PRACE GEOGRAFICZNE, zeszyt 105

Instytut Geografii UJ
Kraków 2000

Rafał Bąkowski

MOUNTAIN AND VALLEY WIND SYSTEM AND 'LIPTÓW WINDS' IN THE SUCHA WODA VALLEY IN THE POLISH TATRA MOUNTAINS

Abstract: On the basis of the prepared criteria, the article divides the winds into a mountain and valley wind system and the Liptów winds in the Sucha Woda Valley in the Polish Tatra Mountains. The frequency of occurrence, directions and speed of the winds were characterised. The probability conditional of the mountain and valley wind system with light winds on the Kasprowy Wierch was defined. Although the existence of the phenomena was already observed in the 1930s, the winds of the mountain and valley wind system and the Liptów winds are still among the least known phenomena.

Key words: mountain and valley wind system, engadynian type winds, Liptów winds, probability conditional.

1. Introduction

The winds which form part of the mountain and valley wind system, just as Liptów winds which genetically belong to the engadynian type winds, develop during the anticyclonic non-advection weather. Due to the fact that these winds belong to the thermally-conditioned winds with a maximum speed of 5-7 ms^{-1}, all advection would thus cause not only the weakening, but disappearance of these winds.

Polish climatology literature has very few studies on this subject. Among them, there are the studies of Kosińska-Bartnicka (1930) and Orlicz (1954). There is especially a dearth of studies on the engadynian type of winds. The only description of the Liptów winds comes from 1930. In the later literature, the authors referred to that study without presenting any recent results.

The profile analysed is represented by the Kasprowy Wierch and Hala Gąsienicowa stations. The distance between the stations in a straight line is 2150 m., and the difference in level between them is 468 m.

The mountain observatory at Kasprowy Wierch (1991 m. above sea level) is situated 1988 m. above sea level. The observatory is located on the main Tatra ridge,

in a depression unfolding across the Tatras, at a distance of 1 km from the geographical border between the Western Tatras and the High Tatras. The southern slope of Kasprowy Wierch lowers towards the Cicha Woda Valley, while the northern slope ends at the Sucha Kasprowa Valley. To the East of the peak, lies the Stawy Gąsienicowe Valley, while to the West – the Kocioł Goryczkowy (Valley). The area surrounding the peak is characterised by vast valley forms and partial cover from the East and West, which has a thorough impact on the anemology conditions on the Kasprowy Wierch.

The meteorological station at Hala Gąsienicowa is situated at 1520 m. above sea level, on the border of the Western Tatras and High Tatras, at a distance of about 1800 m. from the main Tatra line. The station lies in the higher part of the vast Sucha Woda Valley. The valley is open to the north-east, and closed from the north-west by Uchrocie Kasprowe, from the south by the ridge spreading between the Granaty and Kasprowy Wierch, and from the east by Żółta Turnia. The shape of the valley, spreading from the south-west to the north-east, as well as the topographical profile of the nearest surroundings have an impact on the anemology conditions at Hala Gąsienicowa.

2. Conditions for generation of the mountain and valley wind system and Liptów winds

The mountain and valley wind system develops mainly during anticyclonic weather, when the insolation is intensive enough to warm the slopes and the neighbouring air during the day, as a result of which the air pressure is lower in the upper part of the valley than in its lower part, and, according to the barometric gradient, the air moves upwards. Unlike mountain winds, the only force conditioning the anabatic valley wind is the force resulting from thermal differences.

During the night, due to the radiative cooling of the upper part of the valley, the lower part of the valley retains low pressure, which results in the katabatic movement of the cold air along the valley, according to its slope. The daily circulation in every valley will be locally conditioned, as it is dependent on its general position in relation to the parts of the globe (Okołowicz 1969). It seems, however, that mountain winds will always blow according to the scheme presented by Defant, and only the speed of the winds will be dependent on the direction or slope of a valley.

With the appropriate orographic conditions, engadynian type winds may develop. Such winds are known in many mountains areas of the world, but most research on them has been conducted in the Alps, especially in the Maloja pass, where they are clearly observed. The pass is located in the Upper Engadine Valley, hence the name of the winds. The 'Liptów' winds belong genetically to these type of winds. In this case the name comes from the Liptów Valley, in the southern part of the Tatras, where the mechanism for development of the winds was created.

