HIGH ORDER METHODS FOR GENERATION AND PROPAGATION OF ACOUSTICS OF WIND TURBINES IN URBAN ENVIRONMENTS

zEPHYR Marie Skłodowska-Curie project: towards a more efficient exploitation of on-shore and urban wind energy resources

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CONTEXT

Wind energy plays an important role in the goal of using 100% renewable energies. One potential place for this kind of energy harvesting is placing wind turbines in urban environments. Here the acceptance of people becomes a key factor to consider, specially noise generation from the wind turbines. This is why more accurate tools for the assessment of noise are needed.

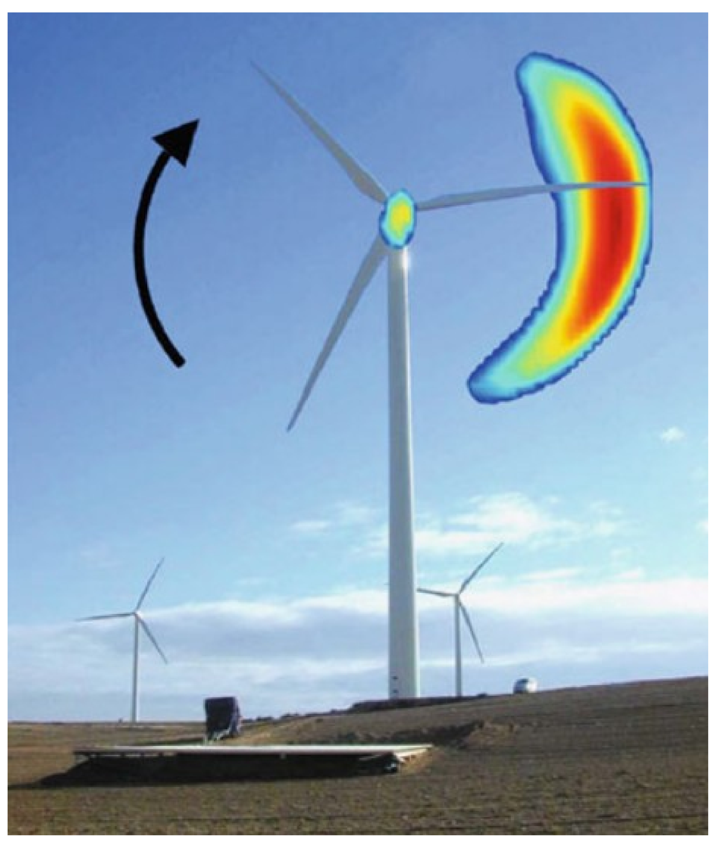


Figure 1. Example of a real wind turbine noise generation, red regions are the strongest sources [1]

