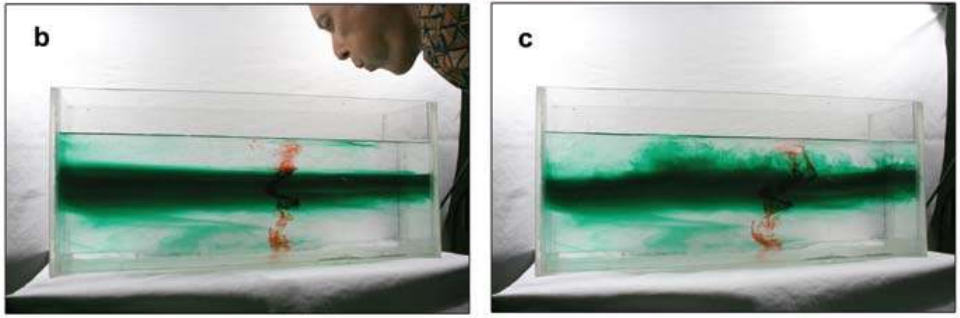


DYNAMICS OF DIURNAL WARM LAYERS

Ken Hughes, Jim Moum, Emily Schroyer

Diurnal warm layers on a tabletop



Franks and Franks (2009)

AUDIENCE

Designed for graduate oceanography courses, this simulation is suitable for students as young as elementary school age, provided the level of discussion is appropriately scaled.

Franks and Franks (2009)

Diurnal warm layers on a tabletop

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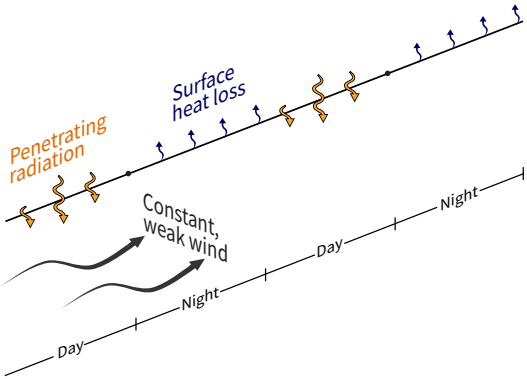
Franks and Franks (2009)

Thin, stratified, and accelerated



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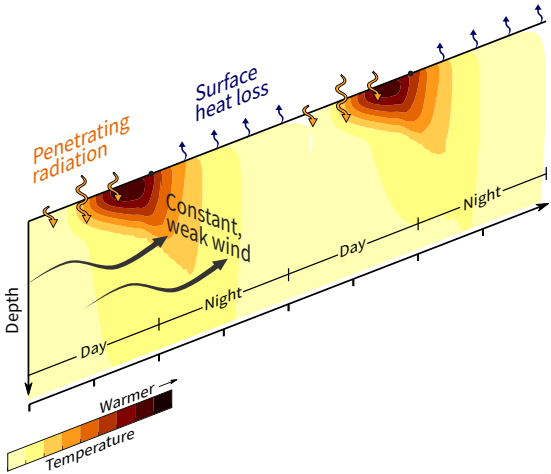

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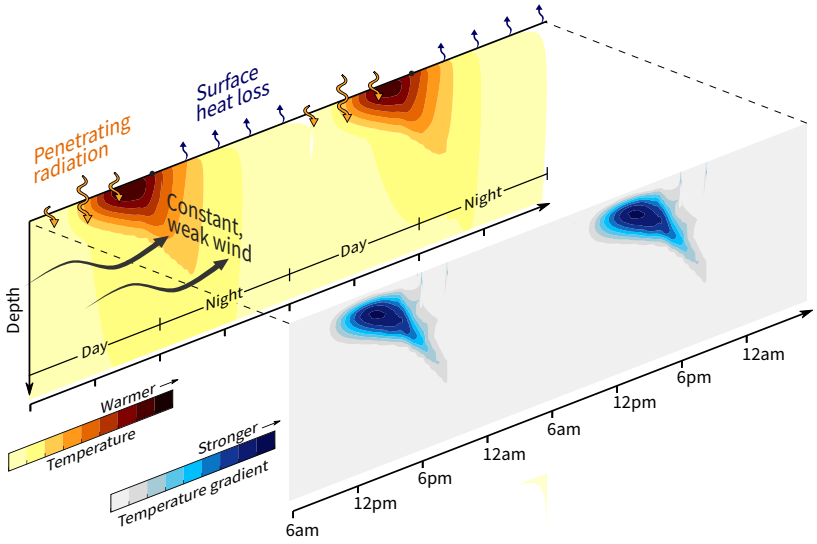

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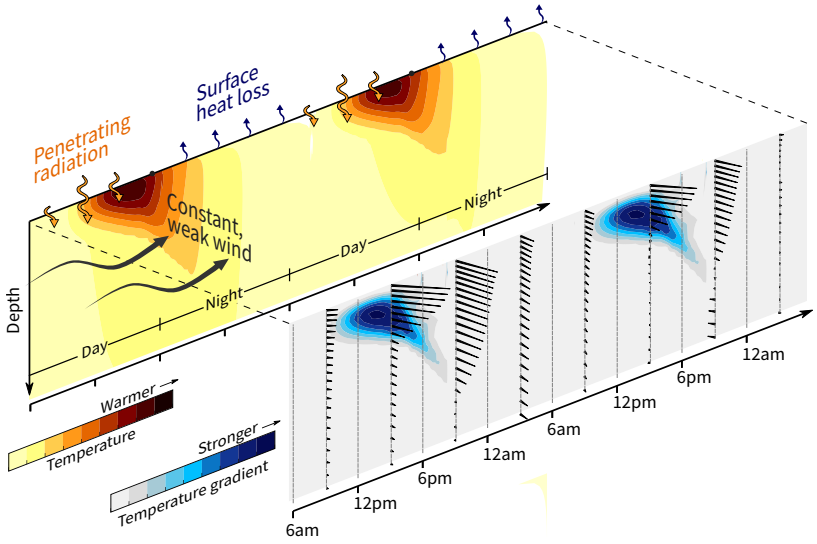
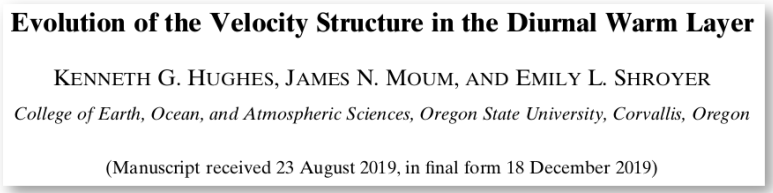


Published, submitted, and a vague idea

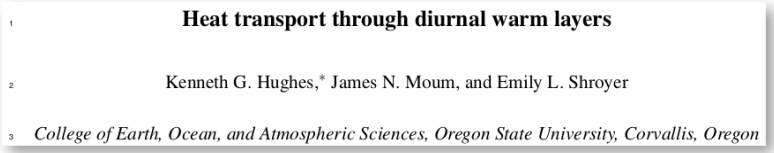


Evolution of the Velocity Structure in the Diurnal Warm Layer

KENNETH G. HUGHES, JAMES N. MOUM, AND EMILY L. SHROYER

College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, Oregon

(Manuscript received 23 August 2019, in final form 18 December 2019)



Heat transport through diurnal warm layers

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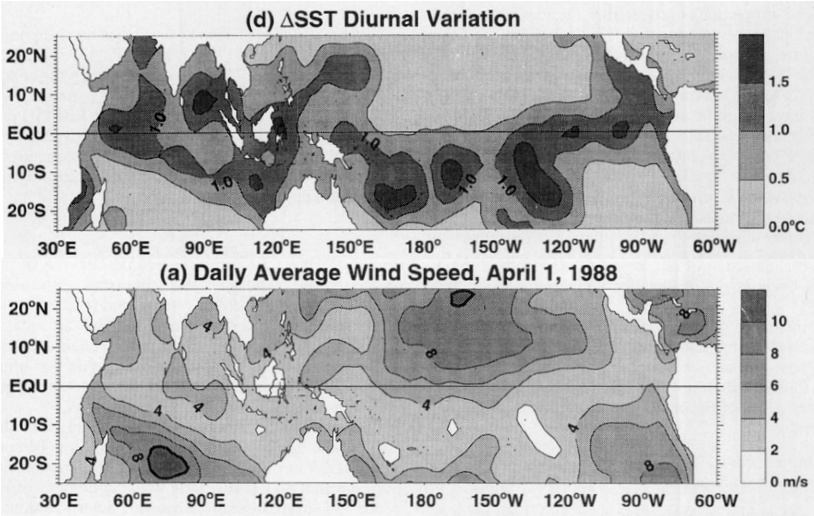
Something about shear instabilities?

