# INSEA FINAL ACTIVITY REPORT

**Period January 1, 2005 – December 31, 2008**

## DOCUMENTATION FORM

### TITLE

INSEA FINAL ACTIVITY REPORT: Project final report. Period – January 1, 2005 – December 31, 2008


### KEYWORDS

Final activity report, INSEA



### ABSTRACT

This report contain an overview of the activities carried out by the INSEA consortium during the project lifetime, a description of progress toward the objectives of the project, a description of progress towards the milestones and deliverables foreseen, the identification of the problems encountered and corrective action taken. As an Annex to this document, an updated plan for using and disseminating the knowledge is presented.


### INSTITUTIONS INVOLVED

| | | |
|---|---|---|
| ☒ IST | ☒ MARIS | ☒ NOVELTIS |
| ☒ HIDROMOD | ☒ UPS-LA | ☒ HCMR |
| ☒ COMSINE | ☒ CNRS-LOB | ☒ NKUA |


### FUNDING

Instrument: Specific Targeted Research or Innovation Project

Thematic Priority: AERO-2003-2.3.3.1a

Contract nº: 012336 (SST4-CT-2005-012336)



### AUTHOR(S)

Adélio Silva and Margarida Nascimento


### REVISION

Ramiro Neves

| DATE | NUMBER OF PAGES | DISSEMINATION LEVEL |
|---|---|---|
| 27/01/2008 | 49 | ☐ Confidential<br>☐ Restricted<br>☒ Public |


**Project Coordinator: Ramiro Neves, PhD.**

**E-mail: coordinationcommittee@ecomanage.info**

**Tel: (+351) 218 417 397 ; Fax: (+351) 218 419 423**

**www.insea.info**

**MARETEC — Marine & Environment Technology Centre**

**Instituto Superior Técnico**

**Secção de Ambiente e Energia — Dep. De Mecânica**

**Avenida Rovisco Pais**

**1049 - 001 Lisboa PORTUGAL**

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# 1 Introduction

This report presents an overview of the activities carried out by the INSEA *consortium*, including the level of accomplishment of the objectives foreseen in the DOW and its milestones and deliverables. The report makes an overall description of the activities carried out in the project framework and an evaluation of how the project effectively contributed to the progress of the science and technology in the different knowledge areas tackled by the project. It also summarizes the problems encountered during the project execution and corrective actions taken to overcome or minimize it.

# 2 General evaluation of the project

With this report the INSEA project officially reaches the end. From an overall point of view it may be said that most of the originally proposed objectives have been achieved. In some areas the progress has been more evident than on the others, but all the subjects that were foreseen in the Technical Annex were tackled and the overall result, at least from the point of view of the INSEA consortium, is very positive.

In a general way one may identify five specific fields where the project proposed to produce improved or new approaches to deal with the problems:

- The downscaling from regional to local solutions;
- The data assimilation schemes;
- The relevance of a correct evaluation of the land nutrient sources for a proper evaluation of the coastal eutrophication (catchments nutrient loads evaluation);
- The integration of different sources of data with models (with a special emphasis to the use of remote sensed data);
- The organization of the data sources and model results in structured data bases accessible and exploitable trough the internet.

By the end of the project we end-up with operational systems running in all of the three sites and with users interested in the project products. The systems are showing capabilities that may help effectively in issues such as the coastal management and safety and, according the consortium experience and feed-back from the stakeholders, the services made available in the framework of INSEA combined with other available services in the framework of the Kopernikus (former GMES) Core Services represent already the basis for the dissemination of operational downstream services.

In any case it is a fact that despite of the all effort put on the subject, some aspects had not gone so far as the project team would like. One of these aspects is the improving the quality of satellite color data. Although important progress has been achieved and the work performed launched the basis for an innovative work with the radiative transfer models the subject revealed very complex aspects that need further investigations to become of current use. In any case it was demonstrated the potentialities of the approach and the work is being continued beyond the project framework. This issue will be object of discussion on a paper that will be submitted to the Journal of Marine Systems.

Also the aspect of the communications did not go as further as the team would wish. Although all the objectives foreseen in the Technical Annex were full achieved, at some time there was some expectation that the technological evolution and the available infrastructure could allow to have a prototype working on the field during the project lifetime. The “proof of concept” foreseen in the Technical Annex has been achieved but the infrastructure it is not yet ready to fully support the satellite communications in the basis proposed in the project. However, according the state of the art described in Deliverable 2.9, the concept proposed is very promising and it may indeed play a relevant role in the near future.

The remaining foreseen activities were focused in the final implementation of the models and selection of proper outputs that may be used and understood by the common users, in the finalization of the remote data exploitation tools and in the dissemination of the INSEA products and services trough the end-users.

In the following chapters a description of the work performed in these different areas will be presented.

## 2.1 Deliverables

A complete list of the deliverables of the project is presented in

Table 1. A general overview of the project status shows that all the foreseen deliverables were successfully concluded. All these documents are published on the project web page.

Table 1. Deliverables List.

| Deliverable | Deliverable title |
|---|---|
| D1.1 | Report characterizing each system. |
| D1.2 | Report describing the objectives and main consequences and conclusions of approaches for dealing with eutrophication problems that were previously implemented in each study site. |
| D1.3 | Data Specification on parameters, formats, spatial and temporal distribution for supporting legal requirements namely indexes for describing environmental status. This information will be compiled together with the previous one in a Join Report. |
| D2.1 | Report describing the methodologies used to nest the local hydrodynamic solution with the large scale ones |
| D2.2 | Report describing the methodologies used to impose the biogeochemical open boundary condition |
| D2.3 | Report describing the best way of coupling local operational systems with large scale ones based in the project experience |
| D2.4 | Coastal sea surface topography database |
| D2.5 | Specification document for remote sensed Ocean colour and SST data processing in coastal zone. |
| D2.6 | Specification document for remote sensed Ocean colour and SST observation operators for their assimilation in the coupled model |
| D2.7 | Technical note for the analysis of the potential gain of remote sensed SST and ocean colour data assimilation in the coupled physical-biogeochemical model |
| D2.8 | Report with the characterization of the available data sources that can be use for data assimilation in each site; |
| D2.9 | Report describing the outcomes of the data acquisition analysis and design tasks |
| D2.10 | Demonstration of wireless data messaging using a proof-of-concept implementation based on the 'PocketSAT' prototype satellite user terminal platform and a test receiver |
| D3.1 | Level 1 maps and time series |
| D3.2 | Level 2 maps and time series |
| D4.1 | Report on Data-Management Workshop, including scientific functionalities Remote Data Access System |
| D4.2 | Meta-Data Handbook |
| D4.3 | Conceptual Design Remote Data Access System |
| D4.4 | Functional Web/Gis Interface |
| D5.1 | Web page and internet discussion forum |
| D5.2 | Report with the minutes of the first stakeholders workshop |
| D5.3 | Report with the minutes of the second stakeholders workshop |
| D5.4 | Printed material for project promotion |
| D5.5 | Demonstration tool |
| D6.1 | Project Management Guidelines |
| D6.2 | Project Detailed Workplan + Quality Plan |
| D6.3 | Leaflet with a Project Presentation |
| D6.4 | Web page of the project |
| D6.5 | Periodic Progress and Management Reports |
| D6.6 | Periodic Management Reports & Cost statements |
| D6.7 | Final Progress Report |

Deliverables D1.1 to D1.3 were merged in one single document in order to be possible to end-up with an integrated document with the sites characterization. This document was entitled "*Description of the ecosystem: Eutrophication DPSIR analysis of the INSEA test sites*".

The same kind of concept were used in the compilation of the Deliverables D2.1, D2.2 and D2.3 which content was merged in a single document entitled "*Coupling local operational models to regional solutions. Methodologies used to nest local solutions with the large scale one and to impose the biogeochemical open boundary solution*". By this way the reader instead of a fragmented vision of the used approaches gets an overview of the models implementation including the physical and biogeochemical components.

The deliverables D2.4 to D2.8 are related with the available data (remote and local) and refers to:

- The description of the Sea Surface Topography data made available by Noveltis in the framework of the project (D2.4);
- The specifications for remote sensed Ocean colour and SST data processing in coastal zone (D2.5);
- The specifications for remote sensed Ocean colour and SST observation operators for their assimilation in the coupled model (D2.6);
- The analysis of the potential gain of remote sensed SST and ocean colour data assimilation in the coupled physical-biogeochemical model (D2.7);
- The characterization of the available data sources that can be use for data assimilation in each site (D2.8)

The deliverables D2.9 and D2.10 describe the work done in the field of the satellite communications providing an evaluation of the state of the art (D2.9) and a description of the concept and the tests made to demonstrate the "proof of concept" of the proposed technologies (D2.10).

The deliverables D3.1 and D3.2 intended to make a description of the models results both in what concerns the "raw" results (level 1) and the processed results (level 2). Also in this case, for the readers convenience the content of both deliverables was merged in a single document.

The deliverables related with work package 4 (D4.1 to D4.4) all refers to the data management and publication issues. D4.1, which in the DOW is referred as "*Report on Data-Management Workshop, including scientific functionalities Remote Data Access System*" was split in two documents: One making reference to the Data-Management Workshop (D4.1) and another making reference to the Data Quality Control (D4.1a). The remaining ones (D4.2, D4.3 and D4.4) were produced according to what was foreseen in the DOW. As a result of the work developed in this work package, a data base and a GIS interface are publically available on www.insea.info/cdi as described in Deliverable D4.4.

Regarding the dissemination activities, to which refers work package 5, a web page (D5.1) was implemented (which includes a web forum for internal discussion and document exchange) and there were produced two documents referring the dissemination actions that were carried out with the stakeholders (D5.2 and D5.3). Also two leaflets, one in the project beginning describing the project objectives and another one in the project end describing some of the project results, were produced according to what was foreseen in the framework of D5.4.

As a final expression of the INSEA success, by the end of the project there are running operational models for the 3 project sites which constitute a demonstration of the INSEA capabilities (D5.5).

# 3 Summary of the activities carried out

As referred before the INSEA activities were specially focused in modelling, remote sensing, data management and communications activities. The work related with the modelling and remote sensing activities was resumed in a series of papers to be published under a special number of Journal of Marine Systems though it is advised its reading for clarification any major technical or scientific detail (and the respective project deliverables). The activities carried out in the framework of the data management and communications are tackling mostly technical issues and, for this reason, the major details of the work are mainly described in the respective deliverables.

In the following paragraphs a brief description of the work carried out in the framework of these activities as well as the major project achievements in each area will be described.

## 3.1 Modelling

The modelling activities foreseen within INSEA project comprises the ecosystems characterization, the models implementation and testing, including the downscaling and data assimilation activities and, finally, the put in place of the operational systems.

During the first stage of the project a characterization of the three INSEA test sites (Tagus estuary and Estoril Coast in Portugal, Gulf of Fos in France and Gulf of Pagasitikos in Greece) has been done. The three systems were characterized following a comprehensive DPSIR approach which enabled to identify the major drivers and pressures to which each one is subjected, their present state, the impacts that may be identified and the responses (technical and legal) that were implemented. The result of this work was compiled on Deliverable D1.1-D1.3. This characterization included also a bibliographic review of the remote sensing literature to discover if any remote sensing data might be used to model implementation and/or validation. A particular attention was paid to the ocean colour data and the approaches to chlorophyll-a estimation as this is the most useful derived parameter from remote sensing data for coastal eutrophication studies.

Relevant advances were achieved in what concerns the downscaling, data assimilation and ocean-atmosphere processes coupling issues. Some examples of this work may be referred such as:

- The implementation and testing of sate of the art nesting techniques for the coupling of the local models with the regional hydrodynamic models (downscaling).

  For the Gulf of Fos site the physical modelling strategy is based on several nested models. The same physical model, Symphonie (Marsaleix et al, 2008), is used at different scales, namely from the scale of the Gulf of Fos, to the regional scale (i.e. from the Catalan Sea to the Ligurian Sea). The lateral open boundaries of the regional model are connected to the global Mediterranean model operated by INGV in the frame of the MFSTEP project. This downscaling strategy enables to take into account the influence of the large scale circulation on the Gulf of Fos system.

  The same MFSTEP regional solution is being used in the case of Pagasitikos to impose the large scale solution.

  In the case of Tagus a high resolution solution of the Northern Atlantic and the Mediterranean basin provided by Mercator-Océan (M-O), PSY2v2r1, is being used to provide the boundary conditions to the Portuguese Coast model. The Mercator solution reproduces accurately the main characteristics of the circulation off western Iberia peninsula namely, the Mediterranean Outflow (MO), several downstream Mediterranean veins (Ambar et al, 2002, Bower et al., 2002 and Iorga and Lozier, 1999a) and also the formation of meddies near Cape St.Vincent and over the Estremadura promontory (Pichevin and Nof, 1996 and Bower et al., 2002). The Tagus detailed model is then using a series of 3 nested MOHID grids as represented in *Figure 1*.

