CENTRE NATIONAL D'ÉTUDES SPATIALES

MODIS-Aqua Calibration as seen by Alternative Statistical Methods over Natural Targets

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Summary

- Introduction
- Reminder for calibration approaches
- Results :
  - over Desert sites
  - over Rayleigh
  - over Sunglint
  - trending analysis
- Synergic analysis
- Further analysis and Conclusion

Introduction - What's behind "Calibration"

- Calibrate a sensor = estimate the A or ΔA coefficients
  - NC = digits
  - MI = Measured radiance
  - CI = Estimated radiance = reference

$$NC = A.MI$$

$$\Delta A = \frac{MI}{CI}$$

→ any difference between MI and CI is assumed to be a calibration error on A

→ but can also be explained by :

- existing errors on CI : i.e. the calibration method accuracy
- many contributors, other than A, could explain why MI is not predictable by CI
  - general formulation for a radiometric model (sometimes very complex)

$$NC_{lp} = \left(\frac{Es}{\pi}.G.t\right).A.g_{lp}.SL_{Xlp}.NL.\left[P1_{lp}.I + P2_{lp}.Q + P3_{lp}.U\right] + SL_{\Sigma Xlp} + C_{lp}$$

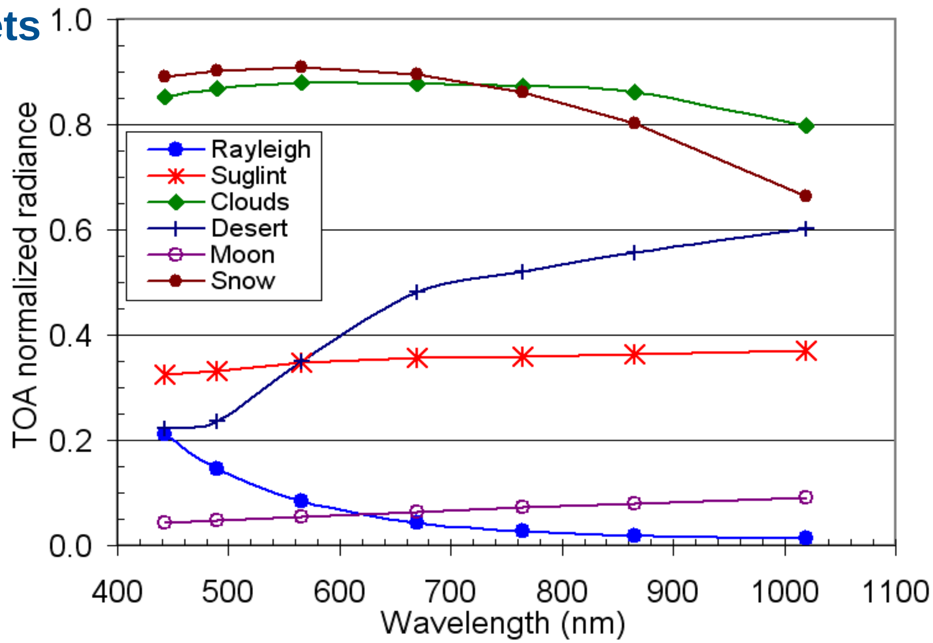
- *Absolute Calibration* (A)
- *Equalization Variation in fov* (g_{lp})
- *Straylight Correction (proportional)* (SL_{Xlp})
- *Non-linearity correction* (NL)
- *Polarization correction* ($P1_{lp}$, $P2_{lp}$, $P3_{lp}$)
- *Straylight Correction (additive)* ($SL_{\Sigma Xlp}$)
- *Dark current correction* (C_{lp})

+ additional terms...

What's behind "Calibration"

- **What appends in the instrument (MI) VERSUS What is assumed (CI)**
  - error in dark current, straylight, non linearity : bias on A derived from bright/dark targets
  - error in polarisation : bias on A derived from polarized/unpolarized targets
  - error in the inter-pixel, or in FOV : bias on A derived from different geometries
  - error in the spectral response knowledge : bias on A derived from different targets

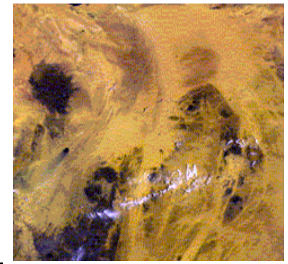
- **Interest to combine multiple calibration targets**
  - from dark to very bright
    - in VIS, and/or NIR, and/or SWIR
  - very different spectral shapes
    - from Rayleigh (λ-4)
    - to white spectrum
    - to desert spectrum
  - other characteristics
    - from polarized to unpolarized
    - from Lambertian to directional



