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Composite Mg II Solar Activity Index for Solar Cycles 21 and 22

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The Mg II core-to-wing index was first developed for the Nimbus 7 solar backscatter ultraviolet spectrometer (SBUV) instrument as an indicator of solar middle ultraviolet activity that is independent of most instrument artifacts. This index is defined as the ratio of the irradiance in the core of the unresolved Mg II doublet at 280 nm to the nearby continuum irradiance and measures solar variability on both rotational and solar cycle time scales. Mg II index data sets have also been derived for the NOAA 9 and NOAA 11 SBUV/2 instruments. The combined Mg II index data record from the Nimbus 7, NOAA 9, and NOAA 11 instruments presented in this paper extends from November 1978 to January 1992. Differences in the absolute value of the Mg II index and long-term response to solar variations due to differences in wavelength scale and band pass among the three instruments require the use of linear regression fits to create a single composite Mg II index data set which includes more than 13 years of data. This paper documents version 1.0 of the composite Mg II index data set, which has been widely distributed on CD-ROM. Using this composite data set, the change in 27-day running average of the Mg II index from solar maximum to solar minimum is approximately 8% for solar cycle 21 and approximately 9% for solar cycle 22 through January 1992. This difference is not statistically significant when the errors in the linear regression fits used to construct the composite Mg II index are considered. Scaling factors based on the short-term variations in the Mg II index and solar irradiance data sets are developed for each instrument to estimate solar variability at mid-ultraviolet and near-ultraviolet wavelengths. A set of composite scale factors are derived for use with the composite Mg II index presented here. Near 205 nm, where solar irradiance variations are important for stratospheric photochemistry, the estimated change in irradiance during solar cycle 22 is approximately 10(±1)% using the composite Mg II index (version 1.0) and scale factors. However, the actual magnitude of ΔF_{205} is probably closer to 9% due to uncorrected SBUV/2 wavelength scale drift in the current composite Mg II index data set.

INTRODUCTION

Variations in solar ultraviolet (UV) irradiance have been correlated with changes in stratospheric ozone and temperature on short time scales of days to weeks [e.g., *Keating et al.*, 1987; *Hood and Jirikowic*, 1991] and long time scales of years to decades [e.g., *Keating et al.*, 1981]. Satellite instruments provide the only direct method of making daily solar ultraviolet observations with wide spectral coverage over long time periods. Long-term data sets of solar UV irradiance measurements that have been archived include the Nimbus 7 solar backscatter ultraviolet spectrometer (SBUV) observations from November 1978 to February 1987 [*Schlesinger et al.*, 1988; *Schlesinger and Cebula*, 1992] and the Solar Mesosphere Explorer (SME) observations from October 1981 to April 1989 [*Rottman et al.*, 1982; *Rottman*, 1988]. Understanding the effects of solar UV variability on photochemistry in the stratosphere requires a knowledge of long-term solar variability near 205 nm to ±1% over a solar cycle (L. L. Hood, personal communication, 1991) which exceeds the capabilities of current absolute irradiance measurements. The variation in solar irradiance at 205 nm during solar cycle 21 has been estimated to be 5–8% from SBUV data [*Schlesinger and Cebula*, 1992] and 2–10% from SME data [*Rottman*, 1988]. Temporal changes in the instrument response of both SME and SBUV have been characterized well enough to allow archival of the irradiance data, but neither instrument is currently producing valid data. The NOAA 9 and NOAA 11 SBUV/2 instruments have been making solar observations beginning in March 1985 and December 1988, respectively, continuing to the present [*Cebula and DeLand*, 1992]. On-board calibration systems were incorporated into the SBUV/2 instruments to aid in understanding changes in the reflectivity of the diffuser plate used for solar observations. Short-term instabilities in the calibration system prevented the determination of diffuser reflectivity changes for NOAA 9, but a quantitative characterization of diffuser reflectivity changes has been derived for NOAA 11 [*Weiss et al.*, 1991, 1993]. The on-board calibration system for the SBUV/2 instruments monitors changes in diffuser reflectance as a correction to the derived ozone abundances. The successful results from this calibration system only provide information on time-dependent changes in one component of the SBUV/2 optical system, with no provision for the end-to-end calibrations required for accurate long-term solar irradiance observations.

The solar ultraviolet spectral irradiance monitor (SUSIM) [*VanHooster et al.*, 1988] and Solar Stellar Irradiance Comparison Experiment (SOLSTICE) [*Rottman*, 1988] instruments launched in September 1991 on the Upper Atmospheric Research Satellite (UARS) are expected to provide absolute long-term solar UV irradiance data in the near future, and the Shuttle SBUV (SSBUV) [*Cebula et al.*, 1991; *Cebula and Hilsenrath*, 1992], SUSIM, and solar spectrum measurement (SOLSPEC) [*Labs et al.*, 1987] instruments make periodic absolute middle UV solar spectral irradiance measurements from the Space Shuttle. However, no long-term absolute irradiance data are presently available for studies of stratospheric variability, forcing the use of proxy indexes for many purposes. The most commonly used indexes of solar activity for such studies have been sunspot number and 10.7-cm radio flux ($F_{10.7}$) both of which have records that extend over more than one solar cycle. Al-

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though these indexes are frequently used as proxies for both short-term and long-term solar UV activity [*Keating et al.*, 1981; *Ebel et al.*, 1986; *Chandra*, 1991], they are not generated in the same layers of the solar atmosphere as UV radiation in the 200- to 300-nm wavelength region, which drives stratospheric ozone photochemistry. In particular, $F_{10.7}$ is generated in the solar corona and exhibits different behavior on solar rotational time scales than mid-UV and near-UV solar irradiance [*Donnelly*, 1988, 1991]. The equivalent width of the He I 1083-nm line has been used as an index of solar UV activity since 1974 [*Harvey*, 1984], but the daily record is only complete at the 60–70% level and contains many data gaps of between 3 and 10 days, which affects studies of short-term variability. Measurements of the Ca II K line at 393 nm have also been made since 1974 [*White and Livingston*, 1981; *White et al.*, 1990], but the observation method of four consecutive dates per month limits the usefulness of these measurements to studies of long-term solar change. Estimates of solar cycle variability using the Ca II K index can also be influenced by large solar rotational modulations at solar maximum, which can have peak-to-peak amplitudes equal to 50–70% of the smoothed solar cycle amplitude for chromospheric wavelengths such as H Ly α [*Barth et al.*, 1990]. In order to identify the contribution of solar activity to stratospheric ozone variations, a proxy index is needed which has a good correlation with solar irradiance variations in the 200- to 300-nm region, approximately daily measurements to allow accurate characterization of short-term variations, and a data record covering one or more solar cycles in order to determine the magnitude and phase of long-term variations.

The Mg II core-to-wing index of solar variability was first developed for the Nimbus 7 SBUV instrument by *Heath and Schlesinger* [1986] and has been extended to the NOAA 9 and NOAA 11 SBUV/2 instruments [*Cebula et al.*, 1992; *DeLand and Cebula*, 1992]. The Mg II index is defined as the ratio of the irradiance in the core of the unresolved Mg II doublet at 280 nm, which is sensitive to solar activity variations in the chromosphere, to the irradiance in the wings of the Mg II line, which approximates the local photospheric continuum. *Donnelly et al.* [1987] have shown that the Mg II index is a good proxy for variations in the far-UV solar irradiance (wavelengths shortward of 200 nm), which are generated in the solar chromosphere and upper photosphere [*Lean*, 1987, 1991] and become significant for ozone variations in the upper stratosphere and mesosphere. Solar radiation near the Al I absorption edge at 208 nm is generated in the lower photosphere, but at a brightness temperature very close to that of the Mg II 280-nm line [*Heath and Schlesinger*, 1986], so that the Mg II index should also be a good indicator of irradiance changes in this critical region for stratospheric ozone variability. Although the solar irradiance in the 210- to 260-nm wavelength region is generated in the upper photosphere at a slightly higher brightness temperature than the Mg II line, *Donnelly* [1988] demonstrated excellent uniformity in short-term solar irradiance variations between 175 nm and 290 nm, allowing the Mg II index to approximate irradiance variations in this spectral region. Because the Mg II index is composed of a ratio of irradiances, wavelength-independent changes in instrument sensitivity cancel out. The use of an irradiance ratio also removes the effects of any errors which may be present in an instrument's spectroradiometric calibration and absolute solar spectral irradiances. Any wavelength-dependent change in sensitivity is dominated by linear components over the 7-nm width of the Mg II index. Therefore choosing the wavelengths for the wing irradiances equally spaced about the Mg II line core also eliminates most wavelength-dependent artifacts from the index.

