Radiative Transfer to Model Ocean Bottom Scattering

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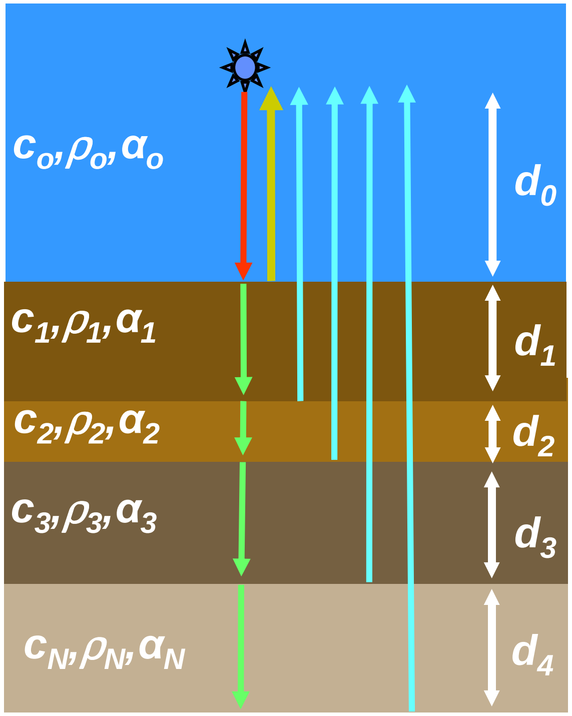
Classical Model with Homogeneous Layers



α_n: attenuation
$R_{n,n+1}$: Ref. coefficient between layers n and n+1
$T_{n,n+1}$: Trans. coefficient between layers n and n+1
k_n: wavenumber, where $k_n=\omega/c_n$

$$B_0(f)=R_{01}e^{-\alpha_0(f)2d_0}e^{-jk_0 2d_0}=R_{01}e^{-\alpha_0(f)2d_0}e^{-j2\pi f\overset{\tau_0}{\boxed{\frac{2d_0}{c_0}}}}$$

or in general

$$B_n(f)=R_{n,n+1}\prod_{q=1}^{q=n-1}T_{q+1,q}T_{q,q+1}\prod_{q=1}^{n}e^{\overbrace{-2\alpha_q(f)d_q}^{\sum\text{attenuation}}}e^{\overbrace{-j2\pi f\tau_q}^{\sum\text{phase}}}$$

