Review on „Small-scale temperature fluctuations in atmospheric flows “

By Robert Grosz

I will begin with a brief summary of the work, supported by general comments and assessments. Finally, I will evaluate the work as a whole and try to place it in a broader context.

Introductory and motivation of the work

Before introducing and explaining the actual scientific fundamentals of his work, the candidate successfully illustrates the overarching problem with the help of a historical, artistic and philosophical excursion. The actual introduction then begins with a discussion of the spatial and temporal scales that play a role in moist convection, as well as a list of the most important measurement campaigns on this topic. Starting with a discussion of the larger scales, the focus is on how such patterns might change in a warming world. At this point, it remains interesting to see how the author will bridge the gap between the discussion on the significance of clouds and convection patterns in a warming world and the small-scale turbulent processes, which, judging by the title, will be the main focus of the work. This is solved in the following chapter on clouds, where the author bridges the gap between the large and smallest scales in the size range of the droplets themselves and explains the significance of humidity fluctuations for the activation of droplets and their growth.

In my opinion, the structure of Chapter 1 is unnecessarily complicated in some places, as it deals with many theoretical questions without first setting a clear direction for the paper. Why is the aim of the paper not stated at the beginning so that the reader understands why individual theoretical questions are dealt with in such detail? But that may also be a question of personal style.

Experimental setup and observations

The second chapter begins with a historical overview of the development of the UFT series at the University of Warsaw. It is impressive to see how these fast, cloud-compatible thermometers have been continuously developed over the last three decades, providing new insights into the temperature structures of warm clouds in particular. The groundbreaking idea of droplet separation before the actual sensor element is not explicitly highlighted and discussed here, but it elegantly solves a fundamental problem of temperature measurement in clouds.

The first temperature measurements presented and analyzed in this dissertation were carried out in the LACIS-T cloud simulator. After a general introduction to LACIS-T and the temperature measurements performed, the focus is placed on the geometric arrangement, as this will play an important role in the interpretation of the data. All UFT observations carried out within the scope of this work were primarily technical tests and were performed under dry, cloudless conditions.

Following LACIS-T, a second laboratory unit – the PI chamber – is presented in, in which high-resolution temperature measurements from the UFT series were carried out as part of this dissertation. Unlike LACIS-T, the PI Chamber takes a different approach and generates Rayleigh-Benárd convection based on adjustable temperature differences between the floor and roof. Temperature measurements were taken at different locations for three different temperature differences. These measurements were also carried out under dry conditions and were planned as measurements to characterize the turbulent temperature field in the PI chamber.

The third application of temperature sensors is the EUREC^{4}A field measurement campaign, which was conducted to describe observations in the cloudy boundary layer of the trade wind region. After a general introduction to EUREC^{4}A, the focus will be on the temperature measurements analyzed here using a small research aircraft. In order to distinguish measurements in clouds from droplet-free regions, the liquid water content is used as a key cloud parameter.

Following the general introduction of the three experiments in which the data basis for this work is described, Section 2.5 explains the technical processing of the data. This is done in detail, but the statement that 'The uncertainty of the temperature measurement is neglected in this study because the sensors are very accurate' is, in my opinion, somewhat provocative. From my own experience, I know that it is difficult to estimate the absolute accuracy of turbulence measurements of any kind, but at least the usable resolution should be estimated and specified. Below what value, for example, do the measurements become white noise?

Chapter 3 describes the actual measurements taken in this study, beginning with the experiments conducted on LACIS-T. One of the most important findings of this study is an asymmetry observed in the temperature fluctuations in the wind tunnel, the causes of which can unfortunately only be speculated upon. Whether these are purely technical causes or a phenomenon caused by the mixing of the two differently tempered flows remains open for the time being, which cannot be attributed to the author.

The next step is an impressively detailed spectral analysis that demonstrates the author's profound theoretical knowledge in this field. Averaged spectra (Fig. 3.5) show the same asymmetry as the skewness in Fig. 3.3, thus providing a consistent picture. The reasoning that the classic inertial range only covers a few centimeters due to the low Taylor-Reynolds number is plausible. Currently, attempts are being made to increase the inertial range with the aid of an active grid, and it remains to be seen what comparable spectra would look like at higher Taylor-Reynolds numbers.

