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Lessons learned: 1st International Land Products Validation and Evolution Workshop, Frascati (ESA/ESRIN), Italy, 28-30 January 2014

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1 SUMMARY

The European Space Agency (ESA) organized a Workshop on Land Products Validation and Evolution (LPVE) held in Frascati (ESA/ESRIN), Italy, 28-30 January 2014.

The objectives of this first LPVE Workshop were to foster the development, assessment and improvement (evolution) of the broad spectrum of capabilities offered by current space-based Earth Observation technologies to address Land stakeholders information needs addressing National, Regional, and International interests. Participants were provided with the opportunity to present their latest research results, including the evolution of products and algorithms, the development of validation and inter-comparison methodologies, as well as new Earth Observation (EO) data usages.

The LPVE participants were asked to specifically address Land EO algorithm and validation issues, primarily for optical imaging, but also from radar, passive microwave sensors, and mixed/fusion retrievals. The workshop agenda (see Appendix A) consisted of 49 presentations with 90 participants from industry, government agencies, academia and national centres of excellence from Canada, US, China, United Kingdom and multiple countries from Europe, structured into the following six sessions:

1. Satellite missions and their Cal/Val plans Session(s)
2. Products and their Validations Session(s)
3. Albedo Session
4. Snow Extent Session
5. Land Surface Temperature Session
6. Radiometric and Geometric Validation Session

All presentations are available online at the ESA Cal/Val Portal:
(http://calvalportal.ceos.org/events/lpve).

The list of participants is given in Appendix B. The list of acronyms and abbreviations is given in Appendix C.

1.1 SESSION HIGHLIGHTS AND RECOMMENDATIONS

The key recommendations from the main topical sessions are summarised in the tables below.

1.1.1 Satellite missions and their Cal/Val plans Session(s)

Reference	Summary
Satellite missions and their Cal/Val plans	• Sentinel-2 - there will be extensive collaboration with other missions and teams in: sharing test sites and the exchange of methods/results; cross mission comparisons of TOA radiances; organisation of shared field campaigns, and; joint workshops for exchanging information on results and methods. • All calibration files should be archived to ensure complete reproducibility of processing of any product. It was also noted that Sentinel-2 Level 0 data would be archived, but not distributed to users. • Proper guidelines for ground measurements are needed, covering measurement devices, protocols, sampling and processing, and a guideline had been proposed. There have been difficulties in getting proper Sentinel-2 simulations from airborne campaigns. • It was considered important that CEOS should reinforce collaboration to leverage networks of sites. • DEMs: the importance of these was reaffirmed and the recommendation for Sentinel-2 to consider alternatives reinforced. • Provision of uncertainties must start with the sensor and should be performed for each step in the generation of a product as well as for the validation. Sensor characterisation and traceability are critical, since these are essential information required by the algorithms. Campaigns also help to focus thinking on uncertainties and traceability.

1.1.2 Products and their Validations Session(s)

Reference	Summary
Products and their Validation	• It was noted that the collection of ground measurements for the Sentinel-3 OLCI would help to increase OLIVE's dataset. OLCI can act as an equivalent of an airborne sensor for some sensor/product validations, even if the difference between sensing times is up to one week. • The difficulties in chlorophyll validation were discussed: this is not easy even at leaf level, and particularly challenging over mixed canopies of species, leading to the need for a good protocol. • Funding for Cal/Val will come to some extent via the MPCs, but campaigns need to be covered outside this. ESA support for ground measurements was considered particularly important. • It was noted that as there is a move to finer scales, the presence of measuring systems and operators could start to influence the measurements. With the scale of current sensor measurements being of the order of 10-20m, this is still minimal. • The quality and provenance of crowd-sourced measurements was noted as a topic

Reference	Summary
	for consideration to be managed. • The focus on Probability Density Functions is observation driven and is valuable in targeting what needs to be done to most improve the measurements, by showing where the limitations are with the input data. • It was noted that it can be difficult to get prior information for completion of the covariance matrices, though these can be inferred from the algorithms and experimented with. Atmospheric composition teams had gone through the process and derived algorithmic uncertainties, which had further improved the models. It was also noted that there is pressure coming from other fields to use optimal estimation. • The importance of differentiating between precision and accuracy was noted, and that both terms of uncertainty have to be defined. In quality terms, there is a need to look at estimates and then define confidence levels. The metrology (and air quality) communities had done this. • The usefulness of the validation stages was questioned. The crucial issue is to be open and positively critical of existing products to look for improvements. In particular, the focus needs to be on products that are not giving good results. • It was also noted that incidental data, e.g. through Fluxnet webcams can be useful and use of such data should be investigated.

1.1.3 Albedo Session

Reference	Summary
Albedo	• The albedo product (GlobAlbedo) does not yet reach the GCOS requirements and much work is still needed. However, it is to be seen if it already can improve climate forecasts. Although the GCOS requirements are important, there is a need anyway to know how good the products and the methods are and how they match with the GCOS field protocols. • Traceability of albedometers is important and ideally several are needed on each site. Overall, there is a need to validate the in-situ data, and e.g. to deal with noisy tower data. • It was noted that albedo has the advantage of measuring a quantity that is of direct interest and is also needed as input to FAPAR.

1.1.4 Snow Extent Session

Reference	Summary
Snow Extent	• From VIIRS experience, the validity of the cloud mask needs to be carefully examined and this is very challenging. It was also noted that snow information is an important input for other products and the use of binary snow presence needs to be interpreted carefully since much of the surface can be a mix. • It was clear that there are many commonalities with the land community, including issues of point/area measurements, cloud identification and the execution of campaigns. It is therefore important to understand how to link and

Reference	Summary
	exchange information between the cryosphere and vegetation communities. For MODIS, there are links with e.g. Crystal Shaaf on the land team and for VIIRS, there is an effort to bring the algorithm and data teams together. Specifically, the cloud masking work could be shared across the communities, and where aerosols/smoke differentiation can have large impacts. • It is clear that the challenges for SWE and SE are different, but both are very important to the hydrology community. SnowPEX is going to be a useful way to allow comparisons between snow products and is welcomed. Uncertainty measurements are important to include in future.

1.1.5 Land Surface Temperature Session

Reference	Summary
Land Surface Temperature	• The SST community has had radiometer comparison exercises and there was some participation from the LST community in 2008. • Further future participation over a land site could be useful for LST, including measurements of emissivity. • The use of Sodankylä was discussed, but an African test site would be more useful. • Measurements of spectral emissivity at test sites would also be valuable.

1.1.6 Radiometric and Geometric Validation Session

Reference	Summary
Radiometric and Geometric Validation	• It was noted that RADCALNET was a very valuable initiative, since it has been harder to get funding for validation. It was aimed to make the data available on the Cal/Val portal as far as possible with consistent outputs (the individual sites could retain data on their own access portals). • The relationship of RADCALNET to other networks was discussed; with it noted that feedback from others would be sought. • Stability was noted as very important, with variability (e.g. in aerosol loading) flagged in the data. Reflectance stability is the priority.

2 PROCEEDINGS

The main points arising from the presentations and discussions are summarised below. Recommendations are identified when they arose in the meeting, and collected in section 1.

2.1 Day 1: 28 January 2014

2.1.1 Introduction

Henri Laur (ESA, Italy) welcomed the participants to the meeting and explained that the workshop was the second in a series initiated by ESRIN, following on from the Atmospheric Composition Validation and Evolution (ACVE) workshop in March 2013 and the Arctic workshop planned for later in 2014 in Canada. The ESA involvement in EO programmes was evolving from pioneering missions such as the European Remote Sensing Satellites (ERS)-1 to the Sentinels, with the first launched in April 2014.

In this changing environment, the European Space Agency (ESA) still needs to maintain and build on the Calibration and Validation (Cal/Val) and algorithm evolution experience developed over the last 20 years. Europe has vibrant, mature and competitive EO communities, with strong institutional support for algorithm development, although less do for Cal/Val infrastructure.

ESA was aiming for the workshop to gather concrete recommendations for future algorithm improvements, Cal/Val requirements/activities and new products and hoped that it would encourage “out of the box" thinking and strengthen the communication between ESA and the algorithm and Cal/Val communities, and among the algorithm and Cal/Val communities. ESA wants to foster coordination between scientists, national space agencies, national research programmes and ESA with respect to algorithm evolution and Cal/Val, and relies on the expertise and support of the participants, as well as national involvement.

Bojan Bojkov (ESA, Italy) provided an introduction to the workshop, explaining that this was timely with the land products included in the Copernicus programme, with the changing environment of financial constraints, upcoming new missions and new requirements and the innovation in Information and Communications Technology (ICT). There is also a mature and dynamic scientific community, covering programmes such as the ESA Climate Change Initiative (CCI), the Support To Science Element/Data User Element (STSE/DUE) and Geoland. Therefore, the time is right to try to make sense of all of these activities, strengths, innovations and new opportunities. The product evolution and innovation cycle for products was shown, and the importance demonstrated of Cal/Val and product intercomparisons in the assessment of current products.

