Assessing the quality of mixing parameterizations

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With contributions from Rebecca Hummels and Tim Fischer (both GEOMAR).

Roadmap

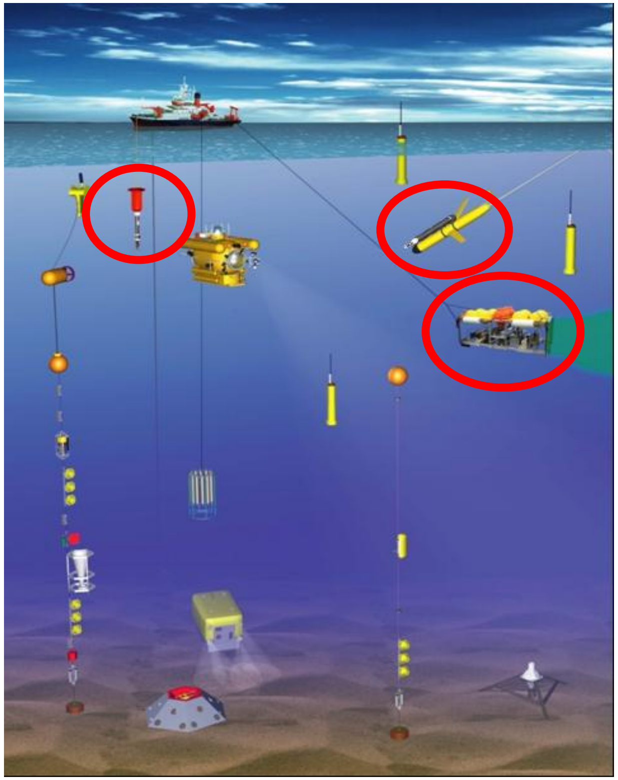
- Mixing Observatories at GEOMAR
- Parameterization of shear driven mixing in the tropical ocean
- Parameterization of internal wave driven mixing
- Conclusions

Mixing Observatories at GEOMAR

GEOMAR

Microstructure Systems

MicroRider / AUV

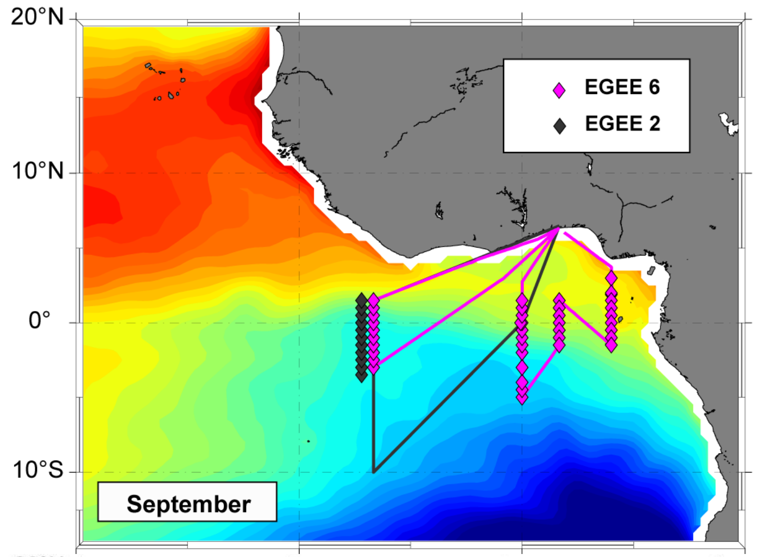


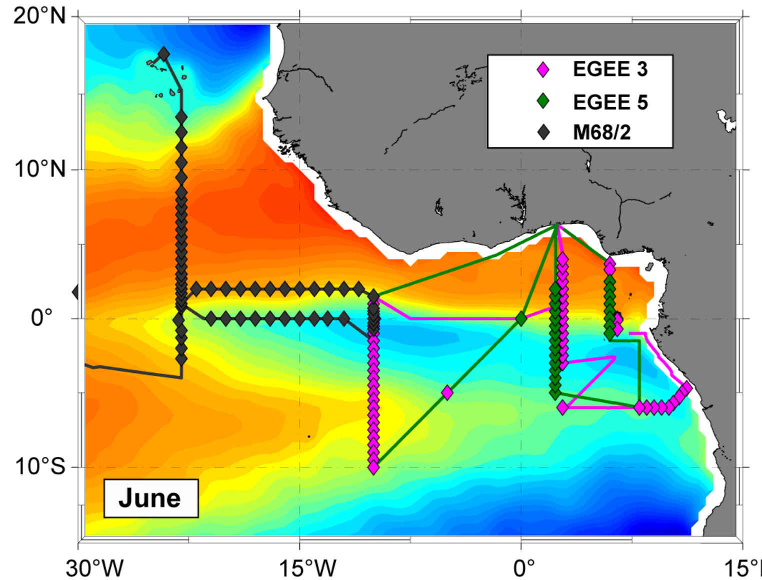
MicroRider / Glider

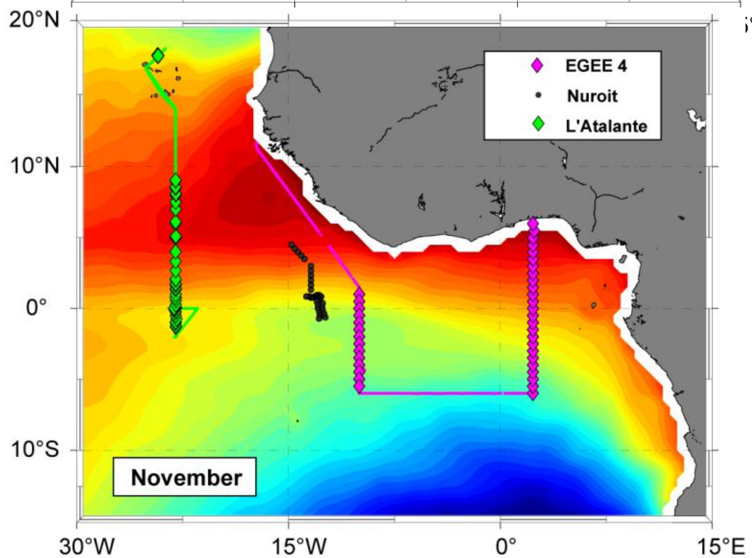
Tracer release sled

Microstructure data from the tropical Atlantic

GEOMAR







- repetitive microstructure sections within the cold tongue region from 8 cruises
- individual stations with at least 3 profiles/station (>1000 profiles)
- CTD stations
- shipboard ADCP measurements

(Hummels et al., 2013)

