Internal Waves in the Ocean

Master 2 — Physique de l'Océan et du Climat

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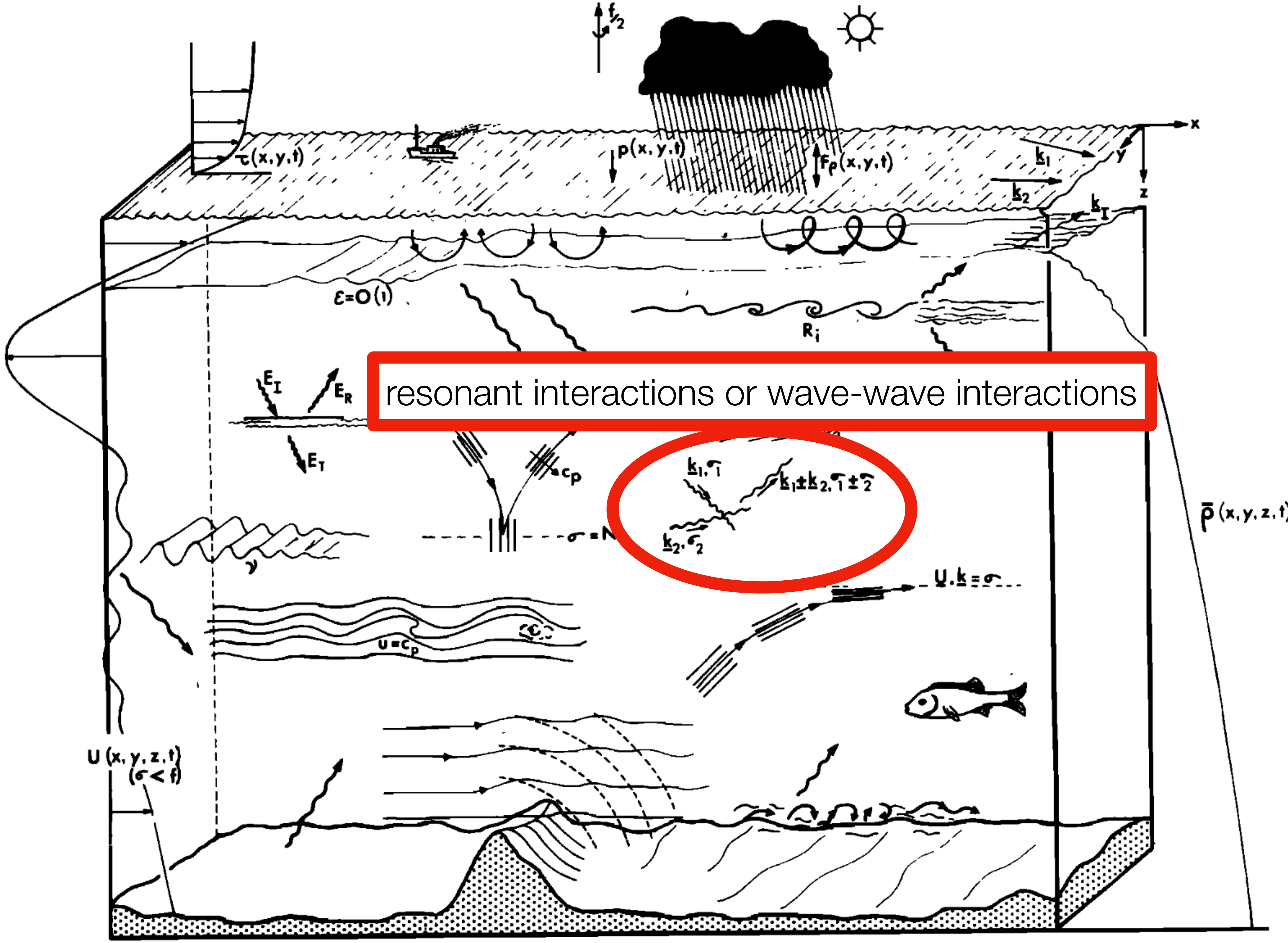
Outline

1. A general introduction to ocean waves
2. What are internal waves ? Why do we study internal waves ?
3. Internal waves in the two-layer shallow-water model
4. Internal waves in the continuously-stratified model
5. Generation of internal waves
6. Propagation of internal waves
7. **Dissipation of internal waves and impacts**

7. Dissipation of internal waves and impacts

Physical processes affecting the propagation and dissipation of internal waves



Thorpe (1975)

7. Dissipation of internal waves and impacts

A resonant second-order interaction between three internal waves characterised by frequencies and wavenumbers $(\omega_1, \overrightarrow{k_1})$, $(\omega_2, \overrightarrow{k_2})$ and $(\omega_3, \overrightarrow{k_3})$ may occur if :

$$\omega_1 \pm \omega_2 \pm \omega_3 = 0$$

$$\overrightarrow{k_1} \pm \overrightarrow{k_2} \pm \overrightarrow{k_3} = 0$$

Under this special circumstance, **non-linear terms efficiently transfer energy from one scale to another**.

Details on theories for wave-wave interactions are given in Chapter 9 in Gerkema and Zimmerman's textbook.

