HF radar pilot project in Morocco

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This project initiated by « la Direction de la Météorologie Nationale du Maroc (D.M.N) », is part of the development activities of the maritime observation network through the use of radar remote sensing techniques and advanced management tools and production of information. Launched in 2014, this installation of two pilot HF radars between Rabat and Casablanca, and the establishment of a radar data concentration and management platform, 2D surface current maps generation and availability of these products on web, is placed in service from 30 March 2016. These radars CODAR technology, operate in a 4438-4488 kHz frequency band and have a range of up to 180km from the coast. They measure the characteristics of surface currents between Rabat and Casablanca and the parameters related to waves in concentric arcs of radii 10, 20, 25 and 30Km of each site. Site selection is done in collaboration with DMN partners, in particular the Royal Navy, Civil Protection and the National Ports Agency. This paper will discuss the project stages, its interest in the monitoring of the marine environment, the challenges, the benefits for the safety of maritime navigation, applications in the areas of search and rescue operations at sea, fight against marine pollution, and the HF radar network expansion prospects.

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1. Introduction

Morocco is a marine country; it has two facades one on the Mediterranean and the other on the Atlantic with a length dimension that is around 3500 km. The Directorate of National Meteorology (DMN) has long suffered from a lack of observational data on the maritime part. Indeed, in addition to observations of volunteer ships that are very rare and satellite measurements that are limited in space and time, several in situ measurements means installation projects have been made by DMN, but that were quickly lost, given the severe marine conditions and difficulties relating to monitoring and maintenance of such equipment. Therefore DMN has established a Maritime Equipment strategy since 2007, which recommends giving priority to remote sensing capabilities in equipment installed on land, easily accessible for maintenance and are safe from harsh maritime conditions and to develop the use of satellite observation data. HF radar project is just part of this strategy.

2. Project Objectives

This pilot project aims to strengthen real-time monitoring of marine environment by measuring oceanic parameters, such as surface currents and wave characteristics over a large area extending from Rabat to Casablanca. The choice of this area is dictated by the presence of several strategic infrastructures, such as the commercial port of Casablanca, the oil terminal, SAMIR refinery and Mohammedia power station, but also many industrial infrastructures built along the coast and tourist complexes experiencing a strong influx of people especially during the summer period.
This system that provides a continuous watch on the marine environment, will enhance the marine weather warning for DMN, and accordingly contribute to the safety of maritime navigation and conduct of operations Search and Rescue at Sea by the use of information of ocean circulation and wave. These data find their application in the context of coastal protection and the prevention of environmental risks especially in the case of marine pollution by oil. Moreover, these observational data will be used in model validation of marine forecasts, operational in DMN and will complement the climatology of the area and improve the knowledge of the hydrodynamics of coastal necessary for coastal engineering decisions.

3. Consistency of the project

In terms of equipment, the pilot project consists of two radars operating in the High Frequency 5MHz with a range of 200km. Each site contains a transmitter, a receiver and a control computer. Both HF radars are concentrated at the headquarters of the DMN at a central platform of Data Management consists of a server "COMBINE" which collects data from sites and generates 2D maps of surface current (with server Backup), and a Marine information server "PORTUS" which processes the information and transforms it into value-added products, integrating measured data into information products, accessible through a multi-user web server (with Backup server).

4. HF radars Operating Principle

HF radars are active instruments that work just like the Doppler radar, which measures the speed of movement of a target moving away or approaching the radar, they are equipped with a transmitter and a receiver. The transmitting antenna sending an electromagnetic wave towards the sea surface, the wave is scattered by the wavelets, a portion returns to the radar receiving antenna. The principle of Bragg resonance shows that the echo is maximum for waves whose wavelength is equal to half the incident wavelength.

HF radars installed in Morocco operating within the 5MHz frequency, this corresponds to a 60 m wavelength, and we shall have a maximum scattering in the presence of waves of about 30m wavelength and a period of about 4.4 seconds.

In principle, HF radars allow the measurement of surface currents on the radial of each site, they detect the radial component of currents moving away and approaching the radar. To get a measure of the total current, we need at least two radars.

These radars also provide the characteristics of waves on concentric arcs around the site (5, 10, 15, 20Km, etc.).
The surface current information and wave characteristics are drawn from the energy spectrum backscattered by the sea surface, the first order corresponds to the surface current and the second order gives information on the waves. The wave measurements are taken from the peak of the second order.