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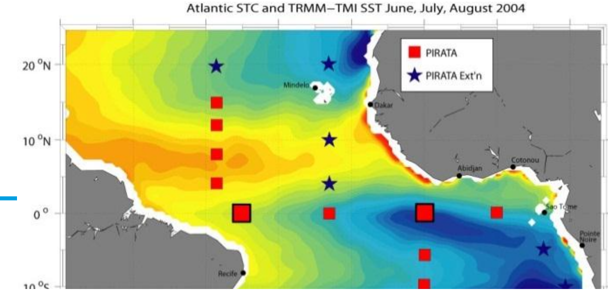
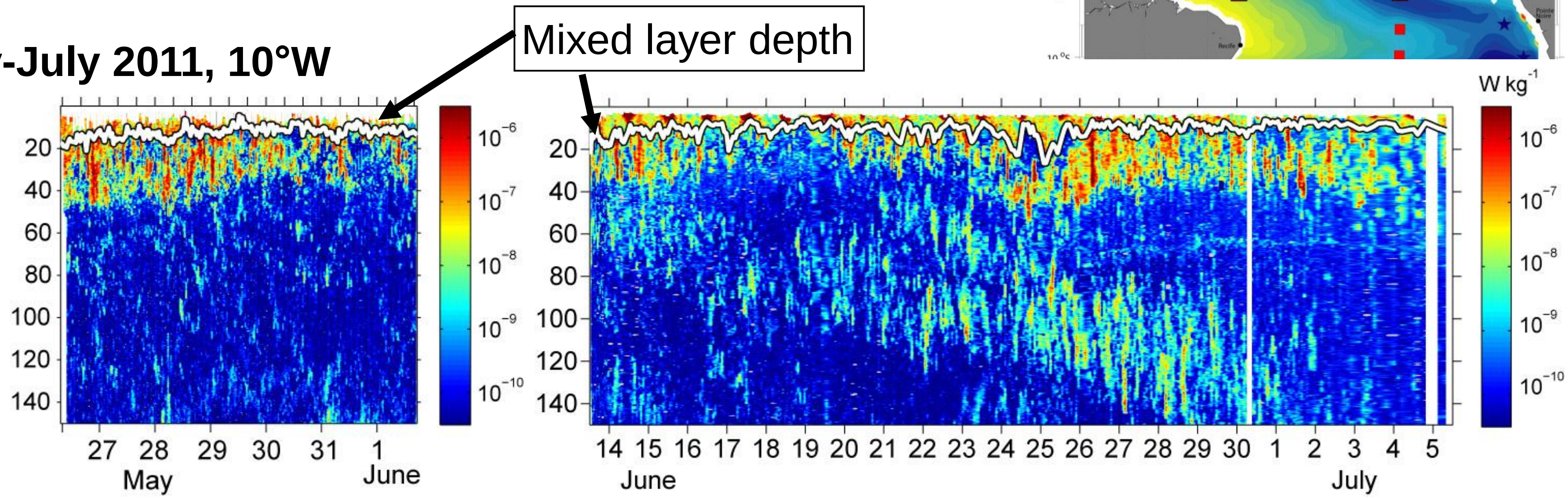
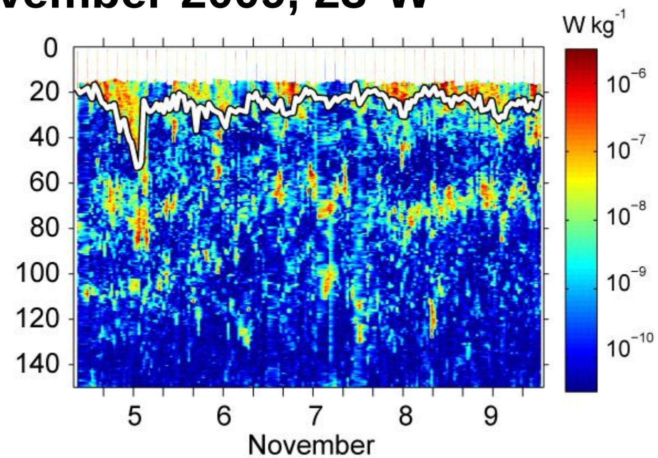


Time series of turbulent kinetic energy

May-July 2011, 10°W



November 2009, 23°W



- strongly elevated dissipation rates (~1x10^{-4} Wkg^{-1}) in the mixed layer between 11am to 6pm
- at 10°W, elevated mixing levels (~1x10^{-6} Wkg^{-1}) below the mixed layer, particularly during night time
- at 23°W depth interval of low mixing disconnected from the mixed layer

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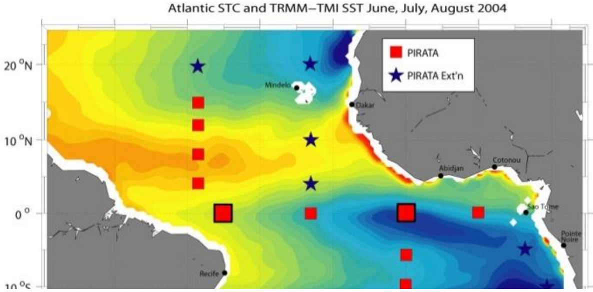
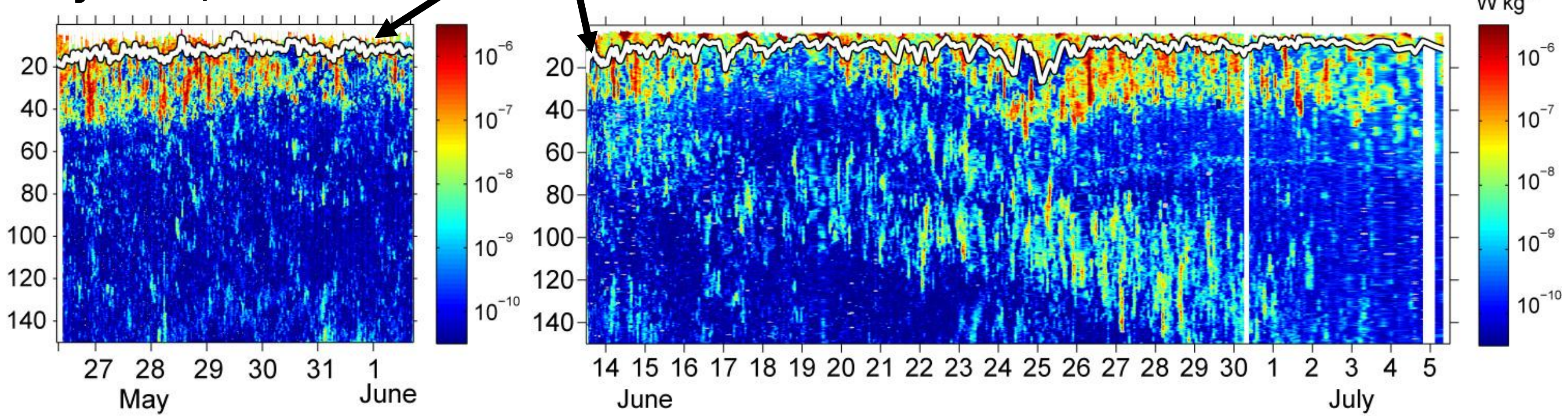
Time series of turbulent kinetic energy

