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NIMBUS 7 Coastal Zone Color Scanner (CZCS)

Level 2 Data Product Users' Guide

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1. THE COASTAL ZONE COLOR SCANNER EXPERIMENT

1.1 Introduction

The Nimbus-7 spacecraft was launched in October 1978, and has been producing data for over five years. The Coastal Zone Color Scanner (CZCS), flying on Nimbus-7, is a multispectral line scanner devoted principally to measurements of ocean color It has six spectral bands (channels); four chiefly for ocean color, each of 20 nanometer band width and centered at 443, 520, 550, and 670 nanometers. These are referred to as channels 1 through 4, respectively. Channel 5 senses reflected solar radiance, but has a 100 nanometer band width centered at 750 nanometers and a dynamic range which is more suited to land. Channel 6 operates in the 10.5 to 12.5 micrometer region and senses emitted thermal radiance for derivation of equivalent black body temperature.

The CZCS scans a width of approximately 1600 kilometers with a spatial resolution at the nadir of 800 meters in each of the 6 co-registered channels. Data acquired from the CZCS are processed at the Goddard Space Flight Center into two product levels. Level-1 products contain earth located raw radiance counts and calibration information. Level-2 products contain derived information such as pigment concentrations, aerosol radiances, subsurface radiances, and diffuse attenuation coefficients which are obtained from the raw data using scientific processing algorithms developed by members of the CZCS Nimbus Experiment Team (NET). Digital tape and film products are produced and archived for both of the product levels.

This guide is intended for users of Nimbus-7 CZCS Level-2 data products The CZCS instrument and theoretical foundations behind the experiment are described in Section 1. Section 2 contains a description of the scientific algorithms which have been implemented at the NASA Goddard Space Flight Center (GSFC) for the derivation of CZCS Level-2 products. As a result of the experimental nature of the CZCS instrument and experience gained in over six years of operation, four distinct processing algorithms have been implemented for production of Level-2 products. Section 3 provides comparisons of the results obtained using each of the four algorithms. Finally, Section 4 describes the CZCS Level-2 tape format and Section 5 provides information on product availability and cost.

1.2 Theoretical Foundations and Objectives

The CZCS is intended primarily as a tool for determining the content of water. It is well known that the content of water, be it organic or inorganic particulate matter or dissolved substances, affects its color. Ocean water, containing very little particulate matter, scatters as a Rayleigh scatterer with the well known deep purple or bluish color of the ocean. As particulate matter is added to the water, the scattering characteristics are changed and the color is changed. Phytoplankton, for instance, have specific absorption characteristics and normally change the water to a more greenish hue although some phytoplankton, such as the various red tide, can change the water to colors such as red, yellow, blue-green, or mahogany. By sensing the color with very high signal-to-noise ratios, the CZCS provides a mechanism for analyzing that color for the content of the water. Inorganic particulate matter in water, such as the terrigenous outflow from rivers, has a different color from organic material typically brownish in color but sometimes varying with red.

1.2.1 Scientific Objectives

The scientific objective of the CZCS is to determine the specific nature of the contents of water as quantitatively as possible and to carry out such measurements over large areas in short periods of time in a way not possible with other techniques such as surface ship investigations. Specifically, the CZCS experiment attempts to discriminate between organic and inorganic materials in the water, determine the quantity of these materials in the water sample to the best degree possible and, in certain instances, attempts identification of organic particulates such as discriminating between various types of red tide organisms.

By conducting measurements over a large area in a short period of time, the CZCS allows oceanographers to view the ocean as never seen before from ships. As an example, in one two-minute data segment, the CZCS covers approximately 1.3 million square kilometers of the ocean surface allowing examination, nearly simultaneously, on a scale never before accomplished. Measurements on this scale allow oceanographers to determine such things as the standing stock of phytoplankton and its distribution in various fishing areas and, potentially, to assess the ability of that area to support a standing stock of fish. In addition to examining the existing fisheries, the CZCS will be used to look for new areas of potential fish production around the globe.

1.2.2 Technical Objectives

The technical objective of the CZCS program is to determine if remote sensing of color can be used to identify and quantify material suspended or dissolved in water. If ocean color measurements can be used to derive such products as chlorophyll and sediment concentration, they will guide further development of the ocean color discipline and help to determine if such an instrument is a candidate for operational satellite use in the future.

The algorithms being developed for the derived products from CZCS are the result of the most extensive ocean color measurements ever made and are a considerable step forward from those available in the past. Corrections for such things as atmospheric backscatter and limb brightening are included in the CZCS processing algorithms. The processing goal is to take the observed radiance, determine the radiance that would be seen directly above the ocean surface, and then derive from that radiance, the content of the water below the ocean surface.

1.3 Instrument Description

The CZCS has considerable flexibility built into it to accommodate a wide range of conditions. The first four spectral bands, for instance, have four separate gains that change, on command, to accommodate the range of sun angles observed during a complete orbit and throughout the various seasons. The gains are changed to utilize the best dynamic range possible without saturating over water targets. Normally, the gain used in the first four channels is determined by the solar elevation angle of the target to be acquired. When a special circumstance is expected, such as a particularly bright material in the water, the gain can be changed to accomodate the special circumstances.

In addition to gain change, the CZCS scan mirror can be tilted from nadir to look either forward or behind the spacecraft line of flight. It can tilt in two degree increments up to twenty degrees in either direction This feature was built into the instrument to avoid the glint caused by capillary waves on the ocean that would obscure any scattering from below the surface. The angle of tilt of the scan mirror is determined by the solar elevation angle. It is normally tilted to avoid sunlight and would only be commanded to look into the glint for a special sunglint study.

The CZCS is a scanning multi-spectral radiometer with a recorded scan width of 1566 kilometers centered on spacecraft nadir. The scanner actually scans through 360 degrees, but the electronics limit the high data rate sampling to 39.34 degrees about nadir. The ground resolution of the IFOV is 0.825 kilometer at nadir and degrades somewhat as the instrument scans away from nadir on either side.

The CZCS has six spectral bands, five sensing backscattered solar radiance and one sensing emitted thermal radiance. The beam is split by a dichroic beam splitter, one portion of the beam going through a set of depolarizing wedges to a small polychromator where the radiance is dispersed and detected by five silicon diode detectors in the focal plane of the polychromator. Radiance in the 10.5μm to 12.5μm spectral band is reflected off the dichroic and then imaged onto an infrared detector of mercury cadmium telluride cooled to approximately 120 Kelvin. Table 1-1 shows the center wavelengths, the spectral bandwidths, and the minimum signal-to-noise ratio specified for the instrument at the most sensitive gain setting, that is, the gain setting that would be used for the darkest targets. The first four channels were selected to cover specific absorption bands and the so-called hinge point. These channels are meant to look at water only and saturate when the field of view is over most land surfaces and clouds. Channel 5 has the same spectral response as channel 6 of the Landsat multi-spectral scanner series. The spectral response of channels 1 through 5 is illustrated in Figure 1-1.

The 10.5μm to 12.5μm channel measures equivalent blackbody temperature as seen by the sensor with a noise equivalent temperature difference of less than 0.35 Kelvin at 270 Kelvin. Atmospheric interference with this channel, principally from weak water vapor absorption in the 10.5μm to 12.5μm region, can produce measurement errors of several degrees. Temperature gradients, however, should be seen quite well because of the extremely low noise equivalent temperature difference of this sensor.

Prelaunch calibration of the CZCS was achieved utilizing a 76 centimeter diameter integrating sphere as a source of diffuse radiance for channels 1 through 5 and a blackbody source for calibration of channel 6. The integrating sphere was especially constructed for calibration of the CZCS and was, itself, calibrated from a standard lamp from the National Bureau of Standards utilizing a spectrometer and another integrating sphere to transfer calibration from the lamp to the sphere.

In-flight calibration of the CZCS is accomplished for the first five bands by using a built-in incandescent light source. This in-flight calibration source was calibrated using the instrument itself as a transfer against the referenced sphere output. The light source is redundant in the instrument so that in case of failure of one of the lights, another one can be ordered to operate on command. After launch, light calibration source number one has been used routinely, with light source number two tested occasionally to verify its stability.

Table 1-1
CZCS Performance Parameters

Performance Parameters	Channels					
	1	2	3	4	5	6
Scientific Observation	Chlorophyll Absorption	Chlorophyll Correlation	Yellow Stuff	Chlorophyll Absorption	Surface Vegetation	Surface Temperature
Center Wavelength λ Micrometers	0.443 (blue)	0 520 (green)	0 550 (yellow)	0.670 (red)	0 750 (far red)	11.5 (infrared)
Spectral Bandwidth Δλ Micrometers	0.433 – 0.453	0.510 – 0 530	0 540 – 0.560	0 660 – 0.680	0.700 – 0 800	10.5 – 12.5
Instantaneous Field of View (IFOV)	← 0.865 x 0 865 Milliradians (0.825 x 0 825 km at sea level) →					
Co-registration at NADIR	<0 15 Milliradians					
Accuracy of Viewing Position Information at NADIR	<2 0 Milliradians					
Signal to Noise Ratio (min.) at Radiance Input N < (mW/cm^2 · STER · μm)	>150 at 5.41	>140 at 3 50	>125 at 2 86	>100 at 1 34	>100 at 10 8	NETD of 0 220°K at 270°K
Consecutive Scan Overlap	25%					
Modulation Transfer Function (MTF)	1 at 150 km target size, 0 35 min. at 0 825 km target size					

