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COMPARISON OF MEASURED AND PREDICTED UNDERWATER ACOUSTIC PROPAGATION LOSS

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1. INTRODUCTION

Acoustic propagation loss measurements were made over a 400 km track in the Norwegian Sea (figure 1). Oceanographic measurements were also made within 48 hours of the acoustic experiment, whilst sometime later, geoacoustic measurements were taken along the same track. This combination of measured propagation loss and the near coincident environmental data, provides an ideal basis for accessing the performance of acoustic predictions from appropriate model(s).

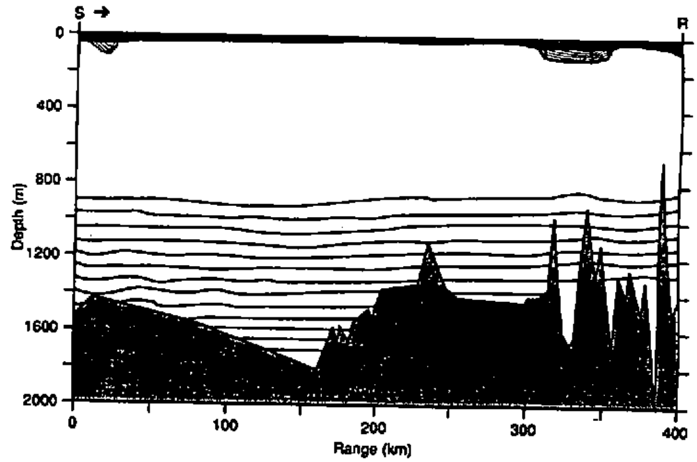

Figure 1. Sound speed structure and bathymetry over the full 400 km acoustic track, S and R indicate relative positions of source (SUS charges) and vertical receiving array.

The normal mode model SUPERSNAP [1] was chosen to study propagation at low frequencies. Due to the experimental configuration, it was necessary to perform a number of predictive acoustic propagation loss runs over the full 400 km track. Acoustic propagation loss models assume that the source would remain stationary and that the receiver progresses in range. This was not true of the open ocean experiment, in which sound sources were deployed with decreasing range to the receiver.

Further to the model/measured acoustic propagation loss comparisons, it was possible to demonstrate the effect of substituting measured sea-bed parameters to those obtained from a data base as input parameters to the propagation loss model. One database provided information of the bathymetry along the track, whilst a second provided the geoacoustic properties of the sea-bed.

2. THE EXPERIMENT

Broadband acoustic sources (SUS charges) were deployed from an aircraft, with three detonation depths, nominally 18, 90 and 457 metres. The acoustic signal was received by a stationary platform, with hydrophones deployed to depths of 10, 20, 90, 246 and 453 metres. The broadband acoustic signal was processed and data was finally presented at a number of frequencies. For this study, the frequency 160 Hz was used.

Oceanographic data along the track were obtained from 22 Conductivity Temperature Depth (CTD) stations, taken within 48 hours of the acoustic run. Coincident temperature profile measurements were obtained by the aircraft using Air deployed eXpendable BathyThermograghs (AXBT's). The data from these probes did not provide as much detail in range or depth as the CTD data, and hence were not used, but did reveal some limited variation in the temperature profile over the 48 hour CTD measurement phase.

The temperature and salinity data from the CTD stations was used to calculate the sound speed profiles [2] along the track. Bathymetry data was measured directly from the ship's echosounder. Geoacoustic parameters were obtained from subsequent measurements made by the Institute of Oceanographic Sciences (IOS), for DRA. All these data were then processed to provide input files to run the acoustic model.

3. ACOUSTIC MODEL

Acoustic Model
Full propagation loss data was available for the frequency 160 Hz. As relatively low frequency propagation was being investigated, the normal mode model SUPERSNAP was employed for acoustic predictions. This model is not generally used in such deep water environments. The variable sea-bed bathymetry would also provide a good demonstration of the validity of the adiabatic approximation [3], which allows the normal mode model to be extended into range dependent environments.