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7. Dissipation of internal waves and impacts

Generation of higher harmonics at boundaries

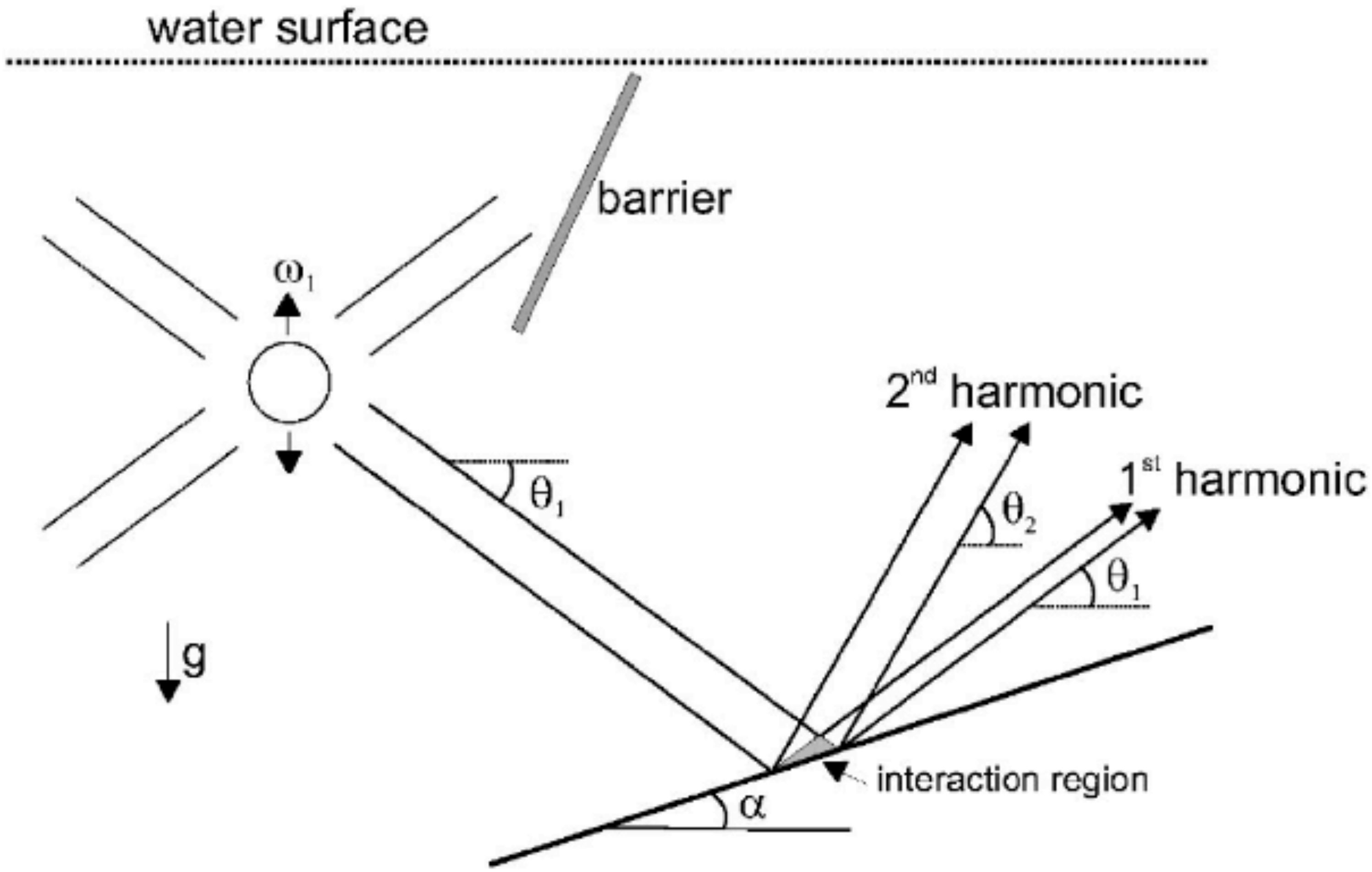

FIG. 1. Schematic of the experimental arrangement.

