

esa

OLINSAR 2003 kshop on Applications

Workshop on Applications

of SAR Polarimetry and Polarimetric Interferometry



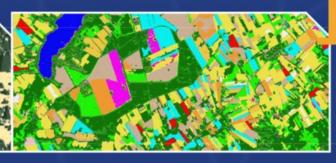




■ Studies on Polarimetry/Interferometry ■ Agriculture/land cover vegetation ■ Advances in Polarimetric Interferometry 📕 Applications development 💹 Envisat early results 📲 Sea Ice 📲 Airborne/Space borne systems and products







http://earth.esa.int/polinsar

envmail@esa.int



The Genesis:

- •2000 ESA POLSAR studies ITT
- 2001 Selection of two // study contracts
- •2002 Decision to present the two // **POLSAR** studies results in a dedicated workshop:
- •2003 POLINSAR





Objectives

POLINSAR 2003

Workshop on Applications of SAR Polarimetry and Polarimetric Interferometry

The main objectives of the workshop are to:

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



Scientific Committee

POLINSAR 2003

Workshop on Applications of SAR Polarimetry and Polarimetric Interferometry

Prof Wolfgang-Martin Boerner *University of Illinois at Chicago, U.S.A.*

Dr Shane Cloude AELc, U.K.

Dr Douglas Corr *QinetiQ, U.K.*

Prof Preben GudmandsenDTU, Denmark

Dr Dirk H. Hoekman SarVision, The Netherlands

Dr Jong-Sen Lee NRL, U.S.A.

Dr Thuy Le Toan Cesbio, France

Dr Pierfrancesco Lombardo *University of Rome, Italy*

Dr Soren N. Madsen JPL, U.S.A.

Dr Alberto Moreira DLR, Germany

Dr Kostas Papathanassiou *DLR, Germany*

Dr Kim Partington Vexcel, U.K.

Prof Eric Pottier University of Rennes, France

Prof Shaun Quegan SCEOS, U.K.

Dr Paul Saich UCL, U.K

Prof Christine Schmullius *University of Jena, Germany*

Dr Masanobu ShimadaNASDA, Japan

Prof Henning Skriver*DTU, Denmark*

Dr Jean-Claude Souyris*CNES, France*

Dr Ridha Touzi CCRS, Canada

Dr Dan J. Weydahl NDRE, Norway

Dr-Eng. Habil. Hiroyoshi Yamada Niigata University, Japan





POLinSAR 2003





POLinSAR activities 2003 - 2023

- 2003: 1st PolinSAR WS; starting to develop PolSARpro
- 2005 January: ESA –JAXA ALOS A.O.
- 2005: 1st Polarimetry course, followed by many others
- 2007: INDREX CAMPAIGN
- 2008: 2nd ALOS Symposium, Rhodes, Greece by ESA in cooperation with JAXA, ASF, GA and GISTDA. BEAM -**POLSARPRO Training Sessions for the exploitation of ALOS** data
- 2009: ESA ALOS-PalSAR In Orbit Demonstration Study; **Exploration / Validation of the INDREX-II Campaign; ESA AO for Cat-1 projects with Radarsat-2 data**
- **European Space Agency** For your highly esteemed contributions over the years in planning, implementing, and conducting ALOS initiatives. With your unflagging dedication, ALOS has pioneered a new world of unprecedented space applications unachievable by other Earth-observing Keiji Tachikawa, Ph.D. 2011: ESA campaign data and ALOS data made available via EOPI; Coordinated PolSAREx Spaceborne

@esa

POLJARPRO

POLSARPRO is a toolbox for the scientific exploitation of polarimetric SAR data and a tool for high-level education

Tool v2.0

in radar polarimetry

The Polarimetric SAR Data Processing and Educational

http://earth.esa.int/polsarpro

- Polarimetric Data Acquisitions (ESA-JAXA-CSA-DLR) over selected test sites with in-situ; PolSARAP (Polarimetric SAR Application Demonstration) study ITT (350k)
- 2013: ESA CSA AO for Radarsat-2 and ESA EO data (SOAR-EU)





Includes teaching

material!

POLinSAR activities 2003 - 2023



- 2014: S-1 launch, with dual-pol capability
- 2015: POLINSAR & 1st BIOMASS WS at ESRIN, supporting the preparation of the full-pol BIOMASS mission; release of POLSARPRO V5.0 with new functionalities; associated training 2015 recommendations include (again): (i) need of an ESA Pol-InSAR mission, (ii) and lack of dedicated PolSAR datasets with simultaneous ground-truth
- 2017: POLINSAR workshop in ESRIN. Support the preparation for ESA & TPM full-pol mission exploitation; release of POLSARPRO V5.1; associated training
- 3rd ADVANCED COURSE ON RADAR POLARIMETRY

 19-23 January 2015 | ESA

 → POLSARPRO V. 5.0
 The Polarimetric SAR Data Processing and Educational Tool

 http://earth.esa.int/polsarpro
- 2019: POLINSAR workshop in ESRIN, selected results published on the Special Issue of Remote Sensing Journal; Prof. Boerner Award for outstanding student contribution; associated training
- 2021: 10th POLINSAR workshop held VIRTUALLY, due to lock-down. Associated online training.
 Report of Technical and scientific recommendations published online. The *number of participants increased from 150 (2019) to 350, from 41 countries!*



2021: publication of a book (deliverable of the PolSARapp project) presenting all progress in PolSAR and PollnSAR made by our worldwide polarimetric community in the last 20 years, covering many different applications

Polarimetric Synthetic Aperture Radar

Polarimetric Synthetic Aperture Radar: Principles and applications

Irena HAJNSEK - Yves-Louis DESNOS editors Springer; 1st edition (Marsh 30, 2021), ISBN 978-3-030-56502-2







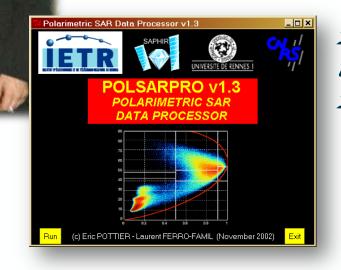
https://link.springer.com/content/pdf/10.1007%2F978-3-030-56504-6.pdf





Eríc and Laurent, in 2002, had the idea to create a símple polarimetric toolbox for PhD students

Its name was already PolSARpro



Presented at the POLinSAR 2003 Workshop, it was then recommended to develop the PolSARpro Software









2005



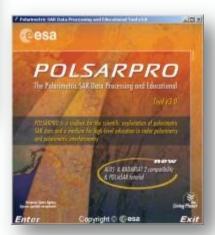
2009





2004

With tutorials and 34 trainings ... From 2005 to 2023 all over Europe and in China!



