, peach ...) during leaf/no leaf periods. CP provides enough information to distinguish high density apple orchards from vineyard, which is difficult with optical data. Surprisingly, due to their primary and secondary branch size, mature cherry trees are less sensitive to polarization diversity than other crops during no leaf periods. As for fully polarimetric data, CP at C-Band is sensitive to the LAI and this can be characterized by the degree of polarization, m-chi representation or the RR intensity.

Soil Moisture Retrieval via a Polarimetric Two-Scale and Two-Component Scattering Model

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The massive advancements in polarimetric radar imaging achieved in last decades allow us to exploit a huge quantity of information about our planet from a larger and larger number of sensors supporting the fully polarimetric operational mode. As a matter of fact, the smart and effective polarimetric processing of such data represents sometimes the only way to get from remote sensing the information relevant to various physical ground parameters, whose knowledge turns out to be of crucial importance for the activities of many private or public bodies.

In particular, the ground permittivity and the soil moisture content play a leading role in the hydrological cycle, as they determine the repartition of the rainfalls into the surface run-off, seepage and evapotranspiration and so their knowledge is useful to predict rivers floods, rainfalls and landslides. Accordingly, in last decades, several works have been addressed to the ground water content retrieval from multi-angle, frequency or polarization Synthetic Aperture Radar (SAR) data. To this aim, recently we proposed a Polarimetric Two-Scale Model (PTSM) [1-4] able to predict the 2nd order statistics of the scattering matrix relevant to a bare soil. Starting from the expressions of such quantities, we developed a retrieval algorithm able to get both the soil-moisture (i.e., the dielectric permittivity) and the ground roughness exploiting measured co-pol and cross-pol ratio, in case of the complete knowledge of the Normalized Radar Cross Sections (NRCS) [1-2], or the co-pol ratio and the HH-VV correlation coefficient, in case that only the co-polar channels are available [4]. It is worth to note that the PTSM intrinsically allows accounting for the effects of the topography of the sensed scene on the estimation procedure, provided that a Digital Elevation Model (DEM) of the observed area is used in the retrieval algorithm [3].

The method was tested comparing estimation results with in situ measurements from several campaigns, and such comparison highlighted good retrieval performances, above all employing L-band data [1, 4].

Of course, since the PTSM was developed to describe the electromagnetic field scattered from a bare soil, reliable estimates are obtained in areas for which the surface scattering mechanism is dominant with respect to the double-bounce and volume scattering ones.

Accordingly, in order to widen the application scenarios over which the estimation method can be effectively applied, we here propose a modified retrieval algorithm able to remove the (secondary) volume scattering contribution.

In particular, we compute all the NRCS and the HH-VV correlation by using the PTSM to describe the surface scattering component, and the theoretical model shown in [5] to describe the volume scattering contribution from the vegetation layer which covers the scattering surface. We then show that suitable combinations of the NRCS and HH-VV correlation, that we term "modified co-polarized ratio" and "modified HH-VV correlation coefficient", are related only to the surface parameters (i.e., volumetric contribution cancels out). This allows us to obtain a reasonable estimation of the soil moisture even in (moderately) vegetated areas, where the volumetric scattering contribution is non-negligible.

The complete theoretical setup behind this new estimation procedure and the relevant retrieval results will be fully shown at the conference time.

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The Chott El Jerid, Tunisia: Observation and Interpretation of a SAR Phase Signature over Evaporitic Soils.

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The presence of water in arid regions is correlated to large evaporitic deposits, with high concentration of salts. Polarimetric SAR observations over such areas show high variations for both the amplitude and phase of the backscattered co-polarized signal. This is due to a large dynamic range for both surface roughness and dielectric constant parameters, between the wet and dry seasons: crystallized salt is rough and presents a low dielectric constant, while salt water corresponds to smooth and conductive surfaces. We observed a complete seasonal cycle over the chott El Jerid evaporitic basin, in South Tunisa, using the C-band SAR on-board RADARSAT-2. One full-polarimetric acquisition was performed every 24 days, from February to September 2009. Besides expected variations in the radar backscattered power, we also observed significant changes in the phase difference between HH and VV channels. In order to explain such a phase effect, we considered the phase behavior of the Fresnel reflectivity coefficient when approaching the Brewster angle, for materials presenting a high loss tangent. Analytical modeling using IEM approach confirms this hypothesis.

Polarimetric L-band ALOS and C-band RADARSAT2 for Sub-Arctic Peatland Characterization and Monitoring

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The Hudson Bay Lowlands contain the most extensive wetlands and thickest peat deposits in Canada. The region is home to unique concentrations of wildlife, most notably polar bears, caribou, and migratory birds. Bears rely on inland denning habitat, caribou are tied to peatland vegetation, and birds intensively graze coastal herbaceous salt marsh and fen. Major wetland transformations have been detected related to isostatic uplift [1], fire [2], and goose grazing [3] Climate change is expected to have important, though poorly understood, impacts on the peatland ecosystems of Wapusk National Park in the Hudson Bay Lowlands of Manitoba, which may include an increased rate and extent of fires, collapse of surficial permafrost, and drying of wetlands. While it is well established that fens change naturally into bogs over time and that bogs can revert to fens, the rate of these changes will likely be significantly altered by climate change and will have important implications for polar bear denning habitat which is entirely within bogs with thick peat deposits. Climate change is a major source of stress of Wapusk wetland that should affect gradually park's fauna and flora biodiversity. Earth observation satellite and in particular all weather L-band polarimetric ALOS, should provide the required information for monitoring the impact of climate change on the integrity of the 11,475 km2 park. In this study, a series of fully polarimetric ALOS and Radarsat2 acquisitions collected over Wapusk National Park between June and September 2010 are analyzed. Extensive field collection of vegetation structure and diversity and measurements of permafrost active layer thickness, peat thickness and water level have been conducted. The Touzi decomposition [4, 7], which has been recently introduced for a unique and roll-invariant characterization of target scattering, is investigated. In contrast to the Cloude-Pottier [5] decomposition, which uses a real entity to describe target scattering type, the Touzi decomposition characterizes uniquely the scattering type with a complex entity, whose both magnitude and phase have been shown very promising for wetland class characterization [6, 7]. The analysis of the Touzi phase derived from the ALOS data confirm the results of [6]. While the multi-polarization intensity (HH, HV, VV) and the most used target scattering decompositions (Freeman [8] and Cloude-Pottier [5]) are not sensitive to the peatland subsurface water, the Touzi scattering type phase permits the detection of the presence of peat subsurface water flow. Such unique capability is very promising for detection and monitoring of bog-fen transformations due to the climate change stress or anthropogenic activities. The added value of polarimetric L-band and C- band SAR information with reference to Optics (Landsat TM) sensors is also demonstrated for enhanced wetland classification. Implications for the operational use of polarimetric L-band ALOS in conjunction with the C-band Radarsat2 for wetland monitoring are discussed.

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NOTES:

Day 4, Thursday 31 January 2013

Session - Applications of SAR Polarimetry: Other

2003-2013 : 10 Years of the PolSARpro v5.0 Software. New uUdates and its Link with the ESA POLSAR-Ap Project.

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The objective of this paper is to make a review of the current status of the PolSARpro v5.0 Software (Polarimetric SAR Data Processing and Educational Toolbox), developed under contract to ESA by I.E.T.R at the University of Rennes 1. The objective of this current project is to provide Educational Software that offers a tool for self-education in the field of Polarimetric SAR data analysis at University level and a comprehensive suite of functions for the scientific exploitation of fully and partially polarimetric multi-data sets and the development of applications for such data. The PolSARpro v5.0 Software establishes a foundation for the exploitation of Polarimetric techniques for scientific developments and stimulates research and applications developments using PolSAR and PolInSAR data.

The PolSARpro version 5.0 will be released in January 2013 and will be available for free download from the ESA Web Portal (Earthnet) at:

http://earth.esa.int/polsarpro. A global overview of all the main functionalities proposed in the PolSARpro v5.0 Software will be presented during the symposium, accompanied with demonstrations of the Tool.

The objective of the ESA funded POLSAR-Ap project is to evaluate and demonstrate the importance of quad-polarimetric SAR data for a wide range of remote sensing applications and to generate appropriate demonstration examples and showcases to be used in a dedicated ESA TM publication. An important component of the project is the integration of the implemented applications in the PolSARpro Software and the generation of the appropriate demonstration examples for demonstration and educational purposes. A global overview of the different WPs involving the PolSARpro v5.0 Software in the framework of the ESA funded POLSAR-Ap project will be presented.

CFAR Test for a Change Detector based on an optimized Power Ratio

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Change detection is an important subject in remote sensing. This is particularly true in the recent years due to the current availability of long time series of SAR data. Polarimetry has the potential to improve significantly the detection capability due to the possibility to discriminate between different polarimetric targets. This paper is focused on a methodology recently proposed by the authors [1] and based on the Lagrange optimisation of an error factor that can be attached to the polarimetric and interferometric coherence after the Equi-Scattering Mechanisms (ESM) hypothesis is employed [1]. It has therefore applications for Pol-InSAR processing, when it is necessary to assess the errors caused by the ESM hypothesis. Moreover, the optimisation has been demonstrated to provide the same solutions of the power ratio between two polarimetric acquisitions (i.e. the ratio of two intensity images varying the scattering mechanism). The latter may be more appropriate for change detection focused on hard targets. The optimisation can be easily performed diagonalising a matrix that has real positive eigenvalues. Please note, the mathematical formulation of the optimisation of the power ratio is formally similar to the Polarimetric Match Filter proposed by Novak [2], however in the latter the optimisation is aimed at hard targets detection in single acquisitions.

This paper is specifically focused on two main points: 1) The solutions of the optimisation (i.e. eigenvectors) are analysed, in order to understand their suitability for extraction of information regarding physical changes. A series of Monte Carlo simulations are performed analysing different typologies of changes, and relating the resulting eigenvalues with the partial targets before and after the change.

2) A statistical test is attached to the result of the optimisation in order to set optimally the threshold. Fortunately, the probability density function (pdf) of the intensities ratio is known [3] and could be exploited in this analysis. In particular, it was possible to investigate the detector behaviour as a function of the number of looks exploited. The first test considers the fit of the theoretical pdf with the real data employed in this paper (E-SAR L-band). The fit seems adequate, therefore, a Constant False Alarm Rate (CFAR) methodology is proposed in order to set the threshold in an optimal way. Moreover, the algorithm is adaptive, and the information regarding the background is extracted with windows provided of guards to avoid contaminations due to the presence of a target.

A validation of the CFAR strategy over E-SAR DLR data (SARTOM campaign 2006) is provided, showing the capability of the CFAR to set automatically the threshold. Specifically, in the exploited dataset there were 4 hard targets (3 corner reflectors and one vehicle) that were removed between the two acquisitions. All of them can be detected by the automatic algorithm. Regarding the false alarms, there were none in the analysed area (where a value of 10^(-5) was chosen for the probability of false alarm).

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Change Detection Analysis for under-cover Detection in L and UHF Band

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During summer 2009, ONERA conducted a SAR airborne campaign, named TropiSAR, in the context of the BIOMASS candidate mission. The main objective was to acquire a data set suitable to explore the BIOMASS mission concept in a tropical forest context. ONERA collected L and UHF band data over the tropical forest in French Guyana during a period of one month. Several corner reflectors were deployed and, for some acquisitions, vehicles were parked on a small road under forest.

In this paper we present results of change detection algorithms on this dataset. Three kinds of algorithms are used according to L Novak's work [1]: mono polarisation, polarimetric, polarimetric and interferometric change detection algorithms. These algorithms were applied on both L band and UHF band data.

We show that change detection techniques are powerful to detect vehicles hidden in the forest or on small roads. It is shown that, in our case, for UHF band, the best criterion is the polarimetric one whereas in L band, the polinsar criterion gives the best results.

We also show that the corner reflector hidden under the forest can be detected in UHF band, and thus gives a measure of the attenuation level of this kind of forest. In this case, the two-ways attenuation due to propagation through a 35 m high tropical forest, for UHF band radar and a 30° incidence angle wave is -15dB.

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Unsupervised Classification Based on Seven Scattering Categories Segmentation

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In the conventional scattering model-based unsupervised classification, proposed by Lee et al.[1], the Freeman-Durden decomposition is usually used to divide pixels into three scattering categories of surface, volume, and even bounce scattering. However, in the event that a dominant scattering mechanism is not clearly defined, the Freeman-Durden decomposition failed to cope with these kind of scattering. So, some new scattering categories to account for these pixels may be necessary. In this paper we introduce two parameters to define these new scattering categories. The classification scheme based on these new scattering categories segmentation will preserve polarimetric scattering characteristics, because these scattering categories are derived based on scattering model.

Introduction
According to Freeman-Durden 3-component decomposition [2], the coherency matrix is modelled as the sum of the three coherency matrices of the three different scattering mechanisms:

T = [t11 t21 0; t12 t22 0; 0 0 t33] = fs[1 β^* 0; β $|\beta|^2$ 0; 0 0 0] + fd[$|\alpha|^2$ α^* 0; α 1 0; 0 0 0] + fv[2 0 0; 0 1 0; 0 0 1];

where the three matrices on the rightmost side of represent first-order Bragg surface scattering, dihedral reflection and volume scattering, respectively. It performs well when there does exist a dominant scattering mechanism whose power is much bigger than the residual two mechanisms. However, it may occur that, for some pixels, two or three scattering powers nearly equal. In this situation, no dominant scattering mechanism can be clearly defined, and trying to estimate the dominant scattering power is not necessary and may yield erroneous results. For this reason, we introduce two parameters to characterize the relative power between surface or dihedral scattering to volume scattering as follows:

$\mu_1 = (t11 - t33)/(t11 + 2t33) = (fs + fd|\alpha|^2) / (fs + fd|\alpha|^2 + 4fv) \approx fs / (fs + 4fv)$

and

$\mu_2 = (t22 - t33)/(t22 + t33) = (fs|\beta|^2 + fd) / (fs|\beta|^2 + fd + 2fv) \approx fd / (fd + 2fv)$

The approximation in the above two equations are accurate when fs and fd are on the same order, because for most nature target $|\alpha|^2$ and $|\beta|^2$ are less than \$0.1\$. When the power between fs and fd are no longer comparable, one of them will be inaccurate. Fortunately, we can decide which one is accurate by resorting to the conformity coefficient [3] which is defined as

$\mu_0 = (t11 - t22 - t33)/(t11 + t22 + t33) = (fs(1 - |\beta|^2) - fd(1 - |\alpha|^2)) / (fs(1 + |\beta|^2) + fd(1 + |\alpha|^2) + 4fv)$

By choosing appropriate thresholds for μ_0, μ_1 and μ_2, we can separate pixels into seven scattering categories:

surface dominant scattering: high μ_0 and high μ_1

double-bounce dominant scattering: low μ_0 and high μ_2

volume dominant scattering: moderate μ_0, low μ_1 and low μ_2

surface and double-bounce hybrid: moderate μ_0, high μ_1 and high μ_2

surface and volume hybrid: high μ_0 and moderate μ_1

double-bounce and volume bybrid: low μ_0 and moderate μ_2

triple hybrid: moderate μ_0, moderate μ_1 and moderate μ_2 This will be used in place of the Freeman-Durden decomposition in the algorithm devised by Lee et al. [1]. More details of the algorithm and the experimental results will be given in the final paper.

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A Simple and Extendable Segmentation Method for multi-polarisation SAR Images

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This work presents a simple feature-based multi-channel SAR segmentation method that produces good, smooth, fast and robust results for image segmentation and interpretation. The method is generic for any number of polarimetric channels, easily extendable with new features and perfectly suitable for multi-source data fusion. The basic approach will be demonstrated with real data examples, for several applications, and with the fusion of additional features.

The general approach is to extract features with a sliding window technique that represent the polarimetric information in the multi-channel SAR image. The choice of window size affects the degree of smoothing and class distinguishing capabilities. Simple transformations, such as the logarithm, are applied during extraction to remove any obvious non-linear spreading of the data to produce features that appear well spread with simple visible clusters. This allows the application of a simple segmentation or clustering method to identify separate classes based on data similarity. For example, a mixture of Gaussian clustering algorithm has achieved good results and is particularly fast when applying sub-sampling before full image classification. Other clustering approaches will also be explored, including Markov random field based contextual smoothing.

We demonstrate a set of five basic features to extract from quad-pol data, which have produced good general results for many applications [1]. These features are an absolute multivariate brightness measure, the cross-pol fraction, the co-pol ratio, and the correlation magnitude and phase. The approach works consistently for dual-pol or single-pol data, although fewer features are available in those cases.
We explore additional features including non-Gaussianity (radar texture) measures, polarimetric decomposition parameter features, as well as advanced correlation and entropy measures. If the initial transformation of the parameters is carefully chosen, then the resulting simple segmentation achieves good results.

Real data examples will be given with application to agriculture, forestry and sea ice analysis. The demonstrations will include the basic five features, at different smoothing scales, as well as adding texture, advanced decomposition features, and SAR-optical data fusion.

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Interpretation of an Insar Image using Geometric Codes

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High resolution SAR image of a urban environment is very complex to interpret because of the presence of many geometric effects including multipath, specular reflection mechanisms, backscattering mechanisms and also electromagnetic effects such as diffraction and diffusion. It is then very difficult to interpret, distinguish and predict all the observed effects.

Through a measurement campaign on an industrial area in Salon de Provence (France), ONERA has acquired Insar data in Ka band with a resolution of 30 cm. The images we used to analyze the different effects contain two buildings with walls of 14 m high separated by a distance of 35 m. The experience consists in illuminating three trihedral corners and a truck located in front of the first building with an incidence angle of 45°. Trying to analyze this image, we have noticed the presence of many bright points inside the canyon and also on the roofs, meaning that we have more responses than expected. Actually, a building can have multiple responses: responses due to the bottom and to the top of the buildings, responses associated to the roof, and interactions with the target. The problem we face is to assign to each bright point the corresponding response: is it due to the targets, and if so, with which mechanism are they seen?

In this work, we are particularly interested in the interpretation of the different phenomena we observe in the image using geometric codes. The approach is to perform our study at first on the simplest configuration of a urban area: the urban canyon, in order to study later more complex areas. This urban canyon is composed by two walls (with reference to the buildings) separated by a horizontal plate (with reference to the street). We suppose that the walls and the plate are PEC and we neglect electromagnetic effects, such as diffraction and roughness. To help understanding the geometric mechanisms, we have developed three simple codes taking into account only geometric mechanisms inside a urban canyon: specular reflection and backscattering. We suppose we are in the case of far field in order to explain later the mechanisms in real case. The first code named urban canyon v1 indentifies according to each canyon configuration the different NLOS (Non Line Of Sight) areas illuminated by specular reflection mechanisms inside the canyon.

As an extension of this code, urban canyon v2 allows studying the detection of point targets inside the canyon. Trihedral corner was chosen as an example of punctual target. Since, in real case, the targets are more complex, we have developed urban canyon v3 to study the canyon response when including an extended target as the parallelepiped target.

These codes were used to simulate the canyon under study in order to extract the corresponding range profile where we can identify for every peak, its origin, its position and the corresponding mechanism. In fact, we have obtained -as expected with urban canyon v2- one peak for every trihedral corner as they are well oriented, then, we have obtained two peaks for the buildings (corresponding to the top and the bottom of every building) and finally three peaks for the truck (due to its right side, left side and roof).

These results obtained with these two geometric codes are in agreement with the Insar and the radiometric images of the canyon under study. In fact, as we obtain for the truck three responses on the range profile, we notice the presence of three bright points on the radiometric image. Then, if we analyze the Insar image, we see that the bright points visible on roofs and corresponding to paths involving the target are seen to zero height, and thus are clearly indentifiable through the interferometric phase.

Thus, we can conclude that our geometric codes are promising tools to interpret the different effects observed in radiometric and interferometric SAR images of urban areas. Indeed, we show that we are able to predict the possible responses of the different scatterers included in the scene, the position of their responses as well as the associated scattering mechanism.

We would like as a midterm objective, to validate the results of urban canyon v2 and v3, and more specially the prediction of the scattering mechanisms leading to these peaks.

In addition, as our codes make us wait also a polarimetric contrast between the different answers, we expect in particular to use POLINSAR data to demonstrate the complimentary combination of polarimetric and interferometric data to urban areas analysis.

A Modified Wishart Distance Measure and Its Application to PolSAR Change Detection

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Fully polarimetric SAR (PolSAR) systems describe the interactions between the electromagnetic wave and the target area by means of the Sinclair matrix, and all the recently launched PolSAR systems have the capability of polarimetric imaging with meter resolution. When compared with single-channel SAR data, PolSAR data contain both phase and amplitude information from radar returns transmitted in two different polarizations, signifying that more scattering information can be utilized when PolSAR data are available for change detection than the single-channel SAR data.

