

## Wind monitoring

Ludovic Thobois, scientific partnership and animation manager for meteorology and aviation, Leosphere

# FLYING HIGH

Obtaining detailed insights into upper air wind behavior above airports is now possible thanks to remote sensing technologies





← Windcube 400S-AT monitoring windshear at Dubrovnik Airport for Croatia Control

**A**irports may be interested in the same characteristics of wind as other industries, but the significance of these factors to the air traffic management (ATM) sector is crucial. Wind speed and direction are principal factors, helping to determine the landing and take-off configurations as well as the procedures for approach and take-off, such as the choice of the runway.

Windshear, for instance, refers to a change lasting several seconds in the direction and/or speed of the wind. A decreased lift will cause the aircraft to drop below its intended flight path, while an increased lift will of course have the opposite effect. A sustained change to the headwind or tailwind of 15kts is classed as significant windshear. It can make planes on approach or departure much more difficult to control, and much more susceptible to the need for rapid corrective action. According to the International Civil Aviation Organization (ICAO), windshear phenomena have caused more than 1,400 deaths in aviation. Its unpredictability is also responsible for the disruption of air traffic management, which can have a substantial business impact on airport operations.

Turbulence is another consideration, referring to the rapid irregular motion of air. It brings about rapid bumps or jolts, but only occasionally does it have a significant influence on an aircraft's intended flight path. However, in severe instances, abrupt changes in the altitude and attitude of the aircraft may occur, the pilot may suffer a momentary loss of control, and passengers may be injured.

Finally, wake vortex is a form of turbulence generated by all aircraft when flying. Wake vortices vary in relation to a number of conditions, including the size of the aircraft creating it and the airport's own local wind and turbulence conditions.

As you'd expect, wind conditions are a major concern for ICAO. At present, however, its current meteorological guidelines mention only conventional surface wind measurements, measured at 33ft above the ground. They fail to address wind conditions in the upper air, especially along the initial take-off and final approach landing corridors (up to 1,640ft). If air traffic management is to operate at its most efficient levels, and if safety precautions are to be at their best, other measurement methods clearly need to be employed. While landing and take-off

represent just 6% of flight time, it's a sad fact that 57% of accidents occur then – which is why winds during these phases are the most important to measure and forecast.

## INTRODUCING WEATHER RADAR... AND LIDAR

At Hong Kong International Airport (HKIA), China, the wind sensor data gathered from anemometers and weather buoys is analyzed by the anemometer-based Windshear Alerting Rules – Enhanced (AWARE) system to issue windshear alerts.

HKIA also employs a Terminal Doppler Weather Radar (TDWR) system, which continuously scans the high runway corridors to detect windshear and microbursts (intense small-scale downdrafts produced by a thunderstorm or rain shower). Being radar-based, TDWR works only when rain occurs. So, what can be done to measure wind at altitude on dry days?

At HKIA, the answer came in the form of a Doppler lidar system, capable of detecting airborne particles as small as 1.5µm and providing real-time detection of windshear at up to 10km (6.2 miles) in the glide slope. HKIA was the first airport in the world to deploy a lidar sensor for wind shear measurement.

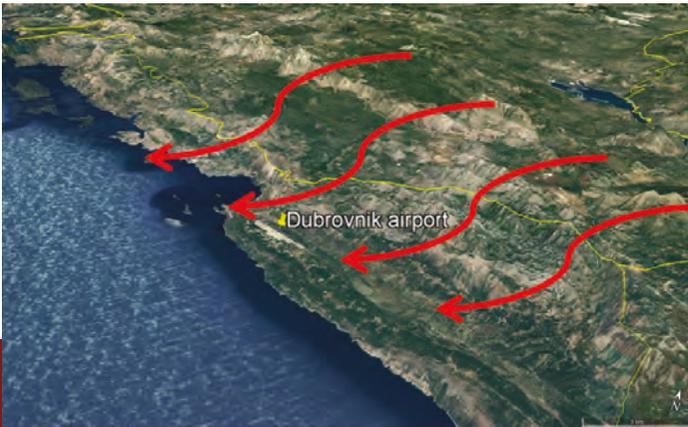
Over the past 20 years, significant improvements have been made in lidar techniques, largely as a result of the introduction of optical fiber technology. The low cost and high reliability of its components, which have led to their widespread use in the mainstream telecommunications industry, are now being appreciated in ATM. Examples of compact, reliable and accurate atmospheric lidar sensors that have been developed and industrialized include those from ONERA, the French aerospace lab, and Leosphere, in the form of the Windcube product series. Further improvements in power, range and reliability are being made all the time.

