CFD for case studies environmental wind engineering: have we gotten ahead of ourselves?

Bert Blocken
Institute of Mechanical, Energy and Process Engineering, Heriot-Watt University, UK
Department of Civil Engineering, KU Leuven, Belgium

Over the past decades, CFD has transitioned from a tool in basic research and some simplified case studies to a tool that is frequently used for complex case studies in research and practice in wind engineering. These studies range from pedestrian-level wind comfort and air pollutant dispersion in actual urban areas, over wind forces on buildings and ships in complex topography, aerodynamics of cyclists, runners, skaters and skiers to urban thermal microclimate including heat waves in urban areas and their amplification by the urban heat island effect. However, not all of these case studies have been successful. Frequently, the deviations between the computed results and the corresponding wind tunnel or field measurements for validation have been so large that the actual simulations have been useless. Deviations larger than 30% in mean wind speed, more than 5°C in air or surface temperature and a factor 10 in gaseous or particulate pollutant concentrations can arguably be considered indicative of a successful validation study.

There are at least a few reasons that can be responsible for this. First, the flows in wind engineering are complex high-Reynolds number flows generally including pronounced impingement, separation and vortex shedding and sometimes complex inlet and wall boundary conditions, while the numerical approach is based on approximate forms of the governing equations, turbulence models and wall models that are based on assumptions that are generally incorrect, and sometimes very incorrect. Second, even though extensive best practice guidelines have been developed for RANS simulations, this has not been the case to the same extent for LES and hybrid RANS/LES simulations, while the latter are considerably more complicated in terms of sensitivity to boundary conditions and numerical settings. Moreover, even in many papers submitted to peer-reviewed scientific journals, the lack of adherence to the existing best practice guidelines is often moderate to poor.

Overall, it appears that in some cases, the application of CFD for complex case studies has gone too fast compared to the required basic research achievements, in terms of at least wall function development and best practice guidelines that should ensure a minimum level of accuracy and reliability. This presentation presents some successes but also some failures in large case studies that were due to these problems. The presentation indicates some of the basic developments that are missing and suggests venues for future basic research to alleviate the present hurdles towards successful large case studies.