On-line Supplement

This supplement providers a detailed description of the different terms that are necessary to estimate both absolute and time-dependent uncertainties for the V8.6 ozone product. The discussion focuses on radiometric uncertainties for both radiance and irradiance data, based on prelaunch and on-orbit measurements. Further details about many parameters and measurements related to the prelaunch tests for SBUV/2 instruments can be found in the calibration data books prepared by the manufacturer and delivered with each instrument (e.g. Ball Aerospace, 2005). While we address the same terms and quantities for all SBUV instruments because of the similarities in instrument design, some quantities have different values from one instrument to another, and other quantities vary significantly with signal level. As a result, we have created one set of tables to describe absolute uncertainty levels (Tables 2-9), and a second set to describe the time-dependent uncertainty estimates for each instrument (Tables 10-17). The absolute uncertainty tables incorporate all items needed to consider any individual instrument on its own. The determination of uncertainty values for a merged long-term data set is discussed in Sect. 5 of the main paper. In all of these tables, the uncertainty values are given in percent for radiance/albedo data, and the column "RSS" represents the root-sum-square of the individual terms.

1 Wavelength scales and radiance interpolation

1.1 Wavelength scales

The nominal wavelengths for SBUV/2 instrument operations were established based on Nimbus-7 SBUV wavelengths. The only significant change made to this wavelength set was the shift of channel 1 from 255.7 nm to 252.0 nm to avoid potential contamination from nitric oxide emissions (Fleig et al., 1990). Since the SBUV/2 wavelength selection uses a grating drive with an optical encoder, the exact wavelengths available for each instrument will depend on its wavelength calibration. Table 1 lists the wavelengths used for normal operations of all SBUV instruments.

1.2 Radiance interpolation to common location

An SBUV/2 instrument scans consecutively through 12 discrete wavelengths in each scan, taking two seconds to integrate each sample and move to the next position. Radiance measurements at 273.5 nm and 331.2 nm, representing the maximum wavelength range used in the ozone profile retrieval, are thus separated by 18 sec in time, corresponding to ~125 km in geolocation along the orbit track. For V8.6 processing, all radiance measurements are interpolated to the position of channel 8 (305.8 nm) to provide uniform input for the retrieval algorithm and to address the effects of latitudinal gradients in total ozone. This process makes use of the Cloud Cover Radiometer (CCR) photometer data at 378.6 nm, which are collected in parallel with every monochromator sample, to help address surface reflectivity variations during the 32 sec between consecutive monochromator samples at each wavelength.

An initial processing of the measurements with the standard V8 algorithm is performed first to establish the surface reflectivity. The reflectivity at each sample location is estimated using the observed reflectivity at 331 nm and the CCR variations within the scan. The radiance sensitivity to reflectivity changes (dN/dR) is then calculated and used to remove the reflectivity contribution to the measured radiance for each channel. This adjustment is negligible for $\lambda <$ 290 nm because radiances at these wavelengths are not affected by surface reflectivity variations.

The adjusted radiance values at each wavelength now have a smooth variation along the orbit, so that a spline function can be used to interpolate these values to the location of channel 8 within each scan. The dN/dR sensitivity values are also interpolated to the same location. Finally, the appropriate surface reflectivity contribution at this location for each wavelength is calculated, and added to the interpolated radiance to create the values used for the V8.6 profile retrieval.

2 Absolute uncertainty

2.1 Radiometric calibration (radiance, irradiance)

SBUV instrument prelaunch radiometric tests are designed to characterize both the radiance calibration of the instrument (using a flat plate diffuser to direct radiation into the aperture) and the irradiance calibration (using the flight diffuser) (Fegley and Fowler, 1991). Sources of uncertainty for the derived calibration constants include the NIST lamps used to illuminate each diffuser (2-3%), the transfer of the laboratory standard calibration to the instrument (1-2%), and the bidirectional reflectance distribution function (BRDF) of the diffuser used in the radiance procedure. The spectral dependence of the derived calibration typically shows broad structure over scales of 20 nm to 50 nm.

Measurements of diffuser reflectivity taken on-orbit with the onboard mercury lamp calibration system prior to viewing the Sun typically show changes of 1% or less compared to prelaunch data. The irradiance calibration can then be validated inflight by comparing initial “Day 1” solar measurements, representing the first exposure of the diffuser plate to sunlight, with other solar irradiance reference data sets (e.g. SSBUV (Cebula et al., 1996)). The observed agreement with reference irradiance data set ranges from ±2% (NOAA-16) to larger differences with 5-10% spectral dependence. Since the solar diffuser is the only unique element in the optical path for irradiance measurements, our initial assumption is that these differences also correspond to radiance calibration errors.

Validation of the prelaunch albedo calibration is harder for an SBUV instrument because of the difficulty in identifying a stable reference. Ozone absorption effects produce albedo variations at wavelengths less than 300 nm, while clouds and surface composition changes lead to significant variations for wavelengths longer than 300 nm. We use maximum albedo values at 340 nm from measurements over Antarctic ice, which are assumed to be cloud-free, for comparison with previous TOMS measurements. It is also possible to examine low reflectivity data taken over open areas of the Pacific Ocean as a basic calibration check, although the potential accuracy of this approach is not as good for SBUV instruments due to the difficulty of avoiding cloud contamination in the large field of view.

