# Marine SDI multiple exploitation: public, private and military applications


## Abstract

The Portuguese hydrographic Institute is a navy organization responsible for producing official nautical paper and electronic charts as well as to conduct studies and research in several marine related disciplines such as physical oceanography, hydrography, marine geology, chemical oceanography and safety of navigation. For the last years, it has been developing a spatial data infrastructure to support its technical-scientific data and product management. This SDI provided the Institute with the capability to respond to several ad-hoc requests, providing decision makers with their raw material - information.

This paper describes the main components of the IDAMAR SDI (spatial data infrastructure for the marine environment), its architecture and functionality. A set of IDAMAR based information products for public service, environmental protection, research and development, private industry and support to military navy activities are also presented.


## 1. Introduction

The Portuguese hydrographic Institute is a navy organization responsible for producing official nautical paper and electronic charts as well as to conduct studies and research in several marine related disciplines such as physical oceanography, hydrography, marine geology, chemical oceanography and safety of navigation. Its mission is to contribute to the safety of maritime navigation, support the Portuguese navy mission, and contribute to the environmental protection of the oceans and their research. To better accomplish this mission supporting its technical-scientific data and product management, it has been developing a spatial data infrastructure (SDI), code name IDAMAR (Portuguese abbreviation for "spatial data infrastructure for the marine environment"). This SDI first started as a departmental GIS (codename SIGAMAR) which scope has been broaden up to better support its development and sustainability. This paper describes the IDAMAR's SDI basic components, functionalities and information products.

## 2. IDAMAR Spatial Data Infrastructure Architecture

Due to the fact that some military communications security rules apply to the office, the IDAMAR SDI is divided into two very similar structures. One is connected to the internet and the other to a private military network. The structure connected to the internet has a synchronization procedure that makes the public part of the infrastructure available to any type of user. The basic components of this SDI are: a set of communications network, databases, data policy, metadata, specialized human resources, outreach & support, software, hardware, internal data management processes, independent distributable products and online services and information products (Figure 1).

