VAISALA

Windshear in aviation

Solutions Brochure

Windshear can pose a significant risk at airports: It occurs at varying heights when aircraft are most vulnerable during takeoff and landing. Large commercial airliners might be unable to adjust to such drastic changes, endangering safety for aircraft plus delays and spiraling costs for airports.

Windshear detection systems help airport decision makers understand and prepare for these weather conditions to keep operations safe and efficient. With several technologies available, the right solution depends on an airport's local weather conditions and specific types of windshear.

This guide provides an overview on the science and characteristics of windshear, the most advanced technologies available, and best practices for choosing and siting a windshear detection system.

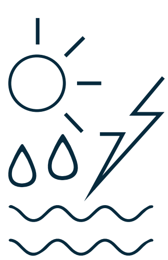
Aviation megatrends: climate change and digitalization

The aviation industry is undergoing changes from four general megatrends: Climate change, renewable energy, the future of mobility and digitalization. While all have an impact, digitalization and climate change offer the most immediate challenges as well as solutions. Climate change increases extreme weather including windshear and creates a chain of environmental and economic consequences. The importance of reliable weather observations and forecasts to protect lives and infrastructure is constantly increasing as a result.

To mitigate the effects of extreme weather, the aviation industry is working to optimize all processes and use proactive measures. This is where digitalization is most effective.

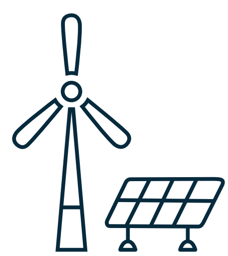
Digital technology such as cloud services makes it possible to combine, visualize and use complex data in innovative ways. To improve the exchange of digital information, ICAO is creating new initiatives such as SWIM which organizations are able to utilize to improve the exchange of digital information.

The core of any weather-related data is the reliability and quality of even the simplest parameter and how it is measured. The more uses there are for a single point of data, the more important it is to ensure its quality and reliability. This requires the equipment to collect data plus an end-to-end solution for disseminating it.



Climate change

- Extreme weather
- Protecting lives and property

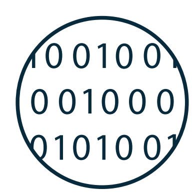


Renewable energy

- Stable energy production
- Monitor, predict, and plan operations

Future of mobility

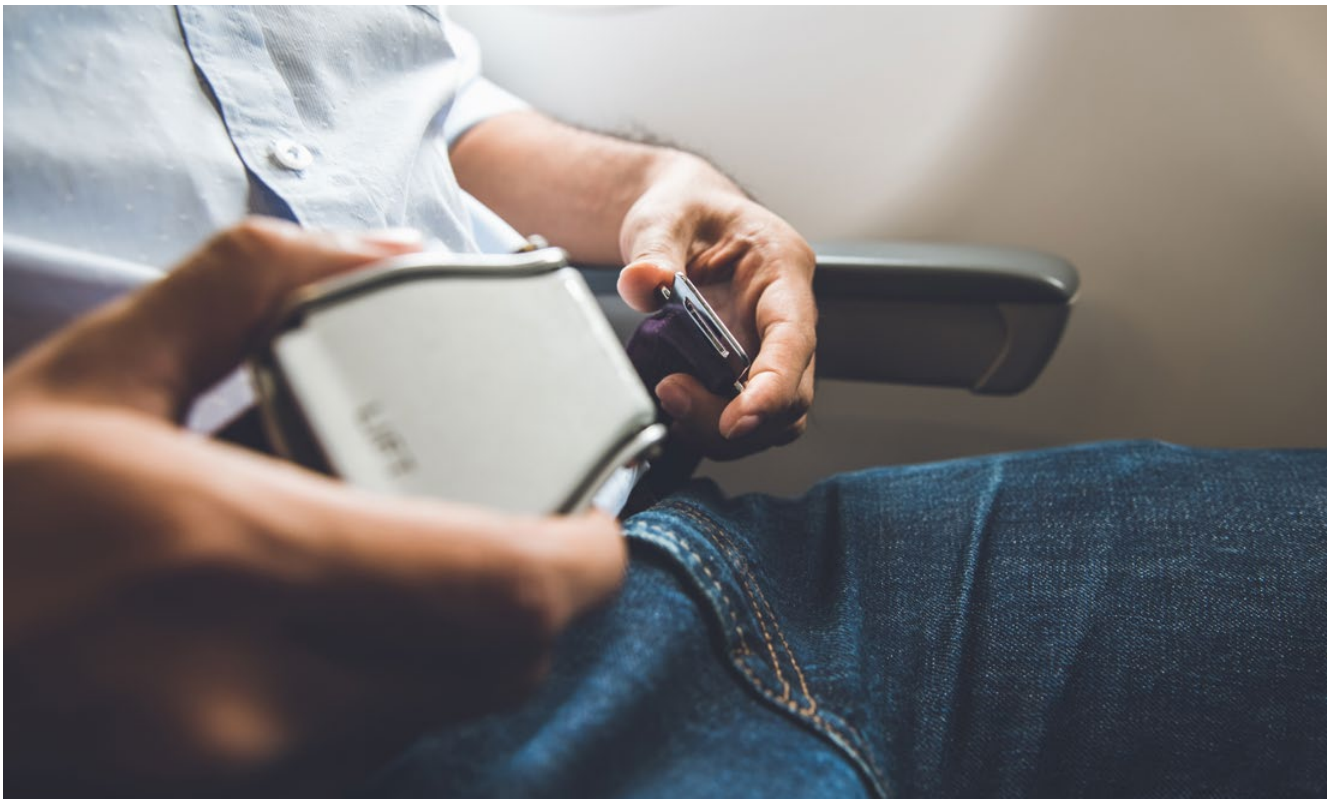
- Safety and efficiency of traffic
- Increasing automation and new forms of mobility



