A Case Study of Low-level Wind Shear in Xining Airport

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Abstract. Low-level wind shear is a hazardous phenomenon for aircraft, a low-level wind shear case of Xining airport selected from pilot reports is analysed in this paper. Using ERA-Interim data, the weather pattern and characteristics of wind distribution are discussed. The result indicates cold high pressure accompanied by strong wind and terrain is the main reason of this low-level wind shear case.

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 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]. When an aircraft encounters vertical wind shear, the lift, altitude and configuration of aircraft change suddenly, because the low airspeed and low altitude, this can be the most dangerous situation for low-level operating. When an aircraft encounter tail wind shear, the airspeed, lift and altitude decrease, the aircraft may hit the ground or deteriorate the obstacle climbing ability, if encounter head wind shear, the landing aircraft may not stop in the runway if the runway is not long enough. If the aircraft encounter cross wind shear, it will veer off the runway. 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 price and maintenance, lack of relative research work, 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, a low-level wind shear case of Qinghai Xining Airport located in the northwest China is analysed. Xining is the provincial capital of Qinghai Province, and Xining airport is an significant airport in northwest China. Mountainous character of Tibet Plateau makes airports in this region vulnerable to low-level wind shear, 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 Xining Airport. In order to provide better meteorological service and avoid incidents and accidents, synoptic scale weather pattern and wind characteristics of the low-level wind shear case are discussed.

2 Data

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 etc., 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. The case is selected from PIRePs of low-level wind shear in Xining Airport.

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 (Cy3r2) and continues to be updated in real time [10]. The horizontal resolution of ERA-Interim is 1°×1°. 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 Results and discussions

Based on the PIRePs, there was a low-level wind shear occur at Xining Airport on the 3rd March, 2014. The report was issued by crew of China Southern Airlines Flight 3630 at 11:25 (UTC). Location that the aircraft encountered the low-level wind shear was about 3000m (above mean sea level) above the long final of NO.11
runway. Reanalysis data of 12:00 UTC on that day was used to show the weather pattern and characteristics of wind field.

### 3.1 Weather pattern

The weather pattern at low level shows that there is a high-pressure region in northwest China, Xining airport is in the front of high pressure (Fig. 1.a). And in this region the iso-geopotential height lines are dense, which indicates there is strong wind.

![Fig. 1. Geopotential height distribution at 850hPa (a) and 700hPa (b), unit: geopotential meter (gpm)](image)

At 700hPa, the airport lies in a narrow high-pressure region (Fig. 1.b) while most of northwest China is not controlled by high pressure at this level. It indicates there is shallow system cold high pressure at low level and it gets weaker with altitude increasing.

The cold high pressure usually results in temperature decreasing and strong wind. The lift force formula (Equation 1) manifests that when the temperature is lower, density of the air ($\rho$) is larger, with the same lift coefficient ($C_L$), airspeed ($v$) variation and wind area ($S$), lift variation is larger.

$$L=C_L(1/2)\rho v^2 S$$  \hspace{1cm} (1)

And strong wind will lead to larger wind variation at low-level due to terrain and buildings, namely low-level wind shear is strong. Therefore, cold high pressure will bring larger lift variation, which will influence safety of flight.

### 3.2 Characteristics of wind field

The wind distribution near Xining airport is complex. At low level, in the north of the airport, prevailing wind is north wind and the wind speed is large (Fig. 2.a) due to this region is in front of the cold high pressure. West of the airport region is dominated by west wind while in east of the airport region east wind prevails.

Wind field distribution at 700hPa is similar to that of 850hPa, Xining airport lies in the convergence region of west wind and east wind, and the zonal wind near the airport region is stronger than other region. The reason probably is that the airport is located in a nearly west-east narrow valley. The strong opposite zonal wind will lead to strong wind shear for departure and landing aircrafts.

At 700hPa, the northwest wind in northeast of the airport and north wind in southeast of the airport are very strong, this is related to the cold high pressure and terrain effect.

![Fig. 2. Wind distribution at 850hPa (a) and 700hPa (b), unit: meters per second (m/s)](image)

Xining Airport locates in Huangshui River Basin, which is on the southeast of Qilian Mountain (Fig. 3.a). It...
is in a long and narrow region surrounding by gorges (Fig.3.b), the funneling 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.

When the cold air moves to Qilian Mountain region (triangle in Fig.3.a), it splits into two branches (thick lines and arrows in Fig.3.a). 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.3.a), 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.

Fig.3. Terrain of Xining Airport (black circle: location of the airport; triangle: Qilian Mountain; five-point star: Huangshui Valley)

At low-level of Xining airport region (800hPa to 700hPa), east wind is prevailing due to the terrain effect mentioned above, wind direction varies with latitude, longitude and altitude. The north and northwest wind in the north, north wind in the south (Fig.4.a), west wind in the west and north wind in the east (Fig.4.b) make it is easy to generate low-level wind shear. And the middle level and high level over the airport region are consistent west wind.

For the aircrafts operating in this region, the wind changes significantly, both direction and speed. It will change the airspeed of the aircraft, lift force, altitude and configuration. On that day, China Southern Airlines flight 3630 was executed by an Airbus 320, the crew reported they encountered strong low-level wind shear and strong turbulence, at last the aircraft landed safely.

Fig.4. Wind distribution of isobaric level - latitude along 102E (a) and isobaric level – longitude along 36.5N, dot denotes the latitude (a) and longitude (b) of Xining airport. The wind barb shows wind direction and wind speed, wind blows along the wind-direction shaft from the side with wind feather to another side, the short line of feather denotes for 2m/s, long line for 4m/s, flag for 20m/s.

The reason of this low-level wind shear case is cold high pressure accompanied by strong wind and terrain effect. Strong wind caused by cold high pressure is a common reason for low-level wind shear in Xining airport. Using PIREPS in 2011-2014, it shows that 12 of 41 cases is related to the cold high pressure. It is necessary to reinforce meteorological service in advance under this weather pattern.

4 Conclusions

In this study, a case of low-level wind shear in Xining Airport is analysed. This case occurred under the weather pattern of cold high pressure in northwest China. The airport is in the front of the high pressure, and is influenced by strong wind in front of the high pressure. The strong wind is a main reason for low-level wind shear.

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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