MG II CORE-TO-WING SOLAR INDEX FROM HIGH RESOLUTION GOME DATA

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ABSTRACT

The Mg II core-to-wing index was first developed for the Nimbus 7 solar backscatter ultraviolet spectrometer as an indicator of solar UV flux temporal variation. It is particularly important because of its long-term precision and insensitivity to instrument artifacts. For almost twenty years, solar activity monitoring from space has provided valuable data from which the Mg II index can be derived. The quality of each Mg II index is related to the calibration of the instrument as well as its spectral resolution. A reasonably good record can be obtained from the unresolved Mg II doublet at 280 nm. However, a higher spectral resolution of an instrument increases sensitivity to both the 27 days rotational modulation and the long term solar cycle variation. The new GOME instrument on board the ERS-2 satellite provides daily solar spectrum observations. Thanks to its high spectral resolution of 0.2 nm at 280 nm we can expect a very good Mg II index product from this instrument. In this paper, we show some preliminary results of GOME derived Mg II index using an algorithm taking into account its high spectral resolution. This algorithm is derived directly from UARS/SOLSTICE Mg II index algorithm at HAO and LASP. A direct comparison with the SOLSTICE index is also presented for a time period of half a year.

1. INTRODUCTION

The Solar chromospheric activity in the ultraviolet region is of great importance to our understanding of both the physical properties of the Sun as a star, and of the Solar influence on the Earth's stratospheric chemistry. In the UV region, the Mg II core-to-wing ratio introduced by Heath *et al.* [5] is one of the most widely used indices of solar activity.

The Mg II doublet near 280 nm is a broad absorption feature with narrow emission peaks in the core. The h and k emission doublet originates in the Sun's chromosphere overlying the denser photosphere. The full disk Mg II index derived from the line core show's the 27-day rotational modulation as well as the long term 11-year activity cycle. Radiation in the line wings originates in the photosphere and shows much less variability. Therefore, the ratio of line core intensity to wing intensity provides a good estimate of solar variability because the use of intensity ratio cancels degradation effects.

The Mg II core-to-wing ratio has become one of the most valuable qualitative indices of solar activity used by both astrophysicists and geophysicists. Solar irradiance has been measured by different space experiments since 1978, and variability over the 11-year solar cycle has been recorded. Instruments which have contributed to solar studies include the Solar Backscatter UltraViolet (SBUV) experiments on board of Nimbus 7 and NOAA satellites and two instruments from the Upper Atmosphere Research Satellite (UARS), the SUSIM and SOLSTICE instruments, both specifically designed for solar observations.

Both UARS instruments, SOLSTICE and SUSIM, have sufficient instrumental resolution to resolve the Mg II doublet. The SOLSTICE F channel has a resolution of 0.24 nm with a wavelength spacing of 0.068 nm at 280 nm. A detailed description of the SOLSTICE instrument can be found in Rottman *et al.*

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Proc. 3rd ERS Symp. on Space at the service of our Environment, *Florence, Italy, 17–21 March 1997* (ESA SP-414, 3 Vols., May 1997)

and in Woods *et al.* [6, 8], and a recent evaluation of its performance with respect to other spaceborne solar observation instruments has been made in Woods *et al.* [9].

Although not fully resolved, the h and k emission lines can be clearly identified at this resolution. To take advantage of the more accurate profiles, a new SOLSTICE Mg II index has been defined. An extensive comparison work of the different Mg II indices has been done by de Toma *et al.* [1]. In order to combine the measurements of the Mg II index from different experiments, it is necessary to determine the effect of their differing spectral resolutions on both short term (days) and long term (years) variability in the Mg II index time series. White *et al.* [7] analyzed the properties of Mg II index series computed at 0.25 nm and 1.15 nm resolution. They conclude that the current measurements describe slow solar variation from 1992 to 1996 and the shorter term variations at periods of 27 and 13.5 days equally well, except during solar minimum when the solar fluctuations are small. The higher resolution measurements at 0.2 nm resolution and a high day-to-day precision are required for accurate measurements of variability at solar minimum.

Since mid 1995, a new European instrument, the Global Ozone Monitoring Experiment (GOME), on board the ERS-2 satellite makes daily solar irradiance measurements for calibration purpose. Its high spectral resolution puts it in the same class as SOLSTICE observations. In this paper, we present a Mg II core-to-wing index derived from GOME solar observations using the SOLSTICE index approach. Although a limited amount of GOME data are available, we show a comparison with the SOLSTICE Mg II index.

