Computational Acoustics in Soundscape Ecology (C.A.S.E)

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Introduction

Soundscape ecology studies ecosystem dynamics by measuring and analyzing patterns in biological acoustic communication in the context of the local environment. Sound propagation is an important component to analysis but is subject to significant temporal and spatial variance at landscape scales. Consequently, acoustic data is subject to variance in filtration through propagation. The challenge is to quantify compositional, spatial and temporal variation in these patterns, but current analyses do not account for either variance in environmental filtration nor patterns in the acoustic field. This limits possible comparative analyses in the spectral domain. The CASE software is being developed to address this challenge; our hypothesis is that simulating terrestrial sound propagation conditions will quantify the impact of variable environmental filtration on acoustic recordings. Moreover, applying the inverse of this filtration gives researchers the ability to analyze across ecosystems by normalizing acoustic recordings. The prototype will be implemented to begin building a database of acoustical parameters, profiles, and patterns for CGS research locations, augmenting the expansive CGS data archive with spatial and temporal simulations of sound propagation.

C.A.S.E. Functionality

C.A.S.E. is a standalone application, written in MATLAB, that utilizes geometric and parabolic methods in computational acoustics in order to model sound propagation. The objective of this software is to normalize acoustic recordings by applying zero-max subtractive filtration derived from the inverse of model receiver responses. The primary contribution of this endeavor is the application of a Gaussian Starting Field to the Green's Function Parabolic Equation propagation model that includes a multiplicative factor to control the level of the model source (Gilbert, 1993). Further development will provide the ability to model, compare, and analyze the acoustical properties of terrestrial environments within the context of animal communication.

