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DOCUMENT

Proceedings from IDEAS-QA4EO Cal/Val WS#1 University La Sapienza, Rome (Italy) 19 – 21 February 2020

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1 INTRODUCTION

During 19 – 21 February 2020 a three days Workshop was held in University La Sapienza (Rome) to present and discuss the Cal/Val and metrology activities proposed in the frame of the new IDEAS-QA4EO ESA contract, which was formally kicked off in November 2019. This document reports the highlights from the Workshop's and the main recommendations arising during the discussion, additional details, including all presentations are available on-line at:

https://earth.esa.int/web/sppa/meetings-workshops/expert-meetings/qa4eo1stcalvalws

1.1 Background

The IDEAS-QA4EO service contract, follow-on of the former IDEAS+ service, was awarded by ESA to a large consortium of international partners lead by TVUK and Serco. The IDEAS-QA4EO service acts on behalf of ESA-SPPA section for ensuring the best data quality of ESA operational EO missions, this includes a wide range of activities, spanning from the Routine Quality Control to the Algorithm Development and Cal/Val (Calibration and Validation) activities.

In the frame of IDEAS-QA4EO consortium, Task 2 is the place where innovative ideas are promoted and incubated with the goal to further improving algorithm baseline, calibration and validation protocols, data quality assessment procedures. In this respect, this task is a continuation of the previous Task 3 IDEAS+, with a reinforced focus on metrology aspects. IDEAS-QA4EO Task 2 projects are extremely varied and cover a wide range of EO disciplines, ranging from characterization and calibration activities to products validation and algorithm development studies in the various EO domains: Land, Atmosphere, Water and Cryosphere.

As part of IDEAS-QA4EO Task2 activities, regular meetings are organized on a 9-12 months basis, for reviewing the status of current projects, discussing potential evolutions, fostering synergies among the various groups and collecting feedbacks and recommendations. The first of such meetings was convened in University La Sapienza (Rome) during 19 – 21 February 2020. The summary proceedings of this meeting and recommendations gathered during the discussion are presented in next chapters following the chronological order of the Agenda.

1.2 Acronyms and Abbreviations

AAI	Absorbing Aerosol Index
AAH	Absorbing Aerosol Layer Height
AC	Atmospheric Correction
ACIX	Atmospheric Correction Intercomparison eXercise
AGB	Above Ground Biomass
AERONET	AErosol RObotic NETwork
ALH	Aerosol Layer Height
AOD	Aerosol Optical Depth
ARD	Analysis Ready Data
ATLAS	A pulsed Tuneable LAser system for the characterisation of Spectrometers
BOA	Bottom of Atmosphere
BPDF	Bidirectional Polarization Distribution Function

BRDF	Bidirectional Reflectance Distribution Function
BRF	Bi-directional Reflectance Factor
Cal/Val	Calibration/Validation
CMIX	Cloud Mask Intercomparison eXercise
CCN	Contract Change Notification
CDR	Climate Data Record
CEOS	Committee on Earth Observing System
C3S	Copernicus Climate Change Service
EARLINET	European Aerosol Research Lidar Network
ECV	Essential Climate Variable
EDAP	Earthnet Data Assessment Pilot
EO	Earth Observation
FCDR	Fundamental Climate Data Record
FDR	Fundamental Data Record
FIDUCEO	FIDelity and UnCertainty in climate data records from Earth Observations
FRM	Fiducial Reference Measurements
FRP	Fire Radiative Power
FUB	Freie Universität Berlin
GCOS	Global Climate Observing System
GRASP	Generalized Retrieval of Aerosol and Surface Properties
HR	High-Resolution
IDEAS	Instrument Data quality Evaluation and Analysis Service
ISMN	International Soil Moisture Network
ITCZ	Inter-Tropical Convergence Zone
LAI	Leaf Area Index
LOA	Laboratoire d'Optique Atmosphérique
MBASSS	Mer Bleue Arctic Surrogate Simulation Site
MM	Maturity Matrix
NMI	National Metrology Institutes
NN	Neural Network
NPL	National Physical Laboratory
OC	Ocean Colour
PFR	Precision Filter Radiometer
PGN	Pandonia Global Network
PMOD/WRC	Physikalisch-Meteorologisches Observatorium Davos – World Radiation Center
PROBA-V	Project for on-board Autonomy-Vegetation

PSR	Precision Solar spectro-Radiometer
QA	Quality Assessment
QA4EO	Quality Assurance for Earth Observation
QC	Quality Control
RTE	Radiative Transfer Equation
RTM	Radiative Transfer Model
SCE	Snow Cover Extent
SD	Snow Depth
SI	International System of units
SM	Soil Moisture
SKYNET	Sky radiometer network
SNR	Signal to Noise Ratio
SR	Surface Reflectance
SZA	Solar Zenith Angle
SWE	Snow Water Equivalent
TCDR	Thamatic Climate Data Record
TCWV	Total Column Water Vapour
TLS	Terrestrial Laser Scanning
TOC	Top Of Canopy
TPM	Third Party Mission
TRUTHS	Traceable Radiometry Underpinning Terrestrial & Helio-Studies
UAV	Unmanned Aerial Vehicle
UAV-LS	Unmanned Aerial Vehicle – Laser System
VHR	Very-High-Resolution
WV	Water Vapour

2 PROCEEDINGS

The main points arising from the presentations and discussions are summarised below. Highlights [HIGH] and Recommendations [REC] are identified and underlined in yellow in the text.

2.1 Welcome and Introduction

Philippe Goryl (ESA) welcomed the participants to the 1st IDEAS-QA4EO Workshop. He recalled that this is the first meeting of the new contract and as such it can be considered as a kick-off meeting. Philippe stressed the relevance of R&D and Metrology in Cal/Val; this was demonstrated during the past contract and acknowledged at DOSTAG level; as a matter of fact, several projects incubated within IDEAS+ are now running in an operational context or supported within dedicated ESA contracts. He noted that the challenge for this new contract would be to keep pushing towards innovations and further strengthen the metrology focus in the various Cal/Val domains.

John Swinton (TVUK) introduced the new IDEAS-QA4EO service, remarking the novelties with respect to the previous contract, as well as the need to ensure smooth service continuation in the transition phase. The QA4EO contract will be implemented in two consecutive phases, spanning 2.5 + 2.5 years. The contract involves a large number of international partners, from private companies, research institutions and Universities, ensuring a wide and comprehensive range of expertise in all relevant EO domains. The different tasks of the contract are recalled: Task 1 includes the operational QC, Task 2 is the R&D and Metrology task, Task 3 comprises the support for web and communication, Task 4 is the on-site expert support to ESA-SPPA and EOP-G Management section. The key personnel and leadership team of the contract are listed and the planned evolutions, which are part of the upcoming CCN2, are briefly presented.

Fabrizio Niro (Serco) illustrated the overall IDEAS-QA4EO Task 2 framework and explained the meeting objectives and expected outcomes. The principles and vision of Task 2 were presented, they build on the approach defined within previous contract, namely: to foster innovation, incubate new ideas, and work towards prototyping these new concepts for the benefit of ESA EO operational missions. This approach can be summarized with the motto: R&D of today could be operations of tomorrow. This approach has proven successful in the previous contract and several success stories were recalled in which a R&D activity provided concrete outcomes in the forms of advanced EO products, improved Cal/Val methodologies and new Cal/Val data. The challenge of the new IDEAS-QA4EO contract will be to further sustain evolutions as well as to reinforce the metrological component, which should now become the central element of Task 2, ensuring that algorithms and validation methodologies follow metrological practices. Finally, the objectives of the current meeting were recalled: to present planned activities covering the first phase of the contract, to facilitate exchanges of ideas, to look for synergies among the various projects and to gather recommendations for service evolution. It was stressed that the recommendations collected during previous Cal/Val WS are being followed-up in the frame of various ESA projects, such as FRM contracts; these recommendations are contributing in driving and shaping the ESA-SPPA overall Cal/Val strategy.

***Discussion** – QA4EO vision and its role in relation to the other Cal/Val and QA frameworks was discussed. QA4EO should be the place where innovative concepts should be prototyped for Cal/Val and advanced algorithms, to be reused in the frame of other projects, e.g., new Cal/Val practices to be reused within EDAP, new methodologies for calibration, AC or cloud mask for the benefit of ARD producers. The new focus on metrology should be further developed in the coming years in collaboration with NPL and PMOD/WRC to enhance traceability for both space and ground-based systems. This is already part of existing QA4EO projects, but it should be further evolved in the course of the contract and an evolution roadmap should be prepared and maintained along the contract.*

[REC-1] – QA4EO to strengthen the focus on metrology with more active involvement of NPL within Task 2 coordination, and exploit synergies with other contracts, namely EDAP. This vision should be summarized in a roadmap document to be maintained throughout the contract.

Nigel Fox (NPL) presented EDAP (Earthnet Data Assessment Pilot), a new framework contract funded by ESA-SPPA, which aims to perform an early data assessment on various existing and future missions with focus on commercial satellites and Third Party Missions (TPMs). EDAP supports the Earthnet Programme in fostering collaboration and cooperation with complementary non-ESA missions, in particular new-Space players, by contributing in assessing their quality and suitability for integration into the overall ESA EO strategy. EDAP is seeking for improving interoperability and foster synergies among these satellite missions, by generating standardized methodologies and guidelines for data quality assessment following metrological practices. In this context, an EDAP QA Maturity Matrix (MM) has been defined, tailoring the concept already developed in the frame of C3S and building on the QA4EO principles (http://qa4eo.org/). The EDAP MM provides an independent and objective assessment of the quality of the considered mission products. The information is provided in a compact and effective manner, by means of a matrix covering all relevant quality aspects, e.g., products format, user documentation, and uncertainty characterization. Each matrix cell is filled with a colour, representing the stage of quality, where the green is the best (Excellent) stage. It could happen, especially for commercial satellite, that some information is not provided or not publicly available, in such case the relevant quality aspect is not assessed. The rationale is to provide the current objective status of the mission data quality, leaving to the users the choice to assess the fitness for purpose of the mission data for their own application, and facilitating data providers, especially ARD providers, to enhance confidence and interoperability on their data.