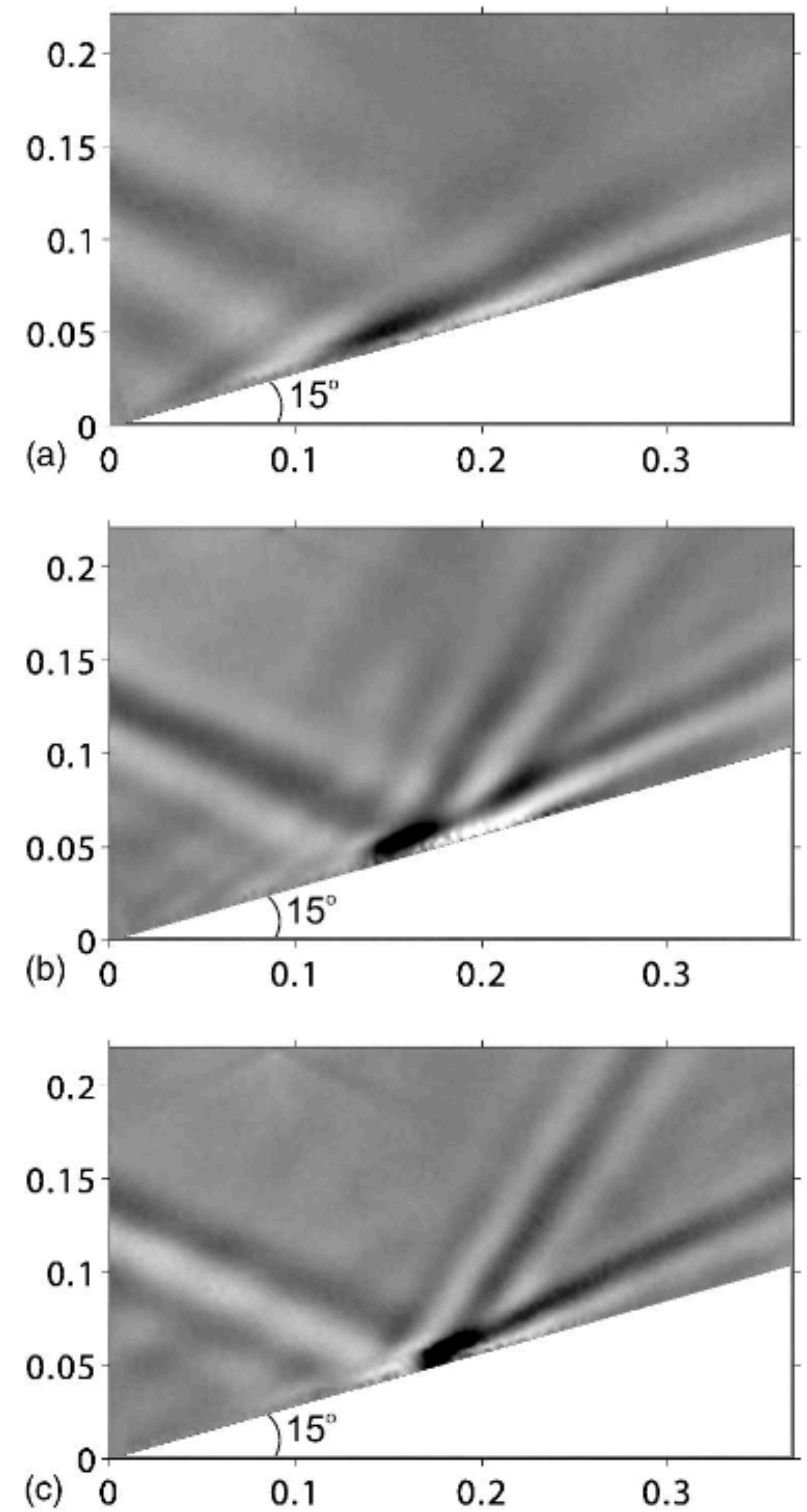

FIG. 2. Images of reflection of a primary-harmonic wave beam for $\theta_2 > \theta_1 > \alpha$. (a) 49 s, (b) 85 s, (c) 146 s. Length scale in meters.

Peacock and Tabaei (2005)

