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Achievements in calibration of solar ultraviolet irradiance instruments in the 1980's

by

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FOREWORD

This note summarizes the paper presented at the 8th workshop on the "Vacuum Ultraviolet Radiometric Calibration of Space Experiments" held in Boulder (USA), March 18-19, 1987.

AVANT-PROPOS

Cette note résume la communication présentée au huitième "workshop on the Vacuum Ultraviolet Radiometric Calibration of Space Experiments" qui s'est tenu à Boulder (USA) les 18 et 19 mars 1987.

VOORWOORD

Deze nota vormt de samenvatting van de mededeling voorgesteld tijdens de achtste "workshop" omtrent "Vacuum Ultraviolet Radiometric Calibration of Space Experiments" gehouden te Boulder (USA), op 18 en 19 maart 1987.

VORWORT

Diese nota ist die Zusammenfassung der Mitteilung vorgestellt während der achte "workshop" über "Vacuum Ultraviolet Radiometric Calibration of Space Experiments" gehalten in Boulder (USA), am 18 und 19 März 1987.

ACHIEVEMENTS IN CALIBRATION OF SOLAR ULTRAVIOLET IRRADIANCE INSTRUMENTS IN THE 1980'S

by

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ABSTRACT

Calibration techniques used in the 1980's are shortly described and strategy for solar ultraviolet irradiance measurements scheduled in the next decade is proposed.

RESUME

Les techniques d'étalonnage utilisées dans les années 1980 sont brièvement rappelées et une stratégie pour la mesure de l'éclairement énergétique du rayonnement ultraviolet solaire au cours de la prochaine décennie est proposée.

SAMENVATTING

De ijkingstechnieken gebruikt in de jaren 1980 worden kort beschreven en een plan voor de meting van de stralingssterkte van de ultraviolette zonnestraling tijdens het volgende decennium wordt voorgesteld.

ZUSAMMENFASSUNG

Die Eichungstechniken gebraucht in den Jahren 1980 werden kurz beschrieben und ein Plan für die Messung der Bestrahlungsstärke der ultravioletten Sonnenstrahlung während des nächsten Jahrzehntes wird vorgestellt.

The absolute measurements of ultraviolet solar irradiance requires, to be reliable, several experimental conditions. One of the most important concerns the laboratory radiometric calibration particularly critical for space observations because of the harsh environment for such experiments. Wavelengths below 300 nm are not measurable from ground based observatory and, therefore, space vehicles including balloons, rockets, satellites and now the space shuttle are needed to extend the wavelength domain in the ultraviolet. All vehicles have their own limitations. For instance, balloon observations are limited in wavelength range due to the residual absorption at 40 km altitude. Absorptions from ozone and oxygen and extinction due to Raleigh scattering have to be removed from the measured irradiances in order to obtain the extraterrestrial flux values. Calibrations can be performed before and after each flight. In-flight calibrations are possible due to the duration of the balloon flight (several hours) but were never performed. Rocket measurements cover an extended wavelength range but are made in a very harsh environment. Post-flight calibrations are only possible in case of safe recovery of the instrument. In-flight calibrations are difficult to implement because of the short duration of the observations (about 10 min.) and the weight and power restriction. Satellite observations are well adapted for long-term monitoring but because of severe aging in the instrument responsivity in orbit, periodic recalibration by using simultaneous rocket measurements are required. Up to now, in-flight calibrations were not integrated in satellite experiments. Obviously, post-flight calibrations are not possible without retrieval with the space shuttle.

The knowledge of solar ultraviolet irradiance was very poor until 1981. Uncertainties in observations varied between 10 and 20 percent for most of the published irradiance measurements performed from space (Simon, 1978 ; Simon, 1981). In addition, their divergences were larger than the quoted accuracies and their uncertainties much larger than the accuracies of current calibration sources used at that time.

The irradiance transfer standards available from the National Bureau of Standards (NBS) in 1980 are presented in table 1 (Madden, 1980). Considering the level of uncertainties on transfer sources which varies from about 6 % to 3 % in the wavelength range 165-400 nm, the accuracies of solar irradiance measurement were expected to be in the same range. The gaps between the current accuracy goals and the achieved uncertainties for the data were actually reaching factors varying from 2 to 7 depending upon wavelength and type of observation. At that time, the Synchrotron Users Radiation Facility (SURF) was not yet used for calibration of solar irradiance experiments.

