Executive summary:

4.1 Final publishable summary report

4.1.1.- Executive Summary.

Automatic Oil spill Recognition and Geopositioning integrated in a Marine Monitoring Network
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Contacts: Michele Cocco, Ph.D., Coordinator, ARGOMARINE Project
C/o Tuscan Archipelago National Park, Loc. Enfola - 57037 Portoferraio-Isle of Elba (LI), Italy
mobile: +39-348 7045202; phone: +39-0565 919411; fax: +39-0565 919428; skype: mike-elba

http://www.argomarine.eu

The concept of the ARGOMARINE Project is the monitoring of the marine traffic due to carriers and commercial ships through environmental sensitive sea areas. This monitoring will be realized by means of sophisticated electronic, geopositioning, and telematic tools connected through a high speed network along with data transmission through suitable data links. Data from different sources will be collected in an independent and remote fashion and sent to a main acquisition and elaboration central unit. Motivation and scope of the ARGOMARINE project is the safe detection, notification and interventions on vessels in emergency situation and the protection of sea and insular environment, endangered by heavy and continuous activities, mainly due to intensive ship traffic, generating a consistent pollution risk. The envisaged goal is connected to the necessity of precise and punctual pollution control in areas and shores which are, for instance, of particular naturalistic value, and/or are exposed to risk of accidental or even intentional contamination due to their vicinity to industrial or highly densely populated settlements, or crossed by a heavy ship traffic. All the data and the information obtained will be merged and elaborated in a Marine Information System (MIS), i.e. an information system where remote sensing data, field experiment results and estimates from simulation models will be integrated, and tools for data storage and retrieval, data manipulation and analysis, as well as for presentation, will available through a common interface.

Project Context and Objectives:

4.1.2.- Summary description of project context and objectives.

The scope of the proposed ARGOMARINE Project is to develop and test an integrated system for monitoring of the marine traffic and pollution events due to carriers/commercial ships as well as recreational boats through environmental-sensitive sea areas. The integrated system is used to monitor ship traffic and marine operations in areas with intense ship traffic and high risk of pollution as well as, for effective interventions in case of maritime accidents. This monitoring is implemented by means of electronic, geopositioning, and tools for transmitting ship navigation data through a high speed communication network. Environmental data from different sensors (SAR, hyperspectral sensor, thermal sensors, electronic noses, acoustic sensors) on satellites, aircraft, vessels, in situ anchored buoys and AUVs are collected in test areas, and sent by telemetric links to a central server where all the data are integrated by use of web mapping technology. Accident modelling and post-accident intervention simulation tools for impact prediction will be implemented and tested through field experiments.

The envisaged goal is connected to the necessity of precise and punctual pollution control in areas and shores which are, for instance, of particular naturalistic value, and/or are exposed to risk of accidental or even intentional contamination due to their vicinity to industrial or highly densely populated settlements, or crossed by a heavy ship traffic. Other areas which can benefit by the results of a distributed sea monitoring are those exposed to environmental risk in particular periods during the year due to an abrupt increase of the human population (i.e. tourist localities and shores).

To monitor marine pollution, data from both satellite and airborne remote sensors and in situ sensors on vessels and buoys have been used to derive information about water quality and spread of hydrocarbons/oil slicks over large areas. Vessel and airborne support have provided by Italian Coast Guard.

Other data have been collected from electronic nose technology, which is being shown as effective to monitor oil/hydrocarbons leakage in marine water. The final sensor device has been scale-reduced and hosted on an autonomous buoy. An electronic control supervises the performance and the activation of the sensor device.

At the same time, tracking of sea ship traffic has been accomplished by ARGOMARINE technology. The system acts as an intelligent transponder through either satellite platforms or ground-based stations. External data such as weather station data, weather operational models and large scale hydrodynamic and wave models are gathered from the external providers. Local implementations of high-resolution mathematical models have been developed for the study sites. The modelling system includes a 3D hydrodynamic model a wave model and an oil spill model. The modelling system runs in pre-operational mode, downscaling the solutions of existing global/Mediterranean operational models.

All the data and the information obtained are merged and elaborated in a Marine Information System (MIS), i.e. an information system where remote sensing data, field experiment results and estimates from simulation models are integrated, and tools for data storage and retrieval, data manipulation and analysis, as well as for presentation, are available through a common interface.

4.1.2.1.- ARGOMARINE: the Rationale

Short Sea Shipping is a central part of the logistics chain for transport in Europe, delivering nearly 40% of the total tonne-kilometres per year, only superseded by road transport with 44% (EC, 2006). Between 1995 and 2004 the transport in this sector increased by 32% in EU-25 countries, and while increase in sea transport can be desirable from an economic point of view, it places a growing burden on the marine and coastal zone environment due to the risk of pollution.

Some ocean areas are particularly exposed to such risks. For example, in the Mediterranean Sea the oil transport is intense, since it gives maritime way to Europe, for the oil produced in Middle East, in the Northern Africa and in Caspian basins. According to Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC, 2002), ship traffic through Mediterranean basin daily consists of 2,000 ferries, 1,500 freight ships and 2,000 commercial crafts, 300 of them are tankers, and approx. 370 million tons of oil and refined products is transported annually through Mediterranean Sea, representing 20-25% of the world total. Maritime traffic in the Mediterranean is characterized by the existence of a large number of ports in the region (more than 300), and by a significant volume of traffic that transits the Mediterranean, without ships entering any of these ports. The East Mediterranean Sea is a high-risk area for pollution as the Black, Red and Mediterranean Seas are interconnected.

Due to very high marine traffic density, Mediterranean Sea is often quoted as one of the places in world with the highest risk of oil pollution. Transportation of large quantities of crude oil and refined products, narrow and congested straits through which ships enter and exit the Mediterranean, large number of ports, large number of islands especially in certain areas with high traffic density are increasing the risk of oil pollution in the region. Thus, decision-makers in this region have a strong need for an efficient pollution monitoring and forecasting system, which supports them in planning and conducting preventive and emergency interventions. Such system must provide timely and reliable access to all available observations and forecasts for the area of interest, and seamlessly integrate these as well as software for analysis, decision-support and dissemination.

Recent events such as the Prestige and Erika tanker accidents have shown that there is also a strong need for improved pollution monitoring and forecasting in other European Seas. In the average, about 60 maritime accidents occur per year, 15 of them involving ships provoking oil/chemical spills. The increase in transport of oil and other dangerous chemicals in Northern European and Arctic Ocean areas, such as the Barents Sea, further extend the demand for marine pollution services to support early warning and planning of mitigation actions to reduce the environmental impact.

Thus, ARGOMARINE project make profit of:
(1) Satellite, airborne and vessel-mounted sensor platforms for:
- Capturing images of the area of interest regardless of cloud cover and weather conditions.
- Capturing images of very high spatial and spectral resolution

- Combining remotely sensed information and improving oil spill detection methods and techniques.

(2) Underwater Monitoring Technologies for:
- Passive acoustic monitoring for detection and preventive action to detect possible unauthorized access
- Autonomous Vehicles for detection and confirmation of accidents and oil spill detection

(3) Mathematical modelling for:
- Predicting the sea hydrodynamics and simulating the fate of oil slicks after spill events

(4) Integrated communication and high-performance data processing for:
- Producing near real time information about ship traffic situation and marine pollution events
- Realizing a fault tolerant integrated communication system between sensors, database, and MIS
- Integration of real time simultaneous data transmission of different kinds of information (different
formats, geo-positioning, etc)
- Realisation of a web-based GIS, accessible by professionals, Authorities and scientists.

The simultaneous achievement of these results constitutes a substantial step beyond the present state-of-the-art in marine pollution monitoring and forecasting, providing new and innovative solutions for integrated communication between sensor networks and data centrals, data mining and analysis, decision-support and data warehouses, as well as web-GIS portals. The envisaged ARGOMARINE system performs like an on-line, early-warning network, able to alert local authorities and environmental control agencies as well as specialized operators

4.1.2.2.- Overall and specific objectives

The overall objective of the ARGOMARINE project have been connected to the development and test of a Marine Information System (MIS) capable of providing precise and punctual pollution control in coastal zone areas with vulnerable or protected habitats, and/or are exposed to risk of accidental or intentional contamination due to their vicinity to industrial or highly densely populated settlements, or crossed by a heavy ship traffic.

The ARGOMARINE project has developed a MIS to meet the needs for improved marine pollution monitoring and forecasting in support of emergency handling. The MIS consists of a network of systems for data storage, data mining and analysis, decision-support and data warehouses, as well as a web-GIS portal for dissemination of products to end-users. An Integrated Communication System (ICS) has also been developed to ensure reliable and efficient data transmission from different types of sensors to the MIS, providing accurate geo-positioning of every data item.

The MIS is be developed in line with recommendations from INSPIRE and GMES initiatives, adhering to de facto W3C, ISO and OGC standards for ensuring interoperability between the different subsystem. The MIS has an open and extensible architecture allowing new components to be "plugged in" as needed, e.g. when new sensors or algorithms become available.

The specific objectives of the project have been:

1. Development and combination of marine observing technologies (satellite, airborne, vessel-mounted sensors along with stand-alone sensors on autonomous buoys, AUV) for more reliable detection and monitoring of hydrocarbon/oil spills in marine environment, in support of preventive and emergency interventions;
2. Development and testing of a pre-operational high resolution mathematical modelling system to forecast hydrodynamic conditions and prediction of oil slick spreading during emergency situations as part of an early warning system;
3. Design and test of an infrastructure able to make the necessary environmental and situational information available to local managers and decision makers within a short response time.
4. Implementation of a geo-positioning/tracking system for ship traffic monitoring based on the integration of AIS with ARGOMARINE technology, so acting as an intelligent transponder through either satellite platforms or ground-based stations;
5. Design and implementation of an integrated data transmission network ensuring high speed/high volume communication with ships, sensor-equipped platforms, including vessels, aeroplanes, helicopters, satellites, autonomous floating buoys, and AUVs;
6. Building and testing of a MIS (Marine Information System) comprised of distributed, interoperable systems for data transmission, data mining and analysis, decision-support and data dissemination to end-users, designed with a component based architecture that can form the foundation of other environmental applications like anti-fire forestry protection and wetland habitat monitoring;
7. Testing the sensor platforms and validating developed algorithms and systems in carefully designed test scenarios where the capabilities of the devised solutions will be assessed, and feedback used to improve their reliability and accuracy;
8. Disseminate regularly towards key end-users such as EMSA (European Maritime Safety Agency), National Parks and other institutions managing protected areas, and organise a dedicated workshop on marine pollution to reach a wider audience in the marine community;
9. Prepare recommendations and plans for post-project exploitation of ARGOMARINE products and services.

4.1.2.3.- ARGOMARINE: the project breakdown

The work plan is organized in eleven scientific and technological Workpackages, including dissemination and exploitation and of the results, and project management, which outline the methodology and the evolution of the project considering both its functional and architectural aspects. The WP articulation has been the following:

- WP1 (SAR imaging and analysis) is dedicated to imaging, and analysis by using SAR (Synthetic Aperture Radar). Long term SAR data will come from satellite-hosted platforms. Meanwhile, new methods have been implemented and tested for detection of oil spills and classification of surface phenomena in multipolarisation high-resolution SAR images.
- WP2 (Hyperspectral-Thermal Analysis) concerns with hyperspectral and thermal infrared image analysis (by using CASI-Compact Airborne Spectrographic Imager, spectroradiometer, TABI thermal airborne broadband imager, and satellite image if available), Airborne sensors were operated and hosted on mobile platforms (helicopter/airplanes). Appropriate methodology and algorithms have been developed for oil spill type and thickness detection. Hyperspectral and thermal analysis have been supported by in-situ measurements. The methodology was be tested and evaluated through project test activities.

