Cours 2 : Physique des vagues

1 - Origines des vagues

2 - Description des vagues

3 - Vitesses des vagues

4 - Les vagues sont des ondes (réfraction, réflexion, interférences)

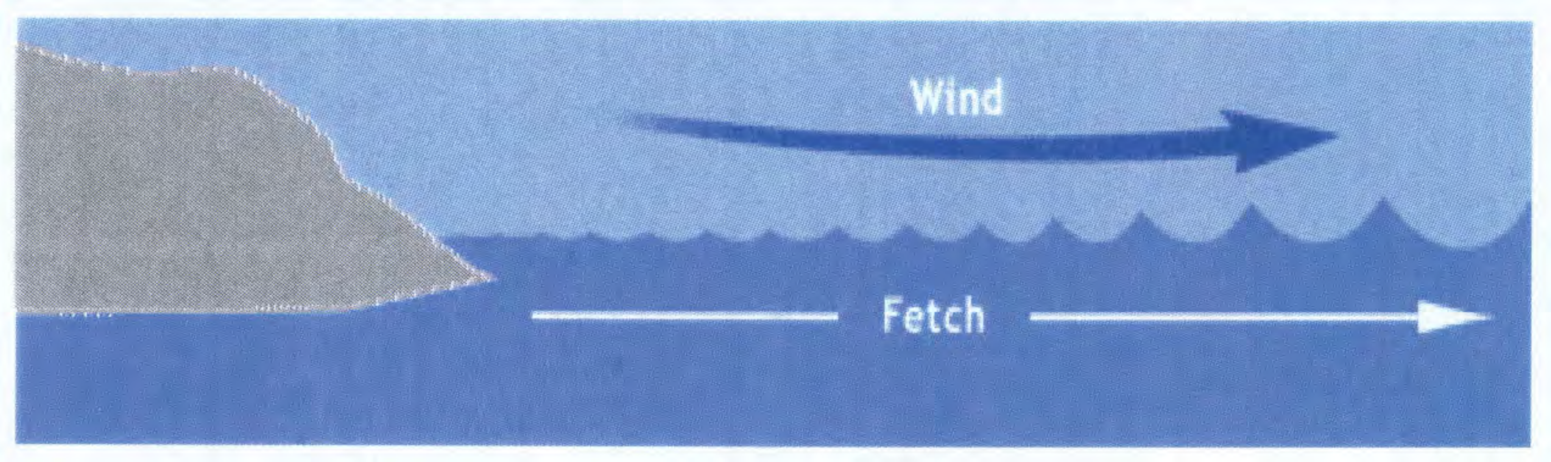
5 - Sillage des bateaux

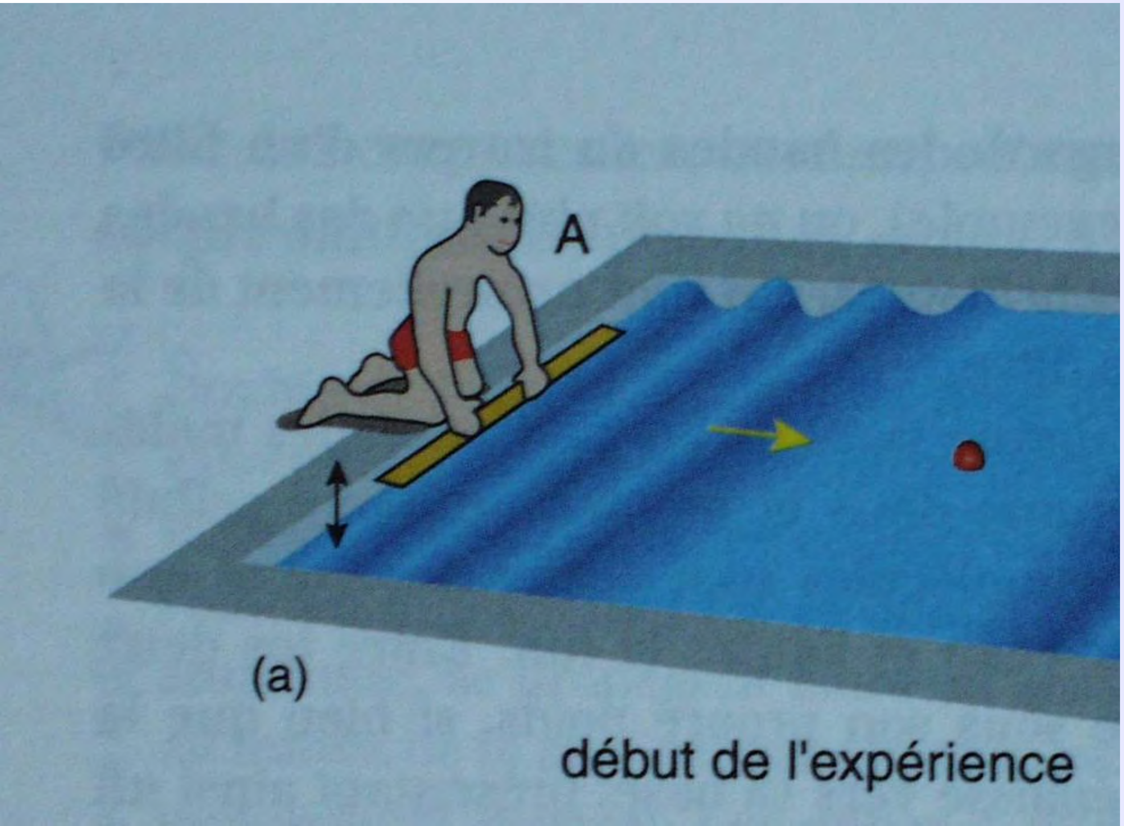
6 - Les ondes longues

7 - Utilisation de l'énergie des vagues

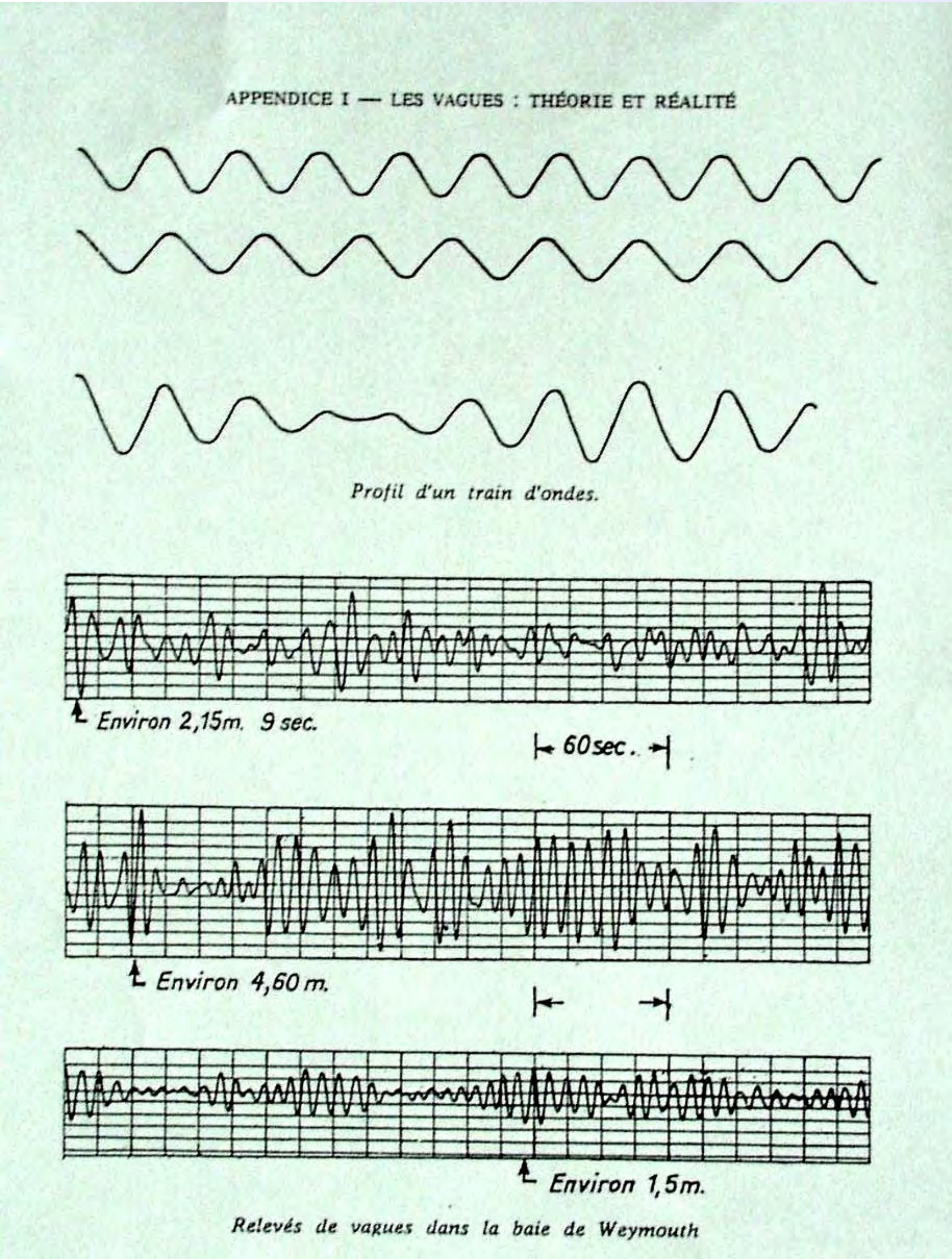
Marc Rabaud, Peyresq, 4 juin 2015