Working in conjunction with TDWR and ground-based measurement systems, Doppler lidar enables airports to create and sustain an all-weather 3D monitoring solution.

## DUBROVNIK: A CASE IN POINT

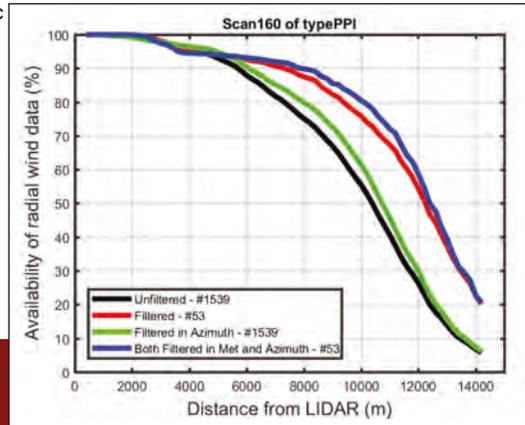
Dubrovnik has one of Croatia's busiest airports, handling more than two million passengers in 2016. The airport is around 15km (9.3 miles) from the city center, near

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← Schematic view of Bora winds on the Adriatic Coast

→ Windcube 400S-AT averaged data availability measured at Dubrovnik Airport



the shore of the Adriatic Sea, about 160m (525ft) above sea level. The Dinaric Alps, a mountain range rising to 1,000m (3,280ft), run closely parallel to the coastline, and slope down to the airport and to the sea beyond.

The prevailing winds are generally low, but in winter the airport is particularly susceptible to what is known as the Bora wind. This is a northern to northeastern katabatic (or down-slope) wind on the lee side of the Dinaric Alps and down to the Adriatic Sea. Bora events can last from a couple of hours to several days, and can induce strong crosswinds of up to 70kts.

These wind events have a major impact on air traffic control at Dubrovnik Airport and also at other airports on the Adriatic coast, causing many delays. They can sometimes cause the airport at Dubrovnik to close, necessitating the rerouting of all incoming flights. Even more importantly, Bora winds have huge implications for flight safety, and need to be fully forecast and mitigated.

The meteorological department of Croatia Control is interested in better characterizing the Bora winds and in improving forecasts at Dubrovnik Airport. It is currently working on a four-year project to develop a Bora event decision support system. As a result, last winter it launched a wind measurement campaign as part of its activities in the SESAR 2020 (Single European Sky ATM Research) and Innovation (R&I) program, including a scanning Doppler Windcube 400S-AT lidar system from Leosphere that could characterize the winds in three dimensions.

This equipment provides remote measurements of winds and aerosols/clouds inside the planetary boundary layer (PBL) with a resolution from 75m (246ft)

to 200m (656ft) under clear air conditions, and with a wind accuracy of better than 0.3m/s (0.7mph).

The Dubrovnik Windcube installation measures the crosswind created by the Bora, especially on the approach of Runway 12, on which it has the greatest impact. It was deployed 1.35km (0.8 miles) away from the runway and close to its threshold. The maximum range exceeds 10km (6 miles) and enables large scale monitoring around the airport.

During the trial, 14 Bora events were logged and measured at speeds of up to 60kts. One of them lasted 1.5 days, with the wind veering from the north to the northeast and strengthening from 8 to 23kts – and gusting up to 35kts. Strong turbulence and fluctuations along the vertical were recorded, and on the RHI vertical slice, a strong wind was measured as well as a great deal of flow separation (turbulence) 2km (1.2 miles) away from the equipment, and thus close to the airport itself.

