Estimating ϵ from fast thermistors χpod ?

Andy Pickering

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1 Abstract

The acquisition of turbulence data from shipboard CTD profiles is attractive, as it has the potential to significantly increase the amount of deep-ocean mixing observations globally. While data from shear-probes are easily contaminated by motion of the instrument platform, the measurement of temperature gradient is relatively insensitive to vehicle vibration, making it possible to measure temperature gradient from a shipboard CTD rosette. The purpose of this note is to investigate the error and bias in estimating the rate of dissipation of temperature variance χ from fast thermistors mounted on traditional CTD casts. The most significant source of error is associated with the fact that fast-response FP07 thermistors resolve only a fraction of the temperature gradient variance at the fallspeed of typical CTD casts. Assumptions must be made about the wavenumber extent of the temperature gradient spectrum, which scales with the rate of dissipation of turbulent kinetic energy, a quantity that is not directly measured. Here we utilize observations from a microstructure profiler with shear probes to demonstrate the validity of our method of estimating χ from thermistor data, and to assess uncertainty and bias. This supports the utility of the measurement as part of the global repeat hydrography program (GO-SHIP) cruises, during which this type of data has been acquired during the past few years.

2 Introduction

The main points are that gamma (computed the way we do) is not equal to 0.2, but when you compute epsilon from chi, if is appropriate to use gamma=0.2 to get the answer right, because, for the epsilons that matter (the ones that dominate the mean), gamma=0.2 gives you the correct answer.

- This document is an attempt to provide an overview/summary of what i've found in my χpod analysis so far.

- The motivation/goal for all this work is to show if /how well the CTD-χpod method works for estimating χ,ϵ, K_T, etc from fast temperature (thermistor) profiles. The idea is to deploy χpods on regular CTD casts on WOCE/CLIVAR cruises etc. to making mixing measurements.

- Before dealing with all the issues with the CTD deployments (depth loops, entrained water, rosette-induced turbulence etc.), I wanted to verify that the method itself worked w/out these complications.

- The Chameleon microstructure profiler has both thermistor and shear probes, so this seemed like an ideal way to test the method. I would apply the χpod method to the chameleon thermistor data only $(\chi_\chi, \epsilon_\chi)$, and compare to the 'true' results computed using the shear probes (χ, ϵ).

- I found that the estimates of χ agreed well, but ϵ_χ was biased low compared to ϵ (Figure 1,2,**??**).

- The χpod method requires assuming a mixing efficiency, and uses the normal assumption that $\gamma = 0.2$. I computed gamma from the chameleon data (formula) and found that it was about an order of magnitude smaller than 0.2; hence the low epsilon estimates?

- The comparison of ϵ_χ to ϵ seems to improve with increased averaging (of either multiple profiles or larger depth ranges).

3 Data and Processing

- Data are from Chameleon profiles near the equator during the 'EQ14' experiment.

- Sally shared w/ me Chameleon data that she and Jim processed. I ended up re-processing it using a smaller fmax (7Hz) because it looked like the thermistor spectra rolled off much lower than the assumed 32Hz.

- `ComputeChi_Chameleon_Eq14.m` : Applies χpod method to Chameleon profiles from EQ14.

- `Make_Overview_Plots.m` Makes almost all the figures in this document.

