The SEVIRI Solar Channel Calibration system: a vicarious calibration algorithm for the Meteosat imagers, using desert targets.

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Meteosat solar band observations: a short summary...

1. Meteosat data : archived data since 1982 ➔ 30 years of archived data
   - Meteosat First Generation / MVIRI (1 solar channel [0.45 to 1.0 µm])
   - Meteosat Second Generation / SEVIRI (4 solar channels [VIS06 / VIS08 / NIR16 / HRVIS])
   - Future: Meteosat Third Generation / FCI (8 solar channels [VIS04/ VIS05 / VIS06 / VIS08 / VIS09 / NIR13 / NIR16/ NIR22], of which 2 non-window channels)

2. What about the specifications on the radiance measurements for the solar channel calibration?
   - MVIRI = no spec
   - SEVIRI = 10% + 5% long-term stability
   - FCI = 5% (FDHSI) / 10% (HRFI) + 2% long-term stability

3. Which calibration method(s) to reach these requirements ?
   - MVIRI / SEVIRI: No on-board calibration system ➔ Vicarious calibration
   - FCI: On-board solar diffusers + Vicarious calibration

FDHSI = Full Disc High Spectral resolution Imagery mission

HRFI = High Resolution Fast Imagery mission

Meteosat solar band calibration : primary objectives

Accurate calibration needed by :

1. Real time / Near real time applications ➔ operational evaluation of the calibration coefficients
2. Reprocessing / climate applications ➔ re-analysis with consistent calibration for the various missions
3. GSICS context / inter-calibration: collaboration with other satellite operators
   - Cross-check of the calibration coefficients and uncertainties
   - Basis for a normalized calibration ➔ global products based on several instruments, using common references
   - Enforce traceability and compatibility in the calibration chains (instrumental and vicarious)

➔Part of the challenge = accommodate various instrument set-ups

- Spectral features (channels, spectral response functions)
- Repeat cycle (30min, 15min, 10min, 5min)
- Pixel size at SSP (3km, 2.5km, 1km, 0.5km)
- Quantization (6, 8, 10, 12 bits)
- Instruments: detectors and acquisition systems
- Etc.

Meteosat solar band calibration : strategy outline...

- Past and current Meteosat imagers: vicarious calibration using as a reference RTM simulations to be compared with TOA radiances + inter-calibration
- Future Meteosat imagers: on-board calibration + vicarious calibration based on the current system / updated system + inter-calibration
- Implementation of the recommendations by GSICS / QA4EO / metrology organizations (BIPM, NIST, etc.)

Meteosat solar band calibration activities

SEVIRI Solar Channel Calibration System

Meteosat imagers

- MFG/MVIRI
- MSG/SEVIRI
- MTG/FCI

Vicarious calibration using desert targets + sea targets (current official calibration)

➔ SEVIRI Solar Channel Calibration System

Lunar Calibration

➔ Collaboration with USGS

Follow activities on MTG instrument side (on-board calibration and sensor characterization)

Inter-calibration with MODIS using Deep Convective Clouds

➔ Implementation of the GSICS ATBD (Doelling, 2011)

Support to reprocessing activities

Further improvements of the current systems (reduced uncertainties, more methods, new/better calibration references, etc.)

WG on Calibration Event Logs

(recom. GSICS/CGMS)

MSG3 commissioning

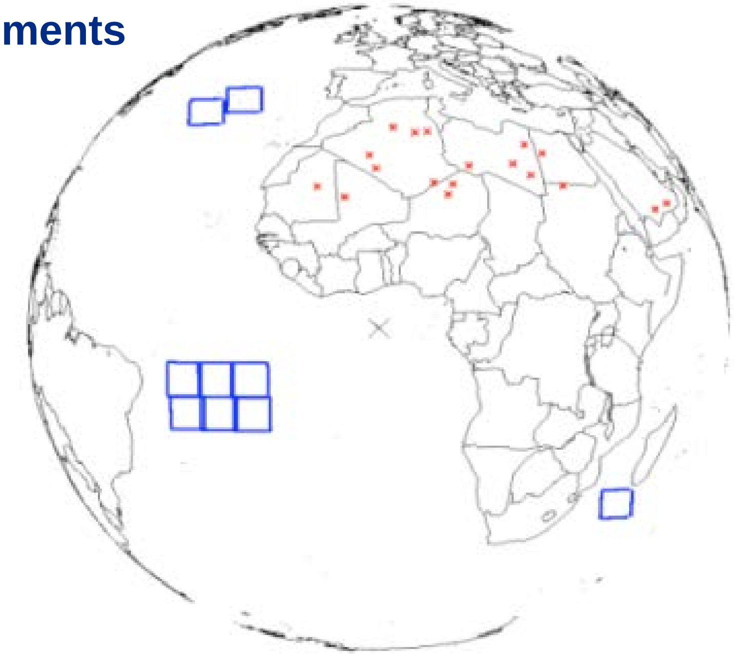
The SEVIRI Solar Channel Calibration system

- **Developed and implemented in 2002/2003 by Y. Govaerts and M. Clerici**
- **System in place for SEVIRI (Met-8, Met-9 and Met 10) BUT ALSO for MVIRI (Met-2 till Met-7)**
- **Vicarious calibration:**
  - **Reference = RTM simulations of Top-Of-Atmosphere radiances**

    Evaluated against well-calibrated polar-orbiting instruments

    (SeaWiFs, ATSR2, AATSR, VEGETATION, MERIS)
  - **Comparison with TOA measured signal**

- **2 target types used for comparison:**
  1. **Desert bright targets (18 targets)**
  2. **Dark sea targets (9 targets) (checking purposes)**



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SSCC references

Govaerts, Y. M. and M. Clerici (2004). "Evaluation of radiative transfer simulations over bright desert calibration sites." IEEE Transactions on Geoscience and Remote Sensing 42(1): 176-187.

Govaerts, Y. M., M. Clerici, et al. (2004). "Operational Calibration of the Meteosat Radiometer VIS Band." IEEE Transactions on Geoscience and Remote Sensing 42(9): 1900-1914.

Govaerts, Y. M., and Clerici, M. (2004). MSG-1/SEVIRI Solar Channels Calibration Commissioning Activity Report (EUMETSAT).

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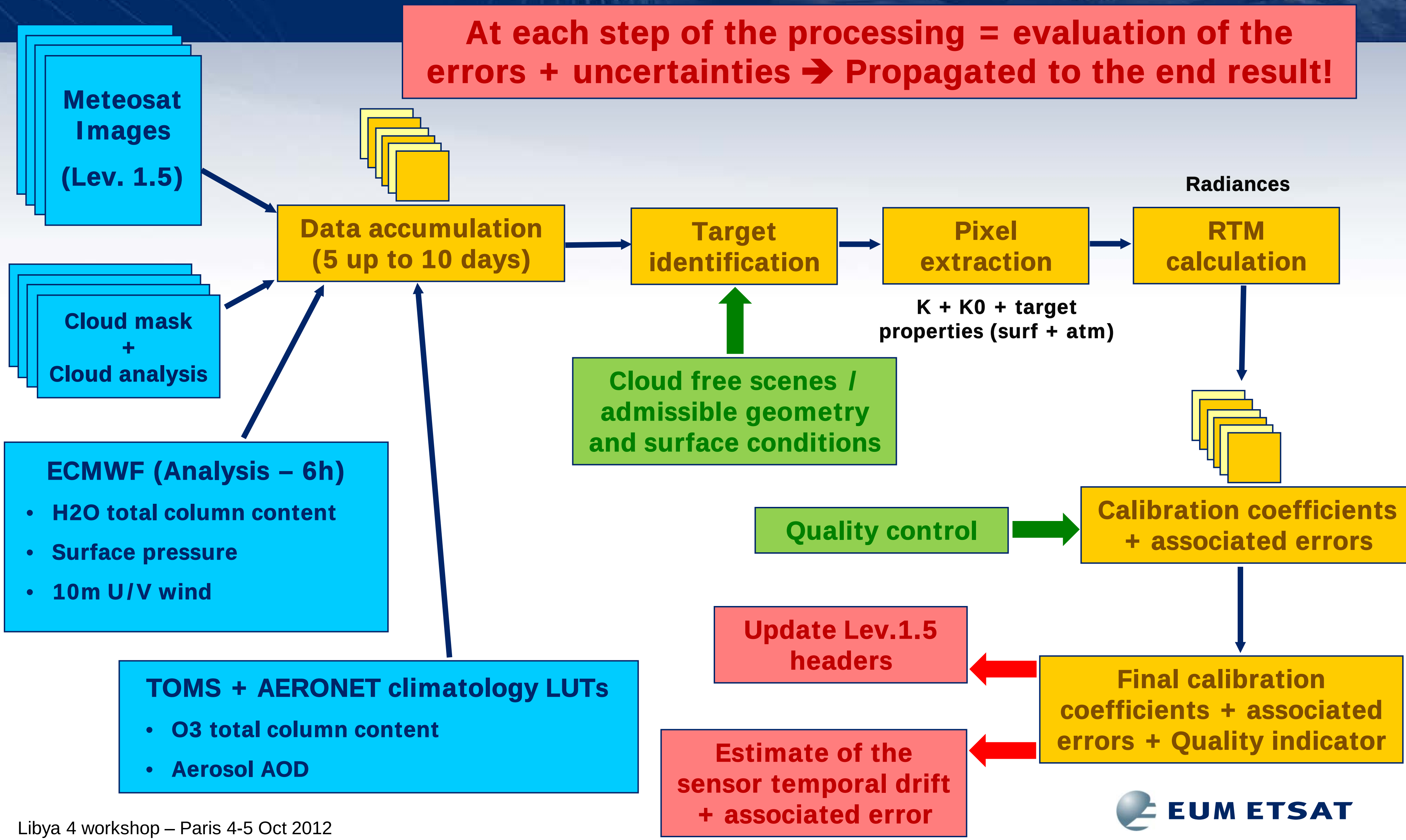
The SEVIRI Solar Channel Calibration algorithm



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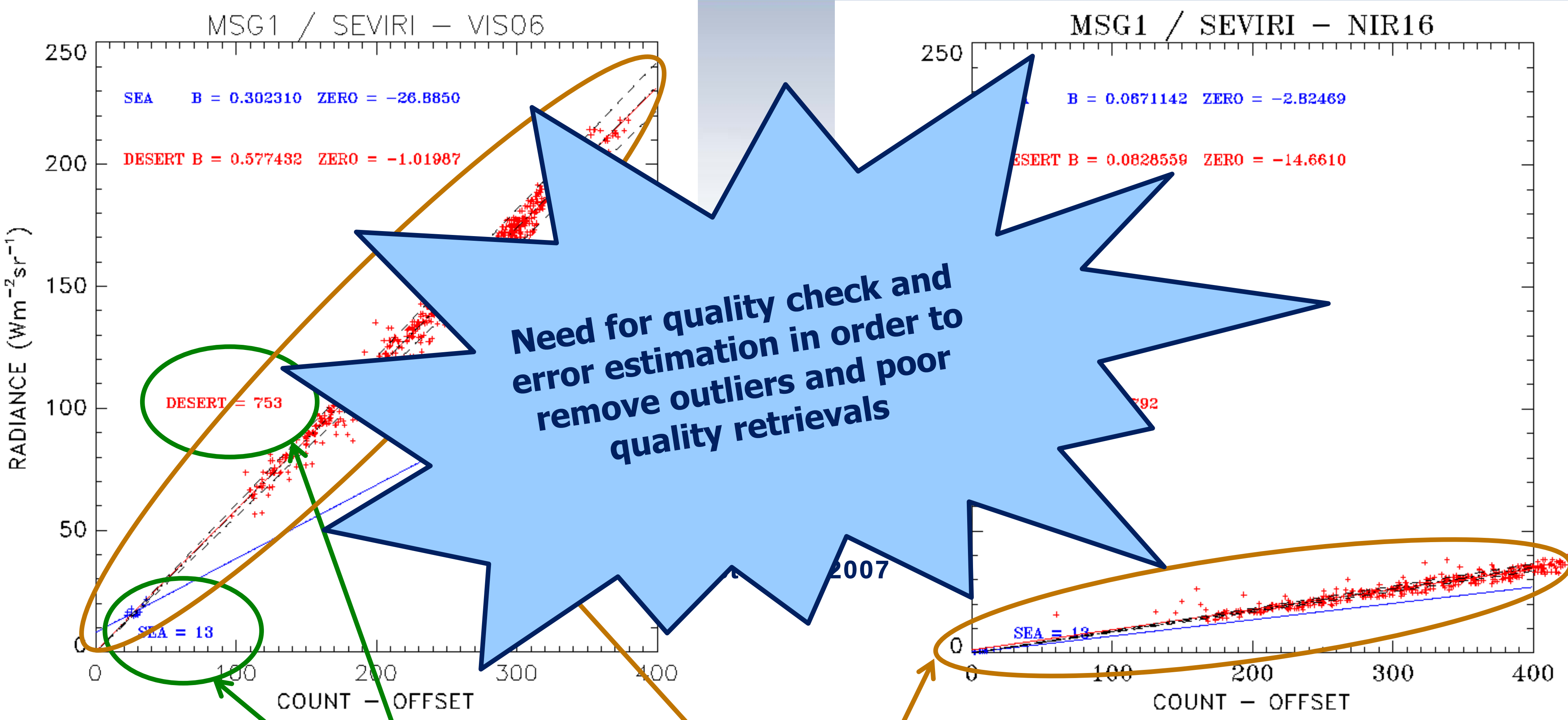
Some details about the RTM box

