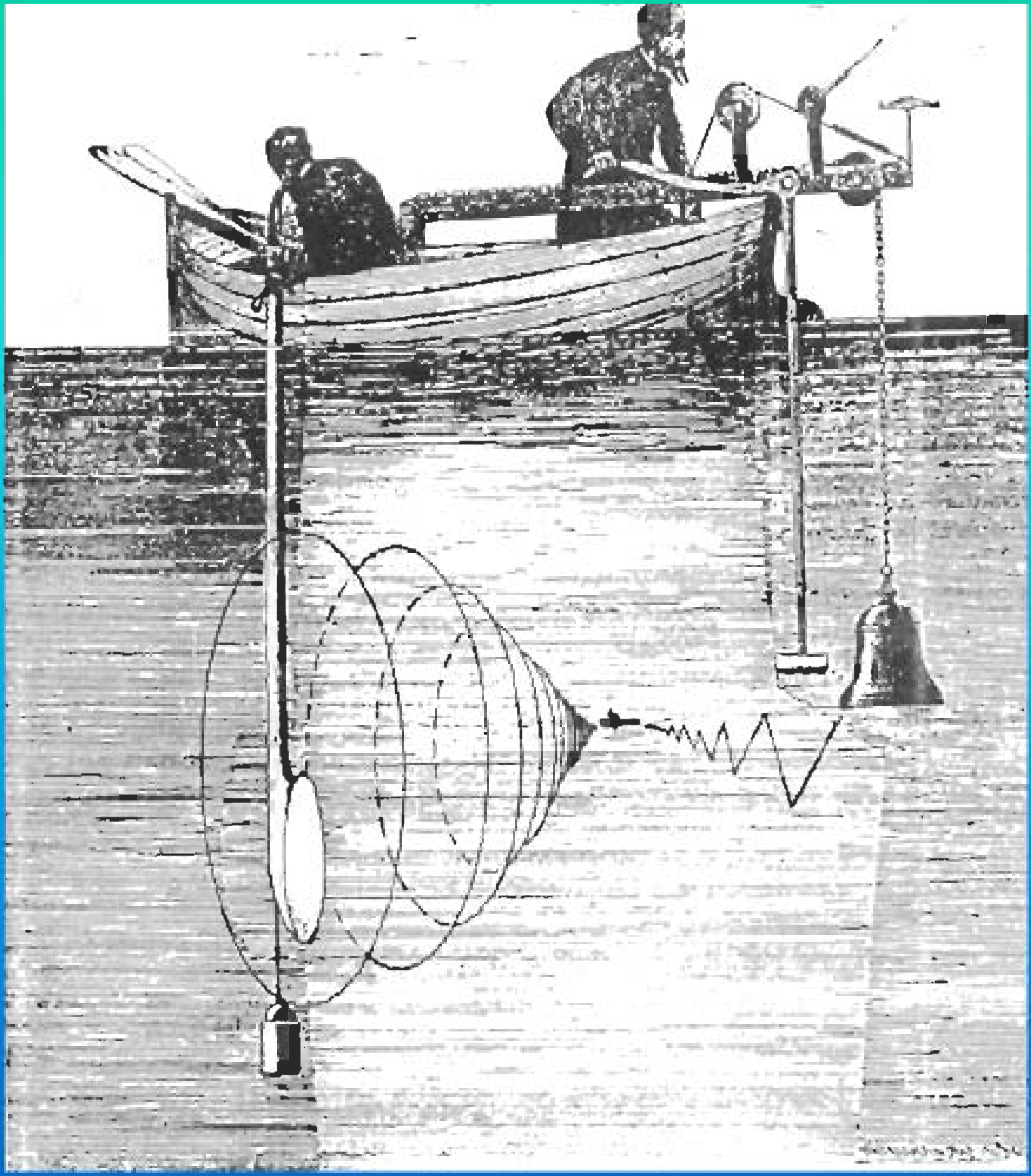
Computational Ocean Acoustics

13.853

H. Schmidt – MIT

Lecture 1

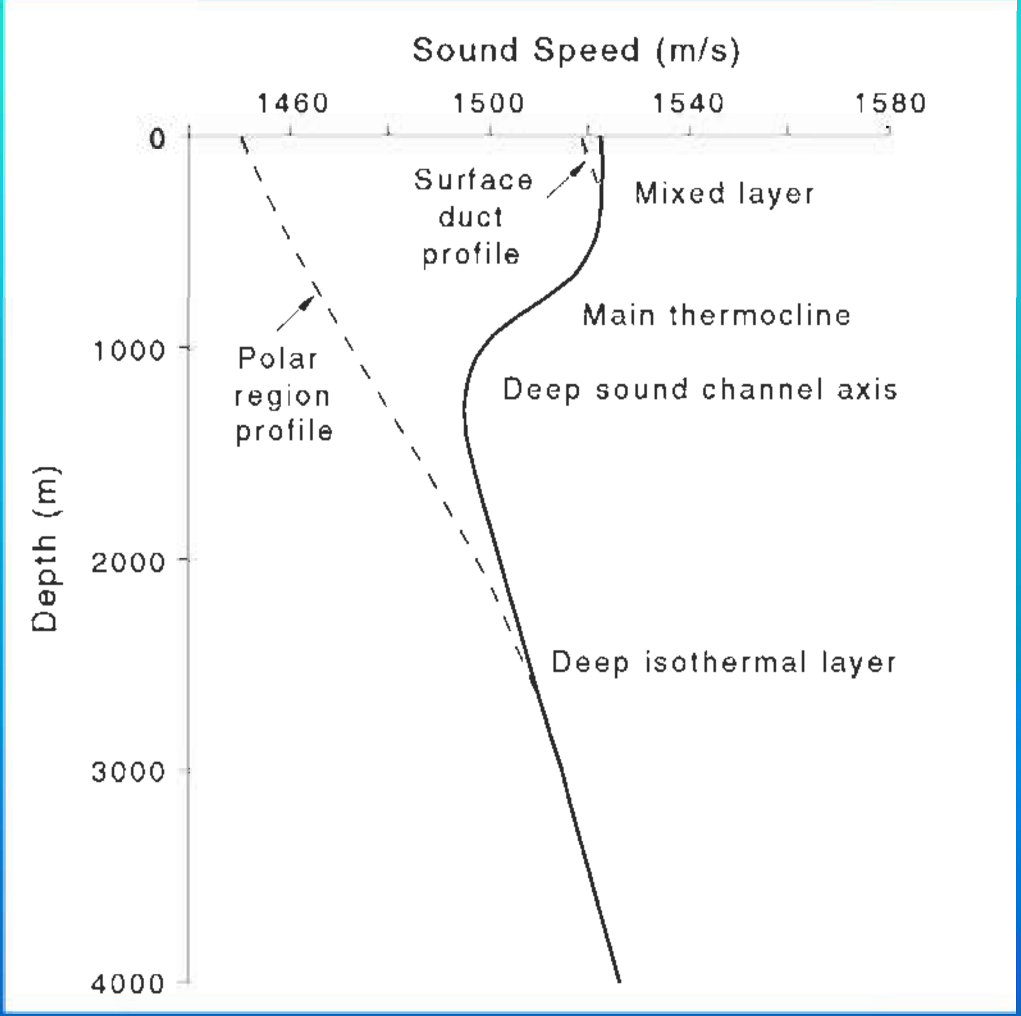
"Active Sonar"



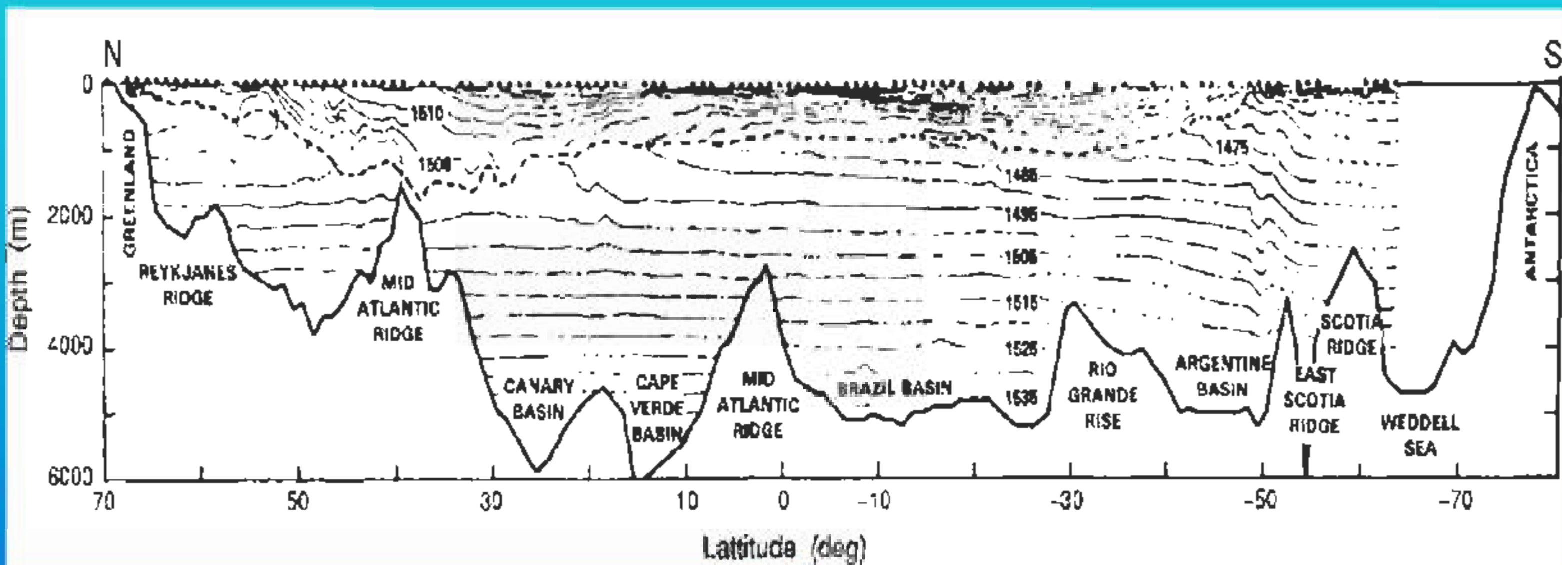
Cut and paste from:

Colladen and Sturm
Lake Geneva 1826

GENERIC SOUND SPEED STRUCTURE



GLOBAL SOUND SPEED STRUCTURE



SOUND SPEED, SNELL'S LAW AND ATTENUATION

Sound Speed

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

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

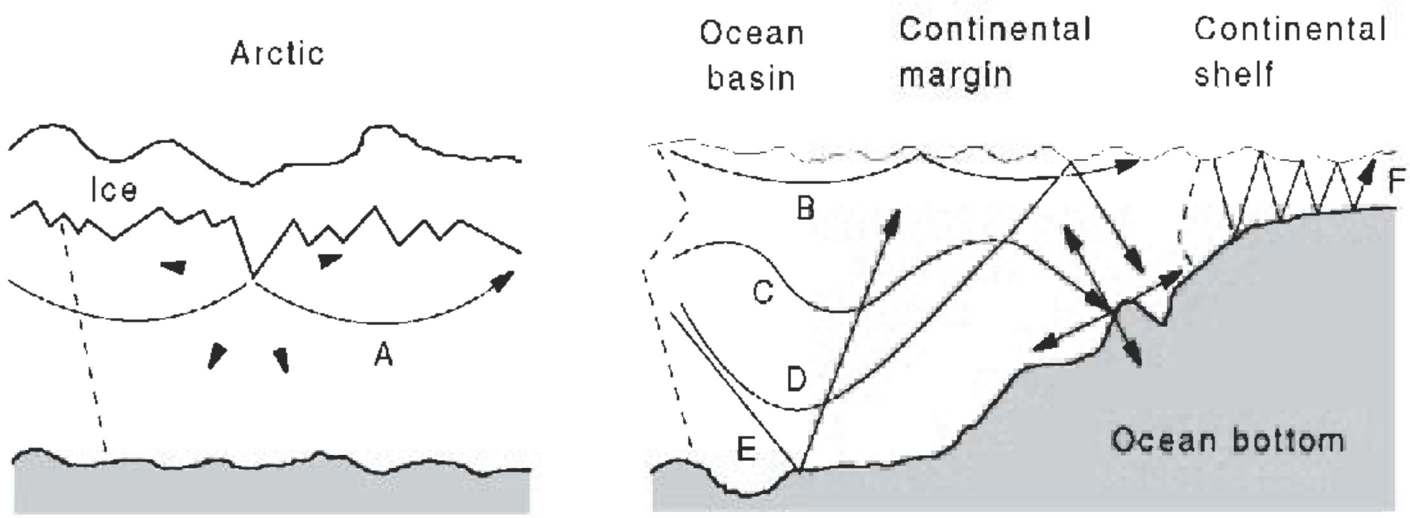
$$A = A_0 \exp(-\alpha x), \quad (28)$$

$$\alpha(dB/km) = 3.3 \times 10^{-3} + \frac{0.11 f^2}{1 + f^2} + \frac{43 f^2}{4100 + f^2} + 2.98 \times 10^{-4} f^2. \quad (29)$$

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).

