

A synergetic combination of measurements and models to assess renewable wind energy in semi enclosed domains

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Abstract:

The paper presents the need to combine high resolution simulations and observations for calculating in a robust manner the highly variable wind, wave and circulation conditions off the Catalan coast. It discusses the limitations of both instrumental equipment and numerical codes and how they must be validated and combined for semi enclosed domains, illustrated here by the Catalan shelf sea.

Keywords: *marine energy, waves, currents, modelling, observations*

1.- Introduction

The present limitations of meteo-oceanographic models in providing accurate and robust estimates in irregular semi-enclosed domains, such as the North-western Mediterranean, together with the challenges to measure directly meteo and oceanographic parameters in a narrow continental shelf require a synergetic approach. Here we shall present the development of a LIDAR buoy developed within the NEPTUNE project and prepared to measure meteorological and oceanographic parameters at a range of water depths, suitable for the Catalan continental shelf. This buoy has been tested in our laboratory flume to optimize the motion compensation (Fig. 1.).

The numerical modelling sequence prepared is based on combining a meteo model such as WRF, a circulation model such as ROMS and a wave models such as SWAN. The use of a variable or nested grid into a validated pre-operational system is a task fraught with difficulties and which requires a careful validation (Fig. 2.). It entails improving the physics of the models, such as for instance, in this case, the physics of the dissipation or whitecapping term to correct for the wave height under prediction (Fig. 2a.). It also implies adjusting the frequency integration interval to compensate for the systematic under estimation of wave periods (Fig. 2b).

The presentation will end with a review of the potential of a synergetic combination of

measurements and models to assess the renewable energy resource and to estimate the interactions of the recovery structures with the prevailing meteo-oceanographic conditions.

2.- Numerical approach: coupling and nesting.

Often, for meteorological, waves and oceanic modeling at regional scales a strategy of nesting and extraction of inner boundary conditions is used to obtain more accurate meteo-oceanographic forecasts than those currently available. However, when working in coastal areas the interaction between the three mentioned fields (wind, waves and currents) is not negligible, and therefore it is recommendable to couple the different models. Various types of coupling are available. A one-way coupling is the simplest option, which consists in getting results from one model and introducing them as an input into the next model. Additionally, there is the option to execute a two-way coupling, so that for each time step all models run in parallel, and every so often they share physical parameters such as the wave height, the current intensity or the atmospheric pressure, thus being able to reproduce more realistically the physical behaviour in coastal areas.

Due to the increased performance of computational means, the use of numerical models to predict natural events is becoming prevalent. To accomplish this, numerical models are not only being pushed to increase their spatial resolution but also to increase the complexity of the simulated physics. Coupling of models is one method to allow an increase in model complexity and, thus, accuracy [5]. The coupling of models allows the effects of larger scale processes to directly influence the smaller scale response. Three-dimensional coupled atmosphere-ocean models have been developed and applied to idealized and realistic scenarios to predict the interactions between the atmosphere and the ocean [1], [2].

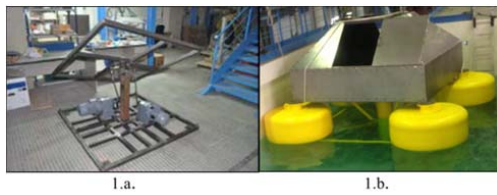


Fig.1. Sample image showing the rotating platform to assess the motion induced errors in the LIDAR buoy (1.a.). The buoy structure and floating volumes have been optimized to avoid and compensate resonant motions for Mediterranean conditions (1.b.).

The scope of the coupling between different models, and in particular the interaction between oceanic models and wave models, are at the heart of the current activity within the scientific community since it requires dealing with a highly complex physical issue, not yet fully resolved, and also some computational complications. To manage the three models running concurrently, and the transfer of information and variables from one to another, the Model Coupling Toolkit coupler has been here used for the NW Mediterranean [4], [3]. In this case, the proposed system implements,

compiles and executes in parallel all the models, taking into account the influence of currents on waves and waves on currents. In these simulations, however, the ocean is not coupled with the atmosphere. The coupling of the three models has been recently implemented and applied by [5] under the name of COAWST system (Coupled Ocean-Atmosphere-Wave-Sediment Transport modeling system), which executes a suite where the three models are running concurrently. This system has been implemented for estuaries, coastal areas and the continental shelf.