Warm layers are ubiquitous



Webster et al. (1996)

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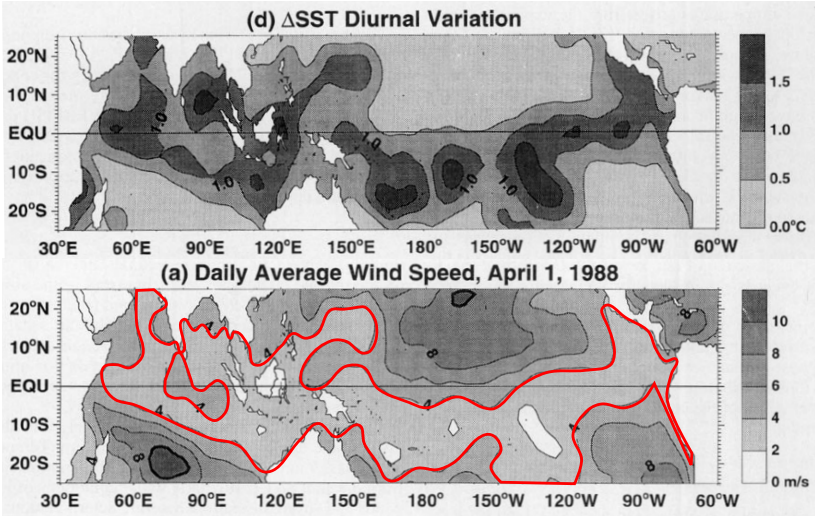

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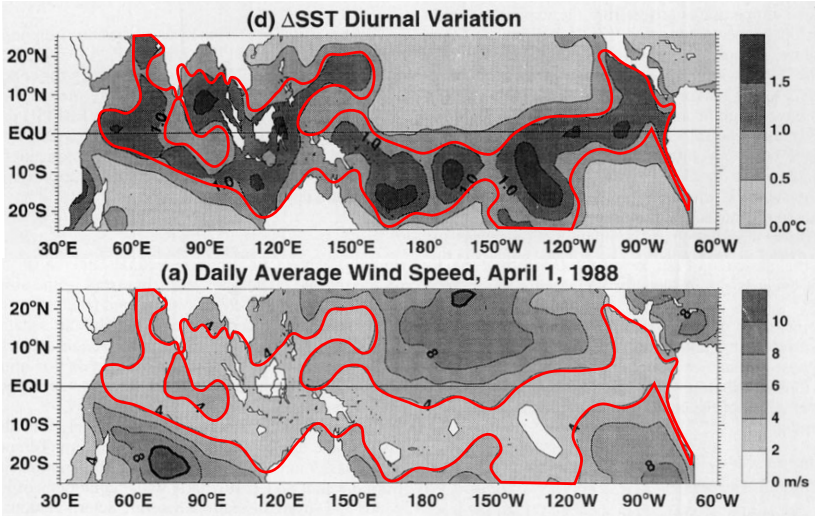

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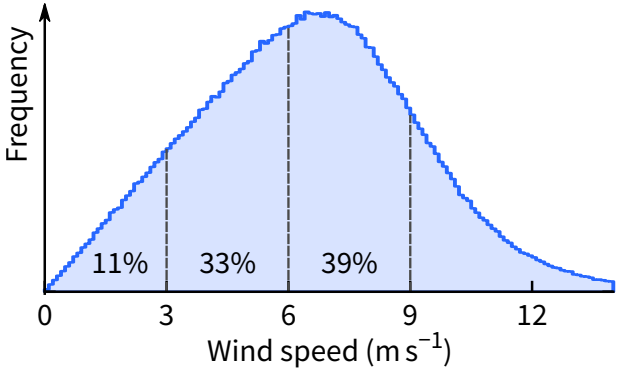
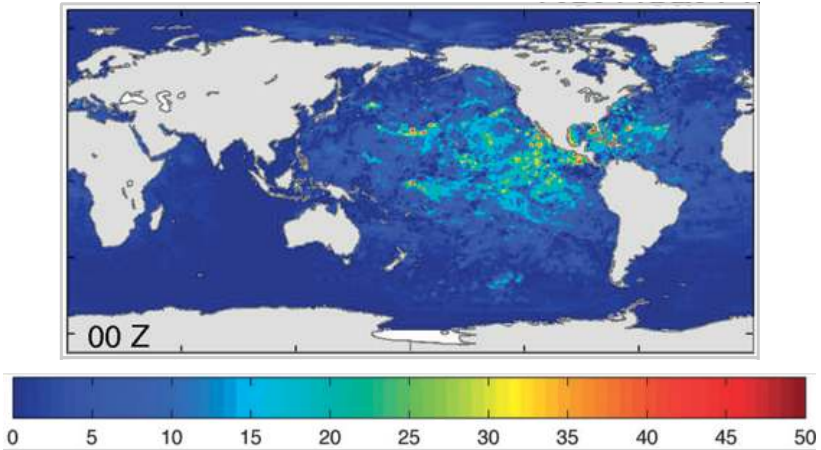
Wind speeds over the tropical ocean



Based on NCEP-DOE reanalysis

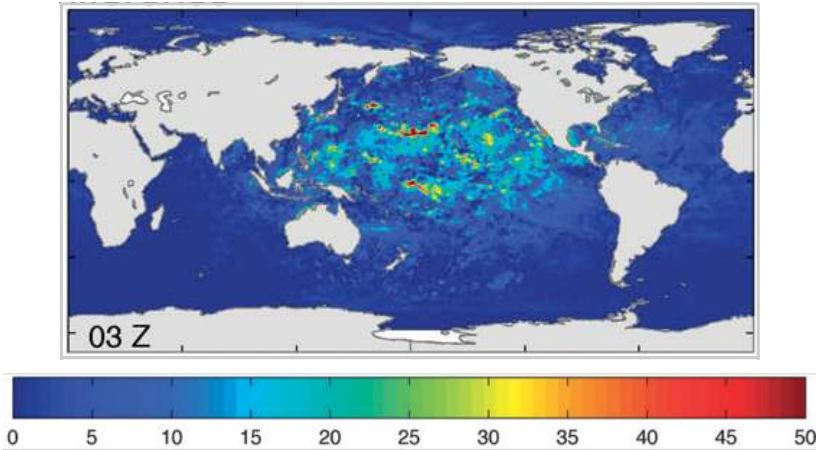
SST governs surface heat flux



Heat flux anomaly when excluding diurnal SST variability (W/m^2)

Clayson and Bogdanoff (2013)

SST governs surface heat flux



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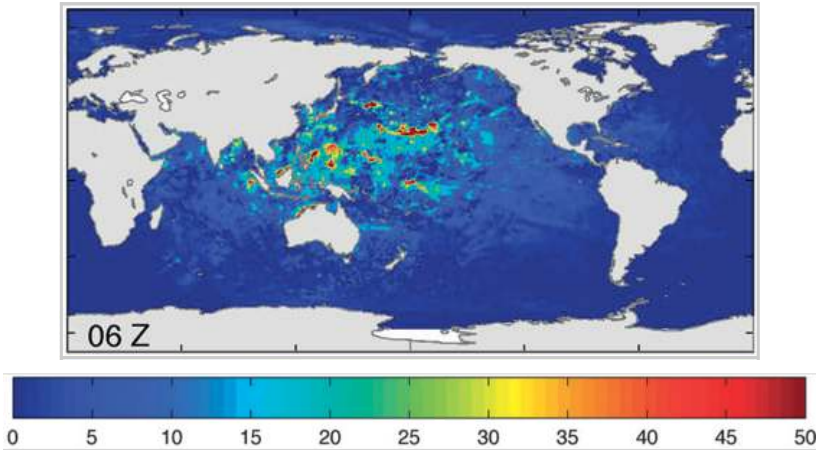