The CNES's Operational Arsenal

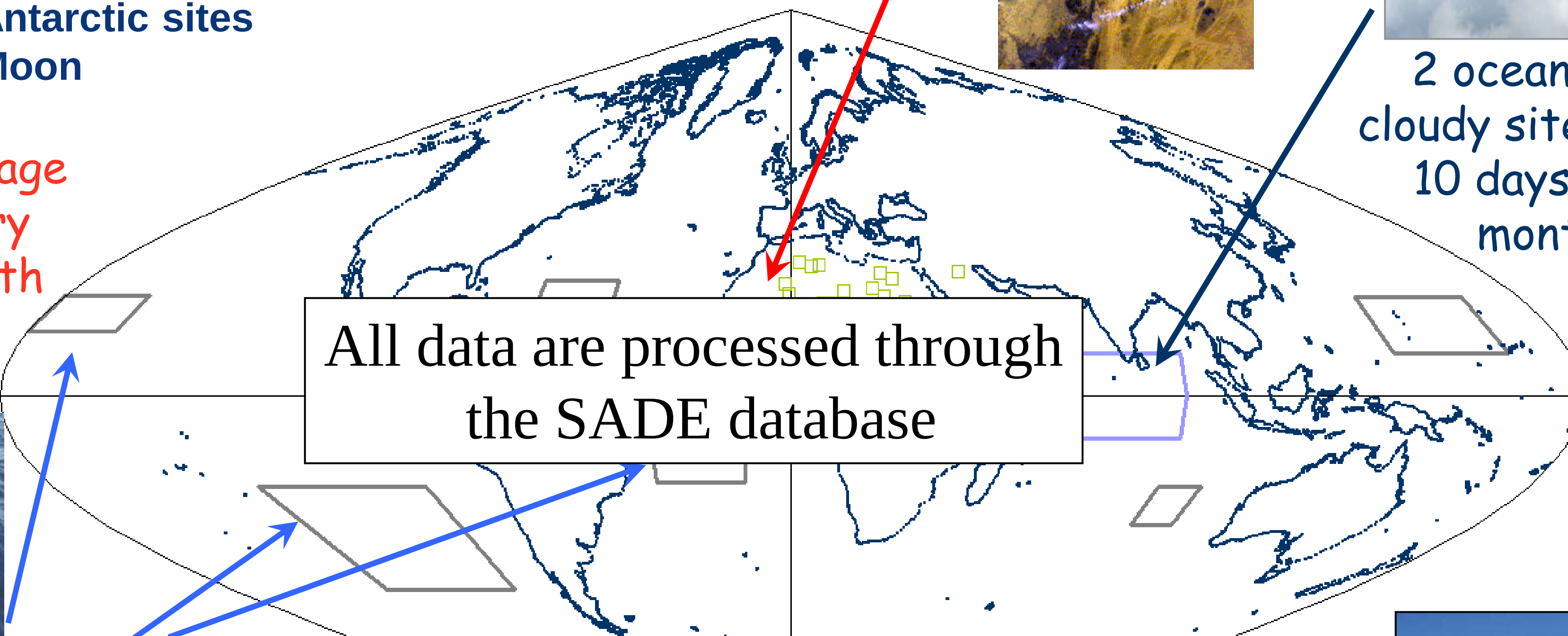
- Rayleigh Scattering
- Deep Convective Clouds
- Sunglint
- Desert sites
- Antarctic sites
- Moon

1 image every month



20 desert sites every day

2 oceanic cloudy sites 10 days / month



All data are processed through the SADE database

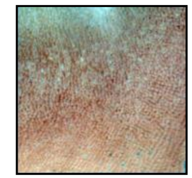
6 main oceanic sites 10 days/month

4 Antarctic sites every day during 3 months

Reminder - Calibration Approaches

- **Absolute calibration over Rayleigh** (Hagolle et al., 1999, Fougnie et al., 2010)
  - Rayleigh scattering predictable
  - reference = Rayleigh scattering (~90% of TOA signal after selection)
  - selected oceanic sites
  - calibration of all geometries (exc. sunglint) for VISIBLE range

- **Cross-calibration over desert** (Lachérade et al., 2013)
  - Use of pseudo-invariant sites
  - reference = one sensor or one date
  - 20 desert sites
  - 2 main steps : geometrical matching (no simultaneity req.) + spectral interpolation



- **Interband calibration over sunglint** (Hagolle et al., 2004)
  - use of the “white” reflection of the sun over ocean – reflective range
  - reference = one spectral band
  - selected oceanic sites
  - sunglint not predicted but estimated using one band

→ All are statistical approaches

Reminder - Calibration Approaches

- **Absolute calibration over Rayleigh** (Hagolle et al., 1999, Fougnie et al., 2010)
  - Rayleigh scattering predictable
  - re
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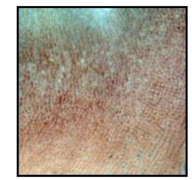
- **Cross**
  - U
  - re
  - 2
  - 2 … nterpolation



- **Interb**
  - u
  - reference = one spectral band
  - selected oceanic sites
  - sunglint not predicted but estimated using one band

Here MODIS, but see also other applications :

- Pleiades in Lachérade et al.
- SPOT6 in Gamet et al.
- PARASOL in Fougnie et al.

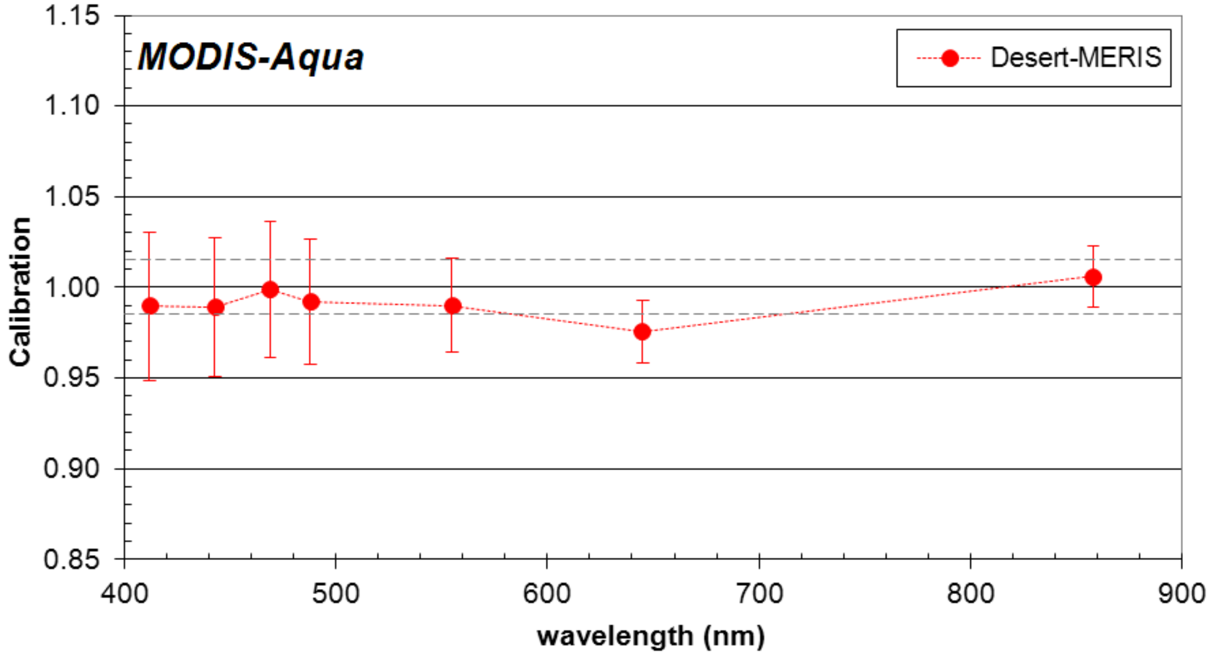
…all in CALCON 2013

→ **All are statistical approaches**

Cross-calibration over Desert sites

- **Cross-calibration with MERIS**
  - **MERIS = good radiometric reference + rich spectral coverage (VISNIR)**
  - **MODIS archive 2003-2011 :**
    - **Level-1 from Collection 5**
    - **saturation for OC bands**
  - **Good accordance within 1%**

