A spectral-element solver for LES of the atmospheric boundary layer

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Simulation of the diurnal cycle in the atmospheric boundary layer (ABL) is complicated by the multiscale processes that take place throughout the day. To date, the associated computational costs have prohibited their analysis by means of LES. The goal of this project is to start filling this knowledge gap, and, as first step in that direction, we are creating the necessary tools to conduct the simulations.

In particular, we are building a flexible and accurate LES solver, capable of massively-parallel runs. The solver is initially developed in the framework of the spectral-element code Nek5000, which has a decades-long track record as a tool for turbulence research. For ABL simulations, we have implemented appropriate subgrid scale models, and also wall modelling based on the Monin-Obukhov similarity theory.

Here, we present the validation study performed for the new solver, which includes results from neutral, stable[1] and convective[2] ABL simulations. We find good agreement with the literature for the collected statistical quantities, and capture the behaviour of the turbulent structures. Illustrative examples are provided in Figure 1. The left plot depicts inclined temperature fronts emerging in the stably-stratified ABL, whereas the right plot shows thermal plumes rising from the heated ground in a convective ABL.

a) b)

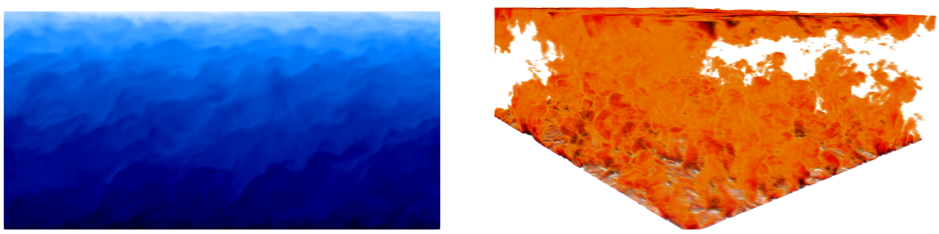

Figure 1: (a) Inclined temperature fronts in a stable ABL. (b) Turbulent thermal plumes in a convective ABL.

In the near future, we plan to transition development to a more modern code—Neko[3]—which is based on the same numerical methodology, but is capable of running on GPU-accelerated supercomputing clusters. Following that step, the design of the diurnal cycle simulations will be considered. At the same time, we will continue to investigate improvements to the numerical methodology, as well as subgrid scale and wall modelling.

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[1] Beare et al., *Boundary-Layer Meteorology* **118**, 247 (2006).
[2] Sullivan and Patton, *Journal of the Atmospheric Sciences* **68**, 2395 (2011).
[3] Jansson et al. DOI: 10.48550/arXiv.2107.01243