7. Dissipation of internal waves and impacts

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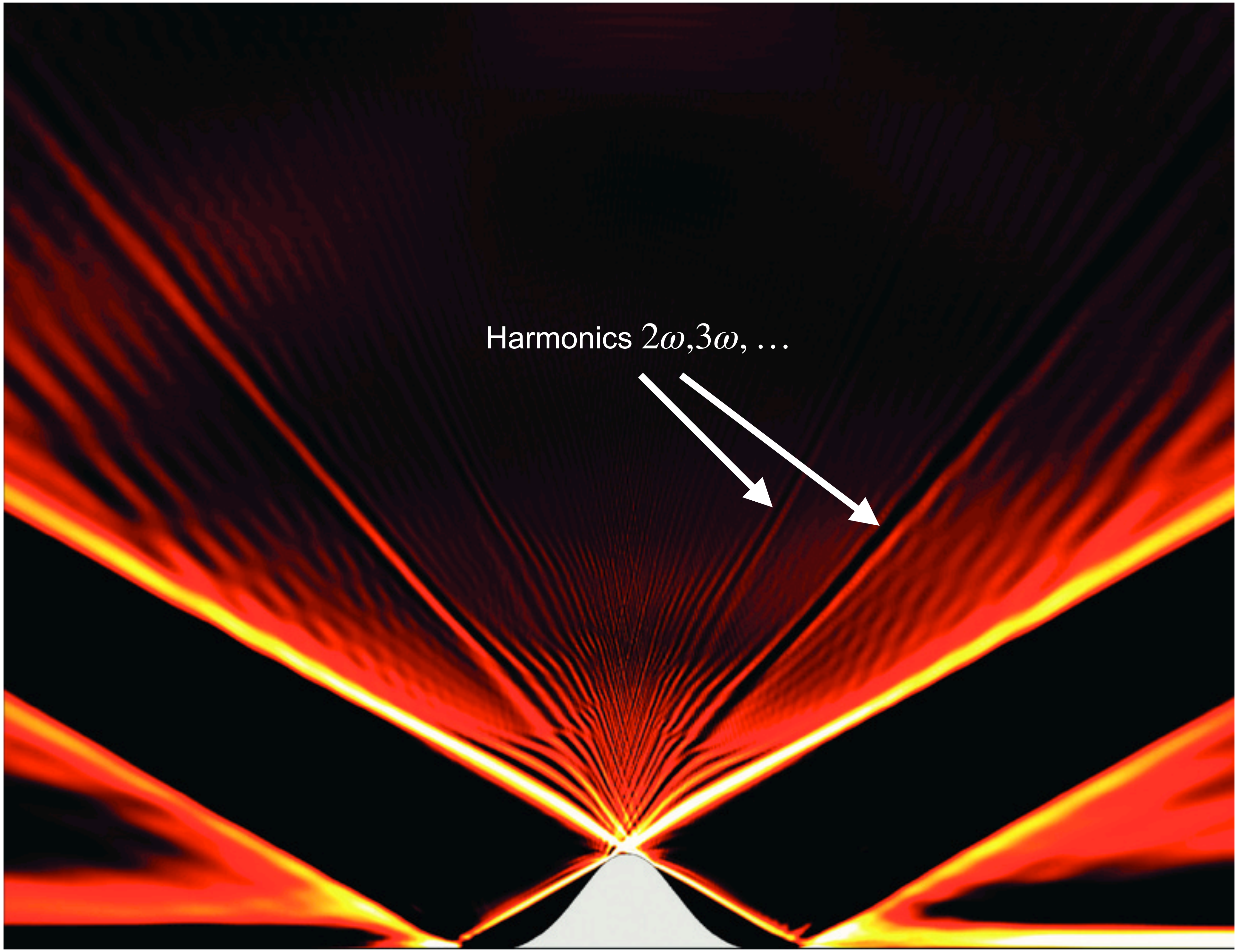
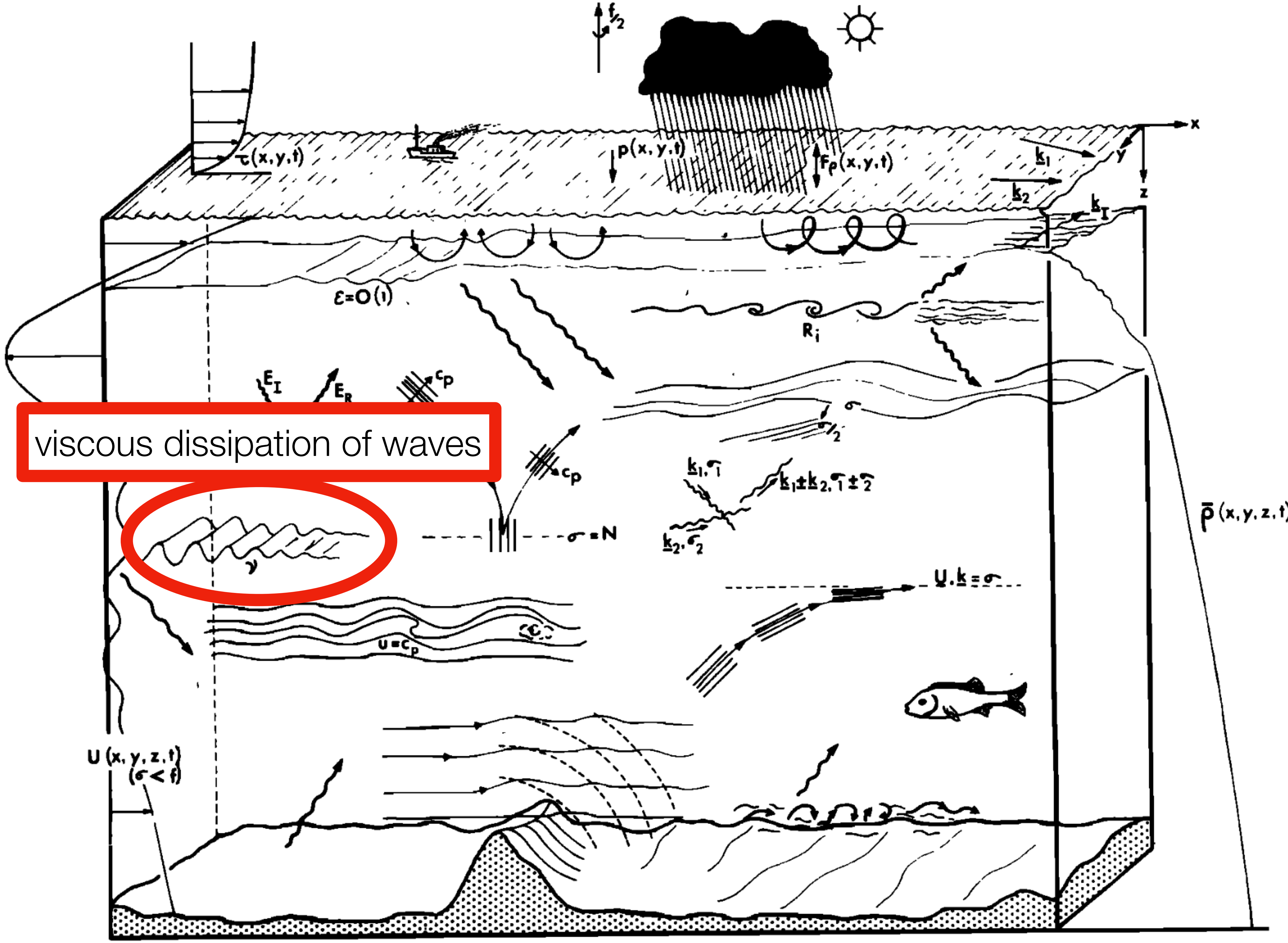


7. Dissipation of internal waves and impacts

Physical processes affecting the propagation and dissipation of internal waves



Thorpe (1975)

7. Dissipation of internal waves and impacts

Viscous dissipation of waves

Internal waves are damped by viscosity. But viscosity acts mostly on small scales.

- Short internal waves (< 100 m) are strongly damped

- Long internal waves (about 100 km) can propagate for distances of 2000 km or more, but will be damped before being able to establish cross-ocean baroclinic standing waves.

