CEOS IVOS Sub-group
(Infrared, Visible and Optical Sensors)

Report to CEOS WGCV 29

Chair: Nigel Fox
National Physical Laboratory
UK

with support from BNSC

IVOS

IVOS MISSION statement

Mission

"To ensure high quality calibration and validation of infrared and visible optical data from Earth observation satellites and validation of higher level products"

IVOS 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.

Workplan/operational mechanisms

- **Meetings at least annual (nominally 9 monthly)**
  (*email members ~ 50, attendees (15 to 30*)

- **Key Activities**
  - **Information exchange**
  - **Focus on developing and addressing GEO task DA 06-02**
    (***Data Quality Assurance strategy***)
    - Initiation of Cal/val portal (for communication)
    - Establish cal/val "best practises"
    - Comparisons to underpin
    - Identification and classification of "test sites" for sensor performance evaluation
  - **Prioritise activities to focus on needs e.g. "Land imager constellation"**
  - **WGCV Lead on CEOS climate Action A5, C7**
    (*Benchmark mission to establish SI traceable measurements in orbit)*

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CEOS IVOS 19

Feb 5-7(8) 2008, Tempe Arizona

Hosts: University of Arizona Remote Sensing Group
Co Sponsor: USGS

Evaluating a “test site”!

CEOS IVOS 20, Tsukuba Japan, Dec 9-10 2008

Hosts: JAXA

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Work plan and progress 1

- **QA4EO – major effort**
  - first draft procedural guideline written
    - Use of Moon for Calibration – Tom Stone
  - Comparison protocol on Dome C in progress
  - Procedure on establishing a test site being drafted by Tubitak Uzay (Turkey)/NPL
  - Hoping to have procedures on Test site characterisation, Use of Rayleigh scattering, sun-glint etc as first priorities
  - Evaluating prospect of incorporating RAMI comparison as an example of models/algorithms
  - Establishing Reference standards and key characteristics

Work plan and progress 2

- **Comparisons**
  - DOME C inter-satellite radiances
  - Terrestrial based radiometers for IR emitted radiance
    - *land and Ocean*
  - Terrestrial based VIS/SWIR solar reflected “radiance” European pilot followed by full open CEOS -
    - *Include multi-satellite comparison*
- **Collaborative research aims**
  - Establishing network of test sites requires
    - “traceably” characterised sites
    - common instrument specifications ideally autonomous
    - consistent means to match sensor footprint (spatial and spectral)
    - Atmospheric correction
    - Site to site coordination for “operational GEOSS service” (Land)

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GHRSST a good example for SST

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CEOS Infrared spectral emitted radiance comparison

Spring 2009 (Probably May)

Hosts: University of Miami (pilot/coordinator: NPL)

Objective:

- Establish degree of equivalence between participants
- Ensure robust traceability to SI (via NIST and NPL)
- Establish protocols to facilitate future comparisons

To be carried out following QA4EO guidelines:

- Circulation of uncertainties prior to comparison to allow "real time" analysis and prospect of "2nd follow-on" comparison ALL results to be public domain

Preliminary invitation circulated and request for funding to CEOS agencies to complement that of ESA

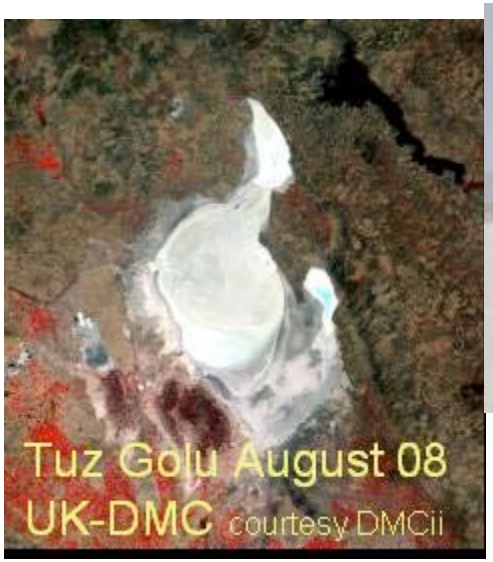
Interest currently expressed from:

- USA, UK, Australia, China, Spain

Land surface: solar reflected radiance comparison

Plan:

- Use Tuz Golu as an accessible CEOS reference standard test site
- Carry out preliminary evaluation and establish draft protocol Dec 2008
- European pilot comparison for Summer 2009
- CEOS comparison Summer 2010