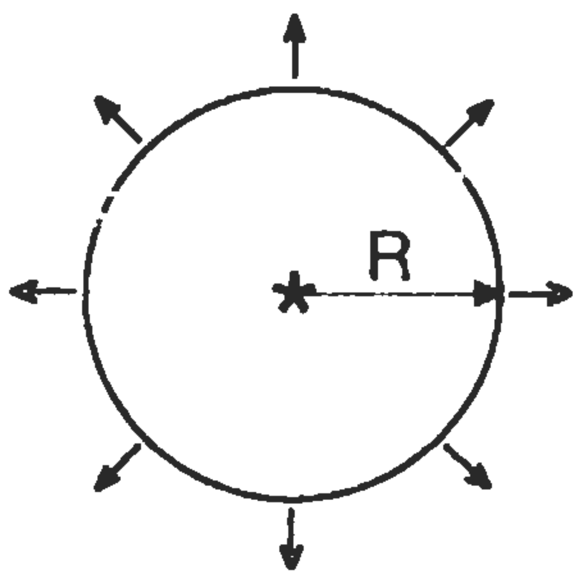
SCHEMATIC OF SOUND PROPAGATION PATHS



A.	Arctic	D.	Convergence zone
B.	Surface duct	E.	Bottom bounce
C.	Deep sound channel	F.	Shallow water

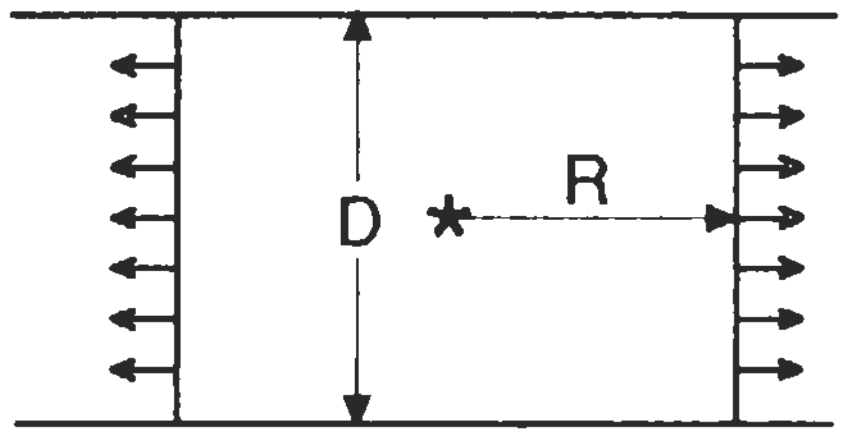
GEOMETRIC SPREADING

(a) Spherical spreading



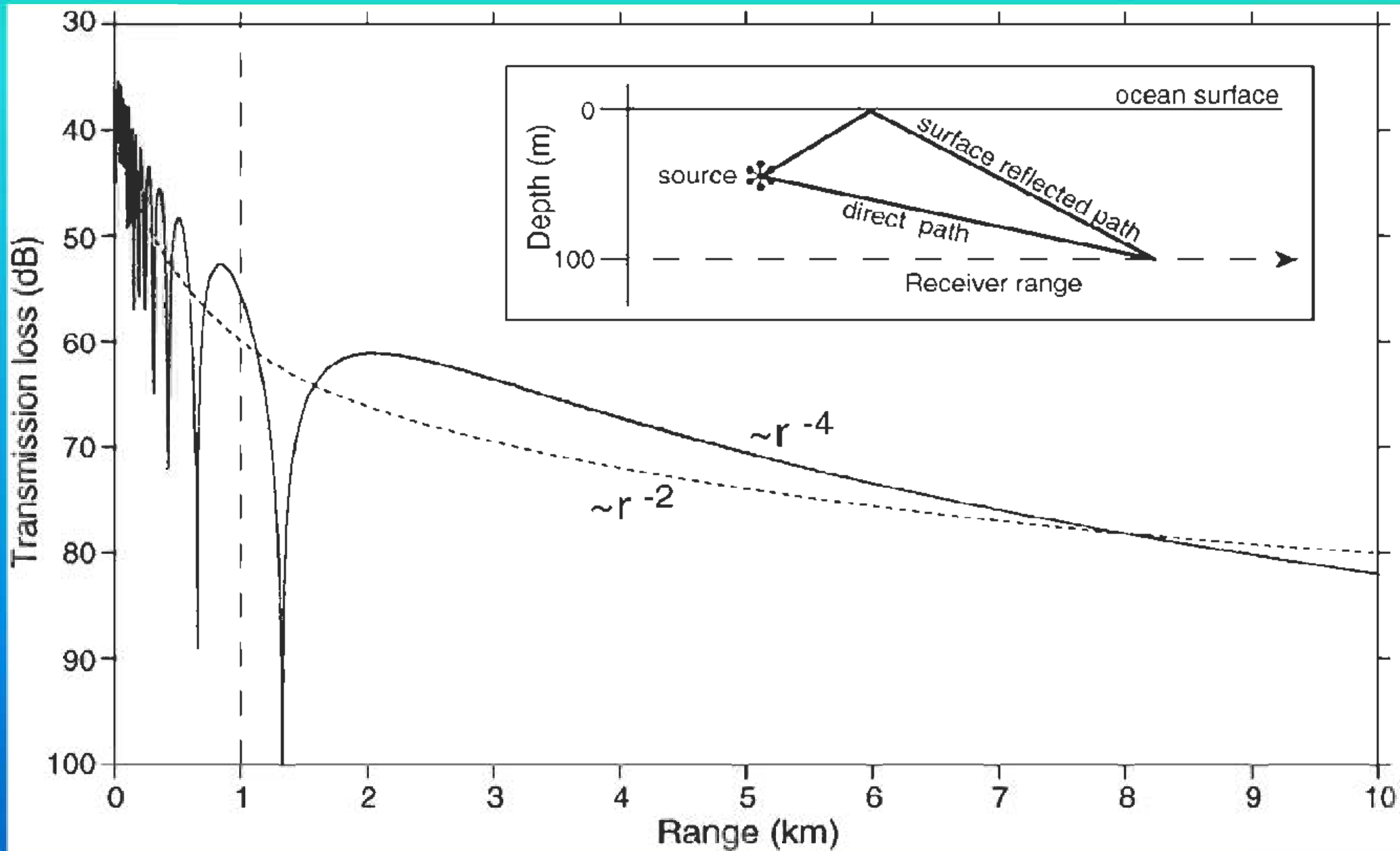
$$I \propto \frac{1}{4\pi R^2}$$

(b) Cylindrical spreading

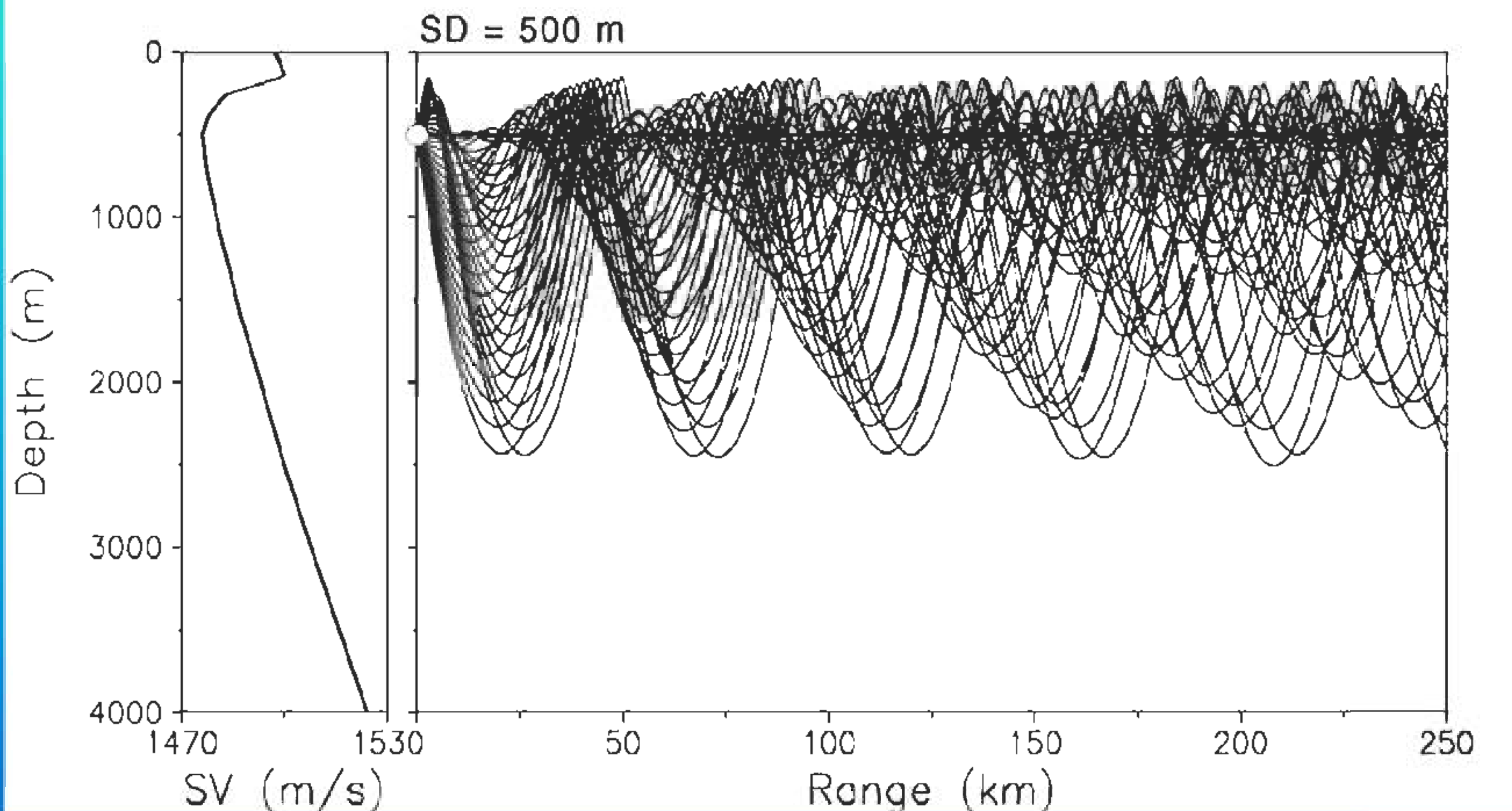


$$I \propto \frac{1}{2\pi R D}$$

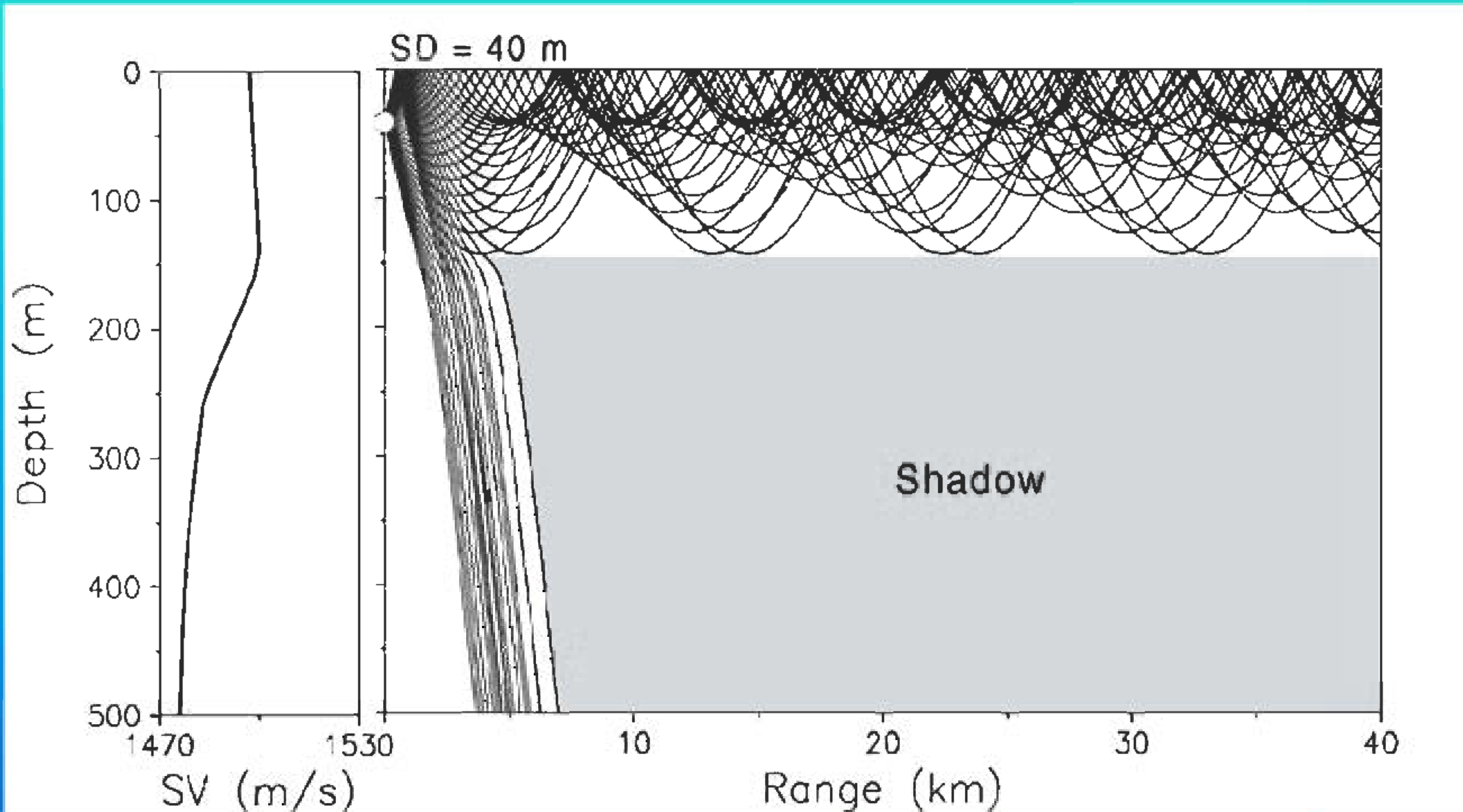
LLOYD MIRROR EFFECT



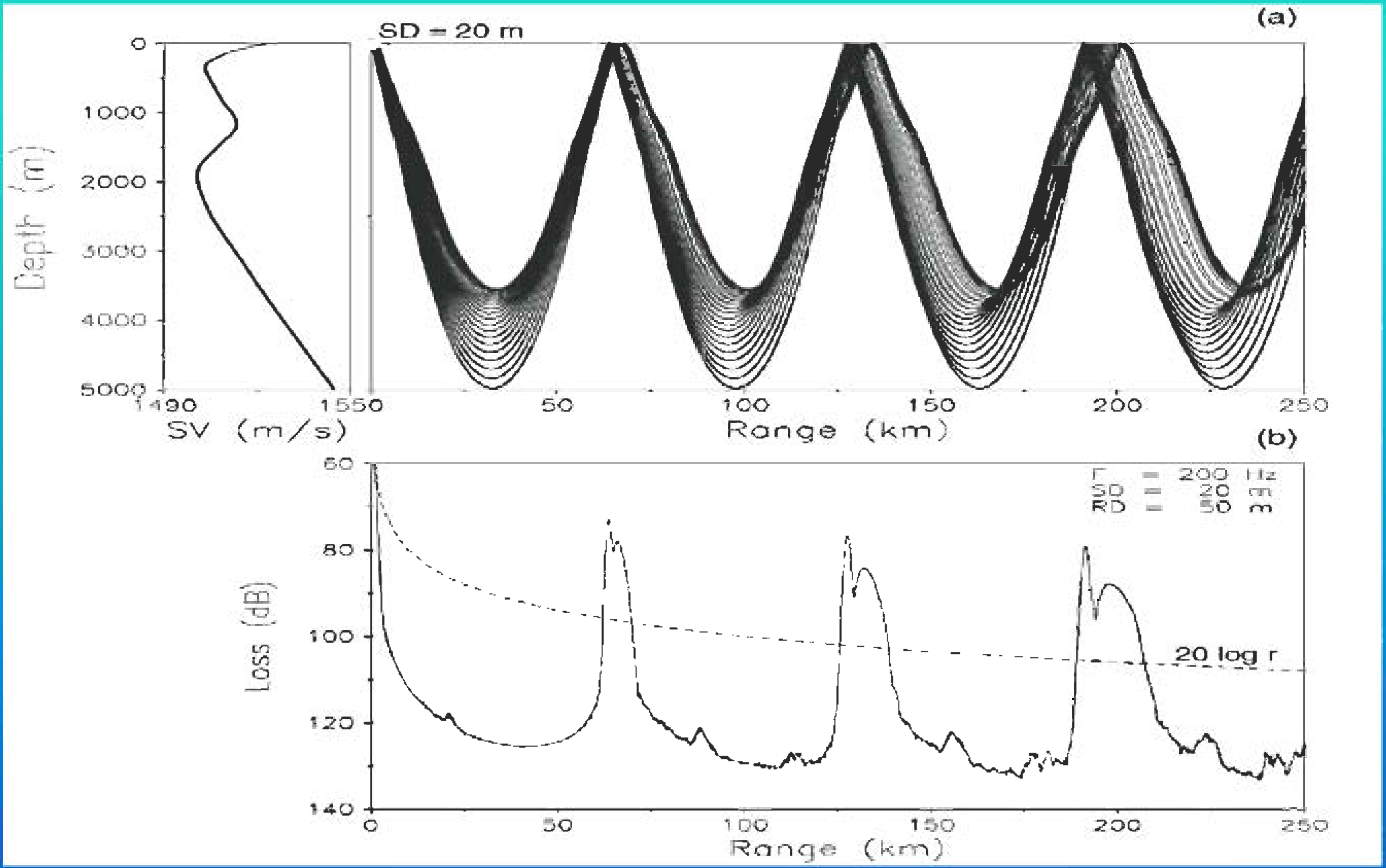
DEEP SOUND -CHANNEL PROPAGATION (NORWEGIAN SEA)



