WIND AND RAIN IN THE DESERT REGION OF XINJIANG, NORTHWEST CHINA

With 9 figures and 2 tables

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Zusammenfassung: Wind und Niederschlag im Wüstengebiet von Xinjiang, Nordwest-China

In Xinjiang im Nordwestteil von China befindet sich eines der ausgedehntesten Wüstengebiete. Um die klimatischen Bedingungen der Luftbewegungen und Niederschläge in diesem Gebiet deutlich zu machen, wurden die Daten der meteorologischen Stationen von Xinjiang ausgewertet, die vorliegenden Literaturangaben gesammelt und die Erfahrungen der ortsansässigen Einwohner berücksichtigt. Folgende Haupt-Windsysteme sind zu nennen (vgl. Fig. 7): (A') Westwinde über dem Nordteil von Xinjiang, (A) Nordostwinde im Südostteil der Wüste, die bogenförmig den Ostteil des Tian Shan-Gebirges umlaufen, (B) Nordostwinde im Nordostteil der Wüste, (C) Nordwinde als Hangabwinde vom Tian Shan-Gebirge, (D) Westwinde von den Pässen der westlichen Gebirgsumrahmung des Tarimbeckens sowie (E) südwestliche oder südliche Winde, die über Pässe von Pakistan oder dem Karakorum-Gebirge einströmen. Die Rangfolge der Bedeutung dieser Windsysteme – zusammen mit Kaltlufteinbrüchen im Winterhalbjahr – lautet (A) > (D) > (B) > (C) > (E). Heftige Sand- bzw. Staubstürme mit Windgeschwindigkeiten über 12–14 m/sec sind häufig mit den Windsystemen (A) und (D) verbunden. Sie werden als Kara Bran bezeichnet und bringen sehr schlechte Sichtverhältnisse mit sich. Auch heiß-trockene Winde treten verbreitet auf.

Zwischen den Windsystemen (A) und (D) ist eine mehr oder minder meridional verlaufende Konvergenzlinie bzw. -zone ausgebildet, entlang derer sich Konvektionsniederschläge bilden können. Regenfälle von 20–30 mm in 24 Stunden sind nicht ungewöhnlich. Die Relation zwischen den Maximalniederschlägen in 24 Stunden und den langjährigen Niederschlagsmitteln erreicht im Südteil der Wüste Werte von 100–300%, vereinzelt sogar 400%.

1 Introduction

The Taklimakan Desert, one of the broadest deserts in China, is located in Xinjiang, Northwest China. In order to assess the climatological conditions of wind and rain in this region, data observed at meteorological stations, study results published by Chinese researchers, and information based on the experience of local people have been collected. The final aim is to study the impacts of wind and rain on geomorphological and hydrological processes, desertification, human activities etc in this region. The present paper is also part of the preliminary results obtained by joint studies of Japanese and Chinese researchers, which were started in 1989, supported by the Science and Technology Agency in Japan.

2 Previous studies and aim of the present study

The climate of the arid and semiarid regions of China has been described in detail by GENG (1985, 1986). In his monographs, the general conditions of Xinjiang, as a part of the desert regions of China, have been well summarized. Many meteorological and climatological studies have been published by the scientists of the Xinjiang Meteorological Bureau and its Research Institute located in Urumqi. For example, ZHANG a. DENG (1987) wrote a comprehensive monograph on the precipitation in Xinjiang from the viewpoint of statistical climatology as well as synoptic meteorology. LI (1990 a, b) edited a monograph containing the studies on climatological aspects in arid and semiarid regions of China and summarized the climatography of Xinjiang (LI 1991).

The special Agriculture Group in the Meteorological Society of Xinjiang-Uygur Zizhiqu (1988) and XU (1989) both published comprehensive volumes on agrometeorology and agroclimatology including a big number of figures and tables.

Desertification, its prevention or modification and landuse problems in the desert areas of China have thoroughly been dealt with in the form of books, monographs or collected papers. Among them, the Laboratory of Desert, Lanzhou Institute of Geocryology and Desert Research, Academia Sinica (1974), the Xinjiang Biology, Pedology and Desert Research Institute, Academia Sinica (1978) and ZHU et al (1989) did not only provide results of studies made during recent years, but also data sources for further research. DONG (1990) described the desertification in China in relation to climate and XU (1990) proposed that the human impact should be considered as a possible cause for the recent change of the arid environment.

There are several descriptions by non-Chinese geographers on desertification and landuse in deserts (KONO 1986, MECKELEIN 1987, ICHIKAWA 1988). But none of them have yet dealt in detail with the wind and rain conditions in the desert areas.

In this paper climatical aspects of wind and precipitation are presented and discussed first. Heavy

