# CDNS or LES, that is the question.

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**Abstract**

The numerical simulation of turbulent flows remains a major challenge, especially at high values of the Reynolds number. While direct numerical simulation (DNS) is feasible at the expense of large computational resources for moderate Reynolds numbers. Developed turbulence is presently still out of reach. Over the last decades, large eddy simulation (LES) has become the efficient tool to tackle those flows, even in industrial applications.

In a LES, the dynamics of the gross structures of the flow is computed by integrating the filtered Navier-Stokes (NS) equations, while the fine structures of the flow that cannot be resolved by the computational grid are modeled. To obtain the LES equations, a low-pass filter built through a convolution operator is applied to the NS equations. In the context of high-order methods like the spectral element method (SEM), the LES implementation favors a complete disconnection between the LES model and the filtering procedure. For example, the dynamic Smagorinsky model may be chosen and the modal or nodal filters represent one of the basic features of the numerical procedure.

A fundamental issue of LES consists in checking the convergence of the model used with respect to some reference benchmark like experimental results or DNS data. Here the two DNS test cases are the lid-driven cavity (LDC) problem and the differentially heated cavity (DHC). Both problems were solved by a Chebyshev spectral method with discretizations resolving all spatial scales till the Kolmogorov scale. LES computations for the LDC are reported by Bouffanais and coauthors, while for the DHC they are detailed in Bosshard's thesis. The LES computations were compared with the DNS results; they showed excellent agreement for first-order statistics and very good concordance for the second-order statistics. Furthermore, in Bosshard, a convergence study is performed showing that when the number of LES grid points increases the LES results get closer and closer to the DNS results.

We want to examine another viewpoint of comparison between DNS and LES. Namely, we will consider the LES results as our test bench and the question examined is "Can a coarse DNS yield comparable results with the LES calculations?". Phrased another way, do we need a LES model if we can achieve the same results through an under-resolved or coarse DNS (CDNS)?