GOME-2 processor version 7 for reprocessing campaign R3 - Lessons learnt from CalVal

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Metop / GOME-2
Timelines for GOME-2 level 1 NRT and reprocessed products

Metop-A / GOME-2 level 1 processor version 5.3/6.1

PPF version 7

Metop-B / PPF version 5.3/6.1

PPF version 7

R3 version 7

Metop-C / GOME-2 PPF version 7

10 Years GOME-2A in orbit

EUMETSAT

EOL Operations Metop-A
Milestones:

**Metop-A**
FM3-1 calibration campaign (2004)
Commissioning and operating FM3 2006 to 2016

**Metop-B**
FM2-1 and FM2-2 and FM2-2delta calibration campaign (2004/2011)
Commissioning and operating FM2 2012 to 2016

**Metop-C**
FM1-1 and FM1-2 and FM1-3 calibration campaign (2004/2012/206 ongoing)

Three key-issues for hyper-spectral UV/VIS/NIR radiance quality have been identified for this type of sensors (GOME-1/SCIAMACHY/GOME-2)

- Thermal stability of the instrument
- Degradation of optical paths (mirrors and lenses)
- Quality of on-ground key-data measurements
Instrument design aspects
Radiometric data quality: thermal control

GOME-2 Optical bench temperature

282 K

275 K

278.6 K

277.4 K

$\Delta T = 3$ K

100 min

Orbital variation

FWHM rel. change 20070127132349 to 20160629095305

$I = F_0 \exp (-\sigma_0 \cdot S)$

$\ln(I) = \ln(F_0) - \sigma_0 \cdot S$

$\ln(I') = \ln\left(F_0 + \frac{\partial F}{\partial \Delta}(\Delta - \Delta_0)\right) - \left(\sigma_0 + \frac{\partial \sigma}{\partial \Delta}(\Delta - \Delta_0)\right) \cdot S$

$\ln(I') \approx \ln(F_0) + \frac{1}{F_0} \frac{\partial F}{\partial \Delta}(\Delta - \Delta_0) - \sigma_0 \cdot S \cdot (1 + \frac{1}{\sigma_0} \frac{\partial \sigma}{\partial \Delta}(\Delta - \Delta_0))$

... has to be addressed by the users (producers of level-2 data)
Instrument design aspects
Radiometric data quality: thermal control

GOME-2 Optical bench temperature

$\Delta T = 3K$

282 K

275 K

278.6 K

100 min

277.4 K
GOME-2 Metop-A/B spectral stability
Spectral stability w.r.t. Temperature

This can be used to adjust the spectral calibration for every measurement using the pre-disperser prism (PDP) temperature provided in the level-1b product.

Instrument design aspects
Thermal control: lessons learnt

GOME-2 Optical bench temperature

282 K

275 K

278.6 K

277.4 K

\[ \Delta T = 3\text{K} \]

- The FWHM (ISRF) stability is a function of the thermal stability of the gratings (GOME-2 is specifically sensitive)
- GOME-2 has a high spectral stability even though the OB is thermally not controlled.
- Still, many effects compromising radiometric data quality can be referred to side-effects of thermal instability
GOME-2 Metop-A degradation component modelling
Sahara – spectral and temporal domain

Modelled Earthshine degradation

Modelled Solar Path degradation

800 nm

Normalised and Spectrally smoothed Trend Earthshine FPAs View Pos: 17 Sahara

240 nm

Normalised and Spectrally smoothed Trend SMR FPAs Sahara


PPF 5.3.0 Jan 2007– Jun 2015

PPF 5.3.0 Jan 2007– Jun 2015
GOME-2 Metop-A Long-term throughput changes
Components of the observed signatures

- Long term change in signal (Earthshine and Solar) is due to Scan mirror degradation + optical path contamination (arathene)!
- Long term change in reflectivity is due to scan mirror and diffuser mirror degradation (diffuser-QVD contribution is small)
- Spectral “wiggles" are likely due to mirror induced polarisation and/or spectral calibration.
GOME-2 Metop-A degradation component modelling
Sahara – temporal domain

