DEVELOPMENT OF MOUNTAIN AND VALLEY WIND CIRCULATIONS IN THE KALI GANDAKI VALLEY IN THE HIMALAYAS DURING THE WINTER

by Ludwig Weickmann, Starnberg, Germany

A Non-OSTIV Paper

Introduction

The international soaring expedition to the Nepalese Himalayas during January and February 1985 was conducted to study the feasibility of soaring in this region. An instrumented motorglider was used to measure pressure, temperature and dewpoint. The flights took place close to or within the Kali Gandaki Valley northwest of Pokhara. This valley with a length of more than 120 km and an average sloping angle of approximately 1,7° completely cuts the Himalayan range and thus connects the vast Tibetan plateau with the Indian plains almost 4000 m below.

A special scientific objective was followed with the observation of the thermally driven mountain and valley wind circulation in this unique exposure. Unexpectedly, however, no properly developed circulations of this kind were encountered with the exception of one flight on 7 February, 1985. A study of synoptic weather phenomena on a larger scale tries to explains this phenomenon.

The investigation took place some time ago. As there are plans for a second Himalalayan soaring expedition, and in view of the continuing efforts of studying mountain/valley wind circulations in different scales, it may nevertheless still contribute useful information.

Evaluation of temperature and dew point data measured by motorglider

For a description of the mission objectives and for technical details of the flights and the instrumentation reference should be made to (1) and, in particular for graphical evaluations, to (2). For this investigation the sounding data obtained by the motorglider are evaluated for height intervals of 500 m between 1000 and 5000 m m.s.l. The heights of temperature and humidity inversions or of stable layers were noted, however weak they appeared in some instances. Two such layers around 2500 and 3800 m m.s.l. were observed more regularly, though with a fairly large standard deviation in their vertical distribution (362 m and 438 m). The lower inversion is at the same height as the upper rim of an abrupt steepening of the valley and a "bend" in its direction close to Kalopani (see 1, Figures 8 and 9). This inversion was normally weaker than the higher one, frequently described as the beginning of a dry stable layer. The additional existence of a shallow ground inversion in the morning can be deduced from the low surface temperature at Pokhara at 00 UTC (06 LT). With the exception of the early parts of the flights Numbers 4

Mean temperatures (T_m) and dew points (T_{dm}) and average height of inversions between 30 Jan. - 8 Feb. 1985;
Surface measurements at Pokhara between 25 Jan.- 9 Feb. 1985.

Height (m MSL)	Number(N) of measurements	T_m (°C)	T_{dm} (°C)	Average height of inversions (m MSL)
5000	5	-11,0	-22,6	above 5000 (see Fig.3)
4500	10	-9,3	-16,6	
4000	16	-6,4	-12,0	
3500	19	-3,7	-7,7	3830 (N = 11)
3000	21	0,1	-4,6	
2500	21	3,5	-0,6	
2000	21	6,9	3,4	2410 (N = 17)
1500	20	11,1	5,5	
1000	19	15,7	7,5	approx. 900 (ground inversion)
Pokhara				
00 UTC	16	8,8	7,8	
06 UTC	16	17,9	10,2	
09 UTC	16	20,3	10,7	

TABLE 1

and 10 (2) this inversion was not found by the motorglider due to the selection of daytime periods more suitable for soaring. It is not considered in this investigation. The results are shown in Table 1.

Many of the measurements are described as "vertical soundings" which were made close to the southern entrance of the Kali Gandaki Valley. No significant change of air masses was observed at the layer of the flights. The mean values calculated from the measurements are therefore regarded as representative for the lower atmosphere at the entrance of the valley during the period of the expedition. They are limited to 09 to 17 LT with a maximum around 12 LT.

Valley winds measured by Flight Number 7 show speeds around 10 m/s in the lower part of the valley, 15 m/s in the upper part and a minimum with 5 m/s in between. This minimum occurs at the height of the bend mentioned above where the slope and the direction of the valley and thus of the wind direction changes. It indicates a separation area of two different valley wind circulations and it is interesting to note that at least the inversion around 2410 m coincides with this discontinuity in the valley floor. While the occurrence of these valley winds was the expected phenomenon, why was it not observed on other days?

