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# Quantification of non-stationarity across the scales of turbulence with information theory

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## ABSTRACT

We propose a multiscale statistical characterization of the stationarity of a stochastic process  $X_t$  based on Shannon information theory. For this, we introduce an index  $\Delta^{(\tau)} = H(\delta_\tau X_t) - h^{(\tau)}(X_t)$  that focus on the difference between: 1) the entropy of the increments of the stochastic process,  $H(\delta_\tau X_t)$ , that measures the information contained at the scale  $\tau$  as defined by the increment  $\delta_\tau X_t = X_t - X_{t-\tau}$ , and 2) the entropy rate  $h^{(\tau)}(X_t)$  of the process, that measures the extra information in the variable at time  $t$  that is not present at time  $t - \tau$ . By varying the scale  $\tau$ ,  $\Delta^{(\tau)}$  quantifies the stationarity of  $X_t$  at the scale of analysis. Consequently, this index is a multiscale quantity that is not restricted to specific statistical moments of the density distribution, nor to the covariance, but that probes the complete dependence structure of the stochastic process. We propose a characterization of the stationarity of the scales of turbulence based on this index. We study experimental turbulent velocity signals from channel flows at different Reynolds numbers.  $\Delta^{(\tau)}$  shows the non-stationary nature of the small scales of turbulence and the transition to stationarity at large scales of the order of the integral scale. Very interestingly,  $\Delta^{(\tau)}$  presents an universal behavior that is independent of both the experimental setup and the Reynolds number of the flow, see figure 1.

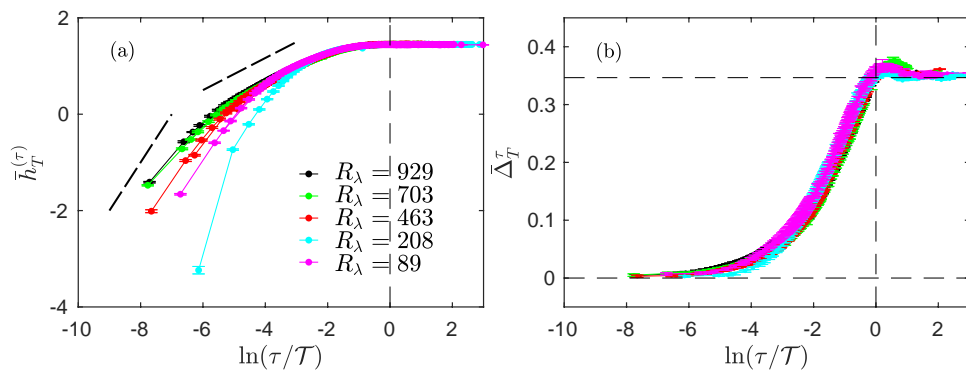


FIGURE 1. Entropy rate  $h^{(\tau)}$  (a) and index  $\Delta^{(\tau)}$  (b), in function of the analysed scale  $\tau$  for experimental turbulent velocity measures at different Reynolds numbers. The dotted straight lines in (a) have slopes 1 and 1/3. The horizontal dashed lines in (b) correspond to the values 0 and  $\ln(\sqrt{2})$ .

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