

# Patch/Gamma Analysis for EQ14 chameleon patches

Andy Pickering

March 20, 2017

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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 EQ14 chameleon profiles, and see if we obtain values close to  $\gamma_{\chi\epsilon} = 0.2$ . A similar analysis was done for TIWE 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 ‘EQ14’ experiment. The data was shared with me by Sally/Jim. My copy is located at :

`/Users/Andy/Cruises_Research/ChiPod/Cham_Eq14_Compare/`

Chameleon data already processed by Sally is in :

`/Users/Andy/Cruises_Research/ChiPod/Cham_Eq14_Compare/Data/chameleon/processed/`

This analysis is in the main folder:

`/Users/Andy/Cruises_Research/Analysis/Andy_Pickering/eq14_patch_gamma/` . This is also a github repository.

# 3 Methods

- `FindPatches_eq14_Raw.m` Identifies patches in the profiles made by `Process_tiwrawprofiles_AP.m`, using potential temperature.
- `Compute_N2_dTdz_patches_eq14_eachcast.m` Computes  $N^2$  and  $T_z$  for patches, using several different methods. Saves results in a structure ‘patches’.
- `add_binned_to_patches.m`
- `run_eq14_for_PATCHES.m` Runs the Chameleon processing (including  $\chi$  and  $\epsilon$ ) for just the patches identified in `FindPatches_eq14_Raw.m` . This calls `average_data_PATCH_AP.m` instead of `average_data_gen1.m`.
- `add_patch_chi_eps_to_patches_eq14_each_profile.m` Adds  $\chi$  and  $\epsilon$  computed over patches (in `run_eq14_for_PATCHES.m` ) to patch profiles.
- `combine_patch_profiles_eq14.m` Combines all patch profiles into 1 structure.

### 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

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     | 0.03           | 0.15            | 0.02           | 0.13            | 9326     |
| 0.4   | 1       | 0.5   | 0.03           | 0.09            | 0.02           | 0.08            | 1301     |
| 0.75  | 1       | 0     | 0.05           | 0.13            | 0.02           | 0.12            | 4075     |
| 0.75  | 1       | 0.5   | 0.05           | 0.08            | 0.03           | 0.08            | 520      |
| 1     | 1       | 0     | 0.06           | 0.12            | 0.02           | 0.12            | 2829     |
| 1     | 1       | 0.5   | 0.05           | 0.08            | 0.04           | 0.08            | 387      |

