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# Comparison of Meteorological Observations at Mt. Everest and K 2: Examples of the 1984 and 1986 Expedition

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With 6 Figures

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**Summary**

Meteorological observations in the eastern part of the Himalayas (Tibetan side of Shisha Pangma and of Mt. Everest, 1984) are compared with observations of the Karakoram (north side of K 2, 1986). Both sites are characterized by different weather patterns within the global circulation. This is evident also in the expedition data obtained during September and October 1984 and 1986. Temperature gradients and the development of the daily wind system of the two areas are shown.

## 1. Introduction

The Himalayas are situated in the subtropical high-pressure belt. In winter the climate is characterized by troughs of low pressure in the westerly circulation, which cause high rainfall in NW Himalaya. In summer the middle and eastern regions are influenced by high monsoonal precipitation. The dividing line separating these two weather regimes is located around 80 °E.

The Karakoram climate is not only strongly influenced by troughs of low pressure during winter, but also by the Indian SW monsoon. This results in maximum precipitation during March and August. In contrast the Himalayan climate of Nepal is largely determined by the moist southeasterly monsoon together with relatively dry air connected with westerly winds. Locations on the south side of the high mountain ranges like Srinagar and Kathmandu show show a moderate climate with maximum daily temperature range of 10 to 20 K. On the north side the maximum daily temperature range at Leh and Lhasa is 30 to 40 K. Here the nights are about 20 K colder than on the south side, whereas the days are no more than 4 K warmer. Precipitation is highest on the windward side of the mountains and lowest in the lee of the mountains. A more detailed description of the Himalayan climate is given in Lüdecke (1983).

During 1984 and 1986 two expeditions were carried out under the leadership of M. Kuhle (Geographical Institute, University of Göttingen) together with the Lanzhou Institute of Glaciology and Cryopedology (Academia Sinica China). The first was to Shisha Pangma (Xixabangma, 8 046 m) and Mt. Everest (Qomolangma, 8 848 m) and the second to K 2 (Chogori or Mt. Godwin Austen, 8 616 m). The main objective of the expeditions was to investigate the geoecology and to verify an autocycle hypothesis of the pleistocene glaciation of Tibet and the onset of ice ages (Kuhle 1988 a, b, c). An analysis of temperature, humidity, wind speed, wind direction, and radiation measurements taken at different heights on the northern sites of these mountains is reported here.

## 2. Materials

The first base camp of the 1984 expedition was situated at 5 000 m at 28°36′ N 85°45′ E on the snow-free Tibetan Plateau on the north slope of Shisha Pangma (Fig. 1). Here is one of the rare regions where the high Himalayas come in direct contact with the Tibetan Plateau without intervention by the Tibetan Himalayas, as is the case for the north side of Mt. Everest (Kuhle, 1988 d). Measurements were taken from 7 September to 16 September 1984 by portable instruments such as a thermohygrograph and a Woelfle anemograph.

Mt. Everest base camp was located at 5 130 m at 28°11′ N 86°51′ E in the forefield of the moraine covered Rongbuk Glacier, about 17 km north of the mountain peak (Fig. 2). Measurements were carried out from 17 September to 4 November 1984 and were taken by the same instruments as on Shisha Pangma.

K 2 base camp was established at 4 130 m at 36°02′30″ N 76°72′ E in front of the moraine covered glacier tongue, about 23 km north the peak (Fig. 3). Besides the type of instruments that were used during the 1984 campaign, a star pyranometer (after Dirmhirm) and a radiation balance meter (type Schenk) were operated from 3 September to 12 October 1986. Glacier camp on top of the middle morain at 4 600 m at 36° N 76°28′20″ E was equiped with a thermohygrograph and a Woelfle anemograph from 11 September to 11 November 1986. Névé camp lay in the firn basin at 5 330 m below the north side of K 2 at 35°54′30″ N 76°29′ E. An automatic station was installed on a snow surface consisting of a temperature and humidity sensor, a combined wind measuring device for speed and direction, a star pyranometer (after Dirmhirn) and a radiation balance meter. Data were obtained for the period 21 September to 7 October 1986.

