Calibrating raw data from the GOME-2 instrument on Metop – Lessons learned

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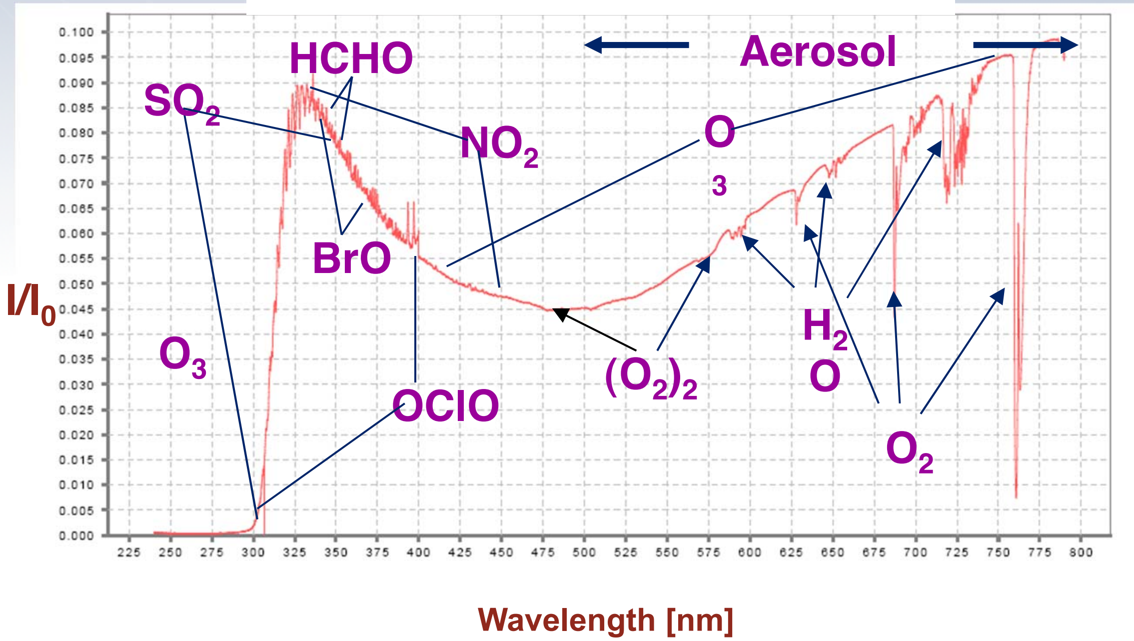
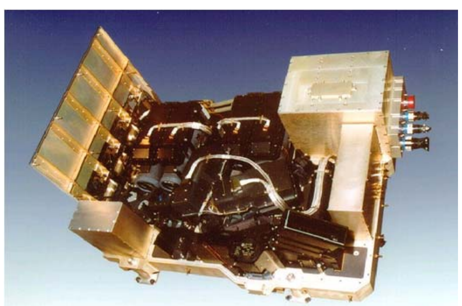
The GOME-2 instrument on Metop

Measuring atmospheric composition

GOME-2 main channel transmittance





Orbit file sizes

GOME-2 L1B ~ 1GB
IASI L1C ~ 2GB

GOME-2:

- series of 3 instruments on Metop (Metop A launched in 10/2006)
- sun-synchronous orbit, 09:30
- 412 orbits (29 days) repeat cycle
- Global coverage 1.5 days
- 240 nm to 800 nm
- 0.25 to 0. 5 nm spectral resolution (FWHM)
- 4 channels with 4098 energy measurements of polarisation corrected radiances (40 x 80 km^2)
- 2 channels with 512 energy measurements of linear polarised light in perpendicular direction (S/P) (40 x 10 km^2)

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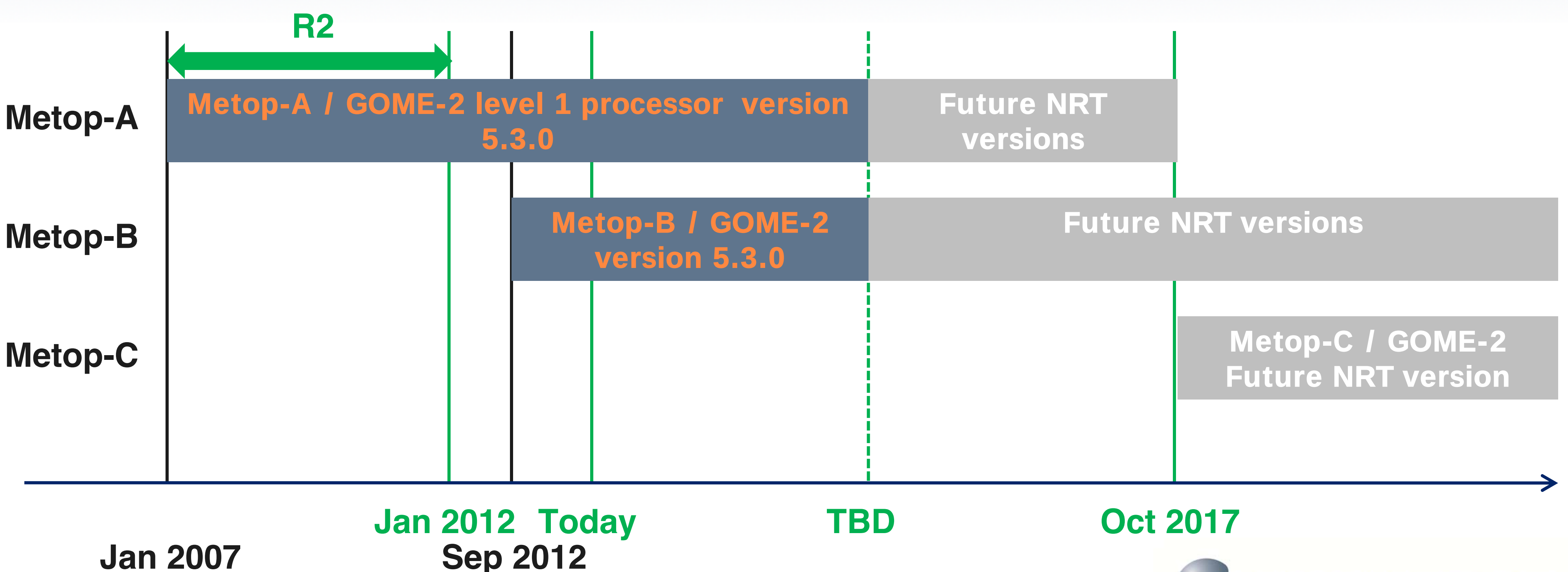
Timelines for the Metop / GOME-2 level 1 products

Processor versions: Reprocessed and NRT data

- Release of second set of reprocessed level 1 data (R2) from Metop-A GOME-2 in August 2012

(Covering: 25th January 2007 to 25th January 2012)

- Metop-B with GOME-2 flight-model 2 (FM2) launched in-orbit 17th September 2012
- Metop-A GOME-2 will continue until launch of Metop-C (October 2017)



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EPS Metop-B Product ValidationReport: GOME-2 Level 1

Doc.No.	:	EUM/OPS-EPS/DOC/12/0760
Issue	:	v3A
Date	:	17 May 2013
WBS	:	

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13th February 2013: Start of pre-operational level 1 dissemination to all users

7th May 2013: Start of operational level 1 dissemination (fully validated; see Cal-Val report)

Mid July: Start of operational dissemination of GOME-2 MetopB level-2 data

Mid July: Start of GOME-2 tandem operations with two different swath width:
- **GOME-2 / Metop-A 960 km (40x40 km)**
- **GOME-2 / Metop-A 1920 km (80x40 km)**

http://www.eumetsat.int/groups/ops/documents/document/pdf_gome_prod_val_metopb.pdf

150 pages!

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GOME-2 optical layout

Scanning grating spectrometer with a **random-access linear silicon photodiode array**

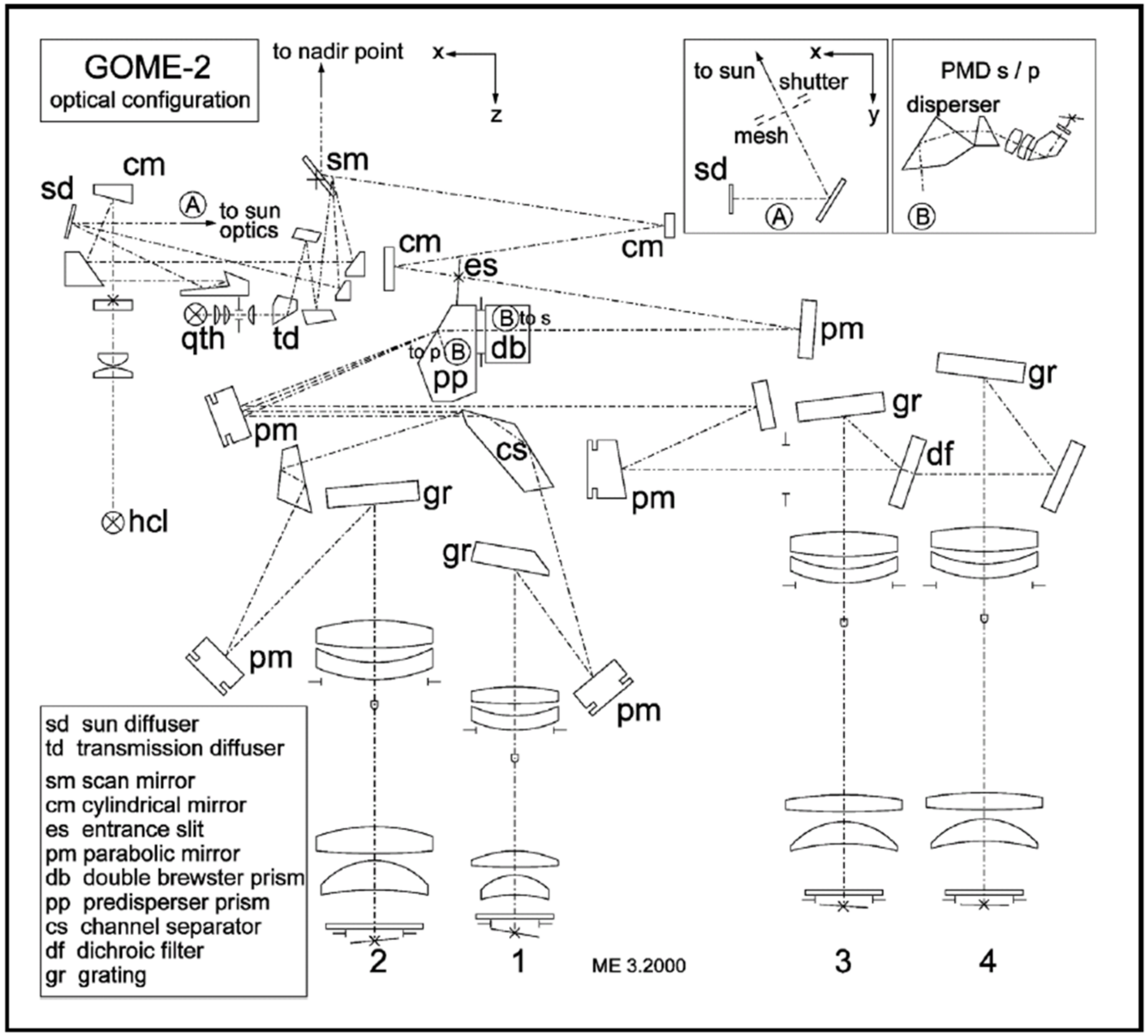

Figure 1: GOME-2 optical layout. The optics lie in one plane (except insets A and B). Nadir is in –Z direction, the flight direction is –Y; X is towards 'East'.

GOME-2 optical layout

Scanning grating spectrometer with a **random-access linear silicon photodiode array**

The generic calibration equation can be rewritten as:

$$I(\lambda_i) = \frac{S_i - SS_i - DS_i}{c_{pol}(\lambda_i, p_t(\lambda_i)) \cdot (R_{0,i}/PPG_{0,i})(\lambda_i) \cdot PPG_{t,i} \cdot m_t(\lambda_i) \cdot E_t(\lambda_i)} \quad \text{where} \qquad (408)$$

subscript *0* denotes the quantity at a reference time $t = 0$
subscript t denotes the quantity at the time of measurement

$(R_{0,i}/PPG_{0,i})(\lambda_i)$ represents the smooth part of the response function as a function of wavelength, for unpolarised input

$c_{pol}(\lambda_i, p_t(\lambda_i))$ is the polarisation correction factor as a function of wavelength and input polarisation

$PPG_{t,i}$ is the pixel-to-pixel part of the response function at detector pixel i

$m_t(\lambda_i)$ represents the degradation correction as a function of wavelength and

$E_t(\lambda_i)$ represents the change in Etalon as a function of wavelength.

PGS 7
http://www.eumetsat.int/groups/ops/documents/document/PDF_TEN_990011-EPS-GOME-PGS.pdf

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Lessons learned: level 0 to 1b calibration

Maturity and criticality

GOME-2: Scanning grating spectrometer with a random-access linear silicon photodiode array

Mature, with limitations, critical

Calibration step	Algorithm	Key-data pre-launch	Key-data in-flight	In-flight measurements	Criticality
Dark signal correction	**mature**	not needed	not needed	needed	Stability and light tightness
Detector pixel-to-pixel differences	**mature**	not needed	not needed	LED	Stable
Stray-light	**Some** limitations	needed but comes with large uncertainties	potentially	potentially	Critical because of characterisation and stability
Polarisation	**mature (although complex)**	Needed but with significant uncertainties	potentially	needed for correction	Stable if combined with in-flight correction

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Lessons learned: level 0 to 1b calibration

Maturity and criticality

GOME-2: Scanning grating spectrometer with a random-access linear silicon photodiode array

Mature, with limitations, critical

Calibration step	Algorithm	Key-data pre-launch	Key-data in-flight	In-flight measurements	Criticality
Geo-pointing and spatial aliasing	**mature**	potentially	potentially	Potentially depending on approach	open
Radiometric calibration	**mature**	Needed but comes with significant uncertainties	potentially with solar calibrations	Potentially for instrument degradation correction	Critical because of characterisation and stability
Spectral calibration	**Mature (avoid use of polynomials)**	not needed	needed	Yes (sun or SLS)	Stable
Slit function	**mature**	Needed but comes with significant uncertainties	Potentially for FWHM not for shape	yes	Critical because of characterisation and stability

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Lessons learned: level 0 to 1b calibration

Maturity and criticality

GOME-2: Scanning grating spectrometer with a random-access linear silicon photodiode array

Calibration step	Criticality	Status and lessons learnt
Dark signal correction	Stability and light tightness	Challenge: Acquire enough statistics (enough measurements per integration time and within dark side eclipse)
Stray-light	Critical because of characterisation and stability	Lack of stable and/or representative in-flight targets and very limited on-ground characterisation: much better on-ground characterisation needed
Polarisation	Stable if combined with in-flight correction	Stokes fractions for special geometries (q=0) can be efficiently used to correct on-ground calibration deficiencies in key-data

Mature, with limitations, critical

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Lessons learned: level 0 to 1b calibration

Maturity and criticality

Calibration step	Criticality	Status and lessons learnt
Radiometric calibration	Critical because of characterisation and stability	1) Much higher accuracies (->0.1%) are needed than currently can be established on-ground end-to end (1-2%) 2) The goniometric diffuser distribution can be evaluated from in-flight but only after one year of stable data-acquisition
Slit function	Critical because of characterisation and stability	For GOME-2 Metop-A a continuous change in FWHM has been observed. The latter can potentially be corrected, however not any potential changes in the shape
Degradation	Critical for S/N and because of differential degradation	• Optical bench needs to be fully thermally controlled. • Cold finger close to detectors or other sensitive parts. • Instrument handling and storage is critical • Contamination through conformal coating outgassing, through ice built-up, UV triggered contamination (ketones) and radiation damage must be mitigated

Mature, with limitations, critical

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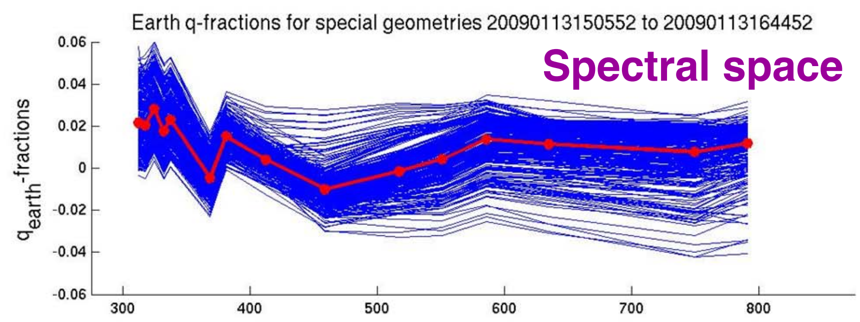
GOME-2 level-1 product status – previous updates

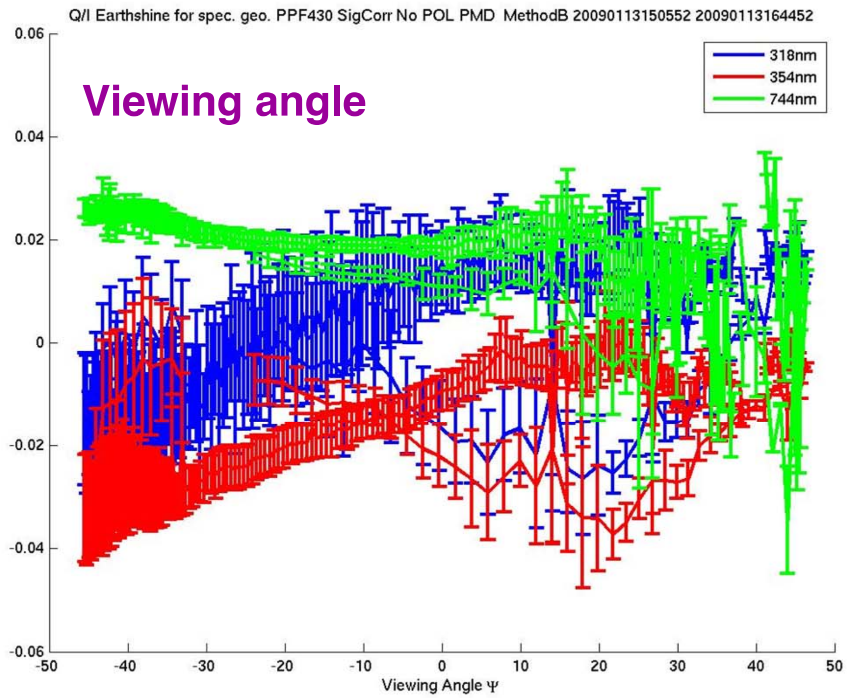
Online Stokes fraction correction – PPF 4.3 and higher

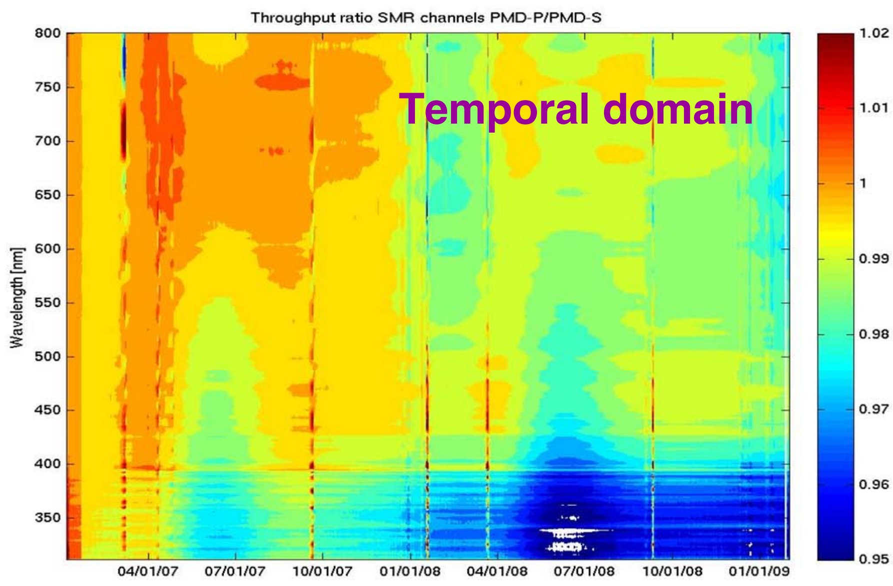
New algorithm development:
Online correction to **keydata** in 3D space

$$\overline{\Delta} = \frac{M_s}{M_P} - \frac{S^S}{S^P} \stackrel{!}{=} 0$$

from approx. 1 day of special geometry band readouts







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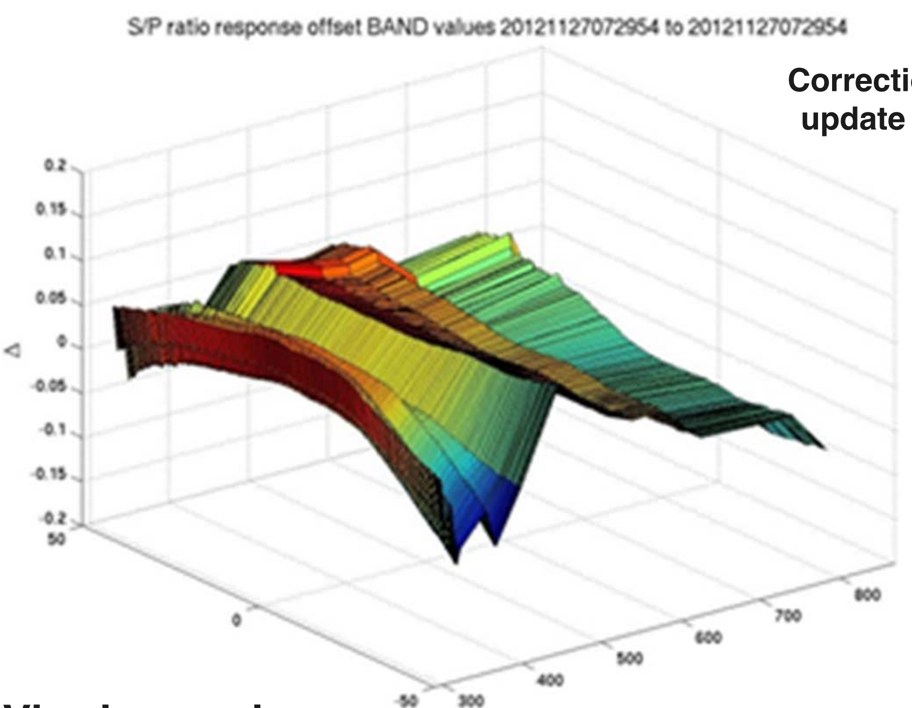
In-flight online (continuous) Stokes fraction correction
Correcting PMD-P and S radiance ratio values

Is polarisation sensitivity a problem? – No!

Online in-orbit correction possible using special geometry Stokes fractions! q=0

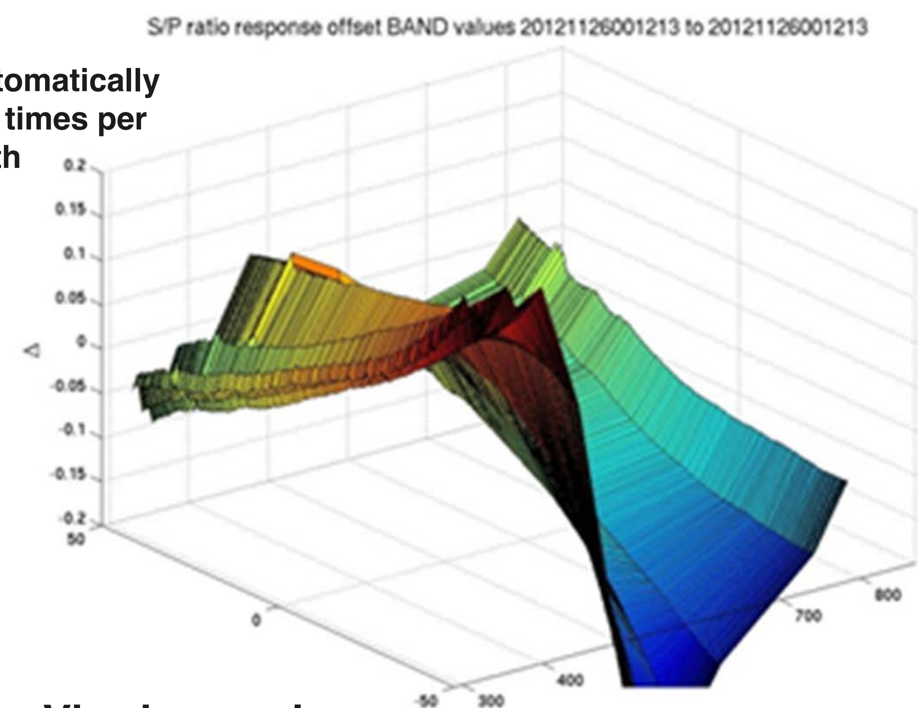
Metop-B / FM2



Viewing angle
Wavelength

Correction automatically update 2 to 4 times per month

Metop-A / FM3



Viewing angle
Wavelength

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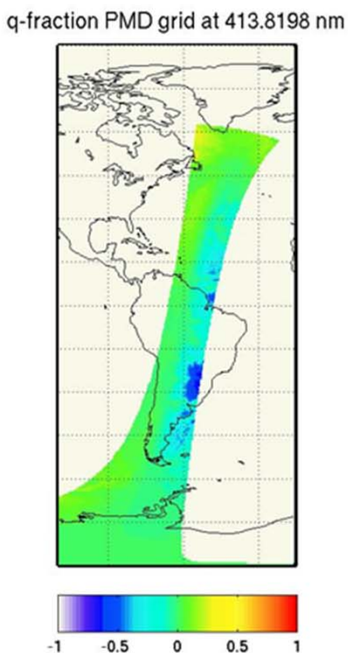
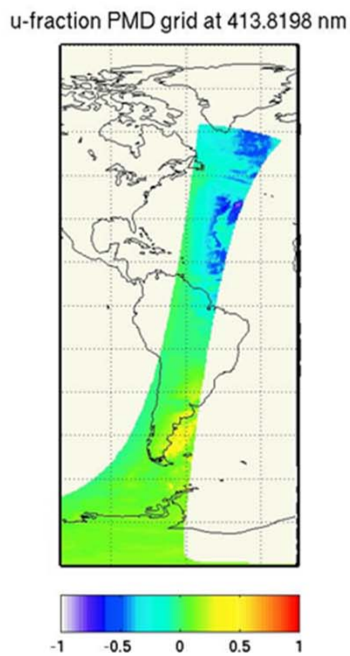
In-flight online (continuous) Stokes fraction correction

Correcting PMD-P and S radiance ratio values – q and u Stokes fractions

Metop-B / FM2

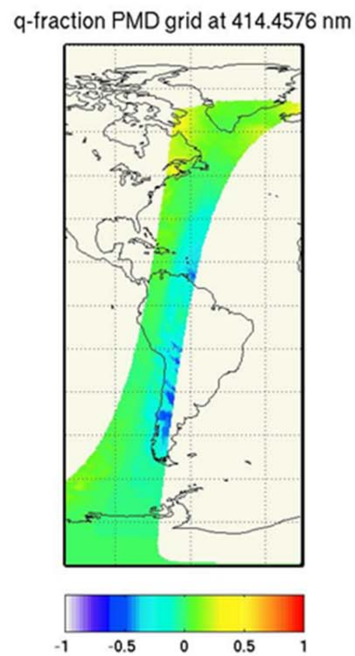


q-fraction

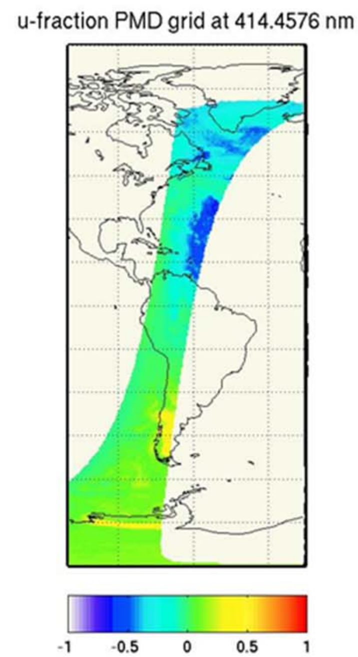


u-fraction

Metop-A / FM3



q-fraction



u-fraction

Assumption used for u: $u = u_{ss}/q_{ss} * q$

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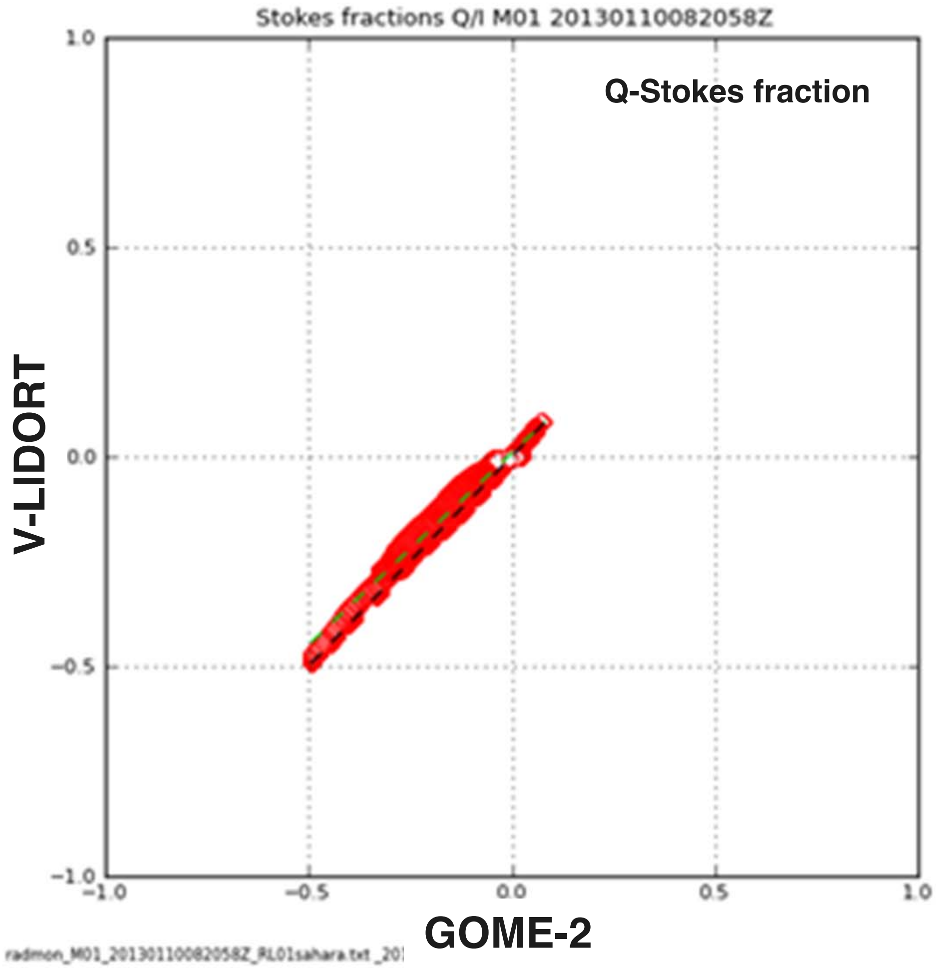
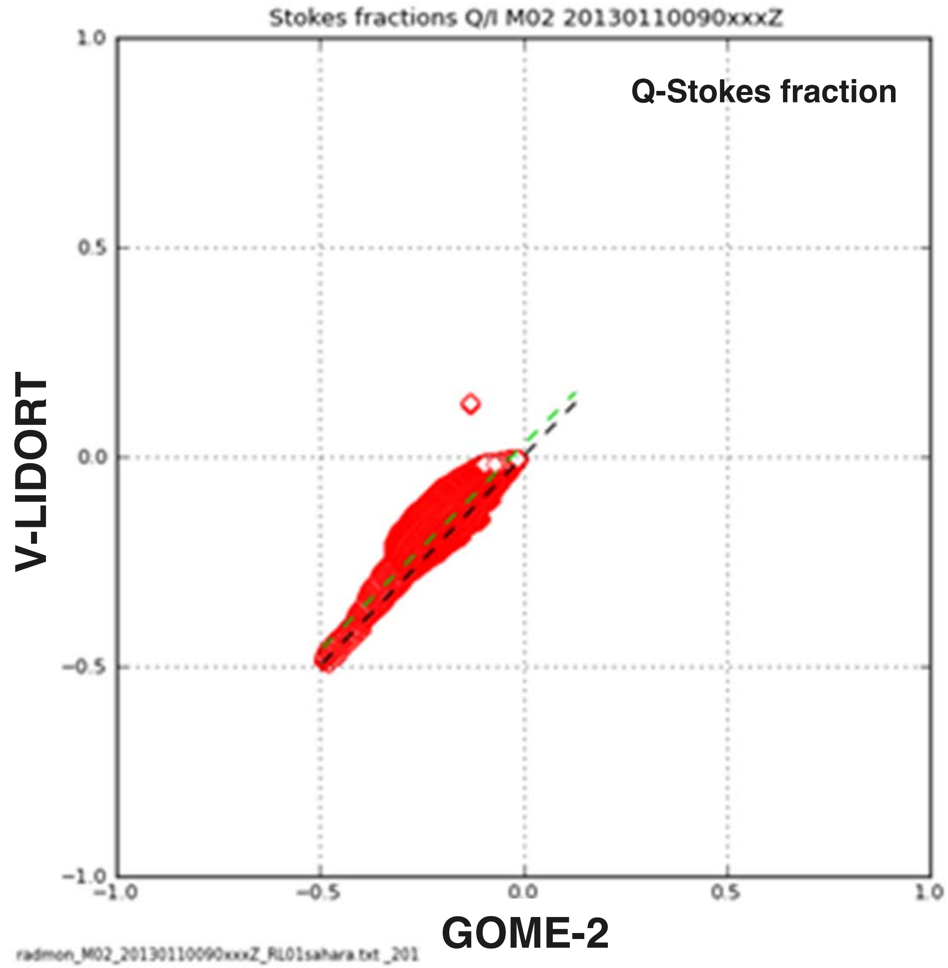
In-flight online (continuous) Stokes fraction correction

