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

Report to CEOS WGCV 34

Chair: Nigel Fox
National Physical Laboratory
UK

with support from UKSA

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.
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.

Operational Structure Modified after IVOS 23 (April 11) see work plan

- **Agency reports to be encouraged but not presented except in exceptional circumstances or if a new member.**
- **Detailed Technical theme each meeting (0.5 – 1 day)**
- **Community technical workshops ~ tri-annual**
- **Theme Champions**

Sector themes:

- Land (reflectance) – Chander USGS
- Ocean (reflectance) colour – Zibordi JRC
- Surface temperature – Corlett Uof Leic

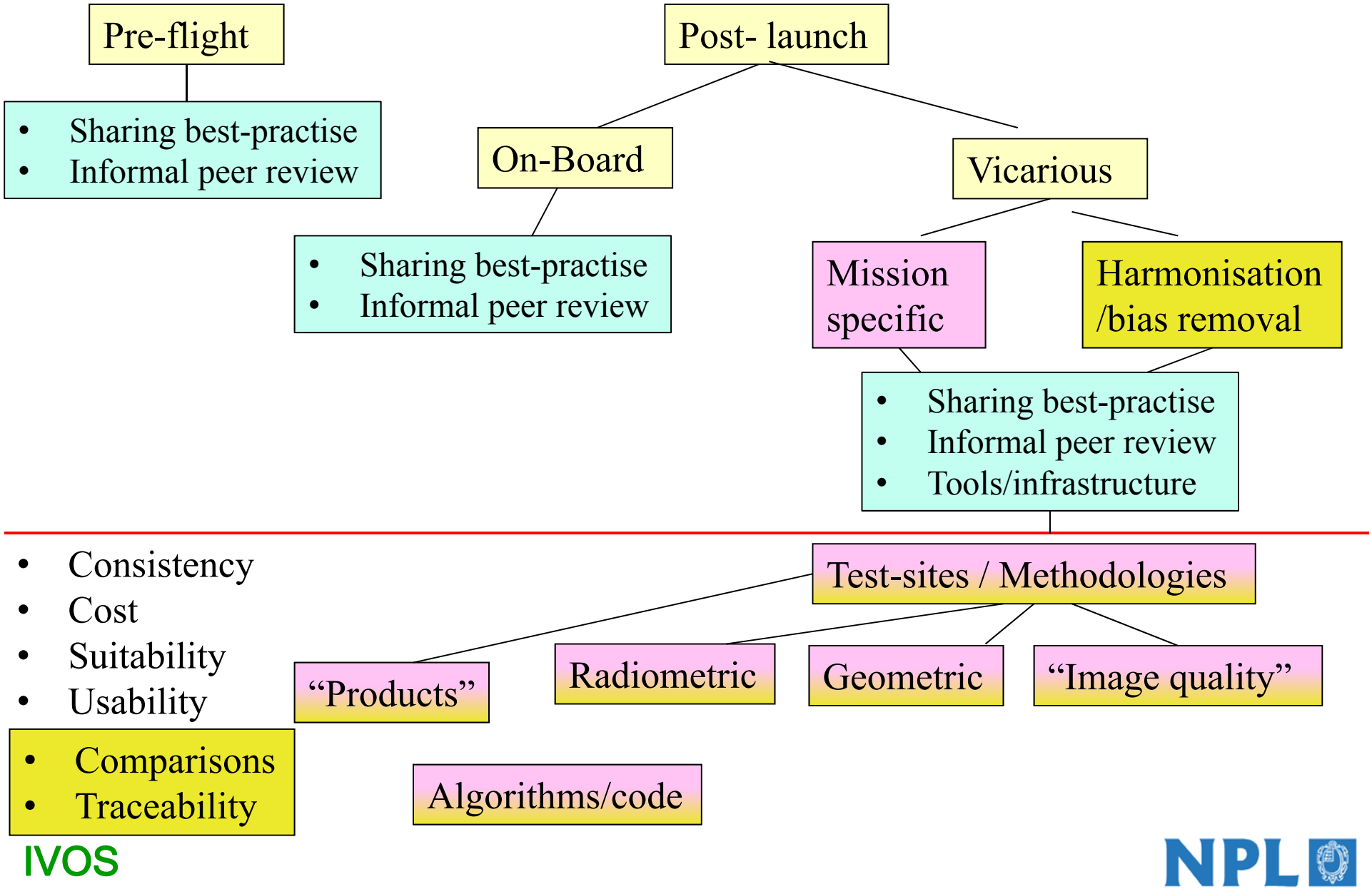
Also more general activities at plenary
e.g. sensor pre-flight calibration

Cross-cutting

- Atmospheric corn – Thome NASA
- Geo/Spatial Quality – Helder UofSD
- Geometric image Quality – TBD
- Sensor to Sensor biases – Fox NPL
- RT code – Widlowski JRC
- Communication/portal – Goryl ESA

- **IVOS as Conduit for existing "community expert groups" - Need to increase engagement**
- **Serving Cal/val needs of constellations - e.g. org of comparison, interface to CEOS**

Work plan for optical sensors: (land/ocean)



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CEOS IVOS 23

Apr 13-15 2011, Toulouse, France

Hosts: Patrice Henry CNES

Attendees ~ 45

Pre- meeting (Apr 11-12) hosted by ONERA to discuss results of Tuz Golu comparison ~ 16 invited attendees

IVOS workshop

Oct 18-20, Ispra, Italy

Hosts: Giuseppe Zibordi JRC

Attendees ~ 70

How to evaluate performance and bias post-launch Solar reflective domain (Land and Ocean)

Special session on "geometric/image" quality

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No sub-group meeting since last report.

- **Held workshop at JRC, Oct 2010 ~ 70 attendees**
  - **Major outcomes now being followed through**
- **Held IVOS 23 at CNES, Apr 2011 ~ 45 attendees**
- **Held focus group on Results of Tuz Golu, Apr 2011 ~ 16 attendees**
- **Results of comparisons – Dome-c, Tuz Golu, OC pilot**
- **Started two new thematic technical areas**
- **Initiated new set of new task groups and actions leading to best practises on vicarious cal and prototype operational cal service in collaboration with GSICS**
  - **Some task (Working) groups initiated activities and making excellent progress**
    - **Methods for comparing medium res sensors using ground sites (not using ground site derived valued)**

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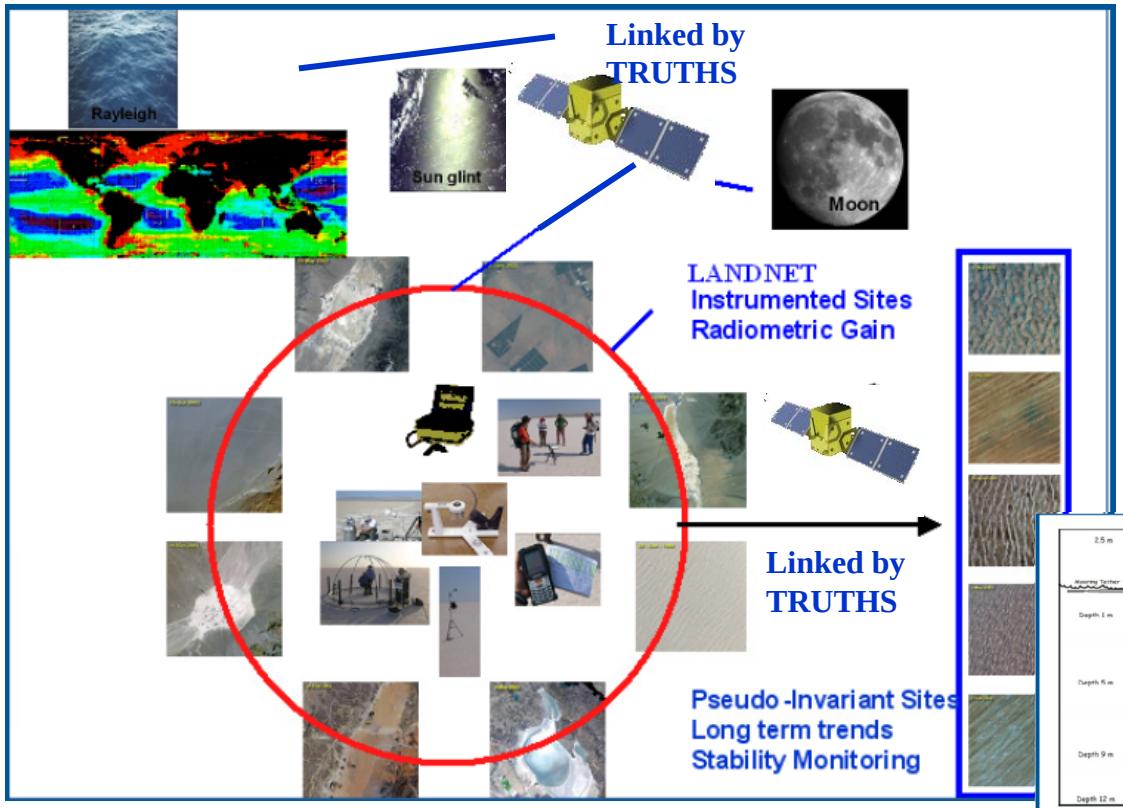
- Next meeting:
  - USGS Sioux Falls May 8 to 10 2012
  - Visit to University of South Dakota

  - Agenda to be defined but will include:
    - Review of progress on vicarious intercalibration working group activities
    - Best practises on ground based instrumented test sites characterisation and requirements
    - Plans for workshop on sensor pre- and in- flight calibration/characterisation
    - Progress on Atmos correction comparison/best practises
    - Work plan and strategy for international coordination of post-launch cal/val

Post launch cal val

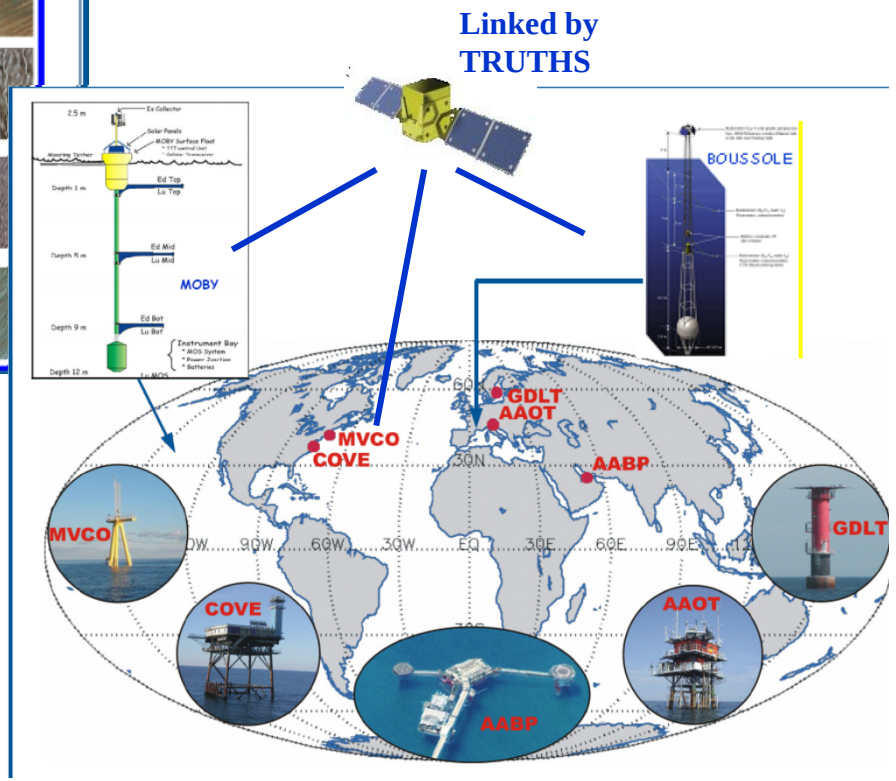
Vision: Operational calibration service through "CEOS standard" sites/methodologies



Networks of test sites and methodologies can become operational calibration service

improved through use of reference standard SI traceable sensor e.g. TRUTHS/CLARREO

(Part of Climate architecture doc)



CEOS endorsed test sites for Land and Ocean can be used as standards to cross-compare between sensors and to ground data providing each site is compared to each other

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CEOS WGCV IVOS workshop: To identify, quantify and verify the post-launch performance and relative biases of Earth Observation sensors

Hosted by:

Joint Research Centre (JRC), Ispra, Italy

October 18 – 20, 2010

OBJECTIVES

- To carry out a detailed review of the results of sensor-to-sensor comparisons with emphasis on the outcome of the recent CEOS land based intercomparison/intercalibration exercises carried out using Dome C and Tuz-Golu but also others as appropriate.
  - To agree upon the relative biases in radiometric gain, between in-flight sensors and publish as CEOS endorsed values (bias correction factors).
  - To agree on optimum procedures/strategy to ensure long-term stability of sensor performance characteristics and their relationship with observations of other sensors: past, present and future.

To review existing and conceptual limitations to the uncertainty achievable in the post-launch calibration/validation of sensors through use of vicarious methods (solar reflective), and to identify priorities for the research efforts of the community.

IVOS - Land and Ocean

http://calvalportal.ceos.org/cvp/web/guest

Understanding sensor biases

Sensor Interoperability, long-term data sets, operational services, "user confidence" require:

- **Unequivocal knowledge of biases between sensor L2 and L1 products.**
- **Can only be obtained by comparison (to another sensor) / accurate robust calibration (I.e. comparison to a reference (standard/methodology) of "known" value.**
  - **SNO, desert site (SADE), Instrumented test-site, Rayleigh scattering, Moon….**
- **Many comparisons have and continue to take place**
  - **Bi-laterals, Multi-satellite, dedicated campaigns, in-direct.**
- **Results can vary depending on nature of site/conditions/analysis etc**
- **SADE provides collation of results for a sub-set of sensors and comparison types.**
- **GSICS also**
- **Need to do for all sensors in transparent and internationally agreed manner, making use of all available information**
  - **Prototype for future optimised system.**
- **First step: Start collation of comparison results and review state-of-the-art and baseline analysis issues.**
  - **Taking account of some level of QA in data**

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Comparisons: Cross-comparison data base workshop Action A2

- Establish fully sort-able database for sensor comparisons (based on any declared method) with any reference standard (site, sensor, “method” etc)
    - Some baseline QA criteria in terms of data population.
- Access to data open to all CEOS but no publication without agreement
- WG to be established to define and agree method of analysis of all data
    - bandwidths, uncertainties (weightings from methods), outliers …
    - Chaired by IVOS chair with Chairs of methodology WGs and few others
- Populate data base with summary of all comparisons for all sensors
- Carry out analysis
- Excel pro-forma on cal/val portal
    - database being constructed
    - CalVal Home - CalValPortal

Intercomparison Summary Proforma

Participating Institution:	RAL Space
Date of Analysis:	13-Oct-10
Type of Comparison: SNO, Rayleigh, DCC, Moon, Direct Surface Measured Test site	SNO
Site Indentifier:	Dome-1
Site Latitude:	-78.5933
Site Longitude:	120.2648
Procedure Reference:	
Sensor Being Compared	AATSR
Sensor L1b Processing Version	AATSR/6.01
Reference sensor:	MERIS
Reference Sensor Processing Version:	
For other reference (origin of comparison values)	
Nominal at sensor solar irradiance	
Special Characteristic of Comparison (e.g. non nadir)	
Date Range of Measurement	02-Nov-08 16-Feb-10
Comparison Sensor/Reference	AATSR/MERIS

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Band Name	Sensor Under Test		Sensor Secondary Band		Reference TOA Reflectance Factor		Ration Sensor/Reference		N. of Samples	Measurement Uncertainties	
	Nominal Band Centre (nm)	Nominal Bandwidth (nm)	Secondary Band Centre for band to band comp (nm)	Nominal Bandwidth of secondary band (nm)	Mean	Std Dev	Mean	Std Dev		Type A (Statistical Random)	Type B (non-statistical)
V555	555	20			25.4177	8.3181	1.0276	0.0072	42	0.001110984	
V659	659	20			26.7018	8.3104	1.0192	0.0075	42	0.001157275	
V870	870	20			25.9726	7.6947	1.0258	0.0077	42	0.001188136	

Additional Information

AATSR Drift Corrections Applied
Filtered For
VZA <5 degrees
SZA<80 degrees
SAZ<90 degrees
Time Coincidence <1 day
No Ozone Correction Applied
Atmospheric code used (if appropriate)

Proposed Actions

- **Submit / collate sensor comparison data for last 5 (10) years.**
  - **Via spreadsheet**
  - **Direct entry on to database when available**
  - **Via submitting reference for extraction**
  - **Summary from other system e.g. SADE**
  - **Need info on procedure used as QA**
- **First screening analysis**
  - **Ensure consistency or normalisation according to processing/gain settings etc**
  - **Identify and if possible quantify anomalies on "reference values" and uncertainties**
  - **Establish linkages and indirect sensor to sensor comparisons**
  - **Sensor to sensor bias variation by site/method**
- **Working group Submit / collate sensor comparison data for last 5 (10) years.**
  - **Consider detailed analysis strategy e.g. bandwidth corrections, Pixel variances etc**
  - **Review and agree weightings for methods (based on other WGs) and any corrections needed**
  - **Re-analyse and publish as "CEOS agreed" values**
- **Update data base and any necessary pre-screening requirements.**

Vicarious calibration methodologies WGs: Work shop Action A1

Several methodologies proposed and demonstrated to facilitate "vicarious" Cal/Val of optical sensors

- "Absolute" to a defined reference (intrinsic or empirical/measured basis)
- Facilitate cross-comparison
- Suggested all could achieve ~1 % uncertainty level
- Likely different methodologies optimum for different applications
  - Radiometric gain
  - Relative Band to band
  - Stability
  - Pixel size, spectral range etc
- Share best practise/knowledge to help all agencies and towards framework of interoperability and "consensus bias evaluation/removal"
- Need to have some commonality in tools:

European Space Agency

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ViCaSEOOS

Long term objective of ViCaSEOOS:

Create a vicarious calibration system for GEOSS

We should start focused:

a) EO optical sensors and medium resolution sensors
b) Only aim at:

- Agreeing upon and documenting standard vicarious calibration methodologies restricting to those exploiting terrestrial sites observations and that do NOT require in-situ data
- Defining a data format to exchange data over these sites
- Defining the overall architecture of ViCaSEOOS ('roadmap')

ViCaSEOOS: Activities to achieve

- **Establish international community project:** Desire to achieve interoperability
  - Define clear goals/objectives (manageable and achievable)
  - Use existing experts/activities to lead and build consensus
  - CEOS and GSICS joint activity
  - Establish Working Groups
- **Facilitate data exchange:** agree on a common data format for EO data over vicarious calibration sites
  - Minimal set of meta-data and "definitions"
  - "Easy" accessible Format convertors
- **Apply common methodologies:** agree on a set of 'standard' methodologies
  - In-terms of principles of operation (not necessarily implementation)
  - Well-documented and transparent access to uncertainties
  - Ideally distributable in implemented form
- **Produce standardized results:** have a common web platform to post the results of the vicarious calibration methodologies
  - Agree on approach to cross-compare

WGs on methodology and data format

- **WG1:** **Use of Deep Convective Cloud**
  Lead: D Doelling (NASA)
  Participant:

  Call for participants & leads still open……

- **WG2:** **Rayleigh Scattering**
  Lead: P Henry (CNES)
  Participant: M Bouvet (ESA)* , L Bourg (ACRI)

  CNES & VITO others?