Digitalization

- Data utilized and combined in new ways
- New kinds of weather-related digital service

Balancing safety and efficiency



Windshear affects both efficiency and safety of airport operations. Extreme windshear can cause accidents, but more often it causes concern and uncertainty for airport operators and pilots.

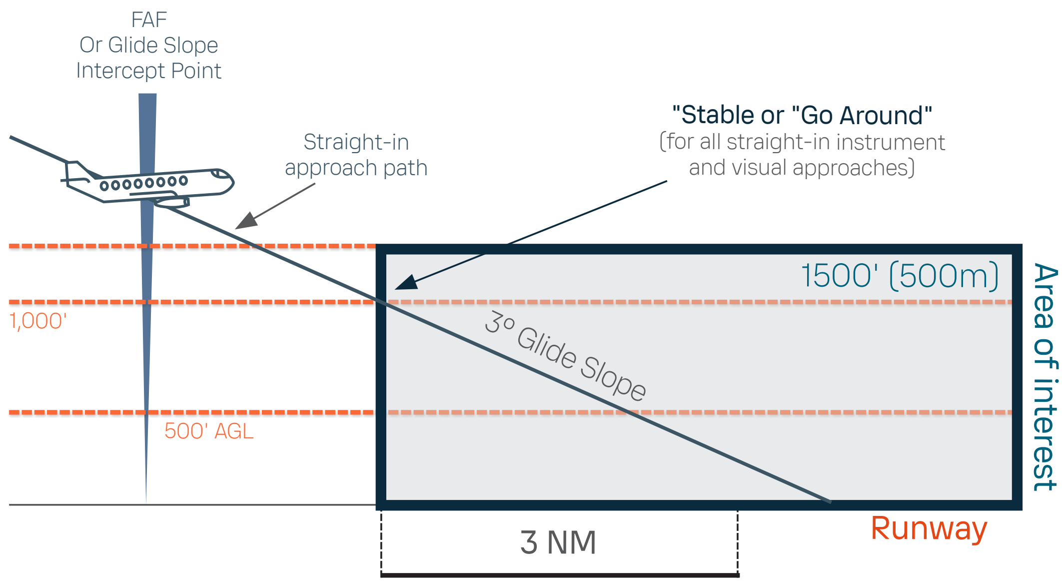
Technology is available to measure and detect this phenomenon, enabling airport operators to take proactive steps that minimize delays and cancellations while keeping operations running as smoothly as possible.

