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Analysis and Simulation of Two Severe Wind and Ice Storms in the Highest Regions of Central Balkan

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Abstract. Two severe wind storms happened in November 1964 and December 2012 in the highest regions of the central part of the mountain Stara planina – the Central Balkan. They caused heavy damages to the technical equipment and the buildings along the ridge of the mountain – in 1964 the roof of the main TV building was blown away by strong north winds and the TV tower itself was broken. The whole area of the damages spreads over 30 km. In 2012 a Mediterranean cyclon hit the same regions with powerful south winds and a smaller radio tower collapsed due to the heavy wind and ice load. The purpose of this study was to evaluate the meteorological conditions during these events with focus on the wind and ice severity. We have analyzed the synoptic condition at different pressure levels in order to estimate the main dynamic of the atmosphere over the Balkan Peninsula and we have used WindNinja version 3.8.1 for simulation of the surface wind field in a smaller region. Finally, using simple icing model we have estimated also the possible ice load. WindNinja is a numeric aerodinamicall diagnostic model developed for analysis of forest fire behavior. It is developed by the Missoula Fire Sciences Laboratory, Forest Service U. S. Departmen of Agriculture. In this research a daily meteorological data from Botev peak and station Mazalat has been used during the time of the respective extreme event (November 1964 and December 2012).

KEY WORDS: climatic changes, rime icing on structures, wind field numerical simulation.

1 Introduction

In November 1964 and December 2012 in the highest regions of the central part of Stara planina - Central Balkan, two strong storms occurred. They caused great damage to the technical equipment on the ridge of the mountain – in 1964 the roof of the main television building was blown away, and in 2012 a radio tower with a height of 77 m has collapsed. The total area affected by icing as well as by the strong wind is over 30 km. The objective of this study is to evaluate the weather conditions during these extreme events with emphasis on wind and icing loads on facilities. As a second step of our research, we had intended to test the numerical aerodynamic model wind calculations with actual wind measurements from meteorological stations on the peak Botev and Hut Mazalat.

2 Analysis of the Synoptic Conditions During the Storms

The wind regime in Bulgaria is characterized by well-defined seasonality. This is caused mainly by the specific geographical location of Bulgaria, a wide variety of relief, and also the presence of a sea coast in the eastern part of the country. Wind speed is the highest during the winter season, when strong winds have a frequent occurrence in the mountainous parts of the country.

2.1 The storm on Botev peak and hut Mazalat on 24-26.11.1964

The weather in Europe is determined by a blocked deep cyclone system with two centers over the north Atlantic and northern Europe and an extensive anticyclone over Western Europe. In height, an intense frontal zone is formed with a direction from northwest to southeast (Figure 1a and 1b, www.wetterzentrale.de).

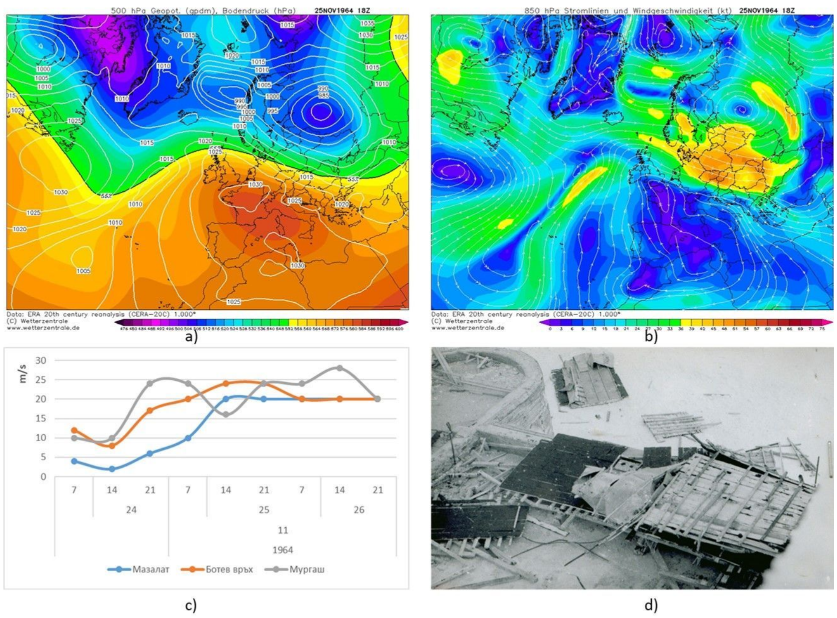
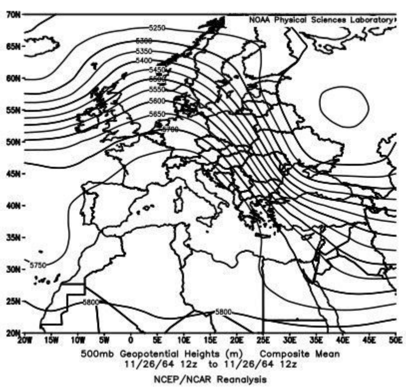


