On H. WILD's Hypothesis in the Theory of Foehn Phenomena

by

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Abstract

Causes of descending current in valley are sought based on the theory that with the fall of separation point the current of foehn descends into the valley. H. WILD'S hypothesis is confirmed by ascending current in the lower boundary of turbulent mixing region of jet stream, by the quotation of W. TOLLMIEN's theory of stationary semi-infinite jet stream. It is shown that the effect of one of H. v. FICKER's theory and H. WILD's hypothesis must predominate on account of topographical influences.

1. Introduction

Why does the stream of foehn descend into the valley? This problem has been investigated by many authors especially in the region of the Alps. Concerning its local causes there have been two theories. One is called H. WILD's hypothesis and another H. v. FICKER's theory.

As no reverse flow in the lee side of mountains before and at the time of foehn was observed,[4] [5] [6] H. WILD's hypothesis was discarded by H. v. FICKER,[1] [6] H. KOSCHMIDE[7] and others. But, for example, the following facts observed by R. STREIFF-BECKER[8] [9] in Glarus, Switzerland, do not fit in with H. v. FICKER's theory. as pointed out by R. STREIFF-BECKER.[8] [9]

1) Foehn-winds always begin at first in the hindermost part of the valley and end there at last.
2) In the western Alps before foehn it is calm in the closed valley.
3) Sometimes foehn occurs only in the hinder part of the valley, and not in the front part. Also, Sometimes the upper part of the valley only have foehn.

These phenomena can be satisfactorily interpreted if we adopt H. WILD's hypothesis, as pointed out by H. WILD,[1] [3] R. STREIFF-BECKER[8] [9] and others. In this report, the mechanism of suction of the air by the foehn-stream will be considered, and the ascending current, observed even by H. v. FICKER, will be interpreted by means of quotation of W. TOLLMIEN's theory of semi-infinite jet stream.[10] [11] [12] It will also be shown that either the effect of an ascending current of that of horizontal divergence must predominate according to the topographical influences.

2. Mechanism of suction of the air by foehn-stream and the jet-foehn

On account of energy loss by friction in the boundary layer, the stream across a mountain-chain do not descend into the valley unless the friction effect is compensated for with acceleration. Thus the well-known separtion phenomena occur.[12] In this case, as the motion do not begin impulsively, the motion is not considered as irrotational, consequently it will not occur that the separation point ascends to the stationary position gradually, and the reverse flow develops. Accordingly, in this case the separated flow will become a jet stream, just as the flow in a diffuser. If acceleration exists, such as the increase of pressure gradient, this separation point gradually descends, and when it reaches the ground in the valley foehn phenomena will occur. The pressure fall in the valley thus contributes to the occurence of the foehn. The local causes fall in the valley are the outflow of air from the entrance to the valley to the plain in the valley closed in three directions, or horizontal mass divergence due to the increase of the friction in the valley, and the outflow of air by the ascendeng current in the horizontal direction in the closed valley. The former two are the effect shown by H. v. FICKER's theory[1] [7] and the latter the effect claimed in H. WILD's hypotehsis.[1] [3] [7] [8] [9] In the following, the latter will be considered. foehns are classified for convenience sake as follows, according to the mechanism of descent into the valley.

1. Jet foehn due to effect of an ascending current.
2. Divergent foehn due to the effect of horizontal divergence.
3. Gradient foehn due to the foellowing effects.
   a). Combination of the effects of 1. and 2.
   b). Non-local pressure fall in the valley or increase of pressure gradient in the lee side of the mountains, such as the upper trough, accumulation of cold air in the windward side and so on.
   c). Anticyclonic foehn due to combinaion 2. and subsidence inversion.

From the above-mentioned considerations. or observations by R. STREIFF-BECKER and H. v. FICKER, if the foehn-strean can not descend into the valley, the separated flow becomes a jet stream. According to W. TOLMIEN's theory of semi-infinite jet stream, ascending currents exist below the turbulent mixing zone. If the horizontal flows that compensate this ascending currnet is interrupted, the pressure in the valley will fall, for in this case this ascending curent is removed horizontally in the turbulent mixing zone. Thus, the separation point will fall and foehn will occur. If W. TOLLMIEN 's semi-infinite stationary jet is adopted as the approximate model on the same assumption, this ascending current will become as follows:

$$V=U_0\Big\{\eta\{(-\alpha c_1 l^{-\alpha\eta})+l^{\frac{\alpha\eta}{2}}\cos\frac{\sqrt{3}}{2}\alpha\eta\Big[\frac{\alpha C_2}{2}+\frac{\sqrt{3}}{2}C_3\Big]+l^{\frac{\alpha\eta}{2}}\sin\frac{\sqrt{3}}{2}\alpha\eta\Big[\frac{\alpha C_2}{2}$$

$$-\frac{\sqrt{3}}{2}C_3\Big\}-\Big(C_1 l^{-\alpha\eta}+C_2 l^{\frac{\alpha\eta}{2}}\cos\frac{\sqrt{3}}{2}\alpha\eta+C_3 l^{\frac{\alpha\eta}{2}}\sin\frac{\sqrt{3}}{2}\alpha\eta\Big)\Big]$$

where

$\alpha\eta_1=0.981,\qquad \alpha\eta_2=-2.04,\qquad C_1=-0.0062$

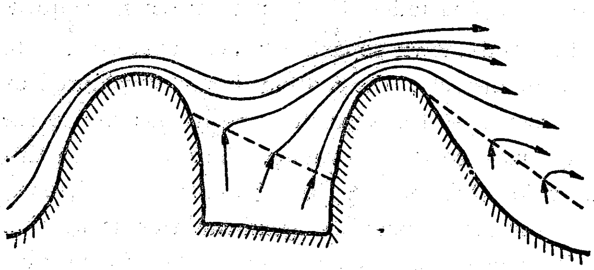

Fig. 1 Model of semi-imflnite jet [L. Prandtl 1935]