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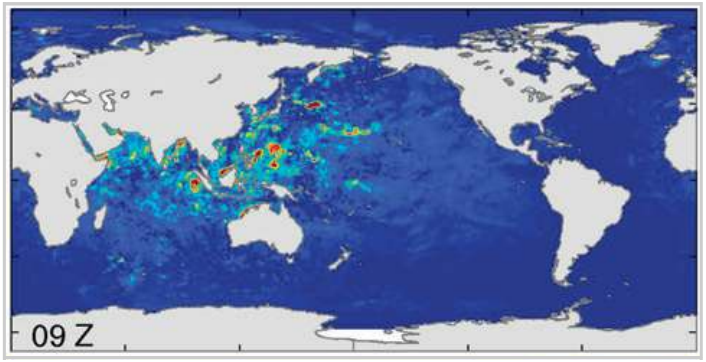

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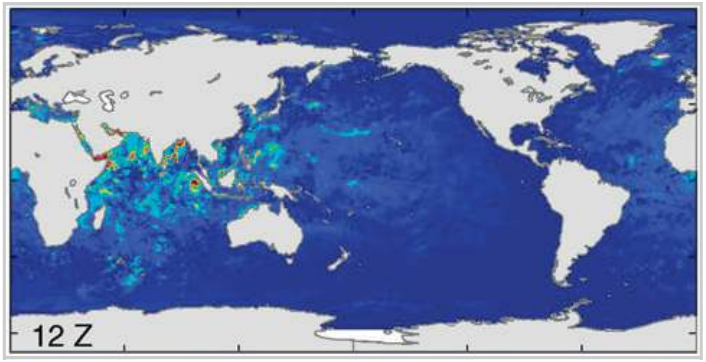

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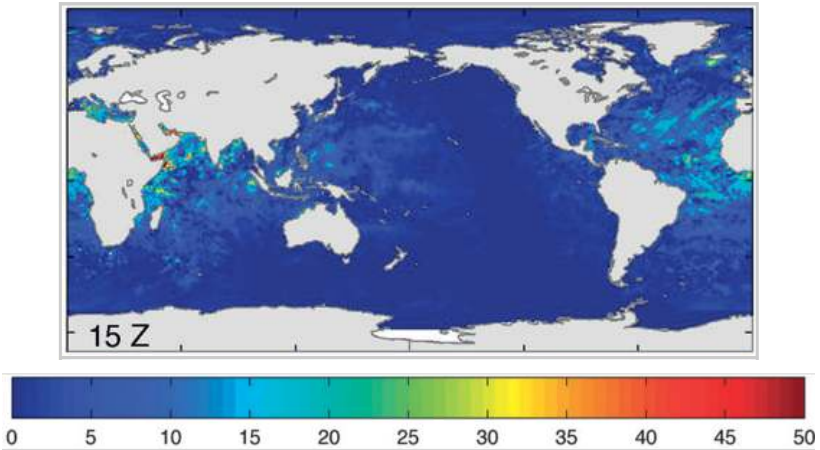

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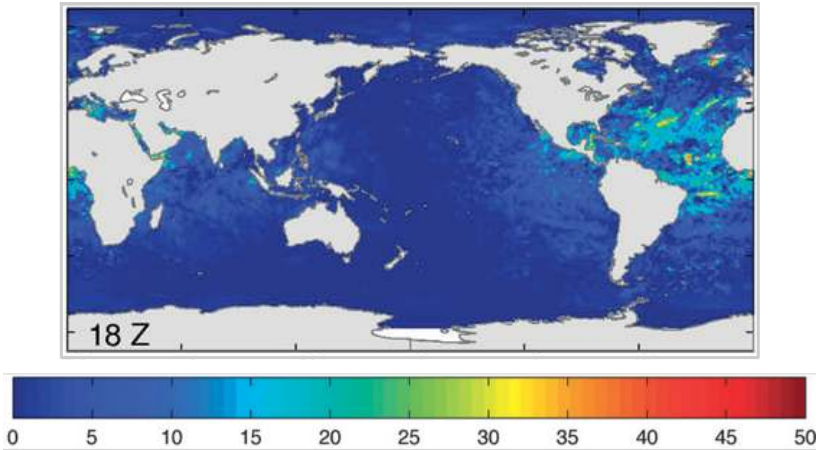

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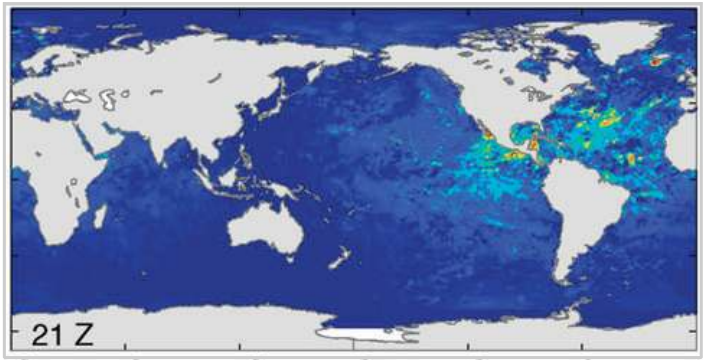

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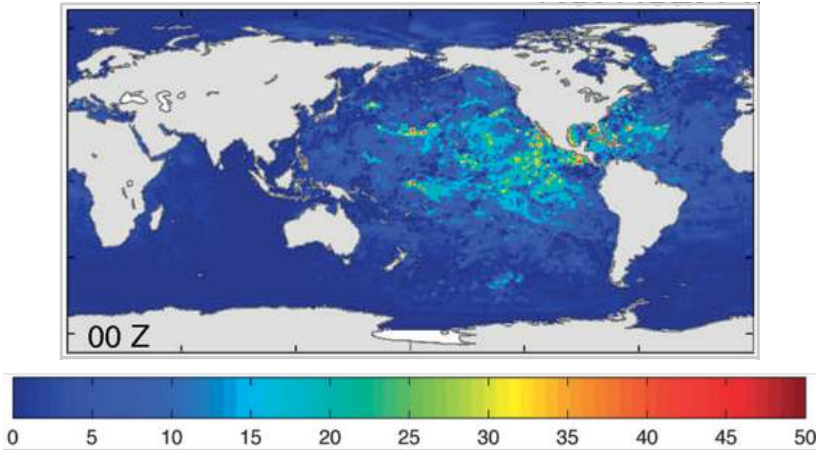

Heat flux anomaly when excluding diurnal SST variability (W/m^2)

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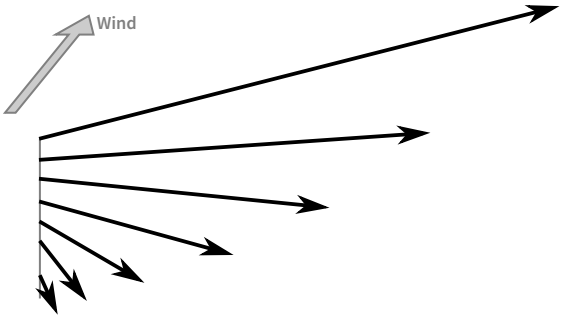
Altered near-surface dynamics



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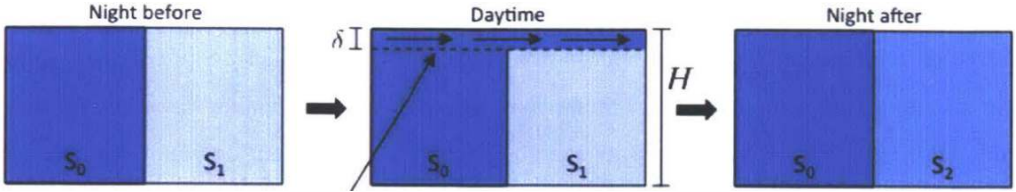
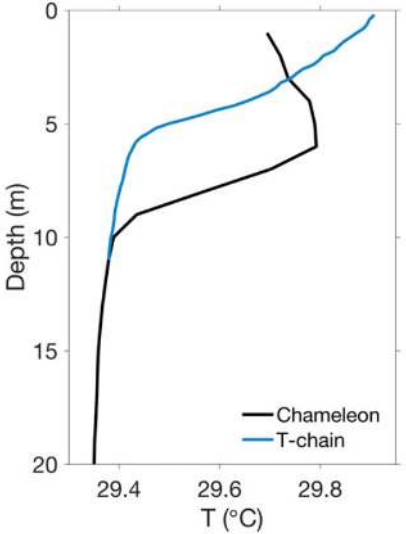


