Mesoscale Measurements for Gliding Forecast in an Alpine Valley

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1. Introduction

1.1 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 (Fig. 1). Characteristic for the 35 km stretch is a step in the height of the valley bottom, where it rises from some 800 m AMSL up to about 1300 m AMSL, the altitude remaining constant for the last 25 km. Ridge heights are around 3100 m AMSL. The measurements were mostly taken near Münster, 46 29 N, 8 16 E, 1350 m AMSL. The many neighbouring valleys are important for the discussion.

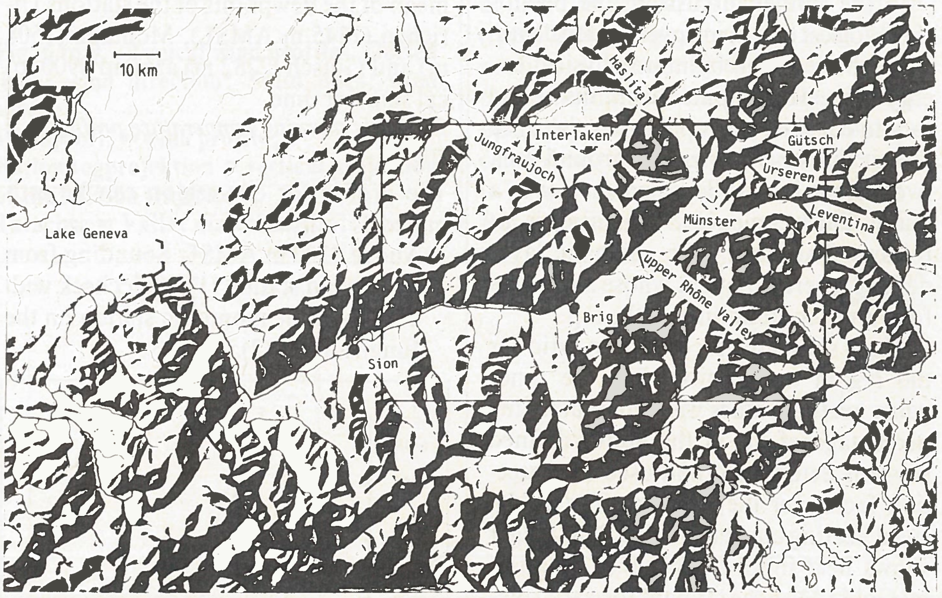


Fig. 1 Topographical map.

1.2 History

For more than 20 years a group of glider pilots have held their annual summer camp in the region. A qualitative knowledge of local weather conditions inspired a closer look at some particular details. Using equipment from Lapeth 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 semi-empirical rules for estimating local profiles without own ascents. (Unfortunately no soundings within the Alps themselves are available, see session papers about the Alpex project.)
- Test flights with a newly developed measuring system for light carriers (e.g. gliders or towing machines).
- Production of time lapse movies to visualize convection and other cloud tracered flows.

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.

2. Forecasting procedure

2.1 Sensible heat

The heat input could be computed from the local temperature soundings and the recorded rise in ground temperature during the day. Due to the lack of humidity profiles, no computations of latent heat could be carried out.

The usual way to express the heating of the atmosphere is to give the thickness of a layer that could be changed from isothermal to dry adiabatic state with the same energy input isothermal to dry adiabatic state. The values for flat land were

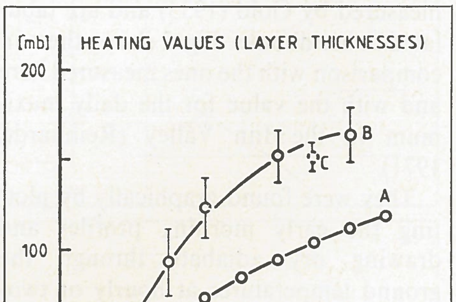


Fig. 2 Heat input as heights of heated air in mb.
A: Flat land (Gold, 1933)
B: Upper Rhone Valley (July, August 1981)
C: Maximum value in the Inn Valley (Reinhardt, Mai 1971)