Inputs to SUPERSNAP allows the ocean environment to be described as a series of range independent sections. Each section can have three layers; water, sediment and a basement. The sound speed profile in the water column can contain up to 20 depth-sound speed pairs. In order to describe the environment of the track as accurately as possible, half of these points were concentrated in the upper part of the water column, where the variability was greatest. The size of each range independent section would also affect the predicted propagation loss, and tests were carried out with decreasing ranges until the propagation loss results converged. Regular sections of 10 km were interpolated from the original data and used in the final input files for SUPERSNAP.

Prior to the main comparison, several SUPERSNAP runs were performed to determine the least depth of sediment that would be needed to obtain accurate results. It has been suggested elsewhere [4] with a deep sediment layer, refracted returns within the layer, and reflected returns from the sediment-basement interface will be attenuated to such a level that results in minimal contribution to the acoustic field in the water column. Both sediment and sea surface roughness were assumed to be flat. At 160 Hz it would not be expected that the sea surface roughness would produce a significant additional loss [5]. Shear wave parameters typical for oceanic basements were included in the basement layer [6].

Reconstruction Of Measured Acoustic Data
As with other acoustic propagation loss models, SUPERSNAP considers the source to be stationary with the receiver progressing away from the source. In the experiment, the receiver was stationary and the sound sources (SUS charges), were moved towards the receiver.

If the environment had been range independent, a single model run would have been sufficient. However, in this case, the environment was range dependent. For this study, 20 individual acoustic model runs were carried out. Each run used a progressively shorter section of the full environment appropriate to the particular SUS charge/receiver range. The value of propagation loss calculated at the end of each range was then used to construct a propagation loss curve for the complete environment. In this study the decreasing ranges were controlled by the position of the CTD stations.

Sea-bed Data
In addition to the comparison of the measured and predicted propagation loss data, it was possible to study the effectiveness of two standard sea-bed databases. The measured bathymetry and geoacoustic data was replaced by data from archival sources. The predictions obtained from SUPERSNAP using this sea-bed environment were compared to the original predictions, where measured sea-bed parameters were utilised in the input files.

4. RESULTS

Measured Environmental Inputs
For the frequency of 160 Hz, results are available for all receiver depths. Acoustic predictions were calculated over the full 400 km range. Measured propagation loss was available for a number of ranges, depending upon receiver depth; 160 km for the 10 metre receiver; 360 km for the 453 metre receiver. Only one source depth of 18 metres was used during this study, data for the other two source depths of 90 and 457 metres was often incomplete.

Measured propagation loss for the 20 metre receiver was available out to 320 km (Figure 2a). To a range of 80 km, differences between the measured and predicted was up to 15 dB. This decreased over the subsequent 80 km, where differences were approximately 2 - 3 dB. Over the remainder of the range, the predicted propagation losses were greater than the measured values, by up to 20 dB.

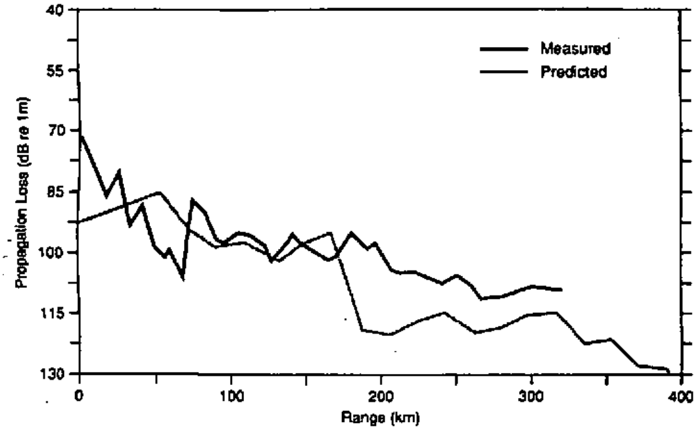

Figure 2a Comparison of measured and predicted propagation loss. Source depth 18 metres, receiver depth 20 metres, source frequency 160 Hz. Full measured environment.

For the three deeper receivers, at 90, 246 (figures 2b and 2c) and 453 metres, agreement between measured and predicted propagation loss was poor at ranges up to 80 km. Between 50 and 70 km an increase in the measured propagation loss is observed, which was not predicted by SUPERSNAP. At longer ranges the agreement improved, and differences were generally less than 5 dB.

