DOPPLER DOES IT

How complex wind conditions near airports can be monitored by wind Doppler laser radar

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Global air traffic is expected to double within the next decade. In this continuously growing context, measuring and forecasting wind conditions in the vicinity of airports is becoming increasingly crucial. Should there be wind shears, gusts or wake vortices, wind hazards on airports can have dramatic consequences on air traffic safety, as appeared to be the case in the crash that occurred in the New York City area on 12 November 2001. The next big challenge for controllers will be to prevent such meteorological hazards more successfully while ensuring a safe increase in the traffic capacity of airports.

This challenge goes hand in hand with high-resolution monitoring of wind. Wind lidars (Figure 1) are laser-based remote sensors that can provide air traffic managers with the accuracy they need. Unlike in-situ instruments, scanning remote sensors have the great advantage of being able to monitor a large volume of atmosphere from one location. They also do a good job of scanning large distances (typically several hundred metres to several kilometres) fast enough to capture the dynamics of wind at a high spatial resolution.

Radars or lidars are both based on electromagnetic waves that propagate at the speed of light. They can both probe large atmospheric volumes in real time and at a high resolution. To get a high accuracy and spatial resolution, the sampling volume must be as small as possible, leading to the use of very short pulses for the electromagnetic source, such as a laser.

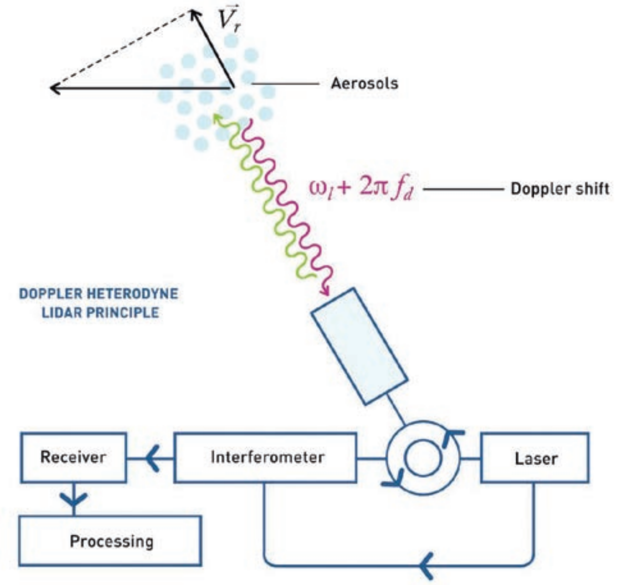

Figure 1: Doppler heterodyne lidar principle

Figure 2: Various wind conditions displayed in RHI mode observed by the Windcube200S lidar at Paris Charles de Gaulle Airport for the SESAR project

For several years some prototypes of lidars equipped with powerful lasers and scanner heads have been developed. Figure 2 represents one long-range scanning pulsed coherent lidar based on a proven technology formerly developed at ONERA (the French Aerospace Laboratory) involving reliable high-power fibred laser amplifiers and telecommunication components at a wavelength of 1.5µm. The scanner head can perform any scanning pattern in 3D space. The diverse topologies of complex wind conditions require the lidar to be able to scan in staring mode, Plan Position Indicator (PPI) mode, Range Height Indicator (RHI) mode and Vertical Azimuth Display (VAD) mode. All modes must be adaptive in order to ensure the monitoring of various flow structures in the atmosphere such as wind shears and wake vortices with the remote sensor.

Wind shears and wake turbulences originate from very different phenomena. The former are generated by geographical disparities around airports, whereas the latter are created by aircraft themselves. Wind shears usually appear in airports near coasts, valleys or mountains. All these topographic elements generate complex wind fields and strong wind shears depending on meteorological conditions. In addition wind variations can be very fast in such situations, which is why the real-time monitoring of large wind fields is necessary to warn the air traffic management about severe weather and to 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

