Diapycnal Mixing in the Equatorial Cold Tongue and its Parameterization

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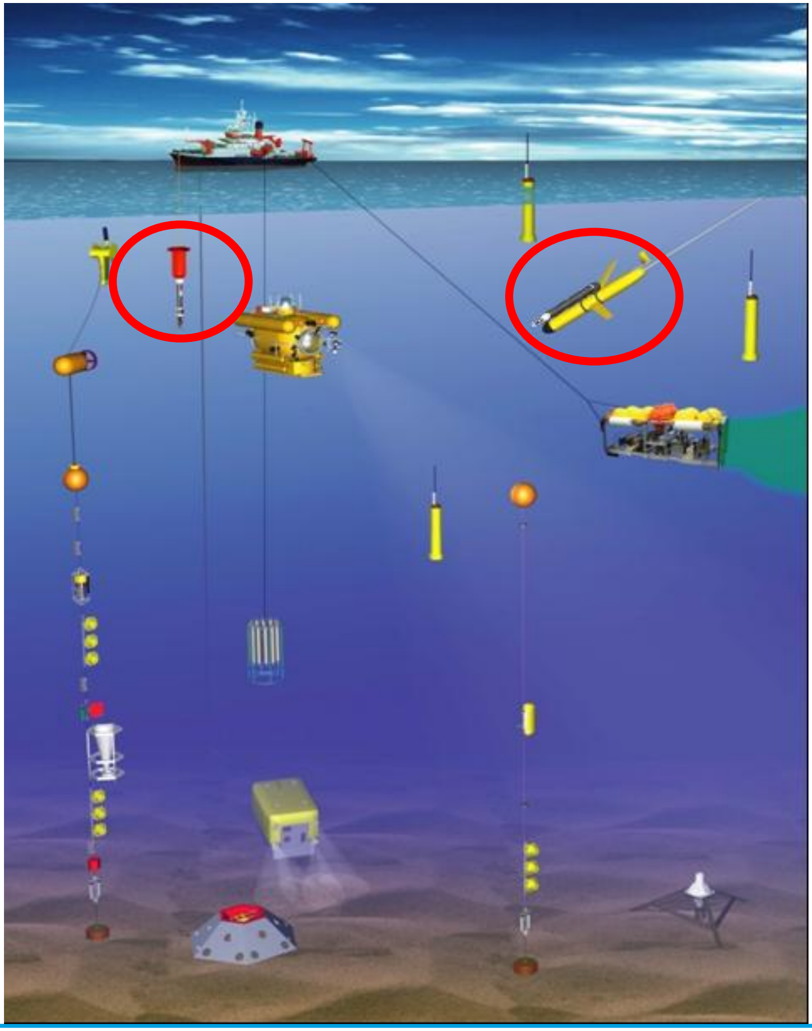
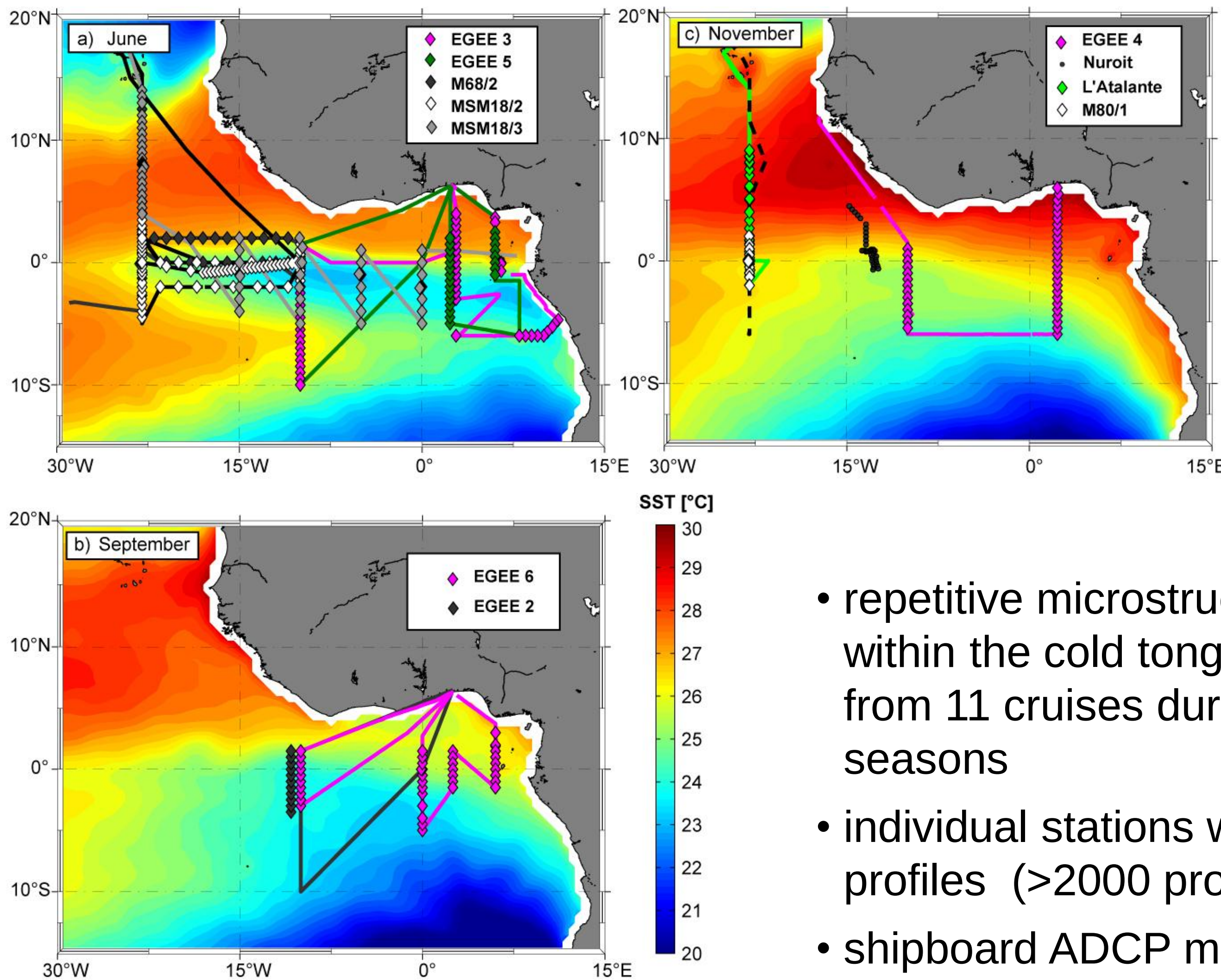
Mixing Observatories at GEOMAR

Ship-based microstructure systems



Autonomous microstructure platforms (MicroRider / Glider)

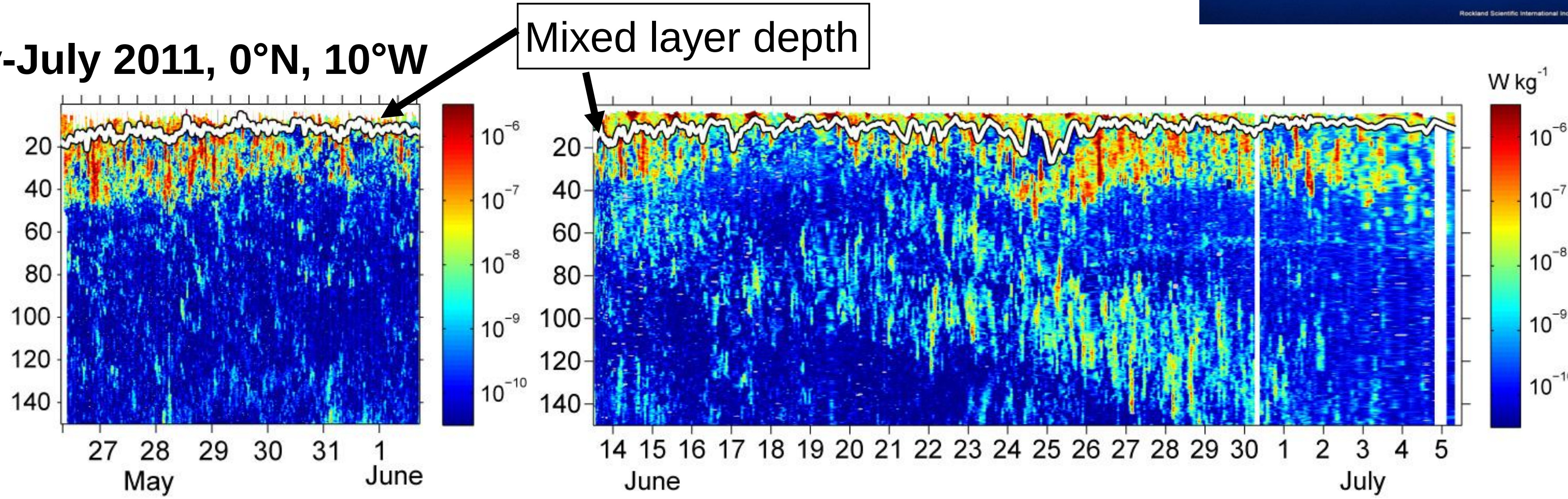
Ship-board microstructure measurements (2005-2011)