Band	*DESERT*
412	0.999
443	0.998
469	1.008
488	1.001
531	
551	
555	0.999
645	0.984
667	
678	
748	
858	1.015
869	



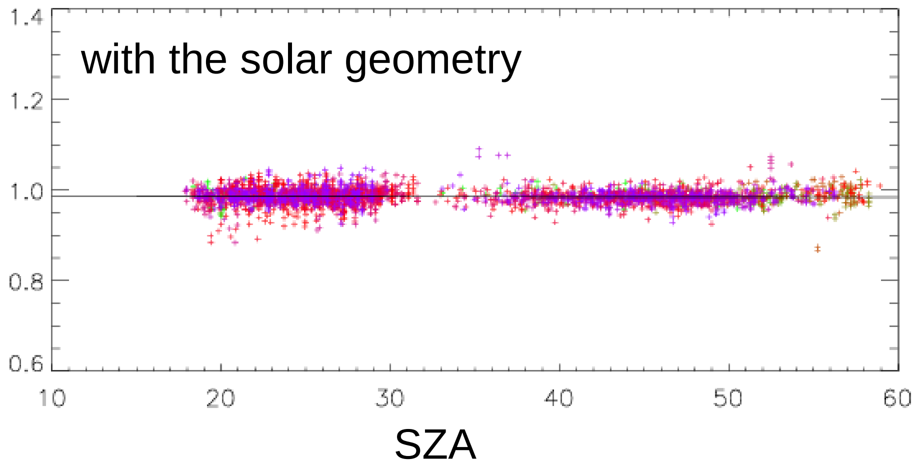
Matchups from Lachérade et al. (2013) with spectral correction from Henry et al. (2013)

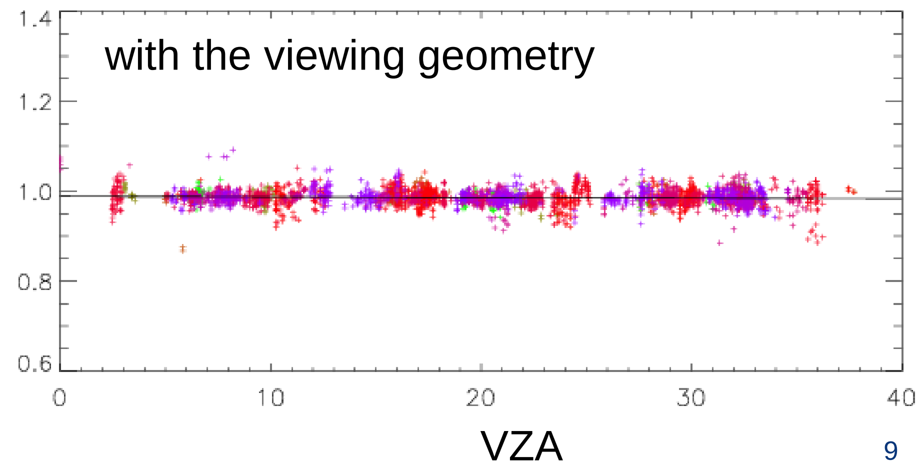
Cross-calibration over Desert sites

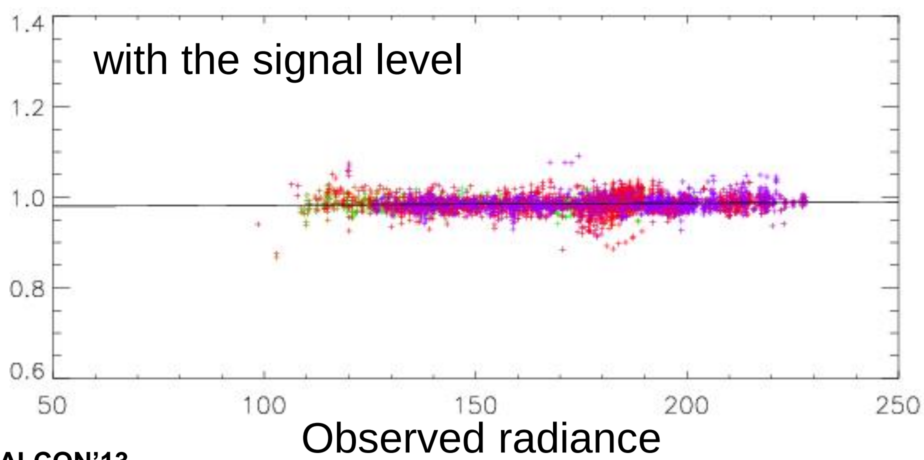
- **Consistency of the cross-calibration with parameters**

