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DOCUMENT

Proceedings from IDEAS+ Cal/Val Workshop#5, ESRIN, 12 – 13 Dec 2017

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1 INTRODUCTION

During 12 – 13 December 2017 a two days Workshop was held in ESRIN to review the status of the various Cal/Val projects running as part of the IDEAS+ Task3 activities. This document reports a summary of the Workshop's presentations and the 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/ideas-calval-workshop-5

1.1 Background

The IDEAS+ (Instrument Data quality Evaluation and Analysis Service) consortium is responsible, 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+ consortium, Task 3 is the place where innovative ideas are promoted and incubated with the goal of further improving algorithm specifications, calibration and validation protocols, data quality assessment procedures. IDEAS+ Task3 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.

As part of nominal IDEAS+ Task3 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 fifth of such meetings was convened in Frascati at ESA/ESRIN premises from 12 to 13 December 2017.

The summary proceedings of the IDEAS+ Cal/Val Workshop and the recommendations gathered during the discussion are presented within the next chapters following the chronological order of the Agenda.

1.2 Acronyms and Abbreviations

AC	Atmospheric Correction
ACIX	Atmospheric Correction Intercomparison eXercise
AERONET	AErosol RObotic NETwork
ALS	Airborne Laser Scanning
AOD	Aerosol Optical Depth
AOT	Aerosol Optical Thickness
ATLAS	A pulsed Tuneable LAser system for the characterisation of Spectrometers
BOA	Bottom of Atmosphere
Cal/Val	Calibration/Validation
CCN	Contract Change Notification
CDR	Climate Dara Record
CEOS	Committee on Earth Observing System
CTO	Ozone Total Colum

EO	Earth Observation
ESA	European Space Agency
ESRIN	European Space Research Institute
FIDUCEO	FIDelity and UnCertainty in climate data records from Earth Observations
FRM	Fiducial Reference Measurements
FUB	Freie Universität Berlin
HYMSY	HYperspectral Mapping System
IDEAS+	Instrument Data quality Evaluation and Analysis Service
ITT	Invitation To tender
KIT	Karlsruhe Institute of Technology
LAI	Leaf Area Index
LOA	Laboratoire d'Optique Atmosphérique
MEP	Mission Exploitation Platform
NPL	National Physical Laboratory
PAI	Plant Area Index
PASTIS-57	PAI Autonomous System from Transmittance Instantaneous Sensors oriented at 57°
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 spectroRadiometer
R&D	Research and development
SNR	Signal to Noise Ratio
SR	Surface Relectance
TLS	Terrestrial Laser Scanning
TOC	Top Of Canopy
UAV	Unmanned Aerial Vehicle
WORCC	World Optical depth Research and Calibration Center
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 5th IDEAS+ Cal/Val workshop. He recalled that this is last workshop of the IDEAS+ Phase 2 contract, where the status of the various projects has to be reviewed, although a continuation of 1.5 years is ensured within next CCN11 – Phase 3. Philippe also highlighted the relevance of Task 3 as the R&D component of IDEAS+.

Angelika Dehn (ESA) also welcomed the participants, informing that Philippe is taking over the responsibility of IDEAS+ management as technical officer starting from Phase 3.

Fabrizio Niro (Serco) introduced Task 3 organisation and scope, stressing the role of Task 3 as incubator of new concepts to be tested, validated, and possibly injected in missions' operations. He also reported the main recommendations from the previous Cal/Val workshop, held in Lille (LOA) on 6-7 April 2017: to reinforce focus on traceability and uncertainty already during mission design phase, to work toward provision of uncertainty in L1 data including the relevant documentation, to ensure sustained support to ground-based validation global networks, to build on the protocols prototyped for surface reflectance and cloud mask validation, to maintain and expand Cal/Val tools and match-up databases, improving accessibility of data. Thus, he recalled the objectives of the current workshop: to review progress since the previous workshop, to discuss final results of Phase 2 activities, and to plan future activities during Phase 3.

2.2 Calibration, Traceability and Uncertainty

Nigel Fox (NPL) reported on the outcome of the *Uncertainties in Remote Sensing* Workshop, held in ESRIN during 24-25 October 2017. The workshop objectives were to review the status of uncertainty estimation in the different EO communities and foster the adoption of common best practices building on the lessons learned in the frame of the FIDUCEO (Fidelity and uncertainty in climate data records from Earth Observations) project. The workshop was organized among three main sessions: one providing the theoretical framework illustrated by NPL and University of Reading; one reporting on the various approach of uncertainties estimation in various EO domains; and last one focusing on discussion and recommendations. The relevance of traceability was specifically underlined, since it is paramount in order to address climate related applications of EO remote sensing data. Evolutions need still to be made, following community-accepted protocols, such as the GUM, and theoretical work needs to be carried out in some specific domains, such as for the uncertainty estimation of classification algorithm or when using Neural Network algorithm. The concept of FRM was also stressed, as valuable contribution by ESA to the adoption of traceable and metrological principles to EO. Several recommendations on how to move forward were gathered during the Workshop, the main ones are reported here below. The Space Agencies and the science community should follow up these recommendations in order to progress on the adoption of common best practices to the problem of uncertainty estimation. The primary goal is to clearly demonstrate the benefit of uncertainty information in EO data, not only for science and climate applications, but also and more importantly for the society, so that to emphasize on the value of Cal/Val activities.

