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OBSERVED SOLAR NEAR UV VARIABILITY: A CONTRIBUTION TO VARIATIONS OF THE SOLAR CONSTANT

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Abstract

Continuous Measurements of the Solar UV have been made by an instrument on the Solar Mesosphere Explorer (SME) since October 1981. The results for the wavelength interval 200–300 nm show an irradiance decrease to a minimum in early 1987 and a subsequent increase to mid-April 1989. The observed UV changes during part of solar cycles 21–22 represent approximately 35 percent (during the decreasing phase) and 25 percent (during the increasing phase) of the observed variations of the solar constant for the same time period as the SME measurements.

Solar irradiance received by the earth–atmosphere system and its latitude distribution represents the ultimate driving force for the ocean/atmosphere circulation and long-term climate of the system. How the system generally responds to the imposed external driving force is reasonably well known. However, many of the details of this response are not as well understood. They originate, from complex spatial interactions and multiprocess non-linear feedbacks, both positive and negative (see, for instance HANSEN et al., 1984). Some theories of solar induced climate variations are based, in part, on whether perturbations of the solar irradiance are effective primarily at the earth's surface (sea surface) (e.g., REID and GAGE, 1988) or in the middle atmosphere (e.g., RAMANATHAN, 1982).

Many models of climate variability involve changes of the total solar irradiance, the solar constant, without regard to the wavelength dependence of such changes. The atmospheric penetration of solar radiation, however, is a significant function of wavelength. It is, therefore, important to determine the spectral distribution of the different contributions to observed solar constant variations. As far as we know, measurements of the time variations of these contributions are currently available only for UV wavelengths. If the recent suggestion (KUHN et al., 1988) of latitude-dependent solar surface temperature variations contribute significantly to the observed solar constant changes, it should be possible to verify this contribution by monitoring the solar irradiance spectral distribution in the visible and near-infrared. Although solar irradiance below 300 nm represents only 1.1 percent of the solar constant, time variations of its relative energy are significantly larger than those of the solar constant (see, for instance, LONDON et al., 1984).

Estimates of the solar constant and its temporal changes have been made using ground-based, balloon, rocket, and satellite measurements (e.g., FRÖHLICH, 1977). The most consistent set of time monitored measurements made so far are the results of satellite observations from two different cavity radiometer type experiments: the Earth Radiation Budget (ERB) Nimbus-7 (e.g., HICKEY et al., 1988) and the Active Cavity Radiometer Irradiance Monitor, Solar Maximum Mission (ACRIM I SMM) (e.g., WILLSON et al., 1986; WILLSON and HUDSON, 1988) programs. Each instrument is capable of observing the total solar irradiance over a spectral range that extends from the short UV to the far IR. The ERB Nimbus-7 measurements started in November 1978, the ACRIM I SMM measurements started in February 1980. Both programs continue to function as of 1 March 1989. For the time period 1980–1987 they each reported approximately 300 mean daily measurements per year. Although there is an average 0.2 percent difference in reported solar constant values, the data from the two systems track each other quite well over the long period of overlapped observations. When the data were subjected to an 81-day smoothing filter, the correlation between the two observation sets was +0.93 for the period Jan 1980–May 1986, largely as a result of the consistent downward trend shown by the two data sets. For the early period of solar cycle 22, (Jun 1986–Oct 1987) the correlation fell to +0.71. For the daily means, the correlations were +0.79 and +0.22 for the two periods respectively. The 81-day smoothed data sets are shown for the period Jan 1980–May 1988 in Fig. 1. Additional ACRIM I data to mid–1988 (WILLSON and HUDSON, 1988), not shown in Fig. 1, also indicate a continued sharp increase in solar constant values starting in early 1987.

Measurements of the time variations of solar UV irradiance have been recently reviewed by (LEAN, 1987). The most relevant observations available for estimating the contribution of long period UV irradiance variations to those of the solar constant are observations derived from the UVS Solar Mesosphere Explorer (SME) instrument. These SME measurements cover the wavelength interval 120–300 nm. The observations started in October 1981 and were terminated in mid–April 1989. Details of the SME experiment, including relative accuracies at different wavelengths are discussed in ROTTMAN, 1987 and references therein. An estimate of UV (175–400 nm) variations (HEATH and SCHLESSINGER, 1984) is also derived from measurements from the Solar Backscatter Ultraviolet (SBUV) instrument on Nimbus–7.

