Goddard / SSFS

IN-45-CR

83987

P-12

Semiannual Status Report for Grant NAG 5-873

The Detection and Interpretation of Long-Term Atmospheric

Change:

Tasks in Association with the Shuttle Solar Backscatter

Ultraviolet Spectral Radiometer

(NASA-CR-180521) THE DETECTION AND INTERPRETATION OF LONG-TERM ATMOSPHERIC CHANGE: TASKS IN ASSOCIATION WITH THE SHUTTLE SOLAR BACKSCATTER ULTRAVIOLET SPECTRAL RADIOMETER (Chicago Univ.) 12 p N87-25636

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August 5, 1987

I. Objectives

The objectives of research performed under this grant are (1) to develop techniques to detect and remove long-term instrument drifts from the operational SBUV/2 data base using periodic measurements made by the Shuttle Solar Backscatter Ultraviolet Spectral Radiometer (SSBUV) and (2) to evaluate the potential effect of scattering by atmospheric aerosols on our ability to detect trends in ozone using SBUV-class instruments. Work during the first six months of this grant, beginning in mid-February 1987, has focused on the first of these objectives.

II. Methodology

A method to combine backscatter albedo measurements from SSBUV and the SBUV/2 instruments for the purpose of removing drifts in the latter data set has been developed and tested. At present the techniques have been applied to a simulated data base which represents the two year lifetime of a single SBUV/2 instrument. The following paragraphs summarize the mathematical model.

The backscatter albedos, $A(i) = I(i)/F(i)$, are the basis for SSBUV-SBUV/2 comparisons, where $I(i)$ is the backscattered radiance which emerges from the atmosphere in the vertical direction, $F(i)$ is the incident solar irradiance, and the index "i" labels wavelength. During a single flight of SSBUV, denoted by the index "j", there will be $k=1,2,\ldots,K$ coincident measurements with the operational

SBUV/2. Let $A_s(i,j,k)$ denote the albedos measured by SSBUV and $A_2(i,j,k)$ refer to nearly simultaneous SBUV/2 data. During a given two year SBUV/2 flight j will take on values j=1,2,3, and perhaps 4. A typical value for K, the number of SSBUV-SBUV/2 coincidences on a single Shuttle flight, is K=30.

We define a "correction factor" c(i,j) which normalizes the SBUV/2 albedos to those measured by SSBUV. This is:

$$c(i,j) = \sum_{k=1}^{K} [A_s(i,j,k)/A_2(i,j,k)]/K \qquad (1)$$

The statistical uncertainty in the correction factor is defined by the variance:

$$\sigma^2 = \sum_{k=1}^{K} [A_s(i,j,k)/A_2(i,j,k)-c(i,j)]^2/(K-1) \qquad (2)$$

The SSBUV-SBUV/2 intercomparisons made on a given day define one correction factor for each wavelength (index "i"). This could be altered in the future if, for example, one wished to derive a single correction factor for an entire SSBUV mission lasting several days. Given several flights of SSBUV during the lifetime of a single SBUV/2 instrument, one can derive a time dependent correction factor by fitting a linear or quadratic curve to the c(i,j), j=1,2,3, and maybe 4.

$$c(i,t) = c_0(i) + c_1(i)t \tag{3a}$$

or

$$c(i,t) = c_0(i) + c_1(i)t + c_2(i)t^2 \tag{3b}$$

where "t" is time in days from the start of data collection by the SBUV/2. A "corrected" set of SBUV/2 albedos, A_c, as a function of time is then:

$$A_c(i,t) = c(i,t)\, A_2(i,t) \tag{4}$$

These corrected SBUV/2 albedos are the data set for use in seeking long-term trends in atmospheric ozone.

A central issue of this study involves definition of how uncertainties in the measured albedos and a lack of exact simultaneity between SSBUV and SBUV/2 influence the derived correction factors. To investigate this we have developed simulated data sets for A_s and A_2 which contain known systematic and random errors.