1. RTM = modified version of 6S (version 4.0, 2003)
    1. Solar irradiance spectrum = Kurucz as of 2003 (and as implemented in MODTRAN 3)
    2. Surface models available for SSCC:
        - Modified Hapke Model (NADIMS) (Pinty, 1989)
        - RPV (Rahman et al, 1993)
        - SOILSPEC (Jacquemoud et al, 1992)
2. Set-up for a target:
    - 5x5 pixel box around site for the low resolution bands (~15x15km)
    - 15x15 pixel box for the HRVIS
    - Same surface spectral properties for all pixels within the box
    - No change in time of these spectral properties

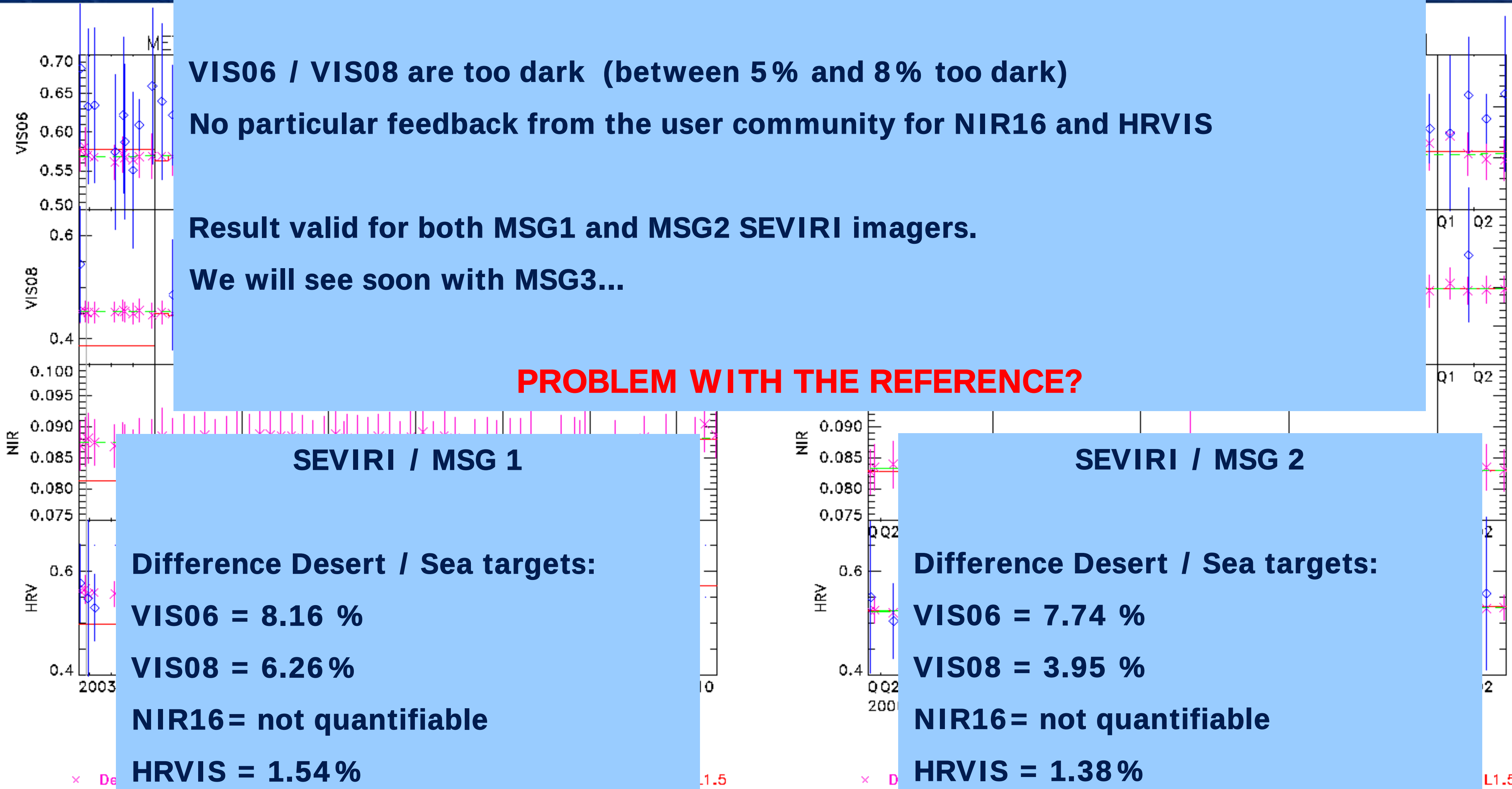
Example of results – MSG1



Large differences in the amount of retrievals

Impact of the nature of the signal on the use of some target types

Current status



Current issue

VIS06 / VIS08 are too dark (between 5% and 8% too dark)

No particular feedback from the user community for NIR16 and HRVIS

Result valid for both MSG1 and MSG2 SEVIRI imagers.

We will see soon with MSG3...

PROBLEM WITH THE REFERENCE?

SEVIRI / MSG 1

Difference Desert / Sea targets:

VIS06 = 8.16 %

VIS08 = 6.26%

NIR16= not quantifiable

HRVIS = 1.54%

SEVIRI / MSG 2

Difference Desert / Sea targets:

VIS06 = 7.74 %

VIS08 = 3.95 %

NIR16= not quantifiable

HRVIS = 1.38%

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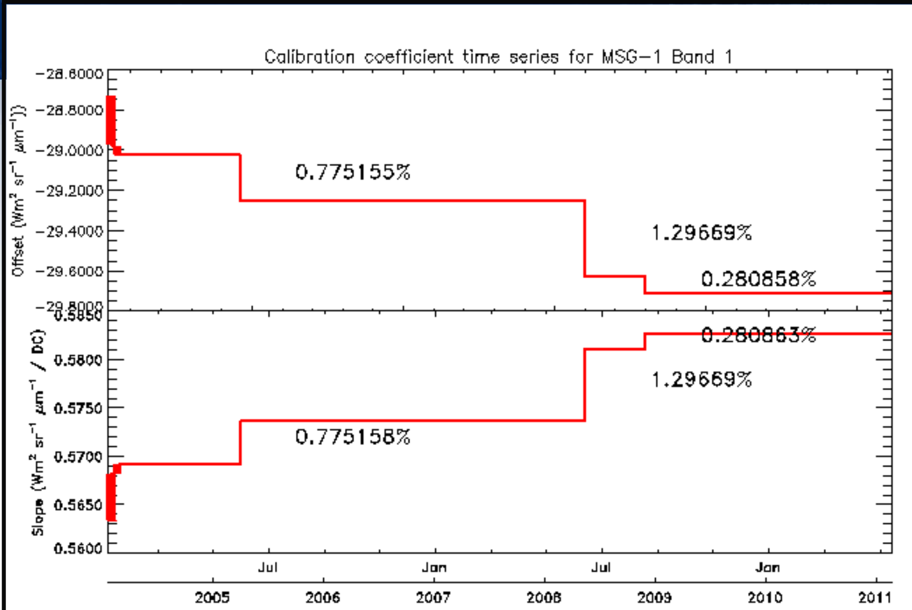
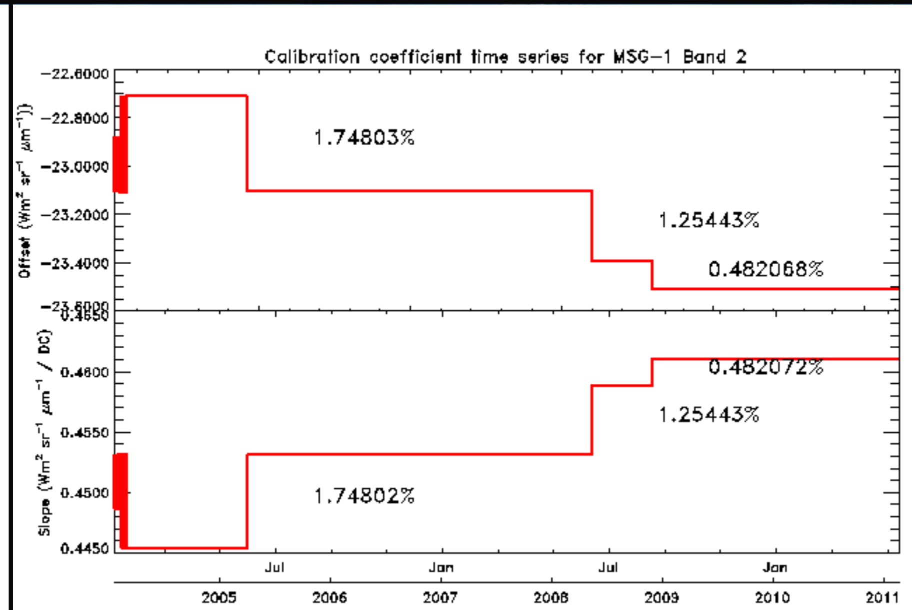
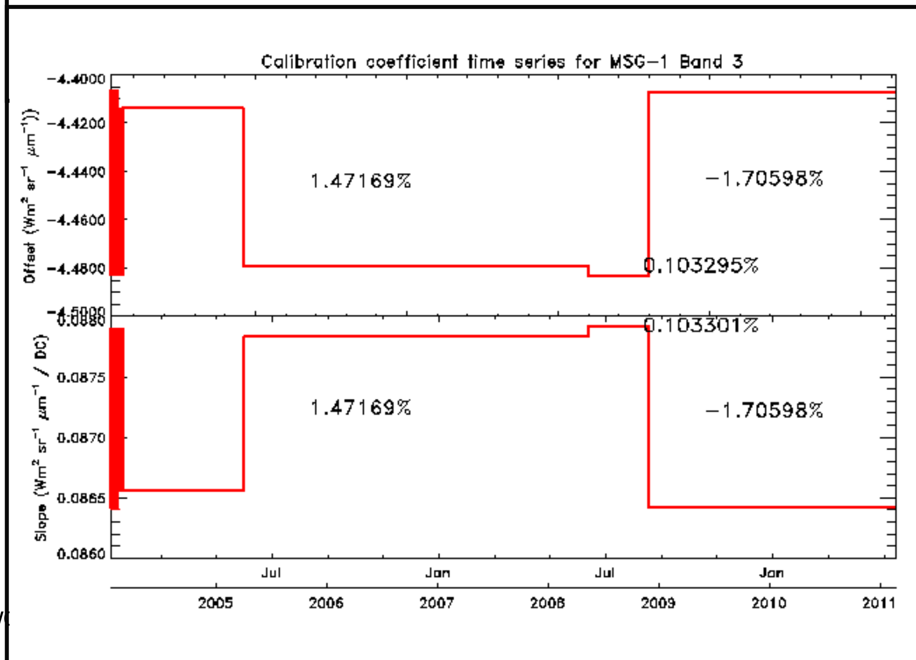
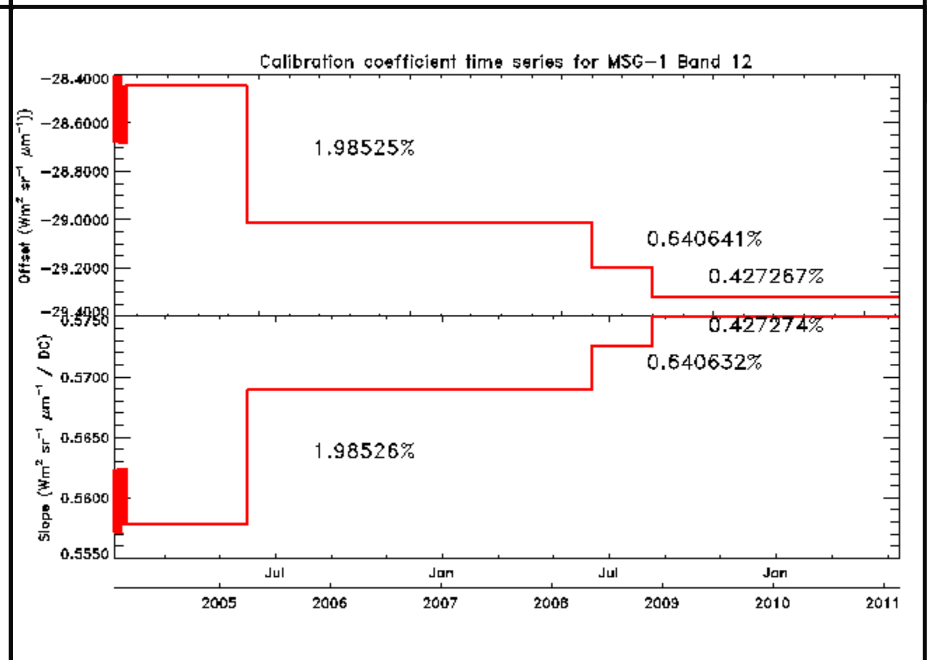
Current status – Meteosat 8 – Level 1.5 Headers



