THE MG II SOLAR ACTIVITY PROXY INDICATOR DERIVED FROM GOME AND SCIAMACHY

J. Skupin, M. Weber, H. Bovensmann, and J. P. Burrows

Institute of Environmental Physics (IUP), University of Bremen, Otto-Hahn-Allee 1, D-28359 Bremen, Germany
Email: jochen.skupin@iup.physik.uni-bremen.de

ABSTRACT

The main purpose of the passive remote sensing instruments GOME and SCIAMACHY is to determine the amount and distribution of a large number of atmospheric trace constituents by measuring Earthshine radiance. In addition solar observations are performed on a regular time grid which offer the possibility to monitor solar variations. This paper summarises the derivation of a proxy solar activity indicator from GOME and SCIAMACHY solar irradiance measurements. This combined GOME/SCIAMACHY Mg II index is compared with the composite NOAA Mg II index (1978-present) showing an excellent correlation of 0.991. It is, therefore, well suited to be combined with these data to establish a long-term time series spanning almost three 11 year solar cycles.

Key words: GOME; SCIAMACHY; Mg II index.

1. INTRODUCTION

The European Space Agency's (ESA) new Earth observation satellite ENVISAT was launched successfully into a sun-synchronous polar orbit on 2002-03-01. Among nine other instruments the passive remote sensing instrument SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) is part of the payload. SCIAMACHY is an 8 channel spectrometer covering a wavelength range from 240 to 2380 nm thus including ultraviolet, visible and near infrared spectral regions [1, 2]. It's predecessor GOME (Global Ozone Monitoring Experiment) with a wavelength range from 240 to 790 nm was launched on 1995-04-21. The launch of a generation of successors (GOME2) on the MetOp platform is planned as of 2005. This family of similar instruments in terms of spectral coverage and resolution (Tab. 1) ensures a continuous record of solar and atmospheric observations from 1995 well into the second decade of the 21st century.

Tab. 1. Family of similar instruments: GOME, SCIAMACHY, and GOME2

Instrument	Launch	Spectral range	Solar observations
GOME	1995-04-21	240–790 nm	daily: solar observation with diffuser plate
SCIAMACHY	2002-03-01	240–2380 nm	daily: solar observation with diffuser plate and in sub-solar viewing geometry (using dedicated sub-solar port) orbital: solar observation in occultation (above atmosphere)
GOME2	2005	240–790 nm	daily: solar observation with diffuser plate

The main purpose of the passive remote sensing instruments GOME and SCIAMACHY is to determine the amount and distributions of a large number of atmospheric trace constituents by measuring Earthshine radiance. In addition several solar observations are performed on a regular daily or even orbital time grid using different combinations of mirrors and diffusers to track the sun. These measurements offer the possibility to monitor solar variations.

Since UV irradiance measurements from space usually suffer from UV degradation and drifts in the instrumental response function (for SCIAMACHY see [3] in this issue), proxy solar activity indicators are used to represent solar UV variability. Such proxy indicators can be given by the core-to-wing ratio of selected Fraunhofer lines where these instrumental effects cancel out. It has been shown that the Magnesium II (Mg II) index derived from daily solar observation of the core-to-wing ratio of the Mg II doublet at 279.9 nm provides a good measure of the solar UV variability and can be used as a reliable proxy to model extreme UV variability during the solar cycle [4, 5, 6, 7]. The major modulation of the Mg II index contains a periodicity of about 27–28 days (corresponding to the mean solar rotation period) and eleven years (associated with the change of solar activity due to the 22-year magnetic cycle of the sun). It could be correlated with atmospheric ozone variations and other relevant atmospheric quantities such as monthly cloud cover.

