Climatology and forecasting of severe wet snow icing in Hungary

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***Abstract*—Weather in wintertime can be very different year to year in Hungary. Severe icing on structures can happen mainly due to freezing rain, but occasionally wet-snow icing and rarely rime icing may cause problems or even damages. In the last winter (January and February of 2009) some significant wet-snow icing events highlighted the importance of this weather phenomenon. These situations motivated us to do some investigations around the climatological background and current forecasting possibilities of this type of atmospheric icing. A case study of wet-snow icing based on an experimental Numerical Weather Prediction model is shown. The results convinced us that available NWP's with detailed microphysics have better potential to describe the conditions suitable for severe wet-snow icing.**

I. INTRODUCTION

The winter period of 2008/2009 went by with some severe weather events in Hungary. While the meteorologists in the northern countries or those who are living in high mountains are used to the severe rime and wet snow loads, but in Hungary similarly dangerous situations have happened with low probability due to the climate of the country. Nevertheless during this winter, more times in a short period such synoptical events happened, which made the formation of dangerous wet-snow load possible. On 27-28th of January, 2009 in County of Vas and County of Zala (Southwestern Hungary), and a little later on 8-9th of February, 2009 (Fig.1.) in Transdanubia Hills (Northwestern Hungary) a considerable electrical breakdown in power line network system has called the scientists' attention to those serious consequences, which could be occurred by wet snow in Hungary. These events have turned not only the meteorologists', but the electrical engineers' and energy provider companies' attention to the potential problems of ice load. Connected with a cooperative analysis of severe wet snow accretion a study was made by the Hungarian Meteorological Service about meteorological and climatological background. Due to the extended damages of power line network system the interest of media had been aroused and a lot of pictures were taken of intact and collapsed power lines.

The Hungarian Meteorolocal Service has been in touch with the biggest Hungarian energy supplier companies, who regularly get forecasts and warnings of expected ice mass in the winter period. There are several situations, when wet snow can accrete, but at the same time remarkable wet snow forms only occasionally. Depending on the weather situation subjective judgment of expected mass of snow load is very difficult. Our goal is to find a well-useable and objective method to the forecast of accumulated wet snow amount.

Based on international literature several algorithms have been adopted, and have been used with background of some operational and now-developing numerical models.

Fig. 1. Cylindrical wet-snow accretion on a conductor. Source: E.ON Northwestern Hungary Electricity Supplying Zrt. (9th of February, 2009., Bakony)

II. THE APPLIED METHODS

In the international literature several methods have been found. A method we have been looked for, whose parameters could be found in the given model itself or could be calculated from the model parameters. Our purpose was not to develop a new method, but to apply some existed methods successfully. The physical process of wet snow – and icing accumulation in general – is very complex to apply exactly in the daily forecasting practice. Therefore, we had applied simple, empirical methods during our work. The two most successful principles are the followings:

1. Sundin and Makkonen (1998) [6]:

$$m = P * t * R \qquad (1)$$

Where m is the amount of accumulated wet snow (kg/m), P is the intensity of precipitation (mm/h), t is the passed time (h), and at last R means the outer radius of snow sleeve (m). In the first time step the cross section of conductor may be given.

2. Poots (2000) [4]:

$$\delta m = P * U * \sigma * a * dt \equiv 2\pi * \rho_s * a * da \qquad (2)$$

where the mass of accumulated snow, δm (kg/m) between (t) and (t+dt) is directly proportional to precipitation, P (mm/h), wind speed, U (m/s), dimensionless accretion factor, σ and outer radius of snow sleeve, a (mm) at time t. ρ_s means snow density in (kg/m^3) which depends on wind speed, U.

In this study the first method was examined in detail, but we have already had some promising results of second method also.

The original goal of the first method was the mapping of climatological characteristics of wet snow based on the databases of measured precipitation and temperature, furthermore type of observed precipitation. According to the method we assumed, that the snowflakes may stick around the wires cylindrically. The observed snowfall becomes wet snow on the objects, when wet bulb temperature is between 0 and 4 ˚C. If the temperature is above 4 ˚C during three time steps (in our case during three hours), the full amount of accumulated wet snow has melted from the wires. Effects of the wind are left out of consideration. The cross section of wire can be given as an input data at the beginning of calculation.