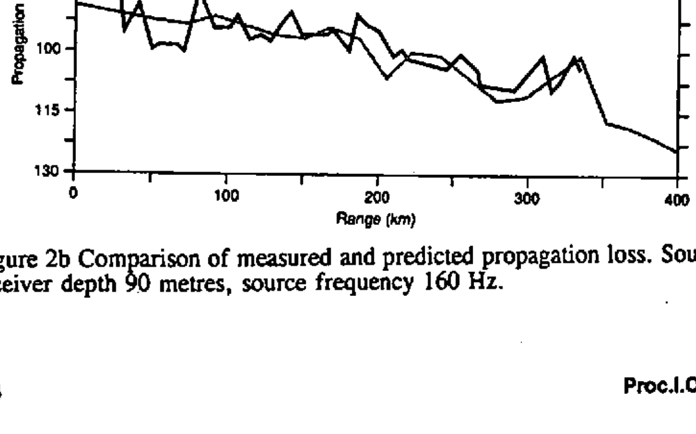

Figure 2b Comparison of measured and predicted propagation loss. Source depth 18 metres, receiver depth 90 metres, source frequency 160 Hz.

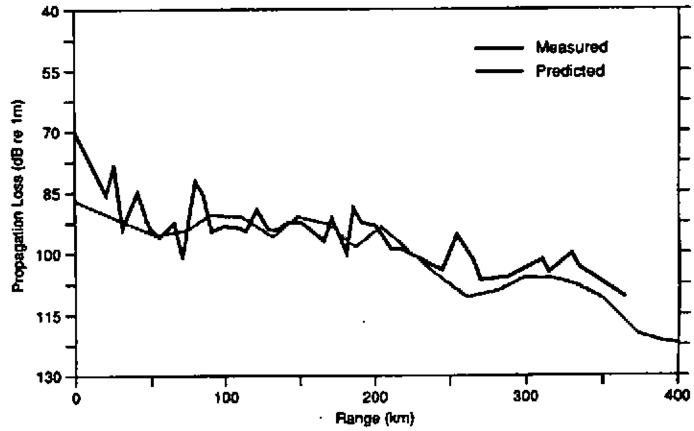

Figure 2c Comparison of measured and predicted propagation loss. Source depth 18 metres, receiver depth 246 metres, source frequency 160 Hz.

Sea-bed Databases
SUPERSNAP runs were carried out using sea-bed parameters supplied from databases. Comparisons of the results from both predictions and measured propagation loss, for a receiver depth of 453 metres are shown in figure 3a. It can be seen that at ranges greater than 100 km, predictions made utilising the measured environmental data were close to that obtained using the sea-bed database.

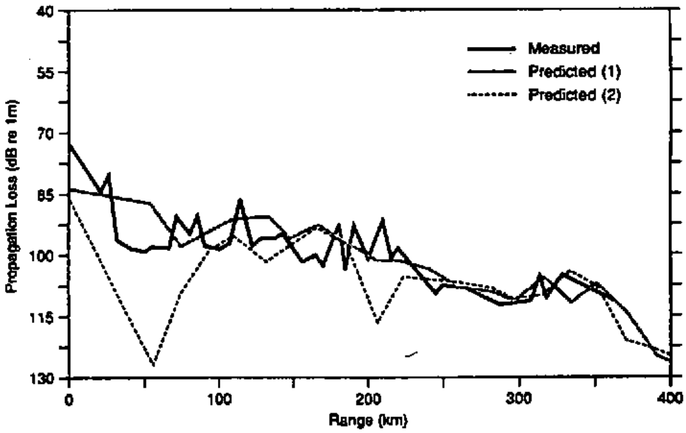

Figure 3a Comparison of measured and predicted propagation loss. Predicted (1) full measured environment, predicted (2) sea-bed data base environment. Source depth 18 metres, receiver depth 453 metres, source frequency 160 Hz.