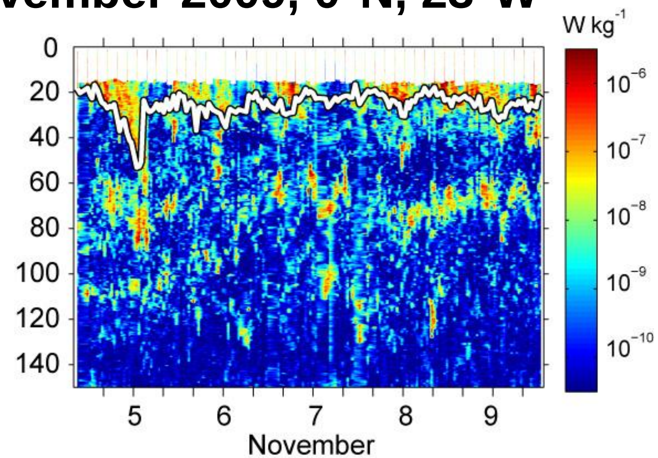
- repetitive microstructure sections within the cold tongue region from 11 cruises during different seasons
- individual stations with at least 3 profiles (>2000 profiles)
- shipboard ADCP measurements

Time series of turbulent kinetic energy

May-July 2011, 0°N, 10°W

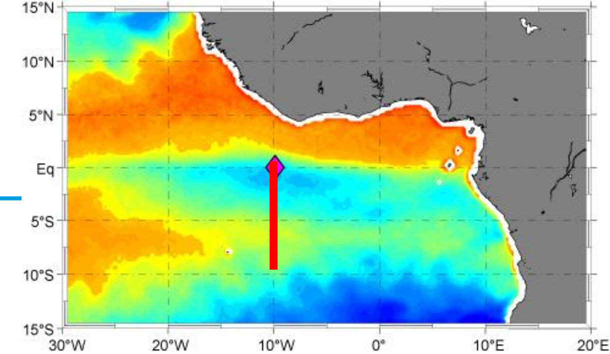


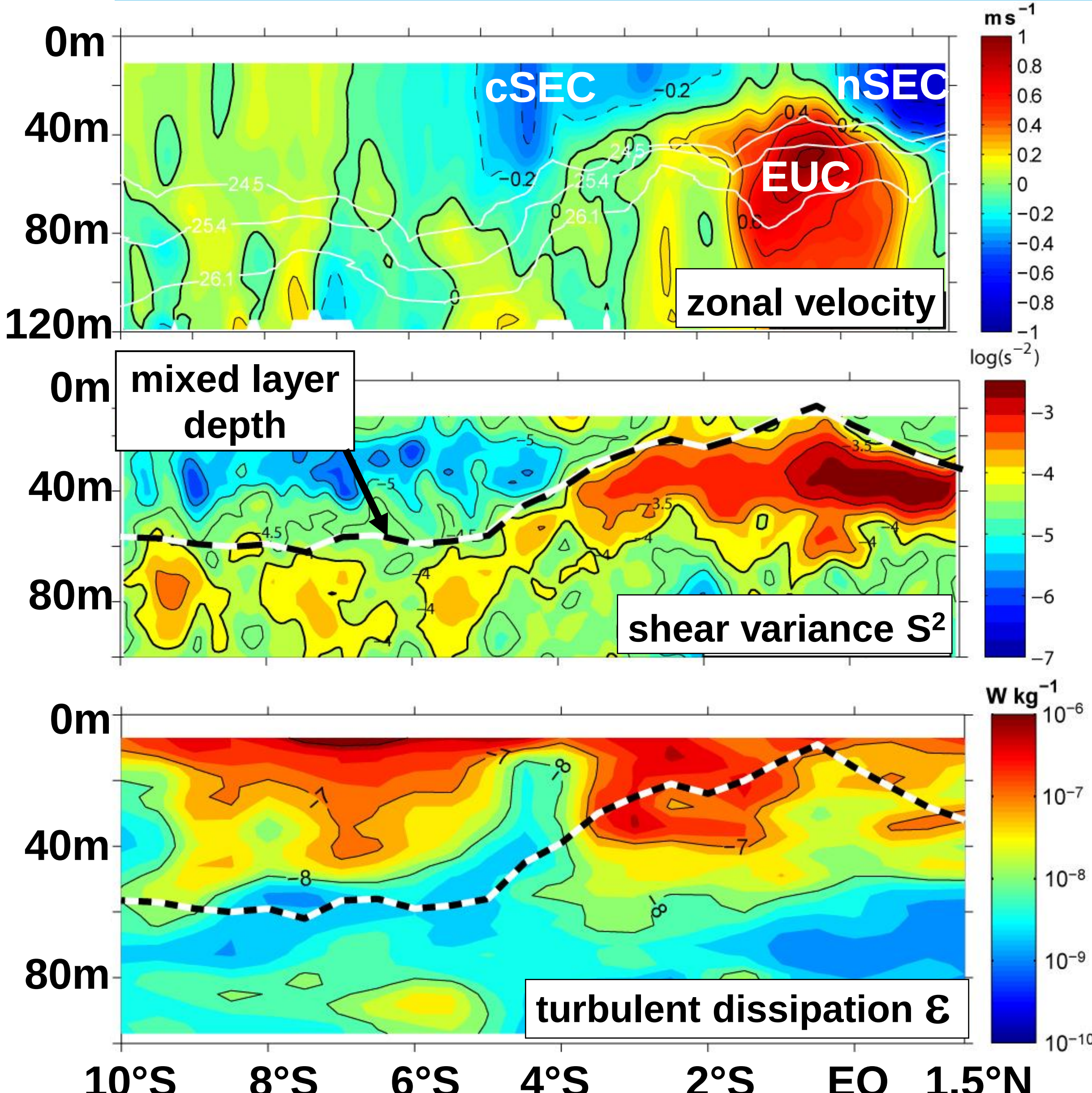
November 2009, 0°N, 23°W



- microstructure probe (Rockland Scientific) attached to a Glider
- measures autonomously for up to 4 weeks
- profiles the water column to 1000m in about 45 minutes

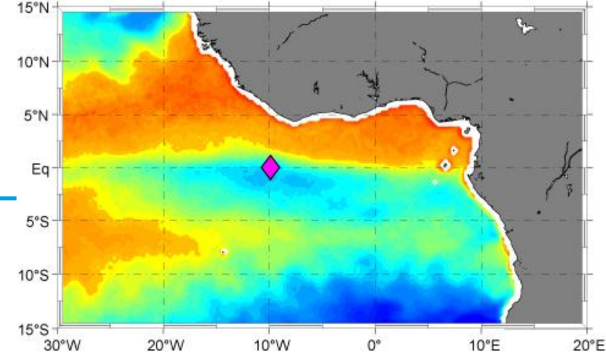
Latitudinal distribution of upper ocean turbulence: Section along 10°W



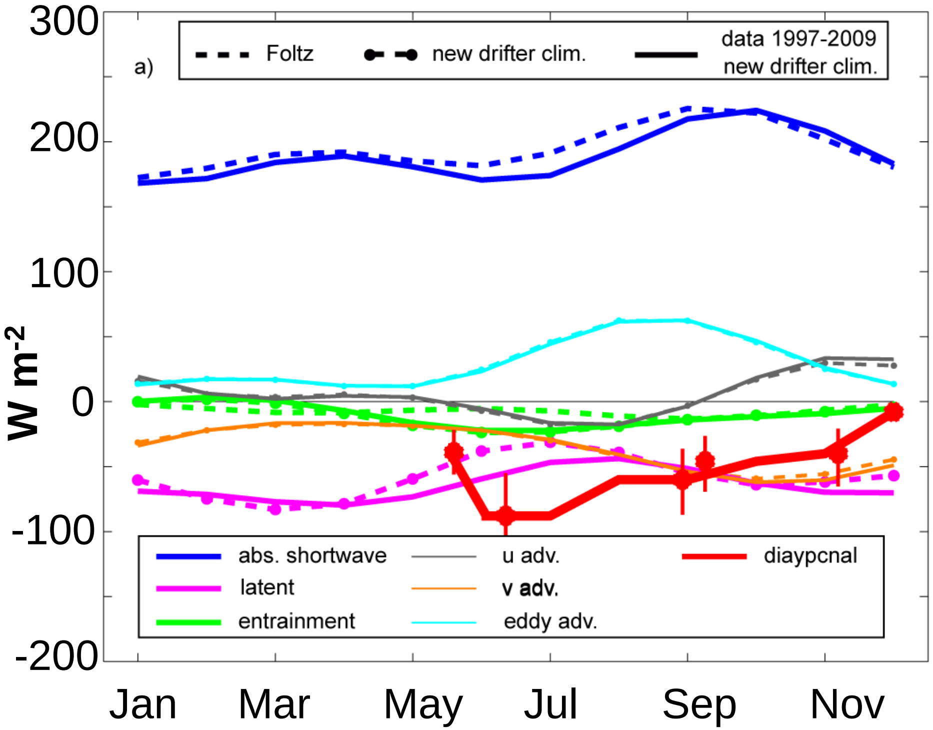


- elevated vertical shear of horizontal velocity at the base of the mixed layer extends from 3°S to 1.5°N
- elevated turbulence levels below mixed layer are found between 3°S and 1°N
- little mixing in stratified layer below MLD south of 4°N

