The HRPT station at IRMA–CNR in Mazara del Vallo for the acquisition and analysis of satellite data in the Strait of Sicily

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Abstract

The satellite data receiving station recently installed at IRMA–CNR is presented. It consists of a set of hardware and software and receives visible and infrared images from NOAA and ORBVIEW satellites. The images are received (NOAA and SeaWiFS) with a resolution of 1 square kilometre. The institute is currently developing treatment protocols for the image processing according to the use the images are destined for. A review of the remote-sensing applications is made for different fields of research and management. A focus is made on the study of the Strait of Sicily where the objective is to connect the knowledge on physical environment to information provided by remote-sensing data. Future application would be to use parameters such as temperature and ocean colour of the sea surface to monitor and forecast the biological productivity of the water column and ultimately the state of the fishery resources.

1. Remote sensing of the Strait of Sicily at IRMA–CNR in Mazara del Vallo

The HRPT–LAC (high-resolution picture transmission–local area coverage) receiving station was installed at IRMA–CNR (Institute of Research on Marine Resources and Their Environment, of the National Research Council) in Mazara del Vallo with the objective of obtaining satellite data and infrared imagery by remote-sensing monitoring of the Mediterranean basin and the Strait of Sicily.

Since May 2002, IRMA–CNR has been one of 128 authorized NASA research stations for SeaWiFS high-resolution LAC data (IRM, Serial no. 2082, Mazara del Vallo).

Another authorized station is MLT at the University of Malta, Euro-Mediterranean Centre on Insular Coastal Dynamics. These two stations can collaborate to develop joint research on the description and analysis of the physical environment of the Strait of Sicily by remote sensing.

IRMA–CNR submitted the "Letter of Agreement for SeaWiFS Direct Readout Ground Stations" and obtained from NASA an agreement that temporarily enables a non-real-time SeaWiFS HRPT station to decrypt real-time data and release it to authorized users , under a research project denominated "Analysis and forecasting system of the fishing fleet in the Strait of Sicily based on satellite SeaWiFS data."

The IRM SeaWiFS HRPT station, after a testing and validation period, has been operational since November 2002 and has collected some images from satellites NOAA 12, NOAA 14, NOAA 15, NOAA 16, NOAA 17 and ORBVIEW-2/SEASTAR.

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2. General description of the IRM–HRPT station

The receiving station (HRPT IPLASAT PC-1800) is of the automated HRPT type and currently receives visible and infrared images from AVHRR sensors on NOAA and ORBVIEW satellites. It consists of a set of hardware and software which includes the orbit calculation programmes, the visualization programme, the power system for dish movement, the microprocessor systems to receive the radio-frequency signal, to transform it into a digital signal and to memorize it on disk.

It is a completely modular system with different possible configurations. While the receiver works for NOAA, ORBVIEW-2/SEASTAR, it also monitors the Russian meteorological satellites (COSMOS, METEOR, OKEAN), the Chinese satellite (FENG YUN) and those of METEOSAT. The OKEAN data acquisition is particularly important because these satellites are equipped with SAR (synthetic-aperture radar).

The station is provided with all the installation equipment and precision mechanics needed for the whole cycle of mechanical processing of the station and thus constitutes a suitable LAC unit. The installed system represents a high-technology system in the fields of mechanics, electronics and computer science. Its highly sophisticated processing packages (ER Mapper, SeaDAS, ERDAS, ARC/INFO, CHIPS, IDRISI and so on) permit the automatic acquisition and memorization of the data transmitted by satellites for the purposes of research and monitoring.

Currently, following the period of testing, the station is used for the reception of the data from satellites NOAA 12, NOAA 14, NOAA 15, NOAA 16, NOAA 17 and ORBVIEW-2/SEASTAR.

The next objective of the Remote-Sensing Group at IRMA–CNR is to upgrade the station to assure the reception of data from the IKONOS, MODIS, ENVISAT and LANDSAT satellites.

All the received images and data are stored in a data base that will be available online with a view to allowing rapid consultation of the data and the use of the images by other research centres.

3. Image analysis and processing

At the moment, the station is equipped for the reception of NOAA and SeaWiFS images. The spatial resolution (the smallest area on earth distinguishable by a satellite's instruments) of these satellites is 1 square kilometre. The on-board sensors record the emission or reflection of electromagnetic waves from objects on earth at different frequencies. What we see as an image is actually a representation of the recorded radiation values. The information content is therefore far greater than that given by simple photography. Particularly, the NOAA satellites transmit in five wave bands, while the SeaWiFS transmits in eight bands (from the visible to the infrared) plus telemetry data. In any case, each received image needs to be processed and the number of treatments depends on the utilization the image is destined for. Typical treatments are geo-referencing, geometric corrections, light corrections, atmospheric-effects corrections and noise reduction. One of our main targets is to create a protocol and some

patterns for the image processing in relation to various classes of homogeneous projects (creation of experienced systems for image processing).

The NOAA advanced very-high-resolution radiometer (AVHRR) covers very large regions of the earth with a high spatial resolution (about 1 km) relative to the area covered (hundreds of thousands of square kilometres).

The remote-sensing applications range from cartography to defence to natural-resource studies. The remote sensing of ocean colour from space provides information on the abundance of phytoplankton and the concentration of dissolved and particulate material in ocean surface water. This information can be used to investigate biological productivity in the oceans, marine optical properties, the interaction of winds and currents with ocean biology and how human activities influence the oceanic environment.

In the field of integrated coastal-zone management, the following applications are particularly interesting:

- geo-referencing by GIS
- chlorophyll maps
- temperature maps
- suspended-solid maps
- monitoring of eutrophication.

