

Estimate of Total Reflectance From the Orinoco River Outflow

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ABSTRACT

The Apollo astronauts photographed the Orinoco River Delta in eastern Venezuela. The photographs show discrete water-color zones that reflect the mixing of the sediment-laden Orinoco outflow with the water of the tropical Atlantic. One transparency was analyzed with a Datacolor/Edge Enhancer System to estimate the range of light reflectance in the scene. Based on this analysis, and assuming a 5-percent reflectance value for the open ocean water, the reflectance of the area studied was found to vary between 4 percent for the jungle and approximately 13 percent for sediment-laden river outflow. These values approximate those obtained by direct measurements of the Mississippi River Delta water. The results confirm that the reflectance from coastal waters will not be so high as to saturate instruments on-board unmanned satellites such as the Coastal Zone Scanner.

INTRODUCTION

The Orinoco River in northern South America, with a drainage area of approximately 841 750 km², delivers much organic sediment to its mouth at latitude 9° N, longitude 61° W. These sediments

and associated dissolved organic compounds have been known to "discolor" the Atlantic Ocean water as far as 80 km from the Venezuela coastline. To aid in the study of this phenomenon, the Orinoco River Delta was selected as an observation target for the Apollo-Soyuz Test Project (ASTP) (ref. 1).

The ASTP photographs, which were taken with a highly color-sensitive film, provide new data on river discharge. The extent of the discolored Atlantic Ocean water due to the Orinoco outflow is the subject of another paper in this volume. This report, however, deals with the reflectance characteristics of the outflow in the immediate vicinity of the Orinoco River Delta.

One ASTP photograph of this delta (fig. 1) reveals numerous variations in water color. The brownish-tan river water directly impinges on the bluish water of the tropical Atlantic. The discoloration is also segmented into discrete color zones with the brownish-tan color decreasing outward from the delta. Although color variations in this case are extreme, the phenomenon is characteristic of most coastal areas near major river deltas.

Even though the range of reflectance of open ocean waters is well known (ref. 2), little information is available on sediment-laden water such as the Orinoco River outflow. Therefore, in this report, an attempt is made to estimate the reflectance characteristics as an aid in the evaluation of data obtained by unmanned satellites.

Existing Earth-viewing satellite systems that sense variations in visible-light surface reflectance must accept some compromise in sensitivity over areas of the Earth where the dynamic range in

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FIGURE 1.—ASTP photograph (AST-21-1683) of the Orinoco River Delta of northern South America.

reflectance is large. This is not a problem over open ocean areas, where the dynamic range is small. However, in the case of the latest Nimbus satellite (the G-series Coastal Zone Scanner), the channels must be capable of sensing water color derived from a wide range of concentrations of absorbing and reflecting substances. Highly reflec-

tive features, such as sand dunes, bottom topography, and certain sediment loads, could saturate the detectors with light and thereby create a "white out" in the imagery. The ASTP photograph of the Orinoco River outflow was used to estimate the reflectance of very bright, sediment-laden water.

METHOD

The ASTP photograph (fig. 1) was analyzed using a Datacolor/Edge Enhancer System by Spatial Data Systems. This enhancer, at the Smithsonian Institution's Center for Earth and Planetary Studies, is capable of producing color enhancements of film transparencies. The film is illuminated and scanned by a vidicon phototube. The density gradient seen by the scanner can be divided into as many as 12 equal bands, and each band is shown on a color television monitor as one of 12 colors. Borders between color bands may be considered as contour intervals, because all points lying along one contour represent the same film density. This "color slicing" allows the observer to view (in marked contrast) the density differences recorded on film.

The ASTP photograph was only "sliced" into six film densities (table I). The range in densities varied between the low reflectance of jungle and open ocean areas and the high reflectance of sediment loads and clouds. To delineate the film density steps, the color presentation was photographed on black-and-white film using a Polaroid

camera (fig. 2). Each film density was emphasized by successively blackening out the areas of least reflectance. This procedure demonstrated that the lowest reflectance was associated with jungle areas (fig. 2(a)). The next lowest reflectance (fig. 2(b)) included almost all of the jungle and some of the open ocean. The next level of reflectance (fig. 2(c)) contained all of the jungle and all of the ocean water. Most of the reflected light was coming from the brown area seen in the ASTP color photograph (figs. 1 and 2(d)). However, one part of this area (fig. 2(e)) was more highly reflective.

