Wind Reporting Systems in the NAS

Oh what a tangled web we weave.
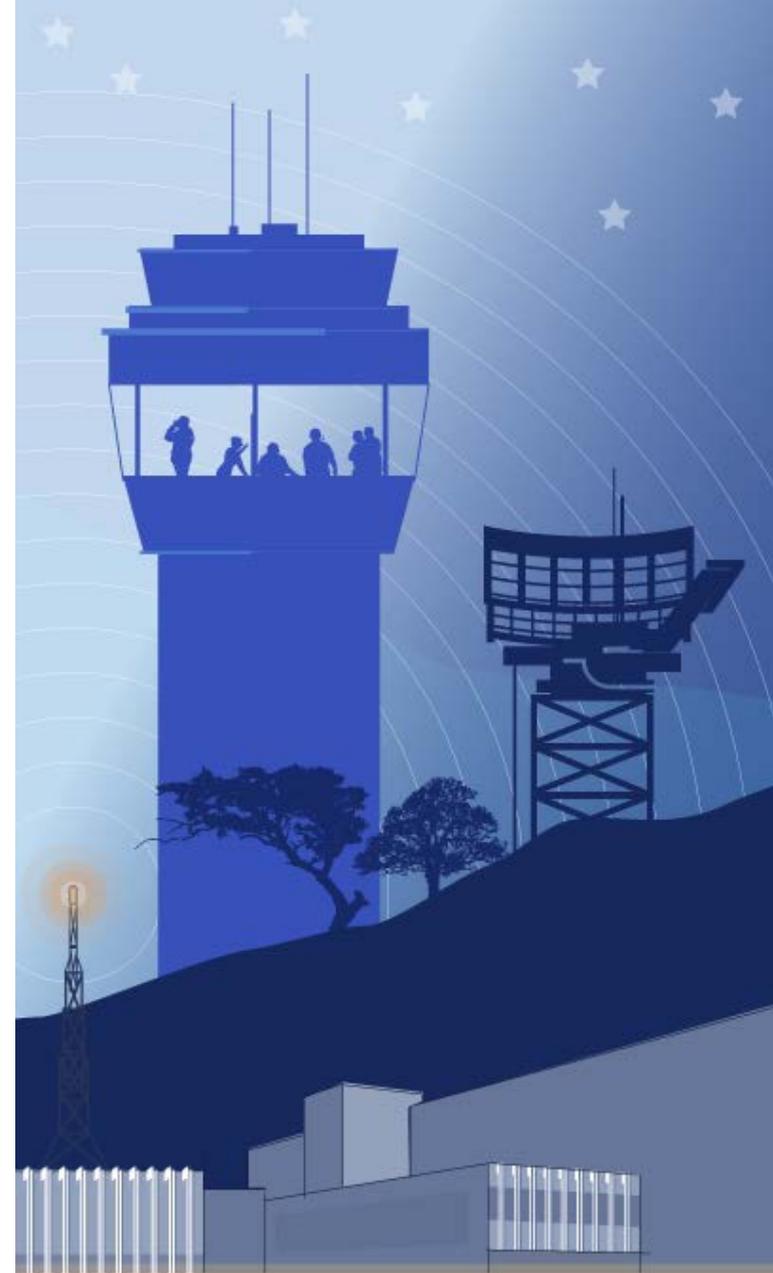
Terminal Services

The Basics

When attempting to measure the wind, we must keep a few important concepts in mind.

- First, always remember that our atmosphere is a fluid. It is a substance (much like liquid) capable of flowing and changing shape.
- Second, when it flows uniformly in direction and speed, it is relatively easy to measure.
    - However, when it moves erratically, we must be careful how we measure the wind if we're to get a value that actually represents its true motion.
- Third, we can't place wind sensors precisely on the touchdown and takeoff areas of the runway or at any given point along an aircraft's flight path. Therefore, our measurements are being made from a point other than where the aircraft will actually be. This distance may be small in some cases, but often it can be hundreds of yards.
- Finally, the point of all this is all these factors can render our wind measurements unrepresentative and less useful.