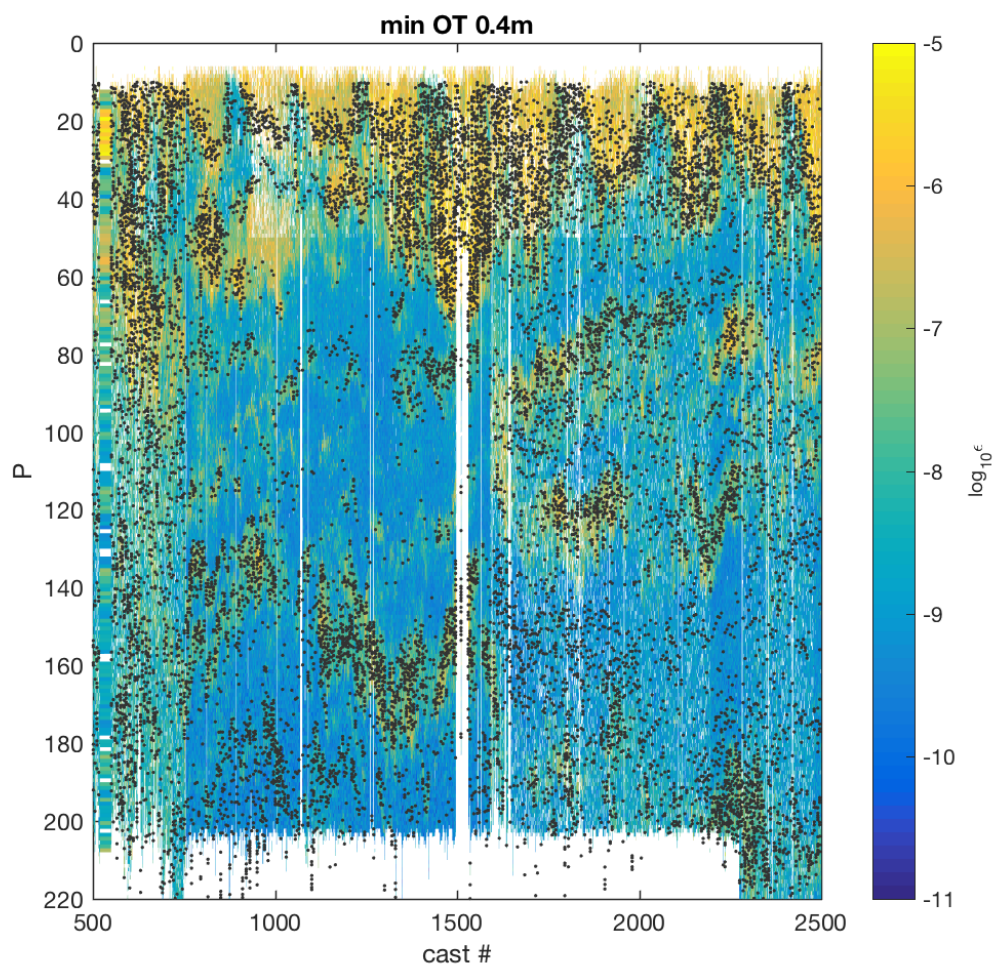


Figure 1: Patch locations (mean depth) plotted on top of epsilon.

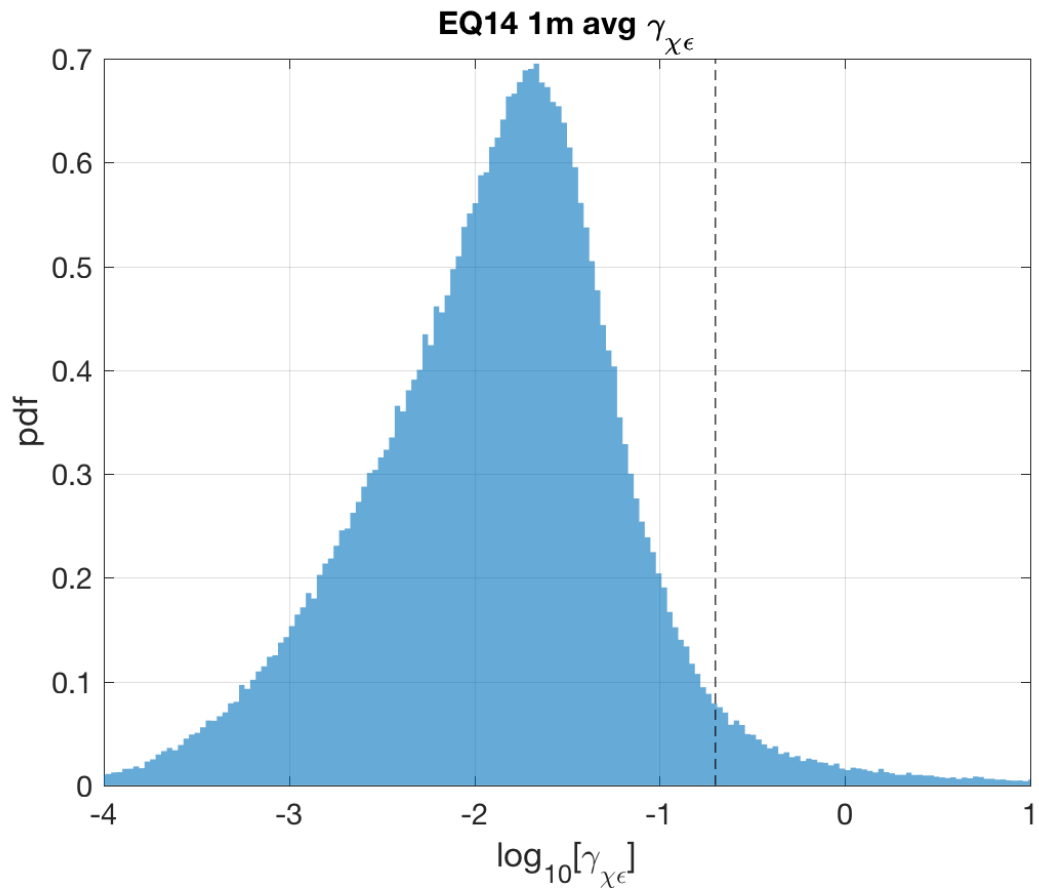


Figure 2: Histogram of  $\gamma_{\chi\epsilon}$  for 1m avg chameleon profiles between 60-200m depth. Vertical dashed line shows  $\gamma = 0.2$ .

