Lattice Boltzmann and Pseudo-Spectral Methods for Decaying Turbulence

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We conduct a comparison of the lattice Boltzmann (LB) and the pseudo-spectral (PS) methods for direct numerical simulations (DNS) of the decaying turbulence in a three dimensional periodic cube. We use a mesh size of 128^3 and the Taylor micro-scale Reynolds number $24.35 \leq \mathrm{Re}_\lambda \leq 72.37$. All simulations are carried out to $t \approx 30\tau_0$, where τ_0 is the turbulence turnover time. We compare instantaneous velocity $\boldsymbol{u}$ and vorticity $\boldsymbol{\omega}$ fields, the energy $K(t)$, the dissipation rate $\varepsilon(t)$, the energy spectrum $E(k, t)$, the rms pressure fluctuation $\delta p(t)$, the pressure spectrum $P(k, t)$, and the skewness $S_u(t)$ and the flatness $F_u(t)$ of velocity derivatives. Our results show that the LB method compares well with the PS method in terms of accuracy: the flow fields and all the statistical quantities — except for $\delta p(t)$ and $P(k, t)$ — obtained from the two methods agree well with each other when the initial flow field is adequately resolved by both methods. Our results indicate that the resolution requirement for the LB method is $\eta_0/\delta x \geq 1.0$, where η_0 and δx are the initial Kolmogorov length and the grid spacing, respectively. The number grid points in each dimension required by the LB method is twice of what required by the PS method.