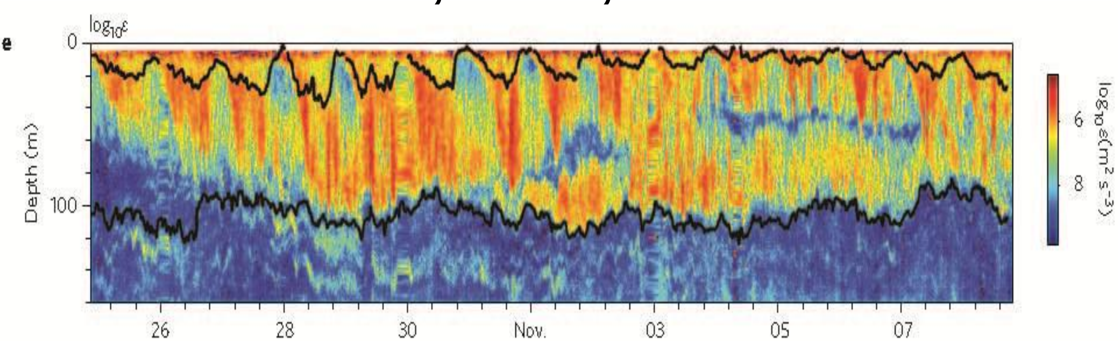


Mixed layer depth

May-July 2011, 10°W



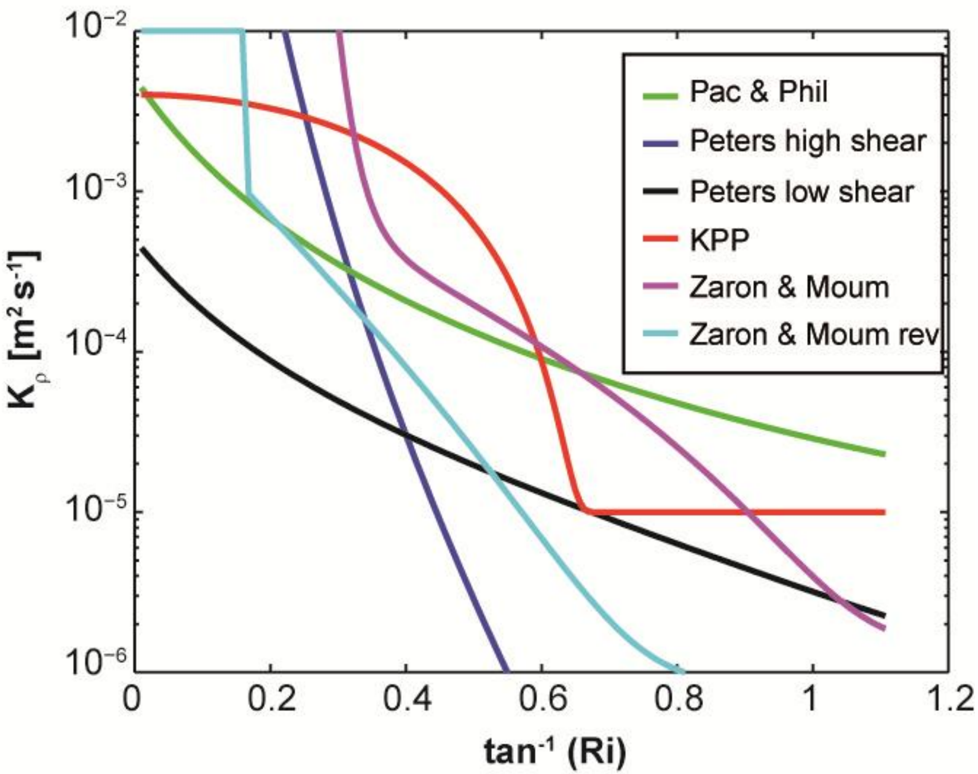
Oct.-Nov. 2008, 140°W, Pacific



- Time series from the Atlantic cold tongue indicate elevated variability on different time scales compared to the time series from the Pacific.

(Moum et al., 2009)

Parameterizations



Pacanowski and Philander (1981)

$$\nu = \frac{50 \cdot 10^{-4} m^2 s^{-1}}{(1+5Ri)^2} + 10^{-4} m^2 s^{-1}$$

$$K_\rho = \frac{\nu}{(1+5Ri)} + 10^{-5} m^2 s^{-1}$$

Peters et al., (1988)

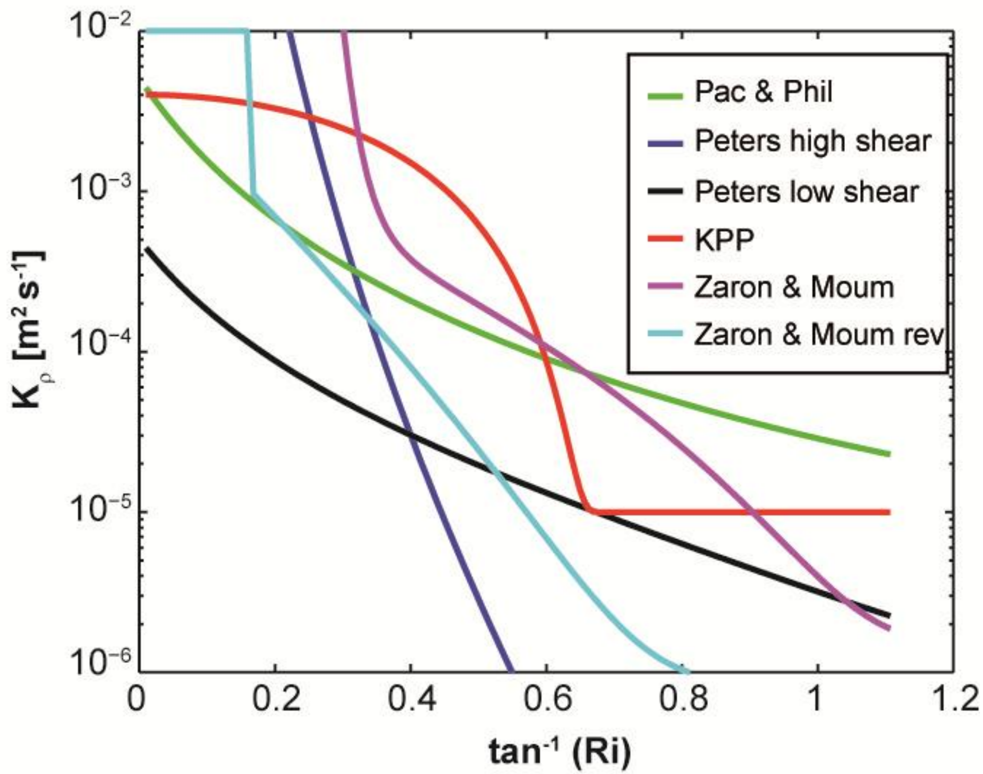
$$K_\rho = \frac{5 \cdot 10^{-4} m^2 s^{-1}}{(1+5Ri)^{2.5}} + 10^{-6} m^2 s^{-1}$$ **high shear**

$$K_\rho = 1.1 \cdot 10^{-8} Ri^{-9.2}$$ **low shear**

KPP
Large et al., (1994)
Large and Gent (1999)

$$K_\rho = 50 \cdot 10^{-4} m^2 s^{-1} \left[1 - (Ri/0.7)^2\right]^3$$

Parameterizations



Zaron & Moum (2009)

$$K_h^{alt} = |V|^2 / S \cdot a\left(\frac{Ri_1}{Ri - Ri_1}\right)^{\alpha} + be^{-\beta \cdot Ri} + c$$

$$K_h^{rev} = |V|^2 / S \cdot \Delta\phi_h e^{-\gamma(Ri - Ri_2)} + \phi_h^w$$

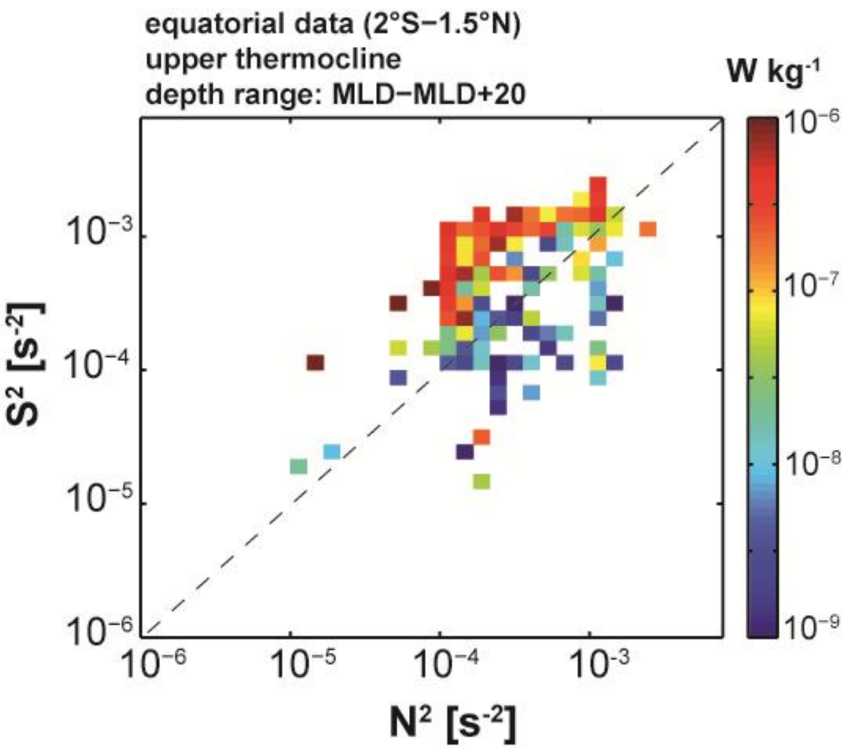
Uses additional parameter:

