High resolution coastal DEM of the Dover Strait: managing dynamic bedforms

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ABSTRACT: The Dover Strait has a high diversity of dynamic seabed sedimentary features. In this paper we present recent work undertaken to compile a high resolution 20 m grid spacing bathymetric digital elevation model extending along British and French coastlines. At this resolution, it is important to take particular precautions on the precision of the datasets (both vertically and horizontally). More importantly, in a highly dynamic environment, we had to take care of the temporal aspect of the dataset and their potential overlap to ensure the best continuity of the bedforms. In order to get the best coverage, a variety of dataset from different data providers, from different surveying systems, referenced at different vertical and horizontal datums, had to be harmonized prior to be interpolated. This DEM is intended to be used by hydrodynamic modeler in the context of the assessment of tsunami wave propagation.

1. INTRODUCTION

Bathymetric DEMs are essential input elements for numerous applications in geosciences, research and civil engineering, hydrodynamic modeling, planning and resource exploitation, mapping and positioning, data validation, military operational works... Specifically, building accurate and up-to-date coastal DEMs is a prerequisite for accurate modeling and forecasting of hydrodynamic processes at local scale in the context of marine flooding, originating from tsunamis, storm surges or waves (Eakins and Taylor, 2010). They are computed from a synthesis of bathymetric information sampled in an appropriate manner that conveniently represents underwater bedforms. However, because of practical considerations, this synthesis can only be composed of various datasets collected through times by various sounders, with various precision and density. A detailed work is needed to select the appropriate sources in order to sample the seafloor accurately, with respect to its temporal component. This is especially true in complex sedimentary environments, where seabed experienced migration and geometry changes.

This study presents the main challenges encountered during the production of the high resolution DEM of the Dover Strait, where surveys of subaqueous dunes and sandbanks were collected by the French hydrographic office (SHOM) for the last decades.

2. WORK CONTEXT

The present work is undertaken within the framework of the TANDEM project (2014-2017), dedicated to the appraisal of coastal effects of tsunami waves on civil nuclear facilities along the French coastlines (Owen and Maslin, 2014). A special focus is brought on the Atlantic and The English Channel coasts where French civil nuclear facilities have been operating since about 30 years (Hébert *et al.*, 2014). For this project, seamless integrated topographic and bathymetric high resolution (20 m) coastal DEMs (Maspataud *et al.*, 2015) are generated for specific coast configuration (embayment, gulf, estuary, harbor, island…). These sites are used to simulate expected wave height at regional and local scale on the French coasts, for a set of defined Tsunami generation scenario, such as earthquake (Roger and Gunnell, 2012 ; Garcia-Moreno *et al*., 2015) or landslide triggering.

3. PRESENT KNOWLEDGE ON STUDY AREA

The Dover Strait area, located between the North Sea and the English Channel, is submitted to semi-diurnal macrotidal regime, with tidal currents with strong alternative character enhanced by the strait configuration. Soft sands along with the tidal regime are responsible for the local complexity of the study composed of superimposed bedforms.

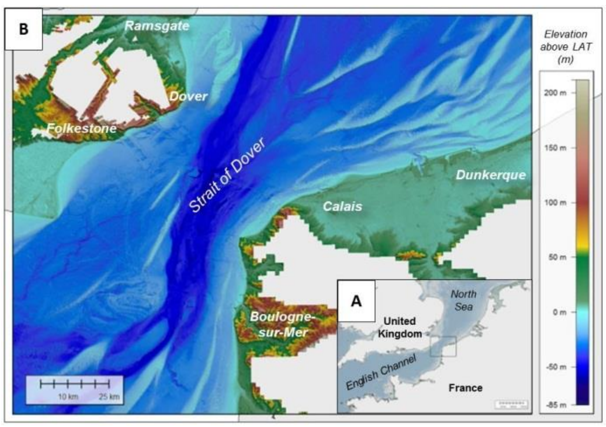

Figure 1. Location of (A) the studied area and (B) the coastal topo-bathymetric DEM prototype on the Dover Strait.

Active sand dunes as part of giant dune fields, or as associative bedforms usually well developed on the flanks of sandbanks, are particularly well organised and dynamic. In the French side, SHOM performs regular surveys to detect the exact position of dune crests, especially in the Dover Strait (Garlan *et al*., 2007, 2008). Previous studies that were based on an optimum recurrence of re-surveying (annual, bi-annual or decadal) identified: 1) the highly sensitive sectors, 2) the direction in which the dunes preferentially move (either NE or SW in this area), and 3) the mean rates of displacement, or those of particular structures (Le Bot *et al*., 2000 ; Garlan *et al.*, 2008).

