First results of airborne measurements of the mountain valley circulation in the Kali Gandaki Valley, Nepal, by motorglider

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Abstract

The mountain valley circulation in one of the deepest valleys in the world, the Kali Gandaki Valley in Western Nepal was studied by an instrumented motorglider. As favourable time between the monsoon periods the months of January resp. February 1985 have been selected for measurements of the three dimensional temperature-, humidity-, and windfield along the valley axis. First results are presented. The very steep mountain range seems to create atmospheric structures of high complexity, not alone effecting the westerly airflow as an obstacle but also forming special circulations by interaction of local and regional scale subsystems under the influence of daily and seasonal variations. The vertical exchange seems to play an important role to be of a multilayer character starting the convection in the highest layer early in the morning then stepping down in the valleys.

Introduction

Mountain valley circulations due to heating of the mountain area are well known and often described [1-10]. But especially for very steep and complex areas like the Nepalese Himalayan mountain range there is less knowledge. Most experience is reported by mountaineers and by pilots who are operating the twin engine, short landing aircrafts for transportation of passengers and material to and from the local - often very remote - airfields in the Himalayan region.

There are also very few stations for surface measurements and upper air soundings and therefore we have not sufficient information about synoptic and mesoscale wind systems at that area.

Thus it was of high interest to study in a first pilot project a mountain valley circulation system that seemed to offer best chances for a well formed system with most regular variations of the windfield during the local day. Such a place was found with the Kali Gandaki Valley, where local people [11,12] experienced and reported about it, and surface observations on wind-shaped trees gave good indication for a well defined system [13].

Area of research

Figure 1 and 2 show the area of the motorglider measurements in the mountain range of the Nepalese Himalayan region with the Kali Gandaki Valley.

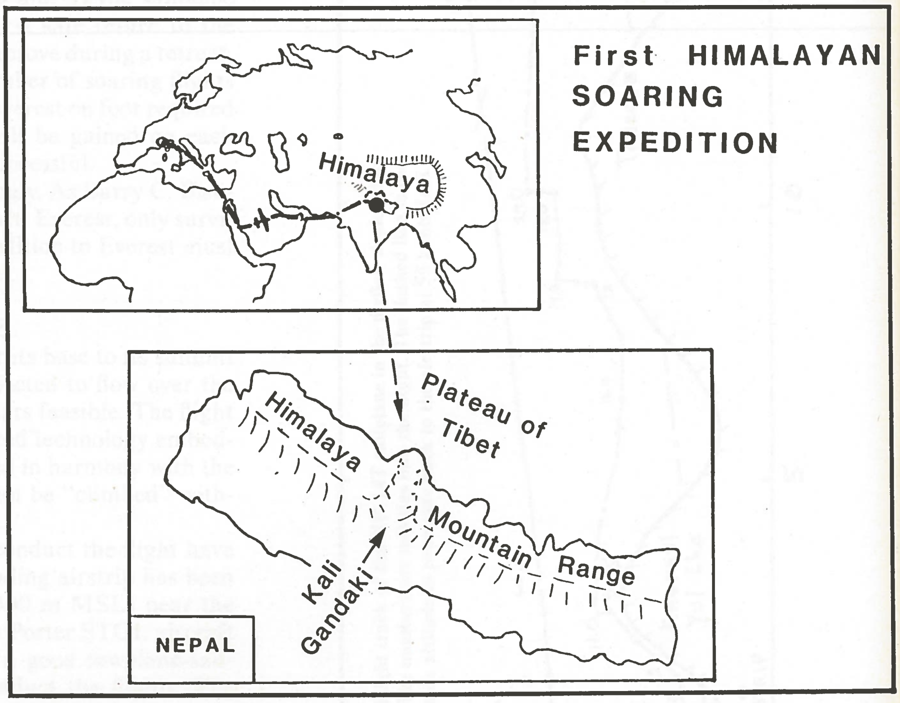

Figure 1: **Area of motorglider measurements in the Nepalese Himalayan mountain range of the Kali Gandaki Valley.**

