Assessment of Grey-Area Mitigation Techniques and their effects on Jet Aerodynamics and AeroAcoustics

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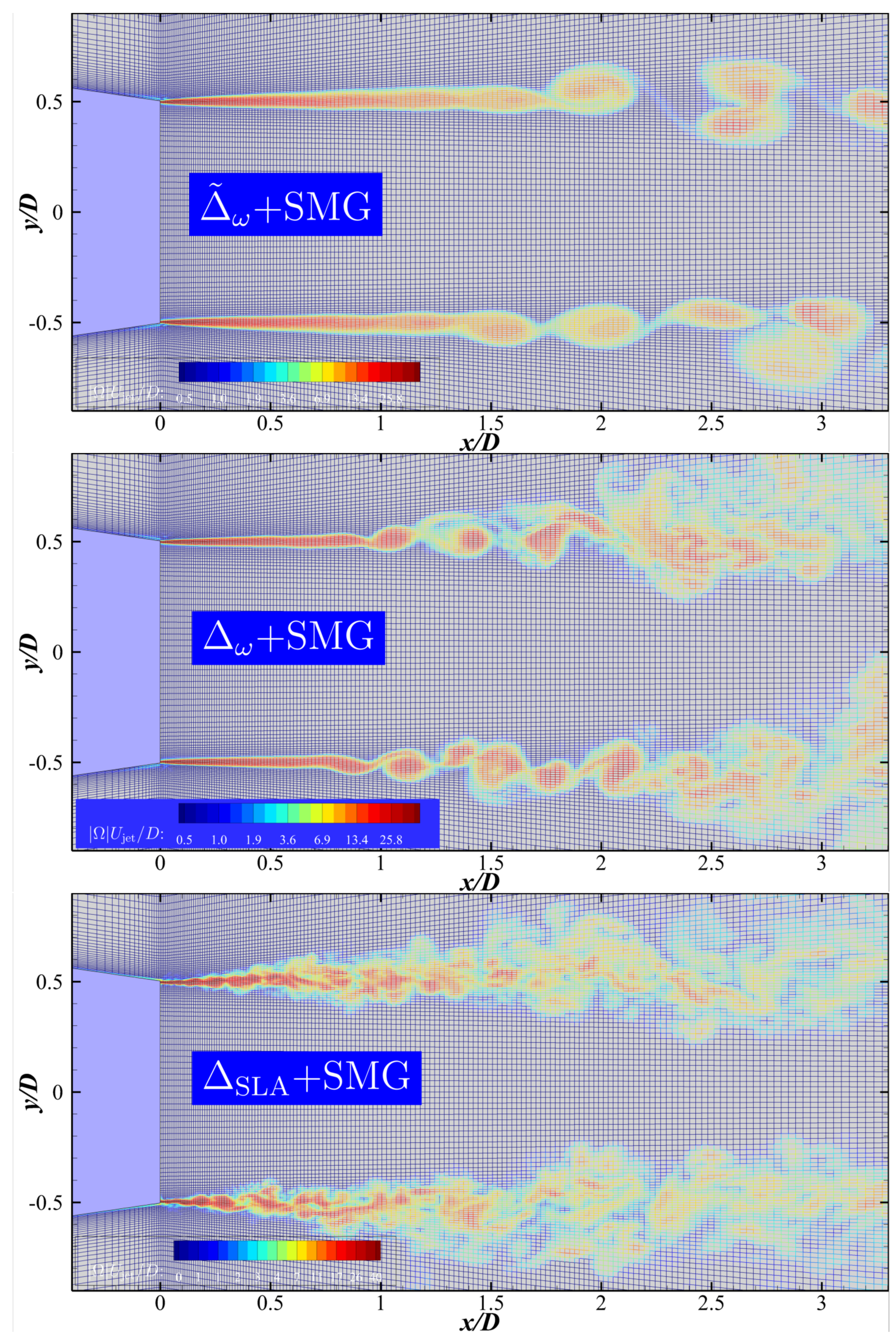
Abstract

This work explores different grey-area mitigation (GAM) methods towards achieving precise aerodynamics and aeroacoustics results of the subsonic turbulent round jet. The GAM technique used is based on a combination of 2D detecting LES models and new adapting subgrid length scales. The numerical simulations are carried out on a set of refining meshes using two different scale-resolving codes: NOISEtte and OpenFOAM. The results indicate that all the evaluated combinations offer appropriate accuracy in predicting noise and show the effect of both the numerical scheme and how subgrid eddy viscosity is modelled.

