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Dissipation rate prediction from predictor-reduced fine-scale parameterizations

SFB 754 — BMBF-Verbundvorhaben SOPRAN — EuroSITES European Ocean Observatory Network

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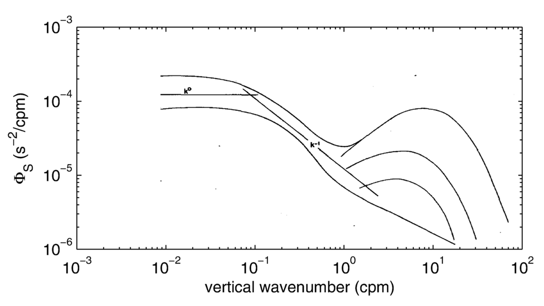
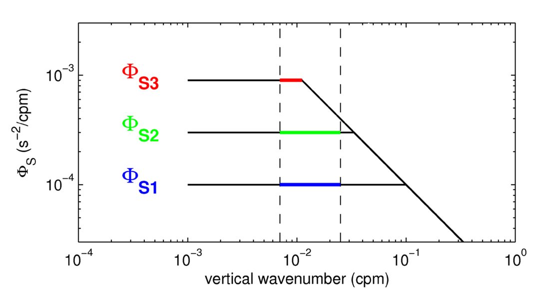
Henyey-Polzin-Gregg (HPG) finescale parameterization to estimate dissipation rate

Measure spectral level of finescale vertical shear



Composite shear spectrum of internal waves (IW) and turbulence (Gargett et al. 1981)



Idealized IW shear spectrum at different IW energy levels

In finescale range accessible to instrumentation, use white part of spectrum to evaluate shear spectral level in relation to Garrett-Munk 1976 IW model:

$$E_{shear} = \frac{\Phi_S}{\Phi_{S,GM}}$$

HPG in terms of shear spectral level, strain spectral level, stratification, and latitude

$$\varepsilon = \mathrm{const}\cdot f^1 \cdot N^2 \cdot \cosh^{-1}(N/f)\cdot E^2_{shear}\cdot F(R_\omega)$$

$$F(R_\omega) = \frac{R_\omega + 1}{R_\omega\sqrt{R_\omega - 1}} \qquad R_\omega = \frac{\Phi_S}{N^2\cdot\Phi_\lambda} = 3\cdot\frac{E_{shear}}{E_{strain}}$$

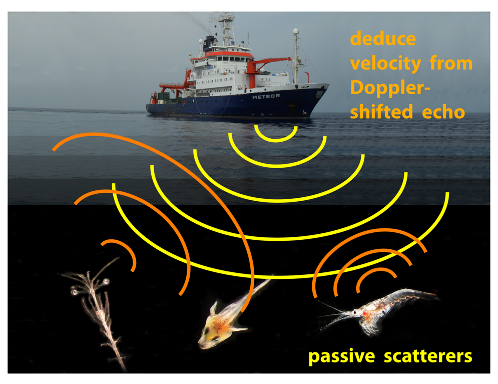
after Henyey et al. 1986, Polzin et al. 1995, Gregg et al. 2003

- ε dissipation rate of turbulent kinetic energy
- f Coriolis parameter
- N buoyancy frequency
- Φ_S shear power spectral density (PSD)
- Φ_λ strain rate PSD
- E PSD in relation to GM76 PSD
- R_ω shear-to-strain ratio

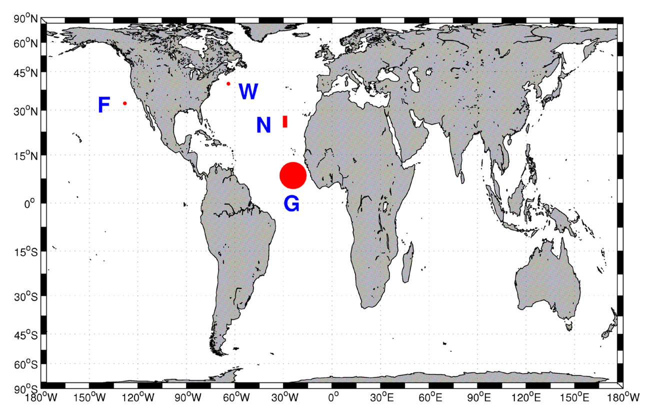
Issue: In field work, often one of the key variables E_{shear} or E_{strain} is missing. That means, no simultaneous knowledge of predictor $F(R_\omega)$.