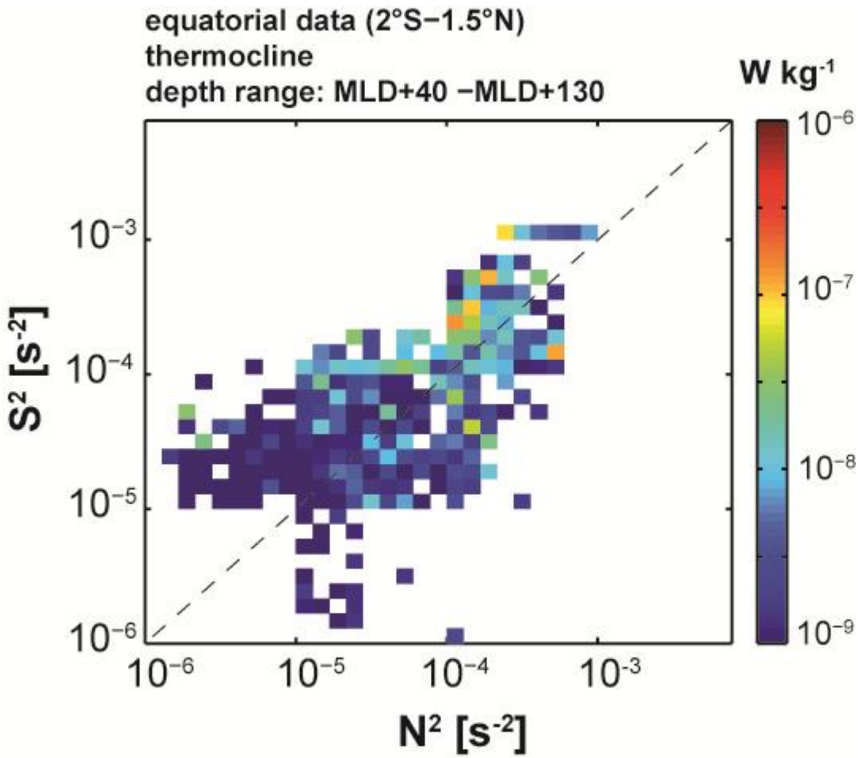
$|V|^2$ – **large-scale kinetic energy**

S – **shear**

Average TKE dissipation rates in N^2 and S^2 bins

Observations (2°N-1.5°S)





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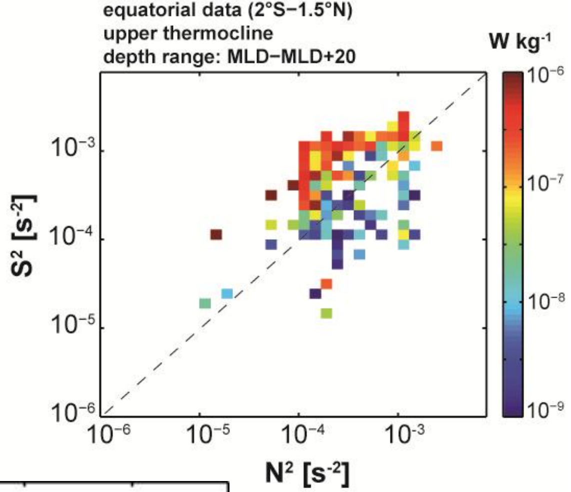
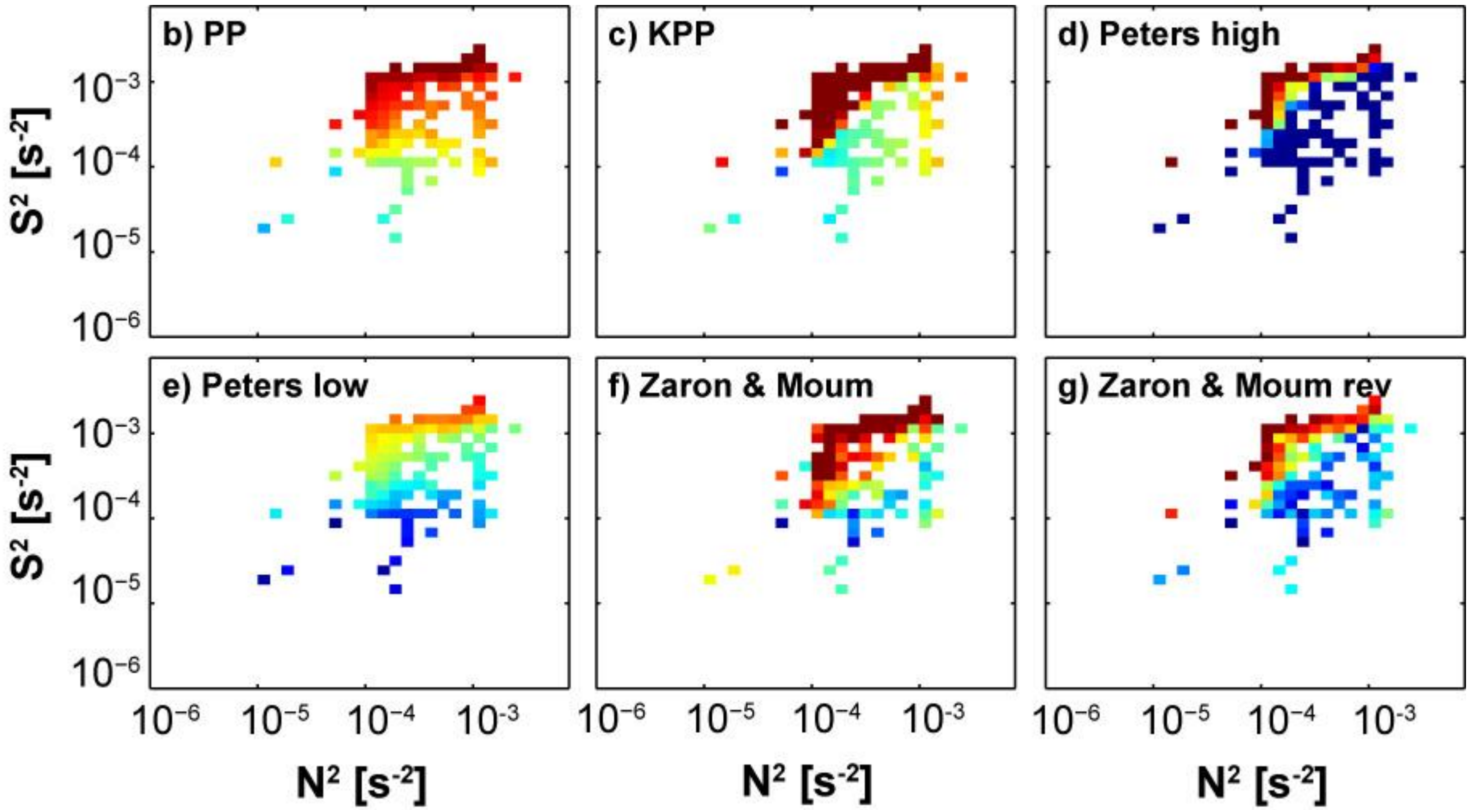


Upper Thermocline (MLD to MLD+20m)



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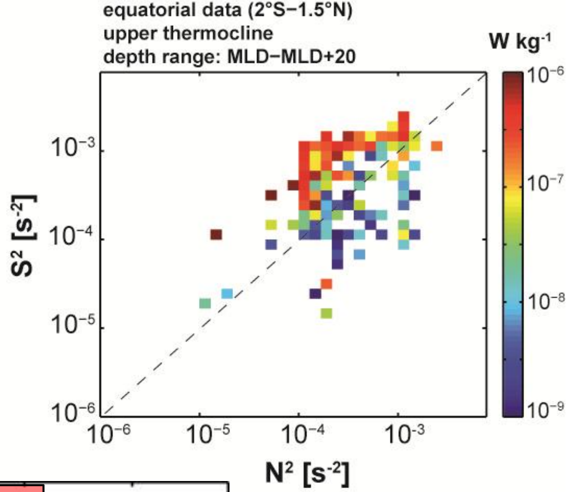

