Minutes of CEOS-WGCV-IVOS Meeting 34

USGS, Reston, Virginia, USA. 29 August – 2 September 2022
Chair: Professor Nigel Fox

Attending in person

Cody Anderson (USGS)
Amit Angal (NASA)
Julia Barsi (NASA)
Jonathan Borletta (Labsphere)
Marc Bouvet (ESA)
Jeffrey Czapla-Myers (Uni Arizona)
Steffen Dransfeld (ESA)
Chris Durell (Labsphere)
Nigel Fox (NPL)
Scott Gish (Labsphere)
Patrice Henry (CNES)
Sam Hunt (NPL)
Carol Johnson (NIST)
Morakot Kaewmanee (SDSU)
Edward Kaita (NASA)
Larry Leigh (SDSU)
Raviv Levy (NASA)
Aimé Meygret (CNES)
Esad Micijevic (USGS)
Jaime Nickeson (NASA)
Mary Pagnutti (I2R Corp)
Nima Pahlevan (NASA)
Katie Ruslander (USGS)
Robert Ryan (I2R Corp)
Stephen Schiller (Raytheon)
Ashish Shrestha (USGS)
Mohammad Tahersima (NASA)
Kurt Thome (NASA)
Norvik Voskanian (NASA)
Zhipeng (Ben) Wang (NASA)
Brian Wenny (NASA)
Emma Woolliams (NPL)
Mehran Yarahmadi (NASA)
Giuseppe Zibordi (JRC)

Joined online:

Bahjat Alhammoud (Argans)
Rajendra Bhatt (NASA)
Emilio Carmona (DLR)
Taeyoung Choi (SDSU)
Odele Coddington (Colorado)
Darren Ghent (Leicester)
Yves Govaert (Rayference)
Alfreda Hall
Md Obaidul Haque (USGS)
Mark Irvine
Grit Kirches (Brockmann Consult)
Ian C Lau (CSIRO)
Cameron MacKenzie (Argans)
Hiroshi Murakami (JAXA)
Peter Minnett
Yvan Nollet
Lluís Pérez Planells (KIT)
Anna Pustogvar (NPL)
Ashley Ramsay (NPL)
Rob Rosenberg (JPL)
Brandon Russell
Benjamin Scarino (NASA)
Jerad Shaw
Yolanda Shea (NASA)
Dave Smith (STFC/RalSpace)
Maddie Stedman (NPL)
Tom Stone (USGS)
Sirish Uprety (NOAA)
Renfei Wang
Howard Yoon (NIST)
Yoshiro Yamada (NPL)
Hirokazu Yamamoto (AIST)

Additional online participants to the Ocean Colour special session:
Andrew Banks
Dirk Aurin
Jean-Françoise Berthon
Brandon Russell
Barbara Bulgarelli
Craig Donlon
David Giles
Davide D'Alimonte
Ewa Kwiatkowska
Robert Fruoin
Gavin Tilstone
Gianluca Volpe
Kathryn Barker
Kenneth Voss
Kersti Kangro
Kevin Ruddick
Krista Alikas
Maddie Stedman
Antonia Mannino
Marco Talone
Gerhard Meister
Michael Van Woert
Min Wei
Pieter De Vis
Riho Vendt
Roberta Ivaldi
Pietro Sciuto
Sherwin Ladner
Ashish… Shrestha
Sirish Uprety
Violeta Slabakova…

Most presentations are available at: IVOS - CalValPortal (ceos.org)

1 Introduction

The meeting was chaired by *Nigel Fox*. Minutes were taken by *Emma Woolliams, Katie Ruslander* and *Sam Hunt*. The meeting was hosted by *Cody Anderson* of USGS. Most presentations are available for download from the CalVal Portal IVOS - CalValPortal (ceos.org)

Cody Anderson welcomed attendees to the meeting and thanked everyone for participating in person or online. Participants in the room introduced themselves and those online introduced themselves in the text chat.

Nigel Fox gave a general introduction to the meeting and the mission of the subgroup and its work over the three years since the last in-person workshop. Tim Stryker of USGS gave a welcome address.

Presentation	By	Filename
Introductory Presentation	Nigel Fox	*01_Fox_Introduction.pdf*
USGS National Land Imaging Program Update	Tim Stryker	02_Stryker_USGS_Land_Imaging.pdf

In Nigel Fox's introductory meeting he discussed how two task groups were not operational at this time. The atmospheric correction task group is covered by other activities and so could close. The 'geo spatial image quality group' should continue, but the previous chair has retired, and the former co-chair no longer available. A new chair is therefore required, and volunteers are requested.

A short discussion considered possible directions for that task group. While the previous task group had a strategy, there is also opportunity to take this into further directions, the discussion encouraged the possibility of linking to the terrain mapping (DEM) activity. An early task for the new chair would be to have a short workshop to define the scope.

AP.2022-1	**Nigel Fox** to email the mailing list to encourage a volunteer for leadership of the geo spatial image quality task group and to appoint a leader before the next meeting. And for the **new chair** to organise a teleconference to define the scope and strategy for the task group.	Next IVOS

Also in Nigel's presentation – a reminder about the new updated solar irradiance spectrum that we recommended previously.

In Tim Stryker's presentation he presented the role, and position in the government, of USGS and its success with 50 years of the Landsat missions. He encouraged participation in the Pecora-22 workshop. In discussion, Patrice Henry commented that CEOS does not do a lot of work on Earth gravimetry (shape / internal dynamics etc) and wondered if USGS could support work in that field. Tim was not sure which USA institute was responsible for the international dimension of that (there are multiple institutes that do aspects of it, and it may not be very coordinated).

1.1 Review of actions from last meeting

Last meeting's actions were not formally reviewed within this meeting. But are given here as reference. During minute review, we encourage action owner (named person) to provide an update. If you want actions to carry on to next year, then please do highlight this.

Action number	Activity	Status
AP.2019-1	**Dave Smith** to consider whether and how a workshop should or could be held on the thermal infrared at the next meeting and to discuss concept with **Nigel Fox**.	Potentially subsumed in action on new wgcv task group on TIRNET
AP.2019-2 Carried over AP.2018-1	**Nigel Fox** to ensure we hold a half to one day workshop to evaluate state-of the art on sensor L1 interoperability and the different methods used for comparisons to prioritise a work plan	To be done after the completion of the template AP 2019-17/18
AP.2019-3 carried over AP2018-2	**Everyone** to identify where possible simple examples at the application level (typically 3 or higher) where the impact of Cal/Val (at Level 1) can be demonstrated particularly quantitatively. **Nigel Fox** to liaise with **Steffen Dransfeld** to get an	On-Going

	appropriate location in the CalVal wiki to store these "stories"	
AP.2019-4 carried over AP.2018-3	**Emma Woolliams** and **Patrice Henry** to explore requirements for the uncertainty analysis for modelling-related case studies (BRDF or spectral modelling of PICS).	
AP.2019-5 carried over AP.2018-4	**Steffen Dransfeld** and **Nigel Fox** to explore prospect of an end-to-end benefit of Cal/Val for SST (Linking FRM4STS and SLSTR/ATSR+ series)	We should try to do this
AP.2019-6 carried over AP.2018-19	**Patrice Henry** to work with **Nigel Fox** to create a "news story" on PICSCAR that shows the link to WGCV priorities.	Perhaps we should still try to do something here
AP.2019-7 carried over AP.2018-21	**Nigel Fox** to find a way of bringing the sea surface temperature good practice guides to come under the IVOS envelope (consider DOI, format/title page layout, putting on portal)	Good practise guides linked to be linked and put on portal
AP.2019-8 carried over AP.2018-22	**Everyone** to find ways of making our impact widely known and to prepare "stories" that show what we have done.	Ongoing awareness
AP.2019-9	**Everyone** is encouraged to pass information about the Microwave Sensors Subgroup to suitable colleagues and to get them to contact the chair of that subgroup and/or **Cindy Ong**, recognising that a new Vice Chair is particularly needed.	Done
AP.2019-10	**Everyone** who wishes to attend the Climate Observing Systems workshop to register at https://ceoswmogsicsworkshop.eventbrite.co.uk and to provide an abstract for any desired presentation.	Complete – event in past
AP.2019-11	**Nigel Fox** to send everyone the logon details for the new calval portal website draft so that people can review the website for checking.	Complete. The CalVal portal is now updated
AP.2019-12	**Everyone** who can comment on the draft new calval portal website should provide feedback (specific suggestions of what to include/change) to **Nigel Fox** and **Emma Woolliams**.	Done but always open
AP.2019-13	**Everyone** should comment on the hierarchy of test sites suggested for the calval portal website and send feedback to **Nigel Fox** and **Emma Woolliams**	Done

