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ANALYSIS OF HIGH ALTITUDE REMOTELY SENSED DATA COLLECTED IN THE NANTUCKET SHOALS EXPERIMENT MAY 8, 1981

CRAIG W. OHLHORST

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NASA

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

SUMMARY

High altitude Ocean Color Scanner ratios of band 2 (456-476 nanometers) to band 4 (539-559 nanometers) and band 1 (418-438 nanometers) to band 3 (498-518 nanometers) had high correlation coefficient values (-0.928 and 0.891 respectively) with seven boat-sampled chlorophyll *a* measurements made on the morning of May 8, 1981. The range of chlorophyll *a* concentrations was small (1.7-2.58 mg/m^3). Each ratio was used to calculate chlorophyll *a* values for the center pixel of each scan line on flight lines 5 and 6 of the May 8, 1981, morning data set. The two ratios produced dissimilar chlorophyll *a* trends. Due to the high noise level in the scanner data, no reliable synoptic chlorophyll *a* map could be generated with either ratio algorithm. Using data collected on the afternoon of May 8, 1981, no significant correlation was found between the Ocean Color Scanner data and chlorophyll *a* values calculated from the Multichannel Ocean Color Sensor.

INTRODUCTION

A multiplatform (ships, buoys, aircraft) investigation of the Nantucket Shoals ecosystem was conducted from May 4 to May 15, 1981. Various physical and biological variables were obtained at over 160 stationary hydrographic stations as well as underway sampling by six vessels. Both low and high altitude remotely sensed data were collected.

The Ocean Color Scanner (OCS) has a field of view of ±45°. It was mounted in an aircraft and flown in this experiment at 12.5 km (41,000 ft). This gave researchers a synoptic view of the Nantucket Shoals ecosystem which was not available from other remote sensing instruments participating in this experiment. Analysis of the OCS data would be conducted to determine if the high altitude remotely sensed data could be correlated with the boat surface measurements in order to generate chlorophyll *a* surface maps of large areas of the Nantucket Shoals ecosystem. A second purpose for flying the OCS was to determine if chlorophyll *a* values calculated from the Multichannel Ocean Color Sensor could be used to calibrate the OCS scanner.

EXPERIMENT

The OCS instrument used in this experiment came from NASA Lewis Research Center. It is not the same piece of hardware that Kim and McClain used in their work (ref. 1) even though the instrument name is the same. The Lewis OCS has 10 bands covering the spectral range of 418 to 804 nanometers. The center wavelengths for the 10 bands are listed in table I. The spectral bandwidth for each band is 20 nanometers. The instantaneous field of view is 4.49 milliradians. At nadir, this is equivalent to a ground distance of 60 meters (196.85 ft) at the 12.5 kilometer altitude. The total field of view is ±45° which is equivalent to a ground distance of 24.5 kilometers (13.2 n mi). The mirror scan rate was 4.126 revolutions per second.

The OCS collected data on the morning and afternoon of May 8, 1981; Wednesday afternoon May 13, 1981; and Thursday morning May 14, 1981. Not enough sea truth was collected underneath the OCS during its flying time to calibrate the instrument for chlorophyll a concentration on the latter 2 days so the data collected on the 13th and 14th were not analyzed. The beginning and ending flight line coordinates, the starting and ending times, aircraft heading, Sun azimuth and Sun elevation for May 8th flights are listed in tables II(a) and II(b). The flight lines used for data collection are plotted on figures 1(a) and 1(b). The flight lines were flown such that they headed either into or out of the Sun plane.

On the morning of May 8, nine oceanographic data stations were collected underneath OCS overflights. The location of these stations are shown on figure 1(a). The intent of the data analysis was to determine if the OCS radiance data could be calibrated using the boat collected data in order to then generate large scale chlorophyll maps with the scanner data.

On the afternoon of May 8, 1981, the high altitude OCS carrying aircraft and the low altitude (2.29 km, 7500 ft) MOCS carrying aircraft simultaneously flew the same flight line (line 3, figure 1(b)) in order to determine if chlorophyll a values calculated from the MOCS could be used to calibrate the OCS radiance data.

ANALYSIS OF DATA

Preprocessing of the Scanner Data

Analysis of the OCS radiance data required preprocessing of the original digital data. One of the preprocess steps was to remove the effect of scan angle variations. The OCS has a scan angle of ±45°. As the angle increases, the distance from the scanner to the water surface element being viewed increases and increasingly greater amounts of Sun and sky radiation scattered by the atmosphere reach the scanner and contribute to the total radiation sensed. At the same time, the longer path-length results in increased atmospheric attenuation of the radiation originating from the water. The scan angle correction normalizes the radiance at non-zero scan angles to that at nadir. For this study, the correction was made empirically. Figure 2 shows the shape of a typical algorithm used to correct the digitized data. The correction differs from channel to channel and can also differ in the same channel from flight line to flight line.

A second preprocessing step was necessary due to a sinusoidal noise component evident in the data. The Lewis Research Center OCS had previously been flown over the Great Lakes region of the United States where there are known to be large quantities of suspended sediment in the water. The instrument was thus optimized to measure relatively large radiance level changes from the water surface. Radiance level changes in waters of the Nantucket Shoals area were small so the gain on the OCS had to be turned up. Since this sinusoidal noise had not been evident in previous OCS data, it is thought to have occurred from the increased gain setting. To correct for this problem, four assumptions were made:

1. the noise component was a single frequency sine wave
2. the period of the sine wave was 28 pixels
3. of the 28 pixels in the sine wave noise function, pixel position 14 had the maximum value

4. the amplitude of the sine wave was 5 counts.

Each scan line contains 387 pixels although the full data swath uses only 341 pixels. About 23 pixels at both the beginning and ending of the scan are available if the airplane should roll. A side displacement of the pixel block is then made to correct for the roll. The displacement is made when converting the high density flight tapes to lower density computer-compatible tapes. Therefore, each line on the computer-compatible tape has the same total number of pixels reserved for roll adjustment, but the number of those reserved pixels at the beginning and at the end may vary from line to line depending on the severity of the roll correction needed. In order not to include any of these outside pixels in the sine wave correction procedure, pixels 54 through 333 were used. The total number of pixels used for each line was thus 280, an even multiple of 28.

For each of the 28 pixel positions, a correction factor in signal counts was determined. The correction factor was calculated such that when the correction factor for each position was added to the corresponding position count value in the noise sine wave, a straight line with each position having the same count magnitude as pixel position 14 would be created. The key to applying the correction was in determining for each pixel in a scan line its corresponding pixel position in the 28 pixel period sine wave.

The following steps were taken on each scan line to determine and apply the correction:

1. Every 28th pixel was summed. The sum of the first position equals pixel 54 + pixel 82 + pixel 110 + pixel 138 + pixel 166 + pixel 194 + pixel 222 + pixel 250 + pixel 278 + pixel 306. The sum of the second position equals pixel 55 + pixel 83, etc. The end result of this step is 28 summations, one for each of the 28 pixel positions.

2. The pixel position with the minimum sum is taken to be the minimum and starting position for a sine wave with period of 28 pixels and maximum amplitude of 5 counts.
3. Knowing the minimum position and knowing that the summation started at pixel 54 is enough information to determine for each pixel in a scan line its corresponding pixel position in the 28 pixel sine wave.
4. The correction factor for the corresponding position in the 28 pixel sine wave was then added to the original pixel count value and all pixels in the entire data block were corrected.

During the preprocessing of the scanner data, it was discovered that the noise level in the radiance count data in band two was larger than in any of the other bands. Figure 3(a) shows a plot of band 2 and 3 for a single scan line. The data shown have already been corrected for scan angle effects. The larger noise component in band 2 is easily seen. The sinusoidal noise is still in both bands but is more easily seen in the band 3 scan line. Figure 3(b) shows a plot of the same data after having the sine wave correction procedure applied to it. A comparison of band 3 in figure 3(a) and 3(b) shows a reduction in the magnitude of the sinusoidal noise, but not complete elimination. Study of other individual scan lines and other bands also led to the conclusion that the sinusoidal noise was reduced but not eliminated by the correction procedure applied. The extent to which the sinusoidal noise is still in the radiance count data set after preprocessing is shown in figure 4. The top photo shows 400 lines of unprocessed data. The sinusoidal noise pattern is very evident. The bottom photo shows the same 400 lines which have been completely preprocessed. The sinusoidal noise pattern is still evident even though the magnitude has been reduced. A clear improvement is seen at the edges of the bottom photo over that of the top one. That is due to the scan angle correction. It was evident that to completely remove the sinusoidal noise component from the data set a quite extensive research effort would be needed. It was also concluded that since the count variation caused by noise was of the same magnitude as that caused by changes in chlorophyll a levels, complete removal of noise would also remove any variations that might be caused by chlorophyll a concentration variations. It was decided to proceed with the data analysis with knowledge that there was still a sinusoidal noise pattern in the radiance data set.

Chlorophyll a Regression Analysis with Boat-Taken Sea Truth

The time of each usable oceanographic station sampled on the morning of May 8th, its position coordinates, sample depth, and chlorophyll a values are listed in table III. Only on the morning of May 8 were there enough ship taken sea truth chlorophyll a measurements to apply regression analysis techniques between the remotely sensed values and chlorophyll a measurements. The range of chlorophyll a values was small (1.70-2.58 mg/m^3). In the remainder of this text, chlorophyll a will be abbreviated to just the word chlorophyll. Of the nine boat stations available on the morning of May 8, seven were located on flight lines 5 and 6. See figure 1(a). It was decided to use only those seven stations in the regression analysis.

The seven boat stations were located in the scanner data. The digital data for each station were obtained from averaging the five columns and five lines of data pixels centered over each site. This was done to smooth instrument noise effects. Since radiance conversion was not available, raw counts were used in the data analysis. The gain setting was changed on band 4 from 1.5 to 2 between flight lines 5 and 6. This required a 0.75 multiplication factor of band 4 counts of flight line 6 in order to combine the two flight lines. Table IV lists the radiance count value for each band as derived from the pixel arrays centered over each of the seven stations.

