Francesco Sarti

ESA

Welcome to the 7th ADVANCED TRAINING COURSE ON RADAR POLARIMETRY, in person again, at SUPAERO Toulouse https://polarimetrycourse2023.esa.int/

	Monday 12/06/2023	Tuesday 13/06/2023	Wednesday 14/06/2023	Thursday 15/06/2023	Friday 16/06/2023
8:00 - 8:30	***Registration***				
8:30 - 9:00	**Welcome from ESA** Francesco Sarti (ESA/ESRIN, Italy)	**PolSAR theory** Carlos Lopez-Martinez *(UPC, Spain)* Laurent Ferro-Famil *(ISAE-SUPAERO, France)*	**Pol-InSAR Theory** Kostas Papathanassiou, Matteo Pardini *(DLR, Germany)*	**Advanced Applications** Armando Marino *(Stirling University, Scotland)* Irena Hajnsek *(ETH Zurich, Switzerland)*	**Advanced Applications 2** Armando Marino (Stirling University, Scotland)
9:00 - 9:30	**SAR Basics** Stefano Tebaldini (Polimi, Italy) Laurent Ferro-Famil *(ISAE-SUPAERO, France)*				
9:30 - 10:15					
10:15 - 10:45	***Coffee Break***				
10:45 - 12:00	***SAR Tomography Theory*** Stefano Tebaldini *(Polimi, Italy)* Laurent Ferro-Famil *(ISAE-SUPAERO, France)*	(continuation)	(continuation)	(continuation)	**ESA's Polarimetric Missions (BIOMASS, ROSE-L) + SAOCOM** Klaus Scipal (ESA/ESRIN, Italy)
12:00 - 13:00	***Lunch Break***			***Lunch Break***	***Lunch Break***
13:00 - 13:30					
13:30 - 14:30	(continuation)	**PolSAR practical 1** Carlos Lopez-Martinez *(UPC, Spain)* Laurent Ferro-Famil *(ISAE-SUPAERO, France)*	**Pol-InSAR Application Practical 1** Kostas Papathanassiou, Matteo Pardini *(DLR, Germany)*	**Advanced Applications 1** Irena Hajnsek *(ETH Zurich, Switzerland)*	**Closing ceremony** / Feedback and presentation of certificates
14:30 - 15:00				***Coffee Break***	
15:00 - 15:30	***Coffee Break***			***visit to Cité de l'Espace***	
15:30 - 17:00	**TomoSAR Practical** Laurent Ferro-Famil *(ISAE-SUPAERO, France)* *Stefano Tebaldini* *(Polimi, Italy)*	**PolSAR practical 2** Carlos Lopez-Martinez *(UPC, Spain)* Laurent Ferro-Famil *(ISAE-SUPAERO, France)*	**Pol-InSAR Application Practical 2** Kostas Papathanassiou, Matteo Pardini *(DLR, Germany)*		
17:00 - 19:00	***Ice Breaker***				

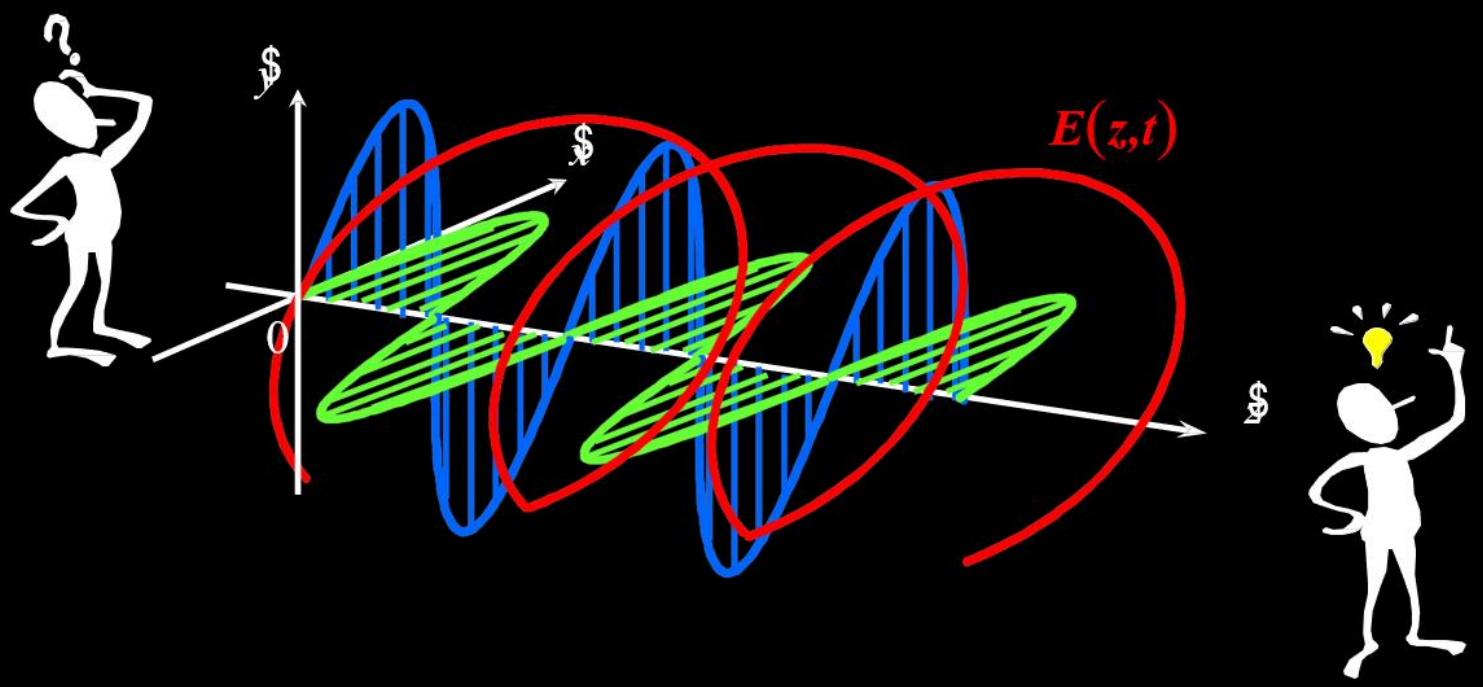
Objectives and Content

- Explain theoretical principles and processing algorithms
- Show use in various applications
- Introduce available tools
- Inform about state of the art in **Radar Polarimetry, Polarimetric SAR Interferometry (POLinSAR) and SAR Tomography (TomoSAR)**
- Prepare for the scientific **explBIOMASSoitation of available polarimetric data** as well as the future ESA polarimetric mission
- **Hands-on processing** exercises (mostly based on MAAP), focusing on full-pol and dual-pol data

Participants

- Post-graduates, PhD students, post-doctoral research scientists and users interested in Radar Polarimetry, BIOMASS and related applications
- familiarity in **SAR Remote Sensing** and in **Python** are an asset

