WORKING GROUP ON CALIBRATION AND VALIDATION

Work Plan

2011 - 2016

Committee on
Earth Observation Satellites

Working Group on
Calibration and Validation

Work Plan
2011 – 2016

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5.5	20-Feb-14	-Changed authorship on title page to read WGCV only. -Section 3 updates to WGCV organizational chart -Section 4.5 Participating Delegations: a) Added note regarding virtual participation. -Updates to membership, Annex A	Eric Arsenault (WGCV Secretariat)

CONTENTS

Executive Summary

This document presents the five-year work plan of the Committee on Earth Observation Satellites (CEOS)'s Working Group on Calibration and Validation (WGCV). It provides a statement of the aims and objectives of the working group and gives an overview of the activities that the WGCV undertakes in support of the Earth Observation (EO) missions and the related projects of CEOS members and associates. The document provides a current and visible record for communicating the activities of the working group, both within and beyond the CEOS community.

The WGCV (http://www.ceos.org/wgcv) plays a vital role in the long-term mission of CEOS. It is a key international player in the development of high-quality satellite data to improve daily operations and to allow users to confidently study global datasets. The WGCV is instrumental in the establishment of a common technical language amongst the numerous users of EO data and customers of satellite-derived products. Through its coordination, documentation and planning for international calibration / validation (cal/val) covering a broad spectrum of disciplines, the WGCV will enhance international EO activities and improve the performance of the numerous national programmes.

The mission of the WGCV is to ensure long-term confidence in the accuracy and quality of EO data and products, and to provide a forum for the exchange of information calibration and/or validation, coordination, and cooperative activities. The WGCV promotes the international exchange of technical information and documentation, joint experiments and the sharing of facilities, expertise and resources. The group seeks to be the recognised first point of contact for the international user-community as far as cal/val, system technical information and EO quality processes are concerned. To this end, the WGCV addresses the need to standardise ways of combining data from different sources to ensure the interoperability required for the effective use of existing and future Earth Observing systems.

The objectives of the WGCV are to enhance coordination and complementarity, to promote international cooperation and to focus activities in the cal/val of EO for the benefit of the CEOS membership, the Group on Earth Observations (GEO) and the international user community. New activities and initiatives occur regularly in the EO community, and both the WGCV and its parent organisation, CEOS, have extremely flexible structures that allow for rapid response.

Much of the detailed technical work of the WGCV is carried out by its six subgroups, which operate as individual entities and focus on specific technical areas related to cal/val. This plan describes the organisational structure of the WGCV, its management process and membership.

1 Mission, Objectives & Implementation

This section outlines the overall aims and objectives of the WGCV and describes the scope for its work.

1.1 The Committee on Earth Observation satellites

CEOS was established in 1984, in response to a recommendation from a Panel of Experts on Remote Sensing from Space, under the aegis of the G7 Economic Summit of Industrialised Nations Working Group on Growth, Technology and Employment. This group recognised the multidisciplinary nature of satellite Earth Observation (EO) and the value of coordination across all proposed missions.

CEOS works through a 'best efforts' approach. Funding and resources required by activities are contributed in-kind by participating CEOS agencies. CEOS does not have a budget or permanent staff.

The work of CEOS spans the full scope of activities required for proper international coordination of EO programmes and the maximum utilisation of their data, ranging from the development of detailed technical standards for data product exchange to the establishment of high-level interagency agreements on common data principles. Access to CEOS is through the Plenary, a working group or the Secretariat. CEOS can provide the framework for efficient coordination across the CEOS agencies.

CEOS coordinates civil space-borne observations of the earth. Participating agencies strive to address critical scientific questions and to plan satellite missions without unnecessary overlap. CEOS has three primary objectives in pursuing this goal:

- To optimise benefits of space-borne EO through cooperation of its members in mission planning and in development of compatible data products, formats, services, applications and policies;
- To serve as a focal point for international coordination of space-related EO activities;
- To exchange policy and technical information to encourage complementarity and compatibility of observation and data exchange systems.

Because CEOS immediately recognised the need to both understand and quantify current and future data derived from EO satellites, the committee established the Working Group on Calibration and Validation (WGCV) in 1984. Since this time, the work of the WGCV has taken on an ever-increasingly important role as the need for high-quality EO data is seen as an essential key to tackling global climate change. The need for quality improvement is led through international programmes such as the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS) and the Global Terrestrial Observing System (GTOS). All require high-quality data over long periods of time.

The WGCV plays a vital role in the long-term mission of CEOS. It is a key international player in the development of high-quality satellite data to improve daily operations and to allow users to confidently study global datasets. The WGCV is instrumental in the establishment of a common technical language amongst the numerous users of EO data and customers of satellite-derived products. Through its coordination, documentation and planning for international cal/val covering a broad spectrum of disciplines, the WGCV will enhance international EO activities and improve the performance of the numerous national programmes.

1.2 Mission

The mission of the WGCV is to ensure long-term confidence in the accuracy and quality of EO data and products, and to provide a forum for the exchange of information calibration and/or validation (cal/val), coordination, and cooperative activities. The WGCV promotes the international exchange of technical information and documentation, joint experiments and the sharing of facilities, expertise and resources. The group seeks to be the recognised first point of contact for the international user-community as far as cal/val, system technical information and EO quality processes are concerned. To this end, the WGCV addresses the need to standardise ways of combining data from different sources to ensure the interoperability required for the effective use of existing and future Earth Observing systems.

1.3 Objectives

The objectives of the WGCV are to enhance coordination and complementarity, to promote international cooperation and to focus activities in the calibration and validation of Earth Observations for the benefit of the CEOS membership, the Group on Earth Observation (GEO) and the international user community.

Specific objectives include:

- **Sensor-specific calibration and validation** -- To document and establish forums for the assessment, recommendation and implementation of current techniques and standards for pre- and post-launch characterisation and calibration.
- **Biogeophysical validation** -- To document and establish forums for the assessment, recommendation and implementation of techniques for validation of biogeophysical parameters derived from EO satellite systems.

Meeting these objectives will include the promotion of:

- The exchange of EO data, technical information and documentation.
- The investigation of possibilities for technical coordination and cooperation for space and ground segments.
- The coordination and analysis of cal/val campaigns and programmes, optimising and sharing of available facilities, expertise and resources as appropriate.
- Agreement on common terminology and definitions.

