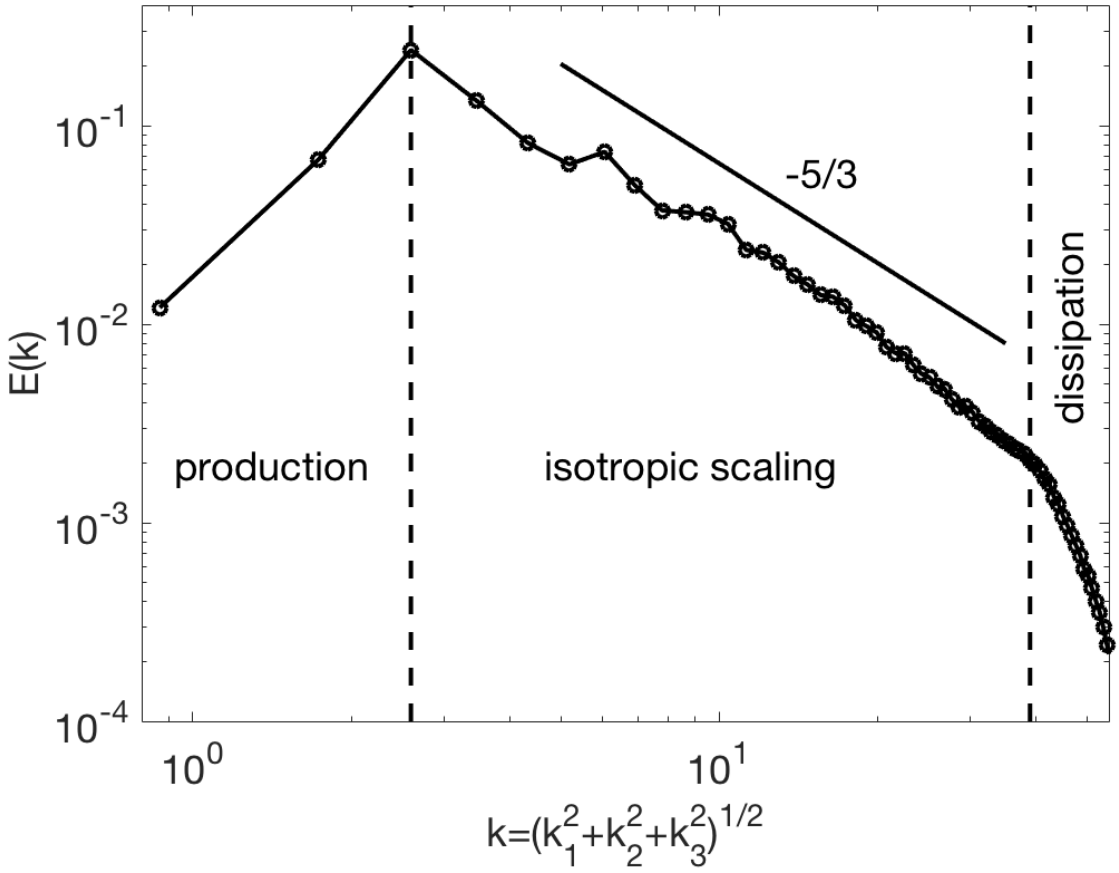
Large-Eddy Simulation of Turbulent Flows

ME EN 7960-003 | Homework #2 Solutions | Due: October 7th

1.) 3D Spectra

Using the isotropic turbulence direct numerical simulation (DNS) data *iso_vel128.mat* (located on Canvas or at http://gibbs.science/les/homework/iso_vel128.mat) from Lu et al. (2008) calculate the 3D energy spectrum function $E(k)$ where $k = \sqrt{k_1^2 + k_2^2 + k_3^2}$. Make a log-log plot of $E(k)$ vs. k. On the plot indicate the isotropic scaling range, the production range, and the dissipation range.

