Parametric instability and mixing in the ocean

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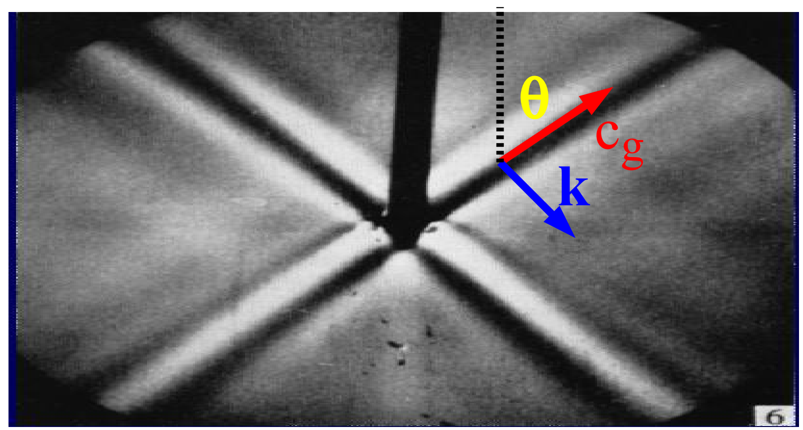
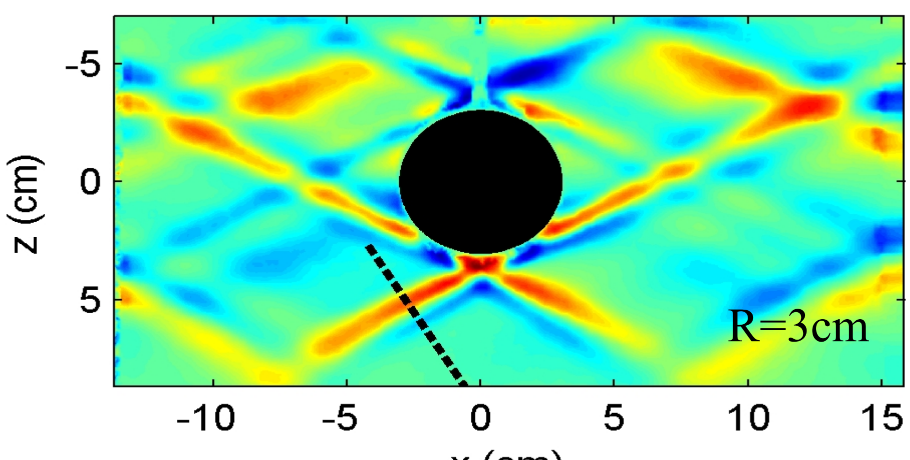
Internal gravity waves propagate as beams



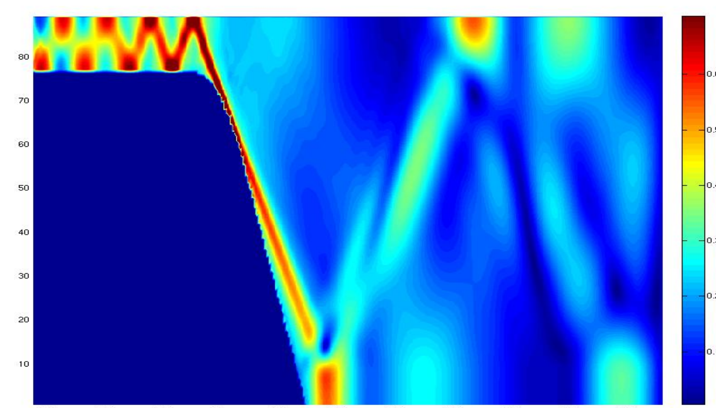
Mowbray & Rarity 1967 (f=0)

Anisotropic dispersion relation: $\omega^2 = N^2\cos^2\theta + f^2\sin^2\theta$ for constant N

