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LIDAR SOLUTIONS

Windshear events continue to cause problems at airports. New scanning lidar technology can help

Safety remains the highest priority for air traffic management, and windshear encounters represent a major weather-related risk. For several decades, low-level windshear alert systems (LLWAS) based on anemometer networks and Doppler radars have been widely deployed at airports to detect thunderstorm-related windshear occurring under rainy conditions. More unusually, Doppler lidars capable of detecting windshear under dry air conditions have also been deployed, for example at Hong Kong International Airport.[1]

For some airports, dry windshears are no less frequent than thunderstorm-related windshears and often occur in coastal regions or complex terrain with mountains or valleys nearby. Numerous airports are situated in such areas and can be subject to strong windshears in clear air conditions. Thunderstorm-related windshears are well known – such as the evolution of downburst to microburst as described by Fujita[4] – but dry windshears have been studied to a much lesser degree.

COMBINATION OF CONDITIONS

Dry windshears depend on a combination of local weather conditions with local orography and/or coastal effects, which lead to a huge variety of root causes and spatial and temporal characteristic scales. One explanation could be that dry windshears might be less intense than wet windshears, where extreme windspeeds and very strong headwind and tailwind changes are usually observed. Nevertheless in many airports strong dry windshears are common.

For these airports, although they are still rarely used, the most appropriate sensors for detecting dry windshears are Doppler lidars. Emitting pulses of infrared light, they analyze the light backscattered by atmospheric particles to determine the Doppler frequency shift linked to the windspeed. They are still sometimes associated with low technology readiness levels, despite this no longer being

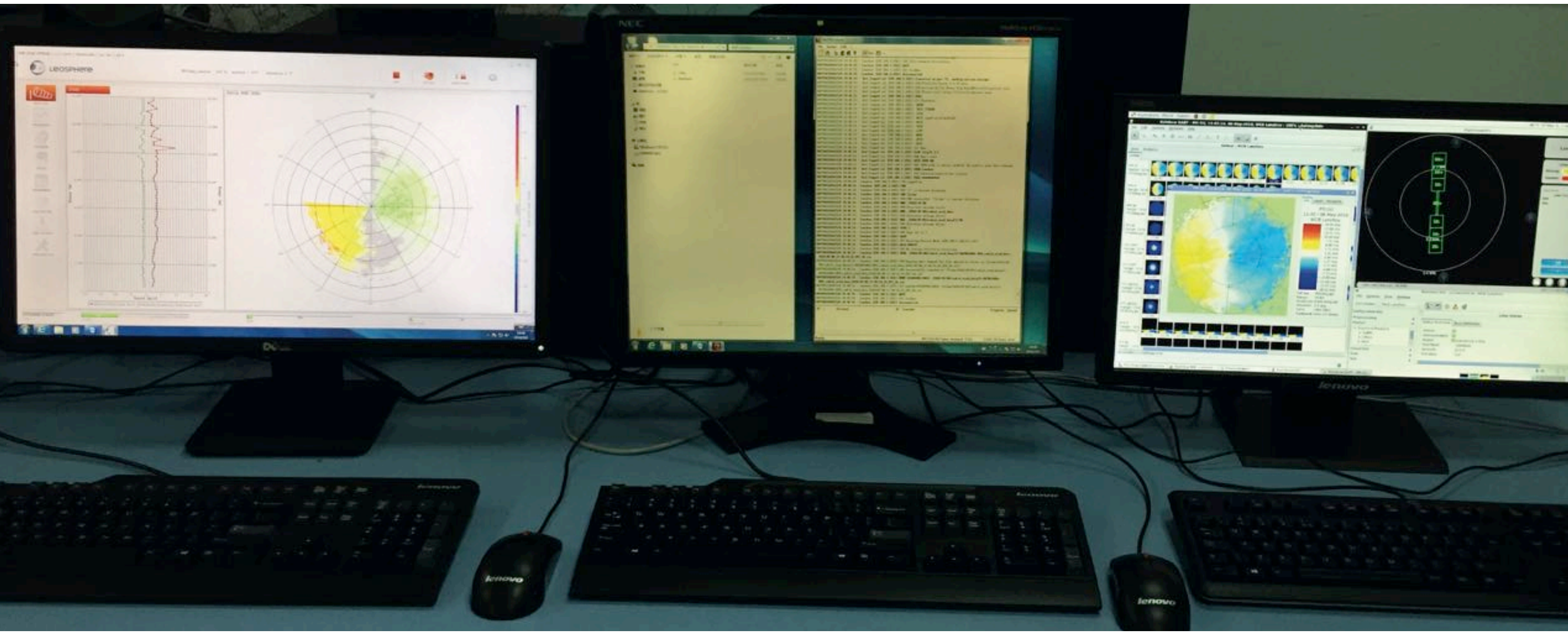


Figure 2: Installation of the Rainbow5 software in the airport

fiber technologies, making it cheaper and more appropriate for operational use. Around 1,500 Doppler lidars based on this technology are in use globally. It has become increasingly popular in the past decade.

