TROLL, C.: Die dreidimensionale Landschaftsgliederung der Erde. H. von WISSMANN-Festschrift. Tübingen, Geographisches Institut der Universität, 1962.
WALTER, H.: Die ökologischen Verhältnisse in der Namib-Nebelwüste (Südwestafrika). Jahrb. f. Wiss. Botanik, Bd. 84, 1936.
WALTER, H.: Die Vegetation Osteuropas. 2. Aufl. Berlin 1943.
VON WISSMANN, H.: Die Klima- und Vegetationsgebiete Eurasiens. Zeitsch. Ges. f. Erdkunde zu Berlin, 1939.
VON WISSMANN, H.: Pflanzenklimatische Grenzen der warmen Tropen. Erdkunde, Bd. 2, 1948.

SOME LOCAL CHARACTERISTICS OF THE WINDS AS REVEALED BY WIND-SHAPED TREES IN THE RHÔNE VALLEY IN SWITZERLAND

MASATOSHI M. YOSHINO

With 4 figures, 1 table and 5 photographs

Zusammenfassung: Die durch die windgeformten Bäume angezeigten Verhältnisse des Lokalwindes im Rhônetal, Kanton Wallis (Schweiz).

Der Talaufwind im Rhônetal ist wohl einer der kräftigsten im gesamten Alpengebiet. In den Windbeobachtungen der meteorologischen Station in Sierre, die den stündlichen Gang der Windgeschwindigkeit anzeigen (Fig. 1), prägt sich der Talwind scharf aus. Seinen Höhepunkt erreicht der Talaufwind in den späten Nachmittagsstunden des Sommers, wenn er gegen 16 Uhr mittlere Geschwindigkeiten von 5 m/s erreicht.

Die lokalen Unterschiede dieser Talaufwinde wurden im Rhônetal auf der Strecke zwischen dem Ufer des Genfer Sees und dem Grimsel- bzw. Furka-Paß vom lokalklimatischen Standpunkt aus mit Hilfe der Winddeformation an Bäumen untersucht. Dies waren meist Süßkirschen *(Prunus avium)*, stellenweise auch Kiefern *(Pinus silvestris)*, Pappeln *(Populus alba, P. nigra var. italica)*, Lärchen *(Larix decidua)* und Fichten *(Picea excelsa)*.

In Figur 3 werden die Windrichtungen an der Neigungsrichtung der Bäume abgelesen und die Deformationsgrade wie auf einer Wetterkarte dargestellt (Legende: Fig 2). Bemerkenswerte Besonderheiten sind folgende: 1. Der Talaufwind ist am stärksten am Rhôneknie bei Martigny und er reicht bis Mörel-Deisch. 2. Vom Seeufer bis Martigny weht der Talaufwind von NNW-N. Dort dreht er allmählich über W nach SW, weht nördlich an Martigny vorbei und folgt dann wieder dem Tal. 3. Südwestlich und südlich von Fully findet sich ein Kalmengebiet, das vom Windschatten des NW-Talaufwindes gebildet wird. 4. Von Mörel-Deisch bis Reckingen-Münster ist der Wind sehr schwach, aber oberhalb von Obergesteln tritt dann ein umgekehrter, NE-Wind auf. Dieser nördliche Wind ist eine über den Grimselpaß hereinwehende Luftströmung.

In der vertikalen Verteilung auf den Hängen (Fig. 4) kann man sechs Lokalwindgebiete feststellen: Region I: Die Komponente des Talaufwindes ist sehr stark (I_1) oder stark (I_2). Region II: Die Komponente des Talaufwindes ist deutlich, aber schwächer als in Region I_2. Region III: Die Komponente des Talaufwindes ist vergleichbar der Komponente des Hangaufwindes. Beide sind verhältnismäßig schwach. Region IV: Die Komponente des Hangaufwindes ist deutlich. Region V: Es herrscht Windstille. Region VI: Der nördliche Wind ist stark (VI_1) oder feststellbar (VI_2).

Zuletzt werden die vertikale und horizontale Grenze dieser Gebiete (Regions) im Vergleich zu anderen Tälern oder in bezug auf andere lokalklimatische Erscheinungen im Rhônetal diskutiert.

I. Introduction

In the Rhône valley in Switzerland marked valley winds blow which are called locally "Walliser Talwind" or "la bise" (Bise). They occur quite regularly and blow strongly in daylight hours, especially in the afternoon, except in cases of anomalous weather and in December and January. This phenomenon is so clearly discernible that many studies have been devoted to its elucidation since the second half of the 18th Century. According to R. BILLWILLER jun. (1914), Albrecht VON HALLER had described the valley winds in this region, their diurnal change and direction along the valley, by compiling his own observations during his stay in the years 1758—64 at Roche, 5 km S.E. of the mouth of the Rhône on the shores of Lake Léman. A. MORLOT wrote a more detailed treatise on the winds along the valley in the Bulletin de la Société Vaudoise Scientia Natura 1856/57. The comprehensive description was then given by A. PUENZIEUX (1897) in his study on the afforestation of this region. CONRAD (1936) mentioned the Valais valley winds and considered the small amount of cloudiness in this region as a possible cause of them. NÄGELI (1943) also described the characteristics of these valley winds in his study on wind breaks in the lowest part of the Rhône valley.

FRÜH (1902) was the first to write about the local wind conditions in Switzerland in relation to the plant life. An approach to the meteorological explanation of the causes of this valley wind was attempted by BILLWILLER (1914, 1915), who employed observations of the barometric change and other meteorological elements at several points in the valley. The wind-shaped trees are also treated in the monograph on the vegetation in Valais by GAMS (1927). BROCKMANN-JEROSCH (1929) described the valley winds and their effects upon the plants in detail in his monograph on the vegetation of Switzerland. FRÜH (1930) has also summarized the wind conditions in Valais.

In these studies it has been pointed out that the effects of the winds are most conspicuous on the form of trees: fruit-trees such as cherry, pear and certain types of apple, poplar, common pine, larch and other trees. By means of observations on these wind-shaped trees, FRÜH (1902) suggested a distribution of prevailing wind directions in the Rhône and other valleys in Switzerland.

After the War, BOUËT published studies on some climatic elements in the Rhône valley. He recently described the wind conditions by using the observed materials collected at the meteorological station at Sierre and Montana (BOUËT, 1961). Over a number of decades there have been many theoretical explanations for these valley winds. A critical summary of these studies, together with the description of the general features of the valley winds, was presented by DEFANT (1951).

The vertical structure of the valley winds was observed in the Inn valley, Tyrol, by EKHART (1931). Recently, the more detailed structures of any given valley were clarified through instrumental observations for long periods in Vermont, U.S.A. (DAVIDSON, RAO 1958), in Mount Rainier National Park, U.S.A. (THYER, BUETTNER 1962), in south-eastern Norway (STERTEN 1961) and in Azau, U.S.S.R. (VORONTZOV, SCHELKOVNIKOV 1956). Their results provide good sources for the discussion of the valley wind structure in the Rhône valley as mentioned below.

