Icing Measurements at the Luosto Test Site

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Abstract— **Main objective of the COST-727 Action was to perform joint icing measurement campaigns at automatic weather stations, to test and verify existing ice detectors and ice detecting methods and to collect a dataset of icing events and ice loads for verification of icing models. In period 2006-2009 performance and reliability of four different ice detectors was tested at the automatic Luosto test station in Finland by Finnish Meteorological Institute. The station is located in northern Finland on the top of Luosto fell (67°08'N, 26°54'E). Results and experiences gathered during the test period showed that performance of the tested ice detectors was not always entirely reliable, especially under heavy icing conditions at Luosto.**

I. Introduction

Atmospheric icing has been measured by various means and several devices have been developed for measuring purposes. In the last years automatic instruments have become important for various activities, such as aviation and wind turbine operation. There is also an increasing need to improve atmospheric icing measurements to get more accurate data for verification of icing models and forecasts.

Main objective of the Working Group 2 of the COST727 project was to perform joint icing measurement campaigns, to test and verify existing ice detectors and ice detecting methods and provide data (icing events, loads) for verification of icing models.

II. Site description

The Luosto station is located in Northern Finland (Fig. 1) on the top of Luosto fell (N67˚08', E26˚54'). Luosto is at the northern end of a chain of arctic fells. Its elevation is 515 m above MSL and the open treeless cap of the fell is 300 m above surrounding terrain.

A. Icing climate

In northern Finland winter days are short with very little solar radiation, wide temperature and humidity range. The Luosto site is prone to heavy in-cloud icing, typically something like 1500 hours in October-April. The site represents an elevated site inland with harsh and frequent icing climate. In the fell areas icing periods are long and a single icing event may last several days. Permanent ice loads started to build up in November. These ice loads accumulated during the winter months does not fully disappear until end of February when amount of received solar radiation increase.

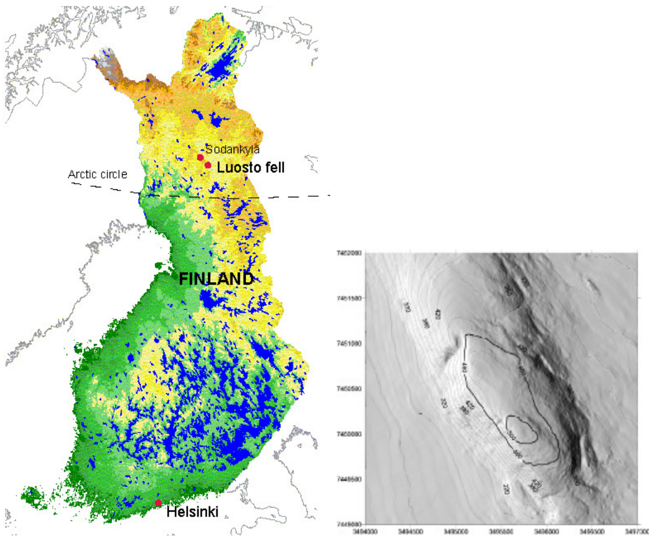

Fig. 1. Location of the Luosto site and details of topography of the fell.

B. Test station

The test station is operated by Finnish Meteorological Institute (FMI). The platform for the instruments was built in the autumn of 2000 for the EUMETNET SWS II project, which studied the effect of icing on meteorological instruments and produced specifications for ice-free sensors [1]. Since then icing measurements and meteorological measurements with ice-free sensors have been performed at the site (Fig. 2).

Meteorological measurement have been carried out using present weather (visibility/fog), temperature, humidity, dew point and wind sensors. Performance of the instruments was monitored continuously with four video cameras.

It is important to have also visual observations at the test sites, because at the moment only these types of observation can give sufficient information on icing events and operation of the tested sensors. At Luosto visual observations have been logged and documented with appropriate digital pictures taken by four cameras. Remote data reading, including camera observations, made it also possible to get online information about device failures so that the site may be visited in proper time.

Fig. 2 The platform for the instruments at Luosto.

C. Data acquisition

The Data acquisition system at the site consists of one PC and four cameras with extra heating systems. The sampling frequency is 1 Hz for most of the instruments. The integration time is 10 minutes. A set of pictures is taken every 15 minutes. The data and digital camera pictures are transferred every 1 hour using ftp transfer system to the server located at FMI in Helsinki, Finland. The real time data is archived at the FMI.

III. Tested sensors

During the test period 2006-2009 performance of four different types of ice detectors was examined. The station was equipped with Rosemount 0872J (prototype) manufactured by BFGoodrich (icing/no icing status), Rosemount Aerospace 0871LH1 manufactured by Cambell Scientific (Canada) Corp. (icing/no icing status), IceMonitor manufactured by SAAB Security former Combitech AB (automatic weighting, free rotation) and HoloOptics T26 icing sensor (prototype) manufactured by HoloOptics (icing/no icing status).

Rosemount 0872J Ice Detector (prototype) was designed for various applications from meteorological measurements to radio tower de-icing programs [2]. The Rosemount ice detector uses an ultrasonically axially vibrating probe to detect the presence of icing conditions. The added mass of accreted ice causes the frequency of the sensing probe to decrease. Ice detector software monitors probe frequency and detects this decrease. At the same point the internal probe heater power is applied until the frequency rises to a predetermined set point. Once de-iced, the sensing probe cools within a few seconds and is ready to sense ice formation again. The ice detector outputs include ice detection indication and fault status indication.

