2nd December, 2013

Vicarious Calibration of OC Sensors Through Statistical Methods over Natural Targets

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Summary

- Introduction and context
- Multi-method calibration
- Overview of calibration methods
- What can be learned ?
- Conclusion

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Introduction and Context

- In the past years, several calibration methods were developed using natural targets
  - various calibration methods, different approaches
  - operational configuration now available
- In the past years, several sensors provided extensive calibration time series
  - a large experience has been developed on the use of each method
  - a feedback exists on the real advantage and limitations
- IOCCG Report#13
  - all possible efforts must be done to reach the best calibration as possible for level-1 products
  - a final adjustment is still needed through a System OC Vicarious Calibration to reach the final accuracy (~0.5%)
  - this System OC-VicCal is a combination of
    - a residual calibration inaccuracy
    - a residue from atmospheric correction
- Today, no calibration method has the ability to do better than the System OC-VicCal
- But the combination of methods can take benefit of each method
- The synergy can be used to reach a validation of System OC cal

Overview of Calibration Methods

Basic approach = compute ratio

Measured / Predicted

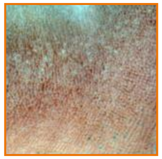
+ Statistics

Map of Calibration approaches

→ All are statistical approaches

- **Absolute calibration over <u>Rayleigh</u>** (Hagolle et al., 1999, Fougnie et al., 2010)
  - reference = Rayleigh scattering (~90% of TOA signal after selection)
  - selected oceanic sites + very non-turbid situations
  - calibration over a wide range of the fov (exc. sunglint) for VISIBLE range

- **Cross-calibration over <u>desert</u>** (Lachérade et al., 2013)
  - Use of pseudo-invariant sites : 20 desert sites - REFLECTIVE bands
  - reference = one sensor (i.e. MODIS or MERIS) or one date
  - 2 main steps : geometrical matching (no simultaneity req.) + spectral interpolation



- **Interband calibration over <u>sunglint</u>** (Hagolle et al., 2004)
  - use of the “white” reflection of the sun over ocean – REFLECTIVE range
  - selected oceanic sites + very non-turbid situations
  - reference = one spectral band (red band around 620-660nm)

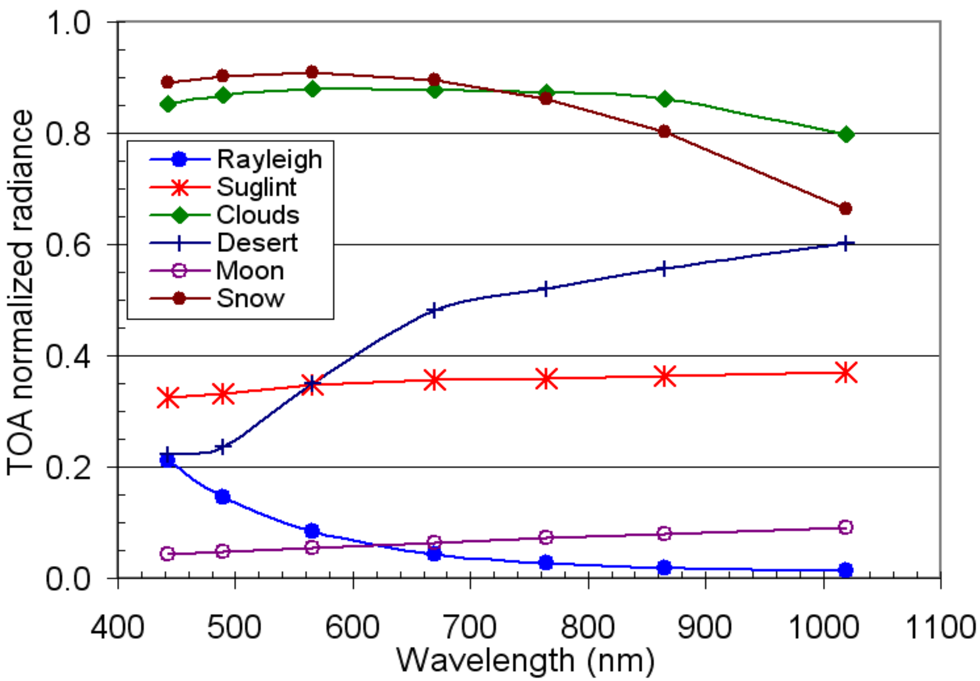
- **Cross-calibration over <u>Antarctica</u>** (Six et al., 2004; Lachérade et al., 2013)
  - Use of pseudo-invariant sites : 4 snowy sites (inc. Dome C)
  - Same as desert sites for VIS-NIR bands

- **Interband calibration over <u>DCC</u>** (Fougnie et al., 2009)
  - use of the “white” reflection of the deep convective clouds – VISNIR range
  - selected very dense and scattering clouds
  - reference = one spectral band (red band around 620-660nm)

Outlines, strengths, limitations

- **Several calibration methods are operational**
  - **Desert, Rayleigh, Sunglint, Cloud-DCC, Antarctica, Moon**
- **Each target has its own behavior :**
  - **Magnitude: from very dark to very bright**
  - **Spectral shape : from white to very pronounced**
  - **Angular signature : from nearly uniform to large BRDF**
  - **Polarized properties : from non-polarized to nearly fully polarized**
  - **Short-term stability : from variable to fully stable**
  - **Long-term stability : from seasonal variable to fully stable**
  - **So efficiency range …**

Indicative behavior of targets



Indicative Classification of Calibration approaches Synergy

- **So the observation is :**
  - **Calibration methods are like "Bordeaux Wines" : every method is good**
    but in fact, all the methods show limitations
  - **it is impossible to address all calibration/radiometric aspects with one single method**

