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EVALUATION OF WATER TRANSPARENCY MEASUREMENTS DERIVED FROM LANDSAT DATA AND GROUND TRUTH: AN EXAMPLE FROM THE TIBER RIVER MOUTH

(E79-10285) EVALUATION OF WATER TRANSPARENCY MEASUREMENTS DERIVED FROM LANDSAT DATA AND GROUND TRUTH: AN EXAMPLE FROM THE TIBER RIVER MOUTH (Telespazio) 18 p HC A02/MF A01 CSCL 08H G3/43

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ABSTRACT

This paper presents the main results of an experimental work carried on jointly by the Water Research Institute (I.R.S.A.) and Telespazio at the Tiber river mouth.

The aim of this work has been to evaluate the correlation between a typical parameter of the sea pollution and the radiance values of Landsat satellite.

The results achieved have confirmed the existence of this correlation.

A further processing has allowed to set up a procedure for studying the dinamics of the coastal corrents.

1. - INTRODUCTION

The study of the sea pollution, by using Landsat satellite data, presents still considerable limitations mainly due to the problems encountered in correlating the radiance values with the parameters which are typical of such phenomena.

In fact the spectral response may be altered by different factors, such as for example, the sea condition, the haze, the amount of the steam, the amount of the clouds, and their altitude in the atmosphere, or even by some parameters related to the observation geometry (mainly the sunlight angle and the viewing angle), etc.

An overview at the international literature confirms the existence of such problems. Till now in fact, the only problems which have been solved quite successfully are those concerning the identification of sea zones having the same turbidity, the discrimination of the suspended sediments and the study of the currents dynamics (assuming that the suspended sediments are used as tracers).

A solution is still to be found as far as problems related to the detection of the main parameters are concerned, which are typical of the marine phenomena and of the pollution, such as for example, salinity, temperature, types and entity of polluting agents, etc.

Based on the above, the Water Research Institute, (I.R.S.A.) of the National Research Council, and Telespazio, decided to verify the possibility of using Landsat satellites for studying the turbidity introduced into sea waters by the rivers.

Sea field measurements were performed by I.R.S.A. during the satellite pass (see IRSA - TELESPAZIO, 1976).

2. - DATA COLLECTION

A test area situated at the Tiber mouth has been selected. The area is at a distance from the coast of about 8 miles and extends for 20 miles.

The measures in the sea have been taken on May 19, 1976 by IRSAMARE ship, during LANDSAT-1 satellite pass.

The weather and sea conditions were steady and the river flow was within the average seasonal values.

The absence of significant solid transportation phenomena, originated by the river, allowed to exclude the forming of large turbidity plumes usually well detectable (and associated with flood events).

In 17 sea truth control points (see Figure 1) Secchi depth transparency measures have been taken with observation of the radiance average values (approximation of 3 pixels: r.m.s. $\simeq$ 210 meters).

Data of transparency and radiance for each spectral band are shown in Figure 2.