- **WG3:** **Sun Glint**
  Lead:
  Participant: S Lavender (ARGANS)

- **WG4:** **Use of fixed ground sites e.g. SADE, DIMITRI, Landnet, invariant desert sites (but not requiring ground measured data)**
  Lead: X Briottet
  Participant: D Smith (RAL), P Henry (CNES), M Bouvet (ESA)*, L Bourg (ACRI)

- **WG5:** **Simultaneous Nadir Observation**
  Lead:
  Participant: S Kumar (ISRO), S Saunier (Mag)

WORKING GROUPS NEED INPUT FROM OTHER AGENCIES TO ENSURE HARMONISATION AND BEST PRACTISE/EXPERTISE

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Proposed WG Terms of Reference

- Write a consensus **documented procedure/protocol** describing how to carry out comparisons using the particular methodology **with a view to CEOS endorsement** at level of a "detailed processing model";

- Document should **follow guidance in QA4EO** guideline …DQK-002 i.e.
  - Include detail on how to carry out
  - Any input parameters
  - Principles of any algorithm / model / (established software)
  - Sources of uncertainty and how to evaluate
  - How to establish evidence that process has been implemented consistently.
  - Define scope of applicability and likely uncertainties for range of situations.
  - ➢ Allow someone of reasonable knowledge in the field to be able to implement (might require writing own software/include different algorithms but should ensure *consistent use of key variables and processes* or ability to demonstrate differences);

- Evaluate applicability of method through at least one implementation using **test-data sets**, where possible the same data sets should be used by all methodologies;

- Consider **results from existing comparisons** using methodology (from Action A2) for community discussion.

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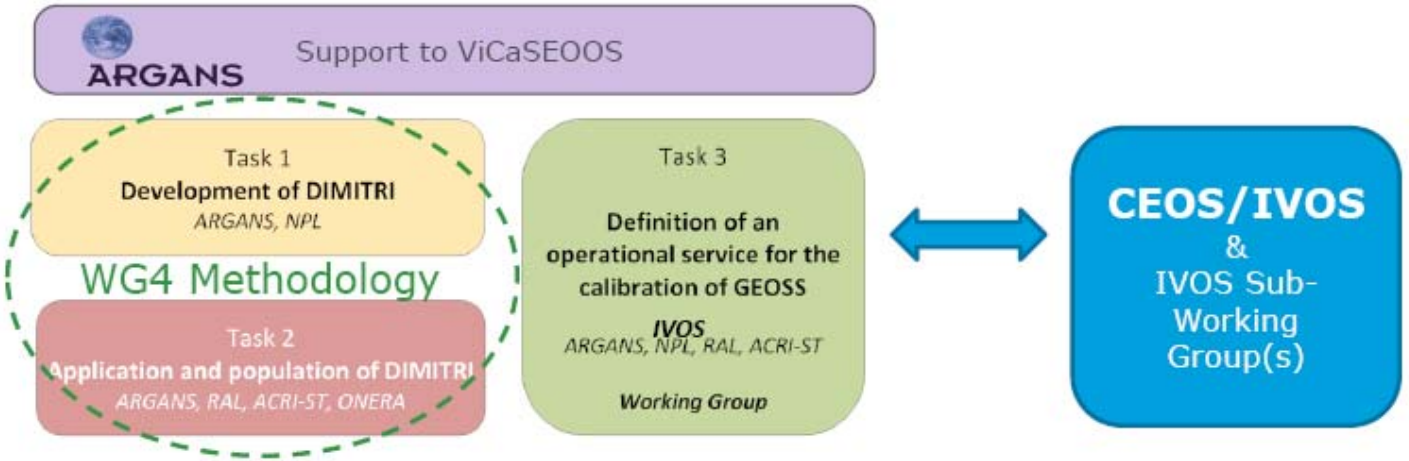
ESA contribution



Contribution to ViCaSEOOS:

via CEOS/IVOS collaboration and WG support

e.g. intercomparisons/analyses as decided between the WGs…
ARGANS, ACRI, RAL, NPL.

CEOS IVOS Working Group 4: Fixed Sites

Methodology intercomparison initial results summary

Chair: Xavier Briottet

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CEOS/IVOS WG4 (Use of Fixed Sites) Intercomparisons

❖ A reference dataset will be produced by ARGANS and CNES consisting of extractions in the CNES SADE format, from 3 sites, 5 sensors and over 4 consecutive years.

❖ The common reference dataset will consist of TOA reflectances averaged over a region of interest. The reference dataset will consist of cloud screened data.

❖ No further cloud screening should to be applied by participants to focus the comparisons on the core of the methodologies rather than the cloud screening approach.

❖ Each participant will systematically apply their method to the reference dataset and produce a set of standardised results.

Libya 4 Niger 2 Dome-C	Polder-3 AATSR MERIS VGT 2 MODIS-A	2006 2007 2008 2009	**ACRI/RAL/ONERA/ESA:** DIMITRI **CNES:** SADE (Desert methodology) **RAL:** Drift Monitoring. **VITO:** RTM simulation over Deserts

Aim

Reference sensor(s)

- MERIS to be the reference sensor.
- Keep in mind the 1.6micron band → AATSR could also be a reference (MODIS-A saturates and is unusable).

Who to focus on which sensors

- **DIMITRI:** **VGT:** ONERA
  MERIS, Polder, MODIS-A, AATSR: ACRI-ST to lead, RAL to support.
- **CNES:** All sensors
- **RAL:** All sensors
- **VITO:** All sensors

Minimum bandset for analysis

560nm, 670nm, 865nm, 1.6mic.

DIMITRI: Intercomparison Methodology

❖DIMITRI contains a suite of IDL routines for the intercomparison of Top Of Atmosphere (TOA) radiance and reflectance values within the 400nm - 4μm wavelength range.

❖Allows angular and temporal matching of concomitant satellite observations from different sensors over fixed validation sites; assumes the TOA reflectance angular distribution 1) obeys the principle of reciprocity and 2) is symmetrical with respect to the principal plane

❖Includes automated and visual cloud screening

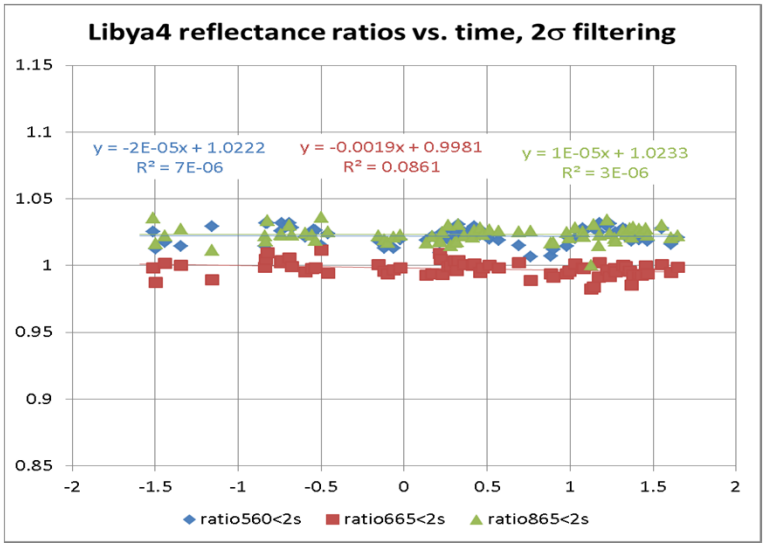
❖Allows user selection on strictness of angular match, ROI coverage, temporal offset, and absolute geometry criteria between observations.

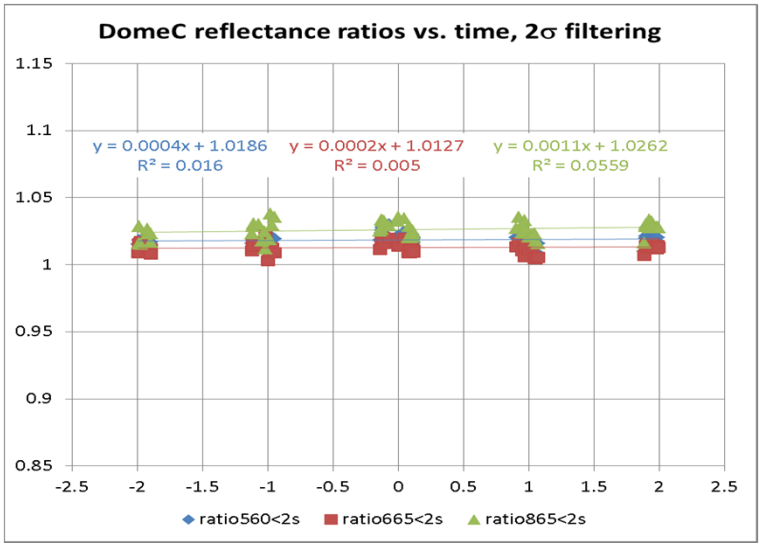
DIMITRI: ACRI results

AATSR vs. MERIS: DomeC and Libya4:

		mean	std	N
560	Libya4	1.0221	0.0063	69
	DomeC	1.0188	0.0045	68
665	Libya4	0.9973	0.0056	69
	DomeC	1.0128	0.0041	68
865	Libya4	1.0233	0.0058	69
	DomeC	1.0265	0.0057	67

- Pretty good match (<2.5%)
- Cross-site consistency (except 665)
- No time drifts (<0.2%/year)
- Low dispersion (<0.5%)





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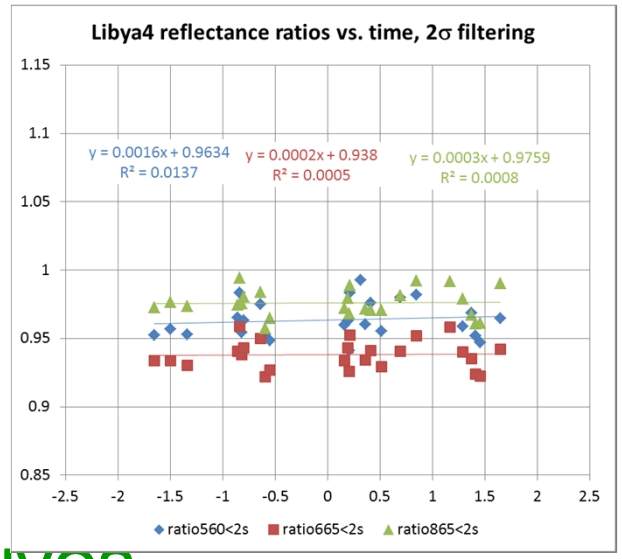
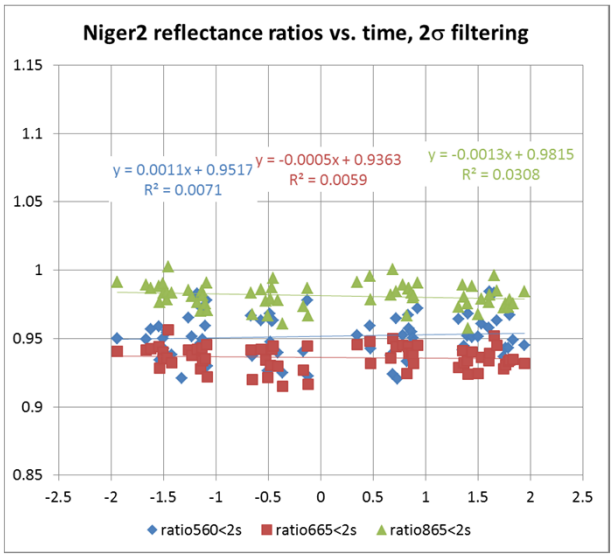
DIMITRI: ACRI results

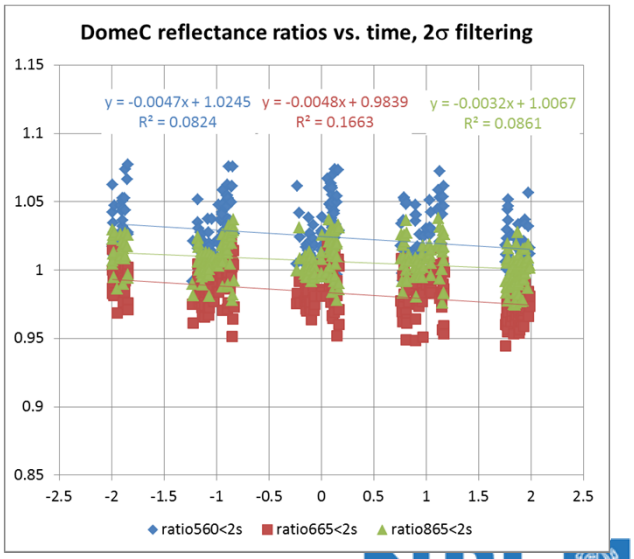
MODIS-A vs MERIS : Libya4 and Niger2:

		mean	std	N
560	Libya4	0.9635	0.0134	25
	Niger2	0.9517	0.0153	68
	DomeC	1.0230	0.0206	333
665	Libya4	0.9380	0.0105	25
	Niger2	0.9362	0.0085	66
	DomeC	0.9825	0.0146	339
865	Libya4	0.9759	0.0103	25
	Niger2	0.9814	0.0090	66
	DomeC	1.0056	0.0137	339

- Significant discrepancies (5%)
- Significant dispersion (1-2%)
- Cross-site inconsistencies
- Visible time drifts at DomeC (0.5%/year)

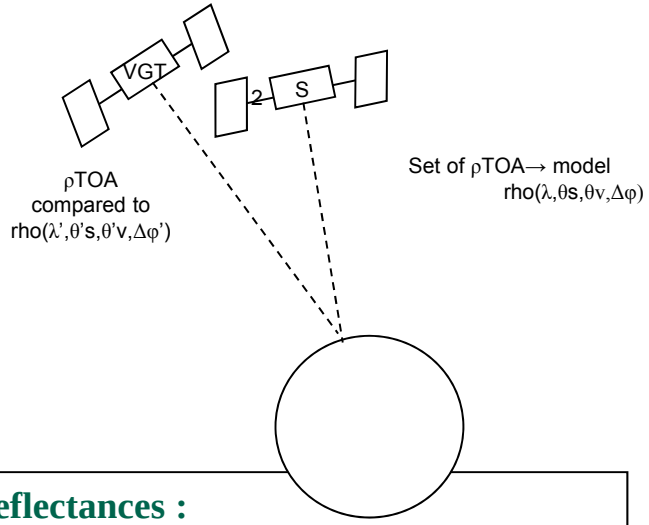






DIMITRI: Simulation Methodology

Radiometric comparison of VGT2 with a super sensor :
Comparison of simulated reflectances with actual VGT2 reflectances



