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Analysis of Solar Spectral Irradiance Measurements from the SBUV/2-Series and the SSBUV Instruments

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Validation of the UARS and ATLAS Solar Ultraviolet Irradiances

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ABSTRACT

The measurements of the solar ultraviolet spectral irradiance by the two Upper Atmosphere Research Satellite (UARS) solar instruments are validated to agree within their 2-σ calibration uncertainties of about 7%, as well as with measurements from the two solar instruments on the Shuttle Atmospheric Laboratory for Applications and Science (ATLAS) missions. Additionally, the precision of the two UARS data sets is better than the original 2% goal, especially at wavelengths greater than 160 nm. This excellent agreement can be credited to accurate pre-flight calibrations, comprehensive in-flight calibrations to track instrument degradation, and a coordinated validation program among the UARS and ATLAS solar instrument teams. The solar irradiance results presented here include those derived from UARS SUSIM, UARS SOLSTICE, ATLAS SUSIM and ATLAS SSBUV measurements on 29 March 1992 during the ATLAS-1 mission and on 15 April 1993 during the ATLAS-2 mission. Two ultraviolet spectra from 119 to 410 nm are derived as the weighted average of the UARS SOLSTICE and SUSIM measurements and are recommended as representative solar spectra for the period of the ATLAS-1 and ATLAS-2 missions. The ATLAS-1 mission occurred during the initial phase of the solar cycle 22 decline when solar activity was moderately high. The ATLAS-2 mission occurred later during the declining phase of the solar cycle 22 when solar activity was more moderate.

Summary of Work Performed During the Current Period of Performance: 1 September 1994 - 28 February 1995:

A key area of this research is the comparison of the SSBUV and NOAA-11 SBUV/2 solar spectral irradiance data with measurements from other instruments that monitor the solar spectrum in the middle ultraviolet. During this period of performance, SSBUV data from the ATLAS-1 (SSBUV-4, March 1992) and ATLAS-2 (SSBUV-5, April 1993) missions were compared with data from the SOLSTICE (Solar Stellar Irradiance Comparison Experiment) and SUSIM (Solar Ultraviolet Spectral Irradiance Monitor) instruments onboard NASA's UARS (Upper Atmosphere Research Satellite) and with data from the ATLAS SUSIM instrument. The primary purpose of this comparison was to validate the initial UARS solar measurements, concentrating on the absolute and "long-term" spectroradiometric calibrations of the two UARS instruments. Figures 1 and 2, which are taken from the recently submitted paper by Woods et al. (1994), present a comparison of each of the four instruments to the UARS average spectrum for the ATLAS-1 mission. Panels a-d are for UARS SUSIM, SOLSTICE, SSBUV, and ATLAS SUSIM, respectively. Because the UARS SUSIM and SOLSTICE data are approximately equally weighted in making the UARS average spectrum, the average uncertainty for those two instruments is about 5% (about one half of the expected total uncertainty of the measurements); whereas the average uncertainty for SSBUV and ATLAS SUSIM is approximately 10%. The agreement amongst these four instruments in the middle UV represents roughly a factor of *five* improvement over previous comparisons. This improvement resulted from meticulous attention to preflight calibration and postlaunch characterization on the part of all experiment teams, supplemented by a rigorous NIST intercalibration campaign.

As discussed in Cebula et al. (1994), we have begun the comparison of the NOAA-9 and NOAA-11 SBUV/2 solar spectral irradiances with the SSBUV solar spectral irradiances. This comparison has revealed small scan-to-scan and day-to-day discrepancies in the initial NOAA-11 sweep mode solar data. We have therefore begun a study of the possible cause of these variations, with the goal of determining which data to adopt as the NOAA-11 "Day 1".

