

14. Internationaler Kongreß
der Internationalen Gesellschaft für Photogrammetrie
Hamburg 1980
Kommission VII
Arbeitsgruppe 4

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EVALUATION OF OCEAN BOTTOM FEATURES FROM OCEAN COLOR SCANNER IMAGERY

Abstract

An attempt has been made to derive bottom features in a coastal area from airborne, multispectral imagery. For this purpose Ocean Color Scanner (OCS) data taken at high tide above the Jade Estuary is compared with a hydrographic map as well as a LANDSAT scene taken at low tide.

1. Introduction

The bottom topography of our oceans is of great scientific, commercial and military interest to a large variety of users. This applies especially to shallow, coastal areas, in which the water depth is strongly affected and frequently changed by storms, tidal movements river discharges and large scale engineering activities.

Although hydrographic maps are nowadays correct with regard to large scale features, small scale deviations from the actual bottom contours are always possible and have to be updated more frequently. Areas which are used for the routing of large vessels for example have to be monitored regularly with regard to water depth.

The most commonly used method for hydrographic charting is by echo sounding. While this is rather reliable and operated on a high technical standard, it is time-consuming and expensive. Already during early phases of manned space flights many photographs taken over coastal regions showed bottom features in remarkable detail. It is therefore not surprising that since then several attempts have been undertaken to use active and passive remote sensing from aircraft and spacecraft so as to map large areas of the sea bottom synoptically. Lasers operating in the green region of the spectrum for example were successfully operated as bathymeter from low flying aircraft / Kim and Cervenka, 1975, Hoge et al, 1980 /. The Multi Spectral Scanner (MSS) on LANDSAT I and II was operated in the high gain mode for a bathymetry experiment in a test area near the Berry Islands/Polcyn, 1976/. The Ocean Color Scanner (OCS) from NASA was operated from the U-2 aircraft in an area off the west coast of Florida /Middleton and Barker, 1976/.

2. Remote Sensing of Water Depth

The application of suitable remote sensing methods depends on the transmitting characteristics of the atmosphere and of the water itself. As a result of the strong absorption of the water molecule, only the visible portion of light (0.4 - 0.7 μm) may penetrate the water to a certain depth. Already at wave-lengths longer than 0.6 μm the absorption rises rapidly and attenuates the transmitted light. The same holds for wave-lengths below 0.4 μm with the exception of very clear oceanic water.

Through processes like particle scattering, pigment absorption and bottom reflection, the intensity and spectral composition of backscattered light within the narrow spectral region is modulated and can be observed from a spectro-radiometer or a multispectral image scanner flown above (water colour). It may thus render information not only on the distribution of dissolved and suspended matter but also on water depth simply by using a passive observation system.

In this paper an attempt has been made to correlate high altitude Ocean Color Scanner (OCS) imagery with submerged bottom features in coastal regions of the German Bight.

	on U-2	on Mystère
PLATFORM ALTITUDE	19.8 km	11 km
IFOV	3.5 mr	5.28 mr
FOOT PRINT	69.3 x 69.3 m	58.1 x 58.1 m
MAX. SCAN ANGLE	$\pm 45^\circ$	$\pm 36^\circ$
SWATH WIDTH	39.6 km	16 km
Nr.		
CENTRE	1	431 nm
	2	472 nm
WAVE-LENGTHS	3	506 nm
	4	548 nm
OF CHANNELS AND	5	586 nm
	6	625 nm
BANDWIDTHS AT	7	667 nm
	8	707 nm
HALF INTENSITIES	9	738 nm
	10	778 nm

Table 1: OCS characteristics

3. The OCS Experiment Above the German Bight

3.1 The Ocean Color Scanner

The OCS, a 10 channel, narrow bandwidth scanner of high sensitivity (Table 1) was designed, built and operated by NASA's Goddard Space Flight Center /Blaine et al, 1977/.

During pre-launch experiments for the CZCS on NIMBUS 7 and for follow-on missions it was flown mainly on a U-2 aircraft over a variety of U.S.

coastal waters so as to measure the variability of the upwelling radiance above the various test sites. During 1977 the OCS was installed on a Mystère-20 aircraft and was flown over various European test sites.

3.2 The German Bight

The North Sea in general and the German Bight in particular is a comparatively shallow area, which is strongly influenced by tidal movements and by polluted discharges from the two major rivers namely the Elbe and the Weser. The tidal effect causes areas up to 20 km off the coast to be alternatively dry and again covered by water. This movement of large water masses results in frequent changes of bottom topography and is also considered to be the reason for a highly varying sediment load. Coastal engineering projects and the dense traffic of ocean-going vessels demand a regular survey of the area and therefore suggest an increasing use of remote sensing techniques.