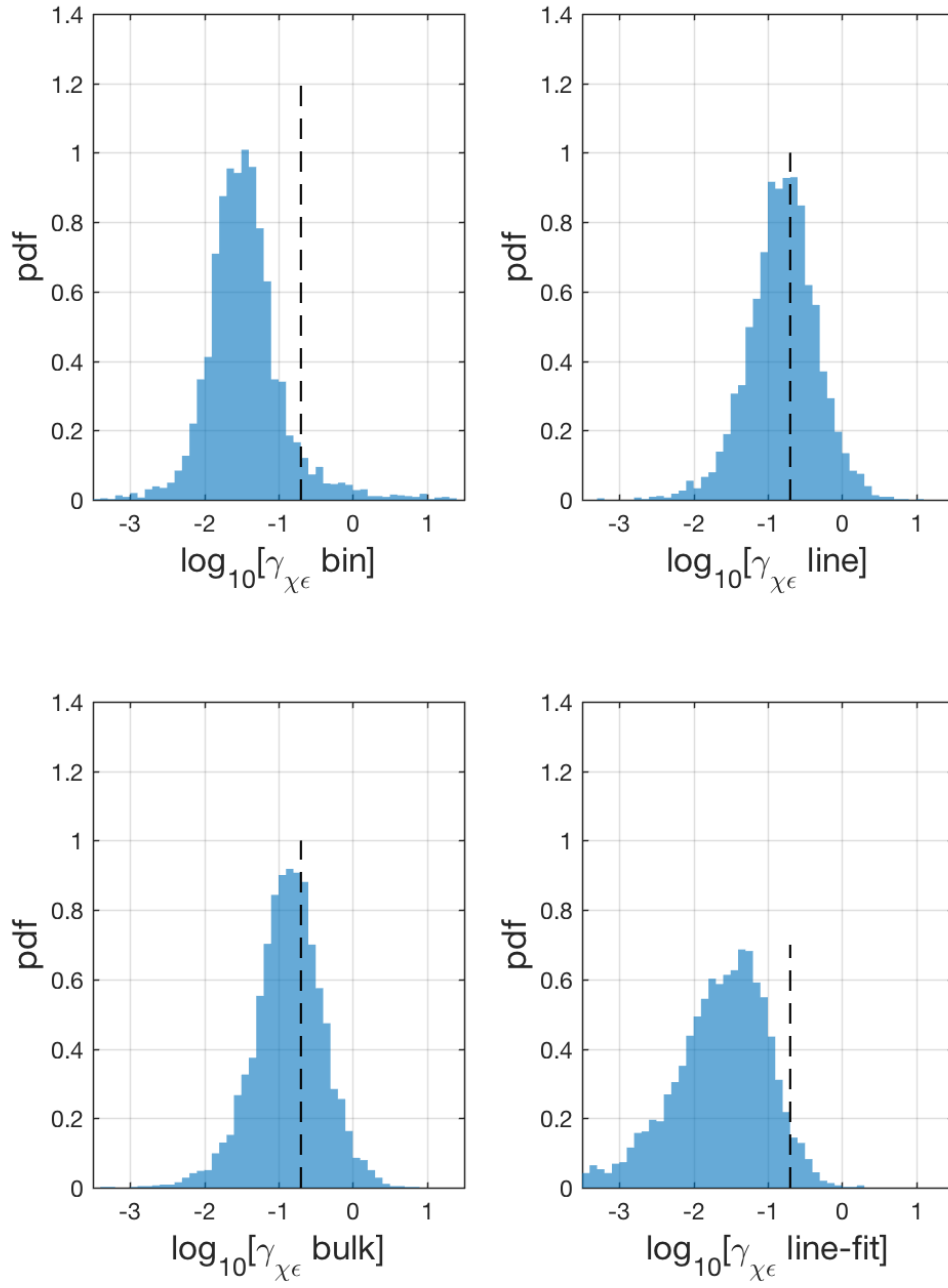


Figure 3: Histogram of  $\gamma_{\chi\epsilon}$  for patches, using different estimates of  $N^2$  and  $T_z$ . Vertical dashed line shows  $\gamma = 0.2$ . For all profiles, all depths.

