Mesoscale - Near-inertial wave interactions and their impact on near-inertial kinetic energy vertical distribution in the Iceland Basin from moored observations

Zoé Caspar-Cohen, Amy Waterhouse and Gunnar Voet ; *Scripps Institution of Oceanography*

Introduction

By propagating and dissipating energy, near-inertial waves (NIWs) play an important role in ocean circulation and mixing. Including the study of NIW interactions with mesoscale is necessary for a better understanding of these mechanisms.
In particular, how does mesoscale activity impact the NIW life cycle (generation, propagation and dissipation)?

1. How is Near-Inertial Kinetic Energy (NI KE) vertical distribution linked to mesoscale properties such as vorticity?
2. How do these interactions impact the seasonality of NIWs?

Data

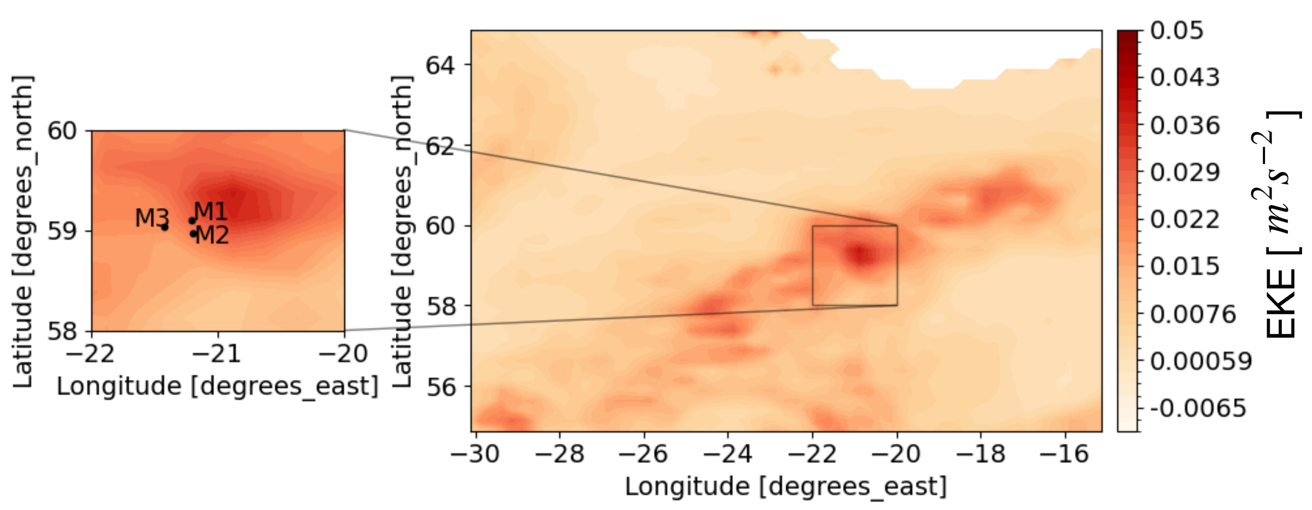


Fig.1: Time mean of eddy kinetic energy in Iceland Basin from satellite-altimetry (E.U. Copernicus Marine Service Information) and (left) zoom in NISKINe moorings locations (black points)

