Complex morphology and organisation of dunes in a giant dunes field

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Abstract

The most recent hydrographic surveys conducted by SHOM in the north and west of Brittany, at depths of 70 to 200m, delineated two very large dune fields, that until now, had been described only by a few old profiles. More than two thousands dunes were identified during surveys of 2011 and 2012. These one have been added to the GIS dedicated to banks and dunes of the French continental shelf. These surveys have highlighted the boundaries of these two dune fields, and the existence of fields of barchan, giant dunes and very large variations in the orientation of the dunes, characterizing the complexity of these environments. The dunes field of the Celtic Sea, cover a surface of 31 000 km^2. The main direction of the transit is to the south west, and most of the dunes are transverse and of some meters high. But when we look the morphology of dunes at the local scale, it appears morphologies that have been rarely described. After describing the Celtic dune fields, we establish a classification of dunes based on their shape, their dynamics and their environment in order to achieve a synthesis of the dunes of the Celtic Sea.

1. INTRODUCTION

During the bathymetric surveys achieved by the French Hydrographic Office (SHOM), submarine dunes were detected in the shallow water zone, at the end of the nineteenth century. We nevertheless had to wait until the late twentieth century, with the arrival of multibeam echo sounder and GPS, to have an accurate characterization of the morphology and location of these dunes. It has thus become possible over the past fifteen years to precisely quantify the speed of dunes and follow their morphological evolution over time. According sediments and hydrodynamics involved, these rates vary from a few meters to tens of meters per year. The study of the dunes is a young science, and knowledge of the movements of the dunes stay must await the results of surveys of different environments on recurring periods sufficiently significant. Synthesis of studies made by Wever (2004), gives the values of dunes displacements reported in the scientific literature. These studies are unfortunately limited to depths less than 40m and it must be necessary to take into account currents and regional characteristics of sediments. As Kocurek says during the precedent MARID « Boundary conditions makes each bedform field unique ». Studies on dunes of the French continental shelf were done at the beginning on some sandbanks environment and on some dune fields of estuaries or near the coast of Calais and Cherbourg (Berné et al 1989, 1993), Since 1988, SHOM has done hydrographic cruises devoted to the study of the dynamics of dunes of the North Sea and the English Channel. Since 2011, these surveys apply now to the Celtic Sea, and the region of dunes explored, will therefore from the border of Belgium to the continental slope of the Atlantic.

The objectives of our works are to answer to some questions about the time needed between hydrographic survey, the impact of these fields on benthic habitat mapping, on offshore renewable energy and on mine burial. In parallel we realised research on dunes (Le Bot, 2001; Ferret et al, 2010; Franzetti et al, 2013) and on numerical

modelling of dune dynamics (Idier, 2002; Idier et al, 2011). We develop a specific GIS on dunes which is the synthesis of knowledge from some decades of surveys (Garlan et al, 2008, Thibaud et al, 2012). This system is used to compare the knowledge of bedforms with charts, to modify the surveying strategy, to look at the historical movement of the dunes and to develop new cartographical products (Garlan, 2009). These works are done in the context of the second SHOM Dune projects (2013 to 2017) which concern research, GIS and products for the safety of navigation, sand mining, mine burial, wind farm, European marine strategy directive, marine protected areas, ...

2. DUNES SURVEYS

2.1. North Sea recurrent surveys

Recurrent hydrographical surveys in the French part of North Sea are done for the safety of navigation. Hydrographic Offices should ensure for sea transport a minimum depth of 26m. If the maximum height of a dune is 22 meters; areas with dunes and a maximum depth of 48m, thus present a potential risk. But we must take into account the impact of the water level, which is critical to the height of the dunes. In fact, the height of the dunes saturation is about 35% of the depth so, for a dune reaches a depth of 26m, it is a necessity that the bottom is of 40m. So, for safety of navigation, all areas containing dunes and whose depths are less than 48m are classified as risky; below 40m, they are classified as high risk. The surveys were done from 1988 to 2000 every 3 years on some specific zones. With a 3 weeks survey/year, a complete survey of the French part of the North Sea traffic separation channel was done from 2000 to 2012. We define a new protocol which consist of survey every 2 years a dozen of dunes all along the zone of navigation and study the movements of these dunes. These observations are sufficient to look at the normality of the dynamics of the dunes concerned by the safety of navigation and of the conformity of the reality with charts.