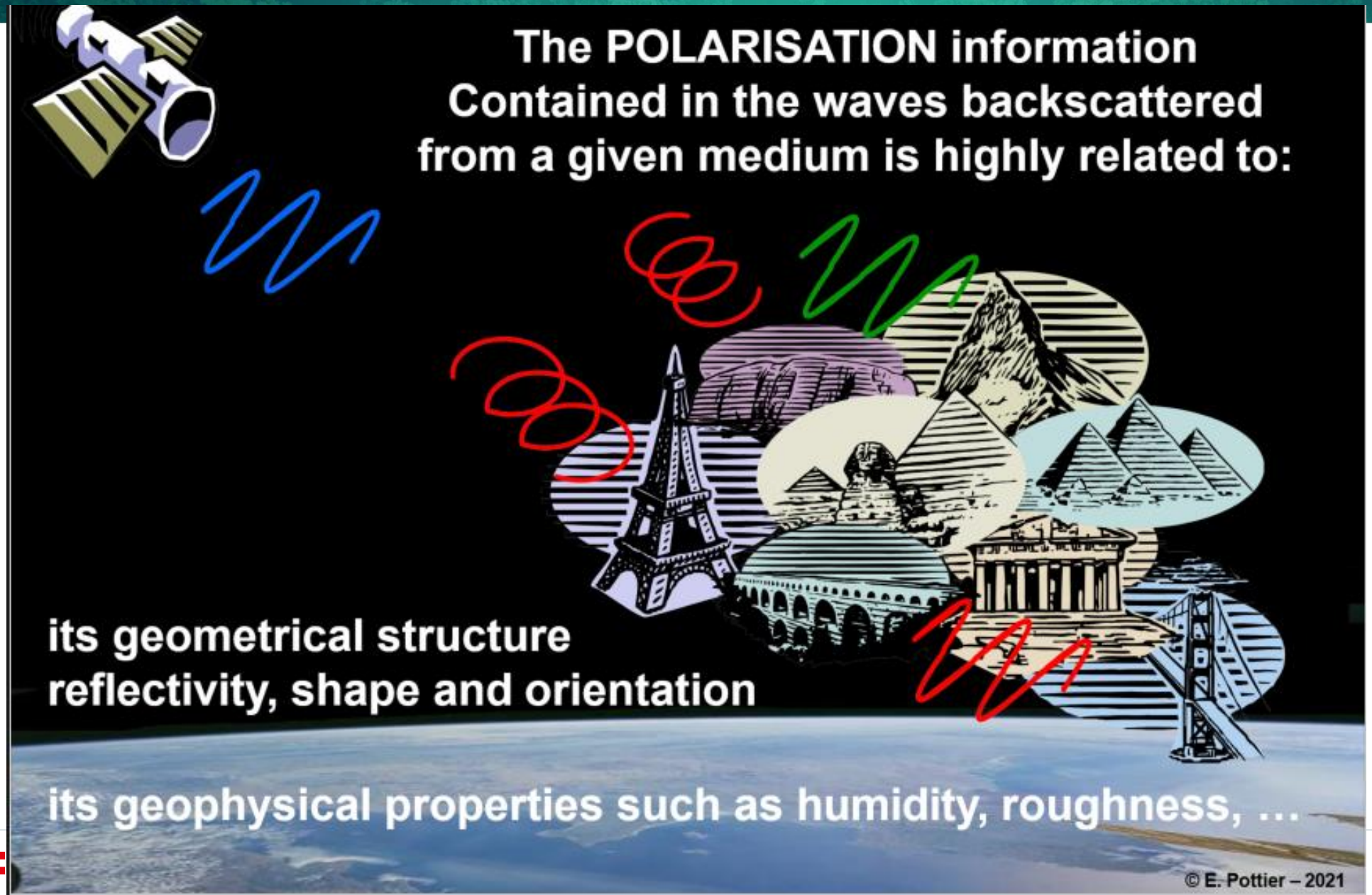
Radar Polarimetry



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

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

Radar Polarimetry



SAR Polarimetry Applications (& Techniques)

Forest Vegetation

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

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

Agriculture

- Soil Moisture Content
- Soil roughness
- Height of Vegetation Layer
- Extinction of Vegetation Layer
- Moisture of Vegetation Layer

- Farming Management
- Water Cycle
- Desretification

Snow and Ice

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

- Ecosystem Change
- Water Cycle
- Water Management

Urban Areas

- Geometric Properties
- Dielectric Properties

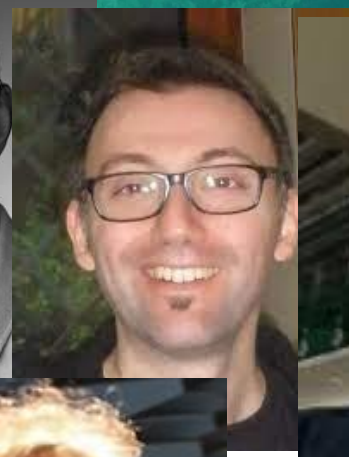
- Urban Monitoring

Courtesy of Dr. I. Hajnsek

Teachers selected among the best experts in SAR Polarimetry

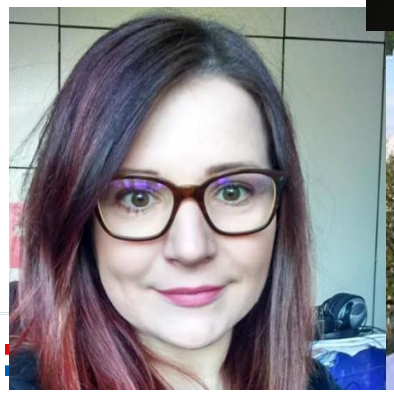
Stefano Tebaldini POLIMI
Laurent Ferro-Famil Supaero
Carlos Lopez Martinez UPC
Kostas Papathanassiou DLR
Matteo Pardini DLR
Armando Marino Uni Stirling
Irena Hajnsek ETH






For many years, the course has been coordinated by **Eric Pottier** Uni Rennes (PolSARPro toolbox creator)

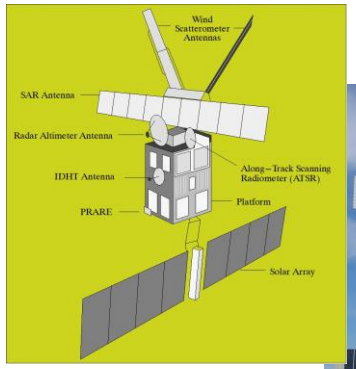
Support by ESA colleagues
Magdalena Fitrzyk, Klaus Scipal, Martin Phillipsen



Short SAR (space) Missions introduction

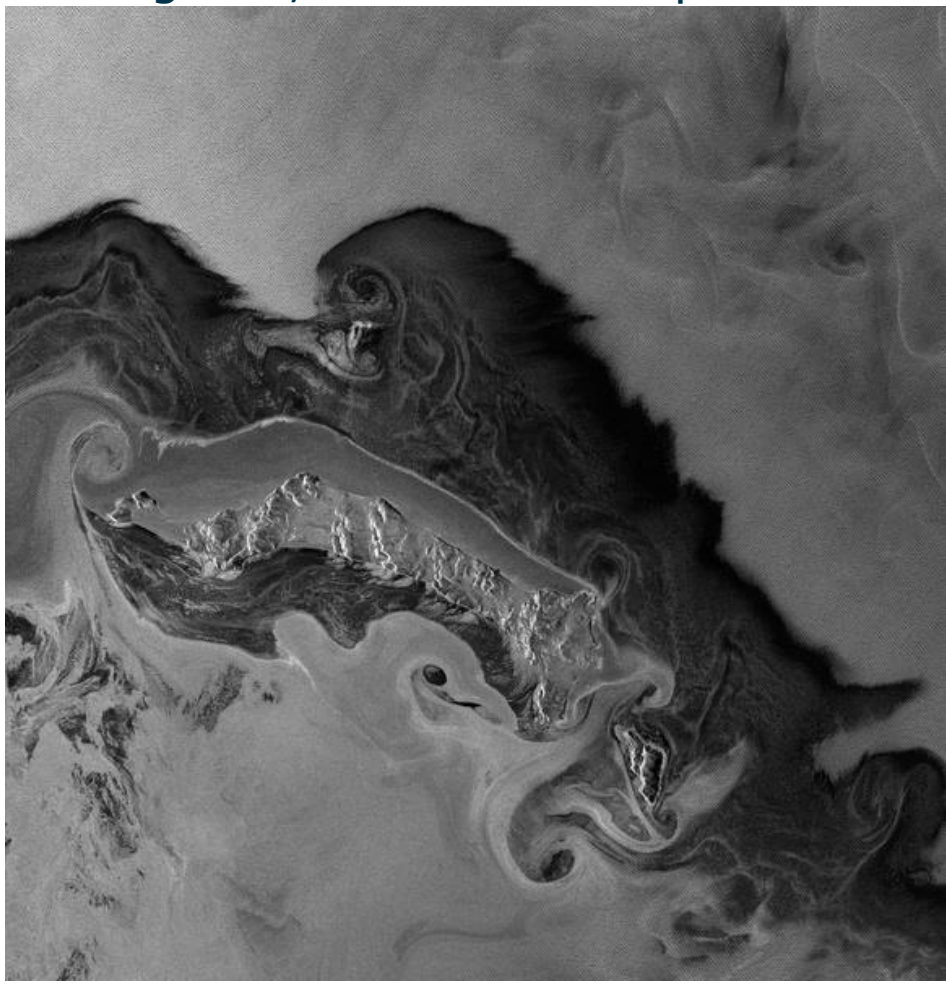
First ESA SAR missions:

ERS-1 / SAR first ESA SAR Mission, single pol (**VV**) **1991**, C-band



ERS-2 / SAR single pol (**VV**) **1995**, C-band

Bering Sea, ERS-1 SAR acquisition

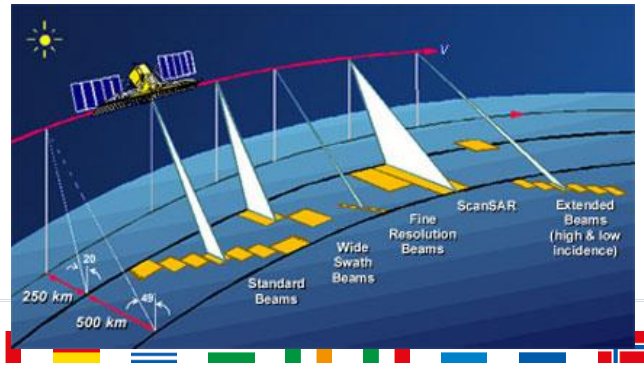


First ESA SAR missions:

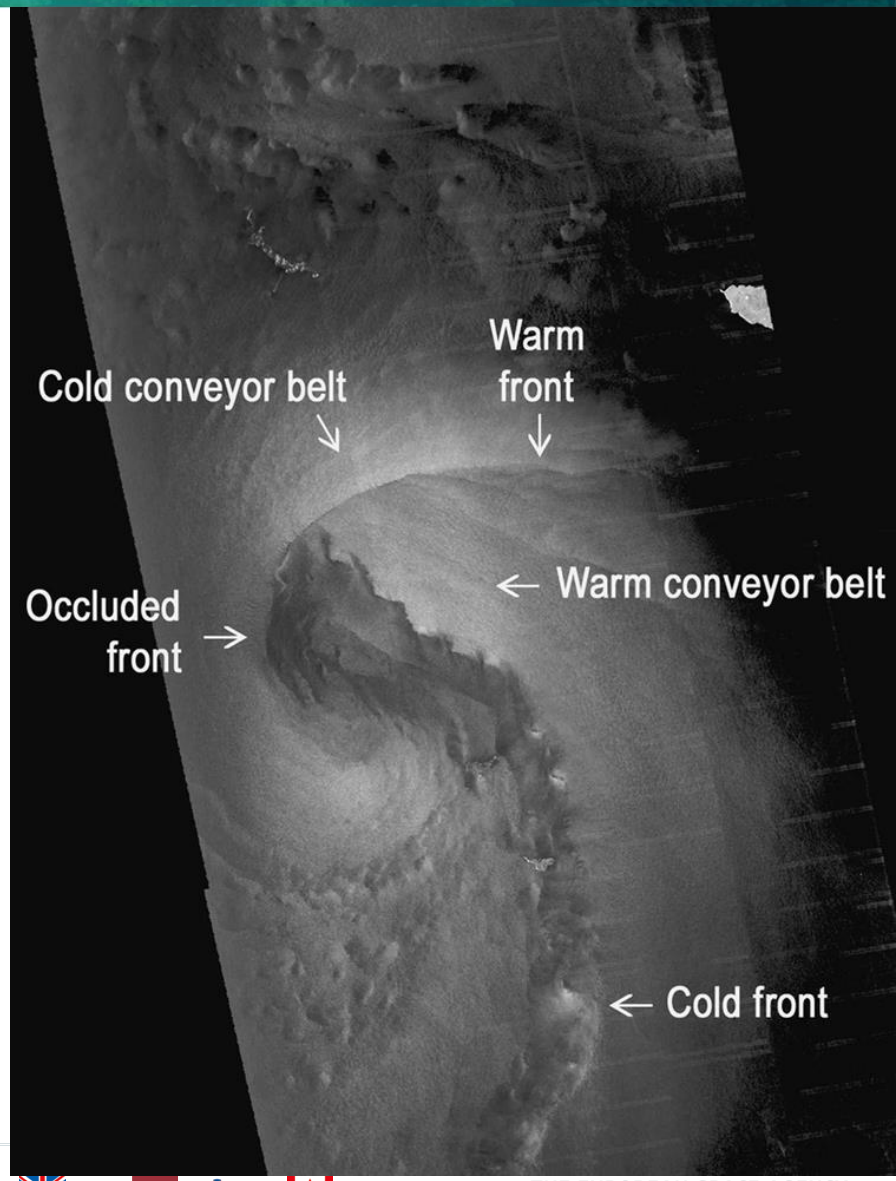
ERS-1 / SAR first ESA SAR Mission, single pol (VV) **1991**, C-band,

ERS-2 / SAR single pol (VV) **1995**, C-band

CSA (Canada):



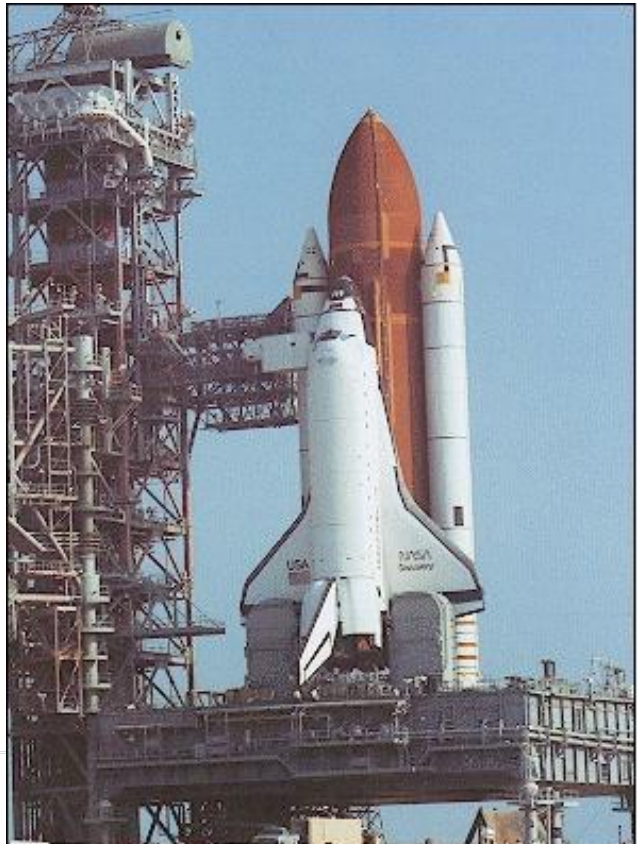
Radarsat-1 / SAR single pol (**HH**) **1995**, C-band



