VERY STRONG FOEHN WINDS IN THE TATRA MOUNTAINS (POLISH CARPATHIAN MOUNTAINS) – CAUSES, COURSE AND CONSEQUENCES

ŚLIWIŃSKA MAŁGORZATA, CIARANEK DOMINIKA[1]

ABSTRACT. - Very strong foehn winds in the Tatra Mountains (Polish Carpathian Mountains) – causes, course and consequences. The foehn wind in the Tatra Mountains is referred to as "halny". It blows from the south and often causes significant temperature rises and drops in air humidity on the leeward side of the mountain range. It is accompanied by strong and abrupt gusts which may cause damage to the forest stand and infrastructure. This paper looks at two cases of very strong foehn winds which occurred in the Tatra Mountains and the Podhale Region in May 1968 and December 2013. It compares the synoptic and weather conditions which accompanied the phenomenon, including wind speed and direction, as well as relative air temperature and humidity. The foehn wind recorded in May 1968 is sometimes referred to as the "wind of the century". Wind gusts at the Tatra peaks reached a speed of 288 $km \cdot h^{-1}$. In December 2013 the wind had less force at Kasprowy Wierch than in Zakopane, but it caused similar amount of damage to the forest stand as the wind recorded in May 1968.

Keywords: foehn wind, very strong wind, Tatra Mountains

1. INTRODUCTION

Foehn wind is a dry, warm and gusty wind blowing on the leeward side of the mountains. The term "föhn" was first used in literature by Julius Hann in 1866 to describe the fall winds in the Alps (Barry 1992). Ever since, the term has been used to denote winds with a similar origin in many mountain ranges in the world, which are also referred to by their regional names, such as "chinook" in the Rocky Mountains, "zonda" in the Argentinian Andes and "ghibli" in the Atlas (Martyn 1977, Jaubert and Stein 2003). In the Polish Tatra Mountains and in the Podhale Region, the foehn wind is known by its local name "halny". It blows from a southerly direction and often causes significant temperature rises and drops in humidity on the leeward side of the mountain range. It is accompanied by strong abrupt gusts, which may even reach hurricane speed (exceeding 32 $m \cdot s^{-1}$, i.e. 115 $km \cdot h^{-1}$) with characteristic periods of pseudo-calms. The foehn wind in the Tatras is a relatively common phenomenon, especially in the cold half of the year. In 1966 and 1985 it blew on between 86 and 130 days per year (Ustrnul, 1992).

[1] Jagiellonian University, Institute of Geography and Spatial Management, Krakow, Poland
E-mail: malsliwinska@gmail.com, dominika.ciaranek@uj.edu.pl

Foehn wind ("halny") was first described in Polish sources at the turn of the 20th century (Lewińska 2000-2001). Many scientists (Stachlewski 1974, 1976, Ustrnul 1992) have analysed the frequency and probability of its occurrence in conjunction with various types of atmospheric circulation.

Despite the numerous paper of cognitive and methodological papers related to the occurrence of this type of wind in Poland, there has not been developed yet the uniform criteria, the frequently used simple criteria are as follows: thermal, humidity and anemological (Lewińska 2000-2001). The main reason for this difficulty is the presence of many transitional forms of foehn (upper, free, anticyclonic, cyclonic and potential as well), dependent on the location and season of the occurrence (Barry 1992). Moreover, foehn wind is not always accompanied by the rain on the windward side of the mountains or *Altocumulus lenticularis* clouds. Therefore, in Polish literature as a criterion for distinguishing foehn wind on the mountain mostly appears: direction (usually 90-270°) and wind speed (> 4 $m \cdot s^{-1}$, commonly ≥10 $m \cdot s^{-1}$), the presence of the strong gusts and wind calms, a sharp rise of the air temperature and decrease of the humidity (usually ≤70%), atmospheric pressure changes and / or specific types of the clouds (Lewińska 2000-2001, Ustrnul 1992).