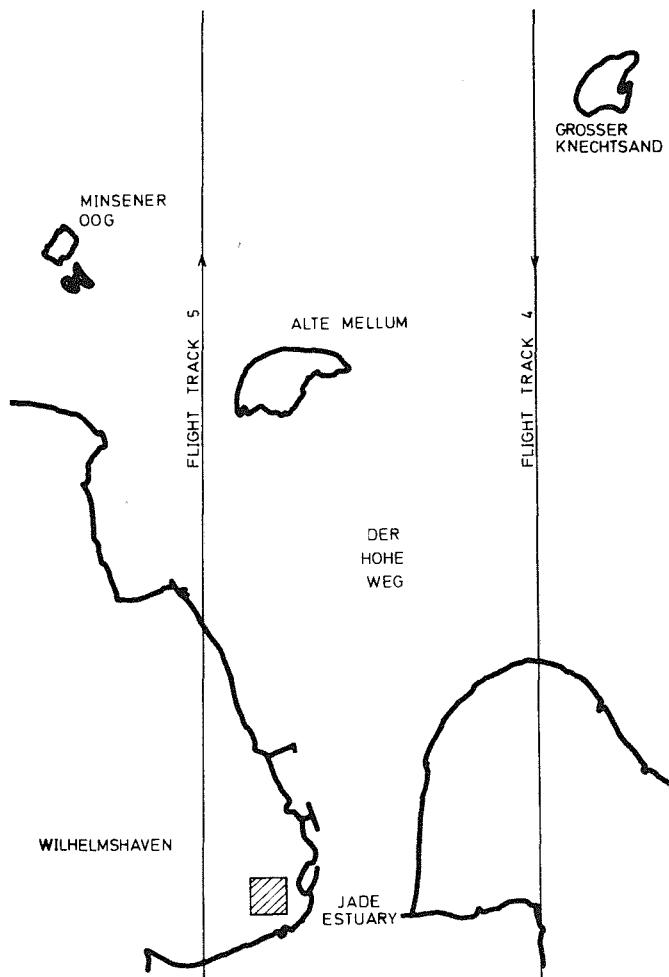


Fig. 1: Flight pattern above the German Bight

3.3 The Flight Pattern

The Mystère-20 of the DFVLR was flying at an altitude of 11 km and followed tracks as indicated in Fig. 1. Due to the size of the optical window in the fuselage, the useful scan angle and thus the effective swath width of the OCS was limited to ± 8 km from nadir. Flights were conducted either in N-S or in S-N direction around noon in order to avoid sun glint. During the time of the overflight the water was either at its highest level or less than 1 hour prior to high tide. With the exception of a few sand patches all the tidal flats were covered by water. The sky was generally clear with only slight haze in certain areas. The sun elevation angle was 34° .

3.4 Recording and Processing of Data

OCS data was recorded on high density digital tape (HDDT), which was converted at the Joint Research Centre of the European Communities in Ispra, Italy. These tapes were reformatting subsequently and reduced to 8 bit so as to match the digital image processing systems of the DFVLR (DIBIAS) and the University of Hannover (IPI/SFB 149).

Processing of the data can be grouped into:

- a) Radiometric correction,
- b) Geometric correction,
- c) Contrast enhancement,
- d) Interpretation.

a) Radiometric correction

The signal received by an optical sensor at an altitude of 11 km is very much affected by the absorption of the atmospheric layer inbetween. This can be corrected for by applying numerical models of the atmosphere so as to calculate its spectral transmission. In this way a computer code LOWTRAN 3 / Selby and Mc Clatchey, 1975 / has been used, which was modified to correct the signals received by scanning sensors like the OCS or any other /SFB 149, 1977 - 78 /.

Figure 2 shows the calculated spectral transmission at nadir for the spectral range of the OCS. The aerosol content of the air path used was parameterized by a visual range specification (23 km). The model used in this case was one for a midlatitude summer atmosphere. The spectral transmission was calculated for all scan angles and applied to image data of all 10 OCS channels.

b) Geometric correction

The first step in the digital geometric processing was to compensate for the varying roll angle of the aircraft. Then the data was corrected for the panoramic distortion and the overscan in flight direction. These results were digitally rectified using a least square polynomial approach with ground control points / Konecny, 1976/. Because of the bad distribution of the fit-points within the image and the lack of points over large water areas, the accuracy of that process was not better than ± 7 pixels (± 407 m in nature). This limited geometric quality is one of the main reasons why a correlation of images with a bathymetric map was not successful. Simultaneous ground truth measurements to support a numerical correlation with water depth were unfortunately not available. Therefore, the results as discussed in section 3.5 should be regarded only as a qualitative interpretation of the scene.