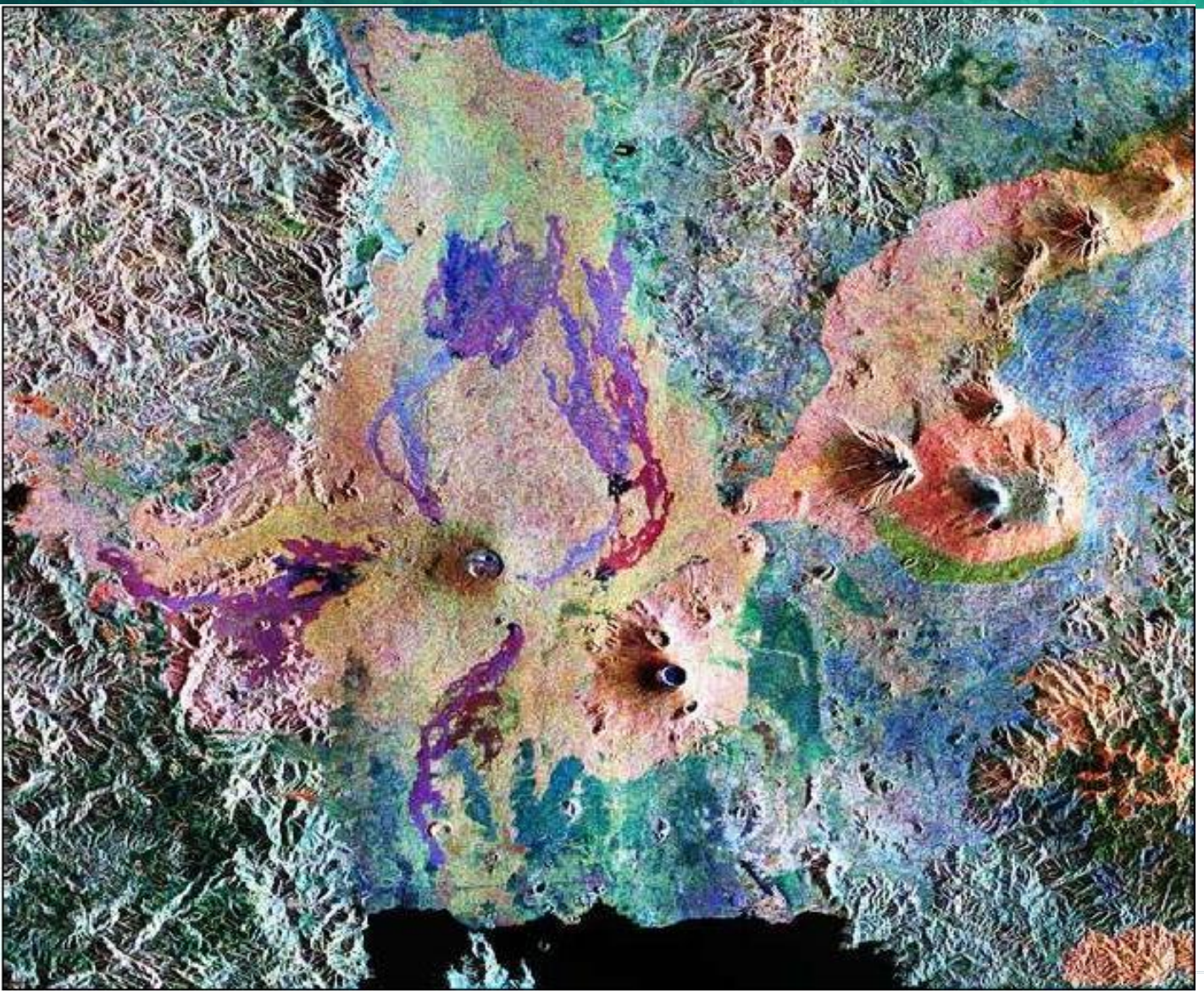
1994:

major milestone in the field of spaceborne SAR observations:
Two NASA Space Shuttle flights with **SIR-C X-SAR**

- Fully polarimetric spaceborne SAR
- Multi-frequency C & L (quad-pol), X (single-pol)

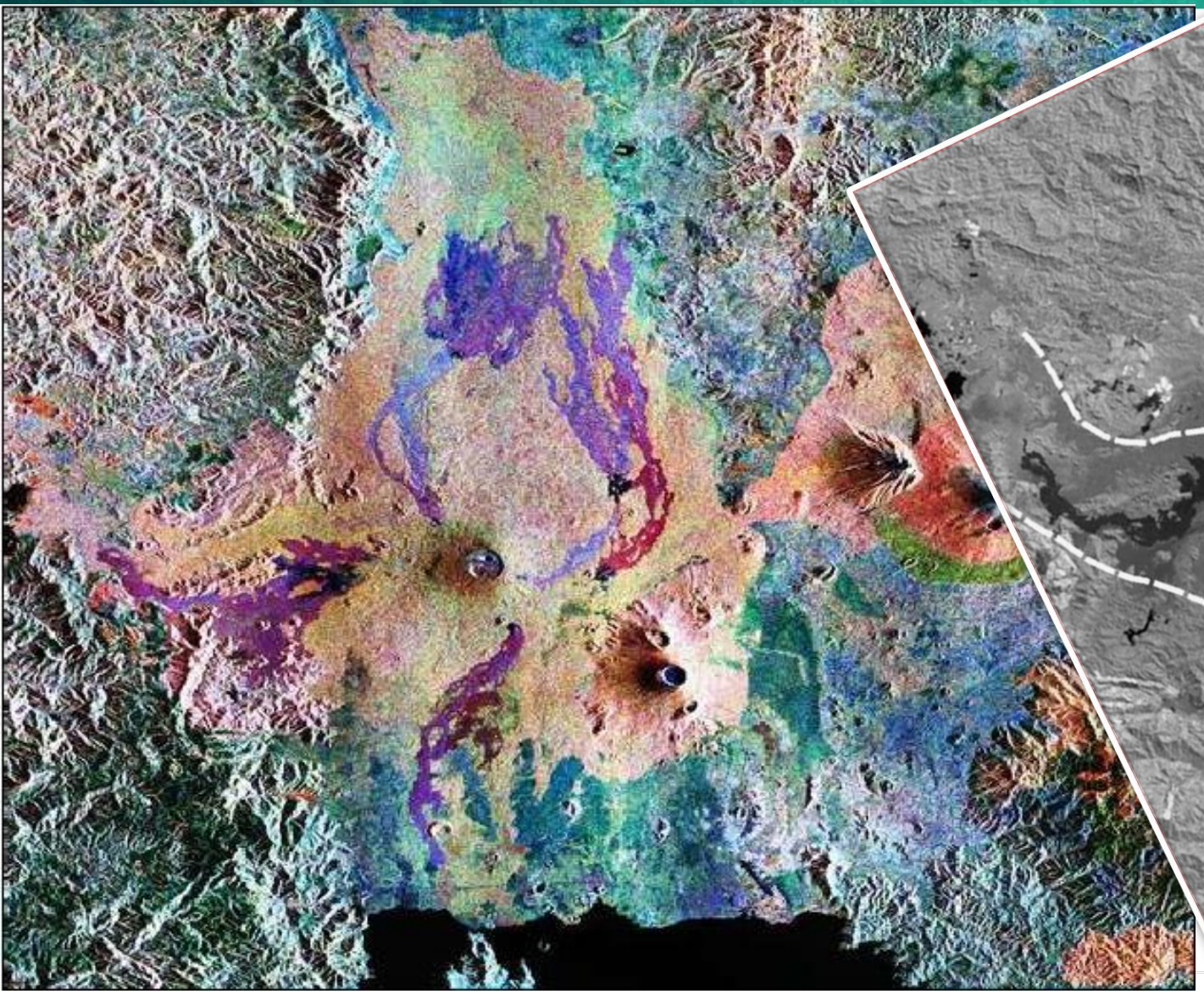


This is **just a RGB color composite** L-HV (horizontally transmitted & vertically received) C-HH band (horizontally transmitted & received); C-HH (horizontally transmitted & received) and **not a polarimetric decomposition, but still very rich from a thematic point of view**