Non-lidar experts persist in thinking the Doppler lidar difficult to handle, but a Windcube400S Doppler lidar at a regional Chinese airport has shown otherwise.

THE LANZHOU PROJECT

Lanzhou-Zhongchuan International Airport in northwest China faces frequent and dangerous windshear events in spring and summer – at least 15 a year – with the majority occurring below 500m and in dry air conditions. This makes the existing radar useless. The Gansu sub-bureau of the Northwest Air Traffic Management Bureau of the Civil Aviation Administration of China undertook to evaluate the ability of a Doppler lidar sensor to detect and better mitigate dry-air low-level windshears at the airport. At the outset, the characteristics of the local windshears were unknown and could not be used to determine the appropriate lidar setting and configuration. A study was performed to identify the requirements for the lidar based on the general requirements and best practices detailed in ICAO Annex 3 and in ICAO Doc 9817.[3] Two types of alert were identified as necessary. The first of these, the windshear alert, would provide automatic windshear alerts that give concise and up-to-date information on the observed existence of windshear involving headwind and tailwind changes of 15kts or more, which could affect aircraft.

The second, the windshear warning, would deliver contextual weather observations to support the preparation of windshear warnings from the meteorological office. These would provide concise information on the observed or expected existence of windshear that would adversely affect aircraft on the approach path or take-off path, or during circling up to 500m above ground level.

Crucially these recommendations and best practices were written for the use of LLWAS and Doppler radar systems, not Doppler lidars, although they can be used as a starting point to establish guidelines for lidars.

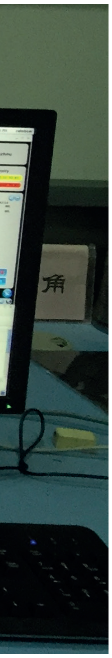
CONFIGURING THE LIDAR

As the characteristics of the windshears occurring at Lanzhou Airport were unknown at the beginning of the project, the requirements for the Lidar configuration have been defined according to the smallest, fastest and most dangerous windshear, the microburst. At least five points of measurement are required in space, to measure the wind profiles inside a microburst, and in time to measure temporal evolution. This gives a spatial resolution of 200m and a refresh rate of three minutes.

The constraints linked to the pilot approach were taken into account, to define at which stage of the approach to issue a windshear alert, and at what refresh rate. The stabilized approach was of particular importance. It is crucial in ensuring safety during landings but it puts pilots under additional pressure as it means that they must maintain the aircraft speed and trajectory within very tight margins. Given a

Putting it to the test

In this example at Lanzhou Airport, the wind direction was originally from the south. The wind above 200m then progressively turned to the northwest during the morning, creating a light windshear with the southerly surface winds. The northern wind then strengthened, and as it brought drier air it created a subsidence. The drier northern winds and the southern winds, both at low altitudes, led to a convergence zone that induced a windshear at the airport, at a maximum of 20kts along the runway. An aircraft attempting to land decided to pull up due to the strong tailwind. A pilot report was issued in accordance with the windshear alerts provided by the lidar 10 minutes before and five minutes after the pilot report. The convergence zone lasted approximately one hour, but with lower windspeeds and therefore no significant windshear. The wind then became more homogeneous from the north.



glide slope angle of 3°, the altitude of 1,000ft AGL, where the stabilized approach begins, corresponds to a distance of 3 nautical miles before touchdown. This is the area noted for attention (ARENA) chosen for the LLWAS to provide windshear alerts.

Pilots need to know before entering into stabilized approach if a windshear has been observed so that they can adjust the aircraft's configuration accordingly or go around. As pilots prepare the aircraft landing configuration after the initial approach fix, at Lanzhou Airport the time between the initial approach fix and the stabilized approach point is three minutes. The windshear alert must then be updated every three minutes.

The final requirements for lidar configuration were based on the ICAO Annex 3 and Doc 9817 recommendations, the study of the characteristics of microbursts and the information provided for the pilots.

WINDCUBE400S-AT AT LANZHOU

The Windcube400S-AT lidar was positioned to maximize the performance of windshear detection for both runway directions and to ensure the measurements of the headwind and tailwind components. Rainbow5 software developed by Selex ES was installed in the forecast office to provide maps of Doppler windspeeds of the lidar, as well as a visualization of the windshear alerts. The configuration consisted of a series of full azimuthal scans at the glide slope angle, repeated every three minutes, interspersed by full azimuthal scans at different elevation angles or by a vertical scan.

A dedicated methodology was developed to evaluate the Windcube400S-AT's ability to detect and operationally alert about dry air windshears at Lanzhou Airport. The uptime ratio of the lidar during the project was 99.6%, and it provided windshear data for 97% of the time.