In climatologic literature, besides works discussing the mechanism underlying the occurrence of foehn wind, numerous papers focus on its impact on human health and wellbeing. Many people, especially including those suffering from meteoropathy, are affected by abrupt changes in atmospheric conditions which accompany the wind. Some authors (Ficker, de Rudder 1943, Coke et al. 2000, Jaubert and Stein 2003) believe that the most unfavourable situation for the human body is when the foehn wind overcomes the air temperature inversion in the valleys. This is connected with a very abrupt change in atmospheric pressure, an increase in air temperature and a drop in relative air humidity (Schiffer 1986a). People suffering from meteoropathy experience headaches and vertigo, an accelerated heart rate, blood pressure drops or increases, anxiety, apathy, as well as aggravating bouts of depression (Schiffer 1986b). The destructive effects of foehn winds must also be borne in mind. Fallen and broken trees are a common sight in the affected areas. In the latter case, even whole tree trunks may be broken. According to Budziszewska and Morawska-Horawska (1969), trees are broken at various heights, ranging from 1 m to more than ten meters above ground level.

This paper aims to describe two cases of very strong foehn wind in the Tatra Mountains and the Podhale Region in May 1968 and December 2013. It compares the associated synoptic and atmospheric conditions, including wind speed and direction, as well as air temperature and relative humidity.

2. RESEARCH AREA, DATA AND METHODS

The Tatras are the highest mountain range of the Carpathian Mountains, rising to up to 2,655 m a.s.l. (Gerlach Peak). The range is 57 km long and 18 km wide. It extends over a surface area of 785 km^2, 22% of which is located in Poland and 78% in Slovakia (Kondracki 1967).

This paper draws on data on wind speed, temperature and relative air humidity collected three times during the day (at 6 a.m., noon and 6 p.m. UTC) on 3-9 May 1968, as well as on hourly data from 22 to 30 December 2013 from two meteorological stations: at Kasprowy Wierch (1,991 m a.s.l.) and in Zakopane (857 m a.s.l.). The authors used synoptic maps of the lower troposphere to analyse the background of the synoptic situations. In addition, this paper also draws on data published by Budziszewska and Morawska-Horawska (1969), in which the authors included a detailed description of a case of occurrence of low-troposphere jet streams in May 1968.

As was mentioned in the introduction, there are a many types of criteria for distinguishing foehn wind. In this paper I used one of the most common, reffering to the Tatras: wind speed $\geq$ 10 $m \cdot s^{-1}$ form the 90-270° direction on Kasprowy Wierch station, the sharp increase of the air temperature and decrease of relative humidity $\leq$ 70% in Zakopane.

Fig. 1. ***Location of weather stations (Source: www.wikimedia.org)***

3. RESULTS

The synoptic conditions prevailing in both cases of occurrence of very strong foehn winds in May 1968 and December 2013 were very similar. The quasi-stationary wedge of high pressure extended at the south-east from Poland. The north-western part of Poland was under a low pressure system. These conditions led to the advection of air masses from the south to the territory of Poland (Fig. 2).

The Tatras, which constitute an orographic barrier, forced humid air to rise along the slopes to the peaks. On the leeward side, heated adiabatic and dry air started reaching high speeds.

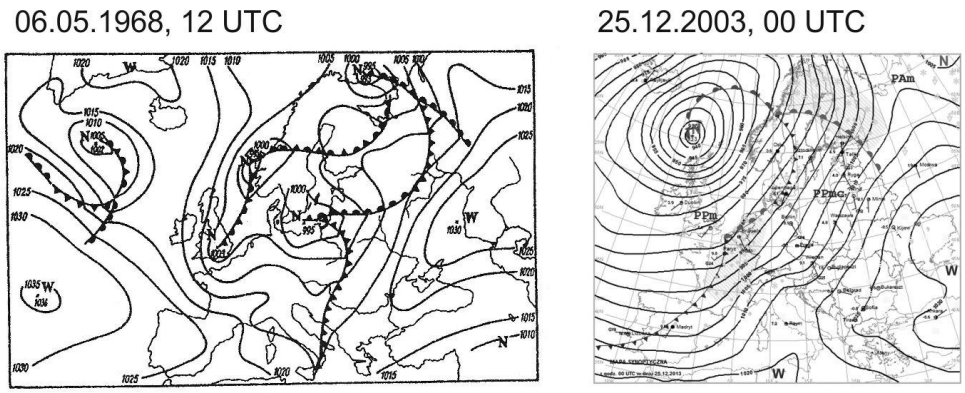

Fig. 2. ***Synoptic map of lower troposphere (Source: Budziszewska and Morawska-Horawska (1969), www.pogodynka.pl)***