Engadynian type winds are connected with the contrast between the temperature of lower air layers on both sides of the border ridge (Orlicz 1954). They are a continuation of the valley wind on the neighbouring slope. The border ridge in the area discussed is the ridge surrounding the Cicha Valley. In this valley, which unfolds from the north-east to the south-west, the valley winds are much stronger than on the

northern side of the Tatras in the Sucha Woda Valley due to its exposure and insolation. The winds, coming to the main Tatra ridge on the northern side, gain the vertical component of gravitation and become katabatic winds blowing along the main axis of the Sucha Woda Valley.

Due to the lack of criteria in literature for distinguishing a mountain and valley wind system or Liptów winds, the criteria were prepared on the basis of the statistical material available from the years 1991-1995, after consideration of the general conditions for the occurrence of winds related to the system described. The following criteria for enabling the distinction of mountain and valley winds are:

1. Synoptic situation – Ca or Ka according to the classification by T. Niedźwiedź (Niedźwiedź 1981)
2. Mountain wind direction (at 7 am and 7 pm CTE) between 180-270°
3. Valley wind direction (at 1 pm CTE) between 360-90°
4. Wind speed not higher than 5 ms^{-1}
5. Change of wind to the opposite direction within a day.

The directions of winds in the mountain and valley wind system was chosen according to the topographic analysis of the area. Topographic maps were used in the scale 1 : 10 000, as well as direct research of the topography of the Sucha Woda Valley. Given the topology and mobility considered of winds, the directions were broadened to include the whole south-western quarter of the horizon for mountain winds and the north-eastern quarter for valley wind.

All the winds in the mountain and valley wind system belong to thermally conditioned winds, and their speed is closely related to the local orography of the area, especially with the exposition and outline of the valley, as well as the slant of its axis. The speeds are not usually greater than 5-7 ms^{-1}, although in certain mountains (like the Alps, the Caucasus, or the Pamirs) they may reach 10 or more ms^{-1}.

Winds forming the mountain and valley wind system are daily winds, thus the criteria must include the condition of the direction change to the opposite one within 24 hours. In order for the air movements within the valley to be classified in the mountain and valley wind system, the change must occur at least once within 24 hours. Yet there were numerous examples where the wind changed direction twice within 24 hours.

Liptów winds were classified on the basis of meteorological conditions on Kasprowy Wierch and in Hala Gąsienicowa:

1. Synoptic situation – Ca or Ka according to the classification by T. Niedźwiedź (Niedźwiedź 1981)
2. Wind direction on Kasprowy Wierch (at 1 pm CET) between 270-90°
3. Wind direction in Hala Gąsienicowa (at 1 pm CET) between 180-270°
4. Wind speed in both stations not higher than 7ms^{-1} .

The wind direction on Kasprowy Wierch was broadened to cover the whole southern part of the horizon, due to the outline of the Cicha Valley in its upper part, where it turns to the east. Thus the ridge surrounding the valley has an exposure almost parallel to the latitude. Just as in the case of mountain winds, the scope of Liptów wind directions in Hala Gąsienicowa was broadened to cover the whole south-western quarter of the horizon.

The maximum speed of Liptów winds was defined as 7 ms^{-1}. It seems that the speed level is low enough to eliminate winds resulting from reasons other than thermal; for example winds related to peripheries of the high pressure area, and high enough so as to distinguish winds which, on reaching Kasprowy Wierch, have a certain speed related to the mountain and valley wind system of the Cicha Valley and additional speed resulting from gravitation. It must be noticed that Liptów winds in Sucha Woda Valley are influenced by slowing forces. These include friction, which is relevant to every wind in the air layer next to the ground, and valley wind from the opposite direction. Therefore the Liptów wind speed was defined as not exceeding 7 ms^{-1}, both on Kasprowy Wierch and in Hala Gąsienicowa.

3. Frequency of occurrence of mountain and valley winds and Liptów winds

On the foundation of such criteria, 115 cases were described within the period of five years between 1991-1995 where winds were formed in the Sucha Woda Valley as a part of a mountain and valley wind system. 82 days were defined in which the system occurred, including 33 days with a double change of direction within 24 hours.

Mountain and valley winds occurred most often in autumn (54 cases) and in summer (26 cases), which equals accordingly 47.3% and 22.8% of the total number of winds of the system described. The winds occur least often in spring – 9 cases (7.9%). The annual frequency of occurrence of the mountain and valley wind system is presented in Figure 1.