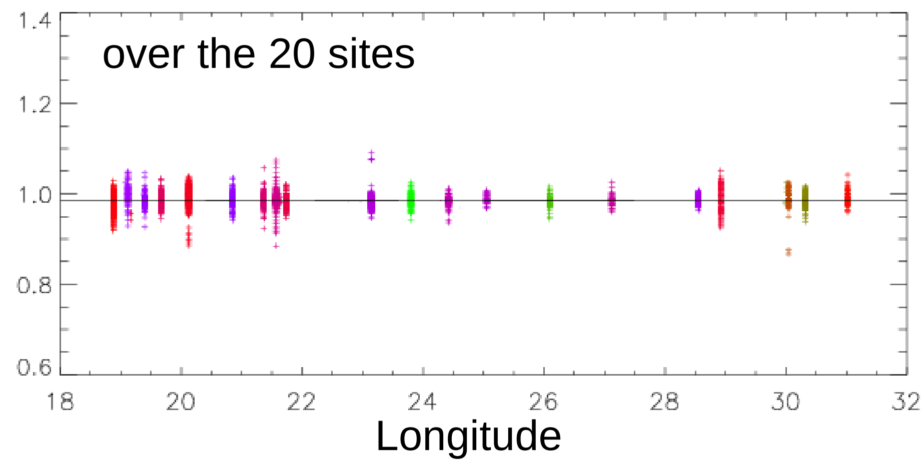
Band#1- 645nm

2002-2011







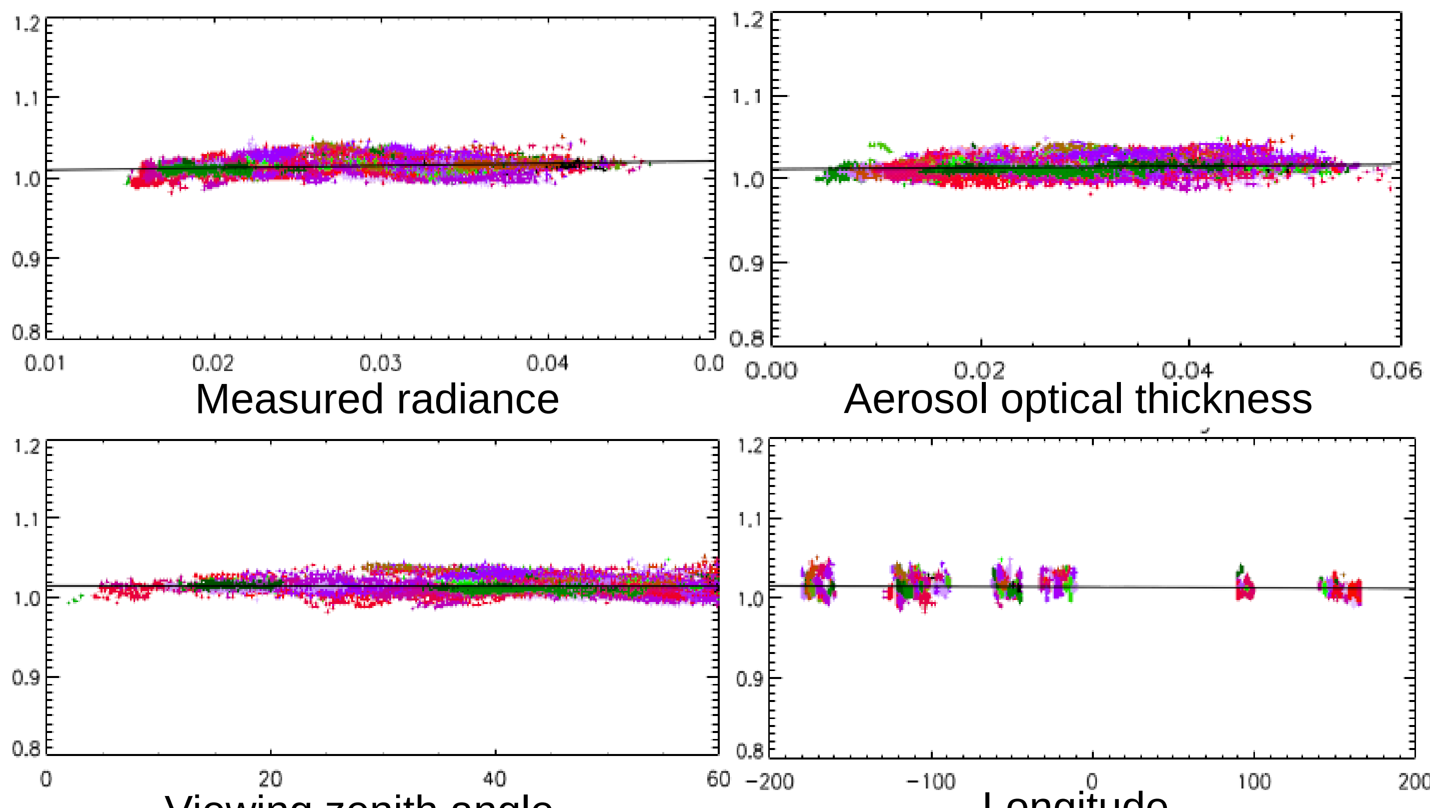


Calibration over Rayleigh Scattering

- **Ratio observed / computed reflectances – absolute evaluation for VIS bands**
  - **MODIS : all bands from 412 to 678nm**
  - **level-1 from Collection 6**
  - **consistency within 2%**
  - **bias for B1-645nm**
    - **significant**

Band	*RAYLEIGH*	
412	0.981	0.019
443	1.001	0.019
469	1.023	0.016
488	1.013	0.016
531	0.999	0.012
551	1.003	0.012
555	1.005	0.011
645	1.042	0.010
667	1.006	0.010
678	1.012	0.010

