PO24E-3001: Energetics of Wind-Induced Internal Wave Radiation from the Base of the Mixed Layer in the North Atlantic

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Motivation Energy transfer mechanisms between atmosphere and deep ocean have been studied for many years, their importance to the ocean's energy balance and possible implications on mixing are widely accepted. The slab model is a well established simulation of near-inertial motion and energy inferred through wind-ocean interaction, but it does not estimate the energy transferred into the abyssal ocean. Within this study the slab model was extended to establish a tool for studying generation mechanisms of wind-driven near-inertial internal waves below the mixed layer and the associated energy fluxes.

The Slab Model following Pollard and Millard, 1970 [2]

· estimates for mixed layer velocities and energy influx

$$\dot{\mathbf{u}} + fR\mathbf{u} + r\mathbf{u} = \mathbf{t} \qquad R = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \qquad \mathbf{t} = \frac{1}{D\rho}\begin{pmatrix} \tau_x \\ \tau_y \end{pmatrix}$$

$\mathbf{u}-$ velocity vector
$f-$ Coriolis frequency
$r-$ characteristic damping frequency
$R-$ rotation operator
$\mathbf{t}-$ vector source function
$D-$ mixed layer depth
$\rho-$ standard density of sea water
τ_i- wind stress component

· solution for velocities in frequency space $(\mathbf{U}, W)$

$$\mathbf{U} = \frac{(i\sigma+r)\mathbb{1} - fR}{(i\sigma+r)^2+f^2}\mathbf{T} \qquad W|_{z=-D} = D\nabla_{hor}\cdot\mathbf{U}$$

· energy flux $\Pi(t)$ into the mixed layer

$$\Pi(t) = D\rho\,\mathbf{t}(t)\cdot\mathbf{u}(t)$$

· hourly wind stress; 0.3° resolution; 1989, 1996: NCEP-CFSR [3]
· climatology for mixed layer depth and stratification: MIMOC [4]

The Hybrid Model following Olbers et. al., 2012 [1]

· vertical velocity from slab model is boundary condition to energetics of internal waves
· energy flux through boundary in frequency space ϕ_F:

$$\phi_F = -\rho\frac{\chi^2}{k_h}\langle WW^*\rangle \qquad \chi^2 = \frac{(N^2-\sigma^2)^{\frac{1}{2}}(\sigma^2-f^2)^{\frac{1}{2}}}{\sigma} \qquad k_h \approx \frac{L_h}{2\pi}$$

$N-$ bouyancy frequency
k_h- horizontal wave number
$\sigma-$ angular frequency
$W-$ vertical velocity in frequency space
L_h- characteristic horizontal length scale

· enables energy flux estimates from the mixed layer into the internal wave field

Energy Fluxes Through the Mixed Layer

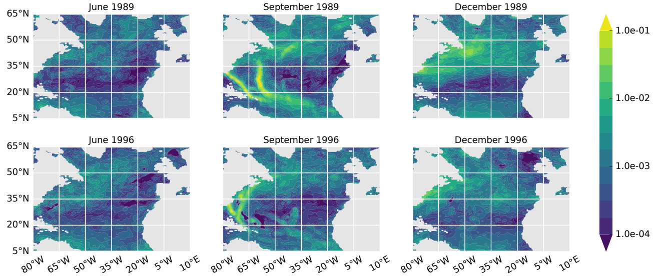

Fig. 1: Monthly energy flux into the mixed layer for selected months in (mW)m⁻². Calm summer conditions, hurricane tracks and mid-latitude winter storms are reproduced.

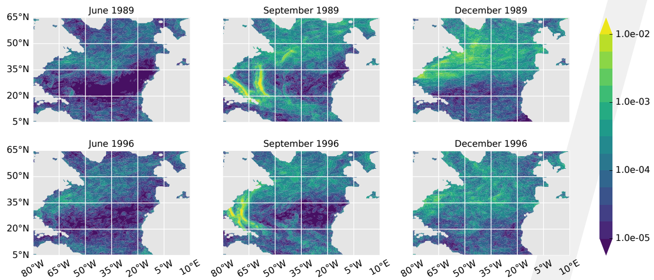

Fig. 2: Monthly energy flux out of the mixed layer for selected months in (mW)m⁻². The large scale patterns of energy influx are mainly preserved. Compare Fig. 1, note the different scales.

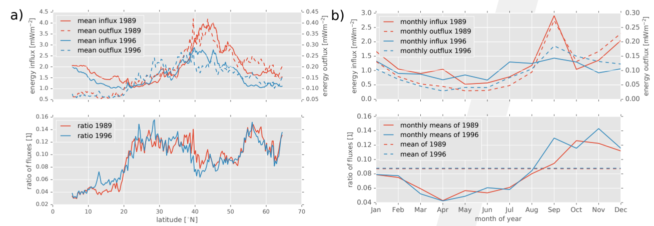

Fig. 3: a) Zonally averaged energy fluxes and ratios. b) Monthly averages over North Atlantic and ratios. The ratio of energy influx to outflux has regional and seasonal dependencies.

Energy Transfer Mechanisms

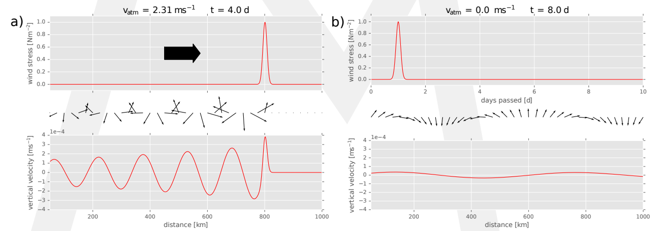

Fig 4. a) An advancing wind front excites vertical inertial oscillations at the base of the mixed layer with characteristic horizontal wavelength. b) A spatially uniform wind stress peak excites weak oscillation due to the beta effect.

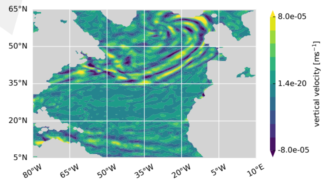

Fig. 5: Snapshot of hourly vertical velocity with 0.3° resolution at the mixed layer base (1989/06/13, 1PM). The field exhibits wave crests and troughs with associated characteristic wave lengths.

Conclusions

· the hybrid model is a suitable tool to study wind induced energy fluxes into the internal wave field
· small and large scale features are well reproduced
· vertical velocities show horizontal wave structure
· advancing atmospheric fronts are identified as the main driver for internal wave excitation
· energy in- and outfluxes and their ratios in the North Atlantic show characteristic annual cycles and meridional dependency
· on average ~10% of the inferred energy is transferred into the internal wave field

References

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Figure 3 is taken from Völker G. S. et. al. 2016 in prep.

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