- WP3 (Electronic Nose) was devoted to the application of Electronic Nose technology to the monitoring of oil/hydrocarbons spills in marine environment. E-nose technology was adapted to this specific goal, and the sensor have been engineered to be remotely controlled, hosted both on an autonomous buoy and aboard of a AUV.
- WP4 (Underwater Monitoring Technologies) was dedicated to the development of underwater monitoring technologies to be used for both preventive action to detect possible unauthorized access to a sensitive protected area (i.e., a marine park), and environmental monitoring and post-accident action to detect and localize oil spillage in a confined area by using AUVs.
- In the WP5 (Mathematical Modelling) a mathematical modelling system have been setup and applied to the study sites. The system was linked to external operational forecast data products already available for the Mediterranean Sea. Such a modelling is be strictly linked with MIS and its Decision Support System.
- Through the WP6 (The ARGO-Geomatrix Platform and the integrated communication system) the ARGO-Geomatrix platform was developed. The purpose had been to set up and realize a telecommunication infrastructure able to:
1) guarantee efficient transport of general purpose information through means of propagation,
2) give full support to several communication devices, high level protocols, and
3) give full and accurate information about the position of each operator (either prepared specialists or casual user) in the End-User (PNAT and NMPZ partners) context (environment).
- In WP7 (The Marine Information System) the implementation of an integrated Marine Information System (MIS) has be approached. Obtained heterogeneous information spatially and temporally distributed, were merged and elaborated through an information system where remote sensing data, field experiment results, and estimates from simulation models are integrated, and tools for data storage and retrieval, data manipulation and analysis, as well as for presentation, are available through a common interface.
- In WP8 (Test and Field Validation), test activity has been carried out. Both static and dynamic were collected. Tests of the various sensor platforms have been performed during the overall length of the ARGOMARINE Project. During the first phase of the project the test activity was carried out in an independent fashion by each group involved, in order to evaluate their analytical characteristics, while, during 3rd year, final integrated test exercises were carried out on the overall system, in real operational situations.
- Dissemination and exploitation of project results have been faced in the WP9 (Dissemination and Exploitation of Project Results): specific actions were set up, along with a workshop and a media-broadcast campaign, in order to promote the achievements of ARGOMARINE. Multiple disseminating actions have been carried out at local, national and international level. Results of the project have been disseminated through different channels.
- Project Management is described in the WP10 and WP11, aiming at a cost-effective development of technical and scientific activities, preventing and overcoming critical situations from both technical, and financial/administrative points of view, and finally ensuring the respect of all obligations of the consortium regarding procedures and deadlines.

Project Results:

4.1.3.- Description of the main S&T results/foregrounds

ARGOMARINE has focused its activities on a pluri-disciplinary approach and the main technological achievements of this project are summarised in the following sections.

4.1.3.1.- Spaceborne SAR imaging and analysis

Oil spills seriously affect the marine ecosystem and cause political and scientific concern since they have serious effects on fragile marine and coastal ecosystem. The amount of pollutant discharges and associated effects on the marine environment are important parameters in evaluating sea water quality. Satellite images can improve the possibilities for the detection and monitoring of oil spills as they cover large areas and offer an economical and easier way of continuous coastal areas patrolling.

The project focus on two study areas: (1) the Tuscan Arhipelago (Italy) and (2) the Zakynthos Island (Greece). The National Park of the Tuscan Archipelago includes seven islands unique for climate, flora, fauna, history and legend: Elba, Giglio, Capraia, Montecristo, Pianosa, Giannutri and Gorgona. They are characterized by diversified natural environments, created by a rather complex geological history. The National Marine Park of Zakynthos is established in December 1999 with the purpose to protect and conserve the most important loggerhead sea turtle (Caretta caretta) nesting beaches in the Mediterranean, a population of Mediterranean monk seals (Monachus monachus), resident and migratory bird species and rare and endemic plants.

The most commonly used remotely sensed system to detect ocean pollution is Synthetic Aperture Radar (SAR) imagery. SAR images have the unique capability to observe the sea surface independent of clouds and daylight, although there is limitation in the detection capability during very low and very high wind speeds (Brekke and Solberg, 2005). SAR systems detect spills on the sea surface indirectly, through the modification that oil spills cause on the wind generated short gravity–capillary waves (Alpers, 1989). The oil film damps these waves, which are the primary backscatter agents of the radar signals. Consequently, provided that a moderate wind field is present, an oil spill appears dark on SAR imagery in contrast to the surrounding clean sea. However, dark areas may be also caused by other phenomena, like locally low winds, currents or natural sea slicks called "look-alikes" (Hovland et al., 1994). Besides its shape, wind and currents conditions, both at the time of the identified slick and the recent history, are key parameters in determining whether the slick is a likely oil spill or caused by some natural phenomenon. Obtaining simultaneous wind and currents data will thus significantly improve the detection and classification accuracy.

There are several Earth Observation (EO) satellites currently in orbit transmitting data applicable to oil spill and ship detection. When selecting sensor and image mode for oil spill or ship detection in the ARGOMARINE project, several factors have to be considered, such as, spatial resolution, area coverage and temporal resolution. Several satellite sensors have been used in the ARGOMARINE project, among others ENVISAT ASAR (Advanced Synthetic Aperture Radar), TerraSAR-X and RADARSAT-2. These sensors offer multi-polarisation radar imagery that has been used to develop new algorithms for oil spill detection and classification in the ARGOMARINE project.

Generally oil spill detection in SAR images can be divided into three phases (Brekke and Solberg, 2005):
1. Dark area detection – aimed at detecting the suspected polluted area.
2. Feature extraction – aimed at extracting features for each dark area.
3. Classification – aimed at classifying, with a certain probability, whether the suspected dark area is an oil spill.

Following these three phases, a methodology for estimation of oil spill density in an area has been developed in the project:
1- The images covering the both study areas and have good examples of potential oil spills were selected by a satellite radar image specialist inspecting quick-looks available through satellite providers' archives.
2- The selected images were stored in a database according to id number data, time, orbit and polarization.
3- The oil spill detection algorithm was applied for all the images (feature extraction).
4- Low wind areas were filtered away and only dark features with high potential to be oil spill were left (classification).
5- Since the algorithm creates polygons features, these features were converted to points (the centroid of a polygon) and a point map was create for each area.
6- A density maps were created using a point density tool in Arc GIS.

Using the above methodology, NERSC has computed maps of oil spill density in the two study areas of the project: (1) the Tuscany Archipelago, Italy, and (2) the Zakhyntos Island, Greece. Seventy two archived ENVISAT ASAR Wide Swath images were analyzed for oil spill distribution and density. The images were downloaded during the project period (2009-2012) from the ESA Rolling Archive through the project's Category -1 project. The images are covering both study areas and they are VV polarization except 2 images with HH polarization.

The oil spill detection algorithm was applied for all the images and only dark features with high potential to be oil spill were analyzed. A density map was created for each study area. Two high density areas (hot spots) were found in the Tuscan Archipelago area, east of Corsica island and the other area is south of Gorgona Island. For the Zakynthos Island only one hot spot was found southwest of the island. This hot spot area was also detected by the use of airborne hyperspectral images by National Technical University of Athens (NTUA).

4.1.3.2.- Vessel detection and tracking

4.1.3.2.1.- SAR-based automatic vessel detection: a further achievement of spaceborne satellite imagery analysis is the automatic vessel detection in the target areas of interest. Satellite images can improve the possibility for the detection and monitoring of vessels as they cover large areas and offer an economical and easier way, comparing to the continuous patrol and monitoring of coastal and open-sea areas. Synthetic Aperture Radar (SAR) systems have been extensively used for the ships in the marine environment. A very important characteristic of SAR-based vessel monitoring systems is the day-and-night operation and their independence from the cloud coverage and weather conditions.

Maritime surveillance generally involves a trade-off between resolution and coverage. Higher resolution allows for higher probabilities of detection, especially for smaller ships, but it comes at the cost of narrower swath widths and longer revisiting times. The coarsest resolution which still allows good probabilities of detection is chosen, so that coverage is maximised.

Also, SAR imagery is sensitive to surface winds and in severe conditions even large ships may not be visible. Likewise ship construction material is relevant and small wooden or fibreglass boats are often not visible.

SAR space imagery analyses for vessel detection, in the two study areas have been studied. SUMO (Search for Unidentified Marine Objects) is an efficient software tool for satellite imagery vessel detection developed by Partner JRC. It fulfills the purposes and targets of vessel detection in SAR images. SUMO software developed by the JRC was used as the main vessel detection tool in automatic or semi-automatic mode and whenever needed has been assisted by human inspection/verification.

In brief, the vessel detection methodology consists of the following steps:
1. Image preprocessing / calibration / registering
2. Land masking
3. Constant False Alarm Rate (CFAR) vessel detector
4. Clustering of the detected pixels
5. Discrimination of the false alarms

The locations of the detected vessels have been reported and the areas with the highest vessel density have been identified. The density has been accounted in terms of spatial and temporal concentration locating the so-called "hot spots", in the test areas of the project. All the detected vessels (location and time) and the potential detected oil spills (location and time) are stored in the Marine Information System (MIS) database. Querying this database for a detected oil spill (location and time) it is possible to associate the oil spill with the vessels detected for that location and time and when combined with AIS data, to identify the potential polluter.

4.1.3.2.2.- Automatic vessel tracking via AIS Data Acquisition: routines for automatic collection and processing of vessel Automatic Identification System data have been developed within ARGOMARINE activity. The Automatic Identification System (AIS) is an automated tracking system used on ships and by Vessel Traffic Services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships and VTS stations. AIS information supplements marine radar, which continues to be the primary method of collision avoidance for water transport. The International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea (SOLAS) requires AIS to be fitted aboard international voyaging ships with gross tonnage (GT) of 300 or more tons and all passenger ships regardless of size. It is estimated that more than 40,000 ships currently carry AIS class A equipment. In 2007, the new Class B AIS standard was introduced which enabled a new generation of low cost AIS transceivers. AIS is intended to assist a vessel's surveillance officers and allow maritime authorities to track and monitor vessel movements.

The look-ahead distance at sea is nominally 20 nautical miles (37 km). With the help of repeater stations, the coverage for both ship and VTS stations can be improved considerably. Ships outside AIS radio range can be tracked with the Long Range Identification and Tracking (LRIT) system with less frequent transmission. AIS transponders automatically broadcast information, such as their position, speed, and navigational status, at regular intervals via a VHF transmitter built into the transponder. The information originates from the ship's navigational sensors, typically its global navigation satellite system (GNSS) receiver and gyrocompass. The signals are received by AIS transponders fitted on other ships or on land based systems, such as VTS systems. The received information can be displayed on a screen or chart plotter, showing the other vessels' positions in much the same manner as a radar display.

The AIS data have been collected from publicly available web sites using a routine which periodically collects and parses the AIS vessel data into an appropriate database. As an average, about 200 vessels were collected every 10 minutes, for the National Park of Tuscany Archipelago (PNAT) at North Tyrrhenian Sea in Italy and the National Marine Park of Zakynthos (NMPZ) at the Ionian Sea in Greece. The AIS vessel positions are inserted into maps for the target areas, a sample map is presented in the figure above for the NMZP area. These maps have been produced using the open source Quantum GIS package and the vessel positions have been imported as layers of points.

4.1.3.3.- Hyperspectral – Thermal Analysis

The main S&T results and achievements of this activity were:
1. A spectral library of oil-spill types based on ground spectroradiometer measurements. The potentials of the spectroscopy for oil type detection and oil spill thickness estimation have been investigated.
2. Evaluation of thermal imagery for oil-spill detection
3. Development of a hyperspectral methodology for near real time oil spill and vessel detection, as well as, oil spill type and thickness estimation through the implementation of the ARGOMARINE field experiments.
4. Development of a hyperspectral methodology for building a spectral library for the marine environment using hyperspectral imagery.
5. Development of a Hyperspectral image compression algorithm.
6. Development of a multispectral methodology for oil-spill detection.

4.1.3.3.1.- Spectral library of oil-spill types based on field spectroradiometer measurements: Different oil types have been collected for the experiments: kerosene, heating, crude, heavy, and marine fuel oil. The laboratory experiments included spectro-radiometric measurements, using a GER-1500 spectroradiometer, of the oil samples at different time intervals and for various oil slick thicknesses (1μm, 10μm, 50μm, 100μm, and 200μm). The measurements of the weathering state of the floating oil lasted 5 days and were repeated every day at 12.30pm, for the oil slick thickness layer of 200μm.