When the proposal for this work was submitted in 1992, we expected to perform the initial processing of the raw SBUV/2 instrument data on an IBM mainframe computer at NASA/Goddard Space Flight Center (GSFC), then conduct further analysis of the processed irradiance data on the GSFC Code 916 VAX system. Since that time, the GSFC IBM has been downsized in preparation for its removal at the end of 1995, and the Code 916 VAX system is scheduled to be removed by February 1995. In response to this situation, all processing code and analysis software (about 7 MB), raw instrument level data for NOAA-9 and NOAA-11 (approximately 1400 MB), and processed solar irradiance data (350 MB) were transferred to a newly available Unix workstation.

A mix of integer and real data is contained in each record of these binary raw data and processed solar spectral irradiance data sets, and between 10 and 15 different record structures exist within each data set. We are currently modifying an existing FORTRAN program to convert these data sets from IBM format to Unix-compatible format, and expect to complete this task by the end of January 1995. We are also modifying the solar irradiance processing code for operation in an Unix environment. Since this code was previously modified to operate on a VAX system, all IBM-specific features have been removed and this change should be relatively straightforward. We anticipate completion by the end of February 1995.

Three refereed articles relevant to this research were published or submitted for publication during the current period of performance. Contributions to the Woods et al. article were directly supported by this research grant and NASA sponsorship is acknowledged therein. A copy of the title page and abstract of that paper is enclosed with this report; a preprint will be furnished once the paper is accepted for publication.

Cebula, R. P., E. Hilsenrath, and M. T. DeLand, "Middle Ultraviolet Solar Spectral Irradiance Measurements, 1985-1992, From the SBUV/2 and SSBUV Instruments," The Sun as a Variable Star: Solar and Stellar Irradiance Variations, J. M. Pap, C. Frohlich, H. S. Hudson, and S. K. Solanki, eds., Cambridge University Press, 81-88, 1994.

DeLand, M. T. and R. P. Cebula, "Comparisons of the Mg II Index Products from the NOAA-9 and NOAA-11 SBUV/2 Instruments," *Solar Physics*, 152, 61-68, 1994.

Woods, T. N., D. K. Prinz, J. London, G. J. Rottman, P. C. Crane, R. P. Cebula, E. Hilsenrath, G. E. Brueckner, M. D. Andrews, O. R. White, M. E. VanHoosier, L. E. Floyd, L. C. Herring, B. G. Knapp, C. K. Pankratz, and P. A. Reiser, "Validation of the UARS and ATLAS Solar Ultraviolet Irradiances," *J. Geophys. Res.*, submitted, 1994.

Summary of Work Planned During the Next Period of Performance: 1 March 1995 - 29 February 1996:

The primary thrust of this research during the next period of performance will be the creation of a fully calibrated NOAA-11 SBUV/2 solar spectral irradiance data set for the period December 1988 through at least April 1993 and possibly through March 1994. (Extension through the latter date is contingent on the receipt of an updated NOAA-11 SBUV/2 instrument characterization for that time-frame. That effort is a separately funded activity.) The SSBUV solar data will be used to detect and correct for long-term drift in the NOAA-11 SBUV/2 instrument's solar measurements. We have previously demonstrated that this goal may, in principle, be realized. During the next twelve months we will develop the software, data sets and techniques necessary to accomplish this goal.

Significant software development and data conversion is required to meet the goal enumerated above. The current SBUV/2 solar irradiance processing code borrows heavily from Nimbus-7 SBUV software, developed in the mid-1970's for an IBM mainframe environment, and thus produces output data sets with features and complexities which are no longer necessary. During the conversion of the existing processed data, the internal format of the output data sets will be revised to simplify analysis. This revision will be extended to the processing code as well during the next period of performance.

Several known issues shall be addressed in this research, including:

1) SSBUV solar spectral irradiances for wavelengths shortward of approximately 250 nm, presently contain an unacceptably large uncertainty due to uncertainty in the spectral irradiance standards. Our effort will supplement a separately funded activity to finalize the SSBUV-4, SSBUV-5, and SSBUV-6 calibrations in that spectral region.