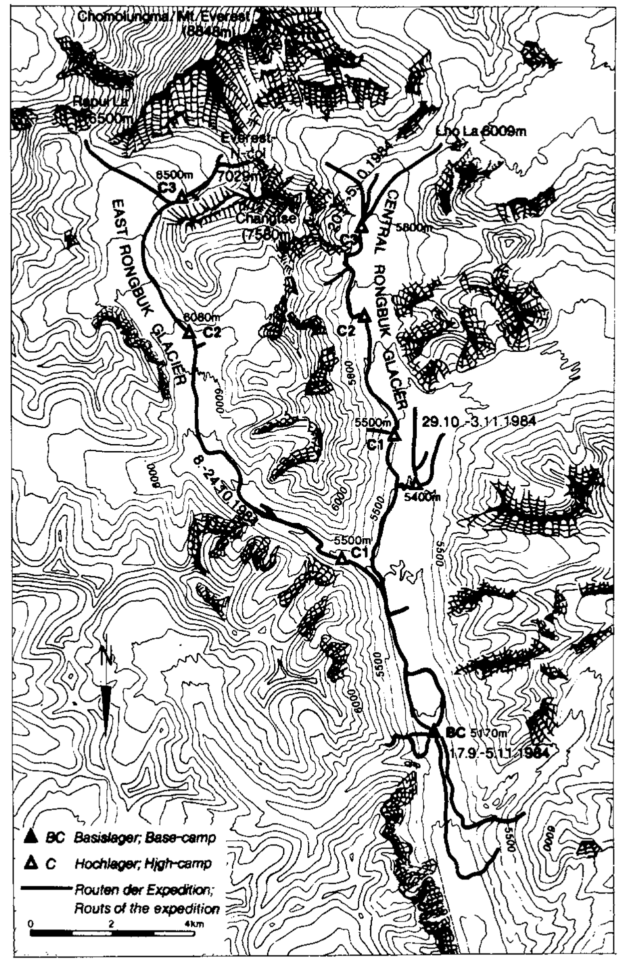


Fig. 2. Sketch of the N side of Mt. Everest with base camp marked as BC. Note S is on top of the sketch

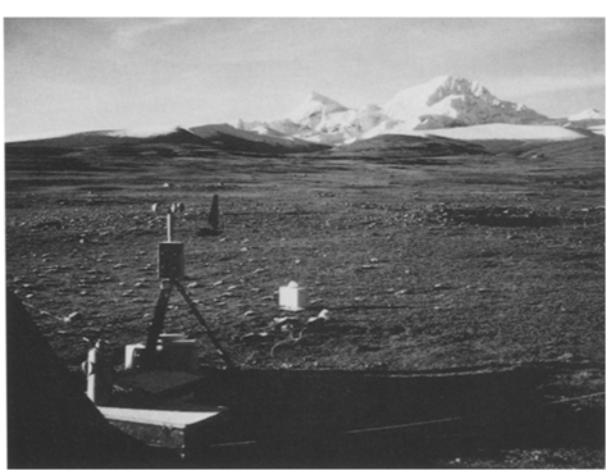

Fig. 1. Base camp of Shisha Pangma (in background) at 5 000 m

All instruments had been calibrated by the manufacturer (Thies, 1984; Lambrecht, 1986). As the thermohygrographs were not specially protected against the sun, an error of 1 K can be expected. During the 1984 expedition, a bimetal actinograph (type Robitzsch Fuess) was used also. The results are already published in Kuhle (1988 a) and are not discussed in this paper.