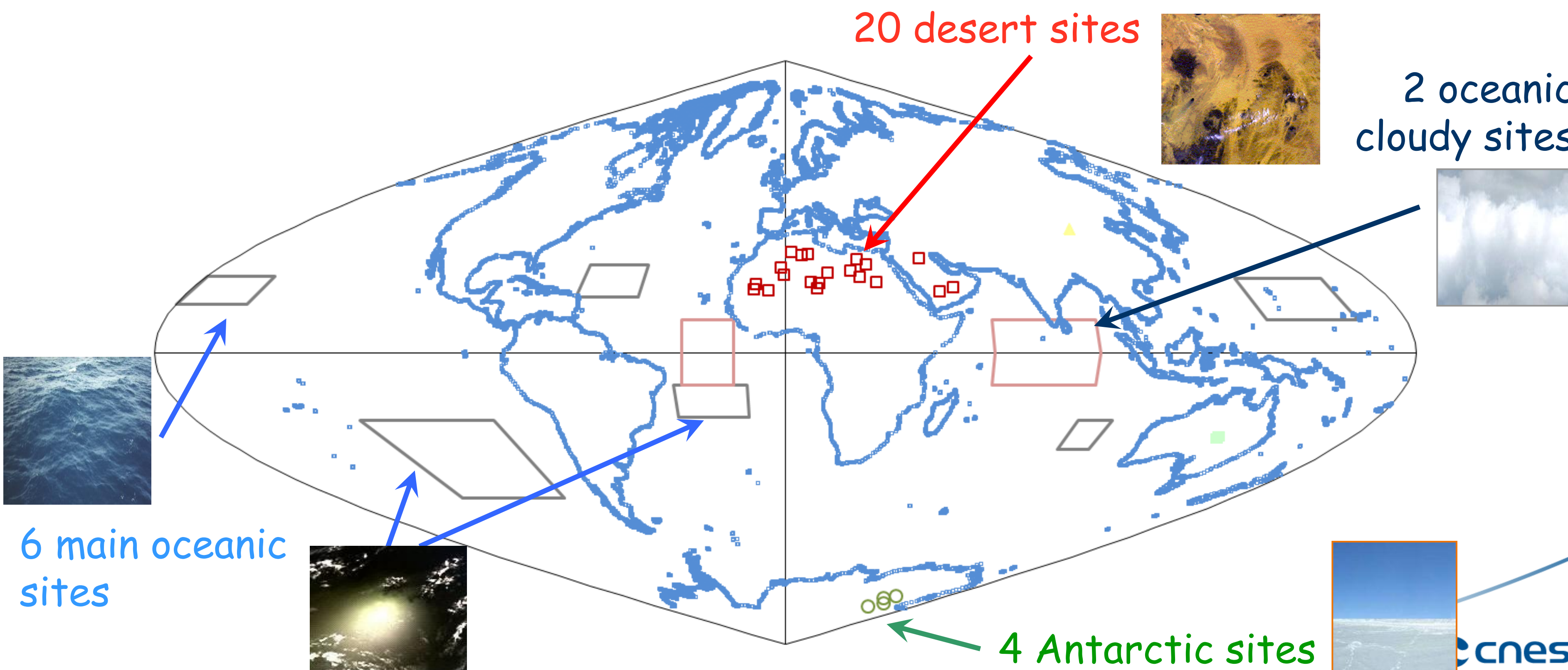
- **Basic idea = develop the synergic use of several method in order to :**
  - **take advantage of the complementarities of all method**
  - **document the confidence from consistency between methods**
  - **improve the "system calibration" when integrating various results**
  - **assess radiometric aspects others that the absolute calibration**

- **"Indicative" cartography – range of efficiency for each method**

Method	Absolute	Interband	Monitoring	Cross-calibration	Within FoV	Reference
Desert		possible	VIS/NIR/SWIR	VIS/NIR/SWIR	possible	1 sensor/date
Rayleigh	VIS		possible	possible	VIS	Rayleigh
Sunglint		VIS/NIR/SWIR	possible			1 band
Domes		possible	VIS-NIR	VIS/NIR		1 sensor/date
DCC		VIS/NIR	VIS/NIR	possible	VIS/NIR	1 band
Synergy	VIS	VIS/NIR/SWIR	VIS/NIR/SWIR	VIS/NIR/SWIR	possible	various

Data Collection

- **Geographically**
  - **Very wide range of location : lat/lon, N/S, land/ocean, large/small areas**
- **Geometrically**
  - **Very wide range of configuration : solar geometries, viewing geometries**
- **Geophysically**
  - **Very wide range of situations : aerosol, surface (type, stable/seasonal), gas**