[REC-1] To follow up on the main recommendations from the Uncertainties Workshop, namely:

- Clear need to improve availability and use of uncertainty information in Level 1 and Level 2 products
- Uncertainty information requests need to be embedded in Space Agencies practices at early phase of mission design (MRD, SRD)
- Work toward harmonization of requirements, methods and terminology across the various community (Level 1, land, water, atmosphere)

- Develop tools, protocols for uncertainty tree to lower level of expertise required to exploit them
- Demonstrate users' benefits both for science applications and for policy definition
- Areas requiring theoretical advances in uncertainties estimation: impact of undetected clouds, NN, classification algorithms, co-location mismatch error

Julian Gröbner (PMOD/WRC) reported on the Phase 2 status of the ATLAS (A pulsed Tuneable LAser system for the characterisation of Spectrometers) project, mainly focused on the validation of Ozone total column and Aerosol optical depth from the comparison of a in house characterised Pandora instrument (P120) and, respectively, a Brewer spectroradiometer (Br163) and three reference precision filter radiometers ("PFR triade"). Julian provided also an outlook of Phase 3 project, where P120 measurements will be validated against a Dobson spectrophotometer and three precision solar spectroradiometers (PSRs). During the presentation, some example of traceability chain and uncertainty budget used for instruments characterisation have been detailed – e.g. straylight correction.

[HIGH1] – NPL and PMOD provide the metrological perspective, which is the foundation of IDEAS+ Cal/Val approach. Synergies between metrological institutes and other Task3 teams should be encouraged to ensure common approach to the problem of SI traceability and uncertainty estimate. The work of PMOD is strategic within IDEAS+ Task3, since it was instrumental to the development and consolidation of the Pandonia network and it will be key to support Sentinel-5P Cal/Val activities.

Jürgen Fischer (Spectral Earth) provided the status of the calibration and verification of six Pandora-2S spectrometers distributed globally in both hemispheres; the instruments contribute to the Pandonia network. The sites have been selected for their extreme environmental conditions, in order to verify the instruments operations in harsh conditions and verify their reliability. In summary: Pandora-2S P126 to be operated in Barbados-Caribbean (sea spray, wind, rain) is currently at SciGlob for maintenance, it will be provided with a new tracker; P127 to be operated in Palau-Micronesia (tropical conditions, humidity, rain) is currently at SciGlob for maintenance; P131 to be shipped to Summit-Greenland (harsh conditions, snow, ice, freezing wind) is in operational mode in the Vanderbilt University but experiencing tracker and temperature issues; P133 operated 3 months in Namibia-Africa (dust, salt, dew) and it is now at KIT for maintenance after high temperature issues; P132 operated at Lindeberg-Germany (countryside conditions) and it is currently at FUB for tracker problems; P130 was used in a ship campaign (moving site) but measuring at FUB (urban conditions) when in rest time. As conclusion, some recommendations to the Pandora factory have been provided: upgrade the tracker system, use of active sun tracking system, higher temperature performance, training on instrument usage, calibration procedures.

[HIGH2] – The deployment of Pandora-2s instruments in various global sites in harsh environment conditions allow to collect a set of practical recommendations on how to improve instrument design and data processing; these lessons learnt are being taken into account in order to enhance the reliability and robustness of the Pandonia network. This is a good example of successful synergy within the IDEAS+ Task 3 teams.

Stephen Mackin (EOSense) provided a summary of his recent work on the automatization of data quality monitoring. The rationale is that nominal images can be used to derive the correction coefficients needed to calibrate the image itself, rather than using vicarious calibrations over fixed targets or characterisation through on-board devices. In addition, this method makes use of every single image, over heterogeneous targets, continuously, providing a huge amount of data quality information. In particular, he showed some examples: on relative gain correction, with possible detection of residual features maybe related to non-linearity effect; on the focus estimation, by monitoring its drifting in time and giving a possible evaluation of the atmospheric effects on the focus itself; on the estimation of signal to noise ratio, by reconstructing the SNR curve and monitoring the behaviour in time of individual detectors; on the absolute calibration drift, by using statistical calculation. Stephen demonstrated that the developed methods could be used as alternative ways to validate the conventional well-established techniques.

[HIGH3] – The use of nominal images for extracting information on data quality provides a complementary tool for in-flight calibration of optical sensors (Sentinel-2, Sentinel-3, Proba-V). This tool allows a real time performance assessment of the relevant sensor, by quick identification of instrument and calibration issues, this feature may be extremely useful in a mission operations environment.

2.3 Land and Cryosphere

Benjamin Brede (University of Wageningen) presented Phase 2 results of the S2L8VegStruc (Retrieval of vegetation structural variables from Sentinel 2/Landsat 8 time series) project, on the retrieval and validation of biophysical parameters in the Speulderbos Cal/Val site (The Netherlands). During the past years dedicated campaigns with different on-ground instruments (TLS, ALS, PASTIS, HYMSY…) have been organised and the measurements have been compared to satellites data (Landsat 7 & 8, Sentinel-2A & 2B …). In particular, Benjamin explained the strategy of deriving LAI daily values by monitoring the canopy phenology with a PASTIS-57 instrument, which presents some clear advantages: low-cost instrument, robust retrieval principles, easy to install and to operate. Secondly he provided details about another campaign for the assessment of a forest discrete structure (at a single tree level), by comparison of TLS and ALS measurements. The ALS (UAV-lidar instrument) is showing very encouraging results in good agreement with TLS, considering a very fast preparation and operation steps. The goals for Phase 3 project are testing the UAV-lidar with full leaf canopy and testing a prototype sensor for the study of sun-induced chlorophyll fluorescence.

