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Atmospheric Chemistry and Physics Discussions



# *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, Prof. Foken, 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.

The flux-gradient similarity according to the Monin-Obukhov similarity theory depends on parameters which must be determined experimentally. These are the von-Kármán constant and the coefficients of the universal function and, in the case of the sensible and latent heat flux, the turbulent Prandtl and Schmidt numbers, respectively. The normal way to determine these parameters is firstly to use near neutral cases of the momentum flux to determine the von-Kármán-constant, and secondly to use near neutral cases of the sensible and latent heat flux to determine the turbulent Prandtl and Schmidt numbers. The third step is to use data of all stratifications to determine the coefficients of the universal function. The authors have done this the opposite way. They assumed correct coefficients of the universal function and determined errors in the von-Kármán-constant. The turbulent Prandtl and Schmidt numbers are ignored, while Businger et al. (1971) determined a turbulent Prandtl number of 0.74 (Foken, 2006). This can be done when the numbers are included in the universal function (Högström, 1988), but this was not done.

As the reviewer correctly indicated, we determined the von-Kármán constant in an opposite way by assuming that coefficients of the universal function were correct. In fact, though the focus of this study was on the estimate of the von-Kármán constant, we also intend to demonstrate the capability of variational method in retrieving parameters in Monin-Obukhov similarity relationships. It is deducible that, if the von Kármán constant (= 0.4) was assumed to be correct, we could also determine the coefficients of the universal function and Prandtl number in a similar manner as we did in this study. We agree with the reviewer that the turbulent Prandtl and Schmidt numbers could be included in the universal function. In the revise paper we have indicated this.

It is not understandable why the authors used, from the large amount of universal functions (Foken, 2008b; Högström, 1988) available, the universal function by Businger et al. (1971) with a von-Kármán-constant of 0.35, which was determined under non-ideal measuring conditions (Wieringa, 1980; Wyngaard et al., 1982) and was corrected by Högström (1988). The authors incorrectly tested their method with an independent universal function by Wieringa (1980), because this is the same function but re-determined with another von-Kármán-constant of 0.41.

The use of Businger et al. (1971)'s universal function was that this set of constants were widely used in micrometeorology. Nevertheless, following the reviewer's comments, in the revised paper we have used Högström's universal function = (19.3, 11.6, 6, 7.8) to recalculate the von Kármán constant in the variaiotnal method. The results



ACPD

8, S7191–S7195, 2008

Interactive Comment

showed almost no difference with the universal function by Businger et al (1971). In the revised manuscript we have deleted Fig. 3 of the previous version of the paper in ACPD and added a new figure 3 that presents the change in the von Kármán constant with the Obukhov length under stable surface boundary-layer using Högström&'s universal function. Foken and Högström's works in this aspect have been also cited in the references of the revised paper.

It is not possible to determine the latent heat flux from an energy balance calculation, because of the "unclosed" energy balance at the surface (Foken, 2008a). Furthermore the radiation sensors used are probably not of a high accuracy (Kohsiek et al., 2007). The input data for the latent heat flux have an error of at least 20 %.

To address the reviewer's point, in the revise paper we have added a new paragraph (the second paragraph from the bottom paragraph) in section 3. We indicated that, though there are some system errors, because the variational method minimizes the differences between the computed and the observed meteorological variables, it can adjust the computed flux toward the measured one. Through this process, the observed meteorological and surface conditions are sufficiently taken into account in the variational computation. In addition, as shown in Table 1 (the table has been recalculated), the elimination of Wh (the weight for humidity profile) had very little effect on calculation of the von Kármán constant.

The CASES-97 (Poulos et al., 2002) data set is, of course, one of the best of the last decade, but to use only two levels is not adequate. The ratio of the measuring heights (2 and 1 m) is much too low to determine gradients in the surface layer with a high accuracy (Foken, 2008b). Furthermore the lowest level can always be influenced by the roughness sublayer. This can only be checked if one has a profile with at least 4-5 levels. Furthermore any information about the canopy, the zero-plane displacement and the roughness height are missing. Therefore systematic errors can be assumed.

We acknowledge that the use of the CASES-97 data is likely a weakness of this work.



ACPD

8, S7191–S7195, 2008

Interactive Comment

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. One of consideration of using the CASES-97 data was that this dataset covered all stratifications and the diurnal variation of wind, air temperature and humidity profile was significant. We also intend to use the SHEBA data with multiple level measurements of wind, temperature and humidity. Further study on this aspect is planned. In the revised paper, the reviewer's concern has been addressed in a new paragraph. Because in the present study we used the information of wind, air temperature and humidity at the two measurement levels (1 and 2 m), the roughness length for momentum, heat and humidity as well as the zero-displacement height were not taken into account. These texts have been added in the revised paper.

Measurements under stable stratification need a very carefully conducted data analysis because of, for example, intermittencies or decoupling. Often a local Obukhov length must be used, and not the Obukhov length. For details about the determination of universal functions under these conditions see Handorf et al. (1999), Andreas et al.(2006; 2005) and others. Generally nothing is said about a data selection according to the fulfilment of turbulent conditions (Foken and Wichura, 1996).

If we impose the condition $k <= 0.7$ in the variational calculation, we obtain k = 0.453 for stable conditions. The number of samples satisfying the condition for the stable atmosphere ($k <= 0.7$) increases from 778 (for $k <= 0.6$) to 859. This suggests greater uncertainties in determination of the von Kármán constant in the stable boundary-layer compared with unstable conditions. In the revised paper, to address the reviewer's comment, we have added a new Fig. 3 illustrating the change in the von Kármán constant with the Obukhov length under stable stratification. As our above response to the reviewer, further study is planned using the SHEBA data (Andreas et al, 2006) which were collected under more stable conditions.

Högström (1996) found, after a very careful analysis of universal functions, that their



ACPD

8, S7191–S7195, 2008

Interactive Comment

accuracy for a given von-Kármán-constant of about 0.40 is, in a range of not very strong stable and unstable stratification, about 10-20 %. The authors found, for the opposite method of calculations for more neutral conditions, the same error. Therefore the results are absolutly not new, are based only on the Kansas experiment (Izumi,1971) and ignore many other experiments, and the method of calculation has many weaknesses. It may be interesting to use the variational method for different examples, which you have already done, but the determination of the von Kármán constant is probably not the best example.

We agree with the reviewer's comments. We did notice and cite Högström (1996)'s work. As we indicated, one of objectives in this study was to demonstrate the capability of variational method in retrieving parameters in Monin-Obukhov similarity relationships. As the reviewer indicated, this method indeed repeats and confirms Högström (1996) and Andreas et al (2006)'s finding, and therefore is useful. We have also inserted a new sentence in the end of the first paragraph of section "Concluding Remarks" to address this point. In fact, we have applied this method to retrieve the roughness lengths and heat fluxes (e.g., Ma and Daggupaty, 1999; Cao and Ma, 2005). More works using this method will be reported.

Minor remarks: What the authors call a universal function is the integrated form. This integration of the Dyer-Businger-type of universal functions was firstly done by Paulson (1970).

We agree!

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 13667, 2008.