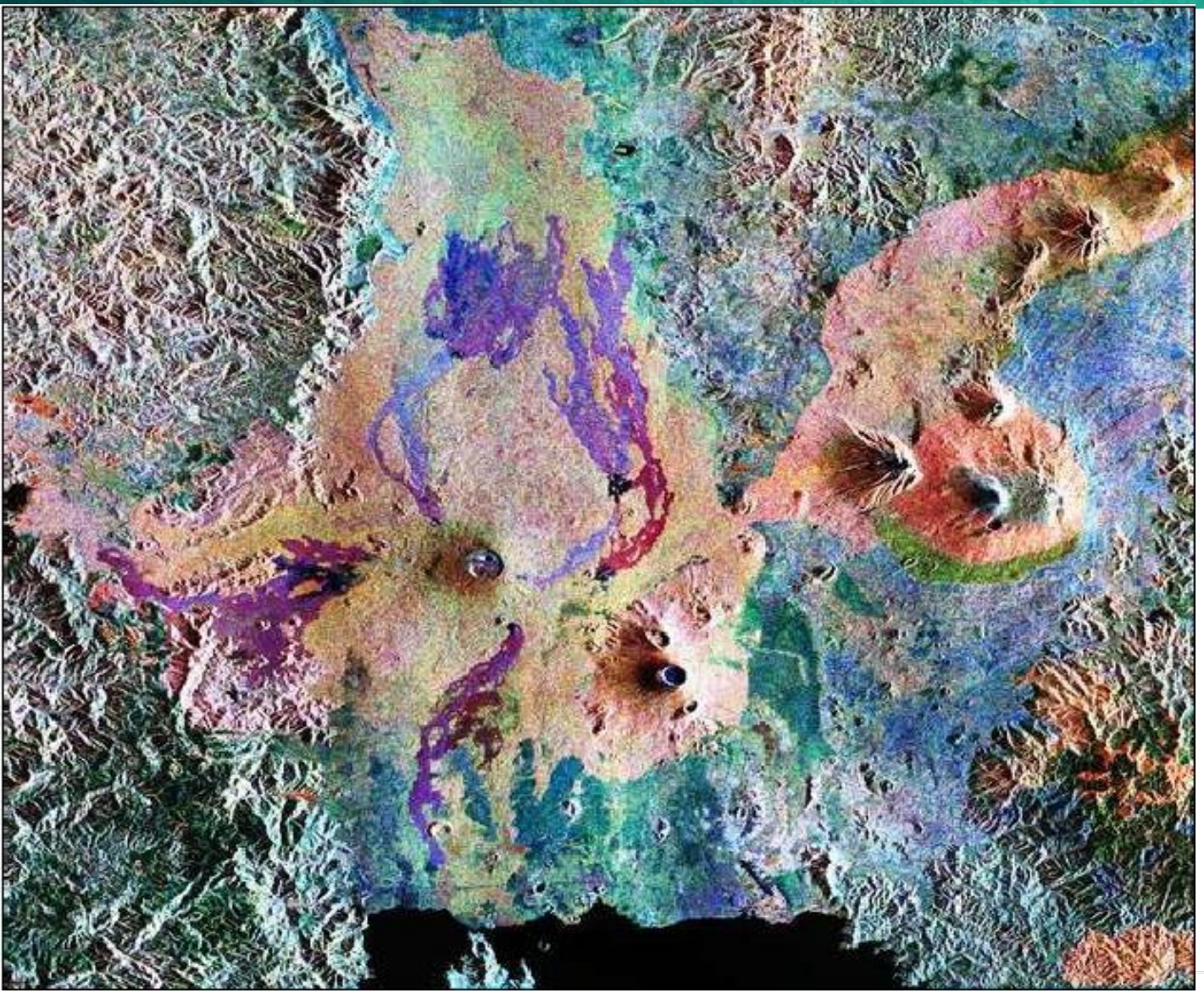
SIR-C/X-SAR false color composite (not a polarimetric decomposition) of Central Africa, obtained on 3/10/**1994** (image credit: NASA)

1994, SRTM



…or radar
…ortunately,
…tellite mission

1994, SRTM



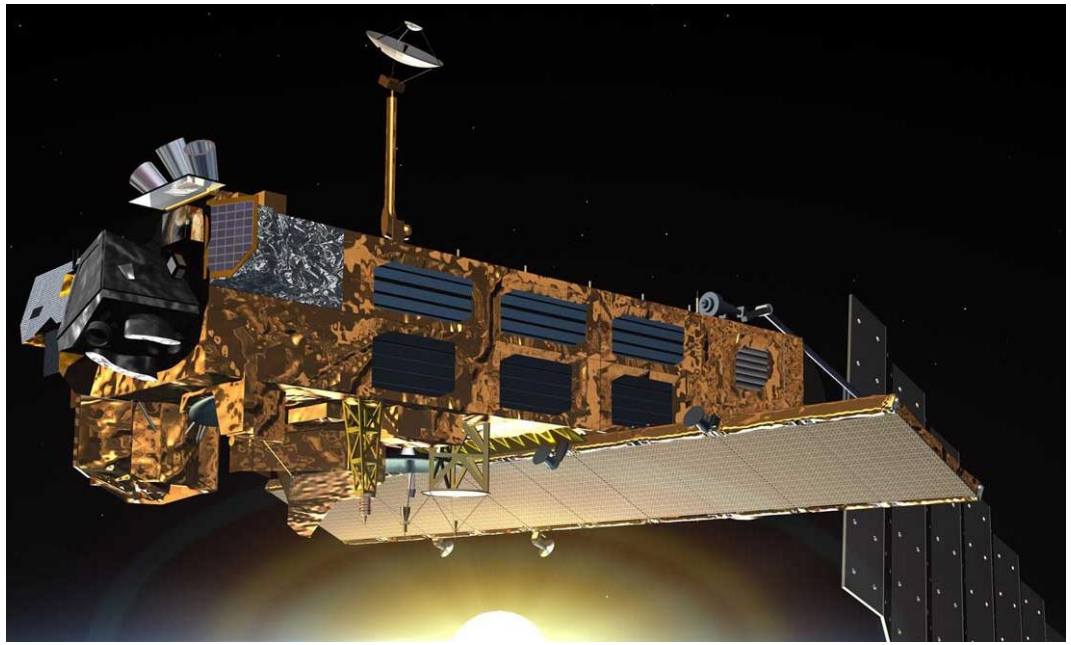
A fantastic "appetizer" for radar polarimetry ….
Unfortunately, ***NOT a "satellite mission"***

New, ambitious and innovative ESA multi-sensor mission with an advanced (A)SAR:

ENVISAT / **ASAR**

2002, C-band, **alt. pol. HH/VV, HH/HV, VV/VH**

(one of the three possible polarisation combinations)



2003: first ESA POLINSAR workshop:
→ recommendations to fly ESA **full-pol** radar missions

- Many **airborne** polarimetric radar **campaigns** followed, since then
- Polarimetric ALOS-1 Palsar available via ESA **TPM** data → See ESA and TPM data access
- **Many polarimetric missions** (ALOS-2, CSK SG, TerrasarX and TandemX) but **not** available via ESA **TPM** (at least not in Quad Pol)
- Polarimetric Radarsat-2 data available via ESA **TPM** data → See ESA and TPM data access

https://earth.esa.int/eogateway/missions/third-party-missions

(follows from previous slide)

- Copernicus SENTINEL-1 A(2014) & B(2016, †23/12/2021), C-band, **dual-pol** HH+HV, VV+VH

- Polarimetric SAOCOM data, 1A (2018) and 1B (2020) ***now*** accessible via ESA AO **PUMAS** Agreement) https://earth.esa.int/eogateway/announcement-of-opportunity/saocom

The FUTURE of ESA SAR missions is hopefully full-pol:

- Future Earth Explorer: **Biomass P-band (launch 2024 / Q1-2025)**
  https://www.esa.int/Applications/Observing_the_Earth/Biomass

first P-band SAR space mission, quad-pol (=full pol), will deliver crucial information about the state of our forests and how they are changing. Interferometry and tomography capability

3-d revisit, ***5 years*** life-time design

The FUTURE of ESA SAR missions is hopefully full-pol:

- Future Copernicus: **Rose-L** Sentinel Expansion mission (**2028**)

SAR in L-band with Dual-Pol and Quad-Pol Imaging Modes **capability** (*)
It will deliver **operationally continuous** information, on a free and open basis, on:
- forests, vegetation, crops, land cover
- surface displacements and geohazards
- surface soil moisture conditions
- sea and land ice….