Important questions need to be asked in several areas:

- Current products assessment: for example, the uncertainties that need to be provided, the resolution of products, validation of low-resolution sensors by high-resolution sensors;
- Cal/Val and intercomparison: for example, whether the level 1 products are meeting the needs of the algorithm communities, whether the existing Cal/Val infrastructure is meeting all needs and if there is a risk of losing this and associated expertise, and;

- Product innovation and evolution: for example, if the turnaround on evolution is fast enough and if there are innovative products outside the established existing set that should be included in reprocessing.

The way forward from this workshop is to:

- Gather concrete recommendations and actions for future algorithm development and improvements;
- Gather Cal/Val requirements and define additional activities;
- Identify the need for new products, and;
- Improve feedback to ESA and the instrument QWGs.

The detailed requirements and actions for the way forward are summarised in this report in section 1.

There are numerous upcoming reprocessing projects of ERS/Envisat products and Cal/Val contracts to be set up, so this workshop can influence these. Innovative thinking is encouraged, to bring external product developments into ESA's operational processing, to encourage new ICT approaches and other technologies and prototyping, and to foster coordination and communications.

Although this workshop is focused on optical sensors, microwave EO is part of ESA's land portfolio. The LPVE workshop is part of a rolling programme, and future meetings can look at other aspects and EO technologies.

The similarities and differences in ESA and the National Aeronautics and Space Administration (NASA)'s interactions with the science teams about algorithms were discussed. The US Science Team is closest to ESA's Quality Working Group (QWG), with the QWG competing on the algorithms to use in operational processing, with the selected algorithm funded by ESA for development. However, ESA is coming to land products later than NASA.

2.1.2 Invited Speakers

Gyorgy Büttner (GIO land team (EEA), Denmark) presented "Copernicus Initial Operations Land: Services, current status and ideas for validation". The three components of the Global Monitoring for Environmental Security (GMES) Initial Operations (GIO) land were explained as global (Joint Research Centre (JRC)), Continental (European Environment Agency (EEA)) and Local (EEA), with data from 20 satellites being used. The workflow in generating the High Resolution Layers (HRLs) includes verification and error reporting, as well as independent statistical validation. The work is distributed in six regional lots covering Europe and harmonisation is required to ensure coherence and homogeneity of the products. All HRLs will be validated, with the plan to complete this by mid 2014.

The Coordination of Information on the Environment (CORINE) is mapping surface features at medium scale (Minimum Mapping Unit of 25m), with a bottom up approach of national teams contributing in a simple workflow. Two verifications take place in each country.

Validation of the HRLs uses higher resolution information, with feedback provided to future updates only and to inform users of the accuracy of the existing products. Validation is primarily of the map products but at least two products are also checked. Commission as well as omission errors need to be classified: there are difficulties to assess omission errors for classes with low occurrence. Sampling can use VHR data over an HR cell and scatter plots. The Validation tool for land cover and land cover change (LACOVAL), has been developed to support validation and provides sample generation, support to sample interpretation and validation report generation. Independent datasets used in validation include national orthophotos (access for these from 39 countries is not simple), Google Earth, Eurostat Land Use/Cover Area frame Survey (LUCAS) and Very High Resolution (VHR) data in a data warehouse.

Validation issues include ensuring consistency in the participation of the 39 countries, image acquisition bottlenecks, timing (with the aim of keeping less than 1 year between image acquisition and provision of the service outputs) and designing a meaningful validation is a challenge.

In summary, GIO land provides continued production of CORINE Land Cover and HRL Imperviousness, with new continental HR layers: forests, grassland, wetlands, water bodies. There are difficulties to have reliable reference data against which to validate and a methodological challenge to validate low occurrence classes. Results are expected from mid 2014 and a freely accessible, validated source of land cover information for Europe underpins a broad range of the European Commission (EC) policies and complements national data. GIO land brings Copernicus land services to a fully operational status.

In the following discussion, managing the outputs of the six service providers was elaborated. The outputs are monitored for semantic checks with final checks at the final European output level. The service provider performs the validation, but independence is wanted and steps are being taken to ensure an independent validation.

The 20m products will be made available, but will not be validated. The use of in situ and airborne data for validation were discussed, but while airborne data are useful, there are issues of practicality.

Patrice Henry (Centre National d'Études Spatiales (CNES), France) presented the Theia Land Data Centre (www.ptsc.fr), which is a land surface data centre involving nine public institutions to address the needs of the national science community, providing products, methods and training. It facilitates access to and use of data and increases the visibility of national efforts.

Theia consists of a Space Data Centre, Scientific Expertise Centres and an overall organisation structure. It includes VHR, HR and biogeophysical products, and is intended to include Sentinel-2 data. It is supplementary to the Copernicus Services portfolio. The Theia portal is intended be developed to provide services for on-line processing. The Space Data Infrastructure is linked together by the core components, and further centres (national or European) could be added.

Theia at a national level provides a platform of collaboration on joint national strategic activities, such as development of the Spot World Heritage project, use of the Pléiades and the Système Pour l'Observation de la Terre (SPOT)-6/7 data and use of Sentinel data (in particular Sentinel-2). Theia at European level facilitates the interface with national efforts in European Core Services, includes networking with other countries. There is frequent contact with the German Aerospace Center (DLR) and long standing cooperation with Belgium (Flemish Institute for Technological Research (VITO), Université Catholique de Louvain (UCL)), Austria (University of Wien), Portugal (Institute of Meteorology (IM)).

Examples of Theia products and correction algorithms were also shown, including simulation of Level 1, Level 2 and Level 3 products, cloud and snow mask validation, atmospheric correction and its validation, surface reflectance validation.

In conclusion, Theia supports future change by paving the way for a wide use of remote sensing data by a larger community of users, specifically preparing for the use of Sentinel data and supporting the needs for long time series of data (consistent data set). It stresses the need for a systematic and rigorous validation of the products through development of automatic processes to validate the product quality (geometry and radiometry), supplemented by external validation (network of validation sites, scientific expertise teams).

In the following discussion, it was clarified that the added value of Theia is in the higher-level products than covered by Copernicus. Theia supports CNES objectives in the SPOT heritage programme of orthorectified data and Sentinel-2 Level 2A processing.

Bernard Pinty (JRC, Italy) presented on "Climate Change Service - State of Play and next steps". European Union (EU) regulation requires access to climate change information from 2016, including climate change fingerprints. A consultation process has been followed including Helsinki meeting and GMES User Forum and the sixth Framework Programme (FP)-7 call prioritises this activity. The regulation supplements that of 2010 in support of climate change adaptation and mitigation, building on the Essential Climate Variables (ECVs), and projections (modelling). The service aims to capitalise on EC and other complementary activities (e.g. by ESA and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)).

The Climate Data Store includes ECVs (observed and simulated), with the Sectorial Information System tailored for the EU, including policy makers, in each of the key sectors. The system includes evaluation and outreach platforms and links or assigns the ECVs to sectors.

The plan is for the operational phase to be in place for 2017/18 and represents a large financial commitment. The information flow is form a delegated body – responsible for delivery – for advisory group evaluation, covering science and applications. Only after evaluation and quality control will information be made available on the portal.

In the discussion that followed, it was noted that there has to be confidence that the first sectors chosen will be successful, and not all can be expected to operational at the start. The selection is not reflecting relative importance of the sectors.

The delegated body has significant power and auditing and oversight were discussed. There is an annual basis of the work plan defining the body's activities and expert groups (not just at the European level) provide review of the activities. MyOcean and other projects have shown that it is important to have continuous evaluation, not just at the start of the project, and this lesson has been included. The Climate Data Store has to include the best and most complete inputs, and the expert evaluation groups can challenge the delegated body's choices. Data sources are also not limited to Europe.

Barbara Ryan (Group on Earth Observations (GEO), Switzerland) presented "Building a Global Land Observation Programme". The Global Earth Observation System of Systems (GEOSS) is a global, coordinated, comprehensive and sustained system of observing systems, providing information for the benefit of society. GEOSS aims to enhance decision making in nine Societal Benefit Areas (SBAs). Translation of these SBAs and science/application derived results to policy makers. GEO has 90 members, with global coverage, although some gaps exist in the southern hemisphere. There are 77 participating organisations, which can serve members as coordinating bodies. It is being broadened further by the commercial sector (data providers, value added providers and downstream users (including in the economic sector). GEOSS' remit includes in-situ data.

GEO's objectives are to improve and coordinate observation systems, advance broad open data policies/practices, foster increased use of EO data and information and build capacity.

As an example of how GEO operates, Crop Information for Decision-Making aims to enhance stability in crop pricing which leads to stability in the supply.

Data sharing principles are for full and open exchange of data, with provision of data and products with minimal delay and cost (cost of reproduction or free of charge, where a government may pay for the reproduction costs on behalf of the end-user).

The GEOSS portal allows users to get access to (or at least discover) all data held e.g. by EEA or the United Nations Environment Programme (UNEP), through the Data Access Broker. Free and open access to data has been proven through Landsat to enhance take up and use of data. When Landsat data were being sold, a maximum of about 53 scenes on average were being bought per day: after free access was given, about 5700 scenes per day are delivered by web. In the paid-for era, users were paying for the data, but often as part of government projects. Since opening up the data, more people are using the products, in particular being able to do large scale surveys and change detection, (through access to archived data) which involve large datasets that would have been prohibitively expensive in the past.

