Marine Waves Energy: A spatio-temporal DSS-WebGIS to support the wave-energy potential assessment in the Mediterranean Sea

GIS technologies are able to provide a useful tool for estimating the energy resource from the sea waves, assessing whether this energy flux is exploitable and evaluating the social and environmental impacts in deep water and/or in the seaboard. The DDS-WebGIS "Energy Waves" represents a tool for displaying and sharing geospatial data and maps, as well as a valuable support for new installations planning, forecasting system and existing infrastructure management.

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Introduction

As part of the activities related to the project "Ricerca di Sistema Elettrico" (Electric System Research), in the framework of an agreement between the Ministry of Economic Development and ENEA, a Web-based GIS (WebGIS) application, called Waves Energy, has been implemented and developed. Designed for sharing and exploiting geographic data and information about the marine and coastal environment, the application has been primarily set up as a tool for estimating the energy resource from the sea waves. The WebGIS can be reached at the following URL: http://utmea.enea.it/energiadalmare/.
The application was realized using Free/Open Source Software (FOSS), including a set of applicative solutions suitable for the above mentioned purposes and implemented in the context of a well-integrated platform and easy-to-use interface. This solution has allowed to publish, via the Web, a comprehensive data-set of geospatial information (thematic maps, marine phenomena trends, coastal environment information, etc.), according to the standards required by the Open Geospatial Consortium (OGC), using a set of specific features for viewing and consulting the maps in a framework, tailored for the Waves Energy application.

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Objectives of the work

The WebGIS Waves Energy was designed and implemented in order to store and manage geographic and spatial data concerning marine and coastal areas of interest and, therefore, to provide support in the estimation of energy resources from the sea, by assessing whether this energy flux is exploitable and the impacts on social and environmental realities located in deep water and/or along the seaboard. The basic geospatial data and the maps produced have been stored and managed in a repository, *ad hoc* structured. In such a way, the WebGIS represents the natural geographic interface of the Decision Support System (DSS) envisaged in the project: basic local information and maps can be visualized and queried via the Web, by means of a standard Web browser or mobile devices (e.g., tablet) and, consequently, the main results are open and accessible online.

The specific objectives of the DSS-WebGIS Waves Energy are to:

- define and characterise the marine and coastal areas investigated;
- support the integrated analysis of the study-areas, along with the identification of specific environmental indicators (e.g., during the phases related to the design of new facilities);
- provide support to monitoring and forecasting activities;
- share data, maps and information via the Web.

Implementing these features has required an advanced and integrated management of:

- basic geo-spatial data, necessary for marine and coastal areas characterisation (e.g., various natural components and infrastructures);
- new geo-spatial data, produced to support management and planning activities (e.g., weather and marine forecasts, etc.).

Among the advantages of using the WebGIS technology, it is possible to include:

- global sharing of geographic information and geospatial data;
- usability (the WebGIS application is exploitable by any common internet browser);
- widespread availability and capability to reach a broader audience of users.

System design and logical architecture

A fundamental, preliminary phase has concerned the implementation and use of spatial analyses and procedures (via GIS algorithms, the so-called *geoprocessing*): the aim was to develop, standardize and organise the available database, as well as to define the geo-statistics processing of data itself. In this context, a key role was played by the data resulting from the simulations carried-out by the numerical oceanographic model used (WAM, model over the entire Mediterranean basin): these data-sets are produced in NetCDF files format (Network Common Data Form); then, through appropriate processing, they are transformed into a GIS-compatible format (ESRI shapefile, .shp) and made available for subsequent processing steps.

Concerning the implementation of the WebGIS application, a client-server architecture was adopted, using FOSS packages. Such architecture has been properly conceived to allow the interchange of geospatial data over the Web and to provide the system with characteristics of originality and applicative versatility.

The WebGIS architecture is shown in Figure 1 and can be outlined by the following logical chain:

Data Repository -> Web Server (GeoServer) -> Library (OpenLayers) -> Map Viewer (WebGIS)

The Data Repository identifies the storage area containing the data-set used (in GIS format). The access is allowed only to devices physically defined at the level of the Storage Area Network, in order to ensure the absolute integrity and consistency of the data themselves.