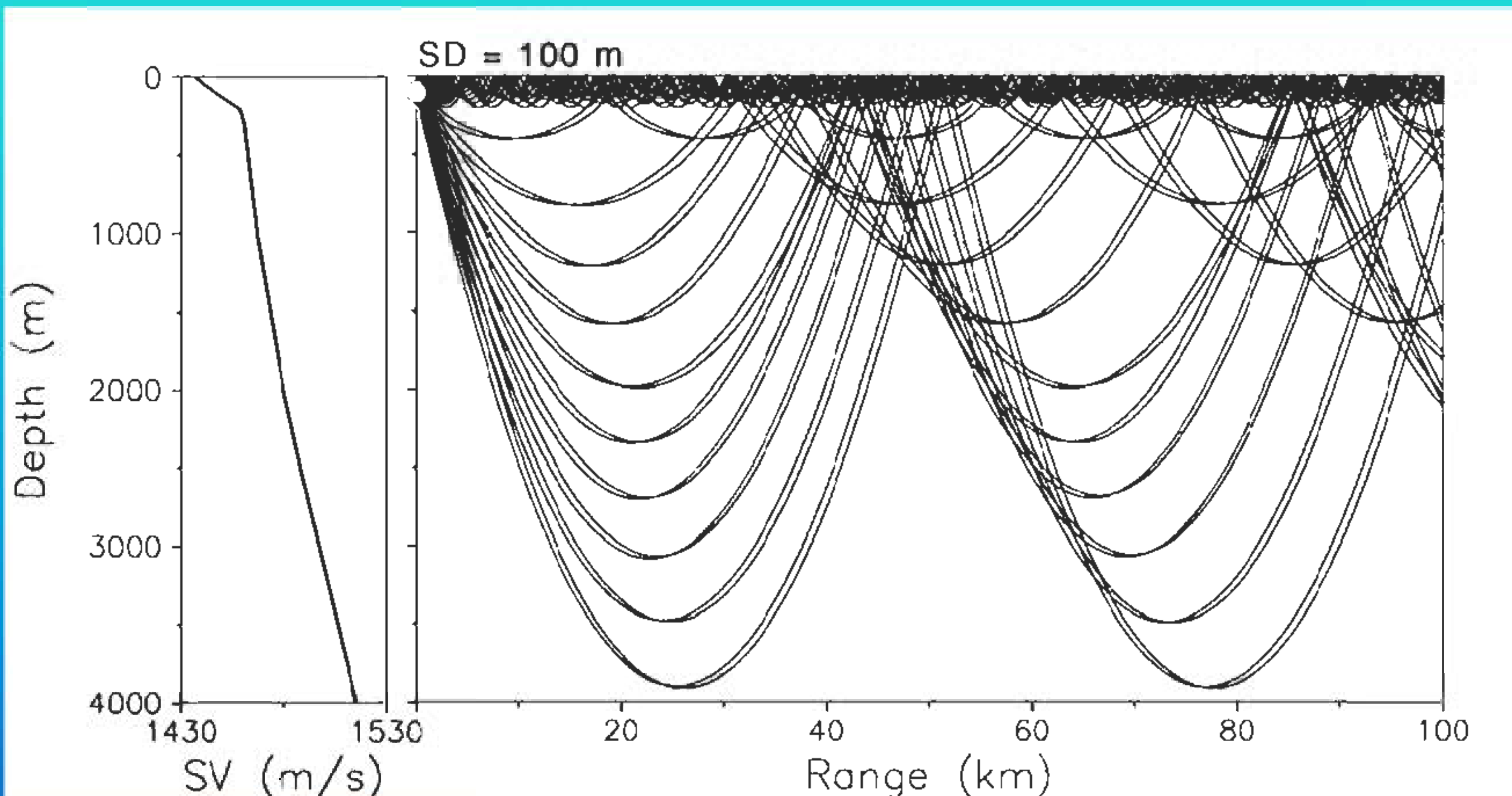
SURFACE-DUCT PROPAGATION
(NORWEGIAN SEA)



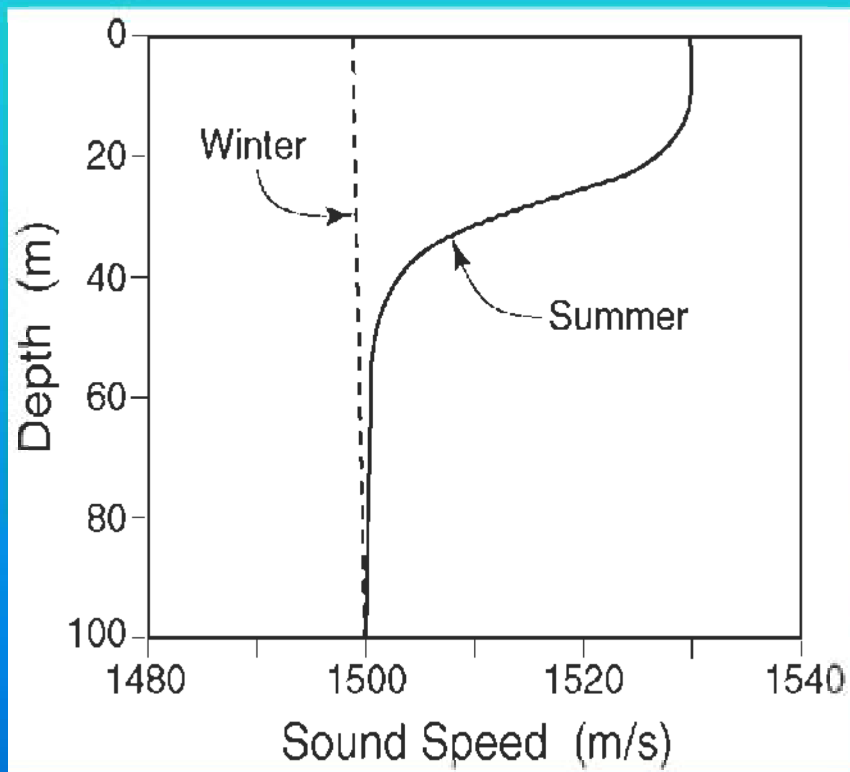
CONVERGENCE ZONE PROPAGATION (NORTH ATLANTIC)