Figure 1. Maps for the 25 November 1964, 18h UTC: a) baric field – ground level and at a height of 500 hPa; b) wind streamlines at 700 hPa; c) change in wind speed in the studied period in the available stations along the ridge of Stara Planina; d) picture of the destroyed roof of the TV apartment building.

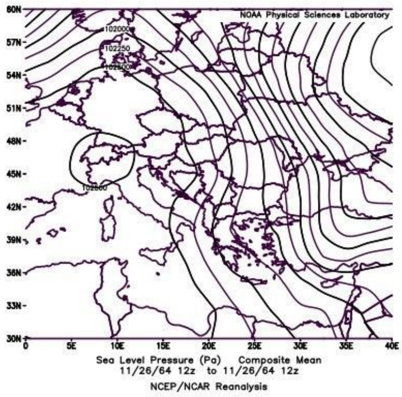
The processes at peak Botev started with the strengthening of the wind on the 24th, when a wind speed of 17 m/s was measured. On the 25th, the wind increased to 20 m/s, and wind gusts of 28 m/s were observed during the day. During the entire period of the storm the wind direction remained constant from the NW. Throughout November 26, a wind of 20 m/s was blowing from the NW on peak Botev. In the period up to 3:10 pm, wind gusts of 40 m/s were recorded from the NW, then from 9:10 pm they decreased to 20 m/s again from the same direction. This information is summarized in Figure 1.

2.1.1 Atmospheric dynamics in Europe and the Balkans on 26.11.1964

Figure 2 presents synoptic maps for the 26 November 1964 extracted from the NCAR-NCEP Reanalysis plotting website following the next link, as is shown [1, 2]: https://psl.noaa.gov/data/composites/hour/.



(a)



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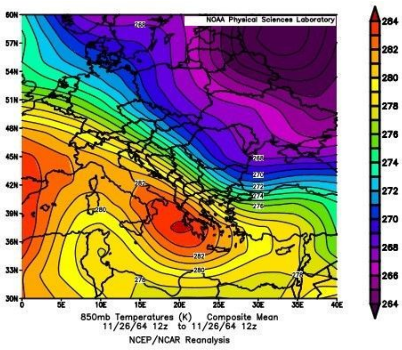

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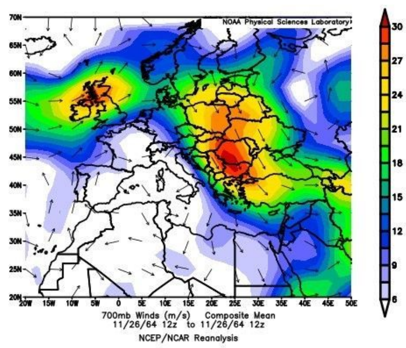

(d)

Figure 2. Synoptic maps for the 26 November 1964, 00h UTC: (a) geopotential height (m) at 500 hPa; (b) sea level pressure (Pa); (c) air temperature (K) at 850 hPa; wind speed (m/s, color scale) and direction (vectors).

The polar front (Figure 2a) and the associated jet (Figure 2d) cross the Balkans and Bulgaria diagonally from northwest to southeast. The core of the cold air mass is over Northeast Europe and the core of the warm air mass is over the Central Mediterranean (Figure 2c). Europe is divided in two zones: high pressure dominates Western Europe and low pressure is centered over European Russia. The strong gradient between the two stretches over Central Europe and the Balkans (Figure 2b). In middle troposphere at 500 hPa the strongest gradient is over Bulgaria and Romania. It reflects in the fact that the strongest northwest winds at 700 hPa are indeed between the two countries and reach levels above 30 m/s (Figure 2d). The observed wind speeds of 40 m/s at the Botev peak on 26 November are naturally associated with the middle level jet. The Stara planina mountain range has zonal stretch and therefore the northwest winds blow across the edge. This strengthens the winds even further in accordance with the Bernoulli's principle.

