13.811
Advanced Structural Dynamics and Acoustics

Fundamentals of OCEAN ACOUSTICS

Figures in this lecture are from Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Generic Sound Speed Structure. Fig 1.1 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Global Sound Speed Structure. Fig 1.2 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

SOUND SPEED, SNELL'S LAW AND ATTENUATION

Sound Speed

$$c = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + (1.34 - 0.01T)(S - 35) + 0.016z. \quad (26)$$

$$\frac{\cos\theta}{c} = constant, \quad (27)$$

$$A = A_0 \exp(-\alpha x), \quad (28)$$

$$\alpha(dB/km) = 3.3\times10^{-3} + \frac{0.11 f^2}{1 + f^2} + \frac{43 f^2}{4100 + f^2} + 2.98\times10^{-4} f^2, \quad (29)$$

Units

- The decibel (dB) denotes a ratio of intensities (not pressures) expressed in terms of a logarithmic (base 10) scale.
- Two intensities, I_1 and I_2 have a ratio, I_1/I_2 in decibels of $10 \log I_1/I_2$ dB. Absolute intensities can therefore be expressed by using a reference intensity.
- The accepted reference intensity is a micropascal (μPa): the intensity of a plane wave having an rms pressure equal to 10^{-5} dynes per square centimeter.
- Therefore, taking 1 μPa as I_2, a sound wave having an intensity, of, say, one million times that of a plane wave of rms pressure 1 μPa has a level of $10 \log(10^6/1) \equiv 60$ dB re 1 μPa.
- Pressure (p) ratios are expressed in dB re 1 μPa by taking $20 \log p_1/p_2$ where it is understood that the reference originates from the intensity of a plane wave of pressure equal to 1 μPa.
- The average intensity, I, of a plane wave with rms pressure p in a medium of density ρ and sound speed c is $I = p^2/\rho c$. In seawater, ρc is $1.5 \times 10^5 \geq cm^{-2}s^{-1}$ so that a plane wave of rms pressure 1 $dyne/cm^2$ has an intensity of $0.67 \times 10^{-12} W/cm^2$. Substituting the value of a micropascal for the rms pressure in the plane wave intensity expression, we find that a plane wave pressure of 1 μPa corresponds to an intensity of $0.67 \times 10^{-22} W/cm^2$ (i.e., 0 dB re 1 μPa).

Schematic of Sound Propagation Paths. Fig 1.6 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Geometric Spreading. Fig 1.5 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Lloyd Mirror Effect. Fig 1.8 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Deep Sound-channel Propagation (Norwegian Sea). Fig 1.11 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

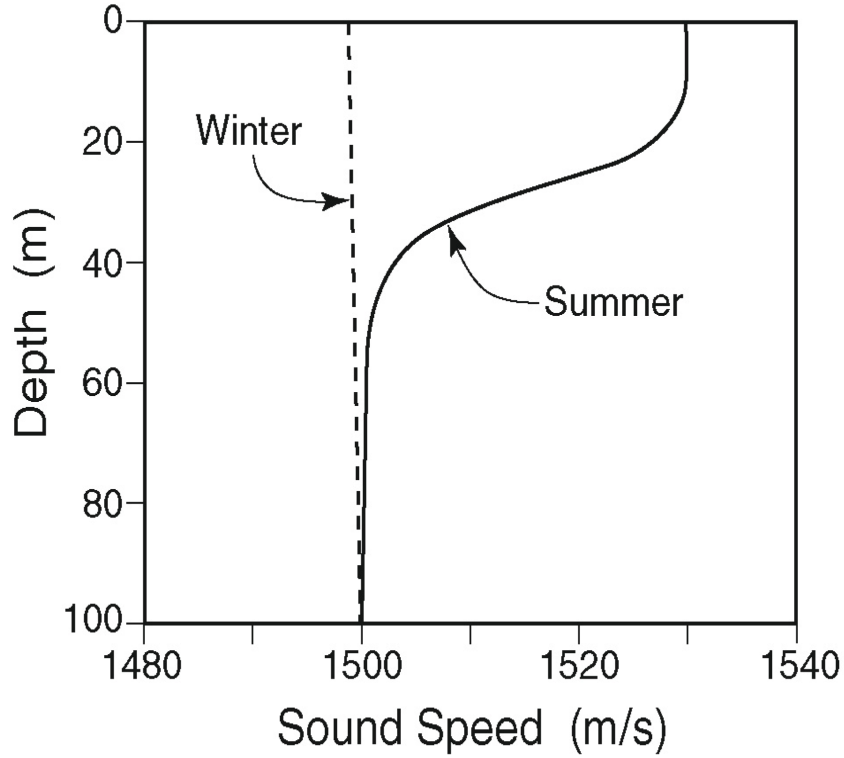
Surface-duct Propagation (Norwegian Sea). Fig 1.12 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Convergence Zone Propagation (Norwegian Sea). Fig 1.9 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

