# THE CHARACTERISTICS OF THE DESERT CLIMATE AT TURPAN, CHINA

With 5 figures and 3 tables

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*Zusammenfassung:* Kennzeichen des Wüstenklimas von Turpan, China

Turpan (Turfan) liegt in der tiefsten Geländedepression Chinas (bis 154 m unter NN), ist von Gebirgen umrahmt und besitzt ein hochkontinentales Wüstenklima, das als trockenstes und heißestes überhaupt in China gilt. Die absolut höchste Temperatur für Turpan beträgt 47,7 °C bei einem langjährigen Julimittel von 32,4 °C, die absolut tiefste dagegen -28,0 °C bei einem Januarmittel von -8,9 °C. Der mittlere Jahresniederschlag von nur 16 mm unterstreicht die ausgeprägte Trockenheit. Das trockenheiße, winterkalte Wüstenklima von Turpan wird in langjährigen Mittelwerten der verschiedenen Klimaelemente wie auch in klimatischen Extremereignissen dokumentiert. Als Gründe für das Wüstenklima von Turpan werden vor allem die Geländeform und ihr Einfluß auf die Zirkulationsverhältnisse aufgezeigt.

Turpan (Turfan, Tulufan) commonly stands for the driest and hottest desert climate in all China and, at the same time, for one of the most hazardous desert climates on earth. As clear evidence, Turpan prefecture is in China popularly known as the "fire prefecture". Economically, however, it is surprising that Turpan represents one of the most flourishing oases on the ancient Silk Road (MECKELEIN 1986, WEGGEL 1985).

This paper aims to present the characteristics of the desert climate at Turpan, by analysing climatological records for Turpan Observatory which is a Chinese category I-observatory under the State Meteorological Administration, located at 42° 56′ N, 89° 12′ E in the center of Turpan City, at an elevation of 34.5 m a.s.l. Basically, 30-year climatic values for the observation period 1952–1981 are analysed; additionally, 10-day temperature and precipitation records were available for a period extended until 1990.

## *Geographical setting*

Turpan gains an outstanding geographical attention and attraction as well, both as an intramontane basin and as an oasis city (Fig. 1). As a basin, Turpan occupies a large tectonic depression which extends more than 200 km from West to East and over 100 km from North to South, located in the rugged southern Tian Shan. Turpan Basin sinks down to 154 m below sea-level at Aydingkol Lake, representing the lowest point in China and the second lowest point on earth. As an oasis city, Turpan is located in the inner part of Turpan Basin, mostly in an elevation between 20 and 50 m a.s.l. Politically belonging to Xinjiang Autonomous Region of China, Turpan Basin and City must be considered as a part of central, respectively continental Asia, expressed by the shortest distance to the ocean of about 2,500 km. Obviously, the geographical setting of Turpan must create an extremely great continentality which governs the climate.

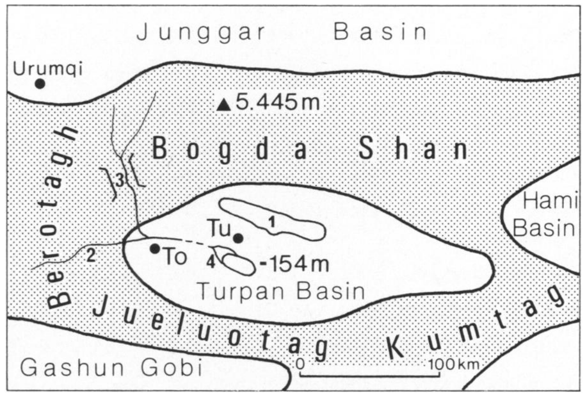


*Fig. 1:* Geographical setting of Turpan Basin and Turpan City (spelling of names according to the local Uighur language). Tu = Turpan, To = Tokshun, 1 = Flaming Mountains, 2 = Ala Gou River, 3 = Baiyanggon River and Pass, 4 = Aydingkol Lake

Geographische Lage des Turpan Beckens und der Stadt Turpan (Schreibweise aller Bezeichnungen in der lokalen uighurischen Sprache)

## *Climatic classification*

According to the climatic divisions of China by Chinese scientists (ZHANG a. LIN 1985, SHENG et al. 1986; see also DOMRÖS a. PENG 1988), Turpan is classified to the 'arid' type of the 'warm temperate' zone; this climatic type occupies the commonly known deserts in northwestern China[1]. Referring to

[1] Surprisingly, the term 'desert' is not used by Chinese scientists from a climatological standpoint, but only from a geomorphological viewpoint, defining a desert by dunes in an arid geographical and climatological setting.