Linear step-wise regression was performed with all bands and all possible band ratio combinations to find correlations with chlorophyll measurements. Table V(a) and V(b) lists the correlation coefficients. The highest correlation between an individual band and chlorophyll was r = -0.779, for band 2. For the ratios, band 2 to band 4 had the best correlation with chlorophyll (r = -0.928). The step-wise regression program generated the following equation

$$\text{Chl } \underline{a}(\text{mg/m}^3) = 34.437 - 18.959\left(\frac{\text{band 2}}{\text{band 4}}\right) \tag{1}$$

Equation (1) had an F-ratio of 31.0 and the Root Mean Squared Error (RMSE) was 0.124. The standard deviation of the seven boat-taken chlorophyll values was 0.361. A plot of the ratio versus chlorophyll a is shown in figure 5. Equation (1) is plotted on the figure.

Equation (1) was then used to calculate chlorophyll concentrations for all of the scanner data on flight lines 5 and 6. Before this calculation was made, all of the scanner data were smoothed by averaging five columns and five lines of data. A look at table III shows that the range of chlorophyll values used in the regression analysis was between 1.70 and 2.58 mg/m^3. Calculation of a chlorophyll value outside the range would be an extrapolation of the regression equation. For flight line 5, 17 percent of the pixels are calculated to have chlorophyll values between 1.70 and 2.59. For flight line 6, 28 percent of the pixels are calculated to have concentrations between 1.70 and 2.59.

The low percentage of pixels having concentrations within the range of the original data set can be attributed to inaccuracies in the equation coefficients due to the small number of stations, the high level of instrument noise in band 2, the residual sinusoidal noise and the fact that the boat positions are not randomly distributed over the two flight lines but are clustered in two geographic regions. See figure 1(a). A study of table V(b) shows that the band ratio that had the second highest correlation with chlorophyll was the ratio of band 1 to band 3. Its correlation coefficient was $r = 0.891$. The least squares best fit equation was generated:

$$\text{Chl } \underline{a}(\text{mg/m}^3) = -19.733 + 27.501\left(\frac{\text{band 1}}{\text{band 3}}\right) \tag{2}$$

The equation had an F-ratio of 19.34 and the RMSE was 0.151. A plot of the ratio versus chlorophyll is shown in figure 6. Equation (2) was then used to calculate the chlorophyll concentrations for all the pixels on flight lines 5 and 6. For flight line 5, 49 percent of the pixels are calculated to have chlorophyll values between 1.7 and 2.59 mg/m^3 and in flight line 6, 71 percent have values in that range. The improvement over the percentages from equation (1) can be attributed to the fact that band 2 was not used. The fact that only 49 percent of flight line 5 and 71 percent of flight line 6 were within the 1.70 to 2.59 mg/m^3 range was again due to residual noises in scanner radiance data and the fact that the sea truth data collected were not randomly distributed over the flight lines.

Figure 7(a) and 7(b) show plots of chlorophyll values calculated from equation (1) for the center pixel along the flight path of flight line 5 and 6, respectively. Figure 8(a) and 8(b) show corresponding plots using equation (2). For flight line 5, equation (1) calculated a downward trend from the beginning to the end while equation (2) calculated just the opposite trend. For flight line 6, equation (1) calculated low concentrations for the first third of the distance then a 0.5 mg/m^3 jump in concentration level and then a slight upward trend for the remainder of the flight path. Equation (2) calculates no trend in chlorophyll levels over the same flight path. This inconsistency between equations for each flight line emphasized the limited use of this scanner data set. From studying these plots, it was decided that the scanner data could not be used to produce synoptic chlorophyll maps over the Nantucket Shoals area.

Regression Analysis with MOCS Calculated Chlorophyll Values

This analysis was conducted to determine if MOCS generated chlorophyll values could be used to calibrate the OCS scanner radiance data. Table VI lists the center wavelength for each of the 20 MOCS bands. The bandwidth of each band is 15 nanometers.

Based on 12 coincident MOCS overflights at 500 ft and ship measurements of chlorophyll, the correlation between log G7 and log chlorophyll was found to be -0.95 for a range of chlorophyll from 0.6 to 3.0 mg/m^3. The correlation coefficient between G7 at 500 ft and G7 at 7500 ft was 0.95 based on a single repeat line on May 13, 1981 (Campbell, Janet W.: Personal Communication, June 29, 1982). Based on the above correlations, use of chlorophyll values generated from MOCS data collected at 7500 ft on the afternoon of May 8, 1981, for sea-truth was assumed to be valid. The MOCS algorithm used to generate the chlorophyll values was

$$^{a}\text{Chl } \underline{a}\ (\text{mg/m}^3) = e^{26.06 - (19.86 \times G7)}$$

$$\text{where } G7 = \frac{(\text{band } 7)^2}{(\text{band } 5)(\text{band } 9)}$$

^{a}coefficients are for radiance collected at 7500 feet altitude

For the afternoon flight line that was simultaneously flown by both instruments, 21 analysis points were arbitrarily located along the flight path. At each point, five columns and five lines of data were averaged together to produce an averaged count value, as with the morning data. Table VII lists the columns and line numbers plus radiance count values of all 10 bands for all 21 points. The same five center columns were used throughout. A corresponding position along the flight path was located in the MOCS data. At each point the MOCS algorithm calculated a chlorophyll value. Those values are listed in table VIII.

Linear step-wise regression analysis was performed with all bands and all single band ratio combinations to find the correlations with the 21 calculated chlorophyll measurements. Table IX(a) and IX(b) lists the correlation coefficients. The highest correlation between an individual band and chlorophyll was $r = 0.572$ for band 9. Of the ratios, band 2 to band 9 had the highest correlation of $r = -0.604$. The ratio of band 2 to band 4 had a correlation coefficient of $r = -0.443$ while the ratio of band 1 to band 3 had a correlation with chlorophyll of $r = -0.263$. The ratio of band 2 to 9 versus chlorophyll is plotted in figure 9. The equation generated with this ratio was

$$\text{Chl } \underline{a}(\text{mg/m}^3) = 5.3892 - 3.1133 \frac{2}{9} \qquad (3)$$

Figure 10 shows a plot of the calculated chlorophyll concentration from equation (3) as a function of distance along the flight path of the afternoon flight line (figure 1(c)). The concentration is seen to increase for a while, then flatten out and then to decrease.

None of the correlation coefficients were sufficient to suggest a significant correlation between the MOCS algorithm calculated chlorophyll values and the OCS radiance data.

CONCLUDING REMARKS

High altitude Ocean Color Scanner ratios of band 2 (456-476 nanometers) to band 4 (539-559 nanometers) and band 1 (418-438 nanometers) to band 3 (498-518 nanometers) had high correlation coefficient values (-0.928 and 0.891, respectively) with seven boat-sampled chlorophyll a measurements made on the morning of May 8, 1981. The range of chlorophyll a concentrations was small (1.7-2.58 mg/m^3). Each ratio was used to calculate chlorophyll a values for the center pixel of each scan line on flight lines 5 and 6 of the May 8, 1981 morning data set. The two ratios produced dissimilar chlorophyll a trends. Due to the high noise level in the scanner data, no reliable synoptic chlorophyll a map could be generated with either ratio algorithm. Using data collected on the afternoon of May 8, 1981, no significant correlation was found between the Ocean Color Scanner data and chlorophyll a values calculated from the Multichannel Ocean Color Sensor.

REFERENCES

1. Kim, H. H.; McClain, C. R.; Blaine, L. R.; Hart, W. P.; Atkinson, L. P.; and Yoder, J. A.: Ocean Chlorophyll Studies from a U-2 Aircraft Platform. NASA TM 80574, August 1979.

TABLE I.- OCEAN COLOR SCANNER INFORMATION.

Bands	Center Wavelength
1	428 nm
2	466
3	508
4	549
5	592
6	632
7	674
8	714
9	756
10	794

Bandwidth 20 nm

Total Field of View ±45°

Instantaneous Field of View 4.49 milliradians

Ground Resolution at Nadir 60 meters (197 ft) at Flight Altitude of 12.5 kilometers (41 000 ft)

TABLE II.- FLIGHT LINE DATA.

(a) Morning, May 8, 1981.

Flight Line	Coordinates Begin	Coordinates End	Start Time EDST	End Time EDST	Aircraft Heading	Sun Azimuth	Sun Elevation
1	40° 46.3' N 70° 15.0' W	40° 34.6' N 69° 14.6' W	8:22	8:28	104°	94°	30°
2	40° 42.9' N 69° 00.5' W	40° 57.9' N 70° 20.3' W	8:37	8:48	284°	97°	34°
3	41° 08.9' N 70° 20.0' W	40° 52.6' N 68° 50.0' W	8:55	9:05	104°	100°	38°
4	41° 01.1' N 68° 35.4' W	41° 18.6' N 70° 10.0' W	9:13	9:25	284°	104°	40°
5	41° 28.9' N 70° 03.9' W	41° 12.2' N 68° 34.3' W	9:31	9:41	104°	108°	45°
6	41° 23.3' N 68° 35.0' W	41° 39.6' N 70° 01.2' W	9:46	9:57	284°	111°	47°

EDST Eastern Daylight Saving Time

TABLE II.- Concluded.

(b) Afternoon, May 8, 1981.

Flight Line	Coordinates Begin	Coordinates End	Start Time EDST	End Time EDST	Aircraft Heading	Sun Azimuth	Sun Elevation
1	40° 55.7' N 68° 32.0' W	40° 53.9' N 68° 39.8' W	15:51	15:52	254°	254°	42°
2	41° 03.9' N 68° 47.0' W	40° 44.3' N 70° 20.2' W	15:59	16:10	254°	257°	39°
3	40° 55.9' N 70° 19.9' W	41° 15.9' N 68° 44.3' W	16:17	16:27	74°	261°	36°
4	41° 24.0' N 69° 00.1' W	41° 06.9' N 70° 20.3' W	16:33	16:43	254°	264°	33°
5	41° 18.6' N 70° 19.7' W	41° 35.3' N 68° 59.8' W	16:49	16:58	74°	266°	30°
6	41° 46.9' N 69° 00.4' W	41° 29.8' N 70° 20.0' W	17:02	17:12	254°	268°	28°

TABLE III.- SEA TRUTH DATA COLLECTED ON MAY 8, 1981.