To apply PolSAR data to change detection, an appropriate distance measure between the corresponding pixel coherency matrices of PolSAR scenes should be defined. Recently, the most widely used distance, considering homogeneous and Gaussian clutter assumption with the generalized likelihood ratio test (GLRT), is the Wishart distance. When no change has occurred the Wishart distance is expected to be low, and when a change has occurred, it will be high.

The conventional Wishart distance is derived under the assumption that the PolSAR scattering vector k follows a zero mean complex multivariate normal distribution, and the sample coherency matrix W is complex Wishart distributed with n degrees of freedom, where n is the sample size used in the average. However, in a practical application, the scattering vectors in the small sample size will have a long correlation length, and it is impossible to make their sum into 0 through mutual offset of positive and negative. Therefore, the zero mean assumption of scattering vector k should be reconsidered. When the PolSAR scattering vector is an independent nonzero-mean complex circular Gaussian random vector, the sample coherency matrix will follow a non-center complex Wishart distribution. In this case, the conventional Wishart distance needs to be revised.

In this paper, we propose a modified Wishart distance measure and apply it to PolSAR change detection. Unlike the conventional Wishart distance only testing the equality of covariance matrices of two-phase PolSAR scattering vectors, the proposed distance is derived by considering the hypothesis that both means and covariance matrices are equal. Subsequently, Kittler and Illingworth (KI) minimum error threshold segmentation method is applied to extract the changed areas. Two Radarsat-2 fully polarimetric SAR images taken at Shihu Lake area in Suzhou, China, acquired separately on April 9, 2009 and June 15, 2010, were used for our experiment. The spatial resolution was 10m*8m. This area was selected for change detection because of the rapid urban expansion in recent years. Compared with the conventional Wishart distance, it is shown that the change detection method using proposed distance will give a good performance to achieve the changed areas of PoSAR images.

NOTES:

Day 3, Wednesday 30 January 2013

POSTER SESSION

POSTER TOPICS

Airborne and Spaceborne campaigns

SnowSAR II: four months of airborne polarimetric simultanuous measurements at X and Ku band

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1 Introduction

As an integral part of Phase A studies for the proposed ESA CoReH2O (Cold Regions Hydrology High-resolution Observatory) Earth Explorer candidate mission, calibrated airborne SAR data are needed to document the backscattering signature of snow and of other terrain types (e.g. trees), to test theoretical backscattered models, to validate retrieval algorithms and to support the end-to-end simulation of mission performance. For this reason in 2010-2011 the SnowSAR instrument has been developped, consisting of a dual-frequency, dual polarization X- and Ku-band mini-SAR airborne system. In march 2011 the SnowSAR has been deployed within an ESA-coordinated campaign to suport the Earth Explorer mission CoReH2O. SAR data have been successfully collected over Sodankylä, Finland, in parallel with another ESA-based project, the Nordic Snow Radar Experiment (NoSREx) II whose main site of the campaign is situated at the FMI-ARC Arctic Research station. The third season of the NoSREx campaign continued, starting November 2011 and continuing until May 2012. Side by side, the SnowSAR has been operated for the second time. The purpose of the campaign was to provide a continuous time series of polarimetric SAR observations of snow cover in a representative location of the arctic boreal forest area, covering the whole winter seasons. This abstract describes the acquisition campaigns and the first polarimetric data. The finale paper will include a detailed analysis of the data performance 2 Campaign description 2.1 Acquisition geometry The SnowSAR II actual set up on board of the Piper PA-32 Saratoga results in a left side looking SAR system, with look angles of 43° and 43.8° for the X-band and the Ku- band, respectively. The acquisition altitude has been chosen as 1200 metres (~3940 ft) on the ground level. This results in an acquisition altitude of 1380 metres on sea level for the Sodankyla area, whose mean sea level altitude has been estimated as 180 metres, and of 1560 metres for the Tundra strip, whose mean sea level altitude has been estimated as 380 metres. The acquisition altitude is 1200 metres for the sea ice acquisition over the gulf of Bothnia. It is to be noted that the hereby given geometry description is the one adopted during the SnowSAR acquisitions subject of the present document, and it should be considered valid over the descriptions previously released in other documents. With the adopted acquisition geometry and with the SnowSAR II antennae characteristics (antenna patterns are similar for the X band and the Ku band subsystems) it is possible to obtain a swath width exceeding the 400 m required for an optimal coverage of the designed area. 2.2 Acquisition sites In Figure 1 a map of northern part of the Scandinavian peninsula is given, showing the main places involved in the SnowSAR II campaign, mainly concerning the Lappish region of Finland, above the arctic circle. Figure 1 Overview of the places involved in the SnowSAR II campaign. MetaSensing team headquarter during the campaign is set in Rovaniemi. Acquisitions have been performed in the proximity of the towns of Sodankyla, Saariselkä and Hailuoto. Main acquisition site for the SnowSAR II campaign is located in proximity of the town of Sodankyla, where the Finnish Meteorological Institute – Arctic Research Centre offers versatile calibration and validation facilities supporting remote sensing missions. There, in parallel with the SnowSAR airborne campaigns, additional ground based measurements (snow-pack morphology, i.e. stratification, grain size and type, etc.) are performed within the ongoing ESA's NoSREx extension project suitable for comparison and validation. The area represents the same site of SnowSAR campaign in winter 2011: a ca. 70 Km2 area located between the river Kitinen and the lake Orajärvi, mainly consisting of open and forest bogs. In the monitored area is included the FMI-ARC, where experimental data on backscattering signatures of snow are being collected within the NoSREx campaign throughout the entire winter season. The measurements would cover also forested areas on mineral soil, fields and meadows as well as the westernmost end of the lake Orajärvi, where NoSREx in situ measurements of lake ice are made. In Figure 2 an overview of the main measurement site is given. Figure 2 Main site for the SnowSAR II airbnorne measurement campiagn, in proximity of the town of Sodankyla. (a) Measurement site, landscape overview, made of open bogs, forrested areas and the frozen lake Orajärvi; (b) aereal view of the FMI-ARC, in which the 32-metres parabolic antenna, the scatterometer tower and the radiometer tower can be spotted out. Figure 3 Designed flight trajectories for SnowSAR II acquisitions over the main site of Sodankyla. Flight trajectories have been designed taking into account as direction of observation the descending path, right looking TerraSAR X acquisition mode, resulting into 25 SSW-NNE (14°) flight lines, 8 Km long, 400 m apart and allowing to reconstruct an image of the entire study area. Referring to Figure 3, the starting point of each trajectory is indicated by the letter 'A', each ending point by a letter 'B', the tracks are progressively numbered from west to east. Two additional ESE-WNW (287°) flight lines, namely tracks 30 and 31, have been taken into account, covering the main FMI-ARC in situ site from a different look angle, perpendicular to the previous ones. When the campaign was already on progress, it has been requested to extend these two trajectories at their beginning, so that the iced lake Orajärvi could be included more extensively within the acquisitions. More than

10 missions have been performed over main site of Sodankyla, from the first one on 19 December 2012 to the last one on 24 March 2012. About 100 Km north of Sodankyla, close to the town of Saariselkä, it is located the Tundra site, a mountainous area representative of the taiga belt, see Figure 4. Figure 4 Aerial view of the Tundra site landscape, in the Northern Lapland region. Two missions have been accomplished over the Tundra site, one at the beginning of the winter season (T1, 20 December 2011) and one at the end (T2, 29 March 2012). For each mission, airborne SAR data are acquired along two 20 km long trajectories, namely track 50 (flown from South to North) and track 51 (flown from North to South). In Figure 5 the flight trajectories are given: they ideally observe the same scenario from two different points of view; track 50 is the one matching with the TerraSAR X acquisition of the area. Figure 5 Designed flight trajectories for SnowSAR II acquisitions over the Tundra site, in the Northern Lapland. A further mission has been performed the 8 of March 2012 to acquire SAR data over an area consisting of frozen sea (Sea Ice, SI); the chosen area is in front of the island of Hailuoto, in the Gulf of Bothnia. Airborne SAR data have been acquired along four 22 km long tracks, see Error! Reference source not found.. Tracks 60 and 61 are flown in South to North and North to South directions respectively, and they ideally illuminate the same sea strip from two different directions; similarly tracks 62 and 63 are flown in East to West and West to East directions, respectively. Figure 6 Designed flight trajectories for SnowSAR II acquisitions over the sea ice (SI) site, in proximity of the Hailuoto island, Gulf of Bothnia. 3 Acquisition schedule From December 19th, flight dates follow closely a 15-day repeat pass cycle. The different SnowSAR II missions over the main site of Sodankyla are running from nr. 1 (19 -20 December 2011) to nr. 10 (22 -23 March 2012). In two occasions, missions nr. 9 and nr. 10, a delay of one day has been experienced due to bad weather conditions. Besides the originally planned two-weeks interval acquisitions, an intensive repeat airborne measurements has been requested from ESA and from the FMI team while the campaign was already on progress. For this reason 3-days interval acquisitions have been performed between the acquisitions of 22 February and 8 March. One mission has been dedicated to the radiometric calibration of the SnowSAR data. A set of 14 reflectors has been used for this task. 4 Result example An example of the obtained results is given on Figure 7: the same track 19 of the main acquisition site is represented relatively to mission 3 (up image, data acquired on 28 January 2012) and mission 4 (down image, data acquired on 7 February 2012). Processed data have been acquired at the Ku-band in this example. Figure 7 SnowSAR images acquired at Ku-band on track 19: (a) mission 3; (b) mission 4.

Applications of SAR Polarimetry - Other applications

RADAR SAR Processing Data-Set For Earth Tomography Investigation A Computer Vision Approach

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Abstract - An accurate SAR Tomographic investigation is successfully reached by a Multi-Baseline RADAR sensor acquisition. This is the natural InSAR topographic remote sensing evolution technique and request either a major sensor acquisition difficulty or a more heavy MB statistical signal processing. In this issue, polarimetry pays an important role for a more accurate target detection and Tomographic reconstruction. In this paper some MB-PolInSAR statistical signal processing state of the art techniques are depicted and new ideas for Tomographic simulated environmental synthesized data-sets evaluation are proposed. One of the principal objectives of remote sensing is to estimate the word forest carbon biomass budget. In this target, P-Band and L-Band offers more forest penetration capabilities. X and Ku-bands data sets processing can accept a lower foliage RF penetration for an effective radar resolution cell improvement. By using the multi-baseline SAR acquisition technique, can be possible to process statistical algorithms for a 3-D elevation direction and resolution cell parameter estimation. In this paper, efficient MB-PolInSAR simulated synthesized dataset method are proposed. The principal referenced software is PolSARProSIM. The PolSARPro software package isn't optimized for such kind of work. How to synthesize interesting SLC MB-PolInSAR data sets for tomographic applications, using the ESA software, is in this paper described. Following this procedure, it's possible to generate interesting simulated vegetation data-set environments. Such synthesized data-sets can be successfully processed to produce polarimetric Tomograms using classical and non spectral estimators. In this paper, multi-band synthesized data-sets Beamforming and Capon non parametric spectral estimators tomograms results are depicted. A considerable limitation offered by such classical estimators is that, to obtain an acceptable vertical resolution, a significant radar tracks acquisition number has to be performed. A valuable method which helps to archive an effective acquisition number reduction or resolution improvement as well, is to proceed through a most modern computer vision oriented signal processing algorithms implementation. In this paper Compressed Sensing and Differential Compressed Sensing signal processing methods results are depicted and with classical spectral estimators results are compared. Results demonstrate the potential of the PolSARPro software package environmental synthesized SLC data sets, being processed by the CS and DCS methodology and at different bands are validated. Compressed Sensing based algorithms, ensures a good coherent targets built-up reflectivity function reconstruction accuracy. This because of it's sparsity nature. Compressed Sensing is some times not very suitable to solve under-sampled tomographic reconstruction problems in presence of vegetation environment. In this paper, a valid method to solve such under-sampled reconstruction problem is reported. Various statistical inpainting methods, based on the L1 norm minimization on non-coherent scattered targets based, synthesized by the PolSARPro software package, are tested.

RCM: Compact Polarimetric Signatures

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Polarimetric signature is an old concept introduced in the 80's. At that time, it was an interesting way to represent graphically part of the polarization diversity function of the target scattering mechanisms. It is also a useful tool to introduce polarimetric concepts to new users. Since the large number of possible transmit-receive configurations, most of the time, signatures are limited to co-polarized and the cross-polarized transmit-receive configurations which are the representative of the scattering interactions.

Compact polarimetric (CP) system configuration has a right circular transmit for the RADARSAT Constellation Mission (RCM). In this case, the large spectrum of polarimetric signature configurations is reduced to only one possible representation. One signature shows all the polarimetric intensity diversity for a target (point or distributed). That provides another argument for fully polarimetric experts who don’t believe in CP. Nevertheless, simplified information (e.g. CP) could ease the interpretation. This poster presents the use of polarimetric signatures under the RCM-CP context. In order to conduct the study under conditions similar to RCM, a tool that simulates all RCM modes, including the new Compact Polarimetric mode has been developed. Simulated products take into account system noise, transmitted polarization circularity purity and spatial resolution specific to each beam mode. Examples of CP signatures over natural land and oceanic distributed targets will be shown. As for fully polarimetric configuration, pedestal height and position (orientation and ellipticity) of the maximum and minimum intensities can be estimated from CP signatures. Effect of the noise floor and the circularity purity of the transmitted signal on the signature is discussed and also how these signatures could help in the characterization/correction of the variation of the circular purity along the swath.

A Polarization-basis-irrelevant Calibration Algorithm for partially Polarimetric Modes

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A fully polarimetric SAR system offers complete polarimetric scattering information but introduces some constrains on system design. As a compromise, a partially polarimetric system that transmits single polarization at each pulse repetition frequency and receives two orthogonal mutually-coherent polarizations is considered to reduce the complexity. Most spaceborne SAR sensors, like ALOS/PALSAR, TerraSAR-X, RADASAT-2 and Sentinel-1 can provide partial polarimetric modes, generally referred to dual polarimetry (HH/VH or HV/VV mode). Recent compact polarimetry modes, which transmit either a linear polarization oriented at π/4 or a circular polarization while preserve polarization diversity in reception (π/4 or CL mode), provide a promising option for polarimetric system. Recent SAR missions, such as ALOS-2, SAOCOM-1 and the Radarsat Constellation Mission plan to provide CP mode.

The calibration of the SAR system in a partially polarimetric mode is a special problem to be discussed. The system acquires only 2 of the 4 elements of the Sinclair matrix, which induces lack of prior information for calibration. Due to the polarization diversity of this kind of system (which operates on different dual and compact polarimetric modes), there has not a general algorithm currently.

In this paper, a new general calibration algorithm is proposed for partially polarimetric SAR systems. This algorithm uses 3 common corner reflectors including trihedral, 0°dihedral and 45°dihedral as the ideal point targets. The transmitting distortion, the receiving channel imbalance and cross-talk can be estimated based on the relation between the measured data and the calibrators' scattering vectors. This algorithm has several advantages to be concerned. The principle of this algorithm is induced without any assumption on the scene and system. The induction procedure is unrelated with polarization basis, so it can be widely applied to diverse polarization modes like HH/VH, HV/VV, π/4 or CL mode. In addition, the calibrators used in this algorithm are simple to construct and slightly affected by the weather, so they can be widely deployed in the scene. Given the advantages above, this proposed algorithm is a practical approach for partially polarimetric data calibration.

The algorithm performance will be evaluated by simulation and experimental results. The effect of calibrator error on the distortion estimation will be analyzed by monte-carlo simulation. Point targets' calibration results and polarization signatures will be used to verify this algorithm.

A Segmentation Technique using Shannon Entropy and Phase-Difference for PolSAR Images

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This paper presents a segmentation technique using quadruple polarimetric (quad-pol) synthetic aperture radar (PolSAR) image. The proposed segmentation technique is based on the Shannon Entropy (SE) and phase-difference (PD) of measured polarimetric backscattering coefficients. Recently, Morio et al. proposed Shannon Entropy Characterization which contained intensity, polarimetry and interferometry contributions of Polarimetric Interferometric SAR (PolInSAR) data [1]. It can be interesting to determine which fraction of the disorder quantified by the entropy comes from intensity fluctuations, from depolarization, and from incoherence. Several of classification and segmentation technique on SAR images which are based on Shannon entropy can be found in various literatures [2]-[5]. As well-known theory, the SE is sum of two contributions related to intensity (SE_I) and polarimetry (SE_P). The SE_I is resulted from intensity contribution which depends on the total backscattered power, and SE_P is calculated from the polarimetric contribution which relies on the degree of polarization. The image pixels of a building area in the SAR observations have high SE values, because dominant double bounce scattering are found in urban areas. On the other hand, the pixels representing sea and bare surface area have low SE values because of the single bounce scattering effects. The PD is defined as ensemble average of the phase difference between the HH- and VV- or HV- and VV- polarizations and related to the physical status of a target area [6].

We used the C-band RADARSAT-2 quad-pol SAR data over the San Francisco in order to verify our proposed algorithm. Our proposed SE-PD method can preserve detail surface's characteristics, and highlight edges of features in the image, while it is able to decrease random noise. The preliminary result will be presented by comparing with the results of Entropy-alpha technique. Although our approach needs to be improved for higher accuracy on the relationship boundary set and segmentation parameters, it can be useful to apply segmentation approach for quad-pol SAR observations.

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Coherent Scatterer Detection Analysis over Different Test Sites using TerraSAR-X Images

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The identification of scatterers having a point-like scattering behaviour in SAR images has become an important topic with a wide range of applications in different scenarios, ranging from image calibration to object characterization and information extraction [3]-[5]. In particular, this work is focused in the detection of the so-called coherent scatterers (CS's) [1], which are commonly associated with high scattering amplitudes, deterministic phases, high spectral correlation and high interferometric coherence values. Additionally, they are widely unaffected by multiple scattering effects and geometrical distortion, allowing a more direct interpretation. The advantage of CS's compared with other point scatterers is that their detection is possible even on a single image basis. In the InSAR literature, a similar approach for scattering analysis and information extraction exploits the so-called permanent scatterers (PS's) [2], a different class of point-like scatterers. The PS's detection is carried out by using large time series of acquisitions, and typically PS's are required to be temporally stable. On the other hand, in the CS detection methods no assumptions are made about their temporal stability, making their usage appealing in fastly temporally variable scenarios like dynamic natural scenarios.

So far, three different approaches were available for the CS detection, based on spectral correlation techniques by exploiting sublook images (i.e. images using only a portion of the available bandwidth) in range or azimuth direction. Recently, a new approach based on the generalized likelihood ratio test (GLRT) has been introduced [6]. After an extensive theoretical performance analysis using the different detection methods and comparing the new proposed approach with the previous ones, the results have shown that the GLRT detector can achieve a better performance level than the other detectors, provided the same degradation of the spatial resolution.

In this paper, the potential of the new CS detection method is tested on real data, over different scenarios (i.e. natural and urban environments), using TerraSAR-X images. In concrete, three different test sites are considered: for natural scenarios, the Helheim glacier (Greenland) and the Etna volcano (Italy) have been selected; and for urban area, the city of Paris (France) has been chosen. In particular, the performance analysis with the experimental data will be compared with the previous theoretical analysis and the impact on polarimetry will be analyzed in the test sites where polarimetric data is available.

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An Analysis of the Application of PolSAR, at Multiple Frequencies, for Archaeological Prospection

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An analysis is undertaken of the utility of SAR at various polarisations and frequencies for distinguishing buried archaeological features. Study areas include the outskirts of Rome in Italy and Northern Sinai in Egypt. A comparison of the backscatter behaviour over areas of known or suspected archaeological sites is made between single, dual and quad pol SAR signals at both C and L band (Radarsat-2, Envisat ASAR and ALOS PALSAR). The SAR data is compared also with optical data and archaeological charts, where available. For quad pol data polarimetric analysis is performed on the T3 and C3 matrices to derive polarimetric decompositions, extract the scattering signature and obtain the optimal polarimetric basis for the visibility of features of interest. A time series for each data type (apart from quad pol PALSAR) is available on which multitemporal speckle filtering has been applied.

