Working Group on Calibration and Validation (WGCV): 41

Infrared Visible and Optical Sensors (IVOS) subgroup: report

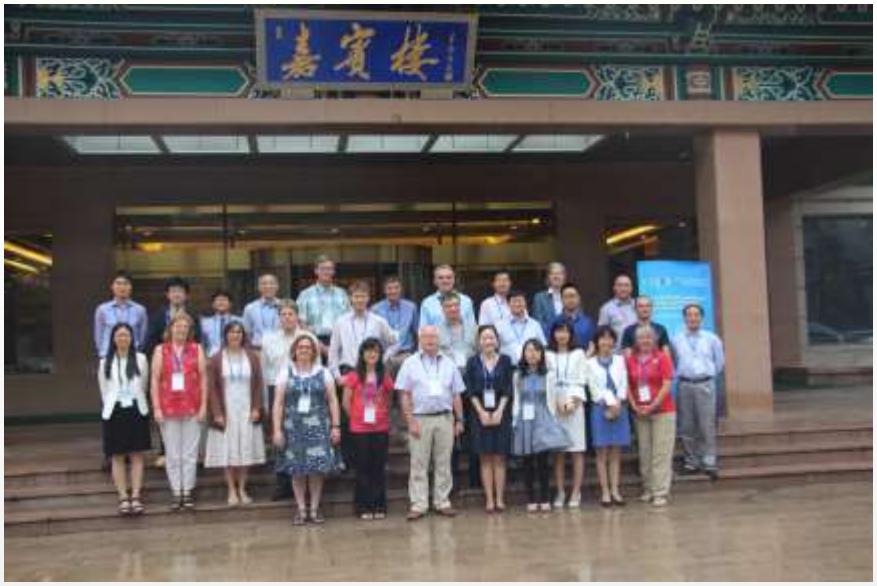
Nigel Fox

NPL (with UKSA support)

WGCV 41

Summary of activities

- IVOS 28 @ Beijing, China hosted by AOE/CAS Jul 2016
- 24 agency/orgs represented
- 30 attendees + 4 remote
- All themes and topics (work-plan discussed or summarised



- **Pre-discussion on 'in-flight interoperability' (Jun 2016)**
- **2nd MTF workshop 'results' (18 Jul 2016)**

Special Projects:

- **RadCALNet team met Jul 2016 @Beijing**
- **SST/LST comparison (under sponsorship from ESA) took place @NPL (June-July 2016)**
- **New PICSCAR project**

IVOS 29 – WK 13-17 Mar 2017 hosted by Uni of Arizona, Tucson, USA

Working Group on Calibration and Validation

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 Best Practices***
- ***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’ (Plus specific projects)**
  - **Look to develop best 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) - ?