The Nimbus 7 SBUV instrument has provided a set of measured albedos which, for test purposes, we take to be the true atmospheric albedo with zero error. We consider data measured over the latitude range 0 to 15°N here. We then generate a two year series of simulated SBUV/2 albedos, A_2, via:

$$A_2(i,t) = [1+f(i,t)+\epsilon(t)]A_T(i,t) \tag{5}$$

Here $A_T(i,t)$ is based on the monthly mean albedo from Nimbus 7 plus a random noise component. Daily values of $A_T(i,t)$ are chosen at random from a normal distribution whose mean is the average Nimbus 7 albedo for the month and whose standard deviation (σ) is 0.333% of this average (3σ = 1%). The function f(i,t) simulates long-term drifts in the SBUV/2 instrument. We have examined both linear and exponential drifts:

$$f(i,t) = d(i)t \tag{6a}$$

and:

$$f(i,t) = d(i)\{1 - \exp[-t/\tau(i)]\} \tag{6b}$$

where we specify d(i) and $\tau(i)$. Equation 6b simulates an instrument which experiences an initial drift but which eventually stabilizes over a time t equal to several times $\tau(i)$. The parameter $\epsilon(t)$ provides for noise in the measurements. We select each value of ϵ at random from a normal distribution whose mean is zero and whose standard deviation is $\sigma = 0.004/3$.

We also simulate a set of SSBUV albedo measurements by:

$$A_{\blacksquare}(i,j,k) = [1+b(j)]\ [1+\epsilon^*(k)]\ A_T{}^*(i,j,k) \tag{7}$$

The index "j" labels a flight of SSBUV, and "k" labels a set of albedo measurements obtained nearly simultaneous with the

SBUV/2. Taken together j and k specify a unique time t in equation 5 for which a comparison between SSBUV and SBUV/2 is possible. The albedo $A_T{}^*$ in equation 7 is selected from a normal distribution whose mean is the Nimbus 7 SBUV albedo and whose standard deviation is 0.333%. Note that $A_T{}^*(i,j,k)$ in equation 7 is not numerically identical to $A_T(i,j,k)$ in equation 5. The common point is that both A_T and $A_T{}^*$ are selected from the same normal distribution based on Nimbus 7 data. The random selection of A_T and $A_T{}^*$ from the same distribution simulates a lack of exact simultaneity between SSBUV and SBUV/2 and the fact that the fields of view of the two instruments cover a different area when projected onto the earth's surface.

The term $\epsilon^*(k)$ accounts for SSBUV repeatability and is determined in the same manner as $\epsilon(k)$ for SBUV/2. The parameter b(j) allows for calibration biases in SSBUV which can vary from one flight to the next. The sample calculations presented in this report select b(j) at random from a normal distribution with a mean of zero and a standard deviation of 0.333% ($3\sigma = 1\%$). Future calculations will specify a known b(j) for each Shuttle flight to examine the sensitivity of the correction factors to SSBUV calibration biases.

III. Sample Results

Figures 1 through 4 present samples of our preliminary results. The top panel of each figure gives the simulated

SBUV/2 albedo data set over a two year period. The origins of the time scales (expressed in days) refer to the start of SBUV/2 data collection. The jagged behavior in the simulated SBUV/2 data set arises from the use of monthly mean albedos as opposed to daily values. This has no impact on the derived correction factors. The stars in the top panels indicate SSBUV measurements. In Figures 1 and 2 we assume three SSBUV missions separated by eight months, while Figures 3 and 4 contain four SSBUV flights separated by seven months. Each star is the mean of six albedos obtained at the SSBUV-SBUV/2 coincidences on a single day, and we assume a five day Shuttle mission. The stars in the center panels of all figures represent correction factors derived for each day of a SSBUV mission.

The solid line is a fit of equation 3a (Figures 1 and 2) or 3b (Figures 3 and 4) to the individual c(i,j) values. The bottom panel of each figure compares the true SBUV/2 drift, A_E-A_T (darker line), with the computed drift, A_C-A_T (lighter, dotted line). If the correction procedure were perfect the two lines would coincide. Figures 1 and 2 refer to wavelengths 273.6 and 287.7 nm respectively and assume a linear SBUV/2 degradation over time at a rate of 4% per year ($d(i) = 0.04/365$ in equation 6a). Figures 3 and 4 refer to an exponential instrument drift followed by stabilization, as described by equation 6b with $d(i) = 0.04$ and $\tau(i) = 182$ days. These results should be regarded as preliminary, although they indicate that SSBUV is capable of detecting and correcting SBUV/2 drifts of the magnitude assumed here to a high degree of accuracy, although the procedure is not totally free of error. Many more test cases must be analyzed here before definitive conclusions are reached. This activity will continue in the coming six month period.