2007

2013 (5.0) to 2018 (5.2)









As a conclusion (message from Eric):



Sincere and warmest thanks from our friend Eric to ESA and to our International Polarimetric Community for this wonderful adventure ...

Many thanks to you ...



Happy Birthday

. and ...



20 years of PolSARpro software...



→ Following the 2021 PolinSAR recommendations, selected routines from PolSARpro are now being implemented also in Python by SATIM (with scientific support by Eric and Armando), for a new standalone version and for integration on the ESA/NASA MAAP platform

... Thanks to Yves-Louis!!!



PolSARPro evolution

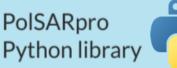


Re-implementation of selected PolSARPro functions in Python, following the scientific recommendations of PolInSAR 2021

The idea is to develop a dedicated polarimetric **Python Library** which will contain some selected PolSARpro procedures, **to easy installation on the ESA/NASA joint platform MAAP**



Toolbox used for decades by worldwide scientists working on techniques and applications of polarimetric radar data





Polarimetric toolbox evolution, in view of the joint ESA/NASA MAAP platform for the joint exploitation of the ESA P-band SAR Biomass mission and the NASA/ISRO SAR NISAR mission.

20 years of SAR Polarimetry in ESA: METHODS / APPS Cesa

Developments in many Polarimetry Applications

Examples:

Forested areas



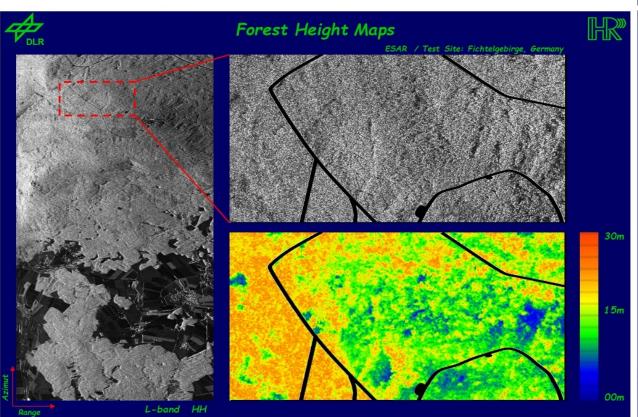


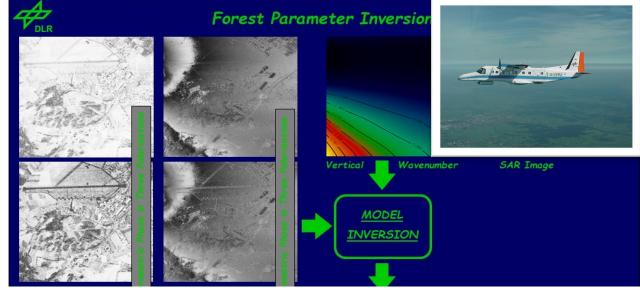
Model Based Forest Height Estimation from Single Baseline Pol-InSAR Data:

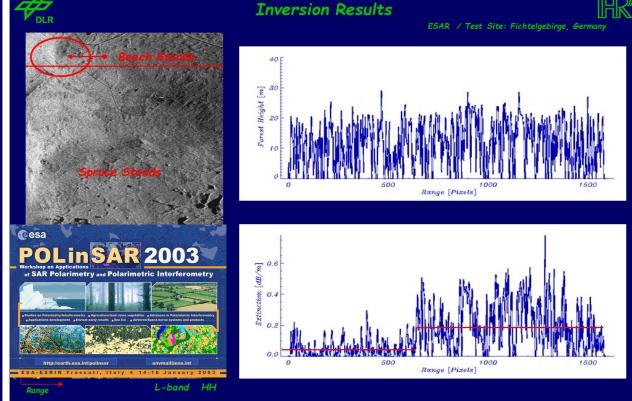
The Fichrelgebirge Test Case

K.P. Papathanassiou, T. Mette, I. Hajnsek, and A. Moreira

German Aerospace Center (DLR)
Microwaves and Radar Institute (DLR-HR)
Pol-InSAR Working Group