RANS-to-LES transition in jets



The accuracy of predicting jet-noise in the far-field region strongly depends on the accuracy of shear-layer evolution. Therefore, a robust numerical method able to quickly transition from RANS to LES is required.

Gray-Area Mitigation Techniques

The usual approach for Gray-Area Mitigation (GAM) techniques follows from the subgrid-eddy viscosity definition:

$$\nu_t = (C_{\rm LES}\Delta_{\rm SGS})^2 \cdot \mathcal{D}_{\rm LES}(\overline{u}), \qquad (1)$$

where $\Delta_{\rm SGS}$ is the subgrid length scale, $\mathcal{D}_{\rm LES}$ is the LES model differential operator, $\overline{u}$ is the filtered velocity, and $C_{\rm LES}$ is the LES constant.

In order to provoke a faster transition from the RANS zone to the LES zone, ν_t should be decreased. This can be achieved by:

- Reducing $\Delta_{\rm SGS}$. Instead of using standard approaches, such as Δ_{Vol} or Δ_{Max}, using special subgrid length scales sensitive to the local flow parameters. Examples of this advanced $\Delta_{\rm SGS}$ include, among others, Δ_{SLA}, $\tilde{\Delta}_\omega$, or Δ_{lsq}.
- Reducing $\mathcal{D}_{\rm LES}$. This can be achieved locally by using LES models sensitive to two-dimensional flow patterns. Examples of these kind of models include σ, WALE, or S3QR.

Used codes

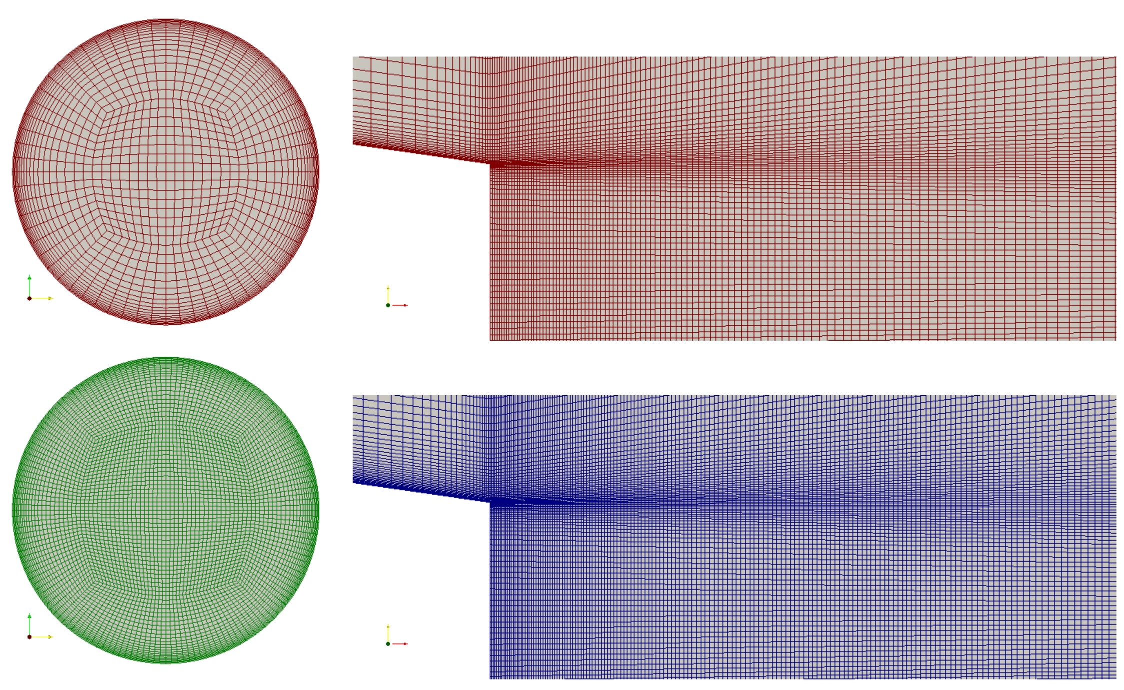
In order to analyse the effect of the numerical scheme, two different codes will be tested: NOISEtte and OpenFOAM.
The main differences among them are summarised:

Characteristic	NOISEtte	OpenFOAM
FVM approach	Vertex-centered	Cell-centered
Hybrid scheme	Guseva et. al. 2017	Travin et. al. 2000
Central scheme	4th order	2nd order
Upwind scheme	5th order	2nd order
Time integration	Implicit 2nd order	Implicit 2nd order
FWH equation	Retarded time	Phase shift

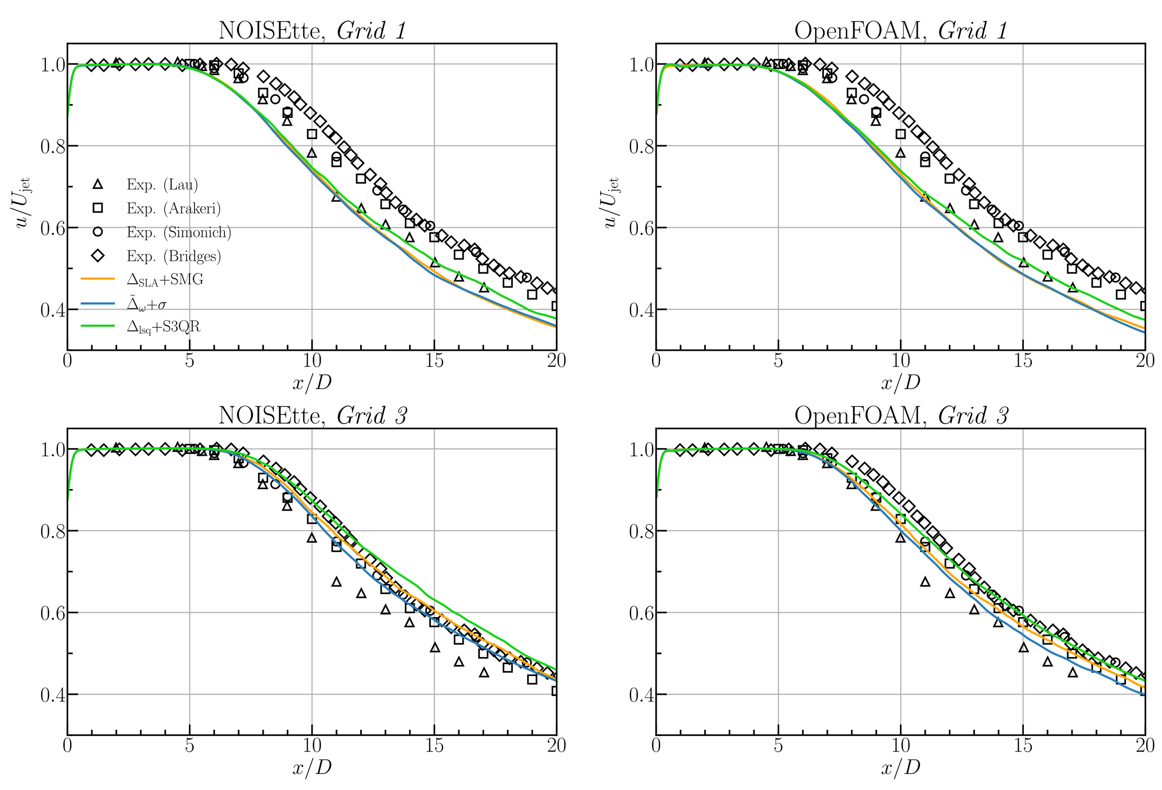
Used meshes

A set of three-refining hexahedral meshes is used to check results' convergence. The main characteristics of the coarser and finner mesh are:

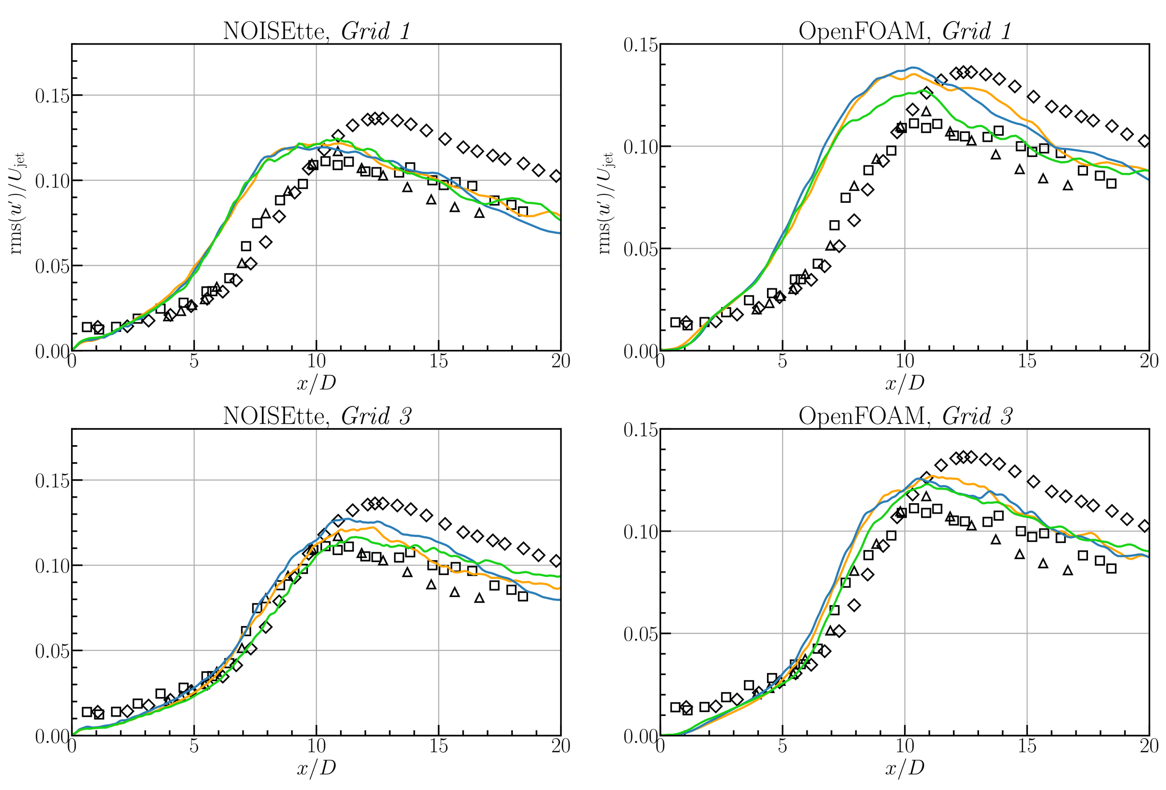
Parameter	G1	G3
N_n	1.52M	8.87M
N_φ	64	160
Δ_x/D at the nozzle exit	0.011	0.008
$\min(\Delta_r/D)$ in the shear layer	0.003	0.0025
$r\Delta_\varphi/D$ in the shear layer	0.05	0.02