Boat	Station	Time EDST	Latitude	Longitude	Depth Meters	Chlorophyll *a* mg/m^3
On Rust	1	8:08- 8:30	41° 29' N	69° 38' W	0+	2.58
	2	11:24-11:35	41° 31' N	69° 29' W	0+	1.70
Edgerton	1	8:30	41° 29' N	69° 37' W	0+	2.43
	2	9:30- 9:40	41° 30' N	69° 37' W	0+	1.78
	3	11:00-11:10	41° 32' N	69° 37' W	0+	1.72
Gloria Michelle	1	9:31- 9:50	41° 25' N	69° 43' W	0+	1.86
	2	10:45-11:00	41° 24' N	69° 41' W	0+	2.18
Albatross	19	8:12- 8:35	40° 57' N	69° 44' W	1	1.63
	20A	10:45-10:55	41° 02' N	69° 43' W	0+	1.47

EDST Eastern Daylight Saving Time

TABLE IV.- OCEAN COLOR SCANNER RADIANCE COUNT DATA FOR THE SEVEN MORNING STATIONS OF MAY 8, 1981.

Boat	Station	Band									
		1	2	3	4	5	6	7	8	9	10
On Rust	1	88.40	136.32	109.16	81.00	73.76	58.08	103.12	83.80	98.20	91.52
	2	90.80	147.20	116.00	84.96[a]	78.56	64.28	115.32	91.08	112.12	104.88
Edgerton	1	88.68	139.88	111.00	82.68	75.76	60.92	107.80	87.52	106.24	96.24
	2	91.64	149.96	118.32	86.88[a]	80.24	66.32	119.04	95.24	116.16	107.80
	3	92.64	147.76	117.40	86.13[a]	79.64	64.32	114.40	92.36	115.44	104.24
Gloria Michelle	1	85.32	138.20	108.32	80.92	74.76	59.52	104.00	84.96	101.88	92.40
	2	87.48	138.48	109.60	81.16	75.64	60.84	106.76	85.68	103.32	92.84

[a]Counts were multiplied by 0.75 to take into account a gain setting change.

TABLE V.- CORRELATION COEFFICIENTS BETWEEN SCANNER BAND COUNT VALUES AND THE SEVEN STATIONS MORNING CHLOROPHYLL SET

(a) For individual scanner bands.

	Band 1	2	3	4	5	6	7	8	9	10
Correlation Coefficient	-.443	-.779	-.684	-.676	-.771	-.759	-.713	-.704	-.752	-.724

(b) For band ratios.

Band in Denominator of Ratio

Band in Numerator of Ratio	1	2	3	4	5	6	7	8	9	10
1	1.000	.878	.891	.673	.776	.810	.797	.782	.843	.820
2		1.000	-.682	-.928	-.618	.501	.506	.312	.668	.636
3			1.000	-.626	-.018	.663	.678	.600	.767	.748
4				1.000	.643	.761	.705	.720	.788	.747
5					1.000	.684	.588	.513	.721	.648
6						1.000	.316	-.289	.616	.531
7							1.000	-.505	.538	.618
8								1.000	.750	.683
9									1.000	.051
10										1.000

TABLE VI.- MULTICHANNEL OCEAN COLOR SENSOR SPECTRAL BANDS.

Band	Center Wavelength (nanometers)	Band	Center Wavelength (nanometers)
1	400	11	552
2	415	12	568
3	430	13	584
4	445	14	601
5	460	15	616
6	475	16	631
7	490	17	647
8	506	18	663
9	521	19	678
10	537	20	694

TABLE VII.- OCEAN COLOR SCANNER RADIANCE COUNT DATA FOR THE AFTERNOON OF MAY 8, 1981.

Station	Line Numbers	Pixel Numbers	Bands									
			1	2	3	4	5	6	7	8	9	10
1	78- 82	192-196	105.40	139.00	161.20	154.68	69.28	54.52	96.96	77.96	90.40	83.76
2	178- 182		105.96	137.52	160.36	155.16	69.04	54.88	95.80	77.60	91.36	83.12
3	278- 282		106.28	136.00	162.40	158.80	69.80	55.44	97.60	77.92	93.44	83.52
4	378- 382		107.16	135.64	164.36	161.00	71.24	56.56	98.52	79.08	93.96	87.00
5	478- 482		108.16	136.72	165.72	162.56	72.40	57.64	100.12	81.44	96.16	85.08
6	578- 582		106.52	134.24	161.92	160.04	71.72	56.72	99.88	79.48	94.84	86.36
7	678- 682		106.88	135.52	160.44	157.28	70.72	56.40	97.64	78.96	95.64	85.56
8	778- 782		105.16	135.12	159.76	156.44	69.60	55.20	97.96	76.68	93.00	85.12
9	878- 882		105.04	137.76	159.72	156.64	69.44	55.40	97.08	77.88	95.84	85.24
10	978- 982		107.04	136.72	158.36	155.40	69.64	55.72	97.44	78.84	93.40	82.68
11	1078-1082		105.16	130.36	156.40	151.56	68.16	55.40	94.96	75.68	91.92	82.08
12	1178-1182		105.44	134.16	154.24	151.28	67.96	54.84	96.16	77.32	92.56	83.76
13	1278-1282		103.92	135.12	154.24	149.60	66.92	54.80	94.80	77.16	91.52	82.52
14	1378-1382		106.60	132.96	154.56	151.08	68.36	55.28	96.00	77.52	94.84	84.52
15	1478-1482		104.72	134.28	154.48	150.00	68.08	54.96	95.56	77.32	91.68	81.76
16	1578-1582		103.60	132.40	150.12	144.32	64.96	51.96	92.40	75.08	89.48	81.24
17	1678-1682		101.76	133.40	148.48	142.84	64.60	53.52	92.20	74.68	90.16	79.56
18	2178-2182		100.56	130.84	145.16	137.92	61.80	50.72	88.68	71.68	86.72	78.12
19	2278-2282		98.40	125.68	142.80	134.00	60.52	49.76	86.28	67.92	81.88	73.40
20	2378-2382		98.36	122.40	141.28	133.44	59.76	48.76	84.96	69.80	80.60	72.24
21	2478-2482		98.44	125.32	140.00	131.88	59.72	48.12	85.16	67.48	78.20	71.28

TABLE VIII.- ESTIMATED CHLOROPHYLL a MEASUREMENTS FROM THE MULTICHANNEL OCEAN COLOR SENSOR FOR THE AFTERNOON OF MAY 8, 1981.

Station	Chlorophyll a mg/m^3
1	0.54
2	0.50
3	0.49
4	1.02
5	1.57
6	0.91
7	0.68
8	0.72
9	0.99
10	1.00
11	0.94
12	0.86
13	0.82
14	0.93
15	0.94
16	0.87
17	0.94
18	0.72
19	0.57
20	0.45
21	0.56

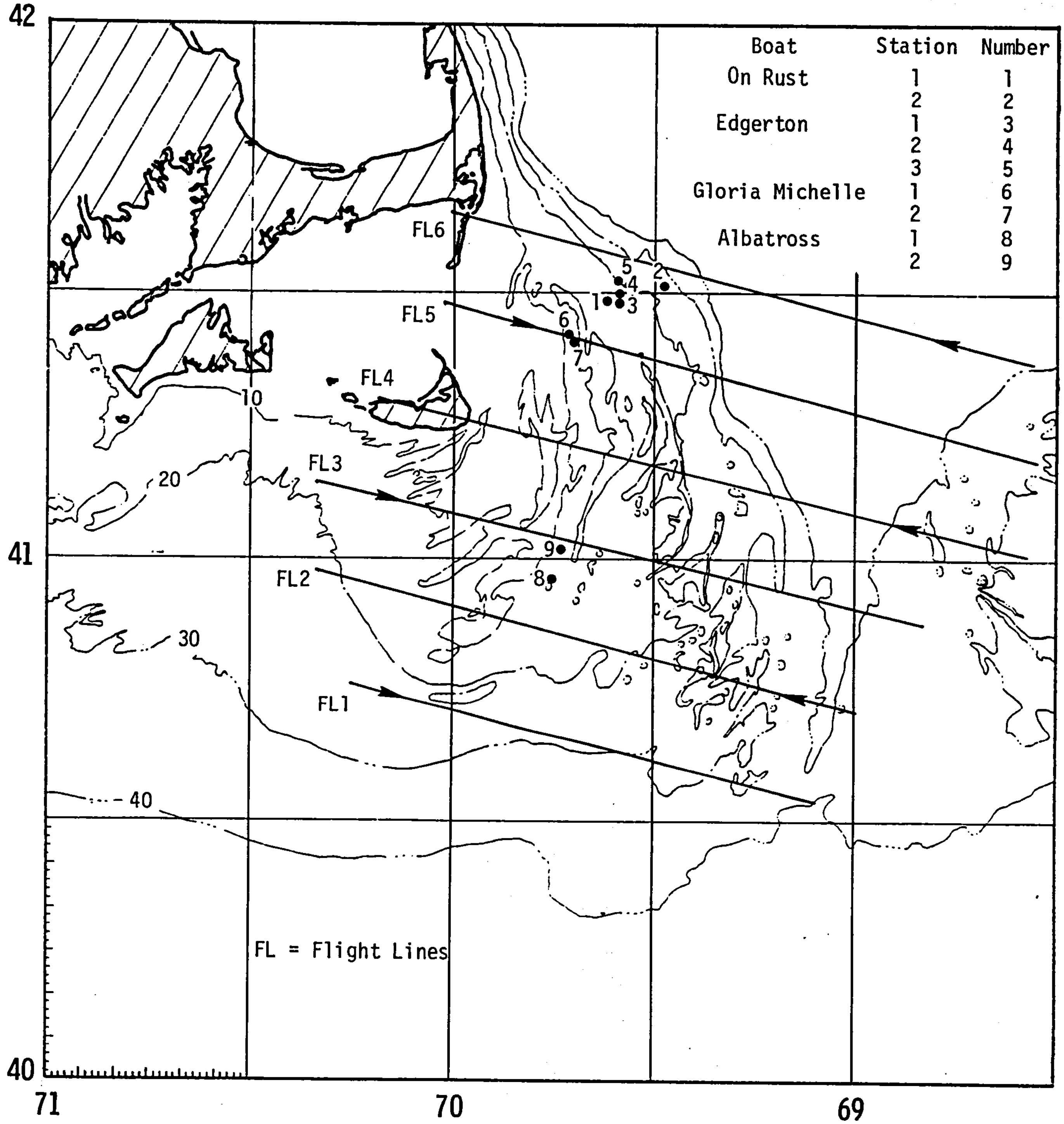
TABLE IX.- CORRELATION COEFFICIENTS BETWEEN SCANNER BAND COUNT VALUES AND THE 21 STATIONS AFTERNOON CHLOROPHYLL SET

