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OCEANOGRAPHIC OBSERVATION OF NEW YORK BIGHT FROM ERTS-1

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Abstract - The Earth Resources Technology Satellite (ERTS-1), made a transit over New York Bight on 16 August, 1972. Imagery from this transit shows several oceanographic features that demonstrate the usefulness of remote sensing for large area, synoptic observation of changes in water quality in the coastal zone. Both the extent and turbulent character of the Hudson river plume are discernable in the image. Residue from a dump of waste acid is visible over a five mile area in the apex of the Bight. Little dispersion of this residue has occured which suggests that this feature will be a persistant signature in images from future satellite transits.

On 16 August 1972, the multispectral scanner (MSS) aboard the first Earth Resources Technology Satellite (ERTS) obtained a set of images of the New York Bight which contain information of oceanographic significance. The images demonstrate the effectiveness of satellite use in observing surface features that indicate changes of water quality. The impact of this technique on coastal zone oceanographic analysis will be widespread.

The MSS aboard ERTS has four channels with band pass filters covering the visible and near infrared bands. Channel 4 covers the 0.5-0.6 μm (green-yellow) band; channel 5 covers the 0.6-0.7 μm (orange-red) band; channel 6 covers the 0.7-0.8 μm (red) band, and channel 7 covers the 0.8-1.1 μm (infrared) band. To determine which bands contain the most information relating to ocean phenomena requires an understanding of the manner in which the solar energy is reflected across the spectrum.

Specular reflectance of solar energy from the sea surface, as measured by a spacecraft, is a function of atmospheric state, water depth, water mass characteristics, sea bottom characteristics, and of sea state. To ensure that information about the ocean was being observed, a calculation was performed to determine the percent of energy which penetrated the sea surface, was reflected from a perfect reflector, and was subsequently seen at the surface. These calculations were made by solving the intensity equation:

$$I = \int_0^\infty \varphi_\lambda I_{o_\lambda} e^{-\alpha_\lambda z} \, d\lambda$$

Where I is the intensity observed at a depth Z through a band pass filter φ_λ, which is normalized over the region of wavelength λ for the appropriate ERTS channel; $I_{o\lambda}$ is intensity at the sea surface and α_λ is the spectral attentuation coefficient [1].

The calculations show that percentage of energy from a perfect reflector at a depth of one meter is 86% for the 0.5-0.6 μm band, 55% for the 0.6-0.7 μm band, 11% for the 0.7-0.8 μm band and 0.2% for the 0.8-1.1 μm band. These results suggest that an oceanographic feature will not be seen in the 0.8-1.1 μm band (reflected infrared). Hence comparison of suspected water features observed in the visible bands with those in the infrared band insures that features such as clouds are not mistaken for oceanographic data. Features discussed here have had such a comparison made.

These calculations also provide a first estimate of the depth of a feature. For example, a perfect target at five meters will reflect 50% in the green-yellow band, 7% in the orange-red band and essentially none in the red or near infrared bands.

MSS imagery in the accompanying figure shows an area in the New York Bight approximately 100 miles by 100 miles. The upper left body of water is Raritan Bay; the land mass at the top is a portion of Long Island. New Jersey is on the left and the image extends along the coast to just beyond Barnegat Inlet. The picture is the bulk processed imagery of the MSS 5 channel (0.6-0.7 μm) just as it is received from the NASA data processing facility. Imagery was obtained at 1507 GMT when the sun's elevation was 53° and the azimuth was 130°. For this transit, the MSS 5 channel was the most sensitive to oceanic features:

MSS 4 is obscured by haze induced by atmospheric scatter, and the other channels show much less detail in sea surface features, as the calculations would suggest.

The large white features present in the right half of the image are clouds. They are present in all bands. Shadows cast on the sea surface by the clouds are the dark areas adjacent to them on the northwest. The haze over New York City comes from metropolitan-produced smoke and haze.

The most prevalent oceanic feature in the New York Bight frame is the existence of visibly turbid surface water near the coast. The light colored water extends a few miles offshore and is produced by the action of waves and tides at the ocean boundary in maintaining suspended sediment. Further from shore, settling and mixing with shelf water decrease the turbidity. Evaluation of the extent of this water adjacent to the southern coast of Long Island is hindered by the existence of high clouds. The general turbid nature of the nearshore water precludes detection of the sea bottom with MSS. Lateral extent of coastal turbid water increases in the area of high water velocities such as would be encountered in Barnegat inlet (lower left hand portion of the image), where a tidal plume is clearly visible.