ARCTIC PROPAGATION

Artic Propagation Fig 1.13 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

SHALLOW WATER SOUND SPEED PROFILES



REFLECTIVITY AND SHALLOW WATER PROPAGATION

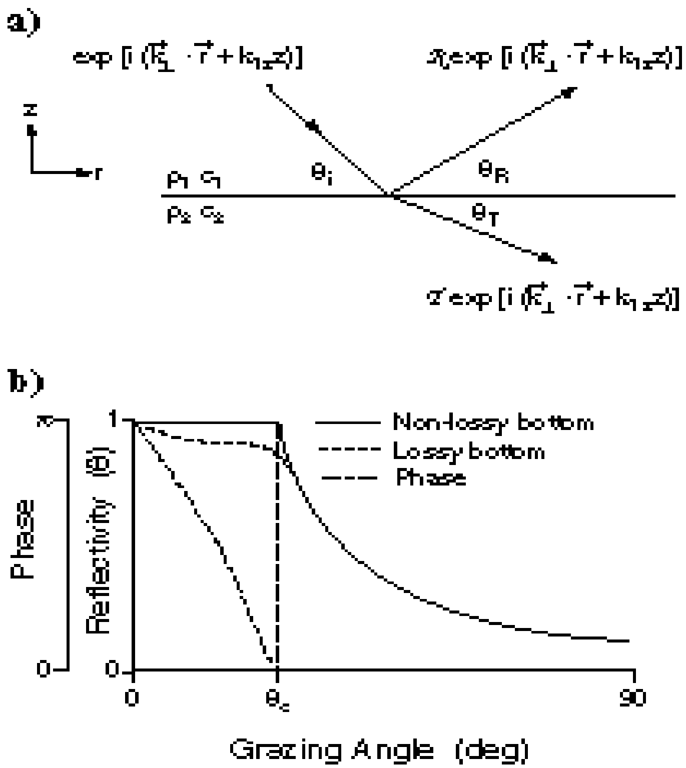
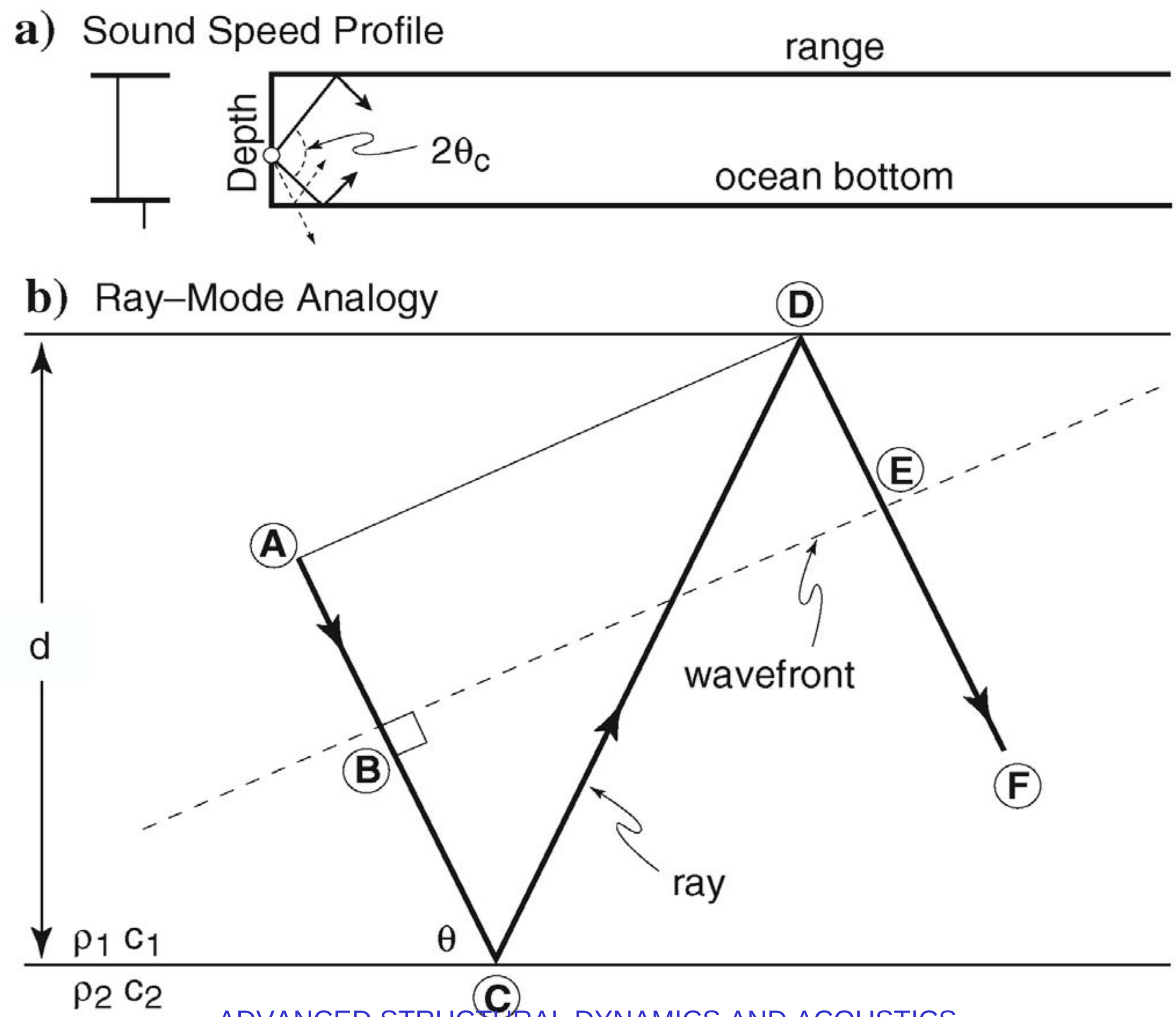
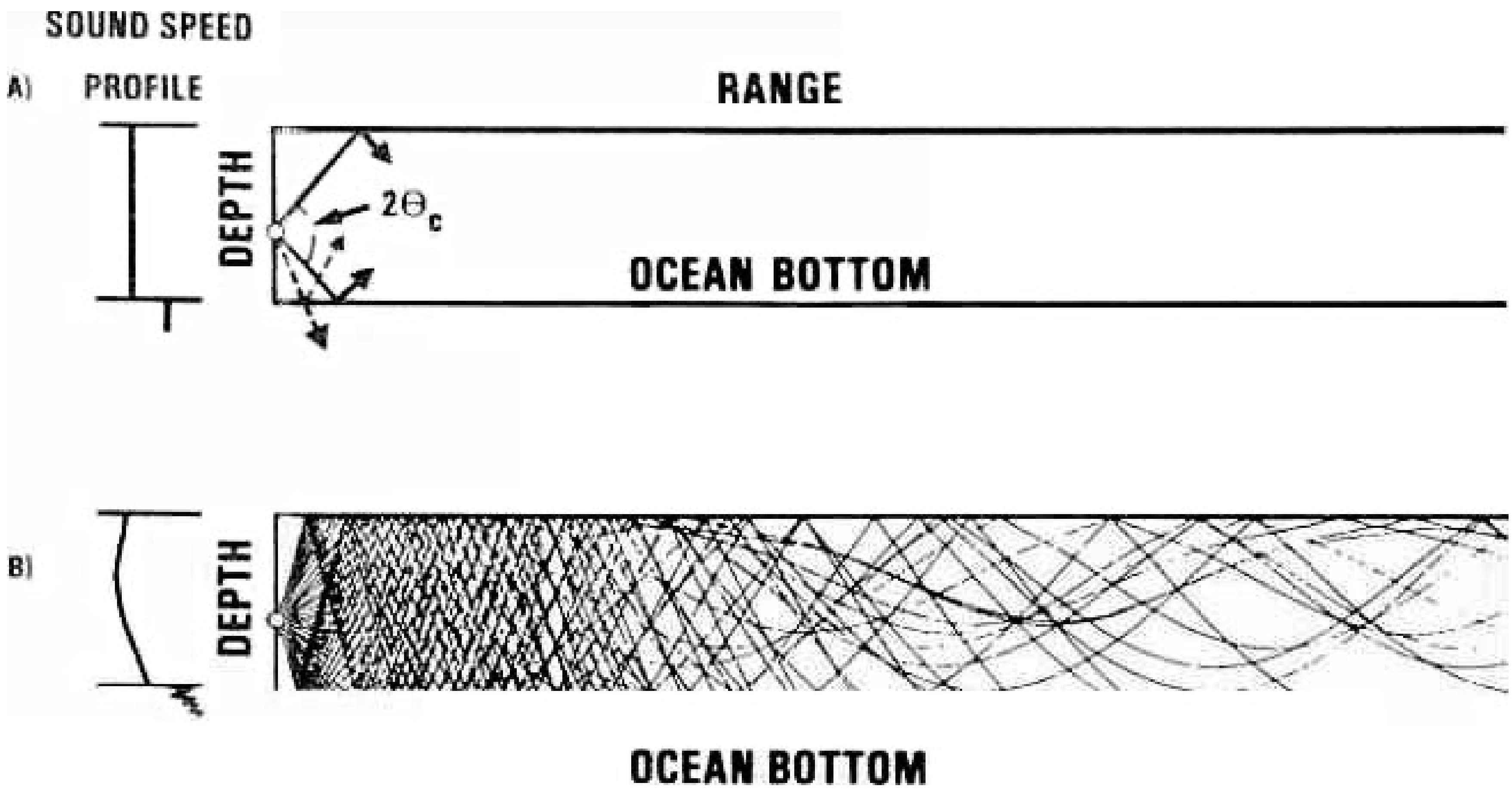


