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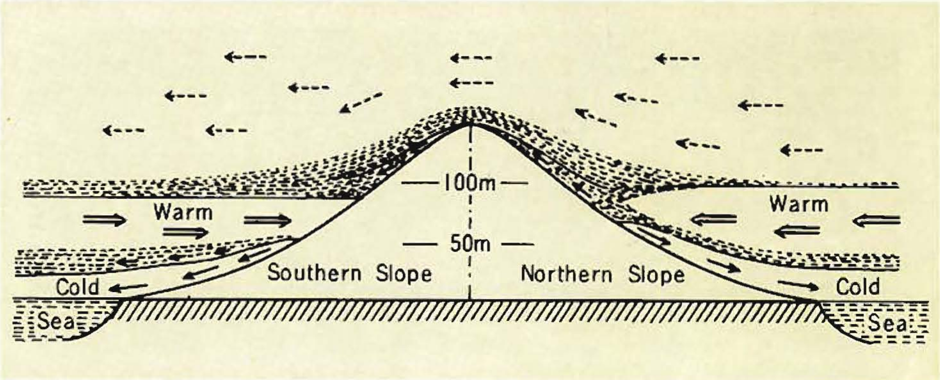

Small-Scale Climate

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Local Winds in the Upper Rhone Valley

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Abstract: Balloon soundings during July and August 1979, 1981 and 1982 showed the vertical structure of the flow in the upper Rhone Valley. Between the low level winds up to a height of about 2000 m a s l and the gradient winds above 3000 m a s l, in 73 % of the 107 ascents, a counterflow was detected. It appeared more often in connection with down-valley flow (89 %) than with up-valley flow (38 %) above the ground. This flow pattern was found to be almost unaffected by the upper winds.

The horizontal structure of the wind was studied with 3 ground weather stations that were separated 2 and 5 km along the valley axis. Up-valley winds occur in the average of 32 fair weather days only around noon. During the time of strongest up-slope winds, the valley wind is down-valley. That was already found in the climatic mean by Yoshino (1964) with wind shaped trees.

As the wind recordings show, the down-valley flow develops first at the end of the valley and the resulting convergence zone moves down with about 2 m/s until it stops above a characteristic step near Fiesch (Fig 6).

An explanation can be given by differential heating within the Rhone Valley itself and due to neighbouring valleys. The measured differences in the diurnal pressure changes of 5 stations is consistent with that hypothesis.

Introduction

Geography

The upper Rhone Valley (Oberwallis, Goms) is the SW-NE orientated part of the 150 km long Rhone Valley above Lake Geneva in southwestern Switzerland. Characteristic for the 35 km stretch is a step in the height of the valley bottom, where it rises from some 800 m a s l up to about 1300 m a s l, the altitude remaining constant for the last 25 km. Ridge heights are around 3100 m a s l. The measurements were mostly taken near Muenster, 46° 29′N, 8° 16′E, 1350 m a s l. The many neighbouring valleys are important for the discussion (Fig 6).

History

For more than 20 years a group of glider pilots have held their annual summer camp in the region during July and August. A qualitative knowledge of local weather conditions inspired a closer look at some particular details. Therefore we began to make windsoundings in 1979. These showed interesting structure in the valley flow. The research continued in 1981 with better defined goals and more equipment including temperature radiosondes. The main activities were:

- Measurement of the sensible heat input as the most important parameter for forecasting convection.
- Comparison of the local radio soundings with the Temp-messages from stations like Payerne, Stuttgart, Munich or Lyon and with data from automatic ground weather stations to derive some semiempirical rules for estimating local profiles without own ascents. (Unfortunately no operational soundings within the Alps themselves are available.)
- Test flights with a newly developed measuring system for light carriers (e.g. gliders).
- Production of time lapse movies to visualize convection and other cloud tracered flows.