(a) For individual scanner bands

	Band 1	2	3	4	5	6	7	8	9	10
Correlation Coefficient	.514	.366	.424	.463	.498	.570	.513	.553	.572	.477

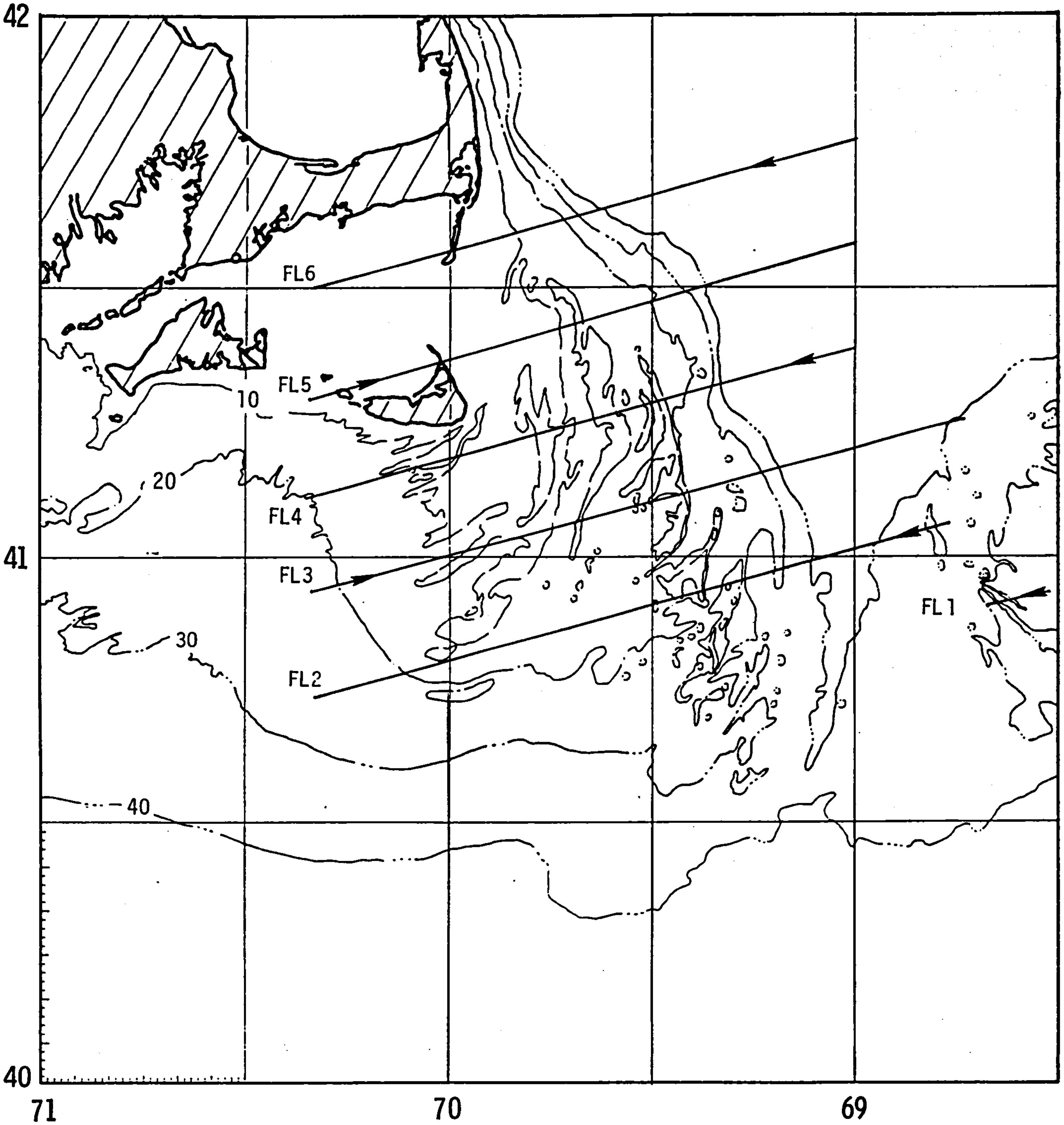
(b) For band ratios

Band in Numerator of Ratio	Band in Denominator of Ratio: 1	2	3	4	5	6	7	8	9	10
1		.162	-.263	-.401	-.461	-.564	-.468	-.538	-.552	-.401
2			-.335	-.443	-.491	-.573	-.522	-.587	-.604	-.476
3				-.540	-.589	-.430	-.325	-.369	-.437	-.278
4					-.002	.047	.236	.078	-.122	.117
5						.067	.347	.100	-.143	.135
6							.299	.050	-.254	.075
7								-.204	-.393	-.118
8									-.267	.036
9										.376
10										



(a) May 8, 1981 morning flight lines and boat locations

Figure 1.- Ocean color scanner flight lines.



(b) May 8, 1981 afternoon flight lines

Figure 1.- Concluded.

