Pourquoi ne faut-il pas craindre le phénomène des «eaux mortes»

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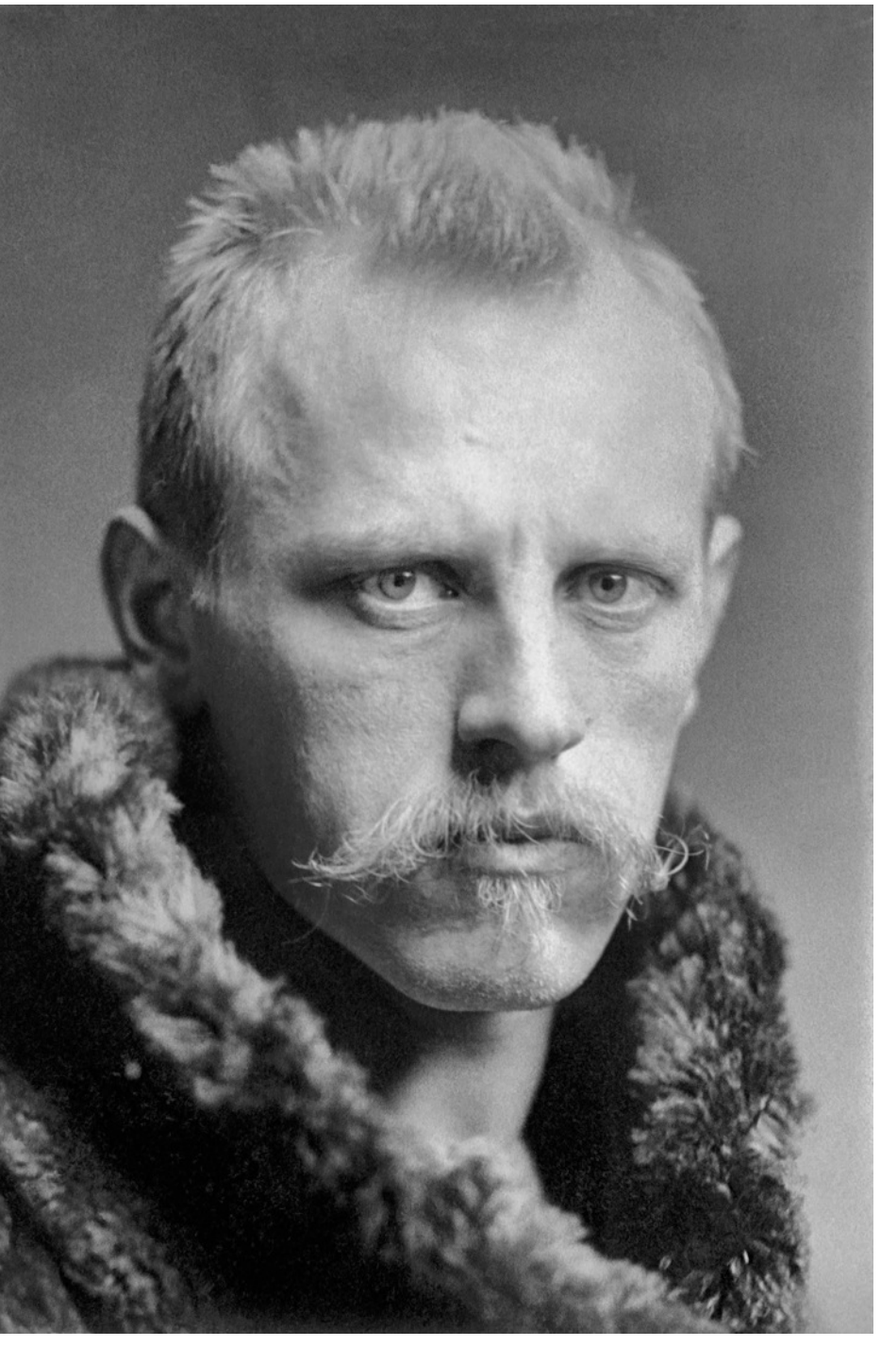
CNRS - Université de Rennes 1