1.4 Implementation

The strategies and activities that will be undertaken in order to meet the objectives of the WGCV, as stated above, are defined within this five-year plan. This plan is to be submitted to CEOS Plenary for endorsement and for subsequent annual updating. The WGCV Chair shall report to each CEOS Plenary on progress and seek their review and guidance, bringing forward recommendations and proposals as appropriate.

1.5 Communication

The WGCV chair and vice chair have the responsibility to communicate information and direction from CEOS leadership which includes information from the CEOS Plenary, CEOS Executive Office, CEOS Secretariat (SEC), and the CEOS Strategic Implementation Team (SIT) to all WGCV members.

This responsibility will happen though communication to WGCV members via meeting, mail, email, or other electronic communication function. The WGCV chair/vice chair/SEC will make minutes and actions from WGCV plenary meetings available via the CEOS web pages to all WGCV members not less than 30 days after the close of the meeting.

The WGCV subgroup chairs are responsible for communicating with the chair/vice chair subgroup meeting minutes, actions, and issues on issues on an “as needed” basis, with a minimum reporting to occur prior to, or during, the WGCV Plenary meeting. Any key highlights or issues relevant to the CEOS SEC or CEOS SIT should be provided to the chair or vice chair on an “as needed basis” at least one week prior to these meetings, as designated by the CEOS calendar. This information will be used by the WGCV chair/vice chair to report to upper level CEOS management as appropriate and with agreement from the subgroup chair. These highlights and or issues should be noted as appropriate for potential CEOS newsletter incorporation.

The WGCV chair/vice chair will hold a minimum of 2 (with a goal of 3) plenary meetings between his/her term starting with their first official plenary meeting as the WGCV chair and their last official plenary meeting (approximately 2 years). The recommended time window for WGCV plenary meetings is approximately every 9 months. The WGCV chair and their organization will be responsible to provide resource to maintain and support the WGCV web pages and the WGCV Secretariat function.

2 Work Plan

CEOS and its subgroups, including the WGCV, function on a "best-effort" basis with no centralised funding available. The emphasis of the WGCV's work plan is therefore dependent upon defining practical and realistic steps that can be achieved with the resources made available by its members and associates. This section outlines the main themes the WGCV will work towards over the next five years.

2.1 Support to CEOS and GEO

The WGCV takes its strategic direction from the CEOS Plenary and the CEOS Strategic Implementation Team (SIT). Active participation of the WGCV's management team at these meetings and in monthly SEC teleconferences ensures that the WGCV has a clearly defined strategy.

A major focus of CEOS in recent years has been to support the Group on Earth Observations (GEO) in its vision for the development of the Global Earth Observation System of Systems (GEOSS). This has directed the WGCV towards the provision of support for the execution of a series of GEO tasks and actions that have been defined to support the development of GEOSS for the EO community. For a detailed overview of all the GEO tasks and the involvement of the WGCV please visit the GEO website at http://www.earthobservations.org/.

The WGCV provides annual reports at CEOS plenary, SIT meetings, GEO-CEOS actions workshops and other relevant meetings / teleconferences. In addition, reporting and discussion at monthly CEOS SEC teleconferences ensure that the work of the WGCV is shaped to meet CEOS member requirements. In particular, the WGCV seeks to support CEOS members in their sensor / instrument calibration and in the validation of data products and key instrument variables.

2.2 Calibration and Validation of Earth Observation Systems

The WGCV will continue to recommend and provide technical support and consultation for pre- and post- launch calibration for all CEOS related systems and functions to include calibration efforts across many sensor domains with multiple agencies. The WGCV will continue to recommend and provide technical support and consultation for the validation of remote sensing products and derivatives for use in earth observation science efforts across many product and sensor domains within multiple agencies.

2.3 Quality Assurance Framework for Earth Observation

The WGCV is taking the lead in a GEO task that sets out to define a Quality Assurance Framework for Earth Observation (QA4EO). The concept is that GEOSS must deliver comprehensive and timely "knowledge / information products" worldwide to meet the needs of its nine "societal benefit areas" (SBAs). The GEOSS community represents a wide variety of disciplines that utilise a multitude of monitoring methodologies and procedures. These all

require an association of a quality metric to their outputs to enable them to be reliably integrated into the various systems and services that support the EO needs of Society. The fundamental principle of QA4EO - that all EO data and derived products has associated with it a documented and fully traceable quality indicator (QI) - addresses this core requirement and is universally applicable to all disciplines. This principle is not in itself novel and is already being practised by many. QA4EO seeks to ensure it is implemented in a harmonious and consistent manner throughout all EO communities to the benefit of all stakeholders. The end-user (customer) is the driver for any specific quality requirements and will assess if any supplied information, as characterised by its associated QI, are "fit for purpose".

QA4EO was initially conceptualised for the space community and the plan is to now expand it to ensure QA4EO's application to all EO disciplines within all SBA communities. The broadening of the scope for QA4EO necessitates a more generic approach and a wider remit to its applicability. The aim is for a wider focusing task team to take over the leadership of QA4EO from the WGCV. This task team would ideally have representation from all SBA communities and would work towards an appropriate implementation and action plan to achieve a solid QA4EO approach for all members to GEOSS. In parallel to this, the WGCV will maintain its focus on QA4EO implementation within the satellite (CEOS) community and will continue to push for quality assured EO data that adheres to QA4EO principles.

Within its subgroup topic and instrument domains, the WGCV seeks to establish / facilitate the establishment of community "best practises" for quality assurance of satellite Earth Observation data. Such best practise guidelines will be derived from within the specialist community, for the community users and remain as "living" documented procedures for community use. The accuracy and precision criteria for relevant satellite data, *in situ* data and/or algorithms will, necessarily, be set by the community and any procedures developed under QA4EO will be peer -owned, -reviewed, -maintained and -updated as required. The WGCV will seek to assist this process and provide advice and support to the CEOS community on QA4EO and its implementation.