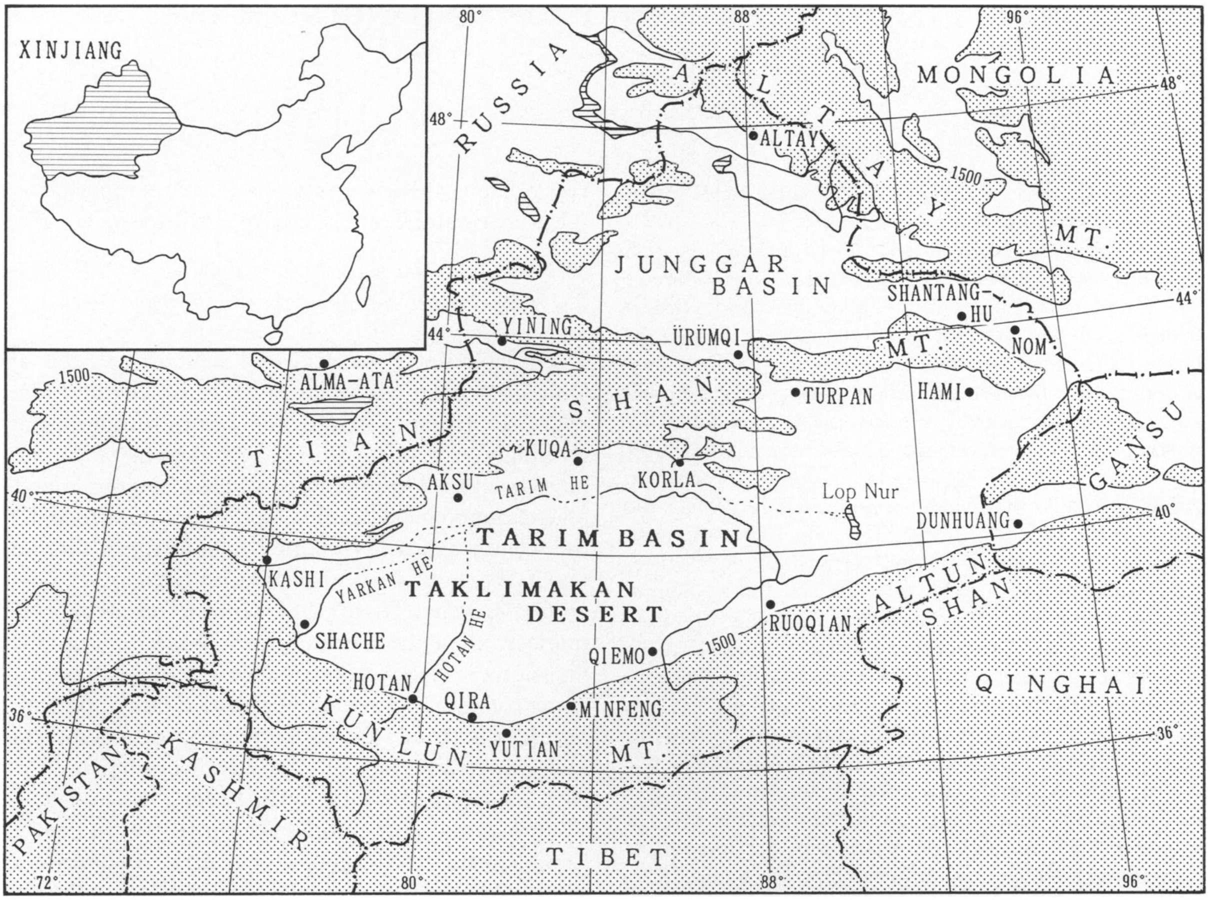

Fig. 1: Sketch map of study region and names of observation stations
Übersichtsskizze des Untersuchungsgebietes mit Namen der Beobachtungsstationen

downpours occur only occasionally. Nevertheless, they are of importance for the formation of the microtopography of deserts, the environment of human, animal and plant life, desertification and its modification, water utilization in the oasis and so on. Secondly, the windfield and atmospheric circulation conditions which result in heavy rainfall in the Tarim Basin are discussed and an empirical model is proposed. The contrast between the central part of the basin and its margin where most oases are located will be discussed. Climatological aspects of the strong wind named Kara Bran (black wind) are introduced. These winds have distinct impacts on landuse and human life in the oasis.

3 Climatological sketch of the study region

The Taklimakan Desert occupies most of the Tarim Basin. The geographical sketch map of the region is shown in Fig. 1. The climate is characterized by a great thermal range, occasional heavy rainfall, and frequent severe sand and dust storms. In other words: it is an extremely dry continental climate (Li 1991, Ling 1990). According to climatic atlases, average annual precipitation in the inner parts of the desert is less than 20 mm, but 50–80 mm in the northwestern oasis region in contrast to 20–30 mm in the southeastern oasis region of the desert. Aspects of interannual rainfall variability are discussed in chapter 5. 60–70% of the annual rainfall is concentrated in the warm half of the year. One characteristic is the prolonged period without precipitation: normally, it lasts longer than 60 days, but up to 290 days in extreme cases.

The yearly climate according to Köppen's classification of climate is BW (desert climate) with a 100% probability of occurrence. This is due to the macroclimatic situation: this region is located north of the westerly jet stream in winter and in contrast, south of the westerly jet stream in summer (Yoshino a. Urushibara 1981). This means that this region is under only scarce influence of disturbances. In the case of invading airflows, the basin is topographically located in the "rain shadow area" on the leeward side of the prevailing winds. As a consequence it is dry all year around.

Ou et al. (1989) presented the distribution of the rainfall deficit, i. e. the difference between observed annual precipitation and potential evaporation. They show that potential evaporation is about 1000 m higher than precipitation in the Tarim and Junggar Basins. According to Thornthwaite's method (1948), the calculated annual water deficit was 750 mm in the Taklimakan Desert region in northwestern China (Yoshino a. Urushibara 1982). There is no explanation for the difference between these two values. It might have methodical reasons (observed evaporation and the calculated evapotranspiration) but could also be of climatological origin. Further studies are recommended. The year-to-year variation of water deficit is rather high, particularly in June, July and August (Yoshino a. Urushibara 1982). But, in the case of Ruoqiang located in the southeastern part of Taklimakan Desert the largest fluctuation occurs in March.

On an average, "sandy winds" are observed on 50 days/year in the desert. "Sandy wind" is defined as a wind with a velocity higher than 4.5–5.0 m/sec at a height of 2 m above sand surface or higher than 6.5 m/sec at 8 m above sand surface, as these values generally indicate the mobilization of sandy particles. In the inner part of the desert, "sandy winds" occur less than 25 times, whereas more than 100 events can be observed at its northern margins (maximum of 125 days/year).

Secondly, it is of importance that the prevailing wind direction does not coincide with the general westerlies in the middle latitudes. Northeasterly wind develops in the region at 90–100° E, 40–50° N. According to previously published maps by the Lanzhou Institute of Glaciology, Geocryology and Desert Research, Academia Sinica (1980, 1990), Geng (1986) etc, air flows from northeasterly directions into the desert region after circling around the edge of the Tian Shan Mountain Range (cf Fig. 7).

The total average of arable land in Xinjiang was reduced from 4,610,000 ha in 1960 to 3,200,000 ha in 1979 mainly as a result of desertification processes due to sand drifting and salt accumulation. Sand dunes advance by 45–50 m/year, occasionally by 50–60 m/year (Xinjiang Biology, Pedology and Desert Research Institute, Academia Sinica/Qira Sand Protecting Study-Experiment Station 1988). Forests along the rivers in the desert existed on a length of 1000 km, but they decreased markedly, because of overcutting and drying up due to overuse of water for irrigation. The frequency of hot, dry wind is higher in the Turpan-Hami Basin and the southeastern part of the Tarim Basin, particularly in the summer. Haze is frequent in spring and summer. Some climatological characteristics of wind and precipitation are presented in more detail in the following chapters.

4 Wind

4.1 Annual wind conditions

"Strong wind" is defined by a wind speed of 17.2 m/sec (wind force 8). According to the 1961–1970 statistics, strong winds occur on less than 20–30 days in the Tarim Basin but on more than 40 days in its surrounding regions. The boundary between these two regimes runs roughly along the Tian Shan Mountain Range. The number increases to more than 100 days/year in the area around Alataw Shankou and Shantanghu.

The distribution of the observed maximum records of wind velocity from 1961 to 1970 is shown in Fig. 2. Values higher than 40 m/sec have been measured in the southern part of the Junggar Basin, the Turpan Basin, and the Ruoqiang area, lower wind speeds are to be found in the Tarim Basin.