Diagram: Fig 1.21 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

CONSTRUCTIVE INTERFERENCE: MODAL PROPAGATION



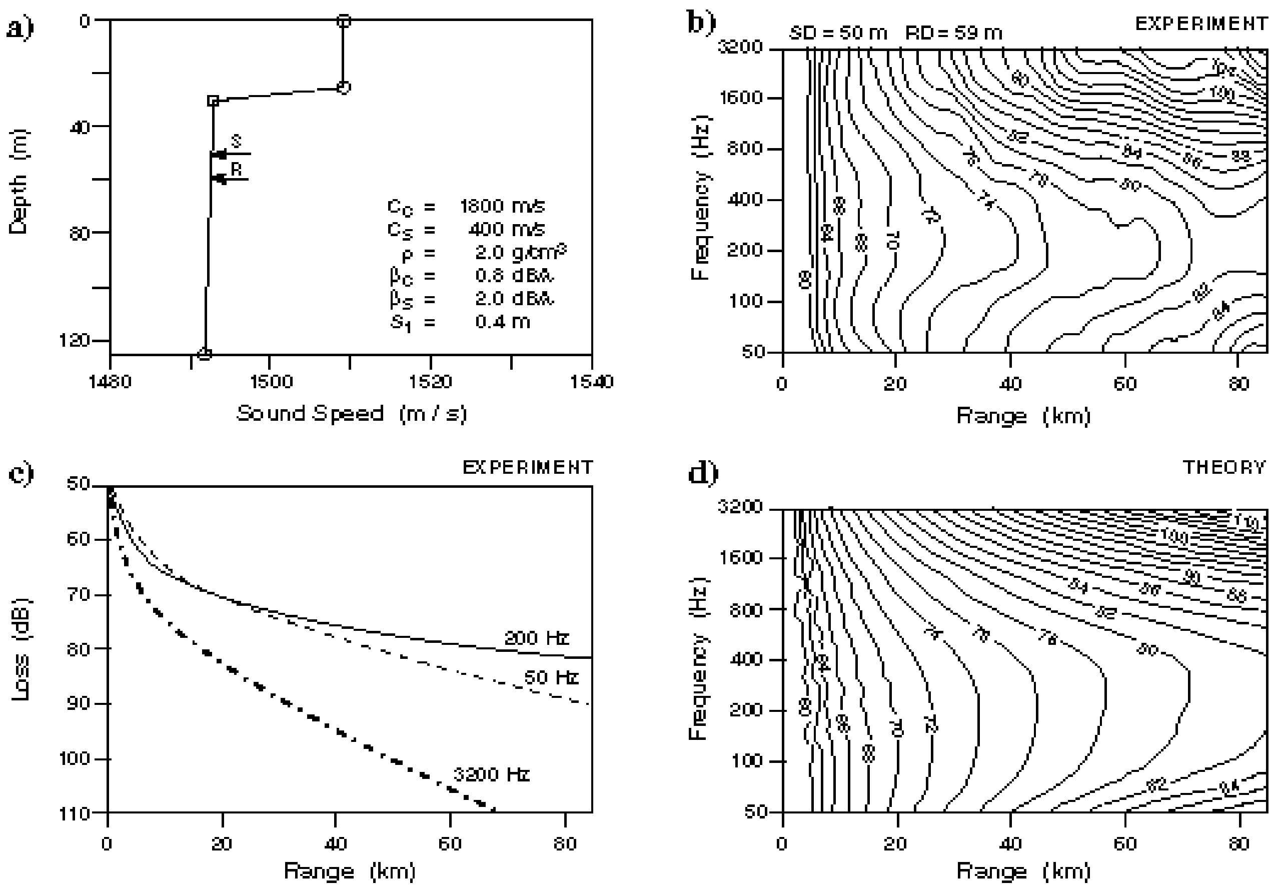
SHALLOW WATER PROPAGATION



Shallow-water Propagation (Summer, Mediterranean) Fig 1.14 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Contoured Propagation Loss: “Optimum Frequency Curves” Fig 1.16 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