[HIGH4] – The use of UAV methods for Cal/Val activities in the Land domain is becoming a very attractive and affordable technique and there is a clear intention on ESA to further explore this opportunity for supporting Sentinel-2, Sentinel-3, Proba-V and Flex missions. In this context, the collaboration with University of Wageningen is crucial and can provide the means to move toward community-accepted protocols for Cal/Val of various biophysical variables using UAV-based sensors.

Georgia Doxani (Serco) summarized the final results of the ACIX (Atmospheric Correction Intercomparison eXercise) project. The purpose of the exercise was to inter-compare different Atmospheric Correction algorithms used for processing S2 and L8 images, in order to better understand and characterise the contribution of uncertainty and eventually improve the operational processors. The exercise included twelve teams with their own processors, the inter-comparison process followed a strict protocol agreed in advance by all participants, 19 AERONET test sites characterised by different environmental conditions were chosen, quality flags per pixel were provided by each team. The output provided by each team was analysed by the coordinators using inter-comparison metrics and validated against atmospheric parameters provided by AERONET: Aerosol Optical Thickness, Water Vapour Total Column and reconstructed Surface Reflectance. The results of the exercise, together with the lessons learnt and the final recommendations will be submitted to the Remote Sensing Journal. A second round of ACIX is under discussion, the first workshop will be held in Washington during October 2018, this second phase will include a dedicated exercise on inter-comparison of various cloud masks, so called CMIX.

[HIGH5] – The first ACIX was successful in prototyping and promoting the adoption of a pragmatic approach for assessing the quality of atmospheric correction algorithms. The second ACIX will address the issues that were put aside in the first inter-comparison, in particular, the cloud mask; in addition, the possibility to use in-situ Surface Reflectance measurements for direct validation will be explored. The long-term goal is to help the developers to improve their algorithms, understanding and solving the main sources of discrepancies and moving toward more consistent and accurate solution to the atmospheric correction (and cloud mask) problem. This goal is of obvious relevance to data exploitation of ESA optical missions, e.g., Sentinel-2, Sentinel-3 and Proba-V.

Erminia De Grandis (Serco) presented the preliminary results of the global validation of Proba-V TOC products over AERONET sites using the Proba-V Mission Exploitation Platform (MEP). This project started recently in September 2017 and the Cal/Val workshop is the opportunity to show preliminary results. The

project consists in applying the ACIX protocol to Proba-V data in order to assess the quality of surface reflectances. The validation tool, a python code, developed within the MEP will be the first attempt to use this platform for Cal/Val applications. The advantages of the MEP for such applications are clear, since the complete data archive can be accessed remotely (no need of downloading data) together with the required processing resources and ancillary tools, furthermore, ground-truth dataset can be uploaded on the platform to carry out the validation exercise (in this case, the complete AERONET dataset). The project will be further developed and the final results will be presented during the Proba-V Symposium, in May 2018. The long-term goal is to make this tool available to the users in order to allow for a quick and efficient quality assessment of Proba-V surface reflectance products.

[HIGH6] – The project on Proba-V surface reflectances validation within the Mission Exploitation Platform (MEP) was the first attempt to use this platform for Cal/Val applications. Exploitation platforms are a valuable tool for Cal/Val and they will be part of the core infrastructure for IDEAS+ evolution.

Raymond Soffer and Pablo-Arroyo Mora (NRC) presented (via Webex) the latest results of the IDEAS+ project called MBASSS (Mer Bleue Arctic Surrogate Simulation Site). The main goal of the project is to support validation of satellite HR sensors, specifically Landsat-8 and Sentinel-2, using an integrated approach of ground based field and laboratory measurements, coupled with airborne hyperspectral image acquisitions. The airborne acquisitions were carried out during July 2016, with few more flights planned for summer 2017, which were not part of the IDEAS+ project. The exploitation of the results is still at an early stage and it will result in several scientific papers, 4 of them are under publication for RS MDPI. One of the major achievements was the capability to model Net Ecosystem Exchange (NEE) over the target peatland site at ecosystem scale using the satellite imagery from L8 and S2. The variation of NEE along different years allows to estimate the CO2 budget and to demonstrate that this peatland was so far a net sink of CO2. The study demonstrates also that S2 has the right characteristics, in terms of spatial and temporal coverage to allow for NEE modeling over this complex ecosystem. Additional results will be presented during LPVE.

[HIGH7] – The MBASSS site has a clear relevance for climate applications, modeling of NEE was possible over this complex peatland site exploiting airborne and satellite imagery. The lessons learnt and the protocols developed within the MBASSS project are extremely relevant in the frame of the overall ESA Cal/Val strategy for Land products, in particular the integrated multi-sensors approach, using in-situ, airborne and UAV-based sensors.

