DOSITS Webinar: Acoustic Propagation Modeling (May 12, 2022)

Question and Answer Summary
(Questions asked/answered in real-time during the webinar or in the Q&A box)

Questions asked/answered live by Dr. Aaron Thode during the webinar:

Question: Would it be more likely for real spreading to be more similar to the lower estimate of spreading (cylindrical), or even lower, due to obstacles in the water column (ex. seaweed in shallow water or schools of fish and so on)?

Answer: (Dr. Aaron Thode) The answer is that in most scenarios it's the composition of the ocean bottom that'll determine whether you're closer to cylindrical spreading or spherical spreading. If you have what we call a very soft bottom like a very muddy bottom where sound can penetrate very easily it's closer to spherical spreading. If it's a very hard bottom like solid rock then that's more like a cylindrical spreading scenario.

Question: Given the diverse sources of noise in the ocean and a shifting baseline due to climate change or other human stressors is there a need for complex systems theoretical approaches in sound propagation modeling?

Answer: (Dr. Aaron Thode) I would say the answer is no. The sound propagation models are sufficiently theoretically developed that if you have sufficient information about the environment, you can accurately reproduce the sound. The exceptions for this are as follows: first there are not extensive models for modeling what's called reverberation, so if sound scatters from the ocean floor, detailed models of that are still theoretical and difficult to come by, as well as volume scattering of fish. That's still a work in progress, because sound bounces not only off individual fish but it bounces back and forth between fish. And so, most of these techniques are designed where you're assuming you don't have significant scatters on the ocean floor bottom. A bigger problem right now is that, although these models are generally accurate if there aren't scatters, getting all the information you need to accurately model what's going on there can be difficult, especially if you have range dependent situations and that's why it's always a good question to ask, Where are the assumptions are coming from when someone's doing an acoustic model and where are they getting their information?

DOSITS: Okay that's good and I suppose for the scattering that would also apply to like a high sediment load estuary situation.

Aaron Thode: Yes, conceivably yeah, although that, you know, if you have a lot of sediment suspended in the water it's really more like a change in the sound speed profile at that point. It really comes to, once again, to the idea of labeling. If the size of the object in the water is about the same as the acoustic wavelength then you get very strong scattering effects, whereas if you've got a wavelength much larger than a small particle like a piece of sediment then you can kind of treat it more as a bulk material that happens to have a different sound speed than the one above it. Wavelength is all.

Questions: Can you define and explain near field acoustic propagation v. far field acoustic propagation and how sound pulses spread in each regime? & Could you please explain a bit more about near field versus far field sound conditions in underwater habitats? Would fish tank acoustics be similar to near field sound propagation?

Answer: (Dr. Aaron Thode) In the context of acoustic propagation, generally by near field we mean anything closer than a few water depths away from the source and far field represents anything more than about let's say three or four water depths away. So certain types of acoustic codes or propagation codes like normal mode codes assume you're in the far field, or a few water depths away, and that is the practical difference between that.

Question: So with ray tracing, how is acoustic information shared across rays, so for example if one ray hits a bathymetric feature and that bends it to the left or to the right, how is not accounted for in nearby rays?

Answer: (Dr. Aaron Thode) Oh, I see. Yes, you can imagine rays as being solid objects that can kind of collide and shatter with each other. You can think of them as that they overlap each other, so the path of one ray is not influenced by the path of another ray. But what happens is when you sit at a particular point in space and see all the rays that cross, you can kind of add those contributions together and that gives you the amplitude of the field, the transmission loss. So, the rays don't influence each other, but you can sum them up together to get the complete field. I hope that answers the question. It's not like bumper cars or anything.

Question: In Fourier Synthesis you say you have to model a number of "tones" to recreate signals. Do you need just the frequency or also the amplitude in the model? So, does the amplitude need to be modeled as a variable at each frequency?

Answer: (Dr. Aaron Thode) Thank you that's a good point. I did try to mention that. So in Fourier Synthesis, not only do you have to have a set of frequencies and results, but you have to know what the amplitude of the source is at each frequency. So, I showed an example, I don't think i'm still sharing my screen here, but an example of the seismic air gun air pulse. Do you mind if I share my screen?

DOSITS: Please your share screen.