Considering the results of these studies, an attempt was made to make clear the local characteristics of the up valley winds [1] in the Rhône valley from the shore line of Lake Léman to the upper-most course of the valley near the Grimsel-Pass and Furka-Pass. The main problems in the present study are:

(1) At which point throughout the length of the valley are the up-valley winds the strongest?

(2) Do they bear any relation to micro- or local topography of the valley?

(3) How do the winds blow in the section around Martigny, where the valley turns through a right angle?

(4) To what point do the up-valley winds extend along the valley and what is the influence of the upper winds on the wind conditions in the upper course of the river?

(5) How strong and how deflected are the winds on the valley slopes as compared with those in the valley bottom?

The observations were carried out by using the wind-shaped trees as indicators of local climatic wind conditions. As KNOCH (1963) has dealt quite recently with the importance of such a method in surveying local climate, the present problems were elucidated satisfactorily by means of this method. In this paper the results of the observations are given firstly and secondly the local differences and the extent of the valley winds are discussed in comparison with those in other valleys.

II. Sketch of the topography and the wind conditions of this region

The region studied is located in Valais, in south-western Switzerland. The valley begins on the western side of the Furka-Pass (2431 m). To the north of Gletsch (1762 m), the highest settlement in the valley, is the Grimsel-Pass (2164 m). In its upper course the valley runs approximately to the south-west as far as Visp, then to the west as far as Leuk and to the west-south-west as far as Martigny. Here the valley turns at about right angles; i. e. it runs to the N.N.W., finally opening out into Lake Léman. In this paper I describe the valley according to the following divisions: the upper course of the river is the part as far as Brig, the middle course that from Brig to Martigny, and the lower course that from Martigny to the shore of Lake Léman.

The valley is narrow in the upper course as far as Morel. It grows wider from Brig to the east of Leuk: the width of the flat valley bottom is somewhat conmplicated because of the large fan called Leukergrund and Pfinwald, and the numerous moraines. In this part of the valley, the inclination of the valley bottom on the longitudinal profile is relatively sharp as shown in Fig. 4. The width of the valley bottom from Sierre to Martigny is 1.5—3.0 km; in the lower course of the river, it becomes narrower again from Martigny to St. Maurice with the width of 1.0—1.5 km. At St. Maurice the valley is very narrow as if it were almost blocked. This topographically abnormal situation is also found as a knick point in the longitudinal profile of the valley as shown in Fig. 4. The lower course from St. Maurice to the lake shore was a wider valley bottom varying between 3.0 and 6.0 km. The heights of the surrounding mountain-tops are 3000—4500 m. and the valley bottom rises from 380 m. at the lake shore to 480 m. at Martigny, 670 m. at Brig and thereafter very rapidly.

The wind conditions may be climatically outlined as follows: of greatest importance are, of course, the "up-valley winds". They develop strongly in fine weather conditions. Using the values given by BOUËT (1961), the change of the wind velocity on clear days at Sierre is illustrated as shown in Fig. 1. This Figure demonstrates (1) that the up-valley winds are found distinctly from February to November and (2), the maximum

[1] In the present paper, I use the terms "up-valley winds" and "valley winds" in their strict meaning. In this region, the "up-valley winds" include the "valley winds", which are produced thermally, and the general "north-west winds", which are modified topographically. Another term "up-slope winds" means cross-currents moving up the side slope of the valley.

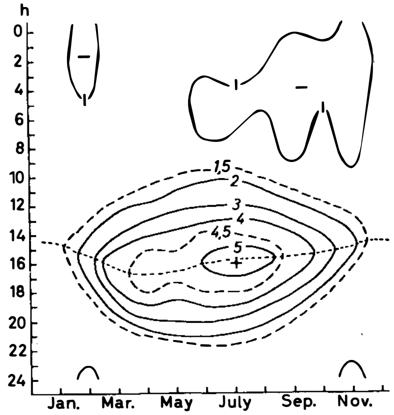


Fig. 1:
Wind velocity (m/s) of "bise" at Sierre in clear day.

wind velocity in the afternoon of over 4 m/s—as a monthly mean—is observed from March to September, while even stronger ones of over 5 m/s prevail in summer from June to August and that (3) whereas the maximum wind velocity occurs between 4 and 5 p.m. in March, April and May, it occurs between 3 and 4 p.m. from June to October.

The peak gust observed in the time of up-valley winds was 10—11 m/s from March to September. Mean or absolute maximum wind velocities are 1/2—1/4 smaller in the case of up-valley winds than in that of the Föhn. However, the frequency of the former is much greater than that of the latter.

The occurrence of the valley winds in the morning, the maximum wind velocity in the afternoon and the cessation of the valley winds are seen at first on the lower course of the river. They gradually shift to the upper course. According to Nägeli (1943), this time lag was clearly observed on September the 11th, 1942, between Roche and Martigny; i. e. the maximum wind velocity (30 minute mean) with 4.4 m/s between 2 and 2.30 p.m. at Roche and that with 6.3 m/s between 3.30 and 4 p.m. at Martigny. Climatological data about these phenomena along the middle course of the river are lacking. As a first approach, however, we can compare the diurnal changes of the wind velocity in September 1942 and in May 1943 observed at Roche (Nägeli 1943), which are average values of one year, with those at Sierre shown in Fig. 1, which are the average values of six years. From this comparison the following facts emerge: the onset in the morning and the maximum in the afternoon are 2 hours later and the decrease of wind velocity after the maximum in the late afternoon is 3 hours or more later at Sierre than at Roche.

The frequency of the wind directions at Sion, Montana, Reckingen and St. Gotthard are given in Table 1 (see p. 32). The values in this Table were obtained from the records summarized by the Swiss Meteorological Central Bureau in Zürich. As given in this Table, the frequency of the S. W. as well as the W. winds at Sion (549 m.) — the up-valley winds — is much greater than that of the N.E. or E. winds including Föhn winds, except in January. The frequency of the wind directions at Montana (1453 m.) on the upper part of the valley slope shows that the wind conditions differ greatly from those in the valley bottom: the E. winds prevail here throughout the seasons, although the W. winds also appear more frequently from April to August. Winds in the valley bottom along the upper course of the river are very weak on the whole: this was observed at Reckingen (1332 m.) by the great frequency of calms throughout the seasons. It is noticeable, however, that the N.W. winds are conspicuous at this station. The mountain station at St. Gotthard experiences a remarkable prevalence of north winds.

III. Method of observation

In the present study, the distribution of the wind-shaped trees is observed as an indicator of local climatic wind conditions. According to the results of the preceding studies, the wind-shaped trees are classified into the following four types (Yoshino 1963):

Type (1): Those whose trunk is vertical but whose branches are bent drastically to the leeward of the tree by prevailing winds during their growing period. The conifers and some species of poplar seem to display this type of deformation.