Discussion – *A general question was raised on how to provide products fit-for-purpose, when purpose changes for different users. This is actually not the proper question; the MM is the way to objectively assess the quality of the considered mission, it will then be up to the user to decide whether this quality is fit for his purpose, e.g., users will look for green cells of the MM, which are relevant for them. Also, the colours of the cell do not say whether the provided uncertainty meet specific application requirements (e.g., 0.01K for SST), it expresses whether uncertainty is actually provided in the products following best practices.*

[HIGH-1] – EDAP Maturity Matrix (MM) provides an objective and independent QA tool for satellite mission data, enabling users assessing the fitness-for-purpose for their own applications and helping ARD providers to enhance confidence and interoperability on their data.

Mario D'Alessio (Serco) presented the ONDA platform, which is part of the suite of DIAS platforms aiming to facilitate the uptake of Copernicus Sentinels data. ONDA, as other DIAS platforms, embraces the new paradigm in EO, i.e. bring users to the data, by ensuring a one-stop-shop for any users providing direct access to satellite-based products, together with the cloud-based processing resources to build their own application. ONDA archive includes the whole set of Sentinels products, comprising Level 1 data, as well as some historical dataset (Envisat ASAR, Landasat-8 over Europe). Cloud processing resources are fully scalable and tailored on the user needs allowing to support computing and memory intensive processing. Use cases of ONDA are illustrated demonstrating how such platforms can enable downstream services under the big data paradigm. The aim of presentation was to stimulate the interest of the QA4EO science community on such tool and to investigate on potential interest in the domain of Cal/Val.

Discussion – *Following the discussion, it seems that such platform is certainly an attractive opportunity, especially for deploying consolidated Cal/Val procedures and testing their operational use. However, it was noted that the development and testing activities, which are at the core of QA4EO Task 2, can still be sustained with traditional data dissemination methods, i.e., user gathering and processing data at their own premises. Question was also raised whether heritage mission data will be included within DIAS archive. At the moment only Envisat ASAR data is available, although cloud providers are open to any request from the customer, in this case ESA Heritage Programme office. It is however not clear whether a cloud-based approach is the optimal one for historical dataset, which are usually well within the big-data threshold, i.e., the data amount could be still manageable using traditional approaches.*

[HIGH-2] – Cloud based platforms represent an attractive opportunity for Cal/Val applications, especially for mature and well-consolidated Cal/Val procedures. On the other hand, development and testing activities, or Cal/Val of historical mission, which are usually well within the big data threshold, could still be sustained with traditional approaches, i.e., user gathering and processing data at their own premises.

[REC-2] – QA4EO to further review the need and interest for Cloud base platform devoted to Cal/Val applications and the potential use of DIAS platforms for the purpose of Cal/Val.

2.2 Metrology and Traceability

Nigel Fox (NPL) explained the principles, challenges and motivations for ensuring metrological traceability in Space. Traceability means, in metrological terms, unequivocally linking an "observation" to an invariant constant of nature (SI: international system of units) through an unbroken chain of measurement comparisons. The need for traceability stems from the practical need of ensuring that measurements made at different time and location using a variety of sensors match to a common, internationally agreed scale, meaning that they are ultimately interoperable. This is clearly the case for satellite EO measurements, which provide potentially complementary information about our Earth changing Climate. EO satellites are nowadays the best way to ensure synoptic and continuous observations of Essential Climate Variables (ECVs) and to study their variation over time. Trends in ECVs are so small that they require decades to be detected, using a series of multiple satellite missions, and unambiguous detection calls for trustable EO satellite measurements to be anchored to invariant references, i.e. SI. The role of metrology in this context is therefore pivotal, by ensuring that long-term data records of ECVs are coherently calibrated to physical units, uncertainty quantified, stable over decades, and properly harmonised to account for the different sensors characteristics. The final objective of this process is to build so-called Fundamental Climate Data Records (FCDRs), which are ready for climate applications and policy making. The endeavour of applying metrological principles to historical EO data was already addressed in the frame of the Fiduceo project. The outcomes of Fiduceo are already being reused in the frame of EDAP and will be also the basis around which the IDEAS-QA4EO project will evolve in the future. As a part of QA4EO activities, training materials will be prepared by NPL building on Fiduceo lessons. Nigel concluded the presentation explaining the long-term vision for attaining traceability in space: the TRUTHS mission, which was recently approved to be part of ESA Earth-Watch EO programme. TRUTHS will be an operational climate-focused satellite mission aiming at: providing a Climate benchmark to enhance our ability to estimate Earth radiation budget, establishing a SI-traceable reference system in space to cross-calibrate all other satellites, in particular the Sentinels, allowing to significantly improve radiometric accuracy to better than 1%. TRUTHS will be crucial for climate applications by ensuring a SI-traceable anchor to long-term FCDR enabling detection of trends at much earlier stage. The TRUTHS orbit is specifically designed to maximize nadir overpasses with sun-synchronous optical sensors, so that to allow Simultaneous Nadir Overpass (SNO) cross-calibration of those sensors to a SI-reference. The capability of anchoring those sensors to a common reference will result into a virtual constellation (system-of-systems) meeting the stringent radiometric requirements of climate applications. The main payload systems of TRUTHS are finally introduced with focus on the main asset of this mission: an on-board calibration system replicating SI-traceable calibration device used in NMI laboratory facilities.

Discussion – *During the discussion, it was argued whether this SI-traceability could be maintained along the mission especially considering ageing and the impact of long-term exposure to the harsh space environment. Nigel replied that there is an extensive experience and reasonable understanding, in particular within the solar community, on the performances of such devices in space, furthermore, the platform will have on-board systems to monitor and accurately characterize ageing in space.*

[HIGH-3] – Traceability in space is crucial to ensure that measurements made at different time and location using a variety of EO sensors match to a common, internationally agreed scale, meaning that they are ultimately interoperable. TRUTHS mission will provide such reference system, allowing to anchor existing and future sensors to a common SI-traceable scale, therefore enabling the concept of a virtual constellation (system-of-systems) meeting the stringent radiometric requirement of climate applications.

Julian Gröbner (PMOD/WRC) presented the planned QA4EO activities, whose main objective will be to address current limitations in ground-based networks for Aerosol and Ozone validation with focus on AERONET and SKYNET networks. These limitations arise from a lack of traceability in the used ground-based sensors. As a matter of fact, the adopted approach for calibration of those networks relies on a so-called master sensor, which is accurately calibrated in dedicated field campaign under pristine conditions (e.g., Langley calibration in Mauna Loa or Izana for CIMEL AERONET sensors). The master sensor is used as reference to cross-calibrate all other network systems. This approach ensures internal consistency with respect to the reference, although artefacts may arise in case of issues during the calibration campaign. Moreover, cross-networks consistency of the measured geo-physical variables is not ensured since the used master sensors may not agree. A rigorous metrological approach allows minimizing such biases by developing full SI-traceability of the relevant ground-based networks, enhancing their inter-operability, i.e., removing inter-network biases. Developing traceability means that sensor characterization and calibration is performed under controlled and reproducible laboratory conditions using well documented procedures demonstrated through audits and inter-laboratory comparisons. The PMOD approach goes along the lines of NPL effort in developing traceability in space, while the focus here is on ground-base observations. The two activities are therefore complementary elements of the same vision of fully exploiting the currently available suite of sensors (space or ground-based) for building a fully inter-operable system-of-systems. The QA4EO activities will support a larger project called MAPP (Metrology for Aerosol optical Properties), which was recently awarded to PMOD in collaboration with LOA and other partners for applying rigorous metrological practices to atmospheric remote sensing of aerosol optical properties with focus on improving traceability of AERONET-Europe and SKYNET networks and with final goal of developing an uncertainty budget for columnar aerosol optical properties. The activities supported within QA4EO will include in particular: i) further operating at Davos a CIMEL sensor collocated with triads of PSR (Precision Spectro-Radiometer) and PFR (Precision Filter Radiometer) and comparing the retrieved aerosol spectral optical depth, ii) installing and operating a PFR sensor at AERONET Europe calibration site during Apr- June 2020, in order to attain traceability of this network to WMO-PFR., iii) accurately characterizing a master CIMEL sensor in the PMOD laboratory facilities.

[HIGH-4] – The endeavour of attaining SI-traceability of ground-based Cal/Val network is essential to overcome limitations of current systems, avoiding biases induced by inconsistencies among master sensors and across different networks. The work carried out at PMOD goes along the lines of NPL effort in developing traceability in space, while the focus here is on ground-base observations. The two activities share the same vision of fully exploiting the currently available suite of sensors (space or ground-based) for building a fully inter-operable system-of-systems.

Philippe Goloub (LOA) reported on the activities that will be performed at LOA for working on traceability applied to ground-based observation of aerosol properties. He initially recalled the main outcomes of the previous IDEAS+ project, in particular the development of an advanced mobile photometer (PLASMA), which have been recently recognized as a complementary element of the ACTRIS ground-based infrastructure. He then presented the activities that will be carried out within QA4EO in collaboration with PMOD to develop SI-traceability of AERONET observations. These include the continuous operation of a PFR/WMO reference sensor collocated with CIMEL master sensor at AERONET-Europe calibration facility at Observatoire of Haute Provence (OHP) and the detailed characterisation of a CIMEL master sensor at Davos laboratory facilities. Furthermore, he reported that periodic collocation campaigns, involving AERONET-Europe and AERONET-NASA master sensors, will be organized at Mauna Loa site in order to verify and maintain the link between the two network's branches. Similar collocation exercise will be performed in Izana to connect with the AERONET-Spain branch. The combination of these elements (laboratory characterization at PMOD + master sensors cross-calibration at the various sites) will allow ultimately attaining full SI-traceability for the whole AERONET network at global scale, with initial focus on daytime AOD observations.

Discussion *– During the discussion it was noted that as a result of this proposed approach, the AERONET network could potentially approach the FRM concept, it is indeed recognized that the additional focus on traceability, with regular inter-calibration exercises and well-consolidated measurement and calibration protocols, will bring this network to fulfill FRM requirements on the longer-term. This is a significant achievement also for QA4EO contract.*

[HIGH-5] – QA4EO will contribute in attaining SI-traceability of AERONET network at global scale, by anchoring master sensor observations to a metrological standard as well as by verifying and maintaining consistency among Europe, NASA and Spain AERONET branches. The long-term vision is to ensure full SI-traceability of AERONET network as a whole, therefore approaching the concept of FRM at global scale.