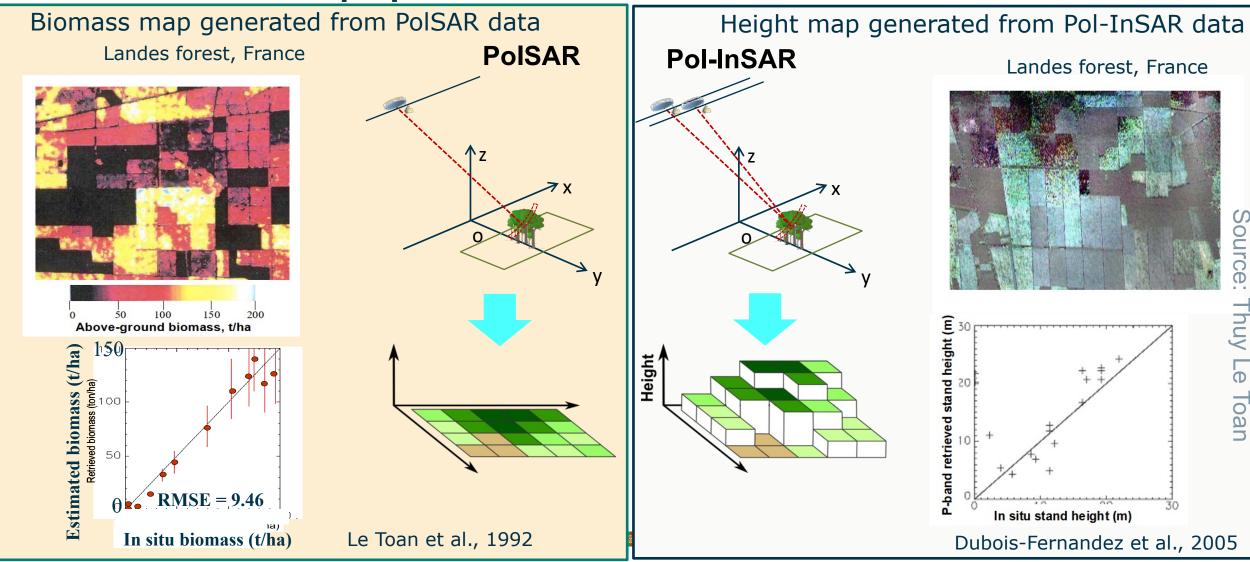




20 years of SAR Polarimetry in ESA: Forested areas cesa



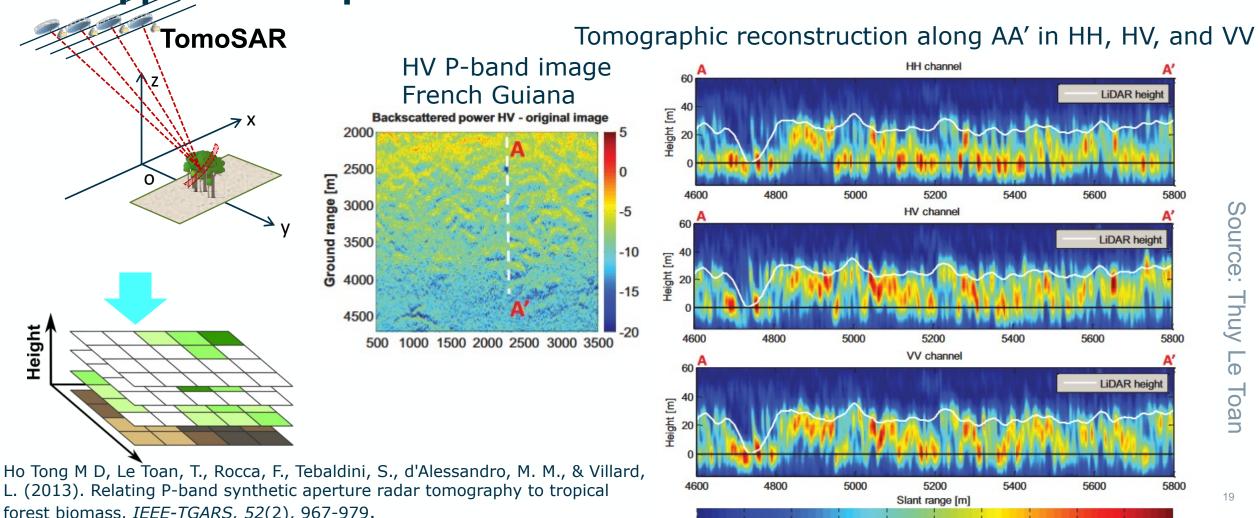
20 years ago, Polarimetric SAR and Pol-InSAR techniques have been proposed for the P-band BIOMASS mission



LiDAR height

5600

To enhance the retrieval techniques, innovative SAR tomography has been applied to map 3D structure of forests



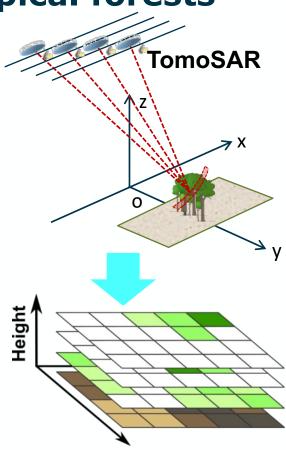
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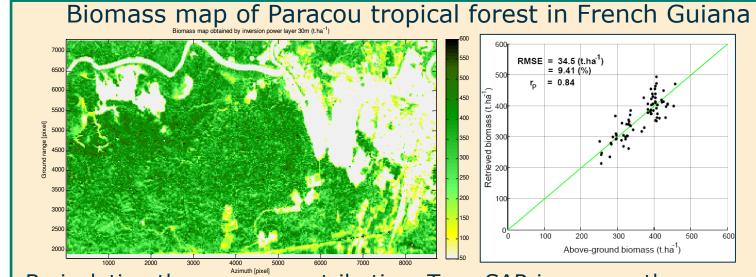
20 years of SAR Polarimetry in ESA: Forested areas



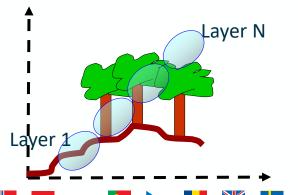
Innovative TomoSAR allows to map the high range of biomass in

tropical forests





By isolating the canopy contribution, TomoSAR increases the sensitivity of the backscatter to biomass, for the whole range of biomass (here, up to 450 t /ha)



SAR Tomography resolution cell.

Enables isolation of

- canopy
- ground,
- topography

→ THE EUROPEAN SPACE AGENCY

D. Ho Tong Minh et al., 2016; Tebaldini et al., 2019

20 years of SAR Polarimetry in ESA: Forested areas



Correlation between Radar intensity and Above Ground Biomass (AGB)

- 2D SAR intensity is poorly correlated to AGB
- TomoSAR intensity at 0 m is poorly and negatively correlated to AGB
- TomoSAR intensity at main canopy height is highly correlated to AGB (≈ 50 Mg/ha per dB)

Sites: Paracou, Nourages (French Guiana)

