CFD for Urban Wind Conditions and Wildfire Smoke Dispersion in Downtown Montreal

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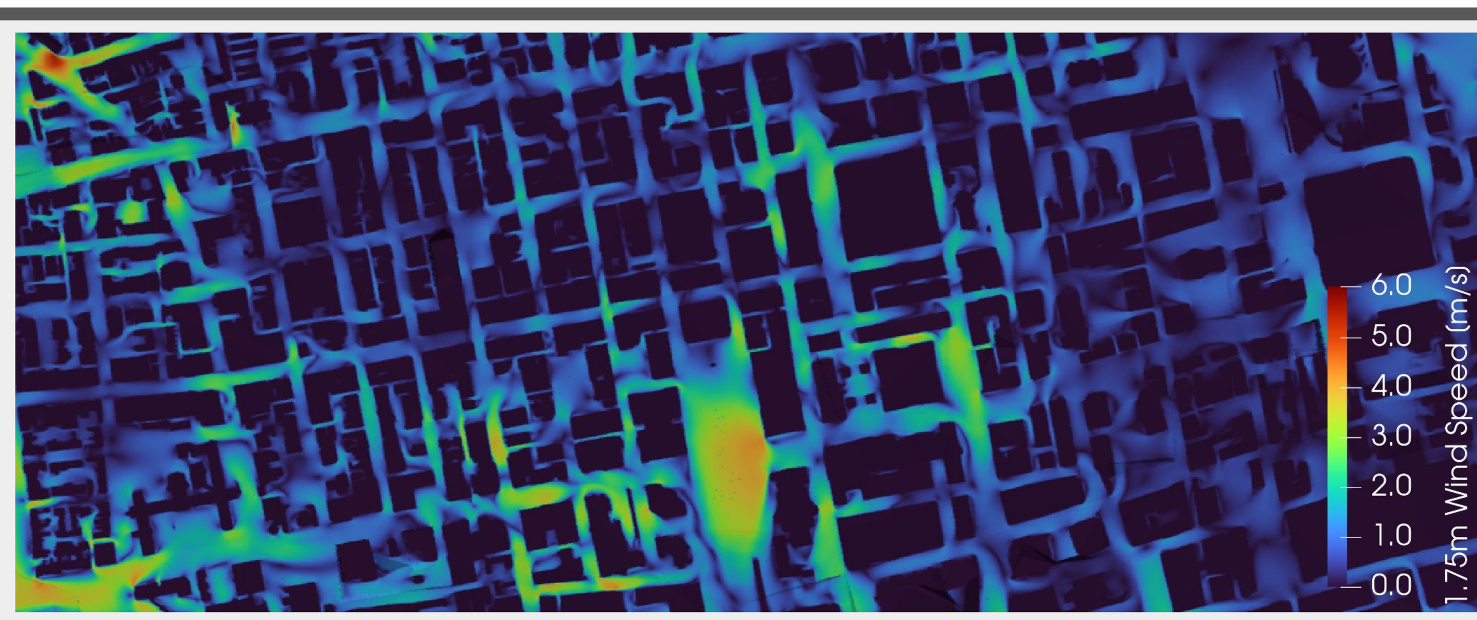
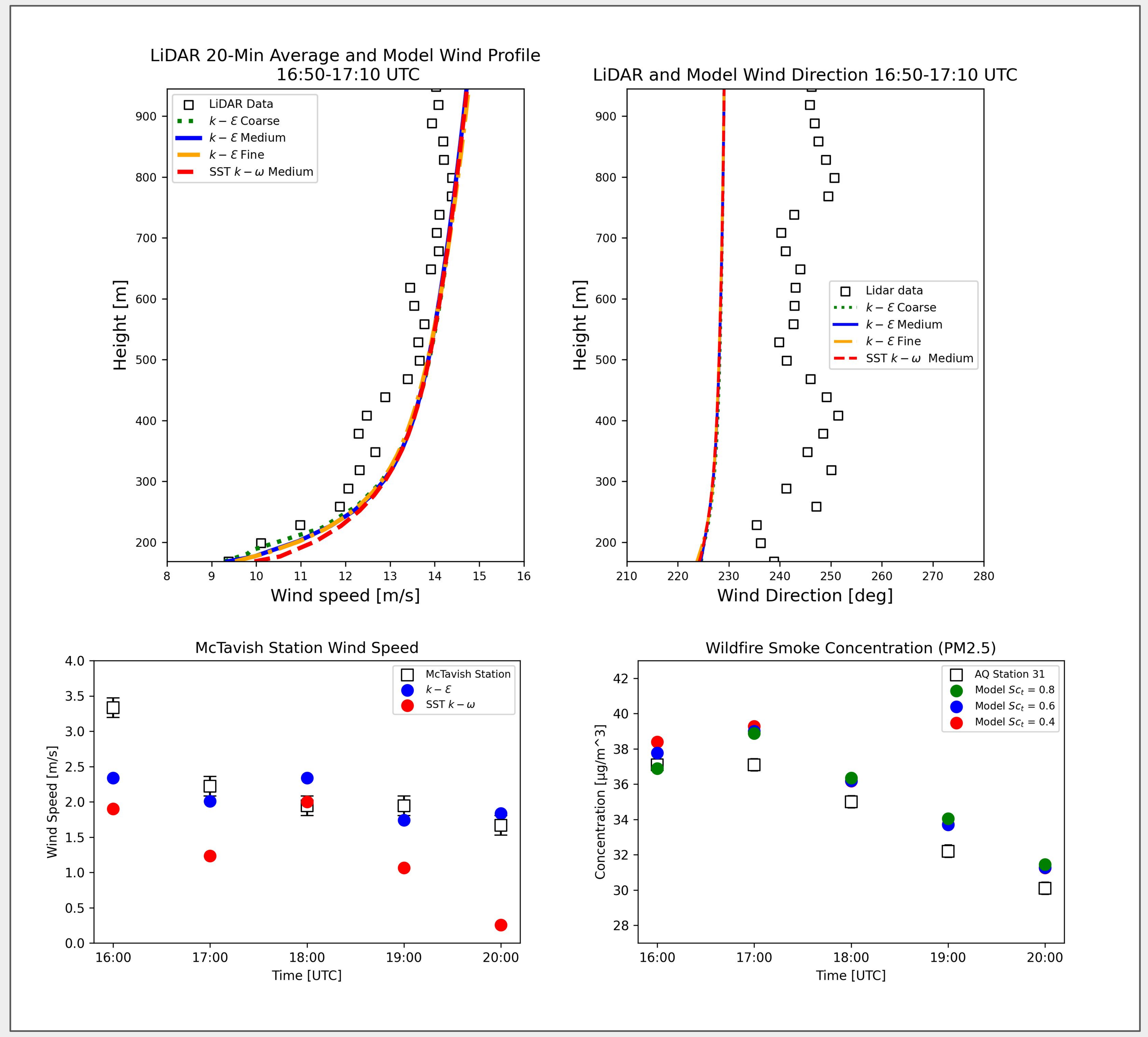
Background