Mg II Index Measurements

The irradiance values used to construct the Mg II index data sets presented in this paper are taken from the average of all sweep mode measurements (labeled "continuous scan" by *Heath and Schlesinger* [1986]) during each day (normally two scans for the SBUV/2 instruments, three scans for SBUV). During sweep mode operations the SBUV/2 instrument continuously scans from 405 to 160 nm with a 0.1-s integration time for each sample and a nominal wavelength separation between adjacent points of approximately 0.15 nm. Long-term data sets of the Mg II index derived from sweep mode solar measurements are now available from three separate SBUV-series instruments. The Nimbus 7 SBUV instrument [*Heath et al.*, 1975] was launched and began making measurements in November 1978. The NOAA 9 SBUV/2 instrument [*Frederick et al.*, 1986] was launched in December 1984 and began solar observations in March 1985. The NOAA 11 SBUV/2 instrument, launched in September 1988, began solar observations in December 1988. Nimbus 7 SBUV solar irradiance measurements have been archived for the period November 1978 to March 1987. The Mg II index time series derived from these measurements is described by *Heath and Schlesinger* [1986], and daily values are shown in Figure 1*a*. Nimbus 7 SBUV instrument problems, which began in March 1987, increased the noise in SBUV solar irradiance data, and sweep mode data beyond this point are not archived [*Schlesinger and Cebula*, 1992]. NOAA 9 SBUV/2 solar irradiance measurements have been processed for March 1985 to November 1991. The orbital drift of the NOAA 9 spacecraft during its lifetime has forced the incidence angle of the solar radiation on the diffuser plate beyond the range of prelaunch calibration of the diffuser angular response [*Cebula and DeLand*, 1992]. Extrapolation of the prelaunch goniometric calibration has been used to process measurements made after September 1990, but some of these data could not be recovered, leading to gaps in the NOAA 9 Mg II index time series during fall 1990 and winter 1991 (Figure 1*b*). There is a data gap of approximately 2 months during fall 1988 when the NOAA 9 SBUV/2 diffuser plate was shadowed by the spacecraft solar array, preventing solar irradiance measurements. For the SBUV/2 instruments the wavelengths used for the Mg II wing irradiances have relatively low signal-to-noise ratios, caused by the electronic gain range transition which occurs at the Mg II doublet [*Cebula et al.*, 1992]. This leads to a day-to-day statistical variation of approximately 1–2% in the derived sweep mode Mg II index values. The NOAA 9 Mg II index data shown in Figure 1*b* have been smoothed with a 5-day binomial-weighted running average [*Bevington*, 1969, p. 257] to reduce statistical noise while preserving most of the strength of the 27-day solar rotational modulation variations. The Nimbus 7 SBUV instrument used a different electronic design that gave higher signal-to-noise ratios at all Mg II index wavelengths, which accounts for the noticeably cleaner appearance of the Nimbus 7 Mg II

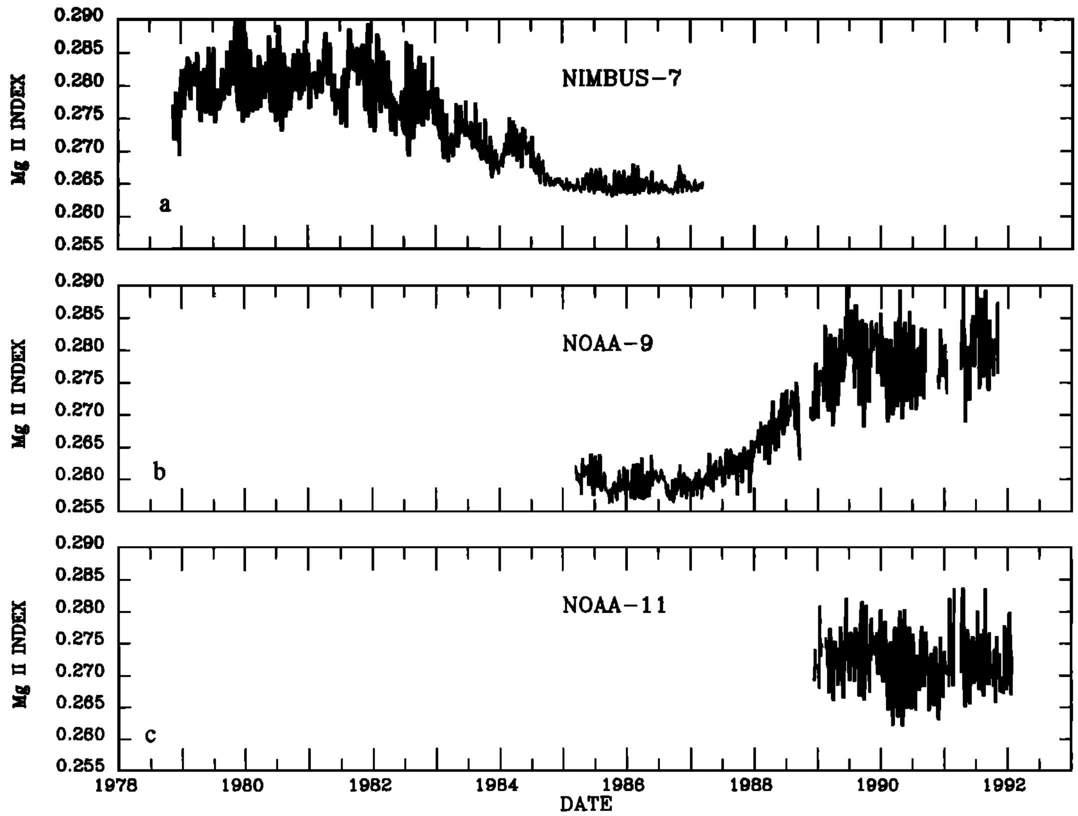

Fig. 1. (*a*) Time series of the Nimbus 7 Mg II index from November 1978 to March 1987, computed from daily average sweep mode irradiance measurements. (*b*) Time series of the NOAA 9 Mg II index from March 1985 to November 1991, computed from daily average sweep mode irradiance measurements. A 5-day running average with a binomial weighting distribution has been applied to the data to reduce the day-to-day noise. (*c*) Time series of the NOAA 11 Mg II index from December 1988 to January 1992, computed from daily average sweep mode irradiance measurements. A 5-day binomial average has been applied.

index data compared with the NOAA 9 Mg II index during the period of low solar activity in 1985 and 1986. NOAA 11 SBUV/2 solar irradiance measurements have been processed for the period December 1988 to January 1992 [*DeLand and Cebula*, 1992], except for the March 1991 data which are unavailable. The 5-day binomial-smoothed Mg II index time series derived from these data is shown in Figure 1*c*.

Figure 2 shows the Mg II index time series for Nimbus 7, NOAA 9, and NOAA 11 together, where for clarity all data sets have been smoothed with a 27-day running average to filter out solar rotational modulation effects. The absolute value of the Nimbus 7 SBUV Mg II index is approximately 2% higher than the NOAA 9 SBUV/2 Mg II index during the 1985–1987 overlap period, while the NOAA 9 Mg II index is approximately 1–2% higher than the NOAA 11 Mg II index during the overlap period of 1989–1990. The difference between the absolute values of the Nimbus 7 and the NOAA 9 Mg II index data sets is primarily due to the differences in nominal wavelength scales and instrument band pass from one instrument to the next [*Hall and Anderson*, 1988; *Cebula et al.*, 1992], and does not indicate a significant difference in the response to solar irradiance variations. The wavelength positions used in the construction of the Mg II index for Nimbus 7 SBUV and NOAA 9 SBUV/2 are shown in Figure 3 on an enlarged view of the Mg II doublet as measured by these instruments. Note that the Nimbus 7 wing wavelength positions (short tick marks), which represent the center locations of the 1.1-nm instrument band pass sampled at 0.2-nm intervals, will give an equal or lower average continuum irradiance than the NOAA 9 wing wavelengths if both sets of wavelengths are used with a nominal spectrum. Similarly, the increased wavelength span of the Nimbus 7 Mg II core wavelengths will give a higher average core irradiance than the NOAA 9 wavelengths. Tests with randomly selected NOAA 9 daily average spectra which were interpolated with a cubic spline from the NOAA 9 wavelength scale to the Nimbus 7 wavelength scale show increases in the derived Mg II index value of approximately 1–2% after interpolation, consistent with the difference in absolute value shown in Figure 2. Differences in medium-term (i.e., 1–3 months) structure during summer 1985 and 1986 are caused in part by a small error in the NOAA 9 electronic gain range characterization. This error is present in the data used for the creation of the version 1.0 composite Mg II index presented here and will be corrected for future versions.

The offset in absolute value between the NOAA 9 and the NOAA 11 Mg II indexes is less likely to be due to instrument measurement characteristics such as nominal wavelength scales, because of the similarities between the two SBUV/2 instruments. However, the wavelength scales of the NOAA 9 and NOAA 11 SBUV/2 instruments are subject to time-dependent drifts. An analysis based on the apparent wave-

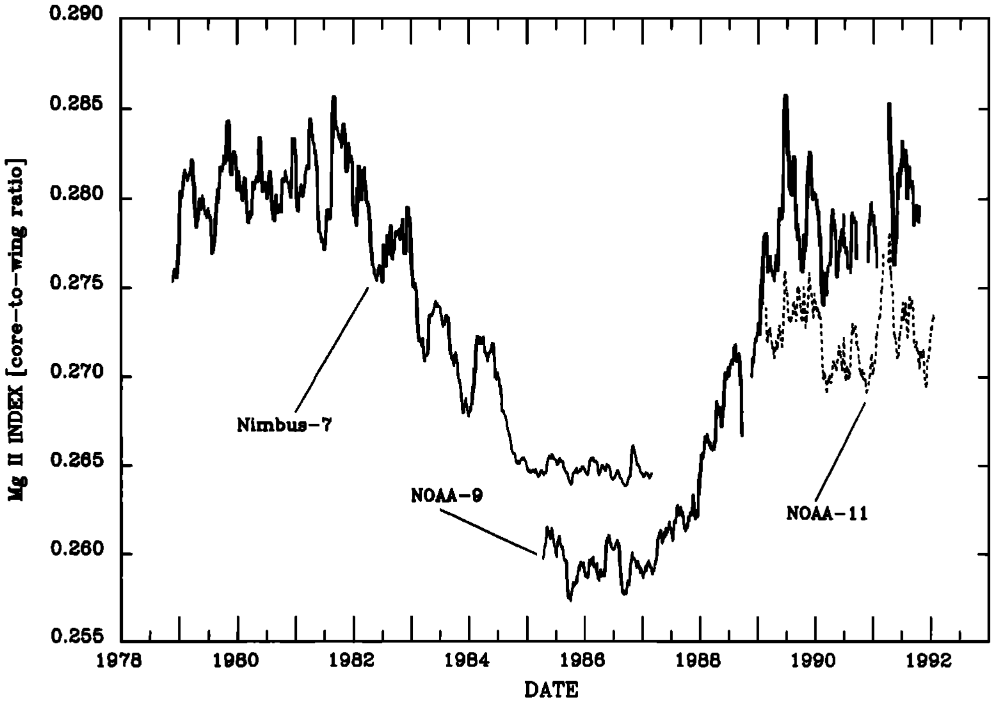

Fig. 2. Mg II index time series for Nimbus 7, NOAA 9, and NOAA 11 (dashed curve). All data sets have been smoothed with a 27-day running average.