2.4 Calibration / Validation Test Sites

Within CEOS there are numerous test sites that have been developed and maintained for cal/val either for specific missions or for the use of particular EO community groups. Some of these sites are instrumented and are in use during specific missions / campaigns. Others are maintained over longer periods. The WGCV have long since identified the need for an internationally agreed (CEOS-endorsed) reference sites that should be appropriately instrumented and maintained as a global resource. Guided by its subgroups, the WGCV plans to define a preliminary set of CEOS cal/val sites that would represent the minimum set of mandatory sites (applicable across all relevant sensor / thematic domains) that should be maintained for the long-term future. This set of sites would be a living list that could be added to as and when appropriate. The ultimate goal would be for CEOS member agencies to agree to collect and provide information over all CEOS-endorsed sites in order to facilitate interoperability and underpin internationally harmonised cal/val. The list will also include recommended resource requirements for active agency support of site instrumentation and maintenance.

2.5 Instrument / Field / Intercomparison Campaigns

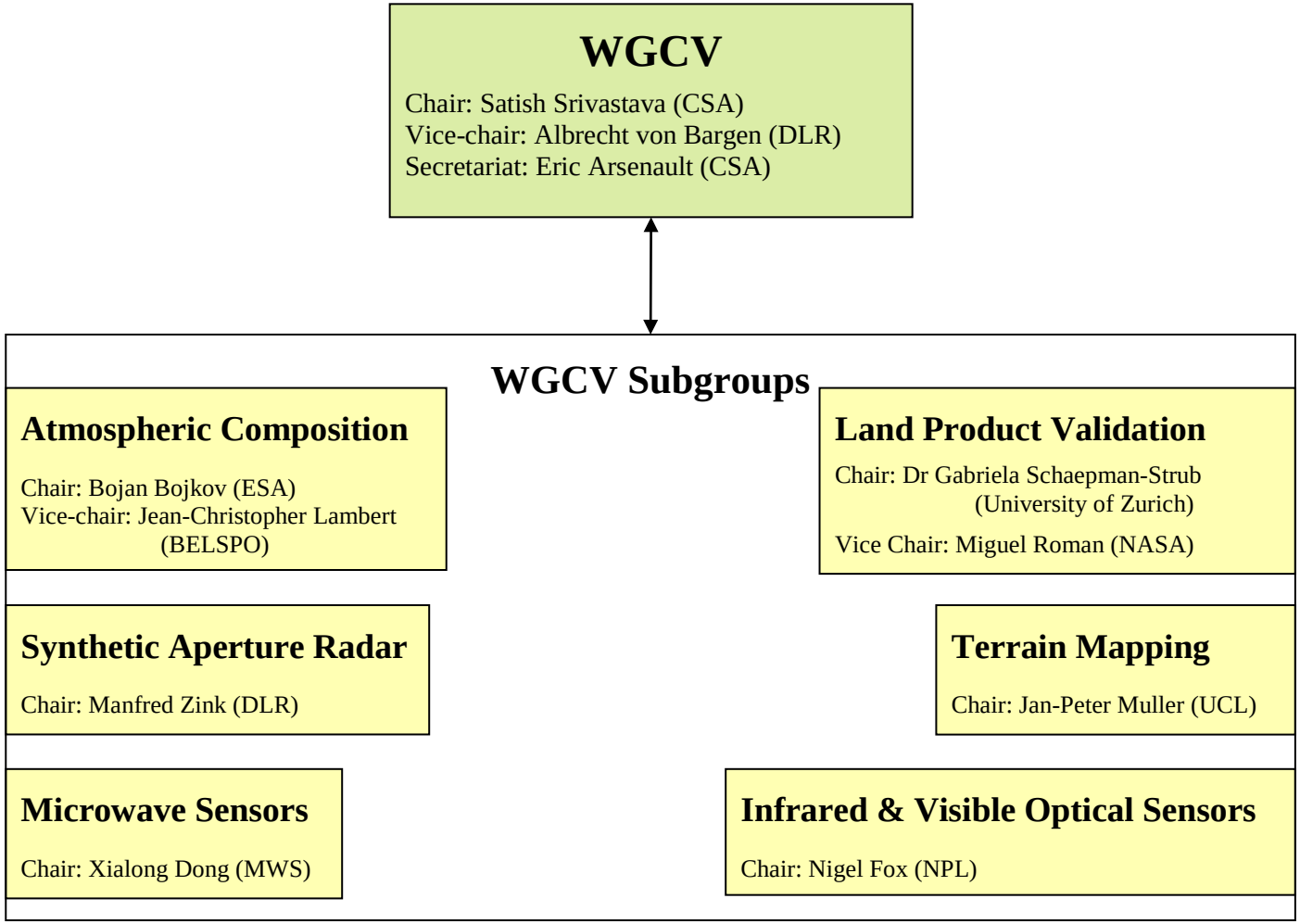
The WGCV recognises the importance of collaboration and active working within the cal/val community. The group will continue to work towards organising, promoting and participating in instrument / field campaigns that are of benefit to the cal/val community. These campaigns could vary considerably in their focus and the need for the WGCV to be involved would largely be led by the WGCV's subgroups.

Collaborative working over community-approved test sites can be of great benefit to the entire community and may assist in the ultimate goal for the definition of a set of CEOS-endorsed cal/val sites. One such example is the DOME-C test site in Antarctica, which is being investigated for its potential as one of the static CEOS-endorsed test sites for a series of different satellite sensors.

Intercomparison campaigns for similar instruments used by CEOS member agencies / relevant communities are a valuable undertaking to investigate how similar instrumentation across the globe consistently monitors like parameters. In recent years the WGCV, led by its subgroups, have led intercomparison campaigns to internationally cross-compare ground cal/val support techniques and instrumentation for visible / shortwave infrared reflected radiance over land and infrared emitted radiance over water. Such campaigns increase understanding and confidence in the quality of data throughout the international EO community.

3 WGCV Organisation

The WGCV is chaired / vice-chaired by elected experts and is supported by a technical secretariat. The WGCV supports six subgroups that operate as individual entities and that focus on specific technical areas related to calibration and validation. The following figure illustrates the structure of the WGCV, its associated subgroups and the responsible members:



The WGCV subgroups were established to coordinate and report on cal/val within the specialised communities of CEOS. There are six subgroups of the WGCV and these are led by a chair and, in some cases, a vice-chair. These appointments and their conditions of tenure are made and maintained by the subgroup as appropriate.

3.1 Atmospheric Composition Subgroup

3.1.1 Mission

The mission of the Atmospheric Composition Subgroup is to ensure accurate and traceable calibration of remotely-sensed atmospheric composition radiance data and validation of higher level products, for application to atmospheric composition, land, ocean, and climate research.