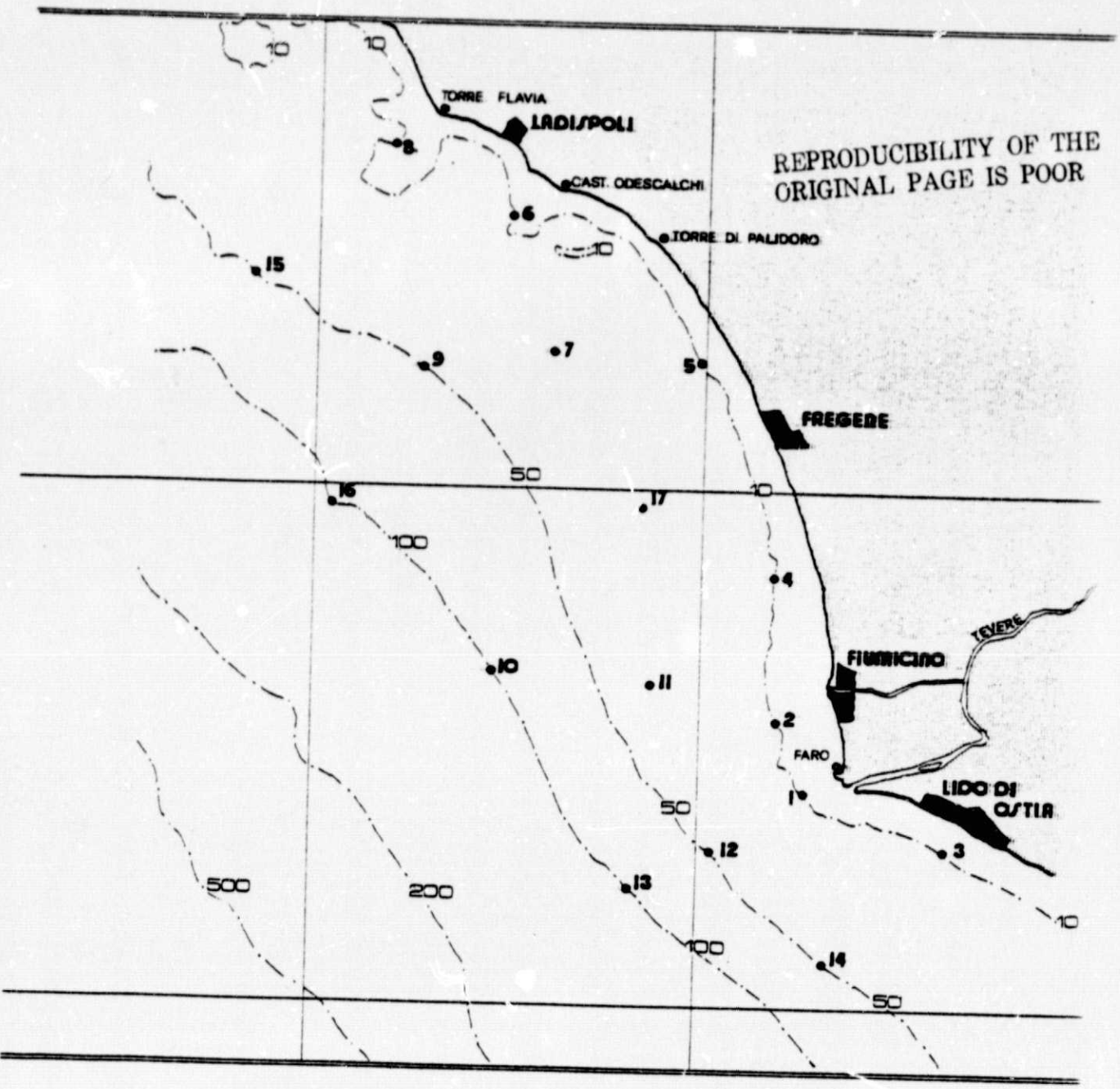


FIGURE 1 - Location of the sea truth stations.

