Formation mechanism and development process of the downburst

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Abstract

The downburst mostly occurs in mature and severe convective storm clouds, and is caused by the downward drag of the heavy precipitation from supercell convective system and the dynamic effect caused by the difference in the density of the cold and warm air. According to the research, the formation of the downburst is closely related to the updraft and collapse of the cloud top of the convective cloud system.

Due to the downburst lifetime is short , which average 4-7 minutes, there is no need for pilot to take risks, or be impulsive to take off or landing. Furthermore, the downburst does not necessarily occur in an environment with thunderstorms or squall lines. As long as the environmental conditions match, it will also appear in other unstable atmospheres. To grasp the characteristics of meteorological radar hook echo and bow echo, perform interpretation analysis and follow-up monitoring, and grasp in advance the location, time, movement trend and intensity change of the downburst . Improve scientific monitoring and enhance the effectiveness of early warning, so as to detect the downburst caused by thunderstorms, and provide meteorological warning information to effectively ensure flight safety.

Key words: downburst, flight safety

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1.Introduction：

Flight safety, safety first. According to the evaluation of civil aviation services in the Asia-Pacific region by the International Civil Aviation Organization, the annual growth rate of civil aviation is about 5%, and the average daily total take-off and landing of Taiwan ’s civil aviation airports is also estimated to be close to 1,000. Therefore, improving

aviation service quality and efficiency is the highest guiding principle of service operations.

When a severe convective storm is born, in addition to the thunderstorm convection system itself, it is often accompanied by unstable and smaller-scale airflow or weather phenomenon. These conditions often cause very serious impact and damage to the flight safety, especially during the time when aircraft takeoff and landing, and downburst is one of them.

2.The definition of downburst:

When a severe convective storm occurs with precipitation, there will be a downdraft. As the rain increases, the downdraft will also increase. Moreover, as the downdraft reaches the ground, it will continues to spread outward. If this outward divergent airflow is very strong (as shown in Figure 1), it will often cause a considerable degree of damage to the facilities or equipment on the ground. And this kind of divergent and powerful downward rushing current is called downburst.

In terms of intensity, severity and damage risk, the downburst is much larger than the updraft or downdraft inside the general convective cell. Moreover, its development process is very fast, and its intensity changes drastically. Thus, greater special attention must be paid!