Bogdanoff (2017)

Surface measurements are difficult



Moulin et al. (2018)

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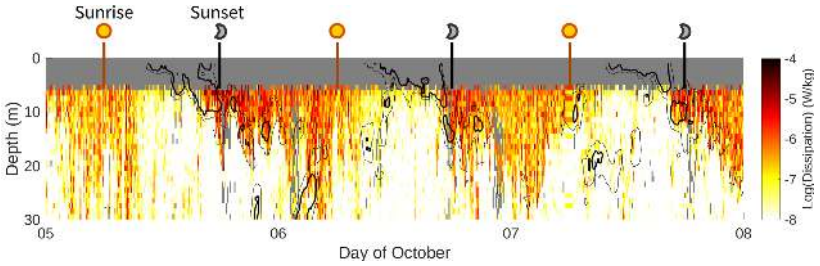
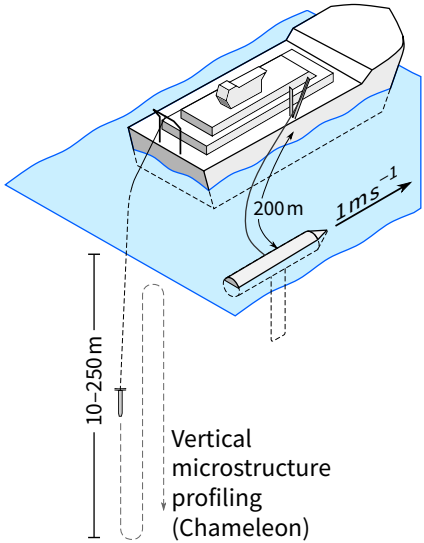
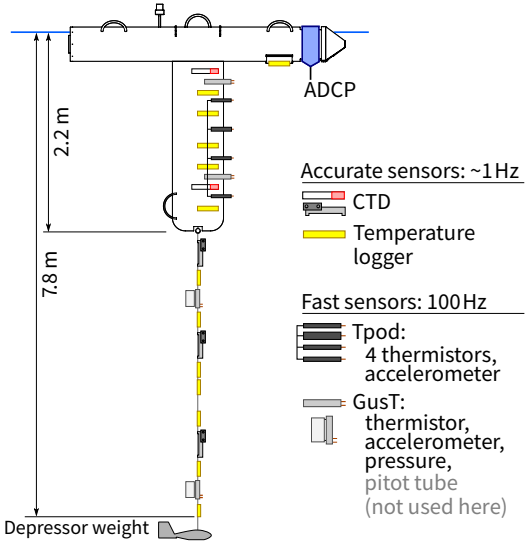
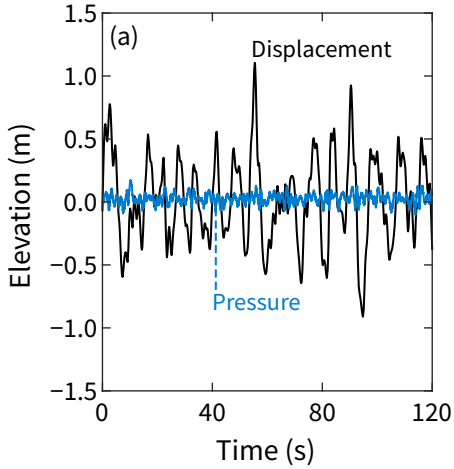




Enter SurfOtter



SurfOtter follows the surface well



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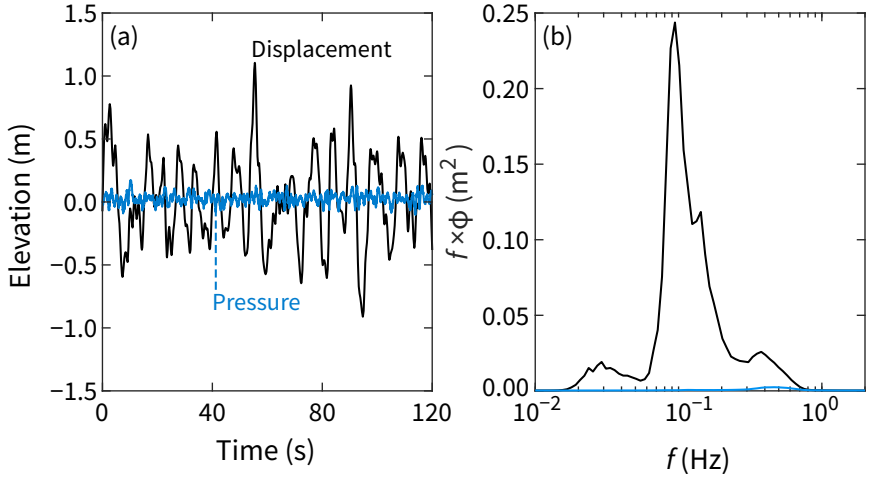
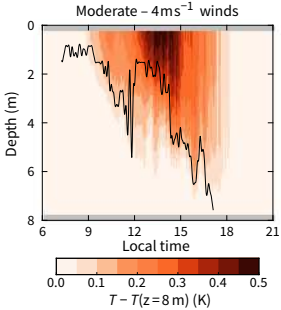


Wind speed controls warm layer structure



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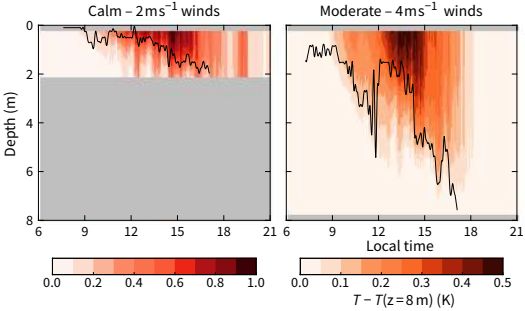

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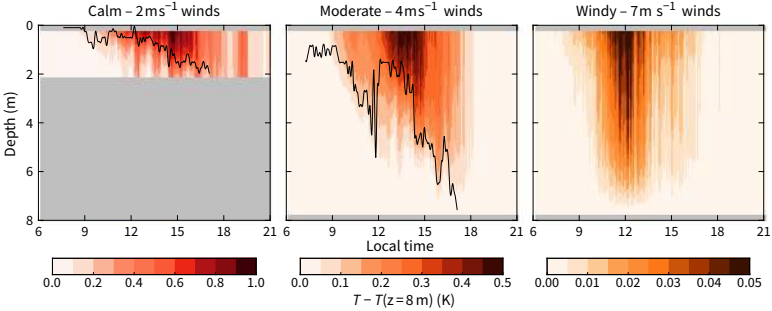

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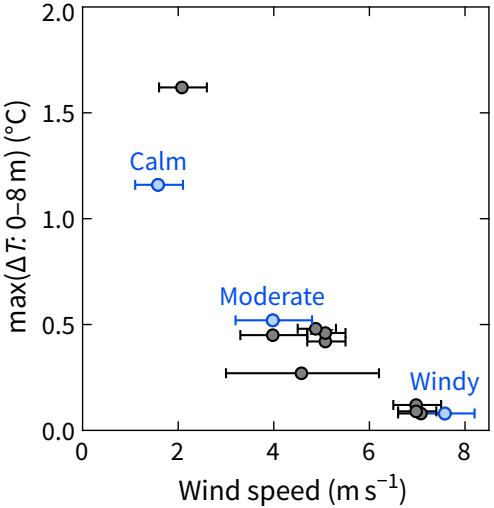

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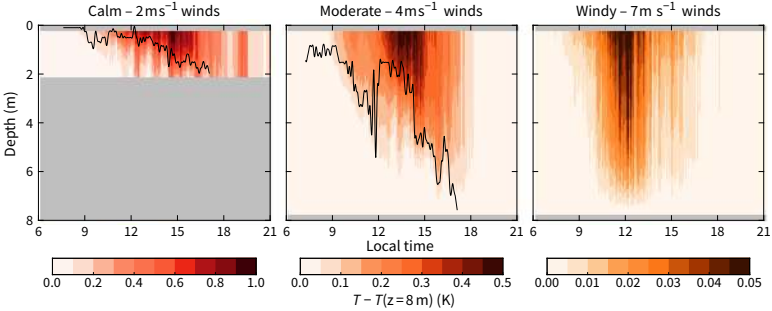