1 – Origine des vagues



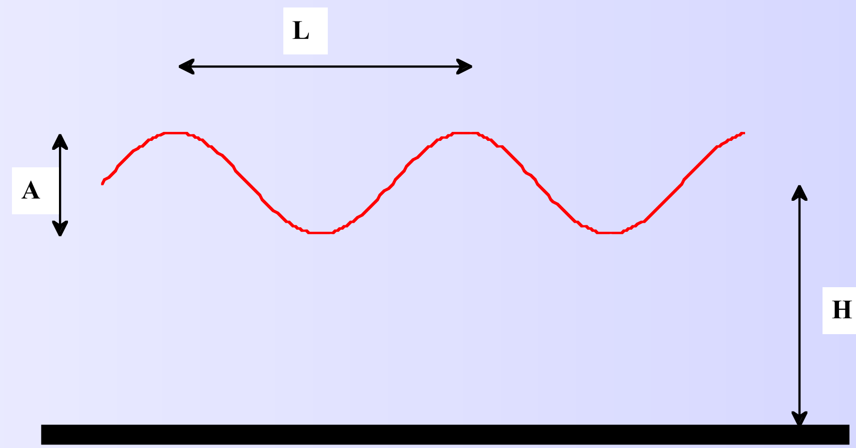


2 – Description des vagues (régime linéaire)



-Transformée de Fourier

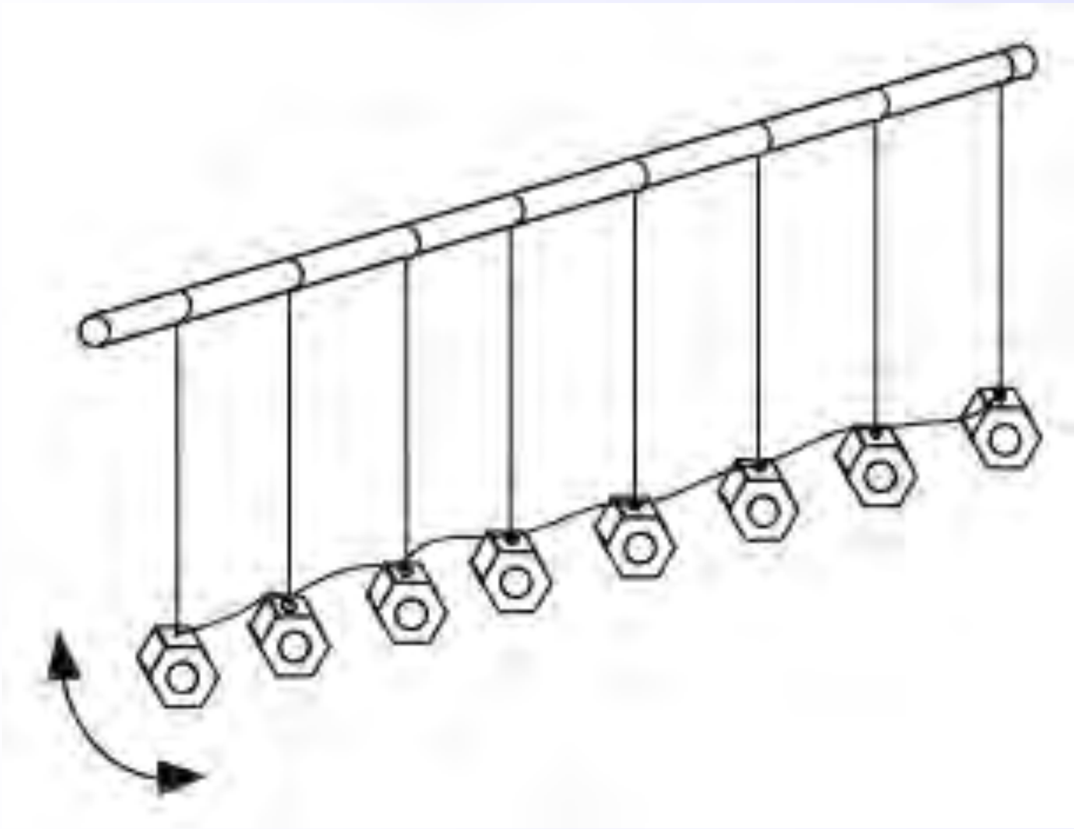
- Analyse modale



$$\lambda = \frac{2\pi}{k}$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

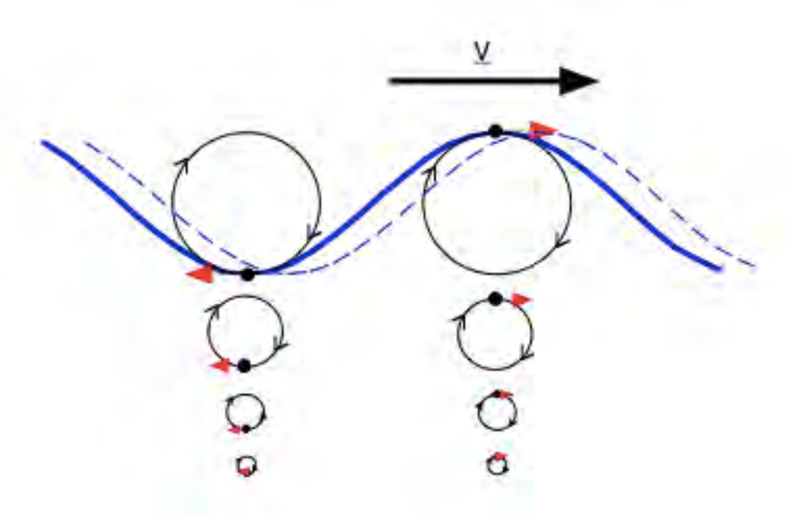
- Les vagues correspondent à des oscillateurs couplés spatialement



