Working Group on Calibration and Validation (WGCV): 44

Infrared Visible and Optical Sensors (IVOS) subgroup: report

Nigel Fox

NPL (with UKSA support)

WGCV 44

Summary of activities

- IVOS 30 @ ESTEC,Noordwijk, Holland. hosted by ESA Mar 2018
- 24 agency/orgs represented
- 30 attendees + 7 remote
- Most themes and topics (work-plan discussed or summarised

- **4 th MTF workshop (Mar 2018)**
- **~ PICSCAR webex (Joint GSICS)**
  - **2nd Meeting (4th inc pre-cursors)**

Surface Temp Val workshop (Oct 17)

Rad cal workshop (Europe focus) Aug 17)

Special Projects:

- **RadCalNet team met Mar 2018 Various telecons**
- **O-colour vicarious Cal comparisons started April 2017 (Workshop Oct 2018)**

Terminology task team established

IVOS 31: WB March 26 2019 + - a few days for test site visits PERTH, Australia.

Terms of Reference

1. Promote international and national collaboration in the calibration and validation of all IVOS member sensors.
2. Address all sensors (ground based, airborne, and satellite) for which there is a direct link to the calibration and validation of satellite sensors;
3. Identify and agree on calibration and validation requirements and standard specifications for IVOS members;
4. Identify test sites and encourage continuing observations and inter-comparison of data from these sites;
5. Encourage the preservation, unencumbered and timely release of data relating to calibration and validation activities including details of pre-launch and in flight parameters.
6. 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.

IVOS: Vision

To facilitate the provision of 'fit for purpose' information through enabling data interoperability and performance assessment through an 'operational' CEOS coordinated & internationally harmonised Cal/Val infrastructure consistent with QA4EO principles.

- ***Pre-flight characterisation & calibration***
- ***Test – sites***
- ***Comparisons***
- ***Agreed methodologies***
- ***Community Good Practises***
- ***Interchangeable/readable formats***
- ***Results/metadata - databases***

Key Infrastructure to be established and maintained independent of sensor specific projects and/or agencies

Work plan

- **Structured into themes and led by 'champions' (effectively vice chairs for CEOS WGCV constitution) (Plus specific projects)**
  - **Look to develop good practises**
  - **Organise comparisons**
  - **Shared learning (research activities)**
  - **Shared infrastructure / tools / Methods**
  - **Recommendations as needed**

Land surface reflectance - Czapler Myers (U of Arizona USA)

Ocean colour (link to IOCCG, VC-OCR etc) - Zibordi (JRC, EU) & Murakami (JAXA JPN)

Surface Temperature (link to VC-SST, GHRSST) - Corlett (U of Leicester, UK)

Geo spatial image quality - Helder (SDSU, USA) & Viallefont (ONERA F)

Atmospheric Correction (Link to AC subgroup) - Thome (NASA, USA)

RT codes (context of IVOS use in calibration) - ?

Specific projects/cross-cutting

- RadCalNet - Bouvet (ESA)
- PICSCAR (with GSICS) - Henry (CNES, F)
- Lunar (led by GSICS) - Wagener (Eumetsat)
- SST/LST cross-comparison (+ VC-SST & LPV (instrument Cal for LST) - Fox (NPL, UK)
- O-Colour Vicarious Cal comparisons - Fox (NPL, UK)
- Vocabulary - Wooliams (NPL, UK)
- Others in progress/development/related
  - Establishing a CEOS Reference and method of use for L1 radiometric interoperability (with GSICS) (including potential tools/databases)
  - Good practise for convolving spectral data sets (solar/surface/sensor bandwidth) Selection of Reference Solar irradiance spectrum(CEOS WGCV (sub-groups) & GSICS) – Partly complete
  - Comparison of Rayleigh and Sun-Glint methods

IVOS 30 Discussion Topics

- Summary of workshops/task groups, MTF, RadCalNet, PICSCAR
- Terminology
- Sensor pre-flight calibration workshop
- Sensor Pre- and In- flight Cal and Uc assessment
  - Inc Moon, Stars
- New Sensors
- Surface reflectance (level 2) validation
- Collaborations/interactions – WGCV, GSICS, VCs, Climate, Carbon ….
- Metrology and Uc evaluation….

- Minutes/Actions and presentations available at: CEOS CalVal Portal

MTF activities & comparison

Task group created in 2015 and very active and successful providing a valuable resource to the small but increasing community (particularly commercial sensors)

Establish good practise and community references

Proposed Framework

- Definition and Importance (short introductory section)
- Measurement (background and basic theory)
- Pre-Flight Estimation (to be developed later)
- On-Orbit Estimation (substantial portion of document)
- Recommendations for Determining Geo/Spatial Quality (final effort)

Proposed Framework

On-orbit Estimation (substantial portion of document)

- Field Methods Survey
- Targets
  - Artificial/Man-made
    - Points
    - Lines
    - Edges
    - Pulses
  - Image feature-based
    - Linear ('Rich') features
    - Bridges
    - Moon
  - Matrix of Targets
    - Type vs. GSD
    - Availability/Maintenance
    - Point of Contact
    - Recommended for operational acquisition
  - Database of Reference Imagery for PSF/MTF estimation
- Data Analysis, PSF/MTF Estimation
  - Image data format
  - Models
  - Parametric/Nonparametric Methods
  - Database of Reference estimation methods

Outcome was current Test Site Catalog

Current status: suite of edge images

Last meeting's major activity

Current Website Status

Current Website Status

Catalogue is being migrated to CalVal Portal

Following completion of list of sites propose to CEOS WGCV acceptance panel for formal CEOS Label to aid community & interoperability

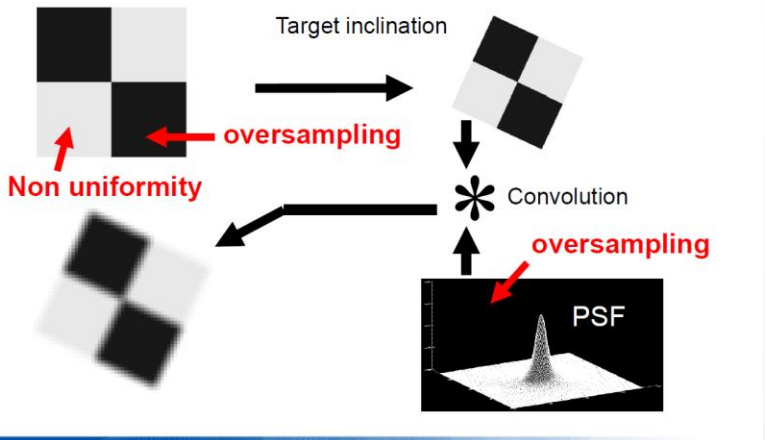
New ISRO site being added anticipate list at IVOS 31 ready to submit

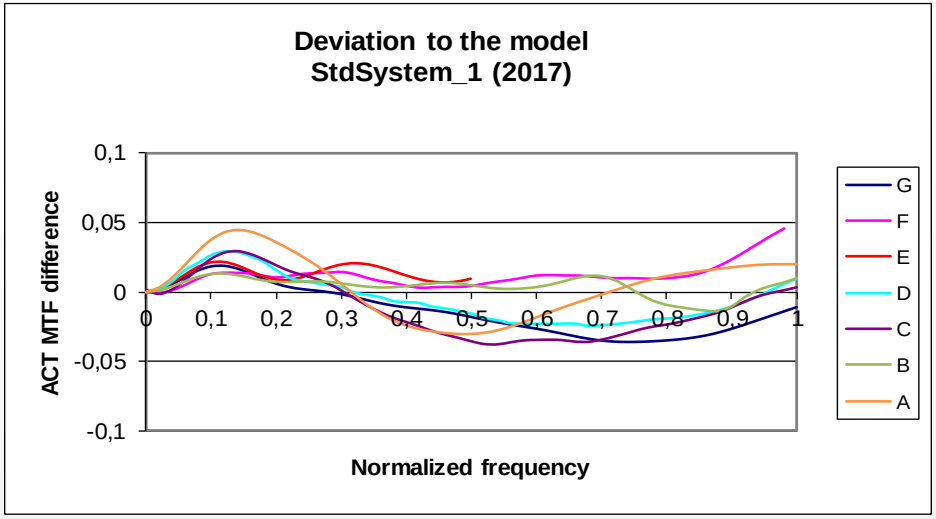
Following WGCV 43: Contact been made with GSICS regarding use of Moon

Bahrain

Comparison of methods

Exemple of synthetic image generation





- Results, methods drafted into paper for submission to Optics letters in Autumn 18 referencing CEOS data set and exercise (**essentially a reference guide)**
- Create reference data set and access policy to allow blind-testing from Cal/Val Portal as CEOS test set agreed at CEOS WGCV 42

DISCUSSIONS started on achieving a test platform on Cal/Val Portal

- **Next steps :**
  - List of metrics besides MTF curve: RER, RER slope, FWHM, …
  - Establish a list of relevant information or feature for each metric: for instance, link with the requirements, sensitivity, link with other metrics, potential use…
  - Evaluate some metrics and compute them as extensions to test data set

PICSCAR Joint with GSICS lead P Henry CNES

Pseuodo invariant sites used for Rad L1 Cal/comparison/monitoring

Work-plan

- Bi-monthly community Telecons/webex to discuss methods and how to establish/compare (BRDF, Atmosphere, surface spectral reflectance)
  - Organise comparison exercises to assess community state of the art
- CNES to establish draft web 'portal'
  - Hosted on/via CalVal portal
  - Good practises on how to use
  - Repository of observations
  - Repository of comparison results
  - Characteristics of PICS and tools for users
- NPL & CNES to consider how to evaluate Uc
- Goal to establish a TOA 'Radiance simulator'