Measuring Wind

- Wind information for use at airports can be considered representative only if it provides an optimal estimate of wind variations we can expect over the runway.
- The purpose of wind observations at an airport is to give suitable short-term wind forecasts to pilots engaged in takeoff and landing maneuvers.
  - This information, even though considered an observation, is really a forecast. How can this be? Remember, when a controller relays the latest winds to a pilot, the pilot anticipates this value to represent winds they can expect upon arrival at the runway.
  - Therefore, in a sense, it really is a forecast. When we determine this "short-term wind forecast," there are three basic errors we can encounter. Let's look briefly at each:

Observation Error

This is the uncertainty of the actual measurement when the average wind speed, direction, and variability are determined for a given observation period at the sensor location. We should sample the wind for a sufficient period of time in order to more accurately determine its speed, direction, and gustiness. We cannot simply rely on an "instantaneous" reading, as this could be a fatal mistake.
The sample period used in the NAS is 2 minutes. Europe uses Ten minutes, but 2 minutes will give us an acceptable statistical error of less than 6 percent. With this in mind, please consider the following: the wind can act like water in the ocean or like water in a nice tranquil pond. If you drop a rock in the pond, ripples (waves) will propagate in all directions. Depending on where you take your measurement, you may detect a wave or you may detect the lull in between. Pilots cannot afford to be told that life is but a peaceful lull only to be met by a tidal wave when they reach (or lift off) the runway.

Translation Error

This is error caused by the necessity to deduce from the data we receive from the sensor location what the wind conditions will actually be in the touchdown or takeoff area. Obviously, we cannot put the wind sensor on the runway itself. Therefore, we are not measuring the wind where the aircraft will actually land or take off. Instead, we "assume" the winds are the same on the runway as they are at the sensor. This is not a good assumption. Again, this reinforces the idea that we must sample over a period of time to increase the representativeness of our measurement.

Anticipation Error

This is error due to the operational time lag of up to a few minutes between the period when the wind information is transmitted to the aircraft and the maneuvering period when the information will actually be used. We can't do much about this one other than to recognize that time lag works against us. We must make every effort to relay the latest winds to the pilot when they are of significant speed or variability.

Wind Equipment Siting

- Siting and Exposure of Wind Equipment. The following gives a brief description of the siting requirements for wind sensors installed to satisfy the general requirement for wind data.
- If the site is at an airport, it should be located near the center of the runway complex such that wind observations will be representative of conditions in the average lift-off and touch-down areas.
  - The site should be relatively level. Small gradual slopes are acceptable but avoid ravines, bluffs, ridges, etc., which cause eddy currents. The site should also be as far as practical from and, if possible, climatologically upstream from objects obstructing the free flow of air.
  - The standard height above the ground for wind sensors is 10 meters (32.8 feet). If local restrictions prevent installing the sensors at the 10-meter standard, install them 20 feet above the ground.

Synoptic vs. Aeronautical reporting of wind

- There are important differences compared to the synoptic requirement for measuring and reporting wind speed and direction for aeronautical purposes at aerodromes for aircraft take-off and landing .
  - Wind direction should be measured, namely, from the azimuth setting, with respect to true north at all <u>meteorological</u> observing stations.
  - At aerodromes the wind direction must be indicated and reported with respect to magnetic north for <u>aeronautical</u> observations and with an averaging time of 2 min.
  - Where the wind measurements at aerodromes are disseminated beyond the aerodrome as <u>synoptic</u> reports, the direction must be referenced to true north and have an averaging time of 10 min.
- (From WMO Chapter 5)

USAF Comments on Wind

Brig Gen Orin L. Godsey, Commander of the Air Force Safety Center, stated, "The purpose of the wind measuring system is not to provide an instantaneous wind picture but to provide, or warn of, wind conditions that can be reasonably expected during a critical phase of flight. Winds, like other atmospheric phenomena, are variable conditions not discrete events, and analyzing them over a statistically significant period of time is the only way to draw reliable, and necessarily generalized, information useful to determine safety of flight. Additionally, due to geographic separation of the wind instrument and the approach/touchdown zone compared to the relative size of gust phenomena, the wind display is unlikely to ever exactly reflect the condition most critical to the pilot."

Wind Reporting Systems in the NAS

The following systems are currently used to measure wind in the NAS:

- TDWR
- ASOS
- AWOS
- LLWAS
- SAWS
- WSP
- F-400 Series
- WME

Terminal Doppler Weather Radar (TDWR)

A series of commercial aviation accidents in the 1970s and 80s led the FAA to commission a sensor capable of remotely detecting low-altitude wind shear phenomena such as the microburst. The resulting product was the TDWR, which is now deployed at 45 major airports around the country.

- TDWR's primary function is to detect wind shear.
- TDWR uses the standard radar reflectivity image, available at each of three different tilt angles of the radar, plus Doppler velocity of the winds in precipitation areas.