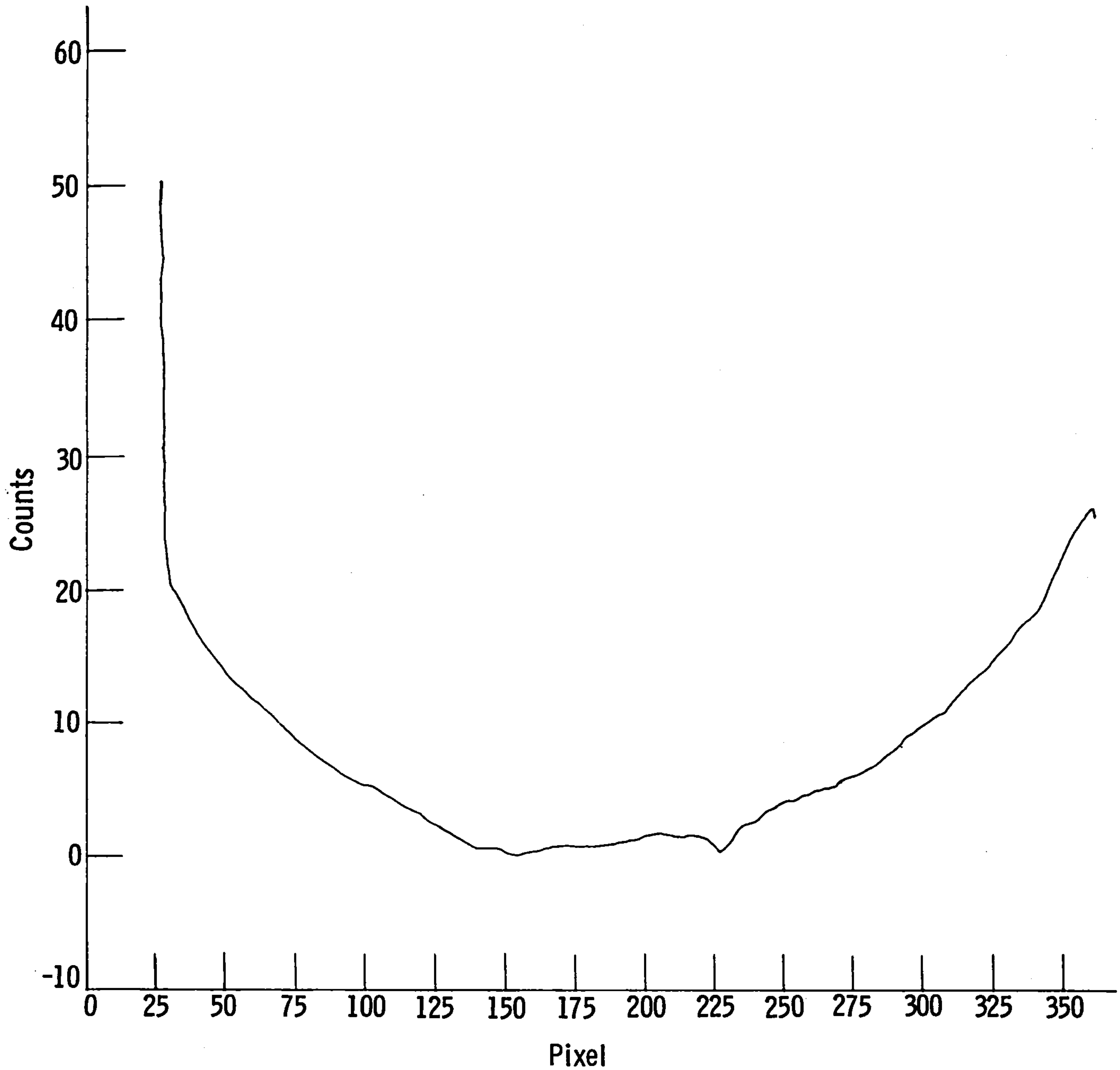
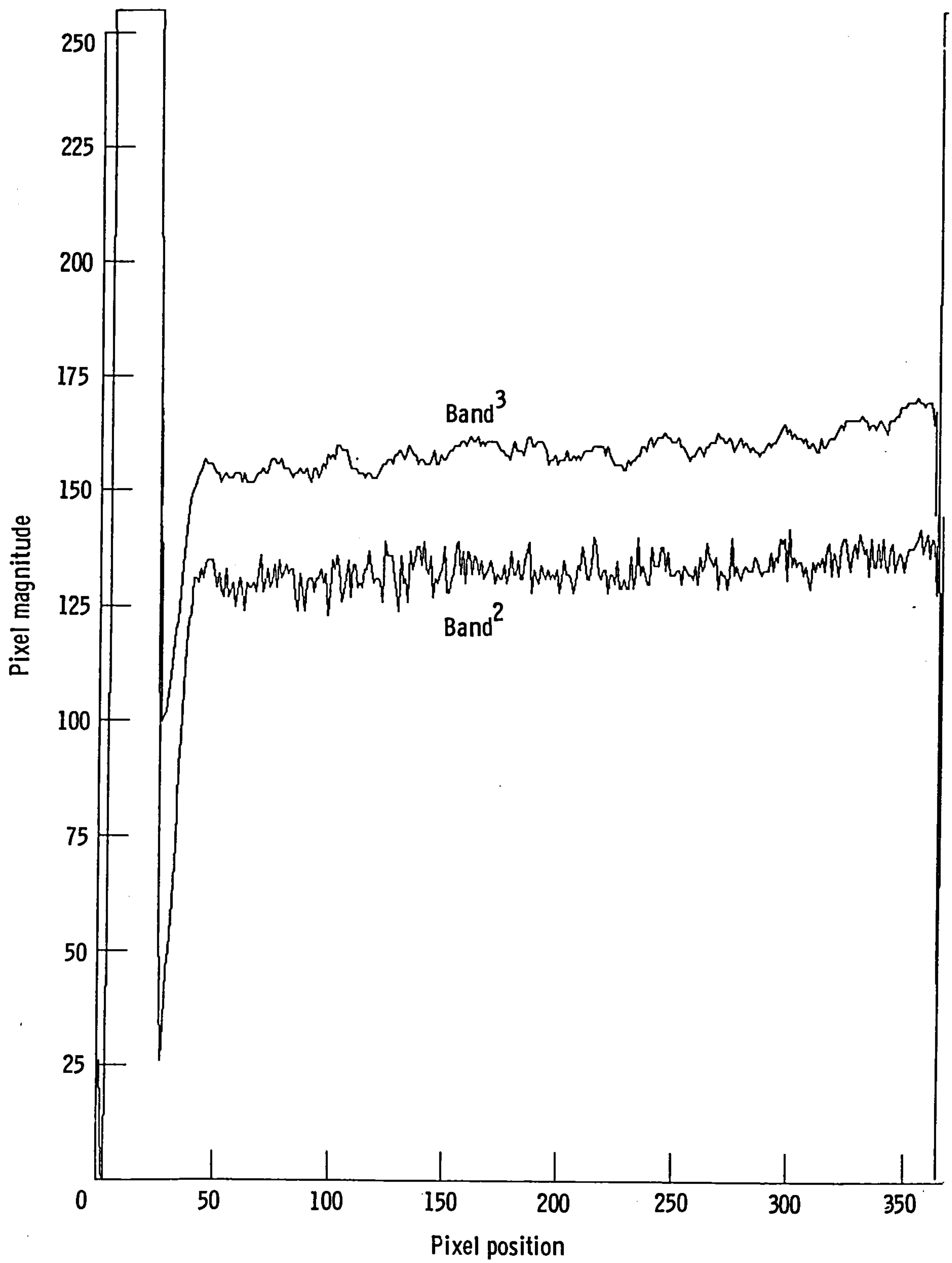
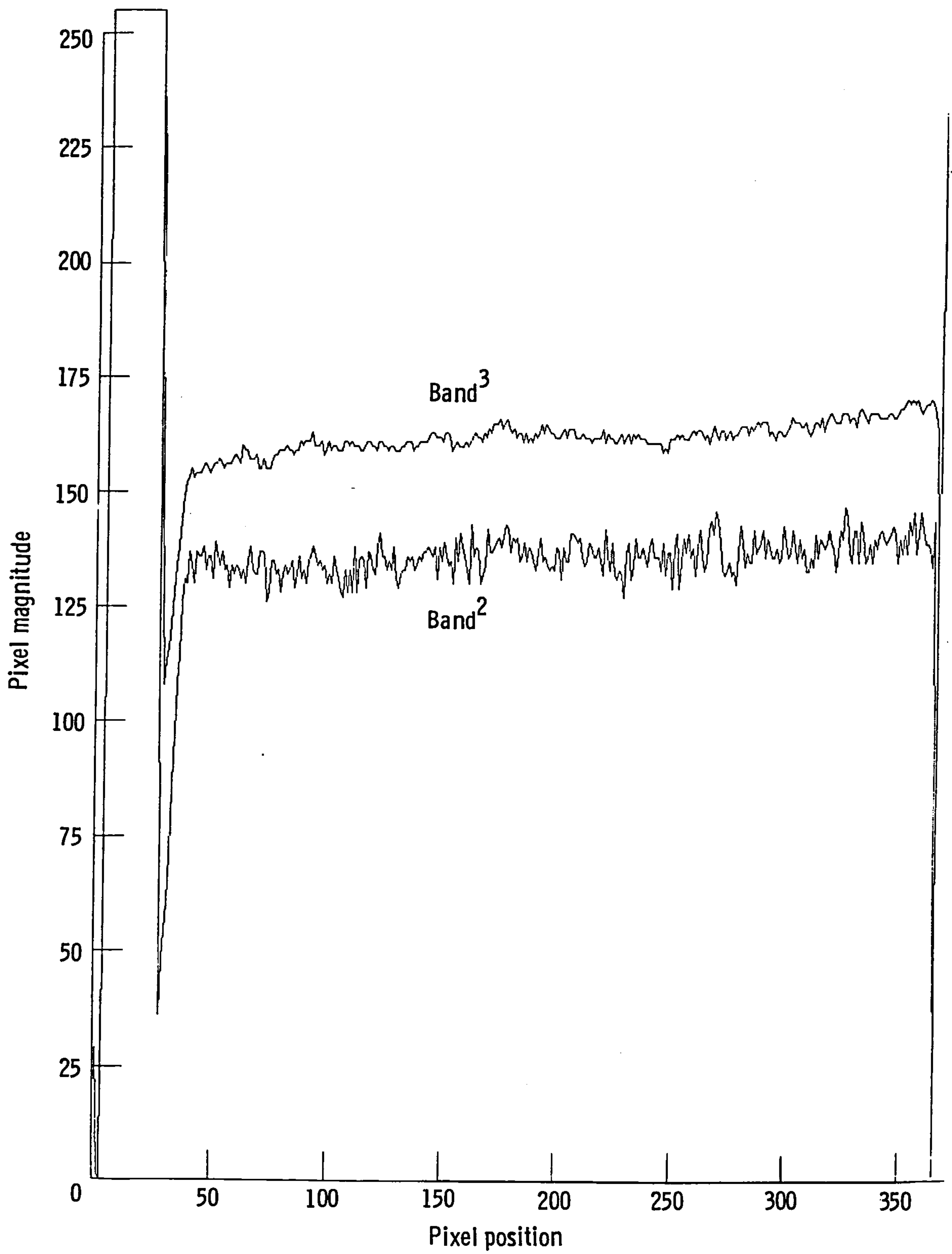


Figure 2.- Plot of typical scan angle correction curve.



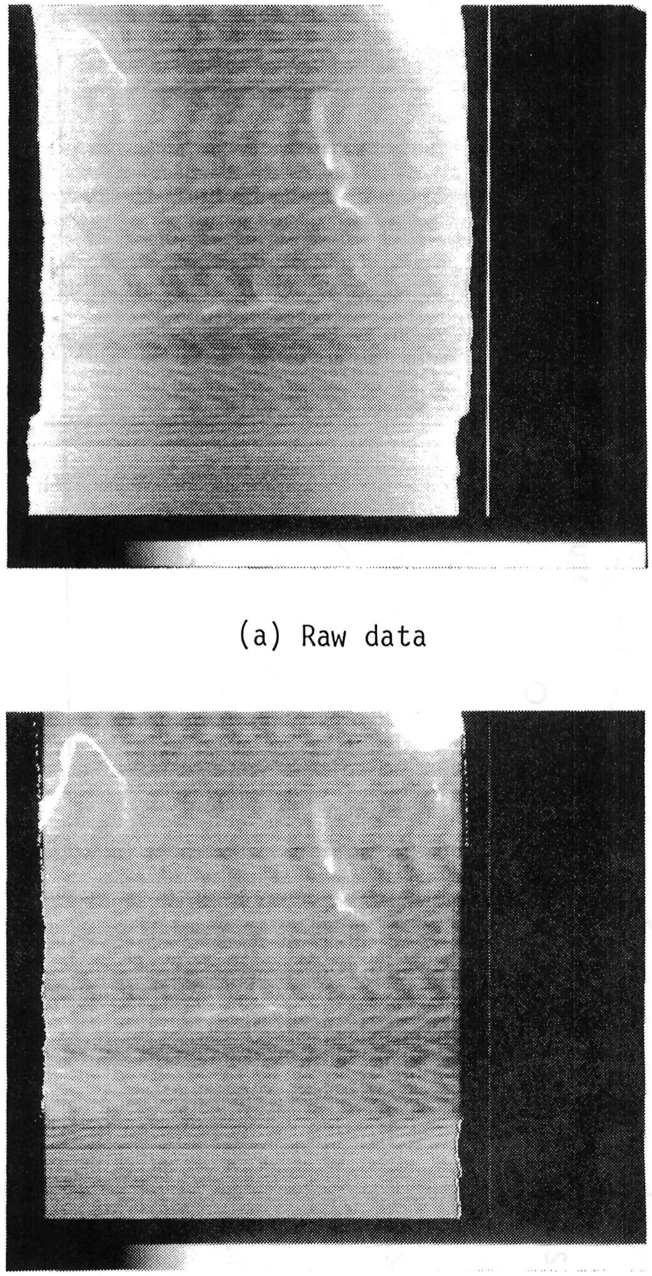
(a) Corrected for scan angle affects only

Figure 3.- Plot of band 2 and band 3 from same scan line.



(b) Corrected for scan angle affects and sinusoidal noise

Figure 3.- Concluded.



(a) Raw data

(b) Preprocessed data

Figure 4.- Pictures showing comparison of raw data versus preprocessed data.

