

# Patch/Gamma Analysis for EQ08 chameleon patches

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# 1 Overview

The goal of this analysis is to compute mixing ‘coefficient’  $\gamma_{\chi\epsilon} = \frac{N^2\chi}{2\epsilon T_z^2}$  for patches in EQ08 chameleon profiles, and see if we obtain values close to  $\gamma_{\chi\epsilon} = 0.2$ . A similar analysis was done for TIWE and EQ14 data. The motivation for this analysis came from working on CTD- $\chi$ pod data; the method assumes  $\gamma = 0.2$ , but it was found for some (1m binned) data this was not true. Therefore the method might need to be applied to patches instead.

# 2 Data

Data are made by the ‘Chameleon’ microstructure profiler near the equator during the ‘EQ08’ experiment. The data was shared with me by Sally/Jim. My copy is located at :

Chameleon data already processed by Sally is in :

This analysis is in the main folder:  
/Users/Andy/Cruises\_Research/Analysis/Andy\_Pickering/eq08\_patch\_gamma/. This is also a github repository.

# 3 Methods

## 3.1 dTdz

Temperature gradient is computed for each patch using the following methods:

1.  $dtdz_{line}$  : Fit a straight line to sorted T using `polyfit`
2.  $dtdz_{bulk}$  : Use the ‘bulk gradient’ from Smyth et al 2001, which is the rms fluctuation from the background (sorted) temperature, divided by the thorpe scale (the rms re-ordering distances).

## 3.2 N2

$N^2$  is computed for each patch using the following methods:

1.  $N_{line}^2$  : Fit a straight line to sorted potential density using `polyfit` to get  $d\rho/dz$ , then compute  $N^2$ .
2.  $N_{bulk}^2$  : Use ‘bulk gradient’ . This is calculated from the bulk  $T_z$ , using a linear fit between density and temperature.

3.  $N_4^2$  : Compute  $N^2$  from the sorted profile (sorted by potential density) using `sw_bfreq`, then take average over the patch. I believe this method is used by some commonly-used overturn codes.

### 3.3 Mixing Efficiency

Mixing Efficiency  $\gamma_{\chi\epsilon}$  is computed from the following equation using different  $N^2$  and  $dT/dz$  values.

$$\gamma_{\chi\epsilon} = \frac{N^2\chi}{2\epsilon T_z^2} \quad (1)$$

$\chi$  and  $\epsilon$  are computed over each patch from the Chameleon data. Gamma is computed for the following 4 combinations:

1.  $\gamma_{bin}$  : 1m binned data interpolated to patch depths.
2.  $\gamma_{line}$  :  $N_{line}^2$ ,  $dtdz_{line}$
3.  $\gamma_{bulk}$  :  $N_{bulk}^2$ ,  $dtdz_{bulk}$

Values where  $\epsilon$  is below the noise floor of  $\log_{10}[\epsilon] = -8.5$  are discarded.

## 4 Results

- $\gamma_{\chi\epsilon}$  computed for 1m avg ('binned') data is about an order of magnitude less than 0.2 (Figure 2). It has a median value of  $\gamma = 0.015$  for data between 60-200m. The data was processed by Sally w/ 2 different c-star values, this doesn't seem to make any difference in the estimated  $\gamma_{\chi\epsilon}$ .
- $\gamma_{\chi\epsilon}$  computed for just patches (Figure 3) varies depending on which method is used. The 'line' and 'bulk' methods have median values around  $\gamma = 0.1$ . The bin and line-fit estimates are much smaller than 0.2

