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An Oceanographic Observation of New York Bight From ERTS-1

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AN OCEANOGRAPHIC OBSERVATION OF NEW YORK BIGHT FROM ERTS-1

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The Earth Resources Technology Satellite (ERTS-1), made a transit over New York Bight on August 16, 1972. Imagery from this transit shows several oceanographic features that demonstrate the usefulness of remote sensing over a large area for the synoptic observation of changes in water quality in the coastal zone. Both the extent and turbulent character of the Hudson River plume are discernible in the image. Residue from a dump of waste acid is visible over a 5-mile area in the apex of the bight. Little dispersion of this residue has occurred, suggesting that this feature will be a persistent signature in images from future satellite transits.

On August 16, 1972, the multispectral scanner (MSS) aboard the first Earth Resources Technology Satellite (ERTS-1) obtained a set of images of the New York Bight which contains information of oceanographic significance. The images demonstrate the effectiveness of using satellites to observe surface features that indicate changes in 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- to 0.6-μm (green-yellow) band; channel 5 covers the 0.6- to 0.7-μm (orange-red) band; channel 6 covers the 0.7- to 0.8-μm (red) band; and channel 7 covers the 0.8- to 1.1-μm (infrared) band. An understanding of the manner by which solar energy is reflected across the spectrum is needed to determine which bands contain the most information relating to ocean phenomena.

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 sea state. To insure that information about the ocean was being observed, calculations were performed to determine the percent of energy that penetrated the sea surface, that was reflected from a perfect reflector, and that was subsequently seen at the surface. These calculations were made by solving the intensity equation

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

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 the intensity at the sea surface; and α_λ is the spectral attenuation coefficient.[1]

Calculations show that a perfect reflector at a depth of 1 m (3 ft) returns 86 percent of the incident energy for the 0.5- to 0.6-μm band, 55 percent for the 0.6- to 0.7-μm band, 11 percent for the 0.7- to 0.8-μm band, and 0.2 percent for the 0.8- to 1.1-μm band. These results suggest that an oceanographic feature will not be seen in the 0.8- to 1.1-μm band (reflected infrared). Hence, comparison of suspected water features observed in the visible bands with those observed in the infrared band insures that above-surface features such as clouds are not mistaken for surface and subsurface oceanographic features. (A comparison of these calculations for all four bands is shown in fig. 1.)

Calculations on energy penetration also provide a first estimate of the depth of a feature. For example, a perfect target at 5 m (16 ft) will reflect 50 percent in the green-yellow band, will reflect 7 percent in the orange-red band, and will essentially reflect no percent in the red or near infrared bands.

MSS imagery, presented in figure 2, shows an area of approximately 100 x 100 mi in the New York Bight. The body of water in the upper

