The remote sensing approach. A modern technique to control sea pollution.
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Abstract

In the following pages, some of the most significant activities, developed at the Remote Sensing Group of the University of Catania in Italy over a near 20-year period in the field of remote sensing related applications for environmental control, are reported briefly. The remote sensing approach is proposed as a new modern technique, to control sea pollution, and more in general the marine environment, having proved its effectiveness as a means to integrate, and in a number of applications, to substitute conventional investigation techniques.

1 Introduction

The pollution of the marine environment is one of the most serious forms of pollution, because of its effects on the biological and ecological balance of life on our planet. The extent of the problem, in terms of quantity and variety of pollutants, and the amount of polluted coasts, require a marine environment surveillance system, to provide rapid identification of pollution.

Today, remote sensing makes available very sophisticated means, for effective monitoring of the marine environment. The experience gained by the Remote Sensing Group of the Institute of Machinery, Faculty of Engineering, at the University of Catania in Sicily, Italy, over a near 20-year activity in the field of remote sensing and related applications, has given rise to a methodological approach, based on a
number of data sets acquired from different monitoring platforms (spacecraft, aircraft, naval craft, fixed platforms).

This approach is proposed as a new modern technique, to control sea pollution, and more in general marine environment. In fact, it has proved its usefulness and effectiveness, as a means to integrate, and in a number of applications, to substitute the conventional techniques of investigation.

2 Remote sensing approach

Remote sensing offers the most effective approach to perform either general or detailed investigations, quickly, repeatedly, and money-wise effectively. Remote sensing techniques allow the selective detection and measurement of the radiation in the ultraviolet, visible, infrared, and microwave bands of the electromagnetic spectrum. Sensors used are photographic, television, scanning, LASER, RADAR, and microwave-receiving systems. They can be installed on particular platforms, such as spacecraft, aircraft, naval craft, fixed platforms.

Data acquired are recorded as imagery, that is not merely photography, recording visible light, but also may record information concerning the invisible parts of the electromagnetic spectrum. Analyzing such imagery with computer-aided interpretation techniques, it is possible to investigate a wide range of phenomena. Large area synoptic views, acquired using remote sensing techniques, provide information, not easily obtainable using conventional investigation techniques [3].

3 Remote sensing of marine environment

Remote sensing of marine environment, and in particular that of sea pollution, is very important, because it provides information in the form of synoptic views, which are difficult to obtain, using traditional surface sampling methods.

Light, near infrared and visible electromagnetic radiation are used, to obtain remotely-sensed information on sea pollution. By studying how the intensity and color of luminous radiation is altered, passing through water, the nature and concentration of elements, present in it, can be inferred.

However, other attenuation phenomena should be allowed for, since they may interfere with the measurement
process. In particular, the primary radiant flux density (sunlight) is modified, as light passes downward through the Earth's atmosphere. According to the position of the sun and the topography of the water surface, part of the radiation is reflected from the air-water interface. Therefore, the signal relating to this radiation does not give any information on sea pollution below the surface. The light, penetrating the water downward, is attenuated by the water itself, and the elements there present modify the light spectral characteristics, through absorption and diffusion. That portion of the diffuse light, reflected by the water toward the sensor, contains the only useful information for detecting and measuring the elements present in the water.

The bands of the electromagnetic spectrum, more significant for sea pollution, are the ultraviolet (UV, 0.3–0.4 μm), near infrared (NIR, 0.7–3 μm), and thermal infrared (TIR, 8–14 μm) bands. In particular, the reflected infrared (0.7–0.9 μm) band provides an effective means, to control the quality of water bodies. In fact, analyzing the alteration of light through water, useful information on existing pollutants can be obtained. Also, appropriate TIR sensors can detect temperature differences in a water body, and particularly amongst the various parts of a water body. For example, the difference between the radiometric temperature of clear water, and that of water covered with a thin oil film, is approximately 1.4 °C, because of the different emissivity. Oil films, as thin as 0.15 μm and 10 μm, are detectable in the UV and TIR bands, respectively [3].

4 Experimental activity

Over many years, remotely-sensed data have been collected by the Remote Sensing Group at the University of Catania, for the monitoring of water quality, and the assessment of sea pollution, in the coastal areas of the Central Mediterranean Sea, and especially those around Sicily.