- Very long internal waves (> 100 km) are damped by bottom friction

7. Dissipation of internal waves and impacts

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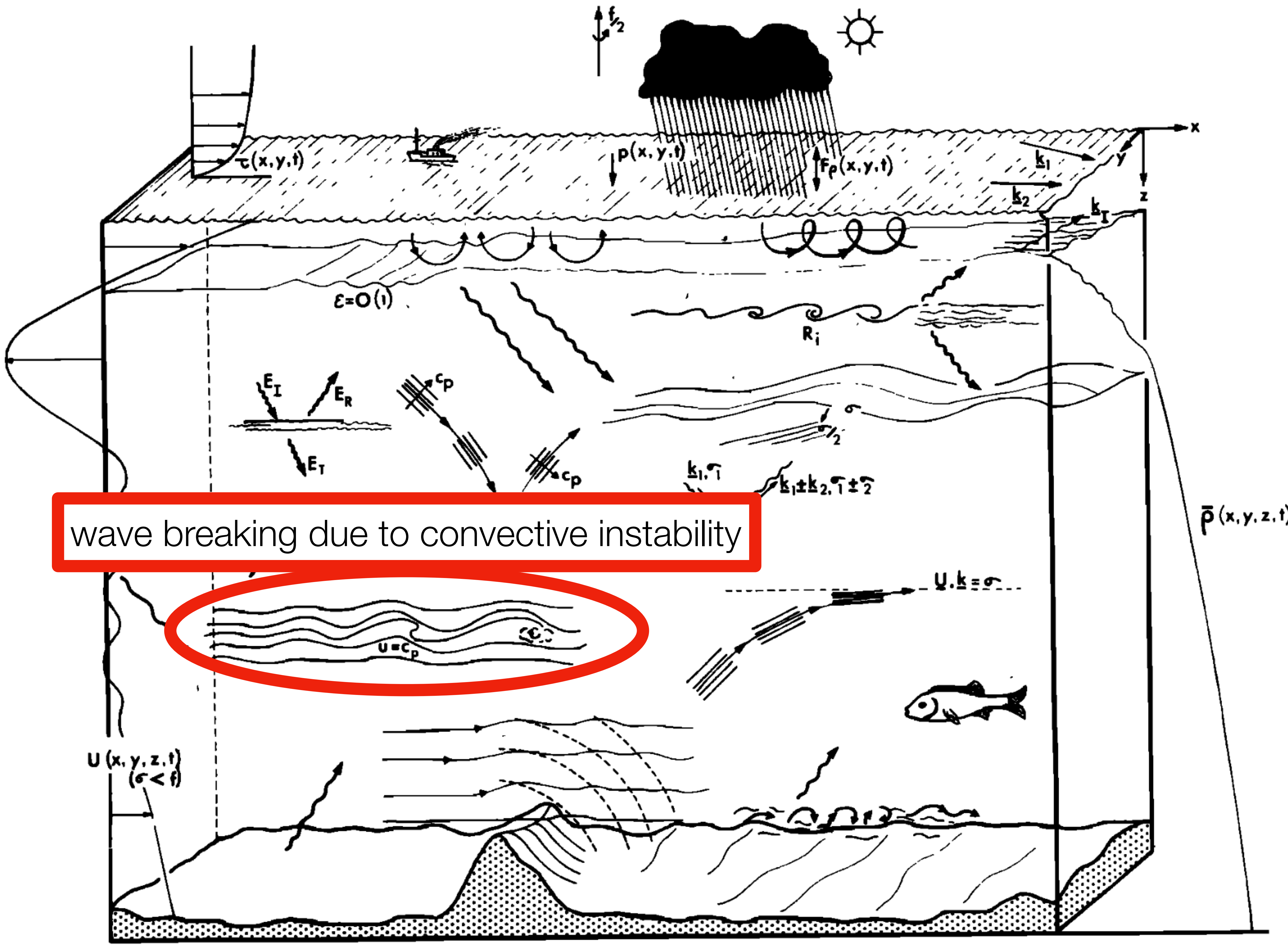

Thorpe (1975)

7. Dissipation of internal waves and impacts

Convective instability : Unstable density gradients may occur where the local horizontal particle speed exceeds the phase speed of the wave.

The crest (or trough) overtakes the rest of the wave, and the wave rolls over similarly to the surf on the sea surface upon approaching a beach.