4.2 Streamlines of the strongest wind

The annually prevailing wind direction is similar to the conditions in April, May or June discussed later. As mentioned above, the inflowing NW winds into Xinjiang become NE winds in the eastern parts of Tarim Basin and Junggar Basin, after having taken their way around the eastern part of the Tian Shan Mountain Range. In contrast to this, winds from N or NE, passing over the western part of the Tian Shan Mountain Range, converge in the Tarim Basin. NW wind develops in the Junggar Basin passing over the Tarbagatay Mountain Range. In addition, air masses from NW flow into the western part of the Taklimakan Desert in the area surrounding Kaxgar.

For May, chosen as a representative spring month (patterns are almost identical in April, May and June), maximum wind speed and wind direction are shown in Fig. 3, as well as the estimated circulation streamlines. These so-called "climatic streamlines" coincide remarkably well with the mean flow fields,

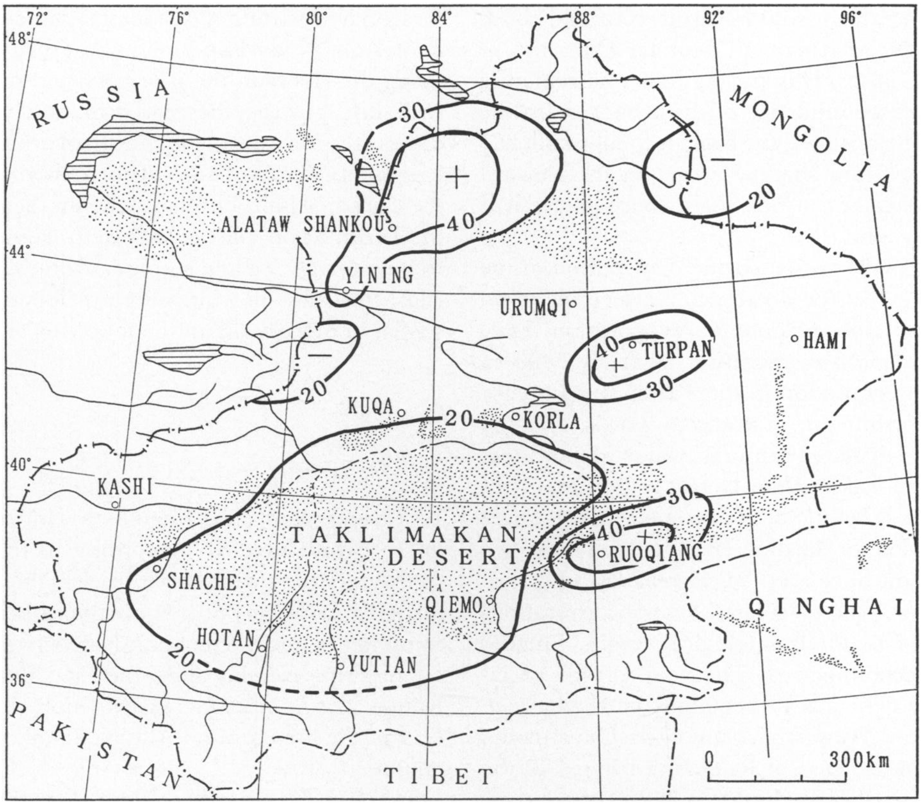

Fig. 2: Distribution of observed maximum records of wind velocity (m/sec) in Xinjiang, 1961–1970
Isoliniendarstellung der beobachteten maximalen Windgeschwindigkeiten (m/sec) in Xinjiang 1961–1970

3 km above the Taklimakan Desert (Ling 1988). In general, these results coincide with the illustration by Geng (1986) as well. The fact that the prevailing air flows converge at the central part of the Taklimakan Desert will be discussed later in detail, as this climatological fact is related to sand storms, heavy rain, desertification etc in the Taklimakan Desert.

5 *Precipitation*

5.1 Duration of rainless periods

The distribution of the number of months without precipitation (p = 0 mm) is shown in Fig. 4. There are more than 6 dry months/year in the Taklimakan Desert and its neighbouring eastern areas. In contrast, in the western part of the Taklimakan Desert the number decreases to 3 months. The distribution of the number of consecutive months with precipitation of 10 mm or less is shown in Fig. 5. It is noteworthy that there are two centers with more than 60 consecutive months. As a monthly total of less than 10 mm rainfall has almost no effect on the occurrence of vegetation, Fig. 5 can also be interpreted in terms of the severeness of aridity. The figure indicates relatively wetter conditions in the western part of the Tarim Basin. The reason why the basins of Turpan and Nomhu are the driest regarding the number of consecutive rainless months is not clear. However, the following explanations seem to be possible: (1) Convection resulting in rainfall does not easily develop in this part, because the descending air stream crossing over the Tian Shan Mountain Range is stronger than in the other parts where the mountain range is wider and higher. (2) In addition, this relatively small extension of the basin is unfavourable for the development of extended convection cells.

A monthly precipitation of more than 20 mm occurs only once in three to five years in the surrounding oasis region of the Taklimakan Desert. But, in the small basins of the eastern part, such as at Hami, the frequency is even lower. In contrast to this, 20 or 30 mm/month are not seldom in the western part of the desert. The impact of such an amount of rainfall

