

# Summary of $\chi$ pod / Chameleon EQ14 Analysis

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## Contents

<b>1</b>	<b>Overview</b>	<b>2</b>
<b>2</b>	<b>Data and Processing</b>	<b>3</b>
<b>3</b>	<b>Results</b>	<b>4</b>
3.1	Overview . . . . .	4
3.2	$\epsilon_\chi$ vs $\epsilon$ . . . . .	7
3.3	Comparing individual estimates of $\epsilon$ . . . . .	8
3.4	Dependence of bias on actual $\epsilon$ . . . . .	12
3.5	Normalized eps vs chi plots . . . . .	14
3.6	Averaging multiple profiles of $\epsilon$ . . . . .	15
3.7	Averaging over different-sized depth bins . . . . .	18
3.8	$\gamma$ computed from averaged quantities . . . . .	21
3.9	Summary . . . . .	22

# 1 Overview

- This document is an attempt to provide an overview/summary of what i've found in my  $\chi$ pod analysis so far.
- The motivation/goal for all this work is to show if /how well the CTD- $\chi$ pod method works for estimating  $\chi, \epsilon, K_T$ , etc from fast temperature (thermistor) profiles. The idea is to deploy  $\chi$ pods 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  $\chi$ pod method to the chameleon thermistor data only ( $\chi_\chi, \epsilon_\chi$ ), and compare to the 'true' results computed using the shear probes ( $\chi, \epsilon$ ).

## 2 Data and Processing

- Data are from Chameleon profiles near the equator during the ‘EQ14’ experiment. On my laptop, they are located in the folder:  
`/Cham_Eq14_Compare/Data/chameleon/processed/`
- 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 normally-assumed 32Hz. These data are located at:  
`/Cham_Eq14_Compare/Data/chameleon/processed_AP_7hz/`
- The  $\chi$ pod method is applied to Chameleon profiles (thermistor only, not shear probe) from EQ14 in `ComputeChi_Chameleon_Eq14.m`
- The noise floor of Chamleon  $\epsilon$  was determined to be  $\log_{10}[\epsilon] = -8.5$ . Values below this threshold were discarded.  $\chi$ pod 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.
- Data including surface convection was identified and excluded in the analysis. The mixed layer depth was identified (`Identify_mixedlayer_eq14.m`) using a criteria of  $\sigma_{-surface} = 0.04$ . This depth is shown in figures 1 and 2.
- `Make_Overview_Plots.m` Makes the figures in this document.

## 3 Results

### 3.1 Overview

- Both  $\chi_\chi$  and  $\epsilon_\chi$  appear to capture the depth and time structure of  $\chi$  and  $\epsilon$  well (Figures 1,2).

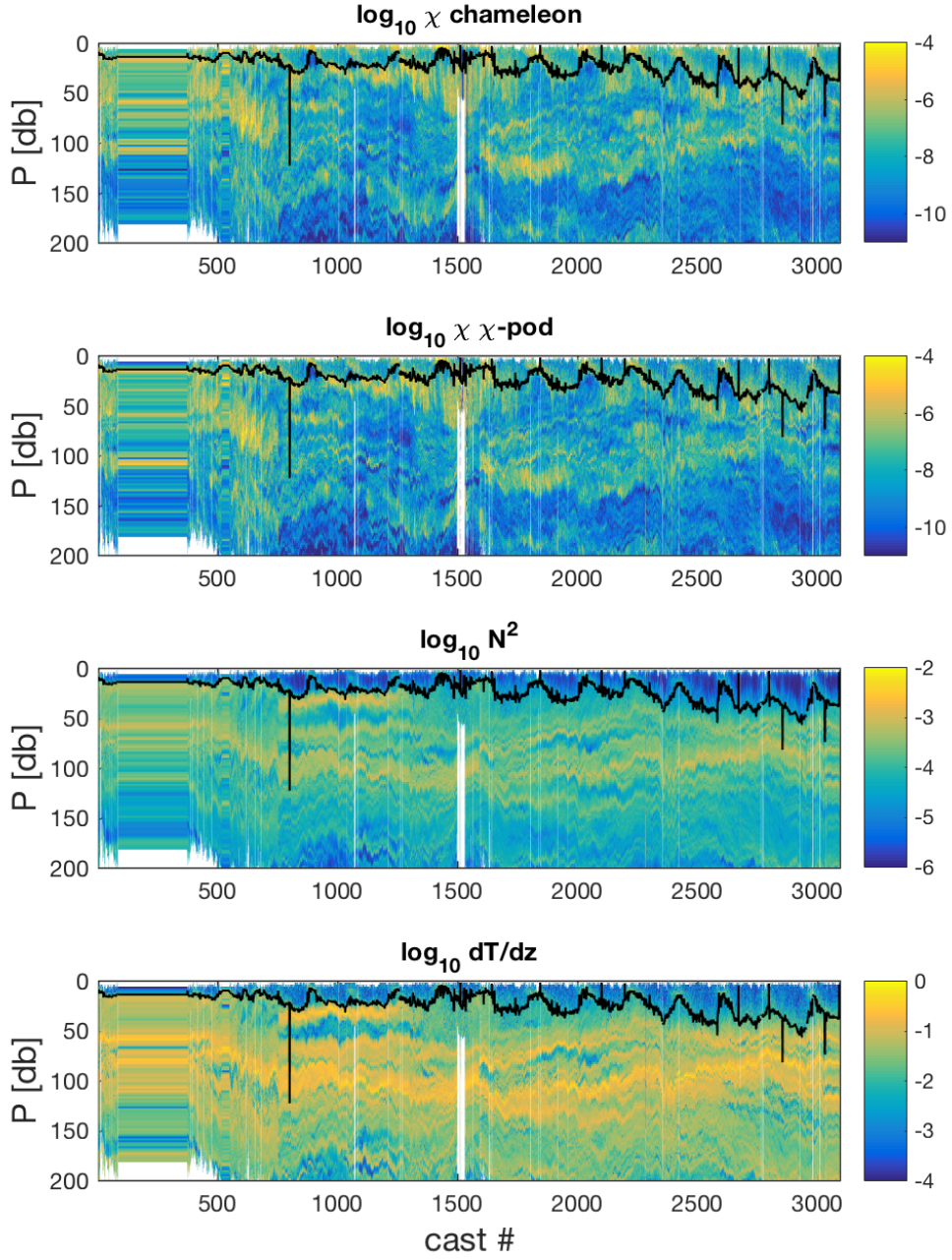


Figure 1: Comparison of  $\chi$  from chameleon method and chi-pod method, for EQ14 chameleon profiles. Each profile was averaged in 2m bins. Black line shows shows convective regions excluded in further analysis.