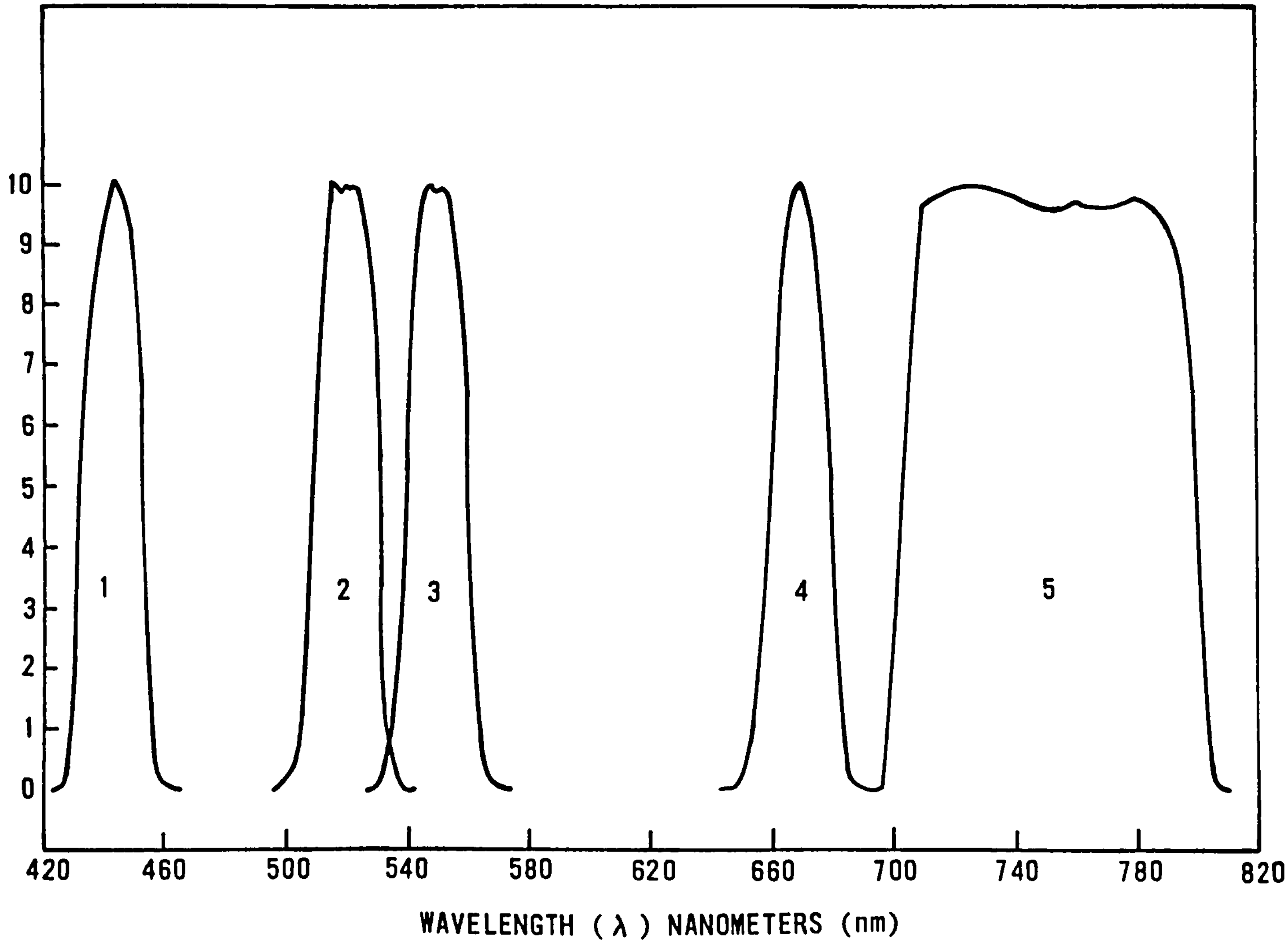

Figure 1-1. CZCS Spectral Response for Channels 1 through 5

Channel 6 is calibrated by viewing the blackened housing of the instrument whose temperature is monitored Deep space is another calibration viewed during the 360 degrees rotation of the scan mirror.

Since Nimbus 7 flys from south to north in daylight, the scan mirror is positioned to look behind the satellite when the spacecraft is south of the subsolar point and ahead of the spacecraft when it is north of the subsolar point. Tilt and gain setting information is transmitted with the CZCS data and is part of the data product records.

The CZCS data is transmitted from the spacecraft to ground receiving stations at a rate of 800 kbs either in real time or in playback of the tape recorder. Whenever possible the data is recorded in real time. However, when the satellite is out of the range of tracking stations, the data is recorded on an on board tape recorder. The tape recorded data will normally be played back at the Alaska tracking station. Nine other STDN's also have the capability to receive these playbacks.

The most important aspect to be understood about the CZCS operation is that the operation is limited due to spacecraft power constraints to approximately two hours per day. Because of the requirement to operate the sensor two hours per day, data must be taken in carefully preselected locations. Minimum on-off data taking time is a two minute segment. Frequently, longer segments are taken - up to a maximum of ten minutes of continuous data

All channels of the CZCS instrument operate simultaneously. During daytime operations all six channels provide useful information. If the sensor operates at night, only data from channel 6 is usable.

2. CZCS Derived Products Algorithm

In the production of CZCS derived products imagery, the oceanic subsurface radiance, the pigment concentration, and the diffuse attenuation coefficient are computed for each cloud free data point over water by correcting the sensor observed radiances for instrument calibration errors, atmospheric absorption, atmospheric backscattering, and refraction at the ocean surface. This section summarizes the basic theory and scientific algorithms which have been implemented by NASA-GSFC for the production of CZCS Level-II user products.

As a result of the experimental nature of the CZCS instrument and experience gained over the course of the CZCS project, four distinct processing algorithms have been implemented for production of Level-2 products. Products generated using each of the four algorithms are identified on user products by an algorithm I.D. code. Table 2-1 lists the algorithm I.D. codes and the orbital range for which data was produced using each algorithm.

2.1 Data Calibration

The initial step in the calculation of CZCS derived products is the conversion of raw radiance count values, as contained on the CZCS Radiance and Temperature Tape (CRTT), into total observed radiance in units of microwatts per square centimeter

Table 2-1

CZCS Level-II Algorithms

Algorithm No.	Algorithm I.D. Code	Orbital Range
1	00 00 00 00 00 01 00 00 00 00	0 - 4000
2	01 00 00 00 00 02 01 00 00 00	0 - 4000
3	02 01 01 00 00 03 02 00 00 00	0 - 8000
4	03 02 02 00 00 04 03 00 00 00	0 - 23,200

micrometer steradians. This, and all subsequent operations, is performed on all picture elements (pixels) with the exception of those which are identified as land or cloud covered. Pixels which exceed the threshold of 21 digital counts in channel 5 are flagged as land/cloud covered. For the remaining pixels an uncorrected total observed radiance ($L_{To}(\lambda)$) is computed using.

$$L_{To}(\lambda) = C(\lambda)\,AR_g(\lambda) + BG_g(\lambda) \tag{1}$$

where AR_g and BR_g are the pre-launch calibration coefficients as listed in table 2-2 and C is the raw digital count value extracted from the CRTT for channels 1 through 4.

The corrected total observed radiance ie (the radiance actually reaching the sensor) differs from L_{To} by an amount attributable to changes in the calibration of the CZCS instrument. The correction is applied in the form:

$$L_T(\lambda) = L_{To}(\lambda)\,F_C(\lambda) \tag{2}$$

where $F_C(\lambda)$ is the calibration correction factor. This factor has been computed differently for each of the four production algorithms. Depending on the production algorithm, $F_C(\lambda)$ is computed as follows:

Algorithm 1:

$$F_C(\lambda) = K(\lambda) \tag{3-1}$$

where: $\lambda = 443$, 520, 550, and 670 nm and $K(\lambda)$ is as listed in table 2-3.

Algorithm 2:

$$F_C(443) = K(443)/(1 - 1\ 5 \times 10^{-5}(N\text{-}3600)) \tag{3-2}$$

$$F_C(\lambda) = K(\lambda)$$

where. $\lambda = 520$, 550, and 670 nm; $K(\lambda)$ is as listed in table 2-3; and N is the orbit number.

Table 2-2

Prelaunch Calibration Coefficients

λ(nm)	GAIN 1		GAIN 2	
	AR	BR	AR	BR
443	.04452	.03963	.03589	.05276
520	.03103	.06361	02493	.08826
550	.02467	.07992	.02015	.06247
670	.01136	01136	00897	.03587

λ(nm)	GAIN 3		GAIN 4	
	AR	BR	AR	BR
443	.02968	.02879	.02113	.03359
520	.02032	.09752	.01486	.05647
550	.01643	.06570	.01181	.04723
670	.00741	.02963	.00535	01604

Table 2-3

Calibration Correction Coefficients

λ(nm)	K	$M \times 10^5$	a	$b \times 10^5$	$c \times 10^{10}$
443	1.069	2.12	1.069	2.32	5.00
520	0.993	1.22	1.024	0.59	0
550	0.955	0.78	1.007	0.28	0
670	1.000	0.00	1.000	0	0

Algorithm 3:

$$F_C(\lambda) = K(\lambda) \times e^{M(\lambda)(N-3200)} \quad (3\text{-}3)$$

where: $\lambda = 443$, 520, 550, and 670 nm; $K(\lambda)$ and $M(\lambda)$ are as defined in table 2-3; and N is the orbit number.

Algorithm 4:

$$F_C(\lambda) = K(\lambda)/(a(\lambda) - b(\lambda)N + c(\lambda)N^2) \quad (3\text{-}4)$$

where: $\lambda = 443$, 520, 550, and 670 nm; $a(\lambda)$, $b(\lambda)$, $c(\lambda)$, and $K(\lambda)$, are as defined in table 2-3; and N is the orbit number.

2.2 Atmospheric Correction

Generally, a satellite viewing the ocean surface will receive radiation contributions from several sources beside that from the water surface (L_W) and perhaps below the surface depending on wavelength. These include contributions due to Rayleigh scattering (L_R), aerosol scattering (L_A) and solar glint (L_G). The relationship is expressed as:

$$L_T = L_W + L_A + L_R + L_G \quad (4)$$

Since the CZCS is equipped with a tilt mechanism which is normally commanded to aim the sensor away from sun glint, the L_G term is effectively zero and is ignored for processing purposes. In order to compute the radiance contribution from the water surface it is necessary to compute and remove the radiance contribution from Rayleigh scattering and aerosol scattering. Radiance contributions from atmospheric scattering may comprise over ninety percent of the total observed radiance in the CZCS wavelengths.

2.2.1 Computation of the Rayleigh Radiance

In modeling the Rayleigh contribution to the total observed radiance, the first computation performed is to define the Rayleigh phase function for incident light. This term is defined by:

$$P_R(\gamma\downarrow) = \tfrac{3}{4}\,(1 + \cos^2\gamma\downarrow) \quad (5)$$

where $\gamma\downarrow$ is the scattering phase angle for incident light. The Rayleigh phase function for reflected light is similarily defined as:

$$P_R(\gamma\downarrow) = \tfrac{3}{4}\,(1 + (2\mu\mu_o + \cos\gamma\downarrow)^2) \tag{6}$$

where $2\mu\mu_o + \cos\gamma\downarrow = \cos\gamma\uparrow$

μ = cos of the spacecraft zenith angle (θ)

μ_o = cos of the solar zenith angle (θ_o)

The Rayleigh contribution for reflected light is dependent on the Fresnel reflectivity. The Fresnel reflectivity terms are defined by:

$$\rho(x) = 1 - 2xym\left[\frac{1}{(x + my)^2} + \frac{1}{(mx + y)^2}\right] \tag{7}$$

where: $x = \mu$ or μ_o

$y = \frac{1}{m}(m^2 + x^2 - 1)^{1/2}$ and

M is the refractive index of water as defined in table 2-4

Using the terms defined in equation 5, 6, and 7, the Rayleigh contribution to the total observed radiance in CZCS channel 1 through 4 is computed at each land/cloud free pixel using:

$$L_R(\lambda) = \frac{1}{4\pi\mu}(F_o(\lambda)T_{o3}(\lambda)\tau_R(\lambda))\left[P_R(\gamma\downarrow) + (\rho(\mu) + \rho(\mu_o))P_R(\gamma\uparrow)\right] \tag{8}$$

where: $T_{o3}(\lambda) = e^{-\left(\tau_{o3}\left(\frac{1}{\mu} + \frac{1}{\mu_0}\right)\right)}$

τ_{o3} and τ_R are the absorbing gas and Rayleigh optical thickness respectively and are defined in table 2-5. F_o is the incident solar flux which is seasonally adjusted from the mean solar flux $(\overline{F_o(\lambda)})$ listed in table 2-6 using the equation:

$$F_o(\lambda) = \overline{F_o(\lambda)}\,(1 - n\cos\alpha)^2 \tag{9}$$

where $\alpha = 2\,\pi d/365$, d = Julian day − 3, and n = 0.0167

Table 2-4

Refractive Index of Water

λ(nm)	m
443	1.347
520	1.342
550	1.341
670	1.337

Table 2-5

Rayleigh (τ_R) and Absorbing Gas (τ_{o3}) Optical Thicknesses

Rayleigh Optical Thickness (τ_R)					
λ(nm)	1	2	3	4	5
443	.2329	.2311	.2316	.2300	.2303
520	.1231	1222	.1224	.1214	1218
550	.0969	.0962	.0964	.0956	.0959
670	.0444	.0440	.0442	.0438	.0439

Absorbing Gas Optical Thickness (τ_{o3})					
λ(nm)	1	2	3	4	5
443	.0066	.0067	.0069	0068	.0071
520	.0166	.0200	.0237	0213	.0275
550	.0261	.0323	.0390	0346	.0467
670	.0158	.0191	.0226	.0202	.0264

Key: 1 - Tropical (0°-25° latitude N and S)
2 - Midlatitude (25°-55° latitude) Summer
3 - Midlatitude Winter
4 - Subpolar (55° latitude) Summer
5 - Subpolar Winter

2.2.2 Computation of the Aerosol Radiance

For the determination of the aerosol contribution to the total observed radiance it is first assumed that the ocean is a complete absorber in CZCS channel 4 ($L_W(670) = 0$) or

$$L_T(670) = L_R(670) + L_A(670) \tag{10}$$

Table 2-6

Mean Extraterrestrial Solar Flux

λ(nm)	Algorithm 1	Algorithm 2, 3, and 4
	F_0	F_0
443	182.5	186.416
520	186.7	185.337
550	186.9	184.760
670	153.6	151.520

Therefore, the removal of the radiance contribution due Rayleigh scattering by:

$$L_{RR}(\lambda) = L_T(\lambda) - L_R(\lambda) \tag{11}$$

where L_{RR} is the residual radiance, yields the aerosol contribution in channel 4, ie ($L_A(670) = L_{RR}(670)$). Given the aerosol contribution in channel 4, the aerosol contributions in channels 1, 2, and 3 are computed using:

$$L_A(\lambda) = L_A(670)\,\epsilon(\lambda)\frac{F_o(\lambda)T_{o3}(\lambda)}{F_o(670)T_{o3}\,(670)} \tag{12}$$

where $\lambda = 443$, 520, and 550 nm and $\epsilon(\lambda)$ is the atmospheric correction factor.