AP.2019-14	**Nigel Fox** and **Kurt Thome** to provide a single coherent set of feedback comments on the website to WGCV	Done
AP.2019-15	**Emma Woolliams** to provide **Kevin Turpie** with information about the difference between the ESA-project lunar model and the ROLO/GIRO model.	Complete – Collaboration started between ESA and NASA teams. See Marc Bouvet presentation in section 3
AP.2019-16	**Nigel Fox** and **Dave Doelling** to organise a teleconference to discuss the solar spectrum with the right community and those interested in this information and to report back to IVOS and WGCV.	Done led to TSIS spectrum
AP.2019-17	**Emma Woolliams** to prepare a draft template of the table to provide uncertainty estimates for different vicarious methods and to make this available on the cloud for people to fill in	See discussion in Section 3. Action to be repeated.
AP.2019-18	**Everyone** to fill in the template table on vicarious calibration methods with the information that they have	
AP.2019-19	**Nigel Fox** to organise a teleconference to discuss and agree a version of the table of vicarious methods that can go on the website	
AP.2019-20	**Lingling Ma** to provide hyperspectral data over Libya-4 to the PICSCAR group from the GF-5 instrument	
AP.2019-21	**Nigel Fox** to develop a strategy on how IVOS, working with GSICS, could collate information on potential methods for pre-flight calibration that meet the requirements of the GHG missions	Action subsumed at WGCV level Will happen post workshop on cal/val
AP.2019-22	**Nigel Fox** to develop a strategy on how IVOS, working with GSICS, could collate information on potential methods for vicarious calibration that meet the requirements of the GHG missions	Subsumed into WGCV action on GHG strategy
AP.2019-23	**Anyone** intending to establish a new RadCalNet site is encouraged to contact the RadCalNet working group	Ongoing
AP.2019-24	**Steffen Dransfeld**, **Marc Bouvet** and **Béatrice Berthelot** to consider how and whether to incorporate the RadCalNet website within the CalVal portal and to make a recommendation to the next IVOS meeting.	Done as a link?
AP.2019-25	**Everyone** to advertise a link to the CalVal portal in their presentations and discussions	Ongoing
AP.2019-26	**Emma Woolliams** to provide a simple initial training pathway to **Steffen Dransfeld** and **Paolo Castracane** to go on the CalVal portal	Complete. Updates made to the www.qa4eo.org website and linked from the CalVal portal
AP.2019-27	**Patrice Henry** to ensure information of CEOS PICS is put on the CalVal portal	Done PICSCAR site is accessible

AP.2019-28	**Francoise Viallefont-Robinet** to consider whether and how to put information on the MTF sites onto the CalVal portal.	For new chair
AP.2019-29	**Emma Woolliams**, building on the discussions in this meeting, to send round a potential definition of "Interoperability" to be discussed as a potential proposal for consideration by WGCV.	Complete – see section 2
AP.2019-30	**Nigel Fox** to consider alternative ways of sharing information about activities of participants to the CEOS-WGCV-IVOS meeting while increasing time for discussion.	Complete – online discussion meetings held during covid times and IVOS 34 structure has more discussion and informal time
AP.2018-31	**Anyone** wishing to propose a location for the next meeting should contact **Nigel Fox**	Complete
AP.2018-32	**Emma Woolliams** to complete the minutes and Nigel Fox to send these to IVOS along with a link to all presentations onto the CalVal portal.	Complete
AP.2018-33	**Nigel Fox** to organise dates and practicalities for the next IVOS meeting.	Complete

Carried over actions

AP.2019-2 Carried over AP.2018-1	**Nigel Fox** to ensure we hold a half to one day workshop to evaluate state-of the art on sensor L1 interoperability and the different methods used for comparisons to prioritise a work plan	To be done after the completion of the template AP 2019-17/18
AP.2019-5 carried over AP.2018-4	**Steffen Dransfeld** and **Nigel Fox** to explore prospect of an end-to-end benefit of Cal/Val for SST (Linking FRM4STS and SLSTR/ATSR+ series)	We should try to do this
AP.2019-6 carried over AP.2018-19	**Patrice Henry** to work with **Nigel Fox** to create a "news story" on PICSCAR that shows the link to WGCV priorities.	Perhaps we should still try to do something here

2 CEOS WGCV and CEOS initiatives

Presentation	By	Filename
Vocabulary Group Report	Woolliams	03_Woolliams_Vocab.pdf
BIPM-WMO joint workshop "Metrology for Climate Action"	Woolliams	04_Woolliams_BIPMWMO.pdf

Emma Woolliams reported on the joint initiative between CEOS WGCV, WGISS and LSI-VC to coordinate the set-up and maintenance of glossaries. She highlighted the group's aim to overcome the challenge in communication between the entities along the EO value chain through creation of an online glossary that was structured in an internally consistent and hierarchical manner. She encouraged further participation in the group.

AP.2022-2	**Anyone** interested in participating in the vocabulary working group to contact Emma Woolliams	Next IVOS

The discussion centred around the terms "continuity" (between, e.g., successive missions) and "interoperability" (between different types of missions. Where there are differences between missions, you may not have identical designs (e.g., different spectral response functions, viewing angles, spatial resolution, times of overpass), but you can still get continuity. Emma proposes the definition, "can you correct for differences between products within the uncertainties of the original product?" This raises the questions of who has the responsibility for such corrections (which level of processing) and how additional information (e.g., BRDF models/spectral surface models) is incorporated.

There was some concern about whether defining some of these types of terms was possible or even desirable. Both Marc Bouvet and Kurt Thome said that concepts such as "interoperability" and "continuity" can be understood without a strict definition and the time should be spent on thinking about the practical aspects, rather than the definitions. Patrice Henry was concerned about the term "interoperability" being used outside a concept of "operate".

In her second presentation, Emma introduced the BIPM-WMO joint workshop "Metrology for Climate Action" (www.bipm.org). She and Nigel encourage people to participate in the discussion to make recommendations for the metrology community, and anyone who cannot participate is encouraged to contact one of them anyway.

AP.2022-3	**Anyone** with recommendations for the BIPM-WMO joint workshop "Metrology for Climate Action" to contact Emma	26th September

3 Calibration Methods

Presentation	By	Filename
FLARE Status	Chris Durrell	05_Durrell_FLARE.pdf
Preliminary Evaluation of the Mirror-Based Empirical Line Method using Flare System	Larry Leigh	06_Leigh_FLARE.pdf
Trending and Inter-sensor Calibration Using SPARC/FLARE point targets	Stephen Schiller	07_Schiller_FLARE.pdf
LIME: Lunar Irradiance Model of ESA	Marc Bouvet	08_Bouvet_LIME.pdf

Chris Durrell gave an update on the FLARE (Field Line-of-sight Automated Radiance Exposure Network) system, including the development of the portable FLARE Lantern system and some of the recent highlights of the application of FLARE. He raised questions around what it would take to get the methodology certified/endorsed by CEOS, for the discussion at the end of the session.

Nigel asks if there are performances differences between the different routes to traceability for the system (calibrated sphere vs. Langley). Chris says they are operationally complementary, with similar uncertainties. Patrice asks about the business model for the use of the FLARE system. For commercial EO vendors, they sell "looks" and "evals" from the larger Beacon systems. They are selling the lantern system to customers, which are also integrated into their network and serviced by Labsphere.

Larry Leigh presented the University of South Dakota work making use of the FLARE systems for Level 2 surface reflectance validation using a "empirical line method". Patrice asks if this was applicable for data on different days for changed atmosphere. Larry says since the comparison is at surface reflectance level this shouldn't matter. Sam asks how this might be used for non-linearity characterisation. Larry says different mirror combinations could be opened and closed to get different signal levels.
Taeyoung Choi asks how large an area is needed to collect the reflected signal. Larry says a 3×3 Landsat image (I.e., ~100 m equivalent GSD), Chris for a commercial sensor 30×30 by necessary.

Stephen Schiller presented how the SPARC/FLARE system may be used to estimate a "zero airmass response coefficient" for sensor calibration trending characterisation and sensor intercalibration using a TRUTHS-like sensor as a reference.

Bob Ryan asks how large a GSD for reference sensor can be tolerated for the cross-calibration concept. Stephen said a 100 m should be tolerable, though more would be possible with a FLARE system with more mirrors – comfortably within the planned 50 m GSD for TRUTHS.

Marc Bouvet presented an update on the Lunar Irradiance Model of ESA activity – including a description of the data collection and calibration, irradiance model fitting and uncertainty analysis, and comparisons with other observations.

Patrice asks about the origin of seasonality in the comparisons between LIME and Proba-V. Marc answers this may come due to changes in observation geometry during the year. Cody says they have observed a similar effect in Landsat comparisons to modelled lunar irradiance, particularly in the SWIR channels.

Taeyoung Choi asks which solar irradiance model LIME uses. Marc answers that to date Thuillier has been used, though following discussions with the air-LUSI team the TSIS spectrum is being considered. The LIME toolbox is intended to allow users choice over which spectrum they would prefer.

Patrice asks if there have been any discussions to use the LIME model to compare to geostationary data. Marc answers this should be possible in future, though no immediate plans. This is intended to be enabled through LIME toolbox compatibility with the GSICS GLOD format. Chris Durrell asks if there have been any comparison to the NIST air-LUSI measurements. Marc answers that a collaboration is already in place between the two groups (a follow on to the IVOS 31 action AP.2019-15) but results are not ready to make public.

At the end of the session there was a return to the discussion about how FLARE can get some form of "endorsement" by CEOS. It was noted that CEOS can't put its name to commercial activity (only to systems where the data is provided for free). However, Nigel reminded us that at IVOS 31 (AP.2019-17) there had been plans to create a summary table of all the different cal/val methodologies with indicative uncertainties (with references to peer reviewed evidence) and the FLARE system could be included in such a table, as well as RadCalNet, Hypernets, LIME, PICS, DCCs etc.

The subgroup was in favour of creating that table and of including FLARE amongst other methods in it. There was a question about how such a table would be checked / approved. Nigel Fox confirmed that the IVOS subgroup would have to agree the table by peer review, and any concerns identified would need to be addressed by consensus discussion, and Kurt Thome said it may then need to be taken to WGCV, but probably not as a system of "endorsement" but just as useful information.