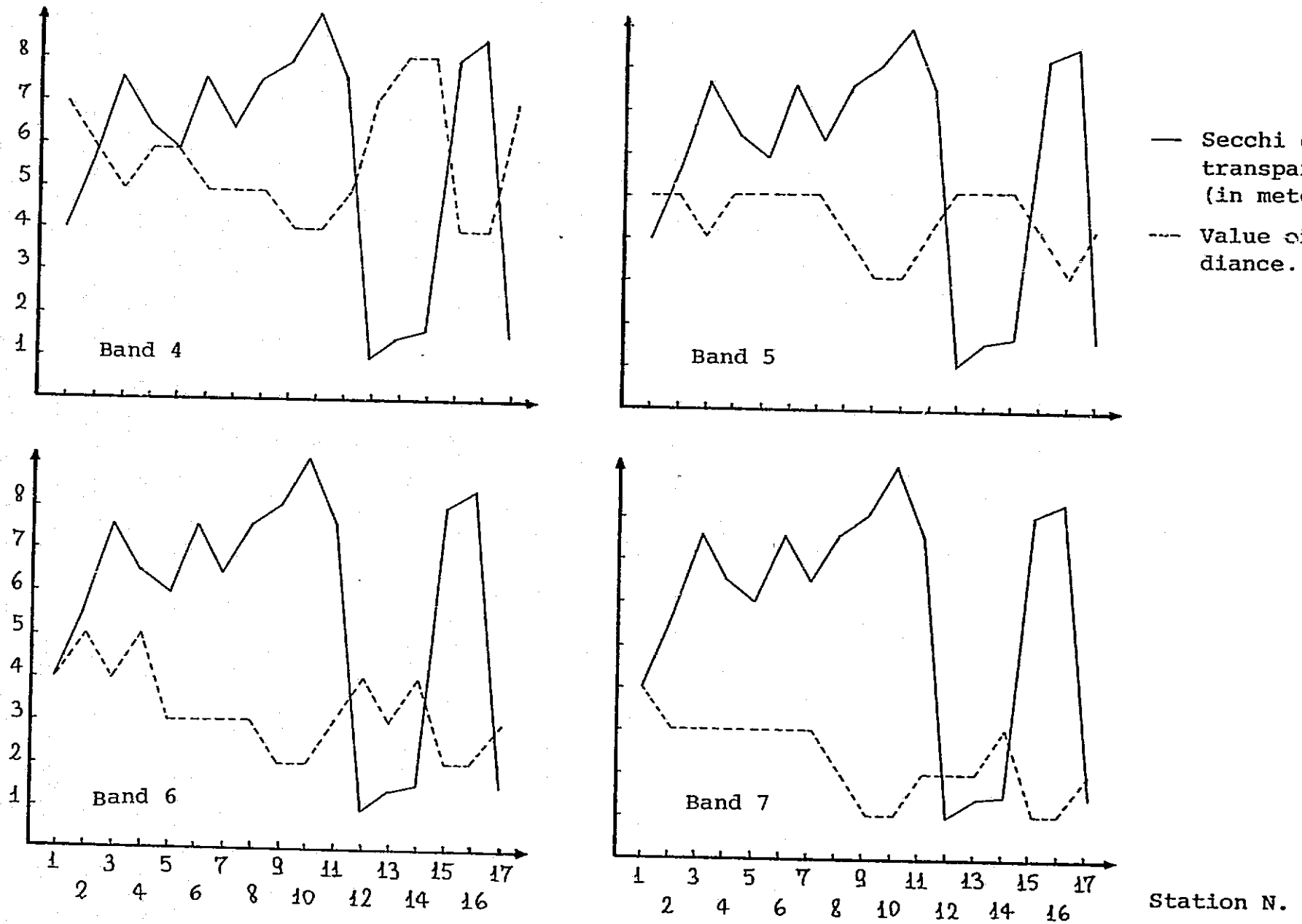


FIGURE 2 - Relationship between Secchi depth transparency and radiance at each station.

3. - DATA PROCESSING

Data so obtained have been processed according to two different correlation processing procedures:

a) Secchi depth transparency measures and radiance values;

b) map of transparencies and map of radiances.

3.1. - TRANSPARENCY AND RADIANCE CORRELATION

From the international experience on this subject, the best correlation is obtained either through the use of band 4 (yellow-green spectral region, wavelenghts 0.5 - 0.6 μm) or band 5 (orange region, wavelenghts 0.6 - 0.7 μm).

In our case band 4 seems to be the most representative of the Secchi depth transparency measures (see Table 1). However from a physics point of view, it is not always possible to clearly fix an order of significant priorities, as the quantification of some phenomena, such as the color of the particles suspended in the sea, the diffused radiance, etc., is very hard.

To eliminate this inconvenience, the first principal component has been used as a spectral indicator for both bands (refer to KENDALL, 1972).

The correlation between this component and the Secchi depth transparency measures has resulted of high significance (see Table 1). This can be deduced from the property of this method to reduce the redundancy between pair of contiguous bands (refer to LOWITZ, 1978).

TABLE 1 - Statistical evaluation of the correlation between Secchi depth transparency and value of radiance.

SPECTRAL BANDS	LINEAR CORRELATION COEFFICIENT (absolute value)	STUDENT'S t TEST	DEGREES OF FREEDOM	LEVEL OF SIGNIFICANCE
4 (0.5 - 0.6 μm)	r = 0.9386	t = 10.5365	15	$P < 0.001$
5 (0.6 - 0.7 μm)	r = 0.5681	t = 2.6736	15	$P < 0.05$
6 (0.7 - 0.8 μm)	r = 0.4254	t = 1.8205	15	$P > 0.05$
7 (0.8 - 1.1 μm)	r = 0.3206	t = 1.3109	15	$P > 0.05$
1st principal axis of bands 4 and 5	r = 0.9021	t = 8.0964	15	$P < 0.001$

3.2. - CORRELATION BETWEEN MAP OF TRANSPARENCIES AND MAP OF RADIANCE

As an integration of the previous analysis, an evaluation of the similarity between the maps of transparencies and radiances has been effected both for the image in band 4 and the image projected onto the first component.