2.2 Albedo calibration (ground)

SBUV V8.6 ozone processing uses directional albedo in the retrieval algorithm, which simplifies some aspects of the uncertainty analysis. For example, the laboratory radiance and irradiance calibrations typically use the same lamps. If the lamp is stable during these tests, the source intensity then cancels out in the albedo calibration. The lamp intensity typically drifts less than 1% during a calibration sequence. Any drift-related effects are further minimized by alternating radiance and irradiance measurements, and by using the same signal levels for both measurements at a given wavelength. These steps reduce other measurement correction uncertainties (electronic offset, PMT gain, non-linearity) to negligible levels. The largest remaining issue is then the BRDF of the flat plate diffuser used in the radiance procedure, as compared to the flight diffuser used for the irradiance procedure. Laboratory BRDF measurements for the flat plate diffusers are performed on a specific grid of wavelengths and viewing angles. A weighted average of these measurements is then used to address vignetting issues, and a polynomial fit determines appropriate BRDF values for inflight wavelengths. Extensive analysis of SSBUV calibration measurements before and after multiple flights suggests that 1% is a reasonable estimated uncertainty for the SBUV/2 albedo calibration. For the older BUV and SBUV instruments, the available information only addresses absolute uncertainty. The Nimbus-7 SBUV prelaunch radiance and irradiance calibration uncertainty is quoted as ±3% (Fleig et al., 1990), but the ratio of these calibrations is known to better accuracy. We adopt ±1.5% as an estimated uncertainty for this analysis. For Nimbus-4 BUV, prelaunch radiometric tests with same lamp and set-up taken 6 days apart showed ~2% changes (Beckman Instruments, 1970), so we have adopted that number for our uncertainty estimate.

For the SBUV/2 instruments, we have additional information from the prelaunch data books to examine spectrally-dependent uncertainty values. The NOAA-9 SBUV/2 prelaunch calibration used a $BaSO_4$ diffuser with observed time-dependent changes in hemispheric reflectance [-2.0% at 252 nm, decreasing to -0.4% at 400 nm] over dates that closely bracket the prelaunch calibration (Ball Aerospace, 1991). We assume one-half of these values as an additional uncertainty term. For NOAA-11 SBUV/2, multiple tests over a period of a few years showed spectrally dependent BRDF variations of 0.4-0.5%. For more recent SBUV/2 instruments (beginning with NOAA-14), the use of a Spectralon laboratory diffuser has greatly reduced BRDF drift concerns. Small-scale structure in the so-called “instrument BRDF” (ratio of radiance/irradiance calibration constants) for these instruments is approximately 0.2%. We include this spectral uncertainty in the “Albedo (ground)” column for Tables 4-9.

2.3 Albedo calibration (inflight)

Multiple techniques based on inflight measurements are used for “soft” calibration of the SBUV V8.6 data sets, so we need to estimate uncertainty values for each one and also identify which instruments use a given technique.

2.3.1 Ice radiance at 340 nm

The consistency of Antarctic December-January average ice radiance values from multiple SBUV instruments suggests that 0.5% is a reasonable uncertainty estimate. These radiance values were checked for all instruments, and wavelength-independent calibration adjustments have been applied for NOAA-16 and NOAA-18.

2.3.2 Coincidence analysis

Hilsenrath et al. (1995) described the derivation of albedo normalization factors (ANFs) for NOAA-11 data based on SSBUV coincidence analysis. We use the ±2 σ values for SSBUV-2 as shown in this paper to assign uncertainty values of 0.8-2.1%, with larger values at longer wavelengths. These ANF adjustments have been applied directly to NOAA-11 data. The NOAA-9 and Nimbus-7 data sets were adjusted to NOAA-11 using coincidence comparisons at the Equator, which have an uncertainty of approximately 0.5% when derived for instruments with similar local times.

2.3.3 Channel-to-channel adjustments

Since the objective of this technique is to get residuals for each wavelength below ±0.1 N-value, we adopt 0.3% as a residual albedo uncertainty. This uncertainty applies directly to the NOAA-17 calibration.

2.3.4 No local time difference comparisons

The wavelength-dependent calibration adjustments derived using this technique for multiple years typically fluctuate within an envelope for each instrument, as shown in Fig. 8 of the main paper. We use 0.5% (~0.2 N-value) as an uncertainty for this technique, which has been applied to NOAA-18, NOAA-16, and NOAA-14 data.

2.4 Signal-to-noise

Raw radiance signals observed at a single wavelength by an SBUV instrument may vary by an order of magnitude or more during a single orbit, including changing from one electronic gain range to another. We have used on-orbit data from SBUV/2 instruments to determine "typical" moderate raw signal levels at each wavelength, as well as reasonable variations above and below these levels. Using SZA = 60° as a reference case, we find that high signal levels observed at SZA = 25°-30° are typically 2-3 times larger than the reference signals. Low signal levels observed at SZA = 85° are 2-3 times smaller than the reference levels for $\lambda < 300$ nm, but can be a factor of 8-10 smaller than reference levels at 306-331 nm where the effects of ozone absorption combine with increased path length.

SBUV/2 instruments have a small signal injected into system to limit occurrences of counter underflow for conditions with no illumination. Monitoring the variability of this "electronic offset" value in night side samples thus provides an estimate of the effective noise for measurements in each gain range. For the lowest signals, measured from the PMT anode in Range 1, noise values vary between 18-33 counts. Range 2 noise values, also measured from the PMT anode, are considerably smaller at ~0.8 counts. For NOAA-9 through NOAA-16, Range 3 samples were measured from the PMT cathode with noise values of approximately 4 counts. NOAA-17 and NOAA-18 SBUV/2 measure Range 3 signals from the PMT anode, so those noise levels are also less than 1 count.

The column "Signal-to-Noise" in Tables 4-9 lists the low and high signal uncertainty values for each wavelength determined by dividing the observed noise level by the nominal signal level. Note that different gain ranges may be used for these signal levels. The larger of these two values (when present) is used to calculate the final RSS uncertainty.

The Nimbus-7 SBUV measurement precision is stated to be < 0.5% (Fleig et al., 1990), which is consistent with measuring all gain ranges from the PMT anode. We assume the same performance for Nimbus-4 BUV, since it used the same electronic design.