2) Significant (greater than 0.1 nm) drift in the SBUV/2 wavelength calibration in time exist. In addition, improvements in the procedures used to correct for wavelength registration differences between the two instruments are needed and will be addressed.

3) Comparison of daily solar spectral irradiances rather than "flight means" (which were used in the preliminary comparisons) will be implemented to improve the validation procedures.

4) Improvements in the NOAA-11 SBUV/2 goniometry, which are needed and which are expected to be derived in parallel under a separately funded activity, will be employed.

5) Determination of the best "Day 1" solar spectral irradiance for NOAA-11 SBUV/2, incorporating calibration improvements, revised goniometry, etc. will be finalized.

6) Revisions to the SSBUV irradiance, incorporating corrections for small time dependent changes in the instrument's calibration during the missions, corrections for thermally-induced wavelength calibration change, etc. will be used.

7) We will investigate the use of spectral smoothing procedures to reduce the random noise

in the sweep solar data, which becomes significant in wavelength regions with low raw count levels. Different algorithms will be investigated to produce the maximum improvement in signal-to-noise, while minimizing the impact on the derived solar spectral irradiance values.

and, possibly,

8) Development of an extension of the SSBUV-based correction to the SBUV/2 irradiances for wavelengths shortward of 200 nm will be investigated.

Once these items are treated, a correction will be developed and applied to the NOAA-11 SBUV/2 irradiances. Spectra for selected dates and time series for select wavelengths will be developed, then compared with corresponding data from external instruments such as SOLSTICE and SUSIM. Coincident with this validation, we will begin to assess short, medium and long-term changes in the middle UV solar irradiance for this period using the corrected data.

In parallel with this activity, we will commence work toward creating a revised composite Mg II index based on the SBUV/2 discrete mode data, and incorporating a full, detailed instrument calibration. This index will be a significant improvement over the Version 1 Mg II index which we have previously created. We will begin Mg II proxy index validation using short-term and long-term variations across the aluminum and magnesium edges and, most importantly, detailed statistical comparisons between the Mg II proxy index and selected NOAA-11 SBUV/2 UV irradiance time series.

Comparison of the SSBUV solar data, especially those data from the ATLAS flights, with other instruments will also continue. We will work closely with Dr. G. Thuillier, the SOLSPEC Principal Investigator, and Mr. M. VanHoosier of the SUSIM project, throughout 1995. A series of publications comparing the measurements from the three ATLAS solar spectral irradiance instruments are planned.