$$\Rightarrow f^2 \leq \omega^2 \leq N^2$$

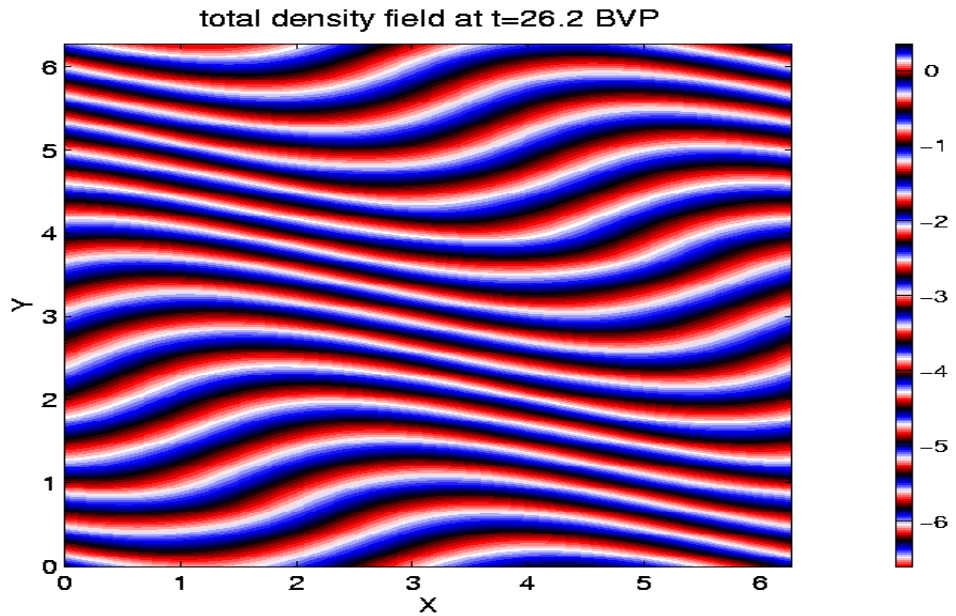


Gostiaux 2006



Pairaud, Staquet, Sommeria et al. 2010

Instability of a plane internal gravity wave



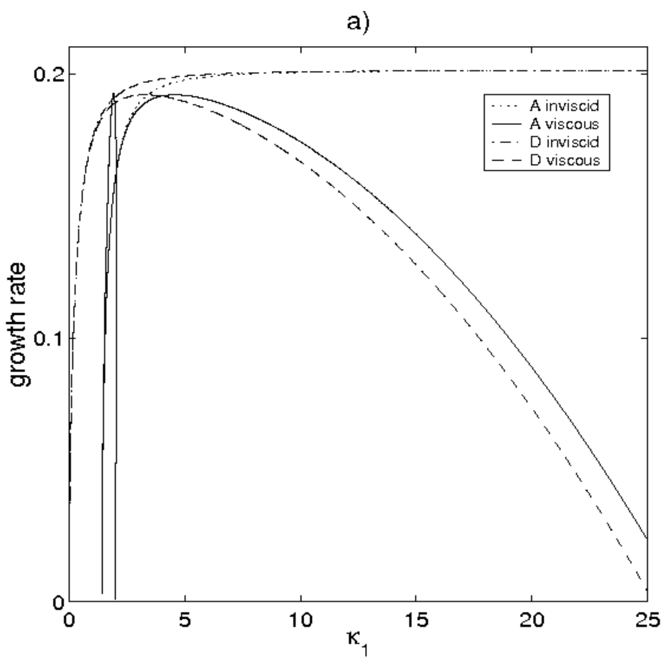
Any monochromatic internal gravity wave of steepness < 1 is unstable to parametric instability, whatever the stratification level of the fluid.

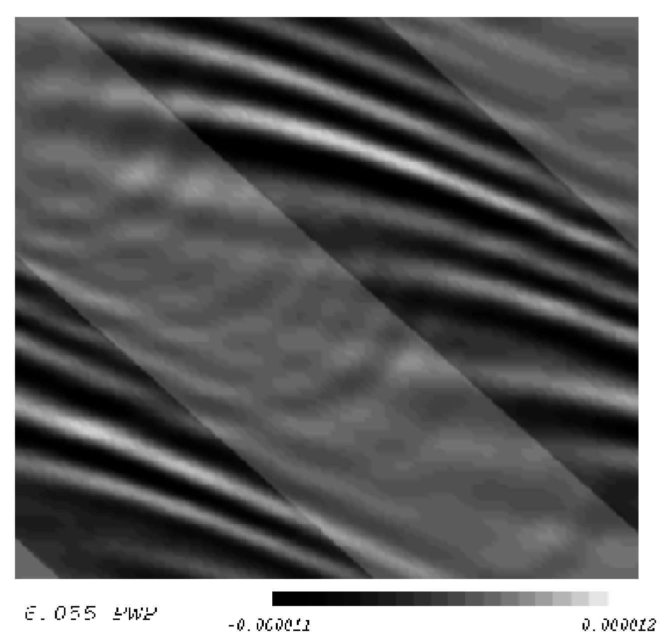
This result can be derived from resonant interaction theory for s « 1 and from stability analysis of the primary wave for s<1.