A plume of light colored water extends from the mouth of the New York Harbor complex south along the New Jersey coast. The plume which is approximately 18 miles long and 7 miles wide represents the core of lower salinity water from the Hudson River. Characteristically this time of year the Hudson River plume is relatively small due to reduced fresh water outflow and is pushed onto the New Jersey coast by the predominant winds. Surface winds for the preceeding day were less than 10 knots generally from the east.

Clearly, the plume is not homogenous. Patchiness is indicative of the turbulent mixing process by which the plume water is absorbed into the ambient Bight water. The relatively sharp eastern boundary of the plume indicates dispersion processes are not isotropic.

Fortuitously, surface salinity data were collected in the general area of the plume [2]. A transect about 10 August and another on 22 August were made perpendicular to Sandy Hook. Although the data are too few to define the shape and size of the plume they indicate that the low salinity Hudson plume was in this general area depicted in the MSS 5 image and that the plume was about 2% lower in salinity than the ambient Bight water.

There is an unusual and interesting feature in the apex of the Bight about 20 miles southeast of the Harbor entrance that apparently is a manifestion of man's activity in the area. The feature consists of a fairly sharp wavy line and a more diffuse circular patch north of the line. These features are located in the general area for waste disposal [3].

The two major dump sites are for sewer sludge and for waste acid [4]. Between 5 and 6 bargeloads of sewer sludge per day are disposed of at a point about 5 miles southeast of Ambrose light station. An average of about 2 bargeloads of waste acid are taken each day to a site some 10 miles to the southeast of Ambrose light station. Disposal of acid is made while the vessel is underway; half the load is dumped over approximately 5 miles in transit to the turning point, the remainder on the way back. Surface color of waste acid is yellow-green, optimally detected in the MSS 4 band; due to atmospheric dispersion, MSS 5 (as processed by NASA) affords higher contrasts in surface features. The acid is slow to mix with the sea water because the waste is of near equal density and hence maintains sharp bounderies for substantial periods of time.

The distinct wavy line is the result of waste acid disposal. The northwest-southwest dimension of the feature is approximately five miles. The less distinct portion of the line may be residue from an earlier dump. A minor discrepancy occurs in that the turning point in the picture is approximately 5 miles nearer the harbor than the authorized dump site.

Normally, dumping occurs on a semidaily basis. Thus the relic dump must be at least 12 hours old and dispersion was very slow. The fact that the recent dump may have drifted some five miles implies that it was made several hours before the satellite transit. Even though wind mixing was low for this day, the implication of the dump durability is that dumping of this magnitude generally will produce a persistant surface feature.

The diffuse circular patch to the north of the waste acid dump is close to the sewer sludge dump site. Surface manifestation of a sewer sludge dump is much less noticeable than waste acid; only a grey-brown slick will remain. Initial low intensity of the target makes the character of the surface patch less discernible.

This single image, taken in an area of complex oceanography and high population density, demonstrates the utility of satellities such as ERTS, equipped for surveying water quality changes, such as location of river discharge plumes and the effectiveness of waste dumping procedures. It seems likely that satellites with sensors optimized to view the ocean in visible and infrared wavelengths, supplying synoptic wide-area data, will make management of the coastal zone on a broad scale much more realistic.

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REFERENCE & NOTES

[1] The attentuation coefficient for pure water was used in this calculation. This provides a conservative estimate since α for even the cleanest sea water is much larger.

[2] Salinity data were kindly supplied by the Ecosystems Investigations, Middle Atlantic Coastal Fisheries Center, Sandy Hook Laboratory.

[3] "Effects of Waste Disposal in the New York Bight." Prepared by National Marine Fisheries Service, Middle Atlantic Coastal Fisheries Center, Sandy Hook Laboratory, Highlands, New Jersey, Final Report, February, 1972.

[4] We acknowledge the description of waste dumping procedures provided by John B. Pearce of the National Marine Fisheries Laboratories, Sandy Hook, New Jersey.

[5] This research was in part supported by the National Aeronautics and Space Administration's Earth Resources Program. The imagry was supplied by the NASA Data Processing Facility at Goddard Space Flight Center for ERTS proposal C315.

Figure Caption

Figure 1: Bulk Processed Imagery in the 0.6-0.7 μm Band of ERTS-1 from New York Bight transit of 16 August, 1972.


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