New GOME/ERS-2 Level-1 Product
In-Flight Calibration and Degradation Monitoring

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Knowledge for Tomorrow
Motivation

- ESA’s **GOME-Evolution** project started in April 2014
  - Modernize L1b product format and improve algorithm documentation (ATBD)
  - Improve and reprocess the complete L1 products 1995-2011
  - Analyze and optimize in-flight calibration parameters
  - Update solar degradation correction and analyze reflectivity degradation

http://earth.esa.int
New GOME Level-1 Product

- NetCDF-4-CF compliant.
- Similar to currently developed or planned EO products, especially to those of the Sentinel missions.
- The similarity to other EO products should lead to reusable reading software with little or no adaptations to the various products.
- The product shall additionally be compliant to following standards:
  - EOP (Earth Observation Programme, ESA)
  - EO-FFS (Earth Observation – File Format Standard, ESA)
  - INSPIRE (Infrastructure for spatial information in Europe, EU based on ISO)
- The measurements will be organized in netCDF-4-groups for modes and bands. Geolocation and other associated data will be incorporated in such a group and match to the measured ground pixels. It will not be necessary to interpolate or co-add geolocation data for certain ground pixels as in older products.
In-Flight Calibration Measurements

Databases

Info
e.g. number of measurements

Leakage
dark current measurements for different integration patterns

Fixed
LED measurements (PPG correction)

Spectral
Lamp measurements (spectral calibration)

Intensity
Sun + PMD measurements
GOME Mean Sun Reference Spectra

Anomalies in 2001 due to gyroscope failure
PMD Measurements and Q-Factors

**PMD Signal**

**Relative Change vs. 1995**

**Q-Factors**

**Q-Factors:**
Relative difference between PMD signal and the expected PMD signal from the corresponding channel signal assuming unpolarized input.
GOME Predisperser Temperature

- Quartz predisperser prism is one of the key elements in the optical system
- Refractive index depends on wavelength and temperature
- Temperature increases along an orbit due to warming of the satellite by the sun and partly because light passes through the instrument
- Temperature changes affect the wavelength calibration
- Long-term increase is due to degradation of the thermal system
- Outliers are connected to instrument and cooler switch-offs

GOME Predisperser Temperature 1995-2011

Slope = 2.5 K/decade
Wavelength Calibration Improvements

- GOME houses a platinum-chromium-neon hollow cathode emission lamp
- Calibration coefficients: fitting a polynomial through pixel-wavelength pairs
- Analyzed individual lamp lines:
  - 67 lines are available (13, 14, 18, 23)
  - analyze line parameters (line position, intensity, skew, FWHM) as a function of time
  - switch-on / -off individual lines for the polynomial fit in each channel
  - investigate stability of the calibration, i.e. standard deviation of each wavelength (assigned to 4x1024 pixels) for a fixed temperature 281.9K
  - In channels 1, 2, and 3: curious lamp lines were identified
  - No changes in channel 4
Spectral Lamp Measurements

Ch 3: 582nm

Ch 4: 668nm
Spectral Lamp Measurements

Ch 2: old coefficients

Ch 2: new coefficients
Dark Current Measurements

- **Integration time pattern: Scan**
  (Band 1a: 12s and Bands 2-4: 1.5s)

- **Integration time pattern: LED**
  (Bands 1-4: 30s)

- **Integration time pattern: Moon**
  (Band 1a: 60s and Bands 2-4: 6s)

→ Increase: 4-6 BU/s / 10 years
Dark Current Noise

Integration time pattern: Scan
Integration time pattern: LED
Integration time pattern: Moon
PMD Noise

Integration time pattern: Scan

Integration time pattern: LED

Integration time pattern: Moon
GOME Solar Degradation Monitoring

CORRECTED SPECTRA OF CENTRAL WAVELENGTH 271.14750 nm: Channel 1

CORRECTED SPECTRA OF CENTRAL WAVELENGTH 353.67040 nm: Channel 2

CORRECTED SPECTRA OF CENTRAL WAVELENGTH 502.41130 nm: Channel 3

CORRECTED SPECTRA OF CENTRAL WAVELENGTH 725.68660 nm: Channel 4

Solar Degradation Correction (1)

1. Polynomial fit vs. wavelength

Ch 1: n_degree = 3

Ch 3: n_degree = 2

Ch 2: n_degree = 3

Ch 4: n_degree = 1
Solar Degradation Correction (2)

2. Apply Savitzky-Golay smoothing filter (vs. time) to each coefficient
3. Store coefficients as a function of time in look-up tables
GOME Solar Degradation Correction - Residuals

Chart 17

RESIDUALS OF DEGRADATION: Channel 1

RESIDUALS OF DEGRADATION: Channel 2

RESIDUALS OF DEGRADATION: Channel 3

RESIDUALS OF DEGRADATION: Channel 4
GOME PMD Degradation Correction

Chart 18
GOME Reflectivity Degradation Monitoring

- Selected 4 of 6 CEOS standard reference test sites
- **Pseudo-Invariant Calibration Site (PICS)**
- Libya-1, and -4, and Algeria-3 and -5
- GOME data for almost the entire period

**Characteristics:**
- temporal stability, uniformity, homogeneity
- high reflectance (sand dunes)
- climatologically low aerosol loading
- practically no vegetation

http://calval.cr.usgs.gov/rst-resources/sites_catalog/ceos-reference-sites/#CEOS
GOME Reflectivity Degradation Correction (325-335nm)

Reflectivity                               Correction (vs. 1995)                               Reflectivity Corrected

GOME Reference Site LIBYA4
Reflectivity @ 325nm
Reflectivity @ 335nm
Reflectivity Correction @ 325nm
Reflectivity Correction @ 335nm
Reflectivity Corrected @ 325nm
Reflectivity Corrected @ 335nm

East   Nadir   West

0 10000 20000 30000 40000 50000 60000 70000 80000
0 10000 20000 30000 40000 50000 60000 70000 80000
0 10000 20000 30000 40000 50000 60000 70000 80000
0 10000 20000 30000 40000 50000 60000 70000 80000
0 10000 20000 30000 40000 50000 60000 70000 80000
0 10000 20000 30000 40000 50000 60000 70000 80000
GOME Reflectivity Degradation Correction (325-335nm)

- Use median of four reference sites

Lerot et al., JGR, 2014
Summary

- Analyzed GOME/ERS-2 in-flight calibration data → monitor the long-term behavior of the GOME instrument
- Optimized calibration settings → spectral calibration and dark current correction
- Recomputed solar degradation correction
- Computed degradation correction for PMDs
- Analyzed reflectivity degradation correction for level-2 fitting window 325-335nm (ozone)
LED Measurements + Pixel-to-Pixel Gain Correction

LED / LED(26-06-1995)

Typical PPG correction factor

PPG Pattern Standard Deviation

Year

Relative Intensity [-]

LED Measurements + Pixel-to-Pixel Gain Correction

Typical PPG correction factor

PPG Pattern Standard Deviation

Year

Relative Intensity [-]
PMD Noise + Zero Offset

Integration time pattern: Scan

Integration time pattern: LED

Integration time pattern: Moon
Outline

- Motivation
- New GOME Level-1 Product
- In-Flight Calibration Data Monitoring
- Solar Degradation Correction
- Reflectivity Degradation Monitoring
- Summary