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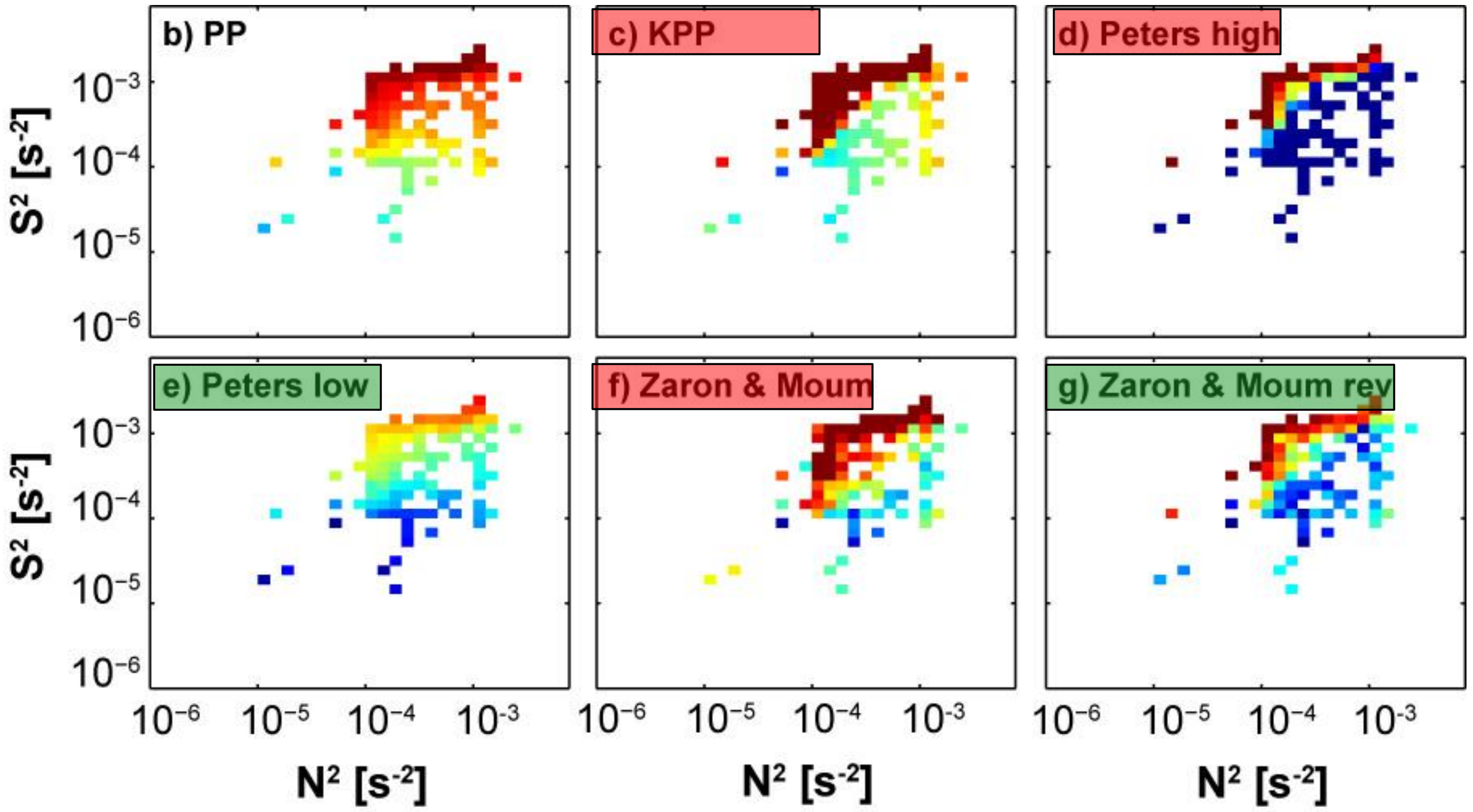
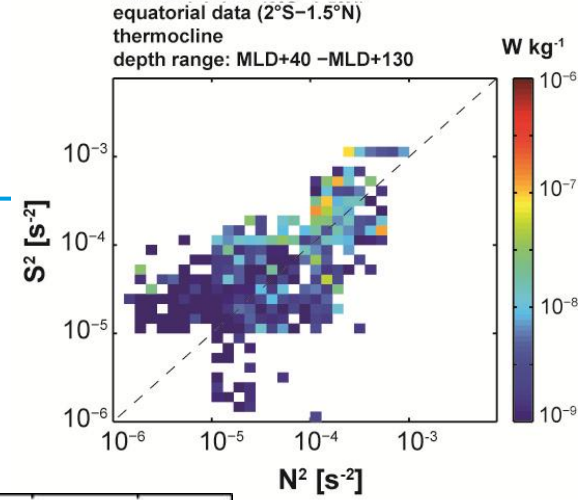
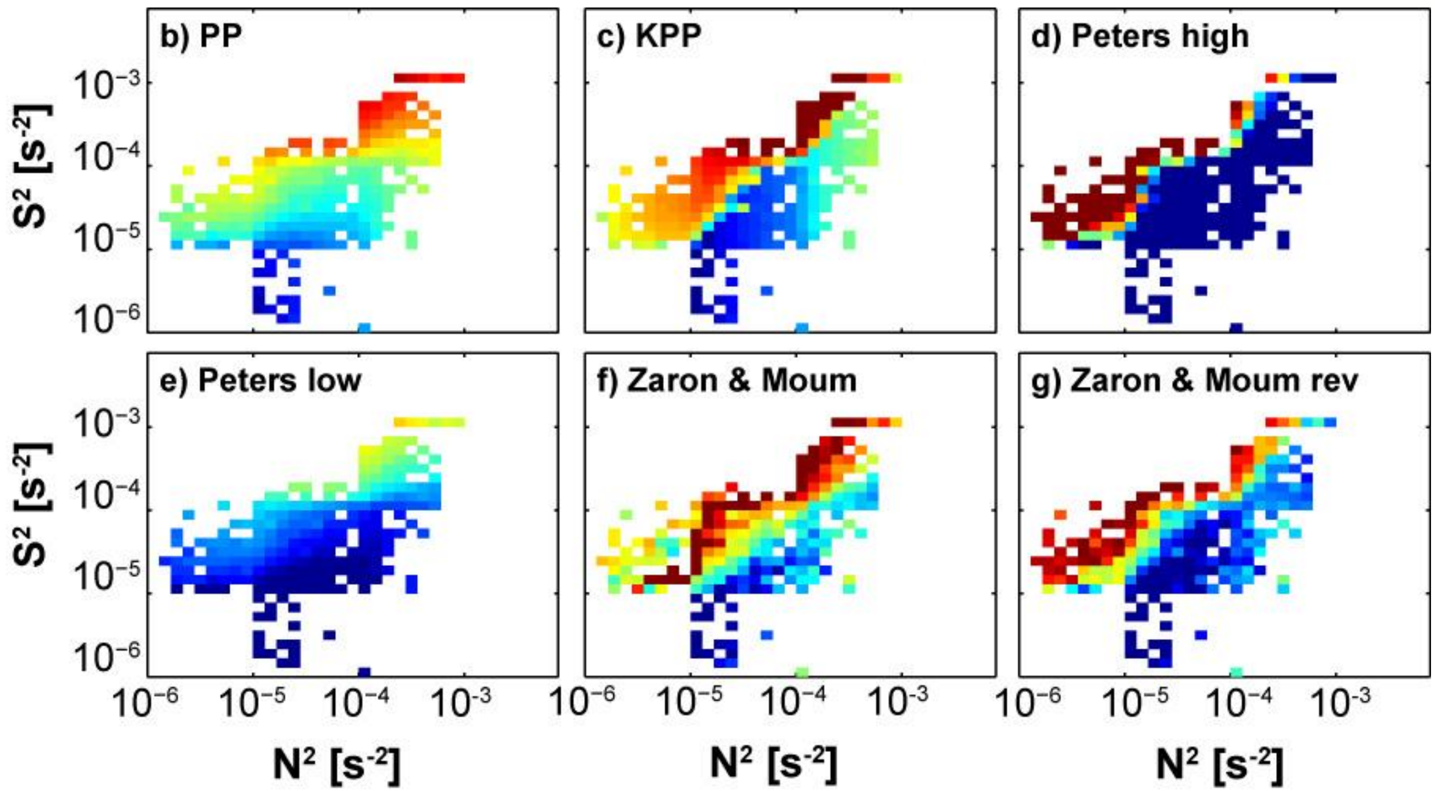


Average TKE dissipation rates in N^2 and S^2 bins



Thermocline (MLD+40m to MLD+130m)



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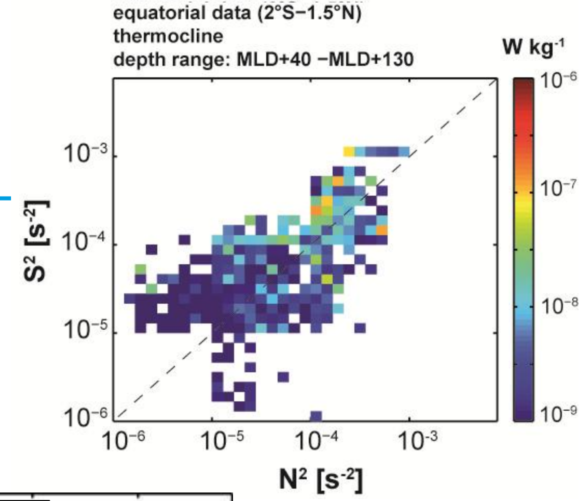