Correcting PMD-P and S radiance ratio values – q validation using V-Lidort

Metop-B / FM2



Metop-A / FM3



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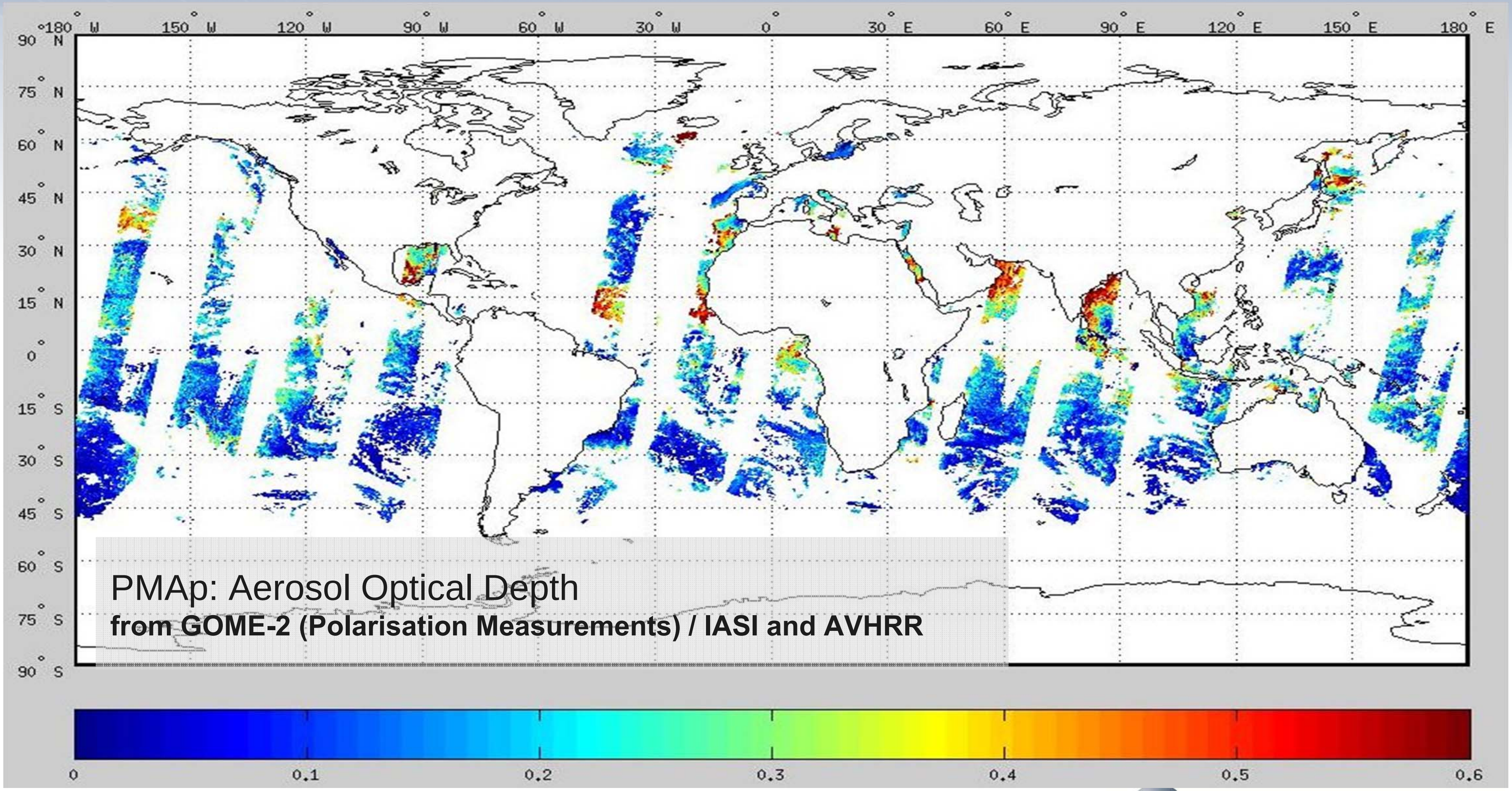
In-flight online (continuous) Stokes fraction correction

Retrievals of aerosol optical properties



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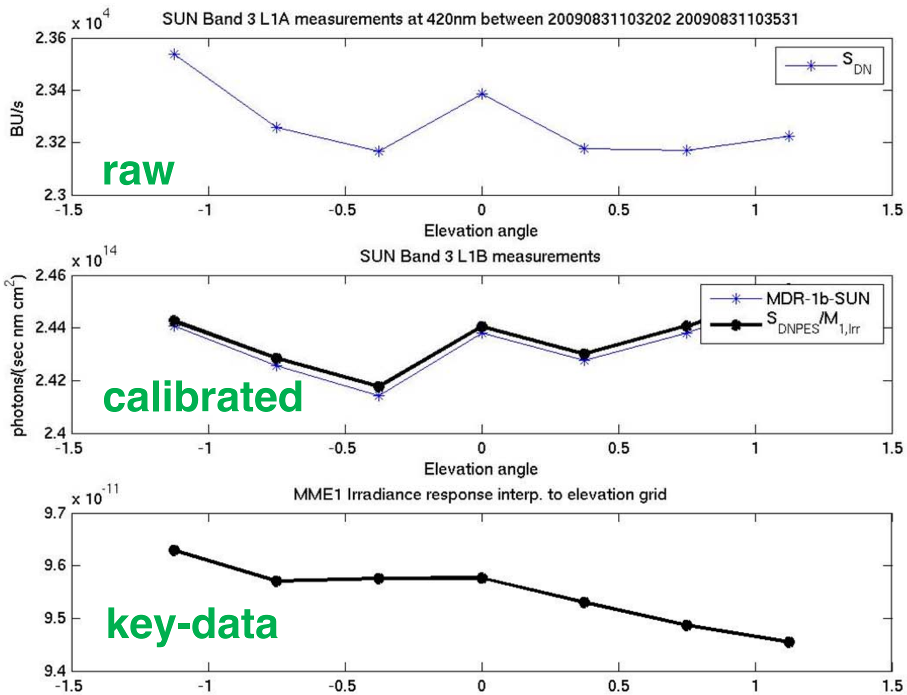
Goniometry: Angular dependence for Solar Measurements (AIRR)

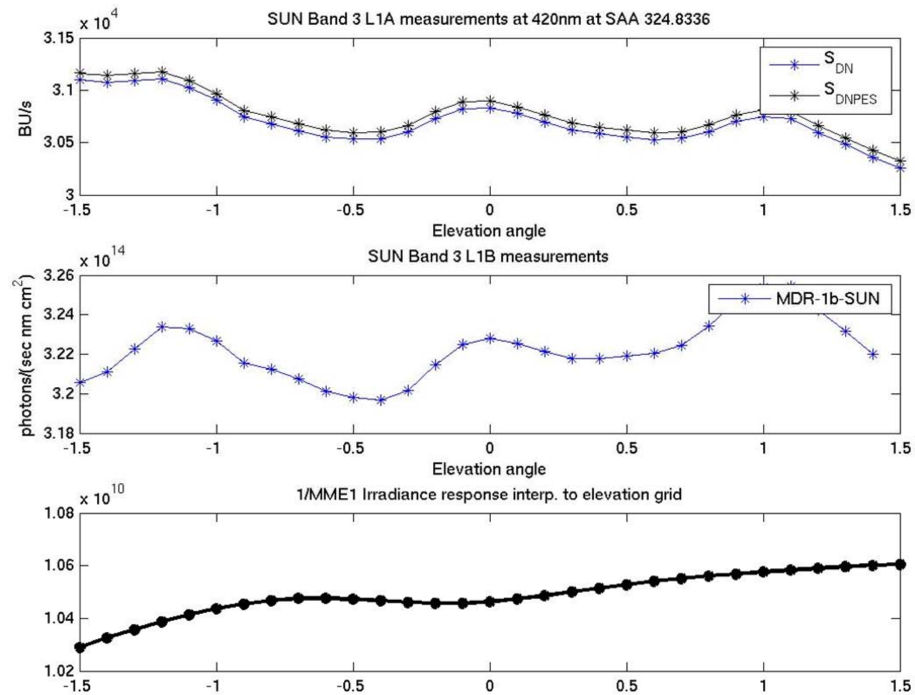
Comparison between current key-data and high res. elevation angle grid

Band 3 solar signals at 420 nm

GOME-2/Metop-A



Solar Elevation angle



Solar Elevation angle

Key-data – angle resolution

In-flight derived values with increased angular resolution

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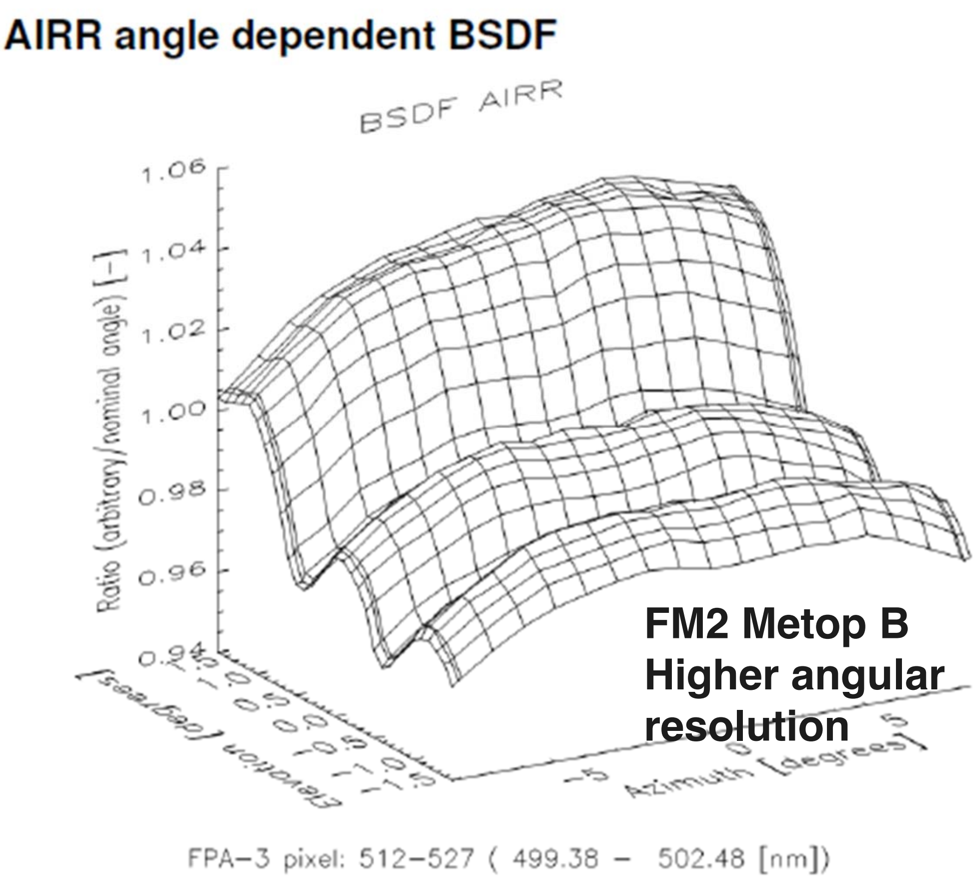
Goniometry: Improved AIRR measurements for FM-2

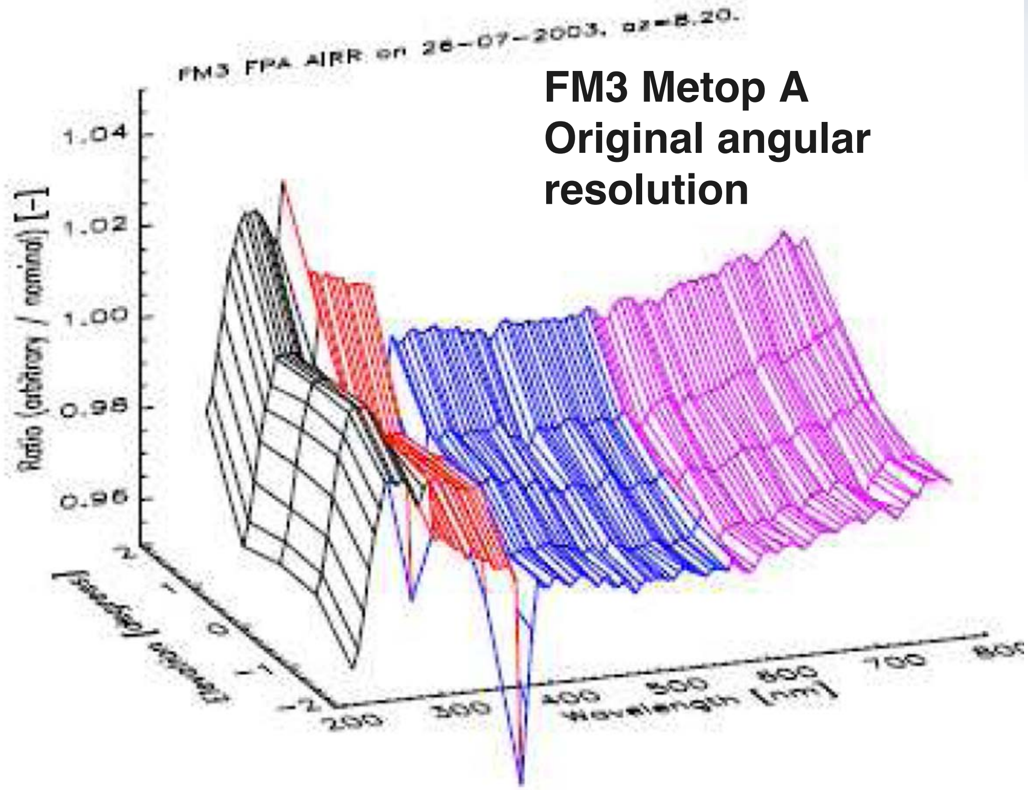
TNO FM2 delta calibration campaign (Kenter et al.)

SAA: 0.5 resolution (317 to 333)

Elevation: 0.1 resolution (-1.5 to 1.5)

Similar to L1-processor angle fine-grid as defined in initialisation file!





Goniometry: Angular dependence for Solar Measurements (AIRR)

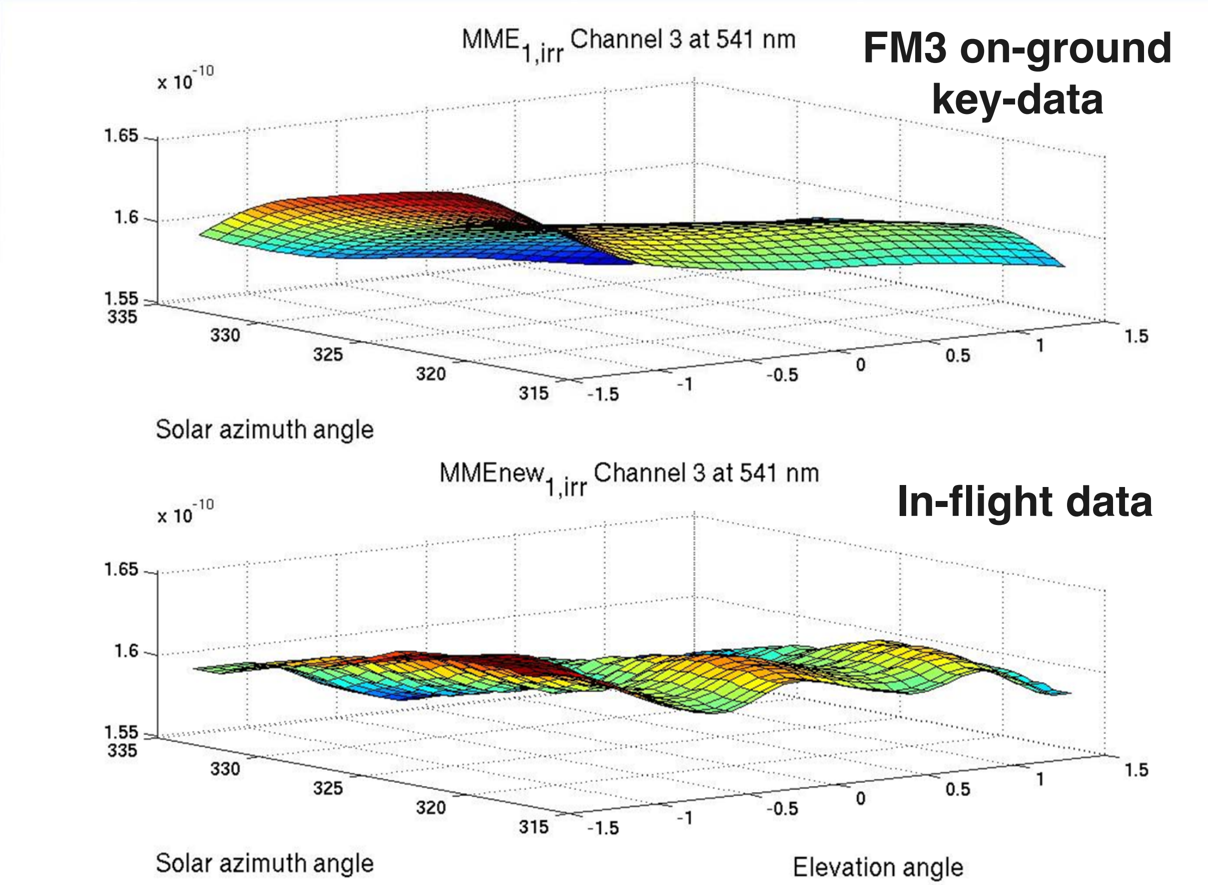
Comparison between current key-data and high res. elevation angle grid

Is the characterisation of the angular dependence for irradiance a problem? Yes and No!

The Angular dependence of irradiance on the diffuser in elevation and solar azimuth $I_0(\phi,e)$ is

- difficult to measure on-ground (long-measurement period / in vacuum)
- but one can derive it from in-flight data
- 1 year of in-flight data needed

Of relevance also for other current and future missions!



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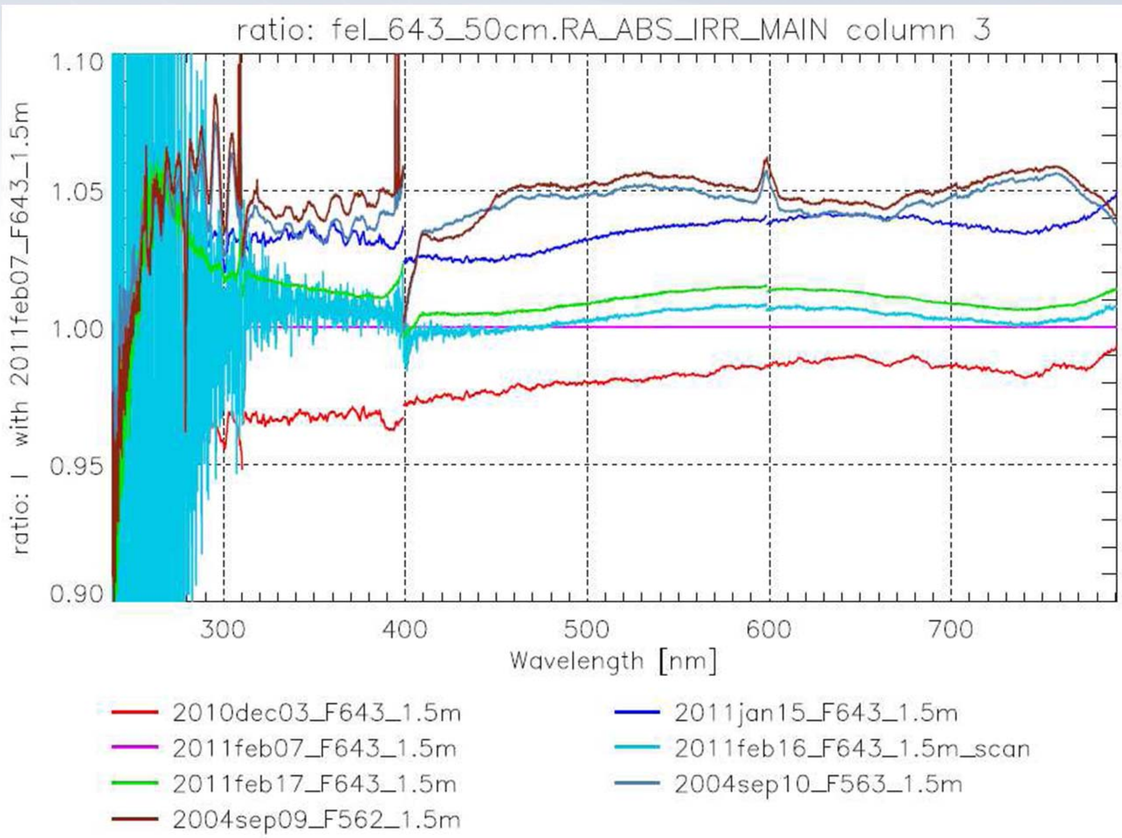
Findings during GOME202-2 Delta Calibration

Radiometric Calibration – On-ground Irradiance response

Irradiance Calibration



Radiometric Calibration Investigations

Same principle setup but measured at different times (i.e. With new realignments)

Large deviations

+/- 4-5% !!!

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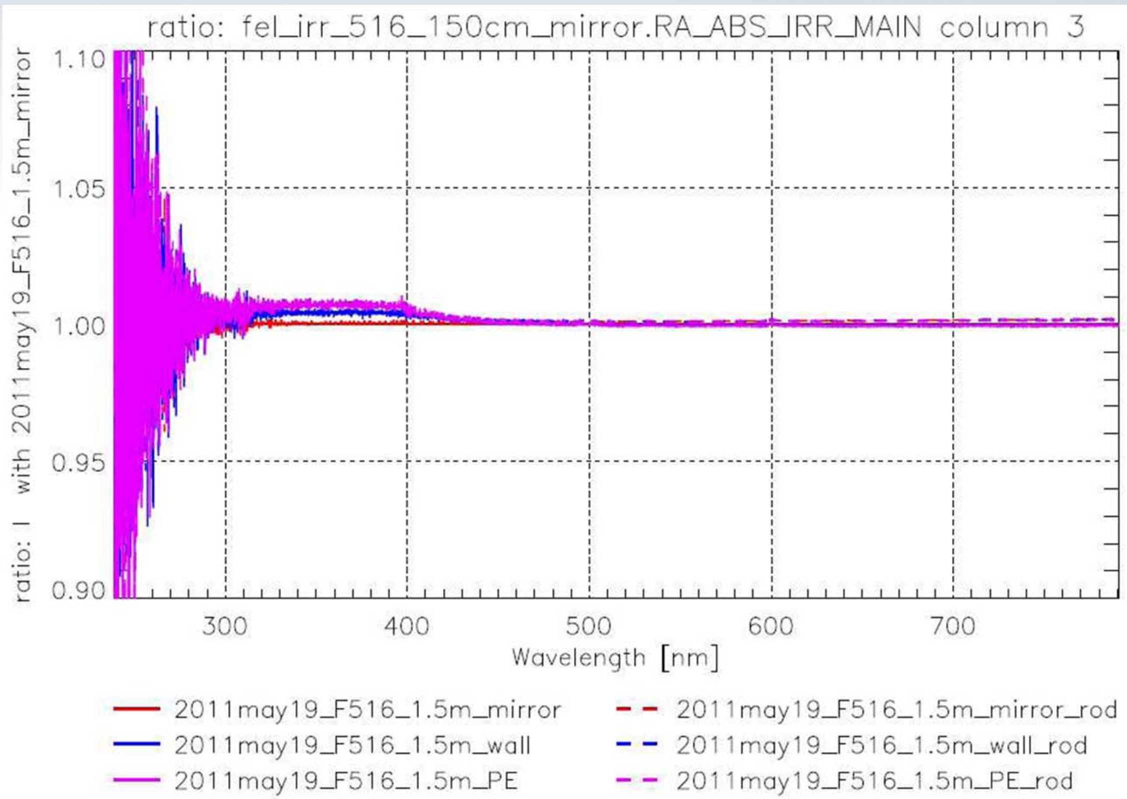
Findings during GOME202-2 Delta Calibration
Radiometric Calibration – Potential stray-light contribution

Irradiance Calibration: Effect of Straylight



Radiometric Calibration Investigations

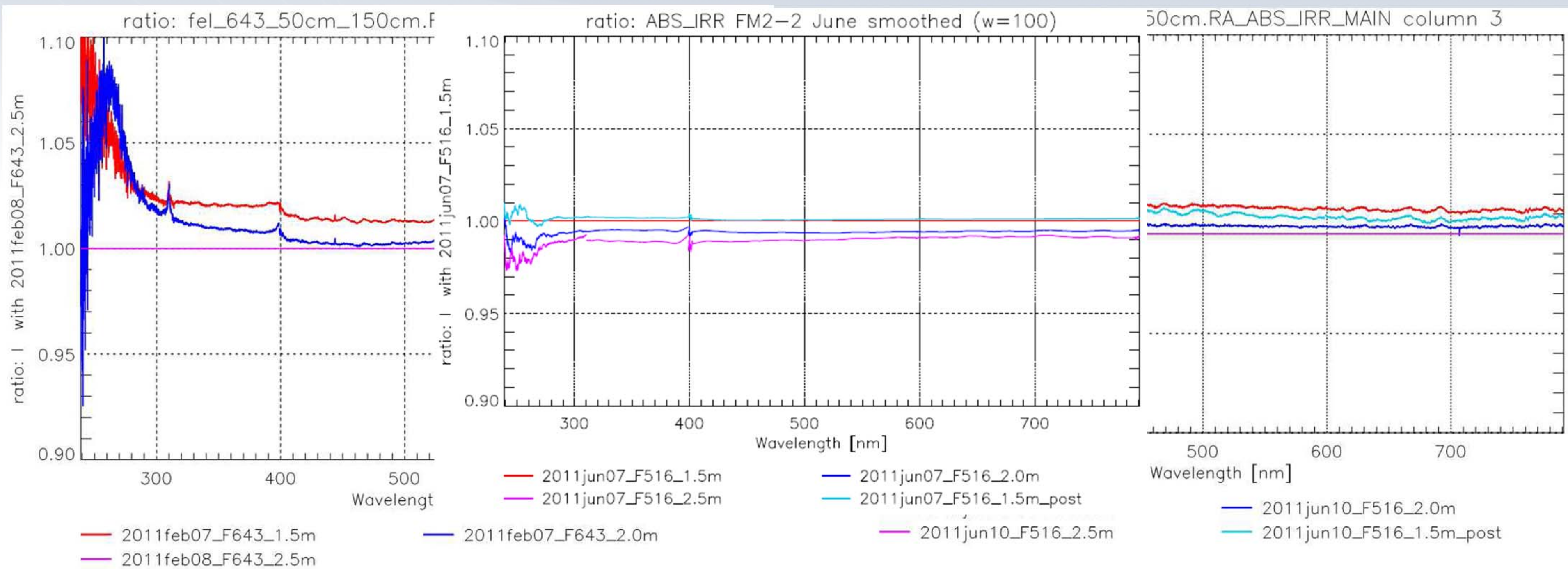
The influence of environmental straylight was in this case small.

Findings during GOME202-2 Delta Calibration

Radiometric Calibration – Alignment issues

Irradiance Calibration: Effect of Measurement Distance

Radiometric Calibration Investigations



For irradiance the effects of deviations due to change in distance between the lamp and diffuser are most likely due to non-ideal geometry of the setup. The closer the source is to the diffuser the more non-ideal the geometry will be. This is confirmed by the fact that the deviation between the measurements for the longest distances are way below 1%, whereas the shortest distance shows a larger deviation.