2.2 The storm on Botev peak at 8-9.12.2012

The weather over Bulgaria is conditioned by a deep cyclone over the Adriatic Sea, leading to a strong southerly flow aloft. The deterioration of the meteorological situation on peak Botev began with the strengthening of the wind at

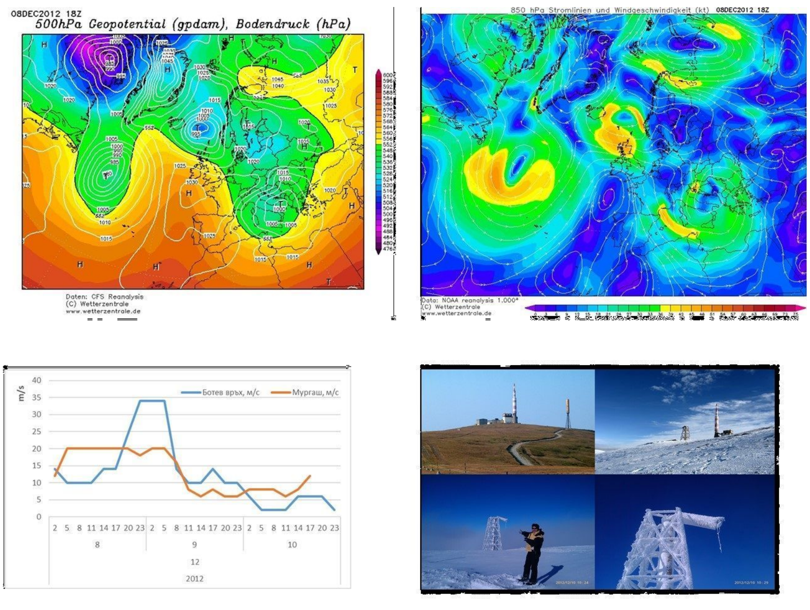

Figure 3. Maps for the 8 December 2012, 18h UTC: a) baric field – ground level and at a height of 500 hPa; b) wind streamlines at 700 hPa; c) change in wind speed in the studied period in the available stations along the ridge of Stara Planina; d) pictures of broken mast.

14:00 on December 8 2012 and reaching a speed of 14 m/s from the NNE. In the evening of the same day (at 5 pm) the wind is reorientated from the SSW, remaining strong (14 m/s). A gust of 24 m/s occurs from the S.

The same evening (20:00) the wind increases and its speed is already 24 m/s, but it is already from the S. From 23:00 on 8 December to 5:00 the next day the wind now reaches a speed of 34 m/s from the S. During the night (up to 6:30 h) wind gusts with the same speed and direction were registered. Information for the synoptic situation, wind variation and fallen mast is presented in Figure 3. The maps shown in Figures 3a and 3b are obtained from the Wetterzentrale website, as following the link: www.wetterzentrale.de.

2.2.1 Atmospheric dynamics in Europe and the Balkans on 8-9.12.2012

Figure 4 presents synoptic maps for the 9 December 2012 extracted from the NCAR-NCEP Reanalysis plotting website following the next link, as is shown [1, 2]: https://psl.noaa.gov/data/composites/hour/.