The goal of Copernicus/Sentinel Expansion missions is to complement the current capabilities of the Sentinels and address gaps in Copernicus user needs.

(*) Copernicus L-band SAR Mission Requirements Document, 2018 (ESA-EOPSM-CLIS-MRD-3371)

The FUTURE of ESA SAR missions is hopefully full-pol:

- **Sentinel-1 NG (launch date >2032)**

C-band, full-pol capability (*)
high resolution and wide swath

(*) The S-1 NG SRD contains a requirement to support quad-pol mode acquisitions, though not foreseen as its main mode of operation (Trade-offs between Dual Pol and Full Pol for operational applications: for most applications dual-pol currently offers the best solution for revisit, sensitivity and duty-cycle which are important drivers for the mission).
Some details will be included in the S1/S1NG/Harmony presentation at PolInSAR 2023.

PolSAR PAST ….. CURRENT …. and FUTURE missions

- ✓ **ALOS-1**: JAXA (Japan), L-band, quad-pol
- ✓ **RADARSAT-2**: Canadian Space Agency & MDA, C-band, quad-pol
- ✓ **COSMO-SkYMed** : Italian Space Agency ASI, X-band, alternating dual-pol
- ✓ **Envisat ASAR**: ESA, C-band, alternating dual-pol, **free access**
- ✓ **RISAT-1**: Indian Space Research Organisation ISRO, C-band, compact-pol

- ✓ **ALOS-2**: Japan Aerospace Exploration Agency JAXA, L-band, quad-pol, it may offer more free data in the future
- ✓ **SAOCOM 1A, 1B**: Argentinian Space Centre CONAE, L-band, quad-pol (**PUMAS Agreement with ESA free limited access, via AOs**)
- ✓ **RADARSAT Constellation Mission (RCM)**: Canadian Space Agency CSA & MDA, C-band, compact-pol, with a specific mode for quad-pol
- ✓ **COSMO-SkyMed Second Generation**: Italian Space Agency ASI, X-band, quad-pol.
- ✓ **GAOFEN-3**: China National Space Administration CNSA, C-band, quad-pol
- ✓ **TERRASAR-X & TanDEM-X**: German Aerospace Agency DLR, X-band, dual-pol (quad-pol experimental)
- ✓ **Sentinel-1**: ESA, C-band, dual-pol, **free access**
- ✓ **NOVASAR-S (NOVASAR-1)**: Surrey Satellite Technology and EADS Astrium UK, S-band, alternating triple-pol
- ✓ **PAZ**: Spanish Ministry of Defense & Hisdesat, X-band, dual-pol

- ✓ **ALOS-4 / PalSAR-3 (2024)**: Japan Aerospace Exploration Agency JAXA, L-band, quad-pol, it could have a free access policy
- ✓ **NISAR (2024)**: NASA & ISRO, L-band and S-band, quad-pol in some areas, **free access**
- ✓ **BIOMASS (2024)**: ESA, P-band, quad-pol, **free access**
- ✓ **ROSE-L (2028?)**: ESA, L-band, quad-pol, **free access**
- ✓ **Sentinel-1 next generation**: ESA, C-band, quad-pol (?), **free access**
- ✓ **TanDEM-L**: German Aerospace Agency DLR, L-band, quad-pol. Still under discussion
- ✓ **Passive receivers**: Several space agencies are evaluating the possibility to send passive receivers to accompany current and future SAR missions. Still nothing decided so far, but the future looks bright for this technology!

UNIVERSITY of STIRLING

Not exhaustive list. Courtesy of Prof. Armando Marino, Univ of STIRLING, UK

PolSAR PAST ….. CURRENT …. and FUTURE missions

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Always check whether data quotas possibly available as ESA TPM

- ✓ **ALOS-4 / PalSAR-3 (2024)**: Japan Aerospace Exploration Agency JAXA, L-band, quad-pol, it could have a free access policy
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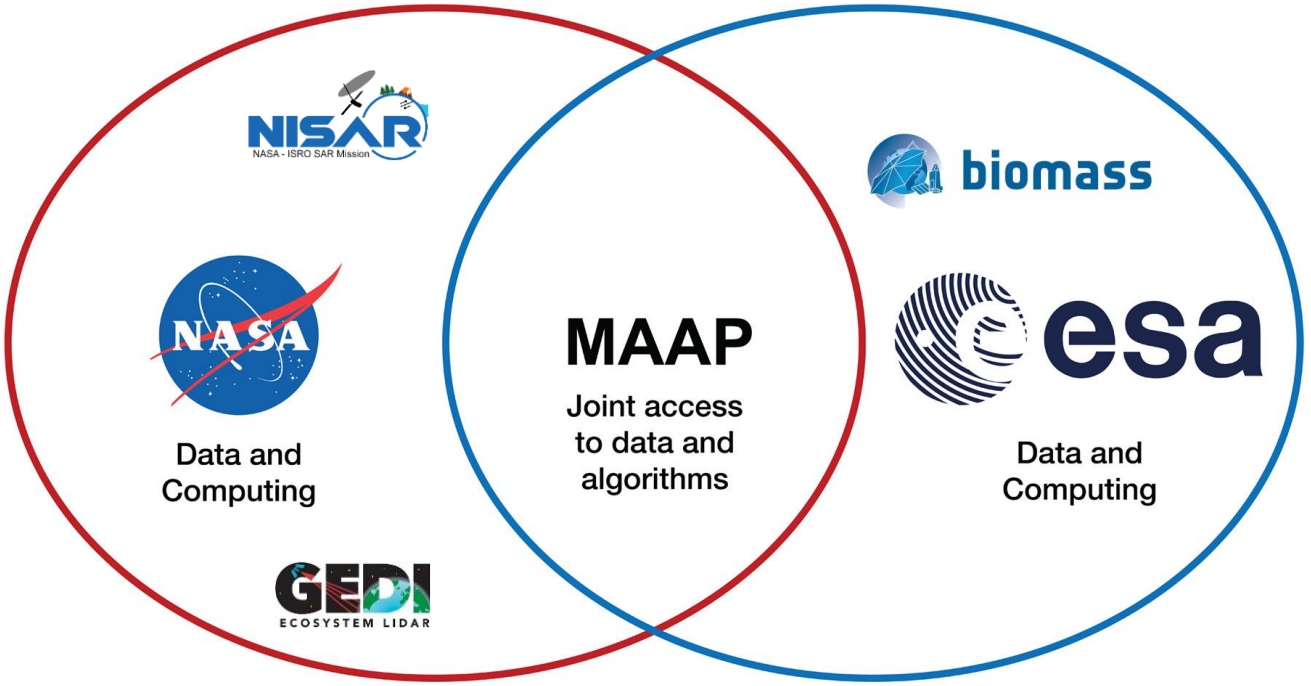
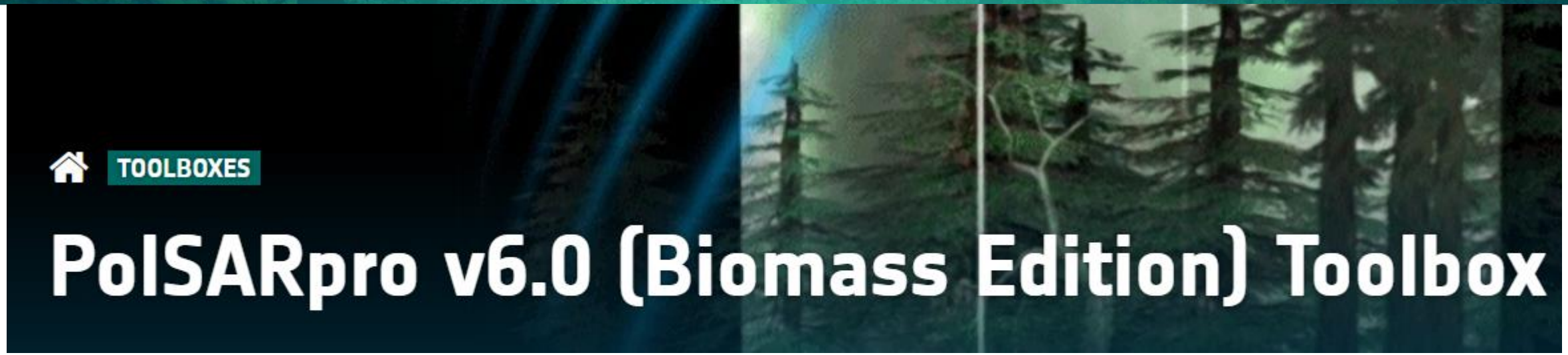