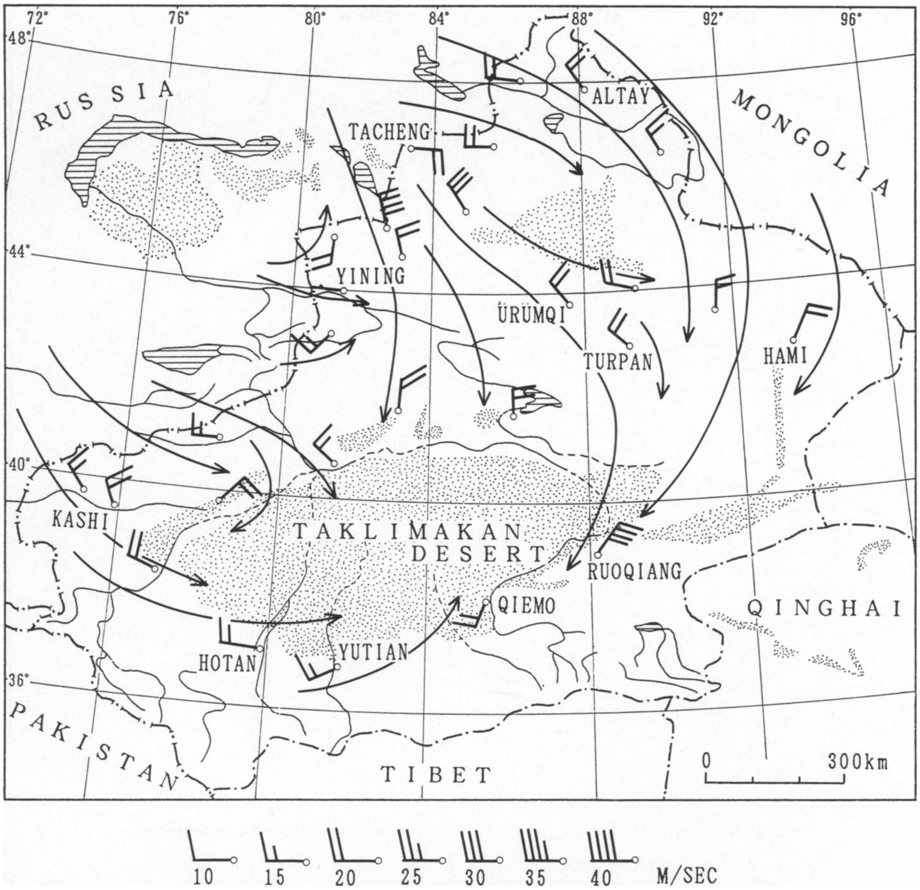

Fig. 3: Maximum wind velocity and wind direction in Xinjiang in May and estimated air flow
Maximale Windgeschwindigkeit und Windrichtung in Xinjiang im Monat Mai sowie daraus abgeleitetes Strömungsfeld

on the sand movement, sand dune formation, vegetation development, desertification near oases and so on cannot be neglected anymore.

5.2 Short period precipitation

As mentioned above, the occurrence of heavy rainfall is unexpectedly high in the desert region. A maximum precipitation intensity has been recorded at Ruoqiang on July 5, 1981: 73.5 mm during 14 hours. According to Zang a. Deng (1987), the so called 'relative intensity' of precipitation (ratio of maximum 24 hour precipitation to long-year mean annual precipitation) is very high in the Taklimakan Desert. The records are 422% at Ruoqiang, 231% at Qiemo and 220% at Turpan. In general 'relative intensity' is about 20% in the northern part of Xinjiang compared to about 40% in the southern part, but it reaches 100–200% in the Taklimakan Desert. The mean number of days/year with heavy rainfall of 20 mm/day or more is 0.5 at Hami, 1.8 at Yiwu, and 4.3 for the years 1959–1984 (Zhang a. Deng 1987). Seasonally, these events occur at Hami from April to July, but at Balikun in the northern mountains from June to August. This slight difference is due to the fact, that the heavy rainfall caused by thermal/frontal showers, formed along the convergence line, is more frequent in the basin, but orographically enforced thermal showers mainly occur in the mountain areas.

Other observed short period records are: 40.8 mm during 24 hours at Ili and 30.3 mm at Kuqa between 15:00 to 16:00 hrs on June 14, 1986. The relationship of the observed records of maximum rainfall during 24 hours and 1 hour or 10 minutes are studied on the basis of data given by the Editorial Committee of the Instruction Note (1986) for 1952–1972 and shown in Fig. 6: in the range of low intensitites there exists a linear relation for the upper limit of daily

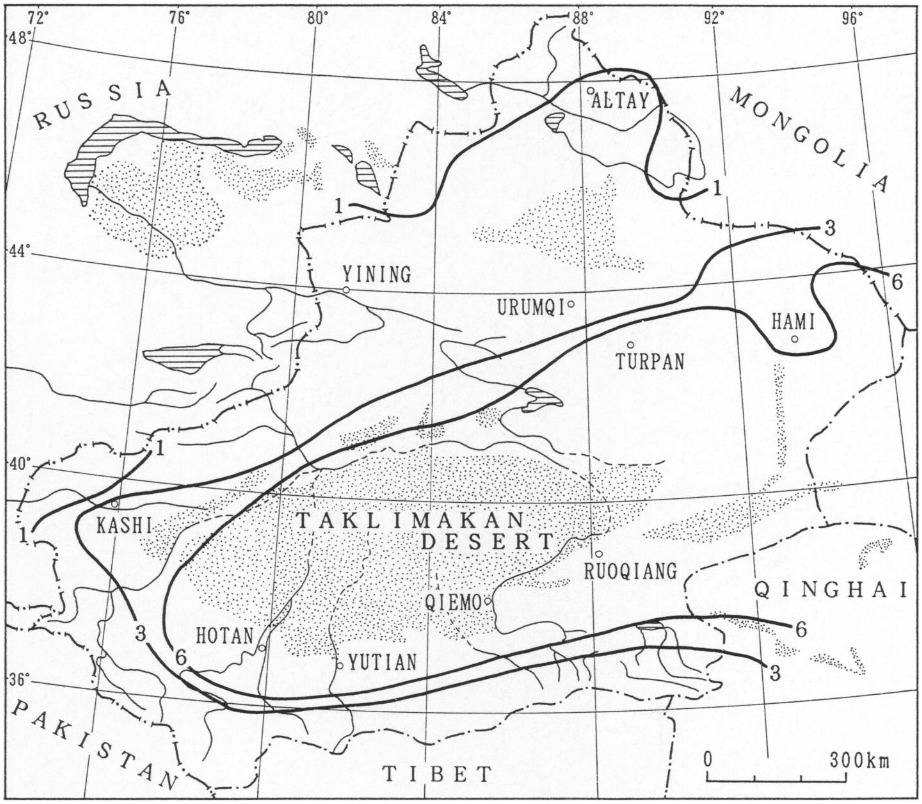

Fig. 4: Distribution of number of months without precipitation
Isoliniendarstellung der Zahl der Monate ohne Niederschlag

and hourly rainfall totals, slightly decreasing with high values of the 24 hour-maxima. This figure indicates that maximum 1 hour-intensity records may remain below 32-35 mm and the 10 minute-maximum below 20 mm.

Maximum rainfall intensities concentrate on the time between 12:00 to 20:00 hrs (local time). This means that strong thermal convection is of importance.

6 Scheme of the circulation system

Summarizing the observations mentioned above, a schematic approach is given for the atmospheric circulation system in the Junggar Basin and the Tarim Basin. In previous studies the annual conditions of the prevailing wind directions were illustrated by GENG (1985), the winter conditions by ZHAO (1985). Therefore, the conditions in March and April, which are important for the uplift of Kôsa, yellow sand or Asian sand, and the conditions in July, which are significant for the local strong convection causing heavy rainfall, are illustrated schematically in the following sections.