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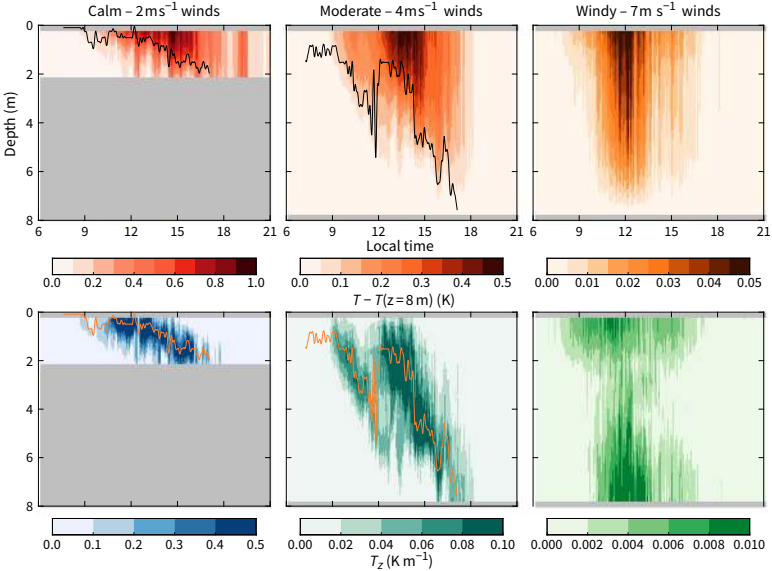

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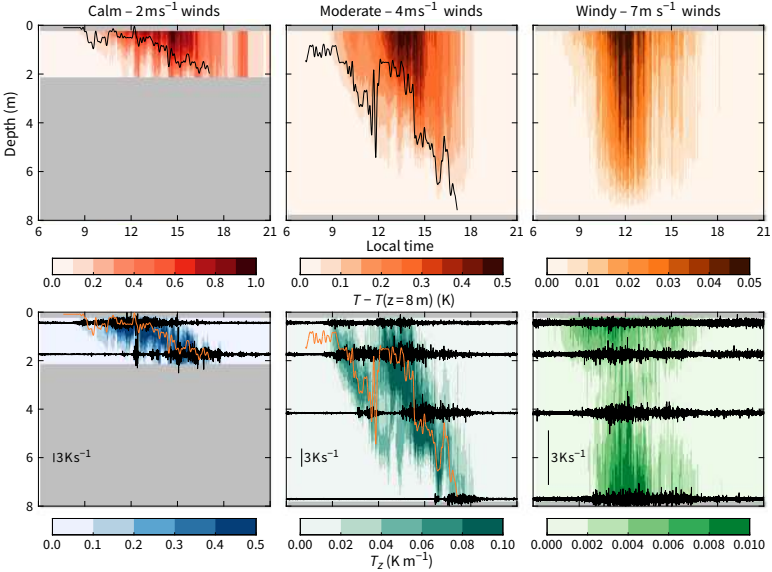
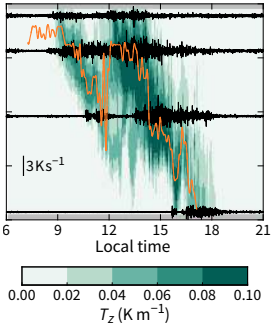


Deriving turbulence from temperature



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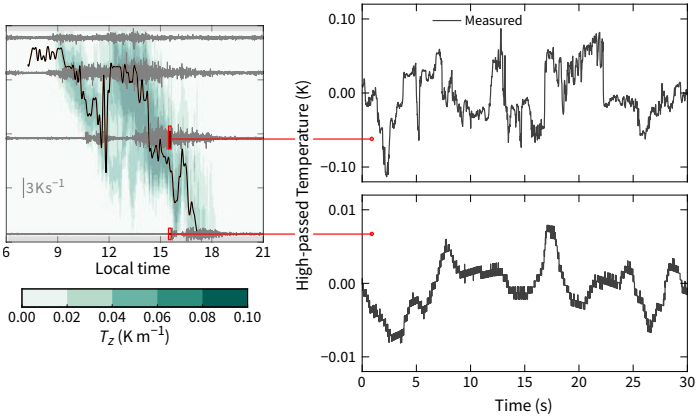

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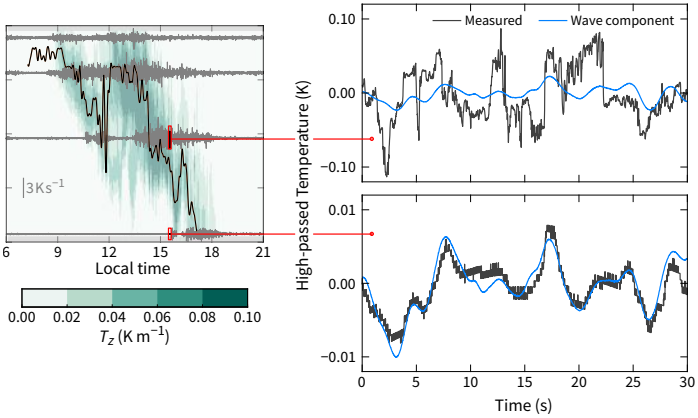
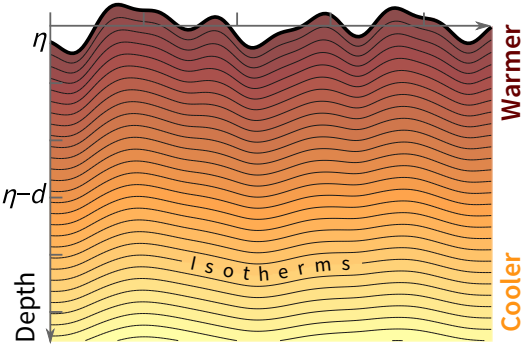


SurfOtter temperatures always have a wave component



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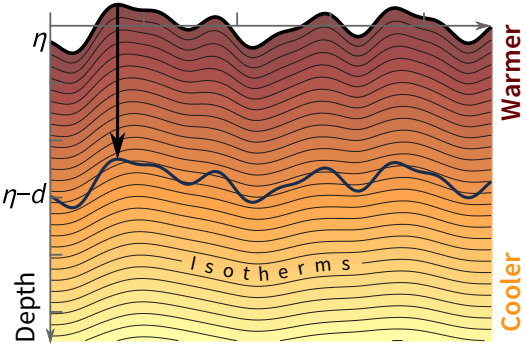

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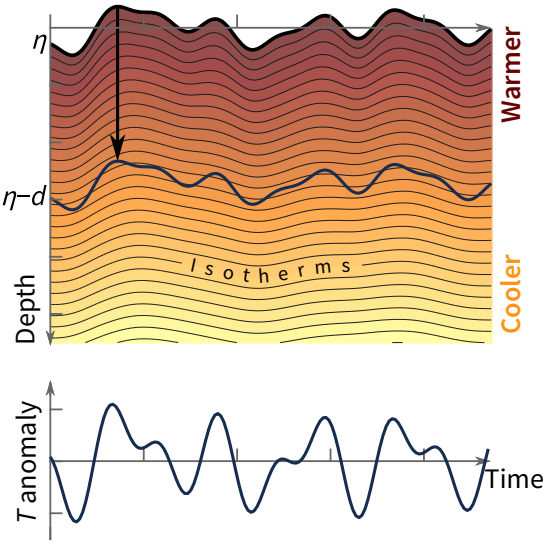