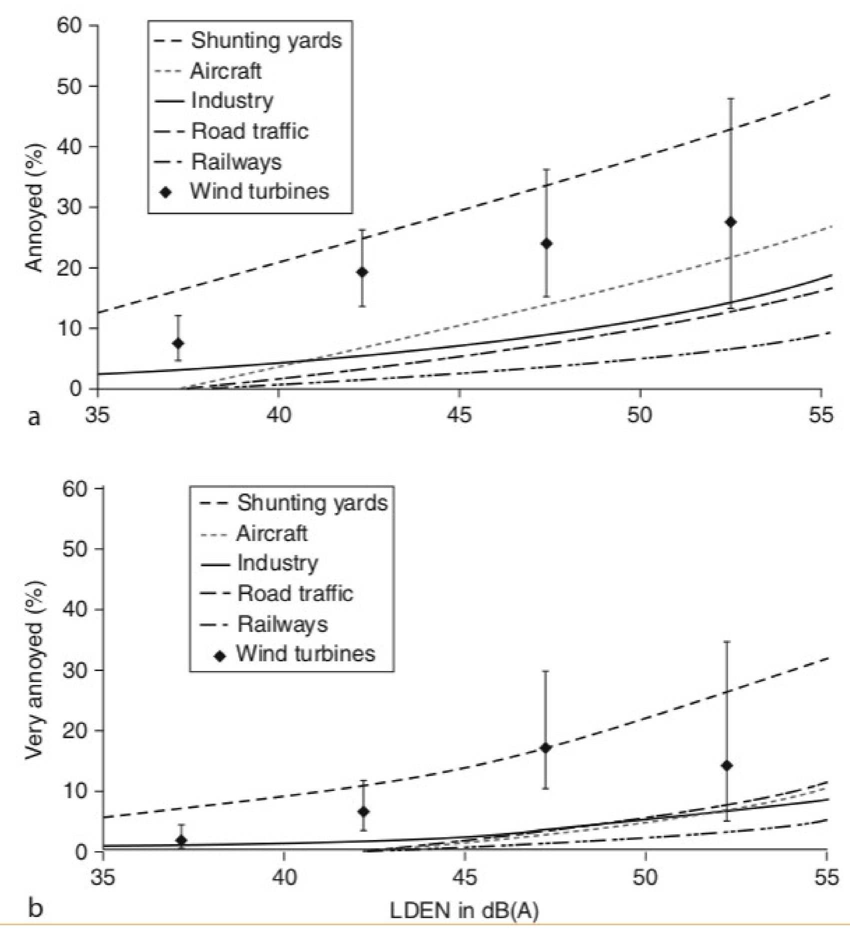


Figure 2. Comparison of 'annoyance' of some noise sources [2]

PROBLEM DEFINITION

The most important sources of wind turbines noise are caused by turbulent structures of the flow, thus it is important to have a good prediction of them.

The most common approach that commercial software use, suffer from non-negligible numerical errors that can increase unphysical dissipation and dispersion of flow structures or acoustic waves and provide unrealistic results. The alternative is to use High order methods, which are characterized by low numerical errors and their ability to use mesh refinement and/or polynomial enrichment to achieve highly accurate solutions.

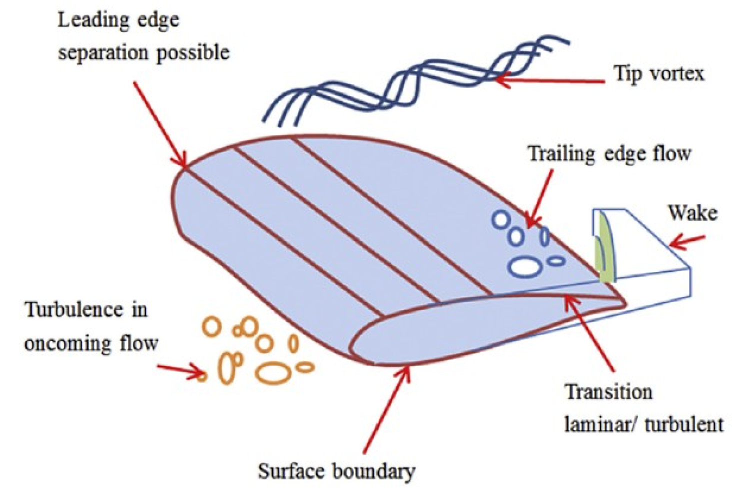


Figure 3. Sketch of wind turbines noise sources [3]