Figure 1

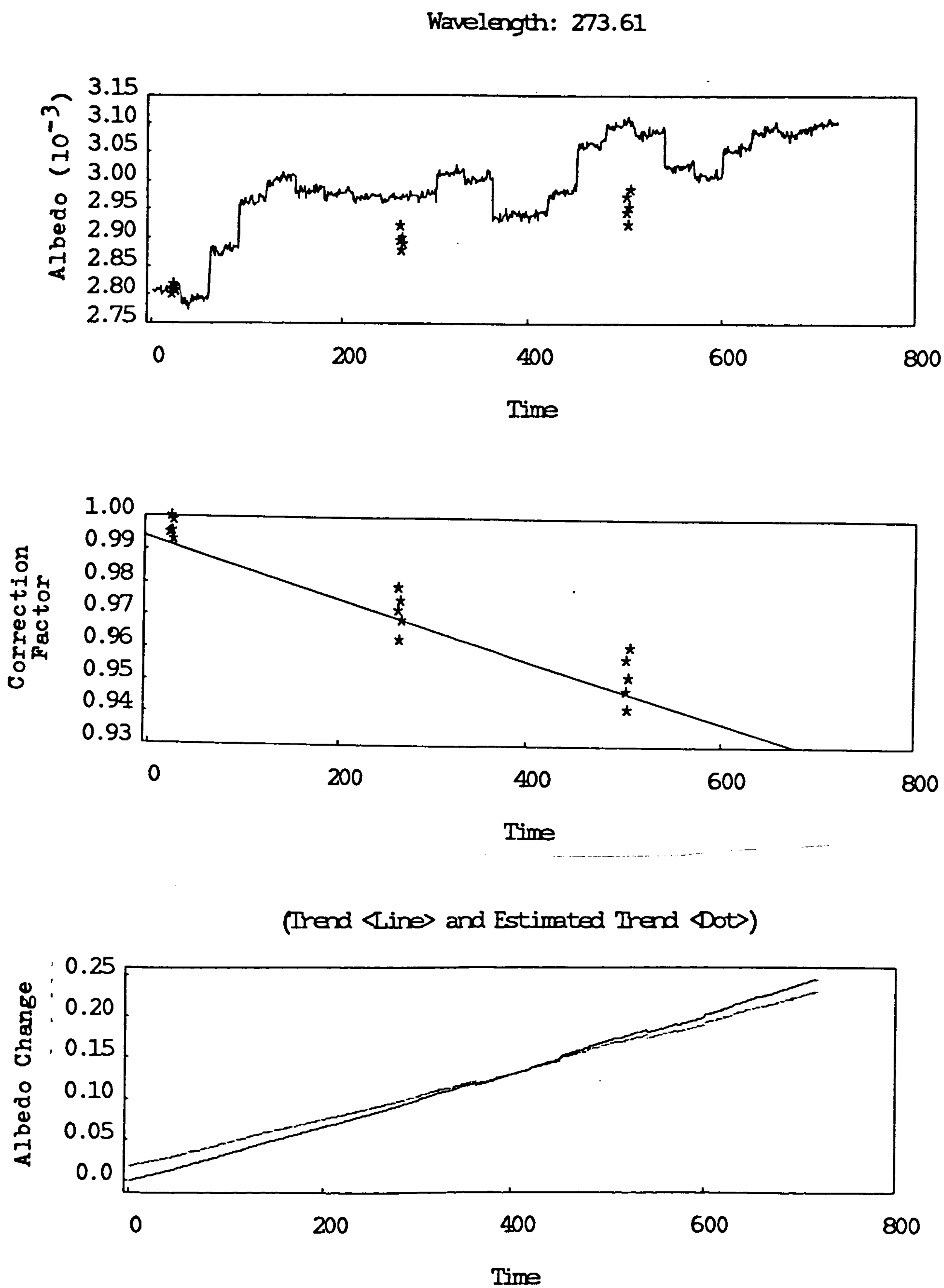

Wavelength: 273.61
Albedo (10^{-3})
3.15
3.10
3.05
3.00
2.95
2.90
2.85
2.80
2.75
0
200
400
600
800
Time
Correction Factor
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0
200
400
600
800
Time
(Trend <Line> and Estimated Trend <Dot>)
Albedo Change
0.25
0.20
0.15
0.10
0.05
0.0
0
200
400
600
800
Time