Using the laboratory spectral measurements an oil spectral library has been developed. Observations and analysis of oil spectral signatures showed that some spectral characteristics of oil are kept constant and can be discerned from water. Reflectance is rising from light to heavy oils at the spectral range of 308.96 nm – 367.84 nm for the whole duration of the experiments. The reflectance values of the oil types were ordered as follows: RWATER less than RKEROSENE less than RHEATING OIL less than RCRUDE OIL less than RHEAVY FUEL less than RMARINE FUEL OIL.

Correlation analysis between oil-spill reflectance values and oil-spill thickness showed that, for each oil type there is a significant correlation in a specific wavelength region. Correlation between oil-spill reflectance values and oil-spill age was also high for specific wavelength regions, for each oil type. The estimated best-fit functions presented high R-squared values, and are promising for the reliable estimation of oil slick thickness and weathering state, in case that the conditions of the oil-spill events resemble the conditions of the laboratory.

In situ experiments in the marine environment included spectro-radiometric measurements of artificial oil-spills at four different oil slick thicknesses. The seawater at the place of measurements was 2-3m deep. A new spectral library, resulting from the marine environment spectral measurements was developed. Analysis of the spectral library revealed the spectral behaviour of the artificial oil-spills. Sea bottom significantly affects the oil-spill spectral signature. Spectral signatures of thin oil-spills and sea water are affected by the spectral characteristics of the bottom of the sea, thus they present similarities. Thicker oil-spills present the typical spectral signature which was also observed during the laboratory measurements. Consequently, the best-fit functions, which had been calculated based on laboratory measurements, were not applicable on marine environment measurements. The thickness above which the spectral signature of the oil is not affected by the sea bottom depends on the density of the oil. Thus, denser oils like the Arabian present minor sea bottom contributions even for thin layers of oil-spills (150μm).

4.1.3.3.2- Thermal imagery for oil-spill detection: Laboratory experiments with a TROTEC IC060 thermal camera were carried out. The highest difference in temperature between water and crude oils (for 200μm oil-spill thickness) was observed at 2-3.30 am. Crude oils with 200μm thickness have greater temperatures than water and they can be safely discriminated from water. Oil-spills cannot be detected in thermal images when their thickness is lower than 10μm. In this case they present the same temperatures with clean water.

Nine ASTER images were acquired for oil-spill detection. 5 ASTER bands with 90m spatial resolution are available in the Thermal InfraRed (TIR) spectral region. The wavelength of ASTER TIR images ranges from 8.125 to 11.650 μm. 12 oil-spills were depicted in these images according to the JRC reference data. After the appropriate processing only 1 of the 12 oil-spills has been detected and verified. 11 oil-spills were not detected and one oil-spill look alike was detected as possible oil-spill.

Based on the above research results the consortium decided not to further investigate the potentials of thermal imagery for oil-spill detection.

4.1.3.3.3.- Development of a hyperspectral methodology for near real time oil spill and vessel detection, as well as, oil spill type and thickness estimation. Implementation of field experiments: On the 14th of December 2011 the 1st ARGOMARINE test experiment has been carried out around the Zakynthos island. During the test experiment, the NTUA acquired airborne hyperspectral imagery using the CASI-550 hyperspectral sensor of the Remote Sensing Laboratory of the NTUA. Images for two test areas have been acquired. The first was a seawater area at the north of Zakynthos over a dense shipway path, and the second was the seawater area of Laganas bay, which is at the southern part of Zakynthos. In this bay a natural non-continuant submarine oil outflow exists, resulting in the appearance of natural oil-spills on the sea surface. During the test experiment inside the Laganas bay, a thin natural oil-spill of small spatial extent has been observed.

NTUA also carried out spectral signature measurements using the GER 1500 spectroradiometer of the Remote Sensing Laboratory of the NTUA. The measurements have been carried out from an NMPZ boat on the same date that the CASI-550 images were acquired.

Several pre-processing steps are required for oil-spill and vessel detection:
1) sensor specific radiometric correction of the raw imagery
2) CASI imagery synchronization with the GPS/IMU positioning data
3) atmospheric correction,
4) image geocorrection,
5) masking land and cloud appearances in the image, and
6) removing or ignoring bands with low signal to noise ratios (SNRs).

It was proven that atmospheric correction plays a key role in the successful application of the hyperspectral methodology. The ATCOR4 atmospheric correction, which has been applied, eliminates effects from aerosols and atmospheric water vapour while it also converts radiance values to reflectance. Effects from aerosols and atmospheric water vapour counterfeit the slight differences in the spectral signatures between water and oil, leading to false processing results. Clouds usually can be easily removed from the images, due to their bright appearance in all the spectral bands. However very thin or transparent clouds present relatively low reflectance, and cannot be effectively masked.

The methodology which has been developed for oil-spill and vessel detection relies on the spectral unmixing theory and includes the following steps:

1. Pre-processing of the hyperspectral image (as described above)
2. Signal subspace estimation (The Intra-StD method has been developed within ARGOMARINE)
3. Dimensionality reduction
4. Endmember extraction (The Improved-SEE method has been developed within ARGOMARINE)
5. SAM classification

The methodology considers that oil, vessel, deep seawater, shallow seawater, phytoplankton, etc. are endmembers (pure classes) in the image and tries to extract them and classify the image. The methodology satisfactorily detected the vessel and the natural oil-spill in the CASI image. The only constraint for detecting the thin and small natural oil-spill was the presence of some very thin clouds over the north-west part of the image. It was necessary to exclude from the processing this part of the image, in order for the oil-spill to be detected. The following pictures show a detail of the classification map which has been produced by the application of the methodology, and two pairs of spectral signatures as well: for oil-spill, and water respectively. The first signature of each pair has been extracted from the CASI-550 image, while the second has been measured by GER1500 spectroradiometer. Discrepancies between the CASI-550 and GER1500 spectral signatures are due to changes in the location and orientation of the targets, since seawater surface is a dynamic area and a time lag between CASI and GER measurements existed.

As far as it concerns the oil type identification, since the observed oil-spill is a natural oil-spill it should be identified as crude oil. Comparing the GER1500 spectral signature of the oil-spill to those derived by laboratory measurements the type of the oil resembles Bunker 3. The oil type identification failure is due to the different environmental conditions between the two measurements. When the same signature is compared to those spectral signatures that were acquired in marine environment, it is successfully classified as crude oil. Therefore, an extensive spectral library of oil-spill types in marine environment should be created in order produce safe conclusions for the type of the oil.

Laboratory experiments showed that there is a wavelength region, different for each oil type, where reflectance and oil slick thicknesses present high correlation. Through exponential and polynomial functions the oil-spill thickness can be adequately estimated. But since these functions are based on laboratory measurements, they fail to give successful results for real oil-spill events. After building an extensive spectral library for the marine environment, appropriate functions based on the correlation analysis of these data could lead to oil-spill thickness estimation.

However, the developed hyperspectral methodology can produce maps of relative thickness for the oil-spill when estimation of the abundance fraction for the extracted endmembers is also performed. According to the hyperspectral theory, estimation of the abundance fraction is the last step of the spectral unmixing procedure. The image presenting the oil abundance fraction per pixel shows the spread of the oil-spill and its relative thickness. This result could lead to absolute thickness estimation in case that in situ measurements in the area with the greatest oil concentration is performed.

In the framework of the ARGOMARINE project, an abundance fraction algorithm, the NBM, has been developed. The results of the algorithm for the detected oil-spill in the Laganas bay are shown in the figure below. The thickest oil areas appear in white.

4.1.3.3.4.- Development of a hyperspectral methodology for building a spectral library for the marine environment The methodology exploits the spectral signatures that are extracted from time series of hyperspectral datasets in order to build and update a Spectral Library (SL) for the marine environment under real biophysical conditions. This spectral library has great potentials to adequately describe the complex marine environment. The use of such a SL could contribute not only to a very detailed detection, identification and quantification of oil-spills, but also to advanced monitoring and management of the marine environment.

The building of the spectral library includes the selection of spectral signatures for various sea related substances, including oil-spills of various types, thickness and weathering stage. For this purpose, a reference pre-processed image is initially used. Endmembers are extracted from the reference image and identified according to in-situ measurements, ancillary data, and/or photo-interpretation methods. These spectral signatures are those that compose the initial spectral library. The spectral library is updated every time that a new hyperspectral image is processed. A relative radiometric normalization algorithm is applied before processing any new hyperspectral image so that it matches the reference image spectra.

The methodology was applied on Hyperion and ASTER satellite imagery, since time series of hyperspectral datasets were available only for satellite imagery. The methodology provided very accurate results. For the evaluation of the methodology, oil-spill events from the JRC data base have been used.

4.1.3.3.5.- Development of a Hyperspectral image compression algorithm Hyperspectral data are images with extensive volume size, which can range up to several dozen of GB. For fast hyperspectral data transmission it is essential to develop a hyperspectral image compression technique, which achieves high compression ratios and high Signal to Noise Ratios (SNR). A new algorithm for near lossless compression of hyperspectral imagery (HIS) has been developed. It is a hybrid algorithm, called H-UNPCA (Hybrid Unmixing PCA), which uses the spectral unmixing procedure and Principal Component Analysis, combined with a lossless generic coding algorithm. The algorithm was applied on 8 HSIs: 4 CASI (airborne), and 4 Hyperion (spaceborne) images. The evaluation of the compression results was accomplished by using index based metrics and calculation of the changes of the classification performance. H-UNPCA can achieve high compression ratios without significant information losses.

4.1.3.3.6.- Development of a multispectral methodology for oil-spill detection: Various very high resolution IKONOS, QuickBird, RapidEye and WorldView2 multispectral images of Beirut (Lebanon), an area with known oil-spill events, have been purchased in order to develop a methodology for oil-spill detection. Furthermore, multispectral RapidEye images of the island of Zakynthos have also been purchased in order to apply and test the methodology in an area that is known to have frequent natural oil-spill occurrences.

The methodology relied on the following photo-interpretation and image analysis results:
- Oil-spill occurrence appears generally brighter than seawater in the visible bands of the multispectral images.
- Between 660 and 760 nm (upper red to near infrared region) is the best region for oil-spill identification through photo-interpretation. Within this region the sea bottom interference is eliminated while the oil-spill appears significantly brighter than seawater. However attention should be given for not confusing oil-spills with clouds.
- In deep waters (no bottom reflectance) the blue-green region is the best for identifying the oil-spill occurrence.
- Discrimination of seawater and oil-spill solely based on their brightness difference is not possible.
- The oil-spill occurrence areas have significantly higher local standard deviation values due to the glint effect and therefore they can be highlighted using a local standard deviation filter. This is extremely useful in case that agitated seawater is presented in the image.
- In case of rough sea, the application of a Gaussian smoothing filter can significantly improve the oil-spill identification.
- The oil-spill occurrence areas show lower values in the [blue band] / [green band] ratio and the [blue band] / [red band] ratio than water and chlorophyll-a concentrations.

The best method to incorporate all of the above observations for oil-spill detection is the use of Object Based Image Analysis (OBIA). The image segmentation, which is the first step in OBIA, creates image objects for which all of the above criteria can be calculated and used to classify the image.

In summary the methodology for the very high resolution multispectral images includes the following steps:

1. Image geocoding.
2. Conversion of the raw image digital numbers to Top of the Atmosphere reflectance and application of relative radiometric normalization on all the subject images towards a reference.

Or

Application of ATCOR3 atmospheric corrections and conversion of the raw image digital numbers to surface reflectance values.

3. Masking of the non-sea areas, i.e. land and clouds.
4. Image multiresolution segmentation in two levels (fine and coarse).
5. Oil-spill detection based on object based classification rules for the previously mentioned observations.

With some changes on the segmentation and the threshold values of the object based classification rules, the same methodology proved to be applicable on high multispectral resolution satellite images, i.e. Landsat TM.

Applying the photointerpretation methodology as well as the proposed methodology on RapidEye images of the island of Zakynthos, a large unknown systematic natural oil outflow near the Zakynthos island has been discovered and served as the best proof for the evaluation of the developed oil-spill detection methodology. The following pictures show the discovered outflow in three different dates. Eventually the different direction of the wind and the currents are the cause of the different orientations of the three oil-spills.

In order to further investigate this occurrence, a series of Landsat 4-5 TM and Landsat 7 ETM+ images have been downloaded from USGS. These images revealed that the natural oil outflow systematically appears every summer for more than 26 years. The natural oil outflow was also verified by spot test from an NMPZ boat on August 1st, 2012. The discovered natural oil outflow would be a very good study area for future oil-spill relevant studies.