Creating the super sensor :

- Identify sensors providing a good description of the site from the spectral and directional point of view
- Compute TOA reflectance for the sensors
- Choose a sensor as reference and identify doublets of observations between the reference sensor and each sensor
- Fit polynomials to the differences over the doublets
- Recalibrate sensors to the reference thanks to polynomials

Simulating the VGT-2 reflectances :

- Fit a BRDF model to all observations of super sensor for a bin of x days
- Use BRDF model to compute TOA reflectances in the geometries of sensor to simulate
- Extend the computation to all spectral bands of reference sensor thanks to multiplicative ratio <rho_λ/rho_ λref> applied to 1st coef of BRDF model
- Correct TOA reflectance for gaseous absorption
- Interpolate to compute spectral absorption free TOA reflectances
- Multiply with gaseous absorption
- Convolve with spectral response of sensor to simulate

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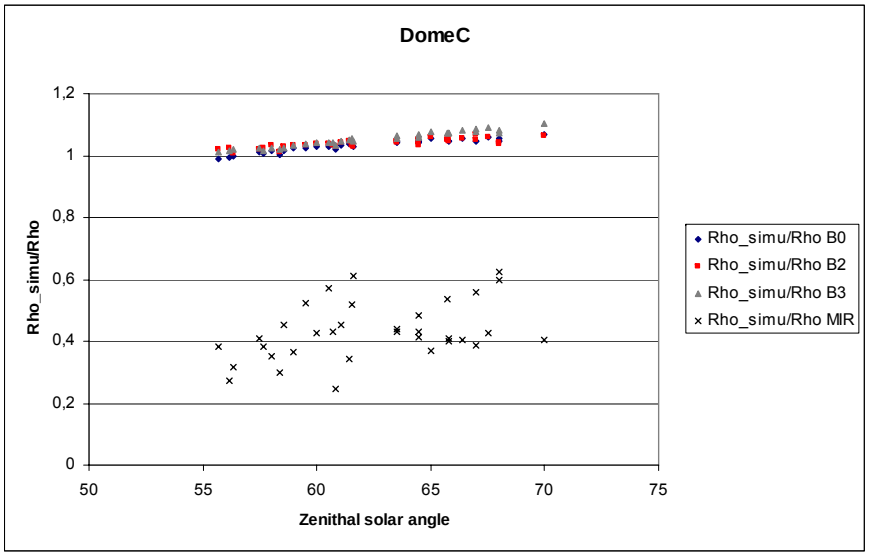
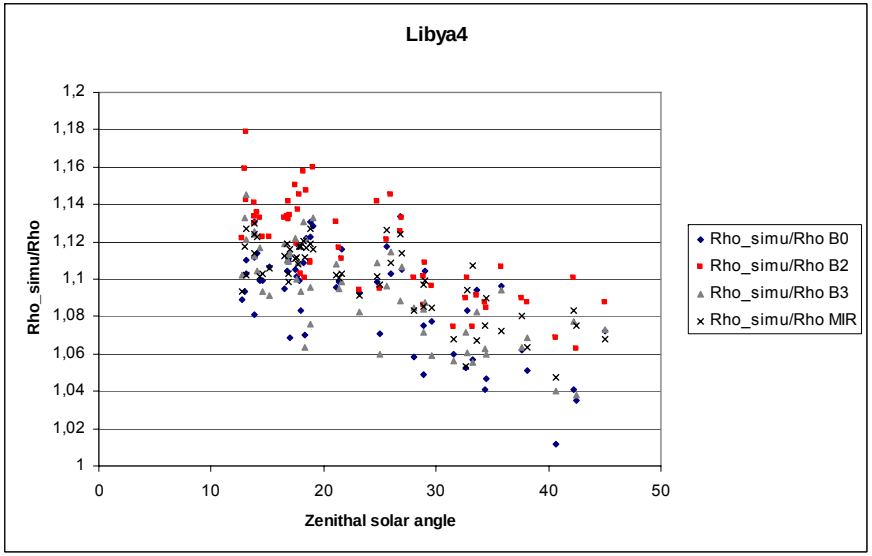
DIMITRI: ONERA Results





Mean	Number of values	(Rho_simu-Rho)/Rho B0	(Rho_simu-Rho)/Rho B2	(Rho_simu-Rho)/Rho B3	(Rho_simu-Rho)/Rho MIR
DomeC	34	0,03	0,04	0,05	-0,568
Libya4	56	0,09	0,12	0,09	0,100
Estimated systematic uncertainty		0,08	0,08	0,08	0,08

Standard deviation	Number of values	(Rho_simu-Rho)/Rho B0	(Rho_simu-Rho)/Rho B2	(Rho_simu-Rho)/Rho B3	(Rho_simu-Rho)/Rho MIR
DomeC	34	0,020	0,015	0,025	0,093
Libya4	56	0,028	0,026	0,025	0,020
Estimated random uncertainty		0,11	0,11	0,11	0,11

- Simulation accuracy better than 5 % over Dome C for B0, B2 and B3
- Simulation accuracy about 10 % over Libya4 for the SWIR band
- Bias between Dome C and Libya4 for B0, B2 and B3

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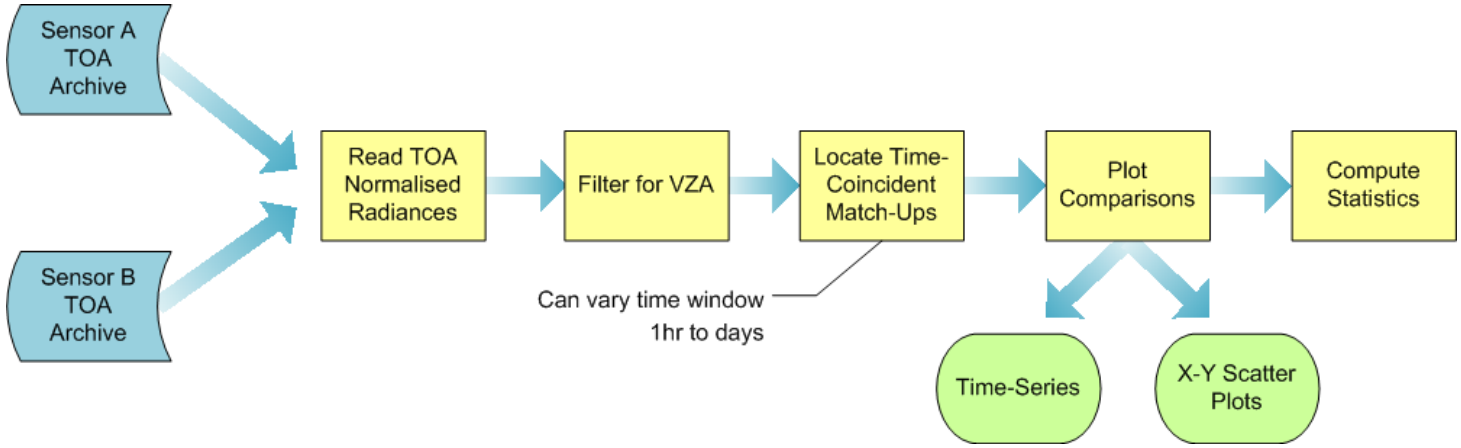
RAL: Direct Matchup Methodology



Parameter being compared is Normalised Radiance at TOA

$R_{scene} = L(l)p/E_s(l) = r_{scene}\cos(sza)$

-where E_s is corrected for sun-earth distance

- Limited number of coincidences
- No good for sensors at different crossing times – e.g. EOS-A/ENVISAT
- Need to account for differences in view/solar geometry
  - Partly overcome by SNOs – but restricted to nadir only observations
- Atmospheric adjustments needed where bands are not coincident

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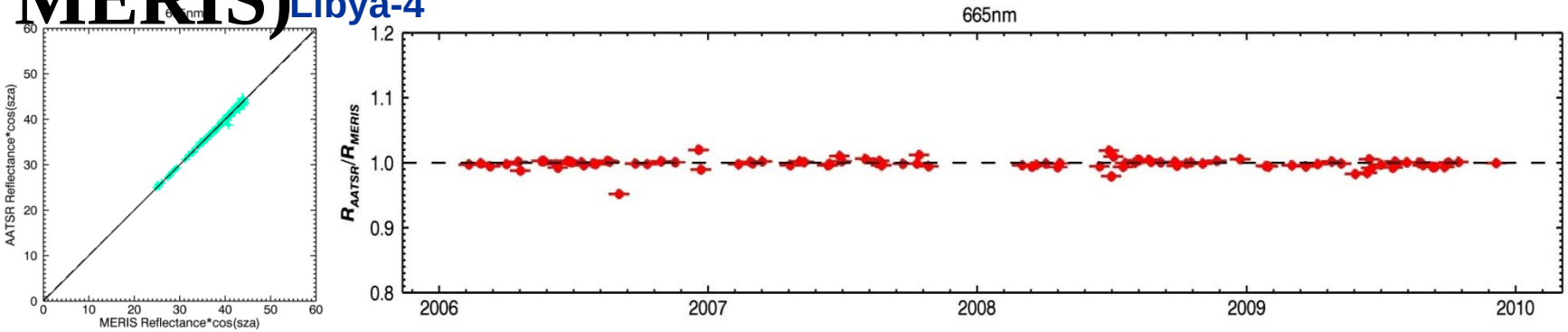
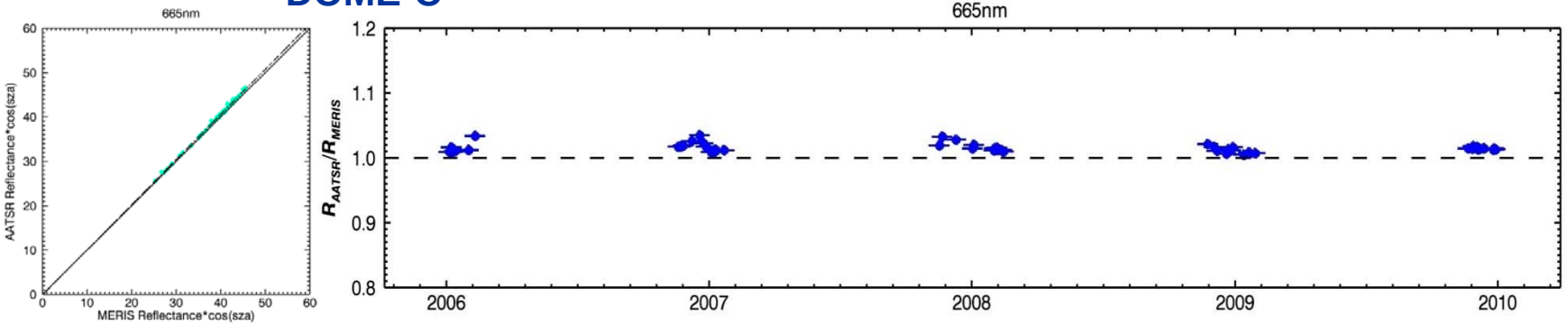
RAL Direct Matchup Results (AATSR vs MERIS)

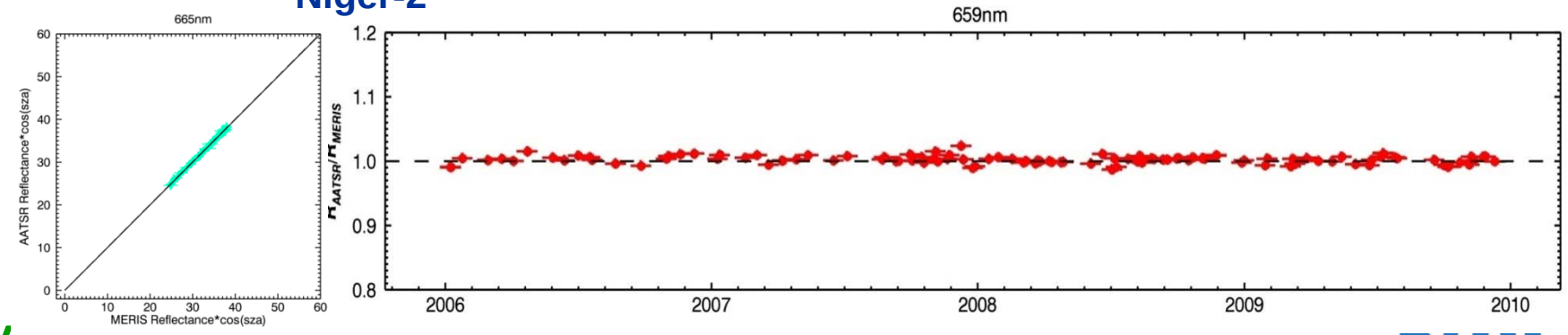
Libya-4



DOME-C

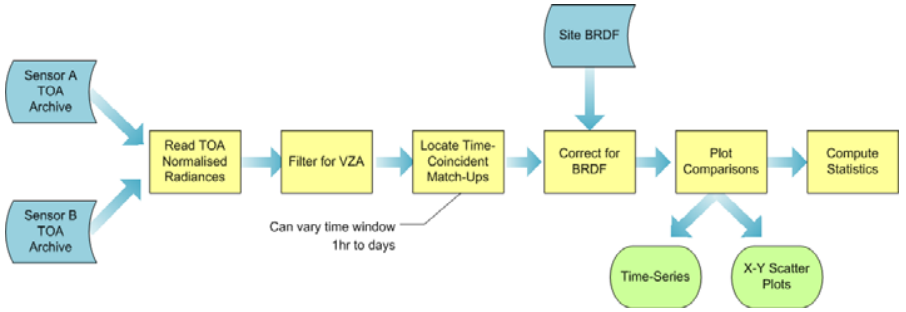


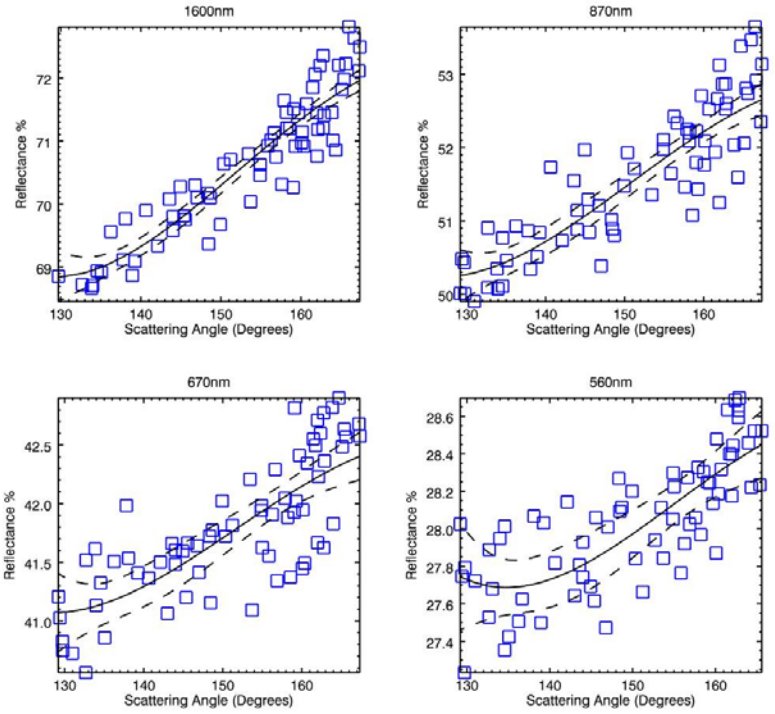
Niger-2



RAL: BRDF Methodology

- For a narrow field of view range (<10°) and assuming that the satellite orbit is stable it is possible to treat the BRDF as a simple function of the scattering angle
- The function is obtained by fitting to data measured early in the mission where the drift is assumed to be low compared to the surface anisotropy, Smith et al 2002.
- The uncertainty in the BRDF, u(F) is taken from the co-variance matrix generated by the function.
- Uncertainties are dependent on the measurement errors provided to the model. For this analysis we assume the standard deviation of the average reflectance measurements over the site.

