Characteristics of low-level wind shear in Qinghai Xining Airport

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Abstract. Characteristics of low-level wind shear in Qinghai Xining Airport are analysed by using pilot reports and reanalysis data. It manifests seasonal and diurnal variation that the frequency is higher in spring and summer, and for diurnal variation, it is higher in afternoon and early night. The weather patterns of low-level wind shear can be roughly divided into four types. Their characteristics are also studied in this paper. And terrain effect is of importance to the cause of low-level wind shear, gorges and mountains lead to strong wind and variable wind direction.

1. Introduction
Low-level wind shear is a change in wind speed and/or direction in space below 500 meters (1,600 ft), including updrafts and downdrafts. It is of particular importance to aircraft landing and taking off[1]. The aircraft may change airspeed, lift force and altitude suddenly and even get out of control when encounter low-level wind shear[2]. Because it is a small scale, it happens suddenly and its duration is short, to observe and forecast low-level wind shear is difficult. Doppler Radar, Lidar and some other up-to-date equipment can be used to detect low-level wind shear to provide alert service[3-7]. Numerical models are also used to study the low-level wind shear[8-9]. While due to expensive equipment and maintenance, lack of relative research, local characteristics and other reasons, only a few airports have developed low-level wind shear alerting system. Low-level wind shear still deserves intensive study.

In this paper, low-level wind shear cases of Qinghai Xining Airport located in the northwest China is analysed. Mountainous character of Tibet Plateau makes airports in this region vulnerable to low-level wind shear, Qinghai Xining Airport is in valley region of Qilian Mountain system in the northeast of Tibet Plateau. Low-level wind shear is a significant reason for flight delay or course reversal in Qinghai Xining Airport. In order to provide better meteorological service and avoid incidents and accidents, characteristics of low-level wind shear cases and synoptic scale weather patterns are studied, and terrain effect are discussed.

2. Data and method

2.1. Pilot Reports, PIREPs
PIREPs is an aviation terminology short for pilot reports. PIREP is a report from pilot who encounter some hazard weather phenomena, such as low-level wind shear, moderate to severe aircraft icing and turbulence, to other pilots or air traffic controllers. A PIREP contains date and time of report, flight number, aircraft type, phenomenon, location, altitude or flight level and strength. PIREPs of low-level
wind shear in Qinghai Xining Airport between 2011 to 2014 (41 cases) are used to analyse characteristics.

2.2. ERA-Interim reanalysis data
In this article, ERA-Interim reanalysis data from European Centre for Medium-Range Weather Forecast (ECMWF) is used to analyse the characteristics of meteorological elements. This global reanalysis data ranges from 1979 to present and it is produced with a 2006 version of the IFS (Cy31r2) and continues to be updated in real time[10]. The horizontal resolution of ERA-Interim is $1^\circ \times 1^\circ$. This reanalysis data has 37 vertical layers from 1000hPa to 1hPa. This reanalysis data has four records in one day: 0000UTC, 0600UTC, 1200UTC and 1800UTC.

3. Characteristics of low-level wind shear in Qinghai Xining Airport

3.1. Seasonal and diurnal variation
Statistics of low-level wind shear cases in Qinghai Xining Airport using PIREPs manifests that it occurs in every season but frequency of low-level wind shear is higher in spring (March, April and May, in Fig 1, using MAM for short) and summer (June, July and August, JJA), especially in spring. Two main causes of low-level wind shear in Qinghai Xining Airport are cold front and westerly momentum downward propagation[11], cold front is a common weather system in spring in Qinghai region, and westerly propagation occurs frequently due to surface get warming in spring lowering atmospheric stability which can lead to westerly propagation from high level. During summer, thunderstorm is a main cause for low-level wind shear. Although thunderstorm is common in summer, when it occurs at or near the airport, arriving aircrafts usually divert to alternate airport and departures usually stay on the ground for safety reason. So, the frequency of low-level wind shear in summer is not the highest one.