*Table 1: 30-year climatic normals at Turpan (Meteorological Observatory), 1952–1981*
30jährige klimatische Mittelwerte für Turpan (Meteorologisches Observatorium), 1952–1981

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean temperature, °C | -9.5 | -2.1 | 9.3 | 18.9 | 25.7 | 31.0 | 32.7 | 30.4 | 23.3 | 12.6 | 1.8 | -7.2 | 13.9 |
| Absolute maximum temperature (°C) | 8.5 | 19.5 | 29.7 | 37.6 | 43.6 | 47.5 | 47.6 | 46.6 | 43.4 | 34.3 | 23.0 | 9.0 | 47.6 |
| Absolute minimum temperature (°C) | -28.0 | -24.5 | -10.4 | -1.8 | 4.7 | 11.5 | 15.1 | 11.6 | 1.3 | -5.7 | -14.2 | -26.1 | -28.0 |
| Mean maximum temperature (°C) | -3.1 | 5.1 | 16.6 | 26.1 | 33.1 | 38.2 | 39.9 | 38.2 | 32.0 | 21.8 | 9.4 | -1.0 | 21.4 |
| Mean minimum temperature (°C) | -14.5 | -8.2 | 2.2 | 11.3 | 17.5 | 22.9 | 25.1 | 22.6 | 15.5 | 5.9 | -3.5 | -11.7 | 7.1 |
| Number of days with Tmin ≤0 °C (frost days) | 31.0 | 27.1 | 10.2 | 0.2 | 0 | 0 | 0 | 0 | 0 | 2.1 | 23.0 | 31.0 | 124.6 |
| Number of days with Tmax ≤0 °C (ice days) | 16.8 | 6.6 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 3.5 | 14.2 | 21.5 | 63.4 |
| Number of days with Tmin ≤-10 °C | 26.5 | 9.6 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.8 | 19.9 | 59.9 |
| Number of days with Tmax ≥40 °C | 0 | 0 | 0 | 0 | 1.2 | 9.8 | 15.5 | 10.0 | 0.5 | 0 | 0 | 0 | 37.0 |
| Mean precipitation total (mm) | 2.0 | 0.3 | 1.0 | 0.4 | 0.5 | 3.0 | 2.0 | 3.0 | 1.0 | 1.0 | 0.4 | 1.0 | 16.0 |
| Maximum monthly precipitation total (mm) | 10.0 | 5.3 | 25.9 | 2.2 | 4.0 | 19.6 | 13.8 | 42.1 | 10.6 | 10.8 | 4.9 | 10.8 | 42.1 |
| Absolute daily maximum precipitation (mm) | 5.5 | 3.6 | 20.7 | 2.2 | 3.8 | 9.0 | 10.9 | 36.0 | 8.5 | 10.5 | 3.3 | 7.1 | 36.0 |
| Total number of rainy days | 2.2 | 0.3 | 0.4 | 0.5 | 0.7 | 2.2 | 2.7 | 2.5 | 1.2 | 0.3 | 0.3 | 1.7 | 15.0 |
| Total number of days with snowfall | 2.1 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 1.6 | 4.5 |
| Mean relative humidity (%) | 59 | 46 | 33 | 27 | 27 | 29 | 31 | 36 | 41 | 49 | 53 | 62 | 41 |
| Cloudiness (./8) | 3.9 | 4.1 | 4.9 | 5.5 | 5.4 | 5.6 | 5.3 | 4.4 | 3.5 | 3.0 | 3.3 | 3.7 | 4.4 |
| Mean daily sunshine duration (h) | 5.8 | 7.3 | 7.9 | 8.7 | 9.7 | 10.3 | 10.3 | 10.1 | 9.6 | 8.5 | 6.8 | 5.3 | 8.4 |
| Frequency of calms (%) | 49 | 37 | 23 | 22 | 21 | 21 | 23 | 26 | 31 | 39 | 44 | 51 | 32 |

global climatic classifications, Turpan is mostly considered as belonging to the "cold desert climate", as, for example, identified by Koeppen (1931).