4.1.3.4.- Electronic Nose

The CNR-IFC (Istituto di Fisiologia Clinica), involved in the project ARGOMARINE, realized an E-Nose technology-based smart system, aiming to detect the presence of hydrocarbons, one of the most dangerous pollutants for marine environment, in sea water. The smart system realized within the Work Package 3 employs an array of sensors capable to detect various kinds of Volatile Organic Compounds (VOCs) in the air. This is related to hydrocarbons' pollution because, with this approach, it's possible to detect the odorous compounds produced by these substances in the air overhanging sea water. The sensors chosen for this purpose are of the type piD (Photo Ionization Detectors), which are characterized by good performances and, as a drawback, a not negligible cost.

The piD sensors, having three different sensitivities for VOCs (indicated with the label colour "Silver", "Bronze" and "Black", depending upon their performances), were placed into a flow chamber, properly designed for this project. The flow chamber was planned with a cylindrical shape, with six radial holes to lodge up to six sensors. The choice for the shape was made in order to assure the same amount of air flow to all the sensors, to avoid false responses and biases. The material employed for the realization of the flow chamber was PEEK, a thermoplastic polymer having an extremely low density, good mechanical properties and good chemical inertia, thus it can be employed even in a severe environment like the sea water. After the sensors characterization, performed on laboratory bench, our work aimed to find the best acquisition electronics for this purpose. Our choice was in favor of Arduino™ Mega 2560, a smart electronic board with good performances and an extremely low power consumption (see picture above). The electronic board above mentioned is capable to manage up to 16 sensors, much more than the ones used in our system, and it's easy to understand that it can manage without any sort of problems the number of sensors expected for this application.

The air sampling system, with air inlet and outlet ports, was realized with pumps and valves commercially available, allowing the system to make cycles during the missions forecasted within the project. A key-issue for the smart system was the prevention of water and/or humidity entrance into the payload. To avoid this possible drawback, a cone for the air aspiration was realized, together with a tool, driven by the humidity sensor placed into the payload, to let the water flow out from the smart system. With the help of this system, the entrance of water and humidity inside the payload, whose rendering is shown in the drawing below, and the flow chamber was considerably reduced, with positive effects on the sensors' and electronic board's life.

The realized system is capable to communicate with the Marine Information System (MIS), placed onshore, in order to trigger alarms depending upon the eventual detection of hydrocarbons, brought by illegal ship transits and/or oil spills, in the marine environment, as in the protected area of the Tuscan Archipelago.

The employment of the smart system described above is into an Autonomous Underwater Vehicle (Folaga AUV, shown in the following picture) for dynamic monitoring of environmental pollution (the AUV sails while performing a loaded mission), as well as inside a moored buoy) to monitor the pollution of a fixed area.

Alarms triggered were divided into three different categories, depending upon danger magnitude (faint, moderate, severe). To divide the stimuli into the classes above mentioned, an Artificial Neural Network (ANN) of the type Kohonen Self-Organizing Map (KSOM) was designed and realized. The data from the piD sensors array and the data acquired by the humidity sensor in the bench tests as well as during ARGOMARINE meetings (Spring Test Meeting, Elba Island, May 2012; Summer Test, La Spezia, July 2012; Final Test Meeting, Elba Island, November 2012) were employed to train the network, that showed good performances in discrimination into these three classes (73.9% of correct classification of the stimuli). Another ANN, of the same type of the previous, was created to discriminate between different hydrocarbons. To train this second network, a dataset composed by sensors' responses to various hydrocarbons (oil, gasoline, diesel fuel, kerosene) was employed, by using data acquired during the ARGOMARINE meetings above mentioned. The performances of this network are obviously slight worst if compared with the first network, with a percentage of correct discrimination of 63.3%, a value good enough for a portable smart system.

The sensor array was capable to detect the presence of hydrocarbons' vapors at concentrations around 100 ppm, thanks to the good performances of the "Silver" piD. On the other hand, "Bronze" and "Black" piDs were capable to detect hydrocarbons at 1000 ppm and 5000 ppm respectively, concentrations at which all the hydrocarbons used for the sensors' characterization were detected.

It's important to remark, anyway, that the employment of the smart system is ideal at a temperature of around 20°C with a Relative Humidity Ratio (%RH) under 70%. Different temperatures don't affect the sensors' output as much, but the %RH has to be maintained lower than 70% because for %RH values over 70% the sensors showed drifts and spans not always correctable in post-processing phases. Anyway, the system seems working correctly in marine environment, being the results obtained during the ARGOMARINE tests reliable and useful.

The smart system based on E-Nose technology could probably form the basis for a future line of portable devices, whose aim would not be to exactly detect the kind of pollutant agent present in a marine environment, but rather to detect the generic presence of pollutants in the air.

4.1.3.5.- Underwater Monitoring Technologies

The task of Underwater Monitoring Technologies concerns the design of two main subsets:

1. a passive acoustic monitoring system for the detection, localization and classification of surface vessels in a peculiar and confined area of interest (e.g., marine parks)
2. autonomous sensing technologies which exploit marine robotics system for real time in situ measurements

4.1.3.5.1.- Acoustic Monitoring In order to track and identify possible sources of pollution in marine park areas, maritime traffic needs to be carefully monitored. Nowadays, the presence of large ships can be accurately monitored either by radar or via AIS system, while small vessels, in particular inflatable boats, which have very weak radar signature, may be easily missed by usual monitoring systems. Continuous passive underwater acoustic monitoring of vessels from a network of distributed underwater sensor stations is envisaged to be a valuable approach as an additional, complementary tool with respect to other remote sensing systems such as SAR or radar.

In the context of ARGOMARINE, NATO STO-CMRE (former NURC) has designed and developed an advanced measurement underwater acoustic system, and the algorithms of data processing, analysis and fusion, which, applied to the acquired acoustic data, allow the automatic detection, localization, tracking and classification of the vessels passing in the area of interest.

The system developed is designed to perform vessel detection and localization through algorithms optimized for small- and mid-sized boats and based on data either from a single underwater sensor station of four hydrophones, or from data fusion between two hydrophone volumetric arrays.

Two prototype platforms have been designed and built at CMRE using cutting edge technologies to reach very low noise levels (below sea state 0, to be able to record all underwater sound sources).

Each platform hosts a sparse tetrahedral array of four broadband (up to 70 kHz bandwidth) hydrophones and an integrated pan, tilt, compass and depth sensor package for monitoring its attitude. Both acoustic and non-acoustic data from the two stations are transferred through electro-optic cables to shore, where they are stored and processed on a PC.

Sounds are recevied on shore by using 1.5 km long optical fiber cables and they deliver continuously an impressive amount of data in terms of bandwidth and dynamic range (120dB) to be processed.

The approach can be applied to cover areas of several km2 by increasing the number of underwater platforms to deploy underwater.

4.1.3.5.2.- Algorithm design and implementation The automatic detection, tracking and classification system is requested to work in a robust and accurate way for any kind of vessel, not a-priori known.

The acoustic signatures of small- to mid-sized surface vessels (ranging from rubber boats to fishing boats and tugs) are much less investigated in literature than those of slow, big ships, and can be extremely diverse. As well, the classification among categories of small- to mid-sized boats is not reported in literature, apart from sporadic exceptions.

As a matter of fact, the characteristic sounds of boats of different kinds significantly vary, in terms of amplitude, frequency bandwidth and frequency components. Figure below shows few examples of signatures represented in the time-frequency domain.

The block diagram of the processing algorithms is shown in the picture below. Direction of arrival and a rough localization estimate are provided on the basis of data from each underwater station separately, and then fused at high abstraction level.

A new algorithm of automatic detection and extraction of vessel tracks from the cross-correlogram of each pair of hydrophones has been developed and applied to data from each hydrophone array. On a single tetrahedron, the compensation of azimuth by elevation computation (by fusing data from all the hydrophones) provides a significant improvement in the estimate accuracy, particularly at short range. However a small error in elevation causes a significant error in positioning. Hence the advantage of fusing localization results from the two arrays is emphasized, especially when the ambient noise is high and the environment is complex.

Real experimental data have been collected in several trials at sea under either controlled (i.e., providing localization ground-truth for comparison) or blind conditions, both in La Spezia harbour and off the North coast of Elba island.

From the analysis of the at-sea data collected during ARGOMARINE project, the maximum position error obtained from data fusion is about 7% within a range of 400 m between the vessel and one of the two stations.

Classification allows distinguishing among few classes of vessels: big ships, intermediate-size boats (such as luxurious yachts) and small boas, such as inflatable boats. Classification is based on the measurement of a number of features extracted from the signature of a detected vessel, represented in the spectral and DEMON spectral domains. Classes are well separated, with a mis-classification rate lower than 8%.

4.1.3.5.3.- Integration of the e-nose into a FOLAGA Autonomous vehicle: The final aim of ARGOMARINE is the detection, notification and intervention on vessel in emergency situation; this project is extended to various and different technology sectors, starting from the satellite observing to fixed detector of contaminating substances.

"eFolaga" Autonomous Underwater Vehicle features in particular for what pertains standard vehicle performances as an application for a re-locatable platform working stationary during air sampling at sea.

Such an autonomous vehicle is capable of performing different missions, from standard propelled trajectories, both above and underwater, to more sophisticated glider missions.

The goal of this task was the integration of an electronic nose into an autonomous vehicle; this sensor equipped vehicle will perform some missions in order to monitor a defined area supposed to be in contamination danger.

In order to provide a wider spectrum of "eFolaga" sampling module potential installations, a set of three different sea autonomous platforms have been explored to compare their dynamic response in the waves to preserve the optimal smelling distance while avoiding the risk of flooding the measuring chamber:

1. torpedo like vehicle: the GRAALTECH eFolaga
2. catamaran vehicle: the Sea Robotic Corporation USV2600
3. wave glider: the Liquid Robotics Wave Glider

A quantitative analysis of each vehicle response in term of heave motion has been carried out also suggesting damping solutions to avoid resonant conditions with wave excitation frequency.

The core part of the study is the integration of the E-nose in the eFolaga vehicle although the module studied for this purpose can be easily installed on other autonomous vehicles cited above.

Based on the output of this tasks, the CNR-IFC together with the manufacturer of the eFolaga, GraalTech s.r.l., Italy, have built a payload module for the AUV to perform the water sampling for the detection and classification of hydrocarbons.

4.1.3.5.4.- Investigation of the most appropriate strategies for the environment characterization Networking is one of the new paradigms brought by UUV technology to observational oceanography. A wide range of spatiotemporal scales of variability are better characterized in vast ocean areas by a network of ocean observing platforms. The sampling strategy can be made more cost effective if the motion of all or part of the platforms is controllable. Under this circumstance, the structure of the network is dynamic and it may be partially modified depending on needs.

For a given sampling strategy, the number of platforms required by a network with controllable motion platforms is substantially less than if nodes were fixed. However, UUV technology does not substitute but complement other sampling technologies. This is the case of Eulerian observatories. These infrastructures provide sustained observations of different bio-geophysical parameters with high temporal resolution. Unfortunately, their spatial resolution is poor unless an unfeasible number of observatories is considered. Exploiting synergism with UUV measurements is of particular interest in this context.

Allocating and complementing observational resources to maximize the information content of the collected data is of interest in different fields of geophysical sciences, including oceanography. The scope is to get the best field estimations on a regular grid from observations gathered at arbitrary locations. The estimated field can then be differentiated or assimilated into a numerical model. Different criteria have been proposed in the literature to measure the optimality of estimations. A-optimality defines the best estimation of the field like that generating minimum average uncertainty in the estimations. G-optimality measures the goodness of the estimation by the magnitude of the maximum uncertainty of the estimation. Finally, E-optimality focuses on minimizing the effect of the main spatial pattern of variability. Which of these optimal criteria is more suited in oceanography remained an open issue. This was investigated in the present study for the specific case of sampling a marine area with a heterogeneous ocean observing network form by a UUV and a mooring.