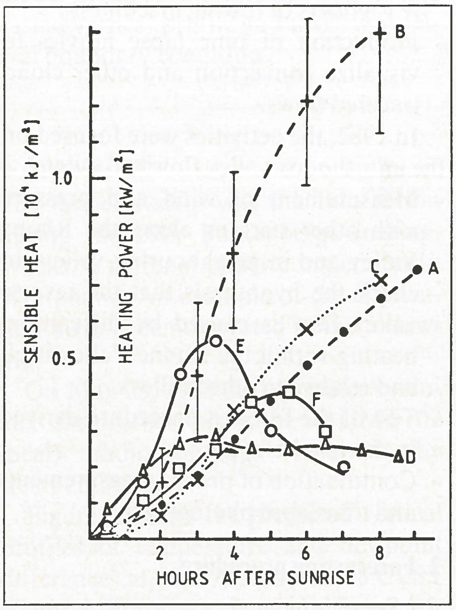


Fig. 3 Sensible heat and heating power
A: sensible heat over flat land (Gold, 1933)
B: Sensible heat input into the upper Rhone valley without geometrical corrections.
C: ... with geometrical corrections (factors see fig. 4)
D: Heating power of flat land
E: Heating power of the upper Rhone Valley (July, August)
F: Heating power of the Inn Valley near St. Johann (Reinhardt, Mai 1971) after applying a rough geometrical correction factor of 50%.

measured by Gold (1933) and are tabulated in handbooks. Fig. 2 shows them in comparison with the ones measured here and with the value for the daily maximum in the Inn Valley (Reinhardt, 1971).

They were found graphically by plotting the early morning profiles and drawing dry adiabats through the ground temperatures at hourly or two-hourly intervals. To check the assumption of adiabatic warming from below, additional soundings by balloons or gliders were made on some days. The effect of warming from above by the subsiding air in the center of the valley was not found to be strong, but was detectable (see Brehm, 1981). Additional humidity profiles would have lead to a more conclusive study of this question.

A more important effect that can cause erroneous values is the often observed superadiabatic layer above the ground. Adiabatically extrapolated

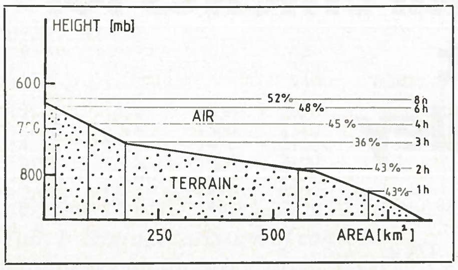


Fig. 4 Air volume in the upper Rhone Valley: The dotted area represents the terrain volume. The fine lines show the volumes in question. To the right, the hours after sunrise are shown together with the average top level of the dry adiabatic layer at those times and the percentages of air in the prisms.

ground temperatures would lead to higher heating values.

In the further discussion, the phenomenological unit in mb over heated depth has to be replaced by more physical energy units. To compute them, it is necessary to consider the topography, because the air mass per horizontal ground area is different in a valley than that over a plain. The geometrical reasoning is as follows: The top of the adiabatic layer defines a vertical prism whose side walls follow the contour lines of the top.

Fig. 4 shows the air to terrain ratio for the region in question. For the times when heating values were computed, the percentage of air in the above defined prism is determined and used as correction factor for the air mass. The so derived heating curve (C) in Fig. 3 no longer shows heat input double that obtained by Gold (A) as the straight forward solution without topography (B) did. The difference is still positive and could have several reasons:

- Error in energy computation due to the superadiabatic ground layer.
- Geometrical correction too primitive.
- less extinction of the sun-radiation due to the higher elevation.
- increased ground area (slopes)
- higher turbulent heat fluxes.

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.

2.2 Cloud base

It was found that the cumulus cloud base is directly related to the dewpoint at the valley bottom. This dewpoint varies even on days with high vertical dewpoint gradient less than expected. This suggests that there is not only static mixing of the air within the valley, but also intrusion of air on lower levels. There must be other effects, because this mechanism alone would require valley winds of about 50 m/s. It remains an empirical fact that cloud base could be estimated with the minimum nightly temperature 1.5 m above ground as representative dewpoint. Another method is to take the mean of the dewpoints of the stations Ulrichen (1345 m AMSL), Montana (1508 m) and Gütsch (2282 m) around 0900 local summer time.

2.3 Early morning temperature profile (Fig. 5)

The profile for our region can be estimated as follows:

- Above 3200 m AMSL: Sounding from an upwind station (1), then check with data from the mountain station on the Jungfraujoch (2).