In the annual frequency of occurrence, October is the outstanding month. In this single month, 31 cases of mountain and valley winds were observed, constituting 27.2% of all the winds discussed; a high frequency of occurrence was also observed in September (14%) and August (12.3%). In the five-year period between 1991-1995 the mountain and valley wind system did not occur in April, and in June and May it constituted 1.7% and 2.6% respectively. October was also the month when most cases of double change of wind direction to the opposite direction was observed. There were 12 such cases in total, while there were no such cases in April, May or June.

In the five-year period analysed, the longest period of constant observation of the mountain and valley circulation was three days. Eight such periods were observed, each lasting for two days.

On application of the above criteria, during the period between 1991-1995, fifty four days of Liptów winds occurrence were observed. In the annual frequency outline, Liptów winds occurred most often in winter (33.3%) and in spring (25.9%). In summer and in autumn the winds constituted 20.4% of all the cases described. The month with the highest number of winds analysed was December (14.8%), while they often occurred in February, March, April or November (11.1% each). Liptów winds did not occur in September, and they rarely occurred in May (3.7%) and July (5.6%). The annual frequency of occurrence is presented in Figure 2.

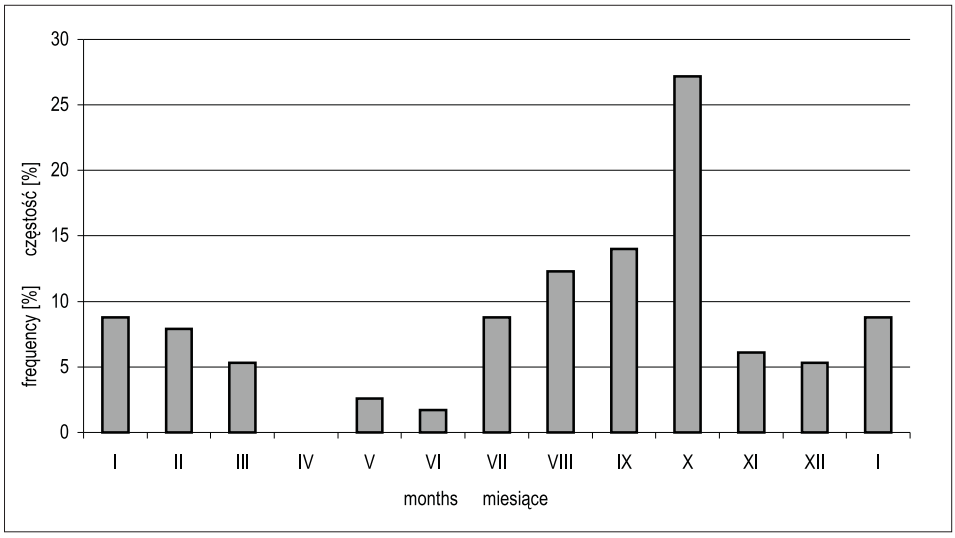

Fig. 1. Frequency (%) of occurrence of mountain-valley circulation in Sucha Woda Valley.

Ryc. 1. Częstość (%) występowania cyrkulacji górsko-dolinnej w dolinie Suchej Wody.

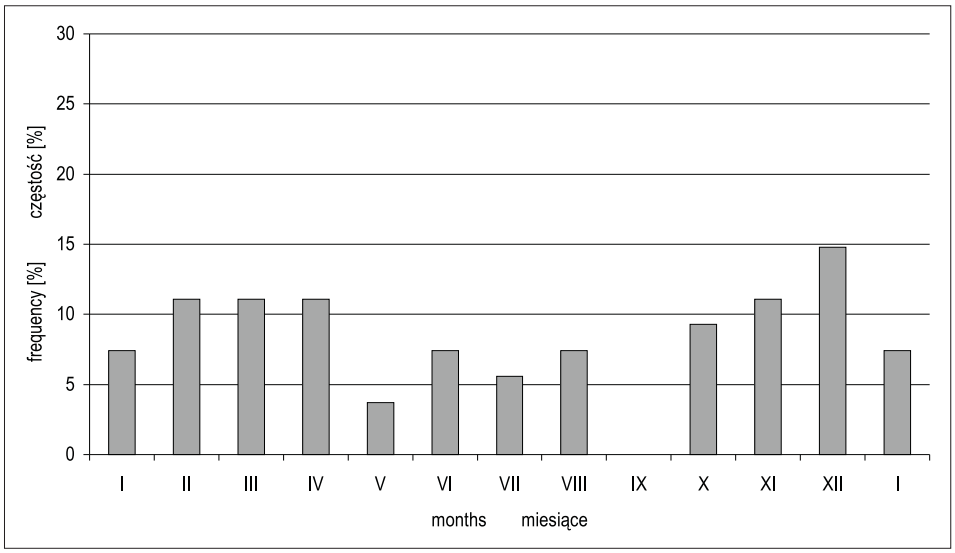

Fig. 2. Frequency (%) of occurrence of 'Liptów winds' in Sucha Woda Valley.