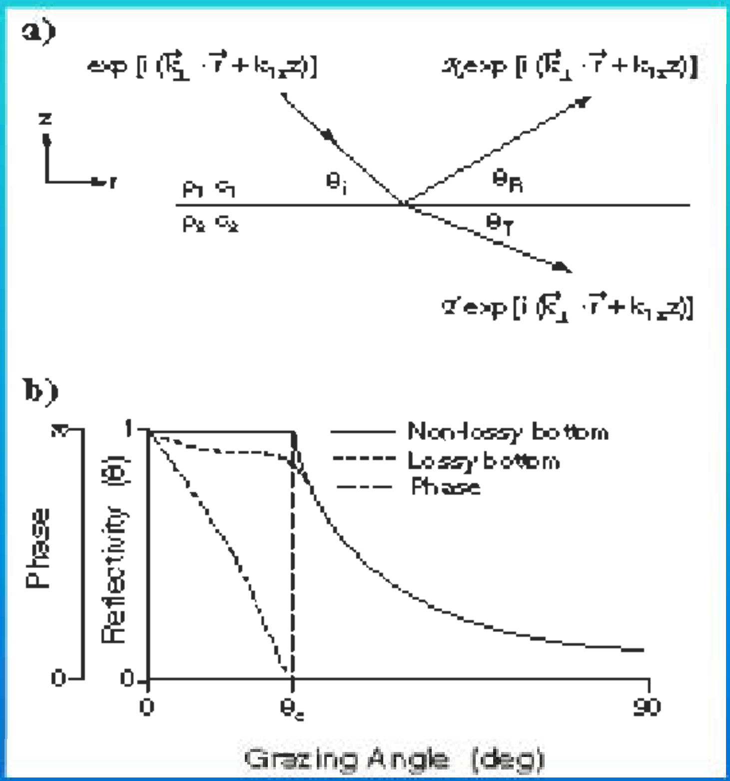
ARCTIC PROPAGATION

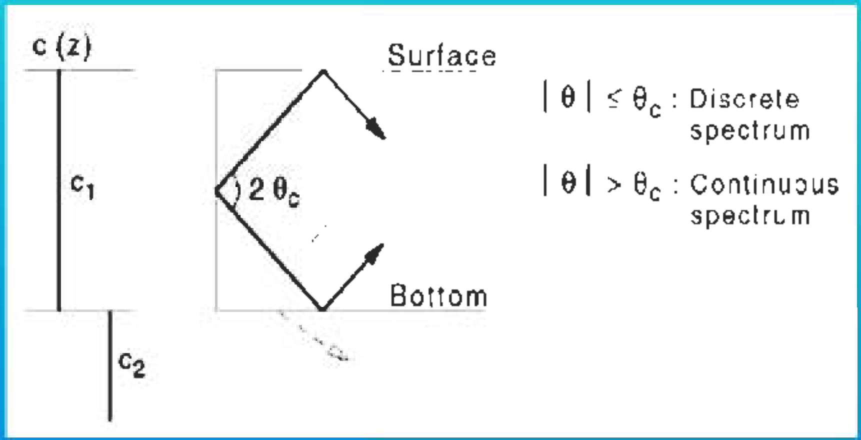


SHALLOW WATER SOUND SPEED PROFILES

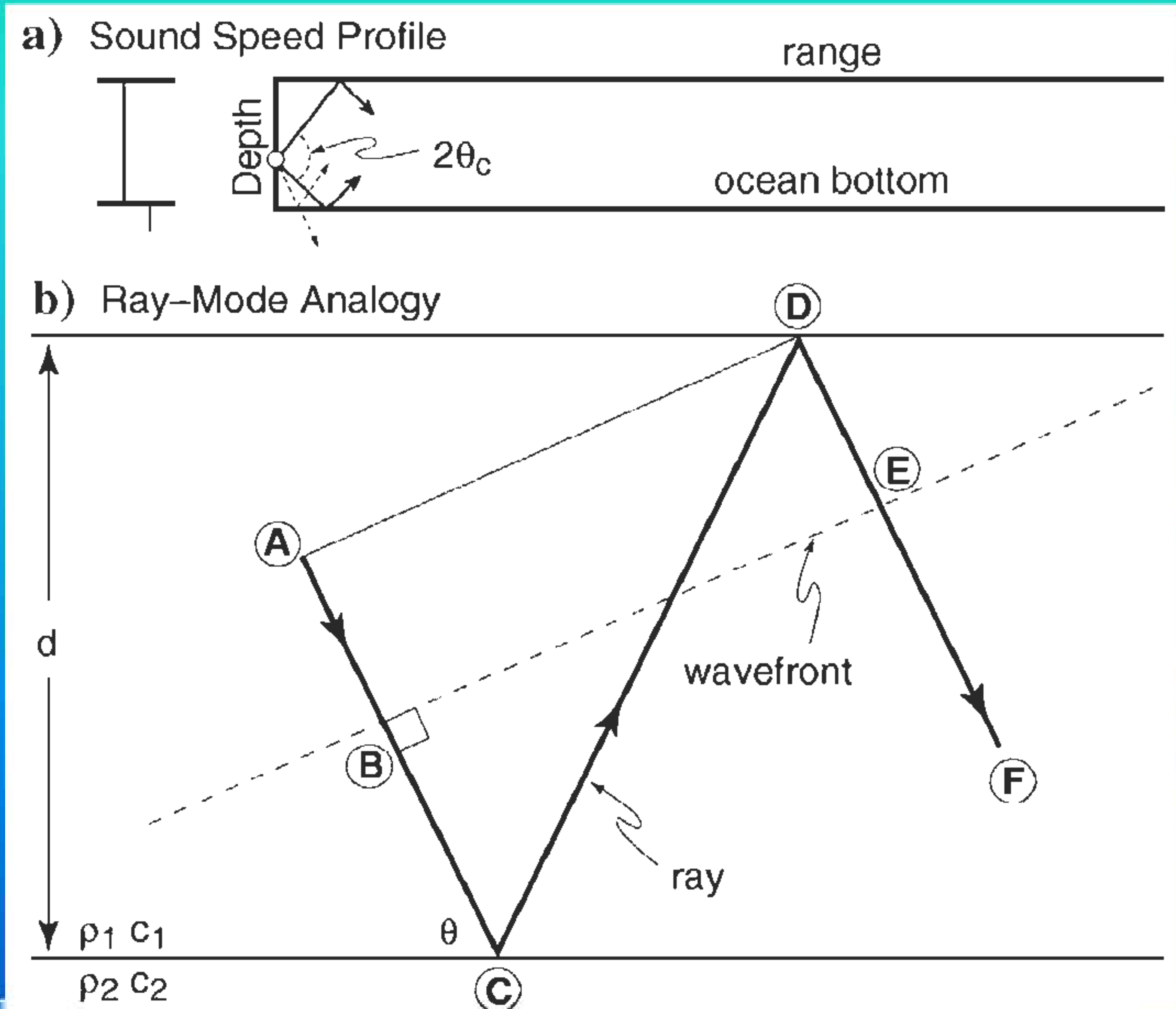


REFLECTIVITY AND SHALLOW WATER PROPAGATION

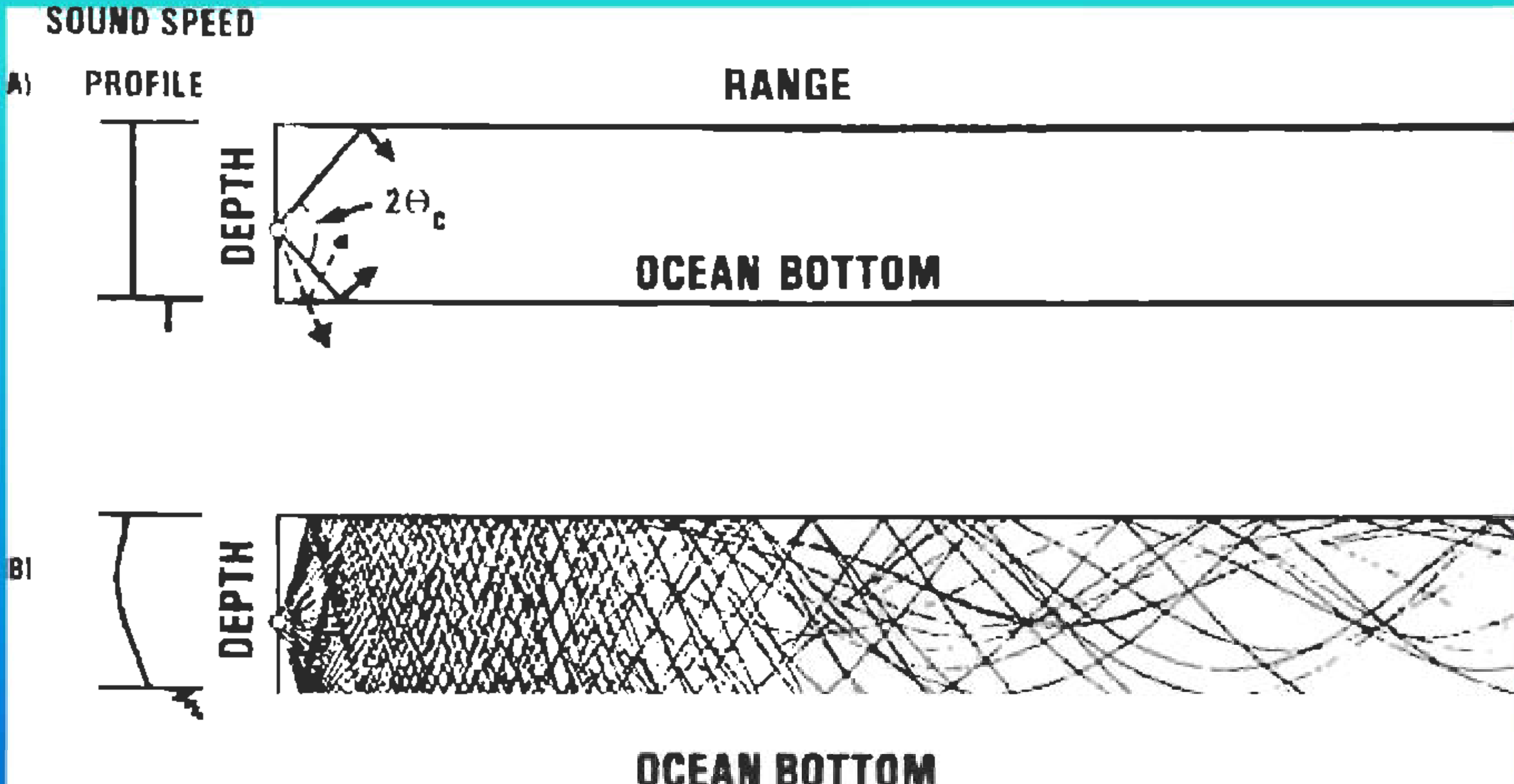