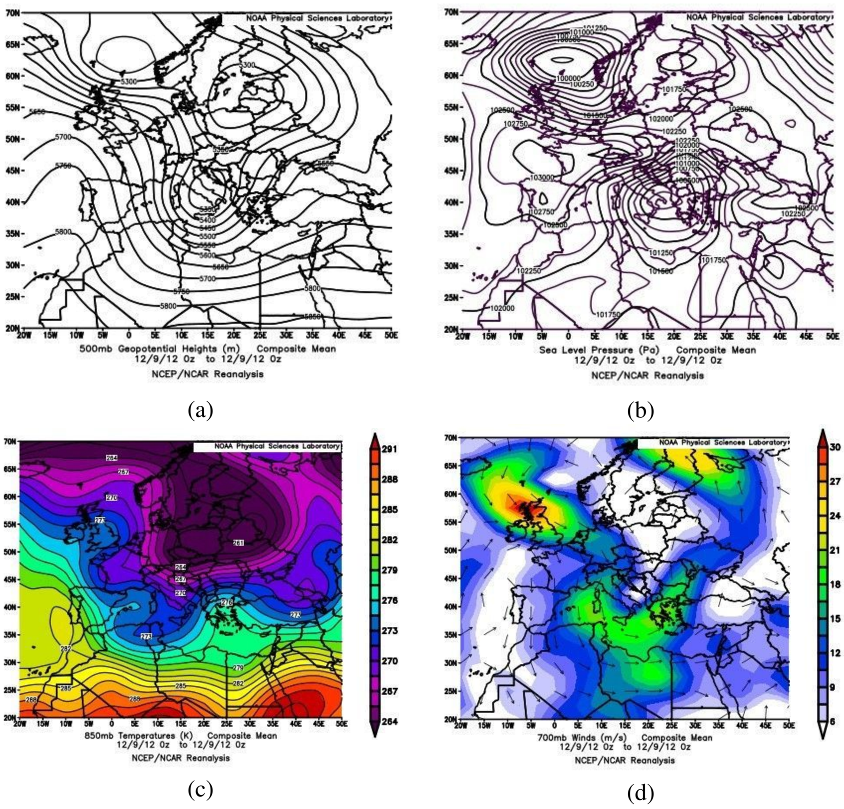

Figure 4. Synoptic maps for the 09 December 2012, 00h UTC: (a) geopotential height (m) at 500 hPa; (b) sea level pressure (Pa); (c) air temperature (K) at 850 hPa; wind speed (m/s, color scale) and direction (vectors).

A well developed Mediterranean cyclone approaches the Balkans and Bulgaria from west (Figure 4b). The front of the higher level trough, associated with the cyclone, crosses the Balkans and Bulgaria from southwest to northeast (Figure 4a). The associated southwestern jet comes to Bulgaria from southwest. At 700 hPa the wind speeds over Bulgaria are up to 25 m/s (Figure 4d). The warm section of the cyclone is well defined on the air temperature map at 850 hPa (Figure 4c). The core of the cold air mass is over the Baltic region. The observed wind speeds of 34 m/s at the Botev peak during the night between 8 and 9 December are naturally associated with the middle level southwest jet. The Stara planina mountain range has zonal stretch and therefore the southwest winds blow across the edge. This strengthens the winds even further.

2.3 About the aerodynamic numerical model

WindNinja is a diagnostic aerodynamic model that allows numerical simulation of the three-dimensional structure of the air flow at the ground level for a given region of interest. The model takes into account both terrain inhomogeneities and the temperature stratification of the ground air layer. It was originally created to model the ground wind field of wildland fire development. We have worked with version 3.8.1 of this numerical aerodynamic model, installed on a PC under OS Windows. In this case, the time values from the measurements of wind speed and direction, air temperature and the amount of total cloud cover at the Botev peak station were used as input data. The model also needs a digital pad with the relief of the area, as well as a parameterization for the character of the vegetation on the terrain. It was developed [3, 4] at the Fire Research Laboratory in Missoula, USA. The simulation in this case was conducted as the wind field at the ground, both in the vicinity of the peak Botev and in a wider area of the Central Balkans, was modeled based on data from the periodic observations at the Botev peak station for two storms that struck in 1964 and 2012. The spatial resolution of the calculations is 390 m.

In Figure 5 it is shown simulated by numerical model surface wind field at the peak of the storms – (a) for Botev peak and (b) and for the cabin Mazalat in 1964 and on (c) and (d) for that storm in 2012 respectively. The comparison of measured and calculated wind characteristics for both storms is represented in Table 1. A good coincidence between the calculated and measured values of surface wind parameters is observed. Relatively larger differences between the calculated and measured wind values are observed for the Mazalat hut, which is due to the distance of the station from peak Botev (about 16 km in the Eastern direction). In Figure 5a it is shown the surface wind field in the peak region at 9 pm (EET) on 25 November. Measurements for Botev peak in this period show a wind speed of 24 m/s from the NW and they coincide very well with the calculations from the numerical model – 23.9 m/s with a NW direction (Table 1).

