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The effects of environmental assessment on model-data transmission loss agreement from sea trial Q290

Sean P. Pecknold
Victor Young
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Defence R&D Canada – Atlantic

Technical Memorandum
DRDC Atlantic TM 2006-007
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Abstract

The DRDC Atlantic sea trial Q290 provided an opportunity to measure and model transmission loss in a shallow-water environment. The transmission loss measurements gathered, along with a complete set of environmental measurements, are used to test DRDC Atlantic's Rapid Environmental Assessment capability and determine the extent to which Rapid Environmental Assessment can improve propagation predictions over predictions predicated on previously perceived parameters. It is found that in this trial environment, using *in situ* measurements of bathymetry and sound speed, as input to a range-dependent Gaussian beam model, provide a better fit to measured transmission loss by 2-3 dB even over quite short (less than 8 km) ranges as compared to historical data from standard databases. The neglect or misestimate of other parameters, including wind speed and bottom type, can also result in large inaccuracies in model predictions of transmission loss and sonar performance.

Résumé

L'essai en mer Q290 de RDDC Atlantique a fourni l'occasion de mesurer et de modéliser l'affaiblissement de transmission en eau peu profonde. Les mesures de l'affaiblissement de transmission recueillies, de même qu'un jeu complet de mesures environnementales, servent à la mise à l'essai de la capacité d'évaluation rapide de l'environnement (REA) de RDDC Atlantique et à déterminer dans quelle mesure la REA permet d'améliorer les prédictions de propagation par rapport aux prédictions fondées sur des paramètres mesurés antérieurement. Lors de cet essai, on a trouvé que l'utilisation des mesures prises sur place de la bathymétrie et de la vitesse du son comme données d'un modèle de faisceaux gaussiens dépendant de la portée donne une meilleure concordance avec l'affaiblissement de transmission mesuré, de l'ordre de 2 ou 3 dB, même à des distances assez courtes (moins de 8 km), par rapport aux données chronologiques de bases de données courantes. L'absence ou une mauvaise estimation des autres paramètres, y compris la force du vent et le type de fond, peuvent aussi entraîner d'importantes inexactitudes dans les prédictions de l'affaiblissement de transmission et du rendement du sonar établies par le modèle.

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Executive summary

Introduction

During DRDC Atlantic sea trial Q290, transmission loss was measured in a range-dependent, shallow-water environment. These measurements were compared to modeled transmission loss based both on historical bathymetry and sound speed values from databases and to modeled loss based on sound speed and bathymetry measured using DRDC Atlantic Rapid Environmental Assessment (REA) tools. The usefulness of the REA tools was then assessed based on the accuracy of the resulting model predictions.

Results

Transmission loss modeled using the REA measurements provided a better fit to the data by 2-3 dB even over quite short (less than 8 km) ranges versus model predictions using sound speed and bathymetry values found in standard databases. In this particular environment, the sound speed profiles seemed to drive the accuracy of the results. It was also found that the Bellhop Gaussian beam model results agree well with the measured transmission loss, while a parabolic equation model that did not include a wind-induced surface loss did not agree as well with the data. Finally, it was found that there exists the potential for seriously miscalculating transmission loss and sonar performance (by tens of dB) in a littoral environment where the bottom type is mischaracterized.

Significance

The utility and impact of Rapid Environmental Assessment is an important question in naval operations, particularly in the littoral. One way to test the usefulness of REA techniques is to calculate the difference they make in knowledge of tactically relevant information. The results presented lead to the conclusion that rapid environmental assessment is desirable for proper modeling of sonar performance.

Further Work

The DRDC Atlantic Rapid Environmental Assessment program will continue to attempt to quantify the dependence of accurate sonar performance predictions on environmental measurements. This includes further planned sea trials as well as the ongoing Geoacoustic Sensitivity Study, a theoretical and model-based study of performance sensitivity to different environmental parameters.

Sean P. Pecknold, Victor Young, Jeff Scrutton and Paul Hines. 2006. The effects of environmental assessment on model-data transmission loss agreement from sea trial Q290. DRDC Atlantic TM 2006-007. Defence R&D Canada – Atlantic.

Sommaire

Introduction

Durant l'essai en mer Q290 de RDDC Atlantique, l’affaiblissement de transmission a été mesuré en eau peu profonde dans un milieu tributaire de la portée. Les mesures recueillies ont été comparées l’affaiblissement de transmission modélisé fondé à la fois sur des données chronologiques relatives à la bathymétrie et à la vitesse du son et des mesures de bathymétrie et de vitesse du son prises à l'aide d'outils d'évaluation rapide de l'environnement (REA) de RDDC Atlantique. L'utilité des outils REA a alors été évaluée d'après la précision des prédictions du modèle qui en ont découlé.

Résultats

L’affaiblissement de transmission modélisé à l'aide des mesures REA a donné une meilleure concordance, de l'ordre de 2 à 3 dB, avec les données, même à des distances assez courtes (moins de 8 km), par rapport aux prédictions du modèle obtenues à l'aide des valeurs de bathymétrie et de vitesse du son trouvées dans des bases de données courantes. Dans le milieu particulier de l'essai, les profils de la vitesse du son ont, semble-t-il, constitué l'élément déterminant de la précision des résultats. On a aussi trouvé que les résultats obtenus à l'aide du modèle de faisceaux gaussiens Bellhop concordent bien avec l’affaiblissement de transmission mesuré, alors qu'un modèle d'équation parabolique qui ne comprenait pas d’affaiblissement à la surface induite par le vent ne concordait pas bien avec les données. Enfin, on a trouvé qu'il y a des risques de sérieusement mal calculer l’affaiblissement de transmission et le rendement du sonar (de l'ordre de dizaines de dB) dans un milieu littoral, où le type de fond est mal caractérisé.

Portée

L'utilité et l'incidence de la REA constituent une question importante dans les opérations navales, en particulier le long du littoral. Une façon de mettre à l'essai l'utilité des techniques REA consiste à calculer la différence qu'elles représentent dans la connaissance de l'information pertinente sur le plan tactique. Les résultats présentés mènent à la conclusion que la REA est souhaitable si l'on veut modéliser comme il faut le rendement du sonar.

Recherches futures

Le programme de REA de DRDC Atlantique se poursuivra pour que l'on puisse tenter de quantifier la dépendance des prédictions précises du rendement du sonar à l'égard des mesures environnementales. Cela suppose la tenue d'autres essais en mer prévus et la poursuite de l'étude sur la sensibilité géo-acoustique, qui examine la sensibilité du rendement à divers paramètres environnementaux et est fondée sur un modèle et une théorie.

Sean P. Pecknold, Victor Young, Jeff Scrutton et Paul Hines. 2006. *The effects of environmental assessment on model-data transmission loss agreement from sea trial Q290* (effets de l'évaluation de l'environnement sur la concordance de la perte de transmission de données du modèle par rapport à l'essai en mer Q290). Document TM 2006-007 de RDDC Atlantique. R & D pour la défense Canada – Atlantique.

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Acknowledgements

We wish to acknowledge the support of the officers and crew of *CFAV Quest*. We also wish to acknowledge the assistance of Dr. John Osler, Paul Shouldice, Dan Graham and Doug Caldwell.

1. Introduction

The utility and impact of Rapid Environmental Assessment (REA) [1] is an important question in naval operations, particularly in the littoral [1,2,3,4]. One way to test the usefulness of REA techniques is to calculate the difference they make in knowledge of tactically relevant information.

An important quantity in determining the effectiveness of active sonar in tactical operations is the transmission, or propagation, loss (TL). During the DRDC Atlantic sea trial Q290, held in October 2005, one of the experiments performed was designed to measure TL as well as sound speed profiles and bottom parameters using a set of REA tools. The results of that experiment are described here. The transmission loss in a littoral area was first measured. Then, the transmission loss was modeled given only historical information about the area. This would be a standard step in determining potential ranges of active sonar in the absence of REA. This modeled TL was then compared both to the data and to the TL as modeled given the use of various REA tools, notably *in situ* measurements of bathymetry and sound speed in the water column. The potential effects of bottom type knowledge are also briefly considered.

2. Analysis

2.1 Measured data

2.1.1 Transmission loss

The transmission loss was measured using the Broadband Acoustic Transmission System (BATS) with a double barrel-stave projector (s/n 30x27-27) to transmit and a type 53D(3) sonobuoy to receive, on the omni-directional channel. The source was towed using a v-fin tow body towed from *CFAV Quest* at a depth of 9.5±0.5 m (depth measurements were taken using a data logger, Vemco Minilog TD 16K, s/n 4171), at an average speed of approximately 2.5 m/s. The receiver was deployed in a moored configuration at 60 m depth at location 43° 55.708' N, 064° 23.026' W (off the coast of Nova Scotia near Liverpool), in water depth of 88.8 m. A transmission loss run was then performed by transiting along a line approximately 12.5 km long. The receive sonobuoy was located along this line, moored to the bottom, approximately 5 km from the start point of the run. The range from the sonobuoy to the towed source was calculated assuming that the source was 90±10 m (36 seconds of travel time at 5 kts) behind the tow ship GPS antenna.