- The noise floor of Chamleon ϵ was determined to be $log_{10}[\epsilon] = -8.5$. Values below this threshold were discarded. χpod values below this threshold were also discarded, in order to make a valid comparison. An upper limit of $log_{10}[\epsilon] = -5$ (determined by Jim?) was also applied.
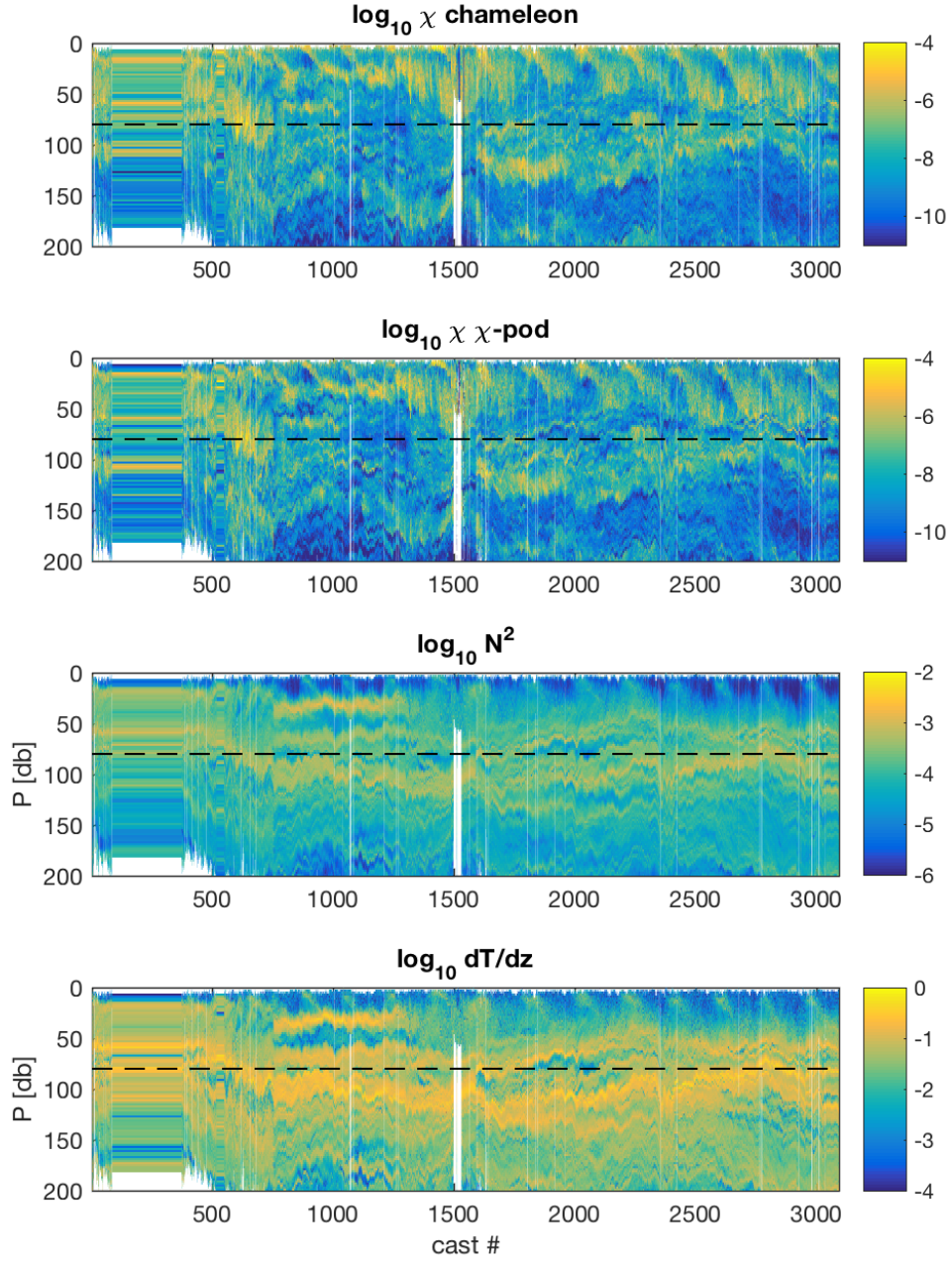
4 Results