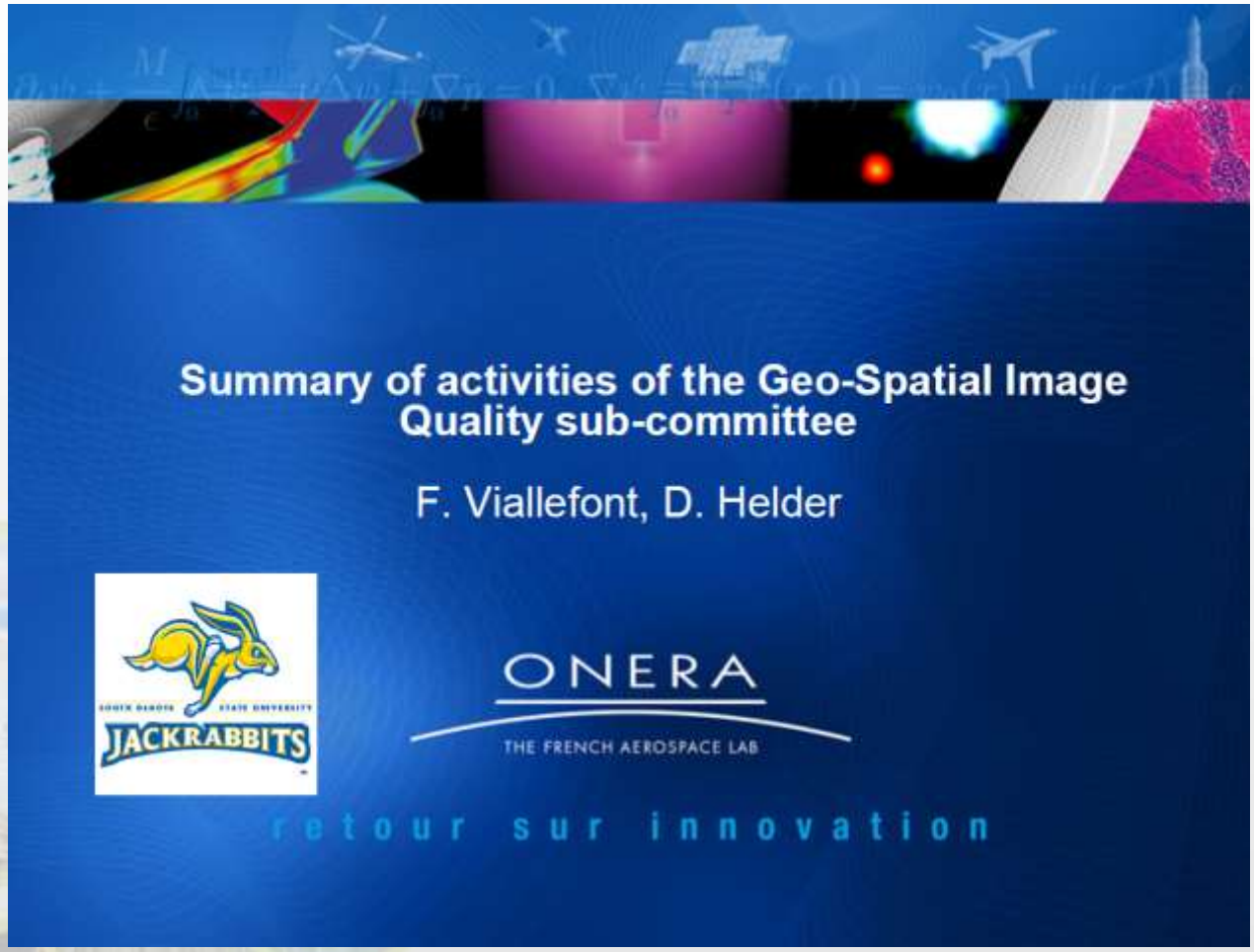
Specific projects/cross-cutting

- **RadCALNet** - **Bouvet (ESA)**
- **PICSCAR (Libya 4 / PICS) (with GSICS)** - **Henry (CNES, F)**
- **SST/LST cross-comparison (+ VC-SST & LPV (instrument Cal for LST)** - **Fox (NPL, UK)**
- **Others in progress/development**
  - **Establishing a CEOS reference (s) and method (s) for L1 radiometric interoperability (with GSICS)**
  - **Best practise for convolving spectral data sets (solar/surface/sensor bandwidth) (CEOS WGCV (sub-groups) & GSICS)**

IVOS 28 Discussion Topics

- Summary of workshops, MTF, RadCalNet
- Hyperspectral (imaging Spectroscopy-surface) needs/issues
- Update on PICS & Initiation of new PICSCAR project
- OC Rad validation
- Sat surf Temp measurements- Rad aspects of Val
- Terminology
- Sensor to sensor interoperability (establishing a CEOS post-launch radiometric reference)
- Sensor Pre- and In- flight Cal and Uc assessment
- New Sensors
- Atmospheric effects on Rad Cal
- Collaborations/interactions – WGCV, GSICS, VCs, Climate, Carbon ….
- Cal/Val Portal – Communications/newsletter….

MTF activities & comparison



Establish good practice 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

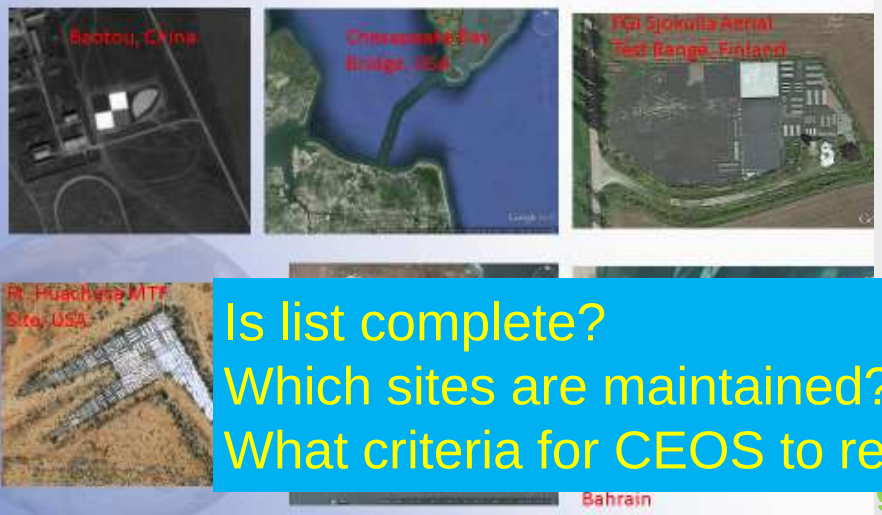
On-orbit Estimation (substantial portion of document)

- 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 'Standard' Imagery for PSF/MTF estimation**
- Data Analysis, PSF/MTF Estimation
  - Image data format
  - Models
  - Parametric/Nonparametric Methods
  - **Database of 'Standard' estimation methods**

Proposed Actions

(from IVOS 24)

Current Website Status



Current Website Status

Is list complete?
Which sites are maintained?
What criteria for CEOS to recommend?

Comparison of methods

Reference dataset

Objectives

Objective 1: share images and begin to understand the MTF differences for each kind of method and target (repeatability and precision)

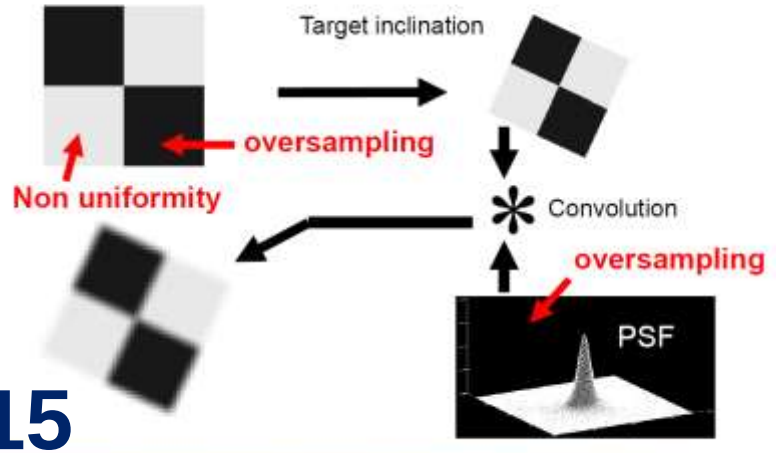
Objective 2: share images with known parameters (i.e. MTF, SNR) for quantitative comparison (accuracy)

→ A need exists for creation of a reference dataset containing:

Actual images: in the coming slides

Synthetic images: initial effort

Exemple of synthetic image generation



NOV 2015

Current dataset

20 edge or draughtboard images

14 actual images: Worldview3 (DIGITALGLOBE), S6 and S7 (AIRBUS_DS)

6 synthetic images: 2 standard systems (AIRBUS_DS), 4 analytic MTF (CSIR)

Thanks to all data providers !