Fig 1 to 4 Typical wind profiles dotted lines: wind direction; solid lines: wind speed; Windprofil = wind profile; Ballonwegprojektion = vertical projection of the balloon trajectory; Talachse = Valley direction;

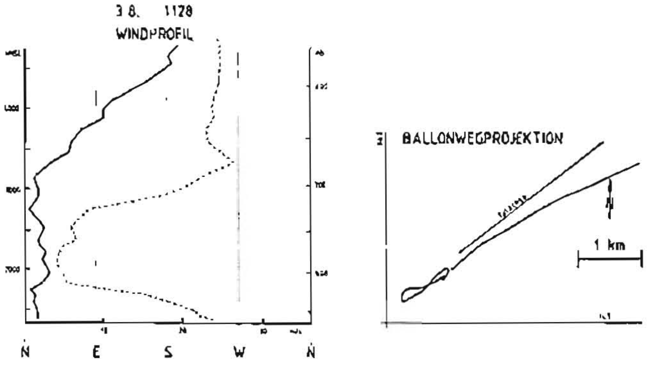
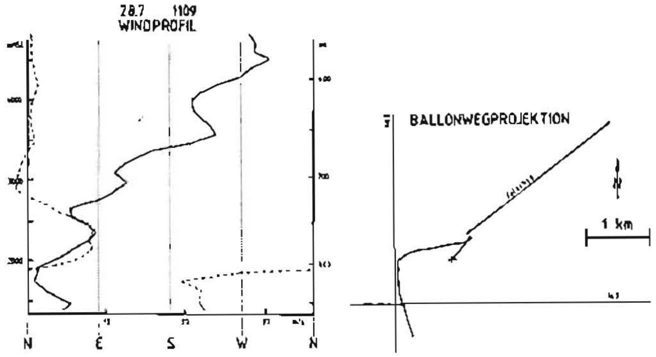
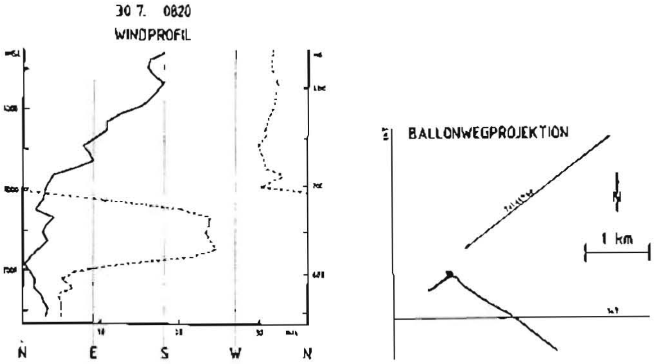


Fig 1 Counterflow even when lower and higher winds have the same direction (SW).





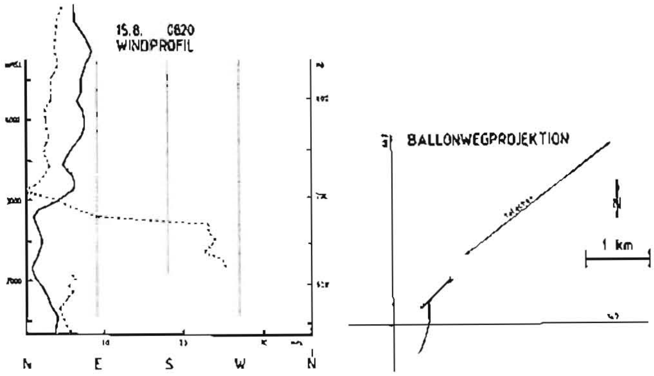


Fig 2 and 3 Same structure of the valley flow, although gradient winds are different.

Fig 4 Another case of strong counterflow with up-valley wind above the ground (it is more common for down-valley winds).

In 1982, the activities were focused on the unorthodox valley flow:

- Measurement of wind and pressure with other stations along the Rhone Valley and in neighbouring valleys to check the hypothesis that the reverse valley flow is caused by differential heating within the Rhone Valley itself and relative to other valleys.
- Test of the forecast procedure derived in the year before.
- Continuation of profile measurements and time lapse photography.

