Monitoring the Black Sea Region Using Satellite Earth Observation and Ground Telemetry

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Abstract. The Black Sea region is affected by important environmental transformations and EO (Earth Observation) is considered a new way to monitor and, possibly, solve some of its critical issues. The ecological alterations, essentially caused by anthropogenic factors, are the main cause of many transformations such as the ecosystem changes, coastal erosion or pollution that affects water quality. The purpose of this paper is to present the environmental measurements performed with ground telemetry systems near the Black Sea coast in the Danube Delta and the fusion of sensor data with datasets from EO satellite applications. We present the BEIA telemetry system that has been installed and is further being developed for the National Administration "Romanian Waters" (ANAR), an automatic system able to continuously monitor the level and water temperature along the Danube, Danube Delta and some of its tributary rivers. Furthermore, we demonstrate how big data processing software can be used for extracting non-trivial correlations from telemetry and EO data. This paper is a general overview of the results for telemetry and EO integration in the Black Sea and the Danube region and could support ESA (European Space Agency) in defining future investments in EO research and development activities to foster EO innovation in the region.

Keywords: Ground telemetry · Satellite observation · Black Sea
Danube river · Water quality

1 Introduction

The Black Sea has been affected by significant ecological alterations caused by the anthropogenic factors. The major issues affecting the environmental state of Black Sea are pollution, loss of biodiversity and coastal degradation [1]. Scientists have identified several serious problems for the Black Sea associated with various types of pollution. One of them is the eutrophication phenomenon of the sea by nutrients which are compounds of nitrogen and phosphorus, as a result of pollution from domestic,

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agricultural and industrial sources [2]. Another type of pollution is caused by oil spills. Oil interacts with the marine environment as a result of operational or accidental discharges from vessels, as well as through insufficiently treated wastewaters from land based sources [1]. Heavy metals such as cadmium, copper, chromium and lead are usually associated with waste from the heavy industry and ash remaining from burning coal usually used for generating electricity. Furthermore, pesticides enter the sea mostly through rivers and streams due to agriculture [2]. Another major problem is the discharge of insufficiently treated sewage waters, which leads to microbiological contamination and poses a threat to public health. Radioactive substances have been introduced to the Black Sea in small quantities from nuclear power plants and in more significant amounts after the nuclear power plant disaster from Chernobyl which occurred in 1986 [3]. An unusual form of pollution from ships is the introduction of exotic species, mostly through exchange of ballast waters or other wastewaters. The final major type of problematic pollutants is solid waste, dumped into the sea from ships and some coastal towns [4]. In that situation, Earth Observation (EO) could provide an opportunity for applications, innovative science and information services to deal with these problems.

The paper is organized as follows: Section 2 presents related work in the field of telemetry. Section 3 presents the proposed solution for tele-monitoring while Sect. 4 analyses the obtained results. Finally, Sect. 5 draws the conclusion and envisions future research directions.

2 Related Work

Through the MarineGeoHazard [5] project, implemented by Romania and Bulgaria, the main focus is to manage natural hazards at the Black Sea and the risks associated with their effects in trans-border area of the Romanian-Bulgarian coast. Also, there was implemented a rapid alert system in real time for the Black Sea, “Black Sea Security System”, implemented in both Romania and Bulgaria, capable of delivering in continuous mode to the authorities of the two countries specific information which may lay at the basis of the decision-making [6].

Furthermore, the EUXINUS [7] project developed the first complex system for monitoring-alarm in real time to the marine hazards, with the risk to the coastal zone of Romania. The network is composed of three buoys EuxRO1, EuxRO2, EuxRO3 which are located on the Romanian continental plateau, in the territorial waters of Romania. For example, Surface Buoy (SRB) with the following features were deployed: solar recharging for the batteries, the management of the electrical supply of the base station, shiftable communications satellite/radio, data acquisition with the integrated management system, the remote control and communication in real time radio/satellite, weather sensors, active and passive radar, optical signals, acoustic output for the management of the communication and transmission of the data with installed submarine equipment. Furthermore, multiparametric wells were fixed at 5 m depth which includes sensors for: current, conductivity, temperature, pressure, oxygen, turbidity, chlorophyll and tsunamometer which is mounted on the bottom of the sea near the buoy [8]. It includes an anchoring system, a battery system for the supply of the sensors and a tsunamometer positioned on the bottom of the sea with acoustic modem for bidirectional communication with the surface buoy with remote triggering system. In [9] the water quality was monitored in the Black Sea region based on two characteristics: ecological status and chemical status. Furthermore, the Romanian National Center for Monitoring and Alarming to Natural Marine Hazards presented in [10] hardware devices used for the evaluation of the impact of the marine geohazards by providing maps in a standard GIS format.

3 Proposed Solution

For the tele-monitoring of the water level and the temperature in the Black Sea region along the Danube and some of its tributary rivers, an automatic system was installed under a continuous development for the ANAR ("Administratia Nationala Apele Romane") [11]. This system consists of some central elements, such as the Data Concentrator (Gateway) and the data presentation server. Data concentrator (Gateway) performs communication with the remote telemetry units (RTUs) and also allows the configuration and management of all RTUs and sensors. The data is presented in various formats so the users with the rights to change it could choose the one who suits their needs. Data processed by the presentation server are continuously and automatically exported towards ANAR's central data and dispatcher systems.

The monitoring system with GPRS has the schematic flow of data as presented in Fig. 1.