#### 4.1 Using smaller fmax?

I believe the Chameleon data processed by Sally used the standard  $f_{\text{max}}=32\text{Hz}$  correction/cutoff for the thermistor data. However when I was trying to apply the  $\chi\text{pod}$  method to that data, I looked at some spectra and it looked like the thermistor rolled off much lower, around maybe 7-10hz. So I re-ran the processing using  $f_{\text{max}}=7\text{hz}$ . Estimates of  $\gamma_{\chi\epsilon}$  are about 2-3 times larger (Figure 4), but still significantly less than 0.2 .

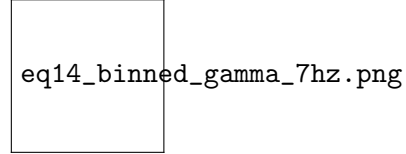


Figure 4: Histogram of  $\gamma_{\chi\epsilon}$  for 1m avg chameleon profiles, for standard  $f_{\text{max}}32\text{hz}$  as well as  $f_{\text{max}}7\text{hz}$ . Vertical dashed line shows  $\gamma = 0.2$ .



## 4.2 Variation of $\gamma_{\chi^\epsilon}$ with epsilon

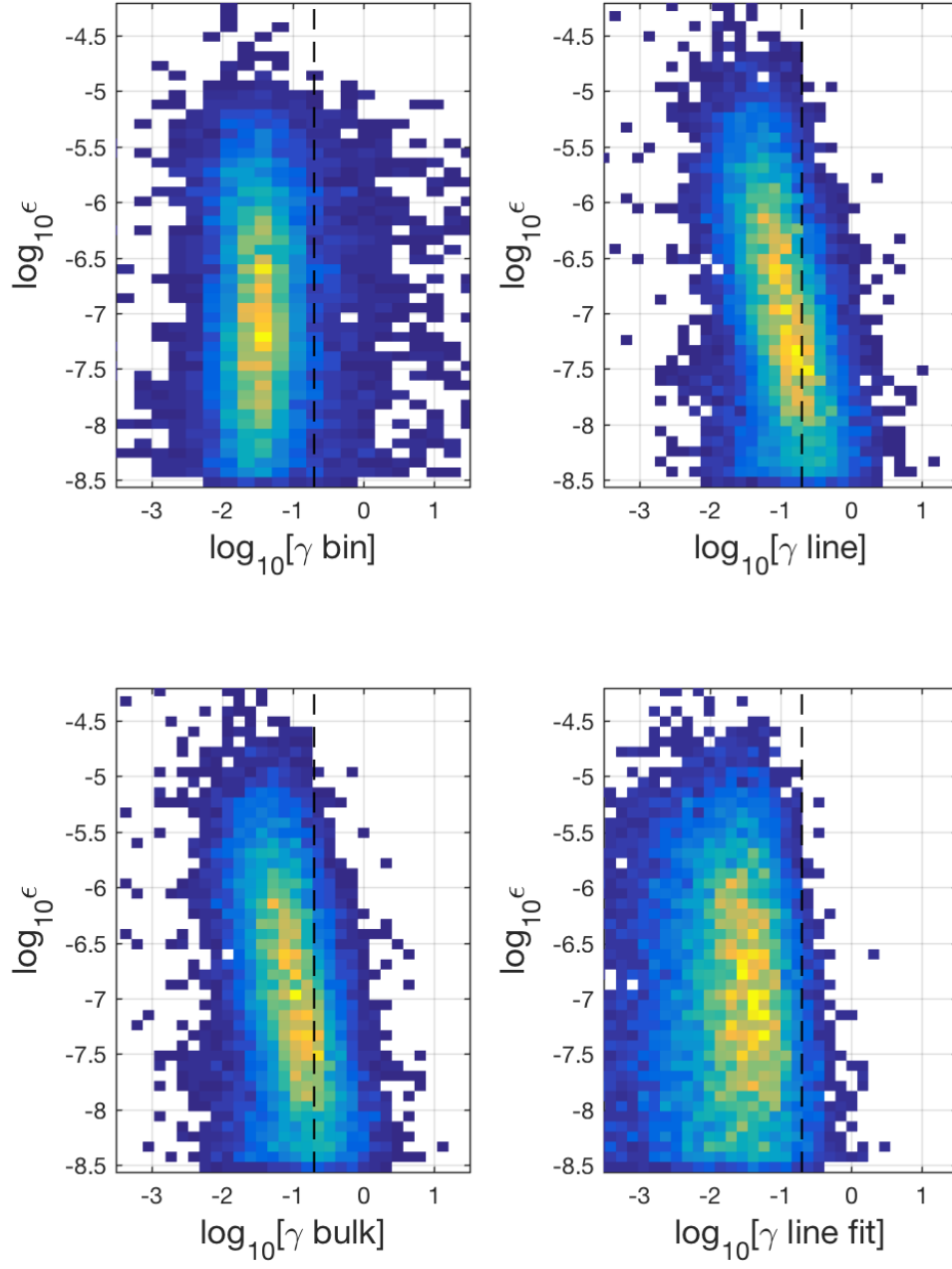


Figure 5: Plot of  $\gamma_{\chi_\epsilon}$  for patches vs epsilon. Vertical line is  $\gamma = 0.2$ .