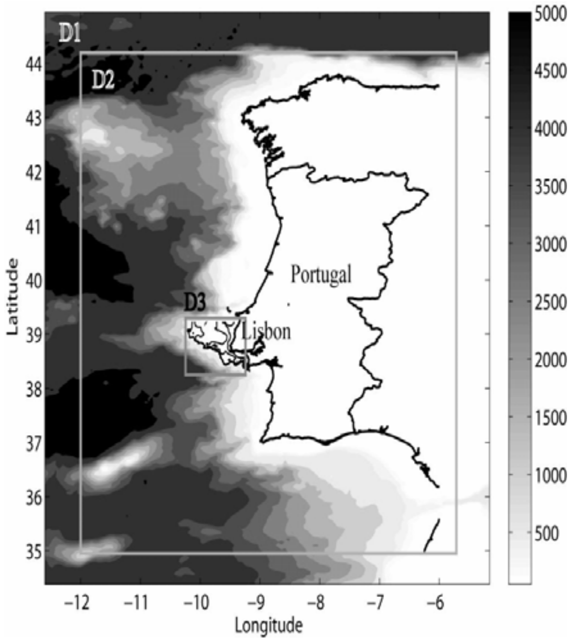



*Figure 1: The MOHID nesting system, showing D1 and D2 and D3 (Estremadura Coast). Gray scale is bathymetry in meters*

- The implementation and testing of data assimilation schemes both for the physical and biogeochemical parameters. In the case of Tagus only physical parameters were object of assimilation techniques but in the case of Pagasitikos and Fos advanced assimilation techniques for the biogeochemical variables were also evaluated.

  For Pagasitikos the singular evolutive extended Kalman (SEEK) filter has been implemented and validated using the technique of twin experiments. The assimilation system tested by assimilating temperature and salinity profiles. Also a set of sensitivity experiments has been conducted with the SFEK, SEEK and SEIK filters in order to determine the most appropriate filter setup to assimilate the weekly SeaWiFS data sets into the ecosystem model for year 2006 and for time period of 10 months/40 weeks (Jan. 4 to the first week of October). For the SEEK and SEIK filters the evolution of the 15 correction directions was done in parallel on a multi-processors SGI machine using MPI programming. A 10-years simulation was performed by the latest version of the Skiron/ETA model for the needs of the data assimilation. A post-processing of the 10-years simulations of ocean-atmosphere model was performed and relevant advances made in what concerns data assimilation schemes and comparison of different filters through twin and hindcast experiments. The performance of the filters was evaluated. Additionally, real satellite sea colour data (chlorophyll-a into the ecosystem model) were assimilated.

For Gulf of Fos a data assimilation experiment was performed in order to test the procedure in coastal regions submitted to high variability in external forcing. The simulation period started on May, 1 until May, 22, 2001. This period corresponds to the ModelFos cruise carried out in Gulf of Fos. On May 12, 14 and 16, in situ measurements of chlorophyll, nitrate and ammonium concentrations were performed on a regular grid of 22 stations. This data set was used to evaluate the efficiency on “assimilation-observed variable” (chlorophyll) but also on “assimilation-non observed variables” (nutrients). It has to be underlined that in situ data were not used in the assimilation process.

For Tagus a simplified extended Kalman filter correcting state along pre-specified error variability modes, based on the SEEK filter scheme. was applied, in a twin experiment, to a 2D hydrodynamic model of the Tagus Estuary (Portugal) and adjacent coast to correct a forecast error derived from mean sea level perturbation, a common source of model forecast error, with tide gauge measurements. Forecast error departures from normal probability distribution are assessed to verify conditions for the filter correction. Considering a system state comprised of water level and zonal and meridional horizontal velocity components, the error variability modes are derived from the EOF analysis of historical model forecast estimates. The filter performance is assessed in several coastal locations in the context of different number of measurement locations and use of different error variability modes.

## 3.2 Remote sensing

The remote sensing activities included tasks related with improvement of the quality of the altimeter data (T2.5) and the specification for remote sensed ocean colour observation operators for its assimilation (T2.6).

Regarding the first issue NOVELTIS developed in 2006 the X-TRACK software. This processing chain processes standard altimetric products like the one distributed by space and meteorology agencies (CNES, ESA, NOAA), and improves the products, in particular for coastal applications (but not only). The improvement comes from new algorithms and correction terms that are not in the standard products. The upgrade consists in:

- adding new geophysical correction terms, in particular the tide and the response of the ocean to the atmospheric forcing;

- implementing regional models that are more accurate than the global models used in the standard products;

- applying a more accurate data quality checking: the standard editing criteria are too coarse for a proper flagging of the data in coastal regions: sometimes good data is flagged as ”bad’ and obviously bad data is flagged ”good’;

- computing a mean sea surface under the satellite ground tracks, with the estimation of the local cross-track gradient, which is useful for research groups working with data re-localized over fixed reference ground tracks.

The X-TRACK data can be used either for the validation of the dynamical models, or for the assimilation in the dynamical models. The coastal sea surface topography database for the Aegean Sea has been delivered to partners on June 2007.The coastal sea surface topography database for the Tagus Area was delivered two months later. Due of the large extent of the area of interest, the X-TRACK altimetric data processor had to be adapted for large datasets (improvement of an inversion procedure). A brief description of the database content was done in Deliverable D2.4.

Regarding the issue of Ocean color (OC), from a questionnaire filled by the partners, NOVELTIS made a review of OC products and algorithms and issued a document listing OC products, how to get them, and read them (D2.5). Based on a review of the state of art, it was proposed to use OC products giving the inherent optical properties (IOP, a data intermediate between the instrument measurement and the biogeochemical models parameters), coupled with the joint use of a radiative transfer model. A description of the proposed new approach was done on D2.6.

Taken into account the complexity of this method, NOVELTIS, IST and HCMR had a dedicated working meeting, during the INSEA Meeting in Toulouse (Jan 2008), in order to discuss the different ways of implementation. NOVELTIS, IST and HCMR concluded that it was important and valuable to initiate this technological development during the INSEA: this new development was approved by the coordinator.

During 2008, an observation operator prototype start to be developed, based on the HYDROLIGHT numerical marine optical model. Starting from models outputs and space products provided by the partners there were processed test cases over the Gulf of Fos (CNRS-LA), Pagasitikos (HCMR) and Tagus Estuary (IST) zones. The prototyping effort was focused on creating an interface to transform models outputs into parameters compliant with the HYDROLIGHT inputs, setting the HYDROLIGHT parameters with the appropriate values, adapting the HYDROLIGHT source code for LINUX environment and adapt it from 1-D point to 2-D grid mode computation, interfacing 3 models outputs formats (from HCMR, IST, CNRS-LA) and 3 EO products (SeaWIFS, MODIS, MERIS) characterized by different spectral bands, taking into account the solar and view angles. The influence of the vertical distribution of the phytoplankton on the remote sensing measurements was also evaluated. NOVELTIS obtained the results from the partners involved in ocean colour data assimilation (CNRS-LOB, HCMR, IST), and made a synthesis of the results obtained, and a set of recommendations.

Also in order to describe and validate the model's assimilation outcomes several satellite remote sensing datasets were used. As referred particular attention was paid to the ocean colour Chlorophyll-a (Chl-a) datasets. Beyond the previous referred efforts around the Hydrolight software, several existing algorithms to assess the surface Chl-a was tried: the Bricaud et al (2002) algorithm applied to SeaWiFS Chl-a data, the Sancak et al (2005) algorithm applied to SeaWiFS data, the Bricaud et al (2002) algorithm experimentally applied to MODIS-Aqua data, and the NASA OCM3 applied to MODIS-Aqua data. Although the tested Chl-a algorithms performed well in the regions that they build for, it seems that this performance it is not extendable to any environment. This was the case of the Pagasitikos Gulf to which it was not possible to get acceptable results with the referred algorithms.

A comparison with in situ data, and a production of a new local algorithm would be ideal. A proper validation of Chl-a should involve a ground-truth comparison with at least hundreds of in situ data of approximately equal spatiotemporal distribution. However, due to the lack of in situ data, here we used several different sensors as well as algorithms in order to have at least an appropriate outcome, based on the empirical knowledge of Chl-a distribution and abundance derived from Petihakis

PhD, 2004. Thus, instead of using local/regional algorithms we attempted to assess the standard products of NASA (SeaWiFS and MODIS) and ESA (Globecolor) by producing weekly data, maps, and time-series for the period of 2002-2006 for Pagasitikos Gulf. Approximately 230 weekly mean composites were processed from each sensor. The comparison between the model outcome and satellite data performed using both visual maps as well as weekly mean time-series. The final result, using these sensors and standard algorithms, was found to adequately explain the spatiotemporal distribution and abundance of Chl-a in the study region. The biggest problem was the lack of data in periods where biology seemed to be important. However, Globcolor product, which offers a merged sensor dataset (MODIS, SeaWiFS, MERIS) was finally chosen in an attempt to overcome a number of gaps of the previously used data. An empirical comparison with the *in situ* dataset, showed that the range of the satellite derived Chl-a values were falling within the expected range.

### 3.2.1 Improvements beyond the state of the art

**Altimetry**

Before INSEA: standard altimetric data (as those delivered by the space agencies) has the following defaults: 1) near the coast, the radar signal may be contaminated by its interaction with land (15-20 km), 2) some invalid data may be erroneously flagged “valid”, and some valid data may be erroneously flagged “invalid” by the standard data editing algorithms that consider only individual low rate data (one per 1 second) measurements instead of considering series of hi-rate data (10 or 20 per second) , 3) some geophysical corrections (tides, quick response of the sea level to atmospheric changes) may not be adapted to coastal zones, but were designed for the open ocean. Moreover, some defaults are not specific to the coastal zones: 4) the mean sea-level provided by the standard products is computed over a fixed period (e.g. 10 or 15 years of altimetric missions), while to be correctly compared with ocean numerical simulations, the mean sea surface must be computed over the same time span; 5) data sampling may be improved: e.g. measurements may projected over a reference along-track grid.

Activity during INSEA: NOVELTIS continued to develop the X-TRACK software by implementing or improving the solutions to the insufficiencies listed above. NOVELTIS processed the requested missions over the periods of interest for INSEA, and provided the partner with a costal altimetry database including 4 missions: TOPEX, Jason-1, ENVISAT, GFO. X-TRACK was used also to prepare data sets for other projects (for ESA, CNES, and research laboratories in Europe). NOVELTIS improved X-TRACK capability to process datasets larger than what was possible the versions anterior to INSEA.

State of the art at the end of INSEA: the X-TRACK software has been improved and can be exploited to produce on-demand coastal altimetry data for other projects. This processing was presented at several oceanography / altimetry workshops (OSTST 2007 Hobart, ENVISAT 2007 Montreux, IGARSS 2007 Barcelona Coastal Altimetry 2008 Silver Spring, OSTST 2008 Nice)

**Ocean Colour**

Before INSEA: Ocean colour products are commonly used under the form of “level-2” products, i.e. chlorophyll concentration derived from radiance measurements from multispectral optical imagers (e.g. Sea WIFS, MODIS, MERIS): “level-1”. The assumptions made for this conversion are so strong that there is a great uncertainty on the “level-2” products obtained (typically several tens of percent of error for the chlorophyll concentration). NOVELTIS had proposed a study to specify how to use the “level-1” products for which the error is better known and consists in the instruments noise and imperfections, and the atmospheric correction.

Activity during INSEA: NOVELTIS made a review of the ocean products available for the INSEA project, on the algorithms used to derive the chlorophyll product, and on their precision. The conclusion is that the precision of such products are difficult to assess, and that chlorophyll products does not contain information on the vertical distribution of the chlorophyll: this is a difficulty when one need to compare them with ocean numerical models (either for model validation or data assimilation). Then, NOVELTIS specified a new method for using “level-1” products by transforming the ocean models chlorophyll concentration into inherent optical properties, and then in radiance as measured by an optical instrument, through the use of the HYDROLIGHT marine radiative transfer model. When it appeared that the method was specified enough, the NOVELTIS undertook to implement the new algorithm, and processed some test cases from partners ocean simulation over the 3 INSEA sites, and from concomitant radiance products (SeaWIFS, MODIS, MERIS).

NOVELTIS realised also a synthesis of the partners experience on data assimilation of standard ocean products.

State of the art at the end of INSEA: A totally new method was specified and prototyped from scratch, whose principle is to transform biogeochemical model output in simulated water leaving radiance, comparable the level-1 ocean colour products. The initial INSEA objective is exceeded, since besides the theoretical study planned, a real exercise was made during the project duration. This pioneer work will lead to a scientific article to be submitted to a scientific revue at the end of January 2008 (A. Banks, Journal of Marine Systems). The method and preliminary results were presented by NOVELTIS at the MWWD 2008 workshop in Dubrovnik. The prototyped method should benefit from further developments in order to become fully operational and user-friendly.

### 3.2.2 Atmospheric coupling

During this period, the NKUA group worked on post processing model data (RAMS model), quality control and comparison with existing observations. The model data for the area of Pagasitikos delivered to HCMR group. In addition, NKUA performed simulations with RAMS for a selected case of the Lisbon area (very high-resolution simulation). Cooperation with the other groups on how to use the RAMS fields in their models. The model output evaluated with existing observations. Additional sensitivity tests were performed. NKUA participated in the organized project meetings in Heraclion, Crete and Toulouse, France while prepared a presentation for Dubrovnic meeting that was presented from the HCMR participant since the NKUA participant had to cancel the participation due to force majore.