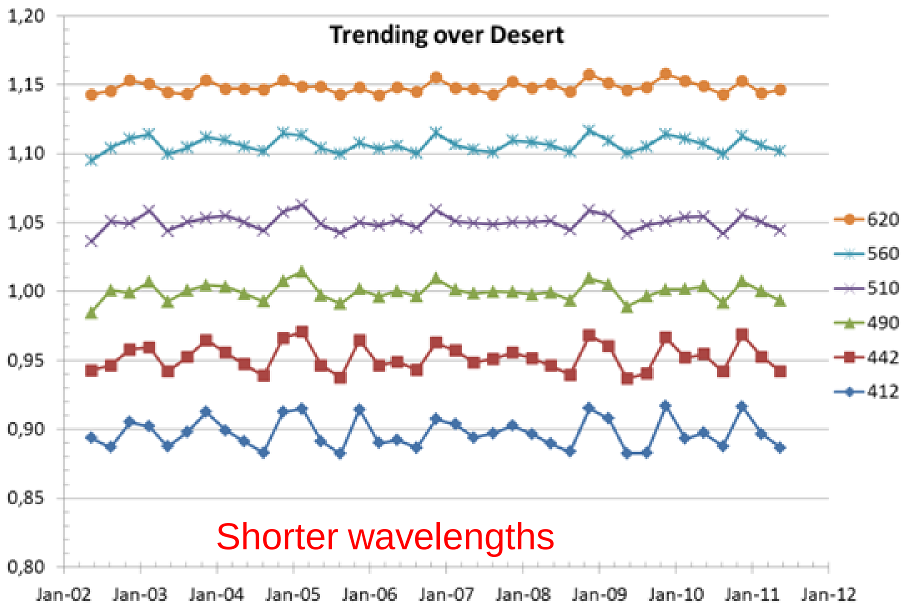
What can we learn

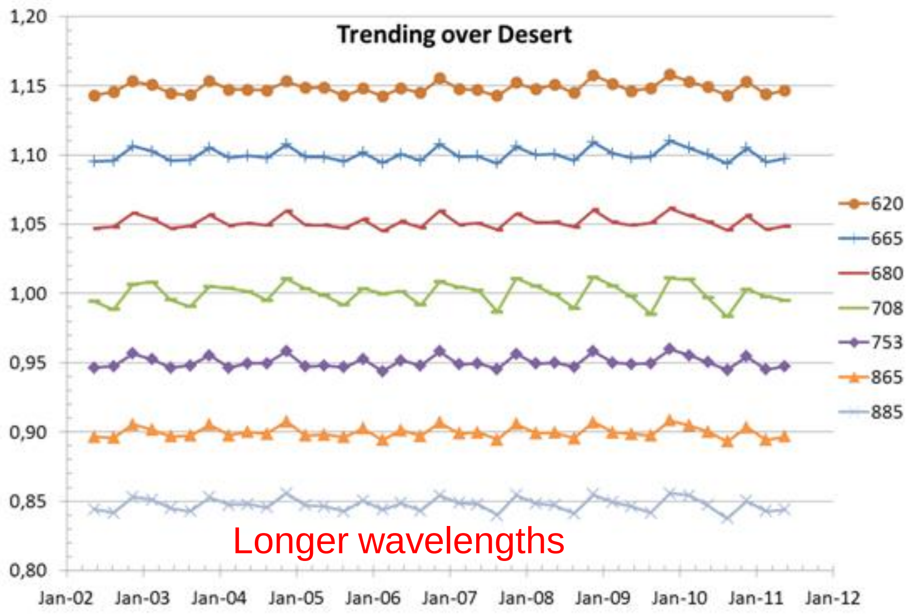
through these

statistical vicarious calibration methods ?

Temporal consistency of time series

- Stability as seen by cross-calibration **over desert sites** (acc. Lachérade et al., 2013)
  - » Perfect long-term stability
  - » Seasonal variations (±1%) are due to periodical change on geometrical configurations





Cross-calibration MERIS with PARASOL - Time series

(Bands are shifted by 0,05 steps for clarity)