Croatia Control is still analyzing the data gathered during the exercise, and is comparing the findings with measurements from on-site anemometers. It is working with the Department of Geophysics in the Faculty of Science at the University of Zagreb. It will also be making a submission to the European

Commission as a contribution to the SESAR2020 R&I program.

In addition to the submission, Croatia Control is also working at a national level with airports, airlines and academia on the Bora Dubrovnik Project. Due to start in 2019, it's a four-year program aimed at developing a Bora event decision support system.

"It's good to see the spatial data that lidar obtains," says Alen Sajko, director of the MET Division at Croatia Control. "It's something you simply don't get with anemometers. We were never able to see patterns like these before. It's very useful. For example, we discovered that one part of the skies above the airport is much more affected by Bora events. The positioning of the anemometers meant we couldn't have picked this up in any other way.

"Lidar has also confirmed that when an aircraft is subjected to these events, its vertical speed can change dramatically in just 20 seconds," he continues. "It is vital information that we can pass on to pilots and to air traffic control, and that we can also use to produce better forecasts."

## WEATHER SYSTEM INTEGRATION

Lidar information can be readily integrated into weather systems. For example, Windcube data can be combined with IRIS software from

## Air traffic management: lidar benefits

### Safety

Detailed data gathered at flying heights to show real-time and trending conditions of:

- Windspeed and direction
- Windshear
- Turbulence
- Wake vortices
- Air traffic management awareness of unmanned aerial vehicles (UAVs, also known as drones) in the air near airports