To define marine habitats, for mine hunting and to choose appropriated zones for marine cables or wind farm, the first need is to know if there is dune in the region and if so, do they move. If the delimitation of dunes and dune fields of North Sea are well known, it is not the case of the west of the English Channel and of the Celtic sea. For these regions the only documents which describe dunes are papers of Belderson et al (1971) and some works on small areas of the Celtic Sea for the research of petrol (SHOM and SNEAp, 1962), and research on Neogene stratigraphy (Reynaud et al., 1999).

2.2. West Channel and Celtic Sea Surveys

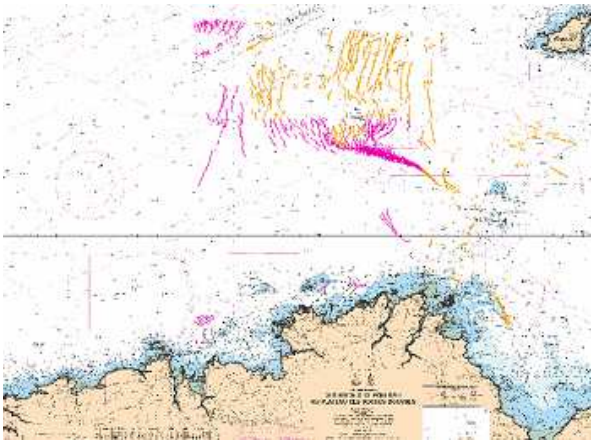

Figure 1. Fields of dunes of north Brittany defined by thirteen recent SHOM hydrographic cruises

From 2002 to 2007, thirteen hydrographic surveys were done in the north of Brittany in regions which had not been surveyed since more than fifty years. These MES surveys had been used to delineate the field of dunes and to characterize their properties.
In this area, tidal currents have a principal direction from WNW to ESE, with intensities of the bottom currents which go from 1 to 1.5 knots. The depth is from 70 to 120 m. 46% of the dunes are large ($10 < \lambda < 100$m, $0{,}75 < H < 5$m), 44% are very large dunes ($\lambda > 100$, $5\text{m} < H < 10$m), and 10% are dunes with heights between 10 and 22 meters.

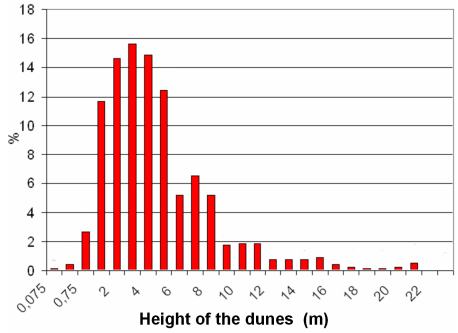

Figure 2. Height of dunes in the north Brittany in the area of 70 to 120 m depth

Studies on twenty parameters, measured on each of these dunes, allow regional comparisons using relationship between the height, the wavelength and sinuosity parameters. It remains to analyze the current meter measurements and sediment samplings which will continue to be performed during planned campaigns in 2013 and 2014.

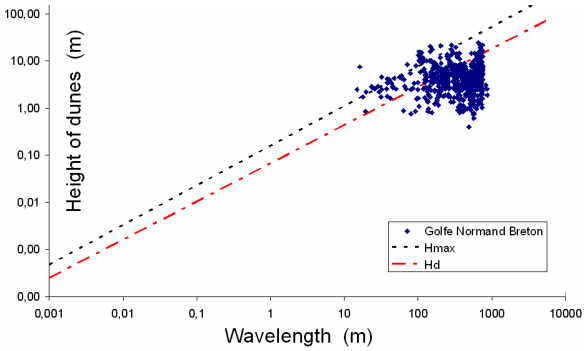

Figure 3. Comparison of Height/wavelength relation with Flemming's results

The characteristics of these dunes change with depth in this region. Height of dunes increases with bathymetry, and the higher dunes are on the edge of the central depression of the English Channel. It is why it is important to go deeper and look at the Celtic Sea with it's depths from 70 to 200m.