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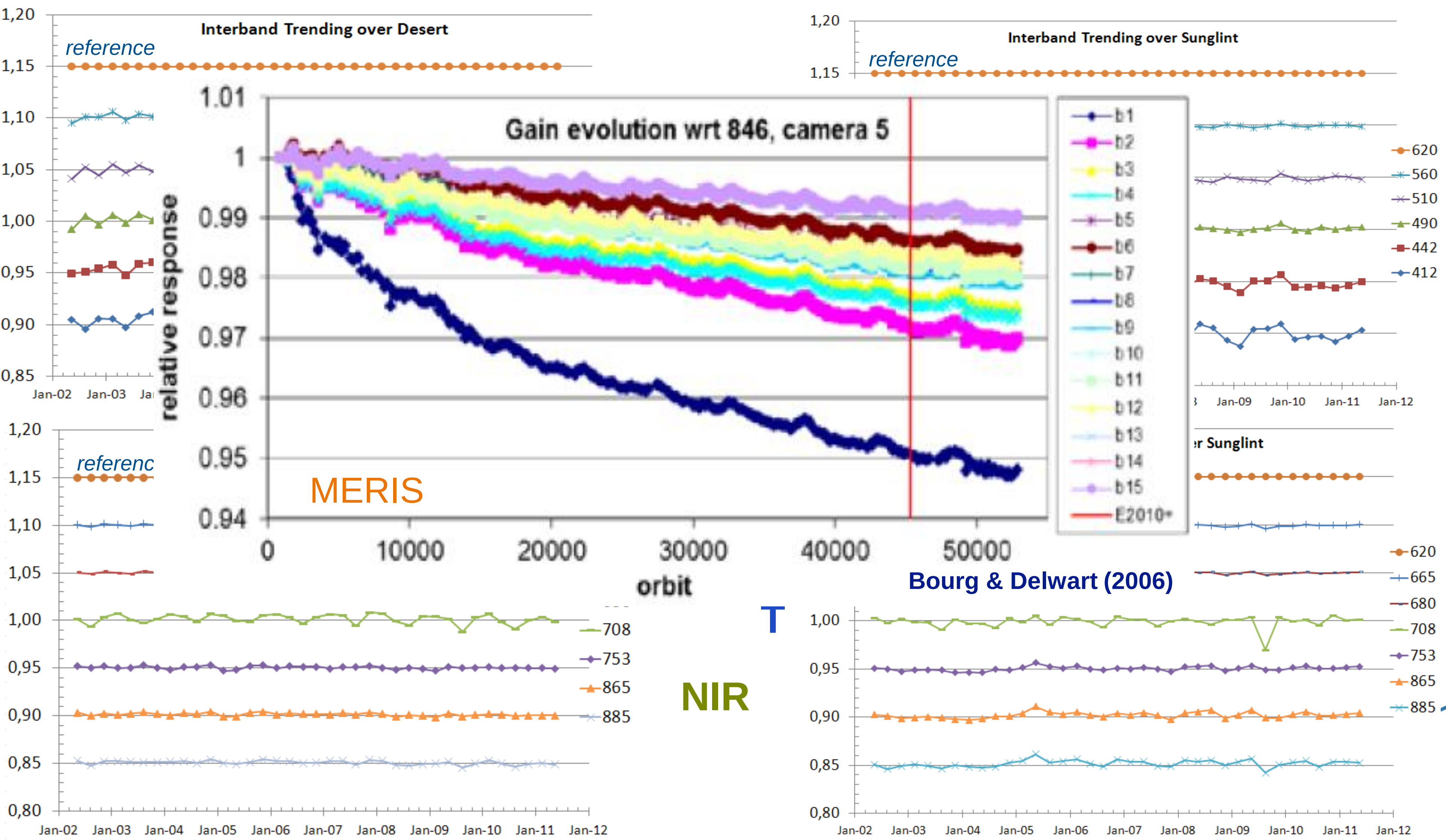
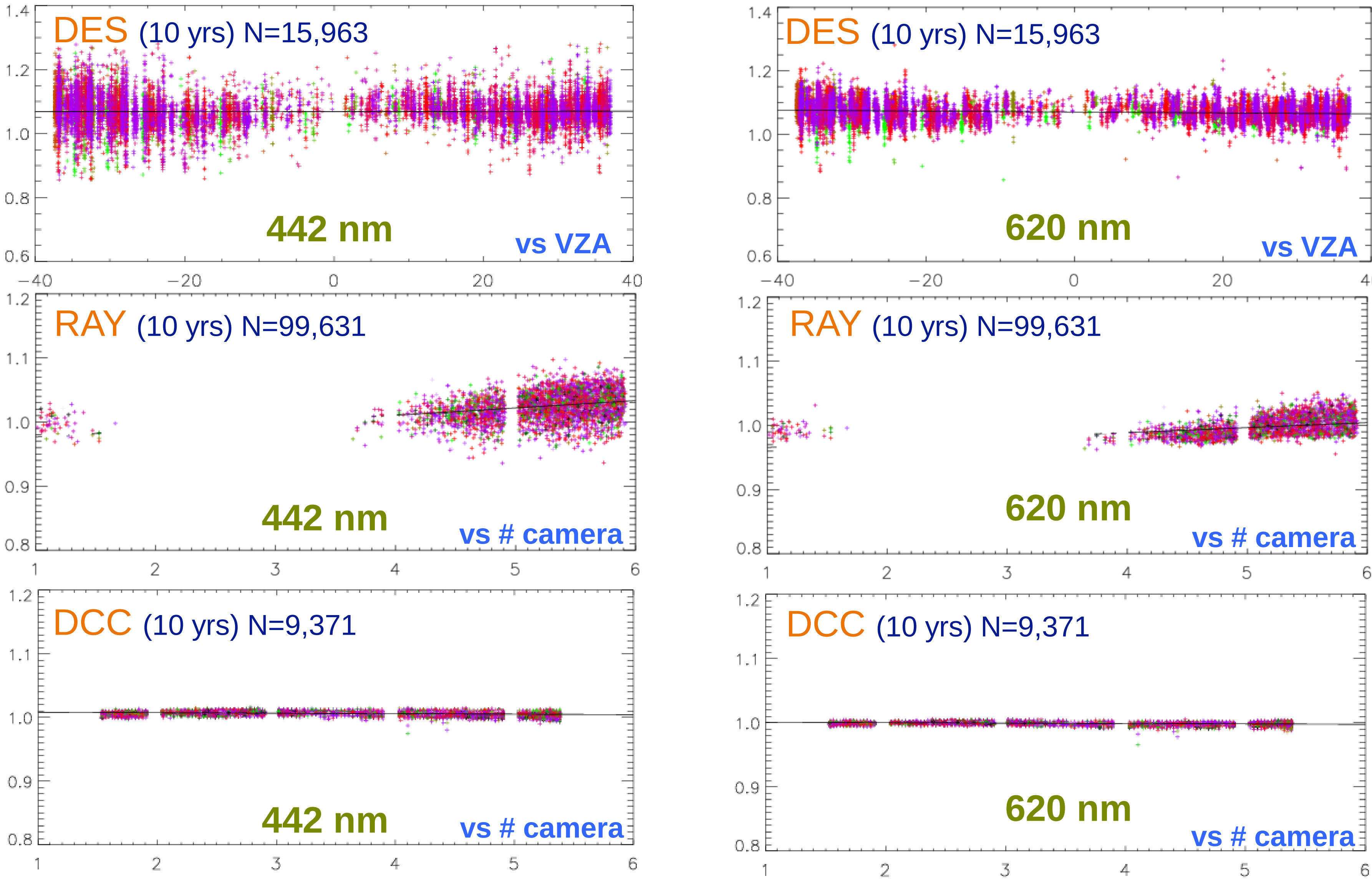
Temporal consistency of time series

- Interband Stability as seen by **Sunglint and Desert sites**
  - » Perfect long-term and short-term stability (±0.2%)