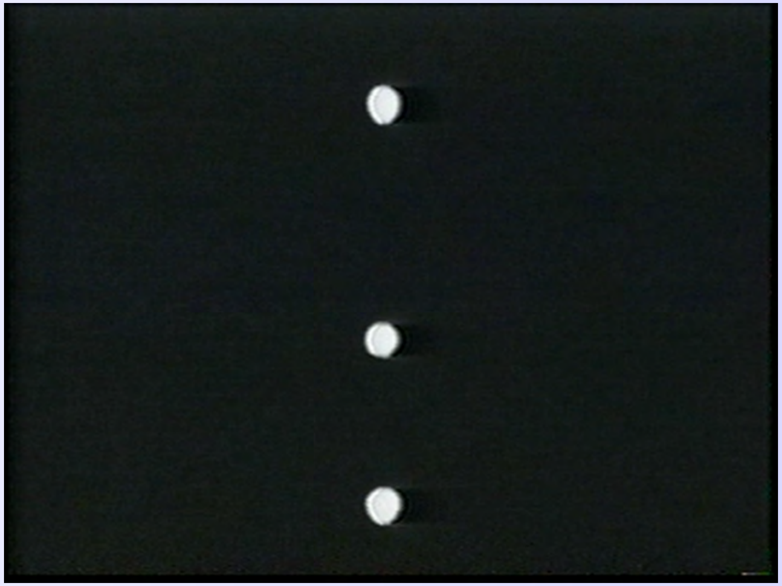
Forces de rappel :
- Gravité
- tension de surface

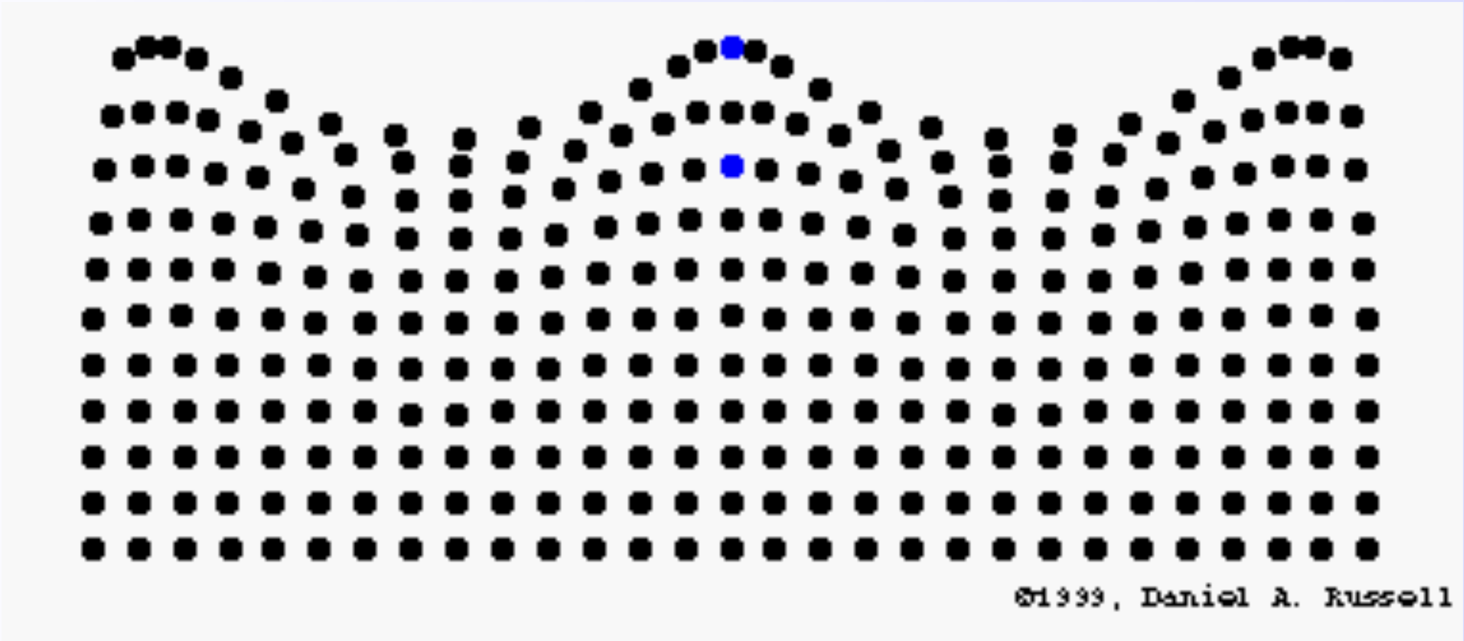
Dissipations :
- Viscosité du liquide
- frottement sur les parois
- déferlement

Mouvement en surface



Mouvement rapidement amorti en profondeur





Ondes de surface : ni transverses (électromagnétisme)
ni longitudinale (son)

Trajectoires toujours circulaires ?

- Eau peu profonde = ellipses

- Non-linearités => dérive de Stokes

$$v_{Stokes} = k^2 A^2 \exp(2kz) v_{\varphi}$$

3 – Vitesses des vagues

- Relation de dispersion $\omega = \mathrm{f}(k)$,
- vitesse de phase
- vitesse de groupe

Ondes planes monochromatiques

=> équation d'onde, solutions en $\zeta = \zeta_0 \exp i(kx - \omega t)$

Relation de dispersion ω = f(k) :

$$\boxed{\omega^2 = \frac{\rho_1 - \rho_2}{\rho_1 + \rho_2} gk + \frac{\gamma}{\rho_1 + \rho_2} k^3}$$

Hypothèses : faible dissipation et faible amplitude

Vitesse de phase $v_\varphi(k) = \dfrac{\omega}{k}$

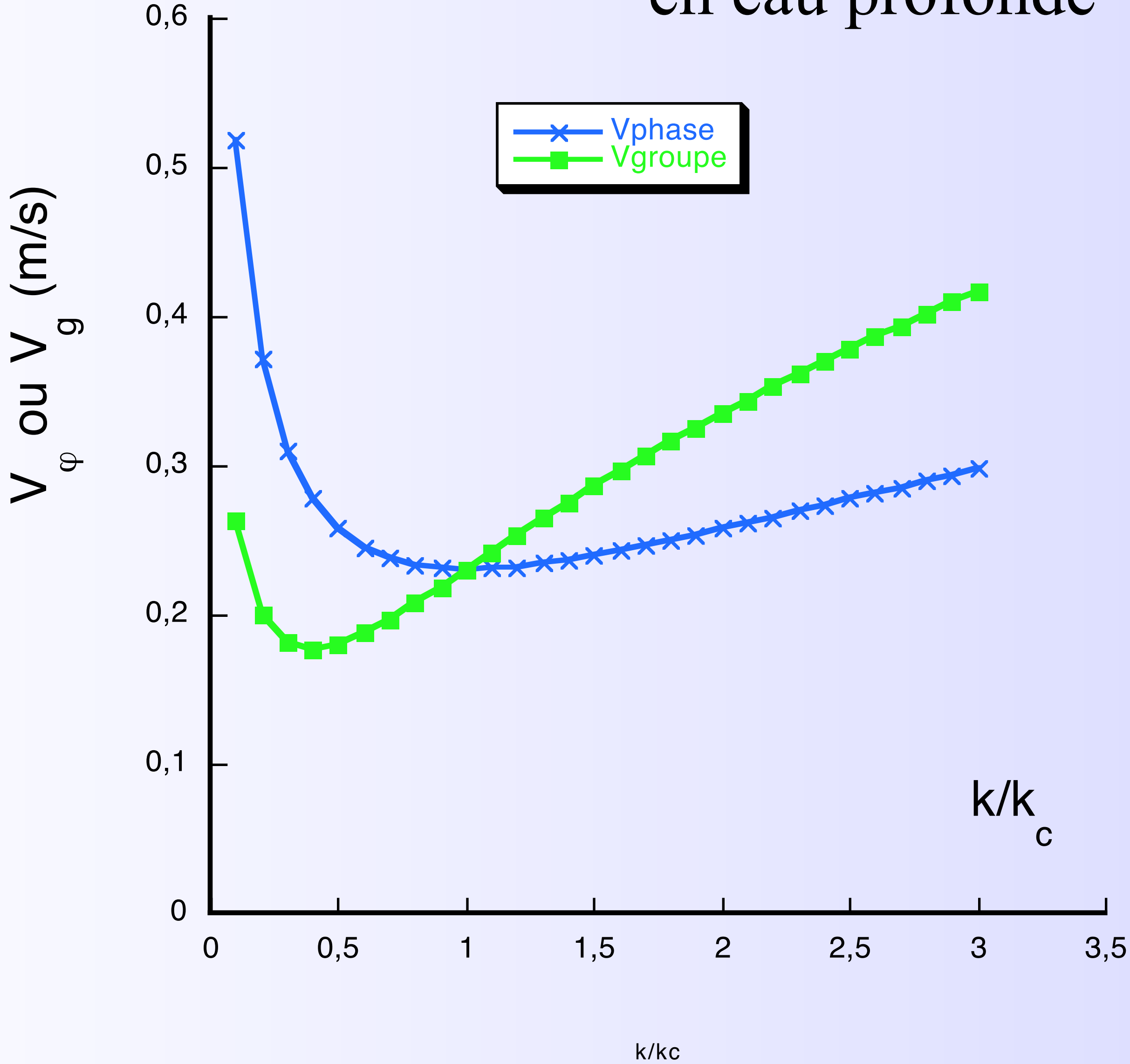
Milieu dispersif
(≠ son, lumière)

