RESEARCH OF THERMAL CONVECTION OF THE HEXI CORRIDOR IN GANSU PROVINCE OF CHINA

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Ten years abstract data of twelve surface synoptic and aerological stations in the Hexi Corridor region of China having been analysed, it is concluded that thermal updraft is rather intense in summer, more so in the west part than in the east.

Further, soaring flight may be carried out from March to September every year; the better period is from May to August. The best month is June. These conclusions are supported by the experiences of soaring flights on the Jiayuguan region of the Hexi corridor in summer of 1984, 1985 and 1986, where climb rates are usually 2-3 m/s, or even 5-6 m/s, and occasionally reach 8-10 m/s.

Finally, it is concluded that the west part of the Hexi Corridor is a good training and competition base for soaring flight; maybe it is the best place for creating a new world record.

1. Introduction

The Hexi Corridor is situated in the northwestern part of Gansu Province of China and within latitude 37°N-42°N and in longitude 93°E-103°E, approximately. The distance from east to west is 1500 km, and the height reaches about 1500 m. To the south is the Qi Lian mountain chain with heights about 4000 m above the sea (Photo 1), and to the north is the Nei Monogol autonomous region which is mainly covered by sand or gravel, like the Hexi Corridor, and the west is contiguous to Xinjuan Uygur autonomous region having a similar surface.

Gravel and sand surfaces are known to be thermal sources of lift for sailplanes. The Hexi Corridor is such a field. Although satellite cloud pictures show vigorous small cumulus over the Hexi Corridor in the spring and summer, further demonstration with meteorological data of surface and aero-

PHOTO 1. CAAC airport of Jiayuguan in Hexi Corridor picture. These mountains are the Qi Lian chain.

logical sounding are necessary. In this paper some problems studied included the following:

(a) At what place in the Hexi Corridor will the thermal updrafts be strongest;

(b) In what months will the thermals be best;

(c) How high will the thermals extend;

(d) How long will the soarability time in a day persist.

2. Data and method

Twelve meteorological stations from eastern Jingtai to western Dunhuang in the Hexi Corridor were selected, including four aerological stations (see Figure 1). Their records in 1971-1980 provide scientific data for research.

Meteorological factors affecting sailplanes are given in references 1,2,3 and 4. In this paper, analysis has been concentrated on factors relating to thermals; cloudiness, cloud form, sunshine, air temperature, temperature difference between air and surface, dew point temperature, temperature difference between air and dewpoint, and rainfall have been statistically analysed. In addition, lapse-rate of temperature, condensation level, depth of thermal and maximum height of thermal have been analysed also, and the synoptic situation. These results are climatic concepts; each factor has been averaged over the ten years (1971-1980) for each region.

3. Synoptic situation

One weather pattern for soaring is a cold anticyclone and upper trough with cold advection existing simultaneously (1, 4). Actually, however, a typical situation is hard to come by, but a cold ridge and upper weak trough are not rare in the summer at Hexi Corridor. One reason for this is the high latitude. There is in fact, more active cold air than at lower latitude, westerly winds decreasing south of 40°N after June, because the Hexi Corridor is located at the edge of the westerlies. This is very advantageous for soaring. For example, it is in the summer of 1984, out of a period of 18 days, there were powerful updrafts on 5 of them, and quite good ones on the remainder. It was similar in 1985.

4. Thermal condition of surface

4.1 Moisture at the surface

The condensation level depends largely upon the difference between the dry-bulb (T) and dewpoint temperature (Td) at the surface.

Table 1 shows monthly mean values of (T-Td) over the 10 year period for 8 and 14 hours Bejing Time (B.T), also the monthly rainfall.

Table 1 shows clearly the large difference between dry-bulb and dewpoint temperature even during the wet season in the Hexi Corridor. The reason for this is that moisture from the Bay of Bengal is obstructed by the Tibet Plateau.

	Time (B.T)	March	April	May	June	July	Aug.	Sept.
(T-Td) (°C)	08	9.1	9.3	9.2	8.3	7.5	7.4	[illegible]
	14	[illegible]	21.9	[illegible]	19.5	17.5	[illegible]	16.7
Rainfull(m.m)		[illegible]	5.5	9.3	15.9	[illegible]	23.5	[illegible]

TABLE 1. Mean (T-Td) and rainfall (1971-1980) of the Hexi Corridor.

The rainfall values support this. The Hexi Corridor is called the drought climate province. Correspondingly the cloud amount is small as table 2 shows.

It is a foregone conclusion that the condensation level is high (see Section 6). In fact, cumulus usually extends to above 3000 m from ground level. There are ideal conditions for soaring.