Type (2): Those whose trunk is vertical, but whose branches are severed by the effects of strong winter winds carrying snow and frozen rain. They are found mostly in the snowy, windy mountainous regions of the temperate zone. As far as the examples reported up to the present are concerned, they are conifers.

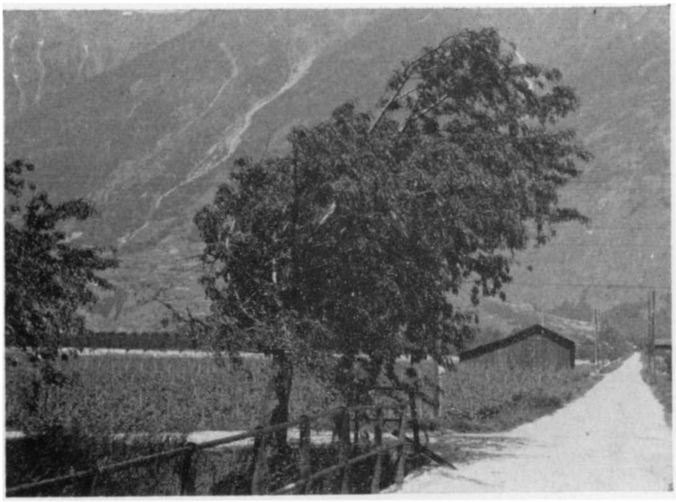
Photo 1: A typical example of the wind-shaped cherry-trees (Prunus avium) in the Rhône valley. This picture was taken 1.5 km SW of the railway station at Saxon. Wind direction: S 30° W, Deformation grade 3.

Photo 2: Pines (Pinus silvestris) on the NW-facing slope (865 m above sea level), about 1.8 km SSW from the railway station at Saxon.

Photo 3: Pines (Pinus silvestris, P. cembra) and larch (Larix decidua) on the SE-facing slope (2018 m above sea level) of the Grimselpass. The trees show the deformation by the prevailing winds during the growing season and the winter period.

Photo 4: Rows of poplar (Populus sp.) 1.6 km N of the railway station at Martigny. Wind direction: N 70—80° W, Deformation grade 3.

Photo 5: Larch (Larix decidua) on the E-facing slope (1610 m) near Eisfluh, north of Oberwald in the upper course of the river. Wind direction: N 10° E.

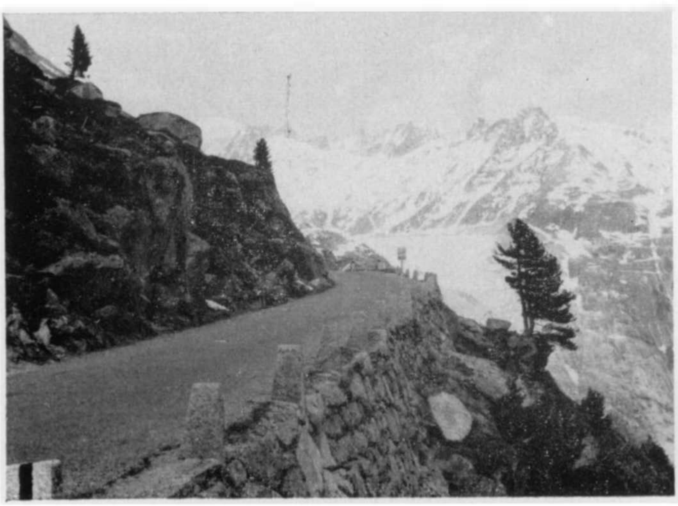


1

4

2

5



3

Table 1: Frequency of wind directions at Sion, Montana, Reckingen and St. Gotthard.

	N	NE	E	SE	S	SW	W	NW	Calm
Sion 7°21'E, 46°14'N, 549 m, 1909—1940									
Jan.	2.7	8.0	4.1	1.0	1.0	6.1	5.4	1.5	63.2
Apr.	2.2	8.4	3.3	0.7	1.1	15.6	15.3	2.8	40.6
July	2.5	7.0	2.6	0.7	0.8	20.7	16.3	3.0	39.4
Oct.	2.5	7.8	4.7	0.8	1.2	12.4	9.2	3.7	50.7
year	2.5	8.1	3.6	0.9	1.3	13.1	11.1	2.8	48.1
Montana 7°29'E, 46°19'N, 1453 m 1929—1940									
Jan.	1.2	8.7	16.2	0.3	0.0	0.2	13.5	4.9	47.8
Apr.	2.2	3.4	17.2	1.3	1.0	3.6	21.2	7.7	32.4
July	2.6	2.2	12.2	1.2	0.9	5.6	24.2	6.3	37.8
Oct.	0.5	4.9	16.7	0.9	0.7	2.5	15,4	4.2	47.2
year	1.7	5.6	16.4	1.0	0.6	2.6	16.9	5.0	41.4
Reckingen 8°14'E, 46°28'N, 1332 m, 1901—1929 and 1934—1940									
Jan.	2.0	1.8	0.6	1.2	0.7	2.3	2.0	6.6	75.8
Apr.	4.1	7.4	1.8	2.2	1.0	3.8	2.4	10.1	57.2
July	3.2	7.5	1.9	3.3	1.8	4.9	3.2	8.7	58.5
Oct.	1.6	3.2	0.8	2.6	0.8	4.3	2.9	8.2	68.6
year	2.8	5.2	1.3	2.3	1.2	3.5	2.4	8.0	63.9
St. Gotthard 8°34'E, 46°33'N, 2096 m, 1903—1940									
Jan.	42.4	5.3	0.8	11.6	12.9	0.3	0.1	2.2	17.4
Apr.	39.2	2.2	0.5	13.0	15.0	0.2	0.2	2.1	17.6
July	44.6	5.6	1.4	9.7	9.3	0.3	0.1	1.2	20.8
Oct.	29.9	4.7	1.0	15.0	14.5	0.3	0.1	1.8	25.7
year	38.4	4.3	0.8	12.3	13.4	0.3	0.1	1.6	20.2

Type (3): Those whose trunk and branches are both deformed by the prevailing winds during the growing period. This type is found most commonly on deciduous and evergreen broad-leaved trees and conifers in the windy parts of the world. In the case of the relatively weak degree of deformation, the trunk and the branches of the tree top are only bent leewards. When the winds are constantly very strong, they are deformed so as to take a creeping shape.

Type (4): Those whose trunk is inclined, but the shape of whose canopy is almost symmetrical. This type may be caused by the occasional but disastrously strong winds. In the region at present under discussion this type was not found.

In the main survey of the present study, Types (1) and (3) mentioned above were observed as indicators of the wind conditions in the Rhône valley: i. e. I observed the degrees of deformation and the prevailing wind directions shown on the wind-shaped trees.

