Enabling the use of unstructured meshes for the Large Eddy Simulation of stable atmospheric boundary layers

Ulysse Vigny [1,2], Léa Voivenel [3], Mostafa Safdari Shadloo [2,4], Pierre Bénard [2], and Stéphanie Zeoli [1]

[1]Fluid Machine Unit, University of Mons (UMONS), Mons, 7000, Belgium
[2]INSA Rouen Normandie, Univ Rouen Normandie, CNRS, Normandie Univ, CORIA UMR 6614, F-76000 Rouen, France
[3]CNRS, INSA Rouen Normandie, Univ Rouen Normandie, Normandie Univ, CORIA UMR 6614, F-76000 Rouen, France
[4]Institut Universitaire de France, Rue Descartes, F-75231 Paris, France

Correspondence: Ulysse Vigny (ulysse.vigny@umons.ac.be)

The authors wish to sincerely thank the reviewers and the associate editor for the globally positive feedback after the first round of reviews of this work. We have addressed all comments below and in the revised paper.

Associate editor

Comment 1*: Figure 2 in frame (a) you have units in italics; these should be normal text. In frame (b), the markers of the previous studies could be filled (and so change the x to another symbol and fill it) for better visualization. Also* U_{mean}*: you have use overbar or angles to describe means and here you have another notation.*

Units are now in normal text. The same notation for the time- and horizontally-averaged velocity is used. Markers are not filled because the test was inconclusive (see Comment 3).

Comment 2*: A column like table 2 will be better than a row like one*

Table 2 has been modified from a row table to a column table.

Comment 3*: Figure 3: similar as 1) for the markers. Also, the "grid" lines you use are too strong, can this made differently?*

Grid lines have been shaded. Tests with filled makers have been performed as shown by Fig. 1 but remain inconclusive to the authors point of view. We agree that Figure 3, 6 and 9 of the article do not allow for easy visualisation and identification of each study plot due to the large number of symbols. However, it still provides an global overview and the general trend of the results of previous studies. Depending on the Editor suggestion, the authors can integrate the filled markers figures into the article.