The measurements of the motorglider flights were restricted more or less to the small scale of layers up to 4-6000 m m.s.l. within the local valley atmosphere. As the area envolved extends from northern India to Tibet over distances of more than 1000 km it is necessary to consider the synoptic background, i.e. circulations at a much larger scale and at higher levels.

Conditions in the upper troposphere

There are no radiosonde stations close to the expedition area. As a substitute it was endeavoured to obtain the required data by interpolating vertical meridional cross-sections available from (3) for the meridian 78 E, for their intersection point with the southern slopes of the Himalayas. Though situated some 5° W and 2° N from the area under investigation the exposition of both locations can be considered as identical. These sections were based on the more distant radiosonde stations from India, the People's Republic of China and the former USSR for the period 28 January to 12 February 1985. The data for India are largely determined by the radiosonde ascents at Patiala (42101), New Delhi (42182) and Lucknow (42369). The next station far to the north is Hotan (51828) in the Tarim Basin. The large plateau and mountain area in between is not represented by any station.

Temperatures at standard pressure levels up to 100 hPa were extracted from the cross-sections. The results revealed two significantly different vertical stratifications. Commencing between 500 and 400 hPa the differences between the highest and lowest temperatures are abruptly increasing almost threefold and are connected with jet stream positions north or south of the area. This could obviously not be recognized at the levels of the expedition flights. One of the important transition days and the only day with strong up-valley winds was even characterized by the remark "weather conditions were completely different despite the fact that the synoptic situation had not changed" (2, Flight NEPAL 11, 7.2.85). It was, incidentally, the day with the warmest troposphere during the expedition period. Table 2 shows the mean values for the period 28 January - 12 February 1985, the mean temperatures at the different jet stream positions and the temperature range between these positions.

Mean temperature (°C) at standard pressure levels (hPa) for the period 28 Jan. - 12. Feb. 1985 and temperatures as well as differences for the northern (N) and southern (S) jet stream positions.

Standard pressure levels	Mean values	Jet positions N	Jet positions S	Diff. N - S
100	-74,5	-77,8	-69,5	-8,3
150	-63,2	-66,2	-60,0	-6,2
200	-50,5	-49,8	-51,5	1,7
250	-44,1	-40,0	-49,3	9,3
300	-37,1	-31,0	-43,8	12,8
400	-25,6	-20,0	-29,2	9,2
500	-15,9	-14,4	-17,3	2,9
600	-6,6	-7,0	-6,8	-0,2
700	+0,9	+1,0	+0,5	0,5
850	+9,6	+11,0	+7,7	3,3

TABLE 2.

The lowest levels can be adjusted without difficulty to the motorglider data (see Table l) which supports the assumption of a very close similarity of the two areas.

An analysis of the upper winds (3) shows three jet stream cores shifting from S to N and back again during the expedition period. Their latitudes, pressure levels and speeds for individual days are shown in Figure 1. The latitude of the entrance of the Kali Gandaki Valley is marked.

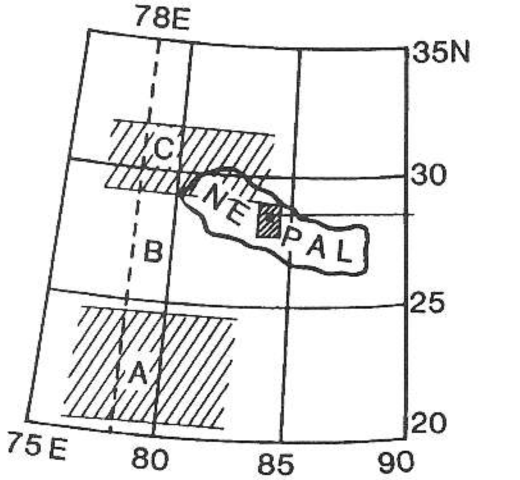

FIGURE 1. Fluctuation of the axis of jet streams within zonal belts A(28 Jan-2 Feb),B (3-6 Feb; 12 Feb), C (7-11 Feb 1985). Dashed line: Position of cross section. Expedition area shown by hatching in Nepal.