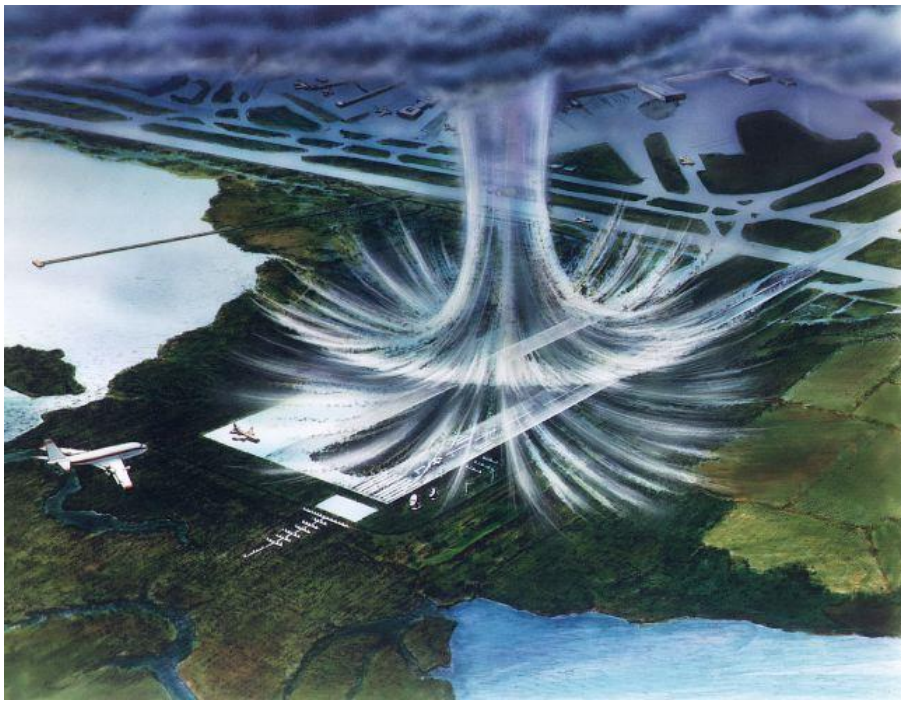

Fig. 1. The downburst schematic diagram〈figure taken from NASA〉

3.The impact of the downburst on flight safety:

The impact of the downburst on flight safety is mainly reflected in the takeoff or landing of the aircraft. During the takeoff or landing phase of an aircraft, when encountering a strong downdraft accompanied by a severe convective storm, the environmental wind shear becomes significant. Due to the sinking motion of the downburst, the airflow quickly diverges out when it reaches the ground. During the aircraft's take-off and landing process, it was originally flying upwind, and once it entered the range of outflow divergence of the downburst, it immediately encountered head wind, and was forced to land. When flying upwind, the airspeed of the aircraft (airspeed is the speed of movement of the aircraft relative to the air) increases. In order to maintain the airspeed, the pilot will inevitably reduce the throttle, and when the throttle is lowered, it will cause the aircraft continues to fly into the downburst zone, which will cause the airspeed of the aircraft decreases and the aircraft suddenly drops. In order to maintain airspeed and altitude, the pilot must increase the throttle, because when the throttle is increased as the aircraft flies into the downwind zone, it is easier to cause speed runaway.

However, If the sinking airflow is not strong and the flying height is high enough with an experienced pilot, it is possible to avoid such a dangerous area or risky situation. In the contrary, if the intensity of the downburst is strong enough, the flying height is insufficient and the pilot is lacking in flight experiences, then the aircraft has higher risk of crashing.(see Figure 2).