Figure 3 is giving a good impression of the overall situation from a birds view. The Landsat visible image shows, how the Kali Gandaki Valley cuts from South to North through the high mountain barrier of the high range of the Nepalese Himalaya, starting with the valley bottom at about 1000 m MSL at the southern entrance between Dhaulagiri I (8167 m MSL) and Annapurna I (8091 m MSL), which both summits are only 35 km apart, and then rising to about 4000 m MSL when reaching the Tibetian plateau about 120 km north of the valley entrance.

Period of measurement

Pre- and post-monsoon period are most favourable times for studying the objectives of thermal induced mountain valley circulations in the Himalayan region. Statistical evaluations of a one years sounding period of an upper air station at Kathmandu for 1978 show in Figure 4 a) and b) very systematic windfield characteristics for the months of January, February and March.

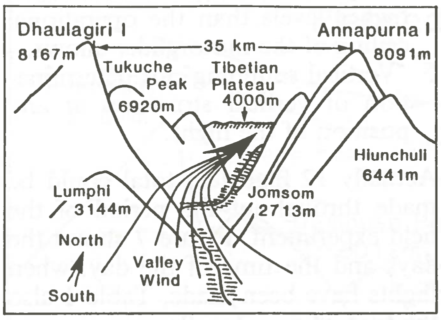

Figure 2: **Inflow region of the Kali Gandaki Valley with its main mountain ranges.**

Besides of local variations the general airflow for the 1200 UT soundings is of westerly direction with the windspeed increasing from an average of 10 knots at 700 hPa to a maximum in average of about 100 knots at 200 hPa during Februar and March. There is a high persistency of more than 90% for the existence of a jetstream with windspeeds greater than 90 knots between 9 to 14 km for the month of February. Figure 5 shows this for the years 1978 and 1979.

Since Kathmandu itself is situated in the foreland of the Himalayan mountains it was expected to find suitable situations in the inner lower range of the mountains, the Kali Gandaki Valley northwest of Pokhara, for development of well expressed mountain valley circulations as well as mountain induced wave formations in the higher levels of the mountain ranges, especially those formed by a perpendicular orientation of mountains to the westerly airflow.