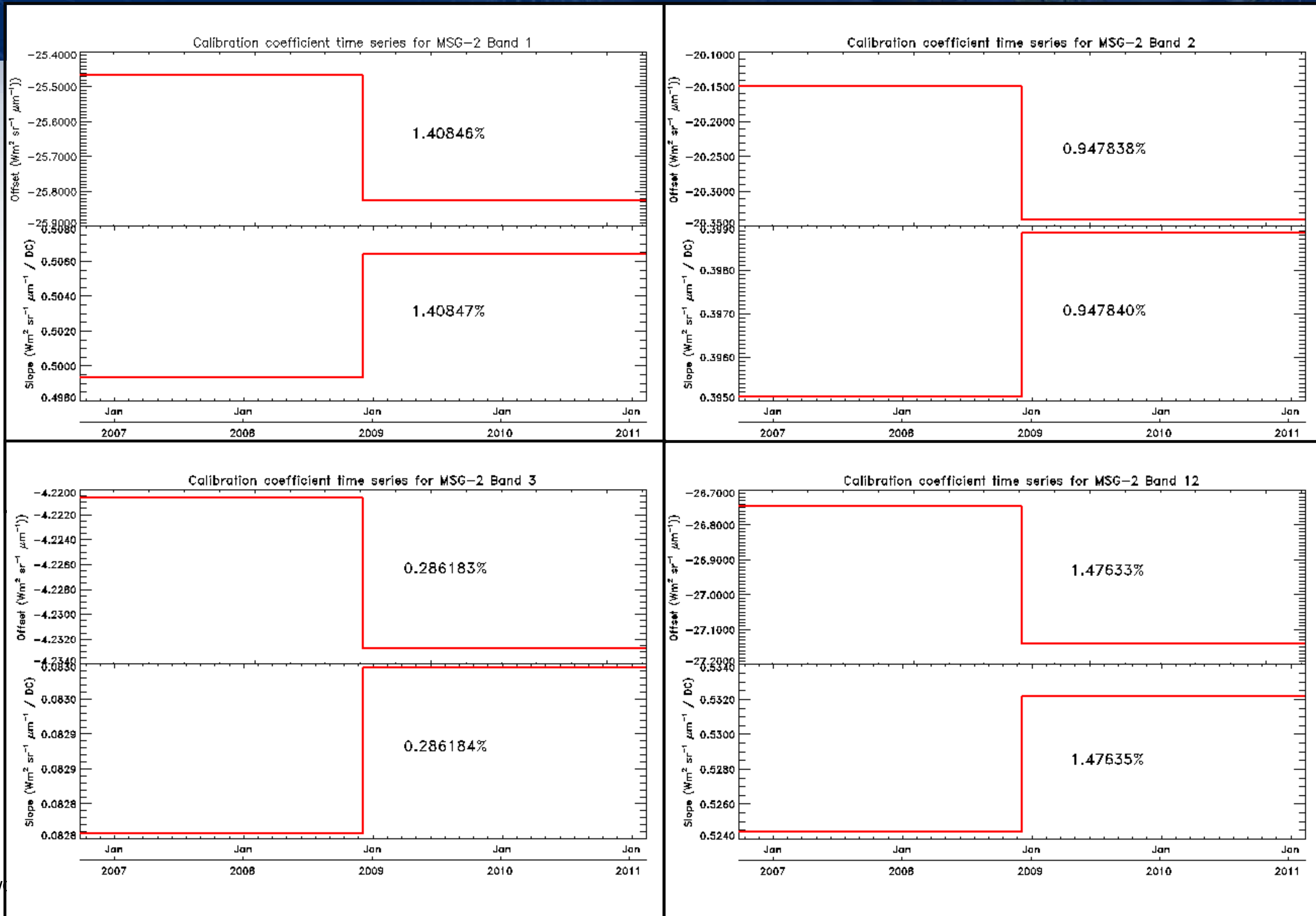




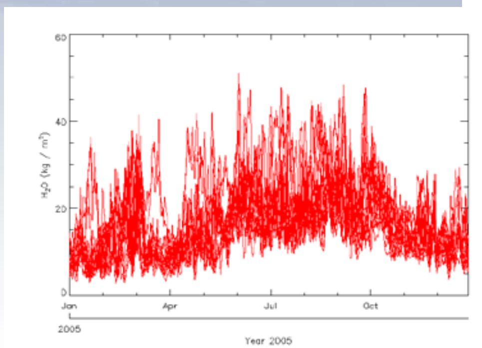
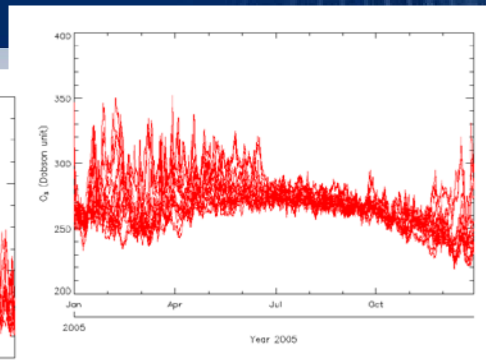


Libya 4 w

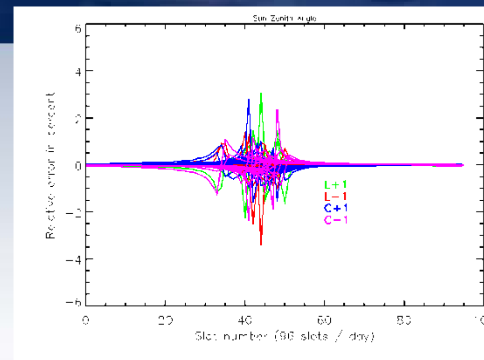
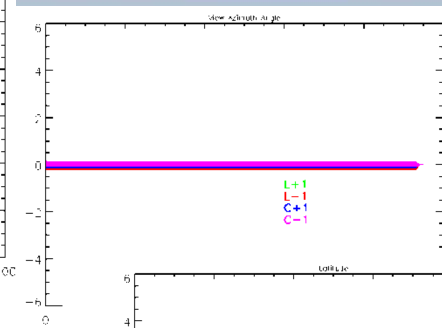
Current status – Meteosat 9 – Level 1.5 Headers



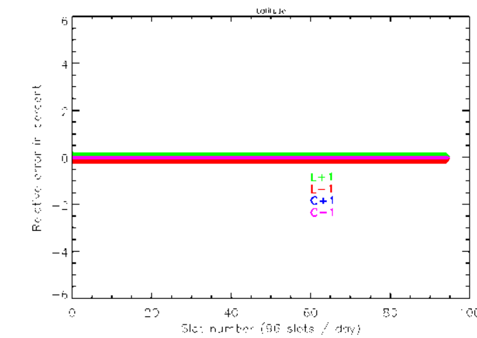
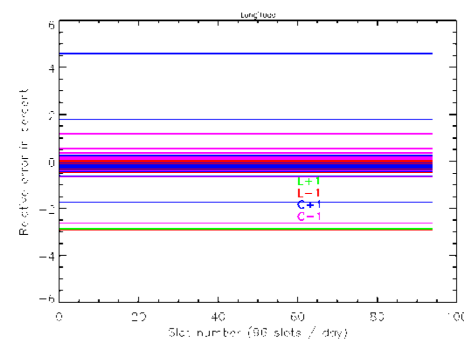
System response to uncertainties... Assessment of the RTM.