## 3.3 Data acquisition

The Data Acquisition activity, described by Task 2.7, concerned the development of a SatCom data acquisition system for coastal waters. The water monitoring activities undertaken by the INSEA consortium will in part be supported through observing water quality parameters from in-situ sensors deployed at the monitoring sites. The way in which observations can be communicated back to a central control centre for analysis is fundamental to this concept. Geographical independence is desirable in deploying sensors, and the use of existing terrestrial communications systems can impose many limitations on this. Therefore there is a specific interest within the INSEA consortium to engage satellite communications (SatCom) for data acquisition, as this is the only form of communications where a high degree of geographical independence can be achieved, and even the most remote and isolated locations can be served.

ComSine was responsible for Task 2.7, with the goal of developing concepts for a Data Acquisition Unit (DAU) based on SatCom. ComSine's work was largely based around using its current 'PocketSAT' terminal development as a baseline to providing a customised SatCom solution that is specifically targeted at the environmental monitoring scenario. In addition to communications, the DAU concept we proposed incorporates the integration of several other technologies including that of sensor integration and high-level access and control of sensors through recognised industry-standard interfaces. The activities of Task 2.7 were composed of several sub-tasks.

Task 2.7.1 focused on determining the requirements for the DAU. In this task we worked with the INSEA partners to gain real user feedback of their expectations and requirements for a DAU product. An online questionnaire tool was used with which the partners could express their requirements with respect to, for example, resolution/sampling requirements, method/frequency of data access, etc.

Task 2.7.2 involved a detailed survey of existing data acquisition solutions that could be applied to INSEA from the perspective of: (1) existing environmental monitoring systems that are currently in operation, (2) a review of the current generation of communications systems that are available, and (3) a review of industry standards than can play a role with INSEA – something which is considered to be fundamental to the success of the DAU concept. Our examination of existing environmental monitoring systems informed the INSEA consortium of the technologies currently in operation today and helped with identifying the constraints and weaknesses of those systems that could be addressed by our proposed DAU solution. On the communications side, ComSine contacted a number of SatCom service providers to obtain information on currently available SatCom services (service type, data throughput, service cost, terminal cost, etc.), again with a view to identifying areas of deficiency that we could look to address in our DAU solution. For the standards activity, the major focus was the Sensor Web Enablement (SWE) standards being developed by the Open Geospatial Consortium (OGC). These standards represent the most promising interoperability programme in the area of high-level sensor access and control.

Task 2.7.3 focused on the development of a System Architecture and Air-Interface, which would borrow heavily from our PocketSAT development experiences, but with the necessary extensions for specifically supporting environmental monitoring applications. This work took into account the knowledge gained from the previous analytical tasks in outlining a proposal for a DAU product/service suitable for INSEA and other applications like it.

The outcomes of tasks 2.7.1, 2.7.2 and 2.7.3 are documented in the deliverable D2.9, In-situ Data Acquisition.

These three tasks also served as input to the final task, Task 2.7.4, Satellite User Terminal Proof of Concept (PoC), in which we developed a PoC system to demonstrate elements of the DAU concept we had proposed.

The PocketSAT user terminal platform on which we intended to base the demonstrations is an on-going research activity for ComSine. An operational SatCom service using this platform would not be available within the timescales of the INSEA project, so at an early stage in the project it was decided we should take a pragmatic approach with our PoC developments to provide the opportunity to demonstrate a system in-the-field at the test sites of the INSEA partners. Therefore we divided the PoC activity into two streams, referred to as PoC-1 and PoC-2.

**PoC-1:** PoC-1 is an operational demonstrator system based around a current commercial off-the-shelf (COTS) SatComs service: Inmarsat D+. It provides a complete end-to-end data acquisition system, collecting example sensor data (from a weather station) and passing this data via a satellite and Earth station to a central server from where the data can be retrieved using special-purpose web-service software. This system has the potential to be deployed anywhere across Europe and at one time there was the suggestion that a live demonstration be carried out at the Portugal test site, interfacing to the IST Sonde. However, it was recognised by all parties that this would not demonstrate anything technically novel, so the idea was dropped in favour of spending additional effort on the PoC-2 activity.

**PoC-2:** PoC-2 is aimed at demonstrating key elements of a more forward-looking DAU solution targeted specifically at remote monitoring applications such as INSEA. The reference for this work was the section in the D2.9 report devoted to designing a new system architecture and satellite air-interface specifically aimed at remote monitoring applications. While the PoC-2 activity does not demonstrate a complete operational service, we have been able to combine laboratory elements with an Internet connection to emulate a full end-to-end communications scenario. Included in the concepts demonstrated are the following aspects of our proposed air-interface and DAU concept:

- The use of ComSine's PocketSAT platform to create an integrated data acquisition and satellite communications unit that interfaces directly to sensors.

- Communication of data packets at L-band RF (in the laboratory) between the prototype terminal and an 'inverse terminal' that emulates the satellite Earth station gateway.

- The use of a return channel bearer for the communication of packets that is of the type proposed in D2.9, based on ComSine's proprietary 'Turbo-ACE' modulation scheme.

- Integration of 'Sensor Web' middleware to allow Internet access to the sensor data via a 'Sensor Web' client.

Taken together, these aspects very effectively demonstrate ComSine's overall vision for a new satellite-based remote monitoring product and service. The concept combines in an integrated way all aspects of the data acquisition problem, from the field sensors themselves right through to the application developer who can access and control the sensors in a standardised way from any location that has an Internet connection.

As a precursor to the PoC activities, a detailed description of both PoC-1 and PoC-2 was included in the D2.9 document deliverable. A live demonstration of the PoC-2 system was conducted in December 2008 to the INSEA coordinators, which effectively showed all the components we had developed operating as an integrated end-to-end system. A further document deliverable, D2.10, In-situ Data Acquisition Proof of Concept Report, was issued after this demonstration to supplement the information provided in D2.9. The purpose of D2.10 was to report what had been shown during the demonstration of PoC-2 and to identify areas of the development that are available to INSEA partners today (e.g. an implementation of the SWE services) and those that will continue to be developed beyond the timescales of INSEA (e.g. the on-going work in developing the PocketSAT user terminal).

During the project ComSine experienced occasions when we were unable to allocate the planned level of engineering resource, which impacted on our ability to complete the work and supply our deliverables within the timescales originally outlined in the DoW. Fortunately there were no dependencies whereby other partners were relying on our deliverables as inputs to their own activities, and hence our delay issues did not impact on other tasks in the project. We took the view that experiencing delays was preferable to compromising the quality of our work. We stand by this decision because ultimately we achieved all the goals we set out to achieve and we produced deliverables of a high standard that have ongoing value internally to ComSine, and which we hope will be of value to the INSEA partners.

There were times when we found it difficult to align ComSine's work with the activities of the other partners in the INSEA consortium. The majority of the consortium members were focussed on the science aspects of the project. Task 2.7 was unique in that it was focussed on a technology stream. The fact that it was hardware-oriented and concerned with developing a concept for a product that could only be realised beyond the timescales of INSEA meant that it was difficult to bring Task 2.7 in line in a practical sense with the other consortium activities. The PoC-1 activity was devised to address this to some extent, however it was recognised at a fairly late stage that this did not demonstrate anything technically novel. With hindsight, much of this effort would have been better spent on the PoC-2 activity. However, it should be recognised that the PoC-1 effort contributed significantly to the integration of the SWE standards with our DAU concept and so a significant proportion of that effort was very effectively used.

In conclusion, ComSine's participation in the INSEA project has benefited our work in a number of ways. It has given us visibility of real-world remote monitoring applications and their requirements, giving us a better understanding of the capabilities and features needed to create a compelling in-situ data acquisition product/service. Through our PoC activities on INSEA we have been able to test many of these ideas and develop a demonstration system that we can use to solicit interest from potential users and investors. We would also hope that the other INSEA partners have benefited from ComSine's participation, through the vision we have presented of what would be an effective solution to their future in-situ data acquisition needs.

## 3.4 Data Management

In the framework of the data management work there have been developed activities in the following topics:

- The development of the INSEA website, Content Management System and forum/extranet
- Metadata and Data Quality indicators within INSEA
- WebGIS interfaces within INSEA for browsing relevant data and presenting dataproducts

In the following pages the results of these actions will be presented.

### 3.4.1 Development of the INSEA Forum

In the INSEA project there was a need for a communication platform for project partners. MARIS has therefore developed an INSEA Extranet that provides the tools to easily distribute project documentation to the partners and allows direct commenting to this. The Extranet access is restricted to project partners only and can be accessed by user name and password at http://www.insea.info/v_forum/welcome.asp. The ***Figure 2*** to ***Figure 6*** screenshots explains how the Extranet works.

After login the users will find an overview of available categories of topics. The categories have been setup according to the INSEA workpackages. Documents and information that users want to share with the other partners can be posted under these categories.

At the top-right of the screen users can choose to access the financial management pages from coordinator IST, visit the agenda, help pages and do a search through all topics. The coordinator can fill in agenda items (and add documents like the meeting agenda) that all INSEA partners can visit.

From the opening page users visit the topic categories. ***Figure 4*** shows an example of the topics available under a category. The name of the user that posted the original message and the last post date are also shown. When a user clicks on a topic the first post including all replies will be shown. Users can reply both to the original post as well as to one of the replies.

Users of the forum can reply via a standard format. It is allowed to add an attachment.

From the Extranet a link has been created that allows access of the partners to the financial management application at IST where the project partners can fill in the hours spent.

