STATISTICS OF THE IRROTATIONAL FLOW REGION NEAR THE TURBULENT/NON-TURBULENT INTERFACE LAYER

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Free shear flows such as wakes, jets and mixing layers (as well as boundary layers) are characterised by the coexistence of turbulent (T) and irrotational (or non-turbulent - NT) flow regions, separated by a sharp turbulent/non-turbulent interface (TNTI) layer[1]. Several small scale features of these layers have recently been shown to be universal[2]. However, it is well known that large-scale features of the TNTI and its governing features are flow dependent[3], such as entrainment and spreading rates (*e.g.* planar jets grow faster than circular jets). In the present work we used new direct numerical simulations (DNS) of wakes, jets, and shear free turbulence (SFT - turbulence without mean shear) with Reynolds numbers of the order of up to $Re_\lambda \approx 400$, to assess the characteristics of the large scale motions of different flows near the TNTI layer. It turns out that the effects of the different flow types in the dynamics of the TNTI, are better assessed by observing the flow statistics in the NT region, whereas in the T region, the intense small scale turbulence fluctuations tend to blur these differences. Indeed, important potential velocity fluctuations exist in the NT region, induced by the large scale vortices from the T region. Moreover, predictions from rapid distortion theory (RDT) allow to highlight these diferences in the NT region.

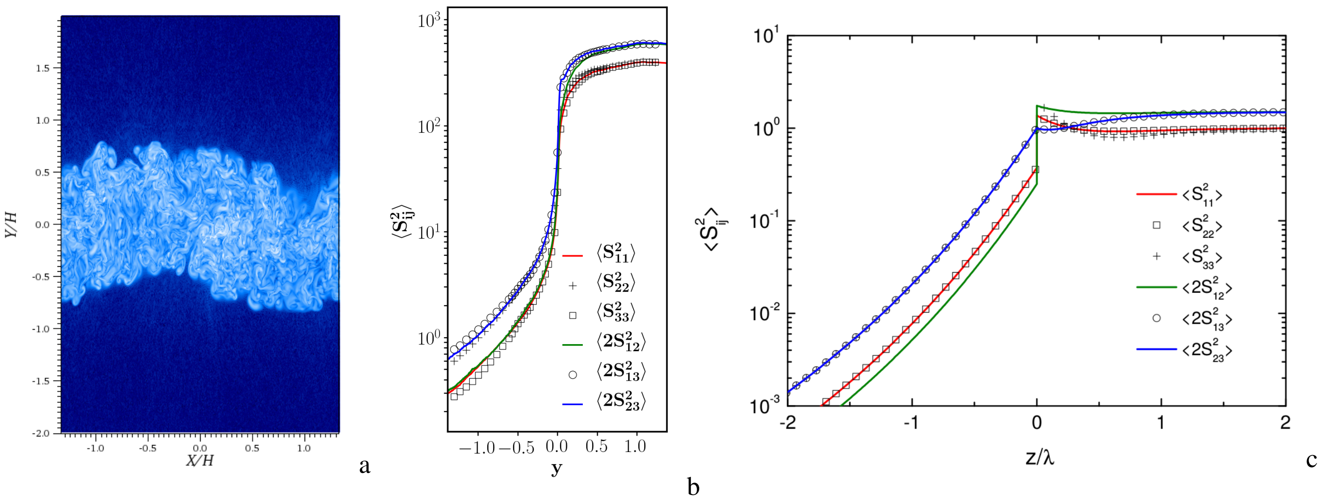

Figure 1. Side view of the contours of enstrophy in a SFT simulation (a), conditional mean profiles of strain components across the TNTI layer (the NT and T regions correspond to $y_I < 0$ and $y_I > 0$, respectively, as obtained from DNS (b); same as profiles predicted by rapid distortion theory (c).

Figure 1a shows a side view of the enstrophy in one of the SFT simulations, evidencing a sharp separation between T and NT flow regions. Figure 1b, displays conditional mean profiles of strain components S_{ij} computed as function of the distance from the irrotational boundary (IB), which is an outer surface delimiting the TNTI layer (in the NT side of the flow). The conditional mean profiles are carried out in a local coordinate system positioned at the IB, and the averaging is computed as function of the distance from the IB. In the T region the strain exhibit $\langle S_{11}^2 \rangle = \langle S_{22}^2 \rangle$ and $\langle 2S_{12}^2 \rangle = \frac{3}{2} \langle S_{11}^2 \rangle$ relations, as in isotropic turbulence. However, these are not observed in the NT region due to inhomogeneities, *i.e* mean shear arising from the large scales, which is flow dependent. Figure 1c shows the predicted profiles for the same flow obtained from RDT, showing a good qualitative comparison in the NT region.
The presentation will discuss how different flow features observed in the NT region can be linked to the different spreading and entrainment rates observed in different flow configurations.

References

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