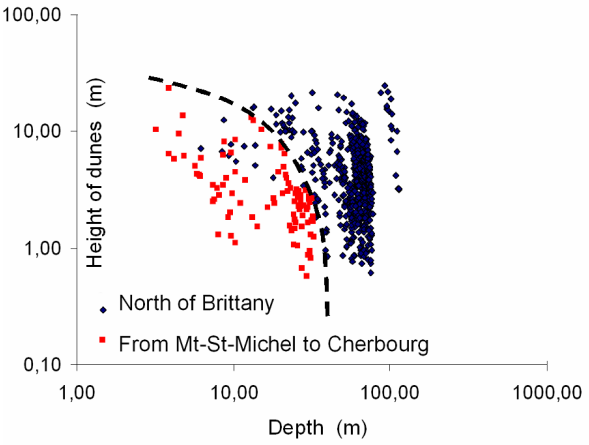

Figure 4. Evolution of the height of dunes with depth in the north of Brittany and between the English islands and Normandy

The study of directions of movements of the dunes shows three regions with a clear direction:

- in the north-east, to the English island
- in the south-east, to the Bay of Saint-Brieuc,
- in the south-west, to the extern part of the Channel.

The fourth part, located in the north-west shows displacement in very different directions and require additional surveys to clarify this system.

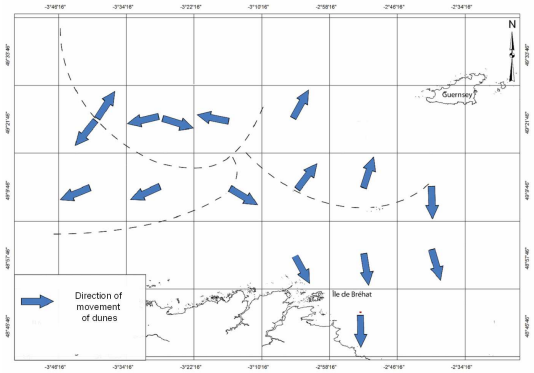

Figure 5. Variation of direction of movement of dunes in the north of Brittany.

3. SOME EXAMPLES OF DUNE FIELDS OF THE CELTIC SEA

The two sedimentological cruises of 2011 and 2012 with the Beautemps Beaupré and the Pourquoi Pas? were realized to define the limits of the dune fields, and to characterized the principal properties of the dunes and of their environment. The west limit of dunes, on the top of the continental slope, and the limit with the Bay of Biscay, where dunes are limited to coastal bays and estuaries, are not completely defined, but the French fields of dunes of Iroise Sea, Celtic Sea and west part of the English Channel are now globally delimited (Figure6).

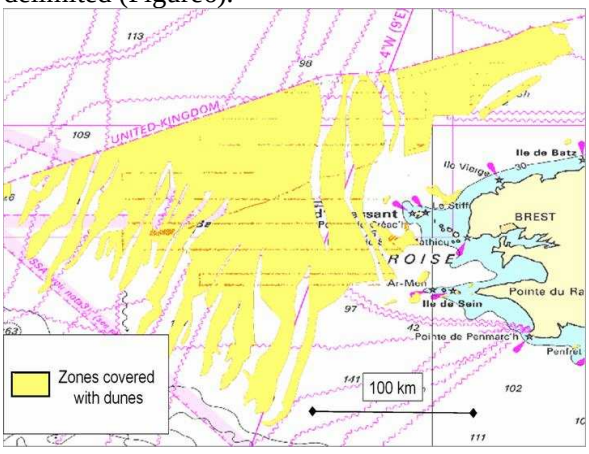

Figure 6. Location of the dunes of the Celtic Sea and the west part of the English Channel

Most of the analysis of the data from these surveys must be done and two new surveys are in preparation. Results on the Four Banks are presented by Franzetti et al (2013), for the rest of our observations, the following chapters show some of the first observations.

3.1. Ouessant sandbank and Ouessant Dunes field

The Ouessant sandbank (Figure 7) is the brother of the Four sandbank, they are at the two extremities of the Fromveur which is a channel with strong bottom currents up to 2.5m/s. In the north, a kind of corridor of dunes, go in the direction of the sandbank. Along this bank, the dunes turning around in an anticlockwise direction with speeds of the order of 20m/an (measured on two surveys spaced to 11 months)

