A Survey of Icing Measurements in Germany

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***Abstract*— Long-term icing measurements were carried out at up to 35 stations in the east part of Germany during 1965-1990. These long-term icing measurements were performed by the use of manually operated icing poles, mostly one-time per day at a single height level. Since 1991 the number of locations with icing measurements has been reduced to a total of five. At present, icing sensors are implemented at the locations Arkona, Chemnitz, Zinnwald, Kahler Asten and Hohenpeißenberg. They are operated continuously at a single height level. Furthermore, the icing measurements at Arkona, Chemnitz and Zinnwald are still carried out by the use of manually operated icing poles. During the last three winter periods icing measurements at three heights (5 m, 50 m and 90 m above ground) were performed at DWD's Meteorological Observatory Lindenberg. These measurements are carried out in order to improve the knowledge of the height dependence of icing. The survey depicts locations and instruments of icing measurements in Germany. Selected results of long term icing measurements as well as recent results of icing measurements are presented. The survey is part of the German contribution to the European COST action 727 "Measuring and forecasting atmospheric icing on structures" [1, 2]. Parts of the paper were presented at BOREAS VII conference [3], they are updated in the current presentation.**

I. ICING MEASUREMENTS IN GERMANY

A. Measurement Sites

Icing measurements were carried out at altogether 40 locations in the eastern part of Germany during 1965-1990 (red points in Fig. 1). The number of locations changed slightly during the years. However, up to 35 locations were operated simultaneously.

The measurements were performed at all locations by the use of manually operated icing poles (for details see next section). A standard measurement procedure defined an exposition period of 24 hours: The pole was exposed every day at 8:30 a.m. at a height of 2 m a.g.l.. In the case of ice accumulation the pole was exchanged after 24 hours. The icing mass was determined and additional information (e.g. icing diameter and direction, ice vane dimension, icing type(s)) was compiled. By using the standard measurement procedure the ice accretion was interrupted at least every 24 hours. In situations of longer ice accretion periods or at locations with good meteorological pre-conditions for an ice accumulation during several icing events the standard procedure underestimated the maximum ice masses.

Therefore the measurement procedure was modified at 11 locations in 1978 (blue circles in Fig. 1). At those locations a second icing pole was exposed. In the case of ice accumulation all the measurements of the standard procedure (ice mass, additional information) were carried out after 24 hours. Afterwards the pole was re-exposed for another 24 hour period. By the application of this procedure it was possible to improve the knowledge about whole icing cycles (accumulation and loss of ice), so they were called icing cycle measurements. One of the main results of icing cycle measurements were 'real' (in distinction to the standard procedure) maximum ice masses.

Fig. 1. Locations of icing measurements in Germany during the time period 1965-1990. Red points: 24-hour measurements. Blue circles: Icing cycle measurements.

The number of locations with icing measurements has been reduced to a total of five since 1991. The icing sensors are implemented at 5 locations (for details see Fig. 2 and Table 1).

Fig. 2. Locations of icing measurements in Germany at present. Continuous icing measurements at all locations.

At present, icing sensors are operated continuously at a single height level (for details see next section). Furthermore, at 3 locations the icing measurements are still carried out by the use of manually operated icing poles (standard procedure and icing cycle measurements, details see Table 1). Since winter 2004/2005 icing measurements at three heights (10 m, 50 m and 90 m above ground) are available at Falkenberg, near DWD's Meteorological Observatory Lindenberg.

TABLE 1: OVERVIEW OF PRESENT LOCATIONS WITH ICING MEASUREMENTS IN GERMANY

Location	Height (m a.s.l.)	Ice Load Measurement		
		Height (m a.g.l.)	Device	Procedure
Arkona	42	2, 5	Ice load sensor Icing pole	continu-ous, standard procedure, icing cycle measure-ments
Chemnitz	418	2, 5		
Zinnwald	877	2, 5		
Kahler Asten	839	10	Ice load sensor	continuous
Hohen-peißen-berg	977	10	Ice load sensor	continuous
Falken-berg	73	5, 50, 90	Ice load sensor	continuous

B. Measurement Devices

An icing pole was the standard icing measurement device during the period 1965-1990. It is still used for measurements at three locations at present (see Table 1). These icing poles have a pole diameter of 0.035 m, a pole length of 1 m and consist of PVC. Fig. 3 shows an example of icing measurement poles, operated at the station Zinnwald.

Fig. 3. Icing poles as used by German Meteorological Service (picture was taken at station Zinnwald, February 2005)

The ice load sensor EAG 200 is the standard icing measurement device since 1990. It is used at all icing measurement locations at present (see Table 1). The ice load sensors EAG 200 have a pole diameter of 0.032 m, a pole length of 0.5 m and consist of PVC as well. Fig. 4 shows an example of the ice load sensor EAG 200.

