Near-Inertial Wave energetics in realistic simulations with 1-way and 2-way atmospheric coupling

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INTRODUCTION

Near-inertial waves (NIWs) in the upper ocean are significantly modulated by background vorticity. Our project aims to understand NIW energetics and their interactions with mesoscale eddies as part of the ONR-funded **Near-Inertial Shear and Kinetic energy experiment in the North Atlantic ocean (NISKINe)**. We use realistic **Hybrid Coordinate Ocean Model (HYCOM)** simulations to study-

(1) NIW energy budget in the NISKINe study area during a storm event.

(2) effects of 1-way and 2-way ocean-atmosphere coupling and Data Assimilation (DA) in HYCOM.

HYCOM SIMULATIONS

We show results from 2 global HYCOM simulations analysed for the period May 20 - June 15, 2019 corresponding with the NISKINe science cruise. NIW energy budget during a storm event in this period is investigated. Both simulations have a horizontal resolution of 1/25 degrees and 41 layers. The simulations are forced with tides, atmospheric forcing, and daily 3DVAR DA. The atmospheric model is NAVGEM-T681L60 (19 km, 60 levels).

EXPT 21.6 has realistic 1/3hr wind forcing, but is 1-way coupled.

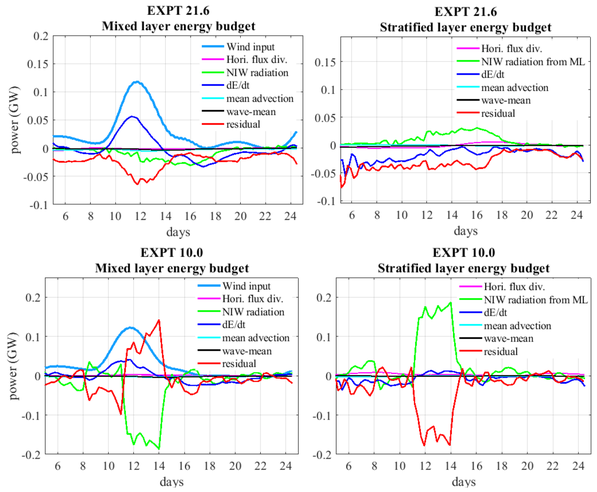
EXPT 10.0 is 2-way coupled with the atmosphere at a frequency of 1/1hr.

ENERGY BALANCE

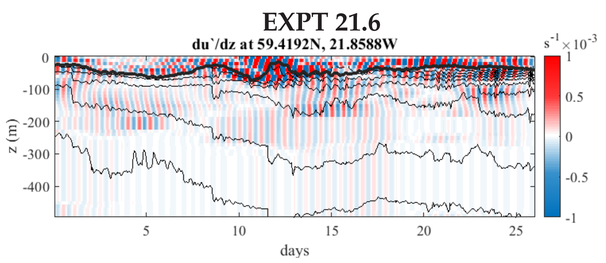
$$\int \left[\left(\frac{\partial}{\partial t} + \overline{u}.\nabla_h \right) \underbrace{\left(\frac{1}{2}\rho_o u'^2 + \frac{1}{2}\rho_o \frac{b'^2}{N^2} \right)}_{\text{NIW KE + APE}} + \underbrace{\nabla.\overline{p'u'}}_{\text{NIW flux divergence}} + \underbrace{\rho_o \overline{u'u'}.\nabla_h \overline{u}}_{\text{wave mean exchange}} \right] dV = \int \underbrace{\overline{\tau' u'_o} dA}_{\text{wind input}} \pm \int \underbrace{J_{z,mld} dA}_{\text{NIW radiation}} + residual$$

We diagnose the above energy balance for the mixed layer and the stratified interior. The wind input is only computed for the mixed layer. The NIW radiation is a sink for the mixed layer and a source for the stratified layer. Each of the terms in the equation is shown in the figures.

- The storm event is well represented by the spike in wind input in both experiments.
- NIW power radiation in expt 10.0 is found to be noisy and exceeds the wind input.
- Wave-mean exchange term is comparatively negligible for both experiments.
- In expt 21.6, the mean wind input to the mixed layer during the storm event (days 8-22) is 32MW, of which 11.6MW is transferred to NIWs.