SpotLight Radarsat-2 Data for highly-accurate DSM Generation without GCP: First Results

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Due to the high spatial resolution of recent spaceborne synthetic aperture radar (SAR) sensors, a large number of researchers around the world have investigated stereo-radargrammetric methods using deterministic and empiric modeling and different image matching algorithms for the generation of digital surface models (DSMs). However, few research works and results were presented with very high-resolution SAR data, certainly due to the recent availability of sub-metre SAR resolution in the last years. Consequently, Spolight Radarsat-2 (R-2) data were acquired at the Canada Centre for Remote Sensing (CCRS) over a well-controlled study site in the north of Quebec City. A digital surface model (DSM) extracted from very high-resolution stereo images using a deterministic geometric modeling, which does not require any control data, was evaluated. The 3D deterministic mode based on the radargrammetric Toutin's model developed at CCRS, used the full advantages of the accurate metadata in order to not be dependent on ground control points (GCP). Because two kinds of orbits could be provided in image metadata, previous research work at CCRS demonstrated using accurate stereo independent check points (ICPs) that the predicted orbit based on different on-board measurements is more accurate than the definitive orbit based on satellite orbitography. The 3D radargrammetric model was then computed with predicted orbits and no GCP. The modeling results were evaluated on dGPS ICPs: root mean square errors in the order on 1-2 pixels were obtained in the three axes. The DSM was then generated using a normalized cross-correlation matching, which already proved to well perform with SAR data. As a matter of fact, more than 95% of successful matched points were obtained. After editing the blunders and the small mismatched areas the DSM was compared to 0.2-m accurate lidar elevation data. Because the C-band SAR phase scattering center typically occurs at 40–60% of the canopy depending on the SAR resolution and the tree characteristics (deciduous, conifer, mixed, height, density, etc.), the comparison with lidar elevation data in the vegetated cover can thus generate both systematic and random errors. Consequently, the results computed over the full lidar coverage do not reflect the true DSM accuracy since the dominant source in the error budget will come from: (1) the footprint and penetration in the vegetated cover being different for both sensors (SAR and lidar); and (2) the compared stereo-SAR and lidar points not being at the same elevation in the vegetated cover (70% of lidar coverage). To have the true elevation accuracy, the error evaluation was performed only on bare surfaces, where the stereo SAR and lidar points were at the same ground elevation. The bare surfaces were also representative of the full terrain relief because they occur not only on low lands and slopes but also in the high lands and slopes (mainly, in the northeast). The elevation linear errors with 68 and 90 percent confidence level (LE68 and LE90) were computed over all land-cover surfaces and bare surfaces only. Preliminary results showed that the solution without GCP achieved slightly worse results either in the radargrammetric modeling computation and the DSM generation. These results confirmed previous experiments with ultra-fine mode R2 stereo data that user-collected GCPs (mainly with dGPS) still perform better than the metadata in the geometric processing, whatever the recent improvements in the non-imaging sensors. It is additionally more important with very high-resolution data. Even if there a small loss in accuracy, this solution with the radargrammetric modeling not using any GCP offers strong advantages in remote and inaccessible environments such as the Canadian North, deserts or mountains. It could be an interesting compromise, mainly for Spotlight data due to the reduced image size, which increases the difficult task of GCP acquisition with SAR data.

On the other hand, the improvement of the DSM accuracy is significantly large when compared with previous results using ultra-fine mode R-2 data. One potential reason is that the R-2 Spotlight mode is (3 by 1 m resolution), is not a "true" Spotlight (1 by 1 m resolution), such as TerraSAR and CosmoSkyMed. The range resolution (3 m) of both R-2 Spotlight and ultra-fine modes, where the elevation parallaxes occur, are thus relatively similar. The gain in accuracy is maybe not worthwhile when compared to the 4-time reduction of ground areas.

Building-up Area Extraction from PolSAR Imagery Based on PU-Learning

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Timely and accurately obtaining and analyzing geographic data of building-up areas (BAs) has become an important issue in sustainable development planning, which provides valuable information for many applications, such as evaluation of ecological environment, population estimation, urban construction and planning, emergency management and fast response to natural disasters.

This work focuses on extracting BAs from fully polarimetric SAR (PolSAR) imagery. However, there are two major challenges. On the one hand, BAs is one of the most complex terrain types, which are composed of various natural and artificial objects. Different materials, sizes, heights and overall layouts of the components result in great differences within BAs in PolSAR images. Second, BAs extraction can be considered as a binary classification problem. Generally, given a set of labeled training samples of two classes (in this case, the BAs are the positive samples, all other terrain samples are regarded as negative samples), we use this training set to build a classifier, which is then used to classify new datasets into the two classes. However, it is very difficult to obtain the complete terrain samples for the negative class, because the negative samples have to cover all other kinds of terrain classes.

In this work, we propose to use PU-learning (i.e. Learning from Positive and Unlabeled Examples) based methods for extracting BAs from PolSAR Images. The key feature of this problem is that there is no labeled negative training data, which makes the traditional classification techniques inapplicable. We present an improved ¡°two-step strategy¡± algorithm for BAs extraction using only positive samples. The experimental results on RADARSAT-2 PolSAR images show the effectiveness of our method, which can achieve the satisfying extraction accuracy with less manual labeling efforts.

Statistical Tests for Symmetries in Polarimetric Scattering Coherency Matrices

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The second order statistics (covariance/coherency matrix) are among the most important observables in Synthetic Aperture Radar (SAR) polarimetry. They are restricted to a particular form provided the target exhibits a kind of symmetry (e.g. azimuthal symmetry). As these constraints are not exactly fulfilled in real data, statistical tests (likelihood ratio test) are proposed for checking the validity of an invariance hypothesis. The distribution of the test statistic of the null hypothesis ultimately rests on the assumption that fully developed speckle exhibits complex circularly-symmetric Gaussian statistics.

Such tests can be used for data analysis (e.g. classification) or as pre-processing steps for model inversions and decompositions, as these are often based on stringent symmetry assumptions. The application of these likelihood-ratio tests to airborne L-band data reveals a strong dependence of the test statistics on both the land cover and the number of looks. Furthermore, temporal changes such as vegetation growth manifest themselves in the results; the connection between symmetries and negative powers (unphysical result) in the Freeman-Durden decomposition, however, is very weak.

Applications of SAR Polarimetry on Cryosphere: Snow, Land Ice and Sea Ice Monitoring

Comparison and Validation of CoReH2O Preclassification Algorithms based on Scatterometer Data

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One of the primary objectives of the dual-frequency dual-pol SAR CoReH2O, one of ESA's candidate Earth Explorer 7 missions, is to estimate snow water equivalent (SWE) on land and to observe the temporal variability of SWE. Before applying a SWE retrieval algorithm, an important step is the detection of areas where the retrieval is feasible. The baseline approach for this preclassification was developed in the ESA study on *Development of Snow Retrieval Algorithms for CoReH2O* and employs (global) land cover maps to distinguish forests, glaciers and open water, while a segmentation algorithm on the SAR data of CoReH2O will be applied to separate dry snow, wet snow and snow free areas. For investigations on the snow segmentation, ground based scatterometer data acquired during the NoSREx campaigns in Finland at the same frequencies and polarisations as the proposed CoReH2O instrument (Ku- and X-Band / VV and VH) are available along with an extensive in situ dataset for three consecutive winters. The scatterometer data shows different characteristics in the available three snow seasons which reveals the challenge of establishing a robust segmentation procedure. Preliminary statistical analyses with a separability measure and the Jeffries-Matusita distance indicate a good segmentation potential of the NoSREx data. Based on this, unsupervised k-means cluster analysis and a decision tree optimization procedure were applied to derive data driven segmentation routines. These were compared to the baseline algorithm and cross-validations on the NoSREx data were used to demonstrate the performance of the different approaches. As a conclusion the pros and cons of the algorithms are summarised.

Monitoring and Study of Mountainous Regions in the Pyrenees Area Based on Polarimetric RADARSAT-2 Data

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Snow monitoring is essential for scientific and social hydrological applications. Information about spatial and temporal variability of snow is needed for the modelling and forecasting of snow involved phenomena such as melt run-of, avalanche prediction and water resources forecasting.

This contribution represents the result of the research work conducted in the frame of the still on-going EOSWAN project, targeting the study of the feasibility of snow monitoring with C-band PolSAR data over mountainous regions in the Pyrenees area, North-eastern Spain. The triggering idea of the research was to look for any polarimetric parameter sensitive to the presence of dry, as well as wet snow at C-band. The study is based on the analysis of an alpine test site through a set of 3 PolSAR RADARSAT-2 images acquired in February, March and October 2011. In addition, 2 ground truth snow measurement campaigns were conducted in February and March 2011 in parallel with the acquisition of the PolSAR images. These campaigns consisted on snow measurements of depth and density, as well as an assessment of the snow status carried out by a snow expert. Ancillary data as temperature, weather conditions and a DEM have been also considered.

The election of C-band and a mountainous region test site was motivated by the horizon of developing a snow monitoring service, which would target seasonal snow in northern hemisphere countries, due to snow's main role in the water management, and which would be guaranteed in continuity by future's ESA's Sentinel-1 and CSA Radarsat Constellation Mission.

The idea of this research was to perform an in-depth study of the sensitivity of PolSAR C-band satellite SAR data to dry, as well as to wet snow. The first part of the study was focused on the study of the volumetric scattering mechanism [1][2], since as shown in the literature [3][4], snow volume is an important mechanism, specially at high frequencies. Likewise, surface scattering of a snow covered scene is also significant and can be different from the non snow case, as it was introduced in [5] for L-band polarimetric SAR data, and in [6] for C-band. Preliminary results obtained from the statistical analysis of the different polarimetric parameters over the area of study have allowed defining new polarimetric parameters that would be sensitive to the presence of snow [1][2].

The main conclusion extracted from [1][2] is that at C-band, polarimetry needs to be complemented with temporal information of the variability of the polarimetric signature to perform a reliable study of the snow pack. Another important conclusion is that the most important scattering mechanism in case of dry, as well as

wet snow at C-band is surface scattering. And the most important aspect is that surface scattering differs for the cases of dry snow, wet snow and no snow. It is well known that the study of the polarimetric return, due to the complexity of the scattering process, can be performed my means of Target decomposition (TD) theorems. In the case of model based TD theorems, i.e., the Freeman-Durden, the Yamaguchi and the van Zyl decompositions, and all its variants, they are focused on the study of forests, paying special attention to the volume scattering. The objective of the work to be presented, based on the fact that in case of snow mountainous regions surface scattering represents the main scattering mechanism, is to present a novel TD theorem specifically designed to the study of this problem. An in-depth study of the real PolSAR data, complemented by the ground truth, has shown that in this particular problem, surface scattering could be modeled by a rough surface, whereas the rest of the signal is due to a mixture of scattering mechanisms that need a different model. The new TD technique shall be tested, based on simulated as well as real C-band PolSAR data and the results shall be compared with the ground truth information.

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Towards an Understanding of the Polarimetric Response of Decaying Sea Ice using C-Band Radar Measurements

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Concomitant with the realization that we are faced with vastly different Polar Regions in the coming decades is a concerted effort to understand and model these environments as complex, adaptive, systems and at increasingly finer scales. Observing variations in the climatologically critical spring-summer sea ice melt season, and coupling these with processes occurring at the ocean-sea ice-atmosphere interface, requires enhancing our capacity for exploiting earth observation data. Here we present times series *in situ* and satellite based C-band polarimetric parameters from first-year sea ice at key stages of melt, using data collected during the *Arctic-Ice Covered Ecosystem in a rapidly changing environment (Arctic-ICE)* project in the central Canadian Arctic from May-June 2012. A fully polarimetric surface-based scatterometer was deployed over homogeneous ice cover targets (melting snow, bare ice, and melt ponds), and backscatter was recorded coincident to data characterising their physical and thermodynamic evolution. Surface parameters are compared to coincident backscatter from the RADARSAT-2 satellite operating in fully polarimetric mode. We examine relationships between sea ice geophysical changes and polarimetric parameters, with the aim of developing a framework for the predictive understanding of regional scale snow melt and melt pond physics in response to a changing climate using polarimetric synthetic aperture radar (polSAR).

Multi-Frequency Analysis of Snow-Covered Areas Using SAR Polarimetry

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Earth's cryosphere, as essential source of fresh water, is distinctively affected by global climate change. Thus, monitoring snow reservoirs and retrieving key parameters, such as snow water equivalent (SWE), is of great importance, since these snow properties and their spatial distribution serve as input variables for hydrological, weather or climate modelling. The dynamic of a snow cover as well as freeze-thaw-processes in the soil and their change in time are analysed by means of a winter time series of multi-frequency, polarimetric SAR data.

The retrieval of snow parameters is approached by different microwave frequencies from Ku-, X-, to C-band. A scattering model from the CoReH2O proposal within the ESA Earth Explorer Core Missions is analysed together with the polarimetric SAR data. The dual polarisation forward model, based on the radiative transfer approach developed by [1], takes ground and volume scattering components into account. For the retrieval of snow parameters, the inversion of the scattering model is performed after [2] using co- and cross-polarizations in Ku- and X-band. The algorithm is solved iteratively for the SWE by minimizing a cost function. Additionally, an eigen-analysis of fully polarimetric C-band data concerning the change of entropy/alpha angle values over an entire winter season is conducted, examining their behaviour during freezing and thawing [3]. The investigations also comprise, whether C-band data can be used for inversion with the CoReH2O model and how sensitive snow parameters are to this frequency.

For the analysis, fully polarimetric Radarsat2 C-band data and dual polarimetric (VV, VH) TerraSAR-X data for a time series in winter 2011/2012, as well as SnowSAR Ku-band data from March 2011 are used. Due to the availability of a time series, the complete period from snow accumulation to snow melt, including soil freezing and thawing periods, can be investigated. Two test sites are examined: Churchill, Canada, and Sodankylä, Finland. The data set is complemented by *in situ* measurements of soil and snow parameters, incorporating air temperature, soil temperature, soil moisture, snow depth and snow water equivalent, partly from the Finnish Meteorological Institute and the NoSREx campaign.

The ground measurements are used for validation of the inverted snow parameters. They help to assess the uncertainties of the retrieved SWE values and the potential of the use of multiple frequencies in general and C-band data within the CoReH2O model in particular.

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Applications of SAR Polarimetry on Hazards: Fire Monitoring, Volcanoes, Flooding, Earthquake

Effects of Inundated Vegetation Parameters on X-band HH-VV Backscatter

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Ability to penetrate forest canopy at certain frequencies and polarisations make synthetic aperture radar (SAR) a very effective tool for detecting inundation beneath forest canopies. However, scattering of microwave radiation in inundated vegetation conditions is dependent on both vegetation and microwave signal properties. With the launch of TerraSAR-X and TanDEM-X missions (TSX/TDX) it is now possible to improve the understanding of factors influencing backscatter at X-band. For inundated vegetation, one scattering mechanism is of great significance: double reflection between the water surface and the emergent vegetation. Presence of the double reflection can be determined using phase information of a signal. Independent of incidence angle, a 180° phase difference for HH and VV polarisations is present in case of backscatter from a perfectly conducting dihedral corner reflector. However, while TSX/TDX offer increased ground resolution, it comes as a trade-off for decreased penetration of vegetation canopy, which may mean that the signal will not reach under the canopy for the double reflection to occur. The purpose of this research is to (1) study the applicability of TSX/TDX images for vegetation flood mapping, and (2) to assess the impact of double-bounce on backscatter and phase difference in different vegetation conditions. Patches containing either a majority of coniferous or deciduous tree species with varying tree heights were selected for the study. Two TSX/TDX images representing unflooded and flooded conditions were used in order to compute the change in backscatter magnitude caused by inundation for HH and HH-VV channels. The complex information of HH and VV channels was used for phase shift analysis. For all cases, an increase from 2.4 dB to 10 dB in HH and HH-VV backscatter was observed due to flooding, with a larger increase observed on HH-VV channel. Double-bounce mechanism in flooded conditions contributed to a phase shift ranging from 14 to 31 degrees. Due to better penetration during the leaf-off season, both a larger increase of backscatter difference and phase shift was observed in patches containing deciduous rather than coniferous tree species. Also, both the backscatter difference and phase shift increased with decreasing tree height. In comparison, no notable increase in backscatter and phase shift was observed for unflooded patches. The results suggest that TSX/TDX images can be used for mapping inundated vegetation. Use of HH-VV channel provides a better separability between flooded and unflooded vegetation due to double-bounce mechanism. Increase in magnitude of backscatter in flooded conditions on HH and HH-VV channels is closely related to vegetation parameters.

Applications of SAR Polarimetry on Land:Forest,Agriculture, Environment and Wetlands

Modelling and Interpretation of Polarimetric Scattering from Sub-arctic Lakes at L-Band

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The presented work contributes to the interpretation of fully polarimetric SAR (Synthetic Aperture Radar) data over (shallow) sub-arctic lakes, on the purpose of investigating SAR capabilities in revealing facts about the subsurface and the inhomogeneities within the ice layer which are dominated mainly by methane bubbles. A model for the polarimetric backscattering from a two layer structure observed by a fully polarimetric side looking synthetic aperture radar at low frequencies (L-Band) is developed in [1]. The upper layer thickness is few metres thick and contains inhomogeneities. The developed model describes the backscattering as the incoherent sum of the three main contributions: subsurface (X-Bragg), volume and dihedral backscattering. The volume is modelled as a cloud of partially vertically oriented ellipsoids. The dihedral backscattering component is modelled as the component reflected on the subsurface after being scattered according to Rayleigh theorem by the same cloud of particles that is responsible for the volume backscattering. This dihedral component predicts a larger horizontally polarized backscattering than vertically polarized, a zero copolarization phase shift for small local incident angles. The mechanism could describe a great part of the backscattering from the sub-arctic lakes.

The model simulations are compared to experimental Quad-pol data obtained by ALOS-PALSAR over frozen shallow sub-arctic lakes acquired over several regions in the northern wetlands. Over the Churchill site located on the shore of Hudson Bay in Manitoba (province of Canada), the lake samples are divided into two groups, one with high backscattered power that is assumed to be floating ice and the other with low backscattered power that is assumed to be grounded ice. The forward simulation with a water subsurface and a certain range of volume characteristics matched the observed polarimetric parameters for floating ice lake samples observed by ALOS. The exact same simulation with the same assumption is performed for grounded ice and it matched the observed polarimetric parameters for grounded ice lake samples observed by ALOS. Hence the model shows the same trend as the observed data for grounded and floating ice. Over the Inuvik site located in the Northwest Territories of Canada, a similar investigation is performed, while assuming the first acquisition to be grounded ice and the second to be floating ice, as ice melting before the second acquisition is verified by temperature measurements. Hence the model could explain this temporal change.

Based on those simulations an Entropy-Alpha colour scheme is generated and Entropy-Alpha colour maps (power normalized) for ALOS images are presented. The images show the temporal changes of the ice and the difference between grounded and floating ice.

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Temporal Detection of Wetland using Polarimetric Radarsat-2 Datasets

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This work deals with the temporal monitoring of wetlands using SAR images in full-polarisation acuired along the mouth of the Seine, a long river in north of France. Five polarimetric images have been acquired in March, April, May, October and December in 2012 by Radarsat-2 over this region in wet and dry conditions. For this abstract, only the three first acquisition date have been processed, the two other images will be presented in the workshop and in the final paper. The pre-processing consists in the geocoding using the NEST software with the extraction of the shadow and the layover.

The first step was to classify open water areas which are mainly hunting ponds using the Shannon Entropy parameter. GPS measurements and aerial photos acquired at the same time than Radar acquisitions over different open water areas have been used to validate the results. These results give an excellent detection of open water areas with an over-estimation on wet bare fields. The α_1 polarimetric parameter is used to overcome this problem. The second step of this study was to analyse and detect the flood vegetation. The behaviour of the different scattering components using Freeman decomposition permits to detect slight changes in the scattered information which are in accordance with the aerial photos. The final results of this study is a map divided in open water areas/strong probability of flood areas/probable flood areas/ no water areas.

One objective of this work was also to decrease the amount of information by using only dual/single polarization. The first results in dual polarisation show that it is possible to detect open water areas. However, it remains still very difficult to reduce the open areas over-estimation contrary to the full polarimetric method. Moreover, in the case of only dual polarization, the flodded prairies are not separable from prairies in wet conditions.

This study clearly shows the importance of the polarimetry in such wetlands to separate different natural media and to get accurate temporal monitoring over flooded areas.

Feature Selection of PolSAR Data for Land Covers Separation

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Using polarimetric synthetic aperture radar (PolSAR) in various remote sensing applications, such as agriculture, mapping land use and land cover, disaster management, forestry, geology, hydrology, etc. has been accelerated by coming of new generation of SAR polarimetric satellites. The aim of this research is to extract the information content of the polarimetric SAR data. Cross products of four features "HH, HV, VH, and VV" could be at least nine features in vector space and by applying class separability criterion, the impacts of each feature, for extracting different patterns, could be tested. We have chosen the large distance between classes and small distance within-class variances as our criterion to rank the features. Due to high mutual correlation between some of the features, it is preferable to combine the features which result in the lower number of features. Also the computational complexity will be decreased when we have lower number of features. Due to these advantages, the goal of this study would be to decrease the number of features in vector space. To achieve that, a subset of ranked features consists of one to nine ranked features will be classified based on maximum likelihood algorithm and the classification accuracy of different subsets will be evaluated. It is possible that some of the new features that have been added to the old subsets change the classification accuracy. Finally different feature subsets which were selected based on the various class-separability approaches will be compared. A subset contains at least ranked features that gives the highest overall accuracy would be the best representative of the nine originally features.