The Web Server represents the hardware/software environment that allows to organize information and make it accessible from the network. In the present case, it was decided to use the *GeoServer* suite. It is a largely used open-source application server, which plays a key role within the Spatial Data Infrastructure (SDI) implemented. It allows to share and manage (using different access privileges) information layers stored in the repository; it also supports interoperability (it reads and manages several formats of raster and vector data).

In the framework of the research activities just described, thanks to the above mentioned characteristics, Geoserver has been chosen to manage the layers (thematic maps, basic information and data, etc.) stored in the geospatial database and to accomplish their publication via the Web within the WebGIS application, according to the standards

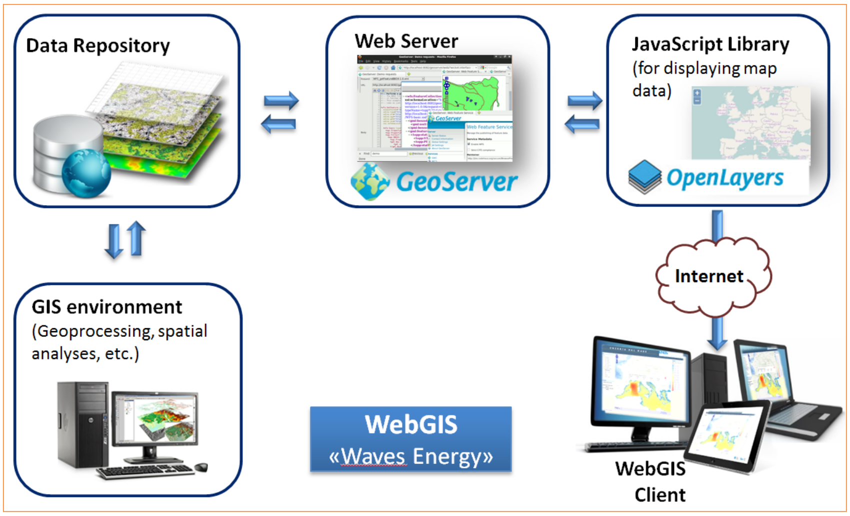

FIGURE 1 WebGIS architecture
(ENEA elaboration)

defined by the Open Geospatial Consortium (OGC), such as, for example, the Web Map Service (WMS). OpenLayers is an open-source JavaScript library, used to visualize interactive maps in web browsers. OpenLayers provides a so-called Application Programming Interface (API) allowing access to various sources of cartographic information on the Internet, such as WMS and WFS (Web Feature Service) protocols, commercial maps (Google Maps, Bing, etc.), different GIS formats, maps from the OpenStreetMap project, etc.
Thanks to the WebGIS interface the user (not necessarily with GIS-specific skills), through his own web browser, can view maps representing the results produced within the project activities. In particular, to visualize the data available, the WMS standard is exploited, by means of a *map-server* approach that allows to produce thematic maps of geo-referenced data and respond to queries about the content of the maps themselves.

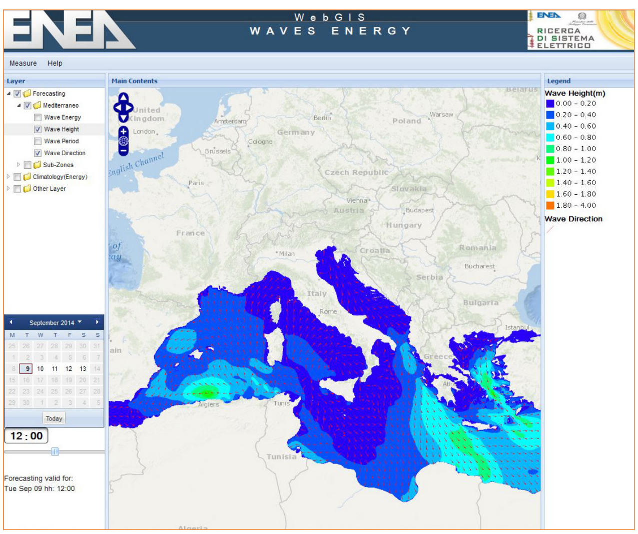

FIGURE 2 WebGIS Waves Energy interface, accessible at http://utmea.enea.it/energiadalmare/
(ENEA elaboration)