Nuit des sciences
06 Juin 2014

Découverte

Fritjof Nansen



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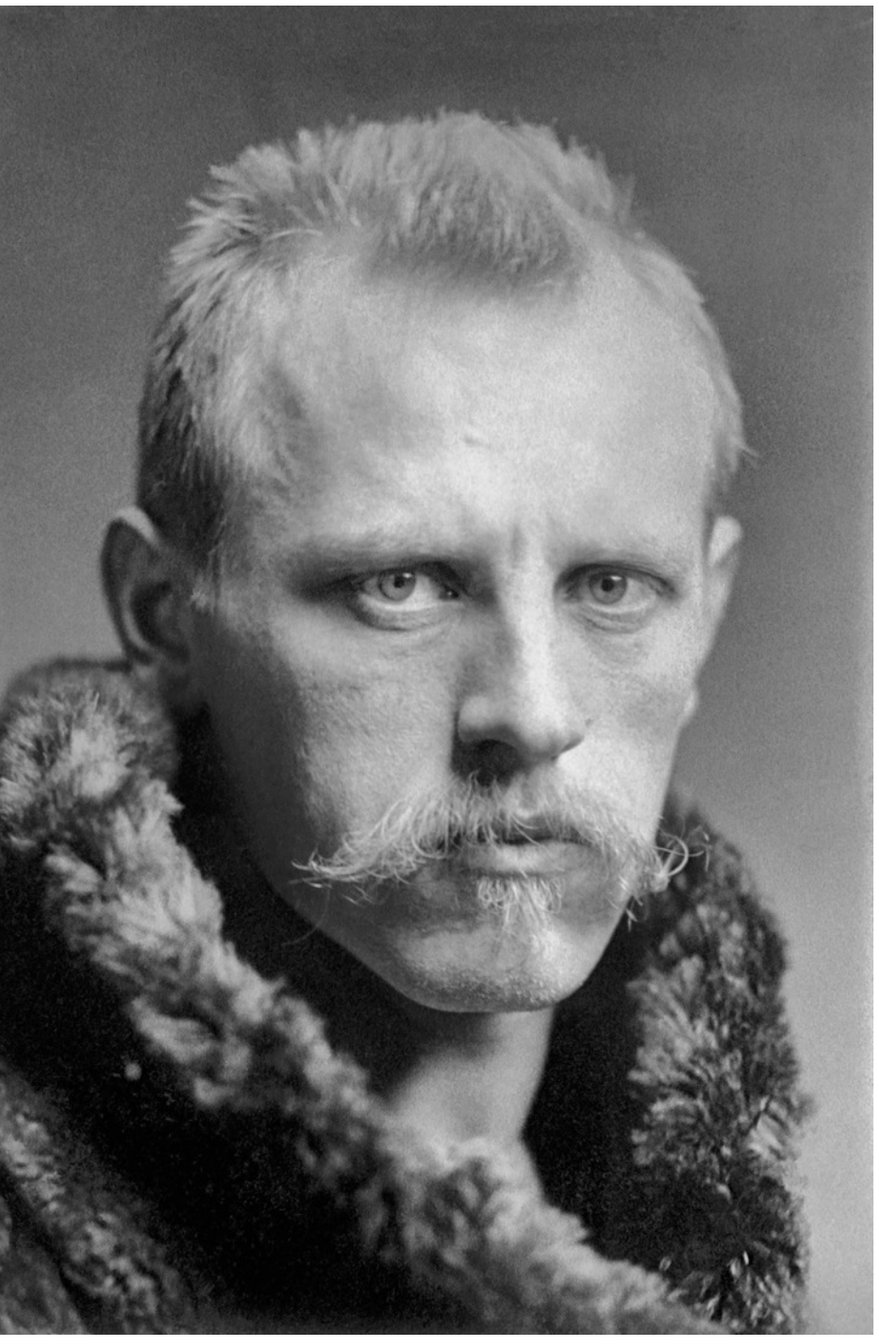
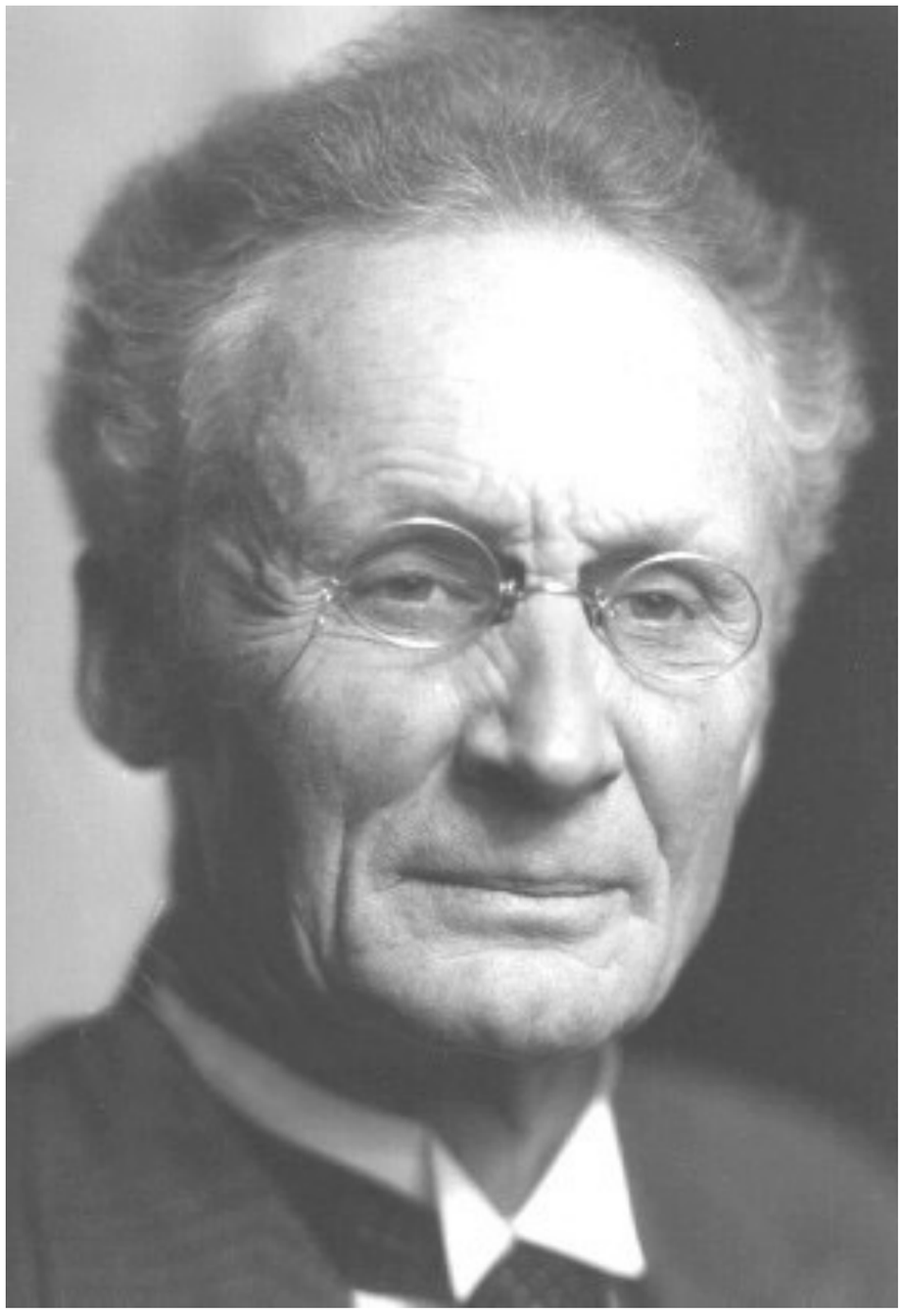


It is a peculiar phenomenon this dead water. We had at present a better opportunity of studying it than we desired. **It occurs where a surface layer of fresh water rests upon the salt water of the sea**. [...] We made loops in our course, turned sometimes right round, tried all sorts of antics to get clear of it, but to very little purpose.

The Norwegian north polar expedition 1893–1896
Nansen Fund (1902)