Figure 2

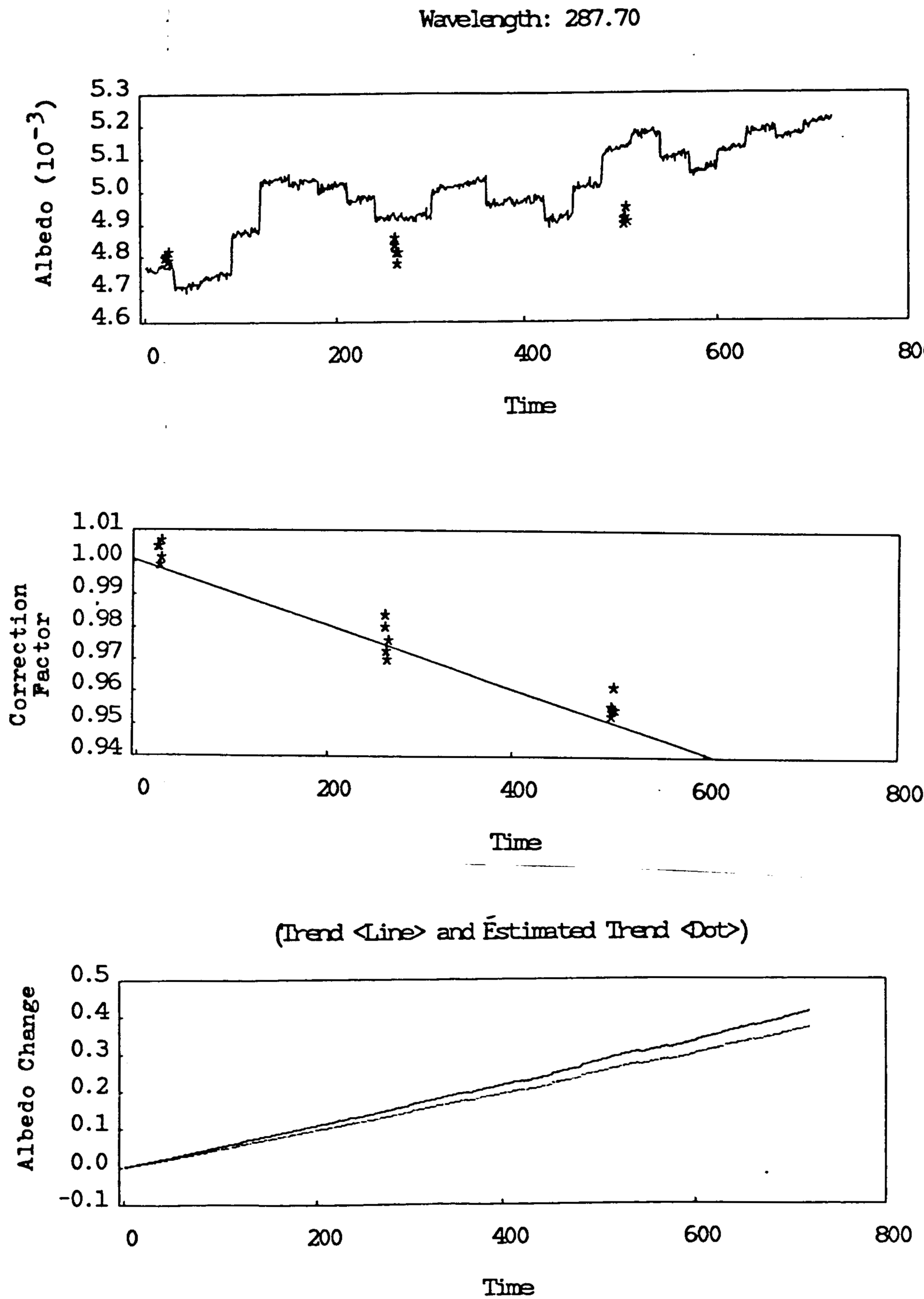
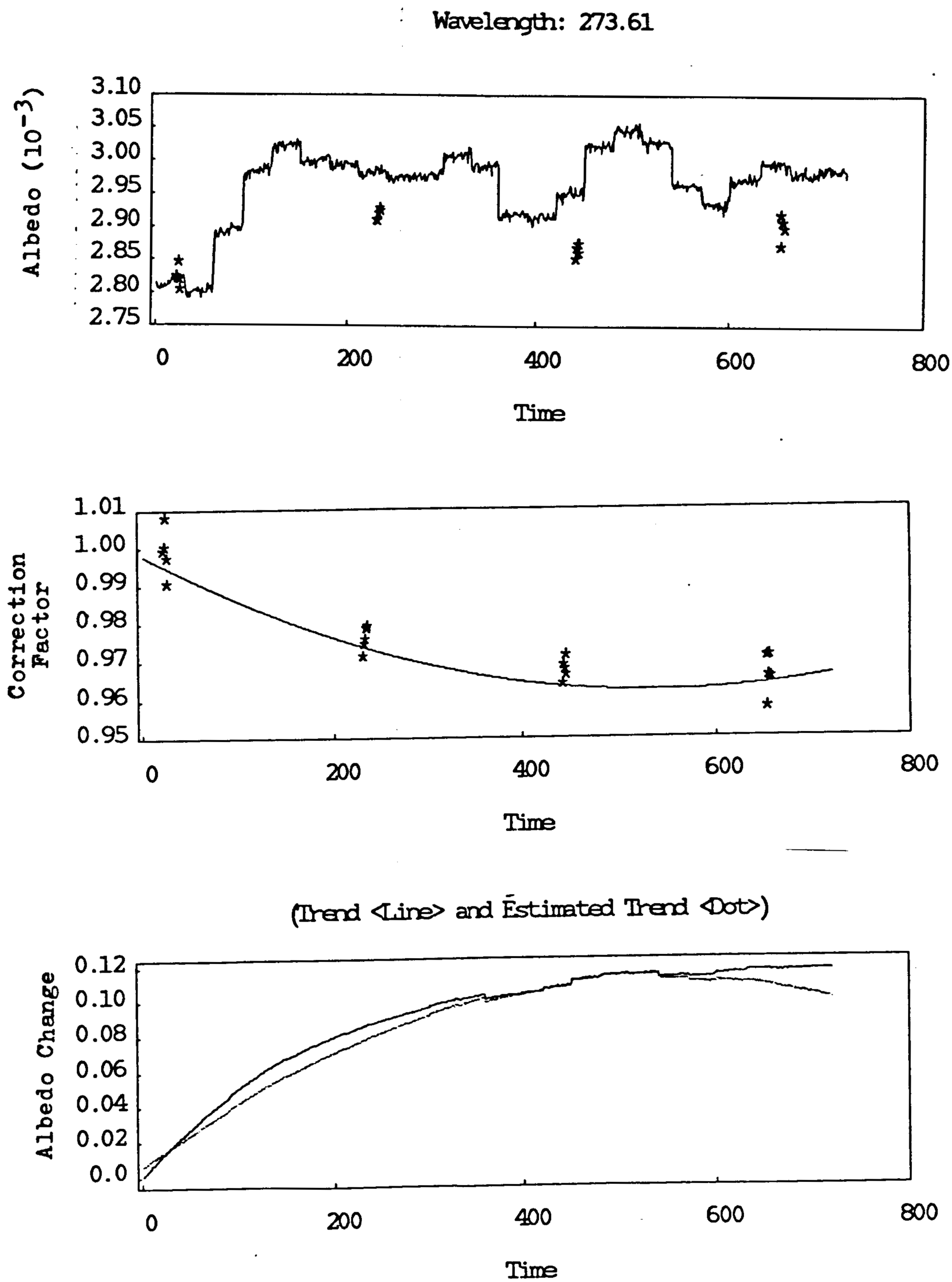

Wavelength: 287.70
Albedo (10^{-3})
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
0
200
400
600
800
Time
Correction Factor
1.01
1.00
0.99
0.98
0.97
0.96
0.95
0.94
0
200
400
600
800
Time
(Trend <Line> and Estimated Trend <Dot>)
Albedo Change
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0
200
400
600
800
Time

Figure 3



Wavelength: 273.61
Albedo (10^{-3})
3.10
3.05
3.00
2.95
2.90
2.85
2.80
2.75
0
200
400
600
800
Time
Correction Factor
1.01
1.00
0.99
0.98
0.97
0.96
0.95
0
200
400
600
800
Time
(Trend <Line> and Estimated Trend <Dot>)
Albedo Change
0.12
0.10
0.08
0.06
0.04
0.02
0.0
0
200
400
600
800
Time

Figure 4

Wavelength: 287.70