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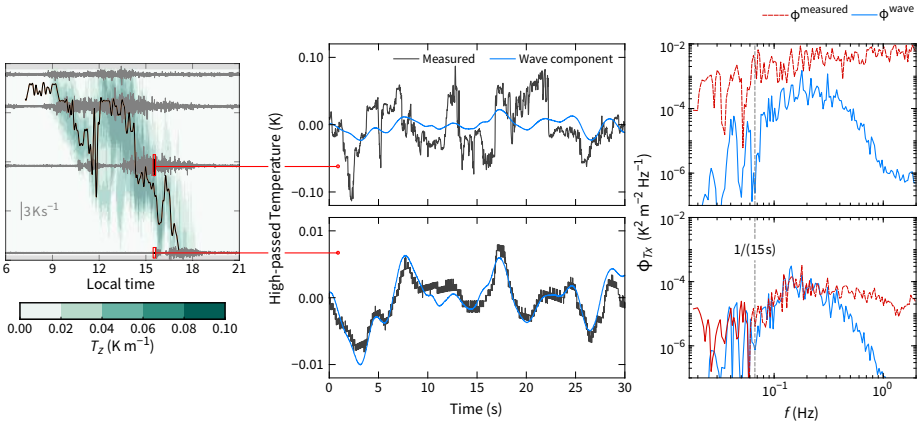

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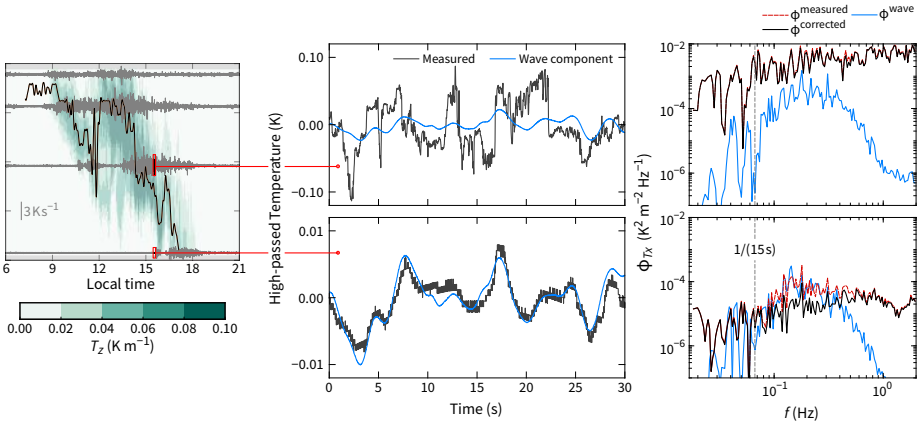

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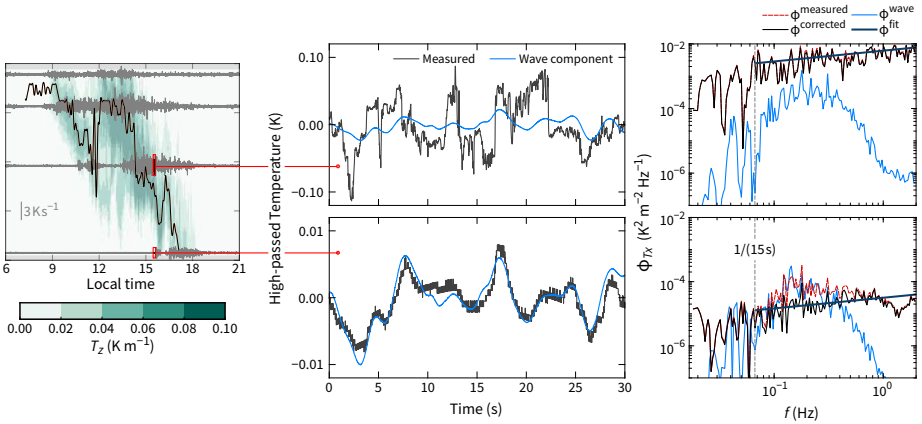
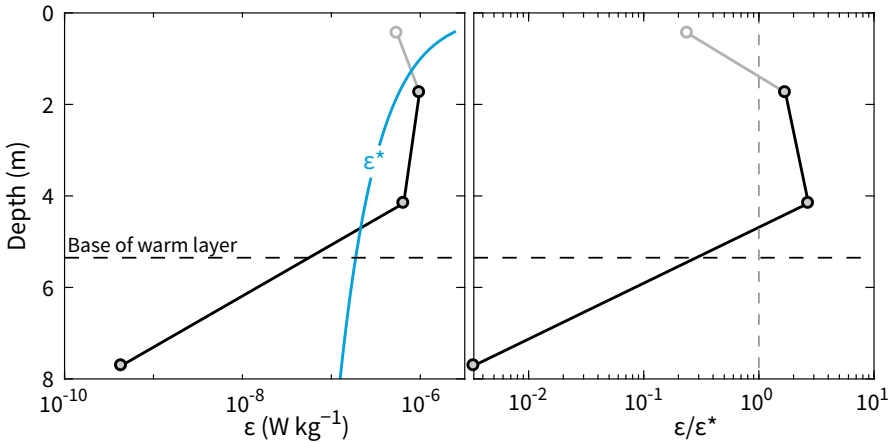


Compare with typical boundary layer turbulence



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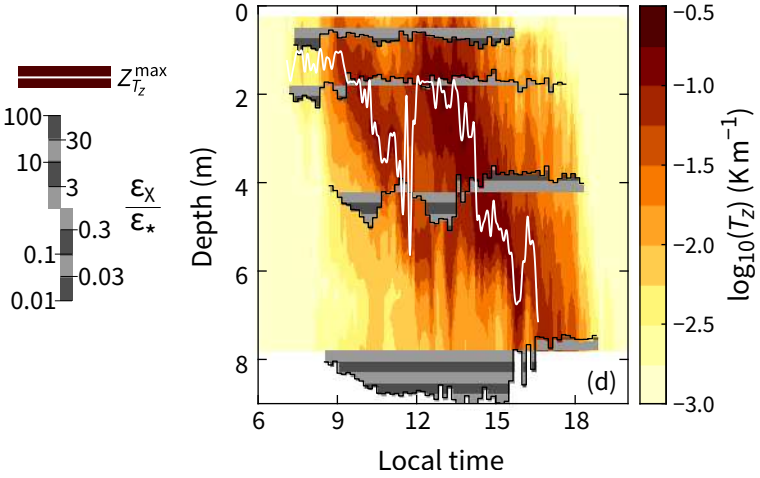
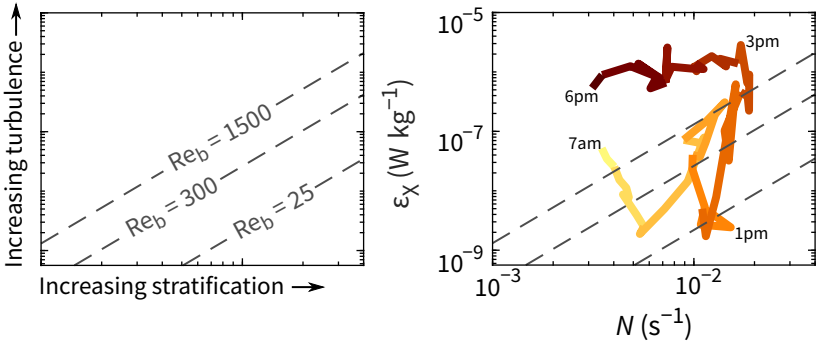
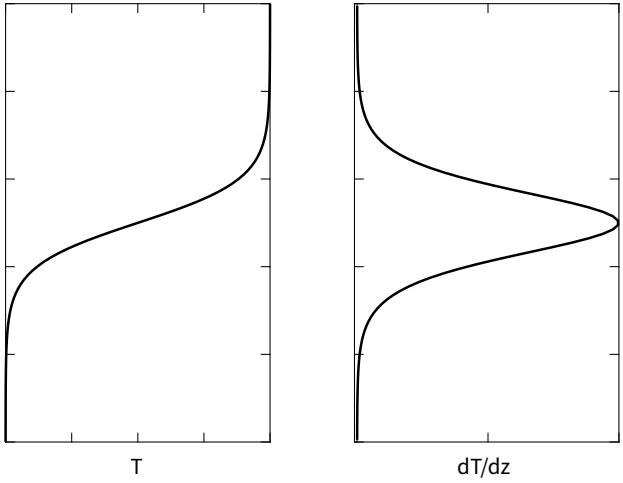


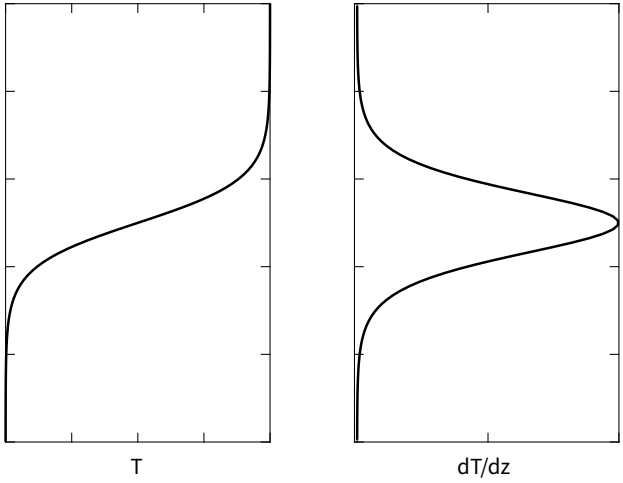
Turbulent buoyancy fluxes completely shut off?