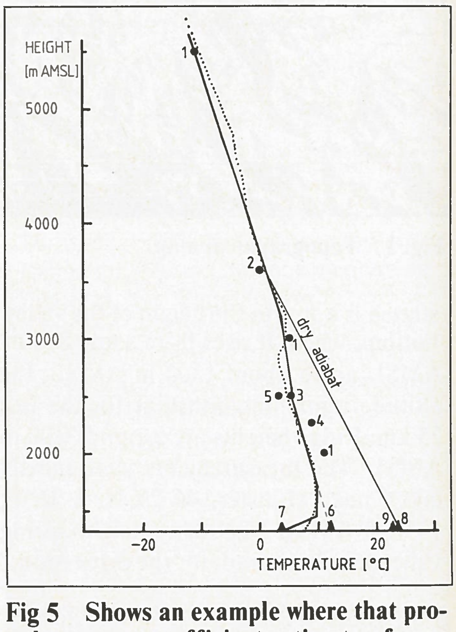


Fig 5 Shows an example where that procedure gave a sufficient estimate of even an extreme cold pool (August 20, 1981). The dotted line shows the measurement at 0820. (8) is the computed and (9) the measured maximum ground temperature. Explanations see above.

- Cold pool in the valley: Temperatures of Säntis (2490 m AMSL), (3), Gütsch (2282 m) (4) and an additional point with the temperature on 3200 m plotted on 2500 m AMSL (isothermal), (5) should be graphically averaged.
- Low level: Connection of the constructed 2500-m-temperature and the ground temperature 1.5 hours after sunrise (6) (ground inversion removed). 1800 m down to 1450 m isothermal. 1450 m down to the nightly minimum temperature (7) on the ground (1350 m).

2.4 Thermal activity

Starting with the temperature profile described above, the daily heating could be computed with the heating values from chapter 2.1.

A criterion for good or poor thermal activity was found to be the height of the dry adiabatic layer after maximum heating. Heights of less than 3700 m (600 m above ridges or 2400 m above ground) led to poor thermals.

Fig. 6 to 9 Typical wind profiles. Dotted lines: wind direction; Solid lines: wind speed;
Windprofil = wind profile;
Ballonwegprojektion = vertical projection of the balloon trajectory;
Talachse = Valley direction;

3. Valley wind system

3.1 Vertical structure

Valley and slope wind models are extensively treated by different authors and will not be treated here. The four examples of wind profiles (Fig. 6 to 9) are typical for the conditions in the upper Rhone Valley. The counterflow between heights of 2040 m (rmsd 270 m) and 2980 m (rmsd 250 m) shows up in 35 out of 42 profiles. It cannot be explained only by the backflow of the air that was brought up-valley 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 (Fig. 10), 3000 m is typical for ridge heights. This suggests an influence from neighbouring valleys that is more obvious in the horizontal.

3.2 Horizontal structure

The wind recordings 5 m above ground from two years (July, August) 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): Up-valley winds do not occur regularly. The mean of the recordings from 1981 (Fig. 11) shows only an up-valley component around noon. During the time of maximum convection, the wind blows down-valley.

There are not enough soundings during changes of wind direction to allow general conclusions to be made, but Fig. 12 shows an example of a series of three pilot balloon wind measurements. In the up-valley flow of 1157 there is no counterflow, only a slower layer around 2500 m AMSL is detectable. After the down-

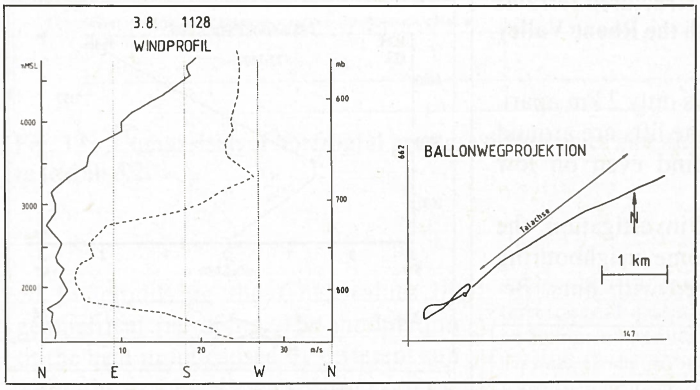
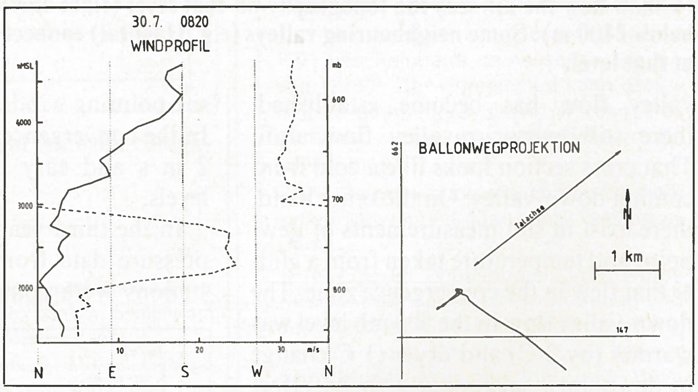


Fig. 6 Counterflow even when lower and higher winds have the same direction (SW).