2.4 Oceans and Coastal Zones

Constant Mazeran (Solvo) reported the latest results on the estimation of uncertainty budget for ESA L2 Ocean Color products. This study, also presented during the Uncertainty workshop, is a good example of applications of community-accepted best practices, the GUM in this case, to the problem of uncertainty estimation. The procedure follows a rigorous mathematical approach, allowing uncertainty propagation following an unbroken chain of processing steps, therefore ensuring fully traceable results. The main challenge is the characterization of the input L1 uncertainties, for which full covariance intra-pixel matrix needs to be defined. The study allows also identifying the impact of the various sources of errors into the final geo-physical products, hence allowing to identify the most important issues to address in order to eventually improve the overall L2 products accuracy. This procedure, for instance allows to better defining the requirements for systematic vicarious gain calibration, both in terms of infrastructure and processing. It is therefore, crucial both in the definition of the Cal/Val plan and in the analysis of the Cal/Val results.

[HIGH8] – The study on uncertainty budget for L2 OC products demonstrated how the use of a rigorous and traceable approach to the uncertainty estimation is crucial for identifying the sources of errors that mostly impact the accuracy of the final geo-physical products. Once these sources are identified, we can establish and implement the proper actions (e.g., upgrade of processors, auxiliary data, Cal/Val infrastructure), enabling to reduce the overall uncertainty budget.

Francis Zagolski (ParBleu) presented his IDEAS+ project on the update of skydome correction tools in the frame of the MERIS 4th reprocessing. The study demonstrated that above water radiance measurements are affected by polarization of the skylight, the impact is particularly important at short wavelength, it should therefore be properly characterized and corrected in order to improve the accuracy of the validation. The correction for polarization could be eventually validated using some of the CIMEL instruments equipped with polarizers. The correction has been included in the POLREF simulator tool, and it was tested for two in-situ validation sites: the Aqua Alta Oceanographic Tower in Venice and the Belgian site offshore Ostend. The overall goal is to improve uncertainty associated to validation of L2 OC products for MERIS and OLCI and to better characterize all source of uncertainties associated to the validation of water leaving radiance.

[HIGH9] – The work on Sky-dome polarization correction is a precious contribution to the theoretical advances in understanding, characterizing and correcting all sources of uncertainties associated to the validation of water leaving reflectance products, the long term goal is to contribute to the overall improvement of ESA L2 OC products.

Jerome Bouffard (RHEA) and Marco Meloni (Serco) illustrated the status of the project on Multi-Scale analysis of coastal altimetry data over the NW Mediterranean Sea. J. Bouffard provided the general context and the major challenges related to coastal altimetry processing and validation, in particular, the need for new approaches allowing to resolve the small-scale coastal signal. The solution proposed in this study is to adopt an integrated approach, where remote sensing data, in-situ data from glidars and regional dynamic models are combined for better characterizing the complex coastal processes. This novel approach is verified in one study area in the Mediterranean Sea, from Ligurian Sea to the Gulf of Lion. The study allows to identify the current limitation in satellite altimeter data for coastal areas and to point to the need for ad-hoc post-processing allowing resolving the small-scale coastal dynamic. The way forward for Phase 3 was also presented, based on the use of models to address these limitations. As a result of the study several papers are in preparation, which will be submitted at JGR and RSE.

[HIGH10] – The use of physical models for the synergistic exploitation of multi-sensor dataset from in-situ and satellite sensors is an attractive perspective for both science and Cal/Val applications, since it allows improving our understanding of the underlying physical processes and of the associated uncertainty sources (e.g., co-location mismatch error). This integrated approach, here applied to altimetry data, is of interest for any type of sensors, e.g., optical, atmospheric sensor.

Jan Wevers (Brockmann Consult) presented the latest results on MERIS/AATSR land/water mask improvement and feedback from the Quality Control of MERIS 4th reprocessing. The land/water mask for MERIS/AATSR was upgraded from 300m to 150m spatial resolution. This mask, fully based on the LC CCI WB products, could be of interest as input to other missions, e.g., altimetry applications for inland water. Example of land/ocean, coastline and inter-tidal masks are presented. This new product will be provided as an auxiliary file and could be used as masking operator within SNAP. Highlights on the quality check of the MERIS 4th reprocessing dataset are also illustrated with examples of quality issues, in particular geo-location issues and undetected and un-flagged stripes in the images. The QC was systematically done on all L1 FR and RR dataset, while for L2, only selective checking on randomly chosen images was performed, though a comprehensive check of L2 is recommended.

[HIGH11] – The new land/water mask at 150m could be of interest to improve processing of various mission data especially for coastal areas, in general, improving accuracy of auxiliary data is an obvious way to reduce uncertainties in the derived geo-physical products.

2.5 Atmosphere

Philippe Goloub (LOA) described the current status of the IDEAS+ project dedicated to the upgrade of the AERONET Europe Calibration Facility for sun/moon/sky photometers. The IDEAS+ work package is intended to support the upgrade of AERONET facilities with modern technologies (instrument, calibration system, traceability) and to develop new AERONET-compatible mobile systems. Latest results on testing new mobile system are presented, in particular the verification during the AQABA (Air quality and climate change

in the Arabian Basin) ship campaign. The aim of the Cal/Val campaign, conducted in summer 2017 sailing from Cyprus to Kuwait along the Arabian Peninsula, is to study aerosol emission in extremely varying environmental conditions, ranging from pristine areas, to very polluted areas and including a wide range of aerosol particles, such as natural and anthropogenic dust and sea salt. The instrument and data processing were adapted to this special conditions and the campaign allows gathering a number of recommendations on how to improve the system for sustaining such campaign. Example results from this ship campaign are presented and verified against micro-tops and near AERONET fixed stations showing a reasonable agreement. An outlook on the planned activities for Phase 3 is shown, in particular the participation to a new ship campaign, where the mobile system will be further tested. The long-term goal is to further develop and operate such mobile facility in the framework of ACTRIS. Additional need is finally identified to have a formal inter-calibration process allowing to link AERONET facilities to a traceable standard in collaboration with the metrological institutes (NPL, PMOD).