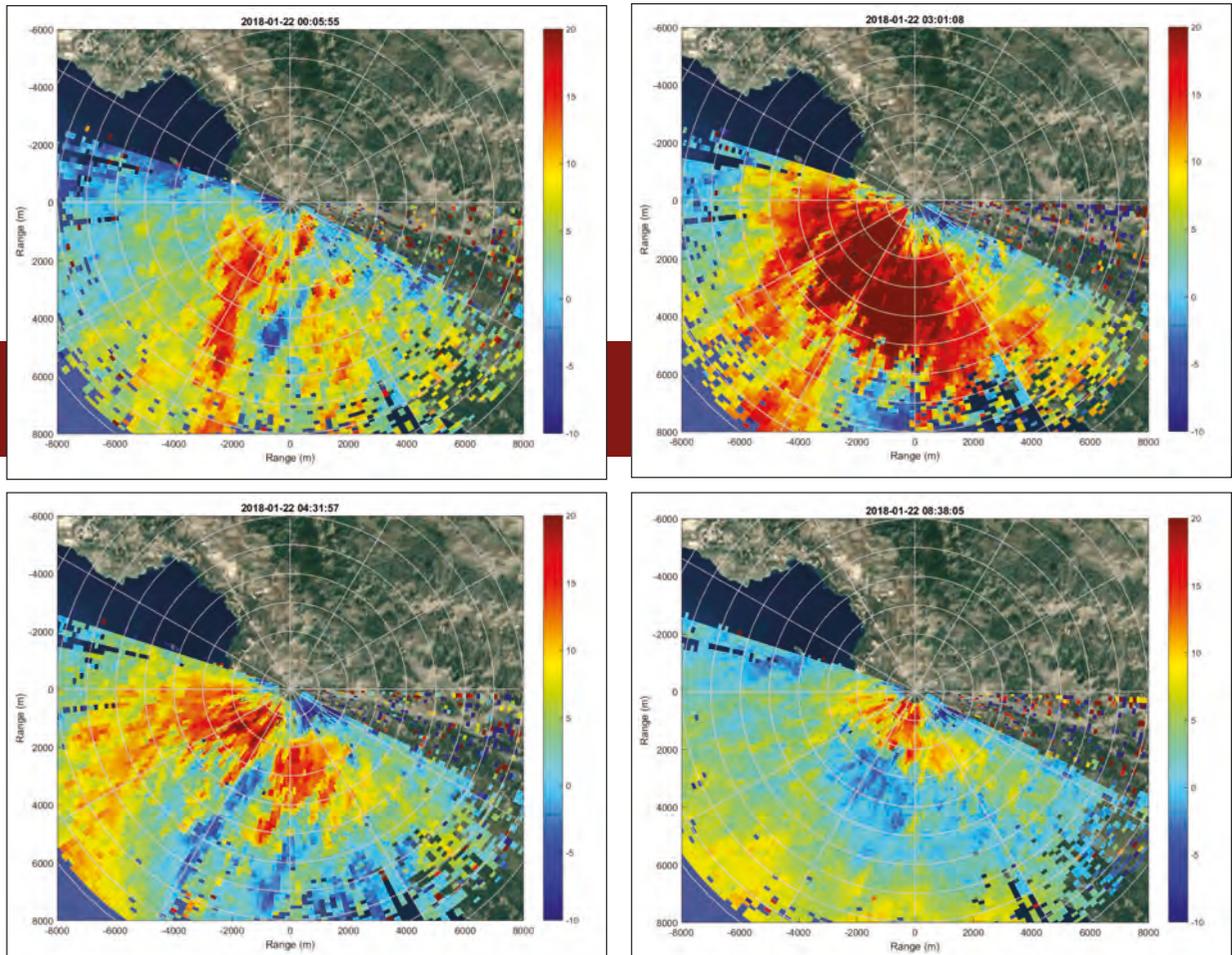
### General conditions

- Weather forecasts – including fog prediction (currently at proof-of-concept stage)
- Cloud base measurement
- Volcanic ash detection

### Performance optimization

- Better runway management
- Better air traffic control management of distance between aircraft on approach and take-off
- Better noise reduction procedures

 Samples of Bora wind measurement by the Windcube 400S-AT



Vaisala and Rainbow 5 software from Selex to display relevant and operational meteorological products such as windshear alerts.

## ADDRESSING WAKE TURBULENCE

Airports are interested in Doppler lidar for another reason. Around 40 years ago, ICAO standards defined wake turbulence categories and their separation distance minima to prevent the risk of wake vortex encounters. Larger aircraft both create and can tolerate larger wake vortices – so minimum safe distances will depend on the size of the leading and following aircraft in the pattern.

For more than 10 years, Eurocontrol, an intergovernmental organization working to build pan-European ATM performance, has worked with ICAO and others to develop a new, optimized categorization of aircraft. Approved by the European Aviation Safety Agency (EASA), RECAT-EU aims to increase airport capacity safely by redefining wake turbulence categories and the minimum safe distances between aircraft.

To implement these new regulations, wake vortex data must be collected by a lidar sensor: in dry weather and at flying height,

there is simply no alternative. Lidar is used for designing new wake turbulence regulations, performing the safety assessment to validate the potential implementation of an existing wake turbulence regulation, and for performing the risk monitoring.

Eurocontrol is also making use of lidar to develop a separate, time-based separation model. “Headwinds affect flight times and distance and so have a bearing on the intervals needed between aircraft,” explains Vincent Treve, runway throughput and wake project manager at Eurocontrol. “We have an implementation at Heathrow, and another is in progress in Vienna.”

In addition to trends calculated from the offline analysis of data, many airports like to cross-check wake data after deployment – so Eurocontrol has developed a lidar-based platform for the continuous monitoring of risk. In addition, the organization is merging databases of data gathered from several sites across Europe – it expects new concepts to emerge from this initiative.

For Treve, lidar’s two principal ATM roles of monitoring risk and measuring wind will in time be joined by a third application:

defining the separation of aircraft as a function of wake behavior captured in the previous 10 minutes. The application is still in development but it is on its way.

## LIDAR MOMENTUM

The interest international airports are showing in Doppler lidar is growing rapidly. By the end of this year there will be four times as many airports permanently equipped with the technology as six years ago, and several more trials are taking place worldwide. It’s likely that as air traffic volumes grow, so too will interest in the detailed measurement of wind in general.

In addition, many other tasks can be performed by Doppler lidars developed originally for wind: cloud base measurement and the characterization of aerosol hazards such as ash plumes. Doppler lidars are also expected to become the super ceilometer, with numerous functions for better mitigating adverse wind and aerosol hazards, and for enhancing the weather resilience of ATM. Combined with its benefits in terms of safety, ATM efficiency, and increased insight, it’s clear why lidar is about to take off. ■