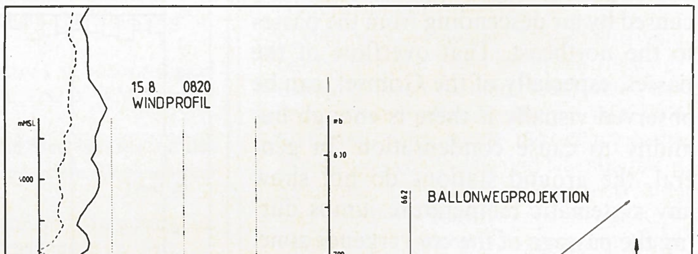


Fig. 7 and 8 Same structure of the valley flow, although gradient winds are different.

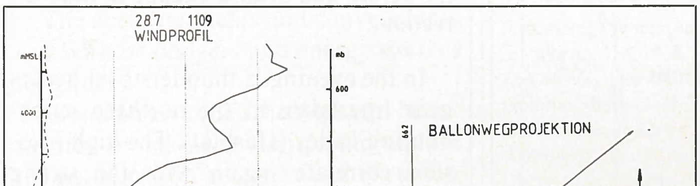


Fig. 9 Another case of strong counterflow with up-valley wind above the ground (it is more common for down-valley winds).

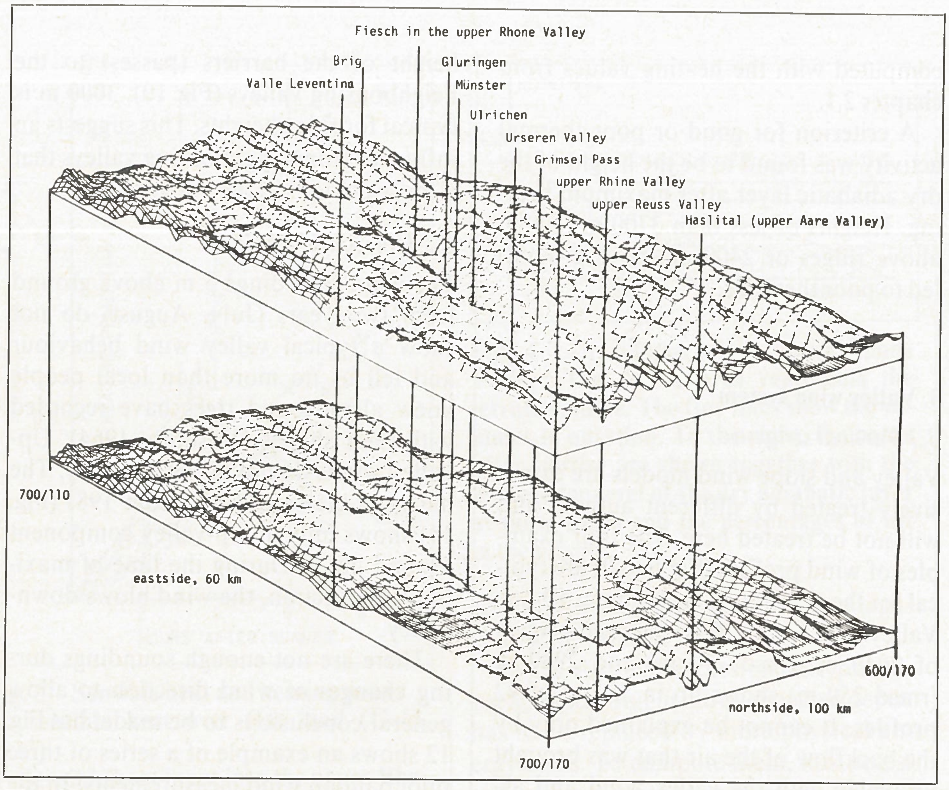


Fig. 10 The upper Rhone valley and its neighbouring valleys. Grid size is 1 km. The northwest corner has the Swiss coordinates 600/170. top: Whole topography (heights are maxima from finer resolved values within the square-km)
bottom: Topography is cut off at the 2100 m level (heights are minima in the square-km) to show how the air sees the topography on that level (flat: barrier, structured terrain: below 2100 m): Some neighbouring valleys (e.g. Haslital) connect with the Rhone Valley at that level.