Intuition

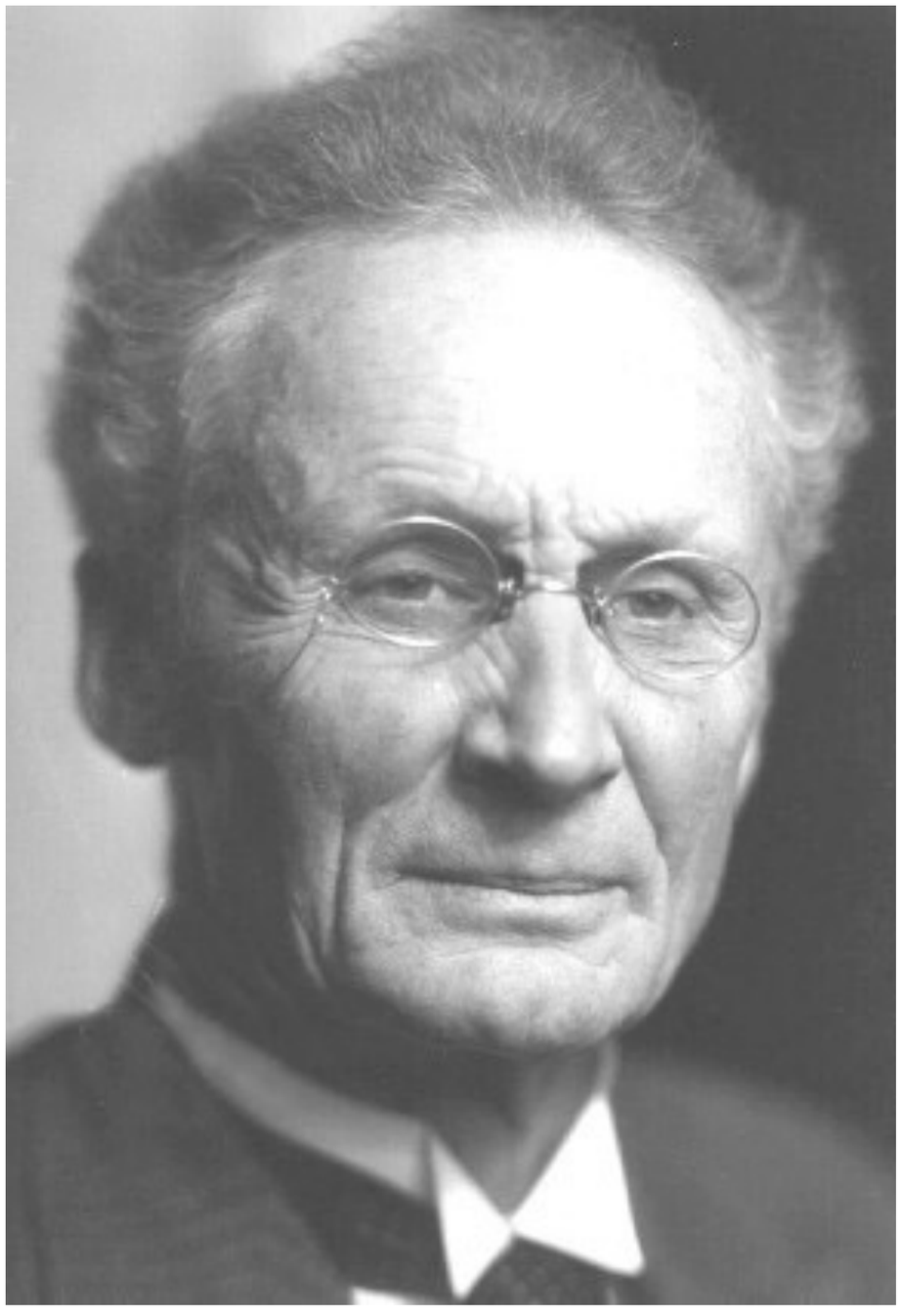
Vilhelm Bjerknes



Intuition

Vilhelm Bjerknes

I remarked that in the case of a layer of fresh water resting on the top of salt water, a ship will [...] **generate invisible waves in the salt-water fresh water boundary below;**



I suggested that the great resistance experienced by the ship was due to the work done in generating these [internal] waves.

Ekman, V. W.
On dead water
Sci. Results Norw. North Polar Expedition (1904)

Étude

Vagn Walfrid Ekman

Étude

The experimental work was performed during the time from the beginning of 1900 to July 1901 […]

The experiments thoroughly confirmed Prof. V. Bjerknes' opinion: the vessel **when moving at low speeds** generated large internal waves […] and **the resistance at these speeds was anomalously increased**.

Ekman, V. W., *On dead water*
Sci. Results Norw. North Polar Expedition (1904)

Vagn Walfrid Ekman

Investigation

Paramètres importants

- Vitesse du navire
- Densité relative des deux couches
- Profondeur relative des deux couches
- Présence d'une brise de mer (?)
- Forme de la coque (??)

Investigation

Paramètres importants

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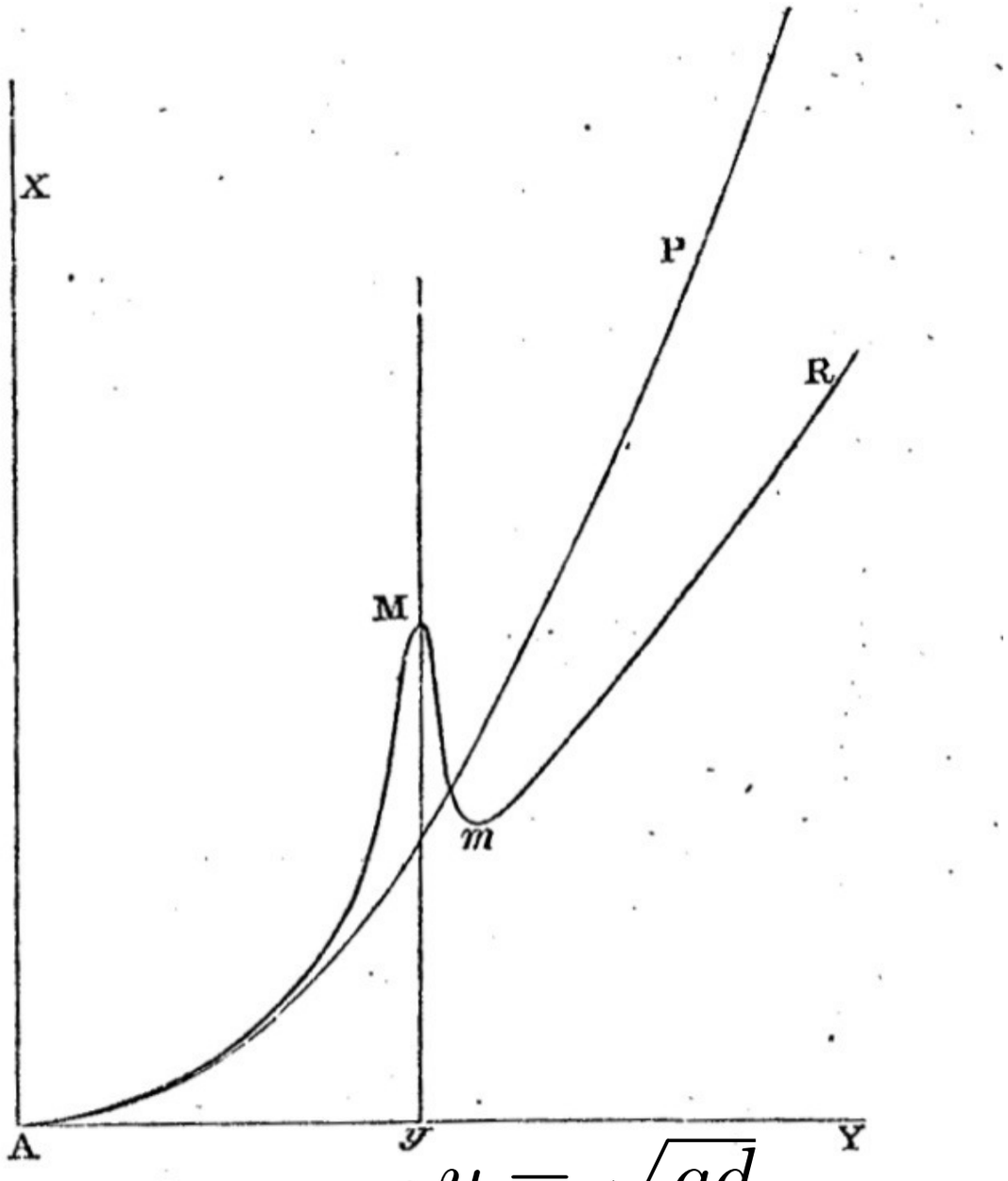
Manoeuvres appliquées (sans succès)

- Dévier la trajectoire
- Verser de l'huile devant le navire
- Faire courir l'équipage d'avant en arrière
- Tirer avec des armes à feu dans l'eau
- Battre l'eau avec des rames
- Faire glisser un filet le long de la coque

