CURRENT SOLAR SPECTRAL IRRADIANCE OBSERVATIONS : A REVIEW

Paul C. SIMON
Institut d'Aéronomie Spatiale de Belgique
3, avenue Circulaire, B-1180 Bruxelles, Belgium

Abstract

Solar spectral irradiance measurements in the ultraviolet part of the solar spectrum will be reviewed and their divergences will be discussed. Deduced variations over the rising phase of solar cycle 21 will be presented, showing that they are still masked by the uncertainties in available observations beyond 170 nm. Future observational needs for climatology and aeronomy will be outlined.

INTRODUCTION

An accurate knowledge of ultraviolet solar irradiance and its variations is fundamental in aeronomy and in climatology of the upper atmosphere. Indeed, ultraviolet solar irradiation in wavelengths ranging from 120 to the visible part of the spectrum initiates the photochemical processes of the neutral constituants in the lower thermosphere and in the middle atmosphere.

The purpose of this work is to present the recent ultraviolet solar irradiance measurements obtained during the rising phase of solar cycle 21 and to discuss their divergences in terms of possible solar variability.

THE H I LYMAN α EMISSION LINE

Irradiance measurements of H I Lyman α line during the rising phase of solar cycle 21 have been performed by satellite and by rockets. The EUVS experiment on board the AE-E satellite provided observations from June 1977 leading to an increase of a factor of 3 from minimum to maximum conditions of solar activity with an estimated minimum value of 3×10^{11} $h\nu/s.cm^2$ (Hinteregger et al., 1981). These observations are not in agreement with those obtained by rocket by Mount et al. (1980) and Mount and Rottman (1981). Measurements made since 1971 are reported on figure 1 for comparison purposes showing important discrepancies mainly in 1979 and in 1980. The dispersion in the rocket data during the previous cycle is also well illustrated. A correct interpretation of these observations should obviously take into account the irradiance variability with the rotational period of the sun because rocket measurements correspond to snapshots. On the other hand, it clearly appears that the long-term variability deduced from the OSO 5 satellite during solar cycle 20 implies smaller changes with solar activity than the one deduced from the AE-E satellite during solar cycle 21.

Bossy and Nicolet (1981) have analysed all the available satellite data and have adjusted the measurements of Hinteregger et al. (1981) to fit a linear relationship between H I Lyman α irradiance and the 10.7 cm flux. According to their formula, the variability over one solar cycle is only a factor of 2 with a minimum value of 2.5×10^{11} $h\nu/s.cm^2$.

Consequently, the H I Lyman α irradiance value is still controversial as well as its long-term variability (see the Hinteregger's paper in this volume).

THE WAVELENGTH INTERVAL 135-175 NM

During solar cycle 20, several rocket measurements have been made in this wavelength interval. Heroux and Swirbalus (1976) and Samain and Simon (1976) have published the lowest full disk values which refer to a quiet solar disk. Rottman (1981) has recently proposed revised values for observations performed in 1972 and 1973. With 3 other flights made in 1975, 1976 and 1977, he has defined a so-called reference spectrum corresponding to minimum condition between solar cycle 20 and 21, by taking an average value of the 5 flights.

The ratios of irradiance values integrated over 5 nm from 135 to 175 nm taking as a reference the mean spectrum of Rottman (1981) are given on figure 2 which clearly shows that the previous values of Heroux and Swirbalus (1976) and Samain and Simon (1976) are 40 percent lower than the reference spectrum. On the other hand, the divergences between the 5 observations of Rottman (1981) give a good idea of the reproductibility reached in this wavelength range by means of snapshot measurements which include the variability related to the 27-day solar rotational period.

The data obtained for high solar activity level by Mount et al. (1980) and Mount and Rottman (1981) are systematically higher than the reference spectrum. The differences represent true long-term variability which is confirmed by the AE-E satellite observations reported by Hinteregger et al. (1981). Nevertheless, data of Heath (1980) obtained in 1978 for intermediate level of solar activity are in better agreement with the minimum values proposed by Rottman (1981) than with the values of Mount et al. (1980). They become even lower beyond 170 nm. Consequently, these differences cannot be interpretated in term of solar variability. Figure 3 gives the ratio of irradiances for maximum to minimum activity obtained from the LASP rockets and by the AE-E satellite up to 190 nm.