### 4.3 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 6).

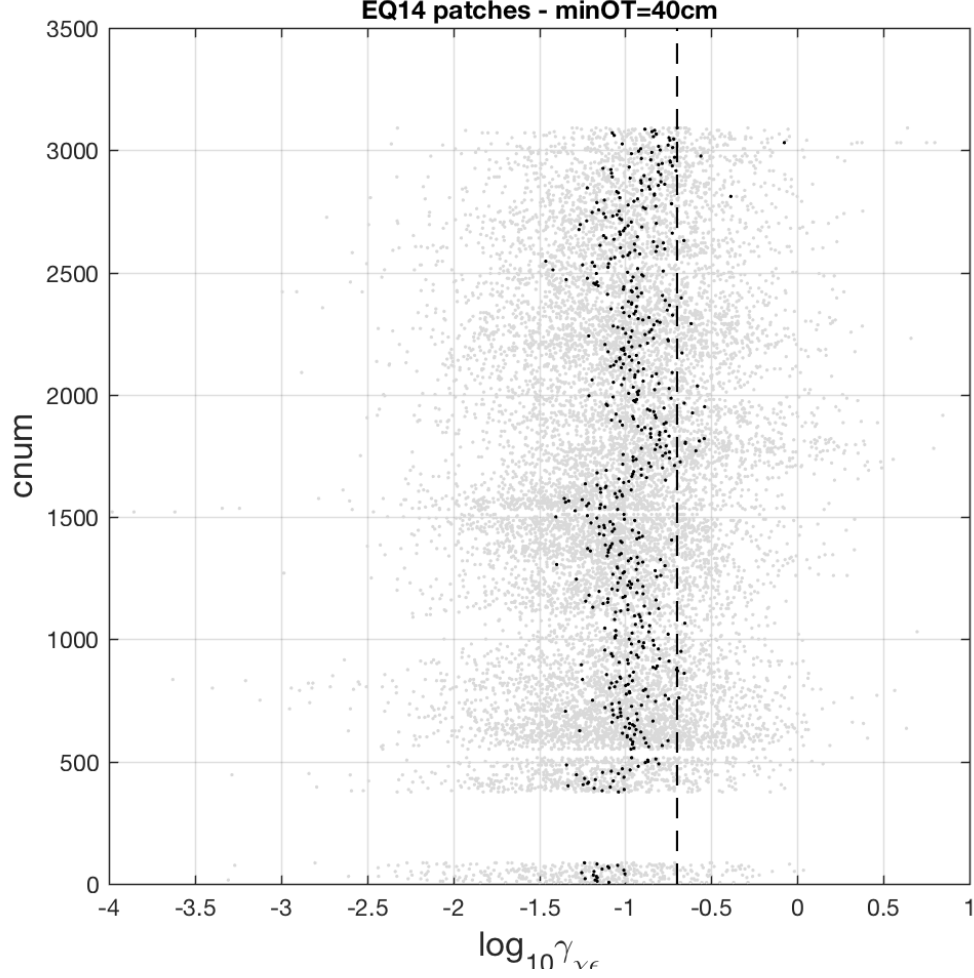


Figure 6: Plot of  $\gamma_{\chi\epsilon}$  for patches vs cast number. Vertical line is  $\gamma = 0.2$ . Black points