Ryc. 2. Częstość (%) występowania wiatrów liptowskich w dolinie Suchej Wody.

4. Direction and speed of winds belonging to the mountain and valley wind system and Liptów winds

According to the criteria, the direction of mountain winds are within 180-270°. The direction 220° visibly prevailed, both at 7 am when winds from this direction constituted 70.6%, and at 7 pm – constituting 73% of all mountain winds. The direction of 200° was also among the most dominant wind directions, constituting 13.7% at 7 am, and 12.4% at 7 pm. Mountain winds from other directions amounted to 15.7% at 7 am, and 14.6% at 7 pm.

Similar differentiation is visible in the case of valley wind, whose directions fall between 360-90°. One could observe the domination of 40° direction, which amounts to 67.9% of total valley winds, and a high number of 360° and 20° directions, which amounted to 12.4%. Other directions were represented totalling 7.3%.

The above data proves that winds of the mountain and valley wind system largely blow in one line: mountain winds – from the 220° direction, and valley winds – from 40° direction. Among all cases of the mountain and valley wind system, the winds which changed their direction by 180° occurred 52 times, constituting 45.2% of the total number of cases of mountain and valley winds discussed.

According to the criteria presented, the mountain and valley air movements are winds of speeds not greater than 5 ms^{-1}, thus they belong to very weak or weak winds. A great majority of both mountain winds (82.7% of the winds observed at 7 am and 76.1% at 7 pm) and valley winds (88.9%) are very weak winds. In the five-year period analysed, no mountain winds of speeds greater than 4 ms^{-1} were observed, while there were 4 such cases in the evening (Figure 3). It is probably connected with the weakening katabatic movement at 7 am, it is time of slow thermal change of mountain wind into valley wind, although it is still a period of mountain wind domination. Moreover, the average speed of mountain wind in the morning (1.9 ms^{-1}) is lower than the average speed of these winds in the evening (2.1 ms^{-1}).

The average speed of valley winds amounted to 1.8 ms^{-1}, and 88.9% of these winds were very weak.

The data presented shows that the katabatic mountain winds have higher speeds than valley winds. After the analysis of the data it was stated that the speed of mountain winds was higher than that of valley winds in 34 cases out of the total of 114, which amounts to 29.8% of all situations where mountain and valley wind systems were observed, and lower in 26 cases (22.8%). Most often, the speed of mountain and valley winds were equal (47.4%).

The engadynian type winds, observed on Kasprowy Wierch, came most often from the direction of 180° - totalling 16.7% of all cases classified, and from directions of 200° and 240°. The scope between 180-250° was represented in 62.9% of all cases. In Hala Gąsienicowa, however, just as in the case of mountain winds, the direction of 220° is dominant, as 74.1% of the Liptów winds came from this direction. Another well represented direction was 180° (11.1%). The winds from the directions within the range 230-270°, amounted only to 5.5% of total winds classified. There were

