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A MULTITEMPORAL ANALYSIS

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(E82-10036) LANDSAT IMAGERY OF THE VENETIAN LAGOON: A MULTITEMPORAL ANALYSIS (Consiglio Nazionale delle Ricerche) 9 p HC A02/MF A01 CSCL 08H
N82-19612
Unclas
G3/43 00036

Presented to:
COSPAR/SCOR/IUCRM Symposium
"Oceanography from space"
Venice, May 1980.

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ABSTRACT

Results from a multitemporal analysis of the Lagoon's environment dynamics in its central basin by the use of Landsat images from 1975 to 1979 are presented.
Utilizing an appropriate methodology for multitemporal calibration of data in the more characteristic bands of marine phenomena, a classification was made to distinguish tide diffusion as well as industrial, agricultural, urban turbidity distributions and algae belts.
The analysis of these factors led to the conclusion that lagoon's environment becomes more and more polluted, confirming sea-truth measurements.

1. INTRODUCTION

The aim of this work was to determine the pollution diffusion, in relation to different tide conditions, in the central basin of Venice lagoon by the use of Landsat data.
To achieve this goal, a selection of images from 1975 to 1979 was performed based on the following criteria:
- same season;
- representativeness of different tide dynamics;
- similar wind conditions;
- availability of useful data.

As to the most suitable season, late spring was selected, because the atmospheric noise effect in the lagoon is reduced.
Referring to tide conditions, a short and a long range period have been considered. The former corresponding to the year 1979, with three images recorded under different tide dynamics. The latter represented by the years from 1975 to 1979 with five images recorded under similar tide dynamics.

2. METHODOLOGICAL APPROACH IN DATA PROCESSING

THE BASIC CRITERIA

The haze conditions and the complex environmental dynamics of the lagoon on one hand, the physical characteristics of Landsat bands on the other hand, have led to utilize an appropriate methodology for multitemporal calibration of the images as basic element in data processing.
This consists in the projection of these images in the same feature space, after due restoration.
The various work steps are:
- partial haze removal;
- residual striping removal;
- spectral bands selection;
- multitemporal data calibration;
- classification.

PARTIAL HAZE REMOVAL

As it is known, an increasing haze has the following effects on MSS data:
- a shifting of most signals towards brighter levels;
- a reduction in the available signal contrast, i.e, in the dynamic range encompassed by the data (refer for instance to Lambeck, 1977).

The first effect has been partially removed by a shifting of the radiance values vs. dark levels. This shift is relatively large for MSS 4 and minimum for MSS 7, considering light scattering as a function of wavelength.
The second effect has been also partially eliminated by means of a normalization of the work images done through their projection onto a common normalized reflectance factorial space. (For the main characteristics of a normalized reflectance space refer to Kauth + Thomas, 1976).

RESIDUAL STRIPING REMOVAL

After destriping processing, a residual striping has still been observed in certain subregions of the Venetian lagoon area.
This fact is normally due to the significant differences between the statistical parameters of the destriping models, computed in the subregions and in the whole area.
To remove these residues it has been sufficient to utilize a smoothing method, based on moving average of line groups.

SPECTRAL BANDS SELECTION

It has been observed that, for marine phenomena, MSS 4 and 5 yield information on circulation, turbidity distribution and biomass (refer to Maul, 1973, Todisco + Zandonella, 1979).
Furthermore, MSS 6 has been proven as very effective in detecting algal blooms, a phenomenon representing extremely high surface chlorophyll concentration (refer to Strong, 1974).
Considering these three channels and some physically significant operations, ratio and sums in particular, the correlations existing among them have been computed for every single lagoon area, in relation to the most representative lagoon phenomena, such as tide, turbidity distribution, algae belts.
Bartlett sphericity test have been interatively utilized for channels selection , by evaluating the null hypothesis for which their correlation matrix is an identity matrix (refer to Zandonella,1978).
The most useful channels so determined have been MSS 4, MSS 5, MSS 4 + MSS 5 and MSS 4/MSS 5.
So selected channels are highly correlated to different types of turbid water and scarsely to algal blooms. This means that during the monitoring these events have not been noticed.

MULTITEMPORAL DATA CALIBRATION

As mentioned above, the calibration criteria is based on Landsat data structure analysis (refer again to Kauth + Thomas, 1976 and also to Zandonella, 1980).
Apart from any consideration on the methodology utilized, which will make the object of a separate specific work, the basic concept of the method consists of data projection in the same feature space.
The criteria is to find a new axis system for which the loss of contrast variance, in relation to the principal axis of the original reflectance spaces, is minimum.
New axis system properties are similar to those of principal components.