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

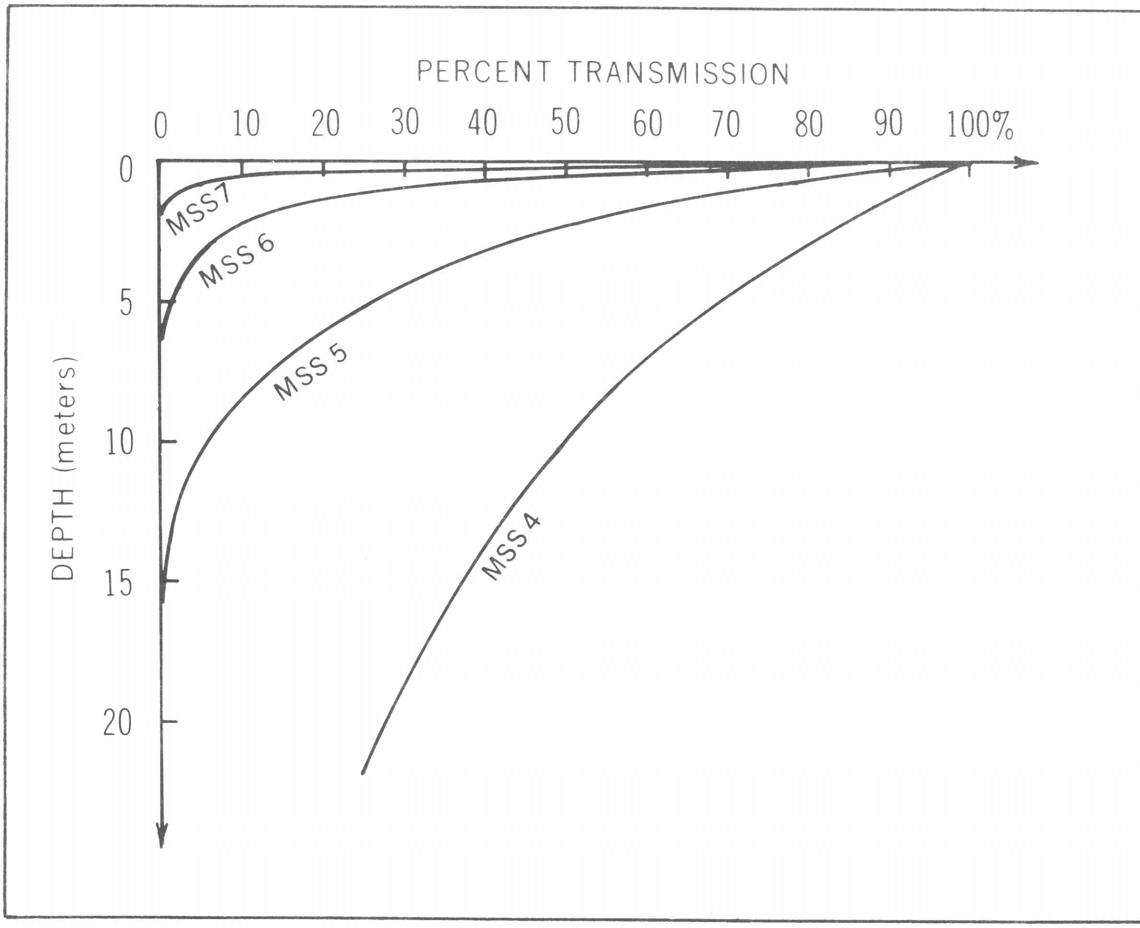

Figure 1. Theoretical calculation of the percent of solar energy penetrating the sea surface that reaches a given depth for each of the four channels of the ERTS MSS.

center left of the image is Raritan Bay; the land mass at the top is a portion of Long Island. The image extends along the coast of New Jersey (land mass on the left) to just beyond Barnegat Inlet. The picture in the figure is the bulk-processed imagery of the MSS 5 channel (0.6- to 0.7-μm) just as it is received from the National Aeronautics and Space Administration (NASA) data-processing facility. Imagery was obtained at 1507 GMT when the elevation of the sun was 53° and the azimuth was 130°. For this transit, the MSS 5 channel was the most sensitive to oceanic features; MSS 4 band was obscured by haze induced by atmospheric