2. THE GOME INSTRUMENT

The Global Ozone Monitoring Experiment (GOME) was launched on-board the ERS-2 spacecraft in April 1995. This instrument is a nadir-viewing spectrometer that observes solar radiation backscattered by the Earth's atmosphere and scattered from its surface. The primary objectives of this instrument are to measure the atmosphere's content of ozone, nitrogen dioxide, as well as other trace gases using a technique known as Differential Optical Absorption Spectroscopy (DOAS). Knowledge of the solar incident radiation is also required to establish the amount of absorption. The GOME instrument can directly measure the Earth's radiance scattered into its spectrometer, or, in an alternate mode using a slightly different optical path, it can measure the solar irradiance directly. The optics of the spectrometer are the same in both configurations, except for a scanning mirror and a diffuser inserted in the optical path for direct solar measurements. Input solar radiation is needed for trace gase measurements but also for calibration of the instrument. The reader is referred to reports from ESA [2] and [3] for details about the GOME instrument. To summarize, the GOME instrument is a 4-channel diode array spectrometer. Each channel detector is a 1024 pixels diode array, and the full wavelength range spans 240 nm to 790 nm. The instrument resolution varies from 0.15 nm to 0.3 nm depending on the channel.

An extensive validation program was conducted during the first six months of the instrument's operation. The goal of this program was to assess the performance of both the instrument and data processing with respect to well known references. This validation program included both the level 1 data (solar irradiance and Earth's radiance) and level 2 data (ozone and nitrogen dioxide total column). Reports on the validation campaign can be found in ESA reports [4]. The solar irradiance measurements from GOME have been compared with SOLSTICE measurements for a limited time period. Although displaying some instrumental artifacts and absolute calibration discrepancies, the solar spectra measurements from GOME show a very good day-to-day accuracy and a very low noise. These characteristics make it an excellent source for solar UV data, and a Mg II index in particular. A more extensive GOME/SOLSTICE irradiance comparison can be found in this proceedings.

3. DATA SETS AND COMPUTATION OF THE MG II INDEX

The GOME instrument makes daily observation of the solar irradiance during its Sun Observation Timeline (SOT), a 42-second timeline inserted into its normal observation sequence when the satellite is close to the Earth's north pole.

For Mg II index computation, only channel 1 data from the GOME instrument is needed. Figure 1 displays both GOME and SOLSTICE solar measurements around 280 nm. Both spectra were recorded on June 28, 1996 and are representative of the solar minimum between solar cycle 22 and 23. Despite the small intensities of h and k lines, the emission doublet shows quite clearly on GOME high resolution spectrum while it is less resolved in SOLSTICE spectrum. This simple comparison already shows the potential high quality of the GOME solar measurements for Mg II index computation. The day-to-day precision of GOME solar measurement is very good ($2\sigma < 0.5\%$). It is quite clear to us that a version of the SOLSTICE algorithm modified for the higher GOME resolution is the best approach for computa-

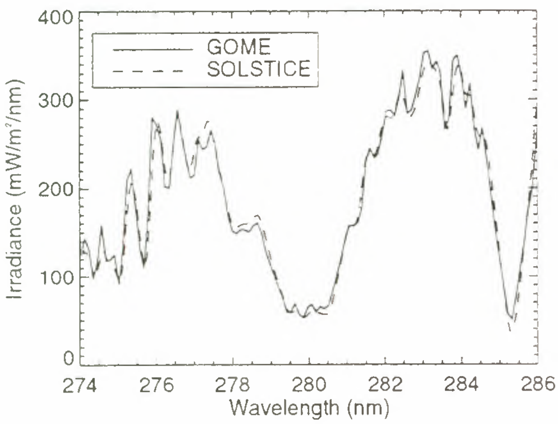

Figure 1: GOME (solid line) and SOLSTICE (dotted line) solar flux measured on June 28, 1996. Both irradiance are normalized to 1 astronomical unit.

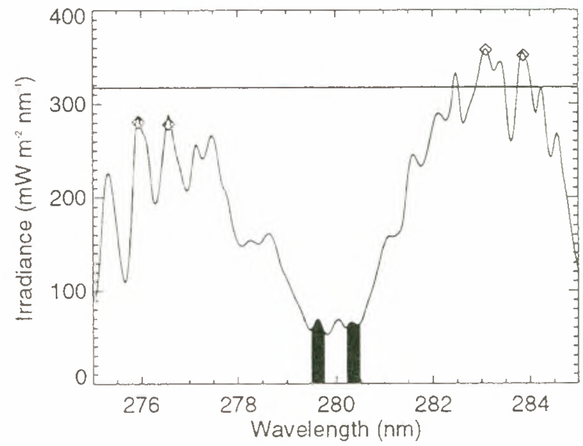

Figure 2: GOME solar spectrum acquired on June 28, 1996. The black area beneath each k and l peaks and the average reference intensity used for Mg II index computation are represented.

tion of the GOME Mg II index.

The raw data (level 0) are processed at the German ground data processing facility (DLR) to produce the level 1 data, i.e. calibrated data both for solar irradiance and Earth's radiance. The data used in this analysis include only data processed using the current operational V1.0 Gome Data Processor (GDP). The GOME data used in this study include the V1.0 level 1 data received from DLR from June 1996 to December 1996. The SOLSTICE Mg II index are provided by LASP from their research database. They are a later version than is presently available in the SOLSTICE database at the GSFC DAAC (http://daac.gsfc.nasa.gov).

