LONG TERM MONITORING OF GOME/ERS-2 CALIBRATION PARAMETERS

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ABSTRACT

After 11 years of successful operation and data processing, the extensive data set of the most important GOME in-flight calibration parameters has been investigated in order to analyse the long term stability of the instrument. This study focuses on the wavelength calibration, especially on the selection of the individual spectral lines from the PtCrNe lamp measurements. Several lines were identified to be inappropriate because of their asymmetric shape and instability problems. They won't be used anymore in operational data processing, in order to ensure highest quality of the wavelength calibration. The detector's pixel-to-pixel gain correction factors are quite small over the whole lifetime of GOME, but nevertheless not negligible, especially for the minor absorbers (e.g. Bromoxide). In channel 2 an increase of the RMS of the PPG correction factor by more than 70% between 1995 and 2002 was detected. In all channels an abrupt decrease took place at the beginning of 2002. The intensity of the sun mean reference spectra show a strong decrease by more than 90% in channel 1 and by more than 40% in channel 2 due to GOME instrument degradation and the ERS-2 pointing problem. Several peaks and outliers that were found in the PMD Q-factor's time series can be assigned to anomalies such as cooler switch-offs, satellite and GOME instrument switch-offs as well as special operations.

1 INTRODUCTION

The Global Ozone Monitoring Experiment (GOME) was launched in 1995 on board of the second European Remote Sensing Satellite (ERS-2). The nadir viewing spectrometer covers the wavelength range from 240 nm to 790 nm with a spectral resolution of 0.2–0.33 nm. After 11 years in orbit it is of great interest to analyse the in-flight calibration results in order to get a first long term monitoring of their behaviour. The calibration parameters are calculated during the GOME Level 0 to 1 processing [1]. Most of them are stored in a database covering the period from June 1995 to May 2003.
The solar irradiance spectra, that are needed for the radiometric calibration, are used to monitor the instrument throughput (Sec. 2). One focus of this study is the wavelength calibration, especially the selection of the individual atomic emission lines from the PtCrNe lamp measurements (Sec. 3). Further important parameters are pixel-to-pixel gain correction (Sec. 4) and the PMD Q-factors (Sec. 5).

2 SUN MEAN REFERENCE SPECTRA

Instrument degradation as well as the ERS-2 pointing problem since 2002 lead to a strong decrease in the measured intensity of GOME spectral channels 1 and 2. Fig. 1 shows the ratio of the sun mean reference spectra from 1997 to 2006 to the corresponding reference spectrum from 9th January 1996. The intensity in channel 1 decreased by more than 90%. In channel 2 the decrease is still 40–50%, whereas the same effect is not visible in channels 3 and 4. The grey shaded areas in Fig. 1 mark features caused by the dichroic filter which separates channels 3 and 4.
The overall decrease of the sun mean reference as a function of time is exemplarily shown in Fig. 2, left panels, for four single wavelengths (290, 325, 502, and 639 nm). The low periodic variation is due to the seasonality

Proc. of the First 'Atmospheric Science Conference', ESRIN, Frascati, Italy
8 – 12 May 2006 (ESA SP-628, July 2006)

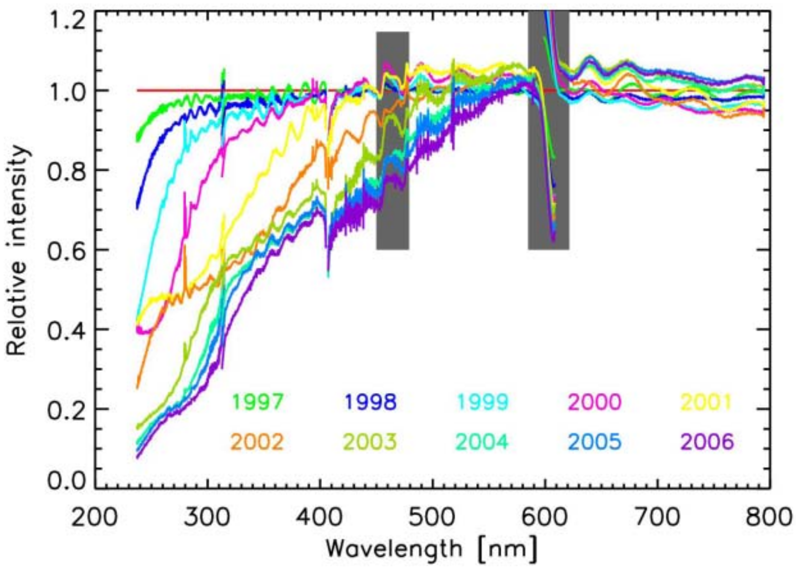

Figure 1: Ratio of the sun mean reference spectra from 9th January 1997 to 2006 to the corresponding reference spectrum of 1996. Grey shaded areas mark features caused by the dichroic filter, which separates GOME channels 3 and 4.