Observations reveal predictor dependence in HPG. That means, HPG should not be used if E_{shear} or E_{strain} is missing. Instead, particular predictor-reduced parameterizations have to be found.

Observations in the eastern tropical Atlantic (150 to 500m) of E_{shear} from vmADCP, N^2 and E_{strain} from CTD, dissipation rate from microstructure probe ...

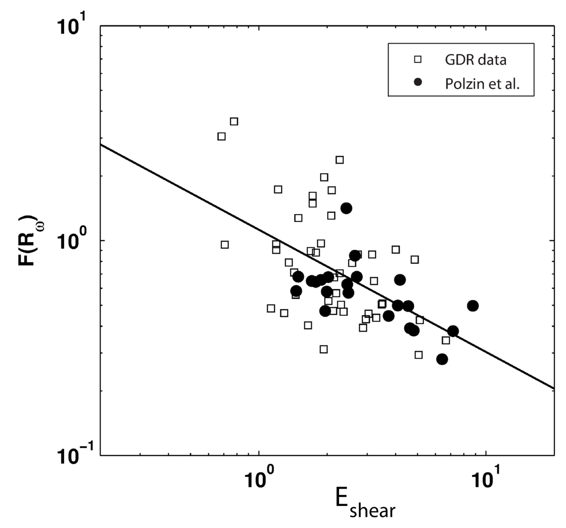


... enhanced with according observational data from Polzin et al. 1995 from HighResolutionProfiler (on the latter data HPG exponent fitting is founded).

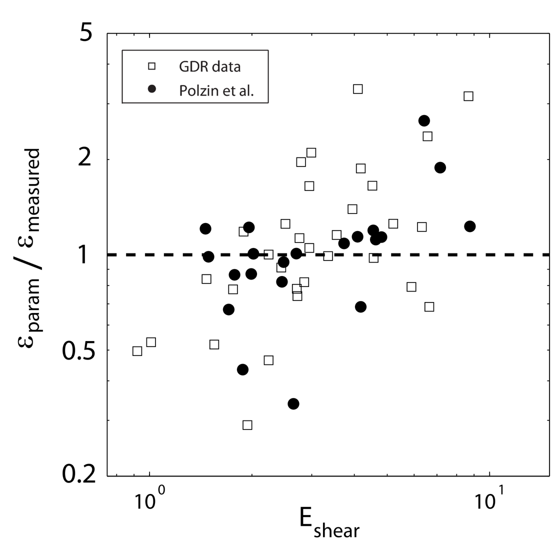


- F Fieberling Guyot (Polzin et al. 1995)
- W Warm Core Eddy (Polzin et al. 1995)
- N NATRE Region (Polzin et al. 1995)
- G Guinea Dome Region (GDR, this study)

Observational data show dependence of HPG predictors E_{shear} and $F(R_\omega)$.



If using HPG with incomplete observational data (e.g. substituting $F(R_\omega)$ by an estimated constant), systematic deviations in predicted epsilon arise.



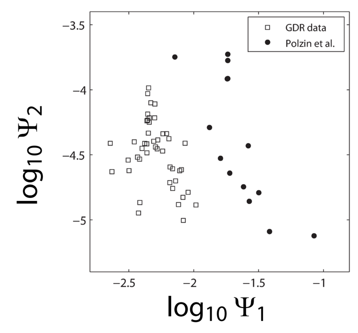
P1: A particular parameterization without E_{strain} - and how it compares to HPG