In this area there is a general tendancy of dune migration imitating the tidal scheme: SE isolated dunes commonly undergo the direct influence of the dominant ebb with SW migrations at the rate of 1 to 12 m/yr, while NW dunes migrate slowly in the opposite direction (to the NE) at an average rate of 3 m/yr (Le Bot *et al.*, 2000).

4. KEY POINTS IN COASTAL DEM DEVELOPMENT

4.1. Strategy and DEM development process

Challenges in coastal DEMs development deal with good practices throughout model development that can help minimizing uncertainties (Eakins and Grothe, 2014). In details, the main tasks to face were (1) making sure of the best detailed data coverage throughout a detailed inventory of available data for the area, (2) ensuring the vertical and horizontal precision of the data by getting access to corresponding metadata or reports and processing (punctual editing, tide correction,…) them if needed, (3) minimizing overlap between redundant dataset collected at different periods in time, (4) horizontal and vertical datum conversions, on the basis (national and/or local) datum conversion grids based on known measurements (Maspataud *et al.*, 2015) and (5) interpolating the entire dataset in order to fill gaps and get a continuous and regular surface. Locally, gaps between marine and terrestrial data have also required the introduction of new methods and tools to solve interpolation. Through these activities the goal was to improve the production line and to enhance tools and procedures used for the improvement of processing, validation and qualification algorithms of bathymetric data and merging of bathymetric data with a special focus on dataset collected in dynamic areas.

4.2. Data assessment

Data collection work required a substantial and precise effort to build a consistent dataset prior to DEM interpolation. This is particularly true as scattered elevation data with variable density, from multiple sources and from many different types (paper fieldsheets to be digitized, single beam echo sounder, multibeam sonar, airborne laser data…) were gathered (Figure 2).

In addition to available surveys from the French bathymetric database in this area (from SHOM and

French harbour authorities), external data were also gathered: from the United Kingdom Hydrographic Office (UKHO) in the British waters and the Belgium hydrographic office (*Vlaamse Hydrografie*) in French waters. SHOM digitized Belgian paper fieldsheets (single beam surveys) available in French waters. Topographic data for the French, British and Belgium coastal parts of the DEM were made available by national topographic offices or international databases.

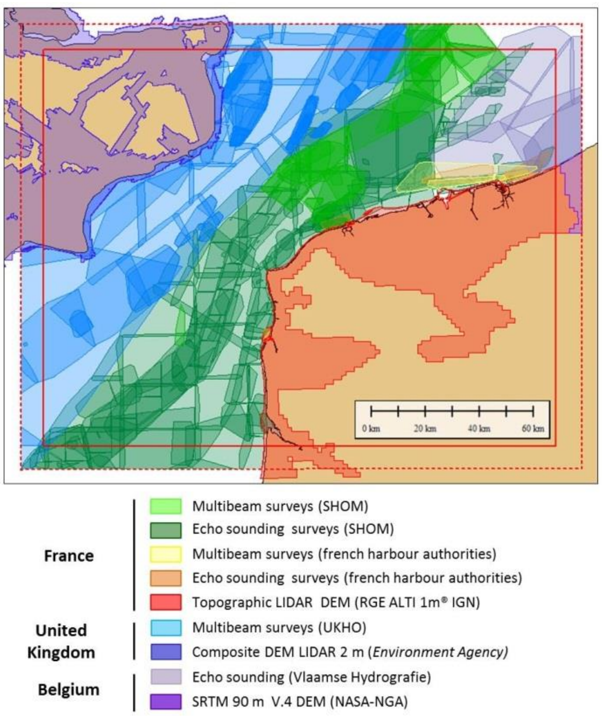

Figure 2. Source, type and coverage of selected datasets, available for each country, on the extend of DEM. Red dash and solid lines respectively represent the extracted data area and the final DEM coverage.

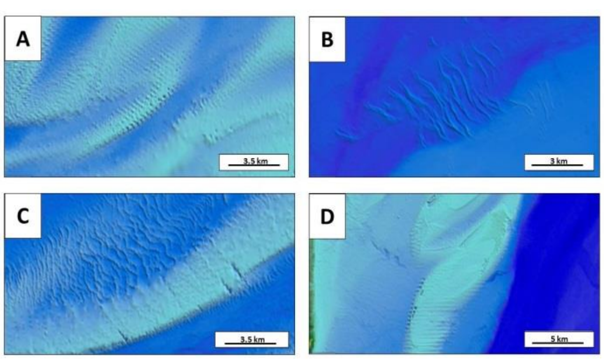

Figure 3. Examples of morphological artefacts of sedimentary bedforms encountered during bathymetric data assessment in the Dover Strait area.