The atmospheric correction factor $\epsilon(\lambda)$ is implemented as a scene global parameter. The correction assumes that the normalized size frequency distribution and the refraction index of the aerosols are independent of horizontal position throughout a given CZCS scene. In order to implement this correction, the inherent sea surface radiance at one point within the scene must be ascertained. Using the assumption that the sea surface radiance $L_W\,(\lambda)$ in CZCS channels 2 and 3 is relatively constant in clear water areas, the inherent sea surface radiances in channels 2 and 3 are theoretically derived for a clear water pixel using:

$$L_{cw}(520) = 0.495\cos\theta_o\, e^{[-(0.5\tau_R(520)+\tau_{o3}(520))/\cos\theta_o]} \tag{13}$$

$$L_{cw}(550) = 0.280\cos\theta_o\, e^{[-(0.5\tau_R(550)+\tau_{o3}(550))/\cos\theta_o]} \tag{14}$$

The aerosol contribution to the total observed radiance in CZCS channels 2 and 3 is then computed by:

$$L_A(\lambda) = L_T(\lambda) - L_R(\lambda) - L_{cw}(\lambda) e^{[-(0.5\tau_R(\lambda) + \tau_{03}(\lambda))/\cos\theta]} \tag{15}$$

Once the aerosol radiances in channels 2 and 3 are known, the atmospheric correction factors for channels 2 and 3 are computed using:

$$\epsilon(\lambda) = \frac{F_o(670)\ T_o(670)\ L_A(\lambda)}{F_o(\lambda)\ T_o(\lambda)\ L_A(670)} \tag{16}$$

The atmospheric correction factor for channel 1 is derived from the $\epsilon(\lambda)$ values computed in channels 2 and 3 by the following equation:

$$\epsilon(443) = \left[\frac{670}{443}\right]^{N(443)} \tag{17}$$

where N(443) is defined as:

$$N(443) = \tfrac{1}{2}\left[\frac{\log(\epsilon(520))}{\log(670/520)} + \frac{\log(\epsilon(550))}{\log(670/550)}\right] \tag{18}$$

Equations 13 through 18 yield the atmospheric correction factors for a given clear water pixel. Depending on the production algorithm, the methodology implemented for locating a clear water pixel which is representative of the entire scene is as follows:

Algorithm 1: This algorithm utilized a manual methodology whereby the level-1 film product was visually analyzed by a trained technician to locate clear water areas. Once a clear water pixel was located, the sample and line numbers were extracted and values for $\epsilon(\lambda)$ were computed using equations 13 through 18. A validity check was then performed to insure that the computed values were monotonic in the sequence $\epsilon(443)$, $\epsilon(520)$, $\epsilon(550)$, 1 and that $\epsilon(443)$ was in the range of 1.0 to 3.0. The procedure was repeated, as necessary, until valid values were derived.

Algorithm 2: The clear water location methodology utilized for this algorithm was an automated procedure whereby $\epsilon(\lambda)$ values were computed for all pixels within the scene which met the following criteria:

1 Spacecraft and solar zenith angles >0.6 radians

2. L_T (670) $<1\ 4$

3. $0.9 < L_T(443)/[L_T(520)] < 2.0$

After rejecting those pixels for which the $\epsilon(\lambda)$ did not pass the validity check as outlined under Algorithm 1, the pixel yielding the lowest $\epsilon(443)$ was selected as the clear water pixel.

Algorithm 3: The clear water location methodology utilized for this algorithm was essentially the same as that implemented for algorithm 2 with the exception that rather than selecting the pixel yielding the lowest $\epsilon(443)$, the pixel which yielded the lowest $\epsilon(443)/L_A(670)$ was chosen as yielding the best atmospheric correction factors.

Algorithm 4: The clear water location methodology implemented for algorithm 4 differs from those utilized in earlier versions in that rather than selecting a single "clear water" pixel as representative of the entire scene, $\epsilon(\lambda$'s) are derived from all "clear water" pixels within the scene and statistically manipulated to derive an atmospheric correction which is more representative of the entire scene. The first step in this process is to derive preliminary estimates of pigment concentrations for all pixels within the scene. This is accomplished by setting all $\epsilon(\lambda$'s) equal to one and proceeding through the remaining computations to derive pigment concentrations (C_{pig}). Clear water pixels in then defined as those for which:

$$0.1 < C_{pig} < 0.25 \text{ mg/M}^3$$

Values for $\epsilon(520)$ and $\epsilon(550)$ are computed for each clear water pixel. $\epsilon(\lambda$'s) which do not meet the validity checks as described under algorithm 1 are discarded. The remaining $\epsilon(520)$s and $\epsilon(550)$'s are histogrammed and the mean and quartile deviation (semi-interquartile range) are computed for each. Finally, the atmospheric correction factors for the scene are computed as:

$$\epsilon(\lambda) = \overline{\epsilon(\lambda)} - \text{Quartile Deviation}(\lambda) \tag{19}$$

where $\lambda = 520$ and 550 and $\epsilon(443)$ is computed from these values using equations 17 and 18.

2.3 Computation of Subsurface Radiances

Once the atmospheric radiances have been determined, the radiance at the surface of the water may be computed as:

$$L_w(\lambda) = L_T(\lambda) - L_R(\lambda) - L_A(\lambda) \tag{20}$$

Given the water surface radiance, the subsurface radiance for channel 1, 2, and 3 is derived by:

$$L_{ss}(\lambda) = L_w(\lambda)\,\frac{m^2}{1-\rho(\mu)}e^{\left[\frac{1}{\mu}(0.5\tau_R(\lambda)+\tau_{03}(\lambda)+\tau_A(\lambda))\right]} \tag{21}$$

This is the ocean subsurface radiance extracted from the satellite observations. This upwelled radiance has been corrected for the refraction of the water and extinction due to Rayleigh backscattering, ozone absorption, and aerosol backscattering. For the wavelength being used, the backward scattering due to aerosol is close to zero and is ignored ($T_A(\lambda)$ is set to zero).

2.4 Computation of the Pigment Concentration and Diffuse Attenuation Coefficient

The pigment concentration and diffuse attenuation coefficient are derived as functions of the subsurface radiances of channels 1, 2, and 3. The diffuse attenuation coefficient (K) is defined by:

$$K = 0.0883 \left[\frac{L_{ss}(443)}{L_{ss}(550)}\right]^{-1.491} + 0.022 \tag{22}$$

where K is in units of meters^{-1}. The pigment concentration (c) is given by:

$$C_1 = 1.13 \left[\frac{L_{ss}(443)}{L_{ss}(550)}\right]^{-1.71} \tag{23}$$

$$C_2 = 3.326 \left[\frac{L_{ss}(520)}{L_{ss}(550)}\right]^{-2.439} \tag{24}$$

where: $C = C_1$ if $C_1 < 1.5$ or $C_2 < 1.5$ and

$C = C_2$ if $C_2 > 1.5$ and $C_1 > 1.5$

The pigment concentration, C, is given in units of milligrams per cubic meter.

2.5 Output Data Scaling

The subsurface radiances for channels 1, 2, and 3, the channel 4 aerosol radiance, the pigment concentration, and the diffuse attenuation coefficients computed above are all scaled to a 0 to 255 count range for output to the Level-2 digital product tape (CRCST tape).

The scaling for the subsurface radiances, the aerosol radiances, the pigment concentration, and for the diffuse attenuation coefficients are given by the following equations where

x is the input value in engineering units

I is the output scaled value in counts.

Channels 1, 2, and 3 subsurface radiances

$$I = \begin{cases} 85\,x & \text{if } 0 < x < 3.0 \\ 0 & \text{if } x < 0 \\ 255 & \text{if } x > 3.0 \end{cases}$$

Channel 4 Aerosol radiance

$$I = \begin{cases} 170\,x \text{ if } 0 < x < 1.5 \\ 0 \text{ if } x < 0 \\ 255 \text{ if } x > 1.5 \end{cases}$$

Pigment Concentration

$$I = \begin{cases} 0 \text{ if } x = 0 \\ 98.38 \log(x) + 136 \text{ if } 0 < x < 1.0 \\ 74.17 \log(x) + 136 \text{ if } 1.0 < x < 32. \\ 255 \text{ if } x > 32.0 \end{cases}$$

Diffuse Attenuation Coefficient

$$I = \begin{cases} 0 \text{ if } x = 0 \\ 184.46 \log(x) + 303.52 \text{ if } 0 < x < 0.5 \\ 255 \text{ if } x > 0\,5 \end{cases}$$

3. CZCS Level-II Algorithm Comparisons

Given the relative complexity of the CZCS Level-II scientific algorithms as described in Section 2, the relative effect of the four production algorithms on final products may not be readily appearant to the user. For comparison purposes, Figures 3.1 through 3.8 have been prepared to illustrate the difference in pigment concentration obtained using each of the four algorithms within the orbital range where overlap occurs. For the orbital range 0-4000 the pigment concentrations obtained using algorithms 1 through 4 are compared (figures 3.1 - 3.6).

For orbits 4000 - 8000 only the results obtained using algorithms 3 and 4 are compared (figures 3.7 and 3.8).