ESA/NASA MAAP: Multi-Mission Algorithm and Analysis Platform

Virtual open and collaborative environment that leverages cloud technologies to facilitate open data use across aggregated data sets.
It will bring together data, algorithms, and computing capabilities in a common cloud environment, to improve our understanding of global terrestrial carbon dynamics.

Purpose: supporting users to share, analyse and process data from field, airborne, and satellite measurements related to ESA and NASA missions.
Data from AfriSAR (preparatory campaign for BIOMASS) and GEDI (Lidar on ISS since 2018) are used as the initial test set for MAAP. Both **planned for 2024**, NASA/ISRO's **NISAR** (L-band SAR studying ecosystem disturbances) and ESA's **BIOMASS** will generate ***huge*** data volumes



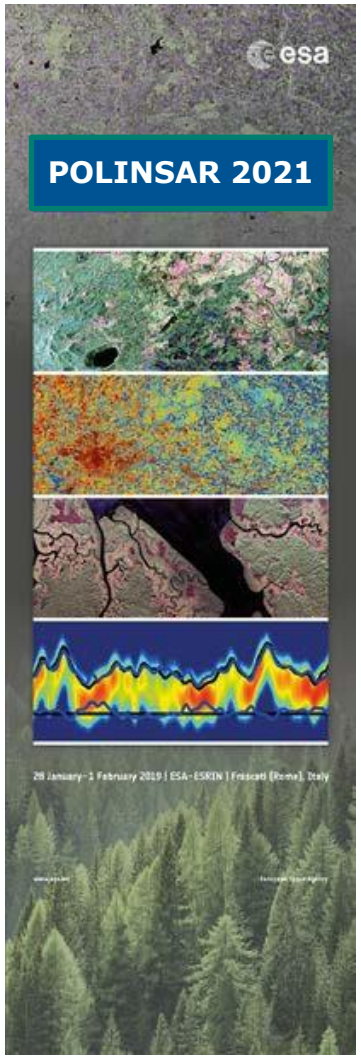
- Current version of PolSARpro 6.0 (Biomass Edition). Developed by Uni Rennes for ESA since 2003
- **Stand-alone** Polarimetric SAR Toolbox for Polarimetric SAR data analysis and processing for the scientific exploitation of fully and partially polarimetric data
- Ingesting data from most polarimetric spaceborne SAR missions (ALOS, CSK, RCM, TSX, SAOCOM, … and soon BIOMASS, NISAR … Rose-L…)
- A consistent library being developed also in **Python** (with implementation on **MAAP**)

Linked to the 2023, 11th PolinSAR/BIOMASS Workshop (20 years of SAR Polarimetry in ESA) next week in Toulouse https://polinsar-biomass2023.esa.int/

		Monday				Tuesday		Wednesday		Thursday		Friday	
Start	End	PolInSAR	Biomass	Start	End	PolInSAR	Biomass	PolInSAR	Biomass	PolInSAR	Biomas	PolInSAR	Biomass
9:00	10:30	Registration / Coffee		9:00	10:40	Biomass Mission Overview		Forest Applications II		TomoSAR Methods		Hydrology Applications	
10:30	11:10	Workshop Opening		10:40	11:10	Coffee Break		Coffee Break		Coffee Break		Coffee Break	
11:10	12:50	SAR Missions		11:10	12:50	Biomass Products and Algorithms		Agriculture Applications	Biomass - Validation & Carbon Modelling	Campaigns		Recommendation & Summary	
12:50	14:10	Lunch Break		12:50	14:10	Lunch Break		Lunch Break		Lunch Break		End of Workshop	
14:10	15:50	Missions & Calibration		14:10	15:50	Biomass Methods		Land Applications	Biomass - Mulitmission Context	Cryopshere Applications			
15:50	16:20	Coffee Break		15:50	16:20	Coffee Break		Posters - Aperitivo		Coffee Break			
16:20	18:00	PolSAR / PolInSAR Methods		16:20	18:00	Forest Applications I				Ocean/Sea Ice Applications	GEO-TREES community engagement		
18:00	19:30	Icebreaker											

Potentially interesting sessions for you

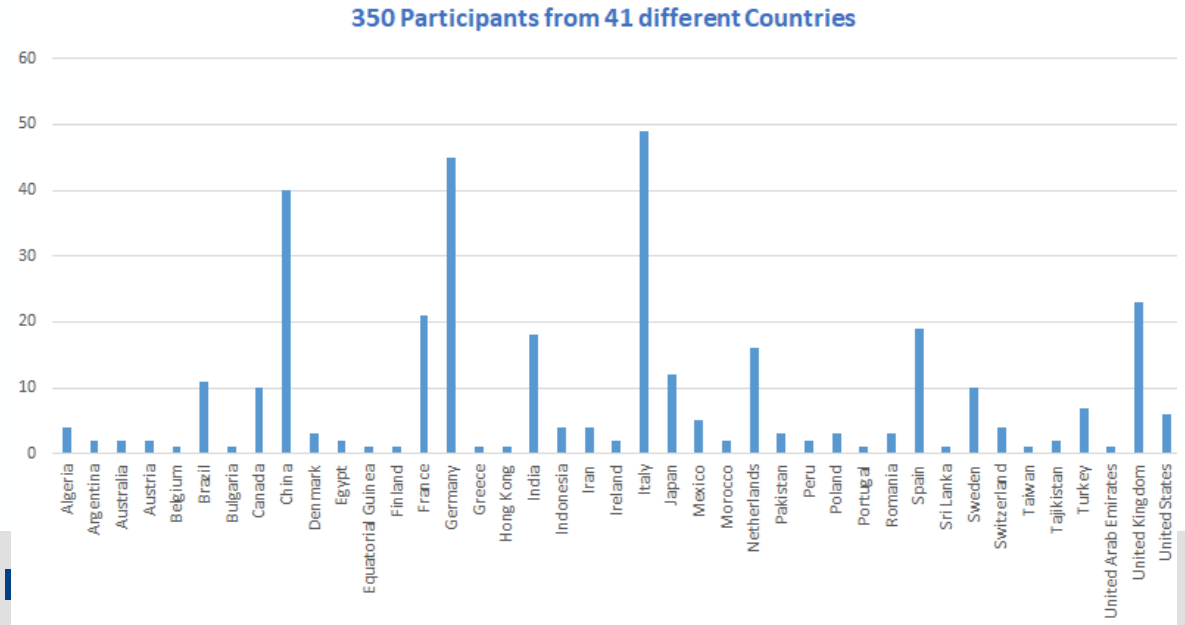
Previous PolinSAR Workshop (2021)