2.5 Non-linearity

Prelaunch testing for SBUV/2 instruments evaluates the linearity of the instrument within each gain range, including overlap regions with any higher/lower range. The observed departure from linearity is normally less than ±1%, and characterization of this behavior with a polynomial fit typically has an uncertainty of less than 0.2%. NOAA-9 SBUV/2 prelaunch data showed larger linearity variations for low Range 3 signals, with limited sampling available to constrain fit. On-orbit analyses with selected Earth view and solar view observations could not produce a non-linearity correction with better than 1% accuracy for this region. This increased uncertainty affects NOAA-9 ozone processing accuracy when channels 9 or 10 are used in the retrieval.

2.6 Interrange ratio

Since SBUV instrument measurements can be collected in three different gain ranges, they must be converted to a common gain range (normally Range 2) for ozone processing. Prelaunch testing establishes these conversion values, which we call interrange ratios. SBUV/2 instruments can validate these ratios on-orbit because neighboring gain ranges overlap and all three ranges are read out simultaneously, so there are specific signal levels where both gain ranges are valid. For conversion between two anode signals (Range 1 to Range 2 = IRR_{12} on all instruments; Range 3 to Range 2 = IRR_{32} on Nimbus-4, Nimbus-7, NOAA-17, NOAA-18), the interrange ratio is an electronic conversion only. No wavelength dependence is expected, although on-orbit values of IRR_{32} do show 0.5% features for NOAA-17 and NOAA-18. The characterization of this ratio is accurate to ~0.1%.

For instruments with Range 3 cathode data (NOAA-9, NOAA-11, NOAA-14, NOAA-16), IRR_{32} is wavelength-dependent over the ozone wavelengths with >5% amplitude (Frederick et al., 1986). Characterization of the spectral dependence of the prelaunch data with a polynomial function is accurate to ~0.5%.

2.7 PMT temperature

Prelaunch testing of SBUV/2 instruments shows a radiometric sensitivity change in PMT anode data of ~0.2% for each 1°C change in PMT temperature relative to 20°C. On-orbit values of T_{PMT} generally vary between 15°C-25°C, so the overall magnitude of this correction is usually less than 1%. Since the characterization of the temperature dependence is accurate to ~10% of the correction value, we assume a 0.1% radiance uncertainty for this term.

2.8 Out-of-band (OOB) response

We observe consistent correlations between fluctuations in SBUV/2 short wavelength ($\lambda < 300$ nm) radiance measurements and long wavelength (331, 340 nm) measurements during the same scan. Since chan. 11-12 measured signals are primarily responding to variations in surface brightness and clouds, this implies that the short wavelength measurements are being contaminated by these out-of-band signals. Averaging data into zonal means shows that the monochromator radiance deviations have a linear response to the observed CCR albedo over a broad range of CCR brightness. We adopt a relative uncertainty of 3% for this linear regression sensitivity factor to represent both statistical fit error and differences from a fitted slit function curve for specific conditions. The calculated OOB correction in absolute radiance has a complex dependence on solar zenith angle, total ozone amount, and surface reflectivity. The NOAA-17 SBUV/2 instrument has the largest OOB correction, and thus uncertainty. We calculated the NOAA-17 correction for an extreme situation with large OOB error (SZA = 30°, reflectivity = 80%, total ozone = 275 DU), and use one-half of the magnitude of this correction to define typical uncertainty values at each wavelength. OOB corrections and uncertainty values for other SBUV/2 instruments are defined as a fraction of the NOAA-17 OOB correction values. Nimbus-4 BUV and Nimbus-7 SBUV measurements do not show any evidence of OOB contamination.

3 Time-dependent uncertainty

3.1 Diffuser reflectivity

The solar diffuser is the only component of the BUV optical system that is not common to both radiance and irradiance measurements. Thus, characterizing changes in diffuser reflectivity is a key element in producing accurate albedo values. The Nimbus-4 BUV diffuser was exposed to sunlight on every orbit, with the result that measured solar signals decreased by more than 30% during the first two months of operation (Heath and Healy, 1974). This rapid change prevented the use of Nimbus-4 solar data for any time-dependent calibration analysis.

Nimbus-7 SBUV reduced the amount of on-orbit diffuser degradation by deploying the diffuser only for solar measurements (typically once per day), but had no direct method for tracking reflectivity changes. By increasing the diffuser exposure rate to every orbit for multiple months at a time, multiple regression analysis could in principle separate exposure-dependent components and time-dependent components in the overall diffuser degradation changes. The initial analysis of these results was presented by Cebula et al. (1988), and a revised analysis was presented by Herman et al. (1990). However, the current long-term characterization for Nimbus-7 SBUV does not use diffuser degradation information, as described further in Sect. 3.3.

The SBUV/2 instruments carry an on-board calibration system to observe relative changes in diffuser reflectivity, using strong emission lines from a mercury lamp (Weiss et al., 1991). If the diffuser exposure schedule is consistent during the lifetime of an instrument, then exposure-dependent changes will map directly into time-dependent changes. We fit the observed diffuser degradation data at each Hg emission line with a simple function (linear or exponential) to determine the time dependence, then fit these slopes with a wavelength-dependent function to get the diffuser degradation correction at each ozone wavelength. Hilsenrath et al. (1995) presents examples of these results for NOAA-11 SBUV/2.