Fig. 4. Ice load sensor EAG 200 as used by German Meteorological Service (picture was taken at station Zinnwald, February 2005)

The ice load sensor EAG 200 measures the weight of ice accumulated on a vertical pole by the use of an electro-mechanical scale system. A comparison of EAG 200 results with those of manually operated poles shows the reliability of EAG200‘s data (see Fig. 9). Experiences from continuous long term measurements show that the system operates well even for short icing periods and for small amounts of ice accretion.

II. Selected Results of Icing Measurements in Germany

Data from locations Arkona (measurements since 1964), and Zinnwald (since 1971) are used to present selected results of icing measurements in Germany.

A. Regional Differences of Icing

The minimum, maximum and mean number of icing days per year for Arkona and Zinnwald are displayed in Fig. 5. The results show, that the number of icing days in general depends on the location’s elevation above sea level, and it’s position itself (e.g. distance from the coast, topography). This findings correspond to the results of other authors (e.g. [4-10]).

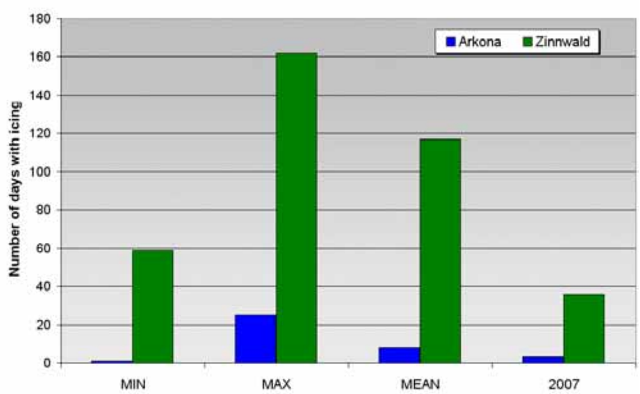

Fig. 5. Minimum, maximum and mean number of icing days per year for the locations Arkona (time period 1964-2006) and Zinnwald (1971-2006). The number of icing days for 2007 are depicted for the purpose of comparison.

The relative occurrence frequencies of icing types for both locations are shown in Fig. 6. As already pointed out for the results in Fig. 5, a general dependence on the location’s elevation above sea level, and it’s position itself (e.g. distance from the coast, local topography) can be observed.

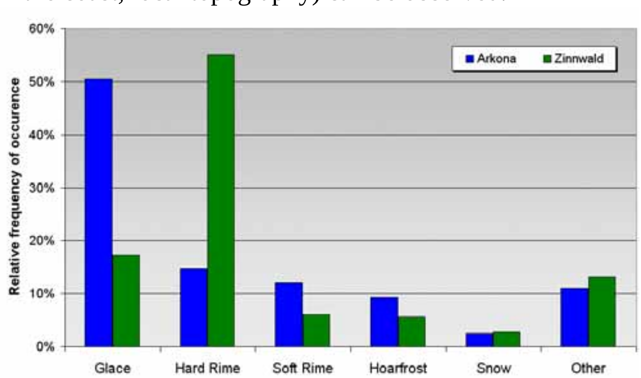

Fig. 6. Occurrence frequencies of icing types for the locations Arkona (time period 1964-2007) and Zinnwald (1971-2007)

At Arkona, not far from the steep coast of the Baltic Sea, glaze occurs noticeable more often than in the mountainous region around Zinnwald. On the other hand, hard rime icing events are observed more often in Zinnwald. These findings match very well with the different ice formation processes. Since glace results from precipitation icing (e.g. freezing rain) it occurs more often at coastal rather than mountainous areas. In contrary, hard rime is a result of in-cloud icing, therefore it is observed more often in mountainous regions. Soft rime is considered to be a result of in-cloud icing processes, predominantly. However, the results in Fig. 6 show a higher relative occurrence frequency of soft rime icing at the coastal area than in the mountainous region, whereas one would expect in-cloud icing conditions more often in mountain areas than at the coast. This apparent discrepancy can be explained by taking the local topography of the surrounding area of Arkona into account: The measurements are carried out not more than 20 m from the steep coast of the island Rügen. Thus, the location is situated on a high elevation relative to the surrounding area (compare, for instance [7, 10]).

B. Long Term Time Series

In Fig. 7 the results for maximum ice loads are displayed, determined by the standard icing measurement procedure at the locations Arkona and Zinnwald. The figure shows the generally higher amounts of ice loads at Zinnwald as well as the annual variability of maximum ice loads at both locations. The results do not confirm any trend in icing as it may be expected by a changing environment due to climate change, for instance.