Significant community interest (inc industry)

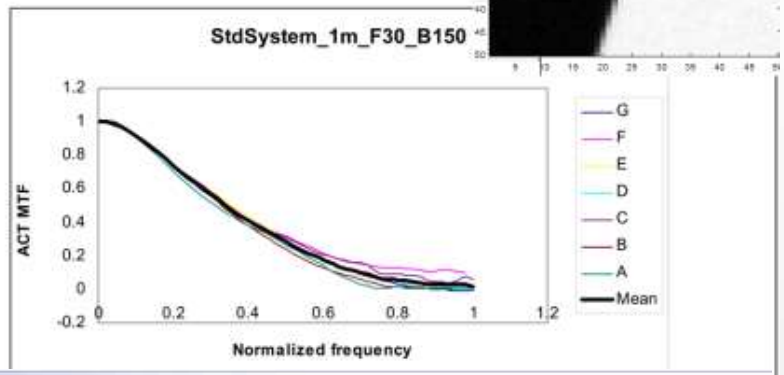
July 2016: Real and Synthetic images supplied And analysed

Working Group on Calibration and Validation

Preliminary Results

First MTF measurement results

StdSystem_1m_F30_B150 :

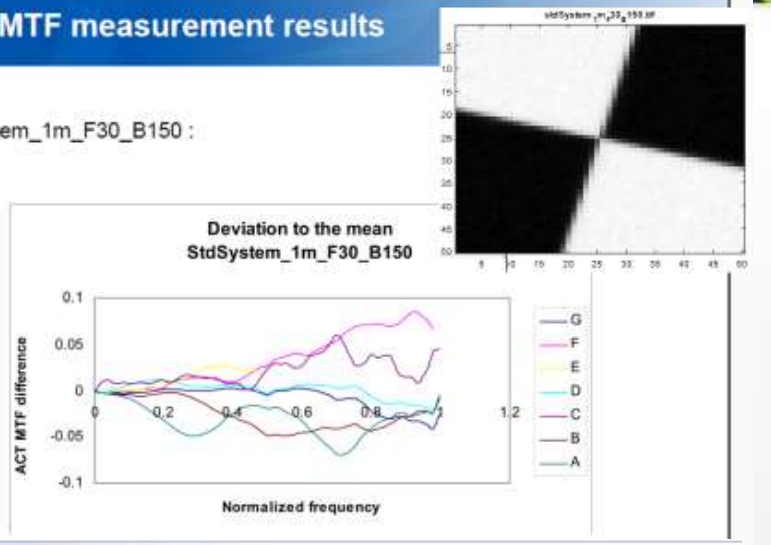


Observations from Data Analysis

- All methods showed consistency as well as differences
  - Very helpful to observe multiple methods and get a sense for what the community produces
  - Both major and minor differences can provide important insights for each contributor
- No one consistently good estimator
  - An approach may work well for one image and not as well on another
- One test image is not enough.
  - More *synthetic* images needed where 'truth' is known as well as the parameters used to build the image
  - More *real world* images needed where 'truth' is unknown for developing confidence in consistent estimates and because simulations ultimately do not perfectly represent the *real world*.
- This has been an excellent initial effort that should provide essential insights for progressing to the next steps!

First MTF measurement results

StdSystem_1m_F30_B150 :



Discussion points from Data Analysis

- Can we agree on a common format for sharing our PSF/MTF estimation results?
- How do we develop a suite of *synthetic* images?
  - What are the key parameters?
  - Do we develop a suite of images or an acceptable software for users to produce their own?
- How do we develop a suite of *real world* images?
  - What are the key parameters?
  - What metadata should be provided to describe the imagery?
  - How do we share our results so that users can develop confidence in their estimation approach?
- How do we develop uncertainty values for our estimates?
- What are the key spatial quality metrics (e.g. MTF@Nyquist, RER, FWHM, Edge Slope...)?
- Are we ready to initialize a database of 'standard estimation methods'?

Next steps

Next Steps

1. F. Viallefont will circulate a desired data format for MTF estimates for ease in comparisons; sub-committee will provide comments. Final format agreement by next meeting

2. All members will make a list of key parameters, along with appropriate ranges, necessary for development of synthetic PSF/MTF images. D. Helder and F. Viallefont will compile, organize to develop a final list. Goal of completion by next meeting.

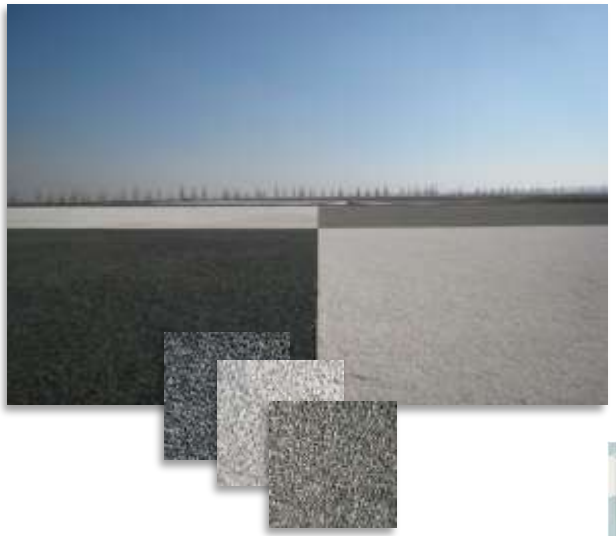
3. D. Helder/F. Viallefont will consult with members of sub-committee to determine who is capable and willing to develop the second set of synthetic images. Goal to complete by next meeting. Stretch goal to have images generated and available for processing by next meeting. *Stretched stretch goal to have a comparison ready by next meeting????*

4. All members will share their PSF/MTF methodologies for edge (checkerboard) targets. Goal to be tabulated at the next meeting for comparison and discussion.