POLinSAR 2021, the 10th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry and BIOMASS preparation was held online

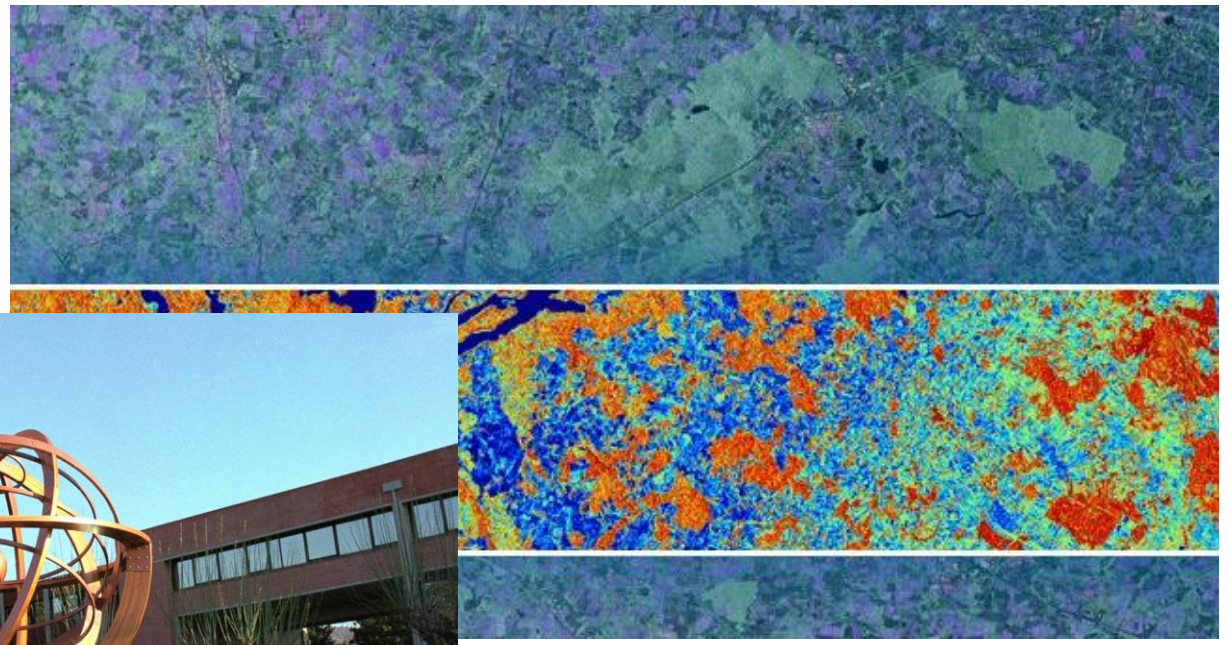
12 different sessions, plus 2 technical discussion sessions (open discussion to collect users recommendations)
A total number of **64 presentations**

350 participants from 41 countries (compared to 150 in 2019 !!!)



Future opportunities

See you all at many more future ESA PolinSAR workshops where you will present your work and your results in SAR Polarimetry !!!!



Many more EO Training Opportunities with ESA

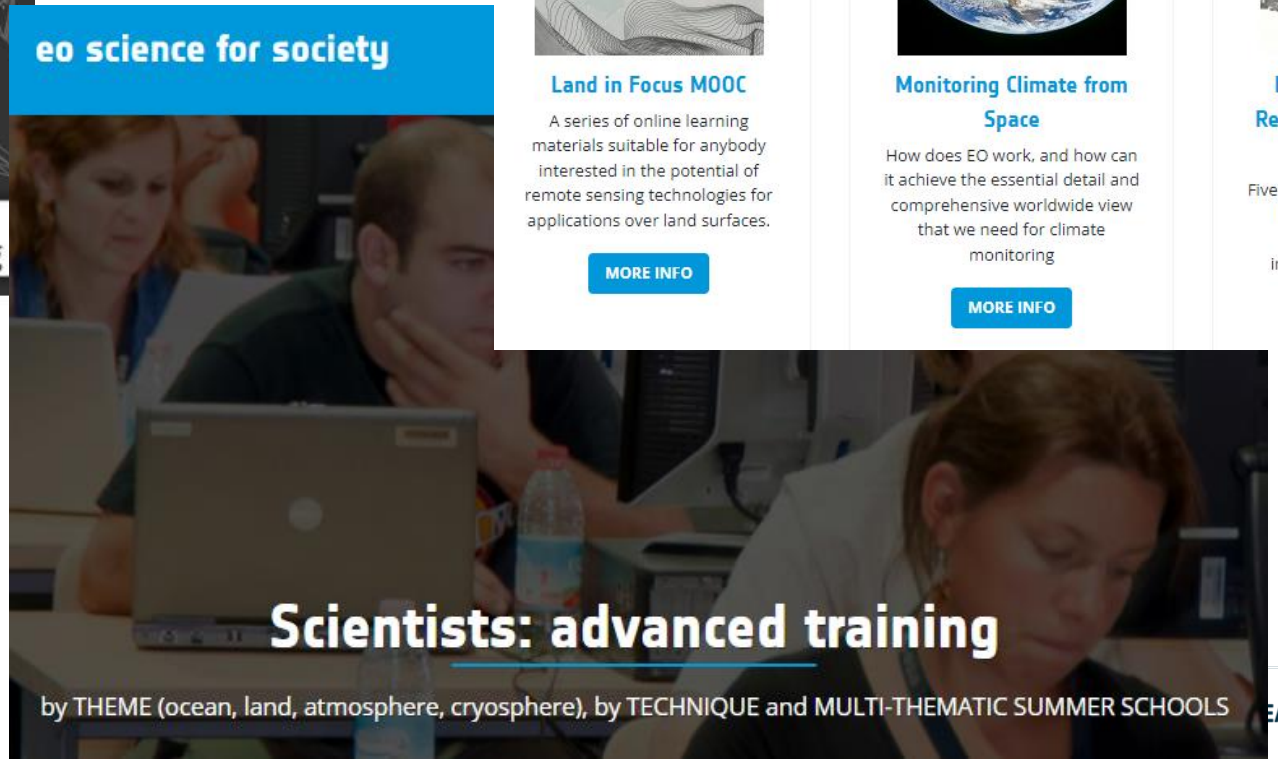
EO Science opportunities and recent results on: https://eo4society.esa.int/communities/scientists/
Follow our present and future training opportunities in Earth Observation on:
https://eo4society.esa.int/training-education/ Including other training courses and MOOCs

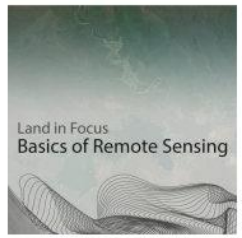
Re-run of "Echoes in Space – Introduction to Radar Remote Sensing"

ESA has opened a re-run of the successful Massive Open Online Course 'Echoes in Space – An Introduction to Radar Remote Sensing'. The re-run is currently accessible free of charge on the eLearning platform EO College (https://eo-college.org), as from **16th September 2019** for a period of 12 months.

Registration is possible anytime during the duration of the course. Students can follow the five consecutive weeks of lessons at their own pace, and will receive a certificate of completion.

'Echoes in Space' is suitable for anybody interested in getting an introduction to Radar images or looking to deepen into the topic. It covers the history and basics of Radar technology and Radar Remote Sensing from space, and gives a unique hands-on experience in diverse application scenarios.





Land in Focus MOOC

A series of online learning materials suitable for anybody interested in the potential of remote sensing technologies for applications over land surfaces.

MORE INFO

Monitoring Climate from Space

How does EO work, and how can it achieve the essential detail and comprehensive worldwide view that we need for climate monitoring

MORE INFO

MOOC on Cryosphere Remote Sensing: Winter, Water, Warming

Five short online lessons suitable for anybody with a basic background on SAR and interested in Canadian SAR applications.

MORE INFO