INTEGRATION OF SPOT AND SAR-ERS IMAGERIES WITH OTHER TYPES OF AERO-SATELLITE AND TERRAIN DATA, FOR STUDIES ON THE DANUBE DELTA, AND THE CONTINENTAL PLATFORM OF THE BLACK SEA.

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ABSTRACT:

In the introduction - background - the aims and the interest for the zone are presented: the Danube Delta, which was declared a natural biosphere reservation and for which objective and comprehensive inventories of the existent state are required, and also for monitoring the evolution of the coastal zone and the continental platform of the Black Sea, for monitoring the geomorphologic evolution on medium and long terms, as well as assessing the impact of the marine drilling platforms (i.e. pollution, a.s.o.).

Our available means are described: graphic station - supercomputer TITAN with peripherals and EASI-PACE software; remote sensing laboratory situated in the Danube Delta, equipped also with a field portable radiometer EXOTECH 1OO AX, linked with a 486 DX2 notebook; some recordings SAR-PRI and Landsat-TM and also repetitive recordings: Landsat MSS and aerial photos, including "in situ" measurements correspondent to the period in which some aero-satellite images were recorded.

In the image processing, interpretation and obtained results section, acquiring and homegenising-compatibilisation of data are presented, rectifying and registration - fusion of the recordings, segmentation of the SAR - ERS images, filters for attenuating the speckle type noise, other processing, RGB and IHS colour composites, including RGB - IHS - RGB transforms, supervised and unsupervised classifications, different type of contrast stretching methods, principal components, comparison between the results using also the confusion matrix. Significant results: (a) seasonal vegetation indices for Danube Delta were obtained in "real time", together with reducing the number of the needed satellite recordings by use of radiometric measurements; (b) monitoring of the sediment discharge and depositing in the sea; (c) monitoring of the morphological coastal modifications; (d) monitoring the influence of the sea state and the wind conditions on the backcattered radar signal; (e) monitoring of the "red blossoming" biological pollution in the coastal zone, in the warm and in the cold season respectively.

In the final part of the paper, some proposals for further developments are made.

1. INTRODUCTION- BACKGROUND - AIMS.

The Danube Delta is one of Europe's most extensive wetlands in a natural state; it forms an unique series of interrelated ecosystems, with its large reed beds, maze of with their mosaic of forests and semi-arid grasslands; the Delta ecosystems cover about 564.000 ha; of this 442.000 ha lie within Romania.

The Danube Delta and the coastal zone of the Black Sea represent areas of high scientific interest; the Danube Delta represents the world's largest surface compactly covered with rush (reed);

The macro characteristics of the chosen test - site are more significant, because this test - site includes the continental platform of the Black Sea, the Danube Delta, the Southern part of the Danube lower basin and a hill - mountain zone with a great seismic interest - the Vrancea zone, in the turning Carpatians;

The interest for the zone: the Danube Delta, which was declared a natural biosphere reservation and for which there are required objective and comprehensive inventories of the existent state, monitoring of its evolution, taking into account also the "historical" recordings; the coastal zone and the continental platform of the Black Sea, for monitoring the geomorphologic evolution on medium and long terms: monitoring the distribution and concentration of suspended sediments, as well as assessing the impact of the marine drilling platforms; evolution studies will be carried out, regarding the bathimetry, surface temperature, wave power, phytoplancton and biological active zones, as well as the pollution of different types. The interest for the area is even more accentuated because of the proximity of the Vrancea seismically zone.

Among several remote sensing studies and projects conceived and applied over the Danube Delta and also over the continental platform of the Black Sea

[1-8], started in 1972, by the Agreement with NASA [6], the present study is attempting to synthetise and up-date the already obtained results, by making use, in the last period of the useful SAR-ERS and SPOT data and mainly of intensive field radiometric measurements, taken with our equipment.

The basic idea in our technological process consists of intensive radiometric measurements, taken as system profiles over sample areas, with the Exotech 100 AX radiometer (using Landsat MSS & TM filters) linked with a notebook PC 486DX, in order to reduce to a minimum the number of satellite images needed; this aspect is of great importance for the East/European countries and, of course, for Romania also; that is, contributions to remote sensing technology, adapted to restricted means. The field and radiometric profiles, taken at convenient times (seasonal data would be most convenient) must be positioned on airborne and satellite images (seasonal data base), using mainly differential GPS kinematics mode; the data obtained on the profiles are extended over the area by using adequate algorithms and models.