The observed day–to–day solar constant measurements are quite noisy, and we, therefore, used an 81–day running mean as a filter for both the SME and ERB Nimbus–7 data sets covering the time interval 1 Jan 1982 to 30 Apr 88, the coincident period for which data from both programs are available.

The 81–day smoothed time variations of the SME total solar irradiance for the spectral interval 200–300 nm and the ERB Nimbus–7 solar constant values for the 6–1/3 year period are shown in Fig. 2. The UV values show an average decrease from Jan 1982 to a minimum in mid–March 1987. During this period there is an indicated oscillation with an average period of about 230 days and decreasing amplitude up to the time of minimum. This oscillation is found at almost all of the 5 nm subintervals contributing to the total SME curve given in Fig. 2. with very good coherence in phase. The ERB Nimbus–7 solar constant data show long–term decreasing values up to early 1986, some increase to mid–1987 and then a pronounced rise in the solar constant values consistent with the UV increase. There is, however, only a loosely corresponding shorter period oscillation analogous to that seen with the solar UV data.

Slope of Trend Line for SME UV Solar Irradiance(*10(-4) W/m^2 yr):

Wavelength (nm)	Slope (a)	Slope (b)
200-205	-4.9	10.9
205-210	-9.2	13.1
210-215	-10.7	31.2
215-220	-16.6	32.5
220-225	-37.5	26.3
225-230	-17.9	46.8
230-235	-29.0	24.7
235-240	-25.1	64.5
240-245	-33.9	29.2
245-250	-16.8	30.3
250-255	-17.8	35.5
255-260	-36.0	36.7
260-265	-32.5	26.4
265-270	-60.5	76.8
270-275	6.0	117.5
275-280	-52.1	434.3
280-285	-38.6	42.1
285-290	-41.6	117.7
290-295	-101.3	76.8
295-300	-38.6	105.3
200-300	-609.1	1406.8
ERB (SC)	-1797.0	6189.0
ACRIM (SC)	-1957.7	531.5

(a) 1 Jan 1982 - 30 May 1986
(b) 1 Jan 1987 - 30 Apr 1988

The UV and solar constant data sets were divided into two intervals covering the joint descending and ascending period of the observed irradiance values in each set. SME observed data were averaged over 5 nm intervals. The computed slope for each 5 nm interval for the two different period as well as the total spectral variation (200–300 nm) and the associated

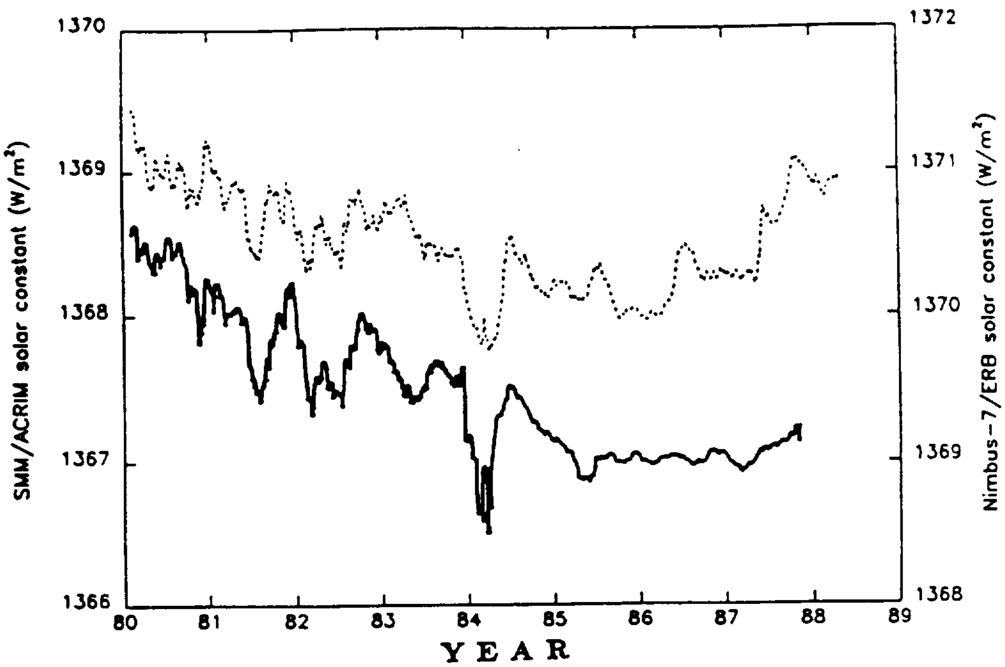

Fig. 1. Solar constant observations, 81–day running means, from the ACRIM I (heavy line) and ERB (dashed line) experiments.