Results suggest that A-optimality is more suited for oceanographic estimations with UUVs and moorings than G and E -optimal designs. Different explanatory reasons could be argued. G –optimal designs are more sensible to point-like anomalies in the uncertainty field and thus, the sampling strategy may be biased to remote locations with high uncertainty and degrading the overall estimation. E-optimal designs are discouraged on basis of the results. Notice the redundancies in observations when the UUV moves nearby the mooring. This is generated by the global character of the criterion making it less sensible redundancies. Also, the high spatial resolution of UUV data could screen the mooring observation in this specific case.

An interesting result derived from the study is that the spatial structure of the uncertainty field seems to be largely determined by the violation of the synoptic hypothesis. This could be region dependent. The proximity of a frontal structure could originate the consideration of synoptic time scales smaller than 4 days in the present case. Notice that this would impact the size of the area to be covered.

4.1.3.5.5.- Integration of the marine sensors with the ARGOMARINE MIS The processing results, in terms of vessel tracks and types, along with the e-nose positioning and status data coming from Folaga AUV, are sent to the central ARGOMARINE MIS for display and possible further fusion with other monitoring data.

The Folaga vehicle can follow a pre-programmed trajectory, made of waypoints, and adapt to a new path as instructed by the ARGOMARINE MIS. This allows the adjustment of the vehicle mission based on the measured in situ data, and is also linked to the optimal sampling mission design output of the model developed by CMRE.

4.1.3.6.- Mathematical modelling

The main achievement of this activity was to develop a mathematical modelling system to predict oil spill evolution in case of accidents. In order to accomplish that purpose, a combination of mathematical models was developed for the study area. That system is composed by 3 levels of nested 3D hydrodynamic models with increasing resolution coupled to a wave model and an oil spill model. The entire system runs in operational mode assimilating data from external operational data systems. It is managed by a centralized tool which performs the pre-processing and post-processing operations automatically and publishes the forecasted results. The various components of the modelling framework are described in the sections below:

4.1.3.6.1.- System of nested 3D hydrodynamic models A local system of nested 3D hydrodynamic models was implemented for the study site. The MOHID model was setup using 3 levels of nested sub models. The entire assembled set was run to produce scenarios for summer and winter situations. Additionally, a review of the known oceanographic characteristics of the region was performed and the results obtained with the model were interpreted in the light of these characteristics. The comparisons enabled to identify the basic oceanographic patterns known for the region. Further comparisons with an independent model (MERCATOR Ocean) were performed for specific dates showed similar results despite of the differences between modelling system and forcing. Validation of the model results were successfully accomplished for several ocean properties (e.g temperature, salinityand elevation) using distinct data sources made available by the MyOcean and NASA OceanColor portals. The following pictures present a snapshot of the model results.

4.1.3.6.2.- Implementation of a wave model: A wave model system for the Northern Tyrrhenian Sea was created using the Simulating WAves Nearshore model (SWAN). The framework was setup using two nested grids of increasing resolution. At first, preliminary validation of the model outputs was performed through comparisons with the results found in the available literature.

Second, a more robust validation was performed comparing the outputs of the wave model system implemented with results obtained by previously validated and independent wave using forcing and bathymetry other than those used in this study. The results obtained showed the ability of the model to simulate the wave sea state during a winter period of more than a month including three different storm episodes in the region. The comparisons with the independent model show generally a good agreement. The picture presents a snapshot of the model results.

4.1.3.6.3.- Multi-mesh Lagrangian transport oil model: A multi-mesh Lagrangian transport algorithm was developed and used for the Implementation of an oil model for the study site. A new lagrangian model was created, enabling the transport of lagrangian particles over an unlimited number of nested meshes running simultaneously and concurrently in the same geographic region. The ability to use curvilinear grids and a more intuitive and simplified input structure was also developed. Testing examples were performed to evaluate the multi-mesh functionality.

The examples show that the methodology developed is adequate; the particles cross between models without any discontinuity and are able to jump between lower priority and higher priority domains and vice-versa. The oil module was adapted to the new structure of the Lagrangian model. Both models were subjected to a series of tests to assure the good behaviour and the validity of the new model implementation. Parallel to this activity, the hydrodynamic and the wave models were ran for summer and winter conditions. Several hypothetical oil spills accidents were simulated using these scenarios, with the oil module being forced both by waves and hydrodynamics. The model was then validated using public available drifting buoy data and data produced inside the project.

4.1.3.6.4.- Integration of the model components with external operational data-products: Forecasting oil spill trajectories with numerical models is very demanding from the data management point of view. It is necessary to download large scale forecast 3D and 4D solutions (ocean circulation, wind waves and atmospheric circulation) to force the high resolution models necessary to accurately simulate oil spill trajectories. After the download, data needs to be interpolated into the higher resolution grids and the model input files must be updated. Subsequently, the models need to be run, the results need to be checked for consistency and stored so they can be used in case of an oil spill event. Having this in mind an operational interface to control in a quasi-automatic way operation of numerical models was developed and implemented. This interface has three main components: a desktop client, a web client and a central server. The client components are in fact graphical interfaces that allow the users to explore in a GIS environment the model results stored in the central server.

The central server has different modules such as:
- Numerical model handler: used for running the ocean and wind waves numerical model;
- Download module: used for downloading the forcing data (e.g. MSF operational solution);
- Data base: where all data is stored in a structural way;
- Scheduler: to trigger automatic tasks;
- User management;
- Web services: to manage the communication between the server and the clients (desktop and web);

The following picture presents a snapshot of the web client.

4.1.3.6.5.- Pre-operational response during the Costa Concordia accident The Costa Concordia accident was a test to the implemented modelling system. From the modelling view a more refined grid was developed for the Giglio Island with a spatial resolution of 100x100 m and coupled to the existing grids using a downscaling approach.

The forcing files were daily forecasts of the SKIRON model (for the atmosphere) and operational SWAN wave model developed for the area. The download of the forcing files as well as all pre-processing operations involved were automatized in order to have a pre-operational forecasting system available. To simulate a possible oil spill, a continuous release of Bunker C Fuel Oil from the Costa Concordia was considered, at a rate of 0.014 m3s-1 during two days. Everyday the model forecasted the spill evolution for the next five days, and results were operationally made available online through the ARGOMARINE website.

4.1.3.7.- The Integrated Communication System

4.1.3.7.1.- The ARGO-Geomatrix platform: The near real time (NRT) monitoring of large marine areas for the control and prevention of oil spill requires adequate means to make the data acquired by distributed sensors timely and fully deployable by the end users of ARGOMARINE platform. This is precisely one of the goals of the Integrated Communication System (ICS) that has been developed during ARGOMARINE project. Indeed, the effective capability of the operative surveillance and the rapid inter-operability between the passive and active actors working for the general prevention of oil spill is based on suitable geopositioning devices, organized in the so-called ARGO-Geomatrix and integrated through the ICS. Such devices are also the basic tools for a fast intervention when an oil spill pollution event takes place. More in detail, the ICS has been developed as an interconnected group of communication adapters for making possible seamless data flow to and from the MIS. As such, the ICS has represented an ancillary but necessary component for the successful implementation of the MIS.

4.1.3.7.2.- Sensor-equipped buoy: In ARGOMARINE, a prototype of sensor-equipped buoy endowed with an E-nose has been designed and implemented. The main purpose is to sense meteorological parameters and water quality measurements and to transmit these data to the platform. The ARGOMARINE buoy is a static and sensor-equipped buoy with a GSM modem for transmitting the data. Moreover, the buoy can be configured sending text messages to the number corresponding to its internal GSM modem, while the acquired data are sent to the platform. There, a suitable application converts the received data, stores them and processes them so that they can be easily used by the operational platform.

4.1.3.7.3.- Argo sentinel and white box: Based on the idea that contribution of volunteers might play a fundamental role in monitoring and protecting the environment, during ARGOMARINE, both a dedicated device and a mobile application were designed and developed in order to allow people to timely report oil spills.

In particular, the White Box device - developed at the CNR - consists in a small box with just 3 buttons (blue, yellow and red) to be used to issue geo-tagged alerts of mild and severe intensity (selected by pressing the yellow or red button after switching on the device with the blue button). Internally, it consists of an electronic connected to a GPS module and a GSM modem. In principle, replacing The GSM board with e.g. an Iridium Short Burst Data (SBD) modem may extend the coverage of white box if needed.

The "ARGO Sentinel" app was instead developed targeting at a wider public. Using this app, volunteers can help to monitor the health of our seas. The use of this new technology could be really important to combat pollution. Indeed, whoever at sea sights a pollution by oil or hydrocarbons is now able to immediately report the event to the Laboratory of Signals and Images SI-LAB (si.isti.cnr.it) of the Institute of Science and Information Technologies of the Italian National Research Council (CNR-ISTI) in Pisa, allowing the realization of a detailed map of the health of our seas. This information is recorded in the Marine Information System (MIS), able to collect data relating to critical and health issues of the sea from various sources (satellites, optical sensors, electronic noses, autonomous underwater vehicles, systems and geolocation) and integrate and generate predictive models to assist the authorities in the management of emergencies.

The "ARGO Sentinel" app is distributed in Italian, English and Greek languages. Current version is developed for Android phones equipped with GPS and is freely available on Google Play (see http://play.google.com/store/apps/details?id=it.cnr.isti.martinelli.argosentinel online).

4.1.3.8.- The Marine information system (MIS)

4.1.3.8.1.- The MIS: One of the main achievements of ARGOMARINE project has been the development of the Marine Information System (MIS). The MIS aims to provide an effective and feasible detection and management of marine pollution events, by integrating and analysing data acquired by a number of monitoring resources, exploited to get useful and relevant information about the controlled sites. The main task of the MIS is to serve as a catalyst for integrating data, information and knowledge from various sources pertained to the marine areas of interest, by means of adequate Information Technology tools. More precisely, the MIS has been conceived as a connected group of subsystems for performing data storage, decision-support, data mining and analysis over data warehouses, as well as a web-GIS portal for the access and usage of products and services released to end-users. Products are herein considered as the marine environmental data acquired by the system or result of its processing; while the services are the processing facilities supplied by the system.

The system has to deal with all these kinds of knowledge for being effective and useful in the environmental management process, which typically consists of four activities in the following order:
1. Hazard identification, which involves filtering and screening criteria and reasoning about the activity being considered. This phase may be characterised as a continuous activity of the system looking for possible adverse outcomes and includes the search for further data to enhance its own performance.

2. Risk assessment, which involves developing quantitative and qualitative measurements of the hazard. The MIS may include the use of numerical and/or qualitative models, which can produce estimations of the degree of potential hazard. The heterogeneity of data coming from various sources and with many different levels of precision may be faced by using a Model-based System using model based reasoning, and/or a Knowledge-based System using rule-based reasoning, and/or by a Case-based System using case-based reasoning.

3. Risk evaluation. Once potential risks have been assessed, it is possible to introduce value judgements regarding the degree of concern about a certain hypothesis. This is possible if the system has accumulated experience solving similar situations using for instance a Case-based Reasoning approach, or an Inferential modelling, where previous experience of risk evaluation is used to assist for future judgements.

4. Intervention decision-making. The system needs appropriate methods for controlling or reducing risks. The system also requires knowledge about the context where the activity takes place and must be able to interpret its results and knowledge about the risk/benefit balancing methods.

MIS has to be very effective in managing and organizing quick solutions to severe and complex environmental problems. Such problems need, due to their multidisciplinary and heterogeneous nature, in order to be solved, the cooperation of many different subsystems which must be integrated, for a wide and more complete view and understanding of the specific situations.

The specific MIS requirements, first of all, take into account all the acquisition sources that are available and used within the monitoring activities, and belonging to specific technological devices, as well as the archiving and storage systems. In order to develop the MIS following

INSPIRE and GMES recommendations, the modalities to communicate and interact among systems, and in general to and from the system have been reviewed. Regarding in particular an efficient management of the information flow within the system, needed for guaranteeing interoperability among the different components. Hence the MIS is designed including as a set of specialized subsystems cooperating among each other.

MIS architecture was designed with independent and re-configurable units in order to guarantee interoperability and portability to the MIS, meaning that single units could be re-designed, or its internal components could be modified to fit to specific different domains of application (or case study), without the need to re-design the whole architecture.

