Paper M 11

OCEANOGRAPHIC MAPPING OF STRUCTURE AND DYNAMICS OF THE NORTHERN GULF OF CALIFORNIA BY THE USE OF SPECTRAL MODELING AND ERTS-1

L. K. Lepley, Gustavo Calderon, and J. R. Hendrickson, *University of Arizona, Tucson, Arizona*

ABSTRACT

Distribution and flow of water masses at four depth intervals were determined by analyzing ERTS imagery through the use of optical models of classes of vertical oceanographic profiles. Data used for these models was obtained from shipboard measurements including surface spectral radiance, and optical and more conventional oceanographic depth profiles. The spectral models obtained were applied to radiance-contoured ERTS imagery in band 4, 5, 6, and 7.

Features mapped by direct photointerpretation of ERTS imagery include submerged shoals, current streamlines, and location of possible upwellings, downwellings and submarine springs.

1. INTRODUCTION

One objective of this effort is to attempt to produce a series of oceanographic maps covering the annual range of seasonal effects and semidiurnal tidal effects in the Northern Gulf of California. Surface spectral data coupled with correlative vertical oceanographic profiles taken from ships can be used to obtain a measure of the vertical dimension to classify water masses seen in ERTS-1 imagery.

2. BACKGROUND

The known properties of sea water (Duntley, 1972; Lepley, 1968) and the results of the Scripps Institute of Oceanography's Fresnel II survey in the Gulf (Austin, 1972) were used to aid interpretation of ERTS-1 imagery obtained before the first University of the Arizona/Mexico surface truth cruises had begun (Hendrickson, 1973a).

The imagery of the ERTS-1 overpass corresponding to our January, 1973 surface truth cruise consisted mostly of clouds, but fortunately the previous December 29 ERTS overpass corresponded to an analogous tidal situation. Our studies of the first half-year of ERTS imagery indicate that the tidal excursions (to 7 meters) at the head of the Gulf are the most important factor in the dynamics of movement there.

3. APPROACH AND METHODS OF ANALYSIS

Reflectance measurements were taken in the discrete wavelength bands corresponding to ERTS MSS bands (.5-.6μ, .6-.7μ, .7-.8μ, .8-1.1μ) from the ship "Adventyr". Turbidometer profiles, secchi disk readings, visual observations, and analysis of water samples provided correlative data. Figure 1 shows the stations where radiometer data was acquired.

The spectroradiometric readings were taken from 2meters above the water surface with an Exotech ERTS Radiometer using a 15° field of view for upwelling radiation and a 160° field of view for downwelling radiation.

The ratio of upwelling to downwelling radiation was then plotted (figure 2) and identified with corresponding turbidometer, secchi disk, ocular, and other observations summarized in table I.

Although many more of these data will attach more (or less) validity to the apparent clustering and correlation of these spectra, the results are encouraging. Table I was constructed to show the classes of water that the spectral curves correspond to. Two assumptions were made in the analysis of the ERTS imagery and surface spectroradiometric data:

1. The transparency of clear water decreases monotonically with increase in wavelength of the four MSS bands.

2. The head of the Gulf is usually made of a wedge of clearer water which thins toward the Colorado River estuary and overlies at least one layer of very turbid water.

Surface spectroradiometric readings taken during the oceanographic cruise of January 12 to 22, 1973 (figures 1 and 3 and Table I) show a tendency to cluster according to: (a) depth of clear water over the underlying turbid layers (b) the amount of plankton in clear water and (c) clarity of the surface layer.

A technique was devised to produce maps of incremental reflectance values from ERTS imagery with the aid of an imaging densitometer. Imagery from the four ERTS channels were processed to produce density contours by the use of a Spacial Data model 704/8 video densitometer. ERTS negative transparencies were used for the analysis because more light is available for densitometry of the infrared imagery of water (very bright in negatives). The density increments were normalized so that the brightest contour corresponded to the wet tidal flats at the estuarine shoreline and the darkest contours corresponded to the darkest water in the image. Each contour corresponds to an increment of reflectance in a spectral band. These four contoured images were superimposed in register. The points of intersection of the contours corresponds to sets of incremental reflectances: spectra. We would prefer to obtain a more extensive space and time distribution of surface truth spectra coupled to imagery from syncronous overflights before attaching much significance to our results. Figure 3 is shown only to illustrate the results of this procedure (from E-1159-17451-4,5,6,7, December 29). The spectral classifications are here normalized at the brightest end to the wet tidal flats at the head of the estuary (1111) and at the darkest end in relatively clear water (3333).

4. RESULTS

We have been able, with a limited amount of surface truth data and a large amount of ERTS data, to construct a working model that relates the spectral reflectance of the Northern Gulf of California, as seen from altitudes of 2 meters and 490 nautical miles, to the thickness of the surficial clear layer, and turbidity and plankton content of the surficial layer.