The Effects of Polarization on Fractal Dimension Maps Estimated from SAR Data

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The availability of new value-added products able to provide meaningful information regarding the imaged scenes is of key importance in order to provide application counterparts to the huge amount of images provided by the ongoing SAR missions and to broaden the scientific community interested in the use of SAR data. To fulfill this goal SAR experts are supposed to focus their attention on the specific requirements of the product end-users. When dealing with the analysis of natural surfaces, the use of appropriate fractal models is in order [1]-[2]. Fractals are widely used by the geologists to correctly model the behavior of a wide set of natural phenomena and, in particular, to characterize the geomorphology of natural surfaces [3]. Within this framework, the fractal dimension is a concise and meaningful parameter with solid mathematical and physical background bearing crucial information for the geophysical characterization of the surface [1]-[3]. In this paper the behavior at changing polarization of a new SAR product is investigated. In [4] the authors introduced new models for the imaging of natural surfaces and discussed results regarding the estimation of the fractal dimension of a natural surface from a SAR image. The proposed approach is applicable to local areas within the SAR image and allows generating as output a new "image", the fractal dimension map, a point by point map of the estimated fractal dimension of the imaged surface. In [5] the proposed algorithm was applied on actual SAR high resolution data and the first examples of fractal dimension maps were presented. The fractal dimension maps generated by this innovative SAR image processing applied to a set of SAR images acquired by the same sensor and relevant to the same area, but with different polarizations, are here analyzed and compared for the first time. For the analysis we employ a set of Cosmo-SkyMed stripmap SAR images relevant to the area of Naples and its surroundings, including part of the urban area and the natural area relevant to the Somma-Vesuvius volcanic complex: resolution is in any case 3mx3m, while the polarization varies in the different images. In particular, all the four polarization cases (HH, VV, HV, VH) are considered. Note that in the present paper, we compare the fractal dimension maps obtained through different SAR acquisitions, i.e. the considered set is not fully-polarimetric.

The fractal dimension map is estimated all over each SAR image, independently if natural or man-made features are present. As a matter of fact, fractal and non-fractal areas are expected to present a very different behavior when fractal dimension estimation is performed. Our model is by hypothesis expected to perform well on natural areas, whose behavior fall within our theoretical model assumptions, and the retrieved values of the fractal dimension are expected to fit well with those typical of natural surfaces. Conversely, in case of application on man-made areas the algorithm does not provide values which can be obviously assumed as the fractal dimension of the imaged area. Our analysis is aimed at highlighting dependencies of the obtained maps

on data polarization. In particular, it will be shown that on natural areas the fractal dimension maps relevant to the two co-polarized cases (HH and VV) are approximately equal, presenting a different behavior from those relevant to the cross-polarized cases (HV and VH, which show in turn very similar features). Conversely, in urban areas the difference between the co-polarized and the cross-polarized cases is larger and also significant differences between the two co-polarized and the two cross-polarized cases can be appreciated.

In the final paper a complete experimental set-up will be provided with detailed comments regarding the polarization-related properties of the presented fractal dimension maps.

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Retrieval of Soil Moisture using extended Polarimetric Surface Scattering Models

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Theoretical surface scattering models such as Small Perturbation Model (SPM), Physical Optics Model (POM) and Geometric Optics Model (GOM) fail to explain depolarization and cross polarization effects of surface scatterer. In order to extend the roughness validity range and to describe depolarization effects of surface scatterer, the above theoretical models are extended to deal with rough soils by assuming the surface as azimuthally oriented reflection symmetric depolarizer. The width of the assumed orientation angle distribution corresponds to the amount of roughness disturbance of the modeled surface. In this paper, an SPM based three polarimetric surface scattering models have been investigated for soil moisture estimation and validation.

a) X-Bragg (XB) model assumes uniform distribution for the width of orientation angle distribution.

b) Modified X-Bragg (MXB) model assumes Gaussian distribution with 1.5 power correlation function.

c) Lee et al (2011) proposed a new surface scattering model with new distribution function.

Moreover, some polarimetric parameters such as linear copol coherence, cross polarization power and orientation angle parameters in the coherency matrix elements (T_{12}, T_{22} and T_{33}) etc., are evaluated for various width of orientation angle distribution. Two inversion methods namely 'H-Alpha method' and 'Copol-Crosspol ratios method' are used for soil moisture inversion using the above three extended polarimetric surface scattering models and the estimated soil moisture is compared with semi-empirical polarimetric surface scattering models such as Oh *et* al. (1992) model and Dubois *et* al. (1995) model. In order to invert and validate soil moisture using extended polarimetric surface scattering models, JPL AIRSAR L-band MLC data acquired on July 3, 2003 over Little Washita watershed test site during Soil Moisture EXperiment (SMEX'03) campaign has been used. ESA PolSARpro software has been used for coherency matrix generation and for speckle filtering. Some polarimetric parameters are analyzed from the modeled XB coherency matrix for different width of orientation angle distribution. The linear copol correlation coefficient is a good surface roughness discriminator. For Bragg surface, this copol correlation coefficient value is exactly 1 with 0 cross polarization power. In XB model, the linear copol correlation coefficient decreases monotonically and cross polarized power increases with increasing width of the orientation angle distribution. The width and crosspol power is controlled by vertical (*s*) and horizontal (*l*) roughness in MXB model. There is an ambiguity in XB

model due to oscillation of "sinc" function in the XB coherency matrix and the width of the distribution confined between 0° and 90°.In order to avoid the model ambiguity and to increase width up to 180°, Lee *et* al. (2011) proposed a new surface scattering model with new probability distribution function for orientation angle distribution. Using this distribution, the modeled entropy and alpha values are plotted for various width and dielectric constants. Though this distribution extends the width of orientation angle range up to 180°, it is not useful to rough surface soil moisture estimation. The maximum entropy reaches up to 0.37, while the maximum entropy value of uniform distribution is 0.48. Moreover, it has been observed from H-Alpha inversion diagram that this distribution considers from 0° to 90°as a smooth surface with very low entropy. Alpha angle decreases as similar to uniform distribution. But, the maximum decrement of this distribution is equal to 55°width of uniform distribution. The linear copol correlation coefficient is not varying up to 90°and decreasing gradually with increasing width of orientation angle distribution. It has decreased up to 0.5 for maximum width of distribution (180°). For soil moisture inversion, two inversion diagrams namely'H-Alpha' and "copol-crosspol ratios" are plotted for various widths of distribution and dielectric constants using the above three modeled coherency matrices. It has been observed that copol-crosspol ratio parameters are less sensitive to vegetation and hence soil moisture is also inverted over sparse vegetation covered soils. RMS errors in soil moisture estimation for using H-Alpha method are 10.6%, 9.4% and 10.7% for X-Bragg, modified X-Bragg and Lee *et* al. (2011) models respectively. Similarly, RMS error using copol-crosspol ratio method is 2.7% for all three models and 1.6% and 3.1% for Oh *et* al (1992) and Dubois *et* al. (1995) models respectively. The ground truth soil moisture range is low over this test site. Hence, the above models and the polarimetric parameters used in the inversion space are need to be evaluated further with more moisture variation in the test site.

Double bounce Component in Cross-Polarimetric SAR from a new Scattering Target Decomposition

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Common vegetation scattering theories assume that the Synthetic Aperture Radar (SAR) cross-polarization (cross-pol) signal represents solely volume scattering. We found that this assumption is incorrect based on SAR phase measurements acquired over the south Florida Everglades indicating that the cross-pol radar signal often samples the water surface beneath the vegetation. The interferometric SAR (InSAR) observations with Radarsat-2 quadruple polarization (quad-pol) mode data over the Everglades wetland in south Florida showed that very similar fringe patterns related to water level changes were found in all four polarimetric interferograms. Based on these new observations, we propose that the cross-pol measurement consists of both volume scattering and double bounce components. The simplest multi-bounce scattering mechanism that generates cross-pol signal occurs by rotated dihedrals. Thus, we use the rotated dihedral mechanism with probability density function to revise some of the vegetation scattering theories and develop a three-component decomposition algorithm with single bounce, double bounce from both co-pol and cross-pol, and volume scattering components. We applied the new decomposition in both urban and rural environments using Radarsat-2 quad-pol datasets. The decomposition of the San Francisco area shows higher double bounce scattering and reduced volume scattering in the urban area with respect to other common three-component decomposition. The decomposition of the rural Everglades area shows that the relation between volume and cross-pol double bounce depends on the vegetation density. The new decomposition can be useful to better understand vegetation scattering behavior over the various surfaces.

Keywords: Polarimetric synthetic aperture radar (POLSAR), Wetland interferometric SAR (InSAR), rotated dihedral mechanism, volume scattering, cross-polarization, polarimetric decomposition, Everglades.

Polarimetric Soil Moisture Retrieval at Short Wavelength

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In the last five years an enormous amount of polarimetric X-band data got available with the successful establishment of TerraSAR-X and TanDEM-X in space. Especially first investigations on agricultural areas fostered the interest for soil moisture monitoring at this short wavelength.

Up to now soil moisture inversion at short wavelength is approached with various algorithms using empirical, semi-empirical and physical scattering models. The main focus is laid on the estimation of soil moisture on non-vegetated (bare) soil surfaces, where soil roughness is an additionally influencing parameter on the scattering signature, but vegetation does not bias the moisture inversion result.

In [1] the IEM model was investigated for polarimetric bare soil scattering at different frequencies from X- to L-band. In the limit of high frequencies, like X-band, the dominant polarimetric alpha scattering angle, corresponding to the dominant eigenvector and eigenvalue, should only depend on the incidence angle and the dielectric constant of the soil, while the dependency on soil roughness cancels out according to the backscatter

modeling in [1]. Therefore a direct link to soil moisture can be established. In addition, polarimetric decomposition techniques can be used to assess, until which thickness the vegetation cover can be removed for X-band to improve the soil moisture inversion under a growing vegetation cover along the phenological cycle.

In order to investigate the potentials and limitations for inversion of soil moisture at short wavelength, the algorithm is applied on fully-polarimetric X-band data of TerraSAR-X during the 2009 campaign and on dual-polarimetric (HH/VV) data of TanDEM-X acquired for the 2011 campaign, both conducted in the Wallerfing region, lower Bavaria, Germany. In order to understand the growing impact of vegetation cover, the dual-polarized TanDEM-X data set comprises a time series from April to July 2011 and will also provide a performance comparison of dual-polarized to fully polarized data inversion.

In addition, in situ measurements including soil moisture and vegetation parameters were conducted for these campaigns. The extracted SAR-based soil moisture values are validated with the corresponding ground measurements of the Wallerfing campaigns for a quality assessment of soil moisture inversion on bare and sparsely vegetated soils.

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Spatio-Temporal Change Detection of Belum-Temengor Forested Area using SAR

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The Belum-Temengor forest, which is one of the oldest evergreen tropical rainforests located at the Northern Region of West Malaysia, is currently facing logging threats that may lead to its disappearance. This study aims to detect spatio-temporal changes of the Belum-Temengor forest using three different synthetic aperture radar (SAR) sensors: JERS-1, RADARSAT-1, and ERS-1/2, over the years from 1996 (ERS-1/2 InSAR), 1997-1998 (JERS-1), and 2004-2008 (RADARSAT-1).

Various approaches are proposed and compared in this study to enhance the classification and to delineate non-forested area form forested area. The result of coherence InSAR technique proves to be very useful in detecting deforestation at highly varying terrain height area. The findings of this work clearly indicate that Belum-Temengor forest is currently facing severe stress due to human interventions.

In order to provide timely data for deforestation monitoring, a new UAV PolSAR system is also proposed in this work. It is a S-band, full-polarimetric SAR with 1 m x 1m resolution operating on a small UAV at moderate altitude and swath.

The Impact of Precipitation Events on the Forest Classification using Multitemporal ALOS/PALSAR Data

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Single, interferometric dual, and quad-polarization mode data were evaluated for the classification of seven land use classes in the Eastern Amazon (Brazil). The Advanced Land-Observing Satellite (ALOS) Phased Array L-band Synthetic Aperture Radar (PALSAR) data were acquired during a six month interval encompassing both rainy and dry seasons. A clear-sky Landsat-5/TM image acquired during the dry season was used as additional ground reference and as ancillary input data in the classification scheme. We evaluated backscattering intensity and texture parameters for classification purposes using support vector machines (SVM). Results showed that the forest classes were characterized by low temporal backscattering intensity variability. Quad polarization mode tends to perform better than dual and single polarizations but overall accuracies remain low and were affected by precipitation events on the date and prior SAR date acquisition. At extreme precipitation events, quad polarization acquired at the rainy season performed worse than dual polarization acquired at the dry season. Misclassifications between classes were reduced by integrating Landsat data and an overall accuracy of 85% was attained. The integration of Landsat to both quad and dual polarization modes showed similarity at the 5% significance level. We show that in absence of Landsat data, polarimetric features extracted from quad-polarization L-band increase classification accuracies when compared to single and dual polarization alone. We argue that the joint analysis of SAR and their derived parameters with optical data performs even better and thus encourage the further development of joint techniques under the Reducing Emissions from Deforestation and Degradation (REDD) protocols.

Monitoring Peat Swamp Forest Deforestation/Degradation with Multifrequency SAR

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We evaluated the potential of different low cost SAR scenes from the Advanced Land-Observing Satellite (ALOS) on board the Phased Array L-band Synthetic Aperture Radar (PALSAR) and the Advanced SAR (ASAR; C-band) on board the Environmental Satellite (ENVISAT) for the monitoring of both forest deforestation and degradation. As a test site we selected the Sabangau National Forest (SNF) located in Central Kalimantan (Indonesia). In the period of April 2007 and April 2011 all available quad-polarization PALSAR (i.e. five scenes) and dual-polarization ASAR (i.e. ten scenes) were selected for this investigation. The motivation was the availability of airborne Light Detection And Ranging (LiDAR) acquired on August 2007 and 2011 as well as high spatial resolution aerial Hasselblad photographs from August 2011 that were used for validation purposes. The SAR data were multi-looked, geocoded at a spatial resolution of 30m and finally converted to backscattering coefficients. Polarimetric features, decomposition techniques and interferometric coherence were also extracted from the datasets. Since an effective monitoring system at a regular basis does not exist in Central Kalimantan, a simulation of the presence and absence of optical Landsat according to the SAR datasets was also evaluated. Landsat images were atmospherically corrected and converted into surface reflectance. We procede with a visual interpretation over the SAR scenes taking into account the temporal changes in the backscattering coefficients and the variations of the scattering mechanism (i.e. surface or volumetric scattering). Relatively large deforested areas were identified from 2009 to 2011. Landsat data was unable to detect early deforestation stages due to the frequent cloud coverage bringing late response in a simulated deforestation system. LiDAR derived Canopy Height Model (CHM) and Intensity as well as high resolution photographs were useful for the characterization of the vertical structure of the vegetation and for the identification of small threats in the forest caused by illegal logging and hunting practices in the main CIMTROP research transect. Small degradation patches were not detected in either SAR or Landsat scenes. We argue that the joint analysis of SAR with optical data and airborne LiDAR and aerial photographs performs even better forest monitoring and thus encourage the further development of joint techniques. The techniques here reported will be improved under the recent "Reducing Emissions from Deforestation and Degradation" (REDD) protocols.

COSMO-SkyMED PingPong Mode Data to observe Vegetation: first Experiments

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COSMO-SkyMed (CSK) is the largest Italian investment in Space Systems for Earth Observation commissioned and funded by Italian Space Agency (ASI) and Italian Ministry of Defense (MoD). The system consist of a constellation of four Low Earth Orbit mid-sized satellites, each equipped with a multi-mode high-resolution Synthetic Aperture Radar (SAR) operating at X-band. Such a SAR constellation ensures a dense spatial coverage and a revisit time lower than 12 hours. Hence, the CSK constellation is of particular relevance for time-changing scenarios, such as vegetated and cultivated areas.

Vegetation is a key element in the Earth ecosystem since it is involved in the regulation of various biogeochemical cycles, e.g., water, carbon, nitrogen, it influences the energy balance at the Earth's surface and within the atmospheric boundary layer and plays a major role in climate change. Vegetation converts solar energy into biomass and forms the base of all food chains, affects soil characteristics over time including soil volume, chemistry and texture, provides wildlife habitat and it is critically important for the production of food. Hence, the observation of vegetation is a key issue for the earth observation.

In the recent years CSK data have been exploited in order to observe forested and vegetated areas. In [1] forest stand height is estimated by exploiting CSK Spotlight Detected Ground Multi-look (DGM) mode data, together with X-band TerraSAR-X data. In [2] the coherence between two CSK Stripmap HImage interferometric mode data acquired on two different days is assessed in order to discriminate forest types of various densities.

In [3] a crop classification is carried out by exploiting multitemporal CSK dual-polarimetric PinPong mode data. Results show that multitemporal information improves the classification accuracy both for the single (HH/HV) and the double polarization (HH+HV). In particular, the co-polarized channel provides worst results for discriminating crops with respect to the use of the double polarization, while the cross-polarized channel becomes comparable to the use of double polarization when the number of HV polarized images increases significatively. In this study, X-band CSK dual-polarimetric (HH+VV) PingPong mode SAR data are first exploited to observe vegetation.

The CSK PingPong mode implements a Stripmap acquisition by alternating a pair of transmitting /receiving polarizations across bursts, i.e. VV, HH, HV and VH, by means of an antenna steering [4]. In this case, the phase link between two polarimetric acquisitions is not preserved.

The CSK instrument operating in dual-polarimetric PingPong mode acts like an along-track interferometer (ATI), with the fore and the aft antennas given by the combination of antenna steering and polarization switching, that acquires two complex SAR images of the observed scene in different polarizations, e.g. HH and VV, at slightly different times. Let's say ôp the time lag between the two complex acquisitions, the correlation between the co-polarized channels must be interpreted in terms of the relationship between ôp and the coherence time of the observed scene.

First experiments undertaken using X-band CSK PingPong mode (HH+VV) data collected on June 12, 2011 over the Campania region, Italy, show promising results.

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Countrywide Forest BIOMASS Estimates from PALSAR L-Band Backscatter to Improve GHG Inventory in Estonia

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Accurately estimated forest biomass and its distribution is a key parameter for forest inventories, vegetation modeling and understanding the global carbon cycle. It is also required by the United Nations and IPCC (Intergovernmental Panel on Climate Change) to provide a comprehensive analysis on estimates of terrestrial carbon fluxes for climate change reports. To improve the understanding of the carbon balance in Estonia, where forests cover approximately half of the land, a methodology has been worked out to map the changes in the forest biomass in yearly basis using satellite and forest inventory data. A country-specific model allows easily to regenerate the forest biomass models with the newest satellite data and produce up-to-date biomass maps.

To assess the aboveground biomass in temperate deciduous, coniferous and mixed forest of Estonia, measurements from SAR (dual polarimetric L-band SAR imagery) and optical remote sensing satellites were used. Forest biomass map of Estonia was created using intensity measures from L-band ALOS PALSAR while optical satellite data (DMCii) was implemented for separating areas of forests from non-forests and classifying forest types into coniferous, mixed and deciduous. Overall 62 FBD HH/HV images from 2010 were processed for the final biomass map and the results were validated with reference data from Estonian Forest Register. Regression analyses were undertaken to determine the correlation equations and conversion factors for converting growing stock (m3/ha) to total forest biomass.

Final results are presented on a web map application created using ArcGIS Viewer for Flex and published in the ArcGIS server. Biomass map application demonstrates the approximate forest biomass density (expressed in t/ha dry weight) and its distribution in 2010. This method enables a more sophisticated calculation of carbon stock that in turn allows Estonia to report at a higher IPCC tier methodology when providing country-specific GHG inventory data.

Dual Baseline Polarization Coherence Tomography for Forest Structure Parameters Retrieval.

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Understanding temporal climatic variations that are related to the carbon cycle is a major goal of ongoing research efforts. According to revised FAO estimates, the destruction of forest and the associated loss of biomass is responsible for about 12% of annual anthropogenic CO2 release into the atmosphere, although the quantitative uncertainties are quite large. The need for better estimates at local and global scales is well known and various remote sensing techniques have been applied with various degrees of success. However, it would be desirable to have remote sensing capability that provides forest biomass estimates with uncertainties at the 20% level and at resolution levels of about a half hectare (which corresponds to local agricultural encroachment practices in many areas).