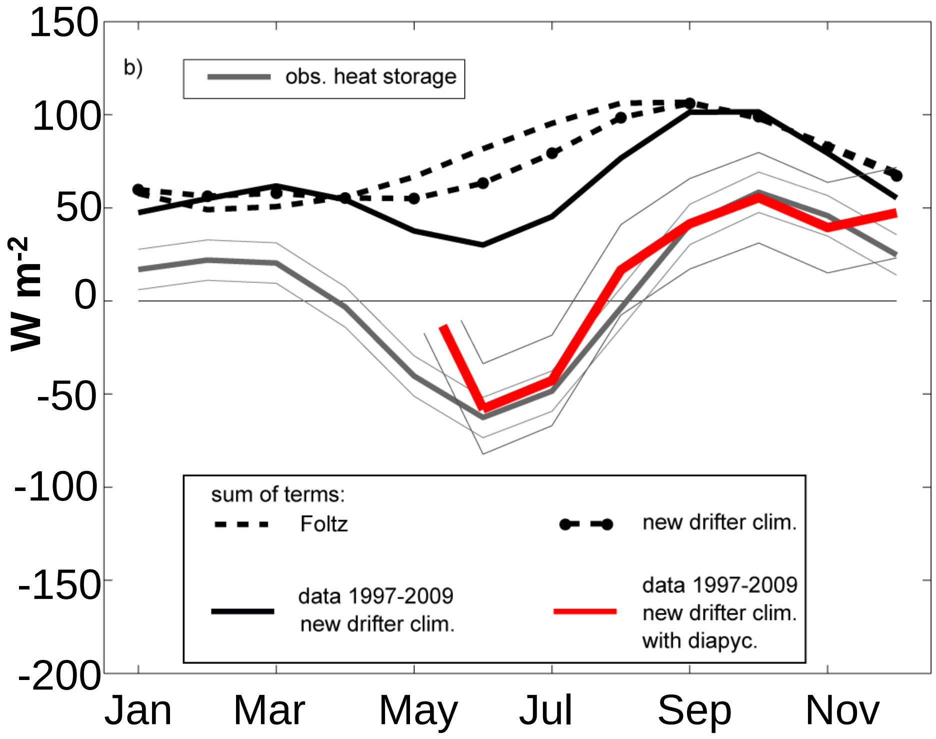
Seasonal cycle of
mixed layer heat budget at 0°N, 10°W



Individual terms of mixed layer heat balance



Sum of terms and heat storage



(Hummels et al., 2013)

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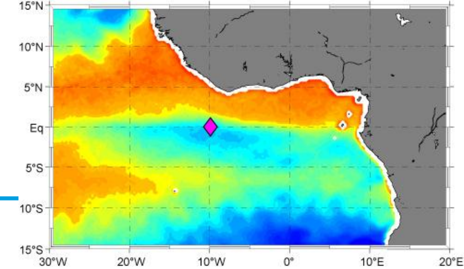
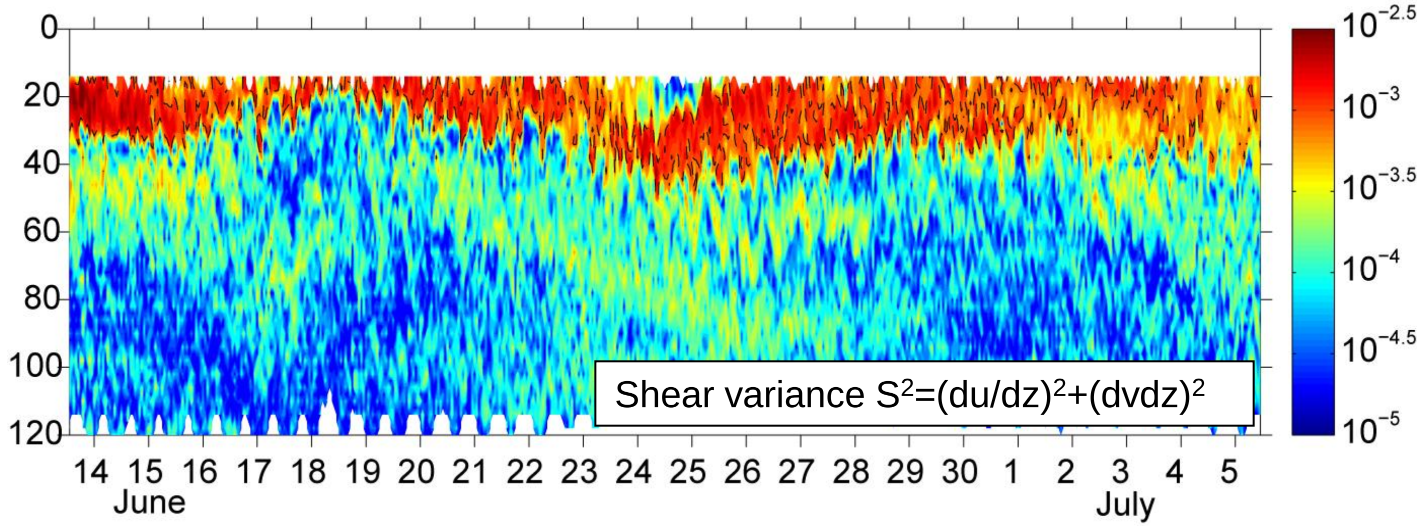
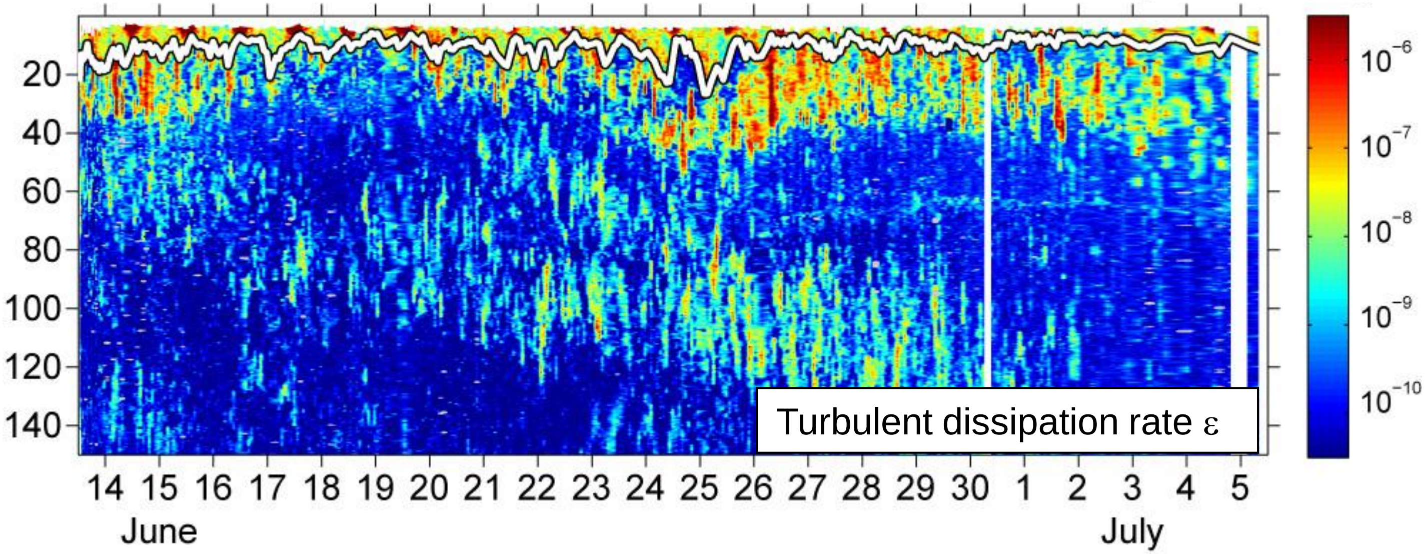
Vertical shear of horizontal current and turbulent kinetic energy dissipation rates