Time (B.T.)	Kind	March	April	May	June	July	Aug.	Sept.
08	low	0.1	0.3	0.5	[illegible]	0.6	0.7	0.6
	total	[illegible]	[illegible]	5.7	5.5	5.5	5.0	5.0
14	low	[illegible]	[illegible]	[illegible]	1.6	[illegible]	1.3	1.9
	total	[illegible]	5.7	5.9	[illegible]	5.9	[illegible]	[illegible]

TABLE 2. Mean cloud amount (1971-1980),

4.2 Sunshine and solar radiation

Solar radiation has long been known as a powerful source of thermal soaring. Due to solar heating of the ground, convective elements are released and rise until they reach a stable atmospheric layer. However, how long the sun shines is an important element determining the value of the solar radiation in a region.

Sunshine time and percentage of possible sunshine and solar radiation at the Hexi Corridor are separately shown in the Table 3 and Figure 1. From Table 3, mean sunshine time in a day is seen to have exceeded nine hours over the summer half year. In west Dunhuang, it is above ten hours in a day from May to August. In fact, sunshine can even reach 11-12 hours during partly cloudy conditions at the Jiavuguan.

	March	April	May	June	July	Aug.	Sept.
Sunshine(hour)	[illegible]	243.[illegible]	290.2	294.[illegible]	[illegible]	[illegible]	[illegible]
Percentage of possible sunshine	[illegible]	[illegible]	66.5	66.4	62.[illegible]	66.[illegible]	[illegible]

TABLE 3. Mean sunshine time and mean percentage of possible sunshine (1971-1980).

Figure 1 illustrates the distribution of the annual total radiation on Gansu province. The radiation increases towards the west. Dunhuang, being 158.14 kilo.cal. per cm^2 per year. The largest monthly value belongs to July. Dunhuang has near 19 kilo.cal. per cm^2 per month. The high radiation is attributable to air dryness and much fine weather.

In conclusion, energy sources for lifting sailplanes are very abundant in this region.

4.3 Sensible heat

Atmospheric energy originates from effective radiation and sensible heat at the ground and condensation latent heat (5) but sensible heat mainly, especially in dry regions. When the sun heats the ground most of the heat is quickly transferred to the air close to the ground surface through sensible heat.

Sensible heat strength is determined by the following equation:

$$SH = C_p \rho \ C_d V \ (T_s - T_a)$$

Where C_p, ρ and C_d are separately constant under some conditions. V is the vertical component of the airflow wind, $(T_s - T_a)$ is the temperature difference between surface and air. Obviously, sensible heat SH is mainly determined by and in direct proportion to the upward flow of V $(T_s - T_a)$.

Monthly means of the temperatures involved and the wind speed are shown in Table 4.

On average, the temperature difference between surface and air during the afternoon are seen to be above 20c, even 23.4c in June, and the daily mean speeds of surface wind are also larger. For the Tibetan Plateau the $(T_s - T_a)$ and V are respectively below 9c and 4.2m/s in the same months (6). It seems that the Hexi Corridor is a region with the strongest sensible heat. This is because the surface is sand or gravel of least heat capacity, which are rapidly heated to above 30°C in 8:00 to 14:00 hours, and the air temperature is lower.

Therefore, the conclusion is that tremendous energy of sensible heat can be used by the sailplane. In addition, the fact that the temperature at both 20:00 and 14:00 are close means that glider pilots may fly until after 8:00 p.m.

	Time (B T)	March	April	May	June	July	Aug.	Sept.
Air Tem. (°C)	08	-4.7	3.8	9.8	14.3	17.0	16.[illegible]	9.7
	14	8.0	14.3	20.1	24.1	25.5	24.7	19.9
	20	3.7	12.5	16.9	22.4	23.7	22.9	16.5
Surface Tem. (°C)	08	7.0	2.6	11.5	17.0	17.[illegible]	15.4	8.0
	14	24.3	34.9	42.6	47.1	46.2	44.3	37.4
Tem. diff. (°C)	14	16.3	20.6	22.5	23.4	20.7	19.6	17.5
Mean speed of wind (m/s)		3.2	3.3	3.6	3.1	2.9	2.7	2.7

TABLE 4. Mean value of (Ts-Ta) and V (1971-1980).

4.4 Special weather

Thunderstorms and gales may give in to danger for the unskilled pilot because of severe turbulence, icing, hail, the risk of lightning, strong downdrafts and strong vertical wind shear, etc.

In the Hexi Corridor, strong thermals exist and cumulus clouds go on growing and develop into cumulonimbus, and give in to thunderstorms because of air dryness. For example, thunderstorms occur frequently during June to August, though only on 4.3 days in July.

Gales maximum wind speed 17m/s or above also mean dangerous weather. Maximum speed may be above 20m/s in April in the Hexi Corridor, but appear with dust devils. However, the mean frequency is relatively low, example Table 5 shows only 1.4-4.9 days per month, most of the gales occurring during spring.

