GOME SOLAR UV/VIS IRRADIANCE MEASUREMENTS BETWEEN 1995 AND 1997 – FIRST RESULTS ON PROXY SOLAR ACTIVITY STUDIES*

MARK WEBER[1], JOHN P. BURROWS[1] and RICHARD P. CEBULA[2]
[1]*Institute of Environmental Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen, Germany*
[2]*Hughes STX Corporation, 4400 Forbes Boulevard, Lanham, MD 20706, U.S.A.*

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Abstract. The Global Ozone Monitoring Experiment (GOME) is the first of a series of European satellite instruments monitoring global ozone and other relevant trace constituents in the UV/visible spectral range. On 20 April 1995, the European Space Agency (ESA) launched the GOME from Kourou, French Guyana, aboard the second European Remote Sensing satellite (ERS-2). In order to obtain the geometric albedo from the backscattered terrestrial radiance measurements, a solar irradiance measurement sequence in the spectral range between 240 nm and 790 nm is carried out once every day. The GOME solar irradiance is recorded at a moderate spectral resolution (0.2–0.4 nm), thus providing an excellent opportunity to contribute to the long-term investigation of solar flux variation associated with the 11-year solar activity cycle from space, which started in 1978 with SBUV (Solar Backscatter UV Experiment) observations on Nimbus-7 and covers solar cycles 21 and 22. This paper briefly describes the GOME spectrometer and measurement mode which are relevant to the solar viewing. Preliminary results from the solar irradiance measurements between 1995 and 1997 and comparisons to SSBUV-8 (Shuttle SBUV) in January 1996 are presented. Solar activity indices used as proxies for solar flux variation are often used to find a correlation with observed variation in atmospheric quantities, for instance, total ozone. Initial results from the GOME Mg II (280 nm) and Ca II K (393 nm) solar activity index calculation are presented and discussed. The coupling of solar irradiance variability to global change is a current source of scientific and public concern. This study shows that GOME/ERS-2 (1995–2001) and the next generation of European remote sensing instruments, SCIAMACHY and GOME/METOP, have the potential to provide continuity in the measurements of solar irradiance from space well into the next century.

1. Introduction

The Global Ozone Monitoring Experiment (GOME) is the first European passive remote sensing instrument operating in the ultraviolet, visible, and near-infrared wavelength regions whose primary objective is the determination of the amounts and distributions of trace atmospheric constituents (Burrows *et al.* 1988a, 1993). The instrument was proposed as a precursor to the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY) to be launched on the ENVISAT-1 (1st Environmental Satellite) platform in 1999 (Burrows *et al.*, 1988b). GOME is a small-scale version of SCIAMACHY observing the atmosphere in nadir sounding only, and having only four spectral channels as opposed to eight channels

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for SCIAMACHY. The GOME industrial management was funded by the European Space Agency (ESA) and the industrial consortium was led by Officine Gallileo. GOME and SCIAMACHY will provide continuous backscattered radiance and solar irradiance data sets in the UV/visible and near-infrared covering the period between 1995 and 2005, assuming an expected lifetime of five to six years for each instrument.

During the commissioning phase of GOME, which lasted from April 1995 until July 1996, a limited amount of data were processed at the Data Processing and Archiving Facility at the DLR Oberpfaffenhofen (GOMEMANUAL, 1995). The major objective during this phase was the validation of the radiometric accuracy of the GOME solar irradiance and earthshine radiance observations and the validation of trace gas and cloud data products. At the end of June 1996, nominal operation of the GOME processing chain, providing continuous calibrated data products, commenced. Some of the early solar irradiances measured by GOME are shown and compared to preliminary results from the eighth SSBUV experiment in January 1996.

Recent investigations link the 11-year solar cycle to the terrestrial climate (Svensmark and Friis-Christensen, 1997, see references therein) and variation in total ozone (McCormack and Hood, 1996; Labitzke and van Loon, 1997, and references therein). Solar cycle variation in zonal mean ozone as a function of altitude and latitude have been investigated by Hood (1997) by correlating SBUV and SBUV/2 height-resolved ozone data to the composite Mg II index provided by the same instruments (DeLand and Cebula, 1993). Statistical analysis of geo-potential height and temperature variation in the lower stratosphere, which show significant correlation to solar activity (Labitzke and van Loon, 1997) strongly indicate that ozone variation in the lower stratosphere and possibly in the upper troposphere are primarily driven by changes in atmospheric dynamics linked to the solar cycle (Hood, 1997; Labitzke and van Loon, 1996).