A parallel was drawn with the World Meteorological Organization (WMO): advances in weather forecasting have been marked from 1987, such that the southern hemisphere forecast reliability is closer to that of the northern hemisphere, this being down to the use of satellite data and open data policies.

In summary, broad open data policies and practices are essential for publically funded collections, with the economic value in downstream elements (value-added products and services). In situ observations and their networks need to be supported. National, regional and international collaboration is essential. Atmospheric developments over the last 50-100 years can serve as a model for terrestrial and oceanic domains.

In the discussion that followed, the importance of a global perspective was emphasised, for example the Himalayan region has huge importance for water supplies, needing not just a national view, also considering the less developed countries in the region.

Bojan Bojkov (ESA, Italy) summarised the key themes emerging from the session, with protected data access proving a particular challenge. Timely access to data (in-situ as well as satellite) is a key need. Validation data and protocols are critical, particularly ensuring access and interoperability of different data sets, algorithms and evaluation processes. GEO can be a good example of the application of many of the points brought up in bringing together so many players and datasets.

Satellite missions and their Cal/Val plans

Ferran Gascon (ESA, Italy) presented on Sentinel-2 algorithms and the Cal/Val plan. Consisting of two spacecraft, the mission will include systematic acquisition of all land surfaces between 56ºS to 84ºN, closed seas, major and EU islands and Cal/Val sites. A Calibration and Shutter Mechanism (CSM) has a diffuse that covers the whole Field of View (FOV).

The products include a Level 2A Bottom Of Atmosphere (BOA) radiance product in cartographic geometry, which is generated via the user toolbox. Geometric and radiometric data quality targets are set for each product. Details are the Mission Requirements Document (MRD) at: http://esamultimedia.esa.int/docs/GMES/Sentinel2_MRD.pdf.

The algorithms have been developed in collaboration with CNES. The Level 2A includes a cirrus correction (using the cirrus band at 1375nm) before Top Of Atmosphere (TOA) to BOA correction.

The Cal/Val Plan defines how the baseline product quality requirements will be met throughout the mission. The Operational phase is planned to start at Launch +3 months after completion of the in-orbit commissioning phase and the Cal/Val activities will be performed by the Mission Performance Centre (MPC). The plan defines the activities for radiometric and geometric calibration and validation at Level 1 and Level 2A. A key activity will be to generate the Global Reference Image (GRI), with the process obtaining a full repeat cycle dataset of well-localized monospectral Level 1B images (band 4, red) which will be used as reference images in the processing chain. The GRI will be available at launch +9 months. Validation sites will include Greenland, other snow sites and deserts, with the aim of validating the equalisation and absolute radiometric performance.

In summary, there will be extensive collaboration with other missions and teams in: sharing test sites and the exchange of methods/results; cross mission comparisons of TOA radiances; organisation of shared field campaigns, and; joint workshops for exchanging information on results and methods.

In the discussion that followed, it was clarified that the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) at 90m will be used, but alternatives are being considered. The effects on the atmospheric correction of the geometry of the pushbroom sensor viewing were discussed. After correction, some misregistration will remain particularly affecting 10 m data over clouds.

Martin Bachmann (DLR, Germany) presented on Data Quality Assurance for hyperspectral Level 1 and Level 2 products: Cal/Val/Monitoring procedures within the Environmental Mapping and

Analysis Program (EnMAP) Ground Segment. The quality assurance activities for EnMAP are founded on meeting the growing need for reliable and well-documented data and follow the Quality Assurance Framework for Earth Observation (QA4EO)'s key requirement that all data and derived products must have associated with them a Quality Indicator based on documented quantitative assessment of its traceability to community agreed reference standards. EnMAP is to be launched at the end of 2017. It has a number of onboard calibration modes and planned intervals for calibration; per example, sun calibration will be assessed during the commissioning phase in assessing drift and considering the lifetime of the shutter and the time to process the calibration data.

Quality control includes automated activities within the data processing chain, interactive procedures and independent validation. For example, at Level 1, the activities include Bad (dead & suspicious) pixel flagging, saturated pixel flagging (including blooming), non-linearity correction, dark signal correction, Residual Non-Uniformity (RNU) correction, gain matching (Visible and Near-Infra-Red (VNIR)), spectral referencing, spectral/spatial straylight correction, radiometric referencing, Quicklook (QL) generation and cloud-haze and land-water masks generation. Data Quality Indicators are grouped in radiometry (e.g. artefacts related to radiometric calibration (striping, banding), artefacts related to dual gain), image properties (e.g. saturation (cross-talk, blooming), other artefacts/suspicious pixel/repetitive pattern, error messages in virtual channel, sensor and processor log files) and environmental conditions during acquisition (e.g. sun elevation, percentage of cloud, haze, cirrus and cloud shadow, average scene visibility/Aerosol Optical Thickness (AOT)/Water Vapour, problems in atmospheric correction, artefacts related to terrain correction/DEM, etc.).

External validation is performed with international partnerships being established for EnMAP Cal/Val activities (e.g. Committee on Earth Observation Satellites (CEOS)). Comparison of EnMAP user products to in-situ reference measurements will be made, including use of field campaigns with in-situ measurements of atmospheric and surface parameters and it is aimed to benefit from joint effort with ground-based science activities. Scene-based further validation from scene-based data analysis will also be performed, with user products and intermediate parameters to be analysed and sophisticated models and image processing techniques involved in what are 'scientific' rather than 'operational' activities.

In summary, the EnMAP data quality and Cal/Val approach includes:

- Calibration and monitoring: on-board calibration sources and sun calibration, with procedures taking into account life-limited items;
- Data Quality Control (QC) within pre-processing chain: integrated within Level 1/Level 2geo/Level 2atm processors, generation of QC-related metadata, QC flags + reports and interactive procedures for additional parameters, and;
- Independent validation, including ground-based Cal/Val activities.

In the discussion that followed, it was confirmed that the Level 0 would be archived with the appropriate calibration data for reprocessing in case of further improvements in knowledge. All calibration files should be archived to ensure complete reproducibility of processing of any product. It was also noted that Sentinel-2 Level 0 data would be archived, but not distributed to users.

Frédéric Baret (Institut National De La Recherche Agronomique (INRA), France) presented 'Validation of Sentinel-2 Biophysical Prototype Products using ESA Field Campaigns'. The objectives are to provide a first evaluation of Sentinel-2 Level 2B potential land biophysical product performances (Leaf Index Area (LAI), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Canopy Chlorophyll Content (CCC) and Canopy Water Content (CWC)) and to propose guidelines for the validation of decametric products as well as additional campaigns. Ground measurements were assessed from existing campaigns, highlighting that different methodologies had been used, often poorly documented, mainly over crops, and showing the guidelines are necessary. Airborne instruments' data had proven hard to match to Sentinel-2.

The results had shown large discrepancies between the LAI algorithms, with the Satellite Application Facility on Land Surface Analysis (LSA SAF) showing higher consistency. FAPAR, CCC and CWC have also been compared and FAPAR has shown good results generally, with also relatively good performance for CCC and CWC.

In summary, proper guidelines for ground measurements are needed, covering measurement devices, protocols, sampling and processing, and a guideline had been proposed. There have been difficulties in getting proper Sentinel-2 simulations from airborne campaigns. There are significant issues over geometric uncertainties, radiometric calibration, atmospheric correction and spectral sampling, hence only a few campaigns have been exploited, and additional campaigns are needed (e.g. over forests). The Sentinel-2 Customer Furnished Item (CFI) algorithm shows potential, and needs further validation including over simulated 3D scenes. Non CFI (spectral indices) probably need a better calibration and all algorithms will probably need fine tuning when actual data will be available. There is potential for application to other sensors (e.g. Landsat-8, Disaster Monitoring Constellation (DMC)) and compositing/fusion algorithms are needed to fully exploit the temporal dimension. There is also a need for specific algorithms for LAI, CCC and CWC exploiting knowledge on the land cover.

In the questions that followed, the horizontal aspects of the FAPAR algorithm were discussed. The edges have tried to be avoided, but in future, the adjacent pixels will be looked at to see horizontal fluxes.

John Dwyer (US Geological Survey (USGS), US) and **Brian Markham** (Goddard Space Flight Center (GSFC), US) presented 'Calibration and Performance Monitoring of Landsat Missions and Validation of Derived Information Products'. The performance requirements driving the pre-launch calibration and commissioning phase of Landsat-8 were described, covering radiometric, spectral, spatial and geometric aspects. The addition of the split thermal channels to the Thermal Infrared Sensor (TIRS) compared to the Enhanced Thematic Mapper (ETM)+'s single band was discussed, with the resolution sufficient for irrigation monitoring.

Calibration acquisitions for the Operational Land Imager (OLI) were discussed; highlighting that Landsat-8 is an agile spacecraft allowing solar calibrations, lunar calibrations, and side slither.

