BERICHTE UND MITTEILUNGEN

THE CLIMATIC DIAGRAM MAP OF HIGH ASIA
Purpose and Concepts

With 4 figures, 1 table and 1 supplement (I)

GEORG MIEHE, MATTHIAS WINIGER, JÜRGEN BÖHNER and ZHANG YILI

Zusammenfassung: Klimadiagramm-Karte von Hochasien. Konzept und Anwendung
Es wird eine Klimadiagramm-Karte für Hochasien und die Vorlandgebiete vorgelegt, die zum einen der großräumigen klimatologischen Interpretation, in erster Linie aber der vegetations-ökologischen Analyse (z. B. Bestimmung potentieller Vegetationsformationen) dienen soll. Basierend auf dem Ansatz von WALTER und LIETH (1960–1967) sind eine große Anzahl neuer Stationsreihen kompiliert worden, teilweise räumlich verdichtet und ergänzt durch Modelldaten. Auf kritische Aspekte der Datenqualität und klimatischer Bedingungen (Höhengradienten) wird hingewiesen und Ansätze weiterführender Arbeiten werden skizziert. Eine ausführliche, stationsbezogene Analyse in Form eines Handbuches steht vor dem Abschluss.

Summary: A new map containing climatic diagrams of High Asia and its surrounding lowlands is presented. Its main focus is to provide a data base for climatic-ecological investigations (e. g. evaluation of potential vegetation cover), whereas purely climatic analysis should consider several critical constraints. The work is based on the approach of WALTER and LIETH (1960–1967) but includes a great number of newly available data sets and is completed by modelled time series. Critical aspects of data quality and climatic conditions (vertical climatic gradients) are discussed and methodical approaches for future work are mentioned. A detailed station based analysis will be published as climatic diagram handbook.

1 Introduction

The Tibetan Highland and its surrounding mountain ranges are an important control factor in the atmospheric circulation of the Northern Hemisphere (FLOHN 1958; BÖHNER 1996). Nevertheless climatic data from this area were only sparsely available up to now. The 'World Atlas of Climatic Diagrams' of WALTER and LIETH (1960–1967) is hitherto the world's most substantial collection of climatic data and includes 47 diagrams for High Asia and its surrounding foothills. In the last decades many additional meteorological stations have been set up by national weather services in the Hindukush, Pamir, Karakoram, Kunlun Shan, Qilian Shan, along the eastern slopes of the Tibetan Plateau and the Himalaya, as well as on the plateau itself. Recent studies on climatic trends carried out by BÖHNER (1996) could include time-series of more than 150 stations. Still one of the major problems for spatial climatic evaluations is the fact that most climatic stations within mountain ranges are located at lower altitudes within valleys and therefore not necessarily representative for larger areas. This is especially true for the Western Himalayas, Hindukush and Karakoram, where dry valley floors (called 'Trockene Talstufe' by TROLL, 1967) show distinct different hygric conditions compared to high altitudes.

Manned stations at altitudes higher than 4500 msl are still an exception: Tianshuihai (4850 msl) on the Aksai Chin Plain, the permafrost research station at the Fenhuoshankou (pass at 4745 msl) in the NE Tibet or the weather station at Pumo Co (5030 msl) in southern Tibet. The station at Fedchenko Glacier (4745 msl) obviously has been disrupted in the past years after running for several decades due to political and financial reasons. Only in recent years and mainly in connection with research programs automatic climatic stations have been installed at higher altitudes, e. g. by WAPDA or the Pak-German research program 'Culture Area Karakorum' (CAK) in Northern Pakistan (MIEHE et al. 1996; CRAMER 2000). Important data have been collected at base-camps of Chinese (Qomolangma) or Japanese expeditions (Kiangjing, Lhajung), although they cover only a period of one year.