Band#1- 645nm Dec-09 to June-10



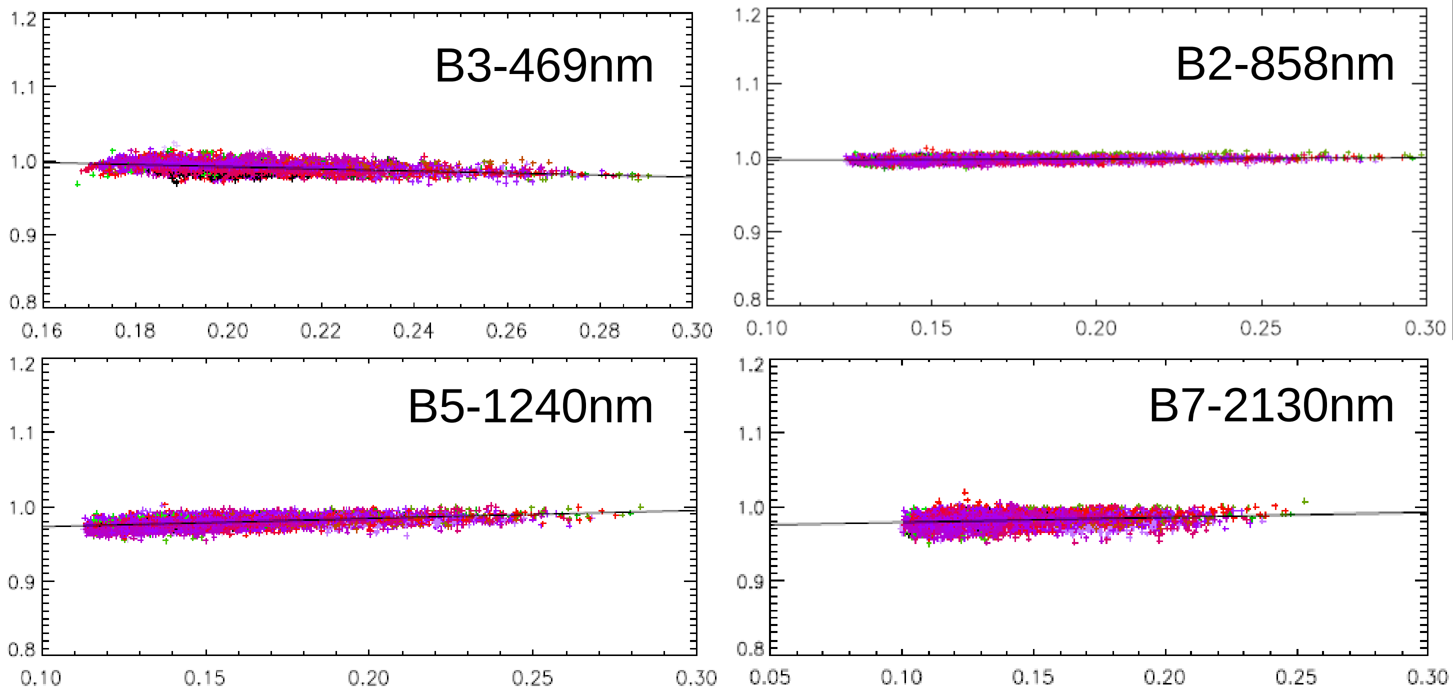
Calibration over Sunglint

- **Ratio observed / computed – interband for the whole reflective spectral range**
  - **MODIS : all bands from 412 to 2130nm – using a reference band (645nm)**
  - **level-1 from Collection 6 – saturation for some OC bands**
  - **consistency within 2% but significant bias for B01-645nm**

Band	*SUNGLINT*		
412	0.941	(0.013)	0.979
443	0.957	(0.011)	0.995
469	0.974	(0.008)	1.013
488			
531			
551			
555	0.952	(0.004)	0.990
645	1.000		1.040
667			
678			
748			
858	0.997	(0.006)	1.036
869			
1240	0.968	(0.009)	1.007
1640	0.986	(0.014)	1.025
2130	0.979	(0.012)	1.018

As a function of measured reflectance

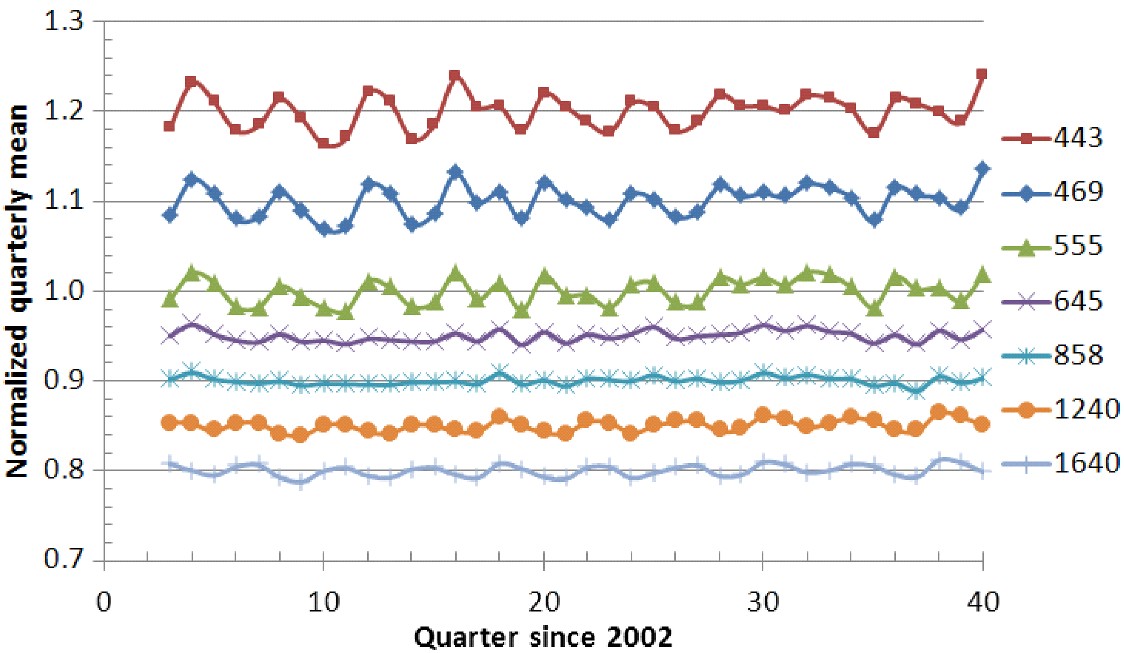
Dec-03

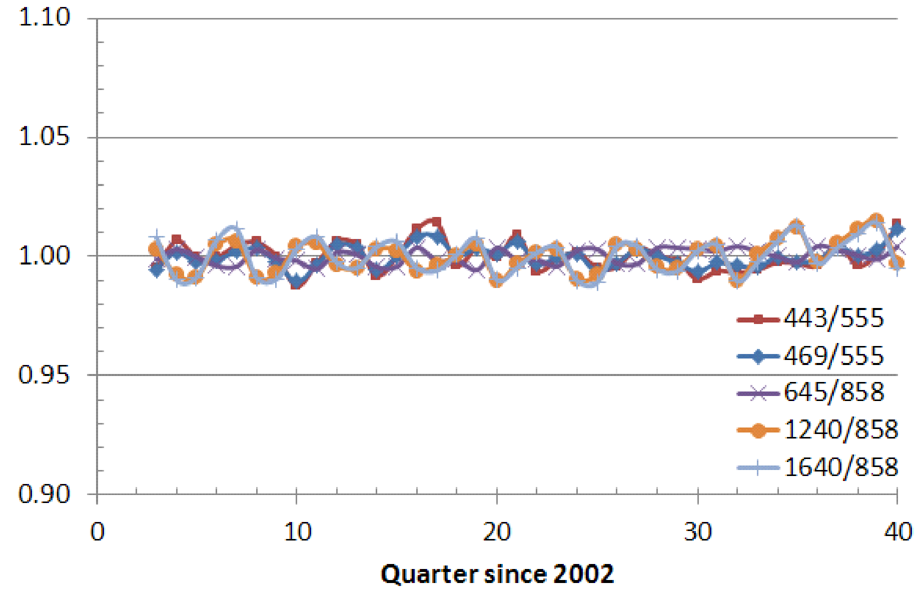


Validation of the trending

- Time series of Quarterly mean TOA reflectance
  - Mean over desert sites = pseudo-invariant targets
  - No significant trend detected – seasonal variations due to geometry
  - Interband perfectly stable within 1%