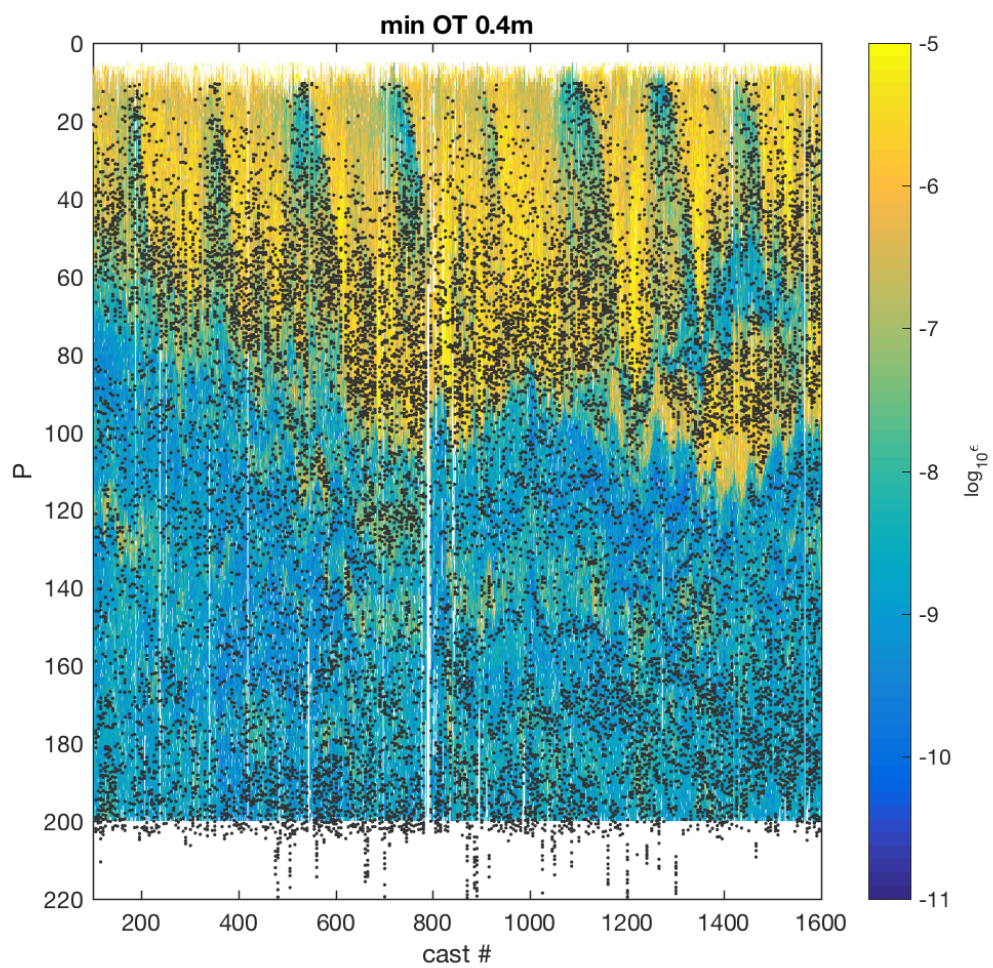


Figure 1: Patch locations (mean depth) plotted on top of epsilon.

Table 1: Statistics for patches using various parameters.  $\gamma$  values are medians for each distribution. Only patches between 60-200m are considered.

minOT	usetemp	minR2	$\gamma_{bin}$	$\gamma_{line}$	$\gamma_{fit}$	$\gamma_{bulk}$	Npatches
0.4	1	0	0.06	0.19	0.08	0.18	20108
0.4	1	0.5	0.07	0.15	0.12	0.15	924
0.75	1	0	0.07	0.17	0.09	0.17	9863
0.75	1	0.5	0.09	0.14	0.11	0.14	614
1	1	0	0.08	0.16	0.09	0.17	6963
1	1	0.5	0.1	0.15	0.12	0.16	517

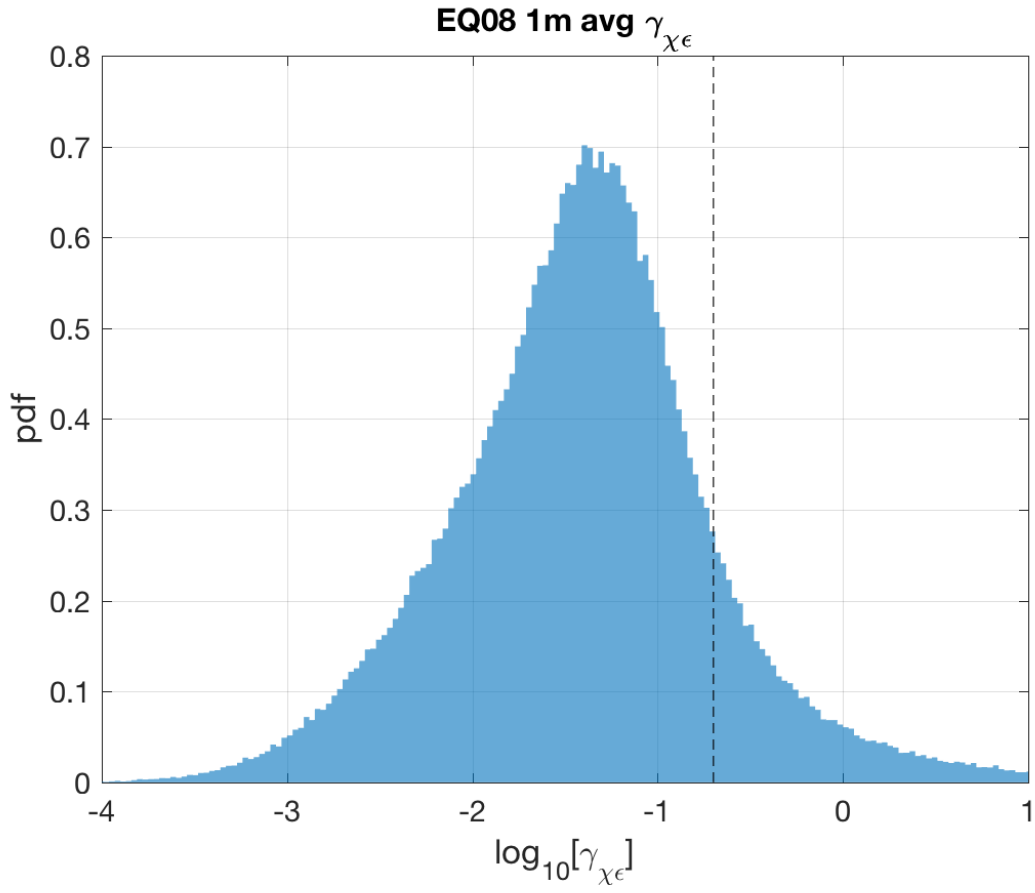


Figure 2: Histogram of  $\gamma_{\chi\epsilon}$  for 1m avg chameleon profiles between 60-200m depth. Vertical dashed line shows  $\gamma = 0.2$ .

