REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
24-08-2018	NRL Publication	

4. TITLE AND SUBTITLE	
The Effect of Langmuir Turbulence in Upper Ocean Mixing	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER 0602435N
6. AUTHOR(S) Y. Fan, E. Rogers, and T. Jensen	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER 73-1G35-07-5

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Naval Research Laboratory Oceanography Division Stennis Space Center, MS 39529-5004	NRL/PU/7320--17-3668
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
Office of Naval Research One Liberty Center 875 North Randolph Street, Suite 1425 Arlington, VA 22203-1995	ONR
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release, distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The goal of this project is to understand the effect of Langmuir turbulence (LT) in upper ocean mixing within a broad parameter space and during complex oceanic conditions through extensive ocean, wave, and Large Eddy Simulation (LES) modeling studies. The results from this project will provide a greater understanding of the generation, growth and decay of the LT, how it is affected by the mesoscale and submesoscale structures and its impact on vertical and horizontal momentum and heat fluxes within the ocean on larger scales

15. SUBJECT TERMS

langmuir turbulence, LES, ocean modeling

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Yalin Fan
Unclassified	Unclassified	Unclassified	UU	02	19b. TELEPHONE NUMBER *(Include area code)* (228) 688-4655

Reset

Title: The Effect of Langmuir Turbulence in Upper Ocean Mixing
Author(s): Y. Fan, E. Rogers, and T. Jensen
Affiliation(s): Naval Research Laboratory, Stennis Space Center, MS
CTA: CWO

Computer Resources: Cray XC40 [NAVY, MS]

Research Objectives: The goal of this project is to understand the effect of Langmuir turbulence (LT) in upper ocean mixing within a broad parameter space and during complex oceanic conditions through extensive ocean, wave, and Large Eddy Simulation (LES) modeling studies. The results from this project will provide a greater understanding of the generation, growth and decay of the LT, how it is affected by the mesoscale and submesoscale structures and its impact on vertical and horizontal momentum and heat fluxes within the ocean on larger scales.

Methodology: The NCAR LES model is validated at ocean station papa with 2 m horizontal resolution and vertical stretched grids with very fine resolution in the mixed layer. The simulation is run for 21 days with and without LT. Model performance is evaluated against observations. Substantial code modifications have been implemented into the NCAR LES model to introduce the large scale environmental motions due to strong horizontal density gradient through scale separation analysis. The improved model is applied to field observations in the Gulf of Mexico (GOM) lead by Jarosz (7332) when the measurement site was impacted by fresh water inflow. Several sets of experiments are conducted to identify the key physical processes that affect the LT.

Results: The model evaluation at ocean station papa suggests that the inclusion of LT has significantly improved model results over that without LT. The results also suggest that instead of reducing the downwind component of the turbulent velocity as observed in the idealized experiments, the Stokes drift vortex force significantly increased it. These results again emphasize one of the major points in our proposal that idealized simulations may not give good representations for real ocean conditions. The real ocean simulations in the GOM have shown that the new model (with large scale gradient forcing implemented) has significantly improved the simulation results over the original NCAR LES model. Model results indicate that the large horizontal density gradient can reduce the mean flow in the ML. It also helps to organize the Langmuir cells and align roll axis along the pressure gradient direction. Because the fresh water inflow causes energy consumption through an increase in the potential energy of the water column through mixing, the buoyancy production is smaller and its crossover depth from positive to negative is shallower and thus helps to stabilize the water column. Correspondingly, more energy is transported downward through the pressure transport, and the total TKE is reduced and hence the turbulence level in the water column. Changes in the buoyancy production and the pressure transport also cause a redistribution of the energy in the shear production, turbulent transport, and dissipation, while the Stokes production remains unchanged.