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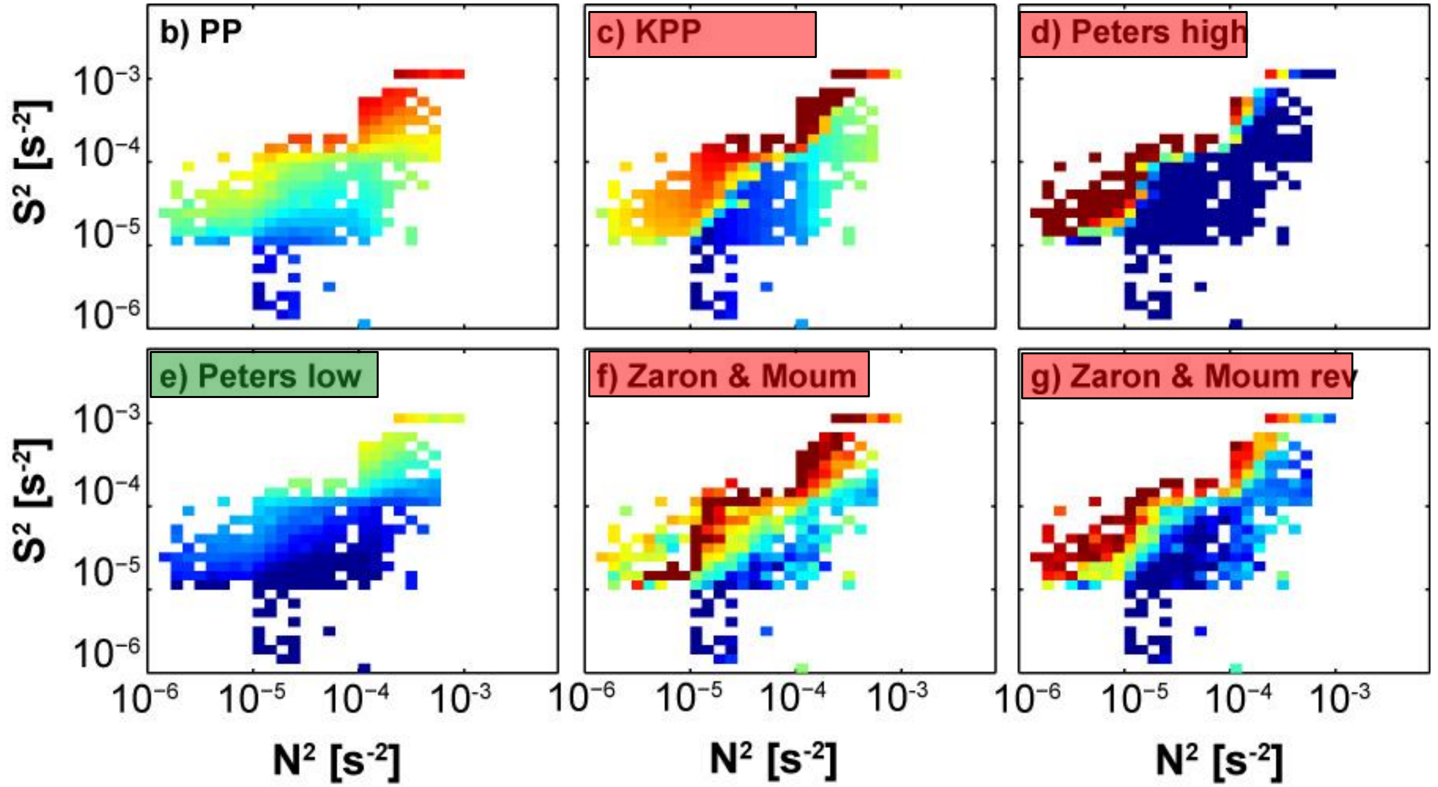

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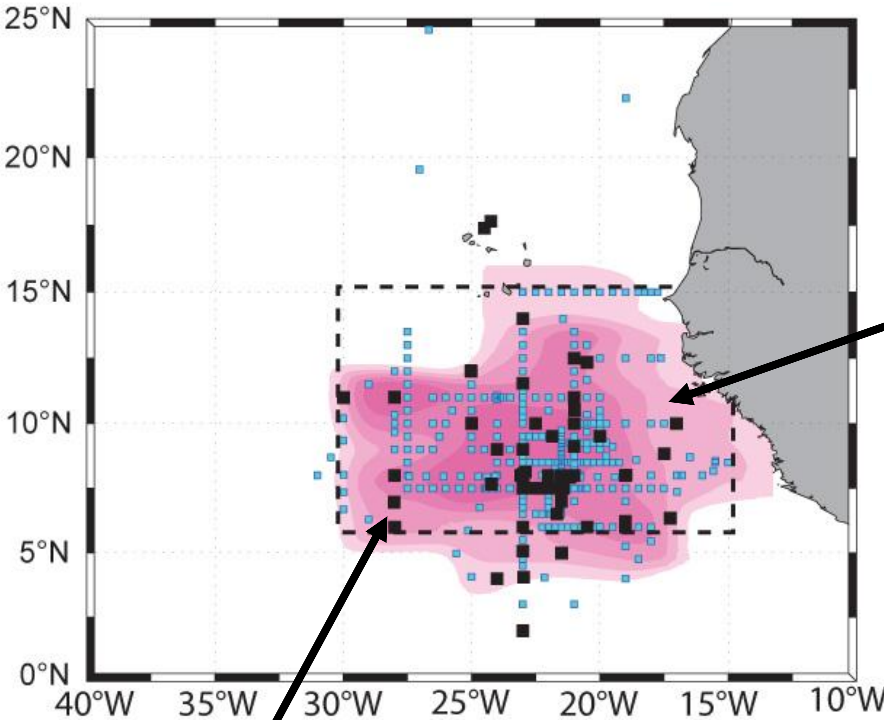
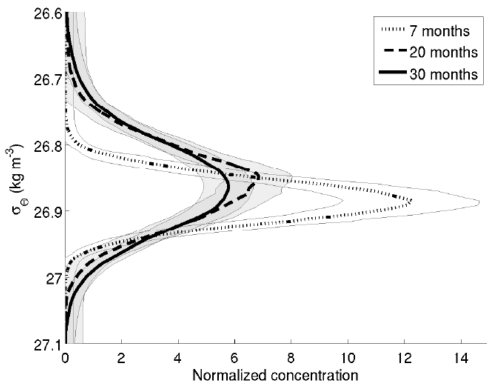
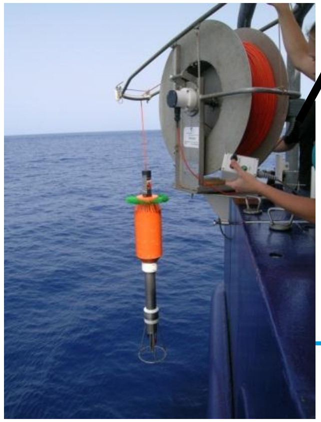
Microstructure data from the Guinea Dome Region



Tracer release experiment



(Banyte et al., 2012)



■ Microstructure profiling stations

(Fischer et al., 2013)

K_z from tracer release experiment and average K_ρ from microstructure measurements agree within 95% confidence