2 Concepts and Purpose

In order to visualize local climatic conditions in a simple and comparable way WALTER (1955) proposed a type of climatic diagrams which combines thermal and hygric conditions and directly outlines humid or arid seasons. Despite their certainly very rough and in many respects also insufficient approach, advantages are obvious: temperature and rainfall are widespread, in many cases the only available climatic data. For ecologic purposes and comparative approaches the cartographic compilation of sets of diagrams provide both: a visual presentation of thermal-hygric conditions and at the same time precise climatic data on temperature

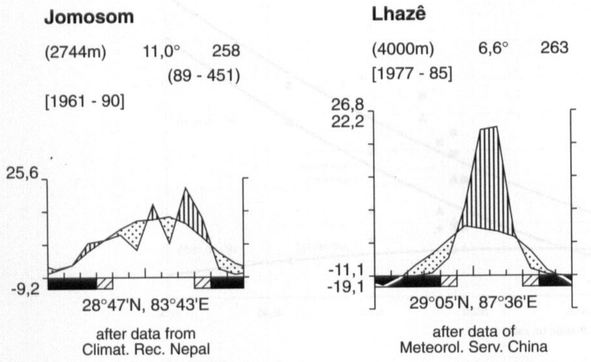

Fig. 1: Climatic diagrams from arid environments in Northern Nepal (Jomosom) with open *Cupressus-Juniperus* forests and actually treeless landscapes in southern Tibet (Lhazê)

Klimadiagramme arider Gebiete aus Nordnepal (Jomosom) mit offenem *Cupressus-Juniperus*-Wald und gegenwärtig baumfreier Landschaften Südtibets (Lhazê)

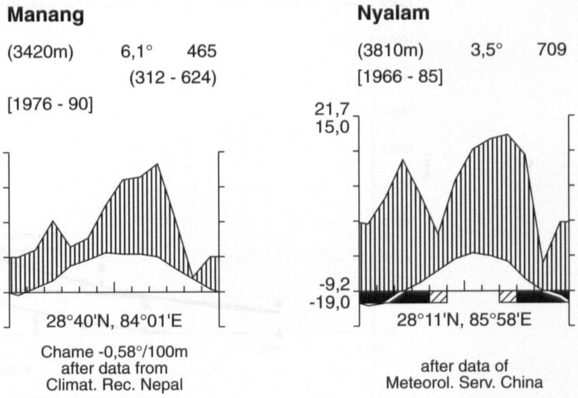

Fig. 3: Climatic diagrams from open to light coniferous forests (*Juniperus indica, Pinus wallichiana*) (Manang) and actually treeless environments in southern Tibet (Nyalam)

Klimadiagramme aus Gebieten mit offenem bis leicht verdichtetem Nadelwald (*Juniperus indica, Pinus wallichiana*) (Manang) und gegenwärtig baumfreien Landschaften in Südtibet (Nyalam)

and rainfall on a monthly basis. In the world atlas of climatic diagrams of Walter and Lieth (1960–1967) a representative set of climatic data sets has been compiled and presented for each continent.

The *Climatic Diagram Map of High Asia* presented here as Supplement I includes a spatially fairly homogeneous selection of climatic diagrams out of a total number of 206 stations available up to now. Emphasis is given to evenly represent climatic conditions of high mountain regions and elevated plateaus. Therefore priority is given to the inclusion of sometimes rather short time series originating from remote stations of up to now insufficiently described areas. On the other hand some well documented data sets have not been included from areas with spatially dense observation networks. For better orientation some diagrams of well-known towns are included.

Forest and pasture resources of High Asia have been changed fundamentally in the past as well as in recent years. This is true mainly for the arid areas, where wood and fodder resources are scarce and therefore under stronger pressure than elsewhere. In addition land use and land cover changes occur regionally differently depending on factors such as accessibility and government or local policies (Schickhoff 1995). In many dry areas of High Asia most forests with a low potential of reproduction have completely been depleted. Classifications based on eco-physiological characteristics of real vegetation (Lauer et al. 1996) might therefore be misled by the actual treeless vegetation cover and consequently classify 'forest-climates' as 'high mountain steppe climates' instead.