Our approach is based on the estimation of forest height profiles by means of complementary polarimetric and interferometric high resolution airborne SAR (POLInSAR) tomography in order to address the fore-mentioned goals in regions of heterogeneous forest. The objective of this research is to determine forest biomass volume through the measurement of the forest structure in 3 dimensions, namely the tomograms, without requiring multiple flight tracks over the same area. The vertical structure function in the complex interferometric coherence definition, which represents the vertical variation of microwave scattering with the penetration depth at a certain point in the two dimensional radar image, is reconstructed using Cloude's methodology of Dual Baseline Polarisation Coherence Tomography (PCT) but applied with a single-pass dual-baseline airborne system. The scattering function over the vertical is assessed by decomposing the biomass profiles by means of Legendre polynomials. Relating biomass through direct in situ measurements is assessed through some relationship with biomass profiles assigned to pre-classification of sub-patches of the forest.

The expected derivation of environmental parameters such as biomass is demonstrated through the recovery of biomass per type of forest sub-patch. In this work, we demonstrate the relationship between the tomogram-derived forest structure and the desired biomass in a limited test-set of forest conditions . In particular we assess the information gain resulting from the higher order terms in the polynomial expansion through use of a dual baseline. The future challenge will dwell on the application of the techniques over different range of species and forest habitat.

Image Texture Dependence upon Sensing and Calculation Parameters

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In this paper it was shown through the statistical method of texture analysis (grey-level co-occurrence matrix) various parameters influence on the textural properties of digital remote sensing images. These parameters can be divided in two groups: the primary (external) parameters determined by surface and sensor characteristics, such as radar frequency, polarization, speckle filtering, spatial and radiometric resolution of the sensor, multispectral (MS) channel, etc., and the secondary (internal) parameters determined by the texture calculation algorithm, where the most important parameter is the size of moving window. SAR, MS and panchromatic images are used for illustration.

Influence of Speckle Filering on Polarimetric SAR Data Classification

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Polarimetric SAR (PolSAR) has emerged as a powerful remote sensing tool to extract bio and geophysical properties of the Earth's surface in all weather conditions. The signals received by the polarimetric sensor for a given location can be in phase or out of phase due to varying degree of surface roughness, which causes brighter or darker pixels in radar images. This interference pattern, a result of signal adding in phase or out of phase is known as fading. This fading is responsible for speckle, which is dominating factor in PolSAR imagery. Speckle is an inherent part which acts as a barrier in the analysis of PolSAR data. It complicates the task of extraction of meaningful information and affects the segmentation and classification of data. Pre-processing of PolSAR data is done using speckle reducing algorithms. PolSAR data without speckle reduction provide insufficient accuracy for the segmentation and classification. Fully Polarimetric ALOS PALSAR and Radarsat-2 data acquired over Mumbai, India are used to test the effect of speckle filtering on the classification. Wishart supervised classifier algorithm is used for classification of the filtered and unfiltered data. Box car, Refined Lee, Lopez, IDAN, Improved Sigma and newly introduced Sequential Filter are analysed for improvement of classification accuracy. Classes used in this study to test the improvement in classification accuracy are settlement, water, forest, mangroves and bare soil. Box Car, Refined Lee, Improved Sigma and Lopez filters are tested initially using 7 x 7 moving window size. To assure the compatibility of the window size, in terms of filtering amount, the number of pixels included in the adaptive neighbourhood of IDAN filter are 50. Sequential filter was tested with smoothing coefficient as 40 and ENL as 4 for both the data sets. Classification accuracy improvement for each class is different and also varies with respect to the speckle filter. Forest and Mangroves classes show dramatic improvement in classification performance (40% to 64%). Settlement and bare soil classes observed marginal improvement (5% to 8%). Lowest classification improvement is observed for water class (1% to 2%). Recently introduced sequential filter is found to be computationally very efficient compared to the other filters. It's performance for classification is comparable with well known filters. The most promising results are shown by Box car, IDAN, Improved sigma and Lopez filter.

Selection of the most suitable moving window size of speckle reducing algorithms is an important step during speckle filtering. Box Car and Refined Lee filters are used to test the effect of speckle filtering on classification by varying moving window size of the filter. Classification accuracy is evaluated for the filtered and unfiltered data sets. The Box car filter with 7 pixels square window and Refined Lee filter with a 9 pixels square window produced highest classification accuracy for data sets used. All classes used in the study exhibit classification accuracy improvement with varying window size but differs for each class. The variation in the classification accuracy depends on the varying size of the moving window. Forest and Mangroves classes shows more improvement in classification accuracy for Radarsat 2 data (9% to 18%) compared to ALOS PALSAR data (7% to 12%) for varying window size. Refined Lee filter found to be computationally more complex than Box car filter. If the considered area for classification has edges and point targets then Refined Lee filter is a good choice.

Box Car filter has a good noise smoothing capability. Speckle in the image can be minimized by increasing size of scanning window. However, this undiscriminating averaging causes a resolution loss in the vicinity of sharp edges and point targets in the image. As the edges in the image need to be maintained, well known Kohonen's Self-Organizing Feature Map (SOFM) is used for this purpose. It helps to deblurr the over smoothed data. To evaluate the performance of deblurring process, quantitative metric such as Improvement in Signal to Noise Ratio (ISNR), Bias factor, Edge Preservation Index (EPI), Edge Save Index Horizontal (ESIH), Edge Save Index Vertical (ESIV) are used. Experimental results concludes that the SOFM enhances fine details of the image with improvement in ISNR. Indices used to study the high frequency components in the image indicates good performance in terms of bias, EPI, ESIH and ESIV. It is also observed that SOFM deblurring process preserves radiometric information and helps for better discrimination of scene targets. The results prove the suitability of the SOFM deblurring approach, to improve the qualitative and quantitative information. This study provides enough information for the selection of efficient speckle filtering algorithm, selection of moving window size to enable good classification accuracy and use of SOFM to deblurr the over smoothed data.

Adaptive Model based PolSAR Classification using Dirichlet Process Mixture

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Unsupervised classification is one of the most basic and important applications for polarimetric SAR (PolSAR) data processing. Many unsupervised classification algorithms have been proposed. Much attention has been taken to the methods which combine scattering characteristics and statistical properties because of considering distribution model and physical mechanism at the same time. Model based decomposition is adopted to characterize the scattering mechanism because it provides better physical understanding of its results. The classification algorithm proposed by Lee et al in 2004 which based on Freeman-Durden decomposition is a typical one and performs well in convergence and can preserve the homogeneous scattering mechanism of each class. There are still some challenges for this kind of methods. One comes from the major limitation of model-based decomposition which assumes the scattering reflection symmetry hold for the observation and may

overestimate the contribution of the volume scattering. The other is to determine the number of clusters adaptively; this is a common challenge for unsupervised classification. This work tries to provide an alternative scheme to overcome those challenges by combining adaptive model-based decomposition and dirichlet process mixture model. The former provides an improved representation for physical scattering mechanism and the latter provides an approach for adaptive model selection of clustering.

In this paper, we propose a new unsupervised classification algorithm for PolSAR data analysis. The adaptive model-based decomposition proposed by Arii et al is used to divide pixels into different scattering categories. We use the dirichlet process mixture model to automatically cluster the data for each category by histogram features of multiple channels. Considering the computing time and robustness, superpixels obtained by oversegmenting are used. The experimental results on E-SAR PolSAR images show the effectiveness of the proposed method.

Identification of Structural Changes in Agriculture by Optical and Radar Data

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In most cases healthy, weed-free cropland has regular structure determined by the unique rate of seed-sowing. Several plant damages, weed infection or drought cause disorders and structural changes in cropland. According to our observation, these types of geometrical changes can be well identified by using standard quad-pol RADARSAT2 data

The objective of the project was to monitor the temporal behavior of structural change of cropland affected by weed infection, Western Corn Rootworm (WCR) damage or drought by integrated use of optical and radar time series data.

Our survey was applied to three individual study areas. Reference data was collected from weed-infected sunflower and soybean parcels, WCR-damaged maize parcels and sunflower parcels hit by drought. Control data was collected from correspondent healthy crops as well.

Reference fields' spectral index features (NDVI, NDWI, NDSI) derived from optical images (SPOT4, Landsat TM7, IRS LISS, IRS AWiFS) were calculated. Polarimetric descriptors of standard quad-pol RADARSAT2 data were determined by using Polsarpro software. Efficiency and accuracy of these features were evaluated by statistical comparative analysis of reference crop fields.

Based on our preliminary results it is established that ragweed infection in sunflower can be well identified by integrated evaluation of radar (acquired in mid-June) and optical (mid-August) satellite images. Effect of drought in sunflower is well recognizable by spectral indexes from optical, as well as "I"-component of Shannon entropy (SEI) derived from radar satellite images.

Ragweed infection in soybean can be well indicated by synergistic application of radar and optical satellite images acquired in the last decade of August. Among polarimetric descriptors, "vol"-component of Yamaguchi ($YAM4_{vol}$) and "I"-component of Shannon entropy have an important role.

Detecting damage caused by WCR in maize field is the most efficient by integrated evaluation of radar and optical satellite images acquired in late-July. Components of Shannon entropy (SE, SE_I, SE_P) have significant role in identification.

This project demonstrates the potential of integrated usage of polarimetric radar and optical satellite images for mapping several types of damages in agriculture.

Satellite image acquisition has been carried out in the frame of our accepted SOAR-EU (called by ESA) proposal (EU-6741) entitled "Identification of structural changes in agriculture by radar polarimetry".

How Green is Glen Affric at Regional and Plot Levels?

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Quantifying above ground biomass (AGB) and carbon sequestration has been a significant focus of attention within the UNFCCC and Kyoto Protocol for improvement of national carbon accounting systems. A multitude of research has been carried out in relatively flat and homogeneous forests, yet forests in the highlands, which generally form heterogeneous forest cover, and sparse woodlands with mountainous terrain, have been largely neglected in AGB studies. Since mountain forests constitute approximately 28% of the total global forest area, a better understanding of the slope effects is of primary importance in AGB estimation both at regional and plot levels. In this work, the understanding of the scattering mechanisms and radar backscatter behavior of the plantation and semi-natural forests in Glen Affric, Scotland are presented. Ground truth measurements were made in several stands which have been selected as the primary study sites. Upon examining and retrieving radar backscatter values from the ALOS PALSAR data, the analysis of the polarization responses of the forest cover is conducted to highlight the useful information carried by the multipolarization data. Three major scattering mechanisms are decomposed and the scattering behaviour are explained using the Yamaguchi scattering model. The contribution from each scattering mechanism to the total backscatter is calculated and their differences for the sites are evaluated. Further investigation was carried out to determine the effect of physical structure of the stands on radar backscatter and the relationship between the biomass carbon and backscatter coefficient.

Classification and Monitoring of Salt Marsh Habitats with multi-polarimetric and Multi-frequency SAR.

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Within GMES there is much interest in the ability of remote sensing technology to deliver operational solutions to many areas of life including environmental management. This paper describes research focused on the application for Earth Observation for Integrated Coastal Zone Management.

Remote sensing of the coastal zone has traditionally focussed on either the terrestrial or the aquatic side. The intertidal zone is not easy to monitor by remote sensing, due to its highly dynamic nature and impact of varying tidal levels on the degree of exposure within the intertidal zone when earth observation satellites overpass. Integrated Coastal Zone Management seeks to find a balance between human use and sustainable functioning of coastal zone ecosystems. Coupled with general interest in ecosystem services, this research explores methods for characterising intertidal coastal zone habitats in terms of the environmental benefits and affordances they confer, thereby providing important information in support of the management of coastal zones. For example, one of the most important services intertidal coastal ecosystems can provide is mitigation against coastal flooding and erosion. However, many intertidal ecosystems are under threat from degradation, habitat loss and human development.

In this study a methodology for aspects of Integrated Coastal Zone Management is proposed, by applying both SAR and optical remote sensing techniques to characterise different salt marsh habitats. One of the main topics of this research is to explore to which extent salt marsh habitats from can be identified from SAR remotely sensed data. Multi-frequency, multi-polarimetric SAR images from airborne (S- and X-Band quad-polarimetric from the Astrium airborne SAR Demonstrator) and spaceborne systems (TerraSAR-X, ASAR and ALOS PALSAR) are used to examine salt marsh habitat classification potential in the Llanrhidian salt marshes in South Wales, UK. This is achieved by characterising their botanical and structural composition, flooding regimes as well as fluctuations in soil moisture. Different SAR features as backscatter coefficient, band ratios and polarimetric decomposition are extracted. These are used as data layers to perform object-based image analysis to delineate the main vegetation habitats and pixel-based fuzzy classification to investigate gradients in vegetation cover and density. In this way the benefit of using SAR as a tool for classification of and monitoring for accurate and repeatable classification and monitoring of salt marsh habitats is researched.

This research seeks to improve understanding of the impact of external fluxes such as erosion, habitat loss and sea level rise. The combination of a multi-sensor and multi-temporal approach gives more insights into long-term dynamics of intertidal land cover and ecosystem functions associated with intertidal habitats and ecosystem services they provide.

Terrain Effect Analyzing based on Freeman-Durden Decomposition

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In this paper, through analyzing the scattering effects from terrain slopes, refined surface scattering component and double bounce component are introduced into the Freeman-Durden decomposition [1]. AgriSAR 2006 data and matched DEM data are selected to validate the model.

Introduction
Terrain slopes takes an important role in influencing the polarimetric scattering matrix of bare soil area. Firstly, it rotates the local incidence polarization plane and brings in cross-polarization terms. Secondly, terrain slopes change the local incidence angle, causing the parameters in surface scattering model renewed. Terrain slopes also have an impact on the local radar cross section. In this paper, the above aspects are studied in the following work:

- Surface profile is derived from the DEM data. Then local slopes among azimuth and ranging direction, local incidence angle are calculated.
- The models of surface scattering and double bounce are refined according to the change of incidence angle, polarization plane and radar cross section.
- AgriSAR 2006 data both in L and C band are investigated using the refined model. The decomposition results are compared with that from classical Freeman-Durden decomposition.

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Comparison of Wishart and Fuzzy Logic Classification Approaches for Paddy Field Detection

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In recent years, there have been two common methods used for the polarimetric classification of agricultural areas, namely, Fuzzy(1) and Wishart(2) classifiers. Both methods rely on distance measurement between the sample and the class prototype. A specific class is assigned to each pixel in both methods. The difference between the principles of the methods based on the information carried out in every pixel. It is known that even with a high spatial resolution provided by new (Synthetic Aperture Radar) SAR images, each pixel has several scattering mechanisms (several classes) included, but it is reported with only one value (class). With the fuzzy logic theory, the variation in the classes within a pixel is described using weighting approach. Furthermore, final classes are obtained after a defuzzification approach. On the other hand, Wishart classification can only assign a sole class to a pixel based on the Wishart distance. In this paper, we present a comparison between unsupervised Fuzzy and Wishart classifications over the paddy fields in the beginning of vegetative stage. Also an automated cluster locator is used for the determination of class center selection. For the image analysis, dual-pol (HH-VV) TerraSAR-X data is used. For the classifications, three polarimetric parameters are used which are entropy (H), average alpha angle (α) and complex coherency between HH and VV (τ). Entropy is used as an indicator for vegetative volume in the field with inclusion of α and ρ. In the calculation of the parameters smoothing is provided by method provided by Lee3. For unsupervised classification, automated cluster locator is used for selecting initial cluster centers. In this method, 3 parameter sample space is divided into specific number of units, each having only one cluster center. Thereafter the Euclidean distance between each sample and cluster center is calculated and initial classification is obtained. In the next stage number of pixels in each class is counted. Classes with less number of pixels compared to the set threshold are eliminated iteratively. The elimination threshold is increased with number of iteration. Iteration comes to an end when it reaches to defined maximum number of classes. In our study we aim to model growth stages of rice. In the rice fields, high level of heterogeneity is expected due to mixed classes of water, soil and different phenological stages of rice. So, we are trying to observe this heterogeneity in the field with an effective classification methodology. In the dataset, outliers are removed from HH and VV sets based on the three standard deviations. Later for the classification, cluster centers are chosen automatically with a starting number of classes equal to 125 to map three classes. In the analysis stage, fuzzy and Wishart classifications are applied for the classification. As a result of the analysis, we found that a significant difference in the classification arises due to closely located cluster centers. And finally, our findings show that fuzzy classification is more sensitive to clusters within a shorter distance.

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Water Body Detection Using RADARSAT2 Polarimetric Data

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I. Introduction

Mapping river networks (urban and peri-urban area) and near real-time urban flood detection is urgently required for urban water conservancy.For the extraction of water bodies in SAR imagery pixel- and segmentation-based classification techniques can be distinguished as the two main concepts. Several algorithms have been proposed such as thresholding, edge detection and so on. But for urban rivers, extraction is difficult and results are not well in practical application. The objective of this paper is to build on a number of aspects of the existing practical algorithms and to take advantage of the superiority of Polarimetric SAR data, in order to develop a near real-time algorithm for urban river quick extraction.

2. Proposed Method

Elongated rivers (especially urban watercourse) or flooded streets only present narrow strips in images and width varies with trees on the both sides. Polarimetric SAR data include plenty of scattering mechanism information of targets, which are helpful in improving performance in target detection, discrimination and classification. In order to quickly and reliably detect urban river, four sequential steps are proposed.

2.1 Data Processing

The recently researches show that quad-polarization SAR data can synthesize certain images to sharpen the contrast of the objects to achieve better classification result and more effectively extract the information£®For Polarimetric SAR image representation, the Pauli color coding is used, and the difference of water and other objects is marked. Furthermore, we convert Pauli RGB image into gray image so that subsequent thresholding segmentation becomes relatively simple.

2.2 Preliminary Segmentation

Water bodies are characterized by homogeneous or low textured areas, with low backscattering values. Thresholding is one of the most frequently used techniques to distinguish water bodies. Thereby, all elements of the SAR intensity data from Pauli gray image lower than a given threshold based on samples are assigned to the preliminary water bodies. One of the main advantages of this method is its fast computational velocity. Additionally, the results are reliable and most of the extent of a smooth water surface can be derived by applying this technique. These are the rapid mapping wanted.

2.3 Morphological Filtering

For the inherent speckles in SAR imagery, it is hard to extract water accurately. Segmentation results usually suffer from a salt-and-pepper effect and a processing, e.g. by filtering becomes necessary. Considering filtering before extraction may has an impact on segmentation of elongated rivers, so we need a noise suppression processing after segmentation. Luc and Pesaresi used the morphological method in various image processing applications and demonstrated the usefulness of this transformation for image filtering and segmentation tasks. In the binary case, the opening by a disc can be used to filter out the small object and tends to smooth outward bumps; the closing by a disc can be used to fill in small holes of water bodies and remove inward bumps, which are mostly caused by speckle noises or point target.

2.4 Post-Processing

In addition to radiation related characteristics of the image objects further parameters like object geometry, texture and contextual information can be used for an improved detection. The importance of shape and size measure could be understood when the natural object are to be identified. Shape and size measures are mostly utilized as complementary to each other. Further, they are always applied in conjunction with the radiation and texture measures. The most common radiation and texture measures include local image statistics (minimum/maximum, mean and variance) and co-occurrence matrix features. Contextual information is also used in conjugation with other measures. Context helps in avoiding fragmentation of a segment and merging.

The above measures can be applied to erase false alarm objects that are wrongly classified as water, e.g. forested areas that are detected as water area because of their low backscatter.

3. Experimental Results and Conclusions

Experiments have been accomplished on various RADARSAT-2 quad-pol SAR data which contain urban and surrounding areas. Synthetic images based on quad-pol SAR data have more details than single channel images and even small objects have enough information for extraction. Besides, water and non-water areas are easier to distinguish and edge of river is obvious. The airfield and crops field in experimental images has not been detected as water because of difference of shape and texture. Especially, extraction of elongated urban rivers produced decent results. Experiments proved the proposed method is valid, measures are effective, and has highly efficient and reliability even in the complicated scenes. It has great practical value in mapping and near real-time urban flood detection in medium-resolution SAR images.

Polarimetric SAR Image Classification Based on SVM classifier Using Radarsat-2 Quad-Pol Data

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Polarimetric SAR Image Classification is addressed based on SVM (support vector machine) classifier, which is a promising binary classifier using Radarsat-2 quad-pol data. Classification of Polarimetric synthetic aperture radar (PolSAR) images can be divided into two stages, (i) extraction of appropriate features, and (ii) labeling of the features based on a set of decision rules (i.e., classifier).

In order to extract appropriate features, the most common used polarization features are initialized as a feature set. Different combinations of polarization features selected from the feature set are used to train SVM model, and corresponding sample training precisions are obtained. The features which decrease the sample training precision are to weed out and those most sensitive to the sample training precisions are reserved. Finally, 16 polarization features are extracted.