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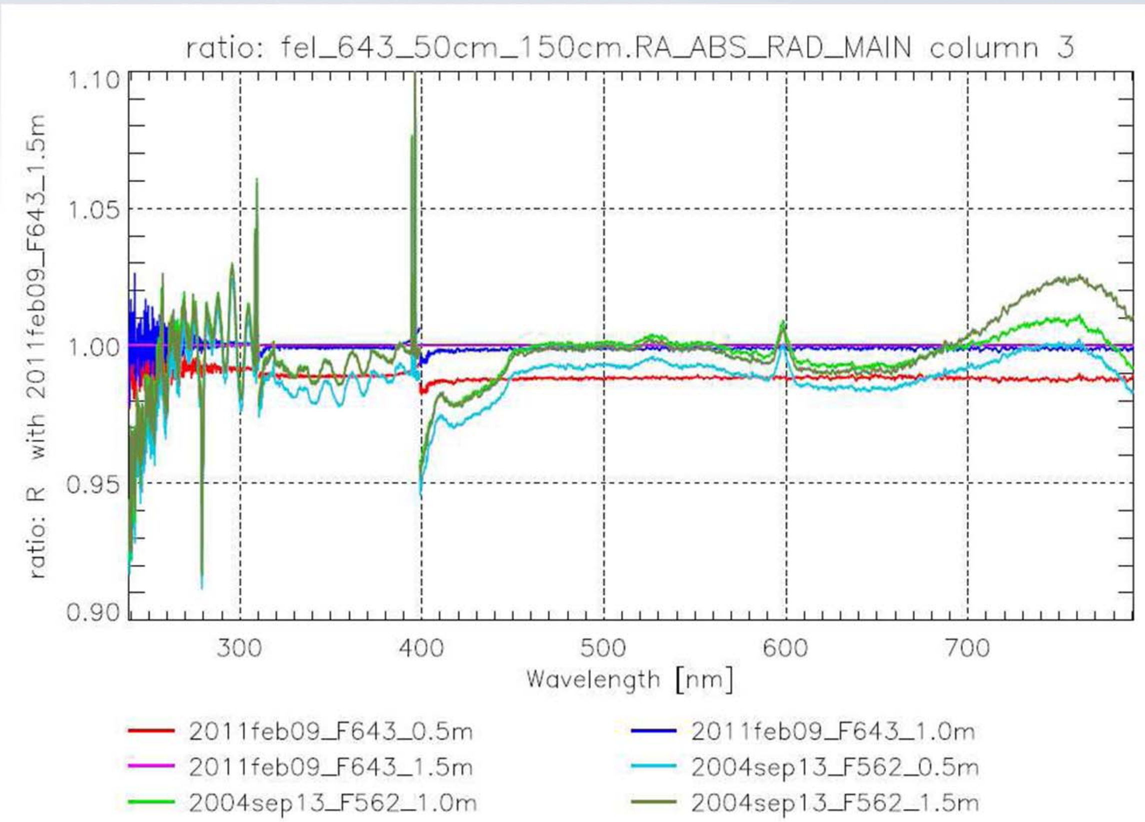
Findings during GOME202-2 Delta Calibration
Radiometric Calibration – Alignment issues

Radiance Calibration



Radiometric Calibration Investigations

Smaller deviations (with evidence of residual etalon from the earlier calibration)

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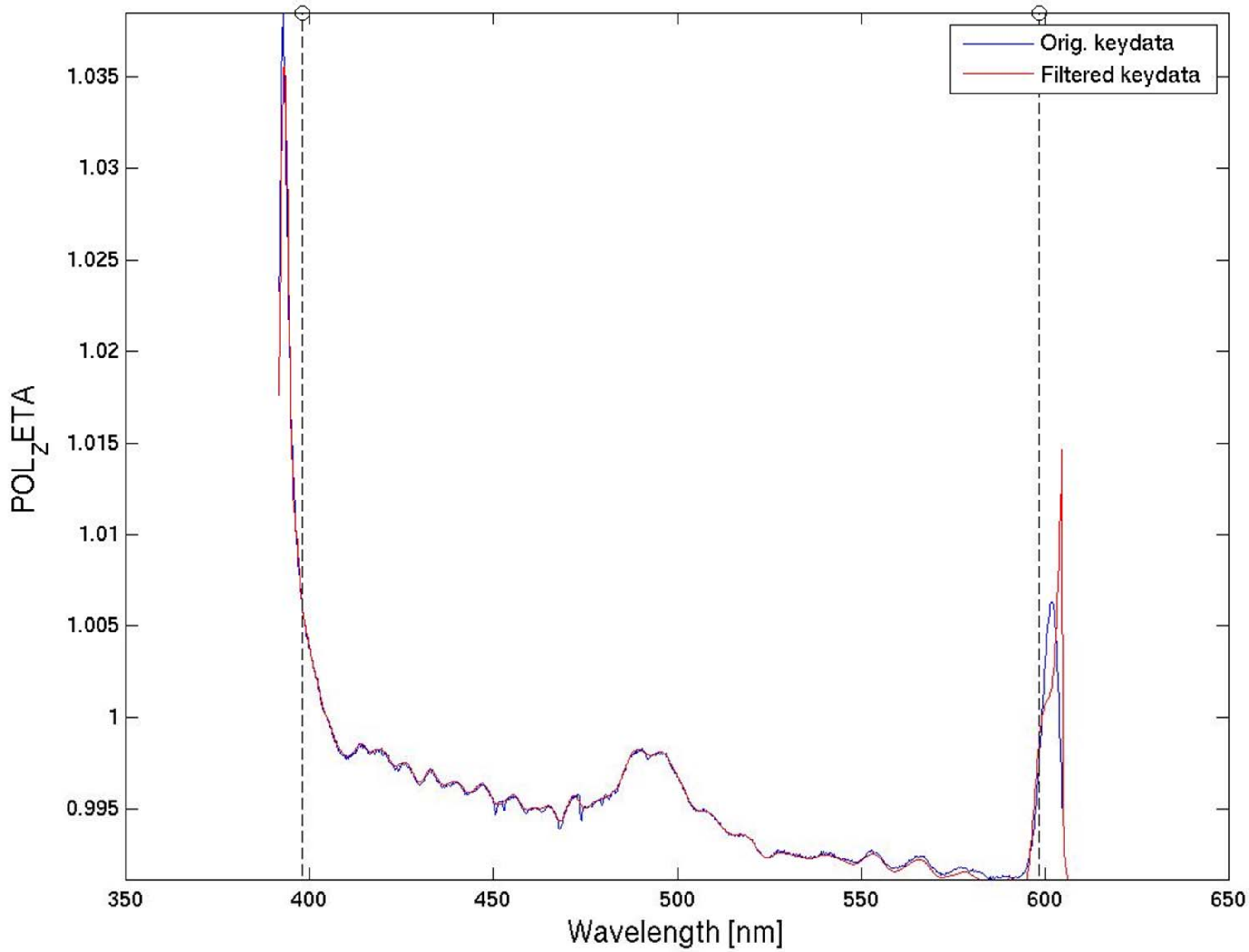
Findings in-orbit after GOME202-2 Delta Calibration
Channel 3: Key-data artifacts

GOME-2 FM2
Metop-B

“Zeta” in channel 3
(pol. Sensitivity for 45 degrees polarised light)

FFT filter removes small scale structure



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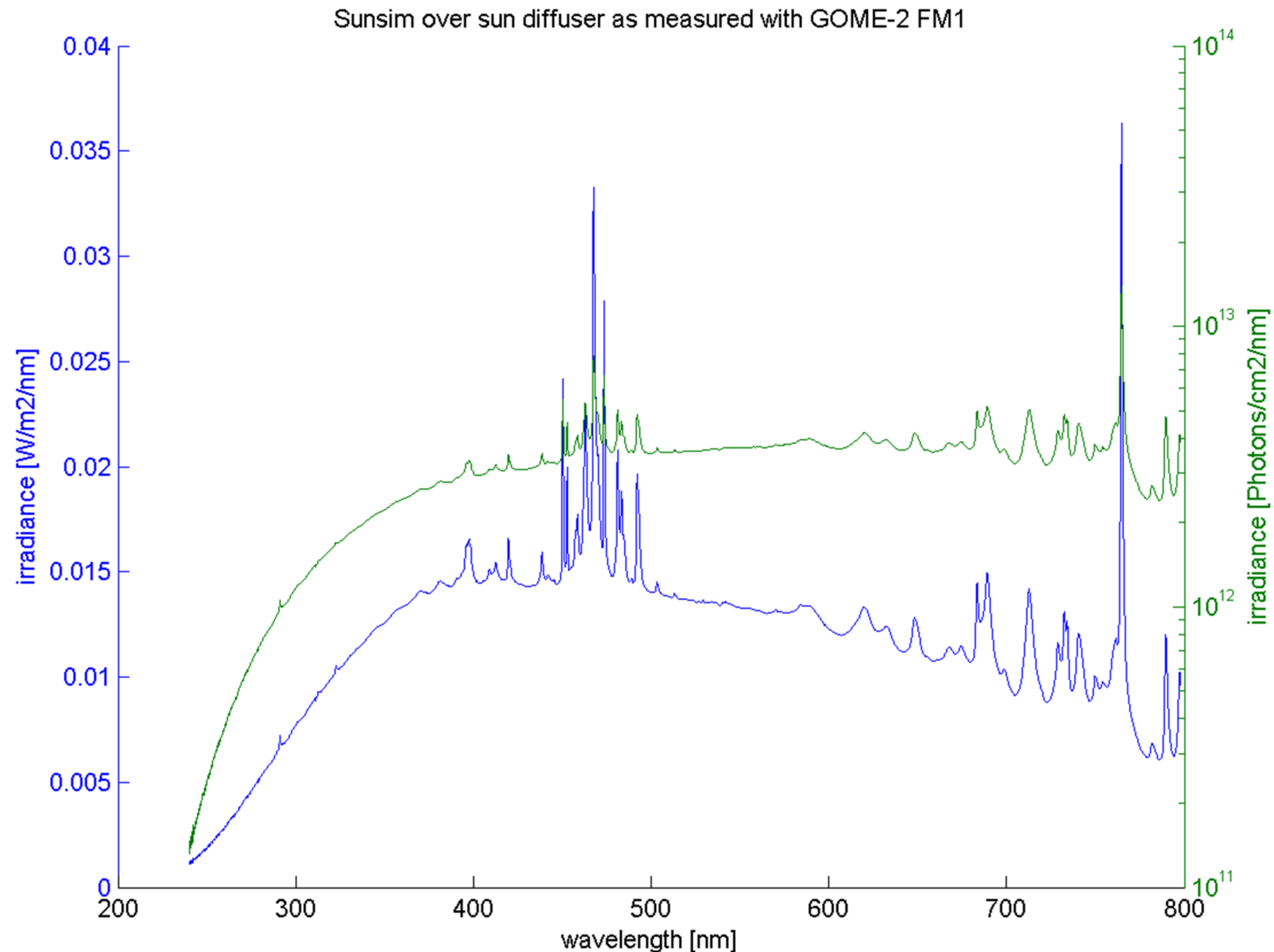
Findings in-orbit after GOME202-2 Delta Calibration

Channel 3: Key-data artifacts – light sources used during calibration

GOME-2 FM2
Metop-B

Origin of small scale structure:
Xe calibration lamp

Residuals are the result of an instability of the lamp during measurement period ***(otherwise the spectral structures are divided out)***



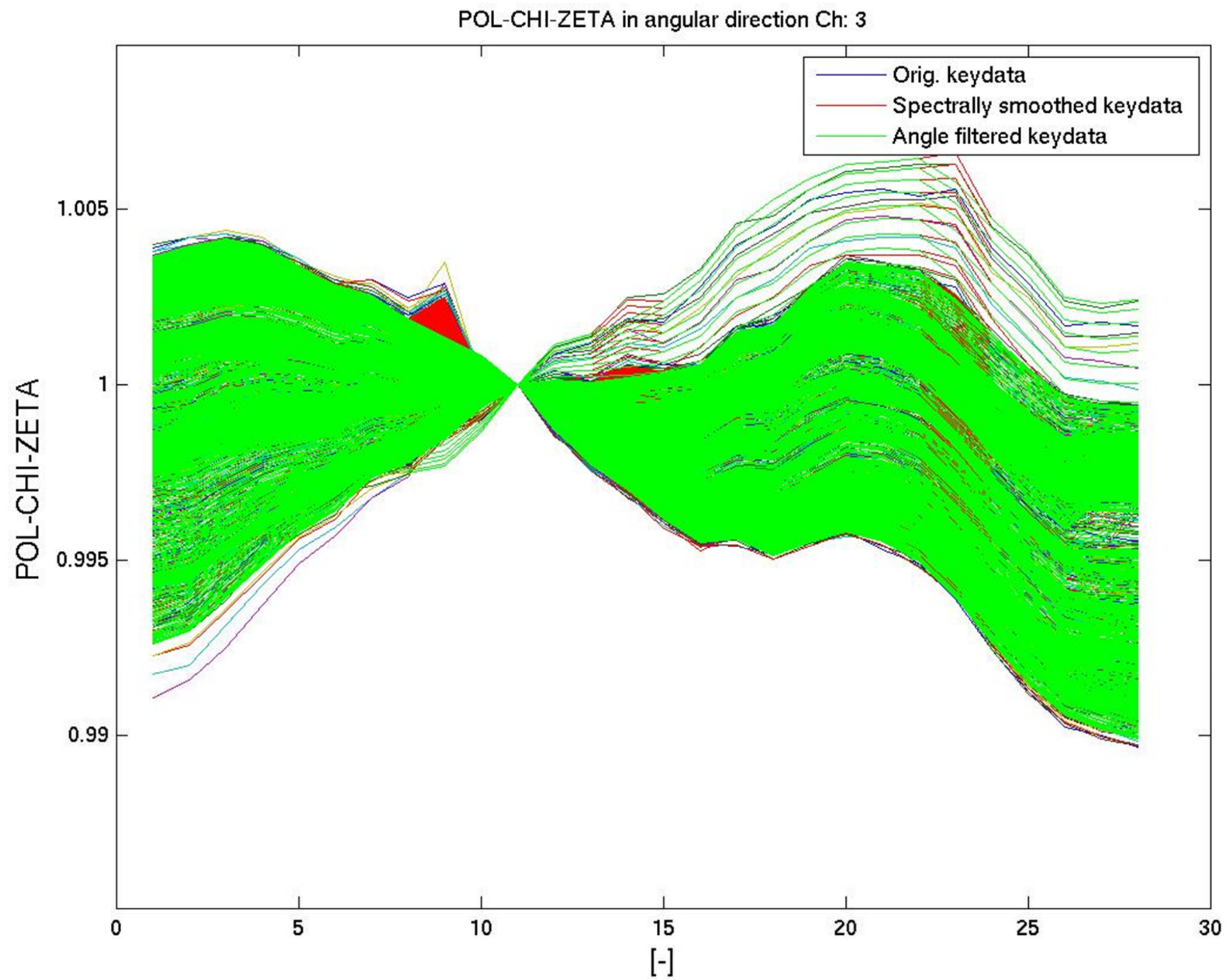
Courtesy G. Otter, TNO/TPD

Findings in-orbit after GOME202-2 Delta Calibration

Channel 3: Key-data artifacts – viewing angle direction

GOME-2 FM2
Metop-B

Angular dependence of "Zeta" in channel 3 (Chi for Zeta)
(pol. Sensitivity for 45 degrees polarised light)



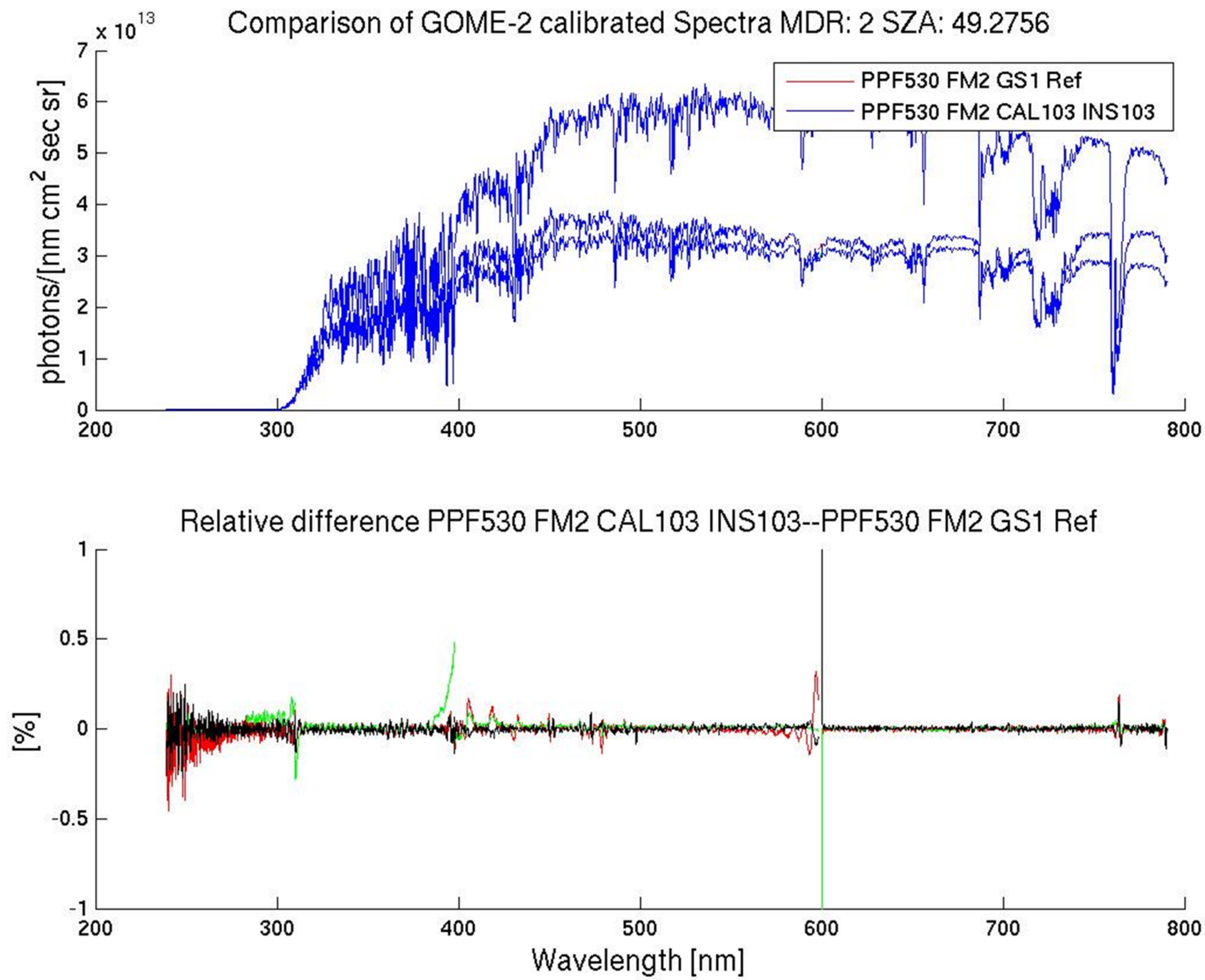
Key-data has been corrected in recent updates for FM2 and FM3 (May/June 2013)!

Findings in-orbit after GOME202-2 Delta Calibration

Channel 3: Key-data artifacts – impact on radiances

GOME-2 FM2
Metop-B

Residuals are small but spectrally persistent and varying in viewing angle

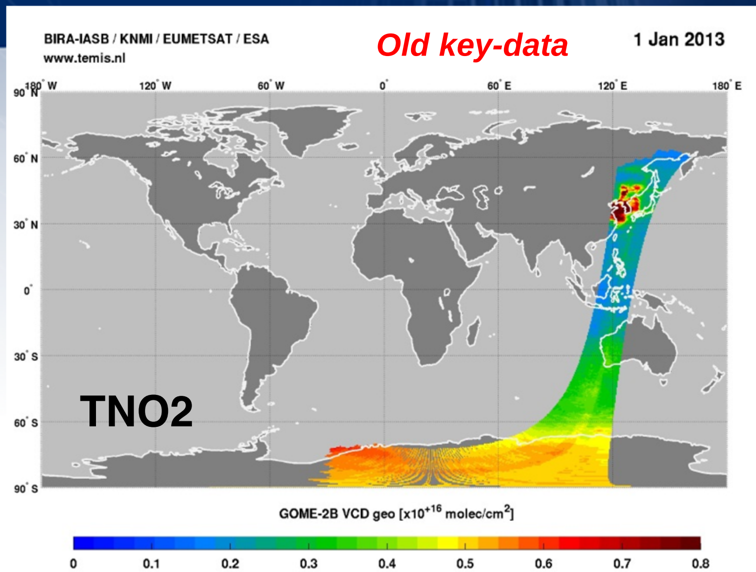


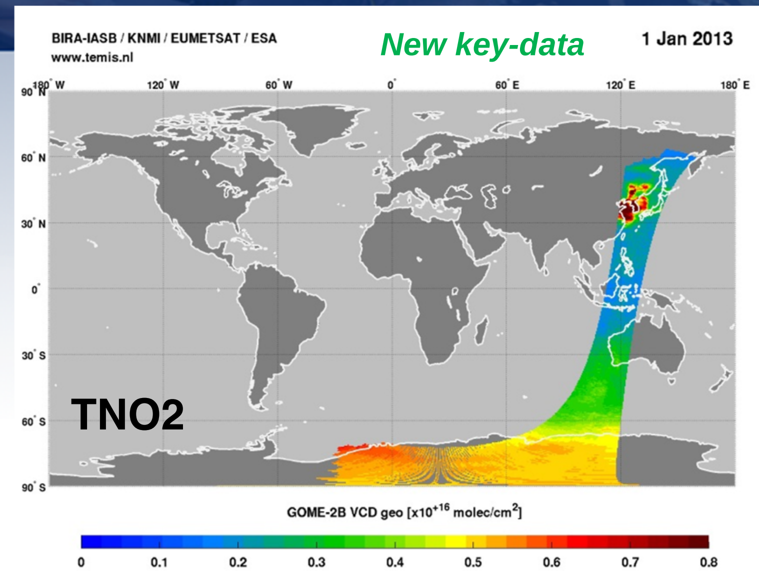
Key-data has been corrected in recent updates for FM2 and FM3 (May/June 2013)!

Findings in-orbit after GOME202-2 Delta Calibration
Channel 3: Key-data artifacts – impact on retrievals

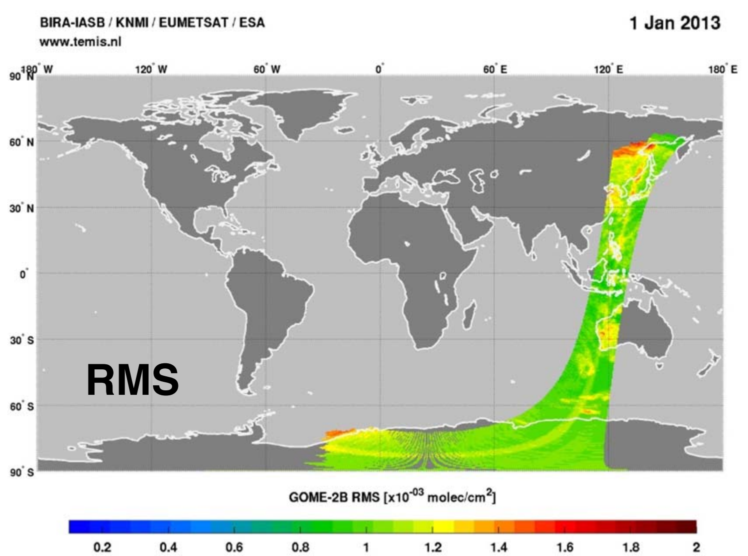
GOME-2 FM2
Metop-B

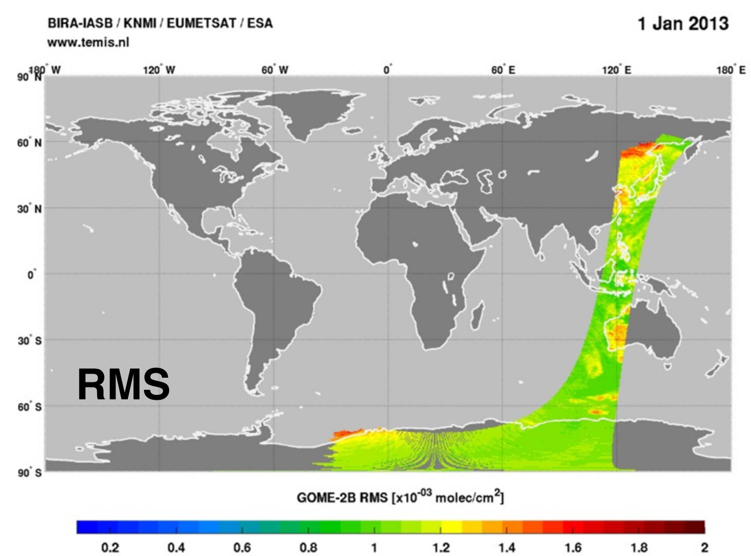
Initial retrieval differences observed (preliminary)





NO2 retrieval:
425 to 497 nm
Courtesy:
I. deSmet, BIRA





Recommendations for On-Ground Characterization

Time Time Time

Considerations for On-Ground Characterisation Campaign (I)

Time … Time … Time

- Characterisation campaigns should be long enough to allow for measurements to be repeated for *consistency checking*
- Assess impact of *lamp position & alignment* errors
- Allow sufficient time for *stabilisation*

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Recommendations for On-Ground Characterization
Environment

Considerations for On-Ground Characterisation Campaign (I)

Environment

- Essential that all characterisation measurements are carried out in thermal vacuum and that the thermal environment including gradients is representative of the in-orbit situation
- Scan-angle dependencies should also be characterized in vacuum

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Recommendations for On-Ground Characterization
Procedures I

Considerations for Measurements

Procedures I

- Alignment procedures should be *documented and reproducible* with photo/video documentation
- Ensure *reproducibility* of distance measurements
- Close attention should be paid to frames of reference, coordinate systems & angles (e.g. GOME-2 flip of elevation angles diagnosed in orbit)
- All *sources* should be well commissioned prior to the start of measurement
- Radiometric calibration must be *connected to standards* e.g. NIST
- All measurements and procedures must be *traceable & under configuration control* including software versions and documentation of which precise measurement is used in the generation of key data
- Data processing should be *automated* as far as possible

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Recommendations for On-Ground Characterization

Procedures II

Considerations for Measurements

Procedures II

- Check *temperature sensitivity* in case thermal stability is not as expected
- Ensure sufficient *angular discretisation* for characterisation of diffuser BSDF
- For slit function characterisation need *requirements from the data analysis* activity (signal:noise, spectral coverage and sampling, source commissioning requirements etc) before planning the measurements
- Ensure that all required *supplementary calibration measurements* (e.g. dark signal etc) are taken close to the time of each measurement (GOME-2 monitoring block)
- Ensure sufficient sampling points for straylight characterisation
- Ensure that the slit is overfilled

Recommendations for In-Orbit Calibration
Summary

Considerations for In-Orbit Calibration & Performance Verification

- Consider taking necessary in-orbit calibration measurements adjacent to Sun measurements if possible
- Take dark measurements under the same conditions as measurements
- Much longer measurement time will be needed for e.g. WLS over diffuser as opposed to WLS direct (if used for monitoring diffuser) so it is necessary to ensure this is compatible with lamp lifetime and recommended use
- Take many monitoring and calibration measurements early in instrument life
- Be wary of coatings etc that will require time to stabilise and outgas
- Be aware of any temperature dependencies of output or aging issues in on-baord targets (e.g. LED/WLS).
- …

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Recommendations for In-Orbit Calibration

Summary cnt.

- Instrument should typically be stored in a container over pressured using nitrogen
- Regular reactivation is required
- Extreme attention to cleanliness required
- Assess what monitoring measurements can be made during regular re-activation in ambient.
- …

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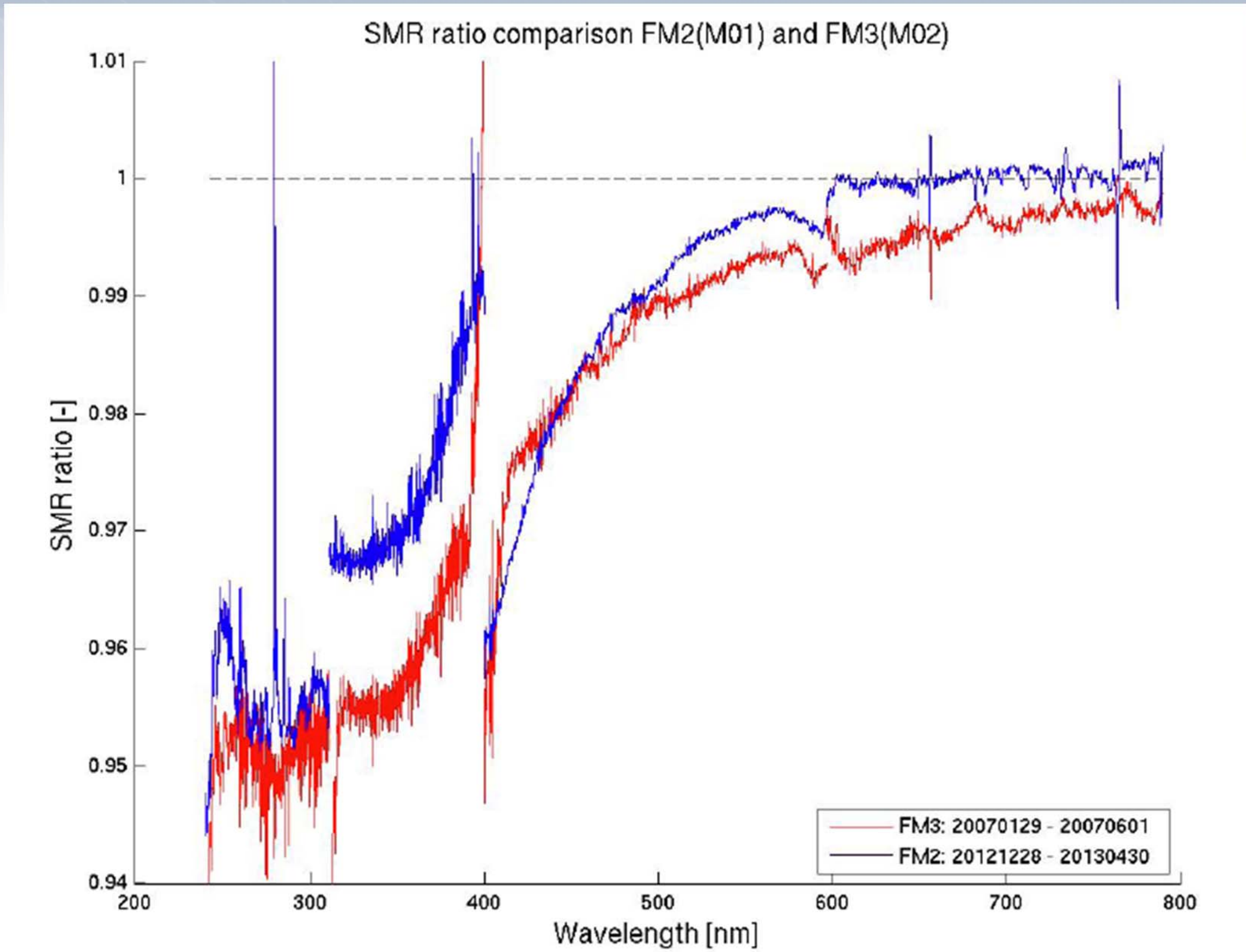
Instrument degradation

Comparison Metop-B/A - first months in orbit



Degradation over four month in-orbit covering the same in-orbit lifetime!

FM2 (Metop-B) degrades roughly in the same way as FM3 (Metop-A) except for channel 2.
...reason yet unkown!

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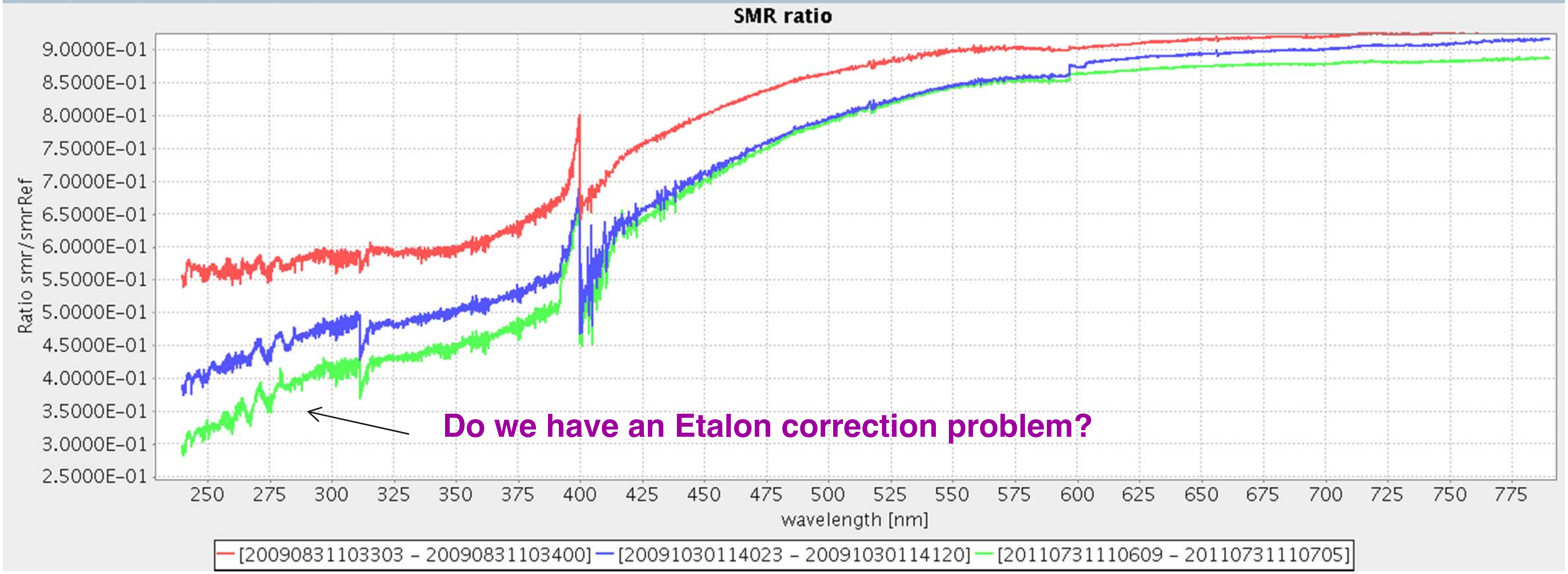
Instrument degradation (Metop-B / FM2)

SMR ratio with respect to February 2007 – R2 campaign



31st August 2009 (before 2nd TT)
30th October 2009 (after 2nd TT)
31st July 2011

relative to February 2007

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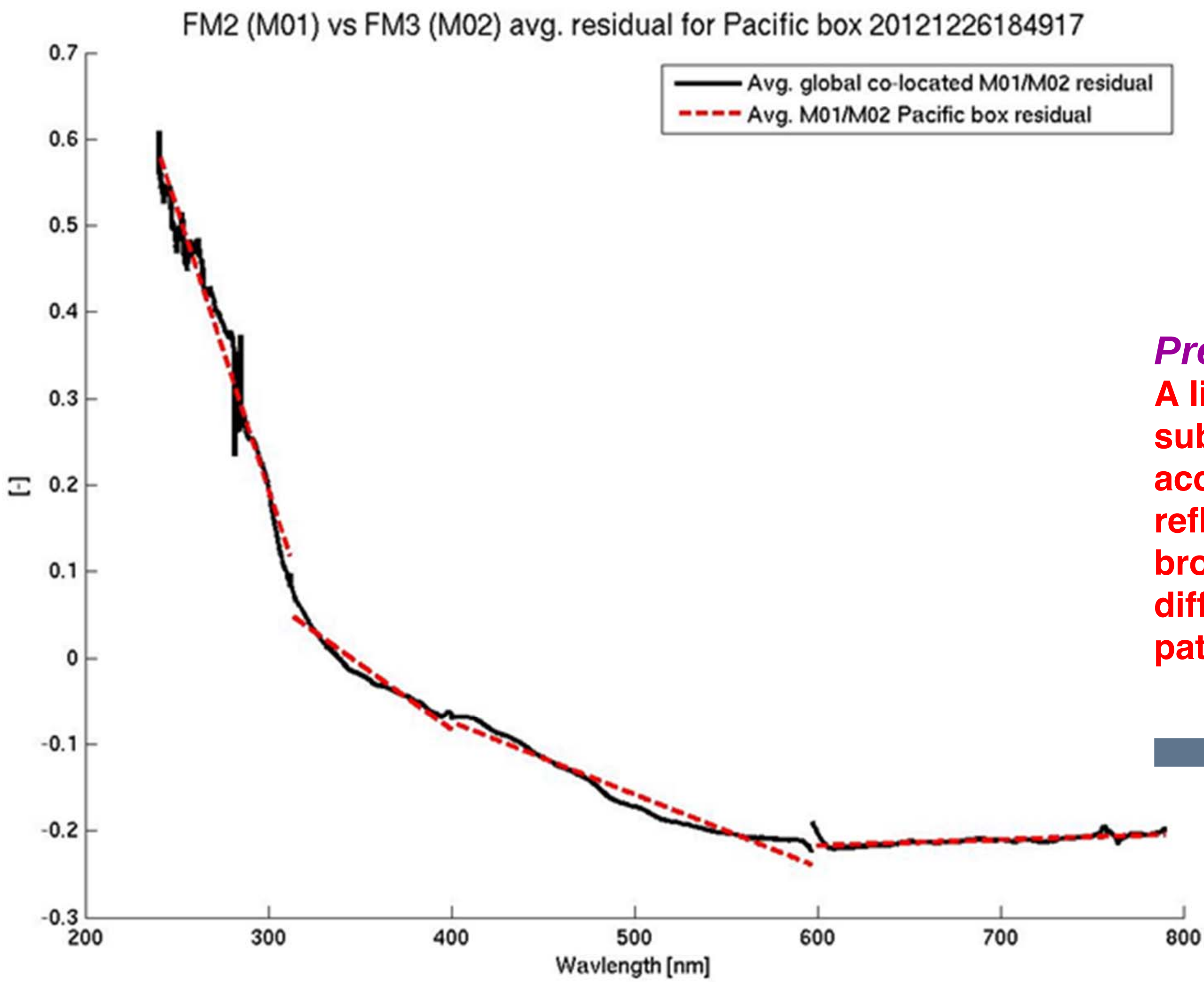
Instrument degradation (Metop-B / FM2)

Earthshine measurement co-location to Metop-A / FM3 / Reflectivity residuals and background



Example for an average over multiple FM2/FM3 residuals in reflectivity.