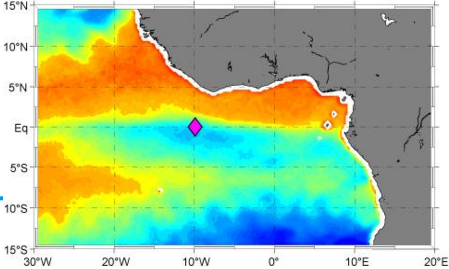


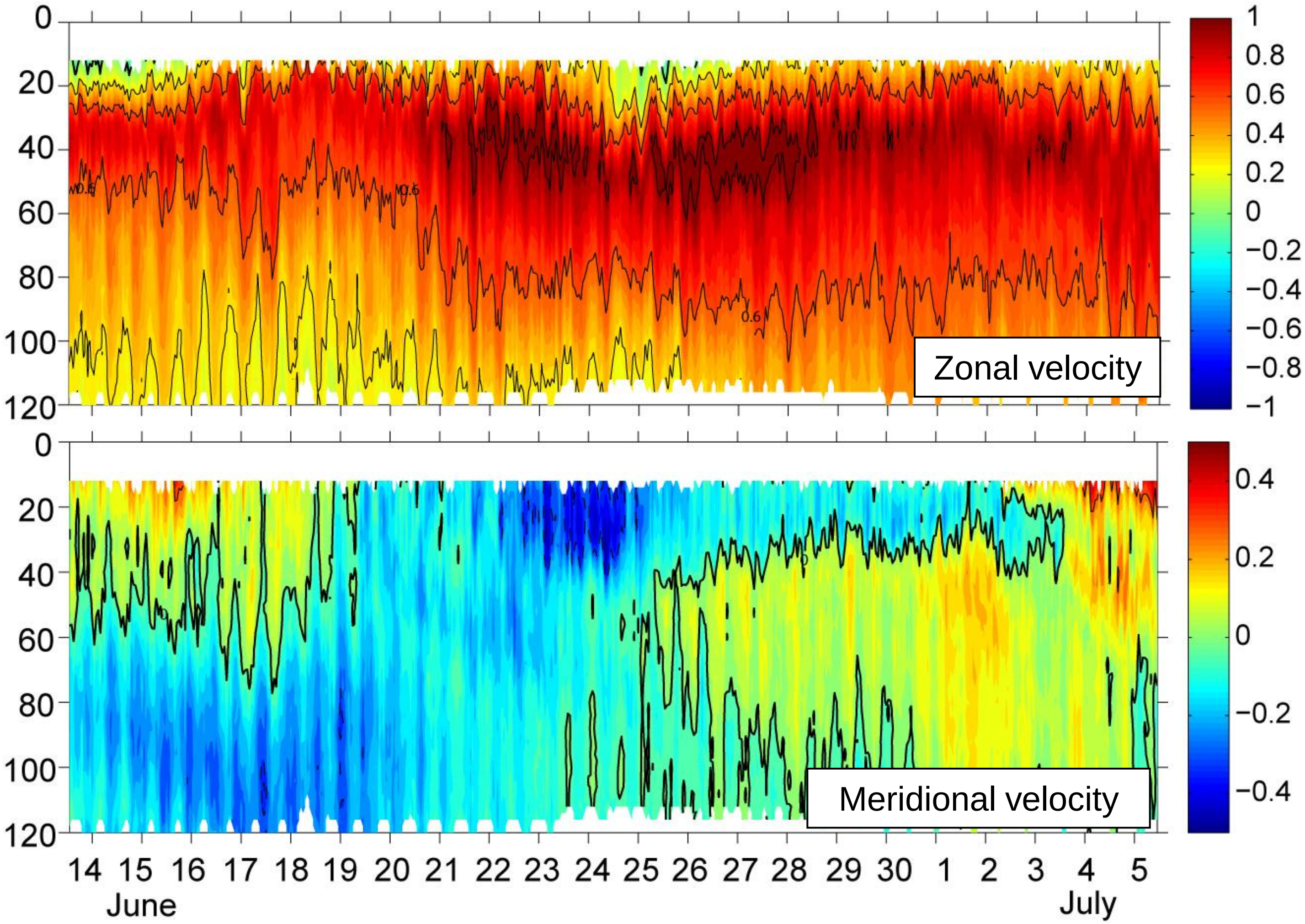




- elevated dissipation rates coincide with elevated shear variance
- bursts of elevated turbulence in the thermocline occur sporadically and last up to a few hours

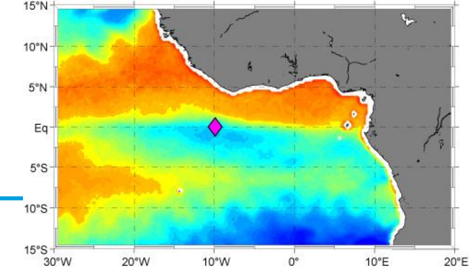
Horizontal currents observed during the MircoRider/Glider mission

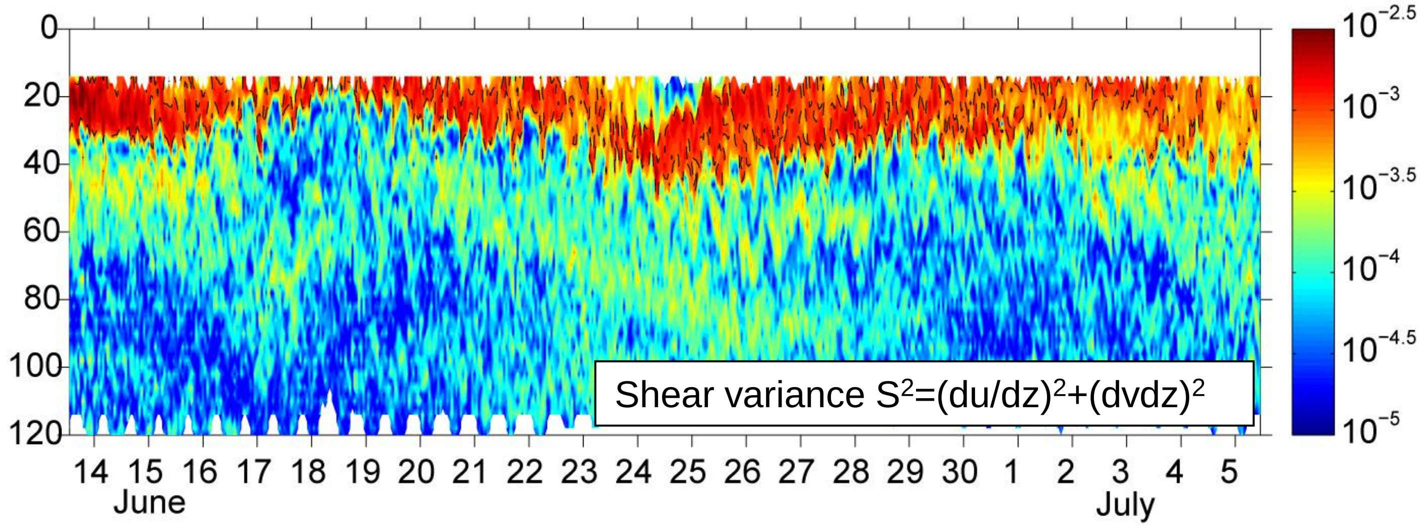


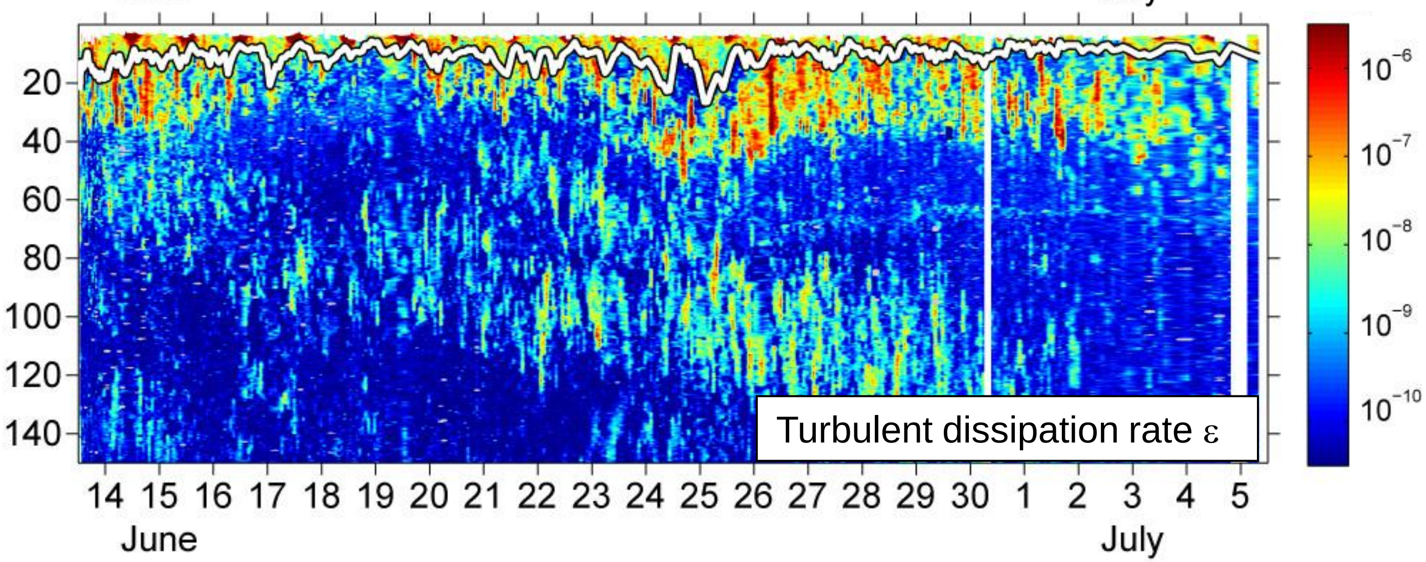


- Strong tidal currents in record with amplitude of ~8 cm s^{-1}
- core of the EUC located at 40m-60m depth

Vertical shear of horizontal current and turbulent kinetic energy dissipation rates







- elevated shear variance above the EUC core
- elevated dissipation rates coincide with elevated shear variance
- bursts of elevated turbulence in the thermocline occur sporadically and last up to a few hours