It is clear from the available data that solar irradiance values refering to a quiet sun exhibit very large discrepancies, reaching a factor of 2 in the wavelength interval 135-175 nm. In addition, variability over the solar cycle is qualitatively evident but further observations are still required in order to give accurate value of variability especially around 170 nm.

THE WAVELENGTH INTERVAL 175-210 NM

Solar irradiance and its variability are very poorly known in this wavelength range. Figure 4 gives the ratios of several observed irradiance values integrated over 5 nm to those of Samain and Simon (1976) corresponding to a quiet sun. Differences at shorter wavelengths could probably be due to long-term solar variability. There are no systematic divergences with wavelength and in addition measurements corresponding to similar level of solar activity are not consistent. It should be mentioned that according to Figure 3 and to the plage model of Cook et al. (1980) the variability during the rising phase of solar cycle 21 beyond 180 nm does not exceed 30 percent if ratios from 180 to 190 nm obtained on the basis of Rottman's measurement are excluded because of larger errors. In addition the data of Mount et al. (1980) are not reliable beyond 190 nm because of experimental problems (Mount and Rottman, 1981). Consequently, the quantitative variation over the solar cycle is still masked by the uncertainties of all measurements in this wavelength range.

THE SPECTRAL REGION BEYOND 210 NM

The wavelength interval 210-330 nm is extensively discussed by Simon et al. in this volume. Beyond 330 nm, new irradiance values are also presented in this volume by Neckel and Labs. These latter values which supercede those previously published by Labs and Neckel (1970) are probably the most reliable in the near ultraviolet and in the visible. According to Table 3 in Simon (1981), they are in good agreement with the observation reported by Heath (1980). The measurements of Arvesen et al. have to be carefully adjusted because of errors in their wavelength scale below 400 nm and of uncertainties due to changes in the spectral irradiance scale of the National Bureau of Standards in 1973.

Long-term variability in this spectral range is generally considered as being negligible from the aeronomic point of view and is also masked by the uncertainties in available measurements. Variations related with the 27-day rotational period of the sun have been recently reported by Heath (1980) from Nimbus 7 observations.

CONCLUSIONS

The current position of irradiance measurement accuracies and of discrepancies between relevant observations is summarized in Table 1. Possible long-term variations are given on the basis of recent measurements performed during solar cycle 21. The requirement related to aeronomy and climatology are specified for future observations for which important improvements are badly needed in order to reduce the uncertainties (see for example Simon, 1981 and NOAA, 1980).

TABLE 1 : Uncertainties on solar ultraviolet irradiance measurements and future needs.

	WAVELENGTH INTERVALS (NM)					
	Ly α	135-175	175-210	210-240	240-330	330-400
QUOTED ACCURACY	30%	30-20%	30-20%	20-10%	10-4%	4-2%
DISCREPANCIES	200%	200%	50%	20%	20%	8%
ACHIEVED ACCURACY	± 30%	± 30%	± 20%	± 15%	± 10%	± 5%
UNCERTAINTIES ON	LAMPS :	10%	6%	5%	3%	2%
IRRADIANCE STDS	←———— SYNCHROTRON : 2-5% ————→					
27-D VARIABILITY	30%	30-4%	4%	4-2%	2-1%	< 1%
11-Y VARIABILITY	200% ?	100-20%	20-0%	←—— NEGLIGIBLE ——→		
ACCURACY	10%	5%	5%	5%	5-2%	2%
GOALS						
PRECISION	5%	5%	1%	1%	< 1%	< 0.1%