7. Dissipation of internal waves and impacts

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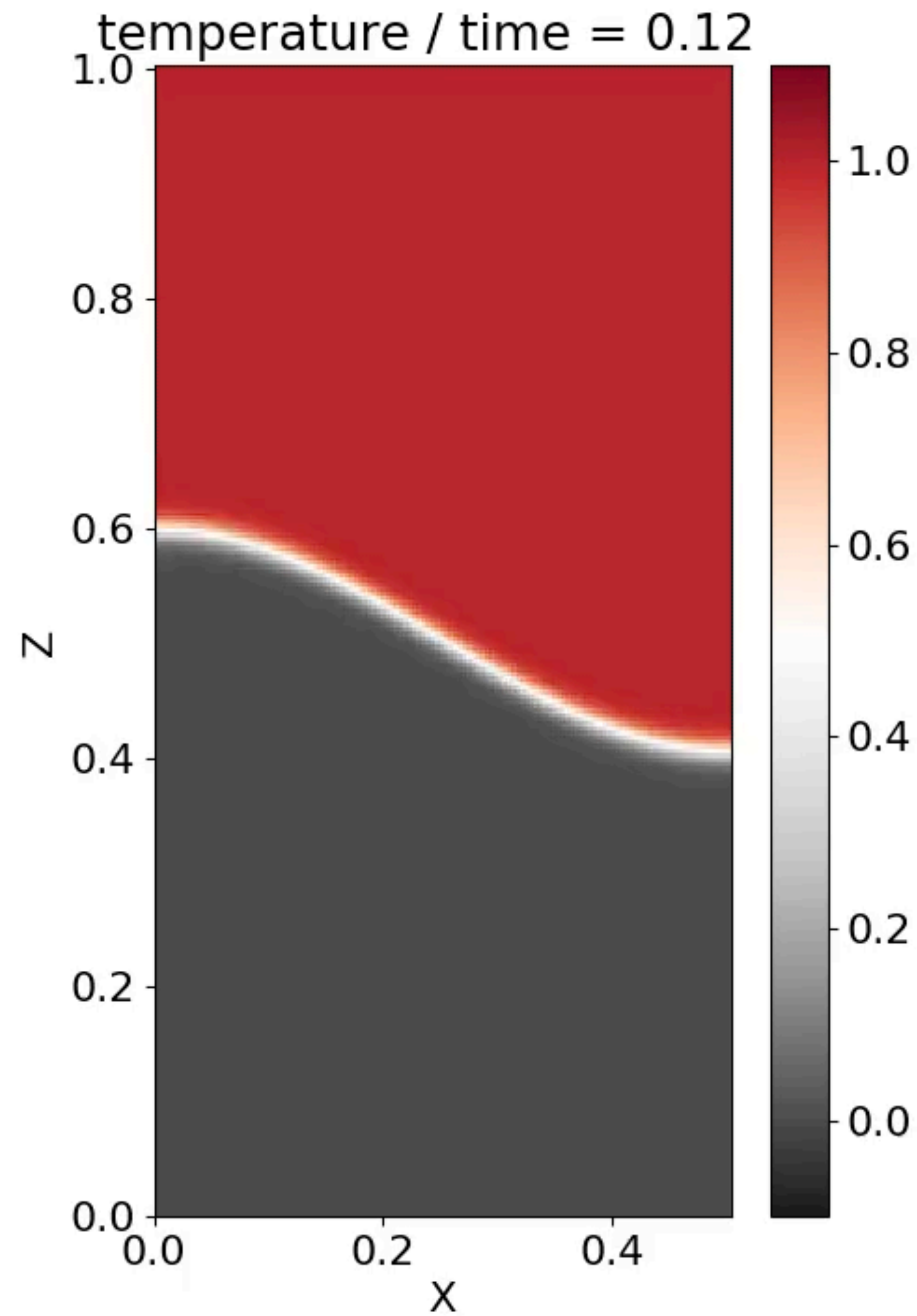