Aaron Thode [sharing screen]: So, going back to this picture here [the one about the seismic airgun trace using Gundalf TM]. This spectrum here shows the amplitude of the various tones comprising this airgun signal. So in your model, yes, when you take the output of your model say at 40 hertz, you then have to weight that by the amplitude shown here. Whereas when you take the output of your model at 85 hertz, you're going to be weighted by an amplitude that's much, much less, 80 dB quieter. So yes, you have to weight each frequency output by the relative amplitude; and the Fourier Synthesis requires you to do that. That's how you can generate any particular sound because you can always find a different combination of amplitudes to weight the frequencies.

Question: I'm wondering what your thoughts are on using AI to "learn" a propagation model? i.e. What, what do you think about using artificial intelligence or machine learning to learn a propagation model?

Answer: (Dr. Aaron Thode) Yes, people are working on subjects and you know in certain instances, it does very well. The issue is with any machine learning algorithm it's really an interpolation scheme, in other words it's best used in applications that are very similar to the data it was trained on. So, if you're training data on a shallow water environment, for example, and trying to model the sound using what you measure there, you just can't take that information and transfer it to a different water depth, for example. So, you end up having to use an enormous amount of data to do the acoustic propagation. A topic of much interest is what they call physics-based machine learning where, Can we use our knowledge of how sound propagates in the ocean to reduce the amount of data you might need for machine learning algorithm? So, it's a research program in progress, it's not something that's used on a standard basis for marine mammals sound impacts.

DOSITS: Okay, great Thank you very much Aaron. We really appreciate your presentation today and you spending your time with us.

<u>Questions asked/answered in the chat box during the webinar:</u>

Question: How much do the wavelengths vary with Temperature? If you are using your rules of thumb can you put some confidence bounds on those?
Answer: Water sound speed varies with temperature; the warmer the water, the faster the sound. From the formula wavelength=(sound speed)/frequency, we see that warmer water will slightly increase the wavelength at a given frequency A one degree Celsius increase in temperature will increase the sound speed by 4 m/sec from 1500 m/sec, which increases the wavelength by about 0.3 percent (4/1500).

Question: For sound spreading (cylindrical) how do we account for the absorption/dissipation and reflection / superposition from the surface and bottom boundaries?
Answer: Thanks for your question! With cylindrical spreading, there is no accounting for absorption or reflection. You would need to add additional information/modeling to account for those aspects.

Question: How do we account for shock waves from pile driving (do they occur) and the thermodynamic raise in temperature (and speed of sound) in the models? Or do *these just get absorbed by the regression to the measurement?*
Answer: The DCSM is based on the shock wave from pile driving. The local increase in temperature caused by the impact is very local, pretty small, and from my understanding not modeled.

Question: Interesting talk. Thank you so much. I was wondering in shallow water habitats how low and high-frequency sounds distribute and whether propagate differently? Any cut off for specific frequencies? Thanks in advance!
Answer: Whether an ocean is "shallow water" depends on the frequency you are considering. For a fixed water depth (say 50 m or less), a high frequency sound will be a sound with a wavelength less than 10% of the water depth. Its propagation will be dominated by sound speed profile effects and bottom effects. Sounds with lower frequencies tend to be more influenced by the bottom properties.

Question: Is the sound channel an area where there is a lot of marine life?
Answer: Thanks for your question! Sound channels are determined by the sound speed profile - the temperature and salinity profiles. Here is a page on DOSITS for more information: https://dosits.org/science/movement/sofar-channel/sound-channel-variability/

Question: Why do they not plot transmission loss in greyscale with dark as the stronger?
Answer: Thanks for your question! Transmission loss could certainly be plotted with greyscale, but it is often easier to discriminate colors so a color ramp is often used whenever possible.