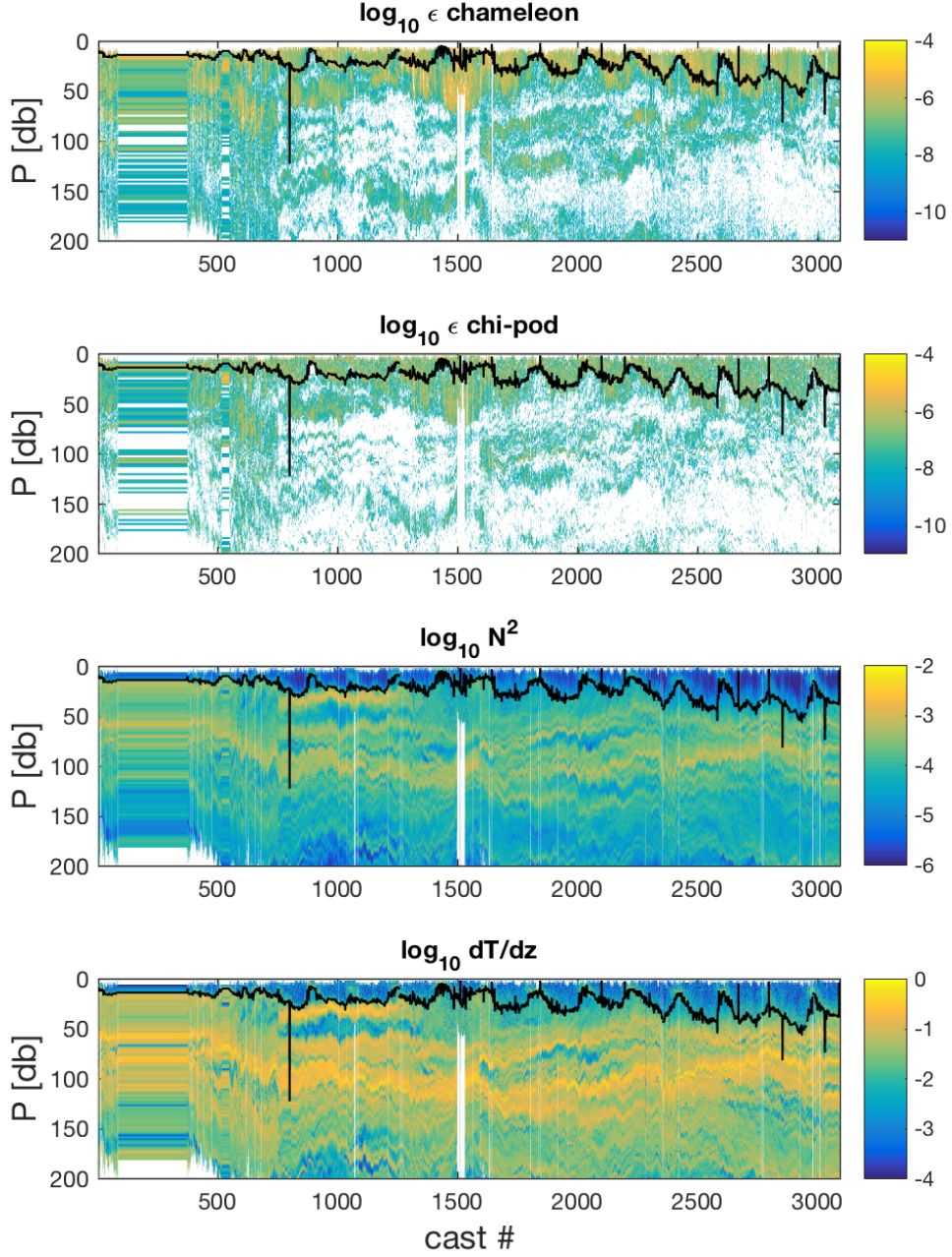


Figure 2: Comparison of  $\epsilon$  from chameleon method and chi-pod method, for EQ14 chameleon profiles. Each profile was averaged in 2m bins. Values of  $\epsilon_\chi$  and  $\epsilon$  below chameleon noise floor ( $\log_{10}[\epsilon] = -8.5$ ) have been nan'd out. Black line shows shows convective regions excluded in further analysis.

### 3.2 $\epsilon_\chi$ vs $\epsilon$

I first compared  $\epsilon_\chi$  vs  $\epsilon$  for the Chameleon data, where

$$\epsilon_\chi = \frac{N^2 \chi}{2\gamma T_z^2} \quad (1)$$

, using  $\gamma = 0.2$ .  $\epsilon_\chi$  underestimates  $\epsilon$ , showing that that relationship (assumed in  $\chi$ pod processing does not hold here.

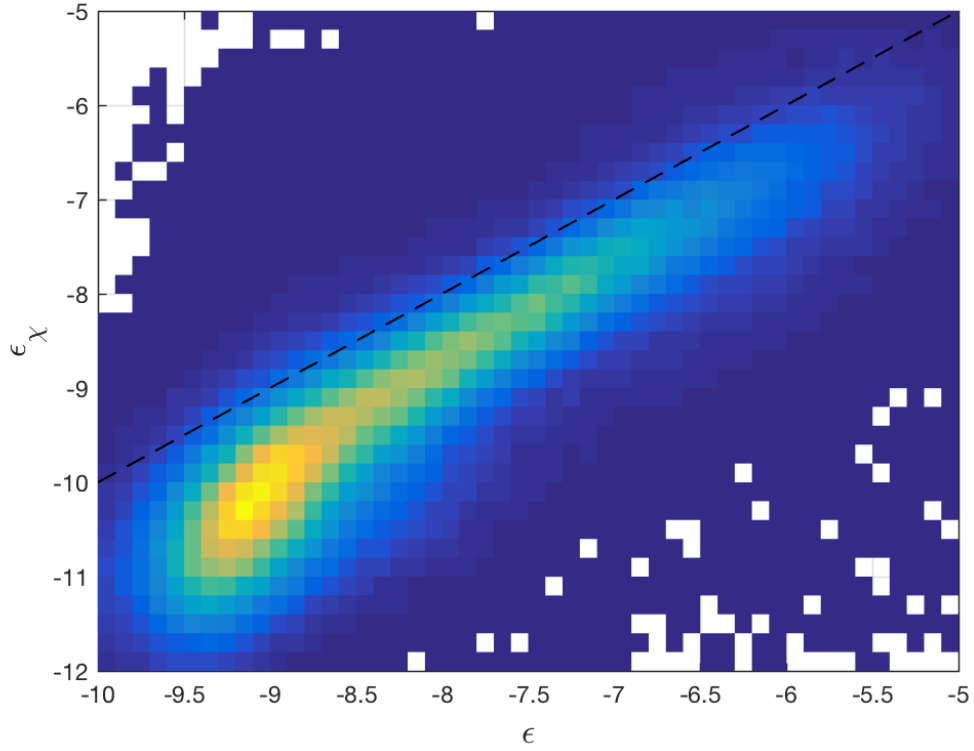


Figure 3: 2D histogram of  $\epsilon_\chi$  vs  $\epsilon$  for Chameleon data.

