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Sandia National Laboratories

Hydroacoustic Network Performance Modelling

National Nuclear Security Administration

B. John Merchant and Kathy Davenport

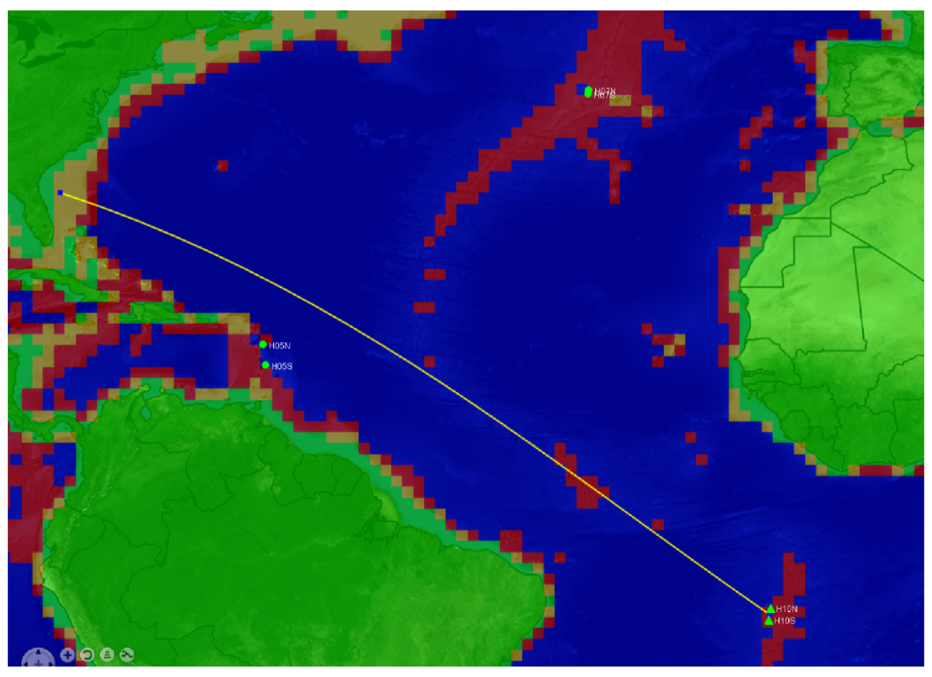
Sandia National Laboratories, Albuquerque, New Mexico, U.S.A.

① Introduction

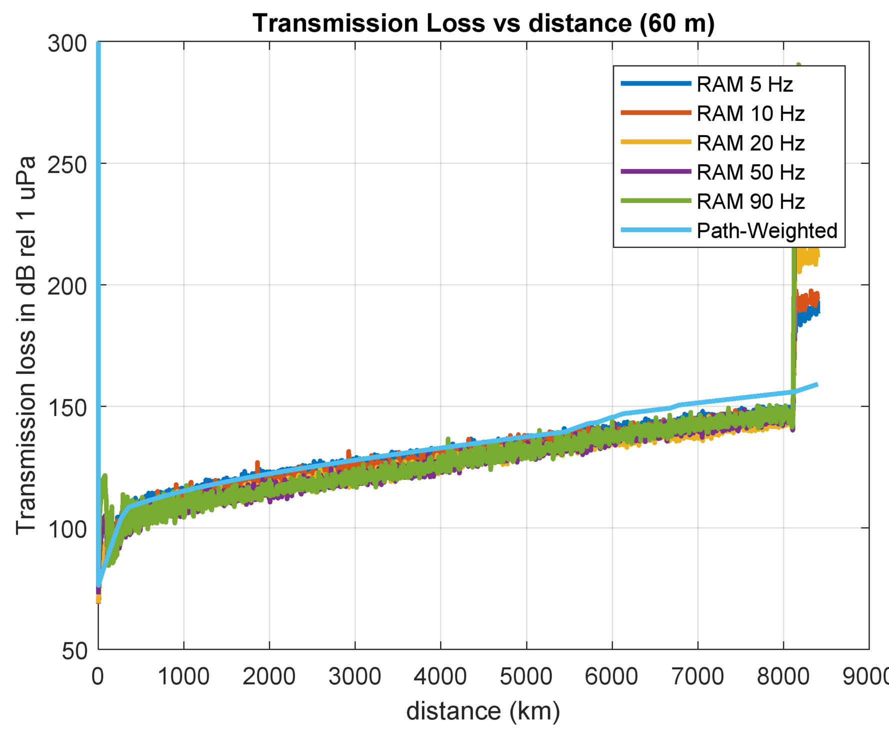
Network modeling is needed for the assessment of station-specific operating conditions, to prioritize station deployment and repair, and to assess the overall IMS and IDC monitoring capability currently and in the future. Sandia National Laboratories (SNL) has developed a software tool, NetMOD, for performing real-time simulation of global seismic, hydroacoustic, and infrasound monitoring network detection performance for nuclear explosion monitoring. Recent work has focused on improving the accuracy and fidelity of hydroacoustic simulations by including higher resolution propagation models. This improvement is being accomplished by precomputing propagation models using the Range-dependent Acoustic Model (RAM) for each station in the IMS hydroacoustic network. These higher fidelity propagation models will allow the PTS to perform continuous, near real-time, assessments of the detection capability of the IMS hydroacoustic network at a global scale.