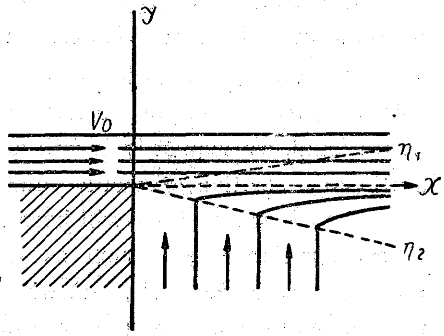

Fig. 2 Model of structure jet of stream

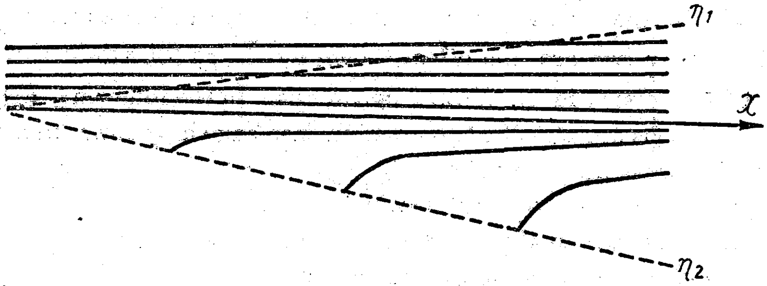

Fig. 3 Streamline in the turbulent mixing zone [W. Tollmien 1926]

$C_2=0.987,\qquad C_3=0.577.$

U_0: undisturbed velocity.

$$\eta=\frac{y}{x}$$

$$\alpha=C^{-2/3}$$

$l=Cx\quad l$: mixing length

Now, we take $\alpha=11.8$, value by the same author.

$$C=0.0246$$

In the case, $U_0=20$m/sec, $\alpha=10$, $x=1$km $y=-200$m,

$$V=0.8\text{m/sec}$$

If the compensating horizontal flow does not exist,

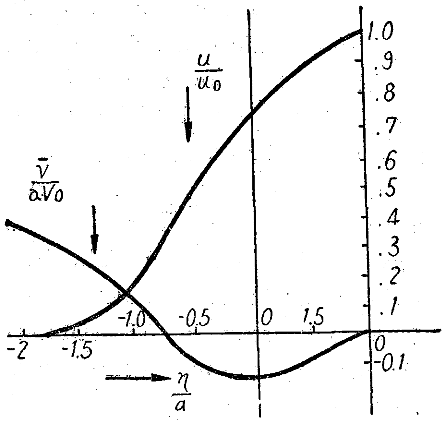

Fig. 4 Velocity distribution [L. Prandtl 1935]

$$\frac{\partial p}{\partial t} = -\rho g w_h = -0.1\text{mb/sec}.$$

This is a vey large value. This indicates enough possibility of the above mechanism being the cause of foehn-phenomena, for if the foehn occurs the pressure fall will cease.

In this case, the width of the turbulent mixing zone is expressed as follows, if the departure from the stationary state is small,

$$b = \frac{x}{0.037U_0^2}\sqrt{gh + \left[\frac{P_i - P_0}{\rho}\right]}$$

where ρ : mean density at height CD in fig. 5.

g : acceleration of gravity.

h : height CD in fig. 5.

P_i : difference between actual pressure and hydrostatic pressure at AD in fig. 5

P_0 : ditto. at BC in fig. 5

b : width of the turbulent mixing zone.

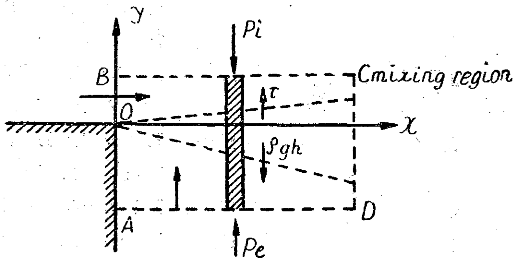

Fig. 5

When ρ decreases, b will increase. Thus in this case as the separation point descends, turbuent mixing zone will extend. Both contribute to the occurence of foehn.

H. v. FICKER's objections to H. WILD's hypothesis may all be answered in the following way:

1. At Innsbruck the Inn valley is open in the direction of Alpenvorland, north of Innsbruck. Then north wind can, frequently enter the valley without crossing the mountains, Kalvendel Gebirge. But south wind can not enter it without crossing the Zillertaler Alpen or the Stubaier Alpen. Thus, in Innsbruck southwind foehn is more freguently seen than north wind foehn, and anticyclonic foehn also fairy frequently on account of the outflow from entrance of the valley. Similar phenomena may be seen at Nagano, Japan, where the topography is analogous to Innsbruck. On the contrary, at Glarus the valley is nearly closed, and the jet foehn preominates, as R. STREIFF-BECKER mentioned.
2. As mentioned above, before and at the time of the foehn, no reverse flow occurs.

If a compensating horizontal flow exists, the jet will be stationary and clouds will sometimes be formed. An example of it which caused snowfall at Nagano was investigated by the present author.(14)

3. Conclusion

H. WILD's hypothesis is confirmed by the quotation of W. TOLLMIEN's theory of semi-infinte jet stream. And aslo it is shown that this effect predominates when the compensating horizontal flow is interrupted, as in a closed valley.

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