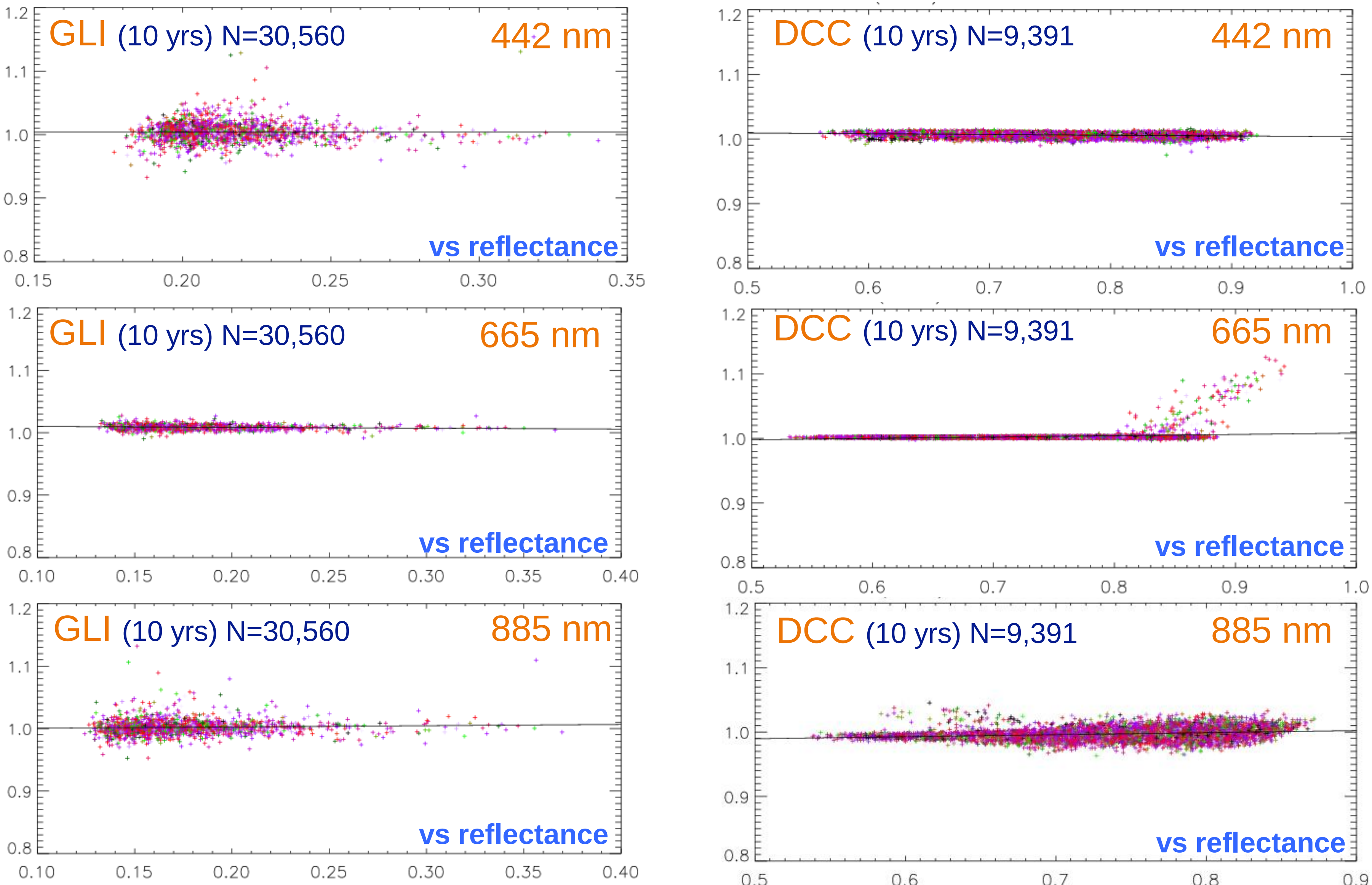
Consistency within field-of-view

- Behavior within fov as seen by **Desert, Rayleigh and DCC**
  - » No significant variation, except for Rayleigh (TBC it is an artifact…)