### *Climatic elements*

The desert climate at Turpan can be described by long-term climatic observations, referring to the 30-year period 1952–1981 (Table 1). Furthermore, extreme and specific climatic phenomena of this observation period are helpful to characterize the desert climate at Turpan (Table 2). In addition, useful climatic information can also be given from 10-day observations from 1952 to 1990.

### *Temperature*

Most typically, temperatures at Turpan vary extremely between a long and hot summer and a cold winter, clearly shown by the various temperature variables given in Table 1. Summer is generally considered from mid-April until end-September, hence occupying 5.5 months, when temperature means are >20 °C. The extremely hot peak of summer is from June until August when the daily maximum temperature usually exceeds 30 °C, thus characterizing all days as "hot days". Furthermore, proof of the extremely hot summer peak is given by the large number of totally 35.3 very hot days with $T_{max}$ ≥40 °C from June until August. This corresponds with a 57% probability of such very hot days. The hot summer is also shown by the absolute maximum temperatures so far recorded in June, July and August, which were 47.5, 47.7 and 46.6 °C, respectively. The 47.7 °C-value is the highest air temperature recorded at Turpan (on July 23, 1986).

Winter is commonly confined from early November until end-February when mean temperatures drop to <0 °C. The cold winter is also shown by the large number of frost- and ice-days between November and February (see Table 1). Even more important is the large number of cold days with $T_{min}$ ≤-10 °C which accounts for 56.0 from December until Febru-

*Table 2: Extreme and specific climatic phenomena at Turpan (Meteorological Observatory), 1952–1980 (after ZHANG 1985)*
Klimatische Kennwerte für Turpan (Meteorologisches Observatorium), 1952–1980 (nach ZHANG 1985)

| | |
|---|---|
| Temperature | |
| - Mean annual range | 42.2 °C |
| - Mean daily range | 14.3 °C |
| Surface temperature | |
| - Mean January | -9.7 °C |
| - Mean July | 39.8 °C |
| - Mean annual | 17.2 °C |
| - Absolute maximum | 76.6 °C |
| - Absolute minimum | -31.9 °C |
| Frost | |
| - First day | 29 Oct |
| - Last day | 2 Apr |
| Mean daily temperature ≥0 °C | |
| - First day | 23 Feb |
| - Last day | 21 Nov |
| - Duration | 272.2 days |
| - Accumulated temperatures | 5731.6 °C |
| Mean daily temperature ≥10 °C | |
| - First day | 23 Mar |
| - Last day | 22 Oct |
| - Duration | 213.9 days |
| - Accumulated temperatures | 5391.3 °C |
| Snow | |
| - First day | 24 Dec |
| - Last day | 4 Feb |
| - Number of snowfall days | 4.5 days |
| - Maximum depth | 17cm |
| Pan Evaporation, mean annual total | 2837.8 mm |
| Sunshine, mean annual total | 3049.5 h |
| Cloudiness | |
| - Overcast days | 55.9 days |
| - Clear days | 106.0 days |
| Thunderstorm | |
| - First day | 2 June |
| - Last day | 25 Aug |
| - Duration | 85.4 days |
| - Number of days | 9.9 days |
| Certain weather phenomena | |
| - Geared frost | 0 days |
| - Soft rime | 0.2 days |
| - Hail | 0 days |
| - Fog | 0.5 days |
| - Gale | 26.8 days |
| - Sandstorm | 6.3 days |

ary and hence expresses a 62% probability of such cold days.

Unlike summer and winter as pronounced and distinct seasons, spring and autumn are only short transitional seasons, each roughly occupying one month only (March and October, respectively).

The pronounced seasonality in temperature can be underlined by 10-day means from 1952–1990, showing the last 10 days of July as the hottest decade (32.5 °C) and the first 10 days of January as the coldest (-9.6 °C). Hence, the annual range of temperature amounts to 42.1 °C, which corresponds with the same high value as in the case of monthly values (42.2 °C).