Users should note that the differences between the four production algorithms are dependent on both the orbit number (computation of the calibration correction factor) and

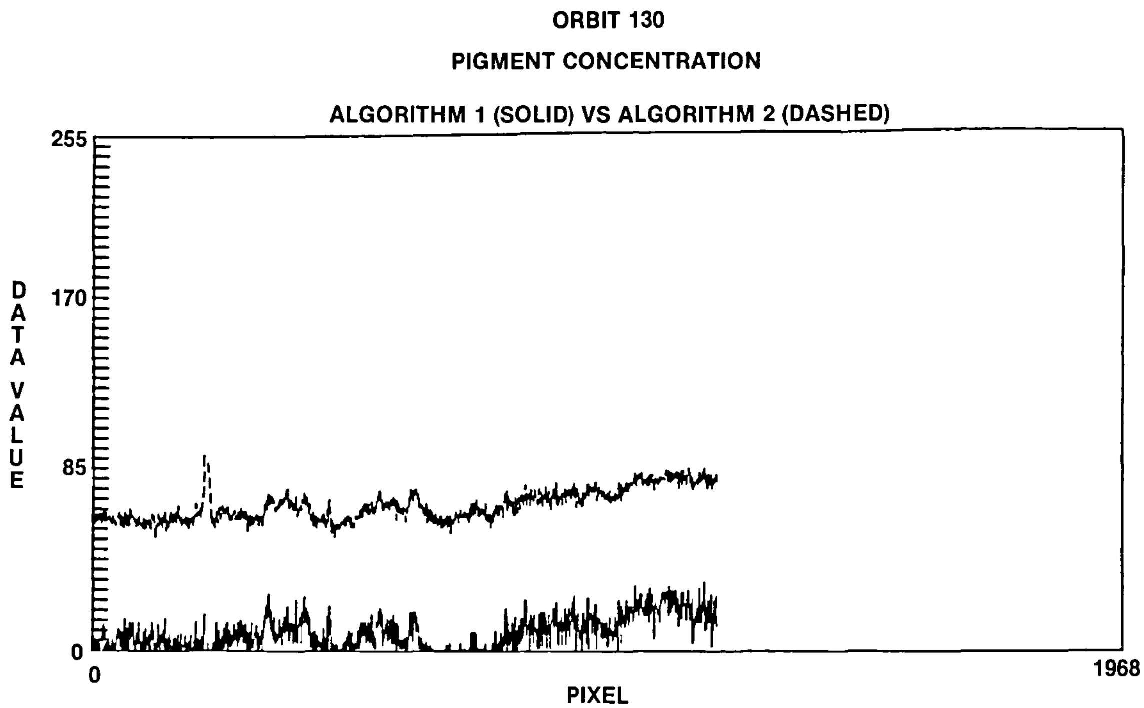

Figure 3-1.

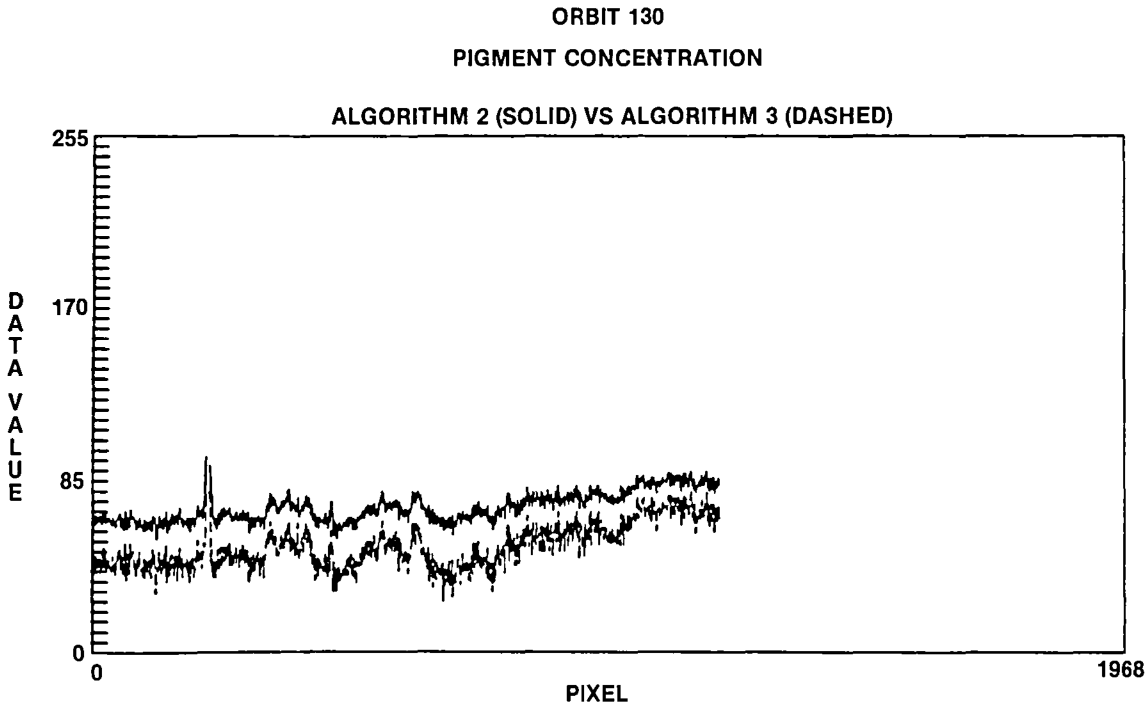

Figure 3-2.

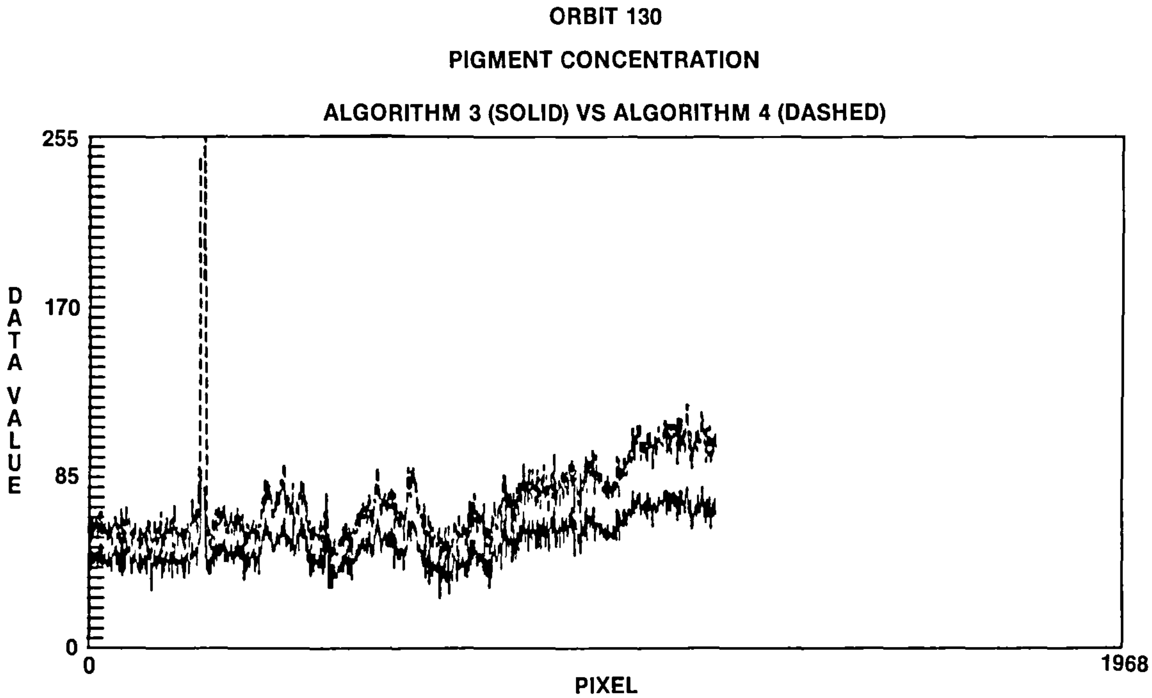

Figure 3-3.

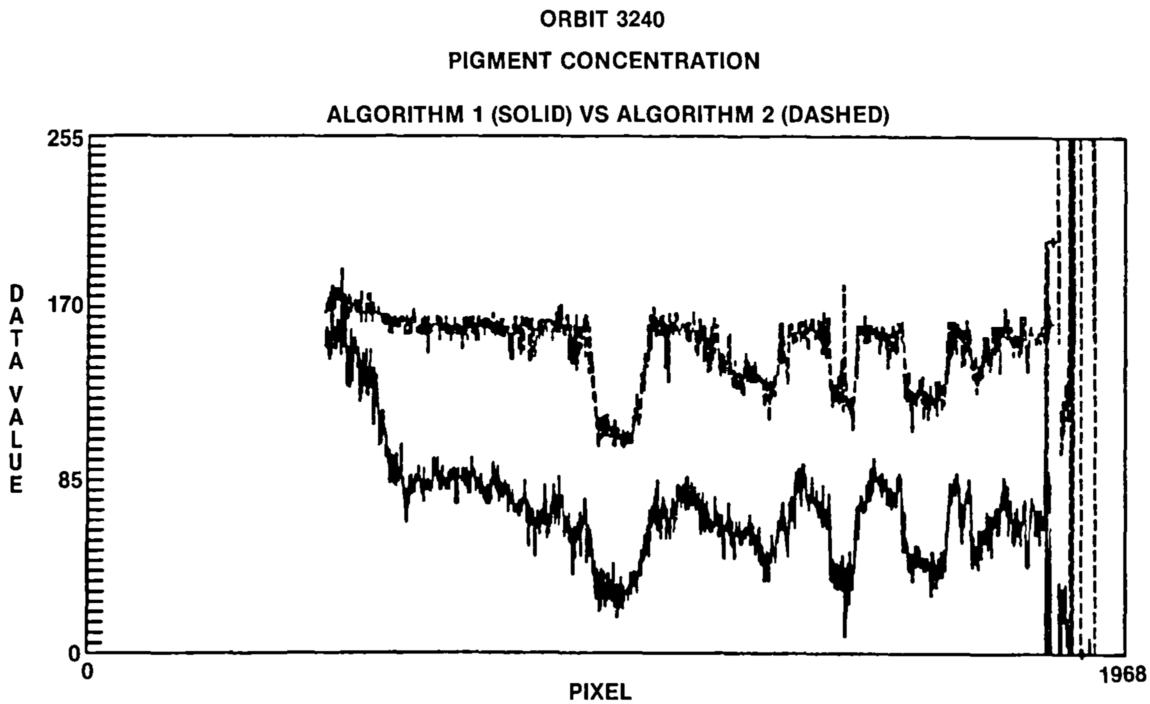

Figure 3-4.

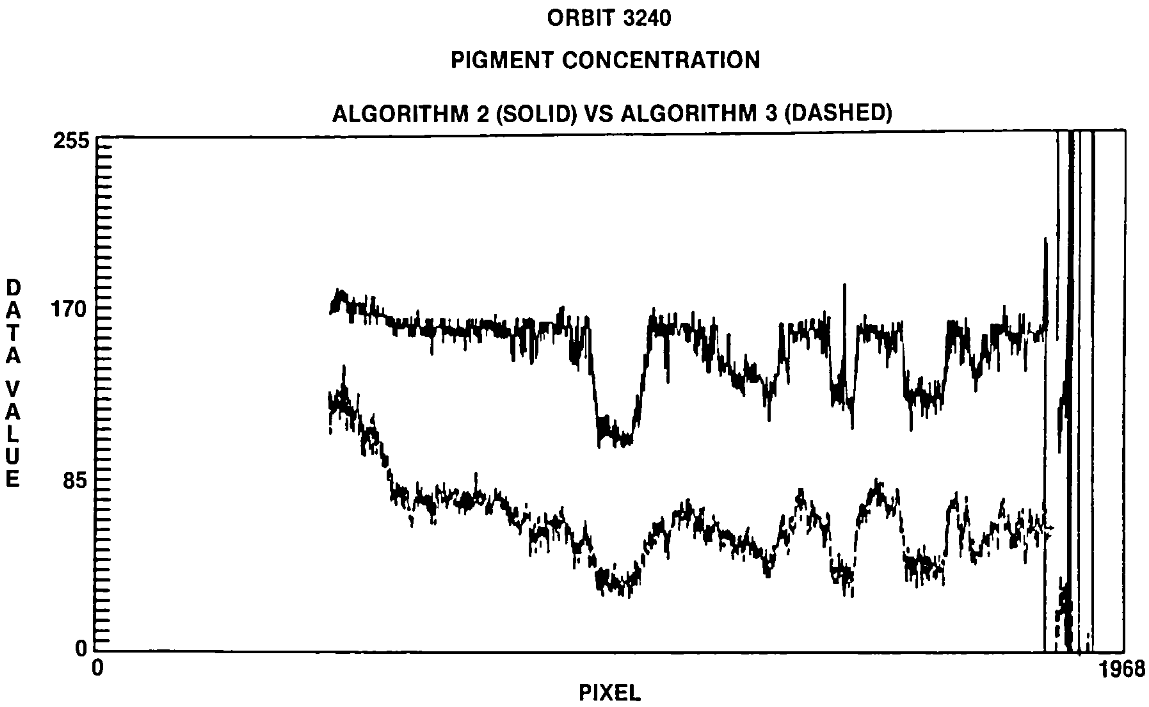

Figure 3-5.