CLASSIFICATION

The criteria followed in the classification is based on three main steps.
The first step has consisted in identifying the potential classes by the use of unsupervised classification, considering also sea-truth data (refer to Zandonella, 1979). The second step has been to utilize a supervised classification method: the Sebestyen quadratic classifier (refer to Sebestyen, 1962 and to Zan

donella, 1979 for the criteria of choosing the quadratic form). As third step, the goodness of the classification has been evaluated both through the use of sea-truth data and through the analysis of the one sigma dispersion ellipses of different classes projected onto the first two axis of the same feature space (see Figure 1). For this type of analysis refer for instance to Benzècri, 1973.

3. RESULTS AND CONSIDERATIONS

The turbidities classification on one hand and the lagoon-sea exchanges, under different tide conditions on the other hand, allowed a comparison of the results obtained (see enclosed image).

On May 4th, 1979 the largest turbidity diffusion was verified, during a low range ebb tide. The NNW wind effect contributes in conveying the waters from the northen basin towards Venice and from the industrial zones towards the lower part of the lagoon.

On May 22nd, 1979 at the outflow beginning the situation was very similar, but a lower rate of turbidity diffusion was verified in the southern part of the lagoon.

A wide clean water area coming from Malamocco entrance during previous tide phase is clearly visible.

On June 27th, 1979 and June 19th, 1977 with similar tide conditions and winds blowing from opposite direction, the industrial pollution still surrounds the historical center.

A similar turbidity diffusion towards Venice was confirmed by the May 27th, 1978 and April 28th, 1975 images, both recorded during inflow tide having high stream speed.

On May 19th, 1976 industrial pollution still surrounded the historical centre even during the inflow and by a very low sea level (below zero). The incoming clean water was gathering in a restricted area around Malamocco inlet.

It appears from the above considerations that the lagoon areas affected by polluting discharges are clearly identified. The concentration of these discharges in specific lagoon areas is deriving from some circulation pattern enhanced in the multitemporal image analysis by the tide inflow/outflow as well as in situ, by traditional oceanographic measurements (refer to Alberotanza + Tonelli, 1978, Dazzi + Nyffeler, 1973, Nyffeler, 1976, Comune di Venezia, 1978, Nyffeler et al., 1974, Nyffeler et al., 1975).

4. CONCLUDING REMARKS

From the results obtained, it was possible to remark that polluted waters are present between industrial zones and the histori

cal centre under any tide condition.
The flow of pollutants is continuous and involves the same areas with variations only in the spatial distribution.
The diffusion in the lagoon of clean water from the sea during flood tide remains limited in restricted areas around Malamocco entrance.
The water renewal from Lido entrance appears more limited.
In relation to the above and to the sea-truth measurements, pollution concentration in a well delimited area is derived both from the short time interval between inflow/outflow and from the distance between the two lagoon inlets and the industrial zones.