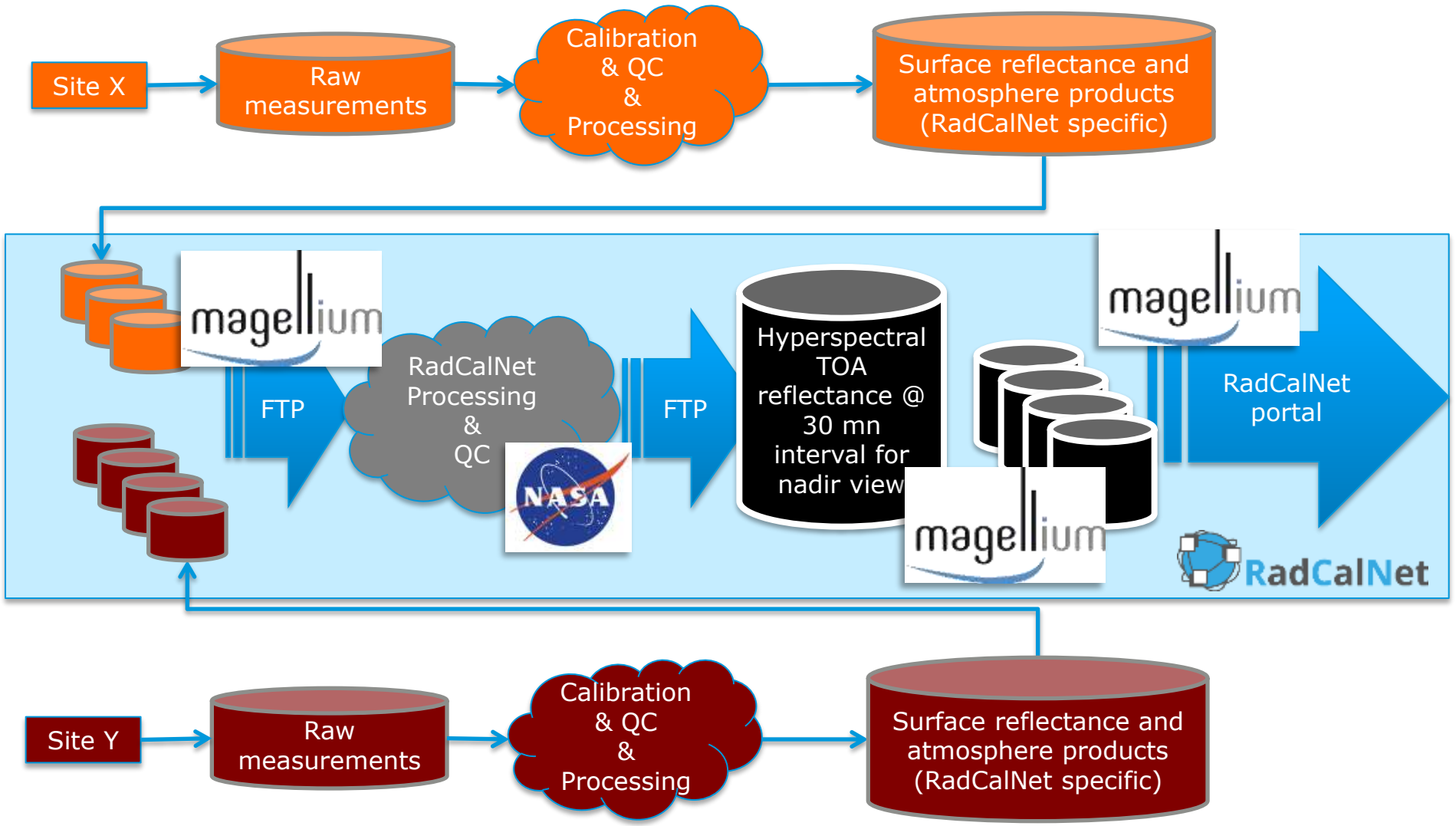
RadCalNet: Status

The sites

- Currently 3 instrumented are providing data to RadCalNet:
  - ✓ Baotou (China)
  - ✓ La Crau (France)
  - ✓ Railroad Valley Playa (US)
  - ✓ Gobabeb (Namibia)



The data circulation… today in practice



The portal

RadCalNet

CEOS Committee on Earth Observation Satellites

esa

Welcome to the Radiometric Calibration Network portal

The portal provides access to all RadCalNet datasets, allowing users to visualize and download data acquired by the four instrumented reference test sites.

- University of Arizona's site at Railroad Playa, Nevada, USA,
- AoE's site at Baotou, China,
- the CNES site at La Crau, France,
- the new ESA/CNES site in Gobabeb, Namibia.

These test sites provide nadir-view top-of-atmosphere reflectance at 30 minute intervals from 9am to 3pm local standard time at 10 nm intervals from 400 nm to 2500 nm. This is calculated from ground nadir-view reflectance measurements, and atmospheric measurements such as surface pressure, columnar water vapour, columnar ozone, aerosol optical depth and the Angstrom coefficient. Correction to top-of-atmosphere will be performed for all sites in the same way using Modtran.
The data are provided in a text format, defined in RadCalNet_File_Specs_v4.pdf.
To download data from a site, please select a site.
To download complete data sets, please press the hyperlink download all data. Users are also asked to consider RadCalNet data policies especially providing appropriate citations when displaying data downloaded from this site.