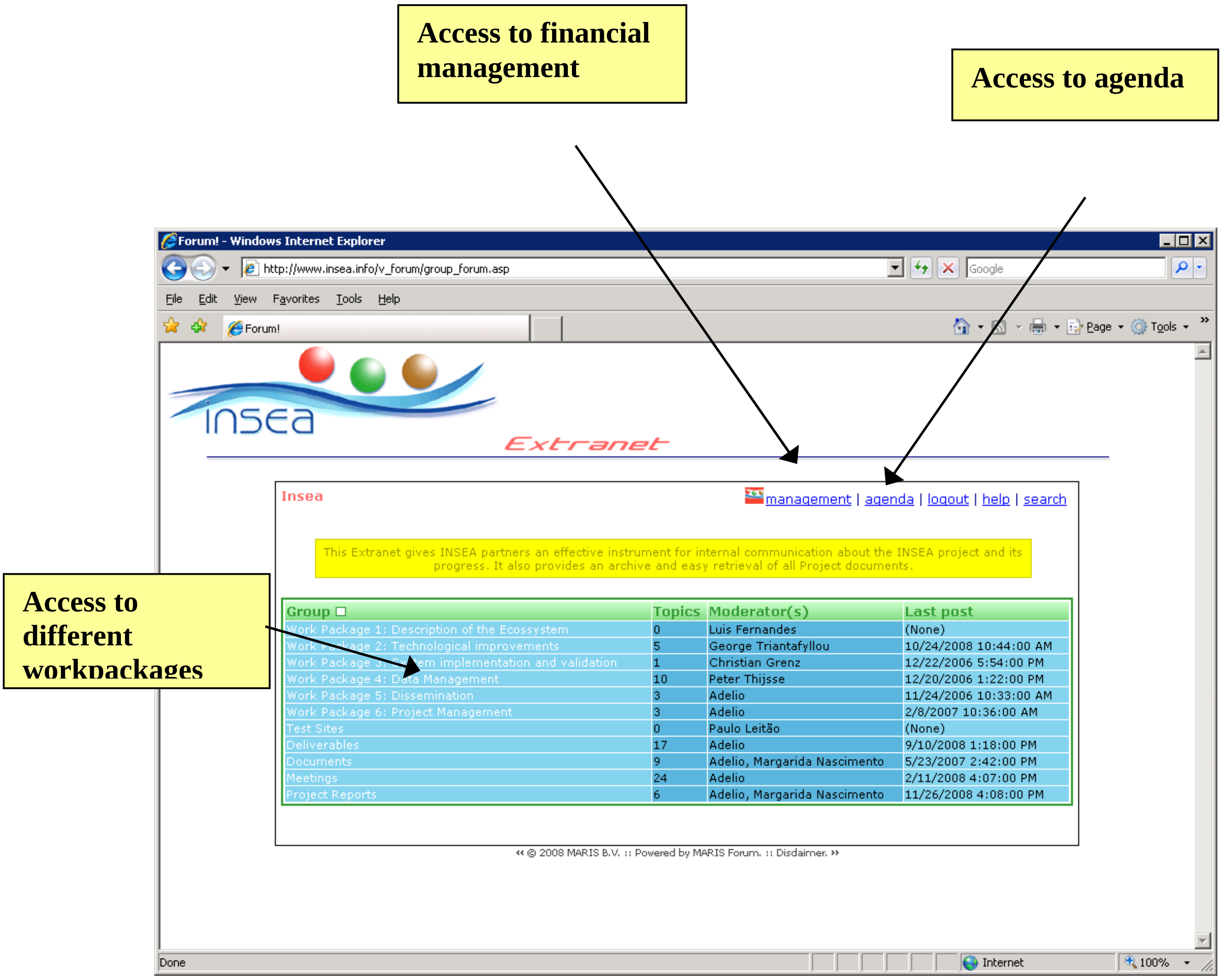


*Figure 2: Opening page Extranet (after login)*

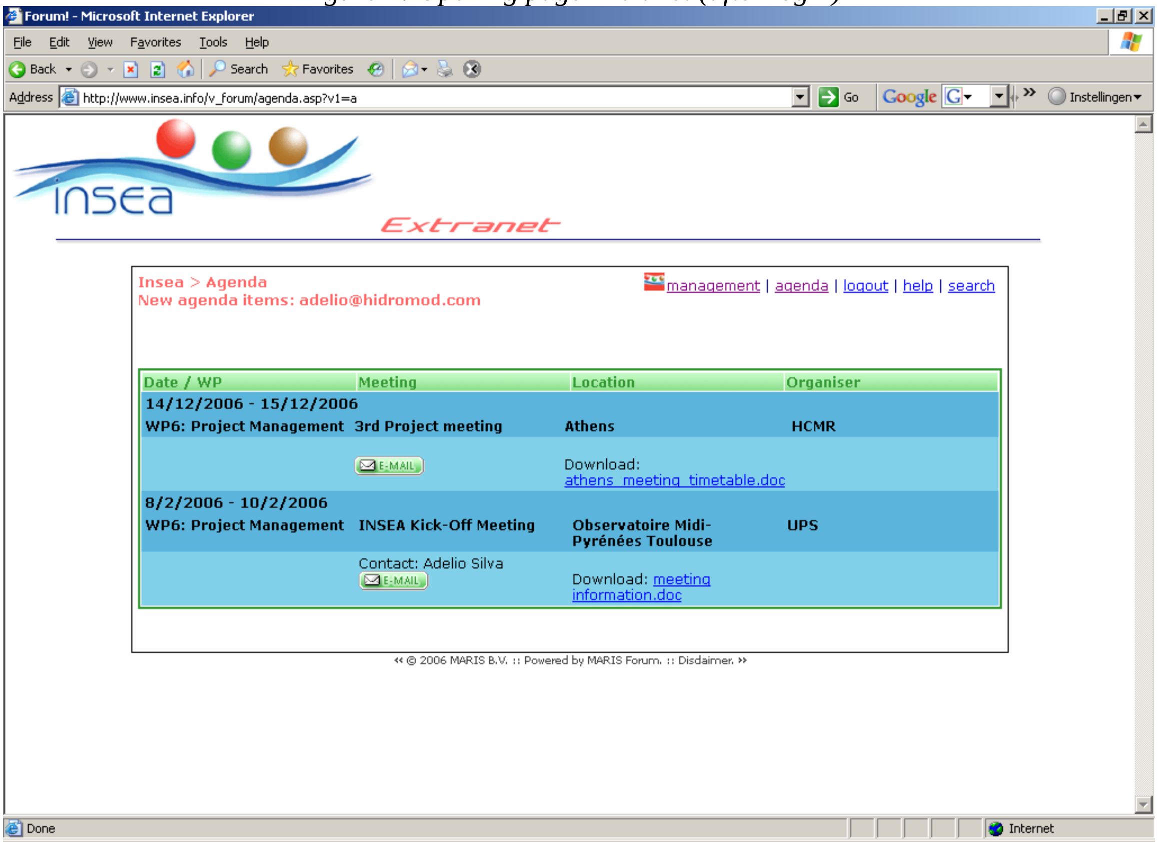



*Figure 3: Overview agenda*

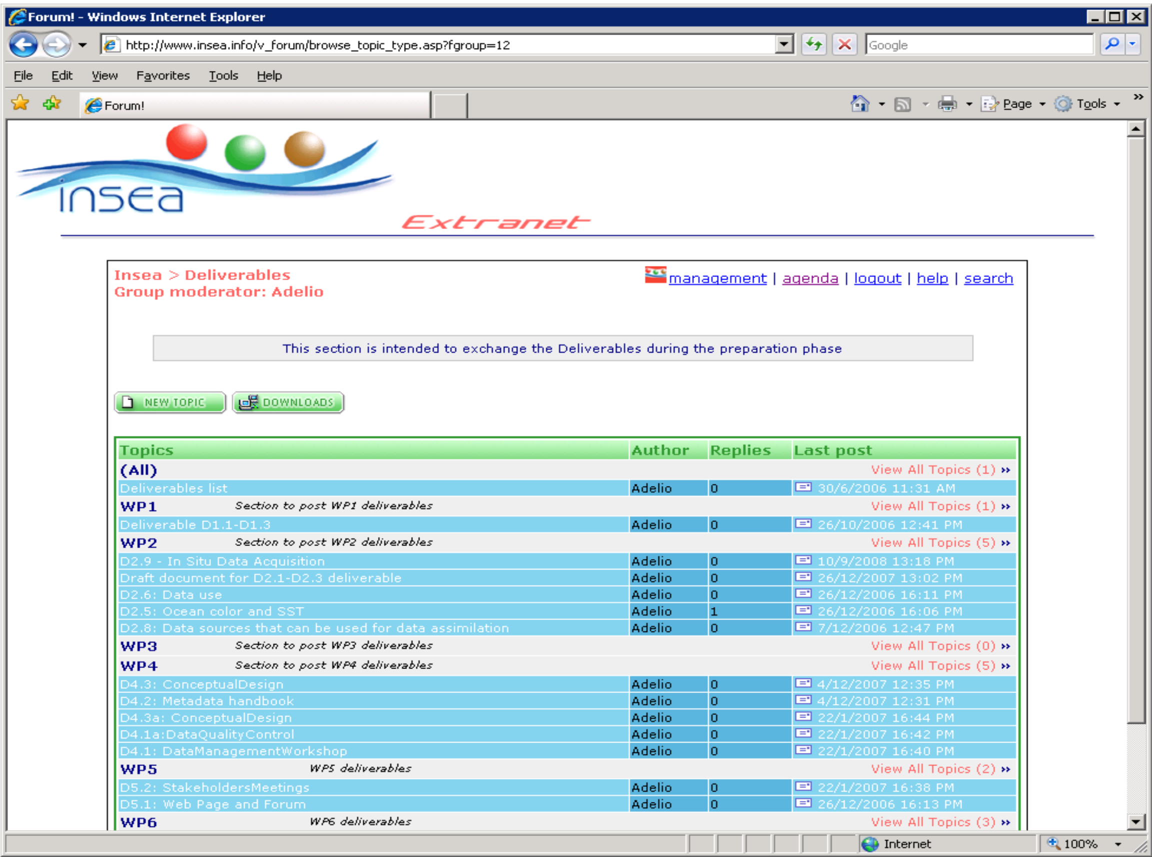


*Figure 4: Topics in one of the categories*

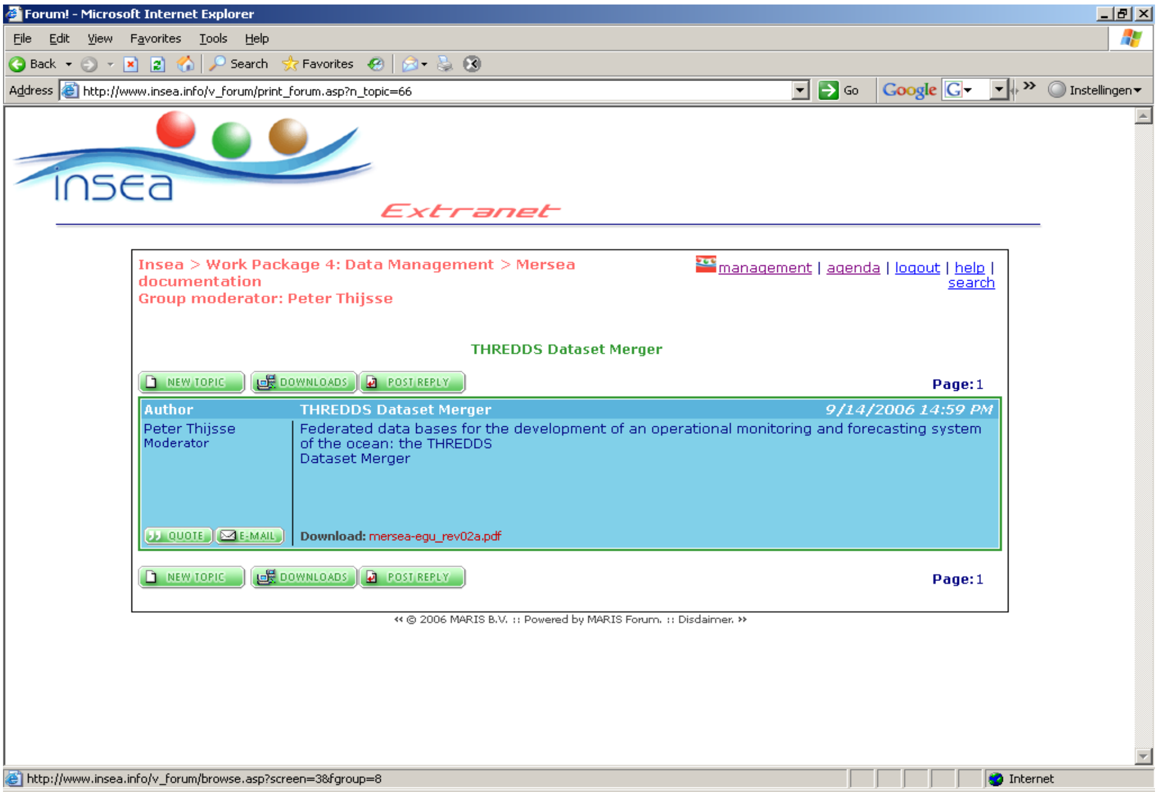



*Figure 5: Example of a posted message*

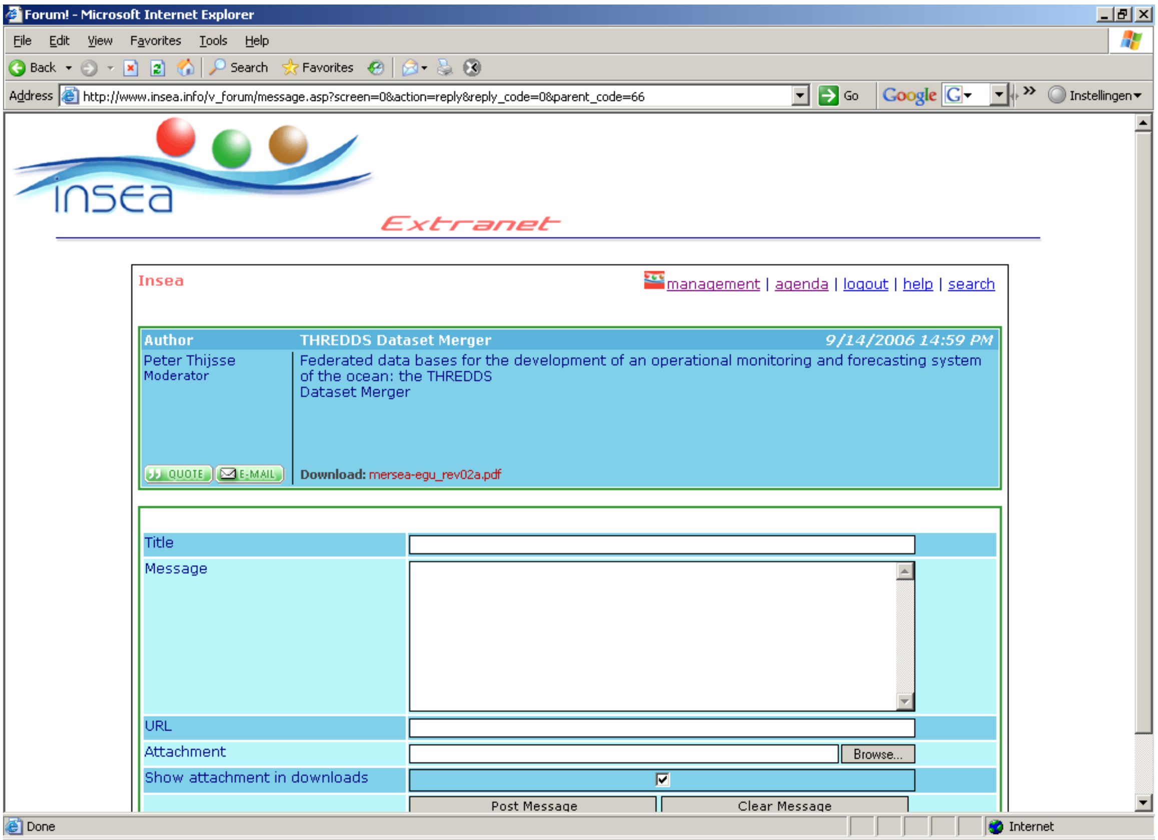


*Figure 6: Example of the reply form*

### 3.4.2 Development INSEA Website – www.insea.info

Within the project, dissemination of information was mainly over the internet, and therefore a project web site has been developed early in the project. This is a suitable format for dissemination to end-users and stakeholders who are interested in the ongoing progress and products of the project. It preceded fuller dissemination at a later stage by other means like publications.

The INSEA website functions as the portal. Databases and map applications used in the project (e.g the Product Viewing Service) will be accessible over Internet. The internet site will use English (and parts in Portuguese) language to broaden the access to the information.