6.1 Atmospheric circulation in March and April

The winter conditions of the westerlies remain in the upper air layer. This is particular obvious in the northern part of Xinjiang. As shown in Fig. 7, a branch of the air stream (A') penetrates the Junggar Basin, but the main air stream (A) flows into the Taklimakan Desert taking a detour route east of the Tian Shan Mountain Range. One part (B) of this main air stream reaches the region surrounding Korla whereas the second one (A) approaches Qiemo via Ruoqiang even farther east. In cases where air stream A is developing strongly, Kara Bran, which means "black wind" in the Wygar language, does occur. The wind speed of these two streams (A and B) is so high and the air is so dry that gusty winds develop markedly. This is due to the fact that surface temperatures in the desert are already high, as the snow cover in the mountains has already been melted at this time of the year.

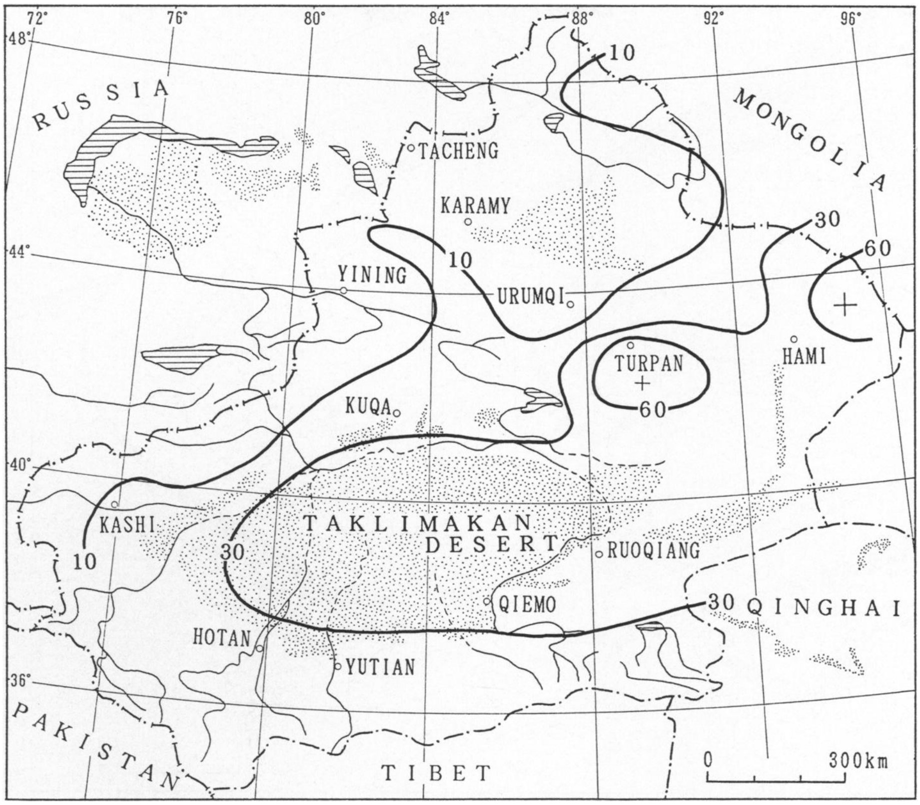

Fig. 5: Distribution of number of consecutive months with monthly precipitation equal or less than 10 mm
Isoliniendarstellung der Zahl der aufeinanderfolgenden Monate mit Monatsniederschlägen von 10 mm und weniger

In contrast, the northerly air stream crossing over the Tian Shan Mountain Range flows into the northern part of the Tarim Basin as a descending hot, dry air stream (C). Along about 40° N another westerly air stream (D) invades the western part of the Tarim Basin over the pass. Consequently, the westerlies prevail in the area surrounding Kashi and Shache. Furthermore, southwesterly air masses (E) approach from Pakistan over the Karakoram Mountains and descend at the southwestern part of the Tarim Basin, resulting in hot, dry and strong winds. These three air streams are all descending from the surrounding mountains into the Tarim Basin causing hot, dry conditions by the Föhn effect. At the same time it should be noticed, that in most cases they do not reach the central part of the Tarim Basin. Therefore, distinct convergence zones which appear in the summer are not formed and convections in a local or synoptic scale are weak or not existing at all in March and April.

The descending air stream (A), taking a longer and larger roundabout route from the higher latitudes is getting warmer and drier and therefore, the south-

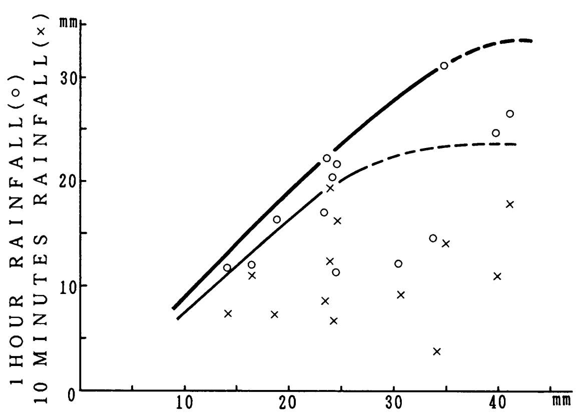

Fig. 6: Relationship between the observed records of maximum rainfall during 24 hours and 1 hour (thick line) or 10 minutes (thin line) in Xinjiang. Lines show the upper limits

Beziehung zwischen den registrierten Niederschlagsmaxima in 24 Stunden und in einer Stunde (dicke Linie) bzw. in 10 Minuten (dünne Linie) in Xinjiang. Die Linien bezeichnen die oberen Grenzen