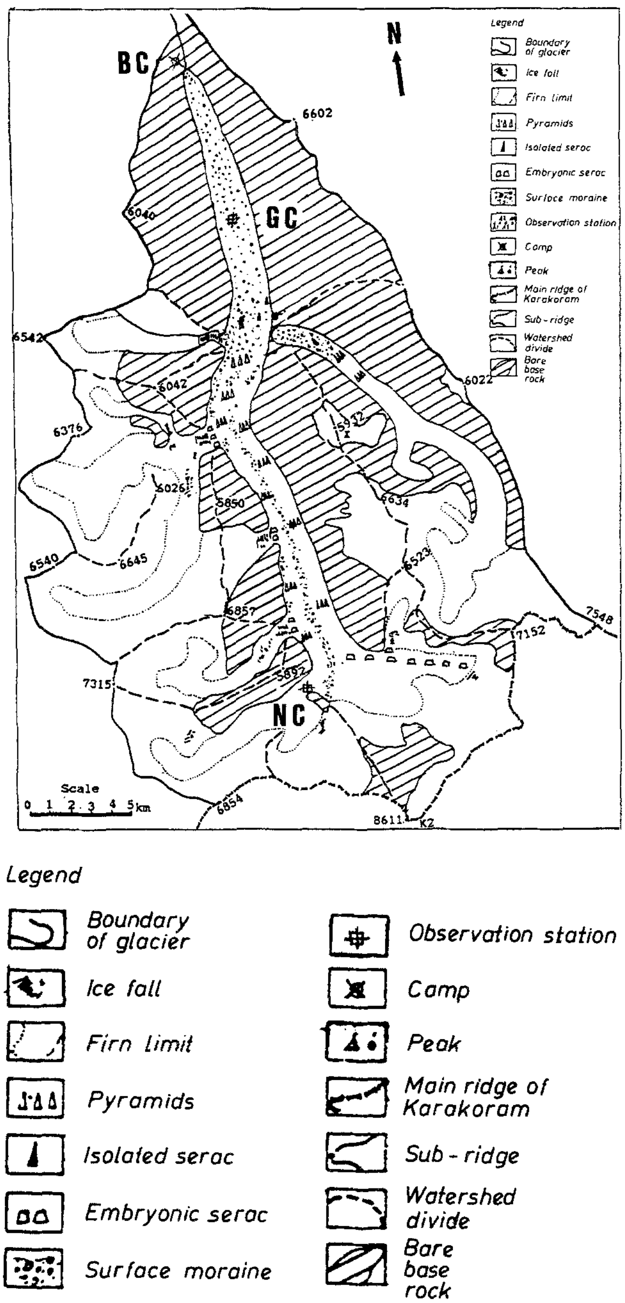


Fig. 3. Sketch of the N side of K 2 with base camp (BC), glacier camp (GC) and névé camp (NC)

## 3. Data

### 3.1 Eastern Himalay

In 1984, the monsoon season ended prematurely and the good weather continued into November with only a few short-lived breaks (Kuhle, 1988 d). From mid-September the wind direction ceased to vary and became stable from a prevailing SSE to SE direction interrupted only by shorter periods of northerly winds at early morning. In the autumnal post-monsoon period, up to 100 m long snow banners streaming from the peaks became very much longer, clearly influenced by the jet-stream.

The short measuring period of Shisha Pangma shows no significant variation in the daily mean of the parameters as temperature, humidity and wind speed. The most prominent mean wind speed per hour is 3 m/s in 30.2% of all cases. The mean values for the period are given in Table 1, the actual data were already published in Fig. 7 of Kuhle (1988 a).

At Mt. Everest (Table 1) the weather was characterized by stable conditions, except during a nine day disturbed period during the first half of October where highest wind speeds occurred. Minimum temperatures were correlated with maximum humidity and lowest wind speeds. Most of the time Mt. Everest experiences katabatic winds from south together with low humidity. The most prominent mean wind speed per hour is 10 m/s in 16.2% of all cases. The highest wind speed measured is 21 m/s (2.2% of the cases). The actual data were also published in Figs. 8–11 of Kuhle (1988 a).