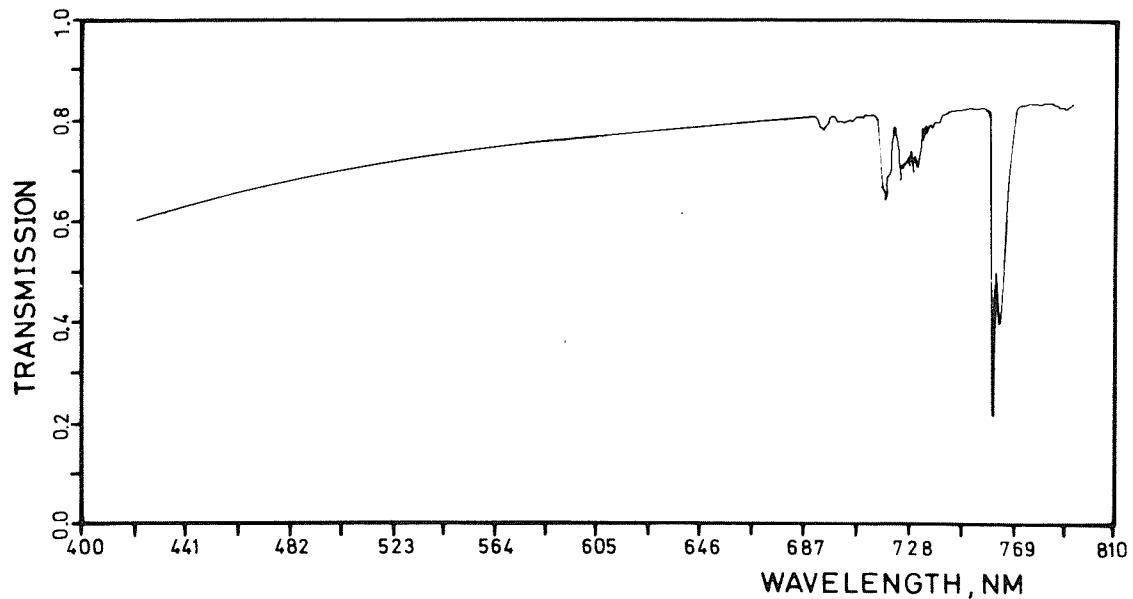


Fig. 2: Atmospheric transmission (mid-latitude summer) calculated for the OCS spectral range, using a modified version of LOWTRAN 3 (altitude: 11 km, visibility: 23 km, temperature: 15° , zenith angle: 180°)

c) Contrast enhancement

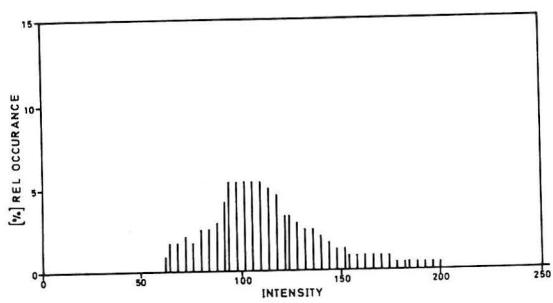
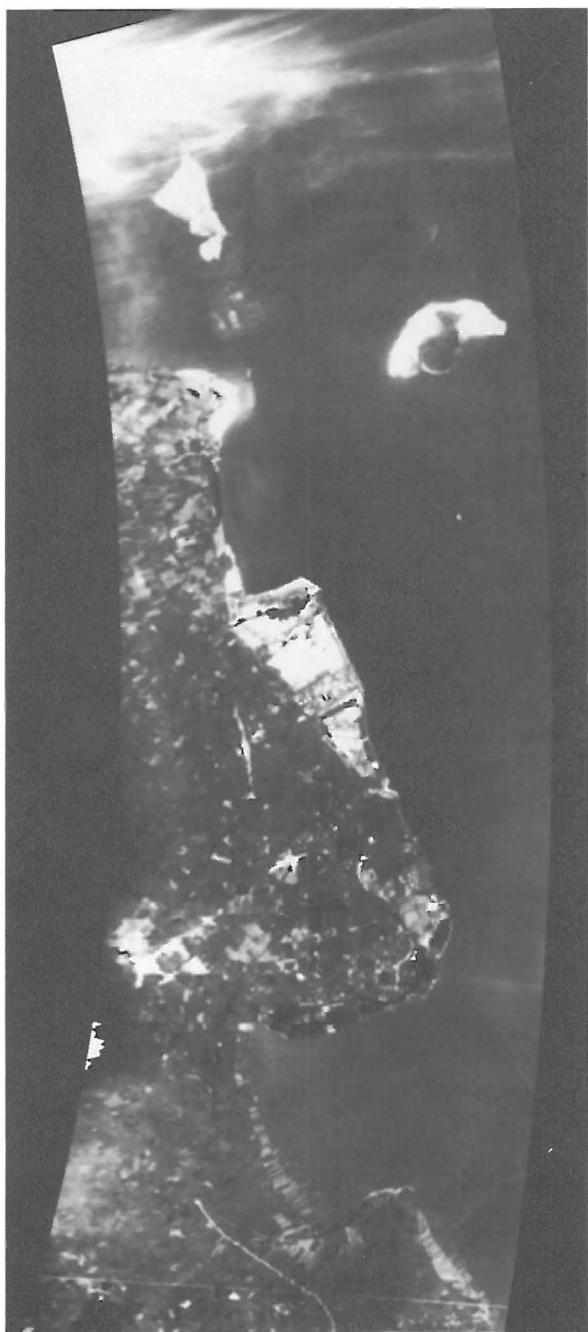
Due to the low albedo, the contrast of the original scene is rather poor over water.