Valley Wind System

Vertical Structure

Valley and slope wind models are extensively treated by several authors (Thyer and Buettner, 1962; Defant, 1949; Vergeiner, 1982 a, b; Freytag 1982; Urfer-Henneberger 1970; Yoshino 1975) and will not be treated here. The four examples of wind profiles (Fig 1 to 4) are typical for the conditions in the upper Rhone Valley. The counterflow between heights of 2040 m and 2980 m shows up in most profiles (Tab 1). It cannot be explained only by the backflow of the air that was brought upvalley with the valley wind and ascended on the slopes (antiwind), because it is too strong to maintain continuity. But the height of 2100 m is typical for the height of the barriers (passes) to the neighbouring valleys and 3000 m is typical for ridge heights. This suggests an influence from neighbouring valleys that is even more obvious in the horizontal.

Horizontal Structure

The wind recordings 5 m above the ground do not show a typical valley wind behaviour and tell us no more than local people knew already and trees have recorded with their shapes (Yoshino, 1964): Upvalley winds do not occur regularly. The mean of the recordings from 1981 (Fig 5) shows only an up-valley component around noon. During the time of maximum convection, the wind blows downvalley. Similar effects were also found in other valleys (e.g. Malojawind).

Tab 1 Statistics about the number of wind profiles with counterflow (c.f.)

	wind direction 0 ... 100 m above the ground				percentage with c.f.
	up-valley		down-valley		
	with c.f.	total	with c.f.	total	
1979	0	7	13	14	62 %
1981	10	16	30	37	75 %
1982	3	11	22	22	76 %
total	13	34	65	73	73 %
	38 %		89 %		

There exist in situ measurements of dewpoint and temperature taken from a glider that flew in the convergence zone. The down-valley flow in the 800 mb level was warmer (by 2 C) and dryer (1 C change in dewpoint), suggesting a foehn effect caused by air descending from the passes to the northeast. That overflow of the passes, especially of the Grimsel, can be observed visually if there is enough humidity to cause condensation ("Grimsel Snake"). But in general, the ground stations do not show any systematic temperature jumps during the passage of the convergence zone. With the three windmeasuring stations Ulrichen, Münster and Gluringen one can normally observe a drift 2 m/s down-valley of the convergence zone. An extreme case showed that the convergence zone persisted for 5 hours near Münster. It was also detectable by opposite pointing windsacks only 2 km apart.

Pressure Measurements

In the third year of investigation, the pressure data from some neighbouring stations were compared with ours. Because of the unknown temperature profiles above the other stations, accurate pressure reduction was impossible. As second best solution, the stations means during the measuring campaign were taken and only the differences to them were used. On many days, observed wind direction changes and inflows above passes to neighbouring valleys could be explained by pure hydrostatic reasoning. The example of July 22 1982 (Fig 7) can be described as follows: Münster (upper Rhone Valley) and Sion (middle Rhone Valley) both show a diurnal variation of the ground pressure. The high mountain station of Jungfraujoch (3580 m) shows a much smaller and opposite change. The upper, SW-NE-oriented part of the Valley is heated earlier, the E-W-stretching part near Sion shows a stronger pressure minimum. Jungfraujoch shows a slight compression because not all the expanded air below escaped out of the region, but rised the atmosphere. The change in wind direction in Münster coincides with the beginning of the pressure deficit in Sion.

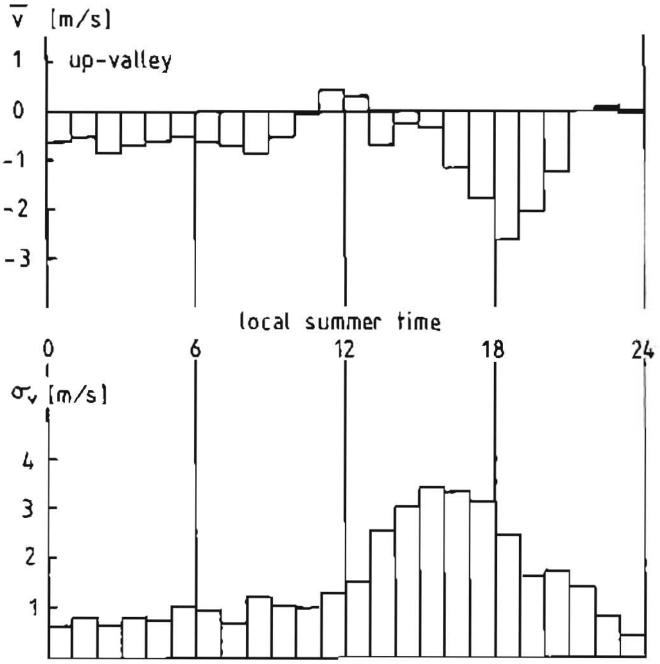


Fig 5 Mean wind speeds and their standard deviations on 32 radiation days in July and August 1981