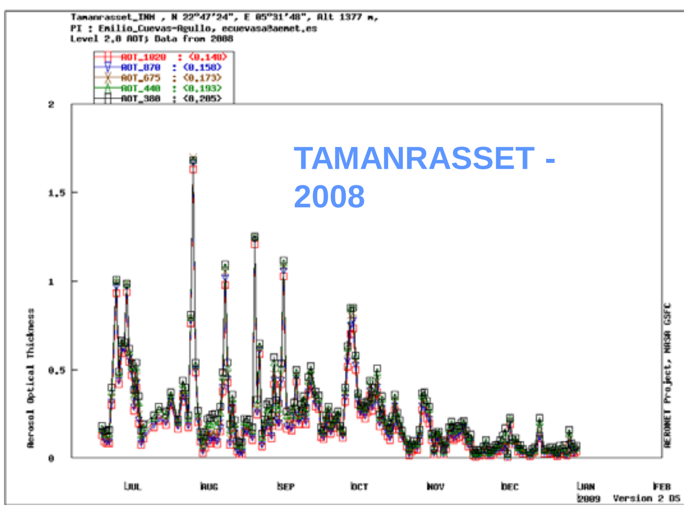
O3 / H2O total column amount

Geometry / navigation

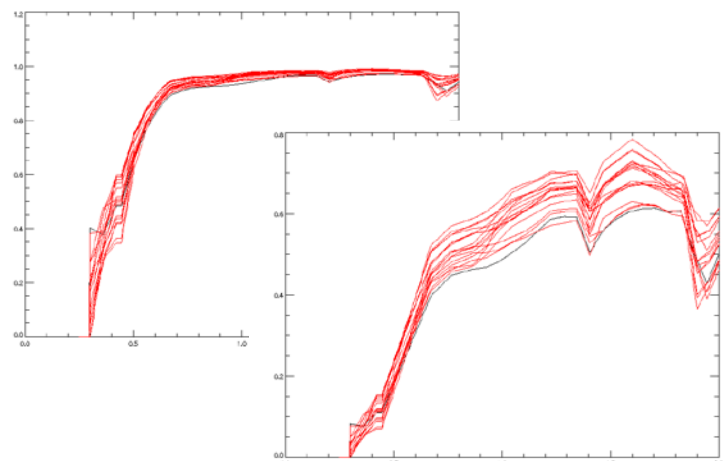



Various variables tested for all desert targets, for all channels



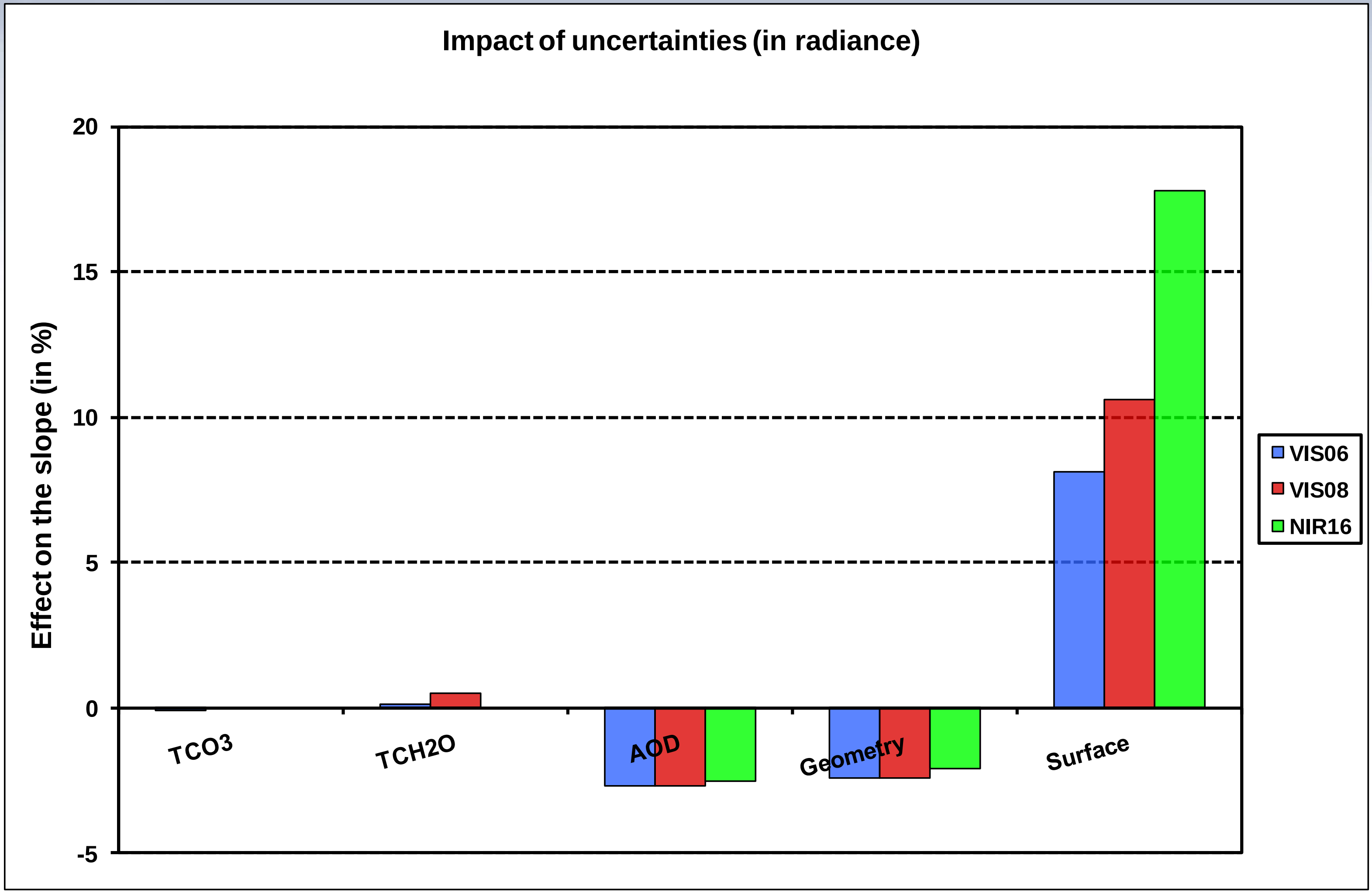
Source : AERONET

AOD



Surface spectral properties

Some preliminary results... In radiance

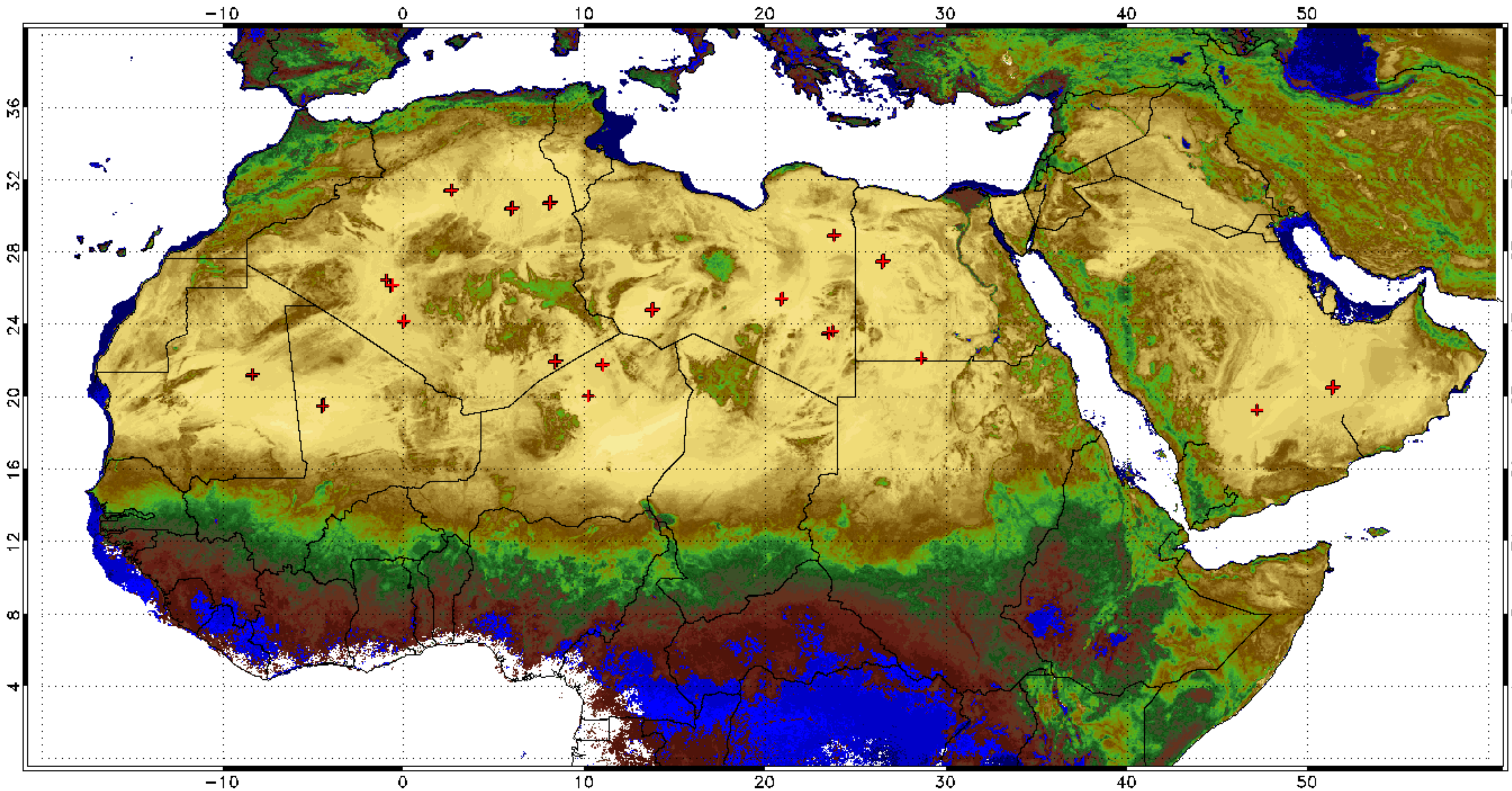


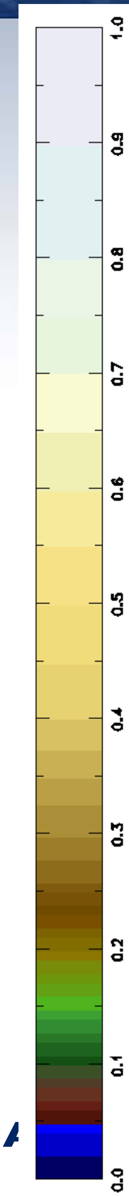
Delta = 30% **Delta = 20%** **Delta = 100% (Ref = 0.1)** **Delta = 2%** **Delta = 1%**

How to improve SSCC?

- Re-assessment of the reference desert targets:
  - Analysis of the desert target temporal stability and spatial homogeneity.
  - Improvement of the Bidirectional Reflectance Factor for these targets.
  - Investigate the possibility to use more targets.
- Possible use of the Meteosat First Generation Albedo product in the assessment of the desert target stability (30 years of data) + analysis of MODIS BRDF.
- Characterization of the aerosol radiative properties in order to improve the radiative transfer.
- Improvement of the radiative transfer processes (in particular the multiple scattering + coupling with gaseous absorption).
- Assessment of the uncertainties of the radiative transfer model with respect to main variables assessed + assessment of the uncertainties of the complete calibration chain.
- Not only desert targets... Implementation of new methods in order to blend the final calibration product (re-visiting Rayleigh scattering methods, Deep Convectives clouds, Lunar calibration...).

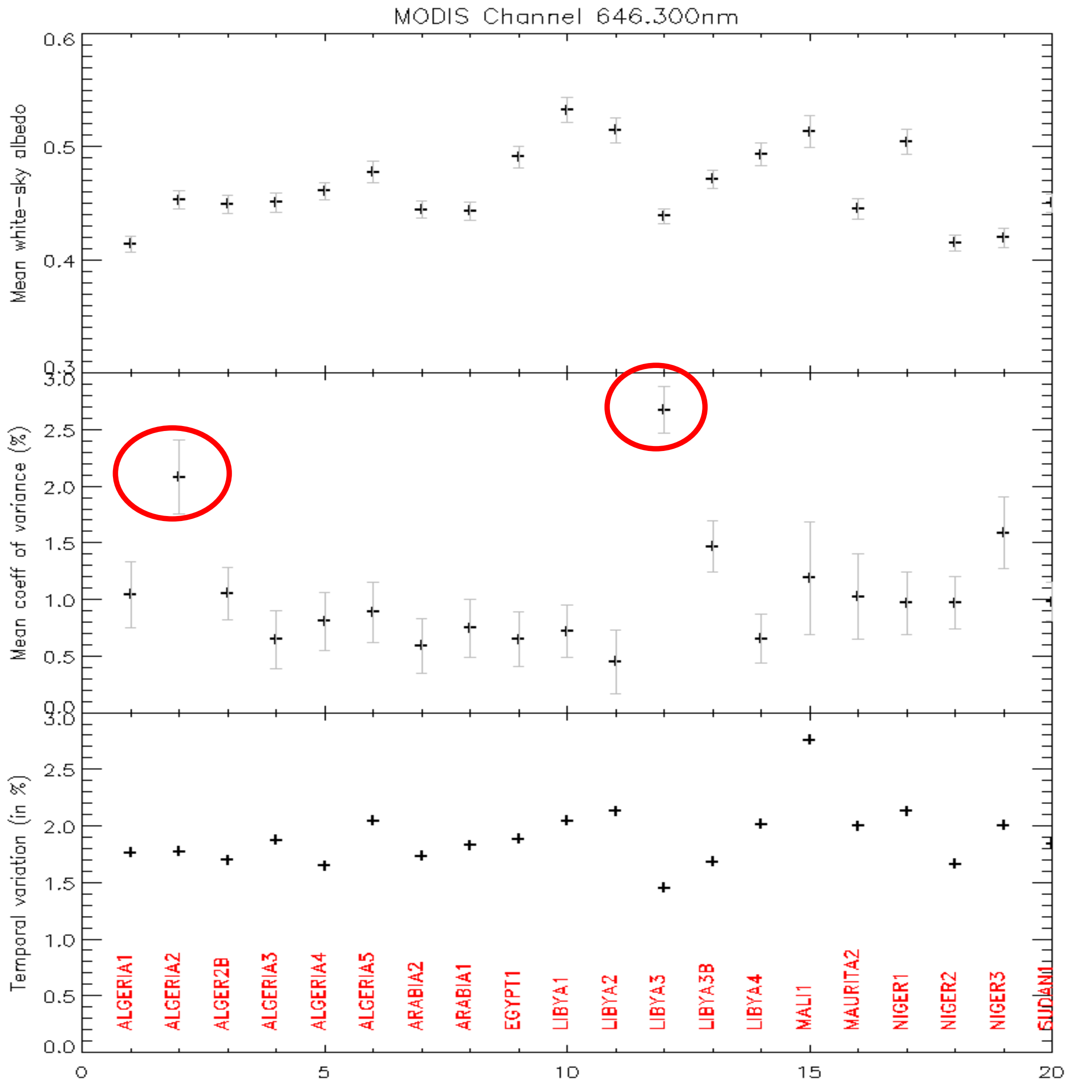
Desert target temporal stability and spatial homogeneity





Temporal average of the BRDF product derived from MODIS observations at 646nm between 2002 and 2008 (courtesy Prof. B.J. Sohn, Seoul National University). In red: SSCC desert targets.

Desert target temporal stability and spatial homogeneity



ALGERIA2 and LIBYA3 ➔ higher spatial heterogeneity than the other targets

ALGER2B and LIBYA3B (not included in SSCC) ➔ Possible alternative targets

OUTCOME: possibly additional/other targets to be used by SSCC

➔ Cross analysis with other data sets

Data extracted from the temporal average of the BRDF product derived from MODIS observations at 646nm between 2002 and 2008 (courtesy Prof. B.J. Sohn, Seoul National University).