Fluid 2D, G. Roullet

7. Dissipation of internal waves and impacts

Convective instability
Direct Numerical Simulation of wave breaking on a slope

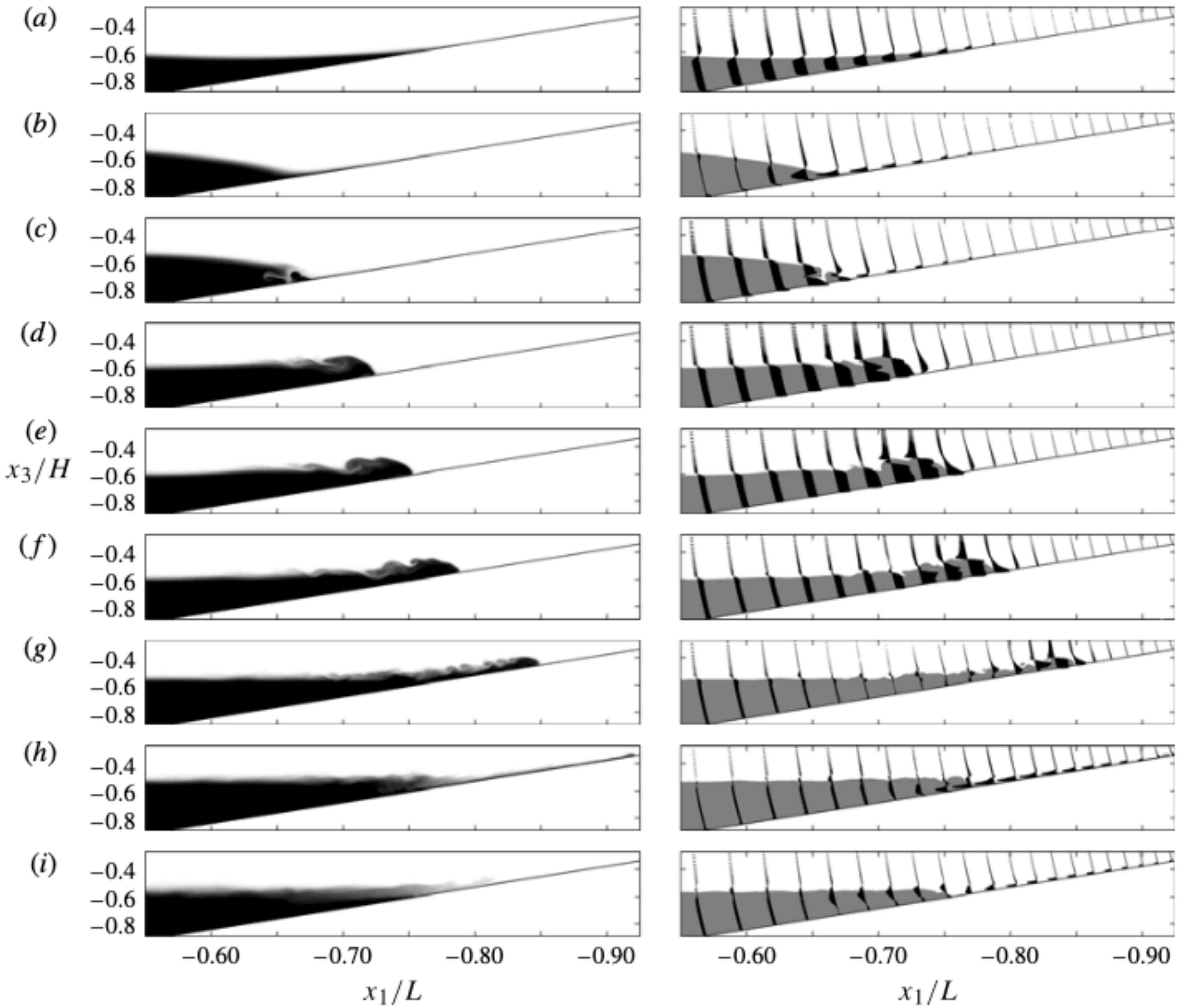
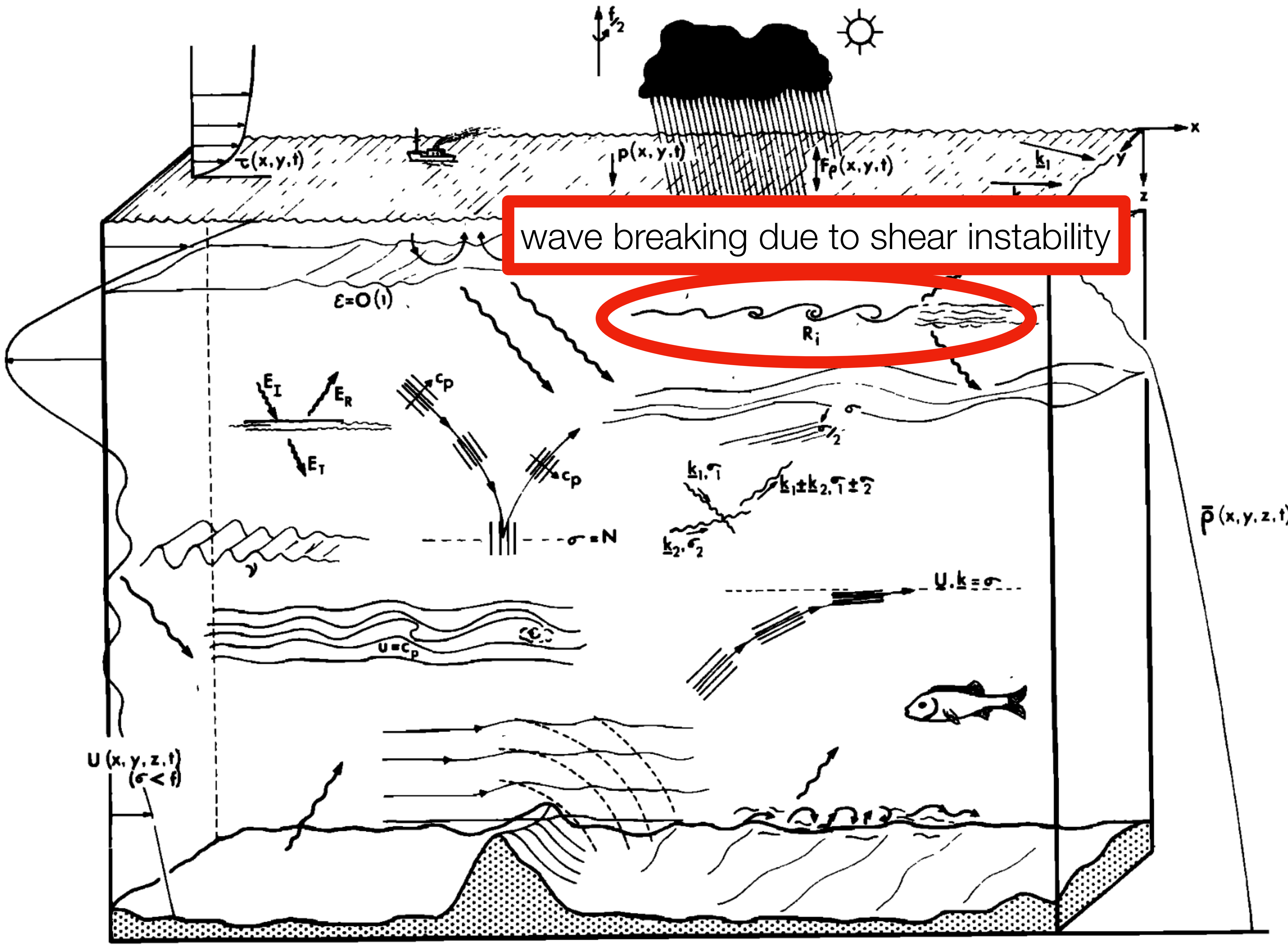


FIGURE 2. Snapshots in time of density structure (left column) and velocity structure (right column) for breaking wave case 3. Results are averaged in the lateral (x_2) direction. In the left column, black corresponds to $\rho = \rho_0 + \Delta\rho/2$ and white corresponds to $\rho = \rho_0 - \Delta\rho/2$. The lower layer ($\rho > \rho_0$) is shown in grey the right column as well. Dots labelled a–i in figures 3, 5, 14, 15 and 23–25 correspond to the labels shown here.