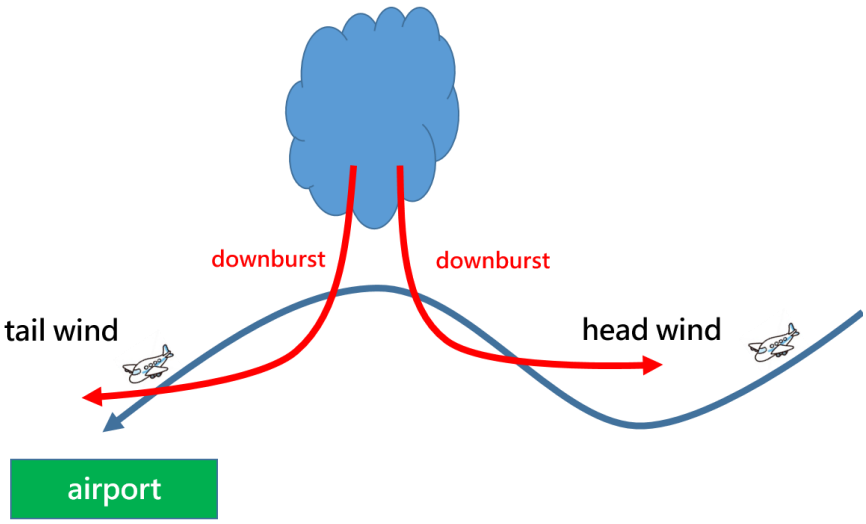

Fig. 2. Aircraft encountered the downdraft schematic diagram

In 1975, during the landing process of the Eastern United States Airplane, it encountered a downburst, a strong sinking divergent airflow and accompanied by a significant environmental wind shear. Consequently, the plane crashed on the ground, and it is the first time a airplane crashed caused by the downburst. In July 1982, a passenger plane that took off at Miami International Airport in the United States encountered a downburst at low altitude, then the aircraft stalled and crashed. All 145 members on the aircraft were killed. In August 1985, a double-decker cruise ship on the Tennessee River in the United States encountered a downburst. Strong winds hit the hull from the left chord and it caused the cruise ship overturned then eventually crashed. The accident caused 11 people on board died and 2 people were injured. In June 2000, a passenger aircraft flying to Wuhan from China's Wuhan Airlines encountered a downburst at Wuhan Wangjiadun Airport, causing the aircraft to crash and killing 49 people. In June 2015, the passenger ship of Chongqing Dongfang Steamship Company of China sailed from Nanjing to Chongqing along the Yangtze River. When sailing to the Damazhou waterway in Jianli County, Jingzhou City, Hubei Province, the passenger ship sank due to a downdraft, causing serious casualties.

The above cases all indicates that the downburst has caused a serious impact on the safety of aircrafts and ships.

4. The formation mechanism and development process of the downburst:

According to the past observations, the downburst is mostly occurs in mature and severe convective storm clouds, and is caused by the downward drag of the heavy precipitation from supercell convective system and the dynamic effect caused by the difference in the density of the cold and warm air. The results of scientific research also show that the formation of the downburst is closely related to the updraft and collapse of the cloud top of the convective cloud system. During the ascending motion of the air parcel, the updraft obtains horizontal momentum from the upper atmosphere, and as the uplift height increases, the kinetic energy of the updraft becomes potential energy and is stored. Afterwards, the water vapor was saturated and condensed, and therefore causing precipitation. Then, the updraft began to weaken and gradually disappeared. At this time, the top of the convective cloud system quickly collapsed, and a downdraft was generated. During the descending process,

the sinking airflow absorbs huge horizontal momentum, accumulates energy continuously, and advances quickly. When it finally reaches the ground, a strong downburst is formed.

Based on the development characteristic of the downburst, we can divide into two types, which is dry microburst and wet microburst. The so-called dry micro-burst starts to mix with the ambient dry air below when the rain falls, so the rain starts to evaporate and the ambient air starts to cool down. This will cause the cold air with a higher density to descend faster. When it approaches the ground, the descending airflow will diverge, causing the descending airflow dissipates quickly. Moreover, the mesoscale dry microburst is usually difficult to detect by eyes. Once it is formed near the airport or the airport runway, it will cause a great risk to aircraft takeoff and landing process. On the other hand, the formation mechanism of the wet microburst occurs when the dry air escapes from above escape into the convective development cloud system. Rainfall will not completely evaporate as it falls, due the fact that the air near the surface of the time during this process is usually warm and humid, so the air is driven directly by the rain and accelerates downwards. When it reaches the ground, the downdraft will spreads out. In addition to the formation of heavy rainfall, this humid and wet micro-burst air flow sometimes falls with hail, and thus causing more the severe weather conditions. (see Table 1).

Anyway, both dry microburst and wet microburst can result in serious flight safety issues.

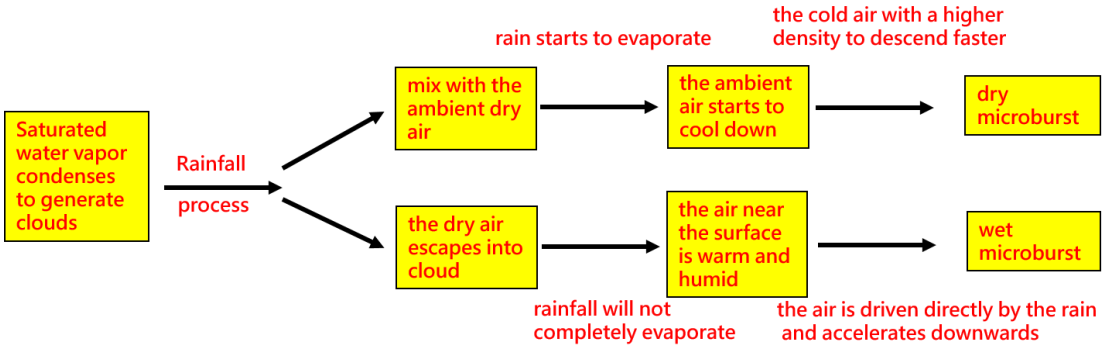

Table. 1. The physical processes of dry microburst and wet microburst

5. Responsive actions and suggestions:

a. Keep hovering or waiting:

When the aircraft is ready to take off or landing, and knows that there may be a downburst near the landing airport beforehand, pilots should

choose to postpone takeoff and hover in the air. Once the weather has stabilized and the situation is clear, then proceed takeoff or landing to avoid flight safety risks.

