

## COUPLING 3D ACOUSTIC PROPAGATION TO OPERATIONAL OCEAN CIRCULATION MODELS

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**Abstract:** *An operational 3D underwater acoustic model is currently being implemented at the Portuguese Navy to estimate real-time ocean ambient noise levels. To achieve this goal, accurate noise source positioning and ocean structure dynamics is required. While noise source information can be obtained from real time AIS data, 3D ocean structure information cannot be obtained only from observations. As such, the present paper aims to be a preliminary study of the use of 3D numerical ocean circulation model, to provide the ocean structure required for operational underwater acoustic modelling.*

*The HYCOM ocean circulation model allows for a hybrid vertical discretization of the ocean structure, enabling high resolution surface Z-levels while maintaining a good discretization of the deep ocean water masses through isopycnal layers. Operational HYCOM outputs are validated and evaluated as the source for the ocean profile required for acoustic modelling.*

**Keywords:** *Ocean modelling, ocean-acoustic coupling, Mixed Layer Depth, numerical noise filtering.*

## 1. INTRODUCTION

The Maritime GEOMETOC Centre (CMETOC) of the Portuguese Navy is developing the SUBECO project, which, amongst others, aims the implementation of an operational underwater ambient noise model for the seas surrounding Western Iberia. AIS data will provide the noise source information while the environmental conditions will be obtained through a 3D operational ocean model.

The sound velocity in the ocean can be calculated from temperature, salinity and hydrostatic pressure. The propagation of sound in the ocean is mainly determined by the shape of the vertical sound velocity profile rather than the absolute values of sound velocity along the water column [1].

While the entire vertical ocean profile is important for accurate calculation of sound propagation, most of the noise resultant from shipping will be restricted in a surface duct. Sound travelling along a duct is prevented from spreading in depth and becomes confined by oceanographic parameters, the ocean surface and the sonic layer depth (SLD). Between these limits the effect of the increasing hydrostatic pressure is greater than the effect of the decreasing temperature and a positive sound velocity gradient exists downwards, with a maximum occurring at the SLD [2].

The SLD is usually placed near the mixed layer depth (MLD), with both often coinciding [3]. The MLD is hard to be precisely defined and as such an approximation is often derived through various methods. Even if many of these methods use temperature differences or gradients it is preferable to use density as this determines the stability of the water column and hence the degree of mixing [4].