19-Nov-2015: The RadCalNet project status was presented at the CEOS/WGCV/IVOS meeting at ONERA in Toulouse (France). Please find the presentation here.
23-Nov-2015: A team for NPL and CNES staff has started a campaign aiming at characterising the Gobabeb site.

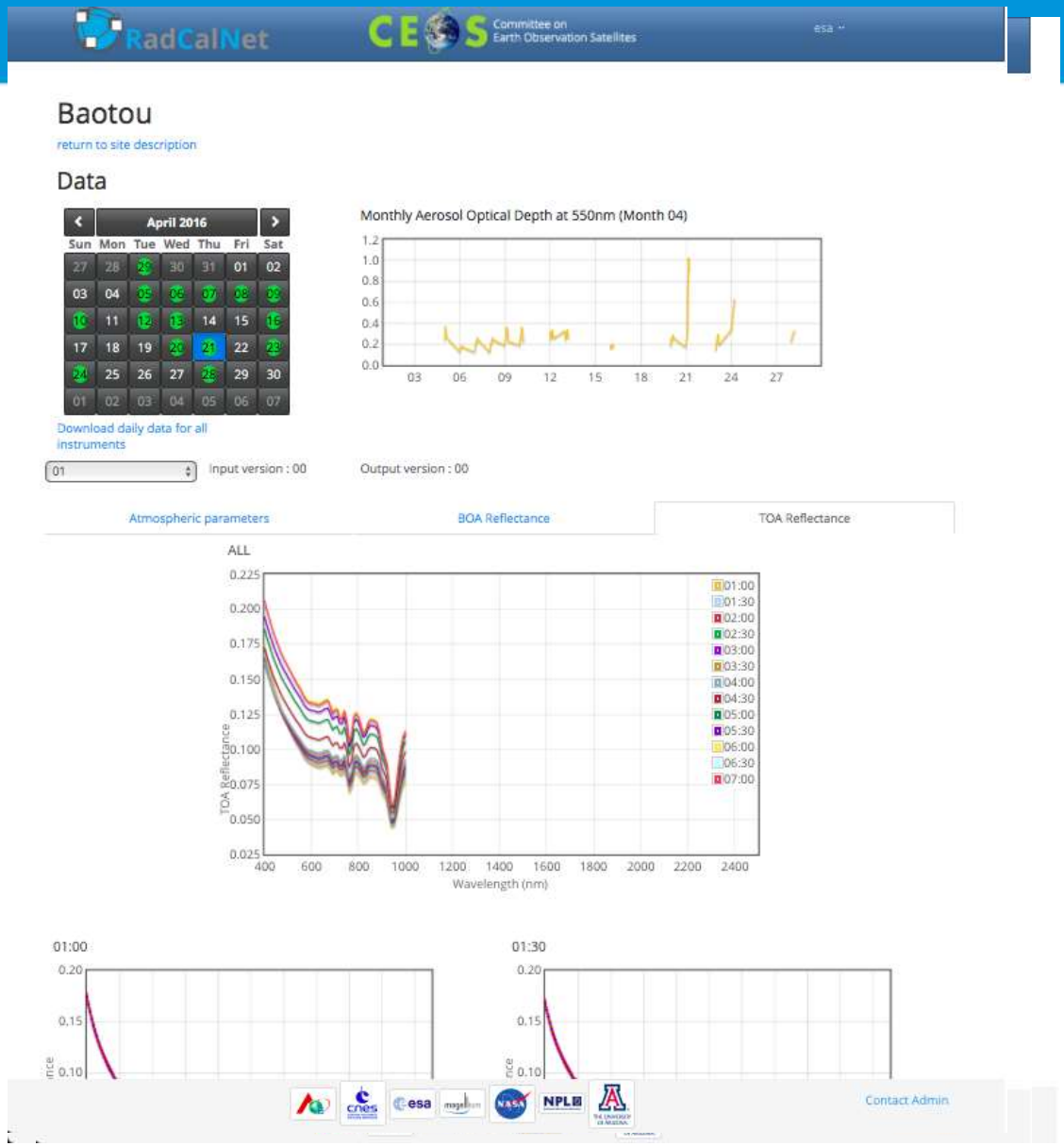
Please select a site :