In our study, as shown in the scheme (Fig. 3.), the atmospheric model runs in three domains with a two-way nesting, and provides wind information to the wave model, also working with three domains (Fig. 4. and Table 1.). The oceanographic model ROMS obtains the boundary conditions from a database provided by MyOcean. Once the models have reached the last (finest) level of discretization the three models are coupled, with a two-way coupling, using the 3km resolution WRF grid with the 1km resolution SWAN-ROMS grid.

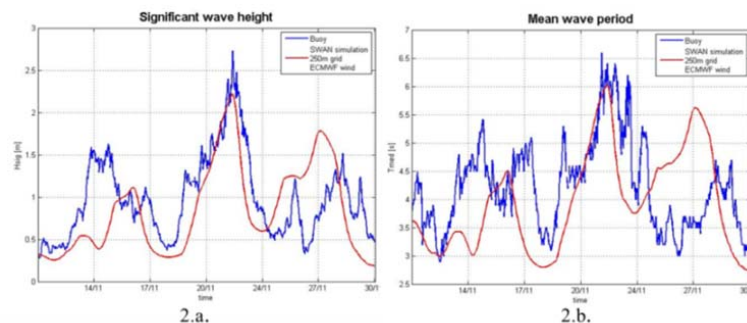


Fig.2. Sample numerical results of significant wave height (2.a.) and mean wave period (2.b.) computed off the Catalan coast using the SWAN model prior to the changes carried out to improve the physics and the resulting numerical simulations. The numerical series are compared with the measurements from a directional wave buoy deployed at 40 meters water depth. The meteo-fields come from the European Centre (ECMWF).

3.- Experimental approach: meteo-oceanographic observations and motion compensation.

Most of renewable wind energy convertors, worldwide, have been installed on-shore. This means that most areas with favourable conditions for wind energy have been already taken, with a considerable land impact. The alternatively, coastal or shelf waters, present harder technological changes and the costs involved are much higher. However they would allow to reconcile renewable wind energy extraction with other coastal resources such as tourism for the Mediterranean. In particular the Western Mediterranean basin offers an interesting wind energy potential near the coast, which requires accurate numerical forecasts and a reliable assessment of the energy resource.

Considering the limitations of the numerical models presented in the previous section, it is required to develop a robust system to take in situ observations, both for model validation and resource estimation. The cost of existing systems (meteorological masts based on bottom fixed structures or remote sensors without enough resolution or accuracy) do not meet these requirements. Because of that in this project we are aiming to develop an oceanic buoy that is able to record in a collocated manner wind, wave and current parameters, together with some ancillary meteo-oceanographic variables also required for model calibration and as “ground truth” for risk assessments.

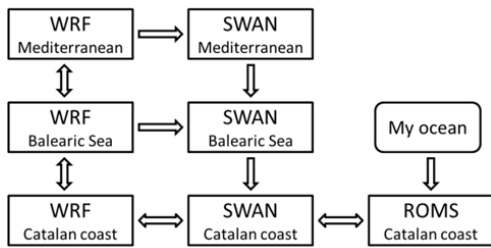


Fig.3. Schematization of the coupling strategy among the various models.

The NEPTUNE buoy should be able to provide conventional meteo-oceanographic parameters plus accurate wind profile measurements up to the blade tip height which is about 250m above mean sea level. The prototype buoys have been tested at the CIEM laboratory facility in UPC-Barcelona and have been next taken to a number of field tests. The development project has consisted of four steps: a) side by side tests of two identical LIDARS (Z300-Zèfir natural power) without motion, to establish accurately the correlation between two units without any super-imposed motion and at close to middle range (up to 40m); b) side by side tests of a fixed LIDAR versus a LIDAR with laboratory induced motion and without compensation; the aim of this part of the analysis was to better understand the influence of the LIDAR motion on the measurements and to derive improvements for evaluating in an accurate manner the recorded variables; c) side by side tests with a fixed LIDAR versus a LIDAR on a motion simulator with a mechanical compensation system; the aim here

was to assess the efficiency of the mechanical compensation system; d) side by side tests of a fixed LIDAR (deployed at an instrumented coastal pier) versus a LIDAR deployed on a floating buoy; this has allowed to assess the robustness and efficiency of the system in the field (see Fig. 5).

The developed buoy prototype turns out to be much cheaper from the construction and maintenance point of view, than some existing prototype meteorological masts. It is also particularly suited to the Mediterranean conditions, since the floating and mooring arrangements have been designed to avoid resonance with the predominant wave periods in that area.

The resulting observational system (Fig. 6) should also be useful for other environments, particularly those with micro-tidal conditions and where the range of sea levels and wave periods can be comparable to Mediterranean areas. The application to other sea environments should be relatively straight forward, given the simplicity and robustness of the system.

