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Detecting non-equilibrium states in atmospheric turbulence.

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In this work we show how to retrieve information about temporal changes of turbulence in the atmosphere based on in-situ wind velocity measurements. The performance of our method is illustrated with the use of high-resolution data taken by a helicopter-borne platform ACTOS (Airborne Cloud Turbulence Observation System) in stratocumulus-topped boundary layer (STBL).

Atmospheric turbulence is a complex phenomenon, characterized by the presence of a plethora of scales (eddies). Turbulence may undergo large space and time variations due to rapidly changing external conditions, it may be locally suppressed or enhanced. To describe characteristic features of turbulence, statistical theories are sought for. In this context, a number of recent research works address the problem of the equilibrium Taylor's law and its failure in the presence of rapid changes of the system. A new, non-classical, although universal scaling is introduced to describe the latter.

In this work we calculate two non-dimensional indicators, the dissipation factor and the integral-to-Taylor scale ratio and study their dependence on the Taylor-based Reynolds number. By analysing these results we can identify regions where turbulence is in its stationary state, with production balancing the dissipation and regions where turbulence decays in time or, on the contrary, becomes stronger. We also detect non-equlibrium turbulence states which indicate the presence of rapidly-changing external conditions. In this case the investigated statistics do not follow the equilibrium Taylor's law, but both, the dissipation factor and the integral-to-Taylor scale ratio become inversly proportional to the Taylor-based Reynolds number.

The presence of non-equilibrium turbulence in the atmospheric boundary layer has important implications, as it indicates that common turbulence closures may fail to predict the dynamics of such systems correctly. Incorporating non-equilibrium effects to turbulence models may largely improve their predictions.