Jackman *et al.* (1996) included the solar cycle variation of the solar flux in a 2D global chemical-transport model and showed that a significant fraction of the fluctuation in the long-term global ozone trend can be related to solar activity. However, two major stratospheric sulphate aerosol events, the volcanic eruptions of El Chichon in 1982 and Mt. Pinatubo in 1991, both occurring near solar maximum, also contribute to the apparent cyclic variation of the annually averaged global ozone and is in phase with the solar forcing (Jackman *et al.*, 1996), since increases in stratospheric sulphate aerosols as well as declining solar activity following solar maximum are associated with observed ozone decreases beyond the anthropogenic trend. The space observations are currently limited to the last two solar cycles, because continuous monitoring of global atmospheric ozone and solar irradiance, starting with Nimbus-7 observations (TOMS, SBUV, ACRIM) has been only available since 1978, which covers just two complete solar cycles up to now. The stratospheric sulphate aerosol issue just mentioned demonstrates the need to extend the solar and global atmospheric monitoring in order to improve the statistics by additional solar cycle observations, which in turn will permit a better understanding of the coupling between solar activity and global change. GOME was launched in 1995 during the solar minimum following solar cycle 22. If as anticipated, GOME and SCIAMACHY are fully operational, both instrument alone will provide complete coverage of the next solar cycle 23.

The advantage of using proxy solar activity indicators rather than directly measured solar flux variations is that they are less sensitive to long-term instrumental drifts and more easily available. One important goal of this paper is to demonstrate the feasibility of deriving proxy solar activity indices from GOME's daily solar irradiance measurements, which will complement and possibly extend solar activity indices, particularly the Mg II index, as derived from other satellite instruments such as the SBUV/2 series (Solar Backscattered UV Experiment, Cebula *et al.* 1988, 1992, 1997; Donnelly, 1991; DeLand and Cebula, 1993, 1997) and the UARS (Upper Atmosphere Research Satellite) instruments, SUSIM (Solar UV Spectral Irradiance Monitor, Brueckner *et al.*, 1996; Floyd *et al.*, 1997a) and SOLSTICE (Solar Stellar Irradiance Comparison Experiment, de Toma *et al.*, 1997).

A preliminary Mg II solar activity index and Ca II K emissivity index are presented and shown to correlate well with SUSIM results, although the comparison is limited to a nine month period at solar minimum condition (July 1996–March 1997). The high quality of the GOME solar activity indices was achieved only after adjusting the absolute radiometric calibration of the GOME spectra to account for an observed etalon fringe pattern in the GOME spectra. The etaloning is caused by a Fabry–Pérot effect observed in a thin quartz layer protecting the detector arrays, which rapidly changes its shape when turning on the detector coolers following an accidential detector warm-up to an ambient temperature near the freezing point. On the other hand the GOME Mg II core-to-wing ratio, used as a solar activity indicator, proved to be rather insensitive to the observed UV degradation, the latter being a common problem of UV measuring instruments in space. This paper concludes with some remarks about GOME and its importance to future space missions for monitoring daily solar flux variations.

2. Instrument Design

The GOME instrument is a double monochromator which combines a pre-disperser prism and a grating in each of the four channels as dispersing elements. A schematic diagram of the GOME optical layout is shown in Figure 1. The irradiance and radiance spectra are recorded with four linear Reticon Si-diode arrays with 1024 spectral elements each. Peltier elements attached to the diode arrays and connected to passive deep space radiators cool the detectors to about $-40\ ^{\circ}\mathrm{C}$. Except for the scan mirror at the nadir view port, all spectrometer parts are fixed and the spectra are recorded simultaneously from 240 nm to 790 nm. The spectral resolution varies between 0.2 nm (UV, Channel 1) and 0.4 nm (VIS, channel 4). Part of the

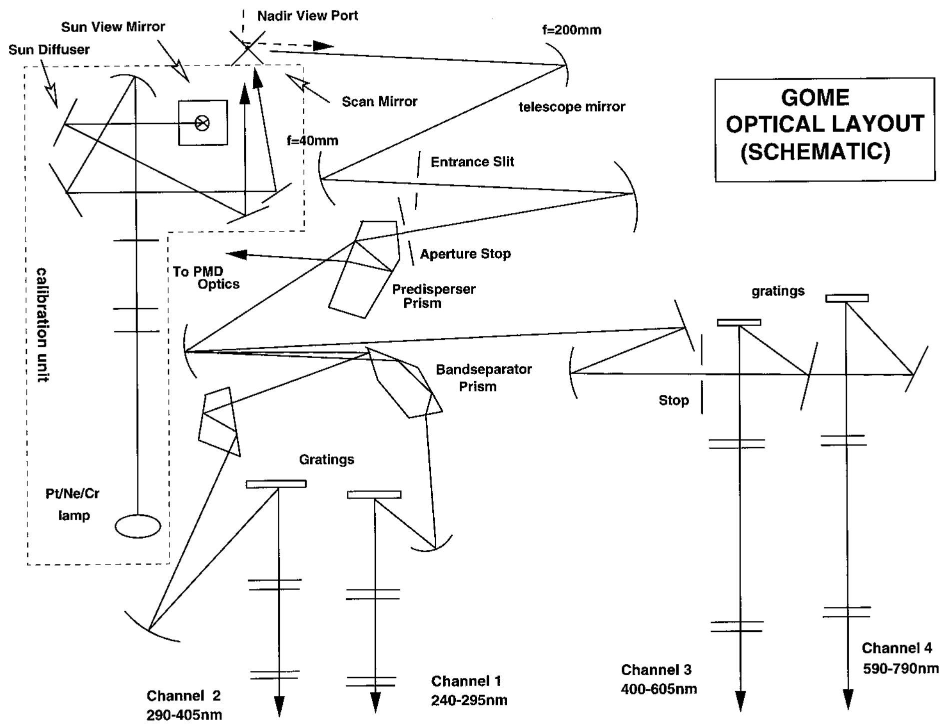

Figure 1. Schematic instrumental setup of GOME. The GOME instrument is a four-channel spectrometer. Attached to the spectrometer is a calibration unit housing a Pt/Cr/Ne hollow cathode discharge lamp and the fore optics for solar viewing. Not shown is an additional mirror which directs the lamp light to the solar diffuser plate for diffuser reflectivity monitoring.