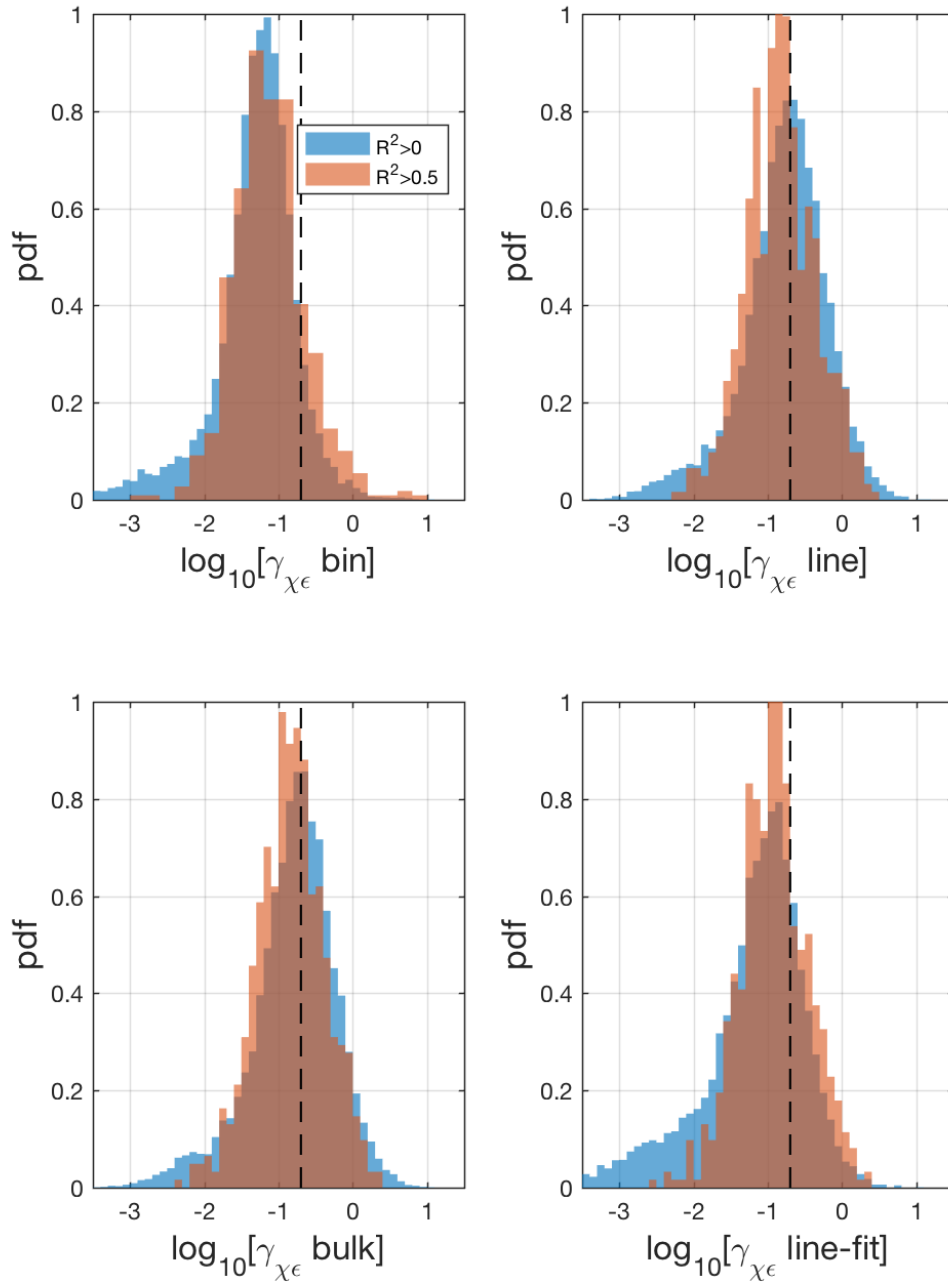


Figure 3: Histogram of  $\gamma_{\chi\epsilon}$  for patches, using different estimates of  $N^2$  and  $T_z$ . Vertical dashed line shows  $\gamma = 0.2$ . For all profiles, all depths.

#### 4.1 Variation of $\gamma_{\chi\epsilon}$ with epsilon

See Figure 4:

- For ‘bin’ and ‘linefit’ methods,  $\gamma$  does not show much dependence on  $\epsilon$ . But magnitude is less than 0.2 .
- For ‘line’ and ‘bulk’ methods, magnitude of  $\gamma$  is closer to 0.2, but shows an inverse dependence on  $\epsilon$ .

