The Johns Hopkins Turbulence Databases (*JHTDB*)

FORCED ISOTROPIC TURBULENCE DATA SET

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The data is from a direct numerical simulation of forced isotropic turbulence on a 1024^3 periodic grid, using a pseudo-spectral parallel code. Time integration of the viscous term is done analytically using integrating factor. The other terms are integrated using a second-order Adams-Bashforth scheme and the nonlinear term is written in vorticity form[1]. The simulation is de-aliased using phase-shift and a $2\sqrt{2}/3$ truncation[2,3]. Energy is injected by keeping constant the total energy in modes such that their wave-number magnitude is less or equal to 2. More information about the data and sample analysis are provided in Ref. 3. After the simulation has reached a statistical stationary state, 5,024 frames of data, which includes the 3 components of the velocity vector, the pressure, and force[4] are generated and ingested into the database. The duration of the stored data is about five large-eddy turnover time.

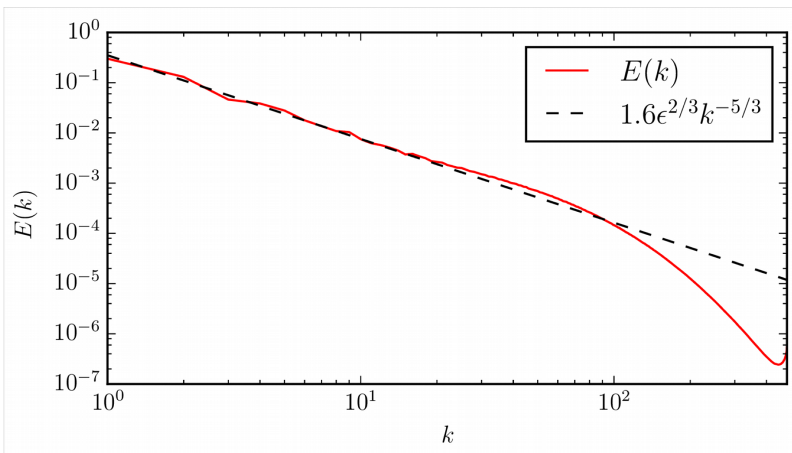
Simulation parameters:
Domain: 2π x 2π x 2π (i.e. range of x_1 , x_2 and x_3 is $[0,2\pi]$)
Grid: 1024^3
Viscosity (ν) = 0.000185
Simulation time-step Δt = 0.0002
Data are stored separated by δt = 0.002 (i.e. every 10 DNS time-steps is stored)
Time stored: between t=0 and 10.048 (5,024 time samples separated by δt)

Statistical characteristics of turbulence, time averaged over t=0 and 2.048:

Total kinetic energy, $E_{tot} = \left\langle \sum_{\mathbf{k}} \frac{1}{2} \hat{\mathbf{u}} \bullet \hat{\mathbf{u}}^* \right\rangle_{time}$:	$E_{tot} = 0.695$
Dissipation, $\varepsilon = \left\langle \sum_{\mathbf{k}} (\nu k^2 \hat{\mathbf{u}} \bullet \hat{\mathbf{u}}^*) \right\rangle_{time}$:	$\varepsilon = 0.0928$
Rms velocity, $u' = \sqrt{(2/3)E_k}$:	$u' = 0.681$
Taylor Micro. Scale $\lambda = \sqrt{15\nu u^2 / \varepsilon}$:	$\lambda = 0.118$
Taylor-scale Reynolds #, $\mathrm{Re}_\lambda = u\lambda/\nu$:	Re_λ =433
Kolmogorov time scale $\tau_\eta = \sqrt{\nu/\varepsilon}$:	$\tau_K = 0.0446$
Kolmogorov length scale $\eta = \nu^{3/4}\varepsilon^{-1/4}$:	$\eta = 0.00287$
Integral scale: $L = \frac{\pi}{2u^2}\int \frac{E(k)}{k} dk$:	$L = 1.376$
Large eddy turnover time: $T_L = L/u'$:	$T_L = 2.02$

Figures 1 and 2 show radial spectrum of E_{tot} and Figures 3 and 4 show time-series of the energy as well as Re_λ. The values corresponding to the data stored in the database are for t>0 and shown in solid lines. This dataset includes as stored variables the 3 velocity components, pressure, and the force. Information about the stored forcefield is provided in Appendix A of Yu *et al.* (2012).

An important remark relates to the accuracy of gradients computed using the finite-difference or spline-based operators available at JHTDB. During DNS, derivatives were evaluated using spectral methods based on FFTs (i.e., spatially global operations). When querying gradients via JHTDB, only spatially local operations are supported (otherwise the full 3D domain would have to be read from disk). Hence, at the relatively coarse DNS resolution used in the *1024isotropic* datasets, there is an inherent error (about 7% rms error) in gradient evaluation. Therefore, when evaluating the divergence or pointwise balance of all terms in the Navier-Stokes equations using these spatially more localized derivative operators, a non-negligible error can be expected.