Pings consisted of a 10%-Tukey windowed 1 second CW, frequency 1400 Hz, with 5 second inter-ping dwell time. The source was driven at voltages varying, depending on range from receiver, of 0.025 Vrms to 0.2 Vrms. The TVR (Transmit Voltage Response) of the projector as measured in the v-fin two body at 1400 Hz is 181±1 dB re 1µPa/V. The receive sensitivity of the sonobuoy is -112.5±3 dB re 1µPa/V.

The received pulse energy was calculated by converting the received level in volts to a level in µPa. A Fast Fourier Transform (FFT) was used to determine the received power in 0.25 Hz bins, with 50% overlap, which were then averaged around the peak receive bin. The transmission loss was calculated as the difference between the transmitted pulse energy and the 4-second averaged received pulse energy in a 4 Hz band around the peak frequency of the received pulse. A 4 Hz bandwidth was selected to allow for variations in Doppler. The received energy calculated in this way was not significantly different from the energy measured using a matched filter (MF), as shown in Figure 1 and Figure 2. The matched filter was computed using replicas that were Doppler-shifted to match the ship motion. The average difference between the FFT method and the matched-filter method is 0.5 dB, with a standard deviation of 2.3 dB, well within the 4 dB uncertainty on the transmission loss calculation. This uncertainty depended primarily on the uncertainty of the sonobuoy receiver sensitivity, which is not time independent, and should appear as a bias. Most of the difference, particularly near the closest point of approach (CPA) of ship to sonobuoy is probably due to Doppler mismatch of the matched filter caused by the rapidly changing relative velocities.

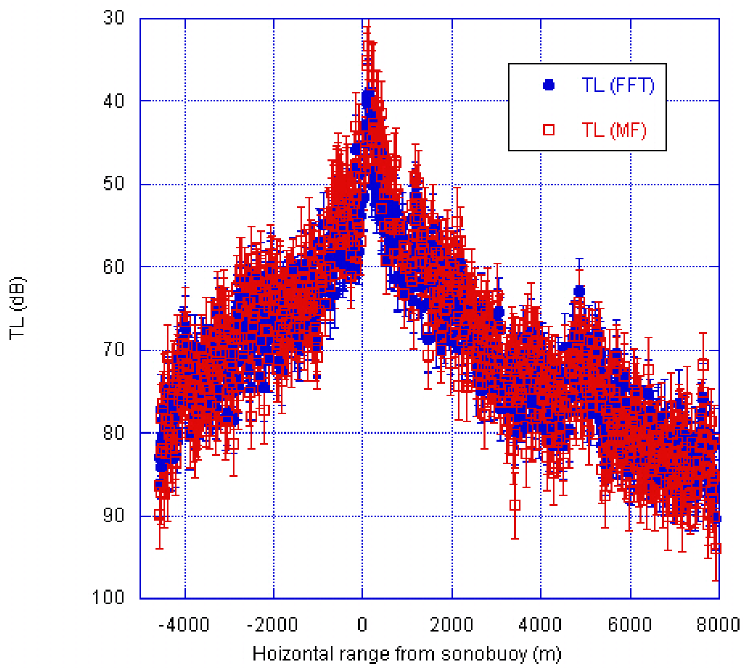

Figure 1. *Comparison of measured transmission loss via matched-filter and FFT energy (4 Hz bin width) vs. horizontal range.*

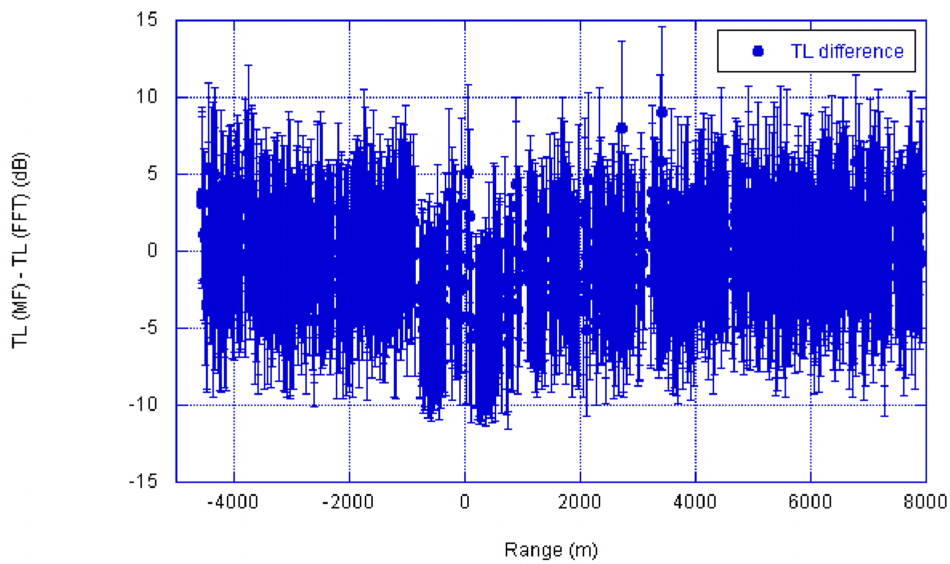

Figure 2. *Difference between measured transmission loss via matched-filter and FFT energy (4 Hz bin width) methods vs. horizontal range.*

2.1.2 Time spreading

The pulse type used for the transmission loss measurements was a 1 second long CW. This waveform was chosen to ensure that there was sufficient energy in a small bandwidth to allow for good signal-to-noise ratio in the prevailing, noisy, conditions. The noise was due both to wind speed and to sonobuoy self-noise due to the mooring. Although this signal type is not well suited for measuring time spreading, it is instructive to compare the predicted spreading due to multipath arrivals to the data gathered during the experiment. The Bellhop model [5] can be used to determine time spreading due to multipath arrivals.

The (normalized) average power for the modeled eigenrays (model input details are described in Section 2.3 below) in 50 ms bins is plotted against relative arrival times for a range of 5 km in Figure 3. This seems to indicate that very little time spreading should be observed, as eigenrays with appreciable amplitude arrive within about ±0.05 seconds of the peak. The -6 dB spread (half amplitude) of the eigenrays is 0.08 seconds. Given that the half-amplitude transmit waveform width is 0.95 seconds, the total time spreading should be 1.03 seconds.

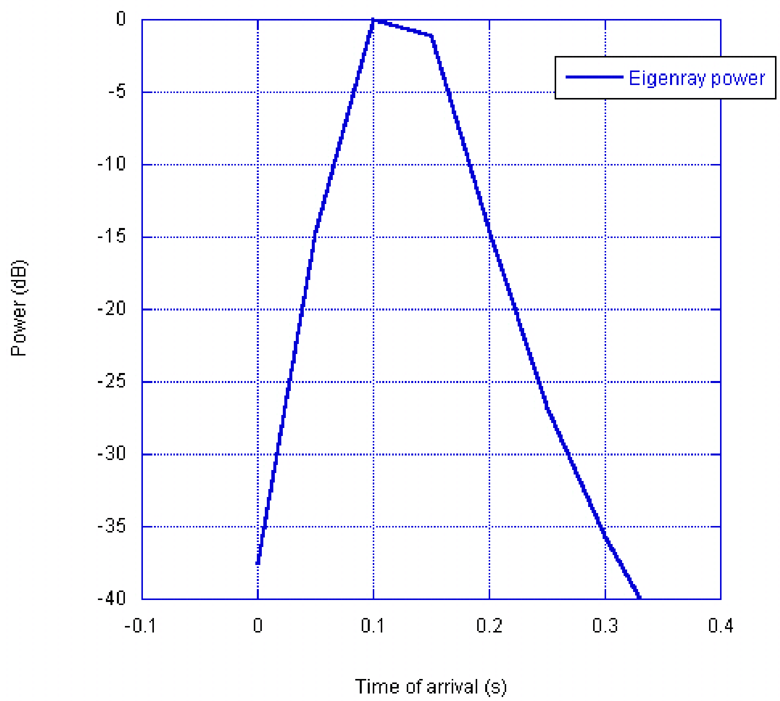

Figure 3. *Power vs. arrival times for eigenrays at 5 km range.*

Observations of the data show time spreading of approximately this magnitude. A set of 45 pings around the 5 km source-receiver range was selected (those pings within 250 m of the 5 km range). A 10 Hz wide band-pass filter around 1400 Hz was used to reduce ambient noise, and then the time series was converted to a dB power scale and smoothed with a 16-point boxcar moving average. The peak for each ping was found, and the -6 dB points calculated. The mean ping width at these points was found to be 0.91 seconds, with a standard deviation of 0.24 seconds. Therefore, the mean time spreading was in fact experimentally 0.12 s shorter than predicted.

One example of a ping arrival at a range of about 5 km is shown in Figure 4, together with the expected arriving ping, as modeled with WATTCH, an eigenrays-based ping propagation model [6]. Both the measured and modeled pings have their peak values set to a time of 0 seconds. The modeled time spread (half-amplitude) is shown with the black lines, while the experimentally determined mean time spread (half-amplitude) and standard deviation for the complete ensemble of 45 pings are shown with the red and dotted red lines.