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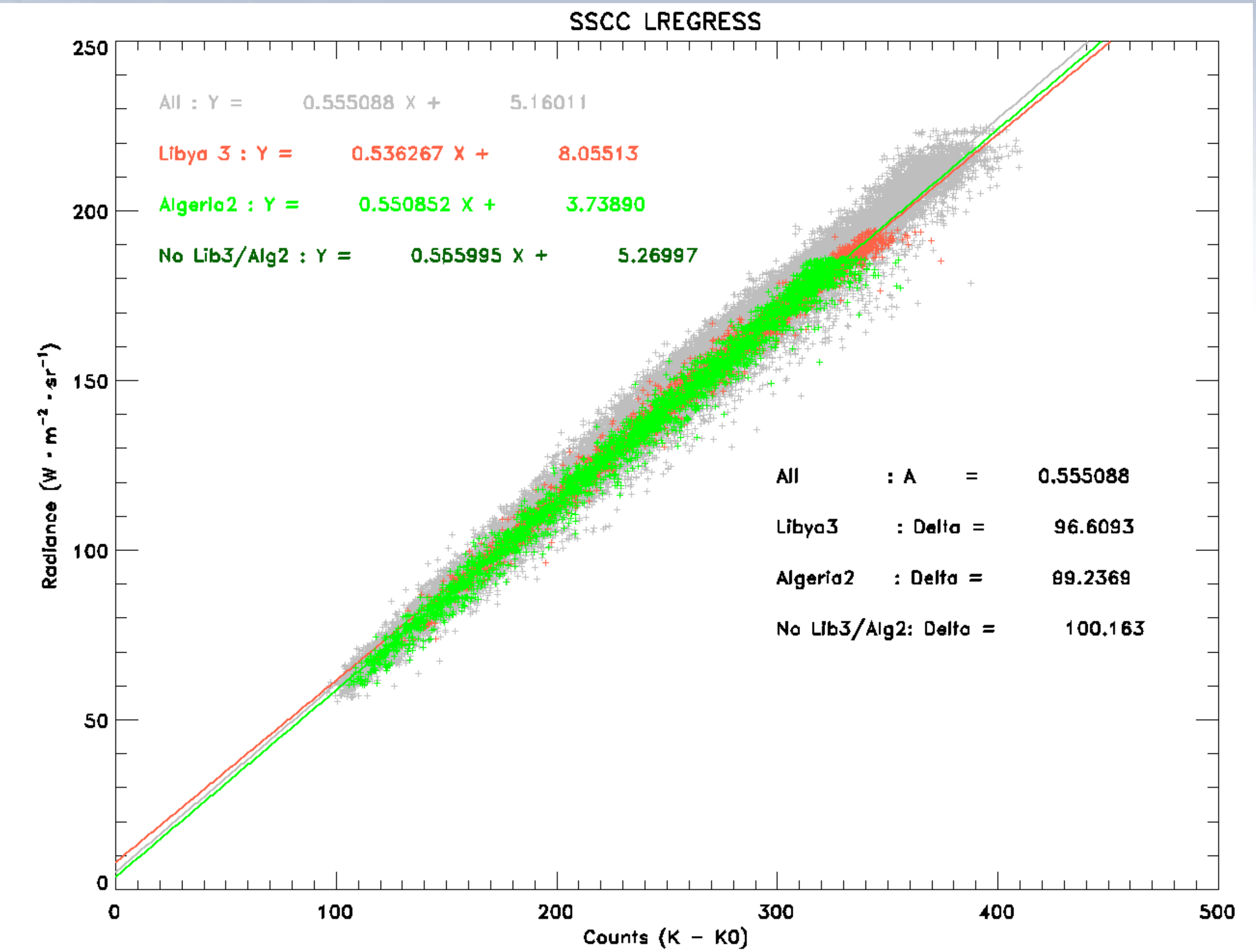
Re-assessment of the reference targets



Example of re-analysis of SSCC results: assessment of the weight of specific targets on the overall estimated calibration coefficients in the VIS06 band.

The linear regression uses the estimated errors on the modelled top-of-atmosphere radiances.

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Conclusion and future work...

In order to :

1. Meet the requirements on MTG/FCI: 5% accuracy (current requirement on MSG/SEVIRI: 10%!)
2. Improve SEVIRI current calibration system
3. Re-visit the Meteosat archive

➔ Need for reducing uncertainties and improving calibration accuracy

What is foreseen with SSCC (but not only)?

- Follow the latest development in terms of target characterization and modelling (closer interactions with CEOS IVOS + GSICS)
- Continue the assessment of the current system uncertainties
- Possibly use of MODIS / MISR / DIMITRI / SADE data in the current system
- Definition of more stable desert targets + characterization of the associated BRF
- Improvement of the RTM (multiple scattering + aerosols)
- Re-evaluation of the reference against reference instruments (MODIS, MISR, MERIS-like, ATSR-like, VEGETATION, PARASOL...)
- Implementation of additional methods such as DCC or homogeneous water clouds (in particular for FCI non-window channels)
- Address the challenge of new instruments and new designs such as FCI detector array
- Re-visit not-well characterized sensor response functions (Met2-6)

Thank you for the attention

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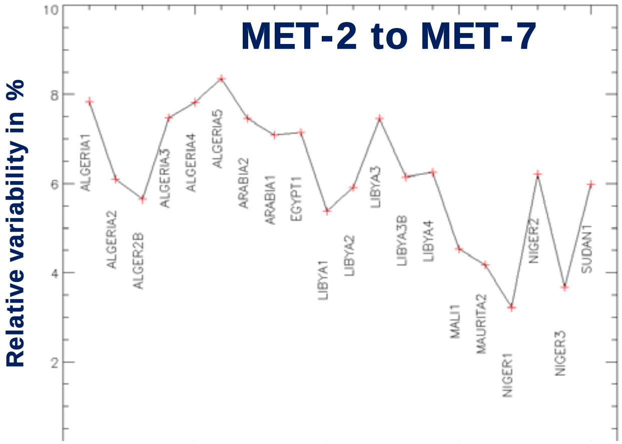
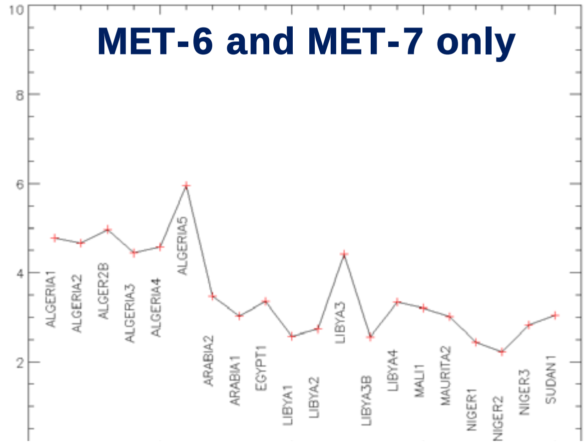
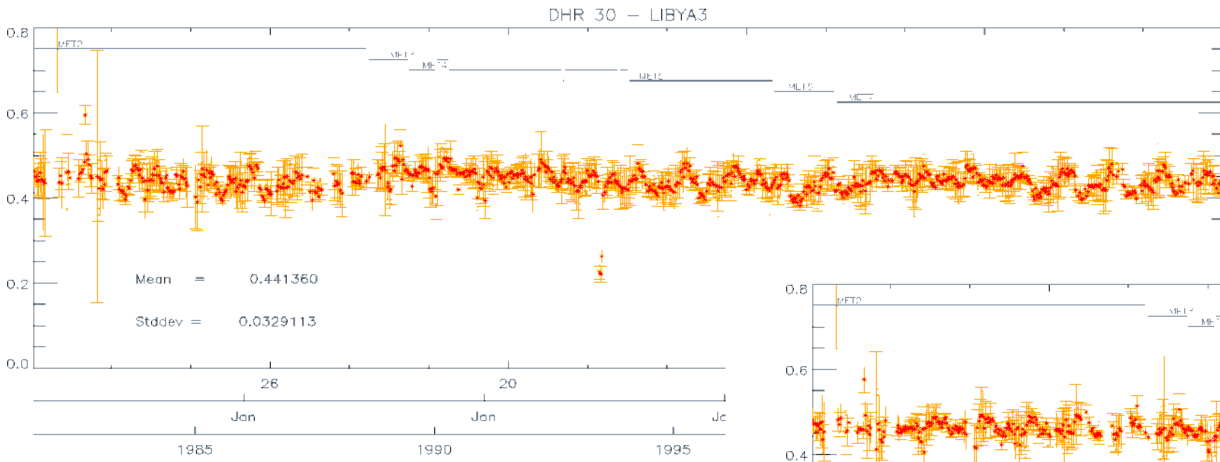
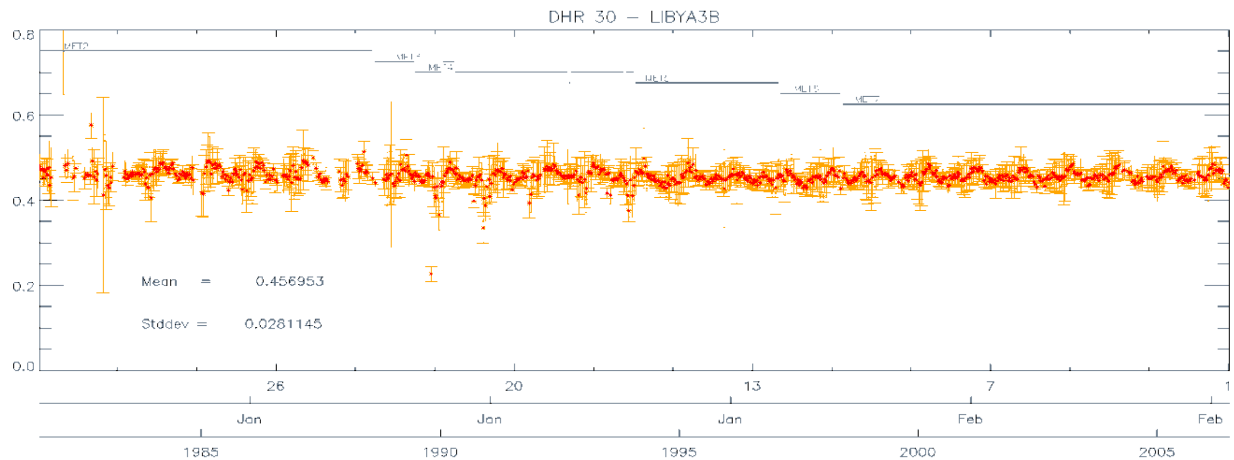
Desert target temporal stability and spatial homogeneity