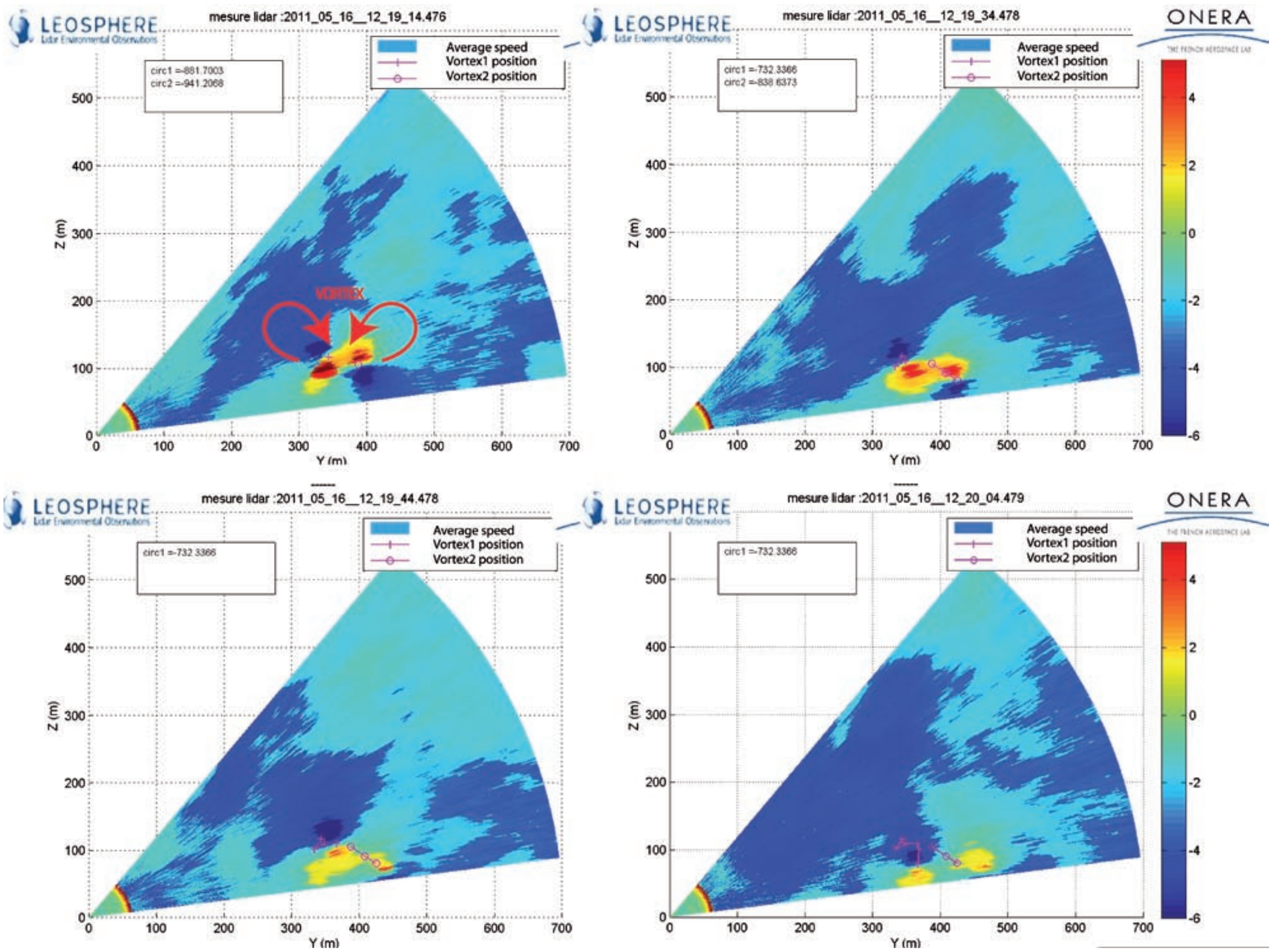

Figure 3: Dynamic of the two counter-rotated wake vortices generated by a heavy aircraft during take-off at Charles de Gaulle airport for the SESAR project

and wingspan. Even if efforts have been made to study and model wind shears and wake vortices, on-site measurements remain the best way to detect them as they depend a lot on meteorological conditions near airports, especially wind and turbulence.

Currently international aircraft regulation imposes a minimum delay between two aircraft taking off and landing, which varies with the weight of the two aircraft. This regulation has been established in standard atmospheric conditions. In practice one can expect that with turbulence in the atmosphere and transverse winds, the effective delay after which wake turbulences are sufficiently dissipated, may be much lower. This would allow controllers to increase the frequency of aircraft take-offs and landings when wind conditions are favourable.

Two preliminary campaigns have been realised in 2011 for evaluating the ability of the lidar to detect wind shears and wake turbulences, in the framework of the European SESAR project and the partnership with Thales Air System. The SESAR project is aiming at modernising European airspace and its ATM over a long period, and is the technological mainstay of the future single European sky.

In Paris Charles de Gaulle Airport, a five-week campaign was recently deployed. Although the airport is not exposed to the hazards generated by wind shears, some have been detected but with a low intensity, which is why they do not affect the air traffic. If the lidar is able to detect weak wind shears, we can expect that it will easily detect strong ones.

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

These 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 thanks to its degrees of freedom, such as scanning speed. Based on the backscattering of light on particles, Doppler lidar can detect aerosol plume as well as fog. Wind Doppler lidar can operate in all weather but naturally weather conditions have a direct influence on the range of the system. Under severe rainy or foggy conditions the coupling of such a lidar with radar would constitute the perfect team.

The greatest challenge that will have to be overcome in the long term will be to convert all the detailed meteorological information that has been measured by the lidar into comprehensive information that can be used directly by air traffic control. ❖