In order to optimize the classification results, besides being performed based on pixels, the classification is also performed based on the objects obtained by multi-scale pre-segmentation technique. The pre-segmentation technique is first applied to PolSAR image and generates object-based segmentation. The pixels in the same object are deemed as a unit with its 16 polarization features averaged by the pixels.

The experimental data are C band full polarimetric data acquired by Radarsat-2 satellite over Suzhou city in 16, June, 2010. The image size is 6224 iÁ 3644. The number of look in the azimuth and range direction is 8 and 5 respectively. The resolution is 8m. The average incident angle is 39iă. A small image is cut from the whole image, in which there exist buildings, farmlands and lush vegetation, and water.The Polarimetric data is corrected using lutsigma file included in the product folder and filtered using improved sigma filter [1].

The SVM classification results are validated using the field survey data. And the confusion matrices and Kappa coefficients are given out. The pre-segmentation technique not only enhances the integrity of the classification results, but also sharply reduces the amount of computation and shortens the run time of the classification algorithm. The experimental results demonstrate that SVM classifier is an effective classifier for PolSAR image and the pre-segmentation technique can improve the visual effect and the accuracy of SVM classification result.

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Applications of SAR Polarimetry on Ocean: Pollution Monitoring, Ship detection, Ocean Parameters Retrieval, Sea Features

Ship Detection with the Polarimetric Notch Filter: a Validation with ALOS-PALSAR Data over Tokyo Bay

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The surveillance of maritime areas is a major topic for security in order to fight issues as illegal trafficking or fishing, piracy, etc. Synthetic Aperture Radar (SAR) has proven to be particularly beneficial due to its any-weather and night-time acquisition capabilities [1]. Moreover, the recent generation of satellites can provide high quality images with high resolution and polarimetric capabilities. This paper is devoted to the validation of a recently developed ship detector, the Polarimetric Notch Filter (PNF) exploiting polarimetric data [2]. The algorithm is originally based on a polarimetric target detector using a methodology introduced by the authors, namely the perturbation analysis [3]. The PNF is able to isolate the return coming from the sea background based on its polarimetric signature. Subsequently, a detection is triggered if the polarimetric signature of the area under analysis is different from the one of the sea clutter. In this context, it acts as a notch filter where the Null is set over the 6 dimensional complex vector representing the sea. In other words, the targets of interest lay in the 5 dimensional subspace complementary to the sea polarimetric vector. The algorithm is adaptive and is able to account for changes of sea background in both polarimetry and intensity.

In this work, the PNF is validated for the first time ever with L-band data, exploiting two ALOS-PALSAR quad-pol acquisitions over Tokyo Bay, during October 12 2008. The acquisitions are accompanied by a ground truth performed with a video survey. The PNF shows good detection capabilities identifying the most of the vessels listed in the ground truth. Moreover, maps were employed to identify small targets of interests not strongly visible in the RGB image, but detectable with the PNF. Finally, a test of two dual polarimetric modes HH/VV and HH/HV is performed.

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Algorithms using SAR Polarimetry to observe Targets at Sea

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Synthetic Aperture Radar (SAR), due to its fine spatial resolution, together with its all-weather day and night capabilities, is the most important remote sensing tool for a synoptic observation of metallic targets at sea, i.e ships and oil platforms. However, SAR-based observation of metallic targets at sea is a very complex problem. Conventional approaches are conceived to discriminate bright (and typically small) spots from the clutter background, according to an established decision rule. However, the performances of these approaches are sometimes lower than expected due to the lack of contrast between the targets and the clutter background, the presence of speckle, marine-induced variations of the sea backscattering, etc.

Nowadays, there is a general consensus that the extra-information provided by the transmit-receive antenna polarizations increases the performance of target detection algorithms. New physically-based polarimetric approaches have been developed to observe metallic targets at sea, supported also by new high-performances polarimetric SARs, e.g. the ones operated on-board of the ALOS, RADARSAT-2, TerraSAR-X and COSMO-SkyMed missions.

In this study, the performance of SAR polarimetry for target at sea observation is discussed by analyzing four polarimetric detectors [1-6].

The Polarimetric Notch Filter, based on geometrical perturbation filters, is able to isolate the return coming from the background and trigger a detection if in the area under analysis there is a target with a different polarimetric behavior. Moreover, the algorithm is adaptive and is able to take into account changes of sea background in both polarimetry and intensity. The approach can operate on both quad- and dual-polarimetric SAR data [1-2].

The ship detector developed by Liu applies a likelihood ratio test with the Neyman-Pearson criterion to define a pixel-based detection criterion. Gaussian distributions for the scattering matrix components were assumed in order to derive an approximate decision variable. Even though the Gaussian distribution does not fit perfectly the data, the test is here presented since it shows good accuracy on real data. The approach operates on quad-polarimetric SAR data [3].

The polarimetric cross-entropy (PCE) is based on the Cloude-Pottier target decomposition parameters. The different polarimetric entropy values resulting from sea surface with and without targets are exploited to conceive a physically-based constant false alarm rate (CFAR) target observation filter [4]. The approach is improved in [5] where a discrimination step is performed to remove false positives. This is accomplished by comparing the squared-modulus HV-polarized backscattering related to the potential targets with a given threshold. The approach operates on quad-polarimetric SAR data.

A dual-polarimetric model to exploit the different symmetry properties of sea surface with and without metallic targets is developed in [5-6]. Hence, a simple and very effective filter to observe man-made metallic targets at sea by full-resolution dual-polarized SAR data is developed that exploits the correlation between co- and cross-polarized scattering amplitudes. The technique is shown to be both effective and accurate in observing targets at sea.

Experiments undertaken using actual polarimetric RADARSAT-2 SAR data confirm the benefit of polSAR data for target at sea observation.

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A Novel Ship Detection Method using Model-based Decomposition as a Polarimetric Band-Stop Filter

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In this study, a novel ship detection method using model-based decomposition is suggested. Model-based decomposition techniques are widely used as primary analytical methods in synthetic aperture radar (SAR) polarimetry. Many studies utilizing them focused on land cover classification since scattering from land is composed of various different types of scattering such as surface scattering, double-bounce scattering and volume scattering. On the other hand, model-based decomposition has not been widely used for ocean applications because scattering from the sea surface is mostly surface scattering and classification on the sea is not as necessary as on land. However the fact mentioned above leads to the following idea: if surface scattering component is subtracted from the total power, most of the scattering from the sea can be excluded, revealing other objects on the sea including ships. In other words, model-based decomposition can be used as a kind of polarimetric band-stop filter to shut out surface scattering (i.e. scattering from the sea). Scattering from the ships are more complex, including not only surface scattering but also double-bounce and volume scattering, than the sea surface. This difference in scattering between sea and ships allows model-based decomposition to be used as a ship detector. Many studies investigate each scattering component individually to analyze their intended targets. Above all, double-bounce scattering component is a good indicator of man-made structure like ships. However, double-bounce scattering is not the only scattering component from ships and if we only focus on single scattering component, it may miss some targets which show strong scattering other than double-bounce scattering.

The Land Observation Satellite-Phased Array L-band SAR (ALOS-PALSAR) polarimetric SAR data and available ground truth data for validation off the coast of Portsmouth, UK, are used in the study and results are compared with other polarimetric analyses. The detection process is as follows. First, a filtered image is made using the four component scattering power decomposition, and land masking is performed. Next, background area (homogeneous sea area where there are no ships or other man-made objects) is chosen from the filtered image in order to analyze statistical distribution of the scattering amplitude from the sea surface. After that, the best fit PDF is chosen depending on similarity criterion. Finally, the targets are detected using adaptive-CFAR methodology based on the selected PDF. This filtering method can also be used to extract targets in the area where there is a dominant scattering component. For example, man-made objects in the forest may be extracted by filtering out volume scattering.

A Ship Detector Based on Azimuth Ambiguities Removal for Polarimetric SAR Data

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One of the main remote sensing applications is related to the detection of targets. Polarimetric Synthetic Aperture Radar (SAR), having high resolution and polarimetric information, is playing a more significant role in this field. A series of classical methods of ship detecting are widely used nowadays and more new advanced algorithms are proposed in many paper.

Considering the mechanism of SAR system, detection of ships on the ocean always shows two types of disturbances: ambiguities of targets in both azimuth and range directions away from real targets and the system noises. Among these disturbances, azimuth ambiguities display the strongest power and are the main difficulty when detecting targets. Results of detectors always show more or less disturbing spots of azimuth ambiguities that may be mistaken for real small ships. So in this paper, a ship detector is proposed based on the azimuth ambiguities removal.

The first procedure is the classical ship detectors. A PWF detector is chosen because of its optimal detection ability with automatic threshold provided by Constant False Alarm Rate (CFAR). The key of the proposed method is to remove the azimuth ambiguities left by existing detectors. Hence, a common PWF-CFAR algorithm is sufficient.

Secondly, remove the azimuth ambiguities away from real ships by the calculated distance with the imaging information. To achieve this goal effectively, outlines of ships must be calculated accurately. Therefore, a Shadow-Selected (SS) algorithm is designed. The SS is a recursion algorithm based on the shadow of targets in azimuth coordinate and range coordinate, respectively. A ship area is selected tightly until it is stable. Recursion process not only raises the accuracy of fixing the target, but also increases the efficiency of the whole algorithm.

Identified ambiguities will be removed with the help of azimuth distance and SS algorithm. However, real ships may appear in the same distance or near so that the simple removal may also delete the real ships. SS algorithm can help but not enough. Thus, a ratio combing real ship and the selected ambiguity computed by

span detector is added to this algorithm. An ambiguity own lower energy than its own real ship. By comparing the energies of a real ship and its ambiguities in the areas signed by SS algorithm, this mistake can be eliminated.

The procedures are shown in the following:

- Given one quad polarimetric imagery g(m,n).
- Use PWF-CFAR union detector to have a detected result r(m,n) consisting of 0--1 pixel. i°1i± pixels are real ships mixed with azimuth ambiguities.
- Locate every target on r(m,n) with the SS algorithm, the coordinates are stored in stack t(k) where k is the number of targets. The biggest target is considered the initial real ship.
- Remove the ambiguities according to the azimuth distance and ratio calculated by the span detector only if the ambiguity is selected by SS algorithm and the ratio is low enough.

Finally, the proposed detector is validated on a RADARSAT-2 Quad Mode data. Effects of the SS algorithm and Span Ratio are analyzed. Detecting result shows the accurate location of every real ship without any disturbance that demonstrates the efficiency and viability.

Other

Structural Characterization of tropical Forest at P Band using Polarimetric SAR Tomography with the RVoG Model

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The Random-Volume-over-Ground (RVoG) model, proposed by Cloude and Papathanassiou, has been extensively used to estimate forest height and its underlying ground topography using Single-Baseline Polarimetric and Interferometric SAR (SB-Pol-InSAR) data. Semi-empirical adjustments leads to accurate height estimations ,but may reach this method has some limitations due to non-respected assumptions, bad conditioning of the inversion problem and an insufficient vertical resolution. In order to overcome those limitations,Huang et al. proposed to use Multi-Baseline Polarimetric and Interferometric SAR (MB-Pol-InSAR) data processed with High-Resolution Polarimetric Tomographic SAR (HR- PolTomSAR) focusing techniques.

In this paper, we propose to combine PolTomSAR focusing techniques and the RVoG model in order to accurately localize the different component of a forested area and estimate some of its physical parameters. This approach is based on three main steps: firstly, the MB-Pol-InSAR information is processed in order to jointly and optimally (in Least-Square (LS) sense) estimate the RVoG lines associated to the different baselines. Afterwards, we show that the respect of the RVoG model implies additional constraints to be taken into account.Secondly, the parameters of the estimated lines are used to retrieve the ground and volume elevations using an LS in an unambiguous way based on tomographic methods. Finally, the physical parameters of the volume component are characterized by using first an MB generalization of the technique derived by Cloude and Papathanassiou and then using an adaptive and HR tomographic approach.

The quality of the parameters estimation is demonstrated using MB-Pol-InSAR data acquired by the ONERA SETHI sensor over forested areas at P band during the the tropiSAR compaign. A study of the sensitivity to the number of the acquired images is led. LIDAR measurements are used as reference to evaluate the estimated height parameters.

Benefits of Multi-Dimensional Filtering in the Context of BIOMASS and CoReH2O

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This poster addresses the issue of SAR speckle filtering in the context of ESA's Earth Explorer 7 mission candidates BIOMASS and CoReH2O, which are currently undergoing phase A feasibility studies. BIOMASS is a fully polarimetric P-band SAR for the estimation of above ground biomass, and CoReH2O is a dual-pol dual-frequency Ku-/X-band SAR to measure snow water equivalent. In support of Phase A activities, campaigns with airborne SAR acquisitions have been conducted in recent years, e.g. NoSREx-SnowSAR, TropiSAR and BioSAR. The necessity of including appropriate speckle filtering in the processing chains for improving the retrieval of the Level 2 products was already indicated in scientific support studies. The campaign data are an ideal test-bed to study different filtering approaches, and their benefit and effect, in the temporal, polarimetric and frequency domain. The different approaches of multi-channel filtering will be compared and first results will be demonstrated in this poster.

Past, Current and Future SAR Missions (e.g. RCM, SENTINEL-1, ALOS-2, NovaSAR-S, SAOCOM7)

TECSAR - Program Status

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TECSAR is a space based Synthetic Aperture Radar (SAR) satellite. The satellite was launched on 21st January 2008, and the radar payload of the satellite was operated successfully after launch. The satellite performs excel-lently since its first activation. After an In Orbit Test (IOT) period, the system was delivered to the customers and is fully operational since then and provides a large number of high quality SAR images. A second generation TECSAR satellite is under development. This satellite, denoted TECSAR II, is similar to the TECSAR I satellite in many details, but defers from it in the antenna diameter and its ability for multi-polarization imaging. In TECSAR II, the antenna is equipped with an Orthogonal (Ortho) feed. This feed can transmit and receive the two polarizations of the electro-magnetic wave, Horizontal (H) and Vertical (V). Thus, the TECSAR II is capable of Multi Polarization (MP) imaging. The satellite can image a single image in any of the four polarizations (HH, HV, VH, VV) and in Ping-Pong mode can get a set of two simultaneous images in any combination of polarizations, e.g. VV and VH or HH and VV. Thus, seven of the feeds are used to SAR imaging and the eighth feed is used to download the gathered raw-data.

The TECSAR Satellite was launched on the 21st of January 2008 at 3:45 UTC to an elliptical orbit with a perigee of about 405km and apogee of 580km. The satellite was successfully launched by the In-dian PSLV (Polar Satellite Launch Vehicle) form the Satish Dhawan Space Center in southern India.

Immediately after launch, the satellite's solar panels were successfully deployed and started charging the buttery. About 18 hours after launch, the mesh re-flector antenna was deployed. The satellite's teleme-try indicated that the SAR antenna was deployed successfully and its ribs were firmly locked into po-sition. The IOT (In Orbit Test) period started immediately after the satellite was launched. During this time, all the satellite's systems were tested, including the Ra-dar payload. As part of the planned tests, the first SAR images where taken ten days after the launch. The ten days gap was determined as a precaution, to evaluate the satellite behavior in space and to en-able the formation of a low pressure vacuum. In re-ality, this period can be shortened to less than one day. This ten days waiting period was used to perform IOT tests that do not use the SAR payload.

During the IOT period the Radar performance and modes were tested including the novel Mosaic Mode γ[18]. All these tests were successfully com-pleted and the results were according to the specifi-cation. After the IOT was successfully completed, the system was delivered to the customers and is operational since then. Since launch, the TECSAR system produces few thousands of images per month to the full satisfaction of the user. Few sam-ples of the TECSAR images are displayed in Figure 1.

A quality check performed on the images reveals the excellent nature of the images. The images are very sharp with very low side lobes. Indeed, the In-tegrated Side Lobe Ratio (ISLR) level is around -18dB, while the Peak Side Lobe Ratio (PSLR) is about -30dB. These measurements were performed during the IOT. Image quality test is performed on regular basis few times a year. Since launch, no degradation in image quality was observed, and the ISLR, PSLR figures remain stable.

Sar interferometry (InSAR) is a well known disci-pline, exploiting SAR phase information from two or more images taken within a suitable geometrical proximity. One of the most common utility is Digi-tal Elevation Model (DEM) formation using two or more SAR images whose (synthetic) antenna cen-ters are separated in elevation. Extending the im-ages' baseline leads to an enhanced elevation sensi-tivity but is limited by image resolution. Therefore, large bandwidth SAR images enable fine DEM formation.

During the early period after TECSAR's launch, some repeat pass images were taken, over several sites within Israel. Using those images the interfer-ometric capabilities of the system were tested. The system's high spatial resolution leads to an enhanced interferometric performance, with potentially fine DEM production capabilities.

Given here are two examples:

1. Ira Hills: It is a desert scene, thus temporal and atmospheric effects are practically absent (Figure 2-a).
2. Haruvit Forest: This scene is partially agricultural while parts of it are covered with pine forest. In the forested, volume de-correlation effects are obvious (Figure 2-b).

Polarimetry and Persistent Scatterer Interferometry (PSI)

Application of Polarimetric Signatures in the coherent Scatterers Recognition on SAR images

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The goal of the presented abstract is to describe the new approach to coherent scatterers identification on SAR images. In this method, the full-polarimetric information is exploited. The presented approach assumes that the coherent pixels are defined as pixels for which one dominant scattering mechanism is characteristic and the total power of received signal is relatively high. The coherent pixels generally correspond with man-made objects such as buildings, bridges, roads, etc.

Several methods of coherent scatterers identification has been already proposed in the literature. The most important are the sublook correlation approach and the sublook entropy approach, based on the correlation among the sublook images in spectral domain (Schneider et al. 2006); the entropy approach, based on the entropy values calculated for each pixel of the SAR image; multitemporal analysis of SAR images, where the values of amplitude dispersion in time are used to identify so called permanent scatterers (PS) (Ferretti et al. 2001); and signal to clutter ratio, where the intensity of reflection from the studied pixel is compared with the intensity of surrounding pixels (clutter) (Lee et al. 2009).

In this work a new approach to coherent scatterers identification is proposed. It is based on the analysis of the polarimetric signatures. Since one dominant scattering mechanism is characteristic for the coherent scatterers, their polarimetric signatures should be similar to the signatures of the canonical objects representing basic scattering mechanisms. In this work three scattering mechanisms are taken into account: single-bounce (represented by trihedral), double-bounce (represented by dihedral) and helix scattering (identified separately as left helix scattering and right helix scattering).The similarity of the signatures is assessed based on the correlation coefficient and the distance of two compared signatures. In contrary, to the previously mentioned methods of coherent scatterers identification, this approach allows not only to identify the coherent scatters, but also to recognize their scattering mechanism.

The proposed method was applied for the test data. The test image was acquired by the TerraSAR-X satellite in the quad-pol mode. The study area covers the region of Mahlow city near Berlin. This region includes different types of land cover (buildings, roads, rail-tracks, fields, forests, etc.). The threshold for the correlation coefficients and for the distance were determined experimentally. The resulting map presents all the coherent pixels representing three studied scattering mechanisms. Most of the resulting coherent scatterers are located within the built-up areas. Some of the identified pixels are located along the railroad with NS direction and along the EW-directed, long, indoor garage. There are almost no coherent scatterers identified within the fields and forests, despite the area where the outcrops appear (in the NW part of the image).

The results of the proposed method of coherent pixels identification in the quad-polarimetric SAR data are promising. The built-up areas are well separated and the buildings oriented along the radar line of sight are well recognized even when surrounded by vegetation. Additionally, what is important, the proposed method allows to determine the main type of scattering mechanism in the identified coherent pixels.

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Polarimetry and Tomography

Compact Polarimetry Assessement of Scattering Models for full Polarimetric Information Reconstruction

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Many recent studies in remote sensing addressed the growing interest to Compact Polarimetry for SAR, this technique is an alternative Dual imaging mode implementation to overcome those limiting factors of Full Polarimetric system design. The first CP approach proposed by Souyris et al. [1] implies reconstruction of FP information from CP data acquisition, based on symmetry properties of natural media.

In the present study, the compact polarimetry theoretical formulation is presented, then the work consist the reconstruction for the pseudo FP covariance matrix and coherency matrices using scattering models. We investigate the performance of CP dataset simulation and FP reconstruction algorithms on some target descriptors. We illustrate our results using a C-band polarimetric data acquisition acquired over the city of Algiers Algeria by RADARSAT2 in 2009.

PolSARPro Synthesized Data-Sets of Multi-Baseline Full-Polarimetric RADAR Acquisition for Earth Tomography Investigation.