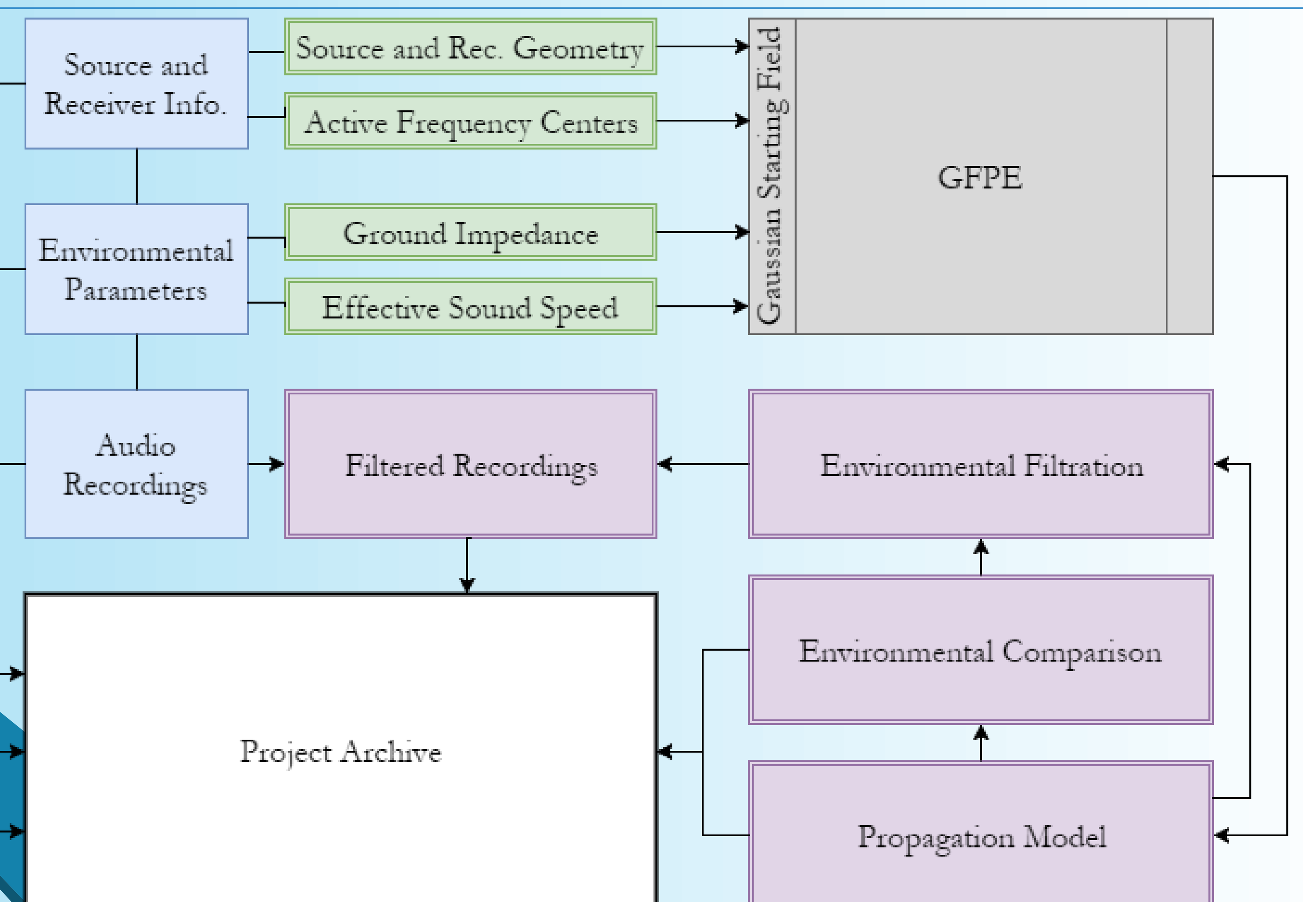


Figure 1: Program Structure and Flow of Data.

Method

GFPE: Gaussian Starting Field:

A starting field was derived by applying a Split-Step Fourier Algorithm to a Gaussian Pulse in the vertical wavenumber domain. A starting field can be produced for a signal of variant spectral intensities and modeled using the GFPE.

$$\Psi(r=0,z) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{ik_z z}\left\{\begin{matrix}\int_0^{\infty}\left(\frac{(L_{source}-L_{ref})}{6}+1\right)*\left(e^{-ik_z z'}e^{-(z'-z_{source})^2}dz'\right. \\ +R(k_z)*\int_0^{\infty} e^{-ik_z z'}e^{-(z_{source}-z')^2}dz'\end{matrix}\right\}dk_z$$

z = vertical height
k_z = vertical wavenumber
$R(k_z)$ = reflection coefficient
L = sound pressure level