The SBUV/2 onboard calibration measurement sequence determines diffuser reflectivity changes using alternating views of the mercury lamp and the diffuser within a 30 min sequence. Long-term lamp output changes are not a concern at the strong emission lines used for data analysis. The scatter between successive weekly calibration measurements is influenced by short-term lamp stability during the 30 min sequence, repeatability of the Hg lamp arc position, the accuracy of the diffuser position, and lamp polarity switching effects (NOAA-14 and later instruments). The magnitude of the short-term scatter does not change with time, so the statistical uncertainty of the individual time-dependent fits improves as the data set gets longer. Derived ±1 σ values for NOAA-11 SBUV/2 fits are 0.15-0.2% yr^{-1} in normalized diffuser reflectivity over 5.5 yr, but later instruments all give uncertainty values of 0.05% yr^{-1} or less. The uncertainty in this correction corresponds directly to albedo uncertainty. We must also consider the wavelength-dependent component of this uncertainty that arises from fitting the observed diffuser degradation rates for interpolation to ozone measurement wavelengths. We adopt 0.1% yr^{-1} as a spectral component for NOAA-11, and 0.05% yr^{-1} for later SBUV/2 instruments. The overall uncertainty associated with the diffuser degradation correction is then estimated by multiplying the regression slope uncertainty over the length of the data set.

The NOAA-9 SBUV/2 instrument had an on-board calibration system, but poor Hg lamp stability made the measurements useless for calibration analysis, so the Nimbus-7 "accelerated deployment" procedure was used to characterize diffuser degradation. This procedure was only run once for a relatively short interval (69 days), so the statistical errors on the derived exposure-dependent degradation rates are very large (0.8% yr^{-1}). Reprocessing the NOAA-9 solar data with a correction based on these derived rates leaves residual steps in the irradiance time series data that are smaller than the uncorrected changes, but not negligible, implying that the statistical errors overestimate the actual uncertainty. However, we have no information about possible changes in the diffuser degradation rates later in the data record, as was observed for Nimbus-7 SBUV (Schlesinger and Cebula, 1992). Coincidence comparisons with other instruments also suggest that the NOAA-9 V8.6 data set contains uncorrected drifts. We therefore adopt 0.3% yr^{-1} as a time-dependent uncertainty for the NOAA-9 diffuser degradation correction.

3.2 Snow/ice radiance

In order to simplify the calculation of long-term instrument sensitivity changes from snow/ice radiance data, we first define a nominal seasonal variation using data from a single reference year. Time-dependent changes during that reference year are approximated by interpolating the average radiance between the preceding and following years. The seasonal variation is then removed from all observations by matching the appropriate SZA values. The remaining scatter in the data for a single season has an amplitude of ~0.5-1.0%. As with the diffuser degradation analysis, the statistical uncertainty in the slope of the linear time dependence fit improves as the data set lengthens. We adopt 0.5% as an overall uncertainty for the snow/ice radiance correction used for NOAA-11, NOAA-17, and NOAA-18.

3.3 Sensitivity change

The long-term instrument sensitivity change correction for SBUV/2 instruments is determined by applying a diffuser degradation correction to the observed solar irradiance measurements, temporarily removing solar activity variations, and then calculating a smooth fit to the weekly measurements to create daily values for use in ozone processing. We use a long smoothing window (e.g. 120-180 dy) relative to the solar measurement sampling frequency because experience and consistent instrument operations have shown that the observed changes are typically gradual. The uncertainty in this time-dependent fit is approximately 0.2% for NOAA-

17 and NOAA-18 with Range 3 anode data, and 0.3% for earlier instruments. The wavelength-dependent uncertainty is considered to be similar, since each wavelength is fit independently. It should be noted that this analysis does not address the possible increase of sensitivity change rates due to the increased flux of short wavelength photons on optics during solar measurements.

The current long-term characterization of the Nimbus-4 BUV and Nimbus-7 SBUV instruments treats all observed changes as instrument sensitivity changes. For Nimbus-4 BUV, the time-dependent albedo calibration was adjusted to give reasonable agreement with profile ozone data from Umkehr stations (Bhartia, private communication). The uncorrected Nimbus-4 radiance data are not available, so we cannot derive a revised long-term calibration using the tools described elsewhere in this paper. For Nimbus-7 SBUV, two separate techniques were used to evaluate changes at short wavelengths and long wavelengths, as described by Taylor et al. (1994).

During summer solstice periods, SBUV ozone measurements can be made at the same latitude (above ~65°) for both ascending node (lower SZA) and descending node (higher SZA) conditions on a single orbit. For short wavelength measurements, it is then possible to identify measurement pairs where the single scattering contribution function for channel N on the ascending node peaks at the same altitude as the contribution function for channel N+1 on the descending node. Thus, if the ozone amount is assumed to be constant within a narrow latitude band, the relative calibration error between channels N and N+1 can be evaluated. This technique was used to derive time-dependent corrections for Nimbus-7 SBUV data at wavelengths between 273 nm and 306 nm. The estimated uncertainty in Nimbus-7 SBUV mid-latitude ozone quoted by Taylor et al. (1994) is ±6.4% (2 σ) at 273 nm, decreasing to ±5.0% (2 σ) at 306 nm. This corresponds to a 1 σ albedo uncertainty of 1.6% at 273 nm, decreasing to 1.1% at 306 nm.

The time-dependent characterization for Nimbus-7 SBUV data at long wavelengths used the pair justification technique described by Herman et al. (1991). SBUV measurements can be used to derive D-pair (305.8 nm, 312.5 nm) total ozone at equatorial latitude with low SZA and low total column ozone amounts. Since D-pair results have low sensitivity to wavelength-dependent calibration drift and high sensitivity to ozone, these results can serve as a reference for results derived using A-pair (312.5 nm, 331.2 nm), B-pair (317.5 nm, 331.2 nm), and C-pair (331.2 nm, 339.8 nm) wavelengths. We assign the albedo uncertainty for 305.8 nm equally to the five longest wavelengths for Nimbus-7 SBUV.

3.4 Interrange ratio

Time-dependent changes in the instrument gain can be characterized using the interrange ratio IRR_{32} with Range 3 cathode data, because the anode gain decreases with time relative to the PMT cathode. On-orbit data allow long-term changes in IRR_{32}, including occasional small jumps, to be tracked to approximately 0.1% accuracy. These time-dependent changes have no wavelength dependence.