AUG 08 campaign
NPL & Tubitak Uzay

Three sites of areas: ~300 m Sq
- Sensors (with acquisitions 18-24 Aug)

- DMC UK, Beijing, Nigeria
- Top-Sat
- CHRIS/Proba next time
- MERIS
- ALOS
- Landsat 7
- AATSR

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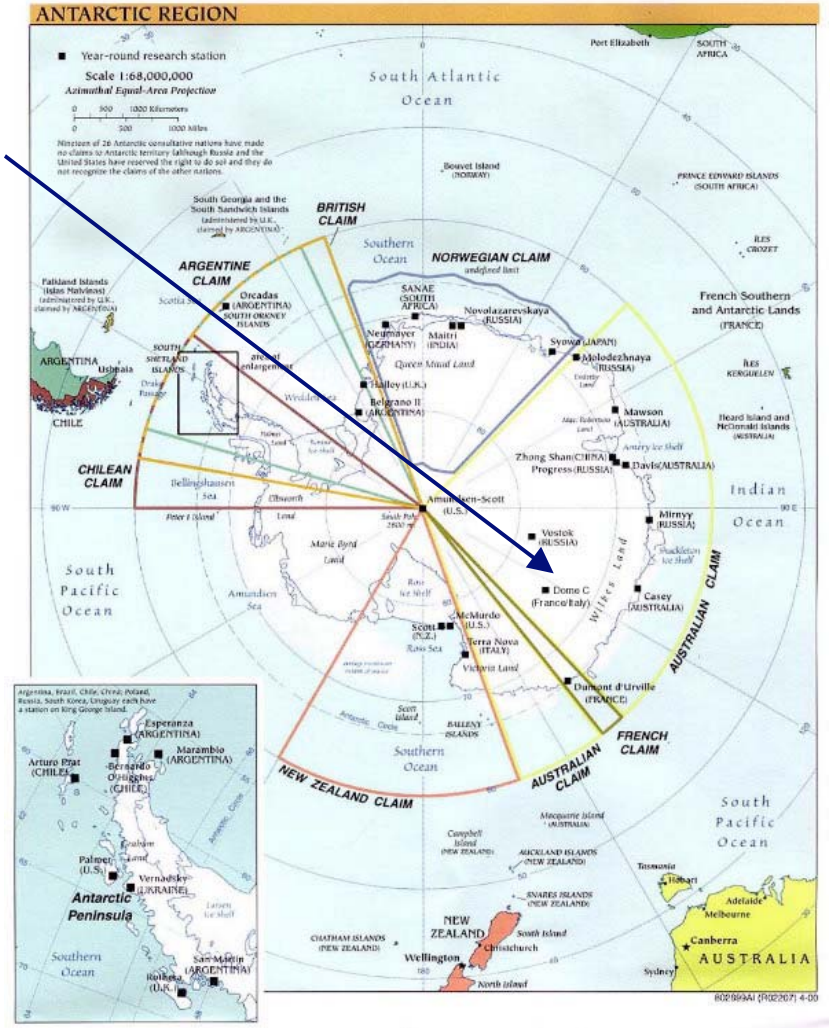
Dome C

- Concordia Station, located on Dome C, is run jointly by France and Italy.
- During the summer there are about 40 to 50 people on station.
- During winter ~ 13 people on station

Photo courtesy Stephen Hudson, Univ. of Washington



Altitude 3250 m, 10,600 feet
Max Temp -18°C on summer afternoons

Dome-C Intercomparisons

- IVOS activity to perform inter-agency comparison of reflectance data over Dome-C
  - ESA (RAL) – AATSR/ATSR-2/MERIS
  - CNES – VGT1, VGT2, Parasol, SPOT
  - NASA - MODIS

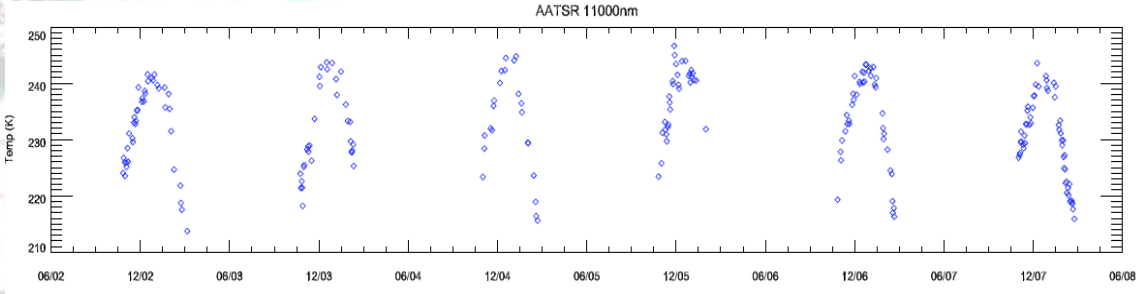
- 4 regions over Dome-C site used for comparisons