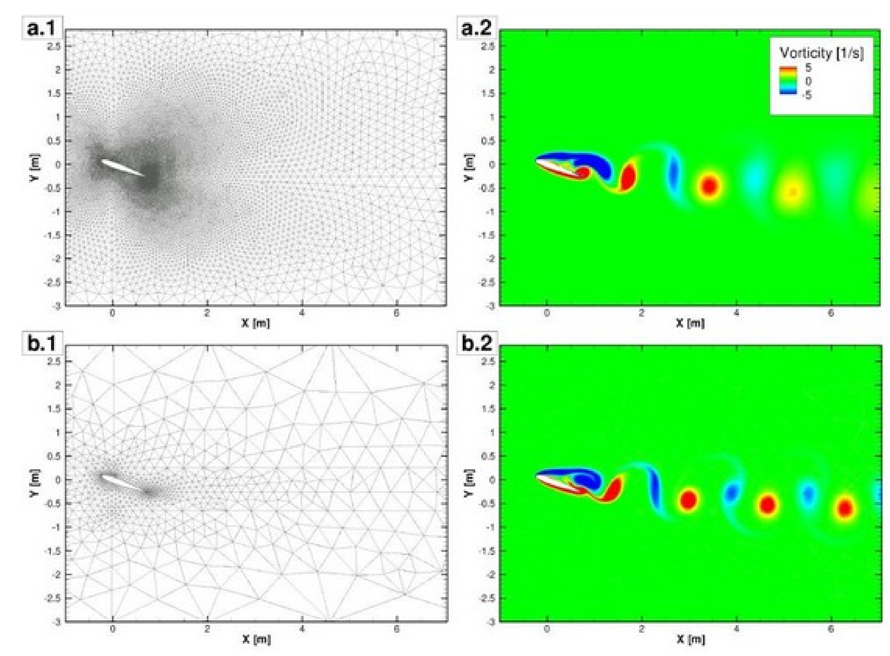


Figure 4. Comparison of classical Finite Volume Methods and High Order Methods [4]

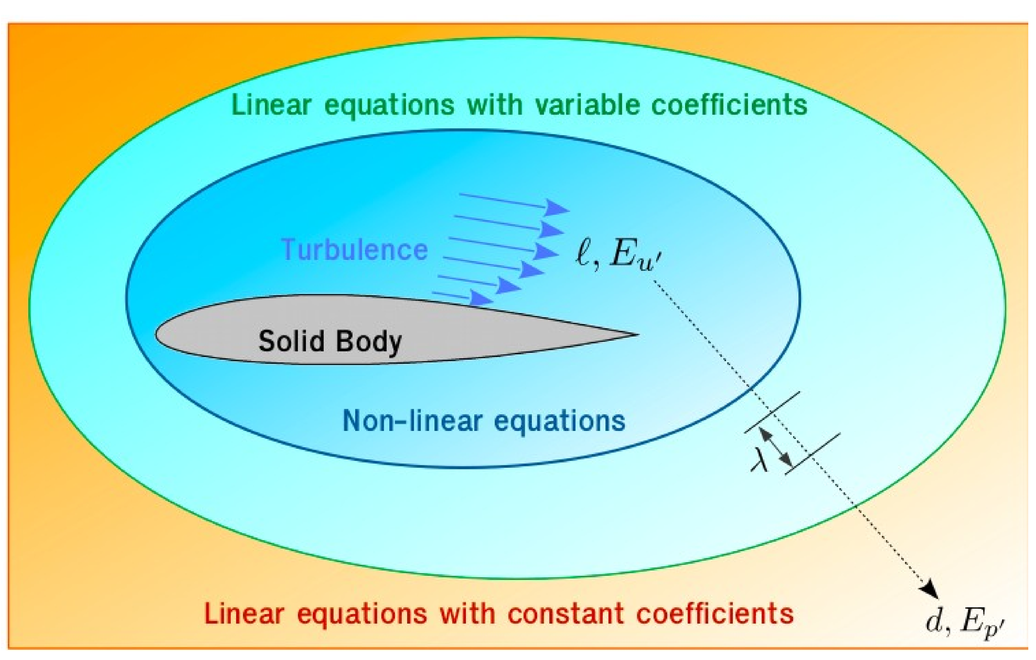


Figure 5. Different regions and scales of aeroacoustics and their scales [5].

Computational Aeroacoustic

Noise generation and propagation is a muli-scale problem.