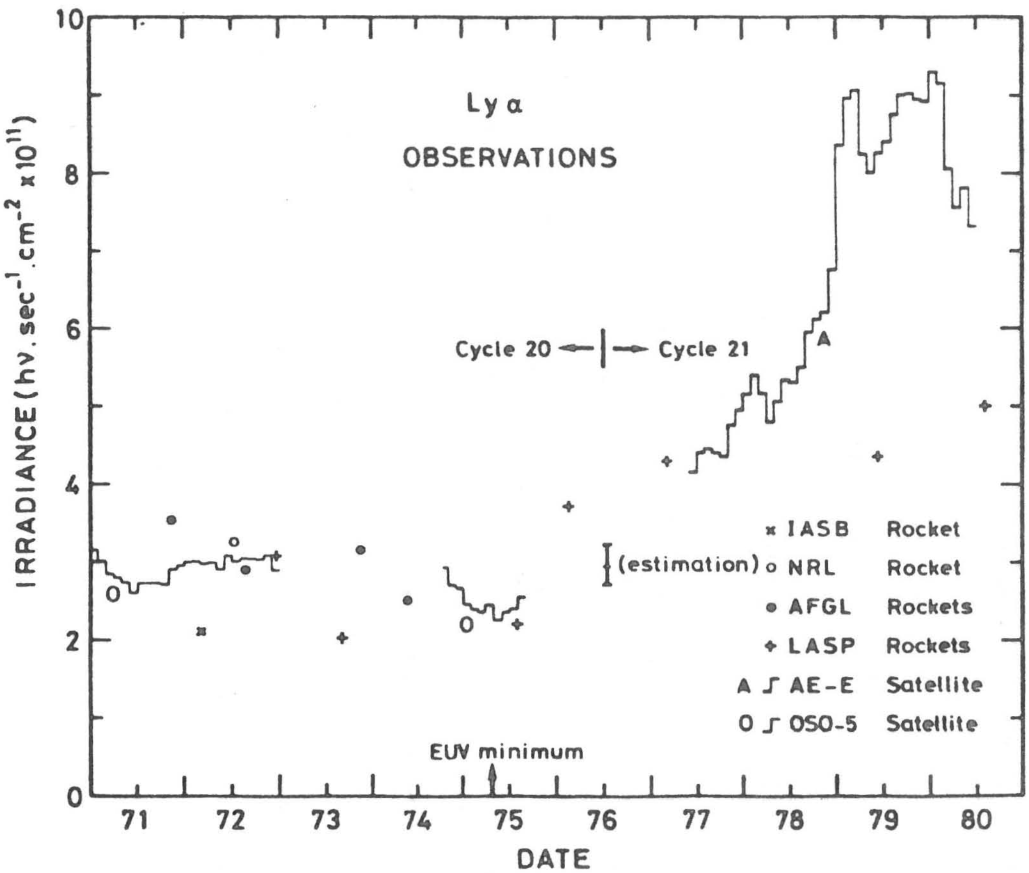

Fig. 1.- Comparison of HI Lyman α irradiance measured since 1971. References : IASB : Ackerman and Simon (1973); NRL : Prinz (1974); AFGL : Heroux and Higgins (1977); LASP : Mount et al. (1980), Mount and Rottman (1981); AE-E : Hinteregger et al. (1981); OSO-5 : Vidal-Madjar (1975), Vidal-Madjar and Phissamay (1980).