The OLI radiometric calibration shows that its performance exceeds the requirements, with in particular the Signal to Noise Ratio (SNR) significantly better than ETMS+. Uniformity of the Fine Pointing Mechanisms (FPMs) still shows some discontinuities (as large as 1%) and reprocessing will correct for some of the inconsistencies. In general, OLI is performing extremely well radiometrically, with good stability, and Absolute Radiance Calibration generally within ±2% of vicarious measurements (SWIR2 is an outlier at 5%) and Absolute Reflectance Calibration generally within ±2% of vicarious measurements (with CA and Blue at 4-5%). It was noted also that over 1200 ETM+ scenes from under-flight of Landsat-7 had been acquired.

For spatial performance, bridge targets and geometric performance of both OLI and TIRS is excellent and meets all requirements.

The co-alignment between OLI and TIRS shows that the TIRS FOV is fully contained within that of OLI. It was also noted that as a consequence of yaw steering, the Landsat-8 scenes are more rectangular (less Earth rotation skew) than heritage Landsat scenes.

TIRS noise levels and spatial uniformity are good, though some issues are still to be closed out, specifically, analysis is continuing on banding/streaking and absolute calibration, using special lunar collects to characterize ghosting, re-examination of TIRS stray light model and enhanced vicarious calibration data analyses.

In comparison to ETM+, the cirrus band is providing additional useful information, and the increased dynamic range avoiding saturation. The decreased noise in the thermal channels is also very positive.

Moving from data to information, an archive of calibrated radiances enables the development of Climate Data Records (CDRs) and Essential Climate Variables (ECVs) covering: Surface reflectance; Surface temperature; Surface water extent (Lake Variables); Burned area (Fire Disturbance); Fraction of snow covered area (Snow and Ice) and; Global 30m Land Cover (Land Cover/Change).

For surface reflectances, the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) uses dark vegetated targets for atmospheric correction and works well for vegetated areas. The Landsat burned area ECV shows some over-attribution and work is continuing. The Landsat/ Moderate Resolution Imaging Spectroradiometer (MODIS) snow fraction covered area validation uses in situ data loggers measuring temperature (which require retrieval for download of logged data).

In the following discussion, it was explained that many of the Landsat-8 calibration sites are CEOS sites, though some are sporadic. The Landat-8 calibration team participates in CEOS and there is strong collaboration between ESA and NASA, also on interoperable products. It was considered important that CEOS should reinforce collaboration to leverage networks of sites.

In the overall discussion of the session, the availability of the Sentinel-2 Test Data Set (TDS) and toolbox was explained, with sample representative data available soon as well as the product specification. The toolbox was under development and would be available end-2014/early-2015. No specific validation campaigns were foreseen for biophysical products at present. Returning to the DEMs, the importance of these was reaffirmed and the recommendation for Sentinel-2 to consider alternatives reinforced.

2.1.3 Products and their validation (1/4)

Gabriela Schaepman-Strub (University of Zurich, Switzerland) presented 'Coordination of Validation Efforts of Satellite Derived Land Surface Products – Role and Recent Achievements of the CEOS LPV Subgroup'. The objectives and goals of the CEOS Land Products and Validation (LPV) subgroup are: to foster and coordinate quantitative validation of higher level global land products derived from remotely sensed data, in a traceable way, and to relay the results so they are relevant to users; to increase the quality and efficiency of global satellite product validation by developing and promoting international standards and protocols and; to provide feedback to international structures for requirements on product accuracy and quality assurance, terrestrial ECV measurement standards and definitions for future missions.

Focus areas have included product specific validation workshops on Phenology – September and December 2012, Soil Moisture – July 2013, Land cover and Fire – April 2013 and FAPAR – January 2014. Information is relayed to users through international meetings (e.g. American Geological Union (AGU) and European Geosciences Union (EGU)) and via the LPV website, http://lpvs.gsfc.nasa.gov/.

Analysis of the status of the validation of products based on the National Oceanic and Atmospheric Administration (NOAA) definition of stages shows that most are currently at stages 1-3, with the emphasis on stage 2. The product specific LPV workflow should follow the definition of a good practice protocol, identification of (in-situ) reference data sets, platforms for intercomparison and validation (e.g. the On Line Validation Exercise Tool (OLIVE)) and finally the evaluation and development of new validation methods.

Examples of Good Practice Protocols include: T10 – FAPAR - validation concept presented in December 2012, updated January 2014; T9 – Land cover – 'Good practices for estimating area and assessing accuracy of land change maps', Olofsson *et al*., in review and; T11 - Leaf area index - Good practices Version 2, released during the LPVE workshop.

Identification of (in-situ) reference data and sites forms an important part of the group's activities as also doe providing feedback is provided from the group e.g. through contributions to the GCOS Terrestrial Observation Panel and will be expanded in future through collaboration with QA4EO and GEO.

For the future, it was noted that space agencies increasingly invest in validation efforts of products. The mission of the CEOS LPV is to foster and coordinate validation (intercomparison and validation with reference data) across multiple products and to support and increase funding for independent operational validation efforts such as OLIVE.

In the discussion that followed, it was noted that CEOS has a commitment for any Cal/Val data provided by agencies to be freely available. Owners of in-situ networks' data can upload data to OLIVE. General support to the in-situ networks is needed to provide enough data. The quality of in-situ datasets is checked before upload to OLIVE, but more generally, quality assurance of in-situ data needs to be ensured in future. It is necessary to encourage in-situ data owners to upload more data to OLIVE.

Fernando Camacho (Earth Observation Laboratory (EOLAB), Spain) presented 'Quality Assessment and Continuous Quality Monitoring of Copernicus Global Land LAI/FAPAR ECVs products'. Global land service is a EU contribution to GEO/GEOSS and involves the production of global biogeophysical variables.

Quality control activities include quality of the products, and quality of the service itself as well as audits. The activities follow LPV guidelines and assess uncertainty by performing an exhaustive scientific validation, as well as continuous monitoring which aims to assess if quality levels are consistent. There is a cross-cutting check of consistency across variables using a Land Data Assimilation System.

Quality requirements have been defined for the variables, and the products assessed against them (e.g. showing that the requirements for FAPAR can be met). The Quality Assurance (QA) requirements include, for example, continuity and temporal consistency. Some of the procedures are already implemented in OLIVE, and some QA issues found can lead to new requirements on OLIVE. As an example of the procedures, comparisons are carried out between GEOV1 and MODIS C5 to assess spatial consistency.

Future evolution includes moving from 1km to 300m products using the Project for On-Board Autonomy-Végétation (Proba-V) and validation over a network of demonstration sites in collaboration with local users (e.g. setup of the Plant Are Index (PAI) Autonomous System from Transmittance Instantaneous Sensors (PASTISPAR) sensors for continuous monitoring of PAI/FAPAR).

In summary, the validation is generally to stage 2 as per the LPV definitions and there is good performance compared to other reference products. To support validation needs, continuous ground data provision over a network of sites is essential for validation of products (to reach Stage 3 and 4) and collaboration with local users is desirable for better assessment of the product quality.

Xiaohua Zhu (Chinese Academy of Sciences (CAS), China) presented 'Study on LAI Sampling Strategy and Product Validation over Non-uniform Surface'. The sampling methodology affects the scaling bias. The question to be considered is how to parameterise the scaling bias when distributed local ground measurements are not complete. Computational geometry models lead to a correlation index to represent how well a specific field measurement represents a specific product's larger pixel. The sampling strategy can then be based on the correlation index.

The Academy of Opto-Electronics (AOE) test site was used for LAI sampling and comparing the traditional and Correlation Index (CI) approaches. The CI results showed an improvement and further work is proposed to improve the process of the correlation index and to carry out a sensitivity analysis via simulation data and to further verify the method via real satellite data, and to improve the capabilities of the AOE site for sampling strategy investigations.

Joanne Nightingale (National Physical Laboratory (NPL), UK) presented 'Global Leaf Area Index Product Validation - Good Practices'. This best practices document has been published based on LAI products derived from 15 satellites. The validation of these products has been sufficiently mature to document in the best practices.

The work on the best practices document started in November 2009, with the first draft in February 2012 and Version 2 released in January 2014. The terms of reference were based on the Global Climate Observing System (GCOS) need to systematically generate LAI and to improve the satellite measurements and in-situ data. The activities included benchmarking and resolution of differences between products. The first version of the document tried to be too 'complete'; therefore certain aspects have been omitted from Version 2.

The document contains clear definitions including that of LAI, being defined as half the total green leaf area per unit horizontal ground surface area, and associated physical parameters and information.

In total, 42 recommendations are defined, for example, the need for archiving existing LAI reference maps and provision of updates of product metadata. The preparation of the document has highlighted the importance of having requirements and protocols defined that help to feed into the specification of mission and instrument requirements.

Nadine Gabron (JRC, Italy) presented 'The CEOS/WGCV LPV strategy for defining FAPAR intercomparison and validation protocols'. This followed a workshop earlier in January at Ispra, Italy. There are several requirements on FAPAR coming from GCOS but FAPAR is seen as a sub-product of other measurements, therefore is not seen as a priority of funding agencies. It was also noted that the definitions of FAPAR vary and products also vary.

