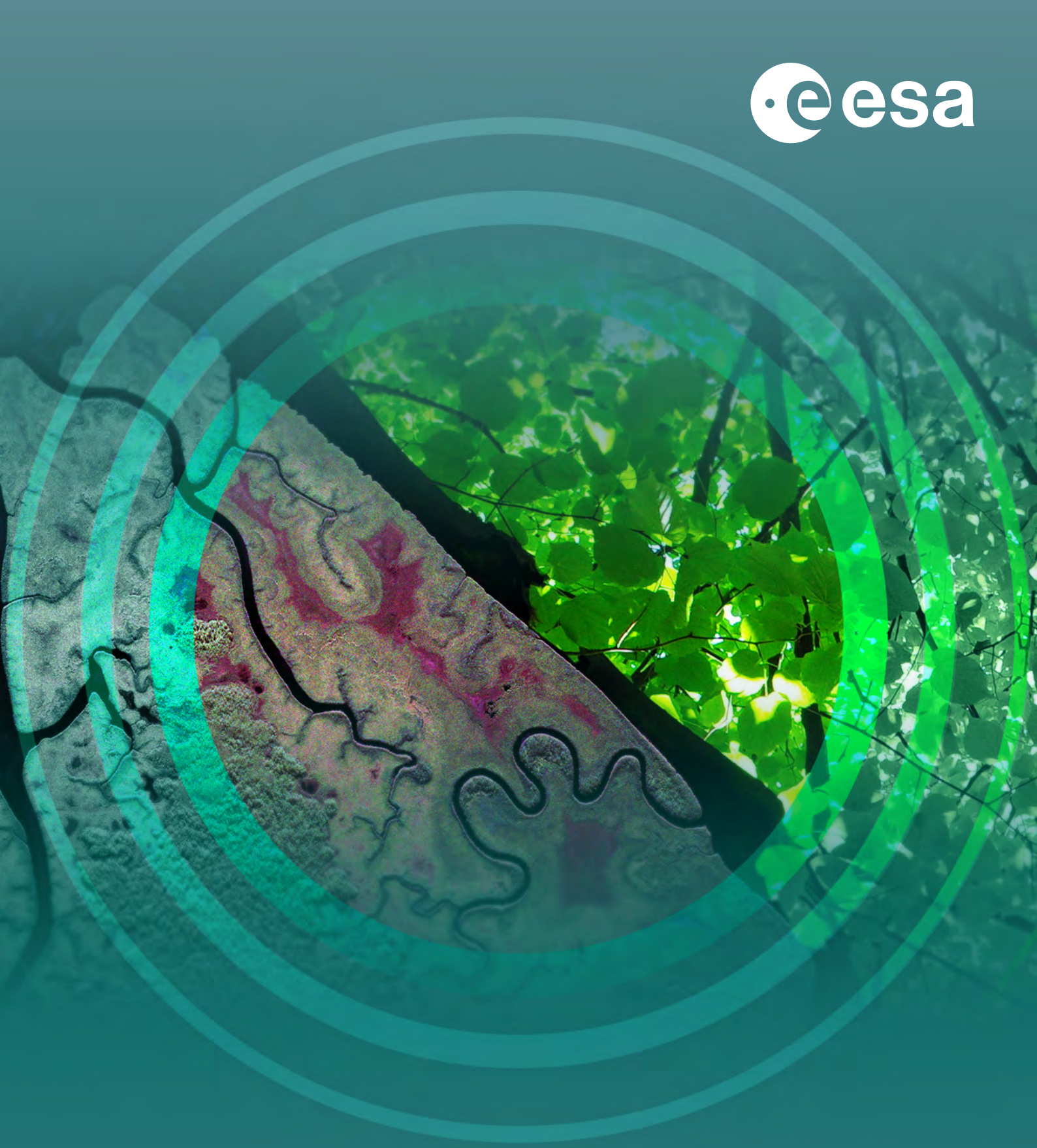

10th PolInSAR Workshop 2021

Report of Recommendations

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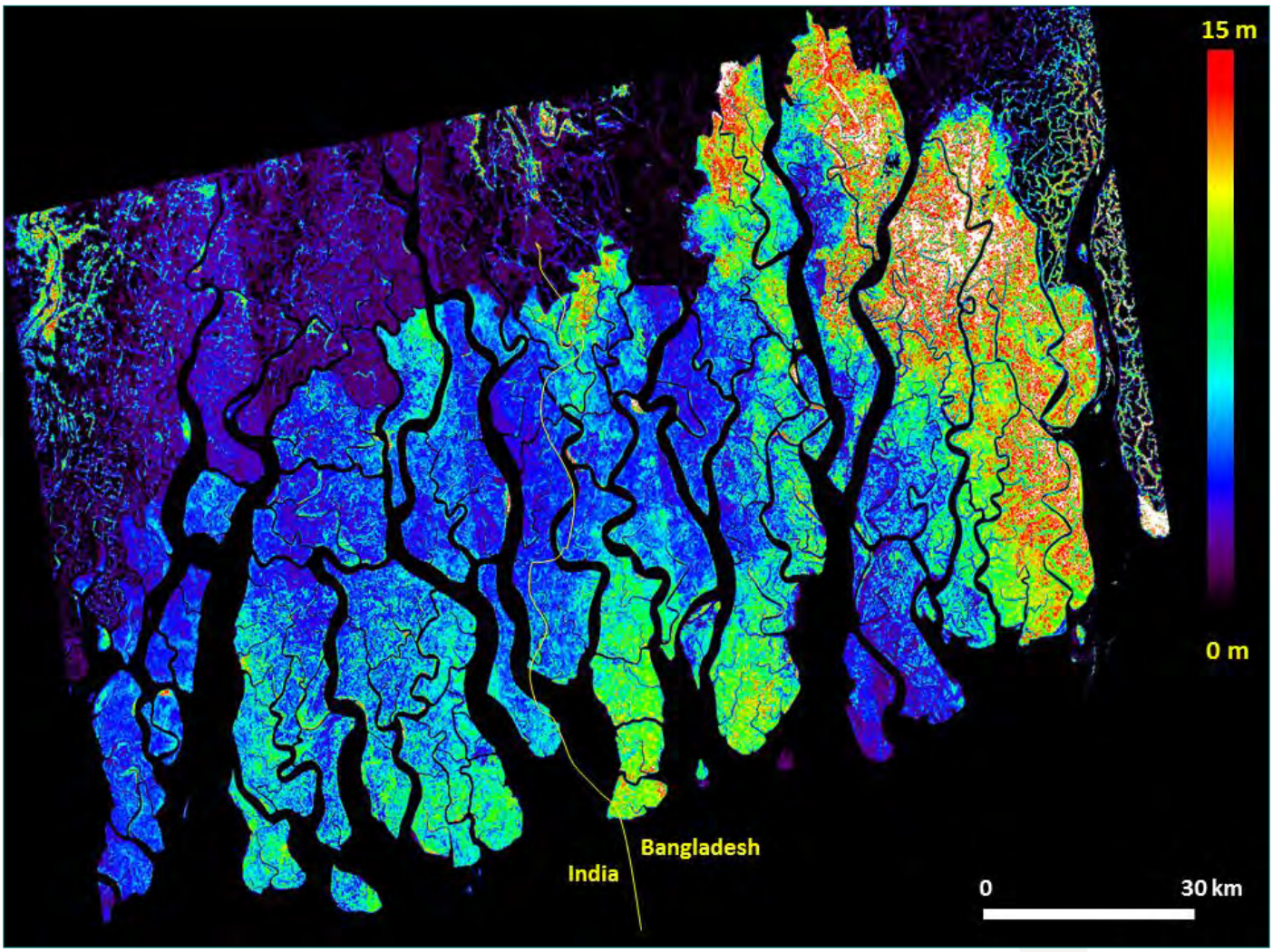
2. Scope of the document

This document presents the list of recommendations collected during and after the **10th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry - PolInSAR Workshop**, following technical meetings, workshop sessions and discussions held with the scientific community.

3. Statistics

The 10th International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry was held from 26 to 30 April 2021 as an online event. The Workshop included 12 scientific sessions and two technical sessions (open discussion to collect recommendations) with a total number of 64 presentations. The event was very successful in terms of participation - 350 participants from 41 countries (compared to 150 participants in 2019) with an average of 100 participants per session.



4. Technical sessions

Two technical sessions were held during the Workshop to collect users' recommendations. The outcome of these sessions is reported in the following sections.

a. Science Recommendations for future polarimetric SAR missions

The purpose of this technical discussion was to collect recommendations from the scientific community regarding the requirements for future SAR missions and the exploitation of data synergy from these missions.