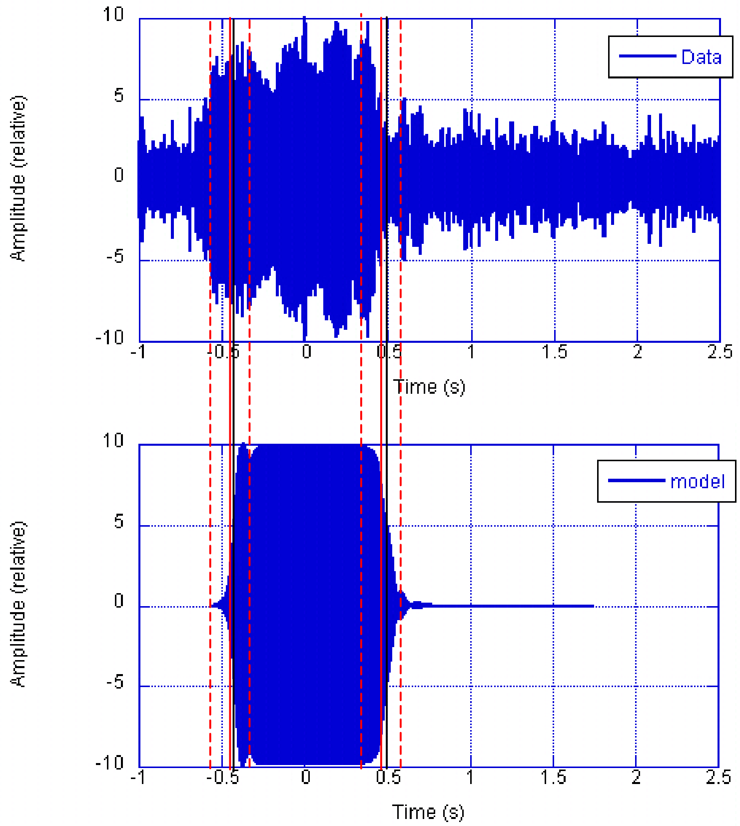

Figure 4. *Measured and modeled ping arrival at range of approximately 5 km.*

It is evident that the time spreading for the measured ping is similar to that of the modeled ping, although the noisiness of the data makes the exact spread difficult to determine. More noticeable is the degree of interference in the measured ping.

2.2 Environmental inputs

To model transmission loss in the experimental area, two distinct sets of environmental inputs were used. The first set consisted of historical data. This included bathymetry taken from the Geological Survey of Canada (GSC) [7], sound speed profiles for the month of October incorporated into the WADER32 model database [8], and an assumed hard sand bottom characteristic of the area [9]. The second set of data was measured *in situ* using an echo-sounder for the bathymetry and the MVP200 moving vessel profiler for CTD (conductivity-temperature-pressure) casts, to determine sound speed in the water column. The second set of data also assumed a hard bottom, which over most of the experimental area was confirmed by using the FFCPt (Free Fall Cone Penetrometer) to determine bottom composition [10].

The bathymetric data from the GSC and as measured using an echo-sounder during the experiment are shown in Figure 5, along with the locations of the CTD measurements.

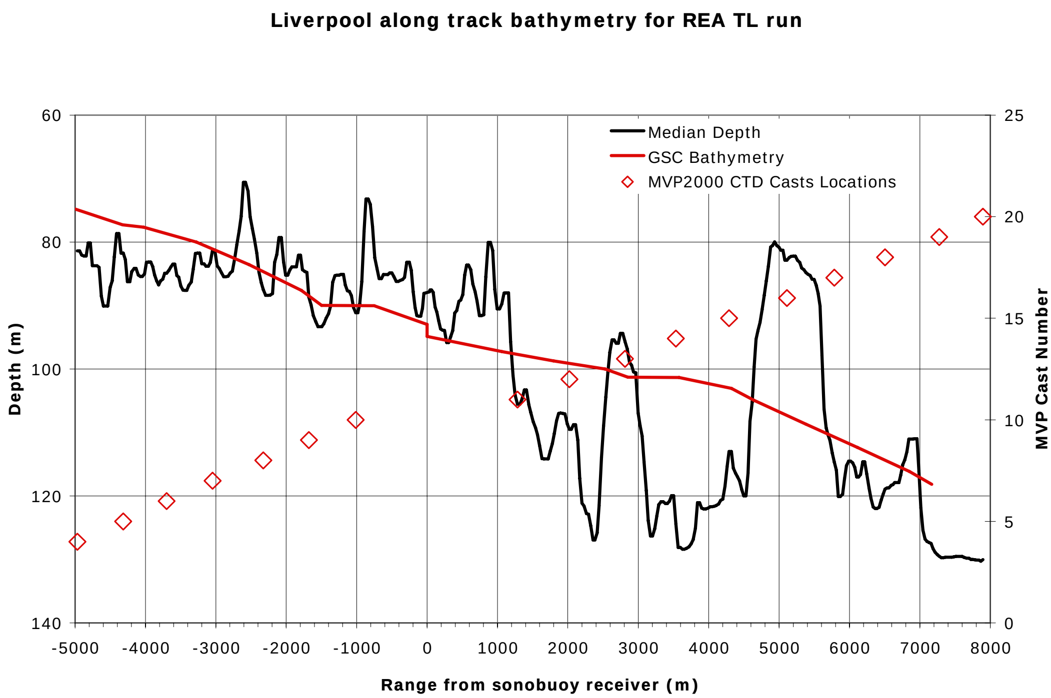

Figure 5. *Bathymetry as measured and from Geological Survey of Canada (GSC). Also shown are the locations of CTD casts plotted vs. cast number.*

For the modeling process, the REA TL track was divided into the two sections on either side of the sonobuoy, namely the "shallow" area (from about -5000 m range to 0 m range) and the "deep" area (from 0 m range to about 8000 m range). Three sets of sound speed profiles were used. The "deep" area sound speed profile set consists of two sound speed profiles, taken from CTD casts 11 and 15 (changing at 4000 m). The "shallow" area sound speed profile set consists of two sound speed profiles, taken from CTD casts 11 and 6 (changing at -3000 m).

Cast 11 was chosen to represent the sound speed closest to the sonobuoy as it included deeper measurements than cast 10. Note that in both cases, only two sound speed profiles were used for modeling, although more were available. It should be noted that the Bellhop model does not interpolate sound speed profiles. Most of the profiles showed the same characteristics. Finally, the historical sound speed profile was used for modeling the “historical” TL for both the shallow and the deep areas. These sound speed profile sets are shown in Figure 6 and Figure 7, with offset x-axes for comparison.

The wind speed measured through the course of the experiment was about 20 knots.

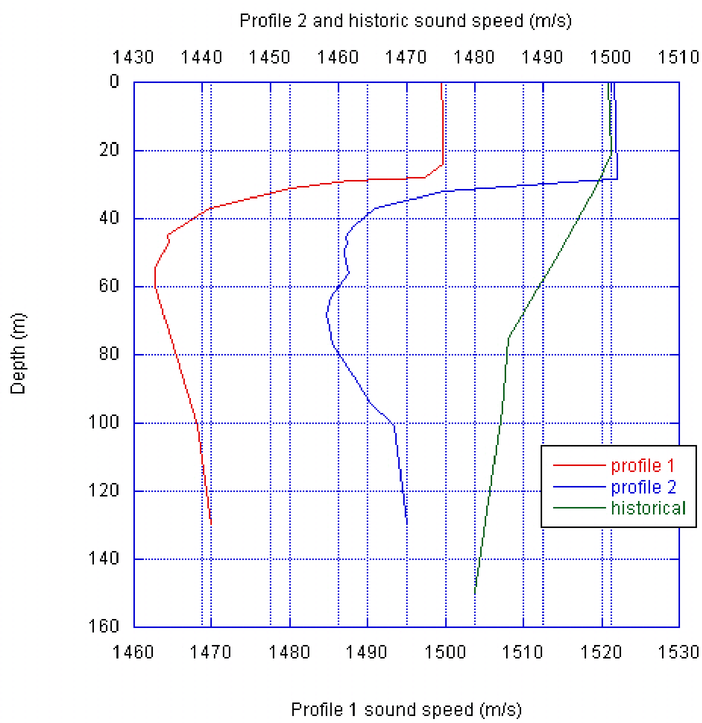

Figure 6. *Deep area sound speed profiles. Profile 1 is CTD cast 11, profile 2 is CTD cast 15.*

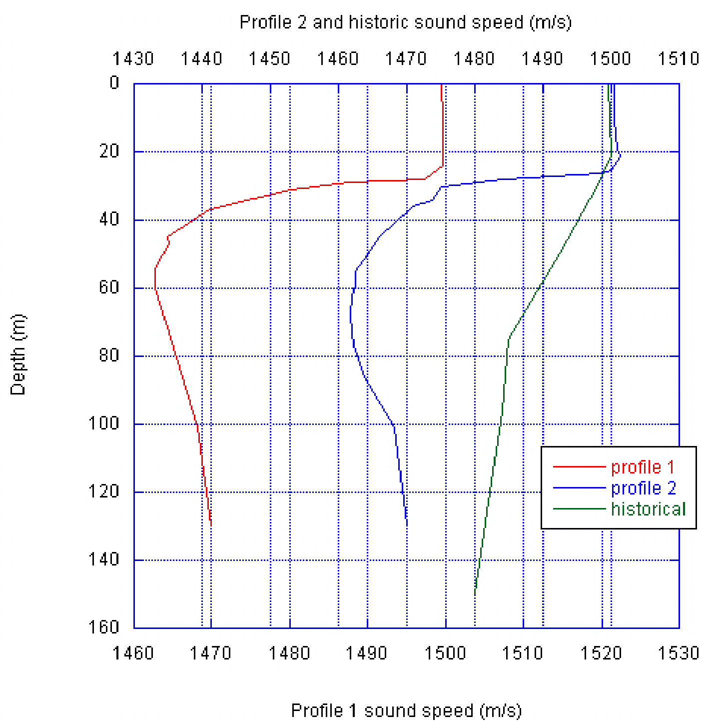

Figure 7. *Shallow area sound speed profiles. Profile 1 is CTD cast 11, profile 2 is CTD cast 15.*