length positions of absorption line minima in the solar spectrum and emission lines from the mercury calibration lamp suggests sweep mode wavelength scale changes of the order of $\Delta\lambda \approx 0.10$ nm at the Mg II line for both NOAA 9 and NOAA 11 during the lifetime of each instrument [*DeLand et al.*, 1992]. This value is comparable to the result calculated for the Nimbus 7 SBUV instrument [*Schlesinger et al.*, 1988], although the physical mechanism causing the drift is

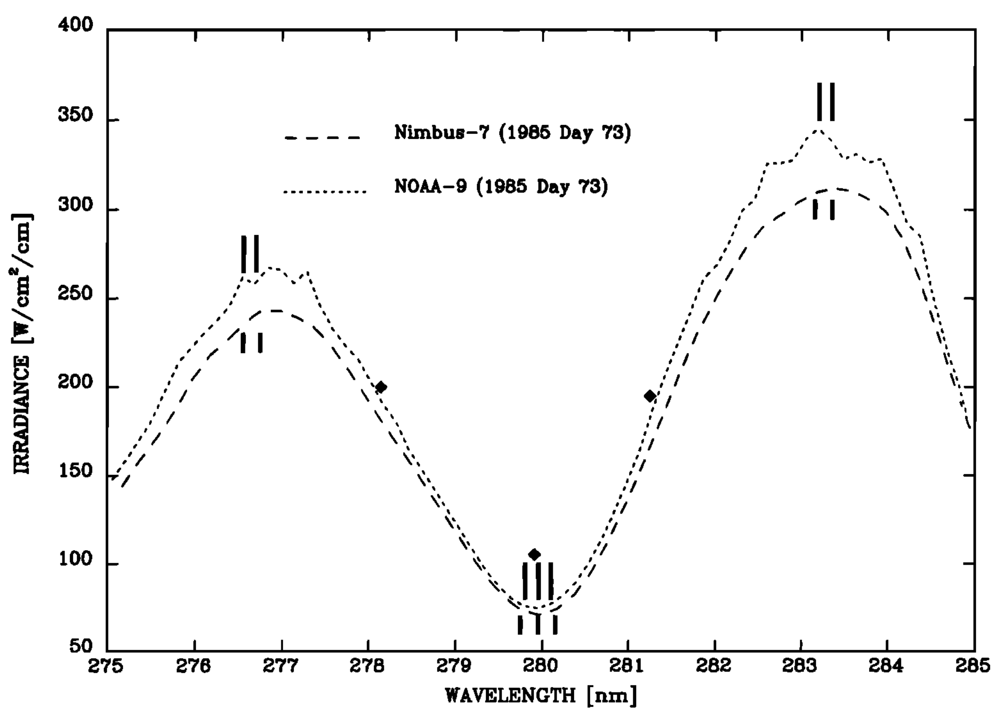

Fig. 3. Enlarged view of the Mg II doublet at 280 nm as observed by Nimbus 7 SBUV (long-dashed curve) and NOAA 9 SBUV/2 (short-dashed curve) on March 14, 1985. The wavelength positions used to construct the Nimbus 7 Mg II index are indicated by the short solid lines below the plotted spectra, and the wavelength positions for the NOAA 9 Mg II index are marked by the long solid lines above the spectra. The wavelength positions used by *Donnelly* [1991] are marked by diamonds.

different between the SBUV and SBUV/2 instruments. An estimated wavelength scale change of $\Delta\lambda \approx 0.06$ nm between 1985 and 1989 would lead to an increase in the derived NOAA 9 Mg II index value of approximately 1% over the nominal Mg II index value during the same period. This effect suggests a possible cause for the initial discrepancy between NOAA 9 and NOAA 11 Mg II index values. Further NOAA 9 wavelength scale drift from 1989 to 1992 may be responsible for an additional 1% increase in the NOAA 9 Mg II index values relative to the NOAA 11 Mg II index values, as shown in Figure 2. As a result of this wavelength scale drift, the magnitude of the solar cycle variation in Mg II index value of approximately 9% as estimated by NOAA 9 by *Cebula et al.* [1992] may be too large, and a solar cycle 22 increase of 8% may be more appropriate. This change will also reduce the estimated solar irradiance variations during 1985–1989 at other wavelengths presented by *Cebula et al.* [1992] for NOAA 9, to approximately 7.7% at 205 nm and 3.1% at 250 nm. All NOAA 9 and NOAA 11 Mg II index results presented here were derived using the nominal wavelength scales for each instrument and have not been corrected for time-dependent wavelength scale drift. Future investigations will be performed to quantify the impact of SBUV/2 instrument sweep mode wavelength scale drift on the composite Mg II index. When revisions to the NOAA 9 interrange ratio algorithm and corrections for NOAA 9 and NOAA 11 wavelength scale drift have been incorporated into the Mg II index data, an updated composite Mg II index data set will be created and published.

NOAA 9 and NOAA 11 SBUV/2 solar irradiance measurements are also made on a daily basis at 12 selected individual wavelengths about the Mg II line (discrete mode), from which a distinct Mg II index product can be computed [*Donnelly*, 1988, 1991; *Cebula and DeLand*, 1992]. The discrete mode measurements, which include the "classical" Mg II index wavelengths of *Heath and Schlesinger* [1986] and additional wavelengths along the sides of the Mg II absorption line, were begun in May 1986 for NOAA 9 and in February 1989 for NOAA 11. An Mg II index data set constructed from discrete mode measurements is less noisy than its sweep mode counterpart because the signal for each irradiance value is integrated for 1.25 s in discrete mode, compared to a 0.1-s sample integration time for sweep mode measurements. The NOAA 9 discrete mode Mg II index results presented by *Donnelly* [1991] also reduce statistical noise by choosing continuum wavelengths approximately 1.5 nm closer to the line core, which brings all irradiance measurements into the same electronic gain range. This method not only avoids the signal-to-noise problem discussed by *Cebula et al.* [1992] but also decreases the magnitude of solar activity variations with respect to the *Cebula et al.* [1992] sweep mode results. While the irradiance variation measured at the core of the Mg II line is the same in both cases, the revised wing wavelengths in the *Donnelly* [1991] Mg II index, shown by the points marked with diamonds in Figure 3, are close enough to the Mg II line core that the irradiance from the wing wavelengths can no longer be considered to approximate the invariant local photospheric continuum. The NOAA 9 discrete mode Mg II index results presented by *Donnelly* [1991] show maximum variations during solar cycle 22 of approximately 9.5% in a time series of daily values, 6.5% in a time series of values smoothed with a 27-day running average, and 5.5% peak-to-peak amplitude for the largest rotational modulation. Constructing a Mg II index data set from sweep mode irradiance data using wavelengths corresponding to those used by *Donnelly* [1991] gives similar results. *Cebula et al.* [1992] present NOAA 9 sweep mode Mg II index results which indicate solar cycle 22 minimum-to-maximum variations of 12% in daily values, 8–9% in 27-day-averaged values, and up to 7% for rotational modulations. These results suggest that the response of the NOAA 9 discrete mode Mg II index of *Donnelly* [1991] to solar irradiance variations in the Mg II absorption line is approximately 80% as great as the sweep mode Mg II index from the same instrument. A linear regression analysis using common data points between May 1986 and December 1989 gives a slope of 0.80 for conversion of NOAA 9 sweep mode Mg II index data to the *Donnelly* [1991] reference scale when both data sets are normalized to their solar minimum values, consistent with the estimate of relative response strength presented here. The correlation coefficient of $R = 0.98$ for this linear regression fit confirms that the NOAA 9 Mg II indexes of *Cebula et al.* [1992] and *Donnelly* [1991] provide comparable measurements of the solar irradiance variations.

The difference in the magnitude of the response to solar variations does not indicate a problem with either Mg II index data set but reflects the amount of solar variability present in the "continuum" irradiance values used to construct the respective ratios. The magnitude of scale factors derived to relate Mg II index variations to solar UV irradiance variations at specific wavelengths will also depend on the magnitude of the Mg II index variability [*Cebula et al.*, 1992]. In this paper the Mg II index data derived from NOAA 9 and NOAA 11 sweep mode measurements will be used for continuity with the Nimbus 7 data, which are only available in this format. The NOAA 9 sweep mode Mg II index data set was also chosen because there is a 2-year overlap with the Nimbus 7 data set, compared with only a 7-month overlap between the Nimbus 7 data and the NOAA 9 discrete mode Mg II measurements.

Due to differences in Mg II index absolute value between the SBUV and the SBUV/2 instruments, a continuous Mg II index data set cannot be created by appending each new data set to the previous one. Additionally, shifting one data set with respect to another to force agreement in absolute value on a given date ignores possible differences in sensitivity to solar variations between instruments. Characterization of such differences is required to achieve $\pm 1\%$ accuracy in irradiance variations over a solar cycle. With sufficient temporal overlap of two Mg II index data sets, such as the 2-year overlap between Nimbus 7 and NOAA 9 and the 1.5-year overlap between NOAA 9 and NOAA 11, linear regression techniques can be used to derive relationships between the data sets. This method has been used to construct a continuous Mg II index data set on a single absolute scale covering more than 13 years, including the maxima of solar cycles 21 and 22.