- Railroad Valley Playa
- La Crau
- Gobabeb
- Baotou

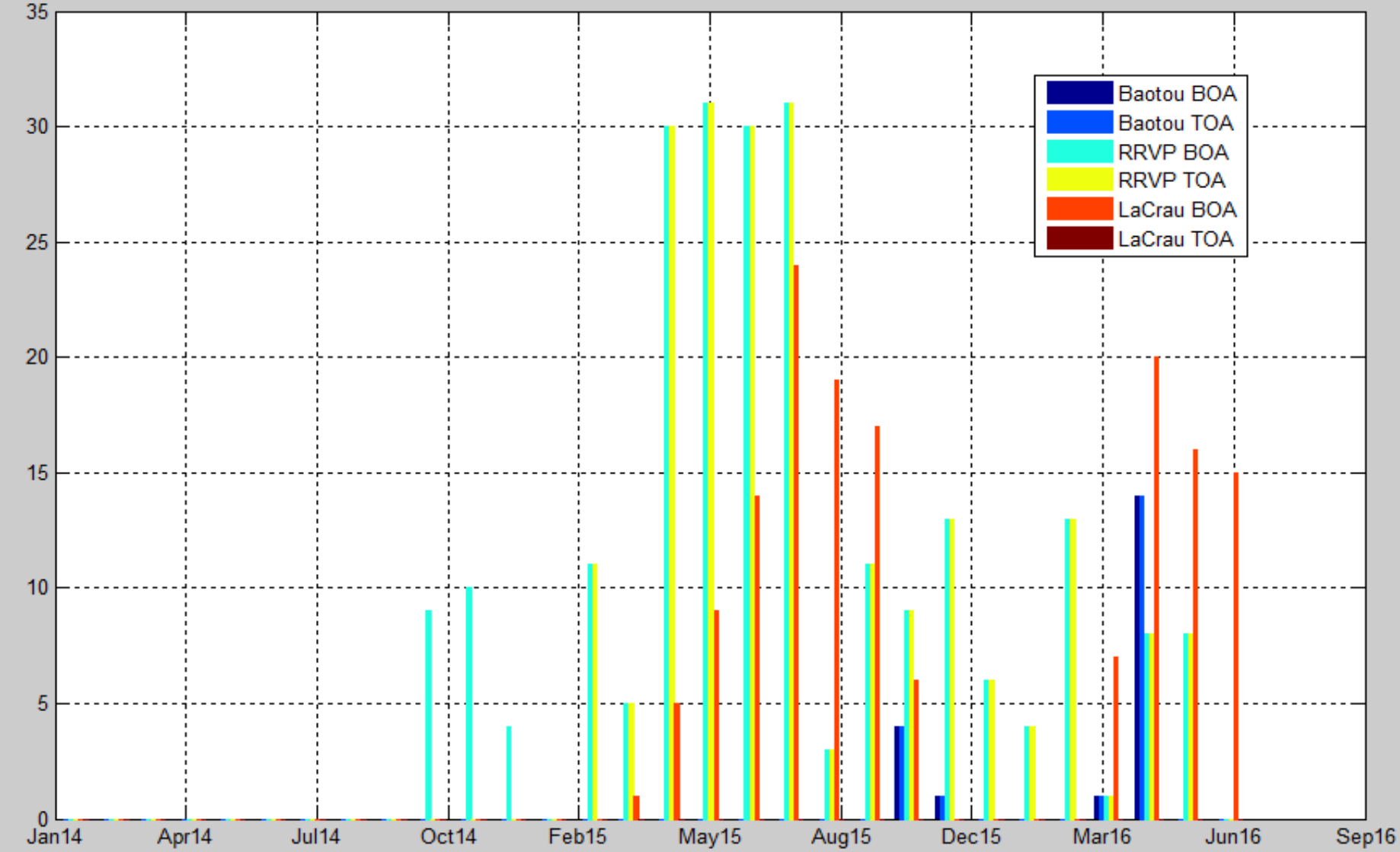
RadCalNet Documents

Contact Admin

The portal


RadCalNet
CEOS Committee on Earth Observation Satellites
esa
Baotou
return to site description
Data
April 2016
Sun Mon Tue Wed Thu Fri Sat
Monthly Aerosol Optical Depth at 550nm (Month 04)
Download daily data for all instruments
01
Input version : 00
Output version : 00
Atmospheric parameters
BOA Reflectance
TOA Reflectance
ALL
TOA Reflectance
Wavelength (nm)
01:00
01:30
Contact Admin

Data currently available



The TOA intercomparison of RadCalNet TOA simulation using space sensors as transfer radiometers

- Objective: identify site-to-site differences in TOA predictions using the space sensors as transfer radiometers

- Plan:
- Intercompare:
  - ✓ Remote sensing TOA data: Landsat-8 / SPOT-5 / Sentinel-2 / + ???
  - ✓ TOA simulations over the sites (both from RadCalNet and from site owners using their own TOA simulation tools)

The BOA intercomparison of RadCalNet surface reflectance using portable transfer radiometers

- Objective: identify site-to-site radiometric differences at surface radiance (reflectance) level

- Plan
  - ✓ First the UoA and NPL transfer radiometers will be calibrated and compared before end 2016
  - ✓ Transfer radiometers will be operated at sites (blindly by site owners and/or with E. Wooliams) early 2017

THE UNIVERSITY OF ARIZONA.

NPL National Physical Laboratory

Planning

- Beta testing from September 2016 to Q1 2017
- Gobabeb site running by end of 2016
- Start intercomparison of sites using the portable transfer radiometer in early 2017
- Beta tester mini-WS in March 2017 (next RadCalNet WG meeting)
- RadCalNet goes public by Q2 2017

FRM4STS: Fiducial Reference measurements for validation of Surface Temperature from Satellites (ceos cv8)

Nigel Fox

NPL (ESA Project)

WGCV Plenary # 40

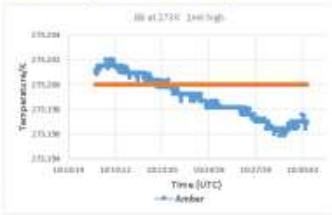
Working Group on Calibration and Validation

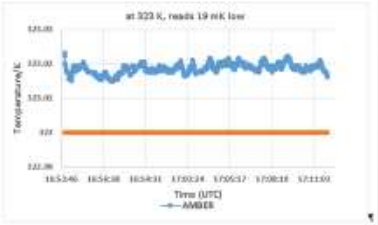
COMPARISONS

BB comparison (June 2016)

1. Miami University - USA
2. ONERA - France
3. University of Valencia- Spain
4. University of Southampton - UK
5. Qing Dao -China
6. RAL - UK
7. CSIRO - Australia
8. KIT- Germany