![Fig 1. Seasonal frequency distribution of low-level wind shear](image-url)

Fig 1. Seasonal frequency distribution of low-level wind shear (DJF for winter months: December, January and February, MAM for spring, JJA for summer and SON for autumn)

The frequency of low-level wind shear also indicates diurnal variation (bar in Fig 2.). Low-level wind shear cases concentrate in the afternoon and early night. One reason is that main causes of low-level wind shear in Qinghai Xining Airport usually occur during afternoon to early night, such as westerly momentum downward propagation and thunderstorm. And another crucial reason is that arriving and departure flight of Qinghai Xining Airport has double-peak character (line in Fig 2.), one peak exists at late morning, another at early night. During the late morning, surface and low-level wind usually stay calm or gentle breeze, this condition does not avail low-level wind shear, so its frequency is low though
the flight sortie peaks. Arriving and departure flight sortie falls during afternoon but still at a high level, and peaks at early night, during this time some atmosphere is relative not stable and make for westy momentum downward propagation, thunderstorm and so on, then the frequency gets higher during afternoon and early night.

### 3.2. Weather pattern characteristics

Weather patterns of each case is analysed using ERA-Interim reanalysis data, geopotential height is used to show the characteristics of weather pattern. The low-level weather patterns can be divided roughly into four types: the aircraft is in the front of high pressure, west of the aircraft is high pressure and east is low, east of the aircraft is high pressure and west is low and around the aircraft are scattered pressure centres.

#### 3.2.1. Front of High pressure, FH

The airport is in the front of high pressure in low level (1000hPa and 850hPa, Fig 3.a and b), and in this region the iso-geopotential height lines are dense, which indicates there is strong wind. In middle level (500hPa, Fig 3.c), the airport lies in the southeast of trough and the iso-geopotential height lines are also dense, the northwest wind in middle level is also strong.

FH type low-level wind shear is the most common type that occurs at Qinghai Xining Airport. 43.75% of FH type of low-level wind shear occurs at winter, 31.25% occurs at spring, and scarcely occur at summer. This type is related to the movement of Mongolian cold high pressure (sometime will cause cold front), it gets strong in winter when the land is very cold, moves to southeast region due to middle and low level prevailing wind (in spring and autumn it also can happen), and brings strong cold wind to where it arrives. Strong wind can cause low-level wind shear because of terrain and surface features.

#### 3.2.2. West High and East Low, WHEL

This type of weather pattern shows a seesaw characteristic in west and east of the airport at low level (Fig 3.d and e). West of the airport is controlled by a high pressure, and east is low pressure. Wind at middle level is nearly northwest, and the airport is behind the trough (Fig 3.f). Most WHEL type low-level wind shear occurs at spring. It is similar to FH type in some aspects, at low level the airport is in the east (front) of a small high pressure but not Mongolian cold high pressure. During spring, the surface is getting warm, reducing atmospheric stability and is beneficial to westy momentum downward propagation, it also can cause low-level wind shear.

#### 3.2.3. East High and West Low, EHWL

A seesaw pattern is also shown in this type, but west of the airport is controlled by a low pressure, and east is high pressure (Fig 3.g and h). The airport is in front of a ridge (Fig. 3.i), and wind at middle level is smoother than other types. EHWL type occurs mainly
in spring but not very frequent. At low level, the pressure field over Qinghai region is complicated, in general the pressure over Tibet Plateau is relatively low.

3.2.4. Scattered pressure centres, SPC. In 9 of 41 cases, there are no unique high or low pressure at certain direction of the airport, instead of them are scattered pressure centres around the airport at low level (Fig 3.j and k). And at middle level, the iso-geopotential height lines are almost straight, there is no significant trough or ridge in Qinghai and even in inner land of China region (Fig 3.m).

Almost all the SPC type low-level wind shear occurs at summer, and concentrates in afternoon and early night (16:00 to 21:00). During summer the Tibet Plateau is a huge heat resource and because the terrain is complex, thunderstorm is a common weather phenomenon. Thunderstorm is accompanied by heavy rain, lightning, downburst and gale. Down burst and gale can cause severe low-level wind shear.