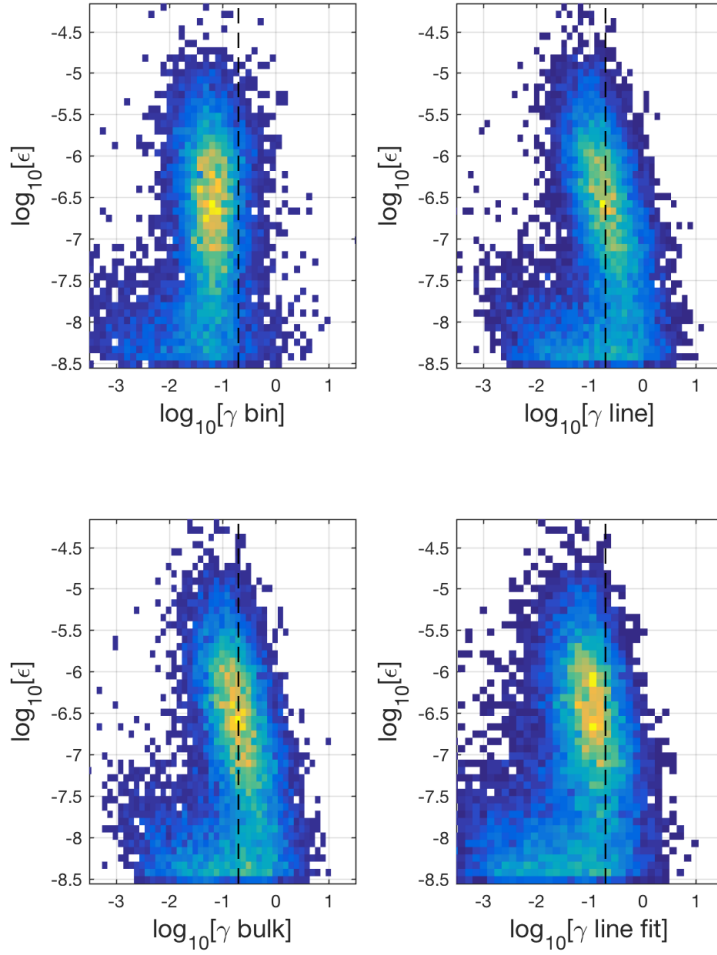


Figure 4: Plot of  $\epsilon$  versus  $\gamma_{\chi\epsilon}$  for patches, depths 60-200m. Vertical line is  $\gamma = 0.2$ .

## 4.2 Variation of $\gamma_{\chi\epsilon}$ over time

To investigate whether  $\gamma_{\chi\epsilon}$  varies over time, I plotted  $\gamma_{\chi\epsilon}$  vs cast number (Figure 5).

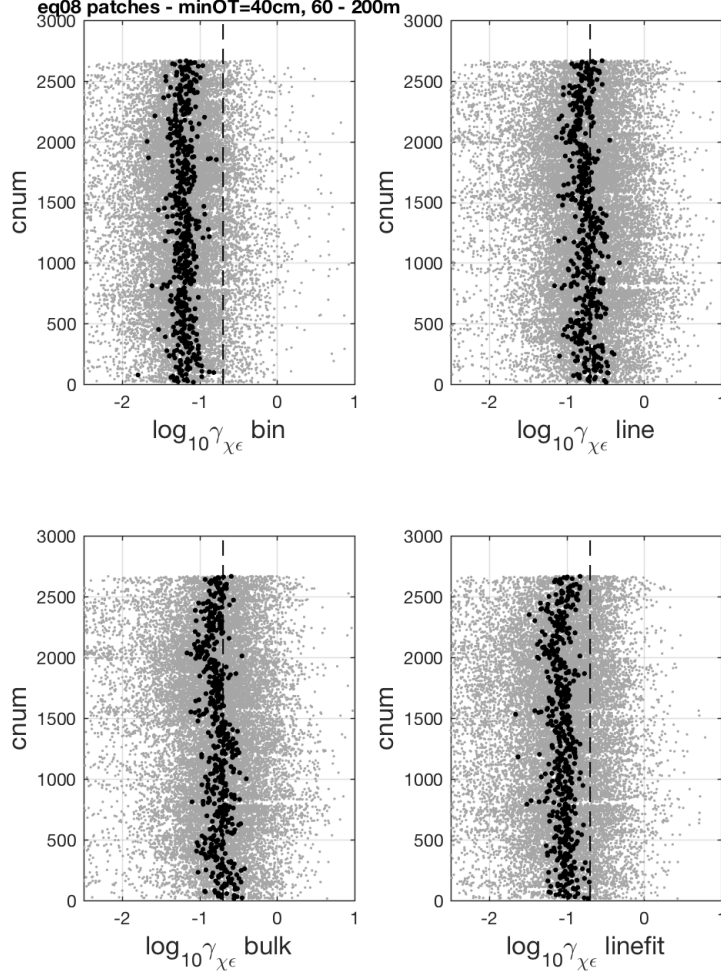


Figure 5: Plot of  $\gamma_{\chi\epsilon}$  for patches vs cast number. Vertical line is  $\gamma = 0.2$ . Black points are the median value for each cast.