valley flow has become established, there still exists up-valley flow aloft. That cross section looks like a cold front coming down-valley. On the other hand, 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. 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 the airfield. It was also detectable by opposite pointing windsacks only 2 km apart. In the convergence zone lifts are around 2 m/s and easy to find even on low levels.

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 differencies 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. 13) 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 later, but 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.

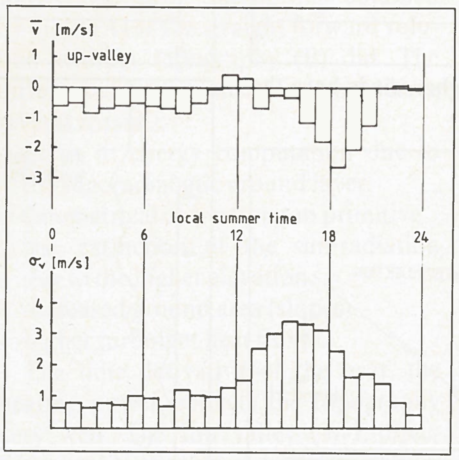


Fig. 11 Mean wind speeds and their standard deviations on 32 radiation days in July and August 1981

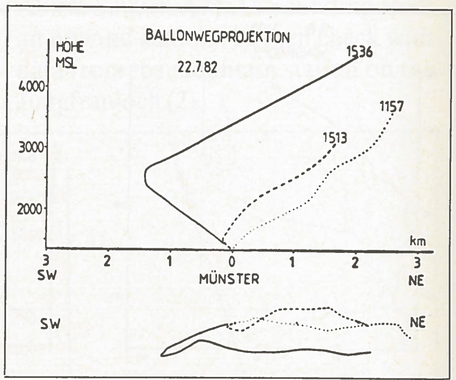


Fig. 12 Sideview and vertical projection of three balloon trajectories along the valley before and after a change in wind direction.

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 Grimsel into the Rhone valley (See Fig.1 and 10).

