§16. Study of Statistics and Field Structure of Scalar Transfer by NS and MHD Turbulence by Using Parallel Massive Simulation

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Huge transport power and strong fluctuations which change with decrease in scales of space and time are characteristics of turbulence. An important nondimensional parameter in the problem of the scalar transfer in fluid and magneto hydrodynamics turbulence is the Schmidt number $Sc = \nu/\kappa$, the ratio of the molecular viscosity to the molecular diffusivity. When $Sc = O(1)$, the dissipation lengths for the velocity and scalar are of the same order, but for larger Schmidt number, the diffusive length $\overline{\eta}_B$ become smaller than the Kolmogorov length $\overline{\eta}$ according to $\overline{\eta}_B = Sc^{-1/2}\overline{\eta}$. Numerical simulation of the passive scaler for high Schmidt number requires very large computational resources when the spectral method is used. Since the spectral method uses FFT, it becomes less and less efficient on the many nodes machine because of large amount data transfer. Therefore there have been demands to develop an alternative way with the same accuracy but more efficient than the spectral method.

We have further proceeded in the development of the hybrid method for the scalar transfer in incompressible fluid turbulence in which the spectral method is used for the turbulence and the combined compact method is utilized for the passive scalar. The hybrid methods which use the 6th and 8th order combined compact scheme were tested for the decaying turbulence. It was found that when $Sc = 1$ the computational time was reduced by 25% and when $Sc = 50$ by 77%. The latter acceleration was achieved by reducing the number of grid points of the velocity because of smoothness of the velocity field in the viscous-convective range. As for the spatial accuracy, the scalar spectrum by the hybrid method is almost identical to the one by the spectral method with the twice number of grid points as seen in Figs. 1 and 2. We have applied this method to the problem of the scalar spectrum in the viscous-convective range at $Sc = 200$ and 1000, and we observed that the spectrum well followed the Kraichnan spectrum [1] as seen in Fig.3

$$E_\theta(k) = C_{\rm B}\overline{\chi}(\nu/\overline{\epsilon})^{1/2}k^{-1}\left(1 + (6C_{\rm B})^{1/2}k\overline{\eta}_{\rm B}\right) \times \exp\left(-(6C_{\rm B})^{1/2}(k\overline{\eta}_{\rm B})\right).$$

where $\overline{\epsilon}$ and $\overline{\chi}$ are the mean energy dissipation rate, the mean scalar variance dissipation rate, respectively. The non-dimensional constant C_B has been considered to be universal, but the definite value is still not known with enough accuracy.

We have tried to compute C_B and our tentative value is about 5, which is consistent with the previous numerical data 4.83 [2].

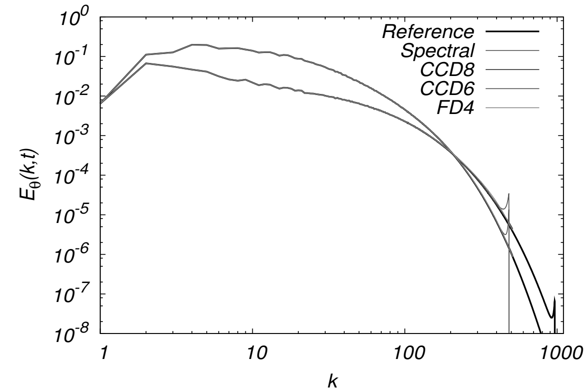

Fig. 1: Comparison of the spectra $E_\theta(k,t)$ at $k_0u_0t = 3.0, 6.0$ computed by using the Spectral, CCDn (nth order CCD), FD4 (4th order finite difference) .

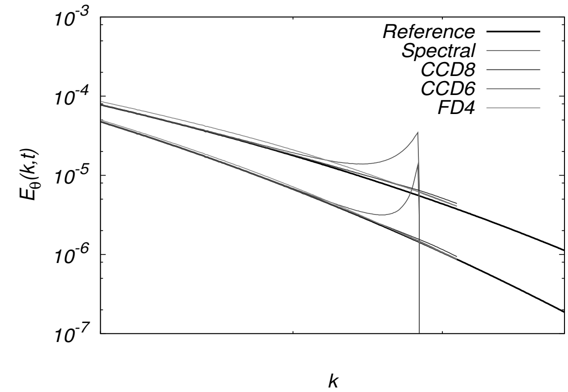

Fig. 2: Close up view of the spectra $E_\theta(k,t)$ at $k_0u_0t = 3.0.6.0$ near the cut off wavenumber.

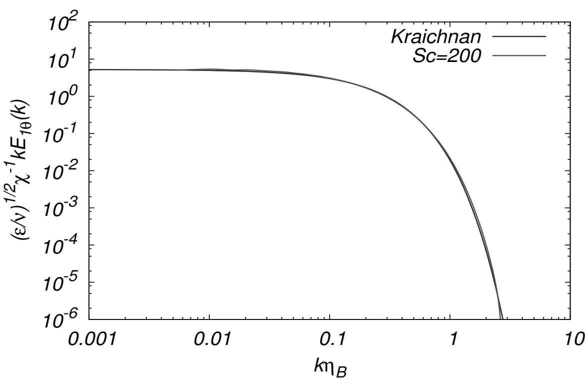

Fig. 3: Comparison of the one dimensional scalar spectrum at $Sc = 200$. Red: present DNS, Blue : Karichnan spectrum with $C_B = 0.53$

1) Kraichnan, R. H. J. Fluid Mech., (1974) **64**, pp.737-762.

2) Donzis, D. A., Sreenivasan, K. R., and Yeung, P. K. Flow, Turb. and Combust., (2010) **85**, pp.549-566.