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REPORT ON THE WORKSHOP ON INTERCOMPARISON OF SOLAR U.V. IRRADIANCE MEASUREMENTS AND RELATED INSTRUMENT CALIBRATION

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The knowledge of the absolute value of the solar ultraviolet irradiance did not improve very much during the rising phase of the solar cycle 21. The variations associated with the solar rotation period have been observed by means of three satellites namely, the Atmospheric Explorer E (AE-E), Nimbus 7 and the Solar Mesospheric Explorer (SME). They led to quantitative values which have been discussed previously. Long-term variations related to the solar activity cycle are not well known. Values were deduced during the solar cycle 21 from the AE-E satellite and the rocket program performed by the Laboratory for Atmospheric and Space Physics (LASP) leading to variations of about a factor of 2 around 150 nm but definitely less than 20 percent beyond 175 nm. Such low level of variation is still masked by the current uncertainties and reproducibility of the observations performed since 1976.

The uncertainties of recent observations are reported in Table 1 with their discrepancies. The gaps between the current accuracy goals and the achievements are still very important. The challenge for the next three years is to improve both the accuracy and the precision of future observations at the level of the available irradiance standards and to measure quantitatively long-term variations of the order of a few percent. The main causes of these gaps have been clearly identified. They are induced by:

1. The diversity of the calibration techniques and standards used for the various solar spectrometers.

2. The calibration accuracy transfer.

3. The lack of intercomparison of standards.

4. The lack of interaction between standards-builders and standards-users.

5. The degradation of the instrument sensitivity due to the contamination of materials.

6. The lack of intercomparison of solar spectrometer responses.

All these problems can and should be solved before the space shuttle program for solar irradiance monitoring starting in 1986 and the launches of the Upper Atmosphere Research Satellites (UARS) scheduled for the end of the 1980's.

The available calibration procedure and performance have been intensively discussed. It turns out that the most accurate spectral irradiance transfer source standards are the Synchrotron Users Radiation Facility (SURF) and the Tungsten Halogen lamp, both being developed at the National Bureau of Standards. The spectral range covered by the tungsten source is limited to wavelengths greater than 250 nm. In both cases, the accuracy in the ultraviolet range is better than ±3 percent. The uncertainties of the SURF have been recently reduced to ±1.3 percent. Its stability is claimed to be better than 1 percent. The main problem occuring in the calibration of solar spectrometers by using this latter standard source is the polarization of the output beam. On the other hand, the uniformity of the beam has been disputed.

Portable sources like the Argon mini-arc and the deuterium lamp are easier to handle than the SURF but their uncertainties are not lower than ±5 percent.

Table 1. Uncertainties on solar ultraviolet irradiance measurements and future needs.

	Wavelength intervals (nm)					
	Ly-α	135-175	175-210	210-240	240-400	330-400
Accuracy	± 30%	± 30-20%	± 30-20%	± 20-10%	± 10-4%	± 4-2%
	± 10%+	± 10%+	± 10+			
Achieved accuracy on irradiance values	± 30%	± 30%	± 20%	± 15%	± 10%	± 3%
Discrepancies	200%	100%	40%	20%	20%	8%
Uncertainties on spectral irradiance transfer source standards		± 10%	± 6%	± 5%	± 3%	± 2%
	± 3%*	± 3%*	± 3%*	± 3%*	± 3%*	± 3%*
27-d variability	100-30%	12%	10-4%	2%	2-1%	
11-yr variability	100%	< 120%	< 20%	< 10%§	< 5%§	< 2%§
Goals: accuracy	± 10%	± 5%	± 5%	± 5%	± 5-2%	± 2%
Goals: precision	± 5%	± 5%	± 2%	± 1%	< 1%	< 0.1%

+ at 2σ level, using the SURF as calibration standard

* Synchrotron Users Radiation Facility (SURF), at 2σ level

§ according to model calculations published by LEAN ET AL. (1982).

New absolute detectors, namely the silicon photodiodes are presently studied for ultraviolet radiometric purposes at the NBS and are very promising with uncertainties less than 1 percent.