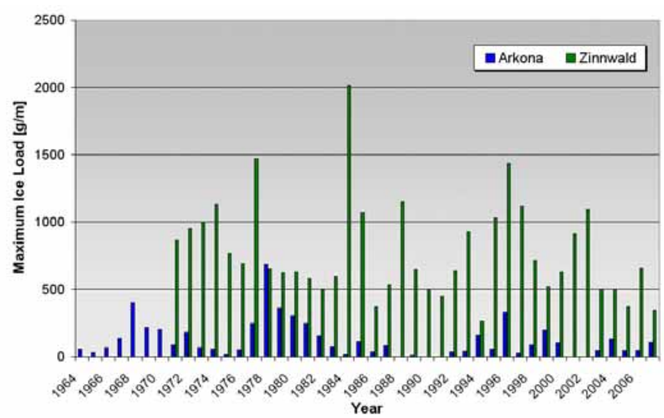

Fig. 7. Time series of maximum ice loads, determined by standard procedure for icing measurements (24 h exposition of icing poles at 2 m a.g.l.) at the locations Arkona (time period 1964-2007) and Zinnwald (1971-2007)

Results of such long term icing measurements are very useful to investigate meteorological preconditions for icing events, to prepare icing climatologies and to provide expertises for the public as well as for the industry and the economy.

C. Comparison of Manually Operated and Automatic Icing Measurements

The icing poles are still used for measurements at three locations at present (see Table 1) in order to compare their results with simultaneous automatic icing measurements by the use of EAG 200. The measurement results of both instruments were evaluated for the maximum ice masses that were measured during whole icing cycles (accumulation and loss of ice). The findings are displayed in Fig. 8.

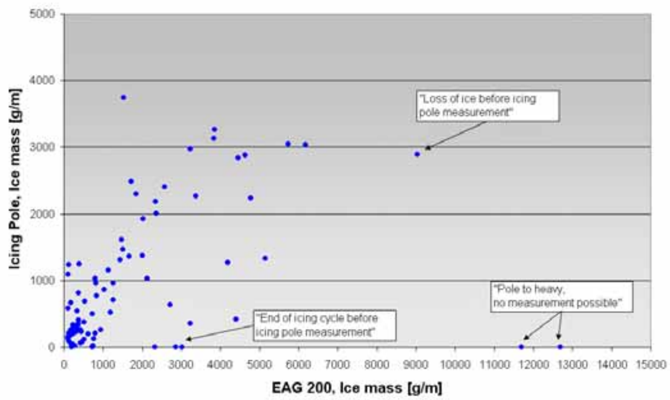

Fig. 8. Comparison of maximum ice masses that were measured in icing cycles by the use of a manually operated icing pole and the automatic icing measurement system (EAG 200) during the period 1996-2004 at the station Zinnwald (depicted remarks are from the measurement protocol of icing pole measurements).

Fig. 8 illustrates the limitations of manually operated icing pole measurements: For very large ice masses either no measurements are carried out, because the impossibility of pole-handling, or the measurements are erroneous. Furthermore the icing cycle may have been finished before the measurement was carried out.

Regression analysis of both measurement techniques shows acceptable results if the unreliable data points are excluded (see Fig. 9). This illustrates that reliable results can be achieved by the use of an automatic instrument. Nevertheless, additional information about the icing types or about the icing geometry (e.g. icing diameter, icing vanes) are missed.

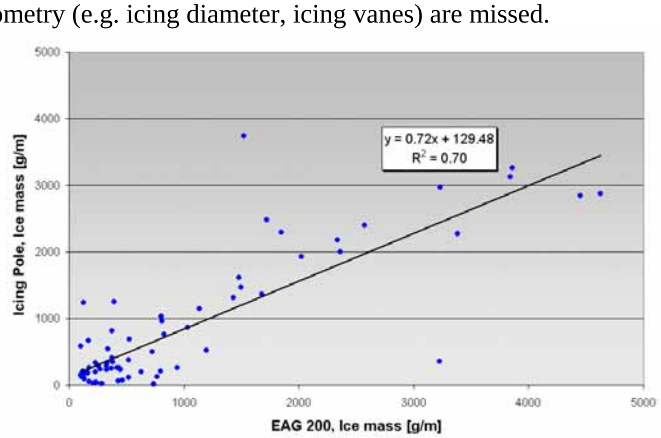

Fig. 9. As Figure A. 28, but without unreliable data points

III. OUTLOOK

Beside the purposes of a general investigation of icing (e.g. meteorological preconditions for icing events, icing climatology, investigation of trends du to climate change) and the supply of special expertises regarding the icing of structures, long term time series of icing measurements from the eastern part of Germany are currently used to prepare icing maps (e.g. occurrence frequencies of icing, maximum ice loads) for entire Germany. For this purpose the measured data are analyzed by a regression analysis in order to detect easy to use interrelationships between icing and auxiliary parameters. Observation data of DWD's weather stations are used to transfer the knowledge from icing measurements in East Germany to the western parts of the country.

IV. REFERENCES

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