Site	Latitude	Longitude
Dome 1	-78.5933	120.2648
Dome 2	-75.7431	113.7356
Dome C	-75.1017	123.3950
Dome 3	-77.3825	128.715

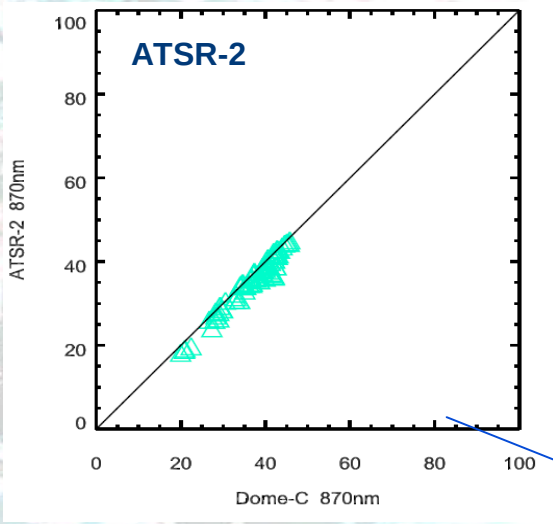
  - Sites are 100km x 100km large centered on the above lat-long coordinates.

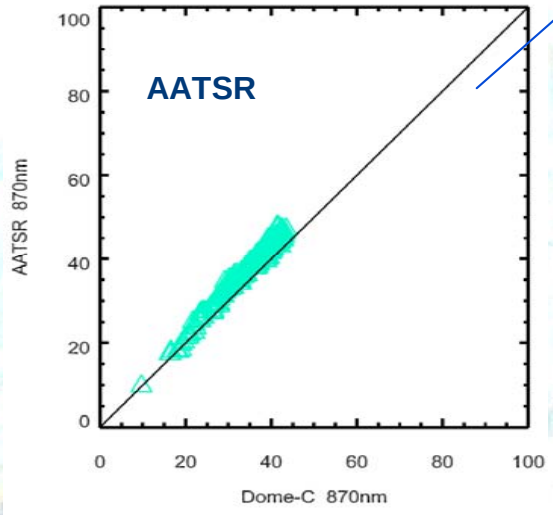
- BRDF measurements of Stephen Hudson et al to be used as reference

- Dome-C also used for low temperature calibration of MODIS TIR channels
  - Comparisons possible for 11um and 12um channel
  - Provides check of non-linearity calibration



Dome-C Multi Sensor Comparisons





Using ground measurements of Hudson et al enables multi sensor comparisons to be made independently of overpass times

Example at 0.87µm

- Less sensitive to Rayleigh or Ozone

R_{Inst}/R_{BRDF} (0.87µm)