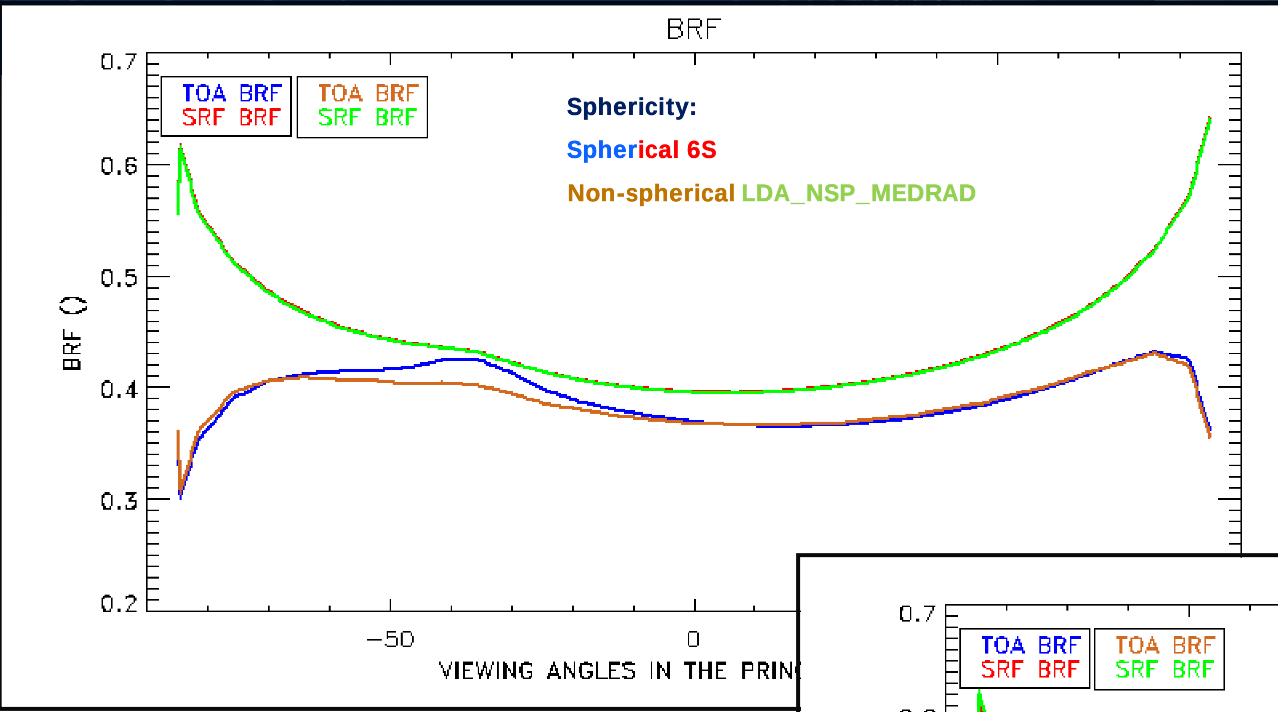


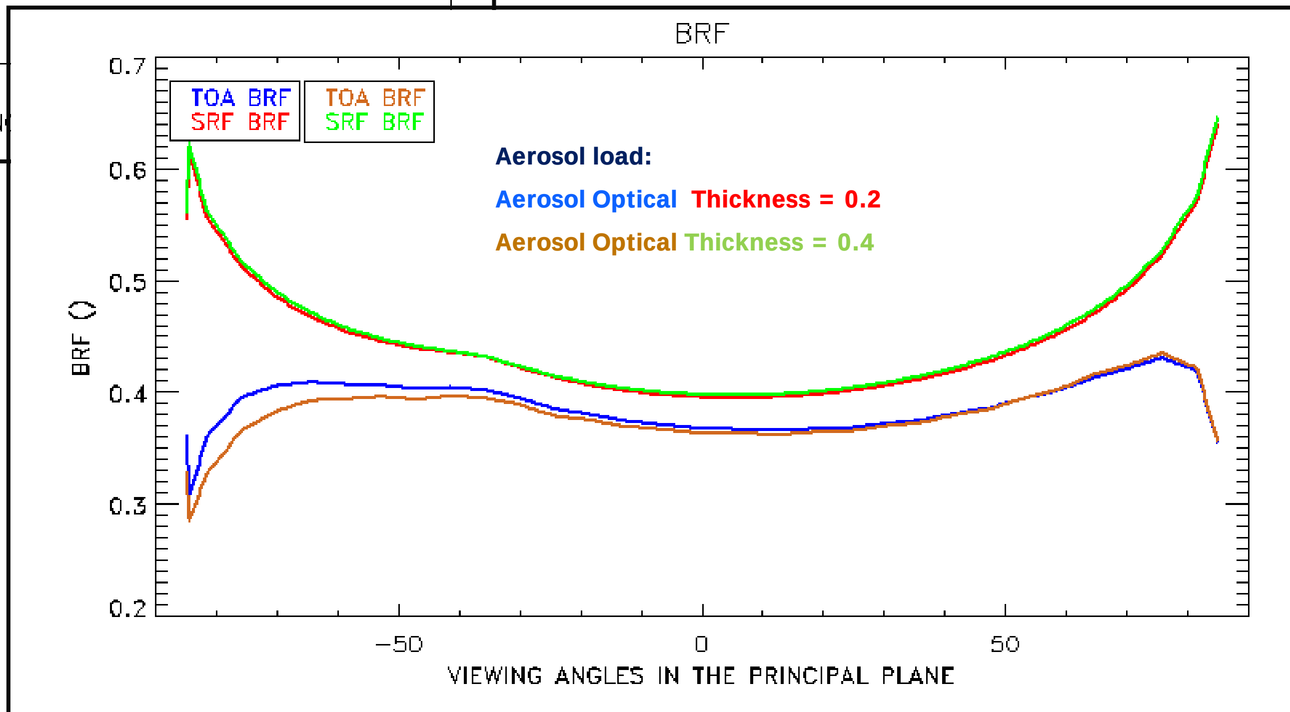
Relative variability in time of the directional hemispherical albedo (at 30 degrees) for each SSCC desert target, as retrieved from the Meteosat Surface Albedo (Meteosat First Generation) .



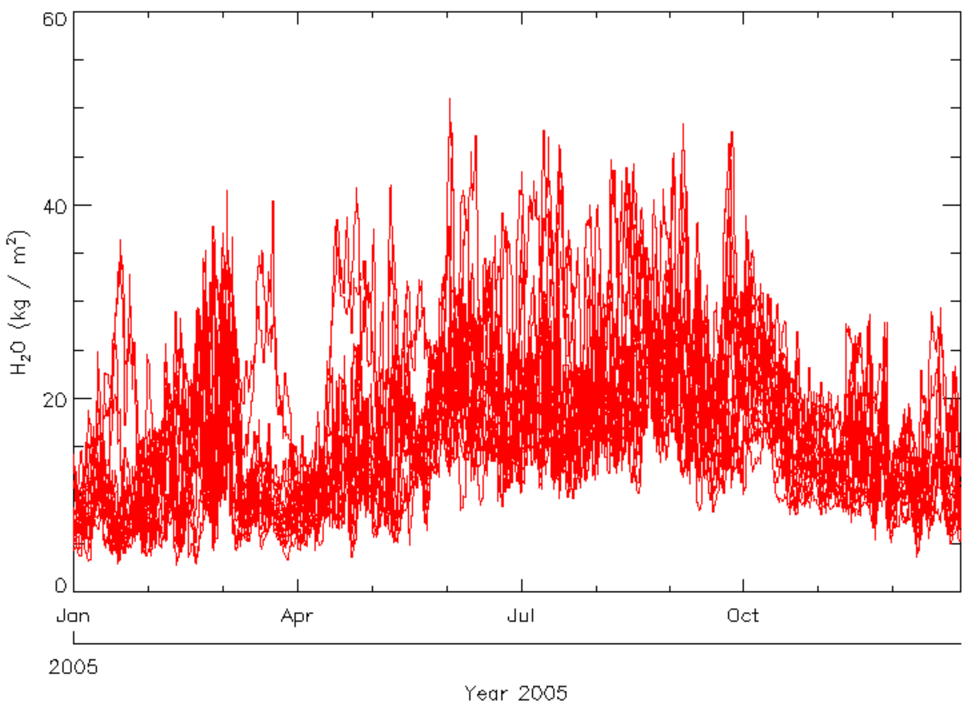


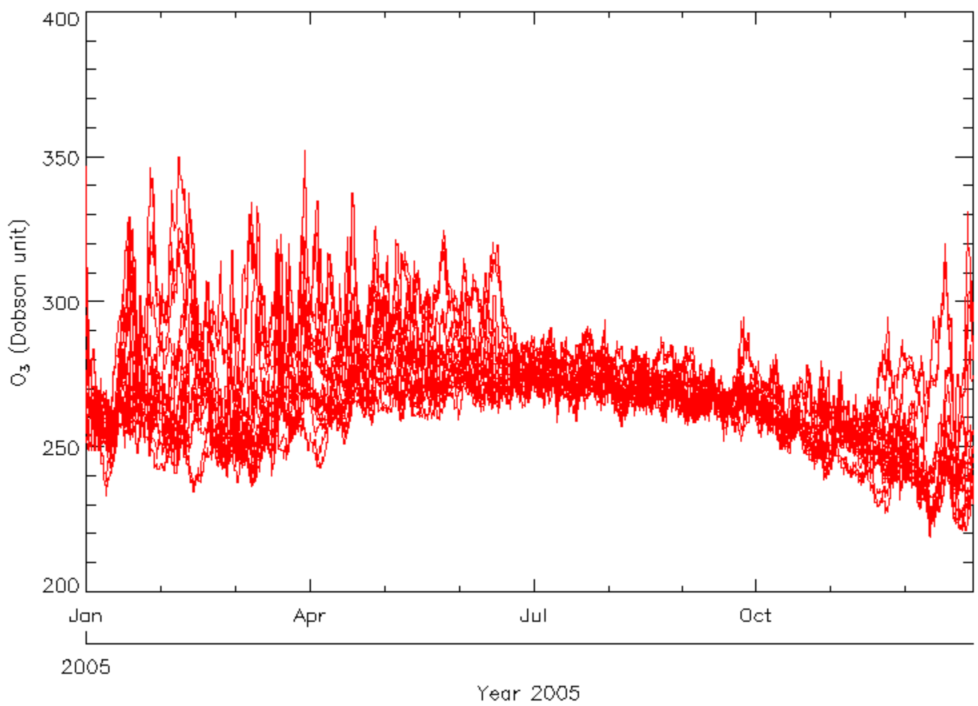
Future work and developments - 2





System response to uncertainties… Assessment of the RTM.





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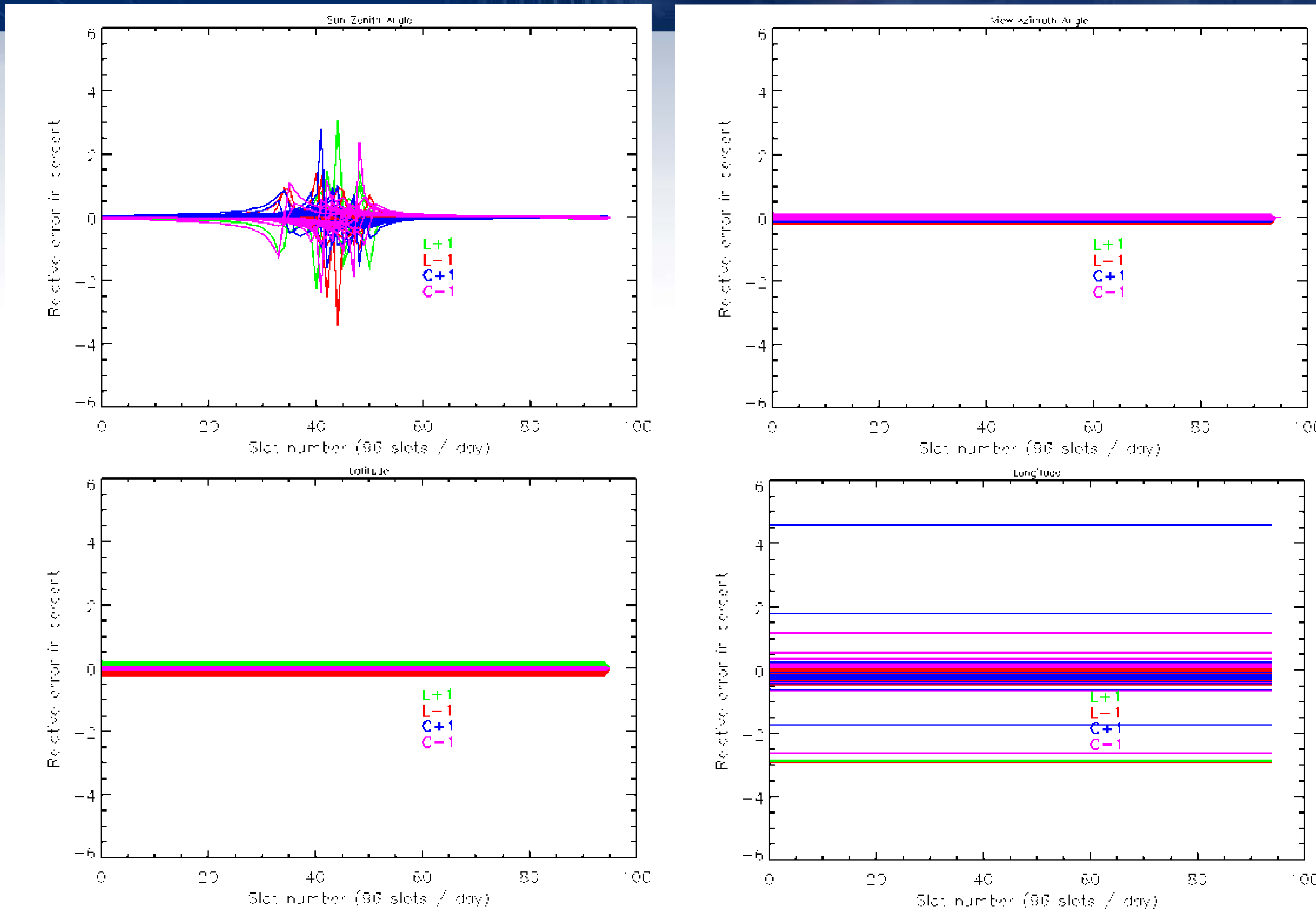