Recommendations regarding missions, campaigns and data		
RQ 1	**Multi-mission, multi-frequency datasets**	· Create and make available free & open multi-frequency fully polarimetric and interferometric SAR data (spaceborne and airborne), user-friendly open reference datasets (well coregistered on the same grid, at L1 & L2) providing a single data access to users for all different missions, acquired on some characteristic sites like agricultural sites, forest, ocean, desert, covered with snow, coastal areas/wetlands · Inter-agency issue to be discussed in the frame of CEOS
RQ 2	**Tools for multi-mission data processing**	Provide tools for multi-mission data processing/exploitation (precise coregistration, data fusion with machine learning, etc.)
RQ 3	**Synergy of satellite systems**	· A trade-off between full pol versus dense time series (or wider swath) needed · Minimise time difference between acquisitions using different satellite missions (ideally simultaneous), to exploit synergy. For Agriculture: Small temporal baseline. For Forests: better separate acquisitions if same frequency; if multifrequency: better as close as possible (ideally simultaneous) · If different missions were synchronised (eg Rose-L & S-1 NG) this would help L-C-band synergy applications enormously. Ideally acquisition synchronization or at least coordination could be attempted also between missions of different agencies: e.g. align orbits of different missions like Rose-L and ALOS, acquire with same incidence angles (idem for Rose-L and S1 NG)
RQ 4	**Multistatic experiments and simulations**	Wish for multistatic experiments (like Harmony) but also coordination between different missions. Simulations in preparation for Harmony are desirable (ground-based, airborne)
Recommendations future studies		
RQ 5	**Studies regarding retrieval & EM models**	Put significant efforts in modelling to prepare studies (and tools) on multi-frequency mission data (presently we cannot easily distinguish if a change in polarimetric behaviour is due to differences in frequencies, incidence angles or temporal changes). Studies/opportunities for the research on retrieval & EM models (forward and inverse) should be launched
RQ 6	**New research sites**	Include Wetland & Coastal Areas among sites for multifrequency acquisitions since of great importance for many nations, incl. Australia – CSIRO
RQ 7	**Science and research opportunities**	New Science Opportunities could include, on top of other suggestions from each session: · Sub-surfaces studies: multi-modal data (combined with frequency, polarimetry and interferometry) will open incredible opportunities to monitor biophysical parameters at different depths (in preparation for Biomass and Rose-L) · Forest Disturbances studies (including Forest Fire Risk) will benefit from full-pol SAR by combining different bands.
RQ 7	**Multimission, multifrequency data synergy studies**	Once these datasets mentioned in RQ1 are available, ESA could launch related challenges and science opportunities for synergy studies.

b. PolInSAR tools for MAAP – discussion and recommendations from users

The purpose of this technical discussion was to collect recommendations from the scientific community regarding the future implementation and integration of tools in MAAP with the particular emphasis on the functionalities of PolSARpro BIO software.

Recommendations about PolSARpro and about the polarimetric processing tools for MAAP		
RQ 8	**Programming language**	Language for the PolSARpro functionalities implementation to be included in the MAAP: Python preferred with the use of efficient computing libraries (NumPy, xarray, zarr).
RQ 9	**Polarimetric decompositions**	More polarimetric decompositions that are already available in PolSARpro on the top of the ones already proposed internally (see Annex 1) (e.g. Van Zyl, NNED) shall be added to MAAP.
RQ 10	**PolSARPro BIO continuation**	PolSARPro should remain a separate toolbox (e.g. for education, research) in parallel of its availability in MAAP (PolSARpro could be completely recoded in Python).
RQ 11	**PolSARpro – SNAP**	We should avoid to duplicate the efforts (between PolSARpro and SNAP) and not reengineer a functionality already available in BioPAL (coregistration).
RQ 12	**PolSARpro support for new missions**	PolSARpro – BIO shall address future ESA polarimetric missions like ROSE-L, Sentinel-1 NG.

Other topics discussed

- More and more online research environments for SAR (Geohazard TEP, sentinel hub, KappaZeta, Google Earth Engine, etc.) are available for the community.
- Joint Mission Algorithm and Analysis Platform: online research environment for joint exploitation of BIOMASS, NISAR and GEDI missions, following open science approach (Permissive open source licenses only).
- Open SAR Toolboxes (different licensing approaches): SNAP, PolSARPro, BioPAL, ISCE 3.0, OTB, etc.
- A list of PolSARpro-BIO functionalities to be recoded/reengineered first (to be compliant with MAAP licensing requirements) was presented as per Annex 1.