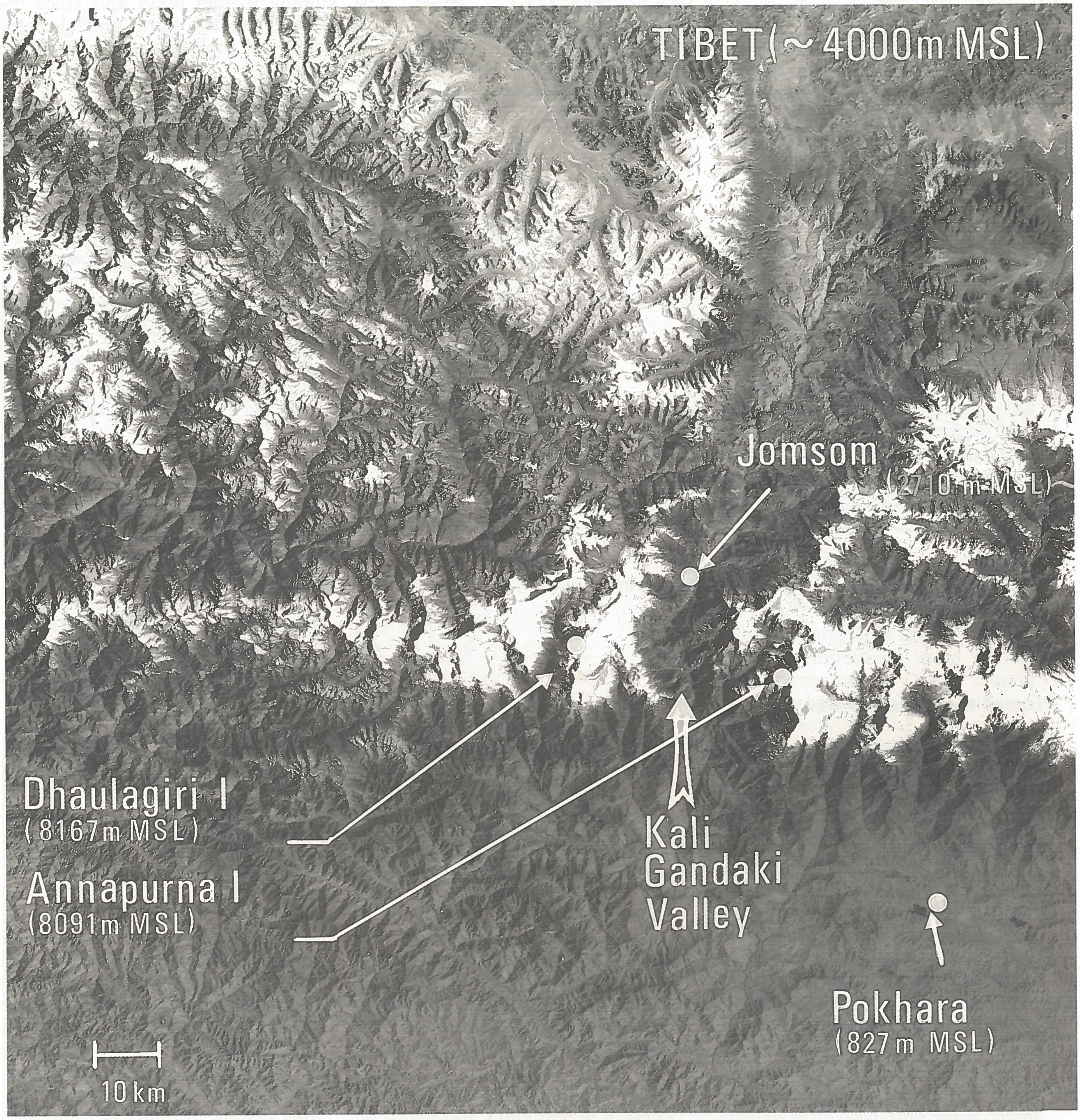

Figure3: **Landsat image of the Western Nepalese Himalayan mountain range with the Kali Gandaki Valley, cutting from South to North through the mountain barrier. (NASA Landsat E-2 Image, 22. March 1977)**