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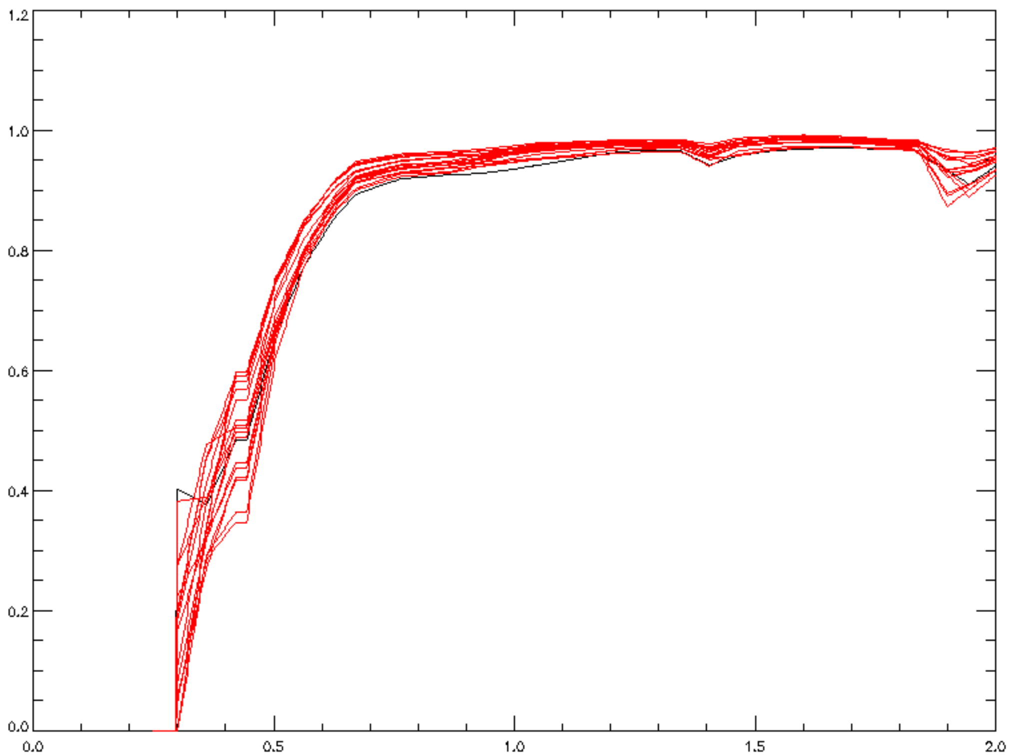

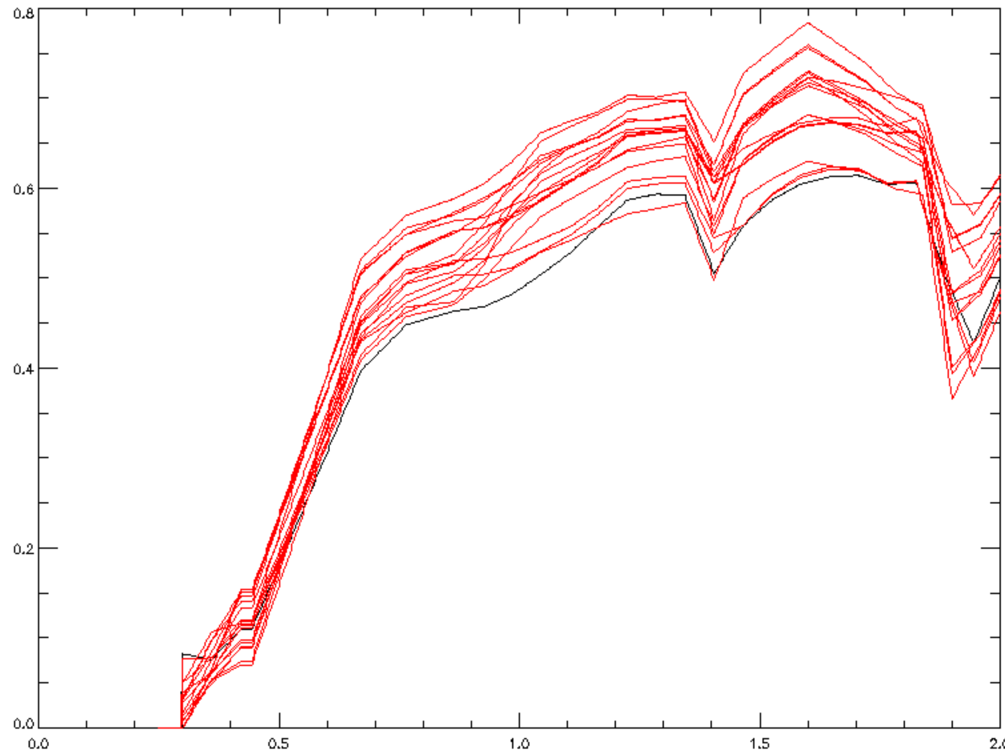

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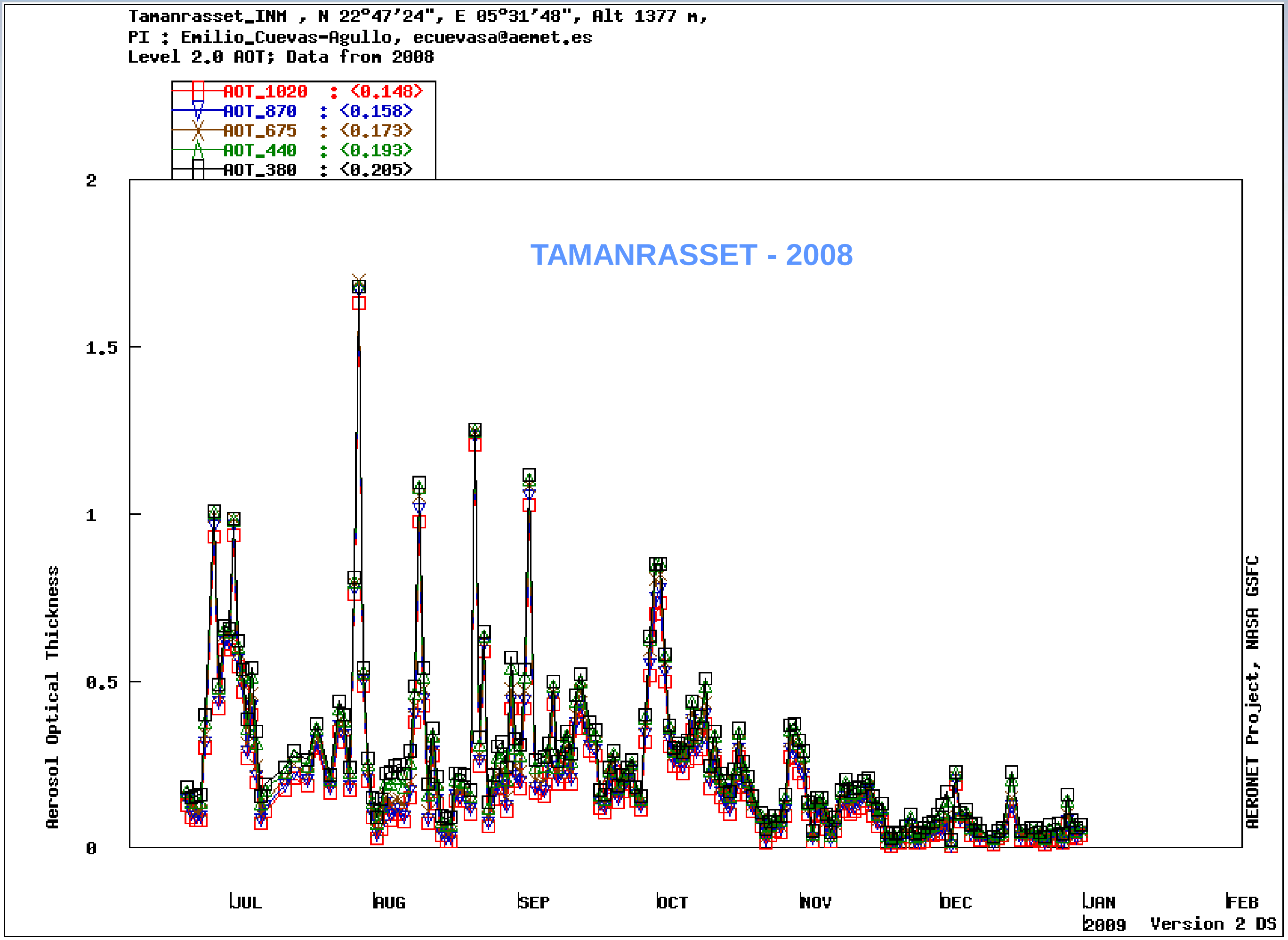