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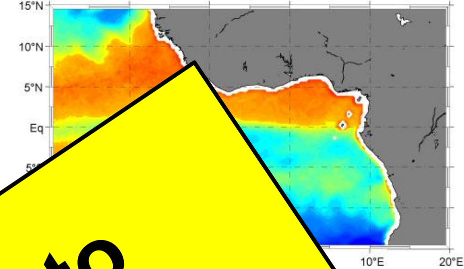
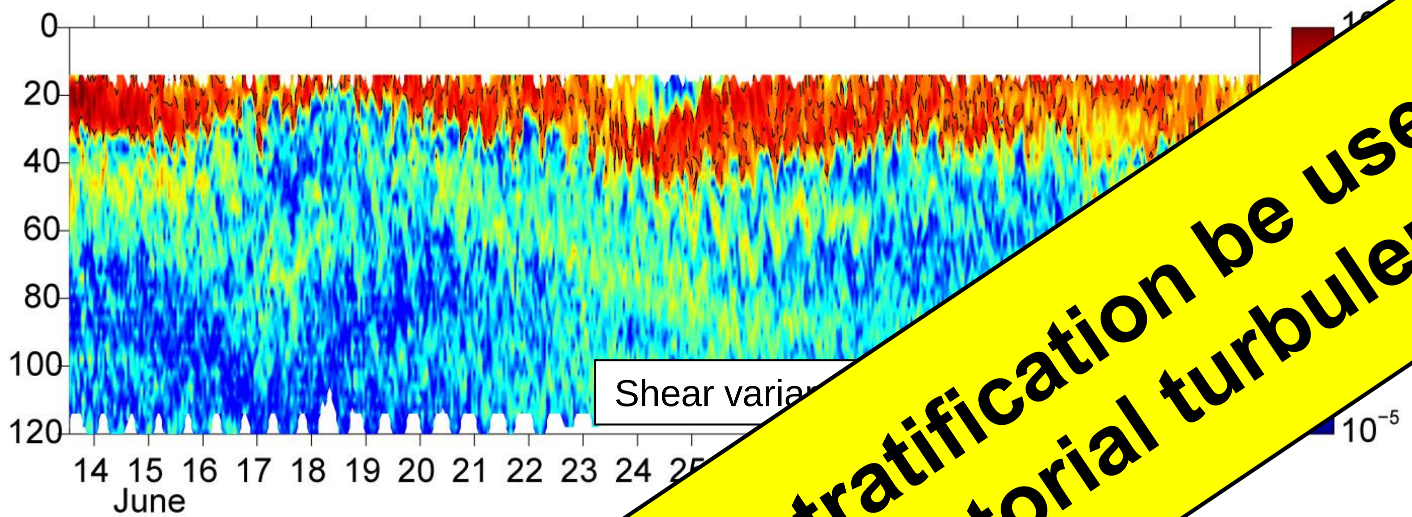
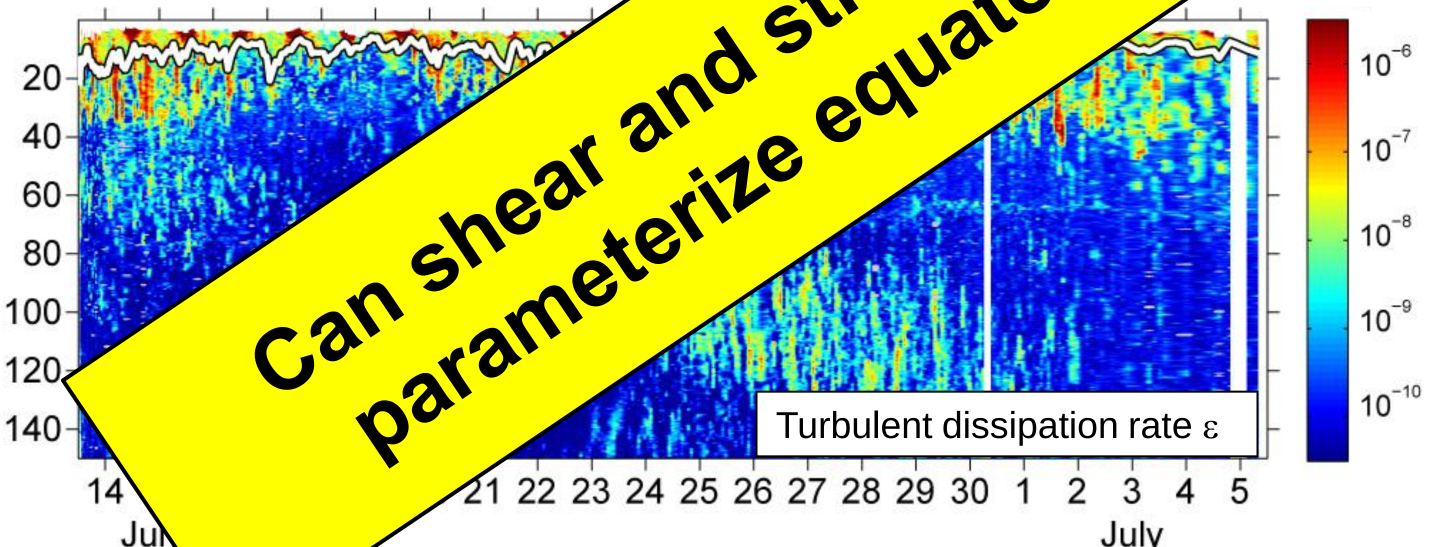
Vertical shear of horizontal current and turbulent kinetic energy dissipation rates







Can shear and stratification be used to parameterize equatorial turbulence?

- … shear … nce above … e EUC core
- elevated dissipation rates coincide with elevated shear variance
- bursts of elevated turbulence in the thermocline occur sporadically and last up to a few hours

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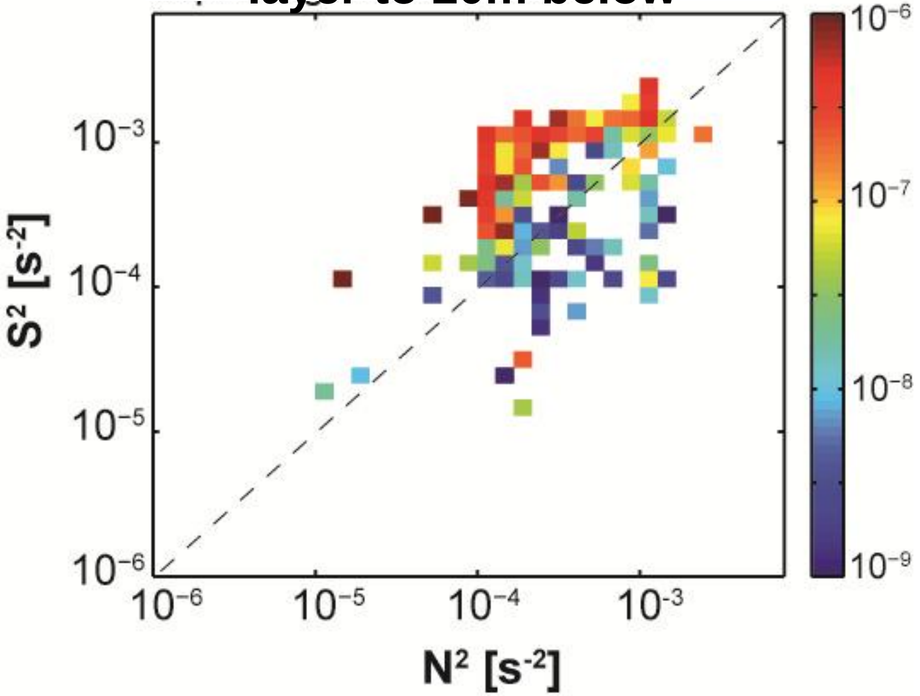
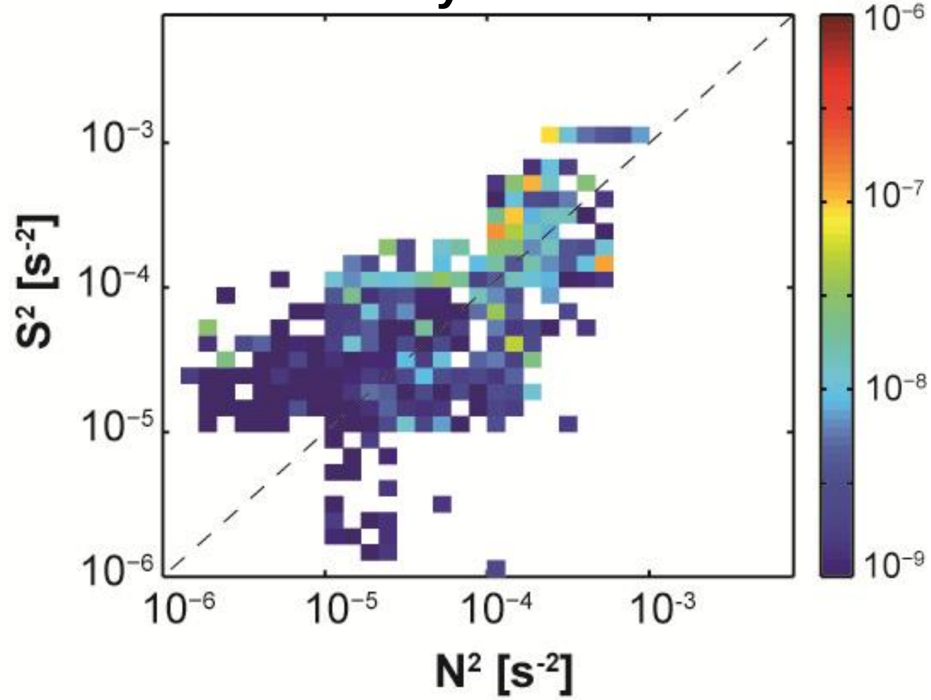
Average TKE dissipation rates in N^2 and S^2 bins

Observations (1.5°N – 2°S)