Modélisation

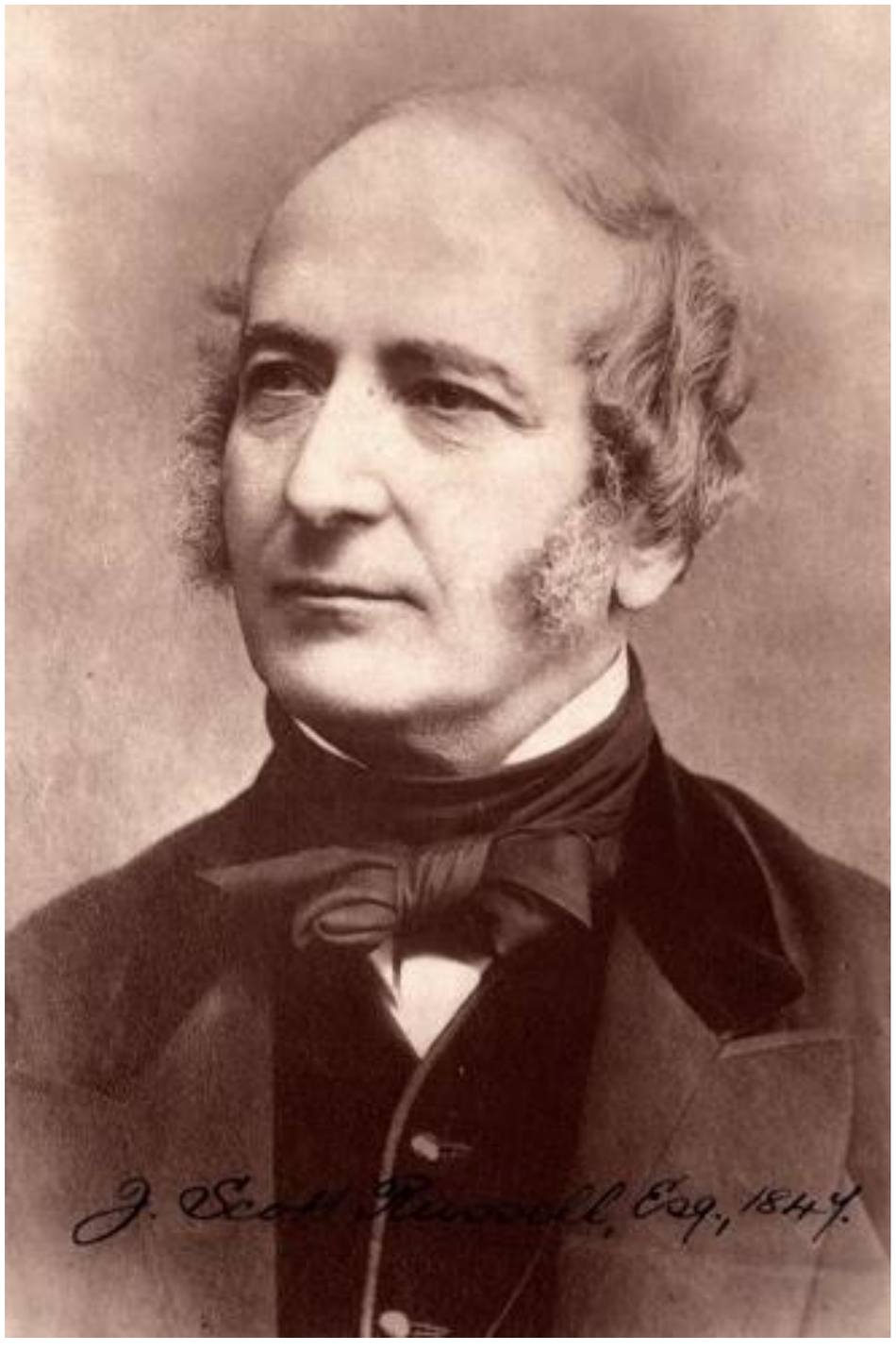
La résistance à l'avancement d'un navire est constituée de

- résistance de frottement ;
- résistance de rencontre.



$$y = \sqrt{gd}$$

John Scott Russell



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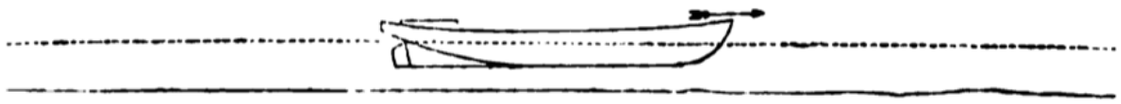

Fig. 5.

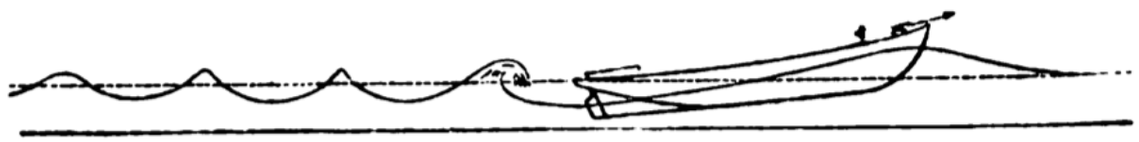

Fig. 6.

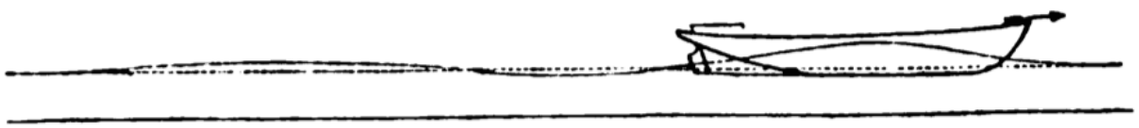

Fig. 7.

Russell, J. S.,
Experimental Researches into the Laws of Certain Hydrodynamical Phenomena that accompany the Motion of Floating Bodies, and have not previously been reduced into conformity with the known Laws of the Resistance of Fluids
Transactions of the Royal Society of Edinburgh (1839)

John Scott Russell

Modélisation

Ekman, V.W., *On dead water*
Sci. Results Norw. North Polar Expedition (1904)