### 3.3 Comparing individual estimates of $\epsilon$

- Both  $\chi_\chi$  and  $\epsilon_\chi$  are biased low (Figures 4,5); the  $\epsilon_\chi$  bias is larger (more negative).
- The bias in  $\chi$  is relatively constant with depth; the bias in  $\epsilon$  is more negative at shallower depths (Figure 6).



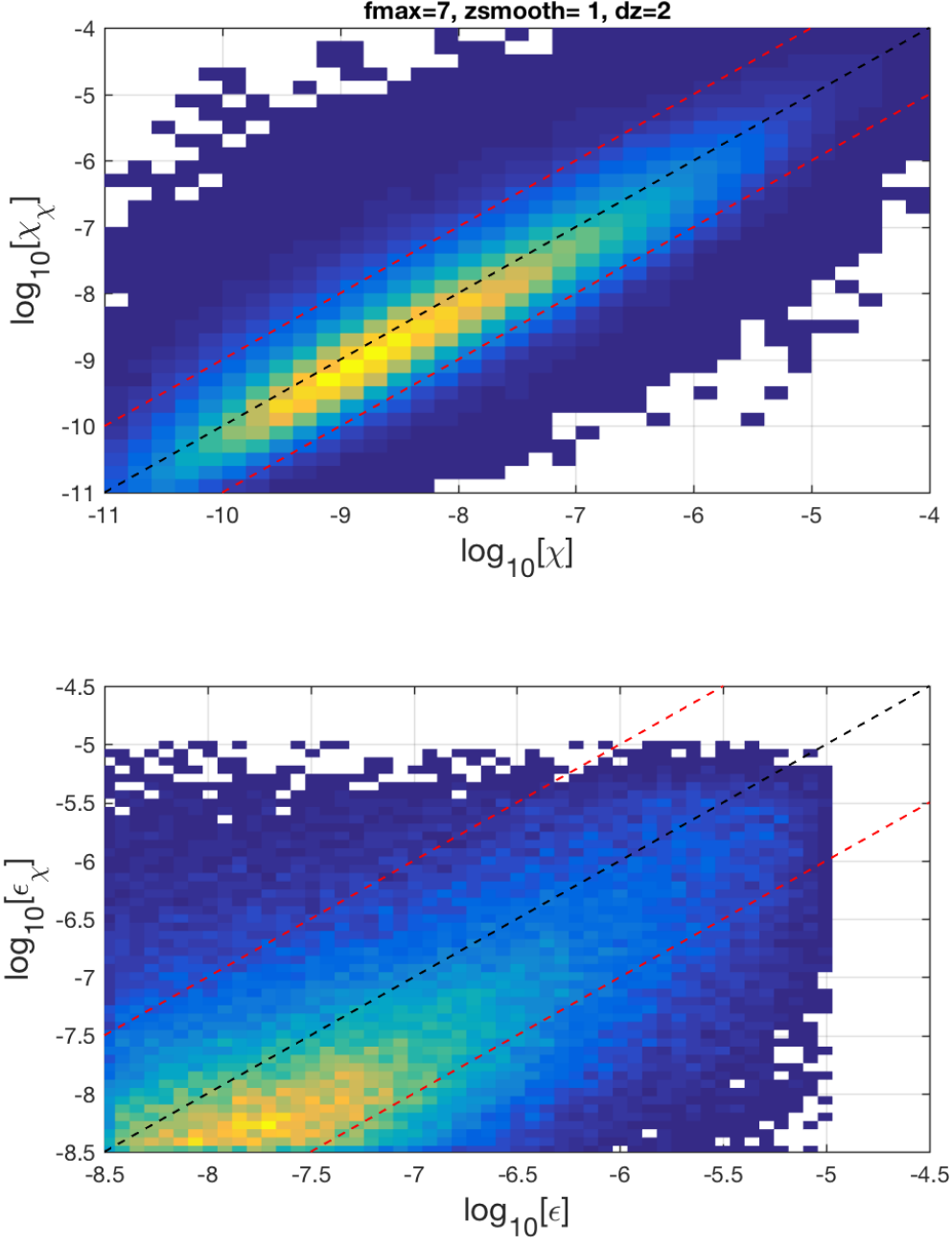


Figure 4: Comparison of  $\chi$  (top) and  $\epsilon$  (lower) from chameleon method and chi-pod method, for EQ14 chameleon profiles. Each profile was averaged in 2m bins. Values of below chameleon noise floor ( $\log_{10}[\epsilon] = -8.5$ ) have been nan'd out. Black line is 1:1, red lines are  $\pm$  order of magnitude.