Jet aerodynamics at centerline

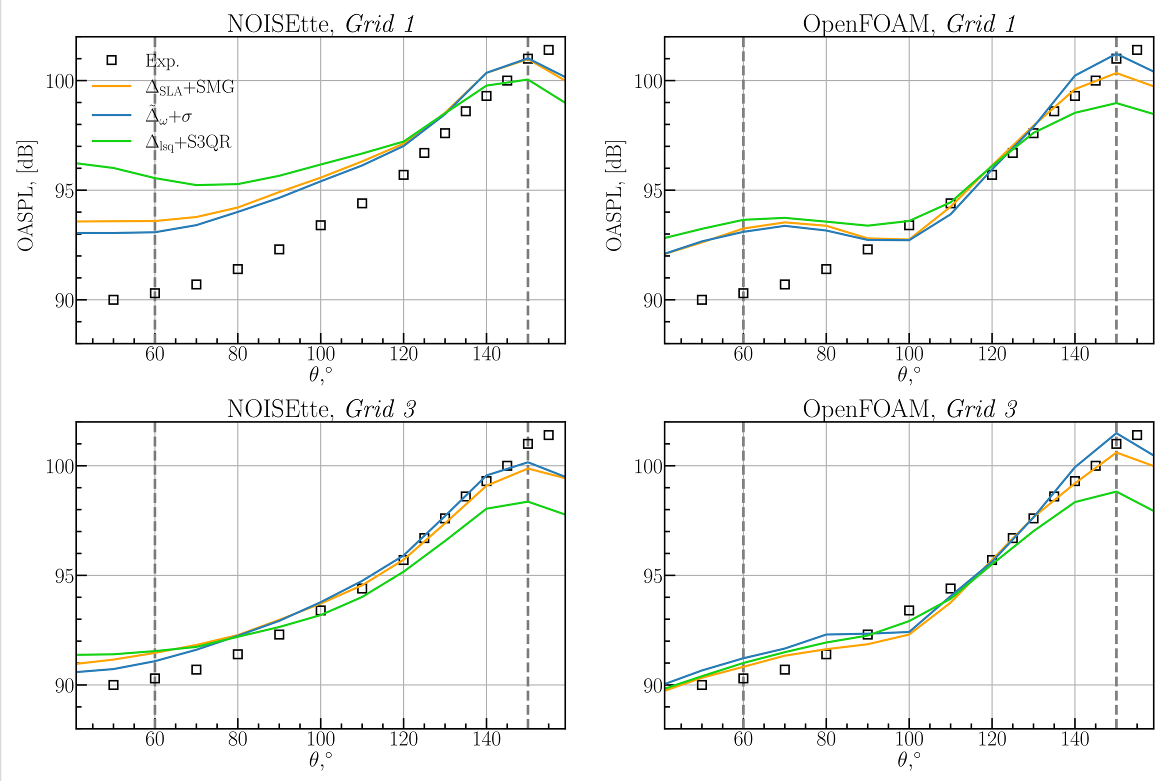


Streamwise velocity.