AP.2022-4 (Reformatted AP.2019-17)	**Nigel Fox** and **Emma Woolliams** to review the template that was developed in 2019 on presenting the different methods, and to produce a fresh table template, alongside a workflow of how the table is filled in, reviewed and published.	Next IVOS

4 Ocean Colour Special Session

Presentation	By	Filename
25+ years of JRC Ocean Colour Cal/Val activities: a synopsis	Giuseppe Zibordi	09_Zibordi_OC.pdf
GCOM-C/SGLU CalVal with AERONET-OC	Hiroshi Murakami	10_Murakami_AeronetOC.pdf
Update on MOBY/MOBY Refresh and MarONet	Kenneth Voss	*11_Voss_MOBY*
Giuseppe	Ewa Kwiatkowska	12_ Kwiatkowska_Giuseppe.pdf
FRM4SOC-2	Riho Vendt	*13_Vendt_FRM4SOC*
PACE: Plankton, aerosol, cloud, ocean ecosystem advancing global and coastal ocean colour science and applications	Antonio Mannino	14_Mannino_PACE.pdf
Landsat-8/9 Level 1 & 2 Consistency Assessments	Nima Pahlevan	*15_Pahlevan_Landsat*
Cross-calibration of polar-orbiting ocean-colour sensors using geostationary observations	Robert Frouin	16_Frouin_crosscal.pdf

Nigel Fox introduced Giuseppe Zibordi who is about to retire, after a long and distinguished career in ocean colour. Giuseppe Zibordi started working with CEOS WGCV IVOS in the 1990s. He gave a comprehensive overview of ocean colour science and the history of the ocean colour community. His presentation focussed on all the different aspects of the observation that affect the uncertainty and how careful you must be to get reliable observations.

Nigel presented Giuseppe with a book as a gift from our community.

Hiroshi Murakami presented a calibration/validation analysis of GCOM-C/SGLU using AERONET-OC data. Some issues were identified related to the aerosol model used. Kenneth Voss presented the status of the MOBY Refresh activity. Ewa Kwiatkowska presented a summary of OC cal/val activities at EUMETSAT in support of the Copernicus programme. She paid particular respect to the role of Giuseppe Zibordi in the progress made by the community.

Riho Vendt provided a description of the FRM4SOC project activities including the development a database of FRM validation measurements processed by a common community processor and field intercomparison exercises. Anyone interested in attending the FRM4SOC project workshop 5-7 December (at EUMETSAT and online) is encouraged to do so through https://frm4soc2.eumetsat.int/

Antonio Mannino presented information about the status and progress in preparation for the PACE mission (due to launch in January 2024). Information is available at pace.gsfc.nasa.gov and on social media @NASAOcean. Nima Pahlevan presented work looking at the cross-calibration of Landsat-8/-9 with the L9 underfly of L8 in November 2021, which shows good agreement. Robert Frouin described

the cross-calibration between two polar-orbiting sensors, using geostationary satellites to provide an intermediary, which increases the number of coincidences significantly vs SNO.

Session closed with Nigel giving good wishes to Giuseppe for his future endeavours.

5 Calibration Methods part 2

Presentation	By	Filename
Preparation of next generation hyperspectral radiometric validation networks for water and land (Hypernets)	Kevin Ruddick	17_Ruddick_Hypernets.pdf
CNES Calibration Activities	Aimé Meygret	18_Meygret_CNES.pdf

Kevin Ruddick presented the status of the development of the Hypernets network which has a wide range of both land and water sites recently established or to be established soon. Nigel commented on the interest of the IVOS community on the use of the sites for visible calibration and possible integration into RadCalNet. Kevin was supportive of this type of action.

Aimé Meygret presented a summary of calibration methods and activities underway at CNES. This included work on reference spectra for PICS, Rayleigh Scattering, DCCs, sun-glint, Moon, stars, and instrumented sites; for both Vis/SWIR and TIR spectral regions. After describing the calibration of several commercial and agency sensors, he ended by describing the SPOT world heritage data set – which is collating, reprocessing and making available all SPOT 1-5 data at https://spot.cnes.fr/en/spot-world-heritage-0.

6 SI-Traceability in Space

Presentation	By	Filename
Outcome of workshop on SI-traceable Space-based Climate Observing System (SITSCOS)	Nigel Fox	*19_Fox_SITSCOS.pdf*
CLARREO Pathfinder Mission Overview and Status	Yolanda Shea	*20_Shea_CLARREO*
CPF-VIIRS and CPF-CERES Direct intercalibration approach	Rajedra Bhatt	*21_Bhatt_CPF-Intercalibration*
TRUTHS: An ESA Earth Watch Mission	Nigel Fox	*22_Fox_TRUTHS.pdf*

Nigel Fox presented the outcomes of the SITSCOS Workshop that was held in 2019. The report is available on the CalVal portal https://calvalportal.ceos.org/siscos-ws and has a DOI: https://doi.org/1047120/npl.9319. Nigel summarised the key information in the report.

Patrice Henry asked how the recommendations are going to be implemented. Nigel confirmed that it had been presented at COP, at GCOS workshop, and so on. Having an executive summary as its own document will help. Patrice said that this is a problem with recommendations – he said that previous recommendations had not reached the decision makers within the hierarchy at CNES. Nigel agreed that this is both important and difficult. **Everyone is encouraged to think about how to get the information to the right people at the right time and if for this specific document further opportunities existed.**

Yolanda Shea presented a summary of the CLARREO Pathfinder mission, which will be hosted on the international space station and launched in December 2023 for operation for nominally 1 year (but with the hope of much longer). It will have a spectrometer operating from 350 nm – 2300 nm with "climate critical high accuracy". https//clarreo-pathfinder.larg.nasa.gov

Marc Bouvet asked about how CLARREO Pathfinder will meet the 0.3% radiometric accuracy for intercalibration. Patrice Henry asked about how this will be transferred e.g., to CERES – which is broadband. Yolanda Shea confirmed that the 0.3% uncertainty is about being able to create a calibration reference from CLARREO Pathfinder that matches, as far as possible, the other sensor – it's not including uncertainties associated with the other instrument, which are beyond the control of CLARREO. These topics are further described in Rajendra Bhatt's presentation. Nigel Fox asked about the spectrometer optical path and the grating – where the order sorting filter is. Yolanda confirmed that there is an order sorting filter within the instrument.

Rajendra Bhatt presented the intercalibration process for CLARREO Pathfinder being used to calibrate other sensors (NOAA-20 VIIRS and CERES).

Sam Hunt asked about the RTM-based angular correction and how information about surface BRDF, and atmospheric state and uncertainties associated with those parameters were feeding in. Rajendra explained that they are not relying on identifying the type of scene; but will look for best-matching scene type from a spectrum library. Matching ~300 spectra from the database, and then interpolation to match for the angles. The spectral library will provide the necessary information.

Nigel Fox presented the TRUTHS mission which is an ESA-EarthWatch mission funded by the United Kingdom, Greece, Switzerland, Czech Republic, and Romania. TRUTHS will provide SI-traceable reference measurements as an operational climate mission. Current schedule is for launch in Q4 2029/Q1 2030.

Cody Anderson asked what the 4 TB data / day means. Nigel explained that the limit is the ground station and this would be the duty cycle with one ground station. However, if more than one ground station were available, the satellite platform could transmit more, but that is not currently baselined.

Patrice Henry asked why the planning/implementation is so long – although, arguably more realistic. Nigel said originally the plan was 2026, but in reviewing the process and estimating a realistic schedule, a longer schedule was likely. It is also impacted by the three-year funding cycles of ESA being used to spread the funding cost of the mission.

Patrice also asked whether other countries would join. Nigel explained that the team is hoping for more countries to join – and there are opportunities for that, although the UK does want to keep control of some of the bigger items. However, they are considering some dedicated specific things that other countries can be involved in.

Cody Anderson asked about the 90-degree orbit. Nigel said their starting point was some of the thinking of the original CLARREO mission. It will not be possible to do comparisons globally at all times of the year due to limited sunlight at some seasons, and the orbit injection point will affect which seasons the overlaps will happen with morning and afternoon satellites. Yolanda explained that with CLARREO Pathfinder on ISS, there is a more frequent precessing orbit and opportunities to do comparisons at more times. Nigel explained that TRUTHS won't only be looking at SNOs, but also using it to calibrate PICS, reference sites, etc, and using intermediary satellites to chain calibrations. Bob Ryan asked Nigel what power the cryogenic radiometer cooler would take. Currently ~100 W for 60 K

– 65 K temperatures. There are trade-offs under investigation with number, manufacture and operational nature of coolers etc.

7 Use and characterisations of PICS

Presentation	By	Filename
PICSCAR presentation	Patrice Henry	23_Henry_PISCAR.pdf
Sentinel 2 L1 radiometric vicarious validation and intercomparison with Landsat over Libya4	Bajhat Alhammoud	*24_Alhammoud_PICS*
Satellite stability and intercomparson using PICS and extended PICS	Morakot Kaewmanee	25_Kaewmanee.pdf
Eradiate simulations of PICS radiance	Nicolas Misk	*26_Misk_Eradiate_PICS*

Patrice Henry presented the PICSCAR working group activity. The group was unable to meet during this IVOS week; but will have an online meeting later in the year. Work has progressed in three areas:

- Database of sensor acquisitions over the PICS, extended and upgraded to include pixel level, atmospheric characteristics, cloud mask and quick look and converted to a NetCDF file. Also to increase to an additional 5 PICS by the end of the year.
- Site stability assessment with TOA, BOA and normalised-to-nadir BOA. Looking at data with and without BRDF correction suggests some over-correction of seasonal geometry issues.
- Monitoring the L8 / S2A intercalibration over Libya 4. The SBAF is significant in some bands, and the current correction model is based on Hyperion data – an improved spectral model for the sites may improve the intercalibration.

The aim is that data from current missions are provided every 6 months. This is happening with CNES and SDSU. In the discussion, Bahjat Alhammoud explained that ESA data will be made available soon (once edits are made on the structure), and Julia Barsi explained that NASA data is also coming. Dave Smith said he was surprised that S3 SLSTR data are not available as these are routinely obtained.

There are different possible activities to take this work forward. It will be good to have a virtual PISCAR meeting later this year. Nigel raises the suggestion that NASA engage with PISCAR through the VIIRS mission, however Kurt pointed out that this is a NOAA mission in this context. Jason Choi says he will investigate the possibility of NOAA participating in the activity. (note during the meeting Jason confirmed that NOAA would contribute.)