In the first of the analysed cases, the synoptic conditions contributing to the occurrence of foehn wind prevailed from 00.00 UTC on 3 May 1968 to 00.00 UTC on 8 May 1968. According to the synoptic analysis conducted by Budziszewska and Morawska-Horawska (1969), the foehn situation was coupled with a significant change in the pressure gradient connected with the secondary deepening of the low pressure centre. On 6 May, a low-troposphere jet stream appeared at 2,000-2,500 m a.s.l., as a result of which wind gust speeds at Kasprowy Wierch exceeded 80 $m \cdot s^{-1}$(288 $km \cdot h^{-1}$).

In the period under consideration, marked by the occurrence of a particularly strong foehn wind (12.00 a.m. on 3 May 1968 – 12.00 a.m. on 8 May 1968), wind both in the Tatra Mountains and in the Podhale Region was blowing from the southern sector, predominantly from the S and SW direction and occasionally also from the south-east.

On 6 May between 4.00 and 6.00 p.m. an abrupt rise in mean wind speed occurred at Kasprowy Wierch, amounting to 20 $m \cdot s^{-1}$ (72 $km \cdot h^{-1}$) (fig. 3). According to Budziszewska and Morawska-Horawska(1969), mean maximum wind speed at ca. 6.00 p.m. reached 50 $m \cdot s^{-1}$ (180 $km \cdot h^{-1}$), with gusts of up to 75 $m \cdot s^{-1}$ (270 $km \cdot h^{-1}$). Such an abrupt wind speed increase was not recorded in Zakopane, where changes on all the days under consideration were rather fluctuational in nature. Mean wind speed did not exceed 6 $m \cdot s^{-1}$, but the maximum mean did exceed 25 $m \cdot s^{-1}$ (90 $km \cdot h^{-1}$), with gusts of up to 40 $m \cdot s^{-1}$ (144 $km \cdot h^{-1}$) (Budziszewska, Morawska-Horawska 1969).