This Internet site will also be a favourable way to engage junior technicians (engineers, biologists, sociologists) from institutional stakeholders (environmental agencies, industrial and port activities, NGO's) in the continued development of the knowledge base during the project, which should remain after the end of the project. This engagement will assure knowledge transfer from the scientific environment to the society.

The INSEA website consists of a front end, the website for the users, and a back end, a Content Management System (CMS). The logo and lay-out of the website have been developed by IST/Hidromod. Based on this MARIS developed the webpages and CMS. Via the CMS the coordinator has the rights to enter the content of the pages, upload images, etc. The website has been developed in two languages: English and Portuguese. The main menu items are:

- News: Presenting latest news about the project
- Site description: Providing a description of all three study areas
- Products and tools: Presenting the products and tools developed within INSEA
- Project roadmap: Describing the stages of the project

- Documentation: Especially for dissemination leaflets and papers are provided
- Partners: Presenting all partners
- Links: Providing links to related and interesting websites
- Partners restricted area: Linking to the Extranet for INSEA partners

Please view the following screenshots of the website and Content Management System (CMS) for a more detailed look on the result. The website presents the three study areas of the project with a short summary of the characteristics.

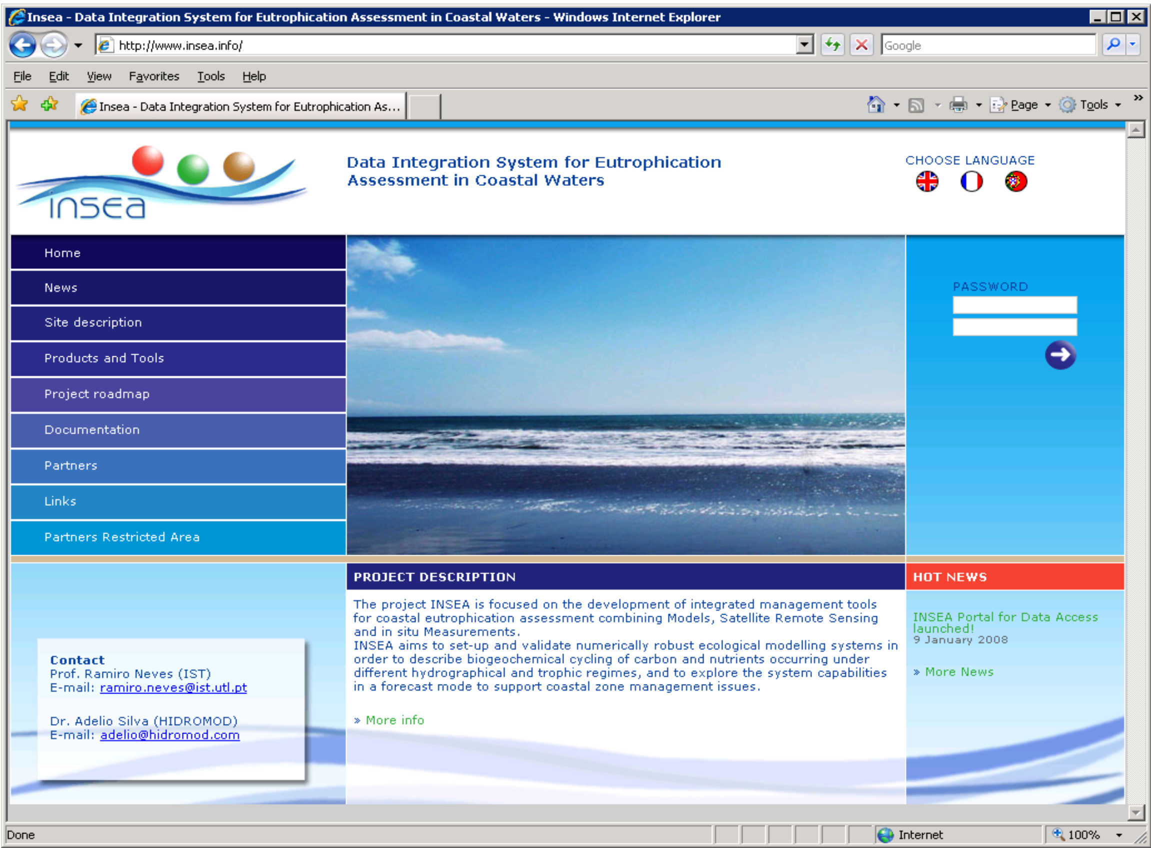


*Figure 7: Homepage of the INSEA website*

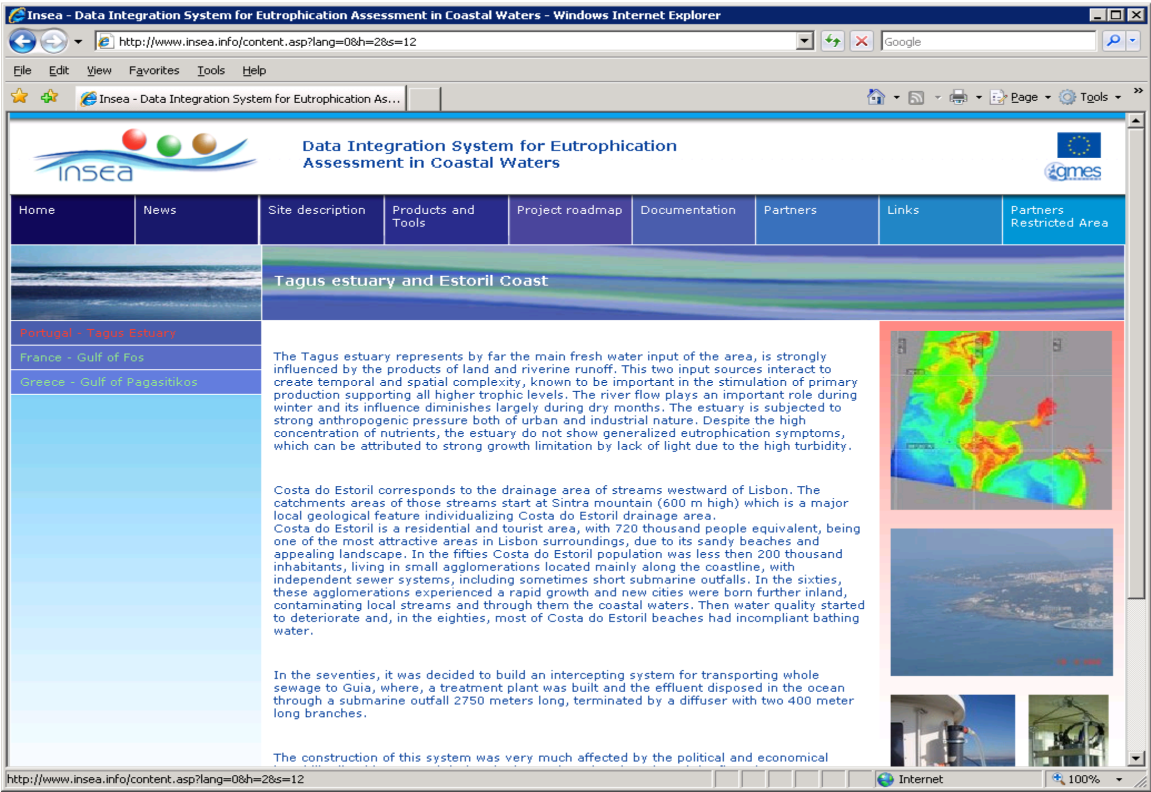



*Figure 8: Example of a webpage - "Site description of Tagus Estuary and Estoril Coast"*

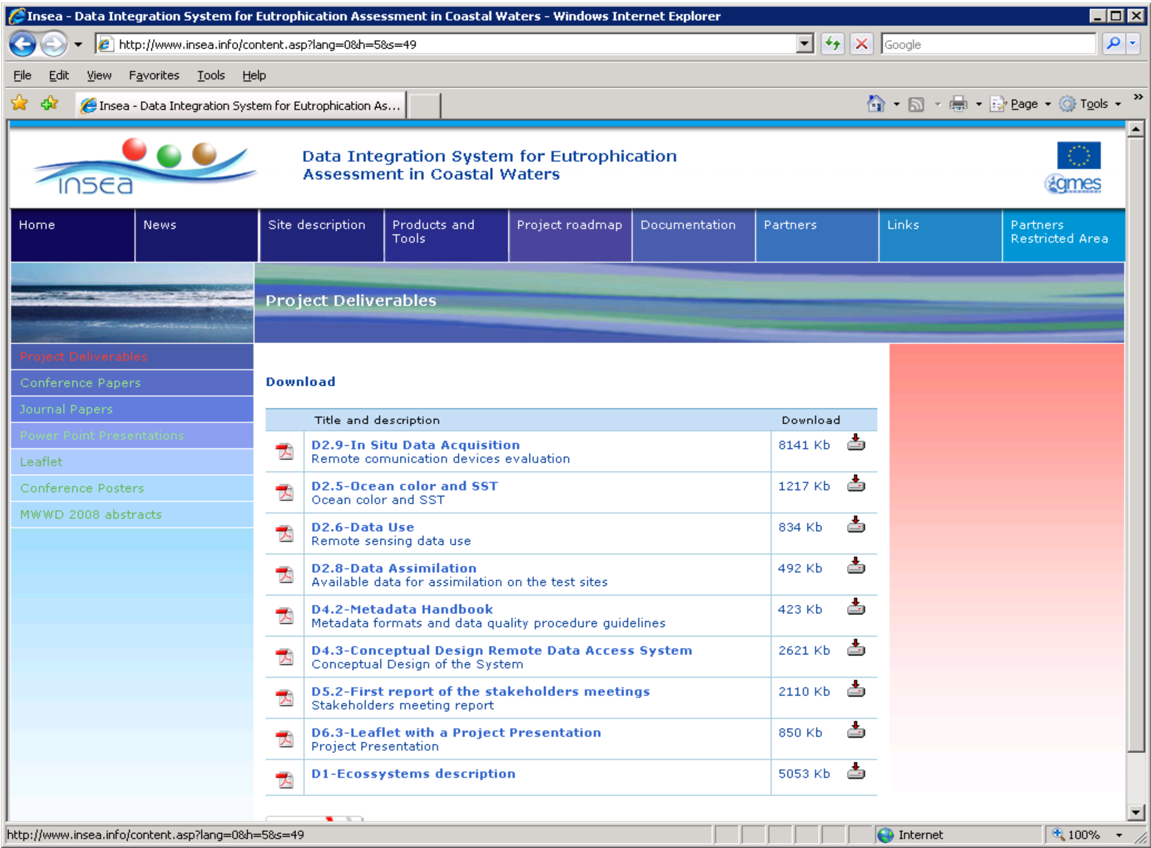



*Figure 9: Example of a webpage – "Documentation: Project deliverables"*

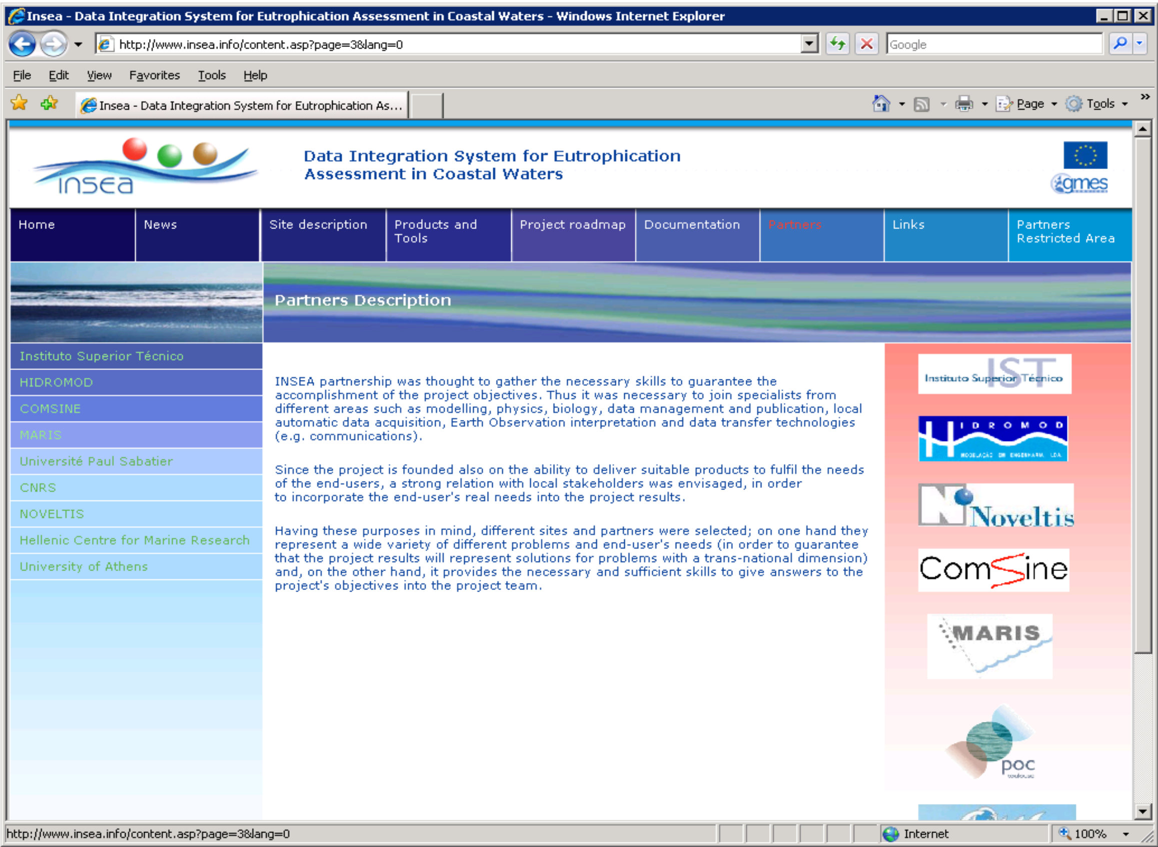



*Figure 10: Example of a webpage – "Partner descriptions"*

### 3.4.3 Metadata and Data Quality indicators

Considering that INSEA deals with large amounts of data associated to different sources and describing complex physical and biological processes, data-management activities represent one of the most relevant issues to achieve efficiency in he project. These data-management activities can (following the DOW) be divided in:

a) Data Quality Control/Assessment

b) Harmonization and conversion of data to agreed meta-data formats

c) Development of Remote Data Access System

A key element in the data identification and access to in-situ data is the Common Data Index (CDI) metadatabase, which is adopted from the SeaDataNet project. For data product identification a product catalogue has been set up. Both catalogues follow the ISO19115 metadata standard. For managing and getting access to data sets (in-situ, remote sensing and model outputs) at partner sites a combination of the methodologies, used in the SeaDataNet project and the MerSea project, has been adopted, depending on the local set-up of partners. This includes access to datasets from CDI to data sets locally managed in a relational database system. And also includes access from the product catalogue to model output stored as NetCDF files on OPeNDAP or FTP servers and indexed by THREDDS.