Rajendra Bhatt of NASA describes recent updates to the BRDF models to include atmospheric parameters. This was recently published at SPIE and he'll make the presentation available. They have a SCHIAMACHY-based SBAF, and an online tool that can do some of these calculations with ~900 Saharan desert footprints, including seasonal dependencies (due to shadows of the dunes that can affect broader SRFs). He is happy to get involved in collaborations. A lot of this is discussed at monthly GSICS meetings – Patrice says that they had previously engaged and PICSCAR was envisaged and created as a joint CEOS/GSICS activity, but it is hard to find people who can collaborate across the groups at present. Whilst he understood topics were raised in GSICS on an ad-hoc basis there are advantages for dedicated collaborative meetings, rather than joining the general meetings of the GSICS groups, or at least to know in advance when the PICS topic might be discussed. Patrice explains that what is currently missing is geostationary data and it would be good to add that to the analysis portfolio.

AP.2022-5	**NOAA VIIRS team (Jason Choi)** will talk to NOAA management (Changyong Cao) on this PISCSCAR future action on VIIRS data.	Next IVOS
AP.2022-6	**Patrice Henry** and **Rajendra Bhatt** to discuss ways that PICSCAR can relink to the ongoing GSICS activities in a time efficient manner (link to Dave Doelling and Fred Wu)	Next IVOS
AP.2022-7	**Patrice Henry** to organise a PICSCAR online workshop and publicise it to bring in new participants.	End 2022

Bahjat Alhammoud presented results of Sentinel 2 radiometric calibration over different instrumented and PICS sites. Dave Smith asked about slide 17 what the "error bars" on this graph were. Bahjat confirmed these were the "total combined uncertainty of the method" which is assumed to be "about 5%" (k = 2). Dave asks further what the dominant uncertainty was and why the uncertainties are so much larger than the scatter on the data. Bahjat says that the MERIS reference is the dominant uncertainty, where there are large differences between the bands and that with a different sensor this could possibly be reduced.

Morakot Kaewmanee presented work on comparisons to traditional and extended PICS. ePICS are established from clusters of stable sites (bright pixels with temporal stability better than 5%), identified with k-mean clustering. Sam Hunt asked about the ePICS being able to be sampled daily – is it not necessary to get pixels across the whole ePICS. Morakot explained that it is possible to sample just a few pixels – it's the same kind of sand in those regions and it is therefore possible to get a representative sample from just a few observations. Patrice Henry asked about the data on slide 30 and whether this is the same data as was sent to PICSCAR – that will be reviewed.

Nicolas Misk presented how the Eradiate RT code can model PICS. As current satellites achieve uncertainties ~3% and future satellites will be working at the ~1% level, then vicarious calibration methods have to be able to get to those uncertainties in terms of transferring from one sensor to another. Eradiate has been developed for vicarious calibration. See www.eradiate.eu. Rajendra Bhatt asked about the availability of the radiative transfer models and what form it is in. Nicolas explained that it is a python package that you can use with a piece of code to simulate the atmosphere. It is openly available and information on how to access it is on the eradiate website.

8 Sensor performance assessment

Presentation	By	Filename
GCOM-C/SGLI Cal/Val L1 and L2	Hiroshi Murakami	27_Murakami_GCOM-C.pdf
Vicarious calibration for ASTER	Hirokazu Yamamoto	28_Yamamoto_ASTER.pdf
Landsat 8 / 9	Larry Leigh	29_Leigh_Landsat.pdf

Hiroshi Murakami presented the different approaches to the calibration and validation of GCOM-C/SGLI. Hirokazu Yamamoto presented the vicarious calibration of ASTER and Larry Leigh talked about the cross calibration of Landsat 8 and 9 during the under-fly tests.

Larry Leigh was asked whether he considered the cross-calibration as final now He answered that the green band may need a few further tweaks, but otherwise this is considered complete. Julia Barsi asked whether the resultant differences could be explained by the SBAF, with very similar spectral response functions, and Larry agreed it was surprising, but does seem to be real – over this wide range

of surface types. Kurt Thome said that the data were collected over the whole globe in a short period of time, and that creates a diverse data set. The discussion now is on minor differences for specific classes. So, it may be too soon, and risky, to read too much into residual differences. Sam Hunt said that these residual issues could also be due to the model – and the old spectral data collated from Hyperion. Dave Smith comments that the graph is showing differences in the fourth decimal place – and it's not appropriate to change the calibration because of trusting at that level.

9 Uncertainty / Traceability and QA

Presentation	By	Filename
Traceability and Uncertainty - Discussion	Cody Anderson	30_Anderson_Traceability.pdf
Framework for EO Product Quality Assurance	Sam Hunt	31_Hunt_QA.pdf
QA4EO framework and a metrological approach to FRMs, FDRs and TDPs	Emma Woolliams	31_*Woolliams_QA4EO*
Landsat 8 L1T Product Radiometric Pixel Uncertainty.pdf	Mary Pagnutti	*32_Pagnutti_L8Uncertainty*

Cody Anderson led off the Uncertainty and Traceability discussion; discussing defining key terms (touched on interoperability: piecing datasets together, especially with so much data now). How can we set up the data to be prepared for this? He reviewed the CEOS Analysis Ready Data (CEOS-ARD) concept, satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis. He also reviewed surface reflectance and temperature requirements and CEOS ARD Verified Datasets.

Action to check status of Sentinel-3 which should probably be on the list for self-assessment Under Development.

AP.2022-8	**Steffen Dransfeld** to check whether Sentinel-3 should be included in the list for self-assessment of the synergy SDR products for CARD4L and to discuss with **Cody Anderson**	End 2022

Nigel Fox brought forward: there is no requirement for traceability / uncertainty (at threshold level) for any of the listed surface reflectance requirements. Cody asked the group – what can we get the commercial data providers to do so that they can understand and represent the quality of their data? How do we get information to scientists and other users that is understandable and useable? Sam Hunt answered, depending on purpose, you would have different set of requirements for users (sliding scale between rigorous SI Traceability and no need for any). Patrice Henry noted that you can generate commercial products with surface reflectance requirements, based on the ARD definition table Cody shared. Cody noted getting the CEOS ARD stamp is a beneficial marketing tool for the commercial companies.

Nigel commented that until we place a radiometric quality requirement into the threshold specification, even if government agencies would assume they needed something here why would the commercial company try to be comparable to government agencies and formerly address quality statements. We need the first step in changing the threshold (or an intermediate level) to have some requirement. So perhaps we need to discuss what is the minimum and what is the target? Chris Durell emphasised by asking why would a commercial organisation try to meet a level of data quality unless it's put in the contract.

Nigel Fox comments that there is a huge gap between threshold and target – so the target is extremely difficult to reach. This conversation could lead to discussions that could define intermediate steps. The implication is that the user community is happy to use the data with no knowledge of uncertainties. We need to make an intermediate level that is doable and viable, and well supported. Kurt Thome supports the provision of methodologies that can help people reach a "doable and viable" standard. This could be as simple as a comparison to L8 and/or S2 over PICS.

Patrice noted we're assuming level 1 and level 2 (assumption that level 2 product will be produced by USGS, or S2A by ESA), but if you don't have traceability at level 1, how could you ever have full traceability at level 2? Kurt Thome noted if you do a comparability between Landsat surface reflectance product to reference dataset and got to match within 5%? He noted that would be a traceable product.

Steffen Dransfield noted – people who pay for level 2 products, do they need uncertainty? Is there a demand for it? Noting if there's a demand, there's an incentive. Sam Hunt noted people might be aware they're interested. Chris Durrell noted you need to connect traceability to money (to the ROI for those providers) so they can have an advantage in the market for good traceability. Cody noted users look to this CEOS user community to know if the data quality is good. Cody asked, what about separating metadata requirements from the data quality requirements to allow the datasets to be CARD4L compliant on metadata side, but not necessarily data quality side?

Nigel noted that would add another criterion, that doesn't have to be passed (adding 2 classes). Cody suggested having 2 standards: meeting all of the metadata standards or meeting the radiometric/geometric corrections. He also noted if you meet the metadata, there's an implied level of data quality (even with no requirements). And rather than having threshold / target, or even threshold / intermediate / target, being clearer that there are separate meta data requirements and quality requirements and a data set meets one but not the other.

Marc Bouvet says it could be possible to raise the quality expectations of requirement – along with simple steps / guidance about how to do it. Also, of course, if the big funding organisations are demanding quality requirements in their invitations to tender, there are more likely to happen. Kurt noted there's a large difference with Level 2 products to still be falling under the 5%. Nigel noted that it would still improve over time, but could drive the marketplace. And Nigel emphasized we need to make it visible and transparent for users to understand the levels (even if it is at 10 or 20%) and see it drive down over time.

Marc Bouvet explains that we shouldn't be saying what the requirements are – but that they should be public – how big is the uncertainty, where is the traceability to, etc – so that users can have that information. The market will decide whether those are acceptable. But Kurt says the market is currently showing us that they don't even want the information. However, as a group we feel something should be there – so we have to push for that.

Sam Hunt presented a framework for assessing the quality of satellite data (framework for EO Product quality Assurance). Within the list, what do we want to know and what do users need? He reviewed ESA EDAP Project which performs an assessment on various existing non-ESA (typically commercial) EO missions and come up with a way to objectively assess the quality and more importantly make it understandable to users, of these missions. Created a maturity matrix and recommend using as guidelines for quality analysis. Note the assessment is only in relation to what the data provider claims e.g. if they say they are delivering a surface reflectance of 10% uncertainty is this justified it makes no judgement if that absolute value is the right one for a particular application nor a

comparison of merit with a sensor that might deliver 1%. Since different applications require different characteristics.