REGRESSION PROCEDURE

The differences in absolute Mg II index value among Nimbus 7, NOAA 9, and NOAA 11 are primarily caused by minor differences in wavelength sampling, which does not affect the ability of each index to monitor solar activity. If sensitivity to solar irradiance variations as measured by the

Mg II index is consistent between different instruments, a linear regression fit between two Mg II index data sets containing simultaneous observations should give a slope close to 1.0 (same magnitude of solar variations). Similarly, the correlation coefficient of such a regression fit, which is a measure of the agreement in day-to-day variations, should also be close to 1.0. The nonnegligible differences between even successive SBUV/2 instruments will prevent complete agreement in the analysis of actual measurements, but the correlations visible in Figures 1 and 2 suggest that good agreement should be possible. By using the equations derived from linear regression fits for normalization, each Mg II index data set can be placed on an absolute reference scale, so that a single Mg II index data set spanning the full range of available data can be constructed. In principle, the choice of the Mg II index data set to use as a reference scale is arbitrary, since the measurements are taken independently. If a self-consistent set of scale factors is used with the Mg II index to calculate solar irradiance variations, the results will be independent of the choice of reference scale. For this paper, regression fits were calculated to convert the Nimbus 7 and NOAA 11 Mg II index data sets to the NOAA 9 Mg II index absolute reference scale. Since the NOAA 9 data set overlaps both the Nimbus 7 and the NOAA 11 data sets in time, this choice allows each data set to pass through only one regression equation to form a composite Mg II index data set, thus minimizing any errors introduced by the regression technique. The increased day-to-day noise in the NOAA 9 Mg II index data set relative to Nimbus 7 and NOAA 11 also supports the use of the NOAA 9 data set as the dependent variable, which is assumed to contain all measurement noise in the linear regression procedure [*Bevington*, 1969, p. 99]. All data sets were smoothed with a 5-day binomial average prior to the regression procedure.

The linear regression fit between Nimbus 7 and NOAA 9 Mg II index data for the period March 1985 to February 1987 gives a slope of 1.005, which suggests that both instruments have almost identical responses to solar variations in the Mg II feature despite differences in the absolute value of the Mg II index.

$$\text{Mg II}_{\text{NOAA9}} = 1.005*\text{Mg II}_{\text{Nimbus7}} - 0.0067 \qquad (1)$$

$$\sigma = 0.0012$$

σ represents the standard error of the regression fit in units of Mg II_{NOAA9}, so that $\sigma = 0.0012$ corresponds to an approximate uncertainty in scaled Mg $\text{II}_{\text{Nimbus7}}$ values of 0.4% at solar maximum. If a representative solar minimum Nimbus 7 Mg II index value (0.262) is inserted into (1), a difference of −2.1% is found in converting to the NOAA 9 absolute scale. Because the Nimbus 7 and NOAA 9 Mg II data used for this calculation are derived from measurements taken during the minimum of solar cycle 21, when solar rotational modulation is weak, the statistical noise in the NOAA 9 Mg II index is expected to significantly reduce the correlation of day-to-day variations. The correlation coefficient of $R = 0.643$ between the Nimbus 7 and the NOAA 9 Mg II data supports this prediction.

Although NOAA 9 solar irradiance data have been processed to November 1991, the extrapolation of the prelaunch goniometric calibration required after September 1990 increases the possible error in Mg II index values derived for that period. NOAA 11 irradiance measurements were taken sporadically during December 1988 and January 1989 as a part of the SBUV/2 instrument activation and evaluation period and are noisier than the regular daily measurements which began in February 1989. For this paper the regression fit between NOAA 9 and NOAA 11 Mg II index data was restricted to the period between February 1989 and September 1990. This regression fit gives a slope of 0.984, which again suggests similar responses to solar variability between the two instruments.

$$\text{Mg II}_{\text{NOAA9}} = 0.984*\text{Mg II}_{\text{NOAA11}} + 0.0103 \qquad (2)$$

$$\sigma = 0.0023$$

Using a representative solar maximum NOAA 11 Mg II value of 0.278 in (2), the NOAA 9 absolute scale is approximately 2.1% higher than the NOAA 11 scale. However, some of this difference may be due to the previously discussed drift in the NOAA 9 and NOAA 11 nominal wavelength scales. The increased magnitude of the solar rotational modulation during 1989–1990 greatly reduces the impact of the inherent statistical noise in the Mg II index for the SBUV/2 instruments, resulting in an increased correlation coefficient for the linear regression fit between the NOAA 9 and the NOAA 11 Mg II index data sets of $R = 0.867$ compared to the result for NOAA 9 and Nimbus 7. This improvement in correlation coefficient between solar minimum and solar maximum is in agreement with the results of *Barth et al.* [1990] obtained for regression fits between 10.7-cm radio flux and SME solar Lyman alpha flux.

In order to create a composite Mg II index on a single scale that extends over the period 1978–1992, specific dates must be selected for the transitions among the Nimbus 7, NOAA 9, and NOAA 11 data sets. Because the Nimbus 7 Mg II index data are less noisy than the NOAA 9 Mg II index data during 1985–1986, the scaled Nimbus 7 Mg II index data are used in the composite Mg II index data set from November 7, 1978, through December 31, 1986, and NOAA 9 Mg II index data are used beginning on January 1, 1987. The date of transition from NOAA 9 to NOAA 11 Mg II index data in the composite Mg II index data set was chosen to minimize the shift in absolute value between the two data sets, based on inspection of 27-day running average values. Therefore NOAA 9 Mg II index data are used in the composite Mg II index from January 1, 1987, to April 30, 1989, and scaled NOAA 11 Mg II index data are used from May 1, 1989, through January 27, 1992, the limit of the archived Mg II index data. The composite Mg II index data set presented in this paper was created by applying (1) and (2) to the daily unsmoothed Nimbus 7 and NOAA 11 Mg II index values, then merging the scaled Mg II index data with the NOAA 9 Mg II index data, as discussed above, to produce a single continuous data set. Finally, a 5-day binomial average was applied to reduce statistical noise.

The Mg II index data set described in this paper is archived on CD-ROM [*Larko and McPeters*, 1992] and should be considered as version 1.0 of the composite Mg II index. The SBUV/2 instrument characterizations are still being refined, and changes to the absolute value of the NOAA 9 and NOAA 11 Mg II indexes will occur when revised characterizations are implemented. Currently antic-

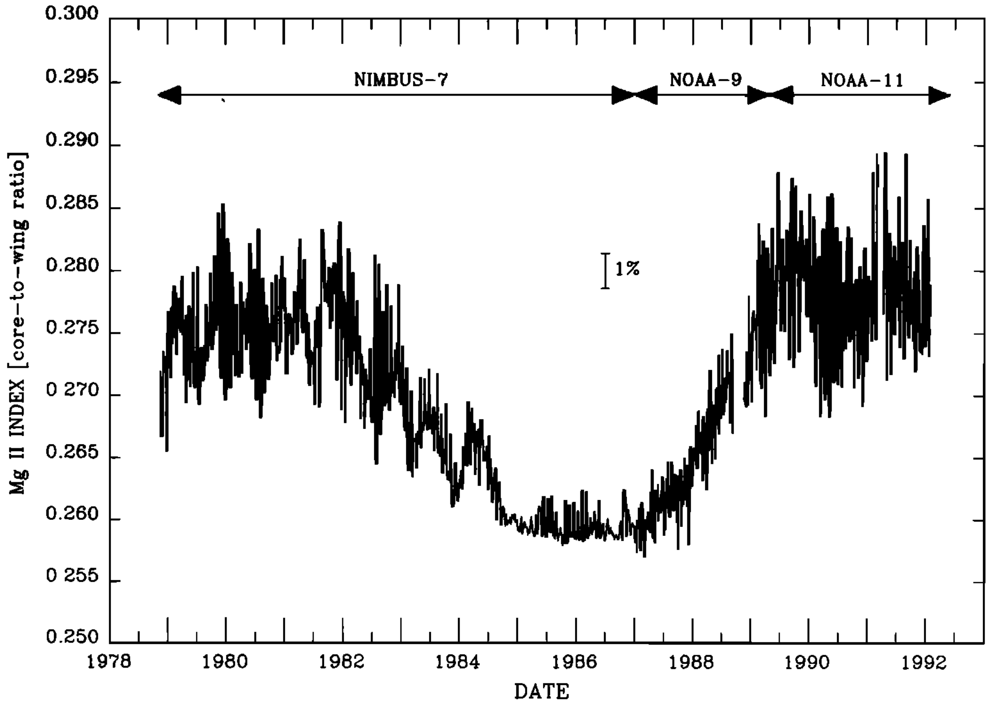

Fig. 4. The composite Mg II index time series Mg $II_C(t)$ from November 1978 to January 1992, smoothed with a 5-day binomial average.

ipated future improvements to the solar irradiance data include updated goniometric calibrations for both instruments, improved characterization of the time dependence of instrument gain changes, and implementation of a diffuser degradation correction algorithm for NOAA 11. Such modifications are expected to change the absolute solar irradiance values by 1% or less in most cases, with a smaller effect on the derived Mg II index because it is constructed from a ratio of irradiances. In addition, a quantitative estimate of NOAA 9 and NOAA 11 instrument wavelength scale changes and the impact on the Mg II index will be determined. The coefficients of the linear regression fit between NOAA 9 and NOAA 11 Mg II index data may also change slightly with time as additional data are incorporated into the fit. While no significant qualitative changes to the conclusions reached in this paper are expected as a result of such revisions, any quantitative changes in the composite Mg II index data set will be described when an updated version is available.

