Observations of the subsurface structure of TKE dissipation rates in the Western North Atlantic Shelf

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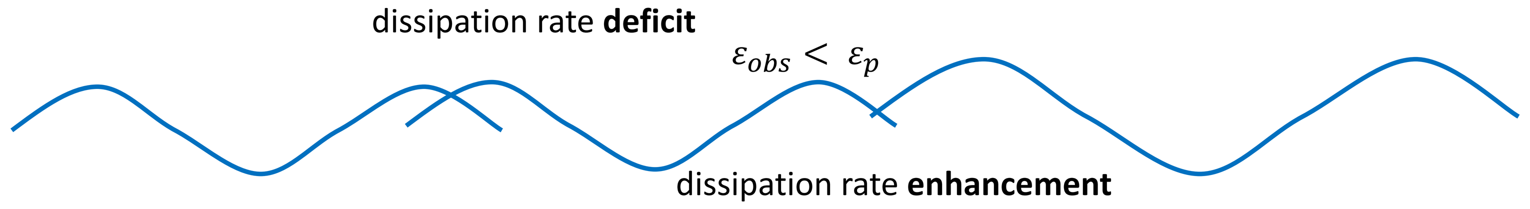
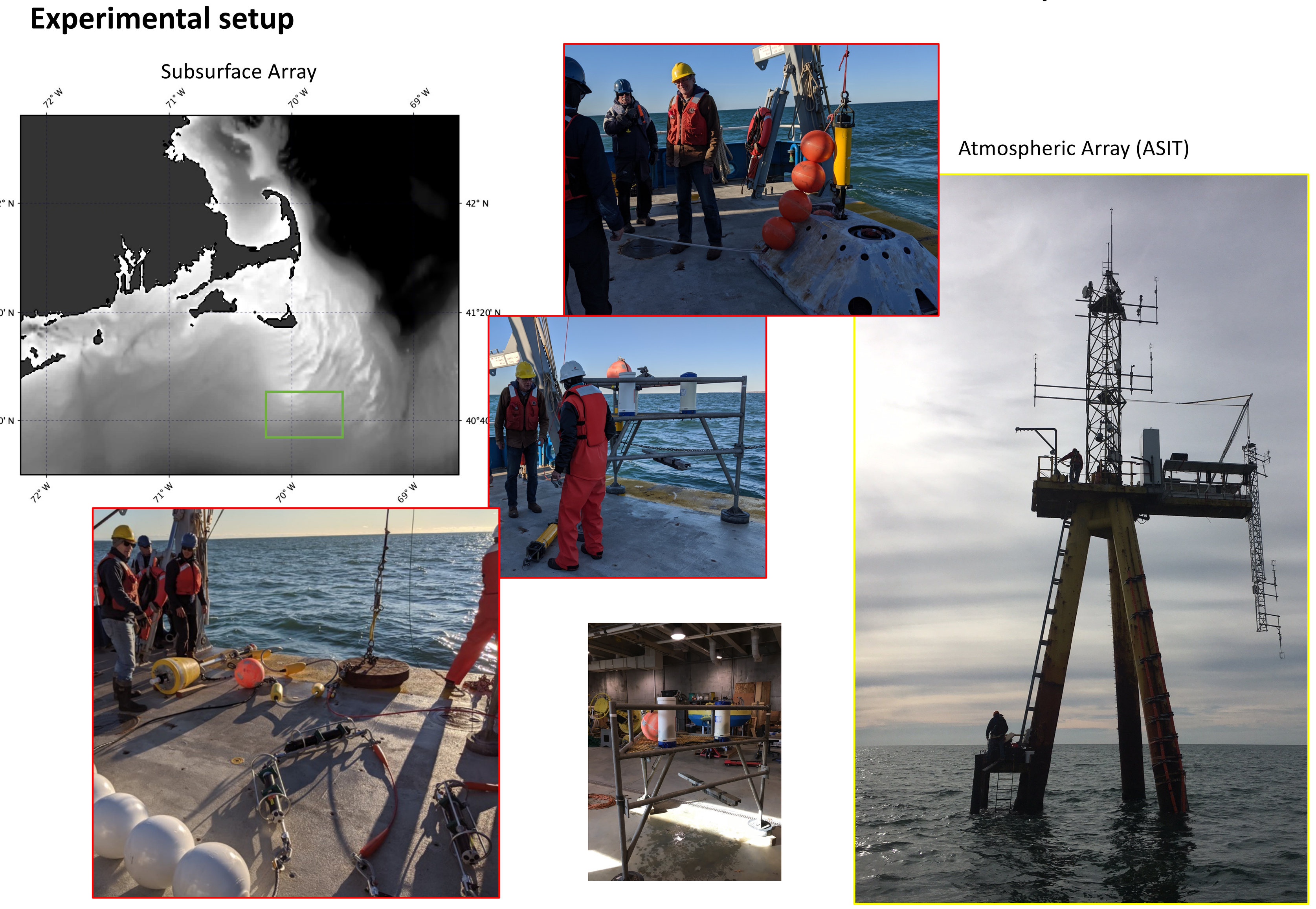
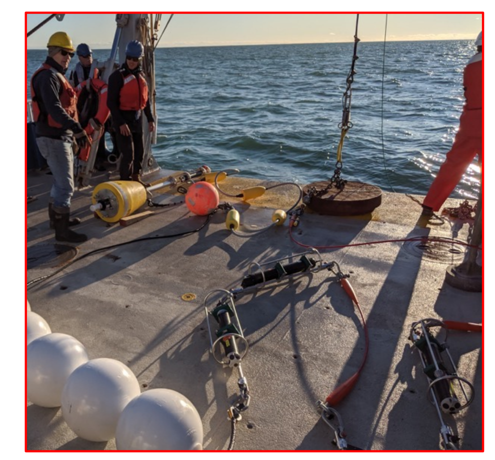
The Air-Sea Turbulent Kinetic Energy (TKE) interaction Experiment was designed to capture dissipation rate deviations relative to the law-of-the-wall scaling on both sides of the air-sea interface.