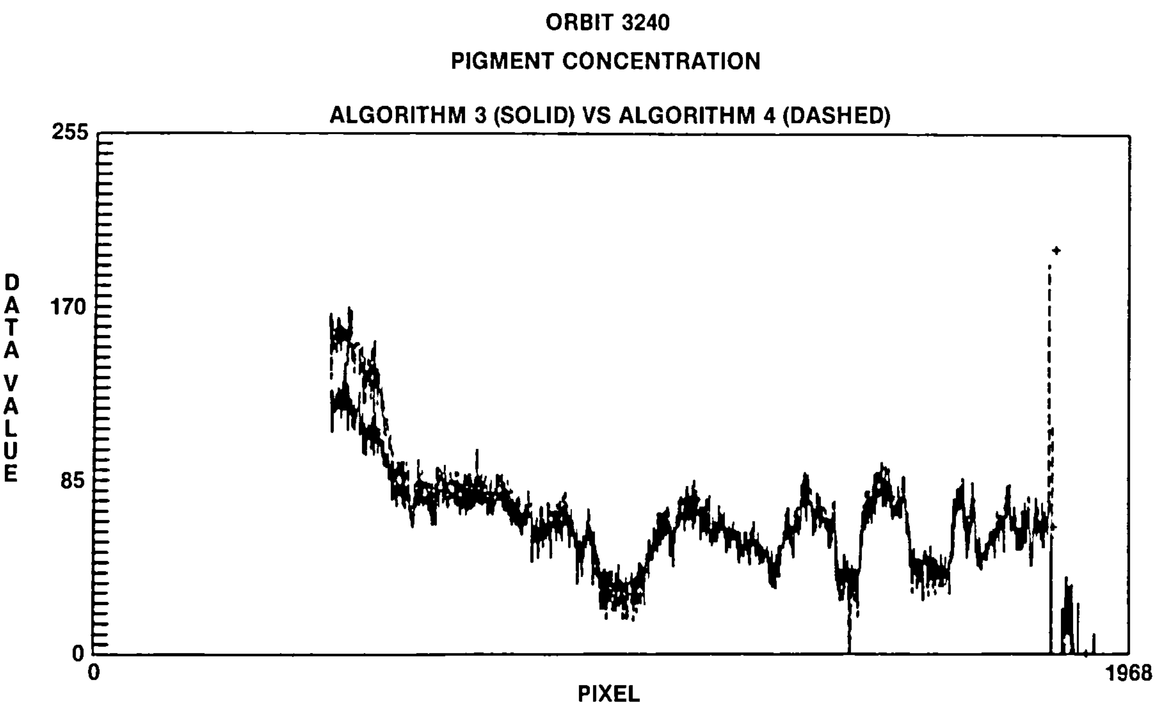

Figure 3-6.

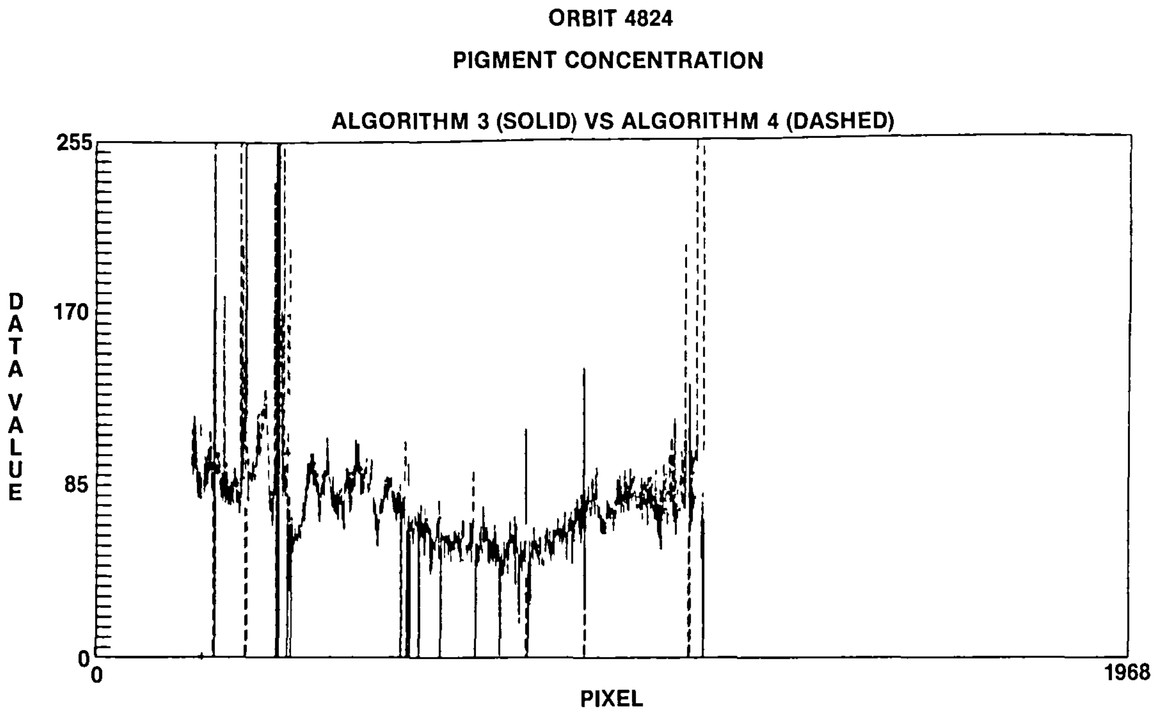

Figure 3-7.

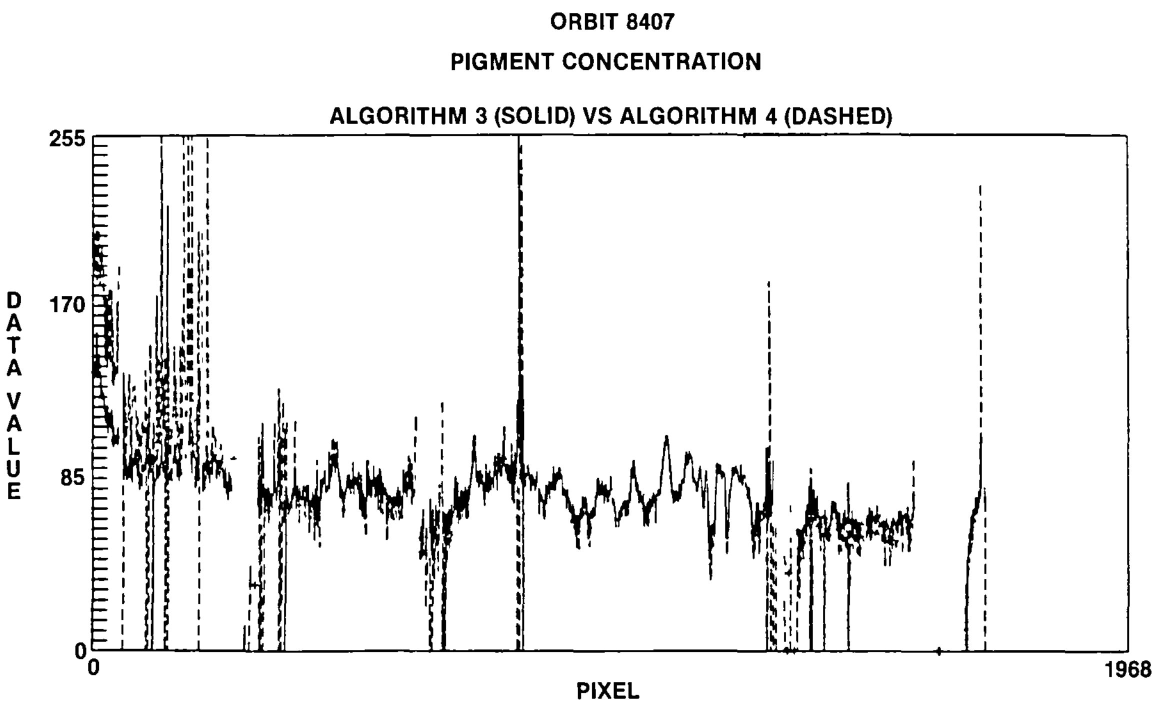

Figure 3-8.