Vitesse de groupe $v_g(k) = \dfrac{d\omega}{dk}$

En eau peu profonde :

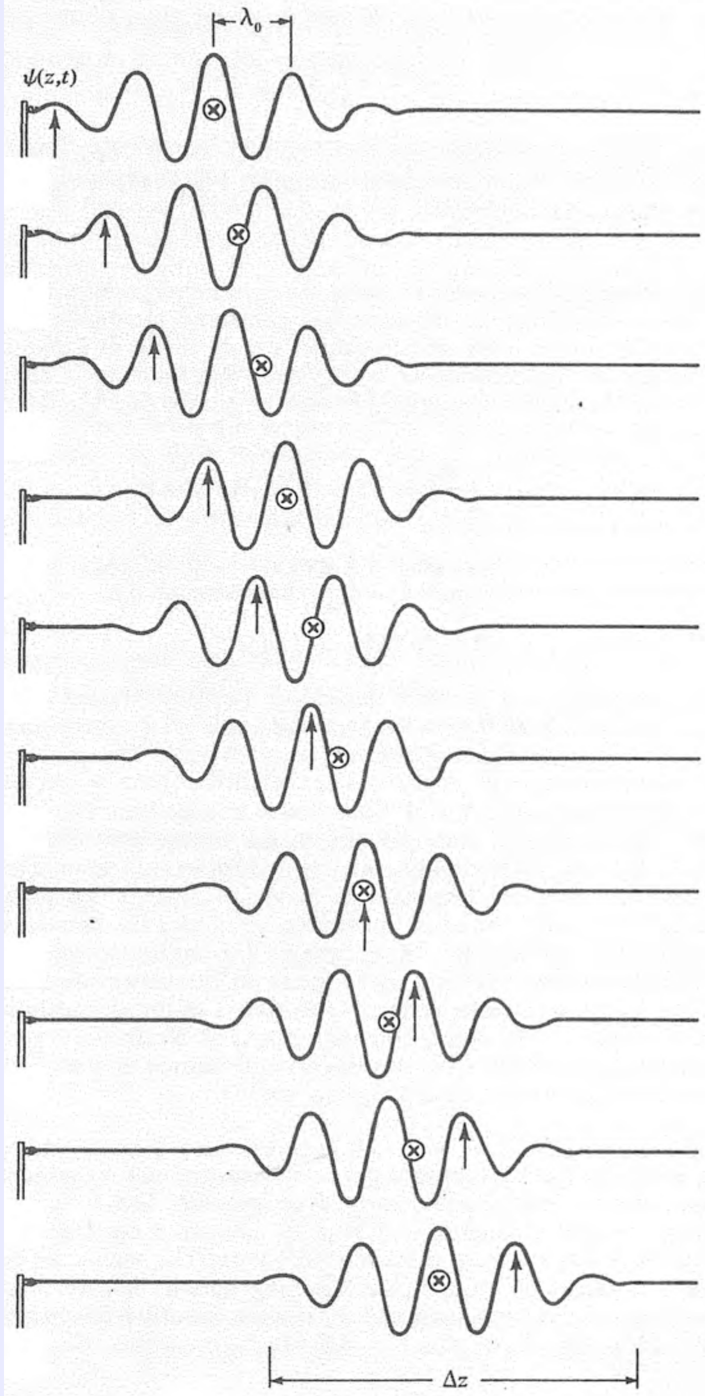
$$\omega^2 = \frac{\rho_1 - \rho_2}{\rho_1 + \rho_2} gk \tanh hk \left[1 + \left(\frac{k}{k_c}\right)^2\right]$$

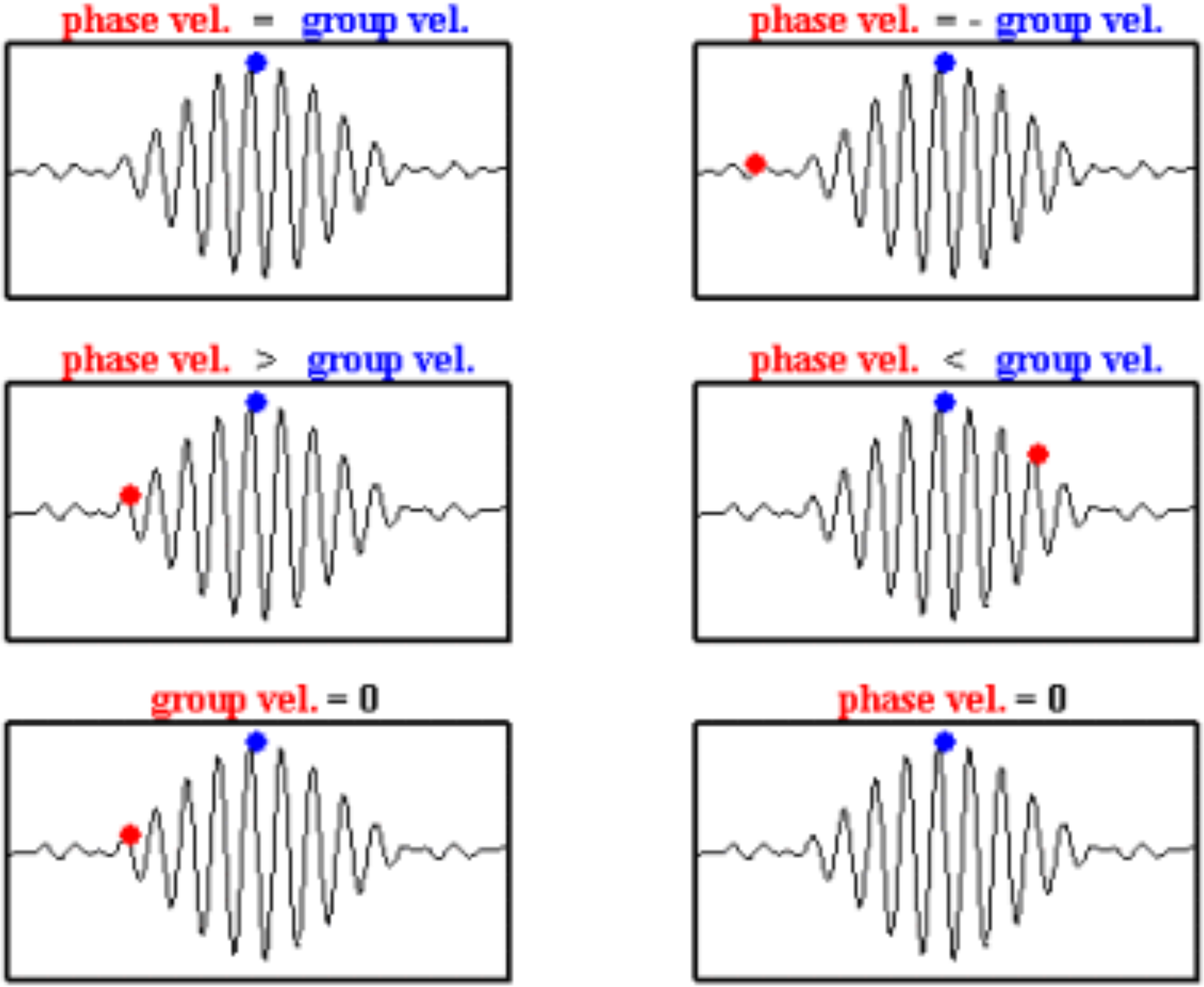
Vitesse de phase et vitesse de groupe en eau profonde



Evolution d’un paquet d’onde : cas d’une onde de gravité.