In the evening, a thunderstorm occurs near Interlaken in the northern neighbouring valley (Haslital). The high pressure correlates again with the strong downvalley flow: Air passed from the Haslital above the Grimsel Pass into the Rhone Valley.

Differential Heating

The following measurements were taken to get values for the input of sensible heat into the valleys atmosphere. The comparison with other measurements (Gold, 1933; Reinhardt, 1971) show the direct influence of the topography. From the known state of the atmosphere in the morning (sounding), the development of the dry adiabatic layer was found graphically using temperature measurements 5 m

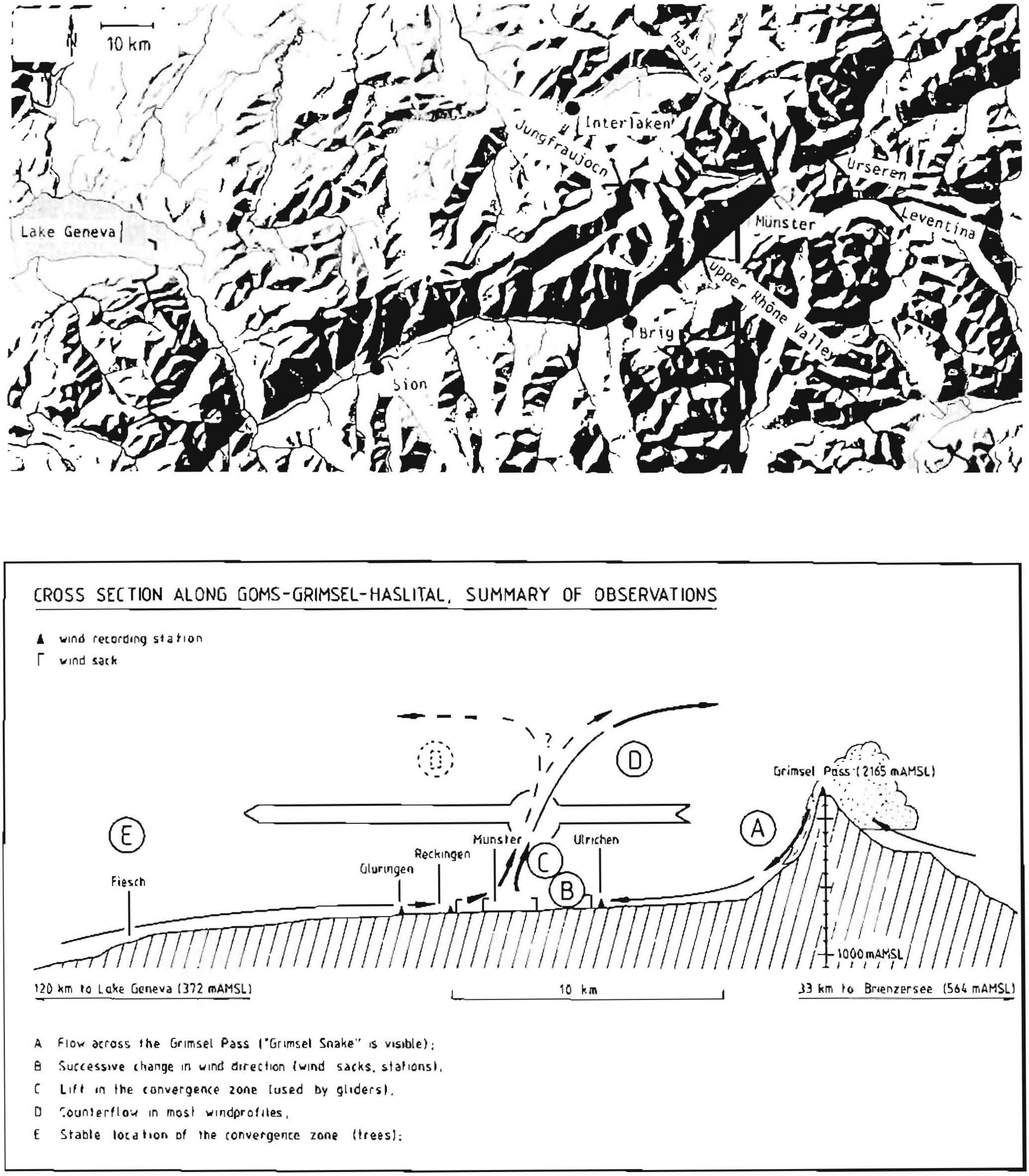


Fig 6 Rhone Valley and eastern neighbouring valleys (Haslital (Aare), Urseren (Rhine), ...). The cross section below is taken along the river in the marked region.

A: Flow accross the Grimsel Pass ("Grimsel Snake" is visible).

B: Sudden change in wind direction successively moving downvalley (4 wind sacks, 3 wind recording stations).

C: Lift in the convergence zone (used by sailplanes).

D: Counterflow in most cases (Balloon soundings).

E: Stable location of the convergence zone (e.g. shown by trees, Yoshino, 1964).