Intercomparison of similar products can be performed at global, regional and site level. The definition of match-up follows that of the ocean community (e.g. defining a temporal variability).

The major actions are focused towards a CEOS LPV FAPAR network (based on actual ones), with best practices for field deployments and for sharing and distribution of field data etc. Towards intercomparison metrics, best practices for intersensor comparison, the role of OLIVE and best practices for intercomparison of algorithms are actions. Future steps include modelling in support of error and uncertainty assessment and assessing and developing emerging tools for FAPAR monitoring (new sensors, Unmanned Aerial Vehicles (UAVs), etc.).

In conclusion:

- For the global and regional comparison of products, agencies have to make an effort for providing global and regional and matchup products to the 'validation' community;
- Validation and comparison of EO products (and ground based data) and their retrieval, methodologies and protocols are mandatory;
- Algorithm benchmark can be provided by simulated EO data and ground-based measurements using 3D radiative transfer over realistic scenes (Radiative transfer Model Intercomparaison (RAMI) sites) and use of actual EO data from various instruments to run a round-robin exercise, and;
- Invitation letters are to be prepared to the main product providers of both EO products and ground-based data with a survey.

In the discussion that followed, it was noted that the match-up criteria are mandatory for oceans due to their rapid transient nature, but less stringent for FAPAR. It is relatively easy to specify the data to extract for match-up datasets, and then these can be routinely extracted. Users involved in validation need to be motivated and to be involved in performing in-situ measurements.

The differences in algorithms by mission were discussed and how they may be tuned to particular in-situ measurements. These are issues to be considered, as well as any assumptions in the algorithms and need to be propagated to the end products. For example, the MODIS algorithm does not deal with the scattering properties of leaves.

More generally, the lack of independence between in-situ data and satellite data is an important issue, and leads to a requirement to have a test sample reserved from the in-situ data for independent checks. It may be that a check of reasonableness rather than a full validation may be sufficient though. It was also noted that some algorithms – by being tuned to particular in-situ data – can only work in small areas and may not evolve to cover wider areas.

Error budgets are important, but also need to be validated.

Model based approaches can be used to compare with measurements. Although comparison issues arise as with in-situ data, models are widely accepted in the climate and ecological communities (though it was noted that the agricultural community is not accepting of models).

2.1.4 Albedo

Crystal Shaaf (University of Massachusetts Boston, US) presented 'Evaluation and Inter-comparison of MODIS and VIIRS Measures of Daily Albedo'.

Both morning and afternoon MODIS data are used, and many quality flags are generated. The retrievals are now daily at a 500m grid in V006, and use multi-date inputs with the emphasis on the centre date. Reprocessing is envisaged as new versions become available.

Validation is at Stage 3, but more validation data is required. Tower albedometry is a significant input, but funding for the networks is not secure. Spatial representativeness of the sites is an issue as well as how the sites change over time. Multi-angle airborne data are used for Bidirectional Reflectance Distribution Function (BRDF).

Snowmelt is an issue for the multi-day product, though more so for the climate modellers. Quality flags show the gap filling.

The Visible Infrared Imaging Radiometer Suite (VIIRS) was launched in October 2011 and the albedo products are not of comparable quality to those from MODIS. The early data were very unstable and showed large scatter compared to MODIS over the Sahara. Using the MODIS algorithms shows improvements. The Landsat-8 albedo product uses MODIS BRDF.

In summary:

- Production of the MODIS Daily V006 product is underway, with validation at spatially representative tower sites to Baseline Surface Radiation Network (BSRN) standards and using LPV protocols;

- Airborne Field campaigns of opportunity are used to provide validation data;
- Global gap-filled 30arc second Climate Modeling Grid (CMG) products are in production;
- VIIRS processing through MODIS heritage algorithms to generate climate quality continuity products and new NPP proposals were due in March 2014, and;
- Landsat Albedo products are available from Landsat-8.

Xavier Ceamanos (Centre National de Recherches Météorologiques (CNRM)/Météo France, France) presented ‘Land surface albedo and downwelling shortwave surface flux from MSG/SEVIRI in the EUMETSAT LSA-SAF project’.

Several Albedo products are generated and include uncertainty data. Accuracy shows 10-20% bias in visible (due to aerosols) and 5% for Short-Wavelength (SW) and NIR, with accuracy better for 10-day products. Two processing chains operate in parallel, the operational chain using aerosol climatologies, with the second using MACC. There are differences between the Monitoring Atmospheric Composition and Climate (MACC) and MODIS over bright targets. Times series field measurements in Portugal in 2010 showed that MODIS and the Spinning Enhanced Visible and Infrared Imager (SEVIRI) diverge at blooming of vegetation. The tower footprint is different compared to the satellite measurements.

For the shortwave radiation at surface product, two chains are also in use. The comparisons with the European Centre for Medium-Range Weather Forecasts (ECMWF) model and ground in-situ measurements showed that the improvement using aeroMix was 4-7 W/m^2. Despite using in-situ data as input to the algorithms, there are still significant differences in the measurements.

In summary:

- Improvements to the surface products are clear from validation;
- The importance of in situ measurements for validation means that:
    - Large spatial coverage and long temporal series are needed.
    - Spatial representativeness is a crucial issue for surface albedo.
- Other satellite and model products are important, but leads to inter-comparison issues;
- The importance of aerosol effects for Visible (VIS) albedo and SW radiation means that high quality aerosol data are needed;
- Continuous algorithm improvement is in the Continuous Development and Operations Phase (CDOP)-2;
- There is global coverage using polar MetOp satellites, and;
- Preparation for the arrival of the Meteosat Third Generation (MTG) is under way.

In the discussion that followed, it was clarified that for snow, comparisons had been performed with MODIS. It was also clarified that the tower is 14m tall, but the instruments are at the tree canopy.

Jorge Sánchez (University of Massachusetts Boston, US) presented ‘Continuous Quality Monitoring of Copernicus Global Land Albedo products based on SPOT/VGT observations’.

The Copernicus Global Land Service has been operational from 1st January 2013. Surface Albedo SPOT/VGT (Vegetation) V0 and V1 are produced every 10 days at 1km resolution.

Comparison to MODIS and direct validation using Fluxnet had shown good results. Spatial continuity was affected by snow/ice and also persistent cloud.

In conclusion, quality monitoring had shown that spatial consistency between the versions has been good. Continuity was worse in northern and equatorial latitudes. Statistical analysis had shown no bias and temporal consistency was with ground data (temporal realism) and previous years, although there were some difficulties in the detection of spurious snow events.

Geoland-2's Albedo Target Accuracy of Optimal: 5% and Target: 10% (AL>0.15) or 0.03 (AL<0.15) and Threshold: 20% had been met, though GCOS requirements were not. MODIS also showed similar accuracy results.

Proba-V will be used for a 300 m NRT product over Europe.

Jan-Peter Müller (University College London, UK) presented 'Lessons learnt from the ESA DUE GlobAlbedo land surface albedo product validation from European sensors'.

The objective of the project was to produce a 14-year record from 1km Land Surface Broad Band Albedo (BBA) every 8 days as well as 0.05º & 0.5º monthly from European space assets to provide an independent capability to generate this Essential Climate Variable. The Along Track Scanning Radiometer (ATSR)-2 and the Advanced Along Track Scanning Radiometer (AATSR) data had not been used due to geocoding issues. The data producers did validation, as they are most familiar with the issues involving production. Validation of geolocation, clouds, etc. was done qualitatively by looking at images.

Albedo validation used tower measurements, the Multi-angle Imaging Spectro-Radiometer (MISR)/MODIS and Meteosat. Only openly available tower data were used, and it was noted that open availability should be a prerequisite. Uncertainties were good over Germany, but worse over Greenland.

Fluxnet BSRN Toravere is a homogeneous site but has noisy data, especially at the start. Noise in other sites could be caused y snow or lack of data filtering. There is a strong correlation of uncertainties with blue-sky albedo

The following lessons had been learnt:

- There is no ideal set of "in situ" blue-sky (Bi-Hemispherical diffuse Reflectance (BHR)) albedo data. It is inherently very noisy and only covers a small fraction of an EO pixel;
- EO-derived results are generally very consistent with each other (with the exception of MeteoSat) but they are often offset from in situ;
- EO albedo results were all lower than tower for snow conditions (N.B. issue appears to be resolved when dealing with daily retrievals such as those from MODIS Collection 6);
- GlobAlbedo uncertainties are positively correlated with Blue Sky Albedo magnitudes and with standard deviation of differences;
- Triple collocation shows that GlobAlbedo and MODIS have similar behaviour even though relative entropy results indicate that there is little influence outside of persistently cloudy regions of MODIS priors on GlobAlbedo, and;

- All 1km tile-based BRDF and albedo mosaics at 0.05º, and all animations of time series are freely available on the website, www.GlobAlbedo.org.

In the discussions that followed, it was noted that the black sky albedo comparisons were included in the report, though not covered in the talk.