Prelim. Approach:
A linear background is subtracted per channel to account for the difference in reflectivity-degradation and for broad-band differences in the different observed atmospheric paths per instrument.

Looking for the small scale structures per channel

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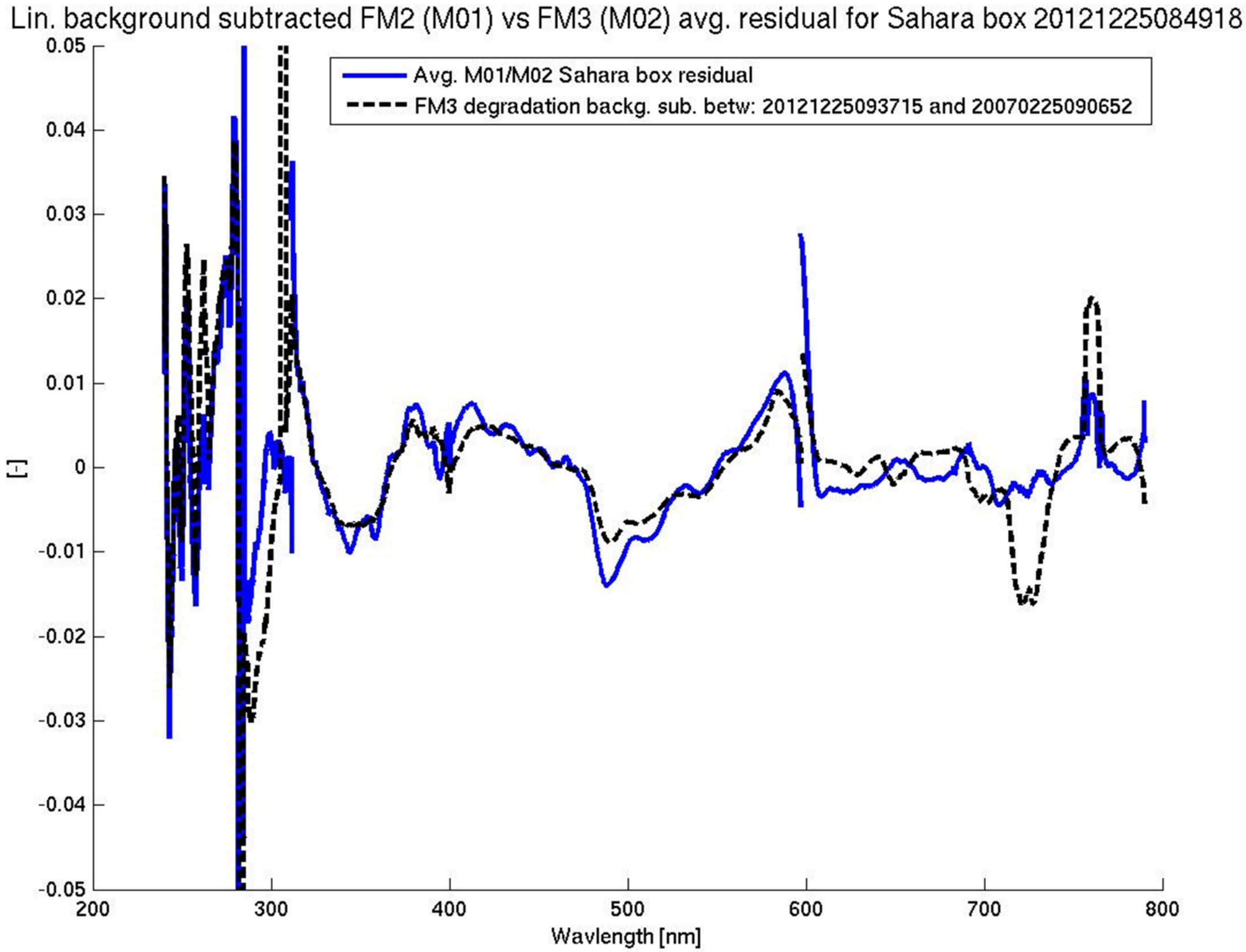
Instrument degradation (Metop-B / FM2)

FM3 co-location (Sahara)

GOME-2 FM3
Metop-A

GOME-2 FM2
Metop-B



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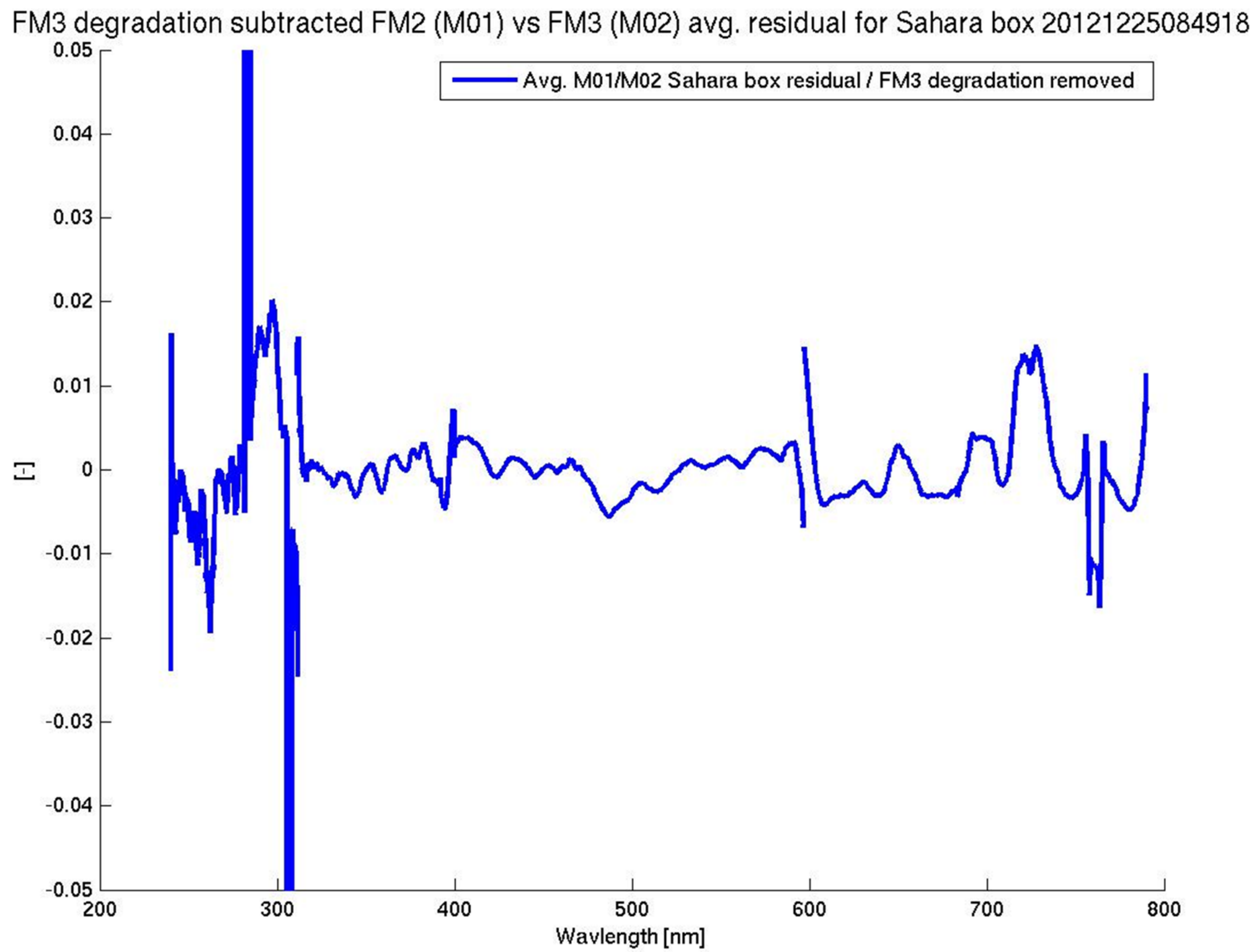
Instrument degradation (Metop-B / FM2)

FM3 co-location (Sahara) – Degradation residual of FM3 subtracted

GOME-2 FM3
Metop-A

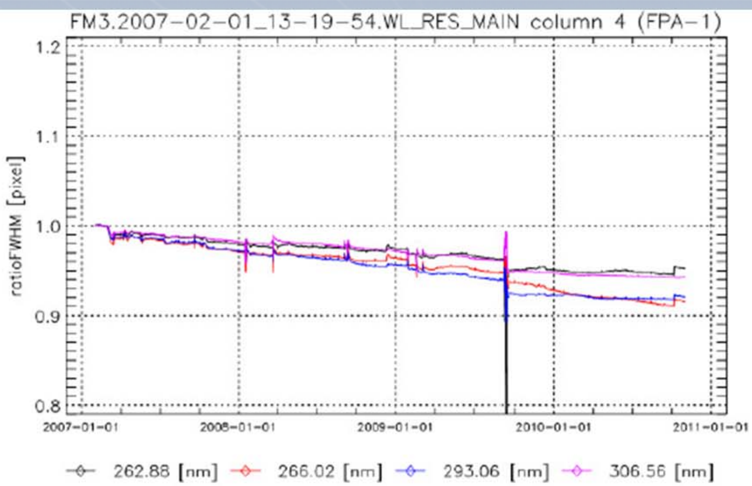
GOME-2 FM2
Metop-B

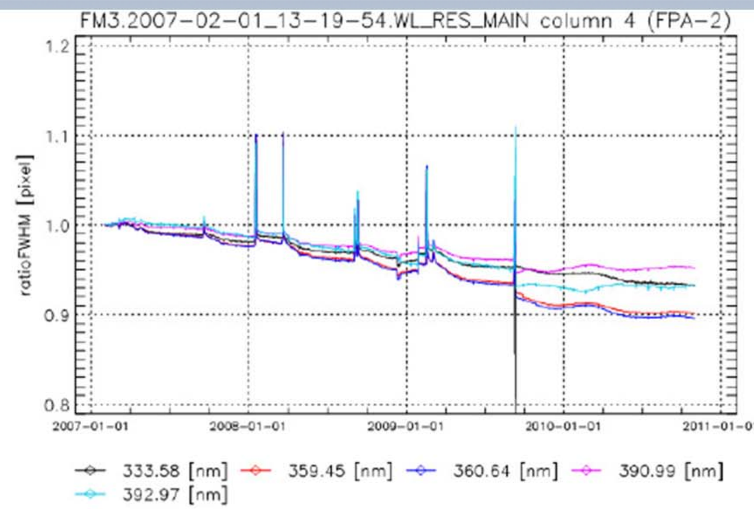


ETSAT

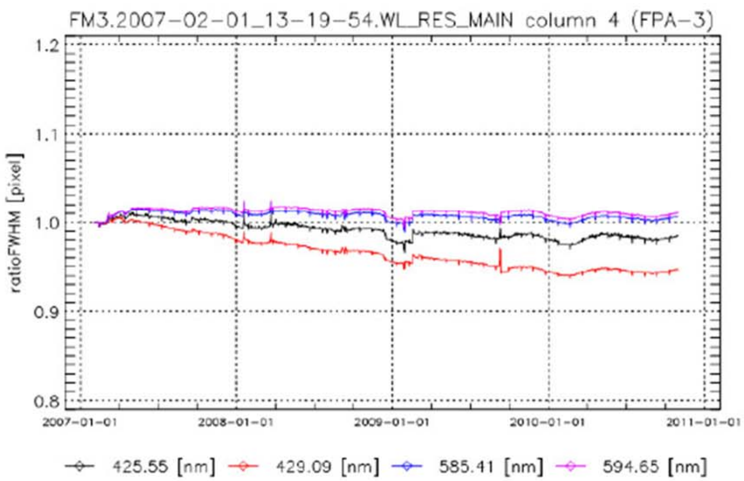
Slit function characterization

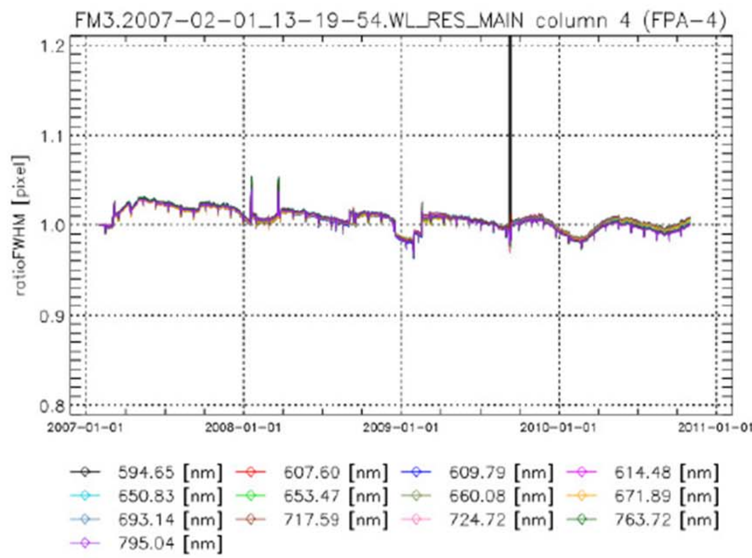
FWHM FM3 from on-board spectral light source – Stability in time





This is very likely not (!) an effect of thermal environment changes(different spectral behaviour)





Hypothesis: slowly decreasing FWHM due to degradation.

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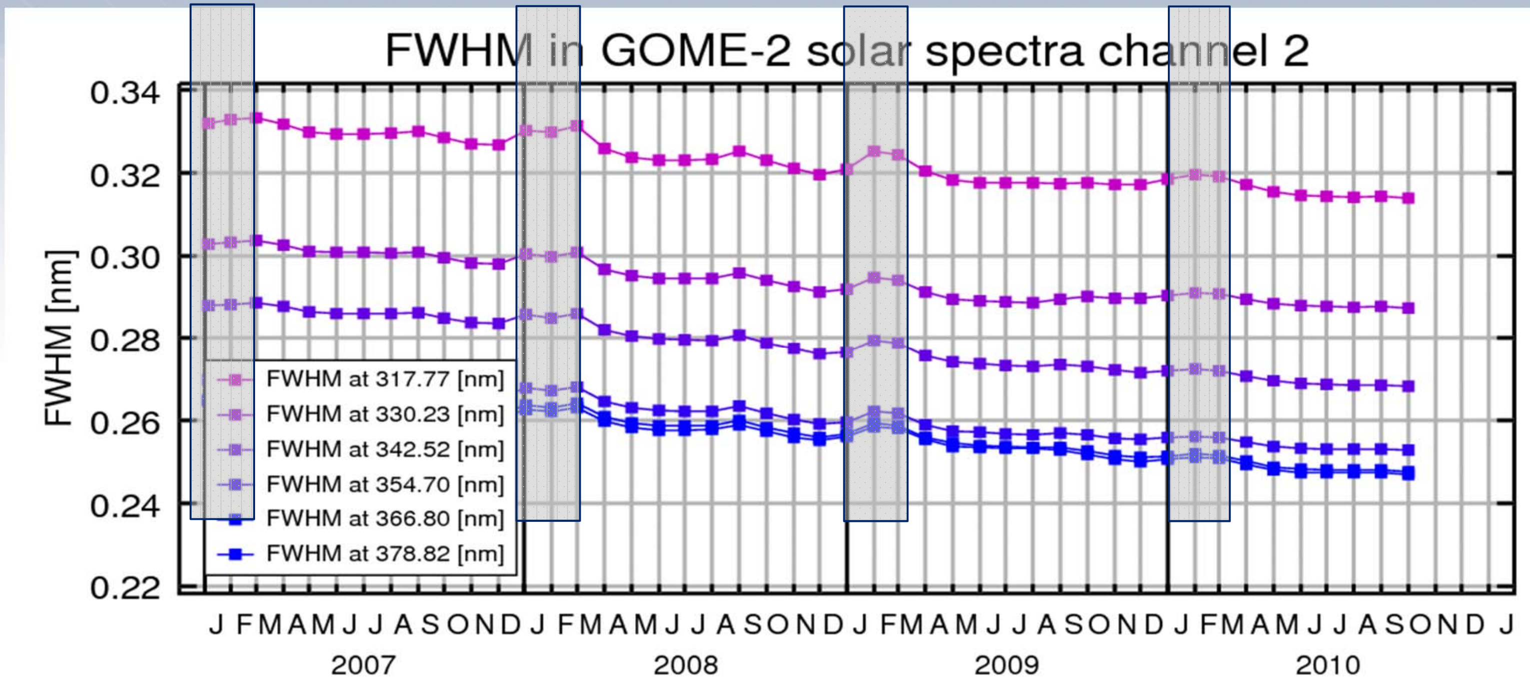
Slit function characterization

Degradation study IUP Bremen (Dikty/Richter)



- In calibration of GOME-2 solar spectra on Kurucz Fraunhofer atlas the FWHM (of a Gaussian slit function) is also fitted
- FWHM changes consistently over channel 2
- FWHM decreases over time
- No effect of throughput test

Instrument degradation

Summary findings after comparing to FM2 - first month in orbit.

- Both GOME-2 instruments on board Metop (FM3 and FM2) degrade roughly speaking in the same way when comparing the first month in-orbit
- FM3 develops a Etalon type signature in channel 1 which is not present in the white light source signal – potentially evolving on the diffuser
- There are indications of a contamination by substances out-gassing from the conformal coatings of the electronics (Arathene signature)
- UV induced contamination or radiation damage of the detectors cannot be excluded
- No 100% conclusive single origin could be identified so far after two dedicated tests in orbit for FM3 (Jan/Sep 2009) and one for FM2 (March 2013).
- Reports are available on EUMETSAT technical documentation web-site

Lessons learned:

- **Contamination and UV/radiation damage have to be considered as very serious issues. Both for pre- and in-flight handling of UV/vis instrumentation.**
- **Full thermal control of the entire optical bench is absolutely essential.**
- **Cold-trap/out-gassing mechanisms are highly recommended.**
- **All electronics should be isolated as much as possible from the optical parts of the instrument.**

Instrument degradation
Way forward for corrections.

Challenges:

- We need to correct all 4096 wavelengths (240 - 790 nm)
- Using V-Lidort forward model works for cloud free / short wavelengths (<350nm)
- Main problem for rigorous correction (using forward model with “best input”) is the surface albedo and the surface BRDF (large investment needed for absolute accuracy
- Vicarious calibration methods and inter-calibration methods achieved accuracies currently not below 2-5%

We need 0.5 to 1% accuracy! ☹

Summary recommendations

Lessons learned from the GOME-2 on Metop mission

• **Key-issues concern the instrument characterisation both on-ground and in-flight**

• **Most issues concerning the applied algorithms are usually of transient importance or meanwhile have been solved.**

The responsible agencies should address instrument key-data issues through the programme (all phases) and lay open and respond to (potential) problems, limitations and uncertainties as soon as possible.

Users have the responsibility to report back the problems they observe in a way which supports the investigations.

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Summary recommendations

Lessons learned from the GOME-2 on Metop mission

Agencies:

1. Lay open all observed or known problems on level 1 as early as possible.
2. Be responsive to user concerns on data quality.
3. Invest in close/short loop cycles between investigation and updates (requires a certain/significant amount of in-house expertise to analyse, address and respond to issues)

Users:

1. Report on issues in a way meaningful for the agencies (i.e. the level 1 quality issues), i.e. fit quality indicators spectrally and angularly and temporarily resolved (e.g. In pre-defined target areas).
2. Try to reduce / separate potential retrieval problems from level-2 problems (don't try to hide your own problems!)
3. Don't start on your personal level-0 to 1 calibration! Its not to the benefit of the whole community (so in the end also not to your own benefit)

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The end

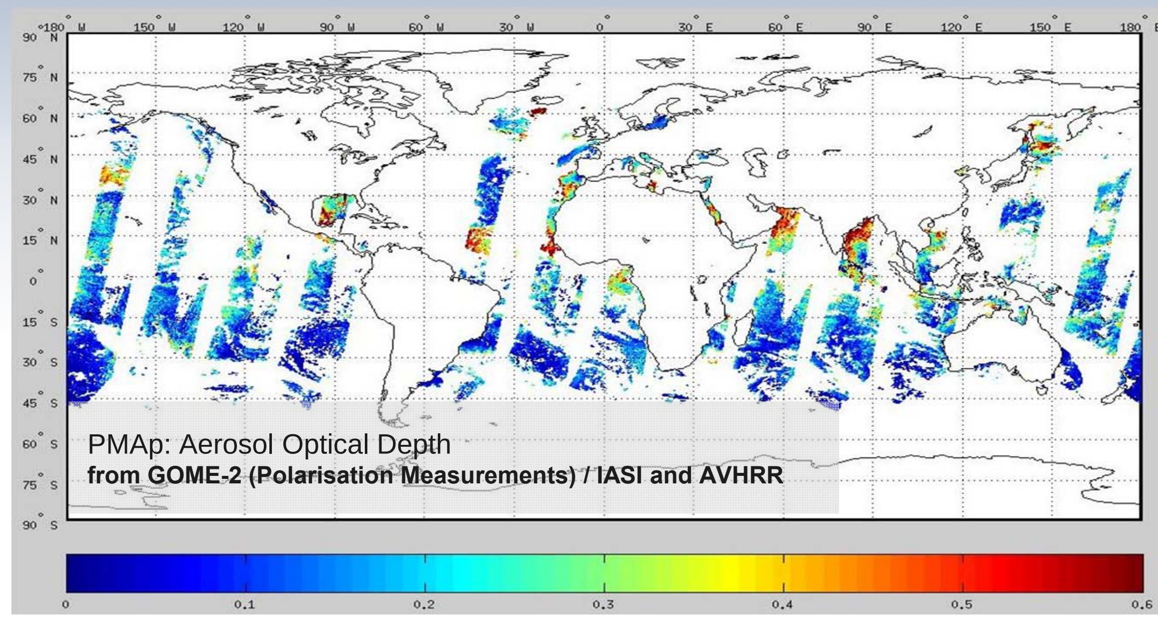
Three myths about GOME-2

Myth 1: Polarisation sensitivity - Is it a problem?

Is polarisation sensitivity a problem? – No!

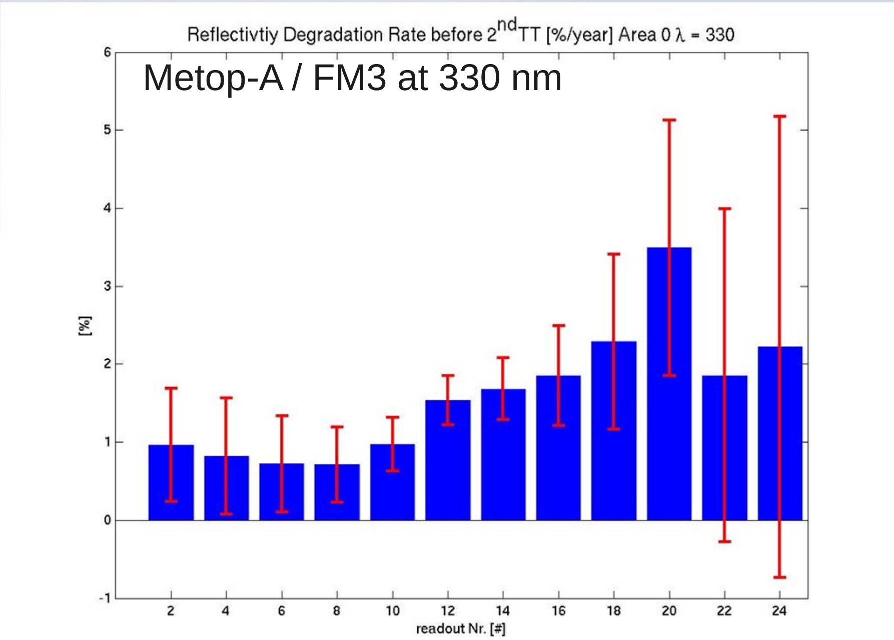
Polarisation sensitivity increases the amount of on-ground calibration key-data applied during level 0 to 1 processing:

- Can be corrected on-line using special geometry Stokes fractions
- Stokes fractions can be used to retrieve additional level-2 information

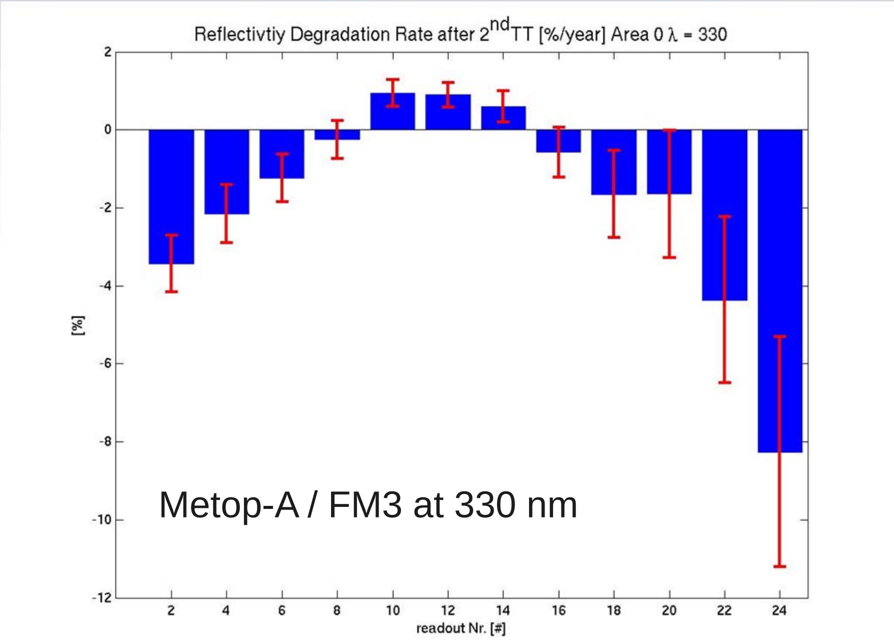


Three myths about GOME-2
Myth 3: Reflectivity degradation

Is signal degradation a problem? – Yes, but....



Jan 2007 – Aug 2009
Reflectivity degradation: 1-2% per year
(Radiance degradation: 16%/year)



Sep 2009 – Aug 2011
Reflectivity degradation: 2-6% per year
(Radiance degradation: 4%/year)

See Level 1 validation report for the reprocessed data-set R2:
www.eumetsat.int > Data & Products > Resources > EPS Product Validation Reports

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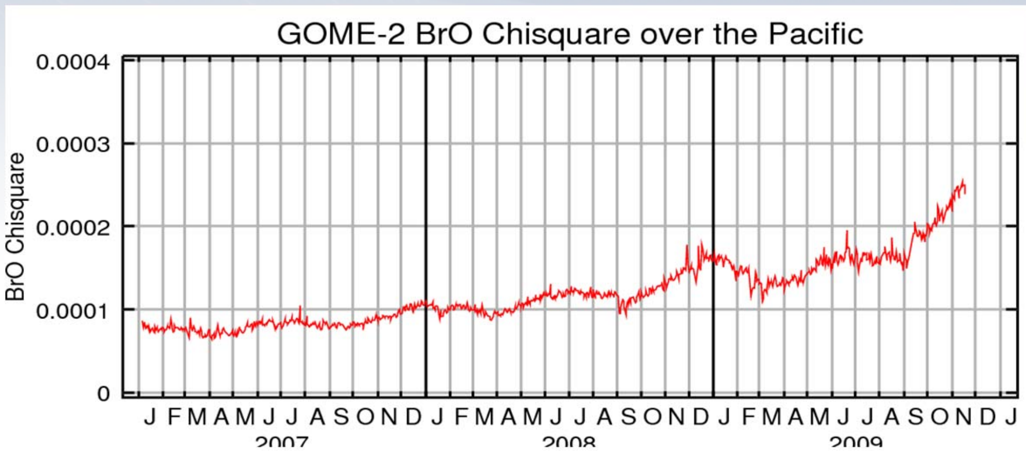
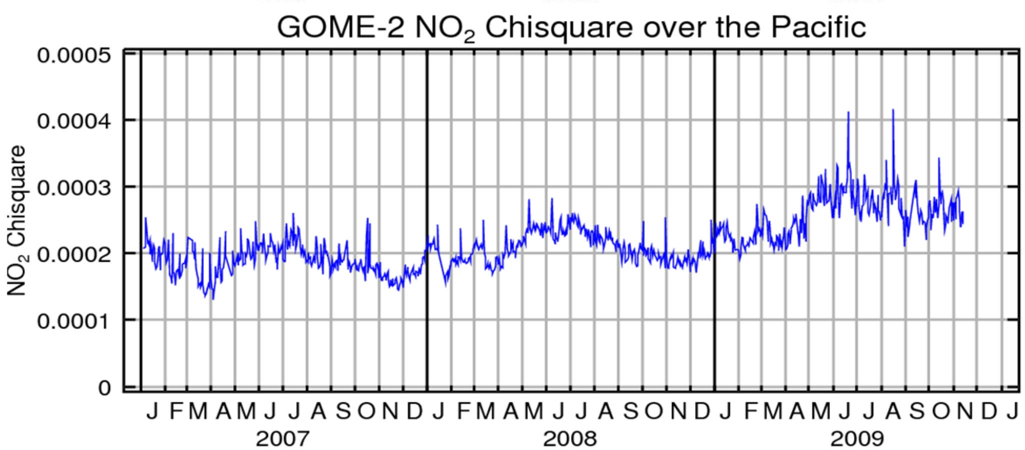
Three myths about GOME-2

Myth 3: Reflectivity degradation

Is signal degradation a problem? – Yes, but....