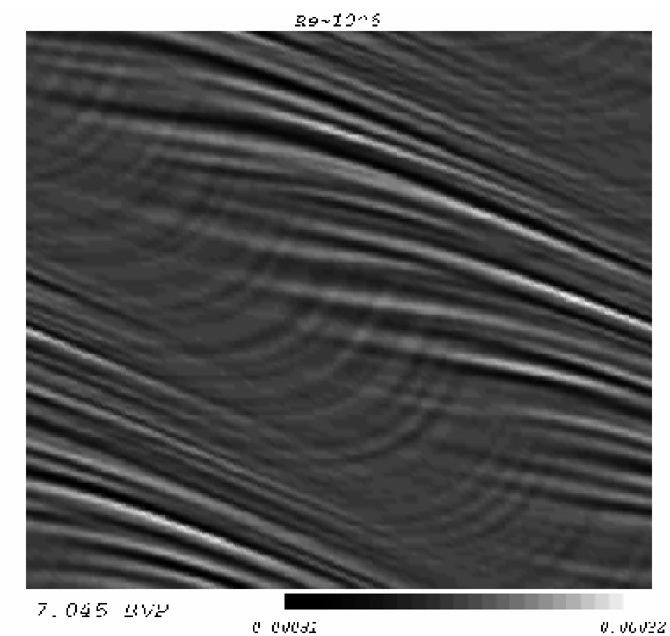
How does the parametric instability manifest itself?

Parametric instability of a monochromatic internal gravity wave

• The instability occurs in the propagation plane (**$\mathbf{k_0}$,g**) of the primary wave : it is a two-dimensional instability.
• The instability is selected by molecular effects and, in a numerical simulation, by the grid size as well.
• The instability manifests itself as “bands” with thickness equal to the molecular-selected scale and with an angle θ_1 such that $N\cos\theta_1 = N\cos\theta_0/2$.