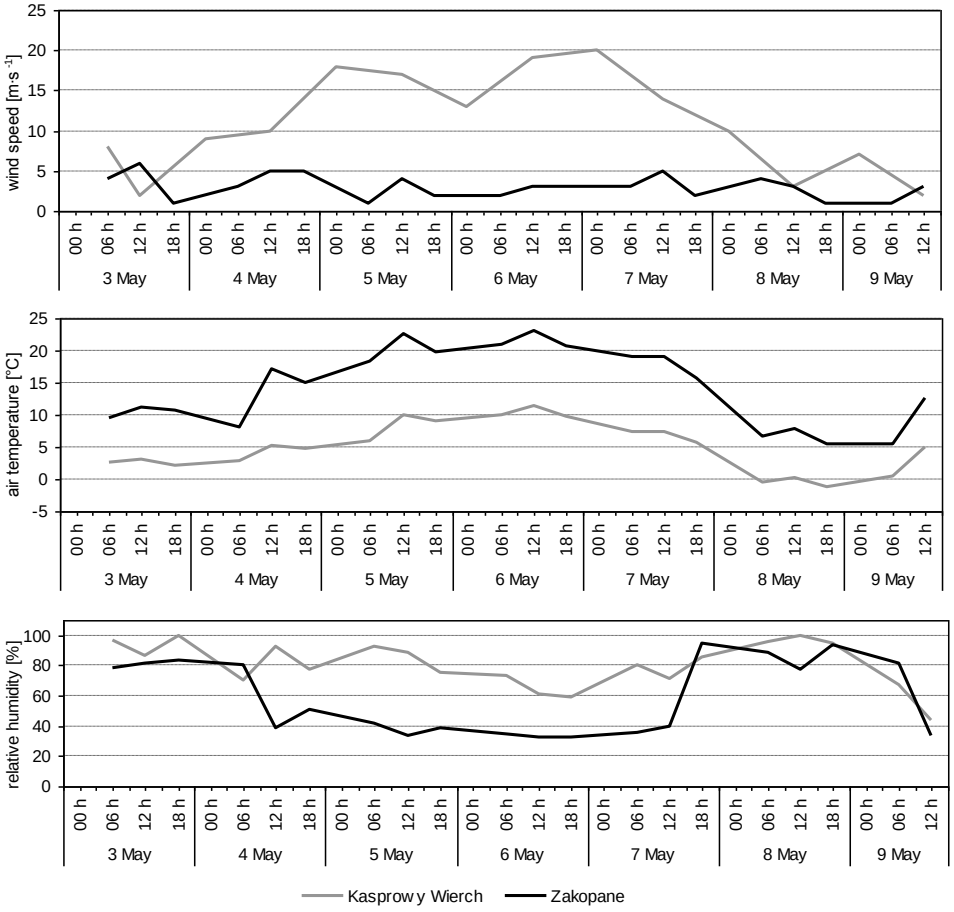

Fig. 3. ***The course of wind speed [m·s^{-1}], air temperature [°C] and relative humidity [%] from 3rd May to 9th May 1968***

Potential conditions for the occurrence of foehn wind in December 2013 prevailed at Kasprowy Wierch from 7.00 p.m. on 21 December to 9.00 a.m. on 29 December (fig. 4). The highest wind speed was recorded on 25 December between 6.00 p.m. and 8.00 p.m. The wind was then blowing at 28-29 m·s^{-1} (100-105 km·h^{-1}), with gusts of up to 49 m·s^{-1} (176 km·h^{-1}).

At the Zakopane weather station, the occurrence of foehn wind was recorded from 5.00 a.m. on 24 December to 3.00 p.m. on 26 December with breaks no longer than 12 hours between hourly measurements. The highest wind speed10-12 m·s^{-1} (36-43 km·h^{-1}) on average with gusts reaching 33 m·s^{-1} (119 km·h^{-1}) was recorded between 1.00 a.m. and 1.00 p.m. on 25 December 2013 (fig. 4).

On 5 and 6 May 1968, both at Kasprowy Wierch and in Zakopane, the daily course of air temperature differed from the normal pattern, which is characteristic of these two stations. On 5 May after 8.00 p.m., despite the sky being

overcast (1-2/8) by high-level clouds (*Cirrus*), air temperature in Zakopane gradually rose, with a simultaneous increase in wind speed (Budziszewska, Morawska-Horawska 1969). On the following day (6 May), i.e. when the highest wind speed was recorded, air temperature reached its maximum value around noon (23.1°C in Zakopane and 11.5°C at Kasprowy Wierch) (Fig. 3).