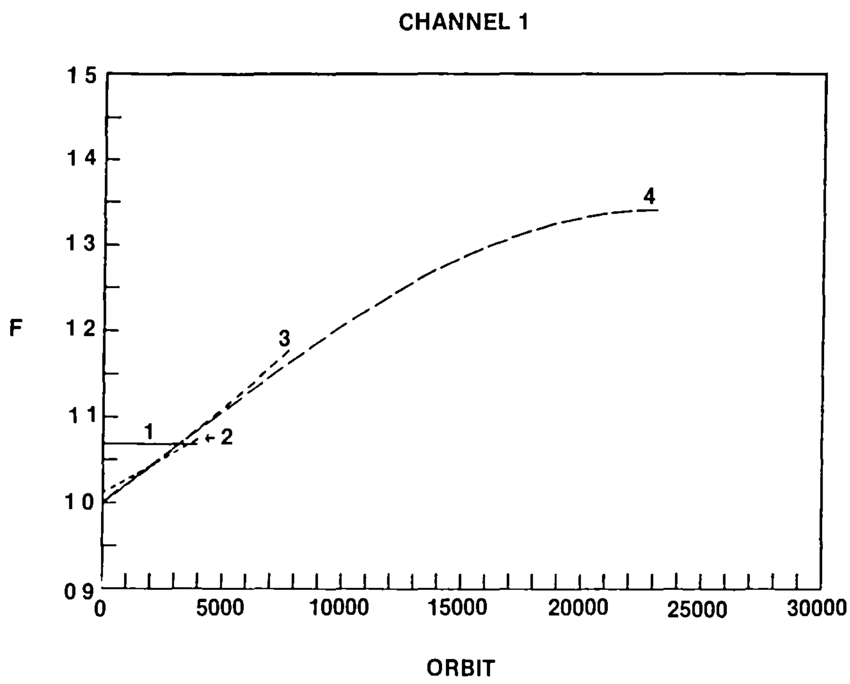

Figure 3-9. F_c vs. Orbıt

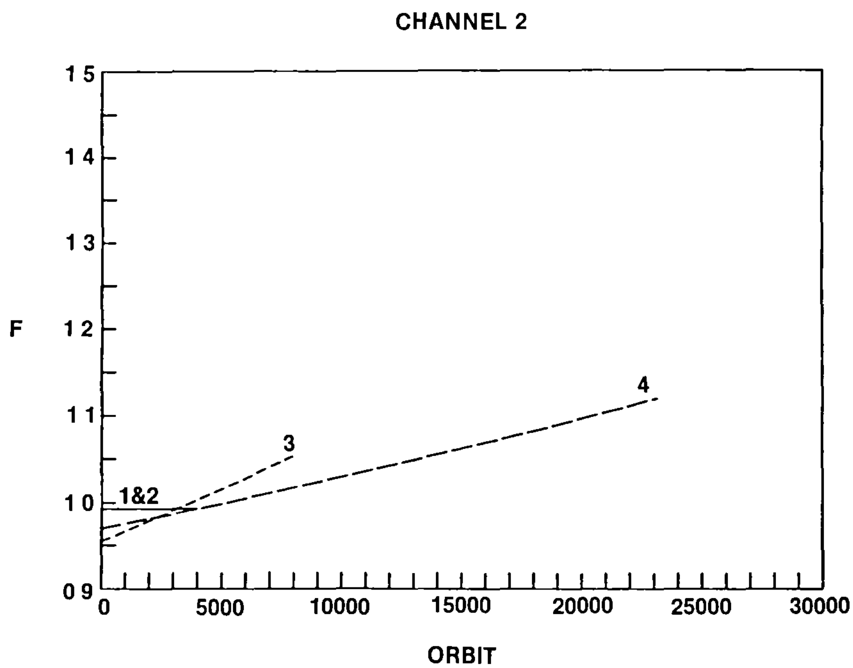

Fıgure 3-10. F_c vs. Orbit

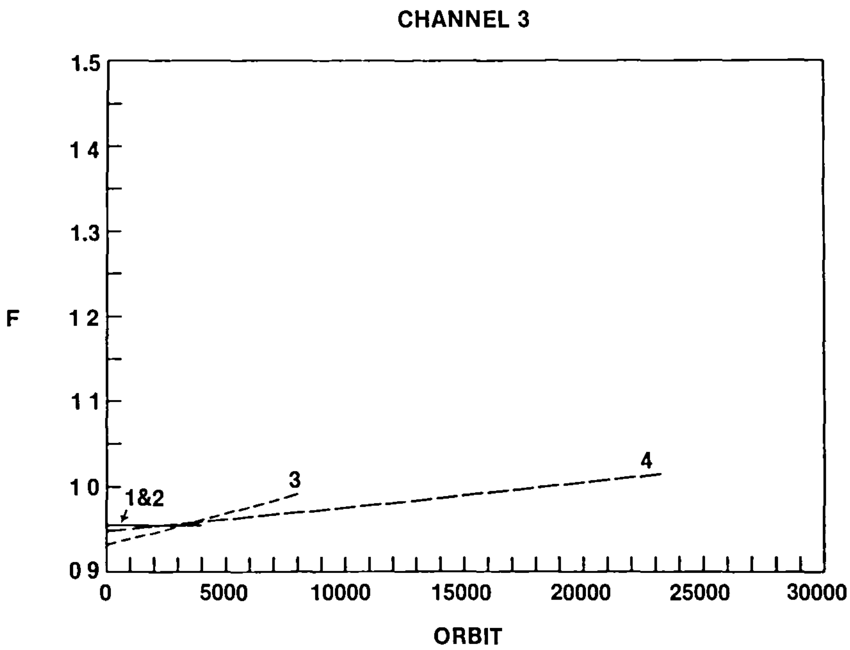

Figure 3-11. F_c vs. Orbit

on the data content of the individual scene (clear water location methodology). The calibration correction factors obtained using each of the production algorithms are illustrated in figures 3.9 through 3.11.

4. CZCS Level-2 Product Tape Format

The CZCS Level-2 processing system creates an output tape called the CRCST tape. The tape can be described in terms of its physical structure and/or its logical structure.

4.1 Physical Structure of CRCST Tape

The CRCST tape is a binary 9-track tape consisting of two files written in fixed block (FB) format at 1600 bpi. The overall structure of this tape is illustrated in figure 4.1

The first file on the CRCST tape is a special file called the standard header or STD HDR. The STD HDR file is written in a standard format common to all archivable tapes produced by the NIMBUS Observational System (NOPS) and contains two identical blocks of 630 characters written in EBCD1C. Each block consists of five 126-character lines.

Line 1 of the STD HDR records contain the following information·

- Nimbus-7 NOPS tape product format specification number consisting of 30 characters written as: $_b$NIMBUS-7$_b$NOPS$_b$SPEC$_b$NO$_b$T734031.
- Tape sequence number consisting of a two character code identifying the tape, a six character sequence number unique to each tape, and a one digit number specifying the copy number. An example for the CRCST tape is: $_b$SQ$_b$NO$_b$ZB2201213.
- Subsystem identification code consisting of four-characters preceeded and followed by blanks. For the CRCST tape this is: $_b$CZCS$_b$.
- Generation and destination facilities consisting of four characters each. An example is: IPD$_{bb}$TO$_b$22$_{bb}$
- Beginning and ending times of data coverage given as:

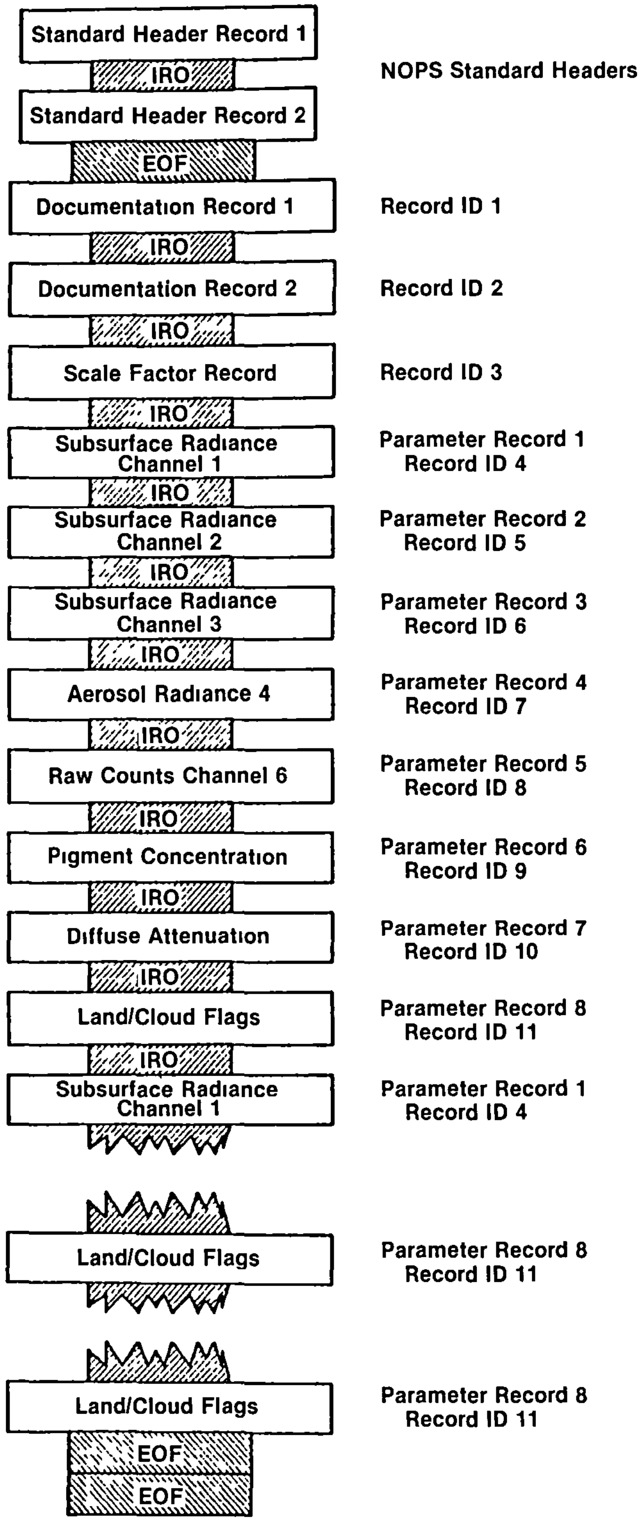

Figure 4-1. CRCST Tape Gross Format

${}_b$START$_b$19YY$_b$DDD$_b$HHMMSS$_b$TO$_b$19YY$_b$DDD$_b$HHMMSS

where yy is the year, DDD is the Julian Day, and HHMMSS are the hour-minute-and second of the day.

- The tape generation date is given in a similar format as:

  GEN$_b$19YY$_b$DDD$_b$HHMMSS.

Line 2 identifies the Level-2 processing software version number. Lines 3, 4, and 5 are written in a similar format to lines 1, 2, and are used by the subsystem analyst to identify the origin of the input data used to generate the CRCST tape. Figure 4-2 is an example of a CRCST tape STD HDR record.

The second file is the derived parameter data file and consists of two documentation records, a scale factor record, and eight derived parameter records for each scan line up to 970 scan lines. The documentation records have identical formats and contain 5328 8-bit bytes written in a single block of the same length. The scale factor record contains 3024 8-bit bytes and occupies a single block of the same length The derived parameter data records are each 3024 8-bit bytes written in blocks of the same length.

4.2 Logical Structure of the CRCST Tape

The CRCST tape data file which follows the NOPS STD HDR file contains up to two minutes (970 scan lines) of CZCS derived parameter data. For most users of three tapes it will be more convenient to treat the data files as a collection of logical records while noting that each logical record corresponds to one physical record.

4 2 1 CRCST Documentation Record Format

The CRCST documentation records for the most part preserve the data found in the CRT documentation records. The formats of the two documentation records are identical; however, depending on the processing mode certain CRT data fields contained in the first

```
1--------10--------20--------30--------40--------50--------60--------70--------80--------90--------100-------110-------120----
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456
HEADER    1 =
 NIMBUS-7 NOPS SPEC NO T734031 SQ NO ZB2834031 CZCS SACC TO IPD  START 1982 190 165308 TO 1982 190 165438 GEN 1984 338 191006
 PRODUCT CREATED BY IBM360 CZCS DPS VERSION 840510. CRT TAPE
 NIMBUS-7 NOPS SPEC NO T744041 SQ NO ZE2834013 CZCS IPD  TO 65   START 1982 190 165308 TO 1982 190 165438 GEN 1984 296  82519
 NIMBUS-7 NOPS SPEC NO T744041 SQ NO ZE2834012 CZCS IPD  TO IPD  START 1982 190 165308 TO 1982 190 165438 GEN 1982 336 181923
 CREATED BY MODCOMP IV CIPS VERSION 820921 USING ILT TP NUM  01931 INV NUM UE8904D.
```

Figure 4-2. CRCST Tape STD HDR Record

documentation record may not be valid. The Level-2 processing system alters certain fields that are pertinent to its own processing. The documentation record format is illustrated in figure 4-3 and detailed descriptions of selected data words appear in Table 4-1. Data fields which may not be valid in the first documentation record are designated by an asterisk in Table 4-1.

WARNING: DUE TO AN ERROR IN THE TAPE COPY PROGRAM, THE SECOND DOCUMENTATION RECORD MAY BE MISSING FROM SOME CRCST TAPES.

4.2.2 CRCST Scale Factor Record Format

The scale factor record contains the EBCDIC - coded values of the coefficients of the equations which are used to convert the derived products output values into 8-bit count values recorded on the CRCST tape. The format is illustrated in figure 4-4 and detailed descriptions of selected data words appear in table 4-2.

4.2.3 CRCST Derived Parameter Data Record Format

There are eight parameter data records given for each scan line up to a maximum of 970 scan lines (7760 records). The eight data types and the record I.D. corresponding to each are given in Table 4-3. The parameter data record format is illustrated in figure 4-5 and detailed descriptions of selected data words appear in table 4-4.