Spectral consistency - VISNIR

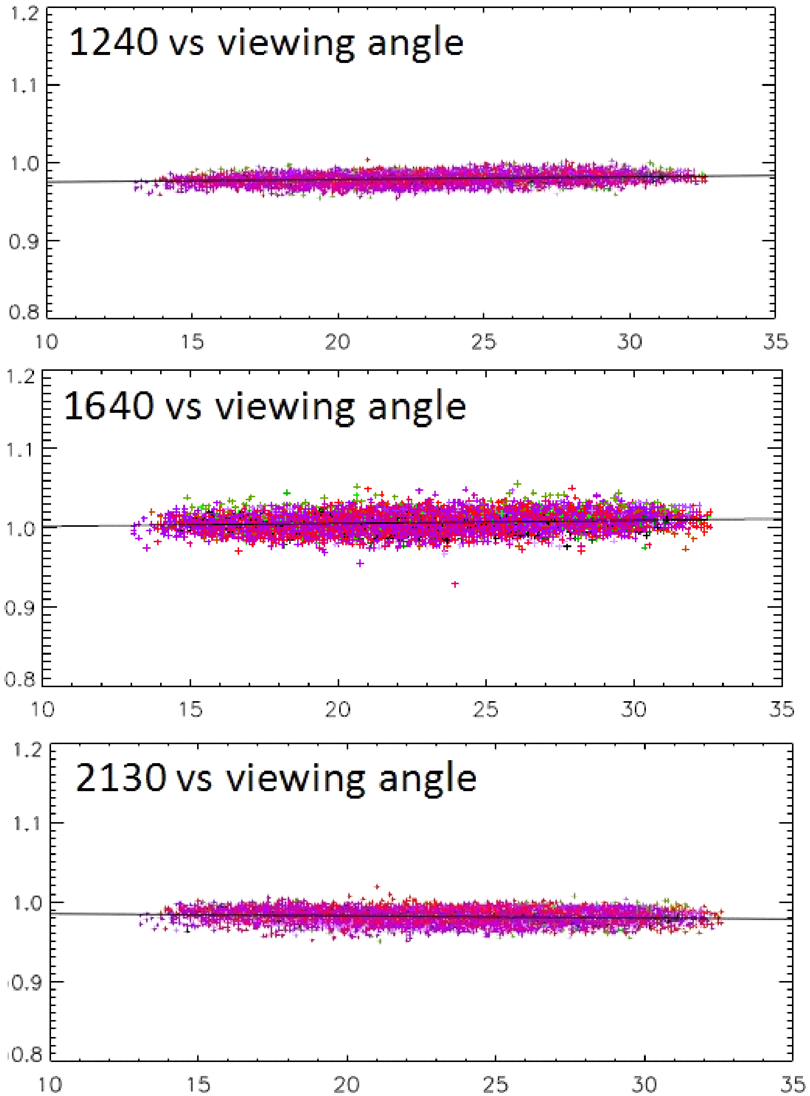
- Interband over **Sunglint, and DCC**



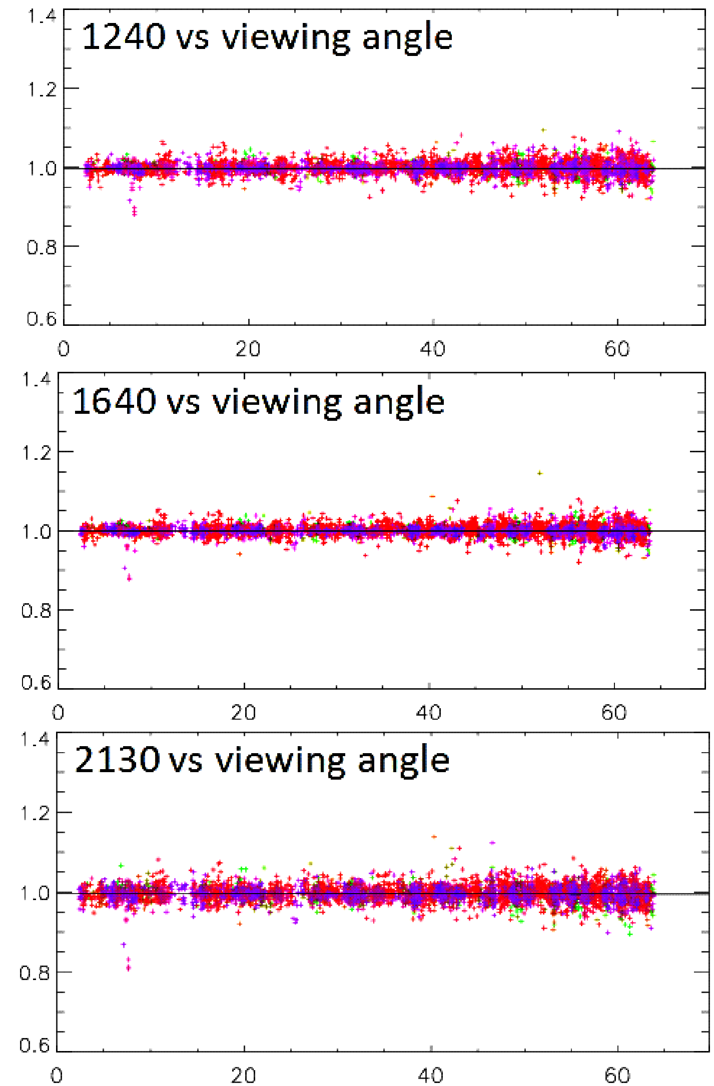
Spectral consistency – Extension to SWIR

- Interband over **Sunglint, and Desert – Application to MODIS**

GLI (Dec 2003 - N=7,861)

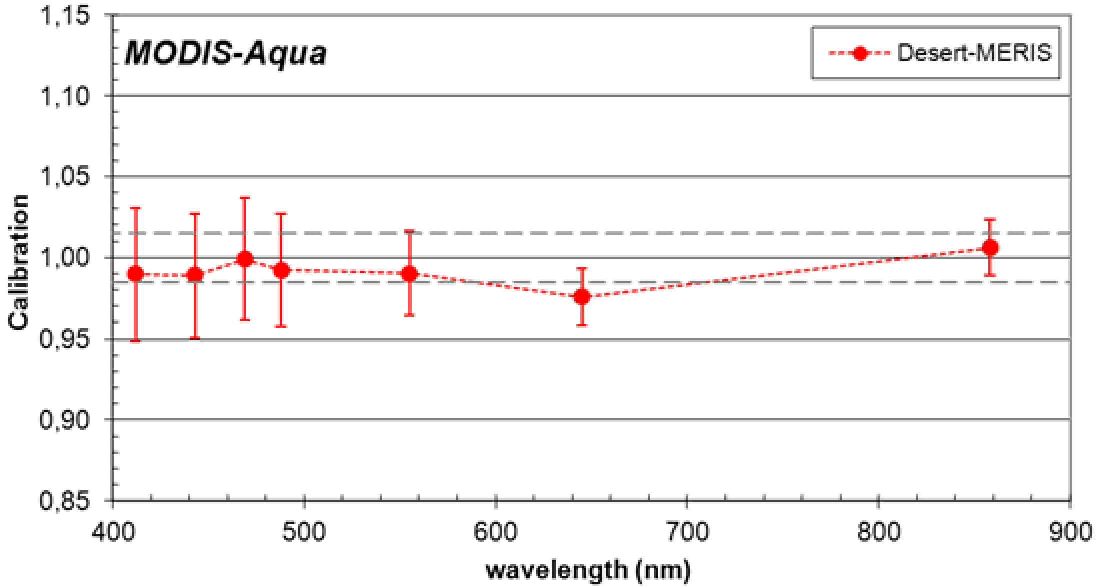


DES (2003 - N=4,839)



Consistency with other sensors

- Cross-calibration over **Desert sites**
  - » MODIS bands saturate over desert site
  - » Only 412, 443, 469, 488, 555, 645, and 858
  - ✦Henry et al. (IEEE, 2013) have documented the spectral errors of the method
    - ✦MODIS calibrated over MERIS is presented (instead of MERIS vs MODIS)
  - » Very good agreement within 1.5%



Cross-calibration of MODIS-Aqua using MERIS as reference.