Yves Govaerts (Rayference) presented the Eradiate project, which aims to develop a community-based 3D Radiative Transfer Model (RTM) with focus on metrological applications, specifically in the domain of Cal/Val of satellite optical missions. The need for metrology in space is key to attain interoperability of different sensors providing complementary radiometric observations in the solar spectrum domain (VIS, NIR and SWIR). Currently, the optical sensors' radiometric calibration is validated against well-characterized ground or planetary targets, so-called vicarious calibration targets (e.g., PICS, DCC, Moon); this involves notably the use of a RTM in order to simulate the at-sensor signal. The main issue at the moment is the variety of procedures being adopted for vicarious calibration, e.g., different description of the considered targets, different ancillary data, different assumptions and methods for solving the underlying RTE. A case study is presented considering MODIS observations over Libya-4 desert site and comparing 4 commonly used RTMs. The results show that simulations performed with the 4 RTMs differ up to 3% in the VNIR-SWIR domains, meaning that the RTM is still a major source of uncertainty, which prevents and limits inter-operability of current optical sensors. If we want to go beyond this limitation and attain a radiometric accuracy of <1% we need to harmonize RTMs and improve their accuracy, working towards a fully traceable and highly accurate RTM. The Eradiate project aims to tackle these theoretical challenges, overcoming the current limitations in RTMs (e.g., 1D plane-parallel approximation, neglected surface-atmosphere coupling) making use of the most advanced 3D Monte Carlo Ray Tracing rendering techniques. The Eradiate development will use an open-source community-based approach, in order to gather expertise from different science communities and fulfill RTM requirements in various EO domains: land, atmosphere, water, and cryosphere. Eradiate is an essential building block in order to ensure interoperability among various sensors and achieve SI-traceability in space, in particular when coupled with TRUTHS reference mission. As a matter of fact, Eradiate will enable simulating TRUTHS at-sensor signal over target vicarious sites to an accuracy of <1%, allowing to tight all optical sensor measurements to a common SI-traceable reference. Eradiate will be in particular valuable for improving SNO cross-calibration capabilities offered by TRUTHS by minimising differences due to slight space and time mismatch or to differences in measurement conditions. Eradiate project is currently under its second phase, during which the core of the algorithm is being coded and validated, while the domain-specific modules will be developed through the community-based approach starting from 2022 by involving the various science communities.

Discussion *– During the discussion, it was noted the importance of accurately simulating the molecular absorption signal, ideally using line-by-line approach in order to avoid uncertainties introduced by approximated methods, e.g., k-distribution. Furthermore, the importance of an accurate spectroscopic database, not only line intensities, but also line shape and continuum absorption modeling was recalled. These issues are being carefully considered within Eradiate development.*

[HIGH-6] – Eradiate is an essential building block to attain SI-traceability in space, complementing and expanding TRUTHS mission capabilities, especially with respect to cross-sensors calibration. While TRUTHS represent a big leap forward in the realization of a reference SI-traceable system in Space, Eradiate is the theoretical counterpart, which will allow to fully exploiting the Space system capabilities by ensuring a traceable and accurate simulation of the at-sensor signal.

Stephen Mackin (EOSense) provided a summary of his proposed methods for the quality assessment of EO optical satellite sensors and presented some preliminary results on Proba-V data. The proposed methods, based on a statistical analysis of raw data from nominal acquisitions, allow deriving relevant image quality indicators, such as: relative gains, SNR, focus, and absolute gains. The approach has proven successful in the past and was verified against standard vicarious calibration or diffuser-based approaches. The main advantage is that the quality assessment can be performed at much higher temporal frequency, ideally as soon as images are acquired and processed to L1, as compared to traditional approaches, which rely on dedicated and sparse acquisitions of ground targets or periodic diffuser calibrations. Furthermore, the radiometric quality of the sensor can be assessed over the full dynamic range, not only at the bright and dark edges, as it is the case using desert/ice or ocean targets. Examples are presented, showing how tiny issues with relative gains can be detected in Sentinel-2, which resulted in visible striping in the imagery; these issues were not visible using bright targets calibration sequences. The long-term objective of the work is to prototype an automated tool for directly estimating (on-the-fly) SNR, focus and relative gains from Sentinel-2 L1b data. The aim is to generate quality indicators as soon as the L1b data are made available in the Ground Segment so that to allow for quasi-real time detection of calibration and quality issues. In preparation to this long-term objective, early results are presented on Proba-V data. Saturation effects are highlighted in Proba-V imagery, which often occur over bright cloudy scenes. Despite of this, good statistics was collected, allowing to reasonably estimating SNR and relative gains for the VNIR and SWIR bands. A distinct non-linearity effect is observed in the SWIR band with clear striping in the relevant images. The method allows to assessing non-linearity and gains separately for each detector in the array, since it is based on raw data, before any interpolation and projection processing. This is the main advantage of the approach, since it allows to better identify issues and to detect mis-behaviour of single pixel on real time basis. Different non-linearity behaviours are actually observed for contiguous pixels in the array and non-linearity could even change over time. The main challenge is to propose a validation method for such novel calibration approach, in particular for those cases, which are not observable using traditional bright targets. Elaboration of a dedicated validation strategy will be part of the work to be carried in the frame of QA4EO.

[HIGH-7] – Statistical analysis of sensor acquisitions over nominal scenes at raw processing level allows assessing critical quality indicators with clear advantages over traditional vicarious or diffuser-based methods, such as: higher temporal frequency, possibility to monitor the full radiance dynamic range (not only the bright and dark edges), capability to support calibration of any sensor, including commercial low-cost platforms, possibility to study sensor performances at pixel level.

[REC-3] – ESA/VITO to follow up the issues observed in Proba-V SWIR band, the observed non-linearity effects will be compared with the VITO results obtained with vicarious calibration approaches.

Paolo Castracane (RHEA) presented the structure and content of the new CEOS Cal/Val portal, which was officially launched in December 2019. The portal (calvalportal.ceos.org) serves as main forum for exchanging and sharing information for the CEOS Working Group on Calibration/Validation (CEOS-WGCV). The portal is also a valuable source of information for any generic Cal/Val and EO scientist, since it provides a comprehensive overview of available Cal/Val resources, e.g., links to existing networks and repository of campaigns data, as well as an inventory of CEOS-endorsed good practices for Cal/Val in various domains. The design and content of the web portal were recently upgraded and an overview of the main sections is provided with summary of the available documentation and data. The documents repository section includes valuable information for Cal/Val users, such as guidelines and standards, as well as terminology. Other sections include: the “Sites” section, which provides an extensive lists of available sites grouped by WGCV domain, the “Tools” section, which lists available software and tools, the “Data” section, which provides access to relevant reference data, e.g., MTF reference dataset, ESA EVDC database, as well as a collection of various campaign data. Work is currently in progress to further upgrade the portal based on internal CEOS review and to host the SAR sub-group section. Feedback from Cal/Val users, in particular within the QA4EO team is strongly encouraged to further improve the portal and expand the content.

[HIGH-8] – CEOS Cal/Val portal is the one stop-shop for Cal/Val and EO users providing centralized access to CEOS-endorsed best practices, available Cal/Val data and tools, relevant Cal/Val sites and key documents and information, such as guidelines and terminology.

[REC-4] – IDEAS-QA4EO to provide input to the CEOS Cal/Val portal, such as campaigns data, documents, and Cal/Val protocols.

2.3 Atmosphere Cal/Val

Stefano Casadio (Serco) presented the status of the BAQUNIN (Boundary-layer Air Quality-analysis Using Network of Instruments) super-site, which was prototyped in the frame of IDEAS+ and it is now supported through a dedicated ESA contract. The super-site for atmospheric composition is composed of a large suite of active and passive sensors hosted in three separate locations around Rome city area: in the center of the city (University La Sapienza), in a semi-rural (ISAC) and in a rural (IIA) environment. This set-up was defined in order to sample a wide range of atmosphere and air-quality conditions, ranging from a very polluted region to a pristine environment. The rationale was to allow validating satellite-based air-quality products for different regimes, and to study dynamic transport processes of the boundary layer within and around a megacity region. The list of sensors hosted in the super-site includes a large variety of instruments, such as: Lidar, Radar, Sodar, Brewer, Cimel and Pandora, allowing the retrieval of a wide range of complementary atmospheric parameters, from cloud/aerosol to atmospheric trace gases properties. The super-site contributed to various validation campaigns and supported the Cal/Val of various ESA mission, in particular S-5P, as well as TPMs, in the frame of EDAP project (e.g., GCOM, GOSAT missions). In the frame of QA4EO activities, the super-site will contribute to two work-packages: one, in collaboration with University of Tor Vergata for improving characterization and validation of BRDF for optical sensors Cal/Val, and the other one in collaboration with NASA and Brockmann Consult for validation of cloud masks of optical coarse and high resolution sensors. In the frame of this latter activity, a set of sky-cameras will be installed in the roof of two Physics Department buildings in University La Sapienza, in order to estimate cloud base height and cloud fraction, following a protocol being developed at NASA. These measurements will be coupled with collocated Lidar Ceilometer measurements, to validate the stereo-based estimation of the cloud base height. The data analysis will be performed at Brockmann Consult and will contribute to CMIX cloud mask validation exercise for Sentinel-2 and Landsat-8.

[HIGH-9] – The BAQUNIN super-site, prototyped in the frame of IDEAS+, is now actively providing key ground-based measurements supporting the Cal/Val of various ESA and TPM atmospheric missions with focus on S-5P. The recent collaboration with NASA will further expand its domain of application by supporting Cal/Val of optical sensors with an innovative approach for cloud mask validation.