Windshear can be a major safety risk

33 accidents + 476 fatalities caused by windshear since 2000*

*Flight Safety Foundation

The physics of windshear



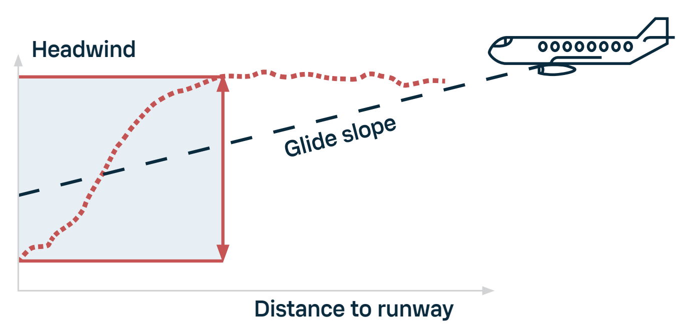
Definition of windshear

Windshear is a strong and sustained change of headwind or tailwind during approach or takeoff. Low-level windshear is defined by ICAO Annex 3 as occurring below 500 meters.

In this illustration, the dotted red line represents wind conditions on the runway approach. At the beginning of the approach the red curve is constant, indicating little to no wind change. As the airplane approaches the runway in the shaded zone, however, there is a significant reduction of headwind—a type of windshear—according to the ICAO definition that causes a significant reduction of lift. There is a greater risk close to the ground when an airplane may not be able to compensate for the windshear and touch ground too soon.

Altitudes impacting aircraft

There is a specific altitude at which windshear poses the greatest safety risk. The most critical area of danger is in the stabilized approach, starting at 1000 feet at the highest. This is when pilots set landing configurations such as flaps to fix the air speed for landing. If windshear occurs during this time it is very difficult to adjust the approach.



Advance notice is critical for pilots to prepare for windshear and and adjust configurations such as flaps and aircraft speed.

Pilots must be informed:

- of headwind changes below 1500 feet (500m)
  - critical area: three nautical miles (NM) of extension for a glide slope of 3°
- along their approach before engaging the stabilized approach
  - 2 to 3 minutes before touchdown

Current recommendations

ICAO states that windshear should be reported. The only effective way to report windshear is from the airport to the pilots; if pilots report it to the airport, there is no opportunity to prepare. The safety and efficiency advantages of proactive notification make an airport windshear detection system a smart investment.

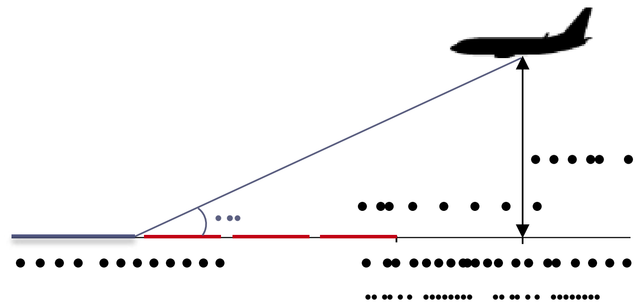
ICAO Annex 3 refers to two types of windshear detection: warnings and alerts.

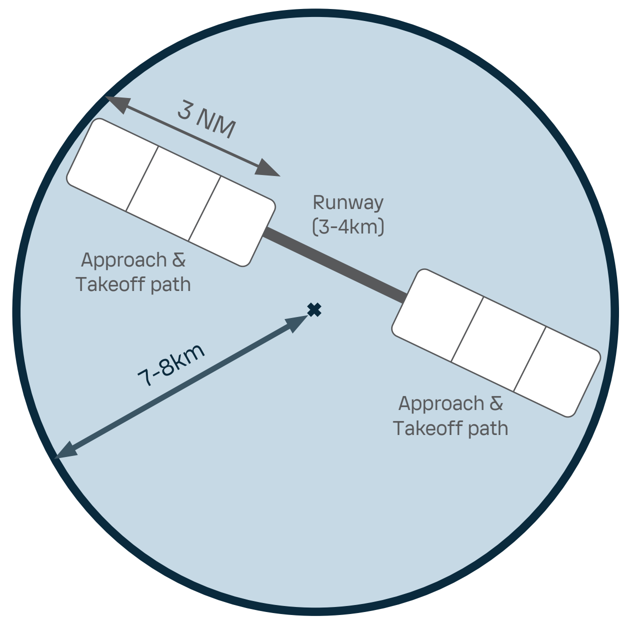
Warnings

- Prepared by airport meteorological office and based on ground-based equipment, aircraft observations and other information
- Concise information on the observed or expected existence of windshear
- <500 m: Approach + takeoff path + runways + circling approach

Alerts

- Automated, ground-based remote sensing or detection equipment
- Concise, up-to-date information related to the observed existence of windshear involving a headwind or tailwind change of >7.5 m/s (15 kt)
- Final approach path or initial take-off path and aircraft on the runway