light that reaches the pre-disperser prism is branched out and recorded with three broadband polarization monitoring devices (PMD), which approximately cover the spectral ranges of the detector arrays in channels 2 (300–400 nm), 3 (400–600 nm), and 4 (600–800 nm), respectively. The PMDs measure the amount of light at an instrument defined polarization angle.

A calibration unit adjacent to the spectrometer part consists of the Sun view port and a compartment housing a Pt/Ne/Cr hollow cathode discharge lamp. The solar radiation is attenuated by a mesh (20% transmission) and directed via a diffuser plate (wet-sanded Al plate with Cr/Al coating) on to the entrance slit of the spectrometer. When no solar measurements are carried out and during nadir and calibration lamp measurements, a protective shutter is placed in front of the solar view port in order to avoid unnecessary UV exposure and to prevent stray light from entering the instrument. The calibration unit becomes optically coupled to the spectrometer by proper positioning of the scan mirror. The various pointing geometries of GOME permit, in addition to solar and Earth nadir viewing, lunar observations (through the nadir view port with scan mirror angle of about 85 deg) at selected times during a year.

The processing of the GOME data, which includes the radiometric and wavelength calibration of the spectral raw data, occurs at the German Remote Sensing Data Center (DFD) at DLR Oberpfaffenhofen. The on-ground calibration includes adjustment of the GOME irradiances and earthshine spectra to account for leakage current, stray light, focal plane area noise (which is related to the voltage controlling the Peltier coolers), and the pixel-to-pixel variability (which is monitored using on-board LED measurements). The absolute radiometrically calibrated GOME spectra (solar irradiance and backscattered radiances) are then referred to as Level-1 GOME data products. For further details about the GOME Data Processor (GDP) the reader is referred to the GOME Users Manual (GOMEMANUAL, 1995).

3. Solar Irradiance Measurements

The ERS-2 satellite moves in a retrograde, Sun-synchronous, near-polar orbit at a height of about 785 km. Once a day (every fourteenth orbit) GOME solar irradiance measurements are carried out when the ERS-2 satellite crosses the terminator in the north polar region coming from the night side. Since GOME is not equipped to actively track the Sun, viewing of the full solar disc is only possible for a time span of about 50 s. Integration times are 0.75 s for all channels, except for the UV channel, where the integration time is doubled. A mean solar spectrum is constructed from the series of measurements during the solar viewing period. Once a month, the internal hollow cathode calibration lamp is switched on over an entire orbit. During this sequence, a series of lamp measurements with and without the solar diffuser permits the investigation of long-term degradation of the Sun diffuser and an update in the wavelength calibration of the spectrometer, respectively. During the GOME commissioning phase, no significant long-term drift in the wavelength calibration was observed.

Prior to launch, the spectral irradiance of the GOME flight model was calibrated by the Dutch firm TPD using a 1000 W FEL lamp, which in turn was referenced to an absolute standard at NIST. The absolute accuracy of the NIST standard is quoted to be 1 to 3% in the range 250–340 nm (Walker *et al.*, 1987). The total calibration error at the shortest GOME wavelength at 240 nm is estimated at 4.5% (3σ), where the major contribution comes from the preflight calibration measurements using the 1000 W FEL lamp (3.8%) and the determination of the bi-directional scattering distribution function (BSDF) of the diffuser plate (2.2%).

A calibrated mean solar spectrum measured by GOME on 22 July 1995, is shown in Figure 2. A qualitative comparison of solar irradiance measurements in the GOME channel 2 with preliminary results from the eighth shuttle SBUV experiment in January 1996 is shown in Figure 3. The GOME spectrum has been convolved with a 1.1 nm FWHM (full width half maximum) triangular function, which best approximates the SSBUV slit function. The most significant feature in the GOME/SSBUV ratio is an etalon structure, with fringe maxima separated