Dimitris Balis (University of Thessaloniki) presented the two proposed activities, which will be implemented within QA4EO CCN2, focusing on the ground-based validation of Aerosol Layer Height (ALH) and ozone profiles. The validation of ALH will use historical EARLINET ground-based data and will support validation of GOME-2/TROPOMI scientific products. EARLINET, the European Aerosol Research Lidar Network, includes 30 active lidar stations spread over Europe, acquiring data on a regular schedule (day/night) and supporting dedicated monitoring of special aerosol events (dust, fires). Standard EARLINET products (aerosol extinction and backscatter profiles) are available in the relevant web site: https://www.earlinet.org. The retrieval of ALH from EARLINET measurements is not straightforward, notably due to the difficulty of disentangling impact of clouds in the lidar extinction and backscatter profiles. For this purpose, an improved algorithm will be developed, potentially using ancillary information, such as CALIPSO data or dust transport model's output. Examples are shown of validation of GOME-2 AAH (Absorbing Aerosol Layer Height) showing reasonable agreement; a similar exercise will be done using S5P/TROPOMI ALH (Aerosol Layer Height), this latter products is not yet operational, since some issues are observed over land, hence this activity can contribute in refining and improving this ESA product. The other activity will focus on the validation of nadir Ozone profiles using Umkher measurements available as part of existing Cal/Val network data. Umkehr observations are performed with both Dobson and Brewer spectro-

photometers measuring the ratio of diffusely transmitted zenith-sky radiance at a wavelength pair in the ultraviolet, one wavelength strongly, the other weakly absorbed by ozone. These wavelength pairs are measured in a series of zenith-sky observations with the solar zenith angle changing from 60° to 90° during sunrise or sunset. Analysis of these special measurements is not routinely performed as part of standard network product, while it could provide interesting Ozone profiles data for satellite-products validation. However, there are currently significant inaccuracies in the existing retrieval algorithms, owing to the stray-light correction or to the used Ozone cross-section and their temperature dependence. The aim of this work-package is to tackle these challenges, by retrospectively analysing long-term EUBREWNET database of Umkher measurements, improving and better characterising the retrieved aerosol profiles and their associated uncertainties. These improved retrievals will be used to support validation of S-5P Ozone profiles scientific product, which is expected to be realised to the user community during fall 2020.

[HIGH-10] – The reanalysis of existing ground-based data for Aerosol Layer Height and Ozone profiles validation, applying advanced retrieval methods, fill a gap in current atmospheric Cal/Val activities within QA4EO, and will support verification and validation of forthcoming TROPOMI geophysical products.

Philippe Goloub (LOA) described the recent LOA activities and the planned ones for prototyping new measurement systems, supporting various aerosol Cal/Val campaigns and for improving the retrieval of aerosol properties by the synergistic use of multiple instruments. The system designed and prototyped in the frame of IDEAS+, i.e., the PLASMA mobile photometer was successfully deployed in various campaigns, over research vessels and on-board other mobile platforms, such as cars. An improved version of this system is now being tested in the LOA laboratory facilities with the intention to build a first series of instruments. Concerning the Lidar systems, work in on going to include a dedicated fluorescence channel, to detect organic particles and better discriminate aerosol layer within clouds. A review of the support to recent aerosol field campaigns is provided, this includes: the DAO campaign in China, to study dust properties in very challenging conditions with combination of Lidar and sun/sky photometer, the MOSAIC campaign on the POLARSTERN ship, where a sun/moon photometer has been installed allowing first time measurements of night-time AOD in very extreme (cold) environmental conditions, the SEA2CLOUD campaign, planned in March 2020 around New Zeeland, to study impact of aerosol on cloud properties, the FIREX-AQ campaign, carried out during Summer 2019 in USA, to study impact of wildfires on regional air quality, involving measurements with the LOA mobile system, and the participation to the MAP-IO (Marion Dufresne Atmospheric Program Indian Ocean) program, consisting in permanently installing a mobile sun/moon photometer in an existing cargo ship to sound aerosol properties over the Indian Ocean. The activities specifically covered within QA4EO are recalled, this includes in particular: further improving PLASMA system to be water-proof, adapting and improving the pre-processing and retrieval chain of mobile photometer observations, further improving aerosol properties retrieval in collaboration with GRASP by synergistically using photometer and lidar data.

Discussion *– During the discussion it was asked whether the FIREX-AQ data could be of interest for validating S3 products, notably FRP and AOD, an action was traced to follow up this activity in collaboration with S3 MPC.*

[HIGH-11] – The advanced mobile photometer, prototyped within IDEAS+, was valuable to support various aerosol Cal/Val field campaigns, and it is now recognized as an active element of the ACTRIS ground-based infrastructure. Several lessons learnt were collected during the deployment of this system; these lessons will be used to further improve the sensor design.

[REC-5] – ESA/MPC to investigate the interest of Cal/Val data collected within the FIREX-AQ field campaign for validation of S3 operational L2 products, mainly FRP and AOD.

Oleg Dubovik (LOA) described the current status and planned activities using GRASP (Generalized Retrieval of Aerosol and Surface Properties) algorithm for further improving retrieval of aerosol and surface properties. GRASP is a highly accurate and versatile algorithm allowing to analyse measurements from a wide range of ground-based and space-borne active and passive sensors for the joint retrieval of aerosol and

surface properties. GRASP builds on a very accurate forward modeling of scattering physical processes, coupled with a statistically optimized retrieval scheme, which allows to tune the inversion scheme to the information content provided by the considered sensor. Thanks to this versatility, GRASP strongly supports synergistic exploitation of multi-sensors remote sensing and this has been already demonstrated within previous IDEAS+ activities, namely with the joint retrieval of aerosol properties from combined analysis of photometers and lidar measurements. The proposed activities within QA4EO aim to further exploiting this synergistic capability, by jointly analysing ground-based and satellite observations, for better constraining aerosol and surface modeling. In particular, improvements in the used BRDF and BPDF models will be investigated, considering that uncertainties in the currently used models can yield to large uncertainties, up to 5%, in the simulation of TOA signal, notably for extreme viewing geometries. An additional improvement will be explored, and could be matter for an optional activity within QA4EO in collaboration with FUB; it consists in expanding GRASP to accurately simulate molecular absorption, allowing extending its domain of applications to trace gases retrievals.

Discussion *– The capability of GRASP to capture high aerosol events was enquired, considering the used retrieval constraints, which could potentially smooth out such extreme conditions. In the response it was outlined that the spatial and temporal constraints in GRASP approach are applied in a flexible way by limiting corresponding derivatives for each parameter independently. These constraints do not eliminate fully even strong variability of the retrieved parameters except high frequency unrealistic spikes. This has been already verified and demonstrated in several studies, where GRASP was able to effectively retrieve severe dust and biomass burning events. Another question was asked about possibilities of estimating uncertainties in GRASP retrieval. The response has pointed that GRASP uses detailed statistical optimization formalism and fully accounts for error propagations. Therefore, the full co-variance matrix (including non-diagonal elements) can be provided for the GRASP retrieved parameters. Moreover, GRASP may provide variances and correlations coefficient for any set of parameters that are not directly derived but cab be estimated from the retrieved parameters.*

[HIGH-12] – GRASP is a versatile algorithm allowing to retrieve surface and aerosol properties from a wide range of active and passive sensors synergistically exploiting their observations. The ability of GRASP to retrieve aerosol properties from the combined analysis of Lidar and photometer data was successfully demonstrated within IDEAS+. The current challenge, to be tackled in the coming months, will be to combine satellite and ground-based measurements for better constraining surface BRDF/BPDF models, which are still a major source of uncertainties in TOA signal simulations.

Alexander Cede (Luftblick) reported the latest status of the Pandonia Global Network (PGN) project (www.pandonia-global-network.org/) and the activities planned within QA4EO to further improve PGN data quality information. The main focus will be on improving characterisation of systematic errors associated with Pandora-2S measurements and perform an in-depth investigation of their impact along the full processing chain, from raw data to L1 and L2 products. The PGN products quality information, currently provided to the users, includes: an estimate of the measurement precision, which is a combination of instrumental noise and atmospheric state variability, together with a summary data quality flag, which provides an indication of the level of confidence in the products. The QA4EO activity aims to enhance this quality information by performing a detailed sensitivity study of all different sources of uncertainties, and by accurately quantifying their impact in the final products. The sensitivity study will include uncertainties induced by instrumental correction as well as those introduced within each processing step along the chain, such as spectral fitting procedure and air mass computation. As a result of this study, a quantitative measure of uncertainty will be associated to PGN operational products, improving their use for validation**.**

Discussion *– A question was raised on the terminology used for the definition of PGN uncertainty sources, some terms are misused, while we need, especially within QA4EO, to agree on common terminology, the CEOS Cal/Val portal can be the tool to facilitate the adoption of common terminology across the various EO communities.*

[HIGH-13] – The PGN has proven successful in providing a global ground-based network for validation of satellite-based air-quality products, with main focus on NO2. While operationalization and global coverage is now ensured as part of the PGN contract, effort still need to be made to further improve quality information of the relevant products for the benefit of users community.

[REC-6] – QA4EO to actively support the adoption of a common terminology for uncertainty estimate following metrological guidelines, the CEOS-Cal/Val portal should facilitate dissemination of these concepts.

Jürgen Fischer (Spectral Earth) presented the planned work within QA4EO for developing advanced PGN products and for further improving and refining the design of the Pandora-2S systems by testing its performances in harsh environmental conditions. New retrieval algorithms will be developed focusing on SO2, CH2O, H2o and its vertical profile, this development was already initiated within IDEAS+ and will be further consolidated within this new contract using MOMO RTM simulations with line-by-line computation of the molecular absorption and accurate spectroscopy input database. The objective is to prototype and to verify new retrieval algorithms for potential inclusion as new operational PGN products. Concerning the support to the instrument design improvements, the collaboration initiated within IDEAS+ with several research institutes will be continued, with the objective to operate and test Pandora-2s systems in six locations (Barbados, Palau, Greenland, Namibia, Lindenberg, and in Berlin) gathering lessons learned on how to further improve their design. This activity has already demonstrated successful in the past for significantly improving system and operations software definition and contributed in the design of the 2nd generation of improved Pandora sensors. As part of these testing activities, Pandora will be also operated during ship campaigns over research vessels and its design will be tailored to support such deployment in a mobile platform, e.g., with the development of a dedicated inertial system and a specific water-proof housing to minimize corrosion of Pandora mechanical and optical/electrical components.

[HIGH-14] – The FUB support to PGN demonstrated successful within IDEAS+ in identifying limitations in the sensor design (e.g., sun tracker), which were then addressed by Luftblick in the most recent sensor generation. The new activities will focus on further improving measurement system robustness and products content, working towards advanced retrieval products (SO2, CH2O, H2o and its vertical profile) to be potentially included in the suite of available PGN operational products.