2.3 Model-data comparison

2.3.1 Comparison of models with differing environments

Several modeling runs were performed to compare modeled transmission loss produced using the different sets of environmental data. Most of the modeling was done using the program Bellhop-DRDC [11], a Gaussian beam program that includes range-dependent bathymetry, sound speed, and bottom type. The bottom type is specified using the High-Frequency Bottom Loss MGS province [12]: better, physically based, bottom types were not available in the model as used. Figure 8 shows a graph of MGS bottom loss vs. incident angle for varying bottom province. The bottom province used was 1 (a low-loss bottom) with losses at 1.4 kHz from 0.2 dB to 6 dB for varying grazing angle. This was used to approximate the sandy and rocky bottom measured using the FFCPt. Sediment "ponds" were found in some of the deeper areas, particularly near the 3500 m and 7000+ m distances in Figure 5. The parameters used for bathymetry and sound speed profile are discussed in Section 2.2 above. The wind speed is input as 10 m/s, as measured. The "shallow" area is that corresponding to negative ranges in Figure 5, with the "deep" area corresponding to positive ranges from the sonobuoy receiver.

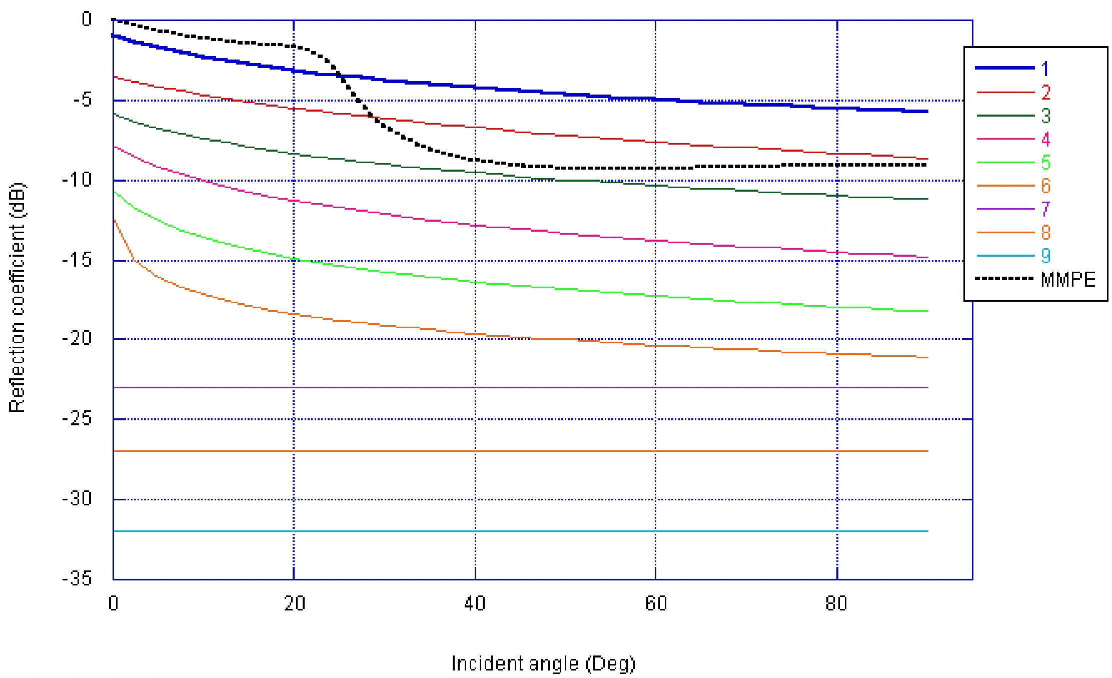

Figure 8. *MGS and MMPE bottom loss by incident angle for varying bottom province at 1.4 kHz.*

Figure 9 and Figure 10 show the coherent transmission loss field calculated using Bellhop in the deep area of the experiment, using measured bathymetry and sound speed profiles for Figure 9 and historical data for Figure 10. The transmission loss fields assume a source depth of 60 m at the actual receiver location, as receiver and source locations may be inverted by time reversal of propagation (reciprocity).

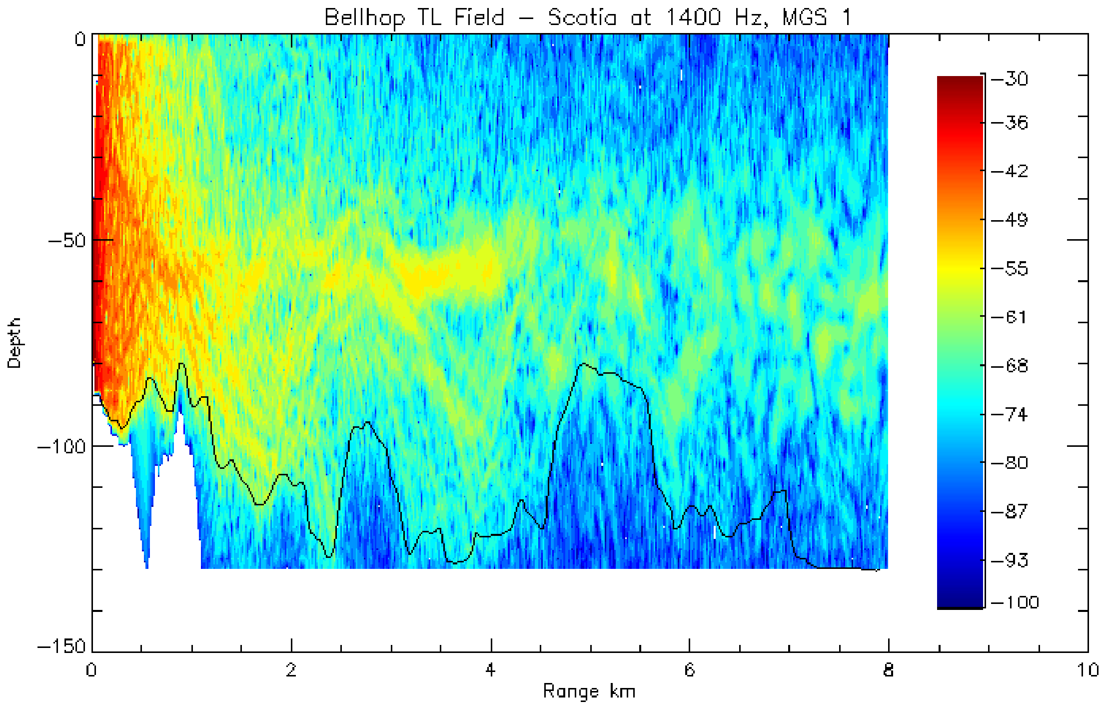

Figure 9. *Transmission loss at 1.4 kHz from Bellhop model – deep area of TL run, using measured sound speed profiles and bathymetry. Colour scale is in dB re 1 m.*

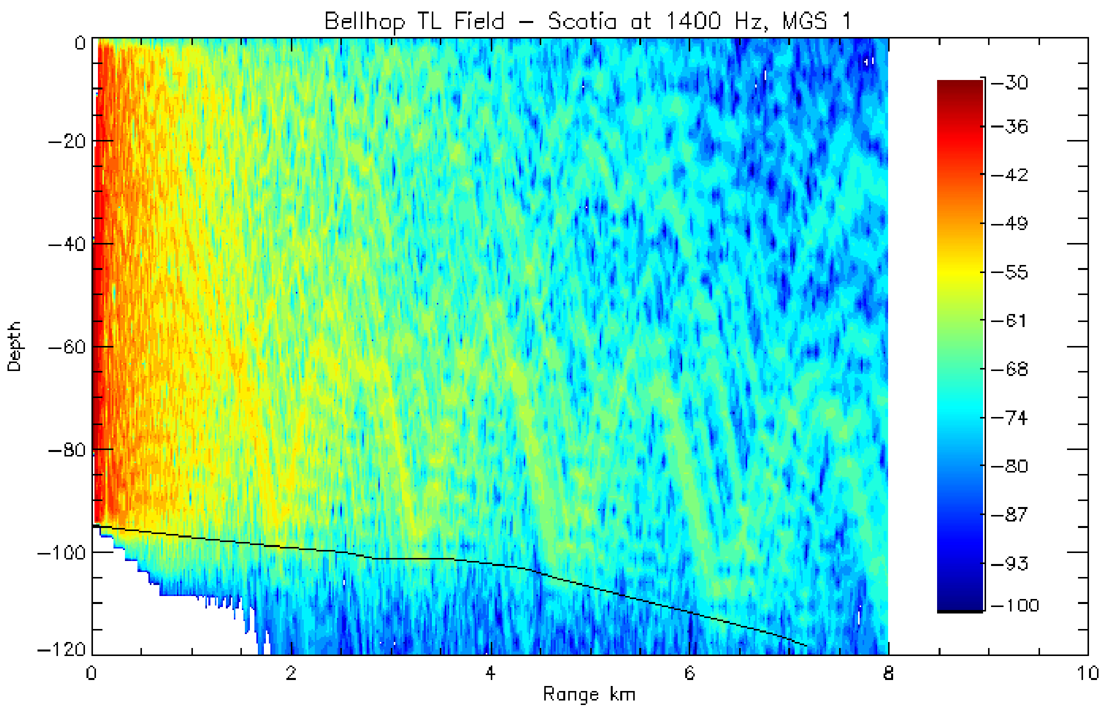

Figure 10. *Transmission loss at 1.4 kHz from Bellhop model – deep area of TL run, using historical sound speed profile and GSC bathymetry data. Colour scale is in dB re 1 m.*

In this case, the transmission loss field modeled using the actual bathymetry and sound speed profiles shows both a more focused area of sound transmission between 50 m and 60 m deep (particularly around 4 km range) and greater transmission loss in the shallower water past 1 km range.