The steps of the procedure are the following:

a) Filtering of transparency data and radiance data, by means of a statistically optimum surface interpolation. This to the aim of filtering not significant data, to enhance only the trend of similar turbidities. The optimum criteria adopted satisfies the following constraints:
   - the polynomial surface of K order fits in significantly;
   - increasing the order of this surface to K+1, no significant increase in the fitting is obtained.

b) Correlation between the polynomial surfaces coefficients of transparency and radiance data, except for the constant terms.

c) Statistics evaluation of the significancy of the so obtained correlation coefficients and, therefore, of the goodness of fitting between both maps.

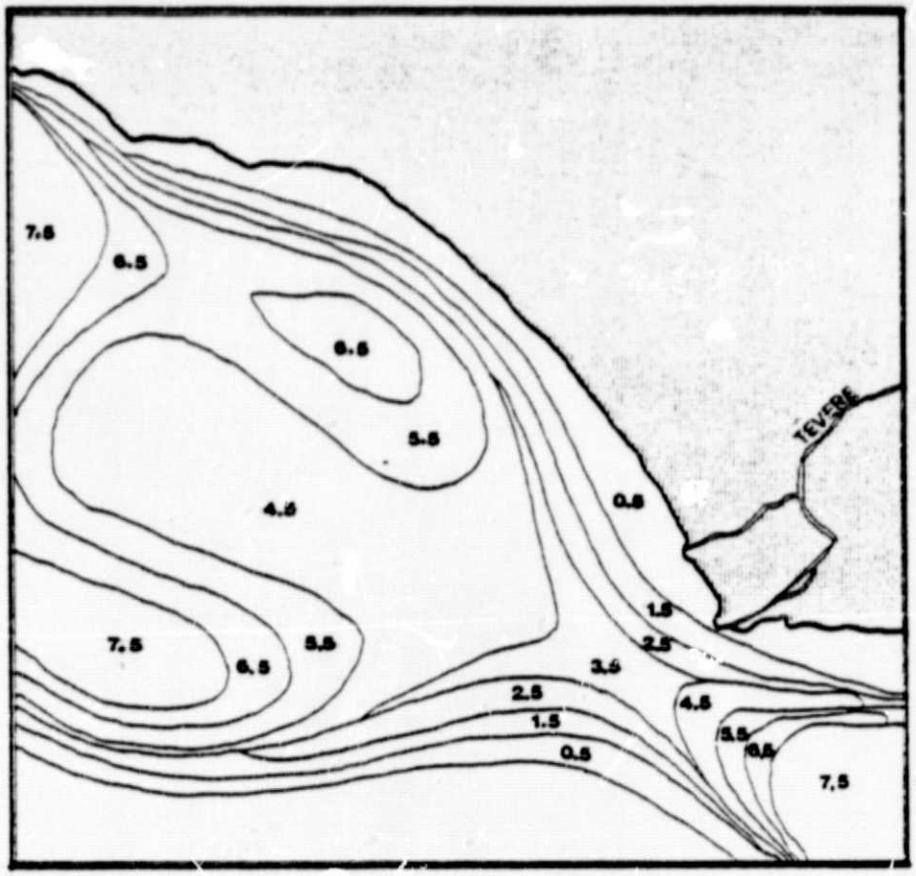
From the application of this procedure, the following results have been achieved:

- the optimum polynomial surface, of both transparency data and radiance data, resulted of the fourth order (15 coefficients, including the constant one);