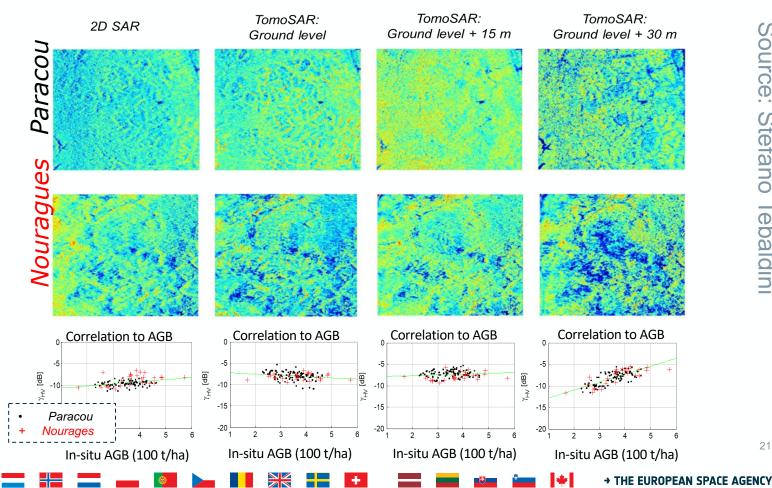
Frequency: P-Band

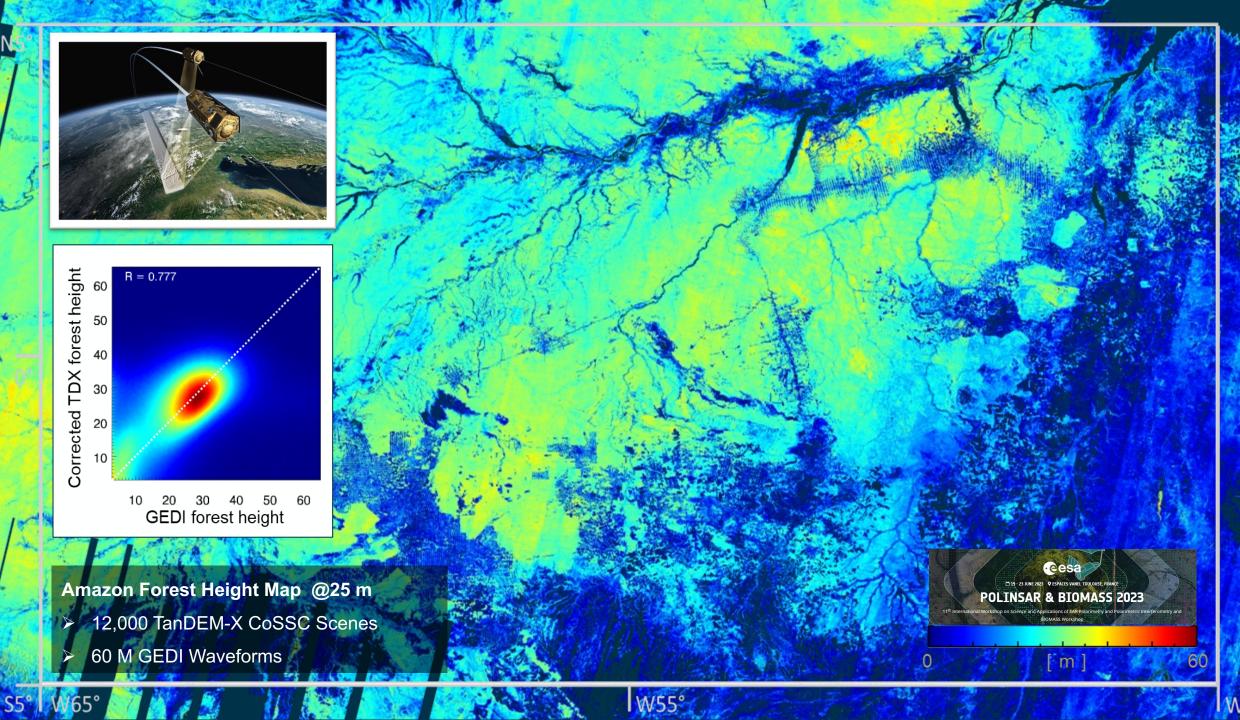
Data-set: TropiSAR (ESA)

Data-set by ONERA

Ho Tong Minh et al., TGRS, 2014

Ho Tong Minh et al., Remote Sensing of Environment, 2016





20 years of SAR Polarimetry in ESA: METHODS / APPS Cesa

Developments in many Polarimetry Applications

Examples:

Glaciers/Ice Sheets

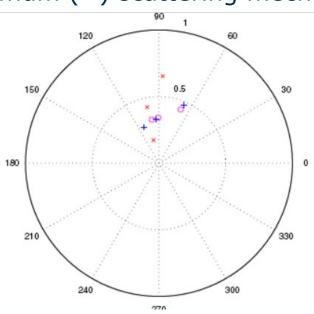




Jiancheng Shi and J. Dozier, "Inferring snow wetness using C-band data from SIR-C's polarimetric synthetic aperture radar," in IEEE Transactions on Geoscience and Remote Sensing, vol. 33, no. 4, pp. 905-914, July 1995, doi: 10.1109/36.406676.

- ✓ pre 2003, several studied had covered the quad-pol behaviour of ice.
- ✓ 2003, the first steps in including interferometric information in models.

Mean coherence for linear (+), circular (o), and optimum (×) scattering mechanisms



J. Dall, K. P. Papathanassiou and H. Skriver, "Polarimetric SAR interferometry applied to **land ice**: first results," IGARSS 2003. 2003 IEEE IGARSS, Toulouse, France, 2003, pp. 1432-1434.



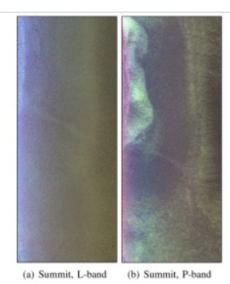
J. J. Sharma, I. Hajnsek, K. P. Papathanassiou and A. Moreira, "Polarimetric Decomposition Over Glacier Ice Using Long-Wavelength Airborne PolSAR," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 49, no. 1, pp. 519-535, Jan. 2011, doi: 10.1109/TGRS.2010.2056692.



- ✓ 2011, models were developed to retrieve the parameters.
- currently, polarimetric tomography is revealing very powerful for this.

