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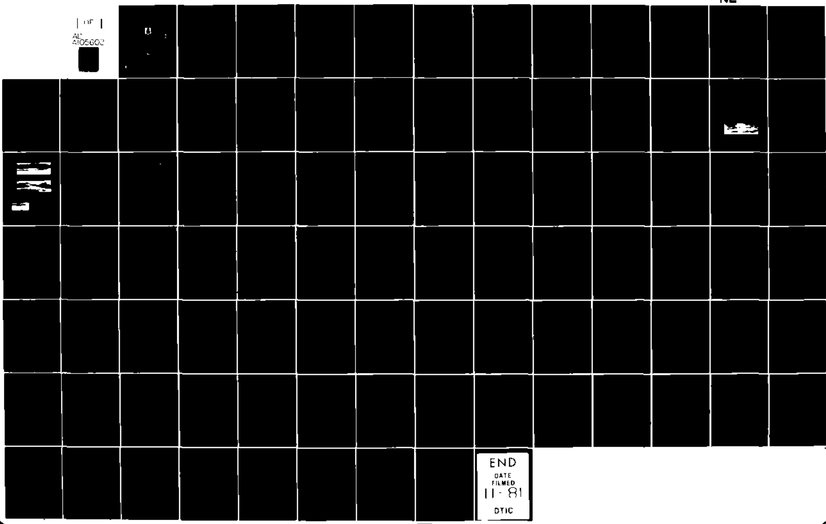

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by

Gerhard Hentschel

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THE HARZ FOEHN AREA

Gerhard Hentschel

A. INTRODUCTION

1 Purpose of the investigation

The orographic influence on climate in the German central mountain chains of Harz and the Thuringian Forest has already been extensively covered by Assmann[1]. In spite of the differences in thermometer positioning, as well as irregular reading terms at the time, the paper conveyed the essential moments occurring in the blocking and Foehn effects. In addition, the entire complex of central mountain climatic peculiarities was opened to questioning. Practically all further research efforts in this regard can be, in practice, integrated into this presentation. Either new points of view were brought to bear, in further elaborations (such as air mass theory, dynamic observation criteria, etc.), or one of the problems outlined were singled out for more detailed investigation, made possible by instrumental improvements, enlargement of observational networks, standardization of observation methods, or the use of aerological materials.

Of the same fundamental importance in the context of orographic climate formation are Hellman's[2] precipitation charts, especially as supplemented by Hoffmeister[3] for the Harz mountains. Later, Dammann[4,5], in his investigation of the precipitation distribution in the Harz as well as of the wet and dry periods, was able to characterize the contrasts between the weather side and the leeward side, by individual treatment of weather types. Finally Janssen[6] analyzed the spatial and temperal oscillations in the position of the leeside dry areas.

Elsner[7,8] dealt in great detail with the vertical temperature distribution, especially between Wasserleben and Brocken. A Foehn effect is indicated by the statement that in general temperature gradients are larger on the central mountain's north side than on their southern side, in spite of the fact that the southern slopes normally are exposed to a much larger radiation sum. Renier's supplement[9] to von Knoch's dissertation "The high Harz winter sun"[10] distinguishes between 19 selected cases of clearing on the northeastern Harz edge.The accompanying wind distribution proved that the clearing was related to winds from the SW quadrant. Elaboration of the data from a special Harz investigation in the spring of 1936 showed the differet influence of the various weather conditions on the Harz area[11]. Here, the NE edge areas of the Harz appeared, on the one hand, as a strongly influenced area, by Foehn, under SW weather conditions; and on the other, as the area suffering the most severe cooling during cold air breaches from NW or N direction. This means, however, that even the normal weather picture can cause extreme contrasts in the total weather picture.Sieger too points out the large contrasts during air body exchanges, especially between T and PM[12].

Last but not least, there are a number of papers on the Harz from the bioclimatic point of view, such as the already mentioned elaborations by Knoch and Renier[9,10]. Schroeder described the Harz as a health resort, with meteorological indications by Schulz[13] . The mountain wind studies by Schulz inBad Harzburg are another contribution in this sense[14].

This brief review shows that the climatic peculiarities of the Harz area and their effects on other lee-side regions has been captured from many directions. The present investigation of the more narrow Foehn are, i.e., especially the NE Harz edge, is determined in the first place by the bioclimatic significance attributed to this area. It contains two larger health resort districts: the Wernigerode-Ilsenburg area on the steep slopes of the upper Harz, with the high-altitude health spa Schierke and the area of Bath Suderode-Gernrode-Harzgerode on the easterly, lower Harz slopes with the spa Friedrichsbrunn. Henz, when the locally often very different Foehn effects and their consequences are pointed out in this area, then such especifications of the Foehn influences are, ultimately, a desideratum essential to the spa.

Hence this effort shall be directed towards the purpose of establishing the causes for the climatic peculiarities of the Foehn area, once it is initially established by a comparative presentation of average values. Locally or areawide increased air temperatures can be due to an increase in absorbed radiation (during the daytime), or a favorable slope wind (at night) but also to a non-periodic Foehn wind rhythm. The human organism will probably not relate to the general statement "increased air temperature"; instead, its reactions will correspond to the specific causes for the temperature increase. Especially strong winds can be caused by increased laminar flow (jet effect), or due to severe gusts. In both cases the organism will react to entirely different requirements. A deficit in the degree of covering need not be coupled in every case to increased radiation intensity. Rather, the latter will depend still significantly from the diathermancy of the lower layers of the atmosphere; hence - disregarding variations owed to different air masses - it will be directed by the kind of local ventilation.

In this sense, the fundamentation for climatic peculiarities becomes a biotropic factor. It is in this context that the considerations below are to provide the fundamental points of view under which the special health-resort climate descriptions of the area are to be viewed.

2. The area of investigation

This investigation addresses itself to the two NE edge areas of the Harz already mentioned. They comprise the steep slopes of the upper Harz, from Brocken (1142 m NN) [NN = Normal null, i.e., normal zero, or above sea level] to Ilsenburg-Wernigerode (250 m NN) and the lesser fall in the lower Harz, from the Viktor height at Friedrichsbrunn (587 m NN) to Suderode-Gernrode (220 m NN). While, however, the upper Harz cone towers significantly above the surrounding landscape, the Ramm mountain, that can also be considered a cone, with the Viktor as its highest point, is embedded in a not significantly lower surroundings.

The northeastern Harz is drained by the Ilse (Ilsenburg), the Bode (Quedlingburg) and the Selke (Harzgerode). The upper Harz massif valleys are narrow and short, those of the lower Harz valleys cut uniformly deeply into the mountain massif on a relatively long way.

To this Harz space, the edge areas of which are clearly marked everywhere, is connected a foreland that is ondulating at first but then levels out towards the NE. The flat landscape is broken only - essentially - by the Huy to the NE of Wernigerode (to 314 m) and the Hackel, to the NE of Quedlinburg (240 m). Hence the terrain is essentially open leeward.

Figure 1 presents an overview of the area of investigation's orography.

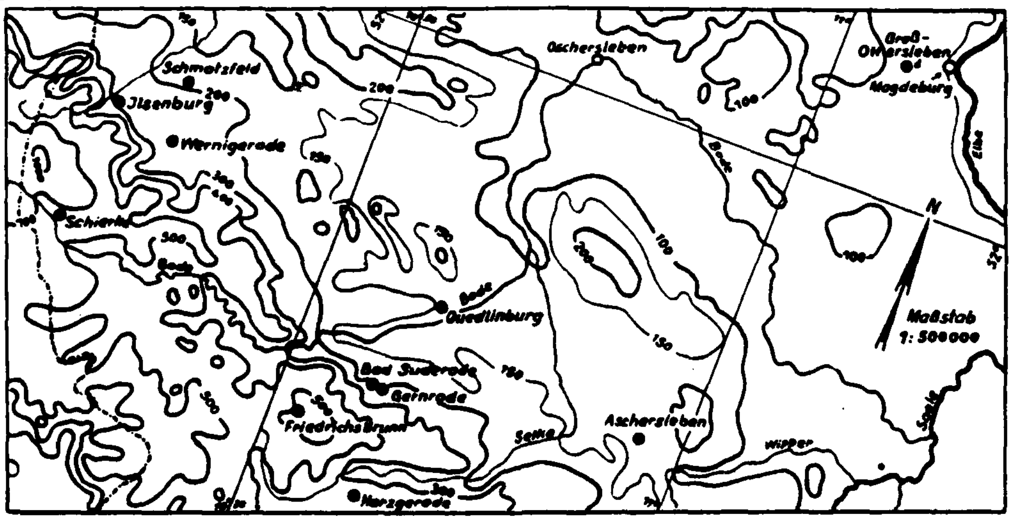

Figure 1. The NE Harz edge with foreland in contour line mapping.

3. The stations

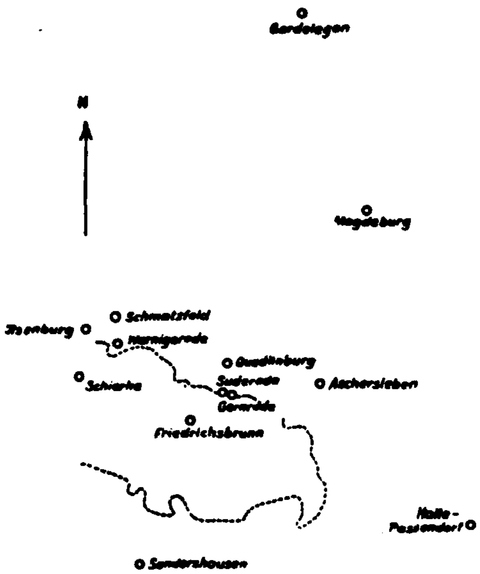

Figure 2. The location of the Harz and comparative stations.

The elaboration is based on the stations in the northeastern Harz, the Harz edge and foreland and, beyond these, nearby stations not under the influence of mountains, the climatic conditions of which are to be used as standards of comparison. The relationship between the area of investigation and the comparative stations chosen are shown in Figure 2, above.

In an evaluation of the stations, a clear distinction must be made, from the beginning, between those in a "representative" location and those whose observations are influenced by the local terrain. The climatic data from representative stations can in any event be used for a comparative study, while those of the remaining stations only in those cases in which the weather situation to a large extent prevents the formation of local peculiarities.

Among the former must be counted especially the stations on a flat terrain, uninfluenced by mountains, such as Magdeburg, Gardelegen and Halle-Passendorf.

The observations from the remaining stations must refer to a more restricted area of utilization. It is not always possible to find a suitable site on or by a mountain area than can be considered truly "representative", in the sense that the meteorological quantities measured reflect only the orography, without additional local peculiarities. This requirement, necessary for an exact comparison of data, is met only by the stations Ilsenburg, Wernigerode, Schmatzfeld, Aschersleben, Quedlinburg (Stumpfburg garden) and Friedrichsbrunn.

The measurements and their results from the remaining stations provide information - to some extent - on the climatic effects of certain ground formations, because of which the purely orographic influence of the mountain chain no longer find their true expression. These situations are:

a) Schierke, with the characteristic local climate of a high valley;
b) Suderode, located on a fairly steep, NE inclined slope, predominantly covered by fruit trees. Wind protection is provided by nearby forests;
c) Gernrode, distant only 1.5 km from Suderode. The station is located in a basin at the very base of the mountain edge, characterized not only by mountain chains right in front of it, but in addition, by a further depression - albeit not as deep - in the station site, in the basin itself;
d) Harzgerode, situated amidst large forests. The station does not represent the area of Harzgerode in the lower Harz, but rather the special climate of forest vegetation;
e) Quedlinburg E Plant, the temperatures of which are significantly incraesed because of the sea of houses surrounding it. Thus, to indicate the temperature conditions in Quedlinburg, the temperature observations - reduced to values of three observation periods - of the station in the Stumpfsburg Garden, set up in June of 1948, were used;

f) Sondershausen, as the station located immediately in front of the southern Harz edge. It was selected primarily to illustrate the contrast with the climatic conditions on the Harz' steep NE slopes; however, it is only partially suited to this purpose because of its location in the Wipper valley, that fully expresses the climatic characteristics of a valley, especially extreme temperatures.

B. CLIMATIC AVERAGE VALUES IN THE FOEHN AREA

Based on the average values of meteorological data established for the usual climate observation periods, we shall in the first place provide some orientation on the climatic deviations in the Harz' Foehn area, compared to normal, flat-land conditions. For this comparison, climate observations at 07, 14 and 21 hours MOZ [Mittlere OrtsZeit = mean local time] were used, taken at the above mentioned stations during the period 1947-49.

Since there is no intention of establishing absolute values, but merely to discover the climatic modifications caused by the Harz, providing the average values for 3 years is quite sufficient. The constancy with which climatic peculiarities appear is documented by the values for individual years.

In second place, this survey is necessary to facilitate a critical evaluation of the individual stations' observed values, before making any further reasoned statements on the climatic conditions of this area are made during further evaluations.

For this purpose, Table 1 below provide the annual averages for the air temperature, relative humidity and wind velocity, and the degree of coverage. Values in brackets suffered reductions. The temperatures were rendered comparable by reduction to the Ilsenburg elevation using the factor 0.58°/100 m , which according to Elsner[7]

TABLE 1. YEARLY AVERAGES OF THE AIR TEMPERATURE, RELATIVE HUMIDITY, WIND VELOCITY AND DEGREE OF COVERAGE. THE AIR TEMPERATURES ARE REDUCED TO THE ILSENBURG ALTITUDE USING THE FACTOR 0.58°/100 m.

	Schierke 613 m	Ilsenburg 275 m	Wernigerode 234 m	Schmatzfeld 198 m	Friedrichsbrunn 530 m	Harzgerode 398 m	Suderode 235 m	Gernrode 210 m	Quedlinburg 130 m	Aschersleben 141 m	Magdeburg 75 m	Gardelegen 47 m	Passendorf 78 m	Sondershausen 186 m
1. Air temperature (°C)														
1947	7,2	8,2	8,1	7,9	8,0	7,2	8,9	—	(7,6)	7,5	7,4	7,0	7,8	—
1948	8,4	9,3	9,1	9,1	9,1	8,5	9,9	(9,2)	(9,0)	8,7	8,6	8,2	8,8	8,5
1949	8,1	9,3	9,2	9,1	9,2	8,3	10,0	9,3	8,9	8,8	8,7	8,1	8,7	8,4
1947—49	7,9	8,9	8,8	8,7	8,8	8,0	9,6	(8,9)	(8,5)	8,3	8,2	7,8	8,4	(8,1)
2. Relative humidity (%)														
1947	78	73	72	72	79	81	72	—	74	74	76	76	76	—
1948	80	75	73	78	79	80	73	—	79	75	79	78	77	—
1949	79	71	74	77	78	86	72	—	79	75	75	79	76	76
1947—49	79	73	73	76	79	83	72	—	77	75	77	78	76	(76)
3. Wind force (Beaufort)														
1947	1,7	1,9	2,5	2,1	1,6	2,2	1,7	—	1,4	2,2	2,4	2,1	1,9	—
1948	1,9	2,1	2,7	2,0	1,6	2,0	1,9	(3,0)	1,5	2,3	2,1	1,9	2,2	1,7
1949	2,1	2,2	2,9	2,0	1,5	2,2	2,0	2,7	1,7	2,5	2,1	2,0	2,1	—
1947—49	1,9	2,1	2,7	2,0	1,6	2,1	1,9	(2,9)	1,5	2,3	2,2	2,0	2,1	—
4. Degree of coverage (Tenth)														
1947	5,8	5,6	6,4	6,7	6,2	5,8	4,6	—	6,4	6,0	5,8	6,4	6,1	(7,6)
1948	6,0	5,6	6,7	6,8	6,0	6,0	5,0	(5,7)	6,8	6,6	6,4	6,7	6,4	7,7
1949	5,5	5,6	6,3	6,4	5,5	5,4	4,9	5,3	6,2	6,0	6,2	6,5	6,3	7,4
1947—49	5,8	5,6	6,5	6,6	5,9	5,7	4,8	(5,4)	6,5	6,2	6,1	6,5	6,3	(7,6)

is the average temperature gradient for the Harz mountains. To avoid sources of error, no reduction to sea level was performed, but to the average altitude, given approximately by that of Ilsenburg (275 m NN).

Compared to the station Magdeburg, uninfluenced by the mountains and the climate parameters of which roughly correspond to the average data of the three flat-land stations Gardalegen, Magdeburg and Halle-Passendorf - and that should be considered as reference values for this same reason - the Harz stations show the following peculiarities, based on this compilation:

1. The temperature deviations of the Harz edge stations, as well as the altitude station Friedrichsbrunn, are noticeably positive. The temperature increases can be represented roughly as a function of the respective distance to the Harz edge. They are summarized in

TABLE 2. Values of the average temperature increases at orographically influenced stations when compared to Magdeburg.

Station	1947	1948	1949	1947—49	Distance of stations
	a) From the foot of the steep NE slope				
Schierke	—0,2	—0,2	—0,6	—0,3° C	—
Ilsenburg	0,8	0,7	0,6	0,7° C	0 km
Wernigerode	0,7	0,5	0,5	0,6° C	1 km
Schmatzfeld	0,5	0,5	0,4	0,5° C	6 km
	b) From the foot of the E, lower Harz slope				
Friedrichsbrunn	0,6	0,5	0,5	0,5° C	—
Harzgerode	—0,2	—0,1	—0,4	—0,2° C	—
Suderode	1,5	1,3	1,4	1,4° C	0 km
Gernrode	—	(0,6)	0,6	(0,6)° C	0 km
Quedlinburg St. G.	—	(0,4)	(0,2)	(0,3)° C	10 km
Aschersleben	0,1	0,1	0,1	0,1° C	25 km

Table 2, above, under a) for the stations on the NE upper Harz and under b) for the stations of the E lower Harz. First, let us point out the uniformity with which the temperature deviation in regard to Magdeburg averages appears in the individual years. The oscillations for stations for which one would expect a determining Foehn effect, are at most ±0.1°. More significant deviations are otherwise found only in in the more or less non-representative stations, such as Schierke and Harzgerode.

Thus, for the immeditate Harz edge a temperature increase of 0.6-0.7° can be established, as a yearly average, both by the steep slopes of the upper Harz as by the considerably smaller altitude differences of the easterly lower Harz (Ilsenburg-Wernigerode, Gernrode). The significance of a only slightly elevated slope station finds expression in the particularly high positive temperature deviations at Suderode, which is only 25 m above Gernrode, for a horizontal distance of 1.5 km. In the context of his Bohemian Foehn studies, Gregor[15] had already pointed out the especially favorable position of such slope locations. As to the altitude stations, finally, Friedrichsbrunn seems the most favored by positive temperature deviations.

In both Assmann's and Schneider's new studies on Foehn effects in the Thuringian Forest it is pointed out that Foehn events are limited to the cold season[16]. Küttner mentions a marked formation of lee waves only in the winter[17], in the Riesen mountains. The reasons aduced are the high position of the condensation level, during summer and the low probability of a ground level layer of cold air being displaced, during the warm season, by Foehn development; it is only by this mechanism that an occurrence typical for this phenomenon could be triggered, in the lee side of the mountains, in the first place. Thus, for an interpretation of the temperature increases here established for the Harz in terms of a Foehn effect, one would have to expect, also, a seasonal dependence; this is illustrated by Table 3, below.

TABLE 3. Numerical value of the average temperature increase at the Harz edge, as compared to Magdeburg, for summer and winter 1947-49.

	Summer	Winter		Summer	Winter
Ilsenburg	+0,2	+1,3	Suderode	+1,3	+1,6
Wernigerode	+0,1	+1,1	Gernrode	(+0,8)	(+1,1)
Schmatzfeld	+0,2	+0,8	Friedrichsbrunn	+0,2	+0,9

We thus can see, at the representatively located stations, that there is a temperature increase only during the cold season, on the average. At the Suderode slope, the summerly overheating and the wind-protected location of the station should probably be interpreted as a radiative effect, in addition to the nocturnal cooling already limited normally for such a location. The situation of Gernrode in a depression is also favored during summerly warming. The same seasonal dependence of the temperature excess also applies to Friedrichsbrunn, where no cyclonal Foehn effects can be expected.

The result confirms, in any event, the favoring of such altitude stations described by Knoch and Renier for winterly high pressure conditions.