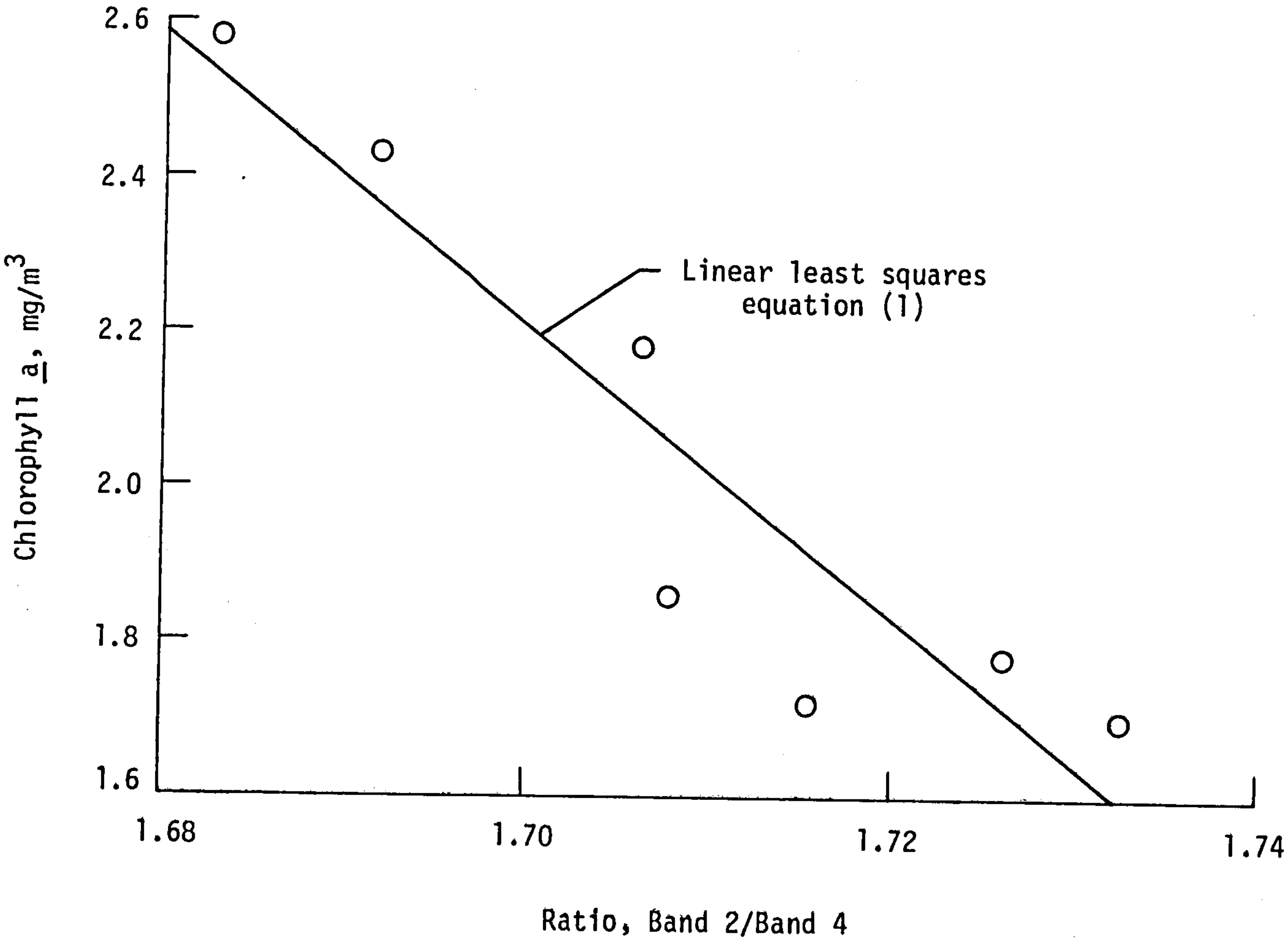


Figure 5.- Measured chlorophyll a concentration as a function of the ratio of band 2 to band 4.

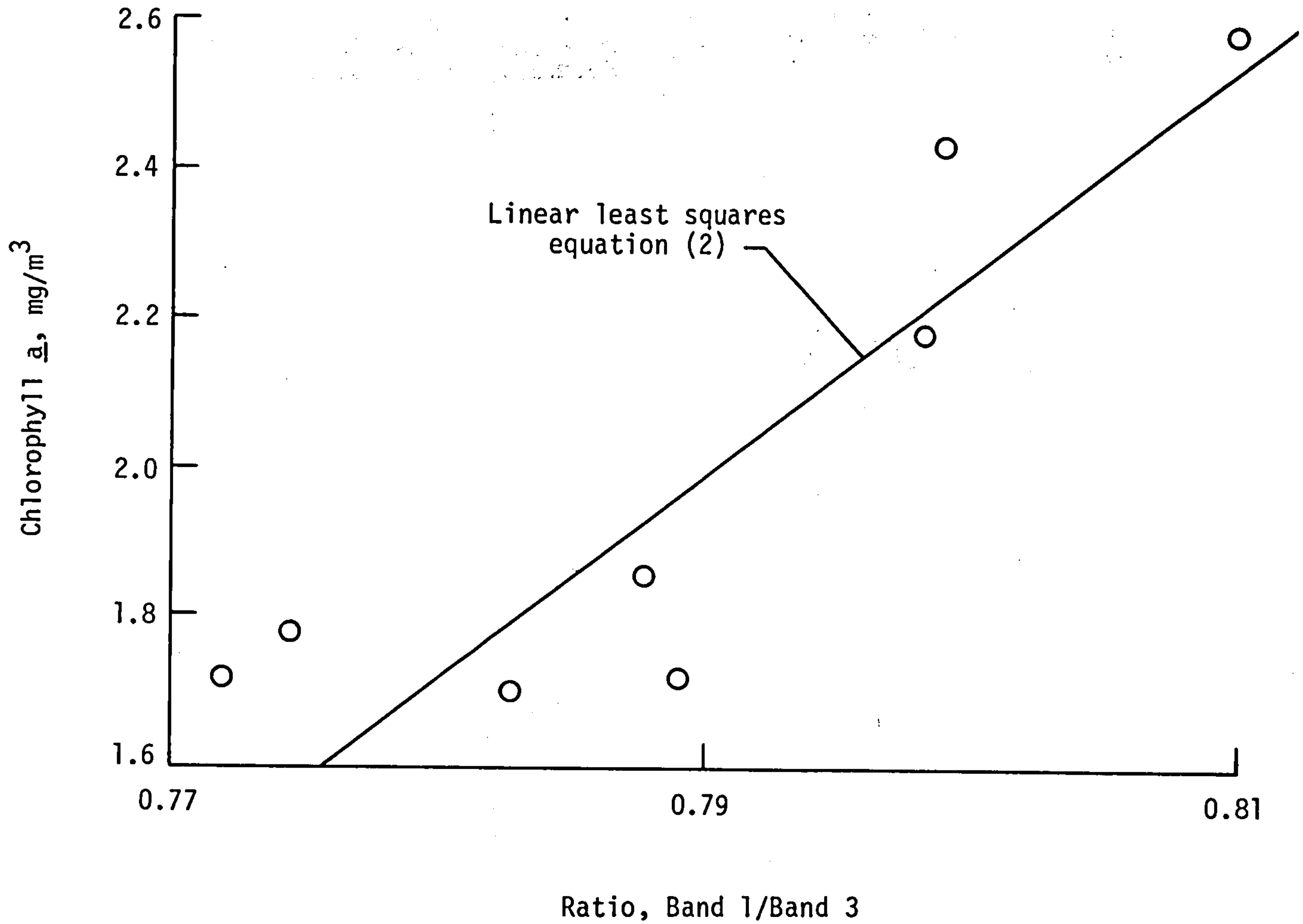
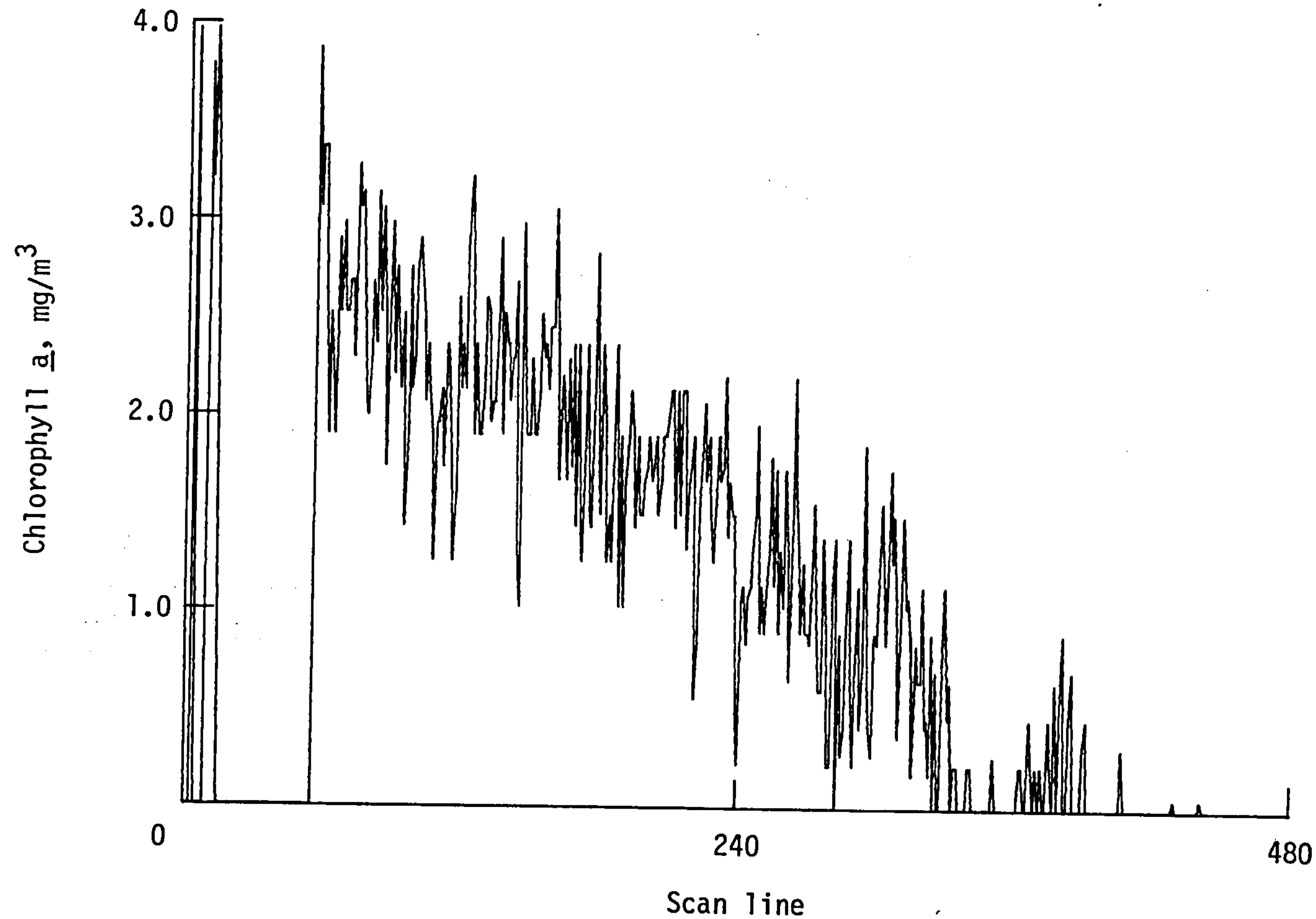
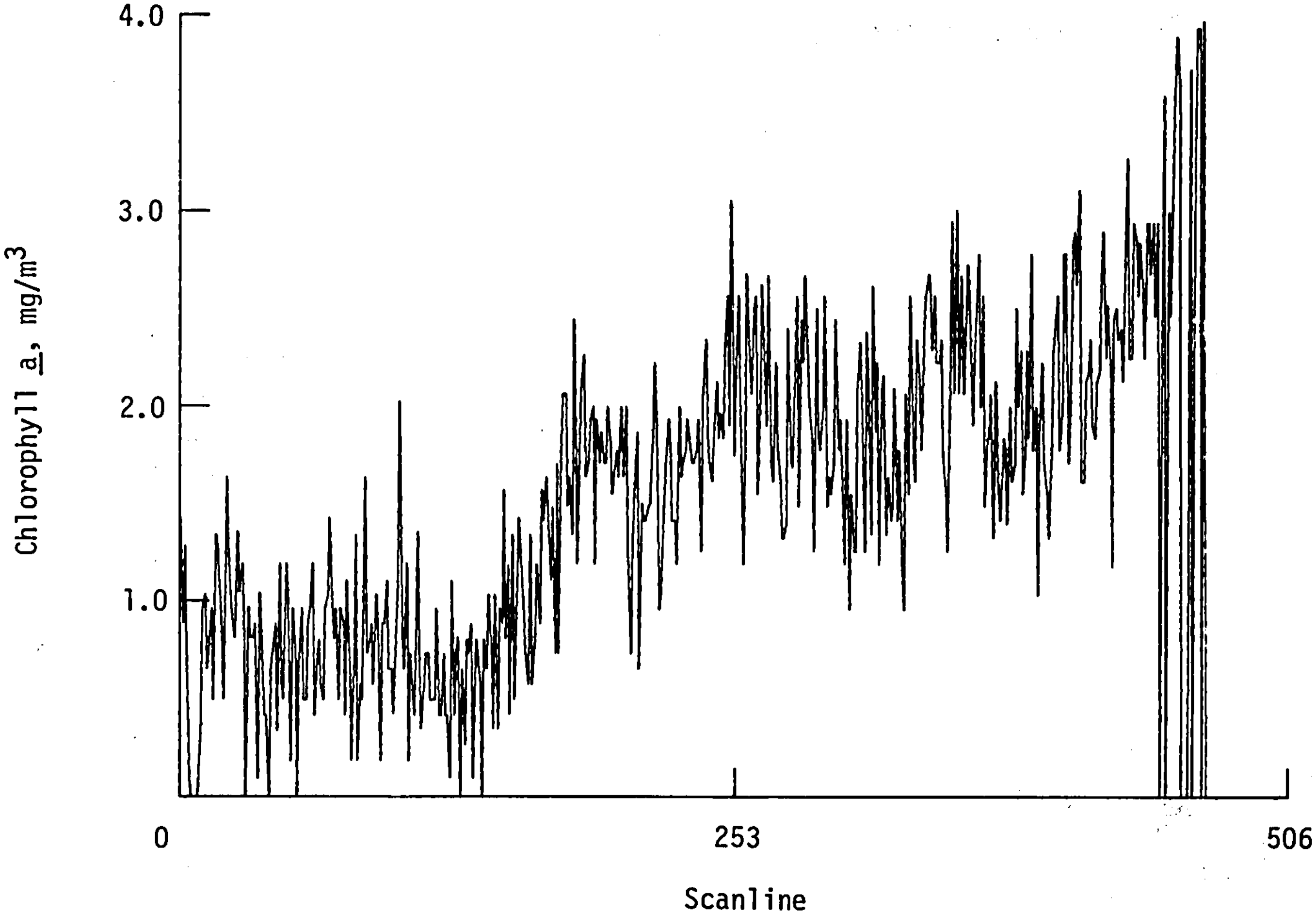