Composite Mg II Index Results

Daily values of the composite Mg II index for solar cycles 21 and 22 constructed from (1) and (2), as described in the previous section, are plotted in Figure 4. The decrease from solar maximum to solar minimum conditions during solar cycle 21 extends over approximately 3 years, from early 1982 through early 1985, while the rise of solar cycle 22 from minimum to maximum took roughly 2.5 years, from early 1987 to mid-1989, with most of the rise occurring during 1988 and early 1989. This asymmetry is qualitatively consistent with the results for the 10.7-cm radio flux and the SME solar Lyman alpha flux reported by *Barth et al.* [1990]. Using a 27-day running average of the composite Mg II index time series to remove the effects of rotational modulation, the change between solar maximum and solar minimum for solar cycle 21 shown in Figure 5 is approximately 8%, where the average of the September 1986 data represents solar minimum values. Solar cycle 22 shows an increase of approximately 9% in the composite Mg II index from solar minimum to solar maximum in Figure 5, although the true increase may be closer to 8% due to the wavelength scale drift on the NOAA 9 SBUV/2 instrument discussed previously. The 2σ error estimates at solar maximum for each regression fit plotted in Figure 5 show that the difference between the magnitudes of cycles 21 and 22 presented here is not statistically significant.

Figure 6 shows the time series of the composite Mg II index for solar cycles 21 and 22 compared with two other proxy indicators of solar UV variability: the 10.7-cm radio flux ($F_{10.7}$) [*Tapping*, 1987] and the equivalent width of the He I 1083-nm line (EW_{1083}) [*Harvey*, 1984]. Each of these data sets clearly demonstrates solar variability on both the 11-year solar cycle and the solar rotational modulation time scales. Quantitative comparisons between the composite Mg II index (Mg II_C), $F_{10.7}$, and EW_{1083} using linear regression fits are summarized in Table 1, where Mg II_C is the dependent variable y in each case. For the period January 1, 1979, to December 31, 1991, when regular measurements of all three proxies are available, the correlation coefficients of regression fits between Mg II_C and $F_{10.7}$ and between Mg II_C and EW_{1083} are extremely good ($R > 0.9$), indicating that all three proxies effectively represent long-term solar variability. This period can also be conveniently separated into the maximum of solar cycle 21 from 1979 to 1981, the declining phase of cycle 21 from 1982 through 1984, the minimum of solar activity between cycles 21 and 22 in 1985 and 1986, the rising phase of solar cycle 22 during 1987 and 1988, and the maximum of solar cycle 22 between 1989 and 1991. Linear

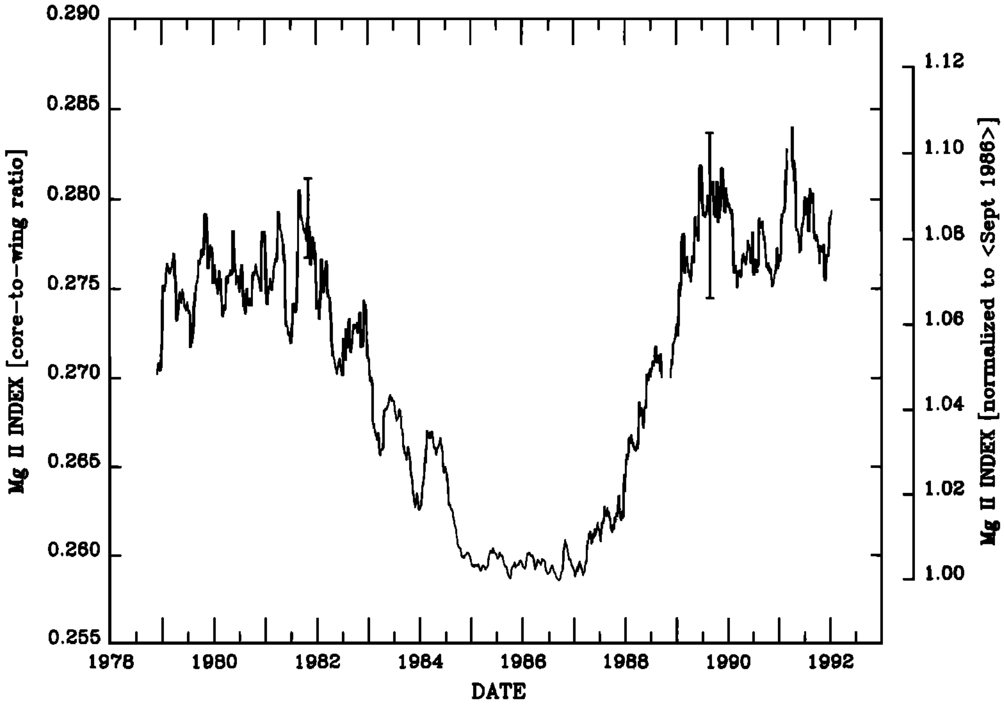

Fig. 5. The composite Mg II index time series smoothed with a 27-day running average. The right-hand scale uses the average of the September 1986 data as a reference value for normalization. The plotted error bars represent $\pm 2\sigma$ errors in the regression fits used to scale the Nimbus 7 and NOAA 11 data.

regression fits for each time interval show the highest correlation coefficients during the declining phase of solar cycle 21 and the rising phase of solar cycle 22, although this result may be affected by the presence of a long-term trend in the data during these periods. The correlation coefficients are lowest during the period of minimum solar activity in 1985 and 1986, when the strength of the solar rotational modulation is greatly reduced and short-term variations are more strongly influenced by measurement noise. The comparatively low linear regression correlation coefficients derived during both solar maximum periods occur despite the presence of strong and persistent rotational modulation. This may be related to spectral variations in active region behavior. For each time interval in Table 1 the correlation coefficient of the regression fit between the chromospheric indexes Mg II_C and EW_{1083} is greater than the correlation coefficient between Mg II_C and the coronal index $F_{10.7}$. This is consistent with expectations based on the level in the solar atmosphere at which the emissions originate.

The time series of the composite Mg II index, the 10.7-cm flux, and the He 1083-nm equivalent width for solar cycle 22 only are shown in Figure 7, with a 27-day running average applied to emphasize the long-term behavior. This figure suggests a more rapid rise in the chromospheric proxies (Mg II_C and EW_{1083}) during 1987 than in $F_{10.7}$. The 10.7-cm flux time series shows instances of large short-term increases even in this smoothed format (e.g., June 1989, September 1990) which are not matched by the chromospheric proxies. This maximum period shows consistent rotational modulation in each of the proxy indexes, as shown in Figure 8. However, the composite Mg II index seems to be better suited for short-term variations such as periods of 13-day rotational modulation, which occur when active regions are present on opposing hemispheres of the Sun simultaneously. $F_{10.7}$ seems to have a different response to such instances because of its coronal origin, and EW_{1083} can miss such occasions entirely due to sampling problems (e.g., July 1990). The results presented here suggest that the composite Mg II index is well suited for monitoring solar UV activity on both short-term and long-term time scales. Determining the extent to which each of these proxies actually represents long-term solar irradiance variation in a specified wavelength interval will require observations with greater accuracy than is currently available.

Composite Scale Factors

In order to estimate solar variability at other ultraviolet wavelengths using the Mg II index, a set of scale factors must be derived to relate changes in the Mg II index to irradiance changes at each wavelength. Scale factors were developed and presented for the Nimbus 7 SBUV instrument by *Heath and Schlesinger* [1986] and for NOAA-9 SBUV/2 by *Cebula et al.* [1992], based on the strength of 27-day solar rotational modulations. The strength of a solar rotation for the Mg II index is determined by taking the ratio of the maximum Mg II index value during a rotation to the minimum index value for that rotation. The rotational strength at a chosen wavelength is then calculated using irradiance values on the same dates, and the ratio of the irradiance rotational strength to the Mg II index rotational strength determines a scale factor for a specific wavelength and solar rotation. By repeating this process for multiple solar rotations, a set of points is derived for each wavelength representing irradiance change as a function of Mg II index change, which can then be fit by linear regression to generate a scale factor value $F_S(\lambda)$ with an estimated error. The percent variation of solar irradiance at a specified wave-