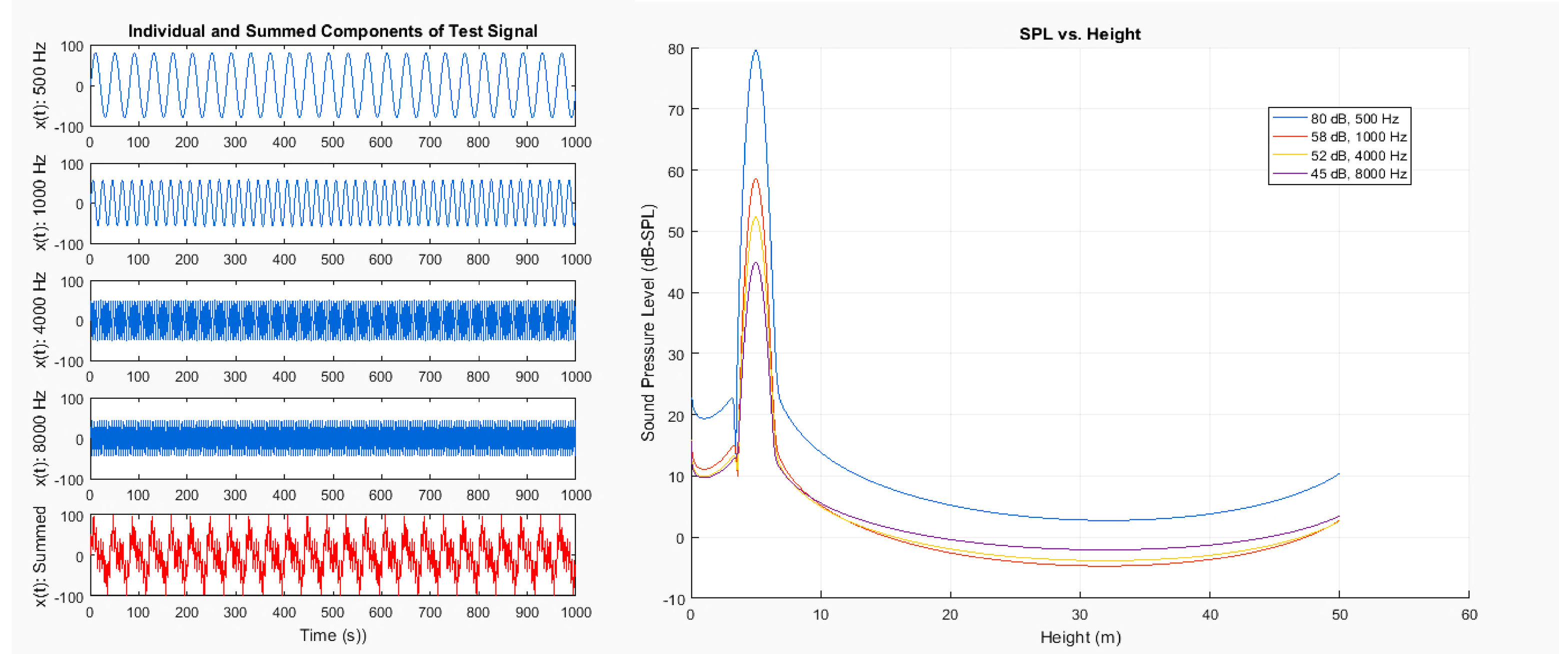


Figure 2: Gaussian Starting Fields for a Test Signal with Varying Intensities for 4 Different Frequencies. Source Height = 5m, Refraction = 1 m/s (Downward Refracting), over a Long Grass Field.

GFPE: Propagation Model:

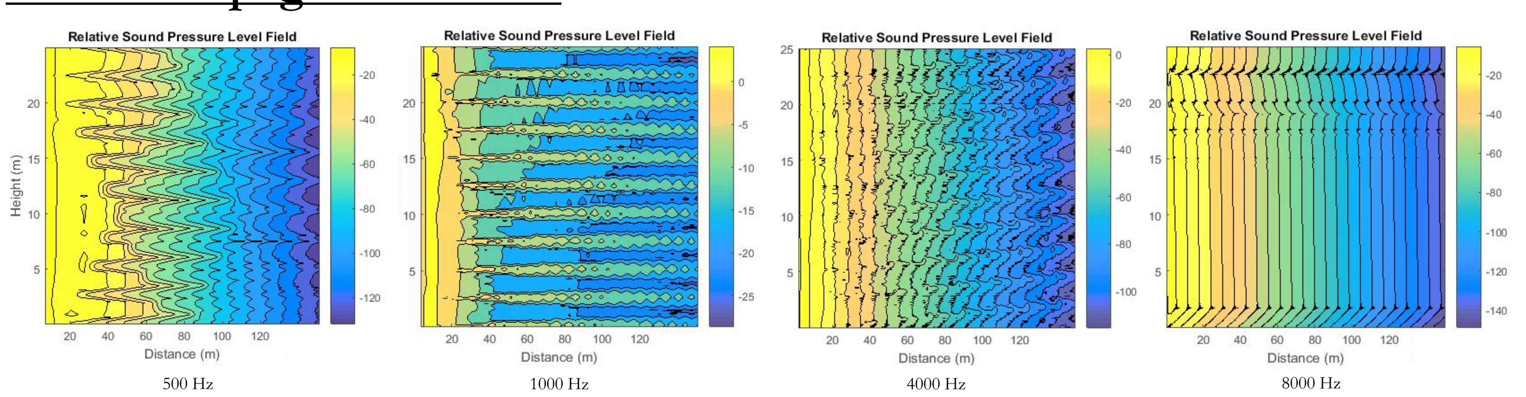
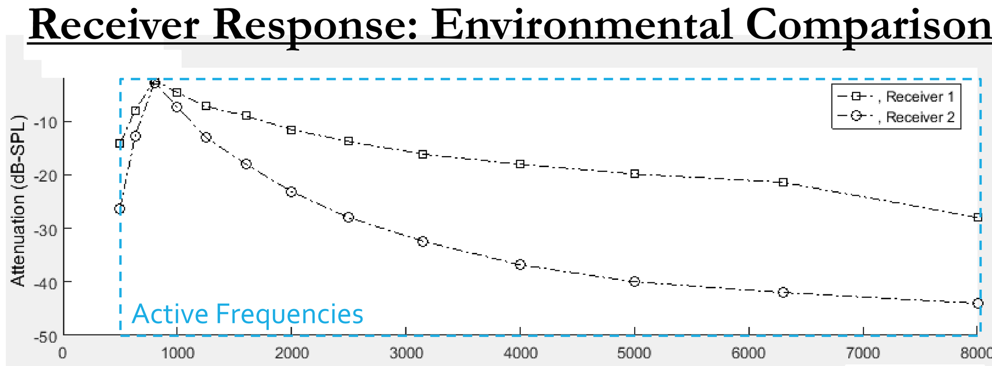