	March	April	May	June	July	Aug.	Sept.
Mean frequency (day)	4.4	5.9	4.9	4.8	3.7	2.5	1.4

TABLE 5. Mean frequency maximum wind speed (1971-1980) (Unit: day).

5. Comparison between east and west in the Hexi Corridor

Table 6 shows 10 years mean values of the data for June, July and August for the localities of Figure 1, in order from west to east.

Some conclusions from Table 6 are the moisture to the west of the Zhangye east and the sensible heat is stronger and is lower than in the mean maximum temperature likewise higher to the west than to the east.

	[illegible]			Monthly rainfall (mm)			[illegible]			Monthly maximum tem. [illegible]		
	June	July	Aug.	June	July	Aug.	June	July	Aug.	June	July	Aug.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Anxi	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Yumen town	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 6 Mean value both of moisture and thermal (1971-1980).

In a word, if sunshine and solar radiation are considered, thermal conditions are more ideal to the west of the Zhangye. This conclusion is reinforced by consideration of the instability of the atmosphere (see below).

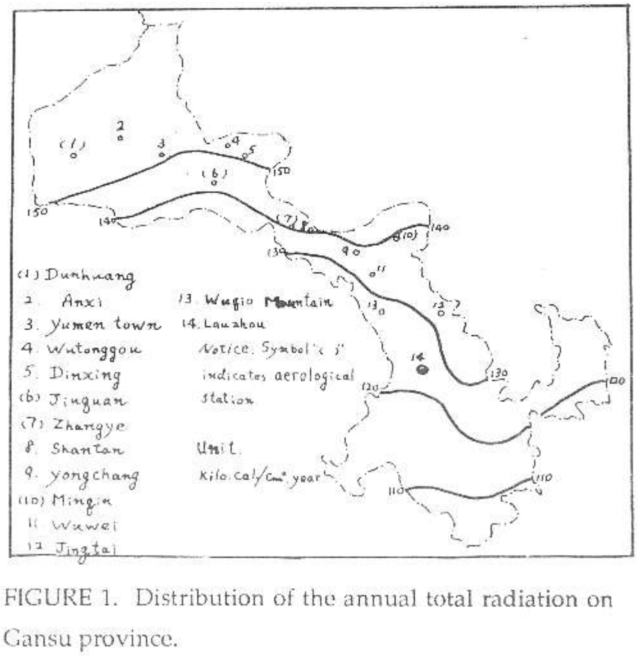

FIGURE 1. Distribution of the annual total radiation on Gansu province.

6. The intensity of convection

Upper air soundings can be applied to demonstrate the intensity of thermal convection of the Hexi Corridor, through analysing lapse-rate of temperature, condensation level, maximum height of thermal, etc. These are shown in Table 7. The table gives mean values for the 10 years from 1971 to 1980.

A. In experimental prediction of thermal strength lapse-rate is more important than temperature. It is often used imprecisely by both amateur and professional meteorologists to indicate the probable development of thermal convection.

Average lapse-rates at four aerological stations, arranged in order from west to east are shown in Table 7.

The fact of having larger lapse-rate at 20 hours is important for the sailplane, because even where this time is equal to about 18:00 of local time, all mean lapse-rates are larger on average than 0.65 C per 100m. Dunhuang has the highest and Jiuquan and Minqin the next highest.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 7. Mean lapse-rate (1971-1980).

B. The level of cloud base is approximately equal to the condensation level. Calculated condensation levels are shown in Table 8.

Condensation level is usually above 2000m in summer and 3000m is reached in June. Dunhuang and Jiuquan are most ideal.

In fact, actual levels of cumulus cloud base can exceed the calculated values by over 500m. For example, the calculated level at Jiayuquan in July 1985 is 2427m, but the actual was 3010m.

Monthly	March	April	May	June	July	Aug.	Sept.
Dunhuang	3750	3750	[illegible]	[illegible]	2625	3125	3000
Jiuquan	3500	3125	3375	3000	2250	2750	2750
Zhangye	3000	2750	2750	2500	2125	[illegible]	2250
Minqin	3375	3250	3125	2750	2250	2375	2125

TABLE 8. Calculated mean level of condensation (1971-1980) (Unit: meter).

C. Maximum height of thermals is often estimated by using maximum temperature on the thermodynamic chart when forecasting for soaring (3). Mean maximum height values are shown in Table 9, based on mean maximum temperature.

Most values are above 2000m, but are slightly lower than condensation levels because of lower maximum temperature on average. Probably, calculated levels are closer to actual ones in the dry regions. Anyhow, thermals strength is excellent in the Hexi Corridor, especially to the west of the Zhangye.