③ Attenuation Model Validation

The weighted average method of simulating path attenuation was compared against the results from running RAM on a radial starting from the east coast of Florida to the IMS hydroacoustic station H10 for a source depth of 60 meters.



The path-weighted estimate of attenuation agrees well with several RAM simulations over the radial path ranging out to over 8000 km of distance.

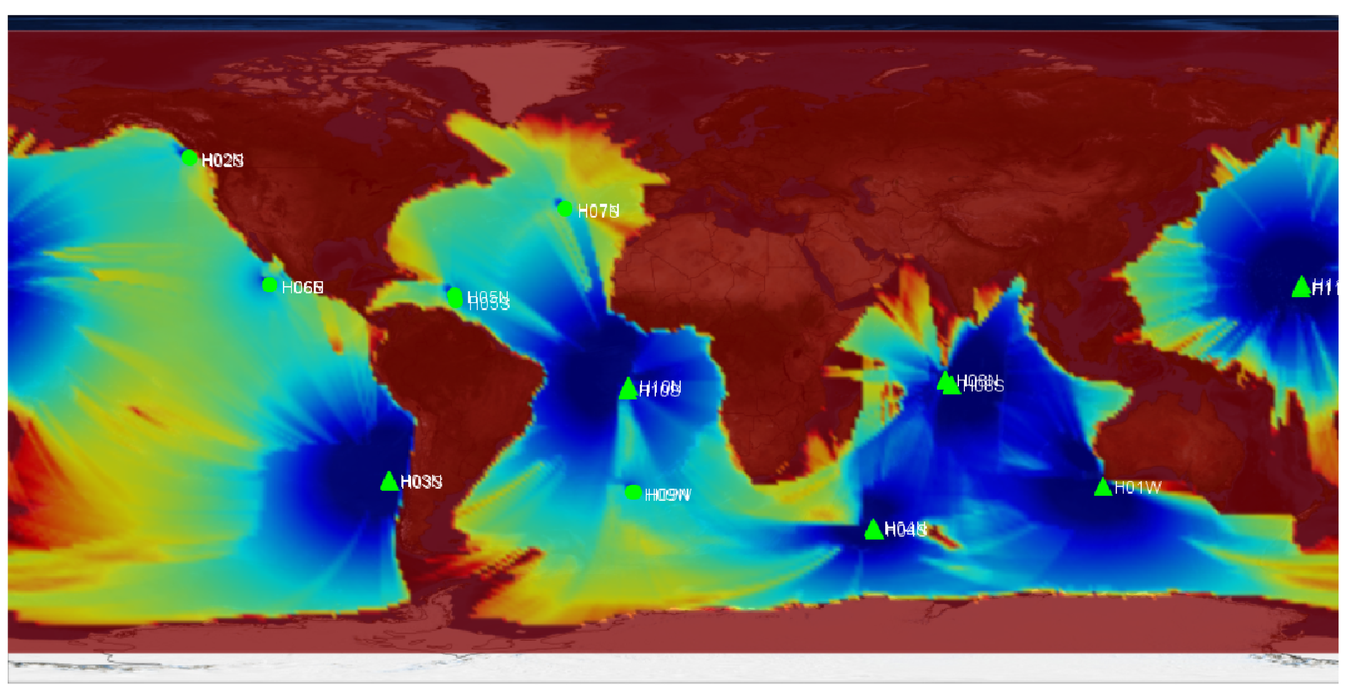


④ Example Network Simulation

The hydroacoustic propagation models may be used to simulate the observed signal amplitudes at each station for any given source location and yield. From these signal amplitudes and accompanying estimates of site noise levels, the probability of detection for individual stations and the network as a whole may be computed.

