Scaling properties of irreversibility indices in fully developped turbulence

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In fully developed turbulence there is a flux of energy from large to small scales in the inertial range, associated with irreversibility, i.e. a breaking of the time reversal symmetry[1]. Such turbulent flows are characterized by scaling properties and we consider here how irreversibility depends on the scale. Two indicators of irreversibility for time series are tested involving triple correlations in a non-symmetric way. The first one proposed by Pomeau is[2]: $Po(r) =< X(t)X(t+r)X(t+3r) > - < X(t)X(t+2r)X(t+3r) >$, where r is an increment and $X(t)$ is the turbulent velocity which is stationary with zero mean. The second indicator has been proposed in the finance literature[3] and was called symmetric bicovariance function: $\gamma(r) =< X^2(t)X(t+r) > - < X(t)X^2(t+r) >$. For time reversible processes, both indicators are zero, whereas their departure from 0 is an indicator of irreversibility. In this work we study these indicators applied to a fully developped turbulent time series, possessing scaling properties and intermittency. The data which are used for the study have been produced in the wave and current flume tank of Ifremer Boulogne-sur-mer, recorded using LDV with a mean velocity of 0.8 m/s and turbulence intensity of 14 %. The characteristics of the flow are the following[4]: $\epsilon = 5.7 \times 10^{-3}\ m^2 s^{-3}$, $\eta = 0.14$ mm, $R_\lambda = 560$. The data have a doi and are freely available[5]. Figure 1a shows the scaling of the second order structure function and Fig 1b shows the indicator $\gamma(r)$ in log-log plot: irreversibility occurs in the inertial range and this indicator is scaling with a slope of 1.12, with a maximum value which is close to the injection scale. This shows that irreversibility has scale-invariant features and is related to the turbulent cascade.

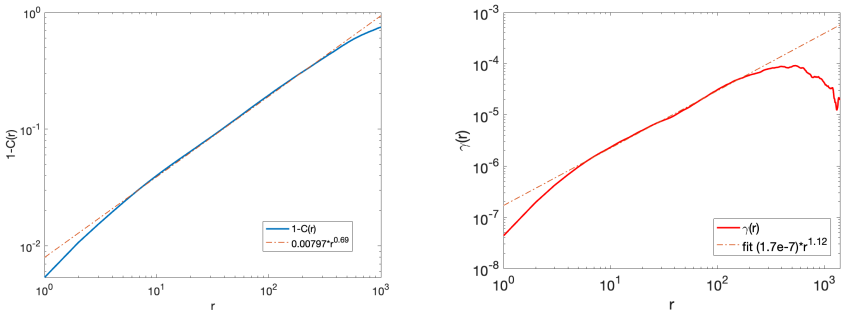

Figure 1: Left: $1-C(r)$ where $C(r)$ is the autocorrelation function, and a fit with slope 0.69, showing the scaling inertial range from $r = 0.04$ to 4s. Right: the irreversibility indicator $\gamma(r)$ in log-log plot with a fit with slope 1.12, found in the inertial range.

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