CMFRI
bulletin 44
Part One

JUNE 1989

NATIONAL SYMPOSIUM ON RESEARCH AND DEVELOPMENT IN MARINE FISHERIES

MANDAPAM CAMP
16-18 September 1987

Papers Presented
Sessions I & II

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
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VALIDATION OF LANDSAT THEMATIC MAPPER-DERIVED PHYTOPLANKTON PIGMENTS THROUGH SYNCHRONOUS SURFACE MEASUREMENTS: AREA OFF CALICUT TO AZHIKAL IN THE ARABIAN SEA

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ABSTRACT

This paper deals with an estimation of phytoplankton pigments from Landsat Thematic Mapper (TM) data after removal of atmospheric effect. The pigments derived from Landsat TM data of October, 1986 and March, 1987 have been compared with corresponding surface values measured during ship cruise programmes synchronous to satellite overpass. In-water algorithm for Landsat TM bands was developed from the sea data collected off Quilon to Malpe in the Arabian sea at different periods of the year. A uniform bias towards underestimation of pigments has been observed in the case of October data and an appropriate modification in the pigment algorithm for Landsat TM has been suggested.

INTRODUCTION

The presence of phytoplankton pigments is associated with algal biomass, forming first link in the marine food chain and therefore remote sensing of phytoplankton pigment abundance provides a useful indication of living resources. An empirical relationship has been observed between chlorphyll pigments and water leaving radiance ratios in visible region of electromagnetic spectrum. This relationship is exploited to estimate pigment from the satellite data. As a first step, the backscattered radiance from water is isolated from the total signal observed at the sensor through elimination of atmospheric scattering effects. Subsequently phytoplankton pigment is estimated with the help of a bio-optical algorithm developed from the sea data. It is desirable to determine absolute values of the pigments with the maximum achievable accuracy if one intends to estimate indirectly the fish stock in a quantitative manner from pigment estimates. An attempt has been made here to compare satellite derived pigments with the corresponding surface measured pigment values. Aspects related to the accuracy of pigments estimates and probable source of error have been discussed.

Rationale for utilization of Landsat Thematic Mapper data

It has been possible to achieve ocean colour measurements from space with Coastal Zone Colour Scanner (CZCS) (Gordon and Clark, 1980; Gordon *et al.*, 1980, Smith and Baker, 1982; Gordon *et al.*, 1983; Singh *et al.*, 1983, Sturm, 1983; Dwivedi and Narain, 1986) with accuracy goal of estimating pigment concentration within accuracy goal of 0.5 log C (where C is phytoplankton pigment) as set by Nimbus Experiment Team. However, avilability of CZCS data is no longer consistent and hence attention of scientists and engineers working in this area has been drawn to Landsat Thematic Mapper (TM), Except for broad bands of TM as compared to CZCS (resulting in loss of sensitivity to detect chlorophyll changes), it has several advantages over presently available Landsat MSS, in favour of its use for ocean colour mapping. Band 1 (blue-green) and band 2 (green) of TM almost match the maximum and minimum absorption characteristics of chlorophyll-a whereas band 3 and 4 in red and near-infrared are useful for estimation of aerosol scattering effects. Eight bit quantification of signal provides increased radiometric sensitivity and dynamic range. Higher Signal to noise ratio of TM is ideal for detecting very weak signal emerging from oceanic waters. Landsat's morning equatorial crossing time prevents sun glint from entering the sensor's field of view. In view of these technological improvements and regular availability of data, TM appears to be an appropriate substitute till dedicated sensor like Ocean Colour Imager (OCI) or Ocean Colour Monitor (OCM) are available for ocean colour mapping in the distant future. In a preliminary study the application of Landsat TM in phytoplankton pigment mapping has been damonstrated (Kim and Linebaugh, 1985; Dwivedi and Narain, 1986).

