MONITORING AND FORECASTING OCEAN DYNAMICS AT A REGIONAL SCALE

MONITORIZAÇÃO E PREVISÃO DA DINÂMICA OCEÂNICO NUMA ESCALA REGIONAL

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ABSTRACT

A new Oceanic Observatory for the North-West Iberian Margin is being developed in the scope of the RAIA project. The objective of RAIA is not only to improve our scientific knowledge of the ocean in this North-East Atlantic region, but also to use the in situ observations and ocean models to derive commercial products and services for a range of marine activities related to: sediment transport, coastal erosion, pollution (spill) monitoring, understanding of marine life, search & rescue and renewable energies. The Coastal & Ocean Dynamics Group at CIIMAR is participating in this project and their contributions are presented here.

Keywords: Ocean Modelling; Sensors; Data-base; Tides.

RESUMO

Um novo Observatório Oceânico da Margem Ibérica Noroeste está a ser desenvolvido no âmbito do projecto RAIA. O objectivo do RAIA é não só melhorar o nosso conhecimento científico sobre o oceano nesta região do Atlântico Nordeste, mas também usar as observações in situ e os modelos oceânicos para a obtenção de produtos e serviços que possam ser de interesse para uma vasta gama de actividades marinhas relacionados com: o transporte de sedimentos, a erosão costeira, monitorização de poluição (derrames), a compreensão da vida marinha, acções de busca e salvamento, e energias renováveis. O Grupo de Dinâmica Costeira & Oceânica do CIIMAR participa neste projecto; as suas contribuições são aqui apresentadas.

Palavras-chave: Modelação Oceânica; Sensores; Base de Dados; Marés.

JEL Classification: Q55

1. INTRODUCTION

In 2009, the RAIA project was initiated with the objective to develop an oceanic observatory for the NW Iberian shelf. This Interreg IV-A project, between the North of Portugal and Galicia in Spain, will run until the end of 2011. It is led by MeteoGalicia and has in all 13 project partners as listed in Table 1. RAIA's main goal is the consolidation of the operational oceanography of the NW Iberian Margin, given the economic importance of the activities developed in this zone such as maritime transport and safety, nautical sports and fishing. Currently, there are too little in situ measurements available to make operational oceanography feasible, especially in the Portuguese ZEE. In an effort to remedy this situation, five new buoys are being installed of which the location is given in Figure 1. Simultaneously to the set-up of this new infra-structure, new hydrodynamic models for the area are under development. These will incorporate the new measurements, allowing more reliable local ocean forecasting. To be useful for forecasting, these new observations have to be accessible in real-time. For that reason an e-infra-structure and links are being implemented by some of the partners, allowing the measurements to be transmitted directly to stations on land. The format of the observations and the output of the numerical models follow internationally established standards and are collected at a single internet portal (www.observatorioraia.org).

A marine cluster is defined as a network of firms, research, development and innovation units, and training organisations that co-operate with the aim of technology innovation and of increasing maritime industry's performance. In this sense, the RAIA project, which is executed by universities and development and innovation units, is providing the technology and information that can be used by the maritime industries to increase their performance.

In this paper we will present details of the contributions of CIIMAR's Coastal & Ocean Dynamics Group to the RAIA project. These include: acquisition of sensors for the Portuguese buoys in front of Leixões and Matosinhos, development and validation of a regional hydrodynamic model, including the river Douro estuary area, construction of a database with remote sensing data and the development of a regional tide model. Finally, we list the services that are now available.

Table 1: The participants in the RAIA project

• Consellería de Medio Ambiente, Territorio e Infraestructuras (MeteoGalicia)	• Centro Interdisciplinar de Investigação Marinha e Ambiental (CIIMAR)
• Instituto Tecnolóxico para o control do Medio Mariño de Galicia (INTECMAR)	• Instituto de Engenharia de Sistemas e Computadores do Porto (INESCP)
• Instituto Español de Oceanografía (IEO)	• Instituto de Engenharia Mecânica e Gestão Industrial (INEGI)
• Instituto de Investigaciones Mariñas (CSIC-IIM)	• Faculdade de Engenharia, Universidade do Porto
• Centro Tecnológico del Mar (CETMAR)	• Instituto Hidrográfico (IH)
• Grupo de Oceanografía Física de la Universidad de Vigo (GOFUVI)	• Universidade de Aveiro (UA) • Faculdade de Ciências, Universidade do Porto

2. SENSORS

Ocean models are not perfect physical representation of the ocean. In situ observations are therefore indispensable to ensure that the model does not deviate too much from reality. The process of integrating observations and models is called assimilation, but the observations also serve to tune the models in order to produce the best results. As mentioned in the introduction, five new buoys are being installed within RAIA. CIIMAR has provided an Acoustic Doppler Current Profiling (ADCP), type Teledyne RDI 300Khz, a Global Navigation Satellite System (GNSS) receiver and antenna, plus a motion sensor for the first buoy that has been installed. This buoy, called Alfredo Magalhães Ramalho, was launched and installed on 23 May 2010 at the continental shelf edge off Leixões by the Instituto Hidrográfico, and will be maintained by this organization.