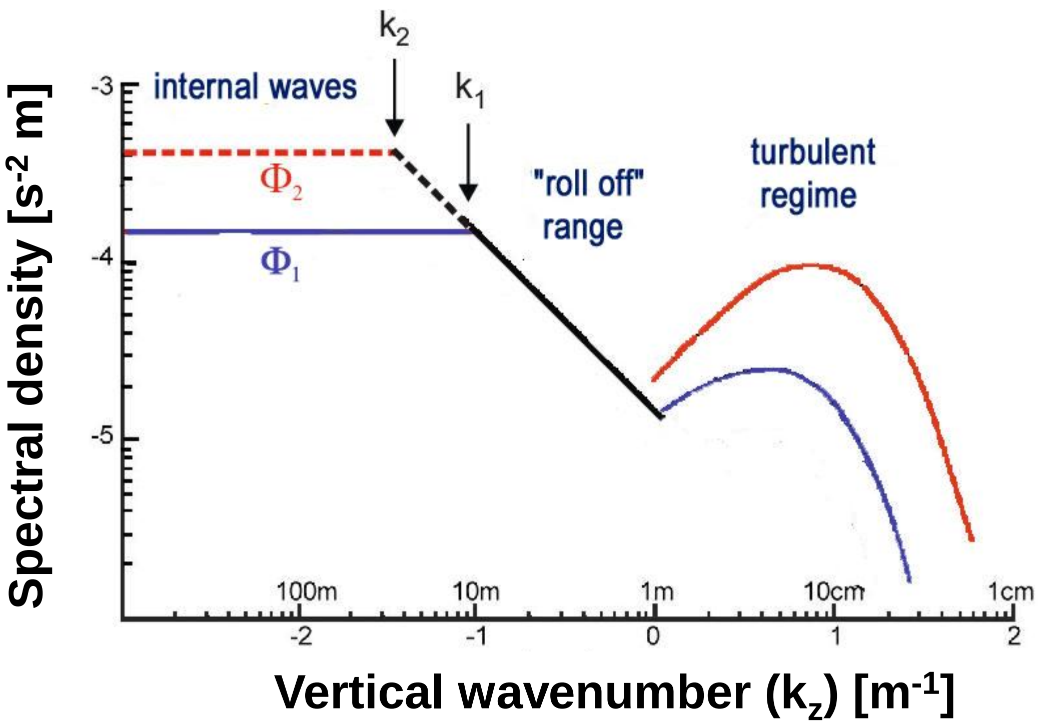
Finescale parameterization of internal wave mixing

$$\varepsilon = \varepsilon_{30^\circ}(N, \Phi_{shear(k)}, \Phi_{strain(k)}) \times L(\theta, N)$$

(Henyey et al., 1986; Gregg, 1990; Polzin et al. 1995; Gregg et al. 2003)

$$\varepsilon_{30^\circ} = 6.7 \times 10^{-10} \left(\frac{N}{N_0}\right)^2 \left(\frac{0.1}{k_c}\right)^2 f(R_\omega),$$

R_ω – shear to strain ratio



$$L(\theta, N) = \frac{f \cosh^{-1}(N/f)}{f_{30^\circ} \cosh^{-1}(N_0/f_{30^\circ})}$$

$$\int_0^{k_c} \Phi_{shear}\, dk = 0.661 N^2$$

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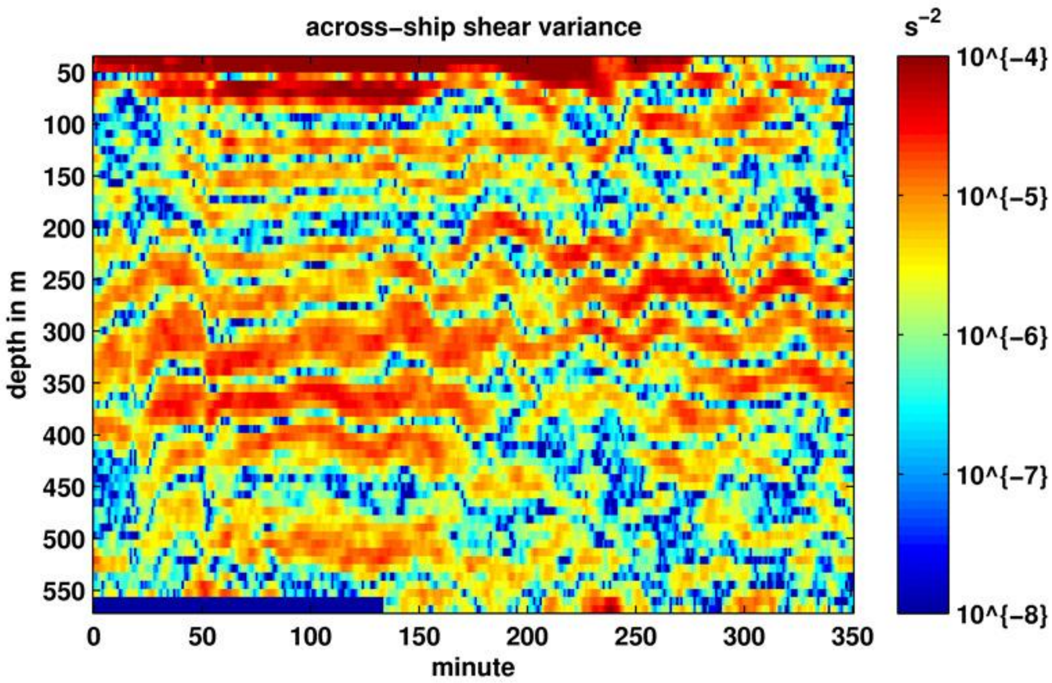

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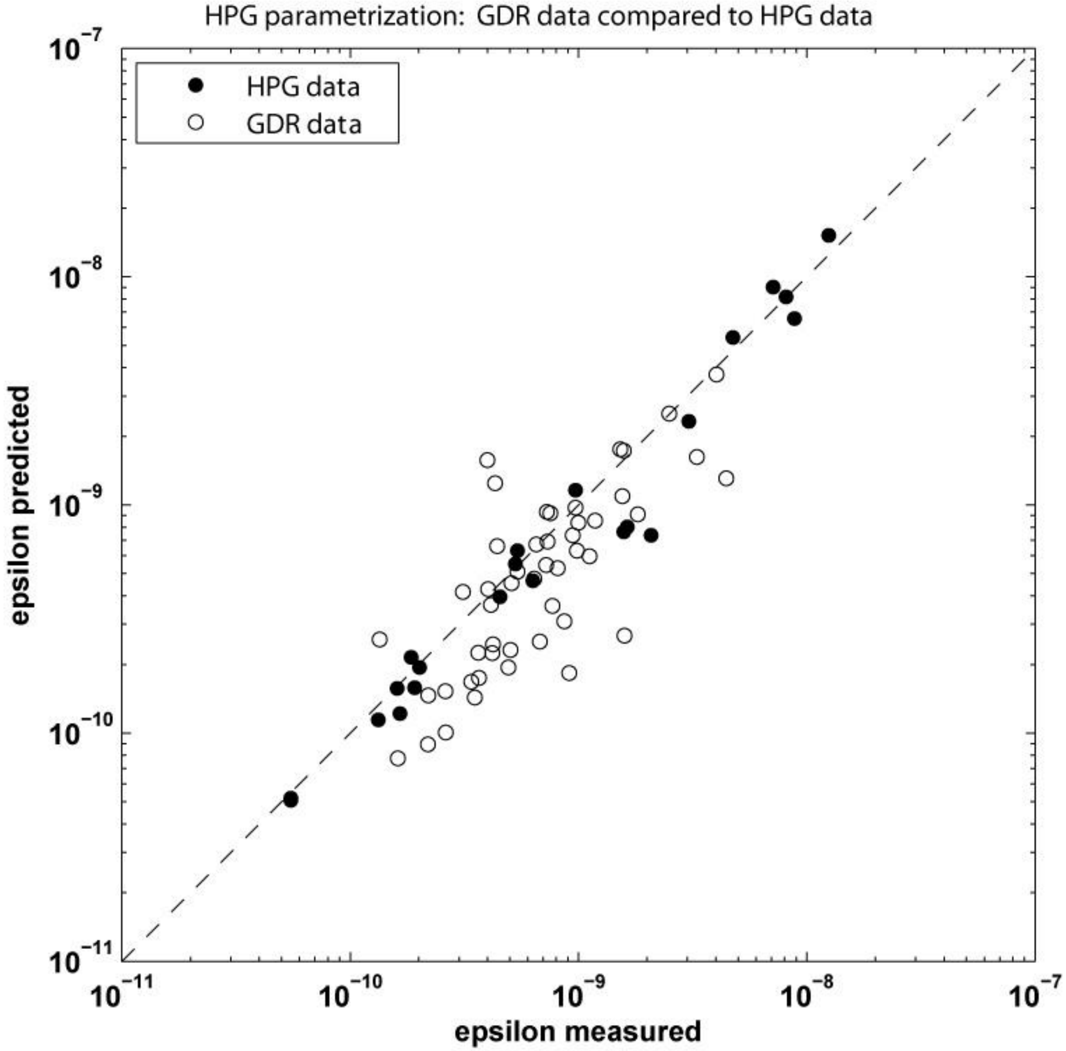
Shear from shipboard ADCP

$$S^2 = \left(\frac{\partial U}{\partial z}\right)^2 + \left(\frac{\partial V}{\partial z}\right)^2$$