The 6 identified units are:
- Service Unit
- Operational Storage Unit
- Knowledge Discovery Unit
- Environmental Decision Support System Unit
- Notification Unit
- GUI Unit

The Service Unit and the Notification Unit have a direct interfacing with the external data sources. This external interfacing in the workflow is identified with a dotted arrow. In particular, the Service Unit is in charge of acting as a data manager for integrating information from all available data sources, including sensors (i.e. ARGO-Geomatrix devices), applications (such as mathematical simulation models and image analysis methods) and repositories (like AIS data). The Notification Unit instead dispatches messages such as alerts and suggestions to personnel enrolled in ARGOMARINE system.

The MIS has been designed with an internal storage unit for guaranteeing timely access to operational data needed for basilar system operation. In particular, a geo-enabled data base and a Multimedia Repository constitute the core of the Operational Storage Unit. The GUI Unit represents the graphical front-end of the MIS, comprising also the Web Portal, the interface for the end-users and the Manager.

The Environmental Decision Support System Unit and the Knowledge Discovery Unit are instead the most advanced services of the MIS. The first aims at providing real-time suggestions to system users, while the second is oriented to offline trend analysis and to the discovery of hidden patterns in the data.

4.1.3.8.2.- The Central ARGOMARINE Portal: As part of the Marine Information System, a web portal was created to disseminate observations, analysis and predictions of oil spill related parameters and phenomena to end-users. The portal is accessible through a common web browser, and does not require any plug-ins to be installed on the end-user's computer.

The web portal and web GIS functionality therein have been implemented using open and widely accepted standards. In the beginning of the project, we investigated available standards and open source tools that implemented these standards. Among the standards investigated were web GIS standards from the Open Geospatial Consortium, Inc.® (OGC) . Two of the most widely used of these OGC standards are the Web Map Service (WMS) and the Web Feature Service (WFS), which are used for exchange of raster and vector data, respectively.

Liferay is an enterprise portal licensed under the MIT open source license. While Liferay is a commercial product, there is also a free version available: the Liferay Community Edition. This version is fully functional and includes more than 60 different portlets and widgets, providing widely used functionality such as blogs, calendars, forums, wikis, document library, to name some. Liferay can run inside many different application servers, including Tomcat, GlassFish, JBoss and WebShere. Liferay has a rich user management model, and offers a role-based permission system and different user grouping mechanisms. Portlets, which are applications that are shown inside a portal page can be written in a number of programming languages, among others, Java, JSP (Java Server Pages) and Python, and may include AJAX components for a richer GUI experience. Based on the openness and versatility of the Liferay platform, it was chosen as the basis for the ARGOMARINE portal. The Liferay Community Edition portal framework is an open source platform which is based on standards JSR-168 (Abdelnur and Hepper, 2003) or JSR-286 (Hepper, 2008) for portlet (portal component) development.

The usage of portal framework and portlet standards enabled the integration of output of external applications, such as the Marine Information System and the AQUASAFE Web Client for met-ocean and oil drift modelling, both developed in the project. The chosen portal framework, Liferay Community Edition, also offers a number of pre-built components (portlets), out of the box. This includes commonly used components such as a wiki, forum and news reader. In addition, a slide show component has been implemented in the project and populated with samples of products and services from the various ARGOMARINE partners.

Potential Impact:

4.1.4.- The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results

4.1.4.1.- Introduction

Around 150 million people are concentrated on the 46,000 km of Mediterranean coastline, with 110 million of them living in cities; some 200 million tourists arrive in the Mediterranean region every year; more than 200 petrochemical and energy installations, chemical industries and chlorine plants are located along the Mediterranean coast. These figures represent the major challenge for the preservation of the Mediterranean environment, with over 80% of pollution originating from human activities on land. However the required infrastructure to sustain these high population densities has often not been implemented or taken into account. The environmental and security threats the marine environment, and the delicate balance of Mediterranean sea, is submitted to are several, many of them contributing to the introduction of pollutants into coastal and estuarine ecosystems, more and more prone to pollution events outburst and pollution chronicization in particular. Oil spills threats are a severe issue especially in waters subjected to huge traffic of ships and low level of internal-external circulation (i.e. Mediterranean sea, Baltic sea). Due to very high marine traffic density, Mediterranean Sea is often quoted as a very high-risk area for water pollution. Transportation of large quantities of crude oil and refined products, narrow and congested straits through which ships enter and exit the Mediterranean, large number of ports, large number of islands especially in certain areas with high traffic density are increasing the risk of major accidents with subsequent important oil pollution in the region affecting ecosystems and human life. According to the World Health Organization (WHO, Millennium Ecosystem Assessment 2011), human existence is entirely dependent on ecosystem services which are indispensable to the wellbeing of all people, everywhere in the world. Human health ultimately depends upon ecosystem products and services (such as availability of fresh water, food and fuel sources) which are requisite for good human health and productive livelihoods. The actual degradation of many ecosystems by anthropogenic activities reduces the quality of these services and thus the quality of our lives.

It's a natural fact that contamination doesn't respect national boundaries, and one country's pollution quickly can, and often does, become another country's environmental and economic problem. Cross-border pollution is a serious environmental reality and a problem that often frustrates national solutions. Thus, an initiative that aims to tackle the problem of pollution within a global, cross border based context is attacking this issue in a more realistic and feasible way. The European border areas has always demonstrated very sensitive to threats to both environmental and security issues, and the problem of oil spills pollution response and remediation has become more and more important the eyes of EU citizens as it can affect the quality of life of millions of people living on near coastal areas, as a transnational and even trans-European question that demands answers at policy, organization and technology levels. ARGOMARINE project scope is inscribed into this context, and especially into the technology level, aiming to produce models and tools for monitoring, fast response and remediation in case of oil spills marine external crisis events.

4.1.4.2- The strategic Impact

In the frame of the needs of the EU to develop technologies and knowledge for reduced environmental impact, and for research which will improve the cleanliness and energy efficiency of industrial processes specific to transport products, ARGOMARINE project, not only has contributed towards the realization of this described vision, but has done it according to the processes, recommendations and guidelines of the FP7 programme. Therefore, ARGOMARINE has strongly contributed towards the Integration and Strengthening of the European Research Area, by exploring pluridisciplinary fields and by combining different science and technology fields, such as ICT with others such as environmental conservation. Moreover, ARGOMARINE has also supported many of the EU policy and social objectives, which are described in more details in the following sections.

In particular ARGOMARINE project can be considered as a pluridisciplinary and cross-thematic research cutting across different themes. The cross-thematic approach of this research project in the specific Transport call thematic is realized through the cover of different areas of the ICT field, the Environment, and the Security thematic.

Furthermore innovative solutions for rapid interventions in case of transport accidents and other natural hazard have been proposed for the protection of marine and coastal environment, in particular technologies for interventions at sea in case of accidents. The environment sector is one of the largest public in the EU. Easy, friendly, fast access, processing and retrieval of relevant environmental information are seen as key-factors for the acceptability of the new technologies. In line with the above, the ARGOMARINE project has kept the balance between (a) the development of generic technologies and services for access, description, fusion, and decision-making and (b) the customization of these technologies and services in the Environmental risk assessment domain. In this respect, the technology and methodology that the ARGOMARINE project has developed are of a standard nature and suitable to be applied to a variety of application domains and frameworks.

The underlying motivation is clearly reflected in the following futuristic environmental conservation scenarios:
- Fishery, both looking towards the safeguard of the fishery economy, and the fisher traffic in coastal and offshore environmental sensitive areas, with fall-out on the pollution control.
- Tourism, is in the sense of safeguard of the economy by means of early warning alerts in events which may negatively influence the marketing perception of the tourist, as a consequence of pollution events
- Wildlife protection against pollution accidents

The main aim of the ARGOMARINE project has been to provide an integrated environmental monitoring and management system mainly to public authorities (security enforcement agents, forest rangers, coastguards), civil protection and fleet operators, to promptly manage oil and chemical spills accidents (or deliberate tank washes) that can cause injuries and fatalities to citizens and environmental disasters, by means of early warnings and alarms. ARGOMARINE project has had the ambitious goal to integrate a large extent of various technologies, from sensor networks, to radar regarding the acquisition of data, from large databases for storing wide historical information, from complex data flow and communications using satellites technologies, to distributed computational systems.

More in detail the achieved impact in the ARGOMARINE project can be detailed as described in the following sections. In particular the project has faced main aspects related to:
- Decreasing the impact of marine transportation modes on both bio-diversity and protected fragile environments.
- Guaranteeing a neutral impact in both environment and climate change issues.

4.1.4.3.- Technologies for the safeguard and for preventive analysis in protected areas

The ARGOMARINE platform will guarantee both a better management of sea and coastal areas with more autonomy and control for the personnel responsible of environmental control and their agencies over their own areas providing a higher quality service, and a reduction in the burden of continuous visits all over the territory in the traditional surveillance modalities. These factors will stabilize or even better reduce the cost of the environmental conservation system and simultaneously will improve the quality and efficiency of agencies that are in charge of control services.

The increasing demand for mobility and for energy production cause more pollutant emissions, and accidents causing fatalities and injuries, in particular during transports of good and crude and refined oil. The systems will mitigate the possibilities of accidents due to uncontrolled routes and navigation system fails by means of creation of a centralized traffic management and a real time positioning system. A controlled traffic will decrease the accidents and the consequent environmental disaster, reducing the exposure of citizens to diverse pollutants lost during accidents itself. The creation of a vessel traffic control (like the airways control for flights) on a large area basis will reduce vessel accidents with severe consequences (e.g. Moby Prince/Agip Abruzzo, Thetis/Eleni, Nassaya/Shipbroker, not to say Costa Concordia and Mersa II, just to mention the last two events in the Tuscany Archipelago). Moreover it will accelerate the establishment of interoperability standards as well as secure and seamless communication of acquired and historical data between all involved partners, including end users.

Effects of the projects will be also on a higher quality remote environmental conservation, and resource savings by reducing costly in site surveillances, and late interventions. The early detection of areas at risk will improve the possibility of a successful intervention, which is significantly higher if the personnel in charge of surveillance is being warned at the beginning of the polluting threat, rather than as it currently occurs when the threat to the environment is at an advanced stage of their pollution.

Satellite radar imagery is a very valuable data source in marine oil spill detection and classification due to its independence of clouds and daylight, and the ability to cover large ocean areas when combining data from multiple satellites. Many satellite radar sensors launched in recent years also offer multi-polarisation images giving a better capability to detect potential spills on the ocean surface. Oil spill may cause severe damage to the coastal zone, among others to vulnerable fauna and birds, as well as to fisheries, aquaculture installations and tourist industry, and hence result in long term environmental degradation as well as substantial economic losses. Better methodologies to detect oil spills and their distribution is thus of high importance both in monitoring and mitigation of oil spills from vessels and offshore installations.

Beyond the direct environmental impact of such a precise post accident monitoring and forecasting system, an effective pollution control with the utilization of the ARGOMARINE MIS will have a positive socio-economic impact to the sea working population (i.e. fishermen) and the relevant tourist businesses. A monitoring and forecasting system capable of reducing the environmental impact of unpredictable oil spill event helps to build a secure framework for economic development (i.e. tourist business investments). This means that the income from the tourist industry raises in safe tourist business investment areas and new jobs are created. Apart form this indirect economic development impact a direct economic impact has to do with the economic losses that can be caused to the tourist business by oil spill event. A big oil-spill event in the Ionian or Tuscan Sea would harm a wide range of touristic establishments and jobs would be lost. The precise post accident monitoring and forecasting system can drastically reduce this negative economic impact since it contributes to effective and fast pollution control. The preciseness of the post accident monitoring based on repetitive hyperspectral image acquisitions is a key element for this system.

4.1.4.4.- Rapid detection and notification of emergency situation in marine environment for sea protection and monitoring

Through the early detection of pollution risk for the environment, ARGOMARINE platform will improve the possibility of quick intervention and treatment of the threat and thus reducing the probability for the accident to become of larger extent. The ARGOMARINE Marine Information System-Central Portal platform integration will grant access to the system at anytime from anywhere, and moreover it will extend the concept of in site surveillance to that of remote mobile surveillance, by allowing the monitoring of the surveillance area status even away of the operative central.