Yana Karol (GRASP) presented the planned activities within the CAWA-2 project, which is not part of the QA4EO framework, but could have some potential synergies with existing aerosol and cloud retrieval activities. CAWA-2 is an ESA funded project, which is a follow-on of the ESA-CAWA project, aiming to use GRASP algorithm for retrieving aerosol properties from the synergistic analysis of MERIS+AATSR full archive dataset. The goal of the project is to valorise this unique historical dataset and build a consistent long-term data record of atmospheric and surface properties, which can be of clear interest for climate applications. Highlights from the CAWA-1 project were presented; during this project the GRASP algorithm was adapted to MERIS sensor observations to jointly retrieve aerosol and surface properties globally over the full archive at 10km resolution. The MERIS retrieval obtained within CAWA-1 were validated against other algorithms and with respect to AATSR retrievals, showing overall comparable accuracy and the capability to detect high aerosol events, such as desert dust and biomass burning. Aerosol retrievals were also successfully validated against AERONET data, showing reasonable agreement in AOD for both land and ocean, although cloud masking was still an issue in analysing MERIS data. Within CAWA-2 the results of the previous study will be expanded by combining MERIS+AATSR observations making full use of GRASP multi-pixel approach. The inclusion of AATSR measurements will strongly enhance information content on aerosol and surface properties as well as for cloud masking, owing to its dual view capability and the additional SWIR and TIR channels. CAWA-2 project has just started during Q1 2020 and it has some obvious interest for the potential extension to S3 OLCI-SLSTR synergistic retrieval.

Discussion *– During the discussion, a question was raised on the spatial resolution of the retrieval, which is currently set to 10km. The resolution seems too coarse considering the potential information content in the data. In principle, GRASP has no limitations in this respect, since retrieval can also be performed at sensor native resolution, although there is an obvious impact on processing time. Increase of retrieval*

resolution will be considered within CAWA-2 and the best trade off will be investigated between spatial resolution and processing time requirements.

[HIGH-15] – CAWA-2 will provide a coherent and consistent long-term data record of aerosol and surface properties from analysis of AATSR+MERIS historical data; this dataset is of clear relevance for climate applications and can pave the way for an advanced synergistic retrieval approach, which could be applied to S3/OLCI-SLSTR measurements.

Massimo Valeri (Serco/CNR) illustrated the status of the AIRWAVE project, which was initially supported in the frame of IDEAS+ contract. The AIRWAVE algorithm was designed to retrieve Total Column Water Vapour (TCWV) from observations of (A)ATSR family of sensors over water surfaces, exploiting the dual view capabilities of this sensor and the observations in the TIR channels (11 and 12 micron). The method is applicable to all ATSR series of sensors, allowing therefore retrieving a long-term data record spanning more than 20 years, which has clear relevance for climate. The V2 of the algorithm included significant improvements in particular introducing a latitude/seasonal dependency of the atmospheric variability and a better handling of the observation geometries. The algorithm was largely validated using satellite and radio-sonde data and it was also successfully used for a number of applications, such as for monitoring the Inter-Tropical Convergence Zone (ITCZ) and for wet tropospheric correction of altimetry signal in coastal areas. The project is now running as a part of a dedicated EUMETSAT contract, in which the AIRWAVE algorithm is being adapted to S3/SLSTR measurements with the objective to develop a new S3 TCWV operational product over water. The latest refinements of the algorithm are presented, including a detailed analysis of the uncertainties related to instrument noise and to the atmospheric variability. Finally, preliminary global map of TCWV and related uncertainties are presented with early validation results, showing latitude and across-track dependence of the uncertainties.

[HIGH-16] – The ARIWAVE algorithm is another example of R&D project prototyped and validated within IDEAS+, which is now being transferred into a fully operational environment, within EUMETSAT Ground Segment, allowing the generation of a new EO products, namely TCWV from S3/SLSTR observations over water surfaces.

Gabriele Brizzi (Serco) presented the status of ESA FDR4ATMOS. This project, started in October 2019, is part of two twin ESA projects, one dedicated to atmospheric products (FDR4ATMOS) and one to altimetry (FDR4ALT). The objectives of these projects are: to ensure long-term preservation and valorisation of the historical missions (ERS-1, ERS-2, Envisat) as part of the Heritage Space Program (LTDP+), to improve inter-sensors consistency working towards harmonisation of the long-term dataset, to extend backward time-series of climate-relevant geo-physical variables, to enhance traceability and uncertainties estimates following metrological practices. Background information on the relevant terminology is recalled, the concept of Fundamental Climate Data Record (FCDR) and Thematic Climate Data Record (TCDR) has been defined since early 2000 and it is now widely accepted within the community and endorsed by GCOS. FCDR are long-term record of calibrated and quality controlled sensor data (Level 1), involving often series of sensors, consistent across missions and stable in space and time to allow climate applications. TCDR are long-term record of the geo-physical parameters (Level 2) derived from FCDR, with sufficient length, consistency and continuity to quantify climate variability and changes. TCDR often spans several decades, since climate trends are small and a long-term record is required in order to disentangle natural variability from human-induced trends. The FDR and TDR are relatively new concepts, which are now finding their way within the EO community. FDR and TDR, in a more general form, are long-term data records with relaxed constraints on length and stability with respect to FCDR and TCDR; yet, they have similar requirements in terms of long-term and cross-sensors calibration consistency, quality information and uncertainties characterisation. The proposed definition for FDR is as follows: "*FDR consists of a consistently reprocessed record of uncertainty-quantified sensor observations that are calibrated to physical units and located in time and space, together with all ancillary and lower-level instrument data used to calibrate and locate the observations and to estimate uncertainty*". The content and expected outcomes of the FDR4ATMOS project are then presented. The project will focus on ERS-2 GOME + SCIAMACHY time series, with the main objective of building a harmonized long-term record (1995 – 2012) of spectrally resolved radiances in the UV-VIS and NIR spectral

range, with clear relevance for O3, NO2, SO2 and clouds climate studies. The ambition, in a longer period, is to include as well GOME-2 sensors family and S5P-TROPOMI data, to further extend the time series.

[HIGH-17] – Time series of consistently calibrated data are of increasing importance, not only for climate, but in general, for EO applications and operational services. The FDR concept aims to address this need, generalizing the FCDR concept developed in the climate community, while sharing the similar metrological rigour, working towards space-time consistent and cross-sensors harmonized record of calibrated and quality controlled sensor data.

2.4 Land Cal/Val

Raymond Soffer (NRC) presented the planned QA4EO activities, which are follow-on of the IDEAS+ project called MBASSS (Mer Bleue Arctic Surrogate Simulation Site). Mer Bleue is a northern peatland site in Canada, which is now part of the list of CEOS-WGCV LPV endorsed Super-sites for land products validation. The main goal of the IDEAS+ project was to support validation of satellite HR sensors specifically Landsat-8 and Sentinel-2, using an integrated bottom-up validation approach, including ground-based, field and laboratory measurements, coupled with airborne hyperspectral image acquisitions. The follow-on project will further focus on Sentinel-2 mission and expand the bottom-up methodology by including UAV-based hyperspectral acquisitions. The UAV-based approach allows improving the upscaling process from the field spectroscopy point measurement to the airborne and satellite pixel scale and to fill the space-time collocation mismatch between the field spectroscopy measurements and the airborne acquisition. Furthermore, UAV allows for easier and more extensive sampling of the considered Cal/Val site, especially for remote and wild locations, which are difficult to reach with operators survey and field spectroscopy. The calibration and processing methodologies developed within IDEAS+ will be reused within this project, although several challenges need to be still addressed, notably for the definition of the best way to operate, calibrate and process UAV-based data. The UAV payload is composed of a sophisticated micro-CASI hyperspectral system covering the VNIR spectral range complemented with another hyperspectral sensor (HySpex), extending to the SWIR range (up to 2.5 micron). These sensors will go through a rigorous laboratory characterisation and calibration against reference standards before deployment. The UAV deployment will be collocated with Sentinel-2 overpasses and near coincident airborne hyperspectral acquisitions and field spectroscopy measurement of a reference calibration panel. Finally, the current Cal/Val capabilities at Mer Bleue site were recalled; in addition to the airborne and UAV hyperspectral imageries, it includes a Flux tower (FLUXNET), methane flux chambers, water table depth and ground temperature. The capabilities under development include the availability of a CIMEL (AERONET), as well as the possibility to measure LST and the deployment of an albedo tower.

Discussion *– During the discussion it was stressed that, in the context of expanding the site capabilities, QA4EO and ESA will help NRC by facilitating support from LOA, for the CIMEL, and from S3 MPC for LST sensor. It was finally argued whether the UAV will eventually fully replace airborne imagery; actually, they complement each other and their combination will provide the best approach in terms of upscaling and spatial coverage.*

[HIGH-18] – UAV-based sensors are nowadays an attractive and cost-effective solution for Cal/Val applications in the Land domain providing hyperspectral imagery of unprecedented spatial resolution albeit over limited spatial areas. An integrated approach, including UAV and airborne, coupled with rigorous field and laboratory characterization, is currently state-of-the art in terms of SR validation. Yet, methodologies for calibration, processing and upscaling of UAV observations still need to be consolidated.

[REC-7] – ESA to facilitate the evolution of MBASSS Cal/Val capabilities, namely, to ease the installation of a CIMEL and a LST sensors, the former in collaboration with LOA, the latter with S3 MPC.

Benjamin Brede (WUR) presented the activities planned within QA4EO using UAV-based active laser systems and multi-spectral sensor for supporting respectively Above Ground Biomass (AGB) and Leaf Area Index (LAI) Cal/Val activity. The use of UAV-Lidar for AGB validation was already tested in the frame of

IDEAS+ over temperate forest site and successfully verified against a ground-based TLS (Terrestrial Laser System). The current challenge is to use UAV-Lidar over dense tropical site, and a field campaign in French Guyana (Paracou research station, CIRAD) was conducted during fall 2019 in order to verify this methodology. During the campaign several tests were performed changing laser power, flight paths and geometry of observations to identify the best configuration for estimating the tree structure and volume in such challenging site with very dense canopy and a high degree of occlusion. Field data are still being analysed to fully assess the capability of UAV-LS over such complex ecosystem; the data will be fed into the ESA-NASA MAAP mission exploitation and analysis platform. The results are expected to be valuable in preparing the Cal/Val activities for the future ESA BIOMASS mission and for the NASA GEDI mission currently on-board the ISS. Another R&D activity, which will be carried out within QA4EO, consists in using innovative open-source low-cost community sensors, based on Raspberry-Pi technology systems, for continuous forest canopy monitoring. These sensors are a cheap solution for Cal/Val applications, which are now becoming attractive for building a potential low-cost field network, although investigations are still required to understand the accuracy of these measurements. Finally, a new campaign will be planned in 2020 over cropland site using UAV-LS complemented with multi-spectral and with an accurate 3D RTM (e.g., DART) for better characterising upscaling of LAI from field measurements to the satellite pixel scale, with focus on S2 10 m footprint.