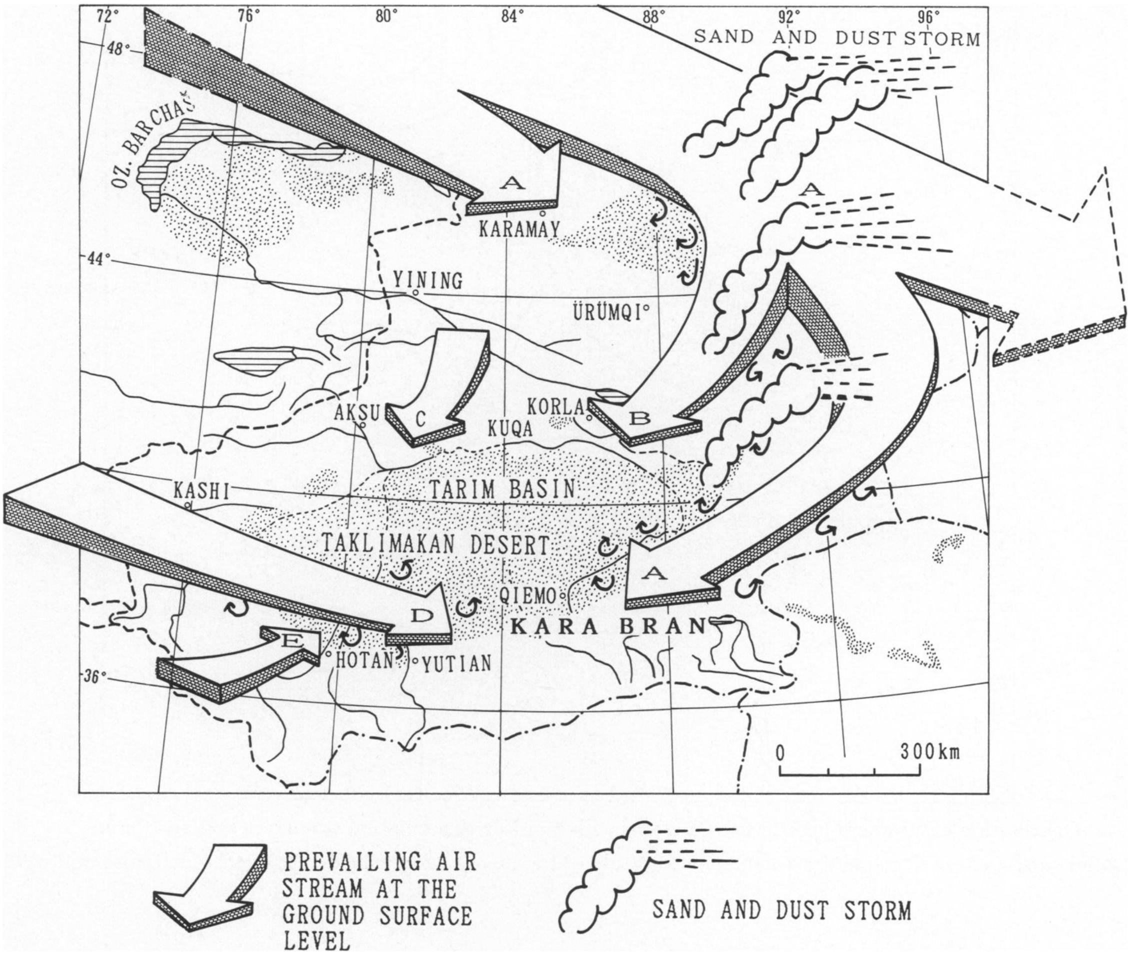

Fig. 7: Schematic illustration of atmospheric circulation in the lower troposphere/air layer near the ground surface in Xinjiang in March and April

Schematische Darstellung der atmosphärischen Zirkulation in der unteren Troposphäre/bodennahen Luftschicht in Xinjiang im März und April

eastern part is the driest of the whole Taklimakan Desert and the desertification is expected to be most serious.

6.2 Atmospheric circulation in July

The upper westerlies in these latitudes become weak in summer (Fig. 8) resulting in an increased local convection in the lower troposphere. The air stream (A) shown in Fig. 7 becomes weak in July. This air stream converges with the air masses (D) along a meridional line approximately at 83–84° E (Fig. 7). Along this convergence line, convection should be stronger, particularly in the central part of the basin.

In contrast, there is a zonal belt, where the upward motion can easily be enhanced due to its position in the lee of the mountains roughly along the Tarim River. These convection areas are illustrated in Fig. 8. Relatively strong showers during the summer can be expected, even though their temporal frequency is low, whereas the spatial variability is high. The probability of showers should be relatively high in the north-south belt along the convergence line, located slightly west of the basin center. This is also the case for the surrounding higher mountain regions of the Tarim Basin and can be concluded by comparing the surrounding oasis regions and the inner desert region.

The annual precipitation in the inner part of the Taklimakan Desert is estimated to be less than 20 mm.

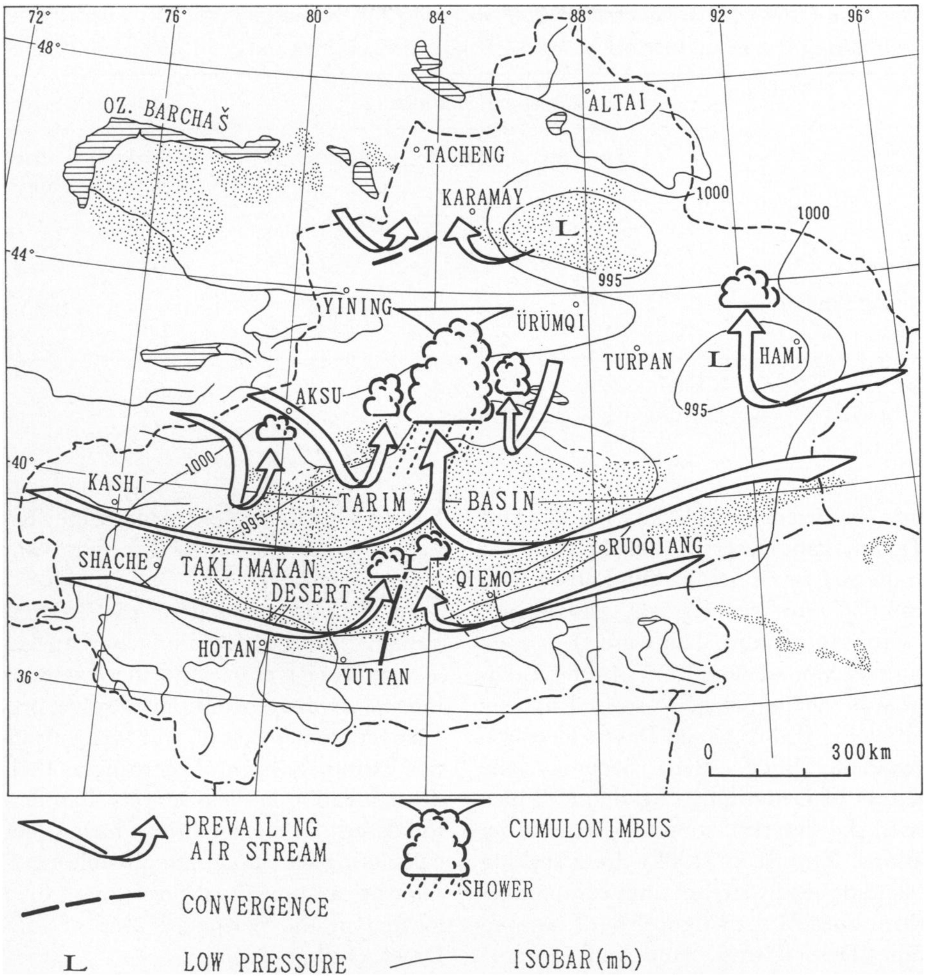

Fig. 8: Schematic illustration of atmospheric circulation in the lower troposphere/air layer near the ground surface in Xinjiang in July

Schematische Darstellung der atmosphärischen Zirkulation in der unteren Troposphäre/bodennahen Luftschicht in Xinjiang im Juli

Corresponding to the relatively high variance, annual precipitation totals may also be higher than 50 mm, as recordings prove for a station located at 40°06′ N, 83°06′ E, 987 m, in 1988 (Li 1990b). This station is located within the convergence zone shown in Fig. 8.