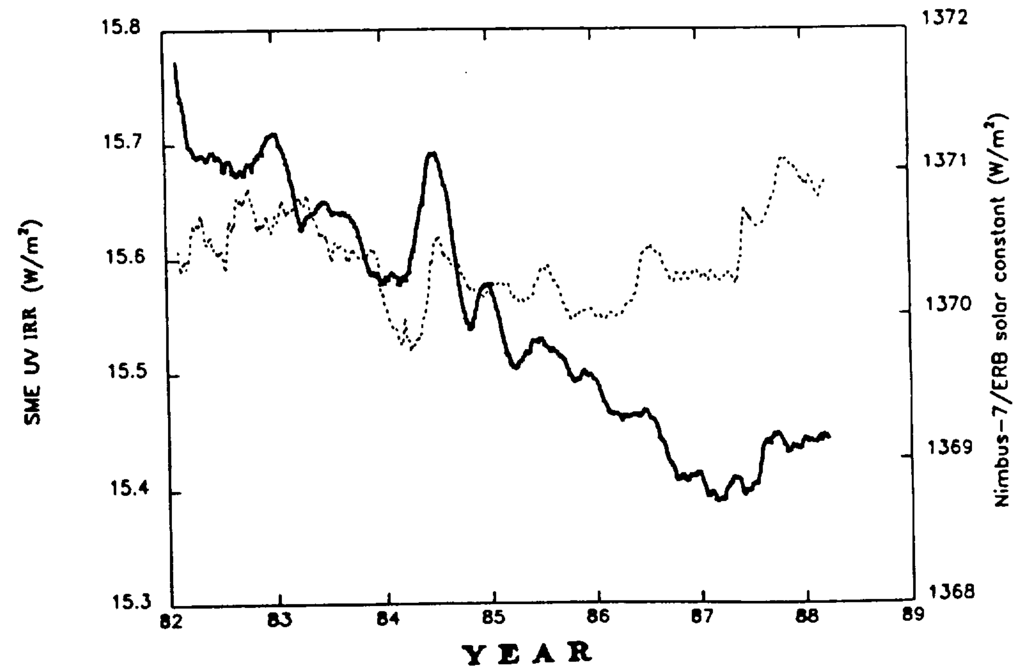

Fig. 2. Solar UV (200–300 nm) (heavy line) and ERB solar constant measurements (dashed line) 81–day running means for the period starting Jan 1982. (See text for details).

ERB change for each period are given in Table 1. For the negative phase of solar cycle 21 the UV decrease is about -0.06 $Wm^{-2}yr^{-1}$. The observed solar constant decrease is about 0.180 $Wm^{-2}yr^{-1}$ (ERB) or 0.196 $Wm^{-2}yr^{-1}$ (ACRIM) giving an average UV contribution to the solar constant change during this period of about 32 percent. For the relatively short period shown for the increasing phase of cycle 22, the values are 0.14 $Wm^{-2}yr^{-1}$ and 0.62 $Wm^{-2}yr^{-1}$ (ERB), giving a percent contribution of the UV irradiance to the observed solar constant increase of about 22.7 percent. As can be seen from the results shown in Table 1, most of the large contributions are contained in the wavelength region 265–300 nm, although, for reasons unknown to us at present, there is a small increase in the spectral interval 270–275 nm. Most of the UV energy beyond 265 nm is absorbed in the lower and middle stratosphere (20–40 km) (see, for instance, BRASSEUR AND SOLOMON, 1986). Thus, we see that a significant portion (~25–35 percent) of the observed solar constant variation is absorbed at levels above the troposphere where there may be important effects on the time varied radiation budget. These effects need to be included in models of solar influences on climate variations.

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