[HIGH12] – The support to AERONET facilities upgrade and development is crucial within IDEAS+, the evolution in the design, characterization and processing of a new AERONET-compatible mobile system is a remarkable achievement of this project, which will allow to better support future Cal/Val campaigns. The need for a formal traceability process so SI within AERONET was identified and it will need to be addressed, also in the frame of IDEAS+, with the contribution of the metrological institutes.

Philippe Goloub (LOA) illustrated the latest results of IDEAS+ project on the development of a retrieval code called GARRLiC (Generalized Aerosol Retrieval from Radiometer and Lidar Combined data) and on the upgrade of a portable multi-wavelength Raman Lidar (LILAS). The long-term goal of the project is to improve aerosol retrieval accuracy by using combined active and passive remote sensing and in-situ measurements. Several updates were implemented in this retrieval scheme, which now allows for the estimation of aerosol vertical concentration, size distribution and complex refractive index. The retrieval was tested using sun/sky photometer and multi-wavelength polarized lidar measurements, acquired during the SHADOW campaign in Senegal (2016-2017) with, respectively, a CIMEL and the LILAS transportable Lidar. GARRLiC synergistic retrieval results were compared against only-lidar results, showing clear improvement in extinction estimation. One relevant finding of the study was to demonstrate that the inclusion of volume lidar depolarization ratio (VLDR) within GARRLiC scheme improves significantly the retrieval of aerosol optical and micro-physical properties. Furthermore, the mobile LILAS system shows very good performances in the characterization of stratospheric aerosol, this mobile system will be a contributing station to the EARLINET/ACTRIS network.

[HIGH13] – The latest development of the GARRLiC algorithm successfully demonstrate the added value of synergistic retrieval of aerosol properties from combined use of passive and active systems. Furthermore, the development of a new mobile lidar system opens new interesting opportunities for supporting Cal/Val activities for different satellite mission, in particular for EarthCARE.

Benjamin Torres (LOA/GRASP) presented the results of a sensitivity study on GRASP (Generalized Retrieval of Aerosol and Surface Properties) retrieval accuracy for different aerosol conditions. The work is part of the IDEAS+ WP called ISTINA and the objectives are to study the fundamental limitations and to identify the potential improvements for the retrieval of aerosol properties from remote sensing observations. Sensitivities tests were carried out with GRASP on sun-photometer measurements with the goal of improving the detailed aerosol characterization, in particular, AOD, size distribution and single-scattering albedo. As example test case, the severe dust event in Europe was considered, during October 2017, when large continental transport of desert dust from Africa mixed with biomass burning from Portugal wildfires was observed. This was actually the highest aerosol event ever recorded in Lille, with AOD@440 reaching 2.9. Almost no AOD data was available in the standard AERONET retrievals, since these extreme values were filtered out in the processing. The tests demonstrated that with GRASP it was possible to retrieve aerosol size distribution and to discriminate the two aerosol modes (dust and biomass burning) using CIMEL almucantar measurements. This test demonstrates how the standard AERONET retrieval methods can be further improved for handling such extreme events.

[HIGH14] – GRASP is a versatile and accurate open source code for the retrieval of aerosol optical and microphysical properties from in-situ and remote-sensing measurements. The tests on CIMEL sun/sky photometer measurements demonstrated the current limitations of AERONET operational retrieval scheme when processing extreme aerosol events. The long-term goal of the project is to further demonstrate the added value of GRASP, which could eventually become the standard retrieval scheme within AERONET European operational processing chain. This project has a clear strategic importance, since AERONET is the World's largest validation network for aerosol, which contributes to the validation of a large number of missions, in particular optical and atmospheric missions.

Martin Tiefengraber (Luftblick) reported the latest updates from the Pandonia Fiducial Reference Measurements (FRM) project. Pandonia is a ground-based Cal/Val network for atmospheric observations, mainly of O3 and NO2 total column. The network is composed of Pandora-2S instrument, which is a technological evolution of the Pandora system, originally developed at NASA. The objective of the IDEAS+ project is to support the instrument characterization and evolution and consolidate the Pandonia network set-up in order to prepare its operational deployment. The Pandonia project, incubated within IDEAS+, is now sustained by a dedicated contract at ESA; however, some additional updates on the instrument and SW side are still supported in the frame of IDEAS+. Upgrade in the NRT processing of Pandonia measurements were presented. In addition, a new and more stable tracker system was prototyped in order to address the operational issues identified in the deployment of the Pandora-2s. The collaboration between ESA and NASA for setting up and maintaining the Pandonia global network is on its way with a clear interest on both parties. Finally, examples of O3 and SO2 total column retrieval from Pandora's measurements are shown.

[HIGH15] – The development and upgrade of the Pandonia global network is a clear example of how IDEAS+ contributed to the advances of validation infrastructure, which are vital for supporting Cal/Val activities of various atmospheric mission, in particular Sentinel-5P. IDEAS+ Task 3 was pivotal to the development testing and verification of the Pandara-2s system, which is now operated as part of the Pandonia ESA network and will serve as main source of validation data for Sentinel-5P mission.