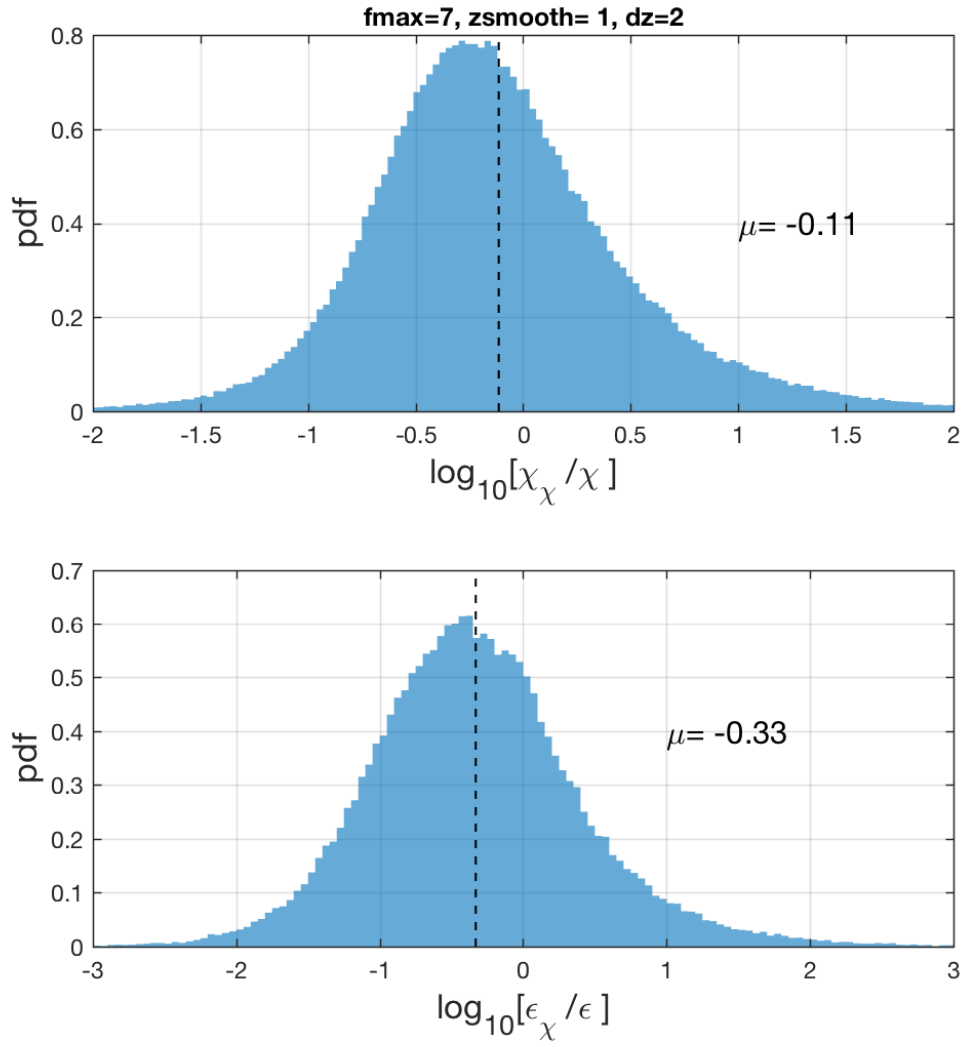


Figure 5: Histograms of the ratios of  $\chi_{\epsilon}/\chi$  (top) and  $\epsilon_{\chi}/\epsilon$  (lower) .

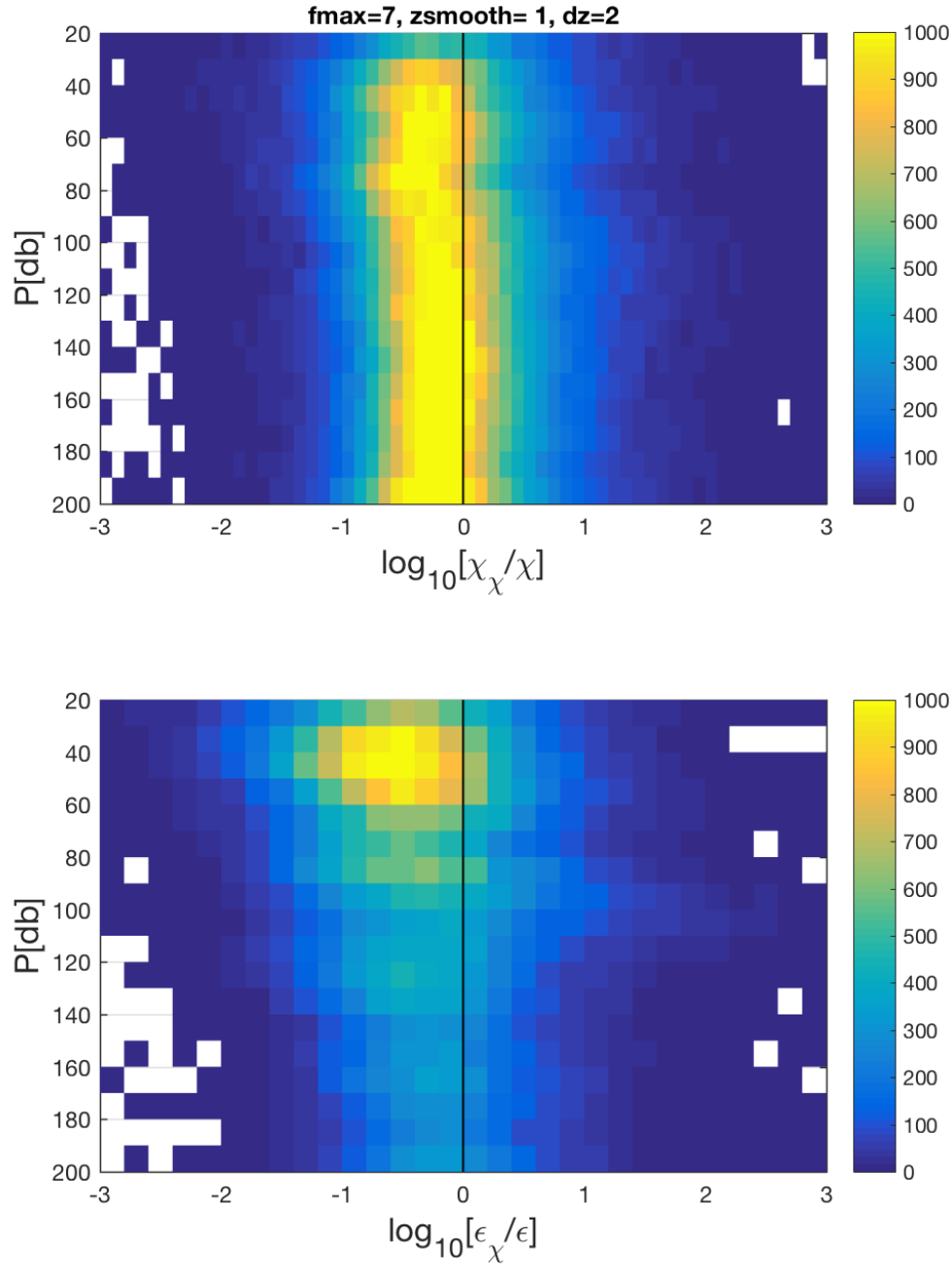


Figure 6: 2D histograms of ratios  $\chi_{\chi}$  and  $\epsilon_{\chi}$  ratios vs depth.

### 3.4 Dependence of bias on actual $\epsilon$

Figure 7 shows that the bias in  $\chi$  and  $\epsilon$  is inversely proportional to the actual  $\epsilon$  measured by Chameleon. The dependence of bias in  $\chi$  not as strong as for  $\epsilon$ .