TABLE I.—Color Density Analysis

Color slice	Area	Figure no.	D_i	B_i percent
Violet	Jungle	2(a)	0.35	4.3
Magenta	Open ocean	2(b)	.30	5.0
Dark red	Delta water	2(c)	.25	6.0
Light red	Delta water	2(d)	.21	7.1
Green	Delta water	2(e)	.12	12.5
White	Clouds	2(f)	0	

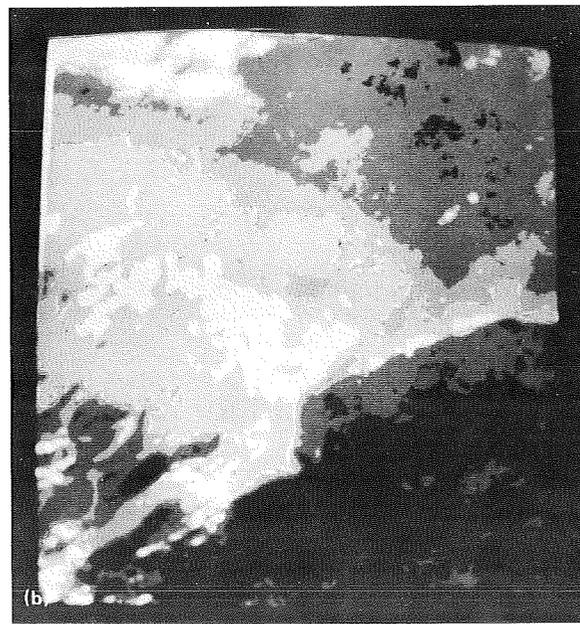
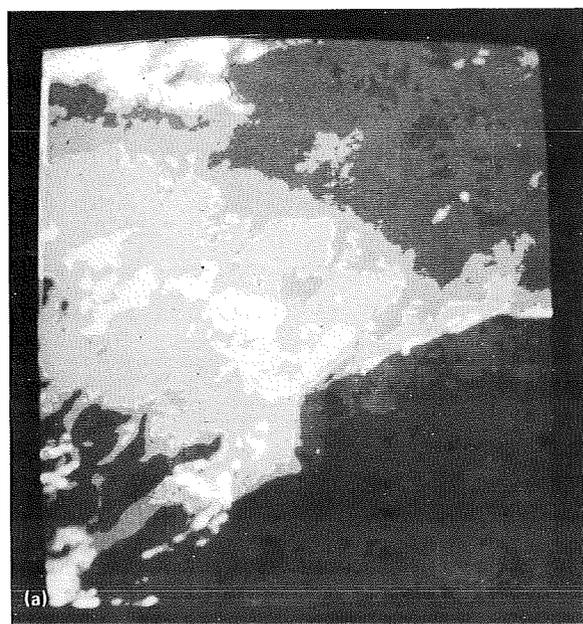


FIGURE 2.—Black-and-white Polaroid prints of color slicing of ASTP photograph showing successive blackening out of areas of least reflectance. (a) Violet. (b) Magenta. (c) Dark red. (d) Light red. (e) Green. (f) White.