273 K to 323 K (0 to 50 °C)





Radiometer comparison

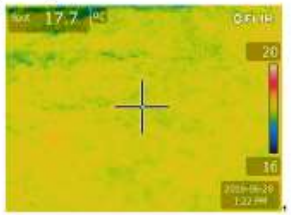
1. Miami University (USA)
2. ONERA (France)
3. University of Valencia (Spain)
4. University of Southampton (UK)
5. Qing Dao (China) -1
6. Qing Dao (China) -2
7. RAL (UK)
8. CSIRO (Australia)
9. KIT (Germany)
10. DMI (Denmark)
11. GOTA (Canary Islands
12. JPL NASA (USA)
13. Ian Barton (Australia)

MAERI (UofM) viewing NPL ammonia Heat pipe

240 K to 318 K

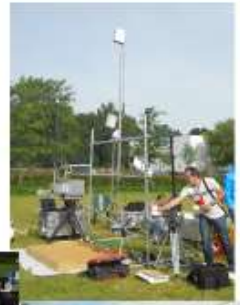
WST comparison @Reservoir near NPL and Heathrow airport July 2016

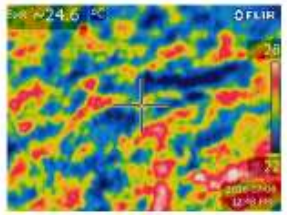
1. University of Valencia (Spain)
2. University of Southampton (UK)
3. Qing Dao (China) -1
4. Qing Dao (China) -2
5. RAL (UK)
6. CSIRO (Australia)
7. KIT (Germany)
8. DMI (Denmark)
9. GOTA (Canary Islands)
10. JPL NASA (USA)



LST (Sun & Cloud) @ NPL sports field and carpark

1. University of Valencia (Spain)
2. KIT (Germany)
3. JPL NASA (USA)
4. ONERA (France)





Emissivity

Working

Ocean Colour

- To help address IOCCG white paper
- Run comparisons of validation instruments
  - Lab
  - Ocean
  - Ref standards
- Ensure SI traceability and Uc to SI
- Draft protocols for how to establish/maintain traceability
- Review requirements for future infrastructure

Fiducial Reference Measurements for Satellite Ocean Colour

FRM4SOC

Project Overview for CEOS-WGCV-IVOS

Andrew Banks (NPL), Riho Vendt (TO), Gavin Tilstone (PML), Kevin Ruddick (RBINS), Christophe Lerebourg (ACRI-ST), Craig Donlon (ESA)

fiducial reference measurements for satellite ocean colour

Outline

Main aim of FRM4SOC:

To establish and maintain SI traceability of ground-based Fiducial Reference Measurements (FRM) for satellite ocean colour radiometry (OCR).

Specific Objectives:

a. Develop, document, implement and report OCR measurement procedures and protocols. It shall design, document and implement both laboratory and field inter-comparison experiments for FRM OCR radiometers to verify their FRM status to help support of CEOS WGCV.
b. International coordination activities to define next generation of Ocean Colour vicarious calibration/adjustment infrastructure (FRM4SOC workshop).

Three types of internationally open intercomparison exercises:

1. LCE-1 For OCR Radiance and Irradiance Calibration Sources
2. LCE-2 For OCR Calibration
3. FICE for OCR field measurements

(End-to-end uncertainty evaluation for FRM4SOC carried out by NPL)

Comparison plan: Open Invitation to CEOS

fiducial reference measurements for satellite ocean colour

Laboratory Calibration Exercise 1 (LCE-1): Reference Irradiance and Radiance Sources

- Scheduled for 1-2 weeks at NPL in April 2017.
- A global invitation and expression of interest form will be released through the FRM4SOC website and if agreed through CEOS, the IOCCG and other relevant bodies.
- Interested participants will need to bring their irradiance sources to NPL for comparison with the primary standards.
- Training – uncertainty budget for absolute radiometric calibration.
- Transfer radiometers will subsequently be sent back and forth to each participant lab for radiance source measurements. The transfer radiometer in this configuration will be used to compare the participant's in-house radiance sources with the NPL derived radiance scale.

fiducial reference measurements for satellite ocean colour

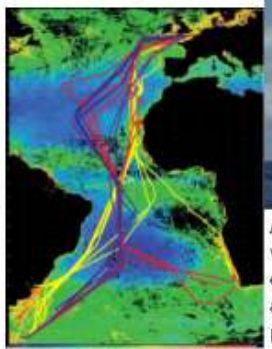
FICE experiments will be conducted on two platforms:
which have a long history of satellite ocean colour validation and development during NASA and ESA missions (O'Reilly et al. 1998; Zibordi et al. 2006).

1. The **Acqua Alta Oceanographic Tower (AAOT),** Gulf of Venice, Italy.
8 days, in ***June-July 2017*** (date tbc).

Purpose built steel tower with instrument house platform to conduct optical measurements under stable conditions to tilt and roll and illumination geometry.

2. The **Atlantic Meridional Transect (AMT)** 27. ***Sept-Oct 2017.***

AMT cruises are conducted between UK & South Atlantic on a NERC ship.