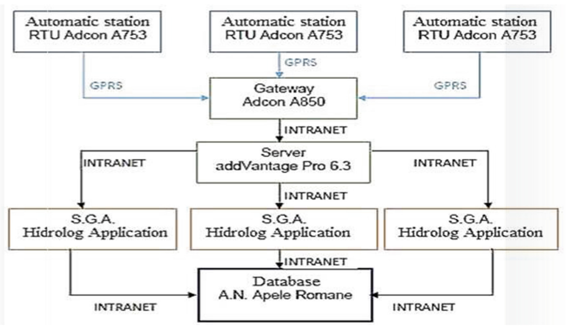

Fig. 1. Schematic flow of data

The RTU and the telemonitoring are powered by a solar panel, while a combo sensor for air temperature and relative humidity can be found at the recently installed ones. All sensors attached to a certain RTU are powered and read during short periodic time intervals. At every 15 min, the RTU computes from periodic measurement results an average value. At every hour, the 4 average values for every of the monitored parameters is sent by the RTU to the A850 central gateway. At the ANAR headquarters, the installation consists of a gateway (Adcon A850) and the application server addVantage Pro 6.3 which transfers data from the gateway and has the following functions: data visualization tools, basic editing tools data and it has a module that allows data export in different file formats.

4 Results

In this section we present and evaluate the results of measurements performed with water quality sensors, for sediments and results of satellite observation of the Black Sea region.

The data are high-resolution radar images obtained by the radars onboard Envisat satellite (till the spring of 2012) and Sentinel-1, starting from October 2014 [11]. Figure 2 shows the cumulative map of oil-containing spills. These pollution events are caused by spillages of oil-containing waters from moving ships. Also near the major ports of Bulgaria, Turkey, Romania and Ukraine a large amount of spills is observed near oil loading terminals.

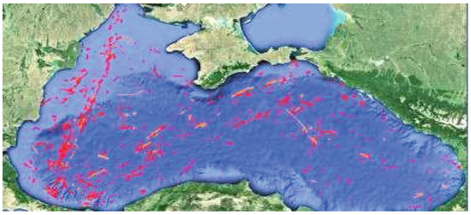

Fig. 2. Map of oil spills on the Black Sea surface revealed from the satellite radar imagery

In Fig. 3 we present some numerical data on oil spills in the Black Sea aquatic area. From the charts it can be seen that over 40% of spills detected in radar images do not exceed 1 km^2 and polluted areas in 80% of events are less than 5 km^2. However the ships discharges wastewaters several times while they are under way and under the influence of the wind and waves, the film spreads over the sea surface covering large areas. During warm season are registered the larger numbers of spills. As an explanation, the better weather conditions are favorable for recognition of spills in satellite radar images.

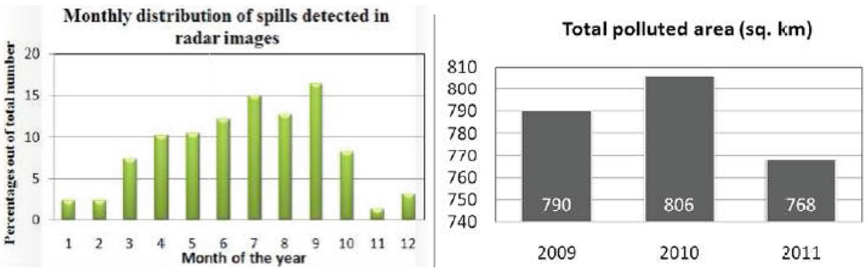

Fig. 3. Statistic data for oil spills

Furthermore, Fig. 4 provides a representation of the oil pollution on the Black Sea and can specify that pollution is produced by different sources as oil spills and under the influence of the wind and waves, the film spreads over the sea surface covering large areas.

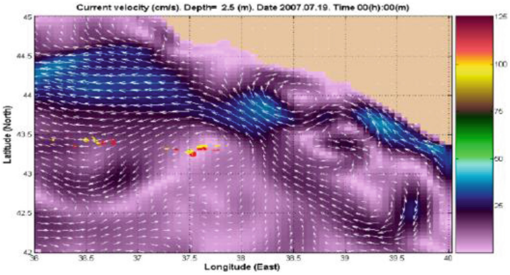

Fig. 4. Surface currents field by Black Sea operational model output. Predicted daily shift of the oil spill from red to yellow (Color figure online)

In Fig. 5 we present the observation of a great mass of water at the monitoring station Unirea (close to Cernavoda), with level changes slower than those at a monitoring station situated about 300 km upstream, at Bechet. Evolutions at Unirea are lagging behind evolutions at Bechet with something like 2–3 days.

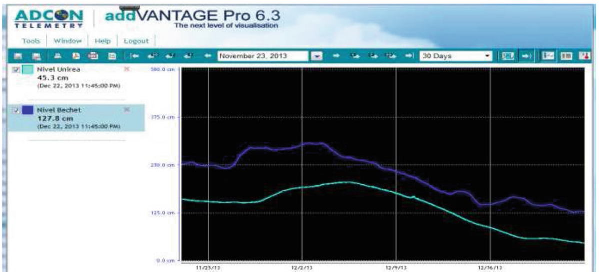

Fig. 5. Water level on the Danube measured using the ground telemetry system

Besides accurately reading and transmitting data from attached sensors, the RTUs also transmit useful data about its own functioning, for example battery voltage, internal temperature, data delay and radio error rate.

5 Conclusions

The Black Sea region is in an advanced state of ecological disequilibrium and in that case is a strong need for developing environmental monitoring and protection in accordance with sustainable development. In this paper we presented an approach for using data from Satellite Earth Observation and Ground Telemetry for monitoring environmental parameters. The performed observations have demonstrated a clear necessity to implement telemetry monitoring on Delta, Danube and Black Sea waters, so the proposed system, which provides water level monitoring, has potential to be extend in order to assess further water parameters.

As future work we will analyze satellite and ground telemetry data to cover further requirements for water quality monitoring, such as pH, dissolved, algae, oxygen and turbidity.

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