The significance of the increased air temperatures at the northeasterly Harz edge stands out especially when they are compared to the value calculated by Perntner for Innsbruck - 0.8° - as air temperature increase for winter and spring. From this we must conclude that the NE Harz edge is considerably more exposed to Foehn effects than Innsbruck, since for the relatively small altitude differences in the Harz the temperature increase effect in the average values is more clearly pronounced than in this Alpine valley.

2. A supplementary confirmation of the Foehn effect due to Harz position, placed in front of it to the SW, is obtained from Ilsenburg's, Werningerode's and conceivably Suderode's average relative humidy values, in Table 1. Schmatzfeld and Friedrichsbrunn do not fall into the pattern, a fact that must be attributed to the influence of the vegetation in the immediate surroundings of these stations. A much better indication of Foehn current effectiveness can be obtained from visibility data at different wind directions, which depend primarily on humidity conditions. For this purpose, visibility data from 1948 observation periods were divided into two steps (10 km or more, and less than 10 km), as a function of wind direction, at the Brocken.

TABLE 4. Visibility in Werningerode as a function of the wind direction on the Brocken (1948).

Wind direction Brocken		N	NE	E	SE	S	SW	W	NW
Visibility (Wgde.)	10 km or more	100	100	100	100	100	100	100	100%
	below 10 km	46	29	77	114	57	18	51	46%

Thus, the best visibility conditions are clearly coupled to the SW direction, which hence leads one to expect the highest Foehn effect at that mountain edge.

3. There are no recorded wind data at any of the stations used. Hence, a critical evaluation of wind force estimates at individual Harz stations could be based only on local experience, accumulated over the last few years. In the context of the remaining weather stations, Wernigerode gains in importance by the fact that here, several observers are employed, such that significant individual influence can probably be ruled out in these observational data.

Accordingly, particular importance should be attached to the relatively high average wind velocity of 2.7 Beaufort, at Wernigerode. The even higher wind force estimate at Gernrode is certainly - in the view of two neighboring observers checked for confirmation, in Gernrode and Suderode - due to a slight overestimation. In any event, however, the NE edge areas of the Harz mountains appear to be subject, in some locations, to winds that are considerably more forceful than those of the flatlands. In contrast, Friedrichsbrunn and Quedlinburg show minimal wind velocoties. However, both of these indications seem unsuited to the general conditions of the local surroundings. In Friedrichsbrunn there is a closely limited protection due to houses around the station. A wind tower protruding over these influenced zone has not yet been erected. But at distances as short as a few decameters from the station, wind forces can be assumed that correspond to approximately 2 on the Beaufort scale under normal conditions, on the average, matching the air movement above the local plateau. The low wind force at Quedlinburg predominantly reflects the wind protection afforded by the city's sea of houses. Thus, the only values that are to be considered certain are those relating to an increased air motion in the mountain edge areas.

4. The estimates of the degree of coverage can also not provide any degree of certainty better than 0.1 or 0.2 tenths, on the average, just as in the case of wind force estimates. Especially at weather stations in which observations are almost always taken by a single person, the personal feeling of the observer can easily

lead to a constantly appearing error. While the experience of cloud cover estimations has shown that the true conditions are really well captured, it is still true that in individual cases a critical evaluation is absolutely necessary. This is shown in the current paper at the immediately neighboring stations Suderode and Gernrode, the cloud cover indications of which should agree in anycase. Both observers were quite surprised, when they saw the differences (Table 1) in the results. Eventually it became especially evident that while at one station 1/10 cover at a long distance from the station - or less - was not considered at all, at the other, any trace of clouding of any kind, where ever it was visible, was assigned a 1/10 value. This slightly extreme estimating methodology - on both parts - can clearly cause the differences found in the average values, for an area with as little clouding as this one. In this case, the mean value of both stations should reflect the true conditions for both stations at the Harz edge.

According to Table 1, the degree of coverage at the synoptic stations Wernigerode, Magdeburg, Gardelegen and Halle-Passendorf - with the most trustworthy values, as a first approximation - stay within the values 6.1 and 6.5 tenths. Considering that we are here dealing with estimates, we can not really talk about differences in the average degree of coverage at these stations. Thus, a noticeable decrease in the degree of coverage then can lead one to conclude Foehn effects, is only visible at the Harz edge stations Ilsenburg and Suderode-Gernrode., but not at Wernigerode, Schmatzfeld and Quedlinburg. Hence the degree of coverage reflects only in places some Foehn currents, obviously. The reduction in visibility due to the rise of the mountains at Ilsenburg and Suderode-Gernrode - with a maximum value of about 10° - can certainly not be made responsible for the significant cloud cover deficit at these stations.

The altitude stations Friedrichsbrunn and Schierke show a degree of coverage slightly below the norm, which according to Knoch and Ranier's papers is due to winterly high pressure weather.

For a judgement on the estimate of cloud cover, often the records on hours of sunshine are called upon. The simple relationship established by Wagner between degree of coverage and duration of sun shine, according to which both quantities - expressed as percentages - add up to 100[18], constitute a very useful criterion for working with flatland conditions. In the mountains, and for stations the visibility of which is reduced because of more or less extensive horizon covering with vegetation, the sum is always going to be less, since both the cloud covering as well as the hours of sunshine will be slightly underestimated, compared to free standing stations.

TABLE 5. Yearly sum of sunshine duration in h. (1947-49)

	Quedlinburg	Friedrichsbrunn	Schierke	Ilsenburg
1947	1790,1	2029,3	1896,5	1938,5
1948	1688,0	1939,6	1735,2	1887,3
1949	1900,0	2056,3	1920,7	1990,0
1947—1949	5378,1	6025,2	5552,4	5815,8
% of astron. possible	41	46	43	44
% of orograph. possible	41	46	45	46

As a first approximation, let us use the values of the stations with a free horizon as reference values. The smallest sunshine duration at Quedlinburg is in agreement with the high degree of coverage at that location. Both values together represent 106%, in agreement with Wagner's formula. Correspondingly, the higher sunshine duration at Friedrichsbrunn is identical to the there prevalent smaller cloudiness, adding up to a combined 105%. The impaired irradiation into Ilsenburg and Schierke manifests itself - in comparison to Fried - richsbrunn - in reduced sunshine duration. If one takes into consideration the vegetation cover of the horizon - the irradiation loss is valued at approximately 1/2 hour daily as a yearly average - than the percentage of sunshine duration is about the same for Ilsenburg and Friedrichsbrunn, with Schierke falling behind but by only 1%. For the same percentual increase in vegetation coverage at both stations these reduced value add up to 104% for Ilsenburg and 105% for Schierke.

We can thus derive, from these values, the special favoring with sunshine of the Foehn area, in comparison with the depression situated in front of it. At Wernigerode, sunshine records have been initiated only recently. It is hence not yet possible to document the degree of coverage there by means of sunshine duration figures.

Without intending to discuss here the value of the relationship B + S = 100 [B for bewölkt = cloudy, S for Sonnenschein = sunshine] attention is called to the fact that the sums for the Foehn area locations here covered are over 100% without exception. Due consideration taken of Goldberg's investigation, this result confirms the typical form of occurrence of cloud cover in Foehn areas. Goldberg was able to prove that such high sums can be explained in terms of broken cloudiness[19]. At the same time, Brooks' opinion, mentioned in the same paper should be pointed out: he places the responsibility on the effect of the sun's rays through thin clouds for sums exceeding 100%. Both the thin as well as the loosely structured cloud cover are, however, characteristic for the Foehn area.

It is thus quite remarkable that even these average values express so clearly the Foehn effects to be expected at the NE Harz edge. Temperature increases, humidity decreases, improved visibility, higher wind velocities, reduced cloud cover and correspondingly increased enjoyment of sunshine - all are thus sufficiently documented. The basis for these values is to be found in the predominant frequency of the S to W, Foehn-effective wind directions in the NE Harz area, representing approximately 60% as documented in the Table 6, below.

TABLE 6. Wind direction frequency at the Brocken (1896-1930)[12]

N	NE	E	SE	S	SW	W	NW	C
6.9	5.4	8.1	7.9	9.0	27.3	22.4	12.1	0.9%

No further conclusions can be derived from the average values. A decision as to whether the Foehn-effective winds are the only factor to trigger the climatic peculiarities of the NE Harz edge is also not possible, just on the basis of the average values.

C. LEEWARD WAVES AND LEEWARD EDDIES

Neither the wind structure nor that of the cloud field are evident from weather observation data. It hence became necessary to institute observations especially for these conditions. There were no instrumental records of measurements to clarify peculiarities of this kind. An introductory survey was to be obtained, to begin with, only for the wind distribution at the different stations.

TABLE 7

	N	NE	E	SE	S	SW	W	NW	C
a) Number of cases per wind direction in 1948									
Magdeburg	70	55	79	83	98	200	248	92	173
Schierke	50	82	103	116	31	146	220	344	6
Wernigerode	21	20	98	88	190	178	238	83	181
Ilsenburg	17	56	258	206	49	180	249	39	44
Schmatzfeld	63	77	225	92	21	117	225	233	45
Friedrichsbrunn	130	64	113	31	54	116	495	82	13
Suderode	13	27	91	70	46	145	459	138	109
Gernrode (VI—XII)	22	82	70	34	11	107	178	138	6
Quedlinburg E.-W.	100	41	173	4	29	40	592	81	38
b) Average wind velocity per wind direction in 1948									
Magdeburg	1,9	1,8	1,9	1,6	2,0	2,7	3,3	3,2	—
Schierke	1,3	1,2	1,3	1,4	1,4	2,0	2,4	2,4	—
Wernigerode	2,4	1,9	2,6	1,9	2,7	4,0	4,0	3,7	—
Ilsenburg	1,7	1,5	1,3	1,5	2,4	2;9	3,2	2,2	—
Schmatzfeld	1,8	1,0	1,7	1,6	2,3	2,1	2,6	2,5	—
Friedrichsbrunn	1,2	1,2	1,4	1,5	1,2	2,2	1,8	1,2	—
Suderode	2,5	2,1	2,0	1,9	1,5	2,0	2,1	2,4	—
Gernrode (VI—XII)	2,8	1,9	2,1	2,7	2,5	3,7	2,8	2,9	—
Quedlinburg E.-W.	1,5	1,6	1,4	1,8	1,3	1,4	1,7	1,8	—

(commas in the above chart denote decimal points)

In the approximately normal wind distribution at Magdeburg, W winds are the most frequent, according to this tabulation; SW winds show an only slightly lower frequency. The distribution is even, increasing from NE to S to W and then falling. The maximum of wind velocities is also at W. Winds with the next highest velocity are from the less frequent NW direction.

The Harz station deviate from this pattern, corresponding to their respective orographic situation:

1. The wind distribution at the altitude stations Friedrichsbrunn and Schierke are strongly influenced by a current channel. At Friedrichsbrunn evidently the Bode valley is still direction-controlling for air movement: the W winds alone have 45% of all cases. In spite of the fact that wind velocity data are given somewhat lowly, the even distribution of the velocities is significant. In Schierke, wind velocity variations are also insignificant. The strongest winds fall to the directions W to NW, in agreement with the normal distribution. The also frequent winds from the E to SE are to be attributed to the diurnal wind system of the Bode valley in conjunction with the opposing directions.

2. At the Wernigerode wind distribution the high frequency of calms is particularly striking, seemingly contradicted by the above-normal wind velocity average. As will be shown later, it is especially the morning observation period that falls within the period with the lowest expected disturbance due to orographic considerations. A further high frequency deviating from Magdeburg is that for S winds. In view of the already considerable average velocity of these winds, the fact mentioned argues for the air currents frequently dodging the upper Harz. In closing, particularly high wind velocities are observed for the SW and W winds blowing down from the mountains, and hence the significant wind velocities at Wernigerode must be attributed to Foehn effects.

In Schmatzfeld, the high E wind frequency must be attributed to the air current blowing against the mountains, in the daytime. The wind distribution, with maxima for W and NW, is already well in agreement with the norm.

Analogously the wind velocity distribution at Ilsenburg substantially parallels that at Magdeburg. The station, located immediately at the foot of the mountain slope, is not reached by the strongest winds, coming from the mountain, but does receive the constant air motion caused by the mountain slope; this is expressed by the low number of calms.

Thus, these three stations corroborate the phenomenon known from other mountain chains that the strongest currents in the lee are not found immediately at the foot of the mountains, but in a strip parallel to the mountain edge, placed at a distance in front of it. The Wernigerode station happens to be located in such a specially influenced wind area.

3. At Gernrode in the E lower Harz slope it is also evident that the strongest winds coincide with the Foehn current (especially SW). Only in the slope area itself (Suderode) are observed even air current conditions. Here, the area of strong winds is immediately at the mountain edge, due to the gentler slope of the mountain side at lower height differences. At least, stronger winds than those at Gernrode are not known from the further removed depression in front of the edge.

More significant, however, is the in part extraordinary gustiness of the Harz edge air movement. Thus, at Wernigerode the winds from the S to W sector occur almost on principle in the form of severe gusts. The very high average wind velocities are thus also in part due to the continuous, severe gusts. In the immediate vecinity of the mountain edge, at the Ilsenburg station, these gusts are less frequent. Within the Ilsenburg city limits the gustiness is just normal. At Schmatzfelt, clearly marked gusts are observed only during certain weather conditions (passage of a cold front, for instance). At the E lower Harz, the gustiness in the strong-wind area immediately at the mountain edge can only be considered normal. A strip of higher turbulence will be found only in the lee of the hills in front of the edge. In the connected depression, the gustiness returns to its normal levels, as can be confirmed by Dr. Kupfer's experience at the former Quedlinburg airport.

It is significant, now, that these partially normal and partially very marked gustiness conditions can be related to the formation of two different kinds of lee eddies. Within the range of particularly severe gustiness are observed exclusively the known lee eddies with a horizontal axis. The normal gustiness of edge areas occurs in connection with the formation of lee eddies with vertical axes. The former, in turn, go back to some orographic structure placed predominantly across the wind path, while the latter relate to those small areas at the mountain edge in which a flow channel in the wind direction structures the air flow. These situations are illustrated in Figure 3, below.

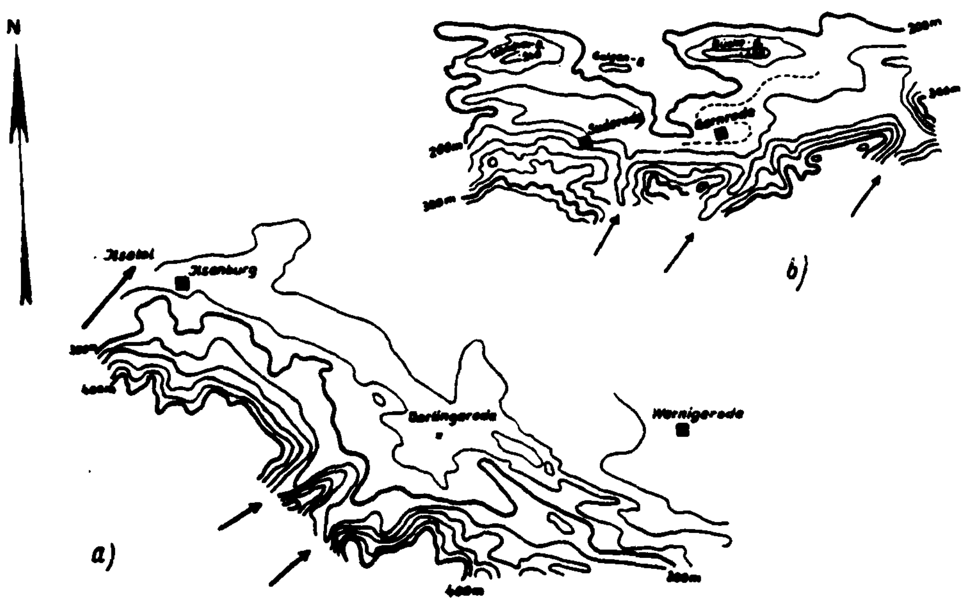

Figure 3. The NE Harz edge. a) Steep slopes of the Upper Harz. b) At the Lover Harz (contours in 20 m steps, at Gernrode - dotted line - 10 m).

The formation of lee eddies with a vertical axis is unquestionably proven for the SW - NE oriented valleys opening towards Gernrode, following smoke evolution; in front of the Ilse valley particularly by the special Harz investigation during the spring of 1936 for winds from the SW quadrants. By the same token, reduced gustiness at the exit of the Darlingerode valleys (between Ilsenburg and Wernigerode) and the Heimburg valleys (between Wernigerode and Blankenburg) leads one to conclude the formation of eddies of similar kind. Immediately to the side of these valleys opening towards the NE begin the areas in which eddies with horizontal axes cause particular gustiness. The limits between these two flow regimes were very clearly marked during snowdrifts in winterly Ilsenburg. At a distance of approximately 50 m NW of the station the strong, but relatively uniform current determined by the Ilse valley, was observeable. The station itself was already within the area of influence of gusty eddies with horizontal axes. The Wernigerode station was always included by the strongest of such gusts, positioned, as can be seen in Figure 3, in front of a chain of hills essentially parallel to the mountain edge of the Harz. The observation of increased gustiness in the lee of the hills in front of Gernrode and Suderode has the same meaning.

Dr. Schulz was able to confirm these observations as collaborator of the special Harz investigation mentioned. It should be pointed out that the scope was clearly limited to observations of the ground-level wind structure. As to supplementing air-borne observations, we refer to Fick's paper, from which we can deduce a special gustiness over the hillchain positioned in front of the Harz edge to the south of Quedlinburg and which on occasion has forced the interruption of school activities. During the weather conditions at that time, the formation of ground-level thermic upwash was not possible as an explanation for the gustiness[20].

A further and essential support is provided by the cloud picture for this relationship expressed in terms of gustiness, kind of lee eddy and orography. The smallest degrees of coverage were observed over Ilsenburg and Gernrode-Suderode, i.e., where the lee eddies with vertical axes occur. The range within which cloud dissolving processes are effective in front of Ilsenburg coincides approximately with the extension over which local lee eddies form. At Gernrode-Suderode, the lee eddies with a vertical axis, limited to the depression between the mountain chain edge and the hills in front of it, are probably responsible for only the portion by the mountains of the total cloudless area that often extends as far as Quedlinburg. For the rest, the further expansion of the local cloudless air space during Foehn current is probably based on the fact that the air masses must traverse a much longer distance to get to Gernrode than to Ilsenburg and, as a consequence, the loss of humidity is considerably larger. Finally, the further leeside sloping between Gernrode and Quedlinburg is steeper than that from Ilsenburg towards Schmatzfeld; hence in the lower Harz there are better conditions for the outflow of ground-level cold air during Foehn period development, than on the steep slopes of the upper Harz. Thus the altitude current finds more favorable conditions on the lower Harz slopes to reach into deeper regions.

The aspect of the sky in these two edge areas takes predominantly only two forms, under Foehn action. Either an extensive, cloud free area is formed, or the density of a closed cloud cover - especially recognizable for intermediate height clouding - is considerably reduced within that same extension. Thus, the development of the lee eddy with a vertical axis and its effect on the cloud picture could be envisioned in the following manner:

The formation of lee eddies with a vertical axis can be compared to a cyclone genesis. The place of warm air is taken by the favorably sucked down Foehn current, in the mountain valley, while that of cold air is represented by the flat, ground-near cold air layer in the depression in front of the mountain (not completely sucked off). Thus, the contrasting air bodies are in contact in only a narrow layer close to the ground. The hence also ground-close, cyclogenetically formed lee eddy now sucks into not only the laterally close layered air bodies but also - considering the third dimension - the upper air layers. It thus forces an additional downward movement of the air higher up, and with it, expanded cloud dissolution. For balance there must be an upward directed motion at the eddy's center. Since this upward current includes predominantly air that has already undergone the Foehn process, condensation phenomena occur only at moderately high to high levels. A Moazagotl tower is formed. Since it is not very wide - it is called tower for this reason - it does not contribute much to an increase in the degree of covering. This complete development stage of the lee eddy with vertical axis could be observed several times in front of the Ilse valley. Unfortunately, due the lack of the necessary equipment, no photographic reproduction can be provided. The corresponding lee eddy at Gernrode must be limited to the depression between mountain edge and the hills in front of it, in terms of this concept, since in general it would be only in this hollow that a flat, ground-close layer of cold air could be formed or, respectively, continuously regenerated. Due to these narrow limits, the upwards directed current in the eddy's center is not sufficient to reach condensation altitude and thus form Moazagotl forms.

