MIM JOURNAL 2024 illuminate your work
Made in Millersville Journal | www.mimjournal.com

Correlations Between Wind Forcing and the Ocean's Upper Mixed Layer Depth in the Vicinity of the New-England Continental Shelf Break

Michael A. Miller, Kyle M. Nazarchuk, and Dr. Robert Vaillancourt

Abstract
We explore seasonal changes in turbulent mixing at the surface ocean, and the consequent effects on vertical mixing at the upper ocean. Atmospheric and physical parameters were extracted from autonomous Webb Slocum glider and surface mooring missions operating within the Pioneer Array site of the Ocean Observatories Initiative, a rectangular glider operation site spanning ca. 25,000 km2 across the New England Shelf Break Front. Preliminary results indicate notable changes between frictional stress from surface winds, and the ocean's mixed layer depth (MLD), or the depth of the water column where properties such as temperature, salinity, and density are relatively uniform from the surface unto a certain depth. Additionally, preliminary findings show connections between the seasonality of net heat flux at the air-sea interface and enhancement or inhibition of vertical mixing here.

Introduction

The ocean's upper mixed layer serves as an area of high primary productivity in the ocean, where sunlight penetrates the sea surface and much of the ocean's properties are well-mixed. Here, phytoplankton utilize a combination of the incoming sunlight as well as the nutrients distributed throughout the mixed layer for photosynthesis, where they serve as the basis of oceanic food webs. The mixed layer depth (MLD) is influenced by various physical processes such as heating of the sea surface, and turbulent wind forcing which mixes the water column downward. Annually, we see seasonal variations in the MLD with winter being characterized by high winds blowing across the sea surface and low surface heating, and summer with low wind stress and high surface heating.
Along the New England Shelf Break lies the Ocean Observatories Initiative's (OOI) Pioneer Array, a rectangular area of operation for autonomous Webb Slocum gliders and surface moorings covering approximately 25,000 km^2. Using data collected from these instruments through 2021, the goal of this study is to gain further insight on the physical controls within this region that influence the deepening and shoaling of the mixed layer, annually.

Methodology

Data was mined from Webb Slocum gliders and surface moorings spanning the area of the Pioneer Array. Surface moorings are stationary instruments, anchored to the seafloor where the Bulk Meteorology package sits atop a buoy in order to collect meteorological parameters at the sea surface. The gliders on the contrary move freely and take profiles of the water column in a seesaw fashion to measure oceanographic variables at different depths. Our analysis is limited, as glider missions are temporally biased where they operate usually for 2-4 months throughout the year, and surface moorings are spatially biased but constantly collect data annually. To accurately couple the atmospheric data mined from the surface moorings and oceanic glider data, we limit our area of analysis to the upper quadrant of the Pioneer Array.

Results & Conclusions

Preliminary findings indicate a proportional relationship between wind stress, or the shear stress exerted across the sea surface by turbulent winds, and the MLD. The mechanism of vertical mixing occurs as a result of the magnitude of wind stress, where higher wind stress at the air-sea interface contributes to mixed layer deepening. Once more, the density of the water column with depth as a result of surface heating plays a role in a deepening mixed layer, where water of differing densities and temperature layer themselves on top of each other with depth. This is known as stratification. Assuming this, we can assume that mixed layer depths in this region maximize during the winter (December – February), with minima in downwelling shortwave radiation, and thus a net output of heat from the ocean, coupled with maxima in wind stress. The opposite is true for the summertime (June – August) here, where we see minima in wind stress annually and enhanced stratification as a resultant of maxima in downwelling shortwave radiation, and thus a net heat uptake by the ocean and shallowing of the mixed layer. Our results shown in **Figure 1** correlate well with this theory and show strong seasonal variability in correspondence to these physical forcings at the Pioneer Array.

Despite temporal biases in the time series, we can confirm that net heat flux into the ocean coupled with low wind stress during the summer results in enhanced stratification, and mixed layer shoaling. Conversely, the winter exhibits high wind stress values in conjunction with low surface heating, which results in enhanced vertical mixing and mixed layer deepening.