Jan 2007 – Jun 2015
PPF 5.3

Solar Reference
Earthshine
Reflectivity

Model/Fit-Results

320 nm
GOME-2 Metop-A degradation component modelling
Sahara – viewing angle domain

Jan 2007– Jun 2015
PPF 5.3

Earthshine & Reflectivity
over viewing angle

420 nm
Ozone: Sonde (WOUDC) – GOME-2A

Collocation with WOUDC ozone sonde data, max. 10 hours and 300 km difference.
Ozone: Sonde (WOUDC) – GOME-2B

Collocation with WOUDC ozone sonde data, max. 10 hours and 300 km difference.
GOME-2 Metop-A degradation modelling

Forecasts

Forecast based on polynomial fit of 2nd order to forecast base time data

Forecast base time

(>= 2 yr)

Forecast time
GOME-2 Metop-A degradation modelling
Forecast quality – 1 year comparison forecast / model

Restrict forecast time to period already measured

Throughput channel 3 at 420 nm Pos: 17 Sahs

Forecast based on polynomial fit of 2nd order to forecast base time data

Forecast base time (>= 2 yr)  Forecast time
Residual between degradation coefficients based on measured data vs. forecasted data

Forecast accuracy over one year:

<1% for channel 2 to 4
<3% for channel 1

Prerequisite: no step functions introduced (eg. by instrument anomalies or switch offs)
GOME-2 Metop-A degradation correction
Towards an offline level-1C processor

• Full version
  • Includes full lifetime matrix of correction coefficients plus forecast time period

• NRT version:
  • Includes polynomial coefficients for NRT correction only (no past data correction possible)

• Standalone correction tool:
  • Correction tool (GOME-2 level-1B file in GOME-2 level-1C file out) available from EUMETSAT (“beta version”)
  • Correction of all main and PMD channel detector pixels
  • Coefficient matrix will be provided by ftp (together with software)

  -> latest version: 1D
  • No format change (level-1C format = level 1B format)
  • Official release planned for PPF 7 (Q2 2017)
PPF 7
Preparing for reprocessing campaign R3 (2017/18)

- Updated and cleaned key-data
- New spectral calibration algorithm
- New diffuser BRDF (goniometric data)
- New solar mean reference data
- Degradation matrix for solar and earthshine data V1
- Stray-light correction
- RT reference

Preliminary scope of R3
- Updated level-1B product
- New level-1C product (degradation and stray-light corrected radiances)

First version available/implemented
First version in development
Conclusions

• The thermal stability of the optical bench influences/determines a significant part of the dynamics and the complexity of observed radiometric data quality features.

• Degradation of mirrors and optical components through contamination or simply aging can be empirically modelled with sufficient accuracy as long as there are not too many operations related interruption of the instrument affecting its thermal balance (e.g. interruptions either through switch-offs or changes in the instrument commanding).

• Repeatability of ground based calibration measurements is key to the understanding the absolute quality of radiometric key-data. The absolute accuracy of (radiometric) instrument key-data is only known if a measurement has been set up twice or multiple times.
The end
GOME-2 Metop degradation component modelling
GOME-2 Metop degradation model version 1D

Data and correction tool for test users available as „beta“ versions

The model (degradation coefficients) is available under

ftp://ftp.eumetsat.int/pub/EPS/out/lang/Level1C/

See also GOME-2 Newsletter #27

www.eumetsat.int > News > GOME-2
Preparing for reprocessing campaign R3 (2017/18)

• PPF 6.2/7: Correction of on-ground key-data (source/instrument instability on-ground) for Metop-B:
  • Cleaning of differential spectral features in key-data
  • Correction of diffuser goniometric calibration with in-flight data