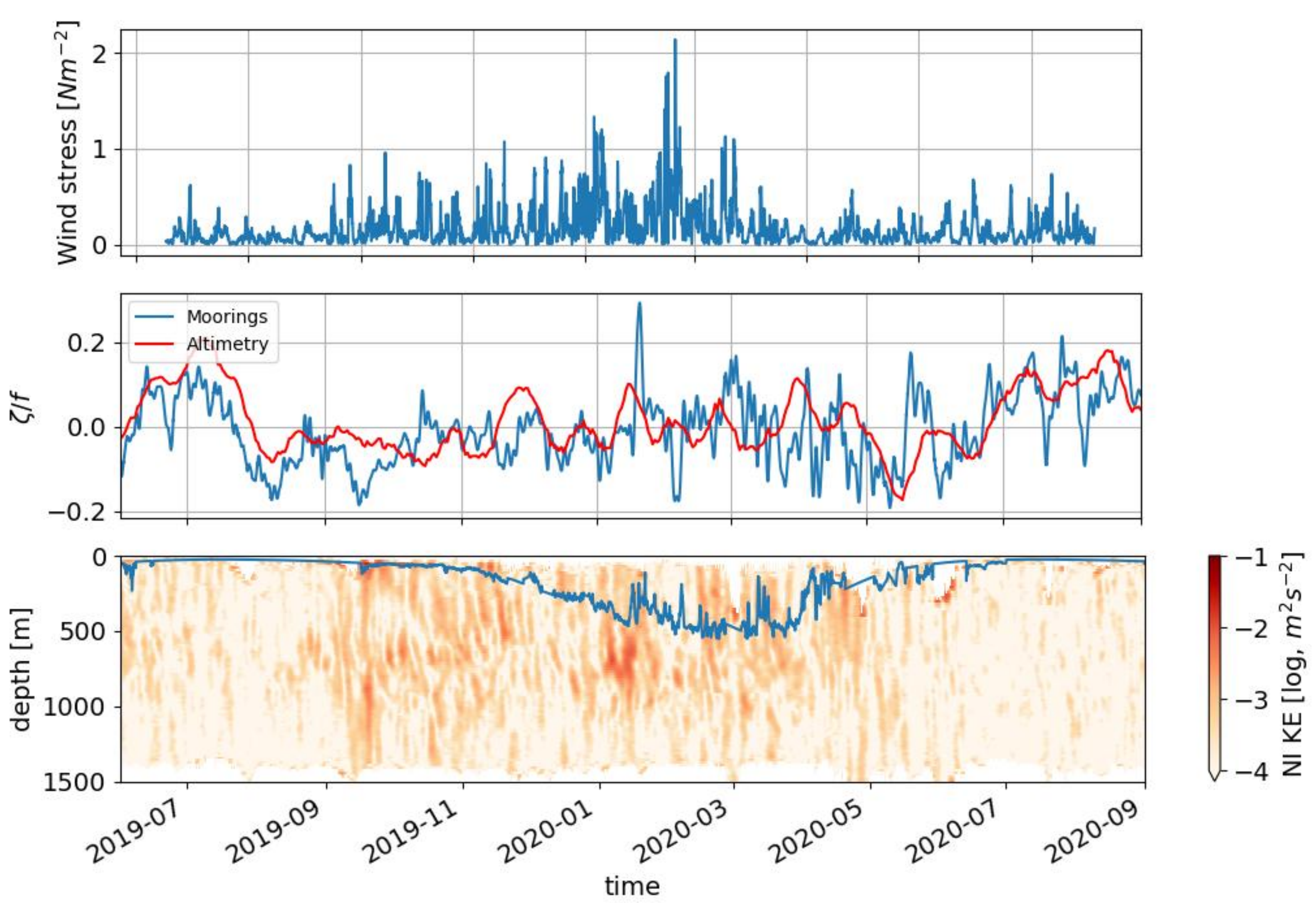


Fig.2: (Top) Wind stress (from ERA5 reanalysis, Hersbach et al., 2023) at M1 location. (Middle) Relative vorticity derived from (red) satellite-altimetry (E.U. Copernicus Marine Service Information) and (blue) mooring velocity time series. Vorticity from altimetry is estimated at the surface while vorticity from moorings is estimated and averaged over the overlapping moorings depth range. (Bottom) Near - Inertial Kinetic energy observed at mooring M1. Blue curve represents the mixed layer depth (MLD)

- Low frequency activity all year: high KE, positive (summer) and negative (fall and winter) vorticity
- High wind stress in Fall and Winter
- Inertial frequency, f ~ 1.72 cpd
- High NI KE above and below mixed layer (ML)