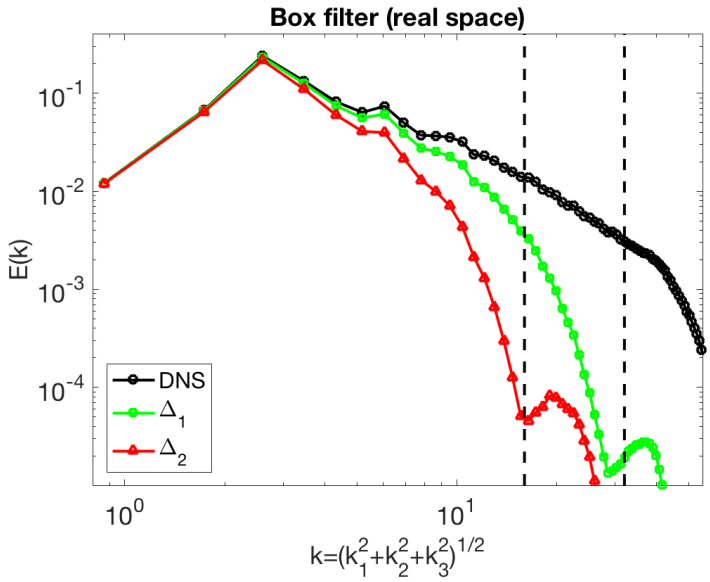


Your plot should look similar, although differences might arise depending on your choice of axes limits

2.) 3D Filtering: Real Space

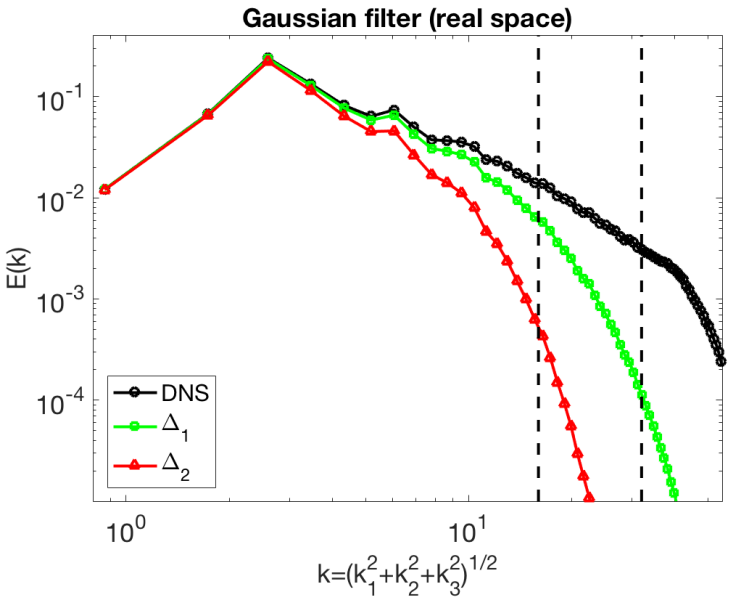
Using the data from problem #1 develop a program(s) that applies a 3D filter to the data in real space at two different scales (of your choice) using:

(a) a 3D spatial box filter



Box filter applied in real space at filter widths of 4Δ and 8Δ

(b) a 3D Guassian filter



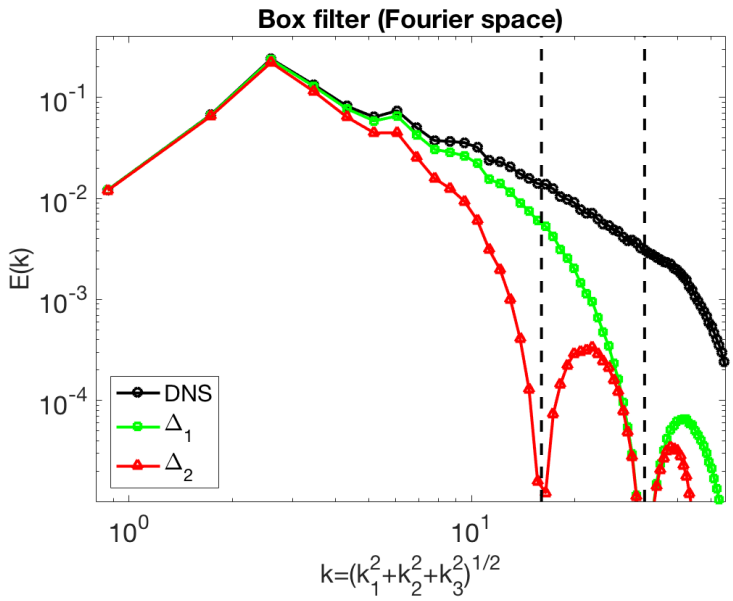
Gaussian filter applied in real space at filter widths of 4Δ and 8Δ

Present your results by plotting the 3D energy spectrum for each filter type at both filter scales along with the original (unfiltered) energy spectrum from problem #1. Make a separate plot for each filter type.

