A METHODOLOGY FOR ANALYZING THE INTERACTIONS BETWEEN "TURBIDITY DIFFUSION" AND "TIDES" IN THE LAGOON OF VENICE THROUGH LANDSAT DATA

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Abstract

The methodology described is based on the analysis of feature and the distribution of reflectance data within Landsat's MSS bands, to study physical relationships between "turbidity diffusion" and "tides" (inflowing) in the Venice Lagoon.

By projecting these data on canonical discriminant feature space it is possible to interpret the relationship between "turbidity transparencies" and "tidal excursions" and to reconstruct relative models as functions of "water brightness".

The goodness-of-fit of these models is assessed comparing actual data with those estimated.

1. Data Analysis

The central basin of the Venice Lagoon was chosen as a test-site for two reasons:

- the zone is limited and quite well-known from an environmental dynamics point of view;
- the experience gained in dealing with images and the possible results which could be obtained from satellite (Alberotanza and Zandonella, 1980) and aircraft (Alberotanza and Tonelli, 1978).

The Landsat images used in the study refer to different acquisition periods under almost the same environmental conditions.

2. Basic Criterium

Considering as input the more representative components of the gravity centers of the phenomena classes "industrial turbidity" and "tide" (inflow), the basic idea of the method consists in projecting these components in their feature space where these result more distinct in the different acquisition periods.

In such a feature space, the form and distribution of data is increased. This allows to interpret more easily the axes (Benzècri, 1973), that is to say the phenomena that they represent.

The canonical discriminant analysis is the method which better satisfies these requirements (see e.g. Rao, 1952).

3. Description of the Method

The canonical discriminant analysis is defined by:

- ${}_{k,t}G$: a matrix of "k" components most representative of gravity centers of the classes relative to "k" phenomena and calculated for each acquisition period "τ", where $\tau \in \{1,-,t\}$.
- ${}_{l,t}Y$: a matrix of $l \leq k$ components of gravity centers linearly transformed and related to "t" acquisition periods.
- ${}_{l,k}C$: a transformation matrix of these components.
- ${}_{k,k}B$ and ${}_{k,K}V$: the scattering matrix "between" and "within" the components of the matrix ${}_{k,t}G$.

The solution to the problem of discriminant analysis consists of determining which ${}_{l,k}C$ linear transformation matrix is better able to distinguish the components of the ${}_{k,t}G$ matrix in the different acquisition periods.

The matrix transformation function can be written as:

$${}_{l,t}Y = {}_{l,k}C \cdot {}_{k,t}G \qquad\qquad l \leq k$$

It is possible to show (Rao, 1952) that the components of the ${}_{l,k}C$ matrix are eigenvectors of the matrix: ${}_{k,k}V^{-1} \cdot {}_{k,k}B$.

4. Application

Landsat images used in this method refer to the period between 1975 and 1979. For more details about the criterium used for their selection and the applied method for automatic recognition of "industrial turbidity" and "tide" phenomena, see Alberotanza and Zandonella (1980).

The components most representative of gravity centers of "industrial turbidity" and "tide" classes are used as input data for the model, considering the classification of selected spectral bands for their recognition, that is: MSS 4; MSS 5; MSS 4 + MSS 5; and MSS 4/MSS 5.

Gravity centers were clearly calculated for each of the five acquisition periods, consequently the G matrix is 2 x 5.

The selection of the components was based on the maximum contrast differences found in the images. For this purpose "τ" relevant to the MSS 4 + MSS 5 image was chosen as the time component.

Center of gravity components were standardized to "free" them from their variances.

Atmospheric attenuation involves, as already known (Lambeck, 1977), dynamic deviations in radiance data from scene to scene.

5. Results and discussion

In Figure 1, the components of the gravity centers of the two phenomena are reported, projected on the 1st two canonical discriminant directions.

According to the position of these components in this new projection, the first direction is interpreted as that indicating "tide excursion" (low vs high) while canonical direction as "industrial turbidity transparency" high vs low). Such phenomena are interpreted in terms of "water brightness". In fact, an increase in the inflow water stream from a hydrodynamical point of view causes an increase in the turbidity concentration around the historical center of Venice (Nyffeler) with a decrease in relevant transparency.

Instead from a physical point of view on radiance, "tide excursion" causes an increase in the "water radiance" in the "tide" class due to bottom sand movements and in the "turbidity" class due to the reduced transparency.

Having only tide excursion data available at the moment of the satellite overflight, the goodness of fit of the model had to be evaluated by comparing actual data with those estimated, the results are reported in Figure 2.

6. Conclusions

The methodology described is based on the analysis of structural relationships of relative brightness data within Landsat's spectral bands. This approach allows to construct models on "tide excursion" (by a series of links) and "industrial turbidity transparency" as a function of water brightness.

The results achieved from the Venice Lagoon affirms that this method of analysis is quite promising and justifies further investigations using Landsat data, even in fields other than oceanography.