### 3.2 Karakoram

From mid-September 1986 onwards, weather conditions on the northern side of K 2 were more or less stable with prevailing southerly winds during most of the time and northerly winds with lower speeds around midday. This pattern is only interrupted by a short period at the end of September.

The daily maxima of global radiation at K 2 reflect a high variation of cloud cover. Two disturbances in the middle and at the end of September are evident, each of which is correlated with a temperature minimum, high humidity and low wind speed. The daily mean temperature and the daily temperature range at K 2 are lower than those on Mt. Everest at the same height (Table 1). At K 2 wind speed is stable in 90% of all cases with speeds between 2 and 4 m/s.

## 4. Results

### 4.1 Daily Weather Development

Most of the time, nights are clear at Shisha Pangma. However, around midday the sky begins to cloud over, reaching 6/8 cover by late afternoon.

Table 1. *Mean Meteorological Parameters Calculated from Hourly mean Values of the Shisha Pangma and Mt. Everest Expedition (1984) and the K2 Expedition (1986)*

| | | Shisha Pangma | Mount Everest | K2 | K2 | K2 |
|---|---|---|---|---|---|---|
| Camp | | BC | BC | BC | GC | NC |
| Height | | 5000 m | 5130 m | 4130 m | 4600 m | 5330 m |
| Date | | 8.9.–15.9. 1984 | 18.9.–3.11. 1984 | 4.9.–11.10. 1986 | 12.9.–10.10. 1986 | 22.9.–6.10. 1986 |
| Days | | 8 | 47 | 38 | 29 | 15 |
| Surface | | rubble | rubble | rubble | moraine | firn |
| $\bar{T}$ | (°C) | 3.8 | 0.9 | 2.3 | 2.2 | −7.1 |
| $T_{max}$ | (°C) | 14.2 | 15.6 | 20.0 | 12.9 | 3.8 |
| $T_{min}$ | (°C) | −4.7 | −12.9 | −8.6 | −3.8 | −14.4 |
| $\Delta T$ | (K) | 16.2 | 15.9 | 17.8 | 10.4 | 11.7 |
| $\bar{h}$ | (%) | 67 | 33 | 46 | 54 | 66 |
| $\bar{v}$ | (m/s) | 2.8 | 7.0 | 3.0 | 3.3 | |
| $v_{max}$ | (m/s) | 8.8 | 20.1 | 7.1 | 6.2 | |
| $\bar{Q}$ | (W/m²) | | | 189 | | 225 |
| $Q_{max}$ | (W/m²) | | | 1012 | | 1047 |
| $\bar{R}$ | (W/m²) | | | 59 | | 20 |
| $R_{max}$ | (W/m²) | | | 608 | | 248 |

BC: Base camp, GC: Glacier camp, NC: Névé camp, T: temperature, h: humidity, v: wind speed, Q: incoming short-wave radiation, R: net shortwave and longwave radiation, index max, min: absolute values, $\Delta T$: mean daily temperature range

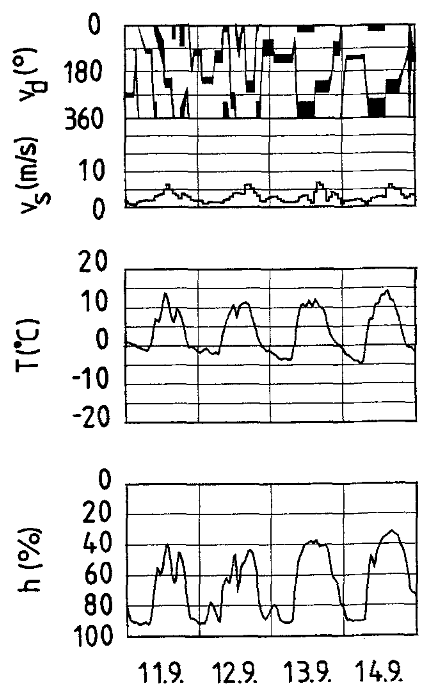


Fig. 4. Wind system at the base camp of Shisha Pangma (5000 m) during 11.9. to 14.9.1984. $v_d$: wind direction, $v_s$: wind speed, T: temperature, h: humidity