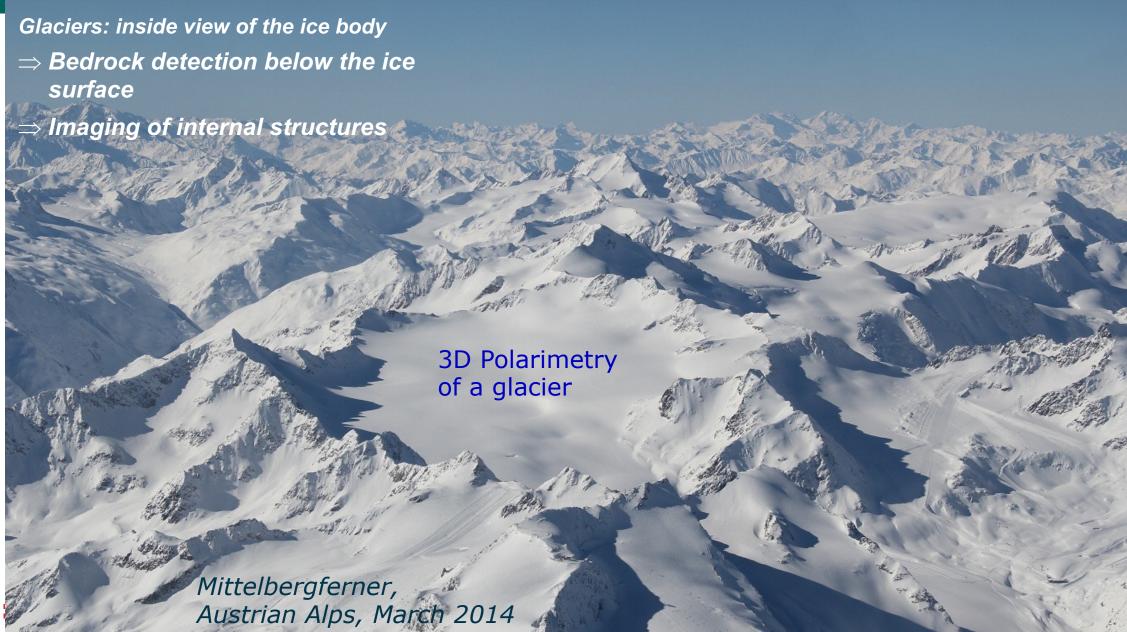
G. Parrella, G. Fischer, M. Pardini, K. Papathanassiou and I. Hajnsek, "Complementarity and Potential of Polsar and Tomosar for Glacier Subsurface Characterization," *2021 IEEE IGARSS*, Brussels, Belgium, 2021, pp. 3065-3068.

Pauli RGB decomposition of March PolSAR data in slant-range geometry of the Austfonna ice cap. Flight (azimuth) direction is from bottom to top, and range direction is from left to right. L- and P-band images represent approximately the same area. E-SAR (DLR)





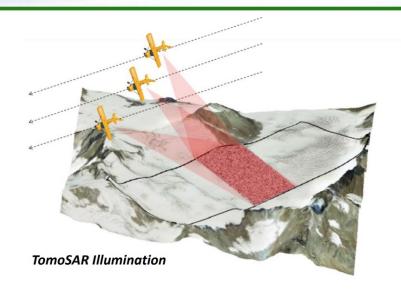


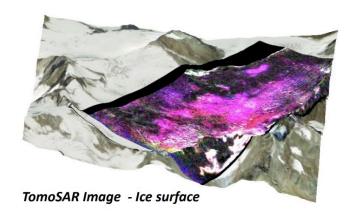


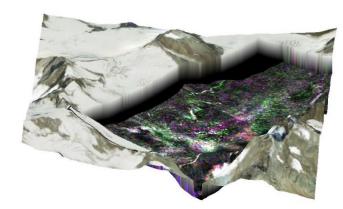


TomoSAR & Glaciers/ Ice sheets

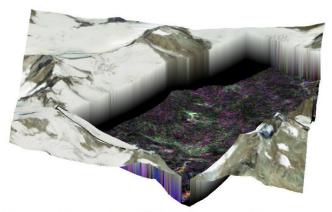








TomoSAR Image - 25 m below the Ice surface



TomoSAR Image - 50 m below the Ice surface

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The Mittelbergferner @ L-Band







20 years of SAR Polarimetry in ESA: METHODS / APPS Cesa

Developments in many Polarimetry Applications

Examples:

Ship Detection

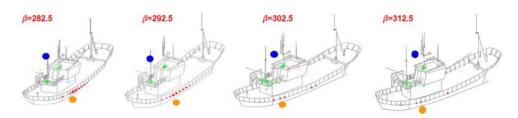
20 years of SAR Polarimetry in ESA: Ship detection

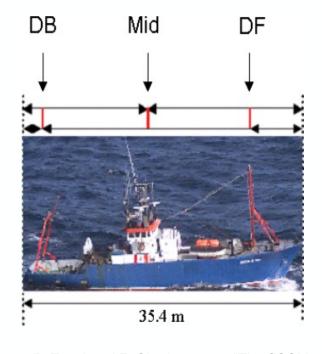


- ✓ 2003, very few were exploring quad-pol data for ship detection (mostly selection of best channel/observables)
- ✓ 2006, interest started turning toward quad-pol data.

C. Liu, P. W. Vachon and G. W. Geling, "Improved ship detection using polarimetric SAR data," *IGARSS 2004. 2004 IEEE IGARSS*, Anchorage, AK, USA, 2004, pp. 1800-1803 vol.3.

G. Margarit, J. J. Mallorqui, J. M. Rius and J. Sanz-Marcos, "On the Usage of GRECOSAR, an Orbital Polarimetric SAR Simulator of Complex Targets, to Vessel Classification Studies," in *IEEE TGRS*, vol. 44, no. 12, pp. 3517-3526, Dec. 2006



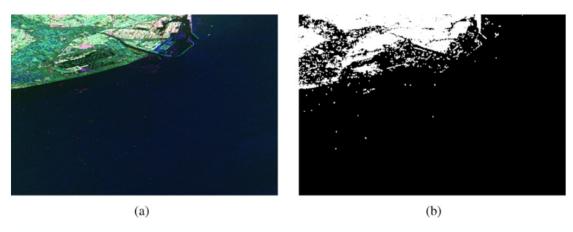


R. Touzi and F. Charbonneau, "The SSCM for ship characterization using polarimetric SAR," *IGARSS 2003. 2003*, Toulouse, France, 2003, pp. 194-196 vol.1

20 years of SAR Polarimetry in ESA: Ship detection



A. Marino, "A Notch Filter for Ship Detection With Polarimetric SAR Data," in *IEEE JSTARS*, vol. 6, no. 3, pp. 1219-1232, June 2013



TerraSAR-X Quad pol date over Barcelona harbor (Mediterranean, 12th of April 2010): (a) RGB Pauli composite image (b) Detection with GP-PNF quad-pol.