In this work the introduced method has been applied for numerical modeling, so we must determine the type of precipitation from the model. During our attempts MM5, WRF and AROME models were used with detailed microphysical schemes. Five different hydrometeors were distinguished in every model. The precipitation could be considered snowfall, if the mixing rate of snow hydrometeors in the model is one and half times bigger, than the mixing rate of rain hydrometeors (60%:40%) [4].

III. The synoptical situation on 27-28th January, 2009

Our work on wet snow modeling has been started for years ago, but we hadn't possessed remarkable case study because of the climate and low height above sea level of Hungary. On 27th January, 2009 a Mediterranean cyclone reached the country, which caused serious damages in electrical power line network. Due to this cyclone we had a magnificent opportunity to continue the work.

On 27-28th January a Mediterranean cyclone determined the weather of Hungary, which gave rise to overclouded and rainy weather (Fig. 3.). The cyclonecentre was located over Adriatic Sea. Milder air masses arrived from east with the airstreams of the cyclone; therefore the precipitation type was rain over the biggest part of the country except in Western Transdanubia, where rainfall had changed into snowfall gradually.

We can give a general overview about the meteorological background of the situation with help of Fig. 3-9. In the evening of 27th January the occlusion point and left-exit region of a sub-tropical jet-stream (Fig. 4.), which belonged to the cyclone, situated over Western Hungary, so the area of the heaviest upstreams and the most intense precipitation falls could located over Transdanubia. This configuration is not uncommon in Hungary, but most of the cases wet-snow, as a phenomenon, could exist only for a short period of time. In this situation the precipitation type was wet snow for many hours with quite high intensity, which is very uncommon. In the critical hours the temperature advection of the lowest layers and the cooling effect of the precipitation were well balanced and it made perfect temperature stratification for wet snow. The temperature near to the ground could stay near 0 ˚C. Fig. 8. shows a radar image in chosen time typically from that period. Based on the reports of synoptic stations, amateur observations and the character of the radar reflectivity field (bright band) we tried to draw the dividing line between the two precipitation types (snow and rain). At that time, when the most of the damages happened, the strongest wind gusts were not higher than ~ 14 m/s (Fig. 9-10.).

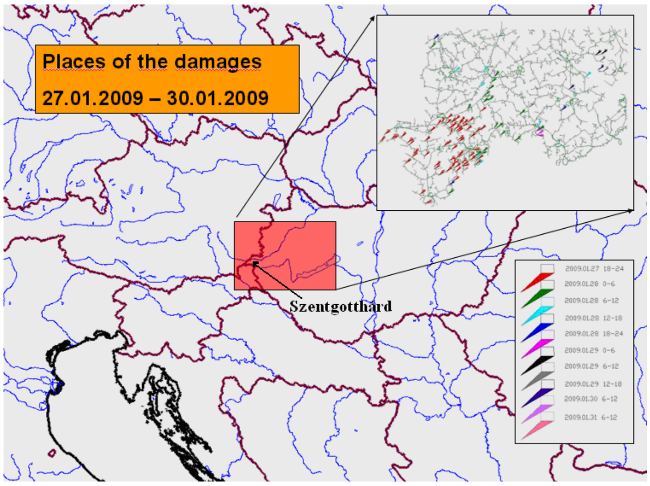

Fig. 2. Territory of damages of the power line network. Extreme weather have resulted in damage to tens of kilometers of overhead power lines and more than 100 transmission poles in the southern part of Vas, Zala and Somogy counties. The places of the damages are signed in the upper-right map with different colors according to the time of the malfunction. The critical time period was evening and night of 27th of January (red and green signs). Source: E.ON Northwestern Hungary Electricity Supplying Zrt.