Annamaria Iannarelli (Serco) presented the status of the BAQUNIN (Boundary-layer Air Quality-analysis Using Network of Instruments) project. The objective of the project is to set up a "super-site" for supporting the validation of satellite atmospheric composition products. The super-site is composed of a suite of active and passive instruments operating in synergy for providing quantitative information on a wide range of atmospheric parameters. The same suite of sensors is replicated in two locations in the Rome area at 10 km distance, one in the urban environment ("La Sapienza" University) and one in the rural sub-urban environment (CNR in Tor Vergata). The rationale of this set-up is to cover two different atmospheric conditions, one in a very polluted area, in the city center, and one in a more pristine environment, so that to allow validating extreme and background concentration of anthropogenic molecules, such as NO2. Examples are shown on the use of the BAQUNIN suite of sensors to study extreme fire events in the Roman areas occurred during summer 2017. The various instruments provide a consistent and complementary picture of the impact of such fires on the atmospheric concentration; in particular, aerosol properties retrieval allows for clearly identify the changes in microphysical properties induced by this anthropogenic emission. This super-site will be further used to support atmospheric process study in the PBL and to support external Cal/Val campaigns, such as the EMeRGe campaign, lead by Uni. Bremen. Additional contribution to the QUATRAM (QUAlity and TRaceabiliy of Atmospheric aerosol Measurements) campaign is presented, to work toward traceability of atmospheric in-situ measurements through inter-calibration and comparison to standard reference instrument.

[HIGH16] – The BAQUNIN project is another example of how the IDEAS+ Cal/Val framework can provide the means to develop, test and prototype new concepts, which can reach the level of maturity to sustain an operational implementation. This project will now continue as part of a new ad-hoc ESA contract, and it will actively contribute to the validation of Sentinel-5P and EarthCARE missions.

Enzo Papandrea (Serco/CNR) illustrated the status and results of the IDEAS+ project on the evolution of the AIRWAVE algorithm. This algorithm exploits the dual view capabilities of ATSR sensors family to retrieve Total Column Water Vapour (TCWV). The method is applicable to all ATSR series of sensors allowing

therefore to potentially retrieving a long-term data record spanning more than 20 years. The v2 of AIRWAVE is an advanced version of the algorithm allowing improved TCWV retrievals. In a second part of the talk E. Papandrea showed the use of the TCWV retrievals to study the Inter-Tropical Convergence Zone (ITCZ) dynamic. Understanding ITCZ variability is essential for improving global climate models. Finally, the upgrade of AIRWAVE algorithm for S3-SLSTR measurements was presented; the first results are encouraging, as demonstrated by validation with coincident SSMI measurements. The main evolution in the next phase of the project will be to extend the applicability of the algorithm also to land, where the dependence on the surface emissivity needs to be disentangled. In order to address this issue, the use of emissivity database or retrievals from SEVIRI is being tested; this will be the subject of future work.

[HIGH16] – The AIRWAVE algorithm allows for the first time to retrieve TCWV from ATSR sensor family exploiting its dual view measurement capabilities and it is directly applicable to Sentinel-3/SLSTR over water pixels. The extension of the algorithm over land required the use of external datasets in order to disentangle the dependency on surface emissivity; this will be the subject of a dedicated study.

Paolo Castracane (RHEA) reported on the status of the ESA project called FRM4GHG (Fiducial Reference Measurements for Ground-Based Infrared Greenhouse Gas Observations). The project builds upon the current state of the art GHG validation network: TCCON (Total Carbon Column Observing Network), consisting on 28 globally distributed sites of Fourier Transform Infrared spectroradiometer (FTIR). The objectives of FRM4GHG is to complement the TCCON network, by carrying out a collocation exercise of several low-cost portable FTIR instruments, measuring the same integrated columns of various GHG, in particular CO and CH4, as well as CO2, H2O and O2. The collocation campaign was performed during Mar-Oct 2017 and preliminary results of retrieved total column concentration are presented. The project will continue with the objective to collect valuable validation measurements to support Sentinel-5P CO and CH4 validation. Furthermore, measurement protocols and guidelines will be prepared for the development of new observation sites, which could complement in the future the TCCON network.

[HIGH17] – The FRM4GHG project is part of the enduring effort of EOP-GMQ section in promoting, developing and sustaining the adoption of a metrological perspective for Cal/Val with focus on SI traceability and uncertainty estimation. This project will eventually contribute to Sentinel-5P validation activities, and provide guidelines for expanding the TCCON network with new validation sites.

Gabriele Brizzi (Serco) presented the status and updates from the IDEAS+ project on the recalibration and reprocessing of Odin SMR mission. Odin is a Swedish-lead mini-satellite launched in 2001 and still operating after more than 16 years in orbit. The payload includes the Sub-Millimetre Radiometer (SMR) and the Optical Spectrograph and Infrared Imaging System (OSIRIS). SMR measures atmospheric thermal emissions in the 486-581 GHz frequency range using a limb scanning observation geometry, target species include: O3, ClO, N2O, HNO3, H2o, CO. The current SMR O3 dataset (v2.1) shows documented biases with respect to other well-validated reference datasets, such as SCIAMACHY and MLS. These biases are the main motivation for this project, which aim is to solve the known calibration and processing issues in order to solve these inconsistencies. Preliminary results from the project were presented showing a substantial improvement in Level-1 quality and long-term stability with resulting improved consistency with correlative satellite measurements.