4.1 Overview

Figure 1: Comparison of χ from chameleon method and chi-pod method, for EQ14 chameleon profiles. Each profile was averaged in 2m bins. Horizontal line at 80m shows region excluded in further analysis because it contains near-surface convection.
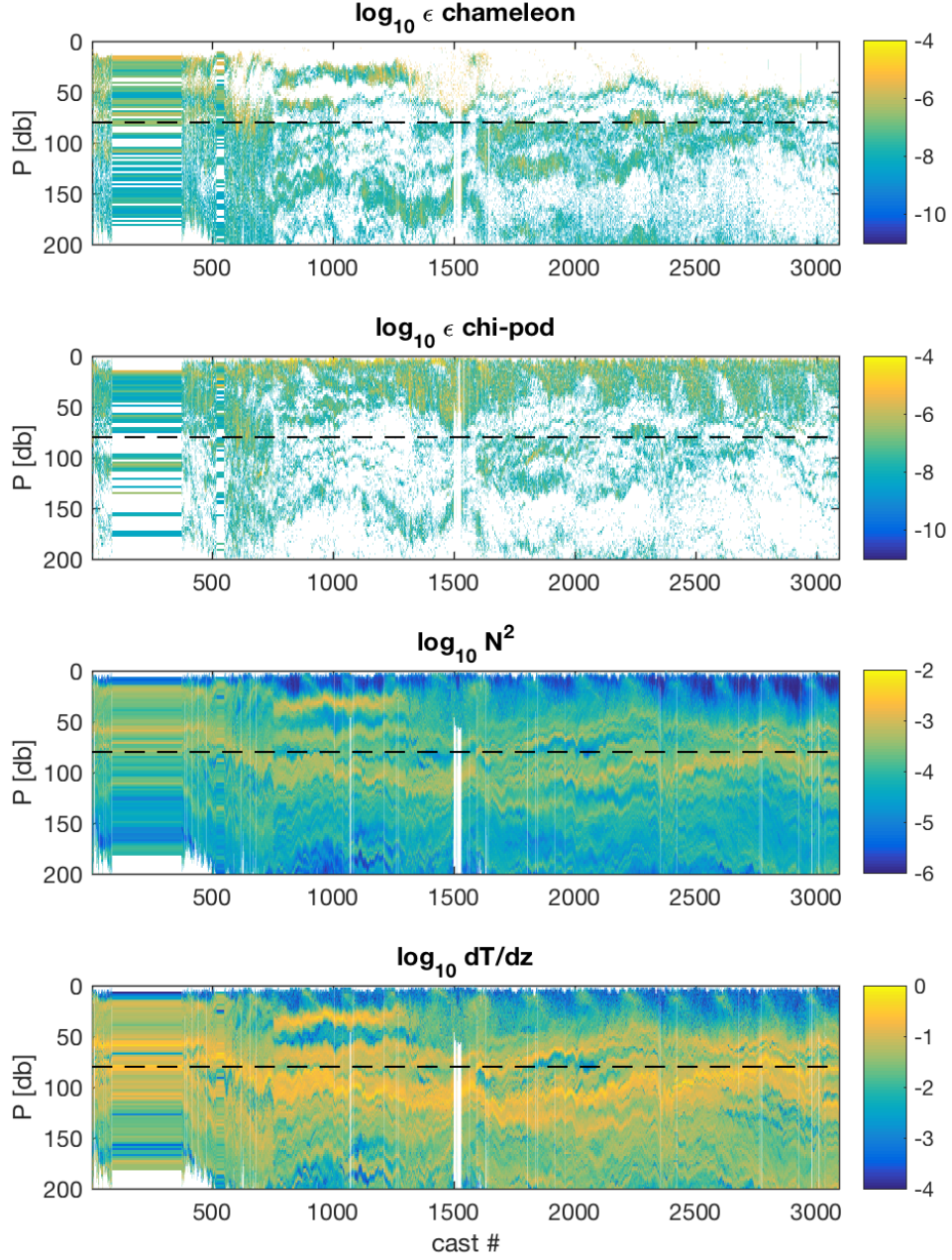
Figure 2: Comparison of ϵ from chameleon method and chi-pod method, for EQ14 chameleon profiles. Each profile was averaged in 2m bins. Values of ϵ below chameleon noise floor ($log_{10}[\epsilon] = -8.5$) have been nan'd out. Horizontal line at 80m shows region excluded in further analysis because it contains near-surface convection.