DESERT



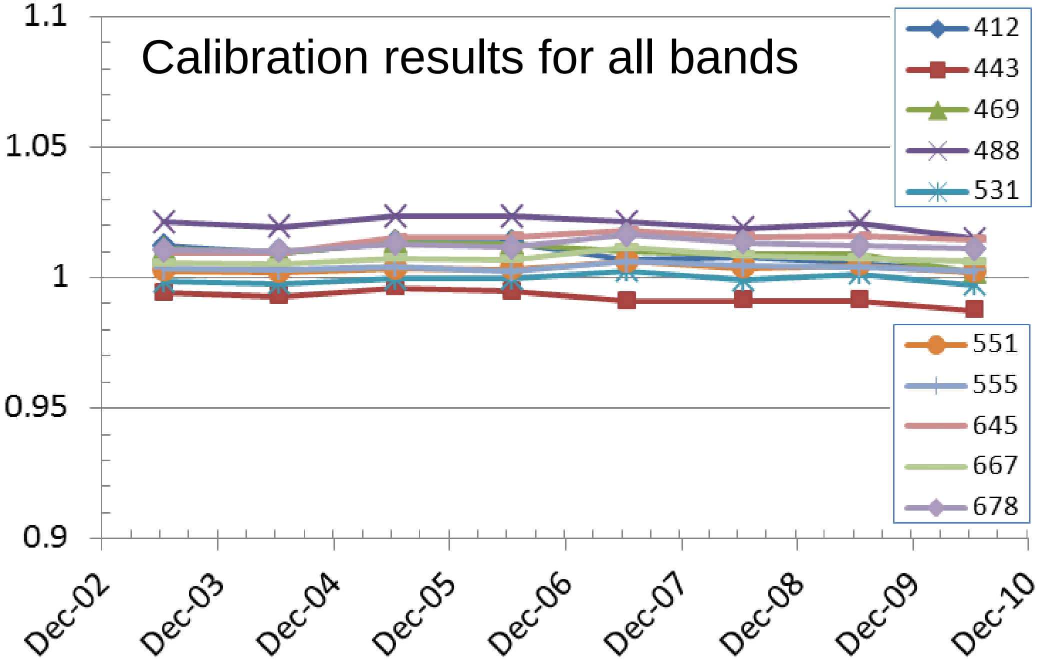


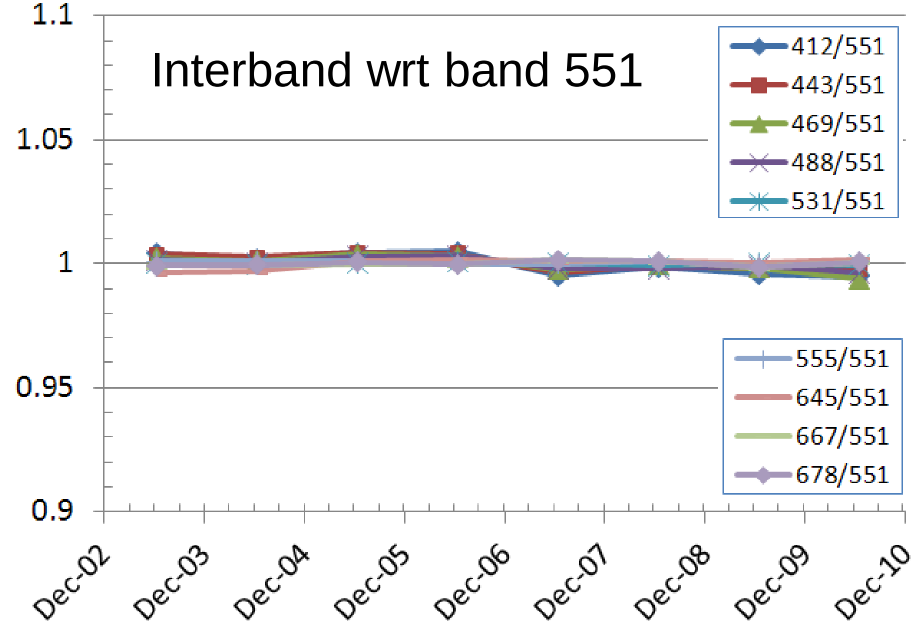
bands are arbitrarily shifted up/down for clarity

Validation of the trending

RAYLEIGH

- **Time series of Yearly ratio Measured to Predicted Radiances**
  - **Yearly mean over calibration results**
  - **No significant trend detected**
  - **Interband perfectly stable within 0.5%**