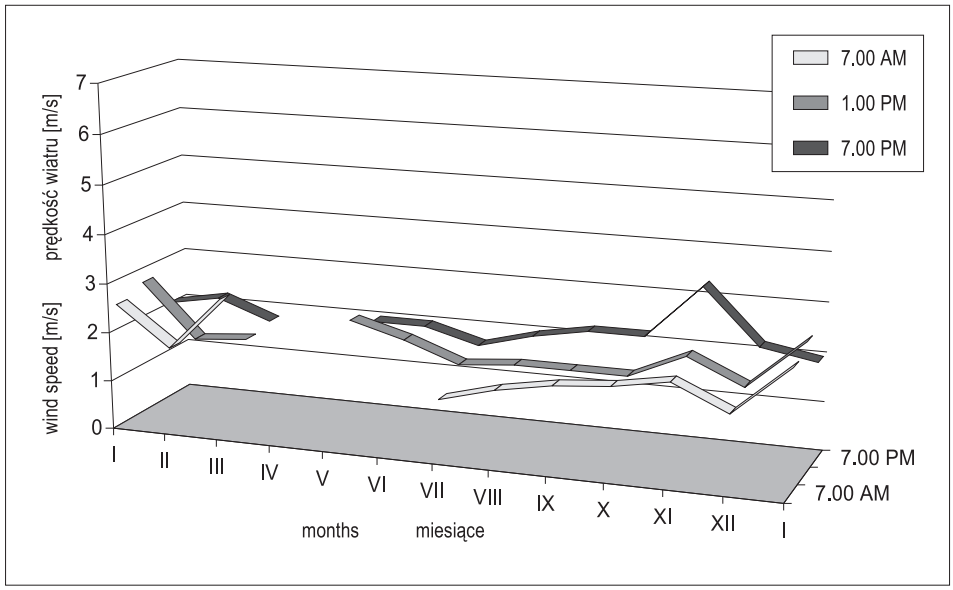

Fig. 3. The annual course of average speeds (ms^{-1})of mountain winds (7 AM, 7 PM) and valley winds (1 AM).

Ryc. 3. Przebieg roczny średnich prędkości wiatrów (ms^{-1}) górskich (o godzinie 7.00 i 19.00) i dolinnych (o godzinie 13.00).

only 6 cases (11.1%) of the Liptów winds which had the same direction on Kasprowy Wierch and in Hala Gąsienicowa.

The average speed of winds analysed on Kasprowy Wierch was 4.0 ms^{-1}, and in Hala Gąsienicowa – 2.1 ms^{-1}. In the annual outline (Figure 4), both stations noted the highest average speed in June (6.2 ms^{-1} on Kasprowy Wierch and 3.5 ms^{-1} in Hala Gąsienicowa) and in March. The lowest average speed of Liptów winds were observed on Kasprowy Wierch and in Hala Gąsienicowa in February and April. In the period analysed, there were four cases, where on the same day the speed of a Liptów wind on Kasprowy Wierch was lower than its speed in Hala Gąsienicowa, while there were 42 cases where its speed was higher in Hala Gąsienicowa. The speed of Liptów winds at both stations were equal in 8 out of 54 cases.

Liptów winds on Kasprowy wierch reached their highest speed if they came from a direction of 270° - 5.2 ms^{-1} on average, and of 200° - 4.9 ms^{-1}; while in Hala Gąsienicowa they reached accordingly: 200° - 2.6 ms^{-1}, and 180° - 2.3 ms^{-1}. The lowest average speed for these winds was observed on Kasprowy Wierch from directions of 90° - 1.6 ms^{-1}, and of 110° - ms^{-1}; while in Hala Gąsienicowa- from directions of 220° and 270° - 2.0 ms^{-1} each. It must be added that this analysis did not include the speed from directions which occurred only once, so as to eliminate accidental wind movements and for the statistical material to reflect natural conditions.

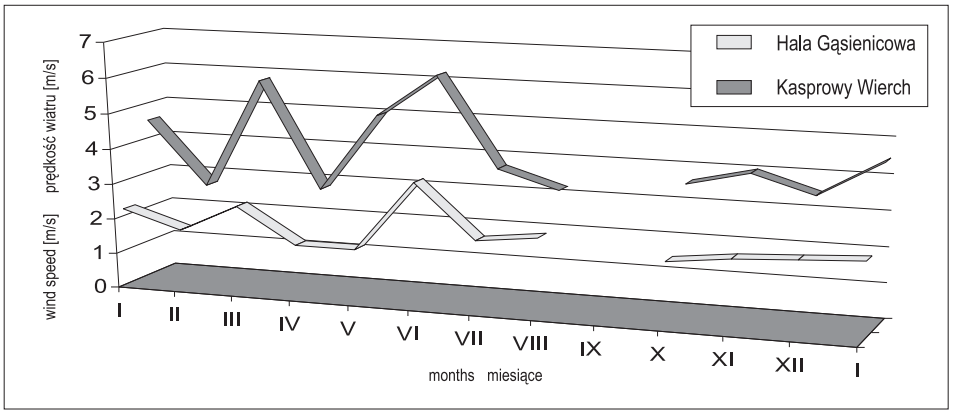

Fig. 4. The annual course of average speeds (ms^{-1}) of 'Liptów winds'.

Ryc. 4. Przebieg roczny średnich prędkości (ms^{-1}) wiatrów liptowskich.