An example map of the minimum yield that may be detected at a 90% probability is shown in the figure below in which smaller minimum yields are shown in dark blue and larger minimum yields are in red. Detection is improved in regions near stations, decreases at larger distances, and is blocked when there is any land located between the source and station locations.

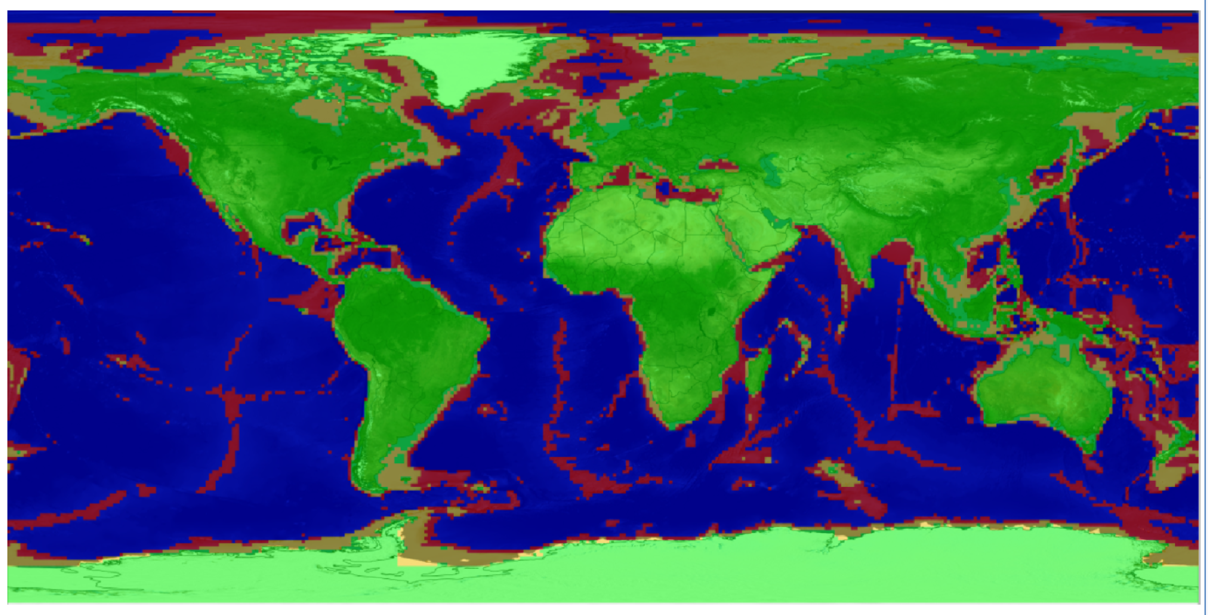
Although this method of network performance simulation does not have the fidelity of more computationally intensive methods, it was able to generate an estimate over the entire globe at a 1 degree spacing in less than 1 hour on a typical desktop computer.