The clouding conditions coupled to lee eddies formed with horizontal axes in edge areas not structured in the direction of air flow: the Foehn current becomes visible (Figure 4 a, below) only by

Figure 4a. Foehnig clearing at the Harz edge near Wernigerode. Taken from Wernigerode towards S and SW at 1400 h on September 10, 1950, during a W wind of force 4 on the ground and W wind of force 7 on the Brocken.

a small breach in the cloud field immediately above the mountain edge. In many instances the clouding remains closed, except that the cloud density is smaller in an equally narrow breach or strip. Connected to this loosened zone, above Wernigerode station there follows a very dense cloud bank, extending WNW up to just before Ilsenburg, disturbed only just before Darlingerode; ENE it extends up to Blankenburg, disturbed only by Heimburg. This bank is again followed by a narrow strip between Wernigerode and Schmatzfeld, that then thickens to a second extended bank. Seen from below, these cloud strips resemble lenticularis bands. This is an unqualified wave process. Even three waves of this kind were observed, while in many cases there is only a loosening at the mountain edge followed by a thickening which may show lighter and darker portions, but no longer reflects the picture of a wave, especially when the altitude current changes from SW further to W. These observations are identical with the lee waves described by Küttner for the Riesen mountains[17]. With the Harz' ingot form it is not surprising that even small changes in the direction of flow can destroy this phenomenon. For this reason and because usually there is additionally existing deeper clouding, this wave structure could not be photographically captured clearly at intermediate level. Hence we present an aerial observation of the lee waves of February 8, 1940, kindly provided by Dr. Schulz. From this observation we can derive the formation of the 1st wave, from Wernigerode to Thale, at 2500 m altitude; the 2nd wave is developing approximately 8 km to the lee at an altitude of 2000 m. The waves were no longer formed in the Ilsenburg and the Suderode-Gernrode spaces.

In contrast, the wave structur over the NE Harz foreland can be represented very impressively for the ground observer, due to the lower eddy currents often combined with the waves; they are responsible for the formation of cloud rollers (see Figures 4b-d, below) . The rotors were photographed from the first Harz ridge of hills near Wernigerode. They begin E of Darlingerode, i.e., to the side of the valles opening in that direction, and end near Heimburg, where the dreck valley and the Klostergrund fade into the NE. Thus the rotors confirm that formation of eddies with a horizontal axis is broken at

Figure 4b). Cloud roller at the NE Harz edge (Wernigerode). Taken from the first Harz ridge at Wernigerode on 1-13-51 at 1300 h with a force 5, gusty SW wind at ground level and a force 10 SW on the Brocken. View NNE-NE

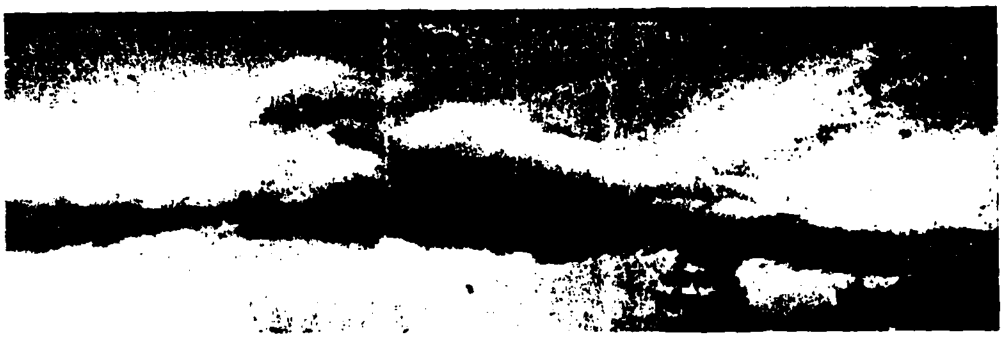

Figure 4c). Cloud rollers over the NE Harz foreland. Taken from the first Harz ridges at Wernigerode on 11-22-50 at 0830 h with a force 3, SSW ground wind, at times gusty and a force 10 SW on the Brocken. View NNW to NNE.

Figure 4 d). A few minutes after photograph 4c. The second cloud roller has also formed in the NNW direction.

valleys oriented in the direction of flow. Küttner made a similar comment, i.e., that the cloud rollers were "twisted" in front of the Schmiedeberg pass, in the Riesen mountains. Figures 4 c) and d) show two such rollers, of which the first lies directly above Wernigerode station. The second one is behind Schmatzfeld, so that the distance is approximately 8 km, the same distance that resulted from Schulze's aerial observations.

The formation of rotors has not been observed in front of Suderode-Gernrode anymore than the upper wave. This, however, means that beyond the local lee eddy with a vertical axis, i.e., beyond the Gernrode depression at the foot of the mountains, there is total outflow of the ground-level cold air during development of the Foehn current; this process had already been resorted to in order to explain the local extensively cloud-free space, which, in turn, was comprehensible in terms of a sufficiently steep slope in the terrain between Gernrode and Quedlinburg. The lee eddy formation behind the hill chains in front of that terrain are conditioned exclusively by these obstacles. Since an involvement of ground-level cold air is excluded from these eddies, the preconditions for the formation of cloud rollers are also lacking according to Küttner's concept, as are those for an extension of the eddy zone into the connecting foreland due to air body contrasts.

The two kinds of eddies and their influence on the cloud picture are represented schematically in Figure 5, below. To represent the eddies with a horizontal axis we selected Küttner's explanations for his Foehn wave theory (Figure 5a.) The conditions at the NE Harz foreland deviate from this schematic only in the sense that for the upper wave only in the fewest of cases completely separated, individual wave characteristics can be recognized; rather, the already described wave-like thickening and thinning is observed. Hence the amplitude of the oscillation is smaller than in the lee of the Riesen mountains. With regard to the eddies with a vertical axis, a particularly illustrative observation of March 18, 1950 at 1600 h was used. Here, the Moazagotl tower shows a spiral-form construction, in the direction of rotation at the eddy's center, with 4 turns (Figure 5 b). The altitude wind blows from the WSW on Brocken, with a force of 6 Beaufort, while at ground level it is a force 3 Beaufort wind from

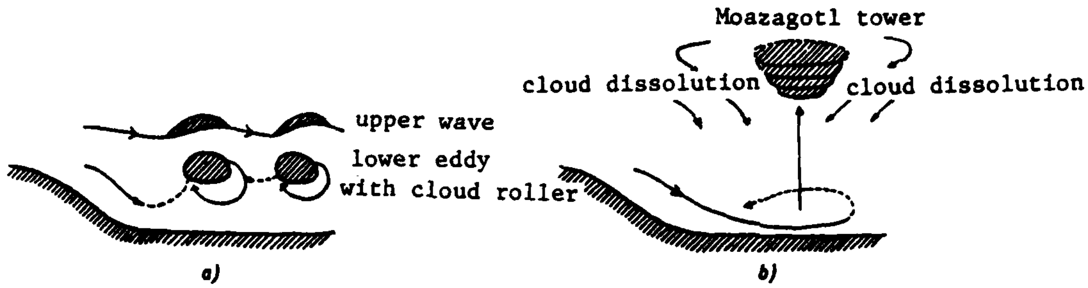

Figure 5. a) Lee eddy with horizontal axis and upper wave in front of the NE Harz edge area not structured in the current direction, during Foehn-effective winds (drawings after Küttner). b) Lee eddy with a vertical axis in front of the Ilse valley, oriented in the current direction, during Foehn-effective winds.

SSW. At 1700 h the altitude wind turned to the S and the ground wind to SSE, destroying the eddy formations within minutes.

With the representation of these locally very different flow conditions, which can be shown to be based on the respective orographic structures and which lead to certain forms in which the cloud picture appears, we have encompassed the factors that make it possible for an observer to recognize the influence of the Foehn in the NE Harz space during winds from the S and the W. From the elaboration it becomes clear that with an appropriate selection of the place of residence, it is fairly simple to avoid the unpleasant area of influence of these Foehn effects. In the end that is, in fact, the significance of the central mountain climate. Climatic attractions are available in the most manifold variations. The appropriate form can be selected according to the desired modification.

D. CYCLONAL FOEHN, ANTICYCLONAL FOEHN, STAGNATION

1. The cyclonal Foehn

Starting from the locally differentiated flow conditions which from the elaboration above impart their own characteristics to the cloud picture we shall show, below, the corresponding reactions of the air temperature and relative humidity. Conversely, these two elements will confirm the observations made about wind structure. Since their recording is relatively simple, they are particularly suited to describe the temporal course of Foehn formation.

In order to obtain a first survey on the average cyclonal Foehn effects, we encompassed those climate observations that promise a Foehn effect in Billwiller's theory[21]. Hence, preconditions are:

a) Condensation in the stagnation area below ridge altitude;
b) Low pressure, oriented geographically in such a manner that the air can be sucked off the mountain's lee side.

After these preconditions, necessary for a Foehn effect, we selected those cases in which the Brocken was inside the stagnation clouds and a wind velocity of at least 5 Beaufort could be observed on this highest Harz peak; this would assure outflowing of the air - corresponding to the wind direction - from the appropriate leeside mountain edge. For the weather observations selected according to this criterion during 1948, the temperature and degree of coverage data for all stations were divided into Foehn-effective (S - W) and stagnation-effective (NW - SE) in the NE Harz space, by wind direction. The properly suctioning-off significance - especially following Küttner's reasoning - must be attributed to the ground level wind directions. If, in spite of this, the division here is still based on the wind direction at the Brocken, to assign observed data to the stagnation or Foehn effective categories, that is because it was only in this manner that comparable values could be obtained for the stations. Disregarding a few exceptions in which local wind currents predominate, and bearing in mind the general right-rotation of winds with altitude in low pressure areas, the directions designated as Foehn-effective on the Brocken correspond to ground level currents from SSE to WSW. Inclusion also of the NW altitude wind as Foehn-effective proved an error, since at the WNW to ESE oriented

TABLE 8. a) Average temperature (°C) b) Average degree of coverage (Tenths) for wind directions on the Brocken that cause Foehn events (S-W) and stagnation phenomena (NW-SE)at the NE Harz edgeand stagnation clouding on the Brocken, and that are observed with a force of 5 Beaufort or larger on the Brocken. (1948 weather data)

a)	Foehn		Stagnation	
	Summer °C	Winter °C	Summer °C	Winter °C
Magdeburg	12,2	5,4	10,8	0,1
Schierke	11,4	5,6	10,8	0,0
Ilsenburg	12,7	6,8	10,9	0,4
Wernigerode	12,8	6,8	10,9	0,3
Schmatzfeld	12,7	6,5	10,8	0,3
Friedrichsbrunn	12,1	5,6	11,0	−0,8
Harzgerode	12,1	5,5	10,9	−0,2
Suderode	13,5	6,9	11,8	0,7
Gernrode	12,9	6,7	10,9	0,5
No. of cases	137	218	39	88

Temperatures are reduced to Ilsenburg altitude by means of the factor 0.58°C/ 100 m. The Gernrode values (June to December) are adapted to the entire year on the basis of the Suderode and Wernigerode station data.

b)	Foehn		Stagnation	
	Summer	Winter	Summer	Winter
	Tenths		Tenths	
Magdeburg	7,7	8,0	6,9	8,2
Schierke	7,9	8,8	6,4	9,1
Ilsenburg	5,9	6,8	7,4	8,7
Wernigerode	7,7	7,8	8,4	9,0
Schmatzfeld	7,8	7,8	8,5	8,8
Friedrichsbrunn	6,9	7,9	7,7	8,9
Harzgerode	7,6	7,7	8,4	8,8
Suderode	5,8	6,6	7,3	8,5
Gernrode	6,2	6,8	8,2	8,5
Quedlinburg	7,8	7,7	8,0	8,3
No. of cases	137	218	39	88

The degree of coverage at Gernrode (June to December) was adapted to the entire year on the basis of the Suderode and Wernigerode station data.

(commas in the above charts denote decimal points)

mountain edge the ground current did not show any significant deviation from this altitude direction; hence, the deflecting influence of ground friction is reduced by the direction-determining mountain edge effect on that current.

Given the numerical values of Table 8, above, the extremely even temperature distribution for stagnation-effective wind directions, especially during the warm season, should be pointed out in the first place. The apparently small temperature excess at the Harz edge stations during winter is probably due to the stronger air movement in the mountain edge domain, which works to reduce the probability of ground-level cold air body formation, while at higher locations cooling is reinforced because of the snow conditions (Friedrichsbrunn). Only Suderode shows a deviant behavior as a slope station, due to higher summer temperatures.

A picture even less influenced by local conditions is that of the Foehn-effective winds, since these normally show higher velocities. Even the Harzgerode station acquires a truly representative significance in this case. According to this compilation, warming due to cyclonal Foehn is limited strictly to the Harz edge area, with a value of 0.5-0.7° compared to Magdeburg, during the summer, and to 1.3-1.5° during the winter. In accordance with the nature of the locality, the temperature increase is slightly lower for Schmatzfeld, located in front of the former. The high, deviant value for Suderode during summer can probably be explained in terms of radiative effects due to the wind-protected location of the station and the low local cloud covering. The altitude stations Friedrichsbrunn and Schierke show no cyclonal Foehn effects. Evidently at Schierke on the average the stagnation effect at the Brocken massif dominates over any Foehn-effect of the ridges positioned in front of it to the SW. For the Friedrichsbrunn station a cyclonal Foehn effect would be unthinkable in any event, just as at the Harzgerode station, located as it is only 100 m below ridge level in the lower Harz.

The degree of covering provides an additional criterion for Foehn and stagnation. For the wind directions from NW to N to SE, the cloud covering values are significantly enhanced at the Harz stations, with the exception of Schierke, where NW winds become Foehn effective. In contrast, the Foehn influence becomes noticeable in the cloud picture only at the stations Ilsenburg, Suderode and Gernrode, i.e., in areas in which the Foehn current find a kind of pass-like course because of the NE oriented valleys, to end in a lee eddy with vertical axis. In the remainder of the Harz edge area, that is predominantly under the influence of lee eddies with horizontal axes and shows a wavelike whirl of the altitude current as well as the formation of cloud rollers at lower levels, the Foehn gap appearing in true cyclonal cases is not sufficient to cause a clear cloud cover deficit, to the extent that the Foehngap shown by the photograph (Figure 4a.) appears at all, and not just a strip of reduced cloud density. Thus, once again the close relationship is made patent in which the individual observations are to each other: wave and rotor formation without special reduction in the degree of coverage in conjunction with the strongest gustiness at ground level. Even flow conditions connected to cloud dissolution. In one case a continuous adjustment must take place between higher and lower tropospheric air masses, while in the other such a confrontation must be extensively avoided. Hence in one case we must assume incomplete suctioning off of cold ground level air, while in the other the outflow must be uniform and nearly complete.

The subsequent discussion of weather conditions shall look into these processes individually. The question regarding Foehn activity during summer, weakly but clearly expressed by the data in Table 8, shall also be postponed until then.

Weather conditions

1. Foehn condition of January 26-29, 1948 (anticyclonal preliminary stage, cyclonal Foehn stage)

The entire month of January, 1948 was under the influence of Atlantic disturbance phenomena, such that only occasional, in-between high conditions brough winterly weather characteristics. Such a case occurred on January 25, where in a flat, ground-level cold air body winds from the E to SE predominated. Above it, strong sinking set in, so that at the Brocken the relative humidity was 40%, under little clouding. The inversion was characterized by a dense altitude mist

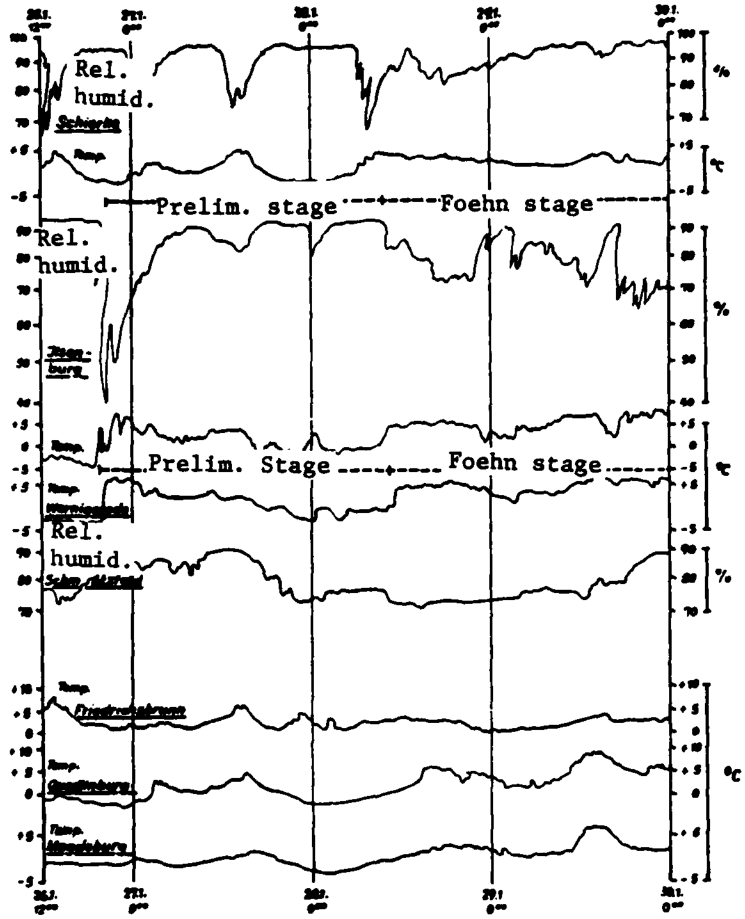

Figure 6. Temperature and humidity records for January 26, 1948 at 1200 h to January 29, 1948 at 2400 h.

layer. The ground station observed moderate to strong mist, many instances of fog which during the night to the 26th spread generally and thickened.

While these conditions remained characteristics of the central German flatlands, at the NE Harz edge and due to the pressure distribution that triggers a altitude current from the SSW over central Germany, Foehn activity sets in.

The downward reaching of the altitude current at the Harz stations is reflected by the temperature and humidity recordings in Figure 6, above.

At Ilsenburg and Wernigerode the ground level cold air body, flowing out in correspondence with the pressure gradient, is already replaced by a severe first and following weaker further Foehn thrusts on the evening of the 26th. Further cooling during the following night is prevented by a renewed, albeit weaker Foehn breach. During these processes, the Brocken remains above the inversion clouding. Thus, in analogy to von Ficker's description for the Alps we are dealing first with an anticyclonal prelimary stage[21]. The cold air body at ground level continues to predominate and is removed only temporarily in a complete manner by Foehn thrusts. In particular, the observation of opposing wind directions (N-NE) at the end of such Foehn thrusts indicate an inflowing of cold air from the depression in front of the ridges, due to a thermal pressure reduction at the mountains' edge. Further cold air inflow occurred by action of the mountain wind from the mountain valleys. Last but not least, the cooled down soil itself contributes to the creation of a cold air layer at ground level, by rapidly converting the warm air brought in by the Foehn thrusts - especially due to their dryness - into flat cold air bodies, until as a consequence of further suctioning off of the air from the lee-side mountain edge a new Foehn thrust is triggered. The outstanding feature of these Foehn thrusts from the anticyclonal preliminary stage occurring in the evening and night hours especially, is discussed in detail during the description of the anticyclonal Foehn.

Only at 1000 h on Sept. 28 does the stagnated clouding wash over the Brocken, thus giving the start to the properly cyclonic Foehn stage. As shown with particular clarity by the Ilsenburg humidity curve, now - in contrast to the preceding, preliminary stage - some deflections in the direction of decreasing humidity are no longer characteristic of Foehn thrusts, but rather the opposite: now deflections in the direction of increasing humidity are indicative of Foehn pauses. Further, while during the course of the anticyclonal preliminary stage the humidity curve remains fairly even - outside of Foehn breaches - during the true Foehn period the curve shows a significantly higher unrest, caused by the variations in the Foehn current by direction and force. The temporal extensions of the preliminary and the cyclonal Foehn stages are shown by limiting lines in Figure 6, for Ilsenburg and Wernigerode.

The situation is entirely different at Schmatzfeld, as characterized by the local humidity record. The anticyclonal preliminary stage is barely marked. There is just some restlesness in the humidity trace during the night of the 26th to the 27th. Already during the second half of the 27th the humidity decreases continuously, remaining eventually at the 75% level, approximately. Thus, while at the mountain edge the conditions of the anticyclonal preliminary stage are still predominant, at Schmatzfeld a uniform, enduring Foehn current is already active. This observation agrees with Schneider's for the Thuringian Forest, i.e., that the lee effect appears only at some distance from the mountains' edge[16], since immediately at the foot of the mountains the local valleys and depressions favor constant growth of the ground level cold air layers.