3.1.2 Terms of Reference

The Atmospheric Composition subgroup was approved at CEOS Plenary 15 in November 2001. The objectives of the Atmospheric Composition subgroup, beyond those of the WGCV, are to:

- Promote international collaboration and technical exchange to ensure the efficient use and maintenance of calibration / validation resources required for atmospheric composition and other missions.
- Verify accurate scientific products by encouraging an end-to-end approach to the calibration and validation of Level 1 and Level 2 data products, and any subsequent re-calibration and reprocessing using established best practice procedures.
- Ensure that validation sensors are calibrated to traceable national standards, with documented statements of accuracy and repeatability.
- Encourage interaction between calibration scientists, Level-1 to Level-2 retrieval scientists, and data users to enable a better understanding of data uncertainties and thematic user requirements.
- Recommend a network of validation sites and instruments and to encourage continuous observation and quality control of data through the use of standard procedures and inter-comparison.
- Develop comprehensive data validation methods that employ ground, aircraft, balloon, and satellite measurements, with appropriate support from models.
- Specify a comprehensive, consistent and quality-controlled multi-mission validation database in an accepted format and employing user-friendly tools.

3.1.3 Action Plan

The membership of the Atmospheric Composition subgroup will be completed by including relevant agencies and organisations that are not yet represented. The subgroup will initiate and support the process of approaching agencies, through CEOS, for partial sustained support for

ground validation networks and the maintenance of these networks between missions. Data validation archival and retrieval for the long term and across present and future mission applications is seen as very important and this will be actively pursued. The subgroup will meet regularly to review and coordinate upcoming validation activities, discuss results and pursue its main objectives. These objectives will be reviewed and updated as required.

3.2 Infrared and Visible Optical Sensors Subgroup

3.2.1 Mission

The mission of the Infrared and Visible Optical Sensors (IVOS) subgroup is to ensure high quality calibration and validation of infrared and visible optical data from Earth Observation satellites and validation of higher-level products.

3.2.2 Terms of Reference

The objectives of the Infrared and Visible Optical Sensors subgroup, beyond those of the WGCV, are to:

- Promote international and national collaboration in the calibration and validation of all infrared and visible optical sensors and, thus, to assist in the improved application of data from satellite sensors.
- Address all sensors (ground-based, airborne and satellite) for which there is a direct link to the calibration and validation of satellite sensors.
- Identify and agree on calibration and validation requirements and standard specifications for infrared and visible optical sensors.
- Identify test sites and encourage continuing observations and intercomparison of data from these sites.
- Encourage the timely and unencumbered release of data relating to calibration and validation activities including details of pre-launch and in-flight parameters.
- In the context of calibration and validation, encourage the full consideration of "traceability" in all activities involved in the end-to-end development of an EO product, including appropriate models and algorithms.

3.2.3 Action Plan

The primary focus of IVOS is to establish an internationally harmonised cal/val strategy, based on the principle of "traceability" as embodied in QA4EO, to include: methods, reference standards and infrastructure, to meet the needs of space-based Earth Observing systems for IVOS-relevant sensors. In particular, IVOS aims to support the development and implementation of GEOSS, the constellations, working groups and subgroups of CEOS, and the needs of other community bodies, e.g., GCOS, WMO and IOCCG as appropriate.

This strategy recognises the critical importance of all phases of a satellite mission: pre-flight and post-launch, with the latter including both on-board and vicarious-based systems / methods. In developing its strategy, IVOS notes that, although much of the "end-user community" is primarily interested in relatively higher-order products, without a good understanding of the Level 1 (L1), it is difficult to develop, assess and interpret them. The IVOS action plan, therefore, without ignoring higher level products, places a strong emphasis on primary Level Zero (L0) and L1 products, even if they are not usually distributed. IVOS further recognises that there are many other existing and active community groups (including other CEOS subgroups) which address the detailed needs (particularly validation aspects) of higher-order products. Thus, IVOS concentrates its efforts on supporting activities where radiometric / geometric calibration and/or instrumentation performance and traceability, together with validation of appropriate models and algorithms, is of particular importance.

The IVOS action plan of the last few years, and the target for next five, has been to work towards establishing a globally useable, internationally harmonised, "operational" calibration system (IVOS sensors) under the auspices of CEOS that utilises the combined efforts of member agencies. The objective of this system would be to facilitate interoperability between sensors at L1 and subsequent higher-level products. This would enable all sensor operators to demonstrate unequivocally and consistently a "quality indicator", in the context of its application, for their products. It would readily allow the identification of any "normalisation factors" that may need to be applied to allow harmonisation / interpretation of data products emergent from different sensors and/or observing environments to the user community. It is envisaged that this "calibration system" will provide a framework and philosophy to collate and regularly update all available knowledge that may affect the performance of a sensor. Information will be drawn from pre-flight calibration and characterisation, on-board systems (where available) and in-flight assessment through a variety of CEOS-endorsed vicarious cal/val methodologies and tools.

IVOS will invest significant effort in the next five-years to building consensus on the capabilities, scope of applicability and weighted interactability of the various vicarious approaches that have been deployed to date, including their potential for improvement. In some cases it is expected that this will lead to best practise guidance on the key principles of a methodology; in others it may be coordinated use of infrastructure, e.g., test sites. It is noted that some agencies already operate such systems for their own use and IVOS will seek to build on these and any associated infrastructure for the benefit of the international community as a whole.

In the longer-term, IVOS will continue to encourage the development and deployment of a space based "SI traceable" benchmark sensor, e.g., CLARREO / TRUTHS, to underpin this international calibration system.

IVOS addresses a very wide scope of activities and, for practical purposes, it sub-divides some of its work into a set of themes (see Table 1), some focused on a particular community with others more of a cross-sector nature. Each theme has a named leader and can organise / operate in whatever manner it considers most effective. In some cases this will be through, or in conjunction with, other communities, making use of meetings of opportunity, email, telecom, etc.