Consequently, datasets were first assessed internally for both quality and accuracy and then externally with other to ensure consistency and gradual topographic/bathymetric transitioning along limits of the datasets. On the overall of the gathered datasets, 67.4% were selected among the approximately 651 available surveys, i.e. 439 selected surveys including 38% carried out from multibeam sensors.

4.3. Managing with complex morphology and bedforms mobility

Sediment dynamics can locally induce artifacts on the resulting DEM or poor temporal accuracy of the representation of these bedforms. In some cases, it leads to unproper shifting of the crests on dune fields (Figure 3 B ; Figure 4 A) or of the overall shape of sandbanks (Figure 3 A, C, D).

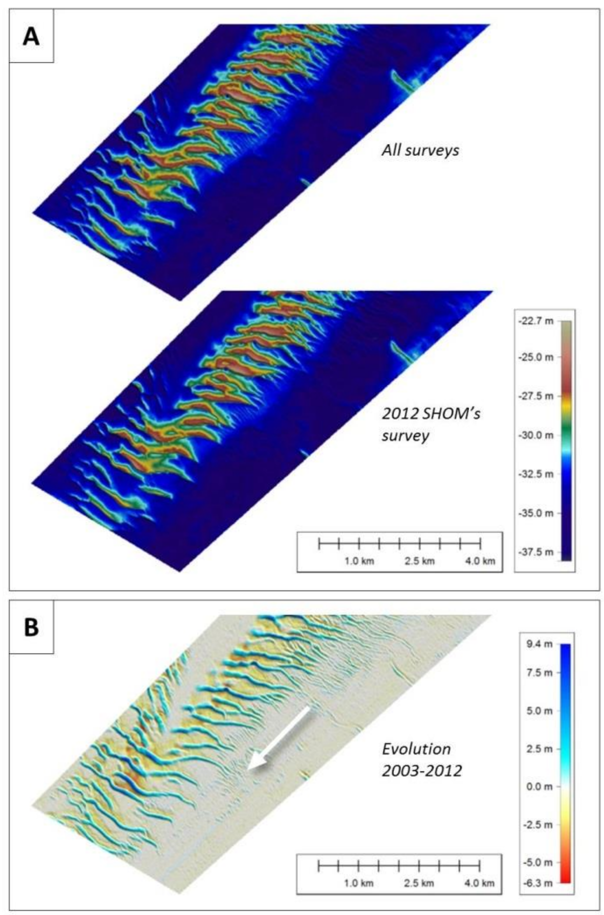

Figure 4. (A) DEM interpolation without and with specific selection between available bathymetric surveys, and (B) difference between 2003 and 2012 SHOM's bathymetric surveys in the North Sea.

This complex sedimentary environment led us to carefully consider the moving rates of sand dunes in this area and estimate whether these values are significant with respect to the expected resolution of the final DTM. Locally, differences with previous bathymetric surveys, on sandbanks and dune fields, are sometimes larger than the grid spacing. In the case of the Dover Strait, considerations on the local sedimentology have been taken into account from:

- decadal survey of specific dunes reveals that they can move from about 50 to 100 m to the SW (or NE elsewhere ; Garlan *et al.*, 2008) as experienced in Figure 4B ;
- dunes movements could reach several meters to several dozen meters per year, up to 17 to 23 m per year, according to their exposure to main currents ;
- isolated dunes in southern North Sea could move 1.5 times faster than dune grouped in dune fields (Garlan *et al.*, 2008).

5. CONCLUSIONS

The navigation channel of the North Sea is unique in hydrographic surveys conducted by SHOM because it is the only environment where surveys are repeatedly carried out, excepted in harbor jurisdiction areas for the French coasts. The data therein acquired are rich in information on the dynamics of sedimentary bedforms but required, in our high resolution DTM production line, a large and attentive work in deconflicting numbers of surveys (varied extent, age and type) for a coherent and realistic modeling of sedimentary seabed.

In particular, the heterogeneous ages of the input data stress the importance of taking into account the temporal variability of bathymetric features, and their migration rates, especially in the most active areas.

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