The wind system consists of three components (see 13.9. and 14.9.84, Fig 4). Normally katabatic winds occur from SE (22.00 to 10.00), in conjunction with a minimum of temperature and a maximum of humidity. Wind then changes to N, coming from the Tibetan Plateau (10.00 to 16.00). At this time temperature reaches its daily maximum and humidity its minimum. Around sun set katabatic winds set in together with temperature decrease and increase in humidity. Maximum wind speed occurs between 17.00 and 18.00.

Throughout the entire measuring period on Mt. Everest the winds are predominantly SE allowing only low cloudiness of 0/8 to 2/8 and bringing in dry air (Fig. 5). If they turn to the north with a simultaneous weakening of speed, extremely humid and cold air is advected and cloudiness rises to 3/8–7/8. On average the daily wind system consists of N winds in the morning ($\approx$6.00 to 11.00) together with dry glacier winds from SE during the rest of the day leading to a maximum wind speed during the early afternoon (14.00 to 15.00).

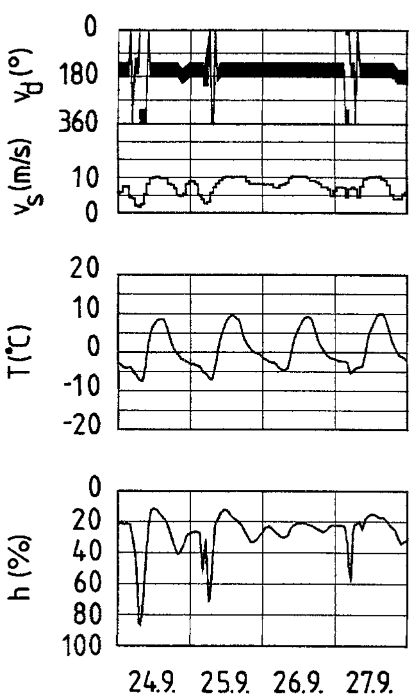


Fig. 5. Wind system at the base camp of Mt. Everest (5 130 m) during 24. 9. to 27. 9. 1984. $v_d$: wind direction, $v_s$: wind speed, T: temperature, h: humidity

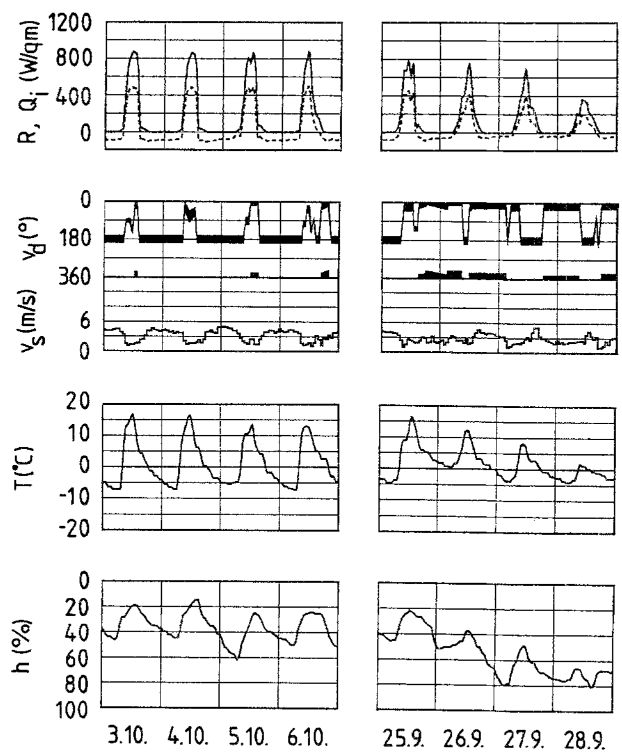


Fig. 6. Wind system at the base camp of K2 (4 130 m), a: during stable weather conditions (3. 10. to 6. 10. 1986), b: glacier wind from S overlaying valley wind from N (25. 9. to 28. 9. 1986). $Q_i$: incoming shortwave radiation (upper curve), R: net shortwave and longwave radiation (lower curve), $v_d$: wind direction, $v_s$: wind speed, T: temperature, h: humidity