In the period of the project MARIS spent time in getting more acquainted with the approach and to find out how a the Common Data Index could be generated from the THREDDS catalogue server in an automatic way. When all was clear the approach for the metadata formats has been described in "D4.2 the INSEA metadatahandbook" which has been made available to the partners. In December 2006 a short workshop was held in Athens – Greece, in which MARIS presented the vision and concept for Data Quality Control (Deliverable D4.1) and the conceptual design of the remote data access system (Deliverable D4.3), including how to organise and prepare metadata. The Workshop was used to discuss the overall approach to data management in INSEA, but also to bring forward a number of questions to partners, concerning their types of data, the frequency and volume of data acquisition, their local data management set-up, their possible cooperation with their National Oceanographic Data Centre (NODC). After fine tuning the "Deliverable 4.3 – Conceptual design of the remote data access system" and the actual implementation (Task 4.3) of the INSEA data management infrastructure could be finalized. The result of the theoretical deliverables will be described in section C.

### 3.4.4 C. WebGIS interfaces INSEA

As a supportive action within INSEA and one of the main components of WP4 MARIS has created two WebGIS interfaces for online data discovery and data product publishing for coastal management:

A combined geographical and database search interface to metadatabases for the collected in-situ data has been developed. This supports the distributed data management systems at partners and provides directions for access to the datasets.

A key element in the data identification and access to in-situ data is the Common Data Index (CDI) metadatabase based on the ISO19115 metadata model, which has been adopted from the SeaDataNet project. This INSEA CDI interface with datasets from the three sites can be found via the INSEA website, see [www.insea.info/cdi](http://www.insea.info/cdi).

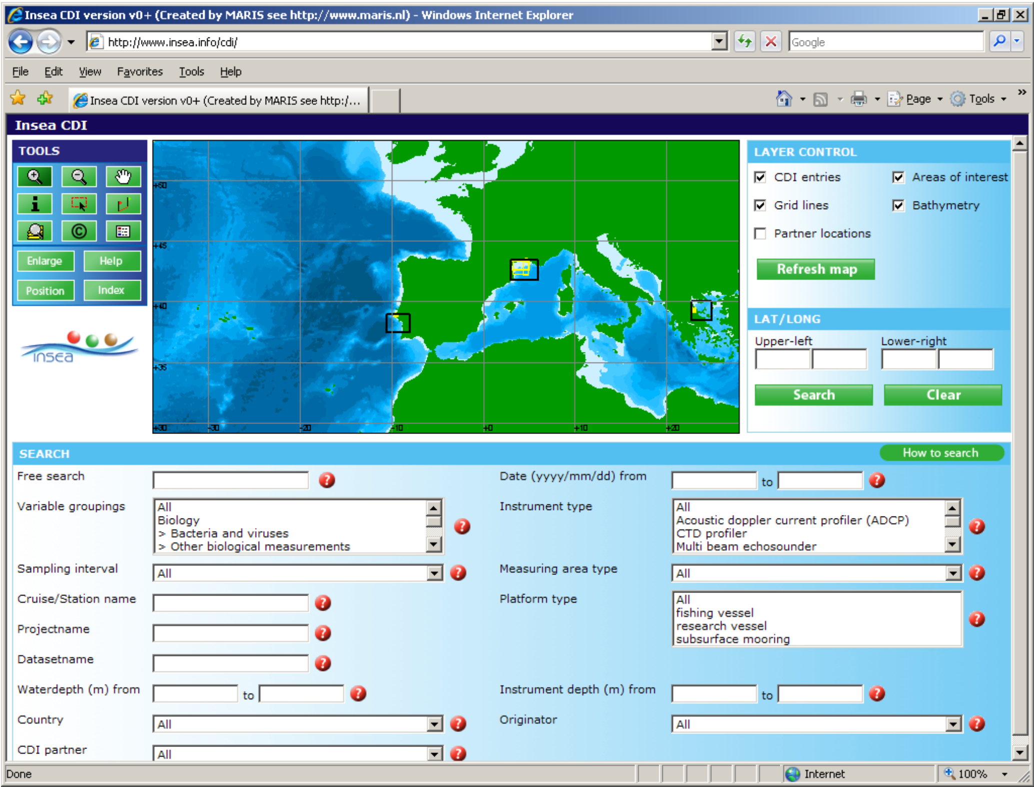



*Figure 11: Search in-situ data*

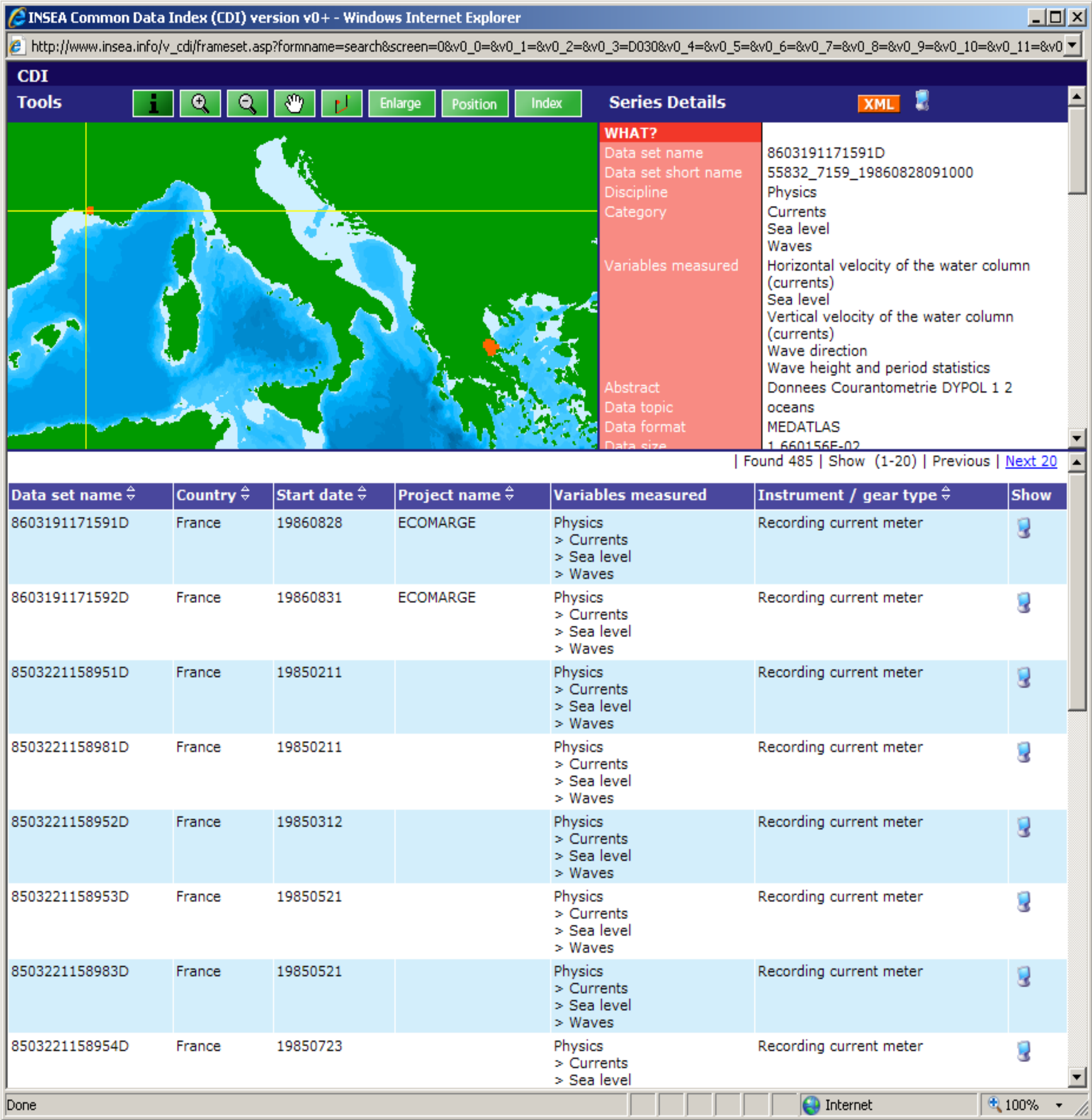
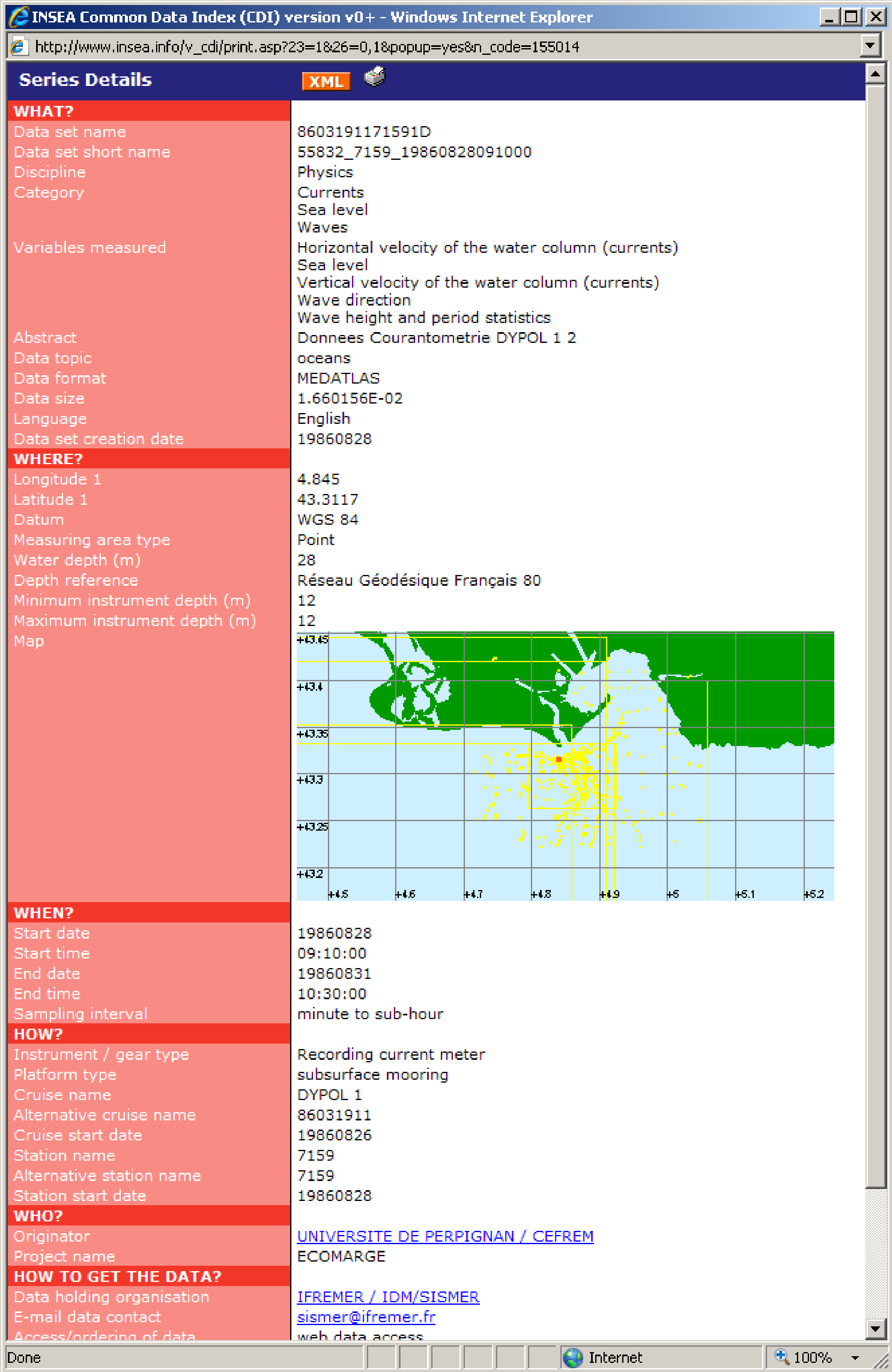



