Assessing the quality of mixing parameterizations

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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

Microstructure Systems

MicroRider / Glider

MicroRider / AUV

Tracer release sled
Microstructure data from the tropical Atlantic

- 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)
May-July 2011, 10°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
Time series of turbulent kinetic energy

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)
high shear
\[ K_\rho = \frac{5 \cdot 10^{-4} \ m^2 s^{-1}}{(1 + 5Ri)^{2.5}} + 10^{-6} \ m^2 s^{-1} \]
low shear
\[ K_\rho = 1.1 \cdot 10^{-8} Ri^{-9.2} \]

KPP
Large et al., (1994)
Large and Gent (1999)
\[ K_\rho = 50 \cdot 10^{-4} \ m^2 s^{-1} \left[ 1 - \left( \frac{Ri}{0.7} \right)^2 \right]^3 \]

Legend:
- Pac & Phil
- Peters high shear
- Peters low shear
- KPP
- Zaron & Moum
- Zaron & Moum rev
Zaron & Moum (2009)

\[ K_{h}^{alt} = \left| V \right|^2 / S \cdot a \left( \frac{R_{i1}}{R_{i} - R_{i1}} \right)^{\alpha} + b e^{-\beta \cdot R_{i}} + c \]

\[ K_{h}^{rev} = \left| V \right|^2 / S \cdot \Delta \phi_{h} e^{-\gamma (R_{i} - R_{i2})} + \phi_{h}^{w} \]

Uses additional parameter:

\[ \left| V \right|^2 \text{ – large-scale kinetic energy} \]

\[ S \text{ – shear} \]
Average TKE dissipation rates in $N^2$ and $S^2$ bins

Observations (2°N-1.5°S)

- Equatorial data (2°S–1.5°N)
- Upper thermocline
  - Depth range: MLD–MLD+20

- Equatorial data (2°S–1.5°N)
- Thermocline
  - Depth range: MLD+40–MLD+130

- Workspace: $W$ kg$^{-1}$

- $S^2$ [s$^{-2}$]
- $N^2$ [s$^{-2}$]
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

Upper Thermocline (MLD to MLD+20m)
Average TKE dissipation rates in $N^2$ and $S^2$ bins

Thermocline (MLD+40m to MLD+130m)
Average TKE dissipation rates in $N^2$ and $S^2$ bins

Thermocline (MLD+40m to MLD+130m)
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Microstructure data from the Guinea Dome Region

Tracer release experiment

Microstructure profiling stations

$K_z$ from tracer release experiment and average $K_\rho$ from microstructure measurements agree within 95% confidence

(Banyte et al., 2012)

(Fischer et al., 2013)
Finescale parameterization of internal wave mixing

\[ \varepsilon = \varepsilon_{30^\circ} \left( N, \Phi_{\text{shear}(k)}, \Phi_{\text{strain}(k)} \right) \times L(\theta, N) \]

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

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

\[ R_\omega \quad \text{shear to strain ratio} \]

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

\[ \int_{k_c} \Phi_{\text{shear}} dk = 0.661N^2 \]

**Diagram:**
- Internal waves
- Vertical wavenumber \( k_z \) [m\(^{-1}\)]
- Spectral density [s\(^{-2}\) m]

- \( \Phi_1 \) and \( \Phi_2 \) spectral densities
- "roll off" range
- Turbulent regime
Finescale parameterization of internal wave mixing

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\[ k_c \int_0^\Phi_{\text{shear}} dk = 0.661 N^2 \]

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) evaluated from data
Finescale parameterization of internal wave mixing

shear-only HPG derivate, \((R_\omega\) constant)

- **HPG** - Data used by Polzin et al (1995)
- **GDR** - Data from the Guinea Dome
Finescale parameterization of internal wave mixing

strain-only HPG derivate, ($R_w$ constant)

HPG - Data used by Polzin et al (1995)
GDR – Data from the Guinea Dome