by Laurent Sauvage & Ludovic Thobois

CLEAR FOR TAKE-OFF

Second-generation LiDAR meets new ATM requirements

Modern Wind Doppler LiDAR is ready for reliable and accurate real-time monitoring of weather hazards around airports, offering improved severe weather forecasting

Should they be wind shears, gusts, wake vortices, volcanic ash or fog, weather hazards at airports can have dramatic consequences for air traffic safety. Although strict ICAO (International Civil Aviation Organization) rules are applied, dramatic events can occur. This was demonstrated by the crash of an American Airlines A300 in the New York City area on November 12, 2001 two months after the September 11 attacks, due to pilot overreaction to a wake vortex.

These events, have, so far, strongly limited any intention of modifying ICAO rules regarding time and distance between aircraft in approach or take-off. The next big challenge for controllers and meteorologists will be to prevent the effect of these hazards more successfully and to enable a safe increase in airport traffic capacity.

Small-scale measurements

Wind shears and wake turbulences originate from very different phenomena. The former are generated by geographical disparities around airports, whereas wake turbulences are created by the aircraft themselves. Wind shears usually appear in airports located near coasts, valleys, or mountains.

All these topographic elements generate complex wind fields and strong wind shears depending on meteorological conditions. Besides, wind variations can be very fast in such situations, which is why the real time monitoring of large wind fields is necessary to warn air traffic management regarding severe weather and prevent air traffic hazards. In addition, wind variations in wake vortices are generated by every aircraft. Size and intensity of wake vortices are directly linked to the flight speed and also by aircraft characteristics, such as weight and wingspan.

Despite the efforts that have been made to study and model wind shears and wake vortices, on-site measurements remain the only way to accurately detect them, as they depend a great deal on meteorological conditions within the proximity of airports, especially in the case of wind and turbulence.

Currently, international aircraft regulations keep a minimum delay between aircraft take-off and landing times which varies with the weight of the two aircraft. This regulation has been established in standard atmosphere conditions. However, in practice, one can expect that, with turbulence in the atmosphere and cross winds, the effective delay after which wake turbulences are sufficiently dissipated may be much lower. This would enable controllers to increase the frequency of aircraft take-off and landings when wind conditions are favorable.

Benefits of LiDAR technology

Wind Doppler LiDARs (LiDAR stands for Light Detection and Ranging) are laser-based remote sensors that can provide air traffic managers with the accuracy they need and help them to adapt their plans in real time.

Unlike in-situ instruments, scanning remote sensors have the advantage of monitoring a large volume of atmosphere from a single location. They also do a good job scanning large areas (typically hundreds of square kilometers) fast enough to capture the dynamics of wind at a high spatial resolution. Radars or LiDARs are both based on electromagnetic waves which propagate at the speed of light.

They are complementary in the weather range where they can operate, LiDARs are optimal in clear air and hazy conditions, whereas radars take the lead under rainy conditions. They can both probe large atmospheric volumes in real-time and at a high resolution. To get a high accuracy and spatial resolution, wake vortices cores must be detected within a few meters and the sampling volume must be as small as possible, leading to the use of very short pulses for the electromagnetic source, such as lasers.

For several years, LiDARs equipped with powerful lasers and scanner heads have been developed in the USA, Japan, and Europe. Figure 2 (overleaf) represents one long-range scanning pulsed coherent LiDAR, based on a proven technology formerly developed at ONERA, the French aerospace lab. It involves reliable high-power fibered laser amplifiers and telecommunication components at a wavelength of 1.5µm. WINDCUBE LiDAR have benefitted from this exclusive technology, which maximizes the stability and toughness of the instrument, while minimizing the cost and maintenance effort. In a vertical wind profiling mode, WINDCUBE technology has been intensively validated against standard sensors, such as cup anemometers and radar wind profilers, during various tests in the USA (NOAA) and in Europe (DWD, Lindenberg). These LiDARs are now used worldwide in hundreds of locations for wind energy, atmospheric research and met observations.

The scanner head can perform any scanning pattern in 3D space and benefits from gearless design. The diverse topologies and complex wind conditions can require the LiDAR to be able to scan in 'staring mode', plan position indicator (PPI) mode (Figure 1, right shows a windfield around the LiDAR), range height indicator (RHI) mode or vertical azimuth display (VAD) mode. All modes must be adaptive to ensure the monitoring of various flow structures in the atmosphere, such as wind shears and wake vortices with the remote sensor.

Next-generation ATM standards

Two campaigns have been realized in 2011 with a WINDCUBE Doppler LiDAR for evaluating the ability of this LiDAR to detect wind shears and wake turbulences. One LiDAR has been deployed at Nice airport in the south of France, to detect any windshear around the airport because it can be very intense in this area, due to the

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Figure 1: Sample of a windfield, measured by the WINDCUBE200S LiDAR on a horizontal plan, showing a south west mean flow

vicinity of high mountains and strong winds. Also, a benchmarking of various technologies has been conducted in the framework of the Single European Sky ATM research program (SESAR) and in partnership with Thales Air Systems.

The SESAR project is aiming at modernizing European airspace and its Air Traffic Management (ATM) standards over a long period, and acts as the technological mainstay of the future single European sky. At Charles de Gaulle airport, a five week-long campaign was recently conducted with a WINDCUBE200S LiDAR. Although Charles de Gaulle airport is not too exposed to the hazards generated by wind shears; some have still been detected but with a low intensity, this is why they do not impact air traffic. If the LiDAR is able to detect weak wind shears, it can be expected that it will be easily able to detect the strong ones.