CONSTRUCTIVE INTERFERENCE: MODAL PROPAGATION

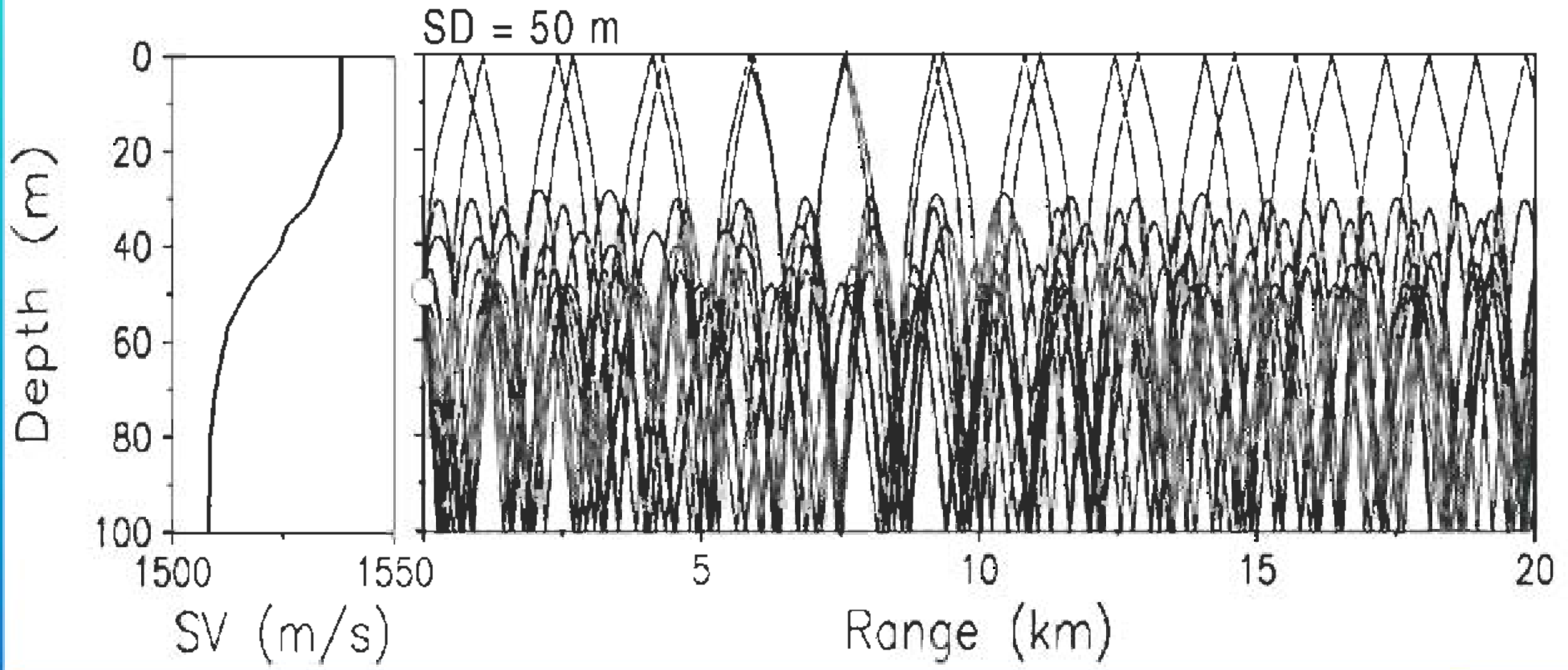


SHALLOW WATER PROPAGATION



SHALLOW-WATER PROPAGATION

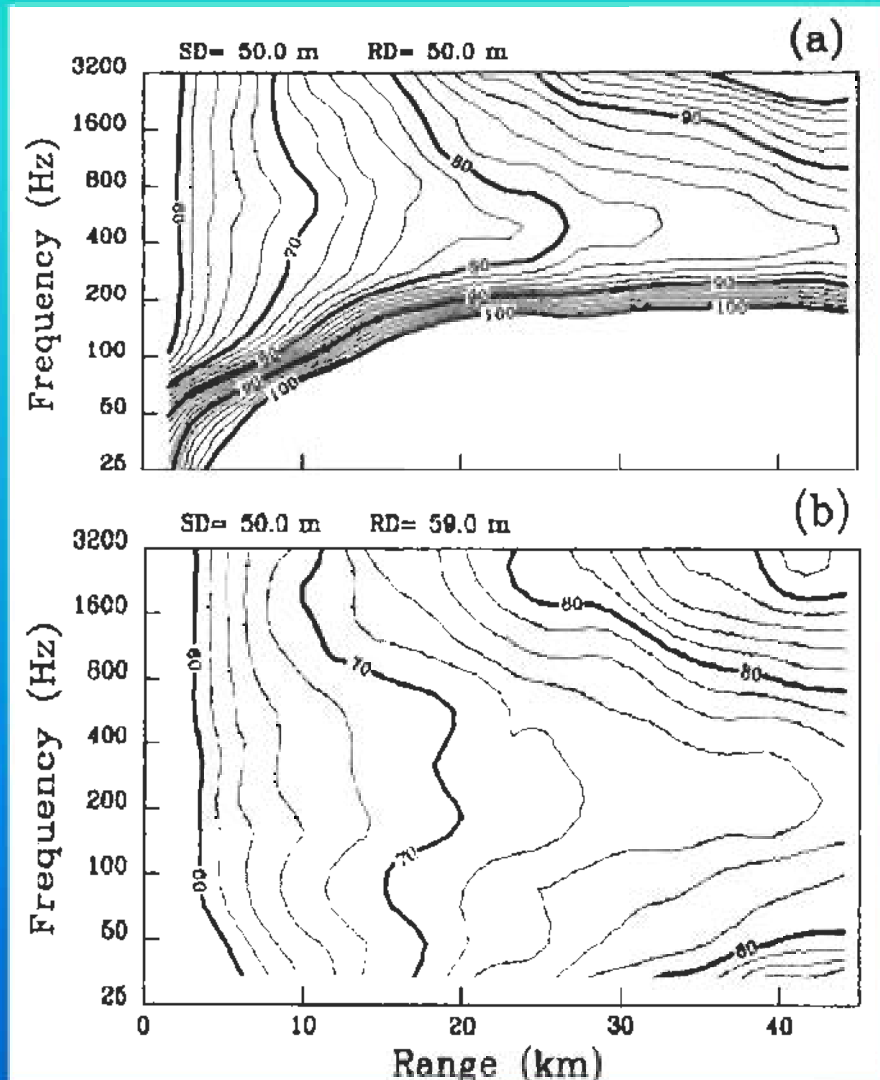
(SUMMER, MEDITERRANEAN)



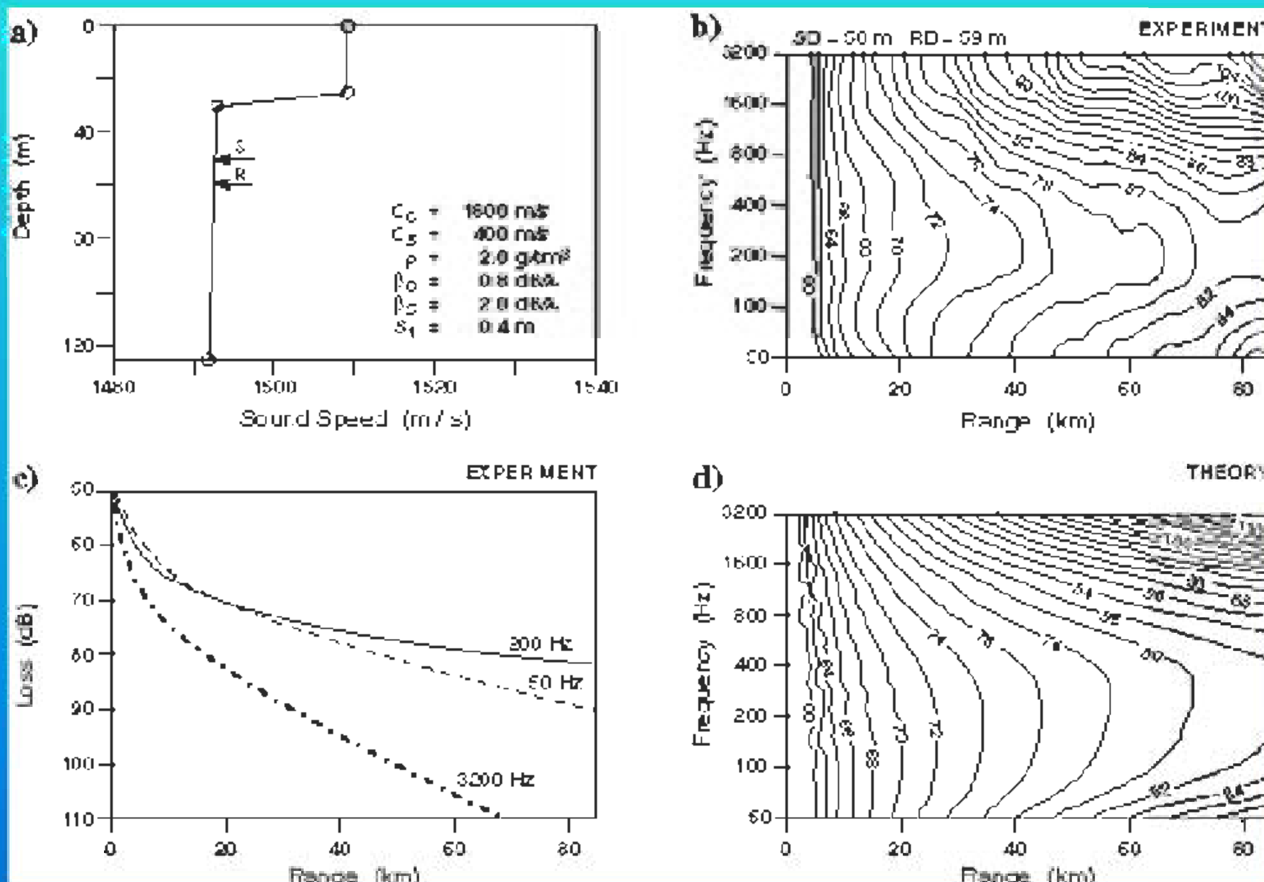
CONTOURED PROPAGATION LOSS: "OPTIMUM FREQUENCY CURVES"