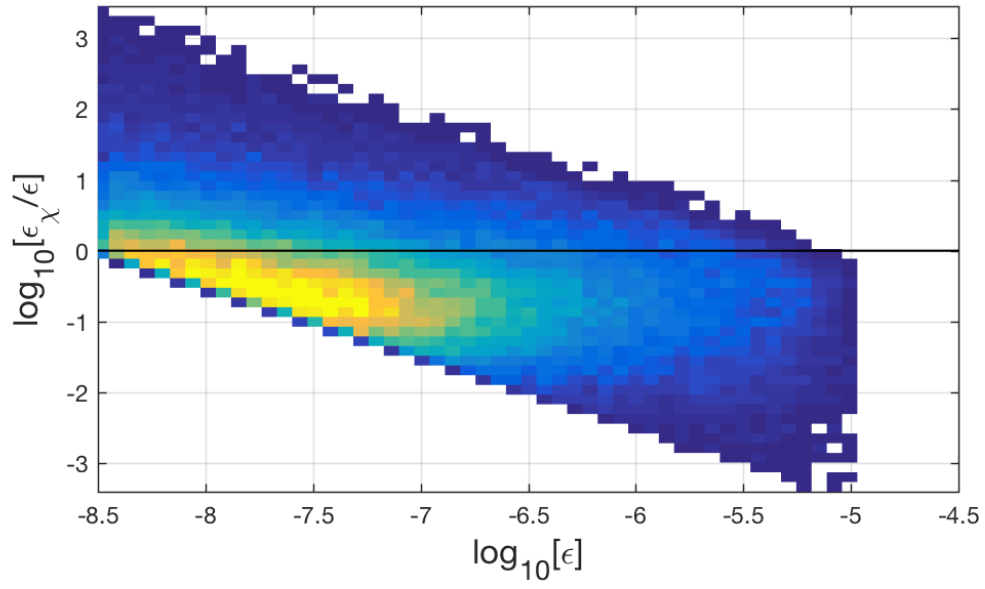
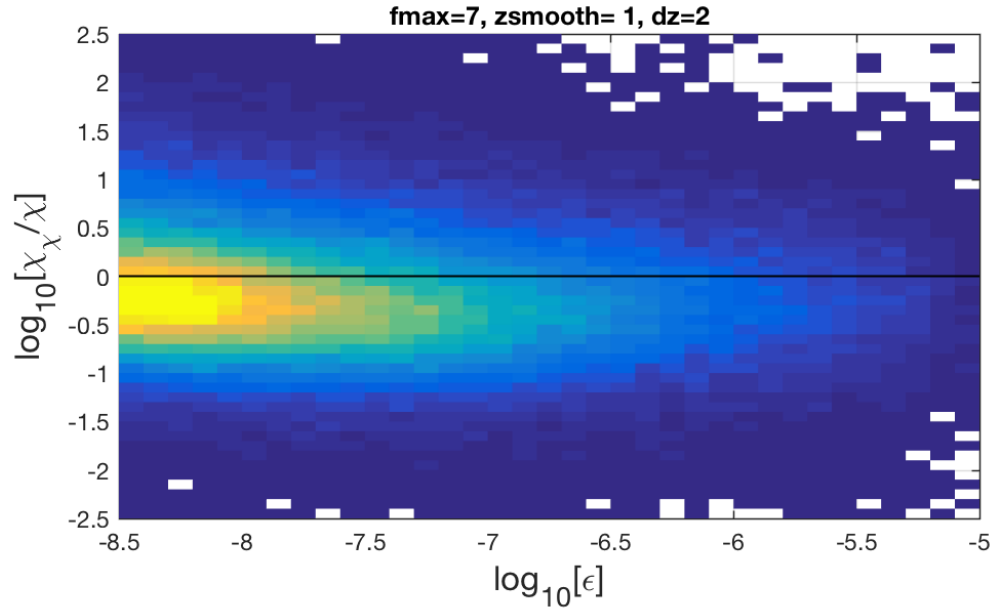


Figure 7: 2D histograms of ratios  $\chi_\chi/\chi$  and  $\epsilon_\chi/\epsilon$  ratios vs  $\epsilon$ .

### 3.5 Normalized eps vs chi plots

Assuming that

$$\gamma = \frac{N^2 \chi}{2\epsilon \langle T_z \rangle^2} \quad (2)$$

, plotting  $[\chi/t_z^2]$  vs  $[\epsilon/N^2]$  should follow a straight line with slope equal to  $2\gamma$ . Chameleon data from EQ14 tend to fall near  $\gamma = 0.05$  (Figure 8).

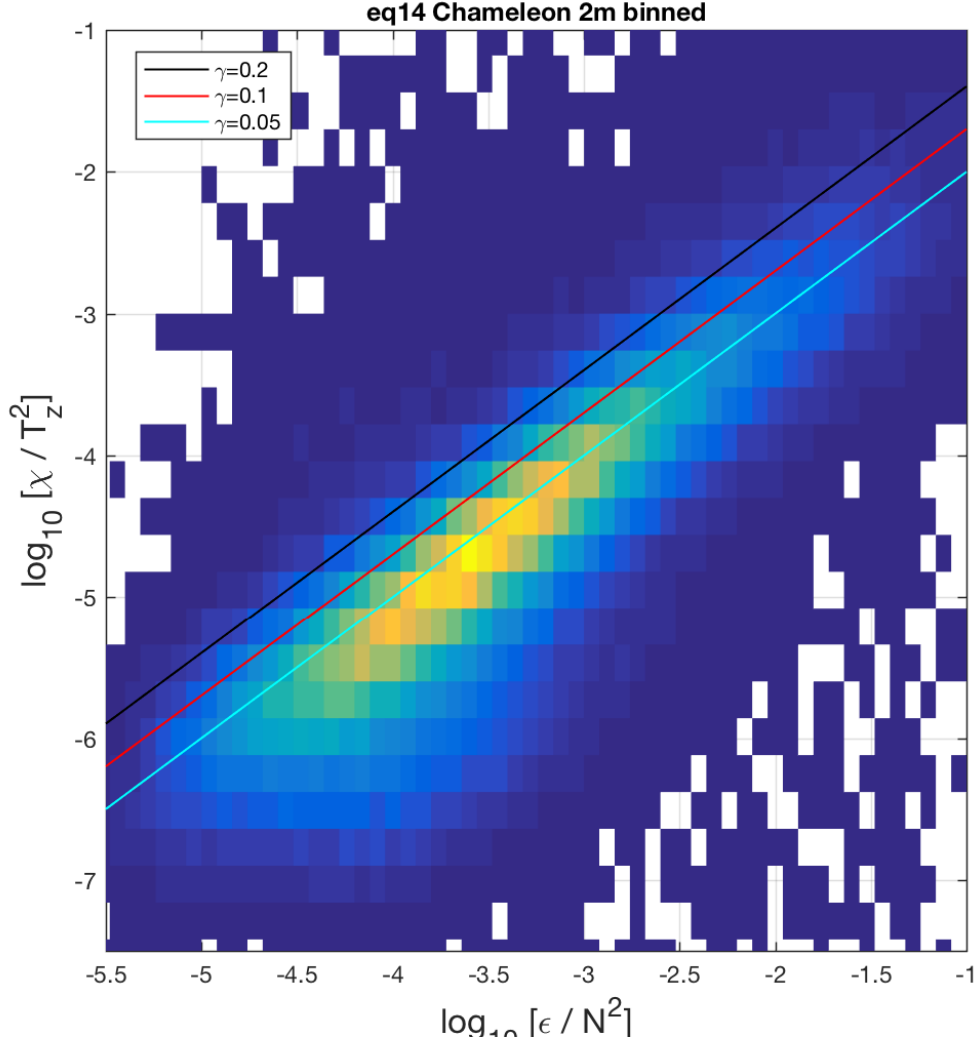


Figure 8: EQ14: 2m binned chameleon  $\epsilon/N^2$  vs  $\chi/t_z^2$ . Lines show different values of  $\gamma$ .