OPTIMUM FREQUENCY CURVES



Propagation in a Range Development Environment. Fig 1.17 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

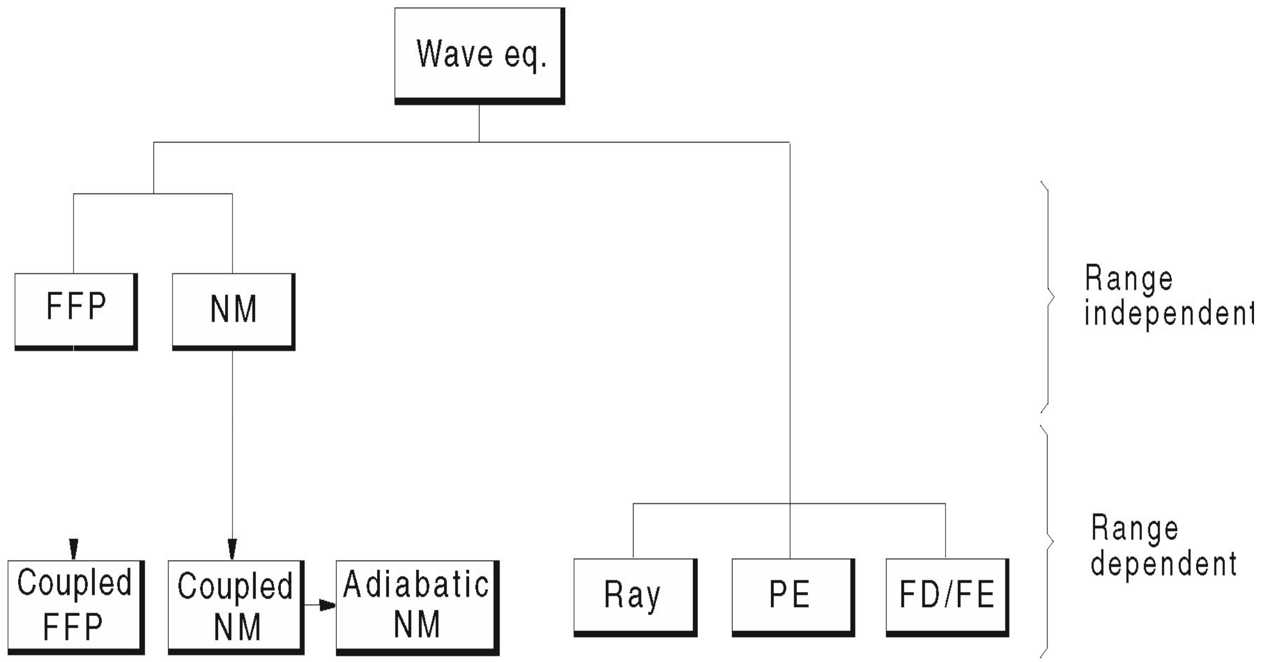
Propagation Over a Seamount (North Pacific). Fig 1.18 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Attenuation of Sound in Seawater (Urick). Fig 1.19 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