4.2 Normalized eps vs chi plots

Assuming that

$$\gamma = \frac{N^2 \chi}{2\epsilon < T_z >^2} \tag{1}$$

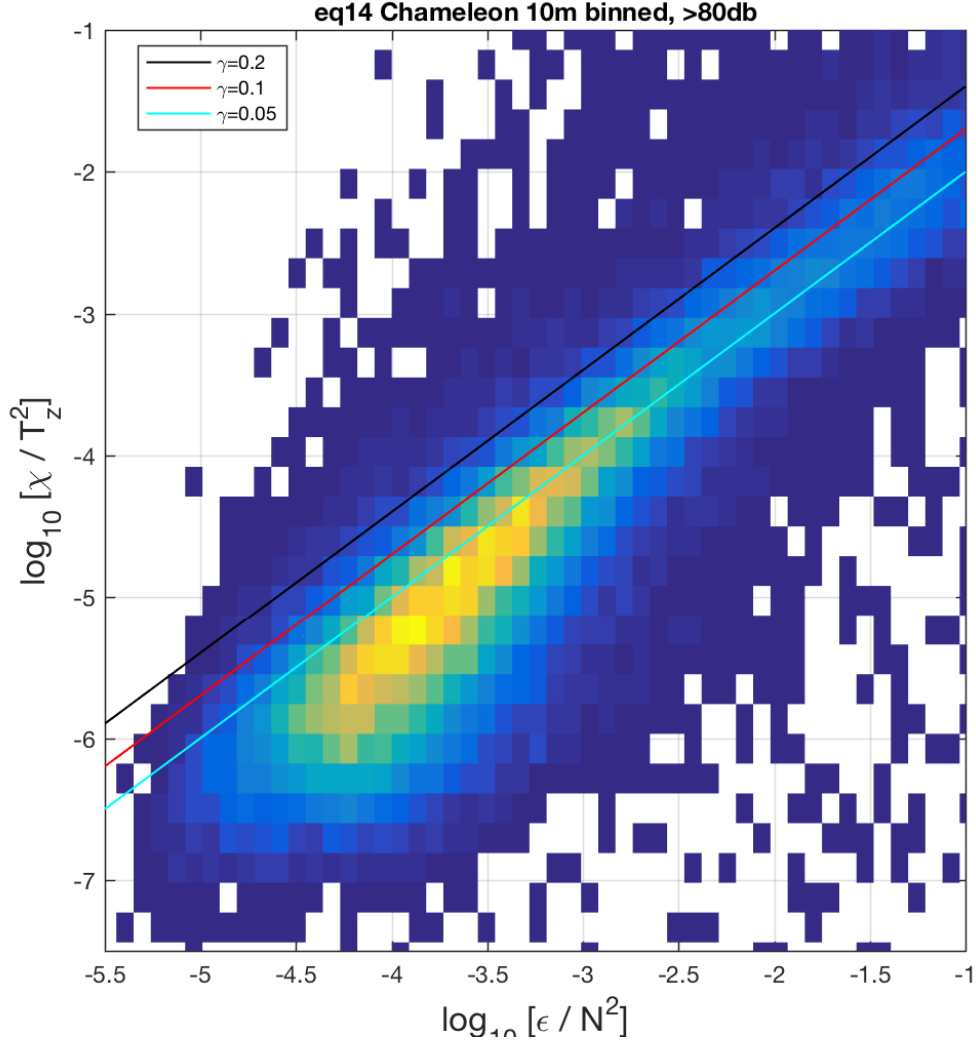, plotting $[\chi/t_z^2]$ vs $[\epsilon/N\hat{2}]$ should follow a straight line with slope equal to 2γ.

Figure 3: EQ14: 10m binned chameleon $\epsilon/N\hat{2}$ vs χ/t_z^2 for *below 80db*. Lines show different values of γ. Values of ϵ below noise floor ($log_{10}\epsilon < -8.5$) are discarded also.