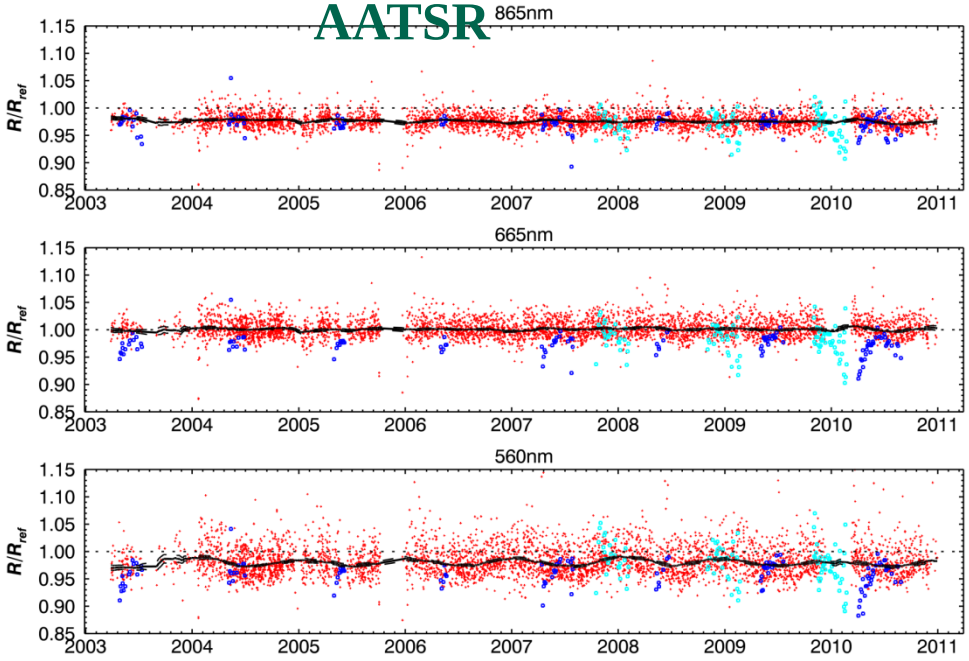




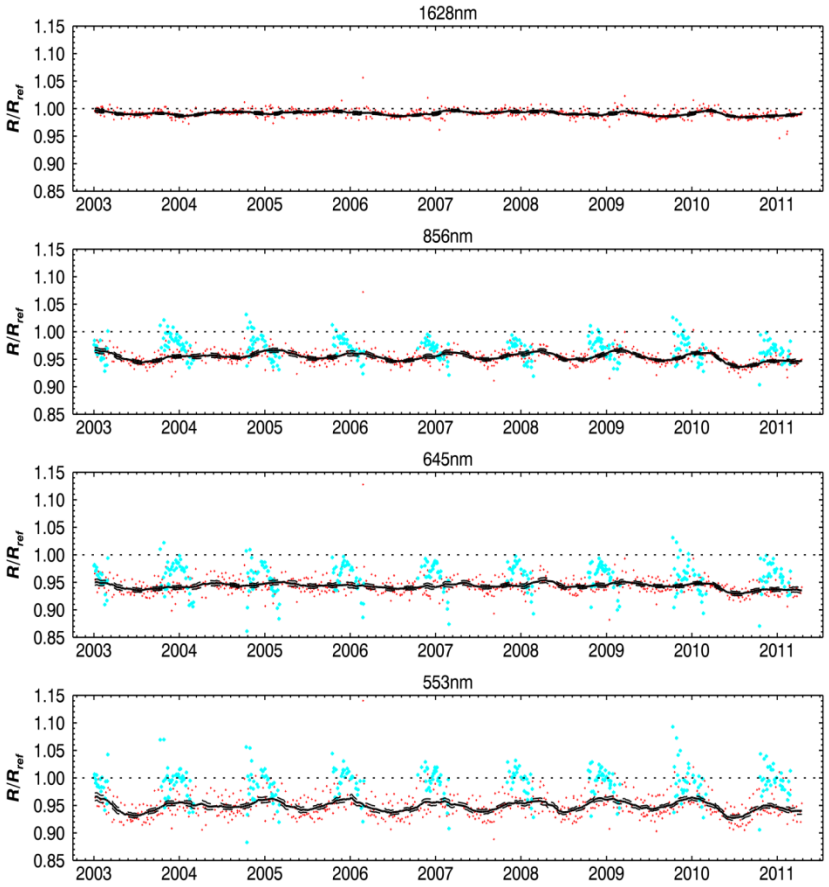
IVOS

RAL: BRDF results (site BRDF)

MERIS vs AATSR



MODIS-A vs AATSR

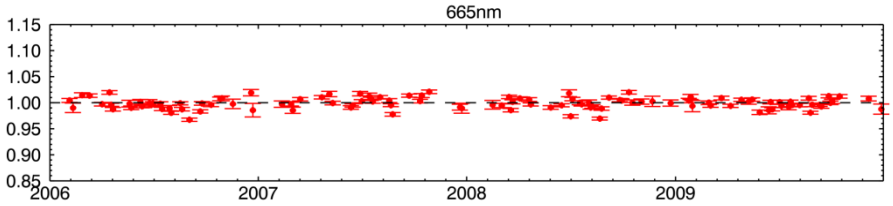


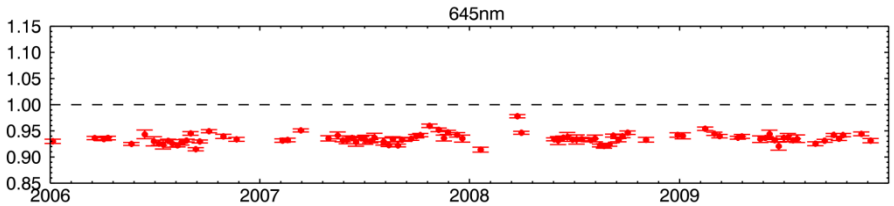
IVOS

RAL: BRDF results (MERIS sensor BRDF)

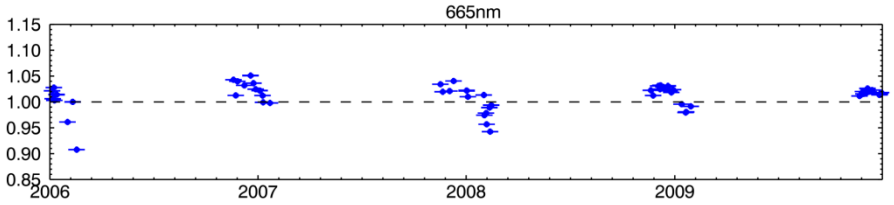
LEFT: AATSR, RIGHT: MODIS-A

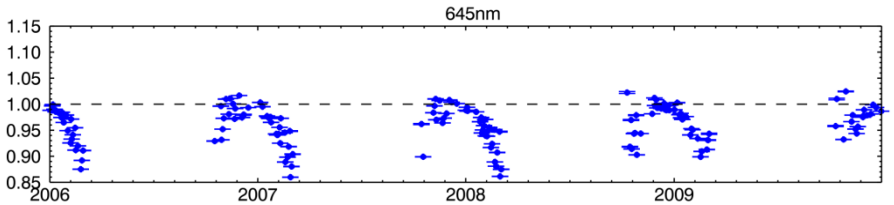
Libya-4



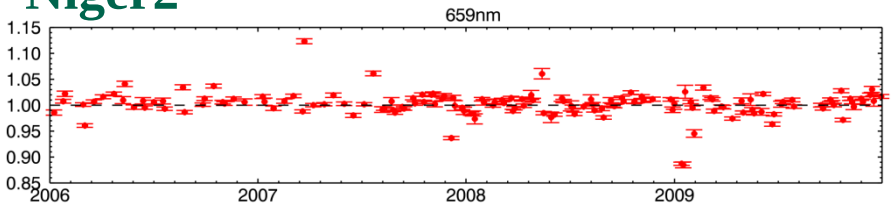


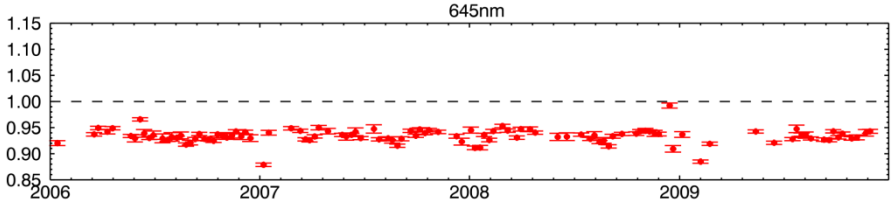
Dome-C





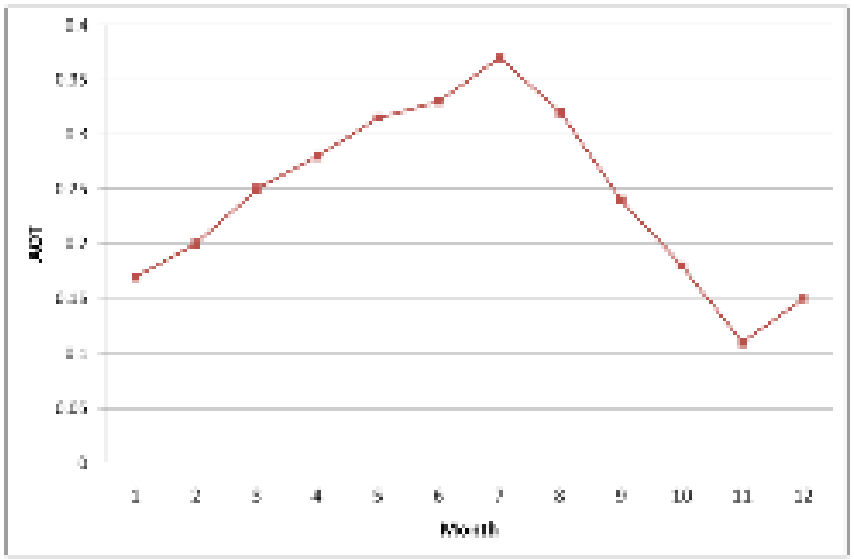
Niger2





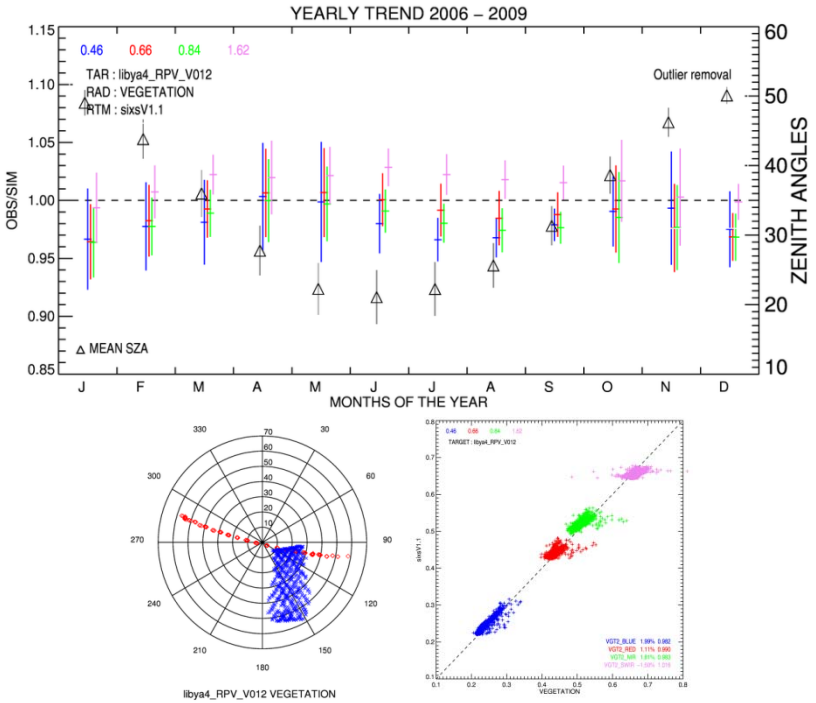
VITO: Desert Methodology

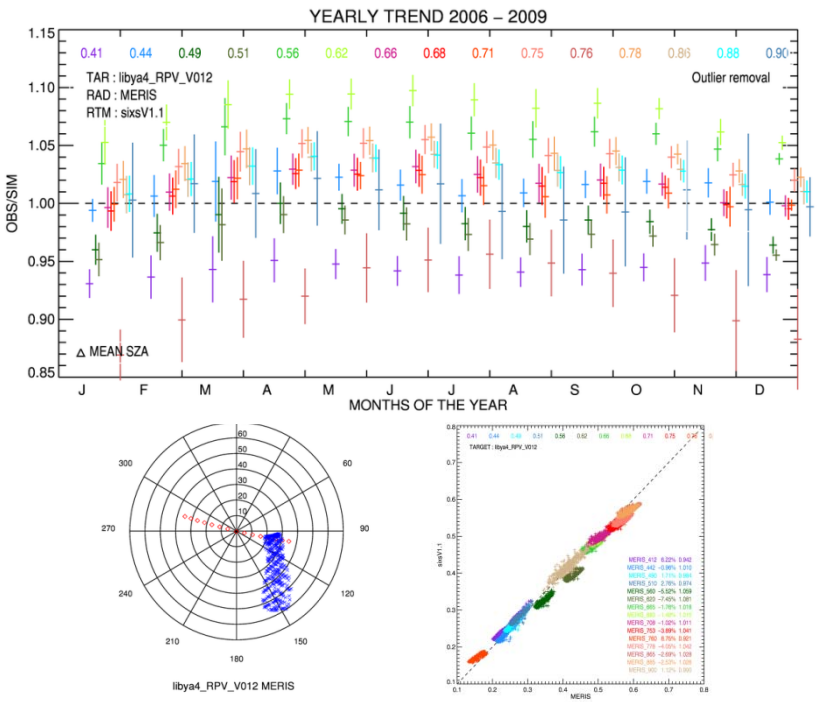
- Simulations of the acquired reflectances over desert sites.
- RTM : SIXSV 1.1 Govaerts, Y.M., and Clerici, M. (2004) Evaluation of radiative transfer simulations over bright desert calibration sites, IEEE Transactions on Geoscience and Remote Sensing, 42,176--187.
- Meteo data from ECMWF ERA-40
- Aerosol model : 6S dust from Shettle (1991, spherical particles)
- Aerosol concentration

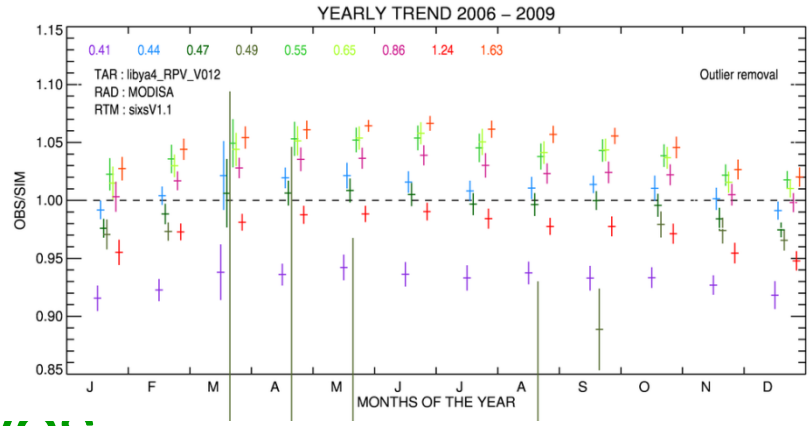


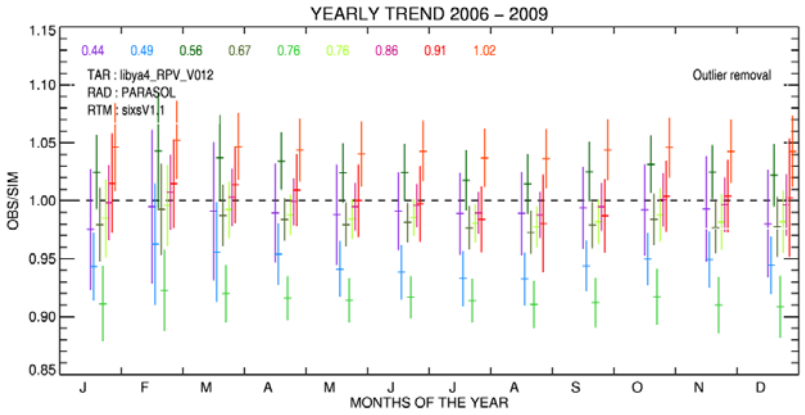
IVOS

VITO: Results (Libya4)