Figure 11 shows the coherent transmission loss field calculated using Bellhop in the shallow area using measured bathymetry and sound speed profiles, while Figure 12 shows the coherent transmission loss field assuming that the bathymetry and sound speed profile were those from historical data.

The modeled transmission loss field for this area shows the greatest differences between the measured and the historical data at the shallower depths. For shallow depths, the actual bathymetry and sound speed profiles give rise to greater transmission loss at ranges beyond 1 km.

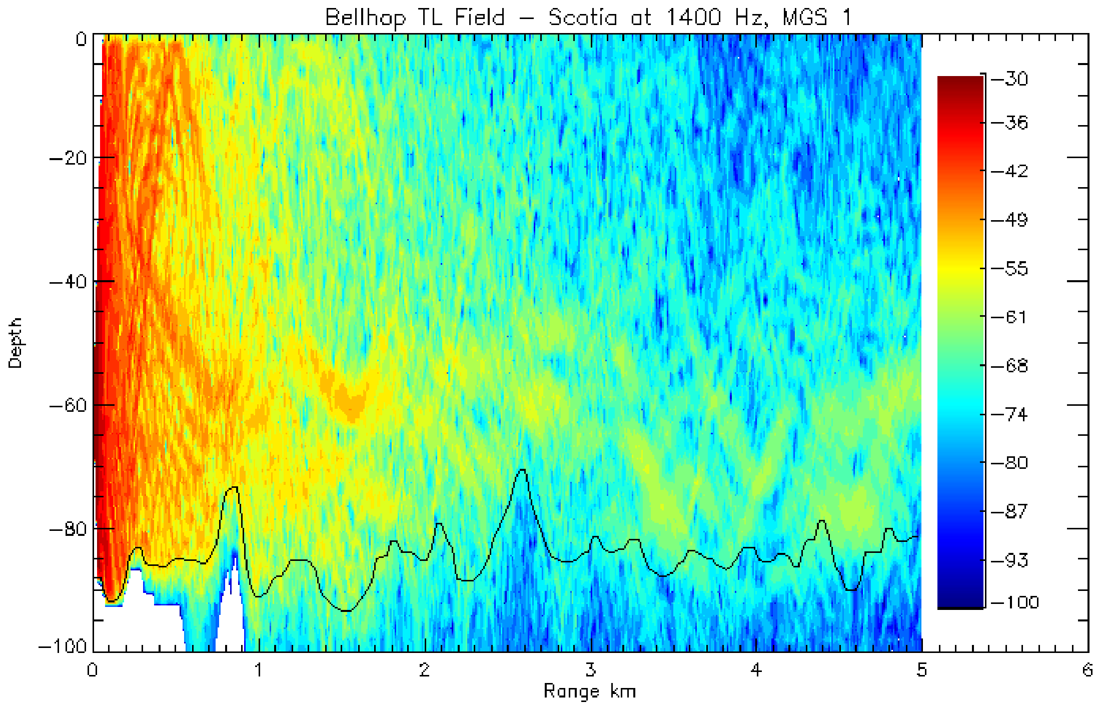

Figure 11. *Transmission loss at 1.4 kHz from Bellhop model – shallow area of TL run, using measured sound speed profiles and bathymetry. Colour scale is in dB re 1 m.*

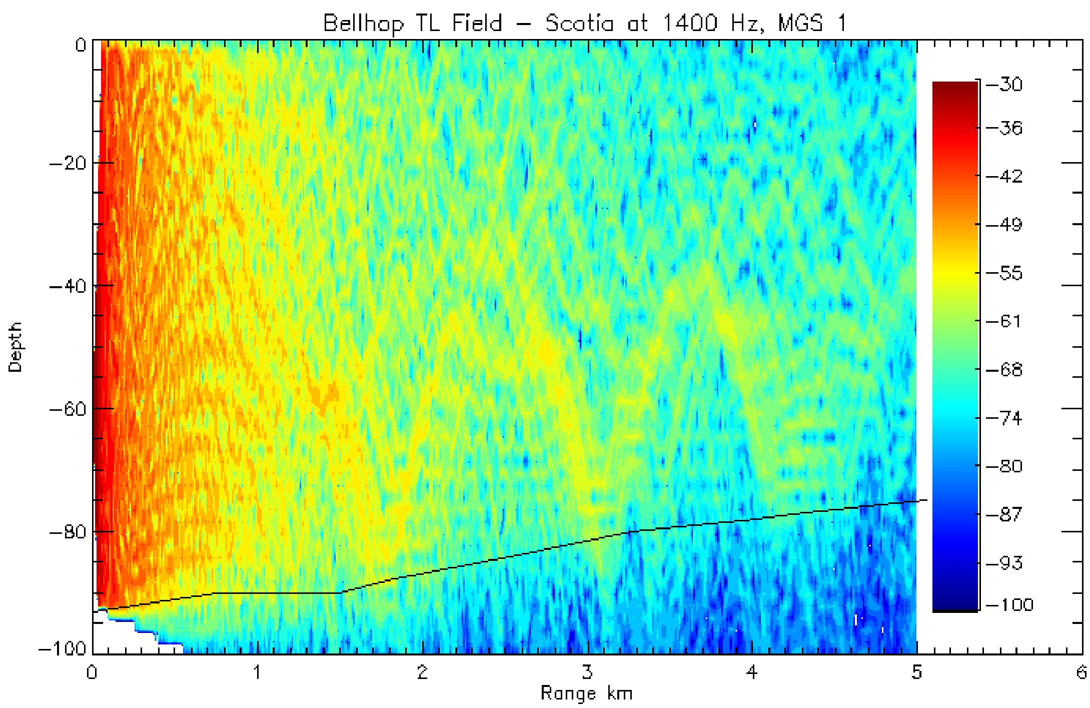

Figure 12. *Transmission loss at 1.4 kHz from Bellhop model – shallow area of TL run, using historical sound speed profile and GSC bathymetry data. Colour scale is in dB re 1 m.*

Finally, the transmission loss field using the measured bathymetry and sound speed profile set was calculated using a parabolic equation model, the Monterey-Miami Parabolic Equation model (MMPE) [12]. The results are shown in Figure 13. Although some of the structure is comparable to that obtained using the Bellhop model, the presumed bottom using MMPE is harder than that for Bellhop, due to an inexact match of the bottom reflection coefficient types included in each model. The parameters used for modeling the bottom properties for the MMPE were those for sand [13] – density 1.9, compressional speed 1650 m/s, shear speed 400 m/s, compressional attenuation 0.8 dB/λ, and shear attenuation 2.5 dB/λ. The loss for this parametrization is less than for MGS province 1 for low incidence angles and greater for high incidence angles (see Figure 8). Also, there is no surface reflection loss included with the MMPE program used. Therefore, unsurprisingly, the transmission loss calculated using MMPE is less than that calculated using Bellhop.