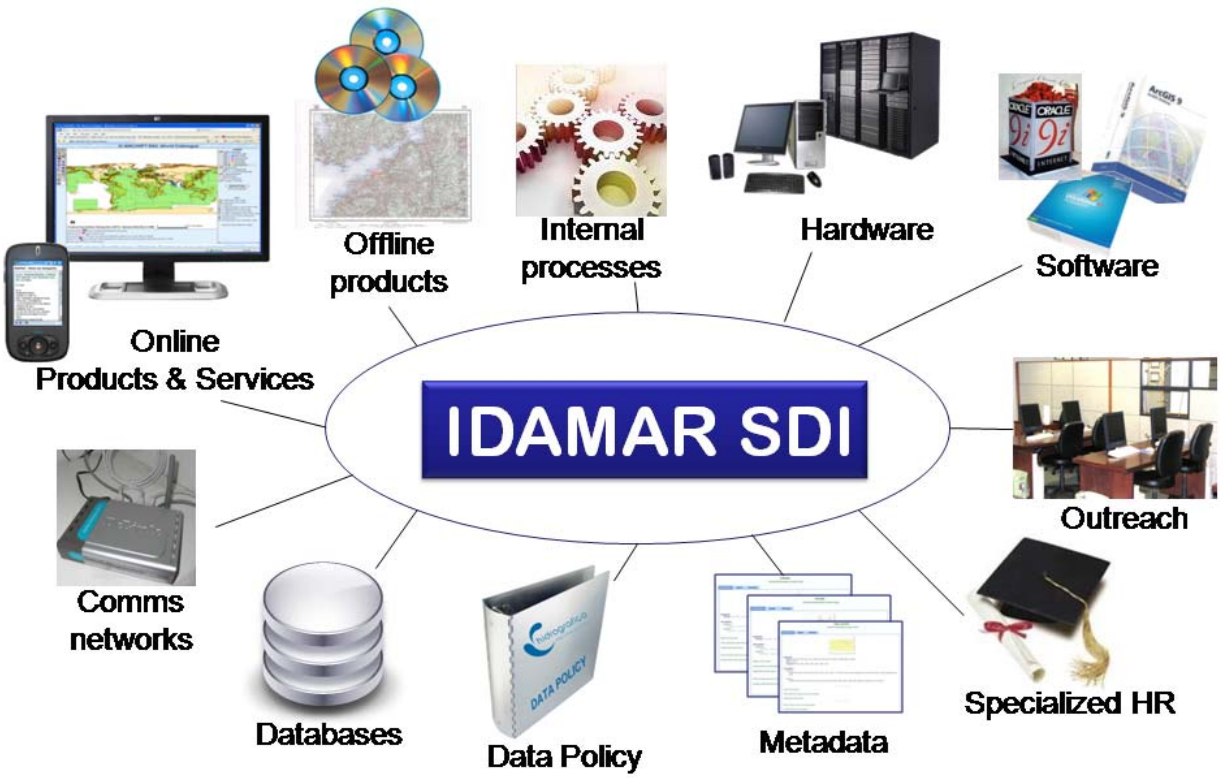


Figure 1 - IDAMAR SDI basic components

## Communications networks

Three communications networks support data transfer and online access to the SDI: an internet connection, a private unclassified military network and a private classified military network. These links are explored in different ways. The internet connection supports data acquisition from several environmental sensors (i.e. wave buoys, radar stations) and information products diffusion to public access at http://www.hidrografico.pt . The private military networks are used to access the full system and support specific data/information requests. These networks support all internal processes for data and information product management.

## Databases and data models

Several databases have been developed using a database management system (DBMS) or a file base storage system, depending on the data type and most efficient usage. The data models for data storage in the DBMS were internally developed for all information processes except for the management of chemical lab analysis. A commercial solution was acquired (Thermal LIMS NAUTILUS), configured and extended in order to easily integrate its data into the whole system. The internally developed data models followed, where applicable, the OHI S-57 standard for hydrographic data transfer. The most relevant developed data model supports the hydrographic data warehouse (HDW). This database stores

every bathymetric sounding acquired by the Portuguese hydrographic Institute (IHPT) and represented a major update on the cartographic production process, reducing production times, eliminating many human error prone procedures and improving final product quality.

Data stored in the databases include sea state (wave height, wave period, wave direction, sea temperature) from oceanographic buoys, tide prediction, tide observations, horizontal control points, nautical charts and cells coverage, sea water and sea bottom sediments chemical analysis, bathymetric soundings, hydrographic surveys coverage, raster historical nautical charts, digital terrain data, sea navigation warnings, medium resolution satellite imagery. Not all data was exclusively acquired by IHPT. Some of the data is not directly related to the technical scientific activities of IHPT but it is related to the Portuguese navy military activities.

## Data policy

A data policy document sets the rules for managing and accessing data stored in IDAMAR SDI. This document sets the rules for classification data (in several scopes), the way data made available, who can access it, what are the associated costs. Responsibility issues are also stated. At this time, some datasets are freely made available to the public: near real-time sea state and water temperature from 5 wave buoys, sea state prediction for several Atlantic and local Portuguese areas, tide predictions for all Portuguese principal and secondary ports, tide predictions for Angola, Cape Verde, Guiné-Bissau, Mozambique, S. Tomé & Príncipe and Macau. Also some maritime administrative limits, one small scale converted electronic navigation cell, covering the areas of continental Portugal and the Madeira and Azores archipelagos, and small scale bathymetric lines are available for public download.

## Metadata

Geospatial metadata fact sheets are essential to inventory, find and describe the quality of geospatial data. These documents are precious for reusing data collected at a certain time, with a certain quality, for a certain project. Reusing data is valuable in scientific and economic terms. Metadata is being produced for every data, product and service made available in the SDI. According to the INSPIRE (European spatial data infrastructure) the standard being used in metadata production is the ISO 19115. A metadata search engine was setup for public access.

## Specialized human resources

Setting up this SDI started with providing several key human resources with advanced know-how in systems analysis, database management systems administration, geographic information systems and web programming. The background of almost all human resources is on geography and earth sciences (i.e. hydrography, surveying engineering, geography, marine geology, marine chemistry, marine sciences and military naval sciences) with master degrees on information technologies (i.e. informatics, geographic information systems, statistics and information management). These resources are used to both develop the SDI and ad-hoc projects.