2. OUR AVAILABLE MEANS.

The means and available possibilities and the ones in elaboration are mentioned:

(1) Graphic Station for processing Aero-Satellite recordings (hardware: super computer TITAN 3000 with graphic terminals and peripherals; software: EASI/PACE (V. 5.3), DORE (V. 5.2), AVS (V. 5.0));

2) Local PC network with graphic peripherals, as colour scanners, plotters and digitizers.

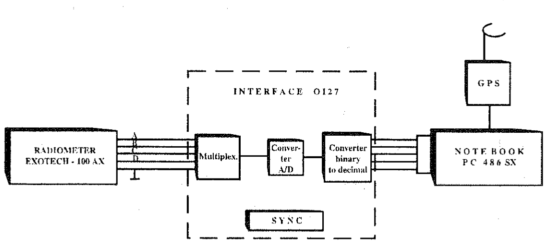

Fig.1. The system configuration for digital recording and processing of the radiometric values using a professional interface 0127 and PC note-book 486DX.(in the future connected with GPS and videography).

3) Equipment for "in situ" data gathering: Exotech 100 AX Radiometer (with filters for LANDSAT MSS & TM) linked with a notebook 486 DX2(see fig 1); a terrain remote sensing laboratory in the Danube Delta with geometric and radiometric targeting system (see fig 2):

4) 3 available recordings ERS-1 SAR PRI taken on the 30.04; 09.07 and 13.08.1993, some SPOT and LANDSAT MSS & TM images, and also repetitive aerial photos.

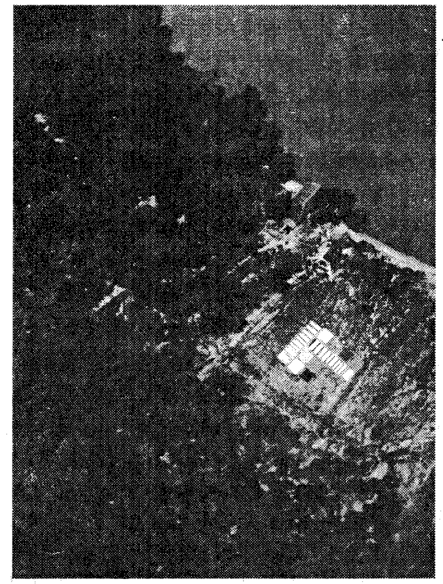

Fig.2 The field remote sensing laboratory from the Danube Delta and the system to calibrate - validate the geometric and radiometric data.

5) "In situ" data correspondent to the three ERS-SAR recordings.

- The ground truth data corresponding to the 1975 LANDSAT MSS image taken on 4 profiles parallel to the shore line, referring to salinity, organic substances concentration and depth, water temperature.

- Radiometric measurements taken on the characteristic profiles, mainly over "The great Deltaic Profile" - (fig 3).

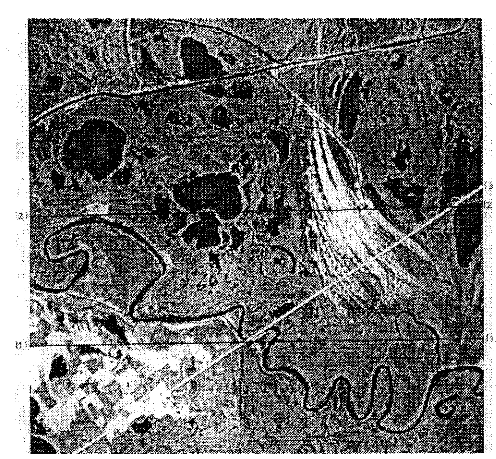

Fig.3. Positioning of the radiometric profile along the scanning line of the SAR - ERS - 1 recording which passes: (1) over the Remote Sensing Laboratory of TU of Civ.Eng.Bucharest; (2) over the Caraorman region of the Danube Delta; (3) over the "great deltaic profile".

3. PRELIMINARY ACTIONS AND PRE-PROCESSING:

3.1.

a) Acquisition and homogenising-compatibilising of endogeneous and exogeneous parameters:
- the 3 multitemporal recordings SAR-ERS-1 PRI;
- repetitive recordings LANDSAT MSS & TM and SPOT;
- aerial repetitive panchromatic photos, IR and colour IR;
- topographic maps with contour lines at 0.25m, pedological maps;
- piezometric profiles, hydrological data, meteo data, quantitative and qualitative profiles, coastal evolution determinations;

b) The three ERS recordings rectifying, taking into account the first one;
- The registration of the LANDSAT MSS & TM and SPOT recordings;