*Figure 12: Example of results - locations and metadata*



INSEA Common Data Index (CDI) version v0+ - Windows Internet Explorer

http://www.insea.info/v_cdi/print.asp?23=1&26=0,1&popup=yes&n_code=155014

**Series Details** XML

| | |
|---|---|
| **WHAT?** | |
| Data set name | 8603191171591D |
| Data set short name | 55832_7159_19860828091000 |
| Discipline | Physics |
| Category | Currents<br>Sea level<br>Waves |
| Variables measured | Horizontal velocity of the water column (currents)<br>Sea level<br>Vertical velocity of the water column (currents)<br>Wave direction<br>Wave height and period statistics |
| Abstract | Donnees Courantometrie DYPOL 1 2 |
| Data topic | oceans |
| Data format | MEDATLAS |
| Data size | 1.660156E-02 |
| Language | English |
| Data set creation date | 19860828 |
| **WHERE?** | |
| Longitude 1 | 4.845 |
| Latitude 1 | 43.3117 |
| Datum | WGS 84 |
| Measuring area type | Point |
| Water depth (m) | 28 |
| Depth reference | Réseau Géodésique Français 80 |
| Minimum instrument depth (m) | 12 |
| Maximum instrument depth (m) | 12 |
| Map | |
| **WHEN?** | |
| Start date | 19860828 |
| Start time | 09:10:00 |
| End date | 19860831 |
| End time | 10:30:00 |
| Sampling interval | minute to sub-hour |
| **HOW?** | |
| Instrument / gear type | Recording current meter |
| Platform type | subsurface mooring |
| Cruise name | DYPOL 1 |
| Alternative cruise name | 86031911 |
| Cruise start date | 19860826 |
| Station name | 7159 |
| Alternative station name | 7159 |
| Station start date | 19860828 |
| **WHO?** | |
| Originator | UNIVERSITE DE PERPIGNAN / CEFREM |
| Project name | ECOMARGE |
| **HOW TO GET THE DATA?** | |
| Data holding organisation | IFREMER / IDM/SISMER |
| E-mail data contact | sismer@ifremer.fr |
| Access/ordering of data | web data access |



*Figure 13: Full metadata of measurement*

For easy access to the relevant INSEA data products and model output a catalogue has been created. This catalogue has been set up including a Content Management System to enter the product descriptions. Just like the CDI metadata model this catalogue follows the ISO19115 metadata standard. The catalogue is accessible via the INSEA website (via [http://www.insea.info/v_products/search.asp](http://www.insea.info/v_products/search.asp)) and provides an overview of the available products in the three regions. It directs the users to the distribution points via the metadata and access to the INSEA viewing service for each product.

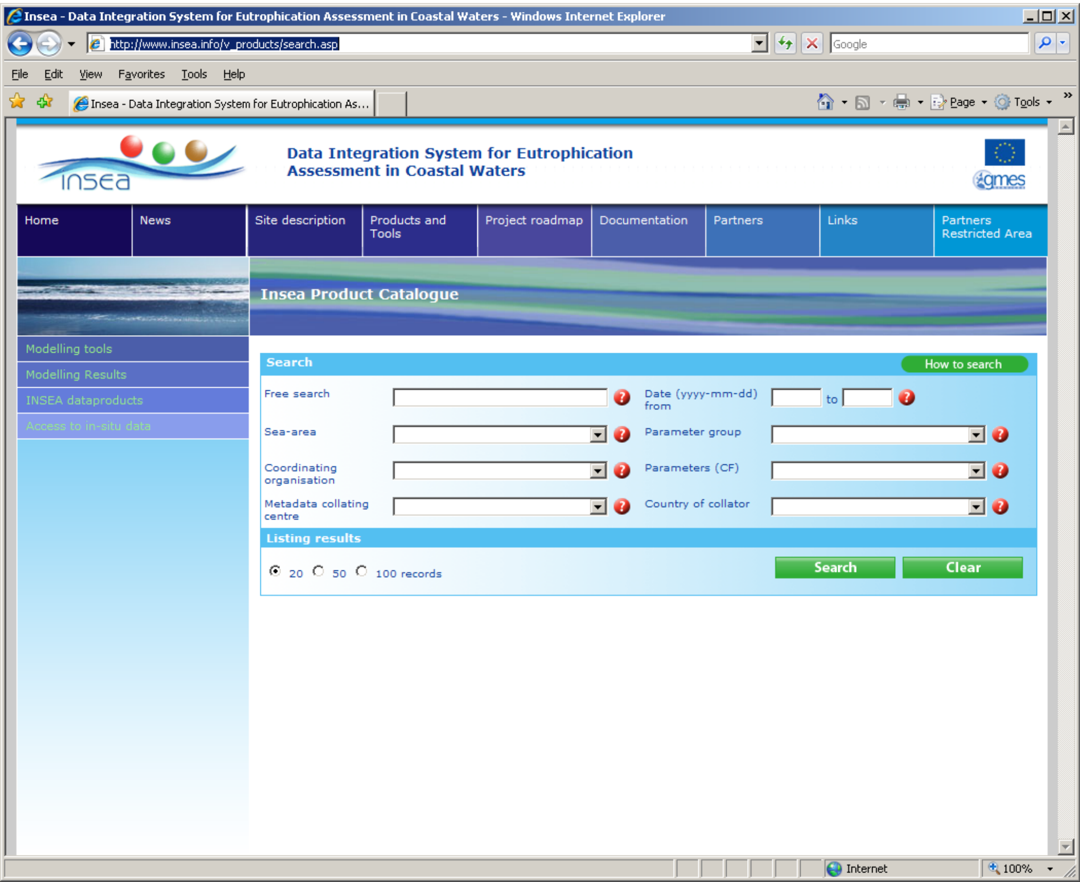



*Figure 14: Access to product catalogue via search on metadata*

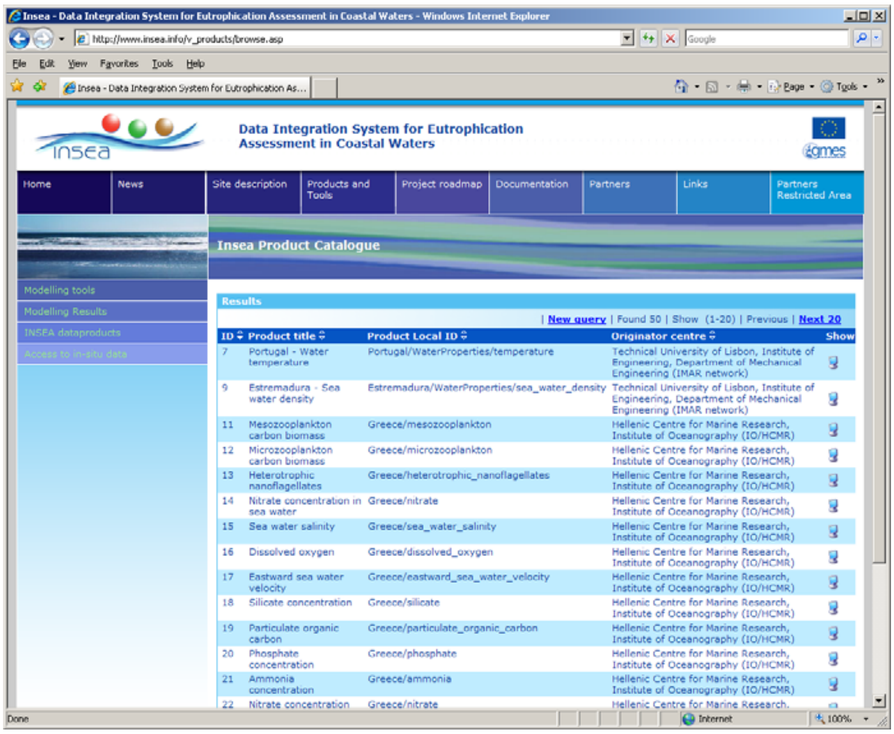



*Figure 15: Listing of products after search*


*Figure 16: Overview of description plus access information and link to viewing service*

The visualization of products is to end-users the most interesting part. It can be used to bring predictions in a visual way directly to the user. To visualize the instances of the product inventory (see above) a viewing service has been set up that contacts the partners web servers (OpenDAP or FTP) containing the product data stored in NetCDF format.