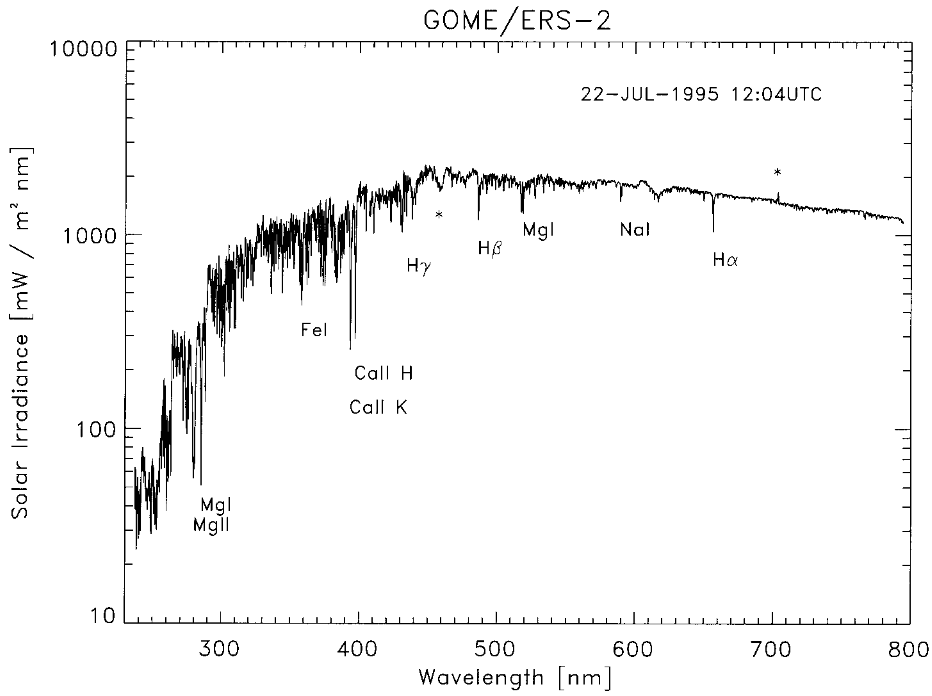

Figure 2. GOME solar spectrum from 22 July 1995. Principal solar absorption features, including the Mg II doublet (289 nm) and the Ca II K line (394 nm), are identified. Asterisks mark instrumental artifacts due to the changing transmission characteristics of the anti-reflection coating on the channel 3 beam splitter (450 nm) and due to a Wood anomaly in the channel 4 holographic grating (700 nm). The overlap regions between the four optical GOME channels are at 315 nm, 405 nm, and 600 nm.

by about 13 nm. Similar features are observed in the other channels. Calculations show that the protective 3 μm SiO_2 layer covering the light sensitive area of each detector array is responsible for creating the Fabry–Pérot pattern. This was already known from the pre-flight calibration and characterization program. Apart from the etalon pattern, the agreement between SSBUV and GOME in the wavelength range 312–400 nm (GOME channel 2) is on average better than 2%, which is within the maximum calibration uncertainty of 4.5% at 240 nm and 3.2% between 300 and 400 nm estimated for GOME (GOMECAL, 1994). It should be noted here, that the SSBUV instrument exhibited excellent agreement with other satellite and shuttle-based measurements (Cebula *et al.*, 1996; Woods *et al.*, 1996).

In the first few days after the Peltier elements are switched off and on, the fringe patterns change rapidly, with irradiance deviations up to 4% (Eisinger, Burrows, and Richter, 1996) between consecutive days. Within a week, the etalon fringes stabilize. During the warm-up phase, the detector may reach the ambient temperature of the focal plane area, which is near 0 °C. The cooling of the detector following the warm-up is speculated to produce a thin ice layer on top of the SiO_2 layer. The solar irradiance ratios show that the periodicity of the fringe pattern

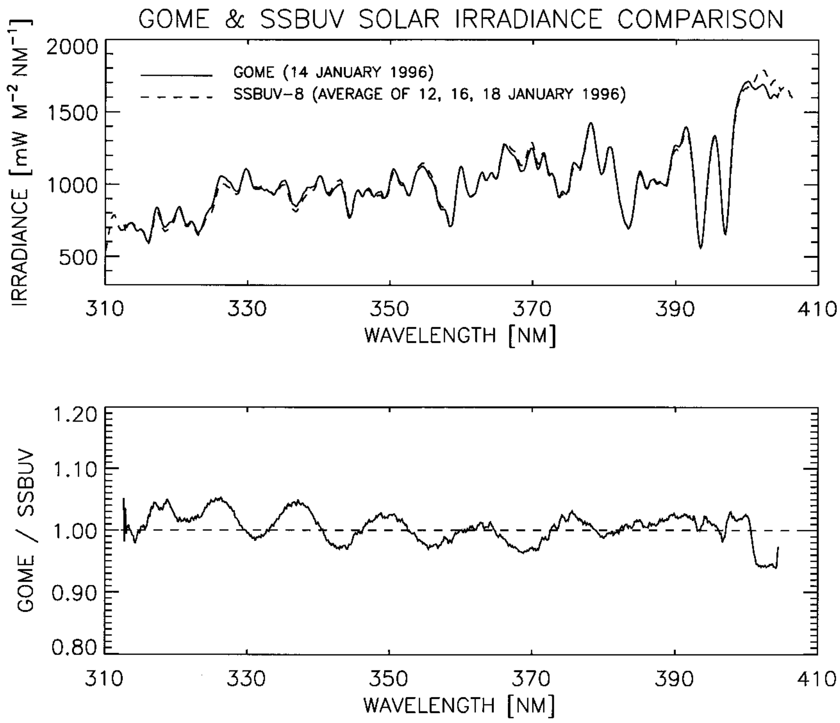

Figure 3. Comparison of the SSBUV-8 and GOME irradiance values (Burrows *et al.* 1997).

remains constant, which is expected if one assumes that condensed ice makes up only a fraction of the quartz layer size and that the etalon period is determined by the quartz thickness. However, solar ratios taken before and after such cooler switching events indicate fringe amplitude changes of several percent. A possible explanation is that the thin condensing layer may act as a reflection coating altering the optical efficiency of the quartz etalon. Without correcting for the shifting etalon, the solar activity index time series derived from the spectral irradiance in the core of a Fraunhofer line, such as Mg II (280 nm) or the Ca II k and h lines (393–396 nm), experience sharp discontinuities after the cooler switching. As shown in the next section, the application of an etalon correction scheme successfully removes the discontinuities.