At the same time, in the Mazalat Hut area, the model calculates 20.8 m/s with

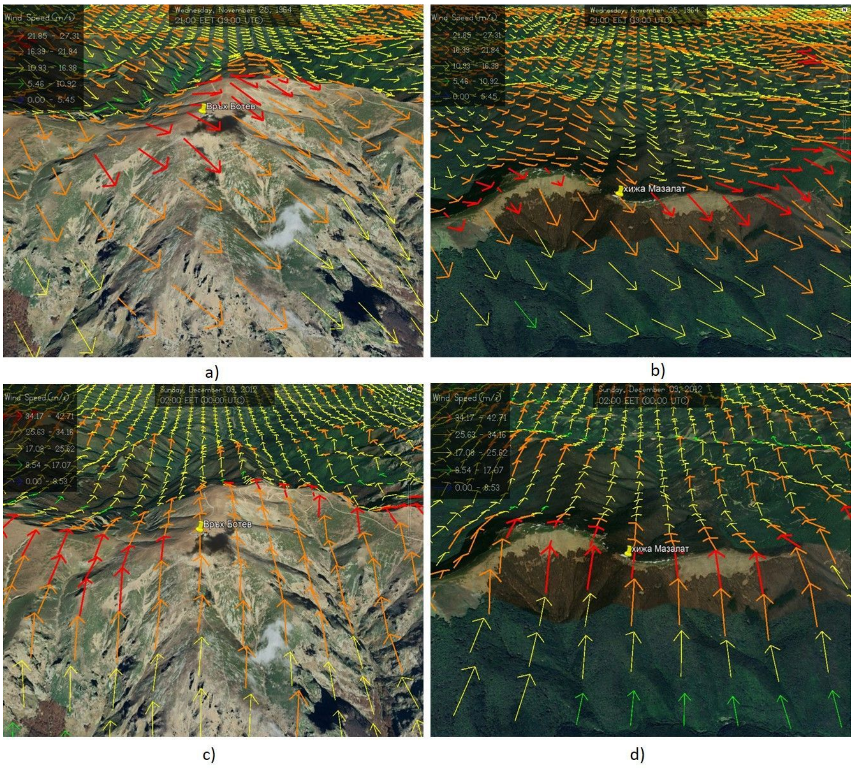

Figure 5. Surface wind field in the area of: (a) Peakt Botev at 21 (EET) on November 25, 1964; (b) at the Mazalat hut at 21 (EET) on November 25, 1964; (c) on Peak Botev at 2 (EET) on December 9, 2012; (d) Mazalat Hut area at 2 (EET) on 9 December 2012.

a NNW direction (Figure 5b), while measurements show wind 20 m/s from the N. During the 2012 storm at 2:00 (EET) on December 9, a speed of 34 m/s and direction S was measured for peak Botev (Table 1), and the numerical model

Table 1. Wind characteristics for Central Balkan region of both storms; V_1 – wind speed calculated by the numerical model (m/s); V_2 – measured wind speed (m/s); D_1 – evaluated by the model wind direction; D_2 – observed in direction

Station	V_1	D_1	V_2	D_2
		25 November 1964, 21:00 EET		
Botev peak	23.9	NW	24.0	NW
Cabin Mazalat	20.8	NNW	20.0	N
		9 December 2012, 2:00 EET		
Botev peak	33.5	S	34.0	S

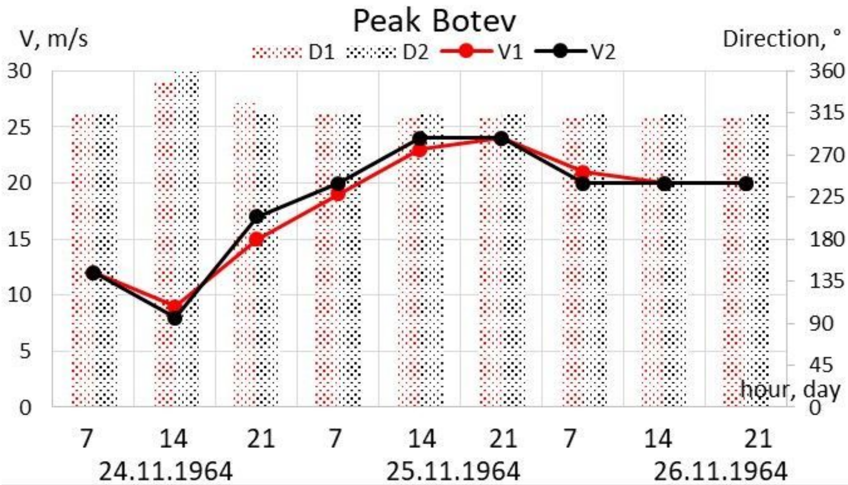

Figure 6. Variation in wind speed and direction during the 1964 storm.

calculated speed of 33.5 m/s and also direction S (Figure 5c). For Mazalat Hut, we have no measurements for this period because the station was closed in the 1990s, but the model shows a wind speed of 36.3 m/s from the S (Figure 5d).