[HIGH18] – The reprocessing of the full Odin-SMR archive (since 2001) with improved calibration and temporal stability will provide a valuable and extended dataset to the atmospheric chemistry community, which could be input to a number of scientific studies.

Daniele Casella (Serco) presented the status and updates from the IDEAS+ project on SMOS Sun Brightness Temperature (BT) assessment from Level 1 products. SMOS is an ESA Earth Explorer mission launched in 2009 with the primary goal to retrieve soil moisture and ocean salinity at global scale. The mission primary payload is the MIRAS (Microwave Imaging Radiometer using Aperture Synthesis) three-arms antenna array. The sun appears in SMOS measurement as an unwanted contamination, which is characterized and removed as part of the Level 1 processing. The idea of the project is to assess the validity of the sun BT signal measured by SMOS by comparison to ground-based observations from the US Air Force

Radio Solar Telescope Network (RSTN). The results are extremely satisfactory, showing a very high correlation with ground-based observation of Solar Flux, especially for major solar flare events. The outlook of the project is further extending the validation and to work toward a tailored SMOS scientific product for supporting space weather applications.

[HIGH19] – The SMOS Sun-BT project demonstrated how an unwanted contamination, the sun signal, if well characterized, could become a new stand-alone product, widening the domain of applications of an EO mission. The first validation results are very promising, showing how accurate the sun signal is estimated and paving the way for the development of a SMOS sun tailored product for space weather applications.

2.6 Final Discussion

During the final discussion session, participants were asked to provide feedbacks on the current status of IDEAS+ Task 3 projects and recommendations for potential improvements.

Overall, the IDEAS+ Task3 concept proved successful in fostering advances in Cal/Val methodologies and infrastructures, algorithm baseline and products definition. Several examples were shown, of concepts being prototyped within IDEAS+, which found their way in an operational environment, such as Pandonia network, the ACIX protocols, the BAQUNIN super-site, the GRASP retrieval, the AIRWAVE algorithm. IDEAS+ framework was also successful in promoting synergies, in particular between instrument experts, metrological laboratories and algorithm developers.

The practice of having 9-months periodic Workshops, bringing together the different members of the IDEAS+ Task-3 contract, was discussed. It was acknowledged that the "formula" of a broad meeting, while being not ideal for discussing very specific question, it's very valuable in addressing crosscutting issues, such as uncertainties estimates, Cal/Val protocols, and retrieval schemes. As a matter of fact, several members of the Task-3 provided a positive feedback on the interest of these Workshops for communication exchange in a very broad and open context.

[REC-2] – It is recommended to continue organising IDEAS+ Cal/Val Workshops with a broad scope, including all Task3 teams; this practice was recognized as instrumental for addressing cross-cutting issues, which are the foundation of IDEAS+ activities, e.g. Cal/Val protocols, uncertainty estimate.

The discussion moved then on the uncertainty, in particular, on the strategy to be put in place to further promote the adoption of a metrological approach in uncertainty estimation. The "Uncertainty Workshop" was successful in providing a state-of the art on the subject and in fostering the use of community accepted best practices. However, there is a recognized need to clearly demonstrate the benefits of uncertainties for the society; a first action consists in identifying some case studies, even if simplistic, to demonstrate evidence of that, in particular toward the policy-makers. This is considered the real challenge, but it is vital in order to better "sell" the importance of Cal/Val activities. ESA SPPA section with the help of IDEAS+ Task 3 teams should work along these lines. Furthermore, education should continue, training should be organised and the adoption of common terminology should be promoted in international Workshops and Symposia.

[REC-3] – To move forward on the need for uncertainties in EO products, in particular, the benefit of uncertainties for the society should be demonstrated with case studies. This will be crucial to better "sell" the relevance of Cal/Val activities to policy makers.

[REC-4] – To continue supporting education and training activities for uncertainty estimation. The long-term objective is to promote the adoption of common terminology and methods.

An additional point of discussion was about data exchange, tools and communication. In particular, links should be facilitated with external Cal/Val teams and projects, such as MPC and FRM projects. ESA is already engaged in ensuring that these links are put in place.

Furthermore, the need for reinforcing synergies and collaboration among the various Cal/Val networks and the metrological institutes was underlined. This is one action to be follow-up in the frame of future IDEAS+ evolution, and it goes along the lines of ensuring traceability of ground-based measurements for Cal/Val.

[REC-5] – ESA to facilitate synergies between Cal/Val network providers and metrological institutes, in order ensure SI traceability to ground-based observations.

Finally, ESA thanked all teams for the high quality presentations, which will be made visible to higher ESA management. The date and location for next Cal/Val Workshop was agreed to be:

11 – 12 October 2018, to be hosted by PMOD, Davos.