The lifetime of a single space instrument is generally in the order of about six years. For solar-terrestrial climate

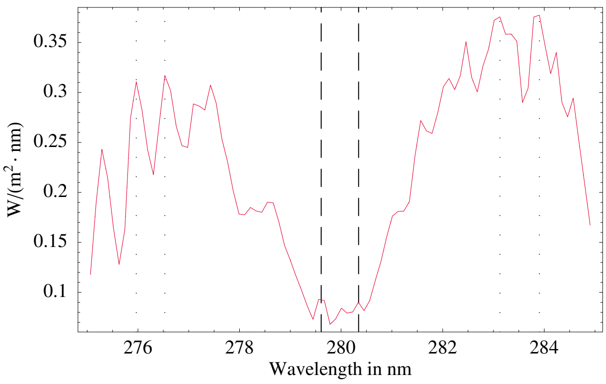

Fig. 1. The Mg II doublet at 279.9 nm *(recorded by SCIAMACHY on 2002-07-22) used for the calculation of the Mg II index core-to-wing ratio. The wing value is derived from parabolas fitted through 4 peaks (vertical dotted lines), the core value is derived from the h and k doublet lines at the centre of the Fraunhofer line (vertical dashed lines).*

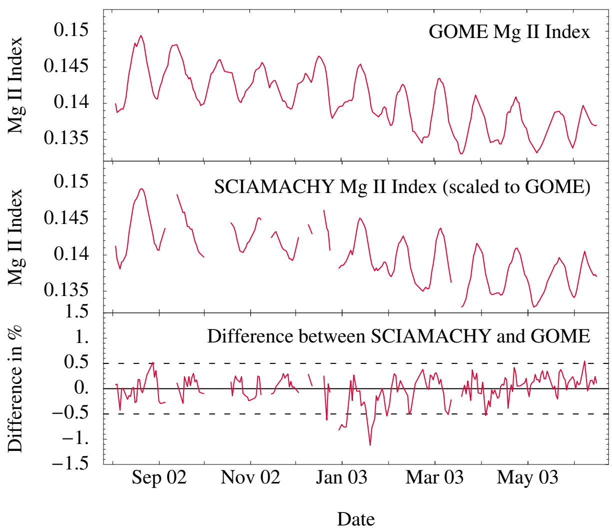

Fig. 2. Comparison of the GOME and SCIAMACHY Mg II indices

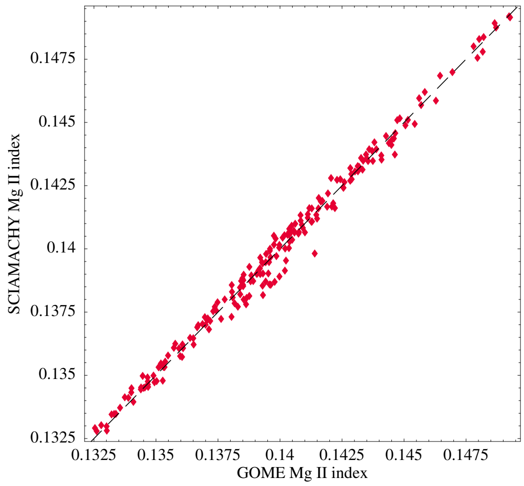

Fig. 3. Correlation of the GOME and SCIAMACHY Mg II indices

interaction an establishment of a long-term time series covering several solar cycles is important that has to be constructed from different satellite experiments.

2. CALCULATION OF THE GOME AND SCIAMACHY SOLAR MG II INDEX

SCIAMACHY started nominal operation in August 2002 and is observing the declining phase of solar cycle 23. It's predecessor GOME (Global Ozone Monitoring Experiment) was launched during the solar minimum following solar cycle 22. The presented solar index is derived from the the Mg II Fraunhofer line centered at 279.9 nm which is located in channel 1 of GOME and SCIAMACHY. The Mg II doublet exhibits the largest solar irradiance variation in the GOME spectral range (240 nm – 790 nm) and is therefore best suited to be used as a proxy for UV solar flux variability. In the core of the Mg II absorption feature emission lines of the Mg II h and k doublet are visible. The spectral irradiance data used to calculate its core-to-wing ratio is taken from sun mean reference spectrum measurements (SMR) which are performed daily using a diffuser/mirror combination to track the sun (Fig. 1).

The wing value is defined as the mean of the maxima of four parabolas fitted through peaks in the wavelength ranges 275.79–276.23 nm, 276.34–276.79 nm, 282.92–283.25 nm, and 283.69–284.12 nm. The SCIAMACHY core value is given by the mean of the maxima of two parabolic fits through the emission line profiles of the h and k doublet (Fig. 1). This slightly differs from the algorithm how to calculate the GOME Mg II index which uses integrated intensities around the h and k doublet lines (as given in [8]).