### 3.6 Averaging multiple profiles of $\epsilon$

- Averaging over multiple profiles does not seem to have much of an effect on the bias in both  $\chi$  and  $\epsilon$  (Figures 9,10).

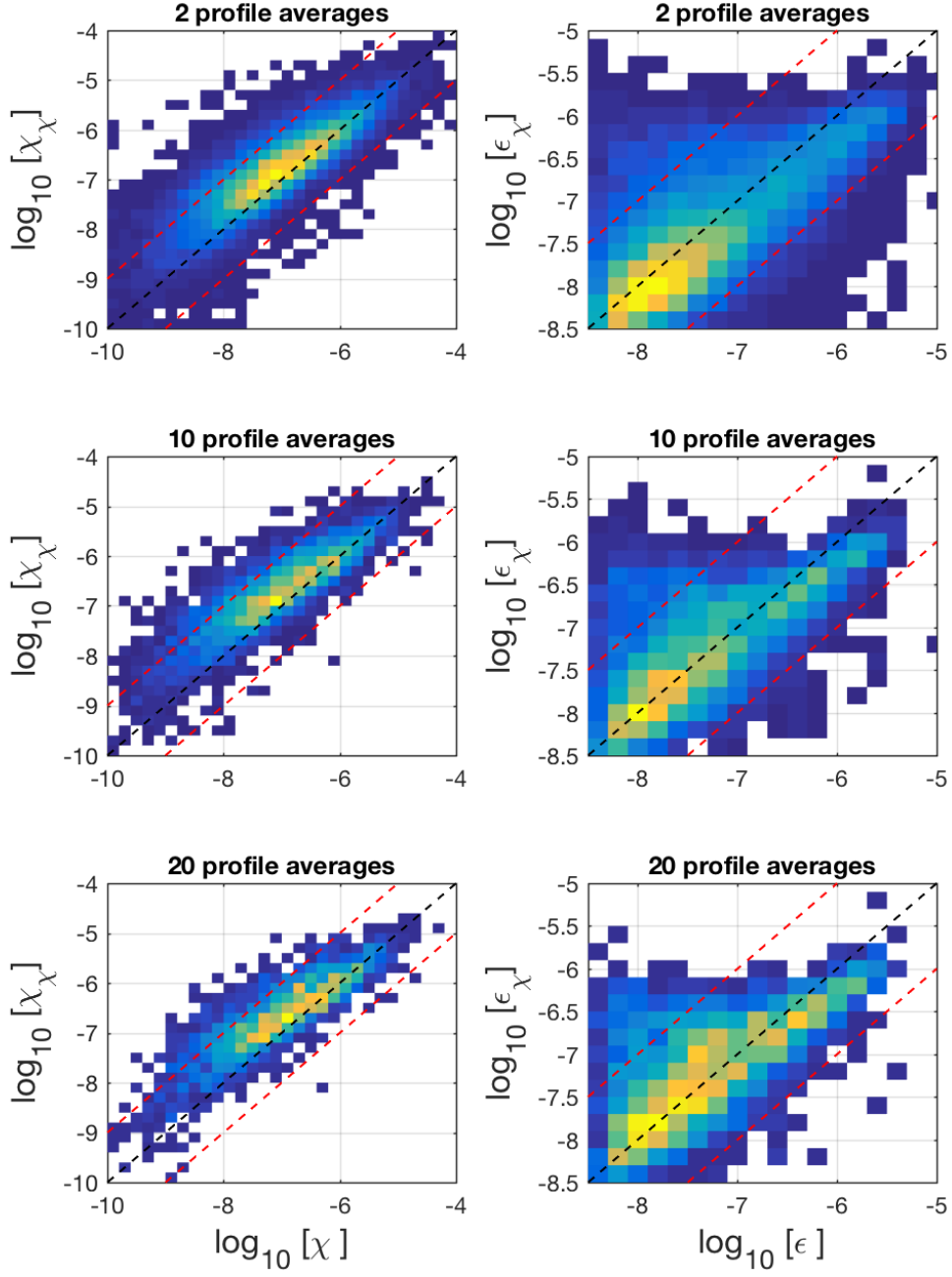


Figure 9: 2D Histograms of  $\chi_{chi}$  vs  $\chi$  (left) and  $\epsilon_{\chi}$  vs  $\epsilon$  (right) for different numbers of profiles averaged.



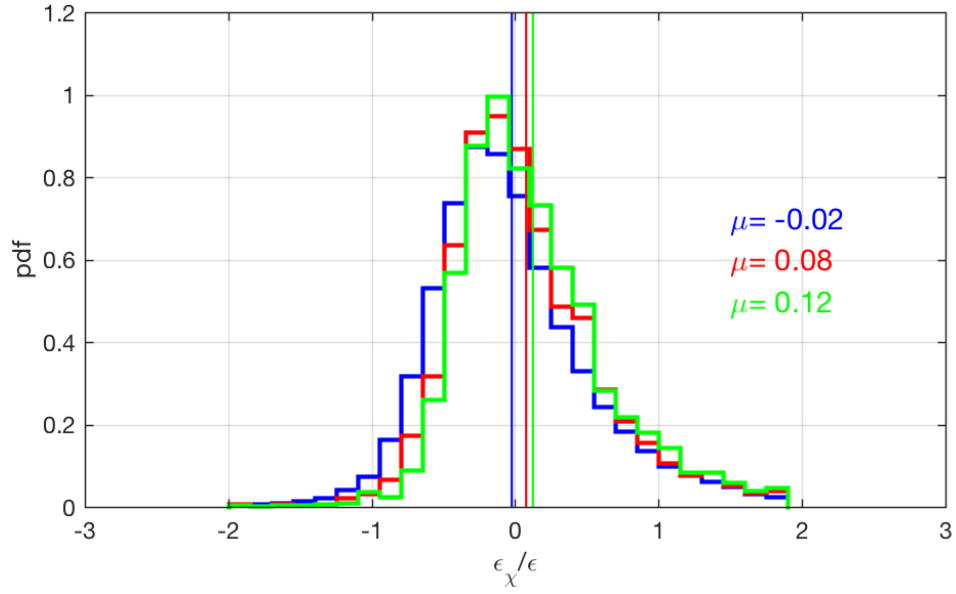
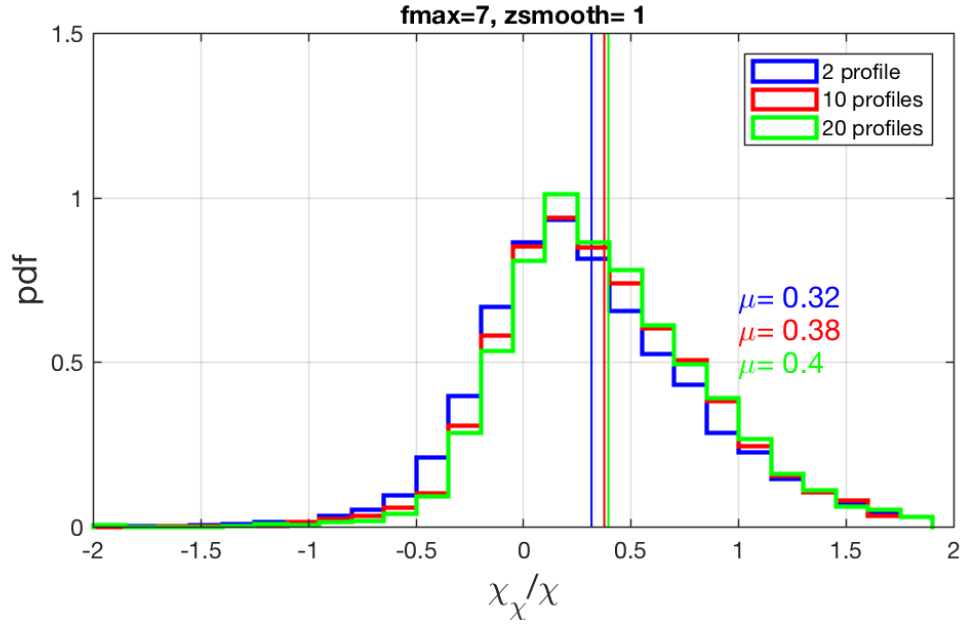