One purpose of this collection is to make data available for different environmental sciences dealing with comparative high mountain research in High Asia. The main purpose, however, is to arrange the diagrams by the vegetation types they may represent. This is certainly a challenge, as in many valleys of High Asia it is dubious, as mentioned before, to which misleading extent the vegetation cover was changed to a more arid habit under human impact. In the past the general trend in science was to underestimate man's influence on landscape changes. In-depth research with a focus on the potential natural vegetation revealed the possibility of far-reaching land use changes in the past. Figures 1 to 3 give examples from sites with actual forest cover and those devoid of forests at present but with a climate which would enable a forest cover. Thus

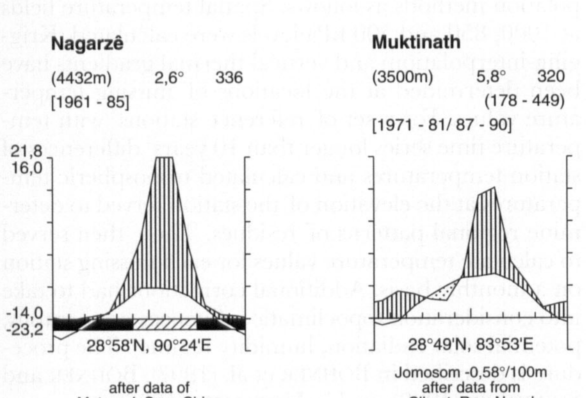

Fig. 2: Climatic diagrams from Southern Tibet (Nagarze) with open *Juniperus*-forest on south facing slopes and actually treeless landscapes in northern Nepal (Muktinath)

Klimadiagramme aus Süd-Tibet (Nagarze) mit offenem *Juniperus*-Wald an Südhängen und gegenwärtig baumfreien Landschaften in Nord-Nepal (Muktinath)

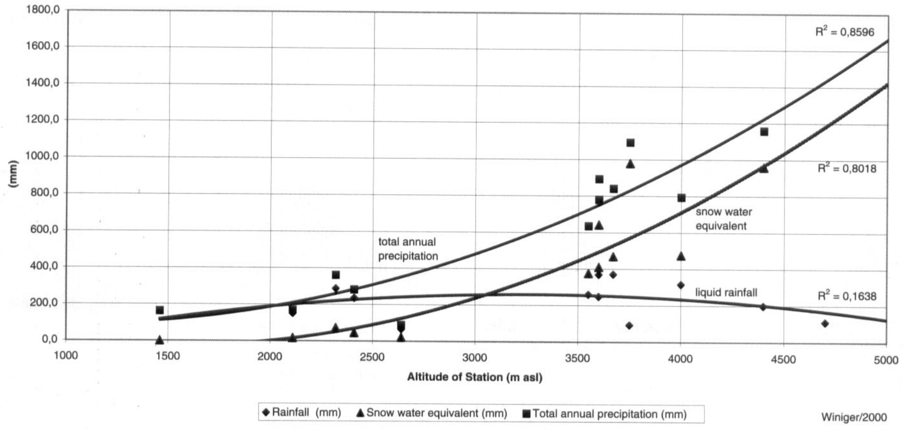

Fig. 4: Vertical gradients of total (liquid) rainfall, total snowfall and total annual precipitation for the central northwestern Karakoram. Data are derived from the station network of the CAK-Research program (evaluation: WINIGER)

Vertikale Gradienten des flüssigen Niederschlages, des Schnee-Wasseräquivalents und des jährlichen Gesamt-Niederschlages für das Gebiet des zentralen nordwestlichen Karakorums. Daten abgeleitet vom automatischen Stationsnetz des Forschungsprogrammes CAK (Auswertung: WINIGER)

climatic diagrams might serve as a tool for considerations upon the potential natural vegetation. If there is evidence that treeless environments may potentially be forested, programs of reforestation by reintroducing indigenous trees might be taken into consideration where appropriate.