In addition, Prof. Yoshio Yamaguchi, from Niigata University (Japan) explained that global ALOS-PALSAR quad-pol data (250,000 scenes acquired in 2006-2011) plus other data sets are available for download from the AIST website (https://gsrt.airc.aist.go.jp/landbrowser/index.html), thanks to JAXA & AIST collaboration projects. This includes also image time-series. It is foreseen that also ALOS-2 quad pol images will be available in the near future. Unfortunately, as noticed by Prof. Eric Pottier (University of Rennes 1, France), the ALOS Dataset from the AIST website cannot be processed by PolSARpro, for the time being, because they are not in the original JAXA data format (CEOS data format). The AIST data are written a TIFF format which can be read by general GIS software such as GDAL. The scattering matrix can be obtained from the data using a simple python script, as explained by Prof. Yamaguchi in the email exchange on July 12th 2021

> *(...) The contents are as follows,*
>
> ***1.*** *The downloadable data format of AIST (AIST SLC) is based on TIFF, and not on CEOS. That is, AIST SLC is written in TIFF format. It can be read by general GIS software such as GDAL.*
>
> ***2.*** *The scattering matrix data can be obtained by this TIFF format data, using a simple python script (attached).*
>
> *For example, from the website, we download the L1.1 (AIST SLC) (...) and we can create scattering power decomposition image (attached). The python script changes TIFF data to flat binary data. It will be possible to obtain scattering matrix data.*

5. Science Sessions

Twelve different sessions presented during the Workshop have covered a wide set of topics and collected a list of recommendations from the scientific and users community: the recurring need seems to be the **Full Free and Open data availability**. Additionally, new inspiring elements for open science application and for Artificial Intelligence application were cited, also considering that many new polarimetric SAR missions are approaching (e.g. BIOMASS, Rose-L. Sentinel-1 NG etc). All the collected recommendations are listed in the following sections.

a. SAR Missions

Chaired by B. Rommen, M. Davidson, F. Sarti, I. Hajnsek

The science community recommended to have more fully polarimetric L-band satellite data available, especially from the ecosystem community dealing with forest and agriculture. Also, the Cryosphere community is strongly requesting these data for land ice/firn analysis that are essential to retrieve physical parameters to observe and monitor essential climate effects.
The science community is requesting to ESA to spend effort on the coordination of an Open data policy for science purposes for all L-band mission already available and for those coming up. Especially the fully polarimetric modes should be made available for science use:

- Coordination between agencies of super test site for fully polarimetric data should be made available for different applications
- The use of common calibration sites could be coordinated between the agencies
- The data – if possible – should be made available over one data portal

There is a strong recommendation for synergies between different missions in C-/L-/P-band, in terms of data coordination, data availability and time series acquisitions.

b. BIOMASS Mission

Chaired by Klaus Scipal, Clement Albinet

- Biomass will be the first PolInSAR mission at ESA. Launch in 2023
- Novel **open source** approach to develop and evolve the **Level-2** and Level-3 algorithms -> BioPal (really NEW approach)
- Novel platform approach to access data and interact with and between the users -> MAAP

c. Methods and Theoretical Modelling

Chaired by Stefano Tebaldini, Laurent Ferro-Famil.

The main recommendation is to continue supporting the science community with the provision of public datasets from well-thought experiments to address falsifiable hypotheses and validate new data processing methods (= reproducibility of results in an open science framework, as done by NASA).

d. SAR Polarimetry and Pol-InSAR

Chaired by Subrahmanyeswara Rao and Ferdinando Nunziata

Recommendations: ESA should support Studies for algorithm development (such as additive noise reduction, vegetation indicators, improved decomposition techniques).

e. Applications of SAR Polarimetry on Agriculture

Chaired by K. Papathanassiou, A. Marino

- The information content of Pol-InSAR data (as for example represented by the coherence region) for agriculture applications is not fully explored especially not with respect to the dielectric properties (more research needed)
- Multi-incidence and multi-baseline acquisitions can be a very powerful tool for biophysical parameter estimation.
- Cloud based computing can boost fast development of algorithms. The community would benefit more from tools like the proposed MAAP that would allow to work with coherent data.

f. Applications of SAR Polarimetry on Land

Chaired by E. Koeniguer and J. Patruno

- Encourage the community to use polarimetry as **a way to improve temporal tools** (detection of PS for example, or on the contrary, optimization of the detection of temporal "breaks" in time-series)
- Encourage the community to **better interface polarimetry with recent developments in AI**
- The added value of polarimetry not yet completely exploited since **few open satellite data** are available
- The possibility to **add polarimetry (quad pol) in the future Sentinel-1 SAR missions** is of great interest of the science community
- **Multi band SAR data and multi-mode** (integration with optical data) availability can provide a powerful tool for some applications

g. SAR Tomography (Tomo-SAR)

Chaired by L. Ferro-Famil, L. Villard

It is recommended to continue promoting studies on SAR tomography in order to better exploit its unique capabilities for the characterization of complex environments. This promotion comprises the delivery of pre-processed and ready-to-use data sets, such as those prepared in the frame of the SARSim or the TomoSense projects, the community could get familiar with and employ for quantitative remote sensing purposes.