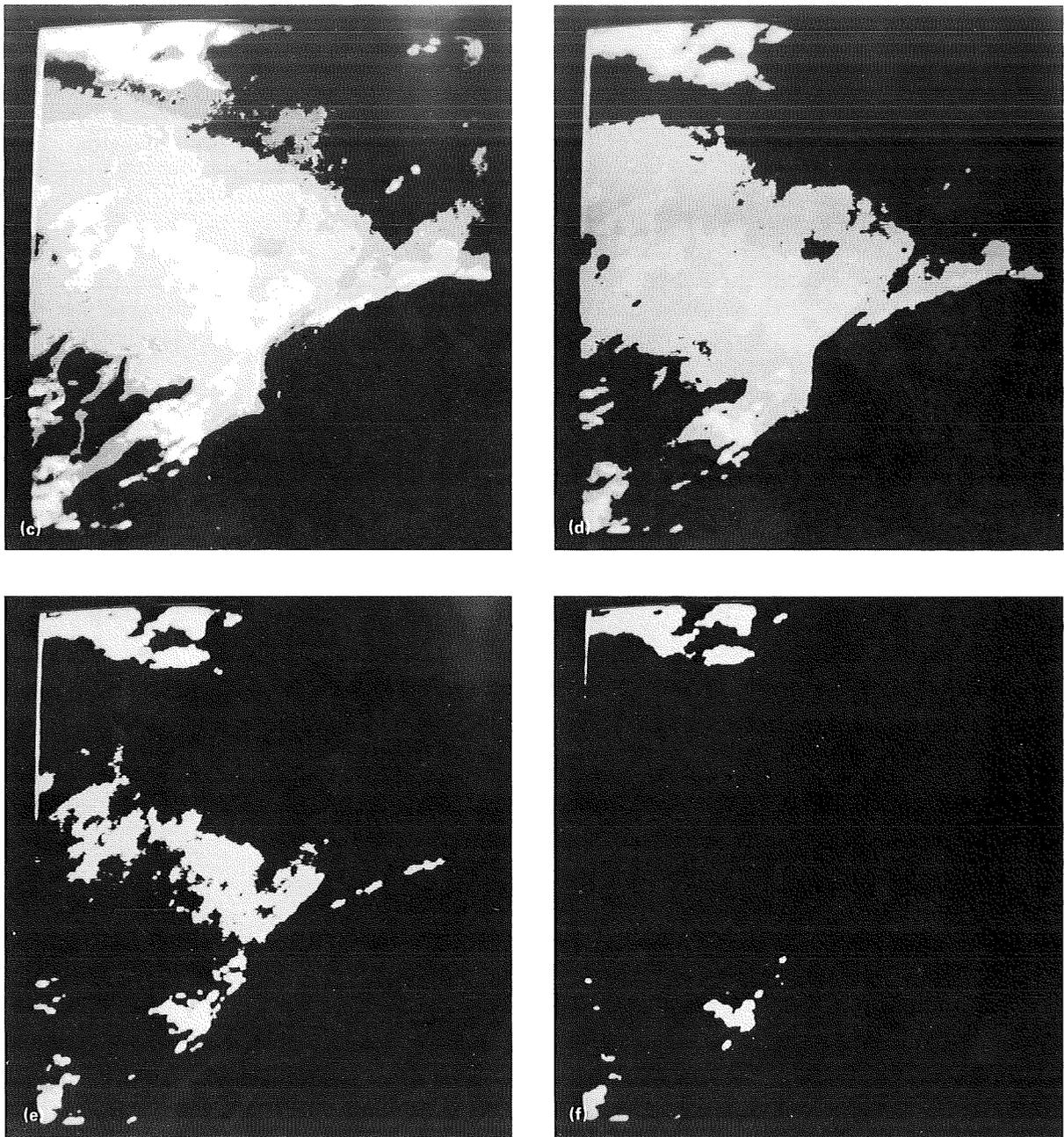


FIGURE 2.—Concluded.

The final step demonstrated that the clouds in the photograph were the most reflective objects in the scene.

The color slicing showed that incoming waters from the many streams feeding the delta were not

carrying as much sediment as is found in the central region of the delta. This result leads one to suspect that wave and tidal action may be strong enough to place much of the sediment in suspension.

To estimate the amount of reflectance, it is understood that an increase in film density D for a positive transparency corresponds to a decrease in backscattering B . The backscattering is assumed to be inversely proportional to the film density and is normalized to the value commonly ascribed to the open ocean: $B_o = 5.0$ percent. The corresponding film density over the open ocean was measured to be $D_o = 0.30$. Then, B_i was determined for other areas by measuring D_i :

$$\begin{aligned} B_i &= \frac{D_o B_o}{D_i} \\ &= \frac{(0.30)(5.0)}{D_i} \\ &= \frac{1.5}{D_i} \end{aligned}$$

The range in B_i (table I) is from approximately 4 percent for the jungle to approximately 13 percent for the heavy sediment areas.

CONCLUSION

Because of the color sensitivity of the ASTP photograph of the Orinoco River outflow, it was possible to estimate the reflectance values of the bright, sediment-laden water. Although this method does not produce absolute reflectance values, the values obtained do approximate those which have been observed in other highly turbid

waters. For example, in the coastal canals around Florida, the first author has observed (by direct measurement) that B_i is 10 to 15 percent. Similar values have been calculated for the Mississippi Delta waters (ref. 3).

Based on these findings, and if the values given in table I are representative of the reflectance range of coastal waters, then sedimentary loads will probably not saturate the Coastal Zone Scanner.

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