3 *Data quality, evaluation procedures*

Although regional climatic patterns are represented with a high degree of reliability, several constraints affect the homogeneity and therefore the comparability of the diagrams on a local scale. The most critical are: (a) Quality of data; (b) Length of observation period; (c) Calculation of missing temperature curves; (d) High altitude rainfall figures.

(a) Quality of data: Although many of the stations have been visited by the authors and most organizations running networks indicate to apply WMO-standards, in many cases the quality of data gathering is affected by instrumental problems, station locality, interruptions of time series etc. Data quality has been checked by visual plausibility procedures, regionally by statistical means (e. g. WEIERS 1995). Nevertheless errors should still be taken into consideration for some stations.

(b) Length of observation period: The data compilation had to rely on time series of different length, covering different periods. Considering the well known facts of the variability of seasonal and annual climatic conditions, as well as climatic long-term trends (global warming, influence of monsoon etc.) special attention has to be focused on the period the diagrams refer to (indicated in most figures). For a number of stations time series of several decades could be included (e. g. Kathmandu: 125 years), on the other hand and as an exception few 1-year data sets have been included for few remote or high altitude sites (e. g. Lingshi). In some cases rainfall and temperature values are calculated from time series of different length or with some months missing. Finally for most stations in Afghanistan data were available only up to 1970. Altogether these constraints affect the applicability of the map for purely climatic purposes, whereas ecologic interpretations certainly can profit to a great extent from the data compiled in the map.

(c) Calculation of missing temperature curves: At 17 weather stations, where only rainfall has been measured, temperature curves were included based on statistical regression procedures combined with geostatistic interpolation methods as follows: Spatial temperature fields at 1000, 850 and 500 hPa levels were calculated (Krigging-interpolation) and vertical thermal gradients have been determined at the locations of missing temperature values. For a set of reference stations (with temperature time series longer than 10 years) differences of station temperatures and calculated tropospheric temperatures at the elevation of the station served to determine regional patterns of residues. These then served to calculate temperature values for each missing station on a monthly basis. Additional corrections had to take into consideration topoclimatic influences (topography, potential solar radiation, humidity regime). The procedure is described in BÖHNER et al. (1997), BÖHNER and SCHRÖDER (1999), and in HORMANN (1986).

(d) High altitude rainfall figures: Beside the specific climatic situation mentioned before (aridity of most valleys in the western and central part of High Asia) vertical climatic gradients are available only in a very few cases (e. g. WEIERS 1995). Temperature gradients might be calculated rather accurately, as described under *(c)*.

High altitude precipitation figures on the other hand are very critical: snowfall becomes increasingly important at higher altitudes but is properly assessed only at manned stations and mainly on the Tibetan Plateau. Only very recently several research programs were focused on the investigation of snow (spatial and temporal extent, snow depth, water equivalents, effect of drifting snow etc.). Combined methods have to be applied in order to assess vertical gradients of the water balance (in situ measurements, remote sensing, physical models). As an example for the western Karakoram vertical rainfall gradients and the changing ratio of liquid rain/snowfall are shown in Figure 4 (data from CAK-stations).

4 Conclusions

The cartographic compilation of climatic data for High Asia should be considered as a first attempt to visualize thermal/hygric conditions and seasonal dynamics mainly for ecologic interpretation and evaluation purposes. Despite constraints related to the data base the approach significantly improves the first comparable data set by Walter and Lieth (1960–1967) and enables differentiated climatic-ecological interpretations on a regional scale. Nevertheless, further critical analysis of the original data base, the inclusion of additional stations, as well as the combination of different methodical approaches (satellite data, meteorologic and climatic modeling, ecologic transfer functions, vegetation analysis) are encouraged.

Acknowledgments

Several national weather services have provided data. Significant additional climatic time series have been provided among others mainly by: Liu Shijian (Chengdu), Liu Jianquan (Xining), Tshering Jamyang (Thimpu), Thomas Hofer (Berne), Paul Bucherer-Dietschi (Liesthal, Switzerland), and Hans-Joachim Fuchs and Manfred Domrös (Mainz). Cartographic work was carried out by Christiane Enderle (Marburg). The compilation could rely on research programs supported by the 'Deutsche Forschungsgemeinschaft' DFG (German Science Foundation) and the 'Gesellschaft für Technische Zusammenarbeit' GTZ (German Technical Cooperation). We acknowledge the generous support by all these individuals and organizations.