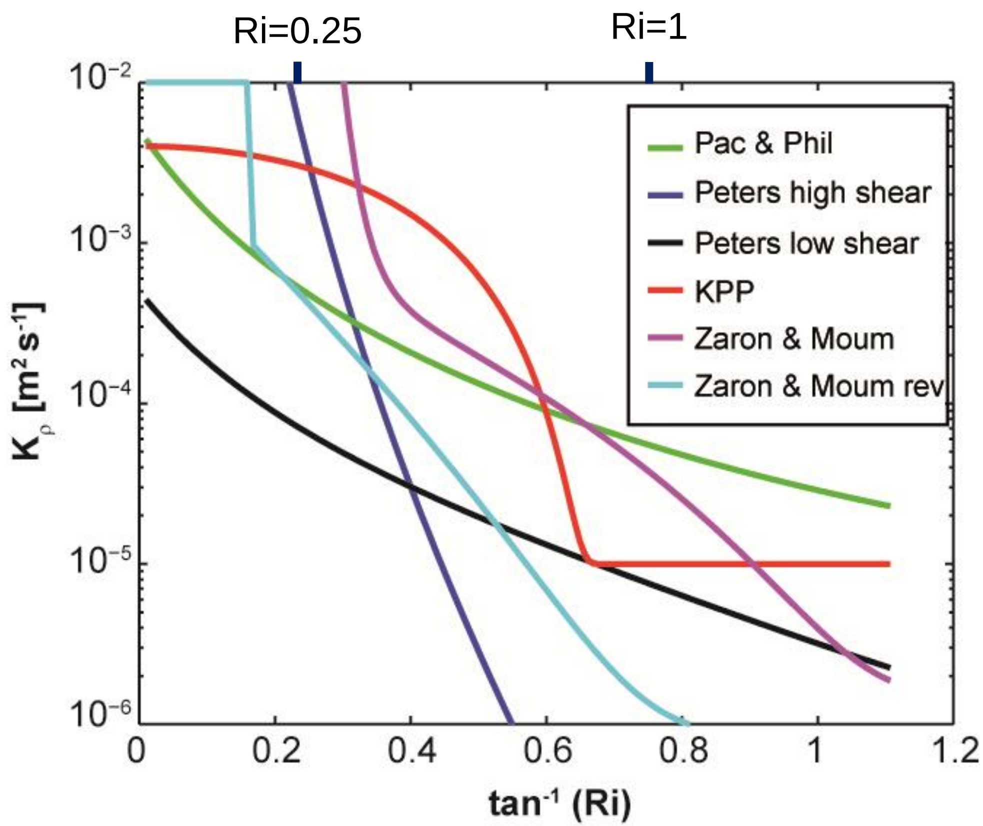
Upper Thermocline (high shear region) from base of the mixed layer to 20m below



Thermocline (lower shear region) from 40m below the mixed layer to 150m



Ri-dependent mixing 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)

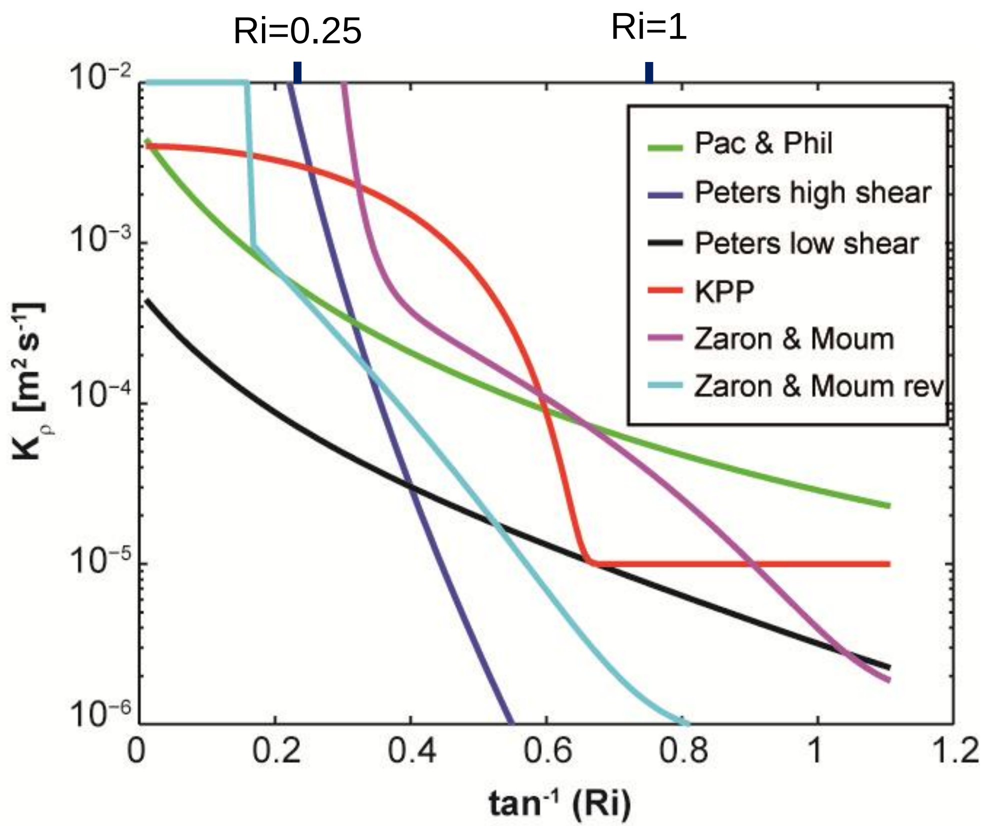
$$K_\rho = \frac{5\cdot 10^{-4} m^2 s^{-1}}{(1+5Ri)^{2.5}} + 10^{-6} m^2 s^{-1}$$ **high shear**

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

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

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

Evaluation of Ri-dependent Parameterizations



Zaron & Moum (2009)

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

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

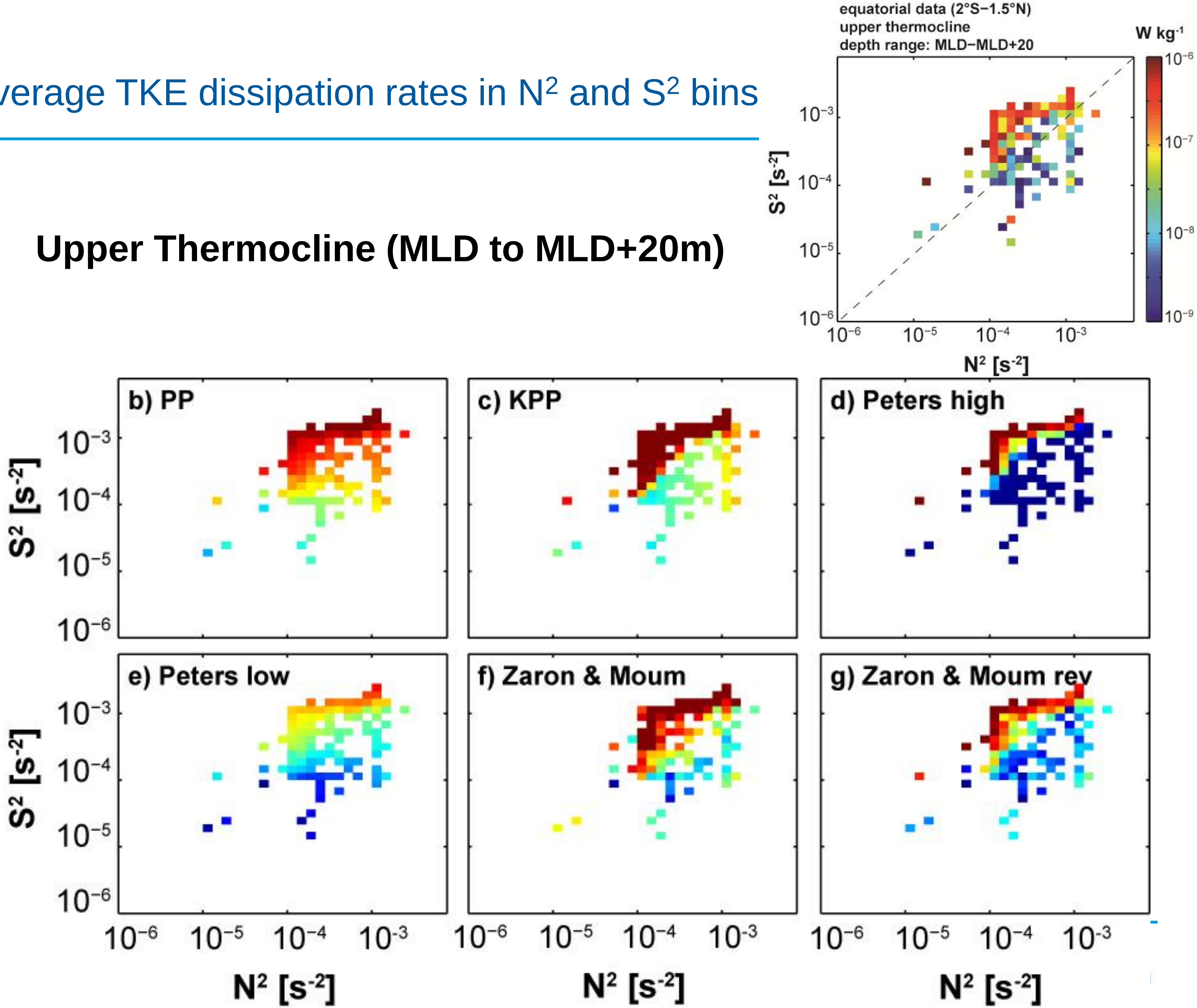
Uses additional parameter:

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

S – **shear**

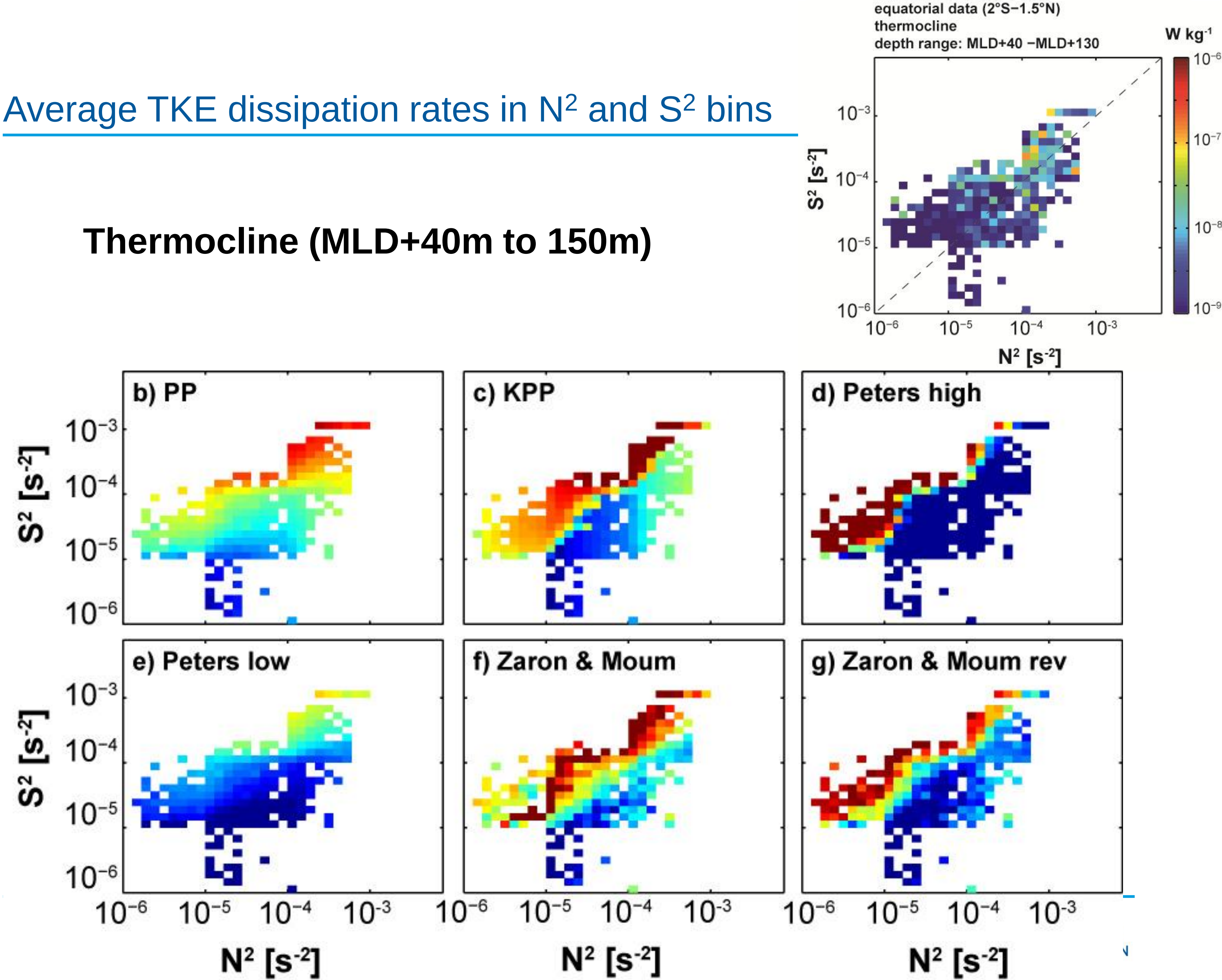
Average TKE dissipation rates in N^2 and S^2 bins

Upper Thermocline (MLD to MLD+20m)



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

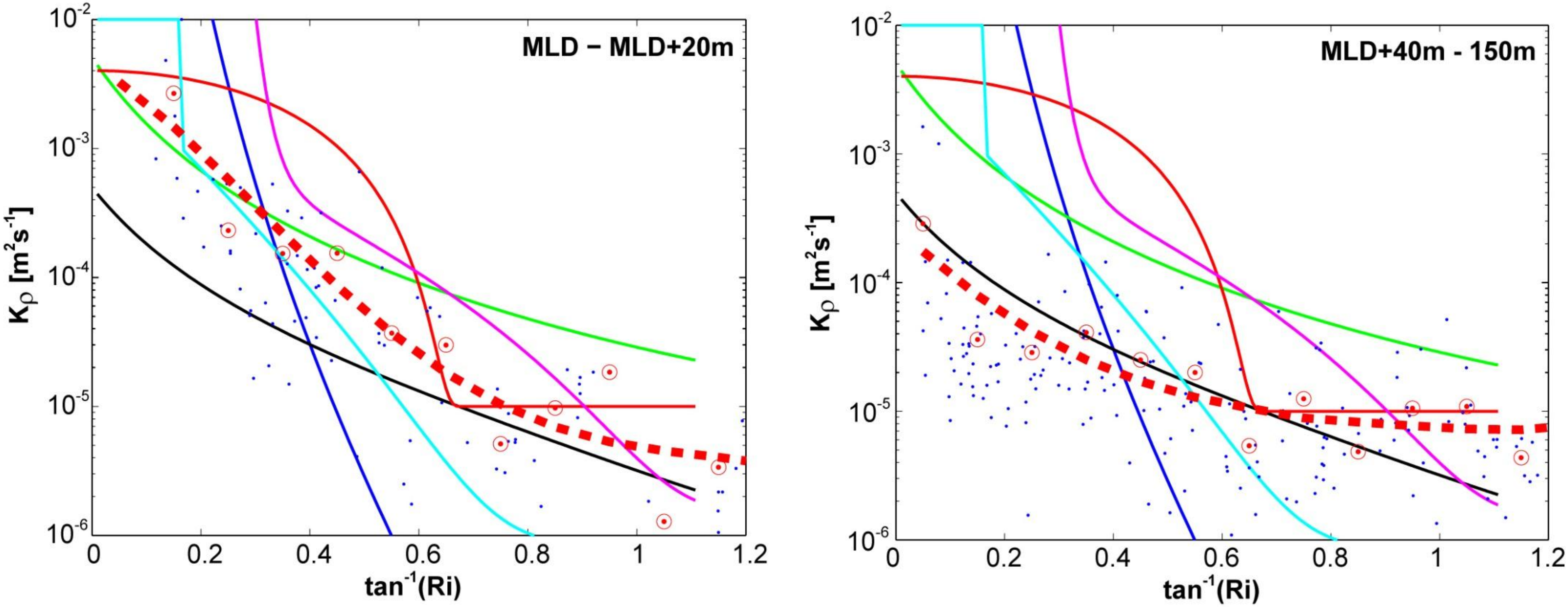
Thermocline (MLD+40m to 150m)



Evaluation of Ri-dependent Parameterizations

GEOMAR

Pac & Phi 81	KPP Large et al 95	**Microstructure data from 2°S-1.5°N**
Peters et al high 88	Zaron & Moum 09	
Peters et al low 88	Zaron & Moum rev 09	



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Evaluation of Ri-dependent Parameterizations

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- Pac & Phi 81
- Peters et al high 88
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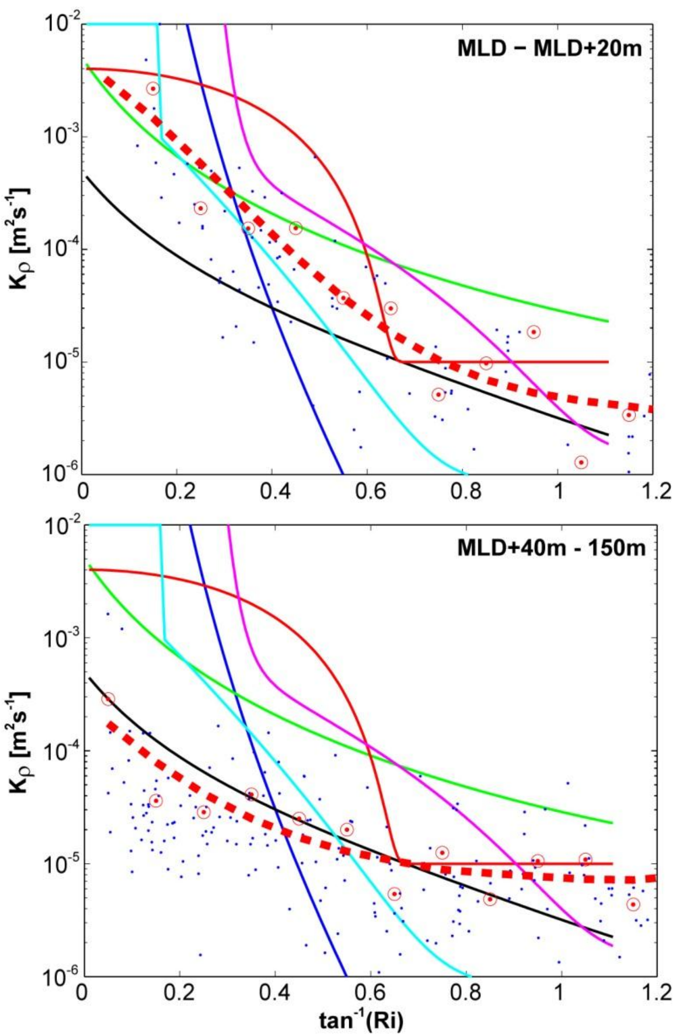
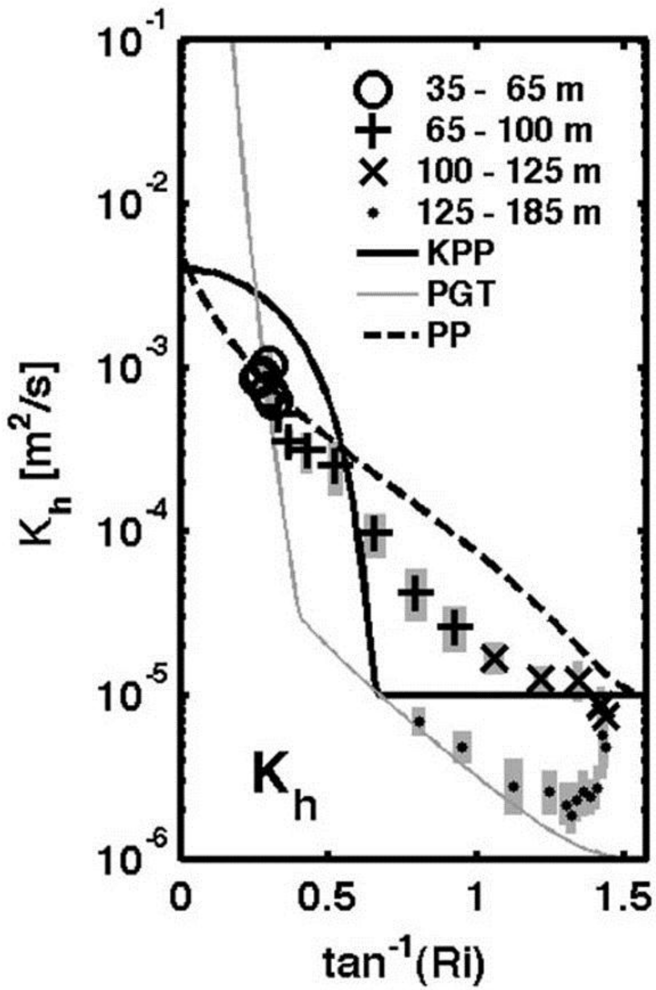
- **Microstructure data from 2°S-1.5°N**