are the median value for each cast.

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

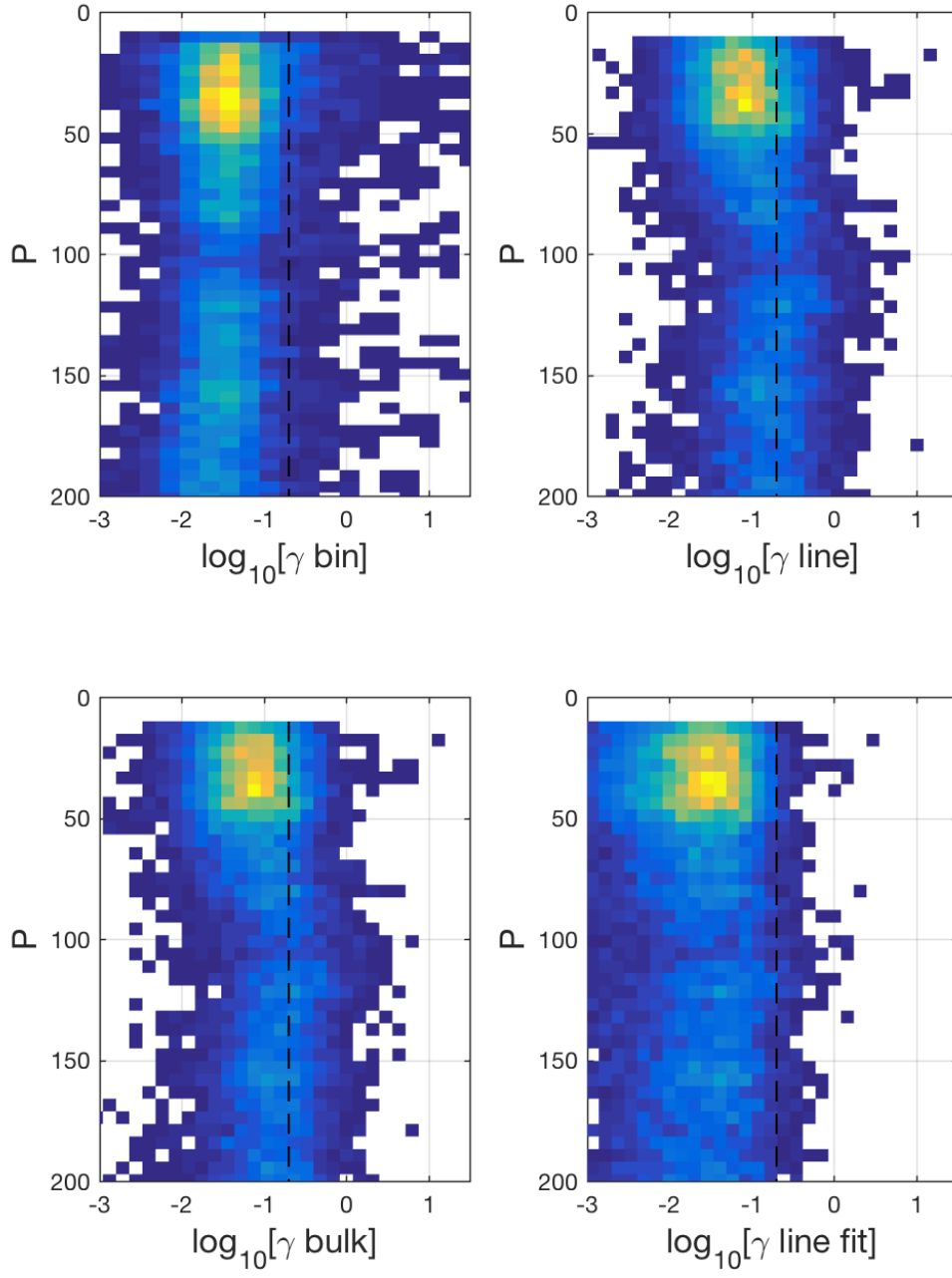


Figure 7: Plot of  $\gamma_{\chi^2}$  for patches vs depth. Vertical line is  $\gamma = 0.2$ .