of the sun-earth distance, which is minimum in January and maximum in July. Each curve contains several small peaks, that occur at different dates for each wavelength, so that they cannot be explained with GOME measurement anomalies. The corresponding right panels of Fig. 2 show the same sun spectra, but including a correction for etalon structures. Most of the peaks disappear, except some large outliers at the beginning of 2001, when severe problems with the ERS-2 spacecraft led to data gaps and anomalies.

3 WAVELENGTH CALIBRATION

In order to assign a certain wavelength to each GOME detector pixel, the instrument houses a PtCrNe hollow cathode emission lamp, that provides a sufficient number of atomic emission lines with well-known spectral position. The wavelength calibration parameters are calculated by fitting a low-order polynomial through the pixel wavelength pairs using the Singular Value Decomposition Algorithm [2] from the lamp measurements as a function of temperature. Each individual emission line has to meet four statistical criteria before it is selected for the calibration: The signal intensity is larger than a given minimum, the Full Width Half Maximum is larger than a certain value, the line is symmetrical (skewness ≤ 0.6), and the standard deviation is larger than a given minimum. The individual thresholds for these criteria have been determined during the pre-flight measurements and the commissioning phase of GOME. The accuracy of the wavelength calibration can be further improved utilising the cross-correlation algorithm [3], where additional polynomial coefficients have been determined using a representative subset of GOME solar measurements.
Fig. 3 shows the percentage acceptance of 67 emission lines for all available lamp measurements. Several lines can be identified, that are never selected or partially only, especially in channels 2 and 3. Those lines do not fulfil the statistical criteria. Mostly, they have an asymmetric shape with a large skewness varying around 0.6 as exemplarily shown for one emission line in channel 1 ($\sim$265 nm) in Fig. 4, left panels. The intensity of the lamp measurements is also affected by instrument degradation shown in the middle panel. There is no certain time pattern for the selection of those lines. If they meet the criteria or not may vary from orbit to orbit, or even within one calibration orbit from measurement to measurement.
Depending on the number of selected emission lines — at least 7 are required per channel — the values of the polynomial coefficients vary. Fig. 4, right panel, shows the correlation between the skewness of one emission line ($\sim$755 nm) in channel 4 and the error parameter for the wavelength calibration, that is defined