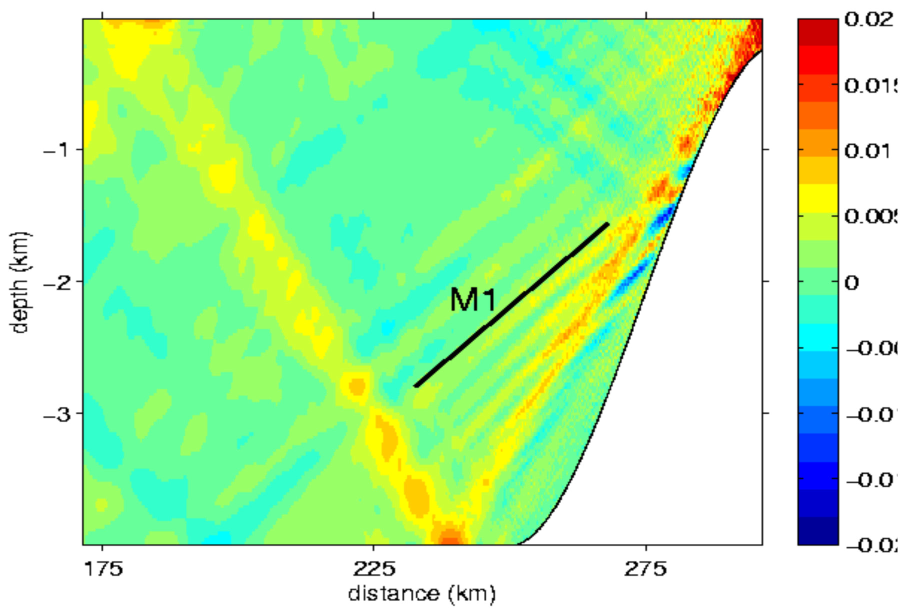


Koudella & Staquet JFM 2006

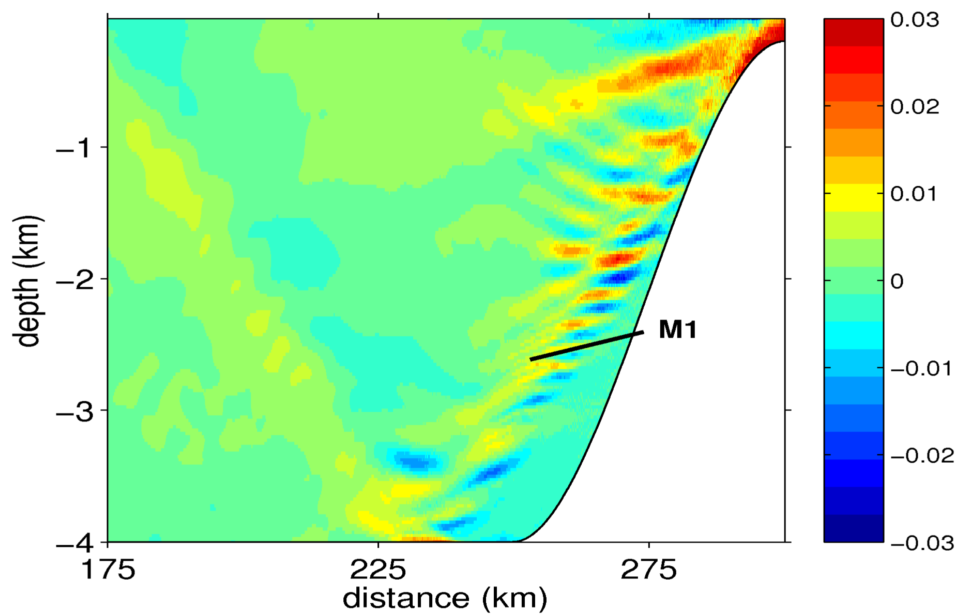
Parametric instability of the internal tide (oceanic context)

Horizontal component of the velocity field filtered at half the forcing frequency

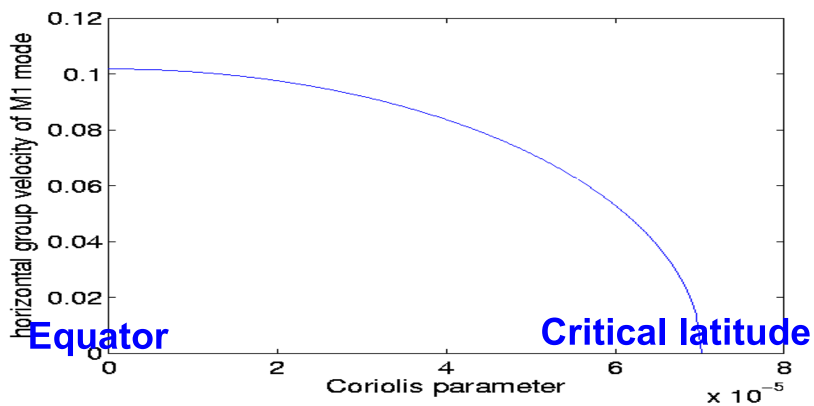
$f=0$ (no rotation $\rightarrow$ Equator)



$f=6.7\ 10^{-5}$ (<critical latitude ≈ 29°)