Comparisons

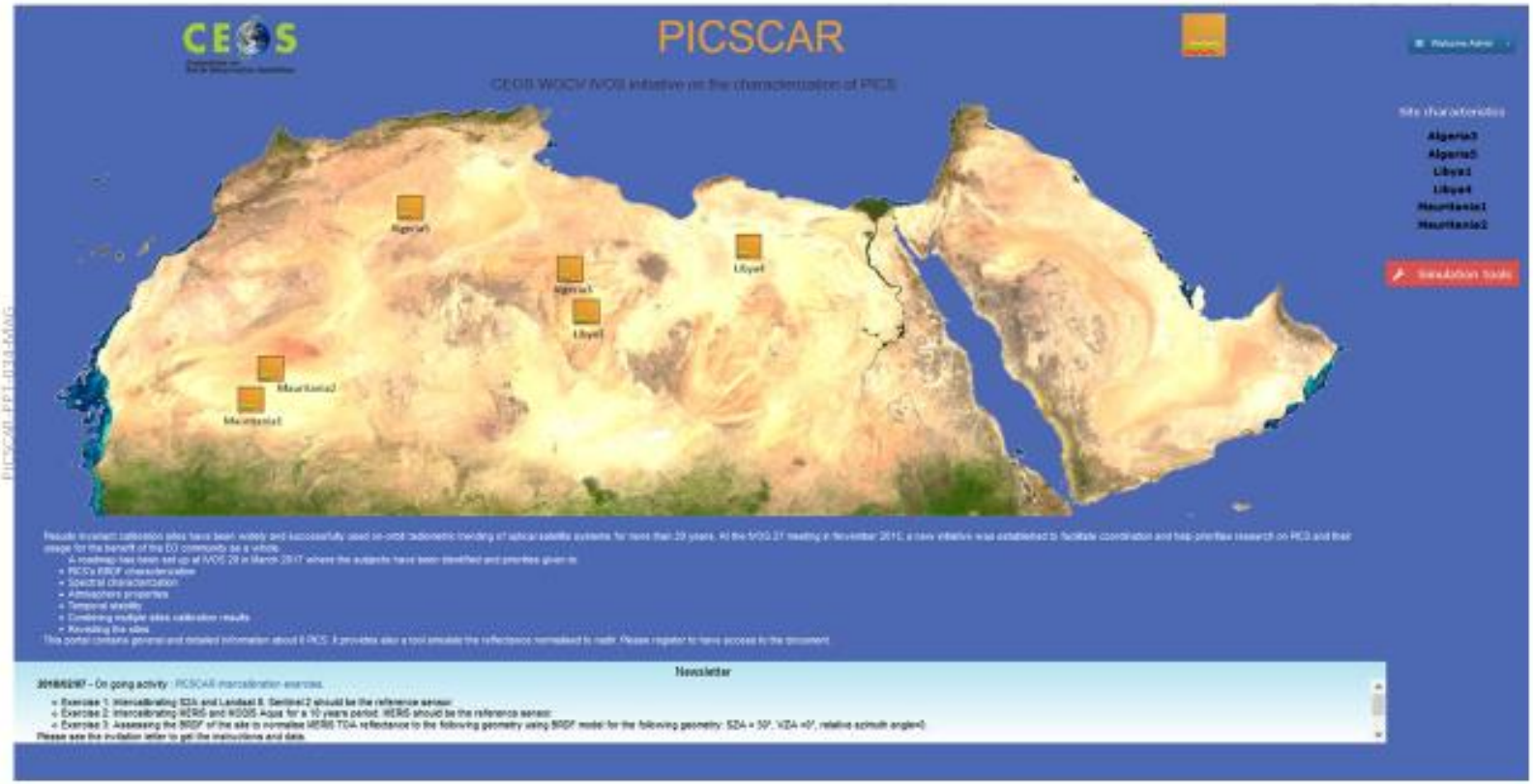
- **Evaluate consistency of data extraction/data sets for Landsat 8 and Sentinel 2 (Libya 4) (initially some variances)**
- **Define and supply a common set of data to participants for independent processing**
- **Exercise 1: Intercompare L8 against S2A as Reference**
- **Exercise 2: Intercompare MODIS Aqua against MERIS**
- **Exercise 3: Assess the BRDF of the site (own model) to normalise MERIS TOA reflectance to a specific geometry.**

Sensor	S2A/MSI	L8/OLI	MERIS	MODIS/Aqua
Green Band	B3 (560)	B3 (562)	B5 (560)	B4 (555)
Red Band	B4 (665)	B4 (655)	B7 (665)	B1 (645)
NIR band	B8A (865)	B5 (865)	B13 (865)	B2 (858)

Five teams so far provided results for Exercise 1)

PICSCAR portal to be linked from Cal/Val portal

Main page: https://picscar.magellium.com/#



Draft content

Pages dedicated to site characteristics

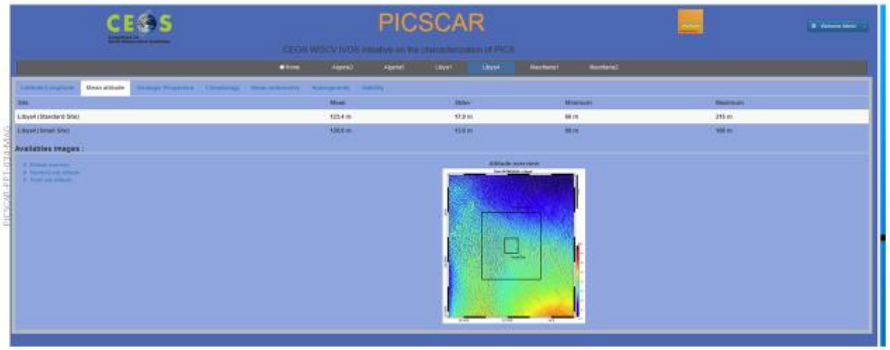
- Latitude/Longitude
- Mean altitude
- Geologic Properties
- Climatology
- Mean radiometry
- Homogeneity
- Stability

Page for Normalised reflectance simulation using PARASOL BRDF model

Functionalities:

- Upload BOA reflectance
- Download Normalised BOA reflectance
- Private access through login permission

For instance , altitude



Results/Analysis

Project to evaluate possible new PICS and surface reflectance

NOVELTIS ONERA LSCE esa

NOVELTIS ONERA LSCE esa

Exploitation of the CEOS Pseudo Invariant Calibration Sites (PICS) for Vicarious Calibration of Optical Imagers

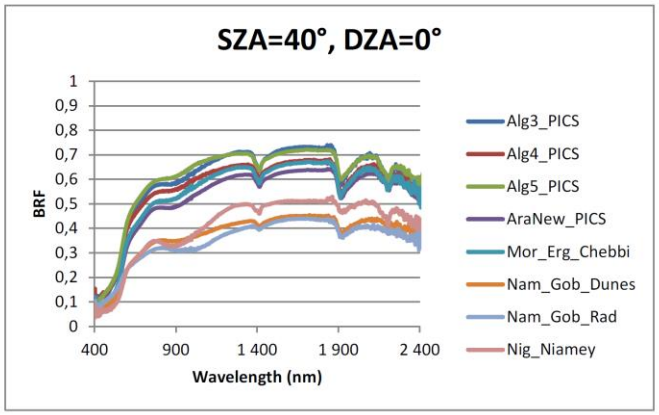
CEOS/WGCV/IVOS n°30 presentation: laboratory BRF measurement of sand samples

ESA: M. Bouvet
Consortium: NOVELTIS: C.Bacour
ONERA: F. Viallefont-Robinet, X. Briottet, Y. Boucher, F. Lemaître, T. Rivière
LSCE: F.-M. Bréon

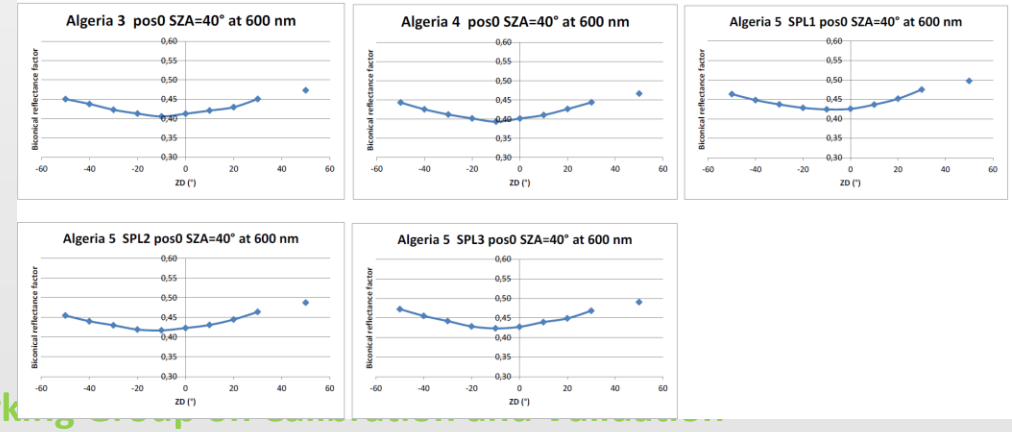
NOVELTIS ONERA LSCE esa

Some results

- Mean spectral behaviours



- Directional behaviour
  - Algeria samples : No strong difference between forward and backward directions (out of backscattering direction) (ZD = DZA)



Revisit selection of possible PICS sites

Establish database of measured characteristics of PICS sand

Attempt to build a BRF model (s)

Supporting CEOS VCs to establish global interoperability and address the needs of climate, carbon actions and meteorology:

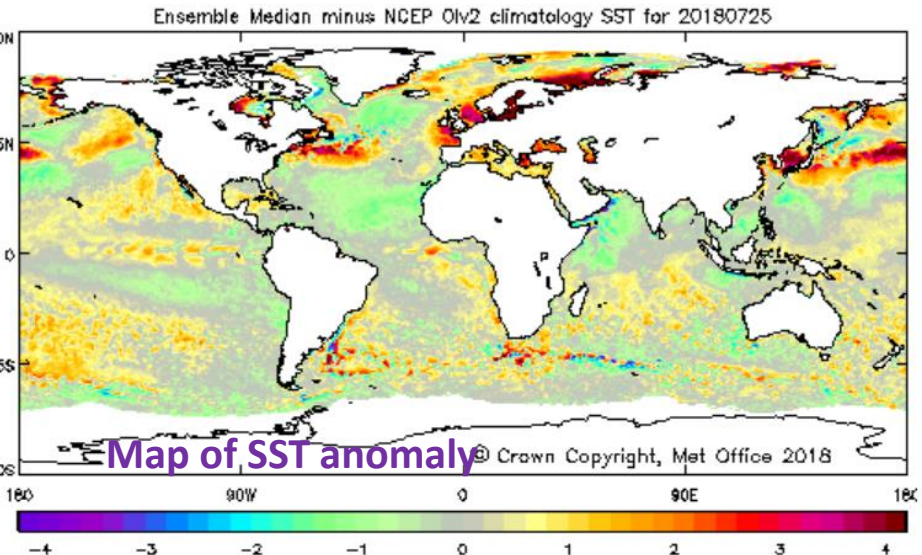
An Ocean based case study

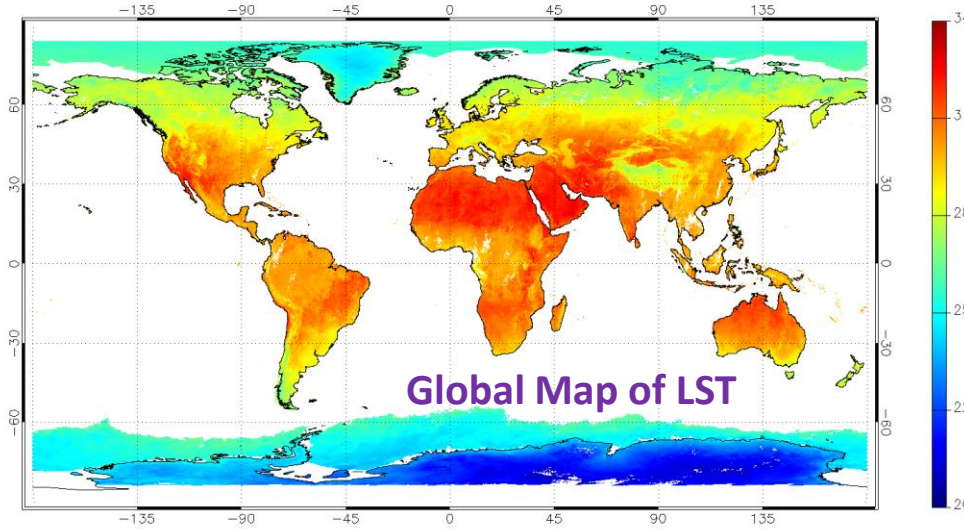
Working Group on Calibration and Validation

NEED: CEOS requests

SST & LST critical parameters for meteorology and climate

- Long-time series (FCDRs) exist (AVHRR, ATSR+) and are being extended with new missions Sentinel 5, NOAA 20
- Anomaly and trend detection require reliable detection of small signals from harmonised data sets
  - Needs trustable uncertainty estimates
  - Robust global validation with buoys & radiometers
- CEOS WGCV historically supported community through organisation of comparisons (Miami 1-3)





2014: CEOS VC-SST & GHRSST (partly in support of WG-Climate) suggested to WGCV it was timely for a new comparison

- 6 yrs since previous CEOS comparison
- Account for new best practise initiatives from QA4EO

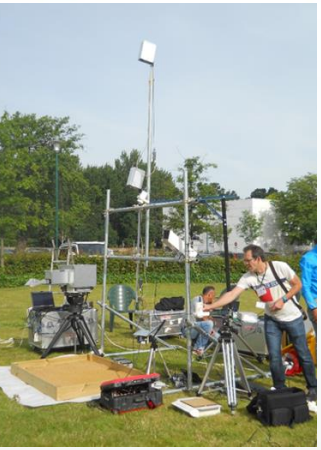
  New teams/instruments increased importance of LST

  CEOS endorsed WGCV proposal for laboratory & field comparison
  - ESA supported by NPL(UK) provided resource www.FRM4STS.org to organise a set of comparisons in 2016/17 to harmonise and ensure SI traceability of worlds validation teams on behalf of CEOS.

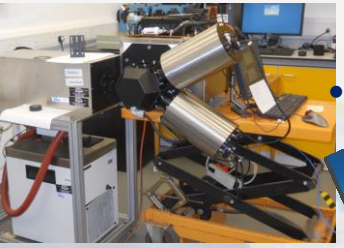
WGCV supported by

FRM4STS

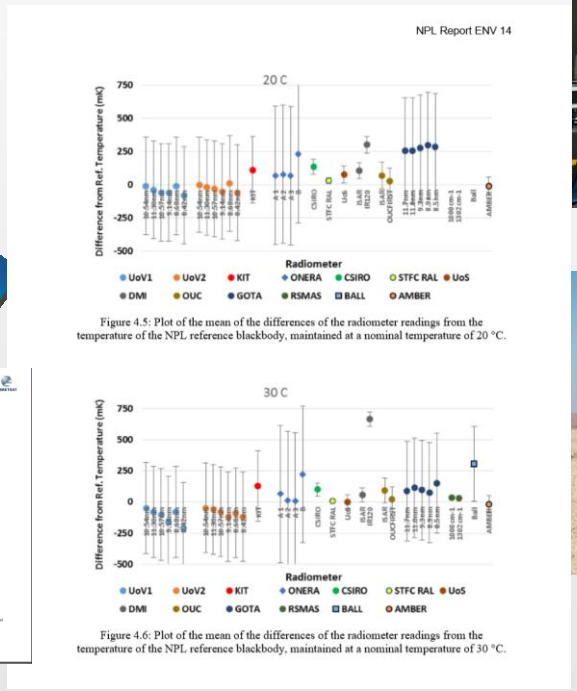
Has delivered to CEOS agencies and sub-bodies

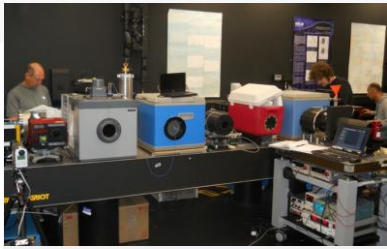


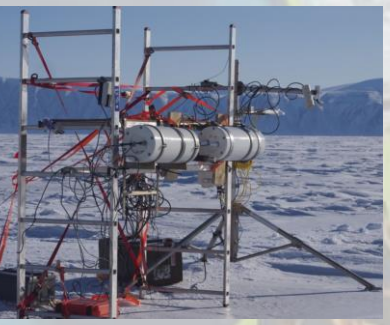
- 10 types of comparison with 12 participants from 4 continents
- 8 best practices or protocols
- Improved confidence, reliability and global consistency in validation of satellite derived Surface Temperature (Ocean, Land and Ice)
- Community Improved knowledge of uncertainty evaluation
- Legacy database to store future results



www.FRM4STS.org







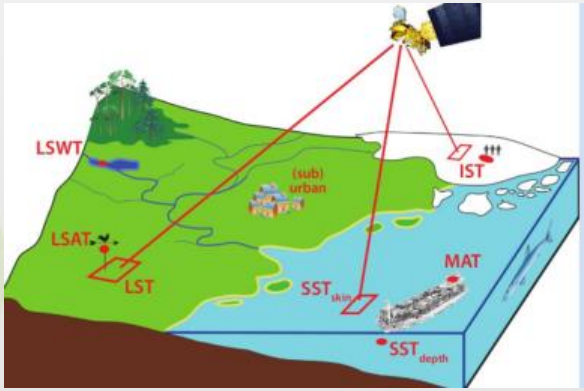
Working Group on Calibration and Validation

CEOS Workshop to develop long term strategy for Cal/Val (Temp)

Oct 2017 40 world experts met at NPL, UK for a workshop to review results of comparisons, endorse protocols and develop recommendations/long-term strategy needed to sustain current and address future community (surface Temperature) needs

Some Key Recommendations

- CEOS to hold regular comparisons
  - greater range of operational conditions
- Improved cloud detection/masking
- Research on 'representativeness of validation
  – scaling, global, 'skin' to bulk (water/snow)
- Training on Uncertainty evaluation
- Good practice guides



- More Buoys & test sites
- Encourage 'super sites' (multiple parameters)

CEOS WGCV provides similar support for VC-OCR/IOCCG & Carbon

Need: Very high accuracy requirements for ocean colour not currently achievable without post-launch vicarious calibration of sensor system (inc. retrieval algorithm) using reference buoys (MOBY/BOUSSOLE) and validation from networks like Aeronet-OC and ship campaigns: **Infrastructure and protocols need to be SI traceable and consistent to ensure interoperability and meet the needs of users particularly Climate & Carbon actions**

- Reviewed IOCCG and VC-OCR Cal/Val strategy documents
- 2017 initiated (with support from ESA FRM4SOC) set of international comparisons on Cal/Val instrumentation
  - Laboratory based measurements
  - Water based (in lake)
  - Water based from 'Venice tower' platform in Mediterranean sea
  - Ship based on Atlantic to Antarctic transect

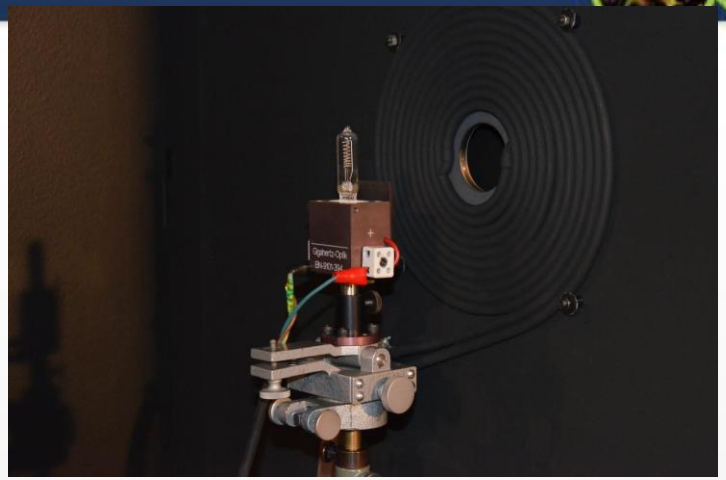
- Developed 5 protocols/good practice guides
- Held an international workshop to consider long term Cal/Val strategies including criticality for reference buoys
- Provides the forum to share best practices/synergy related to sensor pre-flight calibration between land/Atmosphere/Ocean (to be enhanced by forthcoming WGCV/GSICS workshop)