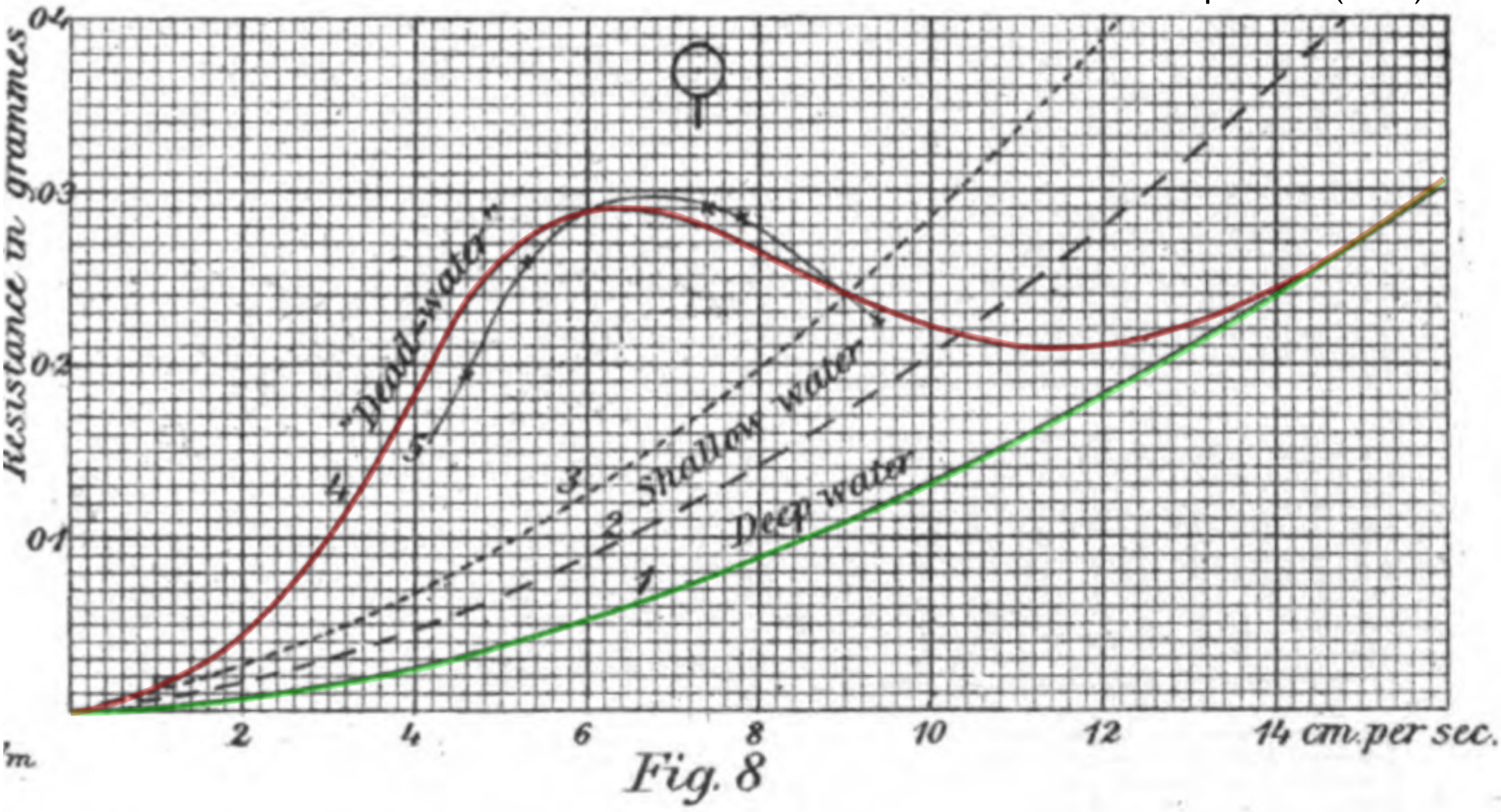

Fig. 8

Résistance à l'avancement en fonction de la vitesse
Eau homogène (en vert) et eau stratifiée (en rouge)

$$\varphi = \sqrt{g(\rho_2 - \rho_1)\frac{d_1 d_2}{\rho_1 d_2 + \rho_2 d_1}}$$

R. Vasseur, M. Mercier, T. Dauxois.