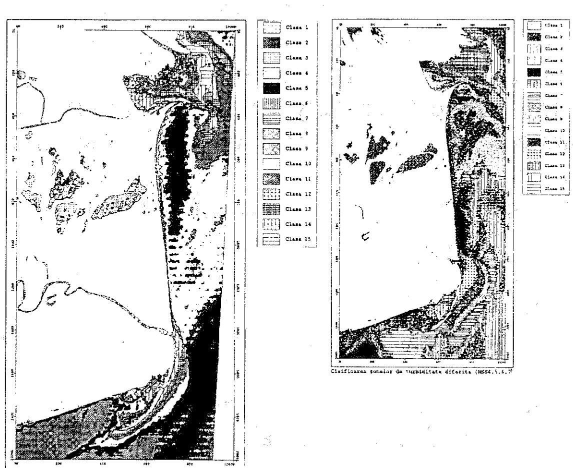

Fig.4.&5. Classification of the different turbidity level waters on the Landsat TM(1,2,3,4) image, from August 1989.& Classification of the different turbidity level waters on the Landsat MSS image, of July 1975.

- The fusion between MSS & TM and SPOT recordings with SAR - ERS taken as reference (the best resolution recording has been taken as base) using polynomial registration; for a high accuracy of registration - fusion of the aero-satellite images we have tried to modify their geometry by enlarging them;
- Marine drilling profiles and their afferent classical determinations positioning on the aerial satellite recordings;
- Radiometric seasonal profiles, built on characteristic and suggestive directions, basically on the "Great Deltaic Profile" and over different ecosystems (see fig 3);

3.2. Preliminary processing of SAR - ERS recordings, taken as relative reference level:

- ERS recordings segmentation:
 (a) on ecosystems basis;
 (b) on hydrographic basins and microbasins basis;
 (c) visual, with successive adjustments using pdf (Probability Density Function);
- Speckle attenuation using:
  - adaptive filters (Lee, Kuan, Frost, Gamma filters); The most adequate filter has been found to be the Gamma filter.
- Geometric filters; these filtrations are performed on the whole recording or on wide hethero-geneous areas, respectively on image segments, with visualisation before and after the application of the filters, with comparisons of the obtained pdf; (Probability Density Function);
- Colour - composed RGB and IHS system processing, as well as transforms from RGB to IHS colour spaces on the whole recording (or wide areas) and on image segmentation respectively.

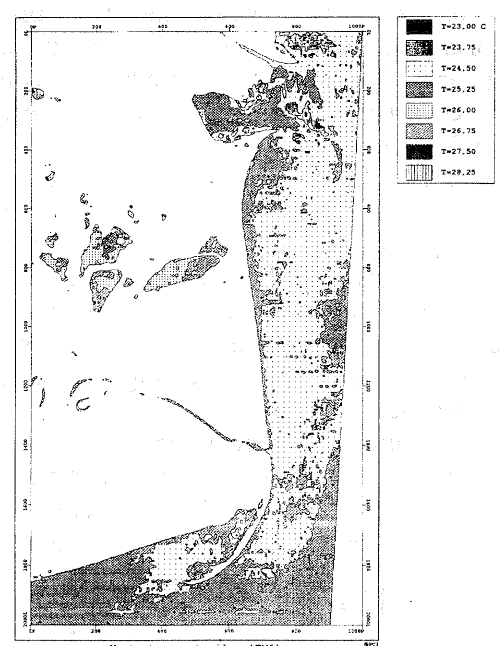

Fig.6. Temperature map on the Landsat TM6 image from August 1989.

4. IMAGE PROCESSING, INTERPRETATION AND OBTAINEED RESULTS.

4.1 Processings using radar recordings combinations and recordings from optical domain: supervised and unsupervised classifications using M.L.R. (maximum likelihood rule) and NN (nearest neighbour) algorithms, results comparisons with confusion matrix use;

4.2 Because the principal components analysis (PCA) is a statistical technique, that transforms a multivariate data set consisting of intercorrelated spectral bands into an uncorrelated data set, with a geometrical dimension less than the geometrical dimension of the original multispectral image,we applied this technique on LANDSAT MSS images, and we verified the signal - to - noise ratio theory (Santiesteban & Munoz - 1978).

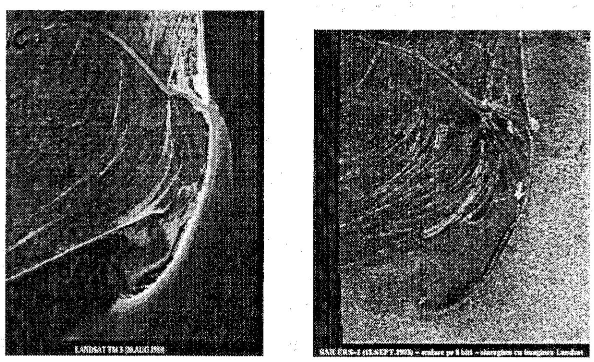

Fig.7. Landsat TM - 1989 image(left), compared to SAR - ERS - 1 (right) showing the morphological changes of the Sacalin Island.