The intercomparison between the various source standards has been initiated by several laboratories and the first results presented during this workshop showed a difference of the order of 20 percent between the deuterium lamp and the SURF, using the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) experiment developed by the Naval Research Laboratory (NRL) for Spacelab 2. The intercomparison of deuterium lamps calibrated at the NBS and the NPL gives an agreement within a few percent for the relative scale but the absolute calibration can vary from 1 to 16 percent for different lamps. This work has to be completed in order to understand the causes of such divergences between calibration results performed by two different laboratories.

In conclusion, the goals in solar ultraviolet irradiance measurements could be reached in the near future only if the following requirements are fulfilled:

(a) Requirements on the Intercomparison of Spectral Irradiance Standards

Three standards are currently used to define the absolute radiometric reference scale: (1) the synchrotron; (2) the hydrogen arc; and (3) the blackbody.

Practically, the Argon mini arc and the Tungsten Halogen lamp are referred respectively to the hydrogen arc and to the blackbody. Therefore, it is recommended to calibrate the same solar spectrometers against the three different radiometric scales in order to see which source is the best suited to become the prime standard in the future. Direct comparison of the SURF with the blackbody and with the Hydrogen are needed for that purpose.

The intercomparison of the available standards should continue in order to measure the error sources related to the absolute calibration and the reproducibility of the ground facilities, and to the calibration accuracy transfer. For that purpose, laboratory spectrometers can be used but current and future solar spectrometers should also be utilized in order to detect the errors specifically introduced by each observing instrument. Scientists involved in both radiometry and solar irradiance measurements should work together in the calibration program in order to reduce the errors introduced during the radiometric scale transfer procedure.

(b) Requirements on the Intercomparison of Solar Spectrometers

All solar instruments used by different groups should be cross-calibrated in order to make possible the intercomparison of the data obtained at different epochs. This is particularly true for rocket- and balloon-borne solar spectrometers used for long term variation studies and for measurements of sensitivity drift of free-flyer instruments over large periods of times. Up to now, the SURF seems the most appropriate standard source in the ultraviolet because of its high level of reproducibility and of accuracy and its wide wavelength range. Nevertheless the other transfer standards should be improved further and each group should maintain their own calibration methods by measures of conservation. It should be pointed out that the calibration procedure against the SURF is an experiment by itself requiring time to be scheduled in the future observing program. Comparisons between various solar spectrometers should also be made using the sun as a common source. Measurements should be performed from the same platform. For intercomparisons at wavelengths beyond 190 nm, large stratospheric balloons can be easily used. Such an intercomparison program could be scheduled for 1984. As this kind of flight deals with comparison of in situ solar irradiance measurements in the same environmental conditions, at the same time and altitude, the uncertainties related to the residual stratospheric absorption corrections applied in order to obtain extraterrestrial fluxes are not introduced when comparing the data.

In the near future, intercomparison on board the space shuttle could be performed in order to cover the full vacuum ultraviolet range. It could also be used to check the instrument behavior in a flight environment comparable to rocket and satellite observations. Studies on instrument degradation could also be made by recovering the instrument after several weeks in orbit.

(c) Requirements on the Satellite Measurements

The errors introduced by the measurement in the space environment should be reduced by appropriate techniques minimizing the causes of degradation of the instrument sensitivity and by controlling their consequences. Future satellite instruments devoted to solar irradiance measurements should satisfy several design requirements in order to minimize the number of optical elements and the number of potentially outgassing surfaces and elements. In particular this can be achieved by completely isolating the electronics from the optics, using tight containers and encapsulated wires and harnesses. The existence of a cold trap on the spacecraft should also reduce the degradation due to outgassing. The assembly, integration and calibration phases should be made using the highest class cleanliness facilities. The solar observations should start several weeks after lift-off to complete the outgassing. Flyable calibration sources should be developed and tested for instance on board the space shuttle, to be available as soon as possible for future missions.