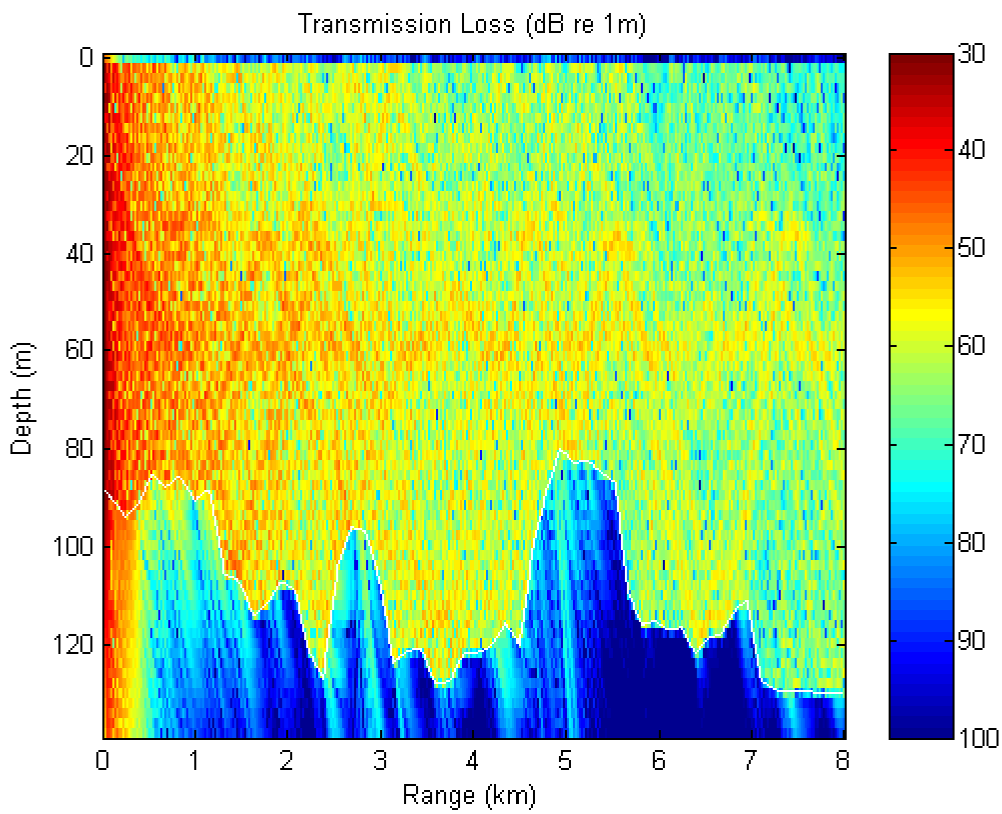

Figure 13. *MMPE transmission loss field for deep area. Colour scale is in dB of loss re 1 m.*

2.3.2 Comparison of modeled results and data

The measured transmission loss data (Section 2.1 above) may now be compared with the transmission loss data from the various model runs. In the following figures (Figure 14 – Figure 22) the error bars have been suppressed on the measured data for easier comparison to the model transmission loss lines.

Figure 14 compares the transmission loss measured over the deep area along the trial run with the modeled coherent transmission loss using both the measured and the historical environment. Figure 15 shows the same comparison over the shallow area of the trial run. The real bathymetry and sound speed sets appear to give a better fit. The data does not appear to have the fluctuations expected from the modeled coherent transmission loss. Given this observation, as well as the appreciable ship motion through the duration of a ping (at least two wavelengths), it was decided to use an incoherent transmission loss calculation for further comparison of measured and modeled data.

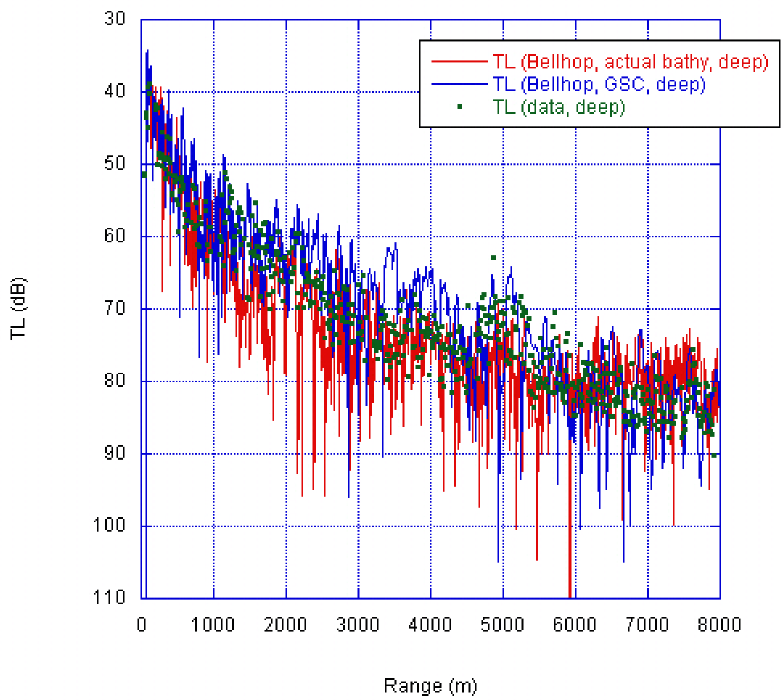

Figure 14. *Comparison of modeled coherent vs. measured transmission loss – deep area of TL run.*

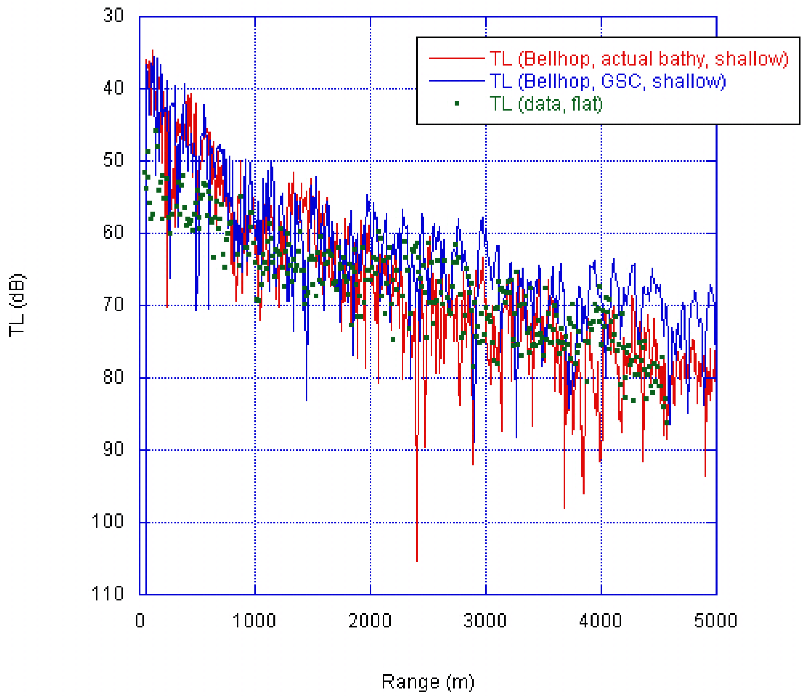

Figure 15. *Comparison of modeled coherent vs. measured transmission loss – shallow area of TL run.*

Figure 16 and Figure 17 show the modeled incoherent loss from Bellhop for the deep and shallow areas respectively for the two sets of environmental data compared to the measured data. In both cases, the data fit is better for the real (measured) bathymetry and sound speed profile. In the case of the shallow area, the root-mean-squared model-data difference is 6.6 dB for the measured parameters vs. 8.0 dB for the historical, with the mean model-data difference being 4.5 dB as opposed to 7.0 dB, showing less of a trend in error as well. The model-data difference was taken using transmission loss in dB, over the entire set of ranges. This was done to avoid biasing the differences to the short-range data. The RMS model-data difference for the deep area is 4.8 dB for the measured environment compared to 6.2 dB for historical, with the mean model-data differences being 2.4 dB and 5.2 dB respectively. The model using measured data also seems to accurately reproduce the dip in transmission loss that occurs at about 5 km range in the deep area (near the ridge), although it erroneously indicates less transmission loss at longer range (7 to 8 km) than was found. This may be due to the higher-loss sediment bottom beyond this range.

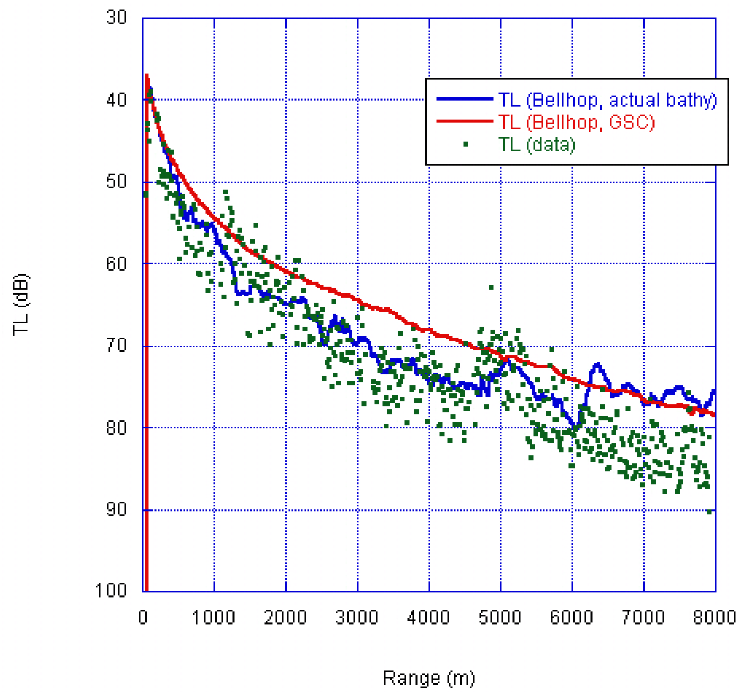

Figure 16. *Comparison of modeled incoherent vs. measured transmission loss – deep area of TL run.*