From the comparison of calibrated GOME UV spectra with the mean SSBUV-8 irradiance, a spectral degradation related to extended exposure of the optical components in the spectrometer to the harmful UV radiation was observed. A monotonic decrease in the GOME UV irradiances has been observed in GOME channel 1 (240–315 nm) since the beginning of July 1995. In January 1996, the GOME irradiances at 240 nm had decreased by 20%, at 245 nm by 15%, and at 273 nm by 8%. The diffuser reflectivity measurements have not revealed a systematic degradation trend since launch. However, the precision of using the diffuser reflectivity measurements up to June 1997 is limited to 20% in the UV channel (channel 1: 240–315 nm) and better than 5% in GOME channels 2–4 (315 –795 nm). The UV degradation was also observed in the lunar spectra, which are recorded from light entering the nadir view port (Dobber, 1997). This means that the loss in optical efficiency is primarily occurring in the spectrometer part (see Figure 1) and, since the nadir scan mirror is the most exposed spectrometer optical element, it is likely that this mirror is mostly affected.

The in-flight calibration measurements, i.e., relative intensities of reference lines recorded with the internal Pt/Cr/Ne calibration lamp, which is primarily used as a wavelength standard, and the lunar observations have not yet been used to correct for instrument degradation with time. A first in-flight calibration based upon intensity ratios derived from the lamp line measurements, which were referenced to pre-flight lamp measurements, was carried out in the beginning of the commissioning phase (Hoekstra *et al.*, 1996), but no further update has occurred since 2 July 1995. For the investigation of the proxy solar activity based upon individual Fraunhofer lines, a simple recalibration of the UV channel spectra (240–400 nm) to account for UV degradation has been applied by referencing the GOME irradiance to the SSBUV-8 measurements in January 1996, as will be described in the next section.

4. GOME Proxy Solar Activity Indices

The original definition of the core-to-wing ratio, which was coined the Mg II index, uses a total of seven wavelength positions about the Mg II absorption near 280 nm. This definition was first successfully applied to SBUV/Nimbus-7 data by Heath and Schlesinger (1986). Because of the enhanced spectral resolution of GOME in the UV Channel ($\Delta\lambda = 0.17$ nm) as compared to the SBUV series ($\Delta\lambda \simeq 1.1$ nm) the GOME Mg II index is here calculated using 10 spectral values as explained in Figure 4. During solar maximum of the 11-year solar cycle, the number of sunspots increases. Associated with the dark photospheric sunspots are chromospheric plages, which are hotter than the surrounding areas and are responsible for the chromospheric emission observed in the core of Fraunhofer absorption lines. The formation of the wing of the Fraunhofer lines originates in the photosphere, where the variation with the solar cycle is known to be small. Although the Mg II doublet is not spectrally resolved in the GOME spectra, the chromospheric emission peak is recognizable at the position of each peak of the doublet (see Figure 4). The corresponding residuals of the series of measurements between and of June 1996 and end of March 1997 relative to the solar irradiance from 14 January 1997, as depicted in the bottom of Figure 4 highlights the variability of the chromospheric emission. The short-term variability of the chromospheric emission is mainly linked to the 27-day rotation of the Sun, which moves active regions in and out the field of view of the instrument.