Finescale parameterization of internal wave mixing

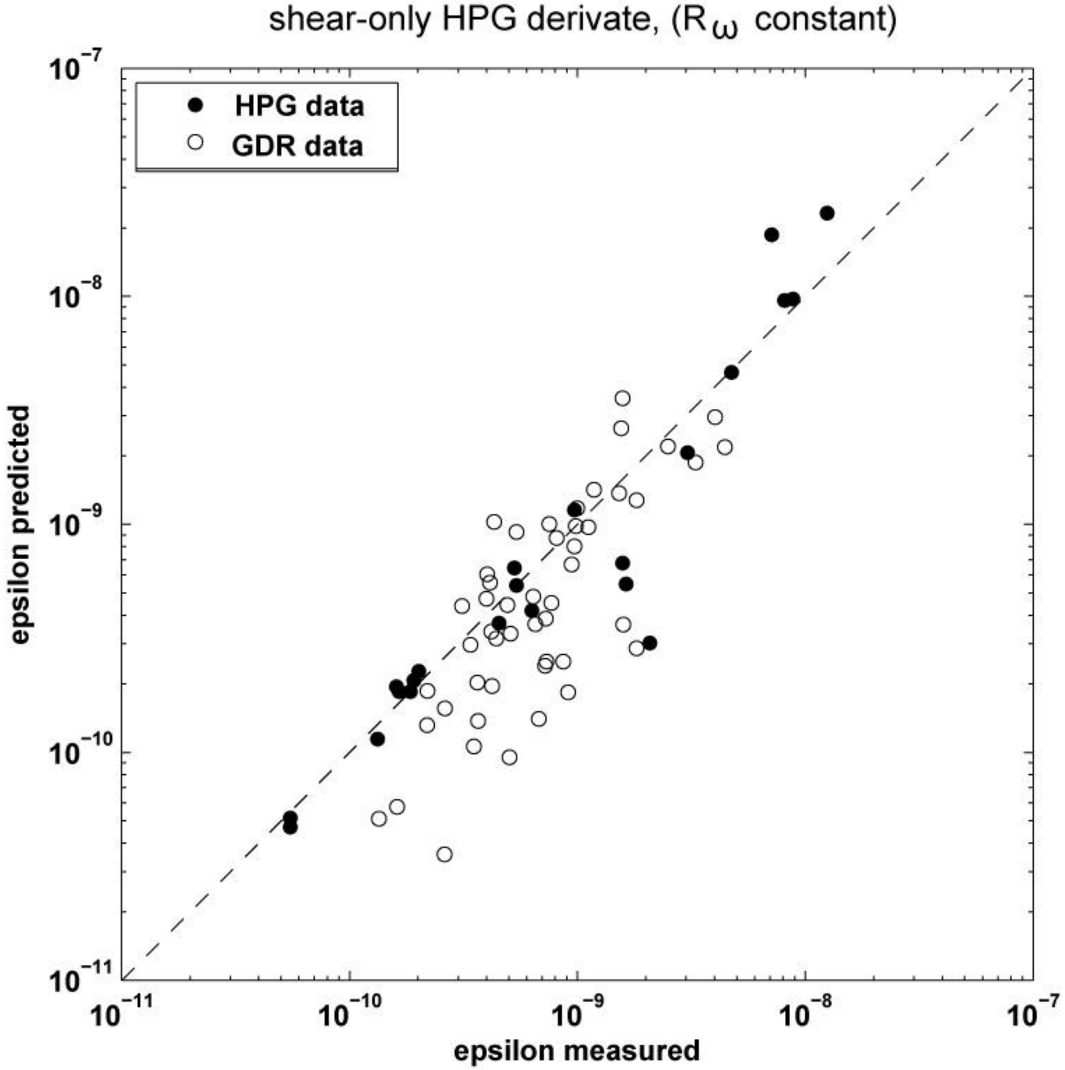


HPG - Data used by Polzin et al (1995)

GDR – Data from the Guinea Dome

All four parameters (f, N, shear, strain) eveluated from data

Finescale parameterization of internal wave mixing



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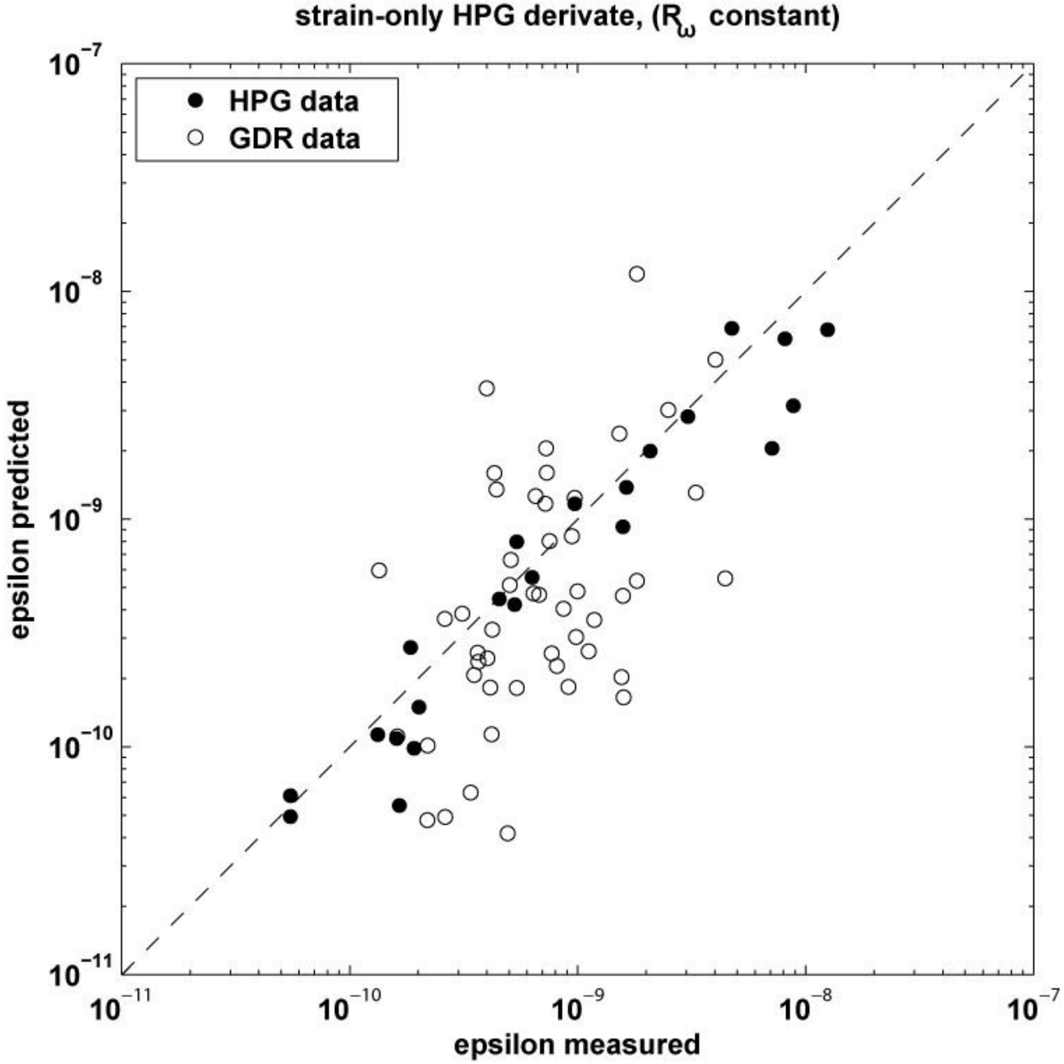

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