Fig. 2 shows the degrees of deformation that were discerned referring to the results of the studies by Walter (1951), Weischet (1951, 1953, 1955), Yoshino (1961) and Barsch (1963) and of the preliminary survey in this region. The directions were measured by clinometer. As a value at a certain point, I measured 2—3 trees in an open situation. The observations were made at 172 points located mainly in the valley bottom. At the same time, however, the observations on the valley slopes were carried out on the N.W.-facing slopes near Saxon, Sion, Sierre, Visp and Brig and on the S.E.-facing slopes near Montana and Oberwald.

The observed trees were mostly cherry trees (***Prunus avium***) (see Photo 1). To assist in the mapping of the detailed wind conditions, pine (***Pinus silvestris***), poplar (***Populus alba, P. nigra var. italica***) (see Photo 4) etc. were observed in the valley bottom and on some lower parts of the valley slopes. On the other hand, conifers such as pine (***Pinus silvestris***) (see Photo 2), larch (***Larix decidua***) (see Photo 5), spruce (***Picea excelsa***) etc. were observed on the valley slopes in general. The field observations were carried out in August 1962 and June 1963.

The results of the observed directions and the degree of deformations are plotted on the map as shown in Fig. 3, expressing them in a manner similar to directions and wind scales in a weather chart.

IV. Results: Distribution of up-valley winds

a) *Horizontal distribution in the valley bottom.*

The distribution of the wind direction and force along the valley that was revealed on the wind-shaped trees, is given in Fig. 3. At this juncture their distribution in the valley bottom is only des-

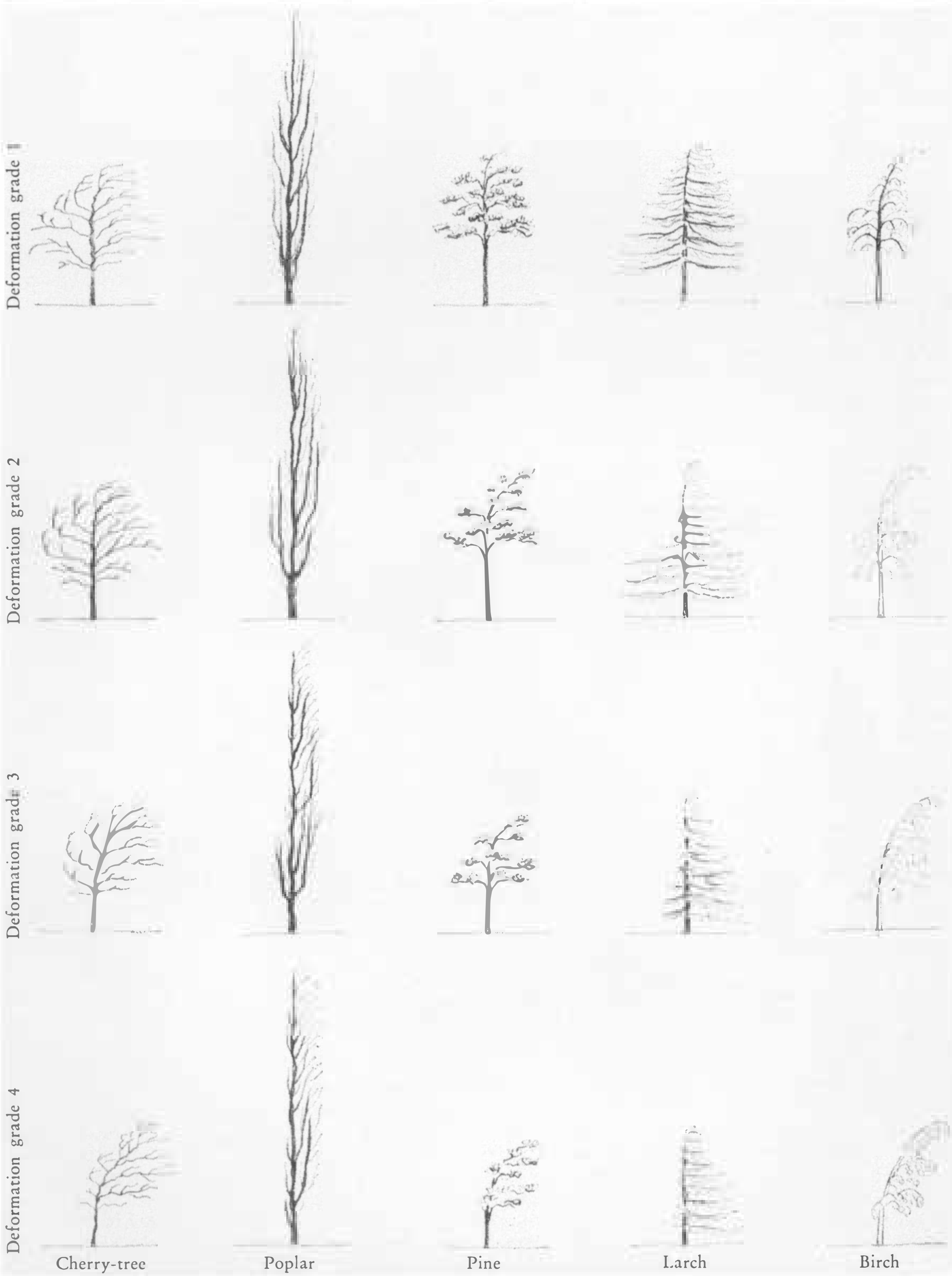


Fig. 2 : Degree of deformation of the wind-shaped trees.

cribed. From the shore line of Lake Léman to the upper course of the river near Mörel and Deisch, the up-valley winds are encountered. Strong winds are to be found especially north of Martigny in the valley bottom.

In more detail, the following characteristics of the distributions in the valley from the lower course are noteworthy: the winds are relatively strong in the middle part between the shore and Aigle. Then they become gradually weaker and have ceased between Monthey and St. Maurice. This region with the calm is considered to be caused by the topographical situation; i. e. the width of the flat valley bottom becomes strikingly narrow from Monthey to the gorge, north of St. Maurice. From St. Maurice to Martigny, the winds become progressively stronger. The strongest winds are to be found in the area between, south of Dorénaz and Martigny. This is more evident near the river course of this area. The directions are almost N.N.W.-N.W. from the shore of Lake Léman to Martigny. At the northern fringe, however, they change gradually from N.W. to W.N.W., and at the north-eastern fringe the prevailing direction is W.S.W. East of Martigny, at the foot of the N.W.-facing slope, they are S.W.-S.S.W. On the other hand, there is a calm in the south-western and southern parts of Fully near the river course. In the south-eastern and eastern parts of Fully the winds blow from the south. From these circumstances, one can easily draw the stream line around Martigny in the valley; i. e. the winds from N.W. along the lower course of the river gradually turn their direction through W. to S.W. along the northern fringe of Martigny and at last they become S. at Fully. Therefore, the calm area mentioned above can be considered as a wind shadow to the up-valley winds from N.W.