Fig 3. Geopotential height field (unit: geopotential meter) of 1000hPa (a), 850hPa (b) and 500hPa(c) of “FH pattern”, 1000hPa (d), 850hPa (e) and 500hPa(f) of “WHEL pattern”, 1000hPa (g), 850hPa (h) and 500hPa(i) of “EHWL pattern”, 1000hPa (j), 850hPa (k) and 500hPa(m) of “SPC pattern”.
3.3. Terrain effect
Qinghai Xining Airport locates in Huangshui River Basin, which is on the southeast of Qilian Mountain (Fig 7). It is in a long and narrow region surrounding by gorges, the funnelling effect increases the wind speed. Around the airport, it is mountainous and the average elevation of the mountains is above 2,500 meters. Strong wind and complex topography lead to significant variation of wind speed, wind direction and low-level wind shear.

As mentioned above, FH is a common type of low-level wind shear, which is related to cold high pressure. When the cold air moves to Qilian Mountain region (triangle in Fig 7), it splits into two branches (thick lines and arrows in Fig 7). One branch moves to southeast quickly along the Hexi Corridor which is on the northeast of Qilian Mountain, and flows backward at Huangshui Valley (five-point star in Fig 7), leads to strong east wind near the airport. Another branch climbs over the Qilian Mountain towards south and east, leads to strong west wind near the airport. Coexist of these two branches can cause low-level wind shear at the airport.

4. Discussion and conclusions
In this study, cases of low-level wind shear in Qinghai Xining Airport are analysed. It reveals that low-level wind shear events of the airport have seasonal and diurnal variation. The frequency is highest in spring, during spring the cold air and west wind momentum downward propagation are active which are main causes of low-level wind shear of this airport. And summer takes the second place mainly because thunderstorm is prevalent in summer and can causes severe low-level wind shear. Afternoon and early night are high frequency time span of low-level wind shear in this airport. It may be related to decreased atmospheric stability which is beneficial to west wind momentum downward propagation and thunderstorm.

The weather patterns of low-level wind shear can be roughly divided into four types. Type FH scarcely occur at summer and common in other seasons, it is accompanied by cold high pressure. And type WHEL is also related to cold high pressure. Type SPC concentrates in summer which is in connection with thunderstorm due to plateau heating effect.

The complex terrain is another contributor for low-level wind shear. Gorges and mountains lead to strong wind and variable wind direction. Qilian Mountain and Huangshui Valley split the cold air can also form beneficial airflow pattern for low-level wind shear.

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References

[1] International Civil Aviation Organization. (2005) Manual on Low-level Wind Shear (First Edition).
https://global.ihs.com/doc_detail.cfm?document_name=ICAO%209817&item_s_key=00571853

[2] Frost W. (1983) Flight in low-level wind shear.
https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19830013440.pdf

[3] Wilson J. W., Roberts R. D., Kessinger C., et al. (1984) Microburst wind structure and evaluation of Doppler radar for airport wind shear detection. Journal of Climate and Applied Meteorology, 23(6): 898-915.

[4] Shun C. M., Chan P. W. (2008) Applications of an infrared Doppler lidar in detection of wind shear. Journal of Atmospheric and Oceanic Technology, 25(5): 637-655.

[5] Chan P. W., Lee Y. F. (2011) Application of a ground-based, multi-channel microwave radiometer to the alerting of low-level windshear at an airport. Meteorologische Zeitschrift, 20(4): 423-429.

[6] Chan P. W., Lee Y. F. (2012) Application of short-range lidar in wind shear alerting. Journal of atmospheric and oceanic technology, 29(2): 207-220.

[7] O'Connor A. (2018) Demonstration of a Novel 3-D Wind Sensor for Improved Wind Shear Detection for Aviation Operations.

[8] Pleim J. E. (2007) A combined local and nonlocal closure model for the atmospheric boundary layer. Part I: Model description and testing[J]. Journal of Applied Meteorology and Climatology, 2007, 46(9): 1383-1395.

[9] Storm B., Basu S. (2010) The WRF model forecast-derived low-level wind shear climatology over the United States Great Plains. Energies, 23(2): 258-276.

[10] Dee D. P., Uppala S. M., Simmons A. J., et al. (2011) The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. Quarterly Journal of the Royal Meteorological Society, 137(656): 553-597.

[11] Wang SH. J. (2013) Preliminary analysis of wind shear at Xining Airport, Qinghai Province. Beijing Agriculture, 27: 120 (in Chinese)