5. Probability conditional for occurrence of the mountain and valley wind system with weak wind on Kasprowy Wierch

Probability conditional consists of calculating the frequency of occurrence of a given phenomenon, in this case – the occurrence of mountain and valley wind system, in the conditions stated; namely the time when wind of a speed lower or equal to 5 ms^{-1} was observed on Kasprowy Wierch.

The probability mentioned for occurrence of the mountain and valley wind system with weak wind on Kasprowy Wierch, was calculated taking into consideration the days when the area analysed was under the synoptic situation Ca or Ka, according to the classification by T. Niedźwiedź (Niedźwiedź 1981). The probability was calculated separately for each of the observation times.

The probability conditional for occurrence of the mountain and valley wind system on Kasprowy Wierch, calculated on the basis of the data from the period 1991-1995, was estimated accordingly: at 7 am – 16.6%, at 1 pm – 26.7%, and at 7 pm – 17.0%. The rather high probability in the early afternoon, as compared to 7 am and 7 pm, is related to the intensive development of the mountain and valley wind system at noon, while the other maximum should occur at night. It seems that the high value of the probability at 1 pm is also influenced by the development of turbulence connected with daily convection. In order to eliminate the last element in calculating the probability mentioned, only mountain and valley winds of speeds exceeding 3 ms^{-1} were analysed. In this way, stronger and more classical winds formed the system discussed. The probability conditional calculated for the above winds was estimated to be: at 7 am – 5.3%, at 1 pm – 6.7%, and at 7 pm – 4.5%. Thus there are no significant differences between the values for the probability at 1 pm and 7 am or 7 pm. The values are of

course lower than the probability conditional value calculated for winds whose speed range from 2 ms^{-1} to 5 ms^{-1}, as the cases where the speed of mountain and valley winds exceeded 2 ms^{-1} amounted only to 33.9% ot the total mountain and valley winds classified.

Translated by Biuro tłumaczeń „Letterman"

References

Barry R. G., 1981, *Mountain weather and climate*, Methuen, London, 89-157.

Klimat Tatr, 1974, Praca zbiorowa, (red. Koncek M.), Veda Vydavatelstvo Slovenskej Akadémie Ved, Bratislava, 1-855.

Niedźwiedź T., 1981, *Sytuacje synoptyczne i ich wpływ na zróżnicowanie przestrzenne wybranych elementów klimatu w dorzeczu górnej Wisły*, Rozpr. Habil. UJ, nr 58, 1-165.

Kosińska-Bartnicka S., 1930, *Wiatry terenowe na Podhalu i w Tatrach*, Prace Geofiz., z. 2, 35-48.

Okołowicz W., 1969, *Klimatologia ogólna*, PWN, Warszawa, 1-335.

Orlicz M., 1954, *O stosunkach anemologicznych na szczytach tatrzańskich*, Wiad. Służby Hydrol.-Meteorol., z. 4, t. 3, 316-335.

Cyrkulacja górsko-dolinna i wiatry liptowskie w Dolinie Suchej Wody w Tatrach

Streszczenie

Stwierdzono istnienie w dolinie Suchej Wody cyrkulacji górsko-dolinnej, potwierdzone wynikami obliczeń prawdopodobieństwa warunkowego wystąpienia tych wiatrów przy słabym wietrze na Kasprowym Wierchu, w tych obliczeniach starano się wyeliminować prądy powietrzne uwarunkowane rozwojem turbulencji związanej z konwekcją dzienną. Wskazano, że wiatry górsko-dolinne występują głównie jesienią, a rzadko pojawiają się na wiosnę. Kierunki wiatrów wchodzących w skład cyrkulacji górsko-dolinnej w zdecydowanej większości są zgodne z przebiegiem głównej osi Doliny Suchej Wody.

Na Kasprowym Wierchu i na Hali Gąsienicowej stwierdzono występowanie wiatrów typu engadyńskiego, pojawiały się one głównie zimą i wiosną. Kierunki wiatrów liptowskich zgodne są z przebiegiem Doliny Suchej Wody, a największe prędkości osiągały w marcu i w czerwcu. Na podstawie analizy układu sieci dolin tatrzańskich można przypuszczać, że omawiany typ wiatrów występuje w większości walnych dolin w Tatrach.

Rafał Bąkowski
Zakład Klimatologii Instytutu Geografii Uniwersytetu Jagiellońskiego
ul. Grodzka 64, 31-044 Kraków