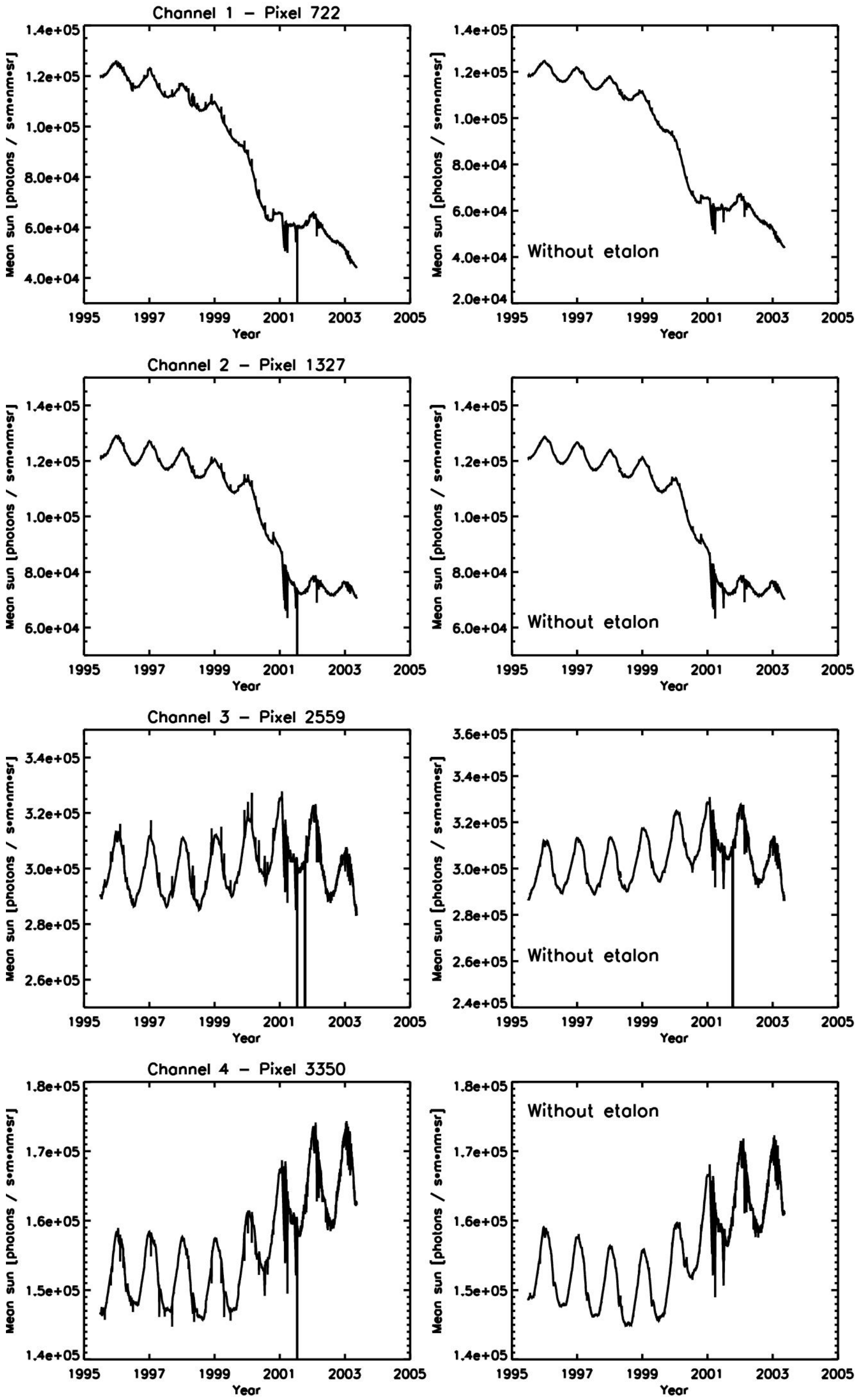

Figure 2: Sun mean reference intensity for four single wavelengths (from top to bottom: 290, 325, 502, and 639 nm) as a function of time (June 1995 to May 2003). Left panels are with etalon structures and right panels are without etalon structures.

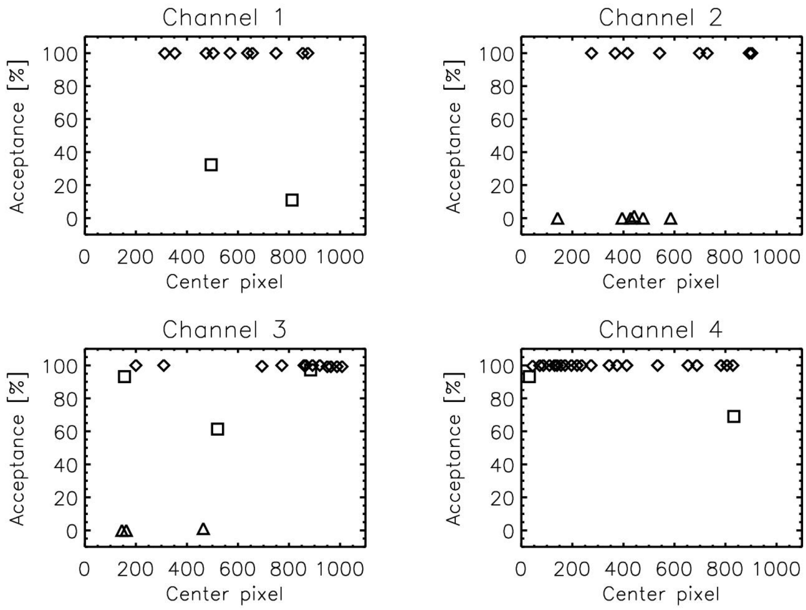

Figure 3: Percentage acceptance of 67 emission lines for all four GOME spectral channels.

as the difference between the precise wavelength and the wavelength obtained from the polynomial fitting. The skewness of this line also varies around the threshold and the wavelength error is larger if this unstable line is selected (skewness ≤ 0.6). Hence it is recommended to omit those lines in order to ensure highest quality of the wavelength calibration.