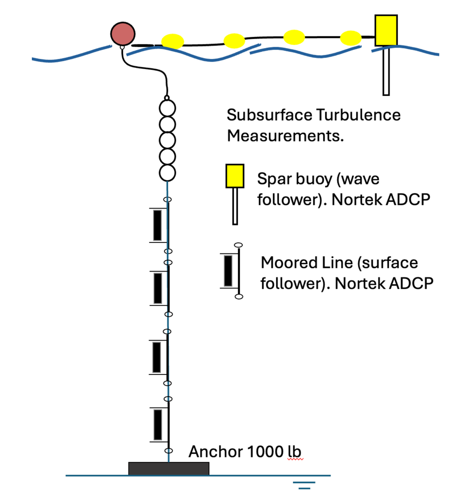


Experimental setup



The Ocean Side Turbulent Kinetic Dissipation rate



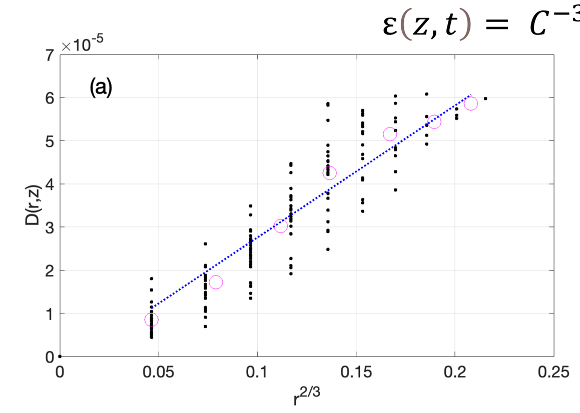


The Aquadopp in HR mode allows for a direct estimate of the second order structure function (Beam velocity coordinates along)

$$D(z,r,t) = \left\langle \left(v'\left(z-\frac{r}{2},t\right) - v'\left(z+\frac{r}{2}t\right) \right)^2 \right\rangle$$