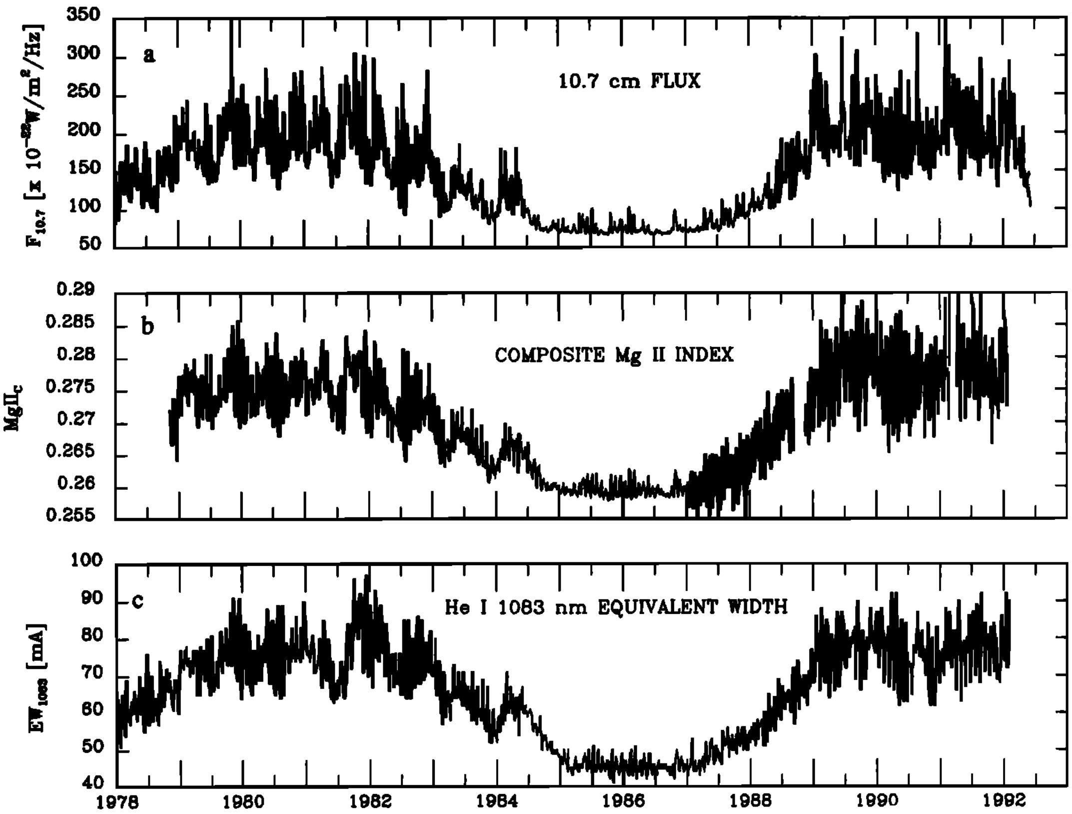

Fig. 6. Time series of daily values for (*a*) the 10.7-cm radio flux, (*b*) the composite Mg II index, and (*c*) the equivalent width of the He I 1083-nm line between 1978 and 1992.

length λ over a chosen time interval *t*, ΔF(λ, *t*), is therefore given by (3), where ΔMg $II_C(t)$ is the percent change in the Mg II index during *t*.

$$\Delta F(\lambda, t) = F_S(\lambda) * \Delta \text{Mg II}_C(t) \qquad (\Delta \text{Mg II}_C \text{ in } \%) \qquad (3)$$

A complementary approach to the determination of long-term solar UV irradiance variations is presented by *Lean et al.* [1992], who derive linear relations between detrended solar UV irradiance and solar UV proxy data.

Specific scale factor values must be calculated for use with each Mg II index data set because of the differences in Mg II index absolute values and response to solar variations caused by the interinstrument differences. However, the wavelength dependence of the scale factor data sets should be similar in each case. *Cebula et al.* [1992] showed that the scale factors derived for the Nimbus 7 and NOAA 9 instruments have the same spectral shape. After correcting for noise in the NOAA 9 Mg II index, the NOAA 9 scale factors

TABLE 1. Linear Regression Fits Between the Composite Mg II Index, the 10.7-cm Radio Flux, and the Equivalent Width of the He I 1083-nm Line

Data Interval	*N*	*R*	Slope	Mg II_c, min
		Composite Mg II Index Versus 10.7-cm Flux		
Jan. 1, 1979 to Dec. 31, 1981: cycle 21 maximum	819	0.800	7.75×10^{-5}	0.2654
Jan. 1, 1982 to Dec. 31, 1984: cycle 21 decline	751	0.913	1.05×10^{-4}	0.2606
Jan. 1, 1985 to Dec. 31, 1986: solar minimum	564	0.791	1.10×10^{-4}	0.2585
Jan. 1, 1987 to Dec. 31, 1988: cycle 22 rise	617	0.856	1.21×10^{-4}	0.2595
Jan. 1, 1989 to Dec. 31, 1991: cycle 22 maximum	1004	0.713	8.50×10^{-5}	0.2664
Jan. 1, 1979 to Dec. 31, 1991: all data	3755	0.939	1.24×10^{-4}	0.2597
		Composite Mg II Index Versus He I 1083 nm Equivalent Width		
Jan. 1, 1979 to Dec. 31, 1981: cycle 21 maximum	501	0.800	4.32×10^{-4}	0.2615
Jan. 1, 1982 to Dec. 31, 1984: cycle 21 decline	406	0.968	5.12×10^{-4}	0.2561
Jan. 1, 1985 to Dec. 31, 1986: solar minimum	319	0.838	4.48×10^{-4}	0.2583
Jan. 1, 1987 to Dec. 31, 1988: cycle 22 rise	366	0.890	5.81×10^{-4}	0.2579
Jan. 1, 1989 to Dec. 31, 1991: cycle 22 maximum	581	0.803	5.87×10^{-4}	0.2582
Jan. 1, 1979 to Dec. 31, 1991: all data	2173	0.950	5.64×10^{-4}	0.2575

N, number of points used in linear regression fit; *R*, correlation coefficient of linear regression fit; Mg II_c(min), value of composite Mg II index calculated from linear regression fit results assuming solar minimum value of independent variable ($F_{10.7}$(minimum) = 65, EW_{1083}(minimum) = 43).

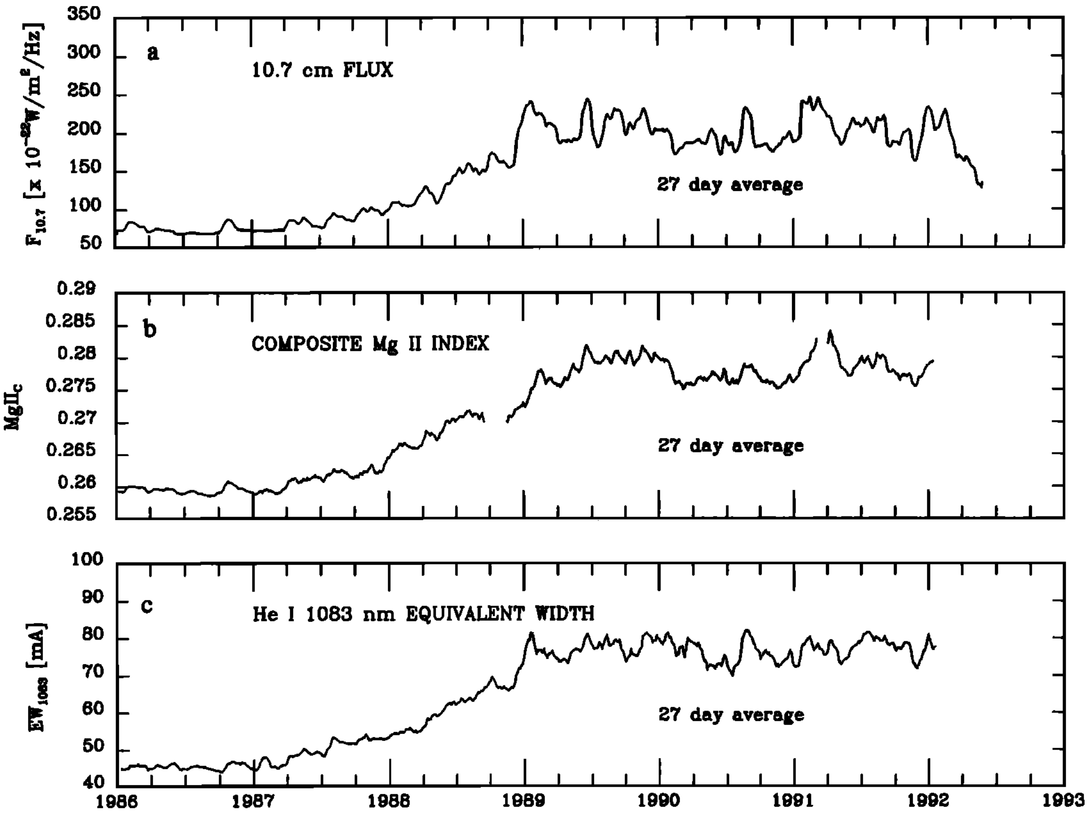

Fig. 7. Time series of daily values for (*a*) the 10.7-cm radio flux, (*b*) the composite Mg II index, and (*c*) the equivalent width of the He I 1083-nm line during solar cycle 22. All time series have been smoothed with a 27-day running average.

agreed with the Nimbus 7 scale factors to within approximately 10% in magnitude over the 180- to 260-nm range, where solar irradiance variability is expected to be greater than 1% over a solar cycle. This agreement is well within the combined standard derivations of the linear regression fits used to derive the scale factors, although the NOAA 9 results have significantly larger errors. The Nimbus 7 scale factors were derived using measurements from 23 solar rotations during 1978–1983 with typical peak-to-peak rotational amplitude of 3–6% in the Mg II index, whereas only 7 rotations from 1987 to 1989 with Mg II index amplitudes of 2–4% were available for NOAA 9. These differences, combined with the additional statistical noise in the NOAA 9 Mg II index discussed previously, led to NOAA 9 standard derivations that are typically a factor of 4 larger than the Nimbus 7 errors for the same wavelength. We have calculated NOAA 11 scale factors following the procedure of *Cebula et al.* [1992] using 14 rotations during 1989–1990, which have peak-to-peak variations of 3–7% in daily Mg II index values. The increased amplitude of the NOAA 11 Mg II index rotational modulation compared with NOAA 9 reduces the effect of the statistical noise in the Mg II index on the scale factor derivation. This improvement in signal-to-noise ratio, combined with the doubled size of the solar rotation data set used in the scale factor derivation, leads to agreement between the NOAA 11 and Nimbus 7 scale factors within 5% at wavelengths shortward of 260 nm. The NOAA 11 and NOAA 9 scale factor data sets agree with each other to within 5–10%.