Further characterizing the hot summer and cold winter at Turpan, the variation of temperature is considered over time from 1952 to 1990 for July and January as well as for the annual mean (Fig. 2). A larger variation occurs for January, ranging from -20.5 to -4.4 °C, showing a variation of 16.1 °C, compared with a long-term mean of -8.9 °C. A much smaller variation of 5.3 °C is observed for July, ranging only from 35.9 to 30.6 °C, compared with a long-term mean of 32.4 °C. Unlike July and January, the annual mean varies only moderately, between 15.4 and 12.3 °C, showing a range of only 3.1 °C while the long-term mean accounts for 14.0 °C.

Underlining the great variation of temperature over time, together with the distinct seasonality in temperature, the number of days with maximum (resp. minimum) temperatures above (below) certain values can also be taken into account. Considering the number of days with $T_{max}$ ≥40 °C (≥25 °C), the highest value is 56 days in 1953 (186 days in 1957), while the lowest value is 23 days in 1958 (167 days in 1955). For $T_{min}$ ≤0 °C (≤10 °C), the largest value recorded is 140 days in winter 1961/62 (208 days in 1972/73), the smallest 61 days in 1981/82 (173 days in 1953/54). Considering the variation of temperature over time (Fig. 2), it remains open whether the effects of global change of temperature also can be observed at Turpan.

For comparison with Turpan, it is worth stressing the temperature conditions of the hottest areas in central Asia. In southern Turkmenistan, average air temperature for July rises >32 °C. In central Kyzylkum, the absolute maximum air temperature reached >50 °C. Daytime surface temperatures have been recorded as high as 70 °C (LYDOLPH 1977). Surface temperatures for Turpan even climbed to a maximum of 82.3 °C (on July 13, 1975; HU et al. 1987). Therefore, Turpan Basin ranks among the hottest areas in Asia.

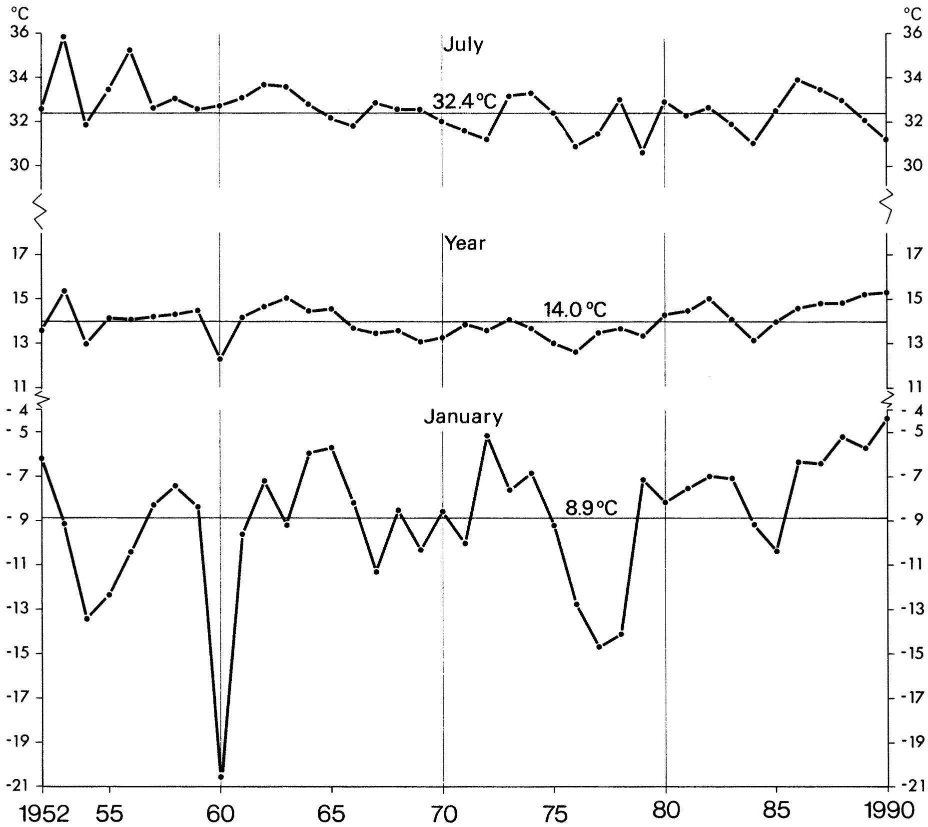


*Fig. 2:* Mean annual, July and January temperatures (°C) at Turpan, 1952–1990
Jährliches Temperaturmittel sowie Juli- und Januarmittel der Temperatur (°C) für Turpan, 1952–1990