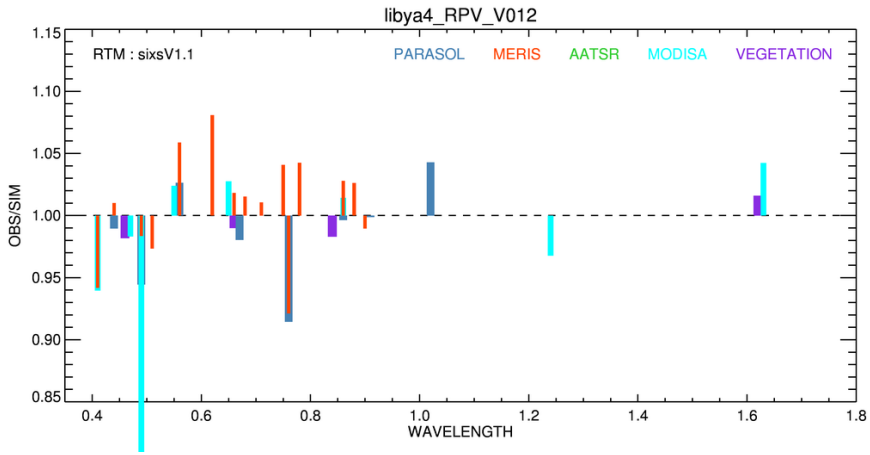




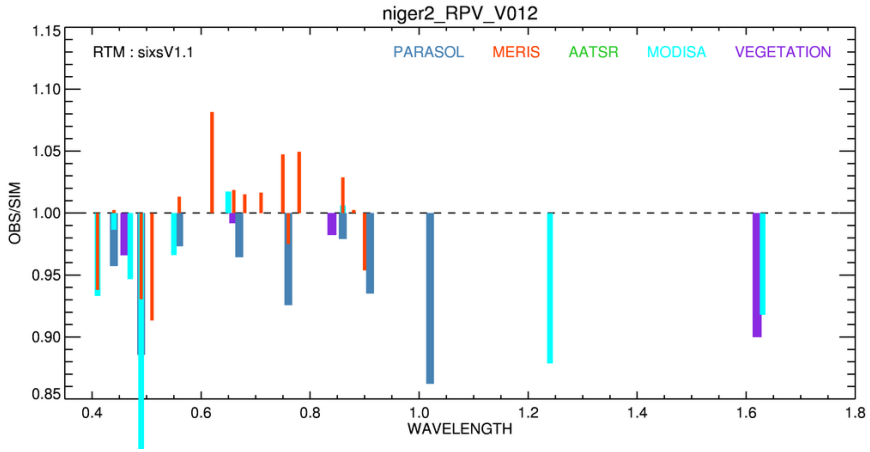




VITO: Results



BAND	0.44	0.55	0.66	0.84	1.82
VGT	-1.83%		-1.00%	-1.70%	1.59%
PARASOL	-1.04%	2.63%	-1.96%	-0.37%	
MODIS-A	0.02%	2.39%	2.76%	1.41%	4.23%
MERIS	1.00%	5.87%	1.82%	2.79%	

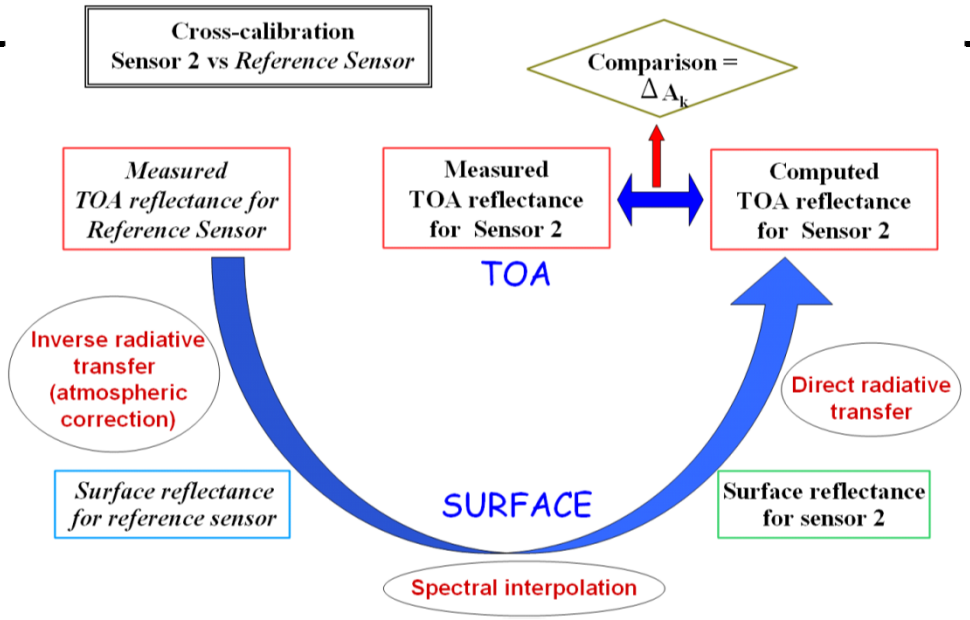


BAND	0.44	0.55	0.66	0.84	1.82
VGT	-3.39%		-0.82%	-1.77%	-10.02%
PARASOL	-4.28%	-2.67%	-3.55%	-2.09%	
MODIS-A	-1.35%	-3.38%	1.74%	0.61%	-8.20%
MERIS	0.24%	1.31%	1.85%	2.88%	

IVOS

NPL

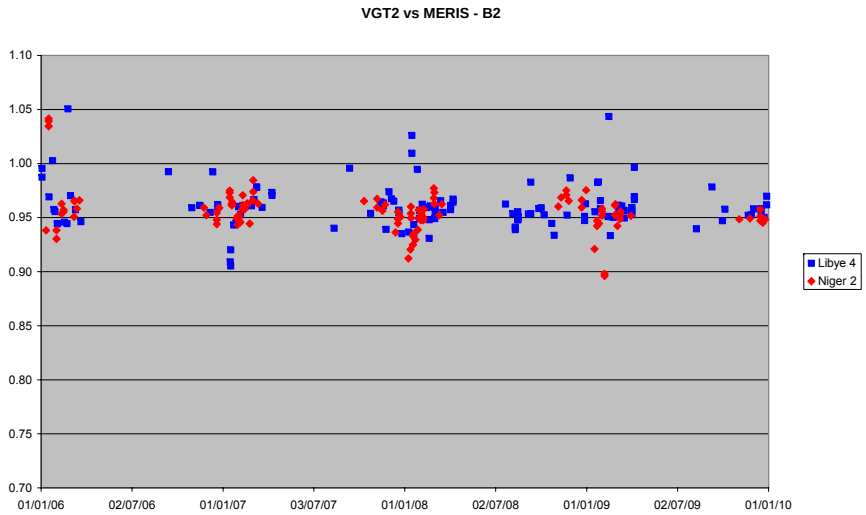
CNES - SADE

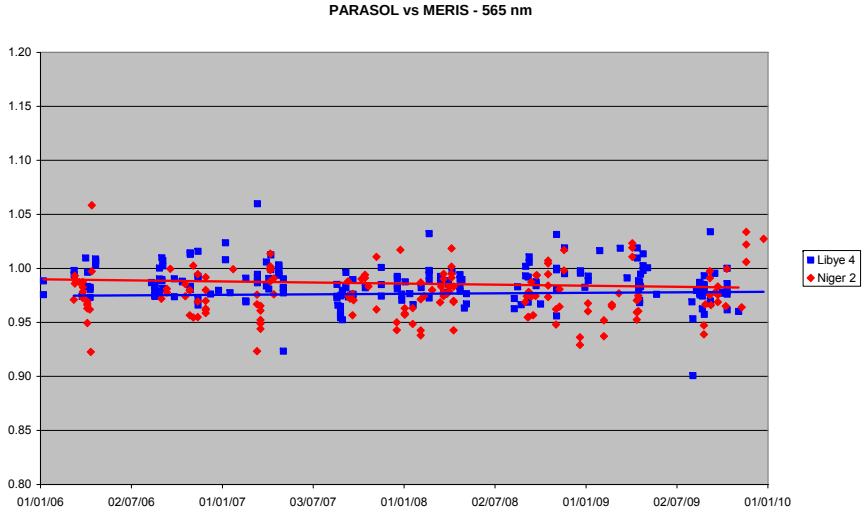


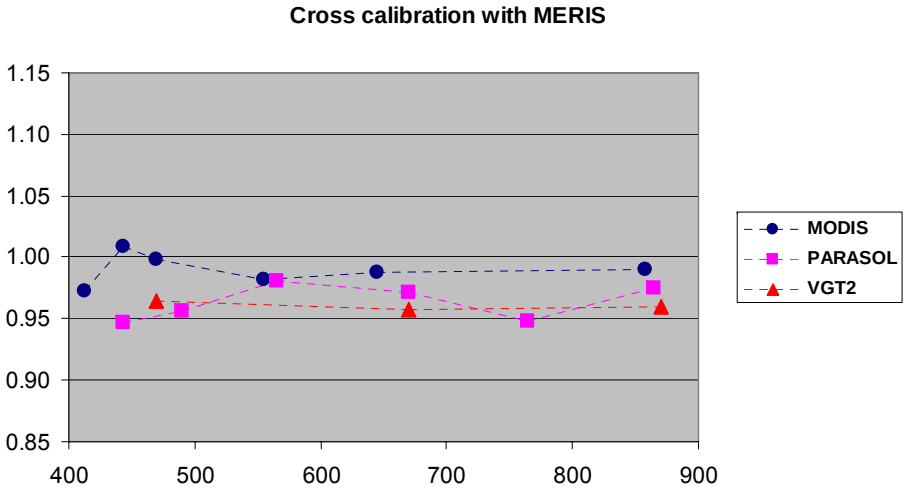
- Meteo data : NCEP + TOMS + fixed aerosol (AOT = 0.2)
- Matchup selection
  - $|DVZA| < 2°$, $|DSZA| < 2°$, $|D(SAA-VAA)| < 5°$
  - Not any constraint on acquisition date (stable sites…)
- Number of obtained matchups (Libya-4/Niger-2)
  - VGT2 133-112, PARASOL 206-155
  - MODIS 20-88 ; use of reciprocity principle ⇒ 55-203

IVOS

CNES: Results







- Good consistency between MODIS and MERIS
- Good consistency between VGT2 and PARASOL
- Good consistency of the results over the 2 sites:
  - around 1%
  - except for the blue bands : 2 to 4% (VGT2)

IVOS

NPL

Issues to date:

- Reference data set needs careful checking
- Longer term some standardised format for comparisons or good translation
- Naming and ordering convention on sensor spectral bands
- Is valuable even for established methods
- Need to keep control of activities to achieve results in good timescales
  - Test overall implementation of methodology full data set
  -
  - Test sub-elements limited data set

LAND SURFACE REFLECTANCE

IVOS

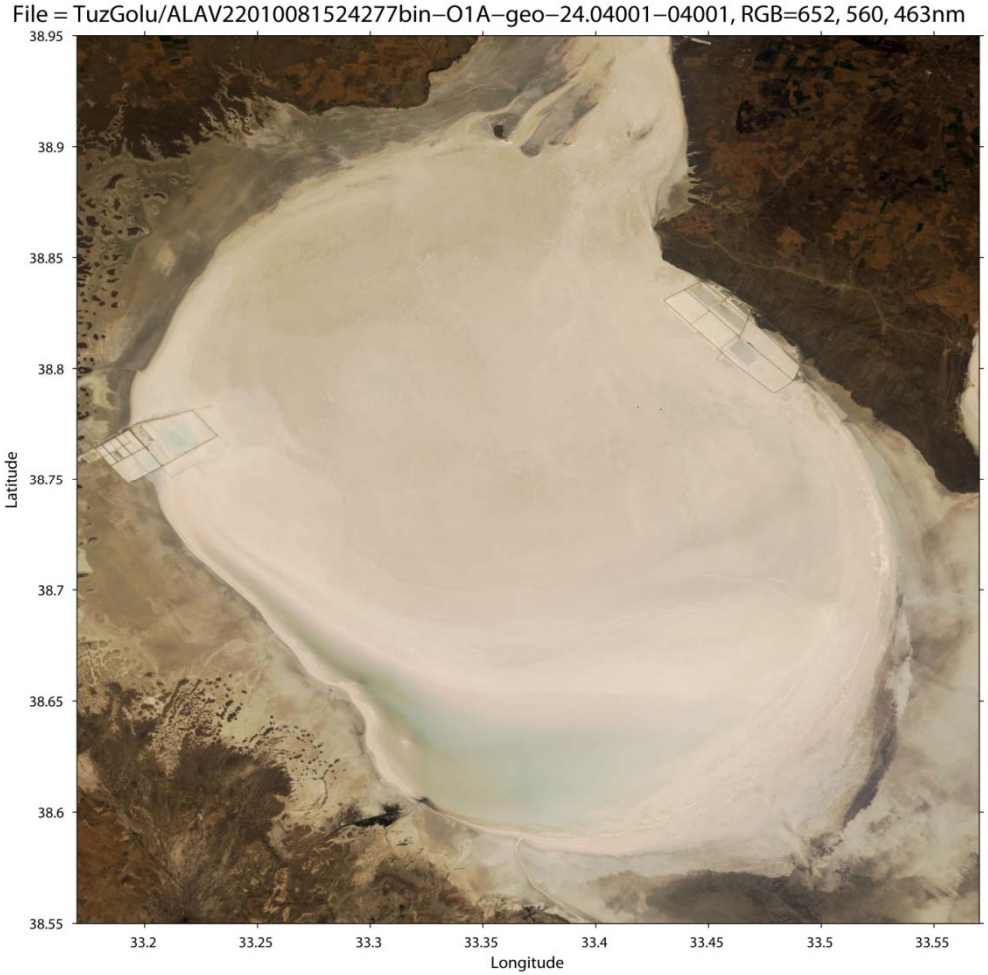
CEOS "Reference Standards" IVOS "test sites"

- Community need
  - Compile a list of consolidated worldwide Cal/Val test sites
  - Compile a appropriate subset of CEOS endorsed reference standards
- Gather complete site characterization data and information
  - Define core measurements (e.g. Instruments)
  - Establish clear quantitative selection crtieria for CEOS endorsement
  - Create an operational network of sites (eg., aeronet, Landnet)
- Encourage agencies to acquire, archive, and provide data to the Cal/Val community over CEOS reference standard test sites
  - Develop online calibration data access infrastructure
  - CNES will release access to SADE and have CEOS test sites any sensor is encouraged to provide data
  - Create tools to identify the potential co-incident image pairs (NASA SEO)
- Establish traceability chain for primary site data & "best practice" guidance on site characterization and its use DRAFT
- Mechanism for long-term maintenance for all CEOS community In-Progress

Tuz Golu comparison: 2010

IVOS

In case you'd forgotten!



This is what we were measuring

IVOS

Objectives

) 1. Evaluate differences in field instrument primary calibrations for
. Reference standards used and traceability (based on “Laboratory” information) and on-site calibrations/validations

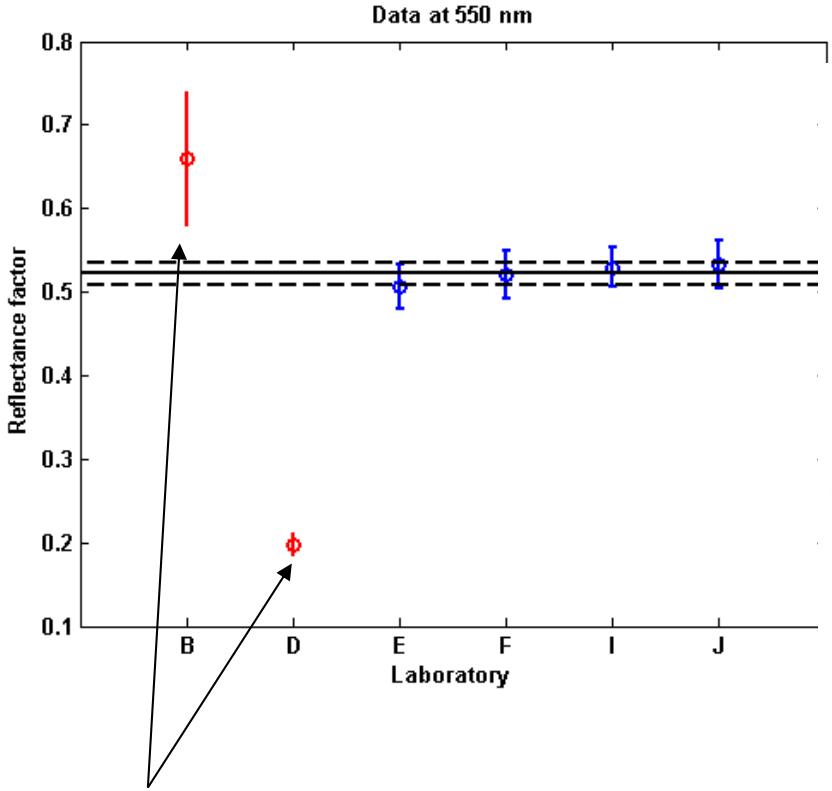
) 2. Evaluate differences in methods for characterising and assigning “radiometric value” to a site, for multiple view angles
. Small area for high-resolution imagers
. Large area for medium-resolution imagers

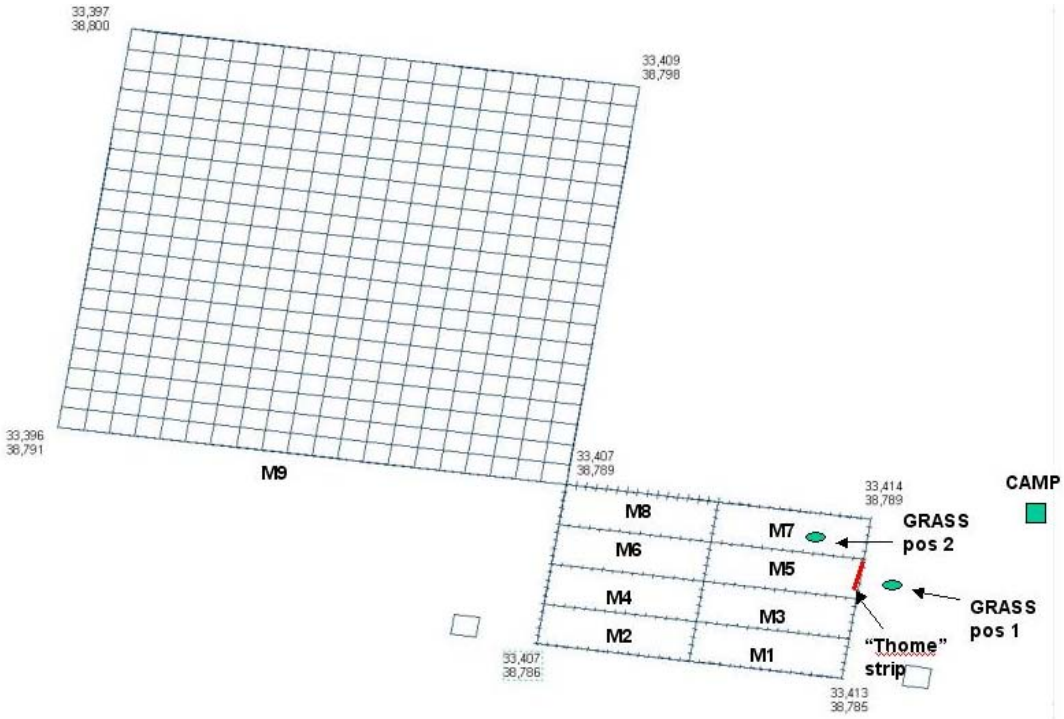
) 3. Establish formal traceability of Tuz Gölü reference site based on an evaluation of all comparison results.