Sector Based Themes

Topic	Indicative Activities	Lead
Land Surface Reflectance	• CEOS Test-sites: LandNet and invariant. • Best practises for: characterisation of sites, • Use of sites, instrumentation. • Comparisons. LSI	G Chander (USGS)
Ocean Colour	• Comparisons, best practises for validation instrumentation • OCR-VC	G Zibordi (JRC-EU)
Surface temperature (SST, LST)	• Comparisons of radiometric based quantities • best practises for above, liaison with • LPV, GHRSST	G Corlett (University of Leicester)

Cross-Cutting Themes

Topic	Indicative Activities	Lead
Atmospheric correction	• Best practises on performance • Sensitivity of different models and associated input parameters	K Thome (NASA)
Geo/Spatial Quality	• MTF (PSF) best practise for pre-and post-launch characterisation • Test-site characteristics • Definitions / terminology / reporting	D Helder (University of South Dakota)
Geometric Image Quality	• Spatial and positional accuracy • Co-registration • Pre- and post-launch characterisation • Definitions / terminology / reporting	To be determined
Sensor to Sensor biases	• Collation, organisation and analysis of comparisons via any vicarious method, including development of consensus on analysis • Best practises for vicarious methodologies in conjunction with GSICS (individual leads).	N Fox (NPL)
Radiative transfer Codes	• Comparisons of (RAMI) best practises • Cal/Val applications	J-L Widlowski (JRC/EU)
Communication / Portal	• Maintain and develop a portal to facilitate exchange of cal/val information to members and externally • Develop and promote best-practices and carry out "projects" in an internationally-harmonised manner	P Goryl (ESA)

Table 1: IVOS Themes and leads

Each IVOS theme will:

- Work towards a common set of core goals, as outlined previously, and will address the key elements of any cal/val system as described in QA4EO, i.e., to establish / agree on best practises, to organise appropriate comparisons to evaluate performance / state-of-the-art, and to seek development and use of internationally shared "reference standards". These activities may be implemented through, and in conjunction with, any appropriate existing internationally structured organisation(s), with IVOS providing the conduit to CEOS via WGCV.

- Report progress / issues, ideally by a representative in person, at each IVOS meeting. The cal/val portal will be utilised for communication and information exchange (at least as a conduit). The IVOS plenary meetings serve to share best-practise between themes and collate knowledge to help demonstrate overall "international sharing" across themes. This is of particular value when seeking resources to support specific activities. The theme leads, via the cal/val portal, will report inter-meeting progress on a quarterly basis.

- Establish its own action plan, with objectives and timescales to be presented and agreed at IVOS plenary. Where appropriate, this is likely to include identification of "key comparisons" needed to support international interoperability, and a timetable for these for an ongoing system. Comparisons should be organised to encourage open participation and maximum coverage.

IVOS plans to hold a plenary meeting at least once per annum (typically once every 9 months) at locations spread geographically across the globe. In addition, it will seek to hold a technical community workshop on a focussed topic on a tri-annual basis. The next of these is planned to focus on pre-flight and on-board radiometric calibration of sensors in Spring 2013.

Membership and attendance at IVOS meetings is open to all, including those from commercial and academic organisations who are not formal members of CEOS. Meeting registration is required to the IVOS chair. Plenary meetings generally cover three days. Each meeting will seek to cover discussion on all aspects of IVOS activities. However, to enable more detailed technical discussion, at least half a day of each meeting will be dedicated to a specific technical topic, on a rotational basis. In some cases, this may include additional days attached to the main meeting.

IVOS recognises the importance of knowledge transfer between agencies and organisations on generic sensor pre- and post- launch cal/val (distinct from sensor specific) and will encourage this across all its themes. IVOS will also seek to facilitate the provision of information and discussion on specific sensors within the community where the sensor owner desires it. Members are encouraged to share information on their organisation's progress and future activities. This will be distributed (ideally before a meeting), as opposed to formal presentation, to enable any appropriate discussion within the meeting. New members and hosts will be offered the opportunity to provide a presentation.

IVOS will seek to identify and meet the needs of all stakeholder communities and publicise its activities broadly. IVOS will work closely with the CEOS constellations (particularly LSI, OCR-VC and SST) and offer to be the principle resource to meet their cal/val needs. This will

similarly be the case for other CEOS working groups and subgroups. In particular, IVOS will consider and address, as a priority, the emerging needs of climate as identified by GCOS and the CEOS Working Group on Climate, working in partnership with WMO, GSICS and others, as appropriate. In terms of Land Surface Temperature, IVOS will work with the LPV subgroup to establish a coordinated approach, with IVOS taking responsibility for radiometric aspects of any activity. For Ocean colour, it is noted that IOCCG takes on most of the responsibilities for best practises. Thus, IVOS will concentrate efforts on areas where its expertise is desired.

3.3 Land Product Validation Subgroup

3.3.1 Mission

The mission of the Land Product Validation subgroup is to foster quantitative validation of higher-level global land products derived from remote sensing data and to relay results so they are relevant to users.

3.3.2 Terms of Reference

The objectives of the Land Product Validation subgroup, beyond those of the WGCV are to:

- Provide the interface between the user community, product developers, CEOS and GEO in relation to product validation requirements, measurement standards and definitions for current and future missions
- Identify opportunities for international coordination and collaboration and promote data sharing
- Develop CEOS-endorsed community consensus “best practice” protocols for land product validation, data collection, analysis and accuracy reporting
- Identify and support global core sites for both systematic and episodic measurements of land surface properties via tower measurements, field campaigns, use of ground and near-surface sensors Contribute to satellite land product inter-comparison activities
- Develop procedures for validation data exchange and management)

3.3.3 Action Plan

The LPV subgroup consists of eight focus areas representing key terrestrial essential climate variables (Table 2). Each focus area is lead by two internationally independent co-chairs that have been actively involved in validation activities within their community. In 2013, the LPV chairmanship will be passed on to the current vice-chair and a new vice-chair will be selected democratically by the LPV working group. Following this, focus area co-chairs may also choose to pass their leadership role on to a willing candidate.