The capability of the Windcube400S-AT to provide relevant windshear alerts was then assessed. Two methodologies were used. A good detection ratio of the dry-air windshears was defined by the ratio of the valid windshear alerts, with the number of alerts provided in real time by the Rainbow5 software. The alerts are considered valid if the changes of the headwind and tailwind profiles in the ARENA are above 15kts. This allows characterization without reference to the performance of the windshear detection algorithm. During the trial, all windshear alerts provided in real time by the lidar were validated, resulting in detection ratio of 100%. Secondly, the pilot reports provided helped determine the probability of detection (POD) of the lidar, which reached 83.3%. The three pilot reports not accounted for by the lidar were cases of low-level turbulence and strong crosswinds. The POD performances were considered satisfactory given the previous studies that tried to match pilot reports with ground-based sensors and given the relatively short evaluation.

The Windcube400S-AT helped characterize the local windshears at Lanzhou Airport, by providing insights into their typical duration, main principles (headwind changes, changes from headwind to tailwind, crosswind components, turbulence) and impact on air traffic delays. Above all, the forecasters used the windshear alerts and the wind data from the lidar to anticipate windshear events, increasing the forecasting score of dry windshears by 24.99%. Finally, the lidar brought a better characterization in space and time to windshear events, enabling alerts to be focused, for example on approaches or departures. Without the Windcube400S-AT, the forecasters could only forecast the existence or absence of windshear events. ∎

[1] *Chan, C M (2008). Applications of an Infrared Doppler Lidar. Journal of Atmospheric and Oceanic Technology, 637-655*
[2] *ICAO Navigation, M S (July 2007). Annex 3 to Convention of International Civil Aviation - Part I Core SARPs – Part II Appendices and Attachments. Sixteenth Edition*
[3] *ICAO manual on low-level windshears, document No 9817*
[4] *Fujita, T (1985). The Downburst – Microburst and Macroburst. Satellite and Mesometeorology Research Project (SMRP) Research Paper No. 210, National Technical Information Service*

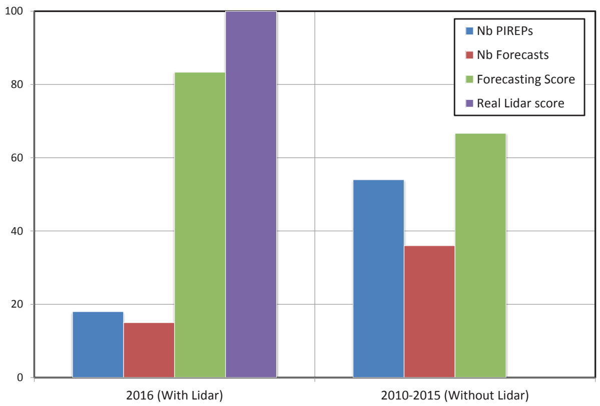


Figure 4: Increase of the forecasting score for windshears by 50% in 2016, thanks to the Windcube400S-AT lidar

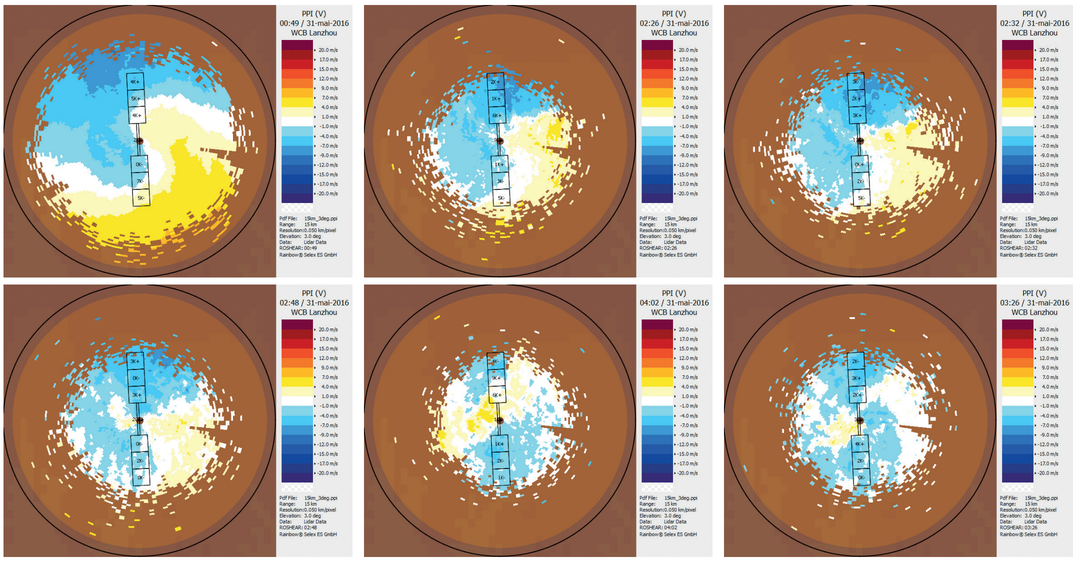


Figure 3: Temporal evolution of a dry windshear event at Lanzhou Airport