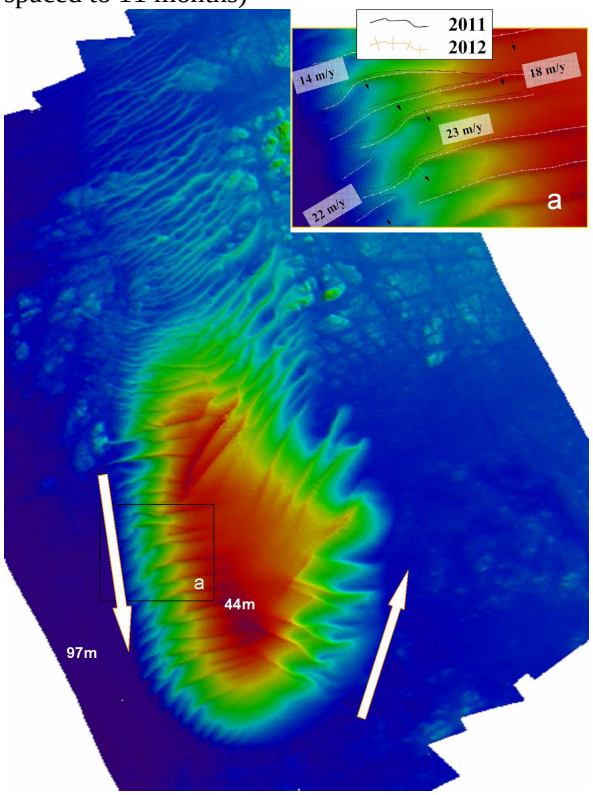

Figure 7. Bank of Ouessant and dunes with 20m/y dynamics

At some nautical miles in the South west of this sandbank, a large field of dunes presents the particularity to be the zone of life for a colony of dolphin. New observations must be done on this particular field.

3.2. Portsall Dunes

As an example of the poor knowledge of dunes of these regions, the Portsall field of dunes is at 50 kilometers to the French coast and it has been discovered during the PROTEVS-Dunes survey of October 2012. At a depth of 90 to 100 meters, more than 300 dunes associated to a low sandbank. 7.7 % of these dunes are higher than 10 meters and some of these higher dunes are barchans (figure 8).

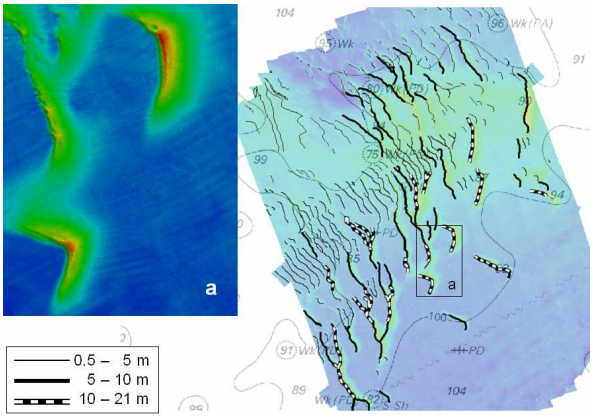

Figure 8. Portsall sandbank and it's very large dunes and barchans

In deserts, barchans are the dunes with the fastest speeds. Portsall sadbanks with barchans and longitudinal dunes, which is near the coast, is a particularly interesting environment to study the dynamics of dunes at depths of 100 meters.

3.3. Celtic Giant Dunes

The new surveys show that all the Celtic Sea shows dunes. These dunes are associated with great sandbanks which had been described since many years (Belderson et al 1962, Reynaud et al, 1999). Before MES, at these depth of 100 to 200 meters, the bathymetric systems didn't had a sufficient accuracy for the mapping of dunes. In 2011 a profile had showed a series of giant dunes with height from 25 to 29 meters. Eleven months after a survey in this area shows that these dunes did not seem to move, and that these symetrical structures are not numerous. These dunes are similar to those described by Van Landeghem (2009) and a study about morphology and regional currents is under process (Figure 9).

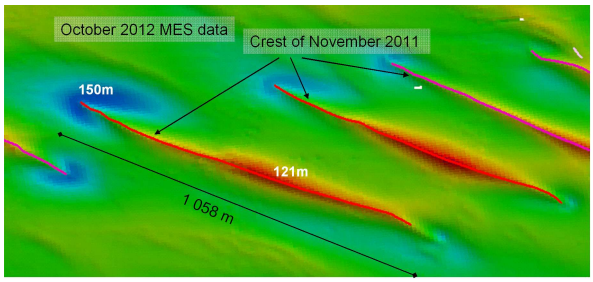

Figure 9. Comparison of 2011(lines) and 2012 (DEM) bathymetry of trochoidal dunes of the Celtic sea.

4. CONCLUSIONS

Dunes observed during surveys conducted in 2011 and 2012 shows different morphologies. The dynamics of these dunes appears possible even at depths of 200m. Many criteria shows that these movements exist locally, it is necessary to continue the measures to support these observations. Surveys on the dunes of the Celtic Sea and Western Channel will continue in 2013 and 2014, including new surveys of MES acoustic imagery and bathymetry, seismic profiles, measurements of currents, turbidity and recurrent photographs.

5. ACKNOWLEDGMENT

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