The two upper cores indicate a splitting of the subtropical jet stream. The height of the lower one between 300 to 350 hPa better corresponds to a frontal jet possibly related to an aged polar front. This may be suported by an airmass boundary found sloping southward with an angle of approximately 1:500 and reaching Hyderabad between 600 to 700 hPa. The lower jet appears to be a phenomenon also observed in other years during the winter (see 1, Figure 4). As mentioned above the temperature extremes are related to jet stream positions north and south of the expedition area. They cover the following dates:

28.1. - 2.2. core of lowest jet stream south of the area.

7.2. - 11.2. core of lowest jet stream north of the area.

From 3.-6.2. and on 12.2. the core was above the area.

The location of the jet streams in relation to the expedition area is shown in Figure 2.

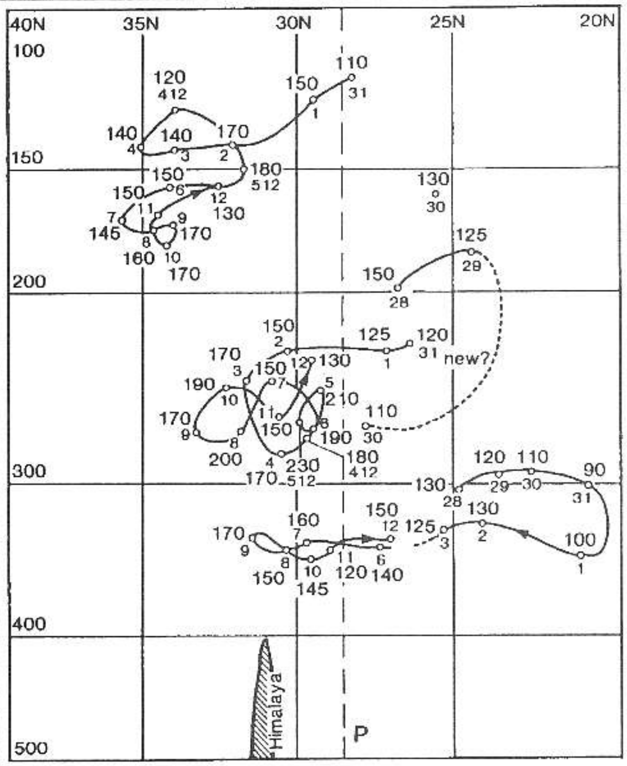

FIGURE 2. Position of jet stream cores for the period 28 January to 12 February 1985. Upper figure at each position = maximum wind speed in knots. Lower figure = date of observation (date without time refers to 00 UTC). Dashed line: Latitude of Pokhara.

The vertical temperature distributions for the northern and southern jet stream positions are shown in an aerological diagram as "synthetic TEMPS" in Figure 3.

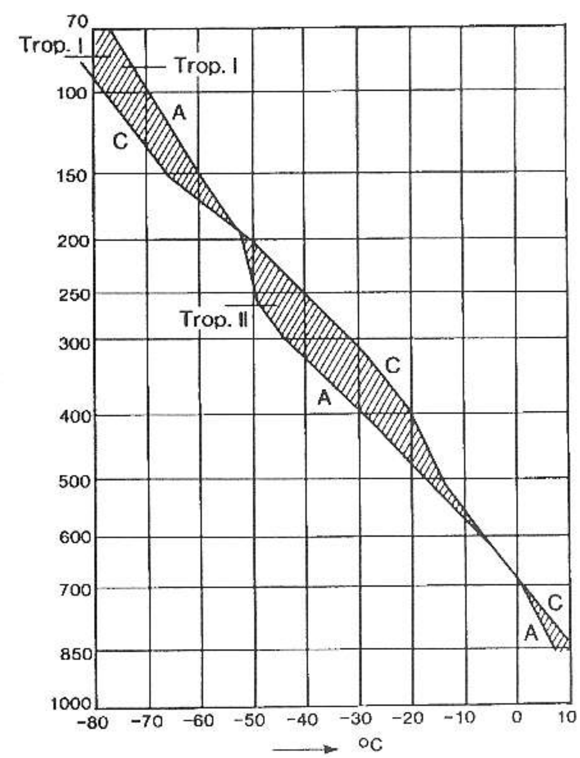

FIGURE 3. Mean vertical temperature distribution and heigth of tropopauses at 30N 78E for the position of jet streams north (C) and south (A) of Nepal.

