MAPPING PAST AND FUTURE SHIPPING NOISE IN EUROPEAN SEAS

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1 Introduction

As the demand for sea transport of goods and people steadily increases, there is an essential need for the development of a dependable marine shipping underwater sound model to assess the effect on ocean noise of operational and technological changes aimed at mitigating the environmental impact of the sector.

The NAVISON (Navis Sonus) project, conducted with the support of the European Maritime Safety Agency and scheduled to run from January 2022 to June 2024, has the objective to develop and apply a specialised parametric vessel source model to produce shipping sound maps in European seas for past, present, and potential future conditions over a time span from 2016 to 2050. In the intended project scope, the new source model is combined with historical ship tracking data from the automated identification system (AIS), or projected shipping densities and mitigation scenarios, to calculate spatial ship noise emissions data for input to a sound mapping tool.

Target project outputs are map layers of sound pressure level and sound energy according to vessel type, season, region, year, traffic volume, and operational and technical measures; from these layers, maps can be generated for user-specified scenarios. Results are presented in two decidecade frequency bands (centred at 63 Hz and 125 Hz) selected for assessing Good Environmental Status in the context of the European Union's Marine Strategy Framework Directive (MSFD) descriptor 11.

2 Approach

2.1 Vessel source model

The first planned task of the NAVISON project was the development of a new semi-empirical source level model for ships, which would be used in the context of the study to estimate the underwater sound produced by shipping in European waters. This task was an essential foundation for the subsequent stages of the project because the accurate estimation of the source levels of ships travelling along their paths is the main requirement for generating sound maps.

The underwater radiated noise (URN) of a ship is mainly driven by its design and by its operational conditions. Most source models only use ship particulars available from AIS data such as ship type and ship length, and in some cases AIS-reported ship speed.

The new model [1], which builds upon and improves existing ones, aims to model separately the main noise sources of the ship using parameters such as propeller design, engine type and mountings, and wake field quality. In addition, operational conditions such as propeller speed and engine power are considered. Some of these parameters can be obtained from commercially available ship databases; others were derived from internal repositories available to the project partners. The model considers the separate contributions from cavitation noise of the propeller and machinery noise of the main and auxiliary engines and is suitable for modelling future scenarios involving various noise and greenhouse gas mitigation strategies, such as speed reduction, propeller design, engine selection, and energy consumption.

As part of the model development, validation was performed using measured source level data from the Enhancing Cetacean Habitat and Observation (ECHO) Program as well as other cases available. Additionally, a comparison was made with existing point source models to determine both the overall agreement between the data sets and the respective uncertainty levels.

2.2 Sound propagation model

The objective of generating maps of shipping noise in European seas required the selection and implementation of a sound propagation model and its parametrisation for the five regions in which European waters were divided for the project: Baltic Sea, Black Sea, Mediterranean Sea, North Sea, and the Northeast Atlantic Ocean. The modelling tool that was developed uses the parabolic-equation method, which was deemed most suitable for this project as it is well-suited for low-frequency sound propagation in range-dependent environments The implementation was built on the widely used RAM code enhanced to account for elasticity in the seabed, and further adapted to make it more suitable for very long-range propagation by accounting for earth curvature and including sound attenuation in the medium, which is typically neglected for low-frequency modelling over shorter distances.

Due to the vast area requirements of the project, the modelling environments were generated automatically from ocean-scale databases of bathymetric, oceanographic, and sediment properties. Methods were developed to interrogate the environmental databases and process the results into input files suitable for the model. The efficiency of the model was also optimised to achieve acceptably short run

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durations over the large modelling regions, by investigating the effect on accuracy and execution speed of varying the depth and range resolution and the number of terms used in the solution of the parabolic equation.