Weakened and considerably later, the Foehn current - both from the preliminary stage and from stationary development - reaches Quedlinburg. However, the Quedlinburg temperature registration no longer characteristically expresses these processes, since turbulence occurrences due to the city cause additional unrest in the temperature curve.

Among the altitude stations, Schierke is still remarkably under the influence of the Foehn from the mountains in front of it, to the S and SW, something unexpected on the basis of the data regarding average conditions during Foehn effective currents, in Table 8. In contrast, the temperature record at Friedrichsbrunn reflects only the anticyclonal preliminary stage, with positive deflections, especially during the night to the 28th. During the stationary Foehn stage, no further aperiodic variations occur. Thus, this temperature course already expresses what is typical for an altitude station during the course of a Foehn period, even though this station's location is not high enough to be enclosed by the Foehn wall during the cyclonal stage. This determination is characteristic for the climatic conditions in the Harz, which take particularly extreme forms for relatively small altitude differences. If at an altitude of 530 m in Friedrichsbrunn - as we shall see again below - the typical conditions of peak stations are already mirrored, this is not due exclusively to the station's location. The phenomena are much more in agreement with the limits of the florescence districts in the Harz, which a considerably reduced altitude range than those of other central German mountain ranges. Thus, according to a compilation by Pörner, the lower forest step, with beeches, spruce and foxglove embraces, in the Harz, the altitude range of 350-600 m, while the same range is 500-800 m in the remaining central German mountain chains. The subalpine mountain heath with rock and gravel meadows starts at 1300 m in the central German mountains, but at 1000 m only in the Harz. This particularly fast vegetation and hence climate change in the vertical direction becomes understandable from the exposed situation of the Harz[22].

In contrast to the phenomena in the Foehn range, the uniform conditions of the flatlands are reflected by the Magdeburg temperature records.

We thus can deduce from the weather conditions that the clear distinction between the preliminary and the cyclonal Foehn stages is limited to the immediate mountain edge zone (Ilsenburg and Wernigerode stations). The Foehn stage proper sets in at the time of the formation of the Foehn wall atop the mountain massif. In the depression farther out from the mountain foot (Schmatzfeld), the Foehn current reaches the ground already when the recordings at the mountain edge still show the preliminary stage. In the foreland, the formation of the Foehn wall atop the ridge causes only a small increase in the Foehn effect, as well as a particularly uniform course of the record. This, however, corresponds to the flow conditions described in the previous section, the special unrest of which is no longer observable at Schmatzfeld.

2. Foehn condition of December 13-14, 1948. (Foehn breach in the Upper and Lower Harz).

As a consequence of the displacement of an E European high pressure area to the S, the inflow of cold continental air to central Europe is impeded and the bringing in of moderate maritime war air is made possible. As of 1200 h on the 13th, the Brocken is within the stagnation cloud; the SW wind increases in force until it reaches hurricane level 12 on the evening of the 14th.

This weather condition shall express the different kinds of Foehn breach occurring at the steep-sloped Upper Harz and the Lower Harz slopes at Suderode-Gernrode (Figure 7, left). On the one hand, it is characteristic for Ilsenburg to indicate both a temperature and a humidity jump during Foehn breach. As in the previous weather condition, the sharp transition has weakend at Schmatzfeld. If the recordings at this advanced station appear as relatively restless

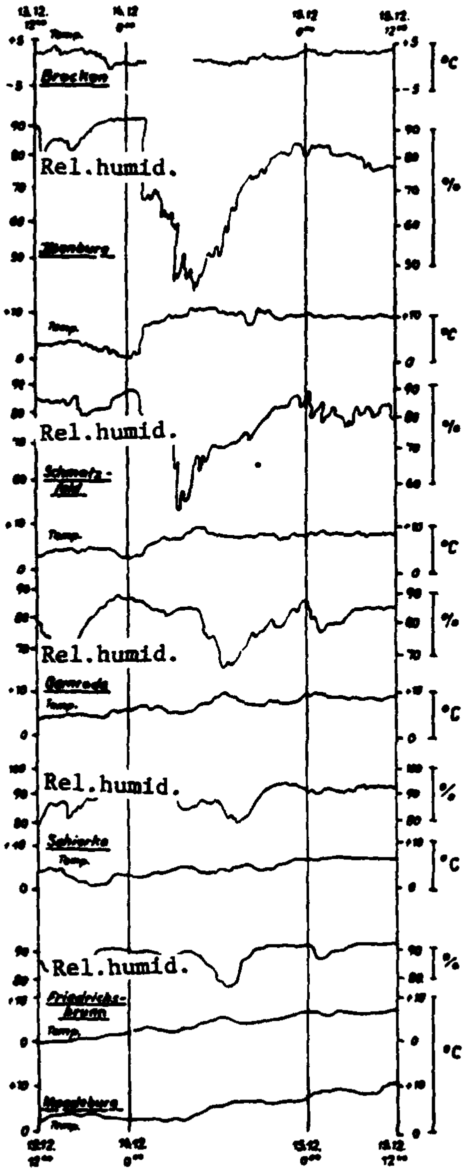

Figure 7. Temperature and humidity records from 1200 h on Dec. 13, 1948 to 1200 h on Dec. 15, 1948.

during the Foehn - which would seem to be in contrast with the description of the preceding weather condition - in this case that is a consequence of the incredible wind velocities. Disregarding the hurricane on top of the Brocken, Wernigerode recorded a wind force of 10 at highest gustiness. It is hence not surprising if the mountain edge gustiness reaches Schmatzfeld and there causes temperature and humidity variations.

It is all the more significant for Gernrode that the Foen current gradually gains the upper hand, there. This process has already started by the time Ilsenburg registers the breach. The course of the relative humidity characterizes particularly clearly the influence of the altitude current: very sudden in the upper Harz, at the lower Harz only very gradually increasing. With this continuous transition Gernrode reflects conditions similar to those occurring for normal wind velocities at Schmatzfeld.

Such contrasting occurrences at the Harz edge near Ilsenburg-Wernigerode and at the lower Harz edge near Gernrode-Suderode, have already been indicated several times in the course of the current elaboration. In the first place, no typical lee eddy formation with horizontal axis was observed in the lower Harz. In the second place, no above-normal gustiness was observed. Thirdly, the cloud picture showed no formations to indicate the development of multiple amplitude lee waves. The lack of lower cloud rollers was further indirect proof of an impediment to eddy formation. Finally, the overall picture given by these observations show the weather course here depicted as a relatively regular transition. Thus, there is no doubt that the ground level cold air layer has a better and stationary outflow possibility at this mountain edge. In conjunction with the laminar flow conditions generated by the NE oriented valleys, a continuous weather transition becomes possible. With this transition, a weather situation is initiated for the lower Harz that can be truly designated as a stationary Foehn stage.

At the observed SW altitude flow, in this case the Foehn effect at the lower Harz is naturally smaller than in Ilsenburg-Wernigerode-Schmatzfeld, as can be derived from the maximum temperatures observed on the 14th. The Foehn effect at the upper and lower Harz, appearing equally strong from the averages in Table 8, are due to the more strongly Foehn-effective W winds in the lower Harz. The establishment of a continuous weather transition in this space, however, during the development of cyclonal Foehn conditions, remains untouched by this.

TABLE 9. Temperature maxima during Foehn breach on 12-14-48.
(The maxima were not reduced to a specific altitude).

Ilsenburg	12.0	Suderode	9.4
Wernigerode	10.1	Gernrode	9.5
Schmatzfeld	11.4	Magdeburg	6.8

At the altitude stations, Schierke once again shows only a weak Foehn effect in the record in Figure 7. At Friedrichsbrunn, there is only a steady temperature increase with increasing SW current.

Hence the uncovering of the differences in Foehn development at the upper and lower Harz edge zones described has the supplementary significance that not in every case the Foehn current must appear in the farther outlying depression, uniformly and lastingly. Even though Gernrode is located immediately at the foot of the mountain chain and in a depression, in general a reaching down of the altitude current can be felt here. The responsibility for this may rest in part with the valleys opening there as a flow channel and in part with the lower altitude of the mountain ridge, compared to the upper Harz. Unfortunately there are no recordings of relevant data for valley openings in the upper Harz; that would make it possible to decide whether the suctioning off of cold ground air layers from the valleys - and the reaching down of the Foehn current facilitated by this - is enough, under strong but regular flow conditions, to create a continuous transition to the Foehn stage; and if not, whether the ridge altitude of the mountains must be considered a further determining factor, in a form such that with increasing ridge altitude, an increased carrying of the Foehn current occurs, over the ground level cold air layer of the mountain edge area into the connected, leeward foreland.

3. Foehn condition of August 21-22, 1948 (Foehn effect during high summer).

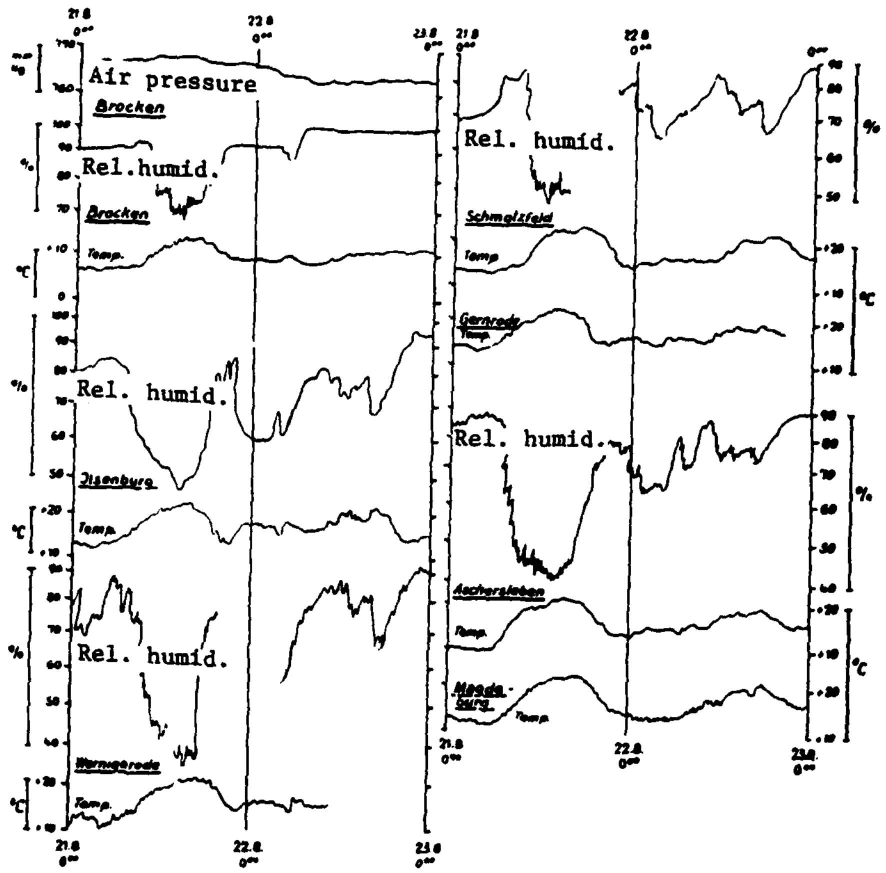

Figure 8. Temperature and humidity records (for Brocken additionally also air pressure record) for August 21 and 22, 1948.

Following the inflow of cold ocean air of moderate latitudes on August 20, by the 21st high pressure had developed over central Europe, with weak winds and general clearing as a consequence. A subsequent Atlantic disturbance brought moderate warm ocean air in on the 22nd, which had to arrive as Foehn current at the NE Harz edge because of the S to SW winds.

The prefrontal precipitation set in on the Brocken near 5 AM on the 22nd, equally so at Wernigerode and 3 hours later in

Magdeburg.The warm front passed the Brocken at 6:50 AM and simultaneously the station is enclosed by the stagnation cloud. The same conditions are reflected on the ground stations, as could be seen from the course of temperature and humidity in winter. According to Figure 8, above, the anticyclonal preliminary stage had already started during the evening of the 21st. This was recorded with particular clarity at Ilsenburg. The recordings at Wernigerode also still react noticeably. At Schmatzfeld, a relatively constant temperature increase begins shortly after midnight. Simultaneously with the processes in the upper Harz edge area, a non-jumping temperature increase starts at Gernrode, and, with some delay, again at Aschersleben. The onset of the Foehn stage itself on the morning of the 26th is expressed more by the course of the humidity during the widespread though reduced precipitation, more by variation than by any sudden, considerable reduction in the humidity. At the Foehn-influenced mountain edge, the recorded precipitation was 0.0 everywhere,at the more distant Quedlinburg 1.2 mm, at Aschersleben 1.7 and on the Brocken, 5.5 mm.

The Foehn effects finds an end already during the night to the 23rd, due to the inflow of cool air masses.

This weather condition was selcted to characterize the Foehn effect during high summer. Let us point out that characteristically, Foehn events occur in the warmer season predominantly on a short-term basis, in the course of a W weather conditions, during the night; and thus, from the poin of view of temperatures, during a winterly daytime.

In the light of these comments, a parallel to Foehn events in the high mountains is immediate. The separation - also adopted for the Harz Foehn - between an anticyclonal preliminary stage and a cyclonal Foehn stage may be disputed, since here the concept "preliminary stage" does not include only a sucking away of the ground-level cold air layer, but also the occasional reaching down of the altitude current, triggered by it. It is this separation, however, that most clearly expresses the fact that up to the development of the Foehn wall itself above the mountain ridge, the sucking away of the leeside cold air is an essential preparation for the definitive and sustained downreaching of the altitude current. Peak stations in the Harz as well as in other high mountains show a particular unrest in the recordings, during the anticyclonal preliminary stage. The noticeable unrest in the records at Ilsenburg during the Foehn stage and especially at Wernigerode is a natural consequence of the manifold eddies at the mountain edge, where structures set across the flow direction predominate. As was already pointed out during the description of wind conditions, the Ilsenburg station is located exactly in the border region between the gusty Harz edge area and the uniform flow zone surrounding the opening area of the Ilse valley. To the restlessness of the recordings at the gusty edge area must be added that not every sucked away air body is replaced by altitude air that has overflown the upper Harz. The upper Harz' block shape provides an opportunity for the air current to flow around higher elevations, such that the Foehn effects do not remain constant. This contribution to gustiness as well as the influence of eddies are not present from the valley opening mentioned above.

During all the descriptions of Foehn phenomena to this point, the question remained open, to a certain extent, as to why the formation of the Foehn wall atop the mountain ridge is the initial point for the stationary Foehn stage. From the weather conditions here presented it has also become apparent that up to the formation of stagnation clouding on the Brocken massif there may occur intensive Foehn gusts (preliminary stage), but that the ground level cold air kept exerting the dominating influence, until and as long as no unobjectionable outflow possibility is provided by the ground configuration, while after the formation of the Foehn wall the downreaching Foehn current predominates over the cold ground level air. This marked change can not be understood in terms of the sucking away of the cold air from the leeside of the mountain edge - as did Billwiller to explain the downpouring Foehn current - and from the corresponding valleys. As has been confirmed by wind velocity data in many instances, the sucking away process is no less effective before Foehn wall formation as after. Hence there is no reason to expect the sucking away process to be significantly reinforced at the moment of Foehn wall formation, thus mandatorily pushing the Foehn current into the stationary stage. We especially point out these processes, because at the steep slopes of the upper Harz the transition from preliminary stage to continued Foehn effect is also clearly recognizable from the recordings. It should thus be convenient to mention here Rossmann's recently developed theory[23], which relates the descent of the Foehn current to the cooling effect of evaporation, an effect that can actuate only when the upper mountain regions are within the stagnating cloud bank. Transferring Rossmann's reason - valid for high altitude mountain conditions - to the central mountain chains, and especially to the exposed Harz location - should be readily permissible. In contrast, in the case of the lower Harz Foehn there is no Foehn wall as a precondition to Rossmann's conception. Consequently, there also is no sudden development of the preliminary stage into a cyclonal Foehn stage. In the lower Harz, the Foehn is caused exclusively by the continuous local outflow of the ground level cold air.

While this theory is also significant for the Harz, it is unlikely that in front of the NE opening valleys in the upper Harz - where a significant reduction in gustiness is also observed - there will ever be such a uniform downreaching of the Foehn current as in Gernrode-Suderode, because at least the formation of a Foehn wall at the upper Harz causes a thrust-like breach of the Foehn. As we have mentioned already, no decision can be reached on this point because there are no records from appropriately positioned stations.

In any event, the Foehn development at the Harz edge states with certainty only that through the formation of a Foehn wall atop the mountain ridge, an additional Foehn effect occurs. Undoubtedly, Rossmann's theory also affords the possibility of representing Foehn development in a logical sequence. No less clear, however, is the picture we obtain if one uses the presuppositions leading to the formation of the Foehn wall, to interpret the processes. One of the presuppositions, however, is - especially following Küttner's reasonong - the accumulation or stagnation of cold air masses on the mountain chain's windward side, while the sucking away process on the leeside has a steadily declining power of the cold ground air as a consequence; in this manner, the level differences at both sides of the mountain chain represent the determining leveling for the altitude current[17]. With continued stagnation, the cold air will eventually achieve its condensation level, thus facilitate the formation of the Foehn wall, overflow the mountain chain and pour down the leeside slopes. This pouring down will be the more severe, the stronger the temperature differences between the stored cold ground air and the air masses brough into contact with it, and the steeper the leeside terrain slopes are.

This representation of the development has the following significance for the Harz: the height of the lower Harz is not sufficient to bring the cold air mass accumulating on the weather side to its condensation point. On the other hand, the earlier the lower Harz will be washed by cold ground level air. The outflow from the leeside slopes occurs in the form of laminar flow, at least at the Harz edge near Suderode-Gernrode, where the ground conformation and the NE opening valleys favor an even outflow. Gradually, here outflow of cold air - which in its effect is similar to the anticyclonal preliminary stage of the Alps - will lead to replacement with warm, altitude current air. In the upper Harz, the stagnation of the cold air on the weather side must be in effect for a longer period, until overflowing onto the massif. Hence the leeside outflow begins later. There it practically begins with the formation of the Foehn wall. As a consequence of the NE upper Harz slope structure and the greater differences in altitude, the down-pouring cold air masses become extensively whirled, a process in which the warmer, upper current also becomes involved. The overflowing of cold air due to weather-side accumulation can thus release an effect similar to that described by Rossmann's theory, since temporarily it coincides with the formation of the Foehn wall and also explains the different forms of appearance of Foehn development in the upper and lower Harz. Even though due to the pouring down of cold air masses there is a reduction in Foehn effect compared to the altitude currents. However, it is probably not significant in view of the strong whirling together with the altitude current.

The decrease in cyclonal Foehn effects during summer shows that there is no fundamental difference between summer and winter effects. Thus, whether a Foehn current manifests itself as a temperature increase at all does not depend in any way on the season, but exclusively on the then prevailing temperature gradient between ground station and mountain ridge. Because of the predominantly high temperature gradients during summer, winds from S-W become Foehn effective only in rare instances, as the temperature increase of only 0.6° compared to twice that value for winter shows in Table 8 above. In contrast, clouding is reduced to the same extent in summer and winter, at Ilsenburg and Suderode-Gernrode. This can be explained in terms of the humid-adiabatic temperature gradients in the cloud air, of approximately 0.5°/100 m, not subject to seasonal variations, since both summerly warming to dry-adiabatic and supra-adiabatic gradients, as well as the cooling in winter to isothermia and inversion-layering is limited to the air layer close to the ground. Thus, at cloud level the Foehn current remains effective to the same extent.

The significance of the previously predominating temperature gradients for the effectiveness of a Foehn current, finally forces the result already emerging from Schneider's Foehn study for the Thuringian Forest, namely that the most clearcut Foehn effects are those observed during the degradation of winterly high pressure conditions. Otherwise, Foehn events at ground level and during summer can become effective only following cold air breaches, when there is not sufficient time to heat the cold air masses, i.e., when a timely very limited in-between high situation is building up. And even then the Foehn effects will appear very noticeably only during the night. This however means:

During summer Foehn effects are limited to periods of cyclonal weather course, to "weather changes", while during winter they are particularly marked during inversion of macroscopic weather conditions (high → low), of "atmospheric conditions" but, in agreement with its nature, also remains in effect at the end of cyclonal periods.