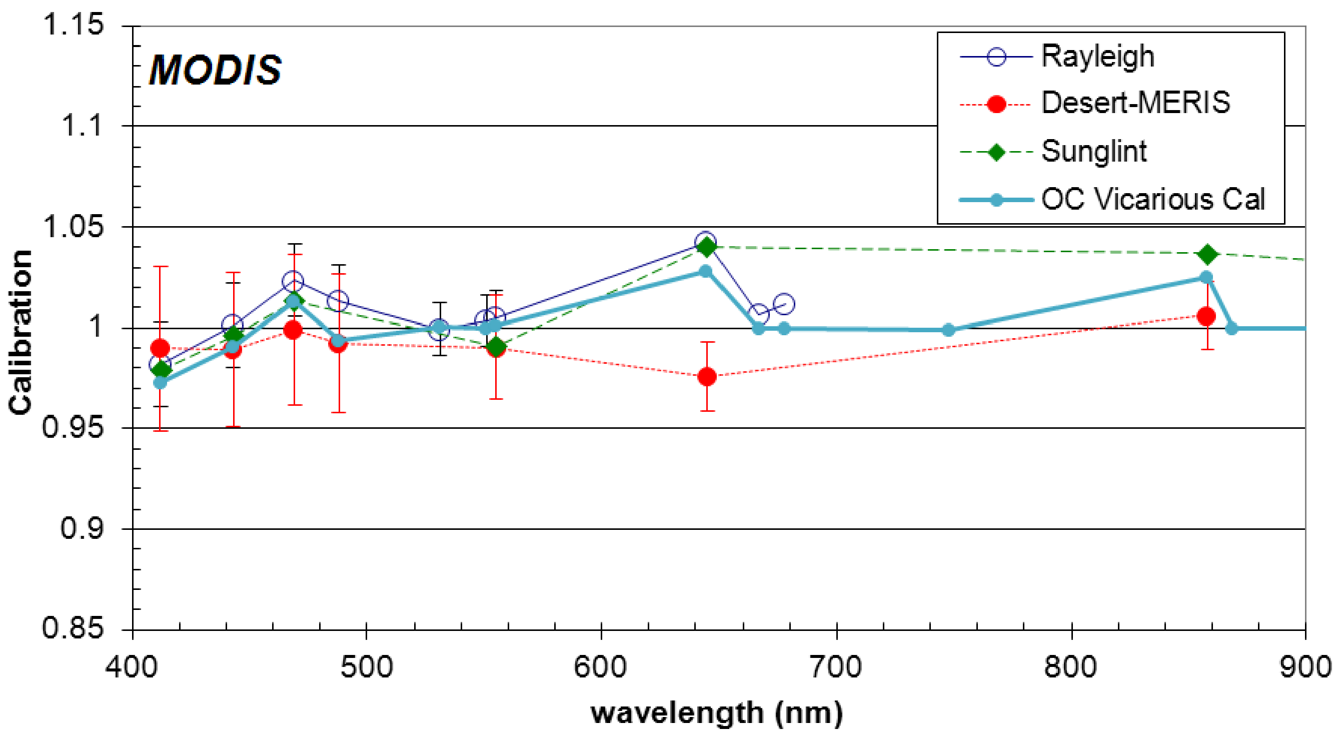


bands are normalized to 1 for clarity

Synergy

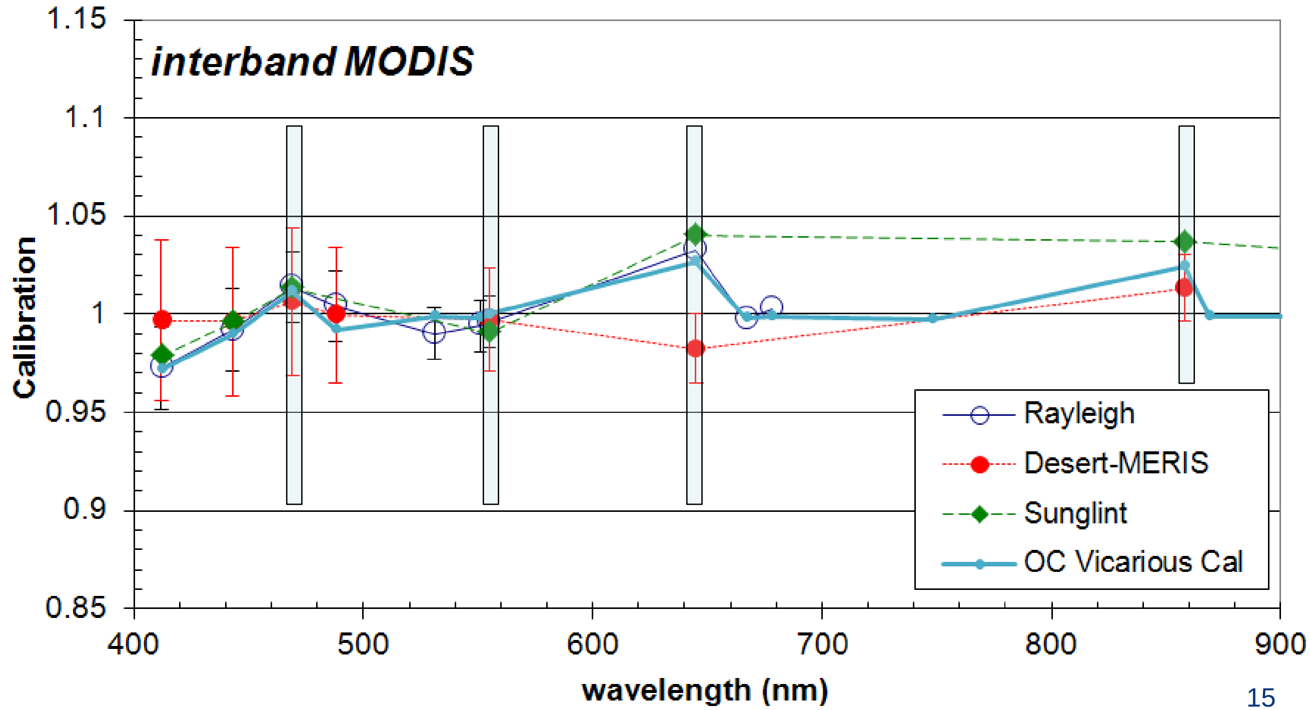
- **Comparison of results from all methods**
  - **DESERT, RAYLEIGH**
  - **Sunglint normalized by <443,469,555>**
  - **OC Vicarious Cal = cal adjustment + residual atmospheric correction**

Band	*DESERT*	*RAYLEIGH*	*SUNGLINT*
412	0.999	0.981	0.979
443	0.998	1.001	0.995
469	1.008	1.023	1.013
488	1.001	1.013	
531		0.999	
551		1.003	
555	0.999	1.005	0.990
645	0.984	1.042	1.040
667		1.006	
678		1.012	
748			
858	1.015		1.036
869			
1240			1.007
1640			1.025
2130			1.018