Focus Group	North America	Europe / Other
Land Cover	Pontus Oloffson (Boston University, US)	Martin Herold (Wageningen University, NL)
Fire (Active/Burned Area)	Luigi Boschetti (University of Maryland, US)	Kevin Tansey (University of Leicester, GB)
Biophysical LAI	Richard Fernandes (Natural Resources, CA)	Stephen Plummer (Harwell, GB)
Biophysical FAPAR	TBD	Nadine Gobron (JRC)
Surface Radiation (Reflectance, BRDF, Albedo)	Crystal Schaaf (Boston University, US)	Gabriela Schaepman-Strub (University of Zurich, CH)
Land Surface Temperature	Simon Hook (NASA JPL, US)	Jose Sobrino (University of Valencia, ES)
Soil Moisture	Tom Jackson (USDA, US)	Wolfgang Wagner (Vienna University of Technology, AT)
Land Surface Phenology	Matthew Jones (University of Montana, US)	Jadu Dash (University of Southampton, GB)
Snow Cover	Dorothy Hall (NASA GSFC, US)	Tao Che (CAS, CN)

Table 2: LPV Focus areas and co-leads

During the next five years (2011 – 2016), the LPV will work toward achieving the objectives the set forth by the following means:

- Focus areas dedicated to the Snow Cover and FAPAR Essential Climate Variables will be implemented in 2011-2012.
- The LPV website and focus area home pages will be maintained. New products and validation activities will be updated along with news on upcoming meetings and field campaigns.

- Topical workshops (at least 1-2 per focus area in said timeframe) will be held to address specific land product validation issues, inter-comparison activities and review of CEOS-endorsed, community consensus protocol documents. CEOS member funded agencies should contribute to these exercises (NASA, ESA, etc.).
- Current focus area leads are responsible for producing a validation protocol for their respective ECV. Protocols will undergo a rigorous community review and be endorsed by CEOS and corresponding organisations (GCOS, GTOS). Protocols will address QA4EO principles and will be published on the LPV website. A summary peer-review paper will be published in the literature. The following timeframe for protocol development and review by community members is expected:
    - 2011 – 2014: LAI, FAPAR, Albedo, Land Cover (area change), Burned Area, LST, Soil Moisture
    - 2012 – 2015:, Active Fire, , Land Surface Phenology, Snow Cover
- Each focus area is expected to contribute to and guide land product inter-comparison studies. The following timeframe is expected to secure funds and define a project team:
    - 2011 – 2015: Land Cover, Albedo, Burned Area, a review and update of LAI inter-comparison study.
- Work with the LPV focus area groups as well as OLIVE / IVOS / WGISS to develop a core set of sites that can be used for validation of land product ECVs (GCOS Action T3). Develop a database and staging area for data access to validation data and results.
- Expand on existing and develop new instrumentation and techniques for scaling and achieving stage 4 validation (Table 3) (expanding on efforts such as OLIVE).

Stage 1	Product accuracy is assessed from a small (typically < 30) set of locations and time periods by comparison with *in situ* or other suitable reference data.
Stage 2	Product accuracy is estimated over a significant set of locations and time periods by comparison with reference *in situ* or other suitable reference data. Spatial and temporal consistency of the product and consistency with similar products has been evaluated over globally representative locations and time periods. Results are published in the peer-reviewed literature.
Stage 3	Uncertainties in the product and its associated structure are well quantified from comparison with reference *in situ* or other suitable reference data. Uncertainties are characterized in a statistically robust way over multiple locations and time periods representing global conditions. Spatial and temporal consistency of the product and consistency with similar products has been evaluated over globally representative locations and periods. Results are published in the peer-reviewed literature.
Stage 4	Validation results for stage 3 are systematically and regularly updated when new versions of the products are released and as the time-series expands.

Table 3: The revised four-stage CEOS Land Product Validation Hierarchy

- LPV chair, vice-chair and focus area leads will seek community support and funding mechanisms for validation activities, sensor acquisition, and inter-comparison studies. Efforts to secure LPV funding and support outside of USA / Europe will be sought.
- LPV will work with new missions (ESA Sentinels, NASA Decadal Survey, JPSS, and NOAA GOES) to coordinate efforts and to assist with land validation needs and implementation plans.
- Collaboration with nationally-funded terrestrial ecosystem networks is anticipated (e.g., TERN Australia, NEON USA) to help with the expansion of CEOS core sites.
- Work with GCOS to ensure that validation-related action items from the GCOS 10-year Implementation Plan (and future versions of this) are relevant and feasible.
- Work with GOFC-GOLD land cover and fire implementation teams to coordinate land product validation activities where possible.
- Outreach of LPV subgroup validation activities and satellite land products to the ecological and climate modelling communities.

3.4 Microwave Sensors Subgroup

3.4.1 Mission

The mission of the Microwave Sensors subgroup is to foster high quality calibration and validation of microwave sensors for remote sensing purposes. These include both active and passive types, airborne and spaceborne sensors.

3.4.2 Terms of Reference

The objectives of the Microwave Sensors subgroup, beyond those of the WGCV, are to:

- Facilitate international cooperation and co-ordination in microwave sensor calibration / validation activities by sharing information on sensor development and field campaigns.
- Promote accurate calibration and validation of microwave sensors, through standardisation of terminology and measurement practices.
- Provide a forum for discussion of current issues and for exchange of technical information on evolving technologies related to microwave sensor calibration / validation.
- Provide calibration/validation support to CEOS virtual constellations and data application groups/communities by coordination of reference sites for both passive and active microwave sensors, and standardization of quality assurance of microwave remote sensing data.

3.4.3 Action Plan

The sensors which the Microwave Sensors Subgroup covers include both passive microwave sensors, such as microwave imagers and microwave sounders, and active microwave sensors except SAR, such as radar scatterometers, radar altimeters, precipitation radar and other active sensors operating in microwave spectrum. Data of the subgroup's concerns are mainly for atmosphere, ocean and large scale land environmental applications.

The plan of action for the subgroup is based on the recent developments and demands for spaceborne microwave sensors, especially the applications for climate and global change applications, which results in calibration requirements of sensors with higher sensitivity, precision and stability, and cross-calibration requirements of microwave sensors flown on different spacecraft and developed by different agencies. The subgroup will also work on calibration and validation of new developed microwave sensors, such as polarized and interferometric microwave radiometers.

The current objectives of the subgroup include:

- Identification and characterization of reference sites for passive and active sensor, especially for L1b data product, collecting data on these sites;
- Identification and standardization of calibration procedure and calibration data processing of microwave sensors, for both prelaunch and in-orbit, to ensure the consistency of data for different sensors on different satellites and developed by different agencies;
- Standards or recommended guidelines for cross-calibration of in-orbit microwave sensors;
- Standards or recommended guidelines for quality assurance of microwave data for climate and global change applications;
- Standardization of radiometric references for passive sensors;
- The subgroup will meets periodically to discuss results and new developments;
- The subgroup implements its action plan by participation of concerned agencies and other groups.