WORD #					
1	PHYSICAL RECORD NO. (12)	SPARE (4)	FILE (2)	RECORD ID (6)	VALID DATA FLAG (8)
2	TARGET AREA CODES 3 8-BIT WORDS (24)				FILE NO. (8)
3	TAPE SEQUENCE NO. (32)				
4	FILM FRAME NO. (32)				
5	STARTING YEAR NO. (16)	STARTING DAY NO. (16)			
6	STARTING MILLISECONDS OF DAY (32)				
7	INCREMENT IN MILLISECONDS TO END OF DATA (32)				
8	ORBIT NO. (16)	NO. OF SCANS IN SEGMENT (16)			
9	LATITUDE OF CENTER OF DATA (16)	LONGITUDE OF CENTER OF DATA (16)			
10	LATITUDE AND LONGITUDE OF CORNER (FIRST IN TIME-LEFT OF SCAN) 2 16-BIT WORDS (32)				
11	LAT. AND LONG OF CORNER (FIRST IN TIME-RIGHT OF SCAN) 2 16-BIT WORDS (32)				
12	LAT. AND LONG OF CORNER (LAST IN TIME-LEFT OF SCAN) 2 16-BIT WORDS (32)				
13	LAT. AND LONG OF CORNER (LAST IN TIME-RIGHT OF SCAN) 2 16-BIT WORDS (32)				
14	ILT FLAGS (8)	PARAMETER PRESENCE (8)	NO OF MISSING SCANS-ALL CHANNELS (16)		
15-17	NO. OF MISSING SCANS-CHANNEL 1,2,3,4,5,6 6 16-BIT WORDS (96)				
18	ALGORITHM ID's CHANNELS 1,2,3,4 4 8-BIT WORDS (32)				
19	ALGORITHM ID's CHANNELS 5&6 (16) 2 8-BIT WORDS	ALG ID LOCATION (8)	SPARE (8)		
20	DECOM RUN NO. 32-BIT BINARY INTEGER (32)				
21	DECOM REEL NO. 32-BIT BINARY INTEGER (32)				

Figure 4-3. CRCST Tape Documentation Record

Word						
22	NO. OF HDT SYNCH LOSSES	(16)	NO. OF HDT PARITY ERRORS	(16)		
23	NO. OF WBVT SYNCH LOSSES	(16)	NO. OF WBVT BIT SLIPS	(16)		
24-39	AVERAGE OF SUBCOMMUTATED DATA 32 16-BIT WORDS	(512)				
40	SPARE	(8)	BP. FLAG	(8)	BASEPLATE TEMPERATURE	(16)
41	LAND/CLOUDS THRESHOLD (COUNTS)	(32)				
42-45	$\varepsilon(\lambda)$ for CHANNEL 1, EBCDIC, E15.9, 15 CHARACTERS, 1 SPARE	(128)				
46-57	$\varepsilon(\lambda)$'s for CHANNELS 2-4	(384)				
58-61	SPARE	(128)				
62	JULIAN DAY OF REQUEST	(32)				
63	YEAR OF REQUEST	(32)				
64	REQUESTOR I.D.	(32)				
65-80	SOLAR FLUX FOR CHANNELS 1-4, EBCDIC, EACH 15 CHARACTERS- 1 SPARE, E15.9	(512)				
81-174	SPARE	(3008)				
175	GAIN	(8)	THRESHOLD	(8)	TILT ANGLE	(16)
176	SCENE CENTER YEAR	(16)	SCENE CENTER DAY OF YEAR	(16)		
177	SCENE CENTER MILLISECONDS OF DAY	(32)				
178	SOLAR ELEVATION AT SCENE CENTER	(16)	SOLAR AZIMUTH AT SCENE CENTER	(16)		
179	SCENE CENTER ROLL	(16)	SCENE CENTER PITCH	(16)		
180	SCENE CENTER YAW	(16)	TOP/BOTTOM TICK LABEL FLAG	(8)	LEFT/RIGHT TICK LABEL FLAG	(8)

Figure 4-3. CRCST Tape Documentation Record (Cont.)

Word				
181	TOP LEFT TICK LABEL (16)		TOP RIGHT TICK LABEL (16)	
182	BOTTOM LEFT TICK LABEL (16)		BOTTOM RIGHT TICK LABEL (16)	
183	LEFT TOP TICK LABEL (16)		LEFT BOTTOM TICK LABEL (16)	
184	RIGHT TOP TICK LABEL (16)		RIGHT BOTTOM TICK LABEL (16)	
185	TOP TICK INCREMENT (8)	BOTTOM TICK INCREMENT (8)	LEFT TICK INCREMENT (8)	RIGHT TICK INCREMENT (8)
186 -198	TOP TICK LOCATION ARRAY 27 16-BIT WORDS			
199	(432)		BOTTOM TICK LOCATION ARRAY	
200 -212	27 16-BIT WORDS (432)			
213 -225	LEFT TICK LOCATION ARRAY 27 16-BIT WORDS			
226	(432)		RIGHT TICK LOCATION ARRAY	
227 -239	27 16-BIT WORDS (432)			
240	CHANNEL 1 SLOPE (RADIANCE) (32)			
241	CHANNEL 1 INTERCEPT (RADIANCE) (32)			
242 -251	SLOPES, INTERCEPTS FOR CHANNELS 2-6 (RADIANCE) 10 32-BIT WORDS (320)			
252 -379	TEMPERATURE CONVERSION TABLE FOR CHANNEL 6 256 16-BIT WORDS (4096)			
380 -385	SLOPES & INTERCEPTS FOR IMAGE ENHANCEMENT EQUATIONS FOR CHANNELS 1-6 12 16-BIT WORDS (192)			
386 -387	SPARES (64)			
388 -1332	CZCS ILT (TAPE SPEC. 724011) TYPE "A" RECORD (30240)			

1332 32-BIT WORDS

Figure 4-3. CRCST Tape Documentation Record (Cont.)

Table 4-1

CRCST TAPE DOCUMENTATION RECORD

WORD	DESCRIPTION
1.	PHYSICAL RECORD NO. (12 BITS) - This number is a sequential number beginning at 1 and incrementing by 1 for each physical record within the data files.
	SPARES - All spare bits are set to zero.
	FILE (2 BITS) - The MSB will be set to "1" to indicate the last record written in a file. The LSB will be set to "1" in all records of the last file on the tape.
	RECORD I.D. (6 BITS) - The Record I.D. for the leading Documentation record will be equal to "1". The record I.D. in the trailing Documentation record will be "2".
	VALID DATA FLAG (8 BITS) - This flag indicates whether or not certain data fields (designated by an asterisk) contain valid information All bits off (0) indicates the data is invalid and all bits on (1) indicates the data is valid.
	FILE NO. (8 BITS) - This number identifies the file number on the CRT tape.
2.	TARGET AREA CODE (3 8-BIT WORDS) - Each code will describe a target area which was covered by the data in the file.

Table 4-1 (cont'd)

CRCST TAPE DOCUMENTATION RECORD

WORD	DESCRIPTION
3.	TAPE SEQUENCE NO. (32-BITS) - The 32 bit integer representation of the "SEQUENCE NO." field in the STANDARD HEADER records.
4.	FILM FRAME NO. (32 BITS) - This 32 bit integer number is the unique film frame number of the film product corresponding to this archive data file.
5.	STARTING YEAR NUMBER (16-BITS) - This number is in the form: 1978 in binary.
6.	START TIME IN MILLISECONDS GMT (32-BITS) - This number is in milliseconds of the DAY in GMT.
7	INCREMENT IN MILLISECONDS TO END OF DATA (32-BITS)* - The number of milliseconds from the start time of the segment to the last data scan in the segment.
8.	ORBIT NUMBER (16-BITS) - The Nimbus-7 orbit number for the data in this file, 16-bit binary number.
9.	GEODETIC LATITUDE "CENTER" (16 BITS)* - The latitudes will be an integer number ranging from 0 at the south pole to (180° x 100) 18000 at the North Pole. This will provide a location of .01°. The center latitude is defined as being the Nadir sample latitude that occurs ½ way between the beginning and end of the frame by time.

Table 4-1 (cont'd)

CRCST TAPE DOCUMENTATION RECORD

WORD	DESCRIPTION
	LONGITUDE CENTER (16-BITS)* - The longitude values will range from 0 at the Greenwich Meridan Eastward to 360° x 100 which provides longitude in 0.01 degrees.
10/ 13.	GEODETIC LATITUDES AND LONGITUDES (8 x 16 BITS)* - Frame corner latitudes and longitudes defined as in (9) above.
14.	ILT FLAGS (8-BITS) - Summary of information available in the CZCS-ILT for this data segment. MSB SUMMARY BIT '0' At leat one set of data not available '1' All relevant data available TIME CORRECTIONS '1' Available SOLAR EPHEMERIS '1' Available DATA QUALITY LOSS '1' Available VIP DATA '1' Available SPACE CRAFT EPHEMERIS (2 BITS) '00' None Available '01' Predictive '11' Definitive PARAMETER PRESENCE CODE (8-BITS) - The 6 CZCS channels correspond to parameters 1 - 6, respectively. A single bit is used to indicate the presence (bit set to '1') or absence (bit set to '0') of data for the corresponding parameter in this data segment. The MSB is for channel 1 ranging to bit 6 for channel 6, while the 2 LSB's are spares.

Table 4-1 (cont'd)

CRCST TAPE DOCUMENTATION RECORD

WORD	DESCRIPTION
	NO. OF MISSING SCANS (16 BITS)* - This 16 bit binary integer is the count of missing scans within the actual data segment. The missing scans can be identified by examining the time or the scan sequence number in the scan data records.
15/ 17.	NO. OF SCANS MISSING CHANNELS 1 - 6 (6, 16 BIT WORDS)* - The number of scans present in the data file in which the respective channel data should be present but is not. These data are 16 bit binary integers.
18/ 19.	ALGORITHM I.D. NUMBERS (8, 8 BIT WORDS) - I.D. words identify the algorithms for parameters 1 through 8, respectively. These are 8 bit binary integer words.
20/ 21.	DECOM RUN NO. AND DECOM REEL NO. (2, 32 BIT WORDS) - On the ARCHIVAL CRTT tapes these words will be zeroed. On the USER CRTT tapes these 32 bit binary integer words will be set by IPD to the documentation run and reel numbers, respectively.
22.	NO. OF HDT SYNC LOSSES (16 BITS)* - This binary integer count states the number of sync losses that occurred reading the HDT_p tape.
	NO. OF HDT PARITY ERRORS (16 BITS)* - A count of the number of parity errors detected on the HDT_p tape during the 2 minute period covered in this file.

Table 4-1 (cont'd)

CRCST TAPE DOCUMENTATION RECORD

WORD	DESCRIPTION
23.	NO. OF WBVT SYNC LOSSES (16 BITS)* - This count states the number of sync losses detected by the pre-processor during generation of the HDT_p tape from the Wide Band Video Tape (WBVT) containing the zip format CZCS data NO. OF WBVT BIT SLIP OCCURRENCE (16 BITS)* - This count states the number of bit slip occurrences detected by the pre-processor during generation of the HDT_p tape from the WBVT tape containing the ZIP format CZCS data.
24/ 39.	SUB-COMMUTATED HOUSEKEEPING DATA (32 16-BIT WORDS) - Average count values 32 housekeeping words. The data is scaled with 8 fractional bits.
40.	BASE PLATE (BP) TEMPERATURE FLAG (8 BITS) - This flag indicates the source of the Baseplate temperature used in calibrating the infrared channel (6). If all bits are off (0), then the baseplate temperature is a normal preset value. If all bits are on (1) then the temperature is obtained from the CZCS-ILT. BASEPLATE TEMPERATURE (16-BITS) - Either a nominal temperature value determined from flight experience or an average value computed from the data values in the time span covered by this file. This word is in binary with a fractional part of 7 bits. (This item will be zeroed except when the channel 6 calibration algorithm requites it).