ATSR-2 = 0.961

AATSR = 1.103

MERIS = 1.031

MODIS = 1.017

R_{AATSR}/R_{INST} (0.87µm) {2006 result}

ATSR-2 = 1.148 {1.14}

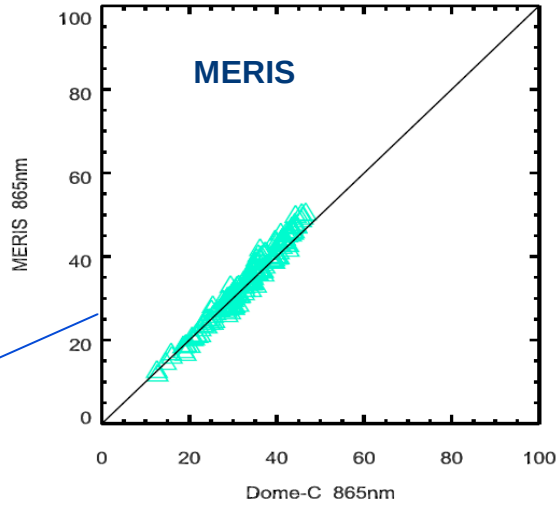
MERIS = 1.070 {1.035}

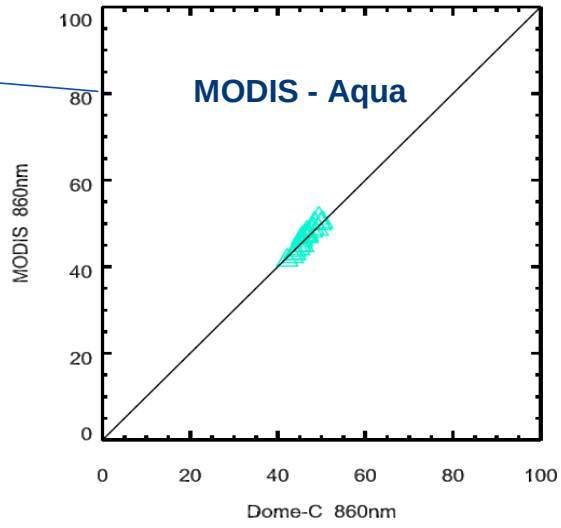
MODIS = 1.085 {1.08}

Desert

I.e. results are consistent with early mission results.

Results are preliminary!





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Update on the activities of the
Radiation transfer Model Intercomparison
(RAMI)

J-L. Widlowski

CEOS, WGCV, 29th meeting, Sep. 30th – Oct. 3rd, 2008, Avignon, France

Institute for Environment and Sustainability

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RAdiative transfer Model Intercomparison

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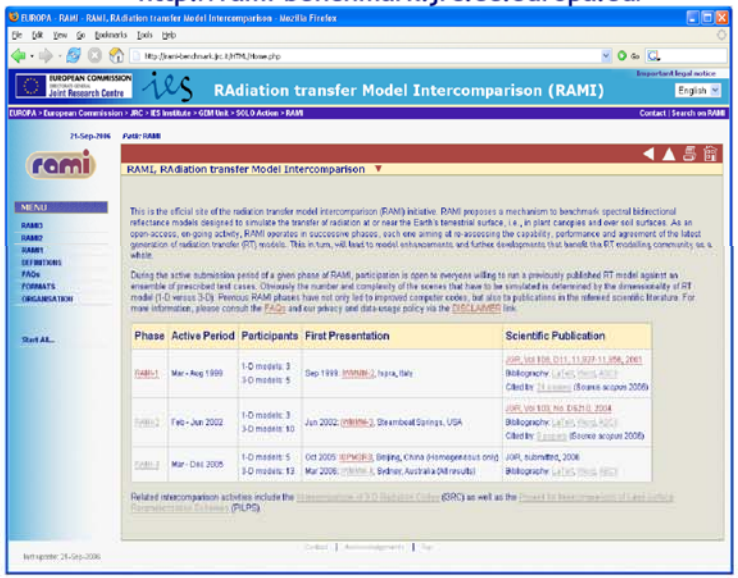
Purpose of RAMI:

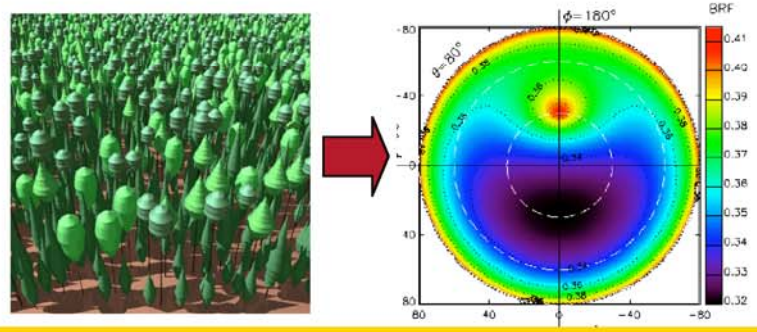
- to act as common platform for intercomparison efforts of canopy reflectance models,
- to document uncertainties and errors among models,
- to establish protocols for the evaluation of RT models,
- to foster scientific debate.