TDWR: Terminal Doppler Weather Radar

The **Terminal Doppler Weather Radar** (TDWR) is a new terminal weather radar based on Doppler techniques. TDWR units have been located to optimize the detection of microbursts and wind shear at selected airports with high operations and frequent weather impacts. In addition, TDWR can identify areas of precipitation and the locations of thunderstorms. The TDWR scanning strategy is optimized for microburst/wind shear detection. The radars are located near airport operating areas so as to provide the best scan of runways and the approach and departure corridors. System displays are located in the tower cab and Terminal Radar Approach Control Facility.

Automated Surface Weather Observing System (ASOS)

The ASOS provides aviation-critical weather data such as wind velocity, temperature, dew point, altimeter setting, cloud height, visibility, and precipitation type, occurrence, and accumulation. These systems process data and allow dissemination of output information to a variety of users, including pilots via computer generated voice.

ASOS determines Wind Character by examining the maximum "instantaneous" wind speed over the 10 minute period immediately preceding the observation.
Every 5 seconds a running 2-minute average wind (direction and speed) is computed and used to further compute wind character.
Once each minute the current 2-minute average wind is stored in memory for 12 hours and made available for reporting in the One-Minute-Observation, GTA radio, telephone dial-in, the METAR/SPECI reports, and the OID displays.

Automated Surface Weather Observing System (ASOS) cont.

Manual vs ASOS Gust reporting:

In the **manual procedure,** a gust is reported when an observer sees rapid fluctuations in sensor wind speed indications with a variation of 10 knots or more between peaks and lulls during the 10-minutes before the observation. The reported gust is taken from the maximum "instantaneous" wind speed observed during this period. The average 2- minute wind is used to report wind direction and wind speed. Conceivably, an average 2-minute wind speed as low as 3 knots (observed in the last minute) may be reported with a gust of 10 knots (observed in the last 10 minutes). Observations of 5 knots with gusts of 10 to 15 knots, however, are the more common minimum values reported.

Automated Surface Weather Observing System (ASOS) cont.

The **ASOS algorithm** also relies on a 10-minute observation period to determine gusts, but uses it in a different way.

- Once every 5 seconds, the ASOS computes the greatest 5-second average wind speed (and corresponding direction) during the past minute, and
- Once each minute stores this information in memory for 12 hours.
- Once every 5 seconds the ASOS computes the current 2-minute average wind speed and compares it with the greatest 5-second average wind speed during the past minute.
    - If the current 2-minute average wind speed is equal to or greater than 9 knots and the greatest 5-second average wind speed (during the past minute) exceeds the current 2-minute average speed by 5-knots or more, then the greatest 5-second average speed observed during the past minute is stored in memory as a gust for 10 minutes.

Ultrasonic Technology

The ASOS now uses the Vaisala WINDCAP® ultrasonic sensor technology for wind measurement. The sensor has an onboard microcontroller that captures and processes data and communicates over serial interfaces.

The wind sensor has an array of three equally spaced ultrasonic transducers on a horizontal plane. Wind speed (WS) and wind direction (WD) are determined by measuring the time it takes the ultrasound to travel from each transducer to the other two.

The wind sensor measures the transit time (in both directions) along the three paths established by the array of transducers. This transit time depends on WS along the ultrasonic path. For zero wind speed, both the forward and reverse transit times are the same. With wind along the sound path, the up-wind direction transit time increases and the downwind transit time decreases.

SAWS: Stand Alone Weather Sensors

The **Stand Alone Weather Sensors** System is a standalone system that consists of a wind speed sensor, wind direction sensor, ambient temperature sensor, barometric sensors, power supply units, sensor unit with maintenance port, control and display unit with maintenance port, transmitter/receiver radio frequency link equipment and sensor display units.

- Wind speed and direction are measured from the Wind Sensor every 1 second.
- Every three seconds the wind speed is scalar averaged and the wind direction is unit vector averaged at the SU and then sent to the CDU.
- This three second average wind is displayed at the SDU as the instantaneous wind.
- At the CDU, running averages are calculated from three second averages passed on from the SU.
- The averaging period is selected at the CDU and may be either a fifteen second, thirty second, one minute or two minute average.

SAWS: Stand Alone Weather Sensors cont.