2. The anticyclonal Foehn

The favoring of altitude stations during anticyclonal conditions, especially during winter, is well known[9,10]. Beyond this, it should be assumed that, determined by the orography, also mountain chain edge areas show better conditions during these situations, than depressions farther removed from the mountains, especially as the temperature increases established for cyclonal Foehn are probably insufficient to adequately explain the heat excesses compared to Magdeburg and calculated for the yearly average.

To provide an overview on temperature conditions during high pressure conditions, in the Table below are given average temperatures, reduced to the Ilsenburg altitude, for all high pressure conditions during the year 1948, calculated separately for summer and winter, according to observation periods.

In winter, then, the mountain chain edge areas, in high pressure conditions, are warmer than Magdeburg at all times during the day, and most clearly so during the morning period. The only exception is Gernrode during the evening hours, because of its location in a depression. Even then the temperature excess of the mountain edge finds expression, at least mornings and afternoons, when the reduction by the factor 0.58°/100 m, arguable for high pressure conditions, were not applied. For the result in principle, it should not be decisive whether there was a reduction, or by what factor. The selection of the average gradient used here, calculated by

TABLE 10. Average temperatures during high pressure conditions in 1948, for observation periods I, II and III in summer and winter. The values are reduced to Ilsenburg altitude using the factor 0.58°/100 m

Station	Summer I	Summer II	Summer III	Winter I	Winter II	Winter III
Magdeburg	12,4	21,7	16,5	—2,6	3,9	0,0
Schierke	11,6	21,6	14,0	—0,5	7,9	0,5
Ilsenburg	14,6	21,8	15,4	0,6	6,5	1,7
Wernigerode	14,2	21,8	15,7	—1,0	5,3	1,2
Schmatzfeld	14,0	22,0	15,3	—1,8	5,0	1,1
Friedrichsbrunn	15,7	21,8	15,7	2,2	8,1	2,7
Harzgerode	12,9	22,4	14,7	—1,7	7,3	0,3
Suderode	15,6	22,6	17,0	1,3	5,3	1,9
Gernrode	14,5	21,8	15,4	—1,7	5,6	—0,6
No.of cases	62	62	62	45	45	45

(The Gernrode values, for June to December, are reduced to the entire year on the basis of the Wernigerode and Suderode station).

(commas in the above chart denote decimal points)

Elsner, is of value only because it permits a comparison with the values for temperatures calculated to this point. Suderode is particularly favores because of its slope position, but Ilsenburg also does not remain much behind. Finally, the strongest temperature excesss is achieved in altitude locations, as characterized especially by Friedrichsbrunn. In agreement with site conditions, Schierke and Harzgerode remain behind with relatively large daily variations.

During the Harz edge summer, the temperatures predominate only during the morning observation period; even cooling is, in fact, slightly more marked than in the depression. Only the Suderode slope is, once again, warmer at all times during the day. Schierke remains relatively cool. In general, however, there are no marked differences between depression and the NE Harz space, during the summer.

Thus, the temperature increase calculated for the yearly average in the NE Harz edge area is due, to a large degree, to anticyclonal conditions, especially during the cold season; this means that the influences favoring altitude locations must either be effective in a weakened form in the edge area or, if equally intense, reaching down only occasionally to the lower locations. Hence, an explanation for the increased temperatures during high pressure conditions at the mountain edge must be thought of primarily in terms of an orographically favored sinking of the atmosphere in these regions. We shall see, however, in the weather conditions investigated below, among other things, that the favoring of the edge areas occurs even when a general atmospheric sinking has not even been observed at the altitude stations, yet, not even on the Brocken. In the second place one would expect the favoring of the edge areas at the steep upper Harz slopes to be much more pronounced, due to the larger altitude differences, than at the lower Harz slopes at Gernrode-Suderode. Evidently this is the case only in winter, during the morning and evening observation periods, if one abandons a comparison with the slope station Suderode and opposes only the less favored site conditions of Gernrode to the upper Harz slope stations. The actual cause for the fact that edge areas are also subject to favoring during high pressure conditions would thus have to be seen in the nocturnal slope winds. The objection, that also the slope winds at the steep upper Harz slopes must be more effective that at the smaller altitude differences in the lower Harz can be debilitated by the consideration of the orographic fine structure in both areas.

According to Figure 9, the rise from the Ilsenburg and Wernigerode stations to the Brocken, especially in the mountain range's lower regions, is often interrupted by depressions. A similar picture emerges if one selects a direction other than that of the Brocken (SW) for an altitude contour. The picture corresponds to the traverse structuring of the mountains, with respect to the main SW flow direction, already expressed during the consideration of the wave and eddy formations. The rise from Suderode or Gernrode to the lower Harz peaks is considerably more uniform. This altitude profile, too, corresponds to the orographic structure determining the flow conditions. The development of slope winds is limited, in the upper Harz, by the hill chains in front of it, before the current at the Ilsenburg station or Wernigerode can become effective. Normally, these stations can resort only to the slope winds formed in the first chain of hills of the Harz edge, to the extent that they can reach outlying stations

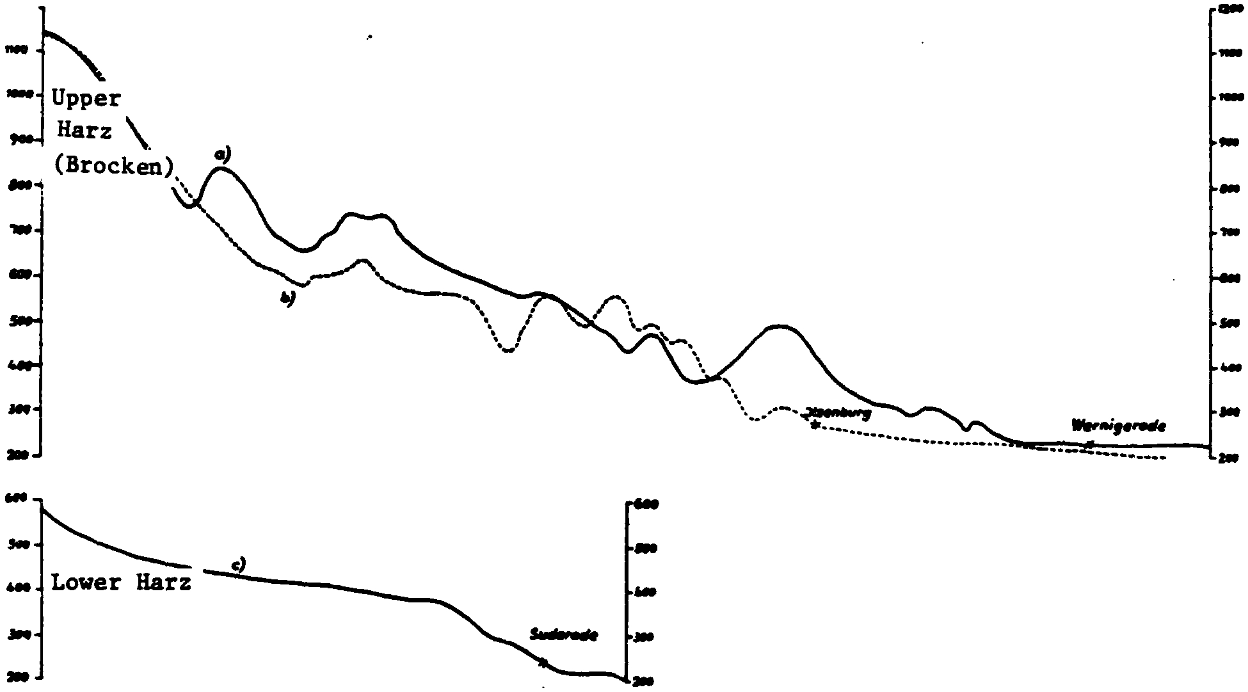

Figure 9. Terrain section (~SW→NE) a) Upper Harz-Wernigerode b) Upper Harz-Ilsenburg c) Lower Harz-Suderode. Scale 1:75,000 increased 5-fold.

at all, such as that at Wernigerode. At the lower Harz slopes the slope wind can develop over the entire available altitude difference and as a consequence its warming effect at that mountain edge will be stronger than in the edge areas of the upper Harz.

In practice, the conditions exert their effect as follows:

At the lower Harz slope, the slope wind manifests itself as an almost laminar flow. The Suderode station is representative of this form of appearance of slope winds. In contrast, the depression at Gernrode is reached predominantly by the cool air bodies brought in by the mountain wind from the valleys opening onto it. At Gernrode, talk is only of the "Cold valley".

In contrast, at the upper Harz slopes there occur only temporary breaches of the slope winds, in the form of very severe gusty thrusts. During clearly marked radiative nights, the downward directed slope currents at the Brocken and the various peaks in front of it involve such a large amount of air, that the valleys and depressions between the heights become filled with it. The initially separate slope wind ranges combine over these air cushions into a large, descending air stream, a process during which cool air bodies in the depressions are carried along, to plunge the more severely into the lowlands. Only after a certain period of time do the depressions become filled again by the outflowing air bodies, so that a renewed breach of the current can occur, towards the lowlands.

These slope wind thrusts area observed once, twice or even three times during the night, at Wernigerode. Gusts of up to storm force occur. The energy of these gusts is derived in part from the energy of the downward directed slope current, with the participation of the overflowing cold air bodies in the depressions, which then does not continue its uniform outflow, but precipitates into the cold ground level air in the depressions; in part it is also due to air body contrasts, between stagnating cold ground air in the lowlands and the precipitating slope air. The whirling together of these two air bodies has as a further consequence that a breach of the entire slope current is not perceived, at the Ilsenburg and Wernigerode station, as just one gusty thrust, but several, rapidly following eddies, the arrival of which is separated by periods of absolute calm.

The process is entirely identical with that described by Küttner for the Riesen mountains, for rotors that are no less developed at the corresponding Harz edge; the only difference is that the cold ground air of the depressions has little power, in the case of slope wind effects during radiative nights, so that the energy of the eddies is rapidly consumed and is not effective up to condensation levels. This anticyclonal peculiarity of the upper Harz slopes is also felt in the same manner as the Foehn thrusts during the preliminary stage of a cyclonal Foehn period. It is also limited to the night hours, so that slope winds must play a causal role in both cases. The additionally effective phenomenon of sucking away of the cold air from the leeside mountain air, occurring during the anticyclonaal preliminary stage, will favor the slope wind current.

Finally, the frequent limitation of the slope wind influence in the upper Harz to individual slope wind thrusts, has as a consequence that following a breach, the temperature drop is all the faster in the adiabatically dried air body. Another observation was also made, corresponding to the anticyclonal preliminary stage: that at the end of the slope wind thrust, there is a brief air flow towards the mountains, by means of which cold ground air from farther outlaying depressions is brought in. The warming up caused by the slope wind thrust can be thereby canceled to such an extent that the same lowest temperatures are achieved as in stations not exposed to any slope wind. The temperature recoding below, from June 9-10, 1948 at Ilsenburg and Gernrode, illustrate these conditions:

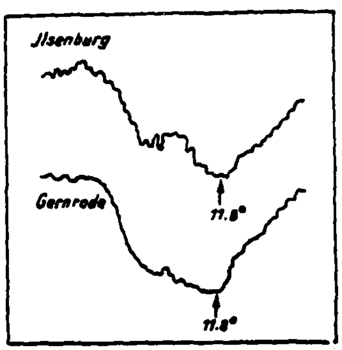

Figure 10. Temperature records of June 9, 1948 at 1200 h to June 10, 1948 at 1200 h

With a cloudless sky and weak, oscillating altitude wind, slope wind thrusts at Ilsenburg in the late evening hours can cause temperature increases of 3°C, while Gernrode is obviously bathed predominantly by the mountain wind current, such that the influence of a slope wind is barely perceptible. The more severe is the temperature drop at Ilsenburg, once the slope current has come to an end. Thus, in the end both stations show the same, minimal night temperatures.

In contrast at the Suderode station, which is constantly under the influence of slope winds, a nocturnal minimum of 15.7° can be measured.

This phenomenon corresponds to the effects described by Anjewsky for the Alps, as they occur at the end of the Foehn stage. Anjewsky compares the "trivial Foehn effect" to the "paradoxal Foehn effect". During the night and at the end of the Foehn current, specially low temperatures are achieved because of increased diathermancy of the air mass, dried out by the Foehn. This case is relatively frequent at the S side of the Alps and the Carpathians, while in the northern Alps the Foehn is usually followed by the passage of a front[24]. The strong temperature decrease in the aftermath of Foehn gusts during the anticyclonal preliminary stage, at the Harz edge, is a phenomenon of the same kind and meaning.

The fundamental difference in the development of slope winds at the NE upper Harz slopes and the NE edge of the lower Harz is not simulated by the location of the stations (Suderode on the slope, Ilsenburg at the foot of the mountains, Wernigerode out into the plain). A slope position similar to that of Suderode in the lower regions of the upper Harz slopes is also subject to gusty slope wind thrusts, determined by the orographical limits of the individual current systems.

Via a detour over the slope winds, it is now justified to talk of a reinforced development of anticyclonal Foehn at the mountains' edge. The development of the process shall be illustrated by means of the weather conditions depicted below.

Weather conditions

1. Winterly high pressure condition of February 24-28, 1948

On February 24, disturbance from the Mediterranean area ceases, while at the same time a high off southern Iceland expands. The high pressure core rapidly is displaced to central Europe, leading to winterly radiation weather. With an altitude current from the SE, the strongest development of atmospheric sinking during this period is observed at the Brocken on the 27th. In the relatively dry continental cold air, fog formation was observed at the ground stations predominantly during the morning hours. There was no opportunity for inversions characterized by precipitation, nor for the formation of other cloud fields.

Conditions in the NE Harz space shall be characterized first by thermograph and hygrograph records (Figure 11, below). The altitude station Schierkeshows a very uniform course of both the temperature and the relative humidity, with large daily variations (high altitude valley). The appearance of mountain and valley winds emerges clearly from the associated weather observations, in that there are NW during the morning and evening observation periods and a SE wind over the noon period. A marked, spontaneous influence due to free sinking processes can not be recognized. Only the general temperature rise from the 26th to the 27th permits the conclusion of atmospheric sinking. The mountain and valley winds also maintain the large diurnal variations, after the sinking processes have caused a general temperature increase. The temperature curve is just displaced more or less severely, in a parallel direction; due to the dryness of the sinking air body, this effect may be even more pronounced. The daily humidity variaitions become correspondingly larger.

In contrast, Ilsenburg shows a considerably milder temperature course. Accompanied by considerable oscillations, a weak temperature increase begins anew already during the evening hours. The nocturnal humidy is always lower than in Schierke. A slope wind breach in

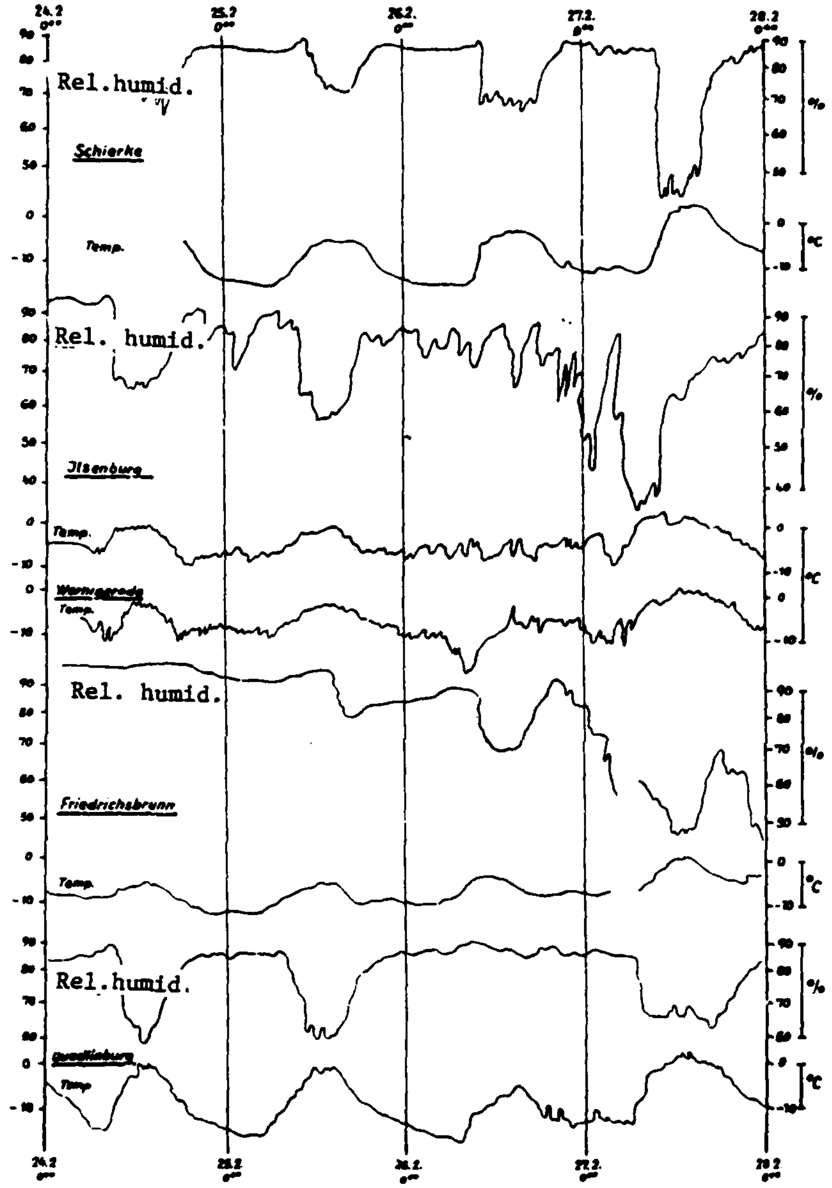

Figure 11. Temperature and humidity records from February 24 to 27, 1948.

conjunction with free Foehn occurred in the night to the 27th, characterized by by a humidity decrease to 45%, Significant is, again, the subsequent, short-term severe temperature drop, until the sinking process becomes completely effective. Wernigerode shows the same "unrest" in the recordings as does Ilsenburg. When on the morning of the 26th the slope wind thrusts were no longer in a position to roll up the cold ground level air all the way down to the depression by the Wernigerode station,a strong temperature drop developed there. The first thrust of the slope wind in combination with free Foehn during the following night was also effective for only a shorter period then at Ilsenburg.

Conditions at Schmatzfeld can not be reproduced by means of recordings. However, that this station remains completely unaffected by the processes charcateristics for Ilsenburg and Wernigerode, even though the terrain falls fairly unobstructedly at least from Ilsenburg to Schmatzfeld, will be shown later. The area of influence of the slope wind thrusts is limited to the lowland closest to the slope.

Friedrichsbrunn shows the picture of a record dominated by atmospheric sinking. The constancy of the temperature during the night of the 25th to the 26th and the very small increase in humidity would have to be considered consequences of the weak sinking process caused by outflow of the slope wind at the Viktor's height massif, while during the night from the 26th to the 27th the general atmospheric sinking took hold. Thus, in comparison with the altitude station Schierke, Friedrichsbrunn is characterized therefore by very limited diurnal variation at the price of the nocturnal temperature drop. Short-period variations are also absent from the course of the records.