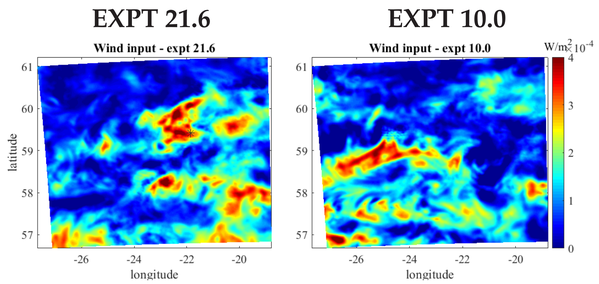


NIWS IN HYCOM

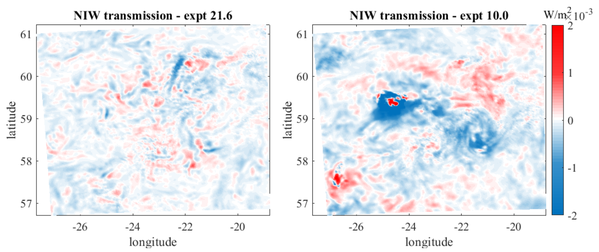


- The above figure shows near-inertial vertical shear (du'/dz) at a point in expt 21.6 where the mean wind input is large during the storm event (shown in the wind input figure).
- The black lines show isopycnals and the bold line shows the mixed layer. We notice deepening of the mixed layer during the storm event on day 11.
- NIWs can be seen propagating downwards following the storm on days 11 through 17 in the figure.
- *Furuichi et al (2008)*[1] proposed using a slab-ocean model that most ($75-85\%$) of the annual wind input is dissipated in the mixed layer. However, they did not account for mesoscale eddies in their model. In this poster, we estimate the NIW power transmitted out of the mixed layer following a storm event using realistic HYCOM simulations.

WIND INPUT & NIW RADIATION



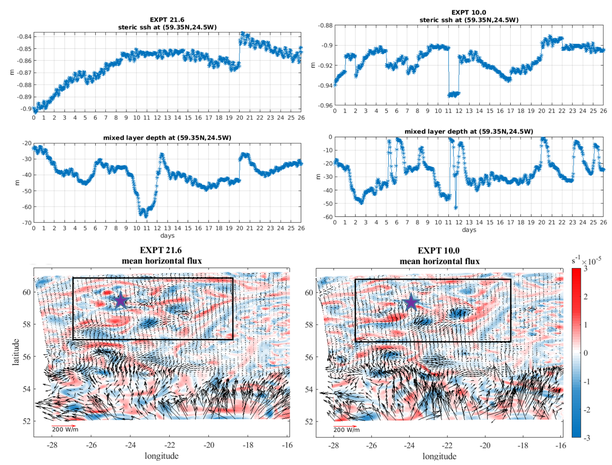
The above figure shows mean wind power input into near-inertial motions for the 2 simulations. The wind input is calculated as, $\tau'.u'_o$, where τ' and u'_o are $1/18hr - 1/13hr$ band surface wind stress and surface water velocity respectively. We notice that wind input differs between the 2 simulations.



Mean NIW power radiating out of the the mixed layer is shown in figure above, estimated as the near inertial vertical energy flux at mixed layer depth, $J_{z,mld} = \overline{w'p'}|_{mld}$. The NIW power transmission is noisy in expt 10.0 with regions of positive vertical fluxes.

SUMMARY AND DISCUSSION

- We find that in expt 21.6, following a storm event, about 36% of the wind power input to the mixed layer is transmitted as NIWs below the mixed layer.
- It is found that data assimilation in 2-way coupled HYCOM (expt 10.0) can cause inaccuracies in NIW energetics.
- Both experiments employ an identical DA scheme for the ocean and atmosphere, but the 2-way coupling in expt 10.0 causes the mixed layer to adjust violently to the nudging of sea-surface height by the DA. This causes the NIW power transmission below the mixed layer in expt 10.0 to be over-estimated. In expt 21.6, a strong nudge of sea-surface height due to DA can be seen only on day 20 followed by an immediate adjustment of mixed layer depth.
- The nudging of sea surface height during DA creates spurious NIWs in a broad frequency band. Spurious waves with super-inertial frequencies can propagate pole-ward. Figure in the bottom panel shows the mean horizontal fluxes for a larger domain. We notice strong pole-ward fluxes south of the NISKINe study area (shown in box). The waves encounter a critical latitude before reaching the study area.

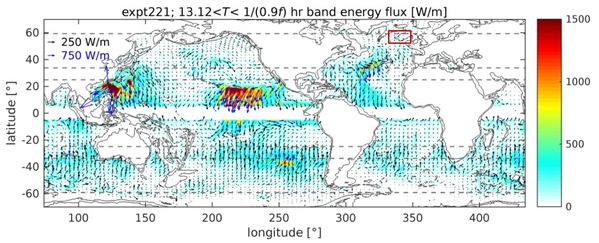


HYCOM SIMULATION WITHOUT DA

Global near-inertial horizontal energy fluxes computed for the month of September 2016 for a $1/25^o$ HYCOM simulation with realistic tidal and atmospheric forcing, but without DA is shown.

In the figure, the least-squares fitted internal tides are removed and the $0.9f - 1/13.1hr$ band is isolated equator-ward of 56^o. The $0.9f - 1.1f$ band is shown pole-ward of 56^o.

The NISKINe study area is marked on the figure by a red rectangle.



FUTURE DIRECTION

To avoid the effects of spurious NIWs, future NIW energy budget analyses will be performed for HYCOM without DA.

A global NIW energy budget is also underway.

Any questions or comments on the poster can be directed to Keshav.Raja@usm.edu.

REFERENCE

1. Furuichi, N., Hibiya, T., & Niwa, Y. (2008). Model-predicted distribution of wind-induced internal wave energy in the world's oceans. *Journal of Geophysical Research: Oceans*, 113(C9).