Patrice asked, here we are speaking of Level 1 products? Sam Hunt confirmed that the framework structure shown is for Level 1 products. Patrice asked, why is there a separate box for Uncertainty? Shouldn't Uncertainty be tied to Radiometry box and the geometry box? Sam Hunt noted that the radiometry box is about the processes of radiometric calibration and characterisation, while the uncertainty box is about how uncertainty has been considered. Each box summarises the key information about how the mission has been developed. Patrice Henry says that you could have high effort for radiometric uncertainty assessment but not for geometric, or vice versa. And is concerned that these could not be distinguished with a single colour for the box.

Sam noted that this table assumes use of an optical image product. Kurt agreed on Patrice's example, there could be a surface reflectance product that has excellent radiometry, but basic geometry (how would you colour the uncertainty box)? Emma suggested adding an uncertainty box for geometry? Sam noted that if we had a surface reflectance product, uncertainty would cover the entire product. The geometry would be covered in geometry only box. Marc Bouvet noted we're discussing auditing of this table – who is the auditor? Sam responded that at present this is space experts/domain experts and this might evolve over time.

How do current users handle the uncertainty box? Nigel Fox noted its either 'just radiometry' or the 'total product', Sam thought it is the measurand of the product (so should have contributions of geometry and radiometry). Cody agreed with Sam Hunt that the final product (surface reflectance) is a radiometry product. Geometry could contribute to it but the final value is a radiometric measurement. Sam noted we need an objective way for noting: is the product sufficient for what the user is trying to achieve, and what are the uncertainty best practices.

Nigel asked, what needs to be done to reach each criterion? Sam noted it would strengthen the document if we had a list of the criteria. Kurt asked, who decided what the criteria should be? Sam: it was discussions within the project team, with discussions on best practices. Chris Durrell noted results may be based on the quality of the auditor. He also noted James Hancock has a paper on a scoring system for this checklist.

Steffen Dransfeld wondered whether the audit should be done independently of the application. Sam replied that there still has to be some basic understanding of application – a climate science mission would be compared against a different set of requirements to an imaging mission. Kurt Thome is concerned about a four-level grading for "traceability", given you're either traceable or not traceable. Sam said that you can have "traceable" and "SI-traceable". At the current level, "traceability to SI" only occurs at "Ideal" level.

Emma commented that there are 4 levels of uncertainty quality in the EDAP framework, while at the moment CARD4L is below the lowest (threshold is similar to "not assessed"), and at a high level (goal is "excellent"), the intermediate levels (basic, good) are not covered by CARD4L. Uncertainty is described in CEOS at "ideal" level. Nigel noted that "SI Traceability" means different things in US and Europe ('NIST' supplied a standard? Or has someone gone in and independently audited the measurement process?). Kurt Thome agreed uncertainty would still have levels; rather than a 'black and white' level of traceability.

Sam noted, there's still work for moving this forward. And the next step is once you have this assessment, what to do with it? Give a recommendation that these type of specs are useful for X application. Chris Durrell noted that this maturity matrix is a communication tool, more than anything

else. Gives us a way to communicate across users how to understand the quality of a product. Last step is how do you apply it (did the sensor meet the objective?)

Kurt asked at what point does this get shown to the customers? Sam noted on the ESA side there's published reports, with the table filled out which can provide the communication on an easy level. Planet has been through this process. Their synthesis is on the EDAP website. (and possibly Maxar, blacksky). We may need more work for outreach to the community. ESA currently using on ESA portals (VHR, HR and MR Optical Missions - Earth Online (esa.int)).

Alfreda Hall from NASA noted that NASA for the first time will be using the same draft/guidelines in a set of evaluation that they're going through now (in on ramp of vendor data). Using this for data quality assessment. They have subject matter experts filling out based on knowledge. More to come on these initial results but plan to use it to determine if they will purchase more data or not. Bob Ryan noted if CEOS could help define an RSR standardization, that would be helpful. (Relative Spectral Response). Need to understand the uncertainty of the RSR. Cody Anderson asked is there per pixel uncertainty? Sam noted that in the 'good' or 'excellent' classification, one of those demands that level of specificity.

Emma Woolliams presented QA4EO Framework and a revamp of its web presence as well as how to establish Fiducial Reference Measurements (FRMs) in a metrological manner. She reviewed the QA4EO Principle and different applications to apply it to. She noted the importance to be able to propagate information and uncertainties from one product level to the next. She also reviewed 5 steps to an uncertainty budget for each product level and the supporting material available on www.qa4eo.org to help people with that material. Emma introduced the CoMet Toolkit (Community Metrology Toolkit), which has been developed to enable easy handling and processing of dataset error-covariance information (helpful training toolkit in Python), available on GitHub and through the qa4eo website.

Patrice Henry asked if the processes is applicable to any product? For example, if you have a level 2 product the starting point is not a measurand but the level 1 product. Emma answered – she believes that the steps apply to whatever product you're making, but if you have a product that's based mostly on a model, your traceability diagram may look different (classification steps or machine learning steps instead of quantitative numbers). Cody Anderson asked how closely does the process they're using for Landsat per pixel uncertainty follow what Emma showed? Bob Ryan answered it does follow up to a Level 1T product but Mary is going to present specific examples.

Mary Pagnutti presented a summary of the L8 L1T radiometric uncertainty algorithm approach I2R has been working in conjunction with USGS. SI Uncertainty is a dominant factor (per scene basis) and she presented examples of radiance uncertainty values based on initial scenes selected. She also explained how sensor noise is propagated through Resampling followed by interpolation.

Patrice Henry brought forward that the radiometric uncertainty she presented was looked at independent from one pixel to another, he noted that it's not always independent. And reviewed example of noise from straylight. Bob Ryan answered that those were considered but need access to per pixel dark frame information. He also noted they're not seeing the dark frame info you typically see (signal to noise ratio is very high). Mary agreed it's a valid point. Emma Woolliams noted that is part of the process of uncertainty analysis that you won't have all the information in the first attempt – it's important to note what you have and have not included. It was also asked about including polarity? Kurt Thome answered that we typically don't have those types of models/information. (this is provided in the requirements from the vendor, but all wrapped up without details).

Mary Pagnutti's presentation included consideration of uncertainty in interpolation using an intrinsic interpolation method. Bob Ryan explained that the initial approach was feature based (edge targets) that fits a sigmoid well and then modelled the error (significant, 15% because of the edge response). They found that Landsat is highly aliasing near the edges. Emma Woolliams pointed out that the cubic interpolator is a good example of her (+0) component in the GUM propagator. Bob Ryan noted there's a difference in that the noise does produce this. The interpolator doesn't know what the underlying function is. Emma noted that's what she means by (+0), the function doesn't represent reality. Emma Woolliams also brought up they have done something similar but a different method and would like to compare (noted action). Esad Micijevic would also like to be part of that discussion.

Patrice Henry also pointed out its important to highlight the end result is not true uncertainty, but a model of uncertainty. Cody Anderson brought forward he sees bringing this to users as a warning (uncertainty high in certain regions). And Mary Pagnutti noted that may depend on the users' application. Cody Anderson brought forward an example of looking at an edge analysis shift along the coast of Africa which ended up due to sand dune shift in the land (this would have been a good case to bring to users emphasising the uncertainty of pixel edges).

Nigel Fox asked if we should continue this topic in another event/time. Agreed it would be good to have a half a day session on Sentinel, Landsat per-pixel uncertainty discussion since it's an early learning curve (action noted). Uncertainty sub-group for IVOS? Uncertainty map as a boundary condition was also brought up by Nigel.

Discussion of when we should bring data curation experts in. As we think about storing and using covariance information – these are huge data sets – even: per pixel, in every band is big. Adding covariance squares the problem. There are methods that have been explored – such as parametrising covariance matrix into smaller information pieces, or having "on the fly" uncertainty calculations. But these types of decisions could benefit from having data curation and dissemination experts to be part of the discussion. The Landsat 8 data set could be the start of such a discussion – it could be provided as an example of what we're considering. Cody Anderson said the Landsat Science Team meeting had participation from the Google Earth Engine team and he said that even for Google, the data itself is becoming too big – let alone including uncertainty information.

AP.2022-9	**Emma Woolliams** to compare the intrinsic interpolation method her team has used in comparison to the results **Mary Pagnutti** and **Bob Ryan** presented on per pixel uncertainty for Landsat. And to include **Esad Micijevic** in those discussions.	End 2022
AP.2022-10	**Nigel Fox** to set up a half day discussion group either online or at the next IVOS meeting to consider Sentinel and Landsat per pixel uncertainty efforts	Next IVOS
AP.2022-11	**Nigel Fox** and **Cody Anderson** to set up a discussion on the curation and dissemination of uncertainty data information (volume / formats) to link WGCV and WGISS, particularly for imaging sensors.	Early 2023

10 Hyperspectral sensors

Presentation	By	Filename
DESIS: Overview and Calibration	Emiliano Carmona	33_Carmona_DESIS.pdf
EnMAP	Emiliano Carmona	34_Carmona_EnMAP.pdf

Detector-based Absolute Radiometric Calibration for Imaging Spectrometer of High Accuracy: a Simulation	Ben Wang	*35_Wang_SpectrometerCal*
Surface Biology Geology Designated Observable	Kurt Thome	36_Thome_SBG.pdf
CHIME Cal/Val Methodology & Status	Antonio Gabriele, Valentina Boccia	37_Gabriele_Boccia_CHIME.pdf
An Overview of the Emerging P4001 Hyperspectral Standard	Chris Durrell	38_Durrell_IEEEHyperspectral.pdf

Emiliano Carmona led off the hyperspectral sensor session with an overview of the DESIS mission and its calibration. Yves Govaerts asked about the sensitivity to polarisation of DESIS, as a potential explanation for the calibration issues in the blue spectral bands. Emiliano says this characterisation has been done, but these issues are thought to be due to instrument degradation.