Finally, the Quedlinburg E -plant record characterizes conditions in the lowlands close to the mountain chain. Diurnal variations are extraordinarily large. The general sinking during the night to the 27th is still efective here, though. However, a significant temperature increase for the night as a whole is destroyed by the short duration of the Foehn thrusts and the subsequent fast temperature drops. With the relatively steep sloping of the terrain from the lower Harz edge to Quedlinburg, a reaching out of the influence to the

TABLE 11. Air temperatures for 2/24-28/48 at Foehn area stations

(commas in the chart below denote decimal points)

	24. °C	25. °C	26. °C	27. °C	28. °C
	a) Absolute maxima				
Schierke	- 3,1	- 4,6	- 2,3	4,4	9,3
Ilsenburg	- 0,5	- 1,0	- 0,8	4,0	6,2
Wernigerode	- 1,4	- 2,2	- 1,5	1,9	4,4
Schmatzfeld	- 0,1	- 1,1	- 5,1	0,4	4,6
Friedrichsbrunn	- 4,2	- 3,7	- 2,2	2,3	12,4
Suderode	- 2,0	- 1,6	- 4,8	5,9	6,0
Quedlinburg	1,6	0,3	5,7	2,6	7,4
Harzgerode	-			3,2	8,9
	b) Absolute minima				
Schierke	- 11,4	12,5	15,0	13,8	8,2
Ilsenburg	- 8,1	10,2	8,3	9,4	6,8
Wernigerode	10,7	9,4	18,2	10,7	10,1
Schmatzfeld	11,0	13,6	15,2	11,0	10,4
Friedrichsbrunn	11,1	12,1	9,6	7,1	5,6
Suderode	6,8	9,2	10,3	8,1	5,4
Quedlinburg	14,2	15,8	17,4	13,7	11,3
Harzgerode	12,8	16,2	17,1	16,9	10,6
	c) Daily variation				
Schierke	8,3	7,9	12,7	18,2	17,5
Ilsenburg	7,6	9,2	7,5	13,4	13,0
Wernigerode	9,3	7,2	16,7	12,6	14,5
Schmatzfeld	10,9	12,5	10,1	11,1	15,0
Friedrichsbrunn	6,9	8,4	7,4	9,4	18,0
Suderode	4,8	7,6	5,5	14,0	11,4
Quedlinburg	15,8	16,1	11,7	16,3	18,7
Harzgerode				20,1	19,5

city district is possible, especially if slope winds and free Foehn were effective simultaneously. A reaction of the hygrograph to the temperature variations is probably prevented by the formation of dew on the instrument's hair, since at the station fog was observed until the afternoon of the 26th, and subsequently a strong mist.

To include those stations for which there are no graphical recordings - especially Suderode and Schmatzfeld, Table 11 shows the absolute maxima and minima, as well as the daily variations of air temperature calculated from them for the period of 2/24-28/48.

The absolutely highest temperature following free Foehn breach is thus measured at Friedrichsburg, with 12.4°, on the previous day at Suderode, with 5.9°. The absolutely lowest temperature are, quite naturally, at the flatland stations Quedlinburg and Schmatzfeld; Schierke is also not much behind, disregarding local station conditions at at Harzgerode. The Wernigerode minimum on the 26th, of -18.2° is an example of the velocity with which a temperature drop can occur, when slope wind thrusts can reach the station only in the beginning. Especially high are the minima primarily at Suderode, but also at Friedrichsbrunn and Ilsenburg. Thus, the latter station deviates from conditions at the lower Harz only in the severe, aperiodic variations of the meteorological elements, if one may assume, on the basis of elaborations to this point, that Suderode, too, has a temperature and humidity course uninfluenced - or influenced only little - by aperiodic variations. This would mean that slope wind thrusts, perhaps in combination with free Foehn, occur so frequently at Ilsenburg during winterly high pressure conditions, that the ground level air bodies, cooled radiantly, are constantly displaced. The strong development of nocturnal slope winds in winter is particularly understandable in the case of snow covered slopes.

The daily variations of the air temperature characterize the conditions already discernible from the recordings. We shall point out once again, as aprticularly noteworthy, the small variations at Suderode and Friedrichsbrunn.

In closing, let us state here that these processes have nothing to do with an anticyclonal preliminary stage. The altitude current remains constant during this period, on the SE. On the groundstations E to SE winds are observed, or wind calms, so that no sucking away of air masses can occur at the NE mountain edge.

2. Winterly high pressure condition of March 1-6, 1948.

During the last days of February, the supply to central Europe of continental cold air was interrupted, while the high pressure itself remained in that area. In the now stagnating cold continental air, a widespread, dense fog bank formed.

In addition to the favoring of altitude locations, the singling out of such a weather conditions in this presentation shall confirm - as a supplement to the explanations on the previous winterly high pressure conditions - the climatic phenomena at the mountain edge stations, which also deviate considerably from the flat land conditions, as well as the stations in the immediately neighboring flatlands. As a fairly impressive criterion, we can here resort to the number of weather observations, during which fog was observed at the different stations.

In contrast to the flatland conditions represented by Quedlinburg, where only fog appeared during the entire period, Table 12 shows that at the Harz edge itself there was a continuous decrease in fog observations as one came closer to the mountains. But this can only mean that the slope winds have a favoring effect on the reaching down of the atmospheric sinking processes. The temperautures - their citation would be superfluous - are increased both in the average and in the extreme values.

TABLE 12. Number of periods of observation with fog during the period March 1-6, 1948.

Schierke	1	Friedrichsbrunn	2
Ilsenburg	6	Harzgerode	2
Wernigerode	9	Suderode	6
Schmatzfeld	14	Quedlinburg	18

3. Midsummer high pressure condition of July 27 to August 1, 1948

On July 27, a high pressure area rested with the core above the central Baltic sea. During subsequent days, the core moved first to the SE, appearing over Scandinavia on July 30 and over northern central Europe on August 1. In the central German space, the altitude current remains constant at SE. In the subtropical continental warm air thus brought in, temperatures of above 30° were frequently reached.

If it is especially the nocturnal slope wind that must be considered the additional factor of influence that gives the mountain edge stations a particular climatic identity during winterly high pressure conditions, than it is to be expected that summerly high pressure conditions in this area will not be modified to the same extent. During winter, the radiative effect of the snow cover causes a particularly intensive formation of the slope winds. Since the development of slope winds extends over the entire height of the mountain massif, this process will be effective even when the lowland itself is free of snow. The more severely the air bodies close to the ground on the upper, snowcovered slope areas will be precipitated down. During the summer, the additional radiation effect of the snow cover are inoperable. The formation of slope winds will then depend exclusively on the ground configuration. To represent this, we shall present the absolute maxima, the absolute minima and the daily variations of the air temperature during the summerly high pressure conditions.

The highest temperatures, according to Table 13, below, are reached in the outlying flatland (Schmatzfeld, Quedlinburg). The highest daily variations - also observable at these flatland stations - are due primarily to the high maximum temperatures, while during the winter months they are a consequence of low nocturnal minima. Thus high pressure conditions bring extreme climatic conditions to the flatland.

Among the minima, Suderode stands out because of its high values. In contrast, the minima at Ilsenburg and Wernigerode do not deviate significantly from those at the flatlands. The slope wind current at the structured upper Harz massif is not intense enough, without the additional effect of a layer of snow, to surmount the separation of the individual wind systems due to the depressions, and to take to the stations an air body warmed adiabatically over a greater altitude difference. The uniformly rising slope surface near Suderode, in contrast, remains almost uniformly favorable to the formation of slope wind currents, both during summer and winter.

TABLE 13. a) Absolute maxima, b) absolute minima, c) daily variatic .s in the air temperature from 7-27 to 8-1, 1948 at Foehn area stations.

(commas in the chart below denote decimal points)

	27. 7. °C	28. 7. °C	29. 7. °C	30. 7. °C	31. 7. °C	1. 8. °C
			a) absolute Maxima			
Schierke	26,3	26,1	26,4	26,4	27,9	28,5
Ilsenburg	29,6	29,2	29,8	29,9	31,6	32,5
Wernigerode	29,5	29.2	29,2	29,4	31,5	31,3
Schmatzfeld	30,5	31,8	30,9	30,5	32,5	32,6
Friedrichsbrunn	27,4	26,5	26,9	29,9	29,3	29,1
Harzgerode	28,2	27,5	28,2	28,4	30,6	31,4
Suderode	29,6	20,0	29,5	29,9	31,4	31,7
Gernrode	28,7	28,5	29,2	29,4	30,5	30,3
Quedlinburg	30,5	30,2	30,3	30,7	32,7	32,7
			b) absolute Minima			
Schierke	11,1	12,0	10,0	9,5	12,0	10,0
Ilsenburg	17,5	14,4	13,1	12,1	15,4	16,8
Wernigerode	16,1	15,3	13,4	12,1	14,6	16,1
Schmatzfeld	16,0	12,8	14,8	12,5	15,3	16,5
Friedrichsbrunn	17,8	14,5	13,0	10,2	16,5	17,5
Harzgerode	14,0	12,9	11,9	10,4	13,4	14,2
Suderode	17,5	16,4	15,7	15,5	17,9	18,7
Gernrode	14,2	13,3	12,2	11,7	14,2	15,1
Quedlinburg	15,1	14,3	13,1	12,6	15,1	15,3
			c) Tagesschwankung			
Schierke	15,2	14,1	16,1	16,9	15,9	18,5
Ilsenburg	12.1	14,8	16,7	17.8	16,2	15,7
Wernigerode	13,4	13,9	15,8	17.3	16,9	15,2
Schmatzfeld	14,5	19,0	16,1	18,0	17,2	16,1
Friedrichsbrunn	9,6	12.0	13,9	16,7	12,8	11,6
Harzgerode	14,2	14,6	16,3	18,0	17,2	17,2
Suderode	12.7	12,6	13,8	14,4	13,5	13,0
Gernrode	14,5	15,2	17,0	17,7	16,3	15,2
Quedlinburg	15,4	16,0	17,1	18,1	17,6	17,4

The daily variations in the air temperature are significantly reduced at this massif during the entire year.

Furthermore, among the altitude stations we shall point out the extreme conditions at Schierke and the mild conditions at Friedrichsbrunn, which maintain their contrast both in summer and in winter. During high pressure conditions, there is a tendency at Gernrode to represent more a valley than a mountain edge area.

4. Late summer high pressure condition of 9/8-11/48.

Conditions similar to those during the midsummer anticyclonal condition of 27-7 to 8-1, predominated during the period of September 8 to 11. This period of time is adequate to reproduce the

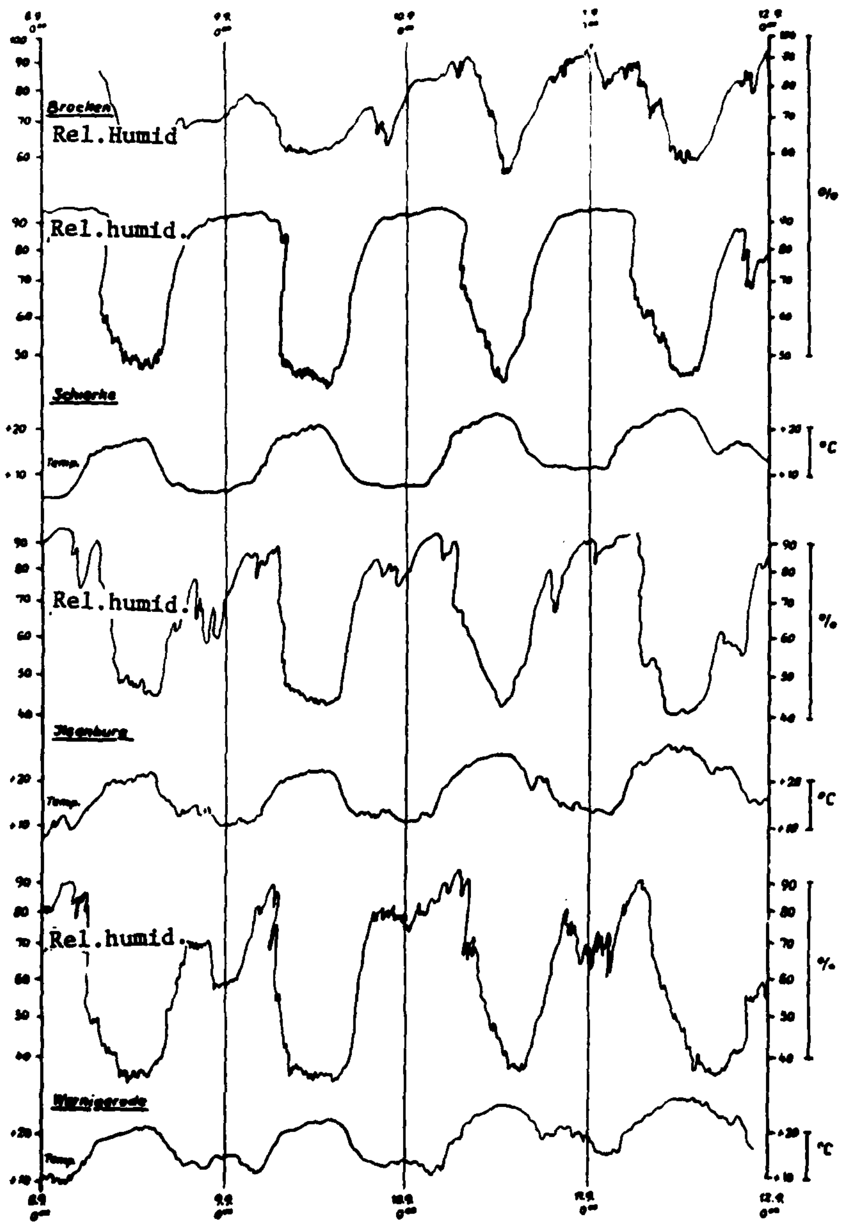

Figure 12. Temperature and humidity records for 9/8-11/48.

corresponding records because there was no break in service at any of the stations (Figure 12, above).

According to the humidity record for the Brocken, sinking processes came through only weakly on the 8th and 9th.Hence, influencing of the edge area itself by the free Foehn was not to be expected. Thus the climatic characteristics of the area must be due only to slope wind effects. Individually, the records confirm the peculiarities to be expected for summerly high pressure conditions, according to explanations offered so far:

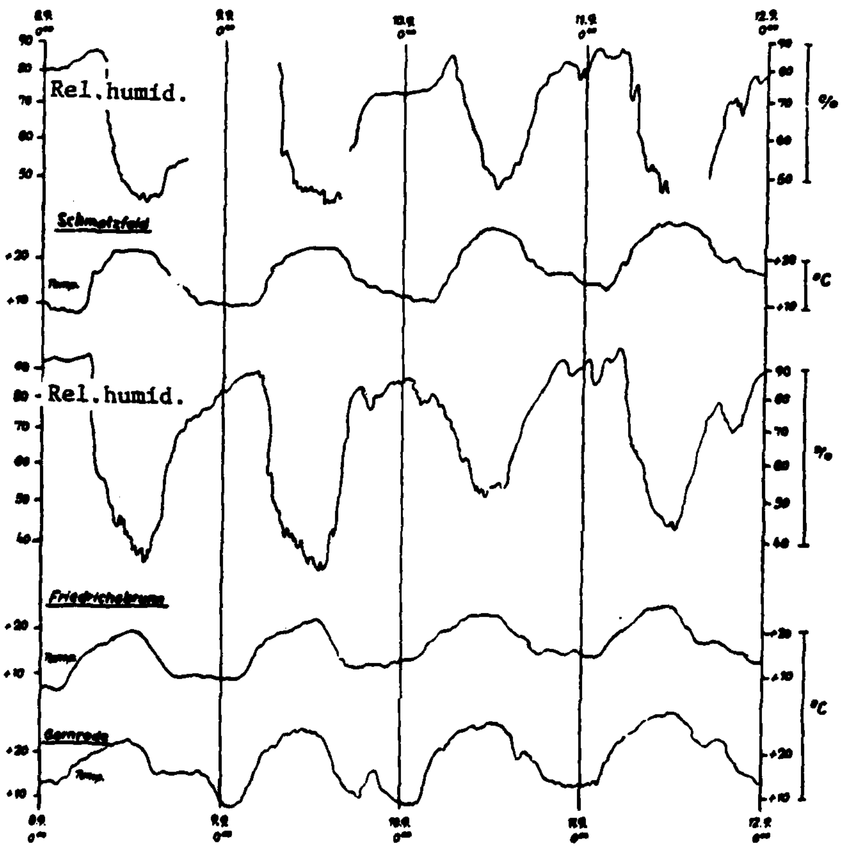

Figure 12 (continued). Temperature and humidity records for 9/8-11/48.

The picture of the record for Schierke is unchanged from winter.

At Ilsenburg, once again we observe the variations characteristic for this station's records. Both the frequency and the intensity of this unrest are smaller, however, than during winter; the number and force of slope wind thrusts is reduced.

At Wernigerode, the unrest in the records is also not as pronounced as in winter. Strong slope wind thrusts, able to reach the station, usually occur only once a night and remain effective for longer periods of time, even though the unrest in slope wind thrusts is considerable because of the whirling described earlier, as can be deduced especially from the humidity records. However, not all aperiodic humidity oscillations can be attributed to slope wind thrusts, at Wernigerode. Rather, because of small variations in the wind direction, sometimes humid ground level air may be brought to the station from nearby ponds, causing temporary unrest in the humidity trace. At Schmatzfeld, the record practically show no aperiodic variations. Slope winds reach that far into the flatland only barely, causing just a hint of a variation on the records.

This period of time is of particular significance for the Gernrode station, because in it are contained all climatic possibilities that can be found there during the night. On September 8, a slope wind currents makes itself felt already in the early evening hours, squelching any further temperature reduction. After midnight, the predominance of the mountain wind current from the Cold Valley is obvious, triggering a rapid temperature drop. During the night to the 10th, the initial cold air flow is so strong, that the Gernrode basin overflows, making further outflow possibilities - especially in the direction of Quedlinburg - possible. Now the slope wind is able to thrust through to the station, briefly. The fact that this is a slope wind effect without significant contribution from a general atmospheric sinking process, is documented by the simultaneous, only weak temperature increase recorded at Friedrichsbrunn. The temperature jump appears very marked at Gernrode only because of the earlier radiative process and the additional, cooling influence of the mountain wind current. The maximum temperature achieved at Gernrode during the slope wind breach corresponds exactly to a vertical temperature decrease of 1°/100 m, to Friedrichsbrunn. The somewhat restless record during the following night suggests that the Gernrode station is at the upper limit of a very flat ground level cold air layer, over which the slope wind passes. The neighboring Suderode station, only 25 m higher, remains totally unaffected by these processes. The nocturnal minima during this period were 7.8, 8.5 and 12.0° at Gernrode, and at Suderode, due to the continuous slope wind current, 10.9, 15.5 and 16.2°.

At Friedrichsbrunn, the constant or only slightly increasing nocturnal temperatures should probably be attributed only to a local sinking process, considering the existing weather condition.

Thus, it was precisely by means of the Gernrode-Suderode pair of stations that considerable climatic differences could be established, which are especially characteristic of anticyclonal conditions in mountain areas. For the differently located altitude stations Schierke and Friedrichsbrunn there result correspondingly extreme contrasts. These modifications of the high pressure weather were determined, in each case, by the orographic conditions of the stations' location. A further modification to which the orographic structure of the entire mountain slope region to the next peak area contributed, resulted from the inclusion of the slope winds as the factor representing the really downward directed air current, or the one making the reaching down of the atmospheric sinking process possible in the first place. The air flow is gusty in structured terrain, laminar in uniformly rising terrain. The intensity of the descending current was significantly increased especially by snow cover, such that during winter the upper Harz edge area also became noticeably affected.

The development of the influencing of mountain edges by descending air currents during high pressure conditions is schematically shown in Figure 13, below. For a station S at the foot of a mountain chain, the layering of the atmosphere above it is represented, for

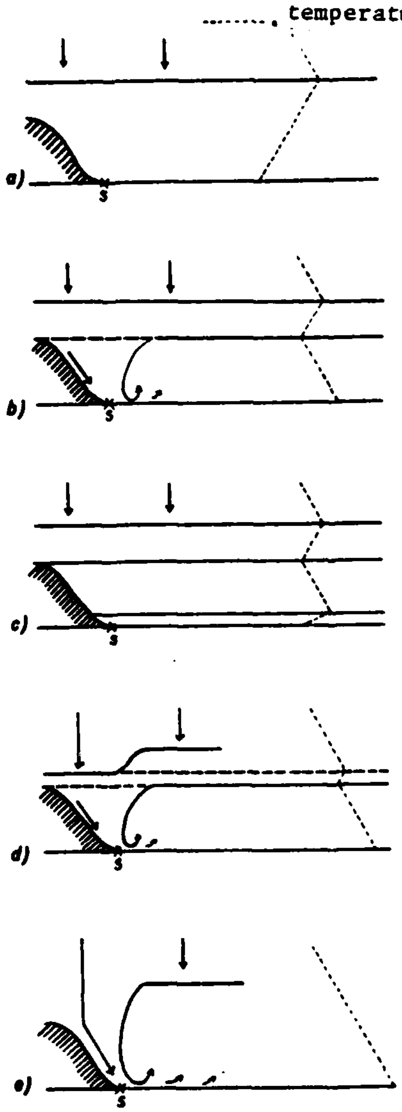

Figure 13. The influence of the mountain edge during anticyclonal weather conditions.

a) Nocturnal cooling of the tropospheric below the sinking inversion, without slope wind influence.

b) Layering of the lower troposphere during slope wind influence.

c) Layering of the lower troposphere following slope wind thrust.

d) Decline of the sinking inversion due to slope wind influence.

e) Combination of slope wind effect and the general atmospheric sinking effect.

the individual development stages, with the aid of temperature-altitude curves. The observation period-bound atmospheric sounding at Wernigerode could not be used to comprehend atmospheric layering at this ground-close a range, because the fine structure in the ground layer's construction would be lost due to the fast ascent velocity.