In other words, according to Fujita research, the downburst can be divided into two types: microburst and macroburst, according to the scale and duration of its occurrence. In addition, the horizontal divergence scale of a microburst is less than 4 kilometers, and the time scale is 2 to 10 minutes of strong downdraft. The maximum wind speed of a microburst can be as high as 75 meters / second. On the other hands, the scale of a macroburst is greater than 4 kilometers, and the duration is 5 to 20 minutes, the maximum wind speed can even reach 60 meters / second. Usually, in the outer flow field of a large downburst, several microburst monomers are often embedded.

Therefore, it is recommended that when an aircraft encounters a warning of a downburst over the airport during the approach, it is recommended to go around; if it receives a warning before the takeoff that the downburst may be caused, the aircraft will be suspended. Simple speaking, because the downburst takes a very short time, lasting up to 20 minutes or so, and averaging between 4-7 minutes. There is no risk, and no rush to take off or landing, because flying safety is always the first priority.

b. The downburst is not necessarily caused by thunderstorm or squall lines weather system:

According to statistical studies, nearly 80% of the occurrences of downbursts are related to severe convective weather systems, especially the environmental conditions with thunderstorms or squall lines. However, in some special cases with cumulonimbus environment, even when there is no thunderstorm and lightning, the downburst will still form; this is related to two factors, one is heavy precipitation and another is the vertical difference in the density of the cold and warm air in the environment. Furthermore, not only microbursts can be excited from air mass convective storms or severe supercell convective storms system, but isolated single-cell convective storms can also produce strong downburst.

The common misunderstanding that pilots has is that only under severe convective thunderstorms or squall line weather systems, will a downburst or low-level wind shear occur. However, as long as the environmental conditions match with suitable conditions, other unstable

atmospheres will also appear. Therefore, before executing a flight mission, one must review high-resolution meteorological satellite cloud images, meteorological radar echoes profiles images, meteorological lightning spatial distribution images, and relevant flight meteorological information.

c. Make good use of meteorological radar echo characteristics for diagnosis and early warning:

According to the past monitoring and surveillance experience, the use of meteorological radar tools has a very beneficial and specific effect on the control and tracking of the downburst; because most of the downburst is often accompanied by two types of radar echo, which is the hook echoes and bow echoes (Figure 3). The downburst is generally located in or around the hook of the hook echo; for bow echoes, the downburst is often located in the front area of the echo.

Meteorological operators with experience in forecasting can use the characteristics of meteorological radar echoes to perform interpretation analysis and follow-up monitoring, in order to grasp information about location, time, movement trend and intensity changes of the downburst beforehand and prompt timely warning to ensure flight safety.