where

$$\varepsilon(z,t) = C^{-3/2}\, r^{-1} D(z,r,t)^{3/2}$$



The structure function then,

$$D(z_i,r) = A\, r^{2/3} + Noise$$

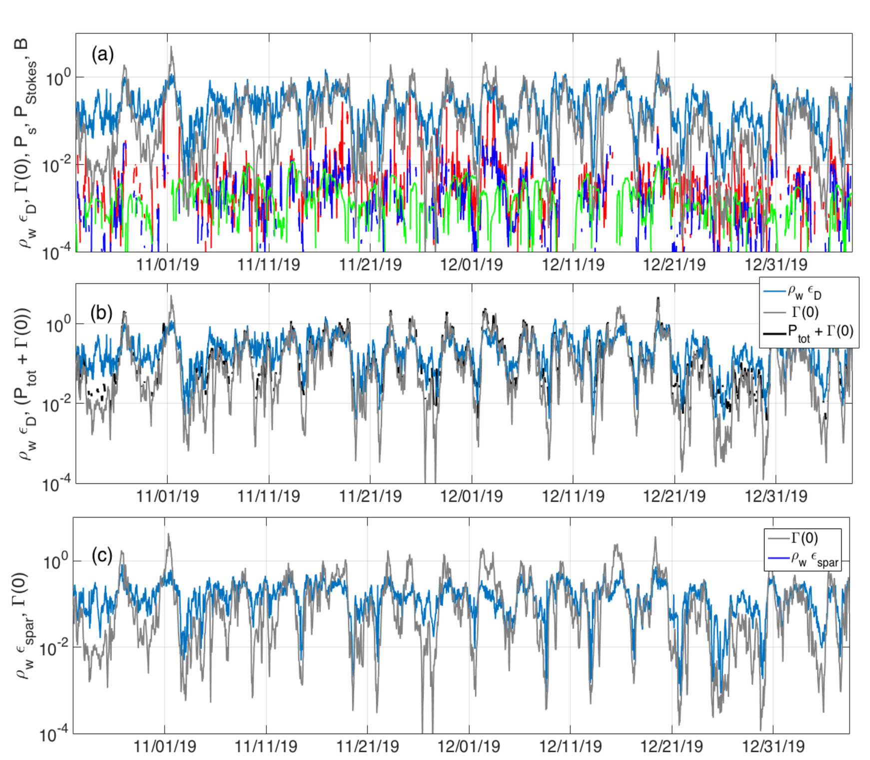
$$A = C^2 \varepsilon^{2/3} \text{ for } Noise \ll A\, r^{2/3}$$

Results from the ASIT TKE Experiment

$$\int_{-Z}^{0}\left[\langle u_i'w'\rangle\frac{\partial u_i}{\partial z} + \langle u_i'w'\rangle\frac{\partial\langle u_s\rangle}{\partial z} + \frac{g}{\rho_w}\langle\rho'w'\rangle + \frac{\partial}{\partial z}\left[\langle ew'\rangle + \frac{1}{\rho_w}\langle w'p'\rangle\right]\right]dz = \int_{-Z}^{0}\varepsilon(z)dz$$

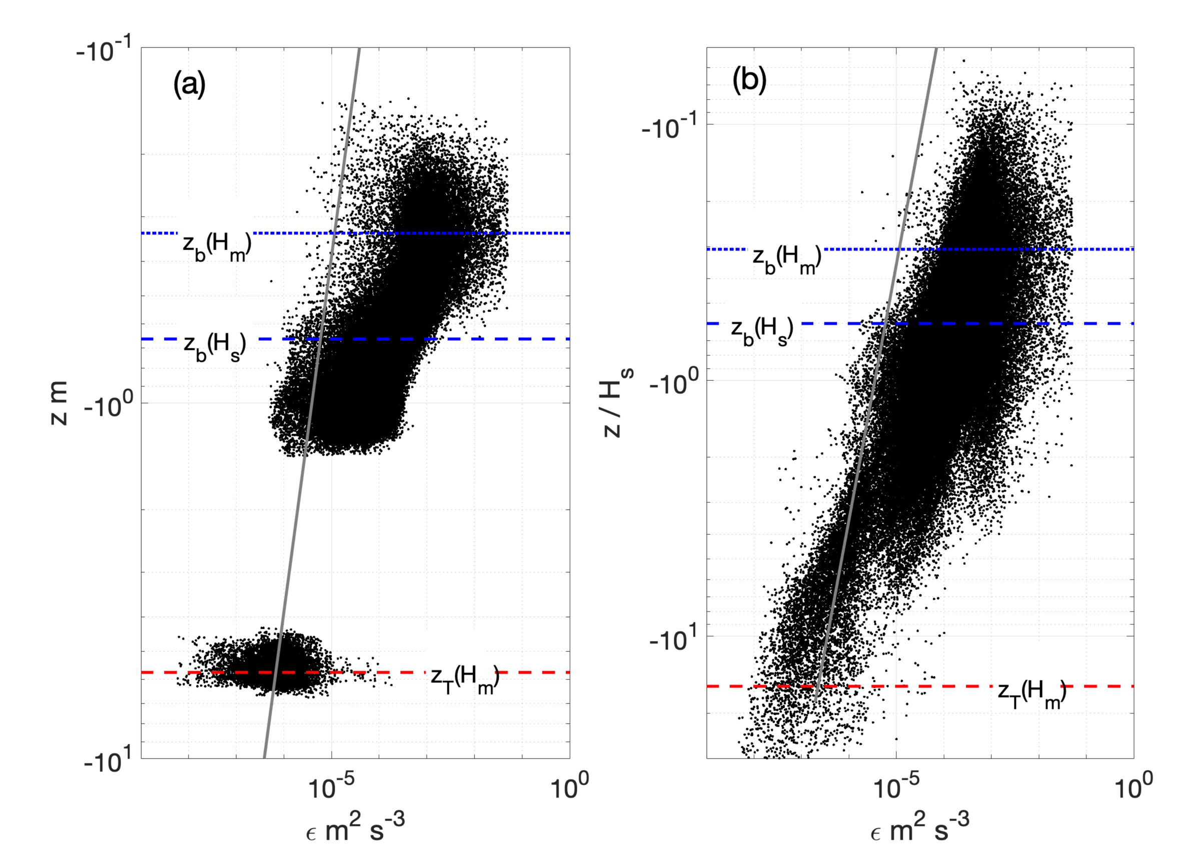
Shear Production; Stokes Shear Production; Buoyancy flux Production/ Consumption; Transport terms; TKE dissipation rate