Since GOME suffers from severe instrument and platform degradation reliable GOME Mg II index data is only available until June 2003. The SCIAMACHY Mg II index starts in August 2002 and has been calculated until end of March 2004 (with gaps caused by incomplete data distribution and instrument decontamination/calibration periods). No special care has been taken to correct for the UV degradation of SCIAMACHY (see [3] in this issue).

In Fig. 2 the GOME and SCIAMACHY Mg II index time series are compared. The plotted differences between the indices are calculated by

$$\frac{\text{Mg II index}_{\text{SCIAMACHY}}}{\text{Mg II index}_{\text{GOME}}} - 1\,,$$

where the GOME Mg II index time series is interpolated to the times of the SCIAMACHY measurements. The absolute values of the Mg II index depend on instrumental slit width (spectral resolution) and the exact definition of the core-to-wing ratio and have to be linearly scaled to match each other.

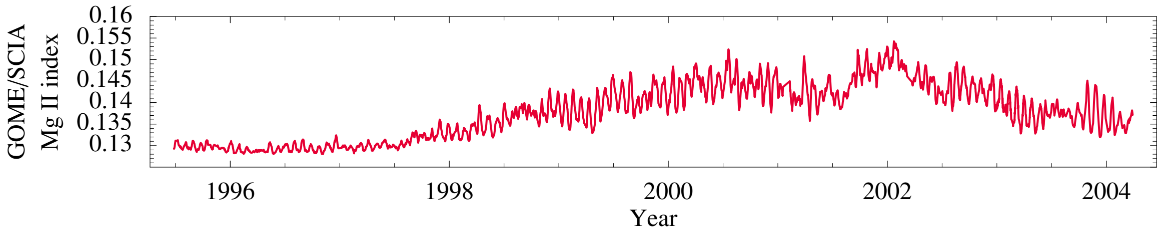

Fig. 4. Combined GOME/SCIAMACHY Mg II index from 1995 to 2004

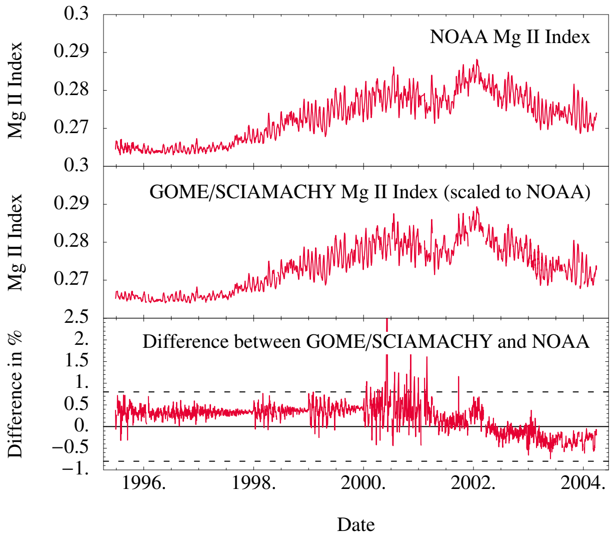

Fig. 5. Comparison of the NOAA Mg II index with the combined GOME/SCIAMACHY index

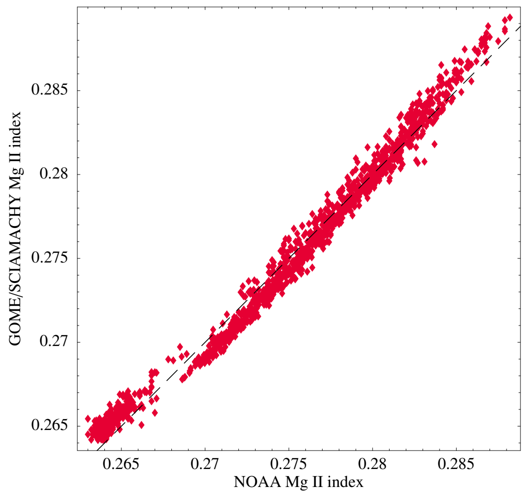

Fig. 6. Correlation of the NOAA Mg II index with the combined GOME/SCIAMACHY index