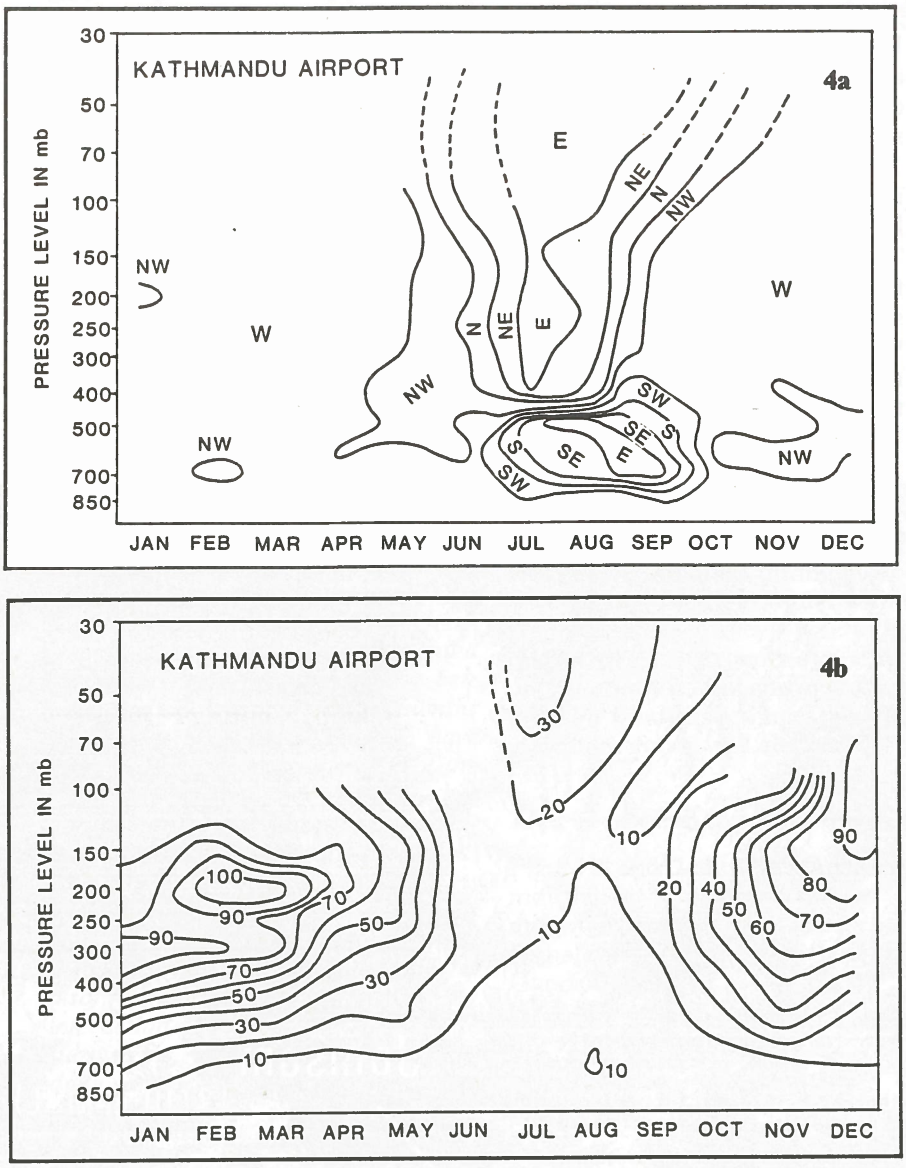

Figure 4: Mean resultant wind direction 4a) and wind speed 4 b) of upper air soundings at Kathmandu Airport for 1978, 12:00 UT.

Planned and actual missions

Based on the above mentioned assumptions of formation of a mountain valley wind system in lower levels during the day and an existing or developing wave formation in the upper levels 4 types of optional missions were envisaged (Figure 6):

1. "Inflow core position" for determination of the wind speed distribution over different valley cross sections along the valley axis,
2. "Inflow core variation" for determination of time variation over the core area,
3. "Gate mission" for determination of the inflow pattern and strength direct at the entrance of the valley,
4. "Wave mission" for determination of the wave pattern in different heights and positions along the valley and its usage for climbing to higher levels than the operational ceiling of the motorglider allows,
5. "Vertical sounding" for determination of vertical structures at any position of the flight.

Actually 12 flights in total could be made throughout the period of the field experiment. Figure 7 shows the days and the time of the day, when flights have been made, Table 1 also the type of missions flown.

Preliminary results

Based on very first evaluations including written notes and voice recorded remarks some general statements and preliminary results can be given:

1. Not all proposed missions could flown at all. As Figure 7 shows, the 3 afternoon flights NEPAL 6, 8 and 11 are relatively short due to the developing convection along the main slope in the afternoon,

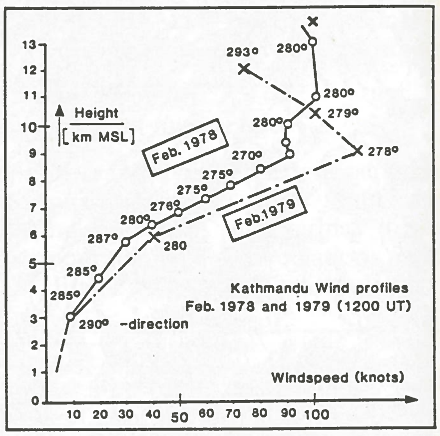

Figure 5: Kathmandu mean wind profiles of February 1978 and 1979 soundings at 12:00 UT.