4.3   Averaging many profiles of ϵ

Figure 4 shows one example. A folder with many profiles is located at: `https://github.com/OceanMixingGroup/Analysis/tree/master/Andy_Pickering/eq14_patch_gamma/figures/chi_eps_profiles_40profavgs`.
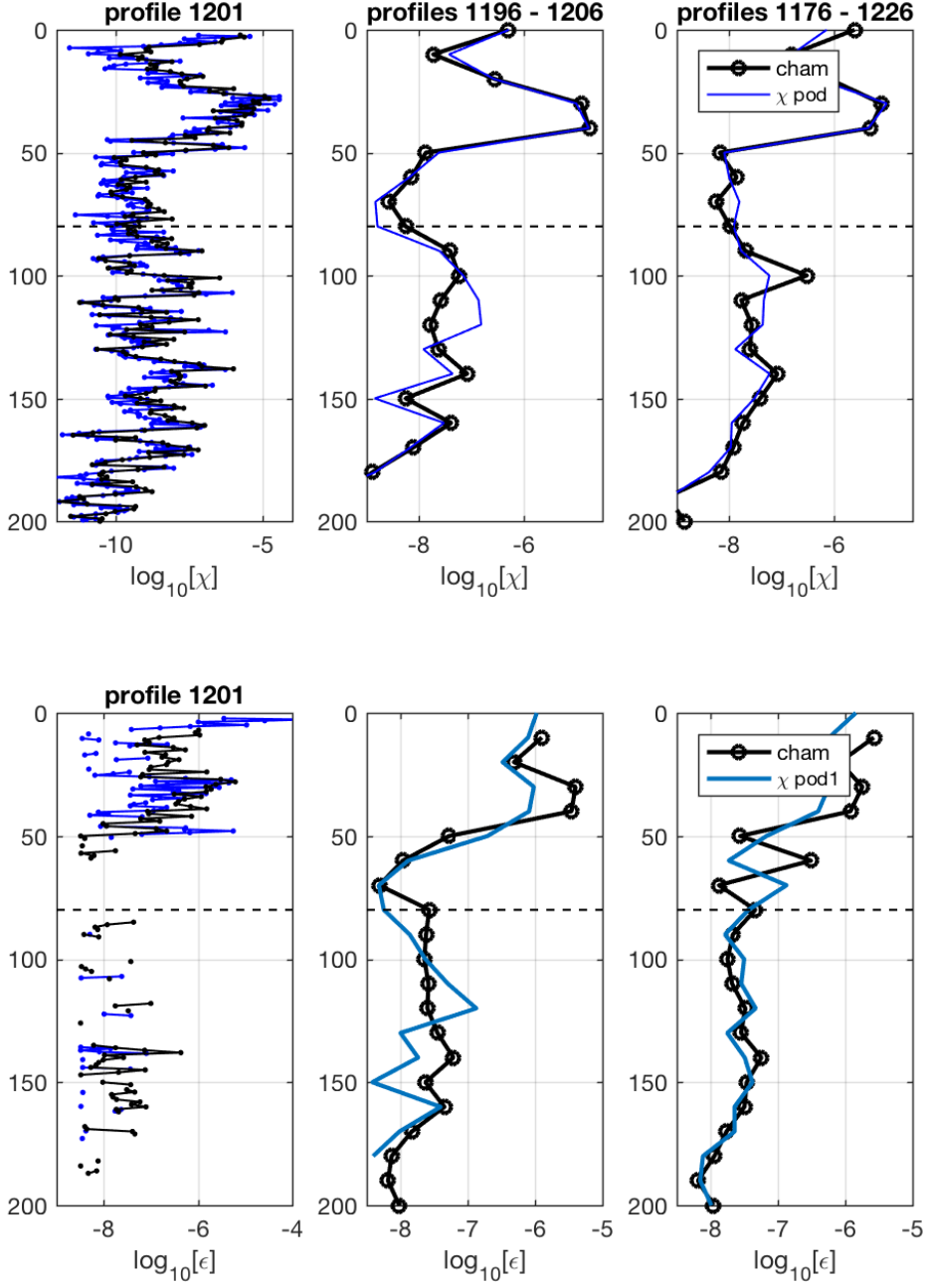
Figure 4: Example of averaging multiple profiles together. Left panels show a single profile from chamleeon and chi-pod method. Right panels show average of $+/-$ 40 profiles, averaged in 10m depth bins.