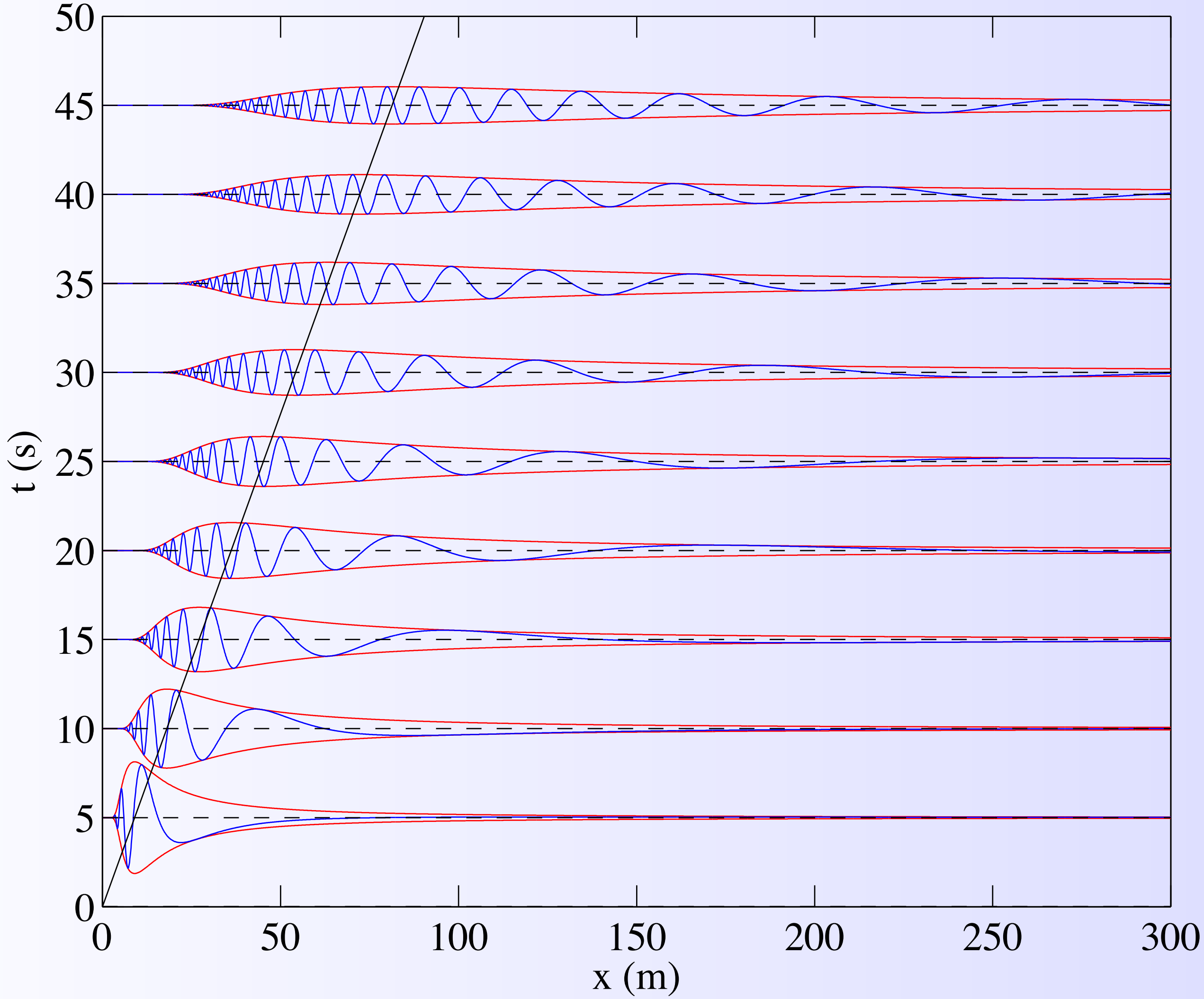
$V_g = 1/2\ v_\varphi$




phase vel. = group vel.
phase vel. = - group vel.
phase vel. > group vel.
phase vel. < group vel.
group vel. = 0
phase vel. = 0

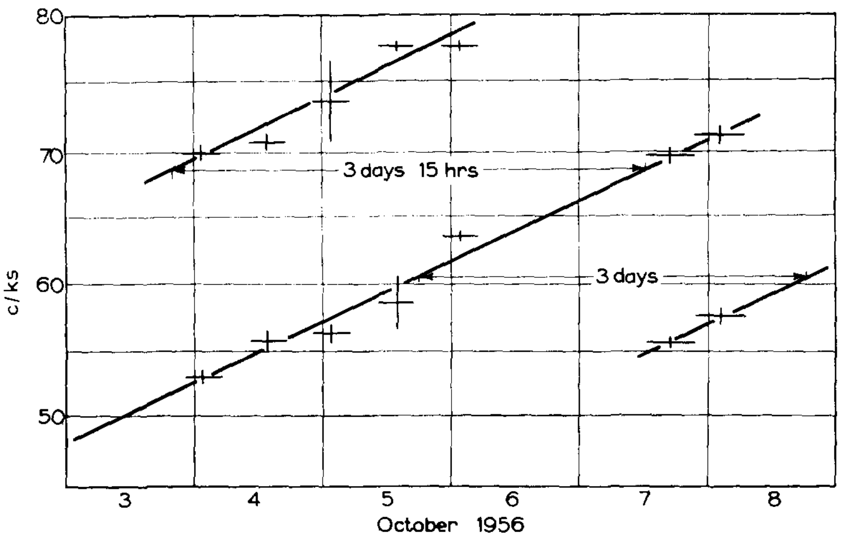
isvr

Jetons un cailloux de taille L dans une mare :



Problème de Cauchy-Poisson (1816)

Munk & Snodgrass (1957)



