

Interactive comment on “The von Kármán constant retrieved from CASE-97 dataset using a variational method” by Y. Zhang et al.

Y. Zhang et al.

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First of all, we would like to thank the reviewer for his comments and suggestions. In response to the reviewer's comments, we have made relevant revisions on the manuscript. Listed below are answers and changes made to the manuscript according to the questions and suggestions given by the reviewer. The original comments and questions from the reviewer are listed on the first follow by our responses.

1. Is the difference between $\kappa = 0.39$ and 0.40 significant, considering the measurement errors?

The measurement errors were considered in the variational computation by introducing the dimensionless weights for wind, air temperature and humidity profiles in the cost function Eq. (1), defined to be inversely proportional to their respective observation

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error variances. This is one of advantages of the variational technique. After relaxing the constraint $0.35 \leq \kappa \leq 0.45$ imposed to the variational calculation, we obtain a kappa value at 0.384. Thus the variational computed kappa value with and without the constraint ranges from 0.384 to 0.390, just within the error range of Andreas et al's (2006) value at 0.387 ± 0.003 . This point has been added to the revised paper. We further estimated the statistical difference between variational computed kappa values and the kappa value at 0.4, which is determined using a t-test. Based on the calculation, the statistic t under the null hypothesis H_0 is equal to 6.27 ($> t_{0.005/2} = 2.6$) with the statistically significant level of 99.5%. This suggests that the statistical difference between kappa values at 0.39 and 0.4 is significant. These statements have been added to the revised manuscript.

2. Because the profiles are not linear, one might expect sensitivity to the choice of observation levels?

It is not clear if the variational calculated von Kármán constant would be sensitive to wind, air temperature and humidity profiles at different observation levels. The CASES-97 dataset provided only wind, air temperature and humidity at two vertical levels. Further study on this aspect is needed by using multiple levels observations. The reviewer's question has been addressed in the revised manuscript.

3. The imposed condition $0.35 < \kappa < 0.45$ probably strongly influences the results. Unless the distribution of kappa within this allowed range is strongly asymmetric, the mean value will be necessarily close to 0.40. Is it possible to put conditions on stability and/or nonstationarity instead of conditions on the von Kármán constant? I think some discussion would be helpful.

The imposed condition $0.35 \leq \kappa \leq 0.45$ was used only in the output of model result, rather than used in the variational calculation. Nevertheless, following the reviewer's suggestions and comments, additional computations were conducted to test the sensitivity of the von Kármán constant to atmospheric stability by relaxing the im-

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posed constraint $0.35 \leq \kappa \leq 0.45$. Instead, we simply impose a condition which requiring $\kappa \leq 0.6$. This yields κ values at 0.428 for stable condition and 0.340 for unstable condition. The mean κ value with total 3563 samples is 0.384 under all atmospheric stability conditions. We further relax all conditions that imposed to κ values and introduce constraints on stable atmospheric conditions by setting the Obukhov length $L > 10, 20, \dots, 10000$. Results show that the von Kármán constant tends asymptotically to 0.4 from very stable to neutral condition. A new paragraph and a new figure (Fig. 3 in the revised manuscript) describing and showing these results have been added to the revised manuscript.

4. If I understand correctly, the majority of the stable cases are rejected by the restrictions on κ . I think this is a very important finding. I agree with the authors that it is probably due to failure of Monin-Obukhov similarity theory, at least at the available observational levels. Since Monin-Obukhov similarity theory is generally applied in models to all conditions, further investigation of the frequent noncompliance cases would be valuable. Presumably the situation becomes rapidly more complex due to the influence of additional length scales. In addition, the relative insensitivity to the choice of the coefficients in the stability functions, found in the present analysis, probably breaks down. I realize this is a major task.

As the reviewer noticed, the determination of reasonable κ values was failed under the majority of stable conditions. As our response to the reviewer's question 3 and shown by new figure 3, if we use the restriction $0.35 \leq \kappa \leq 0.45$, κ values in the stable cases with L (Obukhov length) < 60 would be rejected. If we impose the condition $\kappa \leq 0.7$ in the variational calculation, we obtain $\kappa = 0.453$ for stable conditions. The number of samples satisfying the condition for the stable atmosphere ($\kappa \leq 0.7$) increases from 778 (for $\kappa \leq 0.6$) to 859. This suggests greater uncertainties in determination of the von Kármán constant in the stable boundary-layer compared with unstable conditions. It is important to indicate that, because the majority of the stable cases are rejected by the restrictions on κ in our calculations,

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the mean kappa value of 0.384 is, in reality, weighted to unstable conditions. These statements have been added to the revised manuscript. This is certainly a challenge to the application of Monin-Obukhov similarity theory. Analogous to our response to the reviewer's question 3, we have relaxed the constraint $0.35 \leq \kappa \leq 0.45$ imposed to the variational computed results but simply set a condition which only rejects calculated kappa values that are greater than 0.8, we found that under the unstable conditions $\kappa = 0.340$ using the first group of profile constants and 0.351 using the second group of constants. For the stable cases, $\kappa = 0.493$ using the first group of profile constants and 0.490 using the second group of constants. Nevertheless, we agree with the reviewer that further investigation of the frequent noncompliance cases need to be carried out.

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