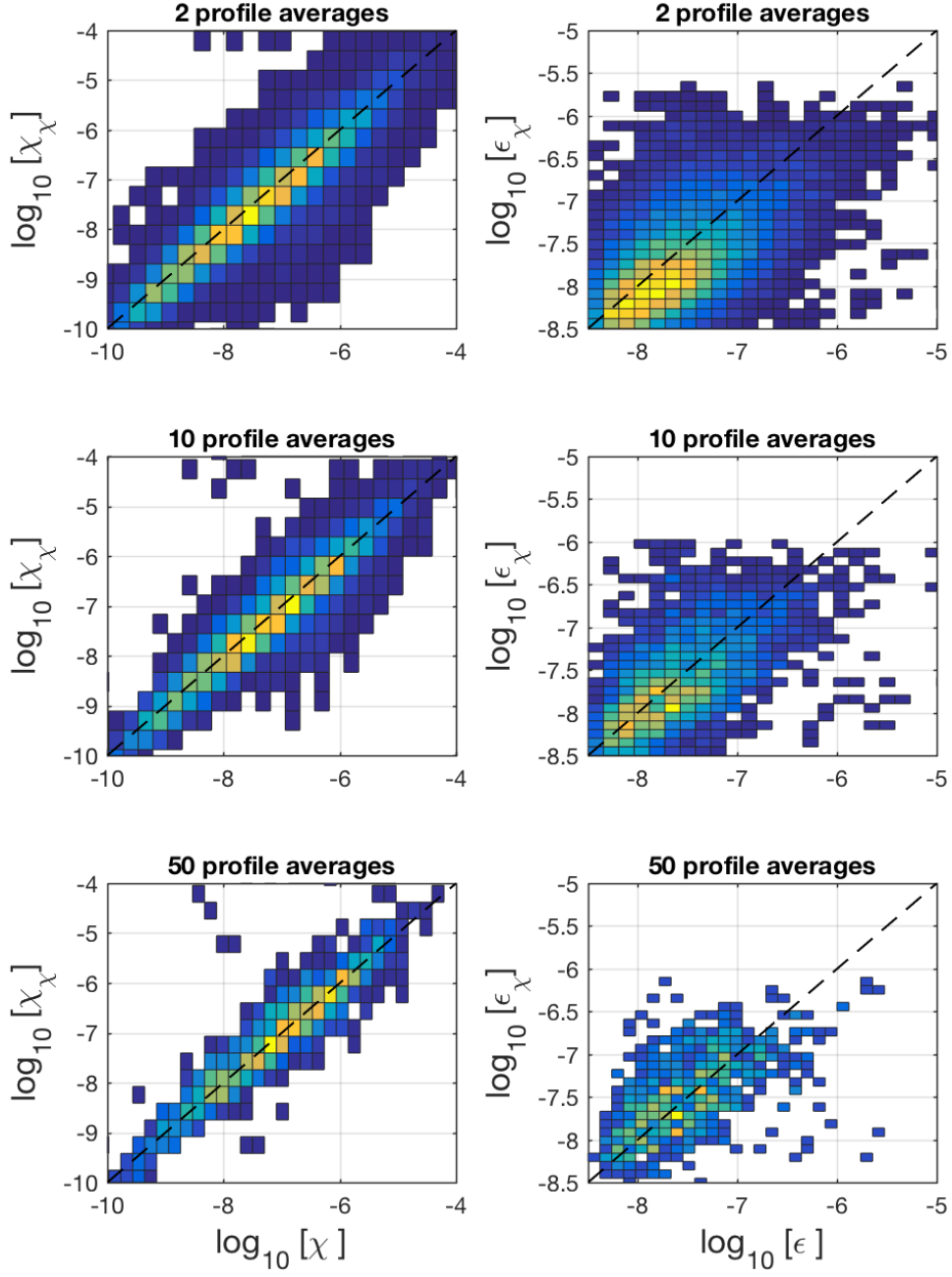
Figure 5: 2D Histograms of χ_{chi} vs χ (left) and ϵ_χ vs ϵ (right) for different numbers of profiles averaged.
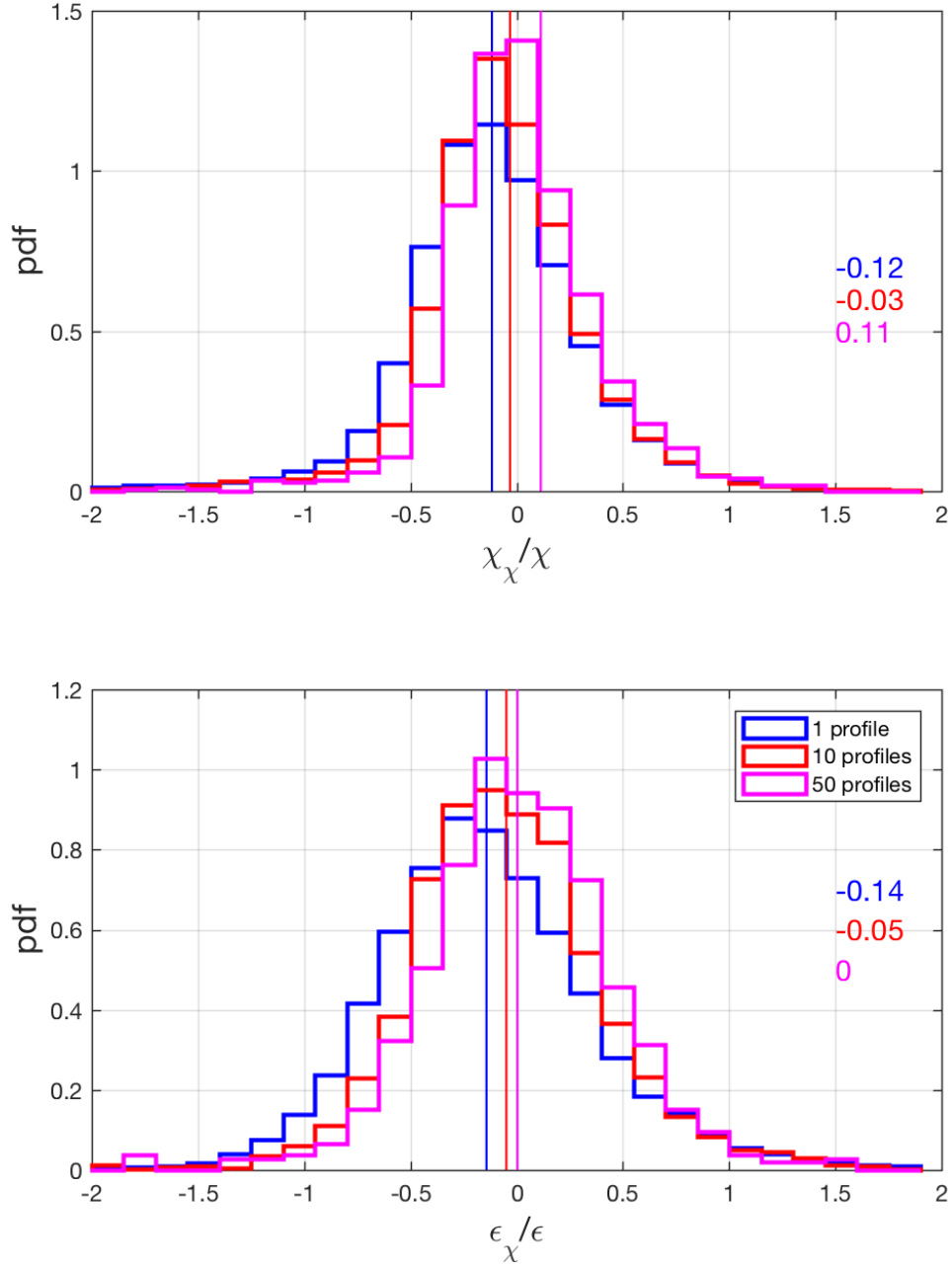
Figure 6: (log10) Ratio of χ_χ/χ (top) and ϵ_χ/ϵ (bottom) for different numbers of profiles averaged. Consecutive chunks of N profiles were averaged, and then (normalized) histogram of the ratios was plotted. Vertical lines are mean of $log_{10}[\epsilon_\chi/\epsilon]$ for each distribution.

5 Summary

- Inidivudal (and 10m binned) χpod estimates of ϵ_χ are biased low compared to Chameleon ϵ.

- This appears to be because γ computed from the Chameleon data is lower than the assumed 0.2

- γ computed from averaged (across profiles) N^2, T_z, χ, and ϵ is closer to 0.2

- Averaging many ϵ profiles reduces the bias (if we use same noise floor for ϵ as Chameleon).

- Increased depth-averaging also reduces bias.