Figure 10: ( $\log_{10}$ ) Ratio of  $\epsilon_\chi/\epsilon$  for different numbers of profiles averaged. Consecutive chunks of  $N$  profiles were averaged, and then (normalized) histogram of the ratios was plotted. Vertical lines and numbers to right are mean of  $\log_{10}[\epsilon_\chi/\epsilon]$  for each distribution.

### 3.7 Averaging over different-sized depth bins

- Averaging over large depth bins reduces the bias in both  $\chi$  and  $\epsilon$  (Figures 11,12).

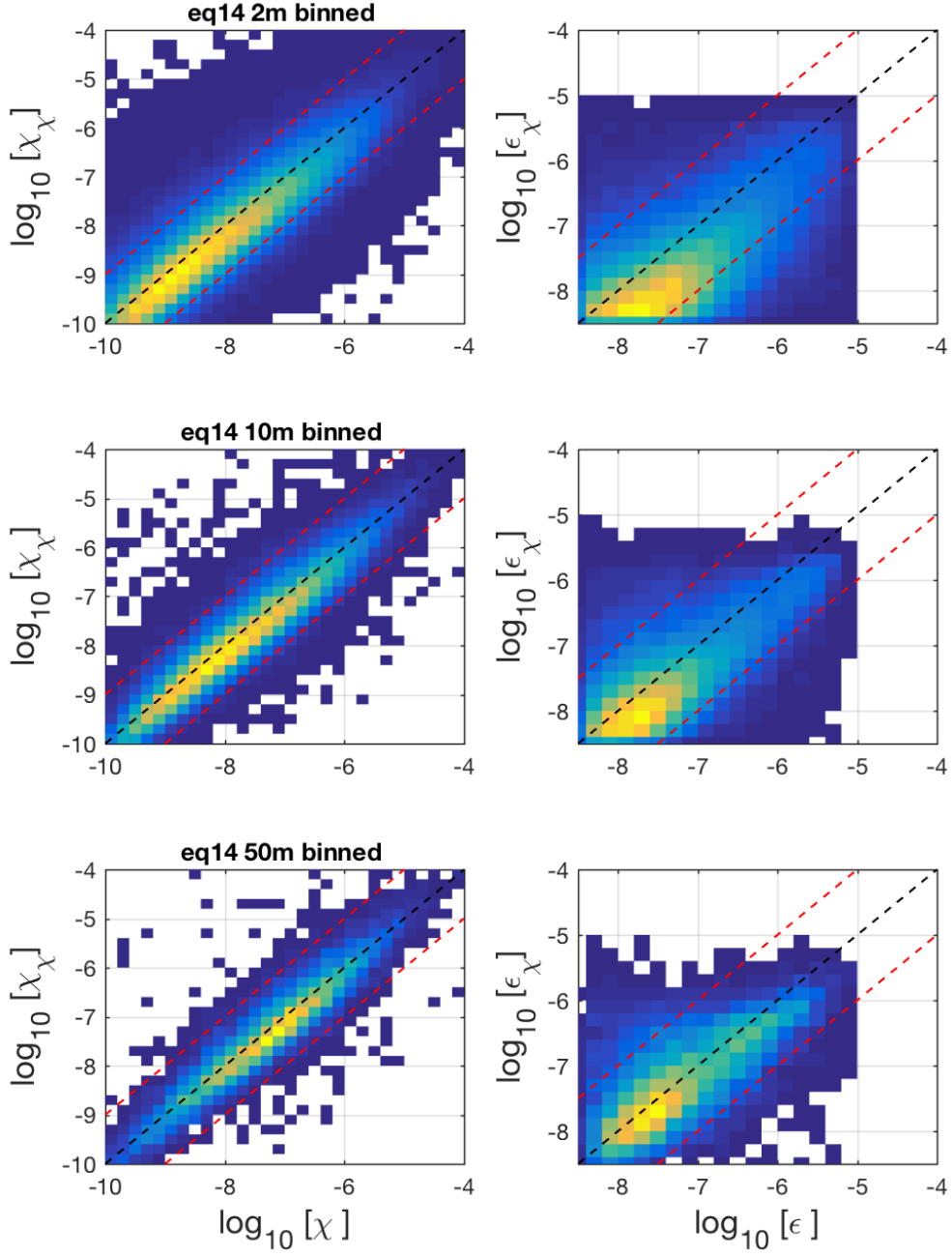


Figure 11: 2D Histograms of  $\chi_{chi}$  vs  $\chi$  (left) and  $\epsilon_{\chi}$  vs  $\epsilon$  (right) averaged over different size depth bins