Organisation of RAMI:

- coordinated by EC - JRC
- steering committee (RAB)
- participation is open to all
- peer-reviewed publications
- held at triennial intervals

http://rami-benchmark.jrc.ec.europa.eu/





models evaluated in direct mode

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RAMI evolution

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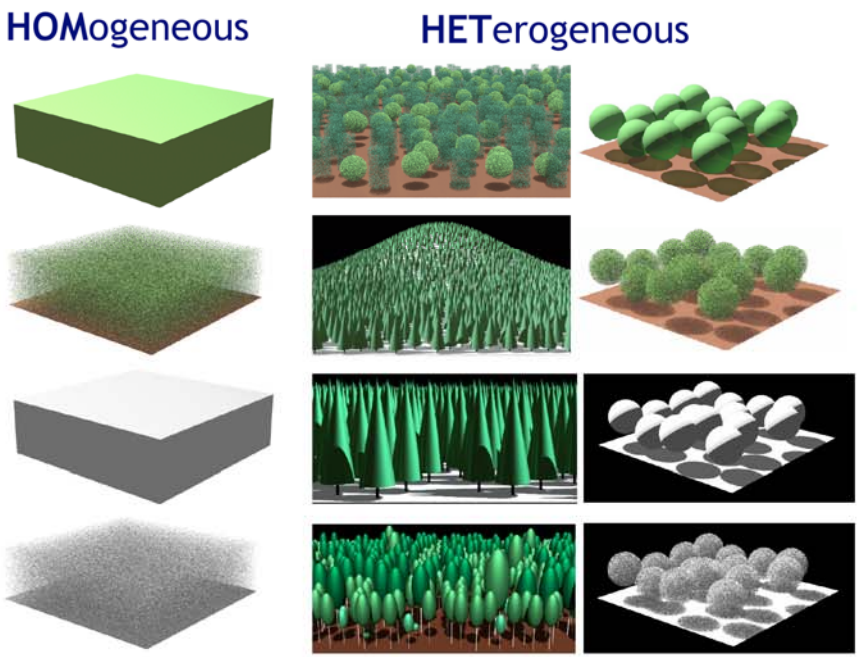
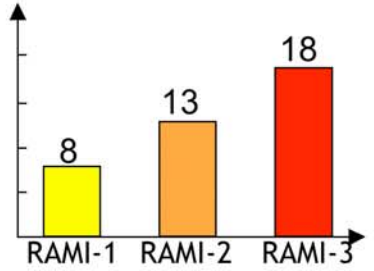
- **RAMI-1** (1999):
  - Very simple 1D + 3D test cases
  - Large scatter between models
- **RAMI-2** (2002):
  - Augment structural complexity
  - still differences for 3D models
- **RAMI-3** (2005):
  - More complex measurements
  - 3D models agree much better

Generate **reference data** set from simulations of six 3D MC models that agree within ~1%

- **ROMC** (2007):
  - Rami Online Model Checker
  - real time evaluation via internet





Pinty et al., 2001 (JGR); Pinty et al., 2004 (JGR); Widlowski et al., 2007 (JGR); Widlowski et al., 2008 (RSE);

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Ongoing activities: RAMI4PILPS

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RAMI4PILPS aims to assess the accuracy of RT formulations used in land surface schemes of NWPMs, SVATs & GCMs

- uses RAMI-3 reference MC model simulations as 'surrogate truth'
- offers 2 evaluation modes (with/without assimilation of albedo)

1-D CANOPIES		3-D CANOPIES	
grasslands	closed forest canopies	shrublands	open forest canopies
			
Given detailed 1-D canopy descriptions, what are the values of the three fluxes R, A, and T?		Given detailed 3-D canopy descriptions and R how is the remaining energy split between A and T?	

- provides 3 direct and 1 diffuse illumination case
- assesses 2 spectral regimes and 3 soil brightness conditions

RAMI4PILPS participation: May 2008 - March 2009

http://rami-benchmark.jrc.ec.europa.eu/HTML/RAMI4PILPS/RAMI4PILPS.php

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Upcoming activities: RAMI-IV

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RAMI-IV strategy:

- Increase the realism of canopy architectures, illumination conditions and measurements
- Participants shall treat available information as 'inventory data' and extract whatever parameters are needed to run their models

New set of scenes (not yet finalised):

- forest stands (deciduous and coniferous)
- agricultural crops (row effects)
- advanced 1D scenarios (non-Lambertian)

Additional measurements (not yet finalised):

- directional gap probabilities (fisheye camera)
- LIDAR return signals

RAMI-IV is anticipated to start 12/2008 or 01/2009

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CEOS "Reference Standards" IVOS