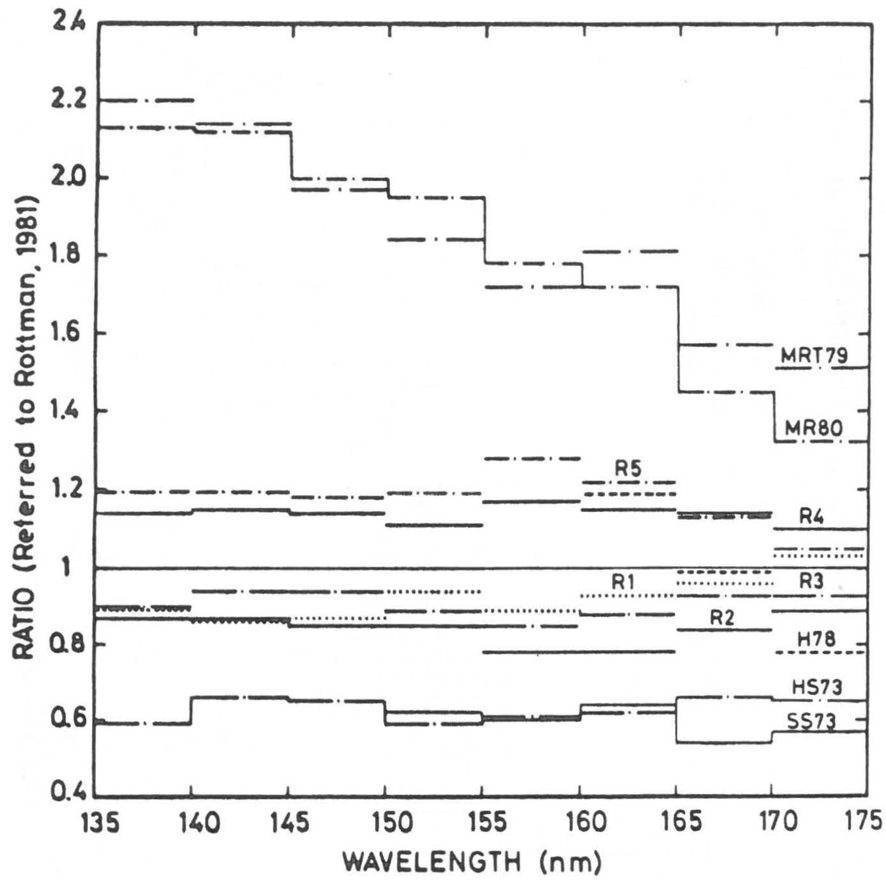

Fig. 2.- Observed solar irradiance in the spectral range 135-175 nm expressed as ratios relative to the solar reference spectrum of Rottman (1981). Values are integrated over 5 nm intervals. The labeling is as follows : HS73 : Heroux and Swirbalus (1976); SS73 : Samain and Simon (1976); R1, R2, R3, R4, R5 : Rottman (1981); H78 : Heath (1980); MRT Mount *et al.* (1980); MR80 : Mount and Rottman (1981).

