Operational Acoustic Transmission Loss Uncertainty Characterization

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Introduction: Uncertainty is an unavoidable part of any physical measurement or prediction process. Uncertainties in directly measured oceanographic quantities such as bathymetry, water sound speed profiles, acoustic system parameters, and so forth are fairly straightforward to quantify. A method for mapping these values into overall uncertainty in sound transmission loss (TL) levels has been developed at NRL. Here, we briefly review this method and demonstrate its use in a larger framework, incorporating environmental and acoustic prediction models and associated uncertainties to give a unified, operationally useful prediction for confidence intervals on acoustic transmission loss.

Technique: It has long been recognized that range-averaging predicted TL will produce a curve that qualitatively matches the results of a frequency average over some system bandwidth. The physical basis for this was later shown to be an outcome of similar mathematical forms of the two types of averages when the solutions were expressed as sums of modes.[1] This averaging equation is also amenable to calculating bounds on a TL prediction if some method exists of determining the uncertainty in the number of modes. Fortunately, such estimation is straightforward if sound directions are locally approximated as straight lines and the maximum propagation angle is known. The algorithm developed[2] consists of three range averages: one for the TL prediction based on system bandwidth as described in Harrison and Harrison,[1] and one for each of the bounds based on a fractional change in averaging interval corresponding to the fractional change in mode count, which is determined by uncertainties in both environmental parameters and bandwidth. This method provides a significant capability, the estimation of TL uncertainty, at low computational cost, and can be used on any acoustic propagation model, mode-based or otherwise.

Two examples of this method are shown in Fig. 4. The environment depicts an upslope path onto a coastal shelf, and the two frequencies used were chosen to bracket the cutoff frequency for acoustic propagation on the shelf. Typical uncertainties for the environment were used, and the bandwidth of the system was set to one-third octave to simulate common oceanographic survey methodology. At the higher frequency (Fig. 4(a)), the small uncertainties in the deeper water expand greatly as the sound propagates upslope. As the total number of modes decreases, uncertainties in the remaining number of modes become proportionally more important. At the lower frequency (Fig. 4(b)), the cutoff range prediction is evident and the TL uncertainty boundaries effectively become range uncertainty boundaries for the cutoff point.

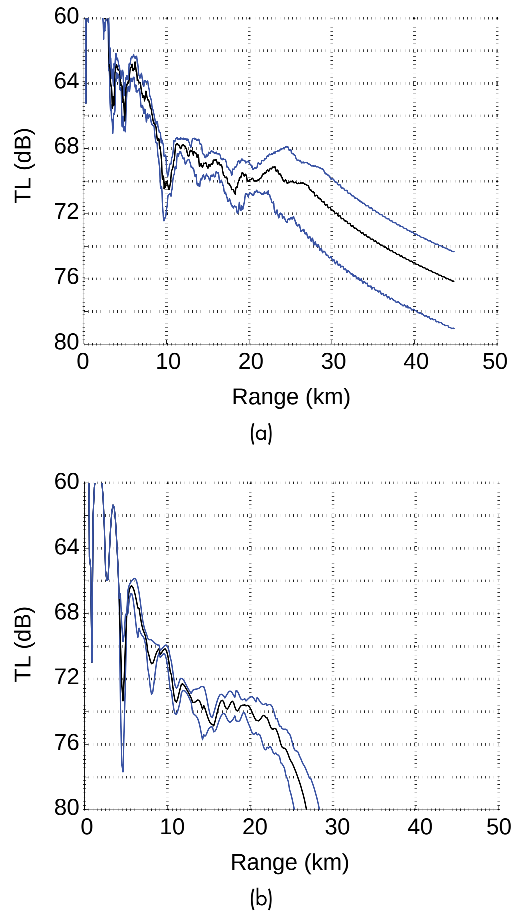

FIGURE 4
Transmission loss calculations for an upslope onto coastal shelf environment at (a) 125 Hz and (b) 12.5 Hz. Mode stripping and, hence, increasing uncertainty with range are shown at the higher frequency, while cutoff depth and the resulting range uncertainty are evident at the lower frequency.