## Outreach

The specialized human resources are not to be the only people to use GIS through the organization. Many basic geospatial analysis tasks can and should be performed by scientists. In order to make them able to use GIS software a small classroom was setup. This classroom is activated for introduction to GIS software classes. These classes go from 3 to 5 full days depending on the specific needs of the attendees. This way, basic GIS knowledge is spread through the organization's scientific community making it easier to discuss advanced geospatial requirements and at the same time providing the necessary tools for independent basic use, leaving specialized GIS human resources available for SDI and advanced information projects development.

## Software

The SDI relies on several software packages. The main suites are Microsoft operating systems, Oracle database management systems, ESRI ArcGIS geographic information systems and several development packages. Especially concerning GIS, at the server level the SDI uses ArcSDE, ArcIMS and ArcGIS Server applications. At the user level, fluctuant and fixed licenses of ArcView, ArcEditor and the spatial analyst, 3D analyst, publisher and geostatistical analyst extensions.

## Hardware

The hardware supporting the SDI at the server level is constituted by a set of 4 servers (2 in the internal networks and 2 in the external networks). At the user level, several different PDA, laptops, PCs, workstations, printers, plotters and high dimension scanners are used. Actually, most of the Institute hardware, although some indirectly, is a part of the system for it is used for some o the SDI functions.

## Internal processes

This SDI implementation re-engineered some of the IHPT production processes and at the same time created new ones. Making the internal production more efficient is a main objective and setting all the rules and workflows was necessary to achieve these type of improvements.

## Offline products

Offline products are normally in the form of independent CD/DVD-ROM GIS system distribution. These are specially requests of information products (ad-hoc), not necessarily related to IHPT internal products, but take the advantage of the existing SDI to solve specific information problems. The main advantage of these projects rely on the fact that at most navy operating scenarios, online connections are very short banded and have to be reduced at a minimum time not to compromise the forces. In these occasions, being able to operate offline systems is an appreciated advantage. Also, some paper products are still used for many purposes, including thematic cartography. In the last 3 years more than 30 ad-hoc GIS projects based in this SDI have been developed.

## Online products and services

Online products and services provide the broad access to the SDI. They are the most visible part of the system. Data catalogues, information products and data services complete the components of the SDI. Supporting the online products and services we have two WWW portals (one internal and one external). Users get to information products and services, mainly, through these portals. Data catalogues, data

visualization, metadata search engine, data download services and data services rely on the two portals for their frontend.

# 3. Information Products

In this section several information product types are described. Some of these are available in one of the WWW portals, some on the two portals and some are offline. The scope of these products varies from public service, environmental protection, navy mission, commercial services and research & development. The list is not exhaustive in available products, but in product types.

## Online data catalogues, data visualization and metadata

Several data catalogues allow users to explore existing data in the databases and make the best use of it. Geographic interfaces for visualization of horizontal control points, chart folios coverage, hydrographic surveys coverage, hydrographic soundings, sea bottom sediment samples, chemical analysis for water and sea bottom samples, tide observations, sea state buoys observations.

The electronic navigation cell (ENC) world catalogue (Figure 2) is one of the most relevant catalogues made available. Although not entirely related to IHPT ENC coverage, since its geographic scope is the world, this catalogue helps sea navigators identify the cells that are already available for their voyage of interest. The effort of collecting the coverage data is made by IC-ENC (international centre for ENC) it is monthly updated and is available at [http://websig.hidrografico.pt/website/icenc](http://websig.hidrografico.pt/website/icenc) .