Flight No.	Date	Inflow mission Pos. 1)	Inflow mission Var. 2)	Gate mission 3)	Wave mission 4)	Vertical sounding 5)
1	30.1.85					x
2	31.1.85					x
3	1.2.85					x
4	2.2.85					x
5	3.2.85	x				x
6	3.2.85					x
7	4.2.85	x				x
8	4.2.85			x		x
9	5.2.85					x
10	7.2.85	x				x
11	7.2.85		x			x
12	8.2.85					x

Tabelle 1. Type of missions flown at Pokhara during the expedition time from 30. January to 8. February 1985.

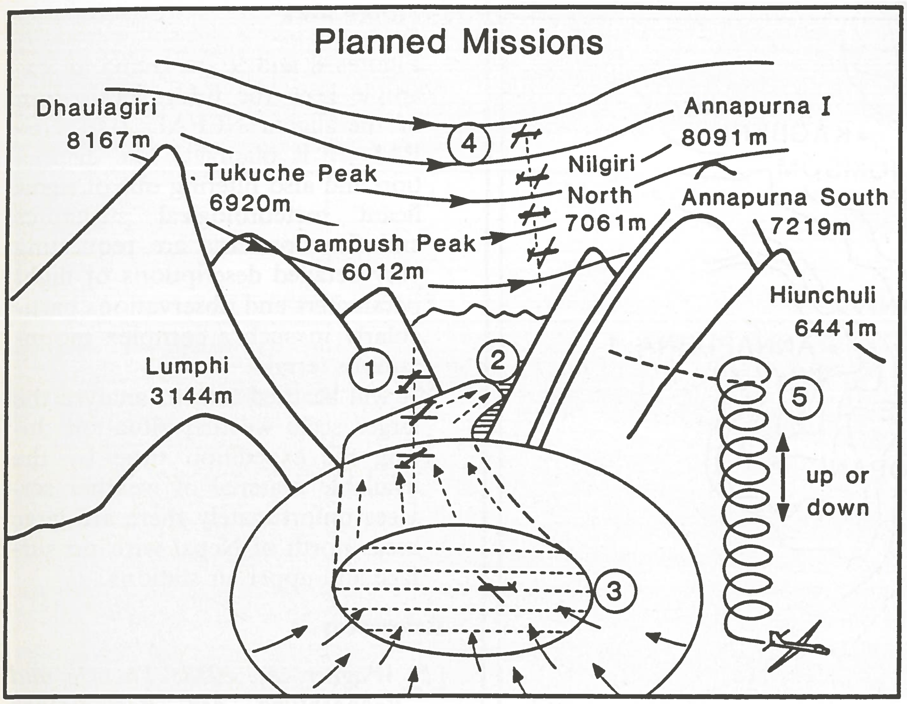

Figure 6: **Planned missions for the Kali Gandaki field experiment: 1) Inflow core position, 2) Inflow core variation, 3) Gate mission, 4) Wave mission, 5) Vertical sounding.**