4. Conclusions

The diurnal variation of the temperature in mountaineous regions can be estimat-

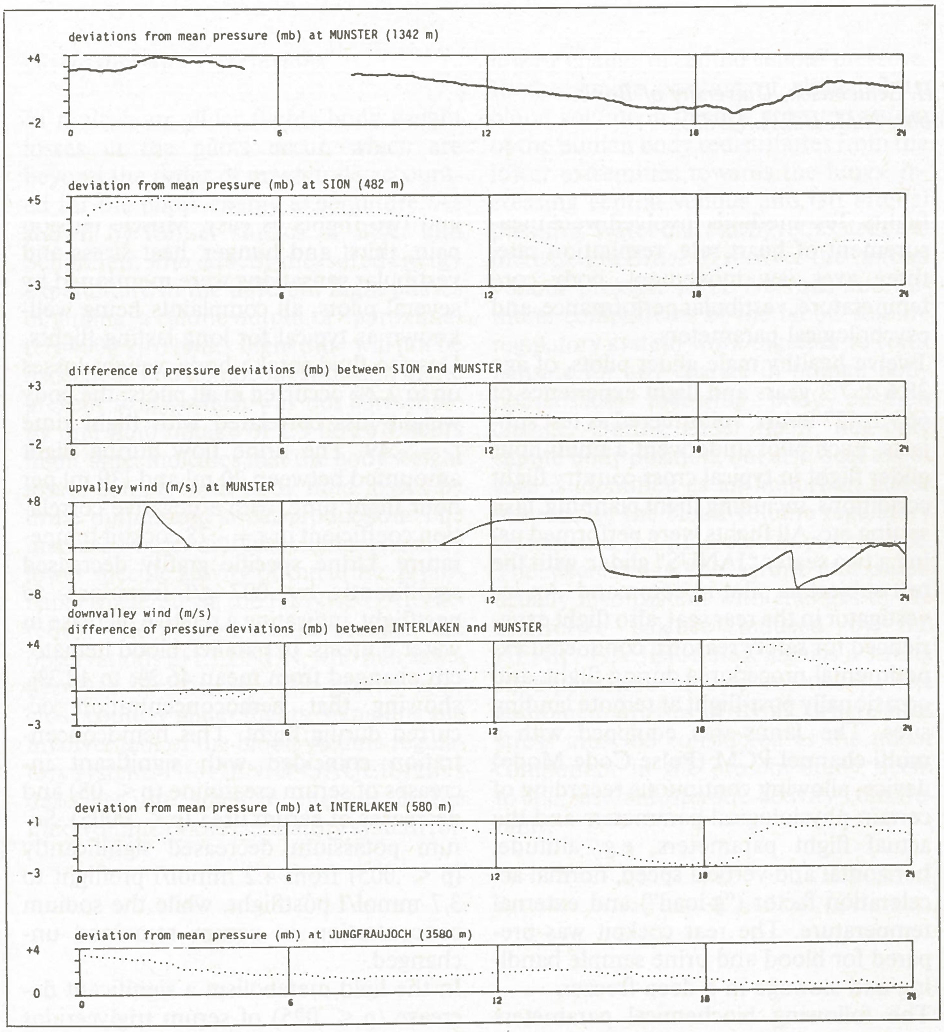


Fig. 13 Comparison of horizontal pressure differencies and wind near Münster compare text in 3.2.

ed by modifying the Gold values by geometrical reasoning. The modulation of the heat input caused by different sun azimuths to the valley axes can even explain valley internal inhomogeneities or interactions with neighbouring valleys.

The occuring shears and convergences can both be dangers and energy sources for gliders.

Cloud bases above the Alps can be estimated by taking the minimum nightly temperature of a ground weather station in the nearest valley as representative dewpoint.

5. References

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Zusammenfassung

Während den Segelflug-Sommerlagern von 1979, 1981 und 1982 im Oberwallis wurden verschiedene mesoskalige Messungen durchgeführt. Die Akademische Fluggruppe Zürich wurde dabei vom Laboratorium für Atmosphärenphysik der Eidgenössischen Technischen Hochschule (LAPETH), von der Schweizerischen Meteorologischen Anstalt (SMA) und vom Fonds für Sportwissenschaftliche Forschung unterstützt.

Während der sechswöchigen Messkampagne von 1981 wurden neben den üblichen meteorologischen bodennahen Messungen Ballonsondierungen mit Temperatur-Radiosonden und Flugzeugmessungen durchgeführt. Letztere erfolgten mit einem neu entwickelten kompakten Messgerät, das in wenigen Minuten in ein Segelflugzeug oder eine Schleppmaschine eingebaut werden kann. Weiter wurden die Wolkenbasishöhen beobachtet und Zeitrafferfilme aufgenommen.

Aus diesem Datensatz wurde ein «Rezept» gewonnen, wie mit den offiziellen Informationen (Radiosondierungen um den Alpenraum und Daten von den automatischen Wetterstationen der SMA) eine lokale Segelflugwetterprognose erstellt werden kann. Primär wurden daraus die lokalen Heizwerte berechnet. Sie waren mehr als doppelt so gross wie die von Gold (1933) für das Flachland gefundenen und zeigten gute Übereinstimmung mit 1971 von Reinhardt gemessenen Werten vom Inntal. Der Unterschied kann grösstenteils geometrisch erklärt werden. Das Verfahren wurde im dritten Jahr erfolgreich erprobt.

Die Daten erlaubten auch das Studium einiger Besonderheiten des Talwindsystems:

a) In 83% der Windsondierungen wurde zwischen der bodennahen Strömung und dem Gradientwind eine Gegenströmung gefunden, die aber stärker ist als der aus dem Modell von Buettner und Thyer (1967) erwartete Antiwind.

b) Während der zweiten Tageshälfte weht der bodennahe Wind oft in die «falsche» Richtung. Auch Yoshino (1964) stellte das anhand windgeformter Bäume fest. Eine Erklärung wird durch die differentielle Aufheizung von Wallis und Nachbartälern gefunden. Die zwischen dem normalen und «falschen» Talwind entstehende Konvergenzzone befand sich bis zu fünf Stunden innerhalb einer Talstrecke von 6 km. Üblicherweise verlagert sich die Zone mit etwa 2 m/s zur Talstufe von Fiesch hinab. Die in der Konvergenzzone auftretenden Aufwinde erlauben Segelflüge ab 300 m AGND und können die Schleppzeiten dritteln.