In the further course of the study, the spectra are compared with various model spectra at great expense and their advantages and disadvantages are discussed. I find this section impressive because, due to the high spatial resolution of the measurements, it touches on spectral ranges that have remained hidden to me in the real atmosphere. The fact that these model spectra can reproduce the measured spectra is in itself a convincing result, and the only question that remains is whether they can now be used to better explain and understand the temperature field and its anomalies in LACIS-T.

The next chapter presents the results of the second laboratory experiment conducted for this dissertation in the PI chamber. The analysis of this experiment has already been published in a highly regarded journal, which highlights the author's ability to conduct independent scientific work; the complete manuscript is included in Appendix C. The analysis tools used to evaluate the measurements in the PI chamber are essentially identical to those used to analyze the measurements in LACIS-T, which is to be expected.

My only criticism at this point concerns the structure and presentation of the results. Perhaps this is necessary, but the inclusion of the accepted manuscript in an appendix and the references to figures in the appendix in the main text are somewhat complicated for the reader, as they have to flip back and forth, which sometimes disrupts the flow of reading. This means that the main topic of the dissertation is somewhat lost. In terms of content, only one question remains open for me: Why should the shorter time series (3 min) show greater variability than the longer time series over 19 min? At first glance, this seems somewhat surprising to me, but perhaps there is something I have not fully understood.

Following the two laboratory investigations, Chapter 4 presents the results of measurements taken in the actual cloudy boundary layer of the trade wind region. This chapter focuses on a single flight (F4), which is evaluated here in detail, while the others are presented in Appendix A as time series for overview purposes only.

In my opinion, the explanations for the temperature structures observed around and within the clouds are somewhat vague and rather speculative in places. For example, the instrumentation of the research aircraft should have made it possible to determine the buoyancy, and the vertical wind speed could also have provided information about the stage of development of the clouds at that time. Furthermore, I find the explanation for the negative temperature deviation when flying through clouds not entirely convincing.

The analysis of spatially high-resolution temperature structures in the cloudy boundary layer is essentially based on the dimensionless temperature dissipation rate and its spatial distribution. Although this newly introduced parameter is not particularly complicated in form, it represents an elegant way of making measurements under different conditions more comparable.

Unfortunately, the author remains somewhat speculative and vague at the end and concludes the analysis with statements such as *'Nevertheless, taking into account the analysed data and the averageRMSE size, the methodology used delivers satisfactory results with good efficiency.'* that do not exactly make it easier to classify the results.

The author himself summarizes the central findings of this part in two points:

First, the temperature dissipation rate spectrum can be effectively described by a power law, where the coefficients are related by a logarithmic relationship. Second, this relationship appears to be universal across the studied atmospheric flows.

In my opinion, these two findings are of great significance for describing the small-scale temperature structure in the (cloudy) atmosphere. Despite a few minor shortcomings in the description and logical structure of this chapter, these findings make a significant contribution to this field of research.

The fact that the results are not completely identical to those of the two laboratory investigations is certainly due, as the author points out, to the different methods of flow generation and thus to the way in which the temperature fluctuations are generated.

Summary and conclusion

I am convinced that the significance of this work will only become fully apparent when one considers that one of the biggest problems in cloud microphysics is determining the supersaturation field, which determines whether aerosol nuclei can condense into cloud droplets and whether and how quickly cloud droplets can grow. The detailed description of the temperature field addresses at least part of the problem. How this correlates with the moisture field on the smallest scales remains a challenge for future work.

In my opinion, the academic work presented here fully meets the requirements of a successful dissertation, and I therefore give it a positive assessment. Above all, the analytical tools used are very sophisticated and detailed and demonstrate a deep theoretical understanding. The impressive scope of the literature cited demonstrates thorough research into the topic. The fact that the key findings have been published in a peer-reviewed journal attests to the acceptance of the work within the academic community.

Only the sometimes very detailed analysis of the data using various numerical tools makes it somewhat difficult for the reader to get the core of the analysis and draw the essential conclusions in some places. However, this should only be seen as a suggestion for future work and not as a serious criticism of the present work.

I sincerely hope and encourage the author to publish further parts of this work in peer-reviewed journals in the near future, as I see a lot of potential in the measurements and analyses presented here.

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