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# LANDSAT Measures of Water Clarity

## LANDSAT reflectance data compared favorably with *in situ* transmittance as a measure of water clarity.

Abstract: *Comparison of* in situ *transmittance and LANDSAT reflectance data reveal a negative straight-line relationship for the values encountered. Such a treatment and result differ from previous work in that* in situ *transmittance is an objective field measure of water clarity. This is significant since it supports and extends existant evidence that the changing character of water clarity can be effectively monitored using LANDSAT type data.*

### Introduction

During the last few years, several workers (Klemas *et al.*, 1973a and b, Scherz *et al.*, 1973, Williamson *et al.*, 1973, Yarger *et al.*, 1973, among others) have reported a relevant connection between the spectral brightness data recorded by the four-channel optical-mechanical scanner on board the LANDSAT and such water clarity phenomenon as secchi disc extinction depths, Jackson Turbidity Units, and the mass/volume of near surface seston. To date, the results reported by these and other workers have demonstrated that high densities of suspended solids correspond to high water reflectances and vice-versa (Kritikos *et al.*, 1974).

*In situ* transmittance is another common parameter of water clarity. Moreover, for many applications it possesses definite advantages over other methods since it is easy to collect and, if taken properly, it is an objective and reproducible optical field measure of the clarity of natural waters (McCluney, 1974). In this study, near surface transmittance values are compared with the fluctuations of the spectral data recorded by LANDSAT-1.

### Study Area

This work was conducted in Gunston Cove, Virginia, which empties into the Potomac River below Washington, D. C. (Figure 1). The cove is from 0.5 km to 4 km wide, has a mid-channel depth of between 1 m and 11 m mean low water, and less than a 1 m tidal range. This body of water was considered a suitable site to test the feasibility of extracting water transmittance values from LANDSAT reflectivity measurements because (a) it has an obvious horizontal seston/reflectivity gradient; (b) two streams emptying into the cove, and the river, provide a continuous contribution of suspended solids; and, finally, (c) currents effectively keep materials in suspension.

### Data Collection

On October 6, 1973 during flood tide, and on November 11, 1973 during ebb tide, *in situ* transmittance measurements were taken at 16 stations along the axis of the cove to the river. Measurements were made at a depth of 0.5m, with a 10 cm pathlength transmissometer, modified with a green filter. Readings at a single depth were adequate because *in situ* transmittance was constant well below the extinction depth of a secchi disc and, according to Klooster and Sherz (1974), only about 1 per cent of upwelling spectral energy comes from below the depth of secchi extinction. Repeated readings at each station increased confidence in these results.

The satellite passed over the area within

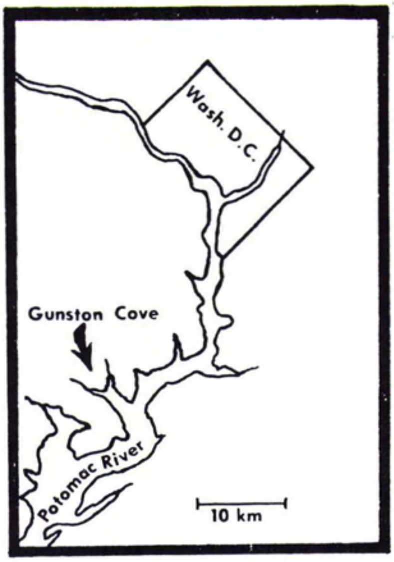


FIG. 1. Location of Study Area.

two hours of the time that the transmittance values were collected. As it passed over, spectral data were recorded in four discrete spectral intervals. Three of these intervals were in the visible part of the spectrum (0.5 to 0.6 $\mu$m, 0.6 to 0.7 $\mu$m and 0.7 to 0.8 $\mu$m), and the other was in the near-infrared spectral region (0.8 to 1.1 $\mu$m). Each value within the cove integrated a region 79 m by 79 m. In order to increase radiometric resolution, reflectance values, around each surface station, for each spectral interval, were extracted from digital brightness data and not photographs.