Wind conditions and air quality within cities are of major consequence for the majority of the world's population. Millions of people every year die from air pollution, while many more face lasting health complications. Wildfires transporting smoke into major urban areas pose a serious health risk, with lesser effects including eye and lung irritation, and more pressingly, the exacerbation of preexisting lung diseases and even premature death (Liu et al. 2015).

Studies must therefore be conducted to assess how urban air quality is affected by atmospheric flow. Computational fluid dynamics (CFD) can be used to investigate atmospheric dispersion processes. This study analyzes the accuracy of two common Reynolds-Averaged Navier Stokes (RANS) turbulence models, the *k-ε* and Shear Stress Transport (SST) *k-ω*, for use in predicting wind conditions and pollutant dispersion. These models are applied to the greater downtown region of Montreal for the day of July 17, 2023, when moderately strong, southwest winds carried wildfire smoke through the city.



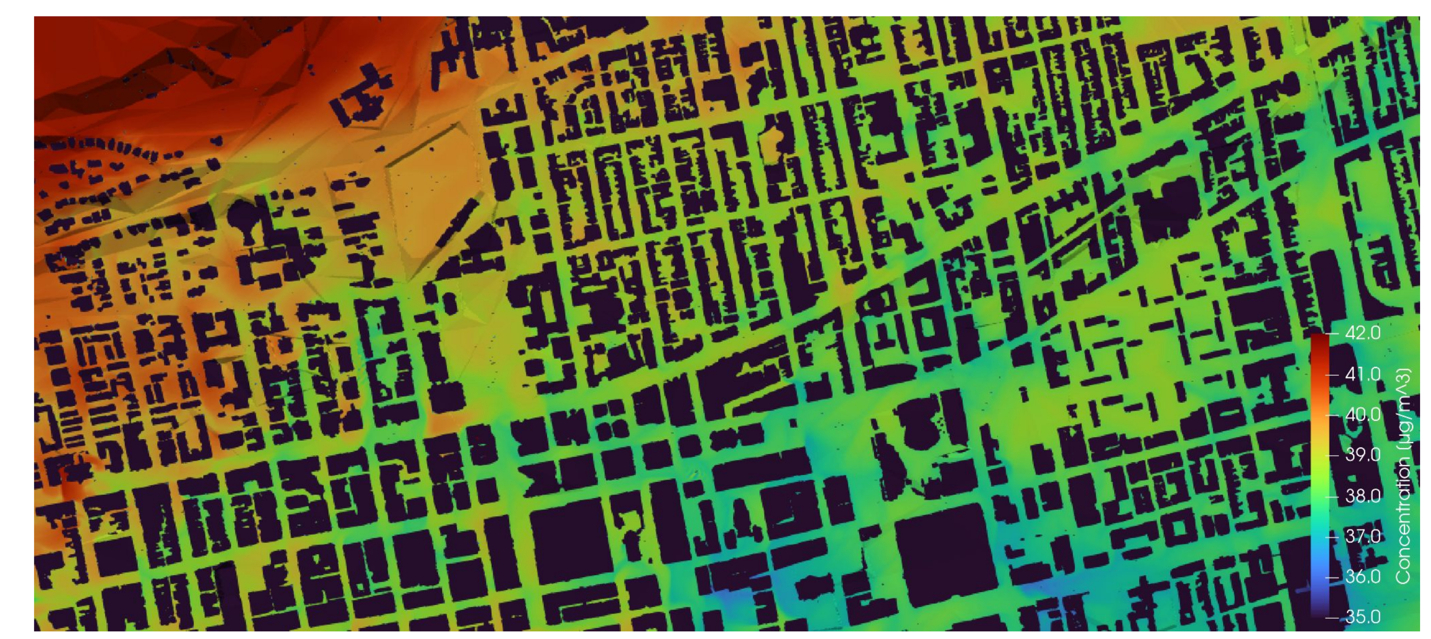


Methods

OpenFOAM, with a modified SimpleFoam solver, was used to solve the RANS equations. Inlet wind profiles were derived based on the Richards and Hoxey (1993) approach using reference velocities from a weather station at the Montreal-Trudeau International airport. Air quality data is taken from monitoring stations around the city. The computational domain, 10×8×1.7 km, was created following the COST Action 732 best practice guidelines (Franke et al. 2007), and was tested to ensure grid independency. The simulated wind fields were then validated using a LiDAR wind profiler and anemometer situated near the center of the domain.

Findings

The *k-ε* model shows the best agreement with measurements for wind speed and direction. Differences in wind direction likely result from the assumption of homogenous inlet wind direction. The overall agreement is fair, however the models seem to suffer under low wind conditions, a common finding with RANS simulations (Blocken et al. 2010). For the moderate, SW winds, the city shows only minor wind comfort concerns. The local topography of Mount Royal likely contributes to this, blocking higher wind speeds from reaching pedestrian level across much of downtown. Areas of higher elevation and some local regions do exhibit potentially uncomfortable wind characteristics.



Multiple values of turbulent Schmidt number were tested, with the value of 0.6 giving the best agreement with the measured data, in line with other studies (Toja-Silva et al. 2017). While the trend in smoke concentration is captured by the model, a slight overestimation is found. Again, the city's topography is found to play a large role, moderating dispersion in the city.

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