(d) Requirements on the Validation of Satellite Data

In order to validate the satellite data, the instrument aging should be measured by monitoring its radiometric characteristics using flyable calibration standards and techniques. Periodic accurate observations by means of balloon-, rocket- and space shuttle-borne instruments should be performed in order to obtain frequent re-calibration of the satellite solar spectrometer. Balloon measurements have the advantage of no outgassing problem and no damage due to solar ultraviolet or X-ray radiation. Post-flight calibrations are possible. These observations are limited in wavelength and data around 210 nm at 40 km need corrections due to the residual stratospheric absorption. Therefore, the achievable accuracy is of the order of 6 to 7 percent in the stratospheric optical window. Beyond 290 nm, the balloon observations can be performed with an uncertainty limited by the accuracy of the available standards (less than 2 percent) and of the calibration transfer. Reproducibility of 1 percent is now achievable and does permit one to distinguish between any free-flyer instrumental drift and true solar variations at the same level of precision. Ground measurements beyond 330 nm need atmospheric correction which reduce the final accuracy and precision of the data. Rocket measurements cover all wavelengths but the flight environment is rather harsh. The short flight duration does not allow in-flight calibration. Post-flight calibrations are also possible. Uncertainties less than 5 percent are now achievable below 200 nm by using adequate calibration standards and transfer procedures like the SURF.

In the near future, the space shuttle will provide an additional platform for calibration purposes. In addition, instrument retrieval by shuttle flights may help to study the reasons for instrument degradation and would permit post-flight calibration of a satellite solar spectrometer.

ACKNOWLEDGEMENTS

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ANNEX

Resolution adopted by the International Association of Meteorology and Atmospheric Physics (IAMAP) at the III IAMAP Scientific Assembly, Hamburg (FRG), 1981.

considering that solar ultraviolet irradiance (i.e., 100-400 nm) and its temporal variations are not sufficiently well known for middle atmospheric science and that new observations are badly needed to improve the accuracy and the precision of irradiance values, and

recognizing that improvements in calibration procedure are expected to close the gaps between current accuracy goals and achievements,

recommends the improvement of calibration of new instrumentation by means of (a) maintenance of synchrotron calibration facilities, (b) intercomparison of the different spectral irradiance standards, and (c) study of the feasibility of establishing a reference to insure the highest possible precision and intercomparability of future observations.

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May 11 and 12, 1982
Washington, D.C.

PROGRAM

Tuesday, May 11

A. Solar cycle 21 observations

Current knowledge of solar irradiance values related to middle atmosphere processes		P. C. Simon
Variability of solar UV irradiance		G. E. Brueckner
New results:	SME/Rocket	G. J. Rottman
	SBUV	G. F. Heath
	Balloon/Rocket	J. E. Mentall
	Lyman-alpha measurements	J. P. Delabeudiniere

B. UV spectral irradiance transfer standards

SURF II	R. P. Madden
ORSAY synchrotron	J. P. Delaboudiniere
Arc sources	W. R. Ott
D2 lamps	P. J. Key
VUV window diode	R. P. Madden
Silicon photodiode	J. Geist
Tungsten Halogen sources	H. Kostkowski

C. Results on intercomparison of spectral irradiance standards

PTB-NBS intercomparisons	R. P. Madden
NPL-NBS intercomparisons	W. R. Ott
D2 lamps - SURF intercomparisons	J. W. Cook

Wednesday, May 12

D. Calibration of available and future instruments for solar UV irradiance observations

Balloon and rocket		J. E. Mentall G. J. Rottman P. C. Simon
Space Shuttle	SUSIM	M. E. Van Hoosier
	STAS	W. H. Parkinson
	Solar spectrum	P. C. Simon

Satellites	NOAA	W. K. Fowler
	SME	G. J. Rottman
	UARS	G. J. Rottman
		M. E. Van Hoosier

E. Definition of future intercomparison strategy

Group discussion on:

- intercomparison of portable standards
- intercomparison of non-portable standards
- intercomparison of instruments
- transfer of radiometric scale on instruments

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