- Degradation predominantly affects fit residuals and scatter
- Retrieved values are less or not affected
- Fitting residuals increase over time
- Effect is largest in channel 2, but NO_2 is also affected
- The same is true for other absorbers (SO_2, HCHO, CHOCHO)
- All operational products of GOME-2 / Metop-A are still within specifications

Study by:
S. Dikty and A. Richter, IUP Bremen

See Level 2 report on the impact of degradation on level 2 products:
www.eumetsat.int > Data & Products > Resources > EPS Product Validation Reports

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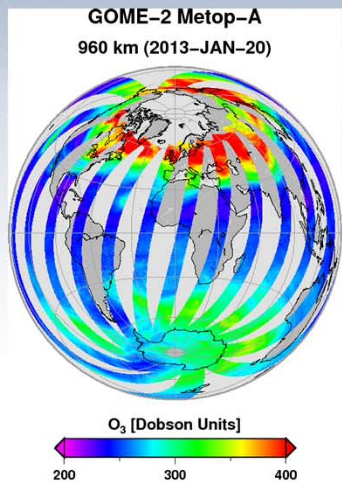
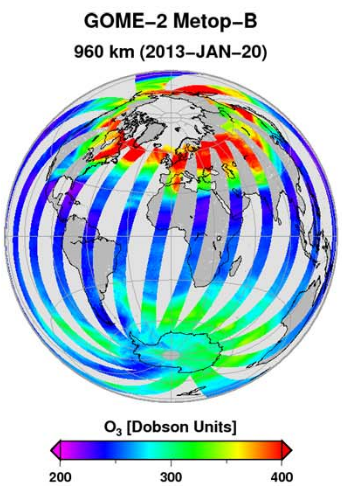
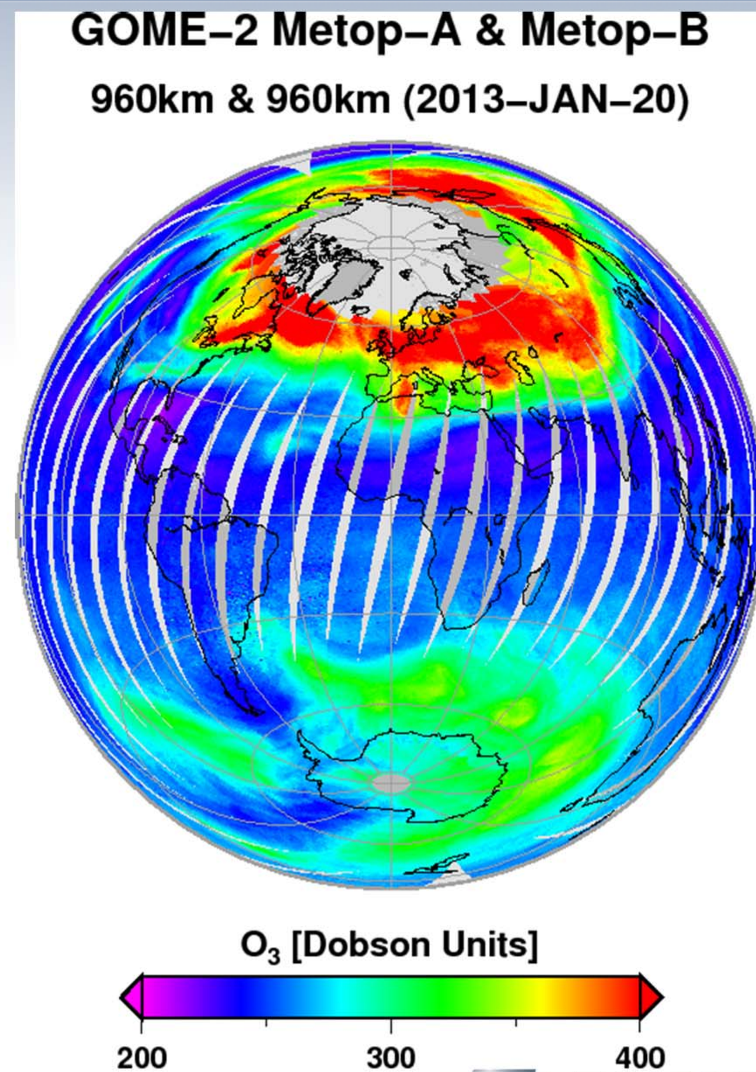
GOME-2 Metop-A/B Tandem Operations

Principle idea





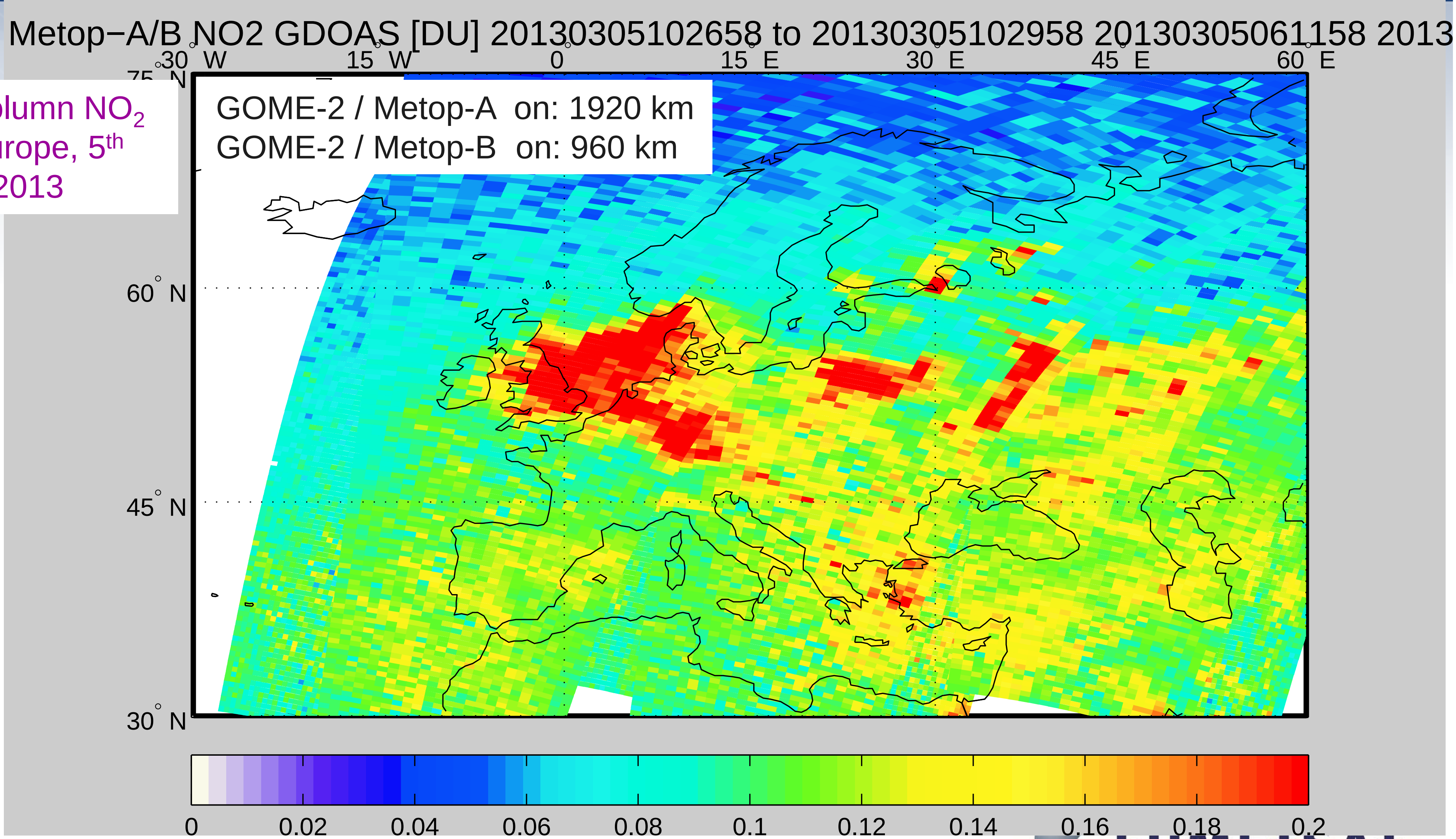


Courtesy O3MSAF / DLR

GOME-2 Metop-A/B Tandem Operations

First, preliminary results from the test campaign

Total column NO_2 over Europe, 5th March 2013



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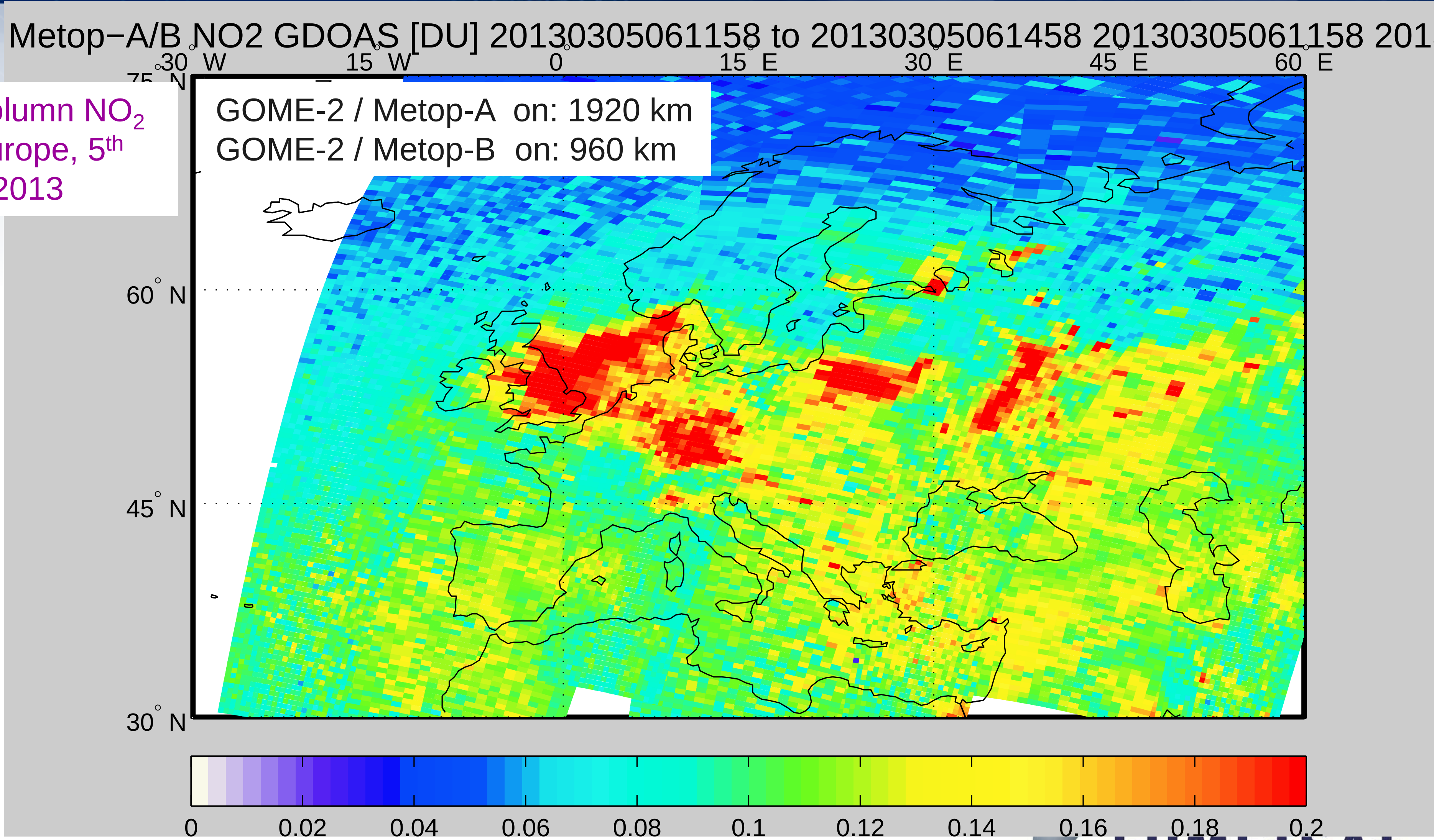
GOME-2 Metop-A/B Tandem Operations

First, preliminary results from the test campaign

Total column NO_2 over Europe, 5th March 2013



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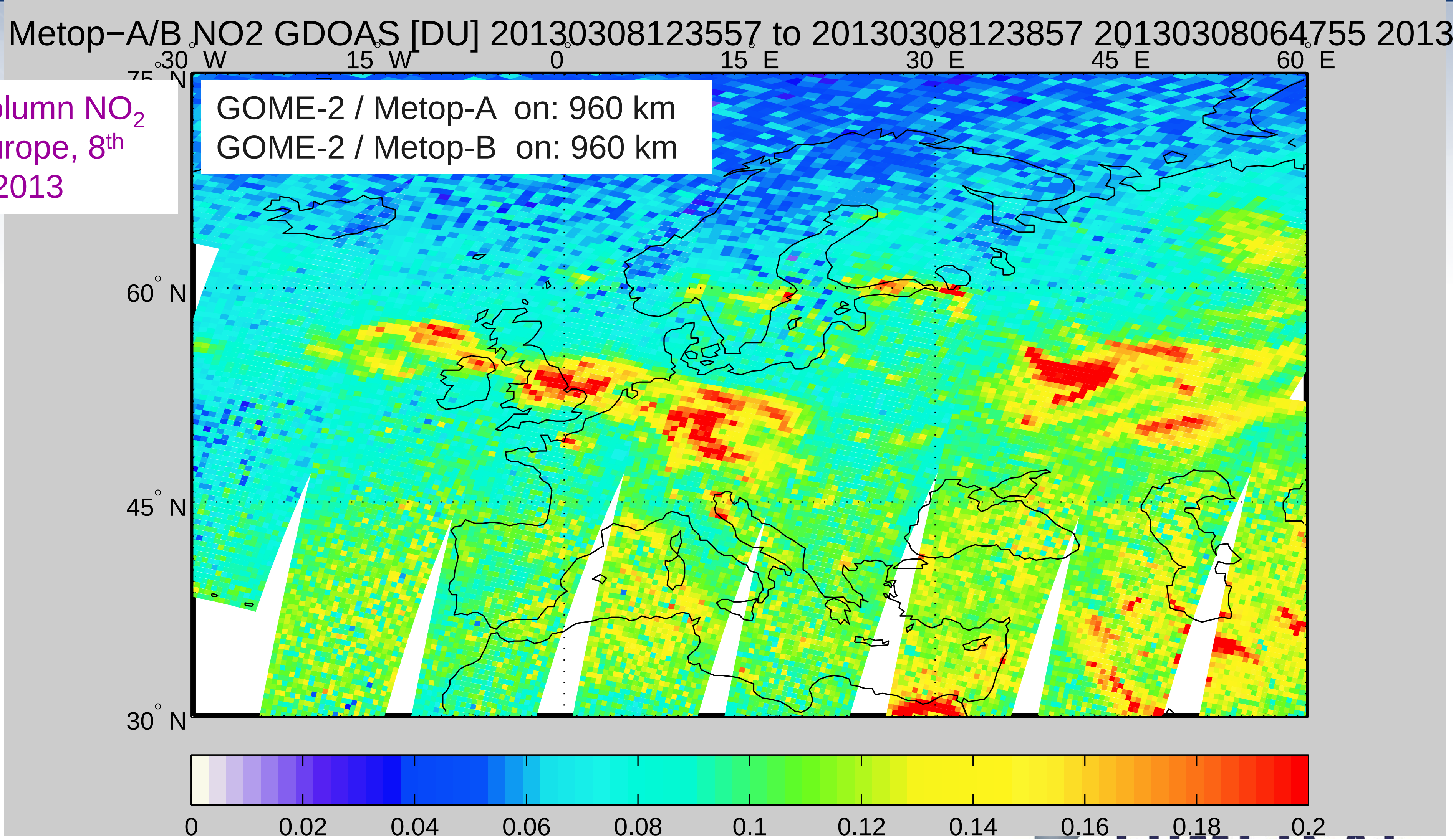
GOME-2 Metop-A/B Tandem Operations

First, preliminary results from the test campaign

Total column NO_2 over Europe, 8th March 2013



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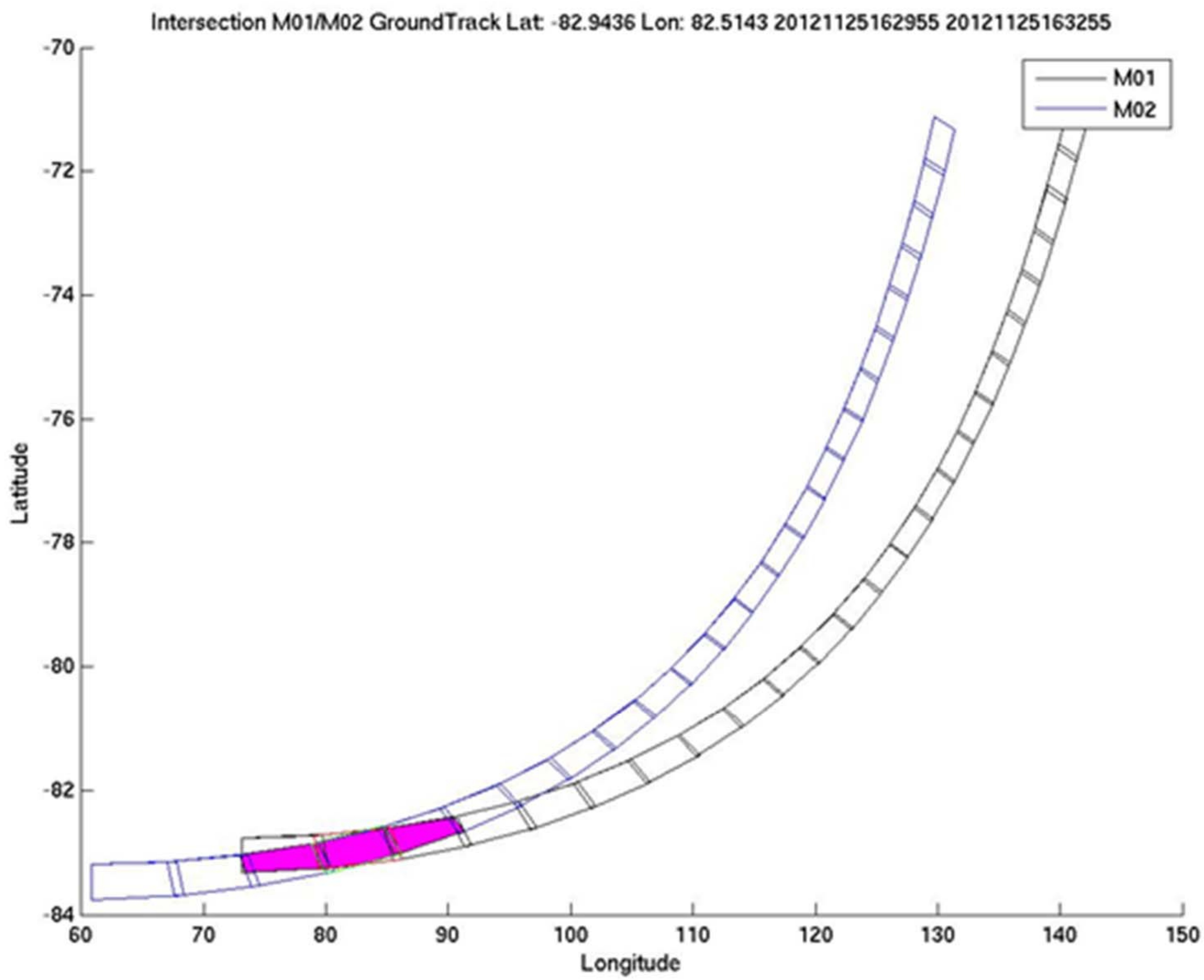
Metop-A/B / GOME-2 Radiometric accuracy and calibration

Earthshine measurement co-location FM2 to FM3 / Co-location criteria



Co-location criteria:

- **Area overlap > 80%**
- **Geo. AMF diff < 2%**
- **Relative O_2 A-Band residual (ROR) smaller than empirical threshold**

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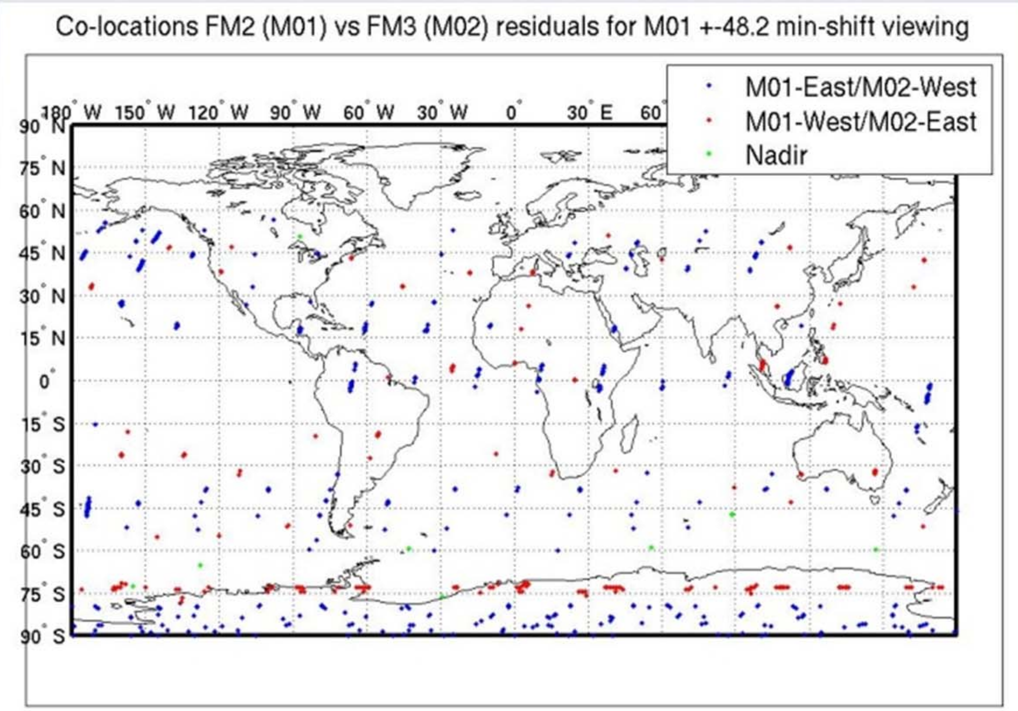
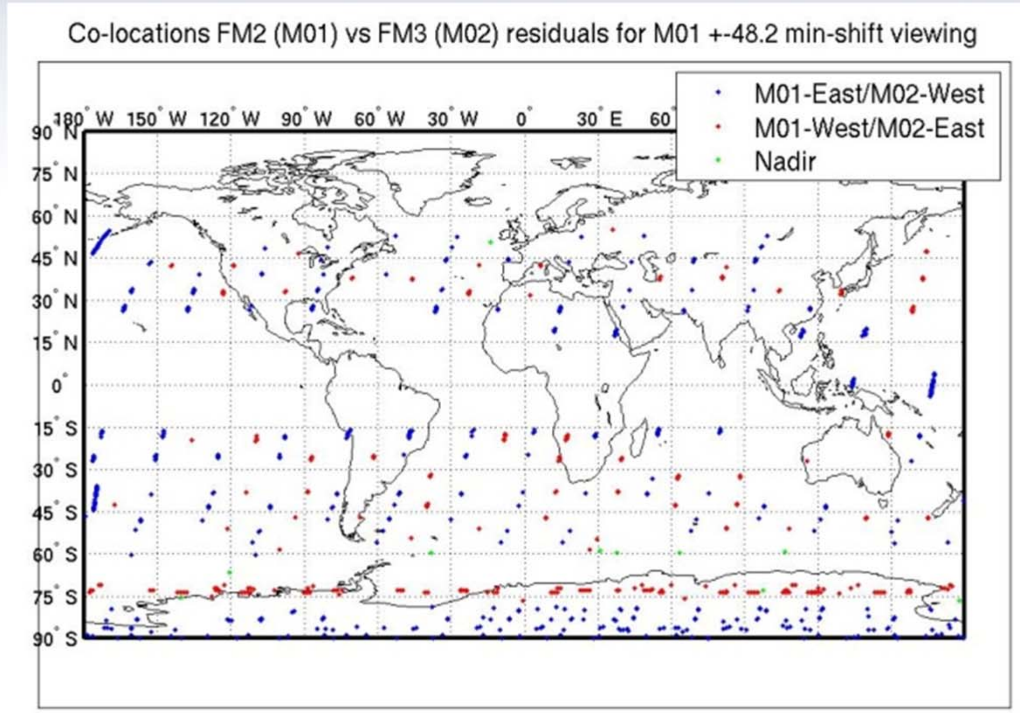
Metop-A/B / GOME-2 Radiometric accuracy and calibration

Earthshine measurement co-location FM2 to FM3 / Co-locations

26th December 2012

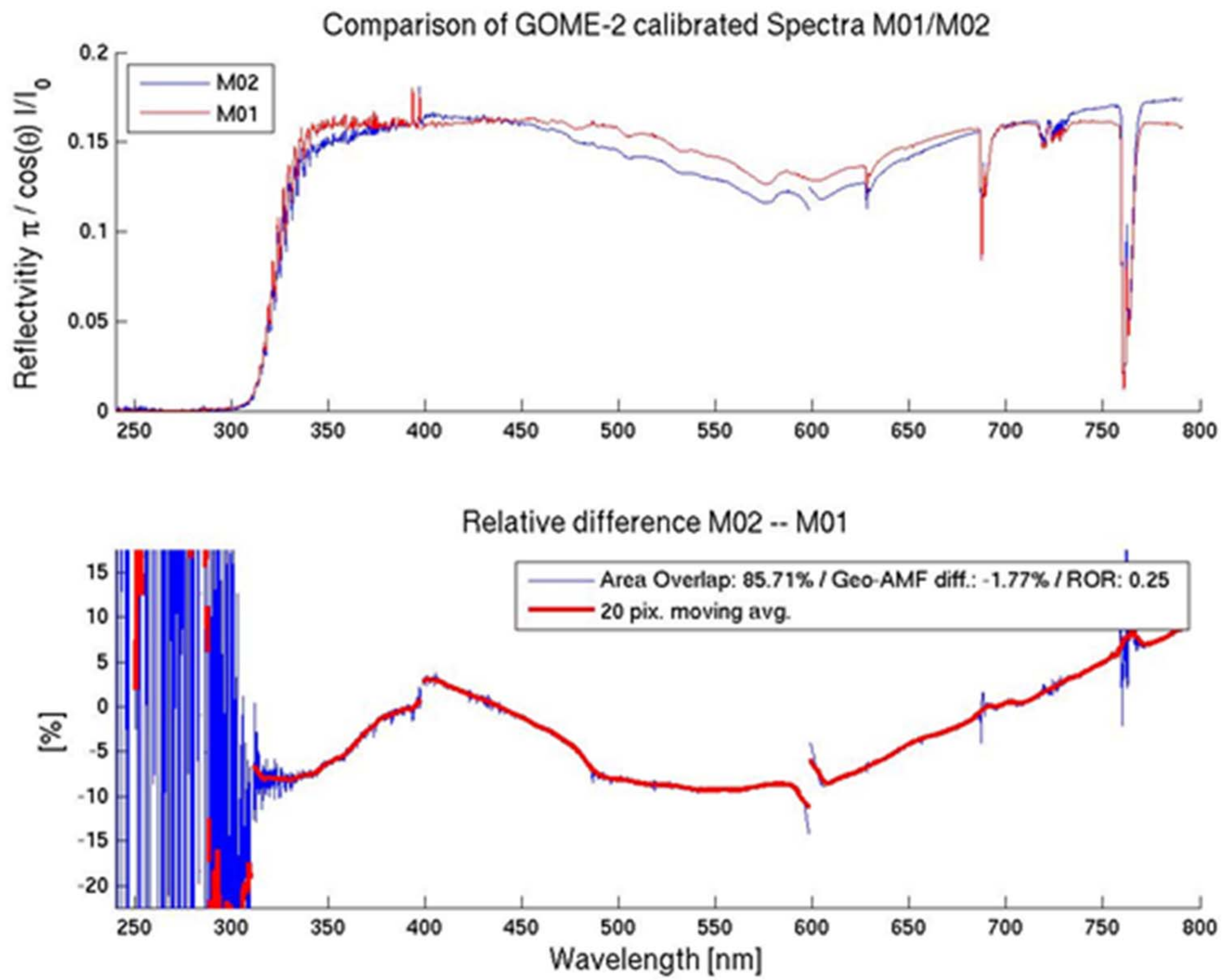


10th January 2013



Metop-A/B / GOME-2 Radiometric accuracy and calibration

Earthshine measurement co-location FM2 to FM3 / Reflectivity residuals



Residual in reflectivity

+ Lin. background subtracted per channel
+ 20 pix. moving average smoothing
+ Relative Oxygen-A band Residual (ROR) selection criterium

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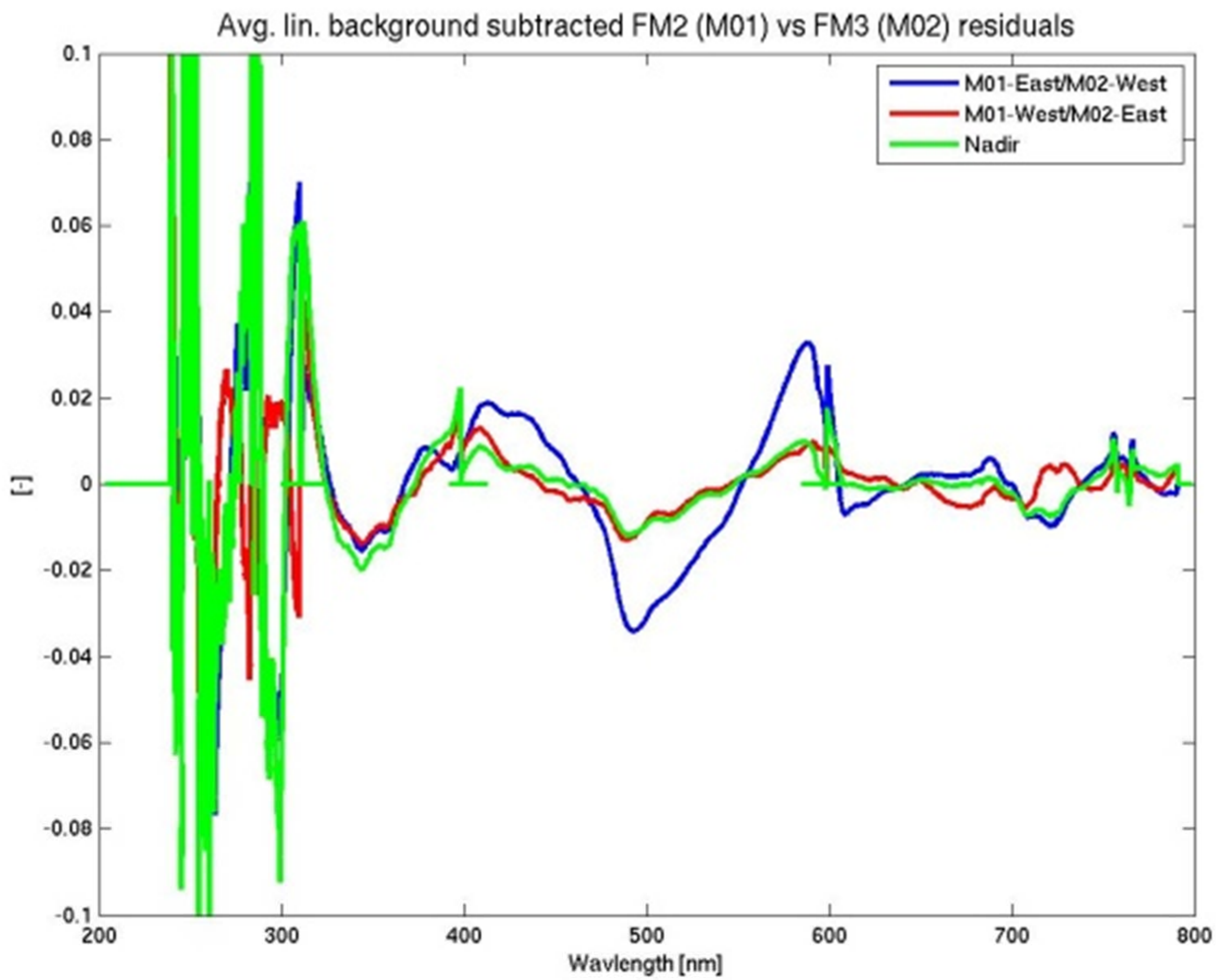
Metop-A/B / GOME-2 Radiometric accuracy and calibration

Earthshine measurement co-location FM2 to FM3 / Average over all Residuals per day