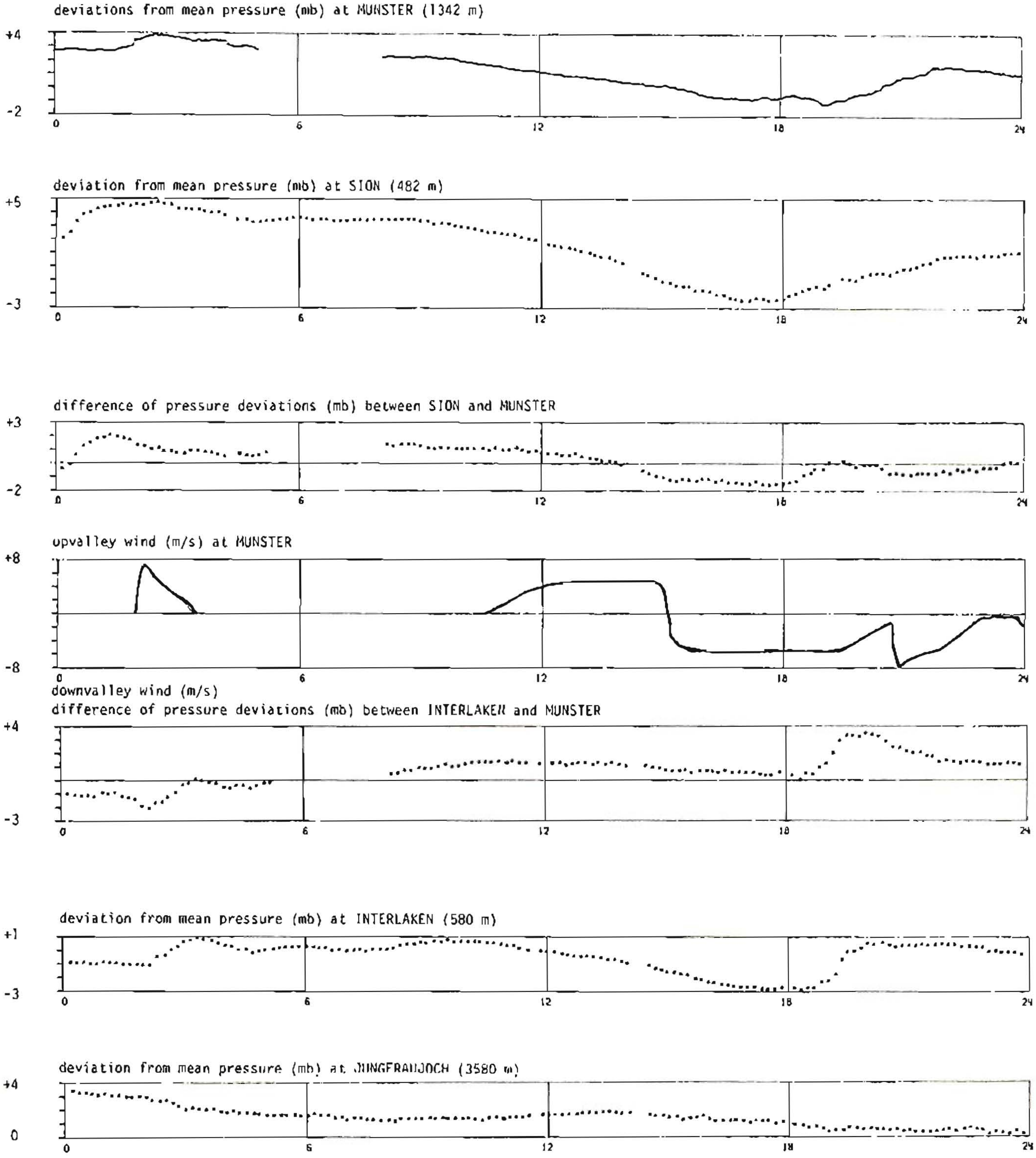


Fig 7 Comparison of horizontal pressure differences and wind near Münster

above the ground. To compute specific energy flow, the air mass involved had to be estimated. The method used is described in more detail by Neininger (1982, 1983).

The time derivative of the heat, the heating power, reflects the topography very well: The Inn valley (W-E-direction) has its maximum some two hours later (F) than the Goms (SW-NE-oriented, curve E). Both show more modulation than curve D for flat topography. This is the result of the different times when the sun's azimuth is perpendicular to the valley axes.

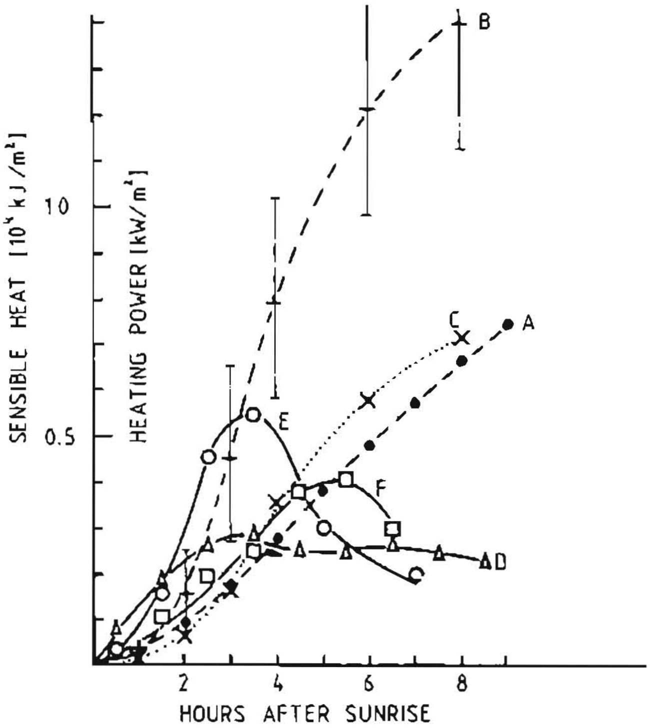


Fig 8 Sensible heat and heating power

A: Sensible heat over flat land (Gold, 1933)

B: Sensible heat input into the upper Rhone Valley without air mass corrections.

C: ... with air mass corrections (factors see Fig 4)

D: Heating power of flat land

E: Heating power of the upper Rhone Valley (July, August)

F: Heating power of the Inn Valley near St. Johann (Reinhardt, Mai 1971) after applying a rough air mass correction factor of 50 %.

Conclusion

The diurnal variation of the temperature profile in mountaineous regions can be estimated by modifying the Gold values by geometrical reasoning. The modulation of the heat input caused by different sun azimuths relative to the valley axes can even explain valley internal pressure- and resulting flow-inhomogeneities or interactions with neighbouring valleys.

The existence of a counterflow above the downvalley flow (anabatic or katabatic) is proved but not thoroughly explained.

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