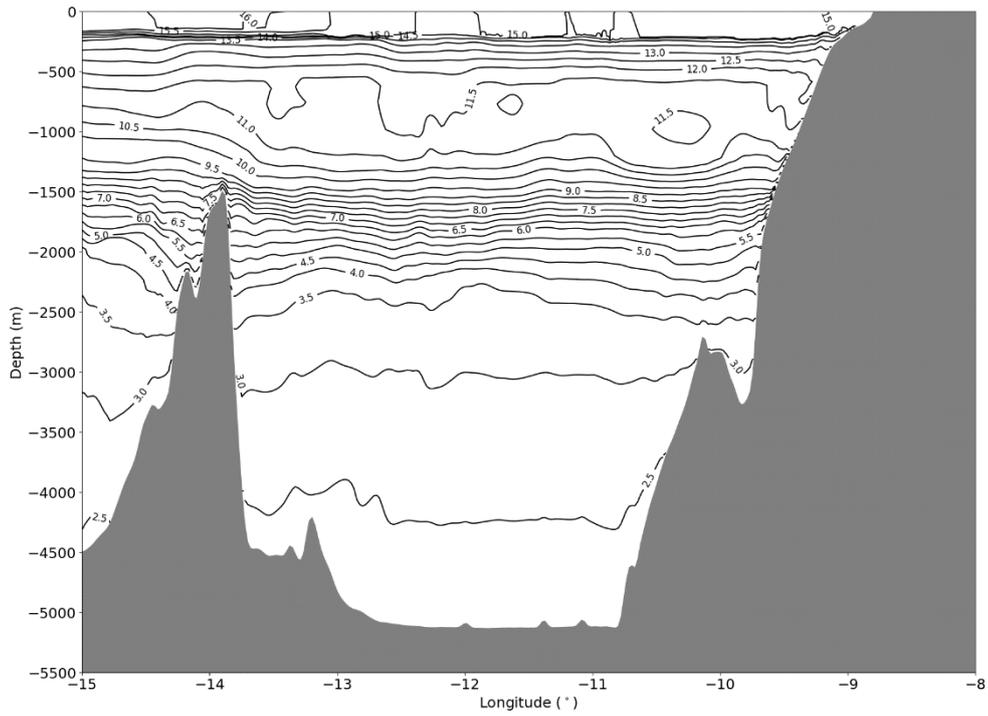
## 2. OCEAN CIRCULATION MODEL

The Hybrid Coordinate Ocean Model (HYCOM) was developed to fulfil the need for an ocean model that allows a variable vertical coordinate scheme. The main distinguishing feature is the possibility to apply any combination of isopycnal vertical coordinates in deep stratified waters, high resolution Z-coordinates in the upper ocean and terrain-following sigma coordinates in shallow waters [5].

CMETOC runs the HYCOM model operationally for the Western Iberian Peninsula. The current configuration consists of 32 hybrid layers and uses ECMWF's model for atmospheric forcing and MERCATOR for boundary conditions.

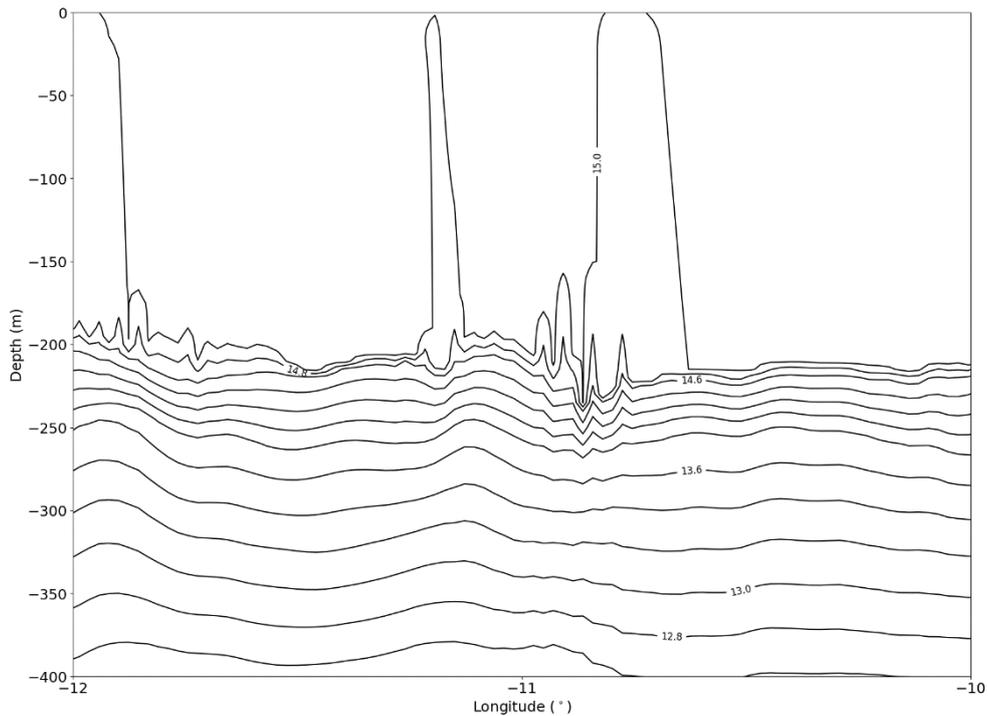
## 3. RESULTS

An ocean temperature section along the 37.5°N parallel, obtained by numerical modelling is represented in Fig. 1. As expected for a winter season, there is a non-stratified upper layer (MLD) followed by a temperature decrease around 200m depth, representing the first permanent thermocline. Around 1000m depth, warmer water masses are found along the west-Iberia margin, corresponding to Mediterranean Outflow veins flowing poleward [6]. Further down another increase in temperature gradient is observed, evidence of other permanent thermoclines, and finally, from approximately 2000m depth onwards, there is little change in the temperature structure, typical for deep waters. All the main structures that influence the acoustic propagation can be observed from the temperature profiles.