### 4.3 Variation of $\gamma_{\chi^e}$ over depth

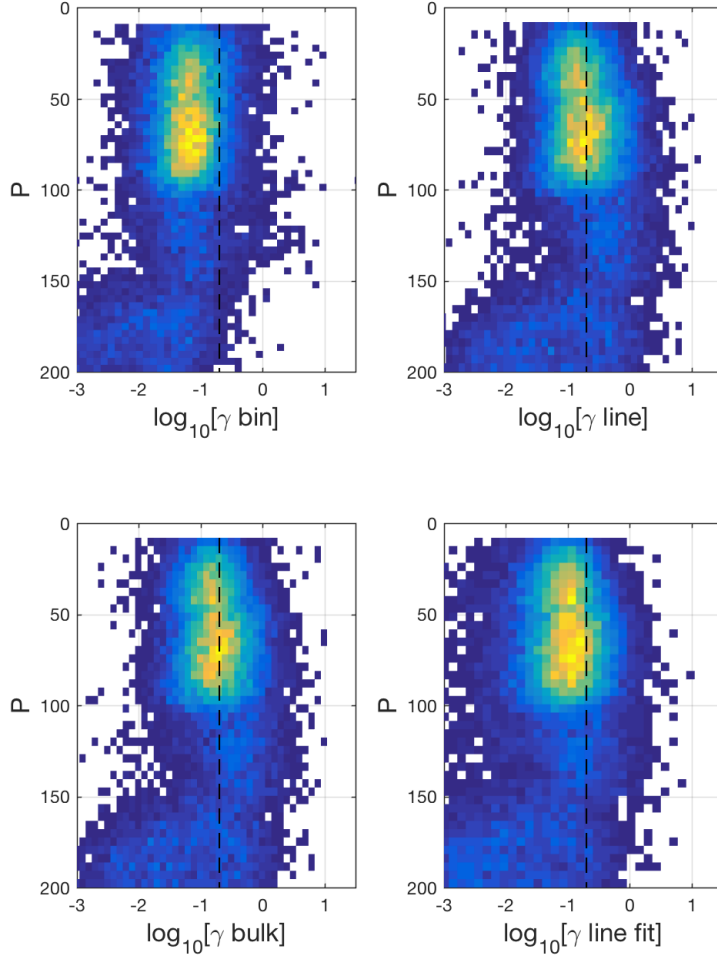


Figure 6: Plot of  $\gamma_{\chi^e}$  for patches vs depth. Vertical line is  $\gamma = 0.2$ .

## 5 Application of $\chi$ pod method to binned data

\* section in progress \*

The  $\chi$ pod method was applied to patches to see if the agreement between  $\chi$ pod-estimated  $\chi$  and  $\epsilon$  improved. Applying the  $\chi$ pod method to the entire profiles gave decent agreement in  $\chi$ , but  $\chi$ pod-estimated  $\gamma$  was biased low by about an order of magnitude (which is what motivated this whole patch analysis).

mfiles:

- `ComputeChi_Chameleon_Eq08.m` : The  $\chi$ pod method is applied.
- `Plot_eps_profiles_eq08.m`
- all the profiles are combined into one structure in `XXX?.m`.

Figure 7: Comparison of  $\chi$  from chameleon and  $\chi$ pod method applied to patches. (Top-left) Comparison of  $\chi$  from patches to binned  $\chi$  interpolated to patch locations. (Top-right)  $\chi$  from  $\chi$ pod method using actual patch  $\gamma$  to patch  $\chi$  from chameleon. (Lower-left)  $\chi$  from  $\chi$ pod method using binned data, interpolated to patch locations, compared to patch  $\chi$  from chameleon. (Lower-right)  $\chi$  from  $\chi$ pod method using a constant  $\gamma = 0.2$  to patch  $\chi$  from chameleon.

Figure 8: Comparison of  $\epsilon$  from chameleon and  $\chi$ pod method applied to patches, using the ‘line-fit’ method. (Top-left) Comparison of  $\epsilon$  from patches to binned  $\epsilon$  interpolated to patch locations. (Top-right)  $\epsilon$  from  $\chi$ pod method using actual patch  $\gamma$  to patch  $\epsilon$  from chameleon. (Lower-left)  $\epsilon$  from  $\chi$ pod method using binned data, interpolated to patch locations, compared to patch  $\epsilon$  from chameleon. (Lower-right)  $\epsilon$  from  $\chi$ pod method using a constant  $\gamma = 0.2$  to patch  $\epsilon$  from chameleon.

Figure 9: Histogram of  $\log_{10}$  of the ratio of  $\chi$ pod estimated  $\epsilon$  to chameleon  $\epsilon$  for patches, for both binned data (interpolated to patch locations), and using only patch data.

## 5.1 Comparing time-averaged profiles of $\epsilon$

Looking at median values and scatterplots might be a little misleading. Maybe what we care about most is the mean profile of  $\epsilon$  (or  $K_\rho$  and  $\chi$  (or  $K_T$ ), which are probably dominated by just a small number of large values.

Figure 10 shows the ratio of  $\epsilon$  estimates (averaged in 10m bins from each profiles) from the  $\chi$ pod method to chameleon  $\epsilon$  values, for both chi-pod method applied to 1m binned profiles, and applied to just patches. In such a point-by-point comparsion, the patch estimates have a smaller bias.