3.5 Goniometry

For the SBUV instruments discussed in this paper, the intensity of the measured solar signal varies by a factor of two during the measurement sequence because of the high incidence angle used for the solar diffuser (θ = 60°-80° for many SBUV/2 instruments). The goniometric response of the diffuser is parameterized for data analysis using the spacecraft-centered elevation angle along orbit plane, which represents most of the incidence angle change, and the spacecraft-centered azimuth angle normal to orbit plane, which incorporates both seasonal variations and any long-term orbit drift.

Prelaunch tests at selected angles provide the data needed to characterize the functional dependence of the goniometric correction to better than 0.5% accuracy. However, we have observed that the orbit precession of SBUV/2 instruments eventually requires further inflight analysis to treat changes in the azimuth dependence. As the instrument approaches the terminator, measurement conditions may not be repeated from the previous year to allow validation of an inflight goniometric correction, which could introduce an error with seasonal extremes. The broad smoothing window in the instrument sensitivity correction fit will minimize the impact of any such seasonal features, so we assign a long-term uncertainty of 0.3% to this term. The goniometry uncertainty term is not needed for Nimbus-4 and Nimbus-7 because their orbits had very little drift, and because solar measurements are not directly evaluated in the long-term characterization for those instruments.

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Table 1: BUV Wavelength Chart

Channel	*Nominal* [nm]	*Nimbus-4*	*Nimbus-7*	*NOAA-9*	*NOAA-11*	*NOAA-14*	*NOAA-16*	*NOAA-17*	*NOAA-18*
1	252.00	255.5	255.65	251.83	251.97	251.99	251.99	251.91	252.04
2	273.61	273.5	273.61	273.48	273.55	273.51	273.64	273.51	273.70
3	283.10	283.0	283.10	282.94	283.08	287.62	283.05	283.05	283.16
4	287.70	287.6	287.70	287.58	287.64	292.26	287.74	287.62	287.73
5	292.29	292.2	292.29	292.14	292.27	297.54	292.29	292.18	292.36
6	297.59	297.5	297.59	297.41	297.55	301.93	297.57	297.53	297.64
7	301.97	301.9	301.97	301.80	301.93	339.84	301.96	301.93	302.03
8	305.87	305.8	305.87	305.74	305.80	305.80	305.90	305.80	305.90
9	312.57	312.5	312.56	312.43	312.49	312.50	312.59	312.49	312.67
10	317.56	317.5	317.56	317.44	317.50	317.51	317.59	317.50	317.60
11	331.26	331.2	331.26	331.14	331.20	331.23	331.23	331.22	331.32
12	339.89	339.8	339.89	339.75	339.80	339.84	339.90	339.83	339.92
Photometer (CCR)	379.0	380.0	343.0	378.62	378.62	378.62	378.62	378.62	378.62

NOTES:

1. Nimbus-7 measurements were made in long-to-short sequence.
2. Nominal wavelengths established for SBUV/2 instruments based on Nimbus-7 SBUV values, with ±0.05 nm desired accuracy in discrete mode. Location of channel 1 shifted from 255.7 nm to 252.0 nm for NOAA-9 in 1985.
3. First year of NOAA-14 data (through 1 January 1996) collected with baseline wavelengths, which were consistent with nominal sequence at all channels but ~0.2 nm longer. NOAA-14 wavelengths shown are for “zig-zag” sequence implemented 2 January 1996 to partially compensate for degraded CCR sensitivity (283 nm measurement removed, 287.6-301.9 nm measurements shifted up one position, second 339.8 nm measurement added at channel 7 to provide limited scene change tracking capability).
4. For NOAA-14, channel 4 wavelength was changed from 292.26 nm to 294.97 nm in June 1998 due to grating drive problems.

Table 2. Nimbus-4 BUV Absolute Uncertainty

Chan.	**Albedo Calib. (ground)**	**Albedo Calib. (inflight)**	**Signal-to-Noise**	**Non-Lin**	**Intrng. Ratio**	**PMT Temp.**	**Out-of-Band**	**RSS (max)**
1	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
2	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
3	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
4	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
5	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
6	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
7	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
8	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
9	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
10	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
11	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74
12	2.0	0.0	0.5	1.5	0.1	1.0	0.0	2.74

Table 3. Nimbus-7 SBUV Absolute Uncertainty

Chan.	**Albedo Calib. (ground)**	**Albedo Calib. (inflight)**	**Signal-to-Noise**	**Non-Lin**	**Intrng. Ratio**	**PMT Temp.**	**Out-of-Band**	**RSS (max)**
1	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
2	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
3	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
4	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
5	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
6	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
7	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
8	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
9	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
10	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
11	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60
12	1.5	0.5	0.5	2.0	0.1	0.1	0.0	2.60

Table 4. NOAA-9 SBUV/2 Absolute Uncertainty

Chan.	**Albedo Calib. (ground)**	**Albedo Calib. (inflight)**	**Signal-to-Noise**	**Non-Lin**	**Intrng. Ratio**	**PMT Temp.**	**Out-of-Band**	**RSS (max)**
1	2.2	0.5	2.00,0.70	0.2	0.1	0.1	0.04	3.03
2	1.9	0.5	0.63,0.14	0.2	0.1	0.1	0.05	2.08
3	1.9	0.5	0.27,0.07	0.2	0.1	0.1	0.05	2.00
4	1.8	0.5	0.24,0.04	0.2	0.1	0.1	0.05	1.90
5	1.8	0.5	0.09,0.05	0.2	0.1	0.1	0.03	1.89
6	1.8	0.5	0.06,0.03	0.2	0.1	0.1	0.02	1.89
7	1.7	0.5	0.05,0.01	0.2	0.1	0.1	0.00	1.79
8	1.7	0.5	0.07,0.01	0.2	0.0	0.1	0.00	1.79
9	1.6	0.5	0.01,0.36	0.2	0.0	0.1	0.0	2.05
10	1.6	0.5	0.01,0.17	0.2	0.0	0.1	0.0	2.02
11	1.5	0.5	0.01,0.07	0.2	0.0	0.1	0.0	1.67
12	1.5	0.5	0.01,0.08	0.2	0.0	0.1	0.0	1.67