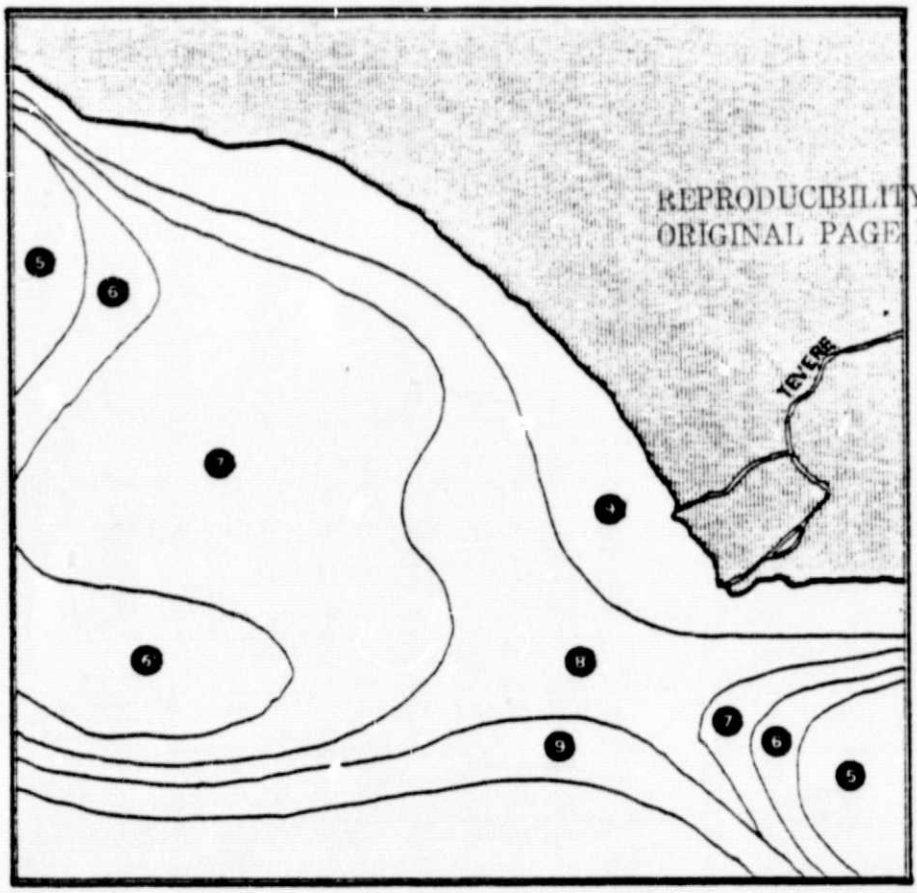
- the fitting between both maps, has resulted of high significance.

Considering the different scale variation of the parameters examined (the transparency assumes 9 different values, while the radiance assumes 5 values), a first idea about the quality of the results obtained is shown in Figure 3. Here the filtered transparency and radiance data trends projected onto the first principal axis are compared.

The analytic evaluation between both maps is shown in Table 2.



(a)



(b)

FIGURE 3 - Comparison between 4th order trend surface:
a) Secchi depth transparency.
b) Image projected on the 1st principal axis of bands 4 and 5.

TABLE 2 - Statistical evaluation of the similarity between maps.

TREND SURFACE MAPS	CORRELATION COEFFICIENTS BETWEEN COEFFICIENTS OF 4th ORDER TREND SURFACE (⊗) (absolute value)	STUDENT'S t TEST	DEGREES OF FREEDOM	LEVEL OF SIGNIFICANCE
Secchi depth transparency and Image in band 4	r = 0.9872	t = 21.4422	12	P < 0.001
Secchi depth transparency and Image projected on the 1st principal axis of bands 4 and 5	r = 0.9929	t = 28.9151	12	P < 0.001

(⊗) Constant term not included.

4. - EXTENSION OF THE PROCESSING PROCEDURE TO THE COASTAL CURRENTS STUDY

The study of the coastal currents dynamics using Landsat images, is normally done by photointerpretation of natural tracers (such as suspended sediments) or artificial tracers (such as biodegrading dyes in the sea). Considering the validity of these tracers as currents trend indicators (refer to KLEMAS and Others, 1973), the procedure previously examined can be extended to such study as follows:

a. Projection onto the principal axis of the images in bands 4 and 5, when using artificial or natural tracers, under condition of minimum solid transportation. This happens under steady weather condition.

   Projection on the first principal axis of the images in bands 4,5 and 7 when using only the suspended sediments as tracers, under very bad weather conditions.

b. Filtering the so obtained image by means of an optimum surface interpolation.

c. Identification of the currents dynamics by photointerpretation of the filtered radiance data, considering the existing negative correlation between radiance and transparency.