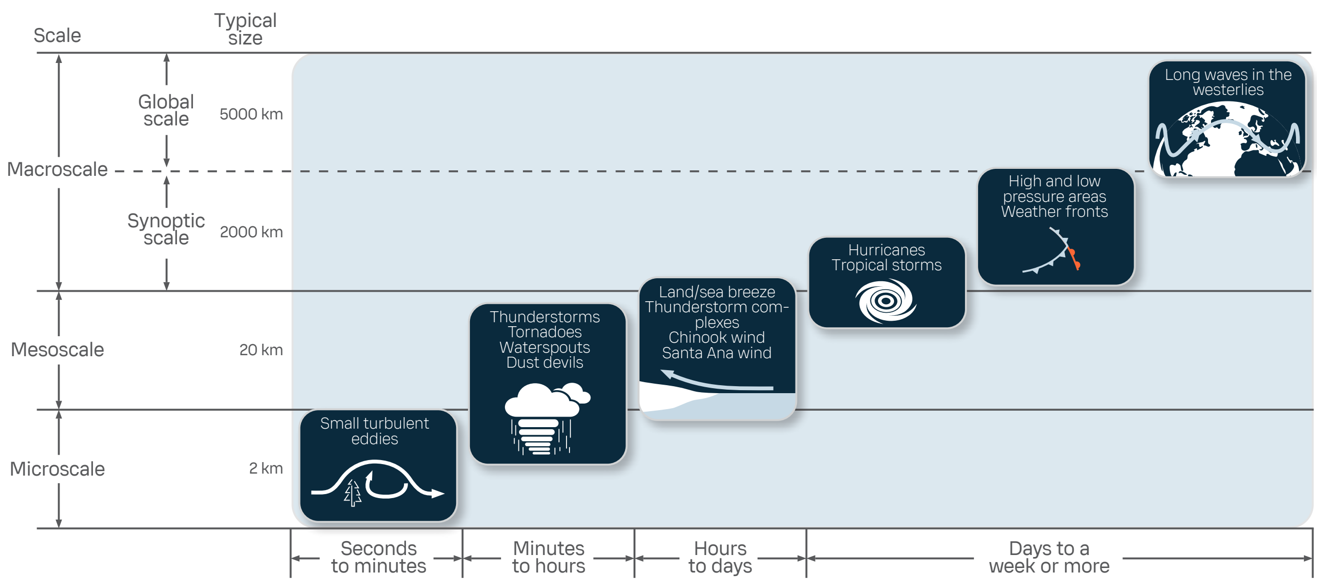


This illustration shows the critical windshear alert area

While warnings are typically manual, an automatic weather observation system can provide timely and accurate automated alerts.

An optimal refresh rate is every few minutes for warnings and alert systems. Best practices are described in more detail in the ICAO Manual 9817, as well as the FAA Aeronautical Informational manual.

The origins of windshear



Wind scales

Scales are important in meteorology for predicting the weather. Wind scales can range from local microscales—a few meters long and lasting up to a few minutes—to planetary macroscales up to 5000 kilometers long and lasting several days or even weeks.

The wind in any given area can have a combination of wind scales resulting in different wind speeds and directions. This combination is what leads to windshear.

Windshear types

Convective

Convective windshear typically occurs during thunderstorms and is distinguished by three types:

- Downdrafts from mature cumulonimbus clouds which often includes heavy rain
- Gust front from the outer part of a thunderstorm
- Microbursts or small-scale downbursts created by an area of descending air, which spreads out in all directions when it reaches ground level

An interaction between the background winds and the gust front can cause wind shear.

Microbursts are the single most dangerous type of windshear for aircraft because they are small-scale, brief and intense and can be very difficult to detect.

Non-convective

Non-convective windshear occurs in all weather conditions. Temperature-driven fluctuations in coastal areas (sea and land breezes), valleys surrounded by mountains and low-level or nocturnal jets can cause windshear. The condition can also be caused by local topography and obstacles such as skyscrapers and urban area bridges.

Measuring windshear

There are three main measurement technologies in use today: Low Level Windshear Alert System (LLWAS), weather radar and wind lidar.

A multi-pronged approach to environmental situational awareness is the best way to serve the entire maritime ecosystem in coastline and port environments — now and into the future.

LLWAS consists of network of anemometers located close to the runway on approach. The number of anemometers used varies according to an airport's requirements. The main advantage of LLWAS is real-time detection of windshear in all weather conditions.