Synergy

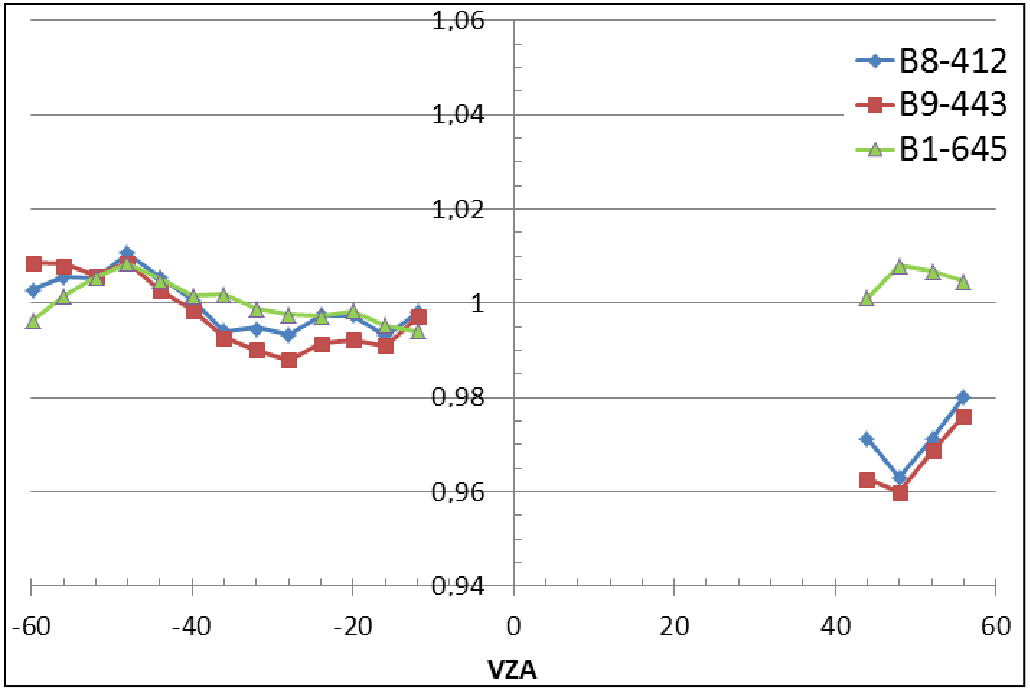
- Comparison of results from all methods – Normalized results by <443,469,555>
  - DESERT, RAYLEIGH
  - Sunglint normalized by <443,469,555>
  - OC Vicarious Cal = cal adjustment + residual atmospheric correction (from SEADAS)
  - Very good consistency for VIS bands
  - Discrepancy for B1-645nm : DESERT known to be less accurate for B1 in this case
  - Agreement for NIR band
  - Relevancy of OC Vic Cal for "Land" bands

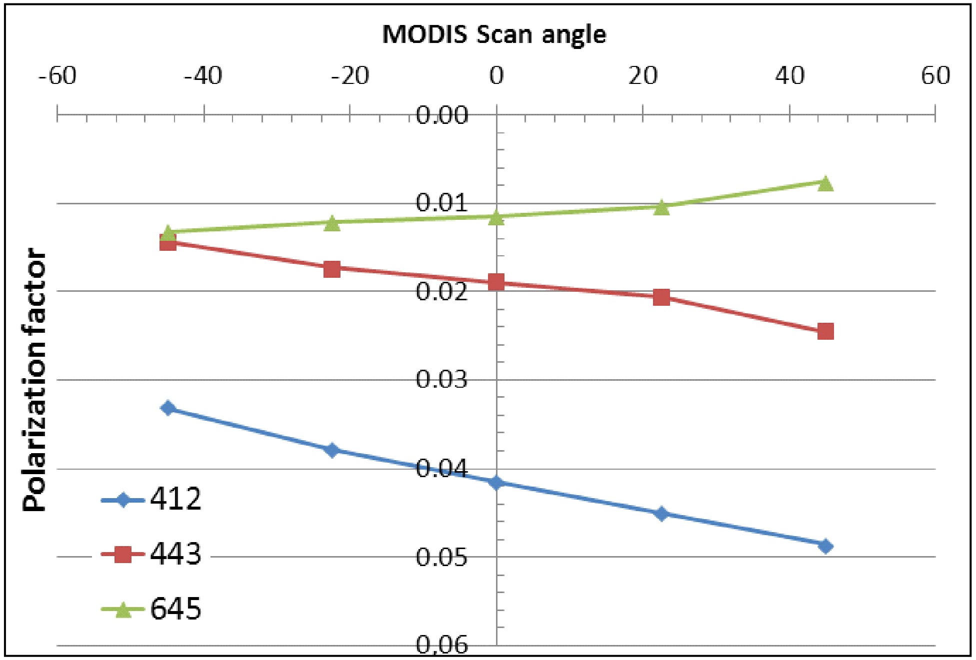


Interband normalization by <443,469,555>

Polarization

- Preliminary analysis: impact of the polarization on Rayleigh calibration
  - All results are averaged into 4°(VZA) bins
  - Sunglint region 0°<VZA<30°
  - ✦ Is the directional signature linked to the polarization sensitivity of the instrument ?
    - ✦ To be investigated …





according Sun and Xiong, 2007

Conclusion

- **Calibration of MODIS-Aqua has been implemented for :**
  - **Rayleigh absolute calibration**
  - **Sunglint interband calibration**
  - **in addition to the existing cross-calibration over desert sites**

- **Synergic analysis :**
  - **generally, a good consistency is observed, mainly for VIS bands**
  - **light biases identified for B1-645 and B2-858 Land bands**
  - **relevancy of OC Vicarious calibration for "Land" bands, B1 to B4 (645, 858, 469, 555), and for B8 (412)**
  - **no residual temporal trending was detected**

- **On-going investigation :**
  - **desert : compare to other sensors to confirm conclusion for B1 and B2 bands**
  - **how the polarization sensitivity impacts Rayleigh scattering results**

Thank you for your attention !

If you want more : Back up slides →

Gaseous absorption

- Typical gaseous absorption :

	Tot	O3	WV	O2	CO2	CH4	NO2
412	1	1	1	1	1	1	1
443	0,997	0,997	1	1	1	1	1
469	0,993	0,993	1	1	1	1	1
488	0,984	0,984	1	1	1	1	1
555	0,924	0,924	1	1	1	1	1
645	0,918	0,940	0,978	0,998	1	1	1
858	0,975	1	0,975	1	1	1	1
1240	0,984	1	0,988	0,997	0,999	1	1
1640	0,980	1	0,996	1	0,983	0,988	1
2130	0,877	1	0,901	1	0,974	0,999	0,994