BARENTS SEA

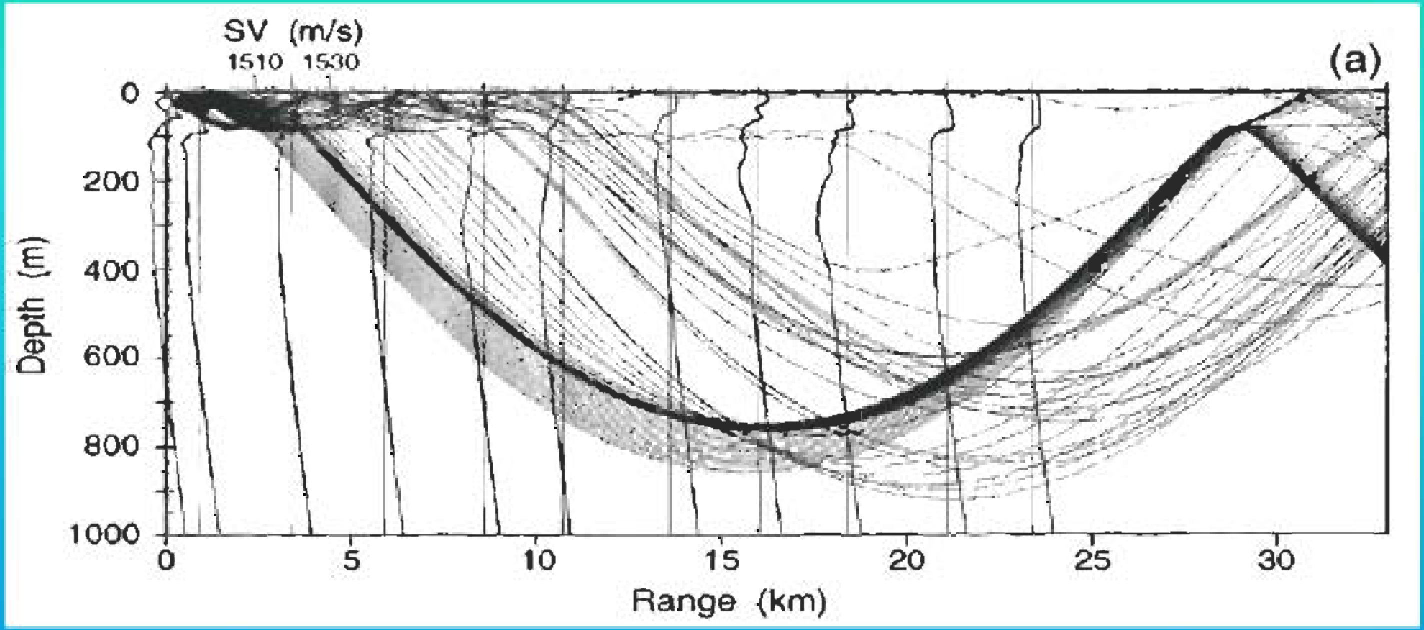
ENGLISH CHANNEL

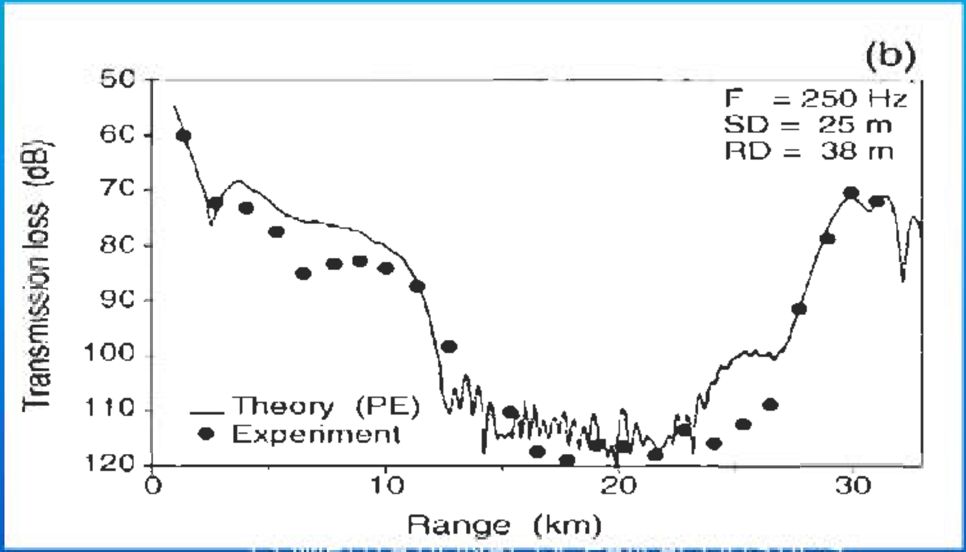


OPTIMUM FREQUENCY CURVES



PROPAGATION IN A RANGE DEPENDENT ENVIRONMENT

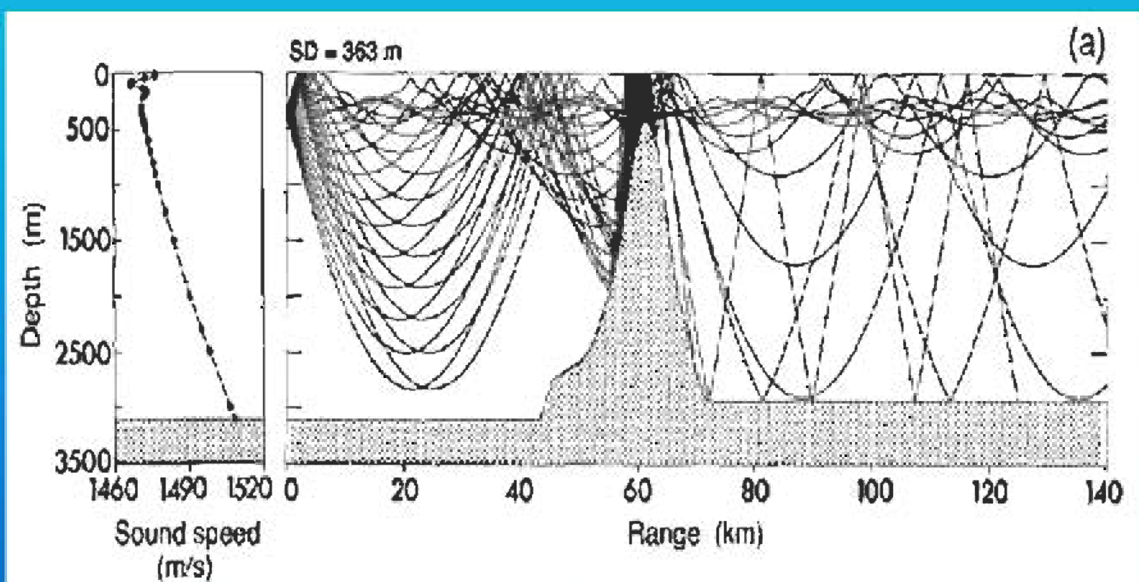


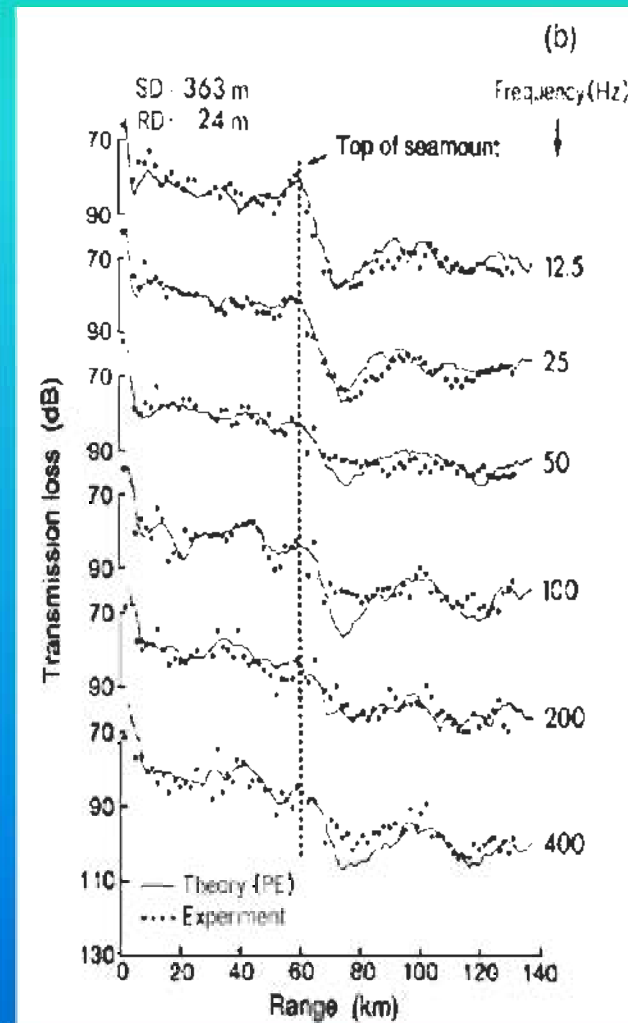


PROPAGATION OVER A SEAMOUNT

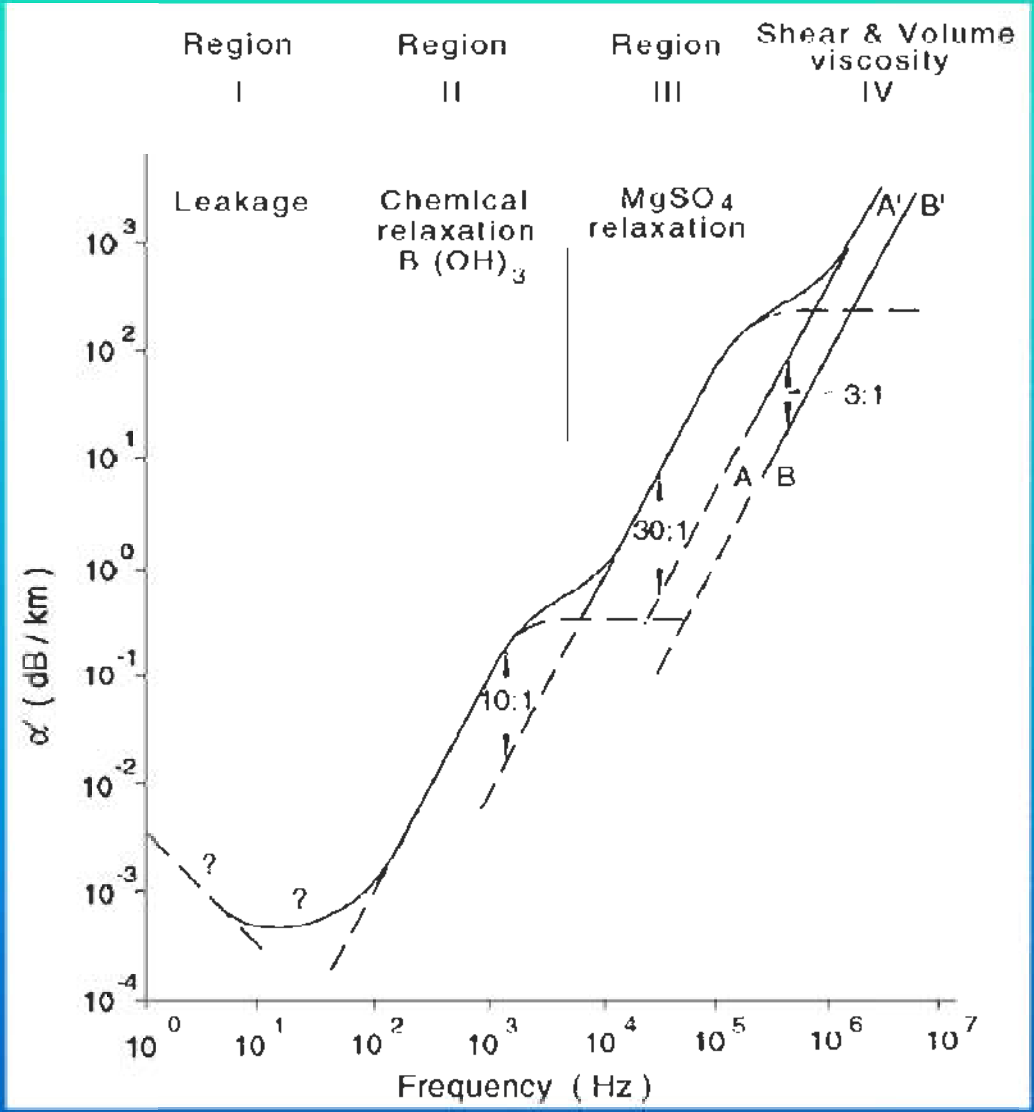
(NORTH PACIFIC)