Dave Smith asked about the dispersion in the RadCalNet comparisons in particular spectral regions is that down to RadCalNet or DESIS measurements. Emiliano answered this dispersion is due to water vapour channels absorption in these channels. Dave wonders if this is something that could be improved. Emiliano also mentions that uncertainty for off-nadir comparisons RadCalNet is a limitation of the current system.

Emiliano continued by presenting the status of the EnMAP mission and its calibration.

Ben Wang presented a detector-based approach to the absolute calibration of imaging spectrometers. This was developed for the calibration of the HySICS instrument on the upcoming CLARREO Pathfinder mission. Ben presented the results of a simulation study investigating the uncertainty sources of the approach as a basis to ensure the forthcoming campaign was adequate.

Nigel Fox asked if there would be a similar exercise for the irradiance measurements, to ensure end-to-end validation of the system. Kurt answered that this is not in the plan due to budget and timeline constraints.

Howard Yoon asked how they expected to achieve 0.3% in-orbit given the uncertainty components for the on-ground radiance calibration presented seem to exceed that. Kurt answered the current expectation is that although the ground calibration may not meet the in-orbit requirements it was still a valuable dataset.

Kurt Thome presented an introduction to the Surface Biology Geology Designated Observable project (SBG mission). A mission concept to deliver applied science across a variety of domains, in response to the NASA decadal survey. Nigel Fox asked if there have been any developments around the instrument designs given the relatively fast launch schedule (2026). Kurt said there have been efforts to consolidate a nominal design using existing concepts. He also pointed out that the review panel were keen to ensure the data validation methodology was established and sustainable in the mission timeframe (e.g., RadCalNet).

Antonio Gabriele and Valentina Boccia presented an overview of the CHIME mission concept and status. Valentina Boccia then presented the CHIME calibration methodology and dedicated data quality activities in support of the mission.

Chris Durrell presented the status of the hyperspectral characterization and calibration standard under development by the IEEE hyperspectral P4001 working group.

11 Missions / Status

Presentation	By	Filename
Landsat Cal/Val Status	Esad Micijevic	39_ Micijevic_Landsat.pdf
Sentinel 3 mission and optical products status	Steffen Dransfeld	40_Dransfeld_Sentinel3.pdf
Cal/Val Portal Update	Steffen Dransfeld	41_Dransfeld_CalValPortal.pdf
Uncertainty for SLSTR/LSTM	Dave Smith	42_Smith_SLSTRUncertainty.pdf
Status of MODIS and VIIRS Instrument Calibration	Amit Angal	*43_Angal_MODIS-VIIRS*

Esad Micijevic presented the status of calibration and validation activities for the OLI and TIRS instruments onboard the Landsat 8 & 9 missions.

Dave Smith asked about slide 35/36 where there is a step change of the responsivity due to changes in the radiometric gains when the thermal properties of the instrument changed. Esad confirmed that these changes were corrected through the onboard calibration, and not through additional processes. Aimé Meygret asked how a vicarious calibration can be done in the TIRS band. Esad explained that ocean buoys and a few stations operating between 3°C and 38°C are used.

Steffen Dransfeld presented the current status of the optical instruments and ESA products on Sentinel 3. This includes new per-pixel uncertainties for OLCI. Sam Hunt asked whether the uncertainties will be provided for future products or also retrospectively. Steffen said that there won't be a global historical reprocessing, so it's for new pixels. Emma Woolliams asked if statistics are being collected on how many users choose to have the uncertainties and Patrice Henry asked which was the default option. Steffen says that the no-uncertainties option will be default and they will collect information on how often people download uncertainties.

Steffen Dransfeld then gave an update on the CalVal portal. There are 1050 registered users. There have been some updates to several subpages, including the SALVAL tool. TSIS page needs approval by Nigel Fox as IVOS chair (noted and done during the meeting) NPL. Steffen encourages more information to be provided.

Dave Smith presented information about the uncertainty analysis for SLSTSR on Sentinel 3 and the plans for LSTM. Steffen Dransfeld asked about the uncertainty tool – uncertainties are available for both visible/SWIR and TIR bands, but unlike OLCI they are available "on demand" rather than "in the product". Sam Hunt asked if there were any plans to apply this methodology to the (A)ATSR series. Dave confirmed that this was being considered for an upcoming reprocessing of AATSR.

Howard Yoon asked about non-linearities and why there was a shape to the uncertainties. Dave Smith said that the blackbodies are basically at fixed temperatures. This could be changed, but as it's an operational mission, can't easily change. He also explained that the

non-linearity was characterised in pre-launch and that operational temperatures did not reach the temperatures where non-linearity was a concern.

Amit Angal presented information about the MODIS and VIIRS instrument status and calibration.

12 CEOS-WGCV-IVOS Activities

Marc Bouvet presented the status of RadCalNet, almost five years after it became a public site.

Presentation	By	Filename
The Radiometric Calibration Network: RadCalNet	Marc Bouvet	44_Bouvet_RadCalNet.pdf

13 Continuation

Cameron MacKenzie gave the presentation that had been missed earlier in the programme about the use of the RadCalNet sites to calibrate and validate Sentinel-2. Jeff Czapla-Myers asked whether the data are normalised to nadir view for the comparisons and Cameron said he'd get back to us on that.

Presentation	By	Filename
Sentinel 2 calibration and validation with RadCalNet	Cameron MacKenzie	*45_Mackenzie_S2-RadCalNet*
Potential new Grassland RadCalNet site	Cody Anderson	*46-Anderson_EROS.pdf*

14 CEOS actions and activities

Presentation	By	Filename
TSIS-1 Hybrid Solar Reference Spectrum and comparisons to MODTRAN solar reference spectra	Odele Coddington	47 Coddington_SolarSpec.pdf
5th CEOS TIR radiometer comparison	Yoshiro Yamada	48_Yamada_TIRComparison.pdf

Odele Coddington presented updates to the TSIS-1 HSRS and comparisons to other solar spectra. She also presented a thorough review of all the (many) solar spectra included within MODTRAN solar spectra. There is a lack of traceability and inconsistency in several of the MODTRAN spectra that link to a Kurusz model. The Fontenla spectra in MODTRAN are based on semi-empirical models that model solar behaviour. The MODTRAN default solar spectrum is one of the Fontenla spectra. These spectra are different from TSIS in the shortest wavelengths, with smaller differences in the IR.

Data are available at https://lasp.colorado.eud/lisird/data/tsis1_hsrs

Odele was asked about the variability of the solar spectrum during the solar cycle. Odele explained that one of the motivations for this work is to support the solar irradiance research activity as that requires a reference solar spectrum.

Marc Bouvet said that Odele's presentation has helped him understand why this has been a confusing situation for solar spectra. He would like to access the presentation to refer to in the future and to understand where to start from. He also has a question about solar variability – is this something that the EO community should be concerned with for wavelengths in the visible and SWIR? And also do we

need to keep measuring the sun; or are we now confident we have a good solar spectrum from the visible to SWIR? Odele explained that the solar spectrum variability is strongly wavelength dependent. It is significant in the UV < 300 nm (can be up to 10%). From 400 nm and longer the variability gets smaller and smaller. In the visible it's about the same level as TSI ~0.1%. There are some wavelengths when it acts "out of phase" with TSI, but still at the 0.1% level. Odele would like to continue this conversation – as methods improve, these issues could become more significant. Applications in the shorter wavelengths may require modelling of variability. Her group has not yet provided a variable solar spectrum – except from the raw TSIS data. In terms of the need for continued measurements – we have not yet measured for enough of the solar cycles to understand variability. As well as the 11-year cycle, there is a 100-year cycle on the sun. We need to continue measurements and conversations between communities.

Sam Hunt asked about the how the measurement errors are correlated along the high-resolution spectrum. Odele answered that there may be areas of the spectrum where the errors may be more or less systematic, the information isn't available to assess this in detail. Nigel Fox asked how to get this into Modtran, recommending that CEOS contact Modtran to request this.

Patrice Henry explained that it's hard to update to a new spectrum in operational services – this spectrum may be the best one, but it's not easy to have a spectrum update in operational services. Dave Smith agreed that this was a concern. Yves Govaerts said that this spectrum will be included in Eradiate. He said that it can be complicated to know what is using what, but that within Eradiate, there are ways of keeping information of the traceability. Kurt Thome says there are differences between HITRAN and MODTRAN, and that MODTRAN was never designed for better than 4%. People are now pushing it beyond that, without understanding the limitations of the methods. Marc Bouvet pointed out that the Thuillier spectrum which has been a reference before is linked to the ATLAS model shown in the presentation.

Aimé Meygret showed some analysis which demonstrates the impact of using the TSIS vs the Thuillier model for RadCalNet comparisons to PRISMA, where the differences were around 2-3%. Kurt Thome pointed out that in the past this hasn't been a problem for multispectral sensors but is becoming so as sensors have higher spectral resolution.

AP.2022-12	**Nigel Fox** and **Odele Coddington** to discuss getting solar irradiance spectrum onto the CalVal portal with notes to users about encouraging the use and being clear about the use. Also to consider how to get it into tools like MODTRAN and into level 2 data products (especially radiance to reflectance).	End 2022
AP.2022-13	**Nigel Fox** and **Odele Coddington** to organise a working meeting and then a wider virtual meeting specifically about using the solar irradiance spectra and the impact of the choice / change of spectrum on communities and operational sensors.	Early 2023

Yoshiro Yamada presented about the 5th CEOS TIR radiometer comparison that took place in June 2022 with both a lab-based and a field-based comparison. Results are not yet available and are expected early next year.