Used predictors and ansatz for P1

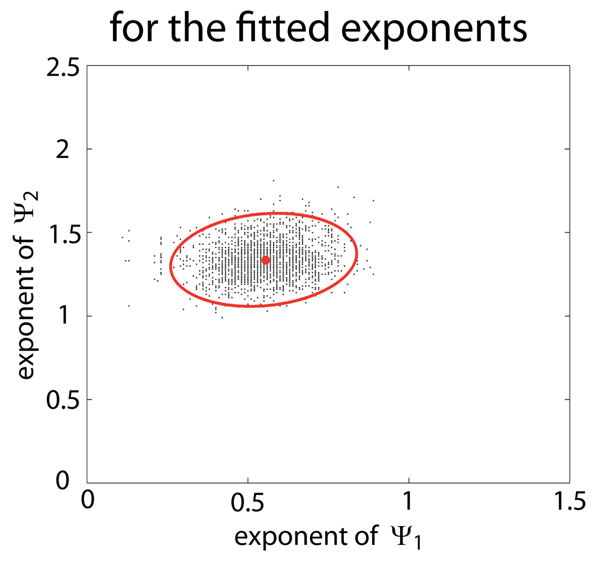
$$\Psi_1 = f/N$$

$$\Psi_2 = N^2\cdot E_{shear} \propto \Phi_S$$

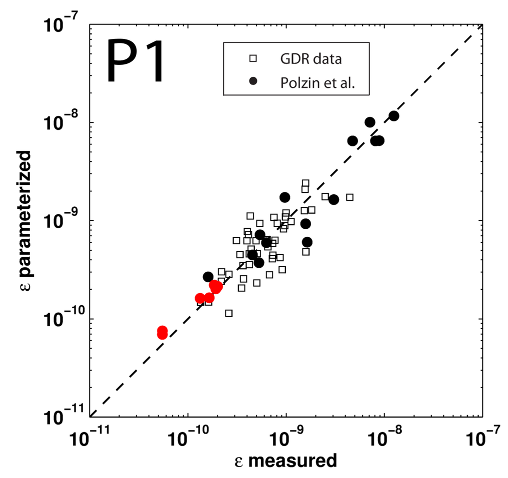
$$\varepsilon = \mathrm{const}\cdot\Psi_1^{\alpha_1}\cdot\Psi_2^{\alpha_2}$$



95%-confidence ellipse for the fitted exponents



P1 and HPG are consistent despite different exponents

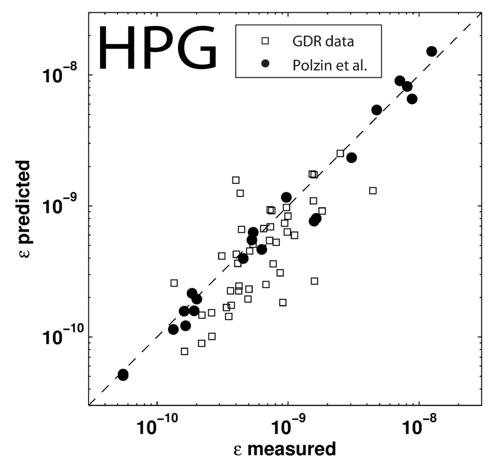


Polzin et al. 1995 data from the deep ocean at very low N^2, which were not part of the parameter fitting.

P1: $\varepsilon \propto f^{5/9}\cdot N^{19/9}\cdot E_{shear}^{4/3}$

HPG: $\varepsilon \propto f^{0.8}\cdot N^{2.2}\cdot E_{shear}^{2}\cdot F(R_\omega)^1$

Fischer et al. 2013



This evokes some questions:
- **Why are P1 and HPG consistent despite different exponents? Predictor dependencies.**
- **How certain are then the HPG exponents? The HPG data allow quite a range of equally well fits.**
- **Could strain rate from CTD enhance P1 or allow a particular strain parameterization? We find E_{strain} too noisy for this.**

Consequences for the practical usage of HPG (seemingly paradox, but a consequence of predictor dependence):
- **Substitution of $F(R_\omega)$ by an accurate average value causes bias and spurious patterns.**
- **Instead calculating a simultaneous $F(R_\omega)$ using a noisy E_{strain} (but complete predictor set) avoids this bias.**

Conclusions:

- **For incomplete predictor sets (the typical case) particular predictor-reduced parameterizations (PPP) are needed.**
- **P1 is a PPP without strain, consistent with HPG, particularly fit for ship cruises.**

References
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