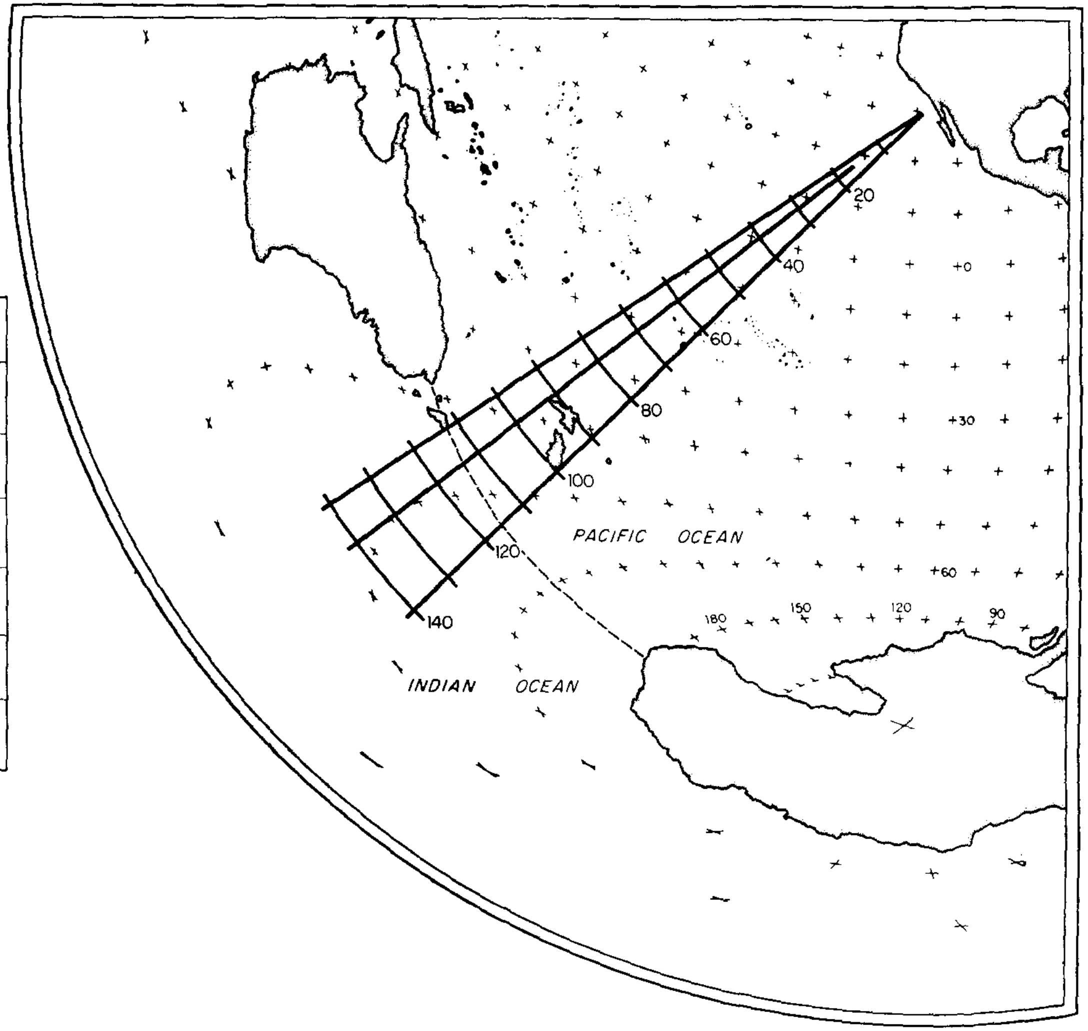


Fig. 6. Azimuthal-equidistant projection centred on San Diego. Distances from Guadalupe are given in units of degrees (1° equals 111 km).

Propagation at the group velocity :

$$\frac{R}{t} = \frac{g}{4\pi f}$$

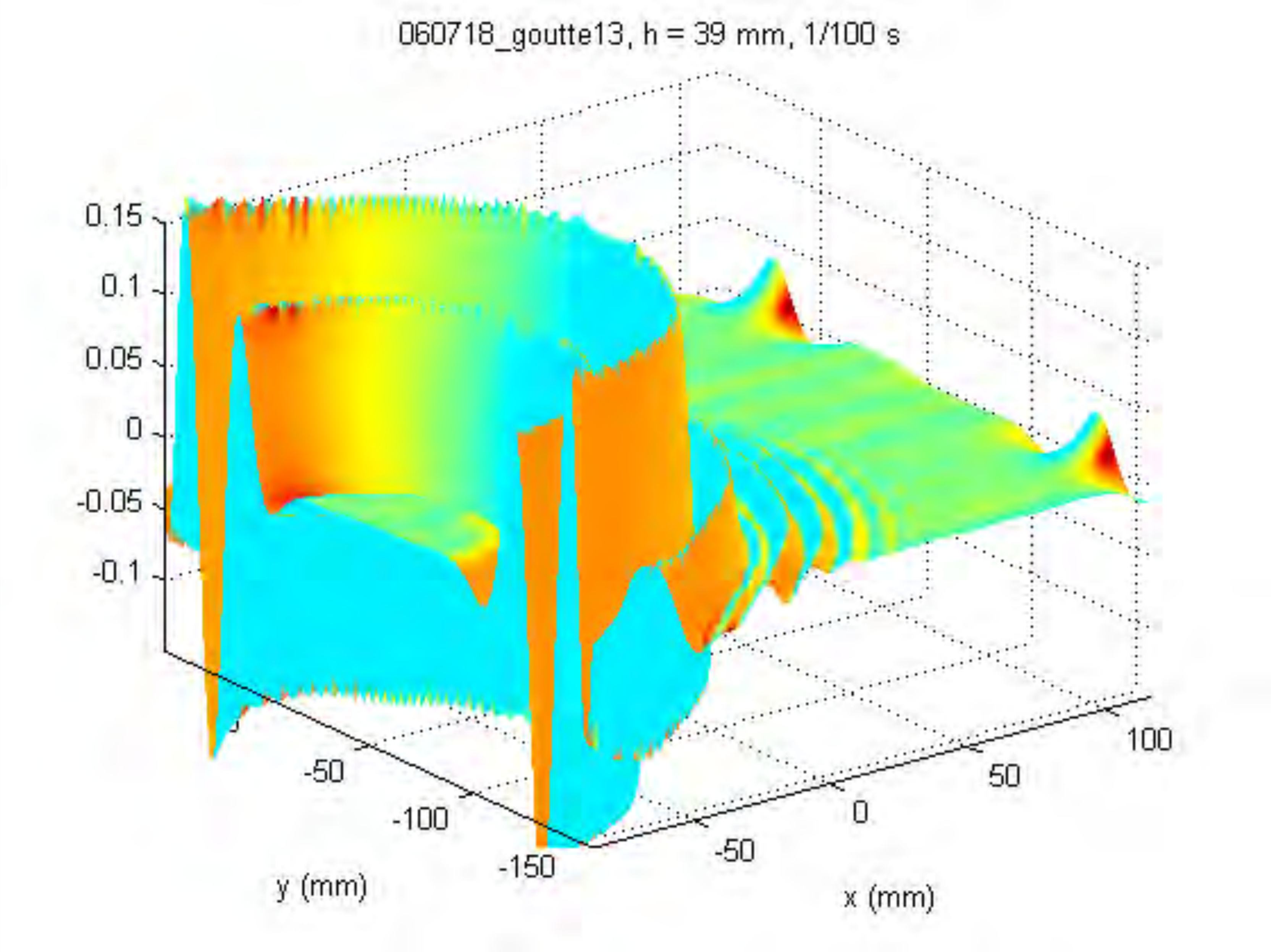
Measured frequency at time t :

$$f(t) = \frac{g}{4\pi R} t$$

The slope gives R.

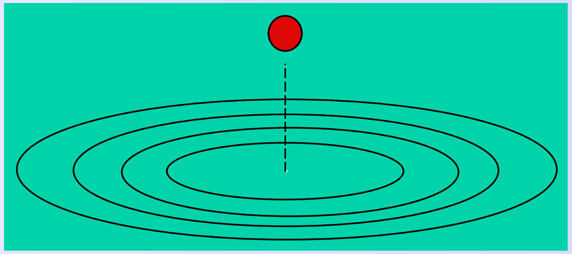
Source with a **range of 14,800 kilometers!** Consistent only with very distant areas of generation in the Indian Ocean, south of Western Australia.