The SOLSTICE approach for index computation has been described in de Toma *et al.* [1] and compared to other available Mg II indices. Since the chromospheric emissions is resolved, integration of the peaks measures the chromospheric radiations alone. The Mg II index is defined as the integral of the area beneath the h and k peaks divided by a reference intensity from the wings nearby the broad Mg II absorption band. Figure 2 shows the corresponding areas and reference intensity for a typical GOME spectrum. The k line position is first identified from the spectrum and the weaker h line center is determined at a fixed offset of 0.7175 nm. The integration is performed over a 0.268 nm band around the line centers. The reference intensities are the maxima of parabola fitted to the four peaks in the far wings of the Mg II absorption feature. The final reference intensity is the average of the four maxima.

4. GOME MG II INDEX

Each daily GOME solar spectrum is an average of around 150 individual measurements when the Sun is in the line of sight of the satellite close to the North pole. The corresponding Mg II value is computed from the average spectrum. On the other hand, daily SOLSTICE Mg II index is an average of Mg II indices computed on the 16 individual daily solar measurements. The current Mg II index time series from GOME is plotted in figure 3 from 28 June 1996 to 5 December 1996 and contains 138 individual measurements.

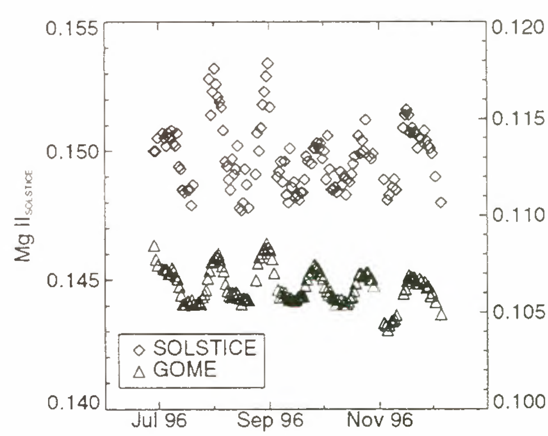

Figure 3: Mg II index computed from GOME V1.0 solar measurements using high resolution approach (triangles) an corresponding SOLSTICE Mg II index (diamonds).

The 27-day rotational modulation shows up clearly on this short time series of 6 months duration. The very low noise of the GOME Mg II data is one of the most striking features of this plot. This is a consequence of the high day-to-day precision of the GOME instrument. Additional work is in progress to quantify more thoroughly GOME's accuracy. The correlation with the SOLSTICE index is good ($r = 0.81$) considering the small amount of data values. The linear fit is showed in figure 4. The sensitivity to solar variability is good but can probably be improved. We note that this short time series shows solar variability during the period of minimum activity between solar cycles 22 and 23. Furthemore, the SOLSTICE Mg II index time series appear noisy. This problem is known and originates in wavelength shift for some days in this 6 months period especially in summer. This may give a misleading view of SOLSTICE Mg II index quality. A better filtering of the SOLSTICE data will significantly improve the correlation.

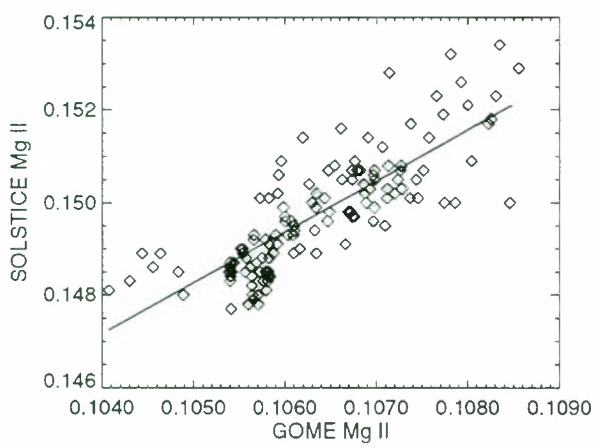

Figure 4: Linear regression of the GOME Mg II index with the corresponding SOLSTICE Mg II index. The solid line corresponds to the least square linear regression.

5. CONCLUSION

We find that a high resolution algorithm for Mg II solar index applied to GOME daily solar measurements provides high quality data. Altough the time series considered in this work is quite short, the day-to-day precision is very good and the signal to noise ratio is high.

These characteristics allow us to be reasonably confident that the GOME Mg II time series could reliably be combined with existing longer Mg II records obtained with either the UARS or SBUV2 instruments.

While not designed specificaly for solar observations, we find that the GOME instrument on board the European ERS-2 satellite to be a good source of high quality solar measurements that complement the current operational solar experiments.

Aknowledgments The SOLSTICE Mg II index used in this work is a research product, which will be made publicly available as part of the SOLSTICE database at the GSFC-DAAC http://daac.gsfc.nasa.gov. This work has been support by PRODEX-UV A.O. ERS2-Project 2 (151903).

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