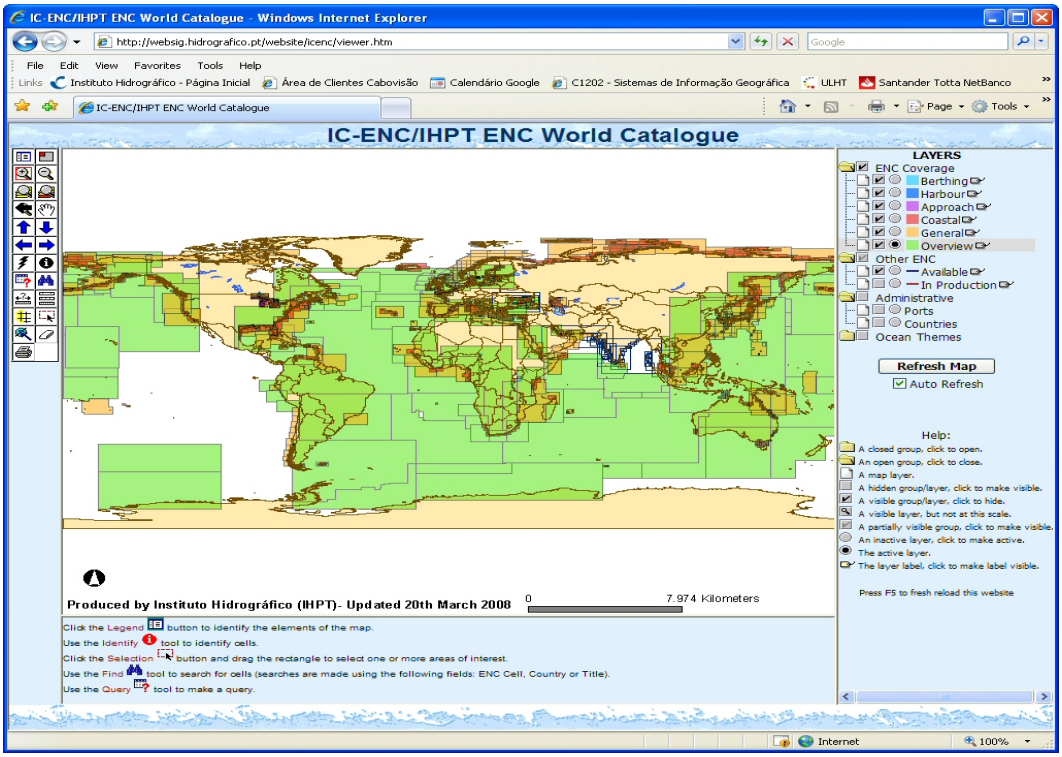


Figure 2 - World ENC coverage catalogue

The way the coastline is seen from the sea is very much relevant to sea navigators. A compilation of visual aids to navigation of the Portuguese coastline is available via an ArcGIS Server website customized with arrow features hyperlinked to pictures. This information is, for example, being to teach young sailors the shape of coastal features for future reconnaissance when at sea (Figure 3).