METHODS

Sea truth data acquisition and analysis

Sea truth data on phytoplankton pigment and upwelling radiance/downwelling irradiance were collected in the Arabian sea using Turner Designs fluorometer model 10 series and Li-cor make underwater spectroradiometer. Data on above parameters were collected at various sea stations between Quilon (9°N) and Malpe (13° 20'N) in the Arabian sea, off west coast of India. The cruises were timed synchronous to satellite overpass using the vassels viz. RV *Skipjack* (CMFRI) and MV *Matsya Varshini* (FSI). An algorithm developed from regression analysis of the ship data was of the following form.

$$C = 1.62 \left\{ \frac{L(485)}{L(589)} \right\}^{-0.63}$$

where r = 0.68; Sy x = 0.12 (n = 18)
and C is phytoplankton pigment (chlorophyll-a + phaeophytin-a) in mg/m³L is radiance in TM band 1 ($C_{\overline{\lambda}}$ = 485nm) and band 2 ($C_{\overline{\lambda}}$ = 589nm).

Approach to digital data analysis

Two scenes of Landsat TM CCT (Path 145, Row 052 of 19 Oct', 1986 and 12 Mar', 1987) covering oceanic areas off south of Calicut to Kasaragod in the Arabian sea were studied for pigment estimation and its validation. Orignal TM data were reformatted in band sequential form and compressed to 20 times through resampling. This compression was performed in view of the fact that oceanic features do not change significantly over a large area and spatial resolution of the order of sub kilometer is adequate for the application. Moreover a technique of data compression prior to processing reduces data handling and processing time. A compressed full image obtained by merging of four quadrents (350 pixels x 284 scan lines) thus could be displayed on Comtal image processing system. The data were corrected for atmospheric effects to retrieve water leaving radiance. Spectral radiance $L_T(\lambda)$ received by the sensor can be expressed as:-

$$L_T(\lambda) = L_R(\lambda) + L_A(\lambda) + tL_W(\lambda)$$

where $L_R(\lambda)$ = Radiance contributed by scattering due to air.

$L_A(\lambda)$ = Radiance due to aerosol component.

t = Diffuse transmittance of the atmosphere.

$L_W(\lambda)$ = Radiance backscattered from water.

$L_R(\lambda)$ and $L_A(\lambda)$ were estimated using solar and sensor ephemeris for the central pixel (Dwivedi and Narain, 1986).

