Some key ingredients for observing an internal gravity wave turbulence regime

V.Labarre & P.Augier & G.Krstulovic & S.Nazarenko

Motivations: Weak Wave Turbulence

(Hasselmann 1962, Nazarenko 2011)

Systems of weakly non-linear waves interacting via resonant interactions

$$\begin{cases} \boldsymbol{k} = \boldsymbol{k}_1 + \boldsymbol{k}_2 \\ \omega_{\boldsymbol{k}} = \omega_{\boldsymbol{k}_1} + \omega_{\boldsymbol{k}_2} \end{cases}$$

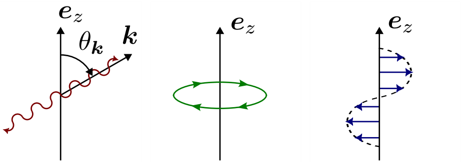
$\Rightarrow$ Kinetic equation

$$\partial_t e(\boldsymbol{k}, t) = \iiint \iiint \left[\mathcal{R}^{\boldsymbol{k}}_{12} - \mathcal{Q}^{1}_{\boldsymbol{k}2} - \mathcal{Q}^{2}_{\boldsymbol{k}1} \right] \mathrm{d}\boldsymbol{k}_1 \mathrm{d}\boldsymbol{k}_2$$

For stratified flows:

$$\begin{aligned} \boldsymbol{\nabla} \cdot \boldsymbol{v} &= 0, \\ \partial_t \boldsymbol{v} + \boldsymbol{v} \cdot \boldsymbol{\nabla} \boldsymbol{v} &= -\boldsymbol{\nabla} p + b \boldsymbol{e}_z + \nu \Delta \boldsymbol{v} + \boldsymbol{f}, \\ \partial_t b + \boldsymbol{v} \cdot \boldsymbol{\nabla} b &= -N^2 v_z - \kappa \Delta b, \end{aligned}$$

Waves | Vortical modes | Shear modes



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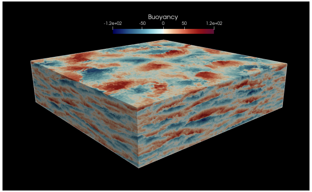
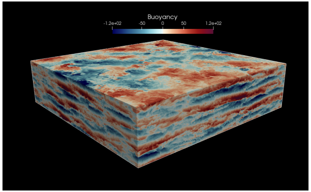
Direct Numerical Simulations:

With vortical modes



Without vortical modes



Forcing: $\hat{v}_{p\boldsymbol{k}}, \quad \omega_{\boldsymbol{k}} \simeq \omega_{\rm f}, \quad T_{\rm c} = 2\pi/\omega_{\rm f}$

Dimensionless numbers:

$$F_h \equiv \frac{\varepsilon_{\rm kin}}{U_h^2 N}, \quad \mathcal{R} \equiv \frac{\varepsilon_{\rm kin}}{\nu N^2}, \quad Pr = \frac{\nu}{\kappa} = 1$$

Conclusions:

- Vortical and shear modes are not the only obstacle to Weak Wave Turbulence
- Vortical modes dominate if $F_h \ll 1$ and $0.1 \lesssim \mathcal{R}$ (ocean, atmosphere)
- Some hints on where a Weak Wave Turbulence regime could be in $(F_h, \mathcal{R})$