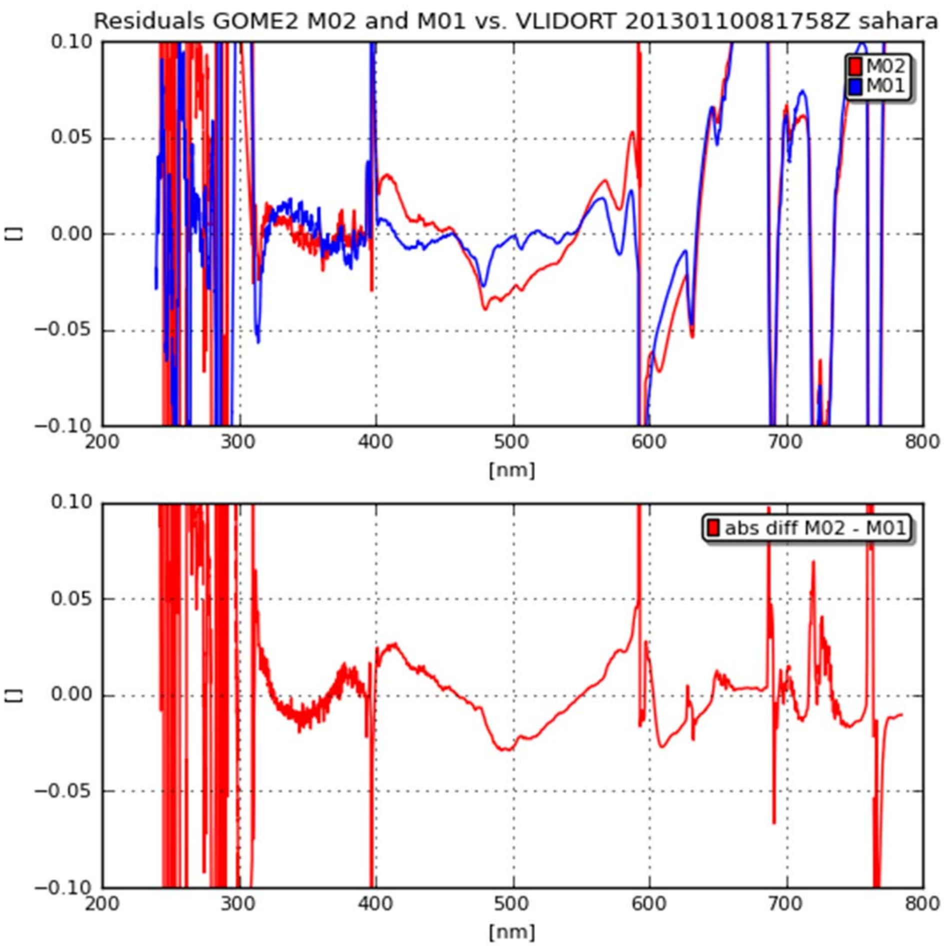


FM2-East/FM3-West
FM2-West/FM3-East
Nadir

Separation between East/West/Nadir at +-20 degree viewing-angle

Metop-A/B / GOME-2 Radiometric accuracy and calibration

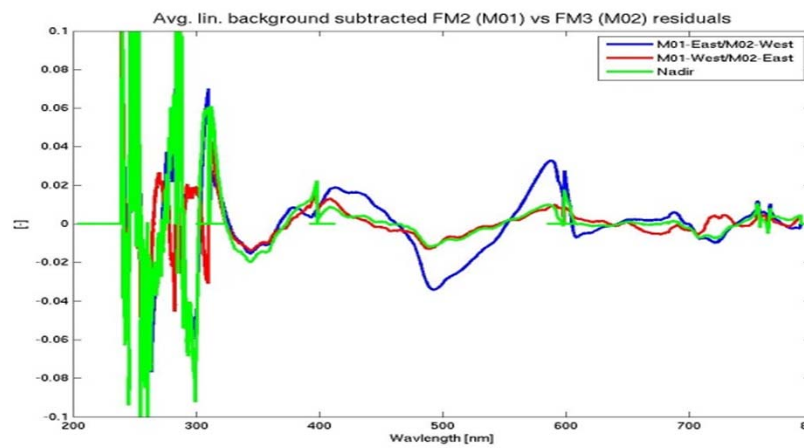
Earthshine measurement co-location FM2 to FM3 / Comparison with V-LIDORT



Left up: **Residual FM3 with V-LIDORT**
Residual FM2 with V-LIDORT

- **Broad-band structure in FM3 channel 3**
- **Small-scale structures in FM2 channel 3**

Bottom: **Residuals between FM3 and FM2**



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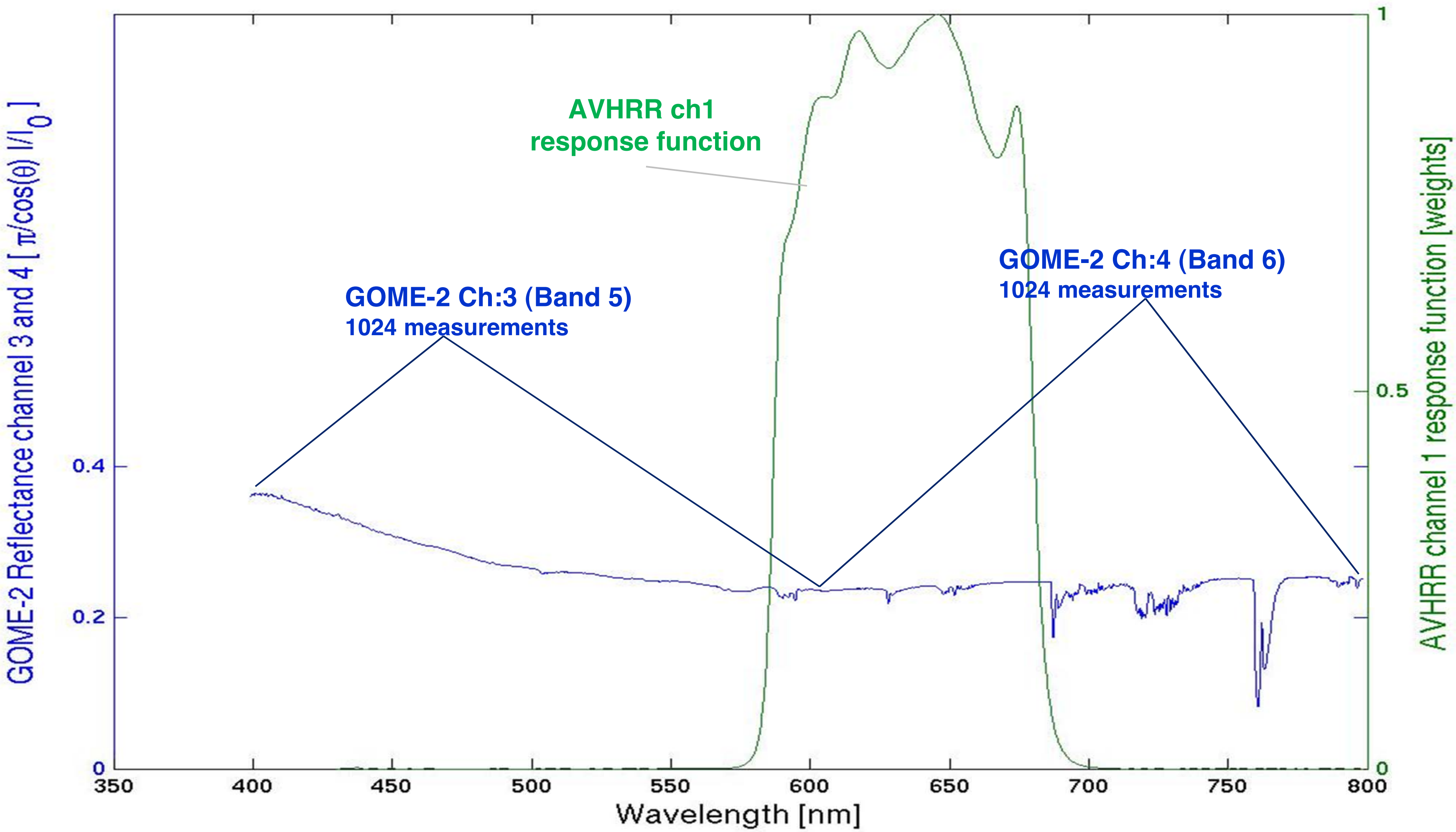
GOME-2 reflectivity inter-calibration

AVHRR ch 1/ Metop-A



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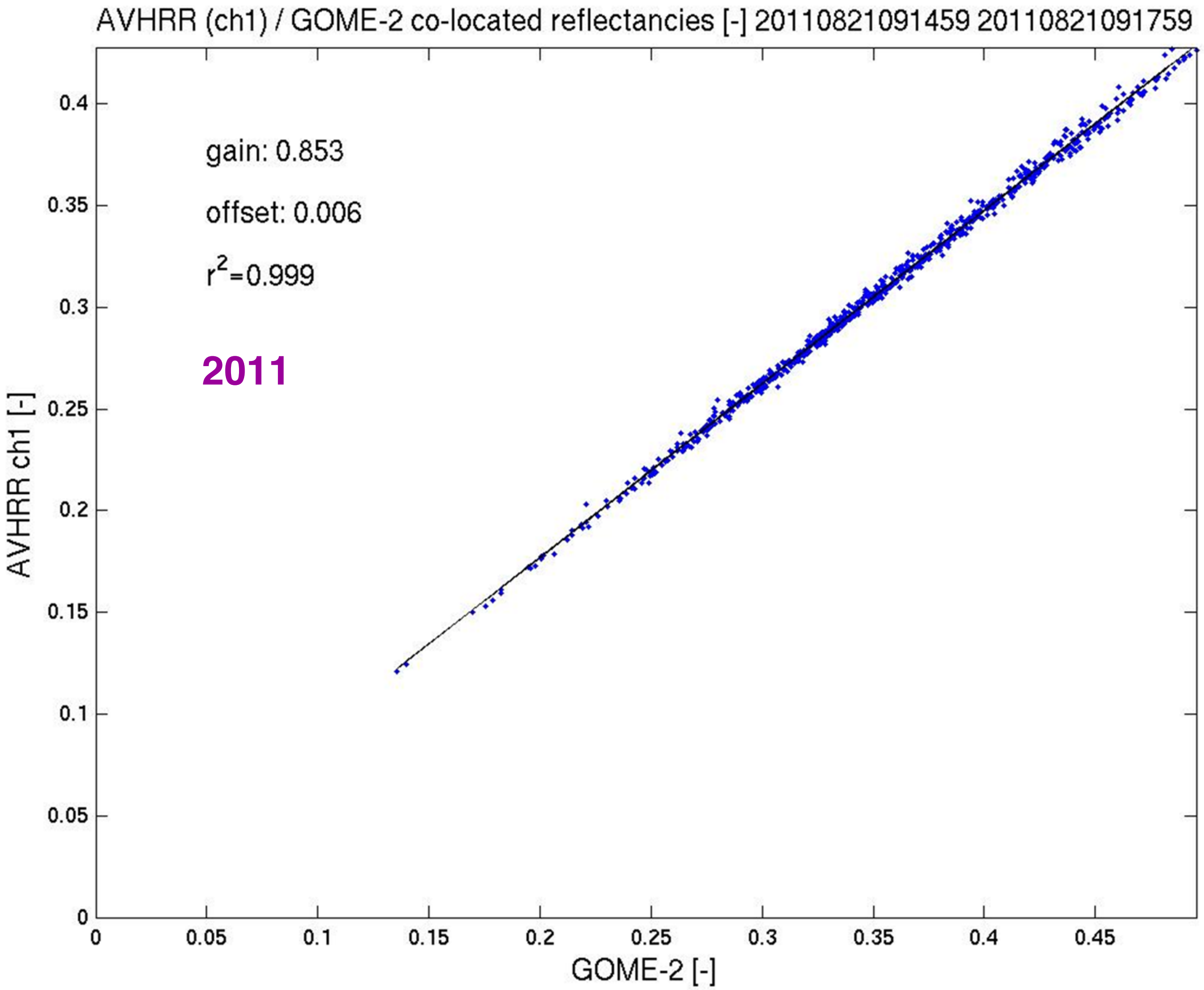
GOME-2 reflectivity inter-calibration
AVHRR ch1 / Metop-A



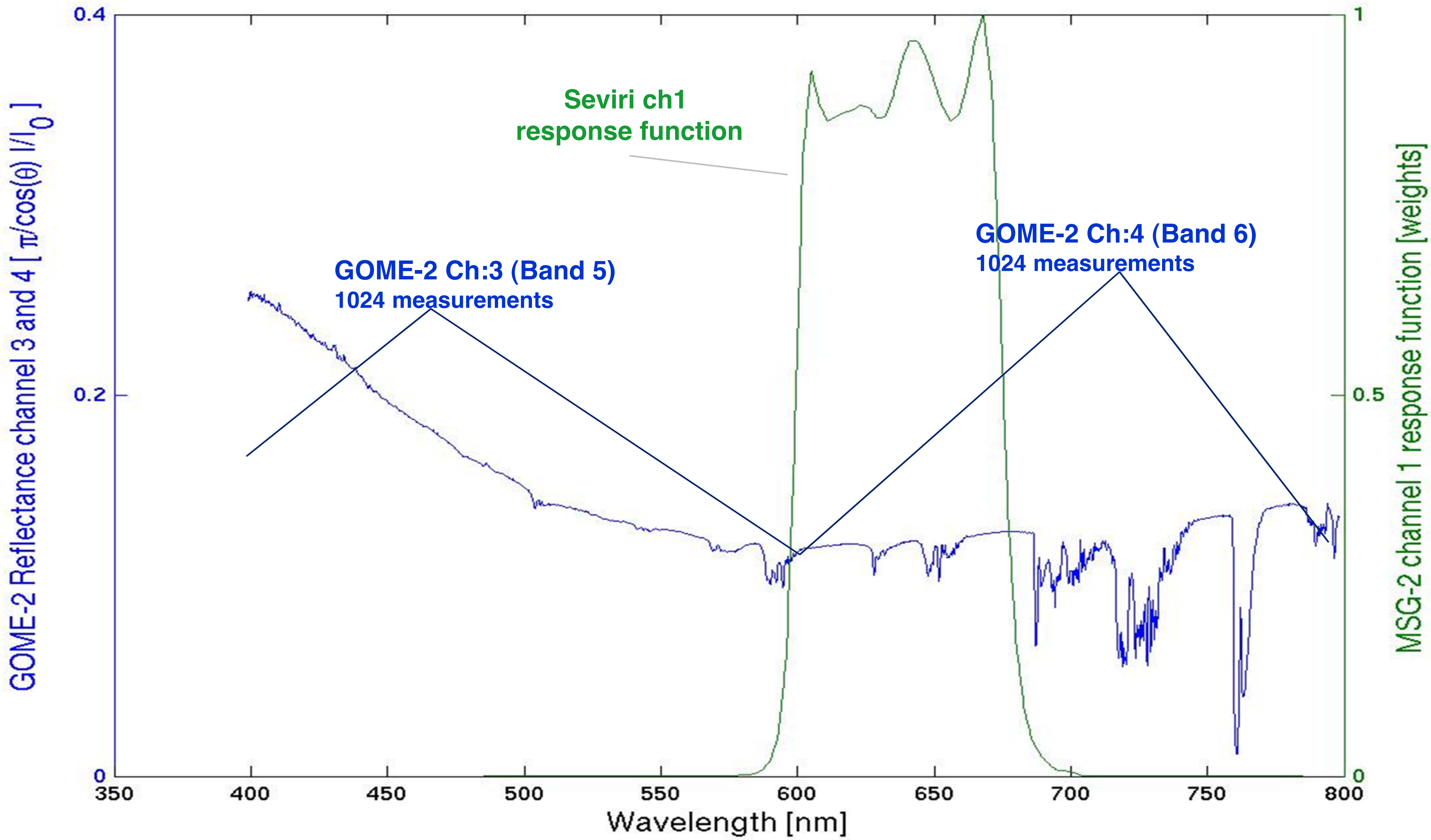
AVHRR channel 1 to GOME-2 offset in reflectivity of ~9% (AVHRR < GOME-2)

Preliminary results indicate that the offset has been quite stable during the last four years.

see GSICS Quarterly Newsletters, vol 5, number 3, *Latter et al.*

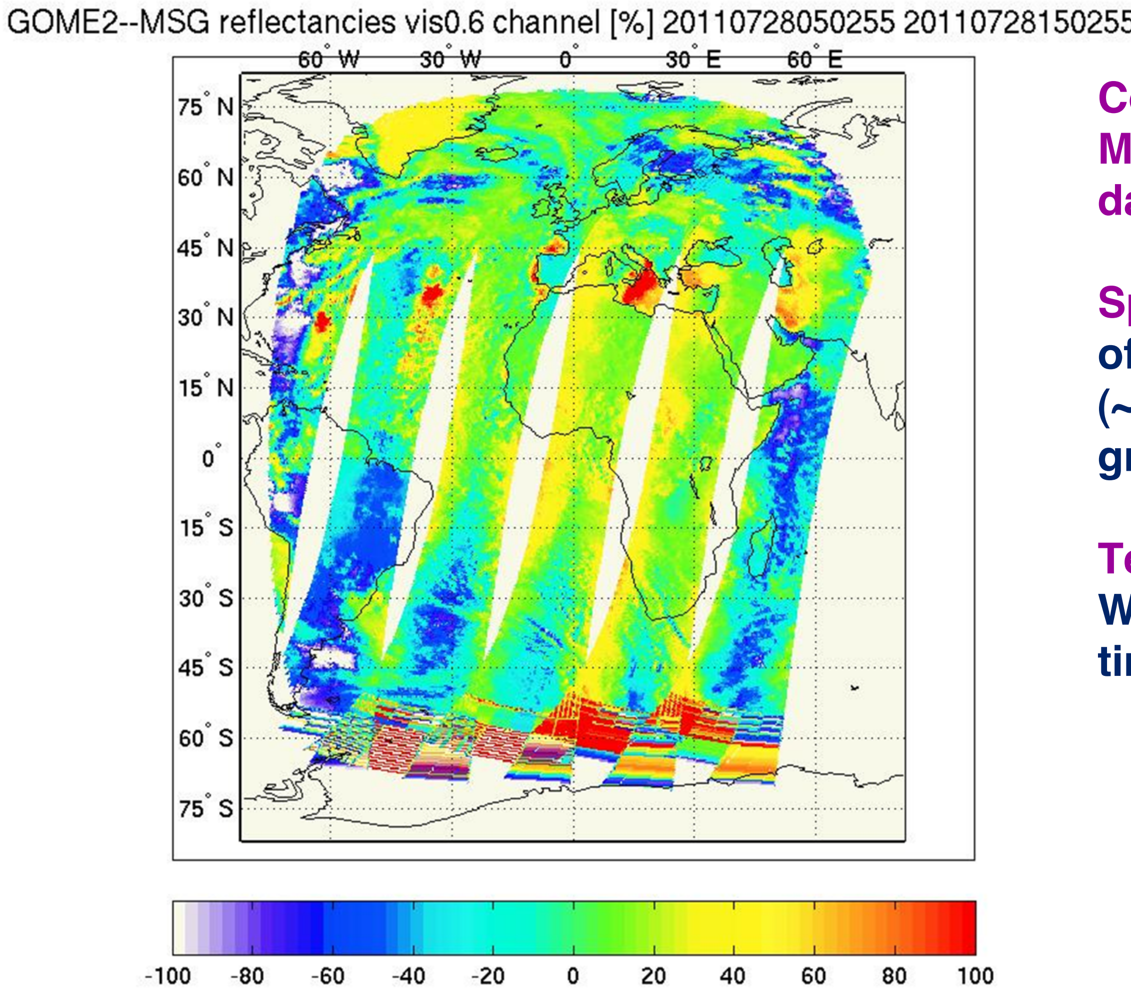
GOME-2 reflectivity inter-calibration

SEVIRI ch1/ MSG-2 – preliminary results



GOME-2 reflectivity inter-calibration

SEVIRI ch1/ MSG-2 – preliminary results



Co-location of GOME-2 Metop-A with Seviri / MSG data.

Spatial collocation: Average of all Seviri measurements (~4km) in one GOME-2 ground pixel (40 by 80 km)

Temporal collocation: Within +- 7.5 min of sensing time.

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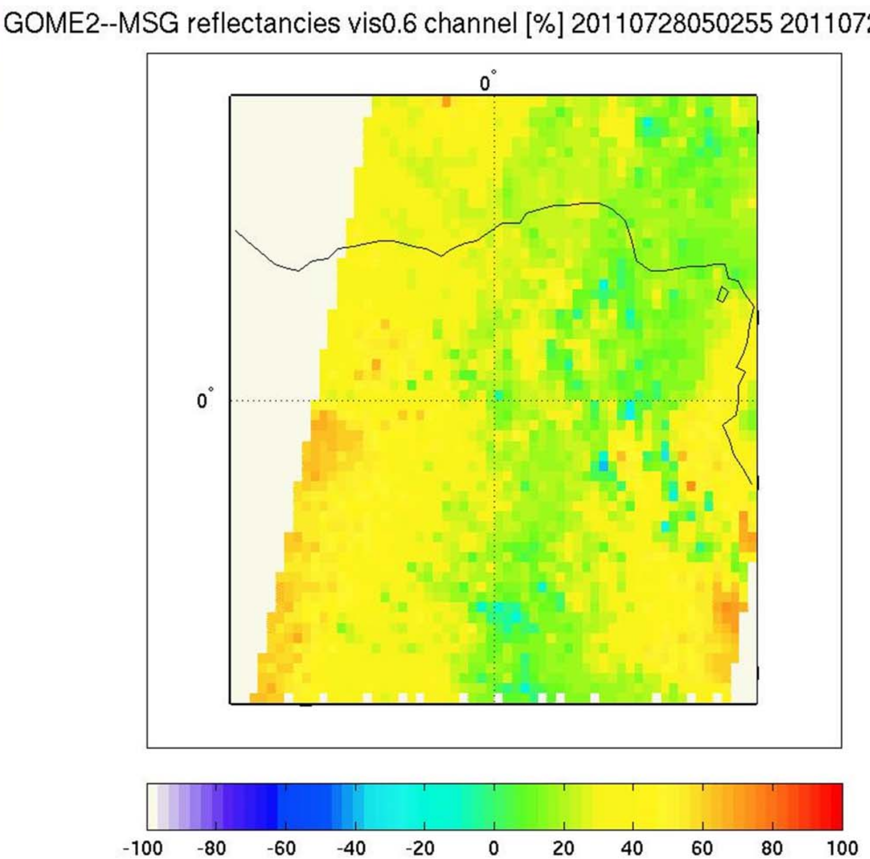
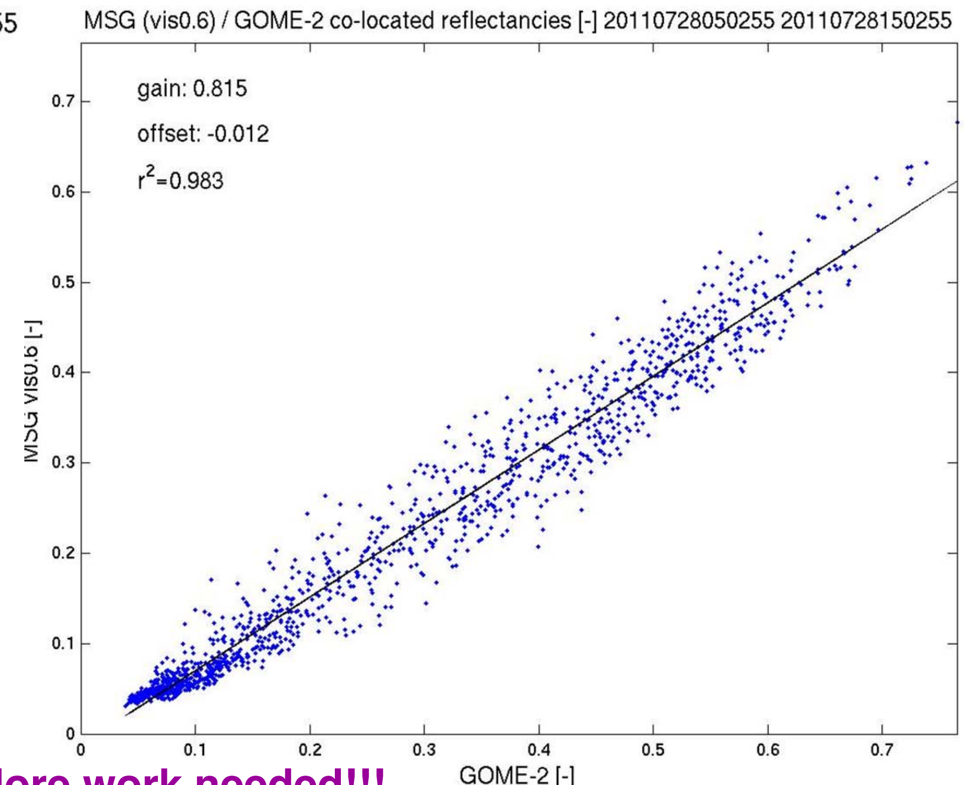
GOME-2 reflectivity inter-calibration

SEVIRI / MSG-2 – preliminary results at 0⁰/0⁰





More work needed!!!

1. **Improve spatial co-location by taking spatial aliasing into account**
2. **Improved temporal co-location still possible at the expense of worse statistics**
3. **Filter for low variability, low path length difference, etc..**

No SNPs yet!

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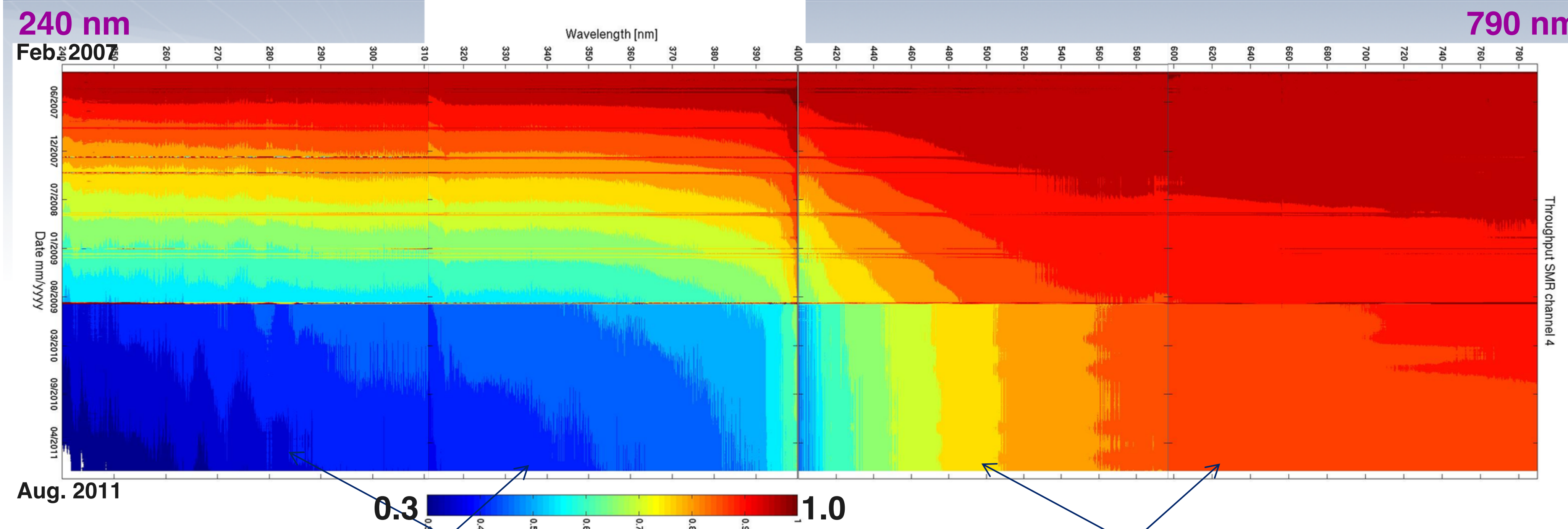
GOME-2 Long-term throughput changes

Solar Mean Reference (SMR) spectrum



Slow onset of degradation observed after 2nd throughput test in channel 1 and 2.

Instrument is stable now in channel 3 and 4.

Reprocessed signals R2 PPF 5.2 until August 2011 relative to February 2007

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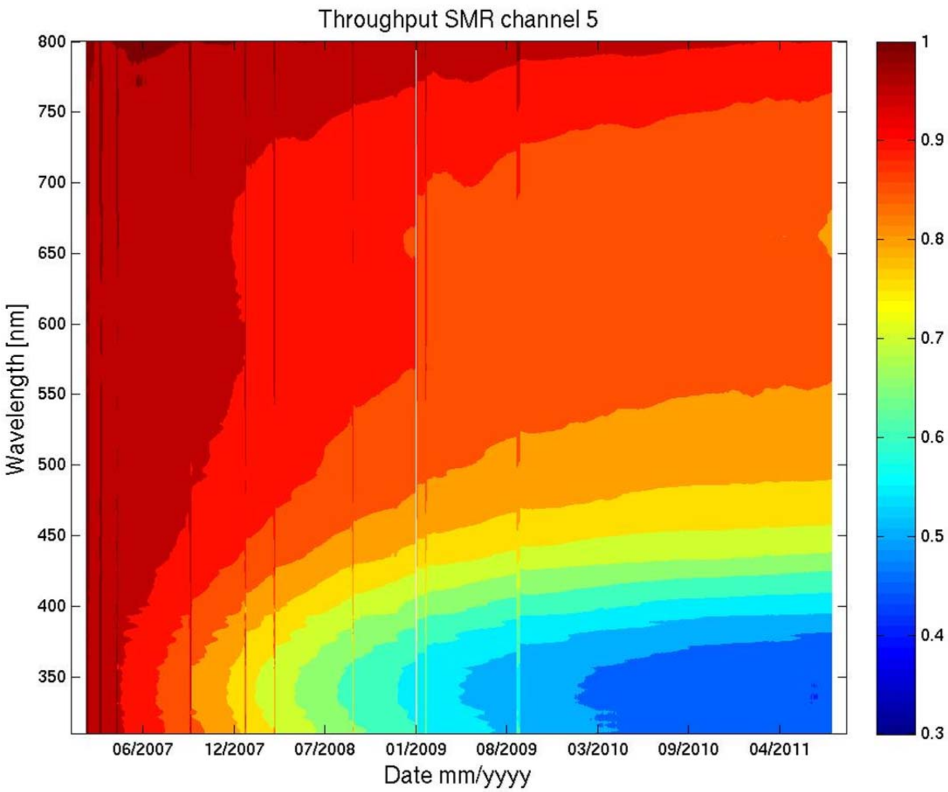
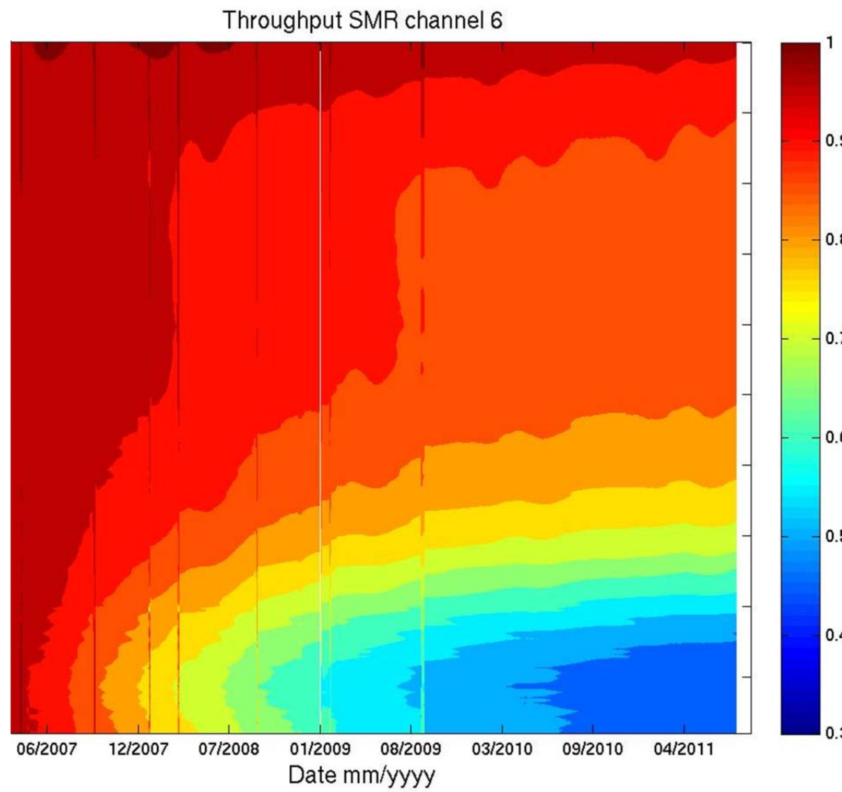
GOME-2 Long-term throughput changes
Solar Mean Reference (SMR) spectrum

PMD-P



PMD-S



Reprocessed signals R2 PPF 5.2 until August 2011 relative to February 2007

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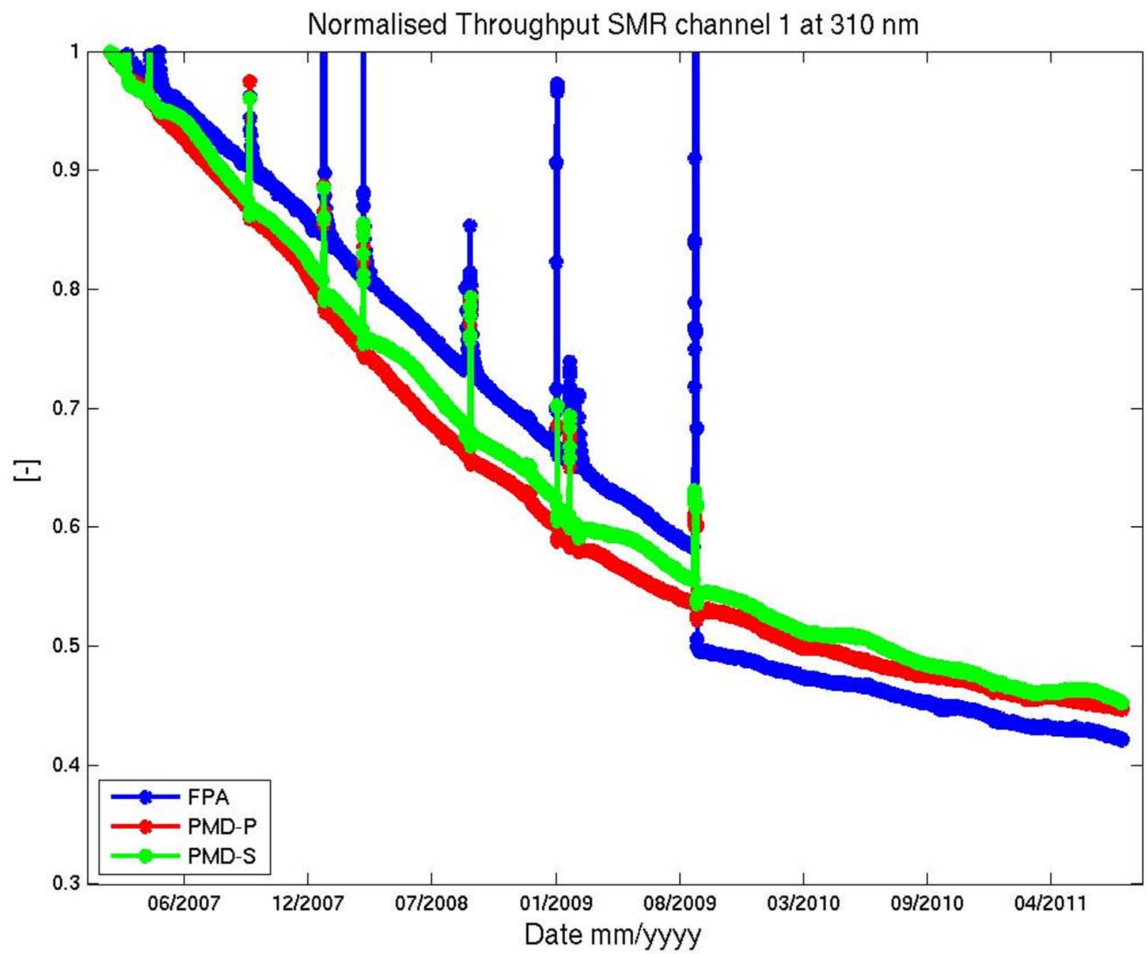
Long-term degradation FPA vs PMD

Solar Mean Reference 310 nm



FPA-SMR smoothed (black line) with PMD spectral response function.