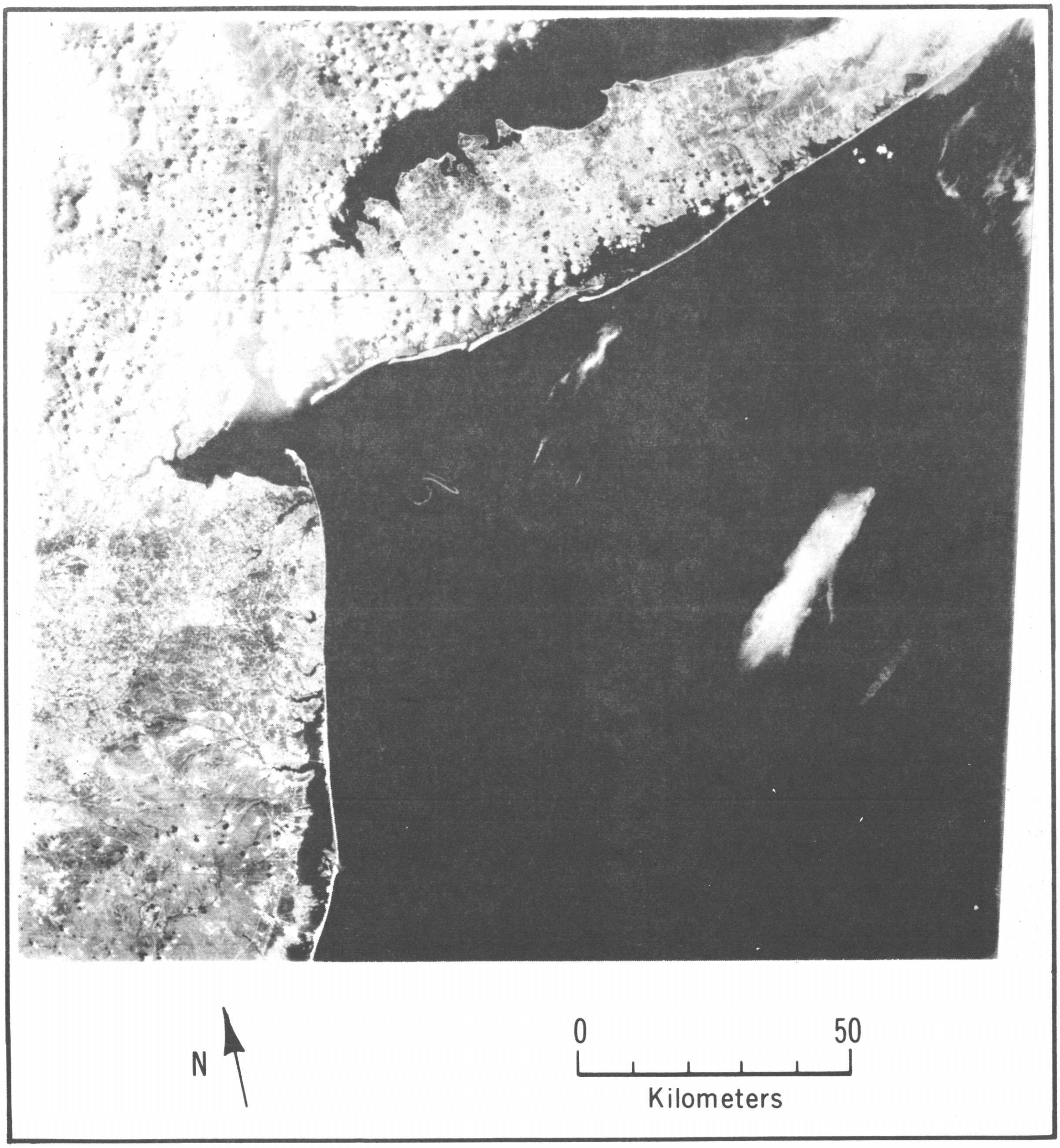

Figure 2. Bulk-processed imagery in the 0.6- to 0.7-μm band of ERTS-1 from the New York Bight transit of August 16, 1972.

scatter; and the other channels showed much less detail in sea-surface features, as the calculations would suggest.

The large white features present in the right side of the image (fig. 2) are clouds. They are present in all bands. The dark areas (to the northwest) adjacent to these white features are shadows cast on the sea surface by the clouds. The haze present over New York City comes from smoke and dust produced in the metropolitan area.

The most prevalent oceanic feature in this New York Bight frame (fig. 2) 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 land-ocean boundary in maintaining suspended sediment. Farther from shore, the settling of sediment and mixing with shelf water decrease the turbidity. An evaluation as to the extend of this turbid surface 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 29 km (18 mi) long and 11 km (7 mi) wide, represents the core of lower salinity water from the Hudson River. Characteristically at this time of year (August), the Hudson River plume is relatively small because of reduced fresh water outflow and is pushed onto the New Jersey coast by the predominant winds. Surface winds for the preceding day were less than 10 kt and were 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 that dispersion processes are not isotropic.

Fortuitously, surface salinity data were collected in the general area of the plume.[2] A transect on approximately August 10 and another on August 22 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 as depicted in the MSS 5 image and that the plume was about two part per thousand lower in salinity than the ambient bight water.

There is an unusual and interesting feature in the apex of the bight about 32 km (20 mi) southeast of the harbor entrance that apparently is a manifestation 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 (NOAA, 1972).

The two major dump sites in the bight are for sewer sludge and for waste acid. Between five and six bargeloads of sewer sludge are dumped daily at a point about 8 km (5 mi) southeast of Ambrose Light Station. An average of about two bargeloads of waste acid are taken each day for disposal to a site some 16 km (10 mi) southeast of Ambrose Light Station. Disposal of waste acid is made while the vessel is in transit: one-half the load is dumped over a distance of approximately 8 km enroute to the turning point; the remainder is dumped on the way back. Surface color of waste acid is yellow-green, optimally detected in the MSS 4 band; because of atmospheric dispersion, the MSS 5 band (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 boundaries for substantial periods of time.

The distinct wavy line is the result of waste acid disposal. The northwest-southeast dimension of the feature is approximately 8 km. 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

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[2] Salinity data were kindly supplied by the Ecosystems Investigations, NOAA National Marine Fisheries Service, Middle Atlantic Coastal Fisheries Center, Sandy Hook Laboratory, Highlands, N.J.

image frame is approximately 8 km nearer the harbor than the authorized dump site.

Normally, dumping occurs on a semidaily basis. Thus, the relic dump must be at least 12 hr old, and the dispersion was very slow. The fact that the recent dump may have drifted some 8 km implies that it was made several hours before the satellite transit. Even though wind mixing was low for this day, the implication for dump durability is that dumping of this magnitude generally will produce a persistent 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 that of waste acid; only a gray-brown slick will remain. Initial low intensity of the reflected image makes the character of the surface patch less discernible.

This single image (fig. 2), taken in an area of complex oceanography and high population density, demonstrates the utility of satellites (such as ERTS) that are equipped to survey the water-quality changes (such as location of river discharge plumes) and to measure the effectiveness of waste-dumping procedures. It seems likely that satellites with sensors, optimized to view the ocean in visible and infrared wavelengths, will supply synoptic wide-area data and will make management of the coastal zone on a broad scale much more realistic.

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