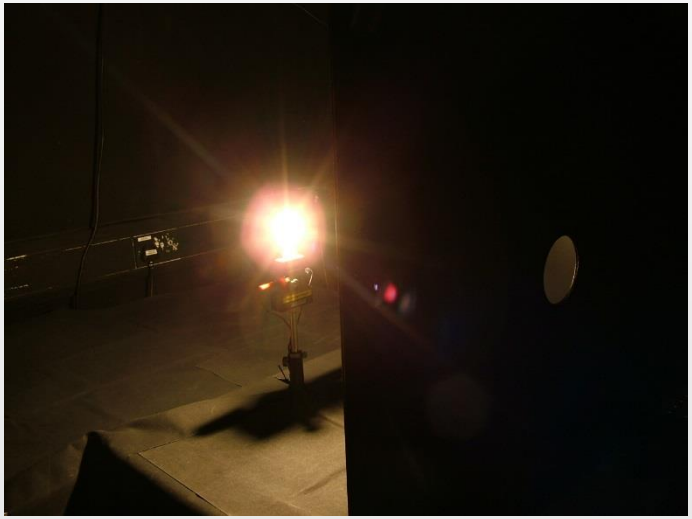
For more info see www.FRM4SOC.org

fiducial reference measurements for satellite ocean colour

Irradiance comparison participants

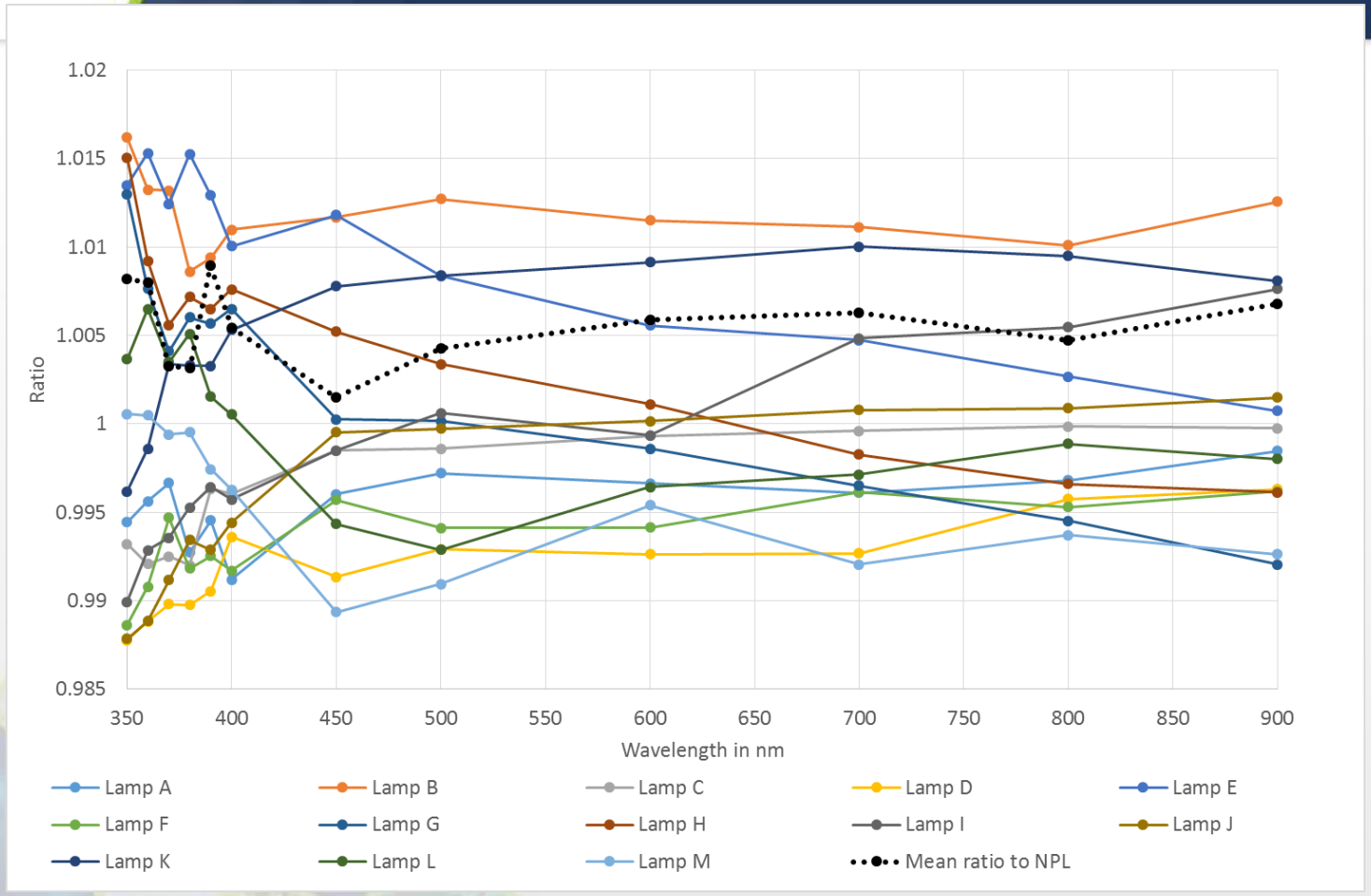
Participant		Country
NPL	National Physical Laboratory	UK
TO	Tartu Observatory	Estonia
Satlantic	Seabird Scientific	Canada
CSIRO	Commonwealth Scientific and Industrial Research Organisation	Australia
NERC-FSF	Natural Environment Research Council's Field Spectroscopy Facility	UK
LOV	Laboratoire d'Océanographie de Villefranche	France
NOAA	National Oceanic and Atmospheric Administration	USA





fiducial reference measurements for satellite ocean colour

Irradiance Source Inter-comparison Provisional



Summary of all lamps used in irradiance comparison

fiducial reference measurements for satellite ocean colour

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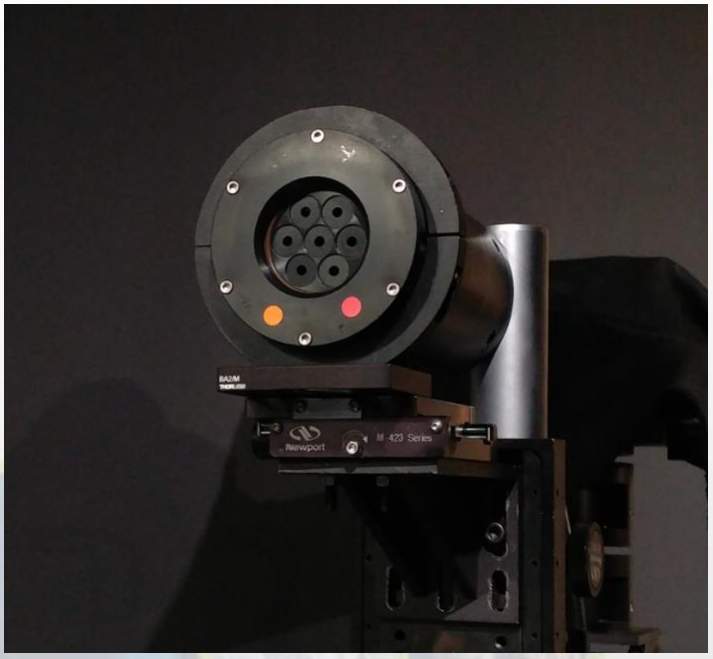
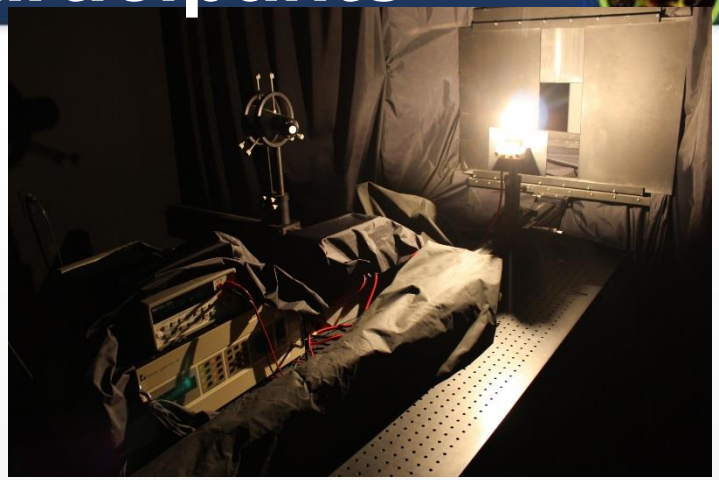
Radiance Comparison Radiometers

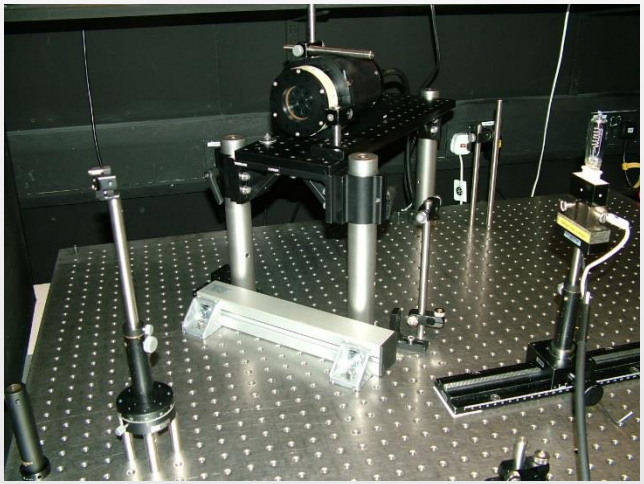


Channel	OCR-051 Wavelength nm	OCR-110 Wavelength nm
1	412.0	413.0
2	443.7	443.0
3	491.0	491.4
4	510.7	510.4
5	556.4	556.2
6	667.1	666.3
7	684.9	684.1