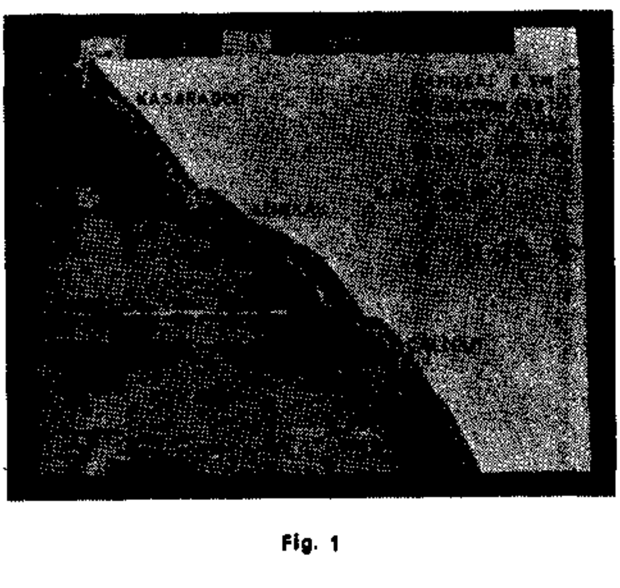

Fig. 1

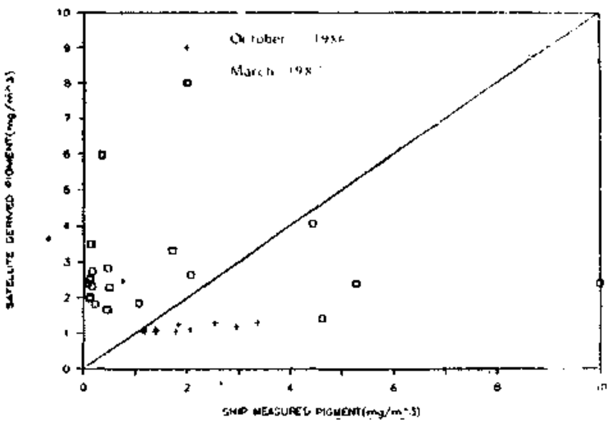

Fig. 2

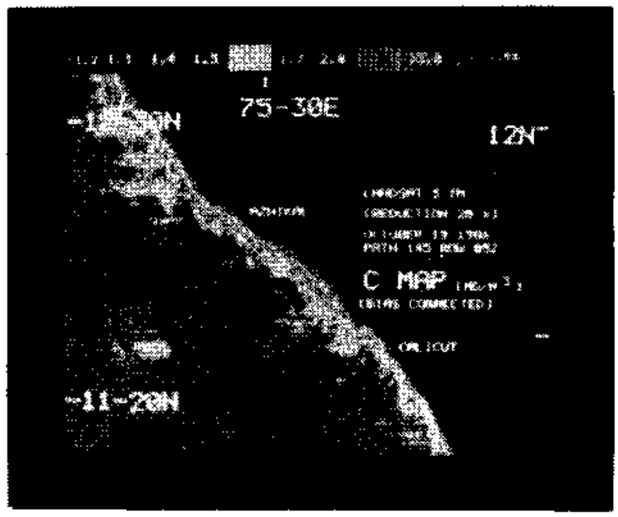

Fig. 3

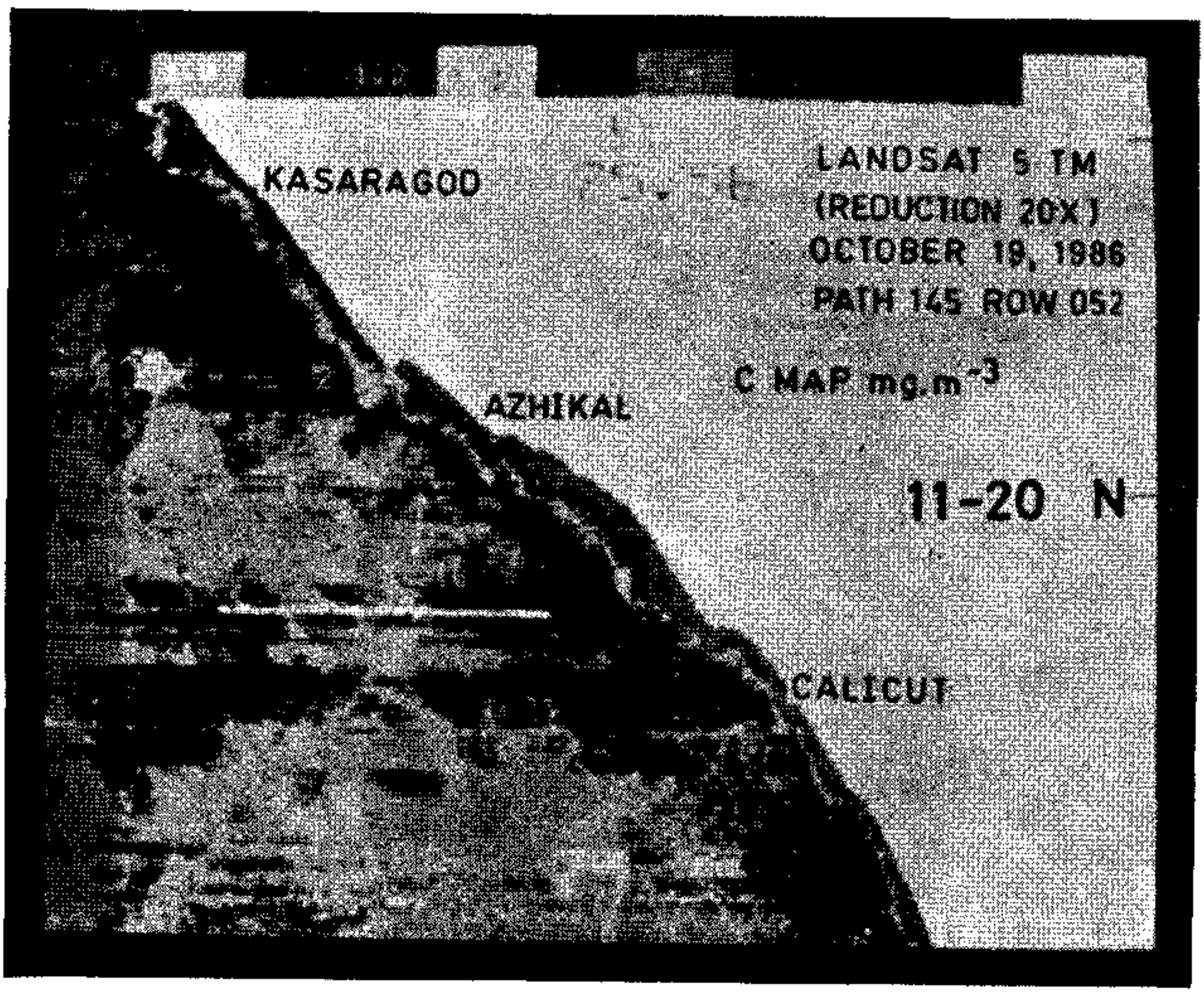

Fig. 4

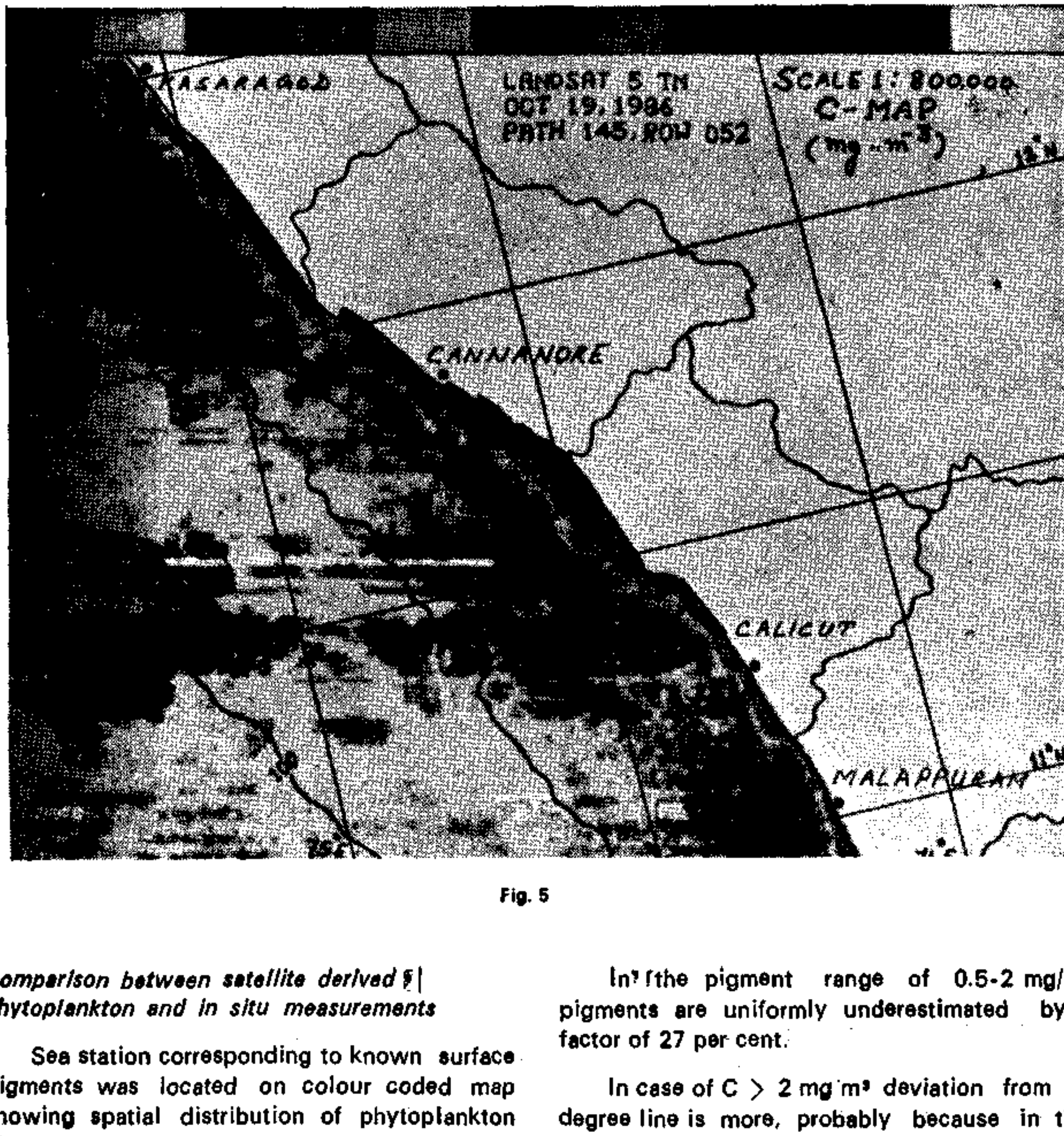

Fig. 5

Comparison between satellite derived §| phytoplankton and in situ measurements

Sea station corresponding to known surface pigments was located on colour coded map showing spatial distribution of phytoplankton pigment (C map) obtained from TM data (fig. 1). As a next step the pigment values derived from TM data and their corresponding surface values were plotted as shown in fig-2. A 45 degree line was drawn along with the scatter plot for comparison (fig. 2). A uniform bias towards underestimation of pigments was observed in case of October scene whereas the pigment values were uniformly overestimated in case of March scene (fig. 2).

Results and discussion

It appears from figure 2 that TM sensor does not yield reliable estimates for pigment concentration in the range 0-0.5 mg/m^3.

In the pigment range of 0.5-2 mg/m^3 pigments are uniformly underestimated by a factor of 27 per cent.

In case of C > 2 mg m^3 deviation from 45 degree line is more, probably because in this case clorophylls act as large particles and contribute more prominantly in terms of back-scattering apart from absorption in band 1. Pigments have been found to be underestimated by a factor of 57 per cent in this range.

A set of two factors as mentioned above have been utilized to correct the estimated pigments. Figure 3 shows a colour coded C map with modified pigment values after bias correction.

Conclusions

Landsat TM data do not show sensitivity towards detection of low value chlorophyll