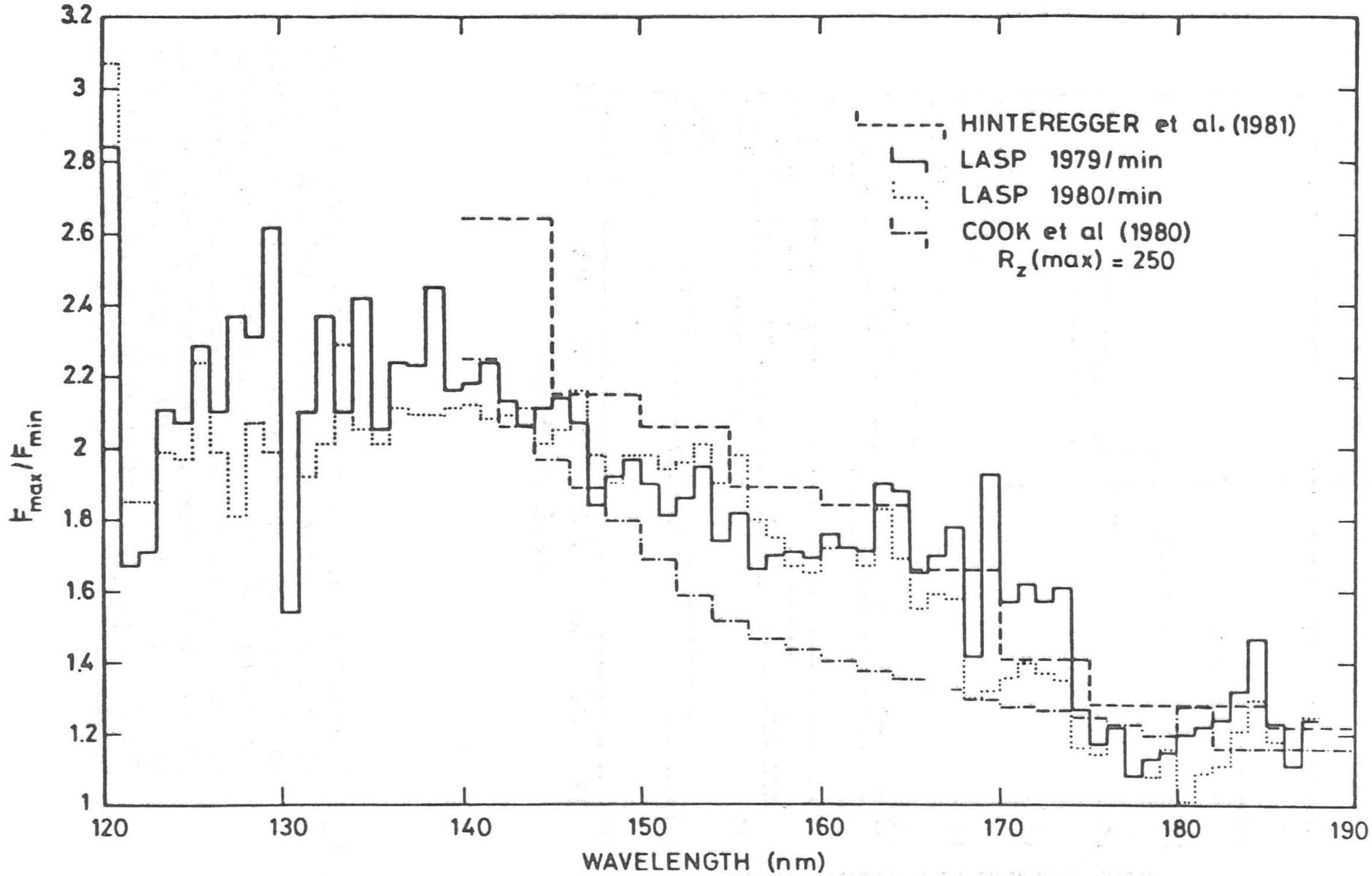

Fig. 3.- Solar irradiance variability related to the rising phase of solar cycle 21 from 120 to 190 nm.