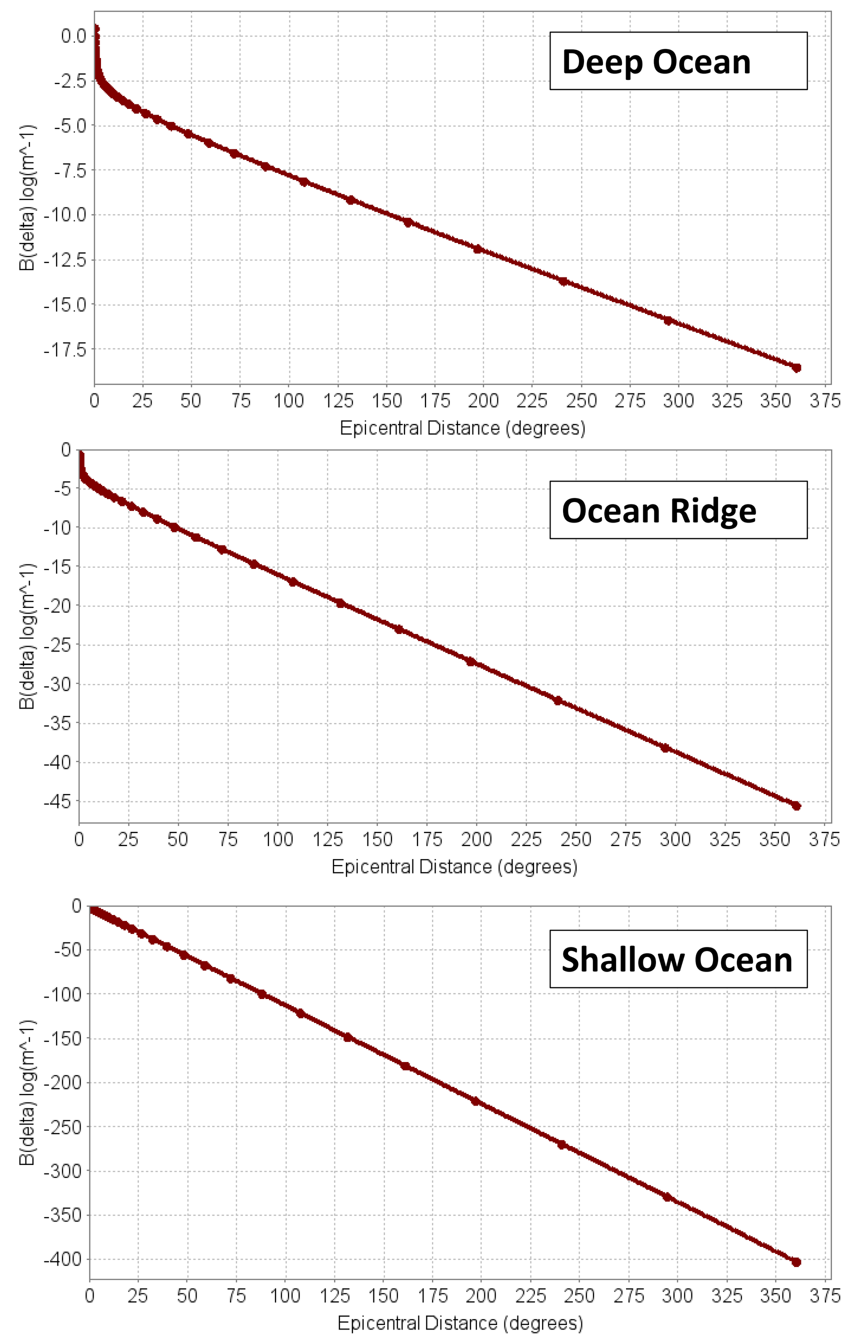
② NetMOD Hydroacoustic Attenuation Model

NetMOD typically uses a propagation model based on ocean depth comprised of 4 regions:

- Blocked
- Deep Ocean
- Ocean Ridge
- Shallow Ocean



Total attenuation is calculated by a weighted average of the media regions passed through by the great circle path between a source location and the station. Any path intersecting land is assumed to be blocked from propagation.



Attenuation models are based on average ocean conditions, without any seasonal variability or dependence on frequency.

Models include geometric spreading and intrinsic seawater attenuation, and the shallow ocean and ocean ridge models incorporate scaled bottom loss parameters for sediment over basalt. These attenuation models provide a reasonable approximation to the transmission loss predicted by RAM for source depths between 50-75 m.

- Spherical spreading $\mathrm{TL} = 20 \log r$
- Cylindrical spreading $\mathrm{TL} = 10 \log r$
- Intrinsic seawater attenuation

$$\alpha' \simeq 3.3 \times 10^{-3} + \frac{0.11 f^2}{1+f^2} + \frac{44 f^2}{4100 + f^2} + 3.0 \times 10^{-4} f^2 \quad \text{(dB/km)}$$

