Master "Turbulence"
TD: DNS and LES of Isotropic turbulence

Introduction

You must provide a report in PDF format with explanation for each question and clear figures (with adapted linear or log scales and adapted and readable legend). You must also provide a tar file (using tar -cvf my_directory) with the full code (without 3D results) used for each question as well as the output of the corresponding run (only the ascii information written on screen). **The quality of the report and the quality of the answers will be taken into account**.

Code and parallelization (~ 6 points)

A1) Write the equations which are solved and explained how they are solved (time and space disctretisation, how the pressure is solved, etc).

A2) Write your own routines for periodic saving of statistics (in a format allowing you to do some plots).

A3) Explain how the program is parallelized with OpenMP and write a short summary on the scaling efficiency by running the code sequencially and with an increasing number of cores (up to the maximum number of physical core of your PC). Provide a short table with the efficiency for "weak scaling" and "strong scaling". Optimize the parallelization efficiency by varying OpenMP parameters. Identify the weak points with low efficiency and explain how the global efficiency of the code could be improved.

Direct Numerical Simulations (~ 6 points)

B1) Simulate a DNS of **forced** isotropic turbulence (forced near k=2) with the highest possible Reynolds number on a grid ($256 \times 256 \times 256$) (or smaller if the simulation is too large for the computer) up to the convergence of statistics. You should first try to converge a simulation with half the resolution in each direction (which will be much quicker) and extrapolate the right parameters to perform a single final simulation at the highest resolution.

- Explain how to choose the Reynolds number and the viscosity to obtain a properly resolved DNS
- Plot time history of energy, Reynolds and different scales (Integral, Kolmogorov, Taylor, ...)
- Plot energy spectra during the convergence and averaged energy spectra after convergence (using log-log scale)
- Plot the averaged energy transfer spectra (after convergence)
- Give all available statistics at convergence (Reynolds, rms velocity, energy, scales, ...)
- Demonstrate the validity of the DNS

B2) Simulate a DNS of **forced** isotropic turbulence (forced near k=2) at Reynolds number 10 times larger than for question B1 but with a coarser grid ($64 \times 64 \times 64$).

- Plot the evolution of energy spectra in time
- Comment the results

return

Large Eddy Simulations (~ 8 points)

C1) Modify the code to implement the "**spectral eddy viscosity model**" (Chollet & Lesieur)

C2) Perform a Large Eddy Simulation of forced isotropic turbulence using the spectral eddy viscosity model at $Re_\lambda = \infty$ using the same forcing and initial random field than for B1) and using the same grid ($256 \times 256 \times 256$).

- Plot time history of energy, Reynolds and different scales
- Plot the time evolution of energy spectra during the convergence and the averaged energy spectrum after convergence
- Analyse your results and the performance of the LES models.

C3) Perform a Large Eddy Simulation of forced isotropic turbulence using the spectral eddy viscosity model using the same viscosity, the same forcing and the same initial field than question B1) but on a coarser grid ($64 \times 64 \times 64$).

- Compare the time history of energy, Reynolds and different scales with the equivalent DNS of question B1
- Compare the averaged energy spectra after convergence with the one of the equivalent DNS of question B1
- Analyse your results and the performance of the LES models.