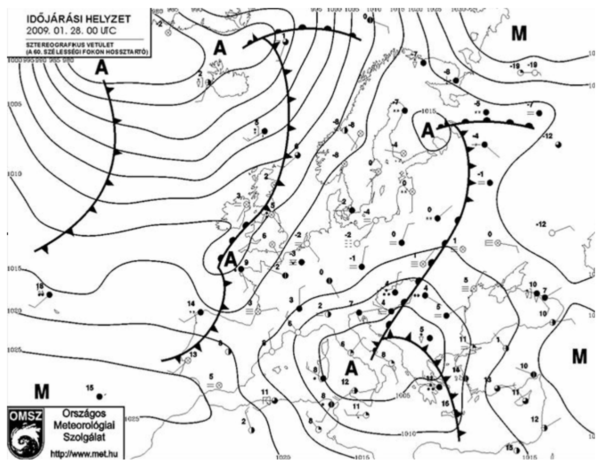

Fig. 3. Weather situation in Europe at 00 UTC, 28 January 2009. The cyclone centre is located over Adriatic Sea. This is a common synoptic configuration with high amount of precipitation in wintertime in Hungary.

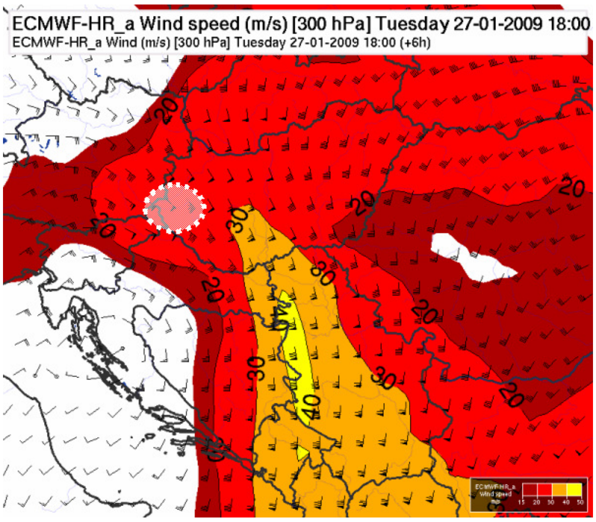

Fig. 4 27.01.2009 18 UTC. Stream on the level of 300 hPa. Western Hungary is situated under the left exit region of a strong sub-tropical jet-stream in which the wind speed exceeds 40 m/s. This configuration supports strong upward motions and precipitation developments. The main territory of the damages is enhanced.

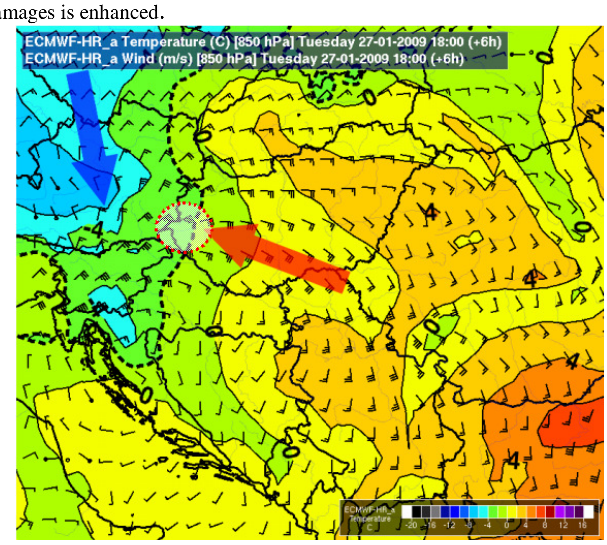

Fig. 5. 27.01.2009 18 UTC. Temperature and wind field above Central-Europe at 850 hPa /based on ECMWF model/. In Western Transdanubia the temperature is around -2 °C in this pressure level. Warm air advected from east (red arrow) to the main area of the damages (enhanced area), but due to the cooling effect of the intense precipitation (rain, sleet and snow) the temperature and its stratification didn't change so much around this time. Later cold advection in the lowest 1000 m had considerable effect, and the typical precipitation type became snow.