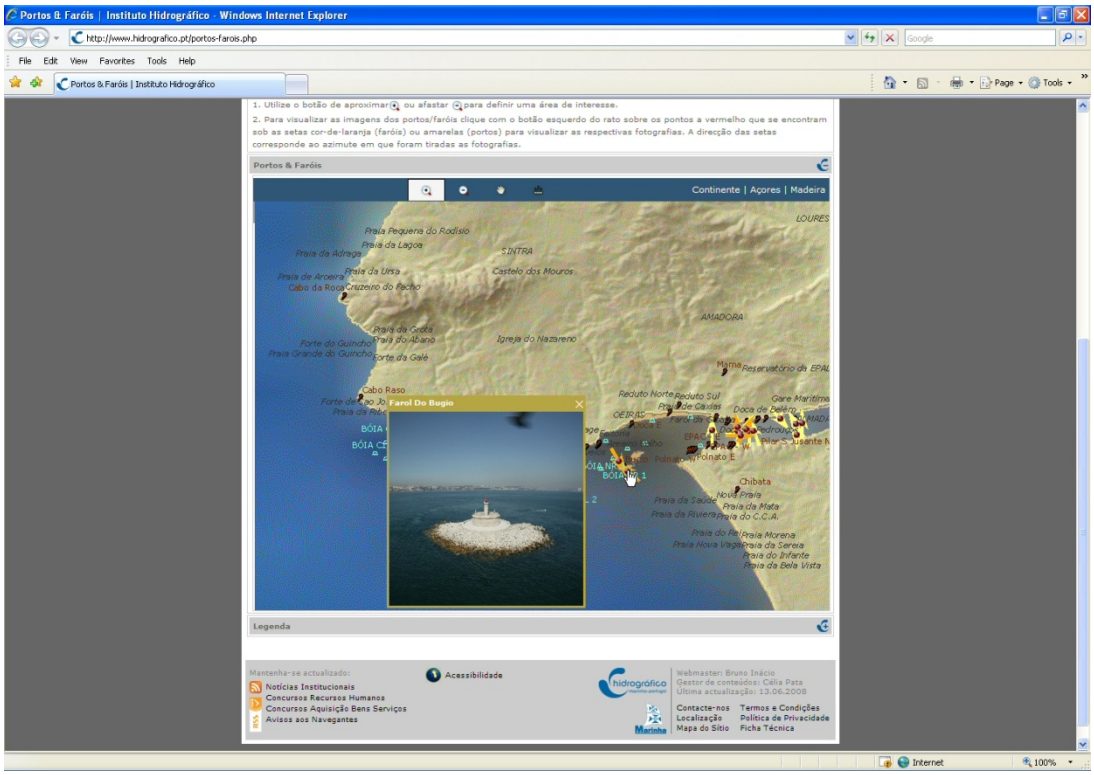


**Figure 3 - Visual aids to navigation information system (Lisbon harbor lighthouse entrance)**

The expected environmental impacts on military resources are of significant importance in mission planning and execution. At first these impacts would be table based using three colors (green, yellow and red) to describe the predicted impact. Since environmental conditions vary from place to place, assessing all impacts for a wide area of military interest would be very time consuming and confusing prone (a table for each location of interest). Since 2006 IHPT has been supporting the navy and the national military joint staff with geospatial based mission impact diagrams. The developed solution describes the variation of the impact through the area of interest and also provides an exhaustive and efficient interface to provide all expected impacts for a certain point of interest. This product is being daily used to access the areas where certain navy activities are to be conducted (i.e. fishing control activities - Figure 4).

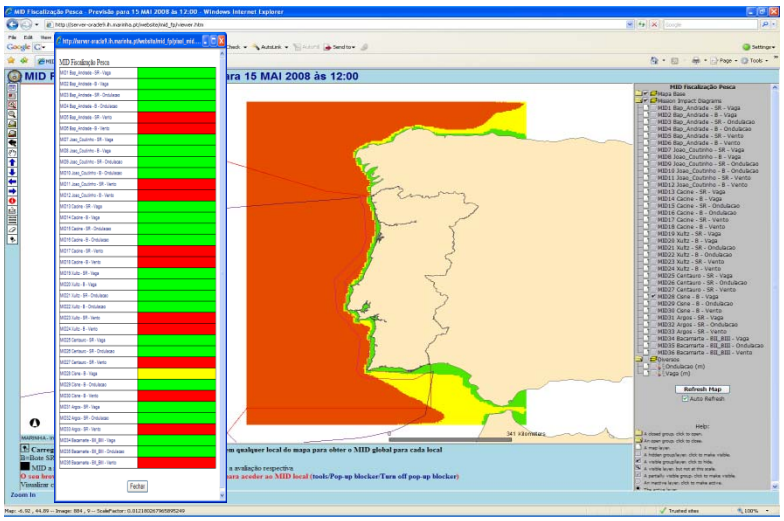

Figure 4 - Daily mission impact diagram for fishing control activities

Support to marine research & development activities is a major objective of this SDI. Several information products have been developed helping scientists to perform integrated analysis of different marine disciplines, to plan field cruise campaigns and outreach research results to the public. The HERMES project (hotspot ecosystem research on the margins of European seas) is a perfect example of this. More than 50 european partners are working on this project, in seven different areas of the European shelf, and a project GIS is setup based on different regional coordination. Each area has its own GIS that is used for awareness of existing data, planning oceanographic cruise activities and presenting results (Figure 5).