Dead Waters: Large amplitude interfacial waves generated by a boat in a stratified fluid (2008)

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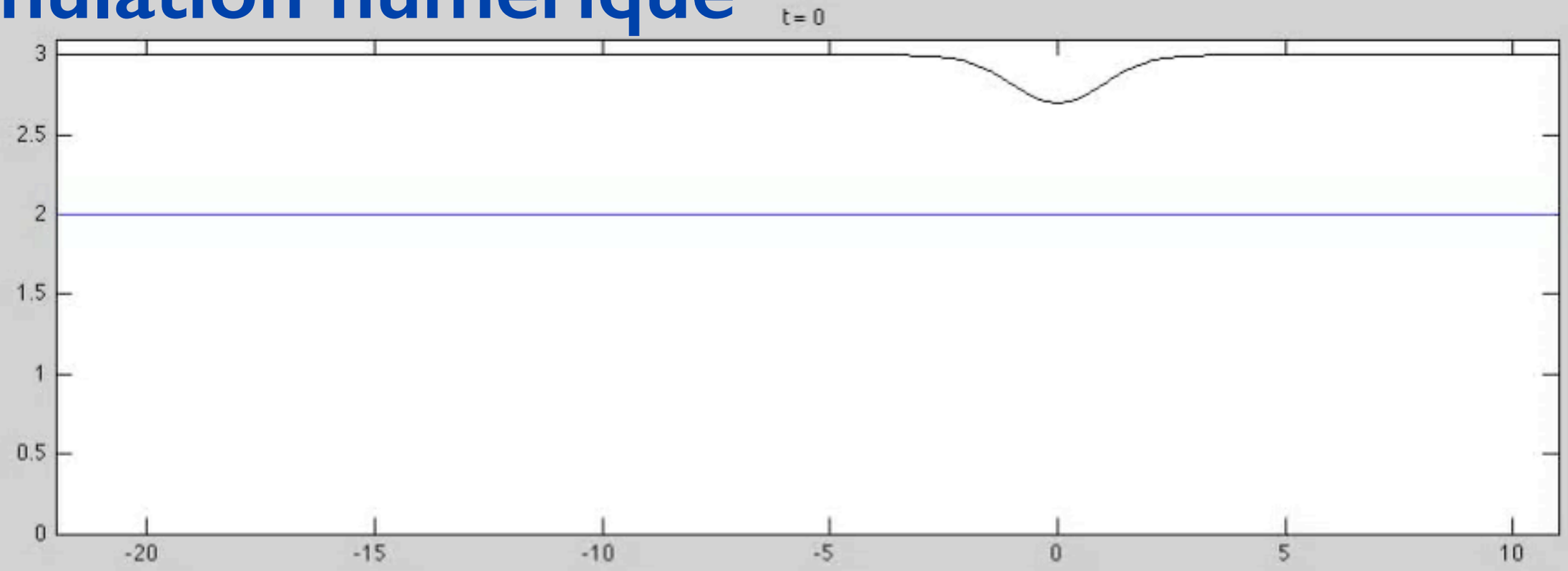
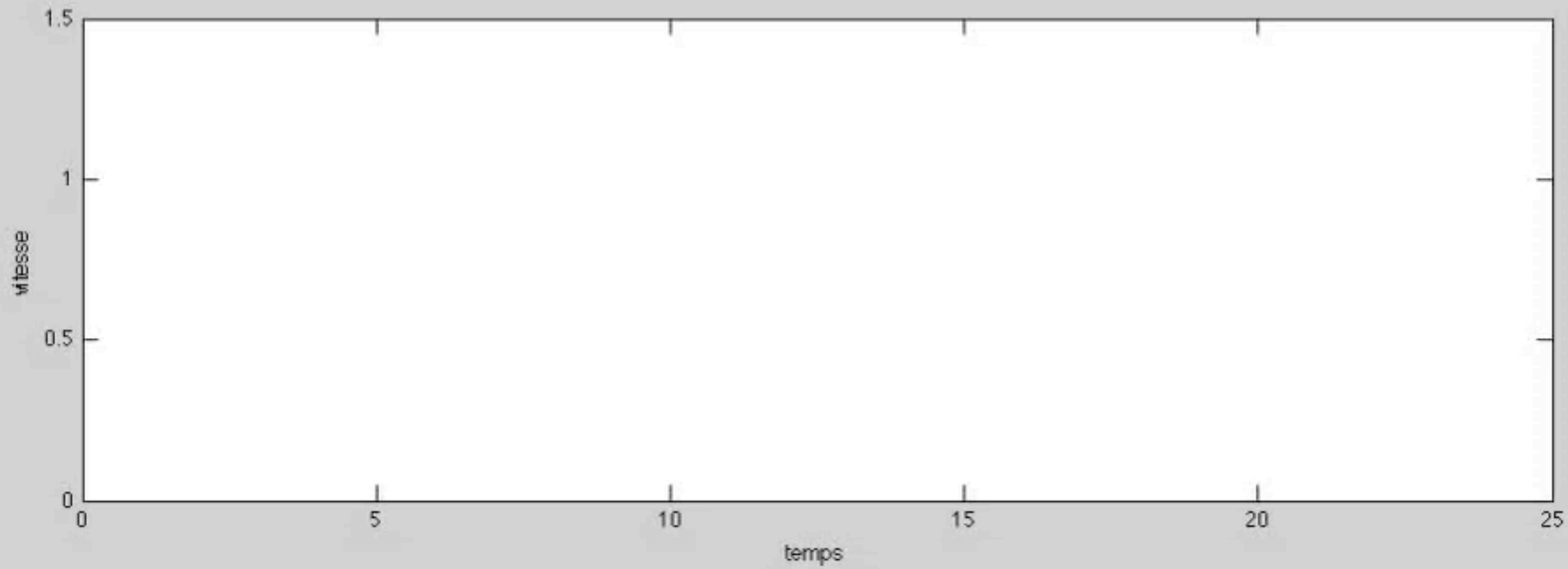
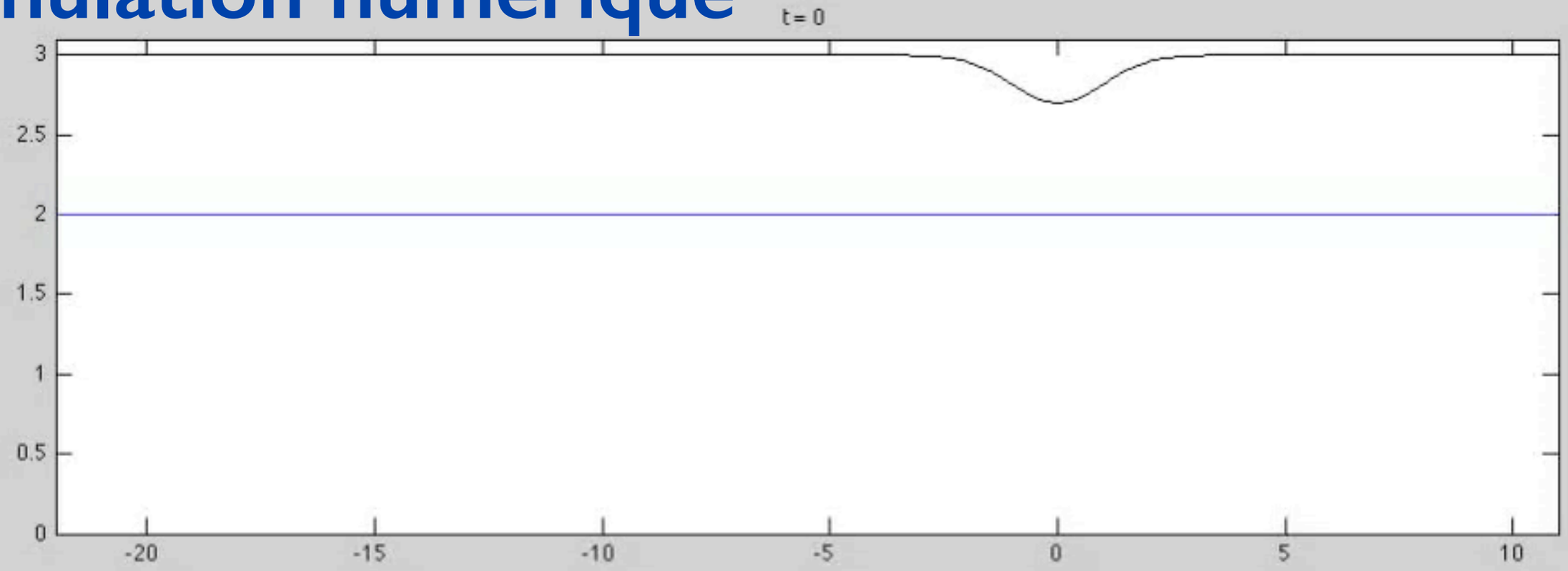
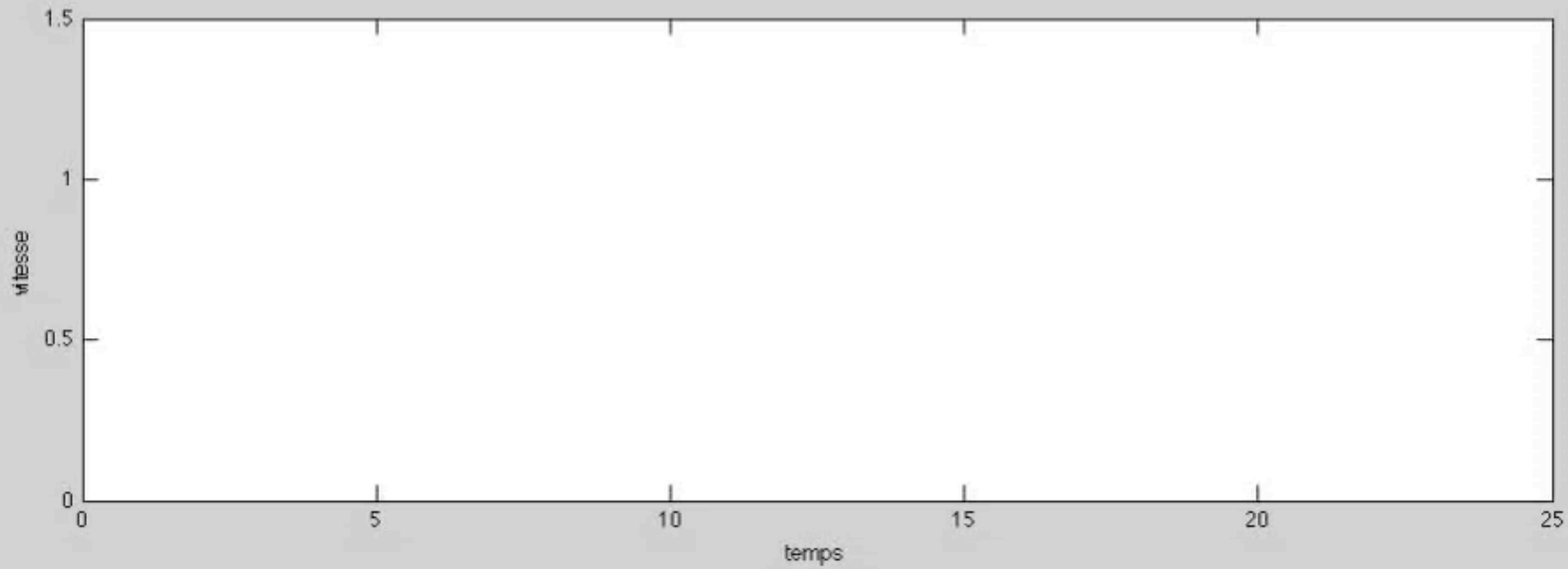
Simulation numérique