The albedo product does not yet reach the GCOS requirements and much work is still needed. However, it is to be seen if it already can improve climate forecasts. Although the GCOS requirements are important, there is a need anyway to know how good the products and the methods are and how they match with the GCOS field protocols.

Traceability of albedometers is important and ideally several are needed on each site. As noted in other sessions, there is a need to validate the in-situ data, and e.g. to deal with noisy tower data.

In conclusion, it was noted that albedo has the advantage of measuring a quantity that is of direct interest and is also needed as input to FAPAR.

2.2 Day 2: 29 January 2014

Relevant discussion complementary of Day 1 has been reported for Day 2.

2.2.1 Snow extent

Chris Derksen (Environment Canada, Canada) presented 'Validation of satellite derived snow cover data records with surface networks and multi-dataset inter-comparisons'.

Sari Metsämäki (Finnish Environment Institute, Finland) presented 'Cloud screening method particularly feasible for snow cover mapping'.

Igor Appel (NOAA, US) presented 'The Influence of uncertainty in cloud masking on the quality of VIIRS Snow Products'.

Kari Luojus (Finnish Meteorological Institute, Finland) presented the 'Evolution of ESA DUE GlobSnow products and Cal/Val Opportunities for Sentinels at the Sodankylä Supersite, Northern Finland'.

Thomas Nagler (ENVEO, Austria) presented the 'Intercomparison of Snow Extent Products from Earth Observation Data'.

Summary/concluding remarks:

From VIIRS experience, the validity of the cloud mask needs to be carefully examined and this is very challenging. It was also noted that snow information is an important input for other products and the use of binary snow presence needs to be interpreted carefully since much of the surface can be a mix.

It was clear that there are many commonalities with the land community, including issues of point/area measurements, cloud identification and the execution of campaigns. It is therefore important to understand how to link and exchange information between the cryosphere and vegetation communities. For MODIS, there are links with e.g. Crystal Shaaf on the land team and for VIIRS, there is an effort to bring the algorithm and data teams together. Specifically, the cloud masking work could be shared across the communities, and where aerosols/smoke differentiation can have large impacts.

In closing, it was clear that the challenges for Snow Water Extent (SWE) and Snow Extent (SE) are different, but both are very important to the hydrology community. SnowPEX is going to be a useful way to allow comparisons between snow products and is welcomed. Uncertainty measurements are important to include in future.

2.2.2 Satellite missions and their validation (2/2)

Miguel Román (NASA/GSFC, US) presented the 'Land and cryosphere Products from Suomi NPP VIIRS: Overview and validation status'.

Philippe Goryl (ESA, Italy) presented the 'Sentinel-3 with an Envisat perspective'.

Else Swinnen (VITO, Belgium) presented the 'Continuous terrestrial vegetation monitoring since 1998 using SPOT-VGT and Proba-V'.

Note: No general discussion at the end of this session.

2.2.3 Land surface temperature

Stefan Wunderle (University of Berne, Switzerland) presented the 'Lake Surface Water Temperature retrieval - a contribution for a LST data set'.

Jose Sobrino (Valencia University, Spain) presented the 'Calibration and Validation of land surface temperature for Landsat-8-TIRS sensor'.

Darren Ghent (University of Leicester, UK) presented the 'Application of a Land Surface Temperature Validation Protocol to AATSR data'.

Zina Mitraka (Tor Vergata University, Italy) presented the 'Uncertainty indices of high spatial resolution Land Surface Temperature over urban areas'.

Summary/concluding remarks:

The Sea Surface Temperature (SST) community has had radiometer comparison exercises and there was some participation from the Land Surface Temperature (LST) community in 2008. Further future participation over a land site could be useful for LST, including measurements of emissivity. The use of Sodankylä was discussed, but an African test site would be more useful. Measurements of spectral emissivity at test sites would also be valuable.

2.2.4 Products and their validation (2/4)

Nadine Gobron (JRC, Italy) presented the 'MERIS/OLCI land products validation'.

Eric Vermote (NASA/GSFC, US) presented the 'Sentinel-3 Science Products: A US Contribution'.

David Morin (CESBIO, France) presented the 'Estimation of Phenological Indicators and Irrigated Areas of Crops with High Temporal and Spatial Resolution Images'.

Dominique Carrer (Météo France, France) presented 'An Accurate Daily Aerosol Product for Surface Retrieval Applications Derived from MSG Geostationary Satellites'.

Summary/concluding remarks:

It was noted that the collection of ground measurements for the Sentinel-3 Ocean Land Colour Instrument (OLCI) would help to increase OLIVE's dataset. OLCI can act as an equivalent of an airborne sensor for some sensor/product validations, even if the difference between sensing times is up to one week.

The difficulties in chlorophyll validation were discussed: this is not easy even at leaf level, and particularly challenging over mixed canopies of species, leading to the need for a good protocol.

For Sentinel-3, there are bilateral agreements for validation between ESA and NASA. The call for validation was still open and allows easier or privileged access to the data. Data policy is free and open anyway, but being in the Cal/Val team will allow privileged and early access. Funding for Cal/Val will come to some extent via the MPC, but campaigns need to be covered outside this. ESA support for ground measurements was considered particularly important.

2.2.5 Products and their validation (3/4)

Frédéric Baret (INRA) presented 'A framework for the validation of decametric products'.

In the discussion that followed, it was noted that as there is a move to finer scales, the presence of measuring systems and operators could start to influence the measurements. With the scale of current sensor measurements being of the order of 10-20m, this is still minimal.

Brice Mora (Wageningen University and Research Centre) presented 'Access to global land cover reference datasets and their suitability for land cover mapping activities'.

In the discussion that followed, the quality and provenance of crowd-sourced measurements was noted as a topic for consideration to be managed.

Luigi Boschetti (University of Maryland, US) presented the 'Design-Based validation of the MODIS Global Burned Area Product'.

Martin Herold (Wageningen University and Research Centre, Netherlands) presented the 'Integrating different data sources for validating large-area Biomass Maps'.

Bernard Pinty and **Jean-Luc Widlowski** (JRC, Italy) presented 'About uncertainties and product validation'.

In the discussion that followed, the general approach was endorsed as had also been seen in work done at Goddard. The focus on Probability Density Functions is observation driven and is valuable in targeting what needs to be done to most improve the measurements, by showing where the limitations are with the input data.

Summary/concluding remarks:

It was noted that it can be difficult to get prior information for completion of the covariance matrices, though these can be inferred from the algorithms and experimented with. Atmospheric composition teams had gone through the process and derived algorithmic uncertainties, which had further improved the models. It was also noted that there is pressure coming from other fields to use optimal estimation.

2.3 Day 3: 30 January 2014

Relevant discussion complementary of Day 1 and 2 have been reported for Day 3.

2.3.1 Radiometric and geometric validation

Stephen Mackin (DMCii, UK) presented 'Self-Calibrating Satellite Imagers, how far can we go?'

In the discussions that followed, it was confirmed that any images could be used for striping detection without pre-selection. Pre-launch and post-launch SNRs can be compared, though the pre-launch measurements are generally at one radiance (according to the instrument requirements), and have shown close agreement.

Kurtis Thome (NASA/GSFC) presented 'RADCALNET, Radiometric Calibration Network of Automated Instruments'.

In the discussions that followed, it was noted that this was a very valuable initiative, since it has been harder to get funding for validation. It was aimed to make the data available on the Cal/Val portal as far as possible with consistent outputs (the individual sites could retain data on their own access portals).

The relationship of RADCALNET to other networks was discussed; with it noted that feedback from others would be sought.

Stability was noted as very important, with variability (e.g. in aerosol loading) flagged in the data. Reflectance stability is the priority.

Eric Borge (DLR, Germany) presented 'DEMMIN – a Calibration and Validation Site for Remote Sensing'.

Sindy Sterckx (VITO, Belgium) presented 'The inflight radiometric calibration of Proba-V: Results from the In-Orbit Commissioning phase'.

Philippe Goryl (ESA, Italy) presented the 'Prototyping a Network of Automated Land Radiometry Measurements: LANDNET'.

2.3.2 Products and their validation (4/4)

Jean-Luc Widlowski (JRC, Italy) presented 'A Model-based Quality Assurance Framework for the Validation of Satellite-Derived Biophysical ECVs over Land'.

Currently, there are very few bio-geophysical remotely sensed products in use in EU directives and environmental legislation. There are needs for a traceable framework of thematic CDRs and definition of product quality objectives (note that GCOS has defined some accuracy criteria). The field protocols of the ECVs need to be checked to see if they satisfy GCOS and allow the assessment of compliancy of ECVs to GCOS requirements. Unfortunately, even intensive field campaigns are unlikely to enable this, with the ability of detect non-compliance decreasing as the uncertainty of the FP increases.

It is important to define the target quantity before defining how to measure it. Typically, the field measurement does not measure all of the actual quantities or the same ones of interest, e.g. sampling leads to upscaling, and field measurements are converted via retrievals. This leads to sampling error and transfer bias.