Band	412	443	469	488	555	645	858
mean	0.990	0.989	0.999	0.992	0.990	0.976	1.006
stdev	0.040	0.038	0.037	0.035	0.026	0.017	0.017

MODIS reflectances lower by 1-1.5%

But very close to the accuracy of method

→ Very good consistency

→ also available : MERIS using MODIS as reference

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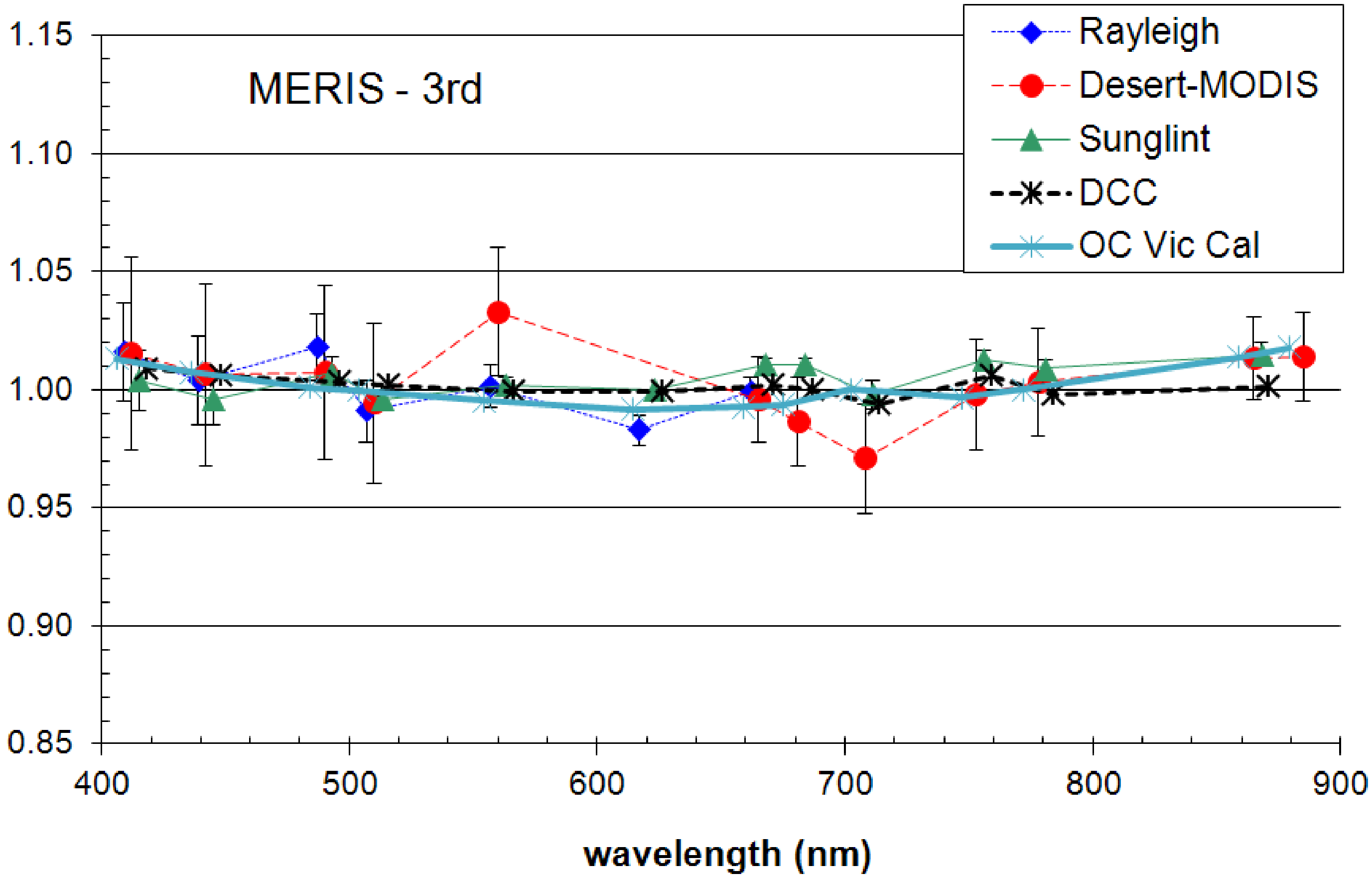
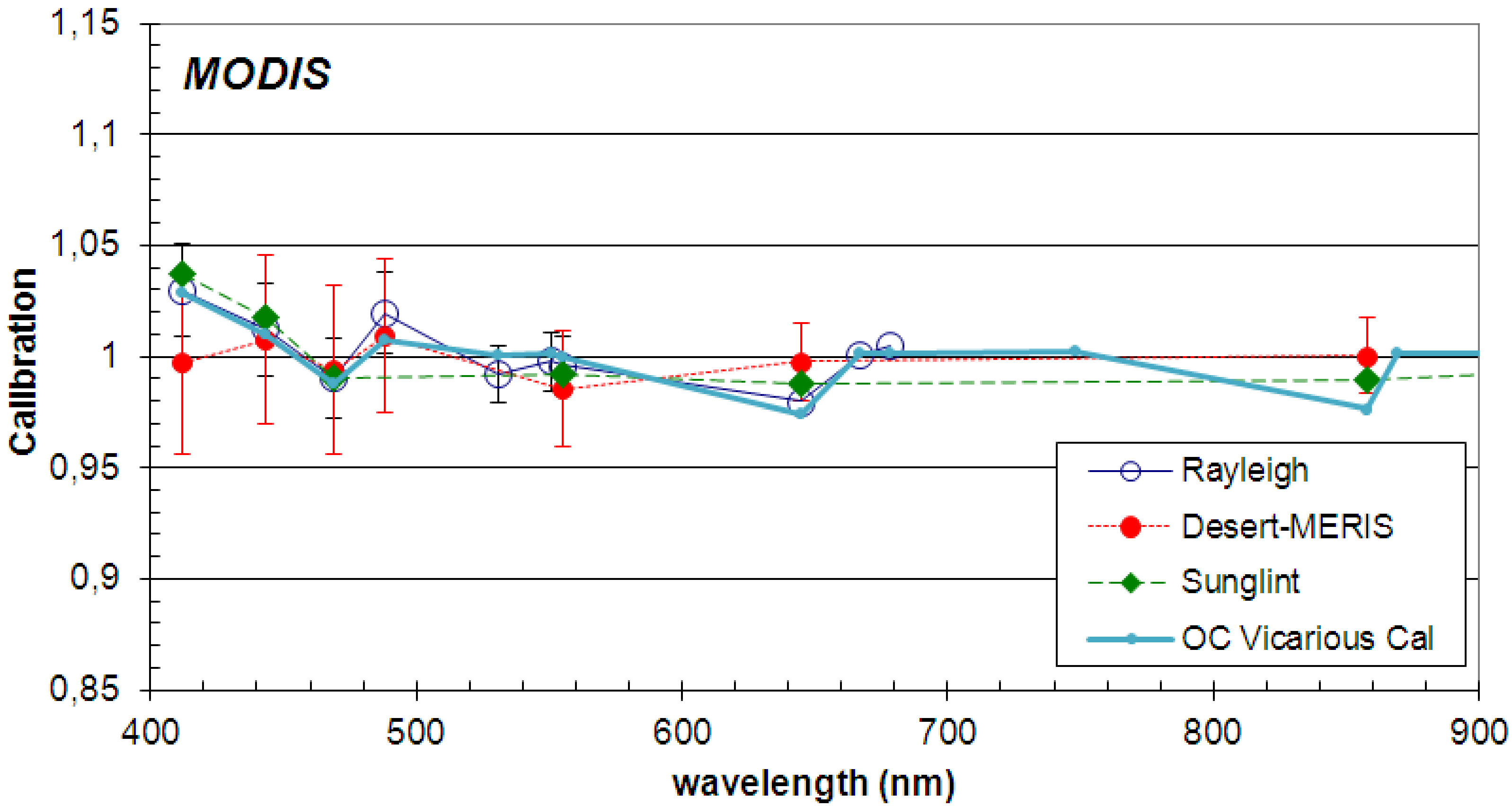
Absolute and Interband from Synergy