4.3. The new image band, the first principal component, is used in image enhancement, for change and edge detection. For edge detection we have used a photogrammetric technique described in the following:

- considering the remote sensing image as a "positive image " we compute its " negative " by subtracting from an established maximum grey level the grey level values of every pixel;
- adding the "positive image" to this "negative", shifted with one line and one column, we obtain the edge of the phenomena appearing in the remote sensing image.

4.4 Classification of different turbidity level waters: (a) a bitmap has been drawn, by thresholding the MSS 7 band in - between 0-4 grey level values and TM 5 band in - between 1-16 grey level values.

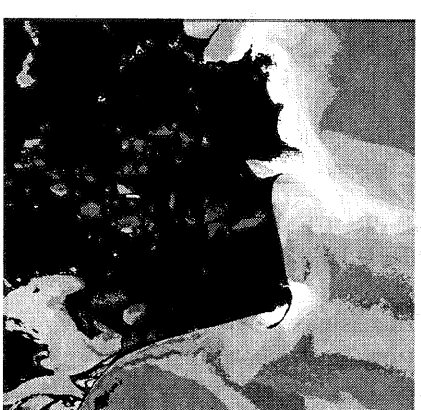

Fig.8. Classification of the different turbidity level waters on the Landsat MSS image of July 1975.

The best spectral bands to detect the suspended sediment concentration are the MSS 4, 5 and TM 1, 2, 3; the MSS 6 is adequate for chlorophil pigment detection; (b) an unsupervised classification was performed (ISOCLUS program, together with extracting the spectral signature for each class; (c)the spectral signatures obtained were used for a maximum likelihood classification (MLC program); (d) an average filter (FAV) and a modal filter (FMO) were used for eliminating the "striping" type noise.

For each of the 2 images classifications (see fig. 4, fig.5) the confusion matrices were drawn; the maximum confusion values obtained were 87-88%.

- An interpretation of the two classified images can be performed having the meteorological conditions in the moment of the images acquisition: for the Landsat TM image (fig. 4) the N-NE wind direction and 10 m/s speed, can explain the narrowing and the direction of the suspended sediments plume (lower part of fig.4), as well as merging of the waters with different turbidity - upper part of fig.4. In the Landsat TM classified image, both of these suspended sediment plumes were much enlarged and the different turbidity level classes very well separated, in good correlation with the wind direction and speed (W,2 m/s).
- Atmospheric corrections were performed on the TM 6 thermal band, in order to extract temperature information (ATCORT O program); the grey levels were transformed into grey levels, corresponding to temperatures, after the atmospheric correction - see fig.6.
- Isodensity lines were drawn (fig.9) over the Landsat MSS, following the algorithm:

Fig.9. Isodensity lines over the Landsat MSS image, separating the calsses of water with different turbidity levels.

- classification over the selected zones (ISOCLUS MLC);

- modal filtering to eliminate the "striping" noise - fig.10;

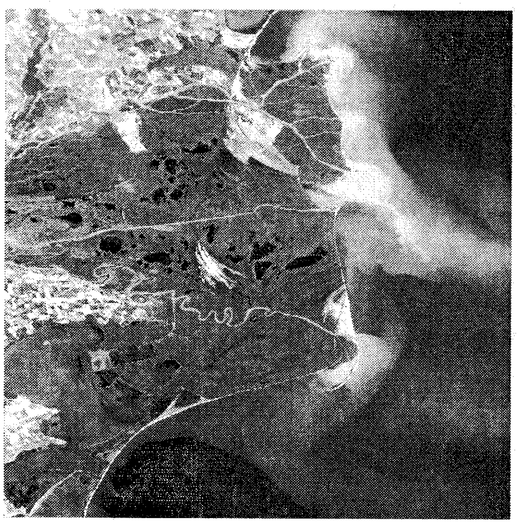

Fig.10. Landsat MSS 6 image of the sudied area.