These data might help to monitor processes like cliff erosion, land-use changes, urban development and the changes in the natural vegetation patterns. Other interesting applications in the environmental sphere, such as the creation of land-coverage maps or the prevention of natural disasters, require the reception and utilization of images with a greater spatial resolution (from 200 m to 10 m), but our station is not yet qualified for that.

4. Main target of research: the Strait of Sicily

The main object of study will be the Strait of Sicily, with the purpose of integrating the knowledge of the physical environment of the region (hydrographical characteristics, bathymetry, sedimentogy, habitat mapping, bottom topography of the fishing grounds) with that furnished by the remote sensing.

The Strait of Sicily connects the two main basins of the Mediterranean, the western and the eastern. At its narrowest point, between Cape Bon (Tunisia) and Mazara del Vallo (Sicily), the Strait is about 130 km wide. It is characterized by a two-layer flux model, like the Strait of Gibraltar. The upper layer, called "Modified Atlantic Water" (MAW), is identified by water with a relatively low salinity flowing from the western towards the eastern basin. The lower layer, called "Levantine Intermediate Water" (LIW), is identified by water with a relatively high salinity flowing in the opposite direction, like an undercurrent.

The complex bathymetry influences the features of the currents in the region. A bottom ridge in the middle of the Strait divides the flow into two parts: one along the Sicilian shelf, which is narrow and deep, the other off the Tunisian coast, which is wide and shallower. Astraldi

and colleagues showed that these two parts have two different flows, for the MAW and for the LIW. Measurements have shown that the mesoscale signal prevails in the upper layer, with the presence of eddies and meanders.

According to Robinson and his co-workers, the MAW motion, called the "Atlantic-Ionian Stream" (AIS), has quite a steady mean path. It enters the Strait from the western side along the Adventure Bank (south-western shelf of Sicily), coming close to the Sicilian coast in the middle of the south coast of Sicily (the deep Gela Basin) and separates again when it encounters the Malta Bank (south-eastern shelf of Sicily).

The AIS encircles two large cyclonic meanders, identifying two sectors, one around the Adventure Bank on the western side, the other around the Malta Bank to the east.

An analysis of the SST, which affects the survival/mortality rates in the early life stages of red mullet, influencing the strength of recruitment at two sites, can be carried out using satellite imagery, in connection with studies on the phenomenon of upwelling.

5. Other fields of research

The relationship between the biological and physical phenomena of the sea is of great interest and the object of study for potential applications, as for instance that of a good knowledge of the state of the resources of the sea (with the possibility to effect assessment and forecasting). This type of information is very useful in the fishery and aquaculture sectors. The use of the techniques of remote sensing as a means of locating populations of pelagic species has been hypothesized since the appearance of the first airplanes.

The best sea parameters observable from space are the temperature and colour of the sea surface: they can be used for the identification of specific currents and the classification of water bodies. The first attempt at aerial observation was in 1970 with measurements of spectral radiance to calculate the concentration of chlorophyll. During the last 30 years, the technology of remote sensing has greatly improved, putting the problem of its use in support of fisheries in evidence. It is not possible to observe a shoal of pelagic fish directly by remote sensing from space. The most appropriate way to use remote-sensing data is to connect the observable physical parameters with the presence of fish species. These relationships must be defined both from theoretical (or empirical) relationships and from "ground-truth" observations. A typical example is the sea areas characterized by upwelling, in which, as a rule, prevailing winds, combined with Coriolis' force, pushes coastal surface water towards the open sea, the consequent deficit being met by deeper and colder water rich in nutrients. These areas of upwelling are among the richest in nutrients and where the greatest quantity of pelagic resources is found. These areas are also in many cases (especially in summer) observable by satellite radiometers both by the presence of colder water and the distinctive colour which therefore serves as a tracer.

A fundamental problem is the location of the areas of high primary productivity and the discrimination of the relationships between the productivity and the observable parameters (colour, temperature and chlorophyll). In view of the objective to evaluate the distribution of the areas of higher than average abundance of marine resources, especially from space remote-sensing data, their spatial and temporal distribution are more important than the absolute value of the biological variables (particularly of the primary productivity). Primary

productivity is correlated, even if only approximately, with the biomass of phytoplankton and can therefore be determined. The photosynthetic pigments of the phytoplankton, especially in the open sea, are the principal modulator of the colour of the sea as observed from space.

Thus from the space observation in the visible spectrum it is possible to correlate certain parameters with the biological productivity, such as the phytoplankton biomass or the chlorophyll concentration (i.e. ocean colour); this has proved to be of fundamental importance in the evaluation of marine biological activity.

The sea-surface temperature is another fundamental indicator, correlated with the ocean dynamics as a major factor in the determination of the thermal gradient and the formation of thermal fronts. In some cases it is used for differentiating pelagic species, based on the fact that certain species have a specific temperature preference and that a direct correlation between the presence of certain species and the temperature gradient exists.

The application potential of these observations is resumed in the possibility of analysing and, in some cases, forecasting the state of the fishery resources and their spatial and temporal distribution.

The sea-surface temperature, in addition to being the parameter most easily observed from a satellite, is also recognized as an indicator, with considerable direct and indirect effects on marine plants and animals, since these have the tendency to move within certain temperature ranges and along thermal fronts, depending on the species.

At IRMA–CNR, with the HRPT receiving station, it will be possible to develop new lines of research in the followings fields:

- seasonal and interannual variability of the SST field in the Strait of Sicily
- integrated study of sea-level anomaly, ocean colour and SST mesoscale dynamics in the Strait of Sicily, based on satellite data.