Question: And how is sound distributed in different frequencies for fish tanks under laboratory conditions? For instance, when we study anthropogenic sound effects on fish behaviour? Any suggestions and recommendations for doing sound-related studies in fish tanks? :)
Answer: Modeling sound in fish tanks is very difficult because the sound is bouncing off all surfaces of the tank, making the modeling complicated. You need a tank much larger than an acoustic wavelength. The article here might be useful -> https://www.researchgate.net/profile/Anthony-Hawkins-2/publication/284888357_Parvulescu_Revisited_Small_Tank_Acoustics_for_Bioacousticians/links/62061e2fcf7c2349ca08cb99/Parvulescu-Revisited-Small-Tank-Acoustics-for-Bioacousticians.pdf

Question: Do acoustic models typically include or account for geophony? Or is that considered negligible?
Answer: Hi Alanna - I am not sure what you are trying to ask. Geophony relates to sounds that are produced by natural occurrences. Do you mean to ask if those sounds can be covered with propagation models?
Alana follows: Hi Kathy, sorry I can't respond on the Q&A. But yes, for example on the Fourier Synthesis slide showing square wave synthesis. I was just curious if geophony is a standard consideration in addition to whatever acoustics are being targeted. Biophony was mentioned. Apologies if that doesn't make sense.
Answer: With propagation modeling, the modeler inputs information on the sound source, which could definitely include natural environmental sounds. Some acoustic models consider how the geology of the region (seafloor interactions) influences the propagation.

Question: How can we best balance using simplifying assumptions with ensuring that our models are representative of realistic conditions?
Answer: You've hit upon the key question! The only way to be sure is to compare model predictions with measurements in the field (often called sound source verification studies). You can also compare the results of a simple model against those of a slightly more complicated model to decide whether the more detailed model substantially changes your estimates.

Question: What about where there are lateral reflections say in a fjord?
Answer: These are 3D propagation effects, and generally are considered a subject of ongoing research, and not typically modeled. There are some 3-D parabolic equation modeling programs. This article may help give you a start: -> https://asa.scitation.org/doi/abs/10.1121/1.5125130

Question: Is there a source to show the depth of the sound channel across both time and space variables?
Answer: Try this webpage: https://staff.washington.edu/dushaw/WOA/

Question: Is there any open-source software for modelling seismic sources?
Answer: There is not an open-source model of seismic sources that I know of, but I'm not sure. OASES by Henrik Schmidt is a prominent free model for seismo-acoustic propagation (http://lamss.mit.edu/lamss/pmwiki/pmwiki.php?n=Site.Oases).

Question: Could you outline the steps in going from calculated modal structure(s) to a full TL field?
Answer: See Eq. 4.25 from this reference: http://oalib.hlsresearch.com/Tindle%20class%20notes.pdf

Question: So, I assume if sound is deflecting off fish then marine debris have effects but in areas of "micro plastic soups." Has research explained what happens in these areas and how the constant/co-efficient of seawater would change? & So, salts affect sound. Are there studies that account for microplastics and marine debris in the same way?
Answer: If the sound wavelength is about the same size as the debris then there is complex scattering that is hard to model. For micro plastic soups, where the particles are much smaller than a wavelength, you can model by adjusting the effective density or sound speed of seawater.

Question: "It is fascinating to learn about the material composition of ocean bottom affects how the sound travels. Is there any further research on material relationship with water sound propagation we can look into? Could you explain a bit more on how clay (as compared to other sediments) change the process for instance? And are there other materials/components other than salt that can change the speed profile of water? Thank you."
Answer: "This is a classic paper on the subject: E.L. Hamilton, “Geoacoustic modeling of the sea floor,” J. Acoust. Soc. Am. 68, 1313–
1340 (1980). Also check out this more recent paper:
https://asa.scitation.org/doi/abs/10.1121/1.420313"

Question: Very interested to know more about wave number integration with respect to working in shallow water environment where near field calculations may be more feasible. I wondered if this is a webinar we can hope for in the future.
Answer: Yes, it was a tough call whether to include or not wave number integration in this webinar, and it definitely has a place for modeling scenarios in flat, shallow-water nearfield (less than a few water depth) environments. OASES by Henrik Schmidt is the most prominent free wave integration model that I am aware of.

Question: Are there modelling programs free to public or students or at a discount; *Are these software modeling programs?
Answer: https://oalib-acoustics.org is all free

Question: In bathymetrically complex areas with islets and depth variation in shallow water, what models are best to use. Does the complexity exponentially increase the effort due to this horizontal complexity?
Answer: In general, complex bathymetry increases the effort of modeling, the main problem being getting good inputs into the model, as well as accounting for differences in sound speed as well as bathymetry.

Post from webinar participant: Another emerging resource is web-based tools that make modeling and environmental data easier. One example is the Canadian-led Kadlu project — https://docs.meridian.cs.dal.ca/kadlu/