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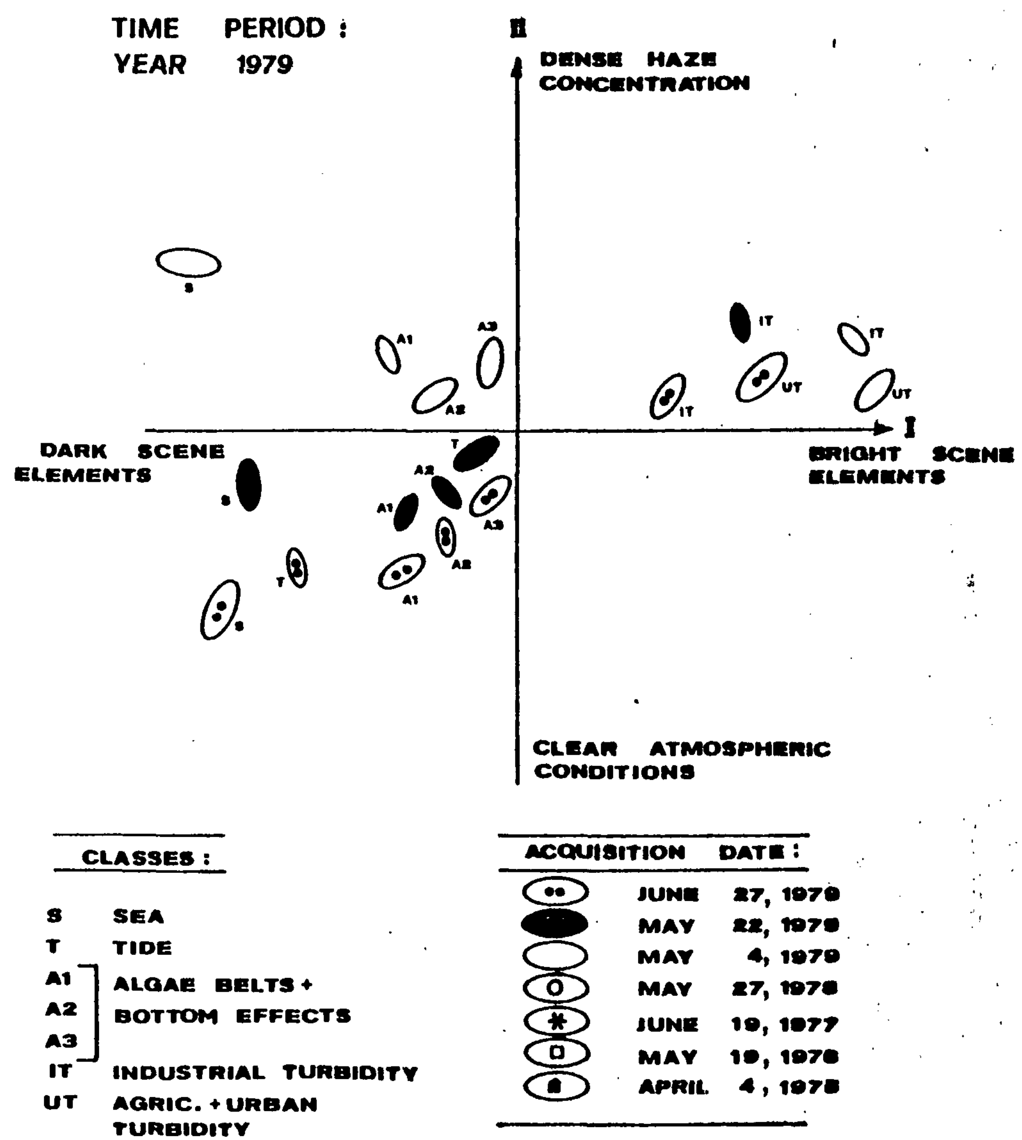

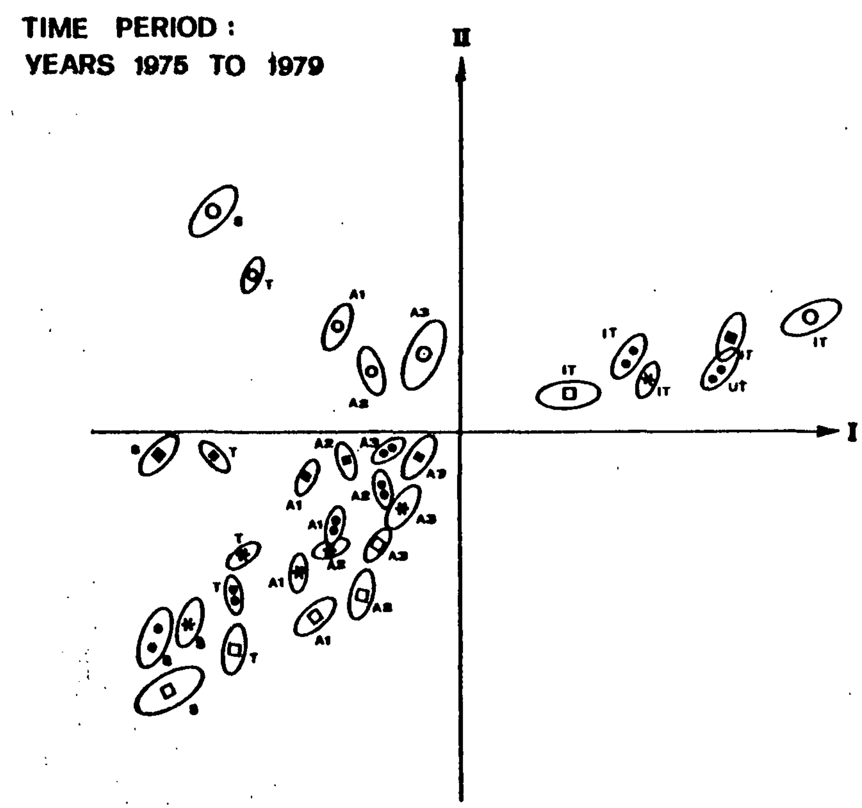

FIGURE 1 - Plot on first two factors, of a common standardized space, of one sigma dispersion ellipses of classes identified in different time periods.