*Precipitation*

Showing a mean annual total of only 16.0 mm and monthly totals averaging between 3.0 and 0.3 mm, the extremely dry conditions at Turpan are clearly expressed. As a typical feature of the desert climate at Turpan, a large number and frequent occurrence of drought months which do not experience any precipitation can be observed (Table 3). September until May are drought months in most years under observation, with a maximum frequency of 90% in February. In June, July and August, a minimum 30 to 40%-frequency of drought months occurred. Out of all 468 months for the whole 39-year observation period, a total number of 307 drought months are experienced, hence corresponding with a large (66%) frequency of drought months.

Proof of the extremely dry conditions at Turpan can also be given by considering the monthly percentages for the following three precipitation classes: 0, >0–5, >5 mm (Fig. 3). Evidently to be seen is again the prevalence of drought months; moreover, very low precipitation totals (>0–5 mm) prevail in all months in case that any precipitation is experienced.

The serious drought conditions at Turpan are also expressed by the large number of drought periods which occupy three or more consecutive months. Over the 39-year observation period, as many as 47 drought periods occurred, among which the longest lasted for even 11 consecutive months, from September 1966 until July 1967.

As another typical feature of the desert climate at Turpan, no seasonality of the meagre annual precipitation total of only 16.0 mm can be observed. Only statistically worth noting are the largest monthly totals in June and August (3.0 mm) and the smallest total experienced in February (0.3 mm). Decade totals show that the first 10 days both of April and November never experienced any precipitation since records are available.

Worth mentioning, but less typical of the desert climate at Turpan are rainstorms which represent a rare phenomenon. The highest precipitation within 24 hours recorded so far is 36 mm and the maximum

*Table 3: Total number of drought months at Turpan for the 39-year observation period 1952–1990*
Zahl der Trockenmonate (ohne jeglichen Niederschlag) für Turpan über die 39jährige Beobachtungsperiode 1952–1990

| J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 35 | 29 | 32 | 27 | 15 | 15 | 12 | 24 | 31 | 32 | 30 |

monthly total 42 mm. Both these totals are more than double the long-term mean annual total, an observation which may prove the great variability of precipitation under the desert climate at Turpan.

Associated with the extremely scarce and low precipitation, a great variation can be observed which can be seen from the January and July totals from 1952 to 1990 (Fig. 4). Regarding the annual total, the highest value accounted for 48 mm (1958), the lowest for 3 mm (1968), indicating a range of 45 mm. The monthly totals (given for January and July) and the annual totals show an irregular distribution over time without giving evidence to any periodicity (Fig. 4). Regarding the type of precipitation, depressional drizzle (mostly in winter) and convectional showers (in summer) occur, both, however, having little practical efficiency, for example for agriculture.

*Wind*

As far as surface winds are concerned, records at Turpan Observatory show prevailing Northerlies from November until February while Easterlies dominate in all other months. Mean annual wind velocity accounts to a moderate value of 1.7 m/s with a monthly maximum of 2.5 m/s (June) and a minimum of 0,8 m/s (December; Domrös a. Peng 1988, Li 1991). Calms are frequently experienced, showing a maximum in winter (December 51 %, January 49 % of all days) and a minimum in summer (June 21 %, July 23 %). Gales (≥17.2 m/s) must be considered as a frequent phenomenon encountered in 7% of all days.

Observations made for the whole Turpan Basin differ, however, from wind records at Turpan Observatory. Northwesterlies are described as prevailing winds and high wind velocities are regarded typical. Meckelein (1986) reports for Turpan Basin a mean annual number of 36 cases showing a wind velocity >8 (Beaufort scale, respectively >20 m/s); the maximum number even rises to 68, while the maximum wind velocity reaches >40 m/s. The longest recorded continuous duration of such windstorms is >9 hours. At Hongqiqou gap, about 100 km northeast of Tur-