The image so obtained can be usefully read by the photointerpreter due to the following properties:

- synthetizes, in terms of contrast variance, the information contained in different spectral bands; (refer again to LOWITZ 1978);
- emphasizes the trend of similar turbidities only;

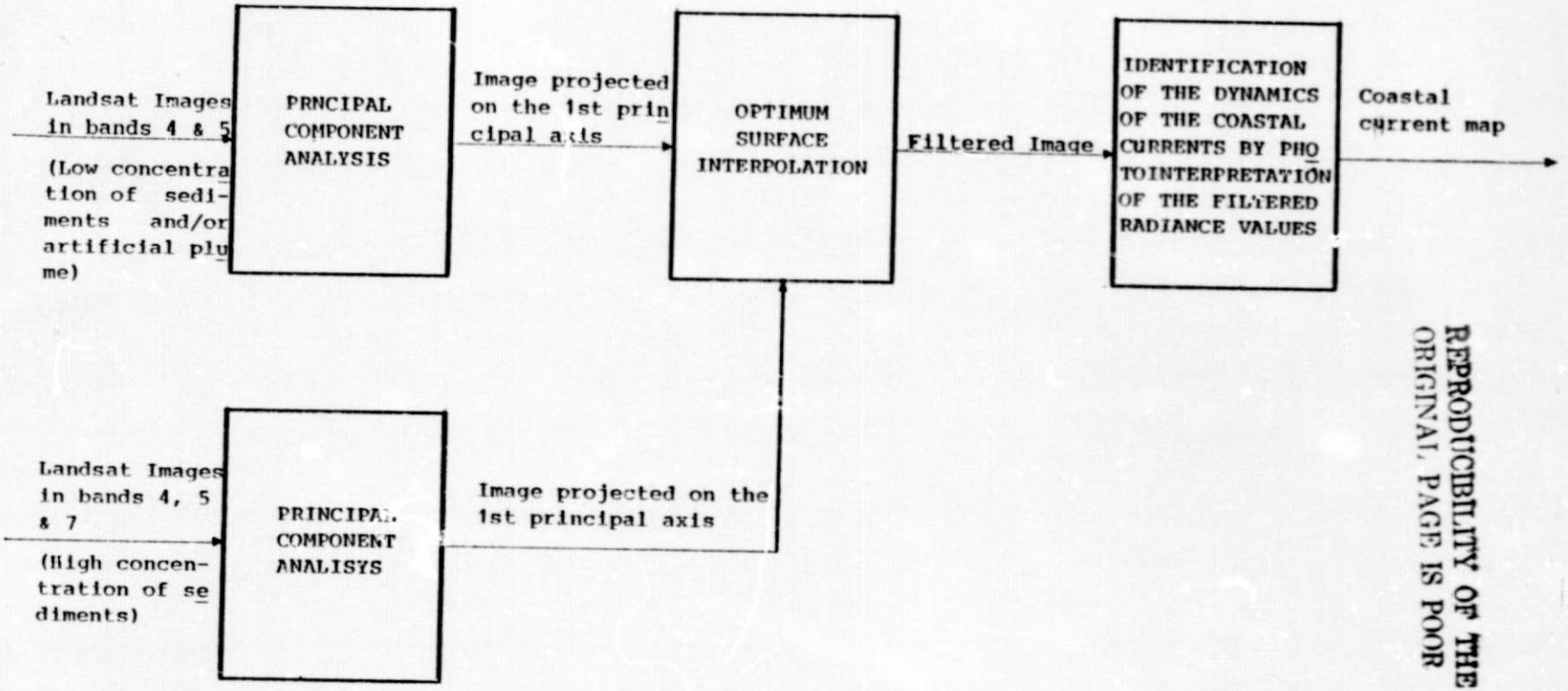
- is statistically correlated to the transparency.

For a better understanding of the procedure, refer to diagram in Figure 4.

Figure 5 gives an example of the results obtained through the photointerpretation. In fact, as it can be observed in this image, the radiance values along the coast and off the Tiber mouth are very high (level 9), which indicates that the transparency is low (in fact it has been ascertained to be of about 0.5 meters). As the radiance levels decrease the transparency increases (cleaner water): at level 5 a transparency of 7.5 meters has been observed.

Assuming the hypothesis of using suspended sediments as tracers, the variation of similar turbidities is an index of currents trend. This trend is represented in the Figure by arrows.

FIGURE 4 - Procedure for studing the dynamics of coastal currents.