- ✓ T. Liu, Z. Yang, A. Marino, G. Gao and J. Yang, "PolSAR Ship Detection Based on Neighborhood Polarimetric Covariance Matrix," in *IEEE TGRS*, vol. 59, no. 6, pp. 4874-4887, June 2021.
- ✓ Z. Xu, J. Geng, Z. Zhao and W. Jiang, "Ship Detection for Polarimetric SAR Images Based on Anchor-Free Network in High Sea State," *2021 CIE International Conference on Radar (Radar)*, Haikou, Hainan, China, 2021, pp. 594-598.
- ✓ Qiu, W.; Pan, Z.; Yang, J. Few-Shot PolSAR Ship Detection Based on Polarimetric Features Selection and Improved Contrastive Self-Supervised Learning. *Remote Sens.* **2023**, *15*, 1874.

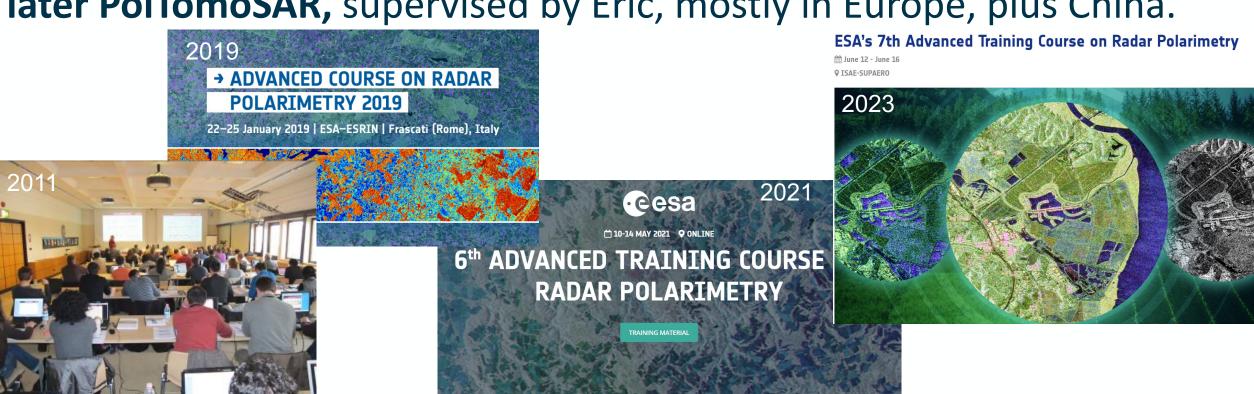
✓ 2013, quad-pol data was shown as clearly outperforming dual-pol.

✓ Currently, the investigation moved to spatial information
 ✓ where there is a wealth of Machine Learning ship detectors based on spatial information of vessels.

20 years of SAR Polarimetry in ESA: Training



The progress over 20 years in Polarimetric research activities benefits from a long series of (34) ESA training courses on PolSAR, PolinSAR and later PolTomoSAR, supervised by Eric, mostly in Europe, plus China.



Recently complemented by (5) online course organised by DLR (two / year) 32

20 years of SAR Polarimetry in ESA: Data availability



In 2003, we only had few datasets (Oberpfaffenhofen, Alling, Traunstein followed in 2004 and 2005) provided by DLR.

Today, polarimetric research is today much more mature, reliable, and closer to some user applications, thanks to the availability of a wide variety of excellent and well documented (lidar + ground measurements) datasets with excellent Pol(In or Tomo) SAR data: BIOSAR I & II, TropiSAR, AFriSAR, Indrex I and II and many other DLR data sets.

20 years of SAR Polarimetry in ESA: Data availability



Dual and full-pol data have been provided over time by EOPI or as ESA TPM, including: ALOS-1 PalSAR, Radarsat-2, many airborne campaigns.

Since 2023, ESA and CONAE make available polarimetric data of the L-band SAOCOM mission via a series of AO's (PUMAS initiative)

Details on:

https://earth.esa.int/eogateway/activities/pumas-initiative

https://eo4society.esa.int/2023/05/17/access-saocom-mission-data

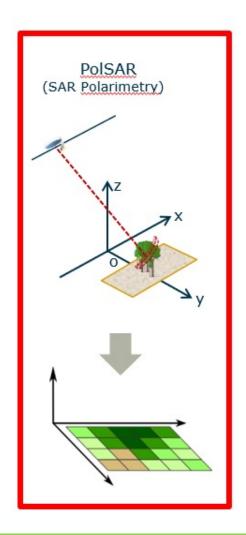


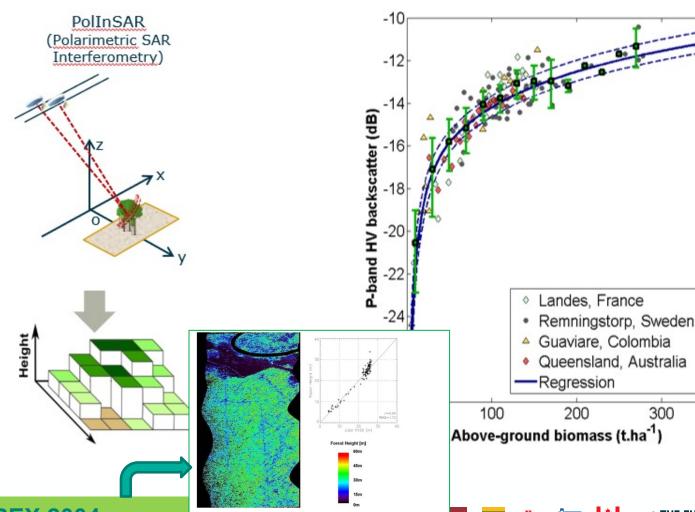


The BIOMASS Mission in 2005 (*Proposal*) A proposal in response to the 2005 ESA Call for Ideas for the Next Earth Explorer Core Missions By