AMT passes through a wide range of environmental conditions and biogeochemical provinces.

fiducial reference measurements for satellite ocean colour

LCE-2 outdoor intercomparison - Lake Kääriku – May 2017

- Controlled outdoor environment near Tartu Observatory, Estonia

CEOS WGCV Comparison for IOCCG & VC OCR

Invites to go out soon

Potential regional follow-on for large numbers of participants

Terminology

Uncertainty IS NOT the same as Error

But also many terms have different interpretations e.g. Harmonisation, Levels 1A,1B, 1C …., Ancilliary data ……

IVOS Activity: To support wider CEOS WGCV initiative NPL to create and administer 'Wikki' web page (via cal/val portal) to discuss/define terminology and establish 'thesauras' of definitions as necessary

Post-launch sensor to sensor interoperability of Level 1

- IVOS 27 significant discussion on what to be done & How?
  - ‘Database’ of results from comparison databases
    - Inc different methods
    - What needs to be stored/format for exchange of data?
  - Tools/methods to facilitate comparison
    - SBAFs, ref curves (solar irrad) …
    - Ref sensor, virtual sensor, ground site, ‘average res’
- Conclusion to have a small scoping workshop as a prelude to a larger community activity (NPL June 2016: NASA, CNES, ESA, GSICS/EUMETSA Facilitated by NPL)

Conclusion

Group shared a common vision and scoped an outline set of activities (many of which already in progress) now ratified by WGCV IVOS 28 for development with wider community (IVOS pilot for WGCV??)

Recognising that WGCV IVOS (together) and additionally many of its members (independently), has for some time been developing a range of strategies/methods/infrastructure (e.g. test sites/databases) to evaluate/correct post-launch biases/ageing of Level 1 radiometric properties of sensors that they operate/use data from and also cross-compare sensors to identify relative differences and noting the increasing interest in combining together data sets for a variety of applications it was timely to consider if CEOS WGCV and particularly IVOS needed to consider its 'vision' and strategy in this context.

VISION;

To work towards establishing a community agreed reference (s) (potentially, to reflect different applications/observation characteristics) for level 1 TOA radiances and the means of how sensors can and should link to it and subsequently communicate results

Scope and User

- **Objective** is to provide a ‘reference’ which allows satellite operators and potentially their customers to readily obtain information relating to the radiometric calibration (initially Level 1) of a sensor and its relationship with others in a consistent manner but interpretation (and any other actions) is responsibility of individual agencies who have appropriate expertise
-
- **Users**
  - **satellite operators (public agencies and commercial) – informing them on calibration status**
  - **Users of L1 data products (e.g. L2 data producers, producers of data cubes, climate data records ..) to help obtain consistency across sensors and between bands – over time and for sensor independent products**

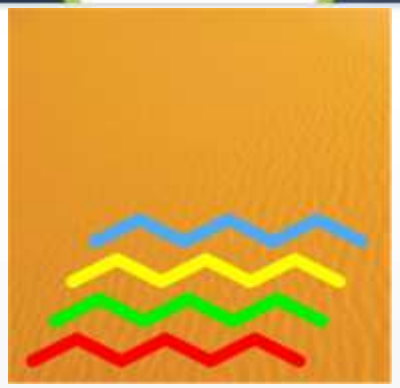
What are the elements of a system to deliver?

- Understanding user needs and the characteristics of sensors that would use the ‘service’
  - who wants it?, why? and what must it be able to do?
- A means to formulate a reference (s) and assign its associated uncertainty
  – Internationally acceptable standard (proxy for SI)
- The means to link sensor measurements to the reference and associated uncertainty – The process
- Communication of information (data, results and methods)
  – Useability and awareness
- Governance, review mechanisms, quality control, maintenance…
  .- Community acceptance

Next steps: Create (IVOS) project as a pilot for WGCV

- **Agree terminology / vocabulary**
  - wider initiative needs WGCV/GSICS/GEO …but IVOS perspective/input
- **Have conversations with users to understand requirements/desires and scope**
  - Probably best done at WGCV level
- **Collect information on existing and future sensor comparisons in common format in a 'restricted' section of Cal/Val portal**
  - Working data-set to identify variances between methods & within methods
  - i.e. summary results (with ref to method etc) from SADE/Muscle, RadCalNet, Bi-laterals, publications etc
- **Continue to develop and evaluate (as community projects) differences between 'methods' for similar activities e.g. Lunar, RadCalNet (BoA & ToA), PICS …** - Ultimately leads to confidence in Uc and potential for SI traceability
- **Consider how best to combine/weight results/information from different methods and assign an Uc (ies) to sensors for particular types of observation**
- **Hold 0.5/1 day open workshop associated with IVOS 29**

PICSCAR: WGCV IVOS + GSICS visible technical group



New project: Lead Patrice Henry CNES

Objective: Improve use of PICS through community project to Coordinate efforts on characterisation and consistency of methods

Background: Have been widely used for 20 yrs for monitoring Stability of cal of sensors

- Have been two workshops to discuss activities and progress
  - Very well attended and range of activities globally
- Aim to define a 2 yr work plan in Q4 2016
  - Questionnaire circulated to collect information on use and applications etc
  - Webex meeting in Q4 2016 to discuss results and actions
  - Workplan defined
- Collect data from multiple sats of Libya 4 for comparison exercise (inc different processing of same sat data) (new and old data)
- ESA project to support with collection of sand and BRF measurements

IVOS Recommendations/info to CEOS WGCV

R.2016-1	IVOS shares a vision on the need to establish a community reference for sensor Level 1 TOA interoperability. It will create an umbrella project (in collaboration with appropriate GSICS sub-groups) and set of related sub-projects/activities to achieve that goal.
R.2016-2	IVOS values a central CEOS-WGCV webportal that is independent of individual organisations for the sharing of results, reports and to collate information. We recommend that the CalVal portal be optimised and redeveloped.

- **Encourage participation in PICSCAR project (data collection)**
- **Participation in OC comparison project FRM4SOC**
- **Support from CEOS WGCV (or other) to identify requirements for Uc and interoperability**

Note: CEOS (USGS) priority for Analysis ready data & sensor to sensor Interoperability etc