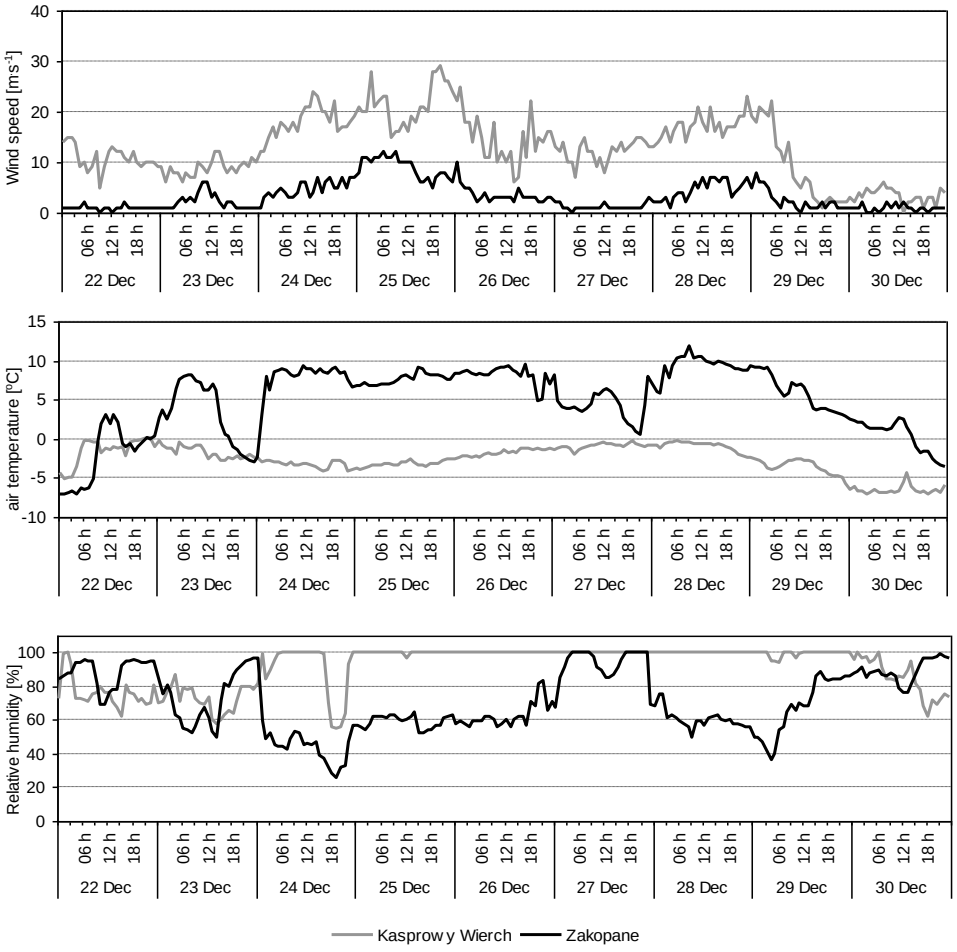

Fig. 4.*The course of wind speed [m·s^{-1}], air temperature [°C], and relative humidity [%] from 22nd December to 30th December 2013*

The course of air temperature from 22 to 30 December 2013 differed at each of the stations under consideration. Air temperature at Kasprowy Wierch rose with 2-4°C. Between 5.00 a.m. on 24 December 2013 and 3.00 p.m. on 26 December 2013, temperature values ranged from -4.1 to -1.5°C, while temperature in Zakopane abruptly rose from -2.9°C on 23 December at 11.00 p.m. to 8.0°C

three hours later (on 24 December at 2.00 a.m.) and later oscillated between 6.6 and 9.3°C (fig. 4).

The course of relative air humidity in both foehn situations was more differentiated than that of air temperature.

Relative humidity at Kasprowy Wierch from 4 to 7 May 1968 ranged from 60 to 93%. In Zakopane, relative humidity at the time when the highest wind speed was recorded amounted to only 33% (fig. 3) and the lowest value was recorded on 7 May at 3.00 a.m. (Budziszewska, Morawska-Horawska 1969).

Humidity values on the three consecutive days (24-26) in December 2013 were significantly different from those which accompanied the foehn situation in May 1968. From 6.00 a.m. to 3.00 p.m. on 24 December, the air at Kasprowy Wierch was fully saturated with water vapour, while relative humidity dropped to 70% only two hours later. The lowest humidity (55%) was recorded at 7.00 p.m. The next days, the mean value was all the time 100%, as a result of the cloudiness an precipitations from the Slovakian southern slope of the Tatra Mountains.

In Zakopane an abrupt decrease in relative air humidity was recorded from 00.00 to 1.00 a.m. on 24 December 2013. Humidity decreased from 97 to 59% within just one hour. Low air humidity persisted until the end of the day, with oscillations of around 20%.

Unfortunately, such a strong and gusty wind caused considerable damage in the Tatra Mountains and in the wider Podhale Region. The area affected in 1968 extended all the way to the Warsaw Basin (Kotlina Warszawska, located ca. 450 km away from Zakopane), although the most severe damage was inflicted within the Tatra National Park itself (Budziszewska, Morawska-Horawska 1969). Forest stand damage consisted in the loss of ca. 150 m^3 of standing timber in 1968 and 153 m^3 in 2013. Although in the first case the wind speed was much higher, a comparable number of trees fell (www.tpn.pl). In 1968 the jet stream enhanced the strength of the foehn wind only around the peaks of the Tatra Mountains and did not descend to lower-lying wooded areas.

