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SCALING OF DOWNBURST OUTFLOWS SIMULATED USING A FULL-SCALE COOLING SOURCE MODEL WITH DIFFERENT AMBIENT CONDITIONS

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ABSTRACT

A downburst is a natural phenomenon that occurs during thunderstorms, creating hazards and damage to infrastructure, notably electricity transmission lines, due to the strong winds produced and the fact that those winds are, laterally, highly correlated compared to everyday synoptic winds. Downbursts are characterized by divergent and generally straight-line winds near the ground, which are naturally observed when several trees in a forest are pushed in one direction. A downburst may be modelled experimentally and also numerically using computational fluid dynamics. One of the experimental methods is the liquid release approach, which consists of releasing a volume of fluid that is slightly denser than the ambient fluid contained in a tank or flume, creating a downdraft that descends to the ground surface. Previous researchers used a solution of water and glycerol as the ambient fluid and an aqueous solution of potassium dihydrogen phosphate solution as the heavier fluid. They proposed length, time, and velocity scaling parameters, R_0, T_0, and V_0, respectively, that allowed comparison of liquid release experiments carried out with different fluid densities, as well as with real events in nature. In addition, these scaling parameters allow comparison of experimental liquid release model data with numerical simulation results. The present project uses these parameters to scale numerical model data obtained by the simulation of a full-scale downburst using a cooling source model. The resulting non-dimensional velocity profiles have similar characteristics to the scaled non-dimensional profiles observed in full-scale field downburst measurements, and similar profiles to data from density-driven downburst experiments. Furthermore, the scaling preserved the vertical location of the near-ground peak wind speed, which is of great interest to wind and structural engineers. These results demonstrated that the scaling parameters, R_0, T_0, and V_0, work well for cooling source downburst simulations. The time scaling parameter T_0 is determined by using the density percentage difference $\Delta\rho/\rho$ obtained from the spatial average of densities within the thunderstorm cloud. This project also examines the influence of the ambient lapse rate on downburst events. Results showed that downbursts are affected by the ambient lapse rate, producing weak peak wind speed when the ambient lapse rate is lower than the dry adiabatic lapse rate, 9.8 K/km. Also, there is a delay in the evolution of the outflow when the ambient lapse rate is lower than the dry adiabatic lapse rate. However, the structure of the downflow and the outflow does not change.

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