h. Cryosphere

Chaired by Irena Hajnsek, Andrea Buono:

- **Consistent data acquisitions in fully polarimetric and longer wavelength are needed** for a better exploitation of sea ice and land ice regions.
- **Dedicated studies** should be launched focused on the **development of methods/ techniques to retrieve physical parameters** from polarimetric observables.
- Proposal for **coupling of firn models with SAR retrieved parameters** to understand the properties of the firn structure.
- **Advanced physical modeling tools and combination of multi-frequency/ multi-mode SAR observations** are needed to improve our knowledge on sea/ land ice properties.

i. Forest and Biomass I

Chaired by Ludovic Villard, Clement Albinet

- Increasing demand for f**orest change products, whether from *in situ* & EO data**, meaning long-term strategies to ensure continuity (despite heterogeneous practices, EO data), which will be a key challenge for future spaceborne missions.
- There is a need of more open/transparent algorithm development and sharing to benefit the **homogenisation** across different sensors and data (in situ and EO). Thereby this will also ensure an improved temporal continuity, which often involves different sensor systems.
- The use of **multi-temporal data** (in particular SAR) seems truly promising **to improve product accuracy & uncertainties** (especially for new intermediate products between L1 & L2, such as G2V ratio), and should be deeper investigated according to the future acquisition's scenarios from the upcoming spaceborne missions. For this purpose, **multi-temporal airborne SAR would be very helpful**.
- Need of **better definitions for different forest classes, as well as forest height** which cannot be easily transposed to various resolutions (e.g. BIOMASS vs GEDI ones).
- **Further work needed to better account for scaling issues (spatial and temporal mismatch)**, whether to compare EO products or to validate them, although advanced statistical metrics cannot replace larger and repeated collection of in situ data.
- **Data quality** and uncertainties r**elated to biomass maps are requested** by the users and should be properly addressed for all the produced maps.

j. Forest and Biomass II

Chaired by Matteo Pardini, Klaus Scipal

- Several open challenges to be tackled:
  - Parameterizations: often driven by the observation space, but many options are open
  - Permittivity inversion model & association to water content
  - New outputs: forest changes, wood permittivity towards a complete data set
  - Role of scales & spatial samplings (e.g. GEDI) continues not to be fully understood
- Fact: 3D measurements (Lidar & TomoSAR) are the key for new inversion solutions and should be further exploited.

ANNEX 1

PolSARPro: Which functions to translate first?

Polarimetric decompositions

- [+] H/A/α
- [+] Freeman-Durden
- [+] Cloude
- [+] Generalized Freeman – Yamaguchi 3-components decomposition?
- [+] Yamaguchi 4-components decomposition (2007)?
- [+] Freeman 2-components decomposition (2006)?
- [–] Huynen
- [–] Barnes
- [–] Holm
- [–] Krogager
- [–] Cameron

Polarimetric Segmentation

- [+] Basic scattering mechanisms identification
- [–] unsupervised, with statistical techniques (Wishart distribution)
- [–] unsupervised, without techniques (H/A/α)
- [–] supervised, with statistical techniques (Wishart distribution)

Polarimetric classification

- [+] Unsupervised Wishart - H / A / α Classification
- [+] Supervised Wishart and / or Gaussian Classification

Polarimetric data processing

- [+] Optimal Polarimetric Contrast Enhancement - OPCE
- [–] PWF, Sub-Apertures, Surface inversion, Data clustering, Edge detectors...

Polarimetric speckle filter

- [+] The J.S. Lee refined
- [–] The IDAN (Intensity Driven Adaptive Neighbourhood) filter
- [–] The P.W.F (Polarimetric Whitening Filter) filter [BoxCar already present in the MAAP]

Surface Parameter Data Inversion using empirical and semi-empirical approaches that provide Volumetric Soil Moisture maps and Surface Roughness maps and which include the following functions

- [–] Sigma-zero generation
- [–] Local incidence calculation from sensor geometry
- [–] Local incidence calculation from available DEM
- [–] Dubois et al. Algorithm for surface parameter estimation
- [–] Oh et al. Algorithm for surface parameter estimation
- [–] 1st Order X-Bragg Algorithm for surface parameter estimation (optional)

Others from SNAP (are they already present in PolSAR Pro?)

- [+] Soil moisture
- [+] Interferogram formation
- [+] Interferogram filtering
- [+] Interferogram unwrapping

PolSARPro Sim

[+] Higher priority

[–] Lower priority