3.5 Synthetic Aperture Radar Subgroup

3.5.1 Mission

The mission of the Synthetic Aperture Radar subgroup is to foster high-quality synthetic aperture radar data from airborne and spaceborne systems through precision calibration in radiometry, phase and geometry, and validation of higher level products.

3.5.2 Terms of Reference

The objectives of the Synthetic Aperture Radar subgroup, beyond those of the WGCV, are to:

- Act as a forum for international technical interchange on the evolving methodologies, techniques and equipment of SAR calibration and validation.

- Determine standard definitions and calibration / validation requirements for synthetic aperture radar imaging systems.
- Support harmonisation of user products and formats as appropriate.
- Facilitate international cooperative programmes in the calibration and validation of SAR systems.
- Educate the SAR community.

3.5.3 Action Plan

A number of new SAR missions have been launched recently, or are being prepared for launch. Primarily based on active phase array antenna technology, these missions indicate a clear trend to higher resolution and increased radiometric and geometric performance. Novel calibration concepts and techniques for such missions are one of the key topics. Future systems, featuring digital beam forming techniques based on multi-channel architectures, will require further sophistication of calibration techniques and procedures.

Identification and characterisation of calibration and validation reference sites (to include both natural and man-made targets), for the purposes of providing an easily accessible source of reference calibration data to data providers, will continue.

The subgroup meets annually to discuss results and new developments.

3.6 Terrain Mapping Subgroup

3.6.1 Mission

The mission of the Terrain Mapping subgroup is to ensure that characteristics of digital terrain models produced from Earth Observation sensors at global and regional scale are well understood and that products are validated and used for appropriate applications.

3.6.2 Terms of Reference

The objectives of the Terrain Mapping subgroup, beyond those of the WGCV, are to:

- Develop specifications for the generation of standardised terrain surface products with known accuracy from similar sensing systems in the context of data continuity.
- Specify evaluation methods and statistics that give transparent information about the quality and heritage of terrain models.
- Update the current dossier of test sites and identify new sites, particularly to satisfy the calibration / validation requirements of future missions and generally improve access to validation datasets.

- Prepare recommendations for the establishment of a global ground control point network.
- Consider how orbit validation could be developed.
- Keep an up-to-date record of the current status of sensors which produce data for terrain mapping and of the Digital Elevation Models available.
- Produce a DEM requirements document with a science rationale, taking into account the output from SRTM.

3.6.3 Action Plan

The objectives of the Terrain Mapping subgroup will be achieved through the following activities:

- Liaison with CEOS Members and Associates' activities, especially the IGOS, in order to determine the Digital Elevation Model requirements of the user community to ensure that calibration / validation procedures are in place to satisfy that need.
- Collaboration with other groups to ensure that common activities are co-ordinated and enhanced by collaboration.
- Holding one meeting a year to review progress, plan future action and discuss results.

4 Management

All activities of the WGCV will be aimed at achieving the objectives defined in this 5-year plan. Work at all levels will be the subject of an appropriate plan defining the work to be done and the outputs expected, and the progress of all work will be monitored by reporting against the plan.

4.1 Membership

Membership of the WGCV is open to all members of CEOS, as defined in the CEOS Terms of Reference, including observers and affiliates. Members may include in their delegations to WGCV meetings any participants who have relevant expertise to contribute to the objectives of the WGCV. The list of members to the WGCV is detailed in Annex A

4.2 Selected Procedures

- The WGCV shall meet when appropriate, at least once per year, rotating the venue amongst its membership.
- The Chair and Vice-chair for the WGCV shall be designated by the CEOS Plenary and shall rotate every two years. The Chair is responsible for, and shall provide, a WGCV Secretariat to run concurrently with the office of Chair. The Chair and Secretariat shall prepare and distribute minutes of each meeting. At each meeting of the WGCV, the time, place and host for the next meeting shall be established.
- For each meeting of the WGCV, each member shall prepare and present a report on the member's current and planned calibration and validation activities.
- The CEOS WGCV shall coordinate its work with other international groups involved in related activities, as described in the CEOS Terms of Reference.
- Subgroups may be established, by consensus of the WGCV, to perform detailed technical work in specific areas. Each Subgroup Chair shall be appointed by the WGCV, based on nominations from the Subgroup. The WGCV shall approve Terms of Reference for each Subgroup. At each WGCV meeting, the Subgroups shall report on their progress and plans.
- Each CEOS member is invited to designate a point of contact for WGCV correspondence, otherwise correspondence shall be addressed to the agency's main point-of-contact within CEOS.
- The WGCV shall coordinate its work with other CEOS working groups, and in particular with the Chair of SIT, who has overall responsibility for CEOS relations with GEO and its subsidiary committees and secretariat.

- The WGCV has the authority to develop processes, procedures and documentation as required to support the calibration and validation community. A CEOS WGCV process, procedure and/or documents shall be peer reviewed and accepted by the WGCV membership prior to official designation as a WGCV artefact.

- The WGCV may propose modifications to the Terms of Reference and such modifications shall be submitted for approval at CEOS Plenary.

4.3 Chair and Vice-chair persons

The CEOS WGCV is administrated by a Chairperson and by a Vice-chair. The organisation sponsoring the Chairperson has the responsibility of maintaining secretarial support throughout the Chairperson's mandate.

The Vice-chair is elected for a period of two years commencing after confirmation of their nomination by the CEOS plenary. The CEOS plenary is traditionally held every year in early November. After two years, the Vice-chair automatically takes the position of WGCV Chair for a further two years. At this time a new Vice-chair is elected by the WGCV delegations.

Vice-chair elections are organised every two years and held during a CEOS WGCV plenary in time for the candidate to be presented and approved by the CEOS plenary in November.

Those WGCV electors not in a position to participate in the WGCV plenary can participate in the election either via mail or electronic mail sent to the WGCV secretariat.

If either the Chair or the Vice-chair's position becomes vacant, the organisation sponsoring the Chair or Vice-chair shall propose a substitute until the end of the planned mandate.

Once the mandate has terminated, the Chairperson has the option of being re-elected as Vice-chair for another period of office.

4.4 Electors

The electors are (one vote each):

- The WGCV Chair

- The WGCV Vice-chair

- Each of the WGCV Subgroups – one vote per subgroup representing the consensus of that subgroup.

