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Mapping mean annual icing hours for the Québec wind energy industry

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ABSTRACT

This paper presents a first icing map for the southern part of the province of Québec which illustrates the combined precipitation and in-cloud icing hours. The paper starts by applying different methods of predicting icing events to the North American Regional Reanalysis (NARR) data. The results are then compared to icing observations from airport data. This comparison indicates that the method using temperature and relative humidity as parameters shows the best correlation between the predicted annual icing hours and the observed annual icing hours. This method is therefore used to produce the icing map. Although the mapping method has its limitations and that further development is desirable, this first mapping attempt shows some agreement with available observations.

KEY WORDS: Atmospheric icing; icing map; reanalysis data; airport data; wind energy.

INTRODUCTION

In Québec, Canada, the wind energy industry is growing rapidly, and with it the need for more information on atmospheric icing climatology. Both precipitation icing and in-cloud icing cause energy losses for wind turbines (Laakso and Peltola 2003). In-cloud icing can be particularly important on hills and mountain summits (Lacroix and Manwell 2000). At the moment, most climatologic studies of atmospheric icing in Canada concentrate on precipitation icing only (Cortinas et al. 2004; Laflamme and Périard 1996; McKay and Thomson 1969; Stuart and Isaac 1999). Therefore, this paper presents an icing map of the southern part of Québec providing the mean annual number of precipitation icing hours and in-cloud icing hours combined. The map is drawn using a prediction method for annual icing hours developed with the North American Regional Reanalysis (NARR) data at a 32-km horizontal resolution. This is a first attempt at mapping mean annual icing hours for the Québec wind energy industry.

The first section of the paper is a short review of atmospheric icing and basic icing prediction methods from the literature. The second section reviews the application of these methods to the NARR data. The results of each method are compared with icing observations from airport data (METAR). Of these methods, the one best satisfying the research objectives is used for the construction of the icing map, which is described in the third section. An interpretation of the map and the results follow. This includes a general look at the precipitation icing maps from the literature as well as a closer look at selected sites. These selected sites either represent areas or periods of extreme icing or, on the contrary, periods or regions where icing has been rare. This last section is followed by the conclusion.

ATMOSPHERIC ICING

The two types of icing studied here are precipitation icing and in-cloud icing. Both occur due to the presence of supercooled water drops or droplets. These remain in a liquid state although their temperature is below freezing. Numerous attempts have been made to identify the presence of supercooled water particles by using either meteorological measurements or data from Numerical Weather Prediction (NWP) models. These attempts range from simple criteria regarding temperature and relative humidity values (see for example Schultz and Politovich (1992)), to elaborate models integrating a variety of data sources (see for example Bernstein et al. (2005)). Within this particular study, the objective is to analyze the performance of only the simple icing prediction methods; the methods that use a unique data source and a limited number of meteorological parameters.

A common way to predict icing events is to detect the occurrences of high relative humidity with subfreezing air temperatures. This method has been used to predict icing events with data from a wind turbine park in Finland (Laakso et al. 2003). It has also been applied to the output of meteorological models for applications related to aircraft icing by Schultz and Politovich (1992) and by LeBot and Lassegues (2004). When more detailed meteorological information is available, other options include the use of cloud base height and temperature. This method has been studied or used by Makkonen and Ahti (1995), Sundin and Makkonen (1998), and Tallhaug (2003). Visibility can also provide information on the presence or absence of clouds or fog and was used, with cloud base height, for the European icing atlas (Tammelin et al. 2005). Finally, information on liquid water content can also be considered. Liquid water content expresses the mass of liquid water in a given volume of air. Hosek (2007) has looked at the possibility of using