Demonstration: Products such as the Naval Oceanographic Office (NAVO) acoustic performance surface and NRL's Integrated Acoustic Multienvironmental Processing System (IAMPS) currently provide high-fidelity, wide-area estimates of acoustic system performance given the spatially and temporally complex environment. The uncertainty estimation method described above has been incorporated into IAMPS and is providing estimates of acoustic performance with uncertainty for large operational areas and time frames. NRL is transitioning this method to NAVO for use in their acoustic performance surface and other related applications, and it is becoming part of their emerging acoustic uncertainty capabilities in support of the Fleet. In addition to providing the ability to include non-environmental sources of uncertainty, this transition precludes the need to compute multiple acoustic realizations based on oceanographic (or other) ensembles, thus saving computational time while still including the ensemble variance.

Figure 5 shows an example of predicted area that would be covered by a generic acoustic sensor for a test area in the Pacific Ocean. The uncertainty methodology was applied and overplotted for areas of high (red contours) and medium (black contours) uncertainty. This type of product is very useful to the oceanographic and acoustic analysts and allows them to better understand the quality of their products.

Summary: The ability to quickly and reliably estimate acoustic uncertainty has far-reaching applications. Among these are confidence intervals on acoustic level and detection range predictions, improved capability and verification of ongoing performance surface predictions, better planning of Fleet and survey operations, and further reduction of the overall error in database products from NAVO. This method and its applications have been fully developed and tested at NRL, are transitioning to Naval operational use, and are fast becoming an integral part of the Navy's ability to estimate acoustic uncertainty for better understanding and improved confidence in products supporting many aspects of acoustic tactics and planning.

[Sponsored by NRL]

References

[1] C.H. Harrison and J.A. Harrison, "A Simple Relationship Between Frequency and Range Averages for Broadband Sonar," *J. Acoust. Soc. Am.* **97**, 1314–1317 (1995).

[2] R.A. Zingarelli, "A Mode-based Technique for Estimating Uncertainty in Range-averaged Transmission Loss Results from Underwater Acoustic Calculations," *J. Acoust. Soc. Am.* **124**, EL218–222 (2008).

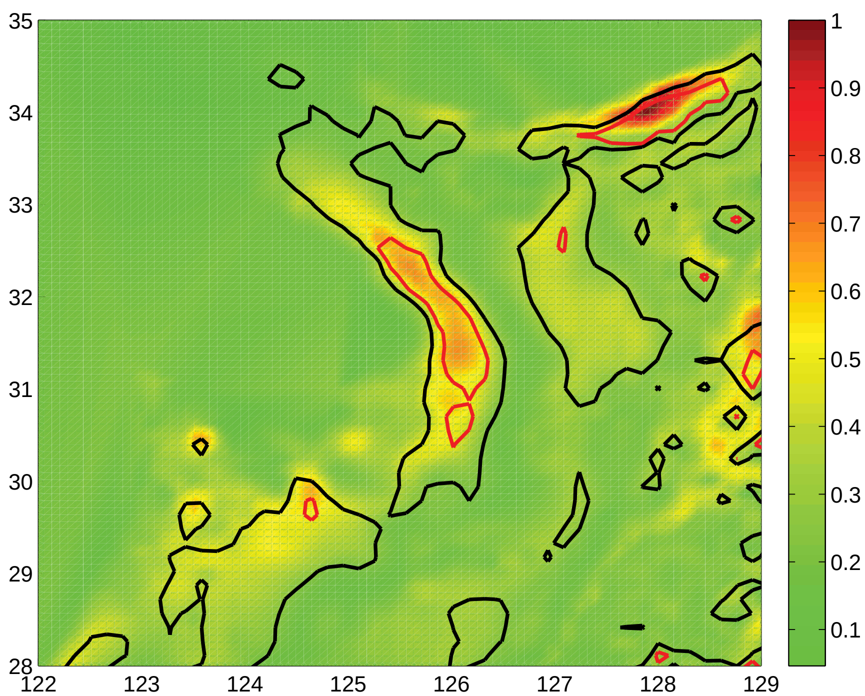

FIGURE 5
Acoustic coverage overplotted with areas of high (red contours) and medium (black contours) uncertainty.