The GNSS system allows observations of the height of the antenna above the reference ellipsoid. Because the GNSS antenna is installed on top of the mast of the buoy and because the orientation of the buoy is changing over time due wave motion, one has to correct for its orientation to obtain the correct sea level value above the ellipsoid. This orientation is measured with an Inertial Measuring Unit. The initial location of this buoy has been chosen carefully to ensure that it lied exactly under the ascending and descending tracks of the ERS Envisat satellite. This satellite carries a radar altimeter on-board that measures the sea level above the reference ellipsoid, which can thus be compared to the sea level observation of the buoy. After the initial six-month test period this buoy was moved to its actual position on the border of the continental shelf.

Figure 1: Location of existing buoys (green) and buoys that are being installed in the scope of the RAIA project (red)

A GNSS receiver/antenna and IMU system, as well as meteorological sensors and associated data-logger, including a GSM communication link, were also provided for the buoy that is installed in front of Leixões and which has been kindly made available by the company INDAQUA. Other types of sensors provided by the other project partners for both buoys deliver measurements for: wind, temperature, humidity, solar radiation, sea temperature and salinity at different levels, as well as oxygen and chlorophyll concentrations.

A third buoy will equipped with meteo and positioning sensors and anchored. This one, designed and built by INEGI, is specially suited for meteorological data acquisition and will be placed north of Leixões, where the bathymetry is around 30m.

3. REGIONAL HYDRODYNAMIC MODEL

To model the ocean of the NW Iberian region, the Regional Ocean Model System (Haidvogel et al. 2000, Shchepetkin and McWilliams 2005) software is used. Its computations are rather intensive and for that reason run on an IBM cluster with 160 CPU's at CIIMAR. The model domain lies between -15º and -5º East and between 38º and 46º North, with a spatial resolution of 1/36 degree. At the open boundaries the model is forced by the daily output of the global Mercator model (http://www.mercator.eu.org). In addition to the oceanic forcing, the ocean is also affected by wind, atmospheric pressure, precipitation, air temperature and solar radiation. These forcing elements are taken from the NOAA/NCEP Global Forecast System (GFS) Atmospheric model (Kanamitsu, 1989,1990; Kalney, 1990).

Initially, the water in the model is at rest and when the forcing is applied it takes time for the model to adjust to the new situation which is called "spin-up". To correct for this effect, the model is first forced for 3 years with climatological forcing. Afterwards the model is forced by Mercator and GFS data.

The model can be used to provide forecasts of up to 5 days ahead (in the future). Observational data is also assimilated into the Mercator and GFS models and one can therefore use their model outputs to run the model back in time to improve previous estimates. This hind-cast is done for up to 10 days (in the past). Model results are presented on the RAIA internet portal and on the CIIMAR website (http://cod.ciimar.up.pt).

To validate this regional ocean model, the computed fields of salinity and temperature were compared to ARGO float data for the period 2003-2006, see Allis et al. (2011). Panel a) of Figure 2 shows the launch of an ARGO float. For a single float, the trajectory is given in panel b). Simple statistical metrics, such as the root mean squared error, mean absolute error, correlation coefficient and bias, were used to quantify the differences between model predictions and observations. The result of the comparison, using a single ARGO float survey of temperature and salinity during three months in 2003, is presented in panels c) and d) of Figure 2. One can see that for most of the time and for most depths, the differences are small. However, there is a clear deviation at depths between 1100 and 1500 metres. This is probably caused by water outflow from the Mediterranean Sea which is not well represented in the model. Work is currently done to remedy the discrepancies, though one should remember that the development of an ocean model is never finished and that the constant comparison of observations with model outputs will allow the model to improve over time. The RAIA project delivers the best available results that can be used by third parties, while scientists continue to work to improve the model.