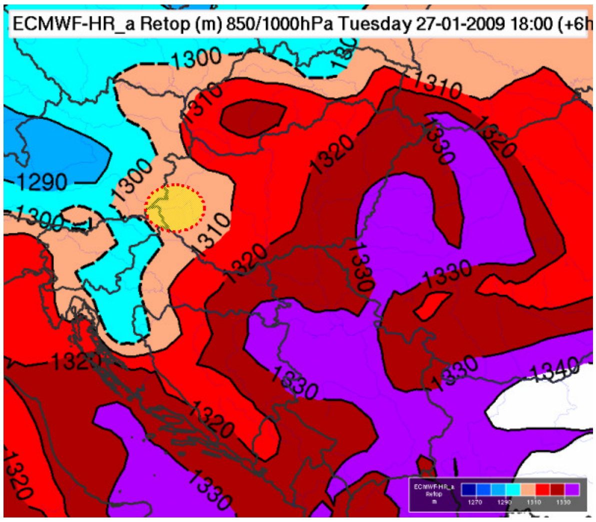

Fig. 6. 27.01.2009. 18 UTC. Layer thickness of 850-1000 hPa (Relative Topography 850/1000) /based on ECMWF numerical model/. The values are proportional of the mean temperature of the layer. Around 1300-1310 m, which is slightly higher than the average, climatological threshold (1300 m) belong to separation of rain and snow. The arrow shows the center location of the damages of the overhead power lines.

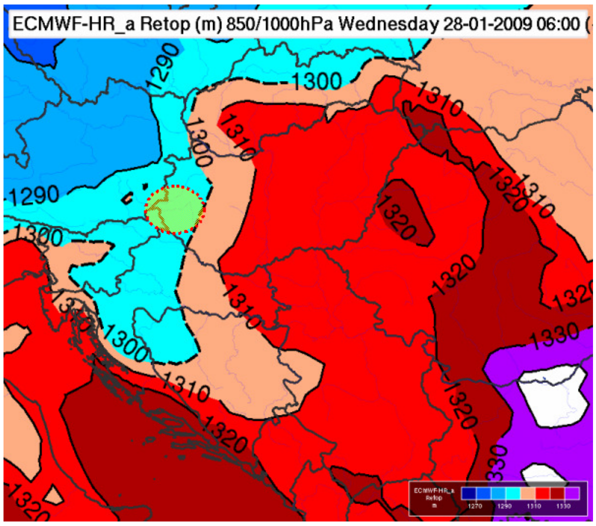

Fig. 7. 28.01.2009. 06 UTC. Layer thickness of 850-1000 hPa (Relative Topography 850/1000) /based on ECMWF/. Till morning the values decreased under 1300 m in most of the part of Western Transdanubia (cold air advection). The main territory of the damages is enhanced.

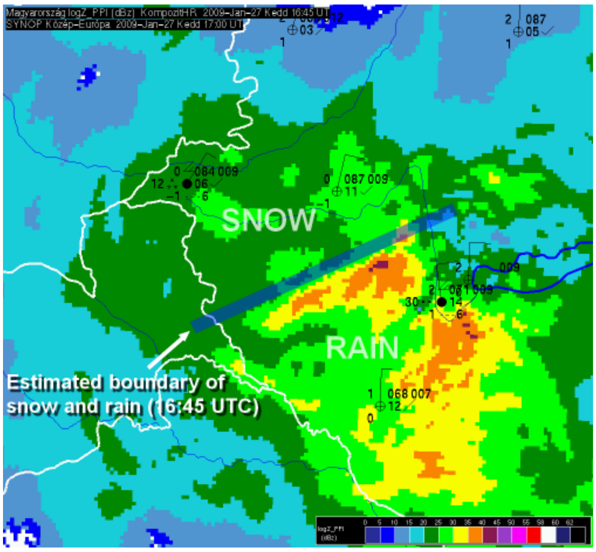

Fig. 8. Radar image and synoptic measurements in a chosen time (16:45 UTC) in the beginning of the critical period. The line separates the typical precipitation type at ground at this time. Generally there is moderate and locally intense wet snow with fresh (5-11 m/s) northerly wind in the area of the power line network damages.