Dave Smith commented on the participants' blackbodies not being temperature controlled. He says that these radiometers are usually themselves at the same temperature as the thing they are measuring – in the field, they would be heated to a similar temperature as the surface. He encourages

a comparison in a warmer location for land surface temperature. Yoshiro Yamada explained that he was aware of these concerns, but the participants had requested these higher temperature measurements and this was all that was possible in this comparison. Dave Smith also asked about the pier protection wires that were visible in the photo. Yoshiro said that as far as possible the instruments were set up not to see these in their field of view.

15 Thermal infrared calibration network

Steffen Dransfeld and Aimé Meygret opened a discussion about a possible thermal infrared calibration network. There are several ground networks with uncertainties at the few K level (though limited SI-traceability / robust uncertainty analysis).

Presentation	By	Filename
Context for a TIR reference network	Steffen Dransfeld	49_Dransfeld_TIRNetwork.pdf

Nigel Fox asked about what the uncertainties in the current network sites are and what is dominant there. Darren Ghent replied that emissivity estimates and site heterogeneity are the largest sources of uncertainty. Radiometry uncertainty of the instruments is less significant in comparison. Kurt Thome asked about how the measurement with the radiometer is representative of the temperature observed by the satellites. Dave Smith explained that for quantities like ice surface temperature there are similar aspects to the water temperature with thermometer measurements – as the thermometers are in the ground. In situ radiometric observations are a closer comparison to what the satellite radiometers are measuring, however additional thermometer measurements are needed for corrections (e.g. for air temperature)

Nigel asks if site heterogeneity may be less of an issue for the next generation of high-resolution sensors. Darren said this would improve the situation, especially at a subset of larger sites. Darren also commented on the fact that there is a very different question about whether you would do validation of BOA or TOA temperatures. For TOA analysis there would be a large number of additional measurements needed. Mark Irvine pointed out that turbulence is also an important uncertainty in the comparison

Kurt Thome said that over a lake target (Lake Tahoe) recent work has achieved TOA uncertainties <0.5 K. He asked people whether this is possible over land sites. Darren explained that there are advantages over water sites – less variable emissivity and smaller dynamic range – but that it should be possible to achieve improved performance on land sites.

Darren said that for TOA, some of the existing LST stations, even over homogenous areas would still need ways of measuring all the other atmospheric parameters. He asks how this is done for RadCalNet. Kurt explained that for the solar reflective domain, we only need total column atmospheric conditions, and not proper profiles. Understanding atmospheric profiles would require sondes to be launched.

Steffen Dransfeld asked whether sondes are necessary. Darren said model data could be used but that the uncertainties in the atmospheric profiles would be large, and may make the 0.5 K aim impossible. Dave Smith said that the other issue with sondes is the pathlength difference as there is a difference between what the sonde measures and what the satellite sees. Sondes are also expensive and can't be done all the time. Kurt Thome said over a small number of sites, microwave profilers may be possible.

Sam Hunt asked whether there are possibilities with artificial targets. Darren said that they could be possible – but there are still the same issues of comparing what is seen on the ground vs satellite – there is still a scale issue. TOA brightness temperatures also require the right instrumentation measuring at the same wavelengths.

Kurt Thome says that there are lots of groups doing surface validation work, so there would be a real benefit of doing a TOA product – but there are lots of questions that would be needed to be sorted. These would include what the product is. Brightness temperature is a spectrally dependent quantity – with high sensitivities in spectral regions of atmospheric absorption lines, but also varying with surface and atmosphere emissivity.

Emma Woolliams asked about how brightness temperature would be defined – it would have to be related to a spectral response function. RadCalNet does not provide surface reflectance integrated to match individual satellites; but based on artificial spectral response functions (10 nm width triangles) and users have to do the mathematics to convert to match their particular sensor. Is this a possibility for TIR sites? Nigel suggested the product might be brightness temperature per some unit of wavelength.

Many ground instruments would be broadband. Darren explained it is possible to have higher spectral resolution instruments (e.g. having an FTIR to measure ground emissivity) it could be modelled to a higher spectral resolution brightness temperatures. Is it possible for a few sites to have a seasonal set of reference spectra for emissivity that could be used to interpolate based on broader-band measurements? Work is needed to investigate options.

Kurt Thome asks who the customers are who would use this information? In RadCalNet we saw the arrival of many commercial imaging satellites that could be calibrated using the RadCalNet data. Steffen Dransfeld said that for the moment the customers would be us – the agencies are putting up thermal infrared sensors. There may be a few commercial operators, but not many for now.

Dave Smith said it may not be necessary to validate TOA brightness temperatures as the primary product is surface Temperature. We are validating product, not calibrating the satellite, which have onboard calibration. Others say that that is also true with several reflective instruments – so this doesn't necessarily mean that TOA calibration is possible. Darren says that the onboard calibration is a limited dynamic range. Cody asks whether TOA calibration over water sites is sufficient, but they also have the same limited dynamic range.

Kurt Thome says that therefore it would better to do this as an internationally-collaborative "experiment" at this stage with different approaches tested. Rather than having a public "RadCalNet style" open data set. Nigel Fox asks whether the vision is for eventually having a public network of sites, eventually that this is the early steps on a roadmap towards, or whether it is more international collaboration for the existing community?

Kurt Thome says that when RadCalNet worked to be operational it was building on 15+ years at La Crau and Railroad Valley. It took another four years to work out how to make it operational and a network. As the TIR is still in that initial phase, it's too early to put effort into making it operational. There is a vision that this will eventually be for the provision of a service. But for now the focus should be on research – and working out how to get consistency, understand uncertainties, sensitivities etc. But this is heading towards operational and knowing that may affect how sites conduct this research.

Work is needed to decide the type of sites that are useful. Vegetated sites are more complex, with turbulence in the atmosphere. Ice sites are also valuable. But some of these more complex sites are

important for validation (ground), but less so for TOA. There was a question about the "adjacency effects" and the variability/homogeneity of surface. Temperatures can change over a few metres, and emissivity is sensitive to soil moisture. Lake surfaces are better.

Kurt Thome, says if we could find another few sites like Lake Tahoe that are high quality sites with that level of understanding. There is value in just getting more water sites. Aim should be to work out where high quality sites are possible. One question would be about whether it's better to have a very high-quality site at a low altitude or a more challenging site at higher altitude with less atmosphere. There was a discussion about the types of sites that would be helpful. Vegetated sites are likely to be harder from a turbulence and homogeneity perspective, but easier from an emissivity basis.

Sam Hunt said it may depend on how the sensors are nonlinear. Dave Smith said you'll need to measure the temperature and emissivity. These things can change rapidly – especially after rainfall etc. You have to measure the humidity of the surface. And you have to make measurements in different channels. If you have measurements in multiple spectral bands you can retrieve the emissivity. Luís Pérez Planells says an emissivity estimate from multiple spectral bands would have uncertainties of a few kelvin. Kurt Thome says that this could be work for steps 3 and 4 of a 12-step project development – so something for later in the roadmap.

Dave points out the issue that commonly used CIMEL radiometers are not be self-calibrating, as shipborne radiometers typically are, and that that is a requirement for high accuracy measurements. Darren agrees. Nigel points out the starting point is to breakdown the potential components of uncertainty, and find what is dominant in order to prioritise efforts.

Next steps are to collate these discussion points and to create a roadmap that defines what we're trying to do, what the aspects to consider are, and how we work towards a vision. Steffen says that this may lead to some scoping studies to understand some of these sensitivities.

Nigel asks how this should be progressed within CEOS – IVOS-specific or a joint initiative. Steffen and Kurt agree that since this is focused on TOA it fits within IVOS primarily. Darren also agrees that this fits in the remit of IVOS.

Kurt Thome asks about the timescale – there is a Landsat meeting at the end of October that this could be interesting to bring into that discussion. Steffen says that there is a MAG for LSTM at the end of September, so that could be the limit. This should also be discussed at WGCV, though Kurt Thome says one of the mistakes with RadCalNet was to go to WGCV too early.

Kurt will circulate the concept around other groups in the US. We can simultaneously look for new sites – to meet more "ideal" conditions, while working with existing sites to test concepts.

Is an ice site just for surface validation, or part of the dynamic range for TOA reflectance? Marine inversion layers may actually be useful because they are stable throughout a day. All of this needs thinking at freshly from a perspective not of LST, but of "what's best for calibration?", which is a different question.

AP.2022-14	**Steffen Dransfeld** and **Aimé Meygret** to produce a draft roadmap and a summary of the topics for discussion to work towards a CEOS reference network for LST to be shared by those interested in this work.	End 2022

16 Final points

Nigel Fox says that CEOS WGCV has an election for a new chair and he wanted to confirm the opinion of CEOS WGCV IVOS for that vote. There was unanimous agreement on how the IVOS vote should be cast.

The meeting was closed with thanks to Cody Anderson and all the USGS team for all the work they have done to organise the meeting. Also, with thanks to all who travelled for enabling the benefit of an in-person meeting.

17 The next meeting

It is still expected that the next IVOS will be a 5-day event including workshops and then the IVOS meeting. The location has not yet been defined and invitations are requested. Typically, we have been rotating between "Americas", "Europe" and "Rest of World" and therefore the next meeting is due to be in the Europe, however other areas may be possible.

There was a preference for having the meeting before the summer (early to mid-June).

AP.2022-15	**Anyone** wishing to propose a location for the next meeting should contact **Nigel Fox**	End 2022
AP.2022-16	**Emma Woolliams** to complete the minutes and Nigel Fox to send these to IVOS along with a link to all presentations onto the CalVal portal.	End September 2022
AP.2022-17	**Nigel Fox** to organise dates and practicalities for the next IVOS meeting.	Next IVOS

Appendix A Complete list of Recommendations

No recommendations were made at this meeting.