Radiance Comparison participants

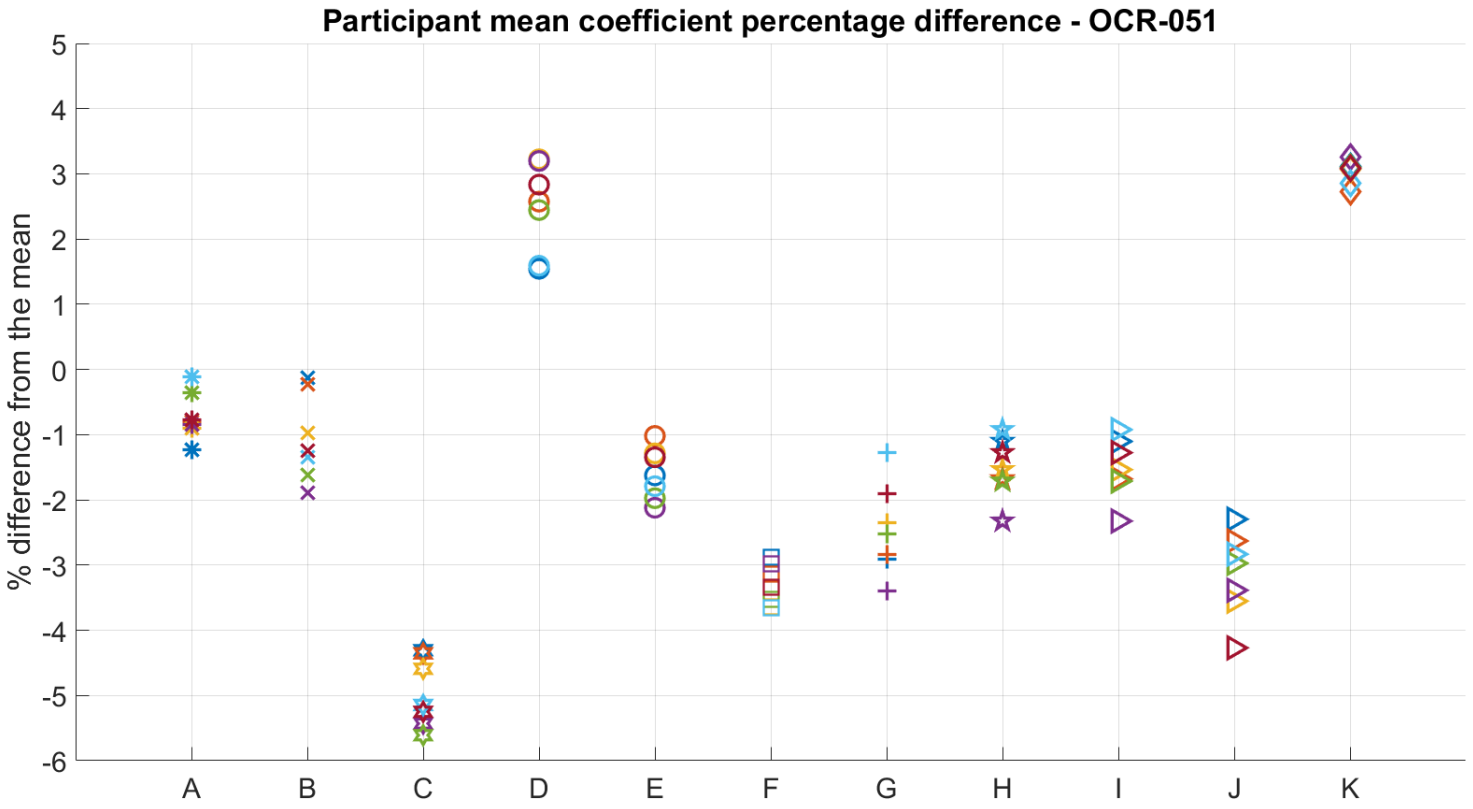
Participant		Country
NPL	National Physical Laboratory	UK
TO	Tartu Observatory	Estonia
JRC	Joint Research Centre	European Commission
Satlantic	Seabird Scientific	Canada
CSIRO	Commonwealth Scientific and Industrial Research Organisation	Australia
NIVA	Norsk Institutt for Vannforskning	Norway
NERC-FSF	Natural Environment Research Council's Field Spectroscopy Facility	UK
DLR-IMF	Remote Sensing Technology Institute, Deutsches Zentrum für Luft und Raumfahrt	Germany
LOV	Laboratoire d'Océanographie de Villefranche	France
NOAA	National Oceanic and Atmospheric Administration	USA





Radiance comparison provisional

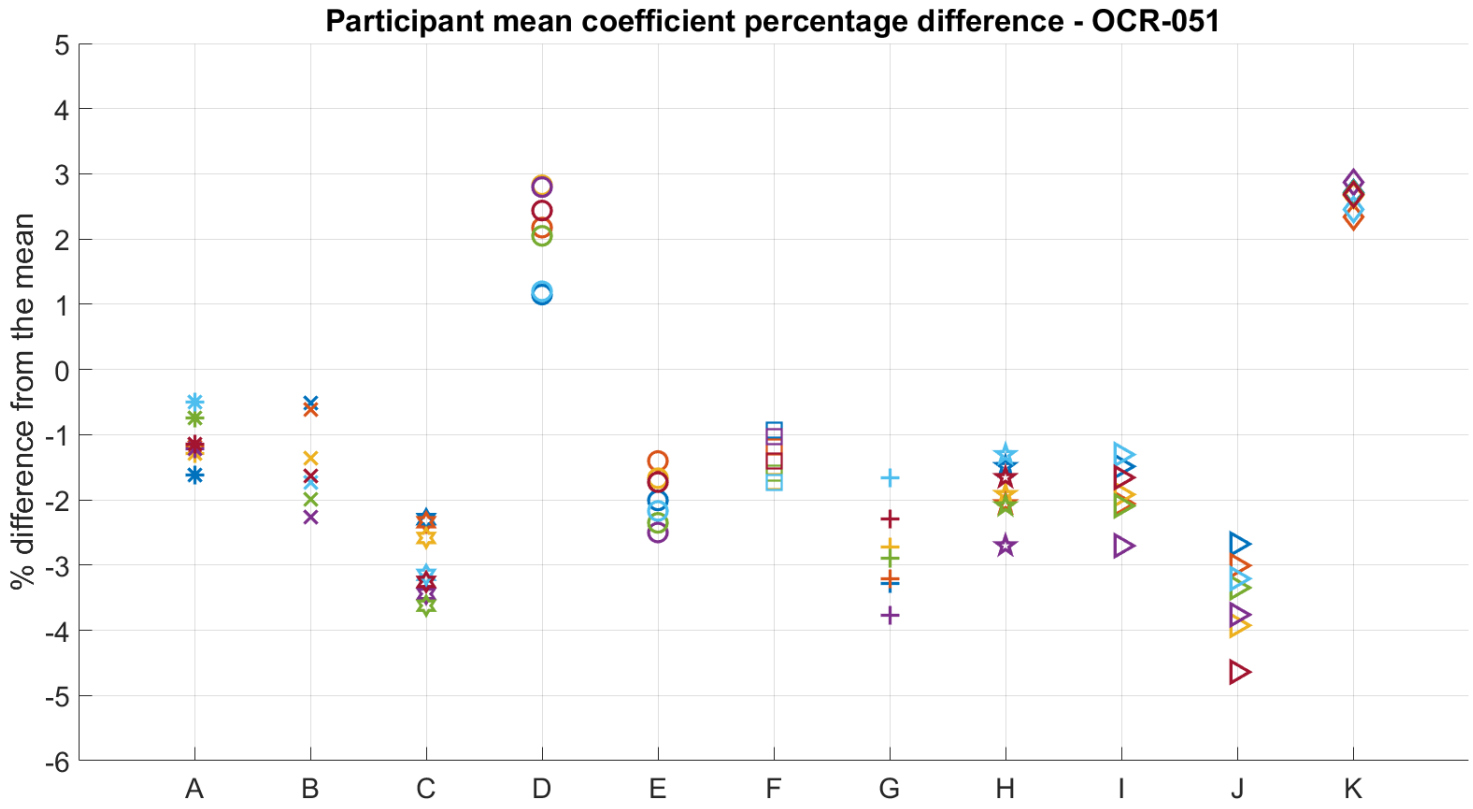
(using original data provided by participants inc 8°/h reflectance)



fiducial reference measurements for satellite ocean colour

Working Group on Calibration and Validation

Radiance Comparison provisional
(after 8°/h - 0:45 correction where necessary)