- General comparison using all results
  - Agreement – validation within 1-2%
  - Some light discrepancies : 1/ known or 2/ unknown limitation from method, or 3/ significant signature
  - Compared to System OC Vicarious Calibration



Absolute and Interband from Synergy

- General comparison using all results – SAME for MODIS-AQUA
  - Agreement – validation within 1-2%
  - Some light discrepancies : 1/ known or 2/ unknown limitation from method, or 3/ significant signature
  - Compared to System OC Vicarious Calibration



Summary

- System OC VicCal is needed and is a complex mix of :
  - a calibration residue
  - an atmospheric correction residue
- System OC VicCal is established on a limited number of location (but of course very well characterized and accurate)

- It could be possible to confirm the System OC VicCal through a synergic approach using multiple statistic calibration method

- This would be useful to :
  - evaluate the proportion between calibration // atmospheric residues
  - conclude the calibration error is dominant (or not)
  - help to interpret the behavior of the System OC VicCal
  - help to extend the confidence on the System OC VicCal at the global scale

Acknowledgments
Collection of data + calibration results

ESA : MERIS data
ACRI-ST : preprocessing
NASA : SeaWiFS data
ICARE and NASA : MODIS data

Other various supports from
ACRI-ST : L.Bourg, V. Bruniquel, G. Fontanilles
CS-SI : B. Lafrance
HYGEOS : D. Jolivet
CAP GEMINI : L. Gross-Colzy, S. Angeli

Thank you !

Back up Slides

Operational Configuration - MUSCLE / SADE

Operational Environment = SADE + MUSCLE

SADE **= Measurement & Calibration Data Repository**

- **Database**
- **3 steps : measurements // elementary calibration result // synthesis results**
- **Various methods for VIS-NIR-SWIR range**
- **Easy data management & traceability**
  - **product identifier, calibration version**
  - **acquisition conditions : dates, geometries, meteorological data**
  - **tool version, processing date and parameters…**
  - **SADE identifier**

MUSCLE **= Multiple Methods Calibration tools + Front-end Graphic**

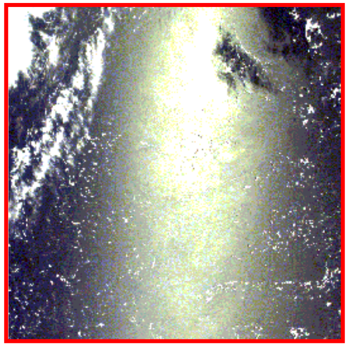
- **Calibration Tools**
- **3 steps : extraction-insertion // calibration // synthesis**
- **Various methods for VIS-NIR-SWIR range**
- **Common calibration tools for all sensors**

Multi-methods Calibration Operational Configuration SADE / MUSCLE

(Database) / (Tools)

Deserts

Snow



Sun Glint

Rayleigh

Moon

Clouds