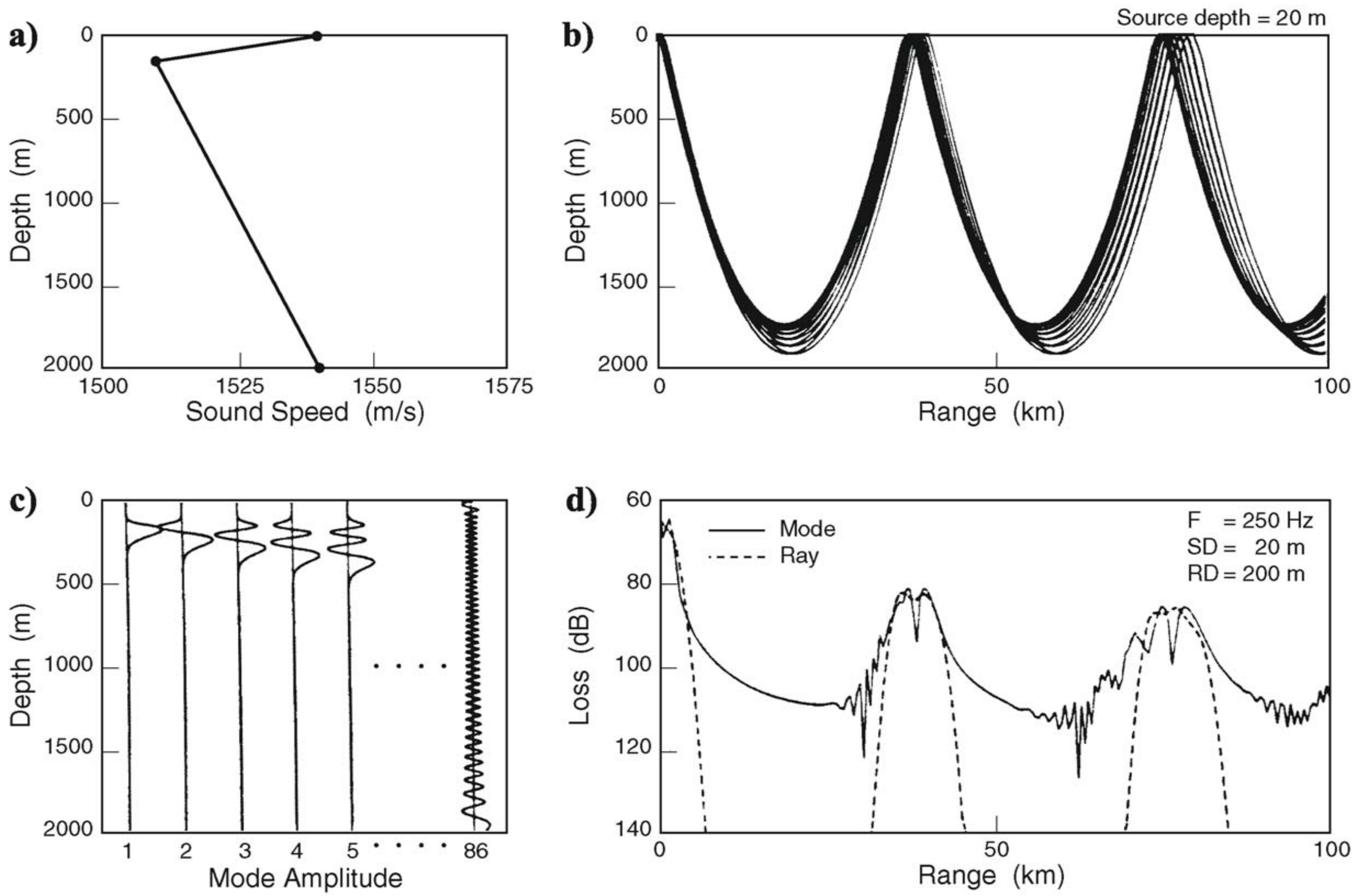
Day and Night Scattering Strengths (Chapman and Marshall). Fig 1.25 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

Ambient Noise Spectra (Wenz). Fig 1.26 Jensen, F.B., W.A. Kuperman, M.B. Porter, and H. Schmidt. *Computational Ocean Acoustics*. New York: AIP Press/Springer, 2000. ISBN 0387520147