According to a map showing the sand dune morphology of the Taklimakan Desert (Laboratory of Desert, Lanzhou Institute of Glaciology, Geocryology and Desert Research, Academia Sinica 1974, Jäkel 1991) the distribution of the sand dunes, sand Gobi and sand accumulation types in the desert can be divided roughly into three regions: (1) north of the Tarim River, (2) west of the convergence zone (south of the Tarim River), and (3) east of the convergence zone (south of the Tarim River).

Drought conditions in the oases caused by the Föhn effect are more striking in the oases located in the foot-zone north of the Kunlun Mountains compared to those south of the Tian Shan Mountains. These conditions might be considered as a driving force for the desertification, particularly in the oases of region (3), such as at Qiemo and Ruoqiang.

7 *Further aspects of the wind and rainfall regime in the desert*

7.1 *Sand dune movement and wind*

Zhu et al (1989) indicate that the total area under subject for desertification in China is now in the range

Table 1: Prevailing wind direction and the shifting direction of sands dunes) at the southern fringe of the Taklimakan Desert*
Vorherrschende Windrichtung und Driftrichtung der Sanddünen am Südrand der Taklimakan-Wüste

	Southwest and south fringe			Southeast fringe
Wind	Direction is relatively uniform			Direction is relatively complicated and velocity is high
Station	Shache	Pishan	Qira	Minfeng
Prevailing wind direction**)	316°	288°	271°	281°
Shifting direction of sand dunes as a whole	312°	291°	277°	272°

*) Data are taken from Zhu et al 1989
**) Composite of wind direction crossing over the sand dunes

of 334,000 km². An area of 176,440 km² (24,223 km² within the Taklimakan Desert), i. e. 52.7%, has already been affected by desertification and an area of another 158,000 km² is potentially endangered (14,200 km² within the Taklimakan Desert).

The shifting direction of sand dunes in the Taklimakan Desert was schematically illustrated first by the Xinjiang Biology, Pedology and Desert Research Institute, Academia Sinica (1978). Secondly, the Xinjiang Institute of Geography, Academia Sinica (1987) discussed the desertification problems using these illustrations. Zhu et al (1989) drew shifting directions of sand dunes by stream lines comparable to the air stream lines in their figures 6–12. A map of Taklimakan "Desert wind, sand and geomorphology" was published by the Lanzhou Institute of Glaciology, Geocryology and Desert Research, Academia Sinica (1980) and in a revised edition in 1990.

These maps, showing "shifting directions of sand dunes" and "wind, sand and geomorphology", clearly reflect the main air stream systems in spring and summer given in Figs. 7 and 8 of this paper. In the southeastern part of the Taklimakan Desert the northeasterly wind prevails taking a circular route east of the Tian Shan Mountain Range. Here the 'complex type' of sand dunes develops markedly. In about two thirds of this part, sand dunes higher than 50 m can be observed. In contrast, in the southwestern part of the Taklimakan Desert, the 'complex type' of sand dunes does not prevail except in areas, where the westerlies are stronger and therefore result in this type of dunes.

In general the difference between the shifting direction of sand dunes and the prevailing wind direction is 3–6°, where a relatively good coincidence is seen, but 9–15° in the complex region (Table 1). In the case of Minfeng, located at the convergence zone between Keriya-He (River) and Hotan-He (River), the difference of the dune/wind direction is about 9°, which is relatively high.

In the northern half of the Taklimakan Desert, namely in the region along Yarkan-He (River) and Tarim-He (River), the northerly winds crossing over the Tian Shan Mountain Range prevail. As has been mentioned before, wind velocity and dryness are not extremely high. Accordingly, their impacts on desertification are less serious than in other parts of the desert. These conditions have been discussed by calculating the maximum possible sand transporting intensity and resultant direction at the oasis stations located at the periphery area of the Taklimakan Desert (Ling 1988).

7.2 Sand storm, sand-dust storm and Kôsa

In the Taklimakan Desert and its surroundings the mean annual number of days with dust and sand storms is higher than 30 days (Zhang 1984). The southeastern part of the Taklimakan Desert has the maximum number of days with sand-dust storms (stronger than 12–14 m/sec): 33.9 days/year on a longterm average, but 55 days in the extreme year at Minfeng. In addition, there are 32.1 days/year and an extreme of 42.0 days/year at Hotan respectively. The dust storm frequency has a significantly negative rank correlation with the amount of rainfall in China (Goudie 1983). This is very striking compared with other arid and semiarid regions in the world. As mentioned above, Kara Bran sometimes develops very strongly; the peak gusts may reach 30 m/sec. When it starts, visibility gets as low as 0–50 m. Generally, the most serious conditions last 2–4 hours. The largest amounts of sand/dust fall-out and atmospheric pollutants observed in the main cities of Xinjiang, 1982–

1988, were to be found in Hami (Hao 1991). As has been analyzed in the Sonoran Desert, USA, flowing dust and temperature alterations affect significantly human activities (Brazel et al 1988). Therefore, further studies are needed on such impacts in the Taklimakan Desert.

It is assumed that the source regions of Kôsa, a yellow sand observed in Japan, are the Taklimakan Desert, the Loess Plateau, the Gobi Desert in Inner-Mongolia, and the Hexi-Corridor. Among those, the source regions east of the Loess Plateau are likely to be dominant (Murayama 1991, Shi 1991).

According to a simulation study on Kôsa (Kai et al 1988, Kai 1991), yellow dust is transported from the Taklimakan Desert to Japan within 5-6 days and from the Loess Plateau within 2-3 days. There is a high possibility that its source region is the Taklimakan Desert.