Source : AERONET

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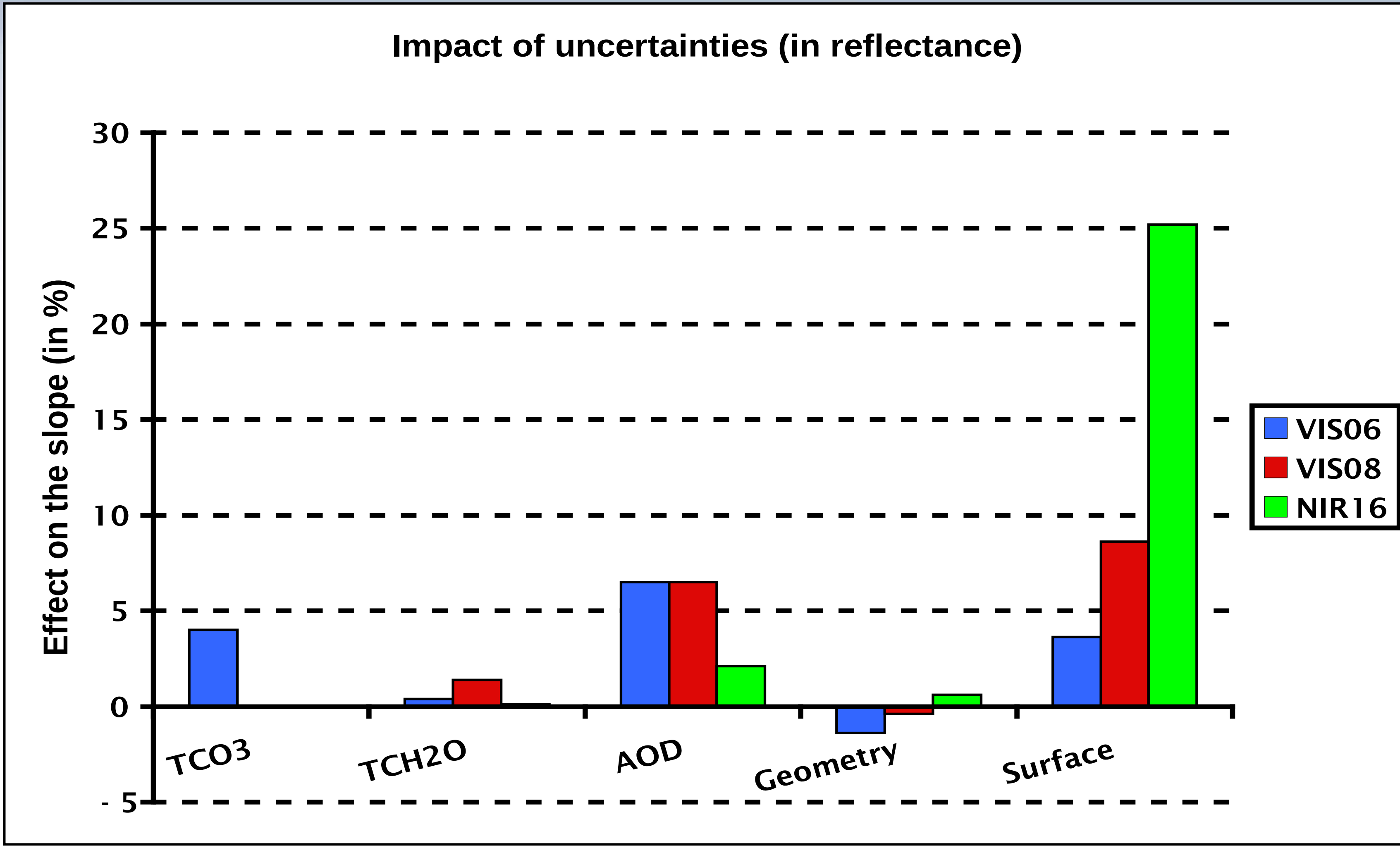
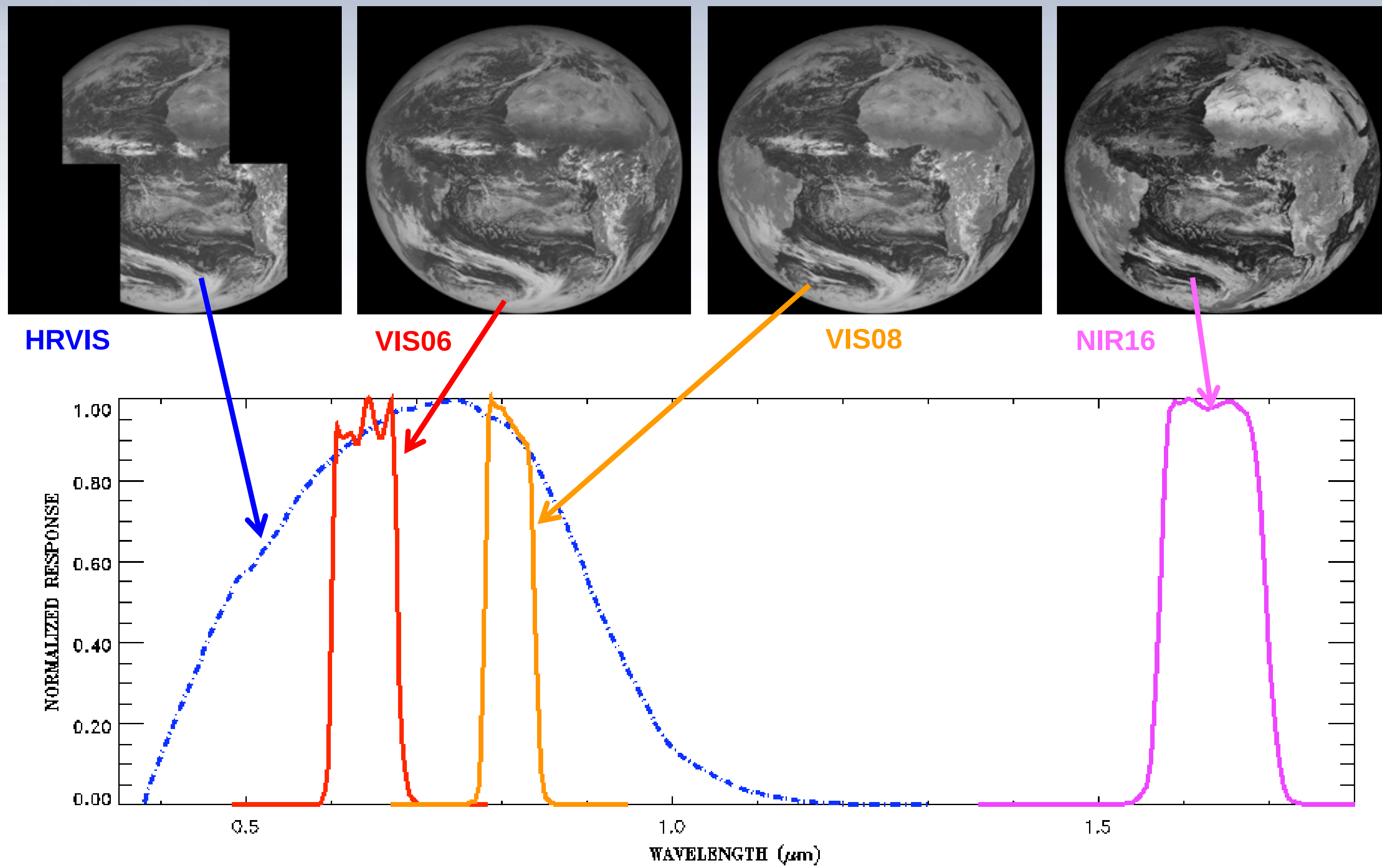
Some preliminary results... In reflectance



Delta = 30% **Delta = 20%** **Delta = 100% (Ref = 0.1)** **Delta = 2%** **Delta = 1%**

Context... The particular case of SEVIRI



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Some preliminary results... In radiance

	Delta	VIS06		VIS08		NIR16	
		Y = aX + b		Y = aX + b		Y = aX + b	
Tot. Col. O3	30%	A= 1.001	B=-2.45	A = 1.0	B=0.0	A = 1.0	B=0.0
Tot. Col. H2O	20%	A=0.999	B=-0.16	a=0.995	b=-0.54	A=1.000	B=0.0
	40%	A=0.998	B=-0.31	a=0.989	b=-1.02	A=0.999	B=-0.06
AOD	50%	a=1.01	B=-1.72	A=1.015	B=-2.17	A=1.013	B=-0.53
	100%	A=1.027	B=-4.15	A=1.027	B=-4.15	A=1.025	B=-1.04
Geometry	1% (lat/lon)			A=1.007	B=-1.13		
	2% (SZA)	A=1.024	B=-6.2	A = 1.024	B=-5.281	A=1.021	B=-1.434
Surface 9% / 13% / 28%	9%	A=0.919	B=6.59	A=0.894	B=6.677	A=0.822	B=2.986

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Some preliminary results... In reflectance

	Delta	VIS06		VIS08		NIR16	
		Y = aX + b		Y = aX + b		Y = aX + b	
Tot. Col. O3	30%	a= 0.96	B=0.01	A = 1.0	B=0.0	A = 1.0	B=0.0
Tot. Col. H2O	20%	A=0.996	B=0.0	a=0.986	B=0.002	A=0.999	B=-0.001
	40%	A=0.993	B=0.001	a=0.973	B=0.004	A=0.999	B=-0.001
AOD	50%	a=0.965	B=0.01	A=0.967	B=0.01	A=0.99	B=0.004
	100%	A=0.935	B=0.03	A=0.935	B=0.03	A=0.979	B=0.008
Geometry	1% (lat/lon)			A=1.007	B=-0.001		
	2% (SZA)	A=1.014	B=-0.005	A=1.004	B=-0.001	A=0.994	B=0.004
Surface 9% / 13% / 28%	9%	A=0.96367	B=0.001	A=0.914	B=0.0196	A=0.748	B=0.114

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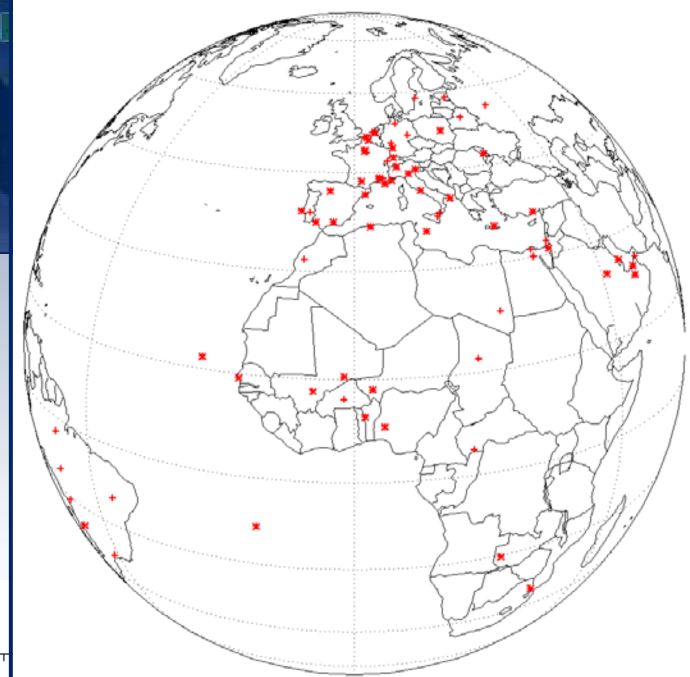
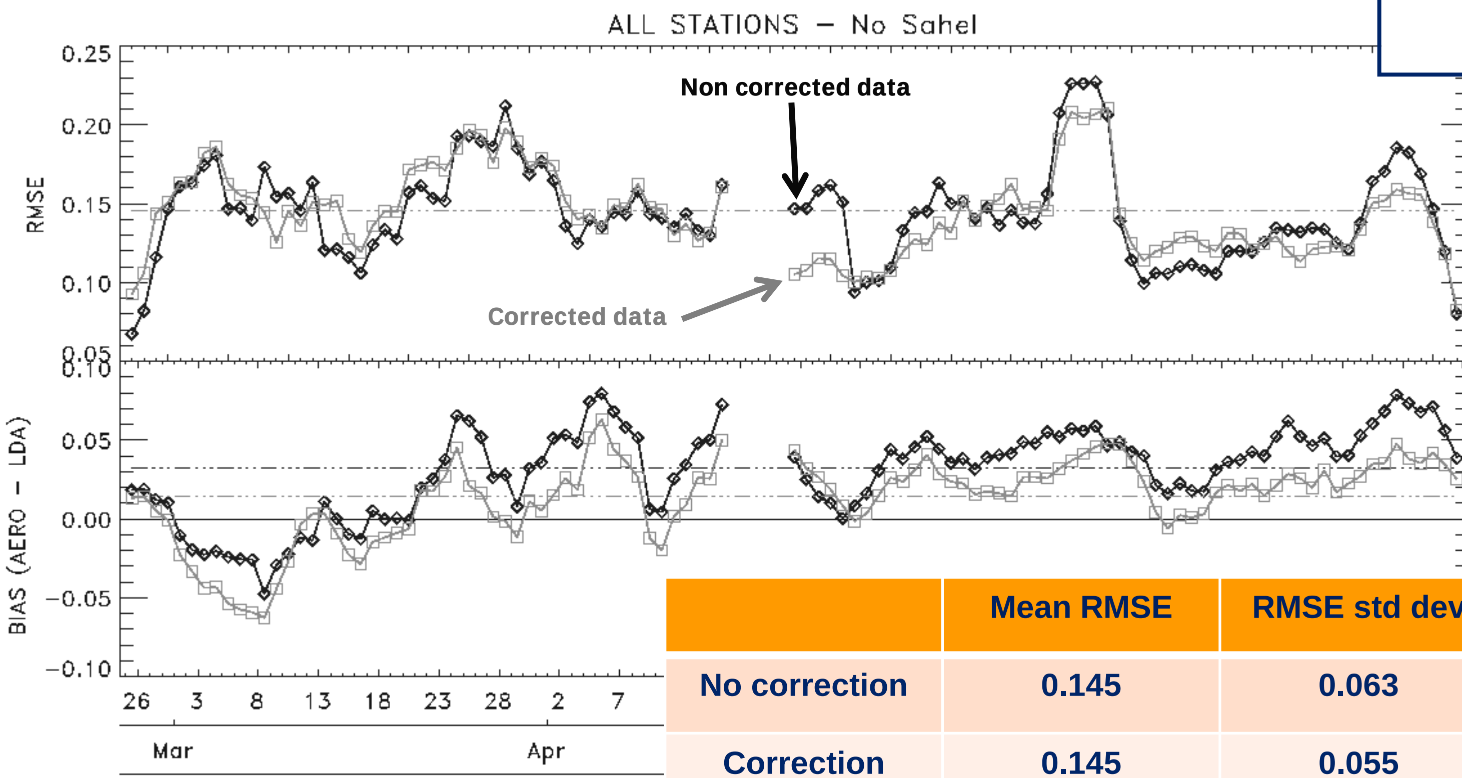
Impact of calibration uncertainties...

Retrieval of the aerosol optical depth using MSG/SEVIRI data from VIS06 / VIS08 / NIR16 ➔ Comparisons with AERONET

(Wagner, Govaerts, and Lattanzio, *Joint retrieval of surface reflectance and aerosol optical depth from MSG/SEVIRI observations with an optimal estimation approach: 2. Implementation and evaluation*, JGR, 2010)





Correction:

VIS06 = 9%

VIS08 = 6%

NIR16 = none

	Mean RMSE	RMSE std dev	Mean Bias	Bias std dev
No correction	0.145	0.063	0.032	0.0480
Correction	0.145	0.055	0.015	0.0476