Characteristics of Icing Events in Quebec

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ABSTRACT

More than 20 years of recorded observations of atmospheric icing are now available from 180 Passive Ice Meter stations throughout the province of Quebec, Canada. The objective of this study is to analyze the data and to develop regional design criteria for telecommunication and electric transmission towers. The first phase of the project is to find the best site-specific statistical model for the intensity of glaze ice accumulation. In order to increase the sample size, an event-based model, in which every icing event is counted as an independent event, is adopted. Different definitions of what constitutes an icing event are examined and compared with results based on annual maximum values. The comparison, based on the goodness-of-fit of different probability distribution functions and the sampling characteristics of the extrapolated right tail of the distributions, shows that the event-based model provides better results from a statistical point of view. The next phase of the project is to develop procedures for spatial interpolation to locations where there are presently no measuring stations. The latter requires the estimation of the recurrence rate of icing storms, their spatial extent, and the identification of site specific features that increase the ice storm hazards. The spatial interpolation of the quantiles of the distributions shows the need for more sophisticated scheme that incorporates other meteorological and topographic parameters.

KEY WORDS: Atmospheric icing, Glaze ice data, ice loads, statistical analysis, spatial analysis

INTRODUCTION

Atmospheric icing of structures constitutes a major problem for designers of electric transmission and telecommunication towers. This natural phenomenon is especially important in northern regions and is the cause of many interruptions of service annually. Freezing rain is one of the main types of atmospheric icing and the most severe in terms of spatial extent and adhesion on structures. Specific data sets on freezing rain are very rare. One of the most comprehensive to date has been compiled by Hydro-Quebec since 1974 on approximately 180 Passive Ice Meters (PIM) deployed across the province of Quebec (Fig. 1). The measurement program was originally implemented to study ice accretion on conductors and structures to develop better design criteria for electricity transmission lines.

Glaze ice storms are associated with frontal systems located between cold (polar) and warm (tropical) air masses. When a warm air mass overruns an underlying colder air mass, a temperature inversion may occur within the bottom portion (1 or 2 km above ground) of the atmosphere (Fig. 2). Snowflakes formed at high altitude, above the inversion, melt as they fall through the warm layer. Water droplets fall through the next layer of cold air and are supercooled (i.e. water droplets remain liquid for temperatures below the freezing point). The supercooled droplets freeze on contact with objects encountered near or at the ground surface and accumulate. Storms do not last more than several hours and are usually restricted to a sweeping but narrow band associated with the warm front. Glaze ice is usually translucent, homogeneous, hard, highly adhesive, and very dense (about 900 kg/m$^3$).

The conventional procedure for developing regional design criteria for icing of structures has three steps: (1) obtain samples of annual maximum ice thickness at each site in the region, (2) estimate the design ice thickness for a given return period by fitting a Gumbel distribution to the sample data at each site, and (3) derive isolines of design ice thickness by qualitatively smoothing the estimates. There are some disadvantages to this approach: (1) there are several stations where icing storms occurred only in a few years; (2) there is no previous studies which justifies the use of the Gumbel distribution for representing icing data; and (3) the spatial variation in design ice thickness is erratic due to the small sample size at each station.

One procedure to address the latter issue is to pool data from neighboring stations to increase the sample size. Laflamme (1993) suggests that pooling of data from three neighboring stations improves the fit of a Gumbel distribution to the sample of maximum yearly observations. The main difficulty with pooling is the identification of a group of homogenous stations with similar climatological and topographical characteristics. Alternatively, an event-based model can be used to increase the sample size at each station by including all major icing observations.

The first step in the analysis of the glaze ice data at each station is to remove reporting errors and to identify icing events both at individual stations and from a regional perspective. Various procedures and definitions were investigated in order to define individual icing events and are discussed in the following sections. Finally, using the processed data, site-specific estimates of the parameters of the probability distribution function of icing severity were obtained, both for the annual-maximum storms and the event-based models.

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