Rosemount Aerospace 0871LH1 Freezing Rain Sensor manufactured by Cambell Scientific (Canada) Corp. is a small sensor designed specifically for use in ground based meteorological applications [3]. The sensor has the same principle of operation as Rosemount model 0872J. It is a one-piece unit that detects the presence of icing condition. The sensor outputs include ice detection indication and fault status indication.

IceMonitor manufactured by SAAB Security (former Combitech AB) is an instrument aimed for automatic weighing ice load on a vertical steel rod, and it has been designed according to the recommendations in ISO 12494 [4]. The rod has diameter of 30 mm and it is 0.5 m long. It can rotate freely to allow ice build-up to form cylindrically. Ice that accretes on the rod is weighed by a load cell with a measuring capacity of 500 N (50 kg). The load cell is connected to an amplifier box that delivers an output signal which is proportional to the applied load on the rod. To avoid ice in the area for the bearing of the rod there is electrical heating of the bearing that is controlled with a thermostat. An updated version of IceMonitor sensor (August 2008) has an electronic regulator to control the temperature of the bearing [5].

HoloOptics T26 Icing-Rate Sensor (prototype) manufactured by HoloOptics is based on a patented digital optronic ice-indicator that indicates the presence of ice on the surface of the probe [6]. T26 is designed for mounting on weather stations, towers, aircrafts and wind-power stations etc. It may also be used as an icing rate sensor. T26 is delivered with an internally controlled probe heating. As ice is detected, the internally controlled probe heating is turned on and once de-iced T26 is prepared for the next indication.

IV. Results And Discussion

Icing measurements were performed in winters 2006-2009 at Luosto, starting each winter in October and ending in April. Many long icing periods occurred during the winters, so several icing events were recorded and performance of the ice detectors was examined.

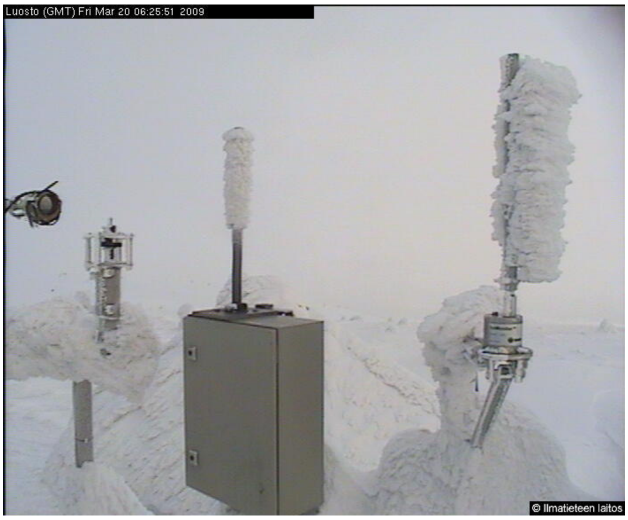

Fig. 3. Ice detectors installed at Luosto.

Results and experiences gathered during the winters showed that performance of the tested ice detectors was not always entirely reliable. The following summary describes the results obtained with the data measured and digital pictures taken at Luosto.

The Rosemount 0872J ice detector provided fairly good measurements and detected presence of icing conditions. The sensor proved to be working correctly most of the time. Heating power of the sensor was powerful enough to keep the sensor probe de-iced and the instrument operational in heavy icing conditions. Nevertheless, it cannot guarantee accurate measurements in soft icing conditions, then ice accretion may exist on the sensor probe especially in the beginning of the icing event and the sensor does not indicate ice accretion.

The Rosemount Aerospace 0871LH1 sensor worked correctly only during a few icing events in the beginning of the short test period in January-April 2009. After that the instrument produced correct-looking data, but did not react to accreted ice on the probe. Unfortunately, reason for this is not yet solved. As the ice accretion increased, due to lack of heating, the instrument got finally surrounded by a lump of ice preventing any ice detection and operation.

The IceMonitor was operational and yielded promising results during the two test winter. It was possible to record several icing events, although oscillations appeared on the measured data. The amplitude of the oscillations has been analysed as function of temperature, wind speed or the heating system without obvious conclusions. The instrument was sent back to the manufacturer in the summer 2008, in order to modify the instrument and to test before sending it back to the station for the winter 2008/09. Results of the modified version of the instrument showed quickly that the expected stability was not achieved and oscillations were still observed in the data. Also, ice accretion on the body causes problems preventing or even stops free rotation of the rod. If the rotation is totally stopped by ice accumulation, the instrument does not produce correct ice load measurements.

The HoloOptics T26 Icing-Rate sensor did not work properly and did not produce reliable data during the test period of the sensor in the winter 2007/08. The instrument has still to be considered as prototype and it will need more developments.

V. Conclusions

The results and experiences gathered during the three winters 2006-2009 at the Luosto test site clearly showed that performance of the tested ice detectors is not entirely reliably. Ice detectors did not indicate the presence of icing conditions or measure ice loads reliably and automatically all the time; especially in heavy icing conditions. It seems that there is still a lack of adequate and operational ice detector on the market.

However, Rosemount 0872J ice detector and IceMonitor ice load sensor proved to be promising instruments for field application. Unfortunately, Rosemount model 0872J is a prototype and the Goodrich Corporation does not develop the version any more. IceMonitor still has to be improved on some details. For instance, the freely rotating cylinder was not really adequate in conditions with heavy ice loads, which restricted or even stop the free rotation of the rod. Better results might be obtained with forced rotation.

VI. References

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[4] Combitech installation manual of IceMonitor^{TM}. 2006.

[5] Combitech installation manual of IceMonitor^{TM}. 2008.

[6] User Guide T26 Icing-Rate Sensor^{TM}, HoloOptics, Stockholm, Sweden.