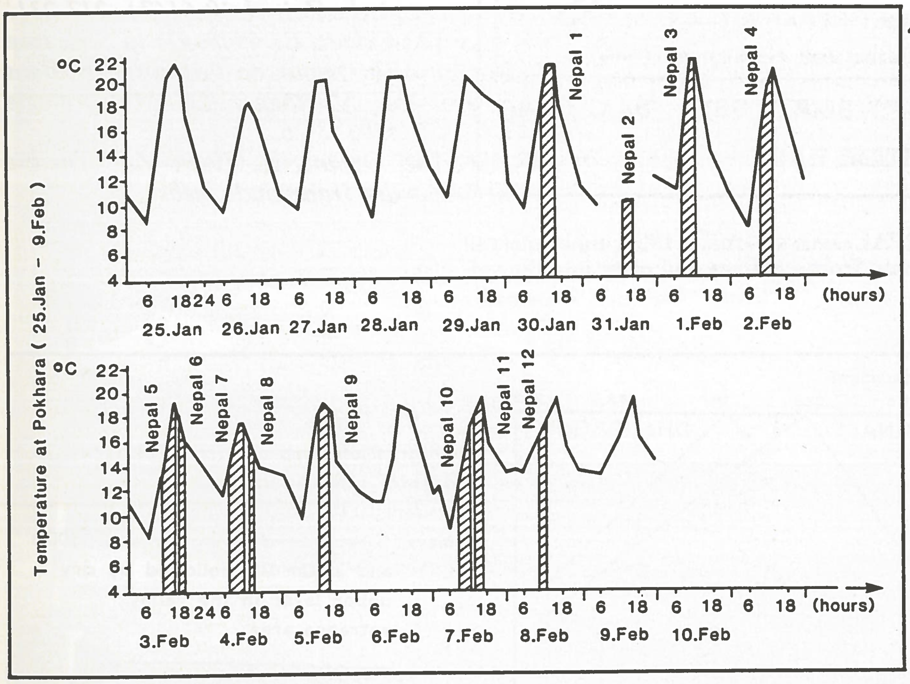

Figure 7: **Daily Pokhara surface temperature variations during the Kali Gandaki field experiment with the flight intervalls of research flights NEPAL 1 to NEPAL 12.**

which closed the valley entrance and made it impossible to enter the Kali Gandaki Valley for continuing the structure flights from the morning. Only flight NEPAL 11 gave opportunity to study and to confirm the daily variation as it was expected from some surface recordings at Jomsom airfield and known from previous observations. Apparently situations of dryer airmasses passing along the mountain barrier in the larger synoptic scale have to be used in the future to study the full developed mountain-valley cirulation by aircraft.

2. "Inflow missions" could be made in four cases. Only one of it, flight NEPAL 11, flown at the same day, shows all characteristics of a well developed mountain-valley wind system.
3. "Gate missions" have been tried, when inflow missions have not allowed to penetrate into the valley due to the cloud situation. For the airflow the terrain of the entrance into the Kali Gandaki up to a position between the two "posts" Dhaulagiri and Annapurna seems to be of high complexity of the valley itself and the influence of the side valleys cannot be neglected. There was no indication of a locally concentrated strong inflow region at any cross section and near to the entrance. The system forms as the valley becomes a more defined shape of its cross section about 20 km north of the general mountain barrier, it seems to be combined with a steplike upsloping of the valley bottom near the "bend", where the valley turns form a north-northwesterly in a north-northeasterly direction and the bottom rises from an elevation of 1200 m MSL near Tatopani to about 2500 m MSL at Kalopani (Figure 8 and 9).
4. "Wave missions" have not been flown.

Normally mountain lee waves could be expected to be formed in combination of the mountain ranges with the always persisting westerly airflow over the Himalayan region. No waves have been encountered during the period of the field-experiment. Observations as in Figure 10 show wave clouds above the high mountain ranges of the Annapurna region. Having very early in the morning a clear laminar lenticularis form of clouds over the mountain range of the Annapurna massiv these clouds are disturbed by an early onset of the convection in the highest layer of 6000 to 8000 m MSL between 07:30 and 09:00 hours local time. Figure 11 indicates this by the rising cloud bubbles out of the laminar lenticularis flow pattern, moving from left to right in the general direction of the jetstream from West to East. The time lapse documentation will allow later on a more exact evaluation of the flow at this height. But it is a clear indication, that on such days and time of the year the convection starts in the highest level between 6000 and 8000 m MSL, followed by a middle layer between 3500 and 6000 m MSL and then developping the convection in the bottom layer as last layer.