Figure 3: SPL Fields for 500 Hz, 1000 Hz, 4000 Hz, and 8000 Hz Using the Gaussian Starting Fields Shown in Figure 2.

Receiver Response: Environmental Comparison and Normalization:



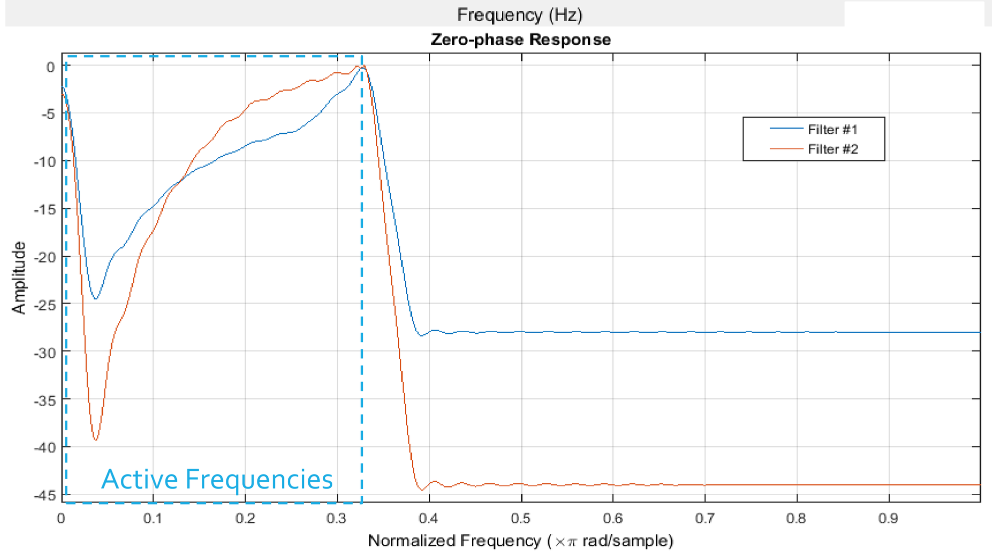


Figure 4: (TOP) Spectral Response Varies for Receivers at (5, 50) and (10, 100) m.

Figure 5: (BOTTOM) Subtractive Transfer Functions Derived from Spectral Responses at Each Receiver Location.