- Each participating delegation (representing the consensus within that delegation) who is a full member of CEOS.

4.5 Participating Delegations

The current list of CEOS members can be found on the CEOS website at http://www.ceos.org/wgcv.

Only CEOS members have the right to vote. CEOS Associates and observers to CEOS do not have the right to vote.

The delegations participating in the WGCV are to be represented at a minimum of two out of every three plenary meetings held over the two-year period between elections. Virtual participation by means of a remote connection (i.e. teleconferencing, GoToMeeting,WebEX, etc.) does not constitute participation in WGCV plenary for voting purposes.

The list of participating delegations to the WGCV who are eligible to vote shall be published and distributed in advance of the plenary meeting during which the election shall occur.

4.6 Candidates

Candidates to be put forward for election shall be declared before or at the beginning of the plenary meeting that is held immediately prior to the one at which the election is to be held.

The candidate shall be sponsored by a CEOS member. A letter, written by the CEOS Principal or on his or her behalf, shall support the candidate for the four year mandate (two years as Vice-chair followed by two years as Chair) as well as guaranteeing secretarial support throughout the two year chairmanship.

Each candidate shall be introduced by the Chair during the plenary meeting immediately prior to the WCGV plenary meeting at which the election is to be held. Each candidate shall have at least 15 minutes to present his or her objectives and programme.

4.7 Elections

The elections are held at the end of the WGCV plenary meeting.

The WGCV secretary is responsible for collecting the votes and preparing the results.

The WGCV Chair announces the results of the vote immediately after collation.

4.8 CEOS Endorsement

The elections are confirmed after endorsement by the CEOS members during the CEOS plenary.

4.9 Additional Criteria for the Selection of WGCV Candidates

If there is no proposal by CEOS member agencies for vice chair or if the candidate for vice chair is not confirmed by the plenary, then the current chair has the following options:

- to notify WGCV membership of any nomination failure prior to terms of reference requirement,
- to request via email to WGCV and CEOS primary members that the WGCV call for vice chair nomination remains open, nominations should be provided two (2) months prior to the next WGCV meeting. If the nominations with a biography are received, all WGCV members will be notified of the nominations and the election will proceed as under the normal election process;
- to act as vice chair after the current vice chair succeeds to the chair position until a resolution to the vice chair position is obtained;
- the current chair and vice chair can choose a subgroup chair to be the acting vice chair until a resolution to the vice chair position is obtained;
- to request that an acting vice chair be provided via the CEOS SIT with approval from the outgoing chair, the current chair and the CEOS plenary.

In the above cases where a chair is appointed upon a vote from the WGCV and approved by the plenary with the caveats that the appointed vice chair agree to the responsibility of the office and that the candidate's organization agrees to the responsibilities of the office, the acting vice chair can be appointed for the current term. The voting process for approval in either of these situations is the same as described in the articles above. The appointee organization must provide a written nomination support agreement.

5 Plan Authorization

This work plan has been approved via a majority vote of the WGCV Plenary at a WGCV approved meeting, and remains valid until updates have been approved.

Annex A: WGCV Membership

The following table details the WGCV Members (current as of 20 February 2014):

Organisation	Name of WGCV Member(s)	Notes	CEOS Member	CEOS Assoc. Member	WGCV Expert
Canadian Space Agency (**CSA**)	Satish Srivastava Eric Arsenault	*WGCV Chair* *WGCV Secretariat*	X		
Centre National d'Etudes Spatiales (**CNES**)	Patrice Henry		X		
China Center for Resources Satellite Data and Application (**CREDSA**)	Fu Qiaoyan		X		
Comision Nacional de Actividades Espaciales (**CONAE**)	Juan Bratina		X		
Commonwealth Scientific and Industrial Research Organisation (**CSIRO**)	Tim Malthus		X		
Deutsches Zentrum für Luft- und Raumfahrt (**DLR**)	Albrecht von Bargen Manfred Zink	*WGCV Vice-Chair* *SAR Subgroup Chair*	X		
European Commission (**EC**)	J.-L. Widlowski (JRC) Giuseppe Zibordi (JRC)		X		
European Space Agency (**ESA**)	Bojan Bojkov Philippe Goryl	*AC Subgroup Chair*	X		
European Organisation for the Exploitation of Meteorological Satellites (**EUMETSAT**)	Tim Hewison		X		
Federal Russian Space Agency (**Roskosmos**)	Pavel Denisov		X		
Geo-Informatics and Space Technology Development Agency (**GISTDA**)	R. Nutpramoon		X		
Indian Space Research Organisation (**ISRO**)	Senthil Kumar (NRSC) B. Karthikeyan (SAC)		X		

Organisation	Name of WGCV Member(s)	Notes	CEOS Member	CEOS Assoc. Member	WGCV Expert
Instituto Nacional de Pesquisas Espaciais (**INPE**)	Leila Fonseca Flávio Ponzoni		X		
Japan Aerospace Exploration Agency (**JAXA**)	Keiji Imaoka		X		
National Aeronautics and Space Administration (**NASA**)	Kurtis Thome Xiaoxiong (Jack) Xiong Garik Gutman Miguel Roman	*LPV Subgroup V-C.*	X		
National Oceanic and Atmospheric Administration (**NOAA**)	Changyong Cao		X		
National Remote Sensing Center of China (**NRSCC**)	Chuanrong Li (AOE) Ling-Li Tang (AOE) Heguang Liu (NSSC) Xiaolong Dong (NSSC)	*MW Subgroup Chair*	X		
National Space Agency of Ukraine (**NSAU**)	Vitaliy Yatsenko		X		
United Kingdom Space Agency (**UKSA**)	Nigel Fox (NPL) Jan-Peter Muller (UCL)	*IVOS Subgrp. Chair* *TM Subgroup Chair*	X		
United States Geological Survey (**USGS**)	Gregory Stensaas		X		
Belgian Science Policy Office (**BELSPO**)	Jean-Christopher Lambert	*AC Subgroup Vice-Chair*		X	
Geoscience Australia (**GA**)	Medhavy Thankappan			X	
Norwegian Space Center **(NSC)**	Einar-Arne Herland			X	
University of Zurich	Gabriela Schaepman-Strub	*LPV Subgroup Chair*			X