• PPF 7: Spectral calibration from solar measurements
  • Addressing anomaly of on-board spectral line source (SLS)
  • Lacking information content in some part of the spectrum form the SLS
  • Thermal instability issue of spectral lamp and spectral calibration algorithm using the SLS signals

• PPF 7: Improved solar mean reference spectrum
• PPF 7: Stray-light correction in band 1 (TBC)
• PPF 7: PMD and main channel cross-calibration (TBC)
• PPF 7: Fresco+ version 2 with GOME-2 LER database
• PPF 7: Update of product format to version 13.0 / netcdf 4 product version
  • PPF 7.x Backup O4 algorithm for CTH (channel 4 Metop-C anomaly) plus “technical” contingency processing solution in case of loss of channel.

Plus offline L1C processor with degradation correction for Earthshine and solar path.

➢ Updated GOME-2 level-1B product PPF 7 for R3, and
➢ new GOME-2 level-1C product (degradation corrected)
GOME-2 Metop degradation component modelling
Summary – user guide GOME-2 Metop degradation model version 1.0C

Time period: 25th January 2007 to 25th June 2015 (Metop-A)
1st December 2012 to 25th June 2015 (Metop-B)

Degradation model version 1.0C / Components

I) New solar spectra with updated in-flight AIRR but NO degradation correction
   \( SMR_{\text{NewAIRR}} \)

II) Two Stray-light offset time series [240;283 nm] and [283;295 nm] in channel 1
   \( c_{\text{Stray,1,2(ch=1)}} \)

III) Degradation coefficients for solar spectrum (SMR) for FPA, PMD-p, and PMD-S
    \( c_{\text{SMR}} (\lambda,t) \)

IV) Degradation coefficients for Earthshine spectrum for 24 fixed angles and for FPA, PMD-
    p, and PMD-S
    \( c_{\text{Earth}} (\lambda,\phi,t) \)

\[
\text{Earth}_{\text{corr}} = (\text{Earth} - c_{\text{Stray,1,2(ch=1)}}) / c_{\text{Earth}} (\lambda,\phi,t)
\]

\[
\text{SMR}_{\text{corr}} = SMR_{\text{NewAIRR}} / c_{\text{SMR}} (\lambda,t)
\]
The GOME-2 instrument on Metop
Measuring atmospheric composition

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 km²)  
- 2 channels with 512 energy measurements of linear polarised light in perpendicular direction (S/P) (40 x 10 km²)

Orbit file sizes
GOME-2 L1B ~ 1GB  
IASI L1C ~ 2GB
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’.
Proposed Phasing:

- **Metop-A**
- **Metop-B**
- **Metop-C**

- **Metop-B EOL**
- **Metop-A phase maintenance on 7/29 orbit phase before EOL**
- **Metop-C commissioning on -6/29 orbit phase before operations on 0**
Proposed „trident“ constellation
Ozone: Sonde (WOUDC) – GOME-2A

Collocation with WOUDC ozone sonde data, max. 10 hours and 300 km difference.
Ozone: Sonde (W OUDC) – GOME-2A

GDOAS COLLOC NorthHem

From O3M-SAF TOZ validation report 2015
Ozone: Sonde (WOUDC) – GOME-2B

From O3M-SAF TOZ validation report 2015
View angle dependent degradation of reflectivity

Strongest spectral features in East looking geometries because of polarisation dependent scan mirror contamination signals!
GOME-2 Metop-A degradation component modelling
Sahara reflectivity – spectral and temporal domain

Reflectivity Trend

800 nm

240 nm
Feb 2007

GOME-2 Metop-A: Residual Reflectivity Uncorrected -- Corrected 20130501 to 20130502 Sahara

View Pos: 1
View Pos: 24
View Pos: 17

R2 campaign
Jan 2007– Jan 2012
OPS phase (same PPF 5.3)
Jan 2012 – Oct 2013

Spectral Level-1B-Level-1C residuals