The causes of these gaps have been discussed several times during workshop discussions reported by Donnelly (1980) and Simon (1982). As far as the calibration is concerned, the following points were raised :

1. intercalibrations of instruments are very strongly encouraged in order to understand the origin of errors in the diversity of calibration techniques and standards and to assess any differences between the flight data.
2. The instruments should be designed and constructed to make possible
   a/ a calibration procedure minimizing the so-called calibration transfer errors and
   b/ the use of the NBS SURF calibration facility.
3. The intercomparison of irradiance standards should be activated in order to decrease the systematic errors between the different radiometric scales. Interactions between standard builders and standard users have to be promoted.

The only measurement not concerned with the gap between irradiance and calibration source uncertainties are the ground-based observations reported by Neckel and Labs (1984) and performed in the 1960's for wavelengths greater than 330 nm. The irradiance values were given with systematic errors not exceeding 1 %. Actually, radiances of the center of the solar disk have been compared, during the observations, with those of absolute calibrated tungsten ribbon lamps. Irradiance values were deduced from center-to-limb variation and the mean solid angle of the Sun. The comparison lamps were calibrated with a black body at the Heidelberg Observatory. The solar spectrometer itself was used for transferring the radiometric scale on the comparison sources.

In the beginning of the 1980's, the calibrations of rocket observations taken in charge by the "Goddard Space Flight Center" (GSFC) and the "Laboratory for Atmospheric and Space Physics" (LASP, University of

Colorado) have been performed by using the NBS SURF calibration facility for their flights, respectively in 1981 and 1982, and the following campaigns. This important step forward in the calibration procedure immediately reduced the data uncertainties to 8 % at 2 sigma level (see the error budget in Mount and Rottman, 1983).

On the other hand, in the late 1970's, two proposals for Spacelab 1 and 2 missions were based on the measurement principle used by Labs and Neckel (1962). The Spacelab 1 and 2 instruments, namely the "Solar Spectrum" and "Solar Ultraviolet Spectral Irradiance Monitor" (SUSIM) have reported new data referring respectively to the black body of the Heidelberg Observatory (Labs et al., 1987) and to the SURF (Van Hoosier et al., 1987). Irradiance values are now available with an accuracy of 5.1 % at 240 nm (Solar Spectrum) and 3.5 % over the whole range (SUSIM). The quoted wavelength represents the lower limit for using the black body as a primary standard in the ultraviolet. In both cases, a new instrument was carefully designed, including in-flight transfer sources, and an appropriate calibration strategy was defined. In one case (Solar Spectrum), very stable transfer sources were assembled in a portable calibration equipment in order to check periodically the instrument responsivity during several years and to detect any change and/or aging in the instrumentation during its lifetime.

The intercalibration in the laboratory of solar spectral irradiance instruments was never realized in spite of the recommendation which came out from the aforementioned workshops. The main reasons are probably :

1. the lack of time left during the integration tests for the Spacelab missions ;
2. the lack of funds for performing this work.

Due to the delays in the schedules of the future flights, this problem could now be addressed in a first step by the exchange of transfer standards in order to perform the first intercalibration between the different laboratories. The quartz iodine lamps (FEL), traceable to various primary standards, would be good candidates because of their stability and reproducibility and the skill of all laboratories in using these calibration techniques. Other sources like the deuterium lamps are also recommended in order to extend wavelength range. The next steps might include the instruments intercalibration by using a primary standard like the SURF.

In conclusion, progress in solar ultraviolet irradiance measurements has been realized mainly by improving the calibration procedures :

1. Since 1981, rocket and space shuttle-born solar spectrometers have been calibrated against primary standards like the SURF calibration facility at NBS and the black body at the Heidelberg Observatory.
2. The uncertainties on SURF irradiance have been reduced from 5% (1980) to 1.3% (1985).
3. The radiometric scale defined by the primary standard has been transferred to the portable and in-flight calibration sources by using the solar instrument itself.
4. The instrument responsivity has been periodically carefully checked by means of calibration sources giving repeatable outputs (better than 1%) during each calibration run.

Further studies are still needed for the in-flight transfer sources in order to reach the required repeatability and to extend the wavelength range to EUV.

On the other hand, the following topics have still to be addressed by the end of the 1980's :

1. The intercomparison of radiometric scale
2. The intercalibration of solar spectrometers to be flown in the 1990's.

TABLE 1

Spectral Irradiance Transfer Source Standards

Source	Wavelength range (nm)	Uncertainties
Deuterium lamps	165-350	6.0 %
Argon mini-arc	138-200	10.0 %
	200-350	5.0 %
Tungsten Halogen	250	2.6 %
	555	1.2 %

Spectral Irradiance Nonportable Source Standard

SURF storage ring	5-IR	2-5 % (1980)
		1.3 % (1985)

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