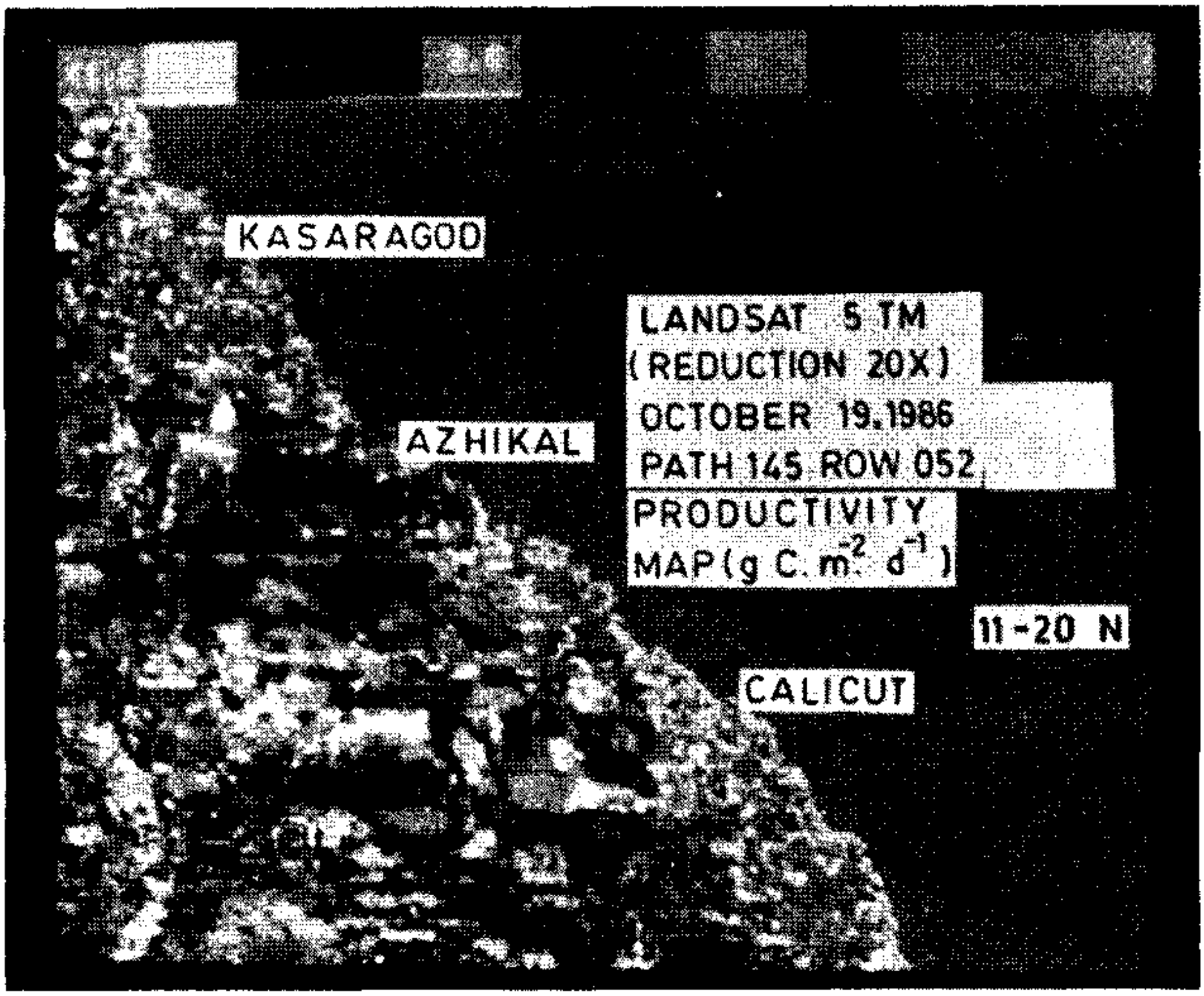

Fig. 6

pigments ($C < 0.5$ mg/m^3) obviously because of its broad bands. However, if season dependent algorithm is developed and applied, better estimate of pigments can be made. A bias corrected C map as shown in figure 3 is expected to exhibit realistic values of pigments since the bias is removed with an appropriate correction factor.

Reduction in sensitivity to detect chlorophyll changes due to TM's broad bands is reflected in figure 2. It is seen that variation in chlorophyll pigment concentration is very small. This is because the corresponding estimated radiance ratios show very little change from pixel. to pixel.

ACKNOWLEDGEMENTS

We are extremely) grateful to the Director General, ICAR, Joint Commissioner (Fishery), Minisry of Agriculture, Shri. P. P. Kale, Director, Space Applications Centre and Dr. Baldev Sahai, Associate Director, IRS-Utilization Programme for their encouragement during the conduct of this work. Thanks are also due to the skippers, engineers and crew members of the research vessels of Central Marine Fisheries Research Institute and Fishery Survey of India.

REFERENCES

DWIVEDI, R. M. AND A. NARAIN, 1986. Remote sensing of phytoplankton pigment from the Nimbus-7 CZCS: Initial comparisons with sea truth in the Arabian sea, scientific, note IRS-UP/SAC/MAF/SN/01/86 (Library: Space Applications Centre, Ahmedabad), pp 32-37.

DWIVEDI, R.M. AND A. NARAIN, 1986. Remote sensing of phytoplankton abundance: An attempt from Landsat Thematic Mapper, Scientific note IRS-UP/SAC/MAF/SN/02/86 (Library, Space Applications Centre, Ahmedabad) 8 p.

GORDON, H. R. AND CLARK, D K. 1980, Atmospheric effects in the remote sensing of phytoplankton pigments. *Boundary Layer Meteorology, 18,* 299.

GORDON, H. R., CLARK, D K, MUELLER, J. L. AND HOVIS, W. A., 1980, Phytoplankton pigments from the Nimbus-7 Coastal Zone color Scanner: comparison with surface measurements. Science, New York 210, 63.

GORDON, H. R, CLARK, D. K, BROWN, J W., BROWN, O. B., EVANS, R H. AND BROENKOW, W. W. 1983. Phytoplankton pigment concentration in the Middle Atlantic Bight: comparison of ship determination and CZCS estimate. Applied Optics, V. 22,20p.

KIM, H. H. AND LINEBBAUGH, G. 1985, Early evaluation of Thematic Mapper data for coastal process studies. *Advances in Space Research* 5, 21.

SINGH, S. M., CRACKNELL, A. P. AND CHARLTON, J A. 1983. Comparison between CZCS data from 10 July 1979 and simultaneous in situ measurements for south eastern Scottish waters. International Journal of Remote sensing, 4, 755.

SMITH, R. C., AND BAKER, K. S. 1982. Oceanic chlorophyll concentrations as determined by satellite (Nimbus-7 Coastal Zone Color Scanner) Marine Bioloey, 66,269.

STURM, B., 1983, Selected topics of Coastal Zone Color Scanner (CZCS) data evaluation in Coastal and Marine Applications of Remote Sensing. edited by A. P. Cracknell (Reading: Remote Sensing Society). p. 137.