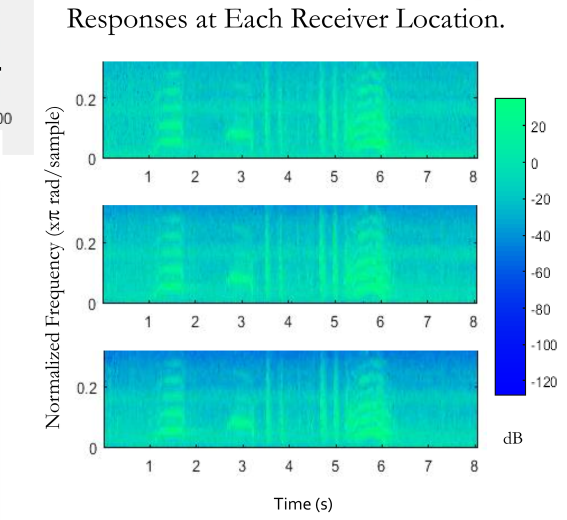
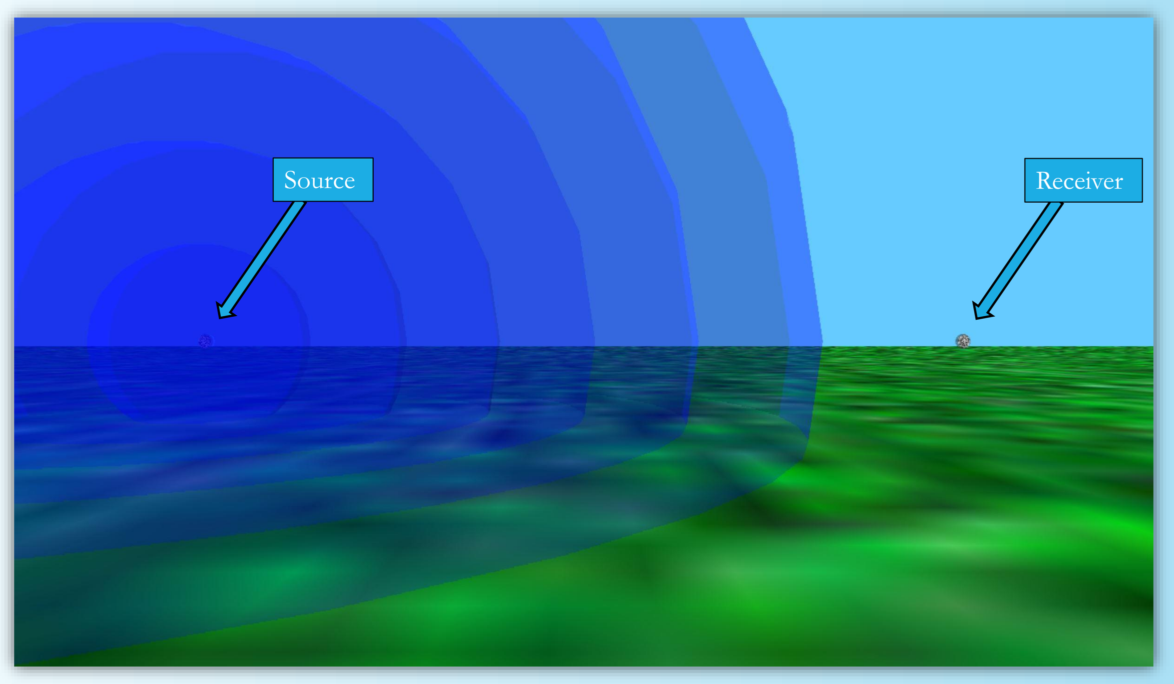
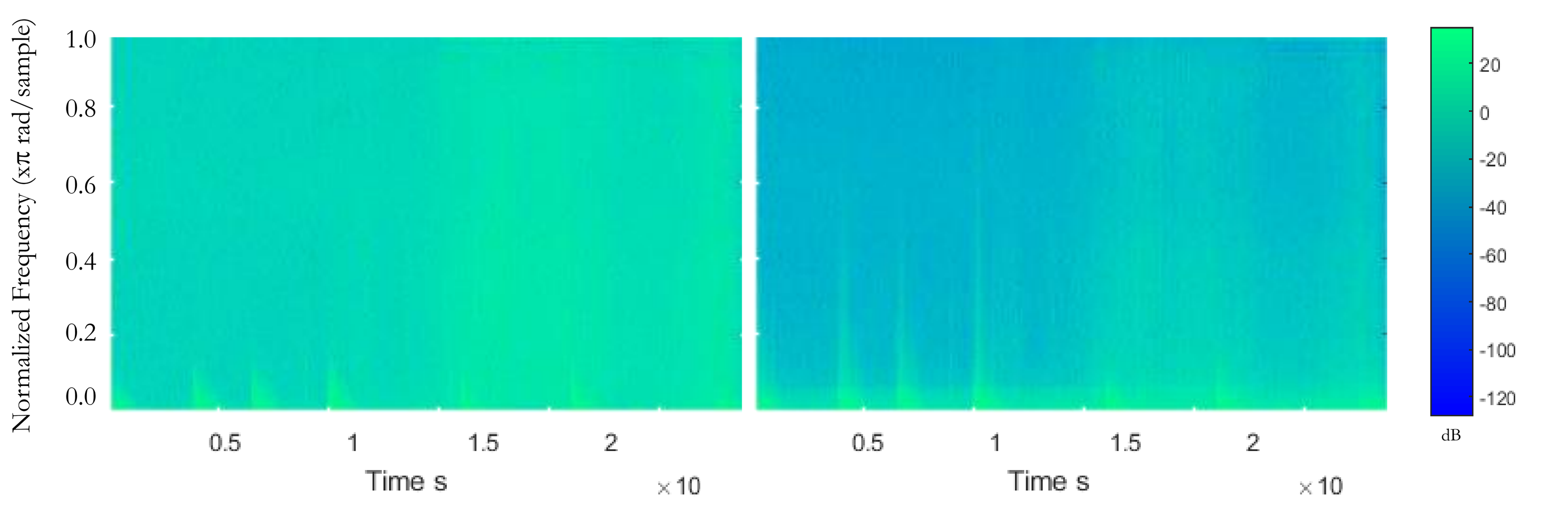