Our project has given us a starting point in looking at the physical drivers of the mixed layer depth, confirming already proven theory within this region. This study has also provided us with valuable data to continue our analysis and has given us valuable insights on the limitations of the OOI instruments in the Coastal Pioneer Array. Moving forward, we plan to further analyze the MLD and its correspondence to phytoplankton blooms in this region.

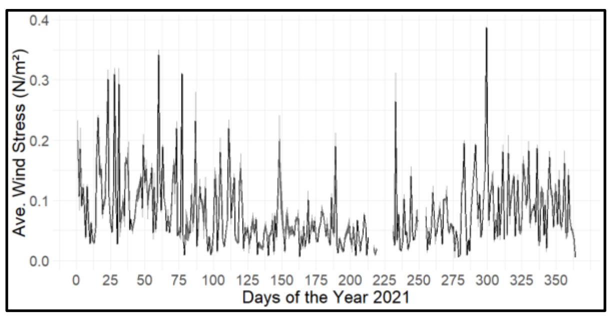

Figure 1a.

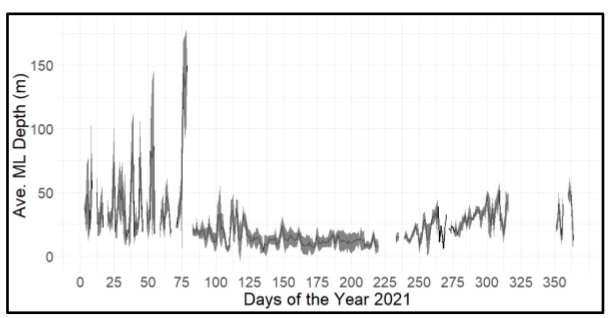

Figure 1b.

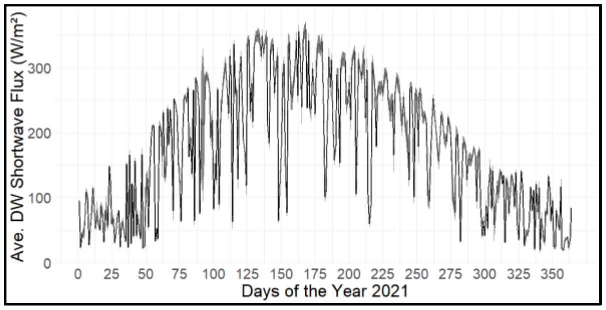

Figure 1c.

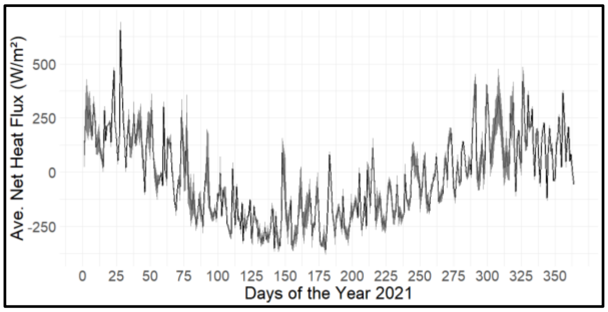

Figure 1d.

Figure 1. *Time series for averaged values between the three moorings for wind stress (a), downwelling shortwave radiation flux (c), and net heat flux (d). Mixed layer depth (b) is averaged between the numerous glider missions in the upper quadrant of the Pioneer Array.*

References

de Boyer Montégut, C. (2004). Mixed layer depth over the global ocean: An examination of profile data and a profile-based climatology. *Journal of Geophysical Research*, *109*(C12). https://doi.org/10.1029/2004jc002378

Kara, A. B., Wallcraft, A. J., Metzger, E. J., Hurlburt, H. E., & Fairall, C. W. (2007). Wind Stress Drag Coefficient over the Global Ocean*. *Journal of Climate*, *20*(23), 5856–5864. https://doi.org/

Kara, A. B., Rochford, P. A., & Hurlburt, H. E. (2000). An optimal definition for ocean mixed layer depth. *Journal of Geophysical Research: Oceans*, *105*(C7), 16803–16821. https://doi.org/10.1029/2000jc900072