"Waves Energy" Application: Features and functions

The "Waves Energy" Application makes various basic features available , which are typical of a WebGIS such as, for example, zoom, pan, transparency, linear and areal measurements, etc. (Fig. 2). In addition, by clicking anywhere on the selected layer, the relevant information is displayed (qualitative or quantitative attributes, the so-called *inquiry* function).
The data-set provided by WebGIS has been grouped, according to its characteristics and specifications, into three distinct typologies:
a) Forecasting (Prediction models outcomes);
b) Climatology (Time series);
c) Other Layers (Basic geographic information).
The first set of data, produced for the entire Mediterranean Sea (with spatial resolution of about 3 km, 1/32 degree), provides 5-day forecasts, at hourly intervals, of the following physical quantities: wave energy flux, wave height, wave direction and wave period. In particular, by clicking a point of interest on the sea map, it is possible to obtain a specific graph,

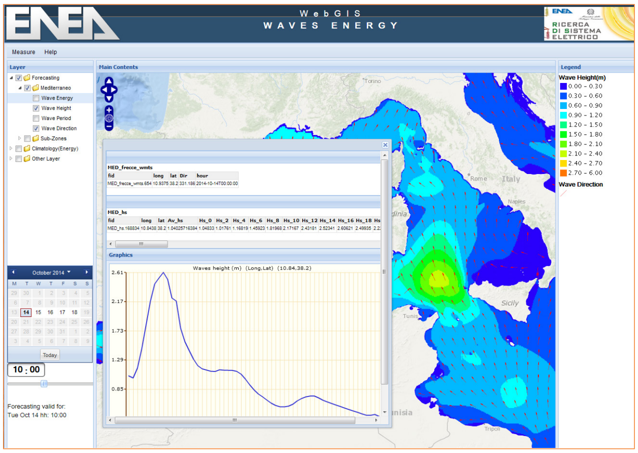

FIGURE 3 Forecasting: thematic maps related to height and direction of waves (GIS overlay), with the relative daily trend chart
(ENEA elaboration)

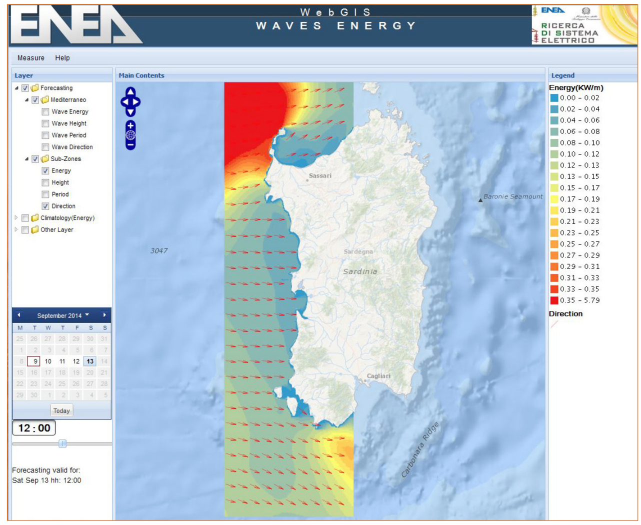

FIGURE 4 Forecasting: subset map of the Sardinian western coast
(ENEA elaboration)

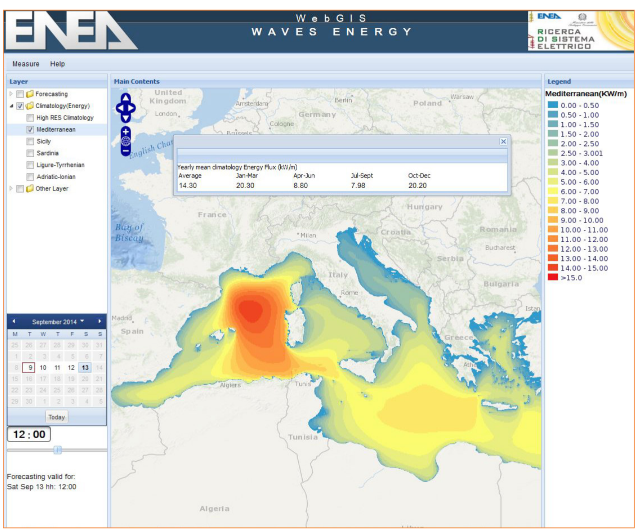

FIGURE 5 Thematic map of potential waves energy flux, derived from climatological data (2001-2010)
(ENEA elaboration)