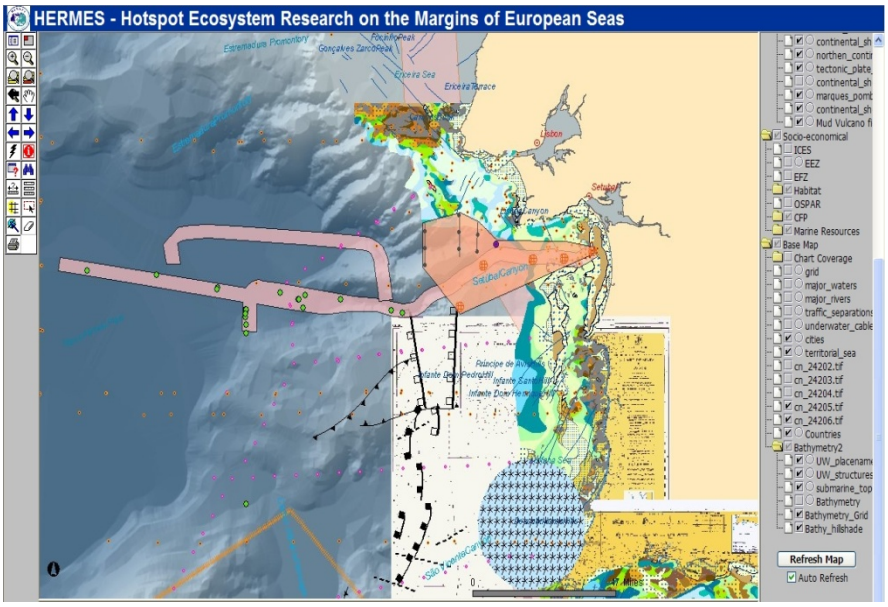


Figure 5 - HERMES GIS for the area under regional Portuguese coordination (IHPT)

Geospatial metadata has long been recognized as the key feature for SDIs to work at full for their users and administrators. Three key aspects are fundamental on metadata:

- Inventory
- Data search
- Data quality.

There are some other aspects related to metadata that are of value, but these three have been the key ones for this SDI. For an organization which production processes are environmental based, it is fundamental that a geospatial data inventory exists. Gathering environmental data, especially marine data, can be very expensive. For some phenomena of interest, getting the same sample twice (if the time factor is considered irrelevant) is a waste of time, money and human resources. We do not have the time with today's means (sensors, platforms, etc) to get the necessary number of samples to know exactly how the ocean works and its related aspects. Spending time doubling data collection is a crucial error. Geospatial search mechanisms are more complex than the traditional text based ones. The fact that we are dealing with multi-dimensional data (spatial and attribute) makes all the difference. Geospatial metadata fact sheets allow fast and objective search of data of interest. As geospatial databases get bigger and surpass several terabytes in size, metadata plays a very important role in the search for existing data. Finally, data quality documentation is necessary to assure it can be reused in future researches and applications. Using data which quality parameters do not apply to a certain application will certainly contribute to a bad output and its corresponding decision based process.

## RSS

Besides the traditional geographic interface for accessing data, this SDI also provides access to some technical-scientific data via RSS (real simple syndication). This protocol is very useful for low bandwidth and PDA or cell phone access to data. Tide predictions for all principal and secondary ports of Portugal and for all principal ports of Angola, Cape Verde, Guiné-Bissau, S. Tomé & Príncipe, Mozambique and Macau are available for the present and the three following days. Near real-time data from sea state buoys are updated every 2 hours for five buoys located just offshore the continental Portuguese coast and Madeira Island. Navigation warnings are also issued in this format. All links for these feeds are compiled at http://www.hidrografico.pt/rss.php . Users only need to install a RSS reader (there are several available only for free download and use) and add its feeds of interest for practical use.