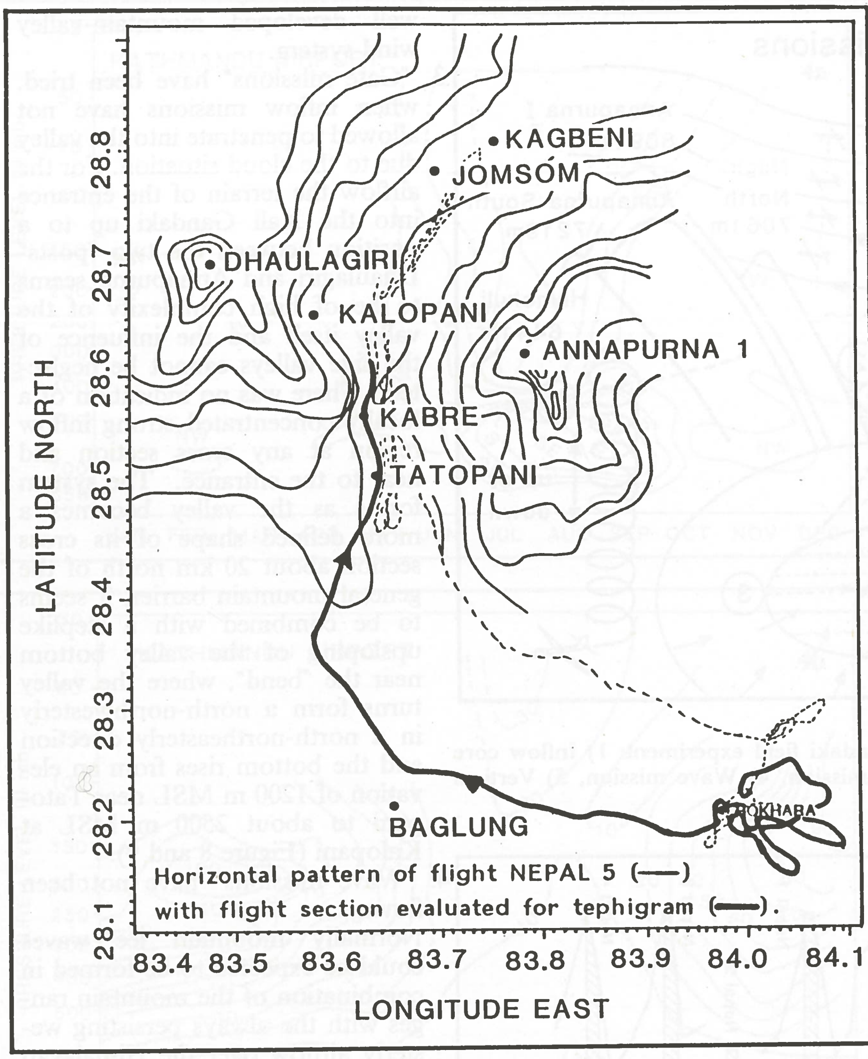

Figure 8: **Horizontal pattern of flight NEPAL 5, 3. February 1985, time intervall 10:39:48 - 12:03:15 local time, here climb-out from Pokhara and entry into the valley.**