Figure 1

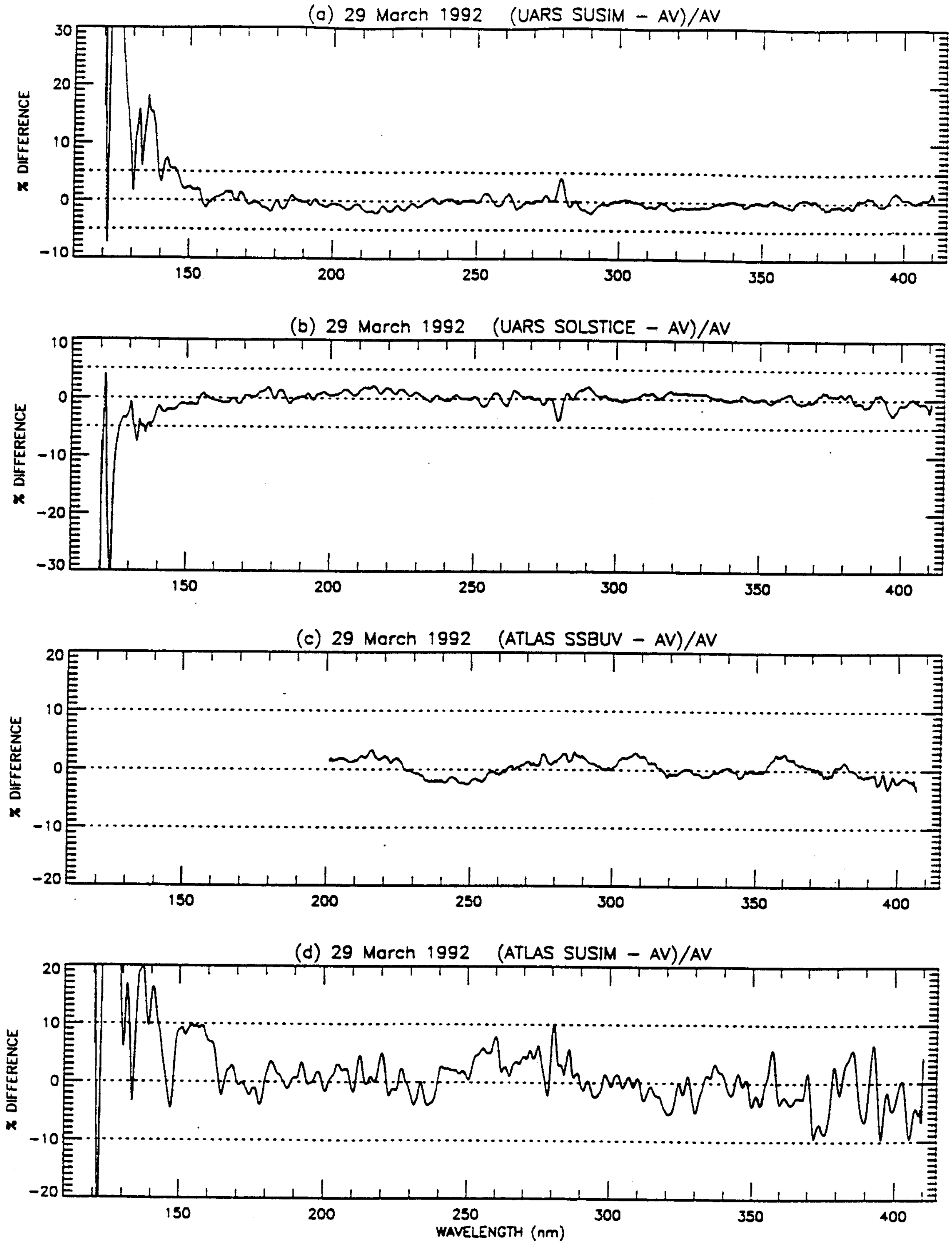
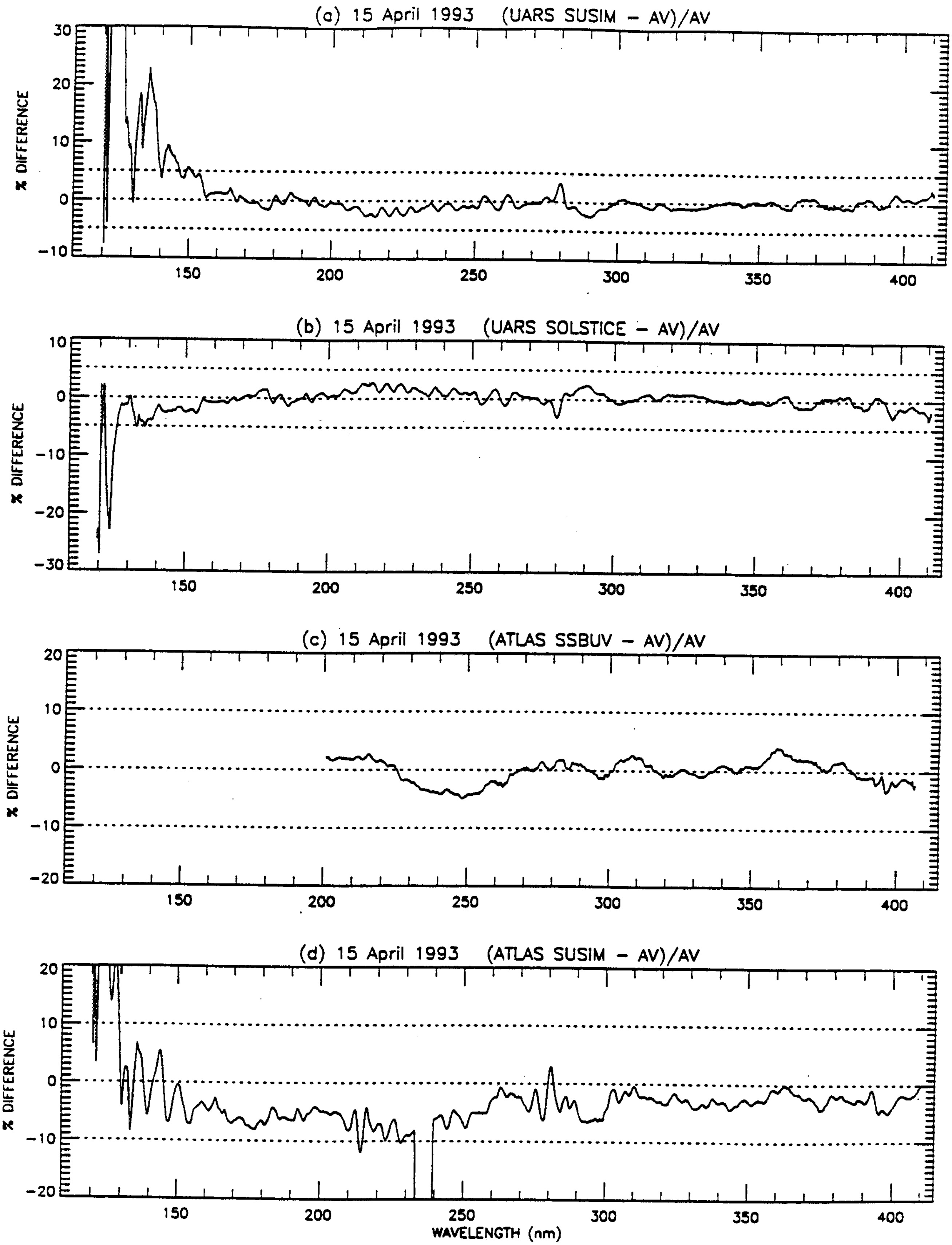