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Radiance comparison provisional
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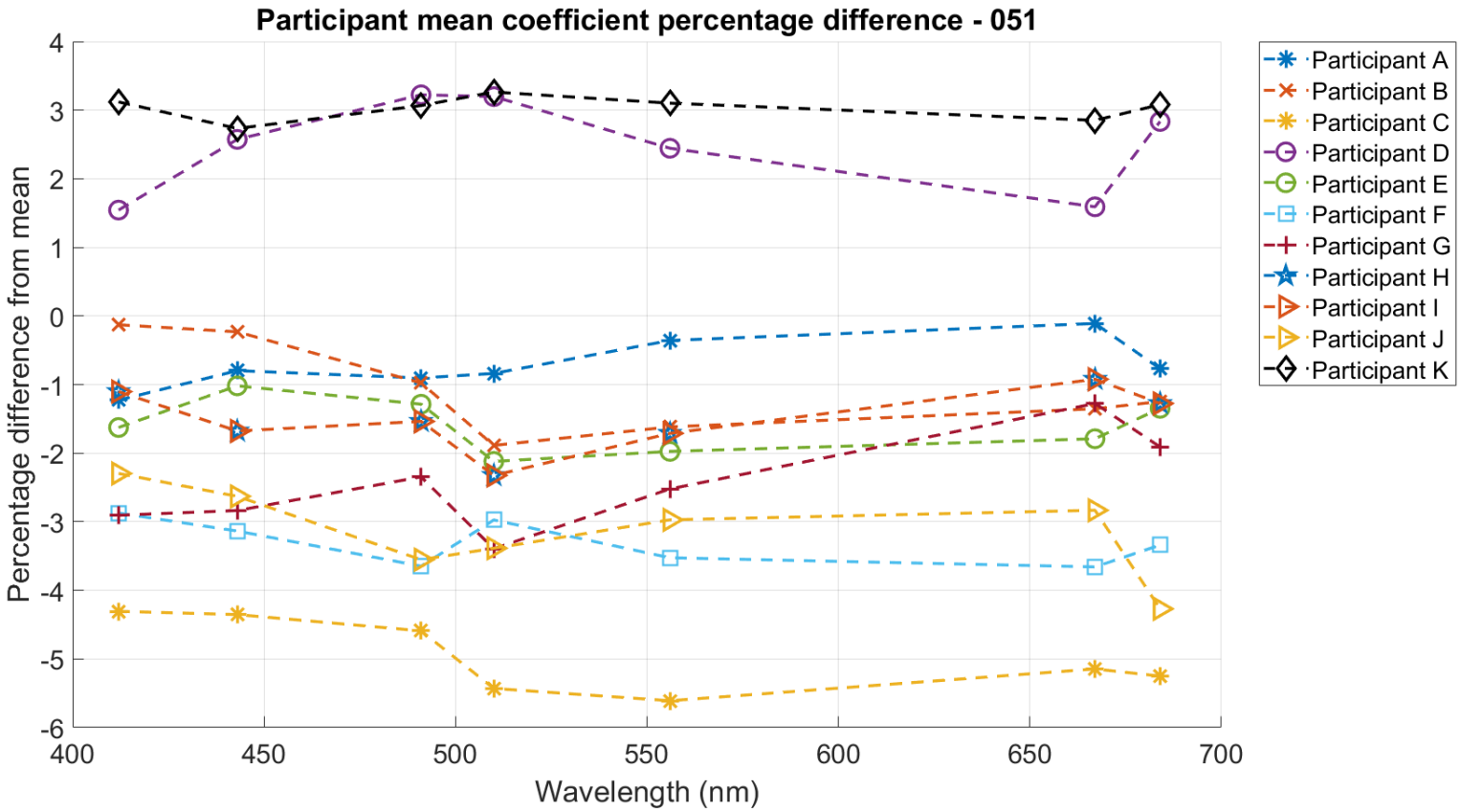
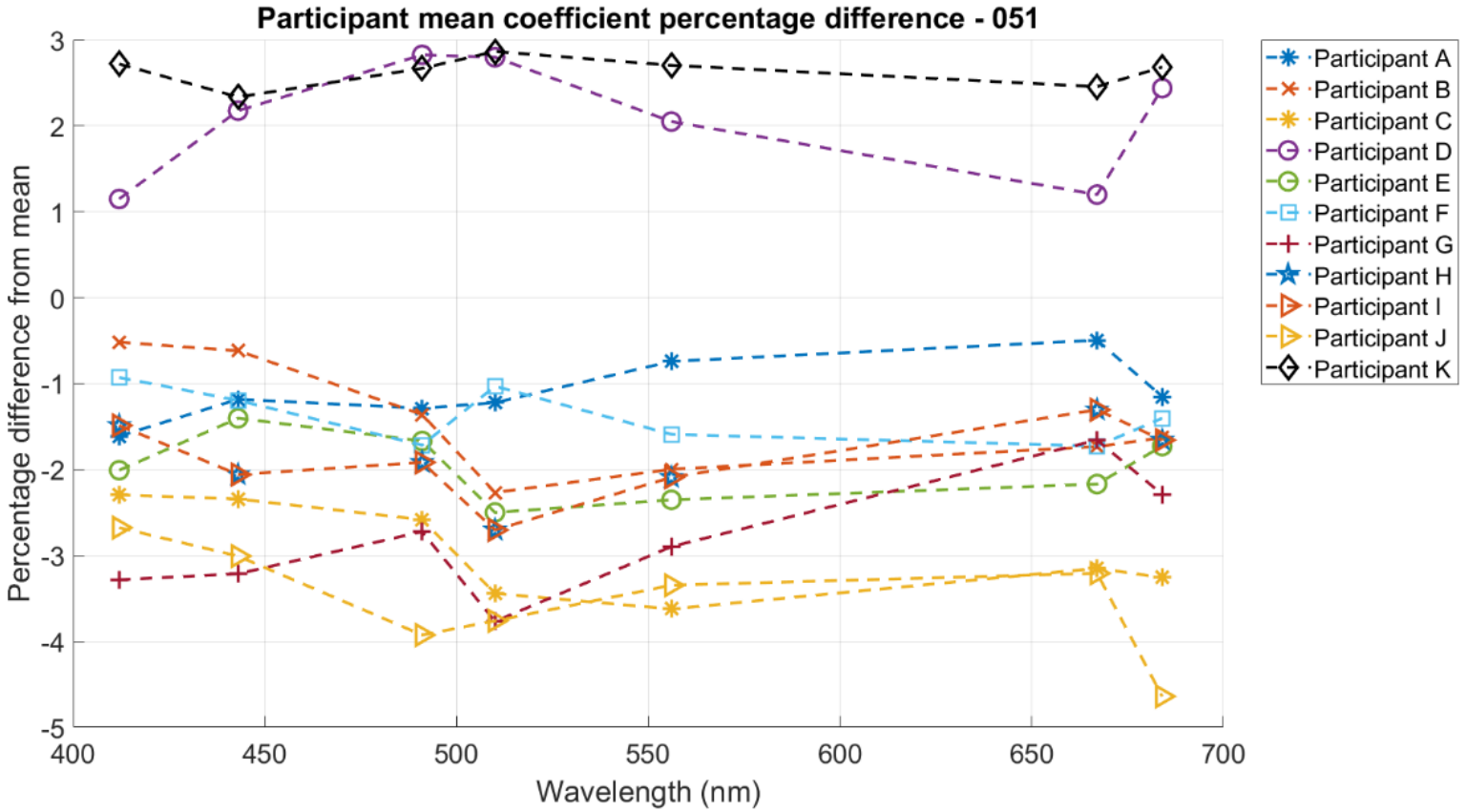


fiducial reference measurements for satellite ocean colour

Working Group on Calibration and Validation

Radiance comparison Provisional
(after 8°/h - 0:45 correction where necessary)



fiducial reference measurements for satellite ocean colour

Working Group on Calibration and Validation

Water based comparison

- **11-12 May 2017, Lake Kääriku, Estonia**
- **Measurement of sky and water radiance and downwelling irradiance**
- **Conditions were not ideal due to cumulus clouds. Only casts with most stable signal were used for intercomparison**

Irradiance and radiance sensors during the outdoor exercise

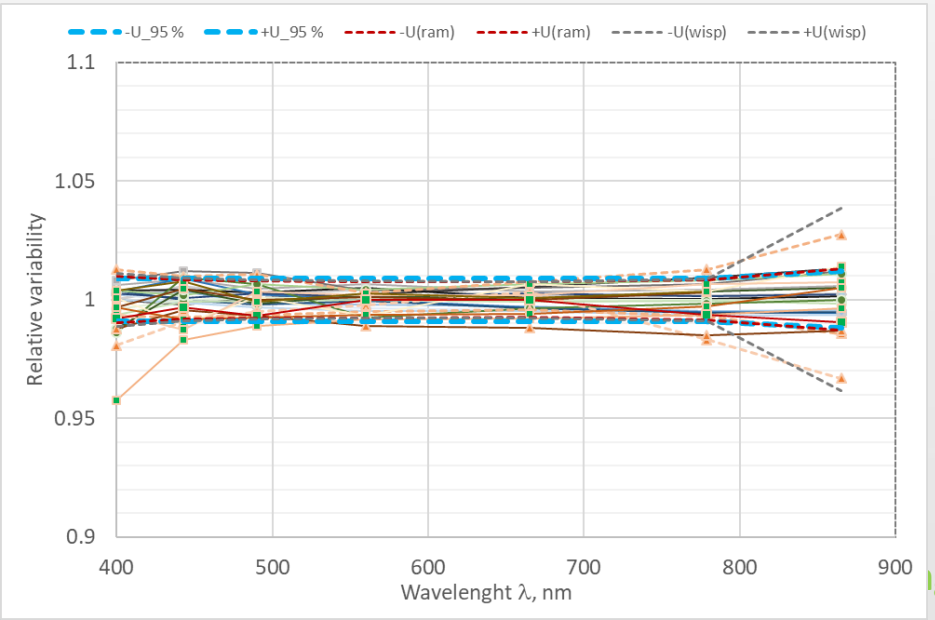
Lake Kääriku

Radiance casts used in the intercomparison with approximate FOV footprints of different radiometers.

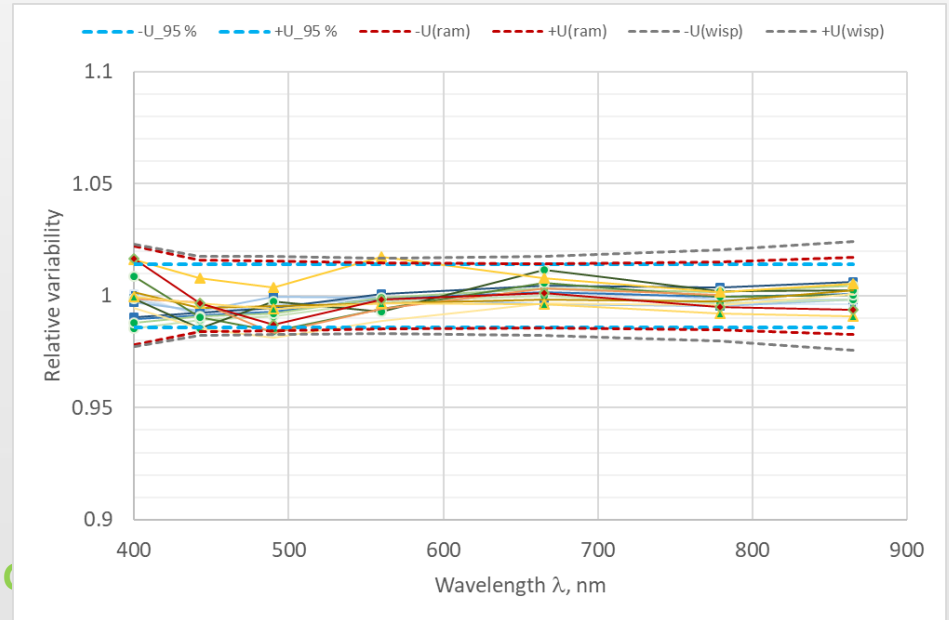
Provisional Lab results prior to water

- Good agreement between participating radiometers was achieved after removal of several data processing mistakes and using unified data handling methods
- The differences would probably have remained unnoticed for typical in situ measurement campaign without possibility to compare with other radiometers.