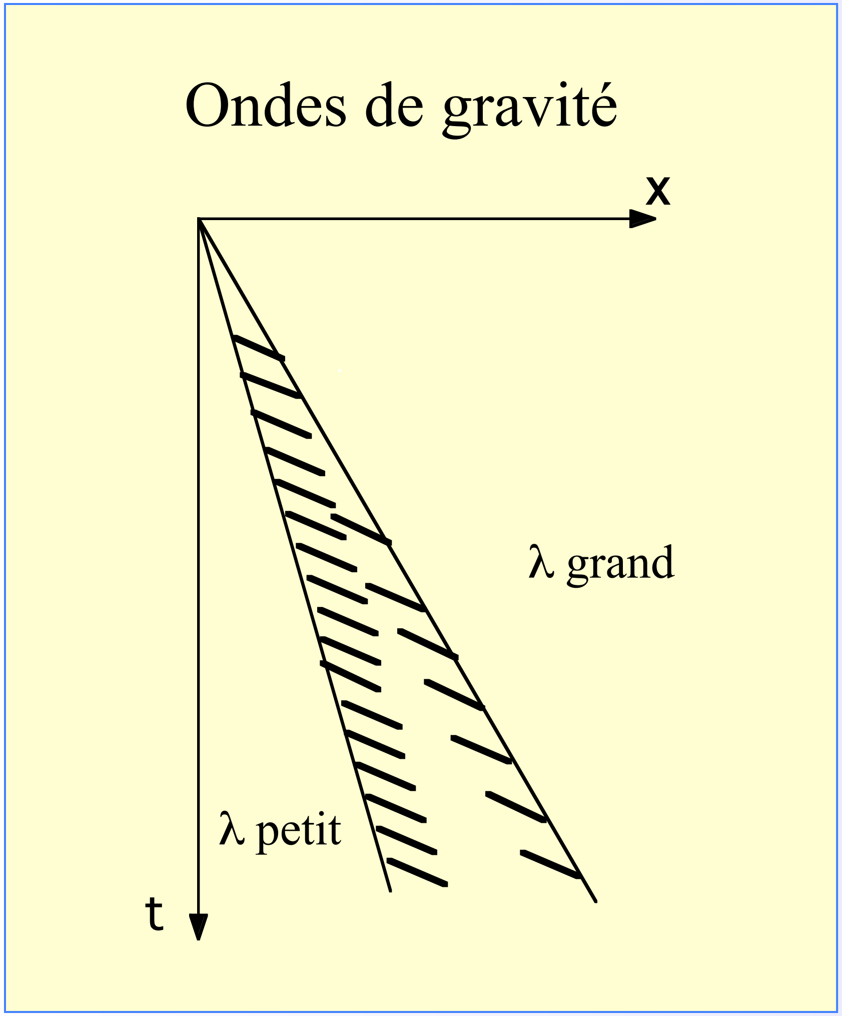
(Transparent B. Gallet)

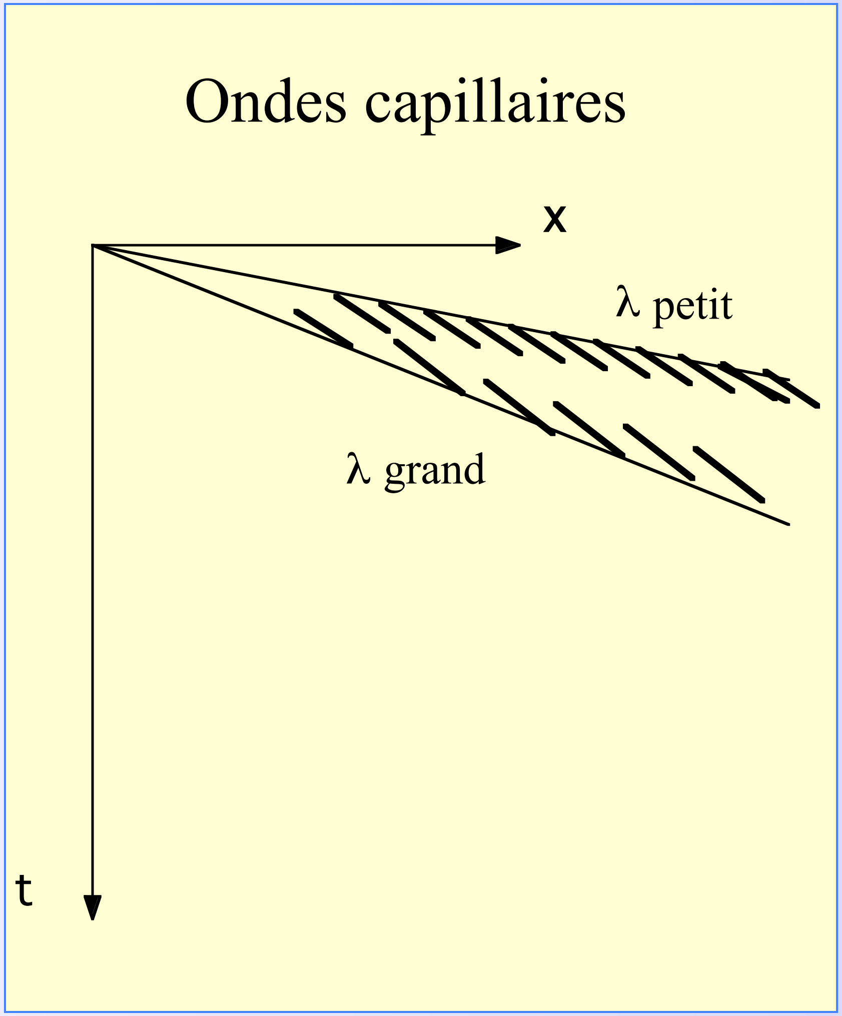


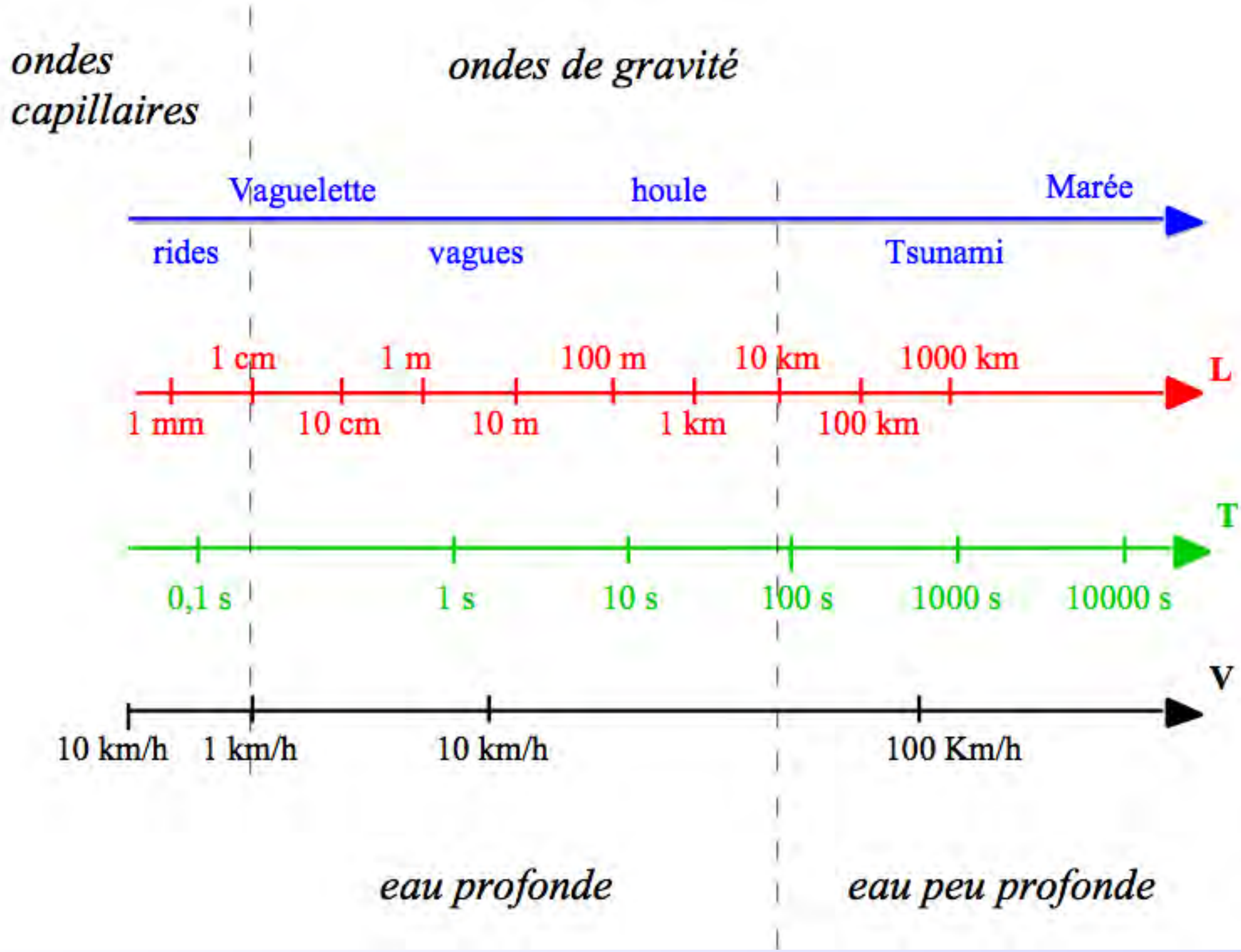
Goutte d’eau tombant dans l’eau, mesuré par PIV