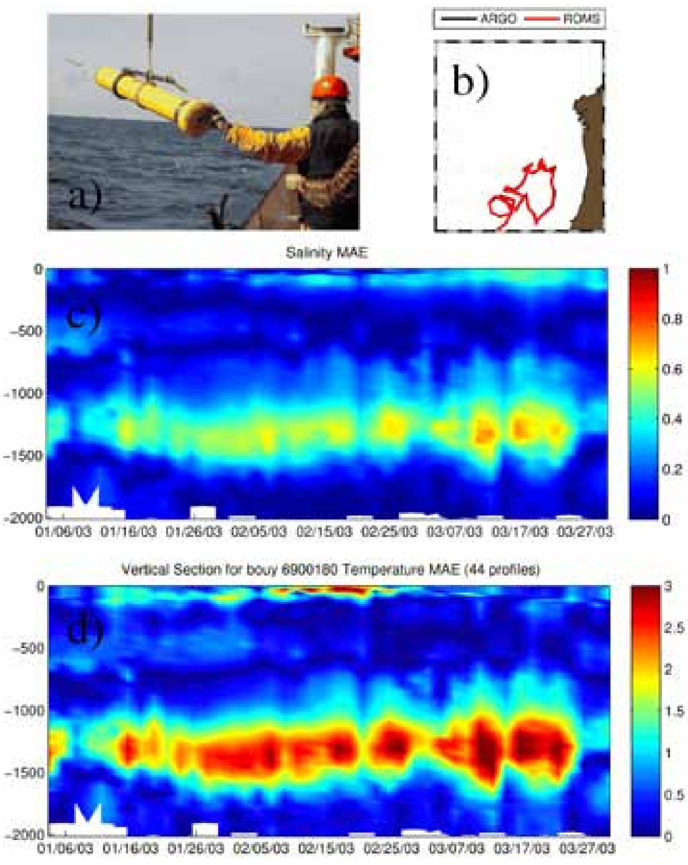
Next, this regional model will again be downscaled to another ocean model for a smaller domain but with a higher spatial resolution of 1/108 degrees. The boundaries of this model will be between the latitudes 40º and 42º North and between the longitudes -11.5º and -8º East. This smaller domain will provide more detailed information of the water temperature, surface currents and sea surface height near the Portuguese coast. This can be of use for local fishermen and provides better information along the Portuguese beaches about the sea temperature and current.

Figure 2: Alfredo Magalhães Ramalho buoy being deployed off the NW Iberian Margin

4. DATABASE

Data from Earth observing satellites also provide valuable information about the ocean along the Iberian margin. To optimize their use, CIIMAR has created a freely accessible database (http://cod.ciimar.up.pt) where one can find: global climatological data, outputs from regional ocean models and satellite data (MODIS ocean colour 8-day and monthly averages). The available climatological data is obtained from the Comprehensive Ocean-Atmosphere Data Set, COADS (Worley, 2005 and Levitus, 1982) which can be used as the forcing at the open boundaries of the regional ocean models. Some further data for areas outside the scope of RAIA are also included in the database, for instance outputs from Atmospheric models for Madeira.

Figure 3: a) The deployment of an ARGO float; b) The trajectory of an ARGO buoy used for this comparison; c) The Mean Absolute Error between the ROMS salinity output and the ARGO observations; d) The same as panel; c) but for temperature



To ensure easy accessibility, the data was stored on a Live Access Server (LAS) which is a web server that allows the user to select the type of data and the domain of interest before downloading. The selected data is also directly shown as a map on the screen (http://cod.ciimar.up.pt/las/getUI.do). In addition, the user can select the period for which he or she wants the data and the type of output files (netCDF, ASCII or arcGrid formats).

5. REGIONAL TIDE MODEL

The regional ocean model discussed in section 3 does not include ocean tides. However, these must be added to obtain the total sea surface height. For this purpose, we have developed a high resolution depth-integrated barotropic model, based on the Laplace Tidal Equations to compute these tides (Egbert et al., 1994). At the open boundaries the tidal elevations were taken from recent global tide models FES2004 (Lyard et al., 2006) and GOT4.7 (Ray, 1999) and the bathymetry was based on ETOPO1 (Amante et al., 2009). We adjusted our model results to fit the altimetry observations at cross-over points from the TOPEX/Poseidon and Jason satellites using smooth interpolation. We also investigated if errors in the open boundary conditions could explain the misfit between model results and observations at tide gauges. Our results show that by optimally adjusting the open boundaries by a few millimetres, the misfit can be reduced by 22% from 4.4 cm to 3.4 cm. Currently, the observations of the newly installed buoys are being processed to allow validation of the tide model and, if necessary, to perform further adjustments.

6. SUMMARY AND DISCUSSION

The RAIA project is building an Oceanic Observatory for northern Portugal and Galicia which will make ocean forecasting feasible and more reliable. This observatory consists of a network of in situ buoys, a collection of numerical ocean and atmospheric models which are accessible through an internet portal available to third parties. Great efforts have been made to ensure that these results are transmitted from the buoys to land in near real-time to increase their usefulness. The Coastal & Ocean Dynamics Group of CIIMAR is contributing to RAIA providing instrumentation for the buoys, processing data, maintaining databases with remote sensing data and developing and validating ocean models. The output of the RAIA project will also contribute to the development of further research related to: sediment transport, coastal erosion, pollution spills monitoring, understanding of marine life, search & rescue, tourism and renewable energies.

The RAIA project has already achieved important scientific results in terms of better knowledge of the state of the ocean. The RAIA project will change after 2011 into the RAIA.co project, ensuring its continuation for the coming years. However, ultimately this Oceanic Observatory must also generate financial income from commercial services to make it sustainable. Therefore, it is our hope that companies and local authorities become interested in using the RAIA results to form a marine cluster that will serve the local economy, serve the people with better information about the sea and provide the means to operate and maintain this Oceanic Observatory.

For more information see http://www.observatoriaraia.org and http://cod.ciimar.up.pt.

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