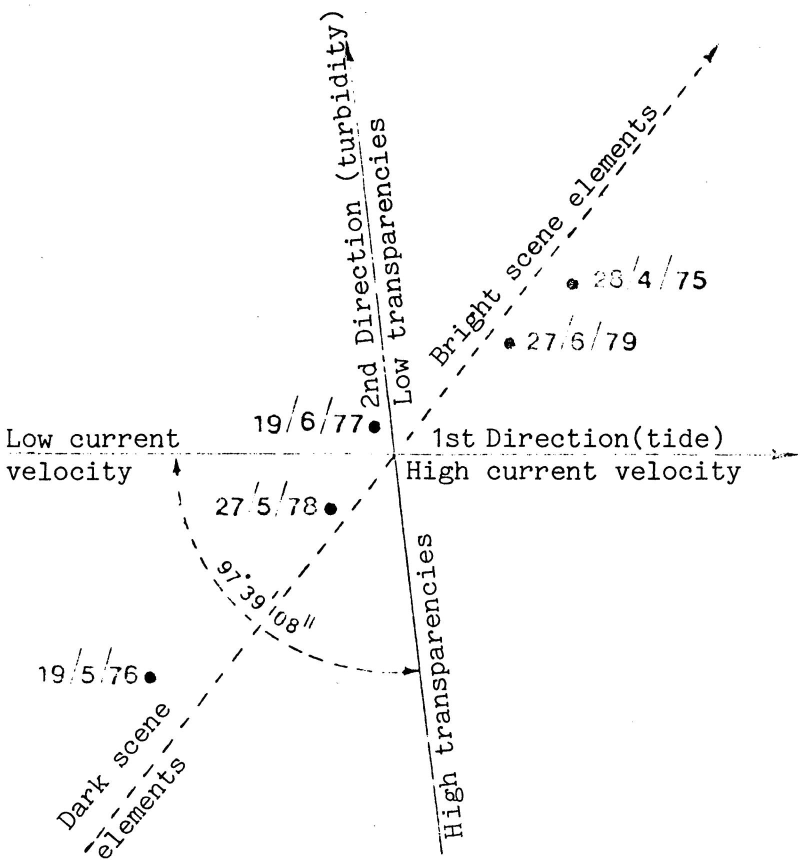

Fig. 1. Projection of gravity center components of industrial turbidity and tide (inflow) in the 1st two canonical discriminant directions. These components refer to the MSS 4 + MSS 5 images.

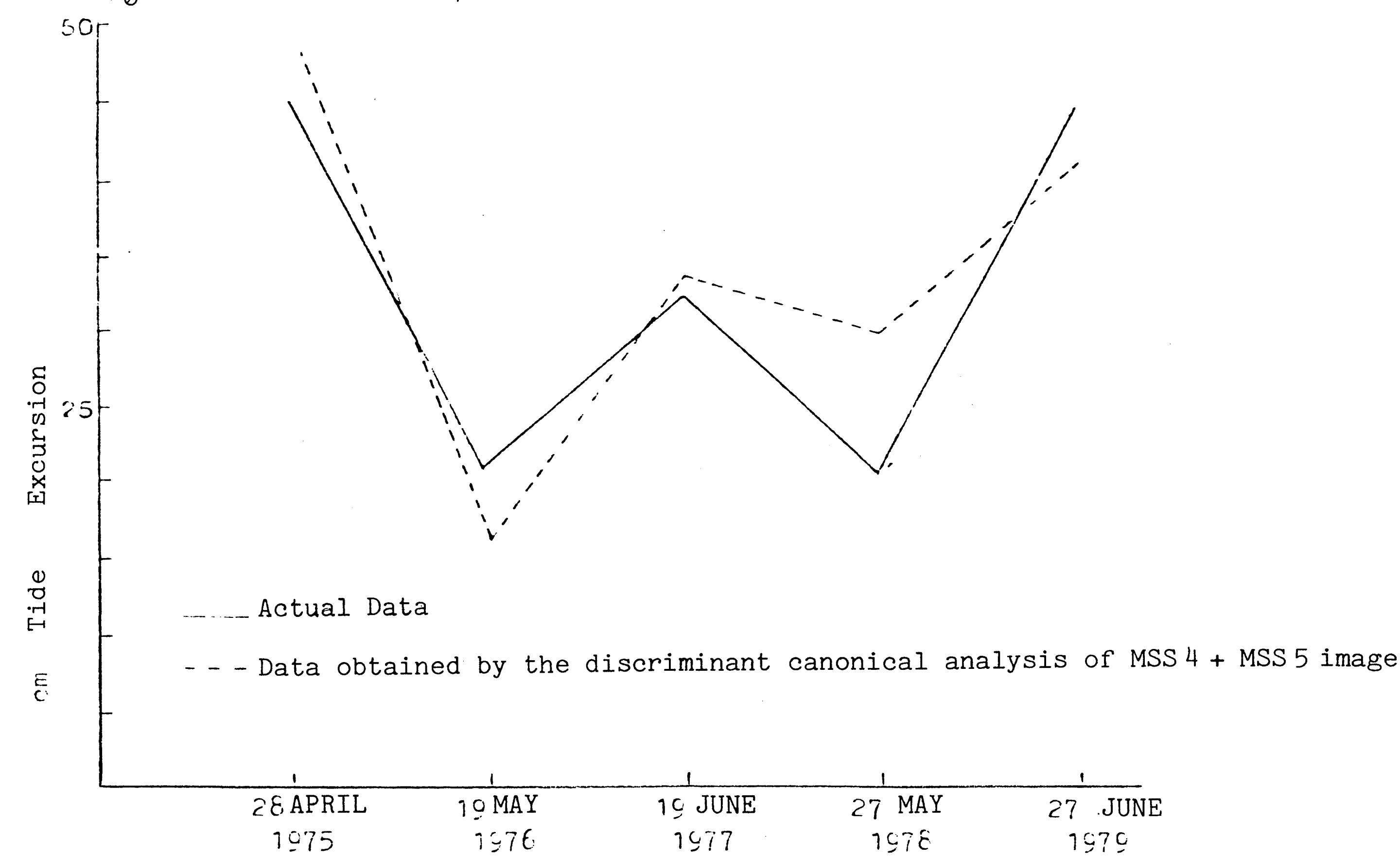

Fig. 2. Comparison of tide excursion (in cm) occurring 2.5 hours before the first satellite overflight with results obtained by canonical discriminant analysis.

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