Equatorial Pacific microstructure data
(Zaron & Moum ‘09)

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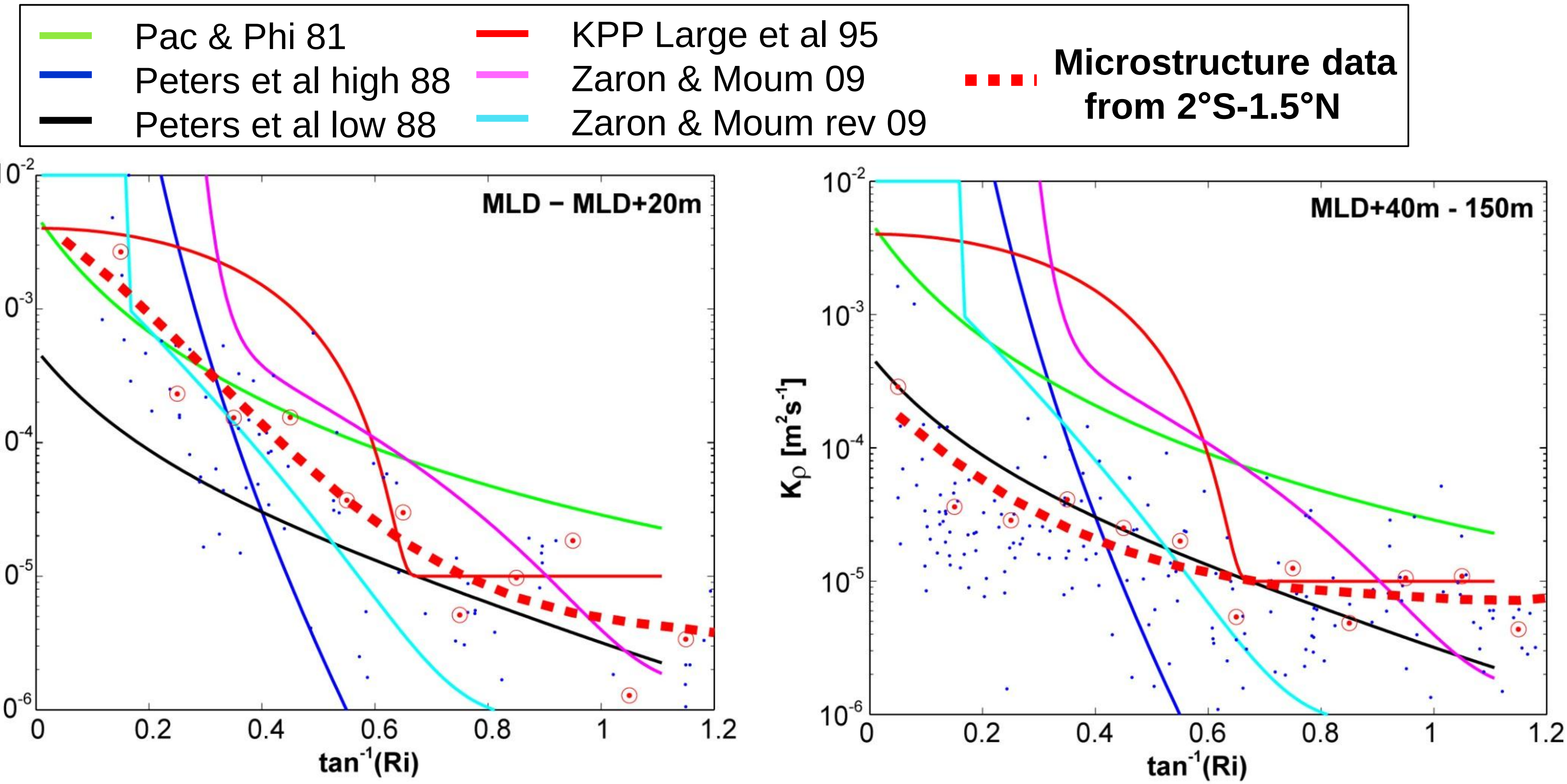
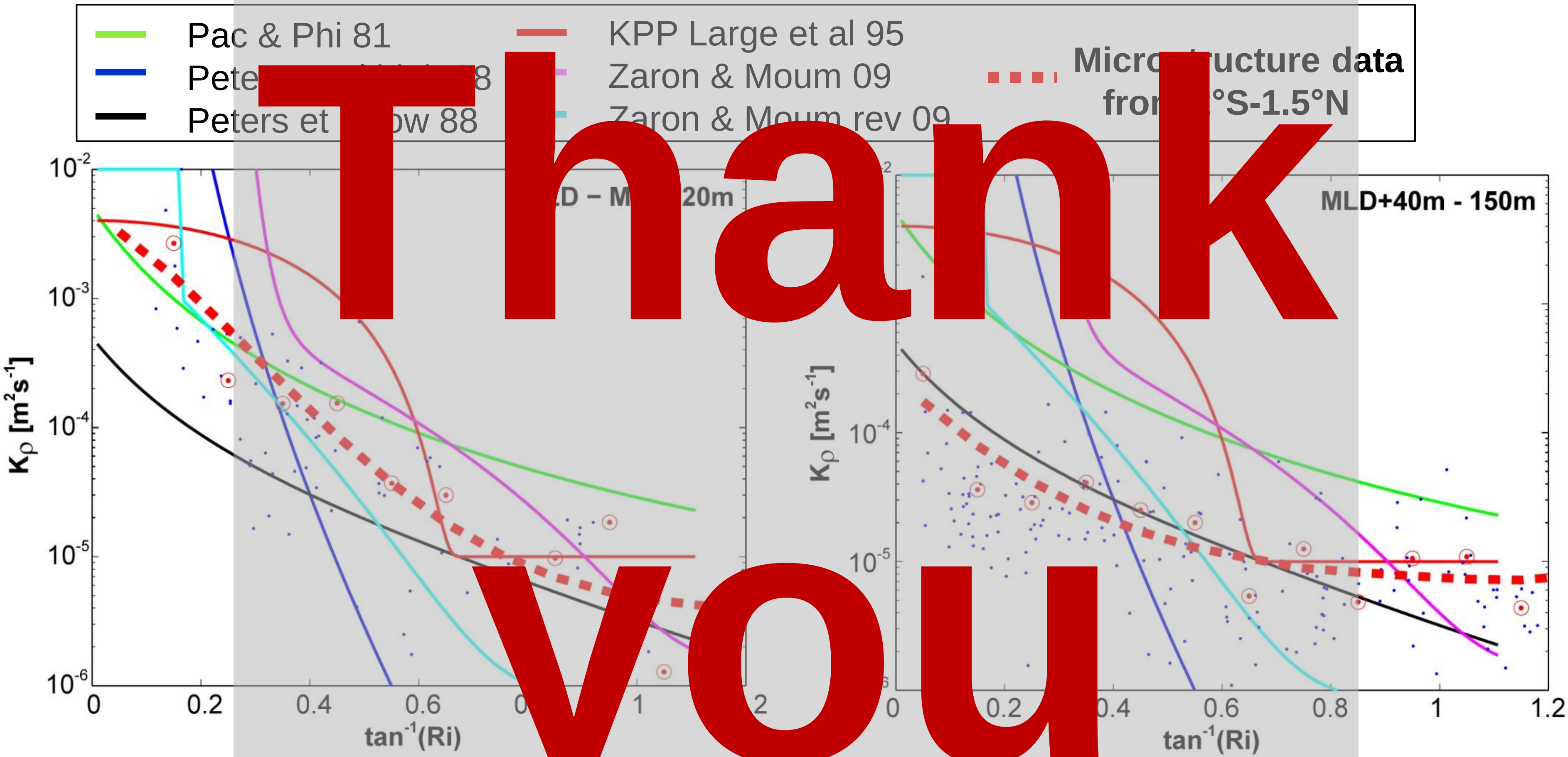
Evaluation of Ri-dependent Parameterizations



Evaluation of Ri-dependent Parameterizations

GEOMAR



Thank you

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Conclusions

- existing Ri-dependent mixing parameterizations do not well reproduce

Roadmap

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