$$H(f)=\sum_{n=1}^{N}B_n(f)$$

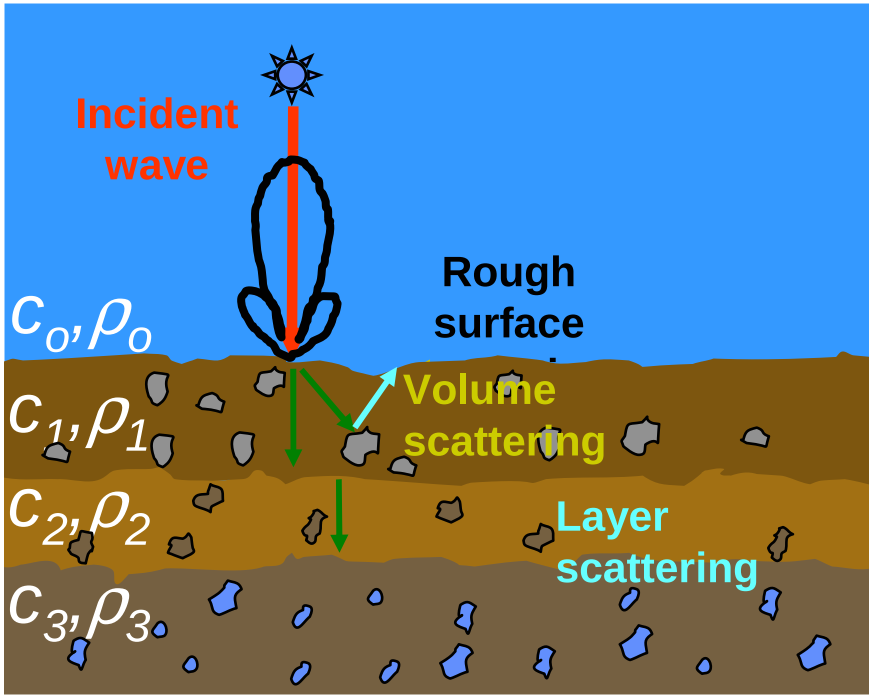
Transfer function

$$h(t)=F^{-1}\{H(f)\}$$

Impulse response of the layered media

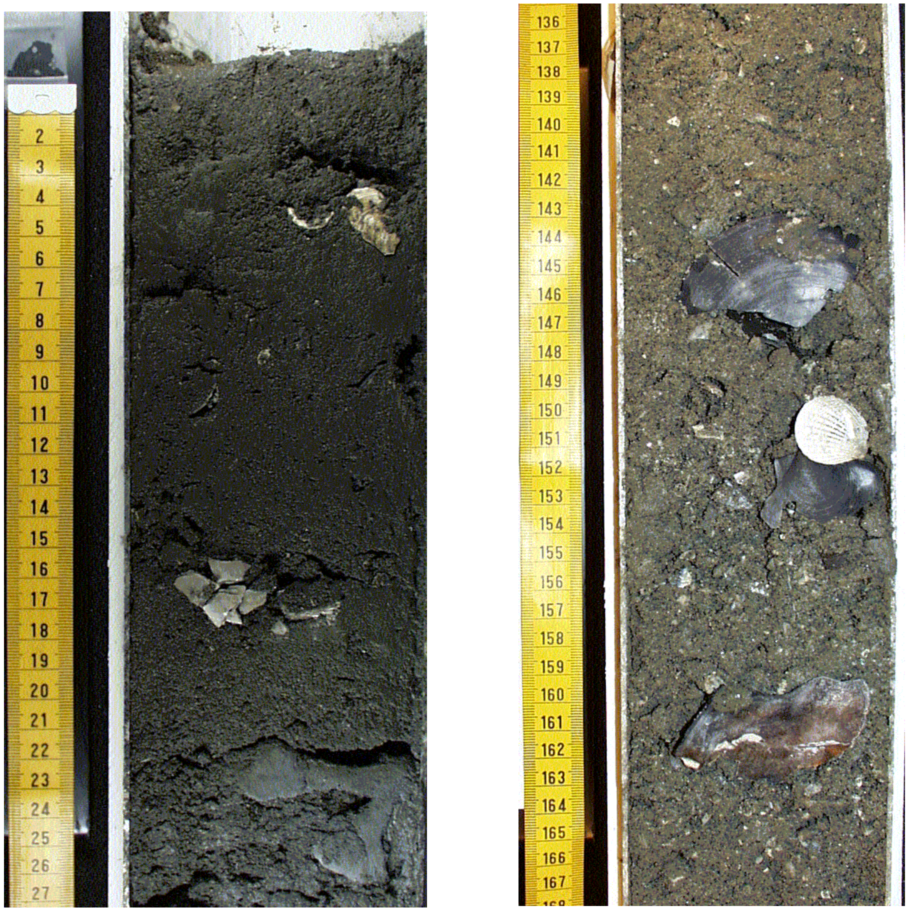
Problem: Can we handle more complex environments based on this formulation?

The Real environment



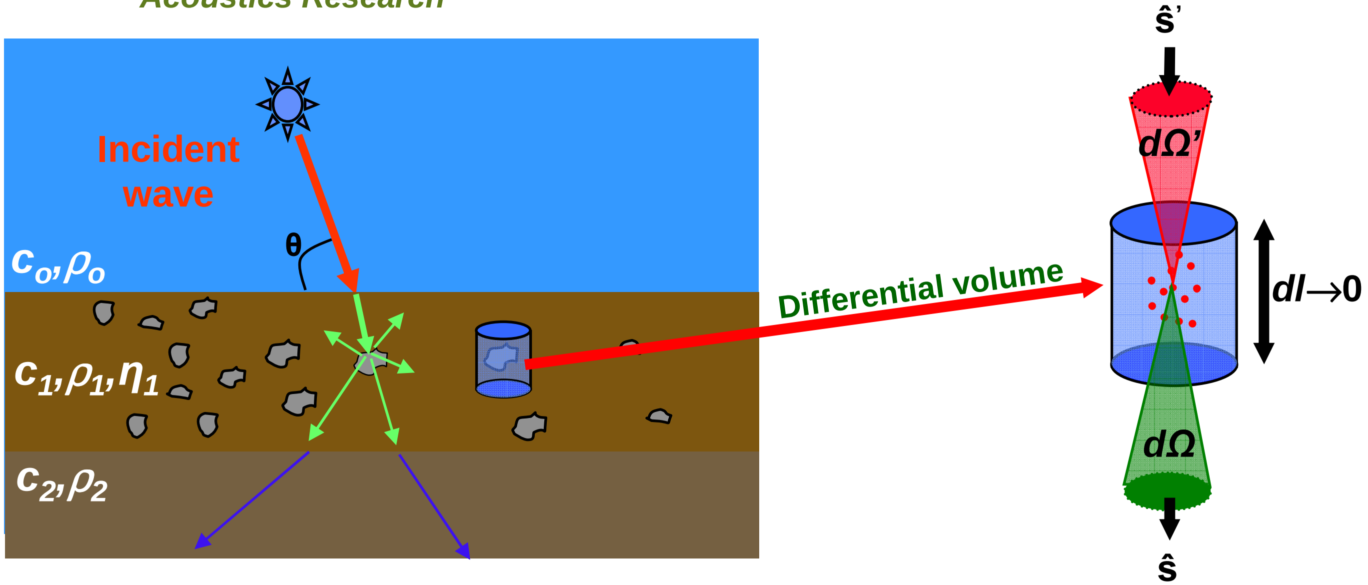
Goal: formulate a mathematical model that includes rough surfaces, volume scatterers and layers.

Examples of ocean bottom sediments



Core samples from the New Jersey shelf, courtesy of Dr. Altan Turgut, Naval Research Laboratory

Proposed Solution: Radiative Transfer Theory



dl: traveled distance
dΩ: diff. solid angle
ŝ': incoming direction
ŝ: outgoing direction

Output energy - Input energy = Emission-Extinction

Or

$$\frac{\partial I(l,t)}{\partial l} + \frac{1}{c}\frac{\partial I(l,t)}{\partial t} = \eta\varepsilon(l,t) - \eta\sigma I(l,t)$$

ε: emission coefficient
σ: absorption coefficient
c: speed of propagation
η: density of scatterers

Radiative transfer

- **Computationally less expensive.**
- **Describes intensity as a function of time, depth, direction of propagation within each layer.**
- **Characterizes layers in terms of emission and absorption coefficients.**