The two curves demonstrate clearly the temperature changes in the upper troposphere connected with the lateral shifts of the jet streams. The changes commence somewhat above the level of the Tibetan Plateau and include the Himalayan peaks. The southern position is connected with two tropopauses corresponding to the

Pressure hPa and surface temperature °C at the Stations Andir/Takla Makan and Pokhara/Nepal, period 28 January to 8 February 1984.													
Date	28	29	30	31	1	2	3	4	5	6	7	8	
Andir (sea level pressure)													
00 UTC	43.4	38.2	35.7	37.2	32.0	26.4	18.7	15.0	17.7	22.4	16.1	09.0	hPa
	-15	-16	-10	-14	-17	-16	-14	-12	-8	-5	-10	-6	°C
12 UTC	39.9	36.9	-	33.3	28.1	22.2	17.6	13.2	-	16.6	09.3	08.9	hPa
	-4	-3	-	+1	+1	+1	+2	+2	-	+7	+7	+6	°C
Pokhara (station pressure, decimals not available)													
00 UTC	922	924	923	922	921	921	921	917	914	914	914	915	QFE
	8	9	9	8	8	6	8	11	10	11	7	12	°C
11 UTC	924	922	921	918	921	919	917	916	911	913	914	913	QFE
	18	18	20	18	14	18	16	16	16	18	18	16	°C

TABLE 3.

the beginning and the end of the expedition period. Moreover, by upward reduction using the midday temperatures it was calculated at which pressure levels the gradient would become zero. Table 4 shows the result.

The zero gradient level and the reversal of the gradient from south to north is always situated below the level of the Tibetan plateau which therefore reaches into the westerlies above. The exact gradient at plateau level is of course not known.. The pressure level at which the gradient through the plateau changes direction was gradually lowering from 751 hPa to 881 hPa. Below these levels the gradients would be directed against the valley winds in the Kali Gandaki valley.

normal winter circulation in this area. The northern position shows only the high tropical tropopause.

Conditions upon the Tibetan Plateau

No surface weather reports were available from the Tibetan Plateau to the north of the Kali Gandaki Valley. From beyond the plateau data from the station Andir (3756N 8339E, 1264 m) in the Takla Makan basin are shown in Table 3 in comparison with Pokhara (2812N 8359E, 824 m). The period with low temperatures in the upper troposphere (jet south of Nepal) is obviously connected with high surface pressure and low temperature to the north and over the Tibetan plateau. This anticyclonic influence has disappeared with the onset of the higher temperatures aloft. The data show the significant warming by about 10 K in the basin during this period, connected with a drop of the sea level pressure of 30 hPa.

Eliminating the effect of pressure reduction to sea level the change still amounts to approximately 20 hPa. The changes of temperature and pressure at Pokhara are considerably smaller during this period.

In order to assess the direction and magnitude of the fictitious horizontal pressure gradients through the plateau between the two stations, disregarding the mountain barrier, the pressure was reduced to comparable levels. This was carried out for the two extreme days at

The one occasion with strong up-valley winds coincides with a minimum of this gradient against the thermal circulation.

Inversions and resulting thermal circulations

The occurrence during the day of three stable layers, i.e. at approximately 2500 m and 3800 m m.s.l. (see Table 1), the third above 5000 m m.s.l. should lead to three thermal circulations, each with a thickness of 1200-1500 m. A fourth circulation without upper limit, if not the tropopause, is to be anticipated above these layers as a combination between mountain waves and thermal currents. At this layer the convection seems to start in the morning, gradually working its way downward (see 1, Figures 10 and 11).

These four circulations are shown schematically in Figure 4.

1. Up-valley circulation from the plains of India and Nepal up to the first stable layer at approximately 2500 m m.s.l.;
2. Up-valley circulation between the first and the second stable layer at approximately 3800 m m.s.l.;
3. Up-valley circulation between the second and a third stable layer found in the cross-sections above 5000 m m.s.l.;
4. Dynamic and convective circulations around summit levels, no thickness limitation.