3.) 3D Filtering: Fourier Space

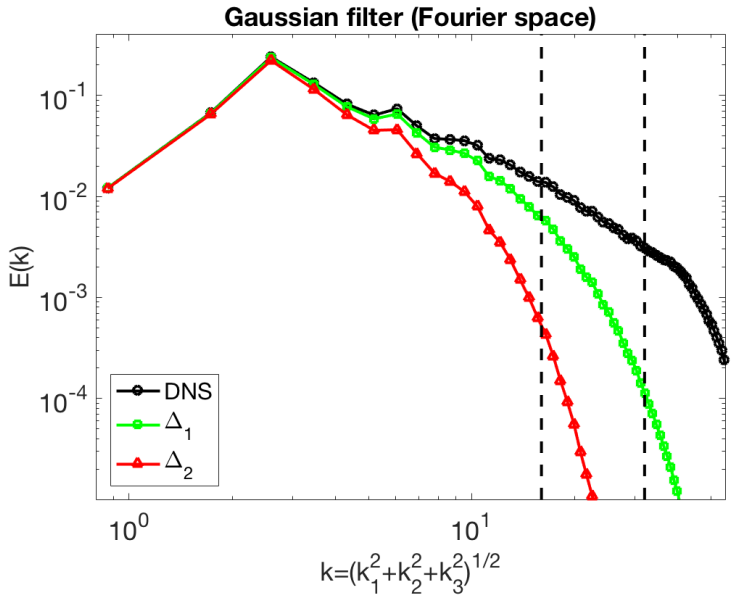
Using the data from problem #1 develop a program(s) that applies a 3D filter to the data in Fourier space at two different scales (of your choice) using:

(a) a spatial box filter



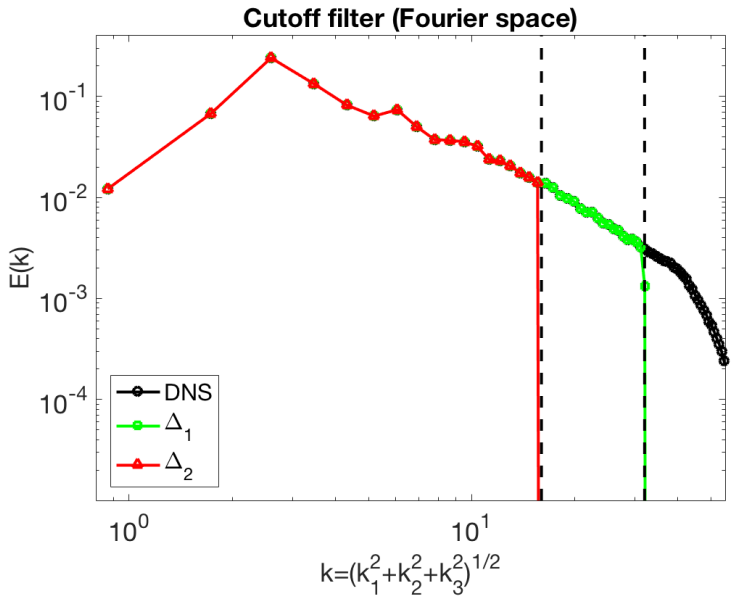
Box filter applied in Fourier space at filter widths of 4Δ and 8Δ

(b) a Guassian filter



Gaussian filter applied in Fourier space at filter widths of 4Δ and 8Δ

(c) a spectral cutoff filter



Cutoff filter applied in Fourier space at 4Δ and 8Δ

Present your results by plotting the 3D energy spectrum for each filter type at both filter scales along with the original (unfiltered) energy spectrum from problem #1. Make a separate plot for each filter type. For the spatial box filter and the Gaussian filter, compare the execution time for your programs from problems #2 and #3.

Times will vary, but you should have noted that real-space filters are more expensive that Fourier-space filters. In real space, a larger filter is more expensive and the Gaussian filter is more expensive than a box filter.