Table 4-1 (cont'd)

CRCST TAPE DOCUMENTATION RECORD

WORD	DESCRIPTION
41.	Land/Clouds Threshold (Counts) (32-BITS) - This is the integer value used as the land/clouds threshold.
42/ 61.	$\epsilon(\lambda)$ (640-BITS) - These are the aerosol radiance ratios for CZCS channels 1 through 4. Each field is 16 bytes of which the last byte is spare. The first field contains $\epsilon(\lambda)$ for channel 1 ranging to the fourth field containing $\epsilon(\lambda)$ for channel 4. The fifth field is spare. The numbers are in EBCD1C in the format E15.9.
62/ 63.	Date of Request (2 32-BIT WORDS) - There are two 32 bit integer words representing the Julian Day and year respectively.
64.	Requestor ID (32-BITS) - The identification number of the NIMBUS-G experimentor requesting processing of this scene. Integer.
65/ 84.	Solar Flux (640-BITS) - There are 5 16-byte subfields, of which the last field is spare. Numbers are in EBCD1C in the format E15.9 such that the last byte of each subfield is spare. Subfields 1 through 4 contain the solar flux for CZCS channels 1 through 4 respectively.
175.	GAIN (8-BITS) - An integer value of 1, 2, 3, or 4, indicating which CZCS gain setting was used for the scene contained in this file. THRESHOLD (8-BITS) - An integer value of 1 (off) or 2 (on) indicating the status of the CZCS threshold function for the scene contained in this file.

Table 4-1 (cont'd)

CRCST TAPE DOCUMENTATION RECORD

WORD	DESCRIPTION
	TILT ANGLE (16-BITS) - The tilt angle of the CZCS for the scene contained on this file. Two's complement integer; LSB weight is 1/1000°.
176.	SCENE CENTER YEAR (16-BITS)* - The year (4 digits) associated with the geographic center of the scene contained in this field.
	SCENE CENTER DAY-OF-YEAR (16-BITS)* - The day-of-year (1 to 366) associated with the geographic center of the scene.
177.	SCENE CENTER MILLISECONDS-OF-DAY (32-BITS)* - The milliseconds-of-day (0 to 86399999) associated with the geographic center of the scene contained in this file.
178.	SOLAR ELEVATION AT SCENE (16-BITS)* - The solar elevation at the geographic center of the scene contained in this file. Values range from −90° to +90°. Two's complement integer; LSB weight is 1/100°.
	SOLAR AZIMUTH AT SCENE CENTER (16-BITS)* - The solar azimuth at the geographic center of the scene contained in this file. Values range from 0° to 360°. Unsigned integer; LSB weight is 1/100°.
179/ 180	SCENE CENTER ROLL, PITCH, YAW (16-BITS each)* - The spacecraft attitude at the geographic center of the scene contained in this file. Values range from −32° to +32°.
	Two's complement integer; LSB weight is 1/1000°.

Table 4-1 (cont'd)

CRCST TAPE DOCUMENTATION RECORD

WORD	DESCRIPTION
240/ 251.	SLOPES AND INTERCEPTS (12, 32-BIT WORDS) - Slope and intercept for the conversion of the 8 bit channel data in the scan data records to radiometric units (mw/cm^2-ster-um) for channels 1 through 6, respectively. This data is signed and 7 bits whole part and 24 bits fractional. In the leading documentation record these are pre-flight calibration values and in the trailing documentation record these are derived from the active calibration and voltage staircases.
252/ 379.	TEMPERATURE CONVERSION TABLE (256, 16-BIT WORDS) - Table of Channel 6 data values in degrees Celsius Each of the 256 positions in this table contains the temperature for the corresponding count of the channel 6 data in the scan data records. This data has 8 bits whole part and 8 bits fractional part.

WORD #					
1	PHYSICAL RECORD NO. (12)	SPARE (4)	FILE (2)	RECORD I.D. (6)	SPARE (8)
2 -157	SPARE (4992)				
158	SLOPE FOR SUBSURFACE RADIANCES EBCDIC-E15.8 (120)				
161	INTERCEPT FOR SUBSURFACE RADIANCES EBCDIC-E15.8 (120)				
165	SLOPE FOR AEROSOL RADIANCES EBCDIC-E15.8 (120)				
169	INTERCEPT FOR AEROSOL RADIANCES EBCDIC-E15.8 (120)				
173	SLOPE FOR DIFFUSE ATTENUATION COEFFICIENTS EBCDIC-E15.8 (120)				
176	INTERCEPT FOR DIFFUSE ATTENUATION COEFFICIENTS EBCDIC-E15.8 (120)				
180	SLOPE 1 FOR PIGMENT CONCENTRATION EBCDIC-E15.8 (120)				
184	INTERCEPT 1 FOR PIGMENT CONCENTRATION EBCDIC-E15.8 (120)				
188	SLOPE 2 FOR PIGMENT CONCENTRATION EBCDIC-E15.8 (120)				
191	INTERCEPT 2 FOR PIGMENT CONCENTRATION EBCDIC-E15.8 (120)				
195					
196 -756	SPARES (17968)				

Figure 4-4. CRCST Scale Factor Record

Table 4-2

CZCS CRCST Tape Scale Factor Record

WORD	DESCRIPTION
1	Physical Record Number (12-BITS) - This number is a sequential number beginning at 1 and incrementing by 1 for each physical record within the data file. Spares (4-BITS) - All bits of fields not used are set to zero. File (2-BITS) - The MSB will be set to "1" to indicate the last record written in a file. The LSB will be set to "1" on all records on the last file on a tape. Record ID (6-BITS) - The record ID for the scale factor record will be "3". Spares (8-BITS)
158/ 195.	Slopes and intercepts (10 120-BIT Fields) - The slopes and intercepts that were used for the conversion of derived products data to 8-bit CRCST tape counts. The numbers are in EBCD1C in the format E15.8. The numbers are written in Slope - Intercept order and correspond to: Subsurface Radiances; Channel 4 Aerosol radiance; Diffuse Attenuation Coefficient; First Pigment; and Second Pigment respectively. The Pigment data is scaled in two ranges and thus has two equations.
196/ 756.	Spare

Table 4-3

Data Types and Record I.D.'s

Order of Parameters	Product	Record I.D.
1	Subsurface Radiance Channel 1	4
2	Subsurface Radiance Channel 2	5
3	Subsurface Radiance Channel 3	6
4	Aerosol Radiance Channel 4	7
5	Temperature Channel 6	8
6	Pigment Concentration	9
7	Diffuse Attenuation Coefficient	10
8	Land/Cloud Flag	11

WORD #					
1	PHYSICAL RECORD NO. (12)	SPARES (4)	FILE (2)	RECORD I.D. (6)	SPARES (8)
2	SPARES (32)				
3	SPARES (16)	SCAN SEQUENCE NUMBER (16)			
4 -80	LATITUDES OF ANCHOR POINTS (2464)				
81 -157	LONGITUDES OF ANCHOR POINTS (2464)				
158 -649	1968 8-BIT PIXELS FOR DERIVED PRODUCT (15744)				
650	YEAR (16)	DAY NUMBER (16)			
651	MILLISECONDS OF DAY (32)				
652 -756	SPARES (3360)				

Figure 4-5. CRCST Derived Parameter Data Record

Table 4-4

CRCST Derived Parameter Data Record

WORD	DESCRIPTION
1	PHYSICAL RECORD NO. (12-BITS) - This number is a sequential number beginning at 1 and incremented by 1 for each physical record within the data files. The count of the derived products record numbers may exceed the largest number that can be contained in 12 bits. When this is the case, the record number will be reset to begin at 1 again and incremented sequentially.
	SPARES - All fields that are not used will be set to zero.
	FILE CONTROL (2-BITS) - The MSB will be set to '1' to indicate the last record written in a file. All other records will be zero. The LSB will be set to '1' in all records of the last file on the tape. That bit will be set to zero in all other files.
	RECORD I.D. (6-BITS) - The record I.D. will depend on the parameter type; see Table 4-3.
3	SCAN SEQUENCE NUMBER (16-BITS) - A number for 1 to 970 that indicates the scan line number within the two minute data periood of this tape. Missing scan lines will be accounted for.
4/ 157.	LATITUDES OF ANCHOR POINTS AND LONGITUDES OF ANCHOR POINTS (TWO SETS OF 77, 32 BIT WORDS) - These words give the geographic locations for the 77 anchor pixels. The geodetic latitudes are given in 77 successive words followed by the corresponding

Table 4-4 (cont'd)

CRCST Derived Parameter Data Record

WORD	DESCRIPTION
	77 longitudes. Each value is a signed 32 bit binary number with a 9 bit whole and 22 bit fractional parts.
158/ 649.	1968, 8-BIT PIXELS FOR DERIVED PRODUCT - (15774-BITS) - The type of the derived product is given by the record I.D. (See Table 4-3). Land/Cloud Flags are scaled True = 1, False = 0.
650.	YEAR NO. (16-BITS) - This number is in the form "1978" in binary.
	DAY NO. (16-BITS) - The Julian day number. Day 1 = January 1.
651.	MILLISECONDS OF THE DAY (32-BITS) - The number of milliseconds since the beginning of the GMT day.
652/ 756.	SPARES - All fields that are not used will be set to zero.

5. Data Availability

All of the data produced for the CZCS program is archived with the National Environmental Satellite Data Information Service of NOAA and is available to any user who wishes to purchase it. Requests for CZCS data should be addressed to:

NOAA/NESDIS
Satellite Data Services Branch
Room 100, World Weather Building
Washington, D.C. 20233

When ordering data from NESDIS, the user should specify the CZCS scene times (start and end times) and the scene location (corner latitudes and longitudes). In order to assist users in locating scenes of interest, NESDIS will run a computer search of its data base and provide the user with a listing of all scenes within a user specified geographic area and time frame. In addition, NESDIS has catalogs available which may be useful as an aid in data selection. One catalog lists all of the archived products, including date, time, orbit number, the coordinates of the four corners of the image, and an estimate of cloud cover. Another catalog shows the orbital passes for each day of CZCS operation in monthly increments and shows areas along the orbital tracks for which satisfactory data was acquired and will eventually be processed if not already processed.

In addition to NESDIS, there are several other places at which photographic data can be viewed. In the United States, there is a partial archive at the Scripps Institute of Oceanography, Visability Laboratory, in San Diego, and a full, geographically cataloged archive at the Satellite Experiment Laboratory of NOAA in Suitland, Maryland. European data is archived by the Joint Research Centre of the Commission of European Communities in Ispra, Italy and South African data is archived at the National Research Institute for Oceanology in Stellenbosch, South Africa. Questions concerning use of these archives, location of NET members, or location of centers that have computer facilities to analyze CZCS data, should be forwarded to Dr. Warren A. Hovis, Chairman, Nimbus Experiment Team.

APPENDIX A

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15 Supplementary Notes

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16 Abstract

The CZCS is a scanning multispectral radiometer designed specifically for the remote sensing of ocean color parameters from an earth orbiting space platform.

This Technical Manual is intended for users of NIMBUS 7 CZCS Level 2 data products. It contains information which describes how the Level 1 data was processed in order to obtain the Level 2 (derived) product. Moreover it contains information needed by Investigators and Data Processing personnel in order to operate on the data using digital computers and related equipment.

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