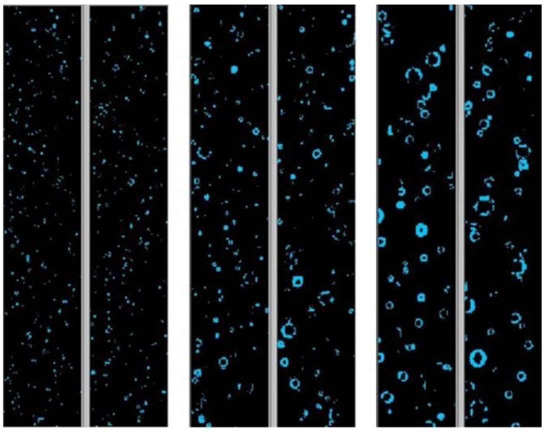
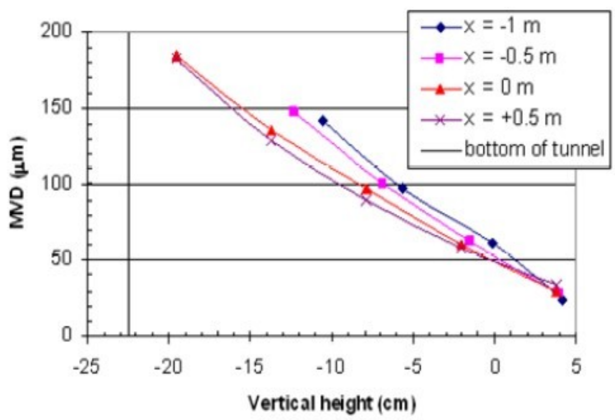
Characteristics of droplet clouds under icing conditions

Atmospheric icing occurs in cold regions on such structures as electrical transmission lines, overhead contact lines of electric railways, wind turbine blades, or aircraft wings. Heavy ice may accrete on the structure during serious icing events, which results in devastating consequences on the structure. The source of the accreted ice may be either cloud droplets, raindrops, snow or water vapour, which are carried in the cold air. The formed clouds are simulated by two-phase flows including water droplets dispersed in the carrying air flow. The severity of ice accretion depends on ambient conditions, and may be investigated by developing models of two-phase flows. The ambient conditions are considered in the characteristics of the two-phase flow or spray that simulates the cloud. A computational model has been developed in Fortran, which predicts the variation of cloud characteristics in flows simulating the natural phenomena leading to icing events. Natural aerosol clouds under icing conditions are also simulated experimentally by injecting water spray into cold airstream in a horizontal low-speed cold wind tunnel; thereby creating a two-phase air/dispersed water flow.



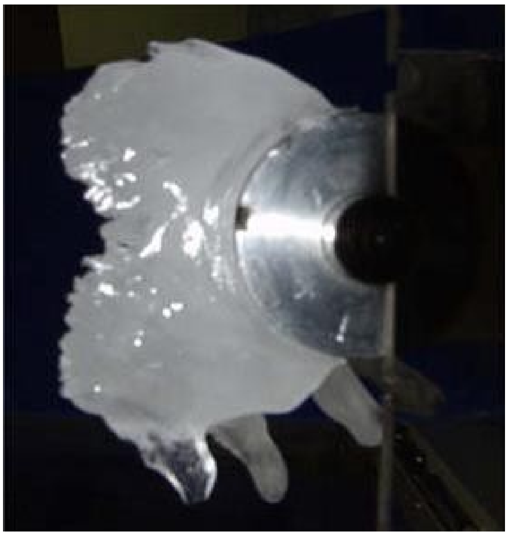


Droplets in air flow as visualized in a horizontal wind tunnel; (a) in-cloud icing conditions; (b) freezing drizzle conditions, middle of tunnel section; (c) freezing drizzle conditions, bottom of tunnel sectionMedian volume diameters in aerosol clouds as calculated at different streamwise and vertical positions in a horizontal wind tunnel

Main achievements

Profile of ice accretion obtained in a horizontal low-speed icing wind tunnel

- Several factors influence the characteristics of the aerosol cloud and its variation until it reaches an icing object. A mathematical model has been developed, which considers the following phenomena: (i) mutual interactions within the dispersed phase, i.e. binary droplet collisions; (ii) thermodynamic interactions between the dispersed and carrying phases resulting in evaporation and cooling; (iii) effects of external forces leading to gravitational settling of droplets; and (iv) turbulence dispersion of water droplets. The model is validated by wind tunnel experiments [1, 2].



- A detailed experimental study has been carried out in order to determine the spray characteristics, particularly droplet size distribution and liquid water content, produced by air-assisted nozzles in a horizontal low-speed icing wind tunnel. Empirical formulae are proposed to express the dependence of (i) the median volume diameter of the droplet cloud near the nozzle outlet on the nozzle dynamic parameters; and (ii) the liquid water content at the mid-height of the tunnel test section on the thermodynamic parameters of the airstream and on the nozzle dynamic parameters [3, 4].

- The variation of the mass and shape of ice accretions on a cylindrical icing object in a low-speed icing wind tunnel has been found when the angle of wind velocity and axis of cylinder is varied around the three mutually perpendicular axes [5].

Selected publications on the topic

1. Kollar, L. E., Farzaneh, M., Modeling and Experimental Study of Variation of Droplet Cloud Characteristics in a Low-Speed Horizontal Icing Wind Tunnel, Chapter 3 in: *Wind Tunnels: Aerodynamics, Models and Experiments*, Nova Science Publishers, inc., Hauppauge, NY, pp. 93-127, 2011. Available (open access item): https://www.novapublishers.com/catalog/product_info.php?products_id=25802
2. Kollar, L. E., Farzaneh, M., Modeling the Evolution of Droplet Size Distribution in Two-Phase Flows, *Int. J. of Multiphase Flow,* Vol. 33, No. 11, pp. 1255-1270, 2007.
3. Kollar, L. E., Farzaneh, M., Spray Characteristics of Artificial Aerosol Clouds in a Low-Speed Icing Wind Tunnel, *Atomization and Sprays*, Vol. 19, No. 4, pp. 389-407, 2009.
4. Kollar, L. E., Farzaneh, M., Karev A. R., Modeling Droplet Size Distribution near a Nozzle Outlet in an Icing Wind Tunnel, *Atomization and Sprays*, Vol. 16, No. 6, pp. 673-686, 2006.
5. Kollar, L. E., Farzaneh, M., Wind-Tunnel Investigation of Icing of an Inclined Cylinder, *Int. J. of Heat and Mass Transfer*, Vol. 53, No. 5-6, pp. 849-861, 2010.