The systematic bias of indirect FPs cannot be known since the transfer bias is not known. Indirect FPs can be evaluated by model-based virtual validation sites. In the remote sensing information extraction process, the characteristics of the measuring device, the observation scheme and the data processing are well characterised, whereas the target environment is not as well done. Verified 3D Monte Carlo RT models can be sued to fully describe the target location and will yield PDFs of bias. The fidelity of the models increases with more detail.

The benefits of the approach include: the ease of increasing the number of test sites; the protocol evaluation is based on performance with respect to a precisely defined reference criterion; all field protocols are tested under identical conditions; the methodology is apt for automation; the QA process is 'neutral' (no conflict of interest); enables selection of field protocols based on objective, criteria, i.e., their quality and 'fitness for purpose'; multiple field protocols can be 'equivalent' (inclusive rather than exclusive approach); allows the identification of issues with/ways to improve FPs and; it allows the assessment of the appropriateness of field protocols for purposes other than the characterisation of test sites. It can also be used for validation of the satellite sensor, as it needs to build on the instrument calibration (e.g. characterisation parameters of the sensor).

Validation can be viewed as a multi-truth problem: both atmospheric conditions and target properties imposed by space retrieval algorithms may deviate from those found or measurable in the field. Model-based QA of retrieval algorithms can deal with differing definitions of the products.

In summary, the requirements for a model-based approach are:

- Validated 3D MC RT model using deterministic objects;
- Detailed description of field protocol/algorithm, and;
- Large set of realistic vegetation environments.

The outputs are accuracy and precision characteristics (possibly subdivided per land cover type, etc.) of field protocols, with the following benefits:

- Cost, neutrality, aptness for automation;
- Evaluations based on absolute reference criteria;
- All field protocols tested under identical conditions;
- Selection of field protocols based on quality criteria;
- Multiple field protocols can be 'equivalent', and;
- Allows dealing with different 'truths' of applications.

In the discussions that followed, the importance of differentiating between precision and accuracy was noted, and that both terms of uncertainty have to be defined. In quality terms, there is a need to look at estimates and then define confidence levels. The metrology (and air quality) communities had done this.

Frédérick Baret (INRA, France) presented the 'On Line Validation Exercise (OLIVE): a web based service for the validation of medium resolution land products'.

Tao Che (Chinese Academy of Sciences, China) presented the 'Development and experimental verification of key techniques to validate remote sensing products'.

Bernard Pinty (JRC, Italy) presented 'A simple approach to evaluate land products from the TIP package'.

In the discussions that followed, the usefulness of the validation stages was questioned. The crucial issue is to be open and positively critical of existing products to look for improvements. In particular, the focus needs to be on products that are not giving good results.

It was also noted that incidental data, e.g. through Fluxnet webcams can be useful and use of such data should be investigated.

3 CONCLUDING COMMENTS

Bojan Bojkov (ESA, Italy) summarised the major points from the workshop in the two major themes of Cal/Val and product evolution.

For Cal/Val, provision of uncertainties must start with the sensor and should be performed for each step in the generation of a product as well as for the validation. Sensor characterisation and traceability are critical, since these are essential information required by the algorithms. Campaigns also help to focus thinking on uncertainties and traceability.

Test sites are essential and they should preferably be fully characterised and instrumented (for example RadCalNet (LandNet), Sodankylä, DEMMIN, etc.). Running specific campaigns may not be optimal for all products, and continuous operations can be needed to characterise annual cycles as complementary to biophysical campaigns. Timely and open access to both fiducial and satellite data subsets are key requirements. Additionally, global validation approaches (Vermote, Nagler, Romàn) are critical to address the representativeness of products on a global scale, which may not necessarily be seen through campaigns.

There is a need for “best practice” processing (like Aeronet, RadCoreNet) which is key for calibration as well as for product validation; feedback of comments and suggested improvements is welcome and essential. Closure experiments (for example that of JRC) can be a promising diagnostics tool. Improvements to Olive can be defined, and can also come from best practices.

For product evolution, the integration of uncertainties is essential if data are to be used for climate studies and is a requirement of GCOS. This requires end-to-end transparency and documentation and access to all data. There is interest in evolution to OE-type algorithms and in simultaneous land-atmosphere retrieval algorithms. Intercomparison protocols are defined by CEOS/WGCV/LPV (and other specialised WGs such as from WMO) and are key but need to applied consistently. Satellite to satellite comparison is an area needing further work.

Section 1 of this report includes the main recommendations of the workshop as collected in the meeting. Several critical needs have been highlighted, including the implementation of RadCalNet and its continued operations after 2016, with consideration needed for an equivalent network for land products. It was also noted that SnowPEX was to kick-off in Q1 of 2014.

The recommendations will feed into the three ESA Scientific Exploitation of Operational Missions (SEOM) Research and Development (R&D) calls for synergy land, Sentinel-2 land, and Sentinel-3 land. In addition, there will be calls for up to 10 projects focussed on Sentinel validation and evolution later in 2014.

Future workshops were welcomed, and it was noted that specific high-latitude workshops were already being planned (e.g. Canada in November 2014 and Poland in 2016). The breadth of this workshop was seen as a key factor in its success, allowing calibration groups to engage with the user communities and for specialised groups to interact to gain a better understanding of the diversity of the land communities, and common goals and issues. The poster session was commented on as needing further promotion.

The recommendations defined during the meeting are tabulated in section 1. These will be treated as action items by the space agencies.

APPENDICES

APPENDIX A: Final Agenda

1st International Land Products Validation and Evolution Workshop: Lessons learned, Frascati, Italy (ESA/ESRIN), 28-30 January 2014.

The presentations are available online at: http://calvalportal.ceos.org/events/lpve

28 January 2014

Introduction	
09.00	Welcome and Introduction (H.Laur, ESA)
09.15	Workshop Objectives (B. Bojkov, ESA)
Invited Speakers	
09.30	Copernicus Initial Operations Land: Services, current status and ideas for validation (G. Buttner, EEA)
10.00	THEIA - A new French Data Centre Dedicated to Land Surfaces (P. Henri, CNES)
10.30	Climate Change Service - State of Play and next steps (B. Pinty, JRC)
11.00	Building a Global Land Observation Programme (B. Ryan, GEO)
Satellite missions and their Cal/Val plans	
12.00	Sentinel-2 algorithm and Cal/Val Plans (F. Gascon, ESA)
12.20	Data Quality Assurance for hyperspectral L1 and L2 products - Cal/Val/Mon procedures within the EnMAP Ground Segment (M. Bachmann, DLR)
12.40	Validation of Sentinel-2 Biophysical Prototype Products Using ESA Field Campaigns (F. Baret, INRA)
13.00	Calibration and Performance Monitoring of Landsat Missions and Validation of Derived Information Products (J. Dwyer, USGS)
Products and their Validations (1/4)	
14.45	Invited talk: Coordinating Validation of Satellite-Derived Land Surface Products – Mission and Achievements of the CEOS LPV Subgroup (G. Schaepman-Strub, University of Zurich)
15.15	Quality Assessment and Continuous Quality Monitoring of SPOT/VGT LAI, FAPAR global products in the Copernicus Global Land Service (F. Camacho, EOLAB)
15.30	Study on LAI Sampling Strategy and LAI Product Validation of Non-uniform Surface (X. Zhu, CAS)
15.45	CEOS LPV Sub-Group Best Practice Recommendations for Global LAI Product Validation (J. Nightingale, NPL)
16.00	The CEOS/WGCV LPV strategy for defining fAPAR inter-comparison and validation protocols (N. Gobron, JRC)
Albedo	
17.00	Evaluation and Inter-comparison of MODIS and VIIRS Measures of Daily Albedo (C. Shaaf, University of Massachusetts)
17.15	Land surface albedo and downwelling shortwave surface flux from MSG/SEVIRI in the EUMETSAT LSA-SAF project (X. Ceamanos, CNRM)
17.30	Continuous Quality Monitoring of Copernicus Global Land Albedo products based on SPOT/VGT observations (J. Sanchez, EOLAB)
17.45	Lessons learnt from the ESA DUE GlobAlbedo land surface albedo product validation from European sensors. (J.P. Muller, University of London)
18:00	**Icebreaker and Poster Session**