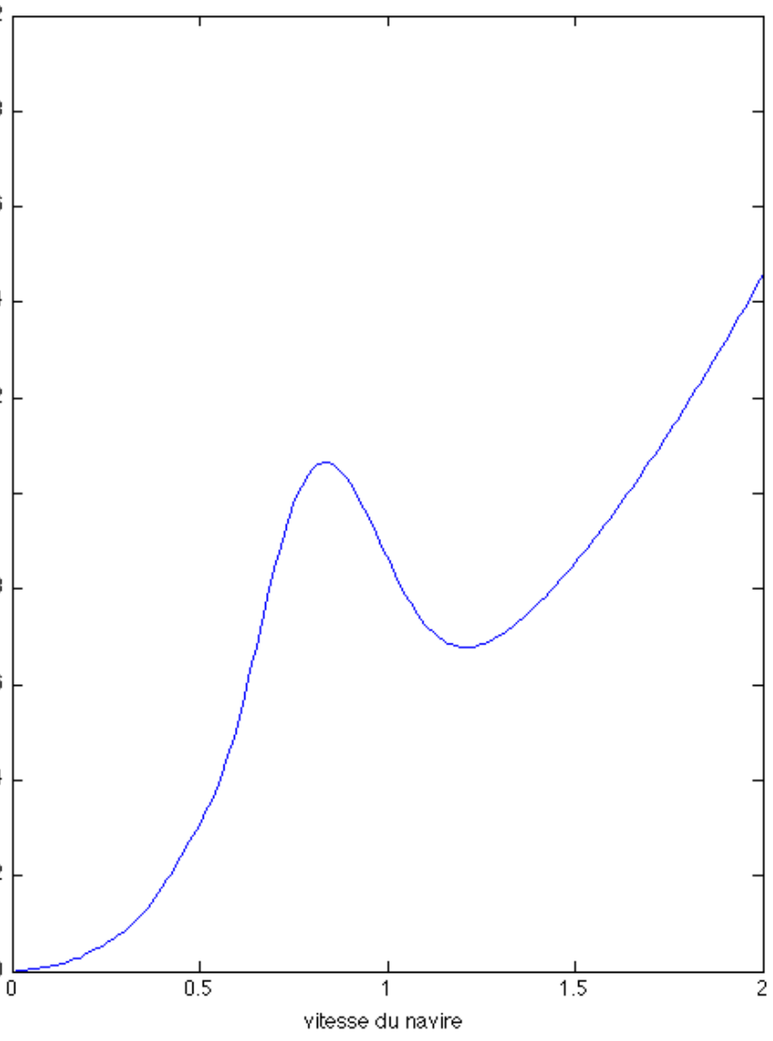


Simulation numérique

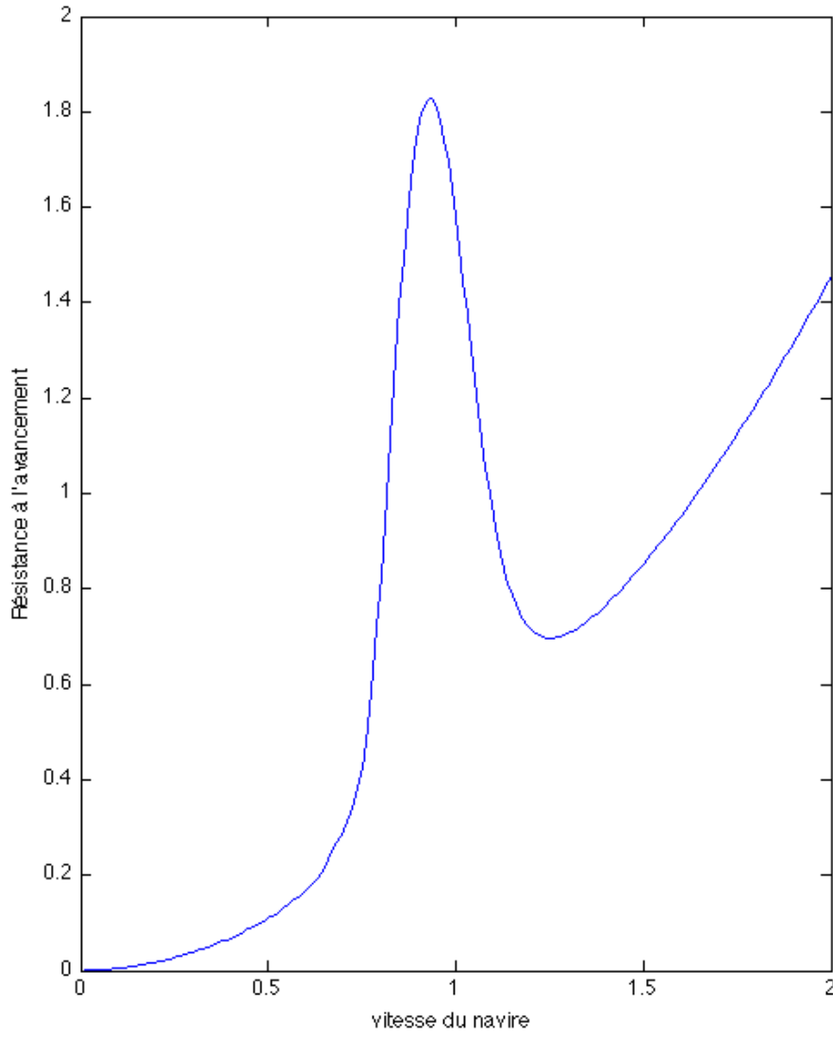




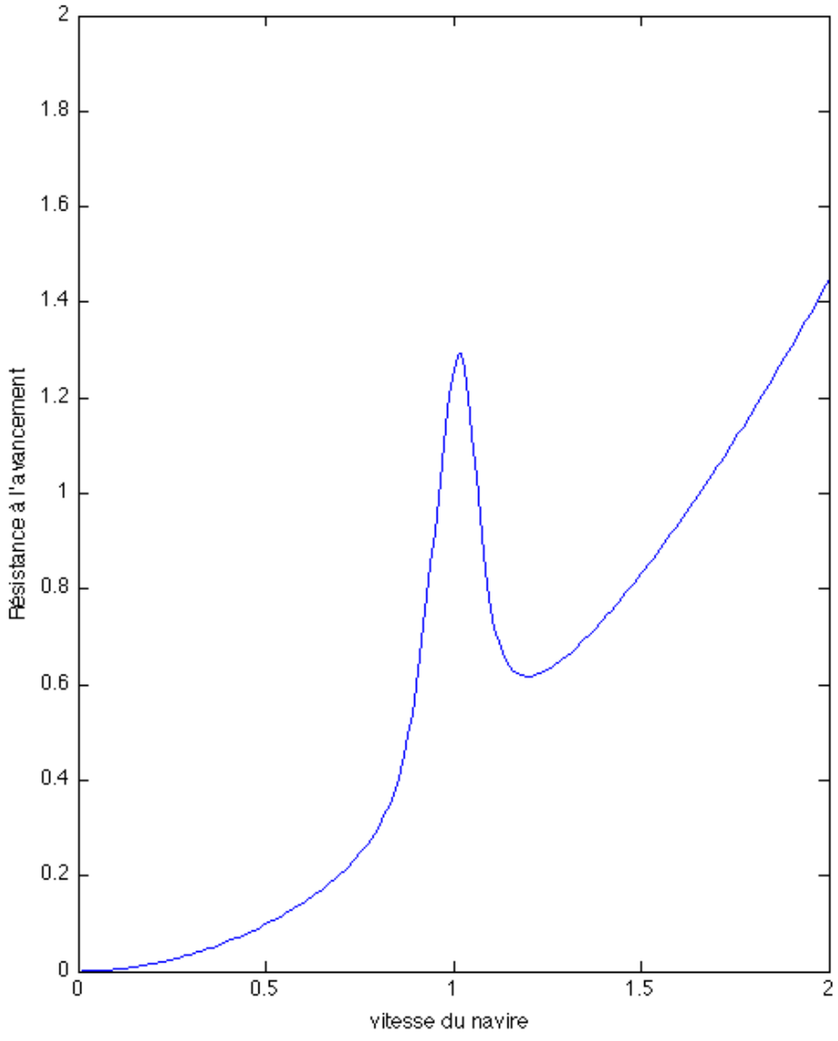
Simulations numérique



Beaucoup d'eau salée

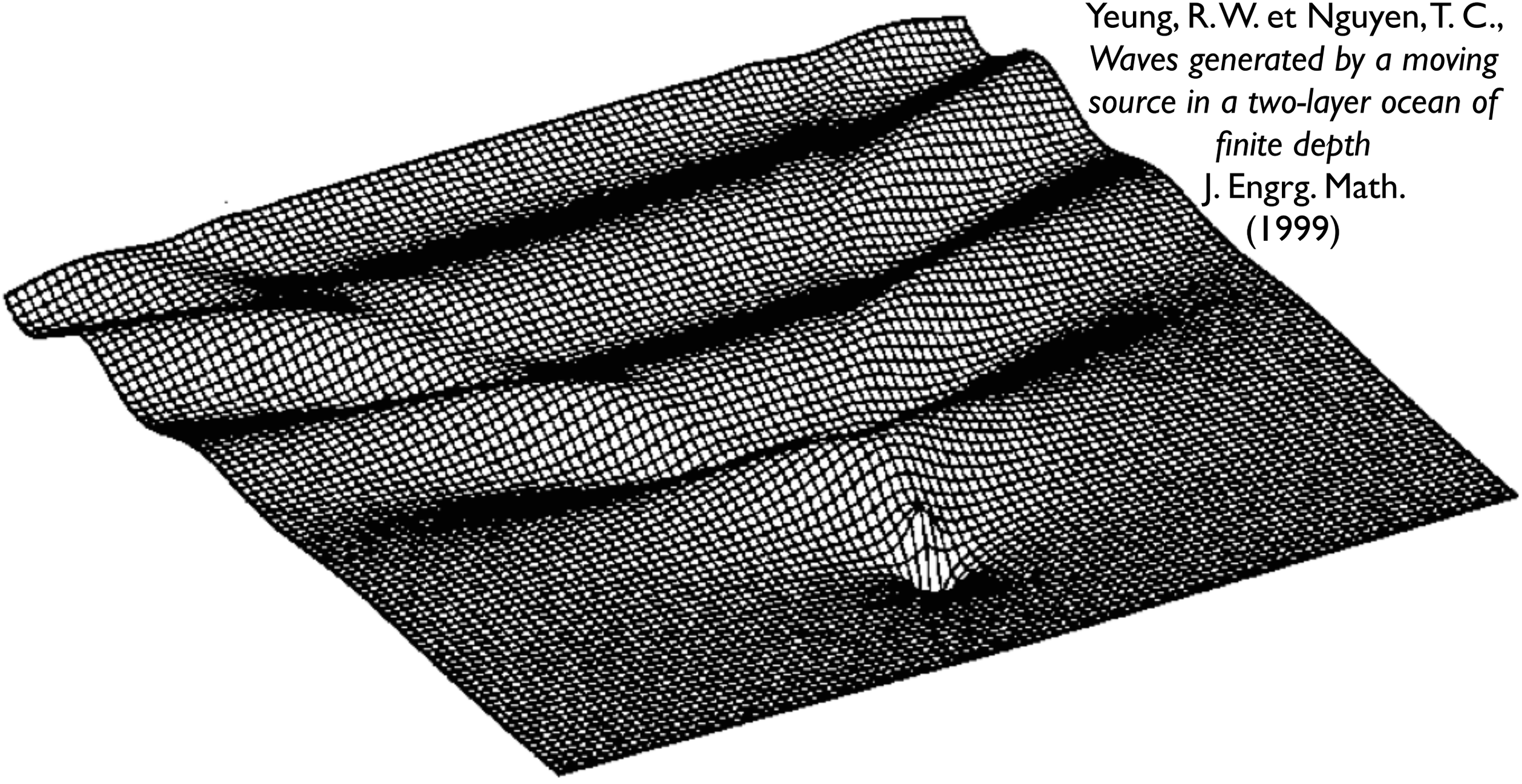


Epaisseurs comparables



Très peu d'eau salée

Conclusion

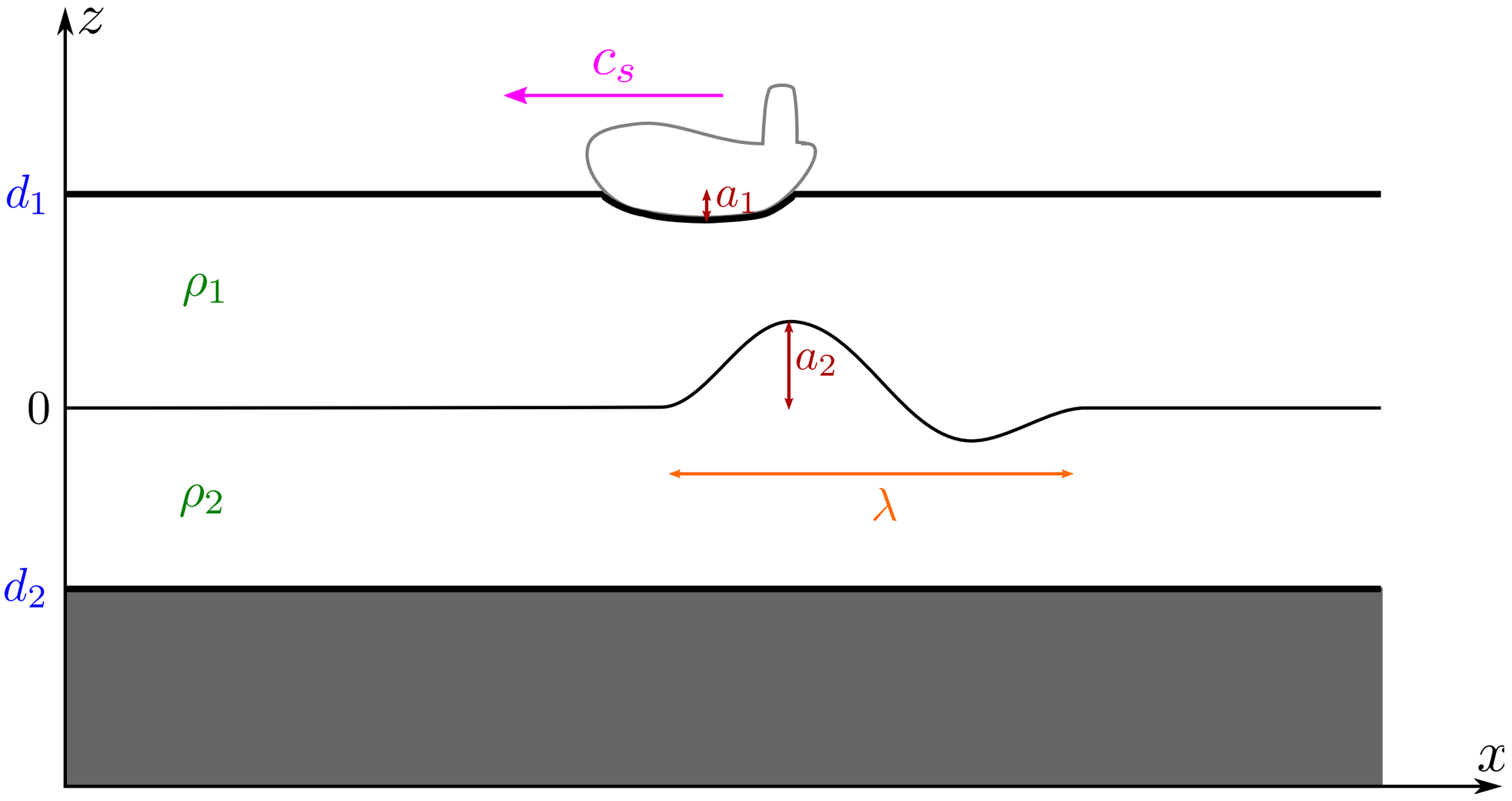


Yeung, R. W. et Nguyen, T. C.,
Waves generated by a moving source in a two-layer ocean of finite depth
J. Engrg. Math.
(1999)

Merci de votre attention!

Modélisation asymptotique

On effectue des manipulations (changements de variable) pour faire apparaître les paramètres pertinents du système.



$$\alpha = \frac{a_1}{a_2}, \quad \epsilon = \frac{a_2}{d_1}, \quad \mu = \frac{{d_1}^2}{\lambda^2}, \quad \mathrm{Fr} = \frac{c_s}{c_0}, \quad \delta = \frac{d_1}{d_2}, \quad \rho = \frac{\rho_1}{\rho_2}$$