4. CONCLUSIONS

The foehn wind recorded in May 1968 is sometimes referred to as the "wind of the century". In the highest parts of the Tatra Mountains the speed of wind gusts reached up to 288 $km \cdot h^{-1}$. The wind was also quite strong in Tatra valleys, where large swathes of woodland were destroyed; however, its speed was lower than at Kasprowy Wierch, which means that the wind did not "descend" to the level of Zakopane. In the topmost parts of the Tatra Mountains, wind speed was enhanced by the jet stream.

The speed of the "halny" wind in 2013 was higher at Kasprowy Wierch than in Zakopane. However, the damage to the forest stand was similar to that in 1968. Comparing the time and the course of selected meteorological elements during two analyzed foehn situations, in May of 1968 and in December 2013 it was stated that:

- potential duration in May was equal 120 hours (12.00 on 3rd May to 12.00 on 8th May 1968), and potential foehn duration in December was approximately 180 hours (7.00 p.m. on 21st Dec to 09.00 a.m. on 29th Dec 2013),
- the first, clearly marking rise of the temperature in Zakopane, occurred on 4th May from 6.00 a.m. till 12.00 a.m. (about 8°C difference) and on 22nd December (9.5°C) at the same time of the day,
- while the highest wind speeds on Kasprowy Wierch was noted, both in May and December, decreasing even by 35% of the relative humidity in two consecutive hours was observed. At the Zakopane station declines were found even more violent (up to 20% per hour).

REFERENCES

1. Barry, R.G., (1992), *Mountain weather and climate*, Routledge, London and New York.
2. Budziszewska, E., Morawska-Horawska M., (1969), *Przypadek wystąpienia niskotroposferycznego prądu strumieniowego u powierzchni ziemi w Karpatach Zachodnich*, Przegląd Geofizyczny 1, 14(22), 43-23.
3. Cooke, L.J., Rose, M.S., Becker, W.J., (2000), *Chinook winds and migraine headache.* Neurology, 54, 302.
4. Ficker, H.,De Rudder, B., (1943), *Föhn und Föhnwirkungen. Der gegenwärtige Stand der Frage*. AkademischeVerlagsgesellschaft Becker &Erler, Leipzig, p.112.
5. Jaubert, G., Stein, J., (2003), *Multiscale and unsteady aspects of a deep foehn event during MAP*. Q. J. R. Meteorological Society, 129, 755-776.
6. Kondracki, J., (1967),*Geografia fizyczna Polski*. PWN, Warszawa. p. 463.
7. Lewińska, J., (2000-2001), *Wiatry halne w Polsce. Przegląd literatury i ocena wyników*, Folia Geographica, series Geographica-Physica, 31-32, 135-150.
8. Martyn, D., (1997), *Wiatry miejscowe i regionalne – nazewnictwo i charakterystyka*, Prace i Studia Instytutu Geografii UW, 22, 225-329.
9. Schiffer, Z., (1986a), *Próba określenia faz pogody i ich wpływu na nasilenie się schorzeń meteorotropowych*, [in:] *Biometeorologia a organizm ludzi i zwierząt*, (ed.) Wojtusiak R.J. PWN, Warszawa-Kraków, 21-33.
10. Schiffer, Z., (1986b), *Wiatr halny a samobójstwa i bójki*, [in:] *Biometeorologia a organizm ludzi i zwierząt*, (ed.) Wojtusiak R.J. PWN, Warszawa-Kraków, 35-43.
11. Stachlewski, W., (1974), *Wiatry fenowe w wybranych miejscowościach wzdłuż profilu Kasprowy Wierch – Kraków*, Przegląd Geofizyczny19 (27), 1, 81-94.
12. Stachlewski, W., (1976), *Wpływ wiatru halnego na temperaturę w Zakopanem*, Wszechświat 6, 154-156.
13. Ustrnul Z., (1992), *Potencjalne warunki występowania wiatrów fenowych w Karpatach Polskich*, Zeszyty Naukowe UJ, Prace Geograficzne 90, 97-111.