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Predicting Urban Pollutant Spread from Accidental Releases: A Turbulence Modeling Perspective

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The dispersion of hazardous pollutants in urban environments presents a complex challenge, especially in the context of nuclear accidents or malicious releases involving radioactive substances. In such scenarios, understanding the transport mechanisms of contaminants is crucial for emergency preparedness, risk assessment, and public safety. Numerical simulations based on computational fluid dynamics (CFD) have become indispensable tools for predicting pollutant behavior in densely built areas. However, the accuracy and reliability of these predictions depend heavily on the choice of turbulence modeling approach.

This study evaluates the performance of three widely used modeling strategies - Reynolds-Averaged Navier-Stokes (RANS), Large Eddy Simulation (LES), and hybrid RANS–LES methods - for simulating the dispersion of hazardous plumes in complex urban geometries. The simulations were carried out using a realistic urban layout and pollutant source configuration based on the 'Michelstadt' wind tunnel experiment, conducted by Hamburg University as part of the COST Action ES1006. The selected scenario reflects situations relevant to nuclear safety, such as accidental releases near nuclear facilities or during the transport through densely populated regions.

The study revealed that the scale-resolving methods, such as LES and Hybrid, provides significantly improved accuracy in predicting pollutant dispersion in realistic urban settings. While URANS captures the general flow and dispersion trends and performs well with enhanced inflow conditions, it tends to underpredict lateral spreading and turbulence-driven mixing, especially in complex downstream regions. In contrast, the scale-resolving methods better resolve unsteady vortex shedding and turbulence structures, leading to more accurate estimates of streamwise and spanwise velocity profiles, and ultimately a more realistic prediction of pollutant accumulation and transport - particularly in recirculation zones and urban canyons. These findings emphasize the importance of turbulence model selection in CFD applications for urban air quality and nuclear emergency planning.

Technical Track

Safety and Severe Accidents

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