4 PPG CORRECTION

One of the characteristics of a diode detector array is the different sensitivity of each individual pixel, known as pixel-to-pixel gain (PPG). To correct for this effect correction factors are required, that are defined as the ratio of a smoothed curve through the averaged signal values of several consecutive LED measurements to the averaged signal of each detector pixel (see [1]).
As the variation of the sensitivity from pixel to pixel is around 0.2%, the absolute error is not very large. Nevertheless for weak absorbers such as Bromoxide (fit window 345–356 nm) the effect is not negligible. Fig. 5 shows the RMS of the PPG correction factor as a function of pixel number and time from June 1995 to May 2003 for a 50 pixel wide spectral window running through GOME channels 2 and 3. The RMS increased by about 70% between 1995 and the beginning of 2002 (orbit number 430) in channel 2 (left panel). Then it dropped down by about 50%. For channel 3 (right panel) the increase between 1995 and 2002 is 5-10% only, whereas the abrupt decrease in 2002 is 20%. The same behaviour can be found for channels 1 and 4. The increase of the RMS is due to an increase of the absolute values of the PPG correction factors, that means, positive deviations from the smoothed curve increase and negative deviations decrease. In order to explain this, an analysis of the original PPG measurements in addition to the computed PPG correction factors are required.

5 PMD Q-FACTORS AND GOME ANOMALIES

The polarisation state of the incoming light reaching the instrument is measured using three broadband Polarisation Measurement Devices (PMDs) corresponding to channels 2, 3, and 4. For each PMD one fractional polarisation value is evaluated, which is assumed to be constant for the given wavelength range. Relative correction factors (Q-factors) transform the fractional polarised measured signal to an unpolarised signal. The time series of these Q-factors are shown in Fig. 6 from June 1995 to May 2003. The strong decrease of the PMD 1 signal (top panel) can be assigned to the degradation observed in channel 2. The

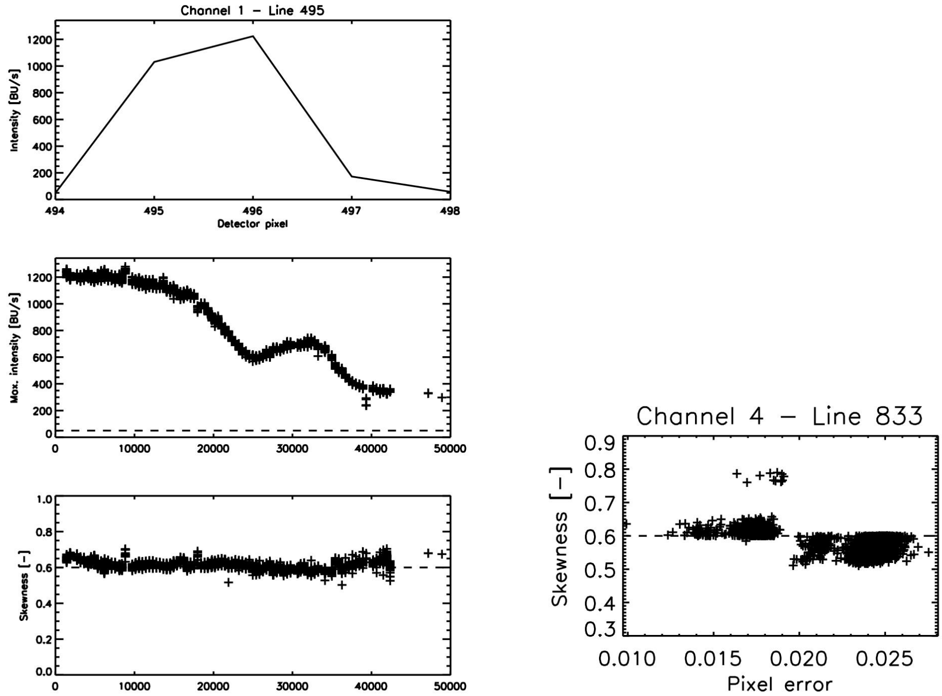

Figure 4: Left panels: Top: typical shape of an emission line (∼265 nm), that is selected partially only due to a large skewness, middle: maximum signal intensity of this line as a function of time, and bottom: skewness of this line as a function of time. Dashed lines denote the thresholds. Right panel: correlation between the skewness of line 833 (∼755 nm) and the error parameter of the wavelength calibration.