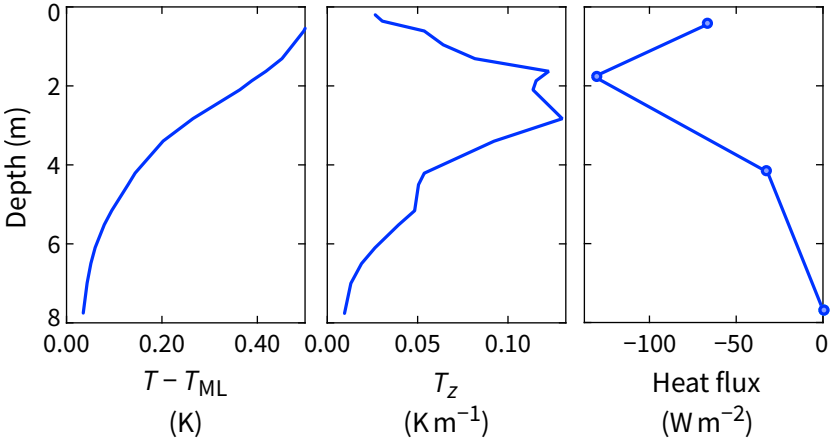
Mixing with constant diffusivity



Mixing with surface-intensified diffusivity



Heat converges where turbulence drops off



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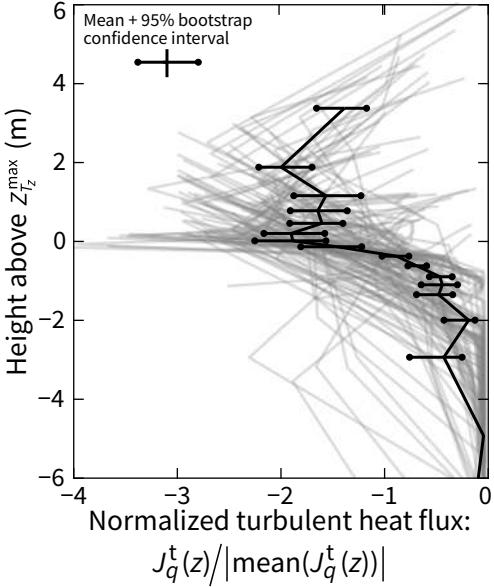

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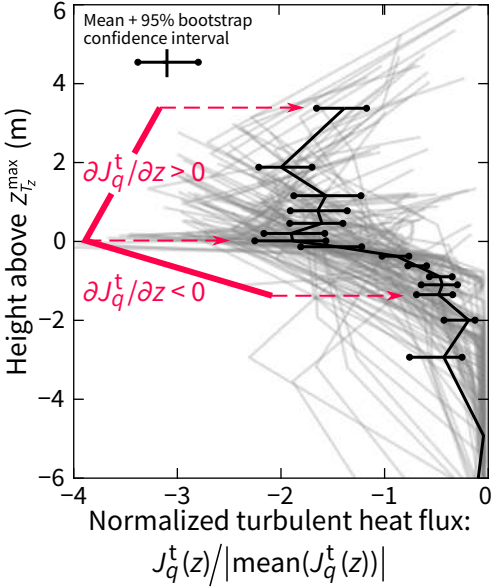
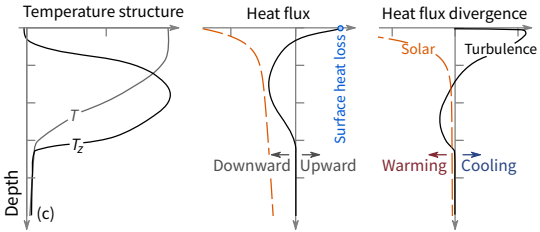


Heat transport through warm layers



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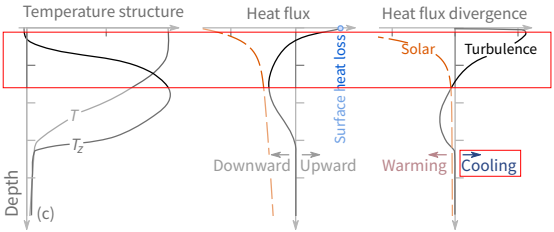
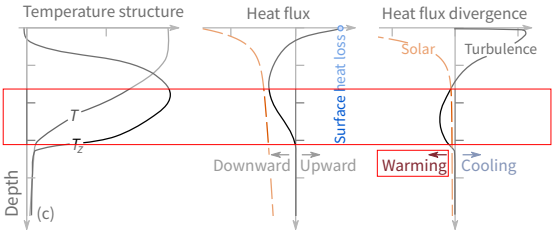
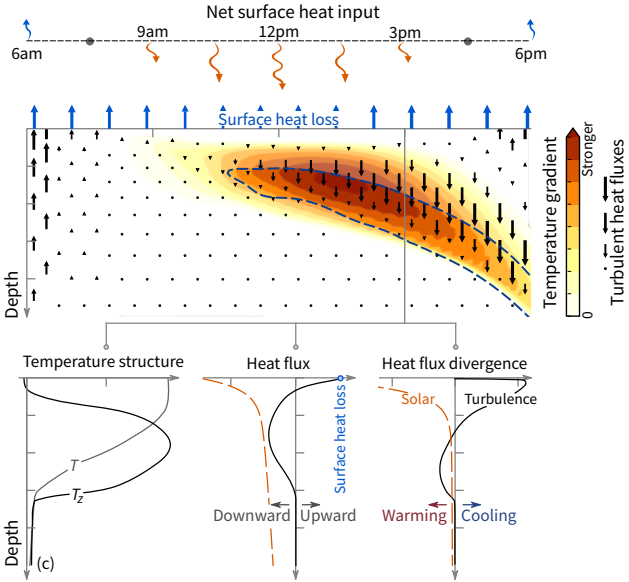


Heat transport through warm layers

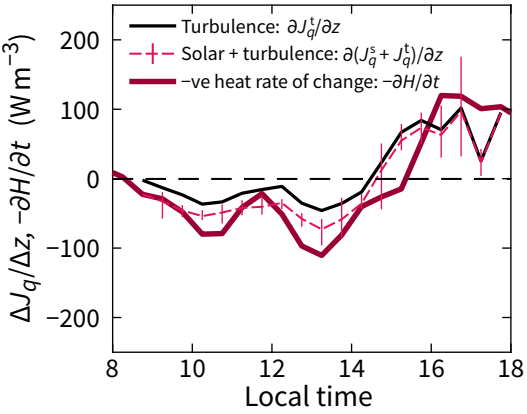


Heat transport through warm layers

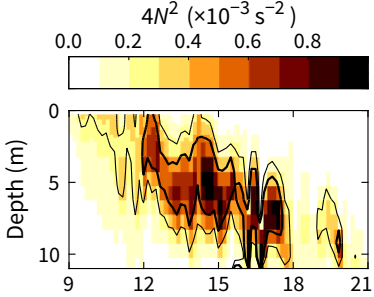


$$\frac{-\partial H}{\partial t} = \frac{\partial J_q^{\mathrm{t}}}{\partial z} + \frac{\partial J_q^{\mathrm{s}}}{\partial z}$$