LANDSAT MSS (Multispectral Scanner) and TM (Thematic Mapper) data, as well as MSS data, TIR imagery, UV and infrared (IR) photography from lightplanes and helicopters are among the remotely-sensed data acquired over a number of study areas.

Helicopters of the Naval Helo Station (MARISTAELI), at Catania in Sicily, were flown several times, using IR photography and TIR imagery. The simultaneous use of multispectral (MS) photography and TIR imagery, as
well as improvements in digital image processing procedures, made it possible to develop a purpose-built remote sensing system for helicopters. This system, named «Pelican», is an Airborne Maritime Surveillance System (AMSS). It utilizes MS photography, TIR imagery, and digital image processing (DIP). The system was, successfully, tested in a number of flights over the Sicilian coastal zone, for monitoring marine pollution [4, 6].

Recently, the Italian Merchant Marine Ministry has acquired a number of Piaggio P.166-DL3 aircraft for the Coast Guard (Capitanerie di Porto), to provide the surveillance of the marine environment. An Aircraft Remote Sensing System was developed, and it was integrated into such platform. The system includes Aerial Camera System (ACS), Bispectral Scanner System (BSS), Multispectral Scanner System (MSS), FLIR (Forward Looking Infrared) System. The surveillance techniques, using this kind of sensors, offer a unique capacity for monitoring the ground, during the night and day. Data, acquired in a number of flights over Italian coastal waters, were used [1, 5].

Also, LANDSAT MSS and TM data were used, to map oil pollution and water quality in Sicily [2, 4, 5, 6, 8].

Frequently, different remote sensing techniques were integrated, in order to experiment the obtaining of the best results, such as for the simultaneous use of LASER and IR techniques from helicopter. Active and passive remote sensing systems, in particular a LIDAR (Light Detection and Ranging) System and a FLIR System, were used, to determine water pollution characteristics with the LIDAR System, inside polluted areas of water, detected, on a larger scale, by the FLIR System. The experiment, named «LIRA» (LASER e Infrarosso per l'Acqua), was carried out, jointly with the National Council of Researches at Florence, Italy, using an Italian Navy helicopter [7].

The Gulf of Castellammare, the Gulf of Palermo, the Gulf of Milazzo, the Strait of Messina, the Bay of Augusta, the Gulf of Gela, oil offshore platforms, and the Maltese coastal waters, are among the sites investigated over many years, [8, 9].

Imagery obtained from aircraft was analyzed, using computer-aided interpretation techniques, through systems for digital image analysis. Highly polluted areas, urban and industrial discharges, illegally discharging vessels, oil slicks, thermal pollution, etc., not only daytime but also at night or under poor
light conditions, were among the features shown, clearly, by processed imagery [1, 4, 5, 6]. Pollution characteristics, such as type of pollutant, type of oil, oil thickness, etc., were detected by the simultaneous use of LIDAR and FLIR Systems [7].

As regards the analysis of LANDSAT data, the general approach involved acquisition of water quality samples from boats, near-simultaneously with LANDSAT overpass, location of samples sites on the LANDSAT scene, extraction of digital numbers from all bands, development and verification of regression models relating values of selected water quality parameters to the spectral data, application of models to the entire study area, and generation of color-coded resultant images.

The interpretation, process, and digital analysis of data, acquired from aircraft and satellite, made it possible to obtain color-coded imagery, showing oil pollution, distinguishing different types of it as a function of the intensity level, calculating their extension [4, 5, 6]. Also, color-coded images, each depicting the distribution of a selected water quality parameter (chlorophyll-a, Secchi depth, surface temperature, and turbidity) were produced [2, 8].

5 Conclusions

In the effort to protect the marine environment, remote sensing is of great importance, providing an effective means to identify critical areas, and to control sea pollution. It offers the capacity, literally, to see what is invisible. Synoptic views of large areas provide information, not easily obtainable with the use of conventional techniques. Thus, environmental elements can be analyzed on an ecosystem basis, where remotely-sensed data may transcend the limits of data acquired with conventional techniques.

6 References


Figure 1: LANDSAT-TM based image, showing the oil spill in the Gulf of Genoa, Italy.

Figure 2: LANDSAT-TM based image, showing the turbidity distribution in the Gulf of Gela, Italy.
Figure 3: LIDAR spectrum, showing an oil pollutant in the Bay of Augusta, Italy.

Figure 4: Aircraft-TIR based image, showing a sewerage outfall into the Maltese coastal waters.