At ranges less than 100 km, the predicted propagation loss obtained from the measured sea-bed data compares more favourably to the measured propagation loss. The database runs predict a large increase in propagation loss, not echoed in the measured results, or in the other prediction.

For the two shallow receivers, the database environment predictions were up to 30 dB greater than propagation loss calculations using the measured environmental inputs and the *in situ* propagation loss (figure 3b).

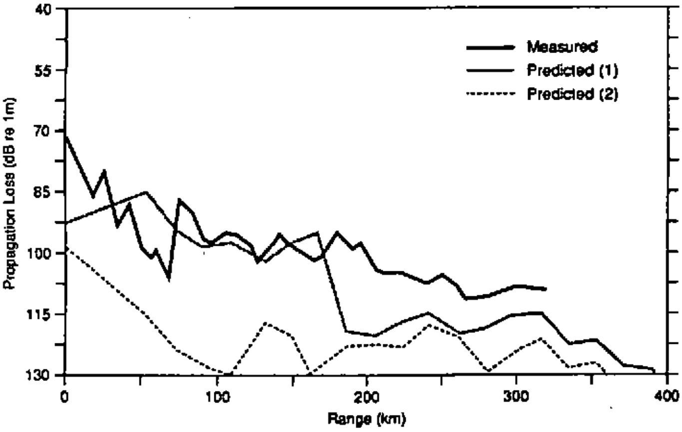

Figure 3b Comparison of measured and predicted propagation loss. Predicted (1) full measured environment, predicted (2) sea-bed database environment. Source depth 18 metres, receiver depth 20 metres, source frequency 160 Hz.

5. DISCUSSION

With a source frequency of 160 Hz, measured and predicted acoustic propagation loss agree reasonably well. This was particularly so for the three deeper receivers (90, 246 and 453 metres). Predicted losses for the two shallow receivers (10 and 20 metres) were generally higher than the measured propagation losses. The improved comparison with deeper sources could be attributed to the low variation in sound speed structure in the deeper water (figure 1), and a more strongly range dependent environment in the upper 100 metres.

Oceanographic measurements made at either end of the acoustic track, indicated that the surface layer fluctuated in depth by as much as 30 metres over the 48 hour period of this experiment. Such fluctuations could have affected actual propagation loss for the shallow receivers.

The underlying bathymetry of the first 80 km was more variable than that observed over the remainder of the full range (400 km). It is possible that this could have caused the deterioration of agreement between measured and predicted propagation loss for this sector.

The sediment sound speed from the database was lower than the corresponding measured value. This would have resulted in a lower critical grazing angle and therefore a greater amount of the acoustic energy penetrating the sea-bed. The source was deployed in the upper water column where the sound speed profile was strongly downward refracting, and hence acoustic energy would strike the sea-bed at high grazing angles. In the situation of a "fast" sea-bed more of this energy would be reflected and returned to the surface layer. However, with a "slower" sea-bed (as observed in the database), more of the energy would be transmitted into the sediment. The sound speed profile in the sea-bed would allow the acoustic energy to be returned to the water column, but attenuated, and hence would have only a slight effect on the acoustic field. The sound energy that would be reflected would be the lower angle sound, which would not return to the surface layers. This could account for the greater losses predicted for the more shallow sources when using the sea-bed database parameters.

Acoustic predictions utilising the measured sea-bed data for the three deep receivers did not improve on predictions using information from the database, at longer ranges. There were however, large differences in acoustic predictions over the first 100 km, when higher losses were observed using input parameters from the database. The difference could be attributed to the resolution of the bathymetric database (5 minute). This could be insufficient to describe the highly variable measured bathymetry over the first 100 km of the acoustic track.

6. SUMMARY

In the environmental conditions described in experiment, it would appear that the predictions of acoustic propagation loss from the model, SUPERSNAP agree reasonably well with measured data when the receivers are situated in deeper water. The agreement between the measured and predicted propagation loss deteriorates when the propagation track is over a shorter range of highly variable bathymetry.

The use of sea-bed databases was also satisfactory, except in cases where the receiver was in the surface layer, or the horizontal resolution of the bathymetry database was insufficient to describe smaller scale variations.

7. ACKNOWLEDGEMENTS

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