Pressure differences (hPa) across the Tibetan Plateau between Andir and Pokhara on 28 January and 8 February 1984						
Level	28.1.		8.2.		28.1.	8.2.
					Pressure differences	
	Andir	Pokhara	Andir	Pokhara	Andir-Pokhara	
m.s.l.	1039.9	1016.9	1008.9	1005.5	23.0	3.4
Pokhara 824 m	938.5	924	914.4	913	14.5	1.4
Zero Gracient				881		0
Andir 1254 m	887.8	877.3	866.2	866.5	10.5	-0.3
Zero Gradient		751			0	

TABLE 4.

With the possible exception of the circulation at summit level it should be emphasized that no direct influence upon the development of thermal circulations at lower levels is expected from the position of the jet streams. Their positions, however, may serve as an indication of a significantly different stratification of the atmosphere north and south of the jet axis and might be more useful for prognoses than weather reports from a few mountain stations at largely different levels. The differences in the up-valley cir-

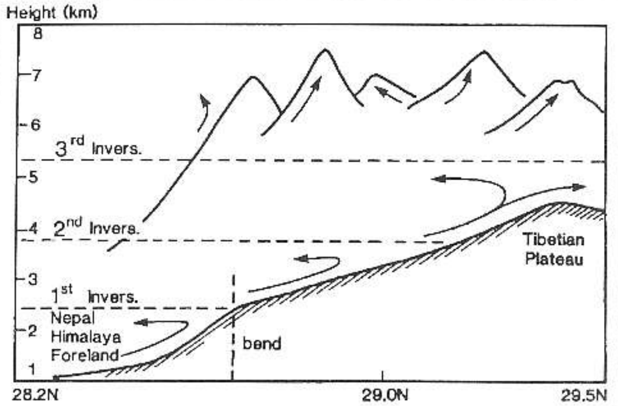

FIGURE 4. Schematic drawing of possible structures of up-valley circulations in the Kali Gandaki valley, Nepal.

culations as observed in connection with the various jet stream belts could thus be explained as follows:

- Jet stream south of the expedition area:
  The plateau is covered by cold air and acts as a heat sink;
  The amount of heating required to initiate thermal circulations is high;
  The barometric pressure upon the plateau is high and favours divergence;
  Up-valley circulations have little chance of development.
- Jet stream above the expedition area:
  Cloud layers forming or drifting in the jet stream will reduce the radiational heating and thus suppress the development of thermal circulations;
  Dynamic lifting or development of lee waves occurs at the highest levels.
- Jet stream north of the expedition area:
  The plateau is covered by warm air;
  The amount of heating required to initiate thermal circulations is low;
  The barometric pressure upon the plateau is low and favours convergence;
  Up-valley circulations have a good chance of development.

The jet stream positions in the south considered above as unfavourable for the development of thermal circulations have covered most of the expedition period. It is understandable, therefore, that only one day with intense up-valley circulations was observed, and this occurred while the jet was crossing the area northwards.

Conclusion

Due to the vertical extent of the Kali Gandaki Valley of almost 4000 m it reaches into fundamentally different circulation regimes. This contrasts with most other, e.g. alpine valleys. The vertical structure of the atmosphere in this valley and above seems to favour the development of up to four circulations one above the other along the southern slopes and between the peaks of the Himalayas. The activation or suppression of these circulations indicates a relationship to the winds in the upper troposphere and on surface pressure gradients. The latter are largely fictitious and difficult to evaluate owing to the extreme mountainous terrain and correspondlng pressure reduction problems. The position of jet streams to the north or south of Nepal may therefore be used as a substitute. This investigation emphasizes the necessity of considering large scale circulations when thermal currents are to be studied in this area.

Literature

(1) First results of airborne measurements of the mountain valley circulation in the Kali Gandaki Valley, Nepal, by motorglider. M.E. Reinhardt et al., OSTIV Publication XVIII, 1985.

(2) Meteorological Aircraft Data Set of the First Himalayan Soaring Expedition. B. Neininger, M. Reinhardt, DFVLR-FB 86-39.

(3) Large scale analysis of meteorological phenomena for the period of the "First Himalayan Soaring Expedition", L. Weickmann, Technical Soaring, Vol. 12, No. 2, p. 46-51 (1988).