References

Böhner, J. (1996): Säkulare Klimaschwankungen und rezente Klimatrends Zentral- und Hochasiens. Göttinger Geographische Abhandlungen 101.

Böhner, J. u. Schröder, H. (1999): Zur aktuellen Klimamorphologie des Tienshan. In: Petermanns Geographische Mitteilungen 143, 17–32.

Böhner, J.; Köthe, R. u. Trachinow, C. (1997): Weiterentwicklung der automatischen Reliefanalyse auf der Basis von Digitalen Geländemodellen. In: Göttinger Geographische Abhandlungen 100, 3–21.

Cramer, T. (2000): Geländeklimatologische Studien im Bagrottal, Karakorumgebirge, Pakistan. GEO Aktuell 3, Göttingen.

Flohn, H. (1958): Beiträge zur Klimakunde von Hochasien. In: Erdkunde 12, 294–308.

Hormann, K. (1986): Berechnete Niederschlagskarten der Himalaya-Länder. In: Göttinger Geographische Abhandlungen 81, 167–183.

Lauer, W.; Rafiqpoor, D. u. Frankenberg, P. (1996): Die Klimate der Erde. Eine Klassifikation auf ökophysiologischer Grundlage der realen Vegetation. In: Erdkunde 50, 275–300.

Miehe, S.; Cramer, T.; Jacobsen, J.-P. a. Winiger, M. (1996): Humidity conditions in the western Karakorum as indicated by climatic data and corresponding distribution patterns of the montane and alpine vegetation. In: Erdkunde 50, 190–204.

Schickhoff, U. (1995): Verbreitung, Nutzung und Zerstörung der Höhenwälder im Karakorum und in angrenzenden Hochgebirgsräumen Nordpakistans. In: Petermanns Geographische Mitteilungen 139, 67–85.

Troll, C. (1967): Die klimatische und vegetationsgeographische Gliederung des Himalaya-Systems. In: Hellmich, W. (Ed.): Khumbu Himal 1, 353–388.

Walter, H. (1955): Die Klimadiagramme als Mittel zur Beurteilung der Klimaverhältnisse für ökologische, vegetationskundliche und landwirtschaftliche Zwecke. In: Berichte Deutsch. Botan. Ges. 68, 331–344.

Walter, H. u. Lieth, H. (1960–1967): Klimadiagramm-Weltatlas. Jena.

Weiers, S. (1995): Zur Klimatologie des NW-Karakorum und angrenzender Gebiete. Bonner Geogr. Abhandlungen 92.

Beilage I zu ERDKUNDE 55,1 Beitrag Miehe / Winiger / Böhner / Zhang

Climatic Diagram Map of High Asia 1 : 4 000 000

Georg Miehe, Matthias Winiger, Jürgen Böhner, Zhang Yili

Map Sources: Atlas of Tibet Plateau, Beijing 1990, Böhner unpubl., Times Atlas, 6th ed., 1981, Atlas of Bhutan, Thimphu 1997, Operational Navigation Chart G 6, 7, 8, 9, H 8, 9, 10, 11, St. Louis, Missouri, Terrain Map of the Xizang-Qinghai Plateau, Shanghai 1990, Haack Weltatlas, 9th ed.,1990, Diercke Weltatlas, 4th ed., 1996, Northern Pakistan (Karakorum, Himalaya, Hindukush), "Culture Area Karakorum" CAK, Bonn 1998, changed. Names refer widely to the Times Atlas, 6th ed., 1981.
Sources of meteorological data refer to Miehe et al. (in prep.): A Climatic Diagram Handbook of High Asia with an Enumeration of High Asian Vegetation Formations.

Cartography: Christiane Enderle. Printed by LVA Nordrhein-Westfalen 2000.