Table 5. NOAA-11 SBUV/2 Absolute Uncertainty

Chan.	**Albedo Calib. (ground)**	**Albedo Calib. (inflight)**	**Signal-to-Noise**	**Non-Lin**	**Intrng. Ratio**	**PMT Temp.**	**Out-of-Band**	**RSS (max)**
1	1.4	0.8	1.50,0.53	0.2	0.1	0.1	0.09	2.22
2	1.4	0.8	0.47,0.11	0.2	0.1	0.1	0.10	1.70
3	1.4	0.8	0.21,0.05	0.2	0.1	0.1	0.10	1.65
4	1.4	0.8	0.18,0.03	0.2	0.1	0.1	0.10	1.64
5	1.4	0.8	0.07,0.05	0.2	0.1	0.1	0.05	1.63
6	1.4	0.8	0.04,0.03	0.2	0.1	0.1	0.04	1.63
7	1.4	1.6	0.03,0.01	0.2	0.1	0.1	0.01	2.14
8	1.4	1.6	0.07,0.01	0.2	0.0	0.1	0.00	2.14
9	1.4	1.6	0.01,0.36	0.2	0.0	0.1	0.0	2.22
10	1.4	1.6	0.01,0.17	0.2	0.0	0.1	0.0	2.20
11	1.4	2.1	0.01,0.07	0.2	0.0	0.1	0.0	2.58
12	1.4	2.1	0.01,0.08	0.2	0.0	0.1	0.0	2.58

Table 6. NOAA-14 SBUV/2 Absolute Uncertainty

Chan.	**Albedo Calib. (ground)**	**Albedo Calib. (inflight)**	**Signal-to-Noise**	**Non-Lin**	**Intrng. Ratio**	**PMT Temp.**	**Out-of-Band**	**RSS (max)**
1	1.2	0.5	1.50,0.53	0.2	0.1	0.1	0.10	2.00
2	1.2	0.5	0.47,0.11	0.2	0.1	0.1	0.13	1.41
3	1.2	0.5	0.21,0.05	0.2	0.1	0.1	0.12	1.34
4	1.2	0.5	0.18,0.03	0.2	0.1	0.1	0.12	1.34
5	1.2	0.5	0.07,0.05	0.2	0.1	0.1	0.07	1.33
6	1.2	0.5	0.04,0.03	0.2	0.1	0.1	0.04	1.32
7	1.2	0.5	0.03,0.01	0.2	0.1	0.1	0.01	1.32
8	1.2	0.5	0.07,0.01	0.2	0.0	0.1	0.01	1.32
9	1.2	0.5	0.01,0.36	0.2	0.0	0.1	0.0	1.45
10	1.2	0.5	0.01,0.17	0.2	0.0	0.1	0.0	1.42
11	1.2	0.5	0.01,0.07	0.2	0.0	0.1	0.0	1.41
12	1.2	0.5	0.01,0.08	0.2	0.0	0.1	0.0	1.41

Table 7. NOAA-16 SBUV/2 Absolute Uncertainty

Chan.	**Albedo Calib. (ground)**	**Albedo Calib. (inflight)**	**Signal-to-Noise**	**Non-Lin**	**Intrng. Ratio**	**PMT Temp.**	**Out-of-Band**	**RSS (max)**
1	1.2	1.0	1.50,0.53	0.2	0.1	0.1	0.04	2.18
2	1.2	1.0	0.47,0.11	0.2	0.1	0.1	0.05	1.65
3	1.2	1.0	0.21,0.05	0.2	0.1	0.1	0.05	1.60
4	1.2	1.0	0.18,0.03	0.2	0.1	0.1	0.05	1.59
5	1.2	1.0	0.07,0.05	0.2	0.1	0.1	0.03	1.58
6	1.2	1.0	0.04,0.03	0.2	0.1	0.1	0.02	1.58
7	1.2	1.0	0.03,0.01	0.2	0.1	0.1	0.00	1.58
8	1.2	1.0	0.07,0.01	0.2	0.0	0.1	0.00	1.58
9	1.2	1.0	0.01,0.36	0.2	0.0	0.1	0.0	1.69
10	1.2	1.0	0.01,0.17	0.2	0.0	0.1	0.0	1.66
11	1.2	1.0	0.01,0.07	0.2	0.0	0.1	0.0	1.65
12	1.2	1.0	0.01,0.08	0.2	0.0	0.1	0.0	1.65

Table 8. NOAA-17 SBUV/2 Absolute Uncertainty

Chan.	**Albedo Calib. (ground)**	**Albedo Calib. (inflight)**	**Signal-to-Noise**	**Non-Lin**	**Intrng. Ratio**	**PMT Temp.**	**Out-of-Band**	**RSS (max)**
1	1.2	0.3	1.48,0.37	0.2	0.1	0.1	0.17	1.95
2	1.2	0.3	0.42,0.08	0.2	0.1	0.1	0.21	1.25
3	1.2	0.3	0.19,0.11	0.2	0.1	0.1	0.20	1.29
4	1.2	0.3	0.19,0.09	0.2	0.1	0.1	0.20	1.29
5	1.2	0.3	0.08,0.04	0.2	0.1	0.1	0.11	1.27
6	1.2	0.3	0.13,0.03	0.2	0.1	0.1	0.07	1.27
7	1.2	0.3	0.08,0.01	0.2	0.1	0.1	0.02	1.26
8	1.2	0.3	0.04,0.01	0.2	0.1	0.1	0.01	1.26
9	1.2	0.3	0.01,0.02	0.2	0.1	0.1	0.0	1.26
10	1.2	0.3	0.01,0.01	0.2	0.1	0.1	0.0	1.26
11	1.2	0.3	0.09,0.01	0.2	0.1	0.1	0.0	1.26
12	1.2	0.3	0.07,0.01	0.2	0.1	0.1	0.0	1.26