) 4. Basis for “best practice” guidance for above and/or knowledge of variance between methodologies.

) 5. A multi-sensor (satellite and aircraft) comparison linked to the ground calibration derived from the multi-team comparison.

Thome's Strip

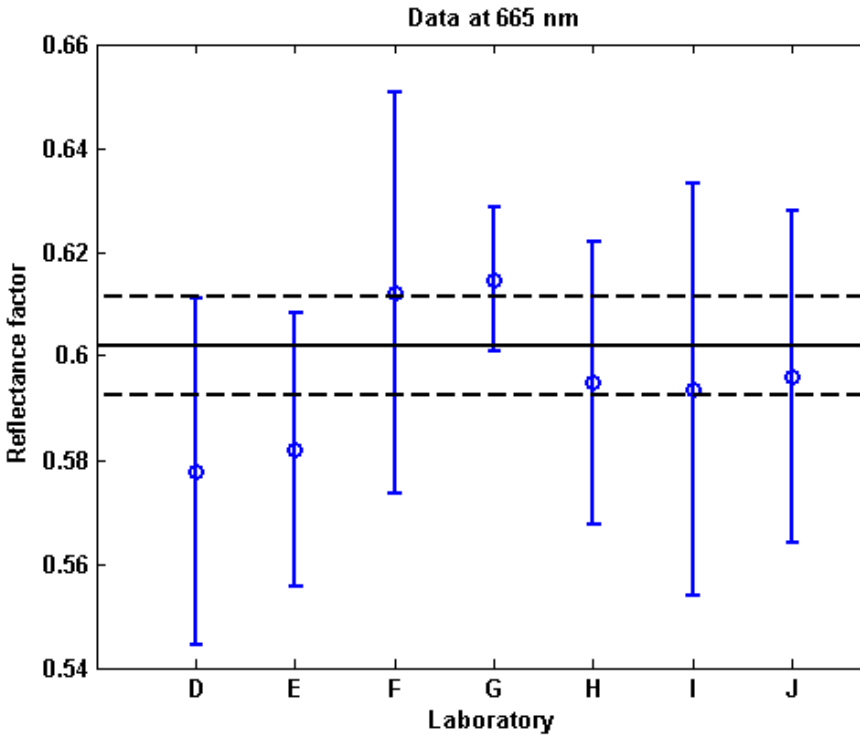


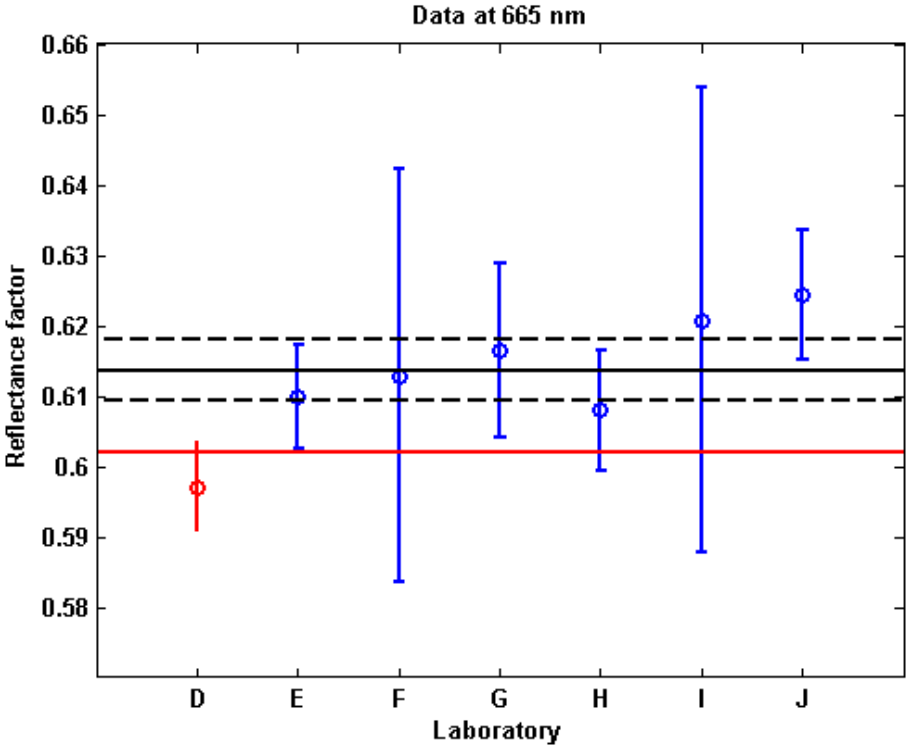


Data not used in calculation of the mean

IVOS

Land surface reflectance:
Site reflectance from different participants





Comparison of results as supplied inc biases and uncertainties from primary calibrations of reference panels.

Comparison of methodologies – type B uncertainties are not considered nor is the uncertainty from the NPL reference panel – tougher test.

IVOS

NPL

Next steps

- **Finalise analysis of data for site - DONE**
- **Use agreed values for atmospheric parameters to compute TOA reflectances/radiances**
  - **Using average of all collected data for all sites M1 to M6 at times close to acquisitions of satellites DONE**
- **Compare with satellite data NEAR COMPLETION**
  - **Use COVE tool to provide necessary observational metadata**
- **Publish results of all above**
- **Establish a work plan to take forward the long-term objectives of seeking to achieve uncertainties of 0.5 to 1% for vicarious calibration including**
  - **Refining best practise**
  - **Agreeing formats for data exchange**
  - **Standardised instrumentation to facilitate improved traceability and consistency between primary test sites.**

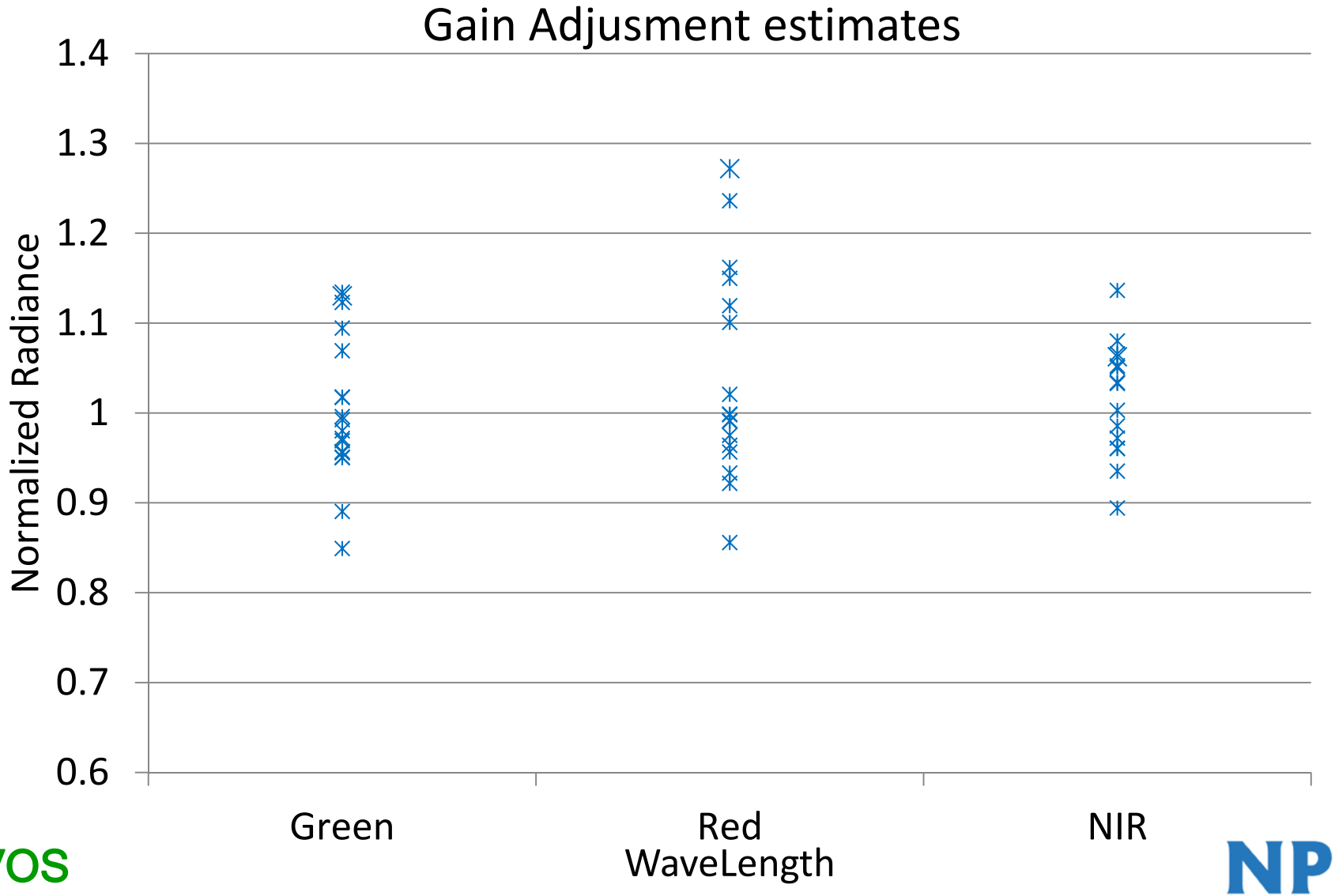
Specific actions/recommendations

- **Use of invariant standard before/after site characterisations to evaluate instrumentation performance**
  - **Also seek to establish method to achieve above during campaigns**
- **Develop a standardised radiometer to act as transfer standard to link test-sites traceability.**
- **Perform "repeatability measurement" before and during site characterisation based on ratio of panel to surface**
- **Individual site "point Measurements" should consist of a statistically significant number typically 10.**
- **Assignment of RF to a panel and subsequently site should be based on a Bi-directional (Gonio) characterisation at an appropriate angle(s) (in some cases with solar Zenith near nadir a hemispherical based calibration may be adequate.**
  - **A look-up table of panel BRF for range of angles will be published on cal/val portal as a first order correction**
- **A standardised format to enable data from such site characterisations to be easily compared will be established**
- **Satellite owners will be asked via CEOS to standardise the information provided in the header in terms of view and illumination angles and acquisition times etc**

IVOS

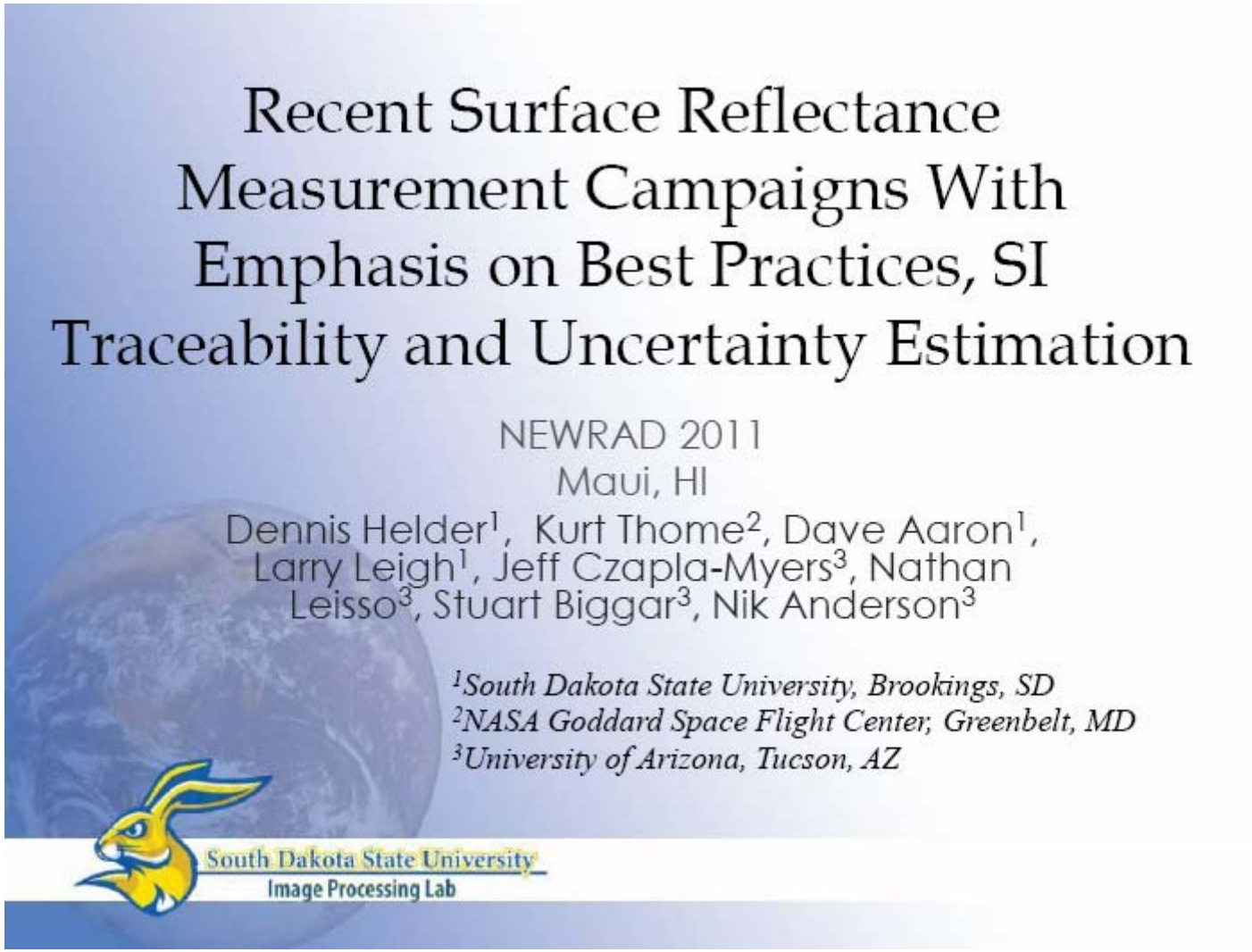
NPL

Preliminary analysis (~15 sensors) using simultaneously measured ground data at Tuz Golu