\\ Figure 1: Radial kinetic energy spectrum, averaged in time between t=0 and 10.056.

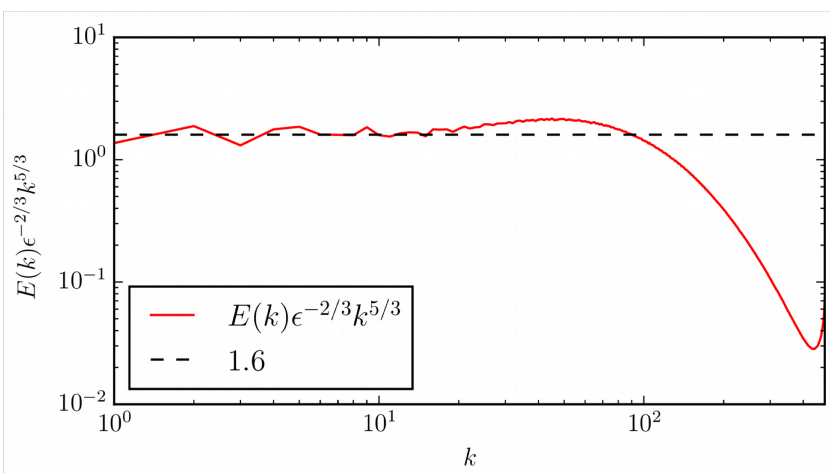


Figure 2: Pre-multiplied spectrum, averaged in time between t=0 and 10.056.

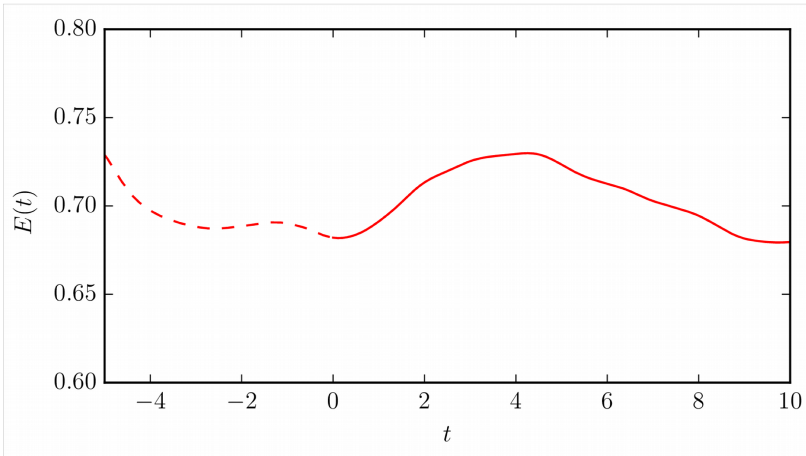


Figure 3: Total kinetic energy as function of time. Dashed line is times before ingestion into database. Data corresponding to the database is show using solid line between t=0 and 10.056.

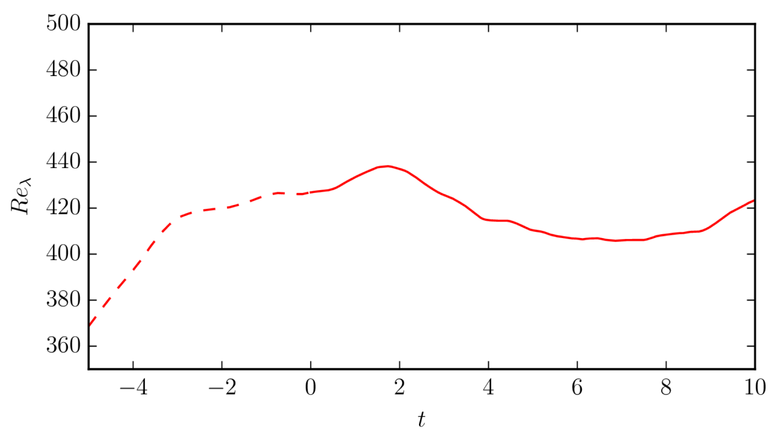


Figure 4: Taylor micro-scale Reynolds number as function of time. Dashed line is times before ingestion into database. Data corresponding to the database is show using solid line between t=0 and 10.056.

References:

1. Cao N.Z. and Chen S.Y., "Statistics and structures of pressure in isotropic turbulence". Phys. Fluids. **11**.2235-2250 (1999).
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3. Li, Y., E. Perlman, M. Wan, Y. Yang, C. Meneveau, R. Burns, S. Chen, A. Szalay & G. Eyink. "A public turbulence database cluster and applications to study Lagrangian evolution of velocity increments in turbulence", J. Turbulence **9**, No. 31 (2008).
4. Yu, H., Kanov, K., Perlman, E., Graham, J., Frederix, E., Burns, R., Szalay, A., Eyink, G. and Meneveau, C., "Studying Lagrangian dynamics of turbulence using on-demand fluid particle tracking in a public turbulence database". J. Turbulence **13**, N12 (2012).