3 APPENDIX A: AGENDA

ESRIN, Tuesday 12 Dec 2017

Introduction

09:00–09:15	Welcome and Introduction	P. Goryl, A. Dehn; ESA
09:00–09:15	Lessons learned from previous IDEAS+ Cal/Val workshops and current Meeting Objectives	F. Niro; Serco

Calibration, Traceability and Uncertainty

09:30–10:00	Summary and main Recommendations from the Uncertainties Workshop	N. Fox | NPL
10:00–10:20	Spectroradiometer Characterisation required for Traceable Solar Radiation measurements	J. Groebner | PMOD-WRC
10:20–10:40	Contributions to Pandonia by six Pandora-2s at globally distributed sites	J. Fischer | FUB
10:40–11:00	Further thoughts on automation of sensor data quality monitoring	S. Mackin | EOSense

Land and Cryosphere

11:20–11:40	Biophysical Parameter Retrieval and Validation at the Speulderbos site	B. Brede | Uni. Wageningen
11:40–12:00	Atmospheric Correction Inter-comparison Exercise for Sentinel-2 and Landsat-8 (ACIX): Status and updates	G. Doxani | Serco
12:00–12:20	First attempt of using the Proba-V MEP for Cal/Val: TOC products global validation over AERONET sites	E. De Grandis | Serco
12:20–12:40	Multi-data access / processing / sharing / export - A door open to on-the-fly (cross) calibration	S. Riazanoff | VisioTerra
13:40–14:10	Land Products Validation for Sentinel-2 and Landsat-8: Results and Lessons Learned from MBASSS project	R. Soffer |NRC (Webex)

Oceans and Coastal Zones

14:10 – 14:30	Uncertainty budget for ESA Level-2 processor for Ocean Colour applications	C. Mazeran| Solvo
14:30 – 14:50	Upgrade of the sky dome correction tools with the MERIS 4th reprocessing	F. Zagolski | ParBleu
14:50 – 15:10	Multi-Platform validations of altimetry for monitoring the variability of Coastal fronts: Status and Updates	J. Bouffard, M. Meloni |RHEA, Serco
15:10 – 15:30	Land/Water mask improvements (300 to 150m) and Quality control of the MERIS 4th Reprocessing	J. Wevers | Brockmann Consult

16:00–18:00	Discussion: lessons learnt, collaborations, recommendations, potential improvements, Phase 3 future activities	ESA. All

ESRIN, Wednesday 13 Dec 2017

Atmosphere

09:00–09:30	Current results on mobile system prototype development for Aerosol Cal/Val activities	P. Goloub | LOA
09:30–09:50	Advanced Aerosol retrievals combining LiDAR and Photometer	P. Goloub | LOA
09:50–10:10	Progress in the analysis of sensitivity tendencies in Aerosol Remote Sensing	B. Torres | GRASP
10:10–10:30	Pandonia updates: processing software and tracker	A. Cede | Luftblick
10:50 – 11:10	The Boundary layer Air Quality-analysis Using Network of Instruments (BAQUNIN)	A. Iannarelli, S. Casadio | Serco
11:10 – 11:30	AIRWAVE-related studies: validation, current applications and possible extensions of TCWV products	E. Papandrea, S. Casadio | Serco
11:30 – 11:50	Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG) project status and updates	P. Castracane | RHEA
11:50 – 12:10	Generation of a consistent Long Term dataset of stratospheric trace gases from Odin SMR data	G. Brizzi | Serco
12:10 – 12:30	SMOS L1 Sun BT Validation against on-ground radio-telescope network	D. Casella | Serco

Discussion and Recommendations

13:30 – 15:30	Discussion: lessons learnt, collaborations, recommendations, potential improvements, Phase 3 future activities	ESA, All
15:30–16:00	Meeting wrap-up and Recommendations Date and scope for next Cal/Val Workshop	F. Niro | Serco

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.	Ferran Gascon	ESA-ESRIN	Italy
5.	Clement Albinet	ESA-ESRIN	Italy
6.	Jerome Bouffard	RHEA	Italy
7.	Paolo Castracane	REHA	Italy
8.	Gareth Davies	Serco	Italy
9.	Fabrizio Niro	Serco	Italy
10.	Stefano Casadio	Serco	Italy
11.	Raffaele Crapolicchio	Serco	Italy
12.	Daniele Casella	Serco	Italy
13.	Gabriele Brizzi	Serco	Italy
14.	Georgia Doxani	Serco	Italy
15.	Marco Meloni	Serco	Italy
16.	Erminia De Grandis	Serco	Italy
17.	Marta de Laurentis	Serco	Italy
18.	Sabrina Pinori	Serco	Italy
19.	Annamaria Iannarelli	Serco	Italy
20.	Enzo Papandrea	Serco	Italy
21.	Philippe Goloub	LOA	France
22.	Benjamin Torres	LOA	France
23.	Constant Mazeran	Solvo	France
24.	Serge Riazanov	VisioTerra	France
25.	Francis Zagoslki	ParBleu	Canada
26.	Nigel Fox	NPL	UK
27.	Javier Gorrono	NPL	UK
28.	Steve Mackin	EOSense	UK
29.	John Swinton	Telespazio Vega	UK
30.	Alexander Cede	Luftblick	Austria

31.	Juergen Fischer	FUB	Germany
32.	Jan Wevers	Brockmann Consult	Germany
33.	Julian Groebner	PMOD-WRC	Switzerland
34.	Natalia Kouremeti	PMOD-WRC	Switzerland
35.	Benjamin Brede	Uni. Wageningen	Netherlands
36.	Fabio del Frate	Uni. Tor Vergata	Italy
37.	Daniela Meloni	ENEA	Italy
38.	Alcide di Sarra	ENEA	Italy
39.	Giandomenico Pace	ENEA	Italy
40.	Monica Campanelli	CNR-ISAC	Italy
41.	Rosamaria Salvatori	CNR-IIA	Italy
42.	Cristiana Bassani	CNR-IIA	Italy
43.	Dario Stelitano	INGV	Italy
44.	Dedalo Marchetti	INGV	Italy