Cheap turbulence modelling with quasi-singularities

Wandrille Ruffenach[1,2], Bérengère Dubrulle[2], Lucas Fery[2,3]

[1] Department of Physics, École Normale Supérieure de Lyon, 69364, Lyon, France
[2] SPEC/IRAMIS/DSM, CEA, CNRS, University Paris-Saclay, CEA Saclay, 91191 Gif-sur-Yvette, France
[3] Laboratoire des Sciences du Climat et de l'Environnement, CEA Saclay l'Orme des Merisiers, UMR 8212 CEA-CNRS-UVSQ, Université Paris-Saclay & IPSL, 91191, Gif-sur-Yvette, France

`wandrille.ruffenach@ens-lyon.fr`

Turbulent flow exhibit spatio-temporal intermittent energy dissipation and transfers. This makes their modelling challenging, as capturing these events require high temporal and spatial resolution. In this contribution, we present a cheap modelling strategy, using the scale separation between the large scale flow and these small scale extreme events. Specifically, we represent these events by localized Lagrangian quasi-singularities of vorticity. The dynamics of these particles is adapted from the vorton model of Novikov [1], to include self-regularization and interaction with a mean flow. As a first application, we consider the case where the large-scale is a pure shear flow. In that case, we observe a transition between a laminar regime where the regularization scale $\eta(t)$ grows like $\sqrt{t}$ and a turbulent regime in which η stabilizes at a statistically steady value solely determined by the Reynolds number. By construction, our modelling strategy is cheap and is yet able to reproduce key features of turbulence.

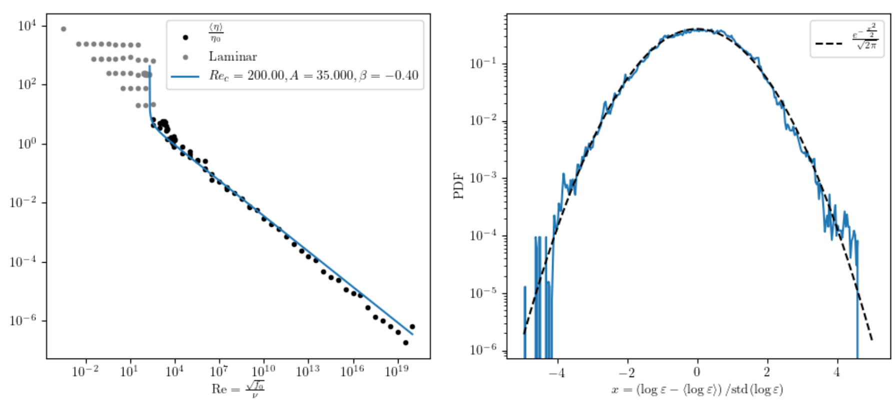

Figure 1. Left: Average regularisation lengthscale in the turbulent (black) and laminar (grey) states. In the laminar state, a plateau of order $\sqrt{\nu t_{simul}}$ is reached. Right: Lognormal behavior of the energy dissipation rate.

References

1. E.A. Novikov, Generalized dynamics of three-dimensional vortical singularities (vortons), *Zh Eksp Teor Fiz*, **84**, 981 (1983).
2. G. S. Winckelmans, Contributions to vortex particle methods for the computation of three-dimensional incompressible unsteady flows, *Journal of Computational Physics*, **109**, 247-273 (1993).