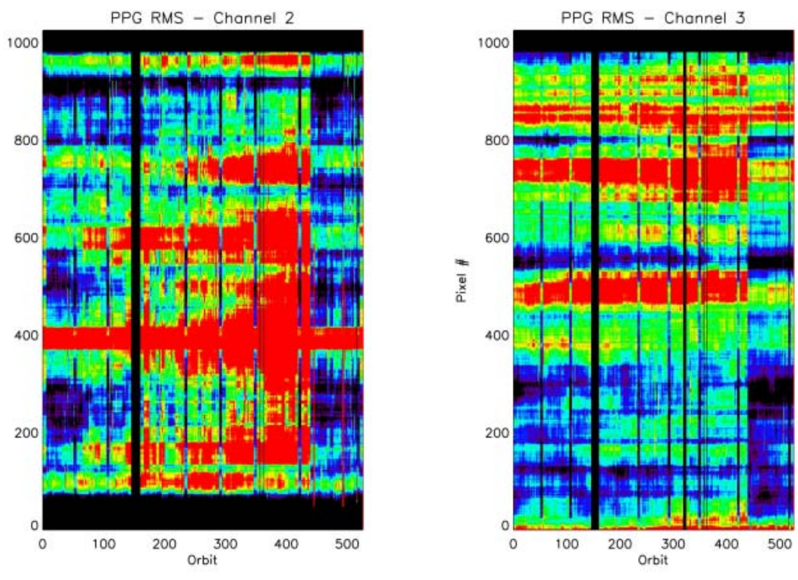

Figure 5: RMS of the PPG correction factor as a function of pixel number (y-axis) and time (x-axis) for channels 2 (left panel) and 3 (right panel).

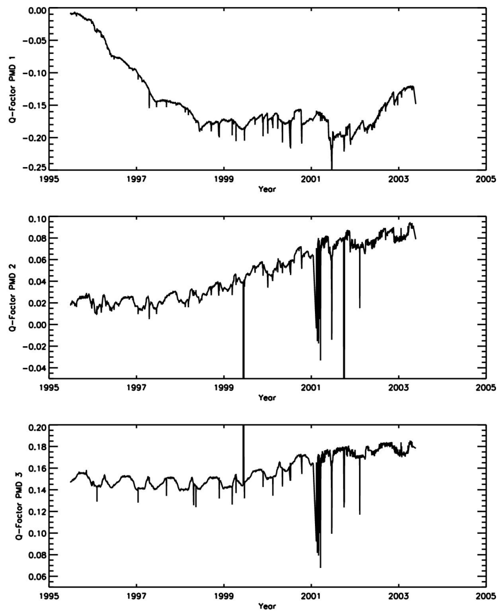

Figure 6: GOME Q-factors for each PMD from June 1995 to May 2003. From top to bottom: PMD 1 (300–400 nm), PMD 2 (400–600 nm), and PMD 3 (600–800 nm).

irregular large peaks and outliers in all three curves are due to GOME anomalies such as cooler switch-offs, instrument or satellite switch-offs, on-board anomalies , or special operations (see GOME yearly anomalie reports `http://earth.esa.int/ers/gome/performance`).

6 SUMMARY AND OUTLOOK

The time series of the most important GOME in-flight calibration parameters have been analysed in order to monitor the long term stability of the spectrometer. The intensity of the sun mean reference spectra decreased by 90% in channel 1 and by 50% in channel 2 due to instrument degradation and the ERS-2 pointing problem. Large peaks and outliers in the PMD Q-factors time series can be explained by GOME and satellite anomalies.

Results of the present study will also be used to further improve the quality of the GOME data products. Emission lines, that were identified to be inappropriate for the wavelength calibration because of their asymmetric shape or instability problems won't be used anymore in operational data processing. An analysis of additional calibration parameters such as original PPG measurements in order to explain the strong increase of the RMS, and the leakage current, as well as a correlation analysis of the individual time series (extended to 2006) are planned.

References

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