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An accurate SAR Tomographic investigation is successfully reached by a Multi-Baseline RADAR sensor acquisition. In this paper some MB-PolInSAR statistical signal processing state of the art techniques are depicted and new ideas for Tomographic simulated environmental synthesized data-sets production are proposed. The principal referenced software is the PolSARPro ESA Software package. The PolSARPro software isn't optimized for such kind of work. In this paper, how to get interesting SLC MB-PolInSAR data sets for tomographic applications, using this software, is described. Following this procedure, it's possible to generate interesting simulated vegetation data-set environments. Such synthesized data-sets can be successfully processed to produce polarimetric Tomograms using classical and non spectral estimators. In this paper, multi-band synthesized data-sets Beamforming and Capon non parametric spectral estimators tomograms results are depicted.

Using Tomography SAR to evaluate the Accuracy of Forest Height Estimation Methods in Boreal Forest

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Boreal forest region is the largest land biome, makes up 29% of the world's forest cover. It plays an important role in carbon stock and species diversity. Forest height is one important parameter easier to measure to indicate forest biomass, growing stock volume and carbon budget, as it is related with forest biomass, growing stock volume and carbon budget in allometric relationship. There are some methods for forest height estimation using Pol-InSAR data, such as complex coherence DEM difference, RVoG (Random volume over ground) topographic phase inversion approach, three-stage inversion algorithm and amplitude-phase combined method. To evaluate the accuracies of these forest height estimation approaches, tomography SAR was applied. P-band multi-baseline fully polarimetric data set acquired by DLR in Remningstorp test site, Sweden was used to generate tomography. Tomography SAR aims to retrieve the vertical distribution of backscattering power within the system cell. It could reflect the vertical distribution of relative reflectivity of targets in forest or in a system resolution cell. The result shows that the three-stage inversion method get a better coincidence with the tomography, the complex coherence DEM difference obtains a largest error result, and the RVoG topographic phase inversion approach could reduce the errors through obtaining a more accurate topography. The amplitude-phase combined method combines the complex coherence DEM difference and Sinc amplitude approach. It could get a better result than DEM approach and Sinc amplitude method. The vertical profile could be compensated but still underestimate forest height. These results may due to the variance of scattering mechanism of ground and volume targets in system cell. All these methods define the topographic phase or volume scattering phase by empirical model such as HH-VV as the ground scattering mechanism, HV as the volume scattering mechanism. These scattering mechanisms contain both ground and volume scattering particles. A better method to obtain a higher accuracy forest height result may from separated ground and volume scattering mechanism like tomography.

Sub-Canopy Ground Estimation From Multi-Baseline SAR Data: Experiments with a Polarimetric RELAX-Based Solution At L-Band

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In the last years, interest has been continuously growing in the derivation of the forest vertical structure from SAR data acquired in baseline and/or polarization diversity, given that low frequency SAR possess the unique ability to penetrate into and through even dense vegetation. In this framework, one crucial step is the estimation of the ground topography. In fact, the availability of the ground topography simplifies (at least in principle) the separation between ground and vegetation scattering. Moreover, ground topography constitutes a product itself with great ecological and also commercial impact. Indeed, the estimation of the sub-canopy topography is one of the essential goals of the mission proposal Tandem-L, which consists of two cooperating L-band space borne radars flying in close formation.

Classical interferometric processing is limited by more or less significant height errors due to the presence of vegetation, even at low frequencies as P-band. A great improvement is obtained through the combination of interferometry with polarimetry. In this way, the increased degrees of freedom allow to relate coherent scattering models to the interferometric-polarimetric complex coherences (Pol-InSAR) in order to estimate the ground topography in addition to the vegetation parameters [1]. In parallel to Pol-InSAR, different strategies were investigated. In particular, SAR Tomography (TomoSAR) techniques have demonstrated their potential in the 3-D analysis of volumetric scenarios, although they are still in an experimental stage [2]-[3]. The accuracy achievable in ground topography estimation by single-polarization tomography-based techniques applied to airborne L-band data has been evaluated in [4]. By analysing scenarios with different levels of biomass, it was found that the ground topography can be estimated with a standard deviation equal to or slightly higher than 2m by employing a very simple iterative relaxation method. The best results have been obtained by processing the HH channel. In the HV channel, a non-negligible estimation bias appears which equals around 1m in the densest forested areas. A satisfactory precision (nearly 3m) has been achieved in the limit case of a dual-baseline HH data set.

This work is aimed at evaluating the performance in ground height estimation that can be obtained by coherently combining multi-baseline fully-polarimetric data. As polarimetric information is essential to characterize the individual scattering processes resolved in height, it is expected to become very important for baseline distributions with low vertical resolution and/or with a low number of acquisitions. Assessing and quantifying this trend appears of key importance also in terms of space borne mission implementation for which the number of suitable acquisitions could be drastically reduced. First of all, a fully-polarimetric extension of the relaxation method in [5] is presented. Assuming valid the random-volume-over-ground hypothesis, the multi-baseline polarimetric covariance matrix can be expressed as the sum of a number of Kronecker products [3]. In this way, it is possible to find a transformation of the multi-baseline polarimetric covariance matrix that makes the polarimetric channels decorrelated at each baseline. As a result, while the relaxation criterion results simple to implement, the mutual information between the polarimetric channels is maximised. The performance of the proposed method is extensively analysed and compared with single-polarization results. Experiments are carried out by processing DLR E-SAR L-band datasets over the Traunstein temperate forest, the Krycklan boreal forest, and the Mawas tropical forest, which are characterized by different levels of biomass and different homogeneity in terms of vertical structure. All of the datasets consist of a low number of fully polarimetric SAR images acquired with a relatively short maximum horizontal baseline (around 30m) and limited temporal decorrelation effects. The topography estimated from radar data is validated against Lidar measurements of the ground height.

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Speckle Filters Evaluation based on Separability and Polarimetry Index

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Radar images are widely used for terrain and land use classification and scene interpretation. Specific applications are crop assessment, forest monitoring, oceanography, natural, man-made disaster monitoring, etc. Radar signals received by the sensor for a given location can be in phase or out of phase due to varying degree of surface roughness. This causes brighter or darker pixels in radar images. This interference pattern, a result of signal adding in phase or out of phase is known as fading. This fading is responsible for speckle, which is dominating factor in Synthetic Aperture Radar (SAR) imagery. The random fluctuations in strength of the received signal is a result of the interaction of the radar pulses with the rough terrain surface. Surface roughness determines the strength of the signals reflected back towards the radar. Radar backscatter increases with increasing surface roughness, which in turn increases the brightness in image.

Speckle has a nature of multiplicative noise which is difficult to deal as compared to additive noise. This complicates the problem of interpretation of the image segmentation and classification. The primary goal of existing speckle filtering algorithms, which are subjective in nature, is to reduce the speckle without loss of information. Various techniques have been proposed to suppress the speckle. Quantitative analysis helps for the selection of effective speckle reduction technique. In this paper we propose, new performance measures such as Separability Index (SI) and Weighted Polarimetric Sum (WPS) to evaluate the effectiveness of various speckle filters. The presence of speckle degrades the class separability, hence SI is used for the evaluation of speckle filters. Better classification of the desired classes can be expected if the data is more separable, which can be achieved using most suitable speckle filtering algorithm. The polarimetirc index WPS describes the scattering behaviour of a target. WPS is a measure of the surface roughness. As speckle is due to the surface roughness, it's expected that WPS can used for the evaluation of speckle filters. SI and WPS measures are used to evaluates Mean, Median, Frost, Gamma Map, Lee, Refined Lee, kuan, Intensity Driven Adaptive Neighbourhood (IDAN), Lopez and Improved sigma filters. This analysis helps for the selection of effective speckle reduction techniques.

The filters are evaluated using fully polarimetric ALOS-PALSAR and Radarsat-2 data acquired over Mumbai, India. Performance of the IDAN filter is found to be superior for class separation. Polarimetric indices suggests that the IDAN, Lopez and Improved Sigma filter are more effective in speckle reduction techniques. This result has been verified with Coefficient of Variation, which is a standard measure of speckle reduction. SI is considerably improved after filtering process. SI is higher for the IDAN filter between settlement and water, settlement and mangroves, settlement and forest, settlement and bare soil class. It is also observed that the standard deviation for a class decreases after filtering process for the mean preserving speckle reduction algorithms. Increase in WPS values indicates a reduction in speckle. Effectiveness of speckle reduction is also observed using Coefficient of Variation for comparison purpose where IDAN, Lopez and Improved Sigma performed very well. Similar trend is also observed for WPS.

Index Terms: Polarimetric SAR, Speckle Filter, Wishart Supervised Classifier.

Unsupervised Classification Preserving Polarimetric Scattering Charactieristics

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Polarimetry has been developed for many years in polarimetric synthetic aperture radar (SAR). Due to the development of the polarimetric technique and the enormous quantity of SAR images acquired by spaceborne and airborne systems, classification became an important application of POLSAR images.

Various classification algorithms are proposed, supervised or unsupervised, based on statistical characteristics or based on plarimetric scattering properties, since single-look complex polarimetric SAR data classification is proposed by Kong et al.[1].

An algorithm which classifies pixels not only uses a statistical classifier, but also preserves the purity of dominant polarimetric scattering properties is proposed by J. S. Lee et al.[2]. This algorithm uses a combination of a scattering model-based decomposition developed by Freeman and Durden and the maximumlikelihood classifier based on the complex Wishart distribution. It first divides the pixels into three categories by applying the Freeman and Durden decomposition, and initially merge clusters from many small clusters in each scattering category according to the smallest Wishart distance measure. Then, the iterative Wishart classifier is applied to classify pixels. Finally, the color of each class is automatically rendered by the average scattering power of each class in its category.

Although the preserving polarimeric scattering characteristics classification proposed by J. S. Lee is effective and efficient in classifying PolSAR images, it still has tiny flaws. This paper will try to do the following three investigations.

1) Using a different decomposition method to replace the Freeman and Durden decomposition. As it is stated in [2], Freeman and Durden decomposition can't distinguish the tilted buildings from vegetations. Therefore, the tilted buildings are green in the classification result. We will use another decomposition to devide pixels into scattering categories. And the forest and tilted buildings are divided into different categories.

2) We will investigate the effect of the scheme to initialize categories. As it is stated in [2], three categories can be initialized by the maximum power of the three scattering mechanisms. However, the fourth scattering category is created if J. S. Lee et al. take account of the situations in which many pixels have two or three scattering powers nearly equal.

Therefore, it is necessary to consider the scheme to initialize categories. Here, we will consider the situations in which many pixels have two and three scattering powers nearly equal, and create more categories.

3) The color rendering scheme is modified. Each class color is rendered by the average Pd, Pv, Ps scattering power. The nature color of the mixed category is not only red, green or blue. However, the color used in decomposition map is approximated to their nature color.

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3D Urban Remote Sensing Using Polarimetric SAR Tomography

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Synthetic aperture radar projects 3D scattering of objects onto a 2D range-azimuth plane. In order to acquire accurate scatter localization and monitoring of displacements, many techniques like persistent scatterer interferometry (PSI), small baseline subset (SBAS) processing have been proposed. Nevertheless, with the presence of steep topograph, phenomenon of layover occurs due to the superposition of signals from multiple scatters. The condition is worse in urban area than in forest area.

SAR tomography (TomoSAR) is a technique combines multi-baseline acquisitions. Since different acquisitions scan the scene from different angles, TomoSAR can separate multiple scatterers in each range-azimuth cell. It has been proven that medium-resolution (ERS) and super-resolution(TerraSAR-X) SAR data have the capability of separating multiple scatterers layer in each pixel.

However, most methods proposed only deal with single polarimetric data, polarimetric scattering mechanism in elevation has not been fully studied. In fact, polarimetric SAR data provide more information of the scatterers than single polarimetric data. For example, by Pauli decomposition, one pixel can be decomposed into three kinds of scattering mechanism, surface scattering, double-bounce scattering and volume scattering. Layover phenomenon is usually caused by interference of backscattering from the ground and facade of a building. The scattering from the ground is a strong surface scattering and the one from the facade is a typical double-bounce scattering. By 3D reconstruction of the surface scattering and double-bounce scattering in each cell, strong scatterers in different elevation and different scattering mechanism could be seen. And a combination of the inversion results of those two scattering mechanism can help to acquire the scatterers in the cell.

In this paper, we intend to reconstruct a 3D scene of SAR image using surface scattering data and double-bounce scattering data, which could acquire by Pauli decomposition of each cell. Since 3D reconstruction using only one of the four polarimetric channel SAR data is also OK, the inversion results of those three methods, namely single polarimetric, single scattering and double-bounce scattering, can be acquired. A comparison between method using single polarimetric SAR data and method using surface and double-bounce scattering data were made to show the potential ability of polarimetric SAR data in separating different scatterers.

RADARSAT-2 Fine Quad Mode data have been used to accomplish this experiment. The data are images of Suzhou China, which is a city in south-east China with lots of highrises. Since layover phenomenon is very severe in areas that are crowded with high building, structures of some buildings may disappear in SAR images, which is very hard for us to validate the accuracy of our experiments. A round-structured stadium, Suzhou Sports Center Stadium with an area of 25,000 square meters and height of 50 meters, is used as an object for our experiment.In place where there are only single scatterers (absence of layover), the inversion results of surface scattering show one strong amplitude in low elevation, which stands for the ground. When it comes to places of multiple scatterers, several strong scattering amplitude can be seen in both surface and double-bounce scattering. From the results of the inversion in single and double-bounce scattering, the height of the stadium can be acquired which is near the height of real data. Comparing to single polarimetric data, the combination of results of surface scattering and double-bounce scattering show more detail of the strong power

in elevation. There are two strong surface scatterings when the two scatterers are at ground and roof respectively. If two scatterers are at ground and facade of the building, there is one strong scattering in the inversion results of surface scattering and one in the results of double-bounce scattering. Thus, we can conclude from the experiments that polarimetric 3D tomography has better performance in the inversion of scatterings in elevation for it can provide more information of the scattering mechanism of those scatterers.

Comparison of Different Methods in Dealing with Layover Phenomenon in SAR Images

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Interferometric synthetic aperture radar (InSAR) has been an important tool for measuring topography and deformation of the Earth. However, due to the side-looking imaging geometry of SAR sensors, problems of shadow and layover can be caused. Such phenomenon is very severe in urban areas that can cause the scattering ambiguity.

To deal with this problem, a technique called the tomography has been proposed by analyzing the scattering in elevation in each cell. This technique stacks acquisitions of the same scene from different incidence angles. Since every acquisition can be modeled to be an integration of three dimensional scattering within the observation angle, a function between the unknown reflectivity in the elevation in each cell and its acquisitions in the sensors can be made. As the number of acquisitions is limited, the function is underdetermined.

Several methods have been proposed to deal with the underdetermined function in SAR tomography, including Beamforming method, SVD method, Capon method, MUSIC method and Compressive Method. However, the efficiency and accuracy of those methods have not been fully compared. In this paper, we intend to analyze the accuracy and efficiency of those methods. In the experiment, both simulated data and real data were used to compare.

In the experiments with simulated data, we assumed two scatterers at two elevations with different amplitudes and phases. Additional zero-mean circular Gaussian noise was also added to the simulated data.

First, equally distributed baselines were used for the simulated data. When two scatterers in the elevation were far away apart, all methods could detect those two scatterers. When the two scatterers got closer, at about 15 meters, BF method, Capon method and MUSIC could not separate those two scatterers. When the two scatterers were as close as 1 meter, SVD could not distinguish those two scatterer, but CS method could also locate them.

Then, baselines of real data were used. It could be seen that the performance of all methods degrade greatly due to the uneven distributed acquisitions. The accuracy of every method went down as half, about 30 meters, as the results with evenly distributed baselines. Only CS method could separate two close scatterers when the power of noise can be acquired accurately.

RADARSAT-2 Fine Quad Mode data were used as real data to compare the performance of those methods. The Suzhou Sports Center Stadium was selected to be the object to be inversed because its structure is very clear. From the experiment, we could find that all methods could find the two strong scatterers at the edge of the stadium in the SAR image. However, beamforming method had a severe and anomalous sidelobe problem caused by the irregular sampling. And SVD method was not stable for it would find wrong scatterers at some points. Capon and MUSIC methods were both based on multi-looking, even though the multi-looking work could degrade Gauss noise, it also degraded the resolution of the elevation. What's more, other scatterers in neighboring pixels could interfere with scatterers in the center cell which may cause wrong phase measurements. The CS method was the most accurate method, but the efficiency of the method would be very low. Moreover, the noise power of each cell was hard to measure, and this was a prior condition when applying CS method. So the accuracy could be affected if the noise power were not properly estimated.

In conclusion, if all acquirements are equally distributed, all methods can be good ways in dealing with layover problem. However, when they are irregularly sampled, all have defects, either in resolution or efficiency.

SAR Polarimetric Interferometry (Pol-InSAR)

Multibaseline PolInSAR using RADARSAT-2 Quad-pol Data: Monitoring Deformation in the San Francisco Bay Area

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Differential Interferometric SAR (DInSAR) techniques are developed in order to measure ground deformation. However, DInSAR effectiveness dramatically reduces in natural terrains due to the low density of suitable pixels. An alternative to address this problem is through the increase of pixel coherence, which results in a higher phase stability. Polarimetric coherence optimization enhances the pixel coherence based on analysis of the scattered signal. In recent years, fully polarimetric SAR images have been available as a result of the launch of satellites such as Radarsat-2. Here, we apply an Equal Scattering Mechanism Multibaseline (ESM-MB) coherence optimization technique on 28 C-band Radarsat-2 images in both ascending and descending mode to increase the interferometric coherence [1].

We perform the comparison of dual-pol optimization versus the quad-pol optimization to understand better the contribution of cross-pol channel. The results clearly show that cross-pol channel plays a more important role in the optimization results for certain types of scattering mechanisms than the others. We further use different parametrization techniques to study the scattering mechanisms of the imaged media in accordance with the optimized coherence. Analysis of results for individual interferograms shows that the coherence improvement with respect to single polarimetric channel is shown to be correlated with the interferometric spatial and temporal baselines.

Finally, we investigate the performance of this technique on the interferometric phase. The optimized interferograms increase the quality of the phase patterns with respect to those phases recovered in a single co-polar channel, e.g. the residual orbital ramps of the RADARSAT-2 images. The optimized channels are used for interferometric analysis and generation of deformation maps in the San Francisco region, where the Hayward fault presents a high risk of seismic hazard. The results confirm that using a full polarization of SAR images favors a better estimation of deformation phenomena both in terms of coverage and phase stability.

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Under-foliage Target Detection using Multi-Baseline L-Band PolInSAR Data

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Hybrid environments refer to a scenario of objects embedded in a host natural environment (e.g. forests). Their scattering patterns consist of a complex mixture of diverse scattering mechanisms, like the volumic scattering from the canopy, the double bounce reflection between the ground and under-foliage objects as well as between an object and trunks, the surface scattering from the underlying ground, etc. The resulting SAR information is characterized by a strong complexity, which makes SAR image analysis difficult by means of PolInSAR data (due to the single-baseline configuration). Multi-baseline PolInSAR techniques can be applied to reconstruct the associated scattering responses and polarimetric patterns. In [Nannini et al, 2008], using single polarization tomograms.The forest profile and truck shape were both extracted using Capon's spectral estimation approach. However, due to the limited spectral resolution and sidelobe suppression of such an approach, parametric and fully polarimetric tomographic approaches are expected to show significantly improved features of under-foliage objects and forests as it has been shown in [Huang et al, 2011]. In [Nannini et al, 2008] [Huang et al, 2011], the applied spectral estimation methods are either nonparametric or parametric. It is known that nonparametric approaches are in general more robust to focusing artefacts, whereas parametric approaches are characterized by a better vertical resolution. It has been shown [Stoica and Nehorai, 1990], [Huang and Ferro-Famil, 2009] that the performance of these spectral analysis approaches is conditioned by the nature of the scattering response of the observed objects. In the scenario of hybrid environments where objects with a deterministic response are embedded in a speckle affected environment, the parameter estimation for this type of scatterers becomes a problem of mixed-spectrum estimation. To isolate and characterize these different scattering contributions, a novel method proposed by Huang et al. is used to extract isolated scatterers from their surrounding distributed environments, called IS extraction in [Huang et al, PolInSAR 2011]. Incorporating the WSF estimator, this method estimates scattering responses within one resolution cell and then distinguishes isolated scatterers from distributed ones by calculating the cross-correlation between the measured data and the estimated scattering responses. Isolated scatterers can be jointly detected and localized using this method. To compare the detection performance for coherent scatterers, in this paper, two statistical methods are firstly applied to analyse hybrid environments: one is a GLRT

(generalized likelihood ratio test) based detection and the other is a WSF-based detection procedure. The former will follow a standard test on goodness of fit. In the detection procedure, the hypothesis that a given number of scatterers is adequate to describe the observed data is tested against the alternative that the data covariance matrix has an arbitrary structure [Ottersten et al, 1993]. The later utilizes the property that the normalized WSF cost function calculated at estimated locations of scatterers is asymptotically Chi-squared distributioned. A threshold is selected for the hypothesis test based on the tail area of Chi-squared distribution with degrees of freedom associated to the number of scatterers. Moreover, a new method based on the properties of spectral correlation is proposed in this paper to separate the volume effects from the coherent scatterers.