Near - Inertial Kinetic Energy Propagation

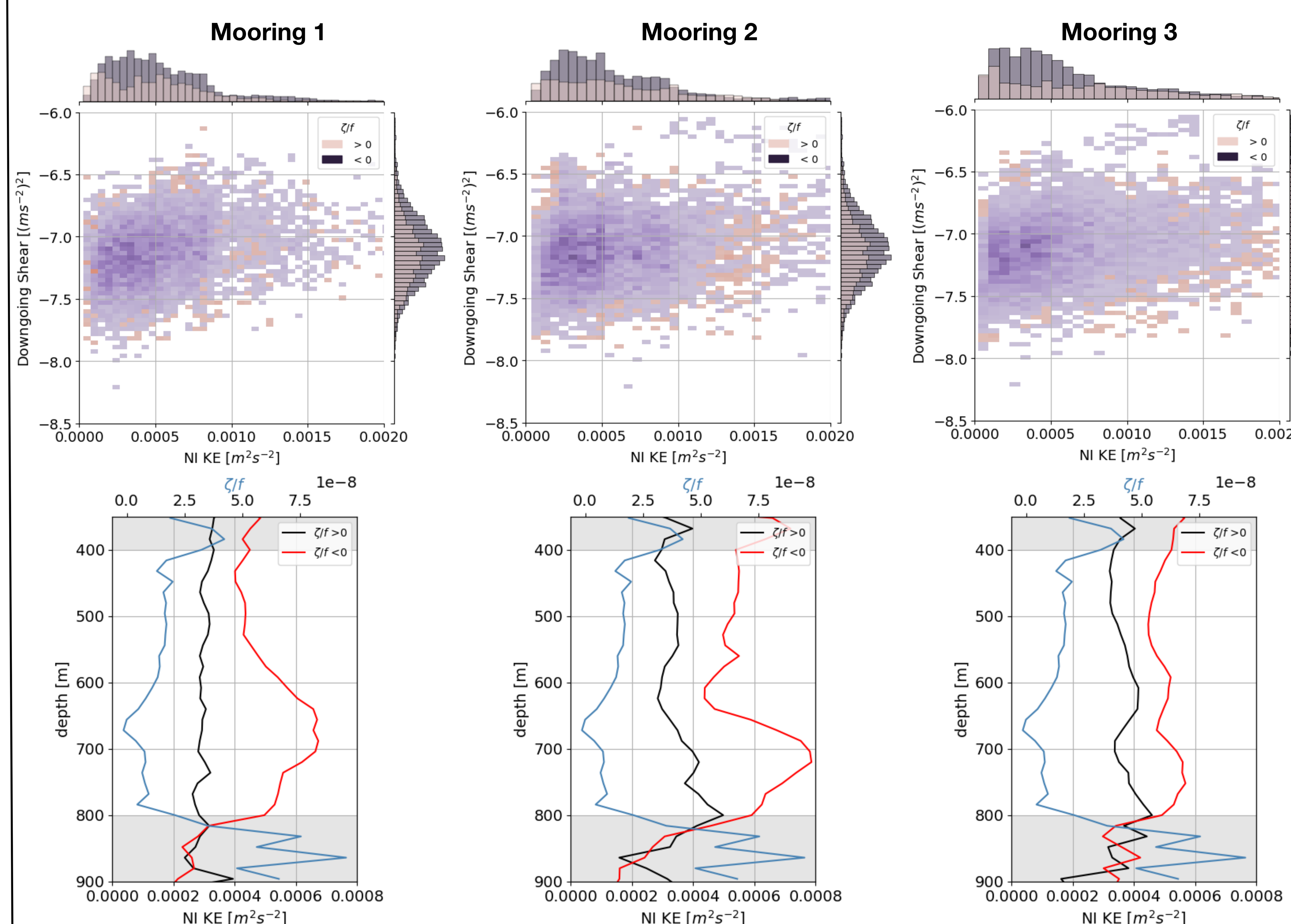
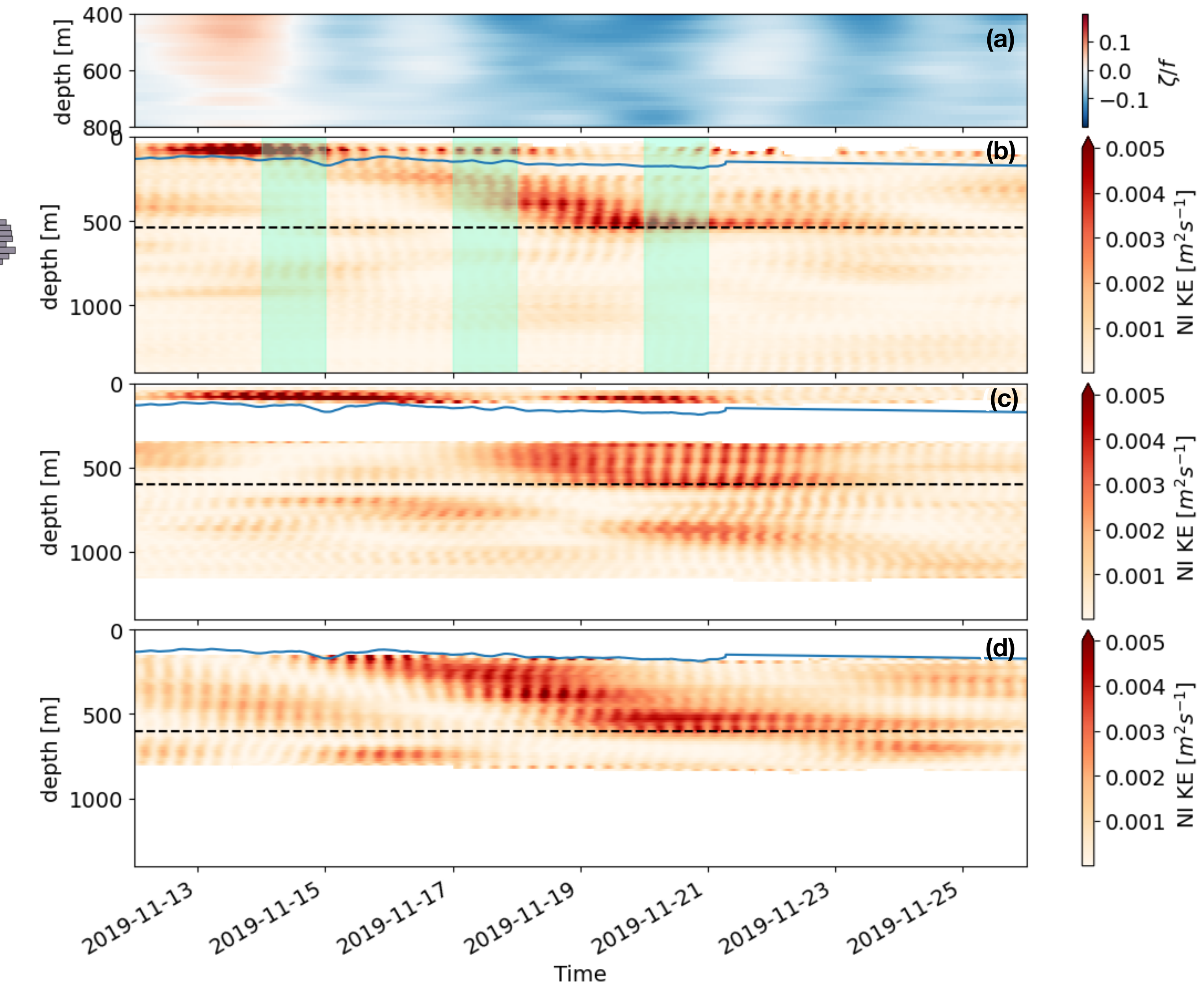