Weather radar has been used since the 1980s and is known for its excellent windshear accuracy and detail, primarily in rainy conditions. Radar can be used to provide hazard warnings and monitor specific phenomena, enabling a better understanding of the structure of a thunderstorm. In addition, radar can also be used to monitor and predict the movements of weather fronts and storms.

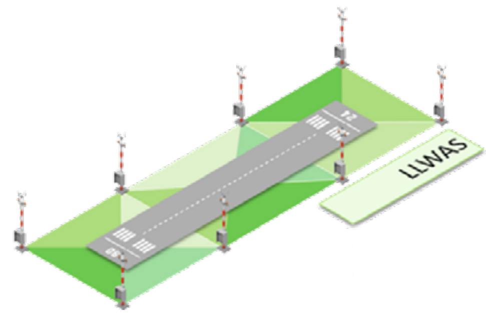
Wind lidar is the newest technology being used at airports for windshear detection. Similar to radar, lidar provides very high-resolution and accurate wind and windshear information, under clear air conditions.

In addition to its windshear measurement capabilities, wind lidar can be used along with weather radar as part of an integrated warning system. This combination provides 3D wind awareness around an airport along with measurements of wind turbulence or windshear.

Weather radar and wind lidar each work under specific weather conditions to detect and measure windshear. Therefore, they can be used together at an airport for a highly accurate windshear detection system.

LLWAS

- Consists of a network of anemometers
- Real-time detection capability in all weather conditions



Weather radar

- Excellent accuracy and availability using solid-state transmitters
- Capable of measuring windshear in detail under rainy conditions
- Advanced warnings of a broad range of weather phenomena including windshear, hail, freezing rain and thunderstorms

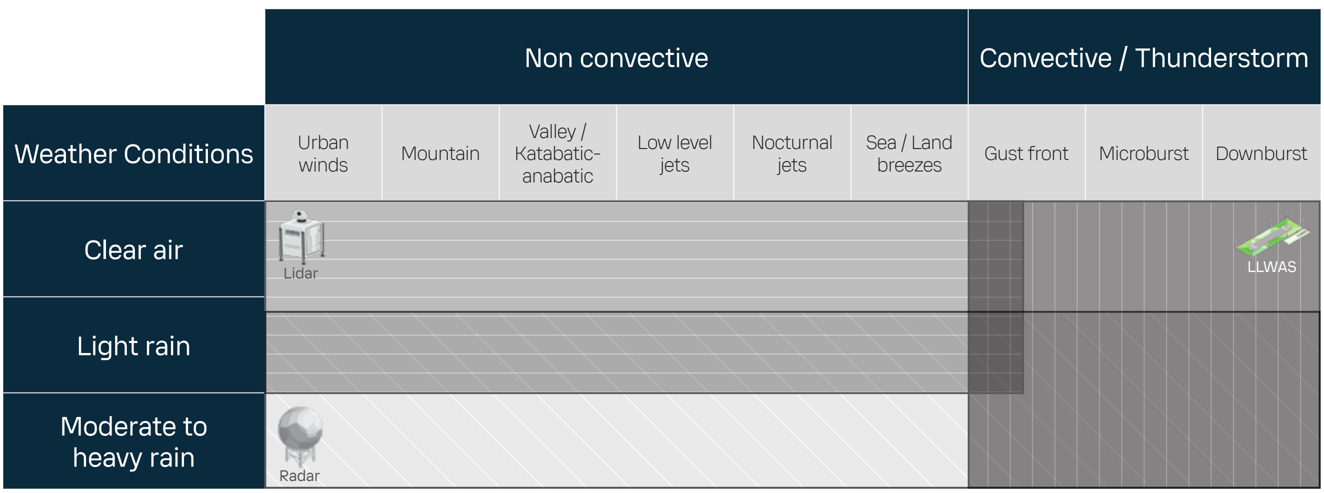
Wind lidar

- High resolution and accuracy of wind and windshear
- Capable of detailed measurement of windshear under clear air conditions
- 3D wind awareness around airports and increased understanding of wind, turbulence and windshear