An early detection of areas at risk from pollution will effectively reduce the costs of polluted areas recovery, and improving the optimization of rescue and surveillance vehicles. Furthermore, the remote management of the areas under surveillance will reduce the number of visits to sites reducing subsequent costly direct in site surveillance. According to the protocols put at the operation during the last project field test experiment, alerting civil protection authorities as soon as the event has been detected will give the chance to coordinate the interventions and to make possible the concentration of instruments, operators and equipment in short time. The variety of employed technologies grants that our project will have a focus on data fusion and especially for a direct and rapid access to distributed information: just as an example, in case of an oil-spill event, repetitive airborne image acquisitions is one of the most effective ways for post-accident monitoring of the affected marine environment. With the use of hyperspectral imagery instead of true-color or multispectral imagery, important details about the spread and thickness of the oil-spill can be accurately estimated and thus, cleaning procedures can focus to the most affected areas achieving the optimum results in less time. The developed hyperspectral methodology is a near real time processing methodology and its results can be produced fast and be uploaded to a Marine Information System like the ARGOMARINE MIS, which is an efficient pollution monitoring and forecasting system. The results of the hyperspectral post accident monitoring methodology can be a valuable input for the pollution forecasting technologies, which have also been developed within the ARGOMARINE framework.

In this way, the ARGOMARINE MIS can provide timely and reliable access to observations and forecasts for the affected area, and seamlessly integrate these as well as software for analysis, decision-support and dissemination. Precise airborne hyperspectral post accident monitoring with reliable forecasting methodologies are key elements of a punctual pollution control for areas and shores which are, for instance, of particular naturalistic value, and/or are exposed to risk of accidental or even intentional contamination due to their vicinity to industrial or highly densely populated settlements, or crossed by a heavy ship traffic. Other areas which can benefit by the results of such monitoring could be those exposed to environmental risk in particular periods during the year due to an abrupt increase of the human population (i.e. tourist localities and shores).

4.1.4.5.- Coordinating and operational activities for efficient crisis support management against marine pollution and post-accident monitoring

The environmental services provided by the ARGOMARINE project will provide a holistic solution for the early detection and management of disaster causing polluting events: one of the benefits of this complete system will be an access to quality environmental conservation information for all, independent of location; quality assurance and performance improvement and improved preventive environmental conservation. The ARGOMARINE project has aimed at the improvement of the quality of life by providing agencies in charge of surveillance with a user-friendly and affordable way of understanding, managing and coping with environmental risk assessment at their location and also on-the-move. This concept provides involved agencies with continuous feedback and management guidelines relevant to their issues and duties.

Areas at risk once identified will benefit from the support of the ARGOMARINE platform, which will be able to detect the first relevant signs of the disaster and to immediately alert the agencies in charge of the surveillance. This will enable the latter to provide appropriate intervention in an effective and timely manner. Considering that polluting events have a greater prevalence and therefore a greater impact on the citizens (e.g. tourists), the possibility of blocking the polluting events will give more confidence to them, so as to continue their normal lives and be a productive part of the work force and active members of the community. It can be foreseen that ARGOMARINE project will bring a valuable contribution to the stabilization of the cost of the environmental conservation systems without compromising the quality and efficiency of environmental institutions. Regarding human health protection, the early warning system can help public authorities to evacuate population or targeted groups, banning e.g. bathing and fishing (both game and professional) in case of chemical or oil pollution (with possibilities of extension to toxic algae blooms like happened last summer in Liguria and Lazio with Ostreopsis Ovata) to avoid threats on human lives.

4.1.4.6.- Management of heterogeneous information in a Decision Support System for marine environment safeguard and marine pollution prevention:

The services provided by the ARGOMARINE platform environmental decision support and the knowledge base system is able to process the available information and to provide through the implemented closed-loop system useful information to the personnel responsible for the intervention about the status of their polluting accident and risks and the evolution of the events.

Different types of sensors capable to detect various pollutants are not useful if used "stand-alone", while the integration between them will give the chance to provide an efficient and prompt intervention.

Besides, managing heterogeneous information in a whole system will grant access to quality environmental conservation information for all, independent of location; complying with quality assurance and improving performance and preventive environmental conservation.

As a further impact, the short and long term analysis of the events occurred will help local/national/transnational authorities to issue laws to prevent and fight the pollutants release in the environment. Eventually, ARGOMARINE addresses oils and lubricants as target pollutants, but the system will permit the integration of any type of sensors for any types of parameters, giving the possibility to integrate any new methods and technologies. Other kind of risks can be investigated, opening the monitoring not only to marine environment but also to land and air.

In a wider perspective, the results obtained in ARGOMARINE through the MIS-Marine Information System show that the basic philosophy underneath the design and development of the project was correct, robust and powerful. It also emerged that this philosophy can be applied to several other sectors in environmental monitoring, safety and security. For example, the approach may be extended to other kinds of pollutants including floating debris. Indeed, given the extensibility and scalability features of its architecture, the MIS is ready to receive and accommodate data from the most disparate sensing platforms. Seamless integration of other computing services for data analysis and interpretation is also feasible. In this way, the potential impact of the whole ARGOMARINE platform becomes greater, since the solutions and tools provided during the project activities can be accommodated to other contexts related to environmental monitoring and protection.

In addition, thanks to the collaboration with Italian Coast Guard, the MIS has been designed and implemented taking into account the actual interventional chain activated in case of accidents. Therefore, the MIS could be integrated in the normal workflow followed by the Coast Guard where it might impact in the daily monitoring activities and give tangible support in crisis response.

4.1.4.7.- Methodologies, models and simulations tools for prompt assistance, organization and interventions in marine protected areas

ARGOMARINE project provides a number of facilities, which will help towards its acceptance by both environment conservation professionals and end-users alike. Easily navigable, user-friendly interfaces, secure data distribution of acquired data and historical records through the Internet are the basis provided by ARGOMARINE for a web service to be offered to stakeholders. Furthermore, it implements an improvement in the productivity of environmental conservation systems by facilitating surveillance services at the point of need and through better information processing.

Citizens are increasingly concerned about the maintenance of the environmental system. An important trend developing throughout Europe, is a move towards greater involvement of citizens in receiving information, in decision-making and choices and ultimately in assuming responsibility for their own environment. People, quite justifiably, are deeply worried about the impact of the technological revolution and the subsequent upheaval in their life and its quality. With this in mind, facilitation of more active participation of citizens in pollution prevention and environment conservation processes will be supported by the project.

Both real and effective case studies in the "National Park of the Tuscany Archipelago" and "National Marine Park of Zakynthos", ARGOMARINE has taken into account to extend the monitoring network not only to all the Mediterranean Sea, but also to North Sea, Black Sea and European Coastal Atlantic Ocean.

Within the ARGOMARINE framework, a methodology for the detection and mapping of oil spill events using very high spatial resolution multispectral images (i.e. IKONOS, QuickBird, RapidEye etc) has been developed, as an addendum to the more precise relevant hyperspectral methodology. The development of such a multispectral methodology has been considered important as each place is much more frequently viewed by multispectral satellite sensors and thus, can serve as a tool for the continuous monitoring of the marine environment. The multispectral methodology was used for early warning detection of oil-spill as an alternative to the SAR monitoring and the hyperspectral detection methodologies, which have also been developed within the ARGOMARINE project. As a side product, this methodology can also be used for detecting unknown natural oil outflows on the sea surface. Applying the proposed multispectral methodology on RapidEye images of the island of Zakynthos, a large unknown systematic natural oil outflow near the Zakynthos island has been discovered and served as the best proof for the evaluation of the developed oil-spill detection methodology. In order to further investigate this occurrence, a series of Landsat 4-5 TM and Landsat 7 ETM+ images have been downloaded from USGS and were also processed. These images revealed that the natural oil outflow systematically appears every summer for more than 26 years. The natural oil outflow was also verified by spot test from an NMPZ boat on August 1st, 2012. This important finding can have an important positive economic impact, as the methodology can be used for the exploration of such an important energy resource. The discovery of a new fuel resource could have tremendous socio-economic impacts to one area. Not all of them can be considered positive as such natural resources are often an economic curse rather than a blessing for a country. The positive environmental impact of the multispectral methodology is obvious and has to do with the cost effective pre/post accident monitoring of an area with the use of satellite multispectral images. For pre-accident monitoring, multispectral satellite images can be used as an alternative to the SAR satellite imagery. Even high resolution multispectral satellite images (i.e. Landsat TM) of very low or no cost can be used. For post accident monitoring, multispectral satellite images are a low cost solution in case that hyperspectral image acquisitions cannot be carried out. In this case identification of the oil type and estimation of the oil-spill thickness cannot be implemented.

4.1.4.8.- Liaisons with National-International operators for marine and submarine interventions

ARGOMARINE project aims to help in the strengthening of the EU leadership in the Environmental Conservation Systems' industry, by including a number of already available consumer ICT products for initial assessment inside the proposed ARGOMARINE platform, including systems and devices for the monitoring and management of the environment status of sea and coastal areas suffering subject to disaster and pollution risks.

At the present stage, contacts are in course:
1) with the Italian National Dept. of the Civil Protection-Presidency of the Council of Ministries to insert the ARGOMARINE technologies inside the National Antipollution Plan to be adopted in the next plan release.
2) with the Italian National General Command of the Coast Guard, to embed ARGOMARINE's MIS into Coast Guard's situation rooms at local and central levels

The Central ARGOMARINE web Portal offers seamless access to data from multiple sources, such as satellite data and derived products, in situ observations, met-ocean and oil spill drift model forecasts, through a unified interface. Having easy access to all data from all the sensors connected to the MIS as well as to other sources (from external parties) in the same system, through a common web browser, will save the operators for a substantial amount of work compared to extracting data from numerous systems. With further development and enhancement of the portal components and the MIS, the portal can contribute to improved oil spill monitoring by ensuring access to all relevant data in a timely manner.

A common monitoring system will coordinate the response of near countries in the case of large accidents or in case of need of a large number of operators, volunteers or decontaminating apparatus. A common response protocol can be adopted and revised regularly by international environmental and health institutions. Another main contribution our project aims at, is giving support to the adoption of standards, protocols and open architecture (e.g. GMES), following also the INSPIRE initiative recommendations, throughout the implementation of our system. Thus reinforced leadership of the EU Environmental Systems industry, including consumer ICT products for initial assessment, monitoring and management of the environment status can be achieved.

4.1.4.9.- A wider enrolment of societal stakeholder: the network of volunteers and the Argo Sentinel case

The results and success of the Argo Sentinel app shows an example of the wider societal implications that can be reached thanks to modern achievements in IT technologies. Indeed, too often technological research and social needs seem to walk on parallel tracks then never find a meeting point. However, it's just a matter of providing the right tools to get in touch technology, research institutions and end-users. And this is what it was desired to achieve with the introduction of the ARGO Sentinel mobile application. PNAT, CNR-ISTI and NMPZ planned an activity for the creation of a network of volunteers specifically in the area of the Tuscan Archipelago,of the National Marine Park of Zakynthos and generally of the Greek seas(associations of maritime operators, fishermen, bay watchers, diving centres, local and national civil protection networks etc.) in order to:
-establish of a network of "sea sentinels" helping to monitor the presence of oil slicks and spills at sea in proximity of coastal areas
-create an "early alert intervention network", which may be awaken and deployed in presence of a spillage event approaching beaches and shores.

- disseminate (in a proactive way) the ARGOMARINE results toward a general audience mainly composed by young people, which might be attracted by the direct participation to this kind of direct involvement.

Besides the basic goal of having a more detailed and immediate knowledge of the conditions of the sea during the period of the project activity, the use of this application is a step forward in marine environmental monitoring, because, in combination with the other technologies that are used by the ARGOMARINE project, it adds the contribution of volunteers who can easily communicate the sighting of a spill.

Making people active observer of the sea helps to raise awareness on the themes of marine pollution, safety and protection. In addition, the distribution of the application represents by itself a dissemination of the project scopes, results and achievements. As a potential impact, knowing that a not accidental spill can be detected by everyone and that this can be reported timely is de per se a deterrent to malicious actions. Possible exploitation plans of the volunteer-based platform may allow for a more effective intervention by the authorities.

The "ARGO Sentinel" app is distributed in Italian, English and Greek languages.