R2 campaign
Jan 2007 – Aug 2011

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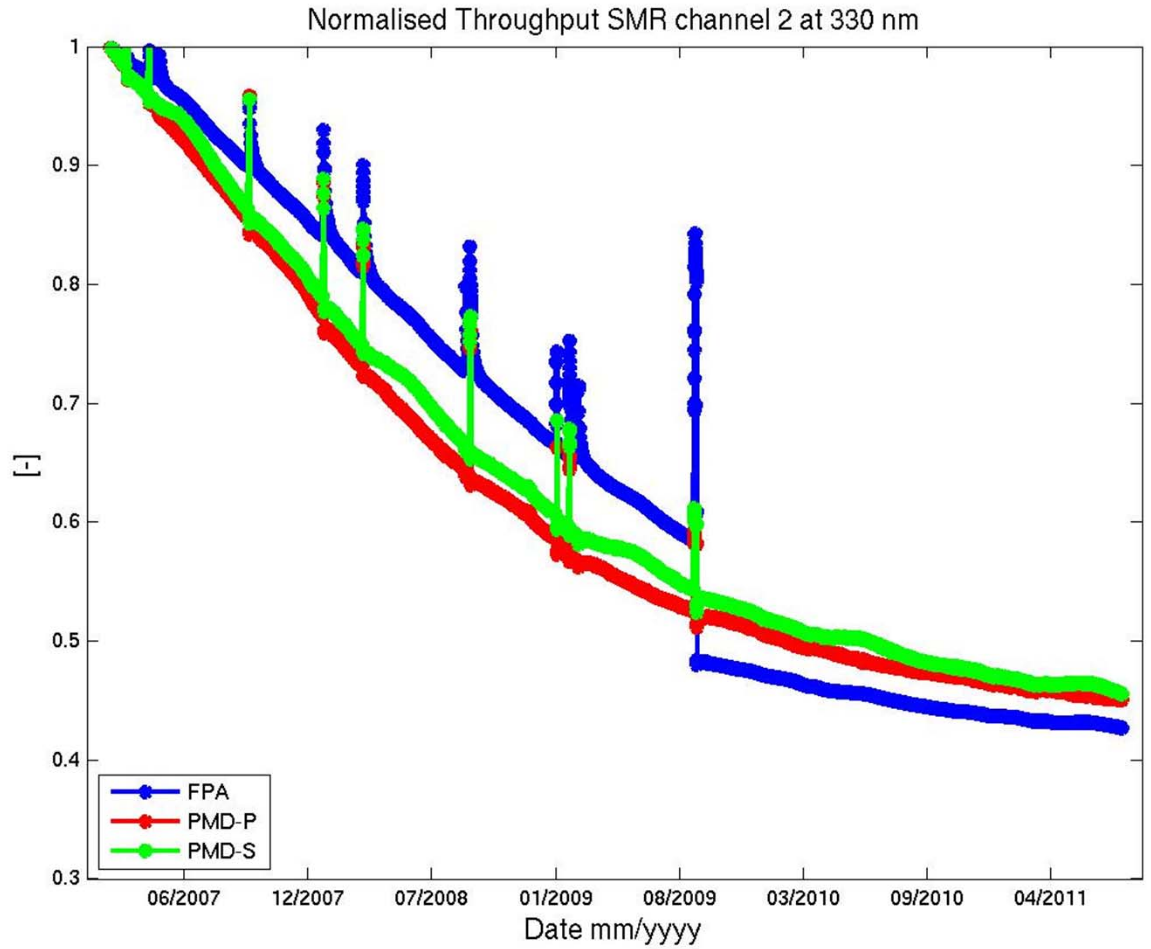
Long-term degradation FPA vs PMD

Solar Mean Reference 330 nm



FPA-SMR smoothed (black line) with PMD spectral response function.

R2 campaign
Jan 2007 – Aug 2011

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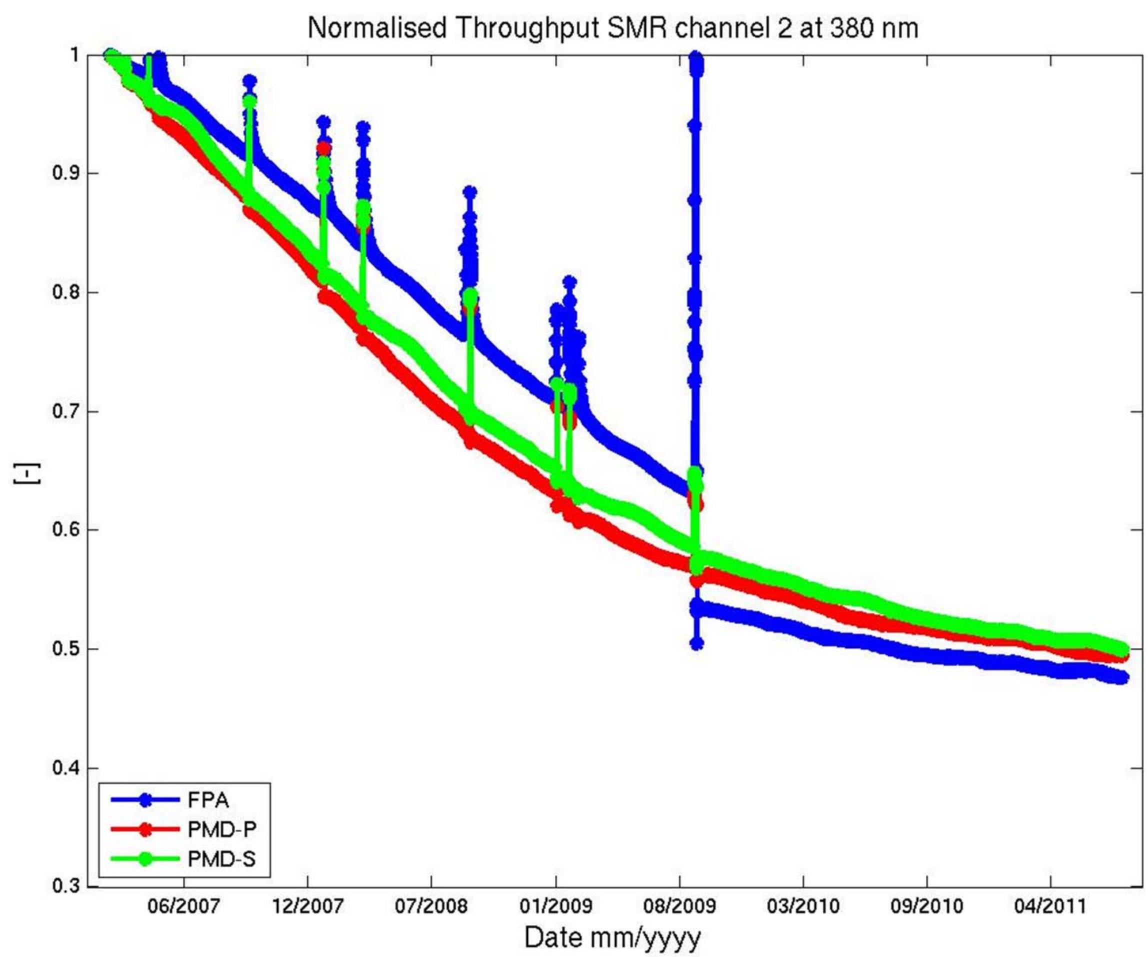
Long-term degradation FPA vs PMD

Solar Mean Reference 380 nm



FPA-SMR smoothed (black line) with PMD spectral response function.

R2 campaign
Jan 2007 – Aug 2011

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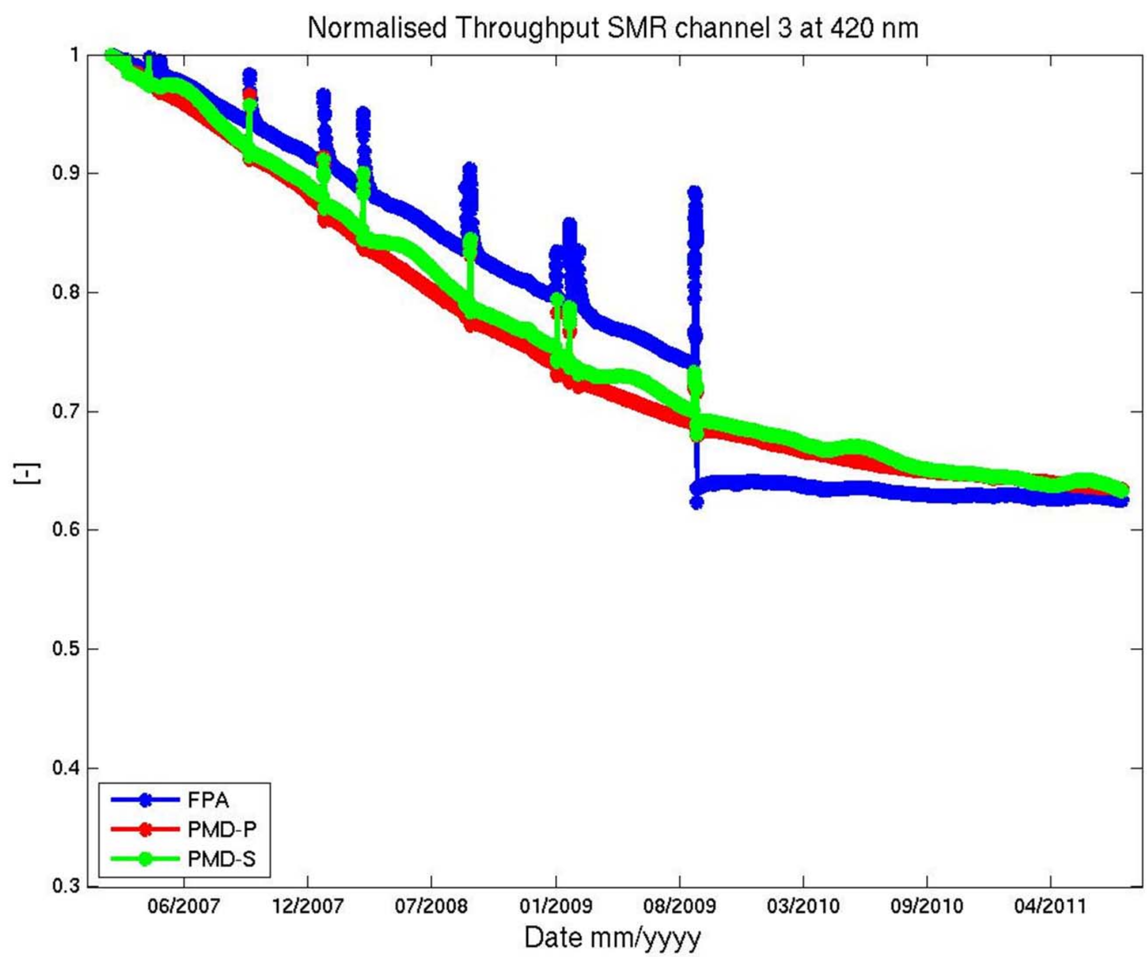
Long-term degradation FPA vs PMD

Solar Mean Reference 420 nm



FPA-SMR smoothed (black line) with PMD spectral response function.

R2 campaign
Jan 2007 – Aug 2011

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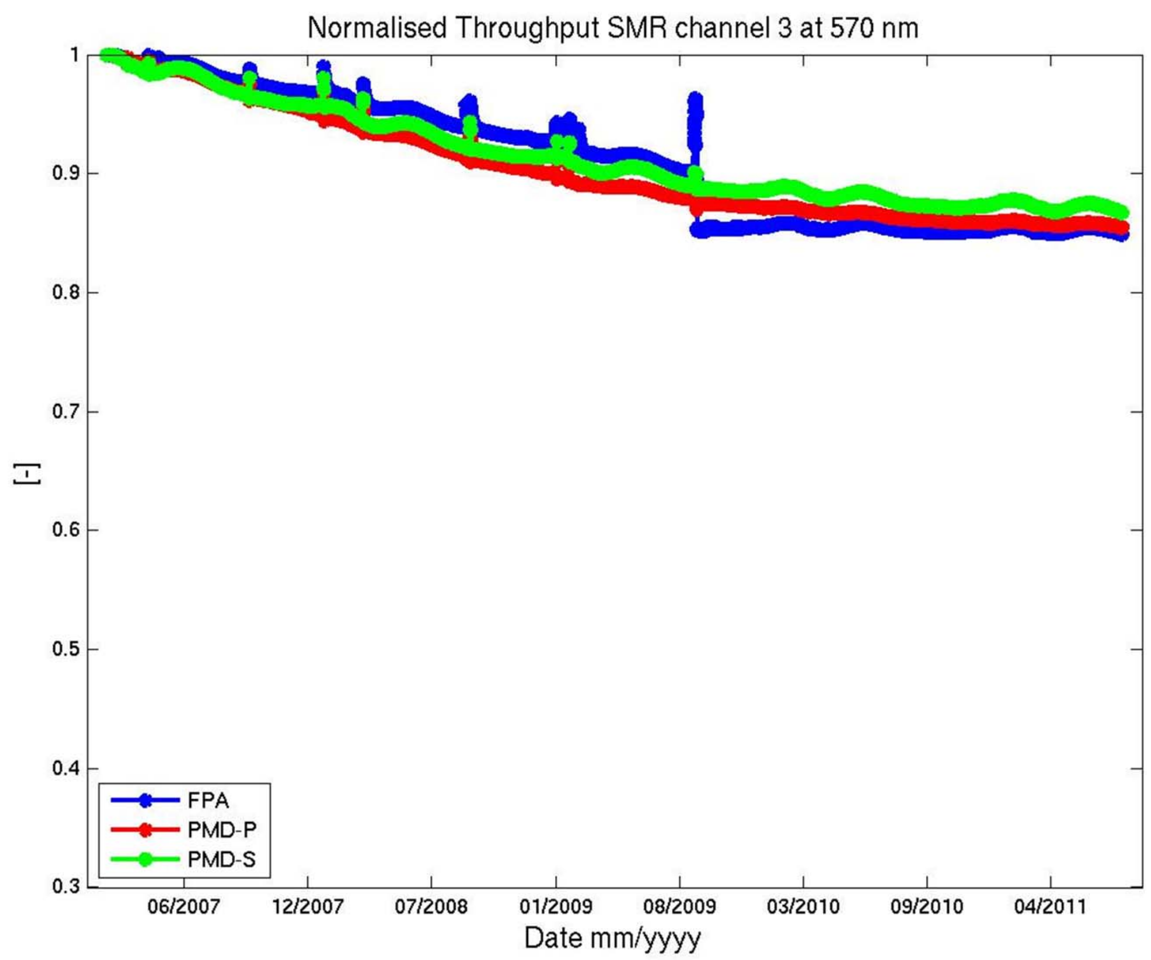
Long-term degradation FPA vs PMD

Solar Mean Reference 570 nm

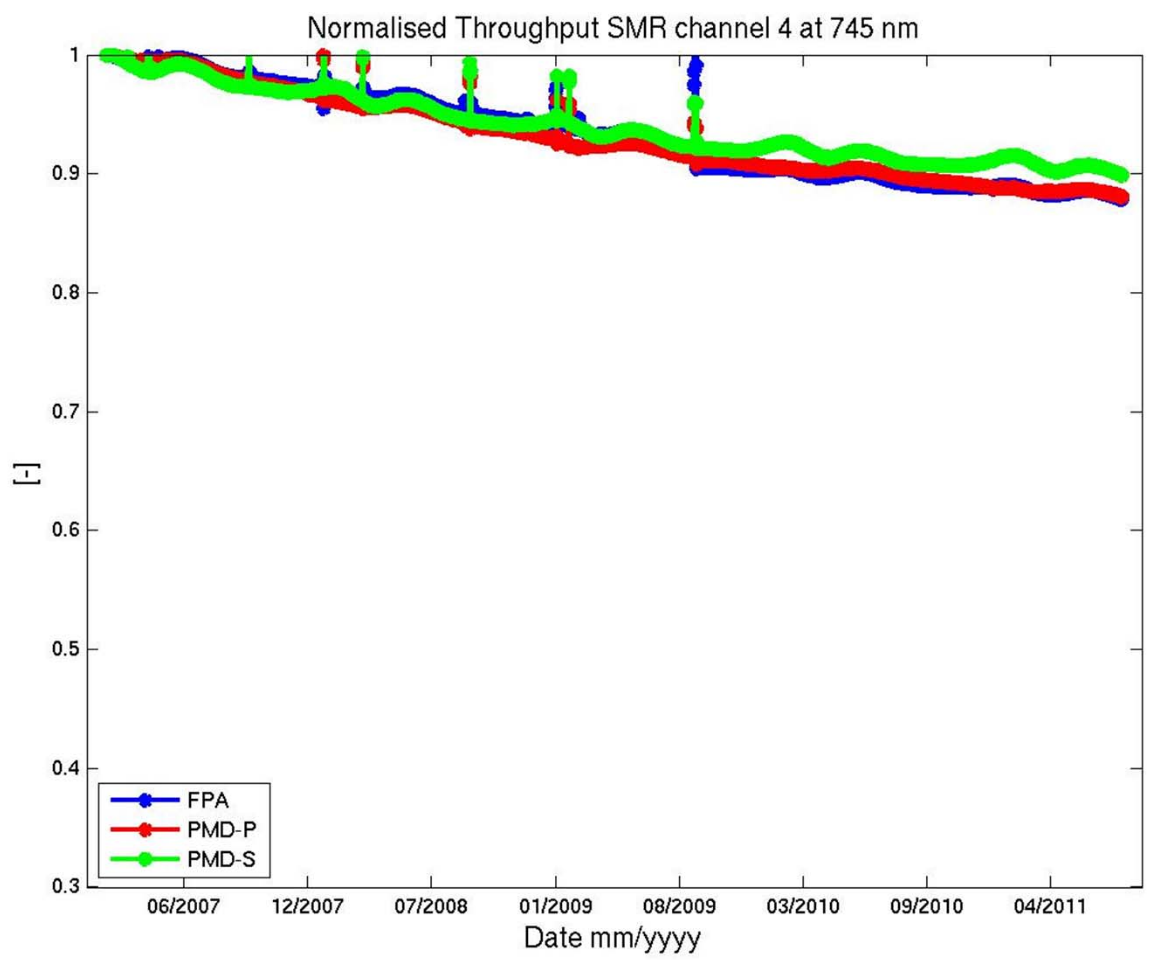


FPA-SMR smoothed (black line) with PMD spectral response function.

R2 campaign
Jan 2007 – Aug 2011

Long-term degradation FPA vs PMD

Solar Mean Reference 745 nm



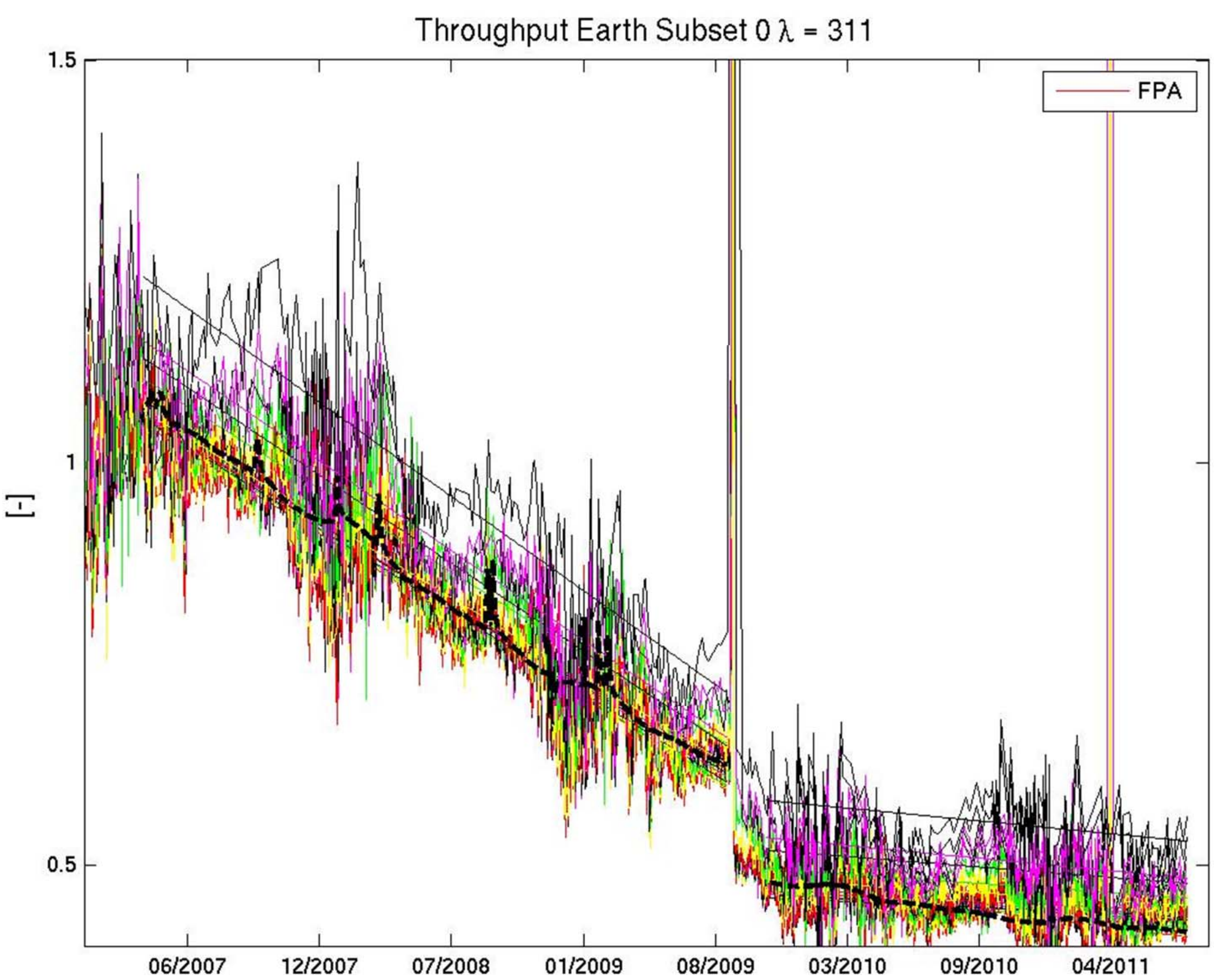
FPA-SMR smoothed (black line) with PMD spectral response function.

R2 campaign
Jan 2007 – Aug 2011

EUMETSAT

Earthshine degradation until December 2010

Sahara – 311nm – relative to mean of 2007



Earthshine Sahara

- **Normalised to 2007**
- **Every 2nd scanner angle position is used (coloured solid lines)**
- **Solar Mean Reference (black dashed line)**
- **Low outliers are due to interfering narrow scan**

R2 campaign
Jan 2007 – Aug 2011

EUMETSAT

Earthshine degradation until December 2010

Sahara – 311nm – relative to mean of 2007 – PMD-P

TBD

Earthshine Sahara

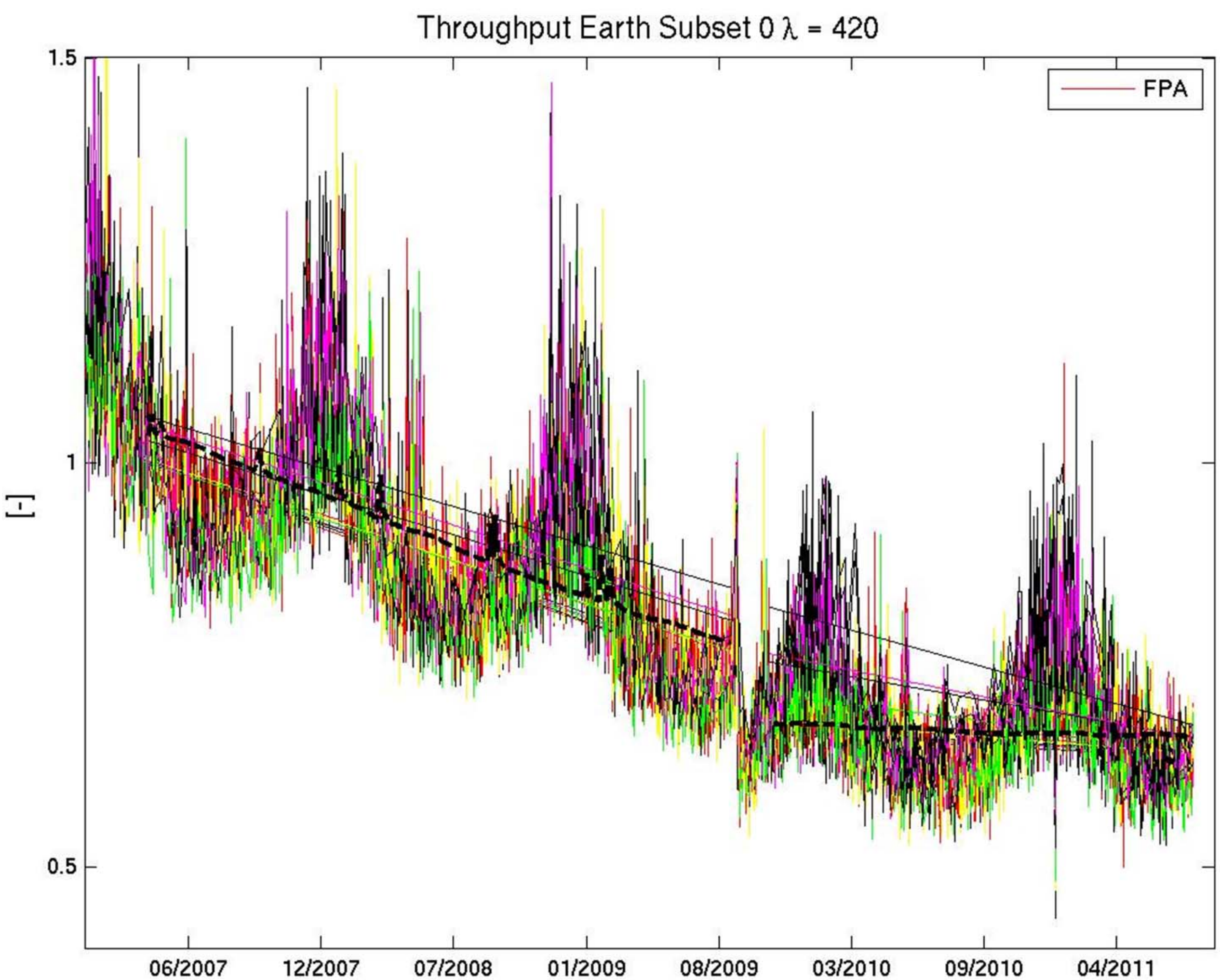
- **Normalised to 2007**
- **Every 2nd scanner angle position is used (coloured solid lines)**
- **Solar Mean Reference (black dashed line)**
- **Low outliers are due to interfering narrow scan**

R1 campaign
Jan 2007 – Dec 2010

EUMETSAT

Earthshine degradation until December 2010

Sahara – 420nm – relative to mean of 2007



Earthshine Sahara

- **Normalised to 2007**
- **Every 2nd scanner angle position is used (coloured solid lines)**
- **Solar Mean Reference (black dashed line)**
- **Low outliers are due to interfering narrow scan**

R2 campaign
Jan 2007 – Aug 2011

EUMETSAT

Earthshine degradation until December 2010

Sahara – 311nm – relative to mean of 2007 – PMD-P

Earthshine Sahara

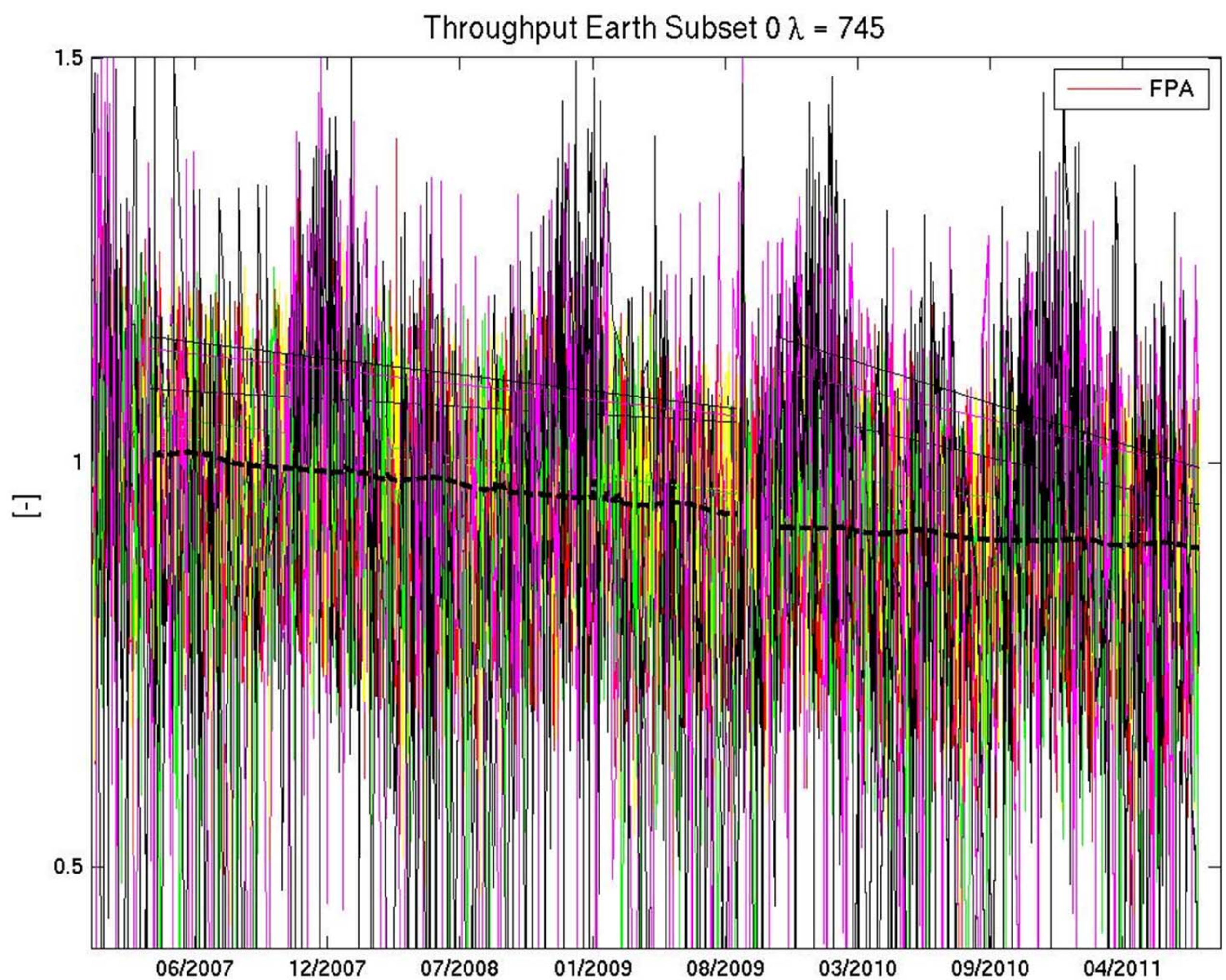
- **Normalised to 2007**
- **Every 2nd scanner angle position is used (coloured solid lines)**
- **Solar Mean Reference (black dashed line)**
- **Low outliers are due to interfering narrow scan**