Figure 11 shows averaged profiles of  $\epsilon$  for several 500-profile chunks of the EQ0-8 data. The average profile of  $\chi$ pod estimates using 1m bins ('bin') tend to agree well with the chameleon average profile, if  $\chi$ pod estimates where  $\log_{10}\epsilon > -4$  are discarded (these are likely bad data due to extremely small dTdz). In fact, the average profile constructed from the binned  $\chi$ pod estimates tends to agree better than the patch profile.

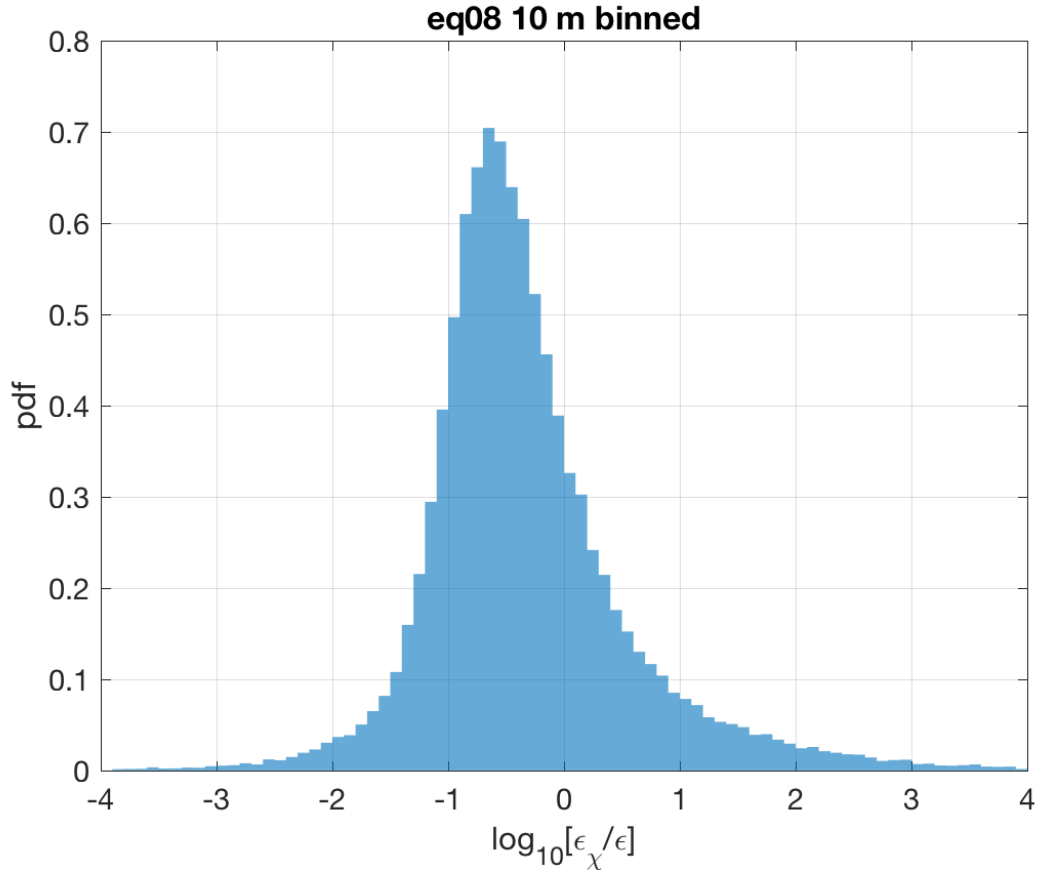


Figure 10: Histogram of the ratio of  $\epsilon$  estimates from  $\chi$ pod method to the chameleon values, for chi-pod method applied to 1m binned profiles. Estimates for each profile were averaged in 10m depth bins.