DoD Impact/Significance: This study can help us improve the Battlespace Environment forecasting accuracy for both ocean and atmosphere (HYCOM, NCOM and COAMPS). Better understanding of the mechanism, growth and dissipation of LT will help us improve the air-sea interaction process in our coupled models (i.e., COAMPS and ESPC), which will lead to more accurate vertical thermal profile simulations in the ocean models and better predication of acoustic and optic properties in the upper ocean.

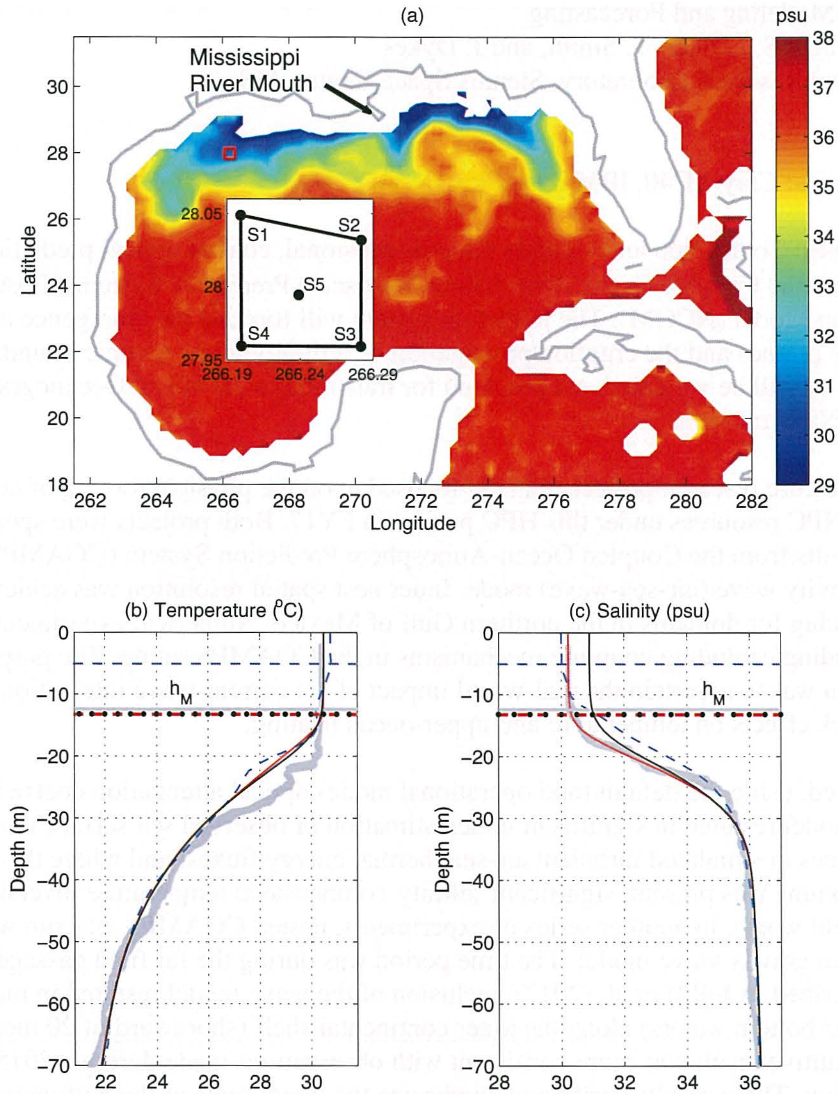

Figure 1. (a) 8-day (July 7–14) level 3 map gridded sea surface salinity (SSS) product derived from retrieved SSS from NASA "Soil Moisture Active Passive" (SMAP) satellite mission. The red open square represents the location of the field measurements with detailed station locations given in the small insert map. Vertical profile of (b) temperature and (c) salinity for initial condition (blue dashed line) and model results on July 13 12:00 UTC with (red line) and without (black line) large scale gradient forcing. The gray area indicates Wirewalker observations within 1 hours of the model results. The horizontal blue dashed, gray, red dashed, and black dotted lines are h_M calculated using initial conditions, Wirewalker observations, model results with and without large scale gradient forcing, respectively.