In most parts of the valley bottom from Martigny to Sierre, except those near the valley slopes, the wind directions are always W.S.W.-S.W.; i. e. the winds blow corresponding to the direction of the valley. The region of the strongest winds ends, however, in the area between Saxon and Riddes. There is a region with very weak winds east of Sion. Then the winds become more or less strong near Sierre. Between Sierre and Leuk, i. e. at the Pfinwald, the winds are stronger.

After the valley's change of direction to the east, the winds blow strongest near Gampel. Immediately before Visp, the up-valley winds are strong. The up-valley winds are observed as far as Mörel at the valley bottom along the upper course of the river, even though they are not strong. Near Deisch they are also found in an exceptional condition, i. e. at the microtopographically exposed situation to the up-valley winds. From Deisch to Reckingen the winds are very weak. This is confirmed by the great frequency of calms at Reckingen as shown in Table 1. One can state that no marked up-valley winds continue to blow in this part of the valley.

Contrary to the predominance of the up-valley winds along the Rhône valley from the lower course to the upper course as far as Deisch, the opposite wind directions are found in the uppermost part of the valley, the so-called "Goms". Namely, the N.E. winds are observed here and there in the valley bottom from Reckingen to Obergesteln and N.-N.N.E. winds prevail at the S.E.-facing slope near Oberwald. Furthermore, at the S.-facing slope north of Gletsch, the N.N.W.-N. winds are detectable. Photo 5 shows one example on the slope at Eisfluh (1610).

These wind directions are clearly seen on the larch trees. Their deformation belongs to Type (1) mentioned above: they were deformed by the prevailing winds during the growing season. However, on the upper part of the valley slope, larch (*Larix decidua*) and pines (*Pinus silvestris, P. cembra*) of Type 2 were prevalent (see Photo. 3). It can therefore be said that the prevailing winds in this part are northerly in summer and winter.

It is thought that the northerly winds in this part are the upper winds flowing from the upper Aare-valley ("Oberhasli") over the Grimsel-Pass. This phenomenon may be attributed to several factors: (1) At St. Gotthard (2096 m.), a great frequency of N. winds is observed as shown in Table 1. It is therefore certain that the northerly winds near the pass situated between the valleys which run in a north-south direction, prevail throughout the seasons. (2) According to Wagner (1931), the wind directions at 3000 m. in the free atmosphere are thought to be W.N.W.-N.N.W. The prevailing directions of the strong winds exceeding 60 knots in the layer between 600 and 100 mb were 250~280° and 310~340°, (where 360° = N., 90° = E., 180° = S., 270° = W.), at Payerne, Switzerland (Gensler 1963). (3) The northerly winds in this region are not the glacier winds although Conrad (1936) described the importance of the glacier winds along the uppermost part of the river. This is because the trees in the valley bottom between Gletsch and Rhône glacier (2268 m.) do not show any deformation.

Thus the horizontal distribution of the wind directions in the valley bottom along the river course in the valley is very interesting. We may distinguish three sections: the up-valley wind region from the shore of Lake Léman to Deisch on the upper course of the Rhône, the region of calm between Deisch and Reckingen and the northerly wind region in the uppermost part of the valley under the influence of the upper winds.

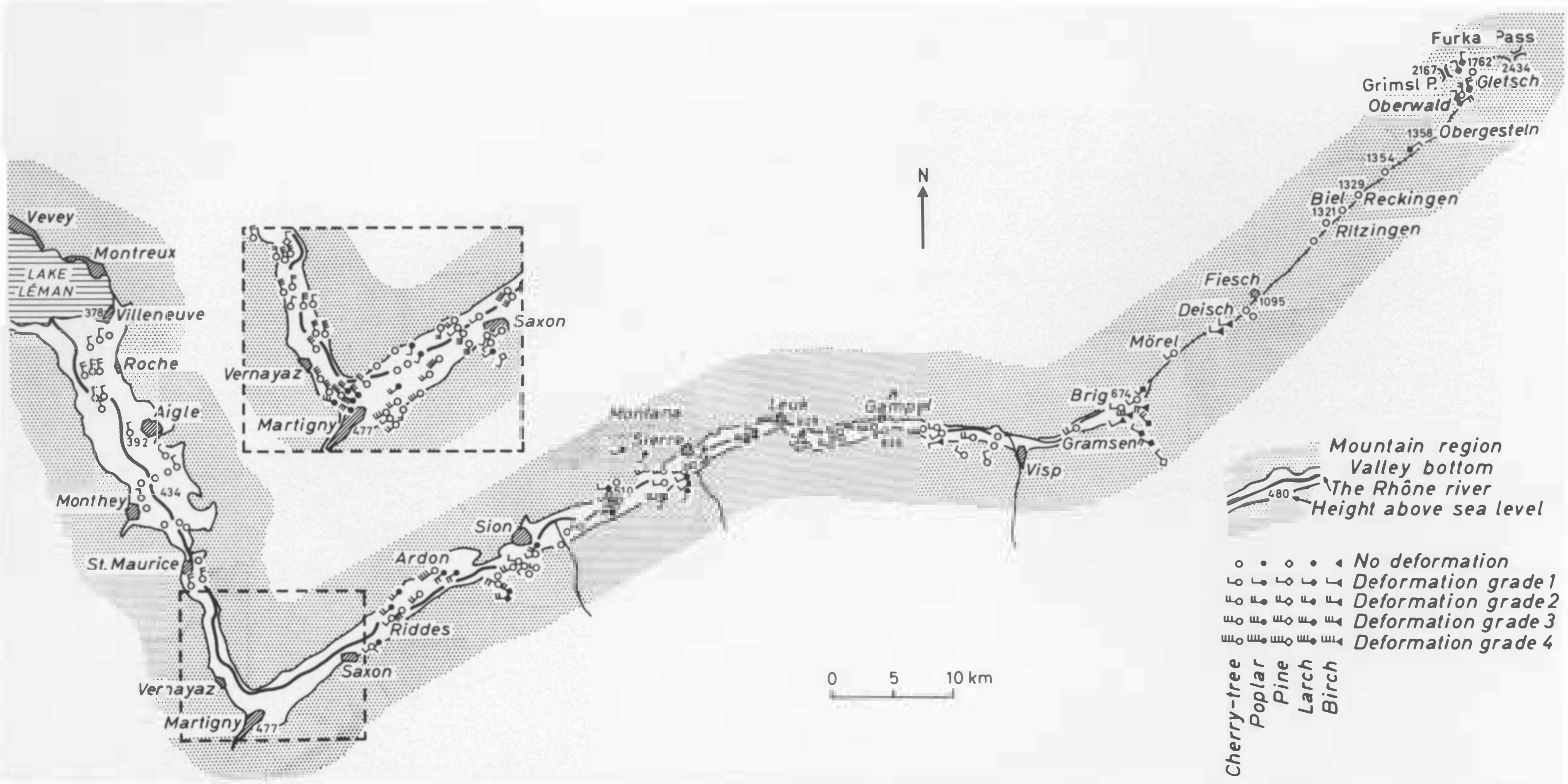


Fig. 3 : Distribution of the wind directions and forces along the Rhône river in the valley bottom, which was revealed on the wind-shaped trees.