5. Project Phases

HF radar project began in late 2014 right after an exploration stage technology. Several contacts had been made with national partners including the Royal Navy, Civil Protection and the National Ports Agency in order to identify potential sites. The contract was awarded to the QUALITAS Env. Company. Here are the milestones of the project:

- April, 2015: Start of field work
- July, 2015: Authorization of the frequency from the National Telecommunications Regulatory Agency.
- September to October, 2015: Trainings
- October, 2015: Equipment delivery
- November, 2015: Installation of Casablanca Radar
- February, 2016: Installation of Temara radar
- March 03, 2016: Installation and Commissioning
- March 30, 2016: Provisional acceptance

6. HF radars installation

a. Equipement Installation

The HF radar equipment was installed at two locations, the first one is a local that belongs to the National Agency of Casablanca port and the second one is a local that belongs to the Civil Protection Command of Temara. The antennas were installed on the top of the civil protection watch station.

b. APM calibration

After installation, the model receiving RX antennas has been calibrated. This procedure called APM (Antenna Pattern Measurement) aims to correct the distortion of the reception model of the RX antenna by neighboring metallic structures and the discontinuity of the ground plane. It consists of moving an electrical device (transponder) around the RX antenna tracing an arc with a constant radius. The transponder receives the signal from the antenna TX and returns with a slight offset to distinguish the noise reflected from the sea. At the same time, the position of the transponder is recorded by GPS every second. From the analysis of the data recorded by the HF radar station and the GPS we can create the RX antenna pattern with the actual distortion. The following figures illustrate the ideal pattern and the parameters of RX antenna without distortion.
7. HF radar products

Both HF radar installed in Temara (Rabat) and in the port of Casablanca, allow having the following products:

- 2D maps, which shows the time fields of surface current (direction and speed) with a resolution of 6 km and a range of up to 200km, these maps can be animated to show the changing structure of currents observed off the Rabat-Casablanca area,

- The system has an application that tracks the drift of floating objects; the map above shows an example of 72H drift of three floating objects placed at different location.

- Waves are calculated on concentric arcs in the vicinity of each site,
- One can also view the features of waves on each arc in the form of time series to see the evolution of the significant wave height, period and direction of propagation.

8. Challenges of the technology

The major challenge of this technology is the choice of suitable sites for installation of equipment, HF radars are to be installed in an open place away from electromagnetic pollution and climatic hazards, the sites will have the means of telecommunication and a suitable power supply. The site must also be secure and easily accessible for maintenance. Furthermore, the use of data and their use in model validation require a mastery of this new technology and knowledge of its limits, to better interpret the HF radar information. For example, during the period 11 to 13 April 2016, the waves height measured by the Temara HF radar exceeded 10m with a maximum of over 16m on arcs 3 and 4 (15km and 20km), as shown in the following figure.

A search of the case showed that solar activity during this period was quite high, as shown in the diagram of the K index estimated by NOAA between 11 and 13 April 2016, in fact, the impact of this activity on the HF radio waves has long been known.

Another challenge facing the operation of HF radars is the change of physical and electromagnetic environment of the sites, indeed urban development and the installation of other antenna in the neighborhood of HF radars can affect the radar signal and attenuate the energy spectrum backscattered by the ocean. Unfortunately this is something that we cannot master.

We were actually in this situation at the Casablanca port site when the port authority decided to construct a new building to house the VTS which was damaged following a collision with a container ship. The following pictures show the environment of the antenna during the installation in November 2015, when the site was completely clear, and just a few months after.
The impact was immediately felt in the second order spectrum that measures the wave characteristics. We expect completion to decide on changing the location of the antennas.

9. Data Validation

Certainly the highlight of HF radars is the surface current measurement, several assessments were made, and many applications have been developed around the world, particularly in the field of search and rescue at sea and marine pollution monitoring.

For lack of in-situ observations data, we will be limited to the comparison of HF radar measurements with model analysis.

The significant wave height time series shows some correlation between the HF radar measurement and WW3 model analysis. The following curves show the scatterplot for significant wave height, wave period and wave direction.

![Time series of significant wave height measured by HF radar (blue) and WW3 analysis (red)](image)

![Scatterplot of HsRad vs HsWW3](image)

Mean Square Error (MSE) of Hs: 0.22m
Root Mean Square Error (RMSE): 0.47m
Mean Absolute Error (MAE): 0.35m

![Scatterplot of TsRad vs TsWW3](image)

Mean Square Error (MSE) of Ts: 3.86s
Root Mean Square Error (RMSE): 1.97s
Mean Absolute Error (MAE): 1.60s
The results show that there is a good correlation of significant wave height (0.84), on the other side, periods are generally overestimated and directions are underestimated.

10. Perspectives

For better use of HF radar measurements, more work must be done; we quote here some priority actions:
- Further validation by in-situ data measuring instruments available from our partners.
- Integration of operational models in DMN, including surface wind parameters and waves characteristics.
- HF radar network extension south to cover the energy port of Jorf Lasfar,
- Extension of the network to the Gibraltar Strait by installing two HF radars on Tanger Med and Cap Malabata and data exchange with Spain to cover the Strait.