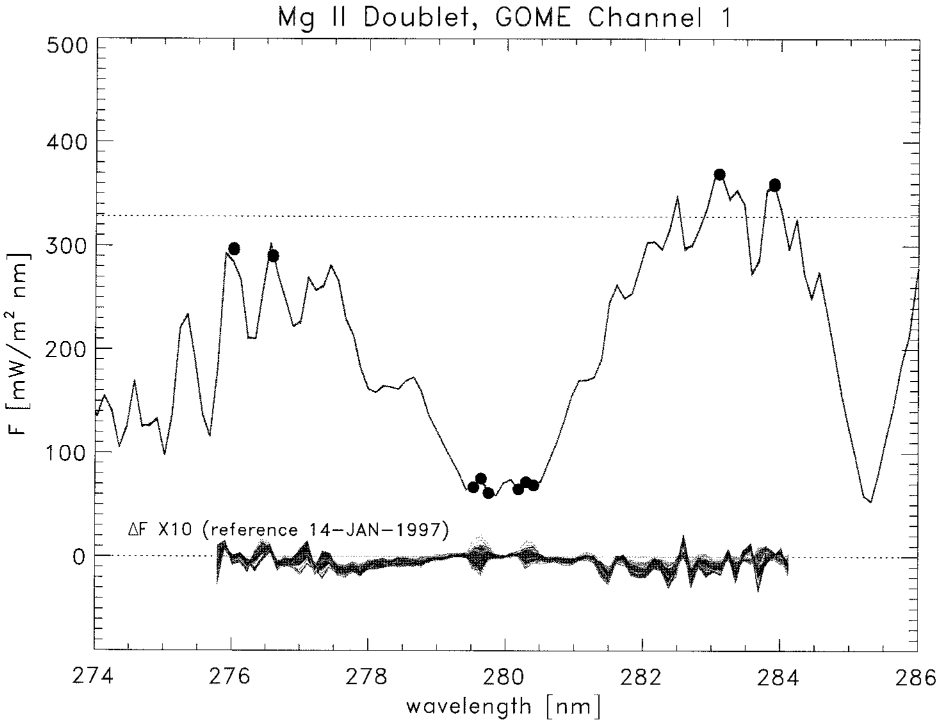

Figure 4. The Mg II doublet at 280 nm as observed by GOME. All 221 spectra used in the time series analysis (28 June 1996–31 March 1997) have been plotted on top of each other. The chromospheric emission in the core region of the Mg II doublet is indicated by three adjacent solid points for each peak. The bottom curve shows the residuals of each of the daily solar spectra relative to the GOME spectrum recorded on 14 January 1997, multiplied by a factor of ten. The variability of the chromospheric emission can be easily recognized in the residual plot. Six wavelengths in the core region of the Mg II doublet are averaged to obtain the core value of the Mg II index. Four points in the wing, which are the maxima of parabolas fitted in the windows, 275.8–276.3 nm, 276.3–276.8 nm, 283.9–283.3 nm, and 283.7–284.1 nm, are used to calculate the wing value. The mean of the four wing values is indicated by the dashed line. The solar activity index is given by the ratio of the mean core values over the mean wing values. The GOME absolute solar irradiance have been corrected for UV degradation with time and the observed etalon effect.

A continuous set of calibrated GOME spectra is available since the end of June 1996 and a corrected time series of the GOME Mg II core-to-wing ratio for the time period 28 June 1996 to 31 March 1997 is shown in Figure 5. In the case of the Ca II K and H doublet, the definition of the transmission background is far more difficult due to the high density of Fraunhofer lines in the spectral region around 390–400 nm. For this reason, the Ca II K peak irradiance rather than the core-to-wing ratio is displayed as a time series in Figure 6. In the same figure the peak irradiances of the individual peaks of the Mg II doublet are also shown. Unlike the Mg II doublet, the chromospheric emission in the absorption core of Ca II Fraunhofer line can not be seen in the spectrum itself, however, a small variation

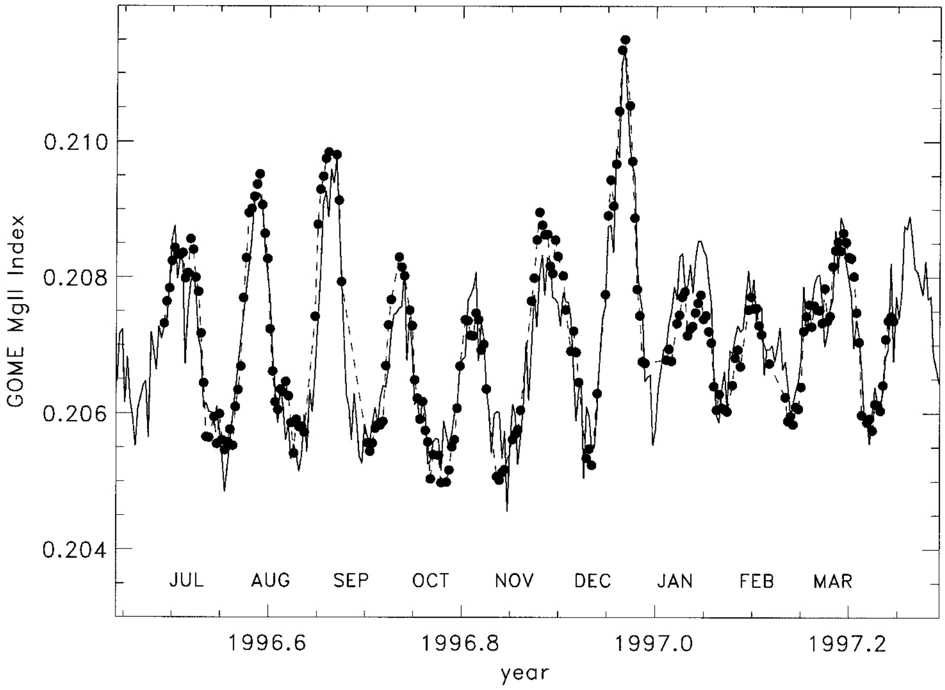

Figure 5. GOME Mg II index times series from 28 June 1996 until 31 March 1997. The points are the daily GOME index values as defined in Figure 4 and the solid line is the SUSIM V19r2 Mg II index, which has been scaled to the GOME index value range by linear regression (see text). From the linear regression a correlation coefficient of $r = 0.924$ between the two time series was determined.

in the peak irradiance is visible in the time series. The modulation of the Ca II peak irradiance is a factor of four smaller than the corresponding modulation of the Mg II core-to-wing ratio.