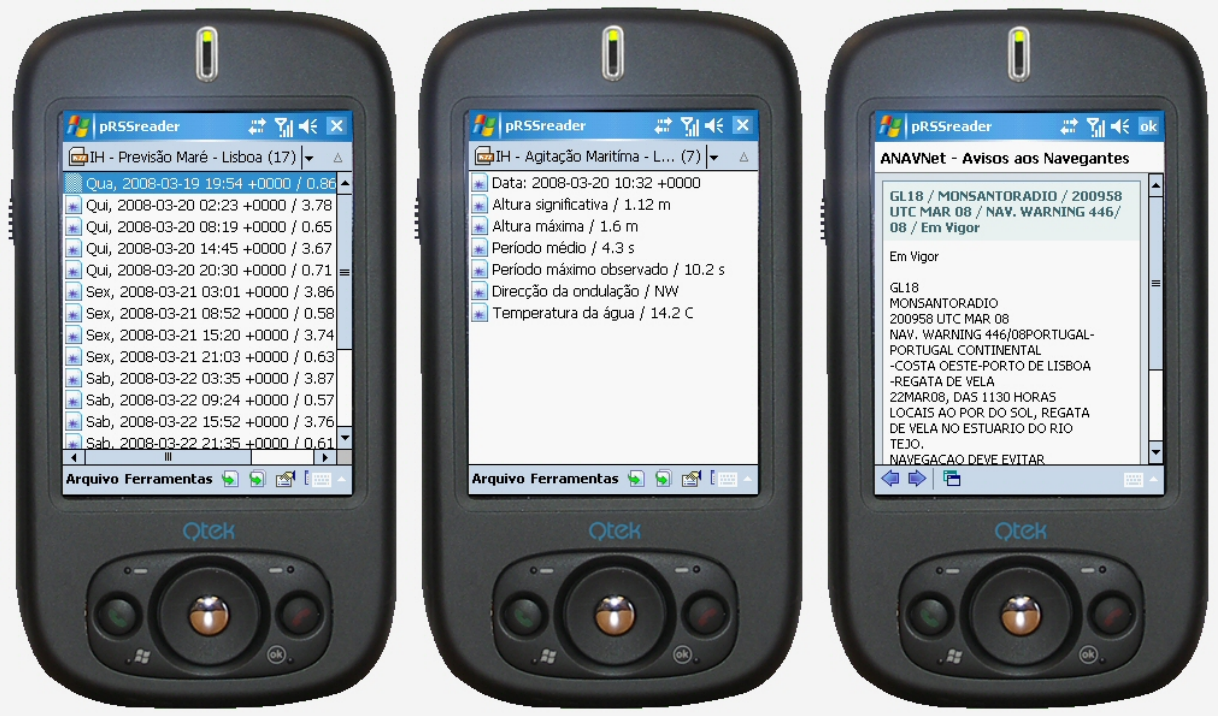


Figure 6 - From left to right - Tide predictions, sea state conditions and navigation warnings via RSS

## Ad-hoc independent projects

Several ad-hoc independent projects have been developed based on the IDAMAR SDI. These projects are normally distributed in CD/DVD-ROM. ArcReader is normally the application used to explore information included in these projects. The following list is not exhaustive, but provides a good insight on the different types of applications developed and under development:

### *Public service*

Maritime Public Domain management
Maritime accidents analysis
Support to police investigation
AIS installation locations
HISKIPPER - Soft navigation planning

### *Environmental protection*

“Prestige” – Ship sinking crisis management
LIMS NAUTILUS – Chemical lab management

### *R&D*

Nearshore drift modeling
Wave energy systems locations
Aquaculture structures locations*
Historical cartography*

Places of refugee*

### *Comercial Services*

Inland water cartography (Alqueva dam)
Aids to navigation planning

### *Navy support*

SIPLANAV – Navigation planning
SICMO – Metoc climatology
SIGPAS - Military protection areas
SICOPA – Visual navigation aids
SIDGAM – National maritime authority
SICENO – ENC content
SIGuiné – VIP protection
SICongo – UNO 2006 Congo elections
Lusíada 2006 – Joint exercise
Rio Minho – Border river patrol
Hera III – Illegal emigrantion
Mediterrâneo – Navy cadets training
Cabo Verde – Military exercise support
REA Contex – Joint exercise support
Maritime Police – Operations support
COA 2008 – Joint exercise support
Spain_Brazil 2008 – Joint & combined exercise support
NATO Q-Routes* - Minewarfare protection support
GEOMETOC support to Portuguese joint staff*

*on going development/process

## 4. Conclusions and future work

The IDAMAR SDI is a valuable asset of the IHPT supporting its major mission objectives: safety of navigation and life at sea, support navy activities, environmental protection and contribute to sea knowledge. Its development started as a departmental GIS (SIGAMAR) and became a spatial data infrastructure as its scope and components were broadened.

This SDI provides several online information products such as data catalogues, specific geospatial information products and data search and documentation capabilities. Many independent ad-hoc projects have been and are being developed based on it. Most of these are CD/DVD-ROM based but many have their output in paper or other digital format (images, fly by movies). The application of these information products are related to public service, environmental protection, marine research and development, commercial services and support to navy military activities.

Direct ongoing work is being made at the data level (converting historical analog data and products to digital format and registering them in the system) and visualization (geospatial portal).

Future work include the development of GeoRSS feeds for technical-scientific data dissemination, and the development of multi-criteria geospatial analysis applied to environmental tactical decision aids (mission impact diagrams).

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