7.3 Hot, dry wind

There is no meteorologically precise definition of hot, dry wind, but, when it blows, air temperature rises by 10 °C or more and relative humidity falls to 20%. It is also important to notice that the daily course of meteorological parameters becomes minimal during the occurence of this wind. Agrometeorologically, it causes severe damage because this wind mainly occurs in the season of the flowering and ripening of wheat (Special Agriculture Group in the Meteorological Society of Xinjiang-Uygur Zizhiqu 1988, Xu 1989). In Table 2 (a), the number of days, the frequency of weather and the occurrence of hot, dry wind at 9 oasis stations are listed. The classes for heavy and light types are defined as given in Table 2 (b). In the southeastern part of the Taklimakan Desert, the wind is stronger than mentioned above. Therefore, the number of days with hot, dry wind reaches about 20 days at Ruoqiang. The other areas, such as the Turpan Basin and the Junggar Basin, also suffer frequently from the damage resulting from hot, dry winds. When the number of days is higher than 10 and this meteorological situation takes place more than 2 times a year, the wheat yield reduces by 10%. The hot, dry wind discussed here is meteorologically different from the sand storm or sand-dust storm mentioned in 7.2, but the strong wind simply called "Dafeng" (great wind) by the local people may relate to both. Further synoptic meteorological and climatological analysis is needed.

7.4 Recent changes and fluctuations

There is quite some evidence that the climate of the Taklimakan Desert has been changing particularly during recent years (Ling 1990; Li 1990 a, 1991). The annual number of fog days in Hotan has changed: 63 days in the 1940s', 10 days in the 1950s' and 2 days in the 1960s' and the 1970s'. In contrast, the number of days with suspended dust weather increased from 152 days to 263 days in 1980. Some of these changes are considered to be caused by the urbanization in the vicinity of the observation points. Therefore, the

Table 2 (a): Number of days, frequency of wheather, and its occurrence frequency by classes of hot, dry wind in Xinjiang

Heiß-trockene Winde in Xinjiang (Zahl der Tage, Wetterhäufigkeit und Häufigkeitsklassifizierung)

Station	Number of days	Frequency of weather	Class: Heavy (%)	Class: Light (%)
Hami	8.0	1.5	35	65
Ruoqiang	19.8	6.9	37	63
Qiemo	9.3	2.2	18	82
Minfeng	8.0	1.9	37	63
Kuqa	6.4	1.1	27	73
Yutian	4.9	1.0	30	70
Hotan	3.5	1.1	5	95
Shache	3.8	0.8	7	93
Kashi	4.5	0.9	12	88

Source: Xu 1989

Table 2 (b): Classes of hot, dry wind in Xinjiang defined by Xu (1989)

Klassifizierung der heiß-trockenen Winde in Xinjiang nach der Definition von Xu (1989)

Type	Class	Max. air temperature (°C)	Relative humidity (%)	Wind velocity (m/sec)	1,000-grain-weight of wheat (%)
Hot and dry	Light	≥35	≤30	≥3	5.66
	Heavy	≥38	≤25	≥3	10.01
Wind and dry	Light	≥28	≤30	≥8	4.76
	Heavy	≥32	≤30	≥10	9.84

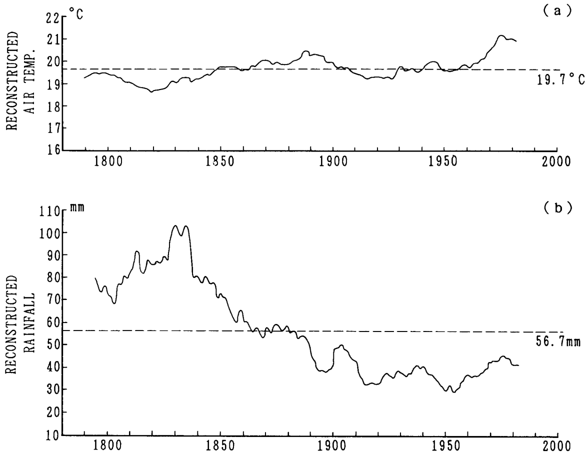

Fig. 9: Reconstructed curves of (a) air temperature (mean from the first 10 days of April to the middle 10 days of October) at Qira and (b) annual precipitation at Yutian. Reconstruction was made by the tree rings of *Populus diversifolia.* Curves are 10 year running means (LING 1990)

Rekonstruierte Verlaufskurven (a) der Lufttemperatur (Mittel von der ersten April-Dekade bis zur mittleren Oktober-Dekade) für Qira sowie (b) der Jahresniederschläge für Yutian. Die Rekonstruktion stützt sich auf Baumringe von *Populus diversifolia.* Verlaufskurven als 10jährige gleitende Mittel

changes are restricted only to the oases and their surrounding areas and do not affect the whole desert. Nevertheless, we should pay attention to this effect when discussing the desertification of the oases and their surrounding areas.

The reconstructed curve of air temperature during the growing season at Qira, 1785–1986, indicates a striking increase since the 1910s' as shown in Fig. 9 (a) (LING 1990). In particular, the increase during the last 30–40 years reached more than 1.5°. The reconstructed annual precipitation curve at Yutian shows a marked decrease since the 1830s' as given in Fig. 9 (b). Roughly speaking, the fluctuation range has been less than 15 mm in this century. But, it must be noted that in general the relatively small but apparent fluctuations of air temperature and precipitation in this century are parallel: minimums in the 1910s' and the 1950s' in contrast to the observed maximums in the 1940s' and the 1970s'.

8 *Summary and conclusion*

This preliminary study on wind and precipitation in the Taklimakan Desert led to the following results:

a) There are five main air streams in Xinjiang: (1) Westerlies or northwesterlies prevail in the upper troposphere in the northern part of Xinjiang. This circulation takes a roundabout route east of Tian Shan and approaches the southeastern part of the desert as northeasterlies. (2) One branch of this air stream reaches the northeastern part of the desert also as northeasterlies. (3) Northerlies flowing down to the southern foot of Tian Shan. (4) Westerlies flowing over the pass of the mountain and descending into the western part of the desert. (5) South to southeasterlies crossing over the pass of Karakoram from Pakistan. They are dry and hot after having descended from the mountains (Föhn effect).

b) Along the convergence zone formed mainly between the first and the fourth air stream mentioned in a), convection may occur, resulting in strong showers. It is assumed that the inner desert area along the convergence zone can receive more rainfall than has been generally expected.

c) A daily rainfall total of 20–30 mm is not rare. Its frequency changes from place to place, but the occurrence should be taken into consideration concerning geomorphological and hydrological processes. The relative intensity of precipitation (the ratio of the observed record of a maximum 24-hour-precipitation to the long-year-mean annual precipitation) reaches 100–300% (locally even 400%) in the southeastern part of the desert.

c) Sand/dust storms stronger than 12–14 m/sec are very frequent, particularly in the southeastern part of the Taklimakan Desert. They occur in this region on 40–50 days/year. Hot, dry winds are also frequent with an occurrence of 20 days/year. When Kara Bran (black wind) blows, the visibility may be as low as 0–50 m in the most serious cases. The impact of these winds on desertification, human life, agricultural landuse etc. should be studied further.

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(* = in Chinese, ** = in Japanese)

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