## 5 Application of $\chi$ pod method to patches

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). The  $\chi$ pod method is applied in `ComputeChi_Chameleon_Eq14_PATCHES.m`, using  $N^2$  and  $T_z$  from patches. It was done using both the actual  $\gamma$  from patches to test, and a constant  $\gamma = 0.2$ . All the profiles are combined into one structure in `Combine_ChipodMethodPatches.m`.

- The magnitudes of  $\chi$ pod estimated  $\epsilon$  for patches are closer to the actual chameleon values when using patch vs binned data (Figure 8, lower panels). However, the slope appears to be less than one for the patch estimates (lower right panel).
- The ratio of  $\chi$ pod estimated  $\epsilon$  to chameleon  $\epsilon$  (Figure 9) is improved when using patches instead of binned data.
- \*\* checking if bulk vs line makes a difference \*\*

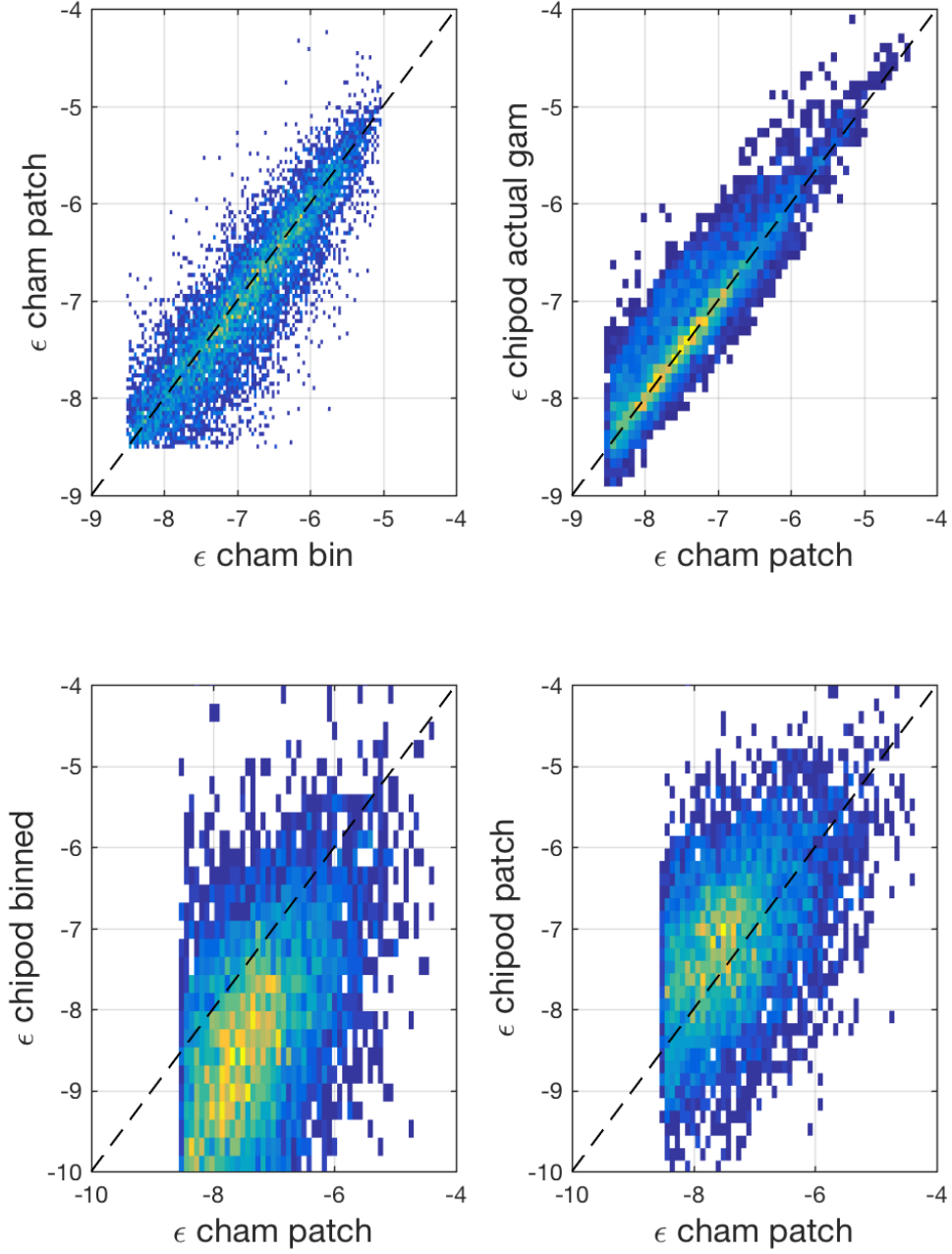


Figure 8: Comparison of  $\epsilon$  from chameleon and  $\chi$ pod method applied to patches. (Top-left) Comparison of  $\epsilon$  from patches to binned  $\epsilon$  interpolated to patch locations. (Top-right)  $\epsilon$  from  $\chi$ pod method using actual patch  $\gamma$  to patch  $\epsilon$  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.

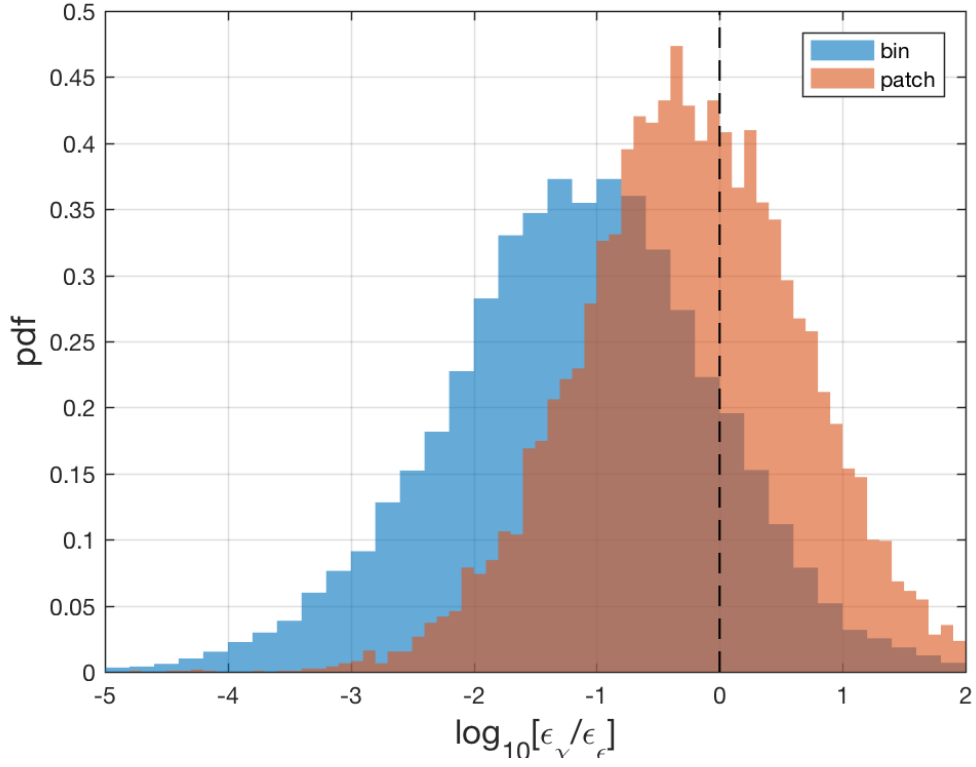


Figure 9: Histogram of  $\log_{10}$  of the ratio of  $\chi$ pod estimated  $\epsilon$  to chameleon  $\epsilon$  for patches, for both binned data (interpolated to patch locations), and using only patch data.



## 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 close to 0.1.