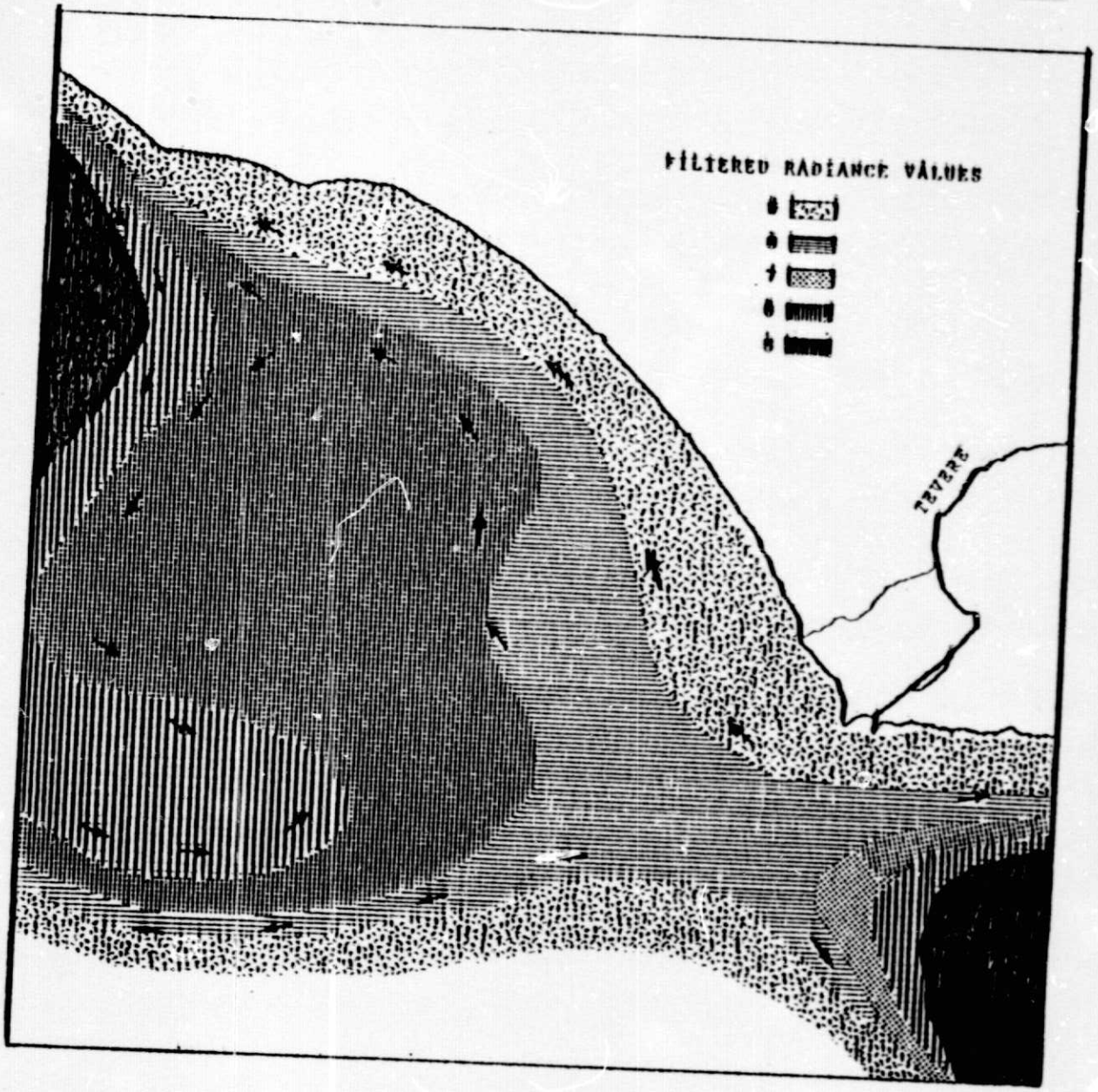


FIGURE 5 - Coastal current trends in Tiber-mouth during Landsat-1 overpass on May 19, 1976.

5. - CONCLUSIONS

The main objective of this work has been to analyze the correlation between a typical parameter of the sea pollution (Secchi depth transparency) and Landsat data.

During Landsat overpasses, see truth data have been collected in a test area (Tiber river mouth).

The comparison made has confirmed the existance of such a correlation.

The following main conclusions had been reached:

- The combination of spectral bands 4 and 5 is a valid instrument for studying the sea turbidity;
- It is possible, using the surface interpolating method, to realize maps representing clearly the turbidity trend in large sea areas;
- It is impossible to know the absolute transparency value using these instruments;
- It is possible to study the dynamics of the currents assuming to use the suspended sediments as natural tracers.

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