[HIGH-19] – The use of UAV-LS for AGB validation, already tested within IDEAS+ over temperate forest, will be further expanded in the frame of QA4EO over tropical dense canopy to support BIOMASS Cal/Val. Furthermore, the prototype of novel open-source low-cost sensors for continuous canopy monitoring can provide an attractive alternative, which could potentially evolve to a ground-based network, although accuracy of these measurements still needs to be fully assessed.

[REC-8] – ESA/QA4EO to review the increasing trend in using network of low-cost sensors for Cal/Val applications (cloud mask, forest canopy, snow cover, air-quality) and to consider how these new solutions can be integrated as complementary elements of the overall ESA Cal/Val strategy.

Fabio Del Frate (University Tor Vergata) illustrated a new project, which will be included within QA4EO as part of the CCN2, to be started in April 2020. The goal of the study is to design, test and acquire UAV-based multi-spectral and multi-looking observations over vegetated site for characterizing and validating land surface BRDF. Despite its strong relevance in the optical community and a vast scientific literature, there is a clear need of acquiring accurate reference data for validation of the theoretical models and of the satellite BRDF-corrected SR products. As a matter of fact, most of the currently available BRDF ground-based measurements are usually acquired using field goniometers, which have a very limited spatial representativeness and coverage, and are generally suitable to characterize a very homogeneous site, such as a calibration target site. The use of a UAV-based based platform, which can be tilted to cover a wide range of viewing angles, can allow effectively sampling much larger regions easing the upscaling process to the satellite pixel scale resolution. The experiment will therefore consist in setting-up a virtual goniometer on-board a UAV platform, sampling the relevant land surface in a wide range of conditions, and to estimate a reference surface BRDF. The platform and payload is presented: the sensor (MAIA) is a multi-spectral imager with spectral bands overlapping key Sentinel-2 bands in the VIS and NIR regions. The imager will be coupled with an Incident Light Sensor (ILS), providing irradiance data at the time of acquisition, to be used for radiometric correction. The payload will be mounted on a UAV-multi-rotor platform allowing up to 30 min flight autonomy with the possibility to remotely control the orientation of the imager in the range from 0 to 90 degree with respect to nadir; this latter feature will be fully exploited for the multi-looking acquisitions. The envisaged test site will be a grassland site in the vicinity of University of Tor Vergata and the first campaign is planned during early Summer 2020. This site is relatively homogeneous and flat over a 1km scale, it is therefore suitable for validation of S2 and S3 BRDF-corrected products.

Discussion *– Questions were raised on the accuracy of the radiometric and geometric calibration, which will be performed respectively with ILS and GNSS sensors. In particular the geo-location of the pixel and co-registration between the different views will be very challenging and it is an essential parameter for the*

proposed BRDF characterization. The accuracy of these corrections will be carefully assessed when setting up the experiment and several tests will be performed to identify the best measurement configuration and calibration processing, post-processing correction will be applied if needed.

[HIGH-20] – Despite the relevance of BRDF in the optical domain and a vast literature on theoretical modeling, the field measurements are still scarce and mostly obtained with heavy ground-based goniometer systems, which have very limited spatial representativeness and coverage. The use of drones can overcome these limitations and fill a long lasting gap in the availability of BRDF reference data, although calibration and processing of these observations will be challenging. This dataset can be of value also within ACIX for validating BRDF correction procedures.

Irene Himmelbauer (TU Wien) presented the latest status of the International Soil Moisture Network (ISMN) project, which will be supported within QA4EO contract, as already did within previous IDEAS+. The ISMN is a global surface and subsurface soil moisture database consisting of more than 2600 in-situ stations providing a reliable continuous dataset, which is crucial for validation of satellite-based soil moisture products. The rationale of the project is to ensure a consistent and harmonized format and quality control process to all in-situ data, to provide centralized database and access point to allow easy discoverability and extraction of the relevant Cal/Val data. The data quality approach is based on statistical and geo-physical consistency checks and it results in a single summary quality flag. The open-and-free data policy, the global coverage, coupled with easy discoverability and clear quality information made the success of this network, which has been already cited in more than 1000 peer-reviewed publication. Among the various data providers, the GROW initiative is recalled, which uses a large number (15k) of flower-power low-cost sensors distributed all over Europe to scientists and citizens, providing an integrated networks for SM validation. The ISMN was the basis to set-up an end-to-end automated and fully traceable on-line validation system, building on CEOS-LPV validation framework, called QA4SM (Quality Assurance for Spoil Moisture, https://qa4sm.eodc.eu/). QA4SM uses community-endorsed validation practices, a reference fiducial dataset, a sub-setting tool for selecting spatio-temporal collocated satellite data and an on-line validation tool. The outputs of this tool are standardized intercomparison and validation reports. In the short term, the ISMN coupled with QA4SM will joint effort in the frame of a future FRM4SM project to be funded by ESA.

[HIGH-21] – The ISMN is a key element of the SMOS Cal/Val Plan and it is widely used within the science community for validating satellite-based soil moisture products, as demonstrated by the large number of citations in the scientific literature. While statistical and geophysical consistency is currently ensured within the internal QC process, more rigorous metrological practices should be applied, in particular with accurate assessment of uncertainty.

Fabrizio Niro on behalf of Georgia Doxani (Serco) summarized the latest results of ACIX-II (Atmospheric Correction Intercomparison eXercise). The purpose of the exercise is to inter-compare different AC algorithms used for processing S2 and L8 images, in order to identify strengths and weaknesses of each method and converge on the long-term to consistent and more accurate results. The first ACIX was completed and the relevant publication is available in MDPI RS journal. The second exercise (ACIX-II) is about to be completed and the final Workshop was held in ESRIN during December 2019. Within this second exercise, the intercomparison was expanded including more reference data and more participants, in addition, three different working groups were identified, focusing on: Land, Water and Cloud Mask; intercomparison for each group was performed separately using different reference datasets and specific protocols and metrics. The results of the Land group were summarized in the presentation. The ACIX-II Land exercise involved many more international teams (13) with respect to ACIX-I; furthermore, the reference dataset was significantly expanded and it includes now about 6500 scenes. The protocol largely builds on the one prototyped within ACIX-I, using synthetic SR dataset computed over AERONET sites with a reference RTM (6SV), but it includes now also RadCalNET ground measurements of SR for Gobabeb and La Crau sites, normalised to the S-2 and L-8 observation geometries. The set of AERONET sites used for validation was significantly increased, by including now all stations, so that to extensively validate the algorithm at global scale to verify their readiness and robustness for an operational implementation. Preliminary results of

comparison of AOD, TCWV and SR over AERONET sites were presented, using scatter plots and APU (Accuracy, Precision, Uncertainty) metrics, as already done within ACIX-I. Preliminary results over Gobabeb and La Crau were also shown. Overall, some clear indications are obtained on the accuracy of the various algorithms for different surface reflectance and AOD ranges. To be noted, that some algorithms were upgraded following the recommendations gather as part of ACIX-I and these upgrades clearly translate in improved performances in AOD and SR retrieval as observed in ACIX-II. RadCalNET sites are still not ideal for SR validation, since they are not representative of typical AC challenging conditions, e.g., non-vegetated sites with very low aerosol loading and dry atmospheric conditions; yet, La Crau provides some interesting insights on the algorithm performances. The final results are being consolidated and internally agreed for a publication, which is expected for Q3 2020. A way forward was also discussed during the WS, with some clear recommendations on how to proceed, this includes notably: further expanding the use of ground-based reference data, validation of SR at pixel scale, assessment of the impact of RTM, investigation of adjacency, BRDF and terrain-correction effects.

Discussion – *A question was raised on whether there was an agreed definition among the participants of what is SR. Actually, the rationale was to consider the various algorithms as black boxes and inter-compare the SR products as they are actually provided to the user community. Yet, the focus was on Rayleigh and aerosol scattering and molecular absorption correction, while any other type of corrections was specifically de-scoped from the exercise (e.g., adjacency, BRDF, topographic), requesting the participants to disable the corresponding modules in their algorithms.*

[HIGH-22] – The ACIX-II exercise significantly expanded the results of ACIX-I by separately assessing algorithm performances over land and water surfaces, as well as by considering the cloud mask issue in a dedicated exercise. Within the land group the reference dataset was largely extended to include all AERONET stations in order to verify algorithm readiness to sustain systematic production. AICX-I was successful in supporting the developers to identify and correct weaknesses in their procedures; as a matter of fact, the upgraded algorithms tested within ACIX-II, clearly demonstrated these improvements.

[REC-9] – ESA/QA4EO to prepare the ground for future ACIX-III; sustaining international efforts in gathering advanced ground-based measurements for SR validation (e.g., through RadCalNET expansion, field campaigns, Hypernet) and for BRDF and adjacency correction validation.