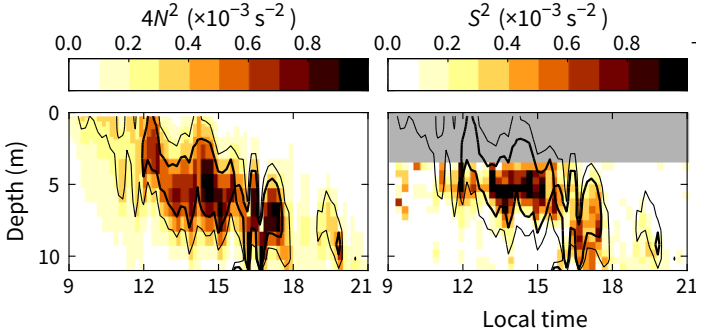
Independent estimates of heat transport agree



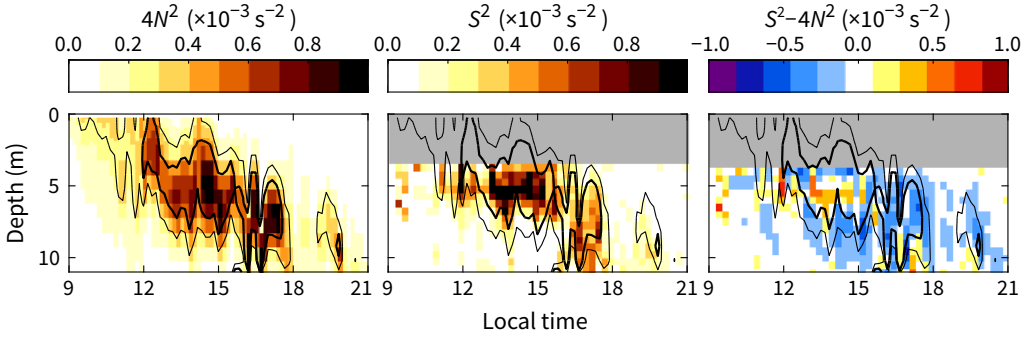
Warm layers exhibit marginal instability



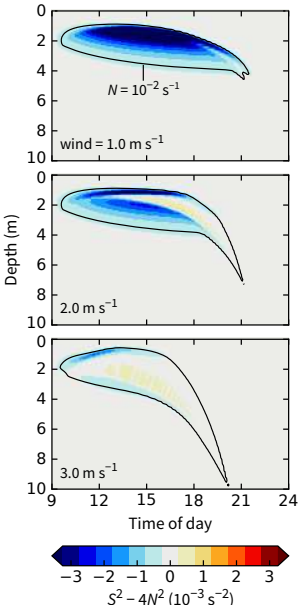
Warm layers exhibit marginal instability



Warm layers exhibit marginal instability



Marginal instability only if wind $>2\ \mathrm{m\ s^{-1}}$



Kinetic energy input:

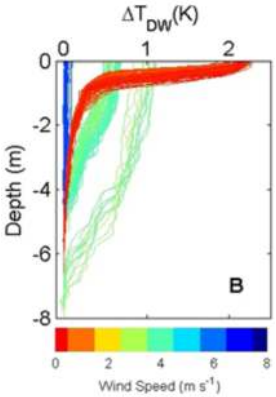
$$\frac{u^2+v^2}{2} = \frac{1}{2}\left(\frac{\tau}{h\rho_{\mathrm{w}}f}\right)^2 (2-2\cos(ft))$$

Potential energy input:

$$J_b t = \frac{g\alpha}{\rho_{\mathrm{w}} c_p} J_q t,$$

$$U_{\mathrm{cr}} \approx 2\,\mathrm{m\,s^{-1}}$$

Other evidence for 2 m s^{-1}



Gentemann et al. (2009)

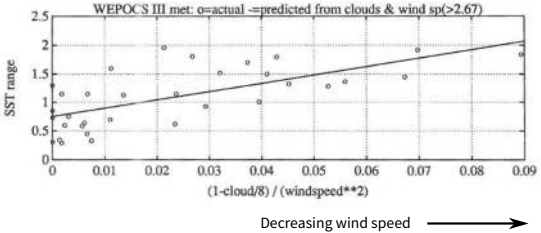
$$\mathrm{dSST} = f + a(\mathrm{PS}) + b(P) + c\ln(U) + d(\mathrm{PS})\ln(U) + e(U)$$

TABLE 5. Coefficients for determination of diurnal sea surface temperature amplitude (dSST) from (6).

Coefficient	$U > 2$ m s^{-1} value	$U \leq 2$ m s^{-1} value
f	0.262	0.328
a	0.002 65	0.002
b	0.028	0.041
c	−0.838	0.212
d	−0.001 05	−0.000 185
e	0.158	−0.329

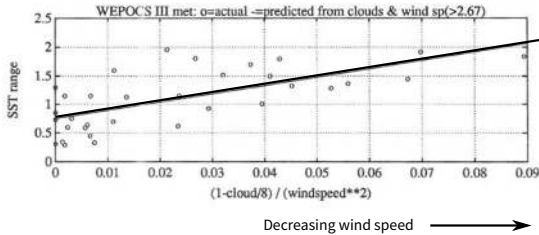
Webster et al. (1996)

Other evidence for 2 m s^{-1}



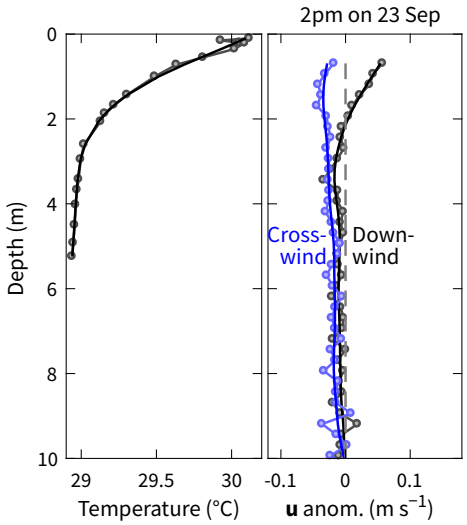
Lukas (1991)

Other evidence for 2 m s^{-1}

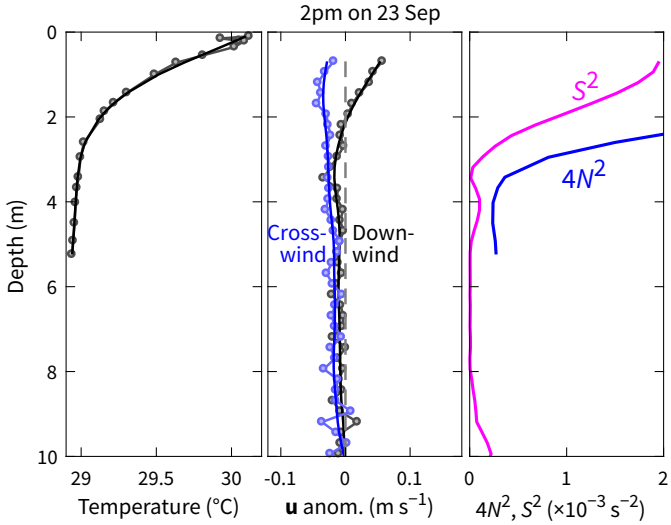


Lukas (1991)

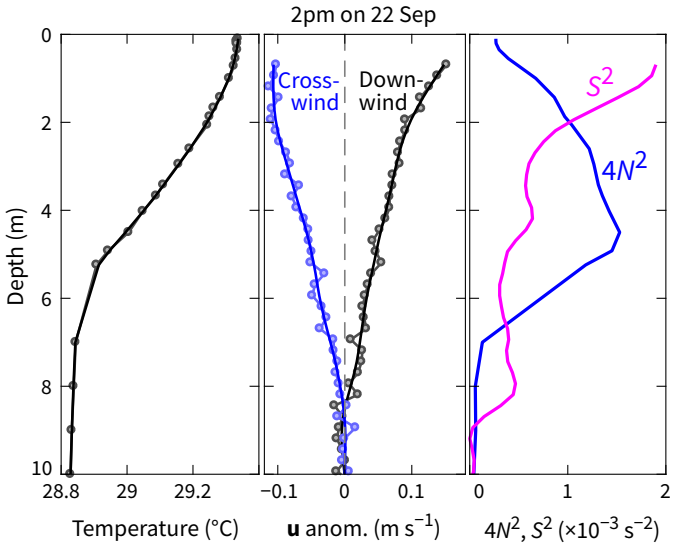
Velocities almost to the surface



Velocities almost to the surface



Velocities almost to the surface



Dynamics of the diurnal thermocline