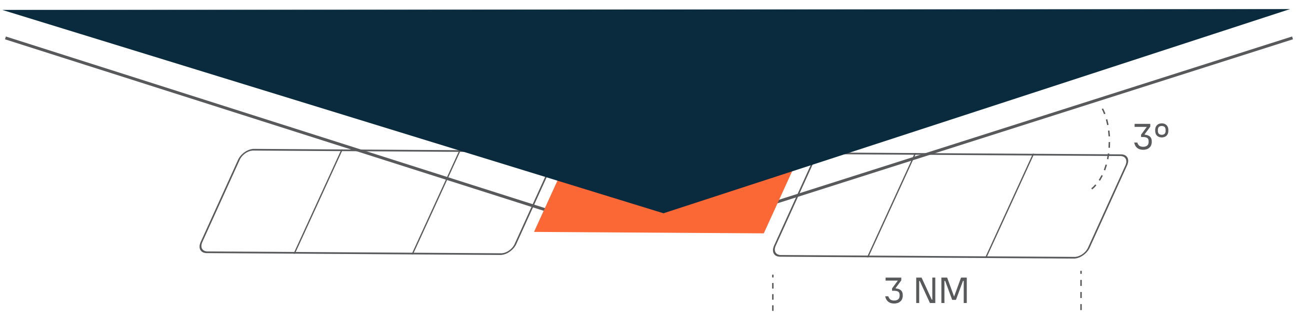
Integrate your windshear detection system

This table includes the most common weather conditions and windshear types to show which sensors are ideally suited for different scenarios. The right sensor or combination depends on local weather conditions as well as windshear types at your airport.

In addition to installing the right sensors, it is crucial to integrate the windshear data into a single system that links to an automatic weather observation system (AWOS) for reporting.

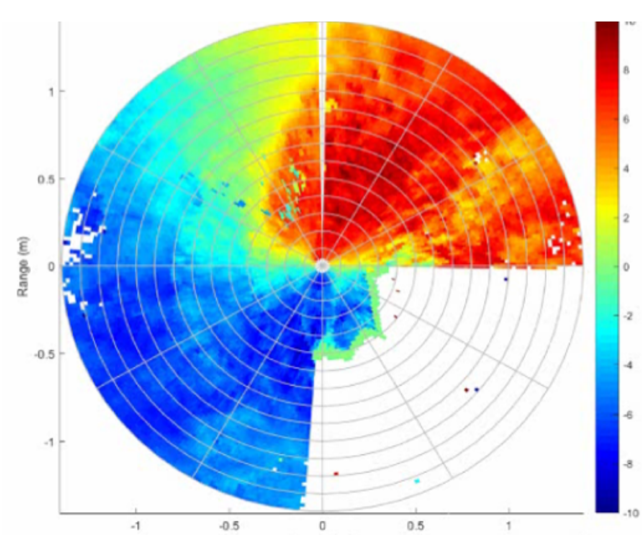


Scanning and siting strategies for wind lidar



Every airport is unique; we recommend conducting a thorough site survey including meticulous planning in advance to determine your airport's specific needs.

A typical scanning strategy for wind lidar is the azimuthal or plan position indicator (PPI) scan. This is a conical scan operated at an upward glide slope and provides a physical resolution of 100-200 meters with an angular resolution of 1-3° depending on the position of the wind lidar and a scanning duration of 1-2 minutes.



Example of measurements of Wind Lidar

Wind lidar:

The illustration to the left is a detailed view of a southwesterly wind reaching coverage of 15 km. The wind lidar is installed at the center of this map. The colors indicate Doppler velocity. Blue indicates wind blowing toward the lidar and red shows wind blowing away.

Scanning strategy

- PPI scan at glide slope elevation
- Physical resolution: 100-200 m
- Angular resolution: 1-3°

Data outputs

- Typical measurement ranges:
- 10 km for wind lidar
- Update rate: Every 1-2 minutes or better

How to choose the site

Site survey

Proper site location is critical to ensuring high availability and accuracy. Before planning your system, obtain a site survey to determine the most optimal windshear detection system for your airport. Then analyze all possible obstacles and ensure the best locations for proper windshear coverage.

The ideal locations for lidar and radar depend on an airport's constraints. Some airports have only one runway, while others will need additional sensors to ensure the most accurate windshear detection.