The creation of a composite Mg II index data set from the Nimbus 7, NOAA 9, and NOAA 11 Mg II index data sets suggests the need for a corresponding composite scale factors data set to allow the estimation of solar ultraviolet irradiance variations. In order to ensure that each set of scale factors registers a consistent response to Mg II index variations, the Nimbus 7 and NOAA 11 scale factors were scaled to the NOAA 9 Mg II index absolute scale using the linear regression slopes derived previously. The NOAA 9 and NOAA 11 scale factors and corresponding errors were interpolated with a spline function from their respective wavelength scales ($\Delta\lambda \approx 0.145$ nm) to the Nimbus 7 wavelength scale ($\Delta\lambda \approx 0.2$ nm) to avoid introducing artificial structure by shifting data from a comparatively coarse grid to a finer grid. A set of composite scale factors was then constructed by taking the weighted average of all three data sets, where the derived scale factor value at each wavelength was weighted by the inverse square of the standard deviation associated with that value. This method tends to favor the Nimbus 7 scale factors, which generally have smaller error bars for reasons discussed previously, but also allows for changes to the Nimbus 7 results based on real differences in the NOAA 9 and NOAA 11 data.

Figure 9 shows the composite scale factors $F_S(\lambda)$, with 2σ error bars shown at selected wavelengths. All results shortward of 170 nm have been omitted from this figure due to the poor signal-to-noise ratio in the raw irradiance data. Significant features that can be seen in Figure 9 include the Si II line at 181.6 nm, the Al I absorption edge at 208 nm, the Mg II line at 280 nm, the Mg I line at 285 nm, and the Ca II K and H lines at 393 and 397 nm. Table 2 presents the composite scale factor values interpolated with a cubic spline function from the Nimbus 7 wavelength grid to intervals of $\Delta\lambda = 1$ nm

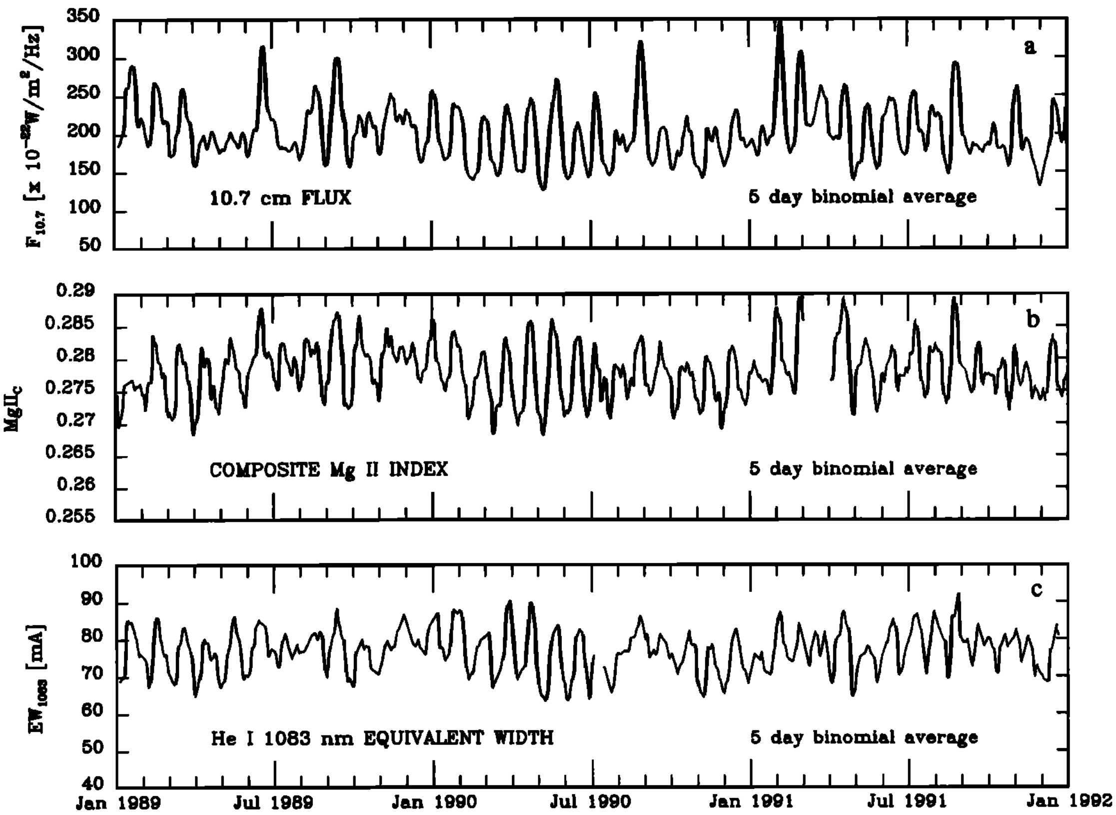

Fig. 8. Time series of daily values for (*a*) the 10.7-cm radio flux, (*b*) the composite Mg II index, and (*c*) the equivalent width of the He I 1083-nm line during the maximum of solar cycle 22. All time series have been smoothed with a 5-day binomial average.

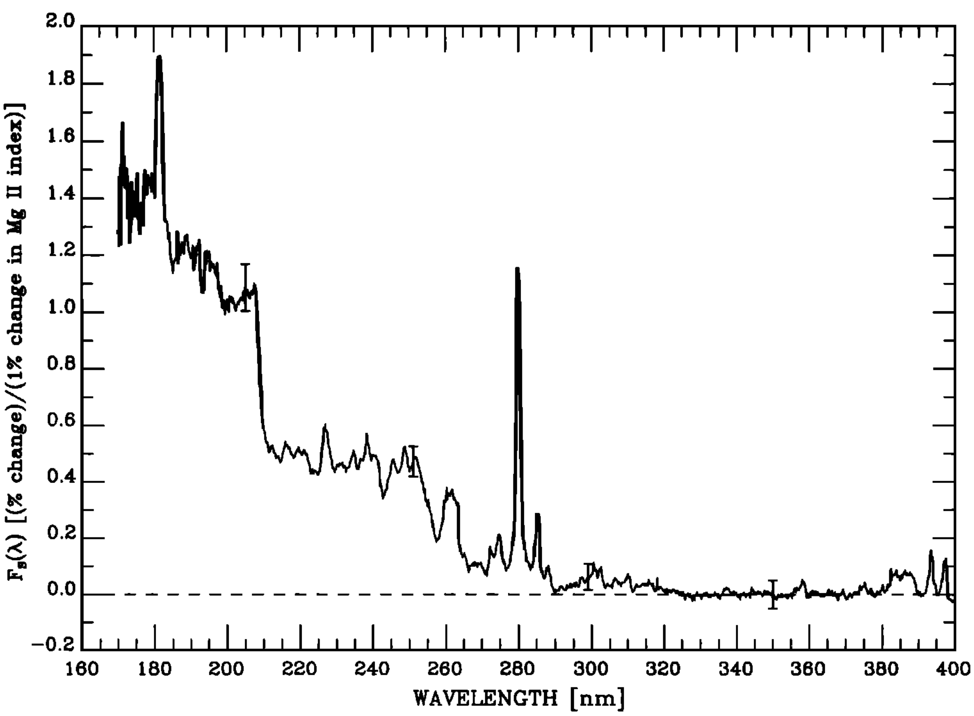

Fig. 9. Composite scale factors $F_S(\lambda)$ for solar ultraviolet variability in the wavelength region 170–400 nm at 0.2-nm resolution, expressed as percent change in irradiance for a 1% change in the Mg II index. The 2σ error bars are shown at 205, 250, 300, and 350 nm.

between 170 and 290 nm and intervals of $\Delta\lambda$ = 2 nm between 290 and 400 nm. The derived scale factor at the core of the Mg II line is greater than 1.0 because the scale factors at the wing wavelengths are slightly greater than 0.0, and we require the Mg II index to be defined as F_S = 1.0. Except for a few identifiable solar features the composite scale factors can be interpreted as showing no solar variability beyond 290 nm within the measurement noise. The close agreement in magnitude between the scale factors at 205 nm [F_S(205 nm) = 1.087 in Table 1] and the Mg II line [F_S(280 nm) = 1.125] supports the suggestion that the similar brightness temperatures of these features will lead to similar responses to irradiance changes.

Since the Mg II index scale factors for solar irradiance variations are derived from the strength of rotational modulations only, the validity of using these scale factors for estimating long-term irradiance variability remains to be proven. *Heath and Schlesinger* [1986] show a consistent wavelength dependence for irradiance variations determined from rotational modulations during different portions of solar cycle 21, which implies that the relative strength between different wavelengths is a constant. *White and Livingston* [1981] found no solar cycle variation in the chromospheric network at equatorial latitudes, except for contributions from the breakup of active regions which are the source of solar UV irradiance rotational modulation. Predictions of long-term solar irradiance changes using the Mg II index and scale factors will only be in error if the relationship between long-term and short-term variability at a given wavelength differs significantly from the relationship for the Mg II line. If the scale factors presented in Figure 9 are assumed to be applicable to irradiance variations on both solar rotational and solar cycle time scales, then the estimated variability of solar irradiance at 205 nm is up to 7% over a solar rotation and approximately 9.8 ± 0.7% (95% confidence level) during solar cycle 22, based on the scale factor values in Table 2 and the 27-day running average of the composite Mg II index shown in Figure 5. This result is in reasonable agreement with the estimates of *Schlesinger and Cebula* [1992] for Nimbus 7 SBUV irradiance measurements. The estimated solar irradiance change at 205, 250, and 300 nm from November 1978 to January 1992 using the composite Mg II index and scale factors is shown in Figure 10, with error bars representing the 95% confidence limit in the derived scale factors. The analysis of *Lean et al.* [1992] yields comparable results for the solar UV irradiance variability over a solar cycle, with excellent agreement in wavelength dependence. The difference in the estimated magnitude of the solar cycle variations (e.g., ΔF(205 nm) ≈ 7% by *Lean et al.* [1992], ΔF_{205} ≈ 8-9% by *Schlesinger and Cebula* [1992], ΔF_{205} ≈ 10% as presented here) will be reduced when a revised composite Mg II index data set is prepared incorporating the wavelength scale drift effects discussed previously, thus reducing the magnitude of the composite Mg II index variation for solar cycle 22.