Appendix B Complete list of Actions

Action number	Activity	Date
AP.2019-2 Carried over AP.2018-1	**Nigel Fox** to ensure we hold a half to one day workshop to evaluate state-of the art on sensor L1 interoperability and the different methods used for comparisons to prioritise a work plan	To be done after the completion of the template AP 2019-17/18
AP.2019-5 carried over AP.2018-4	**Steffen Dransfeld** and **Nigel Fox** to explore prospect of an end-to-end benefit of Cal/Val for SST (Linking FRM4STS and SLSTR/ATSR+ series)	We should try to do this

AP.2019-6 carried over AP.2018-19	**Patrice Henry** to work with **Nigel Fox** to create a "news story" on PICSCAR that shows the link to WGCV priorities.	Perhaps we should still try to do something here
AP.2022-1	**Nigel Fox** to email the mailing list to encourage a volunteer for leadership of the geo spatial image quality task group and to appoint a leader before the next meeting. And for the **new chair** to organise a teleconference to define the scope and strategy for the task group.	Next IVOS
AP.2022-2	**Anyone** interested in participating in the vocabulary working group to contact Emma Woolliams	Next IVOS
AP.2022-3	**Anyone** with recommendations for the BIPM-WMO joint workshop "Metrology for Climate Action" to contact Emma	26th September
AP.2022-4 (Reformatted AP.2019-17)	**Nigel Fox** and **Emma Woolliams** to review the template that was developed in 2019 on presenting the different methods, and to produce a fresh table template, alongside a workflow of how the table is filled in, reviewed and published.	Next IVOS
AP.2022-5	**NOAA VIIRS team (Jason Choi)** will talk to NOAA management (Changyong Cao) on this PISCSCAR future action on VIIRS data.	Next IVOS DONE
AP.2022-6	**Patrice Henry** and **Rajendra Bhatt** to discuss ways that PICSCAR can relink to the ongoing GSICS activities in a time efficient manner (link to Dave Doelling and Fred Wu)	Next IVOS
AP.2022-7	**Patrice Henry** to organise a PICSCAR online workshop and publicise it to bring in new participants.	End 2022
AP.2022-8	**Steffen Dransfeld** to check whether Sentinel-3 should be included in the list for self-assessment of the synergy SDR products for CARD4L and to discuss with **Cody Anderson**	End 2022
AP.2022-9	**Emma Woolliams** to compare the intrinsic interpolation method her team has used in comparison to the results **Mary Pagnutti** and **Bob Ryan** presented on per pixel uncertainty for Landsat. And to include **Esad Micijevic** in those discussions.	End 2022
AP.2022-10	**Nigel Fox** to set up a half day discussion group either online or at the next IVOS meeting to consider Sentinel and Landsat per pixel uncertainty efforts	Next IVOS
AP.2022-11	**Nigel Fox** and **Cody Anderson** to set up a discussion on the curation and dissemination of uncertainty data information (volume / formats) to link WGCV and WGISS, particularly for imaging sensors.	Early 2023
AP.2022-12	**Nigel Fox** and **Odele Coddington** to discuss getting solar irradiance spectrum onto the CalVal portal with notes to users about encouraging the use and being clear about the use. Also to consider how to get it	End 2022

	into tools like MODTRAN and into level 2 data products (especially radiance to reflectance).	
AP.2022-13	**Nigel Fox** and **Odele Coddington** to organise a working meeting and then a wider virtual meeting specifically about using the solar irradiance spectra and the impact of the choice / change of spectrum on communities and operational sensors.	Early 2023
AP.2022-14	**Steffen Dransfeld** and **Aimé Meygret** to produce a draft roadmap and a summary of the topics for discussion to work towards a CEOS reference network for LST to be shared by those interested in this work.	End 2022

Appendix C Full list of presentations

Most presentations are available at: [IVOS - CalValPortal (ceos.org)]

Presentation	By	Filename
Introductory Presentation	Nigel Fox	*01_Fox_Introduction.pdf*
USGS National Land Imaging Program Update	Tim Stryker	02_Stryker_USGS_Land_Imaging.pdf
Vocabulary Group Report	Emma Woolliams	03_Woolliams_Vocab.pdf
BIPM-WMO joint workshop "Metrology for Climate Action"	Emma Woolliams	04_Woolliams_BIPMWMO.pdf
FLARE Status	Chris Durrell	05_Durrell_FLARE.pdf
Preliminary Evaluation of the Mirror-Based Empirical Line Method using Flare System	Larry Leigh	06_Leigh_FLARE.pdf
Trending and Intersensor Calibration Using SPARC/FLARE point targets	Stephen Schiller	07_Schiller_FLARE.pdf
LIME: Lunar Irradiance Model of ESA	Marc Bouvet	08_Bouvet_LIME.pdf
25+ years of JRC Ocean Colour Cal/Val activities: a synopsis	Giuseppe Zibordi	09_Zibordi_OC.pdf
GCOM-C/SGLU CalVal with AERONET-OC	Hiroshi Murakami	10_Murakami_AeronetOC.pdf
Update on MOBY/MOBY Refresh and MarONet	Kenneth Voss	*11_Voss_MOBY*
Giuseppe	Ewa Kwiatkowska	12_ Kwiatkowska_Giuseppe.pdf
FRM4SOC-2	Riho Vendt	*13_Vendt_FRM4SOC*
PACE: Plankton, aerosol, cloud, ocean ecosystem advancing global and coastal ocean colour science and applications	Antonio Mannino	14_Mannino_PACE.pdf
Landsat-8/9 Level 1 & 2 Consistency Assessments	Nima Pahlevan	*15_Pahlevan_Landsat*
Cross-calibration of polar-orbiting ocean-colour sensors using geostationary observations	Robert Frouin	16_Frouin_crosscal.pdf
Preparation of next generation hyperspectral radiometric validation networks for water and land (Hypernets)	Kevin Ruddick	17_Ruddick_Hypernets.pdf
CNES Calibration Activities	Aimé Meygret	18_Meygret_CNES.pdf
Outcome of workshop on SI-traceable Space-based Climate Observing System (SITSCOS)	Nigel Fox	*19_Fox_SITSCOS.pdf*
CLARREO Pathfinder Mission Overview and Status	Yolanda Shea	*20_Shea_CLARREO*

CPF-VIIRS and CPF-CERES Direct intercalibration approach	Rajedra Bhatt	*21_Bhatt_CPF-Intercalibration*
TRUTHS: An ESA Earth Watch Mission	Nigel Fox	*22_Fox_TRUTHS.pdf*
PICSCAR presentation	Patrice Henry	23_Henry_PISCAR.pdf
Sentinel 2 L1 radiometric vicarious validation and intercomparison with Landsat over Libya4	Bajhat Alhammoud	*24_Alhammoud_PICS*
Satellite stability and intercomparson using PICS and extended PICS	Morakot Kaewmanee	25_Kaewmanee.pdf
Eradiate simulations of PICS radiance	Nicolas Misk	*26_Misk_Eradiate_PICS*
GCOM-C/SGLI Cal/Val L1 and L2	Hiroshi Murakami	27_Murakami_GCOM-C.pdf
Vicarious calibration for ASTER	Hirokazu Yamamoto	28_Yamamoto_ASTER.pdf
Landsat 8 / 9	Larry Leigh	29_Leigh_Landsat.pdf
Traceability and Uncertainty - Discussion	Cody Anderson	30_Anderson_Traceability.pdf
Framework for EO Product Quality Assurance	Sam Hunt	31_Hunt_QA.pdf
QA4EO framework and a metrological approach to FRMs, FDRs and TDPs	Emma Woolliams	*31_Woolliams_QA4EO*
Landsat 8 L1T Product Radiometric Pixel Uncertainty	Mary Pagnutti	*32_Pagnutti_L8Uncertainty.pdf*
DESIS: Overview and Calibration	Emiliano Carmona	33_Carmona_DESIS.pdf
EnMAP	Emiliano Carmona	34_Carmona_EnMAP.pdf
Detector-based Absolute Radiometric Calibration for Imaging Spectrometer of High Accuracy: a Simulation	Ben Wang	*35_Wang_SpectrometerCal*
Surface Biology Geology Designated Observable	Kurt Thome	36_Thome_SBG.pdf
CHIME Cal/Val Methodology & Status	Antonio Gabriele, Valentina Boccia	37_Gabriele_Boccia_CHIME.pdf
An Overview of the Emerging P4001 Hyperspectral Standard	Chris Durrell	38_Durrell_IEEEHyperspectral.pdf
Landsat Cal/Val Status	Esad Micijevic	39_ Micijevic_Landsat.pdf
Sentinel 3 mission and optical products status	Steffen Dransfeld	40_Dransfeld_Sentinel3.pdf
Cal/Val Portal Update	Steffen Dransfeld	41_Dransfeld_CalValPortal.pdf
Uncertainty for SLSTR/LSTM	Dave Smith	42_Smith_SLSTRUncertainty.pdf
Status of MODIS and VIIRS Instrument Calibration	Amit Angal	*43_Angal_MODIS-VIIRS*
The RadiomotricCalibration Network: RadCalNet	Marc Bouvet	44_Bouvet_RadCalNet.pdf
Sentinel 2 calibration and validation with RadCalNet	Cameron MacKenzie	*45_Mackenzie_S2-RadCalNet*
Potential new Grassland RadCalNet site	Cody Anderson	*46-Anderson_EROS.pdf*
TSIS-1 Hybrid Solar Reference Spectrum and comparisons to MODTRAN solar reference spectra	Odele Coddington	47_Coddington_SolarSpec.pdf
5th CEOS TIR radiometer comparison	Yoshiro Yamada	48_Yamada_TIRComparison.pdf
Context for a TIR reference network	Steffen Dransfeld	49_Dransfeld_TIRNetwork.pdf