$$\int_{-Z}^{0}\left[\langle u_i'w'\rangle\frac{\partial u_i}{\partial z} + \langle u_i'w'\rangle\frac{\partial\langle u_s\rangle}{\partial z} - \frac{g}{\rho_w}\langle\rho'w'\rangle - \frac{\partial}{\partial z}[\Gamma(z)]\right]dz = \int_{-Z}^{0}\varepsilon(z)dz$$



Cifuentes-Lorenzen, A., Zappa, C. J.,Edson, J. B., O'Donnell, J., & Ullman, D.S. (2024). Exploring the role of wave-driven turbulence at the air-sea interface through measurements of TKE dissipation rates across the air-sea interface. Journal of Geophysical Research: Oceans, 129, e2023JC020308. https://doi.org/10.1029/ 2023JC020308

TKE dissipation rate estimates (ε) shown as a function of (a) depth and (b) depth normalized by significant wave height ($^z/_{H_s}$) where ε observations (back circles) were made using Nortek Aquadopps deployed from a moored line at 5, 7, 10, and 15 m below mean sea surface and a fifth at 1.3 m on a Spar buoy. Included is the depth dependent behavior of ε as predicted by the law-of-the-wall, with z^{-1} (solid gray line) and transition (z_T, red dashed line) and breaking layers (z_b, blue dashed lines).