Figure 6.- Measured chlorophyll a concentration as a function of the ratio of band 1 to band 3.

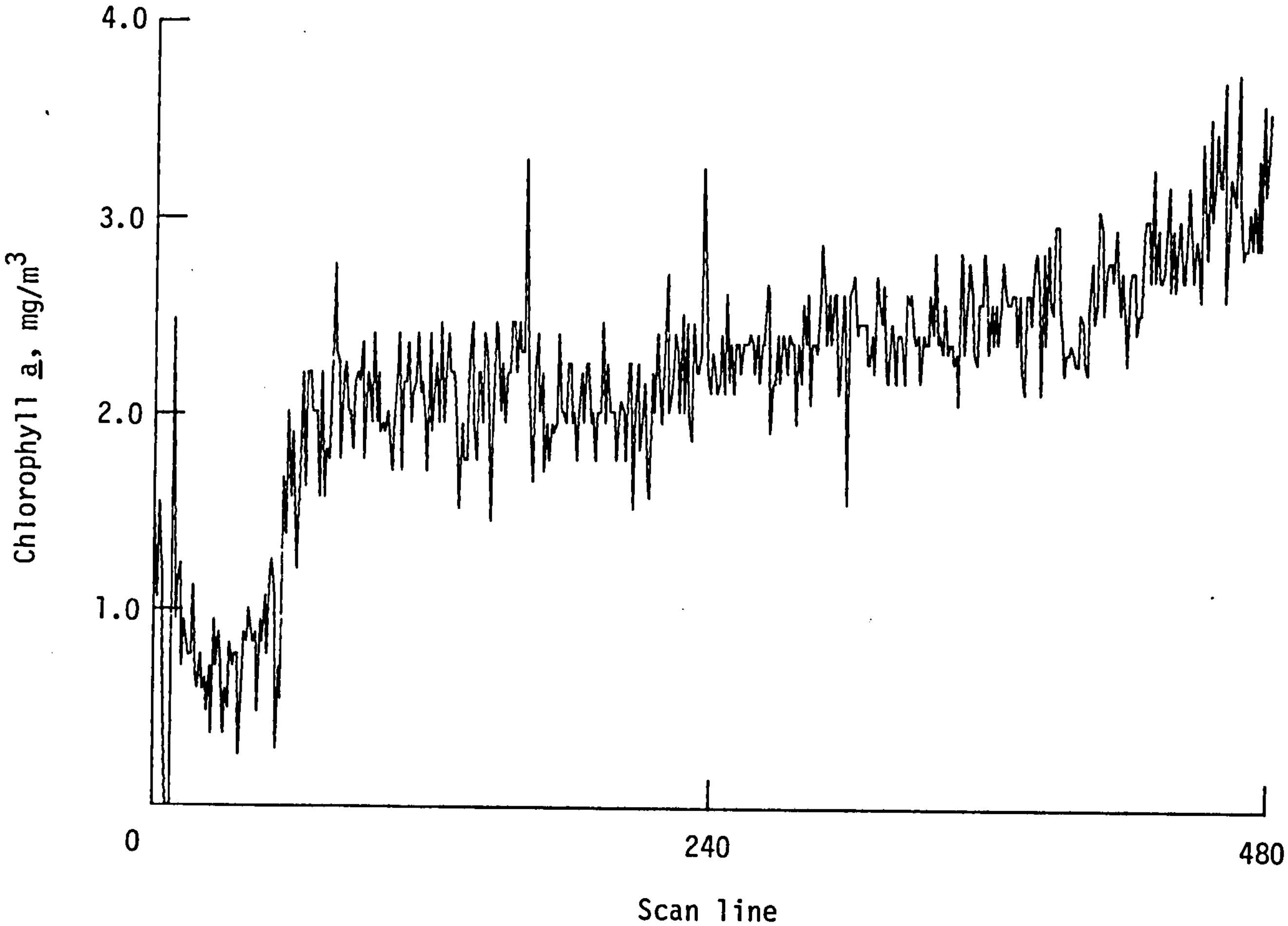


(a) Flight line 5

Figure 7.- Center pixel chlorophyll a concentration calculated from equation (1) as a function of distance along the flight path.

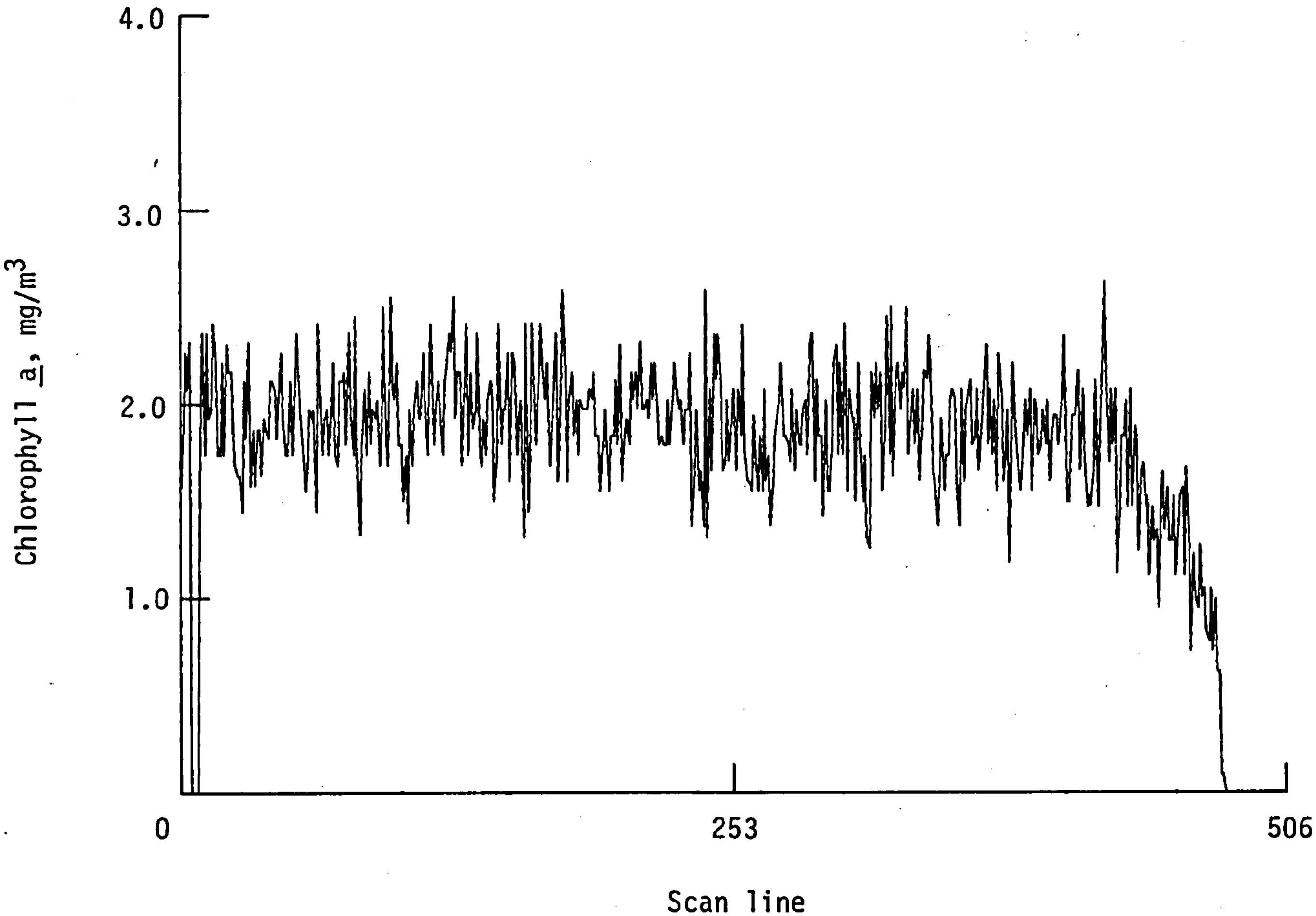


(b) Flight line 6
Figure 7.- Concluded.