From Figure 6, it can be seen that calculated by the numerical model wind speed and direction are fitted very well within the measured wind speed and observed wind direction in the station on the Botev peak. In the same way from Figure 7,

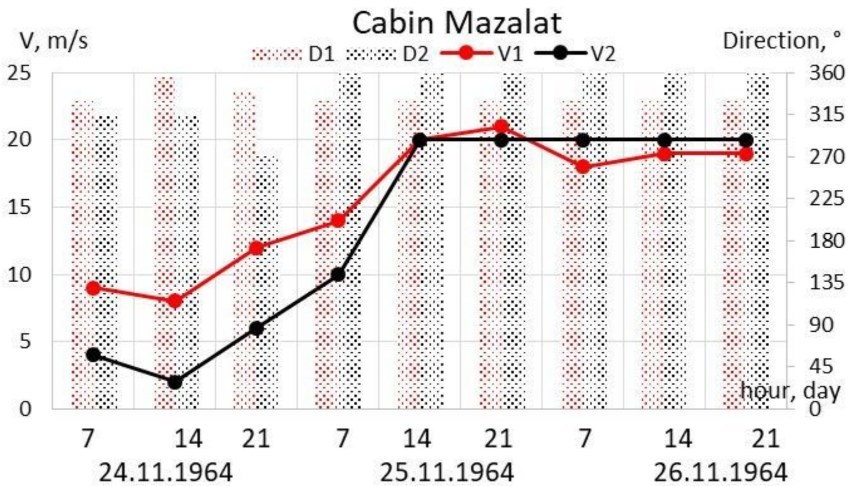

Figure 7. Variation in wind speed and direction during the 1964 storm.

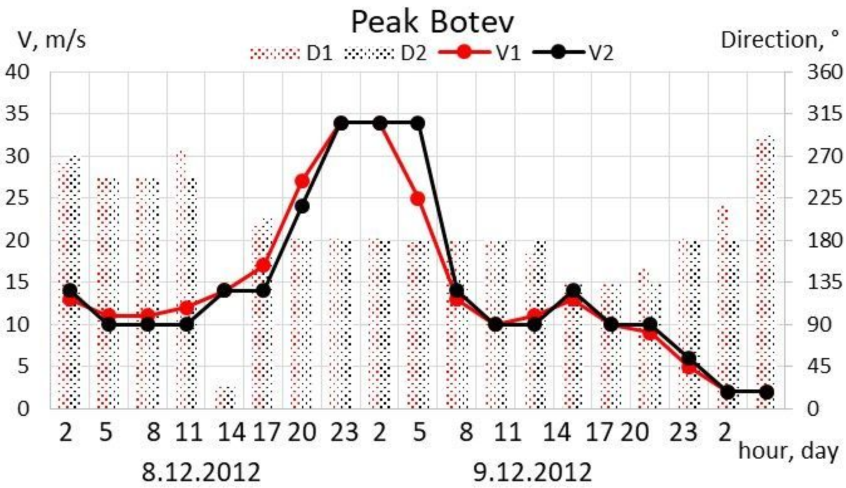

Figure 8. Variation in wind speed and direction during the 2012 storm.

it is seen that model calculated not enough precisely wind speed and wind direction in cabin Mazalat, but with little bit larger variation. This is caused by its relatively bigger distance from the peak Botev (16 km in East direction).

In both Figures 6 and Figure 7 with V (m/s) are represents wind speed values: V_1 calculated by numerical model; V2 – measured wind speed and with D (°) – wind direction; $D_1$1 (evaluated by the model) and D_2 – observed in station wind direction.

In Figure 8, the calculated by numerical model wind speed and direction during the storm in 2012 are shown. As it can be seen the calculated values fitted very well within the measured wind speed and observed wind direction in the station on peak Botev.

2.4 Estimation of the static wind load (wind pressure)

According to archival information in 1964 the roof of the TV station building on Botev peak was blown away. The measured wind gusts speed in this storm was 40 m/s from the NW at 10 m above the ground surface resulting in a static wind load of 0.85 kN/m^2. Another incident occurred during the storm in 2012, when a tower with an antenna installed on it with a total height of 77 m, located in the area of the peak Botev station, was knocked down (Figure 9).