Current version is developed for Android phones equipped with GPS and is freely available on Google Play (see http://play.google.com/store/apps/details?id=it.cnr.isti.martinelli.argosentinel online).

Shortly the IOS version will be also available.

Two press releases were launched (see http://www.ARGOMARINE.eu/index.php/2012/08/28/sentinels-of-the-sea-and-researchers-for-a-day/, http://ARGOMARINE.nmp-zak.org/en/newsDetail.php?id=13 online) with specific Social Media dissemination strategy with the following results:
- From 07 to 17 September 2012, 224 news concerning the ARGO Sentinel launch appeared on web-journals and blogs;
- The news reached more than 500.000 Twitter accounts and impressions;
- Feedbacks of the news and updates were always positive or neutral;

4.1.4.10.- ARGOMARINE the communication and dissemination of results
The ARGOMARINE consortium carried out dissemination activities along the entire duration of the project. These activities were related to the wide diffusion and distribution of knowledge and information related to the project and to the establishment of a close cooperation with potential end-users, the scientific community and environmental organizations.

The aims of ARGOMARINE dissemination activity were:
-to raise awareness of the project and to publicize its activities, particularly its findings and results;
-to provide a mechanism to leverage efforts at European level;
-to identify, define and undertake exploitation activities which will be beneficial to the operators at a pan-European level.

ARGOMARINE main objectives related to the dissemination were:
- to disseminate, promote uptake of ARGOMARINE technology in wider EU community;

- to explain and convince EU users about ARGOMARINE's benefits and capability to tackle innovative and complex problems;
- to disseminate the EU requirements and needed services to ARGOMARINE community;
- to create a bridge between technological development and the communities to reduce the gaps between project results and their marketable applications.

During the 39 months of activities, ARGOMARINE fulfilled all the objectives using the following media:
1. Websites
2. Social Media
3. Press Releases
4. Conferences
5. Workshops
6. Publications
7. Joint workshops and meetings
8. Information material (brochures, leaflets, newsletters, handouts etc)
9. ARGOMARINE Book

4.1.4.11.- Social Media Communication and Digital PR
To increase the visibility of the project to a wider public and to create a real-time interaction between people and researchers, we opened and we managed all the useful Social Media to better disseminate the project, in particular:
a) YouTube Channel: http://www.youtube.com/ARGOMARINE
b) Facebook Page: http://www.facebook.com/ARGOMARINEproject
c) Twitter Channel: @ ARGOMARINE_EU - twitter.com/ARGOMARINE_EU
d) Slideshare Page: http://www.slideshare.net/ARGOMARINE
e) Flickr Page: http://www.flickr.com/ARGOMARINE
f) Telly (ex TwitVid) Channel: http://www.telly.com/ARGOMARINE_EU
g) Soundcloud Channel: http://www.soundcloud.com/ARGOMARINE

4.1.4.12.- YouTube Channel (see http://www.youtube.com/ARGOMARINE online)
The video-sharing website was used to upload videos specifically created to explain the project and to follow the evolutionary steps of the project. The ARGOMARINE Channel was customised and playlists for each type of video were created to ensure an easy navigability. Every video uploaded by ARGOMARINE was also incorporated in the official website in the Media Centre page (see http://www.argomarine.eu/media-centre online).

4.1.4.13.- Facebook Page (see http://www.facebook.com/ARGOMARINEproject online)
The ARGOMARINE page in the social networking site was opened to better share videos, images, events, workshops, news, and to create a network of people interested to the Project. Some customized TABs were created to better link all the ARGOMARINE official presence on the web:

4.1.4.14.- Twitter Channel
The ARGOMARINE Channel in the microblogging website service was created to better communicate thanks to the possibility of the updating of news, pictures, videos and liveblogging of the experiments and events

4.1.4.15.- Press releases and Media Campaigns

Each ARGOMARINE activity was disseminated through a press release. In the last year 21 press releases were disseminate and more than 250 articles appeared on the local and national newspapers and online journals.

A particular attention was paid to involve mass-media in the dissemination process, mainly TV programs oriented to scientific divulgation. As it is possible to see in the ARGOMARINE YouTube Channel (see http://www.youtube.com/watch?v=xpSVdD8pi78&list=PLD9EA0E223FCC1AD5 online), 25 interviews and reports appeared in local and national TV programs in Italy, Portugal and Greece.

A particular contribution to the broadcast diffusion was the realization of professionals videos sent to the national and international TVs (see http://www.ARGOMARINE.eu/index.php/media-center/ online)

The most important Italian, Portuguese and Greek TV and radio broadcasts dedicated reports to ARGOMARINE, and in particular:
Italy: RAI 1 (Audience: 5 mil. of people): Linea Blu, TG1
RAI2 (Audience: 2,2 mil.): TG2
RAI3 (Audience: 2,5 mil): Leonardo, Mediterraneo, Geo&Geo, TG3
Portugal: RTP1 (News Broadcast, Biosfera, Mar Portugues)
Greece: NET: Mediterraneo

E.R.Z (News Broadcast)
ERA NET (Radio Broadcast)

4.1.4.16.- Workshop and Conferences

The dissemination of ARGOMARINE results took place at national and international level through participation in national and international conferences, workshops, and other scientific events. Participation to workshops took place at national and European level to explain the vision and goals of the project. The consortium undertook the responsibility to present the results of ARGOMARINE in a number of international events until the end of the project.

At the end of the second year of the project (15th December 2011), a first workshop was organized in Zakynthos island, by NMPZ. The workshop on "ARGOMARINE: A New Oil Spill Early Warning System" was held among the Scientific Partners of the ARGOMARINE Project and representatives from the competent Local Services of the island who play an important role in the contingency operations against marine pollution events and academic institutes.

This workshop was mainly a short of discussion with the attendants, aiming to:

- Present the ARGOMARINE project as a collaborative work of many experts in different fields, for the first time in front of an audience, where every partner had the opportunity to present and discuss his work and the first results of the project.
- The establishment of a platform for discussion end-user needs, fill any kind of gap, so as to have an integrated system which will be full effective and functional.

Also, among the attendants were local journalists who had the opportunity to have full information about the project which indirectly was disseminated to the general public through the newspapers articles and the news broadcast videos which followed up. Moreover, before the workshop was given a press conference.

Before the end of the project (November 30th, 2012), another ARGOMARINE Scientific Environmental Workshop on "Marine Pollution: Monitoring Systems and Treatment" was organized in Zakynthos island, by NMPZ. In the framework of this Workshop were invited to speak ten specialized scientists from Academic and Research Institutes, National Policy Authorities (Hellenic Ministry of Mercantile Marine, Marine Environment Protection Directorate) and Marine Remediation Companies, as well as the Management Agency of National Marine Park of Zakynthos. For the Workshop were invited and informed about the project High Level Policy Makers (e.g. Greece's European Commissioner for Maritime Affairs and Fisheries, Hellenic Ministry of Environment, Energy and Climate Change and many others) and among the attendants were representatives from Local and Regional Authorities, Environmental Organizations and NGOs, Academic and Research Institutes, University Students and other Stakeholders. The benefits and the achievements of this workshop were multiple in local,national and EU level, as well as the close cooperation with potential end-users, scientific community and environmental organizations,the connection of the ARGOMARINE system with other maritime monitoring and forecasting systems and technologies and the large local media impact.

At the end of the project, a final thematic international workshop (Nov. 22th, 2013) was organized in Elba Island. The attendants came mainly from the end-user institutions (environmental institutions, national parks, health protection, coast guards), academic and research institutes, but also from high level policy makers. One section of the workshop was dedicated to the integration of other detection systems or technologies in the ARGOMARINE system, as well as to discuss the end-users' needs. In addition to the planned activities at project level, the partners of the ARGOMARINE consortium contributed to common dissemination activities of the project participating in workshops, conferences and meetings.

Strong interactions were established with the interested intermediary organisations (European regional governmental bodies, environment professional associations and local associations), by holding, in cooperation, seminars and workshops.

Moreover, to ensure a free exchange of overview information with any other activity linked with ARGOMARINE and to create a cooperation with Authorities, Public Entities, etc., in most of the conferences, horizontal activities of the ARGOMARINE project were identified, including joint works with other EU projects as well as further co-operations and exchange activities (e.g. the joint activity with MEDPan during the EMD or with EGEMP and other EU project during the final international conference).

From the beginning of the project, ARGOMARINE was presented in 31 conferences and workshops and, in particular:

- GIONHA (Governance and Integrated Observation of marine Natural Habitat) Project's Lauch Seminar, Livorno (Italy), February 17th, 2010;
- Oceanology International 2010, London (UK), March 9/11th, 2010;
- ARCOPOL (The Atlantic Regions' Coastal Pollution Response) Project meeting: New tools for better planning, response management and damage assessment in HNS, Inert and Oil Spills, April 30th, 2010;
- Italian Department of Civilian Protection (Meeting conference), Rome, May 1st, 2010;

- EGEMP (European Group of Experts on satellite Monitoring and assessment of sea-based oil Pollution) Meeting, Ispra (VA), Italy, June 8th, 2010;
- CT for sea monitoring – Meeting with the Italian Naval League, Pisa Section, Pisa, Italy, June 12th, 2010;
- EU-7th FP-SPACE Kick Off meeting of the Project SeaBILLA (Sea Border Surveillance), Rome, June 2010;
- IEEE WHISPERS (Workshop in Hyperspectral Image and Signal Processing: Evolution in Remote Sensing) Conference, held in Reykjavik, Iceland, June 14th-16th, 2010;
- Marciana Science Festival, Isle of Elba, Italy, August 2010;
- HIC-2010 - 9th International Conference on Hydroinformatics, Tianjin-China, September 7th, 2010;
- CICC-ITOE (International Conference on Ocean Engineering), Macau, China, March 6th, 2011;
- SEATEC, Carrara (Italy), February 16-18th, 2011;
- MO-MAR (Maritime-Monitoring) project (ITA-FRA Maritime Programme), Portoferraio (Isle of Elba), February 24th , 2011;
- European Geosciences Union 2011 Assembly, Vienna/Austria, April 4-8th, 2011;
- International Symposium on Remote Sensing of the Environment (ISRSE), Sydney, Australia, April 10-15th, 2011;
- International FairIEEE Whispers 2011, Portugal, June 16-19th 2011;
- International Seminar on "Management of Protect Area and Technology for Biodiversity Protection", Shanghai EXPO, September 13th, 2011;
- CEST 2011, Rhodes Greece, September 8-10th, 2011;
- 10th International Conference On The Mediterranean Coastal Environment-MEDCOAST, Rhodes (Greece), October 25-29th, 2011;
- MEDCOAST 2011, International Conference on the Mediterranean Coastal Environment, Rhodes Greece, October 25-29th, 2011;
- Simpósio Margem Sul Portuguesa, Faro/Portugal, November 10th, 2011;
- Encontro Mar Português, Faro/ Portugal, November 17-18, 2011;
- International Conference Interspill 2012, London, UK, March, 13-15th, 2012;
- EMD, European Maritime Days, Gothemburg, May 20-23rd, 2012;
- TAN, Livorno (ITALY), May 26th, 2012;
- IEEE Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), June4-7th, 2012, Shanghai, China.
- "EasyCO" final Workshop, Lisbon, Portugal, June 29th, 2012;
- IEEE Internationak Geoscience and Remote Sensing Symposium, 22-27 July 2012, Munich, Germany.
- Argo Sentinel, a mobile app for sea safety – Meeting with the Italian Naval League, Pisa Section, Pisa (Italy), November 10th, 2012;
- University of Pisa, Faculty of Engineering, Bachelor in Biomedical Engineering. "Sensors for hydrocarbons' detection in ARGOMARINE project". Candidate: Erika Di Stefano. Supervisors: Dr.Claudio Domenici, Eng.Alessandro Tonacci. (December 2012).
- AISEM 2013 – XVII Conference of the Italian Society of Sensors and Microsystems. A.Tonacci, D.Corda, G.Tartarisco, G.Pioggia, C.Domenici. "A smart system to detect Volatile Organic Compounds produced by hydrocarbons on sea water" (poster session)

List of Websites:

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http://ARGOMARINE.nmp-zak.org/
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http://www.facebook.com/ARGOMARINEproject
@ARGOMARINE_EU - twitter.com/ARGOMARINE_EU

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