Carsten Brockmann (Brockmann Consult) presented a new project, which will be started during April 2020, in the frame of QA4EO CCN2. The study aims to gather new ground-based observations in support to cloud mask validation activities, in particular as part of CMIX (Cloud Mask Inter-comparison Exercise). The final results and the main outcomes of CMIX were recalled; these outcomes are actually the main motivations for this study. Cloud detection and masking is a long-lasting issue in optical remote sensing, and undetected clouds still introduce artefacts and systematic error in the downstream geo-physical products. Within CMIX 10 different cloud mask algorithms for S2 and L8 were inter-compared against 7 different reference validation datasets. The algorithms covered a wide range of techniques, including traditional spectral tests, machine learning and multi-temporal approaches; the aim was to identify weaknesses and strengths of the various methods. The validation datasets were mostly based on photo-interpretation of images. The results demonstrate that there are some indications on the performances of the different methodologies for different cloud/surfaces conditions, although there is no clear winner, since the results are highly dependent on the considered validation dataset. One of the main unresolved issues is the detection of thin semi-transparent clouds and the delineation of the clouds at the cloud borders. Some algorithms use cloud dilation with a predefined buffer in order to avoid remaining cloud contamination, this has proven a safe approach in particular for land applications, although the definition of the buffer extent is somewhat subjective and has not objective scientific basis. Overall, there is an obvious need for an objective way of defining and validating the cloud mask. In order to address this issue it seems clear that we have to think about a dedicated ground-based measurement system for cloud mask validation. This QA4EO project addresses this need, by considering ground-based continuous observations of sky, using sky-cameras systems, to estimate cloud fraction and base height. The idea of the project is to prepare, verify and consolidate the basic measurement

and processing concept working towards the establishment of a global network using common protocols and a centralized processing and distribution center. The concept study will start with 2 ground-based sites, one in NASA/Goddard and one in La Sapienza University. In each site, two twin sky-camera systems (Raspberry SkyCam) will be installed, 200 m apart in order to estimate cloud base with stereo approach. The site in University La Sapienza will be also equipped with a collocated Lidar Ceilometer in order to validate the cloud base estimation obtained with the sky-cameras. Dedicated algorithm and processing chain will need to be developed in order to automatically estimate cloud fraction and base height from the twin cameras. The project includes the preparation of requirements and guidelines on how to move from this pilot project to a global network of sky cameras.

[HIGH-23] – CMIX has demonstrated that there is a clear need for an objective way of defining and validating a satellite cloud mask. The proposed pilot project addresses this need by proposing a new ground-based system to gather reference data for cloud mask validation. The precursor system will be initially tested and verified in two sites (NASA/Goddard and University La Sapienza) with the long-term objective of working towards an automated global network.

[REC-10] – ESA to sustain the effort in building a global network for cloud mask validation supporting medium and high resolution optical sensors.

2.5 Cryosphere Cal/Val

David Small (University of Zurich) introduced the planned activities in the frame of QA4EO, which are a continuation of the tasks performed in the previous IDEAS+ contract. The main focus will be to work towards the definition of Analysis Ready Data (ARD) for SAR and test their usage for cryosphere applications, in particular for snow mapping. The rationale is to synergistically exploit the currently available suite of SAR instruments, in particular S1-A/B in combination with Radarsat Constellation Mission (RCM). The approach consists in performing accurate radiometric and geometric terrain correction in order to derive the Local Resolution Weighting (LRW) backscatter composite time series by combining multi-sources data. These L3 composites, allow easy interpretation of SAR data and are directly suited for applications, they can be considered as ARD for SAR. Work is on-going to define and agree ARD for SAR in the frame of CEOS-SAR sub-group, at Level 1 they will be defined as Normalised Radar Backscatter (NRB), while LRW can be considered as ARD at L3. The use of multi-source composites is attractive since it can allow to densify time series, attaining the revisit requirement for some applications, namely for cryosphere, and to fully exploit information from all tracks, combining ascending and descending tracks. Example of such approach for snow and sea ice monitoring in Ellesmere Island in Canada is presented, in a region of severe topographic effects, i.e., where terrain correction plays a crucial role. Sea ice monitoring, in particular melt onset, over this region is presented combining S1 and Radarsat-2 tracks, showing comparable results in terms of temporal revisit with respect to traditional sensors (ASCAT and passive microwave) while significantly improving spatial resolution.

[HIGH-24] – The proposed L3 SAR ARD composite products allow lowering the bar of expertise for users, by providing wide areas 2D images combining multiple sources and orbit tracks. These L3 ARD products are directly suited for applications, namely in the cryosphere domain. This QA4EO activity is crucial to improve uptake of SAR data within the EO science community.

Kari Luojus (FMI) presented the proposed QA4EO activities in the cryosphere domain. He started recalling the background expertise of FMI on snow algorithm development and validation and all Cal/Val facilities currently available within the FMI Sodankyla site. FMI has been strongly involved in satellite-based snow products development and validation, notably being one of the leading institutes within Snow CCI and SnowPex projects. ESA SnowPex project is particularly relevant in the frame of QA4EO, since it builds on the same principles of other algorithm inter-comparison exercises, such as ACIX and CMIX. SnowPex goal was to objectively inter-compare various snow products derived from different sensors and evaluate the derived seasonal and temporal trends to assess their suitability for climate monitoring. Within SnowPex, protocols

and best practices were established for satellite products validation with focus on: Snow Cover Extent (SCE) and Snow Water Equivalent (SWE), furthermore, validation datasets and tools were developed. The new SnowPex-II exercise is currently under preparation at ESA, and it is expected to start in 2020. A second topic of the talk was the presentation of the FMI Sodankyla Super-site facilities for snow validation. This site hosts a very wide range of sensors, including multi-frequency radiometer and radar and optical hyper-spectral camera and ASD spectrometer. The geo-physical variables being measured range from snow properties (SWE, snow reflectance), soil dynamic (freeze, thaw, moisture) and forest canopy monitoring. The site hosts as well an ICOS tower for measuring CO2 fluxes. In addition to the super-site, field survey campaigns are regularly performed for sampling snow depth and deriving SWE. Finally, a new Cal/Val concept was presented; it consists in analysing web-camera images for snow products validation purposes. A dedicated tool was developed at FMI (http://fmiprot.fmi.fi) to process images from camera networks for Cal/Val applications. Examples of Fractional Snow Cover (FSC) and Snow Depth (SD) derived from webcam images are presented. There are already a number of networks of such cameras, which can be used for gathering global data for snow products validation in the Northern Hemisphere. However, work needs still to be done to automatize the data stream and set up an operational processing chain as well as for improving estimation of snow properties from these images. This additional work can be of great value and fully in line with the QA4EO spirit of innovation for improved Cal/Val data, working towards an operational network.

[HIGH-25] – The FMI proposal of exploiting available networks of webcam for gathering Cal/Val reference data for snow products validation (SD and SCE) is in line with QA4EO spirit of innovation, working towards establishment of new practices in Cal/Val, thinking ahead in preparation to a potential global network.

[REC-11] – ESA/QA4EO to exploit synergies between QA4EO and SnowPex exercise working towards common objective of improving validation practices for current satellite snow products.

2.6 Water Cal/Val

Constant Mazeran (Solvo) presented the planned activities to be carried out in the frame of QA4EO for further improving Atmospheric Correction in non-ideal conditions encountered most of the time by ocean colour sensors (complex water and atmosphere, small scale perturbations). He recalled that the previous IDEAS+ activity was successful in improving the traditional MERIS Bright Pixel AC (BPAC) algorithm; this R&D activity, prototyped and validated within IDEAS+, was eventually transferred into an operational context and it is now the basis of the current ESA S3/OLCI processing baseline, to be further improved as part of a dedicated EUMETSAT evolution activity. The plan for moving forward is then presented, going beyond the "black pixel assumption" and using advanced statistical approaches for solving the underlying ill-posed problem. This advanced AC method should in particular tackle the challenges associated with realistic (non-ideal) atmosphere and water conditions, such as: complex marine water, white caps, small scales sun glint effects, locally varying gaseous absorption, complex aerosol mixtures. The proposed methods far tackling these challenges include: the use of extended spectral bands, advanced statistical approaches, constrained retrieval methods or the use of appropriate ancillary data, such as trace gases from atmospheric missions or surface wind data. Examples are shown over river estuarine, where OLCI band at 1020 nm can provide a mean for better estimating atmospheric perturbation over turbid river plumes. Another example demonstrated how the use of a constrained multi-pixel retrieval of aerosol model could improve retrieval of water leaving reflectance. The impact of small scales variability of NO2 total column on coastal water AC is also presented, showing that using static NO2 climatology can yield to large errors especially at shorter wavelength and for high SZA. The proposed study aims to identify the best retrieval configuration in realistic challenging conditions, including the choice of the best set of ancillary data, the required prior information as well as the retrieval constraints. The project outcomes will consist of an ATBD and prototype algorithm as well a roadmap for its implementation in an operational context.

[HIGH-26] – The advanced BPAC algorithm prototyped within IDEAS+ is now fully embedded within the ESA and EUMETSAT OLCI operational chains. This is a clear demonstration of how R&D is essential for stimulating improvements in operational EO products. The future challenge is to move forward, going

beyond the nearly-ideal case to tackle more realistic conditions, such as: complex water, spatially varying atmospheric conditions, white caps, small-scale sun glint effects.

Francis Zagolski (ParBleu) presented his contribution to the advanced algorithm for OC application to be developed in collaboration with Solvo in the frame of QA4EO. The proposed algorithm aims to tackle the current limitations in the available OC codes, such as limited spectral range used for aerosol inversion (only NIR bands), the limited spatial range (retrieval performed at pixel-level with no information gathered from neighbouring pixels), the limited use of potential complementary observations coming from other mission on the atmospheric state or surface conditions. Owing to these limitations, AC in challenging conditions (complex water, absorbing aerosol, sun-glint) still remains inaccurate. The objectives of the study are to verify the use of advanced constrained retrieval methods using multi-pixels and multi-spectral approaches, and to assess the added value obtained when using complementary observations from other sources, e.g., aerosol profiles from Lidar, wind speed from space-borne scatterometer. As part of the study, the accuracy of the current OLCI AC will be assessed by comparing it with an accurate reference computation of the atmospheric perturbation, obtained using a fully polarized RTM combined with input external data for external sources, e.g., AERONET data and aerosol extinction profiles from CALIOP. These reference computations will be used to build a database of atmospheric scattering functions, which will then be the basis to develop the new AC code.

[HIGH-27] – The proposed QA4EO activity aims to tackle the current challenges in AC in actual complex water and environmental conditions. Available external space and ground-based data (from AERONET and CALIOP) on aerosol properties will be used to assess uncertainties of traditional AC methods and build a database of atmospheric scattering functions, which will be the basis of an advanced algorithm.