IVOS

NPL



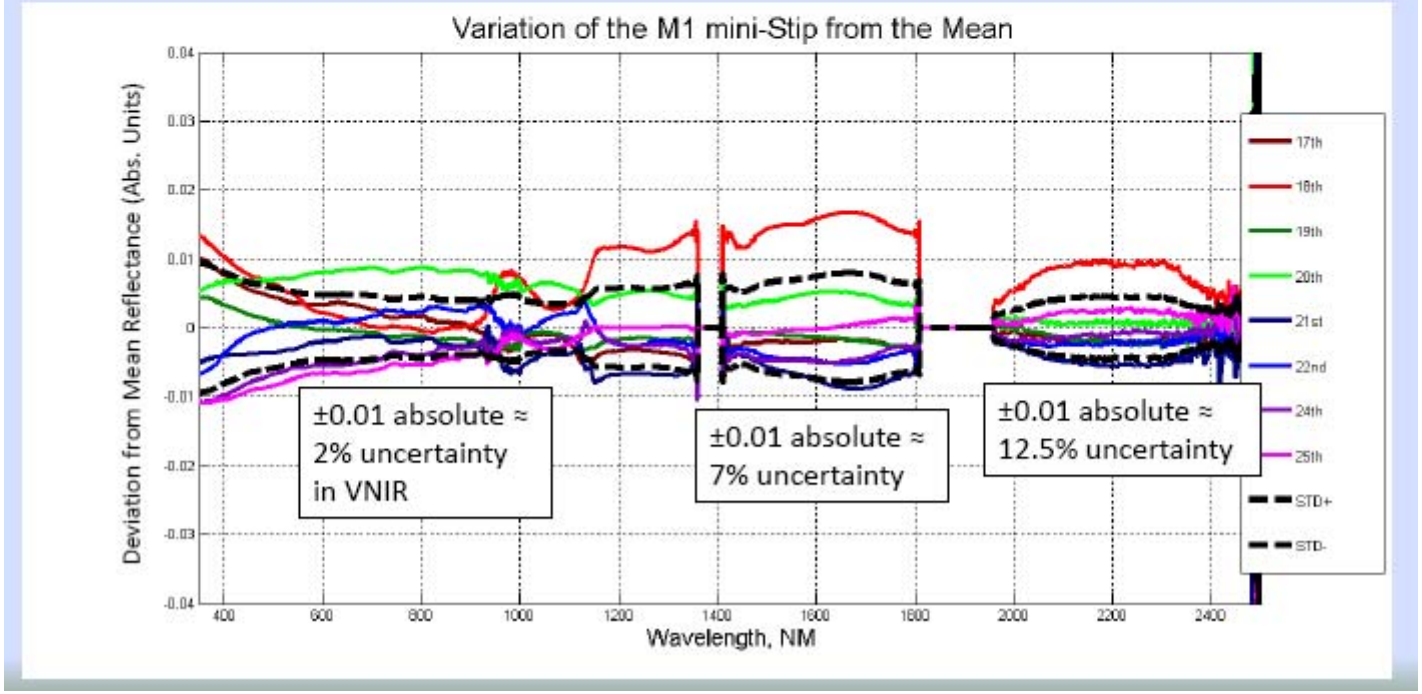
Accepted for publication in "Metrologia"

IVOS

Tuz Gölü Spectral Reflectance Study:

Short Term Stability Study : *M1 mini-strip*

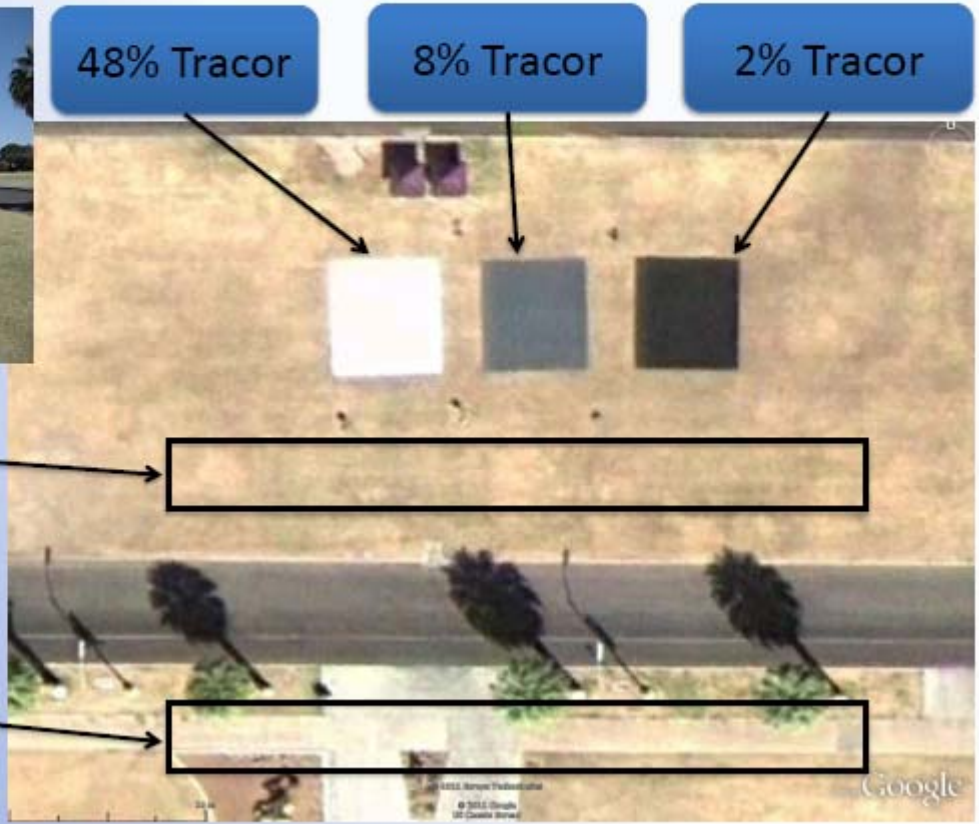
- Reflectance variability for 'limited location, limited time' study is on the order of 0.01 reflectance units.
  - 8 days of consecutive data is shown
  - Black lines represent absolute standard deviation
    - +/- 0.01 in reflectance



IVOS

Reflectance targets

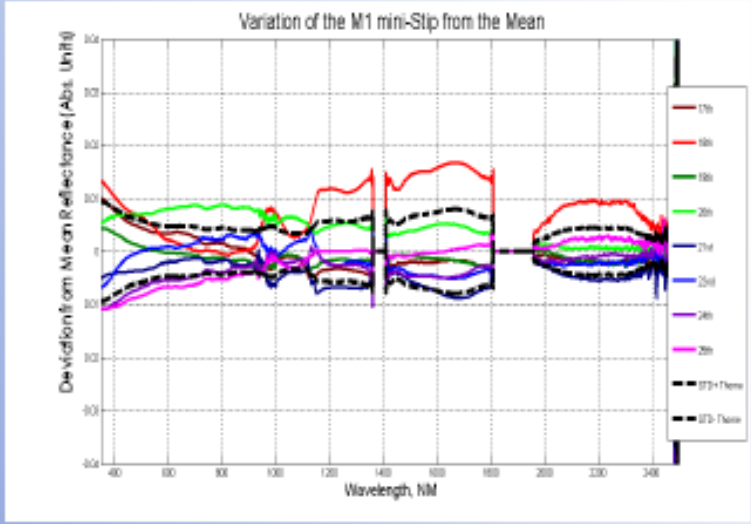
(slide courtesy Nathan Leisso, U. of AZ)

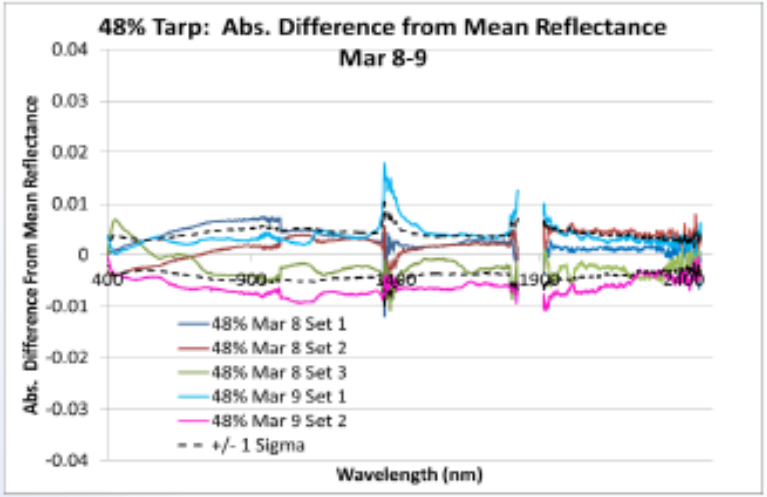


IVOS

NPL

Comparison of Repeatability between AZ and Tuz Golu Field Campaigns





- Tuz Golu results on the left are very similar to the AZ results on the right
  - Tuz Golu M1 Strip measured over 8 days
  - AZ Tracor Tarp measured over 2 days
  - Same operator, same instrument (ASD 16004)
- In terms of absolute units, repeatability of the measurements are similar, with perhaps some advantage with the Tracor tarps.
- Reproducibility is 0.01 or less with $\sigma = 0.005$ or better.

IVOS

NPL

Discussion

- AZ Round Robin
  - Conducted under very good sky conditions
  - Demonstrates the capability of experienced operators
  - Advantages with bright, spectrally flat target
  - Exact sources of uncertainties remain
    - ASD stability
    - Operator stability/repeatability
    - Degradations of target during campaign (debris)
    - Small atmospheric changes?
- Tuz Golu Campaign
  - Conducted under more variable sky conditions
  - Advantages of very large, uniform target
    - However, target was dark in the SWIR
  - Same operator/instrument within 6 months makes an excellent comparison
  - Sources of uncertainty likely very similar to AZ campaign

Conclusions

- Type A uncertainties consistently around 1%, worst case (3 operators) still under 1.5%
- Field reproducibility can be as good as 1%
  - Single operator/instrument: 1%
  - Multiple operators/instruments: 2%
  - Normally under 0.01 reflectance units (abs.) at all wavelengths independent of target reflectance
- Calibration panel uncertainty (Type B?): 1-1.7% (wavelength dependent).
- Total uncertainty can approach 1.5% for certain wavelengths and be as large as 2.5% for other wavelengths.
- These results demonstrated by experienced teams with good field conditions.
- Results using Tracor tarps suggests a means for comparing teams worldwide
  - Rather than bringing teams to a common site, a common target can be shipped to the teams.
  - Each team can measure tarp reflectance using their instrumentation and calibration standard.
  - Care must be taken during shipment of deployment of tarps to maintain spectral reflectance properties.
  - Virtual Round Robin campaigns could be conducted on regular (annual or bi-annual) basis to develop short and long term comparisons

Issues/Actions

- Establish and agree classification criteria for core sites ("best" standards)

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

- Prediction tool for Sat overpass on test sites complete development (COVE)

- Methods for linking sites, propagation of data to satellites, access to information ESA and IVOS

  -Potential issues of service cost?

- Calendar of measurement campaigns Portal

- Resource for test sites Agencies

- Establish optimum instrumentation specification for core sites

  -Automation

- - Identify sites and associated key characteristics for all other cal/val tasks

- Establish "Governance" principles

IVOS

QA4EO Procedures: Land imagers

-Establishing a Land reference test site

- Proposing and Documenting a reference test site

- Radiometric Characterisation of a land site

- Use of Rayleigh scattering for Gain evaluation

- Use of Moon as a calibration standard for Satellites

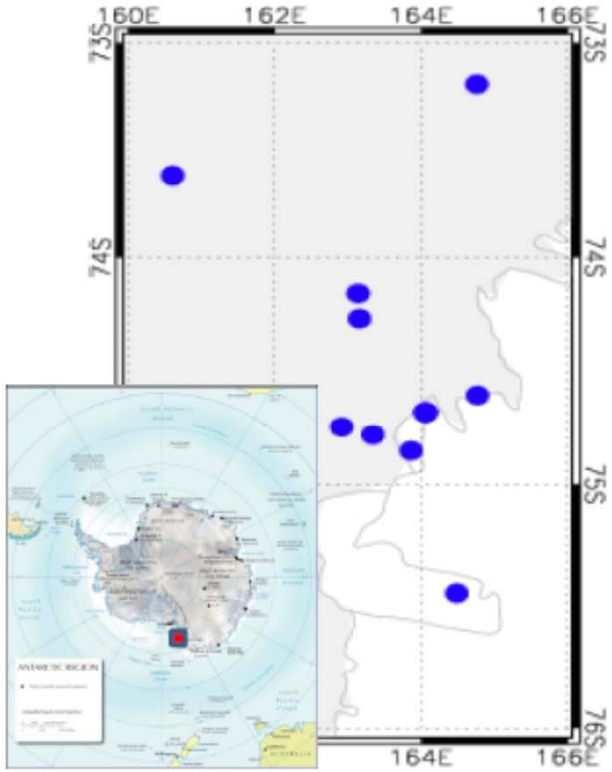
- Protocol for Cross-comparison of Satellites

- Protocol for comparison of ground measurement techniques for test-sites

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

Characterization of the bi-directional reflectance of Antarctic surfaces for the inter-calibration of remote sensing data (2010 activities).

A collaboration project promoted within the framework of CEOS-WGCV and involving: Joint Research Centre (EU), London Royal Holloway College (UK), Experimental Geophysical Observatory (IT), Italian National Research Council (IT) and National Physical Laboratory (UK).



JRC Portable Goniometric Radiometer System (PGRS) allowing for hyper-spectral directional measurements in the anti-solar and sun-normal planes, deployed at various sites in Victoria Land during the 2010 Italian Antarctic expedition.

Prepared by G. Zibordi (2011)

IVOS

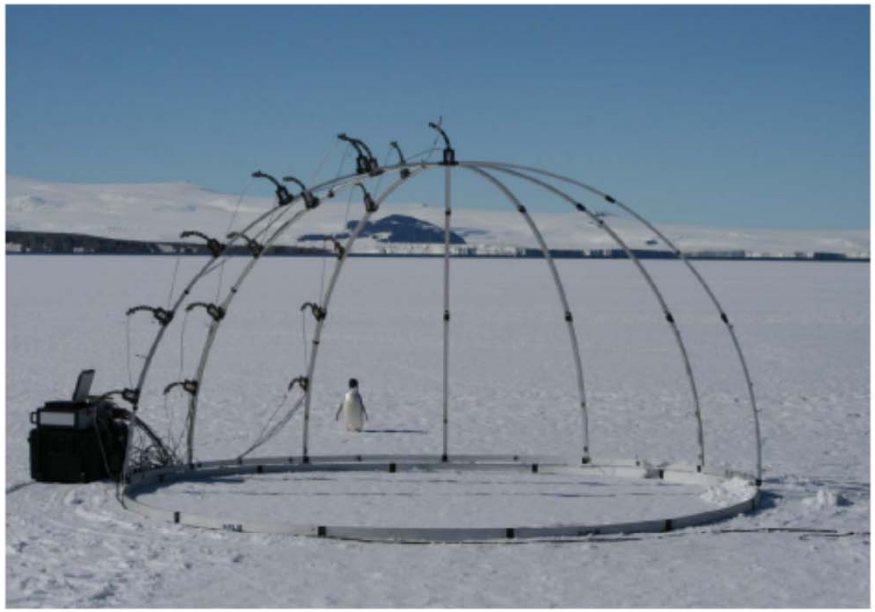
Terra-Nova

NPL

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

CEOS

Gonio Radiometer Spectrometer System (GRASS)



The NPL Gonio Radiometer Spectrometer System (GRASS) tested in Victoria Land (Antarctica) during December 2010 in conjunction with the JRC Portable Goniometer System (PGRS) within the framework of the 26th Italian Antarctic Expedition and likely going to be deployed at DOME-C during the 27th Expedition.

Prepared by G. Zibordi (2011)

2011 – at DOME – C (near base)

- **Opportunity for More detailed evaluation than Warren-Hudson**
- **Sensor overpass**
- **Results to be put on site – no resource for analysis of sensor data**

IVOS

NPL

CEOS IR radiometer inter-comparison

- **Third in a series of inter-comparisons establish degree of equivalence (biases) between participant's**
  - **Reference black bodies**
  - **IR radiometers under lab conditions**
  - **IR radiometers as used viewing Ocean (SST)**
- **Ensure robust traceability to SI (via NIST and NPL)**
- **Establish protocols based on QA4EO to facilitate future comparisons and strategy for maintenance of long-term traceability**
- **Pre-cursor for Land Surface Temperature community Need to establish**
- **Reports now available**

Two parts:

Laboratory (NPL) 21-22 April 2009

Laboratory and ocean viewing (Miami) 11-15 May 2009

(Participants self-funded)

IVOS

Strategy for long term maintenance: climate record

- Validation for SST from space essential
  - Buoys
  - Ship borne radiometers
- Mission independent
  - Avoid data gaps
- GHRSST provides harmonised SST
- Validation programme – not single agency
  - Optimised sampling strategy
  - Independent of sat sensor (focussed on parameter)
- HOW?

- Draft Strategy (for comment/action) (David Llewellyn-Jones AATSR PI)

- Same for all parameters

Ocean Colour

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Assessment of *In Situ Radiometric Capabilities for Coastal Water Remote* Sensing Applications (ARC)

Genesis:
Cal/Val ocean color activity proposed as a CEOS/CVWG/IVOS action, funded by ESA, planned and organized by the JRC in collaboration with NPL.