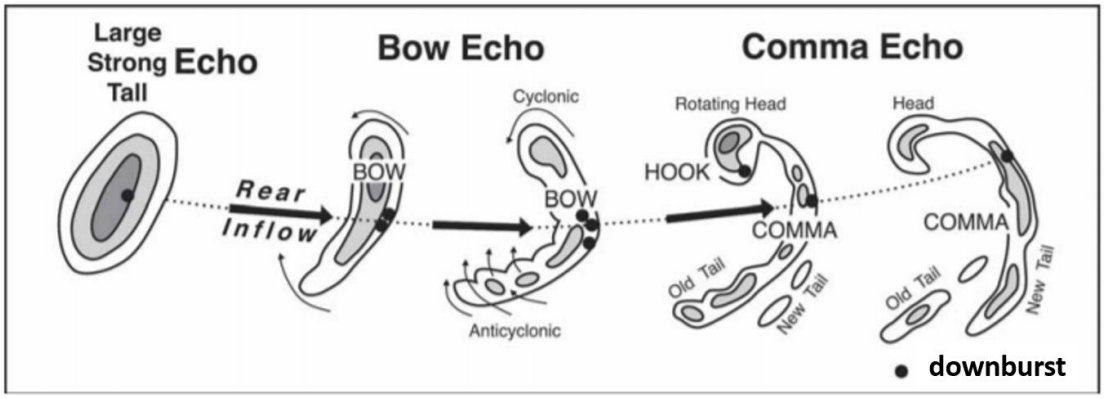

Fig. 3. The relationship of Bow echo and downburst

d. Improve scientific monitor to improve forecasting accuracy:

The latest monitoring devices of the Civil Aviation Administration of Taipei at Songshan International Airport and Taoyuan Zhongzheng International Airport have a low-altitude wind shear warning system (LLWAS). When the downburst is generated, the system will not only provide the air traffic control personnel with the information about the

location of the downburst and wind shear line, it can also provide meteorological information if a dangerous flight is near the runway. However, its biggest advantage is its flexibility. To be more exact, it can increase its monitoring range with the expansion of the airport and the increase of the runway, and it can be deployed at a strategic location relative to the runway at multiple points.

Another monitor device that the Civil Aviation Administration has is the Terminal Doppler Weather Radar (TDWR) located at Taoyuan Zhongzheng International Airport, this Doppler weather radar system can give information of wind shear for the downburst caused by severe convective storms through displayed on the radar echo image, which effectively monitors the smaller-scale convection system that may affect the runway and its vicinity. The system provides instantaneous precipitation echo intensity, radial wind field and turbulent flow field from the ground up to a height of 15 kilometers to achieve the maximum efficiency of effective monitoring.

A weather system processor (WSP) was also installed at the Kaohsiung Xiaogang International Airport to detect the downburst and gust front caused by thunderstorms, thereby providing early warning information for low-level wind shear.

6. Conclusion:

When a severe convective storm occurs, especially when it begins to rain, there will be an downdraft, and as the rain increases, the downdraft will also increase. When the downdraft reaches the ground, it will diverge outward and this downdraft is the downburst.

During the takeoff and landing process of an aircraft, when encountering a strong downdraft accompanied by a severe convective storm, the environmental wind shear becomes significant. It was originally flying upwind, and once it entered the range of outflow divergence of the downburst, it immediately encountered head wind, and was forced to land. When flying upwind, the airspeed of the aircraft increases. In order to maintain the airspeed, the pilot will inevitably reduce the throttle, and when the throttle is lowered, it will cause the aircraft continues to fly into the downburst zone, which will cause the airspeed of the aircraft decreases and the aircraft suddenly drops. In order to maintain airspeed and altitude, the pilot must increase the throttle, because when the throttle is increased as the aircraft flies into the

downwind zone, it is easier to cause speed runaway.

Based on the development characteristic of the downburst, we can divide into two types, which is dry microburst and wet microburst. Anyway, both dry microburst and wet microburst can result in serious flight safety issues.Due to the downburst lifetime is short, only lasts up to 20 minutes or so, and with an average of 4-7 minutes. So there is no need to take risks to take off or landing.

The downburst is not necessarily caused by thunderstorms or squall lines weather system, and as long as the environmental conditions are matched, they will also occur in other unstable atmospheres. To grasp the characteristics of meteorological radar hook echo and bow echo, perform interpretation analysis and follow-up monitoring, and grasp in advance the location, time, movement trend and intensity change of the downburst. Finally, improve scientific monitoring in order to improve early warning accuracy. Monitor devices such as the low-altitude wind shear warning system, terminal Doppler weather radar and weather system processor built by the Civil Aviation Authority can detect the downburst caused by thunderstorms system, and then provide effective meteorological warning information for flight safety.

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