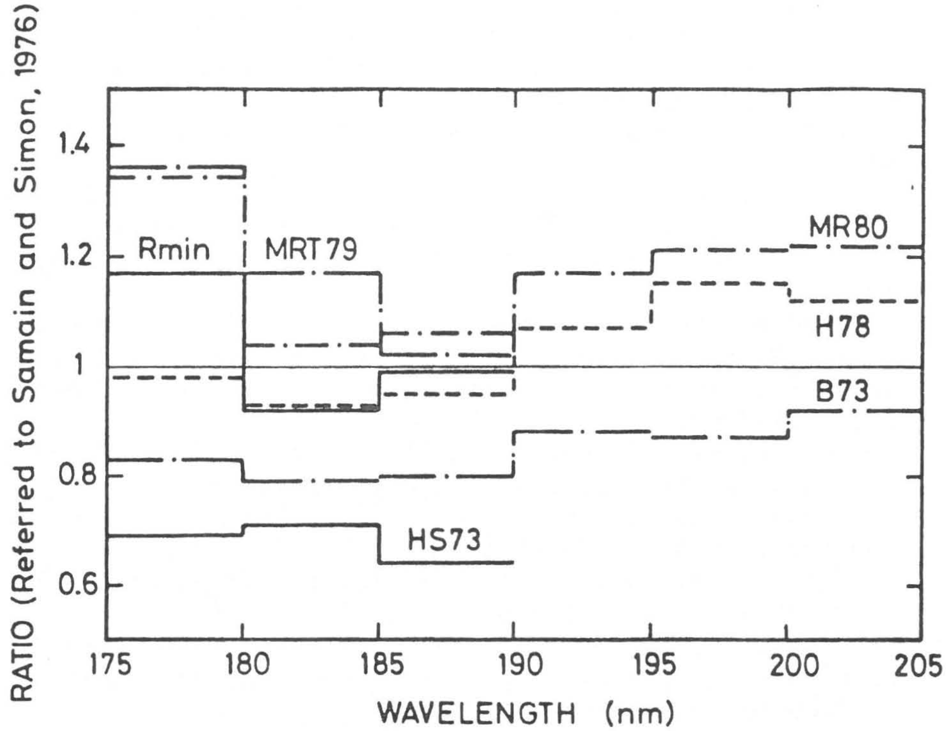

Fig. 4.- Observed solar irradiance in the spectral range 175-205 nm expressed as ratios relative to Samain and Simon (1976). Values are integrated over 5 nm intervals. The labeling is as follows : HS73 : Heroux and Swirbalus (1976); B73 : Brueckner et al. (1976); Rmin : Rottman (1981); H78 : Heath (1980); MRT : Mount et al. (1980); MR80 : Mount and Rottman (1981).

REFERENCES

Ackerman, M. and P. C. Simon, Rocket measurements of solar fluxes at 1216 Å, 1450 Å and 1700 Å, Solar Physics, 30, 345-350, 1973.

Arvesen, J. C., R. N. Griffin and B. D. Pearson, Jr., Determination of extraterrestrial solar spectral irradiance from a research aircraft, Appl. Optics, 8, 2215-2232, 1969.

Broadfoot, A. L., The solar spectrum 2100-3200 Å, Astrophys. J., 173, 681-689, 1972.

Brueckner, G. E., O. K. Moe, and M. E. Van Hoosier, Absolute solar ultraviolet intensities and their variations with solar activity. I. The wavelength region 1750-1210 Å , Astrophys. J., 209, 935-944, 1976.

Bossy, L. and M. Nicolet, Planet. Space Sci., 1981, in press.

Cook, J. W., G. E. Brueckner and M. E. Van Hoosier, Variability of the solar flux in the far ultraviolet 1175-2100 Å, J. Geophys. Res., 85, 2257-2268, 1980.

Heath, D. F., in Proceedings of the International Conference on Sun and Climate, Centre National d'Etudes Spatiales, 445, 1980.

Heroux, L. and J. E. Higgins, Summary of full-disk solar fluxes between 250 and 1940 Å, J. Geophys. Res., 82, 3307-3310, 1977.

Heroux, L. and R. A. Swirbalus, Full-disk fluxes between 1230 and 1940 Å, J. Geophys. Res., 81, 436-440, 1976.

Hinteregger, E. E., K. Fukui and B. R. Gilson, AE-E observations and associated models of solar irradiance, (2) wavelengths below 120 nm, J. Geophys. Res., 1981, in press.

Labs, D. and H. Neckel, Transformation of the absolute solar radiation data into the international practical temperature scale of 1968, Solar Physics, 15, 79-87, 1970.

Mount, G. N. and G. J. Rottman, The solar irradiance near maximum: 15 July 1980, J. Geophys. Res., 1981, in press.

Mount, G. N., G. J. Rottman and J. G. Timothy, The solar spectral irradiance 1200-2550 Å at solar maximum, J. Geophys. Res., 85, 4271, 1980.

NOAA, Proceedings of the Workshop on Solar UV Irradiance Monitors, Space Environment Lab., NOAA, Boulder, Colorado, 1980.

Prinz, D. K., The spatial distribution of Lyman-alpha on the sun, Astrophys. J., 187, 369-375, 1974.

Rottman, G. L., Rocket measurements of solar spectral irradiance during solar minimum, 1972 to 1977, J. Geophys Res., 1981, in press.

Samain, D. and P. C. Simon, Solar flux determination in the spectral range 150-210 nm, Solar Phys., 49, 33-41, 1976.

Simon, P., article submitted to Solar Phys., 1981.

Vidal-Madjar, A., Evolution of the solar Lyman alpha flux during four consecutive years, Solar Phys., 40, 69-86, 1975.

Vidal-Madjar, A. and B. Phissamay, The solar Lyman alpha flux near solar minimum, Solar Phys., 66, 259-271, 1980.