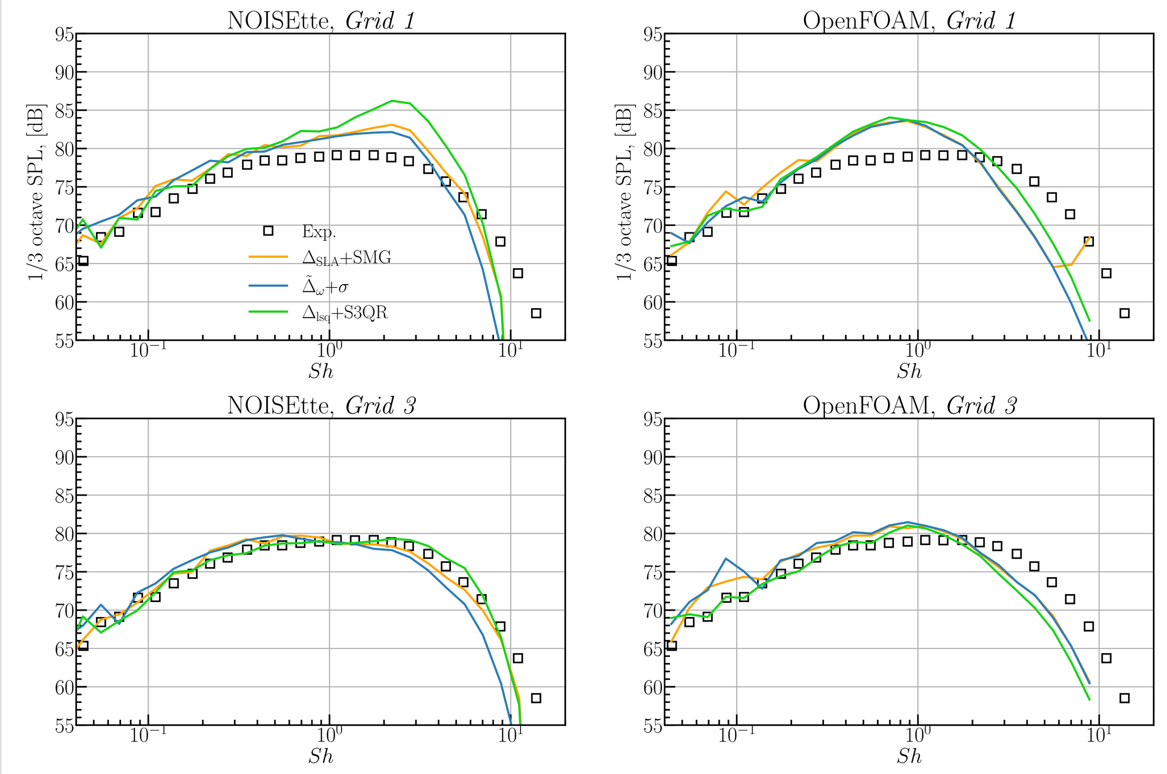


Streamwise velocity pulsations.

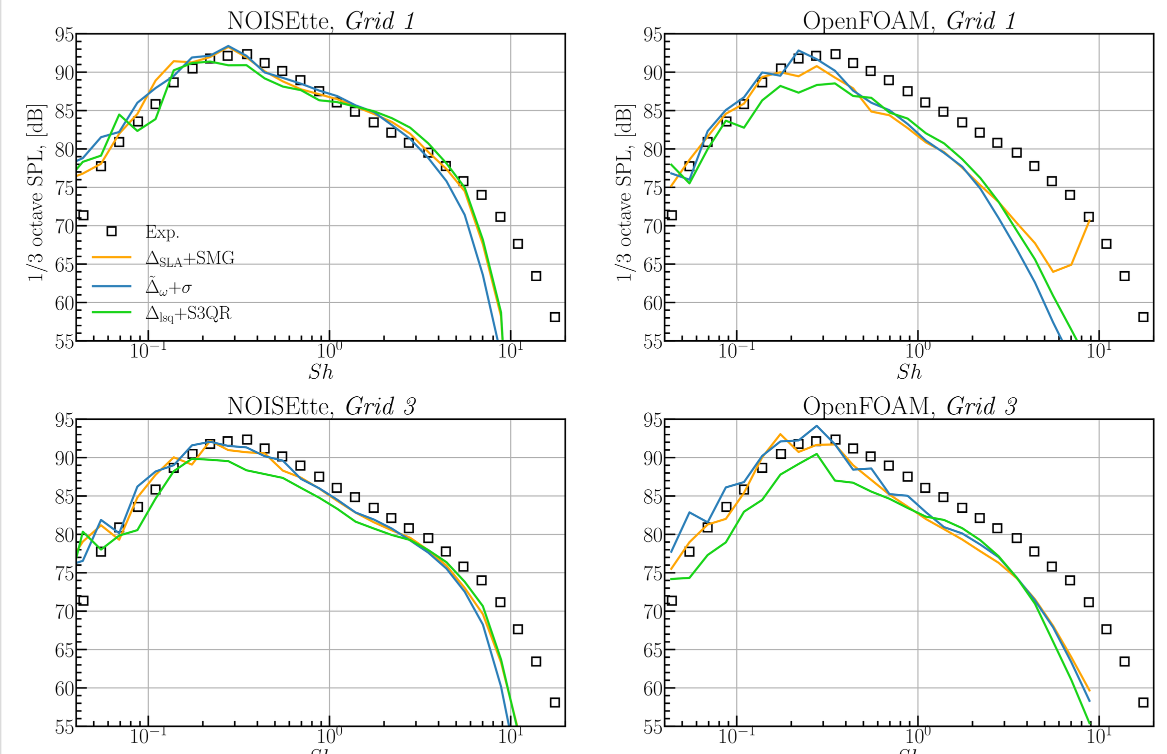
Jet Acoustics at far-field



Noise directivity



1/3rd-octave integrated spectrums at observer angle $\theta = 60°$.



1/3rd-octave integrated spectrums at observer angle $\theta = 150°$.

Conclusions

- NOISEtte, i.e. high-accuracy schemes, provide better results than OpenFOAM, i.e. low-order schemes. Nonetheless, both codes have produced results with an excellent agreement to reference data.
- The joint usage of special subgrid length scales with 2D sensitive LES models is mandatory to obtain a faster RANS-to-LES transition.

References

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