Indoor radiance compared to median



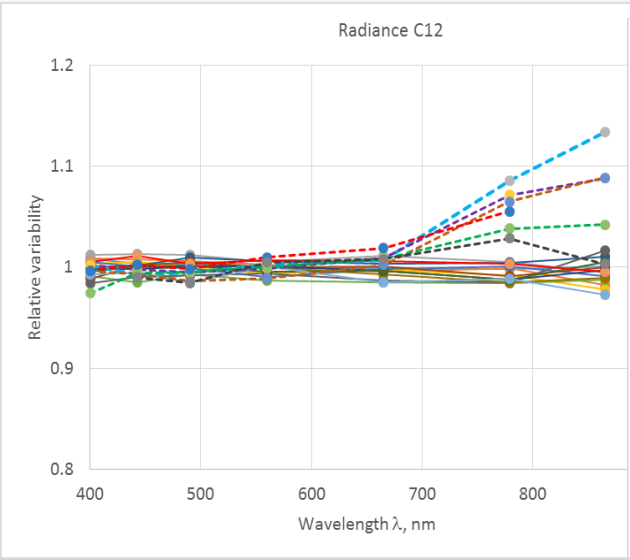
Indoor irradiance compared to reference filter radiometer



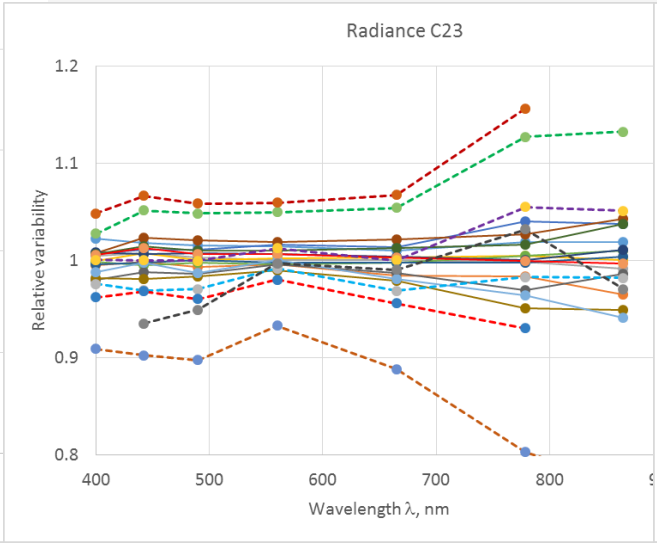
Provisional results Water

- Agreement in outdoor experiment was worse, especially in the NIR
- There were some outliers but their behavior was not always consistent and the reason is not fully understood (possibly nonuniformity of targets and differences in FOV)

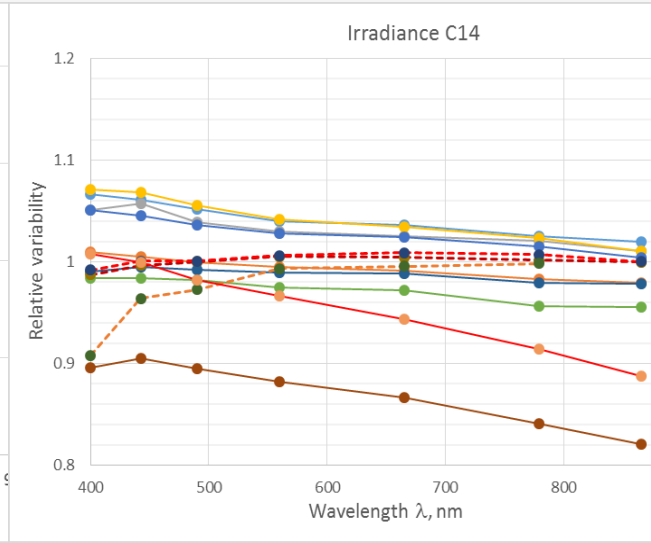
Sky radiance



Water radiance



Irradiance



2nd GSICS/CEOS workshop on moon

Xi'an China, Nov 2017

2014 14 agencies 26 attendees

2017 22 agencies 60 attendees

USGS 'ROLO' new funding

Starting to look at new uses of moon e.g MTF (link with IVOS)

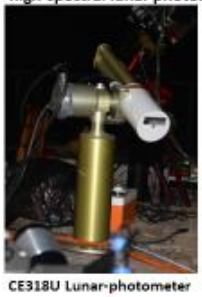
Measurements and Moon observations

- Great effort made by CMA and collaborating Chinese institutes from CAS to:
  - Develop new instruments dedicated to lunar observations from ground
  - Lead measurement campaigns
  - ➔ Goal = achieve SI traceability and develop new models for lunar calibration

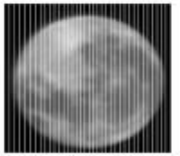
Lunar imager

high-spectral lunar photometer

AOTF imager

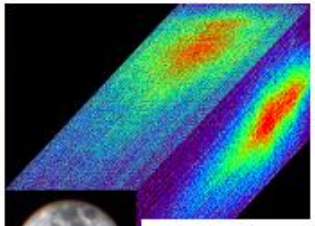


CE318U Lunar-photometer



Sweep Scanning ⇨ Split Joint

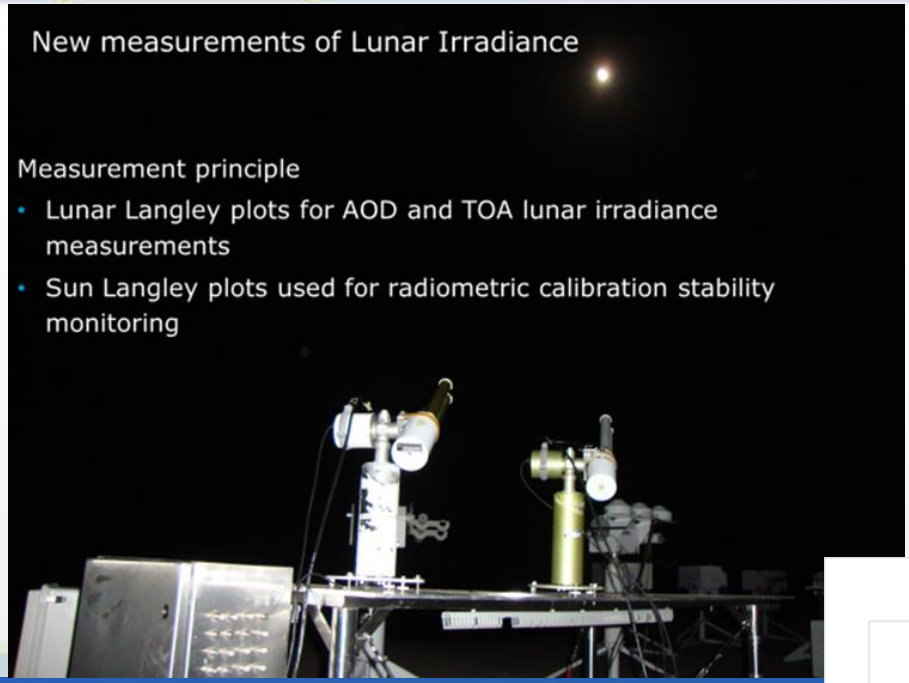
HSFTS

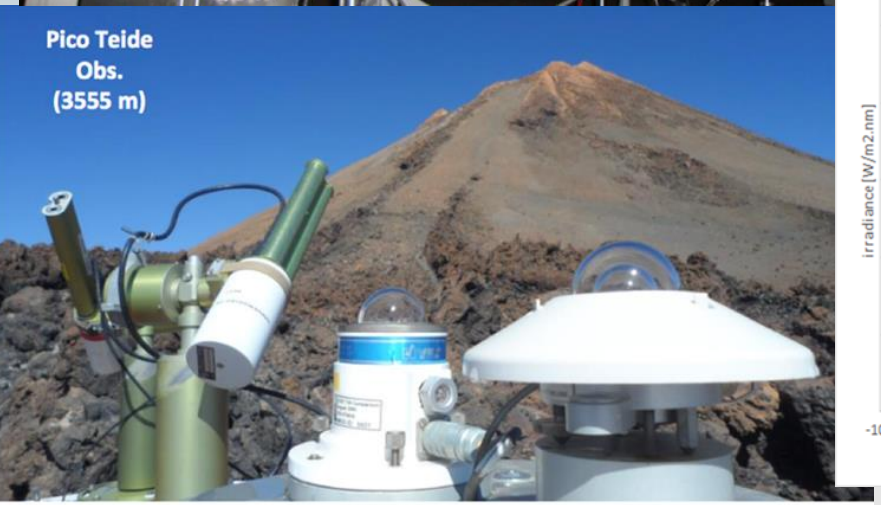


CCD

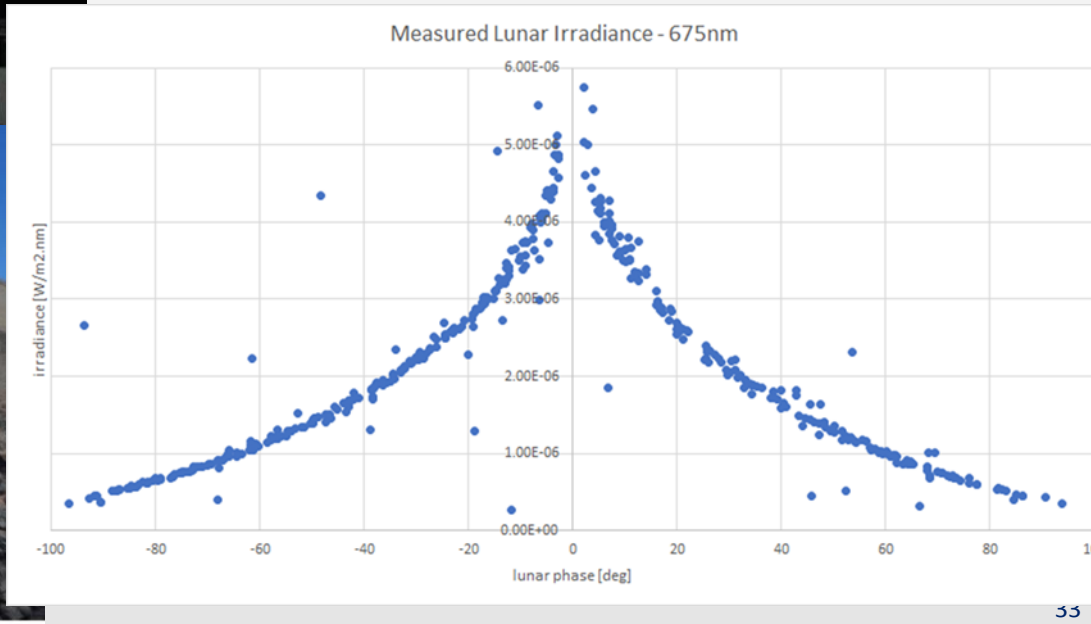
Lunar Spectral Imager,
Y. Wang & al, 2017
Zhang & al.
LCWS2017
#1d