Location guidance

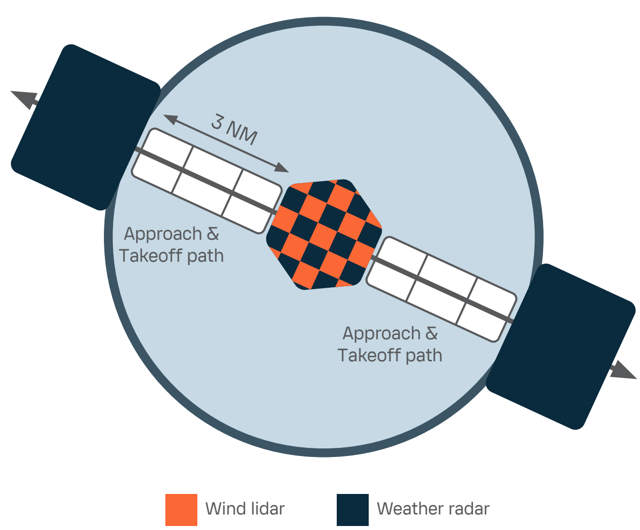
- Address practical and technical constraints
- Ensure high data availability in the area of interest
  - Wind Lidar: Allow a clear view of the approach corridors by locating Lidar close to the runway center to cover both approaches
  - Weather Radar: In addition to clear view to the approach corridors consider other weather radar data use cases when locating the weather radar
- LLWAS system: Perform site survey to ensure locations and access to possible wind mast sites
- Ensure high-quality windshear detection
  - Maximum 30° of angle difference with runway direction for the remote measurement systems to maximize headwind component on radial wind speeds

Practical and technical

Siting wind lidar and weather radar involves a different set of constraints compared to scanning strategy*.

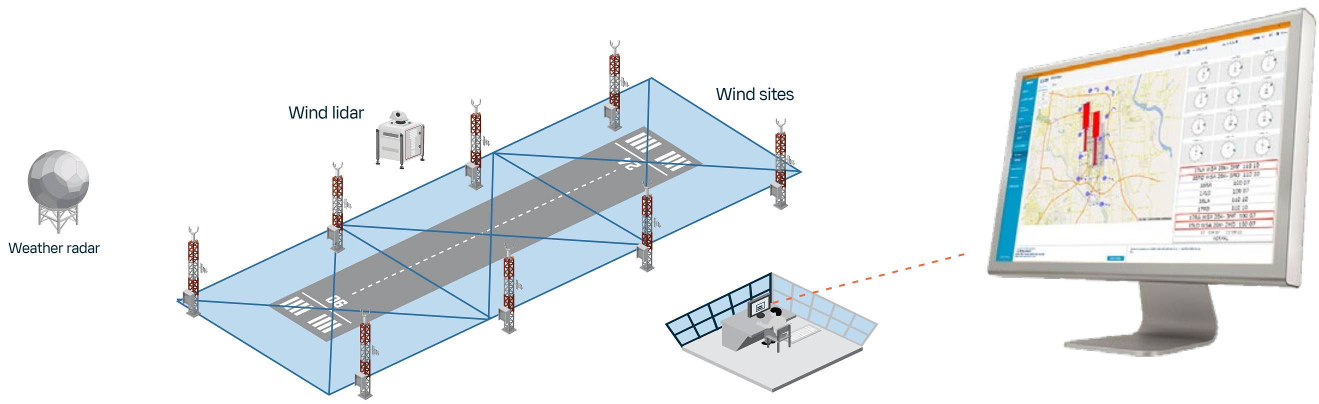
The first set of constraints is practical and technical such as concrete, power, network accessibility for maintenance and runway proximity.

The goal in siting is to get the highest possible data availability in the area of interest on each side of the runway. Since the PPI is cast at 3° from such a low elevation, be sure to eliminate any obstacles around the system.



* Source: FAA TDWR Site Determination Program

Windshear reporting within AWOS



Windshear affects both efficiency and safety of airport operations. Extreme windshear can cause accidents, but more often it causes concern and uncertainty for airport operators and pilots.

Technology is available to measure and detect this phenomenon, enabling airport operators to take proactive steps that minimize delays and cancellations while keeping operations running as smoothly as possible.

Combining windshear information with your AWOS provides detailed automated reporting and increases situational awareness of the local conditions.

Trusted aviation weather from cloud to ground

Why Vaisala?

For over 50 years, Vaisala has been a pioneer in aviation weather technology, ensuring that every measure is taken for unparalleled safety, efficiency, and sustainability.

Our gold standard suite of solutions is trusted in more than 170 countries and over 2000 airports globally. In fact, every commercial flight around the world will use weather observations produced by Vaisala equipment or forecasts driven by our sensor measurements at some point in their journey.

With a commitment to constantly evolving our portfolio, Vaisala remains at the forefront of the industry, continuously exploring new horizons.

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