As discussed earlier, the GOME solar irradiance values in channel 1 (240–315 nm) and channel 2 (312–405 nm) have been corrected for the etaloning and UV degradation before deriving the Mg II core-to-wing ratio and the Ca II k peak transmission. A correction to the solar irradiances have been determined by ratioing the GOME measurement to the SSBUV-8 solar irradiance. Both GOME and the mean SSBUV-8 solar spectrum were spline interpolated to a common wavelength grid in steps of 0.1 nm and then convolved with a 10 nm boxcar, i.e., smoothed, before taking the irradiance ratios. Since the degradation increases monotonically with decreasing wavelength, a third-order polynomial generally sufficed to fit a correction curve to the solar ratios, which is then applied to correct the degradation observed in the GOME data.

In the nine-month period (July 1996–March 1997), for which proxy solar activity index time series were analyzed, a total of five GOME detector cooler switchings were reported. On two occasions the cooler switching also led to a warm-up of the detectors near the freezing point (29 October 1996 and 14 January 1997). Associated with the cooler switching are observed discontinuities in the solar activity indices, which can be on the same order or higher than the modulation observed in the time series. A correction to the shifting etalon patterns was therefore applied by fitting a high order polynomial through the solar irradiance ratios covering about two etalon fringes in the wavelength region 274–287 nm. A small window at the core of the Mg II doublet (279.5–280.5 nm) was excluded from the fit. Similarly, a spectral window between 385 nm and 403 nm, excluding two 2 nm sub-windows centered at the two peaks of the Ca II doublet, were selected in channel 2. The GOME solar ratios were referenced to a GOME spectrum, recorded 4 hours after a detector switching on 14 January 1997, and which most closely resembled warm detector spectra.

5. Discussion

The selection of the Mg II index and Ca II K absorption as surrogates for solar activity variation is not unique. Among the many Fraunhofer lines available in the GOME spectral range, the two candidates here proposed are among the strongest absorption features and are easily observable by GOME at its spectral resolution. Since an operational in-flight calibration routine has not yet been included in the GOME data processor, a correction scheme to account for long-term UV degradation effects and the etalon patterns, observed in the GOME channels 1 (240–310 nm) and 2 (310–405 nm), was implemented. Comparison of the GOME Mg II index with the SUSIM Mg II index V19r2 (Floyd *et al.*, 1998; Floyd, 1997, see Figure 5) enables the correction scheme introduced here to be validated.

In Figure 5 the SUSIM V19r2 index has been scaled by linear regression to the value range of the GOME Mg II index. The linear regression equation was determined to be $y = -0.1107(92) + 1.238(35)x$, where the digits in brackets are the uncertainties in the regression coefficients, x is the SUSIM Mg II V19r2 index value, and y is the scaled SUSIM index value as plotted in Figure 5. From the linear regression a correlation coefficient of $r = 0.93$ between the GOME and SUSIM time series was found. At first sight one might consider the correlation to be somewhat low as correlations between SBUV/2, SUSIM, and SOLSTICE time series tend to be on the order of 0.97 or better (de Toma *et al.*, 1997). However, all comparisons were based on data stretching from solar maximum (launch of UARS in fall 1991) to solar minimum (end of 1995), where the index values have their largest spread. Thus far the GOME time series has been limited to a period during the solar minimum phase between solar cycles 22 and 23. The high correlation between the GOME and SUSIM Mg II indices during solar minimum condition proves that the radiometric calibration correction accounting for UV degradation and the shifting etalon pattern work well.