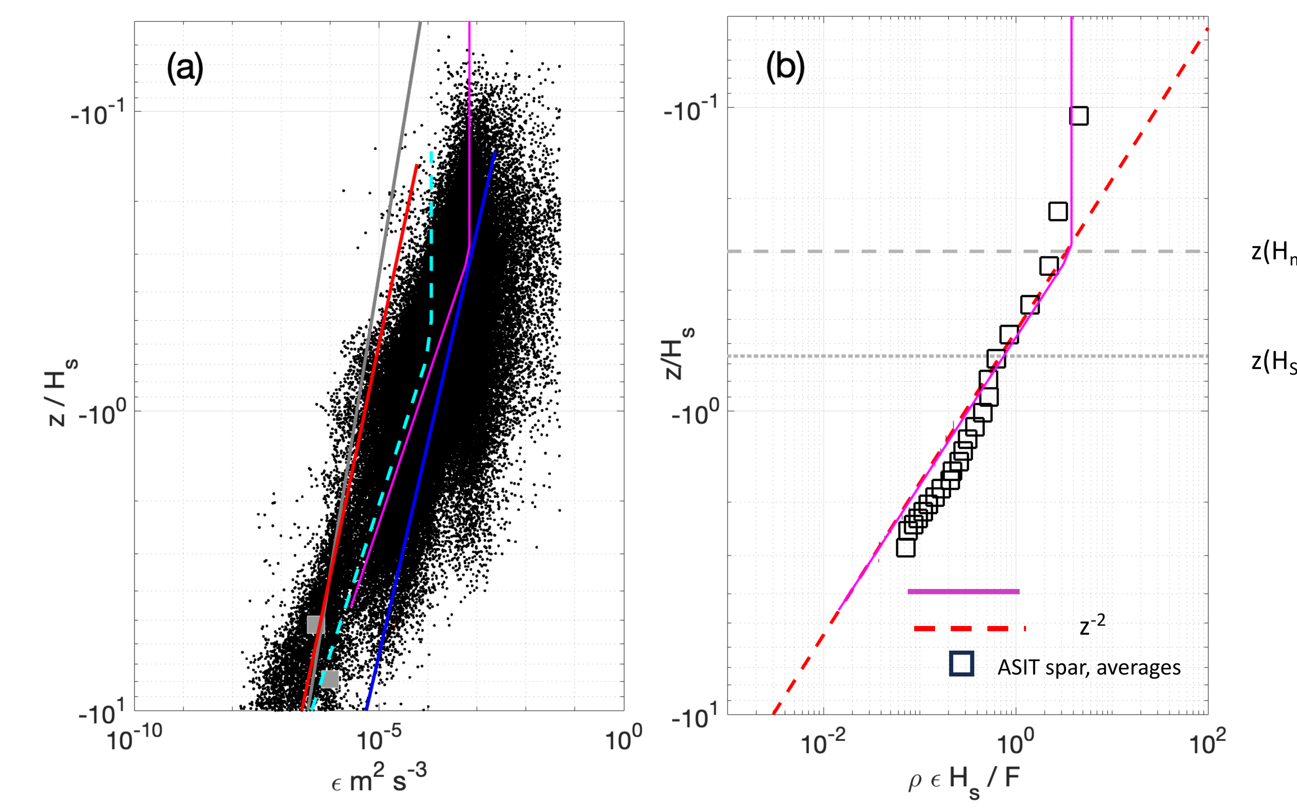
The classic Terray et al. (1996) parameterization, where F is the wind input (energy into the wave field).

$$\varepsilon(z) = a\,\frac{F}{H_s}\left(^{|z|}/_{H_s}\right)^b$$

Included below are depth dependent fit coefficients (a, b). Here, the breaking layer defined by Terray et al. (1996) is used as a reference for change in behavior.

coeff.	$^z/_{H_s}$	$z/H_s \le -z_b(H_s)$	$z/H_s \le -z_b(H_m)$	$-3 < z/H_s \le -z_b(H_m)$
a	0.31	0.46	0.42	0.37
b	-1.62	-2.13	-2.03	-1.38

Observed TKE dissipation rate estimates (ε; depth normalized by significant wave height $^z/_{H_s}$) shown with the depth dependent behavior of ε as predicted by the law-of-the-wall, with z^{-1} (solid gray line); the Terray et al. (1996) parameterization with z^{-2} (cyan dashed line); $z^{-1.41}$ following Thomson et al (2016) (blue solid line); the Esters et al. (2018) $z^{-1.29}$ (solid red line). The $z^{-2.03}$ behavior of Cifuentes-Lorenzen et al. (*in prep*) is included (solid magenta line) with temporally averaged data (grey squares) indicating degree of convergence to law-of-the-wall at depth. The (b) dimensionless TKE dissipation rate in terms of H_s and the wind energy input (F) showing temporally averaged Aquadopp data from the Spar buoy (black squares) from Cifuentes-Lorenzen et al. (2024) and the $z^{-2.03}$ behavior with a constant TKE dissipation rate above the breaking layer in terms of mean wave height, $z_b(H_m)$ (solid magenta line) compared to the constant $z^{-2.0}$ to the surface (dashed red line). Also included is the transition depth suggested by Terray et al. (1996), $z_b(H_s)$ (dotted grey line).