BIOMASS

Thuy Le Toan¹ and Shaun Quegan²

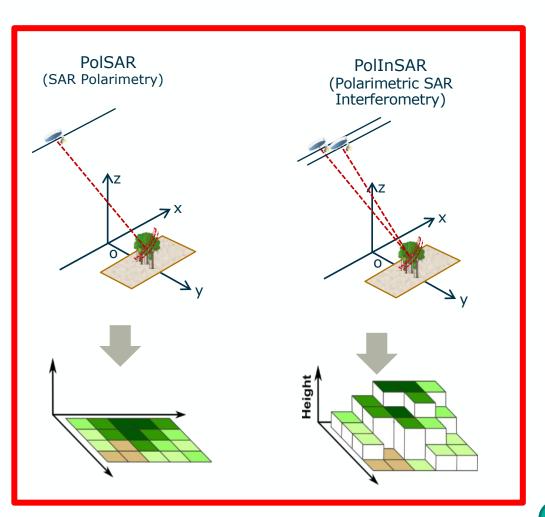


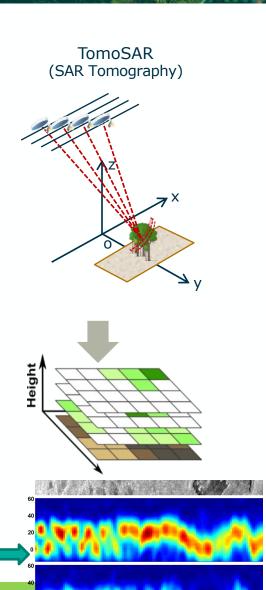


300



The BIOMASS Mission in 2009





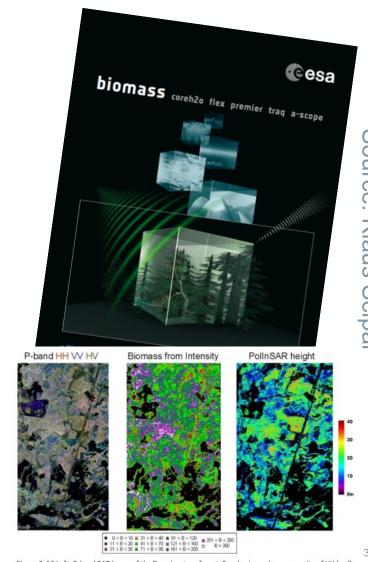
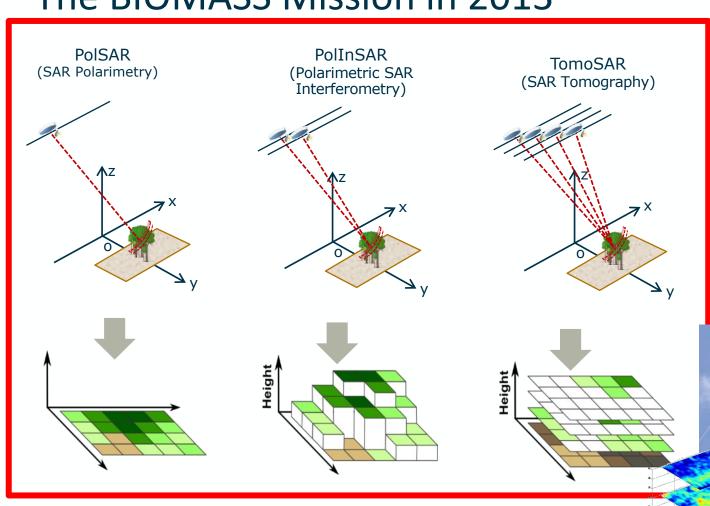


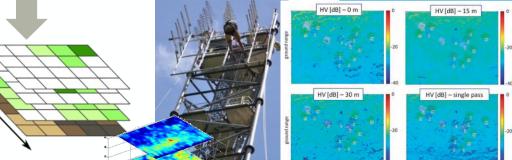
Figure 2. 13 Left: P-band SAR image of the Remningstorp forest, Sweden in a colour composite of HH (red), HH (blue) and HV (green). Middle: Biomass map derived from HV and HH polarisation (the colour code for biomass, B, in t ha-1 is in the box at the bottom). Right: Forest top height from Pol-InSAR. [Credits: Le Toan,

First ESA P-band TomoSAR flights – TropiSAR 2009

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The BIOMASS Mission in 2013

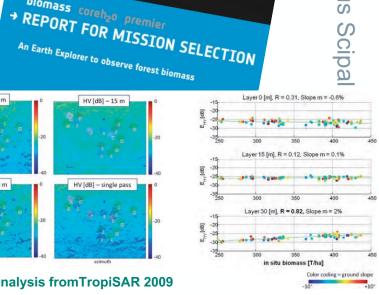




An Earth Explorer to observe forest biomass

Result analysis from TropiSAR 2009

biomass coreh₂o premier



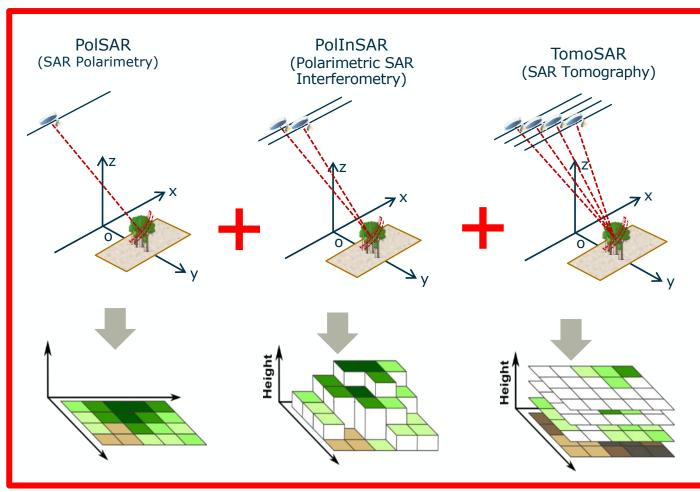
Generating images of different forest layers from multi-orbit SAR images. Tomographic processing. Height and Biomass estimates