b) *Vertical distribution on the valley slopes along the river Rhône.*

As mentioned in the part "Method of observation", the vertical distribution on the valley slopes was observed at seven cross-sections. The results were treated in the following way: (I) As for the purpose of illustration, the deformation grades and the directions in the valley bottom were averaged in every 2—3 km. and then plotted on the longitudinal profile. (2) The observed results on the valley slopes were plotted on the same profile. (3) The isolines were drawn so as to divide the region into the following sections:

Region I_1; the component of the up-valley winds is strongest. This is the region with the deformation grade 3 or higher.
Region I_2; the component of the up-valley winds is strong. This region shows the deformation grade 2.
Region II; the component of the up-valley winds is obvious, but weaker than I_2. This is deformation grade 1.
Region III; the components of the up-valley winds and of the up-slope wind are comparable. Both winds are relatively weak. The trees show no deformation or the deformation grade 1 at the exposed situation.
Region IV; the component of the up-slope winds is more obvious. The characteristic in this region is described later in detail.
Region V; the winds are weakest. Few deformed trees are found.
Region VI_1; the northerly winds are strong.
Region VI_2; the component of the northerly winds is traceable.

The results according to this division are given in Fig. 4. The important evidence to be noted is: (1) Around Martigny the up-valley winds are the strongest and reach highest up the slopes, especially

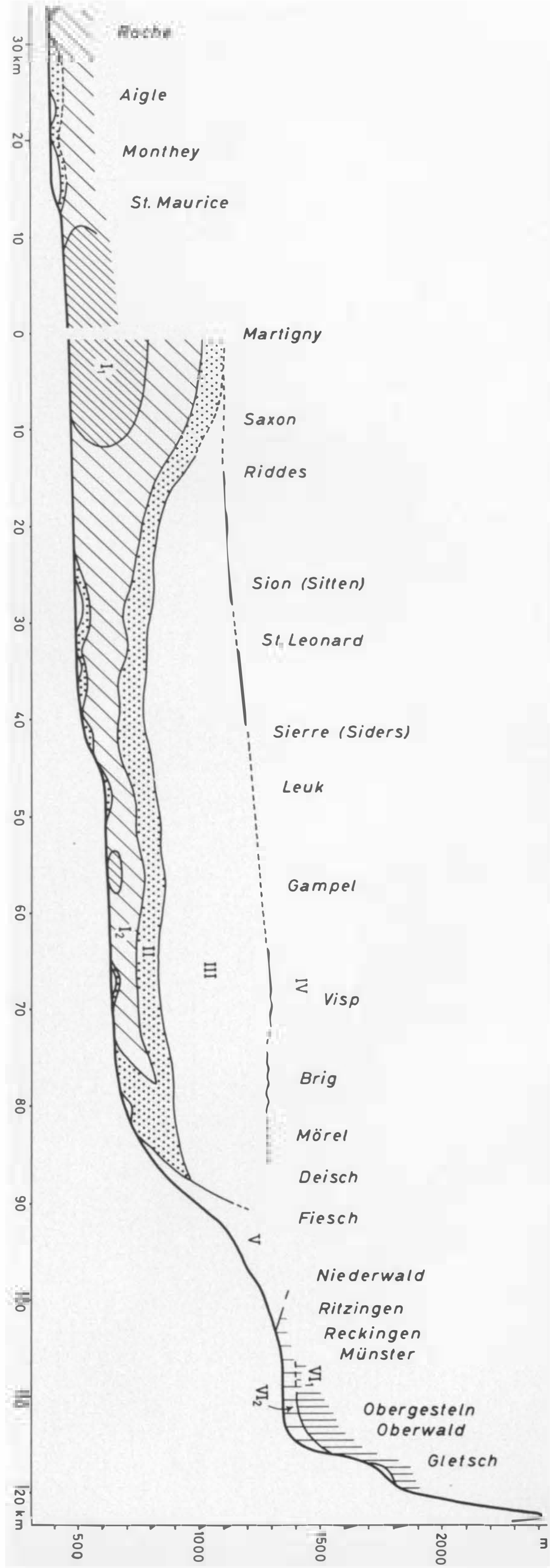


Fig. 4: The wind conditions in the valley bottom and on the slopes along the longitudinal profile of the Rhône valley.
Region I_1: the component of the up-valley winds is strongest.
Region I_2: the component of the up-valley winds is strong.
Region II : the component of the up-valley winds is obvious, but weaker than I_2.
Region III : the components of the up-valley winds and up-slope winds are comparable. The both winds are relatively weak.
Region IV : the component of the up-slope winds is more obvious.
Region V : the winds are weakest.
Region VI_1: the northerly winds are strong.
Region VI_2: the component of the northerly winds is traceable.

on the N.W.-facing slope between Martigny and Saxon. (2) The height of the region with the prevailing up-valley wind component is constantly 200—300 m. with the exception of the Martigny-Saxon part. (3) The boundary line between Regions III and IV was ascertained on several parts of the slopes along the river course. Its height is 600—700 m. above the valley bottom. (4) In the valley the upper northerly winds are traceable as far as a height about 1300 m. above sea level on the E. and S.E.-facing slope of the uppermost course of the river. (5) The longitudinal profile shows that the up-valley winds become weaker in regions located in front of some topographical features such as the gorges at St. Maurice and at Brig. (6) The up-valley winds blow stronger in those parts of the valley which are situated behind gorges and of relatively straight, flat character; e. g. near Roche and near Dorénaz along the lower course of the river, between Martigny and Saxon and near Gampel along the middle course of the river.

Next, some aspects of the winds conditions in Regions III and IV are described. In Region III, the winds are by and large weak, but the wind effects are obvious at some exposed places. Their directions change from place to place in accordance with topographical situation. For instance, they vary between N.N.W. and W.N.W. in the N.-facing slope near Visp and between W.N.W. and W.S.W. on the N.W.-facing slope near Sion. On the S.E. or S.-facing slopes of the region, the winds are much weaker than on the opposite slopes.

In Region IV along the middle course of the river, the component of the up-slope winds is stronger than that of the up-valley winds. Although the directions of the up-slope winds vary also according to the topography of the slope, they tend to have a northerly component in general on the N.W. and N.-facing slopes, probably under the influence of the upper winds. On the other hand, the up-slope winds tend to have a southerly component on the S.E. or S.-facing slopes; e.g. S.S.W. at one place (1228 m.) and W.S.W. at another place (1390 m.) were found on the S.E.-facing slope near Sierre. Up-slope winds also develop at Montana (1430 m.), as has been pointed out by Bouët (1961), but the most frequent direction here is W. as shown in Table 1. The up-slope winds are therefore considered to be much influenced by the topography on these slopes, because of the weaker influence of the upper northerly winds along the leeside of the mountains.