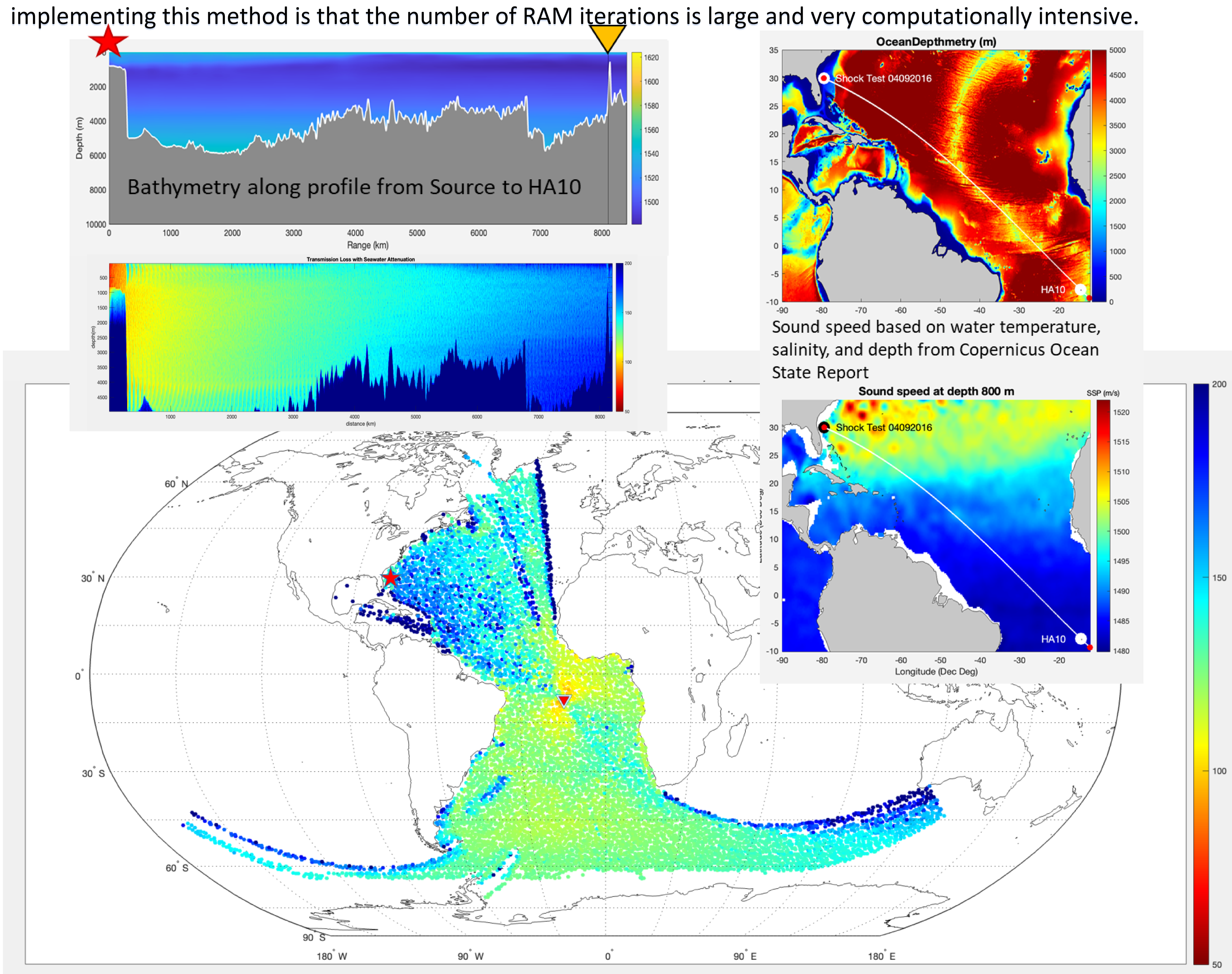
- Transmission Loss as a function of Intensity

$$\mathrm{TL} = -10 \log \frac{|I(r,z)|}{I_0} \quad \text{(dB re 1 m)}$$

Formulas for estimating attenuation parameters are based on *Jensen, F. B., Kuperman, W. A., Porter, M. B., Schmidt, H., & Tolstoy, A. (2011). Computational ocean acoustics (Vol. 794).* New York: Springer.

⑤ Station Specific Attenuation Models

Rather than use an average path-weighted method to estimate propagation from an arbitrary source location to a station, we are attempting to use RAM to precompute a 2D lookup grid of attenuations for each station location. Then, at run-time, the attenuation can be obtained from this grid very quickly. However, the challenge for implementing this method is that the number of RAM iterations is large and very computationally intensive.



Simulated event locations detectable in a 50Hz frequency band at station HA10. Colors represent transmission loss at the station. High transmission loss (dark blue) indicates propagation paths with significant bathymetric blockage.

⑥ Future Work

- Complete the computation of station specific attenuation models for the IMS hydroacoustic stations.
- Integrate attenuation models into a NetMOD project file, which will allow for quick and high fidelity simulations to be run by the IDC.
- Investigate relatively simple corrections that can be made to account for changes in source depth.

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