Comparison to (or with) provides quantitative evidence of traceability

KEY CHARACTERISTICS

- **Well defined (fit for purpose) to suit application, with documented traceable knowledge of key characteristics**
- **Used with an agreed method**
- **Where appropriate traceable to SI**
- **Can in principle be "intrinsic" in nature (as part of the method) e.g. Rayleigh scattering**
- **Can provide cal/val information directly or facilitate transfer**
- **Internationally agreed**
- **Evidence of stability for typical duration of use (for application)**
- **Does not have to be an artifact**

Test sites as “reference standards”

- **Relatively large number being used by agencies, some commonality**
- **Radiometrically usually used for Verification of performance or as transfer medium as uncertainty too large for calibration**
- **Key role - need to improve performance and consistency of use – “prioritise” some sites (different for characteristics, sensor type, resolution etc**
- **<u>IVOS definition</u>: test sites must be geographically fixed - includes distributed components e.g. moored buoys, “networks” (e.g. fixed aeronet)**
- **Need to identify characteristics of sensors/data products that can be evaluated using a “test site” → leading to requirements on the test site → → identify potential sites → classify → CEOS Endorse → ALL Agencies view**

•BIG TASK!

- **Focus efforts on a key priority to start:**

Land Surface Imager constellation – Radiometric Gain (med to high resolution sensors)

(*uniformity, Linearity and stability*)

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Optical sensor characteristics benefiting from a “test site”

- Gain
- Linearity
- Stability
- MTF
- Uniformity (Flat field)
- Stray light (Adjacency effects)
- Polarization
- Spectral
- SNR
- Algorithms
- Geo location
- Camera model
- Band-to-band

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Site classification

TEMPLATE for Site Information now undertaken as part of ESA study via portal

- **Purpose/application**
- **Location/contacts etc**
- **Description**

  E.g Terrain type
- **Imagery**

  photos, satellite
- **Status**

  instrumented, visited, funding …
- **Meteorological constraints**
- **Data policies (ground and satellite)**
- **Surface characteristics and "traceability"**
- **Historical useage**

REQUIRE minimum 10 CORE SITES for Radiometric gain

Discriminatory information to be reviewed following ESA study

- **spatial uniformity of reflectance**
- **Value of reflectance**
- **Accessibility**
- **Data policy**
- **Level of Instrumentation**
- **Cloud free days**

IVOS decision: must be maintained and instrumented

8 sites meet criteria: "LANDNET" others to be encouraged following additional criteria selection

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Actions

- **Identify sites and associated key characteristics for all tasks**

- **Establish and agree classification criteria for core sites (“best” standards)**

ESA Study to support with USGS and IVOS team

- **Encourage agencies to view and provide data to cal/val community over core sites starting with radiometric gain and stability as an immediate priority**

- **Link USGS catalogue to CEOS/GEO cal/val portal**

- **Establish optimum instrumentation specification for core sites**

- **Establish “best practise” guidance on site characterisation and its use**

- **Establish “Governance” principles**

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Recommendations

Recommendation 1.

Recognising the existence of biases between sensors, and the need to combine data sets from different sensors for operational and long term studies it is critical that any (normalisation to a designated “reference sensor) is fully documented and transparent. Since often the cause for bias differences is unknown it is recommended that a non-normalised data set is also maintained and archived as well as any bias-removed data.

Recommendation 2

In defining new missions, agencies are encouraged to ensure that the requirement (and ability where practicable) to cross-compare with existing similar sensors (e.g. common channels) is built into the commissioning programme of the sensor. In particular where two nominally similar sensors are being built for simultaneous flight (similar orbits differing phase) it is important to ensure that a requirement is established to ensure commonality of performance between them.

Recommendation 3

When application specific task groups of experts are established for cal/val e.g. the recently formed group for SST validation, they are encouraged to take advantage of the infrastructure of CEOS WGCV to provide a framework to promote their activities and ensure that maximum benefit can be obtained for the community as a whole through the sharing and use of best practises in terms of QA.

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Recommendation 4.

Recognise that regular comparison of instrumentation and methodologies is an essential component of any data quality strategy, providing evidence of maintained traceability. This requirement includes the key instrumentation and associated methods used to validate/calibrate performance of sensors through ground based measurements. In particular, it is noted that it is timely to repeat the highly successful comparison of IR radiometers used for SST measurements (Miami) and also to initiate a similar comparison for Land based spectroradiometers.
Such comparisons will require commitment from agencies to support participation and also to sponsor the organisation and necessary infrastructure.