This paper contains totally four methods for the under-foliage target detection. That are applied to fully polarimetric L-band airborne data are acquired by DLR's E-SAR system over the test site of Dornstetten, Germany. The investigated scene contains some trucks over bare soil areas as well as beneath forested zones considered as localized targets. The detection results of these methods will be compared and validated against ground truth.

Correction of Ionosphere for InSAR by the Combination of Differential TEC Estimators

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Low frequency spaceborne SAR configurations are favoured for global forest mapping applications and D-InSAR applications over natural terrain. Several missions have been scheduled to be launched / or proposed to be implemented in the next years: JAXA's ALOS-II (L-band), NASA's Destyni (L-band), DLR's Tandem-L (L-band) and ESA's BIOMASS (P-band) are some of them. A common challenge for all these missions is to control / compensate the disturbances induced by the ionosphere. At these lower frequencies the ionosphere effects several components of the SAR measurements performed: It delays the group velocity of the transmitting / receiving pulses, advances their phase(s) and rotates their polarisation state. Accordingly, it distorts not only intensity but also polarimetric, interferometric and polarimetric interferometric observation spaces.

The total electron content (TEC) is the most decisive parameter in the characterisation of the ionosphere. It is defined as the integrated electron number density per unit volume along the direction of propagation. Most of the free electrons are distributed within a relatively narrow altitude range allowing modelling the ionosphere as a thin layer at a fixed altitude. In this case the ionosphere can be characterised by a 2-D scalar field of TEC [1], [2].

Depending now on the SAR configuration and its observation space different correction approaches are possible leading to a wide range of calibration algorithms. In this paper we propose a concept towards the generalisation of ionospheric calibration methodology by integrating a number of individual approaches / algorithms. In this sense, a novel generic correction schema based on a combined (and improved) estimation of the 2-D TEC field (or the associated differential TEC field in the interferometric case) from a set of individual data based TEC and/or TEC gradient estimates is introduced and discussed.

As a special case a combined 2-D (differential) TEC field estimator based on (differential) TEC estimated from Faraday rotation measurements and (differential) TEC gradients obtained from the estimation of azimuth/range (differential) shifts is presented. Both observations are independent, allowing establishing an inverse problem for the (differential) TEC estimation. Geophysical knowledge as the anisotropic nature of the TEC distribution can be incorporated as *a priori* information in the "combined" (differential) TEC estimator.

The performance of the proposed approach is tested using ALOS quad-pol interferometric data sets over several test sites in Alaska. The achieved estimates are characterised by a significantly improved performance: While the FR based estimator suffers from the random granular deviation pattern of TEC after conversion, the proposed combined estimator effectively is free of such artefacts. Emphasis is given in the role of polarisation in the TEC estimation procedure [3] and on the calibration of Pol-InSAR data.

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Supervised Classification using Polsar Data based on K-Wishart Model

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Due to the accelerated advancement of PolSAR techniques, some advanced approaches of supervised classification of PolSAR have been proposed. And the Wishart probability density function has became the most famous model to estimate the statistics of the full covariance matrix. However, this model is used under the condition that assumes homogeneous speckle and ignores the texture information. Thus some heterogeneous thematic classes could not be better fitted because of the complexity of the nature scence and the inherent speckle noise especially for the high resolution SAR. In this paper we focus our interest on the K-Wishart statistic model which is a non-Gaussian model and gives an accurate and concise probability density function. Originated from the well known product model, it not only incorporates the polarimetric information, but also includes the texture variable which has a Gamma distribution for the complex scattering coefficients. In the Bayesian classification scheme, the class parameters are estimated from the training data, and the prior class probabilities are estimated. PolSAR data sets of YiGen test site in Inner Mongolia province of China acquired by the RADARSAT-2 C-band sensor in September 2012 are used. With survey investigation, we have gotten some test data. Evaluated and compared with the general Wishart model, the K-Wishart model has shown better performance on classification.

Analysis of Vegetation Height Estimation Fluctuations of PolInSAR Measurement using the Cramer Rao Bound

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Polarization Interferometric Synthetic Aperture Radar (PolInSAR) techniques have been proposed for environmental applications such as biomass estimation. For this purpose, the random volume over ground (RVoG) model [1] has been developed and several estimation methods based on this model have been applied for L-Band and P-band PolInSAR measurements. Although the ability of these techniques has been illustrated with different examples, there are still open questions on the precision that can be expected.

The limitation on the vegetation parameter precision can result from inefficiency of the implemented estimation method and/or from the lack of information contained in the acquired data. A first step on the analysis of this problem has been recently provided in [2] on synthetic data for which the true values of the parameter are known for P-Band measurements. For that purpose, the Cramer-Rao bound (CRB) has been determined for PolInSAR measurements and parameter estimation methods based on the RVoG model. Indeed, the CRB provides a lower bound of the variance of any unbiased estimation methods. It thus characterizes the information contained in the measurements independently of any particular unbiased estimation method. However, there is in general no proof that such a minimal variance can be obtained with finite size set of measurements. It has nevertheless been shown [2] on synthetic data that, for sufficiently large set of measurements, an estimation method based on the technique proposed by Cloude and Papathanassiou [3] can lead to efficient unbiased results (i.e. with a variance equal to the CRB).

The purpose of this communication is to extend the analysis to real measurements since, as mentioned above, the previous analyses have been mostly performed on synthetic data. It is thus proposed to compare vegetation height precision on PolInSAR measurements with the theoretical bound provided by the CRB. Such an analysis is performed on data acquired in Landes' Forest (France) [4] that contains large and homogeneous regions (around 6000 pixels). The variances of vegetation and topography parameters that result from estimations in sliding window will be compared to the CRB obtained with parameter values estimated in large homogenous regions. Such large regions are determined using the segmentation method developed in [5] for PoInSAR images. This technique allows one to decompose the PolInSAR image into homogenous regions by minimizing its stochastic complexity.

The minimal variances of vegetation height and of ground elevation provided by the CRB will thus be compared to variances of estimations based on the Cloude and Papathanassiou technique. It will be shown on these measurements that the CRB can indeed be useful to analyze the estimation precision obtained on real data. Different issues such as the influence of the size of the sliding window used for the estimations, the spatial correlation of the measurements, the non-uniformity of the vegetation and ground elevations, will be discussed.

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Polarization Phase Difference Analysis for Mapping Inter-Seismic Creep of the Hayward Fault in the Northern California

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We apply a technique for selecting persistent scatterers (PSs) based on their polarization phase difference (PPD) to produce a ground deformation map capturing inter-seismic creep of the Hayward fault in the northern California. For this we analyze a normalized PPD between HH and VV channels averaged over a temporal set of images and select pixels that demonstrate predominantly even or odd bounce scattering properties. We compare selected scatterers to PSs selected by applying an amplitude dispersion threshold as suggested by a standard PS interferometry (PSI) approach and show that both methods are complementary. However, the proposed approach can be potentially used on a small set of synthetic aperture radar (SAR) images, which can be beneficial in the early stage of data acquisition. The coverage and the precision of the produced deformation map are higher than if it was calculated with the standard PSI technique applied to the same data set. Modelling and interpretation of the observed ground deformation is also provided.

Topographic Correction for Pol-InSAR Forest Heights Retrieval : Applications to TropiSAR Data

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In forest height retrieval from Pol-InSAR data, the underlying terrain topography can be the source of significant error. First of all, the estimation of the Pol-InSAR coherences is subject to geometrical decorrelation related to spectral shift, which is closely dependent on the local geometry. Secondly the terrain topography has also a strong impact on the double bounce scattering mechanism -- involving the specular reflection onto the ground -- so that the relative contribution of scattering mechanisms (surface, volume, double bounce)are modified. As a consequence, the resulting complex Pol-InSAR coherences are also modified.

On top of these two phenomena, it can be reminded that the standard height retrieval algorithms are based on the analytical formulation of the Pol-InSAR coherences which mostly assumes a flat terrain. In the case of terrain topography, this assumption leads to a significant error in the retrieved heights, which can be corrected using a Digital Elevation Model (DEM). Assuming that the top of the forest canopy follows the terrain topography, a correction factor is developed in this paper and validated on airborne P-band Pol-InSAR data. These data have been acquired during the TropiSAR campaign in French Guiana, especially over the Paracou test site where the tropical dense forests are overan important topography. The proposed topographic correction enables to get a much better correlation between Pol-InSAR and airborne LIDAR heights. The improvement is significant, especially for the tropical dense forest, where the range of heights is rather moderate (about 25 to 30 meters, for the height averaged over 1 ha). Further work will be performed to validate this approach on other Pol-InSAR data.

The Analysis of Polarimetric InSAR System Based on Vegetation Height Estimation

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Polarimetric synthetic aperture radar (SAR) interferometry is a new technology that fuses the polarimetric information and interferometric information of the landscape together. After firstly introduced by Cloude and Papathanassiou in 1998, polarimetric InSAR technology has been getting more and more attention and a lot of work is done to explore its application potential. In recent years, vegetation height estimation is becoming one of most successful applications of polarimetric InSAR. With this applied technology, we can better understand the polarimetric scattering mechanisms and decompose the backscatter return from different levels in vertical structure of vegetation and measure trees height. Several key parameters of polarimetric InSAR system such as baseline length, precision of baseline measurement, signal-to-noise (SNR) and the precision of polarimetric calibration are studied and analyzed to find the optimized parameters of polarimetric InSAR system based on vegetation height estimation technology in this paper. Two emulator arithmetic containing PolSARproSim arithmetic (recommended by The European Space Agency) and Monte Carlo arithmetic which is firstly introduced by Lee in 1992 will be studied to apply experimental data for different purposes in our experiments. Actually the arithmetic have their own advantages and disadvantages each other. Though the PolSARproSim arithmetic is complex and close to reality, it involves less system parameters which can be involved in our experiments than Monte Carlo arithmetic. In this paper, both of the emulator arithmetic will be used in the analysis of baseline length and the precision of polarimetric calibration while Monte Carlo arithmetic will be used in the analysis of SNR and the precision of baseline measurement. Moreover, taking the TerraSAR-L polarimetric InSAR system as an example, the height of satellite is set to 635km, the indent angle is set to 35iã and the radar system works at the frequency of 1.2575GHz. The experiment result shows that it's really meaningful to analyze the polarimetric InSAR system based on vegetation height estimation to find optical parameters.

Theoretical Modelling

Generalized Target Decomposition Theory

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In this paper we present a generalized approach to decomposition theory in radar polarimetry (which also serves as an up-date of the review in [1]). This methodology not only unites all current approaches but extends them in two main directions. Firstly into bistatic scattering, where we show which decomposition methods are suitable for scaling into the more general scattering case (and which are not). Secondly we highlight several new ideas originally developed in optical polarimetry [2,3], which have direct and as yet unexplored application in radar sciences.

In radar polarimetry decompositions are generally classified as coherent or non-coherent and eigenvalue or model-based. Of these, non-coherent decompositions have made the largest impact on radar remote sensing for geo-physical parameter estimation and scene classification [4] and hence provide the main focus for this talk. Similar developments in optical polarimetry have also centered on non-coherent decomposition methods but based on serial [3] and parallel approaches [2]. In the former a matrix product decomposition is generated to identify key components in a cascade of elements while the latter matches the radar decomposition philosophy of an independent sum of elements. Only recently have these been combined into a general formalism [5], linking parallel and serial approaches for a unified treatment of applications in radar and optical sciences.

In this paper we use these developments to outline a generalized theory for radar polarimetry in three stages.

1) Eigenvalue Methods - The classic eigenvalue approach to interpretation of the coherency matrix T can be written as T=UDU*T. Here D is a diagonal matrix of real non-negative eigenvalues (from which entropy, anisotropies etc. can be derived) and U a set of orthogonal complex unit vectors representing rank-1 scattering elements, each with an alpha angle, which when combined with entropy forms the basis for the H-á classification method. Here we show that this idea may be generalized into a sum of linearly independent unit vectors (scattering mechanisms). The eigenvalue decomposition then becomes but one special case of this more general expression.

2) Model Based Decompositions - The original model based approach was the Freeman-Durden decomposition and recently this has been generalized by several authors. In all such approaches the user begins with an a-priori model for the volume scattering Tv. This has two important forms, namely for random (azimuthal symmetry) or oriented volume scattering with reflection symmetry. The volume amplitude mv must then be chosen to avoid negative eigenvalues in the remainder Ts while still maximizing the volume component. This leads to a rank reduction of Ts. Here we examine the possibilities for generalizing this idea to bistatic systems and we develop a new bistatic version of the Freeman-Durden approach, but now into a cloud of random dipoles plus a rank-3 remainder.

3) Depolarizing Serial Methods - The original serial decomposition was the Lu-Chipman approach, which decomposes an arbitrary rank-1 system into a cascade of retarder (polarimetric phase shifter) and diattenuator (polarimetric absorber). This method was then extended to account for depolarization (rank(T) >1) but in a rather ad hoc fashion, with problems due to reciprocity and symmetry. A symmetric form of a serial decomposition was developed in [3] and has the general form M=M1MDM2, where M are Mueller matrices corresponding to T, M1 and M2 are rank-1 systems and all depolarization is contained in MD. Further this matrix is often diagonal, which means it translates into a diagonal T matrix, and hence the eigenvectors are always the Pauli matrices, for all scattering problems. Here we study the implications of this method for radar polarimetry and speculate on its general utility for analyzing POLSAR data.

We conclude by highlighting potential future directions for the application of decomposition theory to POLSAR data for dual copol, compact, quadpol and bistatic satellite radar systems.

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How to model and validate the Sources of Depolarization of the Forest in Bistatic Settings

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In the field of forest observation, there is a lack of polarimetric bistatic measurement campaigns. To be able to develop tools to retrieve biomass for example, forest models can help us to overcome this lack of radar data. However we need first to validate these models. Alternative experimentation can also compensate this lack of data. This alternative measurement scenario has to respect several constraints. The measurements have to be in a bistatic configuration, and the scene has to look like a true forest with a space and permittivity scale factor. We could collect data in a radar anechoic chamber but an alternative method exists, naturally bistatic and considering a very large number of scatterers. We propose to consider in this paper measurement at the optical scale using an optical ellipsometer that can provide low-cost and fast measurements, in bistatic settings [1].

In this framework, we can use a sample of carbon nanotubes, whose structure is very similar to a real trunks forest. We pay particular attention to the measurement of depolarization. It is a key parameter for studying natural targets in bistatic configuration. Indeed, in this case cross-polarization components of the scattering matrix are no more equal since the reciprocity is no more true. Our goal is to determine the origin of this depolarization.

Measurements were performed for multi-walled carbon nanotubes standing on a silicon substrate. Among the several samples, we focused on a particular one containing clusters of about twelve carbon nanotubes with a hexagonal distribution. This distribution with empty areas compensates the high absorption of carbon nanotubes and may play an important role for the depolarization generation. The measurements are specular with several incidence angles. The full Mueller matrices are collected for the entire visible spectrum and the polarization-generation parameters are calculated from the latter [2]. A significant depolarization is stressed.

In order to understand and validate the measured depolarization, we use a bistatic coherent model, originally used at the meter scale for real tree forest simulations [3], in order to simulate the experiment described above. The ratio between the cylinders length and the wavelength is kept with a global scale factor of 106. Carbon nanotubes have a highly nonlinear behavior and we used the permittivity law in agreement with a Drude-Lorentz model [4], [5]. The model simulates the interactions of the scatterers with the ground but does not take into account the interactions between scattering objects, as well as the direct contribution of the ground. In addition, we have to perform an adaptation of the optical tools for the radar polarimetry domain as studied in [6]. For instance as the polarizations of the waves are not defined in the same way, the Mueller matrices are not rigorously identical.

To reproduce the experimental data, simulation scattering matrices are calculated for several different samples. The coherence matrix and the Mueller matrix are extracted and then we compute an optical parameter that measures the depolarization. We propose to compare results from experimental data and simulations. For this we will focus on the Mueller matrix terms and on the various optical quantities that are usually considered.

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Polarimetric SAR Target Decomposition based on Nonlinear Principal Component Analysis

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In remotely sensed Synthetic Aperture Radar (SAR) images, scattering from a target is often the result of a mixture of different scattering mechanisms. Fully polarimetric data offers the possibility to separate and to interpret them. To achieve this task, several target decomposition techniques have been proposed in the literature. In particular, coherent decompositions are aimed to express the observed scattering matrix as the linear combination of scattering matrices representing basic mechanisms. Aim of this paper is to evaluate a novel approach based on the use of Nonlinear Principal Component Analysis (NLPCA) for the target decomposition. In fact, differently from classical target decomposition techniques, the proposed method is based on the decorrelation of the polarimetric SAR data to extract the inherent information content related to the different scattering mechanisms present in the image. With NLPCA the observed scattering matrix will be expressed as a nonlinear combination of elementary scattering mechanisms. An assessment of the effectiveness of the nonlinear principal component analysis method for target decomposition has been carried out by comparing it with the classical decompositions.

Polarimetric Signatures for full and compact Polarimetry Modes using RadarSAT2 Data

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Recently, there has been growing interest in dual-pol (DP) systems that transmit one polarization and receive two polarizations. Souyris et al. proposed a DP mode called compact polarimetry (CP) which is able to reduce the complexity, cost, mass, and data rate of a Synthetic Aperture Radar (SAR) system while attempting to maintain many capabilities of a fully polarimetric (FP) system. This paper provides a comparison of the information content of full quad-pol data and the pseudo quad-pol data derived from compact polarimetric SAR modes. A pseudo-covariance matrix can be reconstructed following Souyris's approach and is shown to be similar to the full polarimetric covariance matrix. Both the polarimetric signatures based on the kennaugh matrix and the two dimensional scatter plots in the context of this compact polarimetry mode are explored.

We illustrate our results by using the polarimetric SAR images of the city of Algiers in Algeria acquired by the Canadian satellite RadarSAT2 in C-band.

Key words: Polarimetry, compact polarimetry, covariance matrix, polarimetric signatures

The Analysis of Polarimetric Calibration Error and System Key Parameters based on Point Targets

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A polarimetric SAR system measures the complete matrix (amplitude and relative phase) of the illuminated scene using an orthogonal set of polarization configurations, and this information can be used to synthesize the scattering characteristics of the scene at any arbitrary transmit and receive polarization combination. So the polarimetric SAR technology is able to distinguish scattering types of different target on the ground all weather and all day. This technology is increasingly researched in the field of microwave remote sensing and many polarimetric SAR systems have been developed. With an increasing number of operating polarimetric radars, the polarimetric calibration technology which can accurate the polarimetic information becomes a necessary step before an scientific application. However, the polarimetric application is limited by the loss and the distortion of polarimetric information produced by the errors of SAR system. These errors will exit even after the polarimetric calibration process.

In this paper, we choose Whitt's polarimetric SAR calibration algorithm in the step of polarimetric calibration. The algorithm which must satisfy a limited set of conditions makes no assumptions about SARsystem and fits the experiments both in the laboratory and field. Firstly, we analyze the polarimetric distortion model and give an error model of polarimetric SAR system. Secondly, we analyze the amplitude and phase imbalance of polar channels, crosstalk of antenna, targets orientation error and system noise quantificationally based on polarization signature. Finally we obtain the meaningful result on polarimetric SAR system design and polarimetric calibration.

If there are no any other errors except the polarimetric distortion containing the amplitude and phase inbalance of polar channels and crosstalk of antenna, we find that the polarimetric calibration technology will infinitely reduce the errors and perfectly distill the theoretical scattering matrix. However, the system noise and targets orientation error which is coupled in the scattering matrix limit the performance of polarimetric calibration. When the signal-to-noise (SNR) ratio of SAR system is lower than a given level, it's really difficult to reduce the polarimetric distortion influence using polarimrtric calibration technology. In this paper, we use the polarimetric SAR data with 10 man-made point targets in the scene located in middle China. The SAR data are obtained by the airborne P-band polarimetric SAR sensor which is made by an institute in China. The amplitude inbalance of polar channels of this data is about -5dB and the crosstalk of antenna is about -16dB without any polarimetric calibration process. The experiment results also show that the scattering matrices of point targets can be distilled much better in case of high SNR than low SNR of SAR ststem.