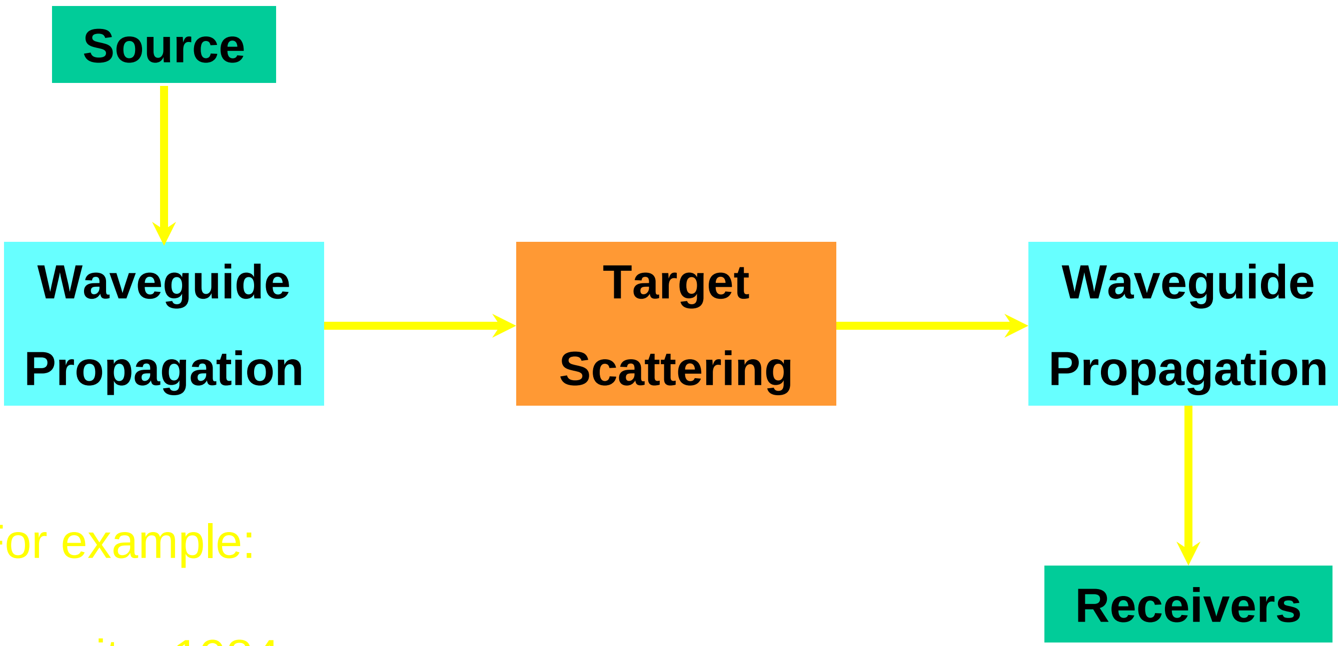
HIERARCHY OF UNDERWATER ACOUSTIC MODELS



MODEL CONSISTENCY: MODES AND RAYS



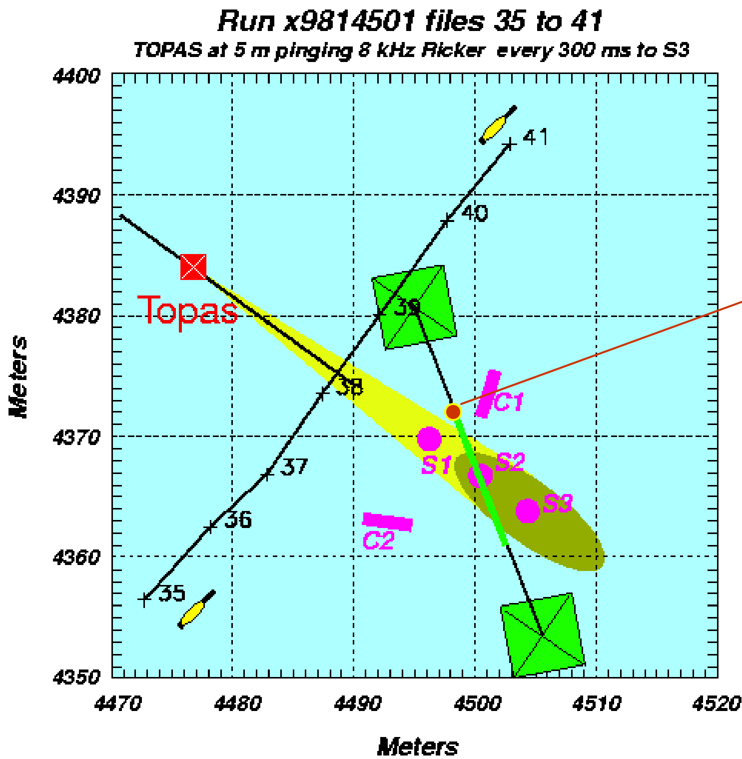
Target Scattering in Ocean Waveguides
Single Scatter Approximation