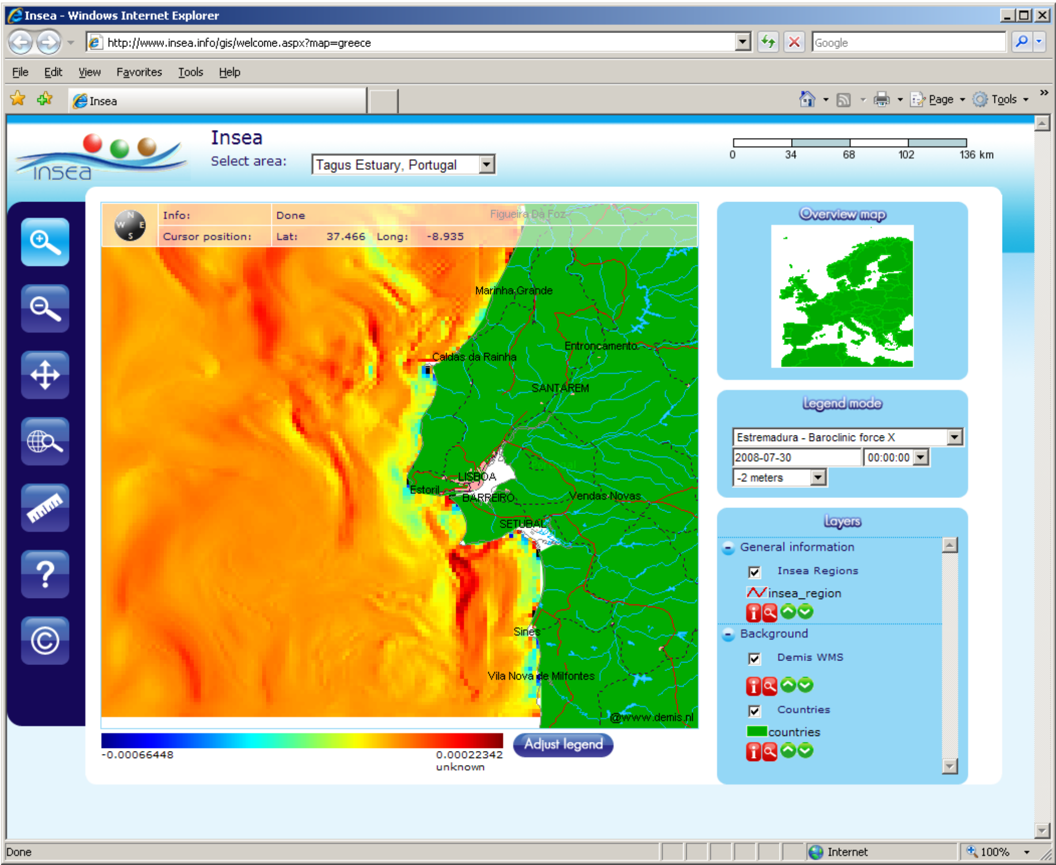



*Figure 17: Example of preview of model output for Tagus Estuary*

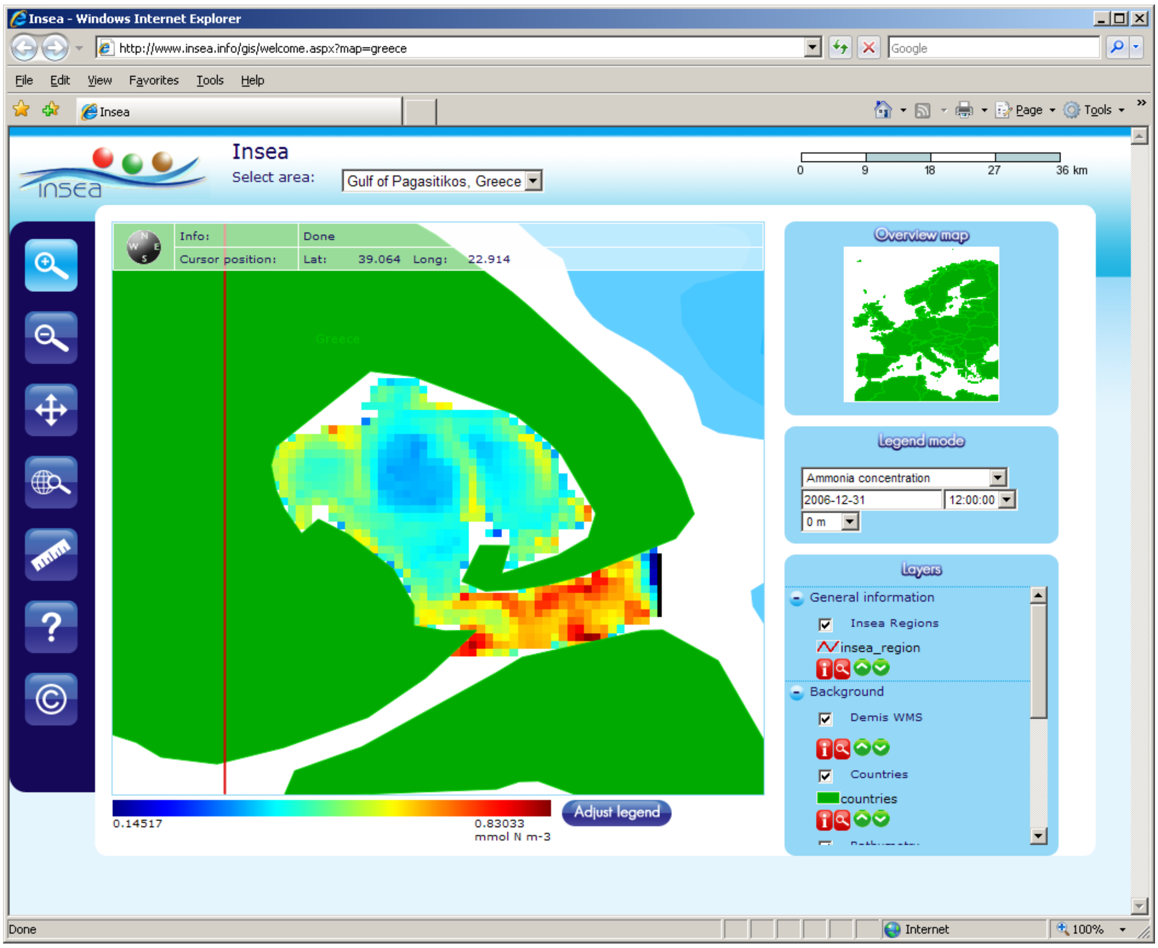


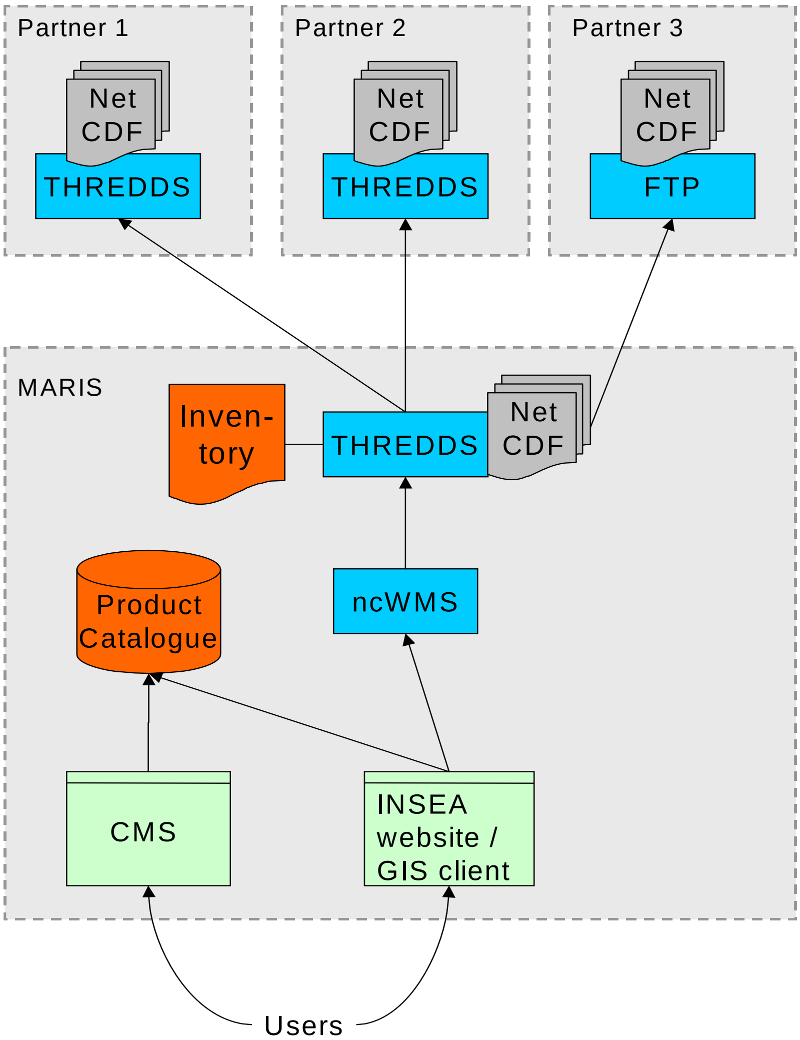

*Figure 18: Example of preview of model output for Gulf of Pagasitikos*

MARIS created this OGC compliant mapping application, which is the basic application for the viewing service at the INSEA portal. It creates on the fly images using NcWMS from NetCDF files, so the user can choose which data and from which date/time should be displayed. Other external WMS output can easily be combined in the application. A more technically detailed description follows in the next section.

### 3.4.5 Underlying system architecture for visualization of INSEA data products and model output

This section describes the technical architecture for managing and viewing product data in the INSEA project. Figure 9 contains a scheme of the architecture.

Model and satellite products are stored as NetCDF files at the partners' servers. This data is made accessible through the Internet by means of an OpenDAP server like THREDDS. This situation is applicable for IST (PT).




The partners who don't have an OpenDAP server will make their data available through FTP. (Provided that both volume of the data and frequency of updates allow this.) The data of these partners will be regularly downloaded to the central OpenDAP server. This situation is applicable for HCMR (GR). For the Gulf du Fos this set up could not be finalized with CNRS (FR) within the timeframe of the project.

A central OpenDAP server is ran by MARIS. This server knows where to find all the data, either remote (located at a partner’s server) or local (downloaded through FTP), through a hierarchical inventory. So this server serves both it's own (downloaded) data as well as a proxy to the other OpenDAP servers.

As part of the INSEA Portal, MARIS will run ncWMS, a WMS server developed by ReSC / University of Reading, UK. This server accesses the central OpenDAP server and converts the data into images. These images are served to a client through the Open GIS WMS (Web Mapping Service) protocol. The ncWMS server is specialized in serving OpenDAP data. Unlike other WMS servers it can easily work with depth (z) and time besides longitude (x) and latitude (y).

The INSEA Portal also contains the Product Catalogue, a database containing information about the INSEA products, such as name, coordinating partner, access restrictions and URL to the data. This data is being maintained by the partners through a web based CMS (Content Management System).

The front-end for users to all the data and information is the INSEA website as demonstrated in section B. This web based GIS client has been developed for the users to search and view the products on a map. The OGC compliant GIS client combines the information from the product database with the images from the WMS server to show to the users.

# 4 Dissemination activities

Throughout the project lifetime there were established and maintained communication channels between partners and stakeholders in order to try to keep the community informed and try to keep in line with the *real world* needs. In Portugal there were created special links with some local partners (cases of Sanest, Simtejo and Águas do Oeste) who always showed their interest in using the knowledge that is being developed in the framework of INSEA to give support to the implementation of effective water quality forecast systems. Their main interest is in direct relation with the new bathing water directive and with the possible consequences over the primary production of the nutrients discharged in the coast (by natural and/or artificial systems) and how (in what extent) the introduction of more effective wastewater treatment systems will affect the primary production in coastal waters.

In Greece, HCMR promoted the INSEA project in Greece contacting several potential stakeholders. During the first year of the project there have been identified and contacted the various stakeholders associated with Pagasitikos in order to make a preliminary assessment of the existing problems as well as the relevant issues. The main concern was the trophic status of Pagasitikos and particularly the appearance of mucilaginous algae at the north parts of the gulf during spring - summer. The role of the industrial park sewage outfall, the drainage of Karla waters, the influence of the two fish farms, the fishing regulations and the industrial development at the coastal area were some of the problems that have also emerged. During the third year, another contact with Pagasitikos stakeholders was achieved in Larissa (February 2008) where a first demonstration of the INSEA system and of preliminary model results, as well as a discussion on their needs and future thoughts took place. Finally, a one day stakeholder meeting was organized in Athens, where an overview of the project was presented with emphasis given in the presentation of the modeling system of Pagasitikos and its capabilities in supporting management issues. Representatives from the Ministry of Environment have expressed their interest in that future environmental impact assessment studies would include such tool evaluations. On the other hand fish farmers considering the need for good quality water conditions for efficient fish growth had clearly identified the need for the operational tool. This was also acknowledged by the rest of the stake holders putting emphasis on future improvements in terms of linkage with socio-economic aspects.

In France preliminary results of the 3D coupled model and the assimilation scheme have been presented during a national meeting hold in Marseille (1 December 2008 - www.ifremer.fr/medicis/projets/metroc.html). Port Autonome de Marseille authorities (Magali Deveze et Jean Michel Bocognano PAM) were particularly interested in using the numerical tools developed by INSEA with respect to environmental forecasting systems. In the same way, new national projects financed by Agence de l'Eau (GIRAC) and EC2CO (Massilia) used the outcomes of INSEA to provide their framework. Finally connections have been set up with PreviMER, a pre-operational system which aim is to provide short-term forecasts of marine environmental states along the French coastlines (www.previmer.org).

Also during the project last year, more generalized contacts were established with other possible partners end-users being a special attention devoted to the South America countries. Taking advantage of some previous contacts between Hidromod, IST and partners from Brazil, Chile, Argentina and Uruguai were made some actions in order to catch their interest for the implementation of local operational models. These actions were made at different levels taking advantage of possible joint actions with other initiatives. For instance during the last year IST promoted MOHID courses in several countries (Argentina, Equador, Brazil, Turkey), Hidromod staff members needed to go to Brazil in the framework of other ongoing consulting projects Hidromod submitted a proposal to the Kopernikus Downstream Services that implied the need to establish discussions with partners from Brazil, Chile, Uruguai and Morroco concerning the best procedures implementation of operational models. All of these actions were also used to disseminate the INSEA products and services.

In order to make a wider dissemination among potential clients, the last project meeting was scheduled to take place together with a relevant conference in terms of potential users. This meeting took place in Dubrovnik where there was a special session dedicated to INSEA and where the different aspects of the project were publically presented.

Still in Greece two applications were carried out, demonstrating the usefulness of the developed modeling system in supporting management issues:

In the first application there were assessed the main variables that may affect the surface biomass of phytoplankton (Chlorophyll-a) using Generalized Additive Models (GAMS), and

In the second one, taking advantage of the modeling tool implemented, the possible effect of the aquaculture sector was explored, since fishing constitutes a significant activity of the primary sector of the prefecture of Magnesia. Thus, the modeling system was customized in such a way as to simulate the presence of the two farms in the south part of Pagasitikos gulf. Simulation performed for a period of a whole year (2003). This activity contributed mostly to WP5 whose scope was the availability of integrated management systems with socio-economic implications.

In the framework of EU Easy project, a web operational tool was also developed to take advantage of the existence of the hydrodynamic forecast for the Portuguese coast. This tool allows any user to select a point over a map to simulate a discharge (quantity and type of effluent). Then, making use of the available forecasts, the system computes *on the fly* the transport and dispersion of the pollutant and identifies an area of probability to have been affected after a chosen time interval. The Tagus operational system is also being used to forecast the area of influence of Guia submarine outfall discharge and to provide data to evaluate the Estoril coast beaches water quality.

Beyond these actions, oral presentations were also given. Among other issues the work and progress of the INSEA project was presented in the framework of papers, conferences and oral presentations. Also a selection of INSEA papers was presented in Cavtat (Dubrovnik, Croatia) – October 27-31, 2008 in the framework of MWWD 2008 – 5th International Conference on Marine Waste Water Discharges and Coastal Environment. The objective of these presentations was to disseminate INSEA results and main applications to a public of specialists and end-users. A selection of the papers abstracts is presented as Annex to this report.

A selection of the main issues that were developed in the framework of the INSEA is discussed in a special number of the Journal of Marine System which under preparation. A selection of the papers abstracts is presented as Annex to this report.

## Journal Papers

Patrick Marsaleix, Francis Auclair, Jochem Willem Floor, Marine Julie Herrmann, Claude Estournel, Ivane Pairaud, Caroline Ulses, 2008, *Energy conservation issues in sigma-coordinate free-surface ocean models*, Ocean Modelling 20, pp 61–89

Patrick Marsaleix, Caroline Ulses, Ivane Pairaud, Marine Julie Herrmann, Jochem Willem Floor, Claude Estournel, Francis Auclair, 2009, *Open boundary conditions for internal gravity wave modelling 3 using polarization relations*, Ocean Modelling, doi:10.1016/j.ocemod.2009.02.010

Fontana C., Grenz C., Pinazo C., Marsaleix P. And F. Diaz, (accepted). *Assimilation of SeaWiFS chlorophyll data into a 3D coupled physical biogeochemical model applied to a freshwater influenced coastal zone*. Cont Shelf Research 1212 (November 2008)

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