Marco Meloni (Serco) illustrated the status of the project on coastal altimetry monitoring and validation using advanced methods. The work was started as part of IDEAS+ activities and most of the outcomes of the work were completed. The presentation covered the final part of the study, which focuses on detection and monitoring of intrusion events in the region of interest: the Gulf of Lyon. The study area, the Gulf of Lyon is influenced by the Northern Current, which, under particular conditions, can enter the continental shelf (intrusion) with strong impact on biogeochemistry and primary production. Intrusion mechanism has been modelled since many years using Symphonie model and an in-situ current meter (JULIO) was installed to measure horizontal currents through the water column. The aim of the project was to develop a new algorithm coupling the model simulations and altimetry data to predict the volume fluxes, which were then verified with the in-situ data. The algorithm was based on NN Random Forest method and the prediction of intrusion events are presented, showing an overall reasonable agreement with 93% of the intrusion correctly predicted with only few false alarms. Several limitations are still observed though, namely the capability of the algorithm weakens when the horizontal wind conditions changes rapidly, furthermore, some remaining inaccuracies in altimetry processing near land may affect the results. The study was summarized in a paper recently submitted for publication in GRL.

[HIGH-28] – The development of new multi-sensors approach combined with theoretical models, prototyped within IDEAS+, allows for exploitation of satellite-based altimetry over coastal zones, with clear benefit for applications, such as detection and monitoring of intrusion events within the continental shelf. Despite the limitations of altimetry processing and calibration near land, the results are very promising, since intrusion events could be predicted with very high accuracy.

2.7 Summary Recommendations

A table listing the recommendations is provided here after, based on the discussion held during the meeting and the final discussion session.

[REC-1] – QA4EO to strengthen the focus on metrology with more active involvement of NPL within Task 2 coordination, and exploit synergies with other contracts, namely EDAP. This vision should be summarized in a roadmap document to be maintained throughout the contract.

[REC-2] – QA4EO to further review the need and interest for Cloud base platform devoted to Cal/Val applications and the potential use of DIAS platforms for the purpose of Cal/Val.

[REC-3] – ESA/VITO to follow up the issues observed in Proba-V SWIR band, the observed non-linearity effects will be compared with the VITO results obtained with vicarious calibration approaches.

[REC-4] – IDEAS-QA4EO to provide input to the CEOS Cal/Val portal, such as campaigns data, documents, and Cal/Val protocols.

[REC-5] – ESA/MPC to investigate the interest of Cal/Val data collected within the FIREX-AQ field campaign for validation of S3 operational L2 products, mainly FRP and AOD.

[REC-6] – QA4EO to actively support the adoption of a common terminology for uncertainty estimate following metrological guidelines, the CEOS-Cal/Val portal should facilitate dissemination of these concepts.

[REC-7] – ESA to facilitate the evolution of MBASSS Cal/Val capabilities, namely, to ease the installation of a CIMEL and a LST sensors, the former in collaboration with LOA, the latter with S3 MPC.

[REC-8] – ESA/QA4EO to review the increasing trend in using network of low-cost sensors for Cal/Val applications (cloud mask, forest canopy, snow cover, air-quality) and to consider how these new solutions can be integrated as complementary elements of the overall ESA Cal/Val strategy.

[REC-9] – ESA/QA4EO to prepare the ground for future ACIX-III; sustaining international efforts in gathering advanced ground-based measurements for SR validation (e.g., through RadCalNET expansion, field campaigns, Hypernet) and for BRDF and adjacency correction validation.

[REC-10] – ESA to sustain the effort in building a global network for cloud mask validation supporting medium and high resolution optical sensors.

[REC-11] – ESA/QA4EO to exploit synergies between QA4EO and SnowPex exercise working towards common objective of improving validation practices for current satellite snow products

3 APPENDIX A: AGENDA

19 February 2020

Welcome and Introduction (start at 14:00)		
10 min	Welcome and Introduction	P. Goryl, ESA (Italy)
20 min	ESA QA4EO general framework and service	J. Swinton, TVUK (UK)
20 min	The QA4EO Task 2 Cal/Val framework: Vision, Overview and Objectives	F. Niro, Serco (Italy)
20 min	The EDAP Framework to Assess Commercial Satellite Mission Quality	N. Fox, NPL (UK)
20 min	ONDA-DIAS platform enabling users to host data and build their applications in the Cloud	M. D'Alessio, Serco (Italy)
Metrology and Traceability		
20 min	Metrological and Traceability in Space: Motivations, Challenges and Methodologies	N. Fox, NPL (UK)
20 min	SI-Traceable ground-based observations for ozone and aerosol properties retrieval	J. Gröbner, PMOD (Switzerland)
20 min	Improving Traceability and calibration in the frame of AERONET-Europe network	P. Goloub, LOA (France)
20 min	Eradiate: 3D radiative transfer community model to support metrological applications	Y. Govaerts, Rayference (Belgium)
20 min	Statistically based approach for estimation of sensor performance indicators: status and way forward	S. Mackin, EOSense (UK)
20 min	The CEOS Cal/Val portal: status and updates	P. Castracane, RHEA (Italy)

20 February 2020

Atmosphere Cal/Val (start at 9:00)		
20 min	Boundary-layer Air Quality-analysis Using Network of Instruments Super-Site (BAQUNIN)	S. Casadio, Serco/Uni. La Sapienza (Italy)
20 min	Ground-based validation of satellite-derived Aerosol Layer Height and Ozone profiles	D. Balis, U. Thessaloniki (Greece)
20 min	Aerosol field campaigns validation using advanced exploratory platforms	P. Goloub, LOA (France)
20 min	Generalized Retrieval of Aerosol and Surface Properties (GRASP): status and way forward	O. Dubovik, LOA (France)
20 min	Improved uncertainty estimation in support to Pandonia Global Network (PGN)	A. Cede, Luftblick (Austria)
20 min	Retrieval of advanced atmospheric parameters from Pandora-2S observations	J. Fischer, SpectralEarth (Germany)
20 min	Advanced Clouds, Aerosols and WAter vapour products (CAWA-2): Status and updates	Y. Carol, GRASP (France)

20 min	Advanced InfraRed Water Vapour Estimator (AIRWAVE): Status and updates	M. Valeri, Serco/ISAC (Italy)
20 min	ESA Fundamental Data Records for Atmospheric Composition (FDR4ATMOS): status and updates	G. Brizzi, Serco (Italy)
Land Cal/Val		
20 min	Land Cal/Val activities in the Mer Bleue Arctic Surrogate Simulation Site (MBASSS)	R. Soffer, NRCC (Canada)
20 min	UAV-based Land Cal/Val activities over temperate and tropical forest sites	B. Brede, M. Herold, WUR (Netherlands)
20 min	UAV-based multi-spectral/multi-looking observations for Surface BRDF characterization	F. Del Frate, Uni. Tor Vergata (Italy)
20 min	The International Soil Moisture Network (ISMN) for satellite-based products validation	I. Himmelbauer, TUW (Austria)
20 min	Atmospheric Correction and Cloud mask Inter-comparison for S-2 and L-8 (ACIX-II/CMIX)	F. Niro, Serco (Italy)
20 min	Ground-based sky-camera observations for cloud-mask validation in support to CMIX	C. Brockmann, Brockmann Consult (Germany)
Cryosphere Cal/Val		
20 min	Towards the concept of Analysis Ready Data (ARD) for SAR: applications to Snow mapping	D. Small, Uni. Zurich (Switzerland)
20 min	Advanced algorithms and Cal/Val protocols for satellite-based Snow products	K. Luojus, FMI (Finland)

21 February 2020

Water Cal/Val (start at 09:00)		
20 min	Advanced retrieval methods and uncertainties estimation for Ocean Color products	C. Mazeran, Solvo (France)
20 min	Advances in Radiative Transfer methods for Ocean Color applications	F. Zagolki, ParBleu (Canada)
20 min	Towards new concepts for Coastal Altimetry validation: status and updates	M. Meloni, Serco (Italy)
Other R&D activities		
30 min	Red-Lab Serco R&D framework for EO: overview and current projects: Solar Flux from SMOS, Sentinels for agriculture, Air quality monitoring	R. Crapolicchio, Serco (Italy)
Discussion		
90 min	QA4EO Cal/Val: synergies, opportunities and way forward	ESA, ALL
30 min	Meeting Wrap-up	ESA, ALL

4 APPENDIX B: PARTICIPANTS

The list of Meeting's participants is provided in the following table.

	Name	Affiliation	Country
1.	Philippe Goryl	ESA-ESRIN	Italy
2.	Angelika Dehn	ESA-ESRIN	Italy
3.	Jonas Von Bismarck	ESA-ESRIN	Italy
4.	Steffen Dransfeld	ESA-ESRIN	Italy
5.	Clement Albinet	ESA-ESRIN	Italy
6.	Philippe Goloub	LOA	France
7.	Oleg Dubovick	LOA	France
8.	Yana Karol	GRASP	France
9.	Constant Mazeran	Solvo	France
10.	David Small	Uni. Zurich	Switzerland
11.	Julian Groebner	PMOD-WRC	Switzerland
12.	Raymond Soffer	NRC	Canada
13.	Francis Zagoslki	ParBleu	Canada
14.	Nigel Fox	NPL	UK
15.	Pieter de Vis	NPL	UK
16.	Steve Mackin	EOSense	UK
17.	John Swinton	Telespazio Vega	UK
18.	Alexander Cede	Luftblick	Austria
19.	Irene Himmelbauer	TU Wien	Austria
20.	Juergen Fischer	FUB	Germany
21.	Carsten Brockmann	Brockmann	Germany
22.	Benjamin Brede	Uni. Wageningen	Netherlands
23.	Yves Govaerts	Rayference	Belgium
24.	Kari Luojus	FMI	Finland
25.	Matias Takala	FMI	Finland
26.	Hiltunen Mwaba	FMI	Finland
27.	Dimitris Balis	Uni. Thessaloniki	Greece
28.	Fabrizio Niro	Serco	Italy
29.	Stefano Casadio	Serco	Italy

30.	Raffaele Crapolicchio	Serco	Italy
31.	Gabriele Brizzi	Serco	Italy
32.	Marco Meloni	Serco	Italy
33.	Erminia De Grandis	Serco	Italy
34.	Annamaria Iannarelli	Serco	Italy
35.	Gabriele Mevi	Serco	Italy
36.	Massimo Valeri	Serco	Italy
37.	Paolo Castracane	REHA	Italy
38.	Marco Cacciani	Uni. La Sapienza	Italy
39.	Fabio Del Frate	Uni. Tor-Vergata	Italy
40.	Daniele Latini	GEO-K	Italy
41.	Cristiana Bassani	IIA	Italy