The derived linear scaling of the SCIAMACHY Mg II index to match the GOME values is:

$$\text{Mg Index}_{\text{SCIA scaled to GOME}} = 0.386 \cdot \text{Mg Index}_{\text{SCIA}} + 0.039 \quad (1)$$

Fig. 2 shows that the GOME and SCIAMACHY Mg II indices agree to within about ±0.5 %. The correlation coefficient is with 0.995 very high (Fig. 3). Pronounced deviations between SCIAMACHY and the GOME Mg II index in Dec 2002/Jan 2003 are correlated with thermal instabilities of SCIAMACHY caused by a decontamination.

With the scaling given in equation (1) a combined GOME/SCIAMACHY Mg II index can be constructed (Fig. 4).

3. VALIDATION OF THE COMBINED GOME/SCIAMACHY SOLAR MG II INDEX

Fig. 7 shows a time series of the Mg II index covering almost the last three 11 year solar cycles 21 to 23 that is available from NOAA [9]. It starts in 1978 and is composed of several satellite instruments (NOAA TIROS, NOAA 9/11/16, UARS SOLSTICE, GOME ERS2) [4, 8, 10, 11, 12, 13, 14, 15].

In Fig. 5 the combined GOME/SCIAMACHY Mg II index time series is compared with the NOAA data. The NOAA Mg II index time series is interpolated to the times of the GOME and SCIAMACHY measurements. The combined GOME/SCIAMACHY solar Mg II index was scaled linearly to match the NOAA values. (For the calculation of scaling factors and correlations the GOME data contained in the NOAA timeseries is omitted.) The derived linear scaling of the combined GOME/SCIAMACHY Mg II index to match the NOAA values is:

$$\text{Mg Index}_{\text{GOME/SCIA scaled to NOAA}} = 0.968 \cdot \text{Mg Index}_{\text{GOME/SCIA}} + 0.140 \quad (2)$$

Fig. 5 shows that apart from the year 2000 differences between the combined GOME/SCIAMACHY Mg II index and NOAA values are below ±0.8 %. For a compared time period of almost 9 years (1995–2004) covering various instruments the correlation coefficient is with 0.991 very high.

4. CONCLUSIONS

A combined Mg II proxy solar activity indicator (Mg II index) has been derived from GOME and SCIAMACHY solar observations from 1995 to 2004. The successful

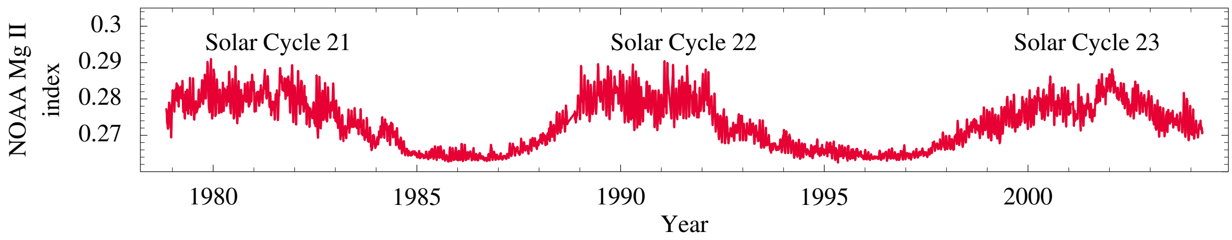

Fig. 7. The NOAA Mg II index from 1978 to 2004

derivation of this index demonstrates the high quality and sensitivity of solar irradiance measurements by GOME and SCIAMACHY.

The combined GOME/SCIAMACHY Mg II index shows an excellent correlation of 0.991 with the NOAA Mg II index. This high correlation shows that GOME and SCIAMACHY can be used in conjunction with other space instruments to provide a continuous long-term Mg II index time series. With GOME2 they will provide continuation in observation of the solar activity throughout the entire solar cycle 23 and the beginning of solar cycle 24.

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