data: Chapman and Ebbeson



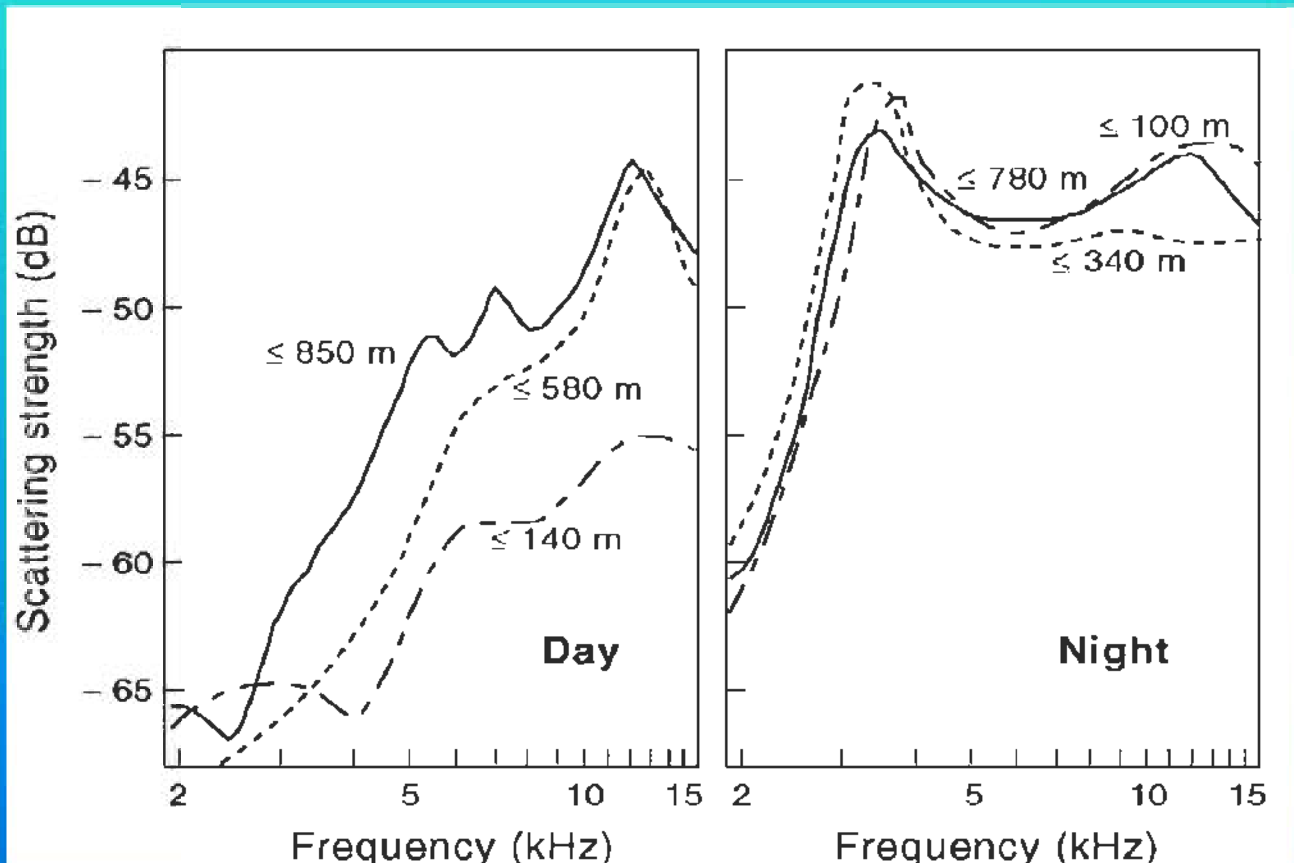


ATTENUATION OF SOUND IN SEAWATER (URICK)

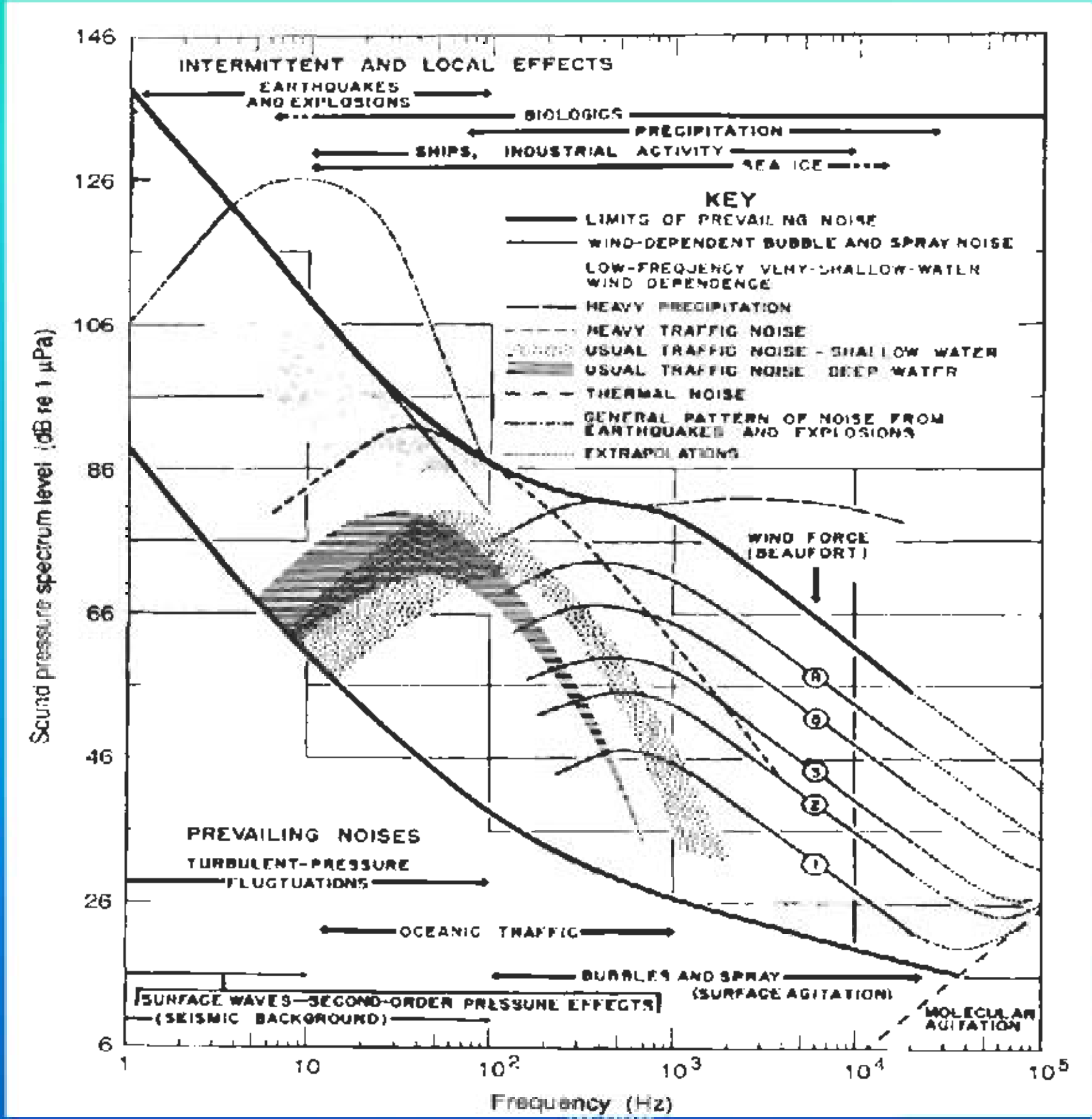


DAY AND NIGHT SCATTERING STRENGTHS

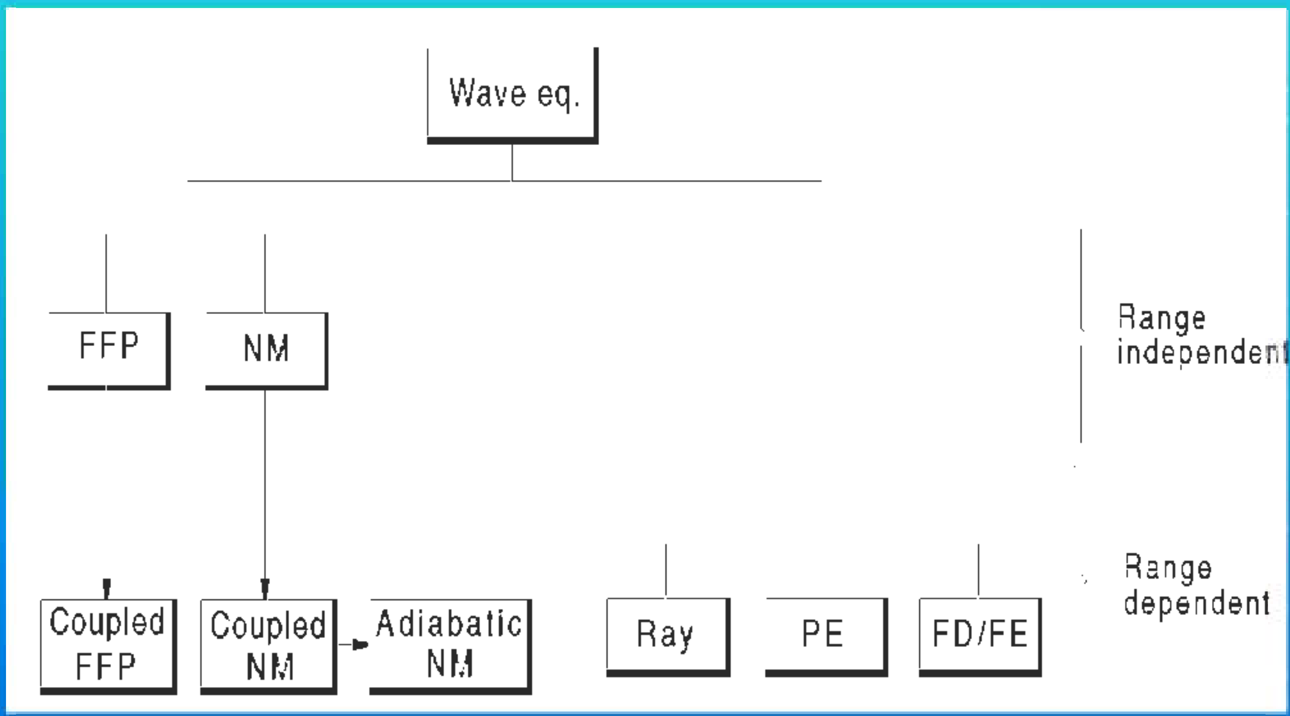
(CHAPMAN AND MARSHALL)



AMBIENT NOISE SPECTRA (WENZ)



HIERARCHY OF UNDERWATER ACOUSTIC MODELS



MODEL CONSISTENCY: MODES AND RAYS