Jetons un caillou dans l'eau ...









ondes capillaires
ondes de gravité
Vaguelette
houle
Marée
rides
vagues
Tsunami
1 cm
1 m
100 m
10 km
1000 km
L
1 mm
10 cm
10 m
1 km
100 km
T
0,1 s
1 s
10 s
100 s
1000 s
10000 s
V
10 km/h
1 km/h
10 km/h
100 Km/h
eau profonde
eau peu profonde

4 - Réfraction, réflexion, diffraction

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Teaching waves with Google Earth

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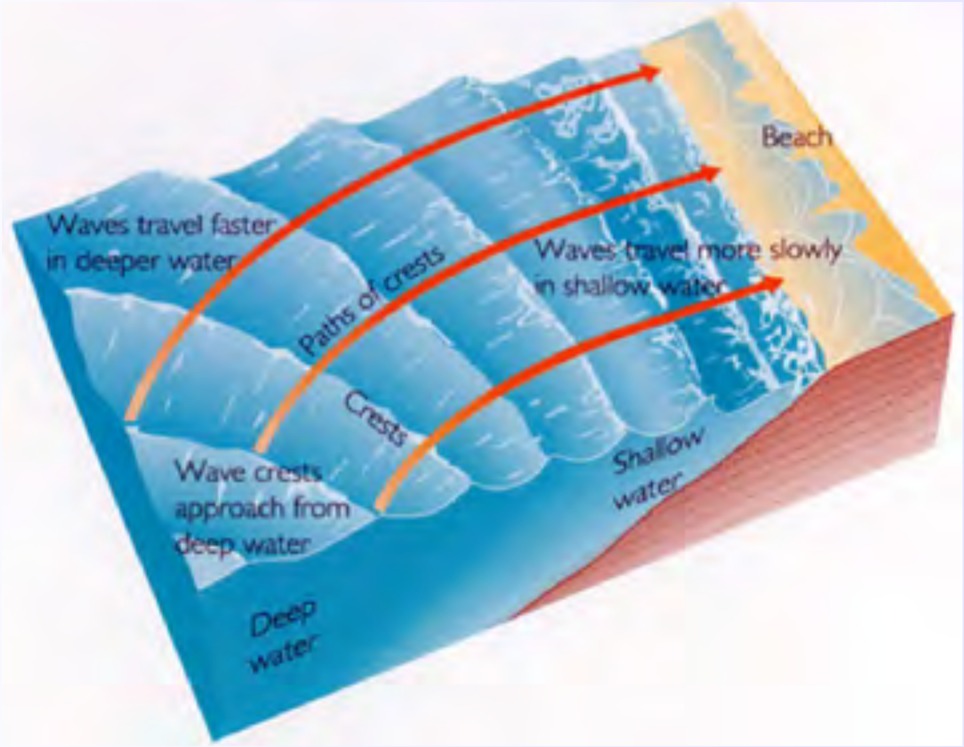
Abstract
Google Earth is a huge source of interesting illustrations of various natural phenomena. It can represent a valuable tool for science education, not only for teaching geography and geology, but also physics. Here we suggest that Google Earth can be used for introducing in an attractive way the physics of waves.

F. Logiurato. Teaching waves with google earth. Physics Education, 47(1):73, 2012.



$$\lambda \propto h^{1/2}$$

et

$$\zeta \propto h^{-1/4}$$

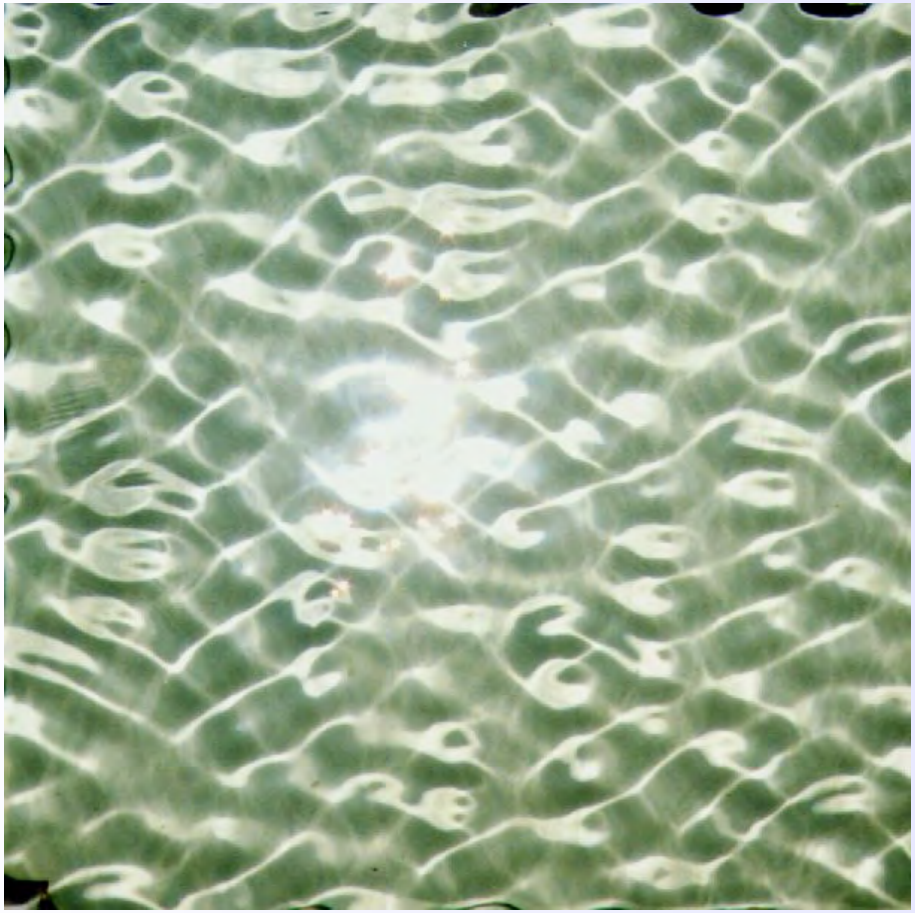
Raidissement des vagues arrivant sur une plage

Réfraction en eau peu profonde

-Variation continu de l'indice

- Effet mirage optique ou acoustique

Réflexion par un mur : clapot



- Dans une piscine

Diffraction par une ouverture ou un obstacle (Principe de Huygens)

$$\lambda \approx d$$

Port d'Alexandrie (Egypte)

Interférences par deux fentes (Principe de Huygens)