It is not clear how the boundary line between Regions III and V continues on the slopes and whither the boundary line between Regions V and VI_2 runs. A further study is needed to clarify these problems.

V. Discussion: some aspects of the extent and the local characteristics of the valley winds.

The upper limit of the valley winds in the valley bottom and on the valley slopes is considered first. According to an isopleth diagram by Ekhart (1931) the height of the valley winds at Innsbruck in the Inn valley extended to about 2000 m. above the valley bottom on a clear summer day. The average of several fine summer days at the same place (Hann-Süring 1943) was about 1500 m. above the valley bottom. From these facts, it is generally believed that the height of the valley winds in the late afternoon reaches the surrounding mountain ridges (Conrad 1936, Defant 1951) or somewhat above them (Defant 1951). A recent study of the detailed observations of the vertical structure of the mountain and valley winds along the Carbon River Valley, Mount Rainier National Park, U.S.A., (Thyer and Buettner 1962) revealed that the upper limit of the valley winds was 800—1000 m. above sea-level corresponding to the ridge-level in this region. In another cross-section of the Carbon River Valley at Alice Falls at 1. p.m., 9th July, 1959, the valley-parallel component in the valley was found up to the upper limit of the valley slopes, ca. 1800 m. above seal-level, where the width of the valley bottom is ca. 500 m. and the height of the bottom ca. 400 m. above sea-level (Thyer 1962).

No observations on the vertical structure of the winds in the Rhône valley are extant. However, it can be supposed that the height of the valley winds in the Rhône valley also reaches the surrounding mountain ridges, 2500 m. or more above sea-level. If this be acceptable, we can infer from the comparison of this height with that of the boundary line between Regions III and IV shown in Fig. 4, that the height of the valley winds is very much lower on the valley slopes than in the valley bottom.

As has been observed at Innsbruck by Ekhart (1931) and summarized by Conrad (1936) and by Defant (1951), the maximum wind velocity of the valley winds appeared generally at 200–400 m. above the valley bottom. Although the height of the maximum wind velocity was not known in the Rhône valley, it is interesting to point out that the height of the upper boundary of Region II in Fig. 4 might be correlated closely to the height of the maximum wind velocity, which should appear also at the same order of height. Gams (1927) described that the driest parts on the slopes along the middle course of the Rhône river were found at an elevation of 80–120 m. above the valley bottom. BROCKMANN-JEROSCH (1929) affirmed this evidence. This driest zone coincides perfectly with the middle height of Region I_2. Therefore, it is considered that one of the important factors for this driest zone is the high wind velocity on this part of the slope.

According to the observations in Valais by GAMS (1927), the upper limit of the valley winds on the valley slopes corresponded with the lower limit of the fog layer on the slope and its height was 1200–1300 m. above sea-level in summer. The boundary between Regions III and IV coincides with this height.

The mountain and valley wind system was observed in detail from August 2nd to September 10th, 1954 in the Azau valley in the U.S.S.R., in which the surrounding mountain ridges have a relative height of 3500 m. and the width of the valley bottom is 1500 m. (VORONTSOV and SCHELKOVNIKOV, 1956). According to their results, the up-slope wind velocity on the slope at 500 m. above the valley bottom was several times stronger than the wind velocity at the same altitude in the valley. Upper winds flowing over the ridges also prevailed in the uppermost part of the valley in the daytime. Comparing these figures with the lower limits of Region IV and Regions VI_1 or VI_2, it is found that the extent and characteristics of the up-valley winds are quite similar in the Azau valley and the Rhône valley.

As has been mentioned above, the wind conditions in Region IV differ on the S.E. or S.-facing slope from those on the N.W. or N.-facing slope and they vary from place to place in accordance with the topographical situation. I have reported the interactions between the crossing upper winds and the up-valley winds in a small valley (YOSHINO 1957) and the different wind conditions between both valley slopes (YOSHINO 1958 a and b). Even though they were the ones observed in the small valley, similar phenomena must also exist in a large one like the Rhône valley. The different tendencies of the wind directions between both valley slopes in Region IV can thus be explained in their different situations of the valley slopes relative to the upper winds. This different tendency is also found as the S.W. slope winds on the S.E.-facing slopes and the N.W.-N. valley winds in the side valley on the N.W.-facing slopes, as shown in the illustration by BOUËT (1951). The role of the topography of the slope is an important one especially in a high mountain area as has been observed in the Gurgl valley in Austria (AULITZKY 1961). The characteristic wind conditions in Region IV were, as described above, seen only at exposed situations. On this account, it is thought that they are clearly affected by the topographical situation in Region IV.

The wind velocity in the valley bottom is strongly influenced by its topographical conditions; the gorges, fans and moraines are the main causes of these conditions. In other words, it can be said that the winds are stronger in the wider, flat valley bottom. This tendency was observed in a small valley in the Sugadaira highland, Japan (YOSHINO 1958 a) and in the Ziller valley, Austria, through the deformation degree of wind-shaped trees (RUNGE 1958).

The upper limit of the up-valley winds in the upper course of the river reaches to about 1000 m. above sea-level in the Rhône valley as shown in Fig. 4. In the Ziller valley, the limit also indicated by the wind-shaped trees was ca. 1250 m. (RUNGE 1958). He observed in the Allgäuer Alpen that the trees deformed by the upper W.-N.W. winds are found at an altitude about 1700 m. above sea-level and that those deformed by the northerly up-valley winds are seen in the situation sheltered from these strong upper winds (RUNGE 1959). According to my observation, the upper limit of the up-valley winds revealed by the wind-shaped trees, was about 1450 m. in the bottom of the Ötz valley, Austria. Therefore it may be stated that the up-valley winds in the upper course of the rivers extend to higher altitudes in the valleys running to the north in the Alps, probably under the influence of the upper north-westerly winds.

Reference

AULITZKY, H.: 1961; Über die Winterverhältnisse einer zentralalpinen Hangstation in der subalpinen Stufe. Mitt. d. forstlichen Bundes-Versuchsanstalt Mariabrunn 59:209—230.

BARSCH, D.: 1963; Wind, Baumform und Landschaft. Eine Untersuchung des Windeinflusses auf Baumform und Kulturlandschaft, unter bes. Berücksichtigung des Mistralgebietes im französischen Rhônetal. Dissert. Bonn 1962.

BILLWILLER, jun. R.: 1914; Der Walliser Talwind. Ann. Schweiz. Met. Zentr.-Anst. *50* 1913, 7:1—13.

BILLWILLER, jun. R.: 1915; Der Walliser Talwind und der tägliche Barometergang. Met. Zeitschr. 423—425.

BOUËT, M.: 1951; Lokalwinde in der Westschweiz. Leben und Umwelt. 41:91—95.

BOUËT, M.: 1961; Le vent en Valais (Suisse). Mémoires de la société vaudoise des sciences naturelles *12* 277—352.

BROCKMANN-JEROSCH, H.: 1929; Die Vegetation der Schweiz. Beitr. z. geobot. Landesaufnahme 12 (Vierte Lieferung) 385—458.