The right tower (Figure 9) has fallen, but the left tower with high of 100 m, still is in good condition and working well, as it was designed. The recorded speed of wind gusts was then 34 m/s from S at 10 m above the ground, which caused wind load of 0.61 kN/m^2 at this level. The normative value of wind speed for peak Botev is 45.8 m/s with static wind load of 1.31 kN/m^2 at 10 m above the

Figure 9. The towers of Botev peak before the 2012 accident.

surface. Estimated wind speed at high of 77 m is 43.4 m/s during the storm and the evaluations carried out according to the methodology and requirements of Eurocode 1 [5] show that a wind with such a speed generates a static load of 1.18 kN/m^2 on the top of this tower. As the same time normative values for 77 m high are 63.4 m/s and static wind load of 2.52 kN/m^2.

2.5 Assessment of the icing conditions

Both windstorms were accompanied by rime-icing processes. In order to assess their severity we have compared their main characteristic with the typical ones

Table 2. Comparison of the main characteristics of both icing process with their typical values in the region of peak Botev, as follow: R_d – Rime-icing duration (hours), T_M – mean air temperature during icing (°C), H – horizontal visibility in fog, V_M – mean wind velocity in cases of icing (m/s), *PD* – prevailing wind direction

Parameter	R$_d$, hours	T_M, °C	H	V_M, m/s	*PD*
Botev peak, averaged values	37	-6.8	52	14.0	NW
Botev peak, 24-26.11. 1964	31	-3.0	50	21.3	NW
Botev peak, 8-10.12 2012	47	-8.7	58	18.3	S

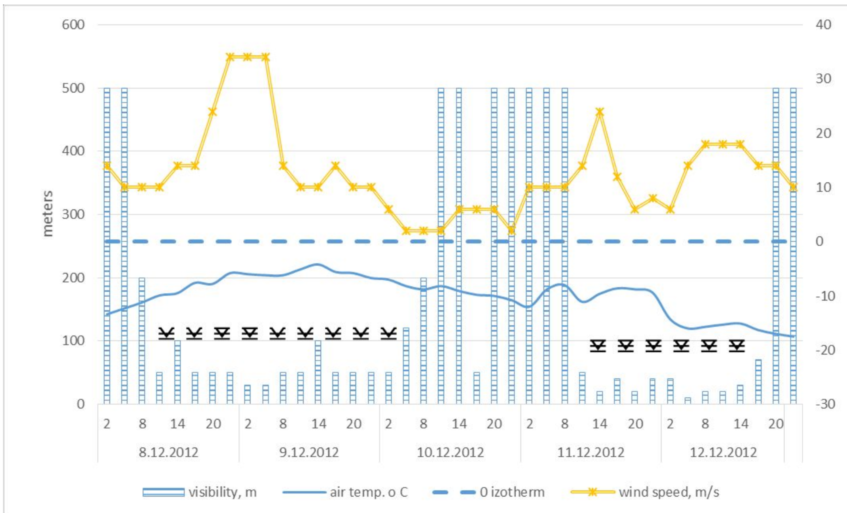

Figure 10. Horizontal visibility (m) – blue bars, wind speed (m/s) – yellow line and air temperature (°C) – blue line, during the rime-icing event and its duration on the peak Botev during 8-12.12.2012.

in the region of peak Botev. This is represented in Table 2. As can be seen except for the wind speed, the other characteristics are close to the averaged local values for this phenomenon. First wind storm did not cause any ice related damages and we have focused only on the second one. In Figure 10 are depicted together the horizontal visibility, the wind speed, the air temperature during the rime icing event and its duration in form of the official meteorological symbol. The next figure presents the wind rose during the event (Figure 11), showing that the prevailing direction of the highest wind speeds is from the south, which is unusual for the riming conditions at Botev peak.

Rime icing was reported from constantly with interruption only on the 10-th December. On the next day, the process started again but the tower had collapsed already at the end of the first day (Figure 12). The duration of this first riming phase of the second event was 47 hours – just 10 hours more than the averaged. The icing intensity was evaluated visually as light to moderate. Icing of such large objects lies beyond the theoretical limits so far and that is way the riming of the tower was estimated using the recommendation of the international ISO 12494 “Atmospheric icing on structures” [6] and the photos of the collapsed tower. Based on all this can be concluded that the icing event on 08-09.12.2012 was moderate as severity and caused ice load of a magnitude between 11 and 20 kg/m.