(a) Flight line 5

Figure 8.- Center pixel chlorophyll a concentration calculated from equation (2) as a function of distance along the flight path.



(b) Flight line 6

Figure 8.- Concluded.

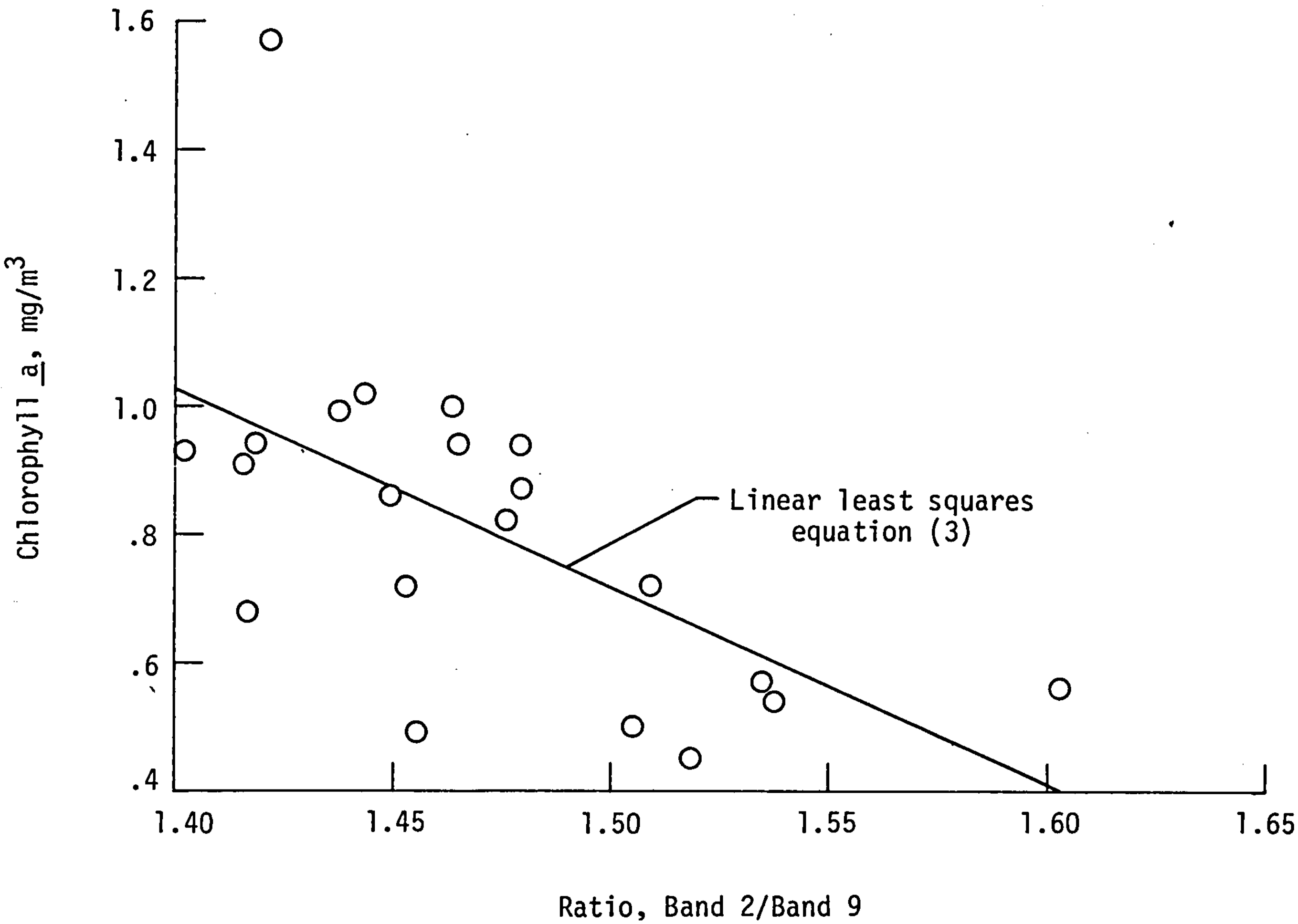


Figure 9.- Measured chlorophyll a concentration as a function of the ratio of band 2 to band 9.

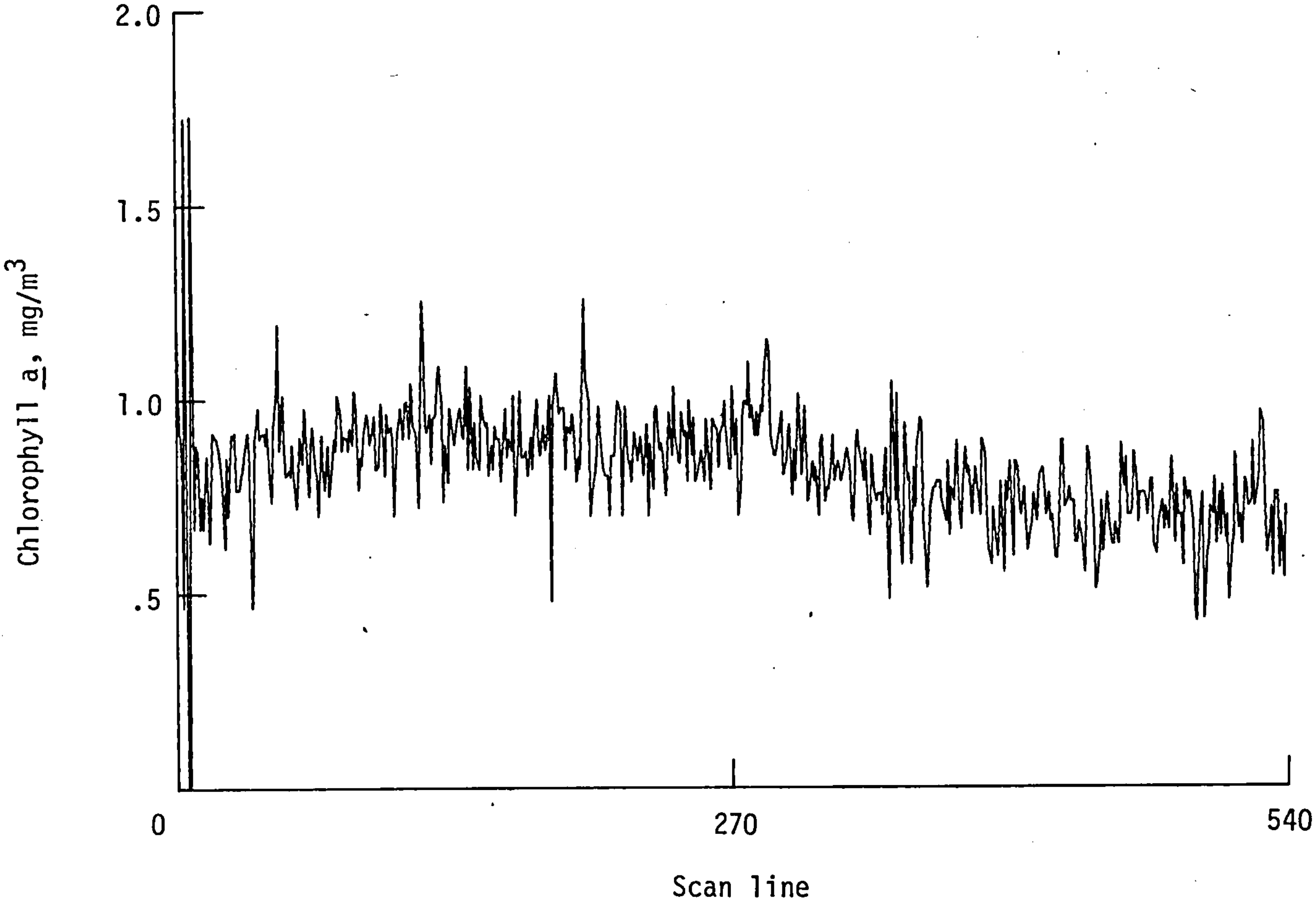


Figure 10.- Center pixel chlorophyll a concentration calculated from equation (3) as a function of distance along the flight path.

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16. Abstract

High altitude Ocean Color Scanner ratios of band 2 (456-476 nanometers) to band 4 (539-559 nanometers) and band 1 (418-438 nanometers) to band 3 (498-518 nanometers) had high correlation coefficient values (-0.928 and 0.891 respectively) with seven boat-sampled chlorophyll a measurements made on the norming of May 8, 1981. The range of chlorophyll a concentrations was small (1.7-2.58 mg/m^3). Each ratio was used to calculate chlorophyll a values for the center pixel of each scan line on flight lines 5 and 6 of the May 8, 1981, norming data set. The two ratios produced dissimilar chlorophyll a trends. Due to the high noise level in the scanner data, no reliable synoptic chlorophyll a map could be generated with either ratio algorithm. Using data collected on the afternoon of May 8, 1981, no significant correlation was found between the Ocean Color Scanner data and chlorophyll a values calculated from the Multichannel Ocean Color Sensor.

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