- **Actions**
  - IVOS has established two working groups with coordination from NPL (Land and Ocean) to establish appropriate protocols, plans and cost for such comparisons. The location for the Ocean comparison is to be Miami, whereas the Land comparison is baselined to take place at the new "core site" in Turkey.
- - Potential sponsor agencies are sought to support the above planning and subsequent comparisons to complement that of ESA
- - Ocean to occur in spring 2009, and Land, Summer 2010 with pilot activities in 08/09.

Status

CEOS SIT action, invite sent on SST and also request for agency funding

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Recommendation 5

Recognising the need to establish international accepted Reference standards where necessary to facilitate interoperability between agencies and missions by ensuring that biases and sensor performance and dependent data products can be assessed in a consistent manner, CEOS WGCV proposes that the following (together with an associated operational best practice) are adopted as international reference standards for their associated characteristics and subsequently used by agencies. The Moon and "CEOS standard Desserts" as reference standards for radiometric gain stability and the "CEOS Landnet test sites" for gain assessment on Land imagers.

- **ACTIONS**

  CEOS IVOS to provide coordinates of LandNet sites on cal/val portal
- CEOS IVOS to provide operational guidance for use of the reference standards
- CEOS IVOS to provide defining characteristics of the associated standards on the cal/val portal
- Agencies to encourage the viewing of such sites in existing and future missions.
- Agencies to ensure resources are made available to maintain and develop such standards and to encourage the development of others to complement the existing LandNet sites to ensure adequacy in number and geographical distribution.

STATUS:

Formally establish these as list items to CEOS and turn recommendation into request to be used and viewed and sites to be maintained.

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Recommendation 6:

To allow data products from an optical sensor to be ascribed an appropriate quality indicator, CEOS WGCV recommends that agencies evaluate and make accessible to the Cal/val community, the results of assessments based on CEOS endorsed best practises. For optical imagers this would require sensor performance to be evaluated through an endorsed method. Currently for radiometric gain these are: the use of a core test site, Rayleigh scattering, cloud, sun-glint, Moon.

It further recommends that as a minimum this should include cross-comparison with other appropriate sensors using a CEOS endorsed method e.g. SNO, the moon, reference test site utilising where appropriate an endorsed reference standard.

Actions:

- IVOS to make available endorsed guidelines through GEO/CEOS cal/val portal
- Agencies to support the preparation and distribution of such guidelines based on existing best practises
- Agencies to encourage the use and publication of results following use of these guidelines

STATUS: This is implementation of QA4EO can highlight as an example or incorporate within another more generic item

Recommendation 7

To ensure that current, historical and future data sets can be seamlessly linked requires an accurate evaluation of uncertainty traceably referenced to an internationally agreed standard. Whilst the infrastructure to allow full (on demand" assessment of performance of sensors and derived data products is established it is essential that a means to cross-compare is established and maintained. This is particularly critical where temporal gaps in data records may occur due to operational constraints. It is thus recommended that agencies are encouraged to establish and make available to the CEOS Cal/Val community regular observations of the full set of appropriate CEOS reference standards e.g core test sites, invariant deserts, Moon.

In particular, it recommends that agencies carry out a detailed cross-comparison exercise using one of these targets, DOME C during the winter of 08/09 using the CEOS endorsed guidelines.

Actions

- IVOS to publish list of invariant standards and methods for their use on Portal
- Agencies to incorporate within acquisitions schedules regular observations of CEOS reference standards
- IVOS to establish protocol for comparison of optical imagers over Dome C
- Agencies to plan to take observations and make available results over DOME C according to guidelines of CEOS IVOS in winter 08/09

Recommendation 8

Recognising the criticality of post-launch calibration/performance verification for the delivery of QA data products for both operational and scientific missions it is essential that agencies seek to ensure that such support activities e.g. core test sites and their associated traceability and developmental needs are established and maintained in a coordinated way for the good of the EO community. In particular when considering operational activities and long term studies (e.g climate change) which require datasets beyond the life of any single mission, it is essential that such Cal/Val activities are supported in a manner that ensures their continued operation beyond the life of any single mission.

Action

- **CEOS WGCV to identify key activities and associated costs**

  CEOS agencies consider ways to coordinate/share resource in an equitable manner for the good of GEOSS.

Status: This is arguably implementation of QA4EO

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