After for each OCS channel the distribution of grey values in the area of interest was established by means of a histogram, the scene contrast was enhanced by linear histogram stretching. The result is shown for OCS channels 5 and 7 in Fig. 3. Below each image the corresponding histograms indicate the stretched grey value distribution for the entire scene (grey values at 0 and 255 were omitted).

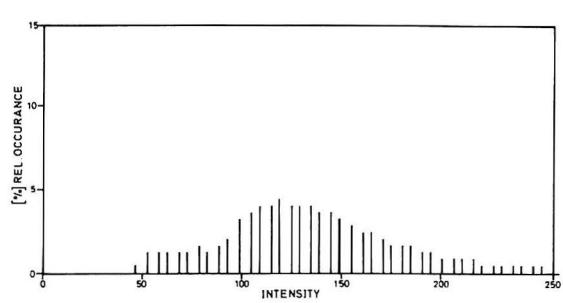
d) Interpretation

At the time of the overflight the "Hohe Weg" a tidal (wadden) area at the right hand side of the image was covered by a water column varying from 3 - 3.2 m in the south to 2.4 m in the north. The water in this area is strongly affected by the tidal movement and therefore cannot be regarded as a levelling plane. In this region the large tidal channels can be seen very well through the covering water body. The same holds for the area of the "Crildumer Watt" in the west and for the "Jadebusen" in the south. Especially OCS channel 7 ($0.655 - 0.679 \mu\text{m}$) shows these structures very well. Bottom features (up to 7.5 m in depth) can be detected even in the deeper areas around the oil peers in accordance with features shown by hydrographic maps.

Fig. 4 represents part of a LANDSAT scene taken on 8/12/76 at low tide so that all the tidal areas are free of water. The scene was rectified ($\pm 45 \text{ m}$) and contrast enhanced / Bähr, 1979 /. A graphic overlay derived from the "Topographische Wattkarte" 9, 10, 11' of 1973 was merged into the picture. This shows a clear relation between boundaries of wadden lands, bottom features and depth information from the maps.



Channel 5



Channel 7

Fig. 3: Contrast enhanced OCS imagery of flight track 5 with histograms
(27/9/77)