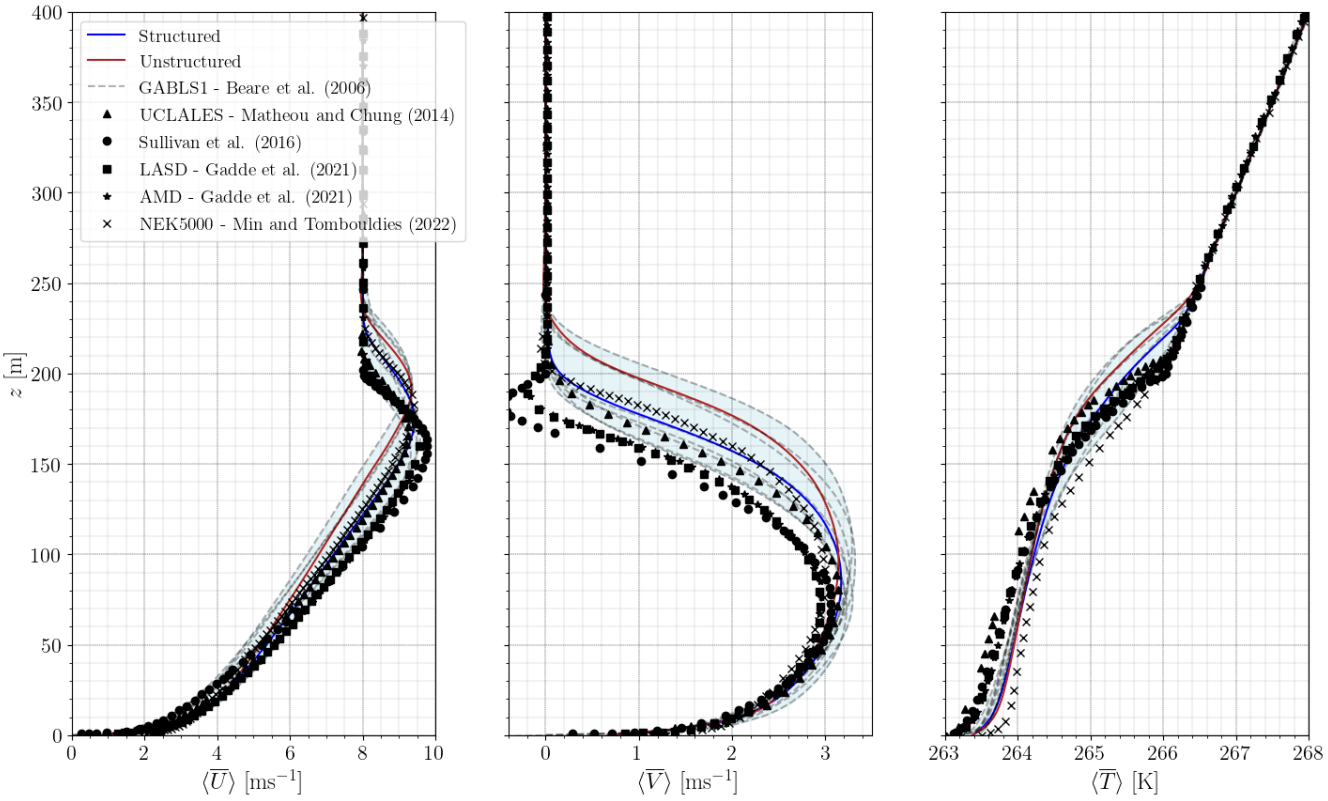

Figure 1. Time- and horizontally-averaged streamwise velocity, tangential velocity and temperature profiles, for meshes $S3$ and $U3$ with cell size $\Delta x = 3.125\,\mathrm{m}$. Markers are filled unlike Figure 6 in the body of the document.

Comment 4*: Figure 4 a: similar as with Fig. 2 frame a*

Done.

Comment 5*: Figure 5 and Fig. 6: similar issue with the markers*

Markers are not filled because the test was inconclusive. See Comment 3.

Comment 6*: Figure 8: have E(k) and k in the axes have units? Also, the legend should follow your previous convention so normal text*

Units for E(k) and k have been added. $E(k) \sim \mathrm{m^3 s^{-2}}$, $k \sim \mathrm{m^{-1}}$.

Comment 7*: Figure 10: Again too strong grid*

Figure 10 has been modified accordingly.

***Comment 8**: Figure 12: no italics for "time"*

Time is no more in italic in Figure 12 and 5.

***Comment 9**: Figure 13: units in U (colorbar) are not consistent*

Units have been modified accordingly.

Anonymous Referee #1

***Comment 1**: "Minor differences can be noted at higher frequencies where unstructured grid simulation exhibits a spectra that decrease faster than the structured ones, resulting in a lightly smaller maximum wave number. This discrepancy is probably due to the marginally smaller number of control volumes in the unstructured mesh. Velocity variance differences are thus not the result of inaccuracies in the energy cascade resolution." This statement is not supported by the evidence in Figure 8. Spectra for both structured and unstructured grid simulations extend to the wave number of about $\kappa = 0.8$, which means that the resolution of both simulations (grids) is comparable. Then, the explanation for the differences in spectral energy at high wave numbers can most likely be attributed to slightly greater numerical diffusion of the unstructured grid. Also, instead of "a spectra" it should be "spectra" and instead of "lightly smaller maximum wave number" it should be "slightly smaller magnitude at highest wave numbers."*

The authors agree with the comment and have corrected the Fig. 8 comments to the final version of the paper following reviewer's suggestions with a more accurate analysis.

***Comment 2**: In Figure 10, in addition to total and subgrid turbulent stress components shown are also resolved stress components already presented in Figure 9. It would be important that Figure 10 is of similar aspect ratio and style (light gray grid instead of black grid) as Figure 10.*

Figure 10 has been corrected accordingly, following the style of Fig. 9.

Anonymous Referee #2

***Comment 1**: Include the Kolmogorov -5/3 spectrum in Figure 8. In its current form, it is unclear whether the observed drop in spectral energy occurs within the inertial subrange of the flow, or at frequencies where neither grid adequately resolves the Kolmogorov spectrum. If the reduction in spectral energy occurs within the inertial subrange, this would imply that the effective resolution of the model varies with the unstructured grid, and this point should be explicitly acknowledged and discussed by the authors.*

We thank the reviewer for this valuable suggestion. Figure 8 has been updated to include the Kolmogorov $\kappa^{-5/3}$ reference slope in the inertial subrange. As shown in the revised figure, both structured and unstructured grid spectra follow the expected trend over a limited range of wavenumbers. The observed reduction in spectral energy for the unstructured grid occurs at wavenumbers beyond the inertial subrange, where neither grid fully resolves the smallest scales. Differences can be noted at higher frequencies where unstructured grid simulation exhibits spectra that decrease faster than the structured ones, resulting in a slightly smaller magnitude at highest wave numbers.