Figure 6: (ABOVE) Original and Normalized Signal in the Active Frequency Band with Varying Filter Strength. (Original, Filter 1, Filter 2)

Results

3D Modeling: The computed propagation data sets the parameters for a 3D animation of wave front spreading (shown right), ground surface reflections, and refraction of sound waves.





Full Band Normalization: The above spectrograms show the original (left) and normalized (right) acoustic recording of a thunder storm. The normalized spectrogram reveals previously masked components of the signal.

Discussion and Conclusion

C.A.S.E. is a tool that allows soundscape ecologists to more accurately compare the spectral components of recorded acoustic data from different environments. With this method, the impact of variant acoustic propagation conditions can be accounted for in soundscape analyses, as well as providing a new dimension in which the analyses can be performed.

C.A.S.E. addresses the aforementioned challenges to soundscape research and reflects the objectives of CGS research by:

- Improving existing recorded data for use in comparative analyses.
- Augmenting the Global Soundscapes archive with computed acoustic data.
- Constructing an interactive visual resource to expand the scope of soundscape analyses.

Further Development	Status	Intended Completion	Ref.
Terrain and Ground Structure	I.P.	December 2017	[9]
Sound Path Modeling	I.P.	December 2017	[9][3]
Sound Detectability	I.P.	December 2017	[2]

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Acknowledgements

Further development of this project's educational applications, highlighting the physics of sound and its relevance to the CGS initiative, can be found at iListen.org.

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