Critical latitude:
$f_C = M_2/2\ (=M_1)$



M1 horizontal group velocity versus Coriolis parameter

→ **mixing at critical latitude ?**

Gerkema, Staquet & Bouruet-Aubertot 2006

Turbulent diffusivity from *in-situ* measurements and numerical modelling

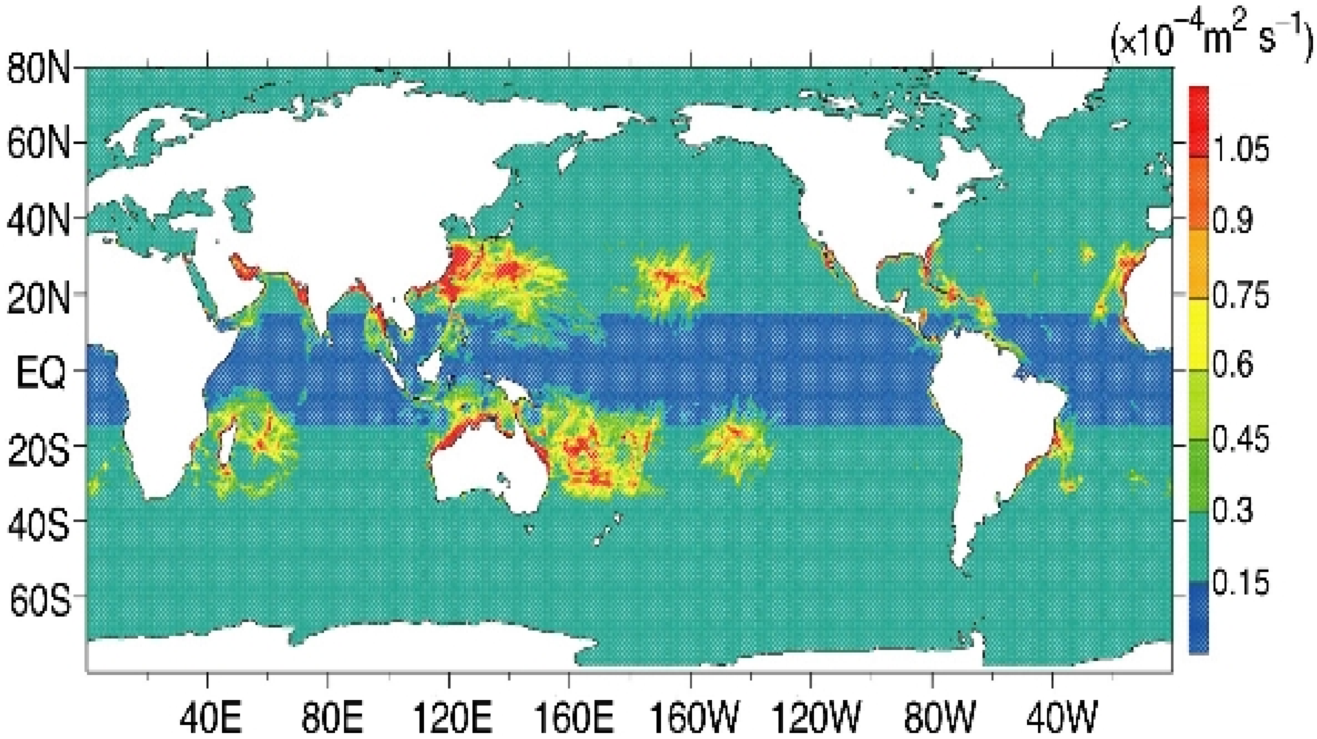


Figure 4. Global distribution of the diapycnal diffusivity calculated by incorporating the numerically-predicted $E(\theta, \phi)$ at each longitude and latitude into the empirical relationship (2).

Hibiya et al. GRL 2006

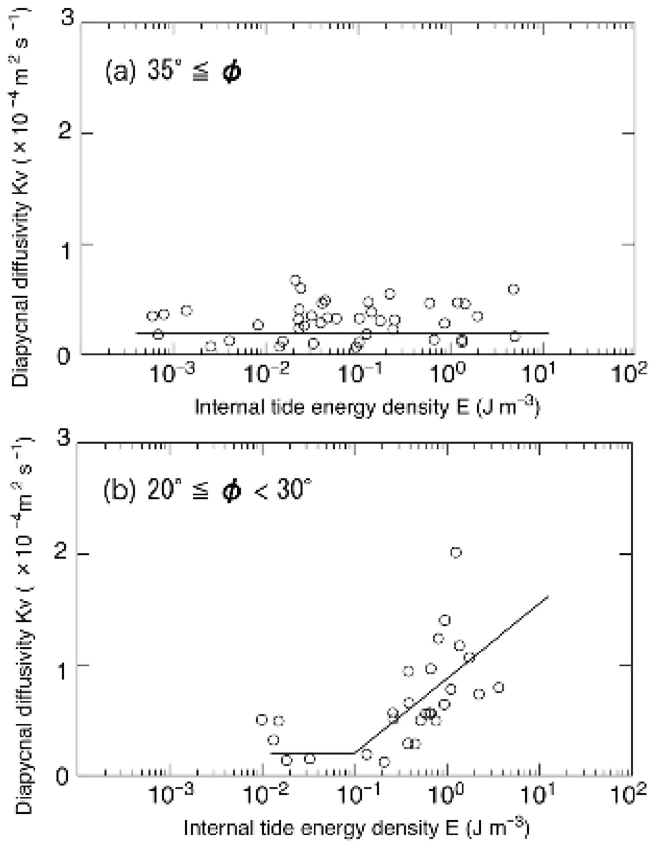


Figure 2. Numerically-predicted local energy density of the semidiurnal internal tide E versus the estimated value of diapycnal diffusivity K_v averaged over a depth range of 950–1450 m at (a) latitudes over 35° and (b) latitudes between 20° and 30°. Empirical relationship summarized as equations (2) is superimposed (solid line).