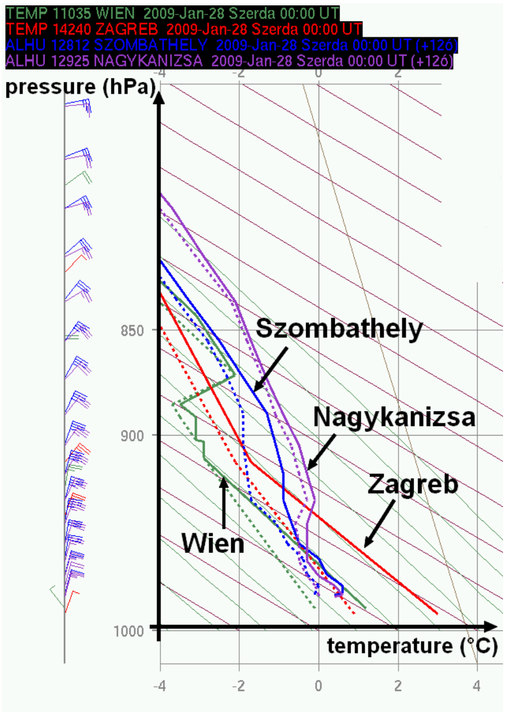

Fig. 9. 28.01.2009 00 UTC. Temperature stratification according the nearest measurements (Zagreb, Wien) and numerical models (two chosen grid point). The freezing level above ground is 450 m in Wien, 1150 m in Zagreb and around 80-160 m in the power network damages area.

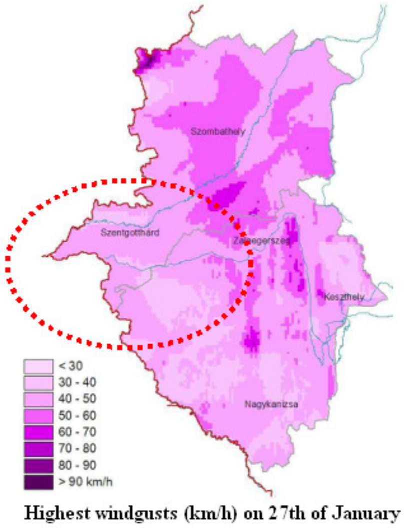

Fig. 10. Highest windgusts in the critical time period of the dangerous wet snow event. Most of the territory of the damages area the gusts did't exceeds 14 m/s in the critical hours. (The map is based on MISH method [7].)

IV. Model Results

However, we have used 3 different numerical weather prediction model backgrounds, 2 methods and several operational and experimental runs during our research, in this study we would like to show only the most successful experimental running. All of the models were successful in forecasting the area and amount of precipitation. The large-scale synoptical processes determined the precipitation area well, so the actual and forecasted weather approximately were identical with each other. The source of problems was that the forecasts of temperature in the lower layers were insufficient. In the contrary to other models, the temperature forecasts of the AROME were the most suitable for applying its runnings to our work. The AROME has been under developing yet at the Hungarian Meteorological Service, but it will be available to the daily forecasting practice in the near future. According to the results of this model, the temperature near to the ground was between 0 and 1 ˚C, which were in the given interval (wet bulb temperature must be between 0 and 4 ˚C) (Fig. 11.). We would like to present from several runnings the 12 UTC running, and which was based on method of Sundin and Makkonen [6]. Like we mentioned before this event occurred on 27-28th January, 2009. Depending on the model we calculated the estimated quantity of the deposited wet snow on a 3 cm diameter wire in kg/m. In Fig. 12-13. we can see the forecasted snow load in the AROME model. The first picture contains the 12th time step, the second shows the 24th time step. By this time the maximum values are around 2,5 kg/m. Fig. 13. shows us that a massive snow load appeared not only in Hungary but in Slovenia. By the foreign information they faced similar malfunctions like Hungary did. Our calculations of the area of the most accumulated snow matches with the actual damages. However the maximum values are underestimated compared the real snow loads which were locally heavier than 4-5 kg/m (Fig. 14.).