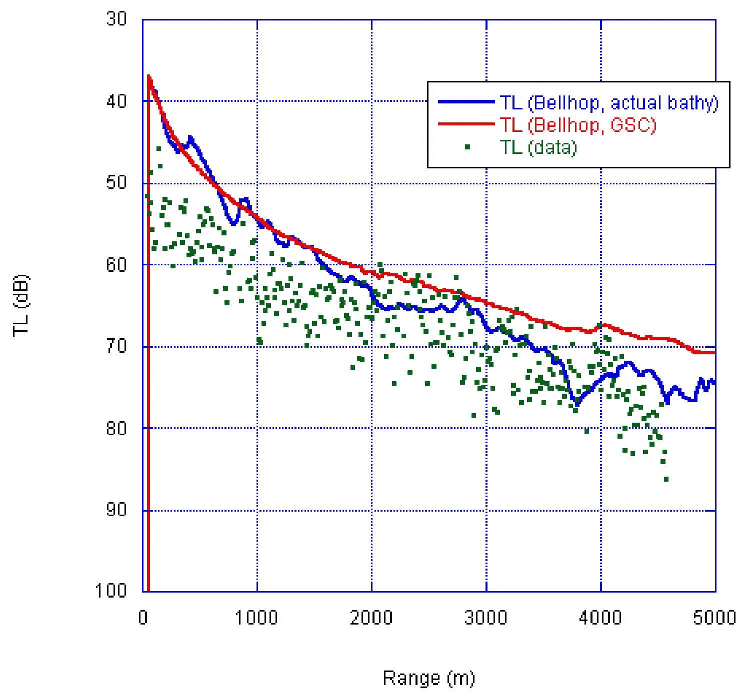

Figure 17. *Comparison of modeled incoherent vs. measured transmission loss – shallow area of TL run.*

Figure 18 shows a comparison for the deep area of the TL run between the data, the incoherent Bellhop model, and the MMPE model (which is a coherent TL model). As expected from the total TL field (Figure 13), the parabolic equation model does not include as much loss as it should.

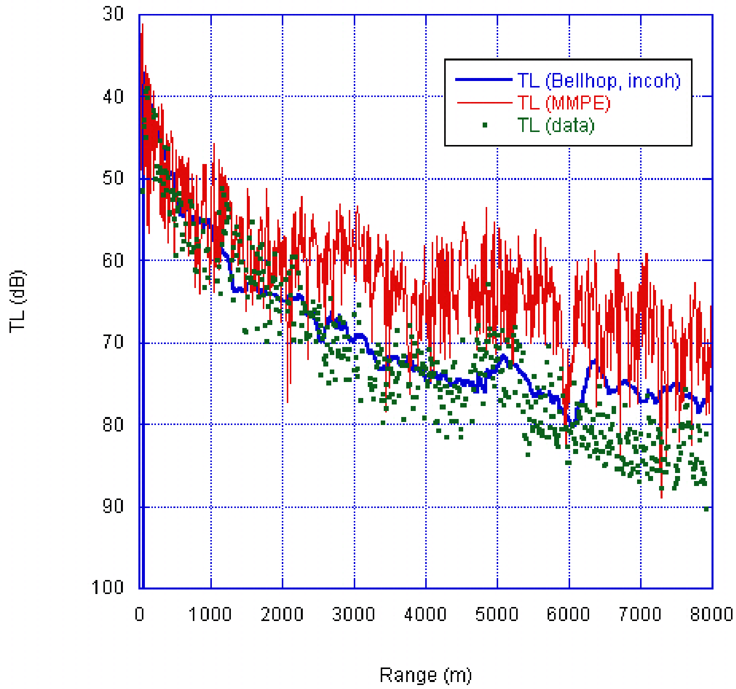

Figure 18. *Comparison of Bellhop, Parabolic Equation and data for deep area.*

The transmission loss modeled using measured bathymetry and sound speed profiles has been found to be more accurate than the transmission loss modeled with historical estimates of bathymetry and sound speed. An understanding of the magnitude of the effect of using measured vs. historical bathymetry and sound speeds is of interest. Accordingly, the Bellhop model was used to compare incoherent transmission loss for the measured sound speed profile with bathymetry from the GSC dataset, and incoherent transmission loss for the sound speed profile contained within the WADER32 dataset together with the measured bathymetry. These are shown in Figure 19 and Figure 20 along with the previously shown model runs.

In the case of the shallow area, the root-mean-squared model-data difference is 6.2 dB for the measured sound speed profile and GSC bathymetry, and 7.2 dB for the measured bathymetry and sound speed profile from the database. Comparing this to the previous values of 6.6 dB for measured parameters and 8.0 dB for the historical values, it is evident that the measurement of the sound speed profile is the most important factor here (and in fact provides a slightly better fit even using the GSC bathymetry). The RMS model-data difference for the deep area is 5.3 dB for the measured sound speed profile and GSC bathymetry, and 5.6 dB for the measured bathymetry and sound speed profile from the database. This is slightly worse than the 4.8 dB for the measured environment, and better than the 6.2 dB for historical data.

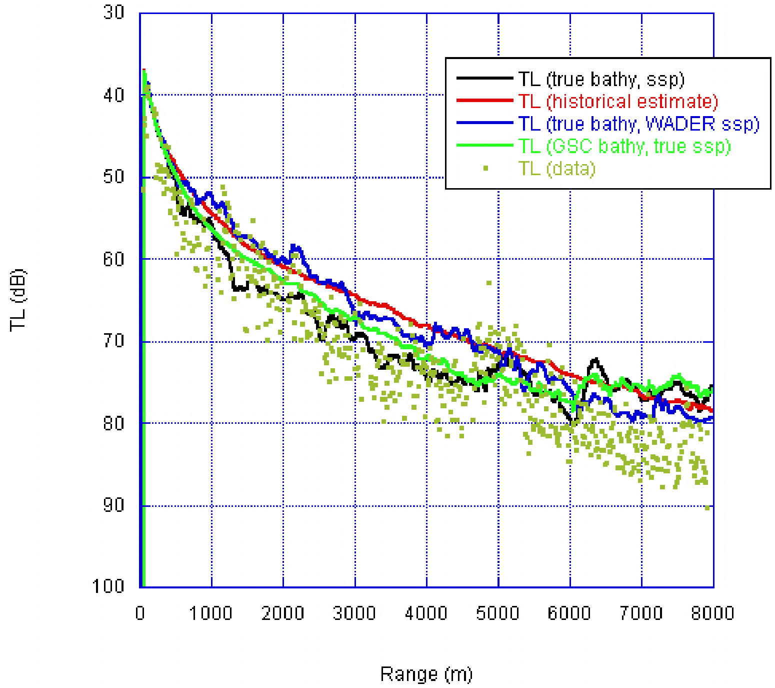

Figure 19. *Comparison of modeled incoherent vs. measured transmission loss with varying environments – deep area of TL run.*

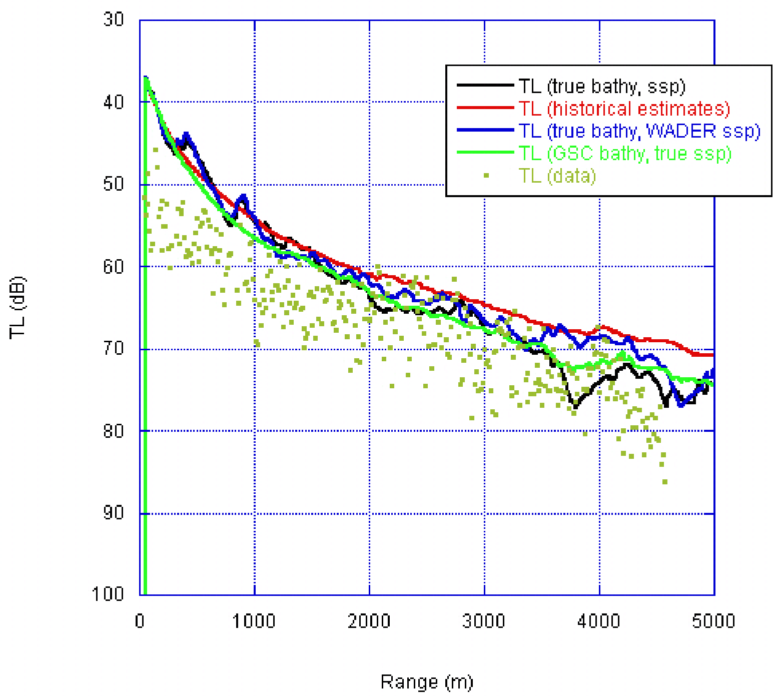

Figure 20. *Comparison of modeled incoherent vs. measured transmission loss with varying environments – shallow area of TL run.*

When compared to the measured data, inclusion of the correct sound speed profile with the historical bathymetry agrees more closely than inclusion of the correct bathymetry with historical sound speed. It is notable that in the deep area, the (inaccurate) flattening of the transmission loss curve at ranges past 6 km is nearly identical given differing bathymetries but the same (measured) sound speed profile, and may reflect a change in actual sound speeds that was not measured or included in the modeling. Alternatively, the existence of sediment ponds at these ranges on the bottom could be the cause of the difference.

Finally, in order to determine the possible effect of an unknown bottom composition, a comparison of measured data to modeled transmission loss was conducted using a high-loss bottom (MGS bottom province 7, which gives a -23 dB reflection coefficient for all angles at 1 kHz), with both historical and measured bathymetry and sound speed profiles. The results for both the deep and shallow areas of the TL run are shown in Figure 21 and Figure 22. The soft bottom results in erroneously high values of transmission loss for any bottom-interacting path. The very large error in these cases highlights the requirement for environmental assessment. Without proper characterization of the seabed, the transmission loss and therefore the predicted effective sonar range could vary enormously even for short ranges.