Table 9. NOAA-18 SBUV/2 Absolute Uncertainty

Chan.	**Albedo Calib. (ground)**	**Albedo Calib. (inflight)**	**Signal-to-Noise**	**Non-Lin**	**Intrng. Ratio**	**PMT Temp.**	**Out-of-Band**	**RSS (max)**
1	1.2	1.0	1.48,0.37	0.2	0.1	0.1	0.07	2.17
2	1.2	1.0	0.42,0.08	0.2	0.1	0.1	0.08	1.64
3	1.2	1.0	0.19,0.11	0.2	0.1	0.1	0.08	1.59
4	1.2	1.0	0.19,0.09	0.2	0.1	0.1	0.08	1.59
5	1.2	1.0	0.08,0.04	0.2	0.1	0.1	0.04	1.58
6	1.2	1.0	0.13,0.03	0.2	0.1	0.1	0.03	1.59
7	1.2	1.0	0.08,0.01	0.2	0.1	0.1	0.02	1.58
8	1.2	1.0	0.04,0.01	0.2	0.1	0.1	0.00	1.58
9	1.2	1.0	0.01,0.02	0.2	0.1	0.1	0.0	1.58
10	1.2	1.0	0.01,0.01	0.2	0.1	0.1	0.0	1.58
11	1.2	1.0	0.09,0.01	0.2	0.1	0.1	0.0	1.58
12	1.2	1.0	0.07,0.01	0.2	0.1	0.1	0.0	1.58

Table 10. Nimbus-4 BUV Time-Dependent Uncertainty (end of record)

Channel	**Diffuser Refl (time)**	**Diffuser Refl (spectral)**	**Snow/Ice Radiance**	**Sensitivity Change**	**Interrange Ratio**	**Goniometry**	**RSS**
1	0.0	0.0	0.0	2.0	0.3	0.0	2.02
2	0.0	0.0	0.0	2.0	0.3	0.0	2.02
3	0.0	0.0	0.0	2.0	0.3	0.0	2.02
4	0.0	0.0	0.0	2.0	0.3	0.0	2.02
5	0.0	0.0	0.0	2.0	0.3	0.0	2.02
6	0.0	0.0	0.0	2.0	0.3	0.0	2.02
7	0.0	0.0	0.0	2.0	0.3	0.0	2.02
8	0.0	0.0	0.0	2.0	0.3	0.0	2.02
9	0.0	0.0	0.0	2.0	0.3	0.0	2.02
10	0.0	0.0	0.0	2.0	0.3	0.0	2.02
11	0.0	0.0	0.0	2.0	0.3	0.0	2.02
12	0.0	0.0	0.0	2.0	0.3	0.0	2.02

Table 11. Nimbus-7 SBUV Time-Dependent Uncertainty (end of record)

Channel	**Diffuser Refl (time)**	**Diffuser Refl (spectral)**	**Snow/Ice Radiance**	**Sensitivity Change (asc/desc, pair just.)**	**Interrange Ratio**	**Goniometry**	**RSS**
1	0.0	0.0	0.0	1.6	0.3	0.0	1.63
2	0.0	0.0	0.0	1.6	0.3	0.0	1.63
3	0.0	0.0	0.0	1.6	0.3	0.0	1.63
4	0.0	0.0	0.0	1.6	0.3	0.0	1.63
5	0.0	0.0	0.0	1.6	0.3	0.0	1.63
6	0.0	0.0	0.0	1.6	0.3	0.0	1.63
7	0.0	0.0	0.0	1.6	0.3	0.0	1.63
8	0.0	0.0	0.0	1.1	0.3	0.0	1.14
9	0.0	0.0	0.0	1.1	0.3	0.0	1.14
10	0.0	0.0	0.0	1.1	0.3	0.0	1.14
11	0.0	0.0	0.0	1.1	0.3	0.0	1.14
12	0.0	0.0	0.0	1.1	0.3	0.0	1.14

Table 12. NOAA-9 SBUV/2 Time-Dependent Uncertainty (end of record)

Channel	**Diffuser Refl (accel. deploy.)**	**Diffuser Refl (spectral)**	**Snow/Ice Radiance**	**Sensitivity Change**	**Interrange Ratio**	**Goniometry**	**RSS**
1	3.3	0.0	0.0	0.3	0.1	0.3	3.63
2	3.3	0.0	0.0	0.3	0.1	0.3	3.63
3	3.3	0.0	0.0	0.3	0.1	0.3	3.63
4	3.3	0.0	0.0	0.3	0.1	0.3	3.63
5	3.3	0.0	0.0	0.3	0.1	0.3	3.63
6	3.3	0.0	0.0	0.3	0.1	0.3	3.63
7	3.3	0.0	0.0	0.3	0.1	0.3	3.63
8	3.3	0.0	0.0	0.3	0.1	0.3	3.63
9	3.3	0.0	0.0	0.3	0.1	0.3	3.63
10	3.3	0.0	0.0	0.3	0.1	0.3	3.63
11	3.3	0.0	0.0	0.3	0.1	0.3	3.63
12	3.3	0.0	0.0	0.3	0.1	0.3	3.63

Table 13. NOAA-11 SBUV/2 Time-Dependent Uncertainty (end of record)