In Karakoram at K2 during stable weather conditions (see radiation data, Fig. 6a), valley winds occur from the north associated with high temperatures and dry air (10.00 to 16.00). Most of the time katabatic winds from S prevail with a maximum wind speed around midnight. Only on days of low temperature gradient can a pronounced glacier wind system be identified advecting dry air (see 27. 9. 86 10.00 to 18.00, Fig. 6b). Here the wind speed reaches its maximum during the afternoon.

### *4.2. Temperature Gradient*

Temperature gradients for September and October were calculated separately for each site using the data from the next meteorological station (Table 2). When one looks at the same height difference (i.e. met.sta.-moun.sta. $\approx$ 750 m), the figures show a surprisingly similar temperature gradient ($\approx$0.44 °C/100 m), except in September when the value at K2 is lower, corresponding to cloudiness. These gradients are lower than those for the free atmosphere due to the influence of the high mountain area and inversion layer in the valleys. If one considers the actual gradient between glacier camp and an névé camp at K2 ($\Delta$h = 730 m) the local influence becomes evident by a mean gradient of 1.3 °C/100 m.

## 5. Discussion

Data obtained during the expeditions to the Tibetan side of the Karakoram and of the eastern Himalayas show a general difference of meteorological conditions. In the morning the sinusoidal diurnal curves of temperature and humidity at Mt. Everest are disturbed by northerly winds of cold and humid air. From midday onwards, southerly winds of warm and dry air blow during the rest of the day, producing maximum wind speeds during the afternoon. In contrast at K2, northerly winds advect warm and dry air during the day and southerly winds cold and humid air during the night with a wind maximum around midnight. Both conditions are determined by local topography. Mt. Everest is situated close to the southern side of the eastern Himalays. On the lee side it

Table 2. *Temperature Gradient in K/100 m Calculated from Mountain Station (moun. sta.) and the Next Meteorological Station (met. sta.) for September (IX) and October (X)*

| | moun. sta | | Shisha Pangma | Mt. Everest | K 2 | K 2 |
|---|---|---|---|---|---|---|
| met. sta. | Δ l | Δ h | BC (5 000 m) | BC (5 130 m) | GC (4 600 m) | NC (5 300 m) |
| Tingri 4 300 m | 100 km | 700 m | IX: − 0.45 | | | |
| Tingri 4 300 m | 70 km | 860 m | | IX: − 0.45<br>X: − 0.44 | | |
| Maza 3 850 m | 70 km | 750 m | | | IX: − 0.30<br>X: − 0.43 | |
| Maza 3 850 m | 80 km | 1 480 m | | | | IX: − 0.72<br>X: − 0.94 |
| K 2 (GC) 4 600 m | 23 km | 730 m | | | | IX: − 1.22<br>X: − 1.38 |

Δ l: linear distance, Δ h: height difference, BC: base camp, GC: glacier camp, NC: névé camp

experiences dry air coming from Nepal and humid air coming from the valleys of the Transhimalayas (≈4 000 m asl.). K 2 develops a different local climate due to its situation south of the hot and dry climate of the desert Taklimakan in the Tarim Plateau (≈1 000 m asl.).

Whereas the small vertical temperature gradients between mountain stations and the next meteorological station of both regions are similar, the local gradients, as could be shown for K 2, are much larger. Differences in the height of the snow line, which is determined as described in Kuhle (1988 b), are apparent also: 6 300 m at Shisha Pangma, 6 000 m at Central-Rongbuk-Glacier of Mt. Everest and 6 350 m at East-Rongbuk-Glacier, whereas it comes to 5 200 m at K 2.

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