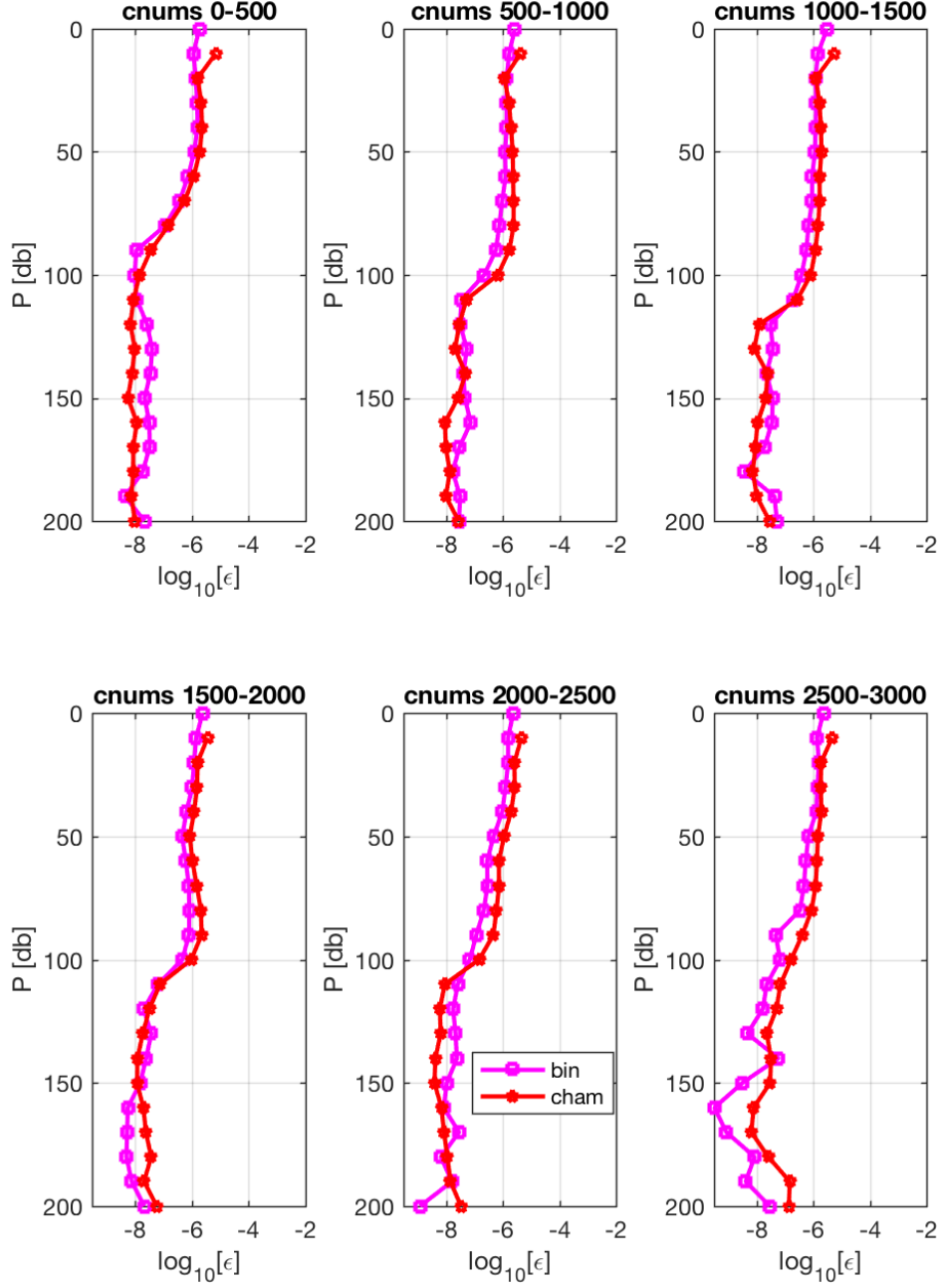


Figure 11: Profiles of  $\epsilon$ , averaged over 500-cast chunks. Different lines are 1m binned Chameleon ('cham'),  $\chi$ pod method applied over 1m bins ('bin'), and  $\chi$ pod method applied to patches ('patch'). \*Note  $\chi$ pod estimates where  $\log_{10}\epsilon > -4$  are discarded.

## 5.2 $\gamma$ computed from averaged quantities

If we compute gamma from time-averaged  $N^2, T_z, \chi, \epsilon$  do we get  $\gamma = 0.2$ ? Estimates from the averaged data are larger (Figure 12) but still slightly less than 0.2 .

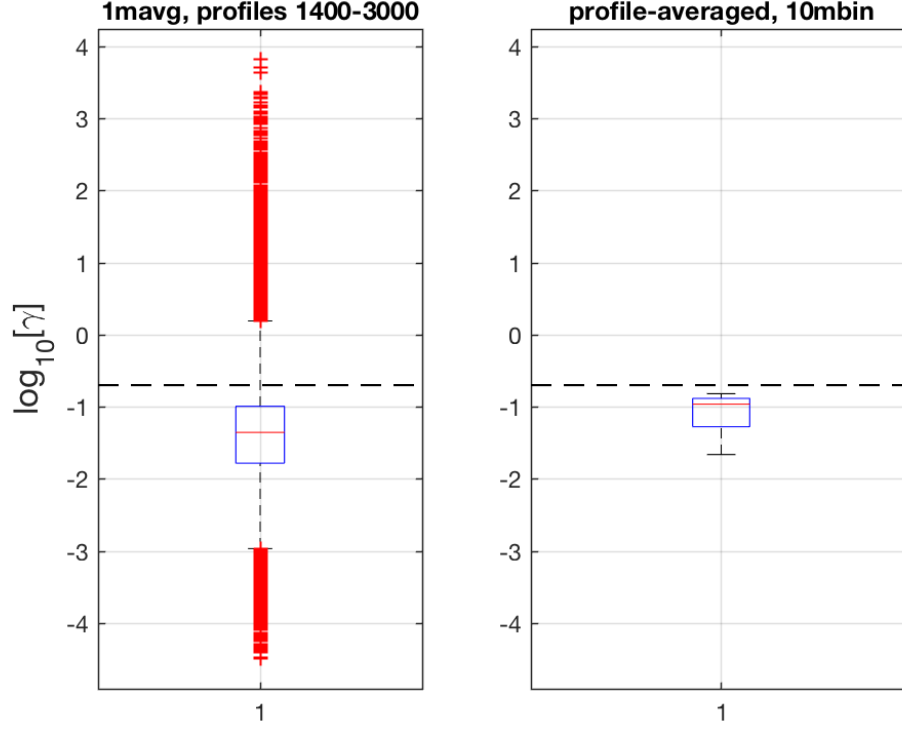


Figure 12: Boxplots of  $\log_{10}[\gamma]$  for a set of profiles from EQ14. Left is for all 1m avg data. Right is for data from all profiles averaged in 10m bins. Horizontal dashed line indicates  $\gamma = 0.2$ .