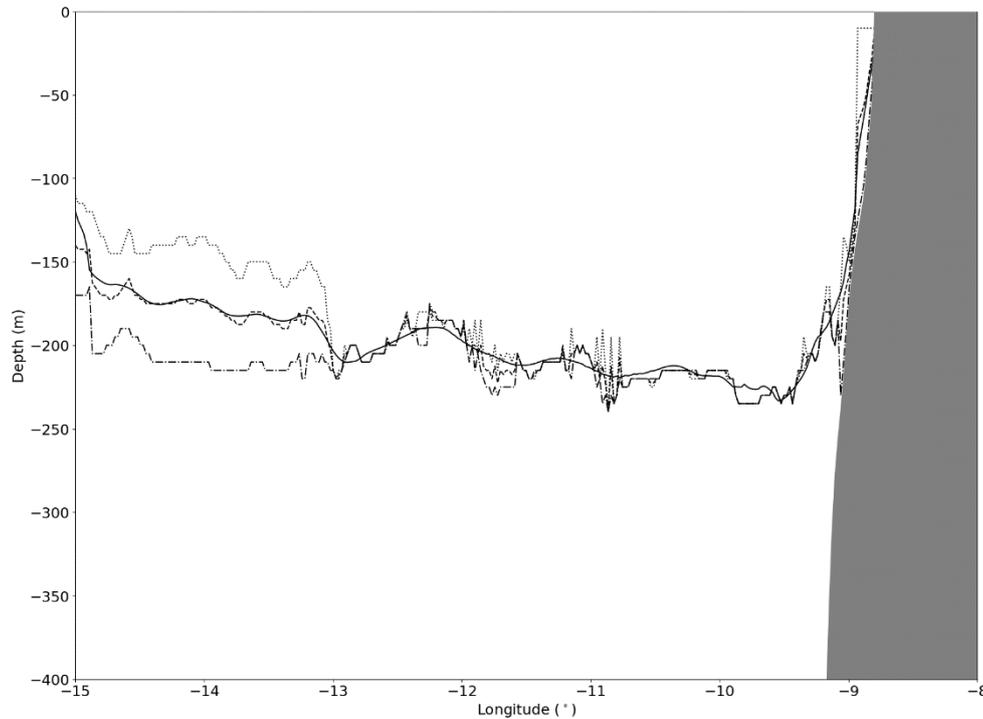
*Fig. 1: HYCOM temperature output for 37.5°N.*

Higher frequency variation seems to be present near the upper layers of the ocean and a detailed look (Fig. 2) shows the occurrence of numerical noise above the mixed layer depth, as can be observed near 12°W and 11°W. Since sound velocity is very sensitive to temperature gradients [2], where even small changes of sound velocity can have significant impact on its propagation [1], this numerical noise is expected to highly impact the underwater ambient noise model solution.



*Fig. 2: Upper layers of HYCOM temperature output.*

In Fig. 3 MLD is calculated by various methods. While differences are expected from each method, we can notice that all of them show solutions contaminated by numerical noise. The fluctuations in the derived MLD and, by approximation, in the SLD will have significant impact in the sound propagation solution. To demonstrate the adequacy of frequency domain filtering, a Wiener filter was applied to the mixed method MLD data. The Wiener filter was selected for its relative simplicity and ease of implementation [7]. The filtered data set is also represented in Fig. 3, showing a great improvement in noise reducing along this interface.



*Fig. 3: MLD profiles calculated with the HYCOM output. The dotted line is MLD calculated via temperature difference, the dot-dash line is the MLD calculated via density gradient, the dashed line is a mixed MLD calculation via temperature difference and density gradient and the solid line is the mixed MLD calculation with a Wiener filter.*

#### 4. CONCLUSION

An operational numerical ocean circulation model can be a valid source of environmental information for an underwater acoustic propagation model. The preliminary results presented in the current study however suggest that numerical noise in ocean model's forecasts can significantly impact the underwater sound propagation solution, leading to inaccurate results.

Frequency domain filtering can mitigate the numerical noise introduced by the ocean circulation model. An in-depth study could lead to the establishment of an adequate filtering technique to be implemented with the operational coupling of an ocean circulation model and an acoustic propagation model.

#### 5. ACKNOWLEDGEMENTS

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