Fig.3: Comparison of NI KE distribution to downgoing shear and vorticity distribution between 300m and 900m for each mooring (from left to right: M1, M2, M3). (Top panels) Distribution of downgoing shear (y-axis) depending on NI KE (x-axis). Light color corresponds to positive vorticity and darker color to negative vorticity. (Bottom panels) NI KE time-averaged for (black) positive and (red) negative vorticity. Negative vorticity vertical gradient (blue) is also plotted. Grey areas corresponds to depth range for which only a few profiles are available simultaneously at all moorings.

Fig.4: NI KE downward propagation in November 2019 at (b) M1, (c) M2 and (d) M3. (a) Vorticity in the mooring area is also plotted. Blue curve represents MLD and dashed black lines the maximum depth below which NI KE generated at the mooring location does not propagate. Colored rectangles in (b) correspond to averaged profiles in Fig.6 .



- High NI KE below ML corresponds to high downgoing shear
- High values for both NI KE and downgoing shear are found for negative vorticity
- NI KE maxima observed at the bottom of negative vorticity
- Generated NI KE propagates downward until critical depth, which varies depending on location

Near - Inertial Kinetic Energy Dissipation

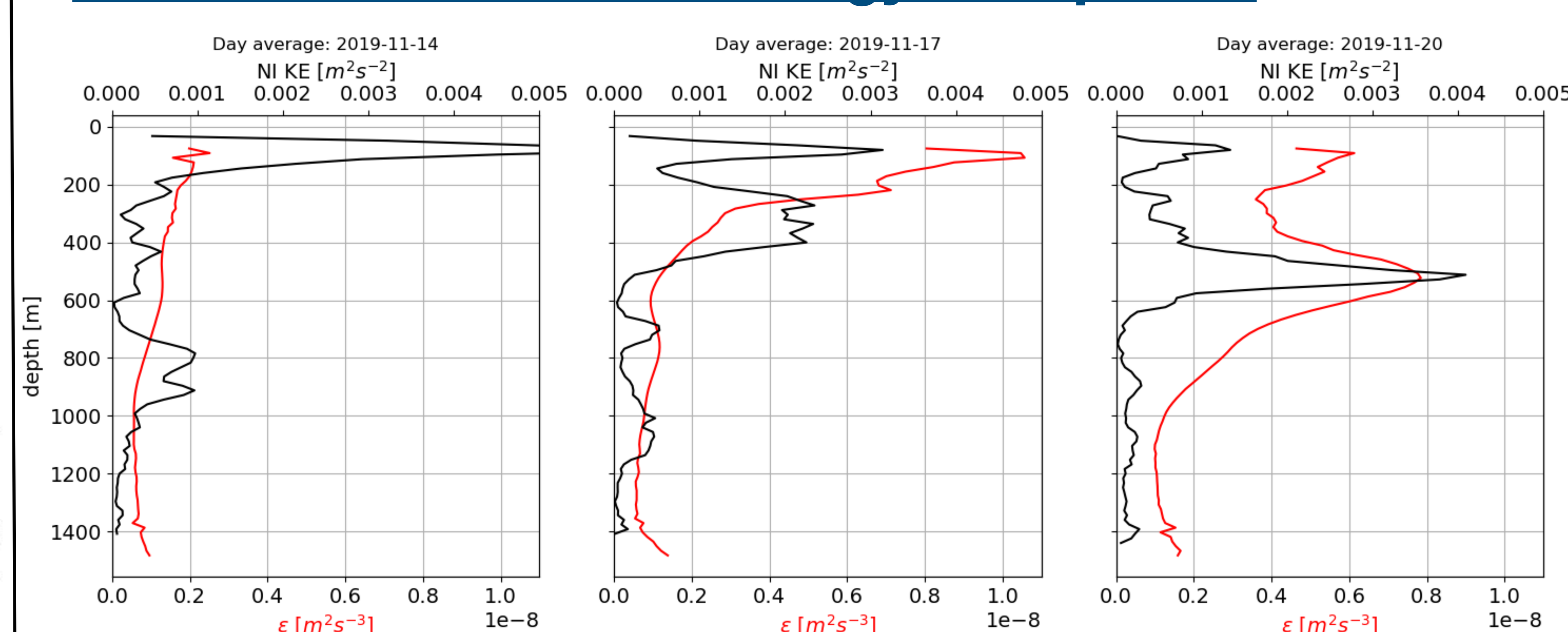
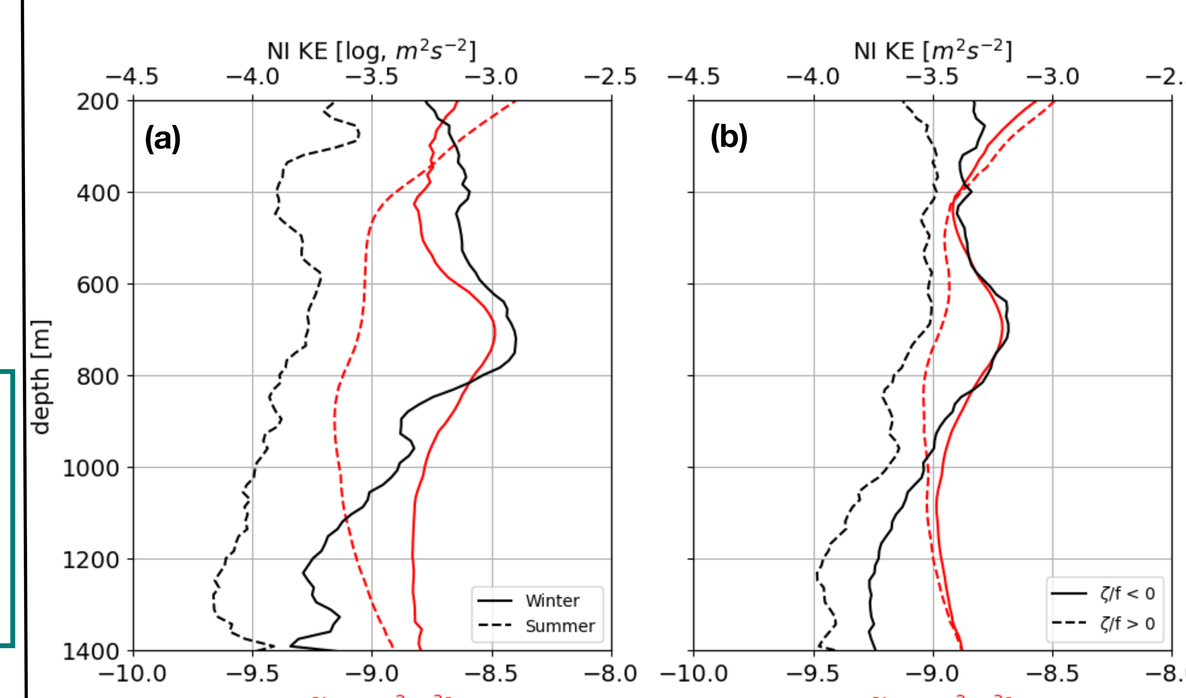