The tropospheric layer below the sinking inversion opens up -

as shown in the Figure - into a further range of descending air flow. If the terrain rise is structured across the outflowing slope current (as in the case of the upper Harz), several branches result for the descending current, which may combine into a single one if the intensity is high enough. If the sinking inversion itself is sucked down, by this process, to the peak region, then eventually the commonly oriented flow components of the slope wind and the general sinking can combine their effectiveness. A typical case of this kind is shown in the records for the night of the 26th to the 27th of February, 1948. It is thus in only a few cases that the sinking process itself can influence the mountain edge area. And only with a common effect of slope wind and anticyclonal Foehn can the descending current reach farther down into the flatlands (Schmatzfeld, Quedlinburg). In most cases, however, the slope winds only simulate a general sinking. The area of influence is then limited to the immediate mountain edge zone, if no further, favorable terrain slope is available. The slope wind effects can, however, be more strongly effective in the mountain edge area, occasionally, than the similarly felt effects of the general atmospheric sinking of high pressure conditions.

3. Cyclonal and anticyclonal Foehn

So far, the processes occurring during cyclonal and anticyclonal weather conditions have been treated entirely separately. Special care was taken, during the selection of high pressure conditions, to ensure that the general direction of both upper and lower tropospheric layers showed no component, that could cause a sucking away of the air from the NE Harz edge. Finally, let us point out the possibility of anticyclonal Foehn effects and effects of the anticyclonal preliminary stage being effective simulaneously and thus leading to particularly marked Foehn events. The preliminary stage of a cyclonal period already constitutes a transition form of both kinds of Foehn. The essential process, however, is the removal of the cold ground level air layer from the leeside mountain edge. An additional anticyclonal sinking process is mostly precluded due to the altitude air masses already approaching. If now the relatively infrequent case occurs (during the cold season), of an anticyclone (instead of a low pressure area) playing the active role in the sucking away of the cold ground level air from the leeside mountain edge, then two things may occur: in the first place, during cloudless skies strong radiative cooling may occur in the ground and in second place, the slope wind effect, reinforced by the leeside outflow of cold air, may become active; thus the radiative processes favored by the cloudless sky can be opposed by two simultaneous, warming factors. This can cause the severest temperature contrast on the leeside mountain edges, especially where gusty downreaching of the altitude currents is the rule, i.e., at the Ilsenburg and Wernigerode stations, since here a total outflow of the cold ground level air can not take place, according to the facts established so far, and at Gernrode, where the enrichment in cold ground level air is favored by the depression location.

Such a case can be reflected by the weather conditions on December 2 to 3, 1948. The core of the high pressure center dislocated from central Europe to Hungary. In the process, the altitude current changed from W - NW to SW, increasing in force on the Brocken to 11 Beaufort. According to the records in Figure 14, below, the relative humidity at the Brocken remains consistently below 60%, often under 40%. The temperature course shows the unrest typical of anticyclonal sinking. The additional sucking away process of the cold ground level air permits the Foehn even to reach into the altitude valley at Schierken. It is only under these conditions that the sinking process can reach this station. Under influence of the sinking process, Friedrichsbrunn is in an extreme condition, such as it can not be reached in the core region of a high pressure area by itself. The relative humidity remains below 40% day and night.

Incredibly high temperature jumps were recorded in the NE edge area. At Ilsenburg, during the late evening hours of December 2 the temperature rose 12° in the shortest time, in spite of the fact that it had not fallen any more since late afternoon, due to continues, brief Foeh thrusts. At Wernigerode the temperature rose by nearly

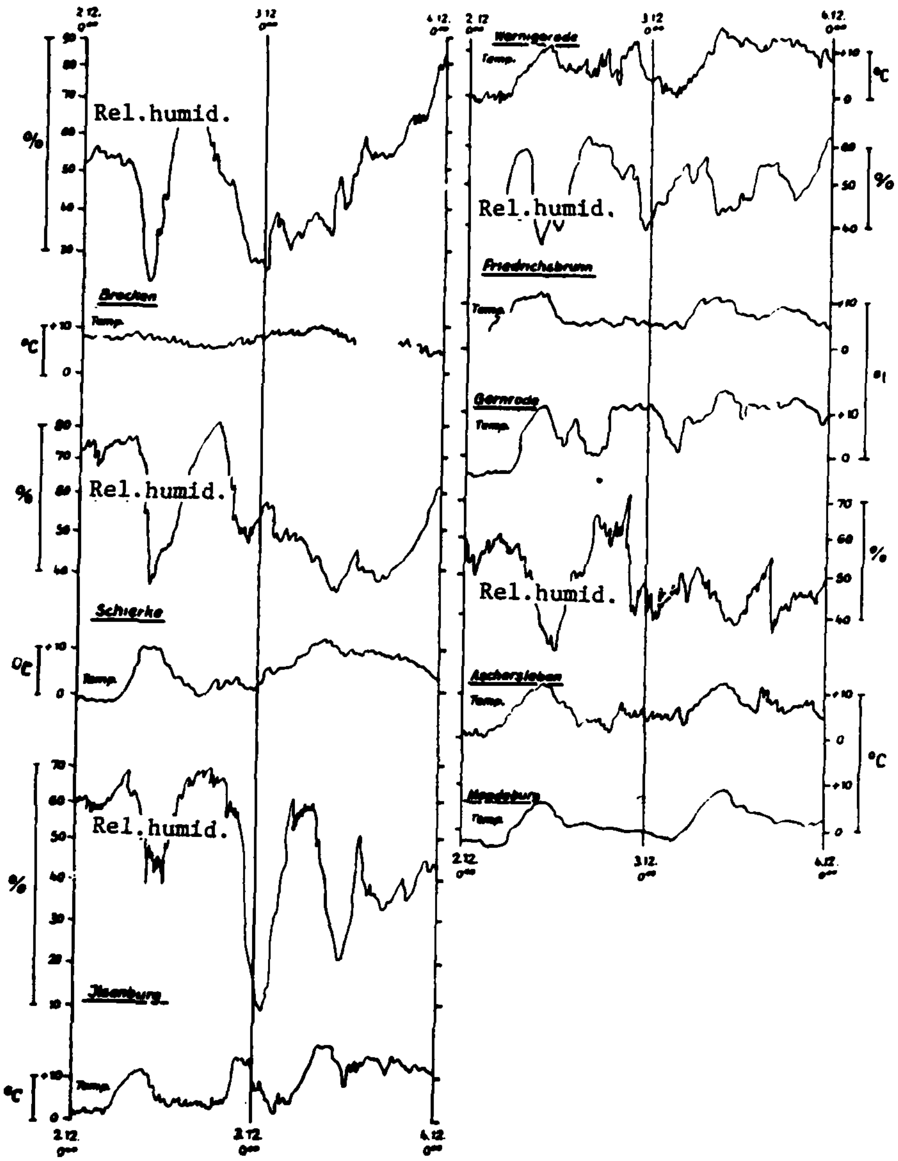

Figure 14. Temperature and humidy record for 12/2-3/48.

11°, with very high gustiness, already prior to the severest Foehn breach. Even at Gernrode the temperature rose almost 12°, since the local depression had previously filled with cold air. As far away as Aschersleben the temperature increase was of nearly 7°, even though the transition was not as sudden as in the edge areas closer in. For comparison purposes, we finally reproduced the temperature curve for Magdeburg, which contains not even a hint of any of these processes except for a general warming, caused by the arrival of maritime air masses in the wake of SW winds. Table 14 below provides an overview of the temperature conditions generated during this Foehn condition.

TABLE 14. Absolute minima and absolute maxima on 12-3-48

Station	Min.	Max.	Station	Min.	Max.
Schierke	—0,5	13,0	Harzgerode	0,4	11,0
Ilsenburg	1,5	17,0	Suderode	6,6	13,8
Wernigerode	—0,1	15,8	Gernrode	1,4	14,8
Schmatzfeld	1,0	13,9	Aschersleben	1,1	12,8
Friedrichsbrunn	2,6	11,4	Magdeburg	—2,5	9,1

(commas denote decimal points)

The lowest temperature of the NE Harz space was recorded at Schierke, since normal altitude valley conditions predominated up to shortly prior to the coupled Foehn effects, while at Friedrichsbrunn the free sinking process had been active already without additional cold air outflow.The Harz edge in general remains frost free. The minimum at Suderode is, again, particularly high. The highest temperature is reached at Ilsenburg with 17.0° compared to Magdeburg's 9.1°. The numerical values are only an indication, however, of the special influence on the Harz edge areas. Climatically more significant is the kind of influence, we can be gleaned only from the records and the simultaneously observed wind conditions.

Thus, the range of effectiveness of the Foehn effects can be encompassed in three steps:

1. Anticyclonal Foehn (slope wind), limited strictly to the immediate mountain edge area.
2. Cyclonal Foehn, showing an approximately continuous decrease with distance from the mountain edge. The effect seems to

fade out at between 10 and 20 km from the mountains. In the depression located in front of the upper Harz and to the NE of it, a somewhat larger area of influence may be expected.

3. Anticyclonal Foehn in combination with cyclonal Foehn effects clearly triggers the most far reaching effects.

The material so far presented is not meant to, and can't, express precisely the corresponding areas of influence. In contrast to the often mentioned rain shadow region (approximate triangle Halberstadt-Magdeburg-Halle), however, an area has been delineated in which the Foehn effects can be captured by temperature and relative humidity records.

4. Stagnation

Compared to the frequency of the Foehn effective weather conditions described, the number of cases with enduring stagnation is very small. On the one hand, this can be seen from the wind distribution (Table 6). On the other, the stagnation-effective wind directions in the NE Harz space - NW to N to SE - are predominantly found in combination with high pressure conditions, so that anticyclonal Foehn effects occur in the mountainous country and the edge area. Disregarding short-lived stagnation episodes, which occur predominantly in the wake of a cyclonal weather course due to backside cold air breaches from a NW direction - and which are presented in the following section as weather intensifying factors - the most characteristic stagnation phenomena occur only when subtropical warm air masses are brought in from the Mediterranean or the Black seas, during Vb conditions. Since these conditions in general are preceded by a cold air breach from the N, the central European space is influenced first in an anticyclonal manner. The cold air rapidly shrinks due to onsetting sinking processes, so that the warm air approaching from a southerly direction can usually overflow the central German space at relatively low altitude. The developing layered cloud picture is then predominantly not a consequence of the actively incoming warm air mass. It rather represents a pure altitude fog, the density and power of which are all the larger, the stronger are the air mass contrasts between the cold ground level air and the altitude warm air. This manner of formation of the layered cloud cover during such Vb conditions also causes the particular uniformity of the cloud picture in the central German space.

This cloud cover achieves its greatest density and force over the central mountains, since here the warm air not only comes into contact with the colder ground air, but frequently with the even more deeply cooled ground itself, which may even be carrying a snow cover, still. The sinking processes orographically favored until the arrival of the warm air, can facilitate an even deeper reaching down of it than over the flatland. Hence in these conditions the mountain country is completely fog covered. In the edge areas there occurs a severe mist with a low, diffuse lower cloud limit. Thus this process is similar to the conditions existing under marked stagnation effects, even though no particularly stagnation effective wind direction is observed. Under particularly stagnation effective winds, the effects are correspondingly reinforced in the corresponding edge areas.

Such Vb conditions, without significant stagnation effects for the NE Harz space during SE current, and with additional stagnation phenomena, are described below. They are underscored especially in contrast to Foehn weather conditions, because for no other weather condition is the uniformity of the weather picture, characteristic of stagnation areas, so clearly marked.

1. Vb condition of February 22-23, 1948

The arrival of cold continental air and radiation led to severe nocturnal frost on February 20th to 21st. Alleviation occurred on the 22nd by reactivation of the disturbance activity from the Mediterranean, by means of which a warm air swell from the western Balkans was directed N, triggering widespread snowfalls. With a very flat ground level pressure distribution, the ground level wind oscillated between S-SE on the 22nd and S-SW on the 23rd, so that stagnation effects could hardly be triggered at the NE Harz edge. Nevertheless, the condensation phenomena in this edge area - and even more so those at higher locations - are considerably enhanced in comparison to the flatlands, in accordance with previous statements. This is clearly expressed by the visibility data in Table 15. In Wernigerode visibility for all observation times on the 22nd and 23rd remains under 4 km. The high stations lie predominantly in fog. In Ascherleben the visibility data are considerably improved, corresponding to those in Magdeburg and Gardelegen. The fact that stagnation effects did not contribute to condensation of the clouds on the NE aharz edge is shown by the precipitation sums of this weather period from Wernigerode, Ilsenburg and Schmatzfeld which do not exceed the sums in the lowlands.

TABLE 15. Visibility for the observation periods of February 22 and 23, 1948 and precipitation sums during this weather period.

Station	Visibility below km						Precipitation sum
	22. 2.			23. 2.			
	I	II	III	I	II	III	(mm)
Magdeburg	10	10	10	10	10	10	7,9
Gardelegen	20	50	10	10	10	20	5,7
Ascheraleben	10	4	4	10	10	10	8,6
Quedlinburg	4	4	4	4	4	4	7,0
Schmatzfeld	—	—	—	—	—	—	6,0
Wernigerode	4	4	2	2	4	4	6,3
Ilsenburg	—	—	—	—	—	—	6,3
Friedrichsbrunn	x	x	1	1	1	1	10,2
Schierke	2	2	1	1	1	1	11,0

2. Vb situation of October 23-29, 1948.

Low pressure over Scandinavia on October 26th brought cold ocean air into central Europe. While high pressure subsequently built to the N, humid, warm air masses from the Mediterranean were pushed over the cold ground level air, leading to widespread, enduring rains. At ground level and even up at the Brocken, E-NE winds are observed, to which special stagnation effectiveness must be attributed in the Harz area under consideration. In contrast to the previous weather condition, this had increased rainfall as a consequence in the NE Harz space. Visibility was considerably reduced even as far away as Quedlinburg.

TABLE 16. Visibility for the observation periods of October 28-29, 1948 and precipitation sums during this weather period.

Station	Visibility below km						Precipitation sum
	28. 10.			29. 10.			
	I	II	III	I	II	III	(mm)
Magdeburg	10	10	10	10	10	10	18,2
Gardelegen	20	20	20	10	20	20	19,4
Aschersleben	10	10	10	4	20	4	28,4
Quedlinburg	2	2	2	1	1	4	22,2
Schmatzfeld	—	—	—	—	—	—	23,7
Wernigerode	10	10	10	2	2	2	31,9
Ilsenburg	2	1	1	1	1	1	28,6
Schierke	1	1	1	1	1	1	53,8

E. THE CLIMATE CHARACTERISTIC OF THE NORTHEASTERN HARZ SPACE

Considerations elaborated to this point recognize the Foehn effective currents of cyclonal and anticyclonal kind as the determining factors to shape the climate of the NE Harz space. However they do not provide a sufficient base - in part even a misleading one - regarding the question of the character of the area's climate. The above average air temperature in the entire Foehn domain, the considerably reduced degree of covering for the area, the partial mitigation of extreme temperatures, all lead one to expect a generally mild, radiation favored climate, characterized by extraordinary air purity due to frequent winds from the SW quadrant, with downward directed flow components. On the other hand we have the gustiness in certain edge areas, with the concomitant restlessness of the remaining meteorological elements.

But principally, the special Harz investigation established that, as a logical consequence of cyclonal Foehn effects - bound to only certain wind directions - many extreme conditions can occur in the course of weather conditions, which seems to strongly contradict the climate mitigation anticipated at first.

Such conditions will appear, in one case, when Foehn effects are triggered by stagnation phenomena. This condition can occur very suddenly, already during the course of termination of a general W weather condition. If a body of warm air follows cold air from the NW, then the warm air, due to Foehn effect by the Harz, will arrive even warmer at the NE edge than at orographically uninfluenced stations. Humidity and precipitation activity are reduced, while due to stagnation effects the cold air can become even more weather effective, as it appeared on its present course. These conditions are documented by Schulz[11] with the magnitude of the temperature decrease during cold air supply at the different stations.

Now the frequency of wind directions that are stagnation effective at the NE Harz edge is relatively small. From the frequency distribution reflected in Table 6, during the course of a W weather condition only 1 in every 4 Foehn effective currents would be followed by a stagnation effective one. Thus, this small number of cases would be hardly sufficient to talk about a significant climate intensification. The interchangeability between snow cover and thawing, as well as between frost and softening at the NE upper Harz edge, is especially known from observations in this regard by Mr. Pörner at the Wernigerode School of Agriculture and is valued as an unfavorable moment for the local agriculture.

The transition from Foehn to stagnation effects, however, is not the only climate intensifying process in the Foehn area. Even when cold air is brought in from a direction that is Foehn effective for the NE HArz edge, in comparison to the previous warm air, an intensification does occur in the course of weather development. The cold air is not subject to the same effects as warm air, when an obstacle rises in its course. It will try first to flow around the obstacle, than flow over such passes as available. Before the entire mountain chain is surpassed, the cold air usually has already flooded the mountain chain leeside. Thus, the breach occurs the less as Foehn, the more possibilities there are for flowing around. The Harz, as a block chain, will especially favor this process during NW winds. In practice, then, an air mass exchange will appear as an intensification in the area, and so considered in most cases.

Beyond this, short, aperiodic weather changes are triggered by intensity variations in the Foehn current itself. The meteorological elements at stations within the Foehn area react also to each change in wind direction within the Foehn effect range and within the same air body, as can be seen from the severe oscillations in temperature and humidity records at Ilsenburg and Wernigerode. The rapid temperature drops at the end of the Foehn or slope wind thrusts - corresponding to Anjewsky's paradoxal Foehn effect - also indicates contrasting conditions within the shortest periods of time. The variations in all temperature and humidity records reproduced here, both during cyclonal and anticyclonal conditions, make it possible to readily recognize that especially in the Harz edge area, structured in opposition to the predominant direction of flow, it is never the weather conditions that play the determining role, but exclusively development processes. Only the rare phenomena combined with Vb conditions can be compared to a "situation", because of the uniformity of the weather course in the NE Harz slope.

The significance of reinforced and additional variations in the weather picture of this mountain edge obviously go beyond temperature and humidity effects. Since the variations are based on all flow peculiarities, there always is an air mass transport connected with it. Thus, within brief periods of time air masses can be brought sequentially over deciduous and coniferous forests, humid meadows, snow fields, agricultural crops and townships, so that not only the variability of the meteorological elements become specifically and complexly effective, but also the respective air masses, as carriers of these magnitudes, over and above the general air mass exchange.

1. <u>Climate characterizations through cold air breaches</u>.

To characterize the climate, first severe cooling episodes - in general, $\geq 5°$ above the daily average - were selected that proceeded rapidly. Here, cooling at the last reached station does not set in significantly later than at the first station reached by the cold air. While the amount of cooling in the flatland is practically the same at every station, in the Foehn area it will depend on the direction from which the cold air breach, as well as the different intensity of the Foehn effect to which the station had been subjected before.

Table 17 below compiles the decrease in daily average temperature during cold air breaches for the individual stations. The cases are arranged according to the previously predominating wind direction and according to that of the cold air. The simultaneous cooling at Magdeburg is presented for comparison purposes.

The coolings mentioned first, which take place while the previous wind directions are maintained, came about in the entire NE Harz space as a nearly uniform temperature decrease. Due to the constancy of wind direction and force before and after the air mass exchange, there was no reason for the cold air to appear with more or less strong temperature descents.

If, in contrast, this cold air supply occurs in calm weather conditions, then the respective Foehn effect at individual stations is expressed during the inflow in the quantity of cooling. The cold air breach from May 26 to 27, from the SW, causes the lowest temperature decrease at Ilsenburg, due to the strongest Foehn at this station with SW winds. But already at Wernigerode, removed just a little from the slope edge, the amount of cooling is significantly larger. To arrive at the Wernigerode station, the cold air has flowed around the upper Harz massif, so that a Foehn no longer takes place. The same is shown in comparison of cooling amounts between Suderode and Quedlinburg. Suderode, as a slope station could be reached by the

TABLE 17. Sinking of daily average temperatures from one day to the next due to cold air breaches at the individual stations within the Foehn area during the year 1948.