Wind gust is determined per the following SAWS gust algorithm:
Definitions:
- $\bar{U}$ Average wind speed over 15, 30, 60, or 120 seconds
- u_{max} Maximum wind speed in 600 second wind buffer
- u_{min} Minimum wind speed in 600 second wind buffer

Tests to establish Gust:
- **IF** $\bar{U} \geq 9$ **kts then** (next test), **else** (no gust displayed)
- **IF** $u_{max} - u_{min} \geq 10$ **kts then** (next test)**, else** (no gust displayed)
- **IF** $u_{max} - \bar{U} \geq 5$ **kts then** (report wind with u_{max} as gust)**, else** (no gust displayed)

Test to sustain Gust:
- IF   umax $- \bar{U} \geq 3$ kts then (report wind with u_{max} as gust)**, else** (no gust displayed)

AWOS: Automated Weather Observing System

The Automated Weather Observing System (AWOS) includes automatic weather data acquisition, processing, recording, display, and transmission functions.

AWOS may include wind, temperature, dew point, atmospheric pressure, precipitation, visibility, and/or cloud height indication (CHI) capability built-in.

- WIND SPEED AND DIRECTION SENSORS. Each sensor is interrogated every second.
- Every five seconds, the CDP calculates a two-minute running average for both the speed and direction.
- The average speed is rounded to the nearest knot, and direction is rounded to the nearest 10 degrees.
- If the speed is less than or equal to two knots, wind speed and direction are reported "calm".
- Although the wind direction sensor is aligned to true north, the weather observation is reported over voice with reference to magnetic north; wind direction is reported with reference to true north to Service A.

AWOS: Automated Weather Observing System (cont.)

WIND GUST
- Each five seconds, the current two-minute average wind speed, and the highest five second average for the past minute, are compared.
- If the two-minute average equals or exceeds nine knots, and the difference between the two-minute average and the five second average equals or exceeds five knots, a gust is calculated.
- Then, every five seconds, the CDP looks at the highest of these gusts during the past 10 minutes, and if it is 3 knots or more higher than the current wind speed, a gust is reported.

VARIABLE WIND DIRECTION
- is reported when the wind direction varies from the two-minute average wind direction by 60 degrees or more, when the wind speed is seven knots or greater. Calculations are similar to those for wind gust.

LLWAS: Low Level Wind Shear Alert System

The Low Level Wind Shear Alert System (LLWAS) provides a low-level wind shear alert warning for use by air traffic controllers in a terminal ATC environment. It consists of a center field sensor and one or more wind shear sensors installed at strategic positions on or adjacent to an airport using telemetering connection to a digital processor with ancillary visual and audible warning indicators in the central operations facility.

The LLWAS is a system of wind sensors and processors that detect and identify hazardous low-level wind-shear phenomena and provides this real-time information to the air traffic controllers in Air Traffic Control Towers (ATCT). The system is designed to warn of wind-shear hazards, which by definition also includes microbursts, to aircraft on approach to and departure from the airport.

LLWAS – Low Level Windshear Alert System

There are currently three LLWAS configurations fielded:
- Network Expansion, NE, (FA-10387) and
- LLWAS-2 (FA-10239 and FA-10240).
- The LLWAS-RS (FA-14100) is installed at major airports and is comprised of a master station controller (MSC), remote sensor stations, displays in the ATCT and TRACON, a Display Selection Device (DSD) in the ATCT, and a system console adjacent to the MSC. The master station receives information from remote stations, and processes the data using wind-shear, microburst and gust algorithms to provide Air Traffic Control (ATC) the wind speed and wind direction, the severity and type of wind events as they relate to a specific runway (LLWAS-NE and LLWAS-RS) or airport sector (LLWAS-2). Center field wind speed and direction and gust speed is reported to the TRACON. All information displayed by LLWAS-RS is relative to a specific runway or sector with the exception of airport center field wind speed, direction, and gust information.

LLWAS – Low Level Windshear Alert System, cont.

The Linear Averaged wind measurements **SHALL** be calculated using a predefined parameter number of 1 second independent wind sensor samples. Calculation of these measurements **SHALL** be based on the following equation:

$$\overline{X} = (1/n)*\sum x_i$$

for all i from 1 to n

where:

x_i = set of one second wind samples

n = total number of wind samples

Used as inputs into the Gust Algorithm. Threshold wind and Center field wind calculations.

This method assume a very short (less than one second) time constant for the wind sensor and electronics to acquire and digitize the wind sensor signals.