Unfortunately we do not know if this estimation is crucial, because its design characteristics are unknown. However, most probably, the collapse was due to the general aging of the construction and the harsh meteorological conditions

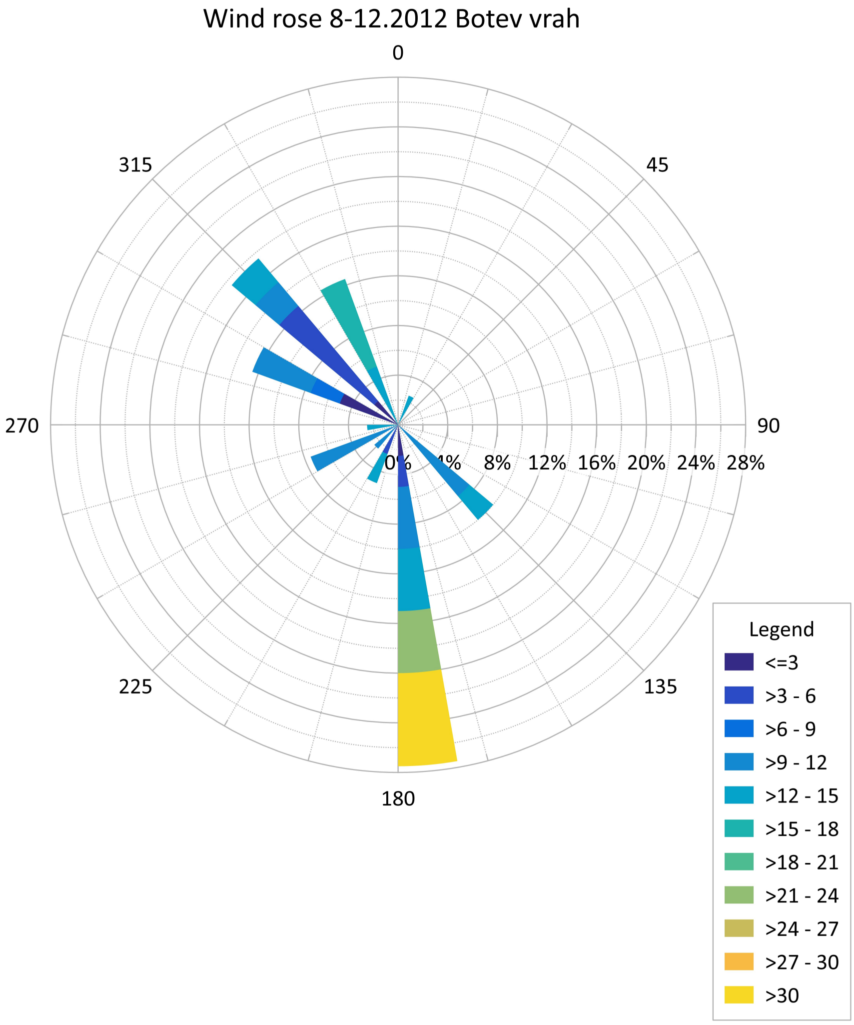

Figure 11. Wind rose during the rime-icing event on peak Botev.

in this region – shortly before this event several days with same wind and ice conditions occurred again.

3 Conclusions

As a result, from the analysis of collected data for both storm cases in 1964 and 2012, as well as from the calculations carried out, we can summarize obtained information, as follow: Weather conditions in the higher parts of the Bulgar-

Figure 12. Remains of the collapsed tower.

ian mountains are often severe – strong winds, thick snow cover, frequent fogs events and a cases of intense icing. This requires that the design, construction and maintenance of the buildings and technical facilities there to take into account very precisely actual meteorological and climatic conditions in these regions. On the other hand, non-compliance with climatic conditions leads to significant damage on the infrastructure and technical facilities. The analysis showed that the wind loads in the case of these two storms did not exceed the normative ones. The icing intensity was evaluated as light to moderate, which not lead to collapse of the tower, as well.

Most likely, the reason for the fall of the tower is the aging of the construction materials and insufficient maintenance of this equipment over the years. This fact shows how important is the maintenance of technical equipment in mountainous conditions to do regularly.

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