First ESA TomoSAR tower experiment – TropiScat 2017

Figure 6.11. Tomographic layering vs. in situ biomass measurements using data from the TropiSAR campaign (6 passes). Left: HV intensity for three different tomographic layers (top left: ground level; top right: 15 m above the ground; bottom left: 30 m above the ground) and for non-tomographic data (bottom right). Right; measured correlation between HV intensity for different layers and *in situ* biomass



The BIOMASS Mission in 2023

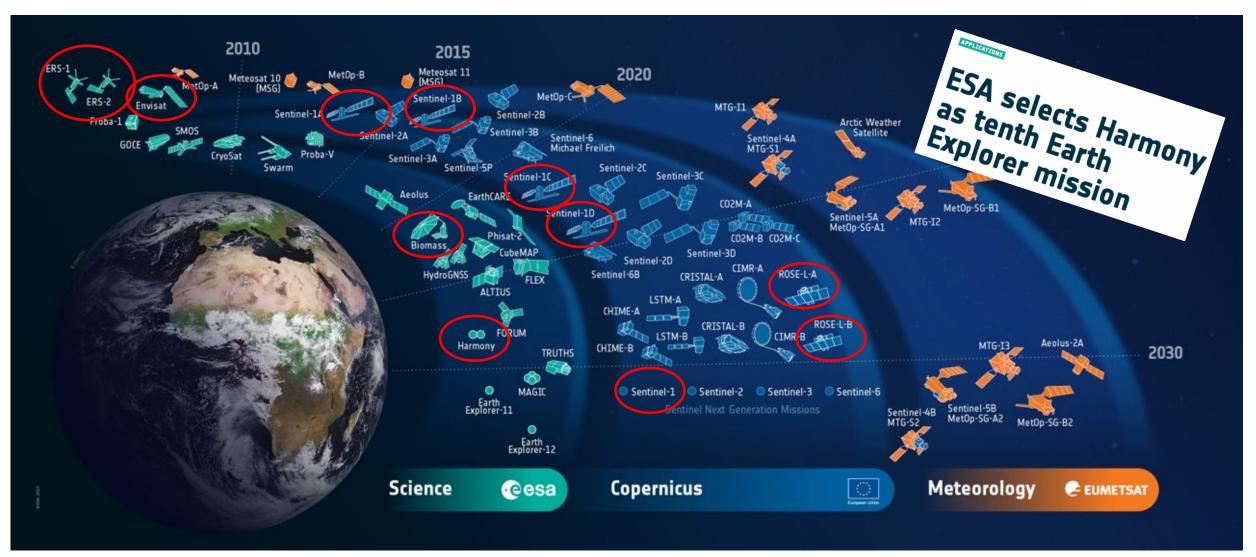




Launch: presumably moved to Q-1 2025 due to Vega constraints

ESA-developed Earth observation missions [54R] missions]







Sentinel-1 First Generation has enabled the development of new operational applications

Sentinel-1 Next Generation at C-band to

- ensure continuity and expansion of services and applications relying on Sentinel-1
- <u>enhance</u> existing services and applications
- <u>enable</u> new application developments building on improved performance and observation gaps (e.g. resolution, revisit and others)

ROSE-L Copernicus Expansion mission at L-band aimed at:

<u>addressing information gaps</u> and providing new information not yet available through current Sentinel missions

Sentinel-1 FG, ROSE-L and Sentinel-1 NG shall be addressed as a system-of-systems (not in isolation)

- ROSE-L same orbit, swath and acquisition geometry as Sentinel-1 (IWS) providing an operational dual-frequency system
- Synergies between C- and L-band expected to lead to enhanced and new information beyond what can be achieved for each mission taken in isolation
- Synergies with other missions such as Earth Explorer Biomass @P-band also need to be further investigated

11th POLINSAR / BIOMASS Workshop 2023, in Toulouse



Monday			Tueso	Tuesday		Wednesday		Thursday		Friday	
PolInSAR Biomass	Start	End	PolinSAR	Biomass	PolinSAR	Biomass	PolinSAR	Biomas	PolinSAR	Biomass	
Registration / Coffee 9:00		10:40	Biomass Mission Overview		Forest Applications II		TomoSAR Methods		Hydrology Applications		
Workshop Opening 1		11:10	Coffee Break		Coffee Break		Coffee Break		Coffee Break		
SAR Missions 11:10 12		12:50	Biomass Products and Algorithms		Agriculture Applications	Biomass - Validation & Carbon Modelling	Campaigns		Recommendation & Summary		
Lunch Break	12:50	14:10	Lunch Break		Lunch Break		Lunch Break		End of Workshop		
Missions & Calibration	14:10	15:50	Biomass Methods		Land Applications	Biomass - Mulitmission Context	Cryopshere Applications				
Coffee Break	15:50	16:20	Coffee I	Break			Coffee Break				
PolSAR / PolInSAR Methods	16:20	18:00	Forest Appl	lications I	Posters - Aperitivo		Ocean/Sea Ice Applications	GEO-TREES community engagement			
Icebreaker											

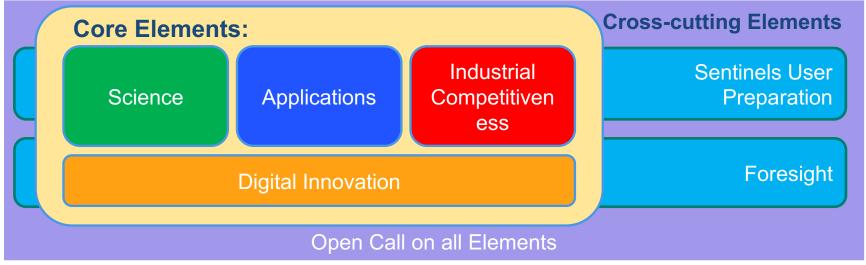


OUTLOOK



- ESA, in cooperation with EC, is providing through Copernicus program (and associated projects & services) an unprecedented and unique Earth Observation dataset from Space with its future expansion to fill in current gaps.
- The ESA Earth Explorer Program continues to develop new scientific missions to view our planet Earth using innovative techniques and technologies.
- ESA will continue to engage with the industrial partners, the research community and stakeholders in SAR Polarimetry applications to further benchmark emerging methods for EO data exploitation including beyond original mission objectives for a wider exploitation and uptake.







Thanks for being here and enjoy this 11th Workshop!