TBD

R1 campaign
Jan 2007 – Dec 2010

Earthshine degradation until December 2010

Sahara – 420nm – relative to mean of 2007



Earthshine Sahara

- **Normalised to 2007**
- **Every 2nd scanner angle position is used (coloured solid lines)**
- **Solar Mean Reference (black dashed line)**
- **Low outliers are due to interfering narrow scan**

R2 campaign
Jan 2007 – Aug 2011

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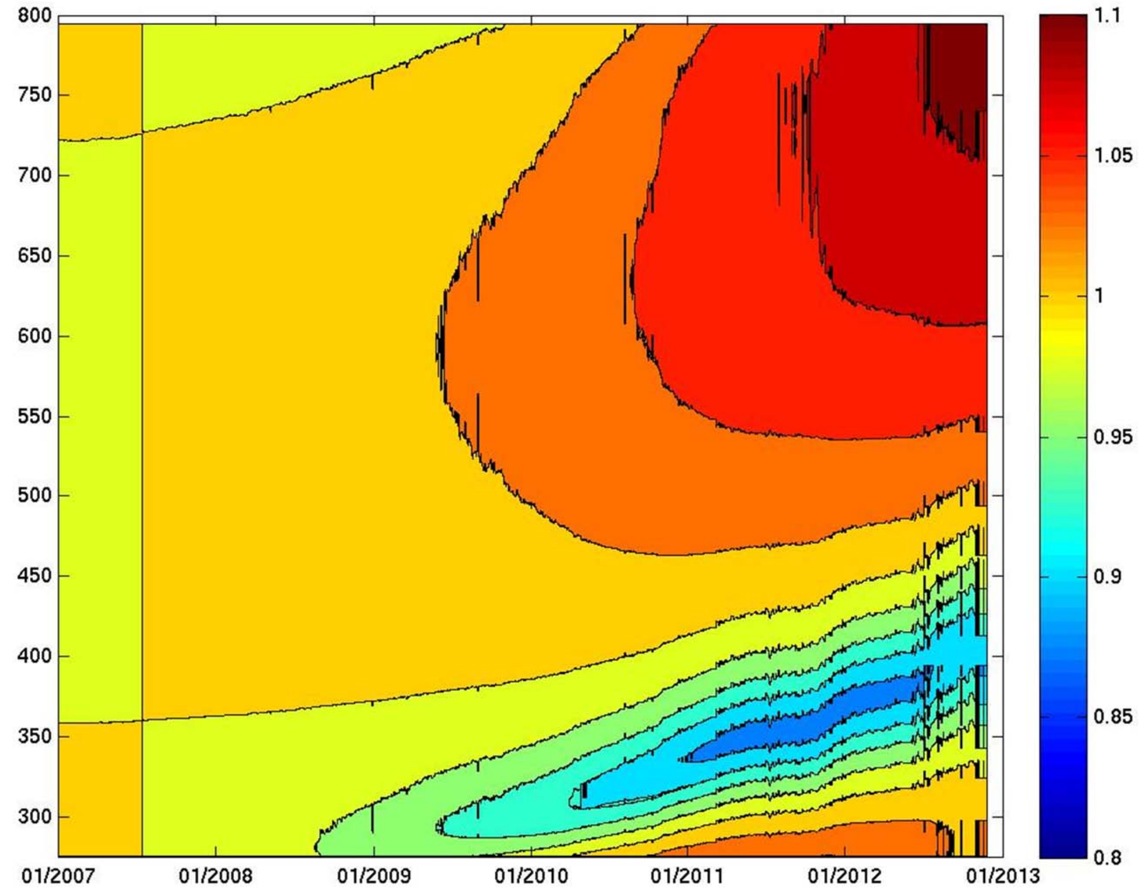
GOME scan mirror contribution

Adapted SRON GOME-1 model results for GOME-2

Scan mirror degradation

Adapted to GOME-2 from GOME-1 in spectral and temporal space



Model data provided by Snel and Krijger, SRON

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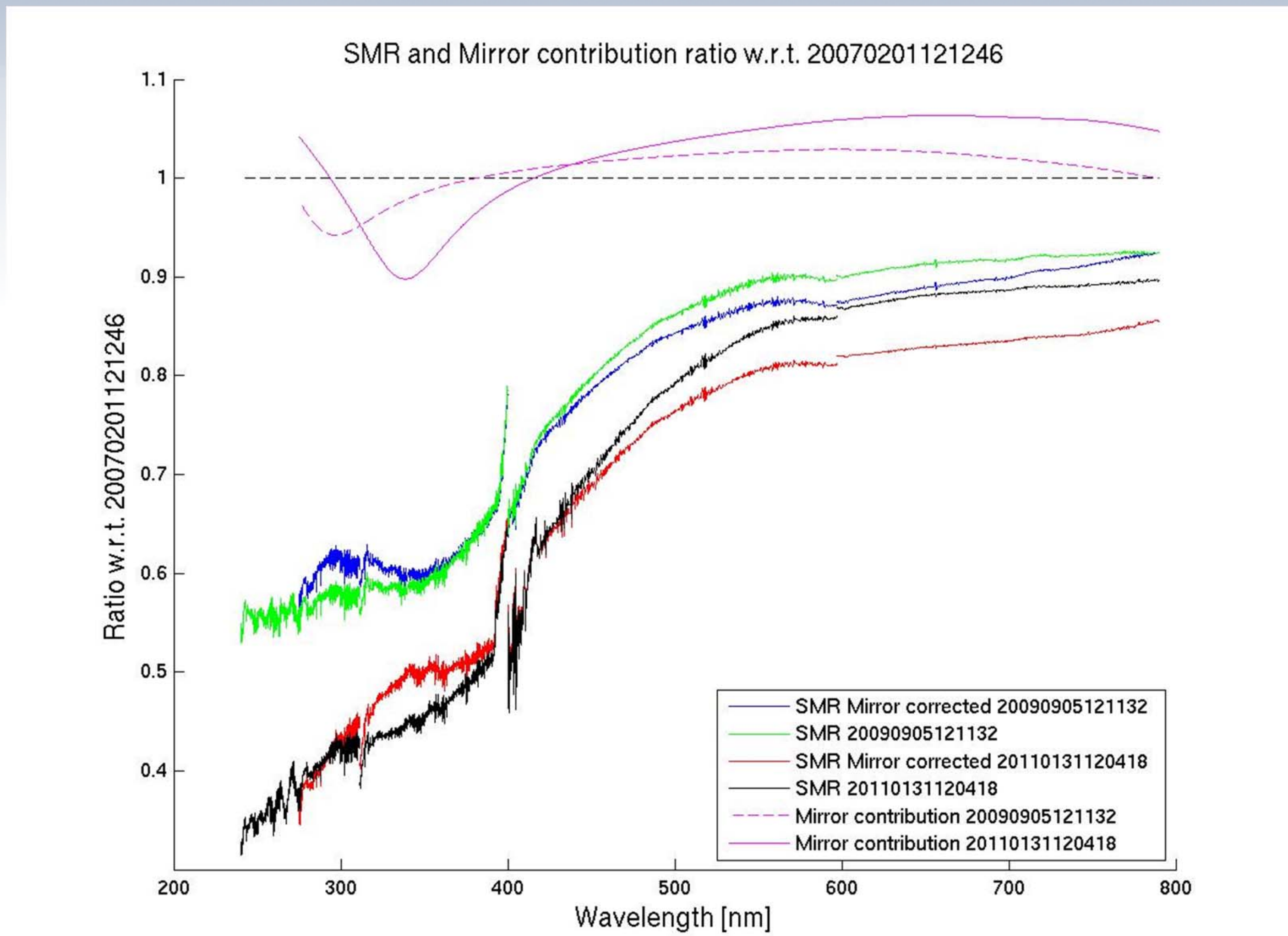
GOME-2 scan mirror contribution vs instrument degradation

SMR and scan mirror contribution

Scan mirror and instrument degradation



Scan mirror model data based on GOME-1 provided by Snel and Krijger, SRON

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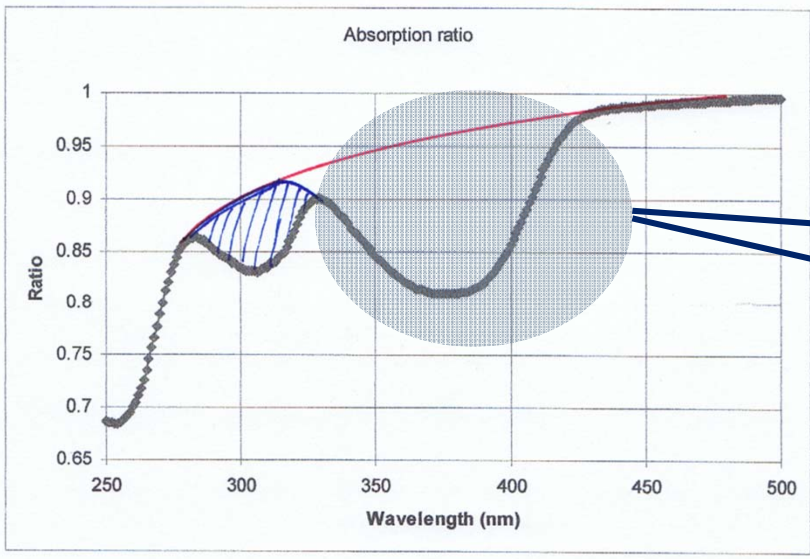
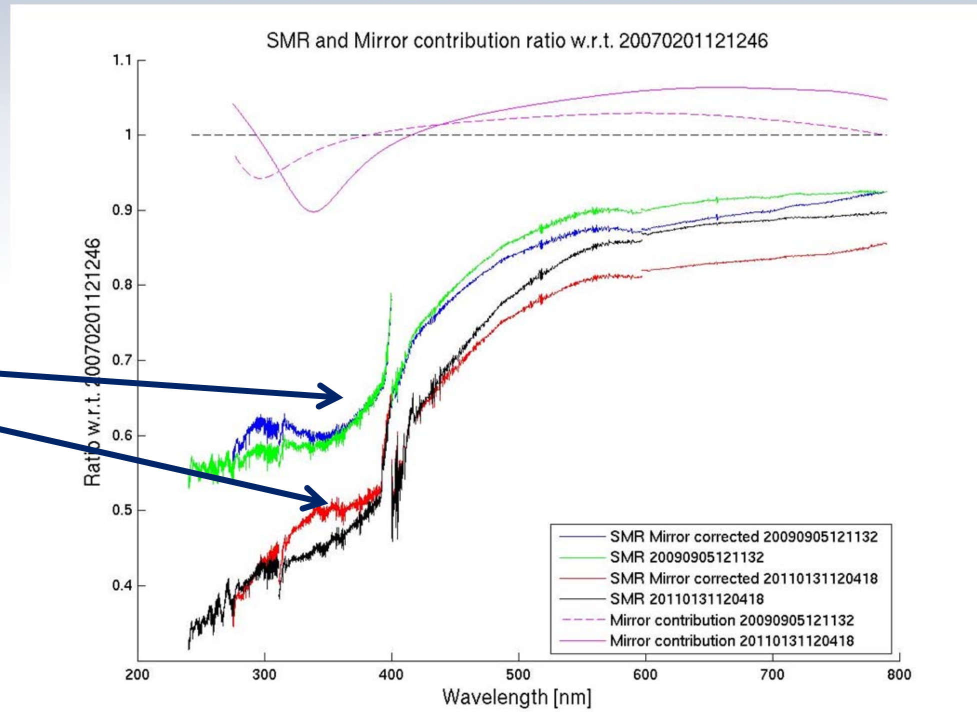
Arathene out-gassing by conformal coatings.
Hyposesis posed by the "ESA/EUMETSAT/Industry GOME-2 tiger team on instrument degradation."



Arathene absorption spectra
"Peak at 310 nm corresponds to a more volatile component in the Arathene, which is effectively removed from the conformal coating by the bake-out process which is applied in the "real instrument PCBs"



Scan mirror model data based on GOME-1 provided by Snel and Krijger, SRON

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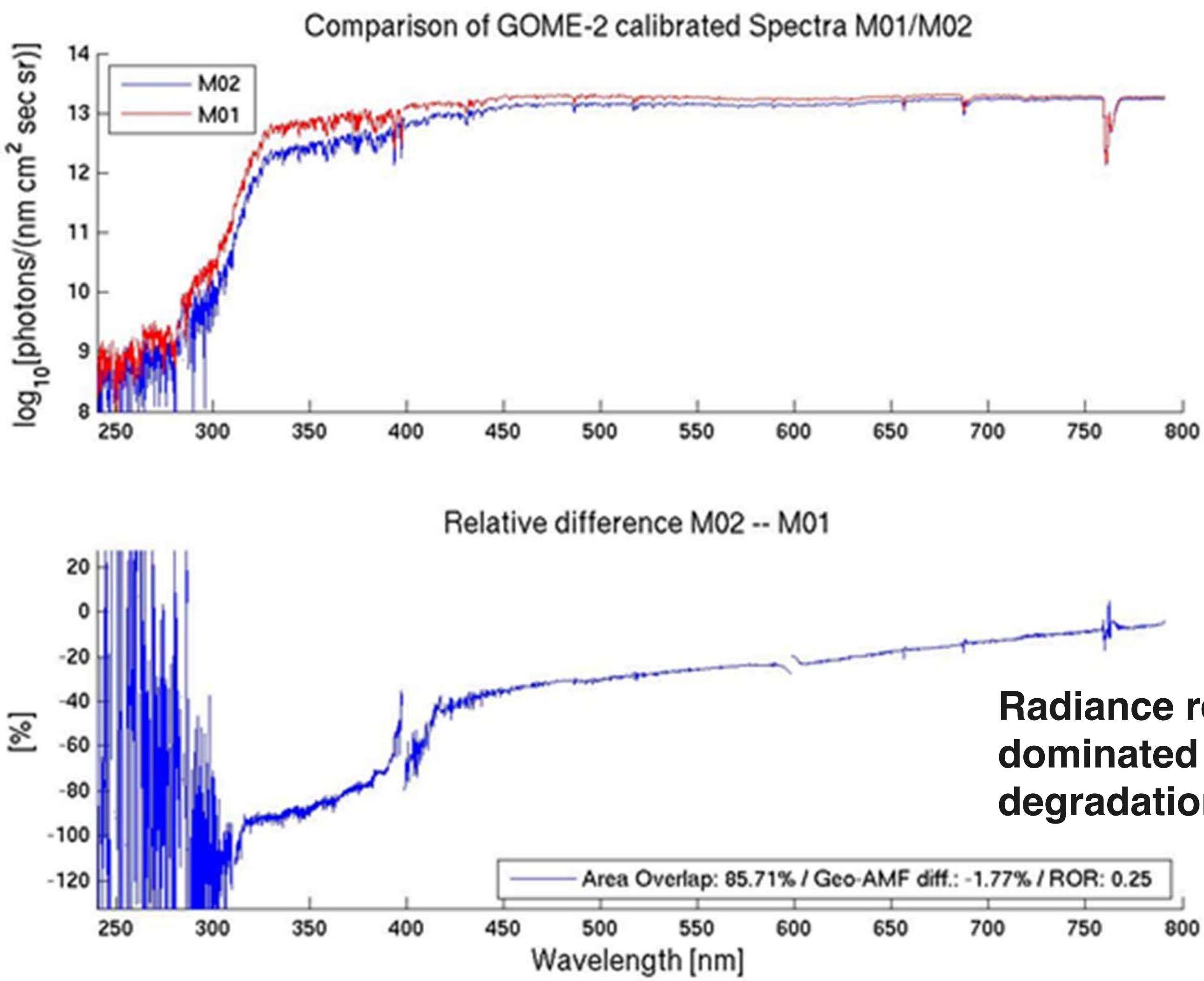
Metop-B / FM2 Radiometric accuracy and calibration

Earthshine measurement co-location to Metop-A / FM3 / Radiances



Radiance residuals are dominated by FM3 degradation signature

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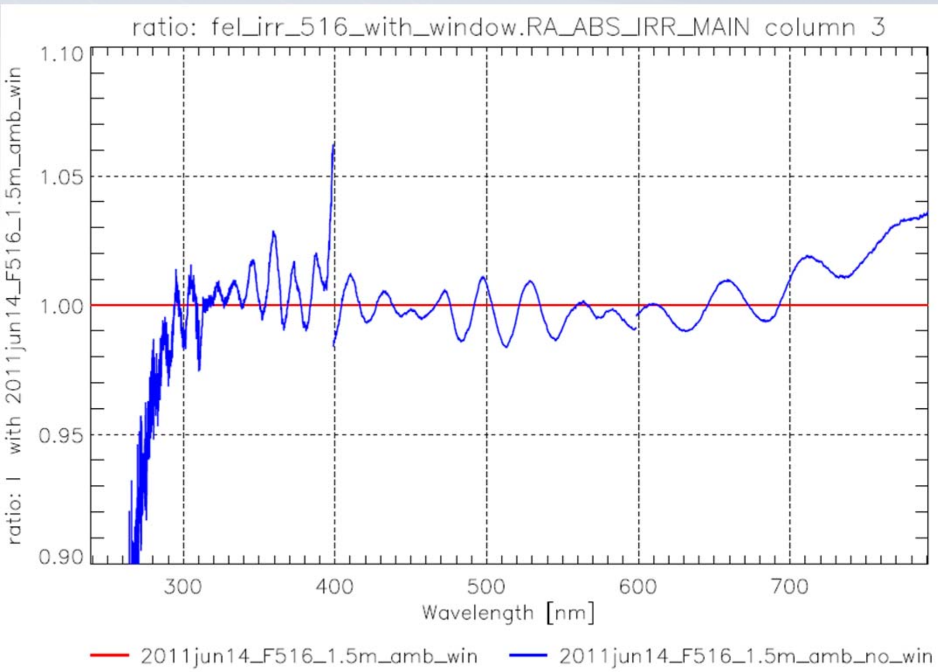
Findings during GOME202-2 Delta Calibration

Radiometric Calibration – Potential stray-light contribution

Irradiance Calibration: Vacuum Window Effect



Radiometric Calibration Investigations

Results for irradiance measured with TVC windows and without TVC window overlap, apart from the wiggles, it is therefore concluded that the window does not introduce any effect on the irradiance measurement results.

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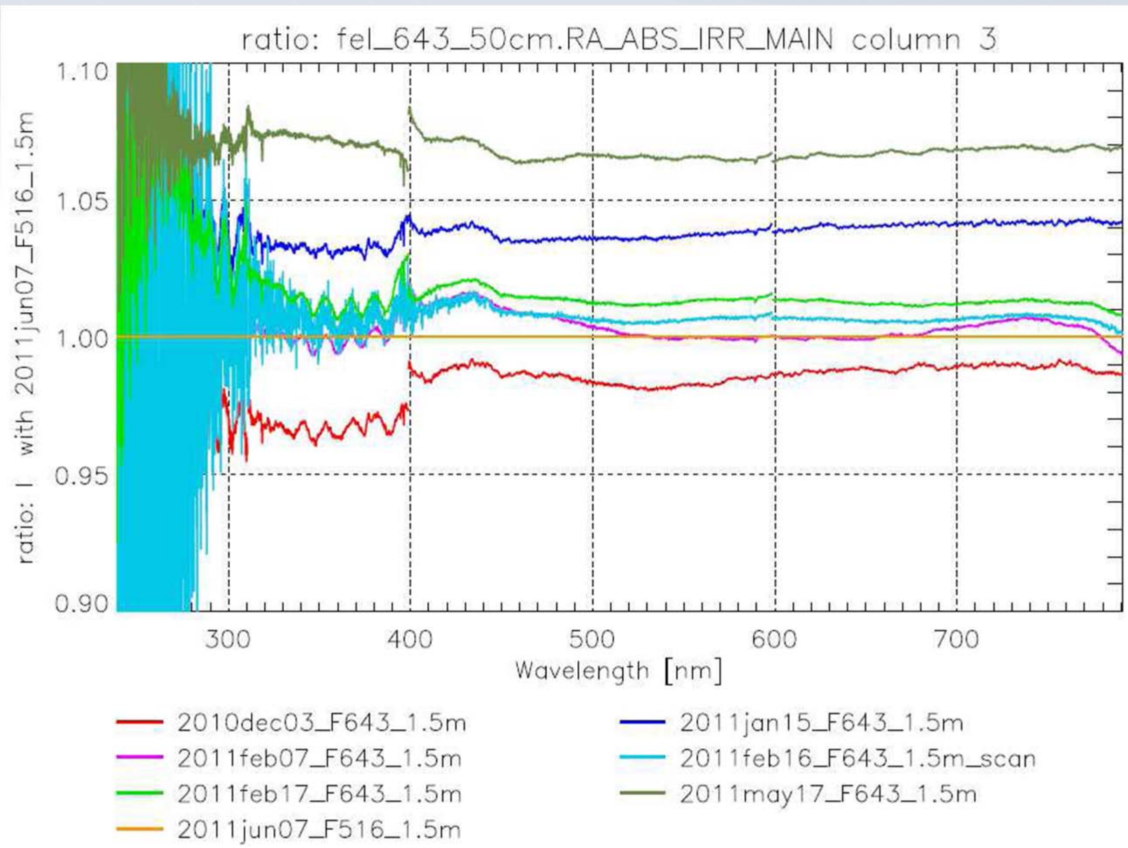
Findings at GOME202-2 Delta Calibration
Radiometric Calibration (6)

Irradiance Calibration: Effect of alignment



Radiometric Calibration Investigations

Irradiance measurements carried out after each alignment show large deviations. The deviation can be caused by a wrong determination of the distance. This was unexpected based on the theodolite procedure and the expected accuracies, but it is considered the most likely explanation.

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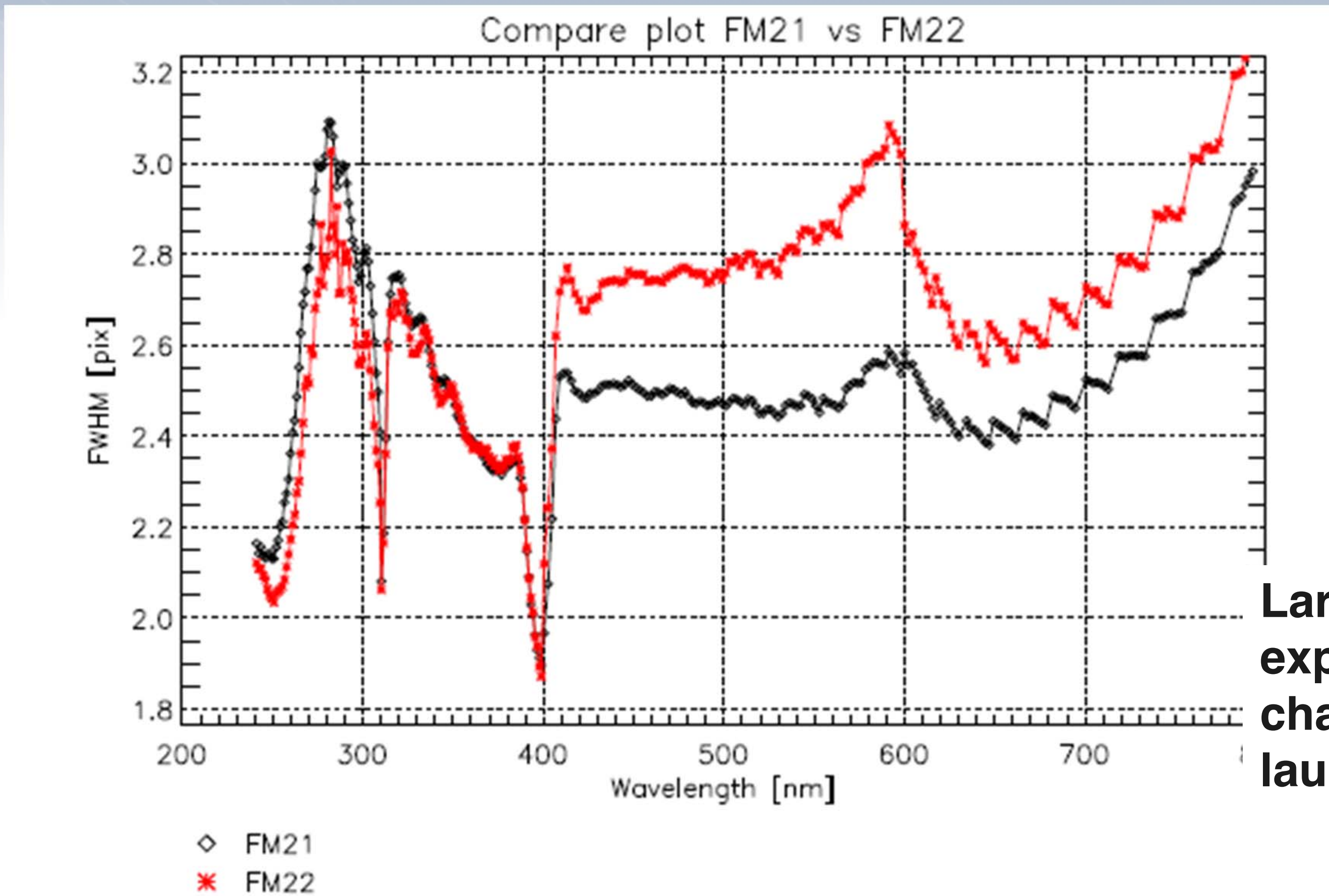
Slit function from FM2/Metop-B

On-ground calibration FM2-1 vs FM2-2



Considered to be an instrument feature from small bending of the gratings due to thermal gradients along the optical bench.

Instrument provider (SELEX/Galileo) report.

Largest effect expected for initial changes before/after launch!

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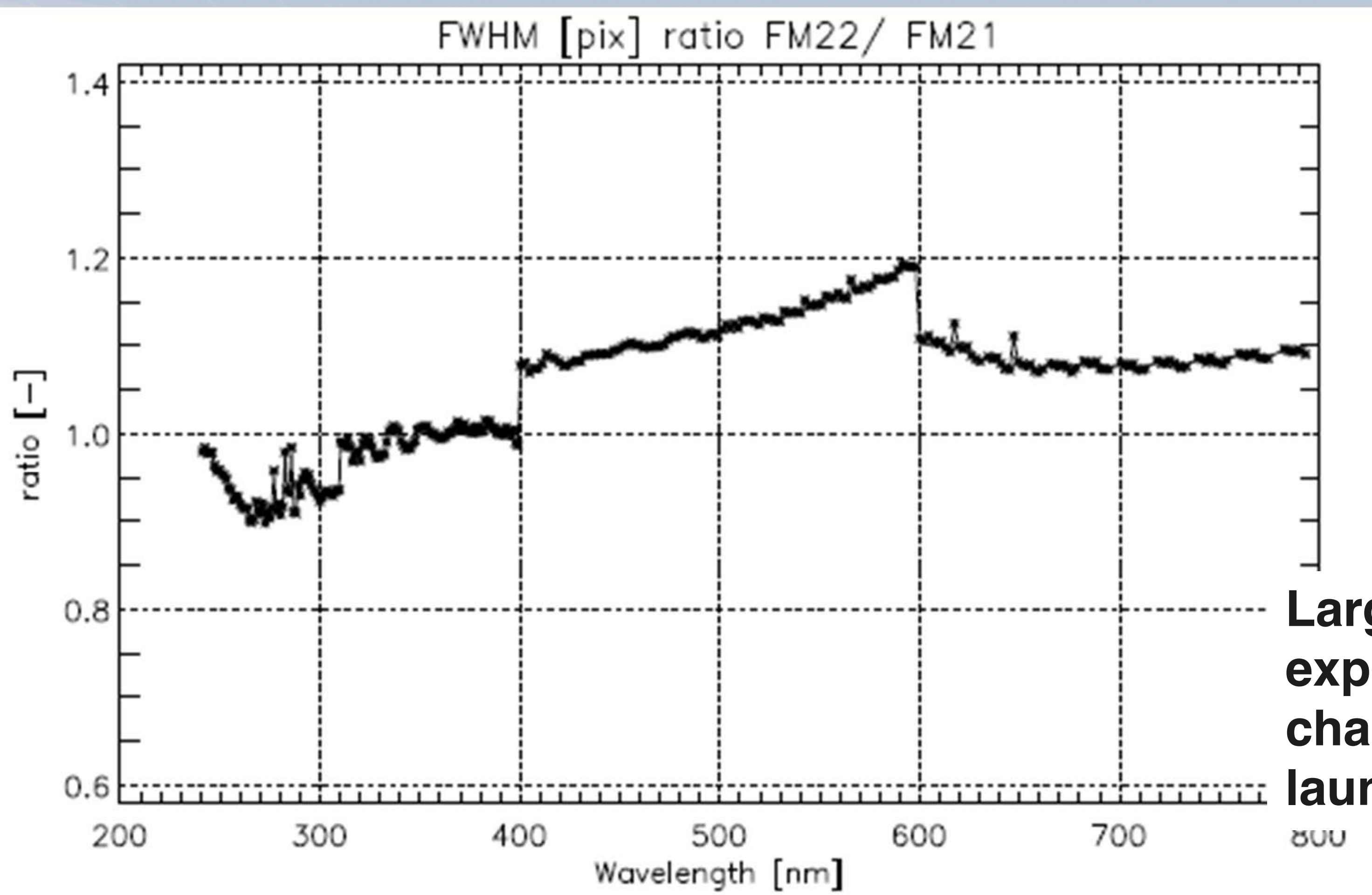

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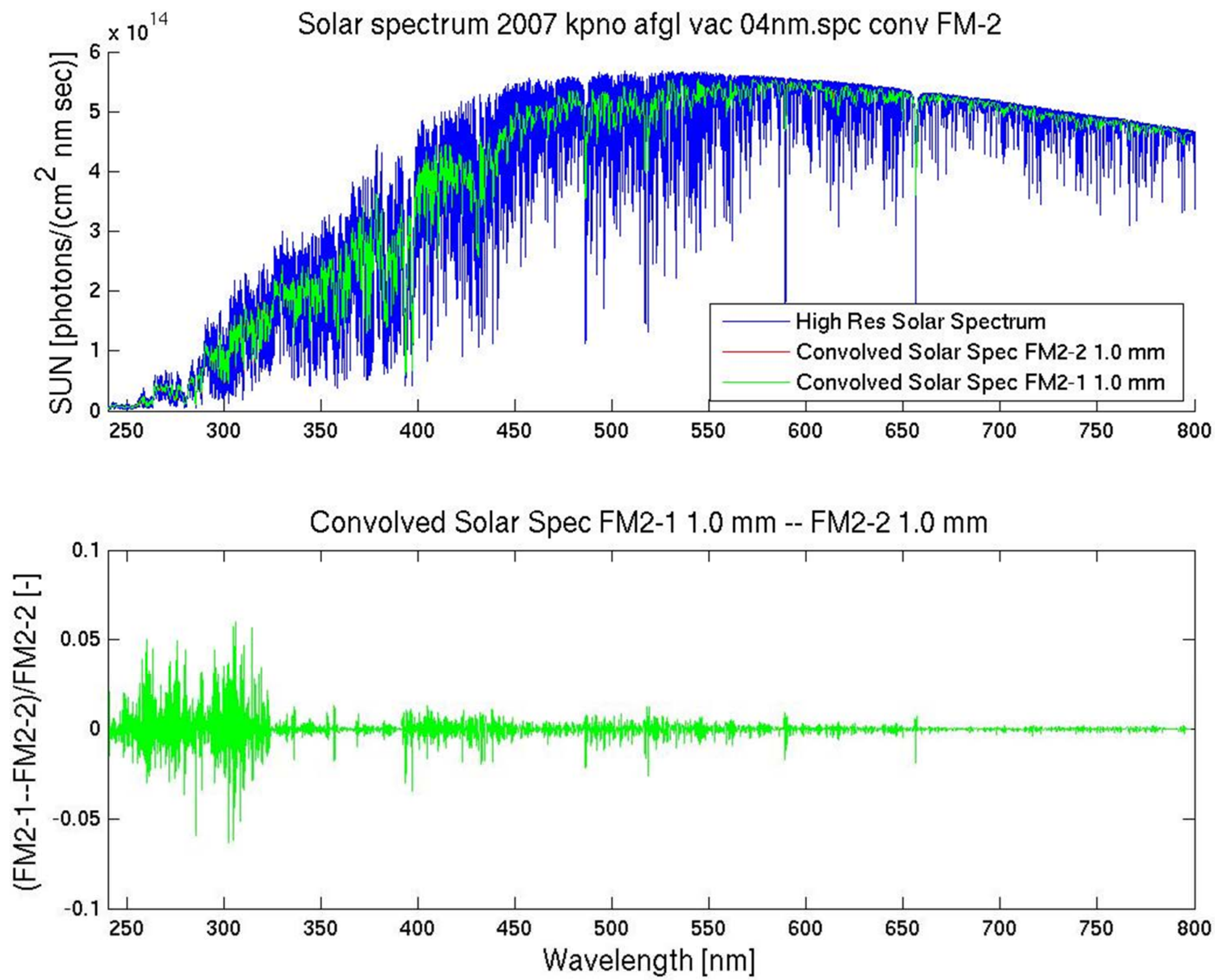

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