ESA project to measure lunar irradiance as a Cal reference





- **Define a strategy to derive the model regression coefficients (ROLO based) from the lunar measurements**
- **Derive regression coefficients from database of measurements**
- **Measurements uncertainty propagation in to the model parameters / regression coefficients**



Terminology

Uncertainty

IS NOT

the same as

Error

Task group on vocabulary formed

Name	Institute	Name	Institute
Emma Woolliams	NPL	Stefanie Holzwarth	DLR
Steffen Dransfeld	ESA-ESRIN	Cindy Ong	CSIRO
Lingling Ma	AOE-CAS	Carol Bruegge	JPL-NASA
Xinhong Wang	AOE-CAS	Cibele Teixeira Pinto	South Dakota State University
Hirokazu Yamamoto	AIST	Martin Bachmann	DLR
Paolo Castracane	ESA-ESRIN		

Select some key terms and also concepts create a dictionary / thesaurus and also small video explanations where useful

Benchmark Calibration/climate sensors

WGCV Infrared and Visible Optical Sensors(IVOS) meeting

China Space-borne Radiometric Calibration Benchmark System Project, MOST

Lingling Ma[1], Na Xu[2], Chuanrong Li[1], Ning Wang[1], Caixia Gao[1]

Academy of Opto-Electronics (AOE), Chinese Academy of Sciences (CAS)

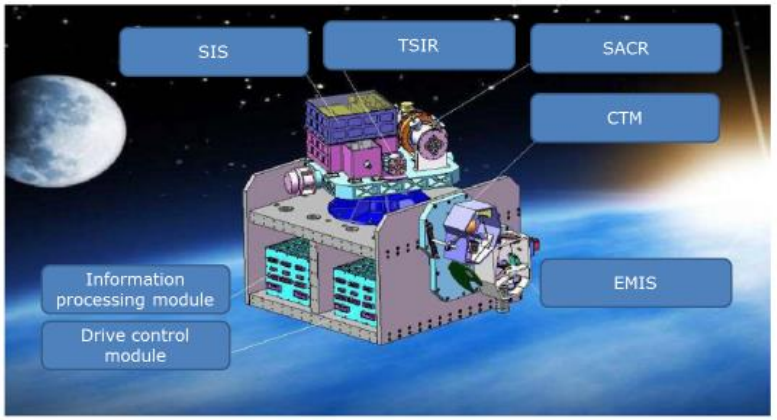
National Satellite Meteorological Centre(NSMC), China Meteorological Administration (CMA)

Mar. 2018

Research Contents

- 1. Space-borne benchmark system in solar refection spectrum

This system consists of 7 components: Earth/moon imaging spectrometer (EMIS), Solar irradiance spectroradiometer (SIS), Total solar irradiance radiometer (TSIR), Space-borne absolute cryogenic radiometer (SACR), Comparison transfer module (CTM), information processing module, and drive control module.



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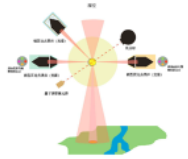
Research Contents

- 2. Space-borne benchmark system in infrared spectrum



Space-borne infrared standard reference sources

- 1 Gallium fixed-point on-orbit blackbody (standard reference source)
- 3 micron phase transition fixed-point variable temperature on-orbit blackbody (transfer reference source)

Temperature range: 250K-330K
Emissivity: >0.999
Blackbody stability: 10mk
Uncertainty of brightness temperature: < 0.1K

Broad spectum hyperspectral

Spectral range: 600 cm^{-1}~2700cm^{-1}
Spectral resolution: < 0.5cm^{-1}
IFOV: 17km
Radiometric sensitivity: 0.1K@270K
Uncertainty of absolute calibration: < 0.2K

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Plan to have a CEOS/GSICS workshop in Europe in 2019 WEBEX to define scope
Sep 13 organised by GSICS

- CLARREO
- TRUTHS
- Chinese Benchmark sensor

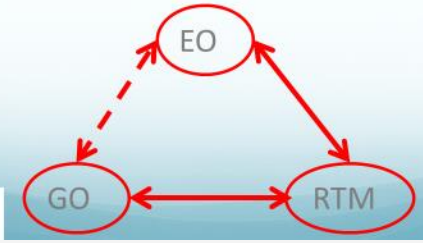
Working Group on Calibration and Validation

A new community 3D RT code

vincent.leroy@rayference.eu

BACKGROUND

- Radiation transfer models (RTM) is the only way to understand EO observations;
- There is a need to have an accurate consistency between ground observations (GO), RTM and EO data.



TOWARD A 1% RTM ACCURACY

- Surface BRF : accounting for topography (e.g., oriented sand dune);
- Molecular absorption: account for species like O4;
- Rigorous calculation of the coupling between:
  - Surface reflectance and atmosphere scattering;
  - Aerosol scattering and molecular absorption;
- Polarization, non flat earth for large zenith angles;
- Improvement of the surface and atmospheric property characterization;

NEW 3D RTM

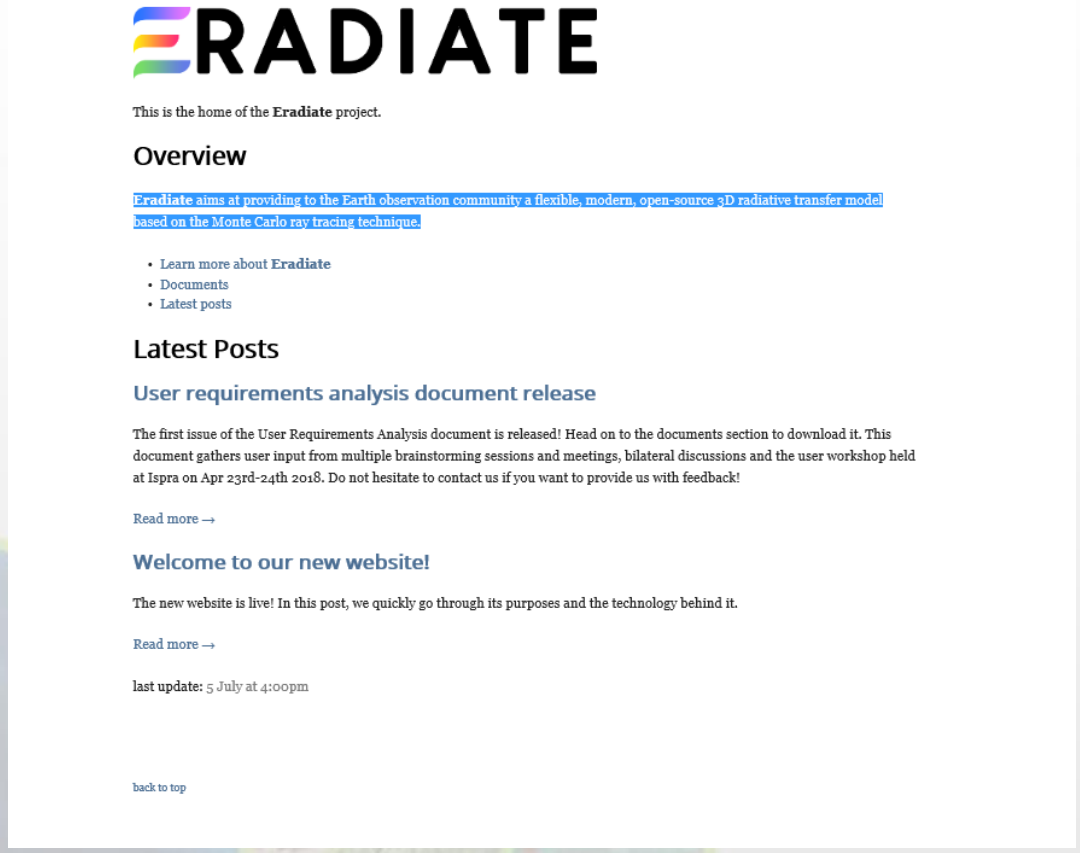
- In the Framework of the MetEOC-3 project, Rayference will initiate the design of a new **open-source community 3D RTM** to support CalVal activities;
- This new 3D RTM will include the following main features:
  - Simulation of satellite observations in the VIS, NIR and thermal IR spectral regions;
  - Simulation of ground observations;
  - Simulation of laboratory experiments.

GENERAL CONCEPT

- Based on the recycling of a state-of-the art Monte Carlo Ray Tracer;
- Open source, community model;
- Includes best features of existing 1D and 3D RTMs;
- Includes standard scenes and 3D scene generators;
- Includes water, atmosphere, snow, ice, …;
- Extensively evaluated with rigorous protocols.

rking

Project website created



- Community interface
- Requirements Specification
- Strategy for development
- Progress

www.eradiate.eu

Summary

- IVOS active team expanding (good global coverage- agency and industry
- Thematic projects working effectively with motivated champions: Number sometimes make logistics for meetings an issue but are working well between IVOS plenaries via webex etc
- Recommendations proposed and agreed at CEOS WGCV 42/43 (MTF sites and comparisons etc are being implemented.
- Looking for good examples of 'impact'
- Many collaborations with GSICS and supporting VCs
- Keen to revitalise and use Cal/Val portal as the community interface
- Plan to have session on Hyperspectral imagers at next IVOS.
- Still need to engage and bring on-board some agencies