## 5.3 How many profiles need to be averaged to converge?

Next I wanted to see how many profiles we need to average for the chi-pod profile to converge to the chameleon profile. Obviously this will depend on the specific profiles used and the characteristics of the turbulence, but here they seem to converge after about 100-150 profiles.

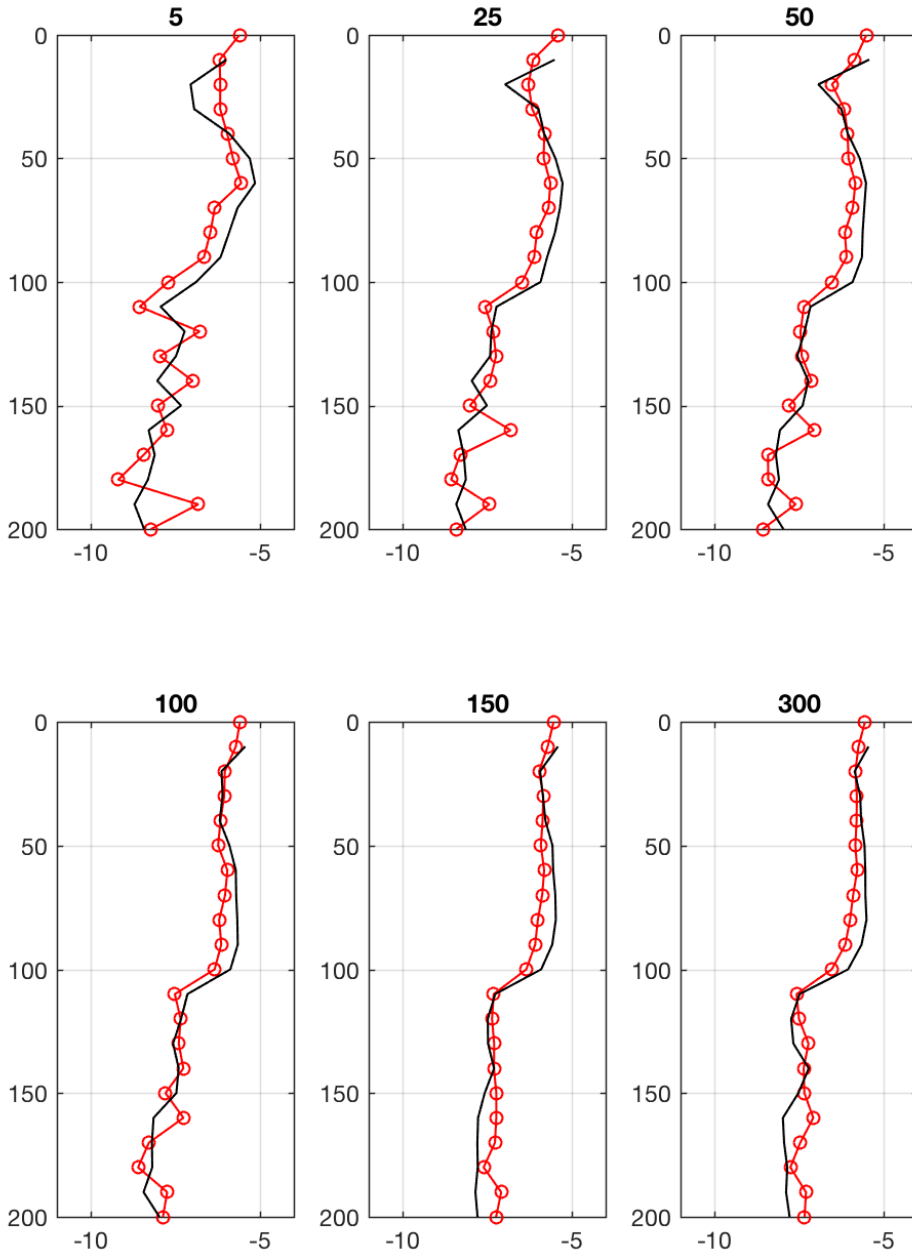


Figure 13: Average profiles of  $\epsilon$  from binned chi-pod method and chameleon, for different number of profiles (given by title).

## 6 Summary

- $\gamma_{\chi^\epsilon}$  computed from 1m binned data (the standard Chameleon processing) is about 10 times smaller than the typical assumed value of 0.2.
- $\gamma_{\chi^\epsilon}$  computed for just patches varies depending on what method of choosing  $T_z$  and  $N^2$  is used. The ‘line’ and ‘bulk’ methods give  $\gamma$  estimates of about 0.15-0.2.