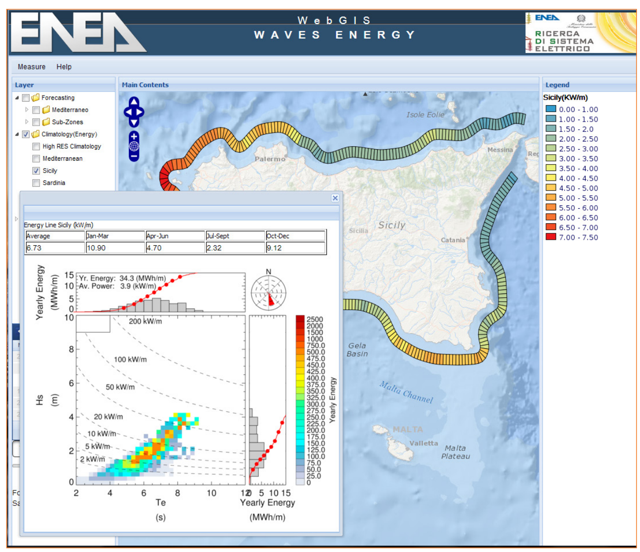

FIGURE 6 Average energy flux values observed during the considered period (2001-2010) and related graphs for the Sicilian coast
(ENEA elaboration)

showing the temporal trend of a selected variable (height, direction, etc.) for the following five days, at hourly intervals (Fig. 3). Furthermore, these same data are available and queryable at a greater detail for some specific sub-areas of interest (Fig. 4).

The Climatology data (listed at point b) are derived from time series and related to the potential energy flux from waves; they contain the average values of energy flux in kW m^{-1} for the time-span 2001-

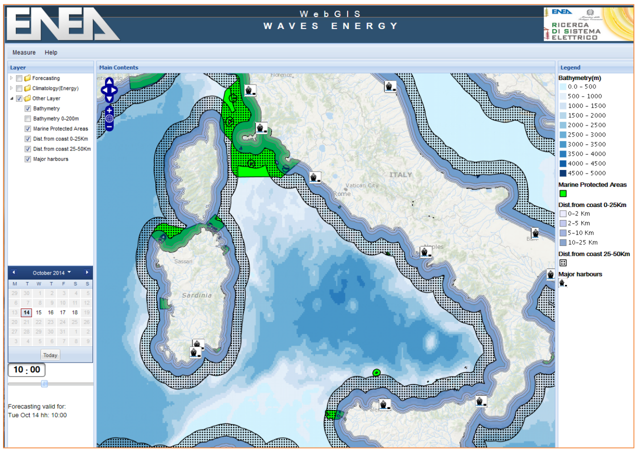

FIGURE 7 Italian Marine Protected Areas and major Italian harbours. GIS overlay with distance from the coast and bathymetry
(Source: SINANET, GEBCO and ENEA elaboration)

2010, subdivided into quarterly periods (Fig. 5). In particular, in the WebGIS data for the entire Mediterranean Sea are included, as well as additional layers representing a specific focus along the Italian coast in a range of 12 km from the shoreline (Fig. 6). The third category (Other Layers, point *c* of the list) includes a series of basic geospatial data and environmental information. Such ancillary layers, in addition to those previously described, allow to provide a better geographic and thematic characterisation of the Mediterranean area considered for the application purposes (Fig. 7). The most significant are: the bathymetry of the Mediterranean Sea (source: GEBCO, General Bathymetric Chart of the Oceans); a bathymetry subset, with depth values ranging from 0 to 200 m (layer specifically derived from GEBCO data); Distance from the coast, articulated in two zones: 0-25 km and 25-50 km; Major harbours; Italian Marine Protected Areas (source: SINANET, Italian Ministry of the Environment and Protection of Land and Sea of Italy).

Conclusions

The capability of digital maps in providing a comprehensive overview of environmental phenomena is universally recognized. Through appropriate descriptions and thematic maps, it is easier to understand environmental features and characteristics, as well to point out patterns and interactions.
The activities described in this paper were aimed at developing a specific spatial DSS, based on a WebGIS application, which served as a means for the publication of the data used as input and produced as results: thematic maps, forecasting data and climate time series. Data and thematic maps were properly structured within the WebGIS application, not only to show a range of information about the areas of interest, but also to support management and monitoring policies related to the exploitation of energy flux from the sea.

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further readings

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