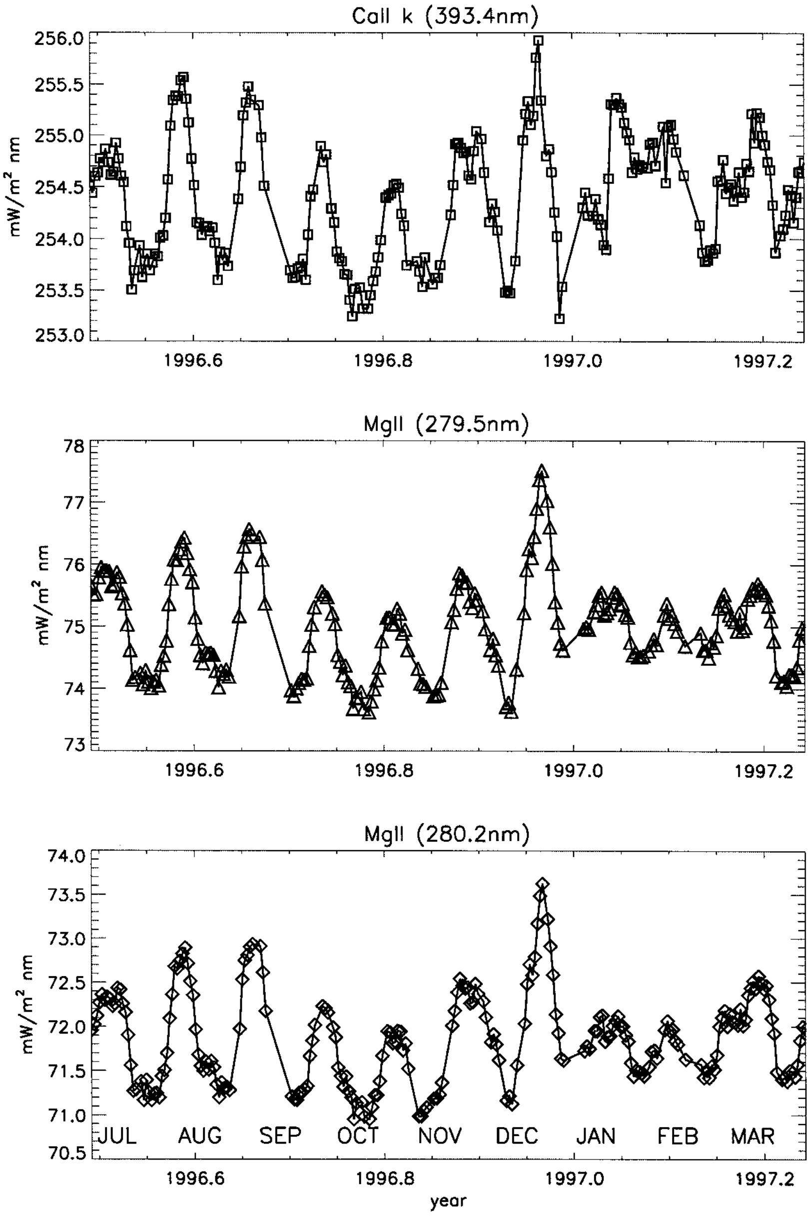

Figure 6. Daily peak irradiance value of Ca II K at 393.5 nm (*top*) and Mg II at 279.5 nm (*middle*) and at 280.5 nm (*bottom*) during the period 28 June 1996–31 March 1997. From the Mg II peak irradiances the Mg II proxy solar activity index (see Figures 4 and 5) was derived. The modulation of the peak irradiances of all three solar Fraunhofer lines are related to chromospheric emission originating from plage areas moving in and out the field of view of the instrument in the course of the 28-day rotation of the Sun.

The absolute activity index values and peak irradiances as derived from two instruments generally differ considerably due to differences in the instrumental slit functions and the associated spectral resolution. High correlation between proxy solar activity indices derived from different instruments are important in order to properly transform different series into each other in order to obtain a time series extending beyond the lifetime of a single instrument.

As expected, the Mg II solar activity index appears to be rather insensitive to the UV degradation, because the chromospheric emission peak was normalized to the slowly varying photospheric background in the wing region. However, the core-to-wing ratio is found to be very sensitive to the rapid changes in solar irradiances resulting from the etalon fringes shifting after detector cooler switchings. Removal of this effect provides an excellent Mg II index from GOME.

6. Discussion

In the first two years of GOME operation, it has been demonstrated that GOME can provide continuity in long-term solar irradiance monitoring from space which was started in the late 1970s. Combining the SBUV and SBUV/2 series (1978–present), the UARS SOLSTICE and SUSIM data (1991–present) and the European series of GOME and SCIAMACHY, long-term space monitoring of solar spectral irradiance and its variability during three complete solar cycles, cycles 21, 22, and the upcoming cycle 23, is required to investigate the links between the natural variability of the solar output and global atmospheric processes. The latter may significantly contribute to the global change issue. If a proper correction to the GOME solar irradiance to account for UV degradation in the short wavelength region and the etalon effect is applied, GOME may provide accurate absolute solar irradiances in the UV/visible, with an overall calibration uncertainty of 5% and better and with a repeatability of less than 1% on a day-to-day basis. One should also note that GOME is currently the only satellite instrument regularly measuring solar irradiance in the wavelength region beyond 400 nm.

A tandem operation of GOME/ERS-2 and SCIAMACHY, an extended GOME version, is planned to provide cross-validation for SCIAMACHY during the first year of SCIAMACHY operation after launch of ESA'S ENVISAT platform in 1999. A second generation GOME instrument is scheduled to fly on METOP, an European operational meteorological satellite being planned by ESA and EUMETSAT. METOP is the European successor to the NOAA/TIROS platform and is planned for launch in 2002. Two SBUV/2 instruments on NOAA-9 and NOAA-14, which are still operational, may provide coverage until 2005. Three new SBUV/2 instruments are planned to fly on three successive missions, NOAA-L, -M, and -N, to be launched two years apart) each starting in 1999. SOLSTICE and SUSIM launched in 1991 are still operating and may continue measurements until the turn of the century. A second generation of the SOLSTICE instrument (SOLSTICE II) was originally scheduled in NASA's EOS-CHEM series, of which the first platform is to be launched in 2002, but has been postponed in NASA's Mission to Planet Earth restructuring in 1995, unfortunately. Alternative flight opportunities for SOLSTICE II are under consideration. At the moment, the follow-up missions of GOME/ERS-2, SCIAMACHY and GOME/METOP, are likely to be the only new instruments providing daily UV solar flux measurements in the near future.

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