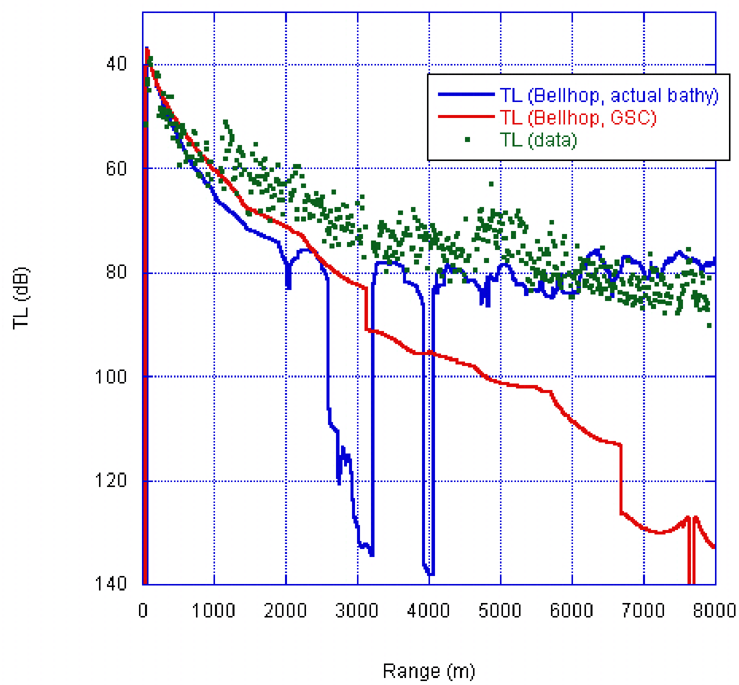

***Figure 21.** Comparison of modeled incoherent vs. measured transmission loss – deep area of TL run (with soft bottom).*

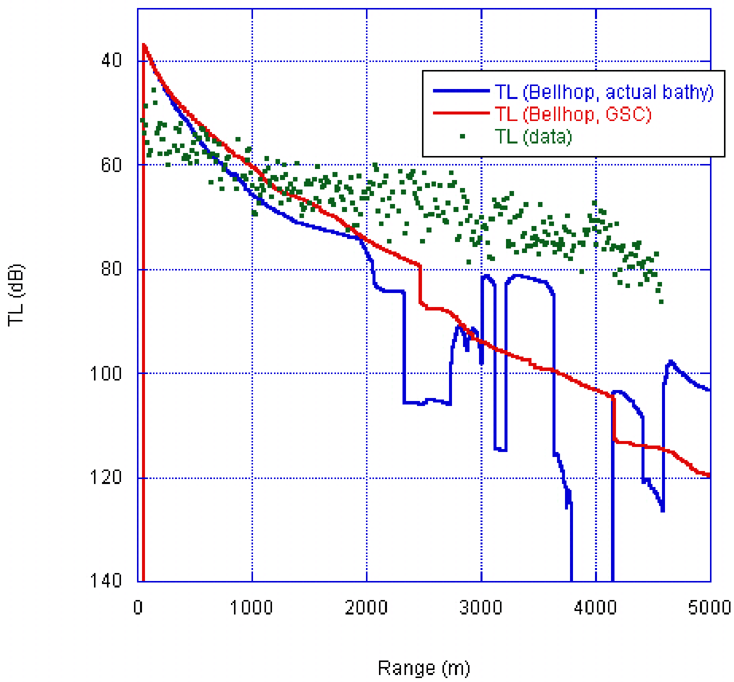

Figure 22. *Comparison of modeled incoherent vs. measured transmission loss – shallow area of TL run (with soft bottom).*

3. Conclusions

The DRDC Atlantic sea trial Q290 provided an opportunity to measure and model transmission loss in a shallow-water environment. Together with a complete set of environmental measurements, this provided a good opportunity to test the capability of DRDC Atlantic's suite of Rapid Environmental Assessment tools to enhance the effectiveness of sonar performance prediction.

In comparing measured transmission loss data to modeled transmission loss using environmental data from both historical sources and that gleaned using REA tools, several important points of information were found. The data obtained using the REA tools provided a better fit to the data by 2-3 dB even over quite short (less than 8 km) ranges as compared to historical data. Models that do not account for all environmental parameters can be quite inaccurate, as evidenced by the errors found using the MMPE model without a wind-induced surface loss. Finally, the potential for seriously misestimating transmission loss and sonar performance (by tens of dB) exists in any littoral environment where the bottom type is mischaracterized.

Although the comparative utility of the various REA tools that exist has not been quantified, it must be concluded that some form of rapid environmental assessment is desirable for proper modeling of sonar performance.

4. References

1. Whitehouse, B. (2004). Survey of ASW Research & Development Opportunities in Rapid Environmental Assessment. (DRDC Atlantic CR 2003-176). DRDC Atlantic.

2. Whitehouse, B.G. (2003). Ocean intelligence in the maritime battlespace: analysis and recommendations for a Canadian Forces maritime environmental assessment program, a final report to Defence R&D Canada – Atlantic. (DRDC Atlantic CR 2003-176). DRDC Atlantic.

3. Hammond, N. (1997). Rapid Response 96 – A demonstration of NATO's rapid environmental assessment capability. In E. Pouliquen, A.D. Kirwan Jr., and R.T. Pearson (eds.), *Proceedings of Conference on Rapid Environmental Assessment*, (SACLANTCEN conference proceedings CP-44). Pp. 21-24. SACLANTCEN, La Spezia, Italy.

4. Sellschopp, J. (2000). Rapid environmental assessment for naval operations. (SACLANTCEN Report SR-328). SACLANTCEN, La Spezia, Italy.

5. Porter, M. B. and Bucker, H. P. (1987). Gaussian Beam Tracing for Computing Ocean Acoustic Fields. J. Acoust. Soc. Am. 82(4). 1349-1359.

6. Theriault, J. A. and Pecknold S. (2005). Impulse Propagation using WATTCH. (DRDC Atlantic ECR 2004-248). DRDC Atlantic.

7. Zevenhuizen, J. (2004). Compilation and interpretation of geophysical and geological data on the Scotian Shelf in support of summer 2004 "Acoustic Geoclutter" field program. Orca Marine Geological Consulants Ltd.

8. Water Column Data. (Online). Ocean Acoustics Development Ltd. http://www.oad.tv/pg_water_column.htm (February 8, 2006).

9. Osler, J. C. (1994). A Geo-Acoustic And Oceanographic Description Of Several Shallow Water Experimental Sites On The Scotian Shelf. (DREA TM 94-216). Defence Research Establishment Atlantic.

10. Osler, J., Furling, A., Christian, H. (2004). A sediment probe for the rapid assessment of seabed characteristics. In A. Caiti, N.R. Chapman, J.-P. Hermand, and S.M. Jesus (eds.), *Acoustic Inversion Methods and Experiments for Assessment of the Shallow Water Environment*. Pp. 171-182. New York: Springer.

11. McCammon, D. (2004). Investigating the Bellhop Acoustic Prediction Model: Capabilities, Tests, Recommendations and Users Guide. (Report for contract W7707-042585/001/HAL). McCammon Acoustical Consulting.

12. Yarger, D. F. (1976). The Users Guide for the RAYMODE Propagation Loss Program. (NUSC Technical Memorandum 222-10-76). Naval Undersea Systems Center.

13. Smith, K. and Tappert, F. (1996). Propagation and analysis issues in the prediction of long-range reverberation. J. Acoust. Soc. Am. 99(3). 1387-1404.

14. Jensen, F. B., Kuperman, W. A., Porter, M. B., Schmidt, H. (1994). Computational Ocean Acoustics. p. 41. AIP Press: New York.

List of symbols/abbreviations/acronyms/initialisms

CTD	Conductivity-Temperature-Pressure
FFCPt	Free Fall Cone Penetrometer
FFT	Fast Fourier Transform
GSC	Geological Survey of Canada
MF	Matched filter
MMPE	Monterey-Miami Parabolic Equation
REA	Rapid Environmental Assessment
TL	Transmission Loss

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The effects of environmental assessment on model-data transmission loss agreement from sea trial Q290

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

Pecknold, Sean P., Young, V., Scrutton, J., Hines, P.

5. DATE OF PUBLICATION (month and year of publication of document) March 2006	6a. NO. OF PAGES (total containing information Include Annexes, Appendices, etc). 34 (approx.)	6b. NO. OF REFS (total cited in document) 14

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered).

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The DRDC Atlantic sea trial Q290 provided an opportunity to measure and model transmission loss in a shallow-water environment. The transmission loss measurements gathered, along with a complete set of environmental measurements, are used to test DRDC Atlantic's Rapid Environmental Assessment capability and determine the extent to which Rapid Environmental Assessment can improve propagation predictions over predictions predicated on previously perceived parameters. It is found that in this trial environment, using *in situ* measurements of bathymetry and sound speed, as input to a range-dependent Gaussian beam model, provide a better fit to measured transmission loss by 2-3 dB even over quite short (less than 8 km) ranges as compared to historical data from standard databases. The neglect or misestimate of other parameters, including wind speed and bottom type, can also result in large inaccuracies in model predictions of transmission loss and sonar performance.

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