Objective:
Compare primary ocean color radiometric products (water leaving radiance) from *in situ* optical measurements applying different radiometers and measurement methods

Execution:
Field measurements at the AAOT (July , 19-23-10)
Laboratory calibrations at JRC (July , 26-29-10)

Site: Acqua Alta Oceanographic Tower (AAOT)
Region: Northern Adriatic Sea
Water type: Case-1/Case-2

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ARC: Field (AAOT - July , 19-23 2010)

Instruments and Institutes (confined to European institutions contributing to MERIS validation activities):

1. **WiSPER** (in-water multi-spectral winched profiling radiometer system) – JRC (EU);
2. **SeaPRISM** (above-water multispectral system with ~1 degree FAFOV) – JRC (EU);
3. **TACCS-S** (in-water multispectral radiometer buoy) - University of Stockholm (Sweden);
4. **TACSS-P** (in-water hyper-spectral radiometer buoy) - Segremarisco (Portugal);
5. **TRIOS-B** (above water hyper-spectral radiometer system) – MUMM (Belgium);
6. **TRIOS-E** (above water hyper-spectral radiometer system) - Tartu Observatory (Estonia);
7. **TRIOS-J** (above-water hyper-spectral radiometer system with reduced field of view with ~3 degrees FAFOV)) – JRC (EU).
8. **JAWS** (above-water multi-spectral radiometer system with narrow field of view (3 degrees FAFOV)) - JRC (EU);

TRIOS-B
&
TRIOS-E

TRIOS-J
&
JAWS

TACSS-P

SeaPRISM

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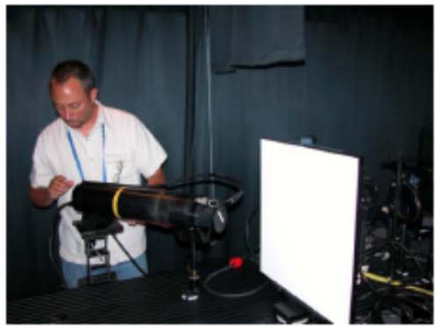
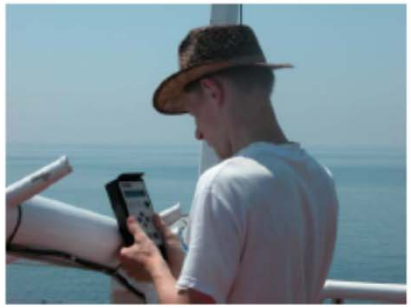
ARC: Lab (JRC -July 26-29, 2010)

Participating Institutes:
JRC (EU), NPL (UK), MUMM (Belgium), University of Stockholm (Sweden), Tartu Observatory (Estonia), Bio-Optika (UK), Segremarisco (Portugal), GKSS (Germany), NIVA (Norway).



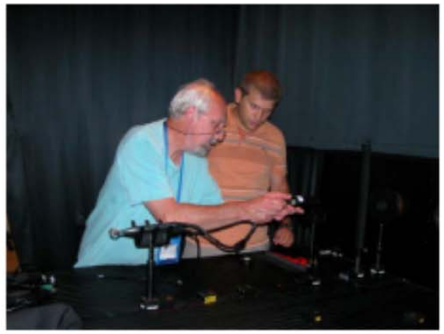


Calibration and comparisons:

a. The absolute calibration of the radiometers deployed at the AAOT during the field inter-comparison (plus a number of additional radiometers currently in use for MERIS validation);

b. The inter-comparison of sun-photometers (additional activity under the responsibility of individual participants);

c. The inter-comparison of spectrally calibrated 1000W FEL lamps (from NPL and NIST traceable) utilized for absolute radiometric calibration.



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In situ determination of the remote sensing reflectance: an inter-comparison

G. Zibordi[1], K. Ruddick[2], I. Ansko[3], G. Moore[4], S. Kratzer[5], J. Icely[6] and A. Reinart[3]

[1] Institute for Environment and Sustainability, Joint Research Centre, Ispra, Italy
[2] Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Brussels, Belgium
[3] Tartu Observatory, Estonia
[4] Bio-Optika, Crofters, Middle Dinnson, Gunnislake, UK
[5] Stockholm University, Department of Systems Ecology, Sweden
[6] Sagremarisco Lda, Vila do Bispo, Portugal

Submitted to the *Journal of Optics* on February 2, 2012.

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Measured differences compared to calculated uncertainties of Remote sensing reflectance

	AD [%]			CU [%]		
λ	443	555	665	443	555	665
TACCS-S	4.5	6.1	21.2	8.3	8.0	9.3
TACCS-P	8.7	7.8	16.1	8.4	7.7	8.8
SeaPRISM	5.7	6.0	7.6	6.7	5.9	11.0
TRIOS-B	7.7	2.7	11.0	8.0	5.5	6.7
TRIOS-E	5.9	3.9	7.2	8.0	5.5	6.7

Absolute differences relative to WISPER of "remote sensing reflectance" (sat equivalent propagated to surface)

Instrument biases due to primary calibration traceability removed

Submitted to the *Journal of Optics* on February 2, 2012.

Zibordi et al (JRC)

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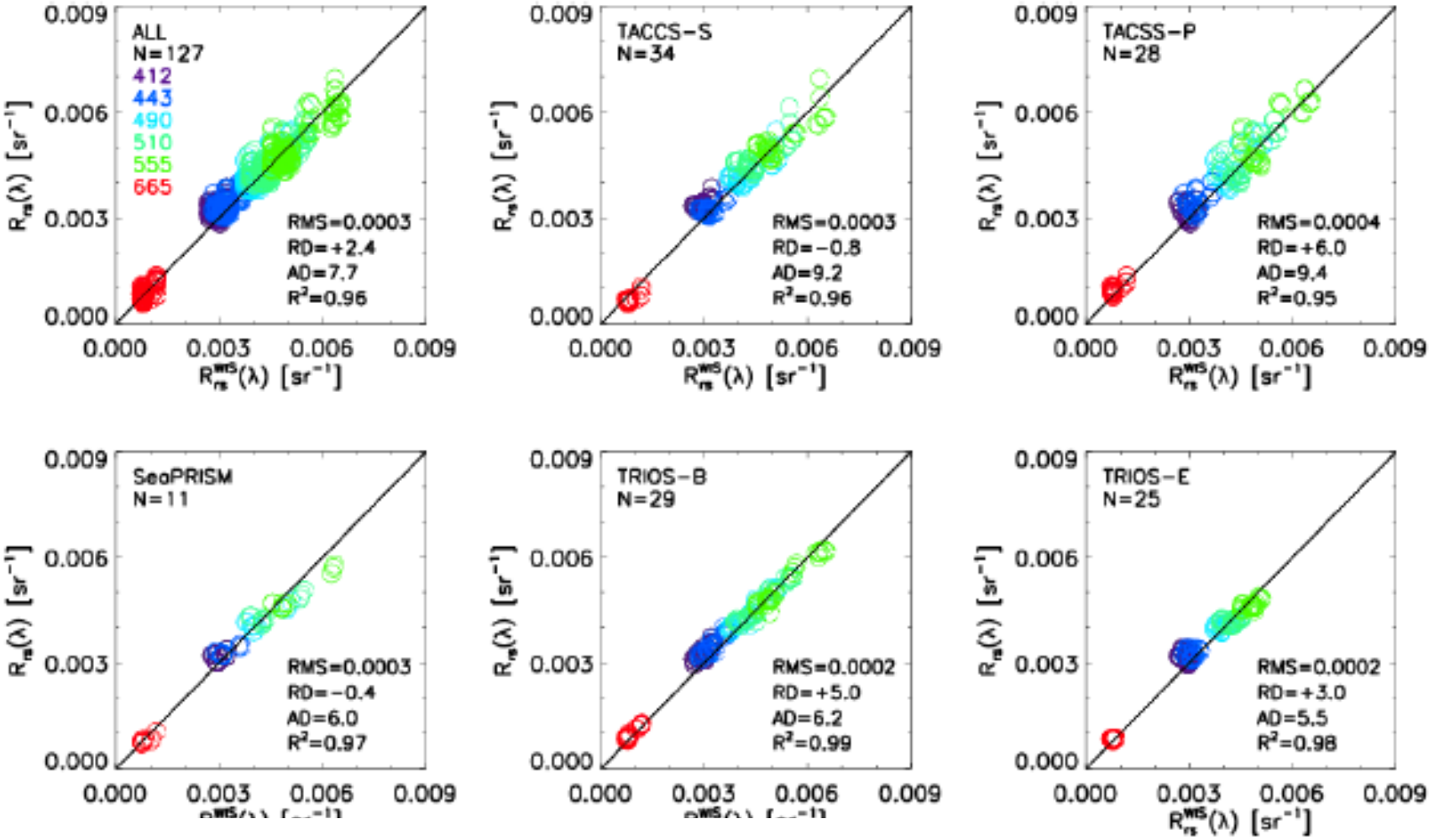
Scatter plots of all results for reflectance compared to WISPER



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Submitted to the *Journal of Optics* on February 2, 2012. Zibordi et al (JRC)

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Atmospheric correction best practices update

K. J. Thome

Biospheric Sciences Branch
Goddard Space Flight Center

CEOS/IVOS 23 Toulouse, April 15, 20[illegible]

Introduction

Ultimate goal of atmospheric correction discussion is to understand impact of errors in the correction

- Similar concept to best practices discussion for laboratory and vicarious calibrations
- Develop a set of recommended approaches to ensure better comparability between different groups
  - Permit development of new methods
  - Create a common starting point for all groups
- Areas for best practices are
  - Radiative transfer code
  - Input parameterization
  - Measurement approaches
  - Instrumentation

Atmospheric parameterization

List of parameters to be reported for a selected overpass time

- Spectral optical depth (total, component)
- Aerosol optical depth at 550 nm
- Angstrom coefficient (Junge parameter, power law exponent)
- Surface pressure
- Column water vapor amount
- Column ozone amount
- Aerosol type (colloquial model as well as real and imaginary index of refraction, minimum/maximum radius)
- View-sun geometry
- Surface elevation
- Sensor elevation

Sensitivity analysis

Summary Statement: Sensitivity analyses also done for many problem types

- Will recommend a methodology for sensitivity studies
- Not clear at this time the best way to do this
- All groups **must** do sensitivity studies
  - Atmospheric variability
  - Surface reflectance
  - Lambertian vs. non-lambertian
- Gives insight into errors with largest impact on results
- Sensitivity will be site dependent

Summary for this IVOS

Tuz Golu meeting has led to path forward for developing best practices for atmospheric correction

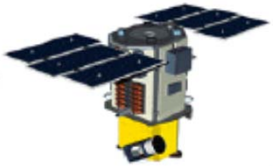
- Continue to move forward on previously discussed approaches
  - Radiative transfer code intercomparison
  - Comments on recommended input parameters
  - Comments on protocols for sensitivity analyses
  - Compile results of past work
  - Comments on recommended measurement approaches for vicarious calibration
- Update progress at next IVOS meeting

Key support from X Briottet ONERA

On-orbit Modulation Transfer Function Estimation

IVOS 23 Toulouse, France

4/14/11



Dennis Helder
Image Processing Laboratory
South Dakota State University

South Dakota State University
Image Processing Lab

Why are we talking about MTF?

- Two types of calibration
  - Radiometric: how much energy is the system receiving?
  - Geometric: where is the system pointing?
- MTF is a measure of imaging system focus or blur
  - How much energy is received from a small region where the system is pointing?
- So, is MTF an important parameter describing the system? Yes.
- But where does it belong?
  - Under Radiometric calibration?
  - Geometric calibration?
  - Spatial calibration/quality?

Outline

- What is MTF and why are we looking at it?
- Methodology & Targets
  - Pulse Method
  - Edge Method
  - Mirror Method
- Results
- How does this relate to IVOS?

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How does this relate to IVOS?

- Probably a given that MTF is an important imaging system 'calibration'
- Does it belong in IVOS?
  - Probably at home as much in radiometric calibration as in geometric. Certainly could be considered multi-disciplinary, similar to atmospheric correction
- QuickBird's spatial performance didn't change over 2003 to 2005 period with GSD change.
- Is there a preferred method or a standard practice?
  - Definitely not!
  - Much work can be done in this area
- A good example is simply how to define parameter to measure!
  - Point spread function (PSF)?
  - Edge (Line) spread function?
  - Modulation transfer function (MTF)? MTF at Nyquist?
  - Relative edge response (RER)?
  - At what level of processing?
- Recommend MTF be given due attention. If not in IVOS, then let's be assured that it is addressed somewhere!

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MTF measurement

F. Viallefont, D. Léger, P. Déliot

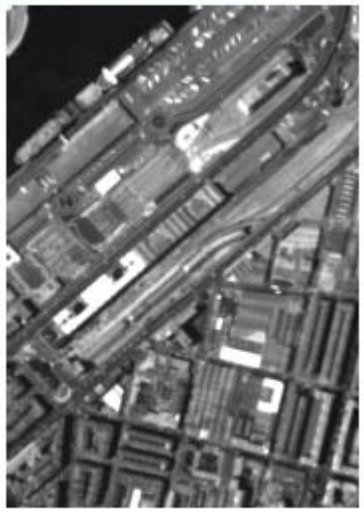
ONERA

INTRODUCTION

What is MTF ?

- **M**odulation **T**ransfer **F**unction
- Description of the ability of the sensor to restitute details of the observed landscape
- Application of theory of linear and invariant system to a camera

INTRODUCTION



« poor » MTF

« good » MTF

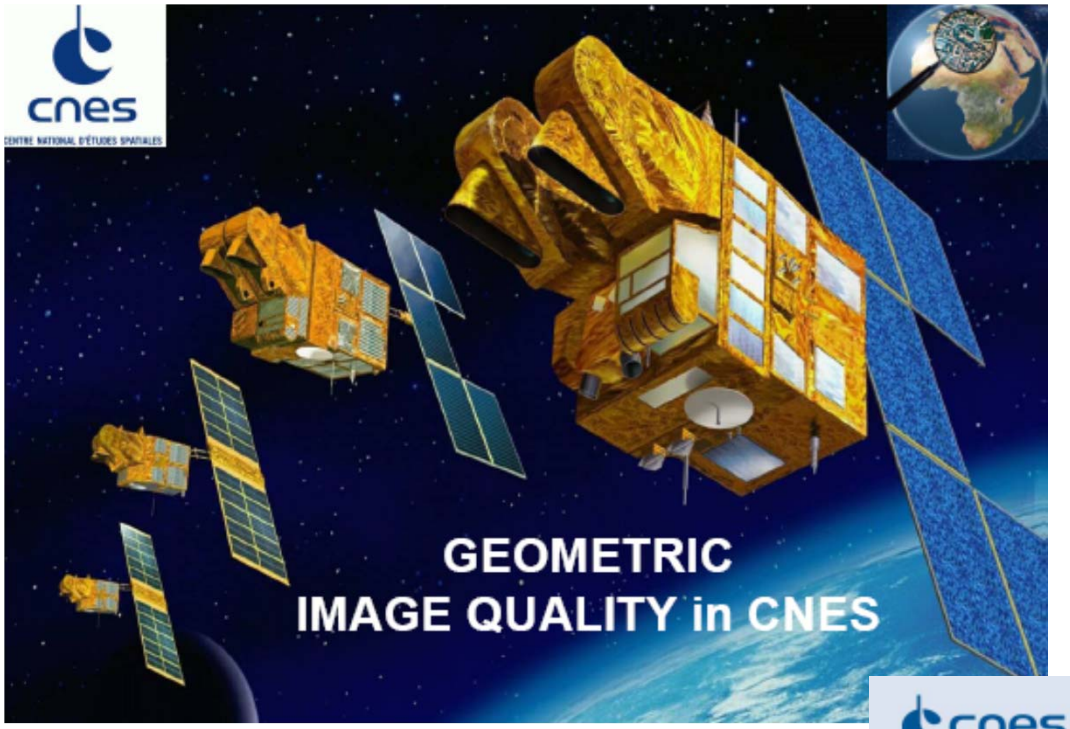
CONCLUSION

Importance of MTF for high resolution imaging systems in terms of :

- Comparison of imaging systems
- Impact on process such as classification
- Calibration methods relying on artificial targets

Interest to gather people working on MTF together : within the CEOS/IVOS frame ?

NEW activity led by D Helder SDSU Agencies interested to participate



Need to standardise on terminology and methods

Also realism of specifications

Identified as an area for collaboration and best practise

Need for a lead

IVOS

cnes

Plan

- **Introduction:**
  - Image geometry: definition
  - Geometric image quality in CNES
  - GIQ criteria and requirements
  - Geometric modelling of image acquisition
- **In-flight geometric image quality:**
  - Geometric calibration
  - Performance assessment
- **Geometric data base**
  - GCPs GIQ sites
  - Example of SPOT GIQ sites
  - Supersite
- **Examples of geometric calibration and performance assessment**
  - SPOT HRS alignment biases monitoring
  - SPOT HRS location performance assessment

IVOS technical workshop

Planning starting for next IVOS technical workshop

Spring 2013

Topic: Pre-launch and on-board calibration of satellite sensors

Recommendations

- **Formed thematic focus group on :**
  - **Geo/spatial Quality**
  - **Geometric Image quality**

  Agencies to support with experts need lead for geometric Image quality

- **Encourage Sensor providers to have consistent and adequate set of metadata in header to enable ease of interoperabilty**

- **Encourage pre-flight characterisation and its reporting of sensor PSF/MTF**

- **Agencies to populate comparison data base on Portal**

- **Agencies to identify a POC for each sensor**

1. **All CEOS endorsed reference standard sites should be incorporated into regular acquisition progammes of all appropriate sensors and the resultant data sets/results made available through the CEOS cal/val portal.**
2. **Agency (ies) to establish plans for an OC surface sites pilot comparison followed by a CEOS comparison in the timescale of 2013? .**