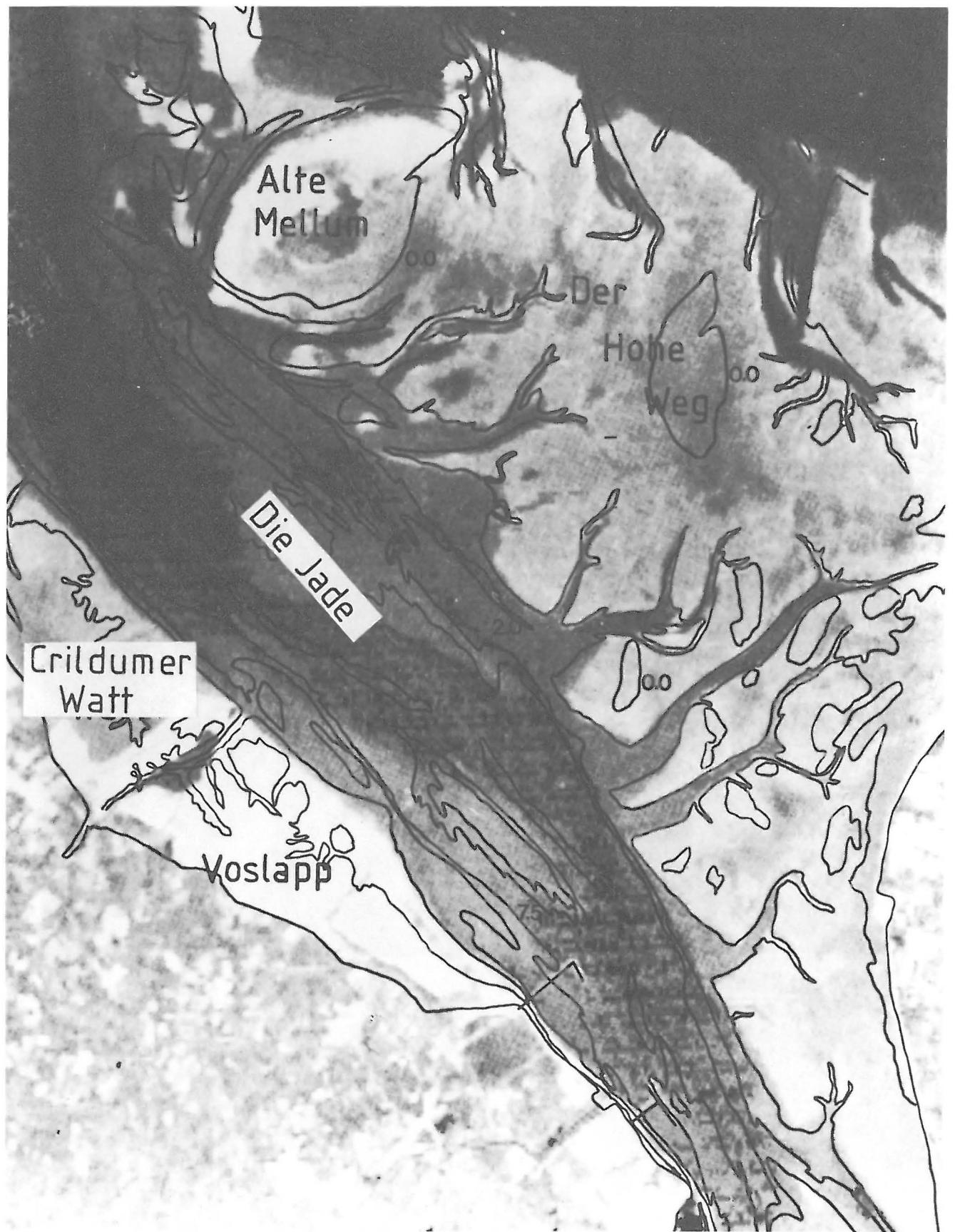


Fig. 4: LANDSAT scene from 8/12/76 at low tide
with isolines from topographic map.

The LANDSAT scene fits very well to the southern part of the "Hohe Weg" and reasonably well to the north. This is in good agreement with observations of the coastal engineering community. The same can be observed by OCS imagery (Fig. 3) in spite of the area being covered by water.

3.5 Discussion

a) In very clear water the spectral transmission is essentially determined by the minimum of the absorption curve in the blue spectral region. With an increasing amount of suspended particles, however, the amount of transmitted light not only decreases, but the transmission maximum is shifted towards longer wave-lengths. If the reflectance from bottom features is to be observed directly, the corresponding wave-length of maximum transmission should be suited best for a maximum penetration of the water column.

Analysis of passive multispectral imagery under conditions typical for the south-eastern part of the Gulf of Mexico indicates that OCS channel 4 ($0.535 - 0.561 \mu\text{m}$) seems to be suited best for the mapping of bottom features. This is followed by OCS channel 5 ($0.574 - 0.598 \mu\text{m}$) and then by MSS channel 4 ($0.500 - 0.600 \mu\text{m}$) operated in the high gain mode / Middleton and Barker, 1976 /.

b) Contrary to this, OCS channel 7 ($0.655 - 0.679 \mu\text{m}$) is suited best in an area like the North Sea. However, it should be kept in mind that in this area the water composition is quite different, especially due to the high sediment load. In addition, the signal received at high altitude does not only consist of the attenuated water signal itself but also of stray light scattered from the atmosphere into the sensor. The intensity of stray light varies considerably with the concentration of aerosols and especially in the blue region of the spectrum may exceed the water signal by a factor of 3 to 5. The contribution of atmospheric stray light decreases towards longer wave-lengths. Therefore, the subtle changes of the water signal caused by depth variations may be detected more easily at longer wave-lengths.

c) Further experimental and theoretical work, especially an accurate comparison of multispectral imagery with actual ground truth, is required in order to establish the general validity of the observations reported here.

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