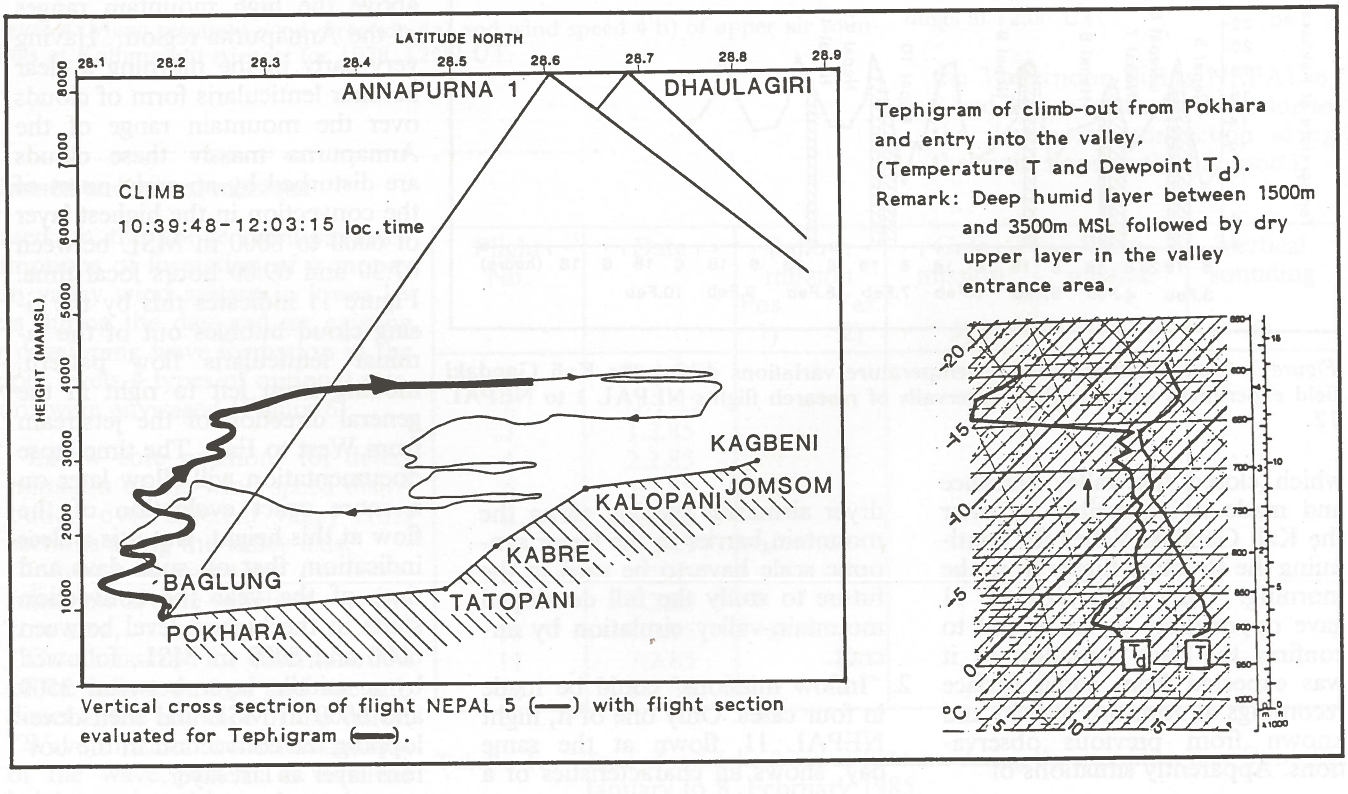

Figure 9: **Vertical cross section of the same flight intervall as in Figure 8.**

Future work

Figures 8 and 9 are giving an example how the future evaluation of the flights NEPAL 1 to NEPAL 12 is planned. The distinction and also filtering out of significant meteorological structures and flow patterns are requesting very detailed descriptions of flight parameters and observations particularly in such a complex mountainous terrain.

It will be tried also to analyze the larger scale weather situation during the expedition time by the available material of weather services unfortunately there are large areas north of Nepal with no surface and upper air stations.

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Figure 10: **Lenticularis wave formation above the Annapurna massiv as observed in the early morning from Pokhara. (Foto by courtesy of M. Rösler, 1964)**

Figure 11: **Lenticularis cloud field disturbed by first thermal activity in the morning between 07:30 and 09:00 hours local time in the height region of 6000 to 8000 m MSL as observed on the 30th of January 1985 from Pokhara.**

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