Direct interpretation of ERTS imagery has yeilded some interesting possibilities (reported in Hendrickson, 1973a) including:

1. Indentification of submarine shoals by their disturbing effects on otherwise smoothly laminated layers of turbid water;
2. Establishing the direction of net rotary transport of water;
3. Identifications of bodies of semi-permanent bodies of clear water, some of which may be plumes of submarine springs.

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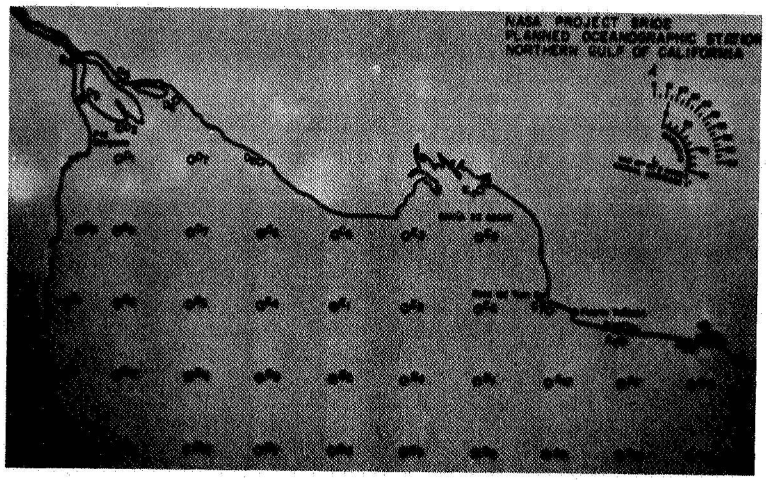

Figure 1. Oceanographic stations obtaining spectro-radiometric and correlative data (solid dots).

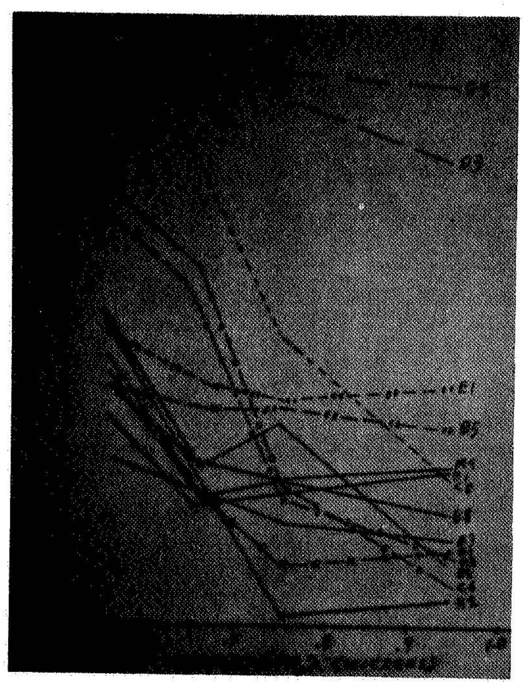

Figure 2. Relative relfectance curves, keyed to figure 1 and table I.

TABLE I

STATION NUMBER	SURFACE OBSERVATIONS
D3, D4	Water completely turbid. Depths less than 4 meters. Secchi disk visible to 15 centimeters.
C8	Thin layer of clear water over turbid water. Water deeper than 7 meters. Secchi disk visible to 1 meter.
C6, B12	Thick layer of clear water over turbid water. Depths around--18 meters. Secchi disk visible to 2 meters.
A1,A2,A9 B3,B8,B12	Very clear waters. No turbid layers. Water deeper than 30 meters. Secchi disk visible to 25 meters.
E1, B5	Clear and deep waters with suspended macro organic particles. No turbid layers. Secchi disk visible to 15 meters.
B9	Clear waters over semi turbid layers below 4 meters. Depths around 30 meters. Secchi disk visible to 5 meters.

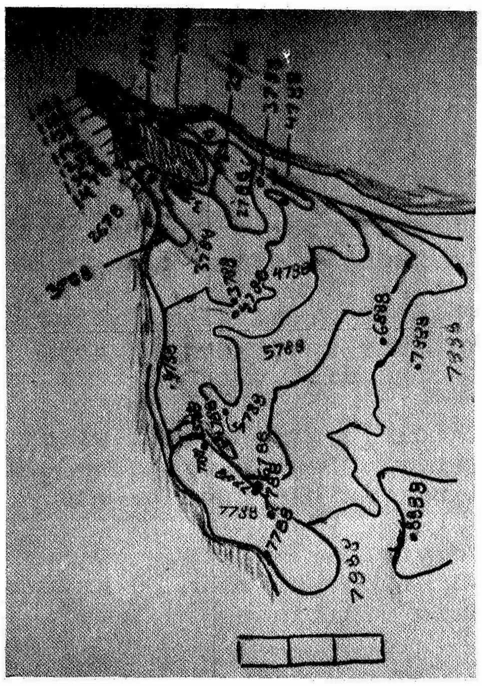

Figure 3. Classification of Gulf of California waters by normalized spectra from ERTS-1159-17451-4,5,6,7.