- Sobel edge detection (SOBEL), fig.11;

- thresholding the edge detected features into a bitmap (THR);

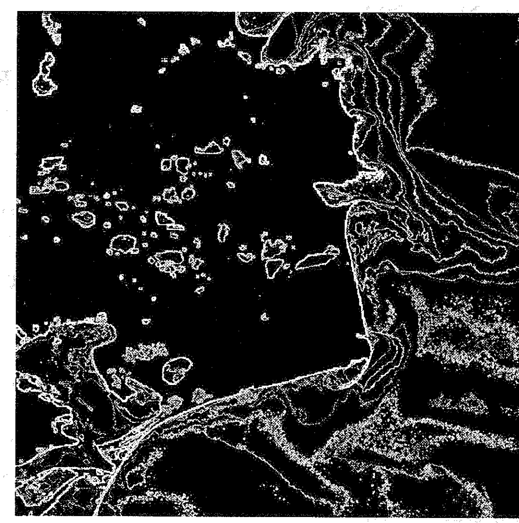

Fig.11. Sobel edge detection filter on the filtered classified image (Landsat MSS).

- encoding the obtained bitmap into an image channel (MAP), showing the isodensity lines - fig.12.

- In order to monitor the morphological changes of the Sacalin Island, the Landsat MSS - 1975 and Landsat TM - 1989, have been fusioned with the SAR - PRI - 1993. The principal components were extracted from the four MSS bands, in order to better visualise the shape of the Sacalin Island. It can be easily observed how the island has thickened in time, due to sediment depositing - fig.7 a and fig.7 b; fig.12 a and fig 12 b.

- Significant results are obtained in monitoring the pollution:

- a proliferation of phytoplancton algae took place in 1975 (mainly Exuviela cordata - 40-50 mil/1); this phenomenon - biological pollution type "red blossoming" may be clearly observed on the Landsat data of 16.06.1975 (fig.13). The phenomenon began to decrease in July, fact which was confirmed by the Landsat image of 25.07.1975. During the cold season of 1976 a new wide-spread "red blossoming" occurred - this time due to diatomee (Scetanema - more than 60 mil/l) which may be clearly seen on Landsat data of 26.02.1976 - band 4,5.

- The Landsat MSS & TM recordings on bands 5 and 7 show the successive stage of the evolution of the Danube Delta, clearly marking the seperation between the fluviatile delta and the marine delta;

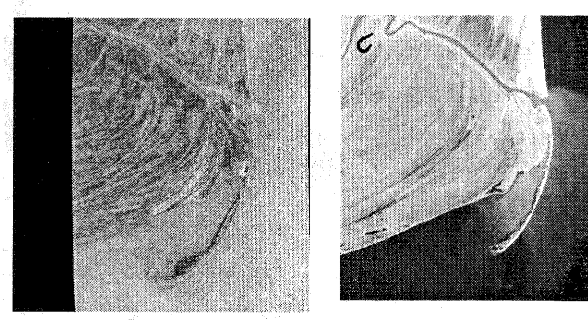

Fig.12. Monitoring the morphological changes of Sacalin Island,between 1975 and 1993 Landsat MSS first principal component(1975-right) and SAR-ERS-1(1993-left) images.

- In order to monitor the beach evolution and to establish the maximum instability areas, field surveyings have been performed, landmark on coastal zone and measurements on profiles, airborne and some correlations with space data, allowing us to monitor the sediment discharge and depositing regime in the sea, near the Danube mouths.

5. SOME PROPOSALS FOR FURTHER DEVELOPMENTS:

- Completing and perfecting our "in-situ" radiometric targenting system, mainly for the radar data. There is an obvious need to adapt the classical (conventional) measurements to the specific remote needs, for static objects-phenomena, as well as for slow, respective rapid variable in time ones.

- Also a sustained activity of standardisation should take place, for the expertise, compatibilisation and complementarity of data, their fusion and integration, thus allowing the interchange between data, information, experience and expertise exchanges;

- Approaching and solving some of our country's major problems: i.e. monitor and control of the national hydro-energetic and hydro-reclamation systems, of large landslides, of deltaic subsidence; drawing up of DEM-DTM, mainly for the micro-relief.
- Regarding the international collaboration - we are proposing to facilitate - on a partnership system basis - exchanges of caracteristic "windows", extracted from the ERS recordings, for each of the operating modes of the SAR-ERS instrument.

Fig.13."Red blossoming" phenomenon - biological pollution, monitored with satellite recordings (LANDSAT MSS - 16.06.1975) on the Romanian coastal area - colour composite - analogical processing.

- Monitoring of oil pollution being of special interest for us, we intend to develop an application of indentification of oil spill pollution based on principal component and linear discriminant analysis.
- Last, but not least, we would like to express our wish and intention not to lose touch with the advanced and top technologies, even in the rather difficult conditions we are passing through.

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