As already explained, flexible modes were required, since wake turbulence detection has been done both for landing and take-off phases on the aircraft runways of the airport, as well as below the landing glides. Figure 3 shows the monitoring of the two counter-rotated wake vortices generated by a heavy aircraft during take-off during a one minute period. The LiDAR detects each wake vortex as one dipole in terms of velocity, one half composed of the highest speeds approaching the LiDAR (red color) and the other half representing the highest speeds away from the LiDAR (blue color).

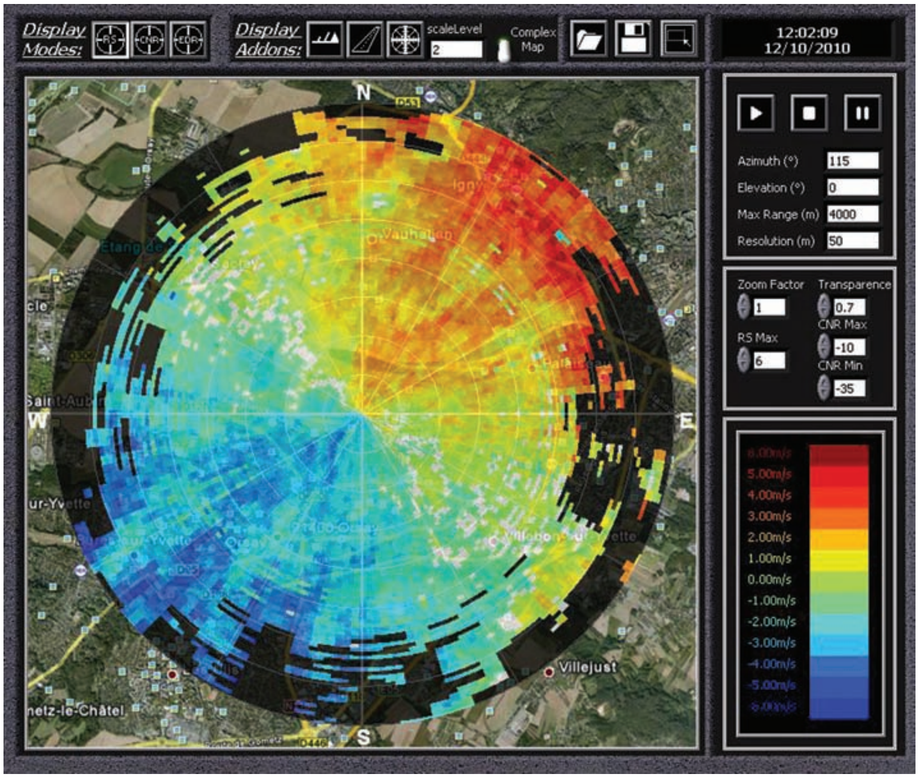

Figure 2 : Various wind conditions displayed in a RHI mode observed by the WINDCUBE200S LiDAR at Charles de Gaulle Airport, France for the SESAR Project

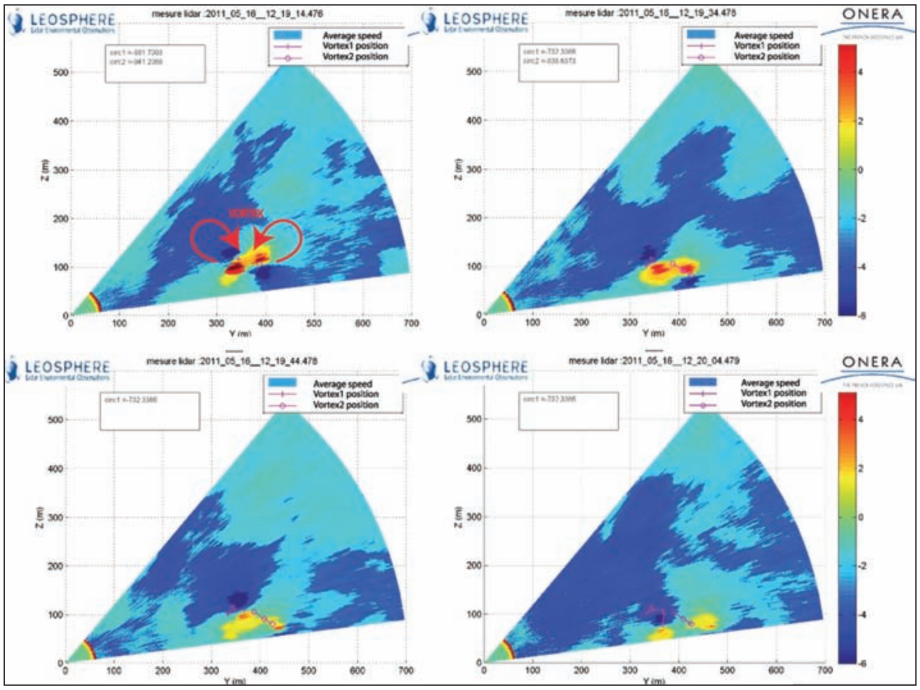

Figure 3 : Dynamic of the two counter-rotated wake vortices generated by a heavy aircraft during takeoff at Charles de Gaulle airport, France, for the SESAR project

Promising times

The results are very promising since various wind conditions have been successfully monitored with the scanning WINDCUBE Wind Doppler LiDAR. Whatever the characteristic times and scales of the wind field, a versatile scanning Wind Doppler LiDAR can accurately monitor the wind conditions, due to its degrees of freedom.

Based on the backscattering of light, Doppler LiDAR can detect aerosol plume, as well as fog. but of course weather conditions have a direct influence on the range of the system. Under severe rainy or foggy conditions, the coupling of a LiDAR with radar would be ideal.

The major challenge that will have to be faced over the coming years is to convert all the detailed meteorological information, measured by the LiDAR, into comprehensive information that can be used directly by air traffic control and the pilot. ∎

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