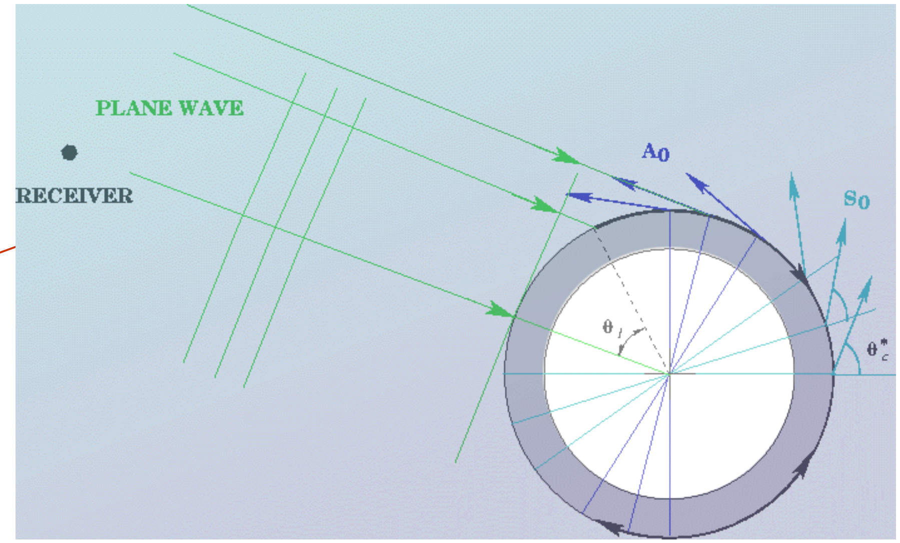


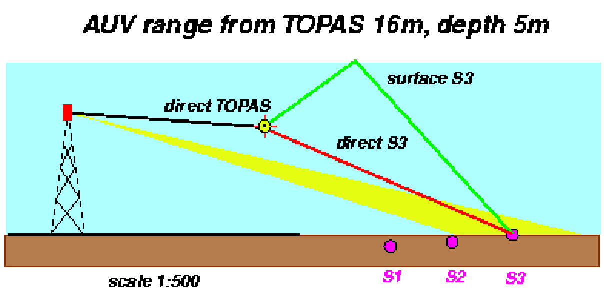
For example:

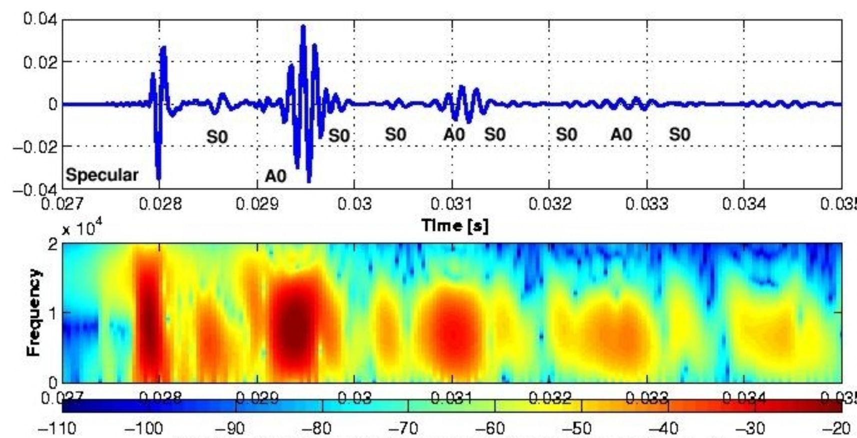
Ingenito, 1984
Fawcett, 1997
Lim, 1997
Schmidt and Lee , 1998
Makris, 1999

GOATS'98
Mono-static, Super-critical Scattering









Analysis by Tesei etal. , JASA 2000