2.3 Integrated shipping URN model

The last development step of the project involved producing an integrated model combining the source level and sound propagation models with vessel traffic data to produce map layers of the URN. The model that was developed under this task permits calculating annual or quarterly URN maps in each region for distinct combinations of ship type, year, and season using vessel density data calculated from historical Automatic Identification System (AIS) tracks. URN calculations are implemented for the two MSFD frequency bands. Georeferenced sound maps are produced from the outputs using dedicated post-processing tools implemented in a Geographic Information System (GIS) framework.

For the final project goal of generating forecast maps of URN under various assumptions, the integrated model was extended to enable it to produce sound map layers corresponding to a diverse range of future regulatory and compliance forecast scenarios. Forecast sound pressure levels are obtained by manipulation of a baseline nowcast dataset to account for the effects of expected future changes in ship traffic volume, greenhouse gas emissions regulations, and the possible application of URN mitigation measures. In further studies, the effect of climate change affecting propagation conditions could also be considered.

3 Results

3.1 Ship traffic URN hindcasting

Having developed the modelling framework as described, the tools were applied to produce sound map layers of past and present underwater sound from shipping, in the five regions of European waters. The task was focused on generating hindcast estimations of underwater sound, based on historical AIS shipping data over the eight-year period 2016 to 2023 inclusive, at quarterly intervals. The output products from this task are georeferenced GIS map layers for selected combinations of parameters (period, region, ship type, and frequency band), which can be manipulated and combined into composite results – for example, aggregate sound level maps for multiple classes of vessels – using Python scripts run directly in the Quantum GIS (QGIS) software package. In total, 2000 sound map layers were produced for the 8 years, 5 regions, 5 vessel classes, 5 quarterly plus annual averages, and 2 frequencies considered in the study. Figure 1 shows as example a quarterly average sound level map computed and displayed in QGIS for the compositing of the five European seas and aggregation of five vessel classes to give a pan-continental, total ship traffic URN estimate for Q1 2016 at 63Hz.

In addition to producing shipping sound level maps, the modelling framework developed in the NAVISON project has been used to generate estimates of the vessel sound energy density in a region. This robust metric [2], which is

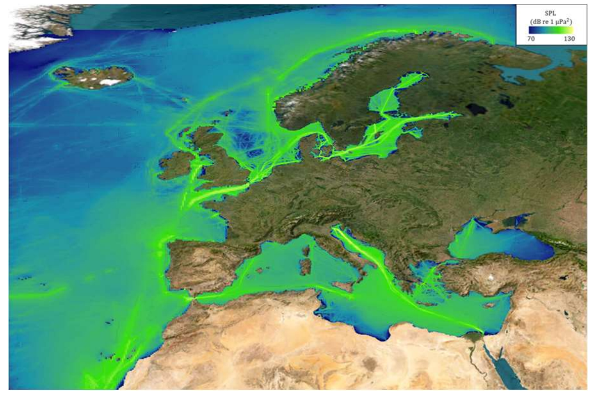

Figure 1: Hindcast map of the total ship traffic URN in European seas for Q1 2016 in the 63Hz decidecade band.

independent of the spatial averaging parameters that may differ from region to region, can be used for a variety of purposes such as tracking the time-trend of shipping sound (thus evidencing effects of factors like the COVID-19 pandemic), comparing the contributions of individual vessel categories, or quantifying the effect of mitigation measures.

3.2 Ship traffic URN forecasting (in progress)

A final set of forecast maps is now being completed for shipping URN for 2030, 2040 and 2050 based on the approach of applying adjustments to a set of baseline sound map layers (from the estimates for 2022), according to anticipated changes in vessel noise emissions and traffic volume. Each forecast scenario involves different adoption rates for mitigation measures that include speed reductions, more efficient and/or quieter propellers, optimised hull form, air injection systems, and hull and propeller cleaning.

4 Conclusion

The NAVISON project leaves as its product, in addition to a rich dataset of hindcast and forecast ship traffic URN maps for the European seas, a substantially progressed numerical framework for estimating shipping sound at basin scale. This tool can be readily applied to other regions, enabling more informed environmental planning.

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