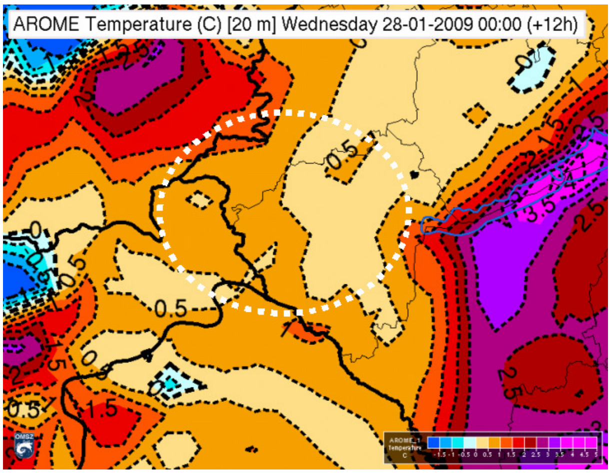

Fig. 11. Temperature field in the AROME model at 00 UTC 28.01.2009 (+12h). The values are around between 0 and 1 °C in the discussed territory.

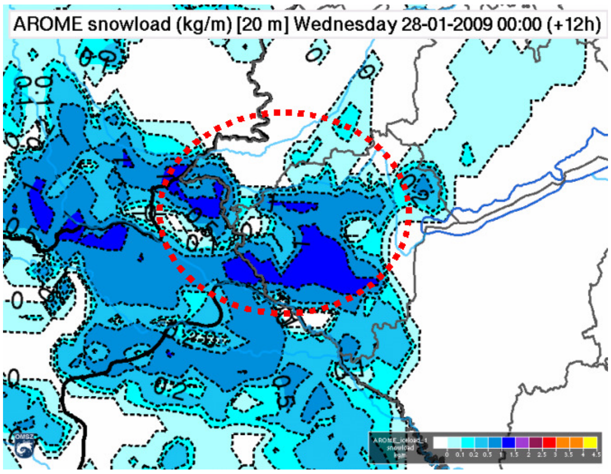

Fig. 12. Forecasted snow load in the AROME model at 00 UTC 28.01.2009 (+12h). The maximum values are around 1 kg/m. The area of malfunctions in power line network approximately falls into the dotted line.

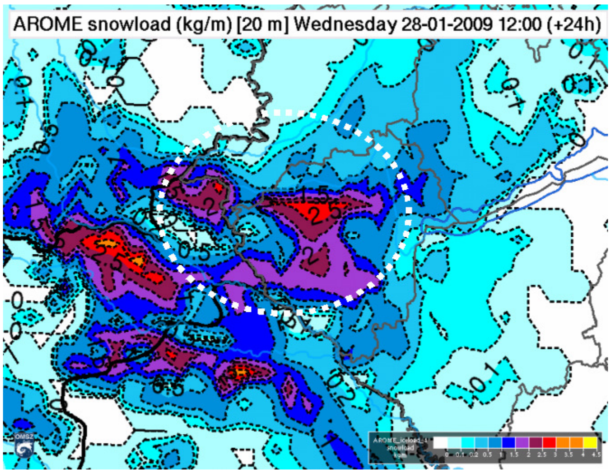

Fig. 13. Forecasted snow load in the AROME model at 12 UTC 28.01.2009 (+24h). The maximum values are around 2,5 kg/m.

Fig. 14. The estimated wet-snow load was heavier than 4-5 kg/m in this case. Source: E.ON Northwestern Hungary Electricity Supplying Zrt. (28th of January, 2009)

V. Climatological Investigation of Severe Wet-Snow Accretion

We would like to answer the following question: How extreme was the showed situation in this part of our country?

A. *Icing measurements in Hungary*

In Hungary icing measurements started in 1966. An instrument was developed by Mihály Csomor in this year, which is in use nowadays also [3]. There are 13 synoptic stations where this manual icing instrument is in operation. The instrument (Fig. 15.) has 4 wire-pieces faced to the 4 points of the compass. The wires are 2 m high above the ground, and 1 m long apiece. Its cross section is 31 mm, because the conductors used to be 31 mm in Hungary. Of course, this standard has been changed, but in the interest of homogeneous database the cross section of our instrument is invariable. The wires cannot rotate, therefore lesser ice mass can accumulate on them supposedly. During the measurement procedure the thickness of accumulated ice (rime, wet snow) is measured in mm even on the wires, then the endure mass of ice is melted into a rain gauge – the wires are movable. The water content can be converted from mm to kg/m.