WME: Wind Measuring Equipment

The Wind Measuring Equipment (WME) is the center field wind sensor that remains after the decommissioning of a Low Level Wind Shear Alert System (LLWAS). It provides wind speed and direction information at previous LLWAS locations where a TDWR or WSP has been commissioned. No wind shear information is provided.

WSP: Weather Systems Processor

The Weather System Processor (WSP) is used primarily to produce timely alerts of hazardous weather conditions to Air Traffic Controller (ATC) personnel. WSP detects and reports two wind shear conditions, microbursts and gust fronts that endanger aircraft during landing and takeoff. It also produces general storm motion tracking and prediction, and generation of six-level, anomalous propagation (AP) free, precipitation maps in the terminal area as an aid in the management of air traffic control. The weather products are used by ATC personnel and external users and displayed on the Weather Display System (WDS).

F420

- From about August 1958 to the present the F420 Series wind instruments were used for determining wind speed and direction.
- The F420 series instruments have cup anemometer and wind vane separated by about 1 m.
- A weather observer uses visual/mental averaging to determine the wind speed and direction during a one-minute time period at the top of the hour.

LLWAS-RS

The Low Level Windshear Alert System Relocation/Sustainment (LLWAS-RS) is intended to upgrade the current LLWAS at 40 LLWAS-2 operating sites and 4 support sites, to last another 20 years.

The LLWAS-RS program is divided into two efforts: pole relocation and system sustainment. The program began in response to the National Transportation Safety Board (NTSB) investigation of the aircraft accident at Charlotte, NC, in 1994. From that accident, a determination was made that LLWAS must regain and retain its original capability. Due to increased obstructions around remote station wind sensors and equipment obsolescence, the capability has been lost over the years. Currently, each airport may have as few as 6 or as many as 32 remote stations. The remote sensor data received is transmitted to a master station, which generates warnings when windshear or microburst conditions are detected. Current wind data and warnings are displayed for approach controllers in the Terminal Radar Approach Control Facility (TRACON) and for ground controllers in the Air Traffic Control Tower (ATCT).

LLWAS (cont.)

A typical LLWAS system includes a network of anemometers (wind sensors) atop tall poles located around the airport (a.k.a. remote stations) out to no more than 3 nm from the end of the runways, a master station that processes system data and communicates with the remote stations, an archiving system, operator console, alphanumeric alarm displays, and in some instances graphical displays.

The wind data at each remote station is processed every 10 seconds to determine if there is divergence or convergence within the network, or station–to–station wind differences between stations aligned with the runways. The divergence/convergence information is processed and if the intensity of the event is large enough, the system will calculate the strength of the along–runway wind losses or gains and generate windshear or microburst alerts (depending on strength), and identify the location of the event.

A microburst is an intense windshear. By definition: Microburst n: A small, very intense downdraft that descends to the ground resulting in a strong wind divergence. The size of the event is typically less than 4 kilometers across. Microbursts are capable of producing winds of more than 100 mph causing significant damage. The life span of a microburst is around 5–15 minutes.

LLWAS (cont.)

Windshear is a rapid change of wind speed or direction over a short distance. In general, windshear becomes a hazard for aircraft if the wind changes more than 20 knots over a distance of 1–4 km (0.5 to 2.5 nm). On either takeoff or landing, aircraft are near stall speeds. When going through a windshear, the headwind decreases resulting in a loss of lift. If the aircraft is near stall, then a little loss of lift can make all the difference to whether the aircraft can continue the flight.

LLWAS provides information on windshear type, location, and intensity. Windshear alerts are issued via radio to arriving and departing aircraft by final air traffic controllers. In the U.S., most airlines require that pilots not continue their arrival or departure if there is a microburst alert valid for their operation. Although most aviation authorities do not close the runways when microbursts are occurring, the air traffic controllers will work with the pilots to reroute aircraft away from the event to a runway that is not impacted by the windshear.

LLWAS provides information on windshear type, location, and intensity. The pilots get the alert from the controller and the pilot is supposed to determine if they feel comfortable continuing the operation. In the U.S., airlines require that pilots do not continue if there is a microburst alert.

Where does that leave us?

From on operational perspective, the Terminal Air Traffic Managers are faced with a sometime bewildering variety of choices on which wind to use for operational purposes.

Currently there are several ATSAP reports and Whistle-blower incidents involving wind reporting in the NAS.

In the 1999-2000 time frame there was an ad-hoc group studying wind issues.

The time has come to form a similar group, chartered by ATO, to sort out the operational issues of wind reporting.