- **Generation in turbulent boundary layer:** very non-linear.
- **Propagation in a background field:** acoustic terms are not present, more linear behavior.
- **Propagation in far field:** more compact waves

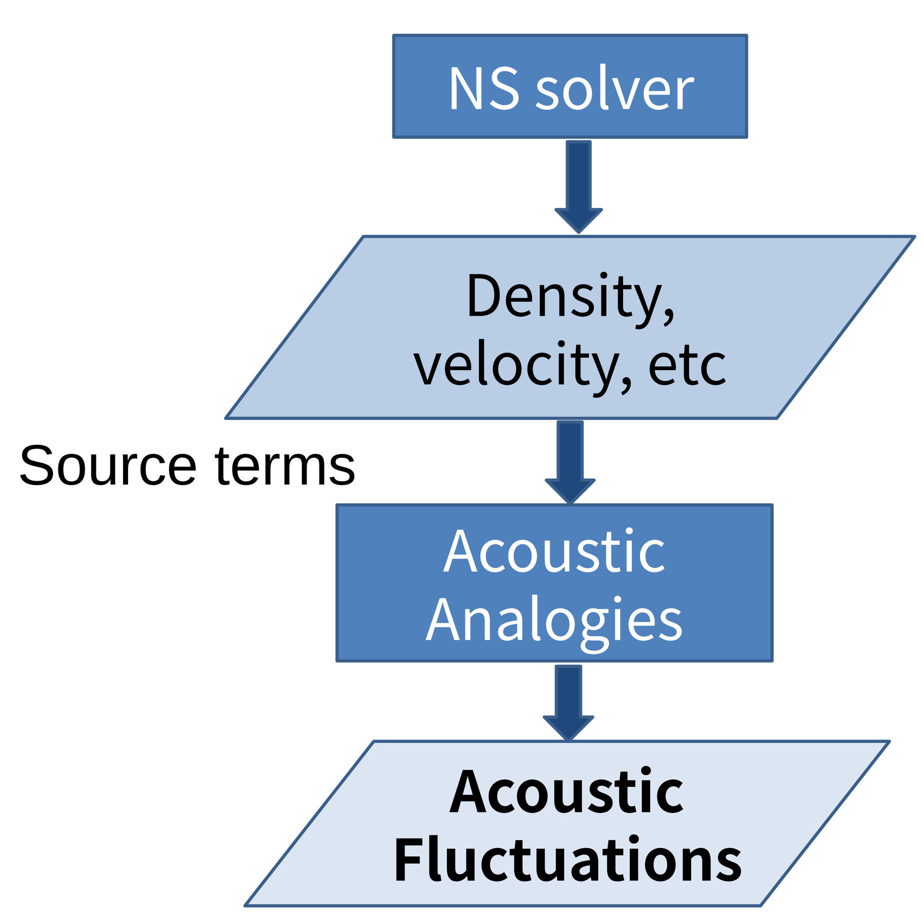
Each region can be solved as a whole (Direct Computation) or apart (hybrid)

- N-S flow equations.
- Linearized Euler Equations, Acoustic Perturbation Equations
- Integral approaches (Ffowcs-Williams and Hawkings)

OBJECTIVES

- Investigate advanced numerical methods based on high order discontinuous Galerkin techniques for generation and propagation of acoustics using LES techniques for wind turbines in urban environments.
- Modelling with and without noise mitigation techniques
- Compared the numerical results against to experimental data for cross-validation.

METHODOLOGY



Two Step algorithm

1. The flow (Navier-Stokes equations) is solved independently of acoustic simulations.
2. The results of the flow simulation are used as input (source terms) for the aeroacustic solver.

[1] Oerlemans S, Sijtsma P, López BM (2007) Location and quantification of noise sources on a wind turbine. J Sound Vib 299:869–883
[2] Pedersen E, van den Berg GP, Bakker R, Bouma J (2009) Response to noise from modern wind farms in the Netherlands. J Acoust Soc Am 126:634–643
[3] W.Y. Liu (2017) A review on wind turbine noise mechanism and de-noising techniques, Renewable Energy, 108: 311-320
[4] Esteban Ferrer, Richard H.J. Willden (2015) Blade–wake interactions in cross-flow turbines. International J Marine Energy 11: 71–83.
[5] Andrea Beck and Claus-Dieter Munz (2018) Direct Aeroacoustic Simulations Based on High Order DG Schemes. Computational Acoustics 579

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