(commas in chart below denote decimal points)

Brocken	Schierke	Ilsenburg	Wernigerode	Schmatzfeld	Friedrichsbrunn	Harzgerode	Suderode	Gernrode	Quedlinburg	Aschersleben	Magdeburg
1. Cold air breaches without change in wind direction or force											
a) Cold air from the NE (2/18-19)											
5,2	5,7	5,2	5,1	4,9	5,2	5,2	4,7	—	5,5	5,8	4,9
b) Cold air from the W (6/27-28)											
5,4	5,3	5,6	6,2	6,0	6,3	6,5	5,9	5,8	5,4	5,7	3,3
c) Cold air from the N (11/23-24)											
5,9	5,4	6,0	5,2	5,0	5,5	4,7	6,0	6,0	5,2	5,9	4,5
2. Cold air breaches without change in wind direction, but increasing (26.—27. 5.): wind force from the SW											
5,2	5,0	4,8	6,6	6,2	4,9	5,7	4,9	—	6,2	5,6	6,0
3. Cold air breaches with changes in wind direction.											
a) Cold air from the SW											
1. Following W-NW winds (6/2-3)											
5,0	5,0	3,8	3,9	4,0	3,7	5,1	3,5	3,7	3,9	3,5	5,1
2. Following calm radiation weather (9/11-12)											
7,5	3,1	7,9	7,9	6,1	5,5	4,7	8,1	7,0	5,5	4,5	4,9
b) Cold air from the W											
1. Following SW winds (1/5-6)											
5,7	5,6	7,6	6,0	6,2	5,5	6,3	5,4	—	6,0	6,0	5,6
2. Following N winds (7/6-7)											
3,4	4,4	5,0	3,8	6,0	4,9	4,2	4,8	4,2	5,8	4,3	4,0
c) Cold air from WNW following SW winds (9/28-29)											
5,5	2,7	5,6	4,8	4,8	3,3	2,7	2,4	2,5	2,8	3,0	2,9
d) Cold air from N following WNW wind (10/3-4)											
6,7	6,8	5,2	6,3	5,4	6,4	6,5	5,4	6,0	5,6	6,1	4,6

cold air only as Foehn current, while Quedlinburg could be reached by flow around the massif.

For the cold air breaches with wind direction change, the different cooling amounts at individual stations provide each with a practical example of the orographic Foehn's effectiveness, in that it either appeared prior to the cold air supply and hence makes a cooling seem more significant, or in that the cold air breach itself occurred locally as Foehn current and was thus weakened.

The cold air breach of June 2-3 from the SW, following W-NW winds, brought the largest temperature drops at Schierke, since the station had been under Foehn effect previously. All other stations are reached by the cold air more or less along the Foehn path, so that cooling is less throughout the Harz stations than at Magdeburg. In contrast, the cold air supply from the SW on September 11-12 followed calm, radiative weather that brought high temperatures especially to the Suderode slope, so that cooling was particularly severe at this station. By the same token, the orographically conditioned sinking of air masses at the remaining NE Harz edge (Ilsenburg, Wernigerode) during the good weather period is enhanced by the strong cooling effect.

The cold air supply from the W following SW winds, of January 5-6, caused the strongest cooling in Ilsenburg, since that station had previously been under strong Foehn effects. The smallest cooling effectwas for Suderode, for this breach, since again this station could be reached only following Foehn-like warming of the cold air. Correspondingly, a cold air breach from the W following N winds, on July 6-7, manifested itself by less cooling at Wernigerode and Suderode. Only the Schmatzfeld and Quedlinburg stations, farther removed from the mountains, were obviously reached just by the cold air that flowed around the mountains. Ilsenburg is also already more sensitive to cold air supply from the W, since there the steepest terrain rise occurs in the SW direction. Because of the frequency with which they occur, cold air breaches from WNW or W, following winds from the SW to WSW acquire a special significance. One case of this kind, on September 28-29, brought the severest cooling to the stations on the upper Harz' steep slopes and correspondingly less cooling to Schierke. The protected location of the E, lower Harz slopes with respect to these cold air breaches must be pointed out: its consequences at Suderode and Gernrode are so pronounced that the local cooling is smaller than at Magdeburg.

If even cold air breaches from the N, following NW winds (October 3-4) have a stronger effect in the Foehn area than at Magdeburg, that is due to additional stagnation phenomena in the mountains which during N winds affects all stations in the Harz space, even those at greater distances from the mountain edge, due to the pre-accumulation described by Moese[25] for Silesia. A corresponding case occurred during the Vb weather condition of October 28-29, 1948, when even at Aschersleben a significantly larger amount of precipitation was measured than in the flatlands, and at Quedlinburg the visibility conditions were particularly bad; hence, stagnation phenomena could be identified with certainty at 10-25 km distances from the mountains.

What is descriptive of the climate's character, then, according to these elaborations, is that the strongest cooling is observed predominantly on the steep NE slope of the upper Harz, even during summer. This situation is mitigated only on those rare occasions in which cold air is brought in from the SW, following W to NW winds. In contrast, much weakened cooling occurs on the E Harz slope near Suderode-Gernrode. In general, because of its relatively low altitude and uniformity, the lower Harz is in general overflowed by the cold air, so that it flows out at the E edge area and becomes Foehn effective. In reality this space is particularly sensitive only to the relatively rare cold breaches that follow in the wake of a high pressure period. The formation of anticyclonal sinking processes is particularly favored by this uniformly downsloping terrain, so that a cold air breach is felt as the more weather effective. In comparison to flatland conditions, however, there can be no talk here of an intensified effect of cold air breaches. In contrast, the temperature decrease at Magdeburg does not lag behind the cooling on the steep slope only in those two cases in which the cold air is brought in from the Foehn effective SW direction, and if the Harz stations had not been under Foehn influence immediately before. However, due to the low frequency of their occurrence, these cases are practically meaningless so far as the definition of the climate characteristics for the steep, upper Harz slopes is concerned.

Besides these regional differences in the effectiveness of cold air breaches in the Foehn area, during cold air inflow from

Foehn effective directions a distinction must be observed between the foreland and the mountain edge itself. The former - and especially the NE foreland to the upper Harz - is in general reached by the cold air that flowed around the mountain massif, while the latter is reached more or less strongly by the cold air that has undergone the Foehn process. Thus, in these cases the mountain edge itself will be under less severe weather conditions than the foreland.

The uniformly high cooling observed at the Brocken during these usually high reaching cold air breaches, are based on the strong vertical temperature decreases in the cold air, and - especially during the transition seasons - on the fact that here precipitation still occurs in solid form and the ground itself may still be snow covered, while precipitation in the lower mountain areas arrives predominantly in the form of rain showers.

In any event, Gregor's elaborations "On the favorable spring and fall periods in the Foehn Area" [15] do not apply, naturally, to the Harz Foehn area, since it is completely unprotected against winds from NW to N to SE. Only at the E Harz edge is there no climate intensification, a fact that however is not sufficient, of itself, to speak of a favoring of the Foehn area in Gregor's sense. Due to its exposed position and to the upper Harz' block form, the northern Harz is exposed to atmospheric condition contrasts of such sharpness as must be unique in the central German space. The altitude stations are less adversely influenced. For Schierke, the pre-frontal weather development is more stagnation effective than Foehn effective, while the backside cold air arrives predominantly as Foehn current. Friedrichsbrunn is not subject to cyclonal Foehn effect. On the other hand, northern Harz stagnation phenomena, to Friedrichsbrunn, lose their weather effectiveness.

2. Climate characterization by means of temperature and humidity variations

The temperature and humidity records of the individual stations were used to obtain a survey on the constant unrest of the climate elements in the Foehn area. The causes for the restless course of the recordings need no longer be aduced individually. The sum of the variations and their diurnal distribution, however, give expression to a summarizing climate characterization, the reproduction of which should not be impeded. All temperature variations above 2° occurring between June and September, 1948 and going counter to the normal diurnal course, were included. The minimum of 2°C was established, for variations in the recordings, to permit the most satisfactory evaluation, since the recordr themselves are, in part, rather broad, so that the determination of a smaller minimum variation would only mean an increase in the uncertainty affecting the observation. The oscillation frequency so obtained is, in any event, a sufficiently clear standard to reproduce local differences in the climate characteristics. Correspondingly, all cases were selected in which humidity variations exceeded 10%, going against the normal course. The selection of only 4 months is due mostly to temporary incompletion of the records. Limitation to the summer months is appropriate because during winter additional instrumentation failures can be expected, due to icing. For the four months under consideration, faultless records are available, except for the relative humidity course at Gernrode and the air temperature course at Wernigerode.

The definition "inclusion of variations running counter to the daily course" is not correct for the time period between the time at which the highest temperature is reached (1400 to 1500 hs) until approximately 1700 h. During this afternoon period, during already slowly descending temperatures, a cooling is still perceived as a deviation, for instance by falling rain. Bearing this in mind, Table 18 contains the total of the variations established from the recordings, with the limiting conditions mentioned, as well as the hour of the day during which the variations occurred.

As expected, the highest frequency in variations falls to the

TABLE 18. Number of aperiodical temperature variations $\geq$ 2.0° and humidity variation $\geq$ 10% for individual hourly periods (June-September 1948)

Hour	Temp. variations					Humid.variations				
	Schierke	Ilsen-burg	Wernige-rode	Schmatz-feld	Gern-rode	Schierke	Ilsen-burg	Wernige-rode	Schmatz-feld	Gern-rode
1	5	1	4	—	—	2	3	7	—	—
2	—	2	6	1	1	—	1	3	—	—
3	2	3	3	—	2	2	2	7	—	2
4	1	2	2	—	—	—	3	4	-	1
5	1	—	1	—	—	1	—	3	—	
6	—	—	1	—	—	—	—	1	—	1
7	—	1	1	—	—	—	—	3	—	—
8	1	1	—	—	1	1	2	4	—	1
9	—	4	4	1	1	5	4	8	1	1
10	1	2	1	—	3	3	1	4	—	3
11	1	3	5	—	6	3	3	4	1	4
12	1	8	5	2	4	1	6	8	5	2
13	4	10	7	3	4	6	8	14	4	5
14	3	3	11	1	1	5	2	16	1	5
15	—	2	2	—	—	—	2	6	1	1
16	—	—	1	—	—	—	3	2	—	1
17	1	—	1	—	—	1	1	6	1	—
18	1	2	—	—	—	1	—	3	1	2
19	2	2	—	—	—	1	5	8	—	2
20	1	5	2	—	4	1	9	8	—	5
21	1	9	3	—	6	2	10	5	—	2
22	—	6	5	1	8	1	6	12	2	6
23	1	7	4	—	5	—	4	7	1	2
24	2	5	5	—	2	1	2	8	—	7
Sum	29	78	74	9	48	37	77	151	18	53

Ilsenburg and Wernigerode stations. Thus, the mountain chain edge area stands out as an extraordinarily disturbed area, compared to Schmatzfeld. Only the disproportionately high number of humidity oscillations at Wernigerode must be attributed, to approximately 50%, to local disruptive influence, already mentioned of the ponds close to the station. For the rest the numbers are representative for the disruptive character of this edge zone, structured predominantly against the most frequent flow direction. The disturbances are absent only during early morning and late afternoon hours.

While the location of the Gernrode station is less adequate to represent conditions at the lower Harz, the smaller number of oscillations still documents the reduction in aperiodic disturbances at the uniforme mountain edge, structured in the flow direction. For Friedrichsbrunn, just one month of uninterrupted records was available, and hence no comparative figures could be given. From the elaboration as a whole, however, the especially even course of atmospheric conditions at this station can be observed, and at the Harz space in general (Suderode).

F. FINAL CONSIDERATIONS

Initially, the necessity was established to obtain the respectively representative climatic peculiarities in the first place, be it for general, climatic considerations, or for a goal-directed study of therapeutic climates in the form of a list, including the establishment in time of threshold values, and to obtain a practical evaluation of these conditions; with the multiplicity of the peculiarities here described, this seems to require information so detailed that it is no longer responsive to the practical requirements but represents a confusing compilation of positive and negative arguments. Thus, during the elaboration it became valuable to let it be recognized that there are no "peculiarities" in the atmospheric phenomena that affect just one individual element, but rather, that necessarily all the remaining meteorological quantities become coinvolved, so that a "peculiarity complex" results that is characteristic - depending on the weather conditions - for a certain mountain area, mountain edge or for the depression located in front of the mountains. In the second place, the point kept coming up that the often very different climatic occurrences within the Foehn area do not occur haphazardly, but in an unequivocal dependence of the terrain's orographic structure. First, the different flow and cloud conditions were explained as a consequence of a uniformly structured downsloping terrain, set across the direction of flow. The structure of the temperature and humidity course fit into the same causal frame. Correspondingly, the anticyclonal Foehn effects reacted at times gustily, at times uniformly. The sum of all phenomena could be expressed as a particularly extreme atmospheric course at the transversely oriented mountain edge, and a mild atmospheric character for the evenly sloped terrain structure parallel to the flow direction. Since in the end the location of the stations used could be considered predominantly representative and the values were fully representative for all stations during cyclonal cases, the relationships derived should be considered valid also for edge areas that so far had not been encompassed by measurements.

If on the one side the therapeutic-climatic indications are constantly being improved and require more precise definition, for certain groups of diseases, on the other side it becomes ever more desirable to derive for each case, the most favorable climatic conditions from among the multiplicity of existing conditions. And this probably is the more readily possible, the better the modifications of the climate due to orography are known. With the aid of the local climate (valley, slope, peak and forest locations) it will then be possible to suppress undesirable irritants and to retain or enhance the necessary ones, thus making the finest climatic shadings available. Nature makes possible all variations. The identification of the relationship between orography and climatic peculiarities in this paper is meant to be a means to finding the particular combinations for each case.

SUMMARY

In this paper, the north-eastern Harz edge is treated as the Harz Foehn area; in it, the preponderant percentage of winds must reach that area as a Foehnlike influenced body of currents, due to the Harz mountains located to the front of it to the S, SW and W. The consequences of this are that in comparison with normal flatland conditions, increased air temperatures, reduced air humidity, better visibility, reduced degree of covering, but also increased

wind force with greater gustiness must be expected. Except for the wind gustiness, these Foehn effects can already be sufficiently proven by the averages of the meteorological elements. Especially in the wind structure and that of the cloud picture as well as covering in general, there are, however, considerable differences within the Foehn area, making it impossible to postulate a single, uniform mechanism as a trigger of Foehn effects. Including the respective geological structures of the mountain slopes as the only possibility for explaining the locally differentiated Foehn effects, led to the following results:

1. In front of the mountain edges structured transversely to the Foehn current, lee eddies with horizontal axes are formed, causing particularly severe wind gustiness in this area; other consequences in connection with these eddies are the formation of cloud rollers while the upper cloud field adopts the structure of a usually doubly swinging wave, the peaks of which are above the cloud rollers or rotors. These phenomena are identical with those describerd by Küttner as lee waves and lee eddies for the Riesen mountains. Except that usually no total clearing occurs - due to the reduced altitude and extension along the wave direction, in the Harz - but rather just a somewhat less dense cloud strip, so that overall the degree of covering is not reduced.

2. In front of the valleys oriented along the direction of the Foehn current, lee eddies with vertical axes are formed, as could already be established during the special Harz investigation during spring of 1936 for Ilsenburg. In these eddies, winds are merely reinforced, without significant gust formation. In the rising current at the eddy's center and due to the overwhelming participation of air bodies that have undergone the Foehn process, occur condensation phenomena only at the moderately high cloud level, and this in the form of Moazagotl towers, built spirally in the sense of rotation at the center of the eddy. Since these eddies are much less marked in the easterly lower Harz - due to the smaller differences in altitude - there are no condensation

phenomena in that area (Gernrode-Suderode). In combination with this kind of eddy there are usually relatively extensive areas of cloudless or cloud-poor sky, in general attributed to the fact that eddy development occurs close to the ground - due to air mass contrasts between the Foehn current sucked down into the valley and the remaining cold, ground level air in the depression in front of it - and that the suctioning force of this eddy close to the ground generates an additional descending air current. Phenomena of similar meaning were determined in the interruption of the cloud rollers over the remaining valleys, structured along the flow direction.

The course of a Foehn weather condition follows these flow peculiarities in the sense that in the gusty, horizontally turbulent area by the upper Harz slopes the Foehn current breaks through in thrusts, correspondingly causing considerable oscillations in the temperature and humidy records; within the range of uniform flow at lower Harz slopes near Gernrode-Suderode, it replaces the previous atmospheric conditions in a continuous manner.

A seasonal dependence of the Foehn effects seems a function only of the gradients between depression and mountain ridge. With the predominantly dry, adiabatic temperature gradients during summer, it is impossible for Foehn currents to become effective. Hence during the warm season Foehn effects are limited to the night hours, following cold air breaches in the wane of cyclonal weather weather courses. By the same token, they become particularly effective during winter, after high pressure periods with strong inversion layering at ground-near level. Because of the constant humid-adiabatic gradients in the cloud air, the degree of covering in the corresponding edge areas is equally reduced in summer and winter, while the formation of waves and rotors in the cloud field - in agreement with Küttners views - is limited mainly to the cold season.

During anticyclonal conditions, beyond the favoring of the altitude locations the edge areas of the mountains are also considerably influenced, but in general not by means of the anticyclonal sinking process itself: instead, they are influenced by the nocturnal down-slope winds, which especially during the period of snowcover on the slopes achieve sufficient intensity to displace the cold air at ground level in the depression by the mountain edge. This air stream flowing down the slopes is instrumental in sucking down the inversion conditions over the mountains (orographically favored sinking), so that finally the downward directed flow of the slope winds and of the free Foehn can combine to form a particularly warming sinking motion. The kind of influence of the slope wind is also attributable to the orographic structure of the terrain. As a consequence of the already mentioned transversal structuring of the upper Harz slopes, at the local edge stations there are observed only slope wind thrusts in severe gusts, once the depressions separating the different slope wind systems have filled with cold air and the different flow ranges combine above such air cushions into a single stream. At the end of such slope wind thrusts the irradiation from the dried air mass can be all the more effective, so that a temperature drop can occur leading to lower temperature minima than in areas not subject to such slope wind influences. In contrast, the slope wind on the more uniformly rising terrain of the lower Harz is a laminar current. Hence in this case it causes a calm, nearly constant nocturnal temperature course.

The Foehn effective weather conditions are faced only occasionally with periods of enduring stagnation occurrences. Only Vb conditions can render the weather picture at the NE Harz monotonous, in that with E winds stagnation effects can be combined with it, on the one hand, while on the other the especially humid, warm Mediterranean air in the mountains often comes into contact with the cold ground itself, during the cold season, so that an exceedingly dense fog and cloud field develops. Much more significant, however, for the climate character of the NE Harz space, are the changing phenomena that occur in the course of the development of a weather condition. While the arrival of warm air on the frontal side of a low pressure area is predominantly associated with Foehn effects, the backside cold air is subject to entirely different flow laws, because of its density and lability. It flows around the mountain massif. This process is favored by the Harz' block form. Labilization is enhanced within the stagnation domain. In any case, a climate sharpening is connected with this change from warm to cold air, especially where the forms has been subjected to the most intensive Foehn effects, i.e., predominantly at the upper Harz slopes near Ilsenburg and Wernigerode. At the E lower Harz slopes, the uniform rise in the terrain's slope once again favors a less extreme form of air mass exchange, since the relatively low altitude of the lower Harz is easily overflowed by the cold air, so that it can flow out down the E slopes as adiabatically warmed slope wind.

The study of the NE Harz space in this form was designed especially to be able to furnish fundamental climatic parameters for bioclimatic investigations and therapeutic climate representations in an area sought basically for recovery and therapeutic purposes. Since the different climatic peculiarities could in all cases within the Foehn area be tied to the corresponding orographic terrain structure, and since the location of the stations used could be considered representative in the majority of cases, a bioclimatic evaluation of these results results is not limited to the narrower station domain, but can be extended also to edge areas not encompassed by station measurements, following the orographic points of view here explained. If local climate peculiarities are owed to orographic parameters of ground structure and ground cover, than climatic separations should become possible to any degree desired.

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