Channel	**Diffuser Refl (time)**	**Diffuser Refl (spectral)**	**Snow/Ice Radiance**	**Sensitivity Change**	**Interrange Ratio**	**Goniometry**	**RSS**
1	0.83	0.55	0.5	0.3	0.1	0.3	1.19
2	0.83	0.55	0.5	0.3	0.1	0.3	1.19
3	0.83	0.55	0.5	0.3	0.1	0.3	1.19
4	0.83	0.55	0.5	0.3	0.1	0.3	1.19
5	0.83	0.55	0.5	0.3	0.1	0.3	1.19
6	0.83	0.55	0.5	0.3	0.1	0.3	1.19
7	0.83	0.55	0.5	0.3	0.1	0.3	1.19
8	0.83	0.55	0.5	0.3	0.1	0.3	1.19
9	0.83	0.55	0.5	0.3	0.1	0.3	1.19
10	0.83	0.55	0.5	0.3	0.1	0.3	1.19
11	0.83	0.55	0.5	0.3	0.1	0.3	1.19
12	0.83	0.55	0.5	0.3	0.1	0.3	1.19

Table 14. NOAA-14 SBUV/2 Time-Dependent Uncertainty (end of record)

Channel	**Diffuser Refl (time)**	**Diffuser Refl (spectral)**	**Snow/Ice Radiance**	**Sensitivity Change**	**Interrange Ratio**	**Goniometry**	**RSS**
1	0.30	1.00	0.0	0.3	0.1	0.3	1.13
2	0.30	1.00	0.0	0.3	0.1	0.3	1.13
3	0.30	1.00	0.0	0.3	0.1	0.3	1.13
4	0.30	1.00	0.0	0.3	0.1	0.3	1.13
5	0.30	1.00	0.0	0.3	0.1	0.3	1.13
6	0.30	1.00	0.0	0.3	0.1	0.3	1.13
7	0.30	1.00	0.0	0.3	0.1	0.3	1.13
8	0.30	1.00	0.0	0.3	0.1	0.3	1.13
9	0.30	1.00	0.0	0.3	0.1	0.3	1.13
10	0.30	1.00	0.0	0.3	0.1	0.3	1.13
11	0.30	1.00	0.0	0.3	0.1	0.3	1.13
12	0.30	1.00	0.0	0.3	0.1	0.3	1.13

Table 15. NOAA-16 SBUV/2 Time-Dependent Uncertainty (end of record)

Channel	**Diffuser Refl (time)**	**Diffuser Refl (spectral)**	**Snow/Ice Radiance**	**Sensitivity Change**	**Interrange Ratio**	**Goniometry**	**RSS**
1	0.5	0.5	0.0	0.3	0.1	0.3	0.83
2	0.5	0.5	0.0	0.3	0.1	0.3	0.83
3	0.5	0.5	0.0	0.3	0.1	0.3	0.83
4	0.5	0.5	0.0	0.3	0.1	0.3	0.83
5	0.5	0.5	0.0	0.3	0.1	0.3	0.83
6	0.5	0.5	0.0	0.3	0.1	0.3	0.83
7	0.5	0.5	0.0	0.3	0.1	0.3	0.83
8	0.5	0.5	0.0	0.3	0.1	0.3	0.83
9	0.5	0.5	0.0	0.3	0.1	0.3	0.83
10	0.5	0.5	0.0	0.3	0.1	0.3	0.83
11	0.5	0.5	0.0	0.3	0.1	0.3	0.83
12	0.5	0.5	0.0	0.3	0.1	0.3	0.83

Table 16. NOAA-17 SBUV/2 Time-Dependent Uncertainty (end of record)

Channel	**Diffuser Refl (time)**	**Diffuser Refl (spectral)**	**Snow/Ice Radiance**	**Sensitivity Change**	**Interrange Ratio**	**Goniometry**	**RSS**
1	0.4	0.4	0.5	0.3	0.1	0.3	0.77
2	0.4	0.4	0.5	0.3	0.1	0.3	0.77
3	0.4	0.4	0.5	0.3	0.1	0.3	0.77
4	0.4	0.4	0.5	0.3	0.1	0.3	0.77
5	0.4	0.4	0.5	0.3	0.1	0.3	0.77
6	0.4	0.4	0.5	0.3	0.1	0.3	0.77
7	0.4	0.4	0.5	0.3	0.1	0.3	0.77
8	0.4	0.4	0.5	0.3	0.1	0.3	0.77
9	0.4	0.4	0.5	0.3	0.1	0.3	0.77
10	0.4	0.4	0.5	0.3	0.1	0.3	0.77
11	0.4	0.4	0.5	0.3	0.1	0.3	0.77
12	0.4	0.4	0.5	0.3	0.1	0.3	0.77

Table 17. NOAA-18 SBUV/2 Time-Dependent Uncertainty (end of record)

Channel	**Diffuser Refl (time)**	**Diffuser Refl (spectral)**	**Snow/Ice Radiance**	**Sensitivity Change**	**Interrange Ratio**	**Goniometry**	**RSS**
1	0.12	0.6	0.5	0.3	0.1	0.3	0.81
2	0.12	0.6	0.5	0.3	0.1	0.3	0.81
3	0.12	0.6	0.5	0.3	0.1	0.3	0.81
4	0.12	0.6	0.5	0.3	0.1	0.3	0.81
5	0.12	0.6	0.5	0.3	0.1	0.3	0.81
6	0.12	0.6	0.5	0.3	0.1	0.3	0.81
7	0.12	0.6	0.5	0.3	0.1	0.3	0.81
8	0.12	0.6	0.5	0.3	0.1	0.3	0.81
9	0.12	0.6	0.5	0.3	0.1	0.3	0.81
10	0.12	0.6	0.5	0.3	0.1	0.3	0.81
11	0.12	0.6	0.5	0.3	0.1	0.3	0.81
12	0.12	0.6	0.5	0.3	0.1	0.3	0.81