Arthur and Fringer (2014)

7. Dissipation of internal waves and impacts

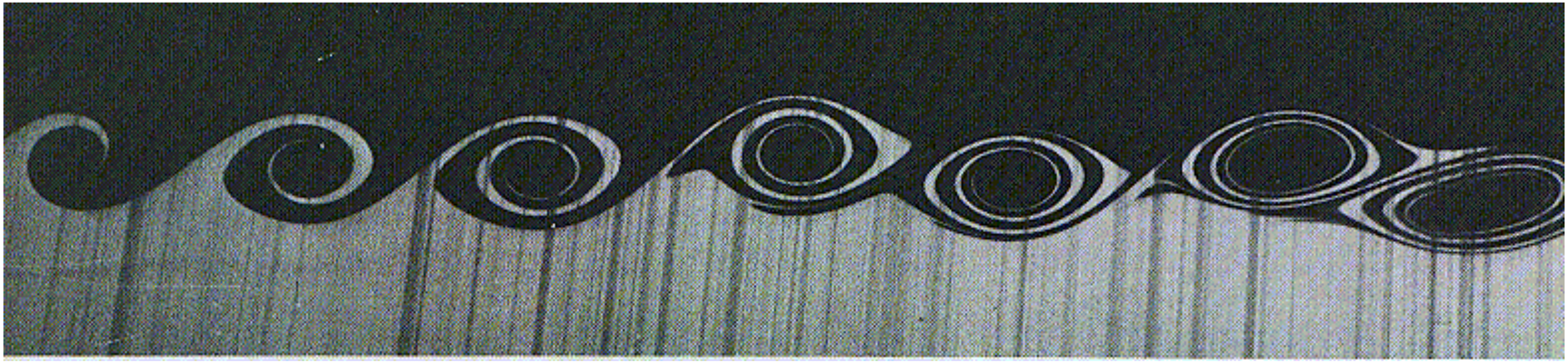
Physical processes affecting the propagation and dissipation of internal waves



Thorpe (1975)

7. Dissipation of internal waves and impacts

If the shear generated by the wave, added to any preexisting shear, becomes so large that the local Richardson number $Ri = \dfrac{N^2}{|\partial u_h / \partial z|}$ falls below a critical value (usually 0.25) long enough for a shear instability to grow and produce density gradients or billows.



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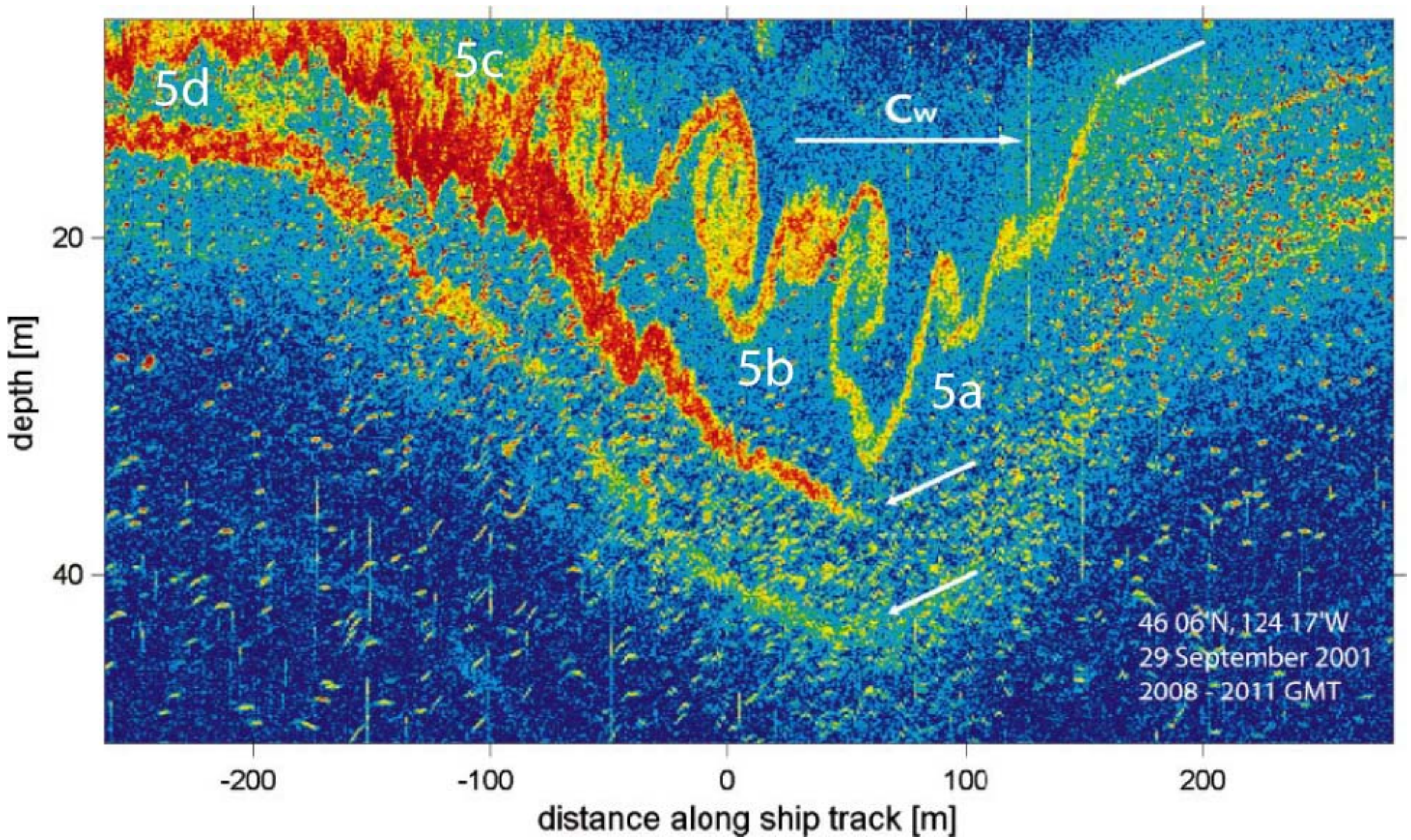

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