ORIGINAL PAGE
COLOR PHOTOGRAPH

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SUMMARY

Results from a multitemporal analysis of the lagoon's environment dynamics in its central basin by the use of LANDSAT images from 1975 to 1979 are presented. Utilizing an appropriate methodology for multitemporal calibration of data in the more characteristic bands of marine phenomena, a classification was made to distinguish tide diffusion as well as industrial, agricultural, urban turbidity distributions and algae belts.
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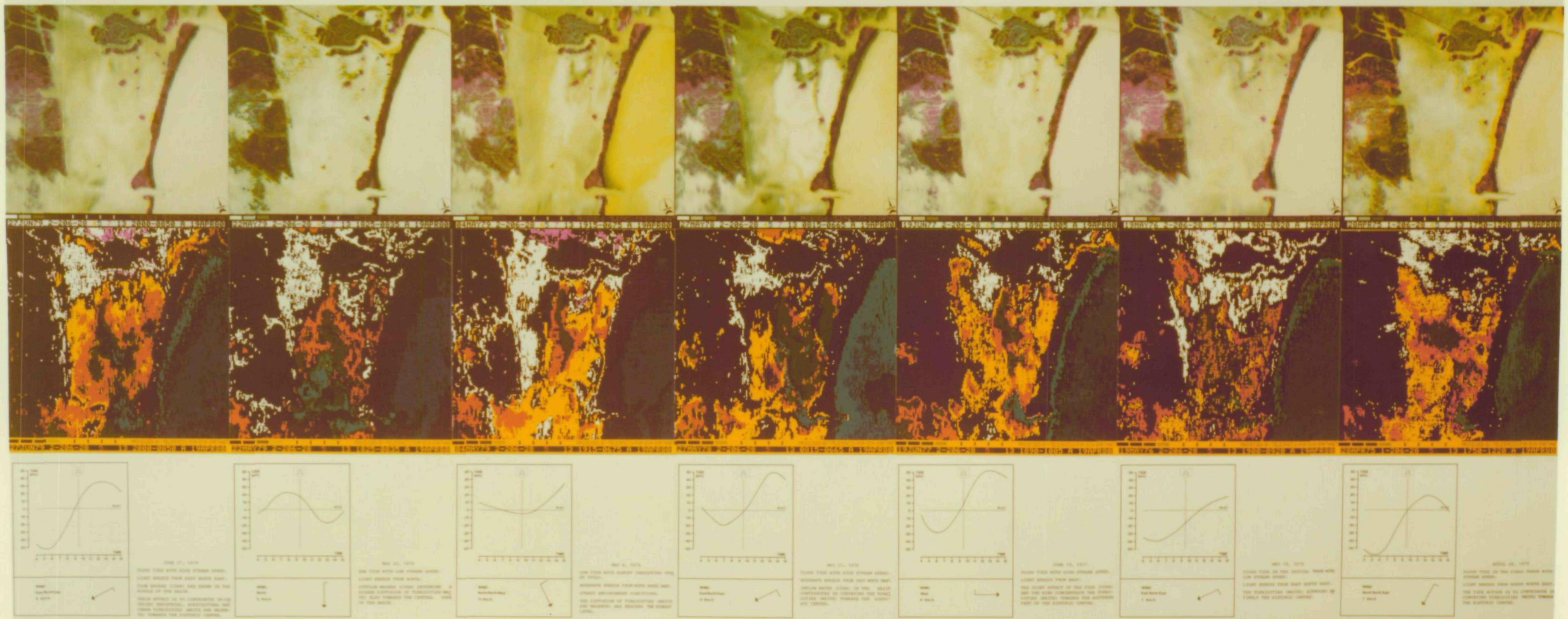

COLOR CODES:

White	- Industrial turbidity	Green	Algae belts + Bottom effects	Cyan	- Tide
Magenta	- Agricultural and urban discharges	Red		Blue	- Sea
		Yellow		Black	- Unclassified

CONCLUSIONS

Areas affected by industrial, agricultural and urban pollution (white and magenta) are clearly shown, in relation to the tide.
Indipendently from tide inflow-outflow, industrial as well as agricultural and urban discharges are always conveyed towards the historic centre.
Water renewal in the central basin is poor, as clean waters coming from the sea (cyan) gather in restricted areas distant from industrial zones.