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	Mediterranean	Balearic Sea	Catalan coast	Ebro Delta
WRF	27km	9km	3km	1km
SWAN	9km	3km	1km	250m
ROMS			1km	250m

Table 1. Summary of grid sizes for the different models and domains.



Fig.4. Schematization of the domains for the simulation. In green the boundaries for the meteo model, in red for the wave/current models. The outer boundary conditions come from a full Western Mediterranean model not shown in the figure.

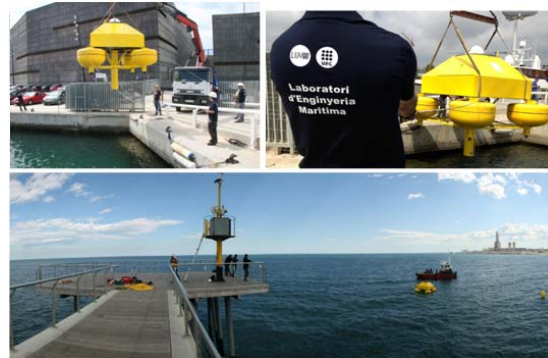


Figure 5: Visual summary of the floating buoy deployment (upper panels) and the two LIDAR systems, seen from the coastal pier Pont del Petroli: the floating buoy on the right hand side of the picture and the fixed one on the left hand side (lower panel).

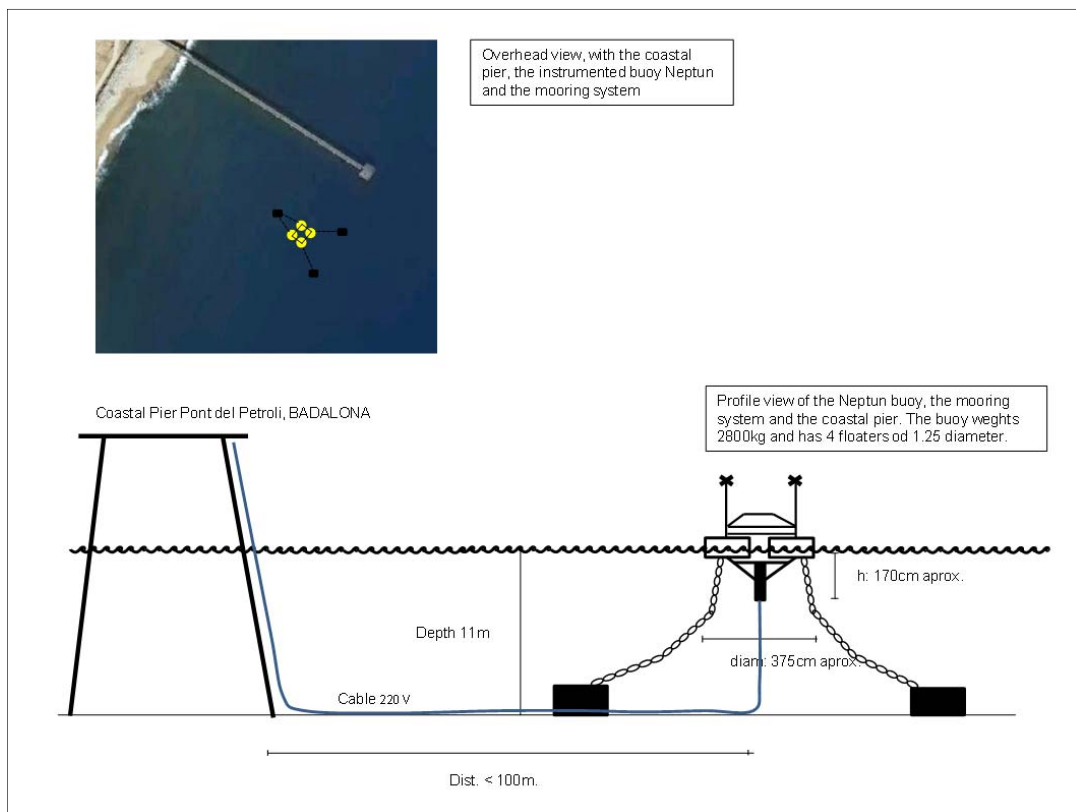


Figure 6: Plan and profile view of the coastal pier Pont del Petroli and the instrumented buoy where the LIDAR is deployed. The mooring system is also schematized, for a water depth around 11m which corresponds to a little bit less than the tip of the pier.

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