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Persistence analysis in convective turbulence

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Persistence is defined as the probability that the local value of a fluctuating field remains at a particular state for a certain amount of time, before being switched to another state. The concept of persistence has been found to have many diverse practical applications, ranging from non-equilibrium statistical mechanics to financial dynamics to distribution of time scales in turbulent flows and many more. In this study, we carry out a detailed analysis of the statistical characteristics of the persistence probability density functions (PDFs) of velocity and temperature fluctuations in the surface layer of a convective boundary layer, using a field-experimental dataset. Our results demonstrate that for the time scales smaller than the integral scales, the persistence PDFs of turbulent velocity and temperature fluctuations display a clear power-law behavior, associated with a self-similar eddy cascading mechanism. Apart from that, we show that the effects of non-Gaussian temperature fluctuations act only at those scales which are larger than the integral scales, where the persistence PDFs deviate from the power-law and drop exponentially.

To advance our knowledge, we also investigate how the turbulent structures associated with velocity and temperature fluctuations interact to produce the emergent flux signatures, a vexing problem but of paramount importance for a plethora of applications, encompassing both engineering and Earth sciences. We discover that the persistence patterns for heat and momentum fluxes are widely different. Moreover, we uncover the power-law scaling and length scales of turbulent motions that cause this behavior. Furthermore, by separating the phases and amplitudes of flux events, we explain the origin and differences between heat and momentum transfer efficiencies in convective turbulence. In summary, our findings provide a new understanding of the connection between flow organization and flux generation mechanisms, two cornerstones of turbulence research.