Monthly	March	April	May	June	July	Aug.	Sept.
Dunhuang	2750	3000	2750	3875	3125	[illegible]	3375
Jiuquan	[illegible]	[illegible]	2375	2375	2250	1875	[illegible]
Zhangye	1625	2375	2375	2125	2250	2125	2250
Minqin	1675	2625	[illegible]	[illegible]	2750	2125	[illegible]

TABLE 9. Average maximum height of thermal (1971-1980).

PHOTO 2. Small, fair-weather cumulus floating in the sky of the Jiayuguan on 30 July, 1986.

7. Conclusion

A. The facts that the Hexi Corridor is located at high latitude and that the ground is covered by gravel or sand are favorable conditions to give long sunshine, intense solar radiation, of the produced and useful synoptic situation and rapid heating of the ground during the day in summer for the sailplane, and are the reasons for our selection of it as a soaring base.

B. Turbulent sensible heat from surface to transfer energy to the air is intense owing to the large temperature difference between the surface and the air. It is the physical reason for the intense thermal updraft.

C. Cloudiness and cloud form are very ideal for soaring flight, because moisture from the Bay of Bengal is obstructed by the Tibet Plateau, resulting in dryness of the air.

D. Sunshine time is long and you may soar from 10 a.m. to 8 p.m. (B.T).

E. Convective condensation level is high, and considerable height may be reached by the gliders.

F. Soaring flight may be carried out from March to September every year; the better period is from May to August, the best months are June and July.

G. The part of the Hexi Corridor west of the Zhangye is a good training and competition base for soaring flight. Good localities include Dunhuang, Wutonggou, Dingxin and Anxi, etc.

H. Jiayuguan (Jiayu Pass) has been chosen as an important base for soaring sport, having favorable conditions, not only thermals but population density and travel facilities.

Jiayuguan, along the railway line between Lanzhou and Wulumugi is situated at 39°50' N and 98°15' E and is about 1500m above sea level. It is located at the western tip of the world famous Great Wall. Wedged between the snow-capped Qilian Mountains and Black Mountain of the Mazong (literally the horse's mane range), it assumes an imposing and menacing stance that has won it the title of "The Most Impregnable Defile under the Sun." It is China's best preserved ancient stronghold. Its surface is covered with gravel or sand. Small fair-weather cumulus floating in the sky, as in photograph 2 is regularly seen. Dust devels as in photograph 3 are much seen also.

PHOTO 3. The dust devil at Jiayuguan on the afternoon of 30 July, 1986. Similar phenomena occurred four times near the airport that afternoon.

8. Evidence

The above conclusions are supported by experiences of both student and expert pilots after many soaring flights at the Jiayuguan in summer of 1984, 1985 and 1986, which showed:

First, in soaring flight at the Jiayuguan from June 21 to August 15, 1984, climb rates were usually above 3m/s, at times even 8m/s on 20 days.

Secondly, from July 16 to 27th, climb rate was normally 3-5m/s and at times even above 8-10m/s, variometers showing readings. Mean time of soaring was more than 10 hours in fifteen days.

Thirdly, conditions were weak in the period of July 19-31, 1986. One of the reasons for this is that general circulation was abnormal, a warm anticyclone (or South Asia high pressure) over the Tibet Plateau or Qinghai-Xizang Plateau, having a ridge stretching northwards over the Hexi Corridor, with the result that lapse rates were small, below 0.6 C per 100m. But, updrafts were enhanced as soon as the high pressure ridge turned south.

For example, 500 km out and return flights along the trunk railway toward west from Jiayuguan were completed in five hours on July 31, 1986 by Mr. Qi Yanjun with his Nimbus 2C. In the day, lapse rate of Jiuquan is equal to 0.7c per 100m at 8:00 a.m. Good ordinary thermals are roughly 300m in diameter, giving a net rate of climb of around 3-4m/s, several times 5-6m/s, and height reached was above 2000-3000m. Mr. Qi Yanjun points out that 100 km triangular flights can probably be made after completing 500km out and return courses, when time over the Jiayuguan is only 6:00 p.m. I think he can succeed in this because a two seater glider piloted by Mr. Wang Lu Chun and Mr. Hu Huisong successfully come back at 8:03 p.m. after completing 500 km out and return course.

The above facts verify that the Hexi Corridor is a good place for sailplanes, especially to the west of the Zhangye. However, it should be compared with other good localities, especially in Australia and South Africa. I hope to investigate this in the time to come.

9. Acknowledgment

Thanks are due to the Chinese National team of specialists in soaring training for the information on actual flight experience. My students Mrs. Liu Xiao and Mr. Yu Bo are thanked for their help in calculation and analysis.

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