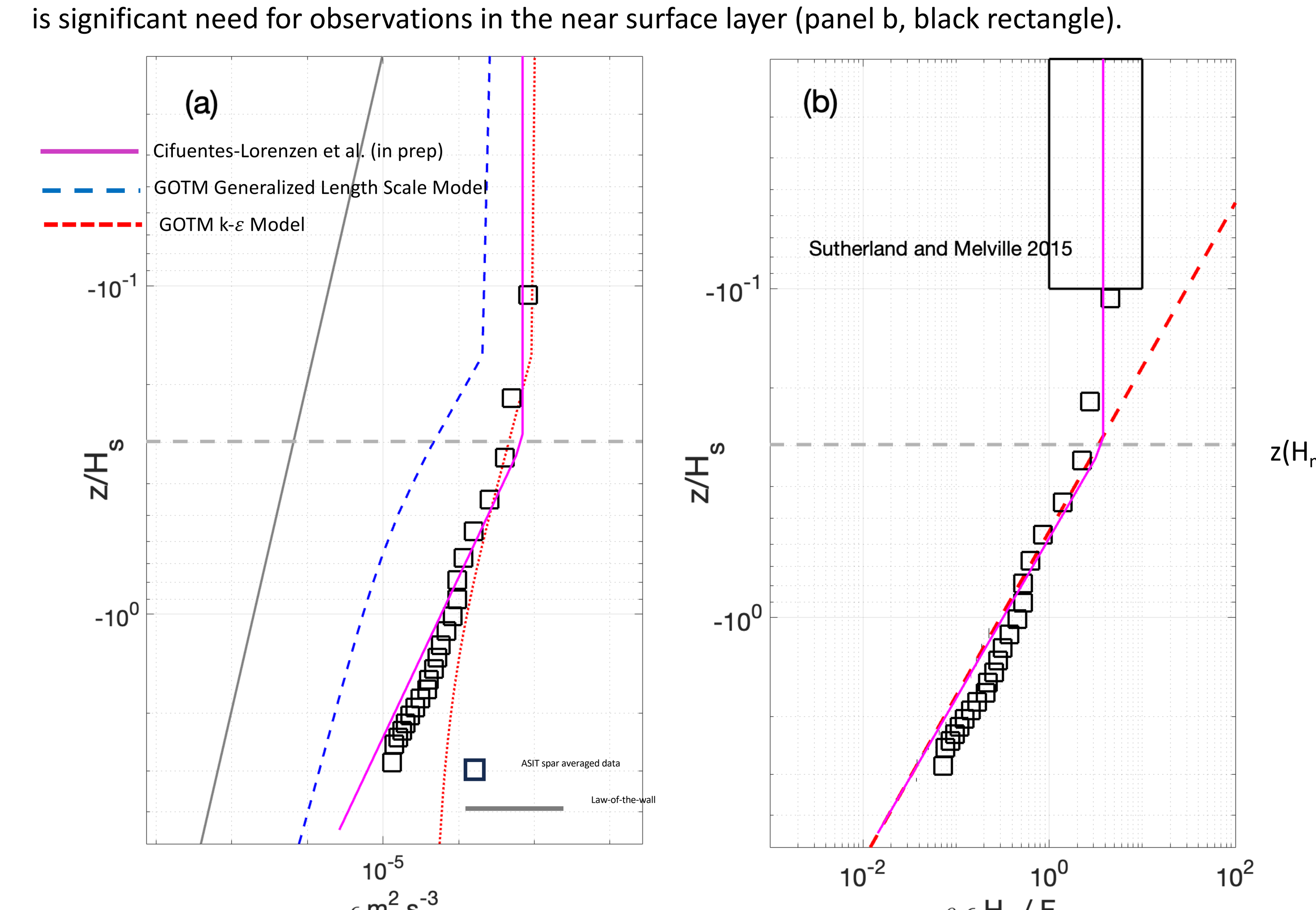


Ongoing and Future Work

Ongoing

Ongoing work includes the testing of GOTM closure schemes against observations with the objective of capturing near surface mixing and transport estimates to improve estimates of oxygen transport (Hypoxia studies in LIS).

GOTM output of TKE dissipation rates shown (a) for two different closure schemes with TKE injection as upper boundary condition (wave breaking injection). The closure schemes were evaluated relative to the proposed parameterization of TKE dissipation rates and observations from the ASIT 2019 Experiment. There is significant need for observations in the near surface layer (panel b, black rectangle).



Future work

Deploy a near surface wave-following ADV to capture TKE dissipation rates at the immediate surface and address the TKE dissipation rate structure and identify the extent of the near-surface breaking layer (Collaboration with LDEO, FAU *pending NSF proposal*)