CONCLUSIONS

The Mg II core-to-wing index data record gathered by the SBUV-series instruments now extends over more than one complete solar cycle. While the absolute value of the Mg II index on a given date is instrument-dependent, the temporal overlap of the data sets allows the use of linear regression

TABLE 2. Composite Scale Factors

λ, nm	F_s, λ	1σ, λ
170	1.308	0.078
171	1.494	0.102
172	1.452	0.101
173	1.433	0.095
174	1.337	0.093
175	1.376	0.116
176	1.276	0.091
177	1.299	0.092
178	1.412	0.082
179	1.464	0.060
180	1.400	0.072
181	1.814	0.056
182	1.801	0.057
183	1.323	0.062
184	1.281	0.061
185	1.137	0.048
186	1.183	0.058
187	1.201	0.057
188	1.246	0.058
189	1.274	0.053
190	1.189	0.053
191	1.154	0.057
192	1.222	0.047
193	1.106	0.045
194	1.167	0.062
195	1.209	0.053
196	1.169	0.045
197	1.127	0.046
198	1.059	0.048
199	1.038	0.049
200	1.045	0.045
201	1.041	0.041
202	1.027	0.033
203	1.036	0.042
204	1.049	0.039
205	1.087	0.041
206	1.051	0.037
207	1.063	0.040
208	1.035	0.044
209	0.751	0.050
210	0.586	0.030
211	0.543	0.026
212	0.525	0.020
213	0.503	0.019
214	0.491	0.023
215	0.482	0.023
216	0.542	0.022
217	0.517	0.022
218	0.493	0.029
219	0.502	0.019
220	0.506	0.019
221	0.513	0.025
222	0.477	0.028
223	0.440	0.027
224	0.441	0.021
225	0.423	0.016
226	0.508	0.025
227	0.604	0.021
228	0.524	0.033
229	0.447	0.019
230	0.455	0.024
231	0.458	0.020
232	0.460	0.020
233	0.448	0.019
234	0.471	0.022
235	0.499	0.042
236	0.445	0.023
237	0.480	0.023
238	0.533	0.031
239	0.520	0.021
240	0.489	0.020
241	0.484	0.027
242	0.383	0.034

TABLE 2. (continued)

λ, nm	F_s, λ	1σ, λ
243	0.354	0.023
244	0.404	0.023
245	0.462	0.033
246	0.465	0.020
247	0.432	0.020
248	0.475	0.032
249	0.509	0.026
250	0.436	0.020
251	0.473	0.027
252	0.482	0.021
253	0.427	0.023
254	0.363	0.020
255	0.314	0.032
256	0.281	0.026
257	0.207	0.024
258	0.201	0.018
259	0.253	0.019
260	0.332	0.022
261	0.358	0.022
262	0.352	0.024
263	0.316	0.038
264	0.167	0.038
265	0.138	0.017
266	0.097	0.018
267	0.101	0.016
268	0.101	0.017
269	0.111	0.018
270	0.098	0.021
271	0.072	0.020
272	0.122	0.024
273	0.143	0.018
274	0.178	0.046
275	0.200	0.035
276	0.112	0.037
277	0.093	0.017
278	0.149	0.044
279	0.405	0.065
280	1.125	0.028
281	0.361	0.079
282	0.154	0.035
283	0.099	0.017
284	0.110	0.031
285	0.276	0.061
286	0.144	0.070
287	0.056	0.012
288	0.096	0.020
289	0.033	0.034
290	0.017	0.021
292	0.026	0.017
294	0.037	0.015
296	.0.034	0.015
298	0.040	0.017
300	0.068	0.027
302	0.087	0.016
304	0.028	0.013
306	0.047	0.015
308	0.037	0.016
310	0.072	0.027
312	0.025	0.021
314	0.037	0.015
316	0.042	0.022
318	0.024	0.029
320	0.011	0.019
322	0.006	0.014
324	0.003	0.018
326	−0.001	0.018
328	−0.008	0.013
330	−0.006	0.013
332	0.001	0.014
334	0.008	0.014
336	0.000	0.019
338	0.011	0.013
340	0.004	0.014
342	0.007	0.013
344	0.019	0.030
346	0.010	0.015
348	0.007	0.010
350	−0.002	0.025
352	−0.009	0.019
354	−0.008	0.012
356	0.019	0.022
358	0.040	0.025
360	−0.013	0.012
362	0.013	0.018
364	−0.003	0.011
366	−0.003	0.012
368	−0.016	0.011
370	−0.011	0.011
372	−0.004	0.019
374	0.032	0.009
376	0.002	0.007
378	−0.007	0.012
380	0.025	0.015
382	0.027	0.039
384	0.079	0.039
386	0.076	0.008
388	0.073	0.014
390	0.006	0.008
392	0.012	0.025
394	0.107	0.057
396	0.013	0.034
398	0.048	0.038
400	−0.015	0.011

techniques to put the different Mg II index data sets on a common scale. The composite Mg II index data set created by this method suggests that solar cycle 22 is comparable in magnitude to cycle 21 as measured by long-term solar ultraviolet activity. By using scaling factors to relate Mg II index variability to solar irradiance changes at other ultraviolet wavelengths, the accuracy of solar UV irradiance inputs for atmospheric modeling use can be improved. The daily composite Mg II index values through January 1992 and the composite scale factors data set at 1.0-nm resolution are available on CD-ROM from the National Space Science Data Center (NSSDC) [*Larko and McPeters*, 1992]. An updated composite Mg II index data set, incorporating revisions to the SBUV/2 instrument characterizations, will be available in the future. Version 1.0 composite Mg II index data extended through December 1992 can be obtained from the authors. In principle, it should be possible to extend the Mg II index scale factors into the EUV wavelength region by using SME data (115–300 nm) and AE-E data (selected wavelengths between 30 and 120 nm), where regular solar measurements are not available for all of solar cycle 22. *Donnelly et al.* [1986] have suggested that the Mg II index can effectively model solar irradiance variations in this wavelength region because of the chromospheric origin of the Mg II line. Additional Mg II index data sets will also become available. Initial Mg II index results from the SUSIM instrument on UARS show good agreement with coincident NOAA 11 measurements [*Brueckner et al.*, 1992]. A similar quantity to the Mg II index has recently been derived from International Ultraviolet Explorer (IUE) spectra to study chromospheric activity in main sequence stars [*Fanelli et al.*, 1990; *Smith et al.*, 1991]. The next SBUV/2

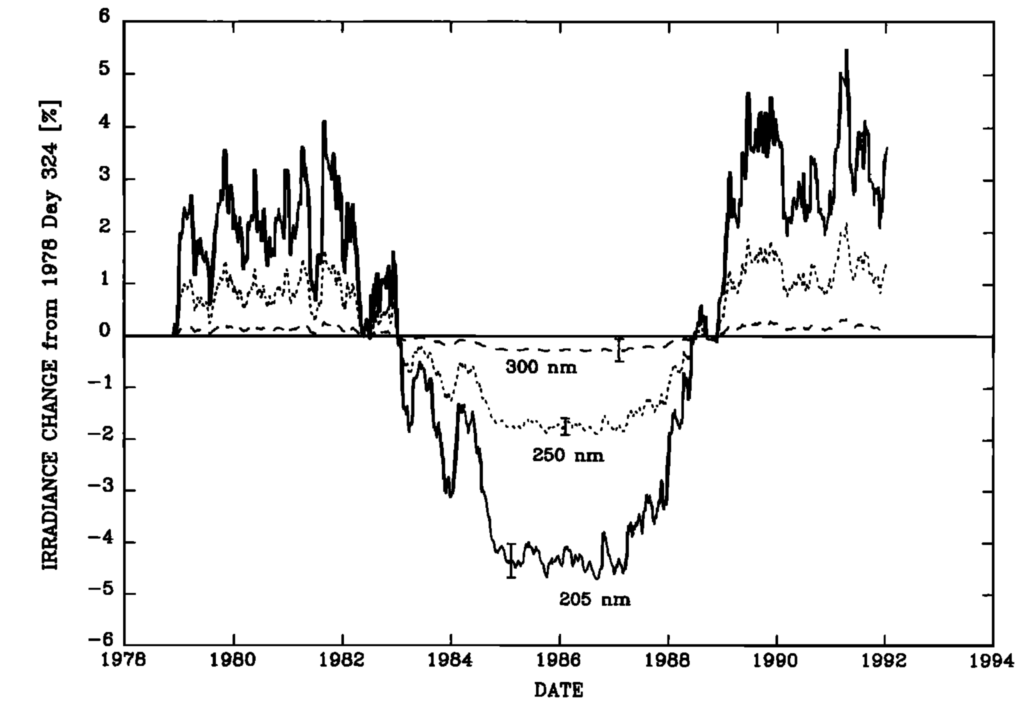

Fig 10. Estimated solar irradiance change at 205, 250, and 300 nm during 1978–1992 as computed from the composite Mg II index and scale factors. The error bars shown represent 95% confidence limits.

instrument is scheduled for launch in mid-1993, and additional SBUV/2 instruments are planned for launch at approximate 2-year intervals through 2000, well into solar cycle 23. Therefore the Mg II index from the SBUV-series instruments offers the opportunity to construct a valuable long-term record of solar middle ultraviolet variability.

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