Fig.5: NI KE (black curves) and dissipation rate (red curves) averaged over 1 day at different stage of NIW propagation in November 2019: generation to dissipation (from left to right)

Methods for dissipation estimation:

- Shear-based finescale parametrization (Gregg–Henyey–Polzin method)
- Integration range: 64m - 320m wavelengths
- Shear-to-strain ratio, R_ω, fixed at 3
- Eq.1:

$$\epsilon = \epsilon_0 \frac{\overline{N}^2}{N_0^2} \frac{< V_z^2 >^2}{< V_z^2 >^2_{GM}} h_1(R_\omega) j(f/N)$$



- High dissipation rate at depth corresponds to NI KE maxima
- In average, depth maximum is around 750m for both NI KE and dissipation during winter / negative vorticity periods
- For one event, dissipation rate maximum follows NIW downward propagation

Fig.6: (a) NI KE (black curves) and dissipation rate (red curves) averaged over summer (dashed) and winter (full) months. (b) NI KE (black curves) and dissipation rate (red curves) averaged depending on vorticity sign: positive (dashed) and negative (full).

Conclusions

- Generation of NIWs by wind forcing mostly during Fall and Winter
- Same period coincides with dominantly negative vorticity causing high downgoing shear, i.e. downward propagation of NIWs below MLD ("chimney effect" or "drainpipe", *Asselin and Young (2020); Yu, X., Naveira Garabato, A. C., Vic, C., Gula, J., Savage, A. C., Wang, J., et al. (2022); and several other studies)*
- High NI KE levels at depth varying depending on location, notably on vorticity vertical structure
- High dissipation rate corresponds to NI KE maxima at depth in average and during NIWs events

Futur woks

- What are the energy transfers between NIWs and mesoscale?
- Can we trace the exact origin of some NI KE at depth outside local NIW generation?

Corresponding author: zcasparcohen@ucsd.edu

Office of Naval Research Science & Technology
UC San Diego
SCRIPPS INSTITUTION OF OCEANOGRAPHY