(a) 29 March 1992 (UARS SUSIM – AV)/AV
% DIFFERENCE
30
20
10
0
−10
150
200
250
300
350
400
(b) 29 March 1992 (UARS SOLSTICE – AV)/AV
% DIFFERENCE
10
0
−10
−20
−30
150
200
250
300
350
400
(c) 29 March 1992 (ATLAS SSBUV – AV)/AV
% DIFFERENCE
20
10
0
−10
−20
150
200
250
300
350
400
(d) 29 March 1992 (ATLAS SUSIM – AV)/AV
% DIFFERENCE
20
10
0
−10
−20
150
200
250
300
350
400
WAVELENGTH (nm)

Figure 2


(a) 15 April 1993 (UARS SUSIM – AV)/AV
% DIFFERENCE
30
20
10
0
−10
150
200
250
300
350
400
(b) 15 April 1993 (UARS SOLSTICE – AV)/AV
% DIFFERENCE
10
0
−10
−20
−30
150
200
250
300
350
400
(c) 15 April 1993 (ATLAS SSBUV – AV)/AV
% DIFFERENCE
20
10
0
−10
−20
150
200
250
300
350
400
(d) 15 April 1993 (ATLAS SUSIM – AV)/AV
% DIFFERENCE
20
10
0
−10
−20
150
200
250
300
350
400
WAVELENGTH (nm)