B. *Summary of an official climatological investigation*

As the January events have been brought to a consequence trial, an independent expert investigation was completed by the Hungarian Meteorological Service and Technical University of Budapest. During our investigation a database of Szentgotthárd synoptic station was used, which is located on the west part of damaged area. However only a 20-year-long database was available at this point for the investigation. According to the so-called Peaks over threshold method the estimated return period of the phenomenon is 40-50 years [1].

Fig. 16. shows us, that this event was the greatest water containing icing event in the last 20 years. It is easy to calculate that the 24,3 mm wet snow in the rain gauge equal to ~ 0,5 kg/m on the wire. (1 mm water equal to 20 gram snow in

the rain gauge) This could seem to be slim but because of the fixed wire the wet snow cannot be accumulating circle symmetrical. Based on the report of Technical University of Budapest the wet snow load on a 12,5 mm wire was ~7-12 kg/m, to which the compressive force of wind was not added [5].

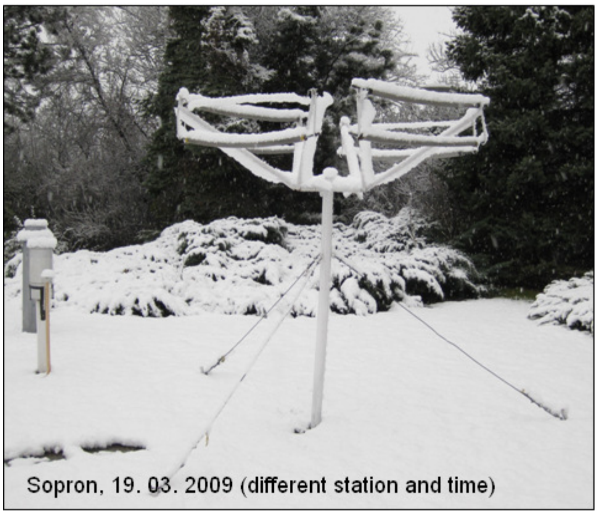

Fig. 15. Icing instrument developed in Hungary in 1966. The movable wires are 2 m high above ground, 1 m long and they face to the 4 points of the compass.

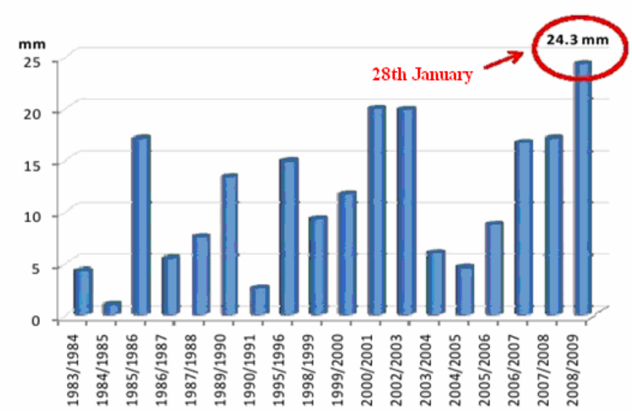

Fig. 16. On 27-28th of January the water content of wet-snow was the greatest in the last 20 years. 24,3 mm melted wet-snow in the rain gauge equal to ~0,5 kg/m on the wire.

Comparing to our model results, the weight of wet snow load is between the measured load on the instrument (0,5 kg) and the estimated load on the real conductor (~7-12 kg/m). According to the model the maximum values are ~2,5-3 kg/m, but the model is not taking into account of the effects of wind.

VI. Conclusion

Our paper describes a part of a preliminary study about current forecasting possibilities of wet snow icing. A Hungarian case study of an extreme wet snow event was shown with a quantitative forecast method. The applied numerical weather prediction background was an experimental model, called AROME. The results convinced us that available NWP's with detailed microphysics have better potential to describe the conditions suitable for severe wet-snow icing. Development of new operational forecasting products regarding wet snow for users, especially for power suppliers will be beneficial.

Based on the Hungarian icing measurement system a method was applied for calculation of the return period of extreme icing event. These results are adequate only for the locations of the measurements.

VII. Acknowledgment

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