29 January 2014

Snow Extent	
09.30	Invited talk: Validation of satellite derived snow cover data records with surface networks and multi-dataset inter-comparisons (C. Derksen, Environment Canada)
09.45	Cloud screening method particularly feasible for snow cover mapping (S. Metsämäki, Finnish Environment Institude)
10.00	The Influence of Uncertainty in Cloud Masking on the Quality of VIIRS Snow Products (I. Appel, NOAA)
10.15	Evolution of ESA DUE GlobSnow products and CAL-VAL Opportunities for Sentinels at the Sodankylä Supersite, Northern Finland (K. Luojus, Finnish Meteorological Institute)
10.30	Intercomparison of Snow Extent Products from Earth Observation Data (T. Nagler, ENVEO)
Satellite Missions and their Cal/Val plans (2/2)	
11.30	Land and Cryosphere Products from Suomi NPP VIIRS: Overview and Validation Status (M. Roman, NASA)
11.50	Sentinel-3 with an Envisat perspective (P. Goryl, ESA)
12.10	Continuous terrestrial vegetation monitoring since 1998 using SPOT-VEGETATION and Proba-V (E. Swinnen, VITO)
Land Surface Temperature	
12.30	Lake Surface Water Temperature retrieval - a contribution for a LST data set (S. Wunderle, University of Berne)
12.45	Calibration and Validation of land surface temperature for Landsat-8-TIRS sensor (J. Sobrino, Valencia University)
13.00	Application of a Land Surface Temperature Validation Protocol to AATSR data (D. Ghent, University of Leicester)
13.15	Uncertainty indices of high spatial resolution Land Surface Temperature over urban areas (Z. Mitraka, University Tor Vergata
Products and their Validations (2/4)	
14.45	The MERIS/OLCI land products validation. (N. Gobron, JRC)
15.15	Sentinel-3 Science Products: A US Contribution. (E. Vermote, NASA)
15.30	Estimation of Phenological Indicators and Irrigated Areas of Crops with High Temporal and Spatial Resolution Images (D. Morin, CESBIO)
15.45	An Accurate Daily Aerosol Product for Surface Retrieval Applications Derived from MSG Geostationary Satellites (D. Carrerr, Méteo France)
Products and their Validations (3/4)	
16.45	A framework for the validation of decametric products (F. Baret, INRA)
17.00	Access to global land cover reference datasets and their suitability for land cover mapping activities (B. Mora, Wageningen University and Research Centre)
17.15	Design-Based Validation of the MODIS Global Burned Area Product (L. Boschetti, University of Maryland)
17.30	Integrating different Data Sources for Validating large-area Biomass Maps (M. Herold, Wageningen University and Research Centre)
17.45	On the importance of an uncertainty budget in EO land products (B. Pinty, JRC)
18:00	**Icebreaker and Poster Session**

30 January 2014

Radiometric and Geometric Validation	
09.00	Self-Calibrating Satellite Imagers, how far can we go? (S. Mackin, DMCii)
09.30	Approaches for sensor interconsistency to achieve climate-quality measurements (K. Thome, NASA)
10.00	DEMMIN – a Calibration and Validation Site for Remote Sensing (E. Borg, DLR)
10.15	The inflight radiometric calibration of Proba-V: Results from the In-Orbit Commissioning phase (S. Sterckk, VITO)
10.30	Prototyping a Network of Automated Land Radiometry Measurements: LANDNET (P. Goryl, ESA)
Products and their validation (4/4)	
11.30	A Model-based Quality Assurance Framework for the Validation of Satellite-Derived Biophysical ECVs over Land (J.L. Widlowski, JRC)
12.00	On Line Validation Exercise (OLIVE): a web based service for the validation of medium resolution land products. (F. Baret, INRA)
12.15	Development and Experimental Verification of Key Techniques to Validate Remote Sensing Products (T. Che, CAS)
12.30	A Simple Approach to Evaluate Land Products from the Tip Package (B. Pinty, JRC)
12:45	**Discussion, Conclusion, Recommendation and Way Forward**

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APPENDIX C: Acronyms and Abbreviations

This appendix lists all abbreviations and acronyms used within this document.

AATSR	Advanced Along Track Scanning Radiometer
ATSR	Along Track Scanning Radiometer
ACVE	Atmospheric Composition Validation and Evolution
AGU	American Geological Union
AOT	Aerosol Optical Thickness
AOE	Academy of Opto-Electronics
ATSR-1/2	Along Track Scanning Radiometer
BBA	Broad Band Albedo
BHR	Bi-Hemispherical diffuse Reflectance
BOA	Bottom Of Atmosphere
BRDF	Bidirectional Reflectance Distribution Function
BSRN	Baseline Surface Radiation Network
Cal/Val	Calibration and Validation
CAS	Chinese Academy of Sciences
CCC	Canopy Chlorophyll Content
CCD	Charge-Coupled Device
CCI	ESA Climate Change Initiative programme
CDOP	Continuous Development and Operations Phase
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CESBIO	Centre d'Études Spatiales de la BIOsphère
CFI	Customer Furnished Item
CI	Correlation Index
CORINE	Coordination of Information on the Environment
CMG	Climate Modeling Grid
CNES	Centre National d'Études Spatiales
CNRM	Centre National de Recherches Météorologiques
CSM	Calibration and Shutter Mechanism
CWC	Canopy Water Content
DCC	Deep Convective Clouds
DEM	Digital Elevation Model
DLR	German Aerospace Center
DMC	Disaster Monitoring Constellation
DMCii	DMC International Imaging
DUE	ESA Data User Element
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential Climate Variable
ECMWF	European Centre for Medium-Range Weather Forecasts
EEA	European Environment Agency
EGU	European Geosciences Union
EM	Engineering Model

EnMAP	Environmental Mapping and Analysis Program
ENVEO	Environmental Earth Observation Information Technology GmbH
ENVISAT	Environmental Satellite
EO	Earth Observation
EOLAB	Earth Observation Laboratory
EPS	EUMETSAT Polar System
ERS	European Remote Sensing Satellites
ESA	European Space Agency
ESL	Engineering Support Laboratory
ETM	Enhanced Thematic Mapper
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FCDR	Fundamental Climate Data Record
FOV	Field of View
FP	Framework Programme
FPM	Fine Pointing Mechanism
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GIO	GMES Initial Operations
GMES	Global Monitoring for Environmental Security
GOME	Global Ozone Monitoring Experiment
GOMOS	Global Ozone Monitoring by Occultation of Stars
GRI	Global Reference Image
GSFC	Goddard Space Flight Center
HRL	High Resolution Layer
JRC	Joint research Centre
JRC-TIP	JRC Two-Stream Inversion Package
ICT	Information and Communications Technology
IM	Institute of Meteorology
INRA	Institut National De La Recherche Agronomique
LACOVAL	Validation tool for land cover and land cover change
LAI	Leaf Index Area
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LPV	CEOS Land Products and Validation subgroup
LPVE	Land Products Validation and Evolution
LSA SAF	EMETSAT Satellite Application Facility on Land Surface Analysis
LST	Land Surface Temperature
LTDP	Long Term Data Preservation
LUCAS	Land Use/Cover Area frame Survey
MACC	Monitoring Atmospheric Composition and Climate
MERIS	Medium Resolution Image Spectrometer
MetEOC	Metrology for Earth Observation and Climate
Metop	Polar orbiting meteorological satellites (space segment component of EUMETSAT Polar System (EPS))

MIP	Most Illuminated Pixel
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MISR	Multi-angle Imaging Spectro-Radiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MPC	Mission Performance Centre
MRD	Mission Requirements Document
MSG	Meteosat Second Generation
MTG	Meteosat Third Generation
MTF	Modulation Transfer Function
NASA	National Aeronautics and Space Administration
NIR	Near-Infrared
NIST	National Institute of Standards and Technology
NMI	National Metrology Institute
NOAA	National Oceanic and Atmospheric Administration
NPL	National Physical Laboratory
NRT	Near Real Time
OLCI	Ocean and Land Colour Instrument
OLI	Operational Land Imager
OLIVE	On Line Validation Exercise Tool
OMI	Ozone Monitoring Instrument
PAI	Plant Are Index
PASTISPAR	PAI Autonomous System from Transmittance Instantaneous Sensors
Proba-V	Project for On-Board Autonomy - Végétation
QA	Quality Assurance
QA4EO	Quality Assurance Framework for Earth Observation
QC	Quality Control
QL	Quicklook
QM	Qualification Model
QWG	Quality Working Group
RADCALNET	Radiometric Calibration Network
RAMI	Radiative transfer Model Intercomparaison
R&D	Research and Development
RNU	Residual Non-Uniformity
RUT	Radiometric Uncertainty Tool
SADE	Structure d'Accueil de Données d'Etalonnage
SBA	Societal Benefit Area
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography
SE	Snow Extent
SEOM	Scientific Exploitation of Operational Missions
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SFM	Steering Front Mechanism
SLSTR	Sea and Land Surface Temperature Radiometer
SNR	Signal to Noise Ratio
SPOT	Système Pour l'Observation de la Terre
SRTM	Shuttle Radar Topography Mission

SST	Sea Surface Temperature
STSE	ESA Support To Science Element
Suomi NPP	Suomi National Polar-orbiting Partnership
SW	Short-Wavelength
SWE	Snow Water Equivalent
SWIR	Sort-Wave Infra-Red
TDS	Test Data Set
TIRS	Thermal Infrared Sensor
TOA	Top Of Atmosphere
TROPOMI	TROPOspheric Monitoring Instrument
UAV	Unmanned Aerial Vehicle
UCL	Université Catholique de Louvain
UNEP	United Nations Environment Programme
USGS	US Geological Survey
UVN	Ultra-violet/Visible/Near-Infrared
VGT	Vegetation
VHR	Very High Resolution
VIIRS	Visible Infrared Imaging Radiometer Suite
VIS	Visible
VITO	Flemish Institute for Technological Research
VNIR	Visible and Near-Infra-Red
WGCV	Working Group on Calibration and Validation
WMO	World Meteorological Organization