## RESULTS

Briefly, transmittance increases and reflectance decreases toward the river on 6 October while, on 11 November, the opposite pattern is observed (Figure 2). Other observations show that this reversal is associated with tidal stage, and that the approach of high tide dams the more turbid river water above the mouth of the cove, thus pushing less turbid water from down river into the cove. During the outgoing tidal cycle encountered in November, the more turbid waters from upriver extend below the mouth of the cove and the intensity of the ebb flow now carries these waters into the cove.

Standard regression analysis of transmittance versus reflectance yields correlation coefficients between −0.60 for the 0.6 to 0.7 $\mu$m spectral region and −0.80 for the 0.7 to 0.8 $\mu$m spectral region in October, and between −0.80 for the 0.5 to 0.6 $\mu$m and 0.8 to 1.1 $\mu$m spectral region and −0.90 for the 0.6 to 0.7$\mu$m spectral region in November. A cumulative treatment of both months had correlation coefficients between −0.60 for the 0.7 to 0.8 $\mu$m spectral region and −0.80 for the 0.8 to 1.1 $\mu$m spectral region. In a similar set of calculations, ratios of various spectral intervals were compared to transmittance because this manipulation tends to minimize errors due to unequal illumination caused by the change in sun angle from month to month (Vincent, 1972, and Yarger *et al.*, 1973). The lowest correlation coefficient was −0.50 for the 0.7 to 0.8 $\mu$m/0.5 to 0.6 $\mu$m ratio, and the highest correlation coefficient was −0.77 for the 0.8 to 1.1 $\mu$m/0.5 to 0.6 $\mu$m ratio. Thus, a direct relationship between *in situ* transmittance and reflectance appears to hold in all spectral ranges even though tests of the correlation structure shows that it is defined amid considerable sample variation.

## DISCUSSION

Needless to say, these data must be interpreted with caution. However, considering that the spectral distribution of upward light peaks at 0.45 $\mu$m in clear water and shifts towards longer wavelengths with increased turbidity, while penetration naturally decreases, the optical uniformity of the vertical transmittance gradient observed at each sta-

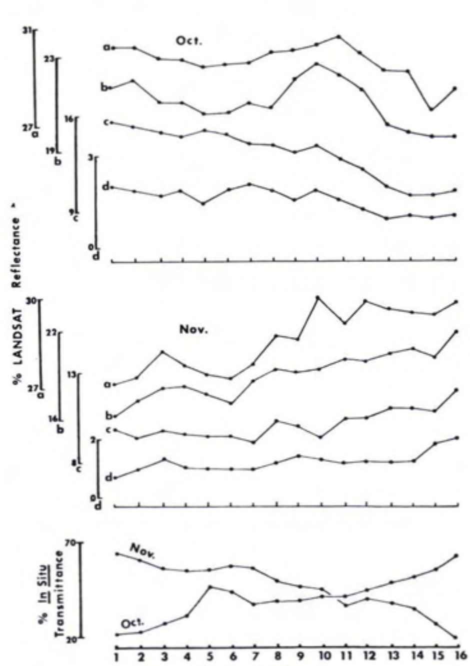


FIG. 2. In Situ Transmittance and LANDSAT Reflectance Data. (a) 0.5 to 0.6$\mu$m, (b) 0.6 to 0.7 $\mu$m, (c) 0.7 to 0.8 $\mu$m, (d) 0.8 to 1.1 $\mu$m.

tion must be responsible for the favorable linear fit found for practically all combinations of LANDSAT generated values. At the same time, even though the monthly results are mutually supporting, the cumulative results might be fortuitous since corrections for atmospheric attenuation were not attempted. Nevertheless, the inverse correlation between reflectance and *in situ* transmittance is logical if it is reasoned that increasing turbidity presents an increasing reflective surface to incident solar radiation, at least in the 0.5 to 1.1 $\mu$m spectral range.

## Conclusion

This is not an attempt to prove but to present the results of a single case study. However, this work provides the first presumptive evidence of a correlation between LANDSAT reflectance values and *in situ* transmittance. And, although work is needed at other locations, in other seasons, and over larger areas, the data collected so far indicate that LANDSAT reflectance values can be used to complement *in situ* transmittance measurements between and adjacent to surface stations, or perhaps used in lieu of the field data when its collection is prohibitively expensive or impossible to achieve.

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