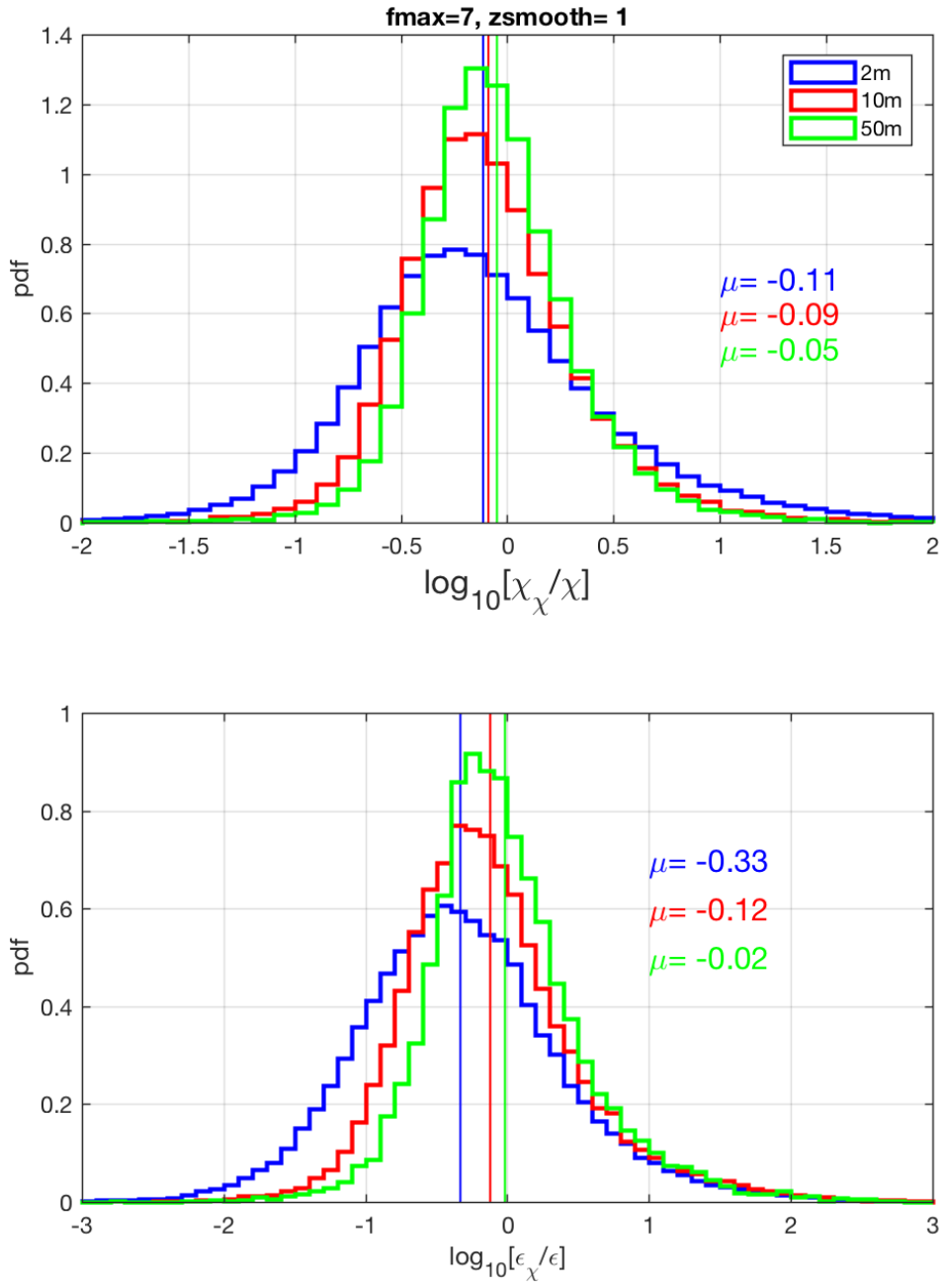


Figure 12: Histogram of  $\log_{10}$  of ratio  $\epsilon_\chi/\epsilon$  for different amounts of vertical averaging. Vertical lines are mean of  $\log_{10}[\epsilon_\chi/\epsilon]$  for each distribution.

### 3.8 $\gamma$ computed from averaged quantities

If we compute gamma from time-averaged  $N^2, T_z, \chi, \epsilon$  do we get  $\gamma = 0.2$  (or a different gamma)? Estimates from the averaged data are larger (Figure 13) but still slightly less than 0.2 .

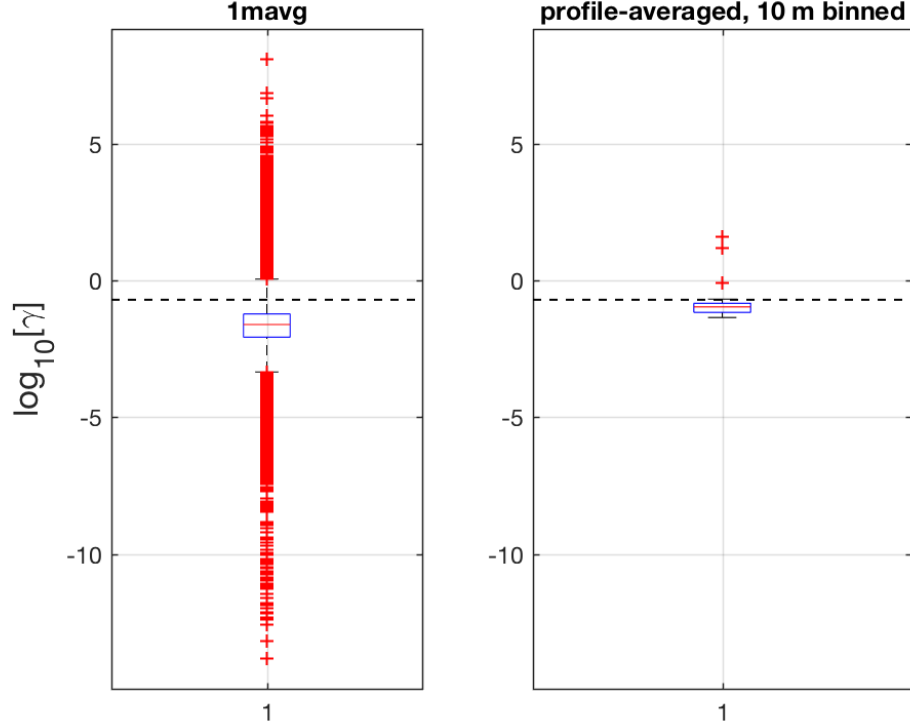


Figure 13: Boxplots of  $\log_{10}[\gamma]$  for a set of profiles from EQ14. Left is for all 1m avg data. Right is for data from all profiles averaged in 10m bins. Horizontal dashed line indicates  $\gamma = 0.2$ .

### 3.9 Summary

- Both  $\chi_\chi$  and  $\epsilon_\chi$  appear to capture the depth and time structure of  $\chi$  and  $\epsilon$  well (Figures 1,2).
- Both  $\chi_\chi$  and  $\epsilon_\chi$  are biased low (Figures 4,5); the  $\epsilon_\chi$  bias is larger (more negative).
- The bias in  $\chi$  is relatively constant with depth; the bias in  $\epsilon$  is more negative at shallower depths (Figure 6).
- Figure 7 shows that the bias in  $\chi$  and  $\epsilon$  is inversely proportional to the actual  $\epsilon$  measured by Chameleon. The dependence of bias in  $\chi$  not as strong as for  $\epsilon$ .
- Averaging over multiple profiles does not seem to have much of an effect on the bias in both  $\chi$  and  $\epsilon$  (Figures 9,10).
- Averaging over large depth bins reduces the bias in both  $\chi$  and  $\epsilon$  (Figures 11,12).