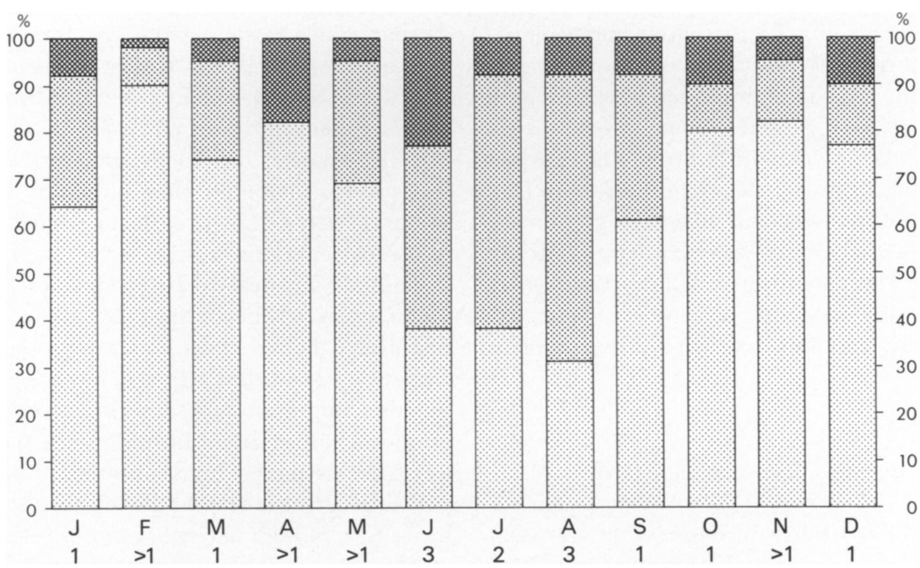


*Fig. 3:* Monthly percentages for three precipitation classes at Turpan: 0, >0–5, >5 mm (observation period 1952–1990)
Monatliche Prozentanteile für drei Niederschlagsklassen in Turpan: 0, >0–5, >5 mm (Beobachtungszeitraum 1952–1990)

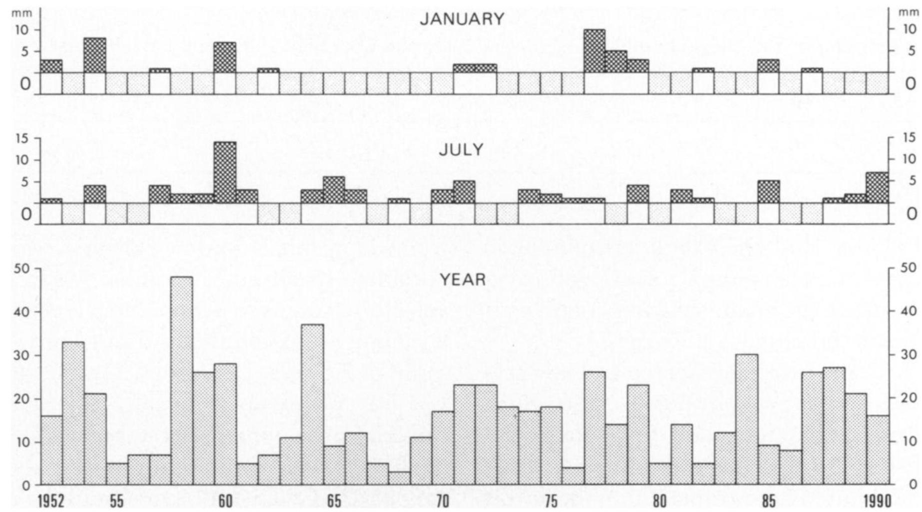


*Fig. 4:* Monthly precipitation totals for January and July and annual totals at Turpan, 1952-1990
Monatliche Niederschlagsummen für Januar und Juli sowie Jahressummen für Turpan, 1952-1990

pan City, >100 days per year with a wind velocity >17.2 m/s are recorded. Maximum wind velocities also exceed 40 m/s. Several train and bus accidents due to strong winds have been reported here. It must be followed that all wind records describe the local, rather than the large-scale conditions of the whole basin.

