Novel approaches to estimating turbulent kinetic energy dissipation rate from low and moderate resolution velocity fluctuation time series

Marta Wacławczyk[1*], Yong-Feng Ma[1], Jacek M.Kopeć[1,2], Emmanuel O. Akinlabi[1], and Szymon P. Malinowski[1]

[1]*Institute of Geophysics, Faculty of Physics, University of Warsaw, Pasteura 5*
marta.waclawczyk@igf.fuw.edu.pl
[2]*Interdisciplinary Centre of Mathematical and Numerical Modelling, University of Warsaw, Pawińskiego 5a*

Introduction

In this work we propose two approaches to estimating the kinetic energy dissipation rate, based on the zero-crossing method [1]. The original formulation requires a fine resolution of the measured signal, down to the smallest dissipative scales. However, due to finite sampling frequency, as well as measurement errors, velocity time series obtained from airborne experiments are characterized by the presence of effective spectral cut-offs. In contrast to the original formulation the new approaches are suitable for use with signals originating from such experiments.

In the literature, there exist several different methods to estimate ϵ from the measured velocity signal. The so called indirect methods are based on the scaling of structure function (SF) or power spectral density (PSD) in the inertial range. Another, direct method is the zero- or threshold-crossing method [1], where the signal zero- or threshold crossing events are counted. Their mean number per unit length N_L is related to the turbulent dissipation rate. The direct methods require the measured signal should be resolved down to the smallest scales. Although this is not the case for moderate-resolution flight measurements, interestingly, the dissipation rates estimated from such N_L, although largely underpredicted appear to be proportional to ϵ calculated from the inertial range scaling [3]. This led us to a question whether it would be possible to modify the zero-crossing method such that it can also be applied to moderate- or low-resolution measurements.

Zero-crossing method for low and moderate resolution time series

In this work we propose two possible modifications of the zero-crossing method. The first one is based on a successive filtering of a velocity signal and inertial-range arguments. In the second approach we use an analytical model for the unresolved part of the spectrum and calculate a correcting factor, such that the standard relation between ϵ and the number of zero-crossings can be used. The fittingness of the new approaches is tested using measurement data obtained during the Physics of Stratocumulus Top (POST) airborne research campaign [2] and data from Direct Numerical Simulations (courtesy Prof. J.-P. Mellado from the Max Planck Institute for Meteorology). Results from POST campaign data are presented in Fig. 1 and compare well with ϵ estimates using standard methods.

Possible advantages of the new approaches, like the increased robustness of ϵ retrieval and different response to errors due to finite sampling and finite averaging window will be discussed during the presentation.

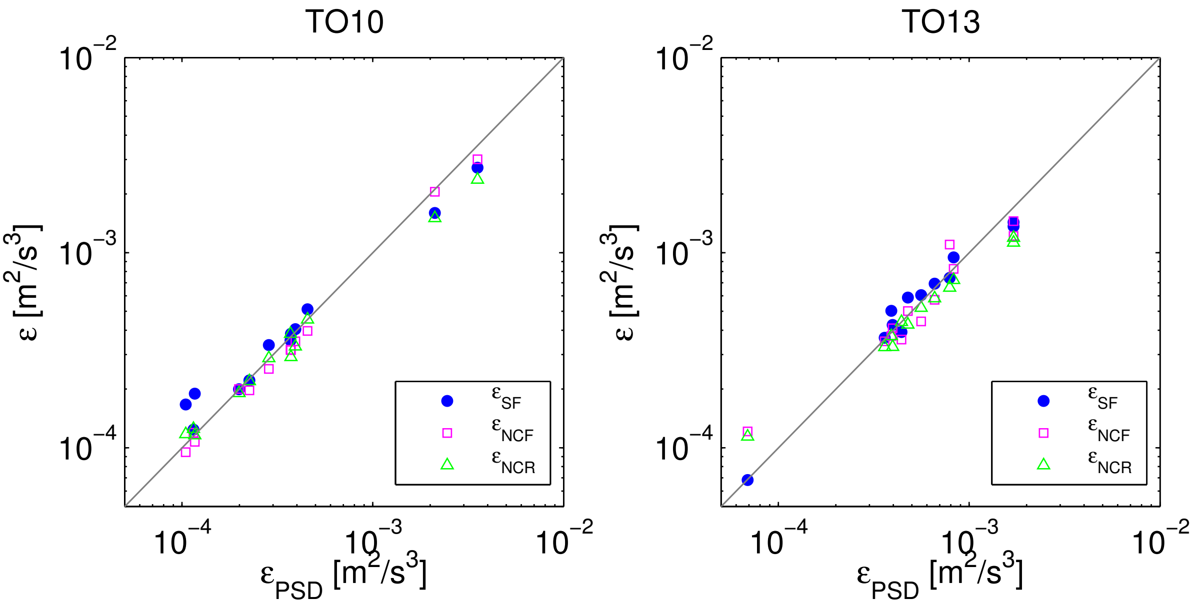

Figure 1: Dissipation rate of the kinetic energy estimated from the structure function method ϵ_{SF}, zero-crossings of successively filtered signals ϵ_{NCF} and zero-crossings of signals with recovered part of the spectrum ϵ_{NCR} as a function of ϵ_{PSD} (from power spectra method). Each point represents a single segment of flight from POST campaign [2], a) flight 10, b) flight 13.

References

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