CONRAD, V.: 1936; Die klimatologischen Elemente und ihre Abhängigkeit von terrestrischen Einflüssen. „Handbuch der Klimatologie" Bd. I, Teil B, 237—247.

DAVIDSON, B., P. K. RAO: 1958; Preliminary report on valley wind studies in Vermont, 1957. College Eng., New York Univ., Res. Div. Final Report AF Contract 19 (604) 1971, 1—54.

DEFANT, F.: 1951; Local winds. "Comp. of Meteorology" 655—672.

EKHART, E.: 1931; Zur Aerologie des Berg- und Talwindes. Betr. Phys. fr. Atmos. *18* 1—26.

FRÜH, J.: 1902; Die Abbildung der vorherrschenden Winde durch die Pflanzenwelt. Jahresber. d. Geogr.-Ethnogr. Gesellschaft Zürich 1901/1902, 57—153.

FRÜH, J.: 1930; Geographie der Schweiz. Bd. I, 297—301.

GAMS, H.: 1927; Von den Follatères zur Dent de Morcles. Beitr. z. geobot. Landesaufnahme 15, 1—760.

GENSLER, G. A.: 1963; Die Struktur der Höhenwindverteilung nördlich und südlich der Alpen. Geofisica e Meteorologia *11* 97—99.

HANN-SÜRING: 1943; Lehrbuch der Meteorologie (Lieferung 6—8). 546—556.

KNOCH, K.: 1963; Die Landesklimaaufnahme; Wesen und Methodik. Ber. d. Deutsch. Wetterdienstes. 85:1—64.

NÄGELI, W.: 1943; Untersuchungen über die Windverhältnisse im Bereich von Windschutzstreifen. Mitt. d. Schweiz. Anstalt f. d. forstl. Versuchswesen *23* 221—276.

PUENZIEUX, A.: 1897; Contribution à l'étude du reboisement de la plaine du Rhône. Schweiz. Zeitschrift f. Forstwesen. 5—8, 58—61, 101—105.

RUNGE, F.: 1958; Windgeformte Bäume in den Tälern der Zillertaler Alpen. Met. Rdsch. *11* 28—30.

RUNGE, F.: 1959; Windgeformte Bäume in den Tälern der Allgäuer Alpen. Met. Rdsch. *12* 98—99.

STERTEN, A. K.: 1961; Local meteorological investigations of the mountain and valley wind system in south-eastern Norway. "Local and synoptic meteorological investigations of the mountain and valleywind system" Norwegian Defence Research Establishment, Forsvarets Forskningsinstitut 9—73.

THYER, N.: 1962; Valley wind theory. Dept. Atmosph. Sci., Univ. Washington Final Report AF Contract 19 (604)—7201, 107—199.

THYER, N. and K. J. K. BUETTNER: 1962; On Valley and mountain winds III. Dept. Atmosph. Sci., Univ. Washington Final Report AF Contract 19(604)—7201, 1—106.

VORONTZOV, P. A. and M. S. SCHELKOVNIKOV: 1956; Opyt aerologicheskogo iissledovanniia nizhnego sloia atmosfery v doline Azau. Trudy GGO 63: 138—167.

WAGNER, A.: 1931; Klimatologie der freien Atmosphäre. „Handbuch der Klimatologie" Bd. I, Teil F, 32—39.

WAGNER, A.: 1932; Hangwind, Ausgleichsströmung, Berg- und Talwind. Meteorol. Ztschr. *49*.

WAGNER, A.: 1932; Neue Theorie des Berg- und Talwindes. Meteorolog. Zeitschr. *49*.

WALTER, H.: 1951; Einführung in die Phytologie. III. Grundlagen der Pflanzenverbreitung. 493—498.

WEISCHET, W.: 1951; Die Baumneigung als Hilfsmittel zur geographischen Bestimmung der klimatischen Windverhältnisse. Erdkunde *5* 221—227.

WEISCHET, W.: 1953; Zur systematischen Beobachtung von Baumkronendeformationen mit klimatologischer Ziel setzung. Met. Rdsch. *6* 185—187.

WEISCHET, W.: 1955; Die Geländeklimate der Niederrheinischen Bucht und ihrer Rahmenlandschaften. Münchner Geographischen Hefte 8:1—169.

YOSHINO, M. M.: 1957; The structure of surface winds crossing over a small valley. Jour. Met. Soc. Japan, Ser. II, *35* 184—195.

YOSHINO, M. M.: 1958 a; Winds in a V-shaped small valley. Jour. Agr. Met. *13* 129—134.

YOSHINO, M. M.: 1958 b; Wind speed profiles of the lowest air layer under influences of micro-topography. Jour. Met. Soc. Japan, Ser. II, *36* 174—186.

YOSHINO, M. M.: 1961; Shôkikô (Microclimate). 1—274.

YOSHINO, M. M.: 1963 (A paper presented to the Committee on ecological climatography, International Society of Biometeorolgy held in Pau, Sept., 1963).

MARITIME GEOGRAPHIE

Die Stellung der Geographie des Meeres und ihre Aufgaben im Rahmen der Meeresforschung

KARLHEINZ PAFFEN

Summary: Marine geography: the place and tasks of a geography of seas and oceans.

With reference to both the memoranda of the Deutsche Forschungsgemeinschaft (Central German Research Board) about the state of marine research and geography in Germany, the place and tasks of a "marine geography" are sketched. Starting from the fact that the earth's surface consists of 361 mill. sq.km. of seas and 151 mill. sq.km. of land, and from the present situation where geography is almost exclusively concerned with the continents only, the question of why geography has largely turned its back on marine-geographical problems is answered by a historical recollection of the relationships between geography and oceanography since the turn of the century. After the emancipation of oceanography as a discipline of geophysics, geography has been unable until the present to close the gap thus originated.

However, since the world oceans are the second major group of phenomena of the earth's surface, and nearly two and a half times as large as the land surfaces, geography should accord them equal attention as intensive and comprehensive as that give to the continents. Since the world oceans differ in many respects so greatly from the land surfaces thev should best be treated in a "marine geography" which gathers together all geographical problems of the oceanic sphere. Corresponding to the dual nature and the scientific system of modern geography marine geography has the following tasks outlined below. These should also give to the subject within the framework of general international marine research as represented by the Scientific Committee on Oceanic Research (S. C. O. R.), a co-operative body of many different disciplines, a more important, in certain respects even an integrating position.

I Physical geography of the sea
   1 Coastal morphology and sea level changes
   2 Topography and morphology of the sea bed
   3 Maritime climate-geography
   4 Ocean geography (= maritime hydro-geography)
   5 Biogeography of the sea
   6 The physical regions of the world ocean

II Cultural geography of the sea
   1 Social geography of the sea
   2 Historical geography of the sea
   3 Political geography of the sea
   4 Economic geography of the sea
   5 Geography of communications of the sea

III Regional geography of the sea (as a synthesis).