Some incidentially rare, but characteristic cases of extreme climatic events further identify the desert climate at Turpan. As a hazardous phenomenon, sandstorms are affecting Turpan with a mean annual number of 6.3 days. In Turpan Basin, sandstorms, due to the strong Northwesterlies, are often observed in summer; they are regarded the main reason for the crucial problems of desertification to the Turpan Basin and its flourishing ancient culture (Meckelein 1986). Worth noting is also an unusually great maximum depth of snow of 17 cm recorded at Turpan Observatory. Thunderstorms must be regarded a characteristic phenomenon in summer, when on average no less than 9.9 days with thunderstorms occur.

### *Main climate controlling factors*

Located in the central-eastern part of the Eurasian continent and surrounded by high mountains, Turpan Basin is governed by a very continental climate. The regional wind pattern above 1500 to 2000 m shows prevailing Northwesterlies throughout the year. Surface winds, however, should be expected as Easterlies persistently occurring throughout the year, due to the governing surface pressure systems that are the Mongolia Anticyclone in winter and the India-Pakistan Cyclone in summer. In practice, however, the surface winds in Turpan Basin are modified as follows (Fig. 5):

- In winter, prevailing Northerlies are observed which result from a strong flow of upper-air Northwesterlies across the Tian Shan and sinking down into Turpan Basin. Particularly, the Baiyanggou Pass, situated about 80 km northwest of Turpan City, acts as a wind gap, channelling the Northwesterlies and pressing them into Turpan Basin.
- In summer, the upper-air Northwesterlies are less strong; therefore, they only sink down to the southern part of Turpan Basin while the northern part experiences Easterlies.

These air-masses which descend into Turpan Basin are progressively becoming drier, due to the strongly established Foehn effect which represents the main climatic force for the extremely low precipitation and the high summer temperatures. Moreover, the geographical setting in an intramontane basin strongly forces the extremely high summer temperatures.

Worth noting is that the global radiation in Turpan Basin is very high and more intense than elsewhere at the same latitude. Annual global radiation in Turpan Basin accounts for around $5900 \times 10^6$ J/m$^2$ (resp. around 187 W/m$^2$ which represents the annual mean), ranging between a summer maximum around

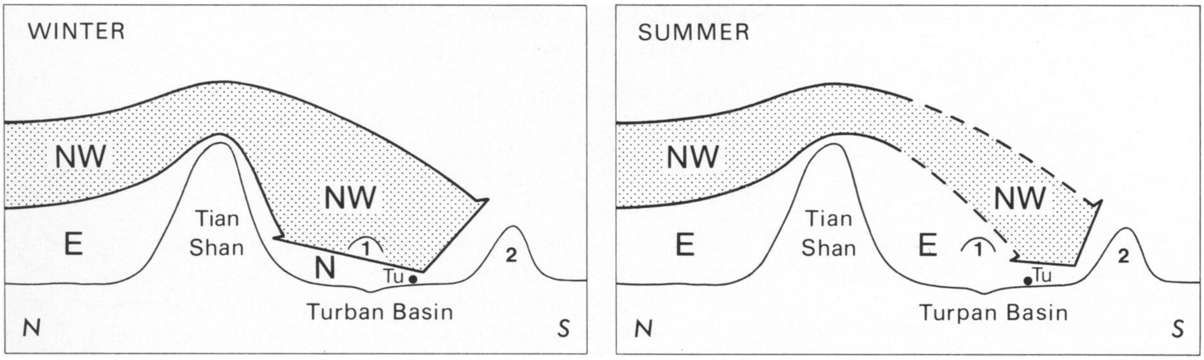


*Fig. 5:* Wind flow model for Turpan Basin in winter and summer. 1 = Flaming Mts., 2 = Jueluotag, Tu = Turpan
Schema der Windströmungen für das Turpan Becken im Winter und Sommer (nicht-maßstabsgerecht)

700–750 × $10^6$ J/m$^2$ (about 261–280 W/m$^2$) in July and a winter minimum around 250–300 × $10^6$ J/m$^2$ (about 93–112 W/m$^2$) in December (LI 1991). Also sunshine duration reaches very high values, particularly with regard to the percentage of maximum duration, showing a summer maximum of 10.3 h/day in June and July (respectively 67 and 69% of the maximum duration), and a winter minimum of 5.3 h/day (respectively 58% of the maximum duration). The largest percentage of sunshine duration falls into September and October, both experiencing 77% of the maximum duration, respectively 9.6 and 8.5 h/day.

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